Perseus in Sicily: From Black Hole to Cluster Outskirts
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Survival of Population III stars

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Abstract. In our earlier study Dutta (2016a), it has been shown that a number of primordial protostars (the 'first stars' in the Universe, also known as Population III or Pop III stars) are being ejected from the cluster of their origin with the velocity exceeding their escape velocity. Hence there is possibility that some of these protostars can enter main sequence and survive till present epoch, even in Milky Way. We ask the question if the protostars can avoid core collapse, and stop accreting before being ejected from the cluster, with the final mass of stars as 0.8 $M_{\odot}$.

Keywords. stars: Pop III – accretion – hydrodynamics – instabilities – methods: numerical

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1. Motivation

The question of survival of the oldest stars in the Universe becomes interesting in the light of recent discoveries of extremely metal poor stars both in the halo of Milky Way as well as in the bulge. Present numerical simulations of collapse of primordial gas inside minihalos suffers from two major shortcomings (Hartwig *et al.* (2015), Dutta (2016b), Dutta *et al.* (2017)). Thus, the final fate of the protostars remains unclear. Here we use the typical orbital parameters of the protostars and the properties of the clusters, as determined from numerical simulations. We then determine a lower limit for Pop III stars that could have avoided the core collapse and survived for a significantly long time.

2. Numerical Method

We develop a semi-analytical model of Bondi-Hoyle accretion (Bondi & Hoyle (1944)) guided by results of cosmological simulations of Dutta *et al.* (2015a) and Dutta (2015b) to study the mass accretion by these protostars as a function of original stellar mass, and other parameters such as angular momentum and gravitational drag due to ambient gas. We also model the trajectories of protostars inside the gravitationally bound system.

3. Results

Mass accretion of the protostars that escape cluster is higher for a lower initial radial velocity. On the contrary protostars that remain in the cluster can have typical mass in the range $\sim 0.1 - 10\, M_{\odot}$ depending on their radial and rotational support. In addition, we have found that the Bondi-Hoyle accretion is a good approximation to understand the evolution of Pop III stars in an unstable self-gravitating disk. Protostars with speed greater than the escape speed can overcome the gravitational drag by the ambient gas and accrete only a small amount of mass before being ejected as low-mass Pop III stars

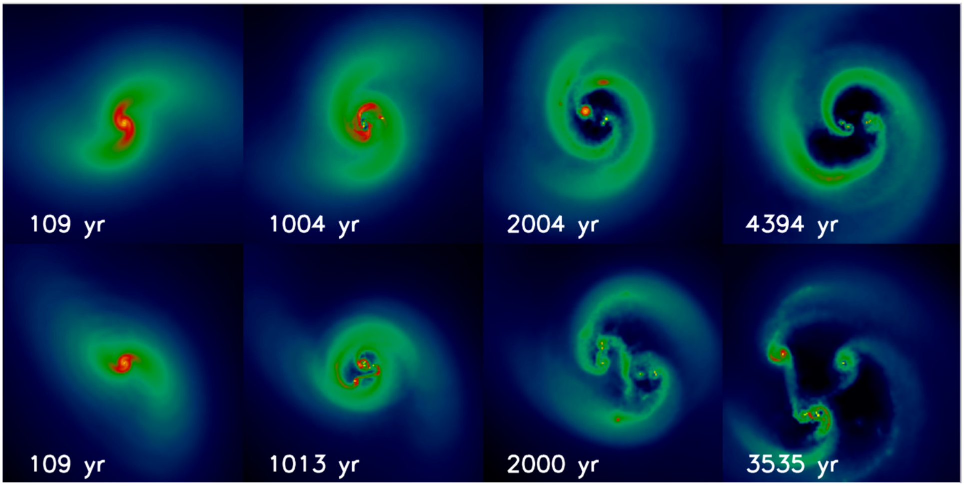

Figure 1. Evolution of gravitationally unstable disk that fragments to form Pop III cluster.

($M_* \sim 0.8\, M_\odot$). We also consider the evolution of a group of Pop III stars in a gas cloud and it is possible that many body interactions lead to a more nuanced understanding.

4. Conclusion

We expect that Pop III protostars that initially form within a certain range of mass and velocity larger than the escape velocity may survive with a mass lower than the cutoff. Hence, these may be found in the Milky Way or its satellites. Based on our theoretical as well as observational investigation, we conclude that the low-mass and low-metallicity stars are likely to exist in the halo or loosely bound structures like low-mass satellites.

5. Discussion

We have investigated in detail the gravitational collapse of primordial gas in minihalos and resulting fragmentation of circumstellar disk. We have ignored star-star interactions that may affect their radial and rotational velocities. During the interaction with ambient medium, stars gain or loose angular momentum that can change their velocity enough to escape the cluster. In future, we will investigate the N-body simulation using the spherical Bondi-Hoyle accretion to get more realistic evolution for their dynamical behaviour.

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