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Star formation efficiency of magnetized, turbulent and rotating molecular cloud

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Abstract. The formation of stars constitutes one of the basic problems in astrophysics. Understanding star formation efficiency of molecular clouds (MCs) of a galaxy is necessary for studying the galactic evolution. Present data and theoretical formulations show that the structure and dynamics of the interstellar medium (ISM) are extremely complex. Therefore, there is no simple model that can explain adequately the star formation efficiency of MCs because of its complex nature. The initial mass of the cloud needed for collapse varies based on the environment in which the cloud resides and the strength of its magnetic field, turbulence, as well as the speed of rotation. In this paper, we estimate the star formation efficiency by combining pre-determined models and the critical mass formulated by Kumssa & Tessema (2018).

Keywords. Stars, star formation, critical mass

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1. Introduction

Understanding star formation efficiency of molecular clouds (MCs) of a galaxy is important for studying the galactic evolution as well as to build a comprehensive theory of star formation. Moreover, Star formation lies at the center of the processes that drive synthesis of elements, formation of planets, and development of life (Krumholz 2014). Due to the complexity of Galactic interstellar medium (ISM) structure and dynamics, either predicting or explaining the star formation efficiency (SFE) of MCs is not an easy task. Therefore, finding SFE and the mass of the star formed from the collapsing cloud using the critical mass, different time scales will provide an additional knowledge on how currently evolving MCs can be converted to stars. The purpose of this study is to theoretically calculate the stellar mass and SFE of magnetized, turbulent and rotating MC.

2. Critical mass and stellar mass

The critical mass theoretically modeled by Kumssa & Tessema (2018) is:

$$M_{crt} = \frac{5R_{core}}{G}\left(\frac{P_g(\rho_{core})}{\rho_{core}} + \sigma_r^2\right)\frac{10R_{core}^3}{3G}c_{rot}\Omega_{core}^2 + \frac{5B_o^2R_o^4}{4\pi G\rho_{core}R_{core}^3}\left(\frac{1}{3} - \frac{1}{2\pi R_{core}^2}\right) \tag{2.1}$$

The analytic model developed by Burkert, A. and Hartmann (2013) is:

$$M_\star(\tau) = M_{crt,0}(\tau = 0)\left(1 - e^{-\epsilon\tau}\right) + \dot{M}_{in}t_{ff}\left[\tau - \left(1 - e^{-\epsilon\tau}\right)/\epsilon\right] \tag{2.2}$$

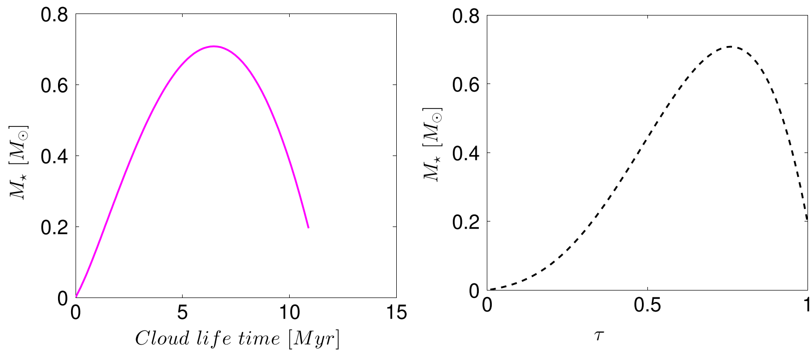

Figure 1. The left panel shows MC life-time (t) versus the stellar mass, while the right panel shows t/t_{ff} versus stellar mass, where $\epsilon = 0.1$, $R_c = 0.01$pc, $\dot{M}_{in} = 10^{-5} - 10^{-7} M_\odot yr^{-1}$, $\tau =$ 0.1–10. $B_o \Rightarrow 0$, $M_{crt} = 1.502 M_\odot$, $R_{core} = 0.01$pc, and $t_{ff} \sim 10^6 - 10^{7.04} yr$.

3. Results

Using analytic stellar mass model described in previous section we define stellar mass as:

$$M_\star = \frac{5R_{core}}{G}\left(\frac{P_g(\rho_{core})}{\rho_{core}} + \sigma_r^2\right)\frac{10R_{core}^3}{3G}c_{rot}\Omega_{core}^2 + \frac{5B_o^2R_o^4}{4\pi G\rho_{core}R_{core}^3}\left(\frac{1}{3} - \frac{1}{2\pi R_{core}^2}\right)(\tau = 0)\left(1 - e^{-\epsilon\tau}\right) + \dot{M}_{in}t_{ff}\left[\tau - \left(1 - e^{-\epsilon\tau}\right)/\epsilon\right] \tag{3.1}$$

The time scale is defined as $\tau = t/t_{ff}$, where t is the life-time of MC, t_{ff} is its free-fall time, while ϵ is its star formation efficiency. Recent studies showed that average values of the magnetic field of MC is ≈ 5-15 μG, while the angular speed of MC is approximately $10^{-15}s^{-1}$ - $10^{-13}s^{-1}$ (Beck 2001; Crutcher *et al.* 2010). In this work we used these values.

4. Summary

By setting SFE $\simeq \frac{M_\star}{M_{crt}}$, we obtained the maximum SFE of ∼ 0.6223 and the minimum of ∼ 0.0233. When life time of the cloud is almost approaching to its local free-fall time we get the maximum SFE ∼ of 0.4660, while if the life time is shorter than t_{ff} SFE is ∼ 0.

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