STAR FORMATION DRIVEN BY THERMAL-CHEMICAL INSTABILITY IN A PRE-GALACTIC GAS CLOUD

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The hydrogen molecule would work as an efficient coolant in a pre-galactic medium which is free from heavy elements. It is shown by linear perturbation analysis that molecular reactions lead to a thermal instability of condensation mode (Sabano and Yoshii 1977, Yoshii and Sabano 1979, Silk 1983). In the present paper we study the nonlinear growth of perturbations by a one-dimensional simulation of gas dynamics, which includes molecular reactions as well as an energy equation. We numerically follow the time-evolution of a spherically symmetric perturbation, which is superposed on initially uniform medium under free-fall contraction, by a Lagrangian hydrodynamical programme with an artificial viscosity (Richtmyer and Morton 1967).

Figure 1 shows time-evolutions of pertubations with masses of $m = 0.1\ M_\odot$, $1.0\ M_\odot$, and $10\ M_\odot$ for initial state of $n_0 = 7.2\times10^9\ cm^{-3}$, $T_0 = 2.2\times10^3$ K, and $f_0 = 4.5\times10^{-4}$, where the linear theory gives a positive growth rate for the instability. Results for the fluctuation with the small mass of $m = 0.1\ M_\odot$ show a rapid growth of density contrast driven by chemical reactions, which is a characteristic of thermal instability of the isobaric condensation mode in the limit of short wavelength of perturbation. Results for the larger mass of $m = 1.0\ M_\odot$ distinctly show the effect of self-gravitation. After the initial growth of the thermal mode, the central density continues to grow, following gravitational contraction. In the case of the largest mass, $m = 10\ M_\odot$, a density maximum arises in the middle part driven by the expansion of the hot and rarefield phase which is brought about after the phase-change of the instability. The density enhancement grows further, also due to self-gravity, forming a shell structure. Since the thickness of the dense layer exceeds the Jeans length at epoch f, the layer break into small fragments by gravitational instability. The fragment mass m_f can be estimated as $m_f \cong \rho\ell^3 \cong 1.4\ M_\odot$ with ℓ being the thickness of the layer when it attains the Jeans length.

We note that the Jeans mass in the initial state, $M_J = 120\ M_\odot$, is much reduced after a phase-change caused by the thermal-chemical instability, and even a low-mass fluctuation with $m = 1.0\ M_\odot$ eventually turns to be bound by self-gravitation. It is thus concluded that a primordial gas cloud would break into fragments, with masses in the range of normal stars, suggesting that Population III objects can be formed as normal stars (see also a review by Sabano and Yoshii 1984).

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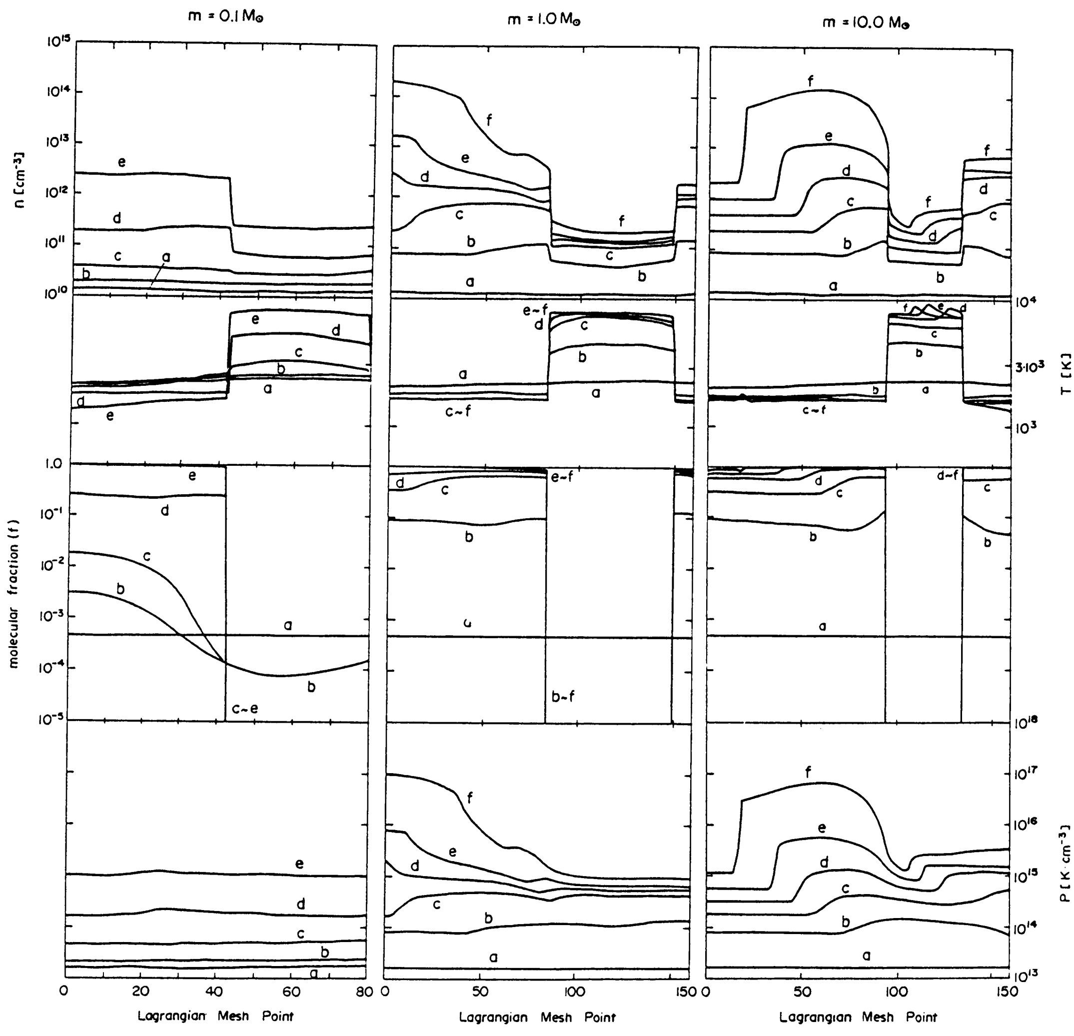

Fig. 1. Time-evolutions of perturbations with masses of m = 0.1 $M_\odot$, 1.0 $M_\odot$, and 10 $M_\odot$. The distributions of number density n, temperature T, molecular fraction f, and pressure P are plotted against Lagrangian mesh points at stages (a) t = 0, (b) 1.32, (c) 2.9, (d) 4.7, and (e) 6.4×10^9 s for m = 0.1 $M_\odot$, at stages (a) t = 0, (b) 4.5, (c) 5.8, (d) 6.0, (e) 6.2, and (f) 6.5×10^9 s, for m = 1.0 M_O, and at stages (a) t = 0, (b) 4.6, (c) 5.9, (d) 6.6, (e) 7.0, and (f) 7.3×10^9s for m = 10 $M_\odot$.

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A SINGLE FRAGMENTATION LAW? THEORETICAL AND OBSERVATIONAL EVIDENCE

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ABSTRACT. In the light of the growing interest for the modes of formation of various astronomical objects, a relevant amount of data were collected and treated to obtain mass spectra. Statistical comparisons of the data suggest that a single process drives the formation of the various self-gravitating objects.

Many authors (e.g. Larson 1973,1985, Silk 1977, Zel'dovich 1978) restricted their attention to the formation of a particular single class of objects (i.e. stars and clusters of galaxies), while Reddish, after

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