CHAPTER-II
LITERATURE SURVEY

2.1 The Process of Dust Charging in Molecular Clouds

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The dark interstellar clouds, are believed to be the ideal sites for star formation. These clouds are sub-divided into clumps of size $\sim 10\,\text{pc}$ and mass $10^3$ to $10^4\,M_\odot$, which undergo gravitational collapse towards the formation of stars. Nakano et al. (1995) have discussed the mass of stars formed in cloud cores. A cloud will successfully collapse into a protostar only when the gravitational energy exceeds the sum of thermal, rotational and magnetic energies. As a result of the existence of nearby ionizing sources (e.g., new born star, associated nebula etc.), some parts of the gas in the clouds are always ionized and dusts present there pick up charges from the plasma environment. Therefore, such a cloud contains dust grains which are charged and the electrostatic forces between these charged dust grains and other charge species in the plasma environment come into existence. Thus it is necessary to find whether, the presence of such forces plays any role in the energy balance mechanism and in the star formation process. In the following sections the research work done on the behaviours
and effects of these charged dusts are highlighted.

2.1 The Process of Dust Charging in Molecular Clouds

In the interstellar clouds a typical value of the degree of ionization has been estimated to be $\sim 10^{-7}$ (Shu et al., 1987). The dust grains present in these clouds are embedded in very weakly ionized plasma and they pick up charges from the plasma environment. The equilibrium dust grain charges can be estimated by the capacitor model which was first addressed by Goertz and Ip (1948). There are numerous other works in literature which explain the charging of dust grains in plasma (Hazelton and Yallowsky, 1994; Walch et al., 1995). Assuming the capacitor model the amount of charge collected by a spherical dust grain of radius $a$, according to literature, is given by,

$$q_d = 4\pi \varepsilon_0 a \phi_f$$

(6)

where $\phi_f$ is the surface potential of dust grain. It yields 700 electrons per volt for a dust grain of 1 micron radius, which is assumed to be a typical size for the dust grains in interstellar cloud. However, the amount of charge decreases with increase in hydrogen in the cloud and also depend upon various other factors including sources of ionization, properties (shape, composition
etc.) of dust grains present in the cloud (Nakano, 1998). The value of $\phi_f$ can be obtained by solving the equation for floating condition

$$\frac{dq_d}{dt} = -\alpha^2 (J_e + J_i - J_{sec})/\varepsilon_0$$

(7)

where $J_e, J_i$ the electron and ion current densities to the surface of the dust grain are functions of $\phi_f$. $J_{sec}$ is the density of current that is emitted out of the grain, by photoemission and/or other secondary emission processes. By neglecting the $J_{sec}$ one can obtain for hydrogen plasma (where $T_i = T_e$) (Spitzer, 1978)

$$\phi_f = -2.5\frac{T_e}{e}$$

(8)

where $T_e, T_i$ are the electron and ion temperature in electron volts.

The electron temperature in a typical emission nebula can be 7000K (Allen, 1983), which can definitely put an upper limit to the corresponding value of the dark cloud. Thus for $T_e = 7000K \sim 0.5eV$, $\phi_f$ can be estimated to be $\phi_f = \sim -1.25V$. The charge in a dust grain is a strongly dependent function of it's size. Finally this gives $q_d \sim 900$ electrons. However, the charge in a dust grain is a strongly dependent function of its size.
2.2 Electrostatic Force

In order that the electrostatic force plays any significant role, it should be of the order of gravitational force, which requires that \( Gm_d^2/q_d^2 \sim O(1) \), where \( m_d \) and \( q_d \) are the mass and charge of the dust grains. Thus, a one micron size dust grain of density 1 \( \text{gm/cc} \) demands \( q_d \) to be \( \sim 10^{-6} \) electrons. This falls much below the value of \( q_d \) obtained by dust charging model. However, for grain of 100micron diameter these two forces become comparable. As the grain size always increases towards the central condensation region, grains of this size or of larger may be found in the inner part of a collapsing nebula. Further, the secondary emission current (like photo-emission etc.) from the grain surface was neglected in the above calculation of \( \phi_f \) and \( q_d \), which otherwise can substantially lower the value of \( \phi_f \) and \( q_d \).

It has been discussed by Umebayashi and Nakano (1980) that the dust grains with electric charge are scarce in dense molecular clouds shielded from uv radiations. As a result Nishi et al. (1991) have considered dust grains with charges only \( \pm 2e, \pm 1e \), and 0 in their work on star forming clouds. For such values of charge, the size of the dust grain has to be few tens of microns, in order that the gravitational and electrostatic are of same order (Dwivedi et
As it is difficult to ascertain the exact size of the dust grains in a cloud, calculations in this thesis are done keeping an open mind towards dust grain size distribution and it may be worth exploring the role of neutral and charged dust grains in the process of star formation.

2.3 Gravitational Collapse of a Molecular Cloud with Dust Grains

Let us consider a cloud mass in equilibrium. The gravitational instability in such a mass distribution has been studied by many authors (Jeans, 1920; Kolb and Turner, 1990; Pandey et al., 1994; Dwivedi et al., 1999 etc.). Within the domain of uniform mass distribution, the equilibrium force of gravity could be unimportant to affect the equilibrium dynamics in a molecular cloud. If the symmetry of uniformity is broken either due to some mass fluctuations, as in the case of a purely neutral dust mass, or due to the charge fluctuations, as in the case of the charged dust mass, the gravitational collapse will take place in a different manner. Considering Boltzmannian distribution for
ions \( n_e = n_{e_0} \exp \left( \frac{e \phi}{kT_e} \right) \) and electrons \( n_i = n_{i_0} \exp \left( \frac{-e \phi}{kT_i} \right) \), and 1-D fluctuation response in radial direction, Dwivedi et al. (1999) have shown that there is a possibility of pulsational mode of gravitational collapse (PMGC) of molecular cloud. However, the frictional forces (drag) in the neutral and charged dust dynamics was ignored in their calculation and it may be noted that the distribution for ions and electrons may not be always Boltzmannian. Moreover the star forming molecular clouds are always magnetized and magnetic field plays an important role along with the charge species in the cloud.

Thus there is a need to study the gravitational instability in a molecular cloud with charged dust grains under the influence of electrostatic forces and other frictional forces.

2.4 Frozen-in Condition

In a molecular cloud, charged particles are frozen tightly into the magnetic field present there. Ambipolar diffusion have been addressed by many authors (Nakano, 1980; Nakano and Umebayashi, 1986; Nishi, Nakano, and Umebayashi, 1991; Nakano, Nishi, and Umebayashi, 1994, Nakano, 1998; etc.). The efficiency
of ambipolar diffusion is checked by the direct attachment parameter $\omega_\alpha \tau_\alpha$ where $\alpha$ denotes a charged species, $\omega_\alpha$ is the gyrofrequency of $\alpha$ and $\tau_\alpha$ is the friction timescale of $\alpha$ caused by the neutrals. In the previous studies available in literature, $\omega_\alpha \tau_\alpha > 1$ means that $\alpha$'s were frozen into the magnetic field.

However the above condition may not always represents the frozen-in condition for charged particles due to collisions between different particles. The phenomena is presented here including as many frictional term as possible in a realistic situation, which prevails in a molecular cloud.

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