Fragmentation of accreting filaments

Seamus Clarke

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School of Physics and Astronomy, Cardiff University

Introduction

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Previous work studying fragmentation has studied **equilibrium** filaments.

This work found a preferential fragmentation scale, $\sim$ 4 times the filament diameter.

But is equilibrium really a good assumption to make?

Here I present results from numerical simulations of initially sub-critical perturbed accreting filaments.

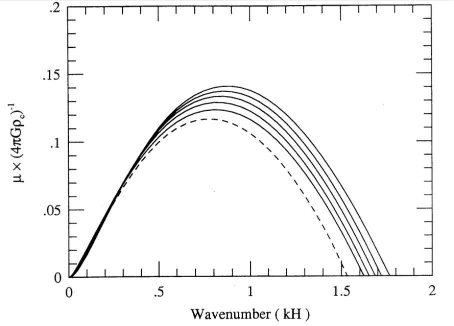


Figure 4 in Inutsuka & Miyama 1992

Setup

The simulations were performed using the Smoothed Particle Hydrodynamics code GANDALF (Hubber & Rosotti 2016).

A cylindrical settled glass of particles is stretched such that a reproduces the density profile,

$$\rho(r,z) = \frac{\rho_{\rm O}\, r_{\rm O}}{r}\left(1 + A\sin\frac{2\pi z}{\lambda}\right), \tag{1}$$

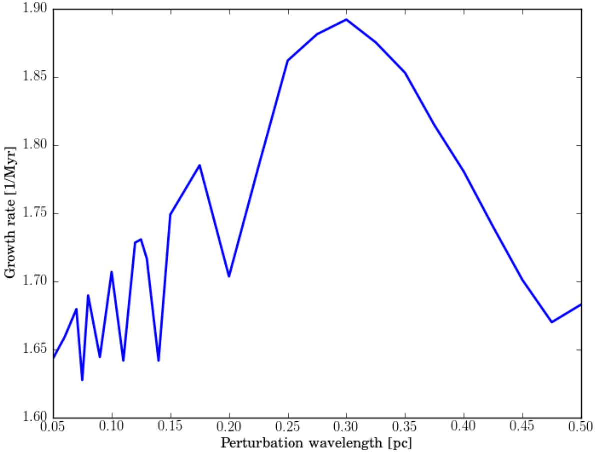
and is given the initial velocity field

$$\underline{v} = -v_{\rm O}\,\hat{\underline{r}}. \tag{2}$$

When the simulation starts, an accretion shock forms on the z-axis and then propagates outwards; the filament is the dense material inside the shock.

Results

Dispersion relation



There exists a series of peaks in the dispersion.

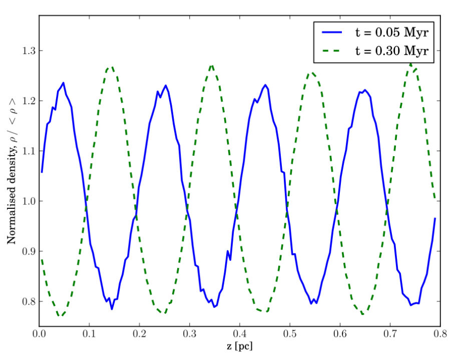
No longer a single maximum.

Longitudinal motions

The density perturbations set up gravo-acoustic oscillations along the longitudinal axis of the filament.

They oscillate with a period of

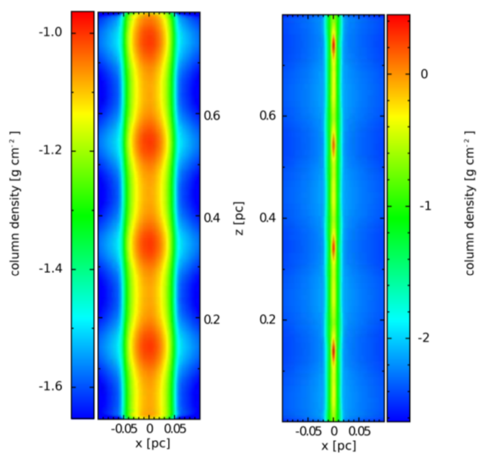
$$\tau_{\rm OSC} = \frac{\lambda}{a_{\rm O}} \qquad (3)$$



Radial motions

The continual accretion flow causes the filament to become supercritical and radially collapse on a timescale

$$\tau_{\rm CRIT} = \frac{\mu_{\rm CRIT}}{\dot{\mu}} \qquad (4)$$



In phase or out of phase

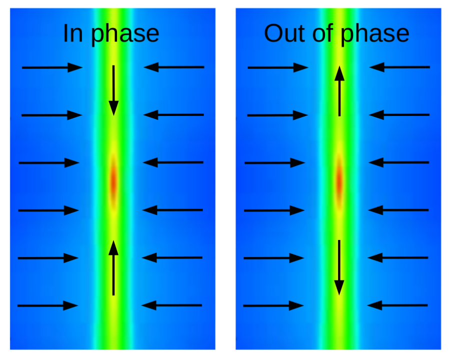
In phase they act to amplify each other and lead to higher growth rates.

Out of phase, they act against each other and cause dips in the growth rate.

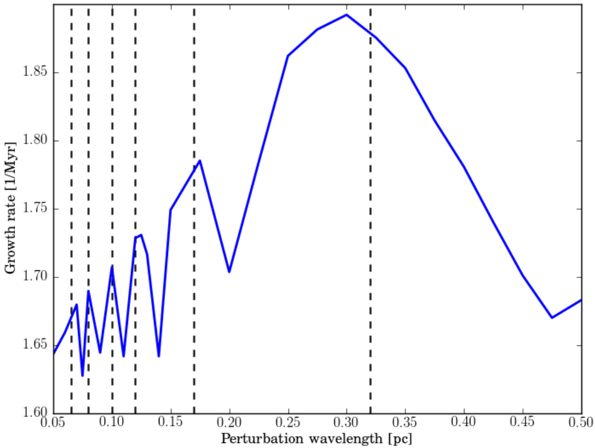
The two are in phase when,

$$\tau_{\text{CRIT}} \sim \frac{n\tau_{\text{OSC}}}{2} \tag{5}$$

$$\lambda_{\text{PEAK}} \sim \frac{2\tau_{\text{CRIT}}\, a_{\text{O}}}{n} \tag{6}$$



Dispersion relation



The dispersion relation shows peaks at 0.33, 0.17, 0.11, . . .
corresponding to n = 1, 2, 3, . . .

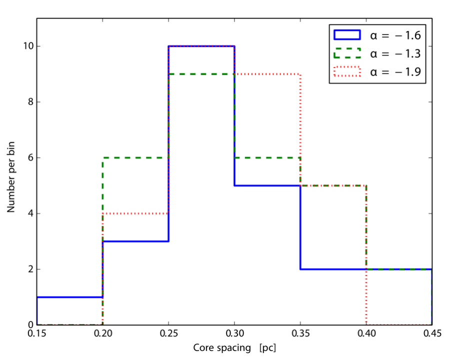
Multi-wavelength perturbations

When a filament is seeded with multi-wavelength perturbations, described by the power spectrum found by Roy et al. 2015

$$P(k) \propto k^{-1.6\pm0.3}, \quad (7)$$

there exists a preferential fragmentation scale.

This fragmentation length scale corresponds to the n=1 peak in the dispersion relation.



Application to observations

This work allows observers to place a lower limit on the age of filament which is fragmenting quasi-periodically by measuring the core separation.

$$\tau_{\mathrm{AGE}} \;\geq\; \tau_{\mathrm{CRIT}} \;\sim\; \frac{\lambda_{CORE}}{2a_{\mathrm{O}}} \tag{8}$$

One can also estimate the average accretion rate onto the filament

$$\dot{\mu} \;\sim\; \frac{\mu_{\mathrm{CRIT}}}{\tau_{\mathrm{CRIT}}} \;\sim\; \frac{2a_{\mathrm{O}}\,\mu_{\mathrm{CRIT}}}{\lambda_{CORE}} \tag{9}$$

Taurus

Tafalla & Hacar (2015) find a significant level of clustering on scales less than 0.5 pc, peaking at 0.2 pc, in the sub-filaments making up the L1495/B213 complex

This work suggest that these filaments are at least 0.5 Myrs old.

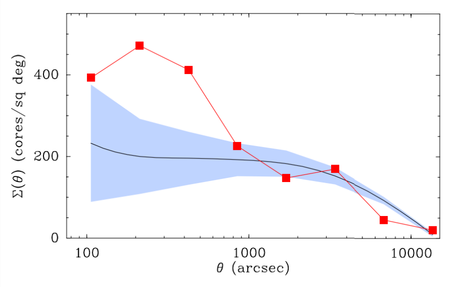
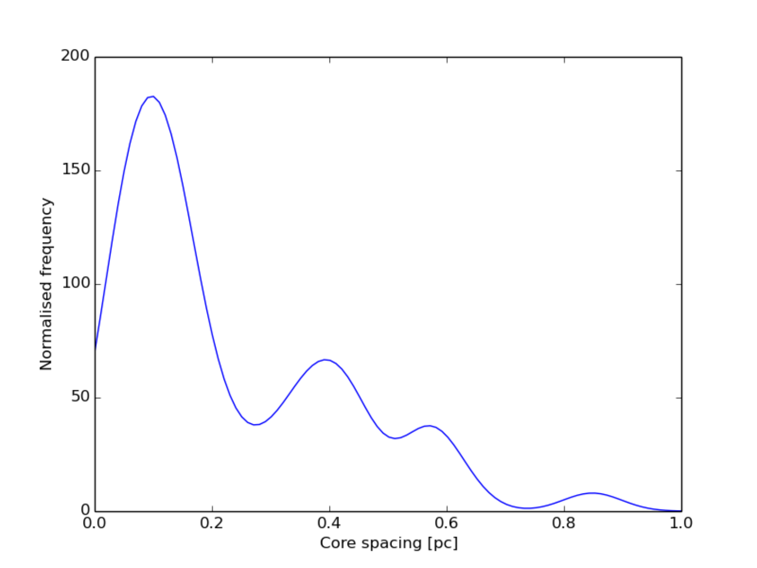


Figure 3 from Tafalla & Hacar (2015)

Furthermore, they experience an accretion rate of $\sim 32\ \mathrm{M_\odot\,pc^{-1}\,Myr^{-1}}$

Palmeirim et al. (2013) infer an accretion rate between $27 - 50\ \mathrm{M_\odot\,pc^{-1}\,Myr^{-1}}$

Preliminary results



Conclusion

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- Theories of filamentary fragmentation must go beyond the ideal equilibrium case
- Gravo-acoustic oscillations determine the most unstable mode.

$$\lambda_{\mathrm{DOM}} \sim 2\tau_{\mathrm{CRIT}} a_{\mathrm{O}} \tag{10}$$

- One can determine the age of a filament and its accretion rate using core spacings.
- Turbulence causes further fragmentation. The larger scale is consistent with the dispersion relation, the smaller scale consistent with the Jeans length.