FORMATION OF SOLAR NEBULA AND MASS DISTRIBUTION IN THE PLANETARY SYSTEM

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Abstract. The formation of the solar nebula and the distribution of mass in its planetary system is studied. The underlying idea is that the protosun, fragmented out from an interstellar cloud as a result of cluster formation, gathered the planetary material and, hence, spin angular momentum by gravitational accretion during its orbital motion around the centre of the Galaxy. The study gives the initial angular momentum of the solar nebula nearly equal to the present value of the solar system.

1. Introduction

It is a common belief that stars have been formed and still continue to form out of interstellar clouds of dust and gas. Observations of our Galaxy show the presence of gas clouds of mass about 1000 solar mass and size about 15 pc. The interspace between these clouds has dimensions of the order of 40 pc and has a density of about 0.01 atom cm$^{-3}$ in contrast to a density of about 8 atom cm$^{-3}$ within the cloud. Since the Sun belongs to a comparatively younger generation, we may assume that the conditions in the interstellar space did not differ much at the time of the formation of the solar nebula than now. Owing to the small size of the Sun it is obvious that it has been formed by the gravitational condensation of a small portion rather than whole of an interstellar cloud. In the present paper the formation of the solar nebula and the distribution of the mass in its planetary system is studied. The idea advanced is that the protosun, fragmented out from an interstellar cloud as a result of cluster formation, gathered the planetary material and hence spin angular momentum by gravitational accretion of particles during its orbital motion around the centre of the Galaxy.

2. Formation of the Solar Nebula

Clusters of stars are known to be produced by random breaking of an interstellar cloud due to turbulence arising from its self-gravitational contraction. With the lapse of time, the stars of a cluster disperse out leaving behind finally a heavy binary at its centre (Hénon, 1971). We assume that the protosun was produced with an initial zero or very little spin angular momentum as a member of any such cluster. The cluster in which the protosun was born must have been completely dissipated by now as the life of such cluster is of the order of $10^8$ years which is quite small as compared to the life of the solar system. After undertaking an independent course of path around the centre of the Galaxy, the protosun accreted gravitationally particles from the interstellar space which had more or less a similar orbital motion. This process of particle accre-
tion by the protosun not only formed an envelope called solar nebula surrounding the protosun but also imparted to it spin angular motion.

The problem of the formation of the solar nebula by particle accretion may be compared with that of the formation of planets (Mitra, 1970a). The only difference which lies in the two cases is regarding the fraction of the total mass of the body which results from accretion. In the case of planets the whole mass of a planet was assumed (Mitra, 1970a) to be accreted from the rotating dust ring. In the case of solar nebula we consider that the protosun, initially having a great majority of the mass $M_0$ of the Sun, accreted only a small mass $M_p$ from the interstellar space. This accreted mass formed a large envelope which may be taken nearly a uniform sphere of radius $r_0$ surrounding the protosun.

Let $r_\phi$ denote the limiting distance of a particle $P$ in the dust ring from the protosun (Figure 1) whose trajectory results in a collision with the protosun $S$. The linear velocity $v$ of such a particle with respect to the protosun when both are moving in their respective Keplerian orbits around the centre of the Galaxy can be written as

$$v = \sqrt{M_G G} \left( \frac{1}{\sqrt{R_0}} \pm \frac{r_\phi \sin \phi}{\sqrt{R_0}} \right),$$

where $R_0$ is the orbital radius of the Sun around the centre of the Galaxy of mass $M_G$, $\phi$ is the complement of the angle which a radius vector drawn from the particle to the

Fig. 1. Section of the ring-shaped cloud of particles in a plane perpendicular to the orbit of the protosun $S$. Dotted lines mark the height of the ring.