*From Interstellar Clouds to Star-Forming Galaxies:*
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# Possible density dependent local variations in the IMF

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**Abstract.** A robust feature of turbulent fragmentation theories is a universal Salpeter like slope (2.2 -2.4), for the mass spectrum of the fragments, at the high mass end. This is so due to the scale-free nature of turbulence and gravity. There are reports of top heavy / flatter Initial Mass Functions (IMF), inferred for many regions where we expect star formation to take place in gas clouds with comparatively higher gas density. Also, a higher Star Formation Efficiency (SFE) for regions of higher gas density has been proposed, to understand the formation of bound stellar systems in which dark matter is not a significant factor affecting the internal dynamics. In turbulent fragmentation models for star formation, we do not expect the mass of the stellar cluster to influence the maximum stellar mass directly and thereby imply a relation between the maximum stellar mass and the cluster mass. However, such a relation may be expected from statistical considerations. In this context, we explore the density dependence of the IMF, that would arise due to denser clouds producing more massive clusters due to the density dependence of the SFE.

**Keywords.** stars: formation, (Galaxy:) open clusters and associations: general, galaxies: star clusters

## 1. Introduction

A robust feature of turbulent fragmentation theories is the universal, Salpeter like slope $(2.2 - 2.4)$, for the mass spectrum of the fragments, at the high mass end. This arises from the scale-free nature of turbulence and gravity (see for example Guszejnov & Hopkins (2015)). The location of the peak in the mass function is seen to be dependent on the 'sonic' mass. In nearby star forming regions, both stars as well as star forming cores are seen to have mass functions that have the same shape, though horizontally shifted by some factor. Against this background it is interesting to notice reports of top heavy / flatter mass functions inferred for many regions where we expect star formation to take place in gas clouds with comparatively higher gas density. Top heavy / flatter IMFs are reported for the central regions of stellar clusters, globular clusters and star-burst systems. Although a flatter IMF may be exhibited by clusters in which significant mass segregation has taken place, detailed analysis, involving observations and numerical methods, on some stellar clusters, indicate that, some of the mass segregation - and hence non standard IMF - found towards the central dense regions of stellar clusters could be primordial (Converse & Stahler (2010), Pang *et al.*(2013)).

(Kruijssen *et al.* (2012)) proposed a density dependence of the SFE to explain the formation of open clusters and globular clusters and this scenario accounts also for the observed relation between the efficiency of bound cluster formation and gas surface density in galaxies (for an alternative view see (Indulekha (2013))). Also large values of the SFE, close to 0.5 has been reported for nearby, dense star forming regions (Wilking Lada (1983)).

In this context we explore a possible density dependence for the IMF that may arise from a density dependent SFE.

## 2. Method

In a star forming cloud the process of star formation is found to take place in the dense dark cores embedded within the clouds. (Elmegreen (2006)) had considered a massive cluster as made up of individual contributions from sub-clusters each of which contribute stars as per the standard Salpeter IMF to the summed IMF. He had analytically as well as by simulations, explored the conditions under which the summed IMF of a massive cluster would have approximately the same slope as the individual IMFs of its sub-clusters. He had concluded that the sum will resemble the individual IMFs, if the sub-cluster mass function had a slope $\sim 2$.

Compiling observational data (Wieidner & Kroupa (2006)) had suggested a relation between $m_{max}$, the mass of the most massive star in a (embedded) stellar cluster to the mass of the whole cluster of stars $M_{ecl}$. Given that turbulence and gravity are scale-free we do not expect the maximum stellar mass to correlate with the total mass of the cluster of stars forming within a given cloud. However even when in the formation of a given stellar system, a universal IMF is randomly sampled by the star forming cores, we would expect the mass of the most massive star in a set of stars to be larger for a set whose total mass in stars is higher. Under the assumption of a density dependent SFE, the mass of the proto-stellar system, forming from a fragment with a higher density will be larger, and by the above arguments, so also will the mass of the most massive star in it be. In this context we explore the integrated IMF from a collection of cores for various values for the SFE of the cores.

With sub-clusters forming from cores with a Core Mass Function (CMF) that has the same shape as a standard Kroupa IMF, we look at the change in the gradient in the slope at the high mass end of the summed IMF, as the SFE for the cores is increased from 0.1 to 0.9. Each core is considered to be randomly sampling from a Kroupa IMF. The $m_{max}$ produced by a core of given mass is fixed using the $m_{max}$ - $M_{ecl}$ relation (Weidner & Kroupa (2006)).

## 3. Results and Discussion

When the SFE is increased from 0.1 to 0.9, the slope at the high mass end, of the summed IMF is seen to flatten by $\sim 0.36, 0.47$ and $\sim 0.5$ for CMF slope $1.15, 2.1$ and $2.35$ respectively.

From the above we see that a density dependence of the SFE can produce flatter IMFs in high density star forming regions. This has implications for the IMFs of Starburst galaxies and high redshift SMGs and thus has significant implications for the star formation history of the universe. We also notice that the above considerations resolve a paradox with respect to elliptical galaxies viz., while a bottom heavy IMF has been inferred for their central regions, Globular Clusters -which occur with a higher specific frequency in ellipticals - have a top heavy IMF. This may be resolved by noticing that while the bottom heavy IMF (in spite of the larger density in the central regions) may result from the fact that the velocity dispersion is high at the centres of elliptical galaxies (more power may be expected at smaller and smaller scales for higher and higher Mach numbers), the top heavy IMFs of the Globular clusters could arise by virtue of their formation in high density clouds with a lower velocity dispersion. We conclude that the $m_{max}$ - $M_{ecl}$ relation which is the reason for the density dependence of the IMF, as illustrated here, merits further exploration and the new as well as upcoming observational facilities will be able to reveal more about the universality / non-universality of the IMF which is a key factor in the evolution history of galaxies.

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