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FRAGMENTATION STATISTICAL MODEL RECOVERING THE IMF

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Abstract. The Initial Mass Function (IMF) of young stars is a critical statistical indicator to investigate whether star formation is a universal process within molecular clouds leaving the same stellar outcomes regardless of the physical and chemical properties of the environment. It is thought that the IMF may directly result from the Core Mass Function (CMF). We aim to introduce a statistical approach to study the evolution of a CMF towards a canonical IMF taking into account discrete multi-scale fragmentation processes. We show in particular that a top-heavy CMF may yield to a canonical IMF from specific fragmentation properties.

Keywords: Stars: statistics, Stars: mass function, Methods: statistical

1 Motivations for this work

The initial mass function of stars (IMF) in nearby clouds generally has very specific characteristics: a peak around 0.1 $M_\odot$ (Chabrier 2003) and a tail for large masses parameterised with a power law, see for example Salpeter (1955) where a -2.35 slope is given to describe the probability density function (PDF). The origin of these properties remains an open question, and it has been suggested (Motte et al. 1998) that, based on the similarities with the Clump Mass Function (CMF), the IMFs could inherit their properties from the latter. In this work we try to relate the mass distribution of large-scale cores (Pouteau et al. 2022) to the canonical IMF of stars by assessing the effect of a hierarchical fragmentation of cores and by extension gas clumps. This fragmentation process is assumed to be discrete and we seek to assess the influence of multi-scale fragmentation on the shape of the IMF. We test this discretised approach in a gravo-turbulent (Hennebelle et al. 2019) framework characterised by scale-free processes.

2 General modelisation

We propose the following modelisation to study the scaling evolution of the mass function (MF) of massive objects that contain the seeds of star formation. We discretise spatial sizes into several levels of scale l, which contain a population of fragments. Each of these scales is associated with a multiplicity model P_l and a mass repartition model M_l (see left Fig.1). The multiplicity model represents the number of fragments produced between the previous $l-1$ and the current scale l with their respective probabilities whereas the a mass model gives the proportion of mass transferred from a parental object to each of its children considering the number of fragments produced. The starting MF goes through all the possibilities that are defined by P_l with a weight before allocating the mass of the new fragments with respect to M_l. The output gives the MF of the objects produced that we can re-inject as an output for the next level.

3 Application on a scale-free model

Starting from the principle that there is no dominant scale in the gravo-turbulent framework, and based on our previous accepted work Thomasson et al. (2022) in which we found a hierarchical fragmentation starting at 13 kAU in NGC 2264, we chose to apply a scale-free model within the [13 kAU - 810 AU] range with four levels of scale and a scaling ratio of ∼2. For each level, an object fragments into one or two objects with respective

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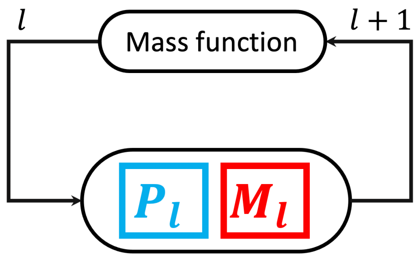
probabilities 0.56 and 0.44 Thomasson et al. (2022). The mass available for the fragments formation is assumed to be governed by a constant mass transfer per unit of level $\epsilon_m = 0.4$ such that we can retrieve the mass interval of the IMF. This means that fragments at level l have to share a mass reservoir made up of 40% of their parental mass. We introduce a mass hierarchy between the fragments: in the case of multiple fragments created, a dominant fragment receives 2/3 (Pouteau et al. 2022; Busquet et al. 2016) of the reservoir while the other one is left with 1/3. In this case for example, the dominant inherits $\epsilon_m^+ = 0.4 \times 2/3$ and the other inherits $\epsilon_m^- = 0.4 \times 1/3$ of its parental mass. As an initial MF, we use a power-law PDF characterised by a -1.9 index (Motte et al. 2018). Because we start at the scale of clumps which is larger than cores, we assume a 10-1000 $M_\odot$ range. The final MF is compared with a continuous log-logistic function from Maschberger (2012) that characterise well the canonical IMF. The resulting MF (see right Fig.1) is derived from all the possible outcome from the first level to the last level of the fragmentation which are all the possible case of the multiplicity model weighted by their probabilities. Combining all these possible cases we obtain a PDF can be compared with the canonical IMF. With this model we retrieve the Salpeter IMF for large masses because of a 'sawtooth' effect. This effect is due to the upper boundary of the initial CMF that is a powerlaw cutted at 1000 $M_\odot$.



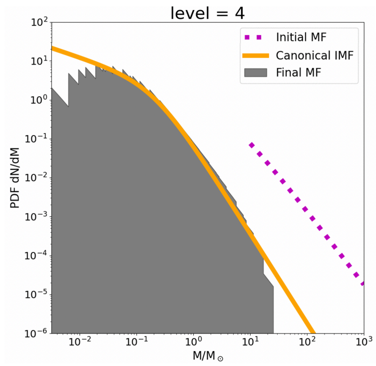


Fig. 1. Left: Procedural computation of the final mass function using a multiplicity model P_l that define the probability to form a specific amount of fragments, and a mass transfer model M_l that distribute the mass of the parent among its children. **Right:** The resulting mass function using the model parameters presented in Sect. 3.

4 Implications of this work

We showed that the final MF may have a steeper slope compared with the initial MF slope provided that there exists an upper mass cut-off in the CMF. In order to retrieve the canonical IMF, it can physically imply at least one of the following. The fragmentation of mass clumps is inhibited above an upper mass threshold, or fragmentation process is not monofractal as in this work, or fragmentation is not sufficient to be used as a direct link between CMF and the IMF. The next step of this work would be to statistically quantify the proximity between the two PDFs such that we can systematically investigate the most likely fragmentation properties from any observable CMF, or finite samples (Thomasson et al. in prep.).

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