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Planets and their satellite systems.

By P. Lowell.

If we compute the speeds of satellites about their primaries in the solar system and compare them with the velocities in their orbits of the planets themselves a striking parallelism stands displayed between the several systems. This is shown in the following table of them:

	Mean speed miles a second:		Parabolic speed at orbit	Ratio speed sat. about primary to planet's speed in orbit
	of primary in orbit V	of satellite about primary v		
Jupiter	8.1		11.5	
Sat. 1		10.7		1.32
2		8.5		1.05
3		6.7		0.83
4		5.1		0.63
Saturn	6.0		8.5	
Sat. 1		9.0		1.50
2		7.9		1.31
3		8.2		1.36
4		6.3		1.05
5		5.3		0.89
6		3.5		0.59
8		2.0		0.34
Uranus	4.2		5.9	
Sat. 1		3.5		0.82
2		2.9		0.70
3		2.3		0.54
4		2.0		0.47
Neptune	3.4		4.8	
Sat. 1		2.7		0.81

The relations here disclosed are too systematic to be the result of chance.

The orbits of all these satellites have no perceptible eccentricity independent of perturbation except Iapetus of which the eccentricity is about 0.03.

In view of the various cosmogonies which have been advanced for the genesis of the solar system it is interesting to note what these speeds imply as to the effect upon the

satellites of the impact of particles circulating in the interplanetary spaces at the time the system evolved. To simplify the question we shall suppose — which is sufficiently near the truth — that the planets move in circles, the interplanetary particles in orbits of any eccentricity.

Taking the sun's mass as unity, the distance R of any given planet from the sun also as unity, let the planet's mass be represented by M and the radius of its satellite's orbit, supposed circular, as r . We have for the space velocity of the satellite on the sunward side of the planet calling that of the planet in its orbit V and v that of the satellite in its orbit round the planet:

$$V - v = \sqrt{\frac{1}{R}} - \sqrt{\frac{M}{r}}.$$

For a particle, the semi-major axis of whose orbit is a_1 and which shall encounter the satellite, the velocity is

$$v_1 = \left(\frac{2}{R-r} - \frac{1}{a_1} \right)^{1/2}.$$

That no effect shall be produced by the impact of these two bodies their velocities must be equal, or

$$\sqrt{\frac{1}{R}} - \sqrt{\frac{M}{r}} = \sqrt{\frac{2}{R-r} - \frac{1}{a_1}}.$$

As $R - r = a_1(1 + e)$ for the point of impact if the particle be wholly within the orbit of the planet and e the eccentricity of its orbit, we find

$$e = 2 \sqrt{\frac{MR}{r}} - \frac{MR}{r} \text{ approx.}$$

for the case of no action, the other terms being insensible for the satellites in the table, since in all $r < \frac{R}{400}$.

Supposing, now, the particles within the orbit of the planet to be distributed inversely as the distance, then as the velocity of any one of them, taking $R - r = R$ approx. as unity, is

$$v_1 = \left(\frac{2}{1} - \frac{1}{a_1} \right)^{1/2}$$

the mean velocity of all of those which may encounter the satellite is

$$\frac{\int_{1/2}^1 \frac{(2a_1 - 1)^{1/2}}{a_1^{1/2}} da_1}{\int_{1/2}^1 da_1} = 2 \left[(2a_1^2 - a_1)^{1/2} - \frac{1}{\sqrt{2}} \log((2a_1 - 1)^{1/2} + \sqrt{2a_1}) \right] = 0.754$$

that is just over three-quarters of the planet's speed in its orbit.

If we suppose the particles to be equally distributed in space we shall have more with a given major axis in proportion to that axis and our integral will become

$$\frac{\int_{1/2}^1 (2a_1 - 1)^{1/2} a_1^{1/2} da_1}{\int_{1/2}^1 a_1 da_1} = \frac{8}{3} \left[\frac{4a_1 - 1}{8} (2a_1^2 - a_1)^{1/2} - \frac{1}{16\sqrt{2}} \log \left((2a_1^2 - a_1)^{1/2} + \sqrt{2a_1} - \frac{1}{2\sqrt{2}} \right) \right] = 0.792 \text{ of the planet's orbital speed.}$$

The speed, v_1 , then, at which a satellite must be moving round the planet to have the same velocity as the average particle within the planet's orbit is

$$V - v_1 = v.$$

This velocity is for the several planets:

	Distribution of particles inversely as their major axes	Distribution of particles equal in space
	Miles a second	Miles a second
Jupiter	2.0	1.6
Saturn	1.48	1.2
Uranus	1.03	0.9
Neptune	0.84	0.7

If the satellite be moving in its orbit less fast than this, its space-speed will exceed that of the average particle; it will strike the particle at its own rear and be accelerated by the collision. If faster the particle will strike it in front and retard it in its motion round its primary.

From the table it appears that all the large satellites of all the planets have an orbital speed round their primaries exceeding those in either column. In consequence all of them must have been retarded during their formation by the impact of interplanetary particles and forced nearer their primaries than would otherwise have been the case; and this whether the particles were distributed more densely toward the Sun as $\frac{1}{a}$ or were equally strewn throughout.

For interplanetary particles whose orbits lie without the particular planet's path the mean speed is the parabolic at the planet's distance, given in the third column of the table. This is the case in either supposition of distribution. The orbital speed of the satellite which shall not be affected by collisions with them is for the several planets:

	Miles a second
Jupiter	3.4
Saturn	2.5
Uranus	1.7
Neptune	1.4

All the satellites but Iapetus have orbital speeds exceeding this and consequently are retarded also by these particles.

For particles crossing the orbit (2) the mean velocity would be practically parabolic 1.4 even if the distribution were as $\frac{1}{r'}$, r' being the distance from the Sun. The effect would depend upon the angle of approach and in the mean give a greater velocity for the particle than for the satellite within the orbit, a less one without; retarding the satellite in both cases. Thus the total effect of all the particles encountering the large satellites is to retard them and to tend to make them hug their primary.

For retrograde satellites the velocities of impact with inside and outside particles moving direct are respectively

	Inside	Outside
Jupiter	2.0 + V	V + 3.4
Saturn	1.48 + V	V + 2.5
Uranus	1.03 + V	V + 1.7
Neptune	0.84 + V	V + 1.4

In both cases the impact tends to check the satellite.

Comparing with these the velocities of impact for direct satellites in a direct plenum:

	Inside	Outside
Jupiter	2.0 - V	3.4 - V
Saturn	1.48 - V	2.5 - V
Uranus	1.03 - V	1.7 - V
Neptune	0.84 - V	1.4 - V

the signs being taken positive when the motion is direct, we see that retrograde satellites would be more arrested than direct ones with the same orbital speed round the primary.

In a plenum of direct moving particles, then, the force tending to stop the satellite and bring it down upon the planet is greater for retrograde satellites than for direct ones which may account for the preservation of the direct.

Incidentally we may notice that this disproves the so-called Planetesimal Hypothesis, the reasoning upon which that is based to wit: that the impact of such particles would accelerate a direct-moving satellite and so prevent its being drawn down on the planet and enable it to survive being exactly contrary to the fact with any of the major satellites.

Percival Lowell.

Nouveaux éléments de l'étoile variable RY Aurigae.

Par M. M. Luizet.

Du 23 avril 1907 au 19 mai 1909, j'ai fait à l'équatorial coudé de l'observatoire de Lyon (ouverture 0.32 m), 124 observations de cette étoile variable du type Algol,

parmi lesquelles 73 se rapportent à l'éclat maximum constant, et 51 à la période de changement d'éclat. J'ai tiré de ces observations les époques de 8 minima inscrites dans