# The resonating solar system

## Relations between planets and asteroids ring a number of changes on the music of the spheres

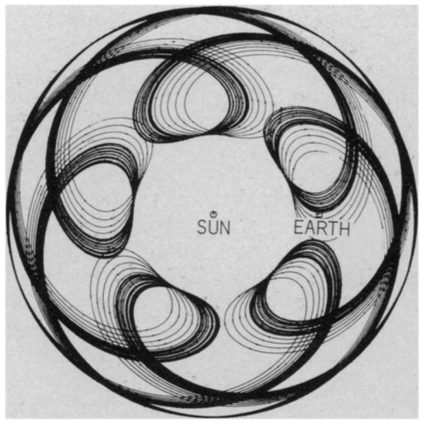
by Dietrick E. Thomsen

For centuries celestial mechanicians have had to deal with the effects of the planets on each other's motion. Small though these perturbations usually are, they have greatly increased the complexities of calculating planetary orbits. As a result of recent calculations it begins to appear that there is a class of perturbations that are not minor, but controlling: resonances between large planets and asteroids that appear to dominate the orbital motion of the asteroids.

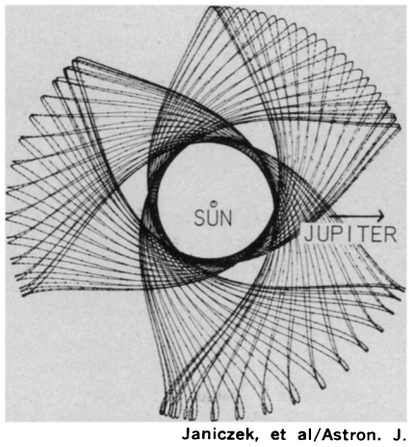
Mathematically a resonance is an even or integral relationship between two motions: The asteroid Toro completes five orbits around the sun in almost exactly the time it takes the earth to complete eight. The moon rotates once on its axis in the time it takes to make one orbit around the earth. When resonances occur in a physical system, they are the result of forces that tend to build them up. The synchronization of orbital and axial motion of the moon, for instance, is attributed to tidal forces that gradually slowed down a more swiftly rotating moon until the resonant condition was reached. In the case of interplanetary resonances, the gravitational force between the two bodies has apparently brought the smaller one's motion into resonance with the motion of the larger.

The first resonance between an asteroid and a planet was reported last year by W. H. Ip and L. Danielsson, who found that the motion of Toro is controlled by a complicated resonance with the motions of the earth and Venus (SN: 9/16/72, p. 186). P. M. Janiczek, P. K. Seidelmann and R. L. Duncombe of the U.S. Naval Observatory now describe a search that tested as many as 1,751 minor planets for resonances with major planets. They considered asteroids, which, at their closest approach to the sun, came within 10 million miles of one of the inner planets.

Many asteroids satisfied the condition for Mars, but only nine satisfied it for Venus and the earth: Eros, Alinda, Ganymed, Amor, Icarus, Betulia, Geographos Ivar and Toro. Of these Toro, Alinda and Amor were considered most interesting by the Naval Observatory astronomers.

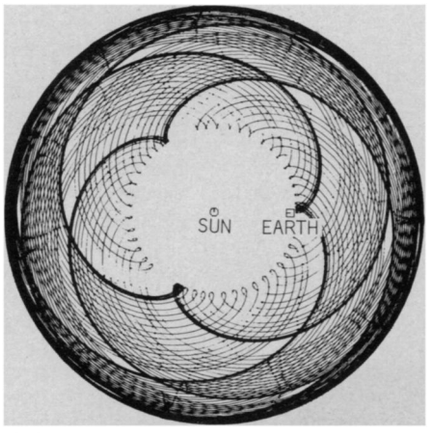



*Orbit of Toro from 1800 to 2000 in a coordinate system rotating with earth.*




Janiczek, et al/Astron. J.

*Orbit of Alinda from 1600 to 1958 in a coordinate system rotating with Jupiter.*




*Orbit of Amor from 1800 to 1950 in a coordinate system rotating with earth.*

The results can be presented graphically by drawing the asteroid's orbit in a coordinate frame rotating with the earth. In this way the motions of the asteroids are plotted as they would look if the sun were the center of the drawing and the controlling planet were drawn at its proper distance but stood still in orbit rather than revolving. On the drawings one can see how the asteroid passes once close to the planet, then loops around for a more distant approach, then close again and so on.

In the case of Toro, the Naval Observatory group found resonance with earth and with Venus (four Toro orbits to seven of Venus) as Ip and Danielsson did and also with Mars (17 orbits to 20). They integrated Toro's orbit forward and backward to give a 600-year period from 1600 to 2200. They tested for resonance with Jupiter but found none. They are not sure that the earth-Venus resonance is stable. Irregularities make it difficult to tell. The fact that Venus, earth and Toro all have resonances with each other argues for stability, but a close approach to either planet might alter Toro's mean motion enough to disturb the pattern.

Alinda seems to be dominated mainly by Jupiter, making three orbits to Jupiter's one. The earth makes a significant contribution over short periods when close approaches occur, but does not affect Alinda's mean motion. Alinda seems to be in a stable situation, according to Janiczek, Seidelmann and Duncombe.

Amor resonates with the earth (three orbits to eight of the earth's) in such a way that, as seen from the earth, its orbit rotates until it has a close approach to the earth. It remains in this condition for several orbits, then rotates 120 degrees and finally comes back to close-approach configuration. Jupiter has a regular effect on Amor, but only on a short term; the planet causing general change in the planet's mean motion is the earth. Since the mean motion is gradually changing there are doubts about the long-term stability of Amor. □