Fragmenting Filaments in Simulations

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Abstract

In the last years, many studies have indicated that filamentary structures are omnipresent in star-forming molecular clouds. Still, it is debated whether filaments are essential stages in this process by fragmenting into pre-stellar cores. We address this question by investigating the evolution of filaments that formed within 3D FLASH AMR simulations of a self-gravitating, magnetised, supernova-driven ISM, and the criteria that lead to their fragmentation. We discuss the results in context of the underlying physics of the simulations.

Scientific Context

Filaments have been actively investigated for years, especially since remarkably high quality data, e. g. by *Herschel*, are available. Most studies, in both observation and theory, have focused on the formation, morphology, and stability of filaments. Recently, other key questions have come into the focus of investigations, namely: What leads to the fragmentation of filaments? And how do the fragments condensate into pre-stellar cores?

In our study, we target those questions by examining the 3D properties and time evolution of the filaments that have formed in simulated molecular clouds and compare their fragmentation behaviour with theoretical predictions.

Models & Methods

- three molecular clouds from 3D FLASH AMR simulations of self-gravitating, magnetised, SN-driven ISM by Ibañez-Mejía et al. (2016)
- total mass of clouds: (`M3e3`:) 3,000, (`M4e3`:) 4,000, and (`M8e3`:) 8,000 $M_\odot$
- following evolution for up to 6 Myr
- column density maps produced by projecting volume density cubes along the three major axes
- filaments identified with `DisPerSe` (Sousbie, 2011) and fragments with `astrodendro` (`http://dendrograms.readthedocs.io`)
- evolution of filaments' line masses compared with theoretically predicted critical line masses $M_{\rm lin}^{\rm crit} = 16.6 \frac{T}{10K} M_\odot\,{\rm pc}^{-1}$ (assuming an isothermal, homogeneous, infinitely long, isolated cylinder following Ostriker, 1964)

Filaments in 3D & 2D

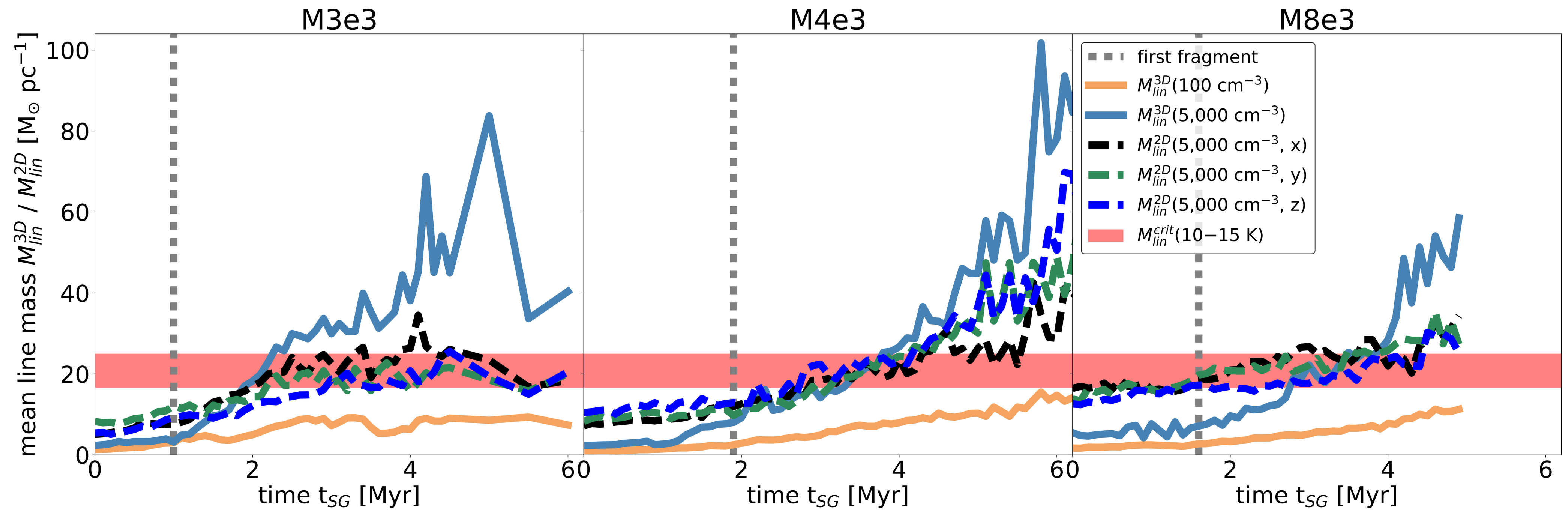

Figure 1. Average line masses of 3D (solid lines) and 2D filaments (dashed lines) as functions of time for `M3e3` (*left*), `M4e3` (*middle*), and `M8e3` (*right*). The grey dashed line mark the times when the first fragments have been detected. The red area illustrate the critical line masses of an isothermal cylinder with temperatures between 10 and 15 K.

- structures and properties of filaments strongly depend on the identification threshold, $n_{\rm thres}$, used to identify them, and on whether they have been detected in 3D or 2D
- both $M_{\rm lin}^{\rm 3D}$ and $M_{\rm lin}^{\rm 2D}$ increase with time, but do not correlate with each other
- first fragmentation occurs within 15 – 50% of clouds' free-fall time while filaments are still sub-critical compared to $M_{\rm lin}^{\rm crit}$
- all 3D filaments have counterparts in 2D, but not necessarily all 2D filaments have counterparts in 3D traced with the same $n_{\rm thres}$

Dense gas in 3D & 2D

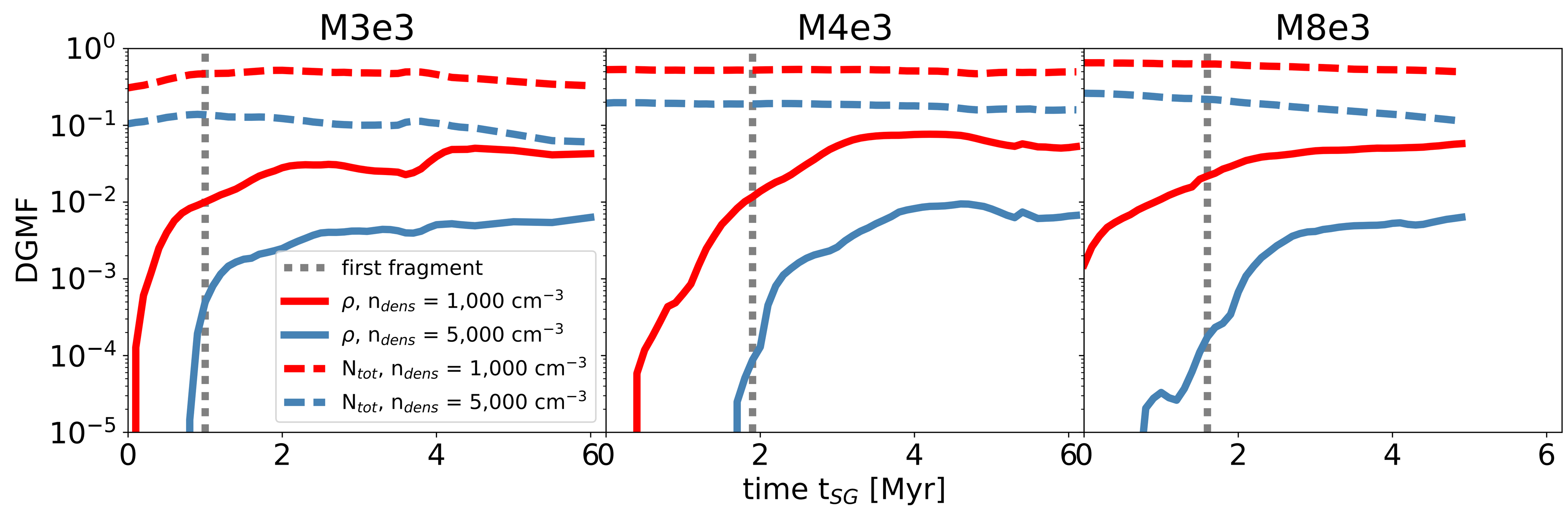

Figure 2. The dense gas mass fraction, DGMF, as functions of time within `M3e3` (*left*), `M4e3` (*middle*), and `M8e3` (*right*). Thereby, the red lines illustrate the evolution of the DGMF defining gas to be dense when the number density increases above $n_{\rm dens}$ = 1,000 cm^{-3}, the blue lines do so with $n_{\rm dens}$ = 5,000 cm^{-3}. The solid lines represent the values measured based on the 3D volume density distribution, the dashed lines those based on the 2D column density maps.

- measured in 3D, DGMF initially increases rapidly due to global, self-gravity-driven collapse motions
- compression stagnates after first few Myr, although the clouds are still collapsing
- measured in 2D, DGMF is almost constant over time, or slightly decreasing, and more than one order of magnitude higher than the maximal 3D DGMF

Take Home Messages

- $M_{\rm lin}^{\rm crit}$ is just a guiding quantity for estimating the stability of filaments, but is no imperative criterion for their fragmentation

  → fragmentation requires more than imbalance between gravity and thermal pressure
- given a certain $n_{\rm thres}$, 3D filaments always have counterparts in 2D, but not necessarily vice versa
- the DGMF does not trace collapse motions within the clouds over all times, neither in 3D nor in 2D

Future Work

- Are the structures virialised and how do they evolve in time?
- Is the fragmentation connected to the velocity patterns within the filaments?
- Is there a typical length scale along which fragments form?

For more details...

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