proving destructive to poultry. On several occasions it has been known to enter the houses in search of roaches and other vermin, and has been captured in rat-traps.

It is strictly nocturnal, and spends the day in caves, holes in the coral limestone rocks and in hollow trees and logs. It is a slow, stupid creature. It is unable to run rapidly, but shambles along with the zigzag, sidewise motions of a plantigrade. It is, doubtless, owing to this that it obtained the native name of "Orso" (bear).

Article XXIV. by S. A. Rohwer is on "A Fossil Larrid Wasp"; the same author contributes article XXV., a discussion of the fossil saw-flies (Tenthredinoidea) of the Florissant Shales. Article XXVI. comprises notes on the skull of *Lysorophus tricarinatus* Cope, by E. C. Case, of which the author remarks, that

Were it not for the extreme specialization of this limbless Gymniophiona-like form it would *occupy almost exactly the transitional position between the amphibians and reptiles.*

Article XXVII., by Dr. Matthew, particularly describes the osteology of *Blastomeryx,* and discusses the phylogeny of the American Cervidæ, in which the writer asserts that

Blastomeryx proves to be a very primitive deer, approximately ancestral to the American Cervidæ, and derivable in its turn from the Oligocene genus *Leptomeryx,* whose relationship to the Cervid phylum had not been suspected. We are thus enabled to trace the ancestry of the American Cervidæ back to the Oligocene, by successive stages known from the entire skeleton, and not merely from the inadequate evidence of teeth and jaws.

Article XXVIII. is by Filippo Silvestri, on the Myriopoda from Porto Rico and Culebra; article XXIX. consists of "Mammalogical Notes," by Dr. Allen; article XXX. is a further contribution by S. A. Rohwer on the saw-flies from Florissant, Colorado.

President Osborn contributes article XXXII. on "New or Little Known Titanotheres from the Eocene and Oligocene." Professor Wheeler discusses the "Ants of Casco Bay, Maine," in a very attractive paper, filled with descriptions of predatory expeditions, slave-making hunts and colonial devices and aspirations, which are picturesque enough in themselves, and are treated with very circumstantial seriousness. Professor Wheeler in this paper engages again in an extended debate on the origin of slavery (*dulosis*), and social parasitism in ants, wherein we are told that Wasmann has repeated Professor Wheeler's experiments on the formation of colonies, has corroborated them, and that "an outstanding difference in interpretation" only now remains between these distinguished naturalists.

The volume concludes with a paper by Dr. Allen, on "Mammals from Nicaragua."

L. P. GRATACAP

SPECIAL ARTICLES

RADIUM IN SPIRAL NEBULÆ AND IN STAR CLUSTERS

IN consequence of a prolonged study of the relation to celestial spectra of the spectrum of radium emanation as published by Sir William Ramsay and Professor J. Norman Collie,[1] I announced on January 19, 1905, the principle of "critical radioactivity" or the transformation of the chemical elements at critical pressures and temperatures in the stars. This explosive transformation of the elements at critical physical states, occurring in the heavenly bodies, I have named "radioaction," in order to distinguish it from ordinary radioactivity.

Radioaction, hypothesis *a,* was announced as a tested theory in the face of Rutherford's statement:

The transformation of matter occurring in the radio-elements is, on the other hand, spontaneous, and independent of temperature over the range examined.[2]

It was also in challenge of the natural inference to be drawn from the statement of Runge and Precht, made at the close of their account of the measurement of the lines of the radium spectrum:

Concerning all strong radium lines, it may be affirmed with certainty that, according to our measurements, they are not found among the measured solar lines of Rowland.[3]

Changes in pressure and temperature are, on all sides, said to produce no marked changes

[1] *Proc. Roy. Soc.,* 73, p. 470, May, 1904.
[2] "Radioactivity," first edition, p. 350.
[3] *Ann. der Phys.,* 317, 412, June, 1903.

in radioactivity, and, moreover, the precise measuremental matching of the lines of the radio-elements with celestial lines is universally held to be essential to their identification in the heavenly bodies. In direct violation of these views, radioaction, hypothesis α, was proposed and confirmed. A second principle, hypothesis β, which need not now be described, was also used from the first, and thence a set of principles of interpretation of celestial phenomena, deduced and verified, which, for brevity, I designate the theory of radioaction.

The theory was originally verified with difficulty by constantly summoning the calculus of probabilities to its aid, and kept from publication on account of obstacles encountered in presenting the vast mass of evidence.

Radioaction, or critical radioactivity, I have used the last five years, as a principle explanatory of many strange and hitherto inexplicable phenomena, of inorganic evolution. I have found radioaction to be an essential factor in cosmic evolution. By means of it I have been able to predict the necessary character of many phenomena peculiar to the morphology, photometry, spectroscopy and electro-optics of nebulæ, stars, sun and comets. Excepting two papers on this subject, read before the American Philosophical Society, one, "Universal Celestial Radioactivity," January 20, 1905, and the other, "Radioactivity in Solar Phenomena," April 14, 1905, both as yet unprinted, I have contented myself, of necessity, with the accumulation of proofs of the theory, until its presentation to the public in the form desired should be feasible.

Lately, however, the data for direct confirmation of this theory have come so freely to hand that I have decided to lay aside, in part, the ideal of aiming to present, as a unit, my theory of radioaction, with all its wide ramifications and interesting consequences.

Recently Mr. A. T. Cameron and Sir William Ramsay have remeasured the spectrum of radium emanation, and Professor E. Rutherford and Mr. T. Royds have also brought to bear all the refinements of physical accuracy upon the same problem; so that now there is available a body of information of the highest value concerning this spectrum.

Reflecting upon the use of this material, my theory suggested an investigation which resulted in a very simple and decisive confirmation of radioaction. This first and peculiar confirmation, due to the later determinations of the spectrum of radium emanation, I reserve for appropriate publication.

It was on April 26 of this year that I received Lick Observatory Bulletin, No. 149, recording the work of Dr. E. A. Fath on the "Spectra of Some Spiral Nebulæ and Globular Star Clusters." This bulletin permitted me, at once, to establish the fact that the absorption spectrum of radium emanation was present in this great nebula of Andromeda, and in other spiral nebulæ, and likewise present in the star cluster of Hercules (probably along with one line of radium), and in two other star clusters. It also came out clearly that the radium series of elements was not disclosed by the spectrum of the Spiral Nebula N. G. C. 1068. Finally, on referring to the observations of *bright* lines in the nebula of Andromeda by Sir William Huggins and Lady Huggins, I was gratified, but not surprised, to find that these lines were plainly identifiable as lines of radium emanation.

It has seemed proper to attempt here only a brief examination of the facts, since the present conditions prohibit a completely tabulated and detailed discussion. First, I must say that it is with no little satisfaction that I find myself reviewing this piece of superb work issued under the direction of Professor Campbell. For, in my study of radioaction, during these five trying years, I have again and again noted Professor Campbell's accurate and painstaking description of unusual celestial phenomena, his balanced review of the work of others (including the celebrated thrust concerning the Purkinje phenomenon), and his remarkable insight into the value of anomalous observations, and of mooted suggestions for their explanation.

The telescope used by Dr. Fath in the work was the celebrated Crossley reflector, with a specially designed spectrograph attached. The difficulties mastered were of the first order.

The total exposures ranged, in the case of the Andromeda nebula, up to $18^h\ 11^m$, accumulated during three different nights, yielding fourteen lines; and in that of N. G. C. 7331 up to $22^h\ 22^m$, accumulated during seven nights and yielding two lines. Of the accuracy of the wave-length determinations Dr. Fath says:

> When measuring known spectra the wave-lengths of the lines usually come within 5 or 6 Angström units of the correct value, although occasionally a larger deviation is found. Thus the third figure given may usually be considered correct.

In the identification of the lines, it is possible that Dr. Fath was unconsciously influenced by Scheiner's emphatic assertion:[4]

> It is thus proven that the Andromeda Nebula exhibits a spectrum of the class IIa, or further, that the greater part of the stars composing the nucleus of this nebula belong to the second spectral class.

The inference that "the spectrum is of the solar type" will, I think, be found to be too hasty. The absence from Dr. Fath's plates of any indication of the bright lines of Huggins was, indeed, quite misleading. Bright lines will, undoubtedly, be photographed, later, in the great nebulæ of Andromeda.

The following table records in the first and second columns the wave-lengths and intensities of the lines in the Andromeda nebula as measured by Dr. Fath, in the third and fourth columns the identifications with the spectrum of radium emanation suggested by myself, and in the last column, the identifications proposed by Dr. Fath.

TABLE I

No.	N. G. C. 244		Ra. E.		Identification by Dr. Fath.
	λ	In.	λ	In.	
(1)	3740	1/2	3739.9	7/1	Solar group, center λ 3735
(2)	3826	1/2	3818.0	2	Solar group, center λ 3830
(3)	3870	1/2	3867 6	4	Solar group, center λ 3872
(4)	3934	10	3933.3	3	Calcium K
(5)	3969	10	3971.9	9	He and Calcium H
(6)	4060	2	4055.7	1	Mean of Solar? { λ 4046 Fe, λ 4064 Fe, λ 4072 Fe }
(7)	4156	2	4166.6	20/1	Solar group, center λ 4150
(8)	4203	1	4203.7	10	H δ
(9)	4230	1	4225 8	2	Ca, λ 4227
(10)	4303	5	4308.3	10	Solar G
(11)	4385	2	4384.0	3	Fe, λ 4384
(12)	4456	1	4460.0	10	Solar group, center λ 4457
(13)	4676	1	4681.1	10	Solar group, center λ 4668
(14)	4855	3	H β		H β

The wave-lengths of the lines of the radium emanation are taken from the table of Rutherford and Royds.[5] The second number in the intensity column of radium emanation records, for line No. (1), the value by "photograph 3," and for line No. (7) the "visual" estimate. It should be borne in mind that for the nebular lines "the third figure given may usually be considered correct." Both schemes of identification are suggested by theory. Dr. Fath's is supported by the theory that the Andromeda nebula is a cluster of solar stars. No conclusive review has been given of such theory. From his own use of Bohlin's parallax of this nebula, he infers that "the 'star cluster' theory is not very satisfactory." He, however, necessarily recurs to solar lines and "groups of lines," selected, chiefly, on the basis of mere matching.

My own identification assumes the theory that all nebulæ whatsoever are electrically luminescent results of radioaction in the associated "stars." This theory has repeatedly been found to be confirmed in accounting for analogous phenomena. It explains why, now bright lines, now dark lines are observed in this nebula. It suggests the kind of chemical elements whose traits are here to be found. It accounts for the variability of this nebula in 1885, by asserting that the "star," variable through radioaction, holds the secret of cosmic evolution. Finally, it banishes the necessity for imagining a lawless collision of a pair of stars for generating spiral nebulæ.

The general agreement in wave-length of this single radio-element with all but one of the nebular lines must be given weight. There are three lines, Nos. (8), (9) and (10), which, both in the spectrum of the nebula and in that of the emanation, follow consecutively. Moreover, their intensities, all conditions considered, are quite consistent with the hypothesis of identity. There is no necessity for reminding spectroscopists that, on account of the wide variation of intensity with changes in excitation, fair agreements in such a case

[4] *Astrophys. Jour.*, 9, 150.

[5] *Phil. Mag.*, Ser. VI., Vol. 16, p. 317, Aug., 1908.

count toward the probability of identity, while disagreements do not count against it. I also call attention to the practical agreement in wave-length and in grade of intensity of lines Nos. (4) and (5). A detailed discussion of the probability of identification of each line seems unnecessary here. Admitting the uncertainty in the measurements of the nebular lines, considerable weight can fairly be given to general agreement. I have nothing to say to the spectroscopist who insists on the absolute matching of lines in wave-length as the final test of "identification" of all celestial spectra.

If radioactive outbursts determine both the bright lines and the dark lines, and account for the appearance and disappearance of the former, the celebrated bright lines of Huggins may supply a test of the theory. In the following table, the first column contains the estimated wave-lengths of *bright* lines observed in the nebula of Andromeda by Sir William Huggins and Lady Huggins,[6] the second and third, the corresponding radium emanation lines and their intensities observed by Ramsay, Collie and Cameron, and the fourth and fifth, those observed by Rutherford and Royds.

TABLE II

No.	N. G. C. 224	Ra. E.		Ra. E.	
	λ	λ	In.	λ	In.
(1)	580	580	(persistent)	583	1
(2)	543	543	faint	539.5	0
(3)	538	537	2	537	0
(4)	511 (a group of 4 or 5 lines)	508	2	512 509	2 10
(5)	495 (a group)	498 494 492	2 2 3	496 495 492	1 1 1
(6)	476	477	2	477	1
(7)	455 (suspected)	458 455 452	3 2 1	458 455 451	1 0 1

For the sake of simplicity of statement, and so as to conform to the grade of accuracy of the estimates by the astronomical observers, only the first three figures of the wave-length measurements of the physicists are given. The general agreement is very satisfactory.

[6] "An Atlas of Representative Stellar Spectra," p. 125.

Line (4) is "a group of 4 or 5 lines," and becomes so, first, because both lines concerned are relatively intense, and secondly, because, as astrophysicists well know, an intense line is at times likely to break up into a group. Line (5) is evidently "suspected" because of decreased sensitiveness of the eye for this region, and because of the low intensity of the three lines concerned.

A more detailed discussion would, I am sure, place this identification beyond any possibility of doubt, but also carry me farther into the subject than I had planned. It is worth while remembering, however, that admitting radioaction as receiving confirmation in other celestial bodies, it may here, with some weight, predict, as it does, the fact of bright lines, their variability, and their character as radioactive products. The two groups (4) and (5), examined on the basis of the strictest principles of electro-optics would alone prove identity, and their testimony is certainly not weakened by the other lines. The difficulties conquered by the famous chemist, and the masterful physicists in furnishing the measured lines of the rare radium emanation are certainly always most gratefully to be acknowledged; and the refined and conscientious work of Sir William Huggins and Lady Huggins in independently examining these evanescent bright lines of the nebula of Andromeda through the weary nights of many successive years, is, I hold, not only emphatically verified by this identification, but their faith in its high and lasting value adequately commended by the result.

The spectra of five other spiral nebulæ were likewise photographed by Dr. Fath at the Lick Observatory, and four of these, consisting each of but from one to three lines, disclosed, in each, identity with radium emanation in one to two lines. The spiral Nebula N. G. C. 1068 discloses, as stated, no known radio-element of the radium series, unless the bright λ 3733 and λ 3878 be helium lines. It is, however, practically certain that the celebrated main nebular lines characterizing the spectrum of this object, and of others like it, are due to radio-elements yet to be identified.

The spectra of star clusters next claim at-

tention. The spectrum of the Hercules cluster N. G. C. 6205, obtained by Dr. Fath is quite remarkable. He says:

It is composed of a number of parallel strips of different intensities, containing a few faint absorption lines. Each strip is probably the spectrum of a single star, or group of stars. No two strips contain the same set of lines. Four of the strips were strong enough to be measured.

In the following table the first column states the number of the strip, the second the wave-length, the third the intensity, the fourth the corresponding wave-length of radium emanation, the fifth its intensity.

TABLE III

Strip.	N. G. C. 6205		Ra. E.	
	λ	In.	λ	In.
(2)	3935	3	3933.3	3
(1)	3966	3	3971.9	9
(2)	3970	3		
(4)	4118	2	4114.9	7
(1)	4294	1	4308.4	2
(4)	4302	1		
(3)	4340	1	4340.8	50 Ra.
(4)	4463	1	4460.0	10
(2)	4790	1	4796.7	1

It will be noticed that to the single line of strip (3), I have assigned the radium line of high intensity, although an emanation line λ 4340.9, intensity 7, also exists. I think the evidence for the existence of radium emanation in this cluster is sufficient to make discussion unnecessary. It will be seen that for the different strips the lines vary. Difference of excitation, due to the difference of physical state of each star, completely accounts for the variation. In the globular clusters N. G. C. 7078 and 7089, the hydrogen lines are, as Dr. Fath indicates, probably evident from $H\beta$ to $H\theta$. Radium emanation must, however, also claim λ 4102.2, λ 3971.9 and λ 3933.3 in each of these star clusters.

It may not be amiss to venture a few suggestions:

1. Each photograph or observed spectrum of a nebula, star cluster, or bright line star, should be treated as a separate entity in publication; otherwise the successive changes in given lines are averaged out of existence.

2. If possible, the spectrum of the nebula of Andromeda should be repeatedly photographed.

3. It should be the aim to photograph as soon and as effectually as possible the spectra of the short-period variables in globular star clusters even if at first integrated results, both as to stars and as to periods, are obtained.

In conclusion, I must state that I am quite conscious of the incompleteness of this discussion. Indeed, it is the manifest complexity of the subject that has made me, hitherto, recoil from a preliminary application of the theory for publication. Radium has been known for at least ten years as a terrestrial element, its spectrum has been repeatedly determined and compared with the spectra of the heavenly bodies, and yet up to the present moment there has been published, so far as I know, no demonstrative evidence concerning its existence in the heavens. On the contrary, careful comparisons made by chemists, physicists and astronomers, have apparently shown that the spectra of radium and radium emanation, the element into which radium is at once transformed, are not identifiable with stellar spectra. It is, therefore, significant that the identifications here made were suggested by the theory of radioaction.

MONROE B. SNYDER
PHILADELPHIA OBSERVATORY,
May 3, 1909

OBSERVATIONS ON THE SHIFTING OF THE CHANNEL OF THE MISSOURI RIVER SINCE 1883[1]

THE radical changes which annually take place in regard to the position of the Missouri River channel and the great loss of property occasioned by the same have presented a problem worthy our careful consideration. In addition to the scores of farms which are washed out annually the railroads suffer greatly by having their roadbeds destroyed. Hence, this becomes an economic problem of vast proportions.

In the following chart we have represented a portion of the river valley near the village of Peru, including ten or twelve miles of the river bed. The upper dotted line represents

[1] Read before the Nebraska Academy of Sciences.