

A universal, turbulence-regulated, multi-freefall star formation law

Christoph Federrath, Diane M. Salim and Lisa J. Kewley

Research School of Astronomy and Astrophysics,
The Australian National University, Canberra, ACT 2611, Australia
email: christoph.federrath@anu.edu.au

Abstract. We develop a new star formation (SF) law based on the density PDF of turbulence and on the multi-freefall concept of gas collapse. We derive a relation where the star formation rate (SFR) correlates with the molecular gas mass per multi-freefall time, whereas previous models had used the average, single-freefall time. We define a new quantity called *maximum (multi-freefall) gas consumption rate* (MGCR) and show that the actual SFR is only about 0.4% of this maximum possible SFR, confirming the observed low efficiency of star formation.

Keywords. galaxies: high-redshift — galaxies: ISM — galaxies: starburst — stars: formation

The rate of star formation controls a galaxy's fundamental properties and evolution (Padoan *et al.* 2014). Nonetheless, the functional dependence of the column density of star formation (Σ_{SFR}) is still one of the most debated topics in astrophysics, with historical parameterizations including the mean column density of gas (Σ_{gas}) (Kennicutt & Evans 2012), as well as the ratio between Σ_{gas} and the average freefall time t_{ff} (Krumholz *et al.* 2012; Federrath 2013; Krumholz 2014).

Significant scatter remains in both these approaches, such that Σ_{SFR} can vary by more than an order of magnitude for any given Σ_{gas} or $\Sigma_{\text{gas}}/t_{\text{ff}}$. Here (published in Salim *et al.* 2015), we improve the single-freefall law by the multi-freefall concept of gas collapse, taking into account the density PDF (Hennebelle & Chabrier 2011; Federrath & Klessen 2012). We find

$$\Sigma_{\text{SFR}} = 0.4\% \times \text{MGCR} = 0.4\% \times \Sigma_{\text{gas}}/t_{\text{ff}} \times \left(1 + b^2 \mathcal{M}^2 \frac{\beta}{\beta+1}\right)^{3/8},$$

where \mathcal{M} is the Mach number, $1/3 \leq b \leq 1$ is the turbulence driving parameter (Federrath *et al.* 2008; 2010) and β is the ratio of thermal to magnetic pressure. Our new SF law implies that SF is inefficient with the SFR reaching only 0.4% of the MGCR. In Salim *et al.* (2015) we show that this new SF law provides superior fits to Milky Way and extragalactic data compared to any previous SF law.

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