UNIVERSITY OF CAMBRIDGE
Cavendish Laboratory

Filament identification and characterisation in Gould Belt Clouds

CAVENDISH ASTROPHYSICS

Carl Salji, John Richer, Jane Buckle

University of Cambridge, Cavendish Laboratory, UK

Introduction

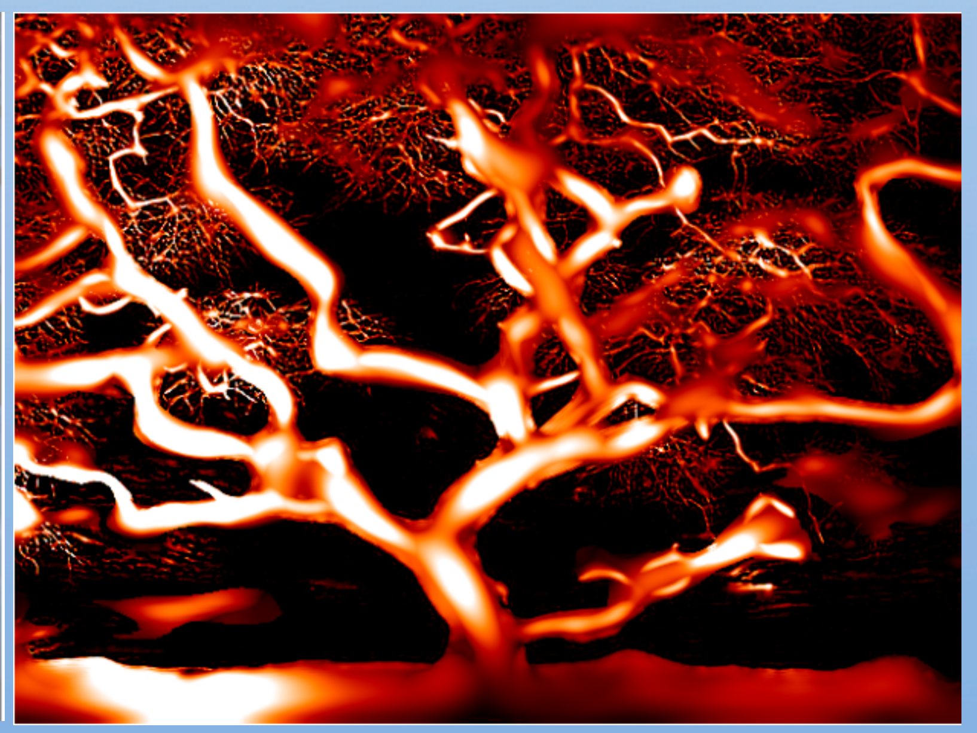
The rapid advancement of sub-mm astronomy has revealed a plethora of filamentary cloud structure associated with star forming cores. A technique allowing for the unbiased identification and analysis of such structure is outlined along with some interesting results.

Theory

The radial density distribution of such filaments depends upon the support mechanisms present. Ostriker's seminal paper (1964) investigated the equilibrium configuration of an isothermal self-gravitating cylindrical mass and resulted in a Plummer-like profile (1) with a fall off parameter p=4.

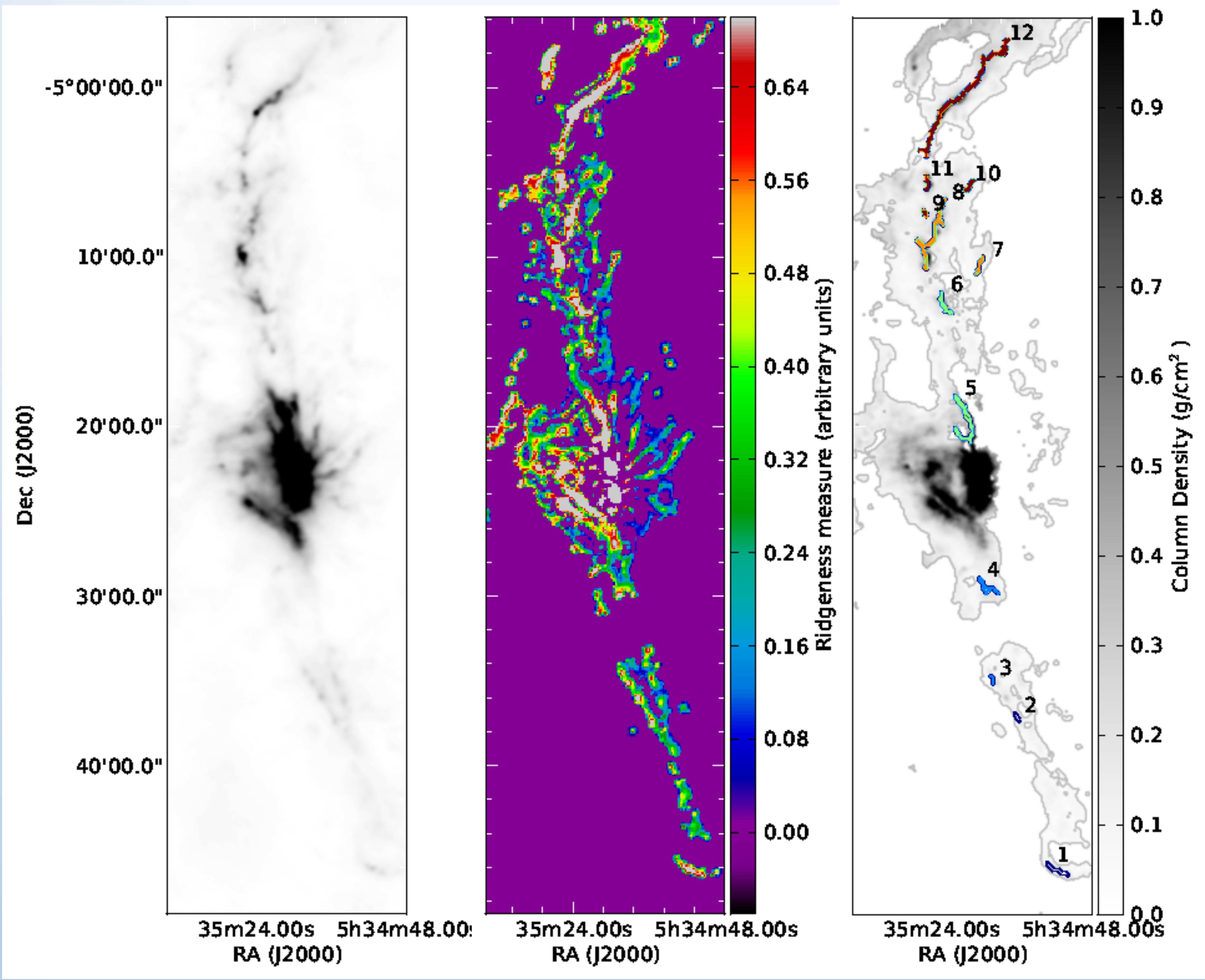
Filament Enhancement

We have developed a Python implementation of the Hessian-based multiscale ridge enhancement technique outlined by Frangi et al. 1998, originally designed for the enhancement of vessel-like structures in biomedical imaging. This process yields a probabilistic style 'ridgeness' map which acts as the basis for filament identification.



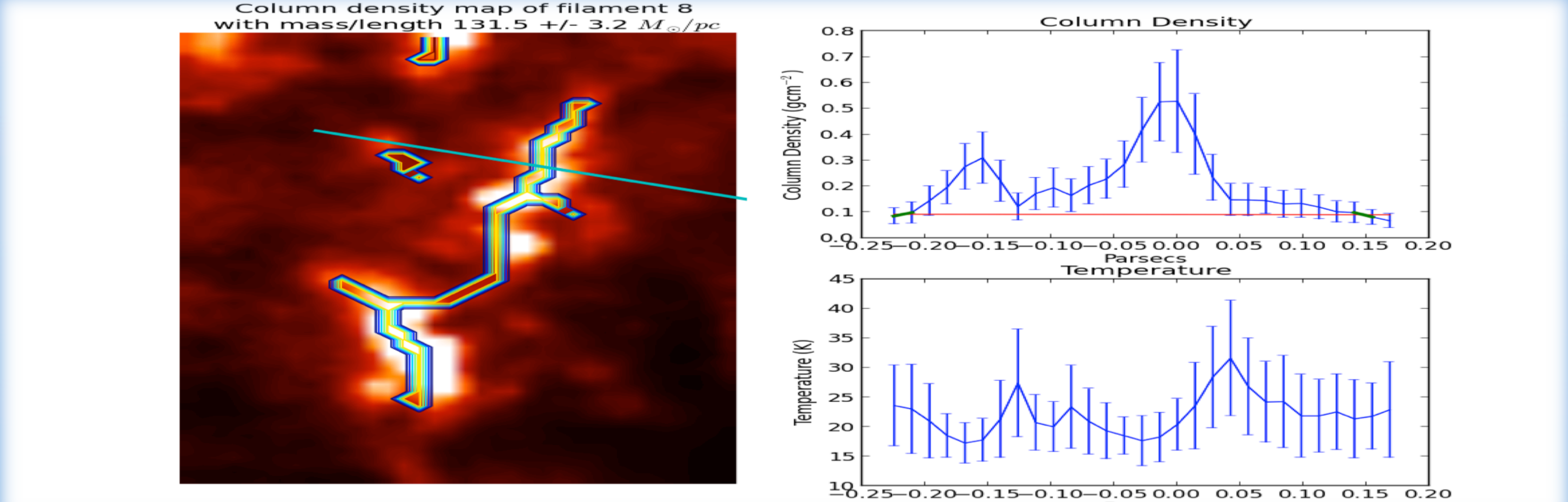
Filament Identification

A simple threshold is applied to the 'ridgeness' map which is then 'skeletonised' or 'thinned' – a commonly used technique in image processing. These filament skeletons/spines act as the central location from which radial slices of the filament are generated.



Application to astronomical datasets

The plots above (from left to right) show the SCUBA-2 850 µm image of Orion A North, the corresponding filament-enhanced column density map and the column density map overlaid with the final filament spines. The filament spine positions are connected with a spatially smoothed minimum spanning tree allowing for simple generation of radial column density profiles. In addition to sub-mm dust observations, high resolution C^{18}O obtained with the Heterodyne Array Receiver Program (HARP) provided velocity information of the filaments. For an isothermal self-gravitating cylinder, the virial equation yields a critical mass per unit length of $3\langle\sigma_{vd}\rangle^2/G$ (McCrea, 1957). *(Data obtained from the JCMT Gould Belt Survey)*

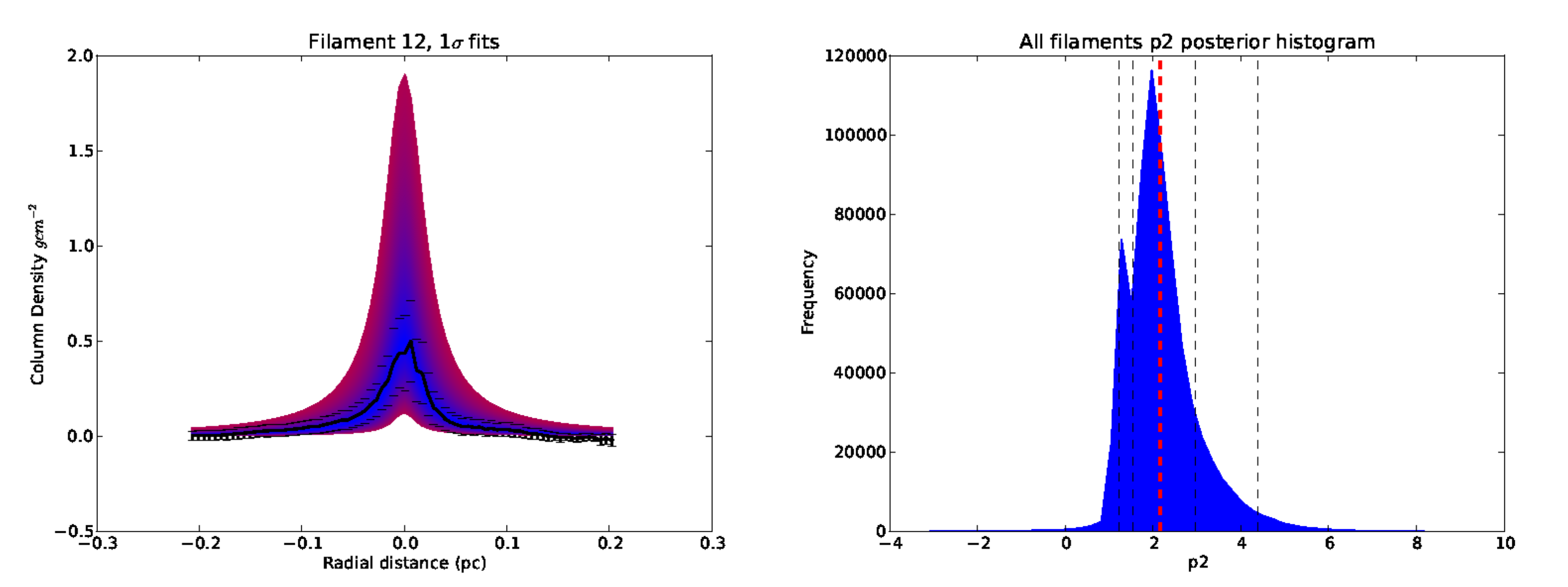


Results

The filament radial profiles of column density were averaged and fitted with the Abel transform of a Plummer-like profile convolved with the SCUBA-2 850 µm PSF.

$$\rho(r) = \frac{\rho_c}{\left[1+\left({r}/{R_{flat}}\right)^2\right]^{\frac{p}{2}}} \Rightarrow \Sigma_{obs}(x) = A\frac{\rho_c R_{flat}}{\left[1+\left({x}/{R_{flat}}\right)^2\right]^{\frac{p-1}{2}}} * B_{850}(x)$$

The Python-based Markov Chain Monte Carlo Bayesian fitting algorithm PyMC was employed to determine the core space density ρ_c, R_{flat} and the radial fall off parameter p.



Number	ρ_c (10^6 cm^{-3})	R_{flat} (pc)	p	Mass/Length ($M_\odot pc^{-1}$)	Protostars	Disks	$\langle\sigma_{vd}\rangle$ kms^{-1}	Theoretical Mass/Length ($M_\odot pc^{-1}$)
1	$1.00^{+1.81}_{-0.52}$	$0.018^{+0.014}_{-0.010}$	$2.65^{+1.02}_{-0.60}$	62.1±2.1	0	2	?	?
2	$2.49^{+12.26}_{-2.22}$	$0.005^{+0.015}_{-0.003}$	$2.38^{+1.22}_{-0.87}$	115.5±5.7	1	3	?	?
3	$1.12^{+6.92}_{-0.83}$	$0.009^{+0.016}_{-0.007}$	$2.01^{+1.18}_{-0.58}$	136.2±6.4	1	2	?	?
4	$1.44^{+4.15}_{-1.11}$	$0.010^{+0.027}_{-0.007}$	$1.42^{+0.38}_{-0.13}$	105.4±2.4	0	7	0.45	139
5	$2.86^{+5.50}_{-1.69}$	$0.020^{+0.018}_{-0.011}$	$2.30^{+0.60}_{-0.36}$	246.7±5.6	3	22	0.67	314
6	$5.00^{+7.18}_{-3.01}$	$0.010^{+0.009}_{-0.005}$	$2.11^{+0.47}_{-0.24}$	229.5±7.1	3	4	0.52	**192**
8	$2.91^{+4.28}_{-1.62}$	$0.016^{+0.013}_{-0.008}$	$2.27^{+0.51}_{-0.31}$	201.4±3.7	11	16	0.39	**107**
10	$1.07^{+5.25}_{-0.81}$	$0.012^{+0.026}_{-0.009}$	$1.59^{+0.66}_{-0.25}$	121.1±3.6	0	1	0.60	255
11	$4.73^{+11.48}_{-3.48}$	$0.008^{+0.013}_{-0.005}$	$2.48^{+1.13}_{-0.64}$	364.2±12.0	4	4	?	?
12	$4.81^{+5.51}_{-2.56}$	$0.012^{+0.008}_{-0.005}$	$2.30^{+0.37}_{-0.25}$	144.8±2.0	11	7	0.47	152

Conclusions

1. We derive p= $2.2^{+0.8}_{-0.6}$ — inconsistent with the Ostriker model at the 96% confidence level but consistent with helical magnetic field support described by Fiege & Pudritz (2000).
2. Comparable theoretical and observed mass per unit lengths suggest virialised filaments supported by supra-thermal motions.
3. The parameters ρ_c and R_{flat} are degenerate leading to poorly constrained final values. This is most likely due to insufficient resolution in regard to the parameter R_{flat} which is unresolved.