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THE IMPORTANCE OF COOLING AND ROTATION IN THE FORMATION OF MOLECULAR CLOUDS AND STARS

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We have examined the role that velocity or pressure fluctuations in the ISM can play in initiating compression of sub-Jeans mass diffuse clouds, paying special attention to the cooling properties of the medium. In the past, <u>equilibrium</u> arguments have usually been used to quantitatively estimate the amplitude that a given external disturbance must have if it is to successfully initiate the collapse of a pressure-supported gas cloud. When a disburbance occurs on a time scale short compared to the sound-crossing time of a cloud, however, equilibrium arguments are inappropriate. We have developed a nonequilibrium model (Tohline and Christodoulou 1988), based on an analytically defined, global free-energy function, that allows us to more accurately estimate the impact that external disturbances have on gas clouds. As a result of the nonequilibrium analysis (see Tohline, Bodenheimer and Christodoulou 1987 for details), estimates of the required disturbance amplitudes are substantially reduced from the previous estimates that were based on equilibrium arguments. Similar points have been made by Whitworth (1981) and by Hunter and Fleck (1982).

Interstellar gas clouds that are particularly sensitive to mild disturbances from their environment are clouds which cool under compression -- i.e., clouds which exhibit effective adiabatic exponents Γ in the range $0 < \Gamma < 1$. Sub-Jeans mass clouds can be induced to collapse gravitationally by pressure fluctuations $\delta P_e/P_e \gtrsim \Gamma/(1-\Gamma)$ or by implosion velocities of Mach number $\mathcal{M}_0 \gtrsim [10/3(1-\Gamma)]^{1/2}$. This result is <u>independent of cloud mass</u> and is markedly different from the behavior found for isothermal gases. This finding, based on a simplified analytical model, has received strong support from a recent set of numerical hydrodynamic simulations (Tohline, Bodenheimer and Christodoulou 1987). Since atomic clouds in the ISM do cool under compression, exhibiting an effective adiabatic exponent $\Gamma \sim 3/4$ (Larson 1985), we propose that farily mild disturbances in the ISM play a primary role in the formation of molecular clouds. Pressure fluctuations $\delta P_e/P_e \sim 3$ and velocity

disturbances $v \sim 2$ km s^{-1} can effectively compress HI gas to molecular cloud densities over a wide range of cloud masses (10^3 $M_\odot \gtrsim M \gtrsim 1$ $M_\odot$).

Including the effects of rotation, it can also be shown (see Tohline and Christodoulou 1988, for example) that gravitational collapse is prohibited if a cloud of mass M has a specific angular momentum larger than $j_{max} = GM/c$, where c is the sound speed in the originating cloud. If binary star systems form naturally from the fragmentation of self-gravitating molecular cloud clumps, therefore, the maximum separation between the binary components will be $R_{max} = GM/c^2 = 2000$ ($M/M_\odot$) $(T/100K)^{-1}$ AU and the maximum orbital period of such systems must be $P_{max} = 2\pi GM/c^3 \approx 10^5$ ($M/M_\odot$)$(T/100K)^{-3/2}$ years.

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