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Gravity or turbulence V: star-forming regions undergoing violent relaxation, Bonilla-Barroso+2022

In this paper, Bonilla-Barroso et. al. explore star cluster formation through simulations, particularly testing two different formation scenarios - a turbulent scenario (TC), and a chaotic collapse scenario. The turbulent scenario takes molecular clouds in viral equilibrium, and adds stability to them by means of supersonic turbulent support. This stability allows a low rate of star formation across the age of the molecular cloud. The collapse scenario takes molecular clouds that have density instabilities leading to contraction towards those instabilities, which are born of magnetohydrodynamical and thermal instabilities themselves. The density instabilities quickly reach high Jeans masses and create massive stars, but start to disperse the main cloud itself. The authors take these scenarios and model them against data of the Orion Nebula Cluster (ONC), of Stars and Planet Formation classroom fame. This is relevant as there is a predominant idea that the formation of the stars in the ONC occurred through a turbulent process.

To compare the star cluster formation scenarios, the authors took two simulations using GADGET-2 and four more using Flash 4.3. Their first set of global collapse simulations worked were given a Mach 8 velocity dispersion, which made them specific to studying gravitational collapse in high Jeans mass cases. The second global collapse simulations took a warm atomic isothermal medium and allowed it to form a molecular cloud that had subsonic turbulence, and evolved it out from formation. The turbulence simulations injected supersonic isothermal turbulence into the molecular cloud, but did not involve the evolution of the system and so the manufactured sink in the simulations was reproduced three times each using random seeds. The empirical data selected a total of 1989 stars from a selected ONC region, noting their parallax, proper motions, masses, ages, and effective temperatures, using the GAIA-EDR3.

For analysis, the authors binned velocity dispersion of sinks per mass for the simulation and empirical data. For their simulations, they found that the the global collapse simulations had a relatively flat velocity dispersion (figure 6). The turbulence simulations showed a range in velocity dispersions, with higher velocity dispersions being associated with higher mass stars, showing a clear difference between the collapse and turbulence scenarios (figure 7)! The ONC histograms also show relatively flat velocity dispersion with no relationship to the masses binned, which visually looked a lot like the collapse scenario (figure 9). The authors do well to analyze the kinematics of a forming cluster, including solving for the expansion factor (which describes the velocity dispersion of stars over time), and questions of binning inaccuracies, which were compelling to read as they had been accounted for.

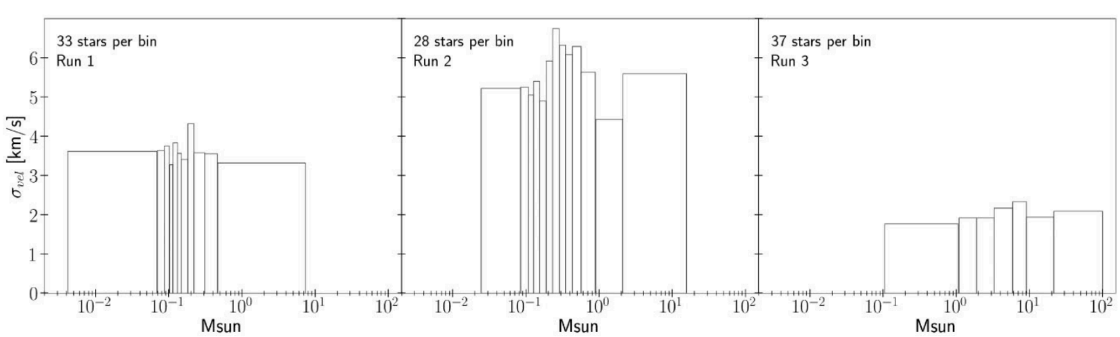

Figure 6. Velocity dispersion per mass bin for sinks in runs of global hierarchical and chaotic collapse (Runs 1–3). The velocity dispersion, although shows fluctuations, is independent of the mass of the stars, as expected from violent relaxation.

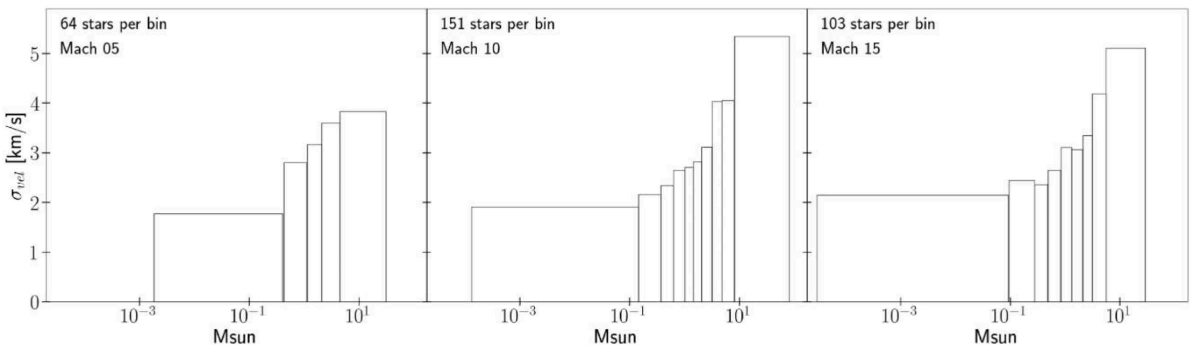

Figure 7. Velocity dispersion per mass bin for sinks in runs of turbulent MCs (Runs 5–7). The velocity increases for larger masses.

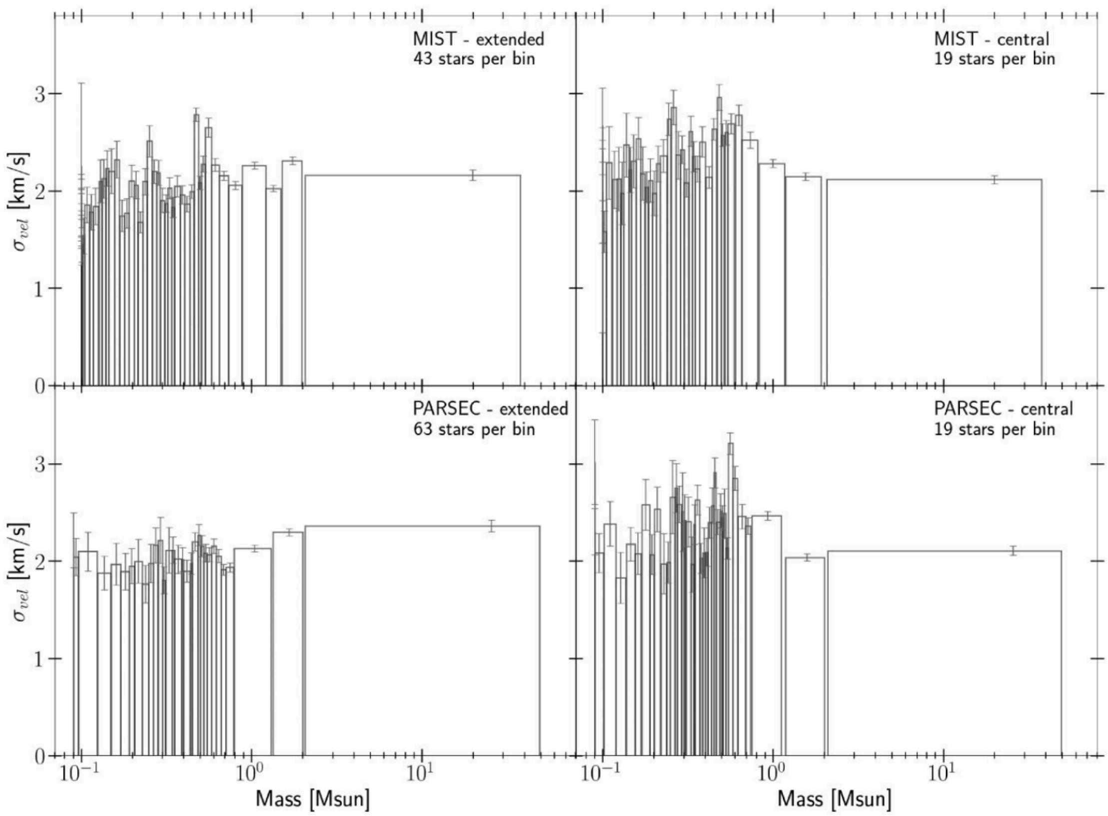

Figure 9. Velocity dispersion per mass bin for stars in the 7 pc size box (left-hand column), and (b) central 1.5 pc of the ONC (right-hand column). In the upper panels, we used the MIST models in order to infer the masses, while the lower panels we used the PARSEC models. The velocity dispersion per mass bin remains nearly constant in both cases, despite the fluctuations and the models used, indicating that the ONC has been suffering global collapse, rather than been a turbulent region surviving many free-fall times.