16.

A. Vibert Douglas University Lectures McGill 1935-38

Notes for Lectures
on
Outline of Physical Science

r G.V.D.
1936

A.V. Douglas.

Refs.

The Foundations of Science
W. C. Dampier Whetham
(Peoples Books - Jacks)
Chs. on Physical, Biological + Psychological Sciences
(Former is not bad,
Archimedes to Lorentz)

Astron. of the Bible
Zodiac + 12 tribes
Pleiades - sweet influences any
the coming of Spring at heliacal rising

H. G. Wells: Outline of Hist.
Description of earth

2

Students must buy
1. Stars at a glance 1/6.
2. Handbook RASC. 25c.

Ref. Books.
1. Mendenhall Rev & Keys.

2. Russell Dugan & Stewart I & II.

3. A.S. Eddington: Stars & Atoms.
4. J.H. Jeans. Stars in their Courses
5. " Through Time & Space

6. Camb. Readings in Lit of Science
7. Source Book in Astron.
8. Greek Astronomy - T. Heath.
9. Manual of Mythology - Murray.
10. A.N. Whitehead: Sci & the Modern World
11. H.G. Wells: Outline of Hist Ch. 1-
12. Kosmos - de Sitter.

Dante

see notes in "Astron in Education".
+ also Red Note Book. 1932 Nov 15 Lecture

Shelley

Influence of astron. knowledge -
Q. Mab 1. 252
"Innumerable systems rolled".
In his notes p. 791 Shelley writes: The plurality of worlds - . . .
His deduction that it is impos to deify the principle of the Universe

Mere plurality of worlds is no argument
mere nos - should not appal
no new principle involved.
Cf Beverly Nichols The fool hath said
our earth is unique - a fact to be faced
The astronomers who measure nos + dist do not draw Shelley's conclusion

over

Shelley – Q. Mab VI. 171-3, 198.
Necessity: thou mother of the world.
see Shelley's notes p. 801.
"The doctrine of Necessity tends ....
utterly to destroy religion"

Contrast: L. da V. Oh divine
Justice of Thee Thou Prime Mover –
To no force hast thou permitted
lack of the order and quality
of its necessary effects –
O thrice marvellous Necessity!

Q. Mab VII. 13.
Note Shelley's: There is no God –
see note p. 803. This negation
affects a Creative Deity not
hypothesis of a pervading Spirit
coeternal with the Universe.

Prime Mover.
See A.N. Whitehead on Aristotle.
p. 202 Sci & Mod. Wld.
p. 249. Princ of Concretion.
p. 257 God the Ultimate Limitation

Pascal: Does nature reveal God.
(1) p. 43.
(2) p. 39. Reason cannot find God.

John Stuart Mill Blue Bk.
Essay. Idea of God in Nature -

Thos Huxley - (Aphorisms Blue Bk
p. 10
p. 22, 32, 33 -

Influence of Sci. on Religion
Bps. Gore + Headlam

Practical Work.

Tree Rings in Redpath Museum.
Measure in $\frac{1}{10}$ th inches or mm.
& plot
Search for Sunspot Cycle.
11.2 yrs.

10 Lab. Experiments.

1. g by pendulum.
2. Archimedes Pr.
3. Expansion Coef. of Rod.
4. Gas thermom. $\frac{1}{273}$
5. Boyles Law.
6. Joules Mech. Equivalent
7. Mag. fields & Induced Cur.
8. Mirrors & Lenses.
9. Spectroscope.
10. Interference.

3 Night observations with R.A.S.C. telescope group

Essay topics:-

Gravitation
Radiation
The Sun
" Moon
" Earth - physical properties & age.
" Planets.
Comets and Meteors
Binary Stars
Variable Stars
Novae.
Star clusters
Spiral galaxies.
Magnetism
Surface Tension
Radioactivity
Cosmic Rays - aurora
Astronomical Speculations of Gk Phil {Kant
Mythology of Constellations. opi
Astronomical ideas & influence in lit.
Astron. & the Bible
" & Religious thought.

System of Marks for 1936-37

2 Essays 5+5	10 %	10
Note book of Literary refs	10 %	10
Laboratory + Practical observations	10 %	10
	2 Tests	10
~~Midterm Exam.~~	~~25 %~~	
Final Exam	45 %	60
	100 %	

Essay + Note book must have Refs.
Essays to be handed in on ~~Wed Mar. 10~~ Wed Dec 16.
Note Book " " " before April 23.

Thurs. pm. Sun Life RASC observers group –

N.B. Dec 16 is too late – say Dec 1–8 next year

To be finished
1936 Dec 16

1st Essay Gravitation. (1)
Elasticity
Earth (3)
Sun
Moon (2)
Planets (3)
Comets & Meteors. (2)
Aurora (1)
Gk Astron
Mythol of Constellns (3)
~~Astron of Bible~~
Astron ideas & references } in Shakes.
~~Dante~~
Shelley.
Chaucer
Spenser.
Keats
Astron ideas in Kants philosophy

Tabulate or list notes with references — not to be expanded into essay form

TOPICS

Variable stars	5
Gaseous nebulae	3
Spiral galaxies	1
Novae	2
Magnetism	1
Polarized light.	1.

Time extended to Mar 17.

for 1937-38 — 2nd term

Take lives & discoveries : Kelvin
Faraday
Helmholtz

1st term

L. da V.
Sir Isaac Newton
Galileo

Astrophysics.

Lecture Outline
Session 1935-36,
" 1936-37.
" 1937-38.

BOOK No. 1

McGILL UNIVERSITY

Name______________________________
(Print carefully in block letters, surname last)

Subject______________________________

Course and Year______________________________
(e. g. B.A.3, M.D.5, Junior Matriculation, etc.)

Date of Examination______________________________

Candidate's Number______________________________
(For Matriculation Candidates only)

Number of books handed in______________________________

INSTRUCTIONS

Fill in the above carefully.

Write your answers on the RULED SIDE ONLY.

Use the unruled side for rough work or calculations only.

Do not tear pages from this book.

If the answer to a question is divided, note at the end of the first section "See also work on page --".

If a page is accidentally left blank, write "P.T.O." on it.

Put additional books inside first book when handing in.

1. Given to 4th Yr + Grad. students 1926-27.
Adapted for 3rd Yr. 1928-29.
2. Revised for PhD students 1930-31
3. Given to 4th Yr. 1933-34.
4 Revised entirely for MSc. 1934-35.
5. Full 2 lecture a week course to 4th Yr 1935-36.
6 " " " " " " " " " 1936-37.
7 " " " " " " " 3rd Yr. 1937-38.

...s in spectrogram
...un -Cornu formula

...n plate
...lesinger's Reduction method.

...nis.

...incipal lines in a typical B-star
...timation of relative intensities of
...s required in H.D. classification.

... of Balmer lines.

...tra on a large Harvard
...le.

... + Dec from Boston; Boss no.;
... R.A. + Dec. Colour Index, Type

Astrophysics Course 11. 1935-36.

Fourth Year Gen. BA (Education Certificate)

Miss Dafoe.

Lecture 1.

1. Fri. Oct 11.	2-5	Scope + Historical. R.A. Dec. Precession. ∥x.
2. " 18	"	Magnitudes app. + abs. & problems.
3. " 25	"	" Colour Index, Spectra - Hist. of ap. Cannon Classes. etc.
4. Tu. " 29	11-12	Planck, Wein, Stefan. Giant Dwarf series.
5. Fri. Nov. 1.	2-5	Bohr Atom, Balmer Series, $E = h\nu$, $\lambda\nu = c$ etc.
6. Tues " 5.	11-12	Temp. scale + methods. (Stratton, Payne etc)
7 Fri. 8.	2-5	Chromosphere, Photosphere, Rev. Layer. + Rad. pressure + Limits to stellar masses.
8 Tu. 12.	11-12	Estimation of pressures. + CHP p. 131. Line max^{ma} Si. Si^{+} Si^{++} Si^{+++}
9. Fri. 15	2-5	Radial Velocity. Doppler Shift. Solar Rotation (Sunspots) Saturn Rings
10 Tu. 19	11-12	Spec. Binaries. Vel - abs. Mag. Correlation - Rotation of Galaxy + M31.
11 Fri 22	2-5	Rot. of Galaxy - Distance to Centre, Total Mass + Period.
12 Fri. 29.	2-5	DeLury's Lecture + H's in Chromosphere — Wave + Quantum Theories.
13 Tues - Dec. 3.	11-12	Interferometer. Double Stars - Stellar Diams - α Ori.
14. Fri. " 6.	2-5	Slides ...... R.S.D. Table of Stellar diams.
15 Tu. " 10	11-12	Binary Star Orbits - Elements -
16. Fri " 13	2-5.	Spec. Binary Orbit. Aitken + Y.O data -
17. Tu. " 17	11-12	Discourse on Sunspots by Miss Dafoe - ESSAY.
		[ESSAY TOPIC for Feb. Variable Stars, Nebulae, Globular Cl., Spirals.
18 Fri. Jan. 10.	2-5	Masses + Densities of Stars.
19 Tu. " 21	11-12.	Correlations of mass — Monoceros pair etc. Ranges of Mass.
20 Fri. " 24	2-5	Proper Motion ... Halley - Boss - clusters.
21 Fri " 31.	2-5	Mid-term Exam.
22 Tu. Feb. 4.	11-12	Herschell - Solar Motion. [Telescopes - Galileo, Newton Herschel ... 200"
23 Fri. " 7	2-5	Tang. Cross + Space Vel. + Equip. of Energy.
24 Tu. " 11	11-12.	Measurements in Redpath Mus. of Tree Rings.
25. Fri. " 14	2-5	Smart's Charts. Correl. abs. mag. + Vel. - W.S.Ad. + Ab.Rad. + D.
26 Tu. " 18	11-12	Star Streaming - Stromberg - Oort - Rotation of Spirals.

Lecture

27.	Fri.	Feb. 21.	2-5	Determination of astron. unit – Asteroids –
28.	Tu.	" 25.	11-12	Trig ||x, Bessel, Struve, Henderson. [Pract: Y.O. Typ. spectra]
29.	Fri.	" 28.	2-5	Typical A plate – (Sirius 2 prism Y.O)
30.	Tu.	Mar 3.	11-12	Secondary ||x methods – Hyp. Av. Cluster & Ceph.
31.	Fri.	" 6.	2-5	Spec. ||x – Giant & dwarf spectra –
32.	Tu.	" 10.	11-12	Spec. ||x Criteria & Widths of H lines.
33.	Fri.	" 13.	2-3	Chemistry of the Universe.
34.	Tu.	" 17	11-12	Mass Luminosity Relation –
35.	Fri	" 20	2-5	Hertzsprung Russell Diagrams – Russell Nat. 1925 Aug. 8., J.H.J. (slide) [M, Type, T, Central T, mass, diam.]
36.	Tu.	" 24.	11-12	Range of Electro mag. radiations.
37.	Fri.	" 27	2-5	Variables & Novae – Spectra etc. [A.V.D. absent]
38.	Tu.	" 31	11-12	" " " .
39.	Fri.	Apr. 3.	2-5.	Star Clusters – globular & galactic.
40.	Tu.	" 7.	11-12	~~Spiral Galaxies~~. [Miss Dafoe absent]
	"	14		~~Mag~~-determinations of Sir. B. Vyssotezky – Hetzler.
41.	Fri	" 17.	2-5	Spiral Galaxies & Universe data.
42.	Tu.	" 21.	11-12	" "
43.	Fri.	" 24	11-12	Age of Universe –

Astrophysics - P. II. 1936-37.

Angus MacMorran. IV Yr. Hon. Math.
Catherine Stewart IV. Yr. Gen.

Lecture	Date			
1.	1936 Oct.	6.	Historical. RA. Dec. ||x.	Lab. Catalogues & Spectral Classes.
2		13.	" & Magnitudes m & M ||x relation.	Lab. spectra & Solar Plate
3.		20.	Giant-dwarf sequence & Correl^ns with Sp.Cl.	Lab ditto.
4.		26.	Origin of Spectra Energy level diagram, ionization.	
5	Nov.	3.	Emission, absorption, continuous - [R C Johnson / Grotrian]	Lab. Rad Vel & Doppler. Har texts
6		5.	Solar atmosphere - Flash spectrum. Mitchell & St J. Heights.	
7		10.	Planck, Stefan & Wien Laws - HNR. D & S. § 690, 809, 810, 811, 812 (Color Index), 813, 814, 815 & 610 ✓	
8		12	Heat Index & Radiation measurements - Pettit - Temp. as in Stratton p. 71-75. Ionization method Saha, F & M. Payne	Lab. 20 Brightest Stars.
9.		17 am	Woolley on Ca Ioniz. Temp. of Sun. MNRAS. 1933 Oct.	
10.		17. pm.	Interferometer formulae & measurements 1. Binaries 2. Diams.	Lab. 61 μ Orionis. Rad. vel.
11.		19.	Aitken - Binary Stars - Elements of an orbit.	
12		24.	Eclipsing Variables - Masses - densities.	Lab. Orbit 61 μ Orionis
13		26	Radiation Pres. Limits Mass Range - & Cometary tails.	
14	Dec.	1.	Solar ||x Mr MacMorran - Proper Motions Miss Stewart -	Lab Orbit HR 5992.
15		3	Def^n 3 Years 2 Months 2 Planetary Periods. & Calendar Reform.	→ OPS. p 11
16		8	Proper Motion & Correction for Suns Way. X & λ charts	R.D.S. p. 637. Verify T from Boss data.
17		10	Edd. Star Drifts - Max Vel Correlation & Equipart. of Energy - J.H.J. 4 attacks on Age of Univ.	
18		15	Rotation of Galaxy & Milky Way Atlas.	
19.		17	Sirius - Bessel	(Lab cancelled)
20.	1937 Jan.	5.	Sirius B. magnitude Vyssotczky & Hetzler methods. grads & de.	Lab. Equipartition of energy R.D.S. p. 637, 640
21		7.	Mass-Lum. Relation. J.C.S. notes.	
22		19.	" " " " & R.D.S. p. 885...	Lab. Hartmann - Rad. Vel. γ Leo. & α Boo.
23.		21.	Giants & Dwarfs. Hertzsprung Russell & J.H.J. diagrams.	
24		26.	Stellar ||x. Trig., Group, & Dynamical.	Lab. Mr MacMorran
25		27	" average, Ceph. & Spect. ||x.	A & S. Stewart
26.	Feb.	2.	Spec ||x	Giant Dwarf Spectra.

Lecture Topic.
Mr MacMorran. Solar ||x & distance.
Miss Stewart. Proper Motions.
for Dec. 1st.

Astrophysics - P11 - Cont^d.

Lecture	Date	
27.	Feb. 5 1937.	Spec // ^{x} JRASC. Table of Criteria. & Shajn Test.
28.	" 9.	Spectrum analysis - Chem. of Stars. atoms & mols. Lab: Spectroscope, Hg & He + He in B star
29.	" 11.	Novae
30.	" 16	Sunspots Spectra & Zeeman Effect.
31.	" 18	Variable Stars. & Planetary Neb. — see Ap. J. 1937 Jan. Atkinson.
32.	March 9	Planetary Nebulae. Cont^d. Nebulae.
33.	Mar. 11	Interstellar gases - Nebulium & other lines. Bowen -
34	" 16.	" " Shapley etc. + Edd. 10^{-24} - "Stationary lines. Ca+ Na + Ti+ see Nature Feb. 1937
35.	" 18	Globular Clusters.
36	" 23	" " & Dimensions of Galaxy. Shapley p. 179. pp 174-176. Shapley Star Clusters. Shewed microphotometer.
37	" 30	Spiral Galaxies - Hubble, Humason Shapley. Sinclair Lewis.
38	Apr. 1.	" " Recession - Vel-Dist. correlation - Eddington. SPACE & TIME Newton to Einstein.
39.	" 6	Einstein, de Sitter, Lemaitre, Eddington. [see Silberstein's Size of Universe book cover] Radius of Curvature of Space
40.	" 8.	P. W. Bridgman - Time Scale of Universe.

Read Whitehead on R Soc meeting 1919 - Einstein announcement.
Red note book. Summary p. 31. Total atoms etc.

40 lectures 22 lab periods -

Astrophysics - P.II. 1937-38.

Miss Graham. III Yr.
" D.E. Guignard. III. Took P.I.B.
" Ruth White. " " "

Lecture	Date		
1	Oct. 5.	Introdn. Galileo. Newton Fraun. Kirch. Huggins - Secchi Types + Cannon.	
2.	" 12.	R.A. + Dec. Precession - Babylonians + Zodiac	Lab. 1.
3.	" 15.	Stellar Magnitudes.	
4	" 19.	" " $M = m + 5 + 5 \log p$. an. ‖x. prc.	Lab 2.
5	" 22.	Slit + Objective Spectra + Telescopes + Nebula Sp. P.	
6	" 26.	Cannon basis of Classification H.D. prepara. O - F	Lab. 3.
7.	" 29.	Discussed Classes G - N - Correlations with Sp. Cl. + began Planck, Wien + Stefan Laws.	
8	Nov. 2.	Saha Ionization Thy. + Stellar temps as in F.J.M.S. p. 70 . . .	(Lab. 4.
9.	" 5	Woolley. Ca^+/Ca for Sun + Summary. Began Solar Atmosphere.	
10.	" 9.	Stellar Atmospheres C. Payne p. 47. Chromosphere, Rev. L. Photos + Flash spectrum.	(Lab 5
11.	" 12	Heights of Chromosphere - diagram. St. John - Width of lines + Doppler effect.	
12	" 16.	Rotation of stars - Zeeman + Stark broadening of lines.	(Lab 6.
13	" 23.	Sunspot cycles Polarized light + Zeeman effect M.S.K. + R.D.S.	(Lab 7
14	" 26	Pressures in stellar atmosphere + Quantum Theory + Bohr atom.	
15	" 30.	Interference + Stellar Diams.	(Lab. 8
16	Dec. 3.	" "	
17.	" 7.	Mizar System - Double Stars. Elements of Orbit.	(Lab 9
18	" 10.	Orbits	
19	" 14.	Sp. Binary Orbits - Masses.	(Lab. 10
20	" 17	Range of masses. Rad. pres.	
21	" 21	Proper Motions - + Pole of Ecliptic	(No Lab
22.	Jan. 7.	" " Solar Motion + Apex	
23	" 11	" " ‖l + Cross vel. + Smart's Charts.	(Lab 11.
24	" 14	Correlations with vel. Rutherford 1860 + Schilt 1937 Pleiades. ~~R.S.A. A.S.E.d. Stromberg etc.~~ (Lect. 14 1931)	
25	" 25.	W.S. Adams, A.S.E.d + R.V.D. Stromberg.	(Lab 12

p. 613. R.D.S. $m_1 = 0.33$ $m_2 = 1.70$
$m_2 - m_1 = 1.37$
$I_0 = I_1 + I_2$ find m_0
$\frac{I_1}{I_2} = (2.512)^{1.37} = 3.53$
$\frac{I_1 + I_2}{I_2} = \frac{I_0}{I_2} = 4.53$
$\log \frac{I_0}{I_2} = 0.655 = 0.4(1.70 - m_0)$
$\therefore m_0 = 0.06$.

Astrophysics P. 11 · Contd. 1938 January.

Lecture	Date		
26	Jan 28	Oort – Rotation of galaxy. M.31. Interstellar Ca etc.	
27	Feb. 1.	Rotation of G. data – Mass of galaxy.	(Lab. 13
28.	Feb. 4	Mass – Luminosity Law. Edd. & J.H.J.	
29	" 8	∥x. Trig. Group & Dyn. –	(Lab 14
30	" 10.	∥x average. Cepheid. (see Ap. J. Nov. 1937. p. 409 Diagrams of Joy)	
31.	" 15	Spec. ∥x	(Lab. 15
32	" 18	"	
33	" 22	"	(Lab. 16
34	" 25	Novae.	
35.	Mar. 1.	" Spectrum	(Lab. 17.
36.	" 4	Planetary Nebulae	(Lab. 18
37.	" 8	" " Calc. RDI. p. 835 + Molecules in Stellar & Cometary &c. Spectra.	
38	" 15.	Interstellar gases.	(Lab. 19
39.	" 22	Transparency of Space.	(Lab. 20
40	24	Glob. Clusters.	
41.	" 29	" Dist. + Dist. modulus.	(Lab 21,
42	April 1.	Spiral galaxies.	
43	" 5	Stark effect in B Stars.	(Lab 22
44	" 8	ε Aurigae System & Sirius System.	

1936 Oct
A. MacLennan IV
C. Stewart IV

Astrophysics

1930 Oct. 11.

(Heard Katzman)

1st Lecture

1. Text Books
   & Reference Books.

2. Astronomy of the Ancients. — see Obsy. 1935 Aug. p. 237 McMichael
   Chaldeans. Chinese etc. Constellations
   Saros 18 yrs. 10 dys + . . . see Fath p. 133.
   Eclipses
   7 wanderers.
   Zodiac. 16°
   Naburianu & Kidinu 54 yr 1 mth Lunar Period.
   Hipparchus of Rhodes ~~150~~ 130 B.C. Precession.
   26,000 yrs.
   Aristotle – nothing – Aristarchus of Samos 300 B.C. see W.M.S. p. 23 et seq.
   Ptolemy – ~~150~~ 137 A.D. (1028 stars)
   (Copernicus. 1543.

3. Galileo – 1610 1st Telescope. Refractor.

4. Newton. 1672 1st Reflector
   & Nature of Light.

5 Modern Observatories. J.R.A.S.C. Sept. 1925 – p. 142.

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6. Solar System.
   Stellar System
   Galaxies

7. Definitions (R.A. Dec.) Fath p. 28 Precession.
   Parallax.

Read Parallax R.D.S. I p. 97. 98.
Solar ||x " p186 + refs. Eros. Smart p. 56-64

Lecture 2.

History Cont^d.

As on p. 1. 3.
4.
5.
6.

Magnitude

1. App. mag.

2. Abs. mag.

3. Distance or parallax.

see. 1924 Colloquium notes.

Read. Magnitudes & Colour Index & Photometers.
R. D. S. II. p. 611–620.

Astrophysics.

Lecture 3

Colloquium Oct 23 1930

Stellar Spectra.

Hist. of Astrophysics - Aristotle to Huggins
Early investigations of Huggins, Draper, Lockyer
Classification of spectra - Secchi
Vogel.
Maury
Cannon

Henry Draper Catalogue -
+ Typical Spectra.

Correlations with Type - Colour
Temp.
Mass
Vol.
Density -
Velocity.

Special spectra
very brief :— Novae
Nebulae
Planetary Nebulae
Comets.

see 1930 Colloquium I.
notes.

Lecture 4. Solar or Stellar Atmosphere 1930 Oct. 25 -

Chromosphere
Reversing Layer
Photosphere

Heights in Chrom. from Flash Sp.
Lecture 12 1937 Nov. 12

see Payne p. 48 - - -

[Outline of Sirius B density problem]

Lecture 5. Colloquium II 1930 Oct. 30.

The Contours of Stellar Spectrum Lines -

Cause of absorption lines -
Width of lines - minimum width.
{ Rayleigh Scattering
{ Intrinsic Width (timing)
Electrical & Mag. Fields.
Stark broadening
& new components.
Rotational broadening
Shajn, Struve, Elvey.

see notes on
Colloquium II. 1930.

Lecture 6 1930 Nov. 1.

Black body radiation

Planck curves. R. D & S. p. 535 # 606 – 614.

Wien's Law $\lambda_{max} T = const = 0.289$

Planck's Law $J_\lambda = c\,\lambda^{-5} / (10^{k/\lambda T} - 1)$

Where J_λ is the amt of energy of λ to $\lambda + \delta\lambda$ leaving surface per cm^2 per sec.

Stefan's Law $E = \sigma T^4$

$\sigma = 5.72 \times 10^{-5}$

E = total energy leaving $1\,cm^2$/sec

To here 1936 Nov. 5.

RDS. derivation of $\frac{M_v}{M_p}$ in detail

Stellar Radiation Measurements.

Heat Index and departure from black body radiation of M & N stars.

see Colloquium 1929 February.

Photovisual Photographic & Radiation Magnitudes

RSD p. 619 # 696 – 704

Photometers Stratton p. 20 # 10(a) – 10(b)

Lecture 7. Nov. 8

Stellar Temperatures

Stratton p. 71 – 77.

& Russell RSD. p 731 – 737. & Summary p. 753.

Nov. 15 Lecture cancelled

~~Nov.~~

from Lecture Notes
1926-27.

Stellar Temp Table.

	Wilsing	Coblentz	Sampson	Plaskett	Russell	Saha	Fowler Milne	Payne	
O						23000	>35000	35000 25000	O
Bo	12 000	13 500	25,000	15 000	23,000	18 000	26500	18000	Bo
B5	11	–	–	–	–	14	–	–	B5
Ao	10	9 500	13,000	–	11 500	12	10	11 000	Ao
A5	9	8 000	11	9 000	–	–	–	–	A5
Fo	8	–	9	–	–	9	7 500	–	Fo
F5	7	6500	7 500	–	–	–	–	–	F5
Go	6	6000	6	(6000 5500	6000	7	6 000	8 000	Go
G5	5	–	5	–	–	–	5500	–	G5
Ko	4 500	–	4	(5500 5000	4000	–	4500	6 000	Ko
K5	4 000	–	3 500	–	–	–	4000	3 500	K5
Mo	3 500	3300	3 400	–	3000	5000	3000	4 500	Mo

~~Stratton p. 74~~

methods p. 71

for Solar Temp.
8 investigations
see Woolley MNRAS Oct. 1933.
p. 703.

Lecture 8.

Stellar Diameters.

R.S.D. p. 737 — 749

$$\frac{x}{f} = \frac{\lambda}{2D}.$$

(a) for Double Stars. $\frac{y}{f} = \alpha$ = ang. separation of components. p. 742.

∴ Making fringes overlap. or $x = y$.

$$\alpha = \frac{\lambda}{2D_0}$$

λ = effective wave length. grid gitter or réseau

a, b width of || wires & separation

$S = \frac{2f}{a+b}\lambda_e$ = dist betw diff^n 1^st order images.

Mizar System. p. 744.

Table of calculated & measured diams.
Size of Betelgeuse, Mira Ceti etc
relative to sun & orbit of Mars.

(b) for Stellar diam. Considering star disc made up of 2 half discs

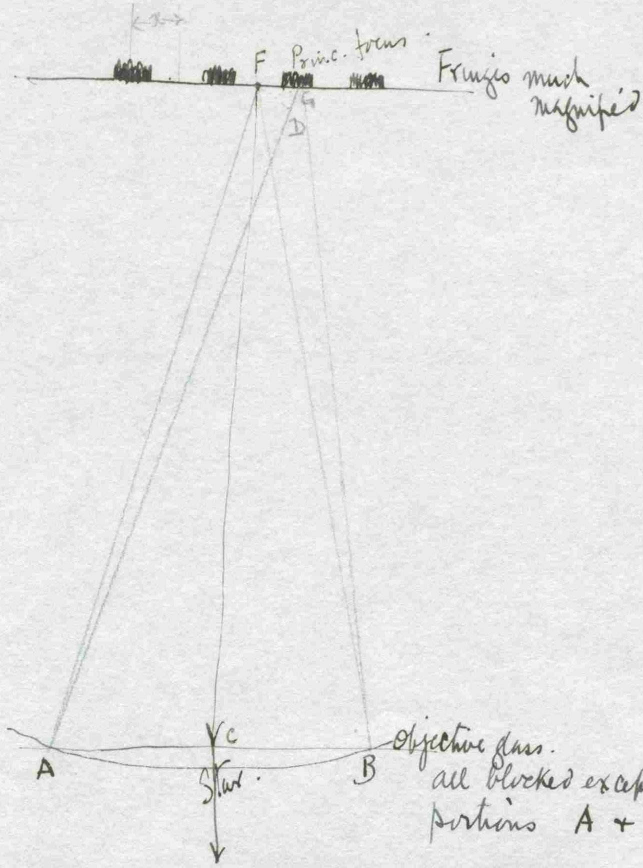
ang. diam β.

effective diam 0.41β.

hence $.41\beta = \frac{\lambda}{2D_0}$ for disappearance of fringes. overlapping from effective centres of the ½ discs

$$\therefore \beta = 1.22\frac{\lambda}{D_0}$$

Lecture 8.



Dependance of fringe position on λ + D.

$$\frac{x}{f} = \frac{\lambda}{2D}$$

$$\frac{x}{f} = \frac{\lambda}{2D}$$

AF = BF $\therefore$ reinforcement

AG − BG = $\frac{\lambda}{2}$ $\therefore$ interference + black fringe G.

Draw FD $\perp^r$ AG.

Δ's FDG, FCA are similar (almost!
$\angle$FAP being so small that $\angle$FAC = $\angle$FGD almost)

$$\therefore \frac{FG}{DG} = \frac{FA}{AC}$$

$$\text{or } \frac{FG}{FA} = \frac{DG}{AC}$$

$$\text{or } \frac{x}{f} = \frac{DG}{\frac{1}{2}D}$$

But AG − BG = $\frac{\lambda}{2}$

and AG − BG = (AG − AF) − (BG − BF) = 2DG.

$$\therefore 2DG = \frac{\lambda}{2}$$

$$DG = \frac{\lambda}{4}$$

$$\therefore \frac{x}{f} = \frac{\lambda}{2D}$$

See R.S.D. p. 746.

1930 Nov 28, 29.

9th lecture

Substituted Visit to D.O. Ottawa

1. Solar Physics - Dr DeLury.

2. Gravity - Dr Millar

3. Seismology - Mr Gold.

4 11 pm to 2.30 am in Dome - Miss Burland.
15-inch refractor
Spectrograms as follows.

β Orionis
α Orionis
α Lyrae
α Can Maj.

Pluto discovery announced by Lowell Obsy
Telegram read to me by Mr Meldrum Stewart
in his office.

5. National Research Laboratories
Dr R W Boyle.

1930 Dec 6. (9)

10th Lecture.

Pressures in Stellar Atmospheres.

Payne Ch. III

7 methods. p. 37 – 45: Table

see Mitchell – Flash Spectrum

" Payne p. 58 for numbers of Balmer lines.

1935 see RSD. II p. 867.

+ for solar atmos. press. § 590, 660-662.

p. 9. inserted before p. 30

Lecture 11

Astrophysics 1930 Dec. 13. (10

Binary Stars.

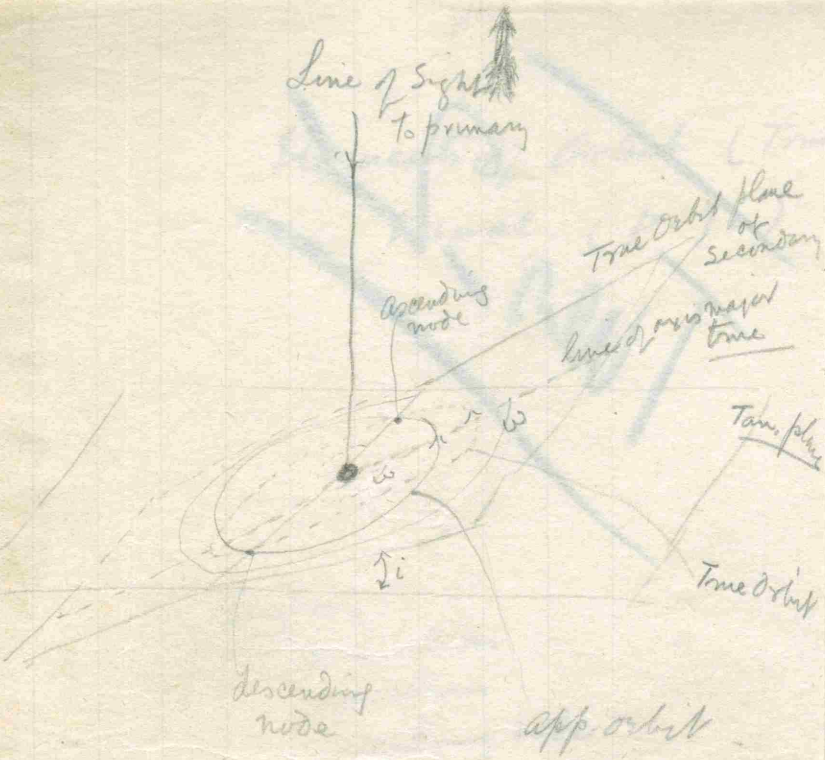
Read Aitken: The Binary Stars [LV. A311]

Ch. I & II

...iew. Riccioli etc

Herschel, Struve, Burnham etc

...(True Orbit)

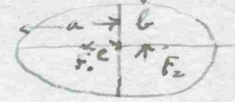


P Period of rev. of companion in mean solar yrs.

T see Julian Days – Fath
Time of Periastron passage.

e eccentricity

$$e = \frac{c}{a} = \frac{\sqrt{a^2 - b^2}}{a}$$



a semi axis major in sec. of arc.

Ω posn. angle (measured from. N to E i.e. anticlock
of nodal pt
between 0° & 180° see p. 72.

ω angle in plane of true orbit
between line of nodes &
major axis
i.e. measure from the nodal
pt. to pt. of periastron
passage in dirn. of Companion
motion.

i inclination of orbit plane

Any observation of a ... star (visual binary) gives
3 things (1) Time of observation
(2) position angle of Companion
(3) Angular distance between the two.

(see resolving power. p.55.

Lick	36-inch	0.″14
	12-inch	0.″42

p. 7. inserted before p. 30.

Astrophysics — 1930 Dec. 13. — (10)

Lecture 11

Binary Stars.

Read Aitken: The Binary Stars [LV. A311]
Ch. I & II
for historical review. Riccioli etc
Herschel. Struve, Burnham etc

Elements of Orbit (True Orbit)

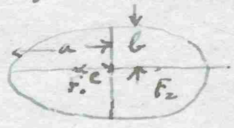
Visual (p. 72)

P Period of rev. of companion in mean solar yrs.

T see Julian Days – Faith
Time of Periastron passage.

e eccentricity

$e = \frac{c}{a} = \frac{\sqrt{a^2 - b^2}}{a}$



a semiaxis major in sec. of arc.

Ω posn. angle (measured from N to E i.e. anticlock →) of nodal pt between 0° & 180° see p. 72.

ω angle in plane of true orbit between line of nodes & major axis
i.e. measure from the nodal pt. to pt. of periastron passage in dirn. of companion motion.

i inclination of orbit plane

Define:
- periastron
- apastron
- ascending node
- descending node
- * Julian Day & Calendar
- line of nodes
- apparent ellipse.

see p. 67.

* Scaliger 1582
Jan 1. BC 4713
∴ 1926 Jan 1 was J.D. 2,424,517.
1930 Jan 1 "

Every observation of a double star (visual binary) gives 3 things
(1) Time of observation.
(2) position angle of companion
(3) angular distance between the two.

(see resolving power. p. 55.

Lick 36-inch 0.″14
12-inch 0.″42

Lecture 11 contd.

Spectroscopic Binary.

Variable (periodic) radial velocity.

see Chap. VI. p. 134.

i is not determinable.

∴ a " "

but $\underline{a \sin i}$ is found in km/sec.

& can be treated statistically to get a mean value of $\underline{a}$.

Ω not determinable.

Note that ω is now always measured from ascending node (not from "the nodal pt." i.e. the one between 0° & 180 necessarily.) where star is receding from observer.

Radial vel has max.^m value at ascending node

" " " min.^m " " descending node.

see Solution of orbit elements of Lehmann-Filhés. pp. 139–149.

Lecture 12. 1930 Dec. 16. 12

Masses of Stars -

(1) From Visual Binaries.
(2) " Eclipsing Variables.
(3) " Spectroscopic binaries.

see Mitchell p 254-258
" Aitken p. 202-209.

(1) Harmonic Law $\frac{D^3}{d^3} = \frac{P^2 (M+M_1)}{p^2 (m+m_1)}$

Where D, (or d) is distance between the two components of the binary system

P (or p) " the period of revolution

M M, (m, m,) the respective masses.

Then for Sun - Earth system

D = 1 astron. unit.
P = 1 year
M = 1 Taking mass ☉ as unit.
M, = mass of Earth. negligible in comparison with M.

Then for any binary system in astron. units, ☉ mass & years.

$$m + m_1 = \frac{d^3}{p^2} = \frac{a^3}{\pi^3 p^2}$$

Where a = semi axis major of orbit in ~~astr. units~~ angular measure (sec arc)
π = parallax of system. (in sec of arc)

(3) Since a sin i & not a
∴ m sin³ i instead of m
∴ mass is at least as great as value of m sin³ i

[average value of sin³ i is 0.667]

2. Eclipsing binaries

Light curve (see Algol.

gives P

& $\frac{d}{r}$

i.e. ratio of separation of components to radius of one.

assume components = in mass

$m = m = 2M = \frac{d^3}{P^2}$ by Harmonic Relation

let ρ be density

$\frac{4}{3}\pi \rho r^3 = M$

$\therefore \rho = \frac{3}{4\pi}\frac{M}{r^3} = \frac{3}{4\pi}\, 2\left(\frac{d^3}{r^3}\right) P^2$

hence knowing $\frac{d}{r}$ & P find ρ.

for 80 of algol type.

$\rho = 1$ approx for solar G.

to 10^{-4} for giant stars.

& super giants ~~hotter~~ less dense still.

Limits of stellar density upper

& lower

See later lecture.

Correlation between mass & Type. see Edd. Stellar Movements p. 160

average mass of B = 8.6 — for systems both components visible. (7 B type / 9 A ...)
" " other types

average mass of B = 6.5 — for systems 1 compt. visible.
" " other type

A.S.E. Stellar Movements p. 160. p. 21–25.

see R D & S. p. 700 – p 704, 705. 706. 707.
p. 719 Table of Eclipsing Binaries.

Plasketts Twins p 704 Monoceros. $m_1 \sin^3 i = 75$ / 63 betw Betelg. & Procyon
Struves Quadruplets. 27 Can Min – Ap. J. 1927 p. 113 Vol 66. p 273 Vol 65. 24 Stars 950 × ⊙

Immense range in luminosity — Trumpler V. massive stars in clusters 2 to 300 × ⊙ See Obsy June 1936 p. 187
Very limited range in mass
Majority of stars between $\frac{1}{3}$ ⊙ to 10 ⊙

Eddingtons Radiation pressure investigation & explanation.

1936 See also Rad pres data from p. E 9. & discuss Comets tails.

Table of relative "etherial" pressure to "material" press. see Colloq. notes 1924 p. {19 20.

10^{32} gms. to 10^{35} gms. Critical balance.

Sun $2 \cdot 10^{33}$ gms.

Most Stars 10^{32} — 10^{34}

Lecture 13.

Stellar Motions.

Read. Smart. Ch. IX pp. 156 – 169.
Eddington (Stellar Movements. pp. 17 – 21
+ Solar Motion. Ch. 5. p. 71 – 79
Star Streams Ch. 6. p. 86 – 104.
R. D & S. p. 628, 629.
+ Ch. XIX. pp. 645 – 661.

Boss. Preliminary Gen. Catalogue (1910) 6188 stars.

μ or μ_α proper motion in R.A. in ~~degrees~~ seconds of time per annum.

μ' or μ_δ " " " Dec. in sec. of arc " ".

Let μ_s be the ~~space~~ p. m. in sec. of arc per annum.

then if π be known (or dist $\frac{1}{\pi}$)

this can be reduced to km/sec thus.

$4.74 \frac{\mu_s}{\pi}$ The factor 4.74 reduces astron. units per annum to km/sec.

thus $\frac{1.49 \times 10^8}{365 \times 24 \times 60 \times 60} = 4.74$.

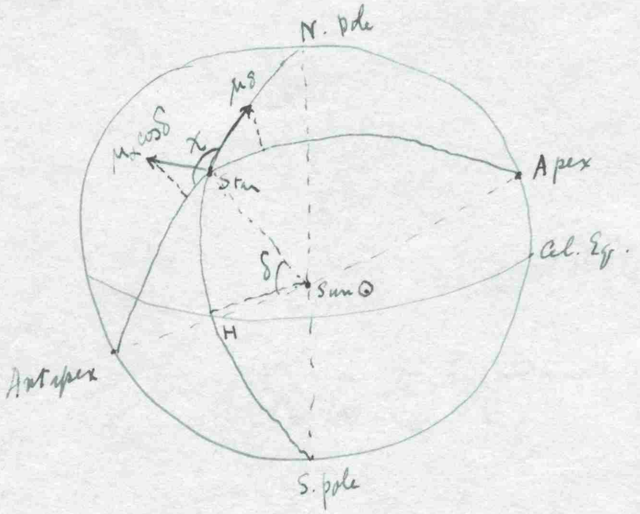
Lecture 13 cont^d.

Solar Motion from p. m.'s of 7 stars by
Sir Wm. Herschel 1783.

Apex of Sun's Way - R.A. 270 Vel. 19.5 km/sec.
Dec +34°

This pt. lies in Constel^n. Hercules
betw. Vega + Arcturus.

To free stellar p. m. from Solar motion
resolve ⊥^r to + ∥^l to Star-Apex direction.



Let dec. SH of Star be δ
" N. pole - Star - Antapex angle be χ
" p.m. along SN be μ_δ
" parallel to cel. equator
will be $\mu_\alpha \cos\delta$
Where μ_α is p.m. along equator
i.e. in Rt. ascension

μ_δ is in " arc.
μ_α " " " time
∴ 15 μ_α is in " arc.

Resolving ∥^l to SA (towards Apex)

$$\frac{4.74}{\pi}\left(15\,\mu_\alpha \cos\delta \sin\chi + \mu_\delta \cos\chi\right)$$ ~~Parallel~~ vel. v_1

Resolving ⊥^r to SA

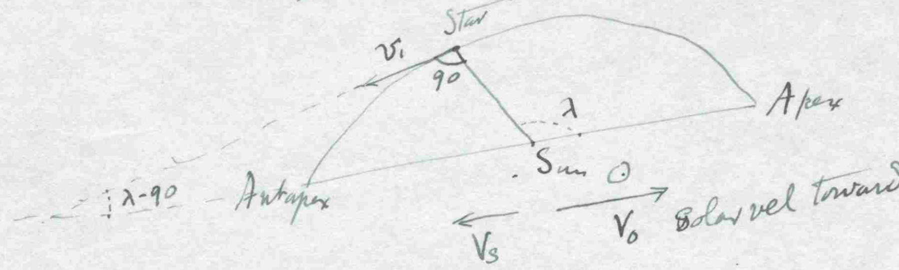
$$\frac{4.74}{\pi}\left(15\,\mu_\alpha \cos\delta \cos\chi + \mu_\delta \sin\chi\right)$$ Cross Vel. v_2

Temp. Space vel. $v = \sqrt{v_1 + v_2}$ on cel-sphere — need rad. vel for TRUE space vel

To eliminate Solar vel. from v_1 divide by sin λ

Lecture 13 ^{contd}

Where λ is the Star - Apex distance.



Let V_S be stellar vel. towards Antapex.
then $V_S \sin 180-\lambda$ or $V_S \sin\lambda = v_1$

or $V_S = v_1 / \sin\lambda$.

then $V_S - V_0$ is vel of star towards Antapex freed from Solar motion.

See Table. p. 640 R.S.D.
find T given μ & π
& given radial vel. V find space vel.

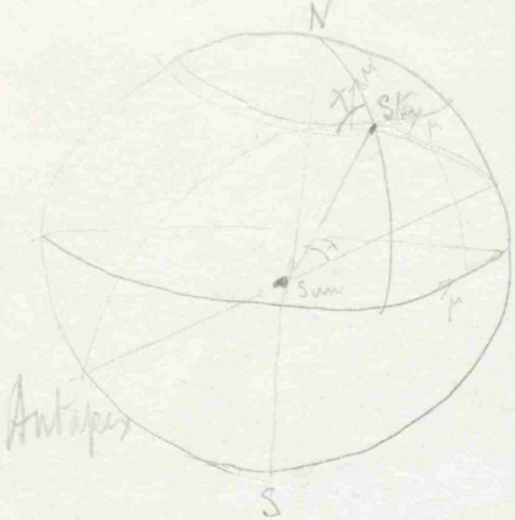
Correlation with Sp. Class. R S D. p. 648. – give Table p. 23 colloq. 1924 Notes W.W. Campbell. & Boss.

" " Abs. Mag. W S Adams.
Eddington & Douglas.

Smarts Pole – Star – Antapex Angle Charts. χ & λ
Pearce " " Apex " " χ & λ

see Table RDS p 637. Verify T column from Boss μ π data
Has he allowed for Solar Motion?
(α Canis Majoris case No 17 without correction
16.7 with correction)

N.B. $\chi_{smart} = 180 + \chi_{Pearce}$.



Star apex distance angle λ.

N. Pole – Star – Ant Apex angle χ

Apex. 1810 273° Ra.
+29.5 Dec.

Proper motion μ in R.A. in sec. of time along equator
μ' in Dec. " sec of arc towards pole

$\parallel \chi = \pi$

$\perp^r$ Apex–Antapex $v_2 = \frac{4.74}{\pi} 15\mu \cos\delta \cos\chi + \frac{4.74}{\pi}\mu' \sin\chi$

$\parallel^1$ " " $v_1 = \frac{4.74}{\pi} 15\mu \cos\delta \sin\chi + \frac{4.74}{\pi}\mu' \cos\chi$

given: p.m. 10.″25 per yr.
find π
π 0″.538

$\frac{1}{\pi}$ = dist in parsecs – but $\frac{1}{\pi}$ in radians = dist in a.u.

$v = \omega r$ where ω is radians
so if both π & ω are sec″ instead of radians
$\frac{p.m.}{\pi}$ is a.u./yr.

$\frac{1 \text{ radian}}{1 \text{ sec}} = 2.06\ 10^5$
& ∴ $\frac{1 \text{ parsec}}{1 \text{ a.u.}} = 2.06\ 10^5$

∴ $\frac{10.25}{.538}$ au/yr × $\frac{1.49 \times 10^8 \text{ km/au}}{365 \times 24 \times 60 \times 60}$ 4.74

= 90 km/sec.

see p. 640

Motions.

(19

Lecture 14. 1. W S Adams - Reprint

Jan 17.

2. A S Edd. "

1938 Jan 14

R.D.S.

3. Star Streaming
+ Ellipsoidal - Stromberg. p 671

4. Assymmetry of Stromberg - Groups. p. 674
Diff. solar apex & vely according to group taken.

No lecture on Jan 24th - and at Compton P.R.

5. Oort - vel. of escape.

Lecture 15 6. Shape of our galactic system.
W. Herschel. Kaptyn. Shapley etc

Jan 31

7. Analogy to spirals.

8 Van Maanen's Vels.

9. Rotation of Galaxy.

Read R S D. p. 668 § 755 - 759.

Jan 25/30. (20)

Why do stars turn down Main Sequence?

Rosseland's answer.

L gradually decreases.
M " "
ρ " ~~increasing~~ increasing
T first increases, then decreases.

$$L = 4\pi R^2 \sigma T^4$$

$$T^4 = C \frac{L}{R^2}$$

$$M = \rho R^3 \qquad \therefore R^2 = \left(\frac{M}{\rho}\right)^{\frac{2}{3}}$$

$$\therefore T^4 = C \frac{L \rho^{2/3}}{M^{2/3}}$$

but L is a function of M
for giants $L \propto M$.
for dwarfs (late) $L \propto M^3$
say $L \propto M^n$
for giants $n = 1$ & for dwarfs $n > 1$ to $n = 3$.

$$T^4 = C \frac{M^n}{M^{\frac{2}{3}}} \rho^{2/3}$$

$$= C M^{n-\frac{2}{3}} \rho^{\frac{2}{3}}$$

If T rising $M^{n-\frac{2}{3}}$ is decreasing ~~less~~ than $\rho^{\frac{2}{3}}$ is increasing

Cont^d from Rosseland.

M^{3n-2} ρ^2

If $n = 1$ M ρ^2

and product is increasing.

i.e. (density)^2 increases faster than M decreasing.

If $n = 2$ M^4 ρ^2

product is decreasing

If $n = 3$ M^7 ρ^2

product decreasing faster.

i.e. late dwarfs. density slowly increasing.

Temp rapidly decreasing

Lecture 16

Astrophysics – 1931 Feb 7.

Outline of Eddington attack on Radiative Equilibrium – Mass Luminosity Relation

A S Eddington: Int. Const. Stars p. 97 Ch. V.

✓ p 99 – (1) Radiation momentum E/c

(2) " energy density $E = aT^4$

(3) " pressure (hydrostatic)

$$P_R = \frac{1}{3}E = \frac{1}{3}aT^4$$

H ergs/sq cm/sec; k = mass coef absn; ρ = density

$$-dP_R = H k\rho \, dx / c \quad \text{Radiative Equilibrium}$$

$$\text{or } H = -\frac{c}{k\rho}\frac{dP_R}{dx}$$

Subst (3)

$$H = \frac{ac}{3k\rho}\frac{dT^4}{dx} = \frac{c}{3k\rho}\frac{dE}{dx} \quad (1)$$

✓ kρ measures obstructive power.

If j is total radiation emitted per gm per sec

$$j = ckE \quad (2)$$

k_1 mean coef absn – arith

k_2 coef opacity. – harmonic

} Rosseland

Ch. VI p. 114.

Fundamental Eqns

Hydrostatic Eqn $\frac{dP}{dr} = -g\rho$ (1)

Radiative Equilib. $\frac{dp_R}{dr} = -\frac{\kappa\rho H}{c}$ (2)

Total Pres. $P = P_R + p_G$ G = gas (3)

(1) + (2) give $dP_R = \frac{\kappa H}{cg} dP$

If L_r is liberation of energy per sec. within sphere of radius r.

$L_r = 4\pi r^2 H$

or $H = L_r / 4\pi r^2$

$g = G M_r / r^2$

$\therefore \frac{H}{g} = \frac{1}{4\pi G} \frac{L_r}{M_r}$

$\frac{L_r}{M_r}$ = average rate of liberation of energy per gm

$\frac{L}{M}$ is boundary value for $\frac{L_r}{M_r}$

Let $\frac{L_r}{M_r} = \eta \frac{L}{M}$

η increases from 1 at boundary to some unknown but not very large value at centre

3

(7?)

$$dP_R = \frac{L}{4\pi c G M} \cdot \eta K \, dP$$

From considerations of necessity

$$dp_R < dP$$

Limiting values for K

Case postulating ηK const $= K_0$

see I.C.S. p 115

Integrating

$$P_R = \frac{L K_0}{4\pi c G M} P$$

see p 116 re const of integration (negligible comp. with P within star.

Let $P_R = (1-\beta)\, P$

$p_G = \beta P$

} these define const β

Then $$L = \frac{4\pi c G M (1-\beta)}{K_0}$$

✓

Thus far formulae do not necessitate "perfect gas" material pr perfect gas p 116

$P_G = \frac{R}{\mu}\rho T$ Charles' Law

Now $P_R = \frac{1}{3} a T^4$ Stefan's Law

$\therefore P = \frac{R\rho T}{\beta\mu} = \frac{aT^4}{3(1-\beta)}$

Eliminate T & get $P = K\rho^{4/3}$ ←
Kappa.

where $K = \left(\frac{3R^4(1-\beta)}{a\mu^4\beta^4}\right)^{\frac{1}{3}}$
Kappa.

Any mass of gas (star)
where $P = K\rho^{\gamma}$ is said
Kappa.
to have polytropic distribution

Emden has made solutions
for various values of γ

here $\gamma = 4/3$ & n (in Emden's eqn =3) p. 81-83

from Emden Tables

$1-\beta = \cdot 00309\left(\frac{M}{\odot}\right)^2 \mu^4 \beta^4$

a quartic equation to find β.

NB β depends only on Mass & mean mol wt μ

p 116

? ——→ & is indep. of rad & opacity.

Yes Opacity depends on temp & dens.

There are thus 3 eqns

(1) $1-\beta = .00309 \left(\frac{M}{\odot}\right)^2 \mu^4 \beta^4$

(2) $L = 4\pi c G M (1-\beta) / K_0$

(3) $\frac{T^3}{\rho} = \frac{3R(1-\beta)}{a \mu \beta}$

(3) gives $\frac{T^3}{\rho}$ constant throughout a star

4 " " all stars of same mass.

Also Temp at *homologous* pts in interior varies as $\sqrt[3]{\text{mean density}}$.

Omit

N.B *Effective* Temp T_e in photosphere is *not* at a homologous pt.

T_e is *defined* by $\pi a c R^2 T_e^4$ (p. 120)

[where Bl. body Radn is $E = aT^4$ & the radn escaping from the surface is $\frac{1}{4} Ec$

or $\frac{1}{4} ac T^4$ (ergs)? / cm²/sec.

Stefans Const $\sigma = \frac{1}{4} ac$

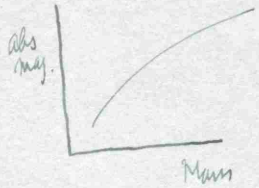
p. 38, 39.

Lecture 17.

Astrophysics.

Eddington: $L = 4\pi c\, GM(1-\beta)/K_0$.

Where β is given by
$$1-\beta = .00309\left(\frac{M}{\odot}\right)^2 \mu^4 \beta^4$$

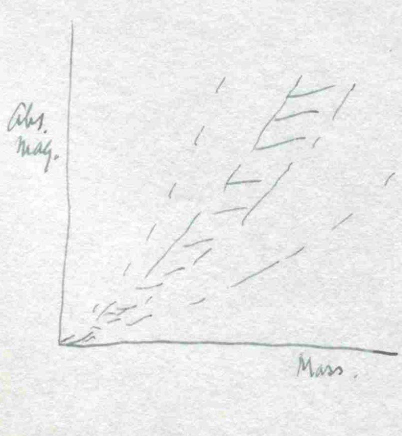


$\therefore L = f(M) + \text{const.}$ (J.H.J. MNRAS. June 1925 p. 792)

Eddington assumes an average value of Opacity-coef. K_0 for whole star & evaluates only remaining constant so as to make Capella fit the relation curve.

J H Jeans $L = F(M) - K \log T_e + \text{const.}$

Where T_e is effective temp & K is almost unity but depends on the power to which T. is raised in the formula for Opacity-coef. (MNRAS. June 1925 p 792)



see Colloquium Oct 1925.

Cepheid theories

On Eddington's theory

for very massive stars $L \propto M^{1.4}$.

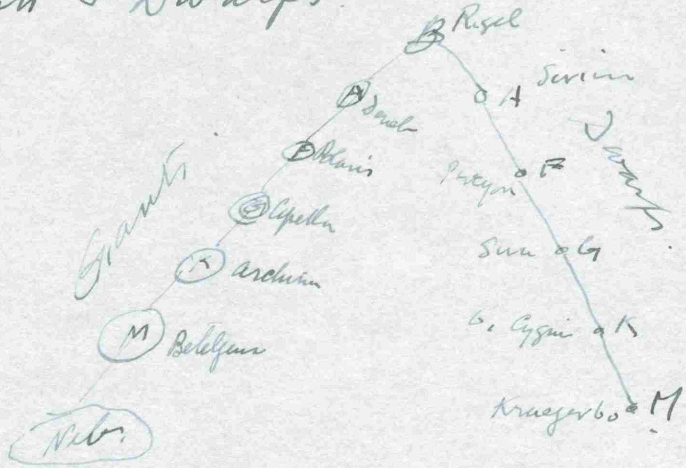
" stars of very small mass $L \propto M^{4.4}$

" stars of average mass.

abs mag 5^M to -1^M $L \propto M^3$

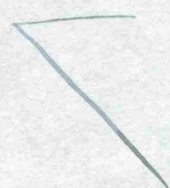
Lecture 18.   Astrophysics   1931 Feb. 21.

Giants & Dwarfs



• White Dwarfs
Sirius Dw.

Hertzsprung Russell



R.D.S. p. 724.
Stellar Mov. & Str. of Univ. p. 171.

Diagram from Nature 8 Aug. 1925

see Colloquium 1925 Oct. Notes. p. 7.

1937 Jan

see diagrams J.H.J. The Univ. around us. p. 271
p. 296.

1931 Mar. 12 -
R. H. Fowler

Stellar Structure.

ASE - mod^n by SAM -

pfct gas.

rad^n not conv^n or conduction (convection)

High local + mean ρ's poss - with pft gas charac

ioniz^n down to K-ring - 24 electrons off.

AS Eddington still holds field

Assumptions - model star

ASE & Milne follows

(1) mass abs^n coef / gm const throughout star

(1) Kρ K per gm const

(2) Source

$$\frac{L}{M} = \frac{\text{Total energy emitted}}{\text{total mass}} = \varepsilon \quad \text{const throughout star}$$

(3) Mech. Equilib throughout

Find Equilib state of such a model

This is determinate, a priori assumption

K, L, M Postulated -

$L = f(M\,K)$

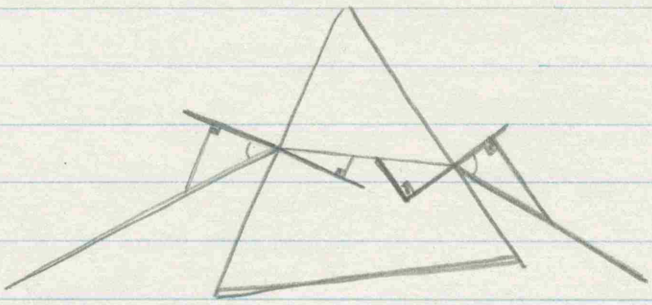
→ Here ε & m part - after getting Emdens polytrope n = 3.

ε takes 1 partic sol^n without further investig

2^nd order diff eq^n 2 parameters

ε fixes 1 param - no exact justification

conceivably right.



E ∴ get M–L relⁿ

~~I~~ thinks theory should not have given

M–L relⁿ at that stage –

Empirical M–L relⁿ

can be made to fit by suitable K –

Pure equilib relⁿˢ do not lead to it.

But fallacious results can be drawn from a relⁿ

merely empirical –

But this K does not agree with quantum mech K

K in a star is a derived phys. quantity –

Come back to the M–L relⁿ [illegible]

We do not know enough about absⁿ to know what

K should be –

∴ Discrep. is not here serious –

Poss. Milne's may be worse than E's –

Central temp $4 \cdot 10^7$. as E.

Abandon E's assumptions & his theory pts

to (not yet proved) 10^{11}

This is satisfactory from physicists –

K.E. at $4 \cdot 10^7$ is electron 5000 volts not enough

but mean KE " " 5×10^6 " might

have an effect

on matter –

If rad^n → matter
& matter → rad^n
Assume thermo dyn. revers.

$\left.\begin{matrix} mc^2 \\ Mc^2 \end{matrix}\right\} \rightarrow h\nu$

We need (1) very hot centre
(2) hottest in biggest star

but supergiants – Betel –
1000x rate of sun ∴ should have
gtr central temps.

But Edd gets reverse –
central temps about the same
& good 10^7 to 10^8.

Given M L K in model star –
(3) $\varepsilon = \frac{L}{M}$ = const for ev. element of mass of star –

p = gas pre
p′ = rad^n " $= \frac{1}{3} a T^4$

$L(r')$ rate of gen at $r = r'$
$M(r')$ total mass inside $r = r'$ –

(1) $\frac{dp}{dr} + \frac{dp'}{dr} = \rho \left(- \frac{G M_{r'}}{r^2} \right)$

(2) $\frac{dp'}{dr} = - \frac{K \rho L(r')}{4 \pi r^2 c}$

} general for all models in equilib

div. 1 by 2

$$1 + \frac{dp}{dp'} = \frac{4\pi c G M}{K L}$$

$\int$

boundary condn $\begin{cases} p = 0 \\ p' \doteq 0 \end{cases}$ approx not questionable —

$$\therefore p = p'\left(\frac{L_1}{L} - 1\right)$$

$$L_1 = \frac{4\pi c G M}{K}$$

Nonsense if $L > L_1$ star blows up.

$\therefore L_1$ is max poss L for stability

i.e. note p/p' in const ratio throughout star

$$p = \frac{R}{\mu}\rho T \quad \text{pft. gas}$$

Insert & get

$$\frac{R}{\mu}\rho = \frac{1}{3}aT^3\left(\frac{L_1}{L} - 1\right)$$

i.e. $\rho \propto T^3$

∴ gradient of temp

$$\frac{4R}{\mu}\,\frac{1}{1-\frac{L}{L_1}}\,\mu^2\,\frac{dT}{dr} = -GM(r)$$

$$\frac{dM(r)}{dr} = 4\pi r^2 \rho$$ —

Tie all together

$$D\,\frac{1}{r^2}\,\frac{d}{dr}\left(r^2\,\frac{dT}{dr}\right) = -T^3$$

new variables — $T = \lambda\,\theta$

$r = \lambda'\,\xi$

∴ equil state is given by

→ $$\frac{1}{\xi^2}\,\frac{d}{d\xi}\left(\xi^2\,\frac{d\theta}{d\xi} + \xi^3\right) = 0 \quad ?$$

Emden polytrope —

Here E's the part

Emden's soln — only one finite at origin

Use this soln & get

E's subsequent work

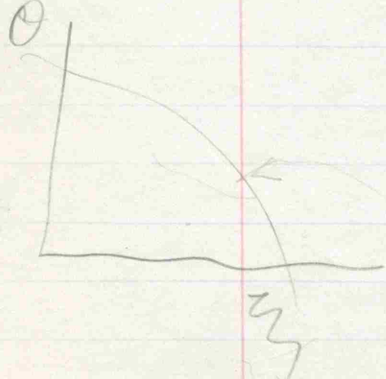
F cuts this

But there are other condns poss

given L M K.

$$M_r = \text{F const L G etc} \left[-\xi^2 \frac{d\theta}{d\xi} \right]_{(r)}$$

at boundary r = 1



Reqd that $\theta_1 = 0$ at $\xi = 1$. by adjusting scale

$$\xi^2 \frac{d\theta}{d\xi} = \frac{1}{\sqrt{C}}$$

C a const fixed if L + K are fixed in advance

Ed says if L is as M-L reln Soln is as on Emden curve

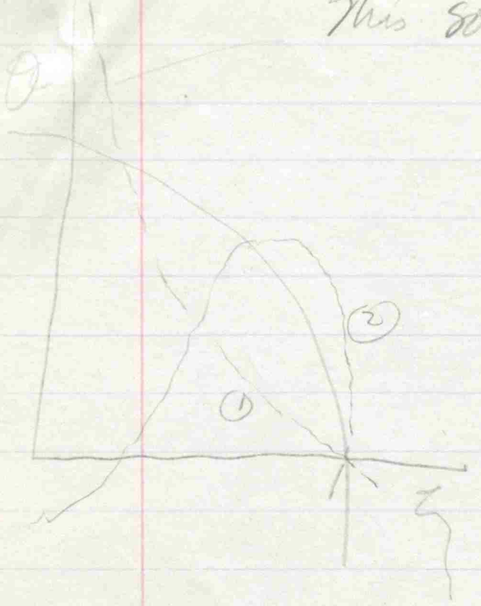
Otherwise not.

As ξ (+ r) $\longrightarrow 0$ $M_{(r)}$ must $\rightarrow 0$

+ ∴ $\xi^2 \frac{d\theta}{d\xi} \longrightarrow 0$

See props of other solns

this solⁿ obeys the ξ relation
given by slope < Emden slope



$$\theta \sim \frac{1/\sqrt{2}}{\xi \left(\log D/\xi\right)^{\frac{1}{2}}}$$

gives ∞ ρ at centre
M + R have proved that
this keeps values of ρ ... .

Take slope > Emdens – get curve ②

Meaning of ②

at max^{m} mass inside = 0
press inside is max

⟶ [values of L + K give slope]

Summary

$L < L_1$ or blow up
Get L_0 for given K – L by Edds.

When $L_* > L_0$ we are on ①
with central condensation

When $L = L_0$ Edds case. finite T + ρ at centre
+ arbitrary radius

When $L < L_0$ only get gas matter into equilib. of rigid boundary, internally supported by a ...

Apply this to actual stars

Imagine this internal supporting boundary + remove it.

collapse follows.

place till perfect internal condensation takes gas laws break down

+ get White dwarf stars

Use Fermi-Dirac degenerate gas

temp 10^9 is the zero temp

...ssor Jan...
see Milne's latest
...marks high temp
high opacity
for degenerate gas

If $L = L_0$ see Edds — full discussion

For Range $L_1 > L > L_0$

see Milne's nov. m.n.r.a.s.

(not neces. all correct

condensation until p. gas laws fail

+ then curve turns over to ordinate

Modification of model neces.

L_0 crit. diving luminos. seems of wide significance

Take point source of energy + get

family of curves same as of Jean

assume the Σ = const.

Astrophysics

Lecture 22
1931 Mar. 21.

finished latter half of Lecture 21.

Lecture 23
1931 Mar. 28.

Most distant objects.

Nebulae.

Hubble's classification
see Ap. J. paper resumé
& "Island Galaxies".

Spectrum of gaseous nebulae — see RSD p. 836.
Lines N_1 N_2 nebulium – Bowen. 1927.

spectrum of extra-galactic nebulae.

Lecture 24

Novae.

Solar Chromosphere. — St. John
Milne.

Chem. of Stars.

Lecture 19

Astrophysics 1931 Feb. 28.

Parallax

1. Historical: see Smart. Chap. XI. p. 178 – S. S. & Universe

Galileo
3 criteria (1) brightness
(2) proper motion
(3) binary stars having short period + large angle of separation.

Steinheil
Arat

(a) Bessel 1838 took 61 Cygni the "flying star 5".2 per annum ||x 0".31
i.e. criterion (2) + (3)

(b) Struve 1837–1840 took Vega criterion (1) + less degree (2) ||x 0".25
p. m. 0".3 per annum.

(c) Henderson 1839. α Centauri satisfied criteria 1, 2 + 3. ||x 1".0
astronomer at Cape

		Early ||x	Present Value ||x
Henderson	α Cent	1".0	0".75
Bessel	61 Cygni	0".31	0".31
Struve	α Lyrae	0".25	0".12

see Sir J. Herschel's address 1841 (p. 184)

2. Present state of investigation.

Trig ||x Gen. Cat. of ||x. Schlesinger Yale 1924

1870 stars

see range – i.e. lower limits + prob. errors

by 1928 2500 stars.

Roy. Obsy. Greenwich 50 per yr.

Nearest star
||x 0".75
= angle subtended by 1 inch 4½ miles away

3. Results. (a) See Table. p. 186.

(b) Absolute Magnitudes

Lecture 19 contd.

Parallax – Methods of Determination.

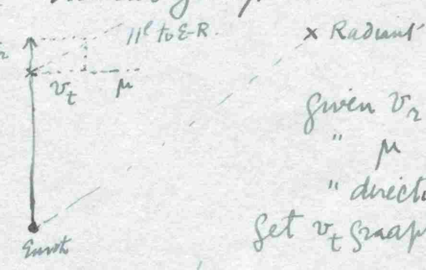
(1) Trigonometrical. 2500 all told by 1931 (Moulton)

(2) Cluster or Group ||x

Moving clusters 1909 L Boss. Taurus group.

see Fath p. 217.

[Ref. Rasmuson]



given v_r in km/sec.
" μ in "arc/yr.
" direction E-R.
Get v_t graphically

then $v_t = 4.74 \frac{\mu}{\pi}$

hence π.

(3) Hypothetical ||x or Dynamical ||x

$$\pi = \frac{a}{\left[\overline{m_1 + m_2}\, P^2\right]^{\frac{1}{3}}}$$

Keplers 3rd Law –

a = semi axis major in "arc.

$\therefore \frac{a}{\pi}$ = linear measure

$m_1 + m_2$ = mass of binary stars

P = period of revolution.

Assume $m_1 + m_2 = 2\odot$

→ Now error in estimate of mass gets reduced to $\sqrt[3]{\text{error}}$ in resulting ||x.

(4) Average ||x see next page

(5) Cepheid Variable Relation

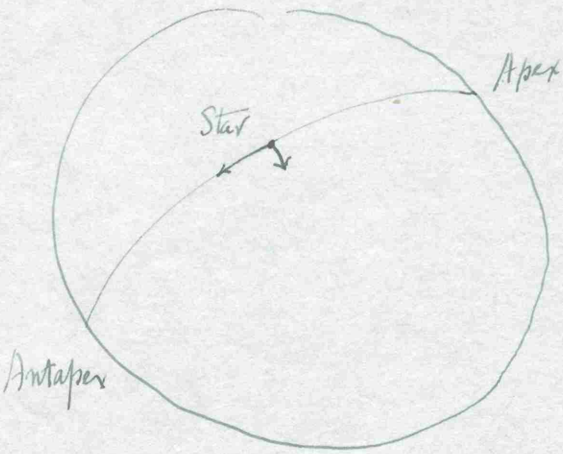
(6) Spectroscopic ||x. 19707 by 1930 + contributions of less than 100 each

Lecture 20

Astrophysics 1931 March 7.

Method of finding $//^x$

No. 4 Average $//^x$



Resolve the p.m. along the gt ○ towards Antapex

ν component.

and $\perp^r$ to apex direction

τ component.

Use average τ comp.

and after subtracting Solar motion find average ν component.

Then Average Radial Velocity

= $\frac{1}{2}$ ~~space~~ proper motion Velocity.

= average τ component.

= average (corrected) ν component.

without regard to sign or direction.

H & R finds τ comp. best for stars > 9 mi./sec.

ν " " " " < 9 mi/sec.

Astrophysics

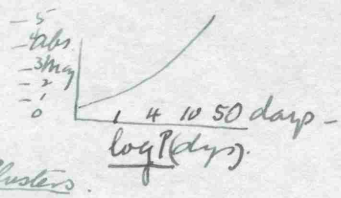
Lecture 20
(2)

Method of finding //x

No 5. Cepheid Variable Relation

see R.D.S. pp 760 – 769. ←

Smart p. 229 - 30 - 31 - 32.



Refer to Shapley on Clusters see his book Star Clusters.
Hubble on Spirals – Ap. J. LXIV. 1926.

Lecture 21
1931 Mar 14.

Spec //x

No 6. see Colloquium 1924 pp. 16 – 18.
& J.R.A.S. Thesis.
Table.

See Stratton p. 129. good plate
– p. 132 see especially last para.

see C.H. Payne p. 140 – 152.

see R.D.S. p. 726 – 731.
p. 870 – 876
Plate p. 872.

$\rho \propto g/K$

$g \propto \sigma M/L$

K = absn coef.
σ = surface brightness

Differential & Absolute //x see RWD (J.R.A.S.C.) p. 269.
"Known //x's"

Shajn Double Star Test.

Spec //x 1970? published by 1930
+ lists of less than 1000 each.