THE SATURNIAN RINGS

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Abstract. The structure of the Saturnian rings is compared with the asteroidal belt and the relative importance of the resonance effects and the cosmogonic effects is evaluated. No visible correspondence to the Kirkwood gaps is expected theoretically, nor is there any observational evidence for such effects. The only possible resonance is the 1:1 resonance with Saturn's spin period.

Cosmogonic 'shadow' effects are responsible for the main features of the ring structure, including Cassini's division, the limit between the B and C ring, and possibly also Guérin's division.

1. Importance of Cosmogonic Effects and Resonance Effects

Like most of the structure of the solar system the Saturnian ring system was formed by cosmogonic processes four or five billion years ago. However, because the Kepler motion of its particles is perturbed by the gravitational force of the satellites of Saturn, part of its structure - especially the fine structure - may be a result of forces acting today. The purpose of this paper is to analyse the relative importance of these effects in the light of new observational and theoretical results. Of these the new photometric curves by Coupinot (1973) are important because together with Dollfus's curve (cf. Dollfus, 1961, 1970) they clarify some of the structural details. Also the better understanding of the cosmogonic processes in general has now made it possible to discriminate between possible mechanisms with increased degree of certainty (Alfvén and Arrhenius, 1970, 1974, 1975).

2. Comparison with the Asteroid Belt

Because in certain respects the asteroid belt is similar to the Saturnian ring system, a comparison is motivated. From a theoretical point of view we should expect that the \((m, a)\) diagram is more relevant to the study of cosmogonic processes than the usual \((n, a)\) diagram \((m = \text{total mass}, n = \text{number of asteroids per interval of semimajor axis } a)\). This is confirmed by the fact that the \((m, a)\) plot gives a much more regular picture of the structure (cf. Alfvén and Arrhenius, 1975; Alfvén, Burkenrod and Ip, 1974). The \((m, a)\) diagram (Figure 1) (Alfvén, Burkenrod and Ip, 1974) shows two conspicuous features.

(a) The belt has very sharp limits both at the inside and outside

As the Kepler periods at these limits do not coincide with any low order commensurability (with Jupiter's period) they cannot be due to resonance effects. Moreover, there is no resonance effect known which can produce such limitations. Hence, this feature
must be due to cosmogonic effects. Indeed it can be understood as a result of a condensation from a partially corotating plasma (cf. Alfvén and Arrhenius, 1970, 1974, 1975).

(b) There are a number of Kirkwood gaps

As these are located exactly at the points of the Jupiter commensurabilities there can be no doubt that they are due to resonance effects. However, attempts to explain the gaps by celestial mechanics effects alone have not been successful. The principal difficulty is to explain the absence of bodies at the Kirkwood gaps but at the same time the presence of bodies at the Hilda and Thule resonances. As shown by Ip (1975) a theory of the gaps must include collisions between the bodies, and the resonance effects which formed the gaps must have been acting at cosmogonic times.

The only asteroids which are massive enough to be conspicuous in the \((m, a)\) diagram are the Hilda asteroids located in the 2:3 resonance point. Also these can be understood as a product of cosmogonic processes (cf. Ip, 1975).

The asteroidal results are partially applicable to the Saturnian rings. There are important similarities: some of the limits, viz the inner limit of the A ring, and both the outer and inner limits of the B ring, are due to cosmogonic shadow effects. On the other hand there are also important differences: the outer limit of the A ring is caused by the Roche limit. Furthermore, there is no observable analogy to the Kirkwood gaps.

3. Kirkwood Gaps in the Ring System

At a superficial comparison between a photograph of the Saturnian rings and a diagram of the asteroid belt it is tempting to identify the Cassini division as an analogy to