ant researches in stellar photography which have recently been carried out at the Harvard College Observatory, see NATURE, vol. xxxv. p. 37.

NEW MINOR PLANET.—A new minor planet, No. 265, was discovered on February 27, by Herr Palisa, at Vienna. This is the fifty-eighth that Herr Palisa has discovered.

ASTRONOMICAL PHENOMENA FOR THE WEEK 1887 *MARCH* 6–12

(FOR the reckoning of time the civil day, commencing at Greenwich mean midnight, counting the hours on to 24, is here employed.)

At Greenwich on March 6

Sun rises, 6h. 37m.; souths, 12h. 11m. 28·1s.; sets, 17h. 46m.; decl. on meridian, 5° 40′ S.: Sidereal Time at Sunset, 4h. 43m.

Moon (Full on March 9) rises, 13h. 39m.; souths, 21h. 29m.; sets, 5h. 10m.*; decl. on meridian, 17° 4′ N.

Planet	Rises h. m.	Souths h. m.	Sets h. m.	Decl. on meridian ° ′
Mercury	6 54	13 15	19 36	3 22 N.
Venus	7 20	13 35	19 50	2 16 N.
Mars	7 0	12 54	18 48	1 58 S.
Jupiter	22 19*	3 21	8 23	12 2 S.
Saturn	12 2	20 11	4 20*	22 28 N.

* Indicates that the rising is that of the preceding evening and the setting that of the following morning.

Occultations of Stars by the Moon (visible at Greenwich)

March	Star	Mag.	Disap. h. m.	Reap. h. m.	Corresponding angles from vertex to right for inverted image ° °
6	*f* Geminorum	6	0 41	1 40	131 289
8	18 Leonis	6	4 1	4 39	67 337
8	45 Leonis	6	18 24	19 14	68 185
8	ρ Leonis	4	20 50	21 54	61 111
8	49 Leonis	6	22 53	near approach	332 —
11	γ Virginis	2½	3 7	3 40	145 210
11	B.A.C. 4277	6	4 22	near approach	186 —

March	h	
12	3	Mercury stationary.
12	20	Jupiter in conjunction with and 3° 34′ south of the Moon.

Saturn, March 6.—Outer major axis of outer ring = 44″·0; outer minor axis of outer ring = 18″·3; southern surface visible.

Variable Stars

Star	R.A. h. m.	Decl. ° ′		h. m.	
U Cephei	0 52·3	81 16 N.	Mar. 7,	19 36	*m*
S Arietis	1 58·6	11 59 N.	,, 6,		*M*
T Cancri	8 50·2	20 17 N.	,, 9,		*m*
R Ursæ Majoris	10 36·7	69 22 N.	,, 11,		*M*
T Virginis	12 8·8	5 24 S.	,, 7,		*M*
S Ursæ Majoris	12 39·0	61 43 N.	,, 10,		*M*
W Virginis	13 20·2	2 48 S.	,, 12,	5 0	*M*
δ Libræ	14 54·9	8 4 S.	,, 9,	23 39	*m*
U Coronæ	15 13·6	32 4 N.	,, 6,	18 46	*m*
R Scorpii	16 10·9	22 40 S.	,, 11,		*M*
U Ophiuchi	17 10·8	1 20 N.	,, 7,	5 46	*m*
			and at intervals of	20 8	
U Sagittarii	18 25·2	19 12 S.	Mar. 9,	3 0	*m*
β Lyræ	18 45·9	33 14 N.	,, 9,	1 0	*m*
S Vulpeculæ	19 43·8	27 0 N.	,, 12,		*M*
η Aquilæ	19 46·7	0 43 N.	,, 9,	5 0	*m*
δ Cephei	22 25·0	57 50 N.	,, 12,	0 0	*m*

M signifies maximum; *m* minimum.

ON RADIANT-MATTER SPECTROSCOPY:—EXAMINATION OF THE RESIDUAL GLOW[1]

I.

THE duration of phosphorescence after cessation of the exciting cause is known to vary within wide limits of time, from several hours in the case of the phosphorescent sulphides to a minute fraction of a second with uranium glass and sulphate of quinine. In my examinations of the phosphorescent earths glowing under the excitement of the induction discharge *in vacuo*, I have found very great differences in the duration of the residual glow. Some earths continue to phosphoresce for an hour or more after the current is turned off, while others cease to give out the light the moment the current stops. Having succeeded in splitting up yttria into several simpler forms of matter differing in basic power (Roy. Soc. Proc. vol. xl. pp. 502-509, June 10, 1886), and always seeking for further evidence of the separate identity of these bodies, I noticed occasionally that the residual glow was of a somewhat different colour to that it exhibited while the current was passing, and also that the spectrum of this residual glow seemed to show, as far as the faint light enabled me to make out, that some of the lines were missing. This pointed to another difference between the yttrium components, and with a view to examine the question more closely I devised an instrument similar to Becquerel's phosphoroscope, but acting electrically instead of by means of direct light.

The instrument, shown in Fig. 1, A and B, consists of an opaque disk, *a b c*, 20 inches in diameter, and pierced with twelve openings near the edge as shown. By means of a multiplying wheel, *d*, and band, *e f*, the disk can be set in rapid rotation. At each revolution a stationary object behind one of the apertures is alternately exposed and hidden twelve times. A commutator, *g* (shown enlarged at Fig. 1, B), forms part of the axis of the disk. The commutator is formed of a hollow cylinder of brass round a solid wooden cylinder. The brass is cut into two halves by a saw cut running diagonally to and fro round it, so as to form on each half of the cylinder twelve deeply cut teeth interlocking, and insulated from those on the opposing half cylinder by an air space about 2 mm. across. Only one half, *h h h*, of the cylinder is used, the other, *i i i*, being idle; it might have been cut away altogether were it not for some little use that it is in saving the rubbing-spring, *j*, from too great friction when passing rapidly over the serrated edge. To a block beneath the commutator are attached two springs, one, *k*, rubbing permanently against the continuous base of the serrated hemicylinder *h h*, and the other, *j*, rubbing over the points of the teeth of *h h*. By connecting these springs with the wires from a battery it will be seen that rotation of the commutator produces alternate makes and breaks in the current. The spring, *j*, rubbing against the teeth is made with a little adjustment sideways, so that it can be said to touch the points of the teeth only, when the breaks will be much longer than the makes, or it can be set to rub near the base of the teeth, when the current will remain on for a much longer time and the intervals of no current will be very short. By means of a screw, *l l*, attached to the spring, any desired ratio between the makes and the breaks can be obtained. The intermittent primary current is then carried to an induction coil, *m*, the secondary current from which passes through the vacuum tube, *n*, containing the earth under examination. When the commutator, the coil-break, and the position of the vacuum tube are in proper adjustment, no light is seen when looked at from the front if the wheel is turned slowly (supposing a substance like yttria is being examined), as the current does not begin till the tube is obscured by an intercepting segment, and it ends before the earth comes into view. When, however, the wheel is turned more quickly, the residual phosphorescence lasts long enough to bridge over the brief interval of time elapsing between the cessation of the spark and the entry of the earth into the field of view, and the yttria is seen to glow with a faint light, which becomes brighter as the speed of the wheel increases.

To count the revolutions, a projecting stud, *o*, is fastened to the rotating axis, and a piece of quill, *p*, is attached to the fixed support, so that at every revolution a click is produced. With a chronograph watch it is easy in this way to tell the time, to the tenth of a second, occupied in ten revolutions of the wheel.

Under ordinary circumstances it is almost impossible to detect any phosphorescence in an earth until the vacuum is so high that the line spectrum of the residual gas begins to get faint; otherwise the feeble glow of the phosphorescence is drowned by the greater brightness of the glowing gas. In this phosphoroscope, however, the light of glowing gas does not last an appreciable time, whilst that from the phosphorescent earth endures long enough for it to be caught in the instrument. By this means, therefore, I have been able to see the phosphorescence of yttria, for example, when the barometer gauge was 5 or 6 mm. below the barometer.

When the earth under examination in the phosphoroscope is yttria free from samaria, and the residual emitted light is ex-

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[1] Paper read before the Royal Society by Mr. William Crookes, F.R.S., on Feb. 17.

amined in the spectroscope, not all the bands appear at the same speed of rotation. At a slow speed the double greenish-blue band of Gβ (545) first comes into view, closely followed by the deep blue band of Gα (482). This is followed, on increasing the speed, by the bright citron band of Gδ (574), and at the highest speed the red band of Gζ (619) is with difficulty seen.

The following are measurements of the time of duration of the phosphorescences of the different constituents of yttrium. The wheel was first rotated slowly, until the first line visible in the spectroscope attached to the phosphoroscope appeared; the speed was counted, and it was then increased until the line next visible was seen. In this way the minimum speed of revolution necessary to bring each line into view was obtained, and from these data the duration of phosphorescence for each constituent of yttria was calculated. The time in the following table represents in decimals of a second the time elapsing between the cessation of the induction discharge and the visibility of the residual glow of the earth:—

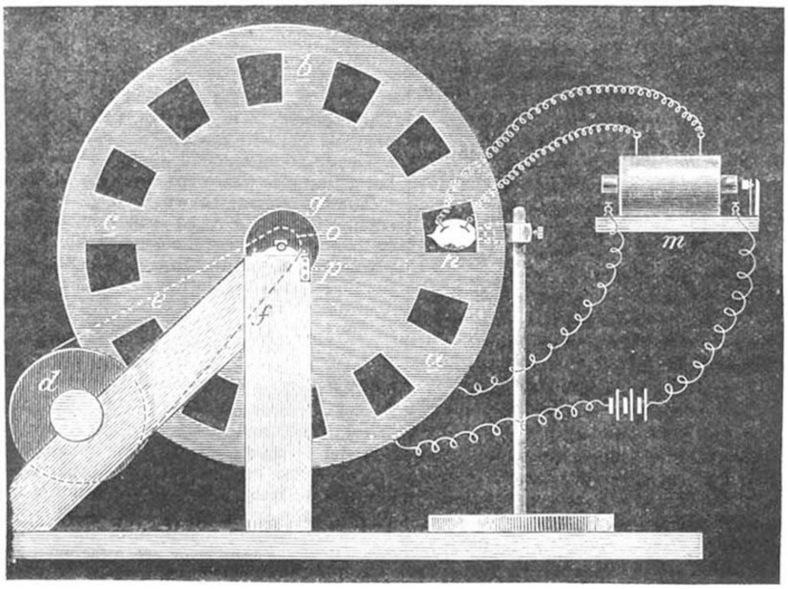

FIG. 1, A.

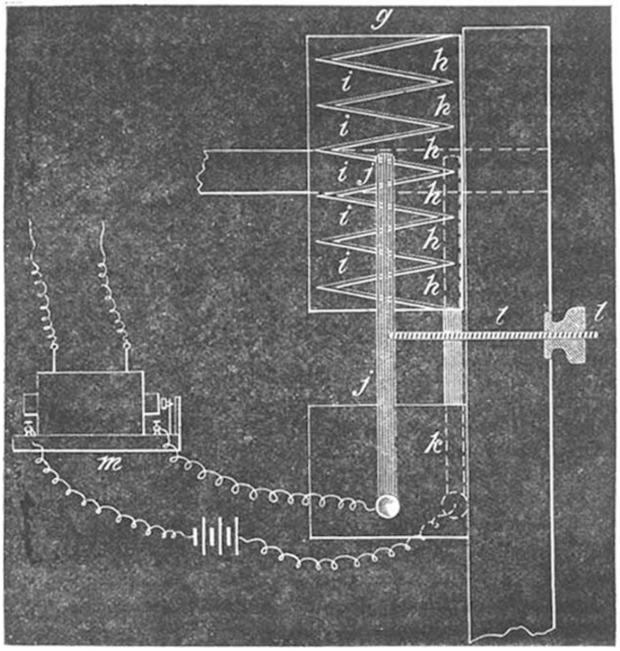

FIG. 1, B.

At 0·0035 sec. interval the green and blue lines of Gβ and Gα begin to be visible.

At 0·0032 sec. interval the citron line of Gδ begins to be visible.

At 0·00175 ,, the deep red line of Gζ (647) is just visible.

At 0·00125 ,, the line of Gδ is almost as bright as that of Gβ, and the red line of Gη is visible.

At 0·000875 sec. interval	the highest speed the instrument could be revolved with accuracy, the whole of the lines usually seen in the yttria spectrum could be seen of nearly their usual brightness.

I have already recorded (Phil. Trans., 1883, Part III. pp. 914–16), that phosphate of yttria, when phosphoresced *in vacuo*, gives the green lines very strongly whilst the citron band is hazy and faint. The same tube of yttric phosphate was now examined in the phosphoroscope. The green lines of Gβ soon showed themselves on setting the wheel into rapid rotation, but I was unable to detect the citron band of Gδ even at a very high speed.

The effect of calcium on the phosphorescence of yttria and samaria has been frequently referred to in my previous papers. It may save time if I summarise the results here. About 1 per cent. of lime added to a badly phosphorescing body containing yttrium or samarium always causes it to phosphoresce well. It diminishes the sharpness of the citron line of Gδ but increases in brightness. It also renders the deep blue line of Gα extremely bright. The green lines of Gβ are diminished in brightness. Lime also brings out the phosphorescence of samarium, although by itself, or in the presence of a small quantity of yttrium, samarium scarcely phosphoresces at all.

In the phosphoroscope the action of lime on yttrium is seen to entirely alter the order of visibility of the constituents of yttrium. In a mixture of equal parts yttrium and calcium, the citron Gδ line is the first to be seen, then comes the Gα blue line, then the Gβ green line, and finally the Gη red line. This may, I think, be explained somewhat as follows:—Calcium sulphate has a long residual phosphorescence, whilst yttrium sulphate has a comparatively short residual phosphorescence. Now with yttrium, although the green phosphorescence of Gβ lasts longest, it does not last nearly so long as that of calcium sulphate. The long residual vibrations of the calcium compound induce, in a mixture of calcium and yttrium, phosphorescence in those yttric molecules (Gδ) whose vibrations it can assist, in advance of those (Gβ) to which it is antagonistic; the line of Gδ therefore appears earlier in the phosphoroscope than that of Gβ, although were calcium not present the line of Gβ would appear first.

Experiments were now tried with different mixtures of yttria and lime as ignited sulphates, to see where the special influence of lime on Gδ ceased.

Yttrium	Calcium	
Per cent.	Per cent.	
97½	2½	Order of appearance in the phosphoroscope.—Gβ, Gα, Gδ, and Gη. The citron line of Gδ is only to be seen at a high speed, and is then very faint.
95	5	Order of appearance in the phosphoroscope.—Gα, Gβ, and Gδ (citron and blue) together, and lastly Gη (red). At a very high speed the green lines of Gβ become far more luminous than any other line.
90	10	Order of appearance.—Gδ and Gα together, then Gβ, and lastly Gη.
80	20	Order of appearance.—Gδ and Gα simultaneously, then Gβ, and lastly Gη. The residual phosphorescence lasts for 30 seconds after the current stops. The light of this residual glow is entirely that of Gδ. The line of Gβ comes into view at an interval of 0·0015 second. At 0·00175 second the line of Gη is just visible.
60 50 40	40 50 60	Order of appearance.—Gδ and Gα together, then Gβ and Gη together.
30 10 5	70 90 95	Order of appearance.—Gδ, Gα, Gβ.
1	99	Order of appearance.—Gδ, Gα. The green lines of Gβ could not be seen in the phosphoroscope; they would probably be obliterated by the stronger green of the continuous spectrum given by the calcium.

The action of barium on yttrium was now tried. The following mixtures (as ignited sulphates) were made:—

Yttrium	Barium	
Per cent.	Per cent.	
95 90 80	5 10 20	In the phosphoroscope the Gβ line appears earliest, but the blue Gα line is the next to be seen, whilst the red line of Gη is the latest in appearing. As the percentage of yttrium increases the blue line more and more overtakes the red and increases in brightness.
70 60 50 40 30 25	30 40 50 60 70 75	Spectrum similar to the above. As the percentage of yttrium increases the spectrum grows brighter. In the phosphoroscope the earliest line to appear is the Gβ green, then the Gη red, and next closely following it the Gα blue.
20 15 10 5	80 85 90 95	In the radiant-matter tube all these mixtures give similar spectra. The Gβ green is a little brighter and the Gδ citron is a little fainter than in the corresponding mixtures of yttrium and calcium, but the whole of the yttrium lines are seen. In the phosphoroscope the Gβ green is the first to appear, then the Gη red. The Gδ citron is not visible at any speed.
1	99	Red line of Gη is much brighter; Gδ is very faint, and the green of Gβ is stronger. In the phosphoroscope the order of appearance is,—first the line of Gβ, then the red line of Gη.
0·5	99·5	Phosphoresces with difficulty, of a light blue colour, but turns brick-red in the focus of the pole. Spectrum very faint. Order of appearance to phosphoroscope,—Gβ first, the others too faint to be seen.

The next experiments were tried with strontium, to see what modification the addition of this body to yttrium would produce. The following mixtures of ignited sulphates were experimented with:—

Yttrium	Strontium	
Per cent.	Per cent.	
95	5	A very good yttrium spectrum. In the phosphoroscope the order of appearance is,—first the green of Gβ, then the Gα blue, lastly the Gη red. No Gδ citron line could be seen.
80	20	In the phosphoroscope the green of Gβ is very prominent at a low speed, standing out sharply against a black background. With a higher velocity the Gα and Gη lines come into view.
60 40	40 60	The ordinary spectrum of this and the neighbouring mixtures is very rich in the citron line of Gδ, but I entirely fail to see a trace of this line in the phosphoroscope at any speed. The line of Gβ is the first to come, then the blue line of Gα.
35	65	At about this point a change comes over the appearance in the phosphoroscope. The blue line of Gα is now the earliest to appear, and it is followed by the Gη red and Gβ green. No Gδ line is seen.
25 15 5 0·5	75 85 95 99·5	These mixtures are very similar to each other in the phosphoroscope. The line of Gα comes first, next the Gη line, then Gβ line. No Gδ citron line has been seen in any of these mixtures.

In a paper read before the Royal Society, June 18, 1885 (Phil. Trans., 1885, Part II., p. 716), I described the phosphorescence spectrum given by a mixture of 61 parts yttrium and 39 parts of samarium, and illustrated it by a coloured lithograph. Also in a paper read before the Royal Society, February 25, 1886 (Roy. Soc. Proc. vol. xl. p. 236), I described and figured the phosphorescent spectrum of an earth obtained in the fractionation of yttria which was identical, chemically and spectroscopically, with an earth discovered by M. de Marignac, and provisionally called by him $Y\alpha$. I repeat here these spectra, and the spectrum of yttrium added for comparison. Omitting minor details, it is seen that the $Y\alpha$ spectrum is identical with that of the mixture yttrium 61, samarium 39, with one important exception—the citron line of $G\delta$ in the former spectrum is absent in the latter. Could I by any means remove $G\delta$ from the mixture of yttrium and samarium the residue would be $Y\alpha$. I have little doubt that this will soon be accomplished, but in the meantime the phosphoroscope enables us to remove the line of $G\delta$ from the mixture. It is only necessary to add strontium to a suitable mixture of yitrium and samarium and view the phosphorescing mixture in the instrument when the wheel is rotating rapidly, to obtain a spectrum which is indistinguishable from that of $Y\alpha$.

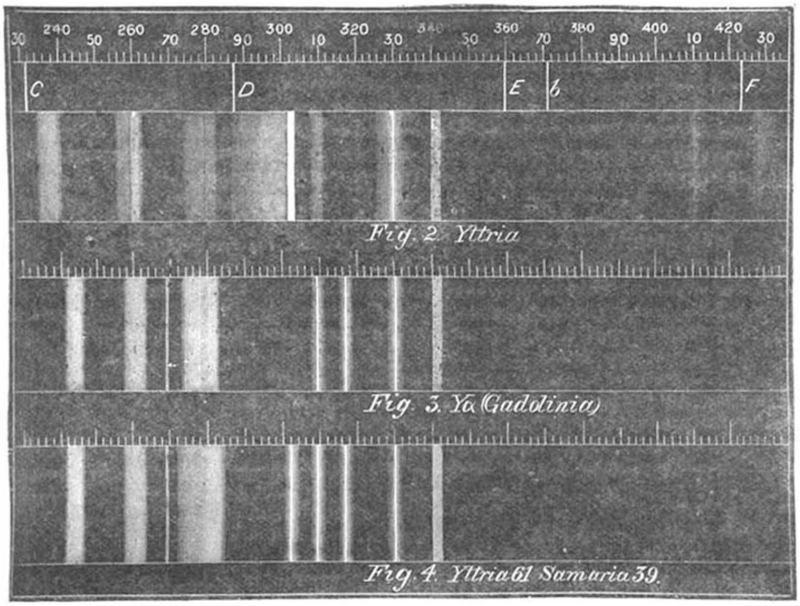

Fig. 2. Yttria

Fig. 3. Yα (Gadolinia)

Fig. 4. Yttria 61 Samaria 39.

(*To be continued.*)

PRE-SCIENTIFIC THEORIES OF THE CAUSES OF EARTHQUAKES

IN the course of a lecture delivered recently before the Rigaku Kyôkai, or Science Society of Tokio, on the causes of earthquakes, Prof. Milne classified the theories as to the cause of these phenomena into three kinds—unscientific, *quasi*-scientific, and scientific. In the former class he included the explanations of the Negro preachers at Charleston after the late earthquakes there, that they occurred in consequence of the wickedness of the population. The Mussulmans in Java recently prayed to the volcanoes there to cease their shakings, at the same time promising reformation of life. That earthquakes are the direct result of man's wickedness is an idea that has always been common. About 1750 earthquakes were felt in many parts of Europe, which were widely attributed to this cause, and innumerable sermons were preached inculcating the lesson that if mankind would live better lives there would be no more earthquakes. In 1786, after a shock at Palermo, the people are recorded to have gone about scourging themselves, and looking extremely humble and penitent. An English poem called "The Earthquake," published in 1750, alleged, in somewhat halting verse, that the disturbances were not due to an unknown force, nor to the groanings of the imprisoned vapours, nor yet to the shaking of the shores with fabled Tridents:—

> "Ah no! the tread of impious feet
> The conscious earth impatient bears
> And shuddering with the guilty weight,
> One common grave for her bad race prepares."

From this theory, which can scarcely have satisfied the poet himself, Prof. Milne passed on to the myths which attribute earthquakes to a creature living underground. In Japan it is an "earthquake-insect" covered with scales, and having eight legs, or a great fish having a certain rock on his head which helped to keep him quiet. In Mongolia the animal was said to be a frog, in India the world-bearing elephant, in the Celebes a world-supporting hog, in North America a tortoise. In Siberia there was a myth, connected with the great bones found there, that these were the remains of animals that lived underground, the trampling of which made the ground shake. In Kamchatka the legend was connected with a god, Tuil, who went out hunting with his dogs. When these latter stopped to scratch themselves, their movements produced earthquakes. In Scandinavian mythology, Loki, having killed his brother Baldwin, was bound to a rock face upwards, so that the poison of a serpent should drop on his face. Loki's wife, however, intercepted the poison in a vessel, and it was only when she had to go away to empty the dish that a few drops reached him and caused him to writhe and shake the earth. The lecturer had no means of collecting the fables of the southern hemisphere; but they would obviously be worth knowing for purposes of comparison. As to *quasi*-scientific theories, these endeavoured to account for earthquakes as parts of the ordinary operations of Nature. It was supposed, for instance, that they were produced by the action of wind confined inside the earth. The Chinese philosophers said that Yang, the male element, entered the earth and caused it to expand, and to shake the ground in its efforts to escape. Its effects would be more violent beneath the mountains than in the plains, and therefore earthquakes in the north of China, which was mountainous, were said to be more violent than those in the south. It was supposed that when the wind was blowing strongly on the surface of the earth, there was calm beneath, and *vice versâ*. Aristotle and many other classical writers attributed earthquakes to wind in the earth. Shakespeare, in "Henry IV.," speaks of the teeming earth being pinched and vexed with a kind of colic by the imprisoning of unruly wind within her womb. Then came the theory of electrical discharges, which was advocated in 1760 by Dr. Stukely, as well as by Percival and Priestley. They are strongly held in California at the present day, where it was believed that the network of rails