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CURRENT PROGRESS IN ASTRONOMY

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GENERAL

Before entering upon my subject proper may I be permitted to say a personal word or two. I feel the honour the Royal Astronomical Society of Canada has done me in electing me for the second time as their President, and I would like to be worthy in some small sense of the trust thus reposed in me. While on the surface it is a very delightful arrangement for myself to be accorded the honour of being President whilst others perform many of the duties attached to the office, yet no one at heart desires to be a recipient of favours without making return in some form or other for the same. As I am separated by a few thousand miles from the Head Office of the Society it is out of the question to attend the Toronto meetings unless other matters should bring me East. If such an opportunity presents itself during the present year I shall be only too happy to serve the Toronto Society, and the other Eastern ones as well, in any way deemed best to themselves.

For the past year it seemed to me that any efforts that might be directed to strengthening the local Society would help the Society as a whole. Such help is hardly necessary where we have such energetic officers as we have in Victoria, but by means of articles in the local papers and magazines and by numerous addresses of a popular nature, possibly some help has been given. A wider circle has been reached by the radio talks given by your

President over CFCT for the past year. Two per month were given last winter, one per month during the summer and present winter, all at a definite hour. From the responses that casually came to hand, it might appear advisable to have similar brief talks in other sections of Canada as well, particularly in the prairie provinces.

But more than anything else your President felt that if any possible help could be given Dr. Chant in securing material of a suitable character for our JOURNAL such would be the most direct way of aiding the Society as a whole. The Editor's job is a particularly trying one, even when he has plenty of material from which he can pick and choose, but it is rendered all the harder if there is an actual dearth of suitable material. While I would not wish to infer that the review of our Seminar meetings at this Observatory and some of my radio talks are most suitable, they have at least been placed at the disposal of the Editor, and I fancy from these and other sources the supply of material is more satisfactory than formerly was the case.

International Union. Any review that aims to cover only a single year's work in astronomy would be rather fragmentary as astronomical researches usually extend over several years. We can keep in mind though for this summary such investigations as have either been completed the past year or from which there has crystallized out some definite and important result. Mention should properly be made of the meeting this year at Leiden of the International Astronomical Union and of some of the conclusions there arrived at, but as the Editor of our JOURNAL was a Canadian delegate and has given us in the November issue a résumé of the proceedings, further reference on my part is unnecessary.

The general plan I shall follow is to treat the material under four headings: (1) Solar System, (2) Stellar Universe, (3) Related Advances in Physics and (4) New Equipment.

(1) THE SOLAR SYSTEM

Solar Activity. The maximum of the present cycle of solar activity seems to have been reached during the year 1927. It is true the early months of 1928 showed an increase which, however, did not attain the high level of 1927. Confirmatory evidence is

seen in the fact that the average latitude of the spots during 1927 was 15°, about where the maximum occurs, while during the past year a decrease in the average latitude was shown, in keeping with the observed tendency for the spots to die out at latitudes of about 10°.

Observations of the solar radiation in ultra-violet light show a marked parallelism with the curve of sun spot numbers. It is evident, therefore, from these observations of Pettit that the principal changes in the light of the sun as a variable star are in the ultra-violet.

Planet Photography: Venus. During the past year considerable work has been done on the photography of the planets. Hitherto photographs of Mars have been made with ordinary plates and with those sensitive to red light only, the latter being assumed to depict the surface features of the planet and yielding smaller images than those in blue light. Mention may be made of recent work of Ross on Venus and of Wright on Jupiter. Ross, at Mount Wilson, photographed Venus in ultra-violet, blue and infra-red light and finds the diameter in ultra-violet light about two per cent. greater than that in red light. The outer atmosphere of Venus is considered to be composed of a thin stratum of cirrus clouds, billowy in character, while the inner atmosphere is exceedingly dense and yellowish in colour. Many investigations have previously been undertaken to determine the planet's rotation period, and one school of observers hold to a period about 24 hours whilst another school believe it to correspond to the period of revolution, namely, 225 days. Dark areas appear on these photographs of Ross, taken with the 60- and 100-inch telescopes, which show a banded structure. The changes in these details are so rapid that it is felt the period of rotation is not nearly so long as 225 days. Spectroscopic evidence is not conclusive, but from a wealth of such evidence at the Lowell and Mount Wilson observatories it would appear that the period must be longer, however, than a day, and so a compromise value of about 30 days is suggested.

Jupiter. Wright's photographs of Jupiter were made with the Crossley reflector and were taken in six different colours from ultra-violet to infra-red. In the infra-red the darkening of the limb

is well marked, while its complete absence from the ultra-violet photographs suggest that the latter represent the planet's outermost layers. The ultra-violet images are thus the larger and are clear cut whereas the infra-red images, representing lower levels of the planet are smaller and lacking in sharpness at the edges. For the first time moving pictures have been made recording the actual rotation of the planet. Its period of rotation is about 10 hours, and by photographing at intervals through three consecutive nights and piecing the films together, an appearance of continuity in its axial rotation was secured by Wright, assisted by Mees of the Eastman Research Laboratory. These films were exhibited the past year at a meeting of the Royal Astronomical Society in London.

Brief mention may be made also of ultra-violet photographs of the moon by Pettit, which show a few areas relatively much darker than on the usual photographs.

Comets. Unlike the previous year 1927, in which many comets were discovered, the past year has recorded but few. Six of the previous year were followed a portion of the year and Stearns, 1927 d, was followed throughout the year. Two new ones were discovered in 1928, the first by Reinmuth on February 22 and the second by Giacobini on March 17. Both were very faint. A third was discovered by Forbes at Cape Town on November 19, but was shown to be the same as one which appeared in 1873 whose period, therefore, is 55 years. Five comets are due to return this year, two in March and one in each of the months August, September and November.

Asteroids. During the last six months of 1926 asteroids to the number of 65 were discovered whilst 101 were added in 1927. Information is not to hand as to the exact number that are new among the later ones, but probably 1,100 would be a fair approximation to the number known at the beginning of 1928. Leuschner at Berkeley is undertaking to check over the published observations and orbits of each minor planet that has been discovered; in short, to write a life history of each.

(2) The Stellar Universe

Radial Velocities. During the past year the Lick Observatory issued Volume XVI of their Publications containing the results of

the radial velocities secured by them in the great programme of work covering almost thirty years. While some of the results have appeared previously in other journals, yet many of them are given for the first time and, moreover, certain systematic corrections are applied to the results to bring them all into a homogeneous system. In this catalogue are included the results from their southern station at Santiago, Chile, which last year was sold to a Catholic College of that city. During the twenty-five years of its existence this southern station secured 10,301 spectra, while about 15,000 spectrograms were secured at Mount Hamilton. Omitting stars whose velocities exceed 60 km. per sec. there remained results for 2,149 stars, and from these the speed for the solar motion was determined as 19.65 km. per sec. directed to an apex at $\alpha = 270°.6$ and $\delta = +29°.2$.

The Cape Town 24-inch telescope formerly devoted to radial velocity determinations is now being used in parallax work. Their radial velocity results, hitherto unpublished in their *Annals*, for 434 stars appear in Volume X just to hand. *A Second Catalogue of Radial Velocities*, as compiled by Voûte, was issued during the year. As the author failed to include the Lick results, just off the press about the same time, and moreover failed to secure many other recent lists of velocities, the catalogue was practically out of date when issued. Discussion is now taking place in the Radial Velocity Committee of the International Astronomical Union as to the best means and time of issuing a new one.

Double Stars. A double star catalogue to replace the monumental one of Burnham's in 1906 is in course of preparation by Aitken of the Lick Observatory and will be issued in the near future. Marked activity is shown in double star observations, particularly in the southern hemisphere, where two new telescopes have entered the field, one at Johannesburg and the other at Bloemfontein. At the latter 410 new double stars were discovered during the first five months of its operation, from May to October, 1928. At the Union Observatory at Johannesburg, according to Van den Bos, they have discovered a visual binary star with the shortest known period, namely, one of 3½ years.

Form and Dimensions of Universe. Our ideas concerning the total number of the stars has undergone many changes in recent

years, but the number seems to be always on the increase. As it is impossible to deal with the whole sky, representative regions are selected, the number within each magnitude interval counted, and this number multiplied by a factor to sum up for the whole sky. The Mount Wilson and Groningen observatories have jointly carried on such an investigation and the results were given by Seares in the early part of last year. The work required the establishment of a scale of photographic sequences in each selected area based upon the standard north polar sequence. For this it was necessary to measure the intensities of about 65,000 star images down to a limiting magnitude of 18.5, a piece of work in itself of no small magnitude.

Seares' conclusions may be summed up very briefly. The number of stars reachable with the 100-inch reflector is about 1,000 million. If the invisible stars behave as we would expect them to behave from the relations found to exist among the stars of steadily increasing faintness, then the total number ought to be about 30 times as great, or thirty billion. The "local cluster" idea is upheld by these counts and Seares deduces that its diameter is of the order of 20,000 light years and that it includes many million stars among which are stars as faint as the fifteenth or sixteenth magnitude. The remainder of the total number of stars are those found in remoter parts of our galactic system considered to be similar to a spiral nebula, 250,000 light years or more in diameter.

Rotation of Galaxy. This idea of our stellar universe being similar to a spiral nebula has in recent years come much to the fore again. With the increased number of radial velocities and parallaxes available in the past few years statistical discussions of the space velocities have been made, particularly by Strömberg, which show marked asymmetry of motion for certain groups of stars. Such asymmetry is a striking feature of stars of high velocity whose space velocities show a marked preference for a definite direction. Such asymmetries of motion would be explainable if, following Lindblad, we conceive our galactic system to be similar to other spiral nebulae and to consist of sub-systems rotating about a common axis. These sub-systems would be symmetrical about the common axis, would be approximately in a state of

dynamical equilibrium and each would have a definite rate of rotation.

Papers by Oort in the *Bulletin of the Astronomical Institute of the Netherlands*, and one by Dr. Plaskett in *Monthly Notices*, and in our own JOURNAL the past year adduce observational evidence tending to verify the soundness of such an assumption. Oort's results indicate that our solar system is distant from the galactic centre about 20,000 light-years only about one-third the distance assigned by Shapley eleven years ago from his discussion of the mean distances of globular clusters. The mass required at the centre to give the requisite rotational velocity to account for the peculiar asymmetries would be of the order of 8×10^{10} times that of our sun, and the question arises as to why we have not visible evidence of the existence of such a great mass.

Galactic Centre and Mass. This central nucleus is situated in the plane of the galaxy and in galactic longitude approximately 325°, in the general direction of the constellation *Sagittarius*. Here the Milky Way clouds are brighter than in other parts of the sky, and Pannekoek examines their total luminosity to see if they would yield the necessary mass. He is forced to admit that on the most favourable assumptions as to their distances and the area that might reasonably be included, the visible stars of the galactic system cannot provide the central attracting mass required. The question arises, would not the dark matter in our system yield this attracting mass. Photographs of distant spirals seen edge-on suggest enormous masses of obscuring material. Similar evidence is afforded nearer home in the almost complete obliteration of faint stars in certain regions of the sky by occulting matter which must be extremely tenuous but nevertheless of great effect when summed up over large volumes of space. Eddington assumes that in interstellar space there is one atom per cubic inch and computation shows that in a sphere whose diameter is less than 20,000 light years the total mass of such obscuring material would be 10^{11} times the sun's mass. If this were in any sense collected locally about the galactic nucleus it would furnish the requisite attractive force.

In this connection brief mention may be made of a paper by Struve published the past year in which evidence is adduced to

support the idea of calcium clouds in interstellar space. There are many objections to such a theory which has been long held but from the strength of the ionized calcium line at 3,933 in about 1,700 spectra there seemed to be an increasing strength of the line shown for objects at increa ing distances.

Harvard Programme on Galactic Centre. The whole question of the real existence of a massive nucleus at the galactic centre is vital to an accurate conception of the form of our universe. At Harvard, Shapley has undertaken a rather ambitious programme on the galactic dimensions and structure and intends to use all kinds of variable stars to the end of securing distances. The aim is to secure complete information of all variables found in 240 selected star fields, most of which are in the belt of the Milky Way. In one region near to the galactic centre a star cloud was found exceptionally rich in variable stars, and from the data secured this cloud is at a distance of 47,000 light years. This is the first result from a programme which is expected to last for ten years at least.

Number of Nebulae. The dimensions of the greater system, in which one thinks of our stellar universe as one of millions, has been added to by the work of Hubble. A previous summary referred to his deduction that the Andromeda spiral is at a distance of a milion light years. It is tacitly assumed that others of smaller angular diameter are at relatively greater distances. The numbers of these fainter nebula can seemingly be increased indefinitely by increasing the exposure. Hubble finds a correlation between exposure time and numbers of nebulae, the numbers increasing at approximately the theoretical rate for uniform distribution in depth. In high galactic latitudes, with an exposure of two hours using the 100-inch, about 170 nebulae per square degree are found. One of these faint distant nebulae was recently found to have the amazing velocity of 4,000 km. per sec. recession from our solar system.

Cosmic Rays. About 25 years ago, when the writer was a student in these halls of learning (University of Toronto), Professor McLennan was conducting experiments upon the discharge of electroscopes, finding that they were discharged by radiations of some unknown character. Of the many workers who have entered the field since those initial experiments the most outstanding is

Millikan, whose researches on these cosmic rays, as this radiation has come to be called, tend to conclusions of a revolutionary character. A very complete summary is given by himself in the September 28th issue of *Science*, which should be read by anyone interested. The evidence obtained by Millikan and his associates is that this penetrating radiation is of extremely short wave length, having oscillations a hundred times more rapid than those accompanying radio-active processes, that it comes to us from interstellar space and is associated with the creation or building up of the more common elements like helium, oxygen, silicon and iron out of primordial hydrogen nuclei and electrons. This is a very revolutionary idea and if the conclusions are substantiated the universe need never be considered in future as one running down all the time, but one in which the energy so prodigally radiated from our sun and distant stars again finds itself transformed into matter.

(3) Related Advances in Physics

Revision of Rowland's Table. I shall dwell now upon some developments in the realms of physics which have a direct bearing upon astronomy. The table of solar wave lengths determined from grating spectra many years ago by Rowland has long been known to contain small errors, and for several years at Mount Wilson St. John and his associates have been engaged in revising the table. There has been a careful elimination of the errors of the older system, and the solar wave lengths are given to three decimals in International Angstrom Units. The table contains a great number of new and revised identifications made possible by our recent knowledge of the series relations of spectral lines. Of the 20,000 lines in the Rowland region 57 per cent. have been referred to their sources. The unidentified remainder are very faint. The presence of six elements not known previously in the sun's atmosphere has been established in the course of this work.

The extension of the table toward longer wave lengths has been made possible by Babcock's investigation of the infra-red solar spectrum beyond the region previously photographed. The principal lines are shown as far as λ11900 and some 1,800 lines up to λ10218 have been measured and are included in the table.

The relative intensities that multiplet lines in stellar spectra should have can be calculated from theory. These theoretical intensities may be assumed to be proportional to the numbers of active atoms producing the lines. Russell, Adams and Miss Moore at Mount Wilson, have thus established a relationship between the relative numbers of atoms producing a solar line and the corresponding Rowland intensity for that line. Such a relationship may be applied to stellar spectra if the Rowland scale of intensities is employed.

Relation of Line Intensities to Physical Conditions. By using high dispersion spectrograms of bright stars Russell and Adams have thus determined the amounts of metallic vapour present above stellar photospheres, their temperatures and other physical conditions. It is found that the assumption of a condition of thermodynamic equilibrium is not a valid one, but after correcting for this by an empirical method, temperatures are derived in good agreement with those found by other methods. The amounts of metallic vapour above equal areas of the photosphere of the cooler *c*-stars like α Orionis seem to be of the order of 100 times as great as in the case of the sun; and the strength of the enhanced lines in such stars suggest that they are produced largely in extensive chromospheres supported by radiation pressure.

Nebulium. Towards the end of 1927 the mystery surrounding the origin of the unknown lines in the bright-line spectra of the diffuse and planetary nebulae was cleared up. The unknown hypothetical element to which such lines were supposed to be due had been designated *nebulium.* From the character of the other elements hydrogen, helium, carbon, nitrogen and oxygen known to be present in the nebulae it was quite certain that these lines must be emitted by some element of low atomic weight. The development of present ideas concerning atomic structure showed that there was no place in the table of elements for such an element and hence these lines must be due to one or more familiar elements existing under unfamiliar conditions. Russell suggested low density as the unfamiliar condition as in the nebulae extremely low densities are the rule. Under such conditions an electron can jump from one orbit to another which, under ordinary conditions, would not be possible or at least probable. The possibilities of such "forbidden

transitions" were examined by Bowen at Pasadena, and with the actual intensities of the nebular lines as a guide he was able to show that nebulium was none other than the chief constituents of the air we breathe, namely, oxygen and nitrogen, the atoms of which, in the extremely rarefied nebular gas, are in a singly and doubly ionized condition. The lines cannot be obtained in the laboratory because we cannot duplicate nebular conditions.

Ether Drift. In 1925 Dayton C. Miller, working at Mount Wilson, obtained results which seemed to show that there was a drift of the ether relative to the earth of 10 km. per sec. As these results involved a considerable readjustment of theories of the ether they again stirred up much discussion on this question which dated from the Michelson-Morley experiment of 1887. During the past year Michelson, Pearson and Pease, working at Mount Wilson with the 11-foot rotating interferometer, find no displacement of the fringes observed by Miller. Certain minor disturbances amounting to some hundredths of a fringe were found which were ascribed, however, to a combination of temperature effects and strains in the interferometer frame. When the interferometer was placed on a cast-iron plate floating in a mercury bath and enclosed in a double room these minor disturbances disappeared and thus their results are directly opposed to those of Miller. It is difficult to know how to reconcile the opposing results as both groups are highly trained workers and have the reputation of exercising care in their experimental work. It seems likely, however, that the effect is null and that Miller's positive results were due to some unknown source of error.

(4) New Equipment

Ordinary Observatories. The last phase of our outline is the new instrumental equipment which the year has seen brought into use or projected. Almost every part of the world shows signs of activity in this regard. Even China is renewing her youth in that she is securing modern equipment for the old established Peking Observatory. Japan has ordered a 26-inch refractor for the Tokio Observatory, and there is also a possibility of a large reflector for a national observatory in the near future. Russia's 40-inch reflector, installed at the Simeis Observatory, two years ago, is producing results in the radial velocity line, while last year

saw the largest refractor in the world 41 inches in diameter, established within her borders. Sweden and Edinburgh both have large reflecting telescopes under way, whilst much activity is shown in South Africa. Here, after many delays, the Ann Arbor Observatory's southern station, known as the Lamont-Hussey Observatory, commenced active work in May last. Close co-operation exists with the Union Observatory at Johannesburg, where similar work started a year or so earlier. The Yale photographic telescope, also at Johannesburg, is rapidly increasing the number of known parallaxes in the Southern Hemisphere. The Harvard College Observatory have removed from Arequipa, Peru, and established a station near the Ann Arbor one at Bloemfontein. They expect to have a new 60-inch reflector in operation soon, and so the southern skies will soon be as well observed as are the northern to-day.

University Observatories. Observatories have come to be almost an essential part of any university aiming to give post-graduate work in science and many new telescopes have recently been completed or are under way for American universities. To mention only a few we have a 12½-inch at Columbia, a 30-inch at Illinois, a 24-inch in the making for Kansas, a large reflector for Texas, where a bequest for $1,200,000 was left for that purpose, and lastly the Ohio Wesleyan University, for which a fine 70-inch disk was cast last January by the Bureau of Standards.

200-Inch Telescope. In a class by itself stands the proposed 200-inch telescope to be erected near Pasadena and financed by the International Educational Board. It is hoped to cast the huge disk, weighing between 25 and 30 tons, out of quartz so as to avoid deformation of the mirror due to changes of temperature. It will be several years before it can be an accomplished fact, but when completed it should carry us out to greater depths of space than have yet been sounded and enable us to resolve some of those distant island universes which are seen now in our largest telescope only as the merest glimmers of light.

The writer recognizes that the foregoing summary is rather fragmentary in character as much of the work of English and Continental astronomers has been passed over. However, to keep the article within the limits suggested, much must be left unsaid, but it is hoped that attention has been drawn at least to some of the high spots in the many advances of the past year.