The Dependence of Stellar Properties on Metallicity

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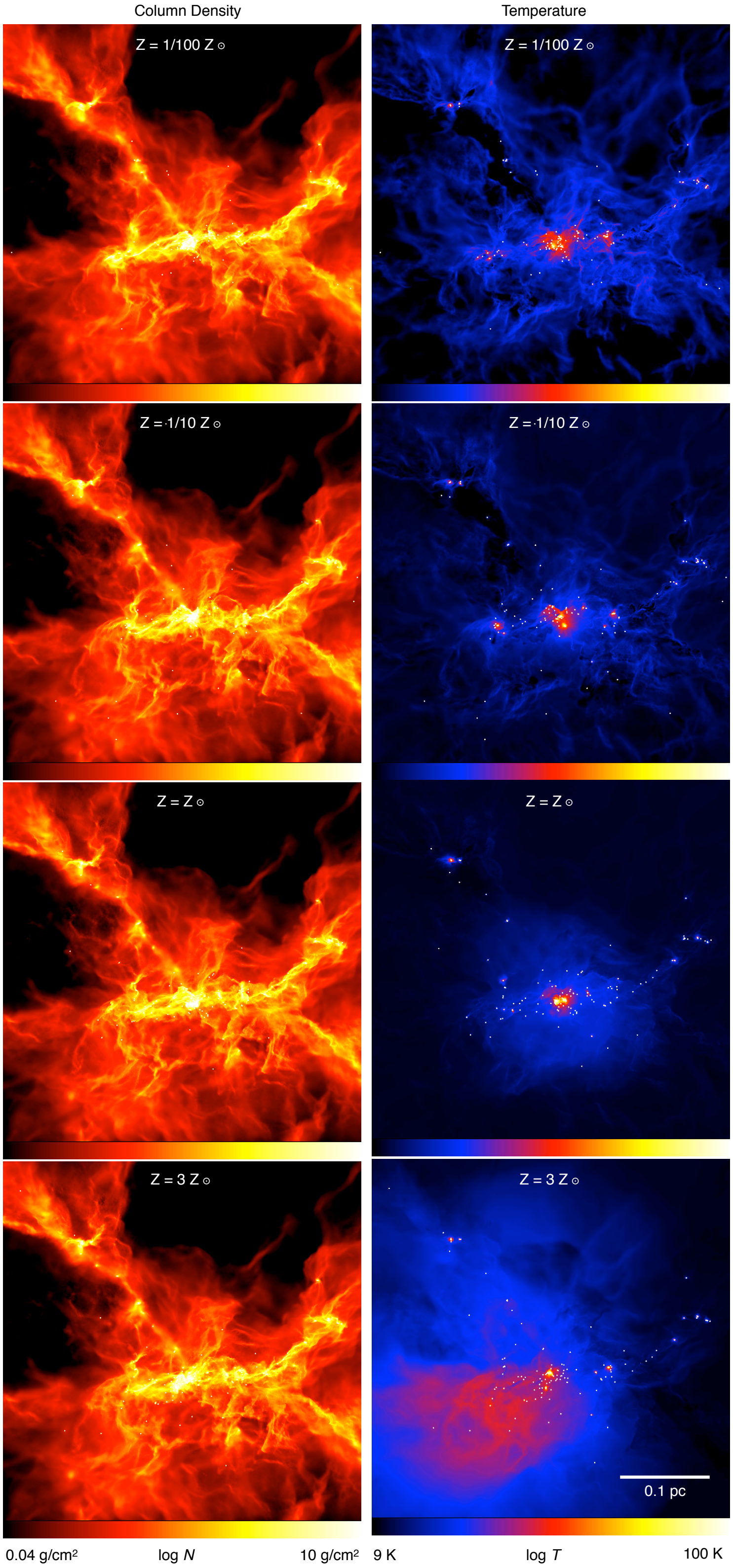
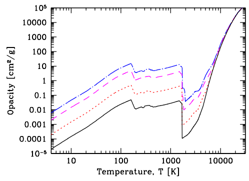
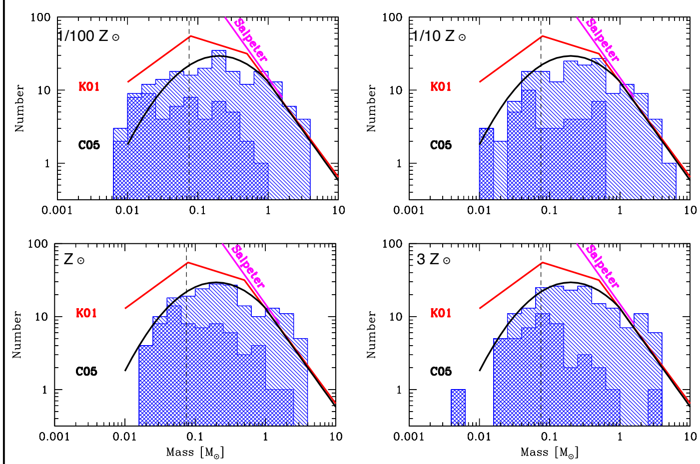


We report results from a series of four radiation hydrodynamical simulations of star cluster formation in 500 solar mass, turbulent molecular clouds that are identical except for their metallicities, which range from 1/100 to 3 times solar.

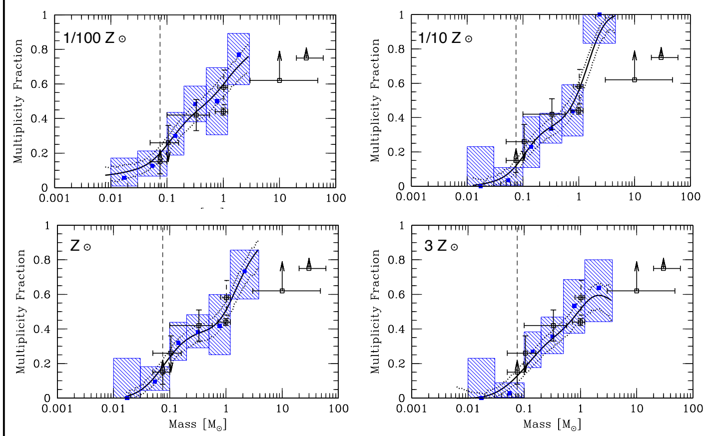


Examples of the Rosseland mean opacities used for different metallicities: 1/100 Z⊙ (solid black line), 1/10 Z⊙ (short-dashed red line), Z⊙ (long-dashed magneta line), 3 Z⊙ (dot-dashed blue line). The opacities are functions of both temperature and density. For this graph, we plot the opacity as a function of temperature in which the density at each temperature satisfies (T/10 K) = (ρ/10^{-13} g/cm^3)$^{0.3}$. This roughly approximates the typical densities and temperatures found during the collapse of a molecular cloud core.

Each calculation produces at least 170 stars and brown dwarfs, allowing their statistical properties to be compared. We find no statistically significant dependence of the initial mass function (IMF), multiplicity, or the properties of multiple systems on metallicity, but there are hints that metal-poor star formation may produce slightly more brown dwarfs. Each calculation produces a population that is indistinguishable from observed systems.



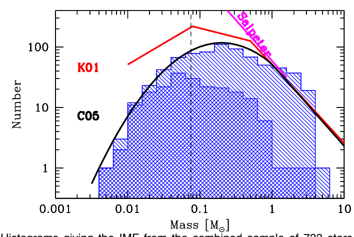
Histograms giving the IMFs of the stars and brown dwarfs produced by each calculation. The double hatched histograms denote those objects that have stopped accreting, while those objects that are still accreting are plotted using single hatching. The numerical IMFs are compared to the parameterisations of the observed IMF of Salpeter (1955), Kroupa (2001), and Chabrier (2005). Despite varying the metallicity by a factor of up to 300, the IMFs are statistically indistinguishable, though we note there is a potential excess of brown dwarfs in the most metal poor calculation.



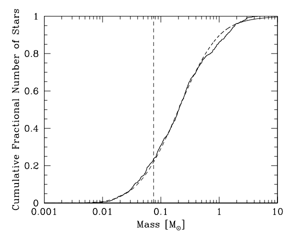
Multiplicity fraction as a function of primary mass. The blue filled squares surrounded by shaded regions give the results from the calculations with their statistical uncertainties. The thick solid lines give the continuous multiplicity fractions using a sliding average, and the dotted lines give the statistical uncertainty in this average. The open black squares with error bars and/or upper/lower limits give the observed multiplicities from the surveys of Close et al. (2003), Basri & Reiners (2006), Fisher & Marcy (1992), Raghavan et al. (2010), Duquennoy & Mayor (1991), Preibisch et al. (1999), and Mason et al. (1998), from left to right.

Combining the results from all four calculations, we obtain a sample of 733 stars and brown dwarfs whose mass distribution and multiplicity are in astonishingly good agreement with observations.

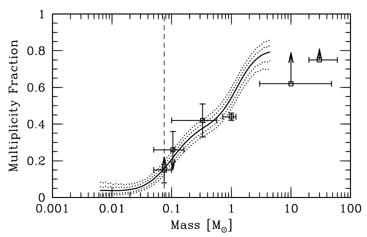
We conclude that the primary ingredients required to produce stellar properties are gravity, hydrodynamics, and radiative feedback. Metallicity variations have little effect above 1/100 solar.



Histograms giving the IMF from the combined sample of 733 stars and brown dwarfs produced by all four calculations. The double hatched histogram denotes those objects that have stopped accreting, while those objects that are still accreting are plotted using single hatching. The numerical IMF is compared to the parameterisations of the observed IMF of Salpeter (1955), Kroupa (2001), and Chabrier (2005).



The cumulative IMF from the combined sample of 733 stars and brown dwarfs produced by all four calculations, compared with the parameterisation of the observed IMF by Chabrier (2005). The level of agreement between the two distributions is astonishing, and the two cumulative distributions are statistically indistinguishable.



Multiplicity as a function of primary mass for the combined sample of 733 stars and brown dwarfs. The solid line gives the continuous multiplicity fraction computed using a sliding average. The dotted lines give the 1-σ and 2-σ confidence intervals. The open black squares with error bars and/or upper/lower limits give the observed multiplicity fractions from the same surveys as above.