A Potsdam spectrograph taken on February 18 shows the typical Nova-spectrum in the stage of decline; broad bright hydrogen bands on a somewhat faint continuous background that could be traced far into the ultra-violet; groups of lines were seen at $\lambda$ 464, and a trace of the green nebula line.

THE MINOR PLANETS.—In 1866, when only eighty-eight asteroids were known, Prof. Kirkwood detected gaps in their distribution, at points corresponding with commensurability with Jupiter's motion. Prof. Hiravama (in Proc. Tokyo Math.-Phys. Soc., 2nd series, vol. ix., 11) re-examines the question with nearly 900 orbits available. The gaps at the ratios 2/1, 7/3, 5/2, 8/3, 3/1 are still very striking, and some others are probably indicated. Prof. Hirayama makes the interesting remark that for values of the daily motion smaller than 500″ the asteroids seek, instead of avoiding, the points of commensurability; thus the four Trojan planets have the ratio 1/1, one planet has 4/3, and six have 3/2. These cases are shown to correspond with librations of a stable character, while the gaps mentioned above correspond with unstable motion. It would probably have been better to omit all asteroids observed at one opposition only, as the elements of their orbits are subject to considerable uncertainty. The new planet DB (daily motion 881″) lies fairly close to the 3/1 point, so its perturbations by Jupiter will be interesting.

As the war has severed relations with the Berlin Rechen-Institut, formerly the centre for discussion and distribution of minor planet information, an independent bureau has been opened at Marseilles Observatory, whence numerous circulars relating to orbits and observations have been sent to us. One of the ephemerides is that of Deianira, which has been observed at only three oppositions since its discovery. Its position on March 22 is R.A. 12h. 19·3m., N. declination 18° 26′, magnitude 13·1.

## *THE ROTATION OF THE EARTH.*

THE *Revue générale des Sciences* of January 30 contains a full abstract of a very interesting paper by D. Korda in *Archives des Sc. Phys. et Nat.* (Geneva) of November 15 last. It appears that Baron Eötvös, in examining the records of gravitation made at sea, found certain anomalies which he traced to the speed and course of the ship. The weight of a thing on the surface of the earth is less than that due to the attraction of the earth by an amount equal to the centrifugal force, which at the equator amounts to $g/288$, and which, resolved in a vertical direction, varies as the square of the cosine of the latitude. Any variation in the centrifugal force therefore affects the weight to this reduced extent. The velocity at the surface of the earth may be 46,500 cm./sec., while that of a ship in the water may be 1000 cm./sec., so that the motion of the ship round the axis of the earth may vary between 47,500 and 45,500 cm./sec. at the equator. Centrifugal force varies as the square of the velocity, so, calling V and $v$ the velocities of the earth's surface and of the ship in the water, the centrifugal force on a body in the ship may vary between $(V-v)^2$ and $(V+v)^2$—that is, through a range of $4Vv$ depending on the course. While $v$ may be relatively small, the large factor V may, and does, at times make the product so great as to introduce an error in the apparent gravity as determined on board ship. For example, in the case supposed, which corresponds with a speed of 19·4 knots and at the equator, the difference in weight as shown by a spring balance going east with the earth and west against the earth would be as much as 1/3355, or more than two grains per pound—quite a serious amount in a gravitational survey.

But it is here that the ingenuity, daring, and experimental skill so typical of Eötvös comes in. Not content with finding serious disturbances in weight resulting from velocities of 1000 cm./sec., he conceived the idea of setting up in the laboratory a small delicate balance on a rotating vertical axis with the accurately balanced masses moving at a speed of about 1 cm./sec., with the view of observing the disturbance of the balance. At the equator with such a speed the two masses would alternately seem the heavier by 1/3,355,000 of themselves, whereas at his laboratory at Budapest, which is very nearly at latitude 45°, the difference would be one-half of this—not a very large amount to play with—but Eötvös was able to make manifest the minute change by employing synchronism and the principle of resonance, and so obtaining the large magnification which is possible with a very small degree of damping.

Unfortunately, the published account is most tantalising; for beyond saying that the period employed was about a minute, that the maximum oscillation could be read in an hour, and that the balance was small, not one of the details which would assist in repeating the experiment is given—length of beam, load at each end, decrement, and stability are alike left undefined. The mode of observation, however, is described. A horizontal mirror is carried by the beam so that a vertical ray of light may be reflected up by it. When an experiment is to be made the beam is arrested and the reflected ray of light traces a small circle upon a screen. When the beam is liberated the two ends, alternately becoming the heavier, set up an increasing oscillation made evident by the departure from the original circle, which settles down to an amount determined by the equation:

$$\text{Maximum amplitude} = 2\Omega \cos \phi \frac{K}{k},$$

where $\Omega$ is the angular speed of the earth, $\phi$ the latitude, K the moment of inertia of the balance, and $k$ its coefficient of damping. This formula quoted by the author is remarkable in that almost every feature of the apparatus and of the earth is eliminated.

The present writer, desiring to verify the formula, obtained a different result, and then, testing both formulæ dimensionally, found the formula at which he had arrived dimensionally correct, while that given above is not. He thinks, therefore, that it is desirable to state very shortly the facts as he understands them. The balance is supposed to be rotated accurately at the speed of true synchronism, taking into account the effect of centrifugal stability discussed in the next two paragraphs. In these conditions, treating the vibrations as the projection of a logarithmic spiral, and using the hodograph as given by Tait and explained more clearly in Clerk Maxwell's "Electricity and Magnetism," vol. ii. [731], the radius A of the spiral grows until the resistance proportional to the velocity is equal to the maximum deflecting moment due to the action of $4Vv$. The value of A, then, is the maximum value, and the spiral has become a circle. When this is reached the actual resistance couple will be found to be $\frac{8\pi A k K}{T^2}$, and this must be equal to the couple $\frac{8\pi K \Omega}{T} \cos^2 \phi$, due to the $4Vv$ action described. From this it follows that

$$A = \Omega \cos^2 \phi \frac{T}{k},$$

where T is the time of a complete rotation of the balance and $k$ is the logarithmic decrement. This A is the angular deviation from the mean position, so if by A is meant the complete amplitude, the expression must be multiplied by 2. It will be noticed that the difference is of serious importance. The cosine should be squared and the moment of inertia of the balance should be replaced by the time of its swing! A little thought will show that K must come in equally on both sides of the equation and so be eliminated. It is somewhat surprising to find T in the numerator, for this would seem to indicate that if the balance did not turn at all there would be—as measured by its tangent—an infinite deflection—*i.e.* 90°. Of course, the real meaning is that while the deflecting couple becomes less as T is greater, the sensibility becomes greater in the proportion of the square of the time, and the deflection goes on getting greater with increasing slowness of rotation until the whole thing becomes unmanageable on account of its too great delicacy, or until the decrement, by its consequent increase, more than compensates for the diminished stability. It is not clear what numerical results, if any, were obtained by Eötvös. By the formula now given, taking T as 60, K as 300 or thereabouts, and $\phi$ as 45°, the amplitude should only come out about one-seventh of the amount that the published formula would require.

It may be worth while to point out that the centrifugal force of the balance about its vertical axis, if the beam is 20 cm. long and turns once a minute, is about 720 times as great as the alteration of weight at the equator, so that if the beam were exactly in neutral equilibrium when stationary and pointing east and west it would have, in virtue of its rotation, a stability given to it under which the change in weight could not produce a steady deflection exceeding about 1/12°. No information is given as to how $k$ was determined, nor is centrifugal stability mentioned. As in any system the logarithmic decrement becomes less as the stability is greater, it would be useless to determine $k$ with any but the correct stability. The only method apparent to the present writer would be the addition of a stability bob equal in effect to the calculated centrifugal stability and a determination with the rotation stopped.

No mention is made of the most interesting feature in the scheme of the experiment. If the balance is in perfectly neutral equilibrium when not rotating, then the centrifugal stability is the only stability, and perfect synchronism is obtained whatever be the speed of rotation, whereas if there had been any initial stability or instability it could never be attained at any speed.

If the direction of rotation is such as to make the north end heavier than the south end, then with very small damping this end should be in nearly its highest, not in its lowest, position, as might at first be expected, at each turn.

This experiment, which, like those with the gyrostatic compass, and unlike Foucault's pendulum experiment, is best done in the tropics, is one of such interest and beauty that it is to be hoped, even in these difficult times, it may be set up and exhibited in some physical laboratory.

It is unfortunate that the author has not done justice to Eötvös, but he has prepared somewhat of a tangle which it has been a pleasure to unravel.

C. V. BOYS.

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## RESULTS OF VOLCANO STUDY IN HAWAII.

THE Hawaiian Observatory was founded in 1912 by the Massachusetts Institute of Technology, and financed in large measure by business men in Hawaii. Its publications have been systematic volcanologic and seismometric bulletins, and two larger reports, as well as numerous special articles. The scientific work has been done by Mr. T. A. Jaggar, director of the station, and Mr. H. O. Wood, associate. Preliminary announcement of results[1] at the end of the first five years of work reveals discoveries which may be of interest to science at large, and some of these discoveries are briefly reviewed here.

### *Nature of Hawaiian Gases and Flames.*

The gas collected from a blowing-cone in the lava pit of Kilauea in 1912 by Day and Shepherd[2] contained dominantly sulphur dioxide, carbon dioxide, and nitrogen, subordinate amounts of the combustible gases, sulphur, carbon monoxide, and hydrogen, and only 4 per cent. of water vapour. The 79 per cent. of $SO_2$, $CO_2$, and $H_2O$ could not, to the writer's thinking, be juvenile, but must in part result from union with atmospheric oxygen. Day had suggested that heat-producing reactions between such gases as free S, $CO_2$, and H, rising through the lava, would raise the surface temperatures so that the lava column might be at its hottest above instead of in the depths. Continuous recording and observation of flames, with experimental measurements of temperature and soundings of the lava for viscosity differences, show that this generalisation is well founded, and, in addition, that atmospheric oxygen is brought in contact with the magmatic gas so as to produce abundant flames of different colours. Air is sucked down at the convectional whirlpools and cascades. It is carried downward in the liquid lava lakes by foundering of porous crusts which cannot melt in the superfused lava glass. Air is also carried down in broken wall rock, in avalanches, and by burial of old talus. Lastly, with 33 per cent. volume shrinkage due to such gas reaction within the lava column as $2H_2+O_2=2H_2O$, even at high temperatures (1100° C. more or less), and with convectional gas pumping, a Bessemer furnace effect through the liquid lava may be created by indraught of air from the walls.

Of the three combustible gases H, CO, and S, sulphur is most in evidence as surface flames, carbon monoxide along with impurities may be represented by rare flames, while hydrogen probably flashes mostly to water-vapour in depth. There are whitish flames occasionally seen, and intensely hot bluish to violet flames play at all times from the glowing grottoes and chimneys. Some work has been done in an effort to photograph the flames with colour filters and panchromatic plates, and there is a promising field here for the study of flame spectra.

### *Nature of a Lava Column.*

While it was known many years ago that some of the Hawaiian lava pools were shallow, few observers have imagined that the liquid lava, rising 600 ft. during a year within a pit much deeper than that would be found by sounding at the end of the period to be only 45 ft. deep, though still fully liquid at the surface. This was the case at Halemaumau, the inner lava pit of Kilauea, in January, 1917 (Fig. 1). Sounding was accomplished by plunging a steel pipe into the lava lake at several different locations, and

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[1] "The Outbreak of Mauna Loa, Hawaii, 1914," by T. A. Jaggar, *Amer. Journ. Sci.*, vol. xxxix., February, 1915, pp. 167–72. "Activity of Mauna Loa, December, 1914–January, 1915," by T. A. Jaggar, *Amer Journ. Sci.*, vol. xl., December, 1915, pp. 621–39. "Lava Flow from Mauna Loa, 1916," by T. A. Jaggar, *Amer. Journ. Sci.*, vol. xliii., April, 1917, pp. 255–88. "Seismic Prelude to the 1914 Eruption of Mauna Loa," by H. O. Wood, Bull. Seis. Soc. America, vol. v., No. 1, March, 1915, pp. 39–50. "Notes on the 1916 Eruption of Mauna Loa," by H. O. Wood *Journ. of Geol.*, vol. xxv., Nos. 4 and 5, 1917, pp 322–36 and 467–88. "Volcanologic Investigations at Kilauea," by T. A. Jaggar. *Amer. Journ Sci.*, vol. xliv., September, 1917, pp. 161–220. "Live *Aa* Lava at Kilauea," by T. A. Jaggar. Journ. Wash. Acad. Sci., vol vii., No. 9, May 4. 1917, pp. 241–43. "On the Terms Aphrolith and Dermolith," by T. A. Jaggar, Journ. Wash. Acad. Sci., vol. vii., No 10, May 19, 1917, pp. 277–81. "Thermal Gradient of Kilauea Lava Lake," by T. A. Jaggar, Journ. Wash. Acad. Sci., vol. vii., No. 13, July 19, 1917, pp. 397–405. "On Cyclical Variations in Eruption at Kilauea," by H. O. Wood, Second Report Hawaiian Vol. Obs. (Cambridge, Mass., 1917).

[2] "Water and Volcanic Activity," by A. L. Day and E. S. Shepherd, Bull. Geol. Soc. Amer., vol. xxiv., 1913, pp. 573–606.