ON THE STAR FORMATION IN EARLY STAGE OF GALACTIC EVOLUTION

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Evolution and fragmentation of a gas cloud are investigated for the primordial chemical composition which is the same as the products of the Big Bang. A pure-hydrogen gas cloud collapses isothermally at 500-1000 K when a low fraction of molecular hydrogen works as a coolant, and breaks into small subcondensations with mass less than 10 $M_{\odot}$ due to thermal instability associated with molecular dissociation. On the other hand a pure-hydrogen gas cloud which contains no molecular hydrogen collapses isothermally at 6000-8000 K in a thermally stable condition, and enters the region where thermal energy exceeds radiation energy when thermal equilibrium between matter and radiation is achieved in the cloud. Consideration of energetics in the subsequent stage of the cloud evolution leads to the mass range of 0.1-20 $M_{\odot}$ for the stable nuclear-burning protostars of the first generation. The thermal behavior of a gas cloud in the regime of z (the ratio of heavy element abundance to solar one) less than 10^{-4} is essentially similar to that in the case of no heavy element, and the heavy element cooling brings about thermal instability in a wide range of parameters in the regime of z greater than 10^{-3}. Linear perturbation analysis gives growth time of the instability much shorter than the free-fall time, and suggests the efficient excitation of density fluctuation driven by thermal instability. Thus the possibility of the initial mass function relatively enhanced in massive star at early times is denied, and the slow rate of metal enrichment in the interstellar medium is suggested.

DISCUSSION

Mouschovias: The wavelength of the thermal instability has an upper bound set by the product of the speed of sound and the cooling time. Isn't it the case that, for the temperature and density you are using, this characteristic size is too small to involve very large masses? And wouldn't you have to collect matter for distances exceeding a kiloparsec along field lines if you include even a weak magnetic field? (Field showed in 1965 that the thermal instability is suppressed, even by a relatively weak field, in the two directions perpendicular to the field.) And wouldn't

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this require much too long a time to take place?

Yoshii: The mass contained within the characteristic length of the thermal instability amounts to 10 $M_\odot$, which is sufficiently large to be bound gravitationally. There are many uncertainties concerning the early evolution of the Galaxy and we intend to clarify the thermal state of the gas in the early stages, assuming no magnetic field. However, it may be, of course, that magnetic pressure has a important influence on star formation in the early stages of galactic evolution.

Joss: In your scenario, some stars from the earliest stellar generations must still be in existence. The exact numbers will depend upon the relevant birthrate function. Is it possible to reconcile your results with the stringent observational upper limits on the present number of stars in the galaxy with very low heavy element abundances?

Yoshii: The earliest stars may mostly be contained in the halo component, for which the observational constraints are, unfortunately, poor at present. As a matter of fact, extremely metal-poor stars have not been detected yet, but we think such objects will possibly be observed in future. However, it should also be remarked that metal-free stars could accrete metal-rich interstellar matter during the galactic evolution, and the metal abundance of the stellar surface could change considerably.