Do All Stars in the Solar Neighborhood Form in Clusters?

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Abstract

We present a study of young stellar object (YSO) surface densities (Σ) in star forming regions based on a comprehensive collection of Spitzer Space Telescope surveys. We show that the distribution of star-formation surface densities is a smooth distribution, being well described by a log-normal function from a few to 10 YSOs per pc², with a peak at ~25 stars per pc² and a dispersion of σ ~ 0.85. We show that previous definitions of clusters, based on surface density criteria, are largely arbitrary. This leads us to conclude that clusters are not a unique mode of star formation, but a continuous distribution ranging from distributed to highly clustered. Such a continuous distribution is expected if star formation proceeds hierarchically. Our results suggest that clusters are not fundamental units in the star formation process, but simply the high density tail end of a continuous distribution.

The Spitzer Surveys (a)
The cumulative fraction of surface densities for the Gould’s Belt (GB), Cores to Disks (c2d), and Orion surveys is shown to the right. Each star-forming region included in a distribution has YSOs > 10 and sufficient field of views to properly calculate stellar surface densities. The Orion survey stops at 80% for the cumulative fraction since the ONC is excluded due to completeness issues.

Field of View Biases (c)
A cumulative distribution plot can be modulated significantly by a spatial cutoff of distributed YSOs. The above plot shows how c2d’s data of ρ Ophiuchus and Gutermuth et al.’s L1688, the central density of ρ Ophiuchus, differ due to distributed YSO cutoff.

GB, c2d, & Orion (b)
The GB, c2d, and Orion surveys are combined for this cumulative distribution plot. We estimate a 65% disk fraction in the star forming regions. The vertical lines from left to right are Megeath et al., Lada & Lada, and Gutermuth et al.’s stellar density requirements for clusters. These values correspond to 10 stars, 35 stars, and 60 stars per pc², respectively (Gutermuth et al. 2009; Lada & Lada 2003; Megeath et al. 2011). The vertical lines from left to right intersect the corrected cumulative distribution curve at 73%, 51%, and 36%. As can be seen, the fraction of star formation in clusters is entirely dependent on the chosen definition.

Cores to YSO Distributions (d)
We see that the Class I & II distributions have the same profile, however they are slightly offset. This offset is due to the different duration timescales of the two classes (YSOs are thought to spend significantly less time as a Class I object than a Class II object) and dynamical evolution. Class IIs are known to be slightly more distributed than Class Is, reflecting early dynamical evolution. However, the similar distribution between these classes leads us to conclude that the distribution of surface densities observed is mainly primordial in nature. To further emphasise this, we show the distribution of protostars (objects younger than Class I objects) observed in the Perseus star forming region (Hatchell et al. 2005). Again we see the same type of distribution, suggesting that we are observing a primordial distribution.

Conclusion

The distribution of YSO Σ in the solar neighborhood is smooth and continuous and is well described by a log-normal function. By comparing the distributions of Class 0, Class I, & Class II from the literature, we conclude that the observed distribution is largely primordial in nature. The smooth and continuous distribution argues against the notion that multiple distinct modes of star-formation exist. We find that previous definitions of what constitutes a “cluster”, with respect to the “distributed” YSOs, are largely arbitrary. Clusters are not a fundamental unit of star formation.