A consistent explanation for the unusual initial mass function and star formation rate in the Central Molecular Zone

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Abstract

We investigate various physical processes that may explain the shallow high-mass slope of the Initial Mass Function (IMF) as well as the low Star Formation Rate (SFR) in star-forming molecular clouds (MCs) in the Central Molecular Zone (CMZ). We show that the strong tidal field and the shear experienced by the CMZ have opposite effects on the collapse of density fluctuations and cannot explain these unusual properties. Similarly, the intense magnetic field in the CMZ provides only a negligible pressure support. For the high densities involved, it should not modify the probability density function of the turbulent gas flow in the clouds, and thus have a negligible effect on the slope of the IMF.

However, we show that, unlike MCs in the Galactic disk, the ones in the CMZ experience only one single episode of turbulence injection at large scale during their lifetime, most likely due to the SN explosion of their most massive stars. Indeed, the short lifetime of the MCs in the CMZ, due to their high mean densities, is similar to one typical turbulent crossing time. Consequently, according to the Hennebelle-Chabrier (HC) theory of star formation, within this 'single turbulent episode' scenario, the cloud experiences one single field of turbulence induced density fluctuations. These density fluctuations eventually lead to gravitationally unstable prestellar cores. This results in an IMF that is flatter than usual and leads to the correct observed slope for the CMZ star-forming clouds. Similarly, this single large scale turbulent event within the cloud lifetime yields an SFR 5 to 6 lower than under usual Milky-way cloud conditions, again in agreement with the observed values (Chabrier & Dumond, 2024). Therefore, we suggest that this 'single large scale turbulence injection' episode can explain both the shallow IMF high-mass slope and the low SFR of clouds in the CMZ.

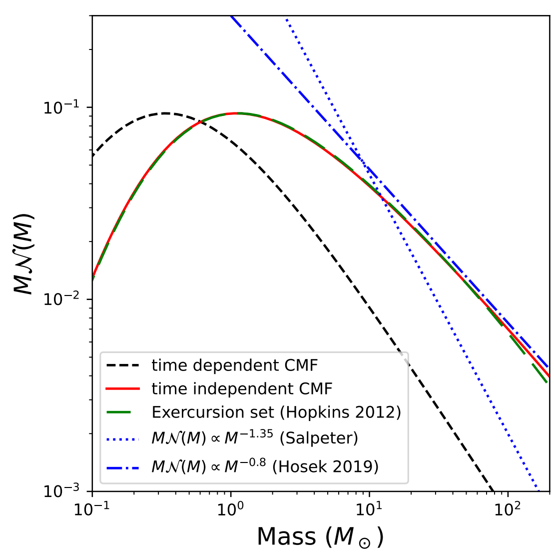

Figure 1: Initial mass function $M\mathcal{N}$ calculated with the time-dependent (short dashed line) and time-independent (red solid line) Hennebelle-Chabrier theory for typical CMZ parameters. Long dashed line: time independent IMF calculated with the excursion set formalism. Dotted line: Salpeter IMF; dash-dot line: high mass slope of the IMF observed for the Arches cluster (Chabrier & Dumond, 2024).