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The smaller bodies of the Solar System

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Two kinds of smaller bodies in the Solar System, the minor planets and the comets, are of interest from the point of view of space exploration and of our System's origin; of these the comets are, for the decade that has just begun, without any doubt by far the more important ones. One of the reasons is purely accidental: the return of comet Halley in 1985–86. Being the only case on record of a periodic comet that has remained an easy naked-eye object after some dozen returns, it provides opportunities for *in situ* studies also, during a fast fly-by mission, which are unlikely to occur again for many years to come. Another reason is that, according to the conviction of almost all workers in the field (cf. the last tri-annual Reports of I.A.U. Commission 15), the comets are among the most pristine objects in the Solar System and most probably closer to the original state than is any other. New insights into their origin have revived the suggestion which had been made already 6 or 7 years ago, that they did not originate in the presolar nebula (ps.n.) itself, but in a satellite nebula or in other nearby fragments of the same parent interstellar cloud, providing another way by which material of a somewhat different early history might have been added to that of the planetary system (Cameron 1973; Biermann 1979). It is my intention to develop this aspect in some more detail.

About two years ago Bodenheimer & Tscharnuter (1979) succeeded in overcoming the ambiguities due to inaccuracies in the numerical integrations describing the contraction of interstellar clouds which had, until then, made it so difficult to use models of contracting clouds as initial stages of a sequence leading to a ps.n. in which planets could form. As a result the initial conditions necessary for the formation of planetary systems could be compared with those that, according to the scheme developed some years ago by Biermann & Michel (1978), would lead to the formation of cometesimals by gravitational instability of an equatorial dust layer in a near-stationary fragment. At that stage, the results of Mestel & Paris (1979) on the combined influence of gravity, rotation and magnetic fields were also applied (Mestel 1980).

More specifically, a fragment with an initially relatively large magnetic flux, that is to say, with a mass well below the critical mass defined by Mestel & Paris (1979), would evolve in approximate corotation with the surrounding material, contracting at a rate determined by the initially slow ambipolar diffusion. The subsequent rapid flux loss must leave a slowly rotating ps.n., which could collapse toward much higher densities before centrifugal forces begin to slow down the contraction. According to recent results obtained by Tscharnuter and coworkers, which were presented at a workshop held in our Munich–Garching institute in March 1980 (Greenberg 1980), such a ps.n. could, under the influence of turbulent friction, indeed lead to the formation of a central star with planets around it. But in such a model no natural way has been discovered in which cometesimals could form in sufficient number in the same ps.n.

On the other hand, for a fragment born with relatively low magnetic flux, that is with a mass

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above the critical mass defined by Mestel & Paris (1979), the initial evolution via a magnetic transport of angular momentum proceeds through states in approximate equilibrium between thermal pressure, magnetic and centrifugal force and self-gravitation. Subsequent rapid loss of magnetic flux by ambipolar diffusion, after a sufficiently low electron concentration has been reached, leads to a rapidly rotating non-magnetic 'long-lived' fragment of only moderate density. Such a fragment should be the natural place for the formation of the equatorial dust layer which, as described by Goldreich & Ward (1973), would become gravitationally unstable; in this case, the planetesimals formed would, as shown by Biermann & Michel (1978), have the chemical constitution and the dimensions observed in comets. How cometesimals formed in a neighbouring fragment could become part of the outer Solar System had been described by Donn (1976) some years earlier.

It thus seems fair to say (cf. Tscharnuter 1981) that a scheme for the formation of cometesimals exists that is consistent with what is known today on the contraction of a rotating magnetized fragment of an interstellar cloud and its dependence on the given initial conditions, which determine whether a double star, or a single star, possibly with planets, or cometesimals form. It has long been speculated that collisions with other clouds are an essential feature of a live cycle of an interstellar cloud; in the context of what has just been said, this would seem to open the possibility that solid material with a somewhat different nuclear history could have been added to that of the Solar System.

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