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Part of the Southern Milky Way with the "Coal Sack of Magellan."
Photographed at the Harvard Observatory in Arequipa, Peru.

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THE TRANSPARENCY OF SPACE.

By Professor J. S. PARASKEVOPOULOS, D.Sc., F.R.A.S.

In Charge of the Boyden Station of Harvard Observatory.

The astronomical observations of the last fifteen years carried out by means of the most powerful reflecting telescopes—the largest of them being the 100-inch of the Mt. Wilson Observatory in California—have revealed objects at depths of space which the light takes about 250 million years to span. Beyond this distance, our actual means of observation are unable to penetrate.

The extent of the observable sidereal universe is, therefore, limited to a sphere whose diameter is about 500 million light years, and the corresponding volume reaches the astounding figure of almost 10^{26} cubic light years (100 million, million, million, million c.l.y.).

The inhabitants of this space are large celestial organizations composed of stars, gas and meteoric dust, known as "GALAXIES".* Single or in the company of several attendants, the galaxies are at an average distance of two million l.y. from each other. Their average luminosity is about 85 million times the luminosity of the Sun. Their diameters are from 2,000 to 10,000 l.y., although some of them are very much larger. Their masses vary from two million to two hundred million times the mass of the sun.

* Spiral Nebulae, is another name for them, not quite appropriate, as in addition to galaxies having spiral forms, there are a great many showing no spiral structure.

The number of galaxies within the above mentioned observable space is estimated to be pretty nearly 100 million. It is astonishing that at the limiting distance of 250 million l.y. from us—at the border of the observable universe—there is no indication that the density of their distribution in space is thinning out. Space at distances of 250 million l.y. from us is as thickly populated by galaxies, as it is at any other smaller distances. In the words of H. N. Russell : "Our deepest soundings show no bottom ". Galaxy after galaxy in an endless array.

The grandeur of these celestial mammoths is dwarfed by the distance; their light is dimmed, and the beauty of their shapes, with the exception of a few nearby ones, is revealed only on long exposure photographs taken with the large reflectors. Millions of them are entirely beyond the reach of our present means of observation, and many millions of them will remain invisible perhaps for ever.

There is evidence that the galaxies are not independent of each other. Groups and clusters of them are well known today under the name of " supergalaxies ". The supergalaxy of Coma, of Virgo, of Pegasus, of Ursa Major, of Gemini, of Boötes, of Centaurus and others, are examples of families of galaxies, each family being composed of members whose number varies from a few up to 500 and even more. Lately, Shapley of Harvard announced the discovery of a cluster or better, of a cloud of galaxies, on plates taken at the Boyden Station of Harvard Observatory, Mazelspoort. This extraordinary cloud, with a membership estimated at nearly 50,000 galaxies, extends over a region of about 40 degrees in length and 15 degrees in width, from near the sky's south pole towards the south galatic pole in Sculptor. Shaped roughly like a narrow stream, it is estimated to be about 50 million light years in length and 20 million l.y. across, and at a distance from the earth of more than 100 million l.y. The photographic magnitude of its members is between 16.5 and 18.5.

Space between the galaxies—the so-called " *Intergalactic space* " appears to be empty.

Inside one of the innumerable galaxies is located our solar system, from where we have undertaken the great task of exploring the Universe.

Being inside the Galaxy, we are in an extremely difficult position to try to find out its exact shape and dimensions. Still, a long and arduous work, in which all the available means of observation have been mobilized, has given us an approximately correct picture of what our own Galaxy is like.

The Region of Eta Carinae.
Photographed at the Harvard Observatory in Arequipa, Peru.

It is a highly flattened system of stars of a discoidal form ; the star density, very high near the centre or nucleus of the system, gradually diminishes towards the borders. The larger diameter of this discoidal system—the equatorial diameter—is between 120,000 and 140,000 l.y., whereas the polar diameter is about one-tenth of the length of the equatorial.

The Sun is situated nearly on the main plane of the system—the galatic plane—but some 30,000-40,000 l.y. from the centre, more than half way between the centre and the border. Looking along the galatic plane, through the greatest mass of stars we see them projected on the sky as a continuous bright belt—the *Milky Way*. Looking away from this plane, at angles gradually approaching 90 degrees, that is, towards the galatic poles, we see through fields of stars whose number decreases very rapidly, and which give the usual appearance of scantiness of stars in the regions of the sky around the galactic poles.

That the galactic system might be rotating was surmised a long time ago ; however, it was only during the past 10 years that the fact was actually proved. At the distance of the Sun from the galactic centre, the period of rotation is about 220 million years.

The rotation of the system, on one hand, implies a symmetrical form of the system ; on the other hand, it gives us the means of computing its mass, which in the case of our own Galaxy is of the order of 200,000 million times the mass of the Sun.

There is a massive bright nucleus to the galactic system, partially hidden forever from our view.

A number of astronomers support the view that our Galaxy has a spiral form, similar to the well known spiral nebulae, and recently Bok of Harvard, on the basis of his star-counts came to the conclusion that one of the arms of the spiral emerges from the region of Carina, and passing through the neighbourhood of the Sun, retreats in the direction of the constellation of Cygnus.

DARK CLOUDS.

Inside the Galaxy.

The non-uniform and patchy appearance of the Milky Way, as seen with the naked eye, attracts the attention of even a casual observer. Bright star clouds are separated by dark obscure regions very poor in stars. The well-known Great Rift—a dark zone—

divides the Milky Way into two branches over one-third of its total length, extending from Cygnus to the Southern Cross. The large dark " Coal Sack of Magellan " in the Southern Cross, the remarkable dark lanes in the constellation of Ophiuchus as shown on photographic plates, and numberless other objects appearing on long exposure photographs, leave very little room for doubt that, although regions poor in stars may exist in the Galaxy, all these vacancies are not regions of the sky devoid of stars—they are not real vacancies or holes in the sky produced by an irregular distribution of the stars. Their frequency is great—much greater than one should expect from a random distribution of the stars.

The recognition that these vacancies are actually dark obscuring clouds or *dark nebulae*, as they are usually called, is due chiefly to the late E. E. Barnard of the Yerkes Observatory at the University of Chicago. At first, he himself called them vacancies, and it was only gradually that he was led to the conclusion that they are, after all, in many instances, dark objects projected against the Milky Way and absorbing its light*.

Distances. Being dark and not directly visible, these clouds are recognised by the obscuration they produce in the fields of the stars. Their distances as well as the degree of the absorption**

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* The titles of some of his papers show this gradual transition in the interpretation of these extraordinary structures :—

Small Black Hole in the Milky Way. Astron. Nachr. 108,369. 1884.

On the Vacant Regions of the Sky. Pop. Astron. 14,579-583. 1906.

Dark Regions in the Sky suggesting an obscuration of Light. (Zeta Orionis). Ap.J. 38,496-501. 1913.

Some of the Dark Markings of the Sky and what they suggest. Ap.J. 43, 1-8. 1916. In this last paper he says :—

> " An important fact that many come from our knowledge of the existence of dark nebulae, is that their masses must be much greater than would be assumed for the ordinary nebulae, because they are perfectly opaque, and must be relatively dense, and hence comparatively massive. If this is so, then, we must take into account these great masses in the study of the motions of the stars as a whole.

On the Dark Markings of the Sky, with a catalogue of 182 *such objects.* Ap. J. 49, 1-23. 1919.

** The transmission of light through a material medium is always accompanied by a certain amount of absorption, regardless of (the colour or) the wave-length of the light.

In a general way we distinguish between two types of absorption :—

General absorption, in which the absorbing power is very nearly the same for all wave-lengths, or at least over a fairly wide range ; and *Selective Absorption*, when the absorbed region is more or less limited in extent. The causes of absorption are radically different in the two cases, though in many cases both conditions may occur simultaneously in one and the same medium. (See Wood's Physical Optics.)

of the light of the stars which they cause, are deduced by means of counts of stars in the area covered by the cloud and in the adjoining fields The visible dwarf stars, for instance,** having very small absolute brightness are close to us, and are situated generally in front of the clouds. These stars give us the minimum distance, that is, the beginning of the cloud. The earlier type stars of the main sequence of the Russell diagram, are found in intermediate distances and surround the clouds in all their extent. The giant stars are at great distances and are in general behind the clouds, thus giving their maximum distance and their total absorption.

This method of the determination of the distances of the dark clouds employed by Schalén, H. Mueller and others, has given extremely interesting results.

In the vicinity of the North America nebula in Cygnus, two dark clouds were found, one in front of the other. The first extending from 75 parsecs from us and reaching a depth of 200 parsecs (245 to 650 light years) with a total absorption of 0.5 magnitude, and the second from 600 to 800 parsecs (1960 to 2600 l.y.) with an absorption of 2 magnitudes in its darkest parts.

The nature of absorption depends upon the size of the particles which the light encounters in its way. If the particles are large, then all wavelengths are scattered in the same amount and the transmitted light is only weakened without changing its colour (simple obscuration as in the case of lamp black). When the particles are smaller—of the order of the magnitude of the light waves—then the short-waves are more scattered according to the Rayleigh Law, and the transmitted light is reddened. This is the case of the so-called molecular scattering, but as Russell points out, dust particles smaller than this critical size may be as much as 100 million times more effective (pound for pound) than gas in producing selective scattering.

Robert Trumpler, distinguished for his work on galactic light absorption, groups the absorption effects so far observed into the following four categories :—

(1) *Monochromatic Absorption*, which is revealed by the occurrence in stellar spectra of absorption lines which originate in interstellar space. (See *Stationary* or *detached interstellar lines*.)

(2) *Selective Absorption*, which varies continuously with the wavelength of light, and which changes the intensity distribution of the continuous spectrum or the colour of the star.

(3) *General Absorption*, i.e., the effect of absorption on the apparent brightness of the star—visual or photographic—and,

(4) *Obscuration effects*, exemplified by the dark nebulae in the Milky Way, the zone of avoidance of extra-galactic nebulae outlined by Hubble and the dark lanes found in extra-galactic systems.

** H. Mueller. Die Sterne 1935, 4/5.

The superposition of the dark clouds is not uncommon. Schalén has discovered several examples ; in the constellation of Ophiuchus there is an indication of three clouds in the line of sight. It is, of course, very plausible that instead of two or more superposed clouds, we deal with a single cloud having varying condensations.

Density and Size.—The density of the dark clouds varies to a very considerable degree. Some of them are quite opaque, whereas others are partly transparent, or very thin veils.

Their size also varies from an insignificant minimum to over 35 parsecs (100 l.y.) across. The great clouds in Taurus and Ophiuchus cover a total area of about 1,000 square degrees. Their mean distance is between 150 and 200 parsecs (490 and 650 l.y.) and the absorption of light in some parts reaches 4 magnitudes. Clouds of smaller size and distances between 50 and 100 parsecs (163 and 326 l.y.) have been found in Auriga, Cygnus, Cepheus, etc. On an average they absorb 1-2 magnitudes and occasionally 4 magnitudes. (H. Mueller. Die Sterne 1935, 4/5.)

The depth of the clouds varies from 50 to 350 parsecs (160 to 1,150 l.y.) and even more, and their volume is enormous. H. Mueller estimates that the volume of the dark clouds around the North American nebula is of the order of 500,000 cubic parsecs or over 17 million cubic light years.

Reflection Nebulae.—Two discoveries made in 1912 by Slipher and in 1913 by Hertzsprung, culminated ten years later in Hubble's work in which it was shown that all bright diffuse and irregular nebulae inside our Galaxy are dark clouds illuminated by neighbouring bright stars. The first evidence on this matter was given by Slipher's work at Flagstaff, Arizona, when he discovered that the spectra of a number of those nebulae were identical with the spectra of the nearby stars. Following Slipher, Hertzsprung of Leyden, Holland, confirmed the discovery a year later by means of measures upon the brightness of the nebulosity surrounding the stars in the Pleiades.

Now, as Russell pointed out, when the star whose light excites the nebula to shine is exceptionally hot, the light of the nebula comes mainly from atoms of gas ; but, if the star's temperature is ess than 20,000 degrees, the nebula shows only a continuous spectrum such as would be expected from reflected light.

To complete the evidence, a last step was accomplished less than two years ago by Struve, Elvey and Roach at the Yerkes Observatory. The stars exciting the nebulae to shine are of different colours. The nebulae with continuous spectrum reflecting

Messier 8.
Photographed at the Harvard Observatory, Bloemfontein, South Africa.

the star light should be coloured accordingly. To test this theory, observations were made by the Yerkes observers, using a Schmidt camera, on the nebulosities in the dark cloud in Scorpio and Ophiuchus. A large nebula was found, extending about one degree to the north of Antares, and only a few minutes of arc to the south. The colour-index of this nebula was estimated as plus 1.9, which agrees satisfactorily with the colour index of Antares. The colour indices of nebulae which surround five B-type stars in Scorpio and Ophiuchus were found to be on the average -0.4 mag., which also agrees with the colour indices of these stars.

Distribution.—The dark clouds are concentrated in the galactic plane. Towards the centre of the Galaxy, among the very bright star clouds of Sagittarius ($17^h\ 30^m$ or galactic co-ordinates 325°, 0°) are the most conspicuous, hiding from our view the centre itself. Shapley, Seares, Lundmark, and other notable investigators of the galactic system have recognised the existence of these clouds and their influence upon the apparent distribution of the stars in the regions they obscure. Some 20 years ago, Shapley mentioned that the dense fields of faint stars in the remote star clouds of Sagittarius are probably all comprised in a single system cut up badly by the intervening dark nebulosity. Lanes of obscuring nebulosity cut off the star cloud, but there can be little doubt that behind the dark nebulosity the star clouds are dense and continuous. A massive galactic nucleous is indicated at a distance 30,000-40,000 light years.

Seares also points out that, as in the galaxies of spiral form, the central condensation of our stellar system is largely hidden behind obscuring clouds concentrated close to the galactic plane.

Observations show that dark obscuring clouds are common in a great many galaxies, especially in those presenting spiral forms, appearing as dark bands coiling around the equator of the main body of the spirals and very plainly visible when the galaxy happens to be oriented edge on or nearly so.

Thus the study of the distribution of the stars in the galaxy presents formidable difficulties. If we look parallel to our galactic plane, that is, in the direction of the bright belt commonly known as the Milky Way, our view is obstructed. The number of external galaxies which can be seen through this belt is reduced to a minimum and in some parts to zero. All along the Milky Way there is a " zone of avoidance " as it is called by Hubble, irregular and assymetrical, its width varying from place to place. Being about 10 degrees wide near Sirius, it spreads to about 40 degrees width in the direction of the galactic centre, and is bordered by a region of partial obscuration 10-15 degrees wide on each side.

Shapley's Galactic Windows.—The Mount Wilson and Harvard surveys of galaxies show several regions along the Milky Way plane where the obscuring matter is very thin or even absent.

According to Shapley, the presence of external galaxies in some Milky Way regions indicates that the troublesome obscuring matter either is absent or greatly diminished. On plates taken with the Bruce 24-inch refractor at the Boyden Station, one such transparent place was found at galactic longitude 300° and latitude–16°, about 30 degrees from the galactic centre. Another was detected in the northern sky, in the constellation of Cepheus and Cassiopeia, not far from the direction of the anti-centre.

It was through these breaks of absorbing matter, or better through these "*galactic windows*" that Shapley pushed forward his investigations. His first attack was directed through the south-eastern window, where in addition to many variable stars, extra-galactic objects were found, with practically the normal frequency for high galactic latitudes. In an area of about 80 square degrees, 715 new external galaxies were discovered, and another 619 in the immediately surrounding areas. In addition, 190 new faint variable stars were found, 100 of which were of the Cluster Cepheid type with an average median photographic magnitude fainter than 15.9. Allowing generously for residual light absorption, he deduced that these faintest variable stars are well beyond the centre of the Galaxy, on the other side of the galactic system, assuming that the distance between the Sun and the galactic centre (at 325°, 0°) is about 10 kiloparsecs (33,000 light years). Five of the most distant variables with average median magnitude 17.57 are at least 13 kiloparsecs (over 42,000 l.y.) beyond the galactic centre—a really remarkable result of modern stellar research.

Obscuration inside our Solar System.—The question has often been asked whether or not the space occupied by our solar system is free from obscuring matter. Is our Solar System involved inside a dark nebula ?

The volume occupied by the solar system, with the planet Pluto at its frontiers, represents a sphere whose diameter is not more than 10 *light hours.* On one hand our everyday experience with meteors falling upon the earth and, on the other, the accepted explanation that the Zodiacal Light consists of a ring of dusty particles encircling the Sun and extending beyond the orbit of Jupiter, suggest that our inter-planetary space may not be entirely free from some sort of obscuration.

The steady decrease of the 3.30 year period of Encke's comet, which between the years 1819 and 1914 was shortened by 2½ days, corresponding to a diminution of its mean distance from the Sun by 275,000 miles, cannot be explained as a result of planetary perturbations. The only reasonable explanation, suggested by Encke himself, is that the comet in its motion about the Sun, meets with some sort of resistance which, retarding its motion, diminishes the size of the major axis of its orbit and, consequently, shortens the time of revolution around the Sun.

During the last ten years or so, the intriguing problem of the transparency of the interplanetary space has been attacked by several investigators from altogether different angles.

First in 1927, the late Professor E. S. King of Harvard, investigating the colours of the bright nearby stars (down to mag. 7.5 in many instances), found that on the average the colour of these stars was redder as the distance grew larger. The value of this selective absorption amounted to 0.003 mag. per 10 parsecs (33 l.y.).

The absorption is greater in the direction of the galactic plane and smaller in the direction of the poles. This value, small as it may appear at first, is in fact very great, and if absorption of this magnitude existed all through space, the distant stars would be extremely red, which is not the case. For this reason King came to the conclusion that our solar system is enveloped in a local absorbing cloud, the radius of which he estimated to be approximately 30 parsecs (100 l.y.).

King's results seem to be endorsed by the more recent investigations of H. Mueller, Schalén, Graff, Gleissberg, W. Becker and lately by Corlin in 1936.

Mueller, studying the general absorption and distance of the great dark clouds in Taurus and Ophiuchus, by means of star counts in selected areas, came to the conclusion that both clouds, which lie almost diametrically opposite in the sky, extend as far as our immediate neighbourhood, not far from the Sun.

Schalén's investigations on the clouds of Auriga and Scutum seem to agree in showing that both clouds should begin in our immediate neighbourhood, because the dwarf stars are influenced by their absorption.

W. Becker, on the basis of his photo-electric measurements of colour-excesses of B-type stars, also concludes that our Sun lies in a narrow band of obscuring matter of several hundred parsecs in length extending from Taurus to Ophiuchus and possibly in a second band extending from Canis Major to Aquila. He sets the value of selective absorption equal to 0.4 mag. per 1,000 parsecs, which agrees closely with King's value.

Finally, Axel Corlin made a statistical study of the nearby stars for which both spectroscopic and trigonometric parallaxes have been determined.

Obscuration would obviously introduce errors ~~in~~ the values of the parallaxes determined spectroscopically (in which the dimming of the star would appear as a distance effect), whereas the parallaxes determined by the trigonometric method would remain unaffected.

Summarizing Corlin's results, we may say that, on the average, the spectroscopic parallaxes put the stars at greater distances than the trigonometric ones, and the difference between these two values is greater in the southern sky, from Scorpio and Centaurus to the Southern Cross, than it is in the opposite region of the northern sky from Cygnus to Andromeda.

Corlin's value for the absorption, being necessarily limited to the investigation of our nearest stars (some 1,100 of them with spectroscopic and trigonometric parallaxes given in the Yale Catalogue of Parallaxes) is very small indeed. These stars, however, show that the space immediately surrounding us is not free from obscuration, and also that the obscuring matter is thicker in the direction of the Southern Milky Way and the galactic centre, and thinner in the opposite direction.

Constitution and Mass of the Obscuring Clouds.—We have no very direct means of knowing the constitution and mass of the dark clouds, and the problem of estimating the mass and guessing at the nature of the absorbing matter is a very difficult one. However, several factors set a limit to our assumptions.

The clouds must be of excessively low density, and they must be opaque. Pannekoek, assuming that the Taurus cloud consists of hydrogen, arrived at the astounding result that its total mass should be of the order of 1,000 million solar masses. Naturally, such an enormous mass would influence the motions of stars to a considerable extent, which is not the case.

A small size cloud, 50 l.y. long and 5 l.y. square, occupies a volume of 1,250 cubic light years. Russell computed that, if the density of this cloud were one million millionth that of ordinary air (10^{-15} g/cc) its mass would be 650 million times the mass of the Sun. A mass one thousand times smaller than this would attract the stars even 50 l.y. away so strongly as to oblige a large proportion of them to move around it in closed orbits. This, of course, does not happen, and we cannot escape the conclusion that the average density of the dark cloud is less than 10^{-18} g/cc, that is less than one ounce in 7,000 cubic miles. Still, a nebula so excessively tenuous should be opaque.

N.G.C. 5128.

Photographed at the Harvard Observatory, Bloemfontein, South Africa.

The clouds cannot consist entirely of gas molecules as we have explained, and the only alternative left is that they are composed of solid particles—of very fine dust—which, as Russell rightly maintains, has the greatest light stopping and light reflecting power. Free molecules and large chunks may also be present, but fine dust is the main constituent.

The size of the dust particles plays a great part in the type of light absorption. If they are larger than the wave-length of light, they act alike upon all colours, simply dimming the light without altering its colour. If, on the contrary, they are of the order of magnitude of the wave-length, they scatter the shorter wave-lengths (blue, violet) and let the longer ones (red) go through, thus producing a reddening (selective absorption) of the light of the stars. In some of the dark clouds, Schalén found a reddening of the star light amounting to 10-15 per cent of the total absorption. H. Mueller has also found that the first dark cloud of the North American region does not absorb selectively, whereas the second one shows a selective absorption amounting to about 15 per cent of the total absorption. In some of the well-known "Barnard's Dark Markings" the amount of selective absorption is still higher, reaching 20-25 per cent.

Not long ago Mie elaborated a theory by means of which it is possible to compute the magnitude of the obscuring particles when the amount of total and selective absorption is known. According to his theory the particles are considered as being metallic spheres. Schalén assuming the metallic spheres to be of iron, computed that the dark clouds may be formed of particles having a diameter of the order of 0.0001 mm. ($100\mu\mu$). The density of the dark cloud in the region of the North America nebula has been found to be 0.5×10^{-25} g/cc, and the total mass equal to about 300 solar masses, which is a very reasonable value. Other clouds investigated by Schalen yield similar results.

METALLIC VAPOURS IN SPACE.

Dark clouds composed of dust, are unfortunately not the only form of interstellar matter responsible for the absorption of light within our Galaxy. Spectroscopic investigations have brought forward evidence to the effect that tenuous metallic vapours are also scattered in interstellar space.

In the year 1906, Professor Hartman of Potsdam, examining the spectrum of Delta Orionis—a spectroscopic binary star—discovered that the well-known K line of Calcium did not share the periodic oscillations of the Helium, Hydrogen and other lines of the spectrum. The oscillations are the result of the orbital movements of the components of the system about its centre of gravity. The H line of calcium, which is often obliterated by the strong hydrogen line close by, was also found to behave in a similar way. Thus the calcium lines retained a relatively fixed position—they were " stationary ".

In addition, whereas the rest of the spectral lines, having their origin in the atmospheres of the stars of the binary system were broad, the Ca lines were narrow and sharp, indicating that the medium which was responsible for their origin, must be of very low density—much lower than the density oft he stellar atmosphere.

Slipher of Flagstaff, Arizona, who had detected stationary Ca lines in the spectra of other stars in 1909, was the first to suggest that the Ca lines originated in a medium consisting of " calcium clouds " in interstellar space, outside the atmosphere of the stars; he also suggested that the Sodium lines in the yellow part of the spectrum might behave in the same manner as the Ca lines—which much later proved to be correct. As a result of the work of Slipher, Plaskett and other noted spectroscopists, it has been established that the stationary lines have their origin in interstellar space, which must contain extremely tenuous clouds composed of Ca and Na. Furthermore, it was discovered that the stationary lines (*detached lines*, as they are called) appear only in the spectra of the hot early type stars. The question may be raised: Why only in the hot stars? The answer is that the spectra of the cooler stars contain broad Ca and Na lines which arise in their own atmospheres and which obliterate the sharp and narrow lines of the same elements produced by the absorption of the interstellar Ca and Na clouds.

Easy as the explanation of the occurence of the detached lines may sound, nevertheless it presented at the beginning a number of difficulties which have puzzled astronomers.

We know that the Sodium atoms which are responsible for the yellow D line are neutral, whereas the calcium atoms producing the H and K lines are ionized. How does this ionization take place? And why should the calcium atoms be ionized and the sodium not?

The answer to this question was put forward by Eddington who showed that the ultra-violet radiation emanating from the hotter stars, aided by the extreme rarity of the interstellar diffuse matter, is responsible for the splitting off of one or more electrons from the calcium atoms. It must be remembered that the determining factor of the ionization is the frequency and not the intensity of the radiation; no matter how far away the stars are, and how much their radiation is weakened by the distance, the frequency of the radiation is sufficiently great to cause ionization.

Regarding the Sodium atoms, we know that they are not as easily ionized as the Calcium ones. In a rare cloud of Sodium and Calcium vapours, most of the sodium atoms are singly ionized and a few neutral ones are responsible for the D lines, whereas the majority of the calcium atoms are doubly ionized and a few, only singly ionized, are responsible for the H and K lines.

Another difficulty which confronted astronomers was: Why do only two elements, Ca and Na exist in interstellar space? There was no reason why others should not exist. The answer to this came as soon as it was recognized that other chemical elements sufficiently abundant in cosmic matter have their most strongly absorbed lines in the far ultra-violet part of the spectrum, which is cut off from our observations by the ozone of the terrestrial atmosphere. Indeed, spectroscopic investigations carried on recently at the Mount Wilson Observatory by Adams and Dunham, have disclosed the existence of titanium lines in the ultra-violet and of potassium lines in the deep red part of the spectrum, all belonging to interstellar matter. It is very likely that new discoveries will show that most of the known chemical elements exist in interstellar space.

The origin of these tenuous vapours in space is not known. Perhaps they may have been there originally, or perhaps they may have been ejected by the stars. This second assumption is deriving some support by the observations of the great eruptive prominences of our Sun which have repeatedly revealed that huge masses of calcium and hydrogen, both abundant in the atmospheres of the stars, are ejected into space.

The highest solar prominence ever recorded was observed at Mount Wilson on March 10, 1938. A gigantic mass of eruptive calcium and hydrogen gas rose nearly vertically from the sun at speeds first of 40 miles per second, then of 80 miles, and when last noted moving at 124 miles per second. When last observed the solar prominence had risen to 970,000 miles above the surface of the Sun (the diameter of the sun is 864,100 miles). Clouds interfered with further observations. The greatest height hitherto observed from a prominence was 621,000 miles on September 17, 1937. (*see* " Science " Vol. 87 No. 2257, April 1, 1938.) Struve of Yerkes Observatory, who detected detached lines in the spectra of several hundred early type (B-type) stars at great distances from the Sun, has been able to prove that the strength of these lines is a function of the distance of the star from the observer, that is, a function of the thickness of the absorbing matter. If the density of the cloud were everywhere the same, the strength of the detached lines would serve as a criterion of its distance; it is probable, however, that local condensations of the clouds occur, which will render the application of this method of measuring distances ineffective.

THE ABSORBING LAYER.

Hubble of Mount Wilson, in his extensive survey of galaxies in regions of the sky free from obscuring clouds, found evidence of the existence of a tenuous medium producing a slight absorption. He estimates that the actual obscuration at the galactic poles amounts to approximately 0.25 magn., and therefore that the " optical thickness " of the absorbing layer is about 0.50 magn. He is of the opinion that the source of obscuration may be pictured as a highly flattened, lenticular cloud, rather than as an indefinitely extended uniform layer of material. The Sun, would lie near the median plane of the cloud, but well away from the centre. It is to be noted that the obscuration produced by this layer is *non selective,* all colours being absorbed in the same degree.

On the other hand, the results of Stebbins and his associates, who have found selective absorption (colour excesses) in globular clusters and early type stars in low galactic latitudes, seem to disagree with those of Hubble. However, as Hubble himself remarks, the most conspicuous cases of Stebbins are within the well-known zone of avoidance, being associated rather with the known obscuring dark clouds, where some selective absorption admittedly occurs.

Eddington has discussed theoretically the physical conditions of diffuse matter in interstellar space and derived a maximum value for its probable density of the order of 10^{-24}g/cc. In the case of calcium, it amounts to about one atom per c.c. (1 c.c. of ordinary air, at sea level and 0°C. temperature contains 27 million, million, million molecules.)

At first glance, Eddington's value appears to be incredibly small. Eddington, however, computed that if all the stars in the vicinity of the Sun should expand so as to fill all the empty space that separated them, the resulting density of matter would amount to two hydrogen atoms per c.c. (or an even smaller number of atoms if instead of hydrogen heavier elements should be considered). It is clear, therefore, that the density of diffuse interstellar matter could not surpass much this value, without affecting the motions of the stars in space by amounts that could easily be detected by observation.

THE SPACE BETWEEN THE GALAXIES.

The question as to whether or not the space between the galaxies—the intergalactic space—is free from obscuration is entirely speculative. Still the consensus of opinion among astronomers is that intergalactic space is transparent and free from obscuring matter. Shapley, referring to some irregularities in the distribution of the galaxies, which could be attributed to obscuring matter external to our Galaxy, writes : " A much more reasonable assumption is, of course, that the irregularities in apparent distribution are real and indicate actual groupings of external galaxies ".

Knox-Shaw, also mentions that : " It seems, that intergalactic space can be given a clean bill of health." Finally, Hubble remarks that : "The only observational evidence which bears on the question is the complete absence of any sensible obscuration out to the limit of the deepest survey. Space absorption, if it exists, is probably less than 0.1 magn. (about 10 per cent.) in a light path of the order of 100 million parsecs, which is about the radius of the sphere of the observable space ".

SUMMARY.

In a few concluding words, the problem of galactic absorption may be stated as follows :—

Space between the stars inside our galaxy is not entirely transparent. Extremely tenuous absorbing matter seems to be concentrated all over its equatorial plane. The nature of the obscuration (general, selective, monochromatic) points to the existence of three types of absorbing matter.

(*a*) Dust Clouds producing both general and selective absorption.

(*b*) Metallic vapours responsible for the appearance of the detached lines in the spectra of the stars.

(*c*) A diffuse medium, forming perhaps the so-called " absorbing layer ", causing a small all-over non-selective absorption. Eddington suggests that the dark clouds may be condensations of a general cloud to which the calcium clouds also belong.

The study of a large number of Galaxies, orieneted edge-on, shows beyond doubt that the absorbing matter is flattened in a higher degree than the system itself.

The density of the diffuse matter may be as large or even larger than the density of stellar matter would be if expanded evenly so as to occupy all galactic space.

Space between the Galaxies seems free of obscuration of any kind.

We must bear in mind, however, that the problem of galactic absorption is still in its first stages of solution. We certainly know that our Galaxy is not suffering from calcium deficiency, but very much remains to be done before we know

STATEMENT OF INCOME AND EXPENDITURE FOR ONE AND A HALF YEARS ENDING 31st DECEMBER, 1938.

Income.	£	s.	d.	*Expenditure.*	£	s.	d.
To Balance 30/6/37 ...	0	3	7	By Printing Journal, Vol. 4, No. 4	40	11	9
„ Contributions :				„ Postage	1	12	0
Cape Centre ...	38	19	9	„ Commission on Cheque	0	1	2
Durban Centre ...	4	4	0	„ Balance carried forward	13	6	9
Johannesburg Centre ...	1	16	11				
„ Sale of Journals ...	3	17	1				
„ Sale of Sundial ...	0	8	10				
„ Donation	6	1	6				
	£55	11	8		£55	11	8

Audited and found correct.

EDWARD J STEER,
Hon. Auditor.
March 16th, 1939.

JOAN R. ROBINSON,
Hon. Treasurer.
March 16th, 1939.

REPORTS OF SECTIONS.

For the Year ended 30th June, 1938.

COMET SECTION.

Since the inception of the Comet Section—in addition to the work done by observers in South Africa—it has been our custom to give a few notes regarding all new comet discoveries made in any part of the world, and interesting facts about periodical comets which have returned during the period under review.

This year we have no new comet discoveries from South Africa to record but the monthly work of sweeping the sky has been assiduously carried on and we feel some confidence there cannot have been much missed.

During the past twelve months there are two new comet discoveries to record, and two returns of previously known comets.

N.G.C. 1566.

Photographed at the Harvard Observatory, Bloemfontein, South Africa.

Comet 1937*f* (Finsler). This comet was discovered by Dr. P. Finsler at Bonn on July 4th. It was magnitude 7 at discovery. Its movement was South and it became an attractive object in our sky for some time. On August 23rd, Messrs. H. E. Houghton and G. E. Ensor observing at Pretoria with a 6 inch reflector reported it as being "Magnitude 6" and as "a circular, hazy object with bright, central condensation". Mr. R. Watson, observing the same evening at Somerset West estimated its magnitude as 6 and described it as "bright in centre but he could not say if it had a nucleus". The writer, observing on August 24th could glimpse it occasionally with the naked eye when its position was once known: with an 8 inch reflector he noted it as "having a tail more than half a degree long; a short tail spurt on one side at about 45 degrees from the main tail and a nucleus, the diameter of which was about one-third of the diameter of the whole head".* By September 21st, it was down to about magnitude 7 or 8 but still showed a suggestion of a tail.

In contrast to the above observations we may mention that photographs of the comet taken at Juvisy showed a stream of the main tail extending for 20 degrees.

Comet 1937*g* (Hubble). This comet was discovered by Dr. E. P. Hubble at Mount Wilson on August 4th. At discovery it was magnitude 13 but was nine months past perihelion. Though it was in South declinations it was not seen by any of our members with small telescopes. Dr. H. E. Wood suggests its possible identity with dArrest's Comet.

Comet Encke (Periodical). The return of this periodical comet was first observed on September 9th by Dr. Jeffers of Lick Observatory when it was magnitude 18. It became a naked eye object in December but none of our members reported having seen it.

Comet Gale 1927 VI. The return of this comet was earnestly looked forward to by the computers and its recovery by L. E. Cunningham at Harvard on May 1st was a source of much satisfaction. It will be remembered that there was much discussion about its orbit. It is now seen that the prediction of the late Dr. Innes was nearest the true one. It is a diffused, hazy object and the writer who saw it on June 2nd when it was magnitude 9 noted that it had much the same appearance that it had when it was here in 1927.

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* There is some difference in describing the nucleus by the above observers and the writer. They describe it as a "Bright centre with no nucleus." The writer describes it as "the nucleus." There was certainly a difference in apparent texture between the centre and the surrounding coma, and a distinct transition from the one to the other. It is doubtful whether to call it a central condensation or regard it as the nucleus.

It has been pointed out, that in our last year's report, by a slight error we give a wrong impression in regard to Comet 1937*a* (Daniel). Dr. Crommelin writes :—" The recovery was not an accident ; Simizu had worked out the perturbations and prepared a search ephemeris ; he found the comet almost exactly in the predicted place which was a fine piece of computing ".

A. F. I. FORBES,
Director.

VARIABLE STAR SECTION.

The total number of observations received during the year was 6,516, contributed as follows :—

A. W. J. Cousins	...	864	observations of	25 stars.
R. P. de Kock	...	2,149	,,	81 ,,
G. E. Ensor ...	...	1,254	,,	125 ,,
H. E. Houghton	...	2,091	,,	93 ,,
Rev. S. Solberg	...	17	,,	8 ,,
E. G. Williams	...	141	,,	11 ,,

Mr. Williams is on the staff of the Radcliffe Observatory, Pretoria, and we are glad to have his help in our work. Messrs. Cousins and de Kock have again contributed valuable early morning observations.

NOTES.

Most of our work is on long-period stars which are comparatively regular in their light changes, but it is desirable that they should be followed fairly closely, especially as most Southern stars are still imperfectly known. The irregular variables on our list have not shown much change during the year ; some are generally bright but fade at irregular intervals, and others are usually faint or invisible but may brighten up.

Nova Pictoris is fairly steady at about magnitude 9.5 ; it is fading very slowly. *T Pyxidis* was invisible. *S Apodis* is still at maximum (10.1) and has not been seen faint for nearly three years. *RS Ophiuchi* has varied irregularly between 10.4 and 12. *RY Sagittarii* was about magnitude 8.0 in July, 1937, and gradually brightened to about 6.4 in June, 1938.

π_1 *Gruis.* Dr. van den Bos drew attention to this star (magnitude 6.65, spectrum S) which appears to be variable. Dr. Wood kindly furnished a chart and the star has been kept under observation. Different observers have reported its magnitude as between 5.8 and 6.9, but no certain variation can yet be deduced : it is a difficult reddish star.

H. E. HOUGHTON,
Director.

ZODIACAL LIGHT SECTION.

Reports and charts of observations have been received from the following stations :—

Station No. 2	Eshowe ...	Rev. S. Solberg.
Station No. 4	Somerset West	R. Watson.
Station No. 6	Hermanus ...	A. F. I. Forbes.

The charts and records accompanying this report are available for inspection of members.

During the period under review the records show that the Light has been only of average brightness: "very faint," or "very bright" being seldom mentioned but there are several records of evenings and mornings, when the sky was apparently quite clear, and when we would have expected to see the Light that there was no sign of it at all. These seem interspaced at random amongst evenings and mornings when the Light was well seen.

In the above records, only one simultaneous record has been made but records on alternate evenings often occur. On account of the variable points made it is difficult to make comparisons but we feel that if we were to give slightly more detail we may get better results ; for instance, we have a group of evenings in August on the 26th, 30th, 31st from No. 2 and the 24th, 26th, 29th from No. 6 but they cannot be compared.

Where the stations 2 and 6 differ most is in the distance of the Apex from the Sun. No. 2 in seven records gets an average of 94° Station No. 6 in 15 records gets an average of 58° This difference probably occurs from the want of a definite system amongst observers of recording where the apex lies.

Mr. R. Watson, writing from Station No. 4, writes :—

"The term 'apex,' however, is slightly misleading as the Light does not actually terminate there but is continued in the Zodiacal Band. 'Bottle neck' seems to be a more descriptive term".

In the writer's experience at Station No. 6, a definite Apex is non-existent or is obscured by the Band.

It is not easy to locate where the position of the apex might lie by merely looking at the sky. It is suggested that observers should make full use of the charts and plot down the sides of the cone as carefully as possible and then, by referring again to the sky they can more definitely locate about where the apex lies. The cone seems to carry its form best at about 35 degrees from the Sun and this is where we have been measuring the width of it.

The writer feels, as he gathers more experience in observing that, despite its apparent variableness the Zodiacal Light cone has a constant and definite size and shape and that it has structural form though the anatomy may be obscured by the very variable surrounding drapery. This becomes more apparent when one tries to separate the different parts. Much observation is necessary to prove whether this is truth or fancy.

The charts clearly show the tendency of the light is to be slightly South of the Ecliptic. In the excellent and painstaking observations in May and June by Mr. Solberg he finds the general tendency is for the light to be stronger on the Southern side and he found the Northern boundary of the Zodiacal Band was along the Ecliptic and well defined while it was almost impossible to find any definite boundary for its Southern edge. This he saw on several successive evenings.

At Station No. 6 the writer has several times noticed a fading of the Light on the Northern side in the mornings and thought he was doing well in recording them but persistent and prolonged watchfulness is necessary as the following note made on June 28th will show :—

" This morning at 5 the light fairly bright ; the Pleiades were in the Light. Soon after I noticed that there was a fading on the North side and the Pleiades was now quite apart from the Light. This continued for about 20 minutes and I was intending making a special record of it but soon after I discovered that this fading was caused by a faint haze in that region. This haze was sufficient to fade out the Light though one could not detect any appreciable effect on the stars."

Observers sweeping the sky often come across hazy patches that are appreciable in the telescope but cannot be seen by the naked eye. When an observer sees a fading in any part of the Zodiacal Light it would be well to turn the telescope on that region and sweep across it ; the cause might be revealed.

The chief question that concerns the Section is getting observers, but important also are our methods of observing, and this has been occupying much of our attention. As we gain more experience at the work we realise more and more the magnitude of the task that is before us and the inadequateness of an amateur whose days are full and busy to give the necessary time to study it. Observing the Light for ten minutes in an evening is not enough. To get to serious grips with the subject it needs much watching and years of experience. We are trying to do our best and are accumulating valuable records that we hope one day may be useful. We hope to have our charts made to a larger scale which would add much to their convenience and usefulness.

A. F. I. FORBES,
Director.

Messier 83.
Photographed at the Harvard Observatory, Bloemfontein, South Africa.

CAPE CENTRE.

Twenty-Fourth Annual Report, 1937-38.

MEMBERSHIP.

Eight new members were elected during the year. One member, Dr. Roberts, died, while four others have resigned. Mr. T. Mackenzie and Mr. H. W. Schonegevel were elected members emeriti. The total roll is now 89, consisting of 79 members, 4 members emeriti and 6 associates.

MEETINGS.

During the year there have been eight ordinary meetings held in the Mountain Club Room at 38 Strand Street. The attendance at these meetings has been very good and the lectures have been of a high standard.

During August, 1937, we had the pleasure of listening to Sir Frank Dyson, the former Astronomer Royal, on " Eclipses " and in May, 1938, to the Union Astronomer, Dr. Wood, who spoke briefly on the progress of the work on the New Radcliffe Observatory at Pretoria and on the forthcoming meeting of the International Astronomical Union.

A Question Night, held in November, 1937, when several astronomical questions that had puzzled some members were asked and answered, proved to be a great success. The other addresses and papers presented during the year were :—

" The Calendar," by Mr. R. Watson.
" Sunspots," by Mr. J. B. G. Turner, F.R.A.S.
" Early Conceptions of the Solar System," by Professor H. A. Reyburn.
" Mason and Dixon at the Cape, 1761," by Mr. T. Mackenzie, F.R.A.S.
" Observations of the Variability of Jupiter's 4th Satellite," by Rev. Canon E. B. Ford, F.R.A.S.
" The Astrographic Chart and Catalogue," by Dr. R. H. Stoy.
" Sir John Herschel's Cape Observations," by Mr. H. E. Houghton, M.B.E., F.R.A.S.
" Navigational Problems," by Mr. J. G. Gwayde.

ARTICLES IN THE PRESS.

Monthly notes with charts of the sky have been published in the " Cape Times." Astronomical articles have also appeared in Afrikaans in " Die Suidestem " and " Die Burger ". Talks on Astronomy have been broadcast from the Grahamstown Radio Station. All the foregoing were contributed by members of the Centre and were greatly appreciated both by members and the general public.

A. MENZIES,
Hon. Secretary.

Committee of Cape Centre.

Session 1938-1939.

Chairman: Mr. H. W. Schonegevel.
Vice-Chairman: Captain D. Cameron-Swan.
Hon. Secretary: Mr. A. Menzies, F.R.A.S.
Hon. Treasurer: Mr. J. B. G. Turner, F.R.A.S.
Librarian: Mr. W. Andrews.
Auditor: Mr. E. J. Steer.
Members of Committee: Messrs. A. W. Long, J. Linton, C. E. Peers and Dr. J. Jackson.

FINANCIAL STATEMENT FOR THE YEAR ENDING 30th JUNE 1938.

Receipts.		£ s. d.	*Payments.*	£ s. d.
In hand 30/6/37 ...		6 16 8	Donation to Telescope Fund	6 1 6
Subscriptions:			Contributions under Art. XIII of Constitution	30 12 3
Arrears	£11 14 3		Subscription to Astronomical Society of the Pacific	2 2 3
Current year	43 14 3		Stationery & Typing ...	4 7 0
Advance	6 0 9		"Cape Times" & Postage to Country Members	4 7 4
	,,	61 9 3	Donation to Astronomical Society of South Africa	6 1 6
Donation		0 9 6	Rent of Meeting Room	7 10 0
Repurchase of Draft by Bank		0 19 11	Rent of P.O. Box ...	1 5 0
			Secretary's Expenses ...	1 15 2
			Treasurer's Expenses ...	0 16 6
			Bank Charges	1 12 3
			Balance at 30/6/38 ...	3 4 7
		£69 15 4		£69 15 4

TELESCOPE FUND.

	£ s. d.		£ s. d.
Balance at 30/6/37 ...	3 18 6	Repayment of first half of loan	10 0 0
Donation from Cape Centre	6 1 6		
	£10 0 0		£10 0 0

Examined and found correct.

E. J. STEER,
Hon. Auditor.
11th July, 1938.

J. B. G. TURNER,
Hon. Treasurer.

NATAL CENTRE.

Fifteenth Annual Report.

This is the Fifteenth Annual Report which covers the 15th and 16th years of the Society's existence.

During the past two years we have carried on our work and have endeavoured to justify our claim as an Educational Institution.

We have held meetings monthly with the exception of the hottest months and though the attendance has not been all that we could have desired, yet we feel that some good work has been accomplished.

Through the kindness of Mr. Chubb we have been able to hold our meetings in the Art Gallery or the Museum.

Among those who have contributed Lectures and Papers have been :—

Messrs. H. J. S. Bell and H. C. V. Bell ; E. C. Chubb ; Sir Frank Dyson ; A. de Charmoy ; F. T. Fox ; Rev. W. H. T. Gahan ; H. E. Houghton ; H. Roadknight ; C. F. Wicks and J. Bennett Mumford.

The Observatory.

The Observatory still continues to attract visitors and the Visitors' Book shows that numbers of people, both residents and visitors avail themselves of this Institution. We much regret the large amount we are still compelled to spend on the Electric Light. We have vainly pointed out again and again to the Corporation that our work there is for the public benefit but we have not been able to get any concession.

During this period, the late Miss Escombe donated to the Centre a 4-inch Telescope formerly the property of her father, and when we can get this instrument adjusted it will prove a very useful addition to our amenities.

More subscriptions are needed as our funds are at a very low ebb.

To all who have assisted to keep the Society going, we express our hearty thanks and hope that we may have a time of increasing prosperity and usefulness.

REVENUE AND EXPENDITURE ACCOUNT FOR TWO YEARS ENDED 31st MAY 1938.

Revenue.	£	s.	d.	*Expenditure.*	£	s.	d.
To Balance Forward ...	6	17	10	By S.A. Centre... ...	4	4	0
,, Donations	8	8	0	,, Sweeping	3	0	0
,, Collections	2	15	11	,, Advertising ...	5	14	9
,, Subscriptions ...	9	19	0	,, Electric Light ...	7	0	8
				,, Stamps & Stationery	2	2	0
				,, Bank Charges ...	0	10	8
				,, Balance, Bank ...	5	8	8
	£28	0	9		£28	0	9

Examined and found correct.

R. MORTON-NEVILLE,
Hon. Examiner.

J. BENNETT MUMFORD,
Hon. Secretary and *Treasurer.*

20th September, 1938.

ASTRONOMICAL SOCIETY OF SOUTH AFRICA.

OFFICERS AND COUNCIL, 1938-39.

President: Mr. T. Mackenzie, F.R.A.S.

Vice-Presidents: Dr. J. S. Paraskevopoulos, Messrs. H. W. Schonegevel and R. Watson.

Hon. Secretary: Mr. A. Menzies, F.R.A.S., Royal Observatory, Cape of Good Hope.

Hon. Treasurer: Miss J. R. Robinson, Timour Hall Road, Plumstead.

Members of Council: Captain D. Cameron-Swan, Messrs. H. E. Houghton, M.B.E., A. W. Long, F.R.A.S., W. Andrews, A. W. Robinson and Dr. J. Jackson, F.R.S.

Alternate Members of Council: C. E. Peers, W. G. Andrews, J. B. G. Turner, F.R.A.S.

Hon. Editor: J. Jackson, M.A., D.Sc., F.R.S., Royal Observatory, Cape of Good Hope.

Hon. Librarian: W. G. Andrews, "Tircreevan," Clifton Road, Mowbray.

Hon. Auditor: E. J. Steer.

DIRECTORS OF OBSERVING SECTIONS.

Comet: A. F. I. Forbes, M.I.A., " Blairythan," Main Road, Hermanus, C.P.

Zodiacal Light: A. F. I. Forbes, M.I.A.

Variable Stars: H. E. Houghton, F.R.A.S., High Commissioner's Office, Cape Town.

Jupiter: C. E. Peers, " Cheshunt," Annerley Road, Rosebank, C.P.

The Society acknowledges the receipt of publications, etc., from the following :—

Harvard College Observatory ; Lick Observatory ; University Observatory, Kasan ; Union Observatory, Johannesburg ; British Astronomical Association, Glasgow Branch of the British Astronomical Association, Sydney Branch of the British Astronomical Association ; New Zealand Astronomical Society ; Argentine Association of Friends of Astronomy ; Yale Observatory ; Royal Observatory, Cape of Good Hope. Die Himmelswelt.

RADCLIFFE OBSERVATORY PRETORIA.

During the past two years great progress has been made with the erection of the new Radcliffe Observatory at Pretoria. The great cylindrical building to house the 74-inch reflector, the administrative building and library and residences for three members of the staff have been completed for some time. The mounting for the reflector has been erected and adjusted so that it is possible to make observations with the 7-inch finder.

As is well known the completion of the telescope has been held up by delays in obtaining the pyrex disc for the mirror. After two failures a successful casting was made in May, 1938, and the rough disc when it had cooled was sent to Sir Howard Grubb Parsons and Co. at Newcastle. The disc has been rough ground and the final stages of figuring have been taken in hand. Following the death of Mr. Armstrong who has figured the optical parts for many telescopes at Newcastle, arrangements were made to have this work done by the well known amateur astronomer, Mr. F. J. Hargreaves. It is expected that the mirror will be figured within the next few months. Thereafter it will be sent to Pasadena in California to be coated with aluminium as there is no plant in England which can be used for coating so large a mirror. It is hoped to have the instrument completed before the end of 1939.

The mirror has an outside diameter of 76 inches, and is about 12 inches thick. It weighs nearly two tons. The focal length is 30 feet, and the telescope has a correcting lens which gives a field of view of about 1° free from serious distortion. For use of the instrument in the Cassegrain form there is a central hole 7 inches in diameter. The outside diameter of the turret is 61 feet. For convenience in using the telescope there are 18 electric motors, the largest two being each of three horse power, for turning the turret. The other motors are for closing the turret, turning the telescope, moving the observing platform, etc.

As the principal part of the initial observing programme will be spectroscopic observations of early type stars, a two prism spectroscope is under construction and should be completed before the mirror is ready. A measuring machine has already been received at Pretoria and the microphotometer is practically ready.

Dr. H. Knox-Shaw, the Director of the Observatory, is leaving for England in April to make the final tests of the figure of the mirror before it is sent to Pasadena. The other members of the staff, Dr. R. O. Redman and Mr. E. G. Williams, are in residence at Pretoria while the Radcliffe Travelling Fellow, Dr. H. Zanstra, is expected later in the year.

Further details concerning the telescope can be found in a pamphlet issued by the makers and reprinted from " The Engineer " for September, 1938. Reference might here be given to articles on the 200-inch reflector which have been published in " Nature " for 25th February, 1939, and Publications of the Astronomical Society of the Pacific for February, 1939.