FORMATION OF GLOBULAR CLUSTERS AND THE FIRST STELLAR GENERATIONS

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Using a new theory of fragmentation via gravitational instability (Di Fazio 1986) a multi-fluid evolution model for a self-gravitating spherical gas cloud (Di Fazio 9186), new opacity functions suitable for media of low density and temperature (Capuzzo Dolcetta, Di Fazio and Palla 1985), the initial collapse, fragmentation and virialization of a protogalactic gas cloud is followed. The chosen initial conditions are: $M = 10^{11}\ M_{\odot}$, $R_o = 50$ kpc, $T_o = 10$ K, $Z = 0$ (only H + He), $M_{fragments}(t=0) = 0^{o}$ (pure gas initially). The difference, with respect to Di Fazio (1986), consists in taking into account the formation and dissociation of H_2, together with its radiative processes. The calculations are performed in the approximation of LTE (besides carrying out an additional calculation with a NLTE-estimated correction factor in the abundance of H_2). The results are compared with Di Fazio (1986). Four generations of fragments are again obtained, with small differences in the mass ranges and slopes. Isothermal phases at lower temperatures (1800 - 2300 K) than before (Di Fazio 1986) are reached. The virialization time for the fragments does not vary, as expected. A mass function is obtained for each of the mentioned four generations. The second generation (peaking at $10^5\ M_{\odot}$) represents (also the shape of the mass function agrees with the globular cluster one) the family of the proto-globular clusters. The third generation (peaking at ~ 100 $M_{\odot}$) is a valid candidate for the first stellar generation. The presence of H_2 allows the formation of lighter objects than in Di Fazio (1986): M can get as low as ~ 40 $M_{\odot}$, instead of 80 $M_{\odot}$. After the explosion of these objects (Δt ~ 2 Myr) a new, metal (C,O)-enriched generation of globular clusters is formed, which fragments into lighter "stars" (mass range [0.035, 100]$M_{\odot}$). The mass function shape resembles that of Pop II stars. (See Scalo 1985.)

It is interesting to note that the accounting for H_2 radiative processes contradicts Palla et al. (1983), which predicted very low mass stars (~ a few times 0.01 $M_{\odot}$) for the first stellar generation. We ascribe this difference to the following reasons: 1. the mentioned

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work does not conserve energy in its computation; 2. it assumes a continued collapse (so that the density is ever-increasing, helping the Jeans mass to decrease, even though the formation of stars would induce a stop in the collapses of the system, as the orbiting system of stars has a "stiffness" $\gamma = 5/3$ to contraction) without calculating the dynamics coupled to the thermodynamics; 3. as explained in Di Fazio (1986), it uses the total density, in place of the gas density alone as it would be correct, in the computation of the Jeans mass, so that the result is smaller. This is not acceptable, as in only a Jeans time (about 1.4 free-fall times in these cases) a predominant fraction of mass is in stars (so that $\rho/\rho_{stars} \ll 1$), and $\rho \sim \rho_{total}$ is no longer acceptable. The Jeans mass would rise again (even though the temperature behavior is isothermal), stopping the fragmentation. So, in conclusion we show that the introduction of H_2 cooling is important only in getting a more precise estimate of the temperatures, and thus of the fragment masses, but that H_2 cooling can by no means lower by orders of magnitude the characteristic masses obtained. The fundamental fact is that the Jeans mass (due both to the gas exhaustion and to the bounce of the system) rises back up in only 1.3 - 1.4 free-fall times.

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