Fragmentation of accreting filaments

Seamus Clarke, Anthony Whitworth & David Hubber

School of Physics and Astronomy, Cardiff University

Introduction

Previous work on filamentary fragmentation has focused on equilibrium filaments (Inutsuka & Miyama 1992; Freundlich et al. 2014). However, it is unlikely that a filament forms, stops accreting, relaxes to equilibrium, and only then fragments.

Here we present numerical simulations studying the co-evolution of filaments and perturbations during the non-equilibrium accreting stage.

Results

We find a dispersion relation linking perturbation wavelength and perturbation growth rate significantly different to that found for equilibrium filaments (Figure 1).

When a filament is seeded with multi-wavelength perturbations, described by the power spectrum found by Roy et al. 2015, there is a preferential fragmentation scale (Figure 2).

Radial and longitudinal motions

Density perturbations set up gravo-acoustic oscillations along the longitudinal axis of the filament (Figure 3). They oscillate with a period of

$$\tau_{OSC} = \frac{\lambda}{a_O},$$

where a_O is the isothermal sound speed. The accretion flow causes the filament to become supercritical and radially collapse on a timescale

$$\tau_{CRIT} \sim \frac{\mu_{CRIT}}{\dot{\mu}}$$

The radial and longitudinal motions can be in phase, or out of phase. In phase they amplify each other and lead to higher growth rates. Out of phase, the diverging longitudinal motions act against the converging radial motion and lower growth rate (Figure 4). For the two to be in phase

$$\tau_{CRIT} \sim \frac{n\,\tau_{OSC}}{2}$$

$$\lambda_{PEAK} \sim \frac{2\,\tau_{CRIT}\,a_O}{n}$$

Application to observations

The preferential fragmentation length seen in figure 2 occurs when n=1. This allows one to place a lower age limit on a filament which is fragmenting quasi-periodically by measuring the mean core separation

$$\tau_{AGE} \geq \tau_{CRIT} \sim \frac{\lambda_{CORE}}{2\,a_O}$$

One can also estimate the average accretion rate onto the filament

$$\dot{\mu} \sim \frac{\mu_{CRIT}}{\tau_{CRIT}} \sim \frac{2\,a_O\,\mu_{CRIT}}{\lambda_{CORE}}$$

Tafalla & Hacar (2015) find a preferential core separation of ~ 0.2 pc in the L1495/B213 complex in Taurus. This suggests that these filament are at least 0.53 Myrs old. Furthermore, they experienced an accretion rate ~ 32 M_{SUN} pc^{-1} Myr^{-1}, in excellent agreement with the accretion rate inferred from observations by Palmeirim et al. (2013), 27 – 50 M_{SUN} pc^{-1} Myr^{-1}.

Feel free to take a paper

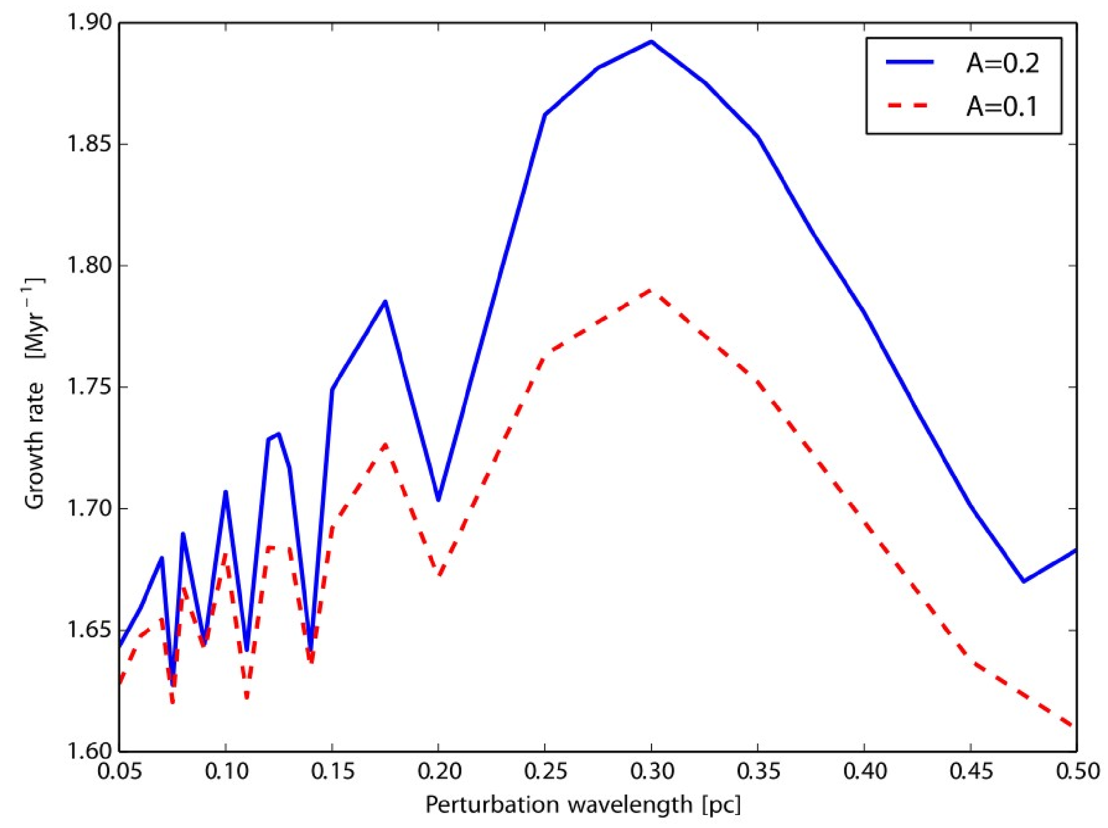

Figure 1. The dispersion relation linking perturbation wavelength and perturbation growth rate. Note the series of peaks and the absence of a single local maximum.

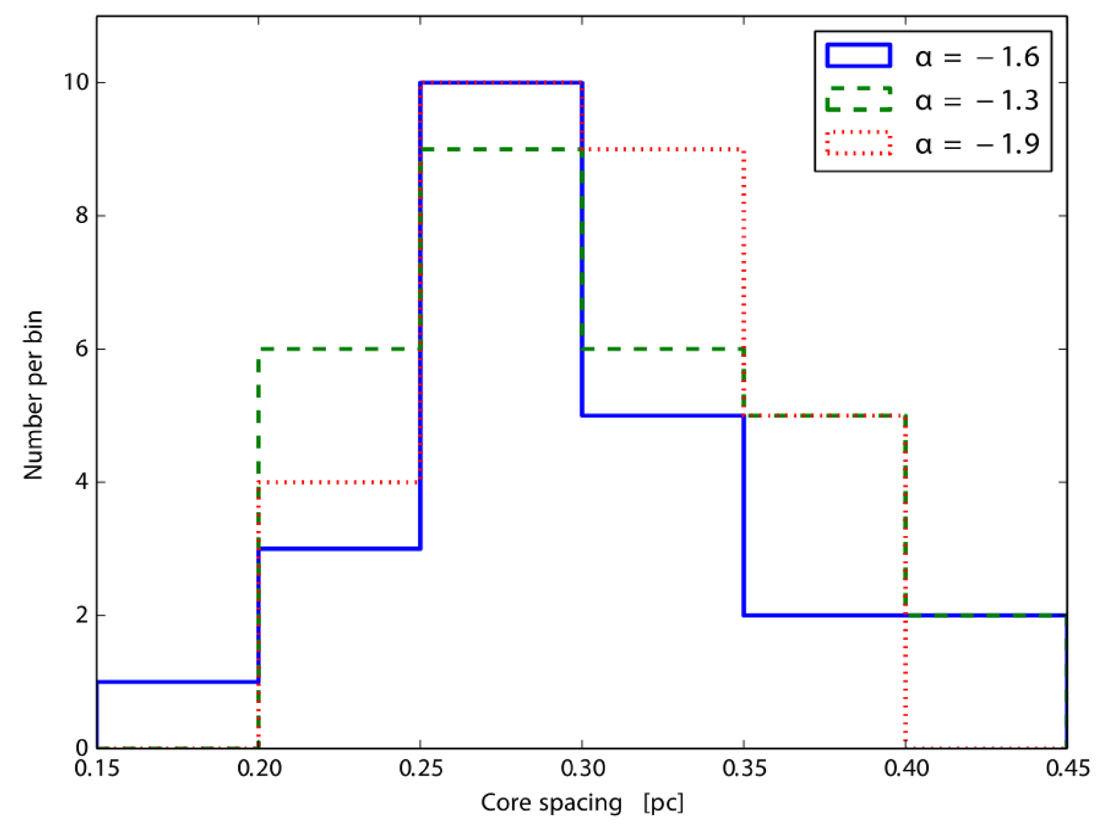

Figure 2. A histogram showing the frequency of core separation distances from a set of 30 multi-wavelength perturbation simulations. There exists a preferential fragmentation length scale of ~ 0.3 pc.

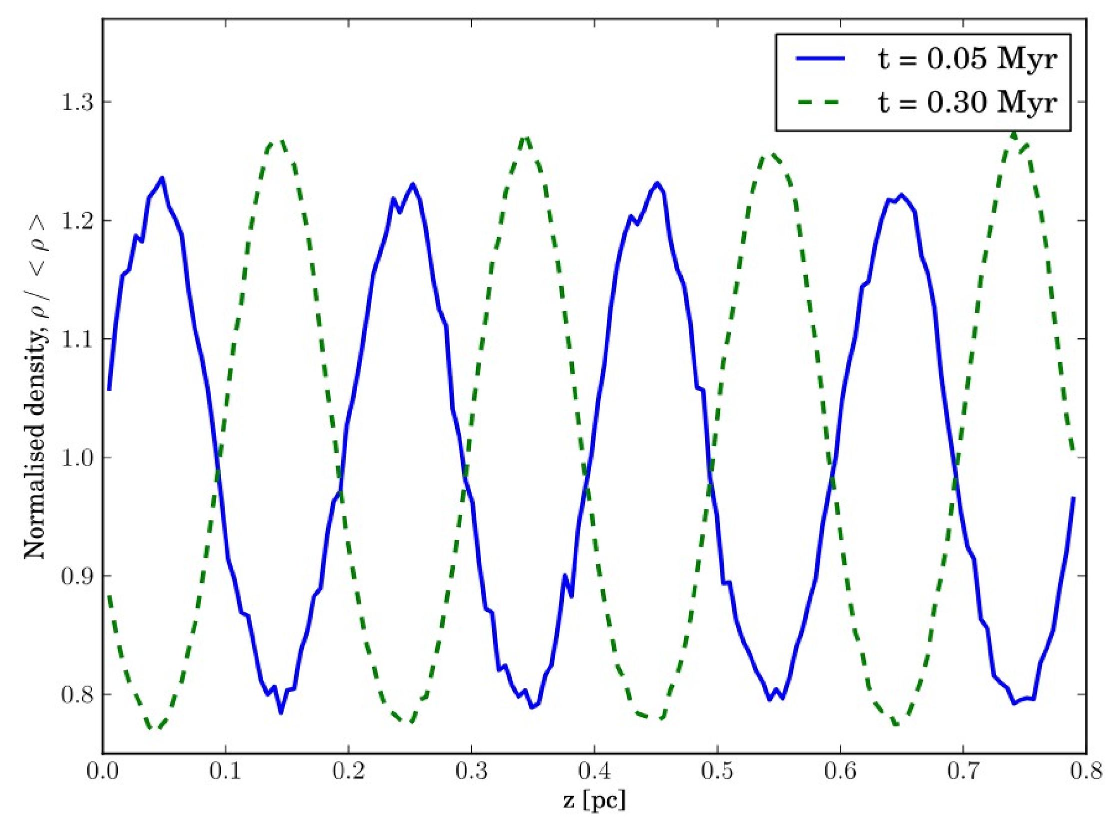

Figure 3. The normalised volume-density profile along the z-axis for a filament at two different times. A standing gravo-acoustic wave is set up along the filament's length and oscillates with a period λ / a_O

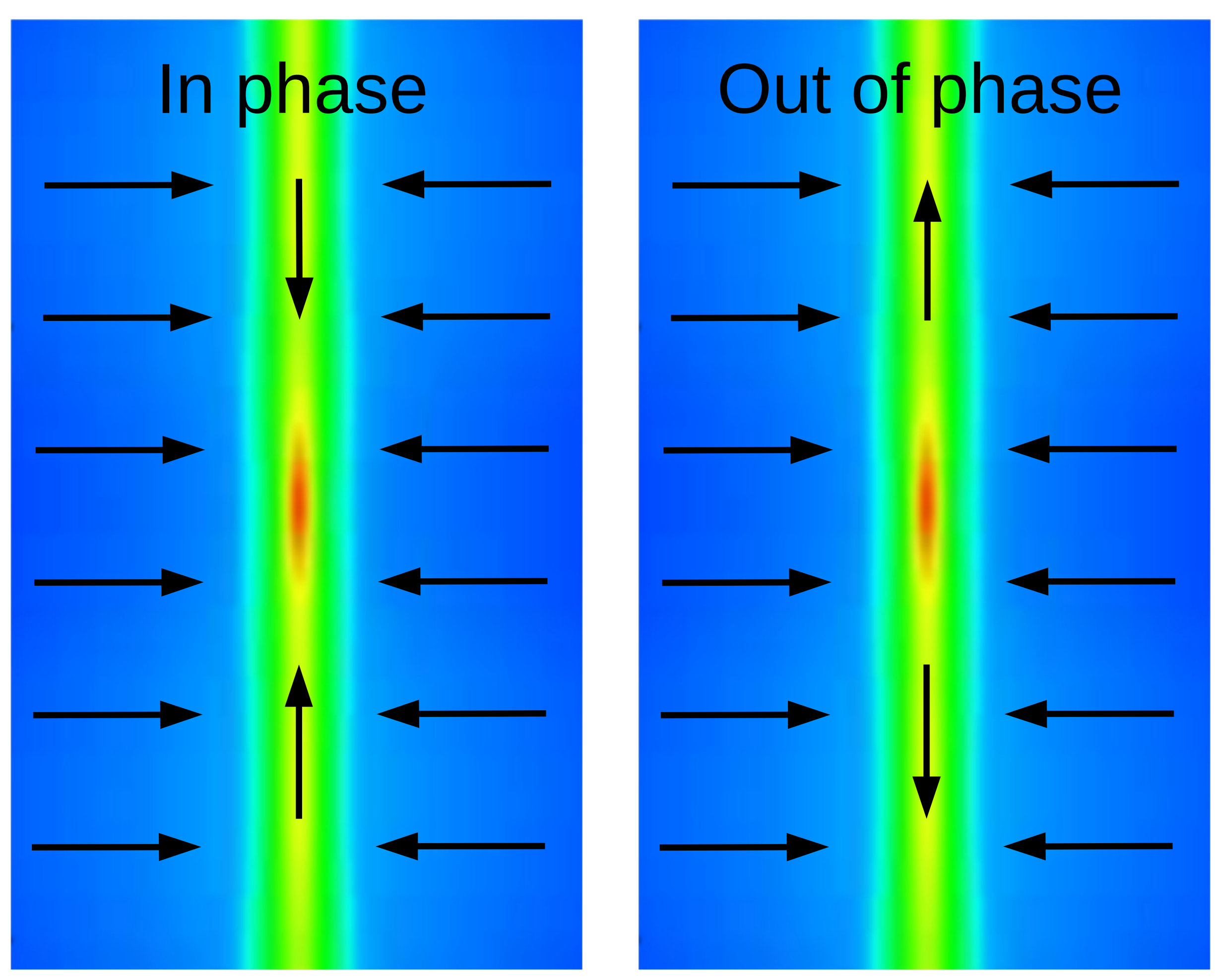

Figure 4. At τ_{CRIT} the longitudinal flows may converge on a density peak, or diverge. If they are convergent then they act to enhance the radial collapse and the perturbation grows more quickly. If the longitudinal flows are divergent then they are out of phase with the convergent radial flow and slow down the growth of the perturbation.