The patterns of distribution of Polynesians in the eastern and western Pacific contrast dramatically[5]. On archipelagos lacking other peoples (from Tonga eastwards, including New Zealand), the Polynesians occupied all islands. On tropical western Pacific archipelagos from the New Hebrides to the Carolines, which are shared with Melanesians and Micronesians, the Polynesians occupied only small or outlying islands. In the Solomons, for instance, Polynesians were confined to Rennell and six other outliers, while Melanesians were on all other islands. How could Polynesians have swept thousands of miles across the Pacific from eastern Polynesia to New Zealand and Rennell, without completing the last jumps of 1,000 and 100 miles respectively to Australia and the central Solomons?

The answer proves to be that Polynesians were excluded by established human populations on Australia and western islands other than small outliers: the Rennellese who reached the central Solomons are known to have been killed and eaten. For Australia, a similar exclusion is inferred from Polynesian-style stone axes found along the east coast. The distribution of Polynesians on Pacific islands is paralleled in detail by distribution of numerous bird, bat, lizard, snail and plant species (termed supertramps), which are similarly confined to outlying islands in western archipelagos by established related species[18]. Other cases of human supertramps excluded from mainlands are the Norse from Newfoundland by Amerindians[19] and West Indian Arawaks from Florida by other Amerindians. □

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Astronomy

Chaotic spinning of Hyperion?

From Carl D. Murray

FOR many people the Solar System is a paradigm of ordered regular motion. Indeed, the origins of mechanics can be traced to the early attempts to explain the observed regularity in the motions of planets and satellites. However, according to recently published work by Jack Wisdom and Stanton Peale of the University of California, Santa Barbara, and François Mignard of CERGA, Grasse, the Solar System probably contains one permanent member, Saturn's satellite Hyperion, whose rotational behaviour is far from regular (*Icarus* **58**, 137; 1984).

A general feature of chaotic motion is that relatively simple equations can give rise to solutions with complicated unpredictable behaviour, the degree of chaos depending on a number of factors. The common analogy of a deterministic yet chaotic system is a pinball machine, where small changes in starting conditions can produce radically different results. Hyperion's orbital motion and its interaction with the satellite Titan are quite well understood, and apparently regular. What Wisdom, Peale and Mignard have investigated is the effect of Hyperion's unusual shape on its spin behaviour.

Most of the natural satellites in the Solar System exhibit what is known as synchronous spin-orbit resonance, that is, the satellite's spin period is approximately equal to its orbital period. The most familiar example of this configuation is the Earth–Moon system, resulting in the Moon always presenting the same face to the Earth. Such configurations are not due to chance but have arisen because of the effects of tides raised on the planet by the satellite, the time scale for the process depending on the mass of the satellite and its distance from the planet. For Hyperion, which is small, this time scale was known to be a significant fraction of the age of the Solar System, even before the Voyager missions, but observations had not produced a definitive spin period. In 1980 and 1981 Voyager images of Hyperion revealed a satellite with a highly irregular shape which has been variously described as resembling a cigar or hamburger (see the figure). Wisdom *et al.* show that it is this unusual shape which will probably prevent Hyperion from ever achieving a stable spin-orbit configuration.

Three images of the saturnian satellite Hyperion from Voyager 2 spacecraft. (JPL and NASA.)

A spin-orbit resonance can occur when the ratio of the spin period to the orbital period is some simple fraction. Near-spherical objects can be trapped in a number of different spin-orbit resonances other than the synchronous one — the planet Mercury is actually in a 3/2 spin-orbit resonance. Each resonance occupies a well-defined region in the phase space and has a narrow chaotic region at its boundary. Only in this narrow region does the behaviour of the spin become unpredictable. If the satellite shape is irregular, with large differences in the principal moments of inertia, then nearby resonances start to overlap and the extent of the chaotic region dramatically increases. A criterion for the onset of chaos as a result of overlapping resonances was first developed by Chirikov (*Phys. Rep.* **52**, 263; 1979) in connection with work on plasma confinement. With parameters appropriate for Hyperion, Wisdom *et al.* show that the chaotic region around the synchronous state is so large that the 3/2 state vanishes and the 1/2 and 2 states are reduced to small islands of apparent stability in a sea of chaos. If Hyperion finds itself in this large chaotic region, its spin period will undergo essentially random variations over a few orbital periods. Nevertheless, Hyperion could still survive in the synchronous state provided that its spin axis remained perpendicular to the orbital plane. But Wisdom *et al.* have also carried out an attitude stability analysis and shown that the synchronous and 1/2 states are unstable to small displacements, resulting in a chaotic tumbling motion. Hyperion's only hope for a chaos-free existence is to enter the attitude stable 2 state. The probability of such an event is very low, however, so Wisdom *et al.* conclude that Hyperion will be found to tumble chaotically.

This naturally leads to the question of what evidence is available in the Voyager images to support a claim for the chaotic tumbling of Hyperion. Thomas *et al.* estimate a rotational period of 13 days (*Nature* **307**, 716; 1984), which, since the orbital period is 21 days, tends to confirm that Hyperion has yet to reach synchronous rotation. They also claim, however, that Voyager 2 images show a spin which is coherent over 61 days and that the derived spin period is consistent between the Voyager 1 and Voyager 2 photographs, even though the sequences were made 220 days apart. If Hyperion has maintained the same spin period for this length of time then the balance swings in favour of ordered rather than chaotic motion. Wisdom *et al.* argue, however, that if the spin is chaotic, with variations over a few orbital periods, then the standard technique of fitting observations made at different times to a constant period is not applicable. The conflicting evidence can only be resolved by an accurate determination of Hyperion's light curve.

Wisdom *et al.* give a convincing demonstration of how some of the techniques of modern dynamics can be applied to the Solar System. It remains to be seen whether or not the 'majestic clockwork' of Kepler and Newton has an unpredictable component. □

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