A. Vibert Douglas "Between the Stars" Publication 109.

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G. V. D.

BETWEEN THE STARS

BY A. VIBERT DOUGLAS

I

ASTRONOMY has made great headway in recent years in the measurement of star distances, not only by the direct methods of trigonometrical survey, but by various statistical and spectroscopic methods, the results of which have justified the various assumptions involved. The result of all this laborious work has been to present a picture of the galaxy of ten thousand million stars surrounding our sun so vast that its emptiness is the first characteristic to attract attention. Three or four minute minnows with the whole Atlantic Ocean as their swimming pool — such similes have been employed to convey some idea of the vastness of interstellar space.

It has long been realized, however, that interstellar space is not entirely empty — in other words, it is not a true vacuum. There is a certain amount of scattering of light traversing these 'empty' regions. This attenuation can only take place if interstellar space contains at least an occasional atom or free electron. Photographs of various regions of the sky, particularly the Milky Way, show that there are vast regions so densely filled with gaseous matter that the light from the stars beyond is almost if not completely absorbed. Some of these gaseous nebulæ have comparatively clean-cut boundaries, whereas others have no apparent boundary, their densities growing gradually less and less until normal sky background is reached. This points directly to the conclusion that there may be and probably is finely scattered matter throughout the whole of interstellar space.

This hypothesis was first discussed in a thorough manner about four years ago when Professor Eddington made it the subject of the Bakerian lecture for that year. With weighty arguments, he set forth the theory that interstellar space is not empty but full of matter. This word 'full' is, of course, used not in its absolute sense of containing so much that no more could be contained, but in the relative sense that there are no vast regions completely devoid of all matter; there are in fact so many atoms dispersed throughout space that there is probably one in every cubic centimetre of space at any instant.

The observational confirmation of this interesting hypothesis has been gradually accumulating and forms one of the most graphic stories which modern astrophysical research has produced. Like many another important discovery, it made its appearance as an incidental and perplexing exception to a general rule in quite a different problem.

II

Sir William Huggins, half a century ago, considering the change of pitch of a sound produced by the motion of the source of sound or of the hearer or of both relative to one another, — a phenomenon carefully investigated by the Austrian physicist, Doppler, after whom it is called, — drew attention to the analogous effect on the color or wave length of light by proposing to use this measurable shift of the spectrum lines to violet or to red, as the case might be, as a means of determining the velocities with which individual stars are moving toward the solar system or away from it. This method of studying stellar motions was taken up by all the leading observatories, which equipped themselves with spectrographs for this purpose, and to-day the radial velocities of many thousands of stars have been measured and recorded.

One of the early workers in this line was Dr. Hartmann of Potsdam, who announced that there was something apparently inconsistent about the behavior of the lines due to calcium in the spectrum of certain stars. These two particular lines known to spectroscopists as the H and K lines were not displaced to red or to violet as were the other spectrum lines. Here was a mystery! A star that was moving rapidly toward us, for example, would show the characteristic shift of the lines in its spectrum toward the violet — that is, all its lines except these calcium ones and sometimes also a line due to sodium.

Other astronomers soon found the same thing and very soon theories were devised to explain the presence of these 'stationary' lines, as they were at first called. Just as the earth moving in its orbit carries with it on its flight through space its own surrounding atmosphere of cool gases, so, too, a star carries with it a vast atmosphere of gases which surround its intensely hot inner gases. It is when the light, or, more generally speaking, the radiations bursting forth from the hot interior of the star, pass through the relatively cooler gases of its own outer atmosphere that certain specific radiations are absorbed by the atoms composing this atmosphere, thus producing the dark lines in the spectrum of the starlight — and these lines by their position in the spectrum indicate the velocity of the star relative to the earth. But now suppose that the star were moving not through empty space but through a vast cloud of highly dispersed gases, so that light leaving the star passed through millions upon millions of miles of this gas on its journey toward the earth. If this gas were in part composed of atoms of calcium in the state of positive electrical charge which renders them capable of absorbing radiation, then the H and K absorption lines should be found in the spectrum of the starlight in addition to all the lines due to absorption by the atoms in the star's own atmosphere; but whereas the latter, the true stellar lines, will be displaced according to the radial velocity of the star, the former or interstellar lines will be unaffected by this velocity.

The question then arose as to the origin and extent of these 'stationary' clouds of calcium and no doubt other gases, as there is no reason to suppose that all the elements known to science are not represented in interstellar space. Are they due to expulsion of matter from the giant stars that are moving through these regions? Or might they be the last remnants of the great nebula from which the stars have been slowly formed by gravitational aggregation?

More light was thrown on the question when Dr. Struve of the Yerkes Observatory showed that the more distant the star from the solar system the more intense were the 'stationary' lines in its spectrum. This pointed unequivocally to the hypothesis that this gaseous cloud extends throughout interstellar space.

The word 'stationary' was soon shown to be inaccurate by several astronomers who found that these lines were not usually completely undisplaced in the spectrum, though they were not shifted to the same extent as the true stellar lines, and the terms 'detached' lines or 'interstellar' lines have now been adopted to replace the obsolete adjective.

The crowning discovery was made when it was shown that the residual shifts of these detached lines can be explained if the vast interstellar cloud of gases and the ten thousand million stars which are moving about within it are all taking part in a majestic rotation. This subject formed part of the George Darwin lecture delivered by Dr. J. S. Plaskett before the Royal Astronomical Society in May of this year, when this eminent Canadian astronomer discussed the observations made by himself and his associates at Victoria, B. C., observations which are considered by many to provide very strong confirmation of the hypothesis of galactic rotation.

III

It is interesting to consider that at any point in interstellar space 'wireless' messages from all the myriad stars known to modern astronomical photography might be intercepted. And not only from the myriads of stars forming the galaxy about us, but from the thousands of other galaxies, the so-called spiral nebulæ, so remote that, though each is probably an assemblage of a thousand million stars, yet only one is sufficiently near our own galaxy to be seen with the unaided eye. Every message, wireless or otherwise, involves a transfer of energy. Hence, at every point in space, energy from every star and every galaxy is rushing past at the characteristic speed of all radiant energy, 186,000 miles per second. Yet such is the marvelous nature of space that there is no interference, no blending, no merging, no loss of identity of a single one of the innumerable messages that are rushing past each point in every possible direction.

Space, empty space, completely devoid of matter, offers no hindrance to the passage of light or heat or any other form of radiation. Each unit or 'quantum' of radiant energy flashes through space like a projectile, yet accompanied along its route by electrical and magnetic disturbances of an undulatory character which suggest the physical picture of wave motion. To complete the picture, to give the mind a tangible representation of radiation passing through space like waves in the ocean, physicists invented the term 'æther,' a hypothetical, immaterial *something* coextant with space. Whether this conception has on the whole helped matters or whether it has merely introduced an unnecessary complexity is a debatable point; but the term is generally understood to mean that immaterial medium filling all space, intergalactic as well as interstellar, through which radiation flows, offering no resistance to its progress, nor indeed to the motion of material bodies whether atoms or aggregations of vast millions of atoms in the form of stars. There have been, it must be added in qualification of the last statement, a few men of science who conceive of the æther as having a viscous property resisting the motion of material bodies like stars and planets; but until incontrovertible experimental evidence is forthcoming the majority of physicists will regard the æther as little if anything more than another name for space.

Radiation only runs the risk of being interfered with on its journey through space when it encounters material particles such as these atoms of calcium that we have seen to be diffused throughout the interstellar regions. An atom may absorb the energy of a radiation falling upon it, or it may simply scatter or deviate it from its course. This obviously is why the astronomer has been able to detect the presence of interstellar matter at all.

IV

Apart altogether from the mysteries with which matter and radiation are surrounded, there is the great challenging fundamental question, What is the nature of space? We are apt to feel that it must be so obvious to everyone just what space is that it is unnecessary to essay the exceedingly difficult task of putting our notions into words. But space, it seems, is not so simple. A ray of light starting out in a certain direction, even if it encountered no matter whatever in interstellar space to dissipate its energy and scatter it to the four winds, would not continue forever in the same straight line away from its starting point (using the term 'straight line' in the sense in which we use it in everyday life). It would, in fact, according to the great thinkers who follow the lead of Einstein, tend to curve round and ultimately come back to its source. Hence space is said by these investigators to be finite though unbounded.

The longest possible path that a ray of light can travel is not infinitely long, the number of stars in the entire universe is not infinitely great, the total energy in the universe is not infinite in amount — and yet on the wings of light, or indeed on the wings of reasonable thought, there is no place to which you might roam where you would feel yourself to be at the edge or boundary of space. You might imagine yourself leaving this solar system, leaving this galaxy of ten thousand million stars, visiting any other of the far-away galaxies, or visiting any point of intergalactic or perhaps even we might say of extragalactic space, yet nowhere having any reason to feel that space did not stretch out equally all around you.

This sounds not only absurd but quite contradictory. Can there be any truth in it? The explanation of the cosmologists involves a four-dimensional line of argument logically apparent to the mathematician but outside the limits of visualization. The words 'curvature' of space and 'warping' of space are used in an attempt to convey by analogy with the three-dimensional objective world of our experience some idea of the state of things in this hypothetical space of the mathematician. It is due to the 'curvature' of space that light travels in a great orbit in space devoid of matter, and that near to a massive star it is swerved from this path because space near a concentration of energy in the form of matter is more highly 'curved.' For the same reason a small body like a planet revolves about its sun, not because the more massive sun pulls it inward continually (as Newton explained the phenomenon), but because space itself, under the mutual influence of sun and planet, is 'curved' or 'warped' so that the orbit is the natural path of least resistance for the planet to move in.

The justification for the belief that this hypothetical space of the mathematician more nearly represents actual space than does our (so-called) 'common sense' idea of space is that the former overcomes certain difficulties and incongruities that both physicists and astronomers had discovered when attempting to harmonize some facts of observation and experiment with the older 'common sense' idea of space.

V

At this stage, when physicists and astronomers have been feeling their way painfully and by devious paths, blazed out for them by three or four pioneer cosmologists, toward a satisfactory theory of space, a new and quite startling discovery has been made in the realm of theoretical research. Space, which according to the views of these thinkers was to be thought of as unbounded but of finite volume, is possibly capable of expansion or of contraction. This theoretical possibility considered in conjunction with the astronomical fact of the recessional velocities of the spiral nebulæ points to the extraordinary conclusion that the universe is slowly expanding — space itself is increasing in volume.

Chapter One of this universal detective tale was published in 1927 in a Belgian scientific journal, the author being Abbé Lemaître, but its significance lay unappreciated for two or more years. Chapter Two was written by Professor Eddington and published only a few months ago. His calculations point to an expansion of space at the rate of double the radius in fourteen hundred million years. This means that superimposed upon the individual motions of stars and of stellar galaxies there is a gradual drifting apart going on all the time. The astronomers of some far-distant date will have even less chance than those of to-day of finding out the secrets of the spiral nebulæ, unless they discover much more delicate and sensitive instruments than any in use at the present time, for this ever-increasing remoteness means that gradually these other galaxies will pass beyond the limits of detection by even the most powerful telescopes yet constructed.

Chapter Three of this strange tale may be expected, perhaps, from the pen of Professor de Sitter. Subsequent installments are certain to follow from other pens, but what they may disclose is beyond conjecture.

How can these things be? The agelong question recurs and the classic reply has never been improved upon: 'The wind bloweth where it listeth, and thou hearest the sound thereof, but canst not tell whence it cometh, and whither it goeth.' It is not only the matters of ultimate importance, the questions of spiritual truth, that are surrounded by mystery. The world of nature around us is everywhere thus enfolded. Mystery should challenge us, not dishearten and depress us.

Mankind may be pardoned for having so long believed in two fundamentally simple starting points of thought — space and time. Now these too have been shown to be far from simple, nor can they be dissociated the one from the other. The mystery of life, the mystery of matter and radiation, the mystery of 'spacetime' — which is the greatest, or are they perhaps not three mysteries, but one? 'Behold, I show you a mystery' — much more remarkable would it be to be shown something that was not a mystery! But would it really interest us?

GUESTS OF THE NATION

BY FRANK O'CONNOR

I

At dusk the big Englishman Belcher would shift his long legs out of the ashes and say, 'Well, chums, what about it?' and Noble or me would say, 'As you please, chum' (for we had picked up some of their curious expressions), and the little Englishman 'Awkins would light the lamp and produce the cards. Sometimes Jeremiah Donovan would come up of an evening and supervise the play, and grow excited over 'Awkins's cards (which he always played badly), and shout, 'Ach, you divil you, why did n't you play the tray?' But ordinarily Jeremiah was a sober and contented poor devil like the big Englishman Belcher, and was looked up to at all only because he was a fair hand at documents, though slow enough at these, I vow. He wore a small cloth hat and big gaiters over his long pants, and seldom did I perceive his hands outside the pockets of those pants. He reddened when you talked to him, tilting from toe to heel and back, and looking down all the while at his big farmer's feet. His uncommon broad accent was a great source of jest to me, I being from the town, as you may recognize.

I could n't at the time see the point of me and Noble being with Belcher and 'Awkins at all, for it was and is my certain belief you could have planted that pair in any untended spot from this to Claregalway and they'd have stayed put and flourished like a native weed. I never seen in my short experience two men that took to the country as they did.

They were handed on to us by the Second Battalion to keep when the search for them became too hot, and Noble and myself, being young, took charge with a natural feeling of responsibility. But little 'Awkins gave us both a great comedown when he displayed he knew the countryside as well as we did and something more.

'You 're the bloke they calls Napoleon?' he said to me. 'Well, Bridgie Ho'Connell was arskin' abaout you and said 'ow you'd a pair of socks belonging to 'er young brother.'

It seemed, as they explained it, that the Second used to have little evenings of their own, and some of the girls of the neighborhood would turn in, and, seeing they were such decent fellows, our lads could n't well ignore the two Englishmen, but invited them in and were hail fellow well met with them. 'Awkins told me he learned to dance 'The Walls of Limerick' and 'The Siege of Ennis' and 'The Waves of Tory' in a night or two, though naturally he could not return the compliment, because our lads at that time did not dance foreign dances on principle.

So whatever privileges and favors Belcher and 'Awkins had with the Second they duly took with us, and after the first evening we gave up all pretense of keeping a close eye on their behavior. Not that they could have got far, for they had a notable accent and wore khaki tunics and overcoats with civilian pants and boots. But it's