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SIR ARTHUR EDDINGTON

Der Entdecker der atomaren Zerstrahlung der Sterne in Licht

Arthur Stanley Eddington war einer der wenigen Menschen, die eine gefühlsmäßige Einsicht in die tiefen Probleme der Natur haben. Er war ein unvergleichlicher Pionier der Astrophysik während der ersten Hälfte des zwanzigsten Jahrhunderts.

Die Bewegung der Sterne, ihr innerer Aufbau, die Bedeutung des Strahlungsdruckes, die Natur der weißen Zwerge, die Dynamik der pulsierenden Sterne, der physikalische Zustand der interstellaren Materie[1] – über alle diese Probleme haben seine Untersuchungen zwischen 1906 und 1944 der Forschung neue Gesichtspunkte erschlossen. Überdies trug er neue Ideen zur Relativitäts- und Quantentheorie bei und stellte Beziehungen zwischen allen wichtigen Naturkonstanten auf.

Eddington wurde am 28. Dezember 1882 in Kendal in Nordengland geboren. Sein Vater war Direktor der Stramongate Schule, einer Quäkerschule, deren Leiter einhundert Jahre vorher John Dalton gewesen war. Drei Generationen hindurch war seines Vaters Familie im Südwesten Englands Mitglied der „Society of Friends", während mütterlicherseits die Quäkertradition bis ins siebzehnte Jahrhundert zurückgeht. Im Jahre 1884 starb sein Vater an einem typhusartigen Fieber, und die Witwe zog mit ihrer Tochter und ihrem kleinen Sohn nach Somerset. Während dieser Zeit besuchte Eddington die Brynmelyn Schule in Weston-super-Mare; dann bekam er ein Grafschaftsstipendium am Owens College in Manchester und 1902 ein Anfängerstipendium am Trinity College, Cambridge.

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[1] Unter interstellarer Materie versteht man sehr dünn verteilte Materie im Raum zwischen den Fixsternen, bestehend aus staub- und gasförmiger Materie, die teilweise ionisiert ist; häufigste Elemente: Wasserstoff, Natrium, Kalium und Kalzium.

Nachdem er die Grundlagen der Physik und Mathematik in Manchester erhalten hatte, folgten zwei Jahre intensiven Studiums der Mathematik in Cambridge. Bei dem Abschlußexamen, der „Mathematical-Tripos"-Prüfung, errang er den hohen Grad eines „Senior Wrangler".

Zwei Jahre später wurde Eddington zum Hauptassistenten an der Greenwicher Sternwarte ernannt, wo er von 1906 bis 1913 blieb. Hier bekam er große Übung in astronomischen Beobachtungen. Im Jahre 1909 wurde er beauftragt, die geographische Länge der geodätischen Station auf der Insel Malta zu bestimmen; 1912 unternahm er eine Sonnenfinsternisexpedition nach Brasilien. Sein erstes theoretisches Werk handelte über die Systematik der Sternbewegungen. Mit dieser Arbeit sind die Namen Kapteyn, Schwarzschild und Eddington verkettet. Im Jahre 1904 hatte Kapteyn eine statistische Untersuchung über Sternbewegungen gemacht und dabei gefunden, daß zwei Richtungen relativ zu unserem Sonnensystem bevorzugt wurden. Zur Erklärung dieser Erscheinung entwickelte Eddington die Zweisternstrom-Theorie[2], und Schwarzschild schlug die Ellipsoidhypothese über Sternbewegungen vor. Beim Vergleich beider Theorien schrieb Eddington 1917 folgendes:

„*Der scheinbare Widerspruch zwischen der Zweistrom- und der Ellipsoidtheorie verschwindet, wenn wir uns daran erinnern, daß der Zweck beider die Beschreibung des Vorgangs ist. Während die Zweistromtheorie öfter bei einfachen Erforschungen der Eigenbewegungen zur Ableitung einer additiven Konstanten in der Formel bevorzugt wird, da sie eine etwas größere Bewegungsfreiheit hat, ist die Anwendung der Ellipsoidtheorie bei der Erörterung der Radialgeschwindigkeiten und der dynamischen Theorie von Sternsystemen günstiger.*"

Eddingtons zwei bemerkenswerte, statistische Untersuchungen der Eigenbewegungen bestätigen im vollen Umfang das Vorhandensein der zwei Sternströme und ermittelten ihre Bewegungsrichtung und ihre relativen Anzahlen[3]. Dies veranlaßte ihn, sich mit weiteren solcher Pro-

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[2] Eddington fand, daß sich die beobachteten Sternbewegungen durch zwei sich durchdringende Sternströme erklären lassen. Die Bewegungsrichtung des Stromes I weist auf das Sternbild des Hasen, die Bewegungsrichtung des Stromes II auf das Sternbild des Pfaus.

[3] Das Verhältnis der Anzahl der Sterne des Stromes I zu denen des Stromes II; dies Verhältnis ist etwa 3:2.

bleme zu beschäftigen: der Verteilung der Sterne nach verschiedenen Spektralklassen, den planetarischen Nebeln, den offenen Sternhaufen, den Gasnebeln, der Dynamik der Kugelsternhaufen. Alles dieses und noch viel mehr veröffentlichte er in seinem ersten, bedeutenden Buch: „*Stellar Movements and the Structure of the Universe*“ (Sternbewegungen und die Struktur des Weltalls, 1914). Es enthält die Kenntnisse über die Kosmologie seiner Zeit; Eddington äußert sich darin kühn über die Möglichkeit, daß unser Milchstraßensystem ein Spiralnebel sei, und bringt manche herausfordernden Probleme vor, die auf eine Lösung warteten. Das Buch hatte großen Erfolg in Europa und Amerika. Eddington hat sich dadurch einen Platz unter den Ersten der astronomischen Forscher gesichert. Als die Plumian Professur für Astronomie in Cambridge im Jahre 1913 frei wurde, erhielt er diese, und im folgenden Jahr wurde er Mitglied der Royal Society.

Der zweite Abschnitt in Eddingtons Lebenswerk begann 1916, als er bekanntgab, daß bei der Gleichung für das Gleichgewicht der Sterne neben der Gravitation und dem Gasdruck eine dritte Größe, der Strahlungsdruck, berücksichtigt werden müßte. Der auswärtsgerichtete Strom der Strahlungsenergie (Wärme, Licht und kürzere Strahlung) hilft, das Gewicht der Sternatmosphäre tragen. Mehr als zehn Jahre früher hatte schon R. A. Sampson in England auf die Bedeutung des Strahlungsdruckes hingewiesen, und später hat Schwarzschild in Deutschland eine Theorie über das Strahlungsgleichgewicht in hohen Schichten der Sternatmosphären aufgestellt; aber erst Eddington dehnte diese Theorie auf das Innere der Sterne aus. Lane, Ritter und Emden hatten konvektives, d. h. auf der Sternbewegung beruhendes Gleichgewicht angenommen; Eddington führte das Strahlungsgleichgewicht ein, und seine Gleichung ($H = -ac/3\kappa\rho\, dT^4/dr$) ist heute allgemein im Gebrauch. Er nahm an, daß die Materie in Riesensternen (acht Jahre später zeigte er, daß dies gleichfalls für normale Zwergsterne anwendbar ist) nahezu ein ideales Gas sei, und er wandte Emdens Gleichung für polytrope Kugeln mit dem Index $n = 3$ an. Dies ist jetzt als das Eddingtonsche Sternmodell bekannt.

Die Tatsache, daß in Sternen hoch ionisierte Materie vorhanden ist,

wurde von anderen erkannt; aber Eddington war der erste, der diese Erkenntnis in die Theorie einführte und zeigte, daß bei hoher Ionisation alle Elemente, mit Ausnahme des Wasserstoffs, ein mittleres Molekulargewicht von nahezu 2 besitzen. Er fand eine Beziehung zwischen der Masse, der Leuchtkraft und dem Absorptionsvermögen (Opazität) gasförmiger Sterne.

1923 begann er seine Theorie des Absorptionskoeffizienten zu entwickeln, seinerzeit streng kritisiert, weil er annahm, daß die Hauptquelle der Opazität, der Undurchlässigkeit der Sternmaterie die Wechselwirkung zwischen Strahlung und Materie ist. Als Kramers Theorie der Absorptionskoeffizienten bekannt wurde, benutzte Eddington sie für das Sternproblem und fand sein wichtiges Masse-Leuchtkraft-Gesetz. Es wurde 1924 veröffentlicht und ist durch die Beobachtungen bestätigt worden. Heute wird es allgemein bei astronomischen Untersuchungen angewandt.

Diese Arbeit überzeugte Eddington, daß alle Riesen- und normalen Zwergsterne nur aus Gas bestehen; da der Wirkungsquerschnitt eines ionisierten Atoms klein ist, kommen Abweichungen vom Zustand des idealen Gases nicht vor, es sei denn, daß Dichten erreicht werden, die wesentlich höher als die der irdischen Substanzen sind. Er schloß, daß bei der Sternmaterie solche außergewöhnlich hohen Dichten möglich sind, und folgerte, daß dies die Erklärung für die weißen Zwerge sein könnte, deren ungewöhnlich hohe Dichte bestimmt worden war, aber noch nicht als echt angesehen wurde. Er schrieb W. S. Adams auf den Mt. Wilson und bat ihn, die Rotverschiebung im Spektrum des Sirius-Begleiters zu messen und festzustellen, ob der Relativitätseffekt vorhanden sei. Adams berichtete von einer Verschiebung der Spektrallinien, die mit den von Eddington vorausberechneten übereinstimmten. Diese überdichte Sternmaterie rief großes Interesse bei den Physikern hervor, und R. H. Fowler zeigte, daß bei diesem „degenerierten“ Zustand der Materie die klassische Statistik versagt und daß man die Fermi-Diracsche Statistik anwenden muß. Als eine Folge der Masse-Leuchtkraft-Beziehung fand Eddington, daß, wenn die vorhandene Reihe der Sternenentwicklung (Hertzsprung-Russell-Theorie) aufrechterhalten werden soll, sich der größte Teil der Masse eines Sterns in Strahlung verwandeln können muß, – und eine sehr lange Zeitskala von Billionen von Jahren für das Alter der Sterne war unumgänglich. Dieses erforderte eine Theorie der Umwandlung von Materie in Strahlung durch Vernichtung von Elektronen und Protonen. Diese Hypothese scheint zuerst 1917 von Eddington vorgeschlagen worden zu sein. Sieben Jahre lang verteidigte er in England, trotz zahlreicher Kritiken, den allgemeinen Gedanken, daß die Hauptquelle der Sternenergie atomarer Natur sei. Nach 1924 erkannten viele Astronomen die Elektron-Proton-Vernichtungshypothese an; aber 1934 drang Eddington darauf, diese Hypothese aufzugeben, da nach der Entdeckung des Positrons[4] die gegenseitige Vernichtung von einem Elektron und einem Positron sowohl eine logisch besser begründete Annahme, wie auch eine Beobachtungstatsache war.

1926 veröffentlichte Eddington sein bemerkenswertes Buch „*Internal Constitution of the Stars*“; die deutsche Ausgabe, „*Der innere Aufbau der Sterne*“, erschien im folgenden Jahr. Es ist auch heute noch ein Nachschlagewerk von unschätzbarem Wert für alle mathematischen Untersuchungen über die Probleme der Physik der Sterne. Zusätzlich zu den schon erwähnten Gegenständen enthielt das Buch Eddingtons frühere Arbeiten über mehrere andere spezielle Probleme.

1918 und 1919 erschienen zwei sehr gründliche Arbeiten von Eddington über die mathematische Theorie der pulsierenden Sterne. Sie stimmten gut mit den beobachteten Eigenschaften der Cepheiden-Veränderlichen überein, besonders was die berechnete Pulsationsperiode betraf; der Hauptwiderspruch mit der Erfahrung war die Beziehung zwischen den Phasen der Lichtkurve und der Geschwindigkeitskurve. Diese Schwierigkeit wurde zum größten Teil 1941 dadurch überwunden, daß er den Einfluß des Ionisationsgleichgewichts in der Konvektionszone[5] des Sterns berücksichtigte. Aber in den ersten Stadien gab ihm diese Untersuchung die Stabilitätsbedingung für diese Sterne, und seine Schlußfolgerungen, obgleich anfangs noch heftig bestritten, fanden ihre Bestätigung durch Hrch. Vogt und James Jeans. 1931 erweiterte Eddington seine Untersuchungen der Grenzen der Zentraltemperaturen und der Sterndichten. Im folgenden Jahr erkannten er und Rosseland unabhängig voneinander, daß die kosmische Häufigkeit von Wasserstoff bei weitem die Häufigkeit aller anderen Elemente übertreffen muß.

Einen bedeutenden Beitrag zur Astrophysik gab Eddington mit seiner Theorie der Bildung von Absorptionslinien im Spektrum der Sternatmosphären. Sie war eine Ausdehnung der Arbeiten von Schuster und Schwarzschild. Deren Methoden paßte er vielen Problemen bei der Bildung von Absorptionslinien an, so daß die Methode weitgehend für die Deutung der beobachteten Linienintensitäten ausgenutzt wurde. Als Bowen 1927 die Hauptlinien einiger diffuser Nebel mit „verbotenen Übergängen“ in ionisierten Stickstoff- und Sauerstoffatomen identifizierte, lieferte Eddington die theoretische Erklärung einer solchen Emission.

Er war der erste, der eine theoretische Studie über die Eigenschaften der interstellaren Materie durchführte, wobei er eine durchschnittliche Dichte von 10^{-24} und eine Temperatur (gemessen an der mittleren Geschwindigkeit der Atome) von 10000° fand. Er zeigte, daß die Calziumatome zweifach ionisiert sein müßten und daß unter 800 Atomen etwa 1 Atom einfach ionisiert sein müßte. Er schloß, daß die sogenannten „ruhenden Calziumlinien“ in Sternspektren durch die Absorption des Lichtes auf dem ganzen Wege vom Stern bis zur Erde gebildet werden, so daß die Intensität dieser Linien ein rohes Maß für die Sternentfernung sein sollte. Diese Entfernungs-Intensitäts-Beziehung wurde von O. Struve und J. S. Plaskett bestätigt.

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[4] Die Atomkerne setzen sich zusammen aus den mit einer positiven Elementarladung versehenen Protonen und den elektrisch neutralen Neutronen; dabei ist die Zahl der Protonen gleich der Ordnungszahl des Atoms und bestimmt damit sein chemisches Verhalten. Elemente mit gleicher Protonenzahl aber verschiedener Neutronenzahl heißen Isotope. Zum vollständigen Atom gehören außer dem Kern, der im wesentlichen die Masse des Atoms bestimmt, noch die den Kern umgebenden Elektronen. Diese haben nur etwa $^1/_{1800}$ der Masse eines Protons. Jedes Elektron besitzt eine negative Elementarladung. Ein neutrales Atom enthält ebenso viele Elektronen wie Protonen.

Beim Aufprall von Strahlung auf Materie können Elektronen von den Atomen abgespalten werden. Atome, die Elektronen verloren haben, nennt man Ionen.

Zum Elektron gibt es ein Gegenstück von gleicher Masse, aber mit einer positiven Elementarladung versehen: das Positron. Das Positron entsteht bei gewissen Kernraumwandlungsprozessen und dem Zerfall von Strahlungsquanten hoher Energie. Während das Elektron stabil ist, hat das Positron nur eine geringe Lebensdauer.

[5] Energie kann erstens durch Strahlung und zweitens durch Konvektion (Bewegung der Materie) transportiert werden. In den Sternatmosphären gibt es gewisse Schichten, in denen Energie durch Konvektion transportiert wird. Diese Schichten bezeichnet man mit Konvektionszonen.

Eddingtons einziges populäres Buch über seine astrophysikalischen Untersuchungen war „*Stars and Atoms*“ (1927), das später ins Holländische, Französische, Deutsche, Spanische, Italienische, Japanische, Dänische, Tschechische, Finnische und Polnische übersetzt wurde. Mit charmanter Unbekümmertheit und in einem hochstehenden, literarischen Stil gab er dem Durchschnittsleser ein aufregendes Gefühl für die spannungsreichen, wissenschaftlichen Entdeckungen und für die Freude des Naturforschers bei seinen nie endenden Fragen nach den wahren Antworten auf die Probleme der Natur.

Von 1914 bis 1944 erfüllte Eddington seine Pflichten als Professor der Astronomie und Direktor der Sternwarte in Cambridge, und er spielte eine aktive Rolle in der Royal Society, der Physical Society und der Royal Astronomical Society, der Britischen Assoziation zur Förderung der Wissenschaft, der Internationalen Astronomischen Union und der Society of Friends. Freundlich ging er auf Einladungen zu öffentlichen Vorträgen ein; er reiste zu wissenschaftlichen Versammlungen durch Europa, Amerika, Afrika, Südasien und Indien. Eddington schrieb 12 Bücher und mehr als 114 wissenschaftliche Veröffentlichungen.

In der Wertschätzung durch die meisten seiner Kollegen in vielen Ländern bilden seine ungeheuer wichtigen und fundamentalen Beiträge zum Fortschritt der Astrophysik seine größte Leistung; aber in der gleichen Periode wirkte er auch auf dem neuen Gebiet der Allgemeinen Relativitätstheorie. Er wurde der erste und größte Ausdeuter der Einsteinschen Theorie in der englisch sprechenden Welt; er gab ganz bestimmte Beiträge zur Entwicklung dieser Theorie, und in seinen späteren Jahren suchte er unverdrossen, die Verbindung seiner eigenen Weiterverarbeitung der Diracschen Entwicklung der Quantentheorie mit den kosmologischen Folgerungen aus der Theorie des expandierenden Weltalls herzustellen. Einem „*Bericht über die Relativitätstheorie der Gravitation*“, der 1915 von der Physikalischen Gesellschaft in London veröffentlicht wurde, folgte 1920 die weniger strenge Ausarbeitung „*Space, Time and Gravitation*“ *(Raum, Zeit und Gravitation)*. Deutsche, französische und spanische Ausgaben wurden ebenfalls veröffentlicht. 1923 erschien seine „*Mathematical Theory of Relativity*“ *(Mathematische Theorie der Relativität)*, eine glänzende Arbeit, die Einstein am Ende seines Lebens als die schönste Darstellung dieses tiefsinnigen Gegenstandes ansah. Dieses Buch wurde sowohl ins Deutsche wie ins Russische übersetzt. Es enthält zahlreiche originale Entwicklungen, die mit der logischen Darstellung von Einsteins Theorie zu einem einheitlichen Ganzen vereinigt sind. Eine besondere Entwicklung war eine Verallgemeinerung von Weyls Theorie der elektromagnetischen- und Gravitationsfelder, und verbunden mit diesem war seine Erklärung des Gravitationsgesetzes ($G_{\mu\nu} = \lambda g_{\mu\nu}$). Dies bedeutet, daß der Krümmungsradius des Raum-Zeit-Kontinuums in irgendeinem Punkt und in irgendeiner Richtung eine Konstante ist. Eddington zeigte, daß dies die folgende Tatsache einschließt: unsere praktische Längeneinheit ist in jedem Punkt und in jeder Richtung ein bestimmter Bruchteil des Krümmungsradius für diesen Punkt und diese Richtung; also: das Gravitationsgesetz ist einfach der Ausdruck für die Tatsache, daß der Weltkrümmungsradius überall die Standardlänge liefert, mit der unsere Längenmessungen verglichen werden. Diese Arbeit führte ihn später zu seiner theoretischen Bestimmung der kosmischen Konstante λ. Indem er das Prinzip zugrundelegte, daß die Wellengleichung, welche die linearen Dimensionen eines Atoms bestimmt, notwendigerweise diese linearen Dimensionen in dem Standardweltradius ausdrücken muß, fand er einen Wert für λ ausgedrückt in den Atomkonstanten, die in der gewöhnlichen Form der Wellengleichung auftreten.

Eddington führte eine der beiden britischen Expeditionen, die Aufnahmen der Hyadensterne als Hintergrund für die total verfinsterte Sonne vom 29. Mai 1919 machten. Diese erbrachten die erste Bestätigung für die Ablenkung des Sternlichtes beim Durchgang durch ein starkes Schwerefeld. Einstein gratulierte Eddington zu dem Ergebnis und betonte die Wichtigkeit der weiteren Prüfung der Relativitätstheorie.

1954 sagte Einstein von Eddington, daß „er einer der ersten war, der erkannte, daß das Feld der Verschiebung von Vektoren der fundamentalste Begriff der Allgemeinen Relativitätstheorie ist, denn dieser Begriff erlaubt es uns, ohne das Interialsystem auszukommen.“ Eddingtons Entschlossenheit, die Quantentheorie und die Relativitätstheorie miteinander zu verknüpfen und die unbedingt nötigen Naturkonstanten aus erkenntnistheoretischen Anfängen zu gewinnen, sowohl die atomaren wie die kosmologischen, führte ihn dazu, seine philosophischen und mathematischen Fortschritte in drei Büchern niederzulegen: *„The Nature of the Physical World“ (1928) (Die Natur der Physikalischen Welt)*, *„New Pathways in Science“ (1935) (Neue Wege der Naturwissenschaft)*, *„The philosophy of Physical Science“ (1939) (Die Philosophie der Physik)*. Von dem ersten dieser Bücher wurden 64000 Exemplare der englischen Ausgabe verkauft; es wurde in 9 Sprachen übersetzt. Ein kleines Buch *„The Expanding Universe“ (1933) (Das expandierende Weltall)* zeigte, an welcher Stelle er von LEMAÎTRES Kosmologie abwich, wie er DIRACS Spin[6]-Theorie ausdehnte und wie er, von grundlegenden Prinzipien ausgehend, die Feinstrukturkonstante 137 und den Packungsfaktor vom Helium (136/137) fand.

Seine Theorie führte ihn zu einer quadratischen Gleichung, deren Wurzeln das Verhältnis der Massen des Elektrons zum Proton als 1 zu 1847.60 ergaben. Sein Buch *„Relativity Theory of Protons and Electrons“ (1936) (Relativitätstheorie der Protonen und Elektronen)* gründete sich fast völlig auf die Spinausdehnung der Relativitätstheorie. Er ging weiter bis zu einer statistischen Ausweitung der Theorie. Die Schwierigkeiten waren ungeheuer. Seine Intuition führte ihn fort mit Sprüngen und Haken zu Gebieten, in die ihm seine Kollegen nicht folgen mochten. Die Kritik war heftig, und starker Unglaube begegnete ihm. Aber Eddington blieb überzeugt, daß die Unklarheiten nur zeitweilig waren und daß die Hauptidee seiner fundamentalen Theorie von großer Bedeutung war. Indem er die Anzahl der Protonen und Elektronen im Universum mit der Anzahl der unabhängigen Quadrupelwellenfunktionen in einem Punkt identifizierte, wertete er diese zu $\frac{3}{2} \times 136 \times 2^{256}$ aus. Dies ist von der Größenordnung 10^{79}, die zusammen mit 137 die Eddingtonschen Zahlen genannt werden können. Er rechnete auch Werte für die Gravitationskonstante, die Plancksche Konstante, die Ladung des Elektrons und 24 andere physikalische Konstanten aus.

Das unvollendete Manuskript dieses mutigen Versuchs einer großen Synthese lag auf seinem Schreibtisch, als er nach einer schweren Operation am 22. November 1944 starb. Trotz mancher unvollendeten Teile wurde das Manuskript später als *„Fundamental Theory“ (1946) (Fundamentale Theorie)* veröffentlicht.

Eddington war ein Mensch von tiefer religiöser Überzeugung. Er ging mit aufrichtiger Einfachheit und mit einem mystischen Gefühl für ihre tiefe Bedeutung an die Dinge heran. In seinem Buch *„Science and the Unseen World“ (1926) (Die Naturwissenschaft und die unsichtbare Welt)* schrieb er: *„Man wird den wahren Geist weder der Wissenschaft noch der Religion verstehen, es sei denn, man suche ihn im Vordergrund aller Dinge.“*

Seine Beiträge zur Philosophie lagen hauptsächlich in seiner klaren Erkenntnis, daß der menschliche Geist in der Außenwelt solche charakteristischen Merkmale sucht, die in bestimmte Formen hineinpassen, und daß das Wissen des Menschen über die physikalische Welt ein Wissen über seine Struktur bleibt.

Eddingtons Größe beruht nicht auf dem Urteil unserer Generation über den Wert seiner letzten Arbeit, die voll von Künstelei, Scharfsinn und beunruhigendem Dunkel ist. Die Zukunft wird vielleicht zeigen, daß in seiner fundamentalen Theorie Gedanken von hohem und bleibendem Wert verborgen sind, die ihn unter die Olympier der Naturphilosophen versetzen. Aber als Astronom und Astrophysiker steht dieser noble Quäker-Gelehrte als einer der „Überriesen“ da. Seine Theorien und Entdeckungen machten die erste Hälfte dieses Jahrhunderts zu einer Ära eines unübertroffenen geistigen Abenteuers.

(Aus dem Englischen übersetzt)

LITERATUR: Nachruf H. Spencer-Jones, E. T. Whittaker, in: Monthly Notices of the Royal Astronomical Society, 105 (1945).

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[6] Die Drehung eines Elektrons im Atom um seine eigene Achse.


GESTALTER UNSERER ZEIT
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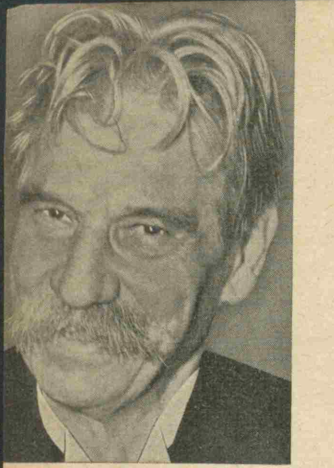

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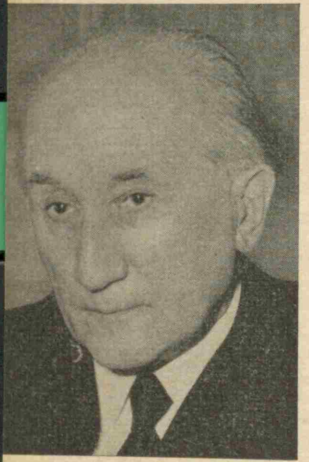

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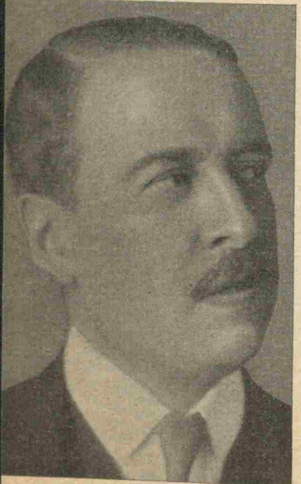

Hugo von Hofmannsthal

Das Reihenwerk „Gestalter unserer Zeit“ will die zeitprägenden Persönlichkeiten unserer europäischen Gegenwart sichtbar machen. Im Herbst 1954 erschienen die beiden ersten Bände:

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Diese beiden Bände sind nicht nach Ländern, sondern nach Fachgebieten geordnet. Sie bringen die großen europäischen Physiker, Chemiker, Erforscher des Weltalls, Erforscher der Erde, Mathematiker, dann die Mediziner, Biologen und Anthropologen.
Jedem Forschungsbereich ist ein Einführungskapitel vorangestellt, das die Haupterkenntnisse im 20. Jahrhundert herausarbeitet und den Rahmen für die dann folgenden Einzelporträts gibt. Beide Bände richten sich an „Hörer aller Fakultäten“. Erste Fachkräfte haben in ihnen die Feder geführt.
Dr. Hans Schwerte, Universität Erlangen, und Dr. W. Spengler, Cheflektor im Gerhard Stalling Verlag, besorgten die Gesamtherausgabe.

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Thomas S. Eliot


Ortega y Gasset


Paul Claudel

Leseprobe aus dem Porträt

JOSÉ ORTEGA Y GASSET

von Prof. Dr. Fritz Schalk

Es ist der künstlerische Geist in Ortega, der seinen Schriften die unverbrüchliche Eigenart sichert. Echt humanistisch gelingt es dem Autor stets, auch das sprödeste Thema aus der Verstrickung in das Spezialistische, in die Fachsprache zu lösen, um ihm in freier Gestaltung Form und Eigenleben zu verleihen. Wenn wir erkennen, wie er in Meditationen, Improvisationen, Fabeln, Glossen das Verfahren seiner Gedanken stets von neuem erprobt oder die Ansprache wählt, die schon durch den festlichen Anlaß über alle Pedanterie hinausgehoben ist, dann sehen wir ihn mit den alten spanischen Meistern solcher Gattung — mit Juan und Alfonso de Valdés, Gracián, Quevedo – aber auch mit dem Formbegriff des Humanismus überhaupt zusammentreffen, und sich ihm von verschiedenen Voraussetzungen her immer wieder nähern. Schloß doch die offene humanistische Form die Subjektivität, ja die Willkür, die Beimischung des Individuellen nicht aus. An zahllosen Beispielen schon der Frühschriften läßt sich erkennen, wie unmerklich die Sphäre des Persönlichen und des Allgemeinen ineinander übergehen und warum der Essay, über dessen Wesen sich Ortega oft ausgesprochen hat, seine sehr persönliche Denkform werden mußte. Der Autor hält den Gedanken fest, der zu dem gewünschten Resultat führen muß, läßt ihn aber oft scheinbar fallen, um den Leser nicht müßig werden zu lassen. In den *Meditationen über den Don Quijote* (1914) verknüpft Ortega verschiedene Themen so kunstvoll miteinander, daß das eine aus dem andern hervorzugehen scheint, als müßte der Gedanke erst aufgelöst werden, ehe man ihn wieder zusammensetzen kann. Diese künstlerische Eigenart setzt sich in allen Schriften fest und gibt ihnen ein einheitliches stilistisches Gepräge, ein Fascinosum.

Die National-Zeitung in Basel (Schweiz) schreibt :

„Das verdienstvolle Unternehmen gründet auf der Überzeugung, daß das überragende Individuum als der geistige Repräsentant seines Landes betrachtet werden darf und daß somit „die großen Kulturpersönlichkeiten unserer Gegenwart in den verschiedenen europäischen Völkern die heutige geistige Substanz Europas“ darstellen. Dieser Konzeption zufolge, die wir für die geeignetste zur Erreichung des geplanten Zieles halten, werden uns durch erstrangige Fachleute die verschiedenen Persönlichkeiten, die europäische Akzente setzten, auf knappstem Raume vorgestellt. Besonders begrüßenswert ist die jedem Porträt beigefügte ausgewählte Bibliographie und die Miniaturanthologie von Texten, die aus dem Werk ausgewählt sind und die einen unmittelbaren Eindruck des Gewürdigten vermitteln.“

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Max von Laue – Der Beweis von der Wellennatur der Röntgenstrahlen

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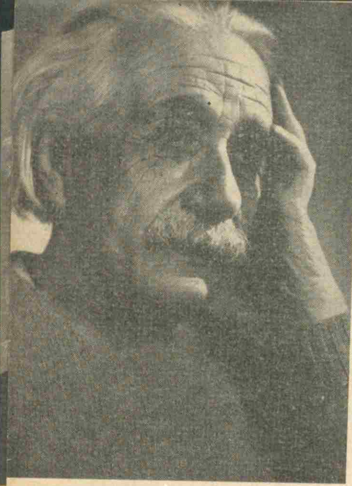
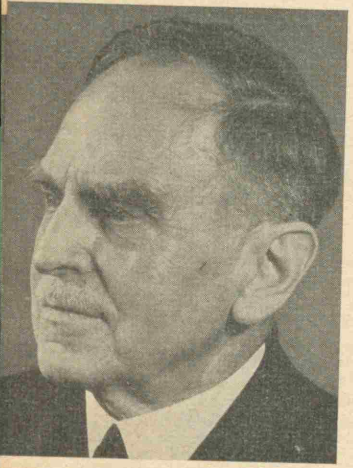


Albert Einstein



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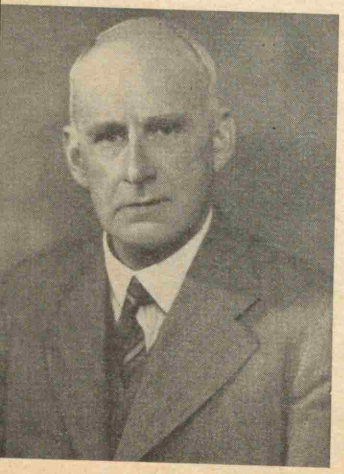

Sir A. Eddington

Leseprobe aus dem Porträt

ALBERT EINSTEIN

Von Prof. Dr. Max von Laue

Albert Einstein ist am 18. April 1955 im 77. Lebensjahr gestorben. Die Physiker, die ihn mit Stolz zu den ihrigen zählen, ja alle Naturwissenschaftler hielten inne in der Arbeit; denn einer ihrer Größten war dahingegangen. Aber auch die Geisteswissenschaftler, voran die Philosophen von Fach, standen in Ergriffenheit da; denn Einsteins Bedeutung ragt tief in die Philosophie der naturwissenschaftlichen Erkenntnis hinein. Ja, selbst jeder, der etwas von dem Einfluß des Geistes auf den Gang der Geschichte ahnt, sollte aufhorchen. Einstein gehört zu der Größenordnung Isaac Newtons ... Einsteins größte Leistungen liegen zweifellos im Bereich der Quantentheorie und ganz besonders bei der Relativitätstheorie, diesem ureigensten Erzeugnis seines Geistes. Die Titel der dafür grundlegenden Veröffentlichungen lauten: „*Über einen die Erzeugung und Verwandlung des Lichts betreffenden heuristischen Gesichtspunkt*" und „*Zur Elektrodynamik bewegter Körper*". Beide stammen aus demselben Jahre 1905 (Annalen d. Physik), welches ihretwegen einen Wendepunkt in der Geschichte der Physik bedeutet. Der Nobelpreis für Physik, den Einstein 1921 erhielt, bezog sich vor allem auf die erstere und eine Reihe anschließender Arbeiten ... Von höchstem Interesse wäre selbstverständlich, zu erfahren, wie es in der Gedankenwerkstatt eines solchen Genies zuging. Aber obwohl Einstein niemals den Blick dahinein verwehrte – im Gegensatz zu manchem anderen bedeutenden Gelehrten –, vielmehr in privater Unterhaltung völlig offen erzählte, was ihn gerade bewegte, ist es doch schwer, darüber einen Bericht zu geben. War einer seiner kühnen Gedanken erst einmal ausgereift, so überzeugte er, ja er verblüffte manchmal durch die geniale Einfachheit der Konzeption. Den Weg jedoch, der ihn so weit geführt hatte, anderen völlig verständlich zu machen, blieb wohl auch Einstein selbst versagt. Immerhin lassen sich einige kennzeichnende Züge seiner Ideenwelt aufzeigen. Das Tiefste daran ist seine Religiosität (nicht zu verwechseln mit Kirchlichkeit). Für ihn war die Welt das Werk eines schöpferischen Geistes, der trotz seiner erhabenen Überlegenheit dennoch den Menschen verständlich bleibt, und zwar im Grundsatz vollständig verständlich, wenngleich sich dies Verständnis nur allmählich, in vielen Mühen und schrittweise dem Sterblichen enthüllt, ja ihm restlos nie zuteil wird.

„Wenn ich in den Grübeleien eines langen Lebens eines gelernt habe, so ist es dies, daß wir von einer tieferen Einsicht in die elementaren Vorgänge viel weiter entfernt sind als die meisten unserer Zeitgenossen glauben!"

Aus einem der letzten Briefe Einsteins.

Zweiter Band: ERFORSCHER DES LEBENS (Auswahl)

Medizin im XX. Jahrhundert

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Ferdinand Sauerbruch – Die Entwicklung der Brustchirurgie

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Otto Warburg – Ein „Künstler" der Zellphysiologie

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Anthropologie im XX. Jahrhundert

Pierre Marcellin Boule – Der Erforscher des fossilen Menschen

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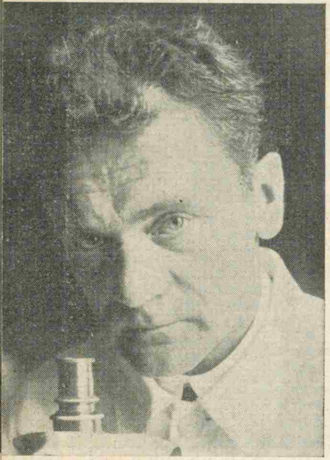
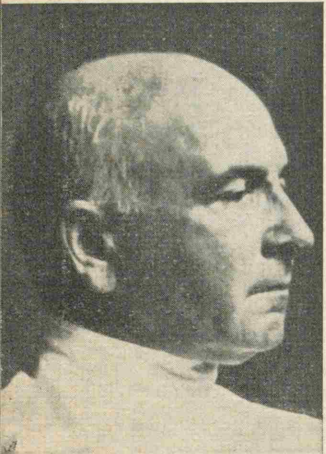
Otto Heinrich Warburg



Karl von Frisch



Alexis Carrel

Leseprobe aus dem Porträt

OTTO HEINRICH WARBURG

Von Dr. Josef Hausen

Wenn ein künftiger Geschichtsschreiber der Medizin seinen Zeitgenossen rückblickend vor Augen führen will, wie die Menschen des Zwanzigsten Jahrhunderts der Krebskrankheit, der letzten großen Seuche, deren sie noch nicht Herr geworden waren, zu Leibe rückten, wie sie sich in Dutzenden von Forschungsinstituten um ihre Ursachen, ihre Diagnose und Therapie mühten, wird er nicht umhin können, abschließend etwa folgendes festzustellen: Nach jahrzehntelangem Forschen und Suchen, nachdem zahlreiche Hypothesen aufgestellt und zahllose Bücher über die Entstehung des Krebses geschrieben worden waren, gelang es Ende 1954 dem deutschen Nobelpreisträger Professor Otto Heinrich Warburg, klar und unzweideutig und mit der Kraft untrüglicher Beweise auszusagen, wie der Krebs entsteht. Damit war eines der bedeutendsten Hemmnisse, das der Vorbeugung dieser heimtückischen Erkrankung im Wege stand – man wußte bis dahin nicht, wovor man einen Menschen schützen mußte, wenn man ihn gegen Krebs schützen wollte – aus dem Wege geräumt. Gegen die Widerstände, die das Verharren in vorgefaßten Meinungen der Ausbreitung neuer Erkenntnisse stets entgegensetzt, wurden die Wege langsam frei für eine planvolle Krebs-Prophylaxe und die Befreiung der Menschheit von einem ihrer ärgsten Feinde.

Der Geschichtsschreiber der Zukunft wird, wenn er korrekt verfahren will, hinzufügen müssen, daß die grundlegende Entdeckung, die Warburg zu seiner These von der Krebsentstehung führte, damals, als er diese erstmalig publizierte, rund drei Jahrzehnte zurücklag. Es war der merkwürdige Befund, daß die krebsig entartete Körperzelle nicht mehr oder nur noch in untergeordnetem Maße atmet, sich ihre Lebensenergie vielmehr auf einem „Ausweichgleis“ des Stoffwechsels beschafft: durch Gärung, das heißt durch Spaltung der ihr als Nahrung zugeführten Zucker ohne Mitwirkung von Sauerstoff (Glykolyse).

Das Reihenwerk „Gestalter unserer Zeit“ erscheint im

GERHARD STALLING VERLAG

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Dieser Prospekt wurde Ihnen
überreicht durch:

SHIPS AHOY!

—The Search for Cosmic Company—

A. Vibert Douglas

Are we alone in the Universe? With our immediate planetary neighbours eliminated by apparent physical conditions, the quest for other abodes of life has spread beyond the confines of our own solar family. What is the probability that other stars may play sun to habitable planets? An astronomer faces this question in the light of developing cosmological theory and observation.

A third of a century has passed since an essay appeared in the *Atlantic* entitled *Other Little Ships.*

First came a word picture:

> "a wide stretch of sea, a vast expanse of sky, a far-off horizon; in the foreground a ship, a small ship tossing upon the ocean billows with great forces playing all around it, and it seems an insignificant thing upon the great broad troubled waters alone—and yet not alone, for over there on the far-away horizon are *other little ships.*"

The metaphor was then developed of the ocean of spacetime and a question was posed:

> "Stately ships are sailing in all directions. No human hand upon the helm directs their courses, an unseen force propels them onward, each ship a star, each star a sun, each sun a glowing ball of gas radiating light and heat in all directions. Look well at the stately ship in the foreground of the picture for about it are circling an attendant fleet of smaller ships, and one of them—a very small ship—is weighted down with a living cargo in myriad forms: flowers and trees, insects, beasts, and *man.* On its prow its name is written—The Earth.
>
> The picture alters as in a dream. We are no longer the fanciful painters upon the canvas of the imagination; we are in the picture, a part of it, and on The Earth we are sailing around our Sun and with it across the ocean of spacetime—from whence we know not, whither we know not. Steered always by an unknown hand, we play no part in the running of our ship, we go where it takes us and we know not why we are on it. We look out across vast spaces and see only other suns and beyond them more suns, and beyond them suns and clusters of suns; and in a moment of oppressive lonelines we cry, 'Are there no other

> little ships? No other little ships like The Earth? Are we alone and unique in the universe of spacetime?' "

The answers to this question were reviewed from the speculations of Laplace a hundred and fifty years ago to the investigations of cosmologists like Chamberlain and Moulton and the more rigorous mathematical analysis of Jeans and Jeffreys which by 1919 had led to the conclusion that the existence of 'other little ships,' of other planets like the Earth was not impossible but highly improbable. Then followed an account of the researches of Eddington and Jeans published in Great Britain in 1924. A greatly increased time scale had been postulated from available evidence, pointing to a million million years for the age of the stellar universe; and the consequence of this was to increase "enormously the chance of solar systems being formed by tidal action . . . planetary systems if not quite the normal accompaniment of a sun, at least fairly freely distributed in space."

And so the essay concluded thus.

> "Are there other little ships? . . . Though you may never dip your flag to a passing ship, nor ever exchange a signal with one far distant, yet you may know that it is highly probable that just over the horizon there are *other little ships.*"

That is where I laid down my pen in 1925, and now I take it up to carry the story through the intervening years.

Twice from the crow's nest of the little ship Earth has come the exciting shout, "Ship ahoy!" Where are these other little ships?—not so far away that we must say with Milton, "distance inexpressible by numbers that have name," but nevertheless so remote that no exchange of signals has been recorded. I shall not anticipate further but briefly review the progress of cosmological thought during these 33 years.

Nothing remains static in the universe of stars, of atoms or of men. Canon Lemaître of Louvain developed the theory of the expanding universe in 1927. This demolished the longer time scale of Sir James Jeans. The evidence at present seems to point to the age of our stellar system being not more than ten thousand million years. But though the time scale is reduced, the hypothesis of an expanding universe implies that stars and galaxies of stars were more closely packed together in the remote past. Hence the probability of the very close approach of two stars was greatly increased and hence, too, the possibility of the

tidal disruption of one by the gravitational attraction of the other. From such a tidal filament of stellar gases the planets were thought to have been formed by condensation and accretion. This continued to be the most favoured theory for many years. In time however the cosmologist became less sure of this than he was a score of years ago. In fact Jeffreys found so many weaknesses in the tidal theory of the origin of the solar system that speculation began running wildly from idea to idea. Imagination went forth, not in William Blake's "uncurbed glory," but in a glory undiminished by the fact that every postulate must be checked with the most rigorous mathematical analysis as to conservation of angular momentum, stability, turbulence, probability.

A satisfactory theory as to the origin of the Solar System is of fundamental importance if we would hazard any estimate as to the likelihood of other stars, some or many of them, possessing similar systems of planetary bodies. By a planetary body is meant a dark mass of matter shining only by reflected light, too small in quantity to maintain its existence through a thousand million years in the hot gaseous condition of a star which radiates heat and light and ultraviolet rays in all directions. Bodies of mass only one tenth to one hundredth of the mass of an ordinary dwarf star will cool by radiation and in due time solidify as dark bodies which are visible only by reflecting the light of their parent star. The planets of the solar system, Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto shine only by reflected sunlight. Their combined mass is less than one seven hundredth of the mass of the Sun.

If the biparental tidal theory is not satisfactory in explaining the existence of planets, what alternatives are there? Men on both sides of the Atlantic Ocean have been speculating and theorizing: Russell, Lyttleton, Hoyle, van Albada have examined the plausible cases of a giant star colliding with one member of a double star system, or of a triple system where two members were close enough that further growth by accretion would result in a coalescence and subsequent catastrophic fission, or a binary system in which one member suffers a supernova outburst and collapse. Lyttleton has pushed his calculations to the rotational instability of a large planetary mass giving rise to two smaller planets.

Discarding a two or three star hypothesis Weizsacker, Edgeworth, Whipple and Kuiper have postulated turbulence and vortices in a disk-like nebula about the Sun, or in a vast nebula of galactic proportions where instability and shear forces might result in the birth of stars and of planets, or on a smaller scale a dust cloud evolving into a solar system—no theory which is only plausible words not backed up by mathematical treatment can carry much weight and all these proposals must be subjected to intensive mathematical scrutiny. The keenest critic is still Sir Harold Jeffreys of Cambridge University and he stated in 1948, "I am not satisfied with any existing theory, but many notable advances have been made in the last twenty years". This opinion he reiterated in 1958 at the conference in Moscow of the International Astronomical Union.

That the most recent studies on planetary origins have moved away from dependence upon a highly improbable chance collision or close approach of two stars is of major interest. "There is no need," wrote K. E. Edgeworth in his 1949 paper to the Royal Astronomical Society, "to invoke some special and improbable coincidence, such as a stellar collision . . . the solar system can properly be regarded as a natural product of normal evolutionary forces." Starting with the postulate that "the material out of which the embryo planets were first formed existed originally in the form of a rotating disk of small solid particles extending beyond the orbit of Neptune," he developed his theme and stated his conclusion with an assurance which has not been justified, but indicated how the winds of thought were blowing.

The progress of science has been due to the fact that theory and observation run hand in hand. One may run somewhat ahead of the other for a time or it may lag behind. Each can stimulate the other, or be a drag upon it. In this matter of planetary bodies, theory has been active for one hundred and fifty years, but observation was confined to the Solar System exclusively until in 1942-43 K. A. Strand pointed to the constellation of Cygnus the Swan, and Reuyl and Holmberg pointed to Ophiuchus the Serpent Bearer—in each of these directions it was thought that a body of planetary size had been discovered. In the metaphoric language of our preface, the astronomers shouted, "Ships ahoy". And yet no eye had seen these two other little ships, no light signal had come from them. The first is still considered a possibility, the second proved to be illusory.

The evidence for their existence was observational but indirect. In 1838 an able German mathematician and astronomer, Bessel, (one of the first three men to measure the distance to a star) announced that 61 Cygni is distant from the Solar System about eleven light years. It is a binary star. 61 Cygni A and 61 Cygni B revolve in orbits about their common centre of gravity in a period of 720 years. Much is known about orbital motion since the days of Kepler and Newton. Observed deviations from a Keplerian orbit imply the existence of a third body whose mass and orbit can be calculated. From the motions of A and B, Strand deduced not only the existence of C but the fact that it revolved about either A or B in 4.9 years and that its mass was only sixteen times that of the planet Jupiter or one sixtieth of the Sun. Too small to be called a star, 61 Cygni C was the first body classified as a planet to be found outside the Solar System.

The second indication of the existence of a planet was based on measurements made on 126 plates taken in the years 1914-42, but so small are the orbital perturbations that the most delicate measurements are required over a longer period. In this case subsequent work has not confirmed the existence of a third body of planetary dimensions.

Might there be life on another planet, vegetation and animal life such as have come into being on the Earth in the course of many millions of years? Terrestial organisms of self-reproducing cells are known to require special chemical and environmental conditions—abundance of carbon and hydrogen, water vapour, and a limited range of temperature being only the most obvious. While the central mystery of life remains a mystery, no logical reason forbids the assumption that living cells will come into being wherever in nature the requisite conditions both chemical and physical exist. In the case of the other members of the Solar System no close approximation to the essential terrestrial conditions is found: too scorchingly hot if near the sun and facing it; too utterly cold if always turned from the sun or in the outer orbits; no atmosphere whatever, or atmospheres almost devoid of oxygen and water vapour but rich in carbon dioxide, or methane, or ammonia as cirrus clouds of crystals hovering over a frozen ocean of solid ice.

Examining the data for the non-solar planet we find that 61 Cygni C revolves about its star in an elongated elliptic orbit which brings it in to about the Sun-Venus distance but carries it far out beyond the Sun-Mars distance. The average distance of this planet from its 'sun' is therefore much greater than the Sun-Earth distance. Both for this reason and because its star is much cooler and less luminous than the Sun, the temperatures may be too low to be conducive to life even if the other conditions were favourable.

This is a tentative solution of the problem which the observational data poses, but further data and possible alternative solutions must be studied before these deductions could be considered as substantiated. They illustrate, however, the alertness of the men on watch as they scan the skies for any evidence of planets other than our neighbours in the Solar System.

At the symposium in Mosow on solar and non-solar planets, perhaps the most interesting contribution to a spirited discussion was that of Professor Fred Hoyle of the University of Cambridge. His hopes are not pinned on any theories of condensation in a dust cloud of protoplanets captured by the Sun, as propounded by Professor Kuiper. Hoyle considers that as our Sun condensed from perhaps one hundred times its present size, some of its gaseous substance streamed out from its equatorial region to distances of its present planetary system. With the aid of the solar magnetic field now known to exist in space this matter, about one tenth of one percent of the Sun's mass, would carry off the large proportion of angular momentum now associated with the planets, leaving the Sun rotating slowly about its axis. The elements of highest boiling point would condense nearest to the Sun, forming the inner planets largely of rocky and metallic material but since not more than 0.1% of the Sun's gases is composed of heavy elements these inner planets are less massive than the outer planets. The latter are largely composed of the light elements, hydrogen, carbon, nitrogen, oxygen, all elements of low boiling point and hence moving far out from the Sun before condensation on a large scale could take place. Professor Urey pointed out one difficulty in this theory, namely the presence of mercury in meteors when by the physical properties of this element one would expect it to have streamed out in the Solar System as far as Jupiter before being trapped. But on the whole he favoured Hoyle's theory.

Obviously this theory is applicable to stars in general, and if one pauses to consider that the galaxy of which our Sun is one humble member contains some hundred thousand million stars, and that there are possibly a hundred million such galaxies within reach of our powerful telescopes, the conclusion is justified that many planetary systems may exist whether the number in any one galaxy be large or small. Amongst all these some few here and there in this galaxy and in the others may happen to provide those very conditions of environment in which living cells may develop as they have developed on the Earth.

In recent years many theories have come and gone and of no currently advocated theory can it be said that it will probably provide the final and complete solution. However no currently advocated theory would make our Solar System unique, and we may therefore hope that in the not too distant future the astronomers on watch in the crow's nest of *The Earth* may be heard to raise their voices with a certainty hitherto impossible and shout "Ships ahoy".

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SIR ARTHUR EDDINGTON, O.M.

BY

A. VIBERT DOUGLAS

① To Q.S.S. Grant Hall 1945 Aug. 12.

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SIR ARTHUR EDDINGTON, O.M.

A. Vibert Douglas

WITH the death of Sir Arthur Stanley Eddington in Cambridge on November 21, 1944, a very great man has passed through the portals into the unseen world.

Born in Kendal in 1882, he was the son of the Headmaster of Stramongate School. From Owens College, that famous training ground of potential scholars, he proceeded to Cambridge. Here he trod the courts and corridors where the spirit of Newton lingers, where brilliant mathematicians had been or were making advances in pure mathematics and in its applications to physical problems and to astronomy—Airy, Cayley, Stokes, John Couch Adams, Larmor, J. J. Thomson, George Darwin. In 1904 he won the distinction of Senior Wrangler and in 1907 became Smith's Prizeman and Fellow of Trinity.

As Chief Assistant at Greenwich Observatory from about that time until 1913, Eddington rose to prominence with his investigations of stellar movements and the structure of the universe, which formed the subject matter and title of his first book, published in 1914. In this year he was made a Fellow of the Royal Society, and in the previous year, at the age of thirty, he was elected Plumian Professor of Astronomy in the University of Cambridge. This chair and the directorship of the Observatory he held with steadily increasing honour and international recognition to the end of his life.

In memory I see him in his classroom off Bene't Street. From my seat beneath the tablet to Cayley and Stokes, I watch a master-mind at work. A slight man of average height, in academic gown, reserved almost to the point of shyness, he rarely looks at his class. His keen eyes look at or through the side wall as he half turns from the blackboard and seems to think aloud the significance of the tensors which he has just written on the board. The mathematical theory of relativity is developed *ab initio* before our eyes and the symbols are made to live and take on meaning. I see his face in profile and hear his low voice as he says as though in soliloquy: "The real three-dimensional world is obsolete, and must be replaced by the four-dimensional space-time with non-Euclidean properties . . . . But the four-dimensional world is no mere illustration; it is the real world of physics, arrived at in the recognized way by which physics has always (rightly or wrongly) sought for reality." One must remember that this was 1922. Einstein's general theory had only been known in England for some five years and very few had the mathematical knowledge to read it; de Sitter's and Weyl's contributions were as yet scarcely understood; and Eddington's *Report on the Relativity Theory of Gravitation* for the Physical Society of London and his less mathematical *Space, Time and Gravitation* were not two years old. The thrill of seeing physical science on the march in a new direction, the sense of something stirring, of new adventure, held us tensely expectant even though we might but half comprehend it; and before us slowly, deliberately, quietly, alternately thinking aloud in symbols and in words, was one of the few men, one of perhaps a dozen men, who at that time had the insight and vision to see whither it was leading.

The scene changes to the Cavendish Laboratory where Sir Ernest Rutherford is presiding at a meeting of the Cavendish Society and Professor Eddington is the speaker. In his usual quiet, reasoned, restrained manner he has given an exposition of his recent theoretical work on electron capture in giant stars. Again one must remember that this is 1922 and physicists are not very familiar with the behaviour of matter at temperatures ranging from 3000°C. to several million degrees, nor with the opacity resulting from extremely high ionization. Questions are put to the speaker like rapid rapier thrusts, and quietly parried. Then Rutherford rises with lust for battle in his eyes and as with a mighty broadsword delivers what he obviously thinks is a final deadly blow. Fire suddenly springs into Eddington's eyes, and steel meets steel with sparks flying. Criticisms based on a physicist's discharge tubes are shown to be inapplicable as applied to the stellar conditions. The attacker becomes the attacked and retires from the fray.

Another scene is a meeting of the Royal Astronomical Society at Burlington House when, as President, he presented the gold medal of the society to James Hopwood Jeans and outlined with brilliant competence the scientific achievements of the medallist. Referring to the series of papers on problems of stellar constitution in which he and Jeans had hurled mathematical missiles at one another over a period of several years, he paused to remark that "the onlooker will perhaps conclude that *someone* was badly annihilated, but it is possible that Jeans and I may still have a difference of opinion—as to precisely whose corpse lies stricken on the field."

Few men of science have a record of achievement comparable to that of Eddington. For twenty years he has stood pre-eminent amongst the astronomers of the world. His papers on stellar structure led him into many fields. Fundamental was his recognition of the part played by radiation pressure, which with gravitational attraction and gas pressure account for the stability of stars and their limited range in the mass. This led to papers on the deep interiors of stars, calculation of central temperatures, of sources of energy, of atomic and electronic states, of pressures and densities, of variable stars and Cepheid pulsation, of stellar diameters, of masses and luminosities, of the densities and gaseous nature of white dwarf stars, of diffuse inter-stellar gases and the rotation of the galaxy. Who that was following astrophysics in those years will ever forget the excitement produced by his paper of March, 1924 on the mass-luminosity relation, and the papers which it evoked from J. H. Jeans in the November following

and from R. H. Fowler about two years later, this last showing how the statistical mechanics of a degenerate gas was applicable to the white dwarfs. Much of this work of Sir Arthur's has proved the starting point of research by scientists of many nations. It was in due course brought together in his *Internal Constitution of the Stars*, and the subsequent Bakerian and Halley Lectures. Many later papers have carried these researches farther.

Epoch-making, in more ways than one, were the verifications of some of Eddington's predictions. With Michelson's stellar interferometer attached to the 100-inch reflector at Mount Wilson Observatory, Pease in 1920 found the angular diameters of giant red stars to be in good agreement with Eddington's calculations. In 1925 W. S. Adams succeeded in measuring the red shift in the spectrum lines of the white dwarf companion of Sirius, thus verifying both the Einstein relativity theory and Eddington's theoretical calculation of the immense density of stars of this class.

Eddington has been the outstanding exponent in the English language of the relativity theory. It was he who first interpreted the ideas of Einstein, de Sitter, and Weyl. It was he who realized the importance of testing Einstein's theory on its prediction that rays of light passing close to a body like the sun would be deflected in the gravitational field, and that this might be accomplished during the total solar eclipse of May 29, 1919. Notwithstanding the war, plans were pushed ahead, and when the eventful day arrived, even though the Treaty of Versailles had not yet been signed, two British expeditions were in readiness to take the crucial photographs, and Eddington at Principe Island and Crommelin at Sobral obtained the plates which gave a first measure of confirmation to the new theory. It was Eddington who interpreted Lemaître to the English-speaking world, and for fifteen years he has upheld the theory of an expanding universe, modifying the original approach of Lemaître by starting from an "Einstein universe." The goal of his endeavours has been the formulation of a theory combining both relativity and quantum theories. During the last few years he has published several papers attempting to make this very synthesis—how successfully cannot be said until the few mathematicians competent to judge have examined it in every detail. Its consequences upon the time scale of the universe are to lengthen the "age" beyond that of recent theories. This was the subject of his last contribution to the Royal Astronomical Society.

My thoughts go to a conversation with Dr. de Sitter in 1931 when I asked him the result of a controversy between himself and Sir Arthur over the effect of space expansion upon our own galaxy. Eddington had maintained that the dimensions of the galaxy would be unaltered; de Sitter had eventually been obliged to agree; and he said to me, shaking his patriarchal head ruefully: "Eddington was right. Eddington is always right." Not everyone has thought this in regard to his most speculative and debatable researches, those on the theoretical determination of cosmological and physical constants.

The number 137 will awaken in the minds of many, memories of a kindled interest, of perplexity, doubt, expectation, and perhaps of moments of great thrill, when thinking back over the last fifteen years. The name of Eddington stands central in these memories. This has been his playground pre-eminently. Some of us have stood fascinated at the edge of the field watching this illusive game played patiently, skillfully, brilliantly by one man, a master juggler with the elements of the theory of groups, with quantum mechanics, and with the basic units of measurement. Some there have been who paused to watch briefly, to smile or even ridicule the Aristotelian *tour de force*. But steadily and doggedly the theory has been pushed forward, until now the evidence seems overwhelming that, with no observational data other than three basic constants, namely, the velocity of light and the Rydberg and Faraday constants for hydrogen, it is possible to calculate theoretically the following thirteen physical constants: charge e; Planck's constant; masses of electron, proton, hydrogen atom; gravitation constant; fine structure constant; nuclear range-constant; nuclear energy-constant; mass of universe; number of particles in universe; Einstein radius of space; galactic recession constant. This is a startling achievement because of its philosophical implications. In his book *Relativity Theory of Protons and Electrons* the foundations of this theory are set forth, and in *The Philosophy of Physical Science* he investigated the epistemological significance of his approach. Let us hear his own account of the factors which influenced him. "A slight reddening of the light of distant galaxies, an adventure of the mathematical imagination in spherical space, reflections on the underlying principles implied in all measurements, nature's curious choice of certain numbers such as 137 in her scheme—these and many other scraps have come together and formed a vision." With humour and apt literary allusion so typical of his writing, he adds "a most rare vision . . . Bottom's dream."

Equating a function of the number of independent wave systems in the universe to the ratio of electrical to gravitational forces between electron and proton, he arbitrarily (and should we say, intuitively) bridged the gap between atomic and relativity theory. Recognizing that two indistinguishable electrically charged particles have 137 degrees of freedom, he understood how this number comes to be imbedded in nature. The apparent arbitrariness of some of the constants of nature has vanished—their values are what they are by logical necessity.

Dingle has been a consistent opponent of Eddington's Aristotelianism as found in these researches. In reviewing Born's recent book, *Experiment and Theory in Physics*, Dingle says, "Like others, Professor Born has not succeeded in understanding the essential parts of Eddington's theory connecting the constants of quantum theory with those of cosmology. That is not to say that there is nothing of great value in the theory. His final comment is perhaps the wisest that has yet been made on this subject: 'I am far from attacking Eddington's theories or from doubting his results. If they should turn out to be right I shall rejoice. But I shall not attribute this (possible) success to Eddington's philosophy, as a doctrine which could be followed by others, but to his personal genius and intuition.' " The world may have to wait a long time for another man with "personal genius and intuition" comparable to Sir Arthur's. When it is fully understood, this entire investigation may yet be ranked as one of the great adventures of the human mind.

Eddington's excursions into philosophy and metaphysics are to be found mainly in three books. *The Nature of the Physical World* (1928) comprises his Gifford Lectures of the previous year; *New Pathways of Science* contains the Messenger Lectures delivered at Cornell in 1934; and *The Philosophy of Physical Science* arose from the Tarner Lectures in Cambridge in 1938. These books are a source of sheer delight to readers trained in the mathematical sciences. To many who have only a very meagre knowledge in these fields, large parts of each book can be enjoyed with profit. To philosophers in general they are illuminating and provocative; and to a few stern logicians for whom a strict and narrow use of words is the beginning and end of wisdom, they are a source of severe irritation. Much of the writing is brilliant exposition. With the aid of simile and metaphor, and oft-times pungent wit (all of which inevitably lay one open to a flank attack by solemn logicians), many of the most abstruse mathematical subjects are put in words so that the layman can at least get some idea of the way science is going—relativity, quantum theory, probability, wave mechanics, indeterminism. He develops his philosophy of physical science, regarding the result as partaking of the nature of both selective subjectivism and structuralism, and then proceeds to "a general philosophical outlook which a scientist can accept without inconsistency."

He is Platonic in his insistence upon the intrinsic part played by mind in the picture of the universe which man constructs for himself. He stresses the purely symbolic character of the world built up by the measurements of the physicists and astronomers. The underlying reality is untouched by these methods of approach. His own world-building, as also that of Einstein, de Sitter, Weyl, or Lemaître, is to be thought of as map-making, a partial representation only. "Symbolic" knowledge, the result of physical measurements, can be put into this map, but "intimate" knowledge, the essential contribution of the mind, cannot be introduced. "Realization that physical knowledge is concerned only with structure points the way by which the conception of man as an element in a moral and spiritual order can be dovetailed into the conception of man as the plaything of the forces of the material world."

see NPS
pp 311
317

A member of the Society of Friends with sincere mystical insight, Eddington lays great stress on recognition of the unseen world. His approach is through intimate knowledge:

> The desire for truth, . . . the reaching out of the spirit from its isolation to something beyond, a response to beauty in nature and art, an Inner Light of conviction and guidance

> —are these as much a part of our being as our sensitivity to sense-impressions? . . . Who does not prize these moments that reveal to us the poetry of existence? . . . We do not ask whether philosophy can justify such an outlook . . . rather our system of philosophy is itself on trial; it must stand or fall according as it is broad enough to find room for this experience as an element of life. The sense of values within us recognizes that this is a test to be passed; it is as essential that our philosophy should survive this test as that it should survive the experimental tests supplied by science . . . . We all know that there are regions of the human spirit untrammelled by the world of physics. . . . There are some to whom the sense of a divine presence irradiating the soul is one of the most obvious things of experience.

Eddington was very careful never to lend support to a rather widespread proclivity on the part of too many religious teachers to grasp some bit of scientific knowledge and distort it into evidence for faith in spiritual values and beliefs. Weyl has written: "Modern Science, in so far as I am familiar with it through my own scientific work, mathematics and physics [and cosmology], makes the world appear more and more an open one, as a world not closed but pointing beyond itself . . . science can do no more than show us this open horizon . . . ." Eddington, in one of his writings, quotes this passage and endorses it thus: "He who views mysticism from the standpoint of scientific philosophy may be compared to a man looking down on a city from a height. . . . It is something that from the present peak of science, the clouds have so far rolled away that we seem able to make out the site of the city . . . . But the domain thus revealed ought to be known from within. To join in this knowledge we must surrender our scientific vantage point, and enter the way by which man has from the earliest times entered into the things of the spirit."

In the closing section of his last book, *The Philosophy of Physical Science*, we find these sentences: "Even in science we realize that knowledge is not the only thing that counts. We allow ourselves to speak of the spirit of science. Deeper than any 'form of thought' is a faith that creative activity signifies more than the thing it creates . . . . In the age of reason, faith yet remains supreme; for reason is one of the articles of faith. . . . A scientist should recognize in his philosophy—as he already recognizes in his propaganda—that for the ultimate justification of his activity it is necessary to look away from the knowledge itself, to a striving in man's nature, not to be justified of science or reason, for it is itself the justification of science, of reason, of art, of conduct."

Eddington was essentially a man of happy nature, fond of sports, of his pipe and fireside, and of his associations with astronomers and other scientists the world over. In a letter from Cambridge written in December, 1943 he says, "We get on pretty well here though things are a bit difficult in various ways. One misses very much the stimulus of research students." His powerful, restless mind found satisfaction not only in the results but in the actual struggle of hard thinking. In his Swarthmore Lecture he had said: "You will understand the true spirit neither of science nor of religion unless seeking is placed in the forefront."

The happiness which he derived from his work was both intellectual and aesthetic. In his last book he contrasts the Pythagorean arithmetic of counting with the assignment of numbers to systems where the process of counting is logically ruled out, and of this latter he says: "it is impossible not to admire the devastating beauty of quantum arithmetic." These words remind one of an astronomer of three hundred years earlier, John Kepler, for whom Tycho Brahe's records of planetary observations had "the fragrance of ambrosia." These are the reactions of great rounded characters: no cold materialistic philosophy will explain the divine fire. "Verily it is by Beauty that we come at Wisdom, yet not by Reason at Beauty."

Sir Arthur Eddington took the universe from atoms to stellar galaxies and likewise the world unseen save by "the eye of the soul" as his hunting grounds, and therein imagination and reason went forth in uncurbed glory. Now this giant among thinking men, "the gentle knight," has gone forth upon a new adventure. "They that be wise shall shine as the firmament of heaven and . . . as the stars for ever and ever."

Truth is a diamond of many facets, darting now one ray, now another, into our lives.

Renan: No passing vision exhausts divinity.

Eddington was a great seeker after the truth —
an inspired + inspiring explorer in two worlds.

Cum illo sint animae nostrae.

Superb math powers –
the universe his lab, the stars his crucibles.
penetrating insight into physical problems
spin the gossamers & forge the anchors of the mind –
Imagination goes forth in uncurbed glory –
endowing astrophys. researches with splendid beauty –

Stellar motions
" Structure
Relativity –
Synthesis of rel & quantum thy –

Philosophy
Measurable & immeasurable.

An Explorer in Two Worlds

Roy. Astr. Soc. Can. Kingston Centre
1979 Apr. 19.

1. June sky N.
2. Dec " N
3. Feb " N
4. Mar " N
5. Proper Motions – plough ± 200 000 yrs Ed Halley 1718
Sirius Aldebaran & Arcturus cf Ptolemy's position.
6. May sky S ~ Antares –
7. July sky S – milky way – Ophiuchus
8. Gt. star cloud in Ophi (~~Yerkes~~) ~~[illegible]~~ 3½ hr exp.
9. Aug. sky S.
10. Gt star clouds in Sag. – dark obscuring matter
& Centre of Galaxy . . 25,000 l.y. ++

– Betelgeuse &c.

naked eye star – Jup. & Comet 1905 III

path in proper motion Bessel 1844 –
P = 49.3 years (1922

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    + Centre of Galaxy . . . 25,000 l.y. + +
11. Dec sky S - Aldebaran - Betelgeuse &c.
12. Jan Sky S - Gemini
13. Gemini region - 5 naked eye stars - Jup. + Comet 1905 III
14. Feb. sky S - Sirius
15. Motion of Sirius - sinuous path in proper motion Bessel 1844-
16. App. orbit of Sirius B. P = 49.3 years (1922
17. 25 nearest stars.
18. The Balances - atom man star.

An Explorer in Two Worlds -

A very great man, an adventurer in ideas an explorer in two worlds died in Cambridge last November 1944 a great man of science, one of the greatest explorers into the secrets of the physical world from atoms to stars & stellar galaxies and also a man who thought & felt deeply about & looked penetratingly into the significance of the things of the spirit.

Arthur Stanley Eddington b. 1882 Kendall
Stramongate School
Dr Alan Brockington - teacher
Owens College
Cambridge Greenwich
Plumian Professor 1913 - 1944.

W M Smart: Equipped with superb mathematical powers & with an invaluable training in practical astronomy. E's outlook on science was primarily & fundamentally that of the physicist — the universe was his laboratory and the stars his crucibles.

Stellar motions, stellar structure, radiative equilibrium, internal temperatures, densities mass & luminosity of a star, diffuse gases in interstellar space -

Harlow Shapley: During the last 20 years E. was the greatest living astronomer

Andrade: The grappling of a master mind with problems of the most fundamental nature - E. was one of the great figures in British science . . . [but] the man was even greater than his work

Superb math powers

the universe his lab, the stars his crucibles,

penetrating insight into physical problems

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The Astronomer Royal: He was a master & a genius, always ready to help & encourage - in the words of Chaucer "a verray parfit gentle knight"

E A Milne: 2 brought [all his research work to life, endowing it with aspects of splendid beauty. He was a leader whose writings have been an inspiration, a dear friend to and encourager of all that was gentle and wise and witty and satisfying in the sciences of which he was a devoted servant.

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13. Gemini region - 5 naked eye stars - Jup. + Comet 1905 III
14. Feb. sky S - Sirius
15. motion of Sirius - sinuous path in proper motion Bessel 1844 -
16. App. Orbit of Sirius B. P = 49.3 years (1922
17. 25 ~~nearest stars~~.
18. The Balances - atom man star.

S + U.W. p. 24

In comparing the certainty of things spiritual + things temporal let us not forget this -
Mind is the first + most direct thing in our experience; all

PPS. preface + end.
+ p. 171. (NO)?

The Domain of Physical Science - p. 217 ±
p. 189 - 190, 191.

Truth is a diamond of many facets, darting now one ray, now another into our lives.

"The specialized property of measurability of the external world." p. 203.

"The division of the ... world into a material and a spiritual world is superficial the deep line of cleavage is between the metrical and the non-metrical aspects of the world.

superb math powers
the universe his lab the sta
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Stella
"
Rela
Sym
Phil

Roy. Astr. Soc. Can. Kingston Centre
1979 Apr. 19.

1. June sky N.
2 Dec " N
3 Feb " N
4 Mar " N
5 Proper Motions - plough ± 200 000 yrs Ed Halley 1718
{ Sirius Aldebaran + Arcturus of Ptolemy's position.
6 May sky S - Antares -
7 ~~June~~ sky S - milky way - Ophiuchus
8 Gt. star cloud in Ophi (~~Yerkes~~) [illegible] 3½ hr exp.
9 Aug. sky S.
10 Gt star clouds in Sag. . dark obscuring matter
+ Centre of Galaxy . . . 25,000 l.y. ++
11 Dec sky S - Aldebaran - Betelgeuse etc.
12 Jan sky S - Gemini
13 Gemini re
14 Feb. sky S
15 motion of S
16 App. orbit (1922
17 25 nearest
18 The Balances - atom man star.

The Encyclopia of Ignorace

An Explorer in two Worlds -

A very great man, an adventurer in ideas
an explorer in two worlds died in Cambridge
last November 1944 a great man of science, one
of the greatest explorers into the secrets of the
physical world from atoms to stars + stellar
galaxies, and also a man who thought + felt
deeply about + looked penetratingly into the significance
of the things of the spirit.

Arthur Stanley Eddington b. 1882 Kendall
St ate School
teacher

mus
1913 - 1944.

equipped with superb mathematical
powers + with an invaluable training in practical
astronomy. E's outlook on science was
primarily + fundamentally that of the
physicist — the universe was his laboratory
and the stars his crucibles.

Stellar motions, stellar structure, radiative
equilibrium, internal temperatures, densities
mass luminosity of a star, diffuse
gases in interstellar space.

Harlow Shapley: During the last 20 years E. was
the greatest living astronomer

Andrade: The grappling of a master
mind with problems of the most fundamental
nature - E. was one of the great figures
in British science . . . [but] the man was
ever greater than his work

SIR OLIVER LODGE

BY

A. VIBERT DOUGLAS

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Vol. XII, No. 1, October, 1942

SIR OLIVER LODGE

A. Vibert Douglas

IT is not always easy to appraise the influence of a man of science who has achieved eminence in his chosen field. To do so becomes an almost impossible task when the scientist lays science aside as his major interest and turns to the realm of psychic phenomena. Thereafter many scientists look upon him with a feeling of distrust, the average man is incredulous and makes disparaging comments, while people least qualified to judge of the value and significance of psychic research are loudest in their scorn and ridicule. A scientific reputation built up by long years of arduous labour and genuine achievement can suffer almost complete eclipse in this way. Only a relatively few sober scholars will not be misled: they will judge the scientific work at its true worth, undisturbed by the subsequent or overlapping activities of the same man in the psychic field. They will acknowledge his greatness even though they may have little or no sympathy with investigation into occult phenomena.

Among other names, those of Emanuel Swedenborg, William Crooks and Oliver Lodge come to mind in this connection. How far has the scientific reputation of each suffered because his name is associated in the general mind with visions and revelations, with mediums and seances? It is the influence of Lodge that particularly interests me. I have heard some of the greatest scientists in the University of Cambridge laugh at his preoccupation with psychic phenomena and deride Raymond's heavenly cigars, yet acknowledge the greatness of Lodge the physicist. I have heard many people who have never read *Raymond*, scoff at it as nonsense, and not one of them when asked about the legitimate scientific work of its author, even knew that he was an experimental physicist by training and the leading pioneer worker in wireless telegraphy.

I have never read *Raymond* myself (being one of those who find problems enough in the physical world), and I am no judge whatever of the value of his contributions in that sphere of thought and experience. But if Lodge the spiritualist has had no marked influence upon me, Lodge the man, and Lodge the man of science, have influenced me considerably. It is for this reason that I have attempted to recapture events of the past in order to present for any who may read what are apparently little known aspects of this remarkable man.

Twenty-seven years ago an undergraduate paused to look at the titles of the books displayed in a shop window. *Man and the Universe* by Sir Oliver Lodge—what a title! And the name of the author was a name to conjure with, because the student knew in a vague way that this was the principal of a university, a physicist and an educationalist, an active member of the Society for Psychical Research, knighted while he was its president. The small book, one of an English shilling series, was purchased and carried away with a feeling of high expectancy and proud possession. Delving into Section I, entitled "Science and Faith," of which Chapter I was headed "The Outstanding Controversy," the undergraduate was enthralled by the challenge with which contradictory points of view were set forth and the unflinching courage of the man who in those pages was seeking for the truth. Picking up a pencil, the student marked certain passages; and then and there some of the ideas of Sir Oliver Lodge made a lasting impression upon the mind of one of his readers.

Today I hold in my hand this little volume and re-read some of the marked passages:

> This is the standing controversy. . . . Is the world controlled by a living Person, accessible to prayer, influenced by love, able and willing to foresee, to intervene, to guide, and wistfully to lead without compulsion spirits that are in some sort akin to Himself?
>
> Or is the world a self-generated, self-controlling machine, complete and fully organized for movement, either up or down, for progress or degeneration, according to the chances of heredity and the influence of environment? . . .
>
> Do we live in a universe permeated with life and mind: life and mind independent of matter and unlimited in individual duration? Or is life limited, in space to the surface of planetary masses, and in time to the duration of the material envelope essential to its manifestation? . . .
>
> We are rising to the conviction that we are a part of nature and so a part of God; that the whole creation . . . is working together towards some great end; and that now, after ages of development, we have at length become conscious portions of the great scheme and can cooperate in it with knowledge and with joy.

My thoughts go back along the years to the first time I read these passages, and then forward again ten years to Cambridge on a Sunday in February, 1923. Between King's Parade and the Market Place, is the historic gray church of St Edward the King, a church of royal foundation, independent of the bishop of the diocese and therefore free to invite whom it will to occupy its pulpit.

Here it was that I first saw and heard Sir Oliver Lodge. And what a man he was—like a commanding prophet of Israel he stood in the pulpit, tall far beyond the average, magnificent in frame, massive head, white hair and beard. From the text "I and the Father are one; . . . the Father is greater than I," out of what he termed "the central chapter of the New Testament," he preached a sermon of stimulating interest and spiritual depth.

The following Monday night was as wild and wet, as dark and dank, as a winter night in the fenland can be. A large college hall was crowded with students. The chairman, Sir Ernest Rutherford, and the Electrical Club's guest speaker, Sir Oliver Lodge, were on the platform. A brief introduction over, Sir Oliver rose to speak on the subject, "The Foundations of Wireless." He told of the vision opened before the minds of physicists by the mathematical work of James Clerk Maxwell in his electromagnetic theory. He himself was fired with the ambition to produce and to detect an electromagnetic radiation of wave length so great that it could be used for signalling. He stirred up the enthusiasm of scientific men at every meeting where they gathered together, notably at the British Association. Men in Great Britain, Ireland, France, Italy and Germany were becoming interested. He himself was at that time a hard-working schoolmaster, his laboratory a shed, his equipment meagre. He described his apparatus and experiments, and paid his tribute to Hertz, who was the man to succeed first among so many other experimenters who were working towards the same end. He then discussed the stages by which these first successes were followed up by one modification after another until the genius of Marconi achieved transatlantic wireless telegraphy.

At the close of the address Sir Ernest Rutherford arose and paid a glowing tribute to Oliver Lodge, the man of science, a great teacher and a research physicist who had pioneered in an untrodden region. He called it one of the chance tricks of fortune that it was Hertz rather than Lodge to whom had fallen the honour of first producing and detecting radio waves. Sir Oliver acknowledged the chairman's words and the storm of applause that had followed them, and then, compelled by some inner urge, he spoke of those things which, in his later years, were closest to his heart. It was a small and perfect gem of a sermon to natural philosophers: with the analogy of the spectrum providing a continuity in the relationships of all the diverse radiations, he confidently hoped that there would be achieved a linking up of man's experiences in the realms of fact and of faith, a continuity of knowledge in the realms of the physical, the psychical, and the spiritual.

A year later Sir Oliver happened to read an article in *Discovery*[1] dealing with a recent investigation by Dr L. Silberstein on the cosmological constant, *R*, the radius of curvature of space time. He wrote to the author a letter which lies before me now. He was then seventy-three years of age and for about twenty years his main line of research had been no longer physics but psychical phenomena; yet his lively appreciation of strictly physical science is obvious in these pages, though his outlook as a physicist had not gone much beyond the Kelvin epoch. The letter is reproduced almost in full because of the light it throws upon the man who wrote it. It is written from Normanton House, Lake, Salisbury, and is dated October 13, 1924:

> I too have been much interested in the new estimate of R, and cannot refrain from thinking that it is much too small. But what interests me is not its magnitude, but the method of arriving at it, and the idea that it has possibly, not only a real, but a calculable existence. I need hardly say that even as to its reality I feel doubtful: it still has to make good its claim. I had seen some correspondence in NATURE about it; but it was your Article in DISCOVERY which caused me to give more special attention to that correspondence, and to the Papers in the PHIL. MAG. So that ultimately I wrote to S. about it, and have recently received quite an interesting reply. He sticks to his guns, and awaits further astronomical data for confirmation.
>
> These Relativity changes in time, apart from any gravitational cause, are very curious: and it is difficult to discriminate between Appearance and Reality. So far as our experiments and observations are concerned, appearance is what we have to deal with: but philosophically we must deal with reality, if we can.
>
> I don't exactly envy, but I congratulate, you young Physicists on the prospect before you. Physics has entered on a difficult but very interesting stage. And what the outcome may be, no one, I suppose, is as yet able to predict. The mathematical physicists who are now active are very brilliant: and though they indulge in speculations alien to the old school of dynamics, and though I expect Lord Kelvin would have been severely critical and perhaps contemptuous about their work, I cannot but feel a strong interest in it, and wish that I had the time and opportunity to go into these new matters more fully.
>
> Meanwhile my business is to cling to the Ether as a sheet-anchor, and to urge the younger men to try to work out the dynamics of the Ether. I have been writing to Horace Lamb about it; not that he is a younger man, but because I conjecture that some day a glorified hydrodynamics will solve the problem, and that meanwhile efforts in that direction constitute a seed-plot containing within itself the promise of future fruit.

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[1] "Measuring the Universe" (*Discovery*, LVII, Sept., 1924).

Six years later, when only a few months short of his eightieth year, Sir Oliver was still keenly following advances in astrophysics and cosmology. He wrote to the author again, this time listing the topics which had particularly interested him in a current magazine article[2]—"several remarkable doctrines, the scattered matter throughout space, the rotation of the galaxy, the question of an Ether, the finiteness of the Universe, and the still more difficult notion of the expanding Universe."

Since the outbreak of war, at the age of eighty-nine years, Sir Oliver Lodge went forth upon the new adventure to which it was his firm belief that death is the portal. It was with a deep sadness that I read the Canadian Press cablegram from London. It stated that the misuse and abuse of scientific discovery whereby death, destruction and agony have stalked the earth, the sea and the air, as never before, had so oppressed the spirit of the aged scientist that four years ago he had said "we know things that we should never have known—things of the devil . . . ," and he had felt that further scientific research should cease until man had learned wisdom in using what is already known. This is the attitude of an old, tired workman, whose tools are now laid by, whose strength is almost gone, who sees what he has helped to fashion put to utterly wrong uses—and himself without the energy to rise up and attack the evil forces around him. W. B. Yeats spoke very truly in lines written when he too was scanning the world anguished and torn once more by the brutal folly of fiendish men:

All things fall and are built again
And they who build them again are gay.

But Oliver Lodge had lived his life; he was old; rebuilding the world was not for him, and faith in the ability of anyone to rebuild it was at low ebb—he could not be gay.

A far happier picture, an inspiring picture, and a later one, is given by an associate and friend of many years, who obviously understood him and holds his memory in admiration and affection. This picture is drawn by the sure and sympathetic pen of the Editor of the *Hibbert Journal*. He quotes the very passage which I had marked twenty-seven years ago and which is set forth near the beginning of this article—but Dr L. P. Jacks knew, as I did not, that it had originally appeared in 1902, in the first issue of the *Hibbert Journal*.

---

[2] "Between the Stars" (*Atlantic Monthly*, Jan., 1931).

The opinion of the late Lord Rutherford is corroborated: "Before all else and to the end of his life Lodge was a man of science" and "temperamentally a seeker for positive proof." Lodge investigated psychic evidence for the survival of human personality with earnestness and patience, convincing himself finally that this was "a scientifically attested fact." But it was more than this, it was a basic belief, that found utterance in his remark when drawing towards the close of his life, "I shall soon be going upstairs." Phrases that are used by Dr Jacks in describing Lodge round out the portrait: "the greatness of his heart . . . , the elemental simplicity of his character . . . , strength that is made stronger by gentleness . . . , a playfulness, a gaiety, a warmth of affection, . . . at home, even in old age, among the dances and delights of the young." Finally there is this testimony: "In my last conversations with him I found him closely attentive to the course of events in these great and terrible days, but inwardly serene. The last phase had the quality of an unclouded sunset . . . his figure was that of an ancient prophet illumined by an inner radiance . . . ." And Dr Jacks closes his tribute with the words *Sit mea anima cum illo.*

Inwardly serene—even though enemy bombs were falling upon the cities, towns and countryside, and around his own home. The questioning, the despair, and the hopelessness of four years earlier were gone, and faith in the ultimate upward trend of mankind had reasserted itself. The conquests of science may be abused, but the search for truth must not—and cannot by man's very nature—be discontinued. And so the old man could look out upon the conflict, dream his dreams, and remain inwardly serene, content to leave to the younger men the task of fighting to translate his dreams and their visions into realities.

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SOME PROBLEMS IN EDUCATION

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There are many problems in education which are common to both the U. S. A. and Canada. Both countries need more teachers; both countries are endeavouring to attract the best young men and women into the educational field; both countries are experimenting in methods of teacher training as well as in schoolroom procedure and curricula; and both countries have a tremendous up-hill task in attempting to overcome some of the detrimental influences which surround our young people.

Upon two or three of these, I shall comment briefly, and I shall begin with the last: One of the bad influences working against education is the abuse of the radio in so very many homes, where it is turned on and kept going continuously, a blare of noise and sentiment intermingling with some good programmes, news, and the ever-interrupting advertisements, forming the background against which too many young people are growing up, eating, talking, studying. Silence, so necessary to rest the nervous system, is seldom experienced and the nervous craving for a background of sound, any kind of sound, makes silence unwelcome. Is this one reason why mental and emotional instability are increasing, and our mental hospitals crowded with neurasthenics? Our young people need to learn the joy and peacefulness of silence, of quiet, yes, even of solitude. They need to ponder over and gradually comprehend the full meaning of Byron's words,—"In solitude when I am least alone."

Another deplorable influence is to be found in the omnipresent comic strip. Thousands upon thousands of children throughout the length and breadth of our two countries go down upon all fours, six days a week, if not seven, to pour over the "funnies." They read the dialogue, many of them spelling out these illiterate words with a beginner's difficulty. While the kindergarten and early grades are trying to teach these young citizens to speak and write grammatically, the day by day influence of these cartoon stories is too often on the side of utterly wrong words and pronunciations. "I should have gone" becomes "I should of gone." Shorten *have* to the Cockney *'ave,* a contraction which is not limited to those born within sound of Dick Whittington's beloved Bowbells (only a symbolic saying now, alas, since the 1940 bombing of London destroyed that historic old Wren church)—but why, why, why replace a verb by the preposition *of?* By this sort of illiteracy, children are confused and misled. It is a great pity that old fashioned grammar, with parsing and analysis, has gone out of fashion in so many schools. In my opinion these form a mental discipline and training in logical thinking comparable to a good course in Euclid. There is so much loose thinking on the part of young people and adults, so obvious a lack of ability or inclination to think things through, that educators cannot too greatly stress the importance of some rigorous basic training in early school years. My purpose in referring to the comics is not primarily to draw attention to their subject matter—some are full of homely wisdom or ironic wit, others are slightly educative, many are utter sentimental or romantic drivel and vulgarity. What I do stress here is the menace to education in the wording—*gonna, whatcha, otter uv,*—and I ask myself whether the comic aspect would be lost if the words were less distorted. A few of these syndicated comics may originate in Canada, but not many. Their detrimental influence upon children's progress in learning and understanding their language is constant and insidious, and presents a problem to which teachers in both the U. S. A. and Canada should not be apathetic. Concerted action by national educational bodies might be effective in this matter.

The problem of drawing larger numbers of able young men and women into teaching is partly a financial one and partly a matter of public opinion in this country. In Great Britain one can approach a group of undergraduates and inquire as to the professions towards which each is heading with some expectation that the replies will include the word—Schoolmaster. Furthermore, it will be said with pride in a great profession—not in any half apologetic tone, as though it were the last resort of the man not ambitious enough to aim at law, engineering, medicine or "big business"! In Canada we need to educate our rural population, particularly, to realize that the schoolmaster or schoolmistress is one of the greatest influences upon their children and upon the future of our country. Until the teacher is so recognized, many will be lost to the profession who might otherwise have been eager to enter it.

Closely tied up with this community recognition is the financial question. In too many rural districts in some of our

Provinces, the salaries paid to teachers are a disgrace and an insult to their calling. There is also the vexed question of the lower salary scale for the woman teacher. It is extremely interesting to learn that in the House of Commons in London recently, on a labour amendment to the government education bill, in which amendment equal pay for men and women teachers was advocated, the Government was defeated—even if only by one vote! This does not mean that equality is now to be established in Great Britain—but it marks an advance in public consciousness of the injustice to women teachers which the lower salary scale perpetuates.

The processes of teaching can be likened to the filling of a tank by means of a pump and pipe. There is a reservoir of knowledge and from this by dint of hard work and much exertion a certain minimum at least is transmitted under pressure through the pipe, which is the School System, into the tanks which are the school children. You think this an inadequate simile? Then let us try again. The process of teaching is like the play of water from a hose when the nozzle is fixed for spray. A child, like a tender plant or a sturdy sapling, is sprayed with many droplets of knowledge. The fountain-like effect can be made very attractive and it is hoped the child will enjoy the shower bath and eagerly absorb learning as the petals, leaves and roots of a plant absorb moisture from the garden spray or the April shower. Is this, too, inadequate? Education is actually not an intermittant process, but, like breathing, it is continuous. 'The Education of Henry Adams' was a life-long process—everywhere he went, in every experience of life whether active or passive, the educational process was operating. Thus we must stress the need for producing a total environment in which the child lives, moves and has his being, breathing in the knowledge of facts and of values, of things useful and of things beautiful, as naturally as he breathes the oxygen and the fragrance of grass, trees and flowers in the air surrounding him.

Education of the *whole* Man for the *whole* of the experiences of living is the ideal to be aimed at, an ideal stressed and elaborated in the writings of that great proponent of sound education in Great Britain, Dr. L. P. Jacks. To achieve this we must train teachers who are themselves well educated, who are enthusiastic about the whole task and challenge of education, and who are versatile enough to vary their approach according to the occasion, the subject matter, or the character of the children as a group or as individuals.

I am a great believer in the value of tossing into the classroom occasionally some idea or bit of information quite off the beaten path, something which every child knows is *not* part of a required course and therefore to be taken or left at will—a quotation from an ancient thinker, an anecdote or bit of travel lore, some recent achievement of science or a philosophical idea, anything that is of such real interest to the teacher that he burns to pass it on to others, and in doing so he pays his class the compliment of treating them like intelligent adults. That is how many a spark has been kindled, a dormant interest aroused, a new Columbus launched upon what is for him at least an unexplored sea of thought. Curiosity is a divinely implanted characteristic of childhood and it is sheer tragedy that too often, in the process of education, the attitude of an impatient or unsympathetic parent or teacher results in deadening, dulling and all but killing this precious trait.

The late Master of Magdalen College, Cambridge, Dr. A. C. Benson, once said that "it ought to be the first aim of education to initiate the imagination of the young into the idea of fellowship and to make the thought of selfish individualism intolerable." The greatest need in the world today is for more and more people in every country who have been educated out of selfish individualism, out of narrow nationalism, into a world-consciousness and a sense of world wide responsibility—men and women who are in a real sense world citizens. Blindness to other people's fine qualities, ignorance of the contributions which they have made and are making to the progress of civilization, intolerance and prejudice, fear and selfishness—these are the great obstacles to world peace. Herein lies one of the greatest challenges to teachers. Theirs is the task of breaking down these barriers and obstacles to international good will. Only teachers who are themselves world-conscious can impart their vision and help to train a generation of world citizens. To this end student teacher and graduate teacher exchanges between the U. S. A. and Canada, and between our countries and Great Britain, continental Europe, and South America, are of tremendous value and importance. Every new step in this direction is to be welcomed and encouraged, for it adds to the potential forces in the world making for international understanding and good will. Education for world citizenship is one of the prime necessities if we would build and maintain a world at peace.

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The Sizes of Particles in certain Pelagic Deposits.

By Miss A. Vibert Douglas, M.B.E., M.Sc.

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XVI.—The Sizes of Particles in certain Pelagic Deposits. By Miss A. Vibert Douglas, M.B.E., M.Sc. *Communicated by* Professor Sir E. Rutherford, F.R.S.

(MS. received March 13, 1923. Read May 7, 1923.)

INTRODUCTION.

THE monumental work of the late Sir John Murray[*] and Dr Renard on the examination and classification of deep-sea deposits has left little to be desired either as regards methods or results. There was, however, one respect in which they were handicapped—no satisfactory method was known of ascertaining the distribution of sizes of the particles of which a sample was composed.

In 1915 Dr Sven Odén[†] of Upsala made known a method of soil analysis whereby he obtained by a sedimentation process data from which he could construct the distribution curve representing the relative proportions of particles of various sizes. He later obtained from the Challenger Office several samples of different types of deep-sea deposit which he subjected to the same form of analysis. His results[‡] were of great interest, not only because each type of clay or ooze showed a distinctive form of curve, but also because the same type of deposit exhibited definite peculiarities according to the ocean from which it had come.

On the return of the *Quest* (Shackleton-Rowett Antarctic Expedition, 1921–22) it was thought desirable by the Geologist of the expedition[§] that the samples of deep-sea deposit which had been obtained in collaboration with the Hydrographer and the Electrician[||] should be examined by the above method. They were accordingly given to the writer for this purpose.

OUTLINE OF METHOD.

One pan of a balance is placed near the bottom of a vessel containing an aqueous suspension of the sample. By continuous weighing, the rate

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[*] Report of Scientific Results of H.M.S. *Challenger* (1873–76). Deep-Sea Deposits (1891).

[†] *International Reports on Pedology*, vol. iv, p. 257, 1915. [Obtainable on loan, in German, from the Ministry of Agriculture and Fisheries, 10 Whitehall Place, London, S.W. 1.]

[‡] *Proc. Roy. Soc. Edin.*, vol. xxxvi, p. 219, 1915–16.

[§] G. Vibert Douglas, M.C., M.Sc.

[||] Commander F. A. Worsley, D.S.O., O.B.E., R.D., R.N.R., and J. D. Dell, C.P.O., R.N.

of deposit on the pan is obtained, and this cumulative weight, P, is plotted against the time, t, forming an "accumulation curve."

The following points have been made by Dr Sven Odén:—(1) If the height, h, of the water column above the pan be varied, the accumulation curve for any given sample remains practically unaltered if the values of t for the abscissa are reduced to some standard value of h—say $h=10$ cm., by the factor $10/h$.

(2) The accumulation curve is independent of the total weight of the sample, within reasonable limits, if P be expressed as the per cent. of the total weight.

(3) Care must be taken to avoid or correct for temperature variations, since the rate of fall of the particles varies inversely as the viscosity, and for water the viscosity changes considerably with temperature. ($\eta=0{\cdot}01307$ at 10° C. to $0{\cdot}01004$ at 20° C.)

(4) The "effective radius" calculated from Stokes' Law, $v=\frac{2}{9}g\frac{\sigma_1-\sigma_2}{\eta}r^2$, has a real physical significance where the number of particles dealt with is so great as to render the investigation statistical rather than individual.

(5) From the accumulation curve, $P=f(t)$, it is possible by a mathematical analysis to obtain a function $F(r)$ such that the area $F(r)dr$ represents the proportion by weight of particles having effective radii between the limits r and $r+dr$. It is found that $F(r)=-\frac{2t^2}{r}\frac{d^2P}{dt^2}=-\frac{2t}{r}\frac{dP}{dt}\frac{dz}{dx}$ where $z=\log\frac{dP}{dt}$ and $x=\log t$, the auxiliary curve (x, z) being adaptable for graphic treatment.

It has been objected by Professor C. G. Knott[*] that the use of Stokes' Law may give entirely fallacious results due to the irregular shapes of the particles, many of which may be of flat flaky form. This objection is emphasised by the recent success of Dr E. W. Wetherell[†] in photographing the tracks of flat solids falling through water. It has, nevertheless, seemed to the writer that it was worth while following Odén's method in view of the extraordinary consistency of the results, the large number of particles involved,[‡] and the fact that, especially in globigerina ooze, the predominance of spheroidal forms is very marked. (See *Challenger* Report, above referred to, plates xii–xv.)

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[*] *Proc. Roy. Soc. Edin.*, vol. xxxvi, p. 237 (1915–16).

[†] *Nature*, December 23, 1922, p. 845.

[‡] In a sample of deposit weighing 10 gms., whose average density is 2·6 and whose average radius is 20 μ, the approximate number of particles is 10^8.

EXPERIMENTAL ARRANGEMENT.

The apparatus employed by Odén depended on an automatic electrical release whereby counterbalancing weights were introduced on to the 2nd pan of the balance as the particles collected on the immersed pan. The writer has substituted a very simple and apparently satisfactory method of compensation, consisting of allowing one or more drops of distilled water to fall, from a small orifice at the end of a drawn-out glass tube joined to the base of an ordinary burette, into a small beaker on the 2nd pan. The times when successive drops were required in order to maintain a balance were noted, also the number of drops, and these two items provide the data from which the accumulation curve can be obtained. Readings were taken at intervals over 24 hours at least, and then the major portion of the water was syphoned off and the amount of undeposited residue obtained. To the cumulative total was added the equivalent weight of the residue which would have settled on the pan in time $t=\infty$, thus giving the total weight corresponding to the value $P=100$ per cent.

It was found that the drops formed a sufficiently accurate scale of weights; and by using a glass receptacle of very small diameter the correction for evaporation during 24 hours was so small as to be practically negligible.

RESULTS.

Sixteen bottom samples were brought home by the *Quest*. They included thirteen samples of pelagic deposits, of which seven consisted of such minute quantities that when slides had been made there was little or nothing left. The other six, however, varied from 10 gms. to 25 gms. Their densities were determined by means of a pycnometer.

Sample Z. 2. Lat. 67° 40′ S. Long. 17° 0′ E. 2356 fathoms.—A diatomaceous[*] ooze with considerable terrigenous material—particles of magnetite and quartz with diameters of 0·06 cm. downwards. Mean density 2·53. 70 per cent. by weight is composed of particles with radii less than 22 μ ($\mu=0{\cdot}0001$ cm.). The distribution curve shows the maximum of smaller particles to be at about 2 μ and the minimum at about 14 μ. 2 per cent. had radii less than 0·7 μ, and was still in suspension after 24 hours.

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[*] Mr R. Kirkpatrick of the British Museum (Nat. Hist.) has kindly examined the micro-slides and named the deposits.

Sample Z. 4. Lat. 69° 8′ S. Long. 17° 11′ E. 1089 fathoms.—A diatomaceous ooze free from coarse terrigenous particles but sprinkled with very finely divided magnetite and quartz and containing a large amount of excessively fine particles which keep the water opalescent even after standing for several days. Mean density 2·67. 60 per cent. by weight is composed of particles with radii less than about 22 μ. The curve indicates maxima at 0·6 μ and at 4·4 μ and a pronounced minimum from 6 μ to 8 μ. 3 per cent. has radii less than 0·46 μ, and had not settled after 42 hours. This sample came from the furthest point south that has been reached at that longitude.

Sample Z. 6. Lat. 66° 52′ S. Long. 14° 27′ E. 2341 fathoms.—A diatomaceous ooze with considerable fine terrigenous material. Mean density 2·75. 50 per cent. by weight is composed of particles having radii less than about 23 μ. The curve shows a main maximum at about 6 μ and minimum at 11 μ. 4 per cent. has radii less than 0·57 μ, and had not fallen within 24 hours.

These three show certain common features:—(1) About half the weight settles within the first 45 seconds ($h=10$ cm.), and is composed of particles having radii greater than 23 μ. (2) Of the finer particles the majority cluster about the sizes given by $2\mu<r<6\mu$, and within this range there are two maxima, this "kink" being a feature of all the curves and appearing also in Odén's curve for "Boden 117 Kosta." (See *Pedology* Report, above referred to, p. 298.)

Sample Z. 14. Lat. 39° 13′ S. Long. 10° 28′ W. 1880 fathoms.—A globigerina ooze. Mean density 1·93. 70 per cent. by weight is composed of particles having radii less than about 60 μ. The curve indicates maxima at 2 μ and 4·5 μ, and it runs fairly close to the abscissa throughout the range 9 μ to 35 μ, almost touching it at 28 μ. 2 per cent. has radii less than 0·8 μ, and remained in suspension after 24 hours.

Sample Z. 15. Lat. 35° 40′ S. Long. 5° 1′ W. 1942 fathoms.—A globigerina ooze. Mean density 2·05. 50 per cent. by weight is made up of particles with radii less than 43 μ. It is evident from the curve that there is maximum distribution between 2 μ and 11 μ, and there appear to be no particles within the range 13·3 μ to 15·2 μ, beyond which the curve begins to ascend gradually. 1·5 per cent. having radii less than 0·8 μ had not settled in 24 hours.

Sample Z. 16. Lat. 35° 41′ S. Long. 5° 10′ W. 1989 fathoms.—A globigerina ooze. Mean density 2·44. 63 per cent. by weight consists of particles having radii less than 50 μ, and these cluster chiefly around the same range as in Z. 15. There are apparently no particles within the region 11·3 μ to 15·8 μ. 1·85 per cent. was found to have radii less than 0·65 μ, and had not fallen after the elapse of 24 hours.

These three fall naturally into one group, and have the following features in common:—(1) From 35 per cent. to 50 per cent. is composed of relatively coarse particles falling within 25 seconds ($h=10$ cm.). (2) Of the finer particles the distribution is greatest for $2\mu<r<11\mu$. (3) In one case there are comparatively few, and in the other cases no particles recorded having radii approximately 13 μ to 15 μ. This result is of special interest because Odén found a complete absence of particles having radii from 12 μ to 20 μ, for globigerina ooze from the Atlantic ocean, a range embracing that obtained by the writer in the case of Z. 15 and Z. 16. This suggests that this genus of Foraminifera is of two classes—"giants" and "dwarfs"—and that the former, at least, are not much affected by the dissolvent action of sea-water, otherwise such a gap as that found by Odén and in part confirmed by this investigation would be most improbable.

In the following tables summarising the results shown graphically below, the value of r is the mid-point of the interval dr corresponding to the value of $F(r)$, and is measured in terms of μ as unit. The figures in brackets are the percentages by weight remaining ungraded, and $\Sigma F(r)dr$ + percentages ungraded = 100 per cent.

In conclusion, the writer has pleasure in expressing gratitude to Professor Sir E. Rutherford for permitting the carrying out of the investigation in the Cavendish Laboratory; to Dr C. T. Heycock for the loan of a balance from the Metallurgical Department; and to Mr G. Vibert Douglas, who provided the material and drew attention to the work of Dr Sven Odén when suggesting the investigation.

CAVENDISH LABORATORY, CAMBRIDGE,
March 1923.

[TABLE I.

Table I.—Diatomaceous.

Z. 2.		Z. 4.		Z. 6.	
r.	F(r).	r.	F(r).	r.	F(r).
μ.	(1·80)	μ.	(3·00)	μ.	(4·11)
1·9	9·85	0·5	11·00	2·1	5·65
3·2	9·16	0·6	15·70	3·8	3·13
3·5	9·74	1·3	9·70	4·4	5·23
4·0	7·23	2·2	4·06	4·9	9·83
4·8	3·47	2·5	7·05	5·4	11·31
5·8	2·20	3·1	7·13	5·6	11·48
7·2	2·50	3·7	9·50	6·6	8·98
8·7	2·16	4·1	12·50	7·4	5·75
10·8	2·48	4·4	14·50	7·7	3·04
13·0	0·79	4·7	8·71	9·2	2·87
15·8	1·00	5·0	7·52	11·1	1·04
22·0	6·45	5·4	5·50	12·4	1·23
		5·7	2·41	14·2	1·76
		6·0	1·52	16·4	1·88
		6·6	1·56	18·8	2·02
		8·1	1·58	22·9	4·84
		8·8	1·90		
		10·6	3·16		
		13·2	2·28		
		15·7	2·33		
		17·6	3·52		
		19·4	3·89		
		22·2	6·63		
	(30·0)		(41·8)		(51·3)

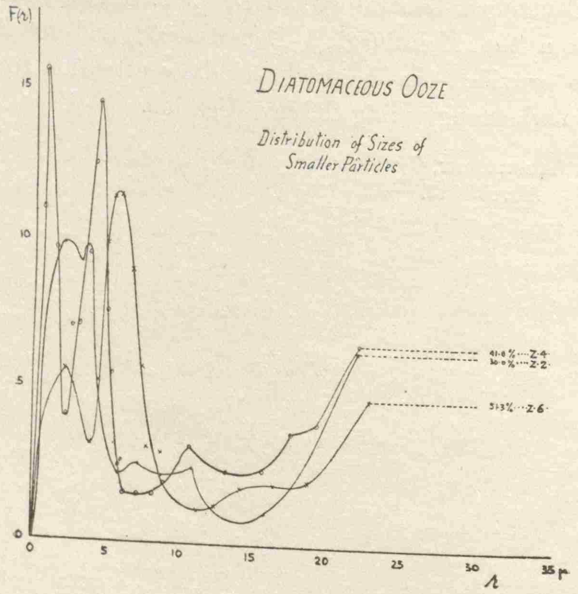
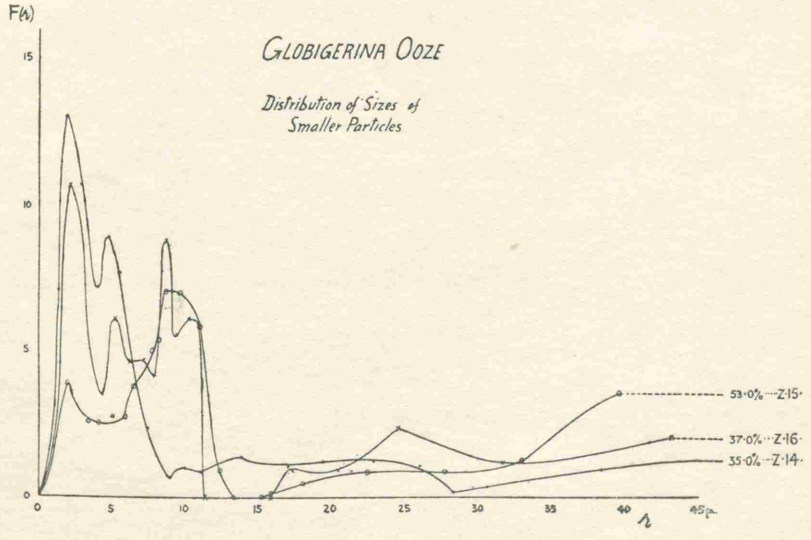


Table II.—Globigerina.

Z. 14.		Z. 15.		Z. 16.	
r.	F(r).	r.	F(r).	r.	F(r).
μ.	(2·44)	μ.	(1·50)	μ.	(1·85)
1·3	7·10	2·0	3·88	2·1	10·65
1·9	13·05	3·4	2·53	4·3	3·48
2·8	10·70	4·1	2·50	5·2	6·08
4·0	7·12	5·0	2·72	6·1	4·54
4·7	8·85	5·8	2·73	7·2	4·67
5·5	7·64	6·4	3·73	7·9	4·06
7·4	2·35	7·1	4·26	8·6	8·75
8·9	0·65	7·6	4·96	9·4	5·45
9·8	0·97	8·1	5·24	10·1	6·06
11·1	0·78	8·6	7·00	10·9	5·92
13·8	1·29	9·6	7·00	13·6	0·00
17·0	0·94	10·9	5·80	17·2	0·90
19·4	1·21	12·4	0·88	20·4	0·83
22·7	1·19	14·3	0·00	24·5	2·26
25·9	1·09	15·8	0·04	31·6	1·08
28·2	0·16	18·0	0·42	43·1	2·07
30·5	0·24	22·4	0·78		
33·4	0·49	27·6	0·83		
38·3	0·95	32·9	1·24		
51·2	1·28	39·5	3·52		
	(29·7)		(53·0)		(37·0)



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A Solution of Fault Problems

By G. Vibert Douglas* and A. Vibert Douglas**

(To be presented at the Annual Western Meeting, Vancouver, B.C., November, 1928)

IT often happens that the field geologist encounters a fault in ground where there is little to guide him with regard to the *throw*, or vertical displacement, and the *heave*, or horizontal displacement. The following construction gives both of these components of the fault, and the writers hope that it may prove a help to others. The construction is applicable to both normal and reversed faults.

Briefly the procedure is as follows: Take a point which is common to the faulted geological feature and to the fault plane and on the downthrow side of the fault. Move this point in the horizontal plane in the direction indicated by the fault striæ. Rebat the point down to the plane of the fault and obtain its throw. Next consider the other side of the fault and truncate it down by the amount of the throw just determined. Then project the line of the geological feature through to the trace of the fault-plane at the lower horizon. The result is the relative positions of the two parts of the original geological feature as severed by the fault.

In Figure 1, let us consider a typical *normal* fault, that is, a fault in which the hanging-wall has gone down relative to the footwall. This characteristic, or its alternative, the reversed fault, is determined by observation on the ground.

Let AB be the line of any geological feature such as the edge of a dyke, vein, or bedded sediment. The plane of which AB is the trace may have any dip; in the present case let us say 70° right. Let FF be the trace of a fault-plane which may have any dip, δ; let us say 35° left in this case.

Examination of the plane of the fault will often reveal striæ whose direction indicates the direction of motion of the hanging-

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wall, whether normally down the fault-plane or obliquely. Let α be the angle in the fault plane from the horizontal to the direction of the striæ.

Having measured α and δ in the field, draw PM in Figure 1, such that the angle $FPM = \alpha$. Draw PX perpendicular to FF. Taking the point M at any convenient distance along the line PM, draw MH perpendicular to PX. The points P, M, H, X are thus all in the horizontal plane. Consider now the vertical plane, of which PX is the horizontal trace, but for the ultimate simplicity of the construction superimpose the following construction in this vertical plane on the diagram already constructed: Draw PQ such that the angle $HPQ = \delta$. With P as centre, PH as radius, draw the circle cutting PQ in Z. Draw ZJ perpendicular to PH. Produce JZ both ways, forming the line $F'F'$. Thought of as passing through Z, $F'F'$ is the trace of the fault plane at a depth JZ below the surface, and the points M and H would both lie on this line if rebatted down to the fault plane. When thought of as passing through J, $F'F'$ is the projection on the horizontal plane of the trace of the fault plane at a depth JZ.

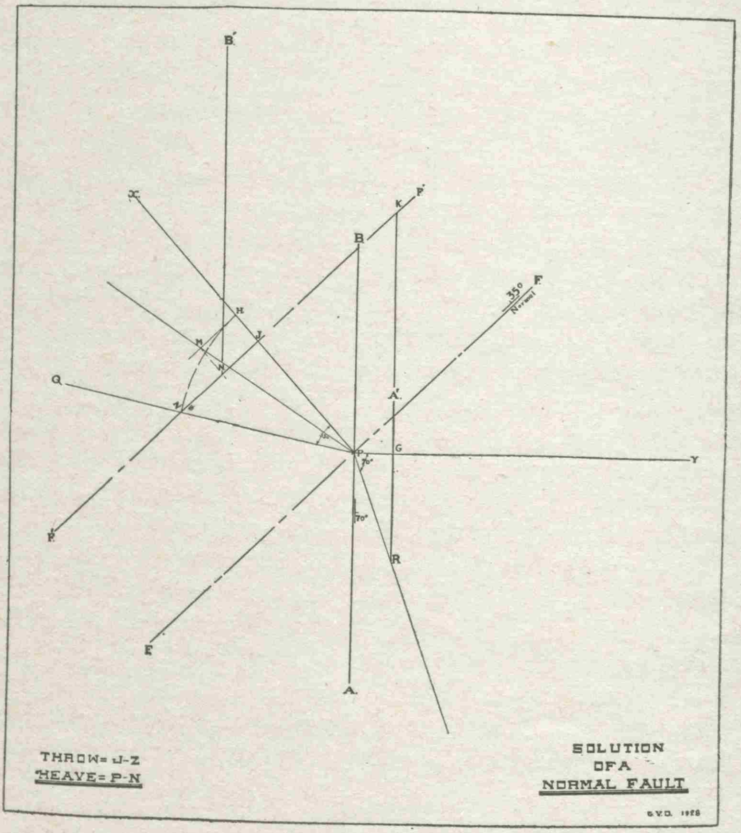

Figure 1.

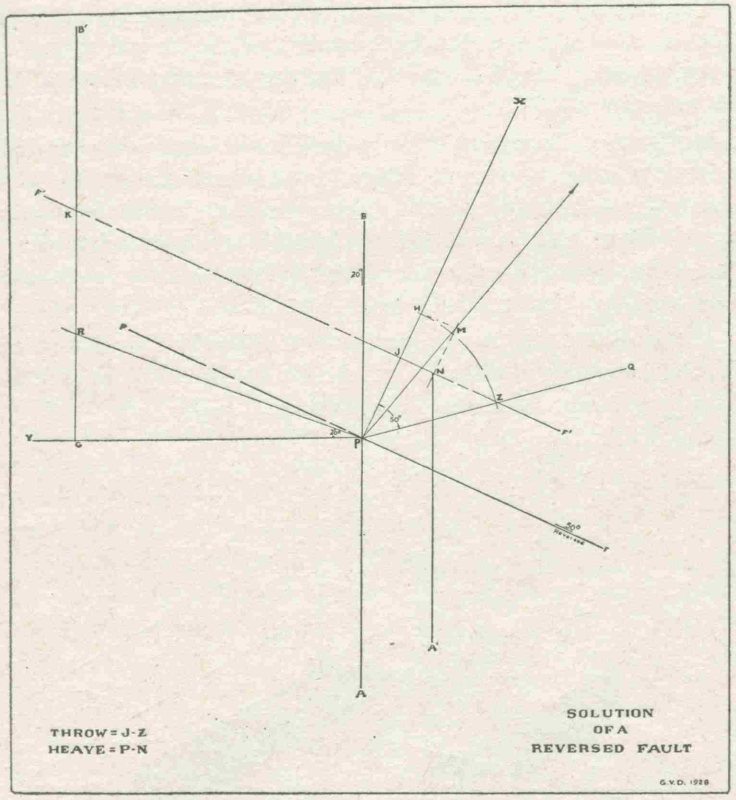

Figure 2.

Draw MN perpendicular to $F'F'$. Then, just as the point H corresponds to a point on the fault-plane vertically below J, so the point M corresponds to a point on the fault-plane vertically below N. Hence PN is the *heave*, its direction being given by the angle FPN, and, as already indicated, JZ is the *throw*.

The upthrow side of the fault should now be considered. Draw PY normal to AB and lay off the angle YPR equal to the dip of the plane of the geological feature AB, in this particular case 70°. Find the point R such that the vertical RG is equal to the throw JZ. Project R parallel to AB, thus finding the point K on $F'F'$. Thinking now of the horizontal plane at depth JZ below the surface, K is the point in this plane common both to the fault-plane and to the AB feature plane; hence $A'K$ and NB' are the severed portions of the original feature AB.

In Figure 2, the construction is carried out for a *reversed* fault in exactly the same manner as before. In this case the dip of AB is taken to be 20° left and that of FF as 50° right. It must be remembered, however, that here it is the footwall that is followed down and not the hanging-wall as in the case of the normal fault, and hence the severed portions of AB will be $A'N$ and KB'.

The measurements which are made in the field are the distance NK, the directions of AB and FF, the dip of the AB plane, the dip of the fault-plane, and the angle α in the fault plane.

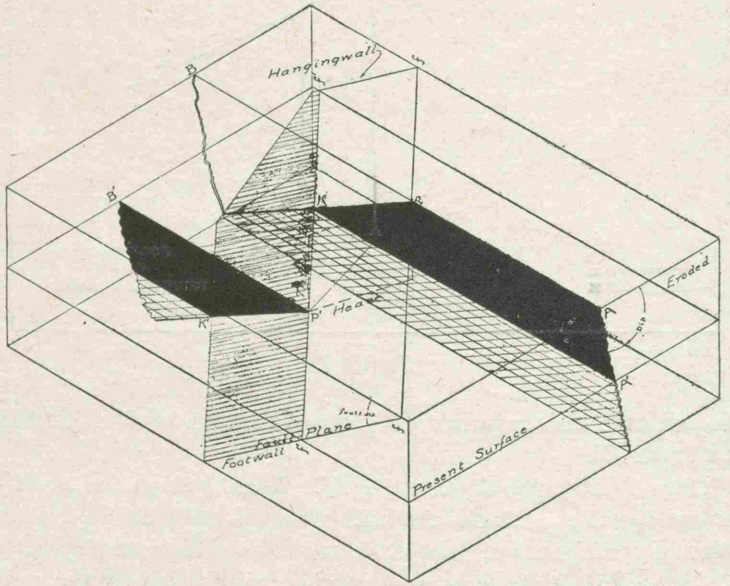

Figure 3.—Block diagram showing Normal Fault.
Points once at P and K have moved to P′ and K′.

It is obvious from straightforward geometrical considerations that the angle FPN determining the direction of the heave is given by the relation

$$\tan FPN = \tan\alpha . \cos\delta$$

(being thus independent of the length of PM used in the construction), so that, if preferred, PN could be drawn at once and NJ drawn perpendicular to PX and produced backwards to meet PQ in Z. The construction then follows as already given. The completely graphical method of finding the direction of PN, however, has its evident advantages.

Although the extent of movement along PN is not at first known, it will be seen that by carrying out this construction two or three times to scale, the point N (or M) can be fixed so that the distance NK does equal (to scale) the distance between the two features as actually measured on the ground.

In conclusion, it may be noted that the angles, which are actually measured from either K or N in the field, are here laid off from P in AB, which represents the position of the geological feature before faulting took plane. This method involves a simpler construction than would be necessary if AB were to be found from the severed portions at N and K. It is obvious that the position of the point P has to be determined before the throw can be measured, for, by definition, the throw is the total vertical displacement of two points which were once one and the same.

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SOME EUROPEAN CONTRASTS

By A. Vibert Douglas

THE impressions gained from a recent sojourn in the British Isles and a short visit to the continent resolve themselves into a series of striking contrasts.

One thinks of the desolation and destruction in London's bombed areas, the gaping voids, the jagged walls, the arched cellars and deep basements where so much of London's life was lived and into which the passer-by now looks from a bus top or over the neat brick walls that have been built around these chasms. I see the burnt-out skeletons of historic churches; whole blocks of dismal dwellings with every window gone, condemned and deserted; the repetition of all this with endless variations in other cities and in some rural districts. I see, too, the places through which I passed in France—Calais, Boulogne, Lille, and some suburbs of Paris—homes, factories, bridges and public buildings blown up by the retreating foe or bombed by advancing victors; rows and rows of locomotives on sidings, out of commission, awaiting repairs or the scrap-heap.

In contrast I see Zurich, Lausanne, Geneva, spotless and beautiful; and Dublin in lovely Eire, land of many contradictions and inconsistencies, tragic or laughable, where some are proud of their neutrality and some ashamed, while others feel that they served the cause of Great Britain best by maintaining neutrality even while sending their sons and daughters by the thousands into the British forces and providing food and other supplies.

Another contrast is at the opposite extreme—devastated Germany. This I could not see for myself, but it is spoken of with awe and horror by many of our men and with a strange excited satisfaction by Frenchmen. I talked with the train porter as we left Calais for Bâle, and expressed grief over the destruction in that old channel port, but his face, at first grim, soon lightened as he said, "It is nothing, it is nothing to the ruin of the German cities . . . you should see Kiel and Hamburg and Mannheim . . . I have seen them. I was there. Nothing is left . . . *rien, rien, rien!*"

Workers in UNRRA and officers recently back in London from Germany speak of the sullen hatred in that once proud and prosperous country. This heaving ocean of hatred grows out of ruin, desolation, homelessness and increasing want. Add to these the spectacle of four victor peoples dominating the land in four separate zones, with no unified policy for its future.

And all about Germany are the countries she attacked and trampled with cruel heel, starving and enslaving their peoples for five years that she herself might be strong. Sufferings untold, cruelties diabolically conceived and executed, these things have bitten deeply into Pole and Czech, French and Belgian, Dutch and Norwegian. One sees their joy and relief at being once more free men and women, able to speak their minds, grateful for the evidences of friendship, sympathy and help from Sweden and Switzerland, from the United States, from Great Britain and the distant parts of the Commonwealth. One sees these same peoples looking with loathing at the German nation, and fearing the possibility of a British and American policy that would favour rebuilding a strong Germany, allowing her to retain the Saar and the Ruhr and thus enabling her to re-arm for conquest. A citizen of Brussels spoke to me in this vein at Zurich: "It is not that we hate individual Germans, but it is the nature of the German nation. They must be prevented from doing this again. We have suffered too much, we know them—it *must not* be allowed to happen again." So, too, spoke French students on the night train to Paris—Bernard F—— and Jean S——, both law students; Jean L—— and Armand de L——, both in engineering courses—all four recently staying at a World Student Relief hostel and only now able to return to their studies.

Jean L—— was studying chemistry and physics in Paris in 1940. He withdrew to Vichy territory and was ordered to work in a factory. After some time he found himself about to be transferred to Germany and realized that he had been virtually working for Germany all the time. He took to the forests, made his way to the Pyrenees, crossed into Spain, was imprisoned three months and became ill from exposure and privation. A transfer of nationals between Spain and North Africa gave him his heart's desire, a place in the Free French Army. There he was trained in radar and from 1943 was engaged in this work. Now at last strong again and filled with ambition, he is about to pursue electrical engineering in Paris. The other lads had likewise suffered and fought. One of them was deported: of some two hundred in his group in Germany only a few came back. These young men could sometimes be gay and light-hearted, sometimes intensely serious. Vehemently they debated the Allies' attitude towards Germany, the merits and demerits of the proposed French constitution, or short-wave radio equipment of one nation and another. But back and back they would come to the future of Germany: she must not be allowed to do this thing a third time. Why did not Britain depose Franco? I tried to make them see that there were sound arguments for our non-interference with Spanish internal affairs, but was overwhelmed with a torrent of words: Great Britain wants the balance of power; she wants a strong Germany for fear France turns Communist; but France will not swing far to the left; just wait for the voting on the constitution! And indeed the result was good evidence that the majority do not want any dictatorial one-party government.

But the real answer to this demand for an impotent Germany appears to go very deep into the interlocking industrial and economic life of these European countries. One of the most influential men in London, my old chief of 1916-'18 days, sitting in his temporary office in the City, having been bombed out of two offices, spoke very gravely of the chaos in Germany, of the stark tragedy which is resulting from the lack of any constructive common policy in the four zones, and of the insanity of thinking that there can be a prosperous Europe around a weak, embittered Germany. As an example he cited the great pre-war fertilizer industry of the French. They imported Spanish iron sulphide, extracted the sulphur for the manufacture of fertilizer, exported the iron to Germany and much of the fertilizer to Germany and other countries. Now France does not want the German iron industry to be restored, but she must have some outlet for her iron. She has ordered iron sulphide and then closed the Spanish border so that it cannot be delivered. Meanwhile she and neighbouring countries, including Germany, need the fertilizer, if food production is to meet the desperate want. Great Britain cannot long continue to divert her foodstuffs to prevent famine in Western Germany; she has sent over seed potatoes; but without agreement regarding the present use of fertilizer in Germany an inadequate crop of potatoes can be expected—and this when the food-level in parts of Germany is falling to the danger-point of starvation, with rapidly mounting hatred and lust for revenge.

This is a gloomy picture. It is confirmed, however, by men of first-hand experience in Germany, men of trained minds and sober judgement. One such man, a professor whose war service has given him four years of close observation, with access to official records, is so weighed down by the tragic mistakes that are being made by the victorious nations, the blind folly, stupidity, selfishness, jealousies and often corruption, the failure to learn history's lessons, that he can hardly face the task of trying to talk to young students in the near future.

But again there are contrasts. Hate, folly and indifference on the one hand; but on the other faith, hope and charity. Both in Zurich and in Geneva I found the latter three in rich measure, and their flowerings are manifest in the courage and renewed vigour of body and mind in thousands who have endured great tribulation. The International Federation of University Women, bringing together its executive and its relief and research fellowship committees for the first time since the fateful August of 1939, met in one of the beautiful old guild-houses of Zurich in April, 1946. There we rejoiced to see Dr. Adamowicz, president of the I.F.U.W., who survived six terrible years in Warsaw. Though frail and worn in appearance, she has a strong and constant faith in international coöperation, and great hope for her own land. The chief enemies of Poland to-day, she thinks, are those Poles in exile who will not return because of their distrust of Russia. They are needed, especially all well-educated Poles, to help build a new Poland, to re-establish schools and universities which suffered so appallingly under the German edict that "a slave people need no higher education". Ten new educational institutions have now been opened. Teachers and students are placed in the category of workers, so that they are assured of at least two meals a day. Private enterprise is permitted on a small scale—that is, it can employ up to fifty workers; larger concerns requiring more than fifty must become nationalized. Medical training is again advancing and gratitude was expressed to the Swedish Federation of University Women for clothing supplied to medical students.

The action of Canada and other countries in sending clothing, food and money for European relief has evoked warm appreciation. Much of the money now on hand from Australia and Canada is to be used to bring to Great Britain for even a few weeks university people from the occupied countries, where they have struggled for existence, cut off from the outer world, during long and terrible years. One realized the value of this in talking with such men and women in Switzerland and in England.

In the home of an eminent London surgeon, I met a Dutch surgeon who had been invited to London for three weeks. His sister is a physician, a specialist in tuberculosis, which is rampant in the liberated countries. Such men and women need the refreshment which comes from change of scene and from renewed contact with scientists of other lands, enabling them to catch up with the advances in their professional fields and with the literature of their subjects. This Dutch surgeon told of eating tulip bulbs and various roots. He told also of the man-hunt in a certain town where his sister and her husband lived, when the Germans rounded up twelve hundred persons and sent them into Germany as slave labourers: only fifteen have returned, and they are decrepit or insane. He described how he hid his radio and how he and his family listened almost daily to the BBC's Dutch broadcast, how the sound of Big Ben became the symbol of their hope of liberation, and how when he stood at last in the London streets and heard Big Ben strike the hour, it had brought a lump into his throat. No words can tell what freedom means to such people.

In Geneva I was privileged to sit in at a meeting of World Student Relief, which coördinates and directs the activities of three international student bodies. Country after country was passed in review and the needs of the students outlined. A grant had been made to help Norwegian students in three cities. Now they are organized and are not only looking after their own needy members, but, particularly in Bergen, they

are planning actively to send aid to students in countries far worse off, such as Poland and Czechoslovakia. In this latter country everything was lacking but the will to resume university work. Norwegian student groups sent writing-paper, Danish groups sent food-parcels, Swedish students sent clothing and shoes; books are going from Great Britain, the United States and from Geneva. To the students of Holland Sweden has sent bicycles, shoes, raincoats and clothing. A student foyer has been started in Athens and efforts to get in food, clothing and books are partly successful, though delays of six months in transportation have hindered progress. With the coöperation of UNRRA, furniture and equipment for this student centre were obtained. Similar student foyers have been established in other countries where student life had been almost completely stamped out or driven underground.

Leaving Geneva early one morning I journeyed to the other end of the lake into the magnificent Upper Rhone valley to Aigle, and thence by cog railway a thousand feet up the mountainside to a green ledge where the scattered village of Leysin faces across the valley to the Dents du Midi. Here Doctor and Mrs. Louis C. Vautier preside over the Sanatorium Universitaire, to the development of which as an international institution they have given everything they possess. Here in four special houses World Student Relief has brought students of seven nations who have developed tuberculosis through hunger, exposure and overwork. In each case there is expectation of recovery; patients are encouraged to study a little at first, but overwork is discouraged as health and vitality improve.

Here I talked with a French law student who had just then passed his examination for the Paris doctorate. The prison camp of Buchenwald had left its mark upon him and, though he was still confined to bed, his zeal to advance in study and his appreciation of the opportunities afforded him were earnest and moving. Here, too, were young Dutch economists and medical students from the resistance movement, a group well enough to be allowed up for lunch, which I was invited to share. One tall fair lad had been through bad years after capture and removal to an unusually brutal prison camp.

The Student Rehabilitation Hostel in Haute Savoie also is financed with the money collected by university students on this continent, in Great Britain and elsewhere. It is run on coöperative lines, with medical supervision. Some 250 young men and women, students or graduates, physically and mentally exhausted by the hardships undergone in the resistance movements or in prison and labour camps, have been given from one to three months here in an atmosphere of friendliness, mutual understanding and helpfulness.

Of only two of these shall I write, though many faces come to mind. Madeleine N—, handsome dark Parisian, doctor of dental surgery, caught aiding the escape of allied airmen who had crashed in France, was deported, shamefully treated in the labour camp, forced to work in a mine, was undernourished, nursed back from typhus, and put to work with pick and shovel on a new airfield. She saw her comrades who could not do the day's tasks combed out and marked down for the gas-chamber. Liberated by the Russians and returned to France, she collapsed through overstrain of the heart and lungs. Not until then did she learn that her husband, taken prisoner in 1939, had been shot in Cologne in 1941. But there were great faith and burning hope in those dark eyes and the will to get well again—if not strong enough to resume her profession, at least well enough to take a secretarial post in some organization promoting international understanding.

I see also the face of Jacques B—, stocky medical student from Southern France. He had three years of study while the underground movement developed. He became more and more involved in its operations until suspicion rested upon him so heavily that he had to disappear into the hills and forests. Eventually he made his way into the Fighting French Army and served in the Tank Corps, was wounded and taken prisoner, was sent to Germany, put to work, fell sick and was found in the prison hospital when liberation came. There at the Châlet des Etudiants at Combloux he is slowly regaining vitality and preparing for his final studies at the medical college in Lyons. Gentle, cultured, kindly and sympathetic, this young Frenchman was an inspiration to all the students there who had suffered as much as or more than himself. Like the Good Physician he has that rare ability to give sufferers the quietness and confidence that are strength.

With a group of these students I stood on their balcony and looked southward towards Mont Blanc. Out of a deep-shadowed valley it rose with massive grandeur, its ice-crowned summit thrust upward into the sunlight or more often into the shining mists made by its very presence out of transparent air-mists which condense upon the mountain slopes and supply the moisture that eventually flows out from the glaciers, down the valleys, across the plains, and makes fertile much of southern France. I turned and looked at the young men and women about me. They have risen above the valley of the shadow of death; their eyes are steady, their minds keen, their spirits awake. Even as the mists about the mountain-top, their visions may yet become streams and rivers that will be for the healing of the nations.

SPECTROSCOPIC ABSOLUTE MAGNITUDES AND PARALLAXES OF 200 A-TYPE STARS

BY

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ABSTRACT

The spectroscopic absolute magnitudes and parallaxes of 200 A stars have been determined.

The material used was the large collection of 1-prism slit spectrograms of the Yerkes Observatory. Eighty stars having reliable trigonometric or cluster parallaxes were made the basis of calibration and seven criteria have been found giving correlations with absolute magnitude, namely—width of K, Hδ, λ4481, and intensity ratios λ4215/λ4227, λ4233/λ4227, λ4535/λ4481, λ4549/λ4481.

Relative to the standard stars, the systematic error of the magnitudes is −0.04 and the probable error ±0.5. Relative to 108 Mt. Wilson spectroscopic magnitudes the systematic error is +0.09 and the probable error ±0.3.

The Shajn Double Star test applied to 12 pairs gives satisfactory evidence in favour of the accuracy of the magnitudes. The magnitudes show correlation with proper motion but not with reduced proper motion.

A comparison is given between Mt. Wilson, Arcetri and the writer's average magnitudes for each spectral subdivision and evidence is given in support of the claim that the magnitudes herein determined have greater individual accuracy than can be obtained by adopting the mean magnitude method.

INTRODUCTION

During the summer of 1925 the writer held an appointment as Volunteer Research Assistant for four months at the Yerkes Observatory, Williams Bay, Wis. The Director, Dr. E. B. Frost, offered the writer, as a research problem, the determination of the spectroscopic absolute magnitudes and parallaxes of A-type stars. For this purpose there were available several thousand spectrograms of about 500 stars of spectral classification A0 to A9, or taking the next sub-class above and below, B9 to F0. A selection from these was to be made including as many stars as possible for which reliable group or trigonometric parallaxes were available, these to form the basis of calibration.

All these spectrograms were taken at the Yerkes Observatory with the 40-inch refractor and Bruce Spectrograph attachment. They are 1-prism spectrograms having a dispersion of 30A to the millimetre at λ4500, while from Hβ to Hε approximately 691A, is 33 mm.

This problem presented many features of interest and of difficulty, for though considerable work has been done on spectroscopic magnitudes of the later type stars (F, G, K, M), comparatively little has been done upon spectra of Class A. In later type spectra (viz., F to M) there are many metallic lines; in spectra earlier in type than A (viz., B stars) there are helium lines, hydrogen lines and spark lines of silicon and of a few other elements; but in the spectra of early A stars, especially A0, there are comparatively few lines well defined with the exception of strong hydrogen lines and the H and K lines of ionized calcium.

Table I summarizes the criteria upon which other investigators have depended in their determinations of spectroscopic absolute magnitudes, and for the sake of completeness the criteria used in the present investigation are included:

TABLE I

Spec. Class	Investigator	Ref.	Criteria
B	Adams, Joy	3	Correlation with spectral class based chiefly on helium and hydrogen lines as in Harvard system, but with "nebulous" and "sharp" subdivisions
B	Edwards	4 5 6	λλ4471, 4388 (helium) with Hγ, λ4144 (helium) with Hδ
B8-A3	Lindblad	8	Comparison of regions λλ3884-3907 and λλ3907-3935
B9-A9	Adams, Joy	2	Correlation with spectral class based chiefly on λλ4026, 4471 (helium) and λλ4326, 4384 (Fe)
A	Struve	9	Width of λ4481 (Mg⁺)
A	Douglas	—	Width of Hδ, K, λ4481; intensity ratios from λλ4215, 4227, 4233, 4481, 4535, 4549
A-F5	Abetti	10	Correlation with spectral class involving trigonometrical, cluster, and all available spectroscopic data from Mt. Wilson, Victoria, Sidmouth and Arcetri
F-M	Adams, Joy, etc.	1	Selected ratios from λλ4072, 4077, 4215, 4250, 4271, 4290, 4455, 4462.
F-M	Lindblad	7	Arc line λ3900; Cyanogen bands λλ4144-4184, 4227-4272, 3993
F-M	Rimmer	11	Selected ratios from λλ4072, 4077, 4215, 4227, 4250, 4271, 4290, 4444, 4455, 4462
F-M	Young, Harper	12	Selected ratios from λλ4072, 4077, 4162, 4168, 4215, 4247, 4250, 4258, 4271, 4290, 4455, 4482, 4489, 4494, 4496, etc.
F-M	Macklin	13	Selected ratios from λλ4174, 4227, 4290, 4326, 4387, 4444

Examination of the Yerkes spectrograms made it evident that new criteria would have to be sought.

The comparison of the density of the regions used with such success by Lindblad is ruled out in the present case because the range of the Yerkes 1-prism plates is from just to the red of Hβ to just to the violet of K, approximately λ4900 to λ3920. Thus the bands at λλ3884, 3907 are beyond the range of these spectrograms.

The widths of the hydrogen lines should, theoretically, show a correlation, but that this extends throughout the range of A spectra is doubted by Harvard investigators.[33], [34]. For the early A stars, however, the writer felt that this line of attack should not be ignored. Likewise the width of λ4481 correlated with luminosity by Struve[9] for 36 stars of types A0 to F0 appeared to warrant careful consideration.

In order to gain familiarity with spectra of this type and to find if possible new criteria upon which to work, the writer made a random selection of plates covering a wide range of absolute magnitudes as determined by Adams. These were studied in pairs on the Hartmann Spectrocomparator which allows of the simultaneous view under magnification and equal illumination of the two spectra in exact contiguity throughout their entire range. The result of the preliminary study and measurements was that the following criteria were adopted:

(1) Widths of $\lambda 4481$, $H\delta$, K.

(2) Intensity ratios: $\frac{4215}{4227}, \frac{4233}{4227}, \frac{4535}{4481}, \frac{4549}{4481}$.

PART I

CORRELATION CURVES

Methods.—In order to avoid any conscious or unconscious bias in the measurements and intensity estimates, the writer decided to make no reductions whatever until all the measurements had been made. The required data for a sufficiently large number of stars were obtained before leaving Yerkes Observatory in September, 1925, and the compilation and reduction of this data was commenced subsequently. Thus the correlations which have been obtained are felt to be free from prejudice and subject only to the personal factor which is inevitable in all such work.

The number of spectrograms of any one star varied from one in comparatively few cases to several score in certain cases of spectroscopic binaries where orbit determination had necessitated many plates being taken. Usually there were several plates and of these the two best were selected, special effort being made to get good definition at the extreme left—the H and K region. After preliminary examination under low power magnification to establish the essential similarity of the two, one was selected for final measurement. Where there were distinct differences between the two, both were measured and other plates of the same star examined. Cases of uncertainty were generally attributable to spectroscopic binary effects where considerable care was necessary lest apparent breadth of line was a result of Doppler displacement rather than an effect of the kind sought. The final measurement, in general, of one plate for each star has obvious advantages and, apart from the writer's own tests, it appears justified by the consistency of records of the widths of $H\gamma$ and $H\delta$ made from different plates of the same star by means of a Moll microphotometer.[34]

The measurement of line widths involves a large uncertainty where the lines are wide and nebulous; in particular, in the A stars, the "wings" of the hydrogen lines are a very prominent feature of these spectra and it is a matter of individual opinion as to where the "line" begins and ends. All that can be hoped is that the measures made by one individual with magnification and illumination kept approximately uniform, will be consistent within themselves.

The measurement or estimate of line intensity presents difficulties which different investigators have sought to overcome in various ways. The writer depended solely on eye estimates endeavouring always to integrate mentally the total intensity from wings to line centre. It is this integrated intensity that is really sought and not merely the central maximum intensity obtained by wedge extinction methods. Eye estimates are relied upon in much of the work of Harvard investigators, even where the comparisons are made between lines on different plates. In the present case, however, comparisons were made only between closely adjacent lines on the same plate, and for this purpose an eye-piece giving magnification 3 was used.

The widths of lines were measured on a Gaertner machine under magnification 15. In order to eliminate temperature or other effects causing lack of complete uniformity in dispersion a factor was recorded for every plate measured, namely the distance between the titanium-iron spark comparison lines $\lambda\lambda 3963$-3969, or when these were indistinct, $\lambda\lambda 3981$-3998. All measured widths were subsequently reduced to the standard given by the average plate factor 0.370 mm. in the former and 0.950 mm. in the latter case.

Each plate was weighted at the time of measurement on the basis: Good 3, Fair 2, Poor 1. Where the plate was not equally good throughout, separate weights were recorded for the different regions as required.

Known Parallaxes.—The stars for which data had been obtained included 31 belonging to the Taurus and Ursa Major Clusters for which reliable parallaxes were available from the work of Rasmuson;[14] also 49 for which trigonometrical parallaxes were given in Schlesinger's General Catalogue of Parallaxes.[15] The Cluster parallaxes being absolute were used as they stand,[16] the trigonometric parallaxes however are differential, but 35 were made use of by W. S. Adams[2] and his value for the corresponding absolute parallax was taken in each case, the remaining 11 were reduced to absolute by the addition of an average factor $+0''.004$.[17] Of these 49, only one had a negative parallax and as it had the value $-0''.003$ the reduction to absolute brought it up to $+0''.001$ thus obviating any necessity of having to introduce the effect of negative parallaxes into the reduction of the data.

These 80 stars formed the basis upon which the absolute magnitude relations were determined.

Absolute Magnitude.—The absolute magnitude of each of these stars was calculated from the relation

$$M=m+5+5\log p$$

where M and m are the absolute and apparent magnitudes respectively and p the absolute parallax. The values of m were taken in every case from the Henry Draper Catalogue—photometric magnitude.

Spectral Classification.—In assigning the spectral class to each star studied, the writer was definitely influenced and guided by the Mt. Wilson classification rather than the Harvard H. D. classification. Following the lead of the Mt. Wilson investigators, the writer classified all the spectrograms studied as *s* or *n* according as the absorption lines were sharp, narrow and clean cut or nebulous, wide and hazy. It seemed evident from the outset that there were many spectra which could not be said to be either definitely sharp or decidedly nebulous; these were labelled *ns* or *sn* and put with the group which they most resembled.

The writer decided to carry out separate reductions for the *s* and *n* stars and having done these quite independently the resulting curves should provide unbiased evidence as to whether this grouping has a physical reality or whether the stars form a homogeneous class.

Reduction Procedure.—With absolute magnitude as abscissae and either line width or intensity ratio as ordinates, plots were made for each of the seven criteria in the case of the *n*-stars and likewise for the *s*-stars, fourteen plots in all. Cluster stars were differentiated from trigonometric parallax stars so that any systematic difference would become apparent. As was hoped, no such effect was evident.

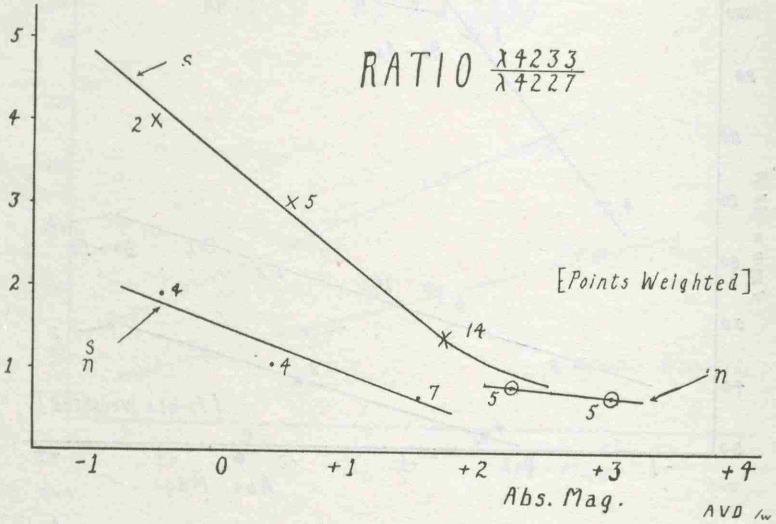
It was at once apparent that no correlation existed in the case of Hδ(n). In the other thirteen cases the points were seen to fall into definite groups and so for each group mean points were computed and the lines of closest fit drawn in. In every case where more than one curve was required to represent the data on either the *s* or *n* graph or on both, it was found by superposition of the graphs afterwards that an *s* and *n* curve practically coincided. Hence the final curves take the forms shown in Figures 1-7.

Systematic Errors.—The absolute magnitudes of the stars used in establishing the curves were redetermined from the curves. Weights were assigned to the estimate from each of the seven criteria based upon its apparent reliability and then the mean magnitude calculated. Comparison was made for each criterion separately with the standard value (cluster or trigonometric), and wherever possible with Adams' value.

In the tables the symbols used have the following significance:

S =the standard value of absolute magnitude whether dependent upon cluster or trigonometric parallax.
A =the spectroscopic absolute magnitude, as determined at Mt. Wilson.
D =ditto, as determined by the writer, from all the criteria applicable.
1 =ditto, as determined by the writer from width of K.
2 =ditto, from width of Hδ.
3 =ditto, from width of λ4481.
4 =ditto, from Ratio λ4215/λ4227.
5 =ditto, from Ratio λ4233/λ4227.
6 =ditto, from Ratio λ4535/λ4481.
7 =ditto, from Ratio λ4549/λ4481.
N =Weight (number of stars).
e =systematic error.
r =probable error.

5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[Points Weighted]
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n
Abs. Mag.
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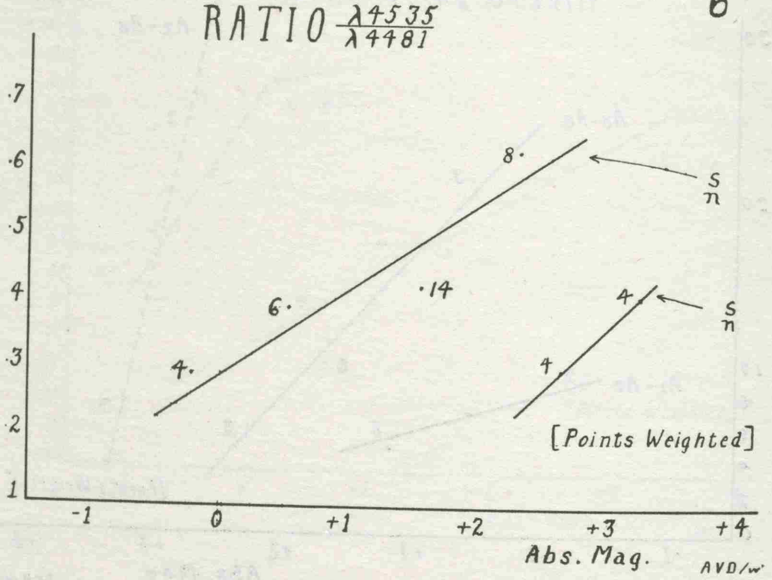
0
+1
+2
+3
+4
1
2
3
4
5
AVD/w

6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n
Abs. Mag.
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+1
+2
+3
+4
1
·2
·3
·4
·5
·6
·7
AVD/w

7

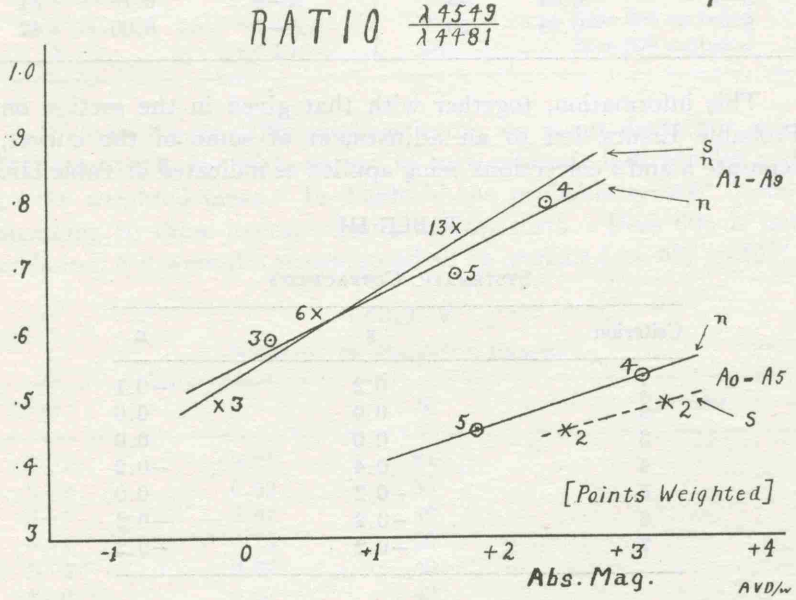
RATIO λ4549/λ4481
A1 – A9
A0 – A5
[Points Weighted]
s
n
Abs. Mag.
-1
0
+1
+2
+3
+4
3
·4
·5
·6
·7
·8
·9
1·0
AVD/w

TABLE II

Systematic Errors

Comparison	e	N	Comparison	e	N
S−1	−0.01	65	A−1	0.33	56
S−2	0.05	30	A−2	0.45	26
S−3	−0.10	50	A−3	0.25	40
S−4	0.30	26	A−4	0.54	19
S−5	−0.01	50	A−5	0.26	42
S−6	−0.34	43	A−6	0.10	34
S−7	−0.28	50	A−7	0.00	42

This information, together with that given in the section on Probable Errors, led to an adjustment of some of the curves, separate *n* and *s* corrections being applied as indicated in Table III.

TABLE III

Systematic Corrections

Criterion	s	n
1	0.2	−0.1
2	0.0	0.0
3	0.0	0.0
4	0.4	−0.2
5	−0.2	0.0
6	−0.2	−0.2
7	−0.2	−0.2

After applying these corrections the weighted mean magnitude was calculated for each star and the systematic error determined. It was noted that one star was largely responsible for the error and as this star (Boss 606) is the one for which the differential parallax is negative, it seemed fair to omit it from the total and consider that the resulting low value of the systematic error indicated that the criteria were satisfactory from this point of view. In Table IV the value of *e* is given both with and without Boss 606. It may be remarked that for this star the absolute magnitude derived from the absolute parallax +0″.001 and apparent magnitude 5.4 is −4.6, whereas the writer's determination is +0.5. It is not included in the Mt. Wilson list.

TABLE IV

Comparison of Systematic Errors

	e	N	Remarks
S−D	−0.11	74	Boss 606 included
S−D	−0.04	73	Boss 606 excluded
S−A	−0.16	69	Boss 606 excluded
A−D	+0.15	66	Boss 606 excluded

Probable Errors.—The average error, or mean deviation, was found for each star with respect to each estimate individually and to the weighted mean. In Table V the probable errors[18] corresponding to these average errors are set forth. Boss 606 is not included; if it were the errors would all be increased by 5% to 10%.

TABLE V

Summary of Probable Errors

	r	N	Remarks
S−1	±0.75	64	
S−2	0.59	30	
S−3	0.67	49	
S−4	0.74	26	
S−5	0.57	49	
S−6	0.67	42	
S−7	0.76	49	
S−D	0.52	73	
S−A	0.60	69	
A−D	0.45	65	
S−D	0.48	71	Boss 3960, 6031 omitted
S−A	0.57	67	Boss 3960, 6031 omitted

It is gratifying to find that the probable error of the luminosities determined in the present investigation is somewhat less than that of the Mt. Wilson results. In their determination of luminosities of later type stars the probable errors vary for various types from ± 0.64 to ± 0.00, the average probable error being given as $\pm 0^{m}.40$.[19] That the corresponding figure in the case of the more difficult A type stars should be as low as $\pm 0^{m}.5$ seems to be all that can be hoped for at the present stage of our knowledge of the complex conditions which evidently exist in atmospheres of stars of this interesting class.

Theoretical Considerations.—While it must be explicitly understood that the relationships that have been obtained are empirical, it is also to be remembered that there is a theoretical basis for relationships of the kind found. Considering first the question of the *width* of an absorption line, there are at least four points to be taken into account:

(*a*) Minimum width
(*b*) Doppler widening
(*c*) Rayleigh scattering
(*d*) Stark effect.

(*a*) For a given instrument and a given slit width, there is a minimum width to be expected for an absorption line of any given wave length. For the Bruce Spectrograph with slit width 0.05 mm. and the ratio $f/D=19$ the minimum width of λ4481 on a 1-prism plate has been calculated by O. Struve[9] to be 0.68A. This is based upon the theories of Schuster[20] and Newall[21] who find that two lines cannot be resolved into separate lines if the difference in the wave length, $d\lambda$ is less than λ/P or at most, $\lambda/2P$, where P the purity of the spectrum is some fraction of the resolving power, R. This $P=pR$ where $0<p<1$. If the slit were of infinitely narrow width then $p=1$ and $P=R$. For the case under consideration, the value of p is believed to lie between 1/6 and 1/7. A glance at the graphs (Figs. 1-3) shows that the lowest measured values are just about at the calculated minimum, the great majority lying well above.

(*b*) A line may be considerably widened as a result of Doppler shifts due to the translatory motion of the radiating and absorbing atoms. That this is not the main cause of widening is evident from the observed fact that line width tends to increase as temperature decreases and pressure increases in the stellar atmosphere. If the widening were chiefly dependent upon thermal agitation the reverse would be true. Stewart,[22] following the treatment of this question by Lorentz, believes the Doppler effect to be negligible except in the case of hydrogen where it may become appreciable though not dominant.

(*c*) An important factor in producing width is undoubtedly *Rayleigh scattering*, "the intrinsic lack of sharpness in the 'tuning' of the active (scattering) molecules." This does not involve "absorption" in the restricted use of the word advocated by Stewart[23] who limits absorption to cases involving transformation of radiant to thermal energy. Scattering does not involve such transformation. The radiant energy taken up momentarily by an atom is re-radiated without important change in frequency and the resultant opacity is due to diffusion in direction of the incident beam of radiation.

Stewart deduces the relation for line width Δ

$$\Delta = 5.8\ 10^{-13}\lambda/\sqrt{n}$$

where n is the number of atoms in a column of 1 cm² cross section in the line of sight above the reversing layer. Thus it is evident that the greater the density of the stellar atmosphere the greater the width of the absorption line, a relation borne out by the graphs in Figs. 1-3.

(*d*) Merton[24] was perhaps the first to draw attention to the broadening effect which will be produced in star spectra by the natural influences of their own *electric and magnetic* fields upon the radiating and absorbing particles. Conditions in the stellar atmosphere, producing closer packing and frequent collisions will thus be accompanied by widening of the absorption lines due to Stark effect and to abnormal electron orbit distortions.

Hulbert[26] has discussed the breadth of the Balmer lines of hydrogen in the stellar spectra by combining the Stark theory with the Saha theory of high temperature ionization. He finds that the observed width in *A*-type stars far exceeds the theoretical width unless either the pressure is equivalent to several atmospheres or there are a very large number of free electrons present. The former assumption is ruled out on many astrophysical grounds, the latter is quite admissible.

The effect of *stellar rotation* may well be a disturbing factor. Lack of observational data renders the question incapable of rigorous treatment, but it may be pointed out that the rate of rotation would tend to increase as a star lost mass through radiation. It is however linear velocity at the extremity of a diameter and not merely angular velocity that affects line width and furthermore the orientation of the star relative to the line of sight is of the utmost importance.

Other causes of broadening are mentioned by Rayleigh,[25, 27] as, for example, the possible rotation of the radiating particles, but it is probable that in general none of these effects become of primary importance.

When we come to investigate the theoretical basis for correlations such as those in Figs. 4-7, the *ratio* is found, in every case, to be that of an *arc* to a *spark* line or vice versa. Indeed these lines were selected with this in mind, because it is an obvious fact that conditions which weaken an arc line may enhance a line arising from an ionized atom. In the early type stars where effective temperature is high and pressure low there is a high degree of ionization, and the proportion of neutral atoms is low. As pressure increases and temperature falls, which corresponds roughly to lower luminosity, the amount of ionization falls off and the intensity of the arc lines is increased. This increase will, of course, not continue indefinitely, there being a definite set of conditions corresponding to maximum intensity for any line. Fowler and Milne,[28,29,30] have evaluated this in terms of the ionization potential, the energy of the given excited state, the partial electron pressure and various constants.

The lines involved in this investigation are the following: λ4215.5 is due to once ionized strontium and has the series relation[31] $1s^2-1p^2$.

λ4226.7 from the normal calcium atom has the series relation $1S-1P$. It grows gradually stronger through the A, F, G, M stars. It is unblended and a very satisfactory basis for comparison.

λ4233 is less simple. It is a blend of ionized iron (Fe^+ λ4233.16) $2p^4-1d'^4$, and normal iron (Fe λ4233.6) $1d'^7-md^7$. In general its behaviour is that of a spark line in the A stars, but an occasional anomalous intensity may be due to complications arising from the blend. Near it are two manganese lines λ4235.2, λ4235.1 of type $1d^4-1p'^4$; but blending with these could only occur in extreme cases of stars having line characteristic *n*.

λ4481 arising from ionized magnesium has series relation $2d^2-3f^2$. It is a close doublet λλ4481.33, 4481.13. It is an admirable line to study being visible on every spectrogram and well situated in the region of best definition and intensity. It is said to reach maximum[32] at A2, its subsequent rise being attributed by C. H. Payne to blending with iron which predominates in the cooler stars. As the present writer is not interested in relative intensities of any one line at different spectral classes but in ratios of two lines, it is sufficient for the present purpose that the intensity of λ4481 increases less rapidly than the intensity of λ4535 and λ4549.

λ4535 is due to neutral titanium. ($1f^5-2f'^5$) Four Ti lines seem to fall close together here: λλ4536.00, 4535.92, 4535.58, 4534.78, the last two being the strongest according to laboratory intensity estimates.

λ4549 appears to be a blend of lines of different kinds; neutral titanium gives rise to λ4548.77 ($1f^5-2f'^5$) of laboratory intensity (35), while ionized titanium has a line at λ4549.64 ($1h^2-1g'^4$) intensity (25) and ionized iron gives λ4549.48 ($2f^2-1d'^4$) intensity (4). Adams describes this line as Fe^+ Ti^+ but the writer's data go to prove that the blend as a whole behaves as an unionized line, the ratio λ4549/λ4481 growing greater as luminosity diminishes.

Thus it is to be expected that the ratios λ4215/λ4227 and λ4233/λ4227 will have a negative slope, whereas the ratios λ4535/λ4481 and λ4549/λ4481 will have a positive slope as in Figs. 4-7. There is certainly no theoretical basis for straight line relations, but the data at the writer's disposal warranted no other more complicated representation.

Correlation Curves.—The writer believes this to be the first time that definite relations have been obtained for the width of K and the width of Hδ with absolute magnitude. That these are real relations seems undoubted.

In the case of Fig. 1 the Bravais-Pearson correlation coefficient has been evaluated for each curve. Let x be the deviation of the individual star magnitudes from the weighted mean and y the corresponding deviation of line width, then the *correlation coefficient* is given by

$$\frac{\Sigma xy}{\sqrt{\Sigma x^2 \cdot \Sigma y^2}}.$$

In the case of Fig. 2, it has been evaluated for the main curve ($A0-F0$). The results are as follows:

Width K (n)	0.67	Prob. error	±0.067
" K (sn)	0.67	" "	±0.063
" Hδ($A0-F0$)	0.68	" "	±0.074

In the application of all these correlation curves, it is evident that uncertainty may easily arise as a result of their multiple character. In general, it has been found that a glance at the spectrogram, or the brief description of it on the writer's records, was sufficient to indicate the general brightness and hence to determine which curve was most applicable in the case of each criterion. Where uncertainty remained, and either one of two curves seemed equally applicable, the usual procedure adopted was to take the mean, and in general to weight this lower than unique values from other criteria.

These curves are definitely *not* built up upon spectral classification, and therefore in so far as the writer has been successful in eliminating the influence of spectral class from the mind in interpreting the curves, the resulting absolute magnitudes should be something more than just averages for spectral class as are the Mt. Wilson[2] and Arcetri[10] determinations of magnitudes of A stars.

PART II

RESULTS AND DISCUSSION

The correlation curves obtained and tested as described in Part I, have been employed to give values of the absolute magnitudes of some 170 stars for which trigonometric or cluster parallaxes are not available.

The weighting of the values from each criterion was done as already described and the weighted mean value alone is recorded in Table VI. In some cases where the data were very meagre it was thought best to exclude these stars pending further study; they belong in most instances to the group Aon which are by far the most difficult to handle in the light of the present investigation.

Table VI contains the spectroscopic absolute magnitudes and parallaxes of two hundred A stars as determined by the writer. In addition to these, six stars are included which belong to the set of standard stars upon which the correlation curves were based, but for these six reliable determinations from the present criteria were impossible.

Successive columns of Table VI give (1) the Boss Number (Preliminary General Catalogue); (2) the visual apparent magnitude; (Henry Draper Catalogue); (3) the reduced proper motion, H; (4) (5) the absolute magnitude, M, and parallax, p, as determined trigonometrically (T) or by group motion (G); (6) (7) (8) the spectral class, spectroscopic absolute magnitude and parallax as determined at Mt. Wilson; (9) (10) (11) the class and spectroscopic M and p as determined by the writer from the Yerkes Observatory spectrograms. The designation "Yerkes" cannot be given to these three columns as might at first glance seem more appropriate, because to do so would be to set the official stamp of approval of that institution upon these results. For defects in this work the Yerkes Observatory is in no way responsible and criticisms of these results must be borne solely by the writer.

TABLE VI

SPECTROSCOPIC MAGNITUDES AND PARALLAXES OF 200 A STARS

Boss	H.D. m	H	Trig. or Gr.		Mt. Wilson			Douglas		
			M	p	Class	M	p	Class	M	p
				″			″			″
10	2.2	3.8	..	..	A1n	1.1	0.060	A1n	1.0	0.059
43	4.4	3.0	..	..	A1n	1.5	.026	A3n	1.7	.029
50	4.5	..	0.6	0.017T	A0n	1.1	.021	A0n	0.2	.014
145	5.0	2.8	..	..	..	..	..	A1n	1.3	.018
154	5.5	2.7	..	..	A2s	1.1	.014	A1s	0.9	.012
203	3.9	4.9	1.5	.033T	..	..	..	A6n	2.0	.042
246	5.2	6.4	..	..	..	..	..	A4n	2.2	.025
269	4.9	2.1	..	..	..	..	..	A4n	1.6	.022
295	5.3	4.0	..	..	A1n	1.5	.018	A2n	1.4	.017
300	4.7	..	0.9	.017T	..	..	..	A2n	2.3	.033
314	2.8	5.2	..	..	A3n	2.0	.068	A5n	2.5	.087
368	5.5	6.2	..	..	..	..	..	A5n	2.5	.025
370	5.5	4.2	..	..	..	..	..	A2s	0.9	.012
422	4.8	5.5	..	..	..	..	..	A0n	0.7	.015
423	4.8	5.5	..	..	..	..	..	A2s	0.6	.014
428	2.7	..	1.9	.068T	..	..	..	A5s	1.9	.069
441	4.8	..	2.1	.029T	..	..	..	A7n	2.1	.029
446	4.7	..	1.2	.020T	A4s	2.0	.029	A3n	2.0	.029
449	4.1	2.3	..	..	A1n	1.1	.025	A1s	1.2	.026
452	5.4	6.2	..	..	..	..	..	A1n	1.4	.016
463Ft	5.2	..	..	..	A3n	1.8	.022	A3s	1.5	.018
463Br	4.3	2.1	..	..	..	..	..	A3s	0.4	.017
466	5.4	2.2	..	..	A2n	1.5	.016	A1n	2.3	.024
476	5.1	3.2	..	..	..	..	..	A5s	1.9	.023
480	4.8	5.8	..	..	..	..	..	A1n	1.8	.025
482	3.1	..	−0.7	.017T	..	..	..	A3s	1.3	.044
522	5.1	3.9	..	..	A1n	0.9	.014	A0n	0.3	.011
550	4.6	0.5	..	..	A3s	1.4	.021	A3s	2.0	.030
560	4.3	2.3	..	..	..	..	..	A0n	0.8	.020
597	5.8	2.3	..	..	..	..	..	A2n	1.6	.014
606	5.4	..	−4.6	.001T	..	..	..	A1n	0.5	.010
628	5.2	6.0	..	..	..	..	..	A6s	2.4	.028
629	4.4	..	2.2	.036T	..	..	..	A7n	1.9	.032
666	5.3	..	..	..	A0n	1.1	.014	A0n	1.2	.015
674Br	5.3	1.4	1.6	.018T	A3s	1.0	.014	A2s	1.2	.015
677	5.2	4.4	..	..	..	..	..	A2n	1.1	.015
730	5.0	4.4	..	..	..	..	..	A1n	0.9	.015

TABLE VI—*continued*

Boss	H.D. m	H	Trig. or Gr.		Mt. Wilson			Douglas		
			M	p	Class	M	p	Class	M	p
				″			″			″
791	5.0	2.6	..	..	A0n	0.9	0.015	A0n	1.1	0.016
850	5.4	4.6	..	..	..	..	..	A4s	1.1	.014
883	5.4	5.7	..	..	..	..	..	A3n	2.5	.026
923	5.1	−0.5	..	..	..	..	..	A1s	0.5	.012
932	3.9	−1.8	..	..	..	..	..	A4s	1.0	.026
971	5.4	−1.1	..	..	..	..	..	A8s	2.5	.026
974	5.1	..	..	..	A1n	1.1	.015	A0n	1.2	.017
986	4.6	4.0	..	..	..	..	..	A0s	0.6	.016
998	5.3	4.2	..	..	..	..	..	A1s	0.3	.010
1007	5.3	..	2.4	0.027G	A9n	2.8	.031	A6n	2.0	.022
1022	4.8	..	2.1	.029G	A6n	2.4	.034	A5s	2.0	.028
1023	5.1	2.4	..	..	A3n	2.0	.017	A2n	2.1	.025
1026	4.4	4.6	1.3	.025G	A3s	1.8	.030	A2n	1.5	.026
1027	5.4	6.0	2.8	.030G	A3n	2.1	.022	A1n	1.7	.018
1029	4.2	..	1.3	.026G	A3s	1.4	.028	A3s	1.7	.032
1033	4.4	..	1.6	.028G	A2n	1.8	.030	A2n	..	..
1034	4.6	..	1.8	.028G	A0n	1.3	.022	A2n	..	..
1046	3.6	..	0.7	.026G	A3s	1.6	.042	A5s	1.7	.042
1047	5.1	..	2.3	.028G	A2n	2.0	.024	A4n	2.1	.025
1051	5.7	..	2.8	.026G	A3n	2.1	.019	A3n	2.6	.024
1054	4.8	..	2.1	.029G	A5s	2.0	.028	A5s	2.1	.029
1067	4.8	..	1.9	.027G	A2n	2.0	.028	A2n	1.2	.019
1087	4.3	..	1.6	.028G	A3n	2.1	.036	A3n	1.8	.032
1088	5.3	4.4	..	..	A4s	2.0	.022	A6s	2.3	.025
1090	4.9	..	1.6	.023G	A3n	2.2	.028	A3n	2.2	.029
1092	5.6	..	2.3	.023G	A5s	2.2	.020	A5s	2.5	.024
1095	5.0	3.3	..	..	A4s	1.7	.022	A3s	1.8	.023
1114	5.4	..	2.6	.029G	A8s	2.6	.027	A5n	2.1	.022
1117	5.4	..	1.4	.016T	..	..	..	A7s	1.9	.020
1122	5.4	..	1.9	.020G	A7s	2.2	.024	A6s	1.8	.019
1143	5.1	..	2.2	.026G	A2n	1.7	.021	A1n	1.7	.021
1153	4.5	1.7	..	..	..	..	..	A0n	1.9	.030
1194	4.7	..	1.6	.024G	A3n	2.1	.030	A4n	1.4	.022
1220	2.9	..	0.5	.033G	A1n	1.5	.052	A0n	1.6	.055
1244	5.1	1.1	..	..	..	..	..	A7s	2.6	.032
1268	5.2	1.2	..	..	..	..	..	A6s	2.3	.026
1352	5.3	3.0	..	..	..	..	..	A0n	1.3	.016
1392	4.9	3.4	..	..	..	..	..	A0n	0.9	.016
1452	5.3	2.3	..	..	..	..	..	A1s	0.7	.012

TABLE VI—*continued*

Boss	H.D. m	H	Trig. or Gr.		Mt. Wilson			Douglas		
			M	p	Class	M	p	Class	M	p
				″			″			″
1453	4.9	0.6	..	..	A2s	1.4	0.020	A1s	0.6	0.014
1482	2.7	..	−0.9	0.019T	A1s	0.6	.037	A1s	0.1	.030
1488	5.3	0.6	..	..	..	..	..	A0n	0.1	.009
1492	5.2	4.0	..	..	..	..	..	A7s	1.8	.022
1516	5.0	−2.6	..	..	..	..	..	A6s	3.2	.044
1575	4.4	..	1.5	.026T	A2s	1.2	.024	A1n	0.7	.018
1690	1.9	..	0.5	.053T	A2s	0.9	.063	A2s	0.3	.048
1714	5.1	5.1	..	..	..	..	..	A1n	1.4	.018
1716	4.9	1.8	..	..	A1n	1.1	.014	A1n	1.1	.017
1759	5.2	3.3	..	..	..	..	..	A0s	0.4	.011
1763	3.6	..	0.4	.023T	..	..	..	A0n	0.5	.024
1782	5.3	0.7	..	..	..	..	..	A4n	1.7	.019
1853	4.1	−0.7	..	..	..	..	..	A0n	0.5	.019
1886	3.6	..	1.5	.038T	A2n	1.5	.038	A2n	1.8	.044
1928	4.5	2.9	..	..	..	..	..	A1s	0.7	.017
1968	4.8	0.0	..	..	..	..	..	A8s	2.0	.028
1974	5.3	0.9	..	..	..	..	..	A5n	2.3	.025
2051	5.1	1.3	..	..	A7n	2.6	.031	A5n	2.0	.024
2078	5.0	3.4	..	..	A0n	1.1	.016	A1n	1.1	.017
2088	5.3	4.5	..	..	..	..	..	A0s	0.7	.012
2091	5.4	3.8	..	..	..	..	..	A1s	1.0	.013
2120	4.6	2.9	..	..	..	..	..	A0n	0.7	.017
2138	5.1	4.8	..	..	..	..	..	A0n	0.6	.013
2185	5.5	−1.0	..	..	A3n	2.0	.019	A3n	1.9	.019
2237	4.0	..	−0.6	.012T	A0n	0.9	.024	A0n	0.1	.017
2264	5.4	5.0	..	..	..	..	..	A6s	2.2	.023
2327	4.7	..	−0.3	.010T	..	..	..	A1n	0.4	.014
2339	5.6	3.0	..	..	..	..	..	A5s	1.2	.013
2398	5.5	5.5	..	..	..	..	..	A2n	2.0	.020
2404	3.1	..	2.9	.090T	A4n	2.2	.066	A4n	1.9	.058
2407	4.3	2.9	..	..	A4s	1.7	.030	A4s	1.8	.032
2479	3.8	..	−0.1	.017T	A1n	1.3	.032	A0n	..	..
2495	4.0	..	1.8	.037T	B9n	0.6	.021	A0n	1.9	.038
2559	4.5	1.6	..	..	..	..	..	A3n	1.9	.030
2584	5.2	1.7	..	..	A5n	2.4	.026	A5n	2.1	.024
2637	4.5	−0.7	..	..	A1s	0.9	.015	A2s	1.2	.022
2642	5.3	..	3.2	.039T	A5n	2.2	.024	A4n	2.3	.025
2655	5.3	1.6	..	..	..	..	..	A1n	0.0	.009
2692	4.5	3.1	..	..	A2n	1.8	.028	A2n	1.3	.023

TABLE VI—*continued*

Boss	H.D. m	H	Trig. or Gr.		Mt. Wilson			Douglas		
			M	p	Class	M	p	Class	M	p
				″			″			″
2697	4.5	1.9	..	..	..	..	..	A0s	0.0	0.013
2729	3.5	4.6	..	..	..	..	..	A4s	1.2	.035
2735	5.4	6.4	..	..	..	..	..	A7s	2.6	.028
2754	4.9	1.9	..	..	..	..	..	A3s	1.1	.017
2900	4.8	3.6	..	..	..	..	..	A0s	0.0	.011
2930	2.4	..	0.8	0.046G	A3s	1.0	0.054	A3s	0.3	.038
2932	4.4	..	0.1	.014T	..	..	..	A4s	0.2	.014
2972	2.6	..	2.2	.085G	A2n	1.7	.066	A1n	1.0	.048
2974	3.4	..	0.0	.021T	A2s	0.9	.032	A3s	0.2	.023
2987	4.8	4.8	..	..	A0n	0.7	.016	A1s	0.2	.012
2990	4.1	4.0	..	..	B9s	−0.2	.014	B9s	0.0	.015
3023	5.3	3.9	..	..	B9n	0.8	.012	B9n	0.4	.010
3063	5.5	6.4	..	..	A4n	2.0	.020	A6n	1.9	.019
3088	5.1	4.3	..	..	A1n	1.5	.019	A1n	1.2	.017
3097	5.2	3.7	..	..	A1n	0.8	.015	A1s	0.6	.012
3101	2.2	..	2.5	.114T	A2n	1.7	.079	A5s	2.4	.110
3117	2.5	..	0.6	.041G	A0n	0.9	.048	A0n	0.7	.044
3126	5.2	3.8	..	..	..	..	..	A0s	0.7	.013
3139	4.6	2.2	..	..	..	..	..	A3n	1.4	.023
3182	5.1	1.7	..	..	..	..	..	F0n	2.9	.036
3190	3.4	..	1.7	.045G	A0n	0.9	.032	A0n	..	..
3210	4.0	3.1	..	..	..	..	..	A2s	1.2	.028
3240	5.2	2.5	..	..	..	..	..	A6n	3.0	.036
3244	5.0	0.6	..	..	..	..	..	A4s	2.6	.033
3266	5.4	1.9	..	..	A3s	1.0	.014	A3s	1.0	.013
3277	5.4	5.0	..	..	B9n	0.6	.010	B9n	0.2	.009
3283	4.8	4.1	..	..	..	..	..	A0s	0.3	.013
3309	5.0	5.6	..	..	B9n	0.6	.014	B9n	0.4	.012
3310	5.5	5.0	..	..	B9n	0.6	.010	A0n	0.7	.011
3323	5.2	5.5	..	..	A6n	2.4	.027	A7s	2.4	.028
3354	5.8	3.0	..	..	..	..	..	A0s	0.4	.008
3356	5.3	2.8	..	..	..	..	..	A0n	0.2	.009
3370	5.4	7.3	..	..	..	..	..	A8s	3.3	.028
3371	2.9	..	1.1	.044T	A1s	0.6	.034	A1s	1.1	.044
3409	4.4	..	−0.4	.011T	A2s	0.9	.020	A2s	−0.3	.011
3450	5.1	2.3	..	..	..	..	..	B9n	0.3	.011
3474	2.4	..	0.6	.044G	A2s	1.1	.054	A2s	0.6	.044
3475	4.0	..	2.3	.046G	A8s	2.0	.052	A5s	1.8	.036
3480	4.0	..	2.1	.042G	A1n	1.1	.026	A1n	2.2	.044

TABLE VI—*continued*

Boss	H.D. m	H	Trig. or Gr.		Mt. Wilson			Douglas		
			M	p	Class	M	p	Class	M	p
				″			″			″
3506	4.9	..	0.6	0.014G	A3s	1.5	0.021	A5s	0.7	0.014
3508	3.4	5.7	..	..	..	..	..	A0n	0.9	.032
3509	5.5	1.7	..	..	..	..	..	A0n	0.8	.011
3512	4.6	5.6	..	..	..	..	..	A0n	0.7	.017
3518	4.9	..	3.5	.052T	A1n	1.5	.021	A1n	1.8	.024
3526	5.5	..	1.4	.015T	A7n	2.5	.018	A7n	2.5	.025
3530	5.3	6.2	..	..	..	..	..	A1n	1.0	.014
3561	5.5	6.4	..	..	..	..	..	A1s	0.6	.010
3612	4.3	1.9	..	..	A1n	1.1	.023	A0n	1.4	.026
3654	4.6	..	1.6	.025T	A4n	2.2	.034	A5n	1.8	.028
3666	4.3	..	2.4	.041T	A1n	1.1	.023	A0n	1.3	.025
3692	5.1	..	1.2	.017T	B9n	0.8	.014	B9n	0.9	.014
3722	3.0	4.3	..	..	A3n	2.0	.062	A5n	2.3	.072
3749	4.9	0.6	..	..	..	..	..	A2s	−0.3	.009
3752	4.4	..	0.4	.016G	A0n	0.9	.020	A0n	0.5	.017
3787	2.9	3.5	..	..	F1n	2.9	.100	A6n	2.2	.072
3911	5.5	1.7	..	..	A2n	1.5	.016	A2n	1.8	.018
3928	3.1	−0.7	..	..	..	..	..	A2s	1.5	.048
3939	5.1	5.0	..	..	..	..	..	A6s	2.5	.030
3960Br	4.2	..	−0.2	.013T	A4n	2.4	.044	A7n	2.7	.050
3961	2.3	..	0.3	.041G	A0n	0.9	.052	A1n	0.8	.050
3998	3.9	..	0.5	.021T	A0n	1.1	.026	A0n	0.8	.024
4004	5.5	4.5	..	..	..	..	..	A1s	0.5	.010
4009	3.7	..	0.6	.023G	A1n	1.1	.030	A0n	0.0	.018
4016	3.6	3.4	..	..	A0s	0.4	.022	A0s	1.0	.030
4022	5.8	0.8	..	..	A6s	2.3	.020	A8s	1.9	.017
4026	3.8	..	1.5	.035T	A6s	1.8	.042	A4s	1.7	.038
4068	5.2	5.2	..	..	A0n	0.9	.014	A0n	1.1	.015
4072	5.0	6.4	..	..	A5n	2.5	.032	A4n	1.8	.023
4081	4.8	1.0	..	..	..	..	..	A3n	1.5	.022
4229	5.6	2.5	..	..	B9s	0.4	.009	B9s	0.4	.009
4232	5.6	2.3	..	..	..	..	..	B9n	0.2	.008
4376	3.2	..	0.4	.028T	A0n	0.9	.035	A0n	1.0	.036
4581	3.7	..	1.5	.037T	A5s	1.8	.042	A5s	2.1	.048
4747	5.1	3.7	..	..	..	..	..	A1n	1.1	.016
4749	5.1	4.1	..	..	..	..	..	A1n	1.3	.017
4752	4.3	1.5	1.4	.026T	A5s	2.2	.037	A4s	1.5	.028
4754	5.9	2.6	3.3	.030T	A1n	1.5	.013	A1n	1.9	.016
4761	4.4	..	3.1	.056T	A2n	2.0	.034	A4n	2.6	.044

TABLE VI—*continued*

Boss	H.D. m	H	Trig. or Gr.		Mt. Wilson			Douglas		
			M	p	Class	M	p	Class	M	p
4802	4.5	2.7	..	..	..	..	..	A1n	1.3	0.023
4803	5.4	3.8	..	..	..	..	..	A1n	1.8	.019
4824	3.3	..	−1.3	0.012T	B9s	−0.2	0.020	B9n	−0.2	.020
4858	3.0	..	0.8	.037T	B9n	0.8	.036	B9n	...	..
4988	3.9	..	0.2	.018T	A1n	1.1	.028	A1n	1.0	.026
5048	3.0	..	1.7	.055T	A1n	1.1	.042	B9n	..	..
5062	0.9	..	2.5	.203T	A2n	1.7	.145	A1n	2.0	.166
5186	5.0	1.1	..	..	..	..	..	A1n	1.6	.021
5187	4.0	−4.6	..	..	..	..	..	B9s	0.6	.021
5337	3.8	..	0.6	.023T	A1n	1.6	.037	A1s	1.0	.028
5480	2.6	..	2.2	.084T	A2n	1.3	.056	A2n	2.5	.096
5600	3.0	..	3.3	.115T	A3n	2.2	.068	A6s	2.2	.069
6031	4.9	..	3.1	.043T	A3s	1.2	.018	A3s	0.7	.014

Comparison with Mt. Wilson Magnitudes.—Of the 200 stars in Table VI, 108 are also contained in the list of Adams and Joy.[2] Comparing the two classifications a close agreement is found as is to be expected; only occasionally is a star classed *n* or *s* by Mt. Wilson given the reverse class by the writer and the decimal subclass is seen to be rarely very different.

Taking the writer's *n* and *s* groups and comparing them with the Mt. Wilson values of absolute magnitude the systematic and probable errors were computed as follows:

TABLE VII

	Systematic error e	Probable error r	No. of Stars N
n	+0.07	±0.31	68
s	+0.14	±0.30	40
All	+0.09	±0.31	108

Thus it is seen that there is a fair agreement, the present magnitudes being systematically smaller by about $0^m.1$ or in other words, the stars are here given brighter than at Mt. Wilson by $0^m.1$.

Comparison with Arcetri Magnitudes.—Of the 81 stars in Table VI for which neither trigonometrical, group nor Mt. Wilson spectroscopic values exist, 22 were found amongst the 275 stars of early type determined by Abetti at Arcetri.[10] His values are given in Table VIII for comparison.

TABLE VIII

Spectroscopic Absolute Magnitudes

Boss	Abetti	Douglas	Remarks
597	1.7	1.6	
730	0.4	0.9	
850	0.9	1.1	
932	1.2	1.0	
971	2.4	2.5	Systematic error −0.027
1352	1.4	1.3	
1452	1.4	0.7	
1488	1.1	0.1	
1759	1.1	0.4	
1974	2.1	2.3	
2088	0.6	0.7	
2754	0.6	1.1	
3139	1.3	1.4	Probable error ±0.30
3182	1.8	2.9	
3283	0.4	0.3	
3354	0.4	0.4	
3356	0.4	0.2	
3749	0.8	−0.3	
3928	1.2	1.5	
3939	2.1	2.5	
4802	1.2	1.3	
4803	1.8	1.8	

Shajn Double Star Test.—As a means of testing the accuracy of spectroscopic parallaxes, Shajn[35] has made use of the relation which should exist between the apparent and absolute magnitudes of components of multiple star systems. Since the parallax should be the same for each component it follows that

$$\Delta M - \Delta m = 0$$

where ΔM is the difference in spectroscopic absolute magnitude

of the two components and Δm is their difference in apparent magnitude. Applying this test to the Mt. Wilson determinations Shajn finds that for 55 double stars of late type

$$\Delta M - \Delta m = \pm 0.28 \text{ to } \pm 0.48$$

while for 139 early type (B, A) doubles,

$$\Delta M - \Delta m = \pm 1.08 \text{ to } \pm 1.24$$

though it is only just to state that these figures hardly do Mt. Wilson justice since Shajn applied Mt. Wilson curves to obtain the magnitude of stars whose spectral classification he took as given by Harvard.

Attention having been called to Shajn's work by Dr. O. Struve, the writer compiled a list of A-type double stars of sufficient apparent magnitude and angular separation to allow of separate spectrograms being obtainable. By the courtesy of the Director, the writer was given permission to use the Yerkes 40-inch telescope throughout the week September 6th-13th, 1925, and every effort was made to obtain these spectrograms. Unfortunately, the nights were unpropitious and only seven plates were secured, but the Yerkes observers have very kindly taken spectrograms of several of these stars and sent them to the writer for examination. Thus it has been possible to apply Shajn's test to the star systems given in Table IX.

In two cases the deviation from zero is somewhat large. For the K Tauri pair, Mt. Wilson shows a departure from zero of −0.7, and Rasmuson's group parallaxes give magnitudes having a deviation +0.5. In the case of the ζ Lyrae pair the trigonometrical values are in good accord, deviation +0.3, but the Mt. Wilson magnitudes give a deviation −2.3.

For the eleven systems, however, the average deviation

$$\Delta M - \Delta m = \pm 0.34$$

is as low as can be expected considering the probable error involved in each determination.

TABLE IX

Boss	Name	Class	Spec. p	Spec. M	H.D. m	ΔM−Δm
			″			
422	5γ Arietis N	A0n	0.015	0.7	4.8	
423	" S	A2s	.014	0.6	4.8	+0.1
463	α' Piscium Ft	A3s	.018	1.5	5.2	
463	α^2 " Br	A3s	.017	0.4	4.3	+0.2
1026	65 K Tauri Br	A2n	.026	1.5	4.4	
1027	67 K^2 " Ft	A1n	.018	1.7	5.4	−0.8
3354	32′ H Camelopardi Ft	A0s	.008	0.4	5.8	
3356	32^2 " " Br	A0n	.009	0.2	5.3	−0.3
3370	12 α' Can. Ven. Ft	A8s	.028	3.3	5.4	
3371	12 α^2 " " Br	A1s	.044	1.1	2.9	−0.3
3474	79 ζ^1 Urs. Maj. (Mizar)	A2s	.044	0.6	2.4	
3475	79 ζ^2 " "	A5s	.036	1.8	4.0	−0.4
3480	80 g " " (Alcor)	A1n	.044	2.2	4.0	0.0
4229	16 Draconis Ft	B9s	.009	0.4	5.6	
4232	17 " Br	B9n	.008	0.2	5.6	+0.2
4747	ϵ' Lyrae Br	A1n	.016	1.1	5.1	
4749	5 ϵ^2 Lyrae	A1n	.017	1.3	5.1	+0.2
4752	6 ζ' Lyrae Br	A4s	.028	1.5	4.3	
4754	6 ζ^2 Lyrae Ft	A1n	.016	1.9	5.9	−1.2
4802	63 θ' Serpentis Br	A1n	.023	1.3	4.5	
4803	63 θ^2 " Ft	A1n	.019	1.8	5.4	−0.4
5186	30 o' Cygni Ft	A1n	.021	1.6	5.0	
5187	31 o^2 " Br	B9s	.021	0.6	4.0	0.0

Reduced Proper Motion and Magnitude.—Reduced proper motion is defined as the same function of apparent magnitude and proper motion as is absolute magnitude of apparent magnitude and parallax.

$$M = m + 5 + 5 \log p$$
$$H = m + 5 + 5 \log \mu$$

where μ is the total proper motion and H is the reduced proper motion. Since μ varies with distance as well as with space velocity, it seems logical to suppose that considered statistically M and H should exhibit a strong correlation. With this in mind the correlation coefficient was worked out rigorously from the data in Table VI, where values of H are recorded for 129 stars including all those for which no trigonometrical or cluster parallaxes are given.

Instead of finding a reasonable correlation the coefficient came out to be 0.030. This low value is not due to a few exceptional stars, but is thoroughly representative of the data, over half the stars having x and y deviations of opposite sign. Adams records a very close correlation between his spectroscopic parallaxes and proper motion, and Struve has demonstrated a like relationship in the case of the writer's parallaxes, concluding that there is all reason to say that these spectroscopic parallaxes agree perfectly with the expected distribution of μ, the remaining dispersion being due largely to the peculiar motions of the stars and in part to the probable error of the spectroscopic parallaxes. It thus seems that in the process of formation of the H function from μ the essence of the correlation with M is lost.

Some Problems of A Stars.—(1) It is disappointing that not one of the criteria is single-valued. In the stars of Class A we are face to face with a serious problem. Some as yet unknown or unrecognized factor is playing an important part in determining the character of the spectrum. Stars of this type are evidently at a critical stage of development, the transition from the giant stage to the dwarf stage. On the older theory of Russell[36],[37] this might be thought of as the transition from the state of a perfect gas to a denser state where the gas laws begin to break down, but since Eddington[38] has shown that the dwarf stars of the main sequence are probably to be regarded as also conforming to the perfect gas laws, on account of the high degree of ionization produced by their great central temperatures, it now becomes necessary to look elsewhere for the cause of complexity. Why do stars turn down the main sequence? Jeans[39] explains it in terms of the automatic reduction in the rate of production of radiant energy at the centre of a star when its central temperature exceeds about 30 million degrees. Fowler and Guggenheim[40] have given quantitative evidence in favour of the assumptions of Eddington and Jeans that at these temperatures there would be 99% ionization. As a star approaches complete ionization, its radiation will be unable to increase further. Though its central temperature will be maintained, its density will continue to increase, accompanied by an increase in the absorption coefficient, and thus luminosity will gradually fall off.

There is in this theory, however, no direct clue to the interpretation of the spectra of stars at the transition stage. The writer's material provides independent evidence that the Mt. Wilson subdivisions, *n* and *s* (according as the absorption lines are nebulous or sharp), are of the utmost importance in forming magnitude correlations but do not represent two distinct classes of stars, there being all gradations in line character from the extremely hazy and ill-defined to the extremely sharp, clean-cut, narrow line.

That there is some as yet unrecognized factor in the atmospheres of A stars seems certain. Harvard investigators have stressed this, pointing out that a one dimensional classification of A stars is inadequate.[41] The Henry Draper classification is based primarily upon the intensity of H and K and is consistent on this basis. Mt. Wilson investigators have adopted a different basis. If the helium lines $\lambda\lambda$4026, 4471, 4636 are showing in a Draper A0 star, they call it B9 and they classify the A stars chiefly by the number and intensity of the metallic lines without reference to the intensity of H and K. The writer followed Mt. Wilson fairly closely until gradually a personal classification was felt to be shaping itself. The presence of the helium " raies ultimes" was considered sufficient to warrant the designation B9, unless there were just a trace of these lines accompanied by well developed K. An A0 star usually showed only $\lambda\lambda$4481, 4227, 4233, 4215, 4549, 4535 with barest traces of anything else (except of course H, K, and the Balmer lines of hydrogen), and even these lines too weak in general for relative intensity estimates to be made. Growing intensity of these lines and the appearance of other metallic lines marked the A1 to A5 stars, but no star was classed by the writer later than A5 no matter how many lines were up unless the hydrogen lines were beginning to stand out less conspicuously. In an A5 star the hydrogen lines are sinking into comparability with the stronger metallic lines and in an F0 star there is equality between the outstanding metallic lines and the diminishing hydrogen lines.

(2) Shapley and Fairfield[34] found no correlation to exist between the width of hydrogen lines and absolute magnitude, but they found slight correlation between width and reduced proper motion for late B and early A stars, indicating that there is a tendency for narrow line stars to have low space velocities. No explanation has been hazarded. The present material throws some light on the question. The *n* and *s* stars must be dealt with separately at least in the case of Hδ—there being no apparent correlation between widths of *n*-lines with absolute magnitude, but a strong correlation in the case of the *s*-line stars (Fig. 2). This together with the failure to find a general correlation between M and H indicates the possibility that the suggested relationship with space velocity is illusory.

(3) A perplexing problem is presented by the stars of c-characteristic whose spectra exhibit lines so narrow and sharp as to resolve the usual HϵH blend into two distinct lines of independently measurable widths. Of the 250 stars studied, 10 stars fall into this class. Three of these stars have well-established parallaxes and in each case the writer's *M* was too low. That the present criteria failed badly in the case of Sirius shook faith in the applicability of these criteria to stars of this extreme class, and pending further study they have been omitted from Table VI.

(4) Certain stars have individual peculiarities which offer problems upon which as yet it is premature to attempt explanations. A few of these may be noted.

Boss 370. 43 ωCassiopaiae A2s. It is very unusual to find λ4535 equal to and λ4549 greater than λ4481, while simultaneously $\lambda\lambda$4215, 4233 are much more intense than λ4227.

Boss 1516. 17 Leporis A6s. λ4481 is very faint and a line at about λ4546 is very strong. This star has the H.D. class A0 which the writer finds difficult to understand for though the K line is certainly faint there are many metallic lines very sharp and intense and Hβ, Hγ, Hδ are waning.

Boss 3749. 29 πBoötis (Br) A2s. The line λ3984 is strong. It is probably the line of unknown origin recorded by Belopolsky[42] in αCanum Venaticorum and by Lockyer and Baxandall[43] in αAndromedae. Another unusual line to be outstanding is λ4137, a very weak Fe^{+} line undoubtedly blended with some line of unknown origin.[44]

Boss 476 12 K Arietis A5s
" 3409 51 θ Virginis A2s
" 3506 78 o " A5s
" 3561 84 Urs. Maj. Als

In these stars a pair of *chromium* lines are present with unusual intensity; they are Cr^+λλ4558.89, 4588.43.

Twenty-four *strontium stars* are amongst those in Table VI, remarkable for the intensity of the Sr^+line λ4215. The Boss number, the name, the writer's classification and magnitude, also the average magnitude for that class are given in Table X.

TABLE X

STRONTIUM STARS

Boss	Name	Class (D)	M (D)	$\overline{M}$ (D)	Remarks
370	ωCass	A2s	0.9	0.7	
423	γArie	A2s	0.6	0.7	
463	α^2 Pisc	A3s	0.4	1.1	Si+λλ4128,31 also strong
476	κ Arie	A5s	1.9	1.9	
550	^{2} Cass	A3s	2.0	1.1	
674	ϵ Arie	A2s	1.2	0.7	
677	−3° 470 Erid	A2s	1.1	0.7	Sr+ λ4078 also strong
850	+70° 257 Camel	A4s	1.1	1.4	
923	γ^9 Erid	A1s	0.5	0.7	Si+λλ4128,31 also strong
1117	4 Camel	A7s	1.9	2.3	Sr+λ4078 also strong
1122	+11° 646 Ori	A6s	1.8	2.3	Sr+λ4078 also strong
1268	19 Aur	A6s	2.3	2.3	
1453	ξ Aur	A1s	0.6	0.7	
1492	2 Monoc	A7s	1.8	2.3	Sr+λ4078 also strong
1968	97 G Pup	A8s	2.0	2.3	
2339	49 b Canc	A5s	1.2	1.9	Si+λλ4128,31 also strong
2932	60 b Leo	A4s	0.2	1.4	Si+λλ4128,31 also strong
3266	21 Com. Ber.	A3s	1.0	1.1	Sr+λ4078 also strong
3475	ζ^1 U. Maj.	A5s	1.8	1.9	
3506	o Virg	A5s	0.7	1.9	
3561	84 U. Maj.	A1s	0.6	0.7	
3749	π Boötis	A2s	0.3	0.7	very abnormal
4022	β Drac	A8s	1.9	2.3	Sr+λ4078 also strong
4026	ϵ Serp	A4s	1.7	1.4	
6031	κ Pisc	A3s	0.7	1.1	

The comparison between *M* and *m* indicates that on the whole the strontium stars are $0^m.24$ brighter than the average stars of the same spectral type, but the scantiness of the data makes generalizations dangerous. C. H. Payne,[45] arguing from proper motion relations and a few individual cases of dwarf strontium stars, concludes that there is no sufficient justification for the statement[46] that these stars are "distinctly brighter than the average." The writer has made as the criterion for the inclusion of a star in this class not any arbitrary scale of absolute line intensity but the one condition that λ4215>λ4227. As indicated in the Table, the other member of the Sr^+doublet λ4077.7 is sometimes also of outstanding intensity.

The *silicon stars* are represented by fifteen given in Table XI, one or both of the pair of Si^+lines λλ4128.1, 4131.1 being unusually prominent.

A comparison between the magnitudes of these stars and the mean magnitude for their respective classes indicates that they are brighter on the average by $0^m.5$.

TABLE XI

SILICON STARS

Boss	Name	Class (D)	M (D)	$\overline{M}$ (D)	Remarks
463	α^2 Pisc Br	A3s	0.4	1.1	4128,31 both strong
923	36 τ^9 Erid.	A1s	0.5	0.7	4128,31 both strong
998	56 Tauri	A1s	0.3	0.7	4128,31 both strong
1046	78θ^2 Tauri	A5s	1.7	1.9	4128 strong
1117	4 Camel	A7s	1.9	2.3	4128 strong
1482	37 θAurigae	A1s	0.1	0.7	4128,31 strong
2088	+79° 265 Camel	A0s	0.7	0.5	" "
2339	49b Cancri	A5s	1.2	1.9	" "
2754	30 H Urs. Maj.	A3s	1.1	1.1	" "
2900	45 ωUrs. Maj.	A0s	0.0	0.5	4128,31 prominent
2932	60b Leonis	A4s	0.2	1.4	4128,31 strong
3409	51 θVirginis	A2s	−0.3	0.7	4128,31 fairly strong
3474	79 ζUrs. Maj.	A2s	0.6	0.7	4128,31 fairly strong
3506	78 oVirginis	A5s	0.7	1.9	4128,31 strong
3749	29π Boötis Br	A2s	−0.3	0.7	4128,31 strong

It is worth noticing that frequently, though by no means always, do the lines of Si^+, Cr^+ and Sr^+ occur with unusual intensity in the same star. Evidently conditions favouring one, favour also the others, and the absence of any one or two given the third is a matter of the abundance of the element in the stellar atmosphere.

Mean Magnitude and Spectral Class.—One of the main problems of the A stars is the question as to whether it is possible to interpret the spectra with individual accuracy or whether the Mt. Wilson and Arcetri method of merely adopting the mean magnitude for spectral class is all that can be done at present.

This investigation has been a definite attempt to maintain the former position. How far it has been successful it is difficult to say. The following table together with Tables IV, V, present the evidence for and against the writer's claim that the magnitudes herein determined have a greater individual accuracy than can be obtained by following the Mt. Wilson and Arcetri methods. What is the true interpretation of this evidence, the writer is not in a position to say, the decision must rest with the critical astronomer.

TABLE XII

AVERAGE DEVIATION

Class	A–D				$\overline{\text{D}}$–D			
	n ±	N	s ±	N	n ±	N	s ±	N
B9	0.22	5	0.10	2	0.21	7	0.23	3
A0	.41	17	.60	1	.38	31	.27	9
A1	.34	15	.42	8	.43	29	.26	15
A2	.45	8	.56	5	.37	12	.51	10
A3	.18	6	.40	8	.31	10	.52	11
A4	.42	6	.30	3	.31	9	.51	8
A5	.43	6	.29	8	.20	8	.35	11
A6– –F0	.38	5	.22	5	.36	10	.32	17
All	0.37	68	0.36	40	0.37	116	0.37	84

In Table XII a comparison is given separately for the *n* and *s* stars between the average deviations of the present magnitudes (D) from the Mt. Wilson magnitudes (A) and from the mean magnitude ($\overline{\text{D}}$) per spectral class. As previously, N indicates the number of stars.

In Table XIII the mean absolute magnitudes for each spectral class are given. The Mt. Wilson figures are averages for the individual means of Adams and Joy.[47] The Arcetri figures are taken from Abetti's diagram,[48] upper full curves, the *s* and *sn* curves being averaged.

The general agreement is good. The Arcetri values are based on all the material available from every source, trigonometrical, group and spectroscopic data being all included and they are to be given greatest weight. The Mt. Wilson values are smoothed by graphical means from the original data of Adams and Joy[49] on 101 *n*-stars and 48 *s*-stars. The writer's values are here given unsmoothed. The group of A6-F0 includes only 5 stars that are later than A7.

TABLE XIII

AVERAGE ABSOLUTE MAGNITUDE

Class	Mt. Wilson		Arcetri		Douglas			
	n	s	n	s	n	N	s	N
B9	0.6	−0.2	0.6	0.3	0.3	7	0.3	3
A0	0.9	0.2	0.8	0.5	0.8	31	0.5	9
A1	1.3	0.6	1.1	0.7	1.3	29	0.7	15
A2	1.7	1.0	1.3	1.0	1.7	12	0.7	10
A3	2.0	1.3	1.5	1.1	2.0	10	1.1	11
A4	2.2	1.6	1.7	1.3	2.0	9	1.4	8
A5	2.3	1.8	1.8	1.5	2.2	8	1.9	11
A6 –F0	2.7	2.4	2.4	1.9	2.3	10	2.3	17
						116		84

Further Investigations.—This work is the preliminary to a more extensive investigation which the writer hopes to carry out in the near future, involving the whole of the A stars of which the Yerkes Observatory has spectrograms. With the permission of the Director of the Yerkes Observatory, many of the spectrograms studied in the course of this work will be re-studied and many others not yet measured will be examined. As Dr. J. S. Plaskett has remarked, the determination of spectroscopic magnitudes is a matter of closer and closer approximations towards the truth. In the light of greatly enlarged material, the criteria used in the present work will probably require modification and readjustment. It is hoped that new criteria may be found, especially in regard to the A0 stars, so many of which had to be omitted from the present list.

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SPECTROSCOPIC MAGNITUDES OF A-TYPE STARS

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ABSTRACT

A study of spectra of A-type stars has resulted in seven criteria being found by which absolute magnitudes and hence parallaxes may be determined. These criteria include both *widths* and *relative intensities* of *lines*. *Parallaxes* thus determined, when compared with trigonometric parallaxes and those from moving clusters and spectroscopic parallaxes from Mount Wilson and Arcetri, seem to indicate that a *greater individual accuracy* can be obtained by the use of such criteria than by adopting a statistical mean magnitude for each spectral subdivision.

INTRODUCTION

Absolute magnitudes of A-type stars have been determined spectroscopically at Mount Wilson, Arcetri, Upsala, and Yerkes observatories. Adams and Joy at Mount Wilson[1] and later Abetti at Arcetri[2] relied upon careful classification of the spectra into decimal subdivisions of class A and then the adoption of the statistical mean magnitude associated with each subclass. Lindblad[3] found that a comparison of the density of the regions $\lambda\lambda$ 3884–3907 and $\lambda\lambda$ 3907–3935 gave a correlation with absolute magnitude for stars of classes B8–A3. O. Struve[4] obtained relations between magnitude and the width of λ 4481 throughout the range of A stars.

During the summer of 1925, by the courtesy of the Director of the Yerkes Observatory, the writer was given the opportunity of making a study of the large collection of one-prism slit spectrograms of A stars taken with the Bruce spectrograph attached to the 40-inch refractor. The aim was to find several criteria for the determination of magnitude, and it was hoped that by the application of these a value of magnitude for a given star might be obtained upon which greater reliance might be placed than can be accorded to the average magnitude per spectral subclass.

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CRITERIA

The spectral regions studied by Lindblad are beyond the range of good definition on the Yerkes plates, so that this criterion was inapplicable. The method of taking the relative intensities of certain arc and spark lines, used with such success by many investigators in the case of stars of later type, was an obvious line of attack. In A0 stars the number of absorption lines is very limited, and of these the number of known origin and series relation which are unblended is yet smaller, so that the choice of lines theoretically suitable is not great. The writer was guided less by theory than by appearances in selecting the ratios λ 4215:λ 4227, λ 4233:λ 4227, λ 4535:λ 4481, λ 4549:λ 4481. But the choice was justified, for in each case correlations were found to exist between these ratios and absolute magnitude.[1] The estimates of ratio of intensity were made by eye, a low-power magnifying lens being used. No attempt was made to record a factor indicative of the intensity of individual lines, the ratio of the intensities of the two closely adjacent lines being estimated directly in the case of each of the four pairs.

The second natural line of attack is that of line width. There are strong theoretical grounds, chiefly involving Rayleigh scattering, that lead one to anticipate relations between line width and absolute magnitude. The writer has found such correlations in the case of λ 4481, $H\delta$, and the K line of calcium.[2] There are intangible factors, such as Doppler effects arising from stellar rotation or from atomic agitation, which might conceivably play an important rôle in disturbing any general relation. It seems unlikely that the ambiguity involved in the writer's relations is due to these causes since exactly similar ambiguities are present in the correlations with intensity ratios. Reference will be made to this again.

The material upon which the criteria are based consists of spectrograms of thirty-one stars of the Ursa Major and Taurus clusters for which reliable parallaxes have been determined by Rasmusson,[3] and also of forty-nine stars having known trigonometric parallaxes. Relative to these eighty stars the systematic error of the absolute magnitudes determined from the writer's seven criteria is found to be −0.04 mag. and the probable error of an individual magnitude, ±0.5 mag.

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[1] *Journal of the Royal Astronomical Society of Canada*, 20, 8, 1926. [2] *Ibid.*

[3] *Meddelanden från Lunds Astronomiska Observatorium*, Serie II, No. 26, 1921.

The spectra were all classified, as is done at Mount Wilson, according to the sharpness (s) or nebulosity (n) of the absorption lines and, provisionally, separate solutions were made for each group with respect to each of the seven criteria. In the case of $H\delta$, a strong correlation was found between its width and magnitude for the s group, but no correlation whatever was apparent in the case of the n group. For the other criteria both n and s groups yielded correlations. The ambiguity above referred to arises from the fact that not one of the criteria is single valued, the plotted data in each case falling into two or more groups, each of which could be fairly well represented by a linear solution. That this is the case both for the widths of absorption lines and for the ratios of intensities of pairs of lines points to some general complexity in the atmospheres of stars of class A.

MAGNITUDES AND PARALLAXES

By the application of the criteria above mentioned the absolute magnitudes and parallaxes of two hundred stars of classification B9–F0 have been determined from an investigation of the Yerkes spectrograms. These results are given in Table I, where for comparison, the corresponding values obtained by trigonometric, group motion, or Mount Wilson spectroscopic methods are also given. This number includes seventy-three of the eighty for which trigonometric or group parallaxes are known, and the probable error of ±0.5 mag. relative to these compares favorably with the probable error of ±0.4 mag. of the spectroscopic magnitudes of stars of later type as determined at Mount Wilson.

Among the two hundred stars are one hundred and eight whose absolute magnitudes have been determined at Mount Wilson. Comparison indicates that the writer's magnitudes are systematically less by 0.09 with a probable error of one difference of ±0.3. Another twenty-two stars not included above are found in the Arcetri list, and relative to these the writer's magnitudes show similar agreement—systematic error, −0.03; probable error, ±0.3.

In comparing the mean magnitude per spectral subclass, it should be remarked that the writer has not adopted the Henry

TABLE I

SPECTROSCOPIC MAGNITUDES AND PARALLAXES OF 200 A STARS

BOSS	NAME	H.D. m	TRIG. OR GR.		MT. WILSON			DOUGLAS		
			M	p	Class	M	p	Class	M	p
10	α And	2.2	......	......	A1n	1.1	0″.060	A1n	1.0	0″.059
43	θ And	4.4	......	......	A1n	1.5	.026	A3n	1.7	.029
50	σ And	4.5	0.6	0″.017T	A0n	1.1	.021	A0n	0.2	.014
145	π Cas	5.0	......	......	......	......	......	A1n	1.3	.018
154	+54°143	5.5	......	......	A2s	1.1	.014	A1s	0.9	.012
203	μ And	3.9	1.5	.033T	......	......	......	A6n	2.0	.042
246	41 And	5.2	......	......	......	......	......	A4n	2.2	.025
269	82 Psc	4.9	......	......	......	......	......	A4n	1.6	.022
295	89 Psc	5.3	......	......	A1n	1.5	.018	A2n	1.4	.017
300	υ Psc	4.7	0.9	.017T	......	......	......	A2n	2.3	.033
314	δ Cas	2.8	......	......	A3n	2.0	.068	A5n	2.5	.087
368	+42°345	5.5	......	......	......	......	......	A5n	2.5	.025
370	ω Cas	5.5	......	......	......	......	......	A2s	0.9	.012
422	γ Ari N	4.8	......	......	......	......	......	A0n	0.7	.015
423	γ Ari S	4.8	......	......	......	......	......	A2s	0.6	.014
428	β Ari	2.7	1.9	.068T	......	......	......	A5s	1.9	.069
441	λ Ari	4.8	2.1	.029T	......	......	......	A7n	2.1	.029
446	48 Cas	4.7	1.2	.020T	A4s	2.0	.029	A3n	2.0	.029
449	50 Cas	4.1	......	......	A1n	1.1	.025	A1s	1.2	.026
452	47 Cas	5.4	......	......	......	......	......	A1n	1.4	.016
463	α Psc Ft	5.2	......	......	A3n	1.8	.022	A3s	1.5	.018
463	α Psc Br	4.3	......	......	......	......	......	A3s	0.4	.017
466	ε Tri	5.4	......	......	A2n	1.5	.016	A1n	2.3	.024
476	κ Ari	5.1	......	......	......	......	......	A5s	1.9	.023
480	58 And	4.8	......	......	......	......	......	A1n	1.8	.025
482	β Tri	3.1	−0.7	.017T	......	......	......	A3s	1.3	.044
522	62 And	5.1	......	......	A1n	0.9	.014	A0n	0.3	.011
550	ι Cas	4.6	......	......	A3s	1.4	.021	A3s	2.0	.030
560	ξ Cet	4.3	......	......	......	......	......	A0n	0.8	.020
597	ν Ari	5.8	......	......	......	......	......	A2n	1.6	.014
606	33 Ari	5.4	−4.6	.001T	......	......	......	A1n	0.5	.010
628	38 Ari	5.2	......	......	......	......	......	A6s	2.4	.028
629	μ Cet	4.4	2.2	.036T	......	......	......	A7n	1.9	.032
666	−4°502	5.3	......	......	A0n	1.1	.014	A0n	1.2	.015
674	ε Ari Br	5.3	1.6	.018T	A3s	1.0	.014	A2s	1.2	.015
677	−3°470	5.2	......	......	......	......	......	A2n	1.1	.015
730	ζ Ari	5.0	......	......	......	......	......	A1n	0.9	.015
791	+54°684	5.0	......	......	A0n	0.9	.015	A0n	1.1	.016
850	+70°257	5.4	......	......	......	......	......	A4s	1.1	.014
883	+25°624	5.4	......	......	......	......	......	A3n	2.5	.026
923	τ^9 Eri	5.1	......	......	......	......	......	A1s	0.5	.012
932	ν Tau	3.9	......	......	......	......	......	A4s	1.0	.026
971	46 Tau	5.4	......	......	......	......	......	A8s	2.5	.026
974	+53°750	5.1	......	......	A1n	1.1	.015	A0n	1.2	.017
986	b Per	4.6	......	......	......	......	......	A0s	0.6	.016
998	56 Tau	5.3	......	......	......	......	......	A1s	0.3	.010
1007	58 Tau	5.3	2.4	.027G	A9n	2.8	.031	A6n	2.0	.022
1022	64 Tau	4.8	2.1	.029G	A6n	2.4	.034	A5s	2.0	.028
1023	66 Tau	5.1	......	......	A3n	2.0	.017	A2n	2.1	.025
1026	κ^1 Tau	4.4	1.3	.025G	A3s	1.8	.030	A2n	1.5	.026
1027	κ^2 Tau	5.4	2.8	0.030G	A3n	2.1	0.022	A1n	1.7	0.018

TABLE I—*Continued*

BOSS	NAME	H.D. m	TRIG. OR GR.		MT. WILSON			DOUGLAS		
			M	p	Class	M	p	Class	M	p
1029	68 Tau	4.2	1.3	0″.026G	A3s	1.4	0″.028	A3s	1.7	0″.032
1033	υ Tau	4.4	1.6	.028G	A2n	1.8	.030	A2n	......	......
1034	71 Tau	4.6	1.8	.028G	A0n	1.3	.022	A2n	......	......
1046	θ^2 Tau	3.6	0.7	.026G	A3s	1.6	.042	A5s	1.7	.042
1047	79 Tau	5.1	2.3	.028G	A2n	2.0	.024	A4n	2.1	.025
1051	80 Tau	5.7	2.8	.026G	A3n	2.1	.019	A3n	2.6	.024
1054	+15°637	4.8	2.1	.029G	A5s	2.0	.028	A5s	2.1	.029
1067	ρ Tau	4.8	1.9	.027G	A2n	2.0	.028	A2n	1.2	.019
1087	90 Tau	4.3	1.6	.028G	A3n	2.1	.036	A3n	1.8	.032
1088	51 Eri	5.3	......	......	A4s	2.0	.022	A6s	2.3	.025
1090	σ^2 Tau	4.9	1.6	.023G	A3n	2.2	.028	A3n	2.2	.029
1092	+7°681	5.6	2.3	.023G	A5s	2.2	.020	A5s	2.5	.024
1095	−12°955	5.0	......	......	A4s	1.7	.022	A3s	1.8	.023
1114	+10°621	5.4	2.6	.029G	A8s	2.6	.027	A5n	2.1	.022
1117	4 Cam	5.4	1.4	.016T	......	......	......	A7s	1.9	.020
1122	+11°646	5.4	1.9	.020G	A7s	2.2	.024	A6s	1.8	.019
1143	97 Tau	5.1	2.2	.026G	A2n	1.7	.021	A1n	1.7	.021
1153	ω Eri	4.5	......	......	......	......	......	A0n	1.9	.030
1194	ι Tau	4.7	1.6	.024G	A3n	2.1	.030	A4n	1.4	.022
1220	β Eri	2.9	0.5	.033G	A1n	1.5	.052	A0n	1.6	.055
1244	14 Aur	5.1	......	......	......	......	......	A7s	2.6	.032
1268	19 Aur	5.2	......	......	......	......	......	A6s	2.3	.026
1352	38 Ori	5.3	......	......	......	......	......	A0n	1.3	.016
1392	49 Ori	4.9	......	......	......	......	......	A0n	0.9	.016
1452	31 Cam	5.3	......	......	......	......	......	A1s	0.7	.012
1453	ξ Aur	4.9	......	......	A2s	1.4	.020	A1s	0.6	.014
1482	θ Aur	2.7	−0.9	.019T	A1s	0.6	.037	A1s	0.1	.030
1488	60 Ori	5.3	......	......	......	......	......	A0n	0.1	.009
1492	2 Mon	5.1	......	......	......	......	......	A7s	1.8	.022
1516	17 Lep	5.0	......	......	......	......	......	A6s	3.2	.044
1575	2 Lyn	4.4	1.5	.026T	A2s	1.2	.024	A1n	0.7	.018
1690	γ Gem	1.9	0.5	.053T	A2s	0.9	.063	A2s	0.3	.048
1714	26 Gem	5.1	......	......	......	......	......	A1n	1.4	.018
1716	12 Lyn	4.9	......	......	A1n	1.1	.014	A1n	1.1	.017
1759	36 Gem	5.2	......	......	......	......	......	A0s	0.4	.011
1763	θ Gem	3.6	0.4	.023T	......	......	......	A0n	0.5	.024
1782	−0°1487	5.3	......	......	......	......	......	A4n	1.7	.019
1853	22 Mon	4.1	......	......	......	......	......	A0n	0.5	.019
1886	λ Gem	3.6	1.5	.038T	A2n	1.5	.038	A2n	1.8	.044
1928	21 Lyn	4.5	......	......	......	......	......	A1s	0.7	.017
1968	−22°1897	4.8	......	......	......	......	......	A8s	2.0	.028
1974	δ^1 C Mi	5.3	......	......	......	......	......	A5n	2.3	.025
2051	4 Car	5.1	......	......	A7n	2.6	.031	A5n	2.0	.024
2078	φ Gem	5.0	......	......	A0n	1.1	.016	A1n	1.1	.017
2088	+79°265	5.3	......	......	......	......	......	A0s	0.7	.012
2091	85 Gem	5.4	......	......	......	......	......	A1s	1.0	.013
2120	−18°2118	4.6	......	......	......	......	......	A0n	0.7	.017
2138	8 Cnc	5.1	......	......	......	......	......	A0n	0.6	.013
2185	29 Lyn	5.5	......	......	A3n	2.0	.019	A3n	1.9	.019
2237	30 Mon	4.0	−0.6	.012T	A0n	0.9	0.024	A0n	0.1	.017
2264	2 U Ma	5.4	......	......	......	......	......	A6s	2.2	.023
2327	γ Cnc	4.7	−0.3	0.010T	......	......	......	A1n	0.4	0.014

TABLE I—*Continued*

Boss	Name	H.D. m	Trig. or Gr.		Mt. Wilson			Douglas		
			M	p	Class	M	p	Class	M	p
2339	49 Cnc	5.6	......	......	......	......	......	A5s	1.2	0″.013
2398	59 Cnc	5.5	......	......	......	......	......	A2n	2.0	.020
2404	ι U Ma	3.1	2.9	0″.090T	A4n	2.2	0″.066	A4n	1.9	.058
2407	α Cnc	4.3	......	......	A4s	1.7	.030	A4s	1.8	.032
2479	θ Hyd	3.8	−0.1	.017T	A1n	1.3	.032	A0n	......	......
2495	38 Lyn	4.0	1.8	.037T	B9n	0.6	.021	A0n	1.9	.038
2559	τ^2 Hyd	4.5	......	......	......	......	......	A3n	1.9	.030
2584	42 Lyn	5.2	......	......	A5n	2.4	.026	A5n	2.1	.024
2637	φ U Ma	4.5	......	......	A1s	0.9	.015	A2s	1.2	.022
2642	22 Leo	5.3	3.2	.039T	A5n	2.2	.024	A4n	2.3	.025
2655	31 U Ma	5.3	......	......	......	......	......	A1n	0.0	.009
2692	21 L Mi	4.5	......	......	A2n	1.8	.028	A2n	1.3	.023
2697	15 Sex	4.5	......	......	......	......	......	A0s	0.0	.013
2729	λ U Ma	3.5	......	......	......	......	......	A4s	1.2	.035
2735	ε Sex	5.4	......	......	......	......	......	A7s	2.6	.028
2754	30 U Ma	4.9	......	......	......	......	......	A3s	1.1	.017
2900	ω U Ma	4.8	......	......	......	......	......	A0s	0.0	.011
2930	β U Ma	2.4	0.8	.046G	A3s	1.0	.054	A3s	0.3	.038
2932	60 Leo	4.4	0.1	.014T	......	......	......	A4s	0.2	.014
2972	δ Leo	2.6	2.2	.085G	A2n	1.7	.066	A1n	1.0	.048
2974	θ Leo	3.4	0.0	.021T	A2s	0.9	.032	A3s	0.2	.023
2987	55 U Ma	4.8	......	......	A0n	0.7	.016	A1s	0.2	.012
2990	σ Leo	4.1	......	......	B9s	−0.2	.014	B9s	0.0	.015
3023	57 U Ma	5.3	......	......	B9n	0.8	.012	B9n	0.4	.010
3063	59 U Ma	5.5	......	......	A4n	2.0	.020	A6n	1.9	.019
3088	ξ Vir	5.1	......	......	A1n	1.5	.019	A1n	1.2	.017
3097	4 Vir	5.2	......	......	A1n	0.8	.015	A1s	0.6	.012
3101	β Leo	2.2	2.5	.114T	A2n	1.7	.079	A5s	2.4	.110
3117	γ U Ma	2.5	0.6	.041G	A0n	0.9	.048	A0n	0.7	.044
3126	η Crt	5.2	......	......	......	......	......	A0s	0.7	.013
3139	π Vir	4.6	......	......	......	......	......	A3n	1.4	.023
3182	+78°412	5.1	......	......	......	......	......	F0n	2.9	.036
3190	δ U Ma	3.4	1.7	.045G	A0n	0.9	.032	A0n	......	......
3210	η Vir	4.0	......	......	......	......	......	A2s	1.2	.028
3240	14 Com	5.2	......	......	......	......	......	A6n	3.0	.036
3244	16 Com	5.0	......	......	......	......	......	A4s	2.6	.033
3266	21 Com	5.4	......	......	A3s	1.0	.014	A3s	1.0	.013
3277	21 Vir	5.4	......	......	B9n	0.6	.010	B9n	0.2	.009
3283	23 Com	4.8	......	......	......	......	......	A0s	0.3	.013
3309	ρ Vir	5.0	......	......	B9n	0.6	.014	B9n	0.4	.012
3310	31 Vir	5.5	......	......	B9n	0.6	.010	A0n	0.7	.011
3323	32 Vir	5.2	......	......	A6n	2.4	.027	A7s	2.4	.028
3354	+84°289	5.8	......	......	......	......	......	A0s	0.4	.008
3356	+84°290	5.3	......	......	......	......	......	A0n	0.2	.009
3370	α^1 C Vn	5.4	......	......	......	......	......	A8s	3.3	.028
3371	α^2 C Vn	2.9	1.1	.044T	A1s	0.6	.034	A1s	1.1	.044
3409	θ Vir	4.4	−0.4	.011T	A2s	0.9	.020	A2s	−0.3	.011
3450	21 C Vn	5.1	......	......	......	......	......	B9n	0.3	.011
3474	ζ U Ma	2.4	0.6	.044G	A2s	1.1	.054	A2s	0.6	.044
3475	ζ^2 U Ma	4.0	2.3	.046G	A8s	2.0	.052	A5s	1.8	.036
3480	80 U Ma	4.0	2.1	.042G	A1n	1.1	.026	A1n	2.2	.044
3506	ο Vir	4.9	0.6	0.014G	A3s	1.5	0.021	A5s	0.7	0.014

TABLE I—*Continued*

Boss	Name	H.D. m	Trig. or Gr.		Mt. Wilson			Douglas		
			M	p	Class	M	p	Class	M	p
3508	ζ Vir	3.4	......	......	......	......	......	A0n	0.9	0″.032
3509	81 U Ma	5.5	......	......	......	......	......	A0n	0.8	.011
3512	24 C Vn	4.6	......	......	......	......	......	A0n	0.7	.017
3518	25 C Vn	4.9	3.5	0″.052T	A1n	1.5	0″.021	A1n	1.8	.024
3526	+11°2589	5.5	1.4	.015T	A7n	2.5	.018	A7n	2.5	.025
3530	82 U Ma	5.3	......	......	......	......	......	A1n	1.0	.014
3561	84 U Ma	5.5	......	......	......	......	......	A1s	0.6	.010
3612	τ Vir	4.3	......	......	A1n	1.1	.023	A0n	1.4	.026
3654	κ Boo	4.6	1.6	.025T	A4n	2.2	.034	A5n	1.8	.028
3666	λ Boo	4.3	2.4	.041T	A1n	1.1	.023	A0n	1.3	.025
3692	+9°2882	5.1	1.2	.017T	B9n	0.8	.014	B9n	0.9	.014
3722	γ Boo	3.0	......	......	A3n	2.0	.062	A5n	2.3	.072
3749	π Boo Br	4.9	......	......	......	......	......	A2s	−0.3	.009
3752	ζ Boo	4.4	0.4	.016G	A0n	0.9	.020	A0n	0.5	.017
3787	α^2 Lib	2.9	......	......	F1n	2.9	.100	A6n	2.2	.072
3911	+52°1869	5.5	......	......	A2n	1.5	.016	A2n	1.8	.018
3928	γ U Mi	3.1	......	......	......	......	......	A2s	1.5	.048
3939	10 Ser	5.1	......	......	......	......	......	A6s	2.5	.030
3960	δ Ser Br	4.2	−0.2	.013T	A4n	2.4	.044	A7n	2.7	.050
3961	α Cr B	2.3	0.3	.041G	A0n	0.9	.052	A1n	0.8	.050
3998	γ Cr B	3.9	0.5	.021T	A0n	1.1	.026	A0n	0.8	.024
4004	+52°1898	5.5	......	......	......	......	......	A1s	0.5	.010
4009	β Ser	3.7	0.6	.023G	A1n	1.1	.030	A0n	0.0	.018
4016	μ Ser	3.6	......	......	A0s	0.4	.022	A0s	1.0	.030
4022	β 946	5.8	......	......	A6s	2.3	.020	A8s	1.9	.017
4026	ε Ser	3.8	1.5	.035T	A6s	1.8	.042	A4s	1.7	.038
4028	36 Ser	5.2	......	......	A0n	0.9	.014	A0n	1.1	.015
4072	+55°1793	5.0	......	......	A5n	2.5	.032	A4n	1.8	.023
4081	π Ser	4.8	......	......	......	......	......	A3n	1.5	.022
4229	16 Dra	5.6	......	......	B9s	0.4	.009	B9s	0.4	.009
4232	17 Dra	5.6	......	......	......	......	......	B9n	0.2	.008
4376	δ Her	3.2	0.4	.028T	A0n	0.9	.035	A0n	1.0	.036
4581	72 Oph	3.7	1.5	.037T	A5s	1.8	.042	A5s	2.1	.048
4747	ϵ^1 Lyr	5.1	......	......	......	......	......	A1n	1.1	.016
4749	ϵ^2 Lyr	5.1	......	......	......	......	......	A1n	1.3	.017
4752	ζ^1 Lyr	4.3	1.4	.026T	A5s	2.2	.037	A4s	1.5	.028
4754	ζ^2 Lyr	5.9	3.3	.030T	A1n	1.5	.013	A1n	1.9	.016
4761	111 Her	4.4	3.1	.056T	A2n	2.0	.034	A4n	2.6	.044
4802	θ^1 Ser	4.5	......	......	......	......	......	A1n	1.3	.023
4803	θ^2 Ser	5.4	......	......	......	......	......	A1n	1.8	.019
4824	γ Lyr	3.3	−1.3	.012T	B9s	−0.2	.020	B9n	−0.2	.020
4858	ζ Aql	3.0	0.8	.037T	B9n	0.8	.036	B9n	......	......
4988	ι Cyg	3.9	0.2	.018T	A1n	1.1	.028	A1n	1.0	.026
5048	δ Cyg	3.0	1.7	.055T	A1n	1.1	.042	B9n	......	......
5062	α Aql	0.9	2.5	.203T	A2n	1.7	.145	A1n	2.0	.166
5186	o^1 Cyg	5.0	......	......	......	......	......	A1n	1.6	.021
5187	o^2 Cyg	4.0	......	......	......	......	......	B9s	0.6	.021
5337	ε Aqr	3.8	0.6	.023T	A1n	1.6	.037	A1s	1.0	.028
5480	α Cep	2.6	2.2	.084T	A2n	1.3	.056	A2n	2.5	.096
5600	δ Cap	3.0	3.3	.115T	A3n	2.2	.068	A6s	2.2	.069
6031	κ Psc	4.9	3.1	0.043T	A3s	1.2	0.018	A3s	0.7	0.014

Draper classification but a personal classification following very closely that of Mount Wilson investigators. Hence it is satisfactory to find that the writer's average magnitudes both for *n* and *s* stars of each subclass show a very close agreement with the means adopted by Mount Wilson and by Arcetri.

A crucial test of the individual accuracy of certain magnitudes is that suggested by Shajn,[1] based upon the fact that the components of a binary system have the same parallax and should therefore have the same difference in their absolute magnitudes as in their apparent magnitudes. In other words, for each pair the following relation should hold:

$$\Delta M - \Delta m = 0 \ .$$

For twelve such pairs the values of absolute magnitude determined by means of the writer's criteria gave an average of

$$\Delta M - \Delta m = \pm 0.34 \ .$$

As this is within the probable error of individual values of M, the conclusion is that this test gives evidence in favor of the accuracy of this method of determining spectroscopic magnitudes.

One pair calls for special mention—Boss 4752, 4754 (ζ^1 and ζ^2 Lyrae). The trigonometric values of absolute magnitude are in good accord, but the spectroscopic magnitudes as determined at Mount Wilson lead to

$$\Delta M - \Delta m = -2.3 \ ,$$

while the writer's values lead also to a large discrepancy, -1.2. The type of the fainter component (A1*n*) is certainly earlier than that of the primary (A4*s*),[2] and its magnitude must therefore be very much greater than the average magnitude (1.3) for stars of class A1*n*. This represents a case where the method of mean magnitude per spectral subclass fails utterly. The present criteria are not completely successful, but they improve matters to some extent and at least give ΔM and Δm the same sign.

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[1] *Astrophysical Journal*, 62, 104, 1925.

[2] H.D. classification for ζ^1, ζ^2 Lyrae, A3, A3; Mount Wilson classification, A5*s*, A1*n*.

The natural expectation that any set of absolute magnitudes would show a correlation with the corresponding proper motions was confirmed by Mount Wilson investigators with regard to their spectroscopic magnitudes and by Dr. Struve with respect to the writer's magnitudes. But an attempt to find an analogous relation using reduced proper motion indicates that no such relation exists, the correlation coefficient evaluated rigorously for H and M in respect to one hundred and twenty-nine stars being 0.030. The applicability of the H function in this case evidently requires further investigation.

OUTSTANDING PROBLEMS

That the spectra of A stars present a peculiar problem has been stressed by Dr. Shapley[1] and others.[2] This investigation is a confirmation of the belief that there is present in the atmospheres of stars, at this critical stage of evolution, some unknown or at least unrecognized factor which plays a part in determining the nature of the spectra. What is the true significance of the *s* or *n* character of the lines in different spectra? Why are intense strontium and silicon lines so frequently associated with a spectrum having sharp lines? What factors are just balancing or merging their effects when a spectrum is neither distinctly *s* nor *n* but of so intermediate a character that two investigators will differ as to the group to which it belongs, while a third investigator meets the difficulty by calling it *sn?*

Perhaps a thorough study of the variations in the widths of lines associated with other spectral characteristics may lead eventually to the understanding of some of these problems.

A paper containing a more complete discussion of the results obtained for the individual stars studied, and the curves used in establishing the criteria, is published in the *Journal of the Royal Astronomical Society of Canada*, for October 1926, covering pages 265 to 302 of Volume **20** of that *Journal.*

McGill University, Montreal
October 1926

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[1] "Report of the Committee on Spectral Classification," *Transactions of the International Astronomical Union*, 2, 117, 1925.

[2] *Harvard Circular*, No. 264.

The St. Helena Observatory and Canadian Astronomy

by

A. VIBERT DOUGLAS

Had it not been for the negligence of Sir John Colborne and the apathy of Sir Francis Bond Head in failing to bring before the legislature of Upper Canada an offer from the Lords Commissioners of the Admiralty, Toronto might have had the first astronomical observatory in the New World.

IN 1825 the Honourable East India Company decided to establish an observatory on the island of St. Helena. Construction was completed in 1828. Observations began the following year under the direction of Manuel J. Johnson, Lieutenant, St. Helena Artillery, who published a Catalogue of 606 Principal Stars in 1835. But about this time a decision was made to close down the observatory, pack all the instruments, and ship them to Woolwich. On the abandoned site in 1840, the Royal Artillery set up a magnetic and meteorological observatory but this also was closed in May 1849 when the detachment of Royal Engineers was withdrawn from the island.

What has all this to do with Canada? The fact is that prior to 1835 no astronomical observatory existed in the whole of North or South America. No standard meridian line existed on this continent. For this reason, the Lords Commissioners of the Admiralty offered to send all the St. Helena instruments, seven packing cases of equipment, to Toronto if a small observatory could be built in Upper Canada. This would be a first for North America and a feather in the Canadian cap! But it was not to be—the pens of government scratch slowly and four years rolled by. In the meantime, Professor Albert Hopkins of Williams College returning from Europe late in 1835 brought with him a sidereal clock, a transit and some other instruments; and in the next few years several small observatories were established in the eastern United States.

My attention was drawn to some of these facts by a letter dated 17 July 1969 from Dr. E. M. Lindsay, Armagh Observatory. The observatory, which eventually received from Queen Victoria the George III collection of astronomical instruments from Kew, had evidently hoped for the instruments which were in the hands of the Admiralty after the closedown of the observatory on St. Helena, but the Chancellor of the Exchequer, Lord Mounteagle, wrote to the Chairman of the Board of Governors of Armagh Observatory, Lord John George Beresford (Arch-bishop of Armagh, protestant Primate of Ireland) that the St. Helena instruments were designated for Canada. At that time Dr. Romney Robinson, the Director of Armagh Observatory, 1823-82, wrote to Colonel Rawdon, M.P. on 30 November 1840 that Lord Mounteagle "was not perhaps aware that the project of a Canadian Observatory originated with me, that my memoir on the subject was adopted by the Admiralty, and that the instruments for Canada are not to be the Kew but the St. Helena set".

Dr. Lindsay concluded his letter to me with the sentence: "I wonder did this lead to the establishment of the first Observatory in Canada or did Robinson's plan to the Admiralty fall through?"

Early records of the British Treasury Board (Ms. Group 12, D12 v. 14-15) show two letters from George Harrison to the Storekeeper General. One dated 23 January 1817 concerns surveying instruments to be received from Mr. Pond, the Astronomer Royal, to be "properly packed and sent to Earl Bathurst's Office in order that they may be forwarded to America by the earliest opportunity". The second letter concerns astronomical instruments provided under the Treaty of Ghent and may have no bearing upon a project for Canada.

My next reference is to the *Journal*, House of Assembly, Upper Canada, where the record of proceedings for Friday, 13 December 1833, is as follows: "Agreeably to the order of the day. . . . The petition of John Harris of Woodhouse, in the London District, praying that the House would take into consideration the propriety of erecting an observatory at or near York."

That nothing came of these suggestions appears to be borne out by the following letters. From the Admiralty to A. W. Hay, Esq. (of the Colonial Office, London) dated 7 July 1835:

> Sir, I am commanded by the Lords Comm.^{rs} of the Admiralty who have had their attention drawn to the advantages which might be derived to scientific objects by the establishment of an Observatory in Canada, to request you will submit to the consideration of Lord Glenelg the propriety of promoting such an object.
>
> A chain of observatories connects the Western Shores of Ireland and of Spain with the Eastern Coast of New South Wales, and thus comprises one half of the Globe, while the other half is in this respect entirely destitute of any such indispensible way of furthering the purposes of Astronomy.
>
> Nor do the more immediate practical objects of Geography feel less the want of an Observatory in that wide interval, as no Standard Meridian nor any point to which comparative Observations may be referred exists throughout the whole Continent of America. The establishment of a small observatory in Upper Canada would supply this important desideratum which has been so strangely overlooked by the United States, and would thus reflect more honour on this Country.
>
> My Lords have been given to understand that the Observatory at St. Helena is about to be dismantled, and that the Instruments which have been in use there would be available for the proposed Observatory, thus reducing materially the expense to be incurred. Should Lord Glenelg see no objection to this arrangement my Lords would suggest that an Inventory of these Instruments should be furnished to this Dept. in order that it might be ascertained what further Instruments it would be necessary to procure for the purpose.
>
> I am (signed) C. Wood.

On 29 July 1835 Lord Glenelg wrote from Downing Street to Sir John Colborne:

> Sir, I have the honour to transmit to you herewith, copy of a Letter addressed to this Department by direction of the Lords Commissioners of the Admiralty recommending that a small Observatory should be established in Upper Canada for purposes of Science; and suggesting that in order to effect this object at the least possible expense, the Instruments which have been hitherto in use in the Observatory of St. Helena, (and of which a list is enclosed) should be transferred to Upper Canada. The Lords of the Admiralty have, as I understand, already communicated upon this subject with the Earl of Gosford. It only remains for me, therefore, to bring it under your notice, and to express to you the satisfaction which I should feel were it in my power to promote the important object which the Lords of the Admiralty have in view. I shall of course be happy to receive for their Lordships consideration any suggestions or information upon this subject which you may be able to afford whether derived from your own immediate experience, or from communication with persons of scientific pursuits within the Province.
>
> I have the honour to be, sir,
> Your most obedt. Servant,
> (signed) Glenelg.

The Inventory accompanying these letters lists 29 items but gives no information about the instruments as to aperture, focal lengths or maker.* In the Introduction to the St. Helena Catalogue the instruments are ascribed to Messrs. Gilbert of Leadenhall Street, London and the clock to Barraud. More details are given in a comprehensive inventory made at Greenwich in 1838 and signed by the Astronomer Royal, G. B. Airy.† Numerical data for three instruments are placed in brackets in the following list which is taken from a copy of the 1835 Inventory.

Inventory of Instruments belonging to the Observatory at St. Helena

1 Transit Instrument (object glass 3.8 inch, focal length 62 inch)
3 Astronomical Clocks
1 Portable Transit Instrument
2 Observing chairs
1 Magnetic Intensity Apparatus
1 Comet searcher
4 Thermometers
1 Celestial Globe
1 8-day Chronometer
2 Agrometers
4 Thermometers and 3 spare Tubes
2 Mountain Barometers with 1 Glass Cistern and 4 spare Tubes

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*Some of this information has been sent to me by Dr. A. G. Thoday, Deputy Keeper, Science Museum, South Kensington, London

†The Astronomer Royal always signed his name Airy, but the amanuensis who copied the inventory spelled it Airey.

1 Refracting telescope on Equatorial Stand (3 ft. 6 in. focal length, 2¾ in. aperture)
1 Mural Circle (4 ft. diam. with telescope 5 ft. in length with object glass 3.1 inch)
2 Horse Shoe Magnets
2 Bar ditto
1 Large Refracting Telescope and Stand
1 Altitude and Azimuth Circle
1 Refracting Telescope
1 Dipping Needle Apparatus
1 Sextant
1 Quadrant
1 case Mathematical Instruments—Incomplete
56 lb. Quick Silver
5 Tubes for Spirit Levels
1 Variation Transit Instrument

The regrettable lack of identifying numerical data in this list suggests that is was hurriedly compiled by a civil servant with no scientific training. But even so it is sufficiently imposing that, with the two stately letters quoted above, one might have expected prompt positive action from Sir John Colborne. One thing he did was to request R. H. Bonnycastle, Capt. Royal Engineers, Western District, Upper Canada, to furnish a report on a suitable site for an astronomical observatory. A five page memorandum from Bonnycastle dated 10 November 1835 extols Toronto as a desirable site: "It would be difficult to imagine a more eligible locality for a national observatory in the new World, in a favorable latitude, being nearly that of 45°." In the margin is written "Latitude of Toronto 43° 39′ 10″ N." The report waxes lyrical on the advantages Toronto affords:

> . . . a City increasing in a ratio unprecedented in the new World. Built on an immense basin of Lake Ontario, its littoral consists of a vast expanse of Water affording an unlimited horizon while the country behind it rises so little as to obscure none of the constellations visible in its latitude. . . . Its iso-magnetic line is nearly connected with that of apparently no variation which crosses Lake Ontario in its vicinity. . . . Its climate is unusually mild a continuance of excessive rigor rarely occurring whilst almost every other part of the Country during winter, is visited with the usual severity of that season in Canada, thus ensuring without difficulty the continuance of Astronomical and Meteorological observations, whilst the known purity of the Atmosphere would prevent injury to the more delicate parts of instruments.

Capt. Bonnycastle goes on to point out that Toronto would benefit "most materially by being the spot selected for unfolding the resources of British Science and if the observatory was connected with the projected university, its effects upon the education of the people would amply repay any outlay which the Mother Country might think fit to expend upon it and erect a monument of imperishable Glory for that Country."

Three possible sites are described. One is "in the new part of the City near where the proposed Military Establishment is to be erected, where the expanse of lake Ontario is uninterrupted, never frozen in winter and seldom subject to land fog." His second suggestion is "the proposed site for the University but as coal from Ohio is now coming into use as a fuel . . . the dense smoke will hereafter obscure the southern aspect." The third site he considers free of all objections, "the Island in front of the City near Gibraltar Point . . . the foundations of the building here would however require to be deep as the Island is sandy."

Seventeen years later Bonnycastle, then Sir Richard, published in London a book entitled *Canada, as it was, is, and may be* in which he erroneously states that "the Government in Sir John Colborne's time had interested the Admiralty and the Royal Society in the establishment of an Observatory," adding that this "has since been carried into effect at Toronto" where Ordnance officers, Captains Lefroy and Younghusband, were superintending magnetic and meteorological observations, Bonnycastle states that as early as 1806 a grant of £400 had been made for the advancement of science, a "splendid set" of "philosophical instruments" had been "sent out from home; which were so highly valued that, in 1832, when I was first quartered at Little York, few persons knew and still fewer cared anything about them, and they were found, venerable with dust and neglect, along with a valuable ecclesiastical library, in one of the rooms of the General Hospital . . ." He hopes this "splendid collection is housed in the Observatory". He then adds "I have some interest in this subject, having been almost the original suggester of the plan of making Toronto a part of a chain of posts of science across the British American territory, from St. John's in Newfoundland to the Pacific, north of the Columbia River, by which a constant succession of observations of the heavenly bodies would be going on within the ring of military occupation, with which Great Britain has encircled the world." (vol. I, p. 48)

Sir John Colborne did not submit to the Upper Canada Legislature the proposal contained in the July letters from the Colonial office and the Admiralty, but on 23 November 1835 he wrote to Lord Glenelg:

> There can be no doubt entertained that the establishment of the Institution contemplated by the Lords Commissioners of the Admiralty will confer the greatest honor on our Country. The clear atmosphere and equable temperature of the climate of Toronto appears peculiarly adapted for astronomical observations. If therefore His Majesty's Government decide on acting on the suggestion of the Lords Commissioners of the Admiralty, I should recommend that the Professor who may be appointed to superintend the Institution be directed to proceed to Toronto as soon as possible, and authorized to select a site for the Observatory.

Colborne then suggests that "the Professorship might be attached to the University of King's College, and the instruments lodged in Upper Canada College, till an observatory be constructed and prepared for their reception," and furthermore that the above mentioned person "should be able to adjust and fix the Instruments." In support of Toronto as the site Sir John enclosed a document from Mr. Dade, Professor of Mathematics at Upper Canada College as well as the Bonnycastle report. He made no offer to defray any of the expenses involved in erecting and maintaining an observatory.

In a letter dated 22 February 1836 the Secretary of the Admiralty, C. Wood, wrote to Sir George Grey at the Colonial Office: "I am commanded by their Lordships to acquaint you that they will feel obliged if you can obtain an estimate of the probable expenses of erecting an Observatory . . . and if you will ascertain whether the Assembly would defray the expense of any portion of the annual charge of maintaining it, with reference to the suggestion its being placed under the superintendance of the Professor of Astronomy of King's College."

On 29 February 1836 Lord Glenelg forwarded this request to Sir Francis Head in Toronto, adding that as "this Despatch can hardly reach you before the Prorogation of the Provincial Parliament, I apprehend that it will not be possible, at present, to ascertain whether the Legislature of Upper Canada would consent to assume the expense of erecting the Observatory or to defray the charge of its future maintenance." He asks, however, for "correct information as to the probability of the proposal meeting with the concurrence of the Legislature."

More than a year went by. Their Lordships' patience wore thin as this letter from Downing St., 14 June 1838, testifies: "I am directed by Lord Glenelg to acknowledge your letter of the 21st ultimo and to inform you in reply that on the 29th February 1836 Sir F. Head was directed to bring under the consideration of the Legislature of Upper Canada the proposals of H.M. Gov't . . . Lord Glenelg however has not received any report . . . He has therefore addressed a despatch respecting it to Sir George Arthur. Until the answer to that despatch shall be received his Lordship would recommend that the Astronomical Instruments . . . should be retained in the Royal Observatory at Greenwich."

The Lords Commissioners, however, made one more effort, dated 21 May 1838, and addressed to Sir George Grey, Colonial Office: "Sir, Mr. Airey [sic] the Astronomer Royal at the Observatory at Greenwich having reported that the seven cases received from Woolwich in September 1837 containing principally instruments from St. Helena have been opened and that having been completely repaired and again packed they are ready for any voyage. I am commanded by my Lords Commissioners of the Admiralty to send you herewith a list of the same and I am to request that you will be pleased to acquaint Lord Glenelg that these instruments intended to be sent to the Observatory at Toronto are now ready and that my Lords are desirous to know what steps have been taken in this subject in the Colony."

There is a revealing letter dated 8 October 1838 from James Fitzgibbon to the Honourable John Macaulay: "After receiving your note on Saturday I was unexpectedly detained at a Meeting of the District Magistrates on an important subject, relating to the land sold to the Presbyterian congregation, which at length [was] finally settled. In answer to the two inquiries in your note I have now to acquaint you that the Despatch No. 157 was not acted upon by the Assembly, not having been referred. Neither have any proceedings taken place in the assembly respecting a proposed Observatory at Toronto." He then says he was not aware of the offer by the Admiralty "nor do I know that any Member of the House knows anything on the subject. Altho' little versed in that science or the kindred sciences yet I cannot doubt but that so far removed as we are from other observatories our position is a good one for their advancement. Dr. Daubeny of Oxford, Professor of Mathematics I believe, was here in the summer of last year on a Scientific Tour, and I conversed much with him on those subjects. I am sure he would have rejoiced at the prospect of having such a scientific establishment here. . . ."

What the result of all this correspondence was it is very hard to say for another wind was blowing from a somewhat different direction. England had been a pioneer in studies of magnetism: William Gilbert (*De Magnete* 1600) and Edmund Halley (*Magnetic variations in the Atlantic 1698, 1699*). But the initiative had passed to the continent and in 1836 Baron Alexander von Humboldt wrote to the President of the Royal Society urging "the claims which magnetic science must be considered to have on a nation possessing such extensive dominions in all parts of the globe, and such unrivalled means of contributing to the advancement of physical sciences, by the formation of suitable establishments in the localities in which researches might best be carried on". In Dublin Professor Humphrey Lloyd, D.D., of Trinity College, set up a magnetic observatory and the next year a similar one was established at Greenwich. The British Association threw its weight behind Humboldt's recommendations and, with Major Edward Sabine, R.A., F.R.S., urged the establishment of four sites, "Canada and Van Diemen Island, as approximate to the points of greatest intensity of magnetic force in the northern and southern hemispheres; St. Helena as approximate to the point of least intensity on the globe; and the Cape of Good Hope, as a station where the secular changes of the magnetic elements presented features of peculiar interest".

An observatory had already been established by the Admiralty at Hobart, Van Dieman Land and the Government undertook to erect and equip the other three observatories. These were to be placed under the Ordnance Department and staffed by officers and soldiers of the Royal Artillery. The officers selected were Lieut. (afterwards General Sir) John Henry Lefroy for St. Helena and Lieut. Charles James Buchanan Riddell for Canada.

The Officer Commanding the Royal Engineers in Canada had his headquarters on St. Helen's Island, Montreal. To him Riddell came in the early autumn of 1839 with instructions to build the observatory in Montreal and commence both magnetic and meteorological observations as soon as possible. His staff of three non-commissioned officers and two gunners with forty-eight packages containing instruments weighing eight or ten tons followed him on a slower boat, 57 days at sea. They reached Quebec on November 1, but already on 18 October, Riddell had come to the conclusion that Montreal was unsuitable for the observatory owing to the magnetic character of the local rock and he decided to move to Toronto.

Here he obtained permission to set up a temporary observatory in an unused barracks of Old Fort York on Bathurst Street and on 25 November he reported this to the Military Headquarters, Montreal, with the further information that his detachment and all his instruments had arrived on the previous day. Throughout December and January he was busy requisitioning rations, fuel, candles, and building supplies, converting the barracks into living quarters and one room with pillars to support three magnetometers. This room he had plastered and fitted with double windows to maintain some approximation to constant temperature. On 20 February 1840 he reported to the Deputy Adjutant General Royal Artillery that he had commenced the regular series of magnetic observations. These he reported at intervals together with meteorological data including any observations of "shooting stars" and aurora to the Superintendent of colonial observatories, Col. Sabine at Woolwich.

Riddell had already approached the Bursar of Upper Canada College regarding a site for the permanent observatory on King's College property. "Two acres and four tenths of an acre" were granted to Her Majesty's Government early in 1840 for this purpose, the land to revert to the college in the event of the discontinuation of the magnetic observatory. The Governor General "was pleased to approve of the grant" in February and the erection of the observatory commenced as soon as weather permitted. Before the close of the year it was occupied and here it functioned until 1854. Lieut. Riddell's health gave cause for concern late in 1840 and in February he requested return passage to England. Lieut. C. Younghusband was given temporary charge until the arrival in 1842 of Lieut. J. H. Lefroy who was transferred from St. Helena to the magnetic observatory in Toronto with orders to carry out a magnetic survey of British North America, a project underwritten by the Royal Society.

This account of the founding of the magnetic observatory is based on a paper by the Librarian of the Meteorological Office, Toronto, A. D. Thiesson, in the *Journal of the Royal Astronomical Society of Canada*, v.34, (1940). In it, however, he makes no mention of the efforts of the Admiralty to establish an astronomical observatory at Toronto. But W. E. Harper in his chapter on the "History of Astronomy in Canada" in *A history of science in Canada*, ed. H. M. Tory, (Toronto: Ryerson Press, 1939), appears to assume a connection for he writes: "The financial condition in Upper Canada was not particularly rosy and so a site was acquired and the building erected in Toronto by the Imperial authorities in 1839. At first it was primarily a magnetic observatory but among the instruments received was a four-and-one-half-inch refractor, a mural circle of four feet diameter and other smaller accessories" (p. 88). These instruments, presumably, might have been part of the St. Helena consignment. The magnetometers certainly came from Woolwich and also the Adie barometer calibrated in August 1839 "at the Royal Society's Apartments Somerset House". This barometer was still the standard barometer for Canada in 1940 when the Controller, Meteorological Services of Canada, Mr. J. Patterson, reported to the Royal Meteorological Society of Canada on "A Century of Canadian Meteorology".

In this paper Patterson recounts the transfer of the Observatory from the authority of the British Ordnance Department to the Provincial Government in the Spring of 1853. The Legislative Council under pressure from the Canadian Institute and other scientific groups had agreed to accept the responsibility. Much of the equipment was purchased from the British Government for £428. Captain Lefroy sold some of his books and handed over his task to J. B. Cherriman, Professor of Mathematics and Natural Philosophy of the University of Toronto, who was made provisional Director. Two years later Professor Kingston came out from Cambridge as Director and Professor of Meteorology with a salary paid two-thirds by the Legislative Council and one-third by the University, the former defraying the expense of maintaining the observatory.

Cherriman replaced the log building with a stone building in which the magnetic and meteorological work and the time service were carried out until 1882 when the site was required for the McLennan Physics Laboratory. The University gave equivalent land just east of the present University College, and the observatory was re-erected there. Eventually meteorology became independent of the other services which went to the Dominion Observatory early in this century. The present Meteorological Service was established in its impressive Bloor Street building in 1909.

The University of Toronto retained the small observatory on its grounds and presumably it inherited what astronomical instruments remained of the 1839 equipment. Precise information on this point has not been forthcoming.

Until the spring of 1971 it has been a moot question whether Woolwich and Greenwich cooperated in equipping the first Canadian observatory or whether any St. Helena instruments ever came to this country. Lieut. Commander H. D. Howse, National Maritime Museum, Greenwich, believed that none came when we discussed this question at the History of Astronomy section of the International Astronomical Union recently. On 5 May 1971 he informed me that in the Astronomer Royal's report for 1849 Airy says he has at Greenwich "some of the St. Helena instruments; which are to be transferred to the Observatory that is to be erected at the Greenwich Hospital Schools". From records at the Schools in 1851 and as late as 1904 "it is evident that the Greenwich Hospital Schools Observatory contained Manuel Johnson's two principal instruments, a transit and mural circle made by Gilbert in 1827, together with a refracting telescope 42 inches in length, equatorially mounted".

"Where these instruments are today", commented Lt.-Cdr. Howse, "I do not know. I wish I did". Quite certainly they are not in Canada, nor ever were.

This historical quest has led ultimately to the sad conclusion that apathy in high places in 1835 and the following years deprived Canada of the fine sets of astronomical instruments so generously offered, instruments which had proved their value and efficiency in the observatory on St. Helena from 1828 to 1835. Thus, too, Canada forfeited the distinction of establishing the first astronomical observatory in the Americas. But thanks to the good offices of Alexander von Humboldt and Colonel Edward Sabine, Canada did get one of the very earliest observatories for magnetic and meteorological science.

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Had it not been for the negligence of Sir John Colborne and the apathy of Sir Francis Bond Head in failing to bring before the legislature of Upper Canada an offer from the Lords Commissioners of the Admiralty, Toronto might have had the first astronomical observatory in the New World.

IN 1825 the Honourable East India Company decided to establish an observatory on the island of St. Helena. Construction was completed in 1828. Observations began the following year under the direction of Manuel J. Johnson, Lieutenant, St. Helena Artillery, who published a Catalogue of 606 Principal Stars in 1835. But about this time a decision was made to close down the observatory, pack all the instruments, and ship them to Woolwich. On the abandoned site in 1840, the Royal Artillery set up a magnetic and meteorological observatory ~~but this also was closed in May 1849 when the detachment of Royal Engineers was withdrawn from the island.~~

What has all this to do with Canada? The fact is that prior to 1835 no astronomical observatory existed in the whole of North or South America. No standard meridian line existed on this continent. For this reason, the Lords Commissioners of the Admiralty offered to send all the St. Helena instruments, seven packing cases of equipment, to Toronto if a small observatory could be built in Upper Canada. This would be a first for North America and a feather in the Canadian cap! But it was not to be—the pens of government scratch slowly and four years rolled by. In the meantime, Professor Albert Hopkins of Williams College returning from Europe late in 1835 brought with him a sidereal clock, a transit and some other instruments; and in the next few years several small observatories were established in the eastern United States.

My attention was drawn to some of these facts by a letter dated 17 July 1969 from Dr. E. M. Lindsay, Armagh Observatory. The observatory, which eventually received from Queen Victoria the George III collection of astronomical instruments from Kew, had evidently hoped for the instruments which were in the hands of the Admiralty after the closedown of the observatory on St. Helena, but the Chancellor of the Exchequer, Lord Mounteagle, wrote to the Chairman of the Board of Governors of Armagh Observatory, Lord John George Beresford (Arch-bishop of Armagh, protestant Primate of Ireland) that the St. Helena instruments were designated for Canada. At that time Dr. Romney Robinson, the Director of Armagh Observatory, 1823-82, wrote to Colonel Rawdon, M.P. on 30 November 1840 that Lord Mounteagle "was not perhaps aware that the project of a Canadian Observatory originated with me, that my memoir on the subject was adopted by the Admiralty, and that the instruments for Canada are not to be the Kew but the St. Helena set".

Dr. Lindsay concluded his letter to me with the sentence: "I wonder did this lead to the establishment of the first Observatory in Canada or did Robinson's plan to the Admiralty fall through?" Sadler say it did fall through

Early records of the British Treasury Board (Ms. Group 12, D12 v. 14-15) show two letters from George Harrison to the Storekeeper General. One dated 23 January 1817 concerns surveying instruments to be received from Mr. Pond, the Astronomer Royal, to be "properly packed and sent to Earl Bathurst's Office in order that they may be forwarded to America by the earliest opportunity". The second letter concerns astronomical instruments provided under the Treaty of Ghent and may have no bearing upon a project for Canada.

My next reference is to the *Journal*, House of Assembly, Upper Canada, where the record of proceedings for Friday, 13 December 1833, is as follows: "Agreeably to the order of the day. . . . The petition of John Harris of Woodhouse, in the London District, praying that the House would take into consideration the propriety of erecting an observatory at or near York."

That nothing came of these suggestions appears to be borne out by the following letters. From the Admiralty to A. W. Hay, Esq. (of the Colonial Office, London) dated 7 July 1835:

> Sir, I am commanded by the Lords Comm.^{rs} of the Admiralty who have had their attention drawn to the advantages which might be derived to scientific objects by the establishment of an Observatory in Canada, to request you will submit to the consideration of Lord Glenelg the propriety of promoting such an object.
>
> A chain of observatories connects the Western Shores of Ireland and of Spain with the Eastern Coast of New South Wales, and thus comprises one half of the Globe, while the other half is in this respect entirely destitute of any such indispensible way of furthering the purposes of Astronomy.
>
> Nor do the more immediate practical objects of Geography feel less the want of an Observatory in that wide interval, as no Standard Meridian nor any point to which comparative Observations may be referred exists throughout the whole Continent of America. The establishment of a small observatory in Upper Canada would supply this important desideratum which has been so strangely overlooked by the United States, and would thus reflect more honour on this Country.
>
> My Lords have been given to understand that the Observatory at St. Helena is about to be dismantled, and that the Instruments which have been in use there would be available for the proposed Observatory, thus reducing materially the expense to be incurred. Should Lord Glenelg see no objection to this arrangement my Lords would suggest that an Inventory of these Instruments should be furnished to this Dept. in order that it might be ascertained what further Instruments it would be necessary to procure for the purpose.
>
> I am (signed) C. Wood.

On 29 July 1835 Lord Glenelg wrote from Downing Street to Sir John Colborne:

> Sir, I have the honour to transmit to you herewith, copy of a Letter addressed to this Department by direction of the Lords Commissioners of the Admiralty recommending that a small Observatory should be established in Upper Canada for purposes of Science; and suggesting that in order to effect this object at the least possible expense, the Instruments which have been hitherto in use in the Observatory of St. Helena, (and of which a list is enclosed) should be transferred to Upper Canada. The Lords of the Admiralty have, as I understand, already communicated upon this subject with the Earl of Gosford. It only remains for me, therefore, to bring it under your notice, and to express to you the satisfaction which I should feel were it in my power to promote the important object which the Lords of the Admiralty have in view. I shall of course be happy to receive for their Lordships consideration any suggestions or information upon this subject which you may be able to afford whether derived from your own immediate experience, or from communication with persons of scientific pursuits within the Province.
>
> I have the honour to be, sir,
> Your most obedt. Servant,
> (signed) Glenelg.

The Inventory accompanying these letters lists 29 items but gives no information about the instruments as to aperture, focal lengths or maker.* In the Introduction to the St. Helena Catalogue the instruments are ascribed to Messrs. Gilbert of Leadenhall Street, London and the clock to Barraud. More details are given in a comprehensive inventory made at Greenwich in 1838 and signed by the Astronomer Royal, G. B. Airy.† Numerical data for three instruments are placed in brackets in the following list which is taken from a copy of the 1835 Inventory.

Inventory of Instruments belonging to the Observatory at St. Helena

1 Transit Instrument (object glass 3.8 inch, focal length 62 inch)
3 Astronomical Clocks
1 Portable Transit Instrument
2 Observing chairs
1 Magnetic Intensity Apparatus
1 Comet searcher
4 Thermometers
1 Celestial Globe
1 8-day Chronometer
2 Agrometers
4 Thermometers and 3 spare Tubes
2 Mountain Barometers with 1 Glass Cistern and 4 spare Tubes

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*Some of this information has been sent to me by Dr. A. G. Thoday, Deputy Keeper, Science Museum, South Kensington, London

†The Astronomer Royal always signed his name Airy, but the amanuensis who copied the inventory spelled it Airey.

1	Refracting telescope on Equatorial Stand (3 ft. 6 in. focal length, 2¾ in. aperture)
1	Mural Circle (4 ft. diam. with telescope 5 ft. in length with object glass 3.1 inch)
2	Horse Shoe Magnets
2	Bar ditto
1	Large Refracting Telescope and Stand
1	Altitude and Azimuth Circle
1	Refracting Telescope
1	Dipping Needle Apparatus
1	Sextant
1	Quadrant
1	case Mathematical Instruments—Incomplete
56	lb. Quick Silver
5	Tubes for Spirit Levels
1	Variation Transit Instrument

The regrettable lack of identifying numerical data in this list suggests that is was hurriedly compiled by a civil servant with no scientific training. But even so it is sufficiently imposing that, with the two stately letters quoted above, one might have expected prompt positive action from Sir John Colborne. One thing he did was to request R. H. Bonnycastle, Capt. Royal Engineers, Western District, Upper Canada, to furnish a report on a suitable site for an astronomical observatory. A five page memorandum from Bonnycastle dated 10 November 1835 extols Toronto as a desirable site: "It would be difficult to imagine a more eligible locality for a national observatory in the new World, in a favorable latitude, being nearly that of 45°." In the margin is written "Latitude of Toronto 43° 39′ 10″ N." The report waxes lyrical on the advantages Toronto affords:

> . . . a City increasing in a ratio unprecedented in the new World. Built on an immense basin of Lake Ontario, its littoral consists of a vast expanse of Water affording an unlimited horizon while the country behind it rises so little as to obscure none of the constellations visible in its latitude. . . . Its iso-magnetic line is nearly connected with that of apparently no variation which crosses Lake Ontario in its vicinity. . . . Its climate is unusually mild a continuance of excessive rigor rarely occurring whilst almost every other part of the Country during winter, is visited with the usual severity of that season in Canada, thus ensuring without difficulty the continuance of Astronomical and Meteorological observations, whilst the known purity of the Atmosphere would prevent injury to the more delicate parts of instruments.

Capt. Bonnycastle goes on to point out that Toronto would benefit "most materially by being the spot selected for unfolding the resources of British Science and if the observatory was connected with the projected university, its effects upon the education of the people would amply repay any outlay which the Mother Country might think fit to expend upon it and erect a monument of imperishable Glory for that Country."

Three possible sites are described. One is "in the new part of the City near where the proposed Military Establishment is to be erected, where the expanse of lake Ontario is uninterrupted, never frozen in winter and seldom subject to land fog." His second suggestion is "the proposed site for the University but as coal from Ohio is now coming into use as a fuel . . . the dense smoke will hereafter obscure the southern aspect." The third site he considers free of all objections, "the Island in front of the City near Gibraltar Point . . . the foundations of the building here would however require to be deep as the Island is sandy."

Seventeen years later Bonnycastle, then Sir Richard, published in London a book entitled *Canada, as it was, is, and may be* in which he erroneously states that "the Government in Sir John Colborne's time had interested the Admiralty and the Royal Society in the establishment of an Observatory," adding that this "has since been carried into effect at Toronto" where Ordnance officers, Captains Lefroy and Younghusband, were superintending magnetic and meteorological observations. Bonnycastle states that as early as 1806 a grant of £400 had been made for the advancement of science, a "splendid set" of "philosophical instruments" had been "sent out from home; which were so highly valued that, in 1832, when I was first quartered at Little York, few persons knew and still fewer cared anything about them, and they were found, venerable with dust and neglect, along with a valuable ecclesiastical library, in one of the rooms of the General Hospital . . ." He hopes this "splendid collection is housed in the Observatory". He then adds "I have some interest in this subject, having been almost the original suggester of the plan of making Toronto a part of a chain of posts of science across the British American territory, from St. John's in Newfoundland to the Pacific, north of the Columbia River, by which a constant succession of observations of the heavenly bodies would be going on within the ring of military occupation, with which Great Britain has encircled the world." (vol. I, p. 48)

Sir John Colborne did not submit to the Upper Canada Legislature the proposal contained in the July letters from the Colonial office and the Admiralty, but on 23 November 1835 he wrote to Lord Glenelg:

but made no offer to erect a small obsy

> There can be no doubt entertained that the establishment of the Institution contemplated by the Lords Commissioners of the Admiralty will confer the greatest honor on our Country. The clear atmosphere and equable temperature of the climate of Toronto appears peculiarly adapted for astronomical observations. If therefore His Majesty's Government decide on acting on the suggestion of the Lords Commissioners of the Admiralty, I should recommend that the Professor who may be appointed to superintend the Institution be directed to proceed to Toronto as soon as possible, and authorized to select a site for the Observatory.

Colborne then suggests that "the Professorship might be attached to the University of King's College, and the instruments lodged in Upper Canada College, till an observatory be constructed and prepared for their reception," and furthermore that the above mentioned person "should be able to adjust and fix the Instruments." In support of Toronto as the site Sir John enclosed a document from Mr. Dade, Professor of Mathematics at Upper Canada College as well as the Bonnycastle report. He made no offer to defray any of the expenses involved in erecting and maintaining an observatory.

In a letter dated 22 February 1836 the Secretary of the Admiralty, C. Wood, wrote to Sir George Grey at the Colonial Office: "I am commanded by their Lordships to acquaint you that they will feel obliged if you can obtain an estimate of the probable expenses of erecting an Observatory . . . and if you will ascertain whether the Assembly would defray the expense of any portion of the annual charge of maintaining it, with reference to the suggestion its being placed under the superintendance of the Professor of Astronomy of King's College."

[illegible] [illegible] this time

On 29 February 1836 Lord Glenelg ~~forwarded this request~~ to Sir Francis Head in Toronto, adding that as "this Despatch can hardly reach you before the Prorogation of the Provincial Parliament, I apprehend that it will not be possible, at present, to ascertain whether the Legislature of Upper Canada would consent to assume the expense of erecting the Observatory or to defray the charge of its future maintenance." He asks, however, for "correct information as to the probability of the proposal meeting with the concurrence of the Legislature."

More than a year went by. Their Lordships' patience wore thin as this letter from Downing St., 14 June 1838, testifies: "I am directed by Lord Glenelg to acknowledge your letter of the 21st ultimo and to inform you in reply that on the 29th February 1836 Sir F. Head was directed to bring under the consideration of the Legislature of Upper Canada the proposals of H.M. Gov't . . . Lord Glenelg however has not received any report . . . He has therefore addressed a despatch respecting it to Sir George Arthur. Until the answer to that despatch shall be received his Lordship would recommend that the Astronomical Instruments . . . should be retained in the Royal Observatory at Greenwich."

The Lords Commissioners, however, made one more effort, dated 21 May 1838, and addressed to Sir George Grey, Colonial Office: "Sir, Mr. Airey [sic] the Astronomer Royal at the Observatory at Greenwich having reported that the seven cases received from Woolwich in September 1837 containing principally instruments from St. Helena have been opened and that having been completely repaired and again packed they are ready for any voyage. I am commanded by my Lords Commissioners of the Admiralty to send you herewith a list of the same and I am to request that you will be pleased to acquaint Lord Glenelg that these instruments intended to be sent to the Observatory at Toronto are now ready and that my Lords are desirous to know what steps have been taken in this subject in the Colony."

There is a revealing letter dated 8 October 1838 from James Fitzgibbon to the Honourable John Macaulay: "After receiving your note on Saturday I was unexpectedly detained at a Meeting of the District Magistrates on an important subject, relating to the land sold to the Presbyterian congregation, which at length [was] finally settled. In answer to the two inquiries in your note I have now to acquaint you that the Despatch No. 157 was not acted upon by the Assembly, not having been referred. Neither have any proceedings taken place in the assembly respecting a proposed Observatory at Toronto." He then says he was not aware of the offer by the Admiralty "nor do I know that any Member of the House knows anything on the subject. Altho' little versed in that science or the kindred sciences yet I cannot doubt but that so far removed as we are from other observatories our position is a good one for their advancement. Dr. Daubeny of Oxford, Professor of Mathematics I believe, was here in the summer of last year on a Scientific Tour, and I conversed much with him on those subjects. I am sure he would have rejoiced at the prospect of having such a scientific establishment here. . . ."

What the result of all this correspondence was it is very hard to say for another wind was blowing from a somewhat different direction. England had been a pioneer in studies of magnetism: William Gilbert (*De Magnete* 1600) and Edmund Halley (*Magnetic variations in the Atlantic 1698, 1699*). But the initiative had passed to the continent and in 1836 Baron Alexander von Humboldt wrote to the President of the Royal Society urging "the claims which magnetic science must be considered to have on a nation possessing such extensive dominions in all parts of the globe, and such unrivalled means of contributing to the advancement of physical sciences, by the formation of suitable establishments in the localities in which researches might best be carried on". In Dublin Professor Humphrey Lloyd, D.D., of Trinity College, set up a magnetic observatory and the next year a similar one was established at Greenwich. The British Association threw its weight behind Humboldt's recommendations and, with Major Edward Sabine, R.A., F.R.S., urged the establishment of four sites, "Canada and Van Diemen Island, as approximate to the points of greatest intensity of magnetic force in the northern and southern hemispheres; St. Helena as approximate to the point of least intensity on the globe; and the Cape of Good Hope, as a station where the secular changes of the magnetic elements presented features of peculiar interest".

linking The [illegible]

An observatory had already been established by the Admiralty at Hobart, Van Dieman Land and the Government undertook to erect and equip the other three observatories. These were to be placed under the Ordnance Department and staffed by officers and soldiers of the Royal Artillery. The officers selected were Lieut. (afterwards General Sir) John Henry Lefroy for St. Helena and Lieut. Charles James Buchanan Riddell for Canada.

The Officer Commanding the Royal Engineers in Canada had his headquarters on St. Helen's Island, Montreal. To him Riddell came in the early autumn of 1839 with instructions to build the observatory in Montreal and commence both magnetic and meteorological observations as soon as possible. His staff of three non-commissioned officers and two gunners with forty-eight packages containing instruments weighing eight or ten tons followed him on a slower boat, 57 days at sea. They reached Quebec on November 1, but already on 18 October, Riddell had come to the conclusion that Montreal was unsuitable for the observatory owing to the magnetic character of the local rock and he decided to move to Toronto.

Here he obtained permission to set up a temporary observatory in an unused barracks of Old Fort York on Bathurst Street and on 25 November he reported this to the Military Headquarters, Montreal, with the further information that his detachment and all his instruments had arrived on the previous day. Throughout December and January he was busy requisitioning rations, fuel, candles, and building supplies, converting the barracks into living quarters and one room with pillars to support three magnetometers. This room he had plastered and fitted with double windows to maintain some approximation to constant temperature. On 20 February 1840 he reported to the Deputy Adjutant General Royal Artillery that he had commenced the regular series of magnetic observations. These he reported at intervals together with meteorological data including any observations of "shooting stars" and aurora to the Superintendent of colonial observatories, Col. Sabine at Woolwich.

Riddell had already approached the Bursar of Upper Canada College regarding a site for the permanent observatory on King's College property. "Two acres and four tenths of an acre" were granted to Her Majesty's Government early in 1840 for this purpose, the land to revert to the college in the event of the discontinuation of the magnetic observatory. The Governor General "was pleased to approve of the grant" in February and the erection of the observatory commenced as soon as weather permitted. Before the close of the year it was occupied and here it functioned until 1854. Lieut. Riddell's health gave cause for concern late in 1840 and in February he requested return passage to England. Lieut. C. Younghusband was given temporary charge until the arrival in 1842 of Lieut. J. H. Lefroy who was transferred from St. Helena to the magnetic observatory in Toronto with orders to carry out a magnetic survey of British North America, a project underwritten by the Royal Society.

This account of the founding of the magnetic observatory is based on a paper by the Librarian of the Meteorological Office, Toronto, A. D. Thiesson, in the *Journal of the Royal Astronomical Society of Canada*, v.34, (1940). In it, however, he makes no mention of the efforts of the Admiralty to establish an astronomical observatory at Toronto. But W. E. Harper in his chapter on the "History of Astronomy in Canada" in *A history of science in Canada*, ed. H. M. Tory, (Toronto: Ryerson Press, 1939), appears to assume a connection for he writes: "The financial condition in Upper Canada was not particularly rosy and so a site was acquired and the building erected in Toronto by the Imperial authorities in 1839. At first it was primarily a magnetic observatory but among the instruments received was a four-and-one-half-inch refractor, a mural circle of four feet diameter ~~and other smaller accessories~~" (p. 88). These instruments, presumably, might have been part of the St. Helena consignment. The magnetometers certainly came from Woolwich and also the Adie barometer calibrated in August 1839 "at the Royal Society's Apartments Somerset House". This barometer was still the standard barometer for Canada in 1940 when the Controller, Meteorological Services of Canada, Mr. J. Patterson, reported to the Royal Meteorological Society of Canada on "A Century of Canadian Meteorology".

Only the mural circle could have been from St Helena

In this paper Patterson recounts the transfer of the Observatory from the authority of the British Ordnance Department to the Provincial Government in the Spring of 1853. The Legislative Council under pressure from the Canadian Institute and other scientific groups had agreed to accept the responsibility. Much of the equipment was purchased from the British Government for £428. Captain Lefroy sold some of his books and handed over his task to J. B. Cherriman, Professor of Mathematics and Natural Philosophy of the University of Toronto, who was made provisional Director. Two years later Professor Kingston came out from Cambridge as Director and Professor of Meteorology with a salary paid two-thirds by the Legislative Council and one-third by the University, the former defraying the expense of maintaining the observatory.

Cherriman replaced the log building with a stone building in which the magnetic and meteorological work and the time service were carried out until 1882 when the site was required for the McLennan Physics Laboratory. The University gave equivalent land just east of the present University College, and the observatory was re-erected there. Eventually meteorology became independent of the other services which went to the Dominion Observatory early in this century. The present Meteorological Service was established in its impressive Bloor Street building in 1909.

The University of Toronto retained the small observatory on its grounds and presumably it inherited what astronomical instruments remained of the 1839 equipment. Precise information on this point has not been forthcoming.

Until the spring of 1971 it has been a moot question whether Woolwich and Greenwich cooperated in equipping the first Canadian observatory or whether any St. Helena instruments ever came to this country. Lieut. Commander H. D. Howse, National Maritime Museum, Greenwich, believed that none came when we discussed this question at the History of Astronomy section of the International Astronomical Union recently. On 5 May 1971 he informed me that in the Astronomer Royal's report for 1849 Airy says he has at Greenwich "some of the St. Helena instruments; which are to be transferred to the Observatory that is to be erected at the Greenwich Hospital Schools". From records at the Schools in 1851 and as late as 1904 "it is evident that the Greenwich Hospital Schools Observatory contained Manuel Johnson's two principal instruments, a transit and mural circle made by Gilbert in 1827, together with a refracting telescope 42 inches in length, equatorially mounted".

"Where these instruments are today", commented Lt.-Cdr. Howse, "I do not know. I wish I did". Quite certainly they are not in Canada, nor ever were.

This historical quest has led ultimately to the sad conclusion that apathy in high places in 1835 and the following years deprived Canada of the fine sets of astronomical instruments so generously offered, instruments which had proved their value and efficiency in the observatory on St. Helena from 1828 to 1835. Thus, too, Canada forfeited the distinction of establishing the first astronomical observatory in the Americas. But thanks to the good offices of Alexander von Humboldt and Colonel Edward Sabine, Canada did get one of the very earliest observatories for magnetic and meteorological science.

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Canada's Lost Opportunity

A. Vibert Douglas

Prior to 1835 no astronomical observatory existed in the whole of North or South America. No standard meridian line existed on this continent. For this reason the Lord's Commissioners of the Admiralty offered to send all the instruments from the recently closed observatory on St. Helena to Upper Canada if a small observatory could be built.

The Lieut. Governor, Sir John Colborne and after him Sir Francis Head, too absorbed by local problems, delayed months in replying to letters from the Admiralty, and refrained from placing the repeated offers before the Assembly, members of which in 1838 autumn had heard nothing about the generous proposal. Thus Canada lost this opportunity and the St. Helena instruments remained in Greenwich in the care of Sir George Airy.

By 1838 another wind was blowing, not from Greenwich but from Woolwich, not astronomical but magnetic and meteorological. This resulted in the Admiralty Ordnance Department sending the Royal Artillery officer Lieut. Charles James Buchannan Riddell to Canada to establish and operate a magnetism and meteorology station in Toronto to complement data from the similar stations at Hobart, Cape of Good Hope and St. Helena. The Woolwich effort of 1838 led to success by February 1839. The Greenwich effort of 1835 led nowhere, a sad tale of a lost opportunity.

STARK EFFECT IN B STARS

Mr. J. Stuart Foster and Dr. A. Vibert Douglas

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STARK EFFECT IN B STARS

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AND
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STARK EFFECT IN B STARS.

J. Stuart Foster, F.R.S., and A. Vibert Douglas, M.B.E.

I. Introductory Discussion of Stark Effect

Stark effects in certain B stars are revealed not only by a great broadening of the Balmer lines which remains unexplained on any other basis, but by the appearance of many electric combination lines in the absorption spectrum of neutral helium. Although the interesting orthohelium line λ 4470 ($2p$–$4f$), most frequently cited as evidence for a stellar Stark effect, actually was found by Struve * with a wave-length and intensity neither of which appears to be due to the influence of electric fields alone, the variety of new evidence from the helium spectrum given below is in somewhat better agreement with simple theoretical expectations, and removes all doubt whatever as to the reality of Stark effects in stellar atmospheres.

Before considering this evidence in detail the main facts concerning Stark effects in helium will be reviewed briefly in order to bring out their interesting complexity, and especially to correct certain representations of the effect which consist in part of an unjustified enlargement upon an early theoretical interpretation.

While the Stark displacements in hydrogen are rather accurately proportional to the external field strength (except in very low fields where effects associated with the fine structure of the lines enter) † it is not possible to give any corresponding simple description of the effects observed in helium or in any other spectrum. By an application of quantum mechanics ‡ it was learned that this circumstance is directly related to the fact that the separations of the helium sub-levels characterised by different values for the quantum number l are large compared with the corresponding separations within the fine structure of the hydrogen level of the same principal quantum number. Since in any case the displacements will become linear with the field only after they are large compared with the above mentioned zero field separations, the result is that one sees in helium under the average experimental range of fields a complexity of displacements and intensities which at maximum field may or may not be smoothened out into a nearly hydrogen-like regularity. That will partly depend upon the zero field separations of the initial levels involved in any line group under consideration as well as the associated principal quantum number, which factors may be said to control in the main not only the related displacements within the group but also through them the intensities. Consequently in

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* O. Struve, *Ap. J.*, **74**, 4, 247, 1931.

† Schlapp, *Proc. Roy. Soc.*, A, **119**, 313, 1929.

‡ J. S. Foster, *Proc. Roy. Soc.*, A, **117**, 137, 1927.

reviewing the entire helium spectrum one may expect to find at any given field strength results as varied as are these factors.

Speaking more specifically, all sharp series lines ($2p$–ns; $2P$–nS) are displaced toward the red without exception by an amount which is usually small because the s or S term has the greatest separation from other terms. As in hydrogen, the displacement increases rapidly with n, and indeed to such an extent that some sharp lines examined in this work show a decided broadening toward the red.

The principal series lines ($2s$–np; $2S$–nP) are of small practical value in this astrophysical research because the few lines which penetrate the atmosphere have no pronounced Stark effect (except parhelium λ 3965, masked by H_ϵ λ 3970), and the values of the final terms ($2s$, $2S$) are such that later members of these series with appreciable Stark effects are thrown into the ultra-violet region. The orthohelium lines are shifted toward the red, while members of the corresponding parhelium series are displaced toward the violet. This contrast is a consequence of the inverted P terms of parhelium.

Diffuse series lines are of importance in any investigation of Stark effects. The lines are strong; and the shifts, which are larger than in the sharp or principal series, are toward the red. An exception with regard to the sense of the displacement will be found in the first member of each series (λλ 5876, 6678) since here there is no close f (or F) term to repel the diffuse term. For similar reasons, this exception applies generally to all first members of succeeding series of types $\left.\begin{matrix}2p\\2s\end{matrix}\right\}-mf$; $\left.\begin{matrix}2p\\2s\end{matrix}\right\}-mg$; $\left.\begin{matrix}2P\\2S\end{matrix}\right\}-mF$; $\left.\begin{matrix}2P\\2S\end{matrix}\right\}-mG$, etc. The shift toward the violet may persist through two or even several members of an electric combination series.

The stronger electric combination lines are usually so close to the corresponding diffuse line that complete resolution in stellar spectra is not possible. The details in each structure of interest will be given later.

We shall now make a few corrections to statements regarding Stark effects which are commonly quoted. (i) High fields are not necessary for Stark effects since 200 v./cm. is enough in either hydrogen or helium to produce observable effects in the laboratory. (ii) The relation of displacement to field strength is not linear in hydrogen and quadratic elsewhere. The linear relation develops in hydrogen at extremely low fields and persists over the observed range with only small second order effects superposed; in helium one finds in the ordinary range of fields the quadratic relation holding at least approximately for most sharp series lines, and for visible members of the principal series while the linear relation is developed at moderate fields for most diffuse series lines. The law applying to the majority of electric combination lines with which we shall have to deal is too complex to permit brief description. (iii) No members of fine structures or individual lines in either hydrogen or helium have ever been found with *symmetrical splitting* in Stark effect. Such marked group symmetry as is often observed is built up from individual line patterns which as a rule show pronounced asymmetry. Thus in the Stark effect for a member of a diffuse series in stellar spectra one may expect a broadening due to absorption; but (aside from limitations already cited) effects due to external electric fields alone may be expected to lead only to red shifts.

II. OBSERVATIONAL MATERIAL

The literature upon Stark effect in stellar spectra prior to 1932 had opened up an attractive and important field of inquiry and had suggested the need of a very thorough investigation of all the evidence possible. Through the kindness of the Director, Dr. J. S. Plaskett, F.R.S., the writers were given the privilege of obtaining spectrograms with the 3-prism spectrograph attached to the 72-in. reflector of the Dominion Astrophysical Observatory, Victoria, B.C.* These were calibrated by means of the wedge in regular use there in 1932. Subsequently Dr. C. S. Beals and Dr. F. S. Hogg kindly took for us several spectrograms in the red and yellow regions. Microphotometer tracings have been made and the intensity graphs or line profiles have been constructed. The stars selected for study are:

(1)	88 γ Peg	B2	$2^{\mathrm{m}}.9$	H.D. 886	16 plates.
(2)	85 ι Herc	B3	$3^{\mathrm{m}}.8$	H.D. 160762	6 plates.
(3)	17 ζ Cas	B3	$3^{\mathrm{m}}.8$	H.D. 3360	1 plate.
(4)	22 ζ Drac	B5	$3^{\mathrm{m}}.1$	H.D. 155763	4 plates.

From this material 12 normal helium lines have been examined, 9 electric combination lines have been definitely identified, and the presence of five others found to be not incompatible with the observed profiles. Due to low intensities and large displacements these latter lines can only be expected to appear as weak band-like depressions of the continuous background. Comparison has been made with laboratory data both as regards displacement at different field strengths and relative intensities at these fields. A general summary of the theoretical behaviour and of the observations follows.

III. SUMMARY OF THE EVIDENCE FROM THE LINES

Wave-lengths indicate zero field positions and the signs + − indicate the direction of displacement with fields

λ	Notation	Theoretical Description	Actual Appearance in Stellar Spectra
3820 (+)	*2p–6d*	Electric fields displace it to red, intensity decreasing with field. Electric combination lines move to violet, intensity increasing with field.	Winged to violet, maximum spread of 10 A. corresponds to 25 Kv./cm.
4009 (+)	2*P*–7*D*	Weak line; fields displace it to red.	Weak line; red wing affected by fields up to 8 Kv./cm.
4007 (−)	2*P*–7*P*	Low fields rapidly spread components to violet.	Definitely present in γ Peg for low field positions. (Regarded doubtful by Struve, *Ap. J.*, 1931 Nov., p. 247.) At higher fields the large displacement causes it to be lost in background.
4026·2 (+)	2*p*–5*d*	Fields displace to red. See fig. 3.	Winged on red side to λ 4030, indicating fields to 40 Kv./cm.
4025 (±)	2*p*–5*f*	Fields to 40 Kv./cm. move line to red 0·2 A. and back beyond zero field position to 0·2 A. to violet.	Only on assumption of the presence of this line with intensities as indicated in fig. 3 can the strong violet wing of the general profile near the zero position of *d* be explained.
4025 (−)	2*p*–5*g*	Fields displace to violet.	Extension of violet wing 4 A. indicates presence of this line with fields up to 40 Kv./cm. Lines *f* and *g* fully account for smoothed violet profile with no further hypotheses required.
4121 (+)	2*p*–5*s*	Fields displace to red.	Asymmetrical, winged to red. See fig. 5.
4143·77 (+)	2*P*–6*D*	Fields displace components to red. Shift 3 A. at 12 Kv./cm.	Red wing extends to 3 A.
4143 (+ +)	2*P*–6*F*	Components cross zero position of *D* and move 2 A. to red with fields to 20 Kv./cm.	Cannot be separately identified as it merges with *D*.
4143 (−)	2*P*–6*G*	Weak components. Maximum displacement 1·6 A. to violet at 20 Kv./cm.	Lines *G* and *H* merge to augment inner violet wing of general profile. They cannot be separately identified.
4143 (− −)	2*P*–6*H*	Weak components, displacement 4 A. to violet at 20 Kv./cm.	
4142 (− −)	2*P*–6*P*	Moves rapidly to violet and becomes more intense with increasing field.	Violet wing of general profile must be largely due to this *PP* line. In ζ Drac and ι Herc it is definitely observed in fields up to 15 Kv./cm.; in γ Peg a line at λ 4137 [recorded as unidentified by Struve (*Ap. J.*, 1931 Nov., p. 231)] could be this *PP* line at fields about 20 Kv./cm. But red wing becomes lost in continuous background at lesser fields.

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* The writers are indebted to the National Research Councils of the U.S.A. and Canada for grants towards the expenses incurred in going to Victoria, B.C.

λ	Notation	Theoretical Description	Actual Appearance in Stellar Spectra
4168·97 (+)	2*P*–6*S*	Fields displace to red.	Very asymmetrical. Red wing extends 2 A. indicating field 25 Kv./cm. See fig. 5.
4387·93 (+)	2*P*–5*D*	Fields displace to red. See fig. 4.	Red wing of profile extends to 40 Kv./cm. position.
4387 (±)	2*P*–5*F*	Displaced to red and back to violet ± 0·5 A. in fields to 40 Kv./cm.	Heavy absorption shown by strong inner portion of violet wing of general profile can only be explained in terms of this line.
4386 (–)	2*P*–5*G*	Displaced to violet 4 A. in fields to 40 Kv./cm.	Lines *F*, *G*, *P* provide a consistent and sufficient explanation of the entire violet wing of the general profile.
4383 (–)	2*P*–5*P*	Displaced to violet 3 A. in fields up to 30 Kv./cm.	
4438 (+)	2*P*–5*S*	Fields displace to red.	Weak asymmetrical line, winged to red.
4471·56 (+)	2*p*–4*d*	Fields displace to red 5 A. at 100 Kv./cm. See fig. 1.	Red wing of profile for stars under consideration indicates fields up to 60 to 80 Kv./cm.
4470·16 (– –)	2*p*–4*f*	Fields displace rapidly to violet.	Wide weak absorption from λ 4470 to λ 4466 is thus explained; but *not* the relatively strong line at λ 4471–4469 which has been almost invariably so identified.
4517·65 (–)	2*p*–4*p*	Fields displace slightly to violet.	Too weak to identify certainly in ι Herc; possibly present in γ Peg blending with weak line λ 4518·06 recorded by Struve (*Ap. J.*, 1931 Nov.) and identified with very weak line *N* III 4518·18.
4713 (+)	2*p*–4*s*	Fields displace to red.	Weak, asymmetrical, winged to red.
4921·93 (+)	2*P*–4*D*	Fields displace to red 3·3 A. at 40 Kv./cm. See fig. 2.	Red wing is explained by fields up to 50 Kv./cm.
4920·6 (–)	2*P*–4*F*	Fields displace to violet 2 A. at 40 Kv./cm.	Part of weak absorption of outer violet wing of general profile is thus fully explained, but *not* the relatively intense absorption near zero field position.
4911 (–)	2*P*–4*P*	Fields displace to violet.	Weak; moves to violet 1·7 A., indicating fields up to 40 Kv./cm.
5876 (–)	3*p*–3*d*	Strong line, very small shift to violet in extremely high fields.	No Stark effect observed.

IV. FIELD STRENGTHS

With the aid of laboratory data, it is possible to estimate from the observed profiles of both helium and hydrogen lines the *upper limits* of the fields that are appreciably affecting the photographic record.

Since the natural width of the lines has not been considered in this determination, some of the values are probably a little high. The earlier members of a series will obviously be expected to give evidence of the presence of higher fields.

Table of Field Strengths

As indicated by helium and hydrogen lines

Line	λ	γ Peg B2	ι Herc B3	ζ Cas B3	ζ Dra B5
(*a*) *He* (weak sharp)	4168	25 Kv./cm.	25 Kv./cm.	15 Kv./cm.	20 Kv./cm.
(*b*) *He* (diffuse; red wings)	4922	50	...	...	...
	4471	70	70	80	70
	4388	40	40	25	20
	4026	40	35	30	30
	4144	15	15	15	10
	4009	8	8	...	...
	3820	...	25	...	...
(*c*) *He* (electric combination)	2*P*–4*F*	50	...	...	...
	2*P*–4*P*	40	...	...	...
	2*p*–4*f*	60	60	...	...
	2*P*–5*F*	40	40	...	...
	2*P*–5*G*	40	40	...	...
	2*P*–5*P*	30	30	...	...
	2*p*–5*f*	40	40	...	...
	2*p*–5*g*	40	35	...	...
(*d*) *H* (Balmer)	4861	150–200	150–200	...	180
	4341	45–60	65	75	75
	4101	35–50	40–50	35	40

V. INTENSITY MEASUREMENTS

1. The upper portion of fig. 1 is the theoretical displacement and intensity chart for 2*p*–4*d* and the accompanying electric combination line 2*p*–4*f*.* An important point which must be very strongly emphasized is that at its zero field position the *f* line has *intensity zero*, while its 10 Kv./cm. position is already 0·34 A. to the violet, and of intensity only one-eighth that of the *d* line at the same field. It thus seems unreasonable to attribute the heavy absorption at and near 4470, as shown in the profiles in fig. 1, to the *f* line.

A quantitative examination of these profiles will now be outlined.

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* J. S. Foster, *Phys. Rev.*, **23**, 6, 1924; *Proc. Roy. Soc.*, A, **114**, 1927, and A, **117**, 1927.

2. λ 4471, *2p–4d*. The peak of this line shows no appreciable shift to the red. Therefore a very large proportion of the atoms must be absorbing, if not actually at zero field conditions, then extremely close to zero, *i.e.* small fields predominate. The inevitable deduction from the spectrum is in general agreement with the theoretical distribution of fields in a hydrogen atmosphere obtained by Verweij,* who, starting with zero number of atoms at zero field, finds that the ascent of the distribution curve is very rapid.

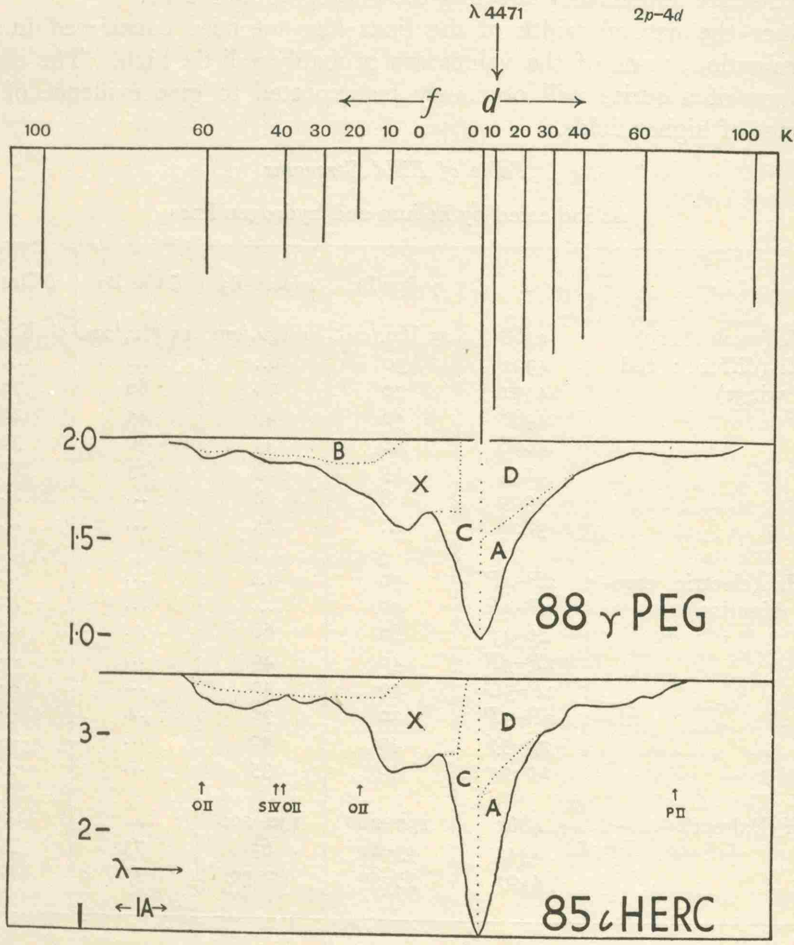

FIG. 1.

As a preliminary assumption we take 50 per cent. of the central ordinate as indicating the contribution to the line made by atoms at fields so close to zero that the term zero field is used in this connection throughout the present paper. This will be practically symmetrical to violet and to red where it can be represented by the area A of the red wing. The remaining area D is the contribution of the atoms being acted upon by appreciable electric fields up to 60 Kv./cm. or more. The ordinates at 10, 20, 30, 40 and 60 Kv./cm. can be measured. If one uses the relative intensities of *f* and *d* lines as shown in the chart to find the corresponding *f* ordinates the resultant values can be indicated at the corresponding positions of the displaced *f* line. This method alone, however, may be misleading as it fails to take account of the differing amounts of displacement of the *d* and *f* lines. Hence the areas of the absorption corresponding to the displacements for field intervals 0–15, 15–25, 25–35, 35–50, 50–70 Kv./cm. are measured in arbitrary units and these areas are multiplied by the ratio *f/d* for a mid-position of each range, viz. 10, 20, 30, 40, 60 Kv./cm. (see Tables (*a*), (*b*)). The resulting areas must then be compared with the available area of the violet wing from the *f* (zero field) position to the *f* (60 Kv./cm.) position. A further refinement takes count of the wing of the *d* (0–15) contribution falling to the violet of the *d* (zero) position. In order to be generous we assume that there may be an overlap to the violet amounting to 33 per cent. of the actual area on the red side of *d* (zero). The corresponding *f/d* (10 Kv./cm.) fraction of this must then be added to the *f* area over the range 0–15 Kv./cm. It is easily seen that since this theoretical *f/d* ratio is only 0·127, it makes very little difference what assumption is made regarding the low field *d* intensity, as even in the most extreme case it is impossible to build up a large *f* area at the position *f* (zero–15 Kv./cm.).

It is seen that the area marked B represents the *f* line, the area C is equivalent to the overlap of the violet wings of the *d* line at fields appreciably greater than zero, plus the equivalent of area A. What remains is a large unexplained area X. No matter what assumptions are made as to the relative areas of A and D, it is impossible to increase B appreciably or in

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* S. Verweij, *Pub. As. Inst. U. Amsterdam*, No. 5, 1936.

(*a*) γ Peg λ 4471.

Fields in Kv./cm.	*d* (observed)	*f* (calculated)
0	66 *	0
0–15	32 †	3·0
15–25	24	7·6
25–35	18	8·2
35–50	16	8·8
50–70	12	8·8
Total absorption in electric fields	102 $D+(C-A)$	36·4 B

d absorption $A+C+D=168$ arbitrary units (see fig. 1).

absorption $X=82$ units.

$$\frac{X}{A+C+D}=\frac{82}{168}=49 \text{ per cent.}$$

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* This represents 2 A.

† This includes the overlap of low field *d* to violet of *d* (zero) position, assumed to be 8 units or 33 per cent. of the portion on the red side of *d* (zero) position.

any other way to decrease X appreciably. In almost all the papers on this subject X is referred to as the *f* line, and indeed one of the chief arguments for Stark effect in stellar spectra has been based upon this unacceptable identification.

In a recent paper by Struve * the point which he regards as requiring clarification, and which he considers to be now "satisfactorily explained" by the hypothesis of collisional damping, is not the existence of the X hump but the fact that between the X hump and the peak of the main *d* line the profile does not more nearly approach the continuous background. *From our investigation it appears that the outstanding problem is the origin of the entire X absorption.* A suggested explanation of this absorption as due to a resonance phenomenon augmenting the *d* line will be given in Section VI.

In order to test the effect of a slight change in the position at which the continuous background is drawn in, the following alternative table for γ Peg λ 4471 is constructed. The continuous background has been lowered one arbitrary unit.

Fields in Kv./cm.	*d* (observed)	*f* (calculated)
0	66	0
0–15	31	3
15–25	21	6
25–35	15	6
35–50	11	7
50–70	6	5
Total absorption in electric fields	84	27

d absorption $A+C+D=150$ units.
absorption $X=67$ units.

$$\frac{X}{A+C+D}=\frac{67}{150}=45 \text{ per cent.}$$

3. λ 4921, 2*P*–4*D*. Regarding this anomaly of the strong absorption at and near λ 4470 in orthohelium, we would point out that there is an exact parallel in the case of parhelium. In fig. 2 are the profile of λ 4921 from one spectrogram of γ Pegasi and the corresponding chart of line positions and relative intensities. A quantitative treatment of this profile on similar lines to that just outlined results in the absorption area X remaining completely unexplained in terms of the Stark theory applied to the *D* and corresponding *F* lines, and again we are driven to the resonance argument of Section VI to account in any reasonable way for this absorption. It will be seen that the very weak *PP* line appears over a 1·5 A. range beyond its zero field (zero intensity) position at 11·3 A. to the violet of the *D* zero position.

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* O. Struve, *Observatory*, **61**, 53, 1938 Feb.

(*b*) ι Herc λ 4471.

Fields in Kv./cm.	*d* (observed)	*f* (calculated)
0	80 *	0
0–15	59 †	7·5
15–25	29	9·2
25–35	17	7·8
35–45	12	6·8
45–55	9	6·0
55–65	6	4·0
Total absorption in electric fields	132 $D+(C-A)$	41·3 *B*

d absorption $A+C+D=212$ units (see fig. 1).
absorption $X=102$ units.

$$\frac{X}{A+C+D}=\frac{102}{212}=48 \text{ per cent.}$$

(*c*) γ Peg λ 4921.

Fields in Kv./cm.	*d* (observed)	*f* (calculated)
0	100 ‡	0
0–20	132 §	24
20–40	97	32
Total absorption in electric fields	229 $D+(C-A)$	56 *B*

D absorption $A+C+D=329$ units.
absorption $X=140$ units (see fig. 2).

$$\frac{X}{A+C+D}=\frac{140}{329}=42 \text{ per cent.}$$

Some unidentified absorption lies to the violet of *F* (40) at approx. λ 4917.

4. λ 4026, 2*p*–5*d*. In fig. 3 we see that a more complex system of overlapping lines is obtained, due to the *f* and *g* levels being very close together. Similar assumptions to those made in 2 with regard to the red wing of the *d* line lead to the calculation of the absorption to be expected

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* This represents 2 A.

† This includes 15 units assumed to be the overlap of low field *d* to violet of *d* zero) position, being 33 per cent. of the absorption (0–15) on the red of *d* (zero) position.

‡ 100 = 2 A.

§ This includes 33 units or 33 per cent. of the (0–20) absorption of *D* red wing, assumed to be the overlap on violet side of *D* (zero) position.

for the *f* and *g* lines at various fields. It is seen that the *f* line rises rapidly from zero intensity to 60 per cent. of the intensity of the *d*(10 Kv./cm.) line moving in towards the *d* (zero) position, then at successively higher fields, it moves back toward and beyond its zero position, overlapping the low field positions of the *g* line. Thus all the absorption due to *f* components will lie very compactly upon the violet wing of the *d* line, whereas the *g* absorption will be spread out weakly for more than 3 A. to the violet beyond the *f* region. Quantitative work on these lines explains the smoothed profile without any difficulty. There is here no remaining ambiguity or unexplained major feature and no additional hypothesis seems to be required.

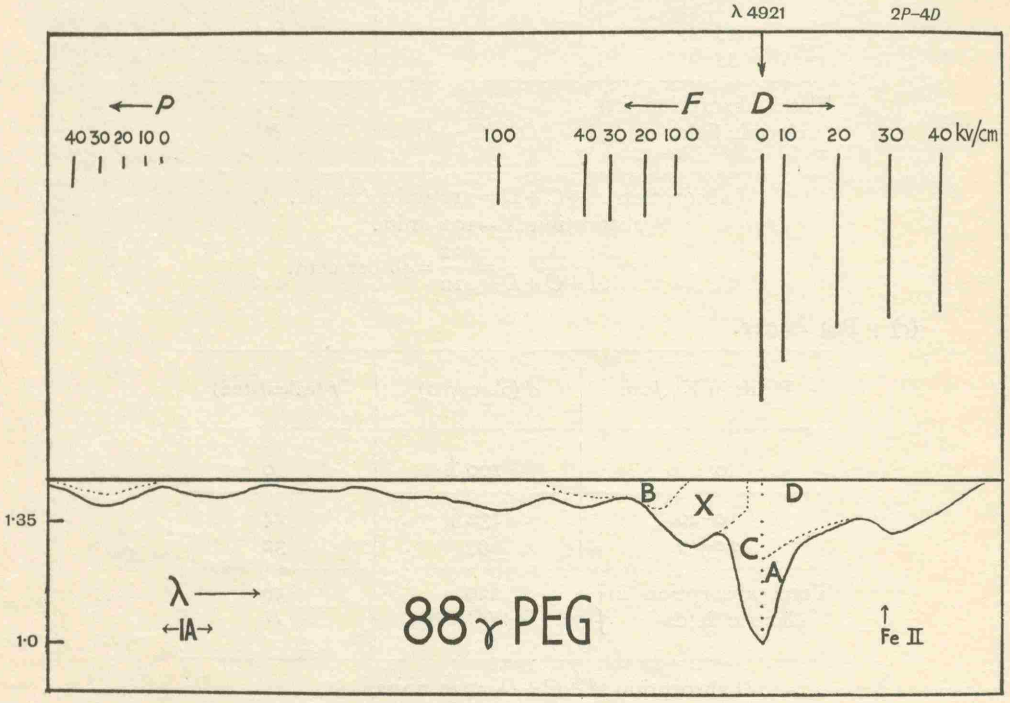

Fig. 2.

Hence agreement is very satisfactory for both γ Peg and ι Herc. It may be noted that there remains unexplained a weak absorption near λ 4022 in the *g*(25–30) region. This amounts to 12 per cent. of the total *g* absorption in γ Peg and 16 per cent. in ι Herc, or in terms of the total *d* line, 4 per cent. in γ Peg and 5 per cent. in ι Herc.

5. λ 4388, 2*P*–5*D*. The corresponding transitions in parhelium are represented in fig. 4. The chart shows how the *F* lines press in very closely upon the *D* (zero) position for fields up to 25 Kv./cm., afterwards moving somewhat beyond the *F* (zero) and *G* (zero) positions. Thus all the *F* absorption to be expected corresponding to the *D* absorption of the wide red wing will strongly augment the violet wing of the *D* line and will necessarily overlap somewhat to the red of the *D* (zero) position, thus slightly

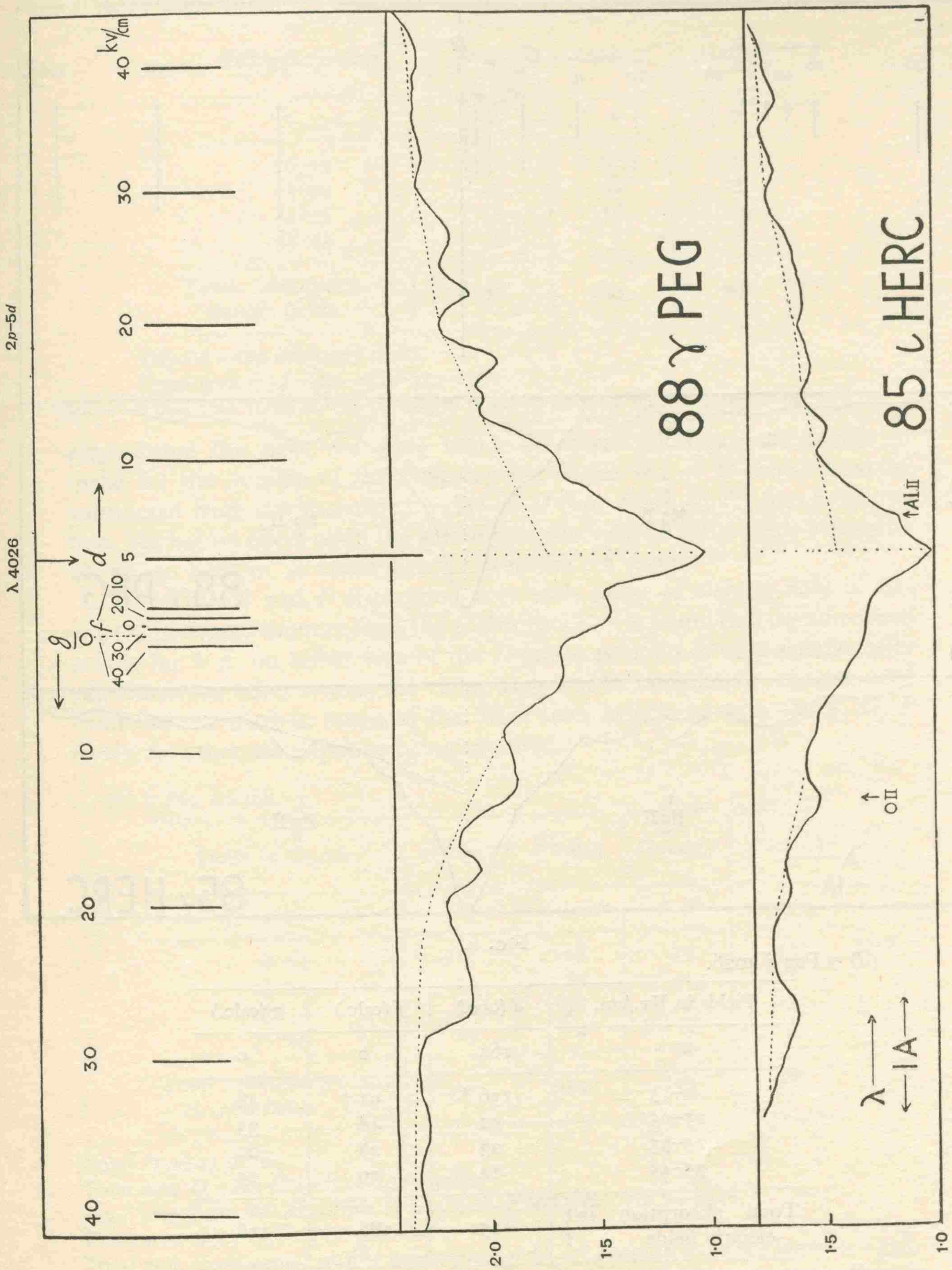

Fig. 3.

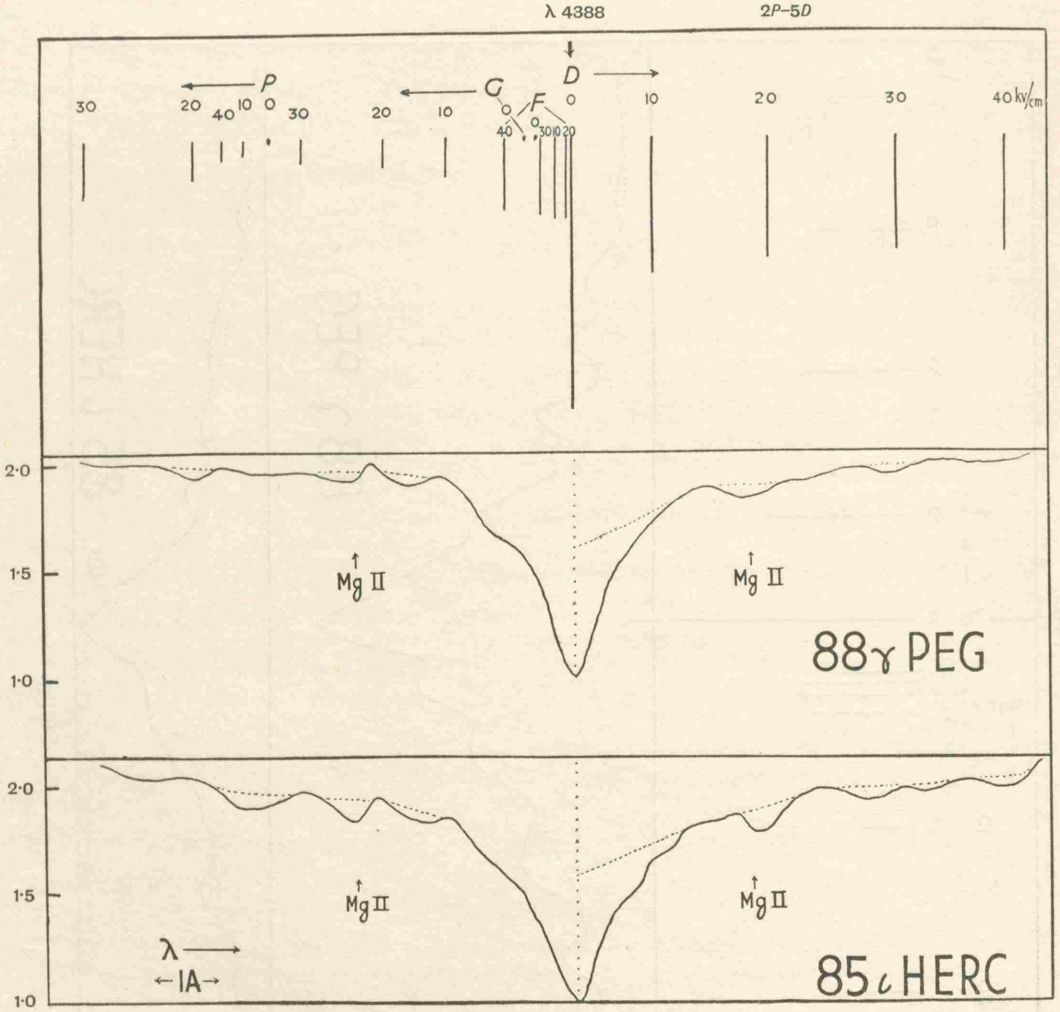

Fig. 4.

(*d*) γ Peg λ 4026.

Fields in Kv./cm.	*d* (obs.)	*f* (calc.)	*g* (calc.)
0	164	0	0
0–15	136 *	91 †	48
15–25	52	48	33
25–35	23	28	20
35–45	14	19	15
Total absorption in electric fields	225	186	116

Total $d = 389$ arbitrary units. Total area $d + f + g(0–15) = 623$ units.
Total area from actual profile to position of g(15 Kv./cm.) = 652.

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* This includes the assumed overlap of d(0–15) to violet and excludes the assumed overlap of f to red of the d (zero) position.

† This excludes the assumed overlap of d(0–15) to violet and includes the assumed overlap of f to red of the d (zero) position.

(*e*) ι Herc λ 4026.

Fields in Kv./cm.	*d* (obs.)	*f* (calc.)	*g* (calc.)
0	64	0	0
0–15	78 *	52 †	26
15–25	40	38	25
25–35	15	18	13
35–45	5	7	5
Total absorption in electric fields	138	115	69

Total $d = 202$ arbitrary units.
Total area $d + f + g(0–15) = 343$ units.
Total area from actual profile to position of g(15 Kv./cm.) = 352 units.

augmenting the near red wing also. Whatever allowance we decide to make for the overlap of the *F* absorption to the red of *D* (zero) must be subtracted from the postulated value of *D* (low fields–15 Kv./cm.) absorption, but has no effect upon the amounts of absorptions at the fields averaging 20, 30, 40 Kv./cm. as taken directly from the red wing.

When the *G* and *P* absorption over each range of electric field is calculated in similar manner from the *D* absorption, it is found that the smoothed profile for 6 A. on either side of the *D* (zero) position is very satisfactorily explained—in other words, the violet wing can be completely reconstructed from the red wing in terms of the Stark lines associated with the *F*, *G*, *P* levels, no other assumptions being required.

(*f*) γ Peg λ 4388.

Fields in Kv./cm.	*D* (obs.)	*F* (calc.)	*G* (calc.)	*P* (calc.)
0	314	0	0	0
0–15	210	128	59	22
15–25	124	87	31	41
25–35	46	31	9	23
35–45	15	9	3	9
Total absorption in electric fields	395	255	102	95

Total $D = 709$ units.
Total area $D + F + G(0–15) = 1023$ units.
Total area from actual profile to position of G(15 Kv./cm.) = 1057.
Total area $G(15–45) + P(0–30) = 118$.
Total area from actual profile over range of G(15) position to P(30) position = 130.

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* This includes the assumed overlap of d(0–15) to violet and excludes the assumed overlap of f to red of the d (zero) position.

† This excludes the assumed overlap of d(0–15) to violet and includes the assumed overlap of f to red of the d (zero) position.

(*g*) ι Herc λ 4388.

Fields in Kv./cm.	*D* (obs.)	*F* (calc.)	*G* (calc.)	*P* (calc.)
0	306	0	0	0
0–15	315	192	88	33
15–25	168	118	42	55
25–35	84	56	16	41
35–45	30	19	6	17
Total absorption in electric fields	597	385	152	146

Total $D = 903$ arbitrary units.
Total $D + F + G(0–15) = 1376$.
Total area from actual profile to position $G(15$ Kv./cm.$) = 1433$.
Total area $G(15–40) + P(0–30) = 172$.
Area available from smoothed profile over this range is approximately 250.

The exact placing of the continuous background largely determines the closeness of the fit between the actual and the theoretically expected areas of absorption.

Small residual amounts of absorption are seen to be in the overlapping region of the low field *P* and higher field *G* absorptions.

VI. CONCLUSION

The evidence presented in this paper confirms and strengthens the view that Stark effects are present in the helium spectrum of certain Class B stars. Woolley * has stated that "the position at the moment may be fairly summarized by saying that Stark effect accounts *qualitatively* for all phenomena shown by *H* and *He* lines in stellar spectra *except* the observed high central intensities of the *H* lines." Our evidence shows that *most* of the phenomena shown by *He* lines are not only qualitatively but *quantitatively* explained by Stark effect, but that *some* features, *e.g.* the heavy absorption near λ 4470 and near λ 4921, are neither qualitatively nor quantitatively so explained without introduction of features quite unrelated to the Stark effect.

In an effort to find some reasonable explanation various possibilities have been considered. That intercombination lines between ortho- and par-helium are not the cause was seen by plotting the positions of such lines.† Nor could satisfactory explanations be based upon assumed doppler effects nor upon relative intensity changes in absorption as compared with emission.

The possibility that this large effect is due to rapid variations in the electric field in stellar atmospheres must not be overlooked. There are, however, arguments in favour of the slowly varying fields presupposed in the existing Stark effect theory. The asymmetry expected in the case of

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* R. v. d. R. Woolley, *Observatory*, **60**, 239, 1937 Sept.

† Foster and Douglas, *Nature*, **134**, 417 (fig. 2), 1934 Sept. 15.

certain sharp series lines (λ 4121, λ 4168) is definitely present, and the quantitative analysis of the diffuse series lines, λ 4026 ($2p$–$5d$) and λ 4388 ($2P$–$5D$) together with the group of electric combination lines around each,

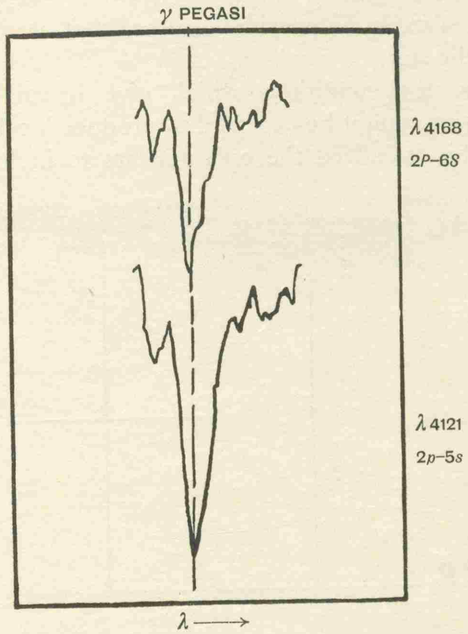

FIG. 5.

results in intensity profiles very nearly as expected from the theory of Stark effect in slowly varying fields.

A new line of attack must therefore be sought in explanation of the surprisingly high absorption X and the fact that it lies rather closer to the *d* line than would be expected if it were due to $2p$–$4f$. Now just these disturbing features may actually be expected—even in the absence of electric fields—if stellar conditions are such as to give (1) diffuse lines three or more angstrom units in breadth and (2) a reasonable departure from the Boltzmann distribution among atomic states. Fixing attention upon radiation characteristic of the zero field position of the electric combination line, and referring to the important cycle in fig. 6, we note that events taken in the direction indicated are certainly more probable than the reverse order.* In so far as this cycle controls the situation, there will be relatively strong net *d* absorption in the region of the *f* line, even if no electric fields are present to produce an *f* line, since emission accompanying the absorption will be especially weak at this point due to leakage *via* the route $4d \rightarrow 4f \rightarrow 3d$. In agreement with the observations, one should expect in varying fields the $2p$–$4f$ line to be augmented at zero field position

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* The importance of cyclical transitions was pointed out by S. Rosseland in 1926 (*Ap. J.*, **63**, 218) in connection with the origin of emission lines in stellar spectra.

with maximum intensity shifted slightly toward the *d* line. There should be no sharp division between the two lines.

On the present view, we must consider that the anomalous absorption X is a secondary maximum in the *d* absorption. Its existence in a stellar spectrum could scarcely be considered proof that electric fields exist in the atmosphere of the star.

Nevertheless, the conditions which give broad absorption, through collisional damping, might be expected to produce local electric fields. The evidence that this is indeed the case appears to include (1) the extended absorption on the violet side of the diffuse line. Certainly one cannot expect the *d* line itself to be broadened more toward the violet than toward the red, hence the more extended violet absorption actually observed cannot rest upon the above basis. It is, however, just what must be expected in the presence of electric fields, and in that case is due to well-known electric combination lines. The observed violet broadening shows on the whole a convincing excess over the red and the position of weak maxima correspond very well to the known lines, some of which are far removed from the *d* line, as $2p$–$4p$, $2p$–$5p$, $2p$–$6p$. (2) The broadened red wing of sharp series lines (fig. 5). (3) The greatly extended wings of Balmer lines explainable in no other way.

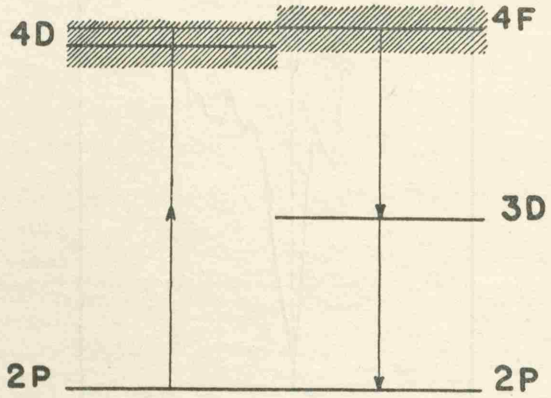

FIG. 6.

We must conclude that this entire "line" almost invariably referred to in the past as the *f* line is mainly due to the transition $2p$–$4d$—especially near the *f* zero field position—but that as one proceeds towards the violet the contribution of $2p$–$4f$ becomes gradually the more important; and this is equally the case in interpretation of the $2P$–$4D$ and $2P$–$4F$ absorption.

It appears then that the *d* line is reduced to its ultimate form by emission over its entire spread, this emission being less near the *f* zero field position because of a relatively small net leakage from the $4d$ state to the $4f$ state and the subsequent emission of that energy in two stages. Hence the assumptions in Section V, § 2 above, by neglecting the broadening due to collisional damping, obviously overestimate the amount of absorption attributable to low electric fields, but by so doing we have thrown into greater relief the impossibility of accounting for the X absorption on Stark theory alone.

A test of this leakage might be found by comparison of the intensity of the yellow line λ 5876 in a B giant and a B dwarf. We would expect it to be relatively somewhat weaker in the dwarf where other spectrum evidence indicates broader lines.

Similar effects must certainly be present in $2p$–$5d, f, g$, and $2P$–$5D, F, G$, but the closer packing of the levels renders impossible the separation of Stark effects and effects due mainly to this resonance phenomenon.

In view of this interpretation it would seem fortunate that the separation of $4d$ and $4f$ lines is such as to give some indication of the extent of the total absorption as it would appear if there were no associated emission.

Summary.—In the course of an investigation of some typical dwarf B stars, twelve normal helium lines have been examined, nine electric combination lines have been identified and the presence of five others found to be not incompatible with the observed profiles. From these combination lines and from the broadening to red of sharp series lines the effective electric fields are determined.

Quantitative analyses are given for the groups of lines associated with λ 4471, λ 4921, λ 4026, λ 4388. The absorption near λ 4470 is much too great and too near λ 4471 to receive the usual interpretation as $2p$–$4f$ at low fields.

It is suggested that this absorption (and similarly the absorption near λ 4921) is indeed part of the original broad *d* line overlapping the *f* zero field position, but while subsequent emission reduced much of the line the absorption remains relatively strong in the position of the *f* line owing to resonance between the $4d$ and $4f$ levels and a predominantly one-way energy cycle.

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Student Nurses

To Know, To Do

A. Vibert Douglas

I AM GRATEFUL for this opportunity to congratulate the graduating nurses on the completion of their years of training for the diplomas which they have won.

I congratulate their instructors and supervisors. I have not been an educator for 30 years without knowing well the satisfaction of seeing a class arrive at their graduation after the long hard climb upwards towards the goal of their aspirations.

Some time ago I was in London and, walking down from Piccadilly Circus towards St. James's Park, I looked at the bronze statues of Florence Nightingale and of Sidney Herbert, whom she made her spokesman in Parliament. I thought of this graduation ceremony to which I was invited and the contrast between the status of nursing 100 years ago and today. How much the world owes to courageous pioneers who, not content with the *status quo* but seeing a great need or an opportunity for constructive improvement, go forward undaunted by apathy and opposition. By effort and thought and faith they achieve the almost impossible. No wonder the British government in 1907, when Florence Nightingale was 87 years of age, advised the King to confer upon her the high and most exclusive distinction — the Order of Merit.

There is a little-known poem by Lord Warren, Baron de Tabley, which I am going to quote because it portrays two attitudes to life — that of the complacent drifter and that of men and women of the calibre of those who have been leaders in the medical and nursing professions:

To know, to do, and on the tide of time
Not to drift idly like a cockle sailor
Whose pearly shallop dances on the blue,
Fanned by soft airs, and basking in brief sun,
Then as a cloudlet sinks, with scarce a ripple;
But to steer onward to some purposed haven
And make new waves with motion of our own,
That is to live.

There is the challenge to the young graduate. *To know, to do — to make new waves with motion of our own.* Neither knowledge alone, nor action alone is enough. The French philosopher, Bergson, put it thus: "Think like a man of action; act like a man of thought."

A good teacher is not one who helps students successfully to memorize a static list of facts but one who gives students the vision of knowledge as a great river flowing through the centuries, gaining volume and momentum by the trickles and streams and tributaries of new knowledge being added to it continually. This dynamic picture of knowledge implies that we must continue to learn and to study if we are to keep abreast of knowledge. It is hard work but it is essential if you are to maintain your professional standing. You will come to take a pride in so doing.

I hope some of you will go on sooner or later to post-graduate courses. I hope you will become research workers while you practise your profession with minds and imaginations open to new ideas, possibly new methods and approaches to old problems. Some of you may become teachers and, if you do, put all the enthusiasm of which

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Dr. Douglas is dean of women at Queen's University, Kingston, Ontario. This address was delivered at the graduation exercises of the Women's College Hospital, Toronto.

you are capable into your teaching and keep the dynamic picture of knowledge before you.

Your profession is often described as both an art and a science. As a science it demands conscientious accuracy and sound basic knowledge of the fundamental subjects of chemistry, physics, biology, anatomy, bacteriology; it demands skills and techniques undreamed of before the discovery of radiology and the many new substances used in chemotherapy; it calls for comprehension of the scientific method, observation, induction, deduction, experimentation, fertile imagination and critical assessment of results.

As an art, nursing calls for great human qualities of heart and hand, of mind and spirit. No one can possess and develop these great human qualities whose outlook is narrowed to the purely professional aspects of the day's work. You will be dealing with people who have been strong and active, who have carried responsibilities, have read and thought perhaps widely and deeply, who may have renewed their spirits with music and the arts, who have been citizens, perhaps with vision beyond the municipality to the nation and out into the international field.

Can you do a first-class job for the sick people entrusted to your care unless you are yourself an educated woman in the best sense of that word? You should make time to read widely, to see what is beautiful and interesting in art and drama, to hear some good music, to keep aware of current events. "Reading makes a full man", wrote Bacon and your aim should be to make for yourself a rich, full life, so full that your zest and ideas overflow, bringing fresh ideas and stimulating thoughts to your patients from time to time and according to what you discover to be their interests. Anyone with "a sizzling enthusiasm for life," to borrow Osbert Sitwell's phrase, will be like a breath of fresh air, like a stimulating ray of ultraviolet light, bringing new hope and encouragement to the sick in body and mind and spirit. No one can overestimate the influence of a nurse of character who has gentleness and dignity, kindliness without sentimentality, efficiency with deep sympathetic understanding — over and above all, a woman of character.

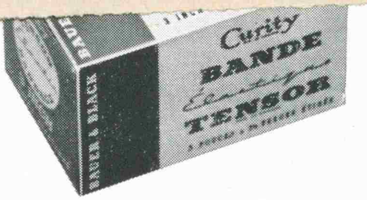
You who are pledged to the tasks of restoring and of maintaining health are part of a vast international army whose campaigns are wholly constructive. When the World Health Organization came into being with 61 nations signing its Constitution on July 22, 1946, a challenging definition of health was put as an ideal before the world — health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."

We should all make the effort to know more about and talk more about the great work being done by these agencies of the United Nations — WHO, FAO, IRO, UNICEF, and Unesco. How many people realize the tremendous task which faced IRO in 1947 and the unparalleled achievement which was reported to the General Assembly of the U.N., meeting in Paris? I have seen some of those D.P. camps in Germany and know something of the difficulty of restoring and maintaining health in these crowded camps of war victims — men, women, children — many of them weak with undernourishment, exposure and hardship, after forced labor camps or resistance work, overwrought with tragedy and loss of relatives, of home and homeland — people for whom the future was one large question mark. In its four and a half years IRO transported to new homes all over the globe more than 1,000,000 people, many in its own ships — at its height said to be one of the greatest fleets in all history. It repatriated 73,000 but over a million others for political reasons could not return home and were resettled in other countries. Eighteen member governments contributed $400,000,000 for this stupendous task, "probably the most remarkable achievement of any international body in peacetime."

I think we do well to remind ourselves, and those with whom we live and work, of the many things going on around us which are good and true and constructive. Only by so doing can we avoid being oppressed and discouraged by the evil, selfishness, suspicion and unrest which exist in the world today. We need the stability which comes from facing the facts of existence courageously and honestly. No wishful thinking can produce stability. Let us seek the truth and think our way through to a philosophy of life and behavior that rings true to our experience.

I think our mental and spiritual stability depends upon the sincerity of our belief in the ultimate supremacy of good over evil, of truth over falsehood. But truth is the daughter of time, as Bacon realized three centuries ago. The forces of nature, including human nature, work slowly, with few exceptions. It is imperative that we learn to think in centuries. We must not be discouraged because the millenium is not here now or likely to be achieved in our lifetime. We must have faith that everything that is true and good, tolerant and kind, is not lost but is constructively built into the future of mankind. And it is the sum total of all the little acts of today that partly determine the nature of tomorrow.

My message to you is, therefore, first, that of Zoroaster: "Do thy tasks and live thy life and neither fear nor worship the powers of evil"; and, secondly, that of Renan who pointed out the example of Jesus of Nazareth with these words: "He infused into the world a new spirit . . . the perfect nobility of the children of God."



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THE SUMMER SKY

BY

A. VIBERT DOUGLAS

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THE SUMMER SKY

By A. Vibert Douglas

THERE are many who love the restful quiet of a summer evening and are wont to wander forth to watch the last rays of the setting sun and the soft after-glow which gradually fades away leaving a star-studded sky. But how few, comparatively, can point out more than two or three constellations or name the half dozen brightest stars which shine forth from the summer sky! "The study of the heavens," said Sir Robt. Ball, "of boundless interest and of exquisite beauty, leads to the contemplation of grand phenomena in Nature and great achievements of human genius."

The natural starting point in a survey of the heavens is Polaris. This giant star, of absolute magnitude —3.0, is so far distant from our little Solar System that it has only an apparent magnitude of 2.1. It might perhaps be explained that the apparent magnitude of a star is measured on a logarithmic scale of brightness, the 6th magnitude being fixed traditionally and each magnitude above that (namely 5, 4, 3, 2, 1, 0, —1, —2, etc.) indicating approximately two and a half times more light. The classification is done both visually and by photometric means. The absolute magnitude ofa star can only be ascertained if it's distance be known. By convention the scale of absolute magnitudes is formed by calculating what would be the apparent magnitude of the star if its distance from the Sun were 10 parsecs, the parsec being a unit of distance defined as that distance which corresponds to a parallactic angle of one second. The parallax of a star is the angle subtended at the star by the radius of the earth's orbit. Since the distance from the earth to the sun is known with great precision, and the angle of parallax for a star can be obtained very accurately by methods similar to those used in land surveying or by a spectroscopic method, highly developed in the last few years, it becomes a simple trigonometrical computation to ascertain the distance of the star. A parsec is approximately equivalent to the distance traversed by a ray of light travelling for three years at a speed of 186,000 miles per second.

The altitude of Polaris, or its angular distance above the horizon, is the measure of the latitude of the place where the observer is stationed. In the vicinity of London, Eng., this angle is 51°, at Montreal 46°.

Two well-known constellations lie one on either side of Polaris —Ursa Major and Cassiopeia—the former known as the Great Bear, the Dipper or the Plough, and the latter as the W. The esries of bright stars, more or less equispaced, under and around the end of the W, known popularly as Cassiopeia's Guards, form parts of two interesting constellations. Those under the W belong to Andromeda while the next two with two others behind them, forming a great square, are in Pegasus, the Flying Horse.

In the mythology of the ancients, Cassiopeia was the beautiful wife of Cepheus, King of Ethiopia, and Andromeda was their daughter, who, to appease the wrath of Neptune, was chained to a rock to be devoured by a great monster, this awful fate being averted by her rescuer, Perseus, whose wife she afterwards became.

The constellation of Perseus lies too low on the north horizon to be well seen in summer, but in the winter sky it is almost at the zenith and is interesting because it contains the remarkable variable star, Algol. Better placed at this season is Cepheus which lies just above Cassiopeia towards the zenith. King Cepheus, one of the renowned Argonauts, who under the leadership of Jason sailed from Greece to Colchis to bring home the Golden Fleece, was supposed to have been changed into a constellation at his death.

Turning now to the southern or southwestern sky, the brightest object, far exceeding all the fixed stars, is the planet Jupiter. Fourth but largest child of our parent sun, he sweeps around his great orbit in about 12 years, while his motion relative to that of the earth in her orbit makes him seem to move gradually backward or forward amongst certain of the constellations.

Of the fixed stars the brightest in the summer sky is Arcturus, well up in the west. Its apparent magnitude is 0.2 but it is comparatively near our sun and its absolute magnitude is only 1.2. The group of smaller stars about it form with it the constellation of Bootes, the Herdsman.

Low in the south is a very beautiful group looking like a giant rocket bursting forth its stars: this is Scorpio, supposed to be the scorpion which Diana sent to sting to death the giant Orion who had offended her. Orion, not visible in summer, is the chief glory of the winter heavens. Antares is the brightest star of Scorpio and its immensity and distance can be judged from the figures, absolute magnitude —2.7 and apparent magnitude 1.2.

Very high in the east and almost as bright as Arcturus is Vega, the gem of the constellation Lyra, the Harp from which Orpheus drew forth his strains of all-compelling melody. A line joining this star to Arcturus passes first through the constellation of Hercules and then through Corona. It is interesting to note that it is towards a point in the vicinity of Hercules that our Solar System appears to be moving. This point, termed the Apex of the Sun's Way, gives the direction of motion of our sun relative to the controid of all the known stars. One of the "great achievements of human genius," surely, was the approximate location of this point by Sir Wm. Herschel towards the close of the 18th century, from his observations of the movements of only seven stars. One of the main objects of modern investigators has been to determine the motions of some thousands of the stars, so that the Apex is now known with what is probably a fair degree of precision.

Not far from Vega towards the north-east is another bright star, Deneb, in the group known as Cygnus, the Swan. It lies in the Milky Way distinguishable as a cross with it's head, Deneb, towards Cassiopeia. There is a double star of historic interest in this constellation known as 61 Cygni. In the years 1837-39 the great mathematician and astronomer, Bessel, observed this pair of stars and determined their distance from the sun with a precision never attained before his time. For many years it was thought that, with the single exception of Alpha Centauri, visible as a 0.3 magnitude star in the southern hemisphere, these stars were our sun's nearest neighbours but modern measurements have revealed three other stars to be slightly less distant than 61 Cygni.

Below Vega and Deneb in the south-east is another bright star, Altair, in the constelation of Aquila, the Eagle. Mythology tells of Merops, King of the Island of Cos, who was transformed into an eagle and set among the constellations.

Two other bright stars must be mentioned though both lie too near the horizon to give their full brillance: Spica low in the south-west and Capella low in the north. Spica, in the constellation of Virgo, is an important star in navigation, its distance (angular) from the moon being used in one of the ways in which a mariner may determine his longitude. The ancient poets sing of the Golden Age when Astraea, the virgin Goddess of Justice, dwelt among men; and of the succeeding age of wickedness when she wearied of mankind and, returning to heaven, was placed among the constellations as the Virgin holdiing in her hand the Scales of Justice.

Capella, brightest star in Auriga, with an apparent magnitude of 0.7, lies almost in a straight line with Polaris and Vega, its nearest easterly neighbour being Perseus. It is in the winter sky that Capella shines forth with greatest beauty, being the highest in the sky of that marvellous group of bright stars—Castor, Pollux, Procyon, Sirius, Betelgeuse, Rigel and Aldebaran—now for a season withdrawn from our view.

The summer sky differs in many respects from the winter sky but who shall say that the glory of the one exceeds the glory of the other, for each presents one aspect of an unfathomable universe whose "boundless interest and exquisite beauty" refresh the mind and soul of the thoughtful star-lover, and doubly reward the persistent investigator by yielding up one by one some of the secrets of time and space?

McGill University,
Montreal, Que.

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Symbols In Stone

By **DR. A. VIBERT DOUGLAS**

Dean of Women

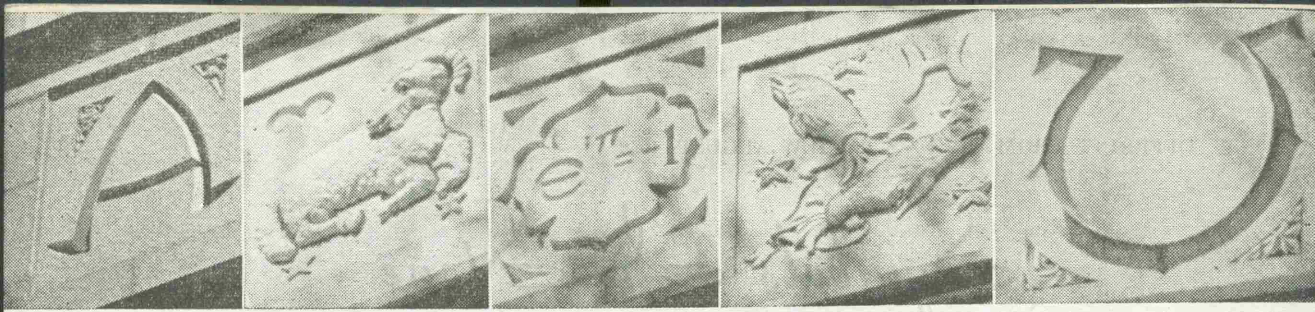
WHEN plans for the extension to Ban Righ Hall were nearing completion it became apparent from the architect's drawings that five large rectangular and five smaller square stones were to be carved and placed above the first and second bay windows immediately over the arch of the entrance at the corner of University and Stuart streets. Instead of conventional geometric and leaf designs, it seemed appropriate that these ten stones should convey in symbolic form some of the ideas and the ideals most closely associated with a university whose traditions are those of learning and of religion, a university whose crest contains the words *Sapientia et doctrina stabilitas,* words based upon a verse in Isaiah 33: "Knowledge and wisdom shall be the stability of thy times." The verse which precedes this reads: "The Lord is exalted, He dwelleth on high, He hath filled Zion with judgment and righteousness."

In the light of these thoughts, it seemed appropriate to place in the upper row the symbols for God, in whom we live, move and have our being, in whom and to whose glory all our works are begun, continued and ended. Hence on the first and fifth stones are carved in plain simplicity the Greek letters *Alpha* and *Omega.*

The second and fourth stones, in contrast to the symbol of the Eternal, portray finite time, the natural unit of time which we measure our opportunities to grow in knowledge and wisdom, and measure off the span of human life. Thus the ancient symbols for the beginning and end of the year, the first and twelfth signs of the Zodiac, Aries the Ram and Pisces the Fishes, are portrayed in close accord with the beautiful seventeenth century drawings of Bayer. These drawings were based on Aratus' descriptions of the old Babylonian and Chaldean constellation figures which were current at least as early as 2700 B.C.

The historian Esdras relates a contest which took place in the court of Darius, King of Persia, when the young men in attendance upon the king competed as to which of them could say the wisest thing. One said, "Great is truth and mighty above all things . . . it endureth and is always strong, it liveth and conquereth forever more", and King Darius gave judgment, "Thou art found wisest". How best can truth be symbolized? Not relative truth but absolute truth, independent of epoch and the relativity of human affairs? The marvel and the mystery of numbers, the beauty of the mathematical relationships between numbers, between even irrational and imaginary numbers, can be illustrated by the following equation $e^{i\pi} = -1$. The letter 'e' represents an infinite series whose sum is an irrational number, the base of Naperian logarithms; 'i' is the imaginary number whose square is equal to -1; and π is the well known ratio of the circumference of a circle to its diameter in Euclidean geometry. This equation is carved on the central stone on the upper row. There is sublimity in this amazing relationship which the mind of man has discovered but did not invent – it partakes of the nature of absolute truth and the more one thinks about it the more one feels something of that awe which Moses felt when he seemed to hear a voice saying, *Take off thy shoes from off thy feet for the ground on which thou standest is holy ground.*

The Irish writer, Don Brynne, tells of a certain man – "He went out upon the mountain side to gather a few sticks and he found – the burning bush." This is an experience which we covet for every one of our students, so that each at some instant of revelation may see below the



surface of things and feel impelled to say with Christopher Fry, "Reality is incredible! Reality is a whirlwind!" or with Henry Vaughan, "I saw eternity the other night . . ." To some students this flash of insight may come through philosophy, to others through literature or history or science; to many it will come through religion, to others through art; to some by a direct apprehension of "the wonder of the beauty that is manifest in the world", or, as was the case with Pascal, by recognition of the divine in human personality. However it may come, its importance to the student and the scholar is immeasurable; and so the central stone of the lower row is an unconventional representation of the burning bush.

On either side of this central stone are modern representations of classical goddesses. One, symolizing Light and Learning, with a lamp of learning in her right hand and a scroll in her left, may be identified by Queen's undergraduate women with their Roman goddess Levana. The other holds the scales of justice in her right hand while a dove of peace is perched on her upraised left hand. She may be identified with the Greek goddess of justice and fair play, modesty and truth, Astraea, daughter of Zeus; and not without reason would the dove of peace alight upon her hand, for Astraea is no blind goddess like her mother, Themis.

The two remaining stones are placed one beyond each goddess. At the north side the carving represents the arts, music and painting. An artist's palette with brushes is in the upper left, a Greek lyre in the lower right, and diagonally across the rectangle are two bars of music, the notes being taken from the *Women's March* composed by Dame Ethel Smyth early in this century. At the south side is carved an open book, the book of knowledge, with ancient plume and modern pen placed behind it to symbolize the task of discovering and recording knowledge in the past, and the challenge of seeking out, finding and compiling new knowledge. Across the pages is inscribed the date, 1951, when the building was begun.

These then are the ten symbols in stone over the entrance to the large new Adelaide wing of Ban Righ Hall. It is fitting that grateful tribute be paid Mr Colin Drever who gave generously of his artistic talents and time to design these carvings with only the simplest small sketches as starting points. Perhaps for many years to come students entering and leaving this building, and others who pass by, will cast a glance up at these carvings and find their curiosity stirred and their interest awakened. If these symbols give pleasure to some and lead any to think out their significance, they will serve the purpose for which they were planned.