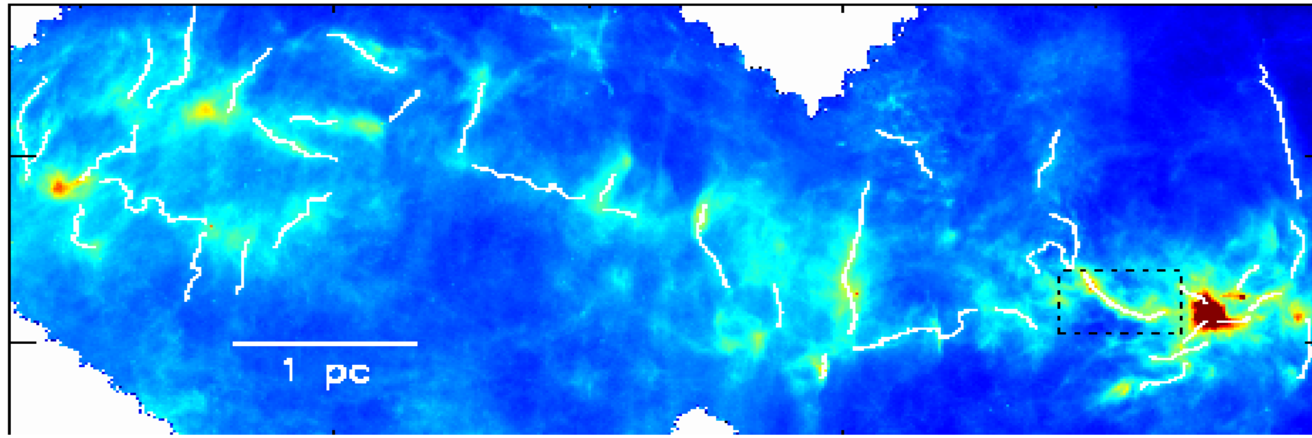
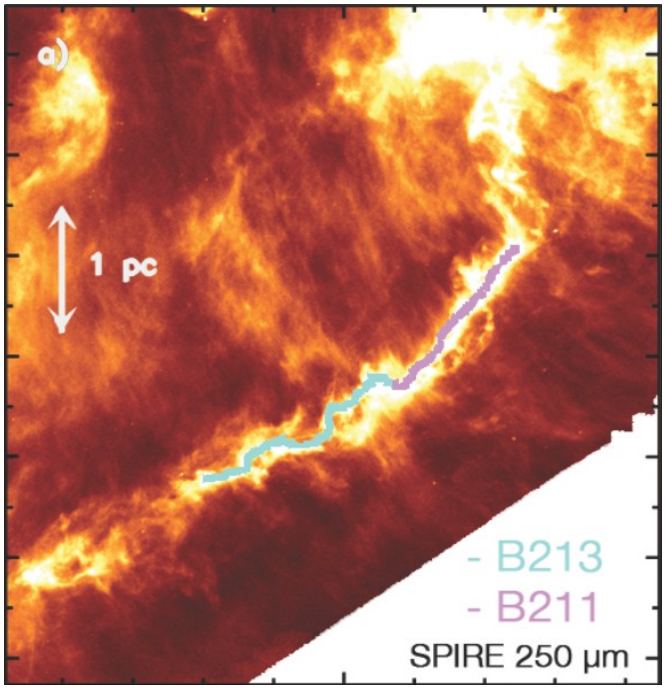
Investigating the global collapse of filaments using SPH

S. D. Clarke & A. P. Whitworth

Filaments are everywhere

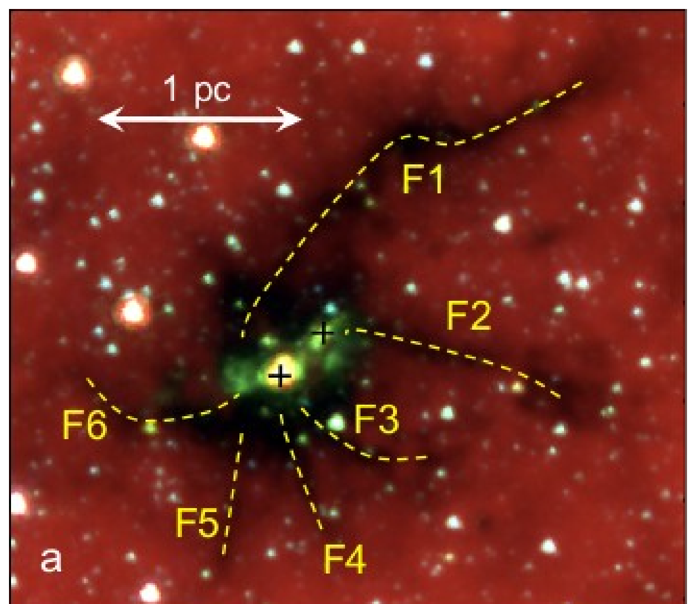
Roy et al. (2015)

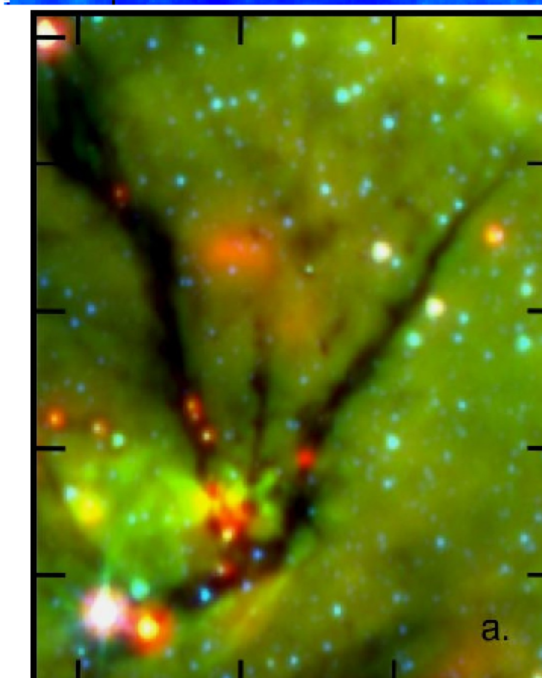




Palmeirim et al. (2013)

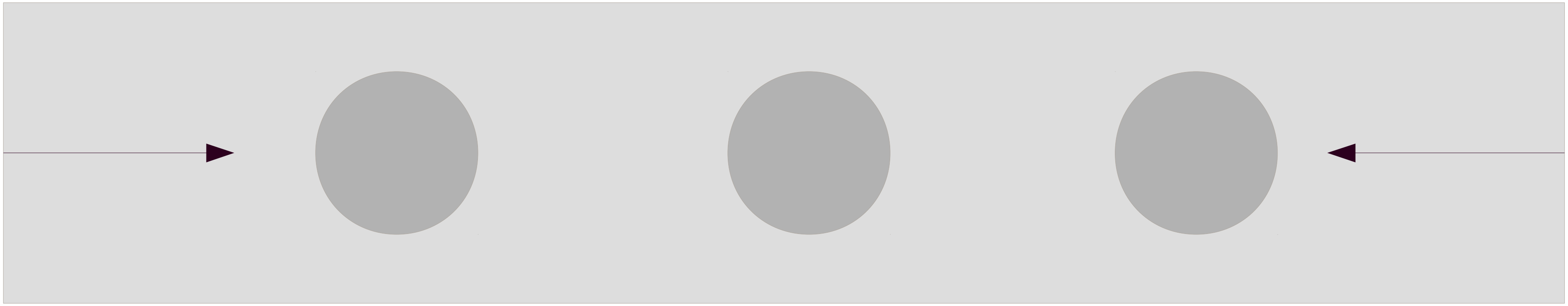
Peretto et al. (2013)





Peretto & Fuller (2010)

Global collapse and fragmentation

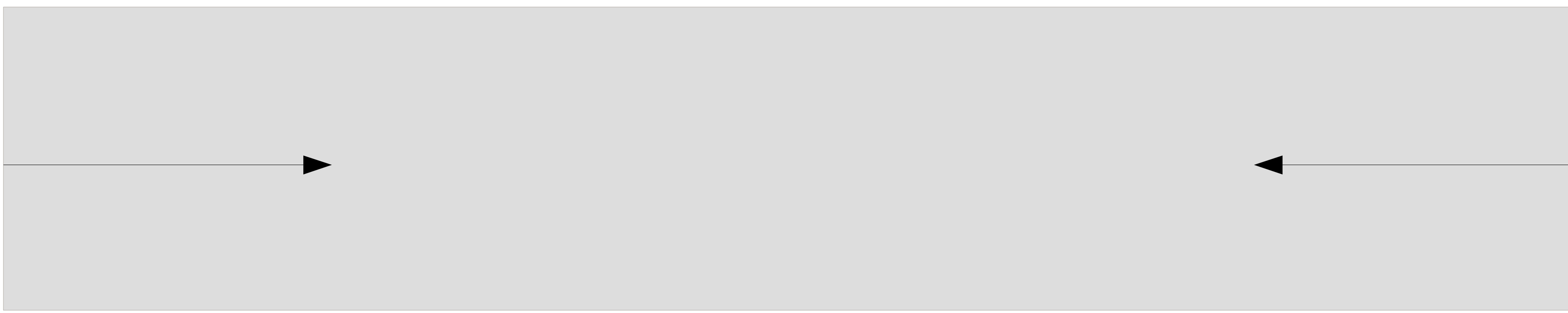


Bastien (1983)
Burkert & Hartmann (2004)
Pon et al. (2012)

$$t_{1D} > t_{3D} = \left(\frac{3\pi}{32 G \rho} \right)^{1/2}$$

Nagasawa (1987)
Inutsuka & Miyama (1992)
Pon et al. (2011)

Homologous collapse



Pon et al. (2011)
Toalá et al. (2011)
Pon et al. (2012)

Homologous collapse

Pon et al. (2011)
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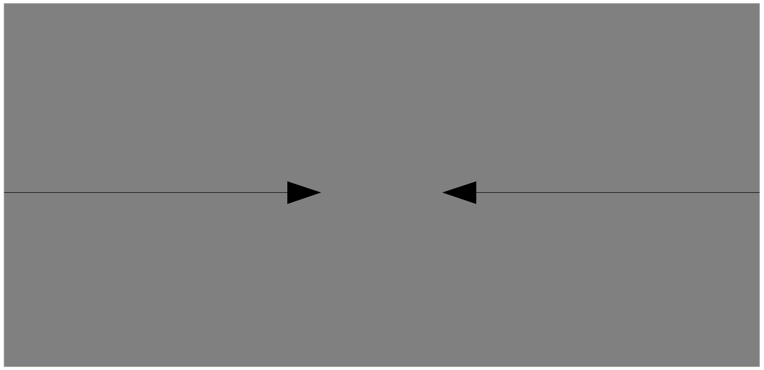
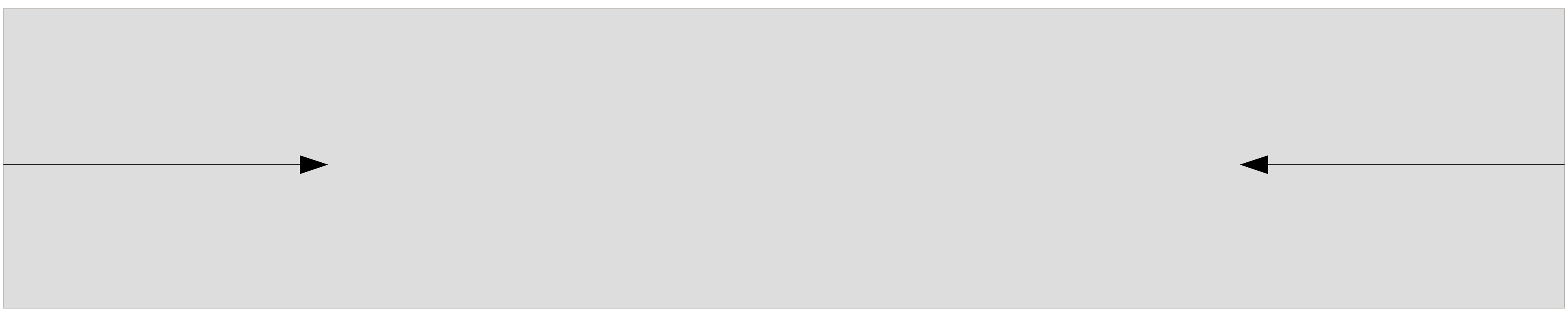
Homologous collapse



Pon et al. (2011)
Toalá et al. (2011)
Pon et al. (2012)

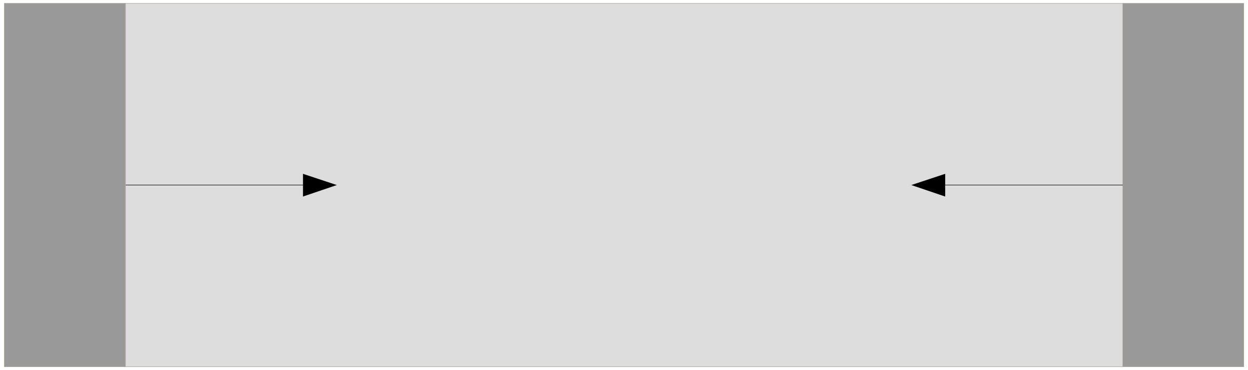
$$t_{1D} \approx \frac{0.44\,A}{\sqrt{G\rho}}$$

End-dominated collapse



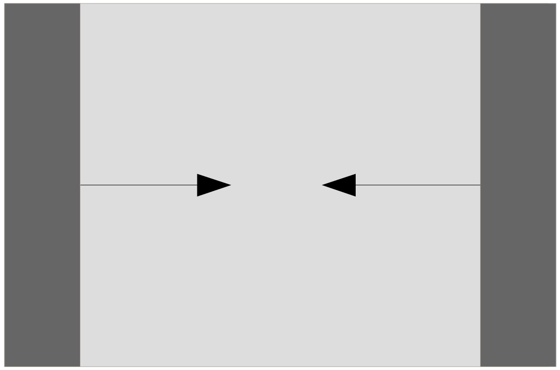
Pon et al. (2011)
Toalá et al. (2011)
Pon et al. (2012)

End-dominated collapse



Pon et al. (2011)
Toalá et al. (2011)
Pon et al. (2012)

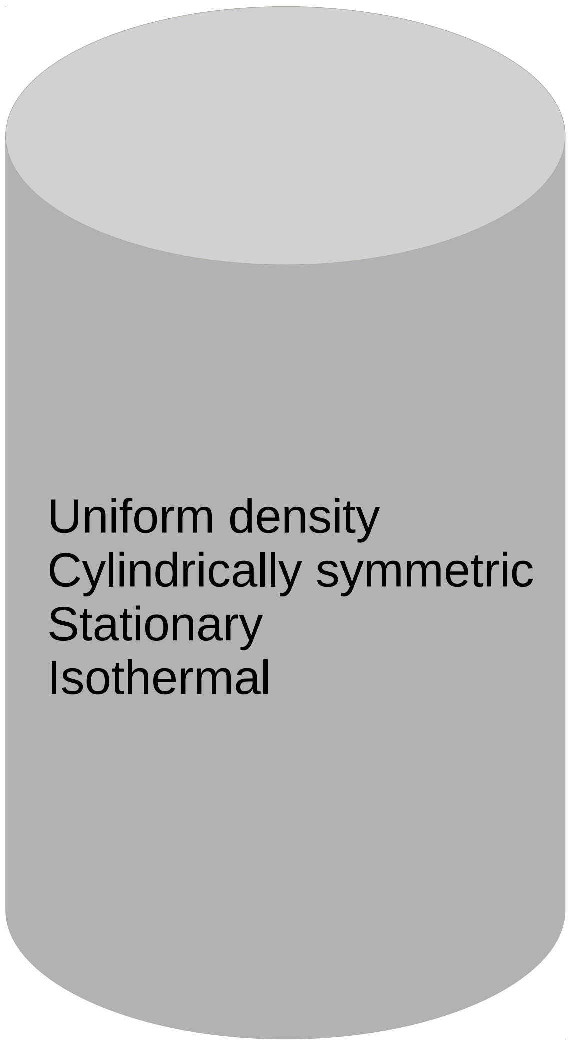
End-dominated collapse



Pon et al. (2011)
Toalá et al. (2011)
Pon et al. (2012)

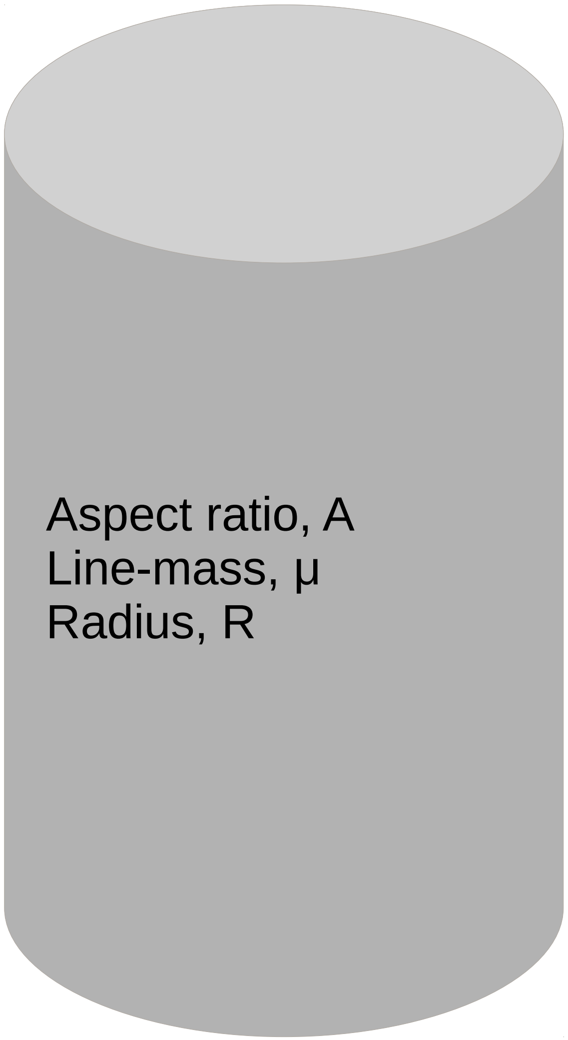
$$t_{1D} \approx 0.98 \sqrt{\frac{A}{G\rho}}$$

Numerical set-up



- SPH code GANDALF
- Grad-h SPH
- Gravity and hydrodynamics
- T = 1 K as we wish to approximate free-fall
- Radial motion suppressed, $v_x = v_y = 0$
- 100,000 – 200,000 particles used

Numerical set-up



$2 \leq A \leq 20$

$2\ M\ pc^{-1} \leq \mu \leq 50\ M\ pc^{-1}$

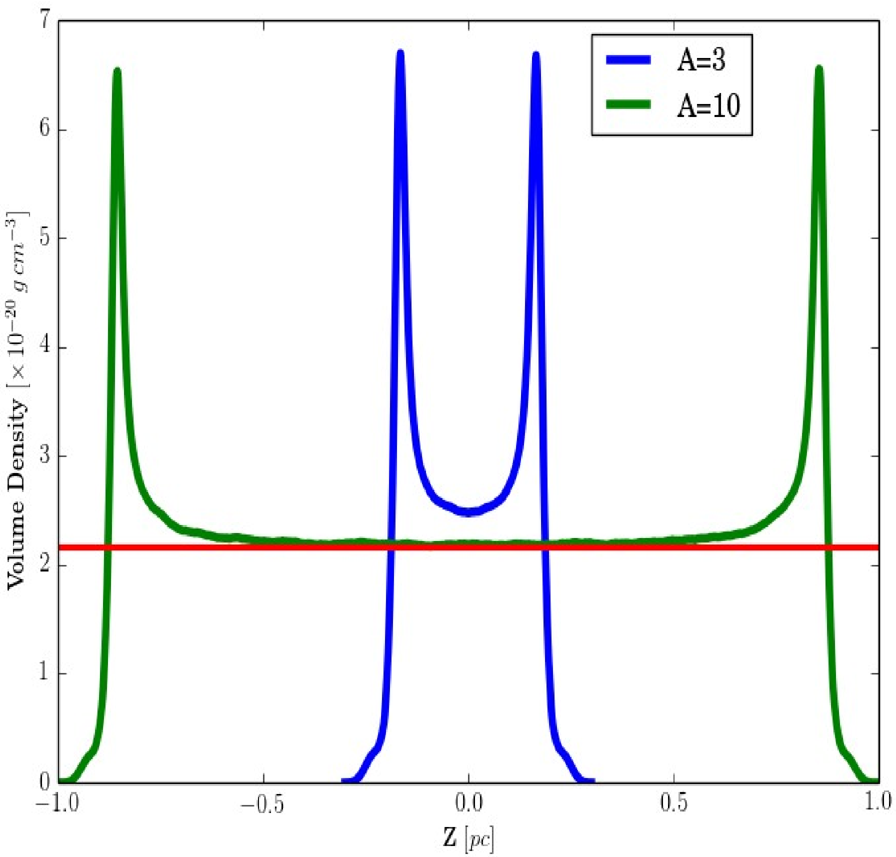
$0.05\ pc \leq R \leq 0.15\ pc$

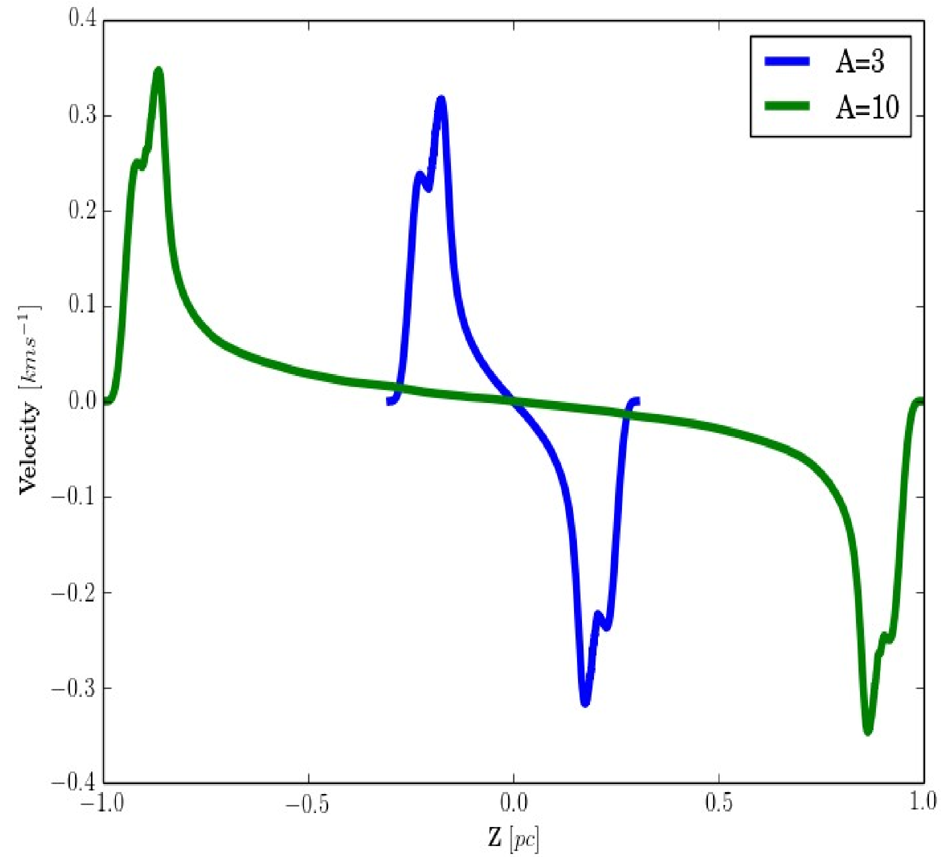
Fiducial case:

$A = 10$, $\mu = 10\ M\ pc^{-1}$,

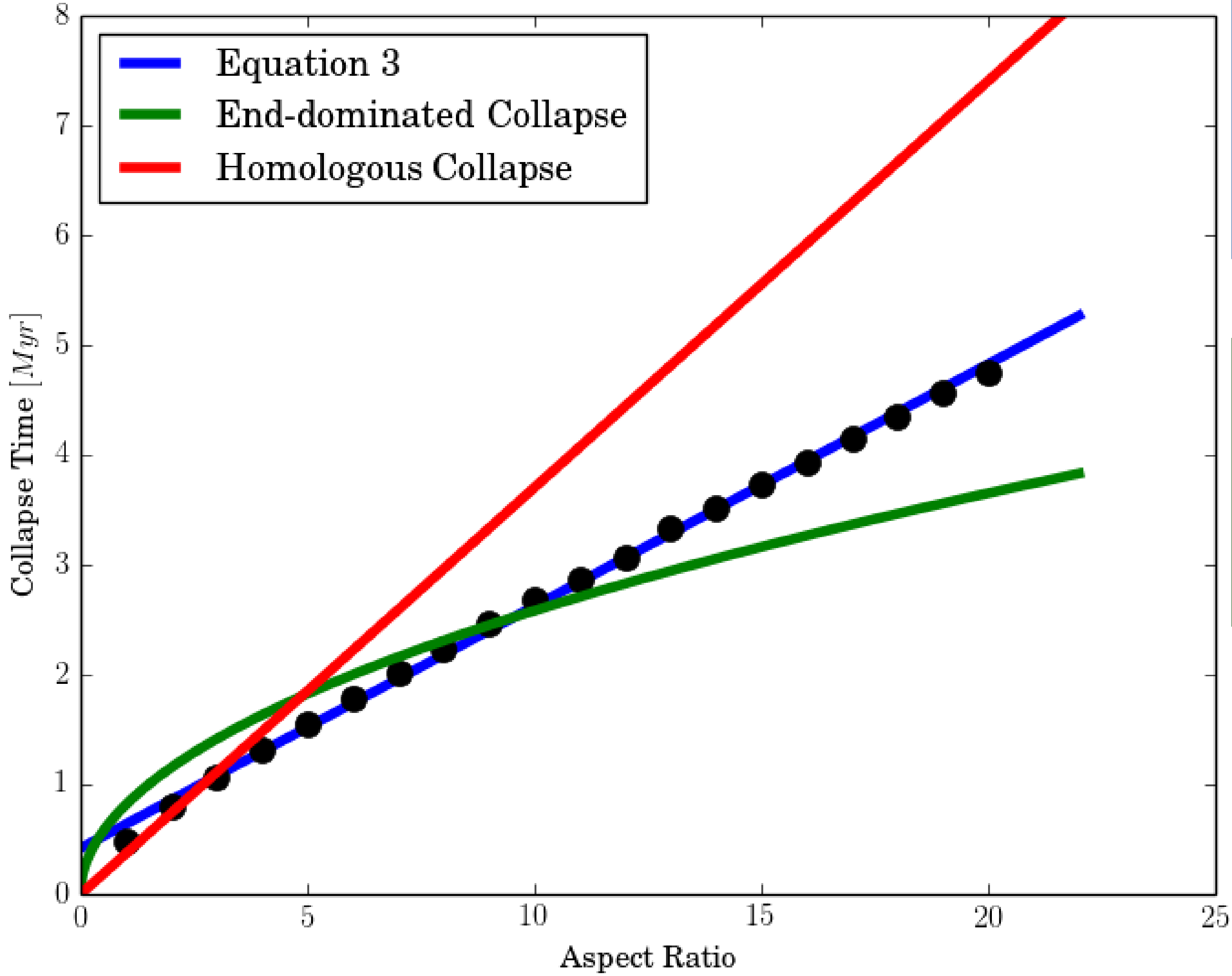
$R = 0.1\ pc$

No homologous collapse





Collapse time

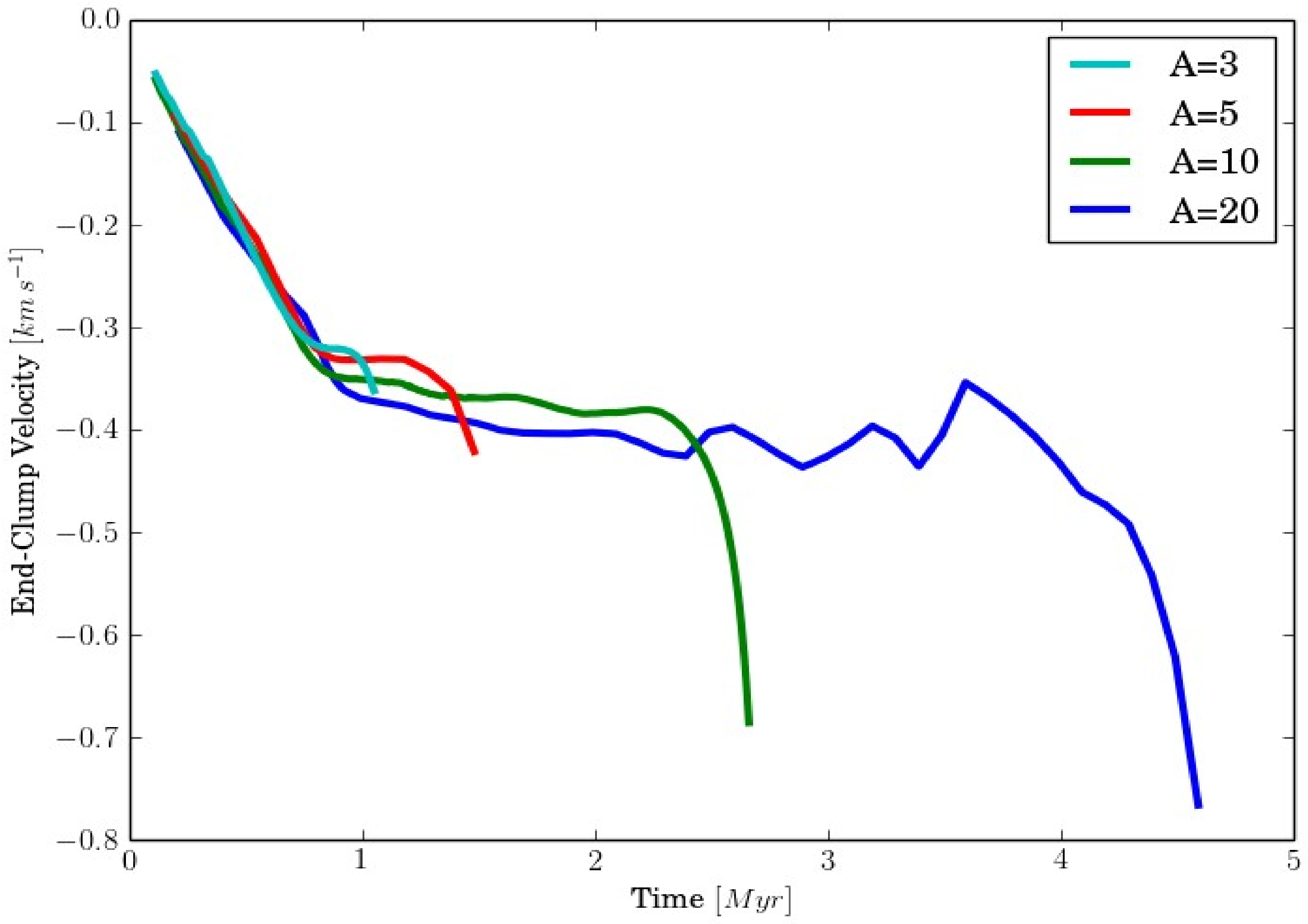


$$t_{1D} = \frac{0.49 + 0.26\,A}{\sqrt{G\rho}}$$

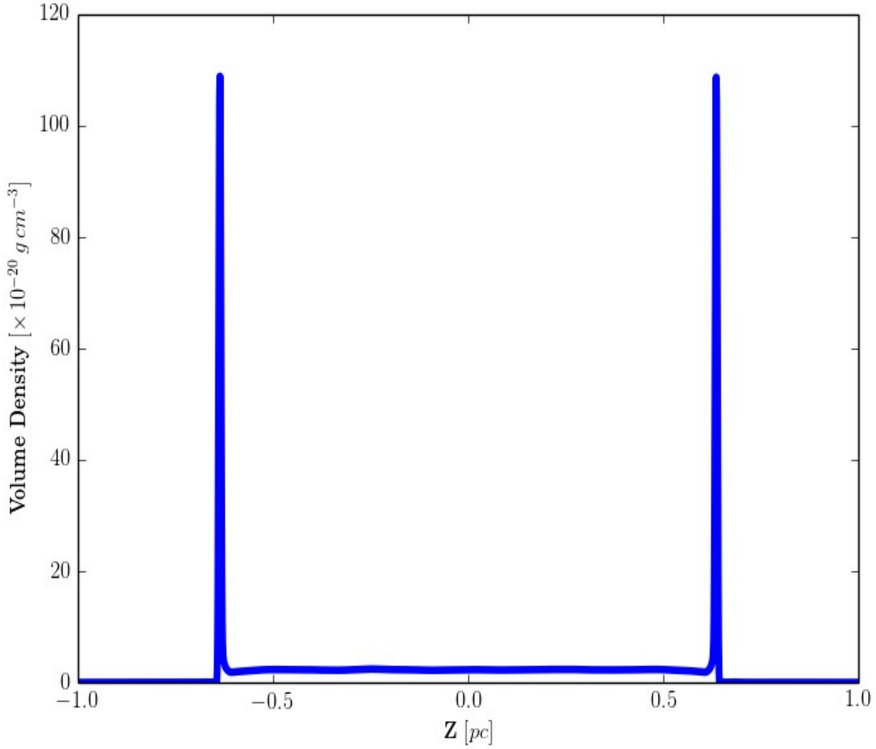
$$t_{1D} \approx 0.98\sqrt{\frac{A}{G\rho}}$$

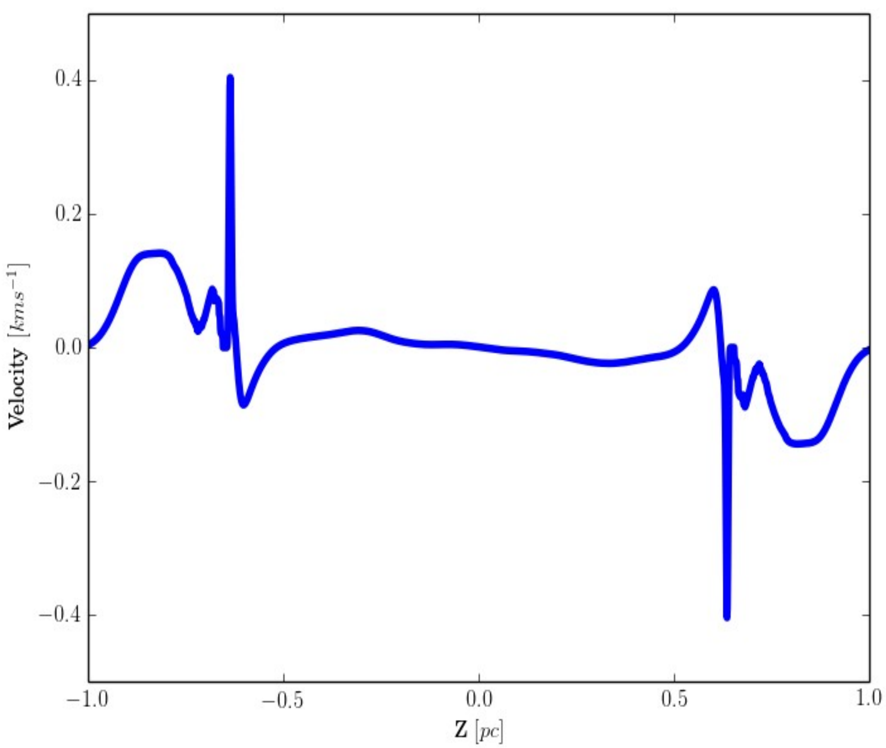
$$t_{1D} \approx \frac{0.44\,A}{\sqrt{G\rho}}$$

End-clump velocity

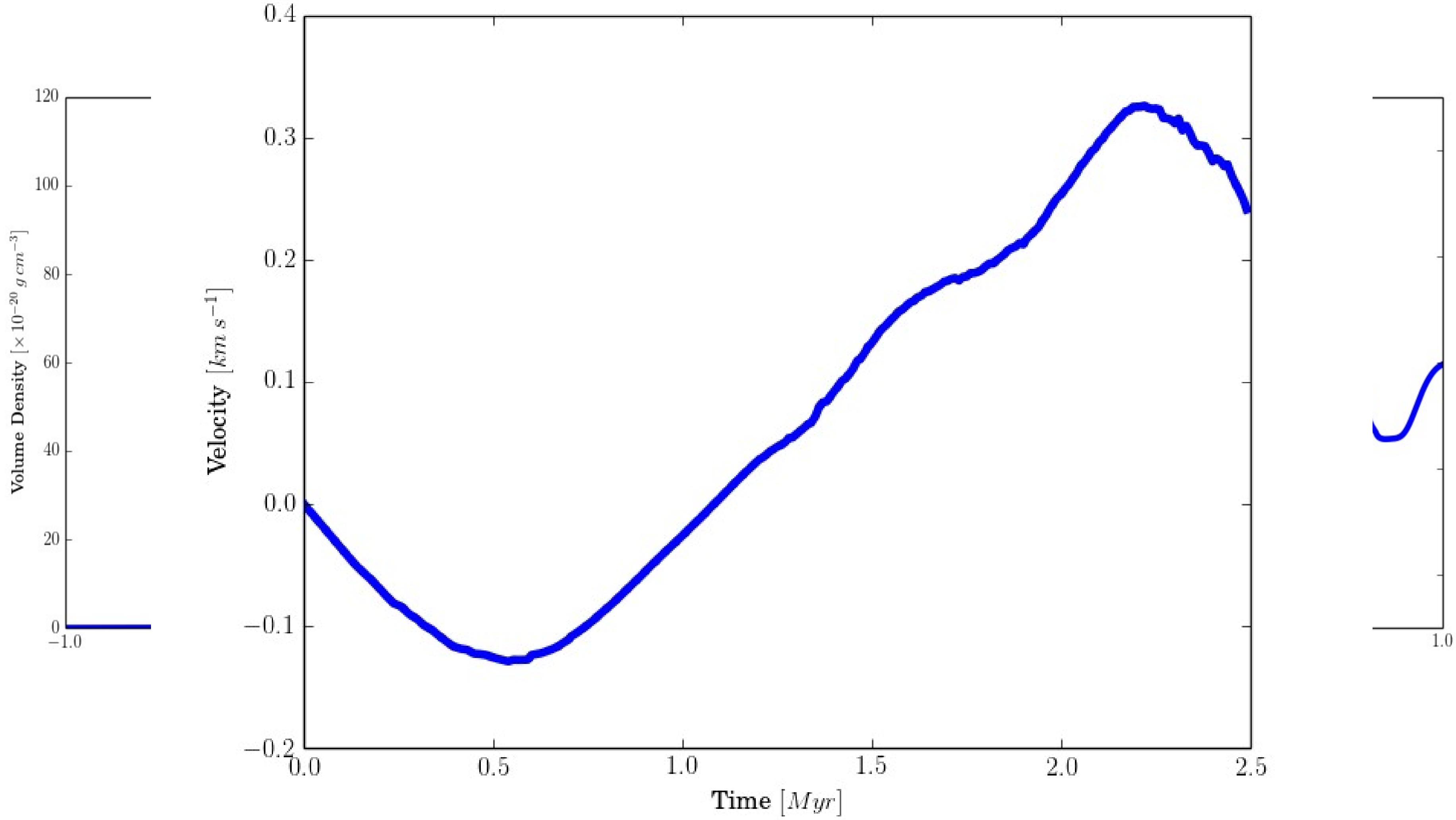


How to explain this terminal velocity





How to explain this terminal velocity



Seamus Clarke, Cardiff University

Semi-analytical model

$$\frac{d^2 z}{d t^2} = -\alpha \left(2 \pi G \rho R \right) + \frac{\rho v_{rel}^2 \pi R^2}{M(t)}$$

End-clump acceleration

Gravitational acceleration inwards

Ram pressure exerted by swept-up material

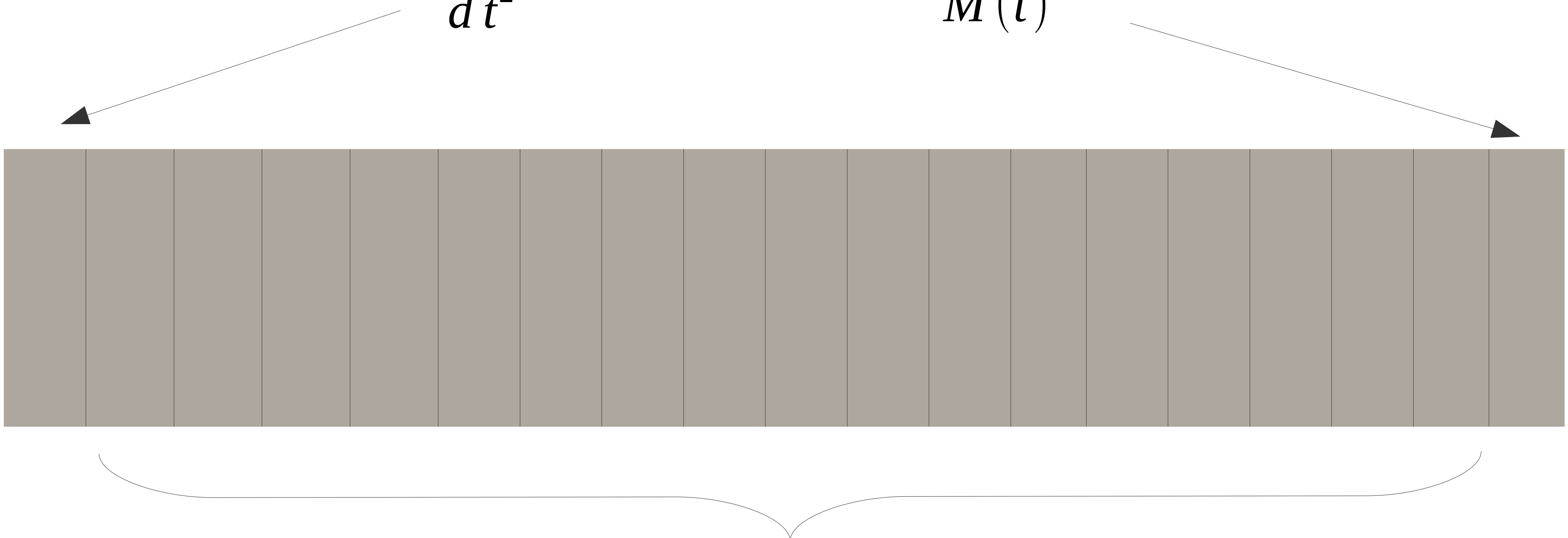
$$\frac{d^2 z_I}{d t^2} = -\alpha \left(2 \pi G \rho \right) \left(2 z_I(t) + \sqrt{R^2 + \left(z(t) - z_I(t) \right)^2} - \sqrt{R^2 + \left(z(t) + z_I(t) \right)^2} \right)$$

$$+ \beta \left(2 \pi G \rho \right) \left(Z_O - z(t) \right) \left(\frac{z(t) + z_I(t)}{\sqrt{R^2 + \left(z(t) + z_I(t) \right)^2}} - \frac{z(t) - z_I(t)}{\sqrt{R^2 + \left(z(t) - z_I(t) \right)^2}} \right)$$

Gravitational acceleration outwards due to the end-clump

Semi-analytical model

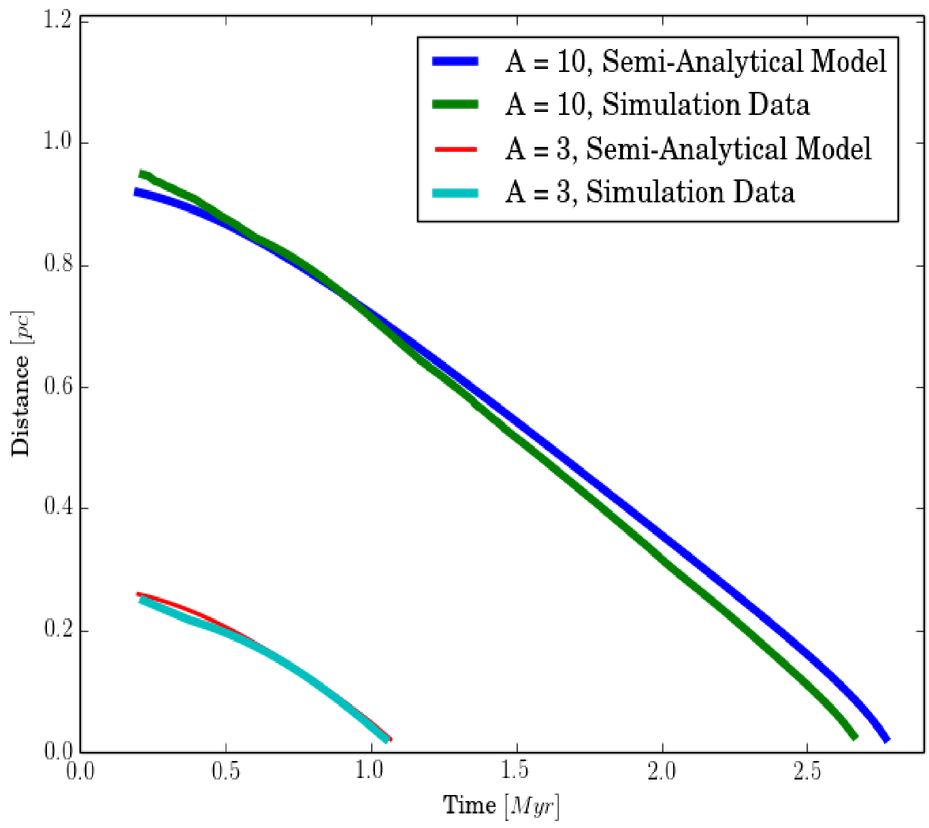
$$\frac{d^2 z}{d t^2} = -\alpha \left(2 \pi G \rho R \right) + \frac{\rho v_{rel}^2 \pi R^2}{M(t)}$$

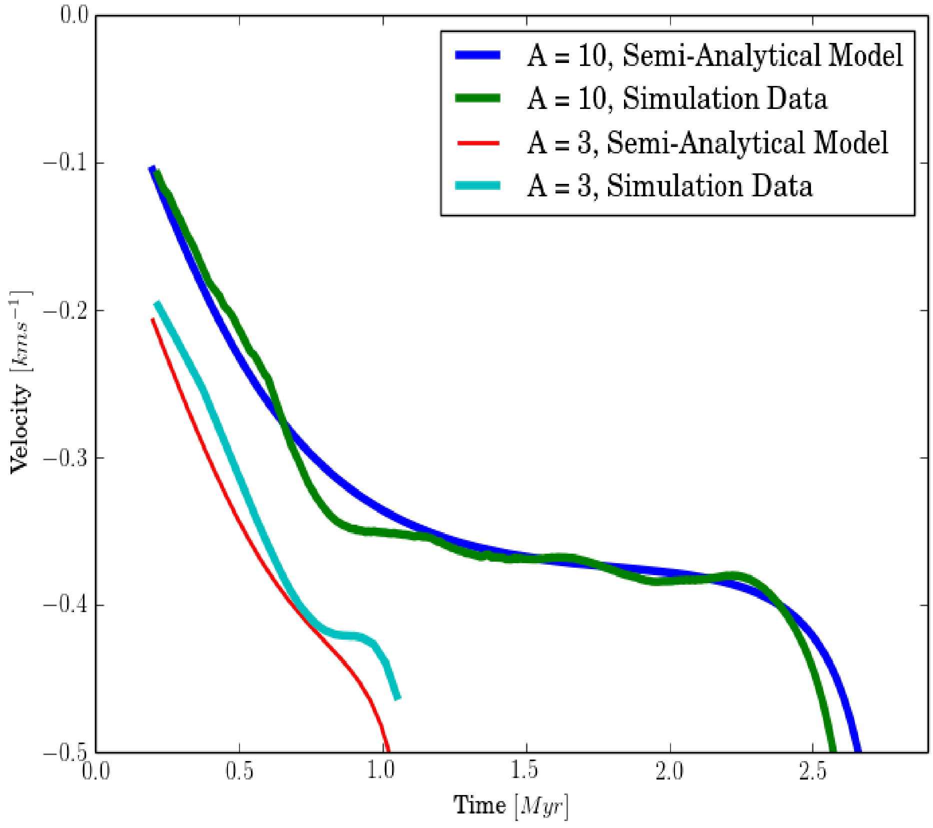


$$\frac{d^2 z_I}{d t^2} = -\alpha (2 \pi G \rho) \left(2 z_I(t) + \sqrt{R^2 + (z(t) - z_I(t))^2} - \sqrt{R^2 + (z(t) + z_I(t))^2} \right)$$

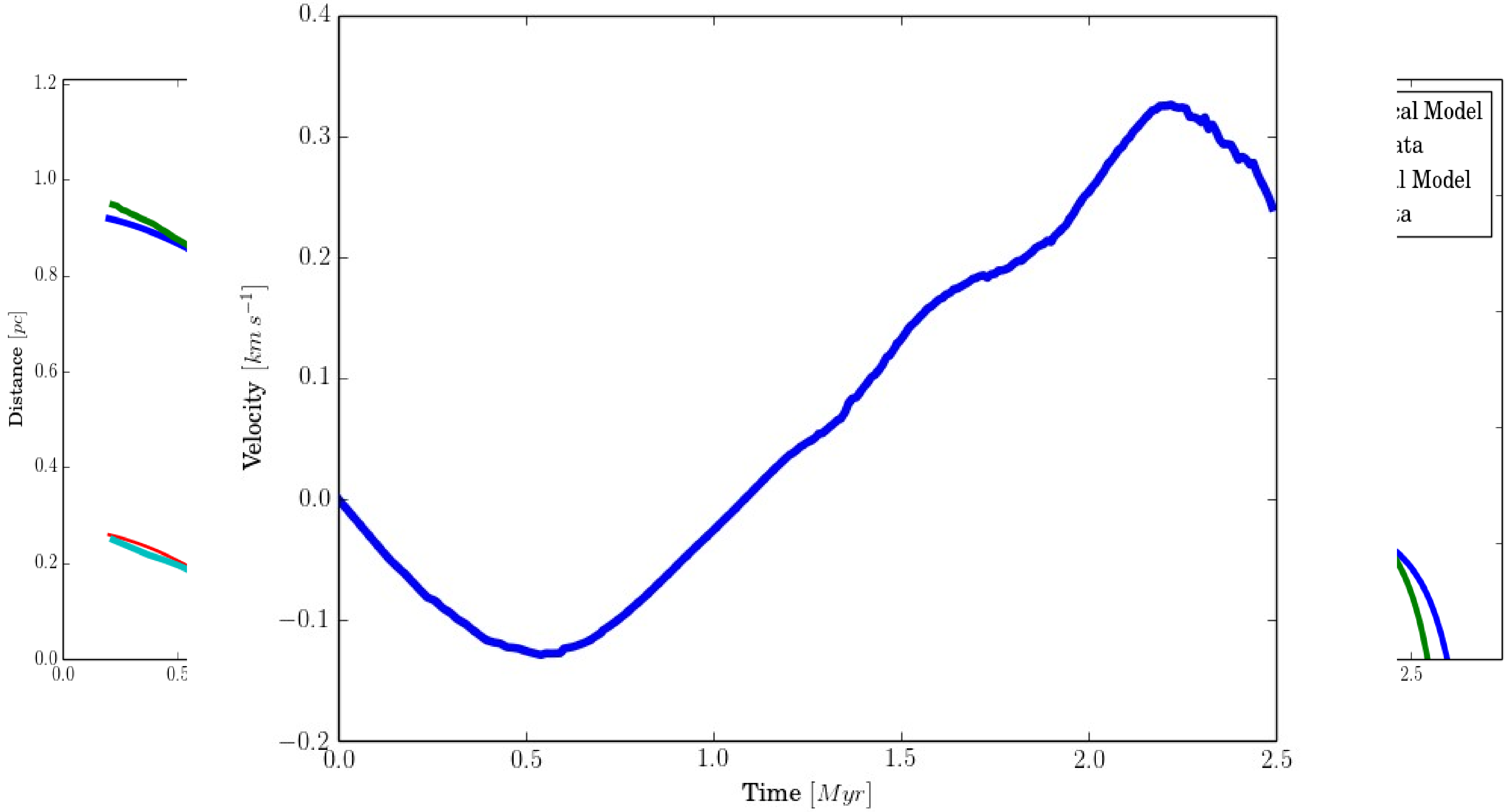
$$+ \beta (2 \pi G \rho) (Z_O - z(t)) \left(\frac{z(t) + z_I(t)}{\sqrt{R^2 + (z(t) + z_I(t))^2}} - \frac{z(t) - z_I(t)}{\sqrt{R^2 + (z(t) - z_I(t))^2}} \right)$$

Testing the model

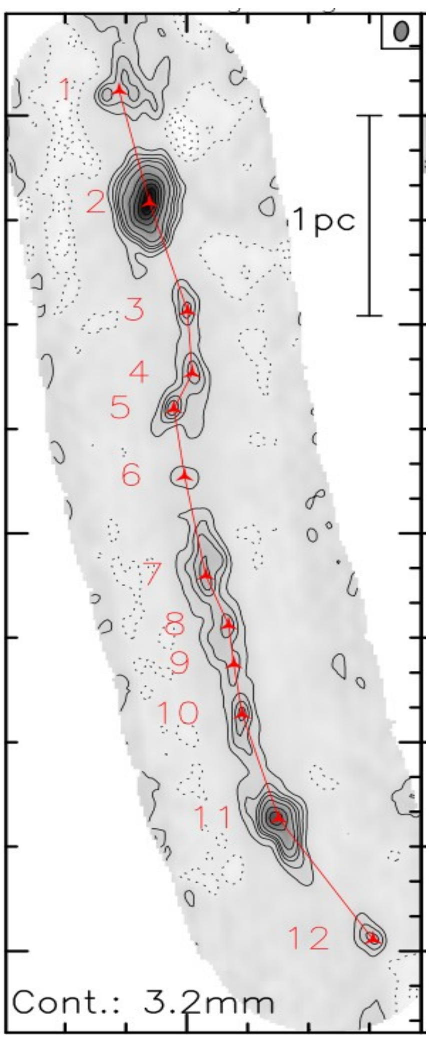




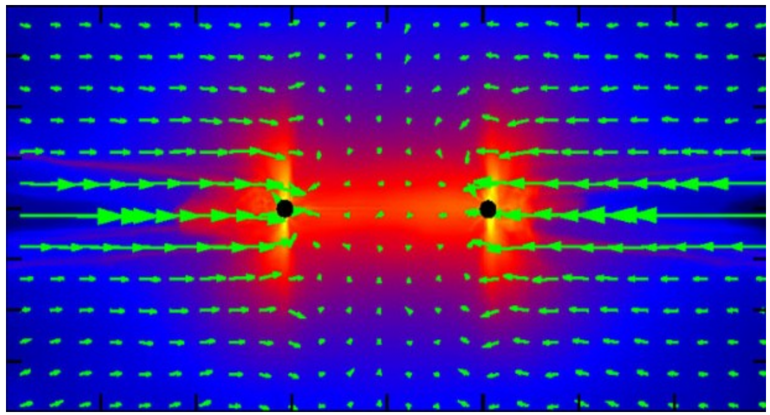
Testing the model



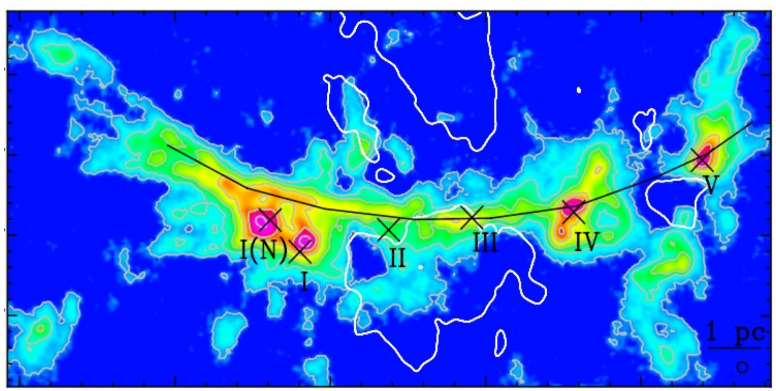
Observational evidence



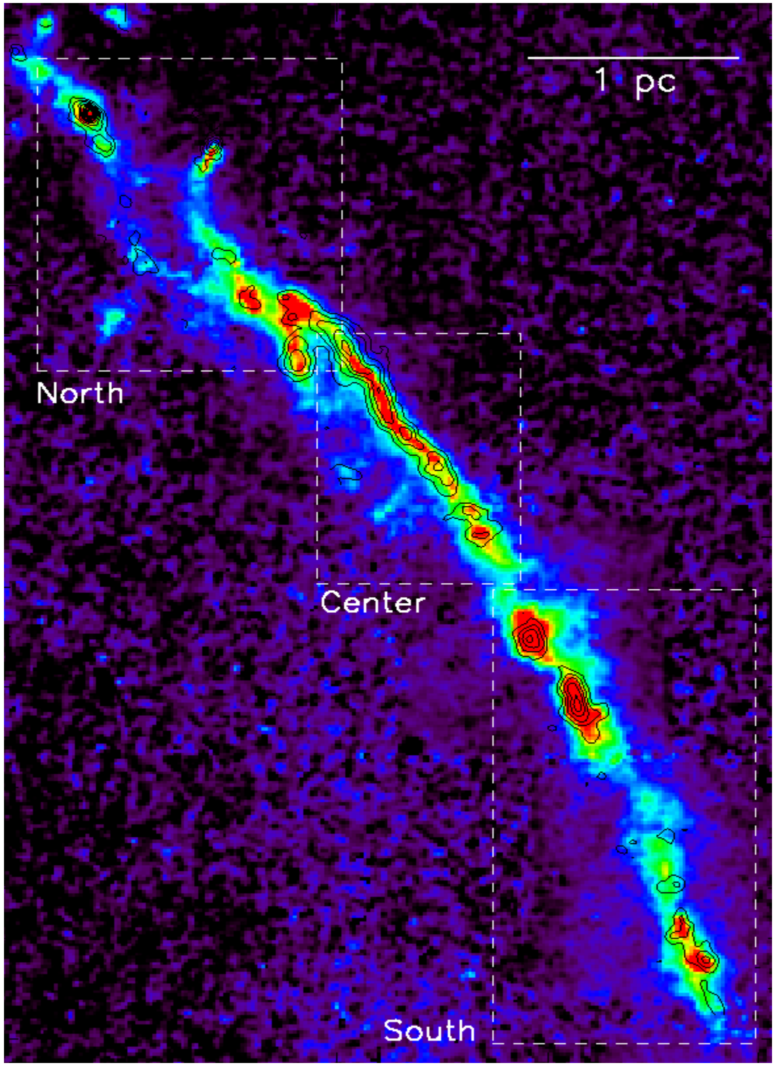
Beuther et al. (2015)



Seifried & Walch (2015)

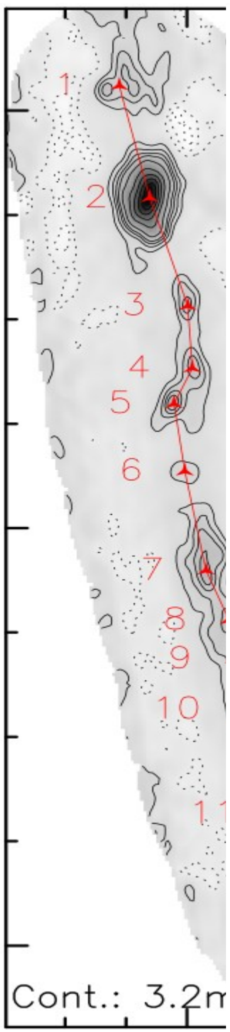


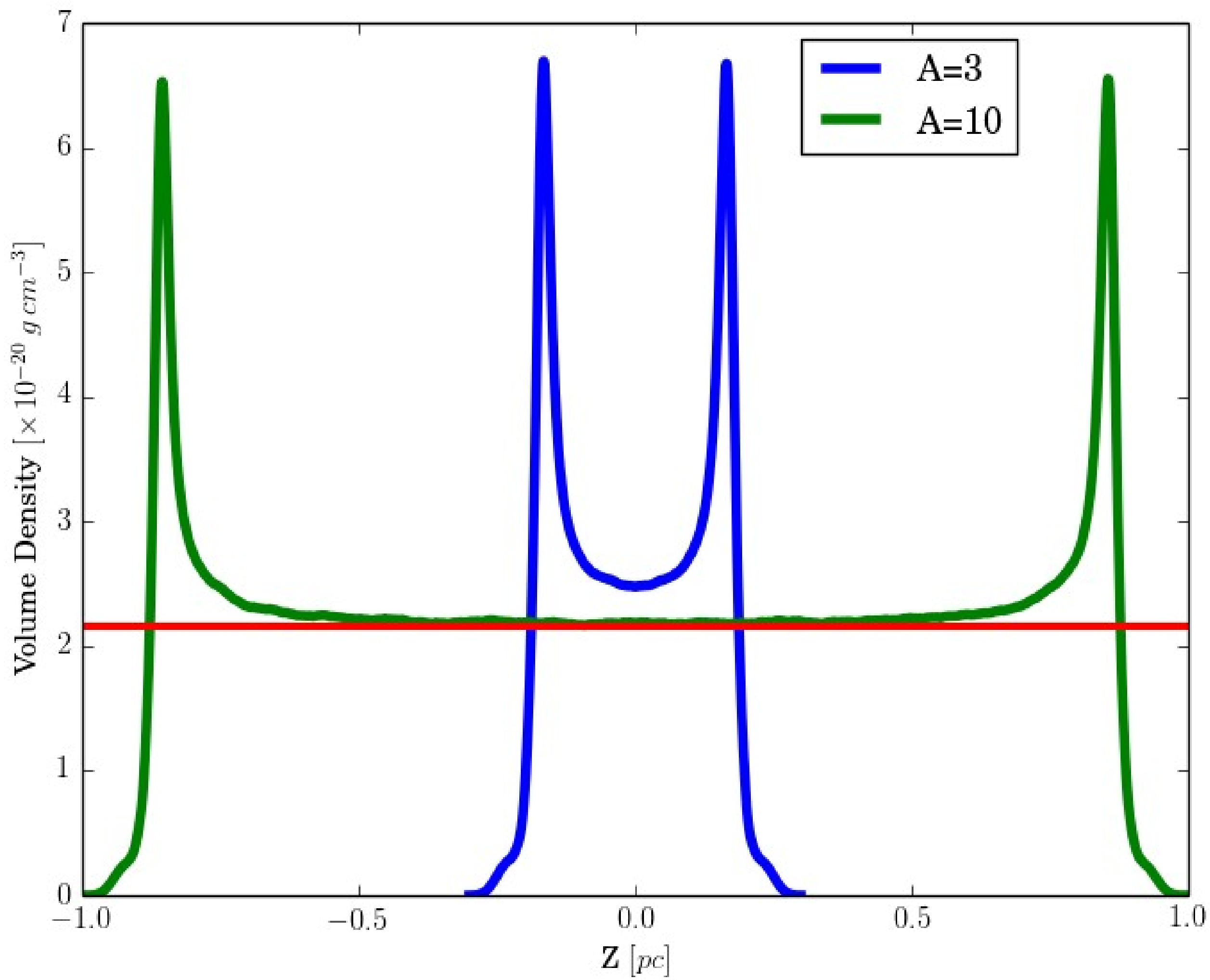
Zernickel et al. (2013)

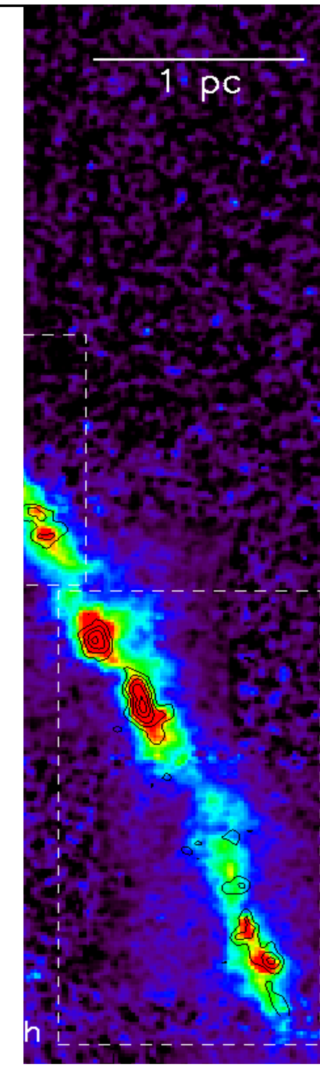


Kainulainen et al. (2015)

Observational evidence







Beuther et

Kainulainen et al. (2015)

Conclusions

- Filaments collapse and fragment differently than higher dimensional objects.
- Global collapse occurs via the end-dominated mode, which produces high density end-clumps.
- The free-fall time of filaments is given by the equation:

$$t_{1D}=\frac{0.49+0.26\,A}{\sqrt{G\rho}}$$

- Global collapse is much longer than in 3D, this makes filaments perfect sites for fragmentation.
- Observational examples of end-clumps in isolated filaments have been found.