OUR ASTRONOMICAL COLUMN.

COMET 1907*b*.—From a note published in No. 4175 (p. 366, May 10) of the *Astronomische Nachrichten* we learn that the comet discovered by Mr. Mellish on April 14 had been previously seen by Mr. Grigg, of Thames, New Zealand, on April 9. A set of elements computed by Mr. Merfield from observations made on April 9, 10, and 11 is given.

In the same journal Dr. Ebell continues his ephemeris for this object up to June 19, showing that the comet is now approximately half-way between ι and θ Ursæ Majoris. R.A. = 9h. 2·6m., $\delta = +51^\circ\ 18'$.

THE VALUE OF THE SOLAR PARALLAX.—The discussion of the Greenwich photographs of Eros, the results of which were communicated to the Royal Astronomical Society (*Monthly Notices*, vol. lxvii, No. 6, p. 380) at its April meeting, gave $8''\!\cdot\!800 \pm 0''\!\cdot\!0044$ as the value of the solar parallax. This result was obtained from the measurement of 151 plates taken with the Astrographic 13-inch refractor and 103 plates taken with the Thompson 26-inch refractor, between October 14, 1900, and January 15, 1901, and agrees very closely with the value, $8''\!\cdot\!802 \pm 0''\!\cdot\!005$, published by Sir David Gill in 1897.

EARLY AND LATE PERSEIDS.—In a paper recently communicated to the Royal Astronomical Society Mr. Denning gives a list of the apparent paths of probable and possible Perseids observed by him during the periods July 7 to 22 and August 17 to 25 inclusive, from 1876 to the present time. The observations suggest that true Perseids may be looked for after the first week in July, but not until July 19 does the stream become conspicuous enough to enable a good radiant to be determined. Mr. Denning asks other observers to supply data from which the radiant during the earlier period might be determined with more certainty; at present there is reasonable doubt that the shower commences so early as July 7. Similarly the extension of the date of apparition to August 25 is in question, although Mr. Denning is sure that true Perseids have been observed as late as August 20.

A list of the radiants determined is also given, and the author states that quite possibly the shower extends over a period of fifty nights (*Monthly Notices*, vol. lxvii., April, p. 416).

NEW ELEMENTS OF JUPITER'S SEVENTH SATELLITE.—From twelve observations distributed evenly along the observed arc passed over by Jupiter's seventh satellite during the period January 3, 1905, to September 25, 1906, Dr. F. E. Ross has computed a new set of elements for that satellite. The principal perturbations have been included, and the observations are represented by the elements with an average error of only $0'\!\cdot\!4$. The inclination of the satellite's orbit, referred to the earth's equator for the epoch January 0·0, 1905 (G.M.T.), is given as $25^\circ\ 18'\!\cdot\!6$, whilst referred to Jupiter's orbit the inclination is $27^\circ\ 58'\!\cdot\!3$. The period, according to these elements, is 260·06 days.

Observations secured by Prof. Max Wolf on December 22 and 23, 1906, and by Prof. Perrine on November 23, are not consistent with these elements, the respective residuals in R.A. being $+10'\!\cdot\!0$ and $-3'\!\cdot\!3$ (*Astronomische Nachrichten*, No. 4175, p. 359).

THE COMPUTATION OF COMETARY ORBITS.—In Circular 128 of the Harvard College Observatory, Prof. E. C. Pickering points out what needless duplication occurs in the computation of cometary orbits. For comet 1907*a* three almost identical sets of elements were communicated to the Harvard College Observatory, whilst others, giving similar values, were published elsewhere. To obviate this waste of energy Prof. Pickering suggests that these computations should be carried out on some cooperative system, each computer taking them in turn, and further suggests that the labour thus saved might with advantage be expended on the computation of orbits of minor planets, of which objects so many are now being discovered regularly.

ASTROGRAPHIC CATALOGUE WORK AT THE PERTH OBSERVATORY (W.A.).—Although most of the Government Astronomer's report of the work performed at the Perth (W. Australia) Observatory during the year 1905 is devoted to meteorological observation, Mr. Cooke has a few words to say about the regrettable delay in the prosecution of the Astrographic Catalogue work undertaken by the West Australian Government.

The zone apportioned to the observatory was from 32° to 40° south declination, and includes 1375 regions; of these 145 remained to be taken at the date of the report. But the operations of measuring and reducing the plates were not then commenced, and there is a grave possibility that the plates may deteriorate sufficiently to render them useless. The taking of long-exposure plates for photo-mechanical reproduction was commenced, but was afterwards stopped on account of the expense. Some 10,000 standard stars have to be observed by means of the transit circle, and Mr. Cooke suggests that "this will form the basic work of the Perth Observatory, probably for centuries."

THE TOTAL SOLAR ECLIPSE OF AUGUST 30, 1905.—During the total eclipse of August 30, 1905, Prof. Schwarzschild, of the Göttingen Observatory, together with Prof. Runge, made observations with a prismatic camera and a coronagraph at Guelma, in Algeria. Part xxx. of the *Astronomische Mitteilungen der königl. Sternwarte zu Göttingen* contains a complete discussion of the results obtained. The brightness and spectral photometry of the corona are first dealt with at some length, and then the spectra obtained are discussed, the origin, wave-length, intensity, and extension of each arc being given; the region photographed was from λ 4590 to λ 3330, and the identifications include the elements Yt, Zr, La, Ce, Nd, and Yb.

THE ERUPTION OF KRAKATOA AND THE PULSATION OF THE EARTH.

THE vibration of the earth may be caused by volcanic eruptions and earthquakes, but it is doubtful if any regular pulsation can be called forth by a sudden impulse such as an earthquake or paroxysmal outbursts of volcanoes. If any rhythmic pulsation ever comes into existence, it is most probably due to some exciting cause of long duration, such as volcanoes of continuous activity giving rise to occasional explosions, thus causing frequent blows to the earth. The eruptions of Krakatoa afford an example of such a method of excitation, and we have reason to believe that there were pulsations with a period of about 67m.

The exact time of several minor explosions before the great outburst at 10 a.m., August 27, 1883, is not well known, but if we assume that the air was simultaneously affected, the record of the gasometer at Batavia gives us valuable information as to the sequence of the numerous explosions beginning on August 26. The regular succession of remarkable excursions in the indications of the gasometer, reproduced in the Royal Society report on Krakatoa eruption, is at once evident from the following table:—

	h. m.	Time interval h. m.	h. m.	m.
August 26 ...	5 20 p.m.	6 49 =	3 24·5 × 2 =	68·2 × 6
,, 27 ...	0 9 a.m.			
	1 55 ,,			
	2 38 ,,	3 20 =	66·7 × 3	
	3 30 ,,			
	4 41 ,,			
	4 55 ,,			
	*5 43 ,,	3 27 =	69·0 × 3	
	*6 57 ,,			
	8 25 ,,			
	9 42 ,,	3 22 =	67·3 × 3	
	**10 15 ,,			
	*11 15 ,,	1 00 =	60	

The great explosions are marked with asterisks, while the sign is doubled for the principal outburst.

The whole interval = 67·2m. × 16. The mean interval of successive explosions on August 27, if those at 1h. 55m. and 2h. 38m. and at 4h. 41m. and 4h. 55m. are counted as a single phenomenon, is also 67m. The recurrence of several explosions at multiple intervals of 67m. shows that they were not always irregular, but had a rhythmic character. Another remarkable fact is the recurrence of explosions at intervals of about 3h. 20m. Recent investigations in surface seismic waves show that the principal phase of world-shaking earthquakes travels once round the earth in about 3h. 19m., which almost coincides with the recurrence intervals in the several explosions of Krakatoa. Thus the outburst of the volcano after the explosion of 5h. 20m. p.m. happened after the surface wave had made two complete revolutions round the earth. In the absence of the seismograph records at that time, we are quite ignorant of the existence of seismic waves during those explosions, but the magnetograph records at Batavia show distinct evidence of the vibrations of the ground. The repetition of explosions at regular intervals of time, which has such significance in the propagation of seismic waves, does not seem to be a mere chance coincidence. The surface seismic wave requires nearly the same time in traversing the different major arcs of the earth, so that they will meet at the antipodal point almost simultaneously, and in returning will again coalesce at the centre of excitation, in the same manner as the Krakatoa air waves. The disturbance at the origin must therefore re-accumulate at the interval of about 3h. 20m., and tend to call forth a new explosion, if the preceding explosion has already excited the seismic waves. This will probably account for the repeated occurrence at such stated intervals. Without laying too much stress on the effect of the seismic waves, which may have been associated with the spasmodic activity of the volcano, we have another reason to believe that the ground vibrated with the period of about 67m.

In spite of the numerous theories which may be advanced as to the cause of the Krakatoa sea waves, a simple hypothesis of the existence of vibrations with a period of about 67m. both before and after the explosion removes most of the difficulties that will be felt in accounting for the definite periods observed in tide-gauges scattered in different parts of the world. The activity of Krakatoa continuing from May to August 27, 1883, the exciting causes would naturally have been numerous during that interval of time to start sympathetic vibration of the earth. Whether the movement of the ground was confined to the region in the immediate neighbourhood of the volcano or extended round the whole earth could not be easily answered, and whether the period coincided accidentally with the natural mode of vibration of the earth or not is a matter of doubt, but the various data hitherto accumulated as to the rigidity of the earth from various phenomena connected with it tend to show that such supposition is efficacious as a working hypothesis.

The examination of mareograms in different parts of the world shows that the times of arrival of the Krakatoa waves are by no means definite, and the diagrams are sometimes markedly different from each other. In some the waves are blended together with the proper oscillations of the bay in which the instrument was placed, while in others they appear as regular secondary oscillations. In all cases they present long-continued disturbances; the more conspicuous waves are, with the exception of that at Batavia, preceded by minor oscillations, which sometimes merge insensibly into the higher waves, so that it is difficult to decide where the disturbance begins. According to the recent investigations by Messrs. Honda, Terada, and Yoshida, the secondary oscillations in numerous bays on the Pacific coast of Japan can be looked upon as forced oscillations by the waves of the same periods, which already exist in the surrounding ocean. During the Krakatoa eruptions the waves made their way into the surrounding seas and ocean, and the regular succession of waves in bays is to be attributed to the effect of forced vibrations.

The periods of Krakatoa waves recorded on mareograms are:—in Batavia, 122m.; Port Blair, 63m.; Negapatam, 68m.; Madras, 81·2m.; Dublat, 65m.; Beypore, 58m.; Karachi, 69m.; Aden, 67m.; Port Alfred, 64m.; Port Elizabeth, 70m.; Table Bay, 62m.; Port Moltke, 61m.; Colon, 70m. The average period of this wave series, with the exception of Batavia and Madras, is about 66m., which almost coincides with the mean period of explosions from 0h. 9m. to 11h. 15m. on gasometer records. This remarkable coincidence can be corroborated with simple physical experiments in the following manner.

When a pendulum with a magnet attached to it is set in vibration by intermittent current acting underneath, the period is double that of the exciting current, or when the pendulum support vibrates in a vertical path, the frequency is half that of the vertical motion. The well-known experiment of Melde, by which a string is set in sympathetic vibration by a tuning-fork of double frequency, and the crispation produced by the vertical vibration of the support, as observed by Faraday, are examples of forced vibrations with period double that of the exciting force. In the application to the Krakatoa eruption, we notice that the motion of the sea-bed near the place of eruption was nearly vertical; consequently, if the sea vibrates in an analogous manner as a pendulum, the period of the excited wave would be double that of the exciting body. The tide gauge at Batavia shows a big wave of 132m. ($=2\times66$m.) after the great eruption, and the mean period of the successive fourteen waves is 122m., which is nearly double the mean period of previous explosions. It is quite remarkable that if the rigidity of the earth lies between that of steel and that of glass, the mean fundamental period of spheroidal oscillation is about 67m.

According to Lord Kelvin, the tidal effective rigidity of the earth is about the same as that of steel. I have also lately shown that the prolongation of the Eulerian period to the Chandler period of about 430 days is closely connected with the velocity of seismic waves, and tends to point to the same conclusion as regards the rigidity of the earth. According to Bromwich (Proc. London Math. Soc., xxx., 1899), the periods of fundamental spheroidal vibration of an incompressible elastic solid sphere of the size of the earth are 55m. and 78m., when the rigidity is equal to that of steel and of glass respectively. In the above calculation the effect of gravity is also taken into account, which is to reduce the period by a considerable amount; with the rigidity of steel, the period is 66m. without gravity. The period of 67m. is the mean value when the rigidity lies between that of steel and of glass.

The prevalence of waves of the said period in the tide gauges scattered over the different parts of the earth's surface is a striking coincidence, and may be explained by assuming that the source of the waves was excited by vibrations corresponding to the fundamental mode of oscillation of the elastic gravity waves propagating round the earth. That most of the mareograms show continued disturbance before the appearance of big undulations suggests the probable existence of previous vibrations. Since such vibrations are radial and tangential, the waves appearing in bays at some distance from the exciting source would have mostly the same period as the source, while those observed in the neighbourhood of the eruption, as Batavia, would be double. Some doubts may be expressed as to whether the observed period is not peculiar to these bays, so that whatever may be the period of the exciting source, such undulations should invariably appear. With the exception of Aden and Colon, the proper period of the above-mentioned bays generally differs from that of the Krakatoa wave.

The above considerations favour the view that the vibration of the ground near Krakatoa was extremely slow, and had a period of about 67m. Whether this vibration extended all over the earth, or was confined to the vicinities of the volcano, is a question still to be solved. If the said period is really due to the spheroidal vibration of our planet, we shall have opportunities of determining more exactly the period of vibration when volcanic eruptions of the same character as those of Krakatoa take place, or sometimes even with world-shaking earthquakes. It will be worth examining seismograms, if great earthquakes do not give signs of the existence of vibrations of very long period by enhanced disturbances at regular intervals corresponding to the period of vibration of the earth. Another means of detecting the presence of such vibrations would be to examine the mareograms in bays with the proper period of about 67m. Long-continued observation in such bays will probably reveal the nature of the spheroidal pulsation of the earth, if such really exists.

H. NAGAOKA.