Mem. S.A.It. Vol. 88, 726

Memorie della

Fragmenting filaments in simulations

R.-A. Chira[1,2], J. Kainulainen[1], J. C. Ibáñez-Mejía[3,4], Th. Henning[1], and M.-M. Mac Low[5,6]

[1] Max-Planck-Institut für Astronomie, Königstuhl 17, 69117 Heidelberg, Germany
e-mail: `rox.chira@gmail.com`
[2] ESO, Karl-Schwarzschild-Str. 2, 85748 Garching bei München, Germany
[3] I. Physikalisches Institut, Universität zu Köln, Zülpicher Strae 77, 50937 Köln, Germany
[4] Max-Planck-Institut für Extraterrestrische Physik, Giessenbachstrasse 1, 85748 Garching, Germany
[5] Dept. of Astrophysics, American Museum of Natural History, 79th St. at Central Park West, New York, NY 10024, USA
[6] Institut für Theoretische Astrophysik, ZAH/Universität Heidelberg, Albert-Ueberle-Str. 2, 69120 Heidelberg, Germany

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, SN-driven ISM, and the criteria that lead to their fragmentation. We discuss the results in context of the underlying physics of the simulations.

1. Introduction

We study three molecular clouds, with masses of 3,000, 4,000, and 8,000 $M_\odot$ (`M3e3`, `M4e3`, and `M8e3`, hereafter), that have formed within the 3D FLASH AMR simulations of a self-gravitating, magnetised, SN-driven ISM by Ibañez-Mejía et al. (2016). We follow their evolution for up to 6 Myr from the time self-gravity has been set on. We identify filaments within the clouds with `DisPerSe` (Sousbie 2011), using identification thresholds at $n_{\rm thres}$ = 100 cm^{-3} and 5,000 cm^{-3}. We apply `DisPerSe` on both the original volume density cubes (hereafter, 3D filaments) and column density maps (hereafter, 2D filaments) that are produced by projecting. For tracing the forming fragments we use `astrodendro` (`http://dendrograms.readthedocs.io`). We compare the line masses of the filaments with theoretical critical line masses $M_{\rm lin}^{\rm crit} = 16.6 \,\frac{T}{10K}\, M_\odot\, {\rm pc}^{-1}$, with T being the gas temperature and assuming that the filaments can be described as isothermal, infinitely long, isolated cylinders (Ostriker 1964).

2. Results

A more detailed description and discussion of these results are given in Chira et al. (prep).

<u>Filaments in 3D & 2D</u>

We study the properties and time evolution of the 3D and 2D filaments and summarise the results: (i) the filament properties strongly depend on $n_{\rm thres}$ and on whether the filaments

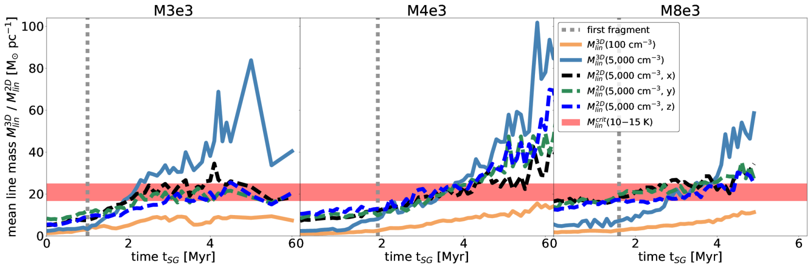

Fig. 1. Time evolution of average M_{lin} of 3D (solid lines) and 2D filaments (dashed lines) for the three clouds. The grey dashed lines mark when the first fragments have been detected, the red area does so for $M_{\mathrm{lin}}^{\mathrm{crit}}(10\text{–}15\ \mathrm{K})$.

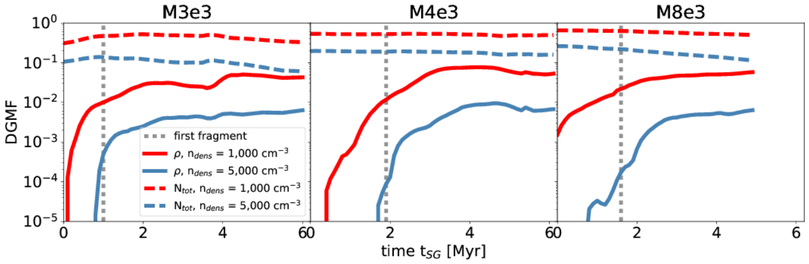

Fig. 2. Time evolution of DGMF within the clouds. Red lines illustrate the evolution when n_{dens} = 1,000 cm^{-3}, blue lines do so with n_{dens} = 5,000 cm^{-3}. Solid lines represent the values measured based on the 3D density distribution, the dashed lines based on the 2D density maps.

have been detected in 3D or 2D; (ii) $M_{\mathrm{lin}}^{\mathrm{3D/2D}}$ (see Fig. 1) increase with time, but do not correlate with each other; (iii) fragmentation occurs while filament is still sub-critical; thus, *$M_{\mathrm{lin}}^{\mathrm{crit}}$ is just a guiding quantity for estimating the stability of filaments, but is no imperative criterion for their fragmentation*; (iv) *for a given n_{thres}, 3D filaments always have counterparts in 2D, but not necessarily vice versa.*

Dense gas mass fraction

We measure the dense gas mass fraction, $\mathrm{DGMF}(\mathrm{n_{dens}}) = \int_{\mathrm{n_{dens}}}^{\infty} p(\mathrm{n})\,\mathrm{dn} \,/ \int_{100\ \mathrm{cm}^{-3}}^{\infty} p(\mathrm{n})\,\mathrm{dn}$ (Kainulainen et al. 2011), within the clouds, with $\mathrm{n_{dens}}$ being the number density above which the gas is defined as dense, and $p(\mathrm{n})$ the probability density function of number density. Fig. 2 shows that the 3D DGMF initially increases rapidly due to global, self-gravity-driven collapse motions, but stagnates after the first few Myr, although the clouds are still collapsing. Contrary, the 2D DGMF is almost constant over time and more than an order of magnitude higher than the respective 3D DGMF. *In summary, the DGMF does not trace collapse motions of molecular clouds or the line mass growth of filaments over all times, neither in 3D nor in 2D.*

Acknowledgements. R-AC acknowledges the support ESO's Studentship Programme provided. This project has received funding from the EU's Horizon 2020 research and innovation programme under grant agreement No 639459 (PROMISE). JCI-M and M-MML received support from US NSF grant AST11-09395. M-MML also thanks the A. von Humboldt-Stiftung for support.

References

Ibañez-Mejía, J. C., et al. 2016, ApJ, 824, 41
Kainulainen, J., Federrath, C., Henning, T. 2013, A&A, 553, L8
Ostriker, J. 1964, ApJ, 140, 1529
Sousbie, T. 2011, MNRAS, 414, 350