PLANETOCENTRIC VERSUS HELIOCENTRIC IMPACTS IN THE JOVIAN AND SATURNIAN SATELLITE SYSTEM; G.P. Horedt and G. Neukum, Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt (DFVLR), 8031 Wessling, West Germany.

Our contribution is concerned with the following question: Were the observed craters on the satellites of Jupiter and Saturn produced by bodies orbiting initially in heliocentric orbits round the Sun or were the bodies in planetocentric, elliptic orbits round the parent-planet? These questions have qualitatively been addressed recently by us (1) and by Strom and Woronow (2); quantitative arguments will be given here. At present, the sole observed reservoir of cratering projectiles is clearly in heliocentric orbits, namely Jupiter-crossing asteroids, short and long period comets (cf. 3). Therefore it is tempting to assume an increasing density of these heliocentric projectiles in the past, and to calculate in analogy with the Moon a cratering chronology also for the Jovian and Saturnian satellites (3). Unfortunately there are indications from two observational sides that seem to contradict this simple and elegant picture: (i) The observed cumulative crater frequency for the Saturnian satellites is in better agreement with planetocentric, elliptic orbits of impactors than with heliocentric ones (4). (ii) There is not observed a marked asymmetry of crater frequency between leading and trailing hemisphere of the synchronously rotating satellites (5,6), contrary to theoretical estimates for heliocentric projectiles, predicting an apex-antapex crater frequency ratio of the order of 10, (3,7). Cratering by planetocentric projectiles, however, would not lead to any marked asymmetry.

To discuss these points further we need a relation connecting crater diameter to impact energy (8,9,10). We have used Gault's (8) equation. Taking into account the gravitational focussing effect of the parent-planet and of the satellite we have calculated the cumulative crater frequencies (relative to Hyperion) in the Saturnian satellite system (Figs. 1 and 2): The observational data (1,4) approximated by the dashed line are in much better agreement with planetocentric orbits of eccentricity between 0.01 and 0.6 than with heliocentric projectiles. However, because of the extremely short mean collision lifetimes of planetocentric objects for most satellites ($\lesssim 10^4$ yr) (4), it seems difficult to maintain cratering by planetocentric projectiles over periods of time of 10^8 - 10^9 yr, as suggested by looking at the cratering record of the Jovian and Saturnian satellites in combination with their probable geological evolution. Ways out of this problem could be: (i) The method (11) used for calculating the lifetimes may not be adequate for the special conditions in the satellite systems of Jupiter and Saturn, because close gravitational interactions possibly lead to stable resonances and longer survival times. (ii) A second possibility could be that the smaller Saturnian satellites with the exception of Rhea, Titan and Iapetus, and the small Jovian satellite Amalthea have been destroyed by major impacts as suggested by (7). They may have reaccreted and then may have been cratered by planetocentric remnants, thus exhibiting cumulative crater frequencies close to the observed ones (Fig. 1).

Although the observational data, especially the lacking apex-antapex asymmetry seem to speak more in favor of cratering by planetocentric objects, some uncertainties remain: (i) There may have been nonsynchronous rotation of satellites when the major part of their cratering record was implemented. (ii) The simple two-body approximation (4) used to calculate the apex-antapex asymmetry may be inadequate.

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In conclusion: The data presently favor cratering by projectiles in planetocentric orbits, but the uncertainties are such that cratering by projectiles in heliocentric orbits is still a possible alternative explanation.

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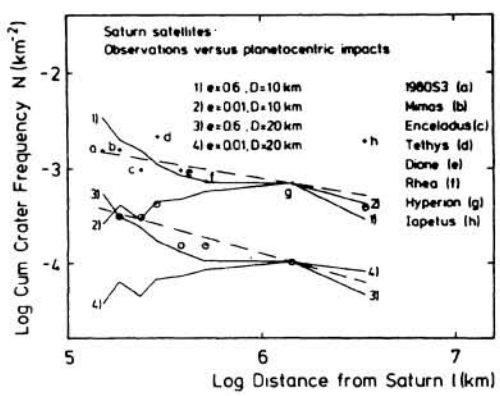

Fig. 1: Cumulative crater frequencies for Saturnian satellites. Solid lines denote theoretical frequencies for planetocentric projectiles of eccentricity 0.01 and 0.6, respectively. Dashed lines show average of observations.

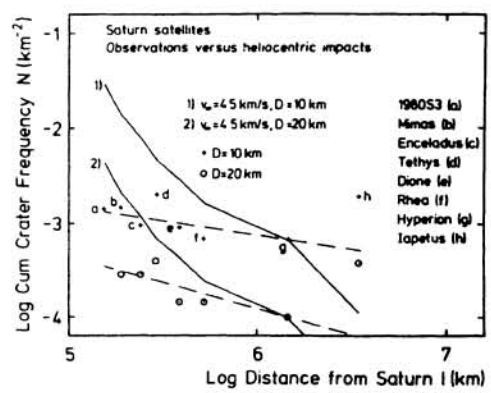

Fig. 2: Same as Fig. 1, but for heliocentric projectiles of eccentricity 0.6.