

Early Evolution of Stellar Clusters: Effects on Forming Planetary Systems

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This poster presents the results from a theoretical study of the dynamical evolution of young groups and clusters, from their embedded stage out to ages of ~ 10 Myr. Using N -body simulations of stellar systems (Aarseth 1999) ranging from $N = 100 - 1000$ members, we explore how the evolution of such systems depends on the system size (N) and the initial conditions. Recent observations suggest that stellar groups begin their evolution with subvirial speeds (Walsh et al. 2004). Specifically, this work compares subvirial (“cold”) starting states with virial (“hot”) starting states and shows that the differences are significant. For example, “cold” starting conditions lead to a denser central region, larger interaction rates, and more radial velocity distributions. Multiple realizations of equivalent cases (100 realizations per initial condition) are used to build up a robust statistical description of these systems, e.g., the probability distribution of closest approaches and the probability distribution for the radial location of cluster members. These results provide a framework from which to assess the effects of groups/clusters on the process of star and planet formation, and to study the evolution of observed clusters. The distributions of distances from the cluster centers are used in conjunction with the probability distributions of the expected FUV luminosities (calculated here as a function of cluster size N) to determine the radiation exposure of circumstellar disks. The resulting distribution of FUV flux, in conjunction with existing calculations of disk evaporation as a function of flux (Adams et al. 2004), determines how the ensemble of forming solar systems is affected by FUV radiation from the background environment. The distributions of closest approaches are used in conjunction with scattering cross sections (calculated here as a function of stellar mass) to determine the probability of disruption for newly formed solar systems. In general, small clusters have relatively little effect on star and planet formation, whereas large clusters can have a substantial impact. Taken together, the results of this work provide probability distributions for the possible occurrence of various disruptive events. Selected specific results are illustrated in the figures on the following page.

References:

- Aarseth, S. J. 1999, *PASP*, 111, 1333
- Adams, F. C., Hollenbach, D., Laughlin, G., & Gorti, U. 2004, *ApJ*, 611, 360
- Lada, C. J., & Lada, E. A. 2003, *ARA&A*, 41, 57
- Porras, A., et al. 2003, *AJ*, 126, 1916
- Walsh, A. J., Myers, P. C., & Burton, M. G. 2004, *ApJ*, 614, 194

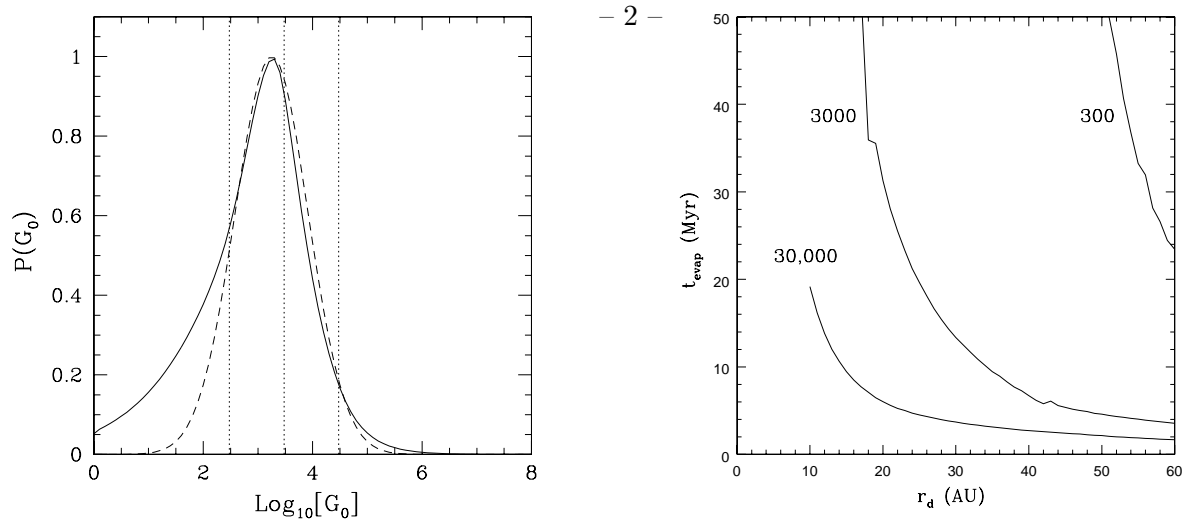


Fig. 1.— The left panel shows the distribution of FUV flux experienced by forming solar systems, where this distribution is the composite resulting from the distribution of radial positions, the distribution of FUV luminosity for groups/clusters with a given size N , and the observed distribution of cluster sizes N (Lada & Lada 2003; Porras et al. 2003). The vertical dotted lines show benchmark values at $G_0 = 300$, 3000 , and 30000 . The right panel shows the predicted evaporation time scales, plotted here as a function of disk radius, for these benchmark flux values for circumstellar disks orbiting solar mass stars (from Adams et al. 2004).

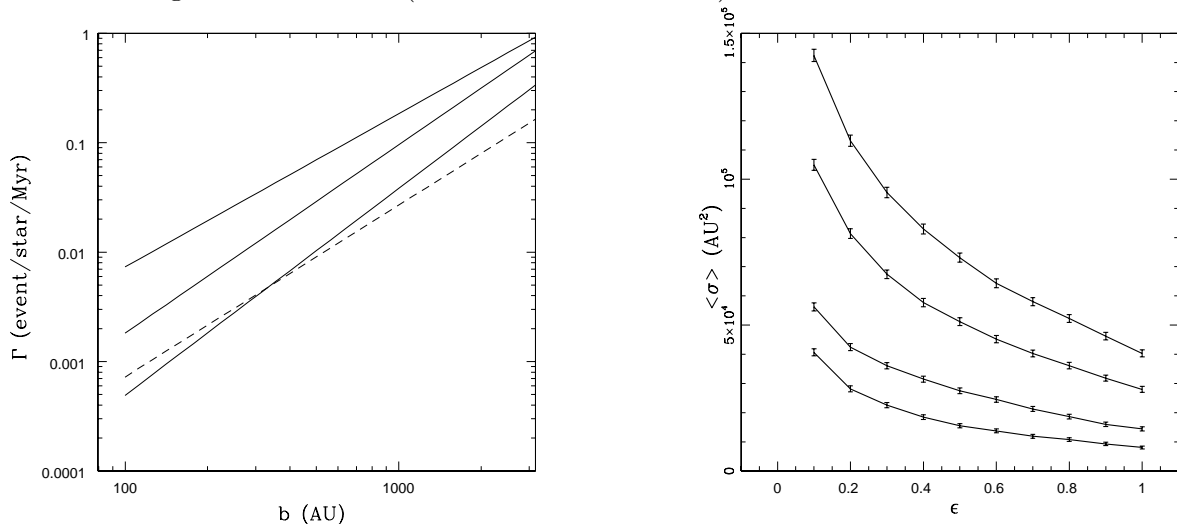


Fig. 2.— The left panel shows the distribution of closest approaches for four starting configurations. The three solid curves show the distributions for $N = 100$, 300 , and 1000 (from top to bottom) with subvirial ("cold") starting conditions. The distributions are obtained by fitting the results of 100 realizations of the given initial conditions. The dashed curve shows the distribution for $N = 300$ and virial ("hot") starting conditions. The right panel shows the cross sections for the interaction of solar system analogs with passing binaries in a cluster. The cross sections, given here in units of $(\text{AU})^2$, are plotted as a function of eccentricity increase, where $\epsilon = 1$ corresponds to ejection. The four curves correspond to analogs of Neptune (top), Uranus, Saturn, and Jupiter (bottom).