longed to a radiant in Cassiopeia, and possibly to the same system which furnished the fireballs of April 10, 1874, and April 9, 1876, with radiants at 19°+57° and 17°+57° respectively, according to Von Niessl. A fireball seen on May 30, 1877, had a radiant at 20°+58°, which is virtually the same position as the others. I would be glad to hear of any additional observations of the large meteor of April 15, 1893, or of any of the meteors seen at Bristol on the nights of April 18, 20, and 21 last, and referred to in the first of the foregoing tables.

W. F. DENNING.

Smithsonian Institution Documents.

I DO not know whether your numerous readers realise that many of the public documents published by the United States Government and the Smithsonian Institution can be obtained by direct personal application to the author, at least as long as copies remain undistributed.

The volume entitled "Mechanics of the Atmosphere," recently published by the Smithsonian Institution, was compiled in the confident hope of stimulating the study of this difficult subject by English-speaking scholars throughout the world; further volumes will follow if it becomes evident that this hope is being realised. This collection of translations appeals especially to the mathematical physicist, and I should be pleased to hear from any one who desires to study or teach this subject.

CLEVELAND ABBE.

Weather Bureau, Washington, April 15.

THE GENESIS OF NOVA AURIGÆ.

IT is a common belief that everything is created for a beneficial purpose, and a commoner one that the chief purpose is the delectation of mankind. Without occupying the stilted position involved in the acceptation of such an idea, it can be said that all things that are made are useful for the extension of knowledge. Viewed from this standpoint, the universe is a field containing an infinite number of facts which have to be reaped and garnered before they can be threshed. In the case of the new star that appeared in Auriga last year, a rich harvest of facts has been gathered in. Astronomers from their watch-towers have scanned the celestial visitor through optic-glasses; estimated its glory; measured its place; photographed it, and caused it to weave its pattern in the spectroscope. But it is not enough to make observations and store them up in musty libraries without the proper understanding of their import. At all events, the greatest possible good should be wrung from the facts, and an attempt should be made to discriminate the theory that best explains them. For this reason the subject of Nova Aurigæ is here resuscitated. Theories galore have been propounded to account for that star's genesis, and the most important are described in this note, so that every one can judge for himself the explanation which sufficiently satisfies the phenomena.

Before the advent of the new star of 1866 the general opinion was that such objects represented new creations. Spectroscopic observations then caused a revulsion of that idea, and we find Dr. Huggins suggesting in an italicised expression, that "*the star became suddenly enrapt in burning hydrogen*" ("Spectrum Analysis," p. 28, Huggins, 1866). To quote more fully, "In consequence it may be of some great convulsion, of the precise nature of which it would be idle to speculate, enormous quantities of gas were set free. A large part of this gas consisted of hydrogen, which was burning about the star in combination with some other element. This flaming gas emitted the light represented by the spectrum of bright lines. The greatly increased brightness of the spectrum of the other part of the star's light may show that this fierce gaseous conflagration had heated to a more vivid incandescence the matter of the photosphere. As the free hydrogen became exhausted the flames gradually abated, the photosphere became less vivid, and the star waned down to its former brightness." More or less modified forms of this theory of a fiery cataclysm were afterwards put forward, to account for the formation of Nova Cygni in 1876. Mr. Lockyer, however, advanced the idea that the outburst was due to cosmical collisions (NATURE, vol. xvi. p. 413). In his words, "We are driven from the idea that these phenomena are produced by the incandescence of large masses of matter because, if they were so produced, the running down of brilliancy would be exceedingly slow. Let us consider the case, then, on the supposition of small masses of matter. Where are we to find them? The answer is easy: in those small meteoric masses which an ever-increasing mass of evidence tends to show occupy all the realms of space." Practically all the theories with regard to the origin of new stars are modifications of one or the other of these; either an internal convulsion, or an external collision, is hypotheticated. Let us see how each will stand the test put upon it by Nova Aurigæ.

The discovery by Mr. Lockyer that the bright lines in the spectrum of the new star were accompanied by dark lines on their more refrangible sides seemed at once to be a striking confirmation of his views. The interpretation naturally put upon such a composite appearance was that two discrete masses were engaged in producing the body's light; one, having a spectrum of dark lines, was rushing towards the earth, while the bright-line star or nebula was running away. As Mr. Lockyer remarked in a paper communicated to the Royal Society on February 7, 1892, "the spectrum of Nova Aurigæ would suggest that a moderately dense swarm [of meteorites] is now moving towards the earth with a great velocity, and is disturbed by a sparser one which is receding. The great agitations set up in the dense swarm would produce the dark-line spectrum, while the sparser swarm would give the bright lines." In spite of its simplicity, however, and its ability to account for the observed facts, the meteoritic theory did not commend itself to the minds of some astronomers. Dr. Huggins clung to the idea that the outburst was the result of eruptions similar in kind to those upon the sun, but the acquisition of knowledge of the light changes of stars forced him to withdraw the original suggestion that the luminosity of a Nova is produced by chemical combustion (*Fortnightly Review*, June 1892, p. 827), in fact, to relinquish entirely the crude conception of a burning world propounded in 1866. In its place Dr. Huggins put the view that Nova Aurigæ owed its birth to the near approach of two gaseous bodies. "But," he admits (*Ibid.* p. 825), "a casual near approach of two bodies of great size would be a greatly less improbable event than an actual collision. The phenomena of the new star scarcely permit us to suppose even a partial collision, though if the bodies were diffused enough, or the approach close enough, there may have been possibly some mutual interpenetration and mingling of the rare gases near their boundaries."

"An explanation which would better accord with what we know of the behaviour of the Nova may, perhaps, be found in a view put forward many years ago by Klinkerfues, and recently developed by Wilsing, that under such circumstances of near approach enormous tidal disturbances would be set up, amounting, it may be, to partial deformation in the case of a gaseous body, and producing sufficiently great changes of pressure in the interior of the bodies to give rise to enormous eruptions of the hotter matter from within, immensely greater but similar in kind to solar eruptions." Serious objections to the Klinkerfues-Wilsing hypothesis are pointed out by Herr Seelinger (*Astr. Nach.*, No. 3118, and NATURE,

December 8, 1892). He shows that the statical theory of tides that has been applied is entirely inappropriate to the case, and also that the hypothesis involves assumptions amounting almost to impossibilities. In the first place, the pairing of the bright and dark lines makes it necessary to assume that the two bodies engaged were of similar chemical constitution, one having an absorption spectrum and the other an equivalent radiation spectrum. But even if we make this unthinkable supposition, a fatal objection has been pointed out by Mr. Maunder (*Knowledge*, June 1892). It is that the bright lines ought to have their refrangibility increased, not decreased as the spectroscopic observations show them to be. In other words, the erupted matter would approach the earth, not recede from it. This single undisputable fact effectually disposes of the chromospheric hypothesis to which reference has been made.

Another chromospheric theory in which only a single star is involved has been put forward by Father Sidgreaves (*The Observatory*, October, 1892). After describing the spectrum he says, "It is only necessary, therefore, to consider the conditions under which the blue-side shift of the Nova's lines should produce the absorption effect while the red-side parts show unclouded radiation. A great cyclonic storm of heated gases would produce this double if the heated gases were rushing towards us in the lower depths of the atmosphere trending upwards and returning over the stellar limb. In the lower positions the advancing outrush would be screened by a great depth of absorbing atmosphere, while as a high retreating current its radiation would be along a clear line to our spectroscopes." This explanation is plausible enough, but it does not go to the root of the matter. How, for instance, does Father Sidgreaves account for such a tremendous eruption as that required by his hypothesis? It is difficult to believe that internal forces could sustain, for two months, a stream of gas rushing earthwards with a velocity of about 400 miles per second, and then curving round and receding at the rate of 300 miles per second. And the idea becomes still more incomprehensible when we remember that the body possessing this marvellous store of energy was quite invisible before December, 1891. Until Father Sidgreaves explains the machinery by which the terrific whirl of chromospheric matter was started and kept up, his theory can hardly be seriously discussed.

As has already been remarked, Mr. Lockyer was the originator of the theory that Novas represent the result of the collisions of small masses. On this theory the broadened character of the lines in the spectrum of Nova Aurigæ is explained by supposing that different parts of the colliding swarms of meteorites were moving with different velocities, or with the same velocity in different directions. Several modifications of the meteoritic theory have been published. Mr. W. H. Monck has suggested that a star, or a swarm of meteors, rushing through a gaseous nebula afford the best explanation of the phenomena. The only difference between this idea and that of Mr. Lockyer's is that the nebula is supposed to consist of gaseous instead of meteoritic particles. But, from a dynamical point of view, there is no distinction between the two, for it is well known that Prof. G. H. Darwin has proved that the individual meteorites of a swarm would behave like the individual particles of a gas. Referring to the collision with a gaseous nebula, Mr. Monck says (*Journal of the British Astronomical Association*, January, 1893): "The previous absence of nebular lines, even if clearly proved, would not be conclusive as to the non-existence of such a nebula, for its temperature may not be high enough to produce these lines until raised by the advent of the star. A considerable proportion of Novæ, however, appear to be connected with known nebulæ. Irregularities in the nebulæ would produce the observed fluctuations of light, and if the relative velocity was considerable the bright gas-lines of the nebula would be distinguishable from the dark absorption lines of the star. The bright lines would be broader than usual, because the velocity of the portion of the nebula adjoining the star would be partially destroyed and the luminous gas would thus be moving with different velocities. The heating being confined to the surface of the star, the cooling would take place more rapidly than after an ordinary collision. But if the star travelled far through the nebula in a state of intense incandescence, portions of the surface would from time to time be vaporised and captured by the nebula, the mass of the moving star thus diminishing at every step. It might even end in complete vaporisation, as meteors are sometimes vaporised in our atmosphere. Herr Seelinger has worked out mathematically a theory (*Astr. Nach.* No. 3118, and NATURE, vol. xlvii. p. 137) very similar to that of Mr. Monck. He supposes that a body enters a cosmic cloud, such as Dr. Max Wolf's photographs show to be widely scattered through space. Whatever the constitution of such a nebulous mass, collision with it causes an increase of temperature, and a vaporisation of some of the constituents of the colliding body. The process is precisely similar to the entrance of a meteor into the earth's atmosphere. According to Herr Seelinger, Nova Aurigæ was produced in this wise. A dark body was rushing earthwards through space; it came to a mass of nebulosity, the light of which was so feeble that the eye could not appreciate it; the collision caused an increase of temperature and of luminosity; the heaping up of the glowing vapours in front of the colliding body produced the spectrum of dark lines, and the bright-line spectrum was given by the vapours left behind as the body moved onwards. These vapours would quickly assume the velocity of adjacent parts of the nebula, hence the dark lines would appear on the more refrangible sides of the bright ones in the manner observed.

Mr. Maunder also favours a collision theory (*Knowledge*, June 1892), his idea being that a long and dense swarm of meteors rushed through the atmosphere of a star, and produced the phenomena exhibited by Nova Aurigæ As the stream passed periastron, the spectrum of the glowing meteorites, and that of the constituents of the stellar atmosphere with which they were colliding, would appear together with the absorption spectrum of the star.

From what has been said it will be seen that none of the collision theories are substantially different from that laid down by Mr. Lockyer in 1877. It has been asserted that the meteoritic theory is not competent to explain the observed facts, but the opponents have generally omitted to specify its imperfections. One of the commonest objections is that the collision of two meteor swarms would be accompanied by a very considerable slackening of the rate of movement. Against this can be urged Seelinger's proof that the great relative velocity indicated by the spectrum could remain practically unchanged, and, in spite of this, enough kinetic energy could be transformed into heat to cause a superficial incandescence. Another objection is that it is impossible to conceive of meteor swarms of such magnitude that though rushing through one another with a relative velocity of more than seven hundred miles per second, disentanglement did not take place until two or three months had elapsed. In the light of latter-day revelations of astronomical photography, this objection becomes a mere cavil. The long-exposure photographs taken in recent years show that space is full of nebulous matter, and the "stream of tendency" is towards the idea that such masses are not gaseous but of meteoritic constitution. Now a simple calculation proves that even if Nova Aurigæ had a parallax of one second of arc, the whole of the luminosity received up to the end of April, 1892, could have been produced by the collision of two bits of nebulous matter, each of which would subtend an angle at the earth of less than half a minute of arc.

Surely it is not too much to assume the existence of meteoritic swarms of such comparatively small dimensions.

In some incidental remarks upon temporary stars, Mr. Maunder agreed with Mr. Lockyer in 1890 (*Journal of the British Astronomical Association*, vol. i. No. 1, p. 29) that they "must be stars in quite another sense to our sun. The rapidity with which their brightness diminishes is plain proof of this. Only small bodies could cool so rapidly, and since despite their vast distance (for their parallax is insensible) these Novas show themselves conspicuous, we are obliged to explain their brilliancy by considering them as consisting of aggregations of such small bodies; the total extent and mass of the swarm making up for the insignificant size of its components."

It will be seen that Mr. Lockyer's theory fits in with these observations most aptly. "New stars," he says (Roy. Soc. Proc., vol. xliii. p. 154), "whether seen in connection with nebulæ or not, are produced by the clash of meteor swarms. Clearly, as the swarm cooled down after the collision, we should find its spectrum tend to assume the nebular type." It is quite immaterial whether the chief nebular line is considered to be due to magnesium or not. According to the meteoritic hypothesis, a new star, as it diminishes in brilliancy, and presumably in temperature, must degrade towards the condition of a nebula. Accept the observations in proof of such a transformation, and the idea that nebulæ are entirely composed of glowing gas becomes untenable, unless it is believed that a Nova increases in temperature as it diminishes in brightness. On the other hand, the change of a new star into a nebula gives strong support to Mr. Lockyer's view that nebulæ are low temperature phenomena. In a paper "On the Causes which Produce the Phenomena of New Stars" (Phil. Trans., vol. clxxxii. (1891) A. pp. 397–448) Mr. Lockyer shows that the spectroscopic observations of Nova Coronæ, Nova Cygni, and Nova Andromedæ are in agreement with his hypothesis. It was therefore expected that Nova Aurigæ should assume the characteristic badge of a nebula. The expectation has been strikingly realised. In August, 1892, the star revived, and on the 19th of that month Prof. Campbell, of the Lick Observatory, wrote the following account of his observations of it (*Astr. Nach.*, No. 3133):—"The brightest line previously observed was resolved into three lines, whose wave-lengths were about 501, 496, and 486, which were at once recognised to be the three characteristic nebular lines. The same morning Prof. Barnard, using the 36-inch equatorial, observed the Nova as a nebula 3″ in diameter, with a tenth magnitude star in its centre. Thus the nebulous character of the object was independently established by two entirely different methods." Writing on the same subject, Prof. Barnard remarks (*Astr. Nach.*, No. 3143):—"I think it unquestionable that had any decided nebulosity existed about the star at its first appearance, it would have been detected in observations with the 36-inch, especially when the star had faded somewhat. So it is clearly evident that there has been an actual transformation in every sense of the word of a star into a nebula within an interval of only four months." Herr Renz has also observed the nebular character of the Nova by means of the Pulkowa refractor. On the other hand, one or two observers have been unable to detect the nebulosity, and it does not appear on Dr. Roberts's photograph of the region. It is impossible, however, to think that an observer of Prof. Barnard's calibre could have been deceived in the matter; hence the conflicting observations are probably accounted for by fluctuations in the extent and brightness of the nebulosity. The fact that Dr. Max Wolf's photographs of the Nova fail to show any haziness round the star goes for nothing, for a patch 3″ in diameter could not be distinguished from a point upon the scale of his pictures.

The spectroscopic evidence of the nebular character of Nova Aurigæ in its old age does not rest merely upon Prof. Campbell's observations. Prof. Copeland examined the spectrum on August 25 and 26, and also Mr. J. G. Lohse. From the measures obtained the mean values assigned to the two brightest lines were λ 500·3 and λ 495·3, while a fainter line was seen in the position λ 580·1, which is also the position of a bright line found in the Wolf-Rayet stars and Nova Cygni (NATURE vol. xlvi. p. 464). Mr. Fowler has also observed the two lines at 5006 and 4956 (*Ibid.* vol. xlvii. p. 399). But perhaps the most convincing of all testimonies is contained in a paper by Herr Gothard on the spectrum of the new star in Auriga as compared with the spectra of planetary nebulæ (Monthly Notices R.A.S., vol. liii. p. 55). The author has photographed the spectra of a number of nebulæ, and compared the results with his photographs of the Nova spectrum. "Each new photograph," says he, "increased the probability, which may be considered as a proved fact that the *spectrum not only resembles, but that the aspect and the position of the lines show it to be identical with the spectra of the planetary nebulæ.* In other words the new star has changed into a planetary nebula." In the face of this array of facts nothing could appear to be more satisfactorily established than the descent of the Nova to the condition of a nebula. Up to the present only one observer, Dr. Huggins, has delivered himself of a contrary conviction. His observations have led him to believe that "the bright band in the Nova spectrum is resolved into a long group of lines extending through about fifteen tenth-metres" when a high dispersion is employed (*Astr. Nach.*, No. 3153). This observation, however, has not been confirmed, hence it cannot be "implicitly accepted." It can hardly be discussed until Dr. Huggins gives a more explicit description of the number and positions of the individual lines he has seen.

Such are the theories with regard to the origin of Nova Aurigæ and new stars generally. From the survey we see that Huggins' theory of burning worlds suggested to account for the appearance of a new star has gone the way of Tycho Brahe's idea that such bodies are new creations. Any and all chromospheric theories fail to explain the transformation of the Nova into a nebula, so they should be abandoned. And finally, the whole sequence of spectroscopic phenomena is explainable on the hypothesis that the light was produced "by the clash of meteor-swarms." From the point of view of the meteoritic hypothesis things could hardly have turned out more satisfactorily than they have, yet at least one carping critic, after being forced to admit the testimony of his eyes that the Nova now exists as a nebula, has ventured to say that the fact tells against it. How, forsooth? Simply to make such a statement without backing it up reminds one very forcibly of mud-throwing. Let the blows to the hypothesis be fairly given, and as fairly met, for only by such means can the truth prevail.

RICHARD A. GREGORY.

THE ROYAL SOCIETY SELECTED CANDIDATES.

THE following fifteen candidates were selected on Thursday last (April 27) by the council of the Royal Society, to be recommended for election into the Society. The ballot will take place on June 1 at 4 p.m. We print with the name of each candidate the statement of his qualifications.

WILLIAM BURNSIDE, M.A.,

Professor of Mathematics at the Royal Naval College, Greenwich. Formerly Fellow of Pembroke College, Cambridge. Author of the following papers among others:—"On Deep-