The velocity characteristics of dusty filaments in the JCMT GBS clouds

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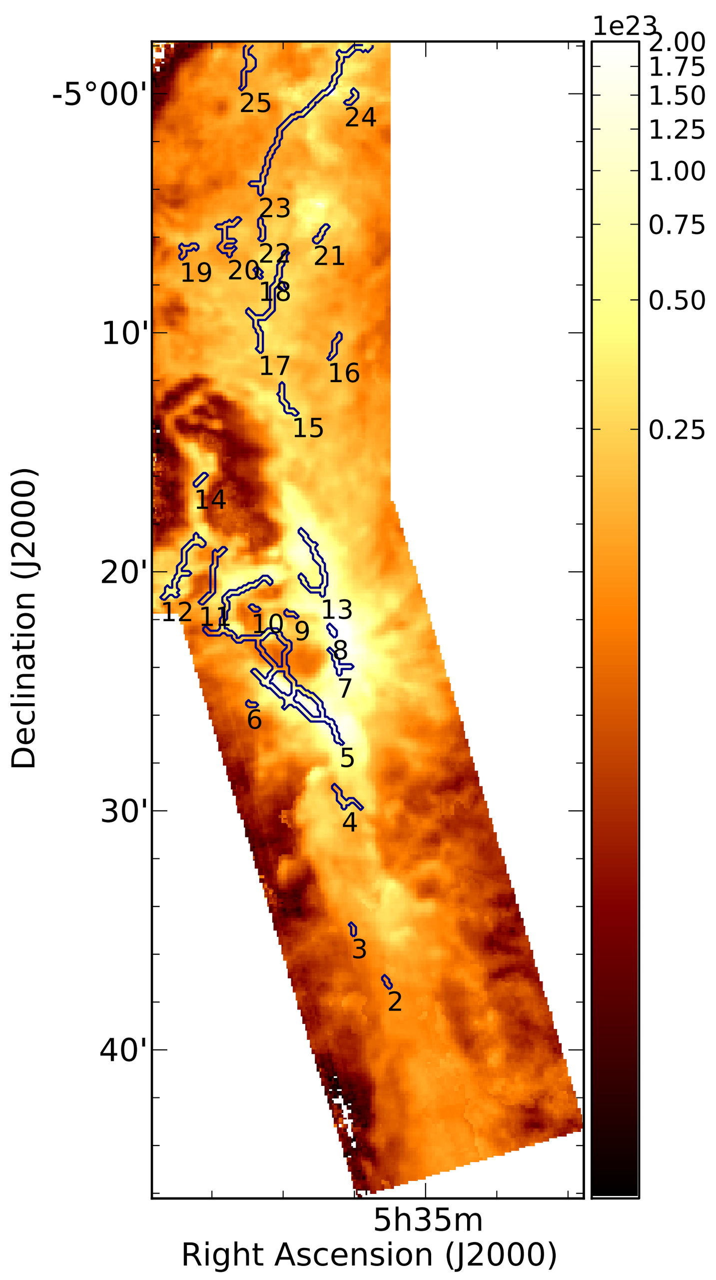
Introduction

Filamentary structure in molecular clouds is associated with the formation of dense molecular cores and clusters where star formation occurs. Recent models (Arzoumanian et al. 2013, 553, 119; Hacar et al. 2013, A&A, 554, 55; Kirk et al. 2013, ApJ, 766, 115) attempt to incorporate filament characteristics:

- ❑ as parent structures of star-forming cores
- ❑ as a conduit for accretion flows providing a mass reservoir for star-forming clusters
- ❑ in an evolutionary scenario for star forming clouds and cores

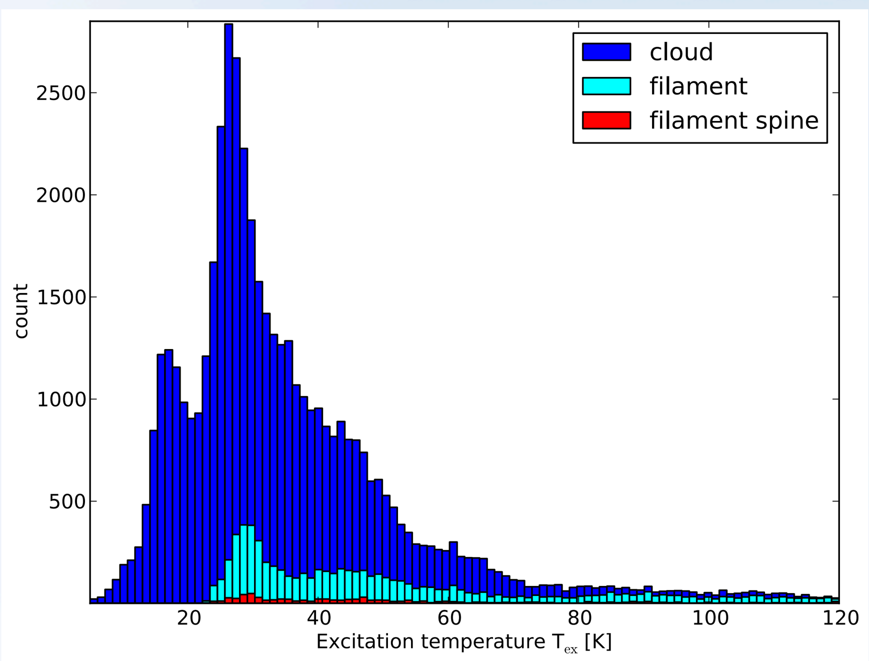


The JCMT GBS Survey

The JCMT Gould Belt Survey with SCUBA-2 and HARP (Ward-Thompson et al. 2007, PASP, 119, 855), provides large-scale, high-resolution dust continuum and $^{12}CO/^{13}CO/C^{18}O$ J=3-2 spectral line maps of nearby molecular clouds. We present results for Orion A. Fig. 1 (left) shows the $N(H_2)$ image of Orion A, calculated from temperature and opacity corrected $N(^{13}CO)$, and overlaid with filament spines generated by Salji. et al. 2013 (see poster #1S019).

Line ratios of $^{12}CO/^{13}CO/C^{18}O$ are used to estimate opacities, and ^{13}CO is used for excitation temperatures (T_{ex}). $C^{18}O$ is used for other filament properties. Total velocity dispersion (σ_{tot}) and sound speed (c_s) are calculated using T_{ex}. σ_{tot} values are based on Gaussian fits to $C^{18}O$ line profiles.

The filaments are generally warmer than the surrounding material. Fig. 2 (below) shows the distribution, with median values in the cloud, filament and filament spines of 30K, 45K and 46K respectively.



Velocity characteristics

Fig. 3 (below) shows average spectra from individual filaments. ^{13}CO (blue) and ^{12}CO (black) spectra are shown scaled by 0.5 and 0.75 respectively, $C^{18}O$ (green) spectra are not scaled. Broad line wings and multiple velocity components can be seen, highlighting the need for multi-transition spectral line mapping of filaments. The central region has particularly strong line wings, while more quiescent filaments are seen to the north and south.

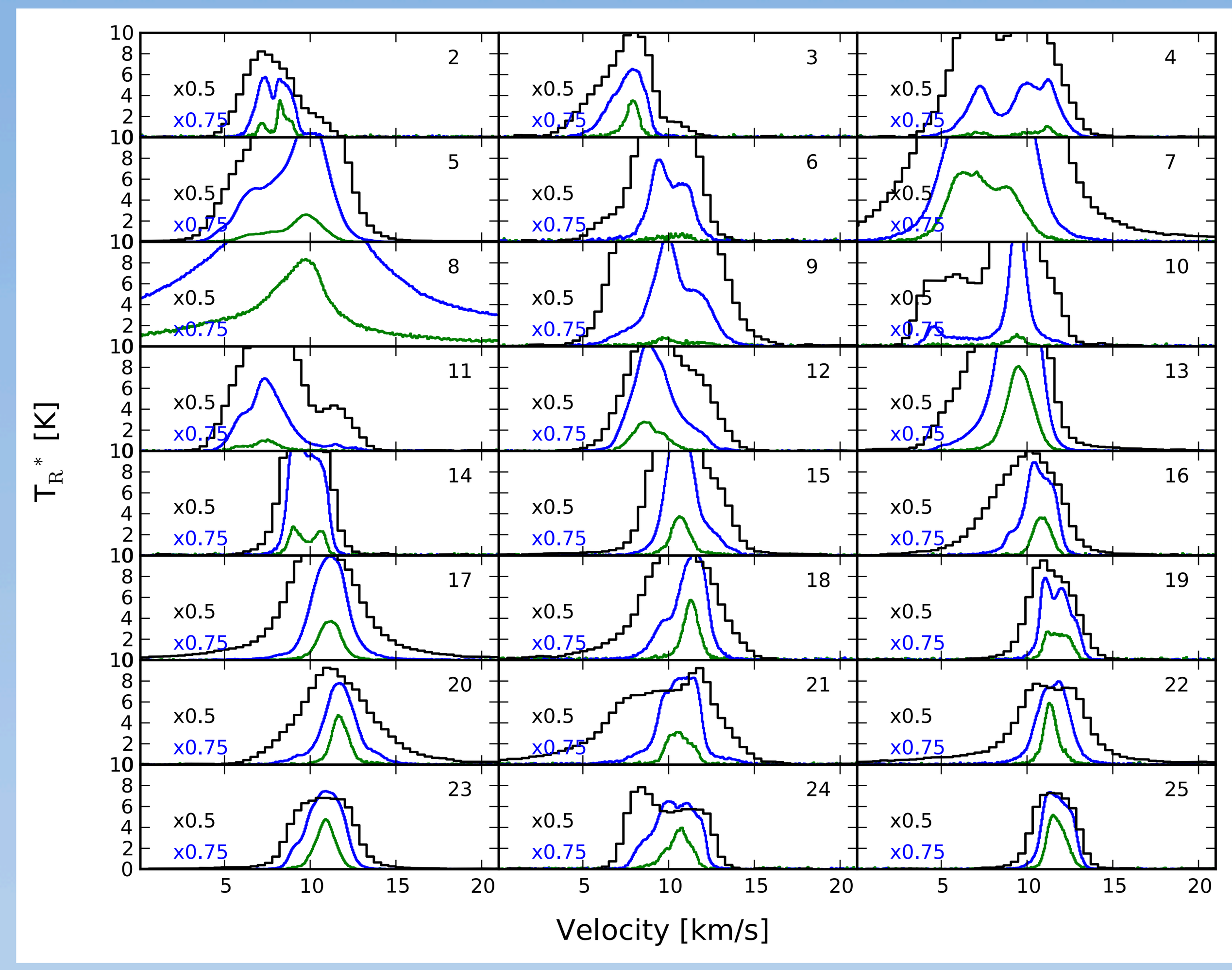
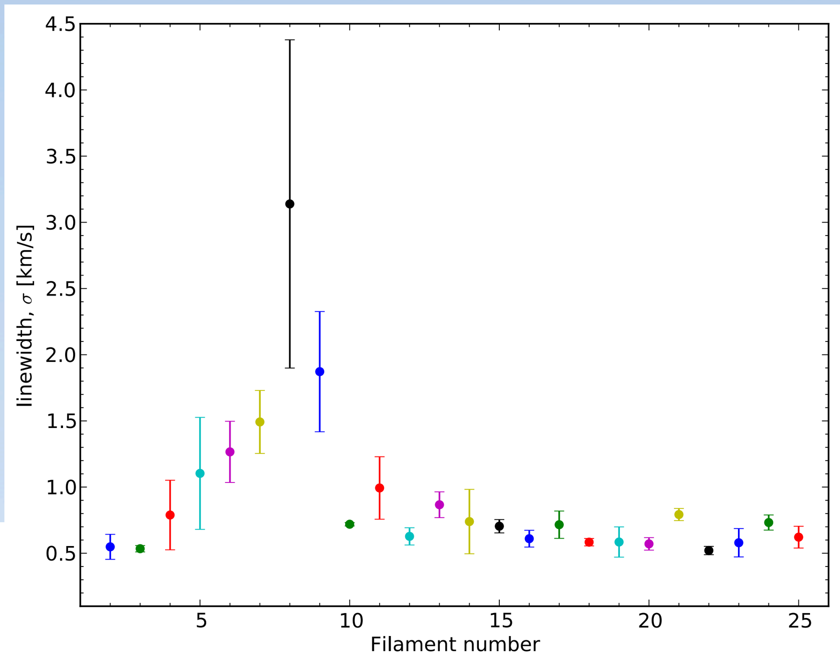


Fig. 4 (right) shows the mean and standard deviation of $C^{18}O$ linewidths for each filament. The presence of outflows, especially near OMC1, increases both the linewidths, and the range of values.



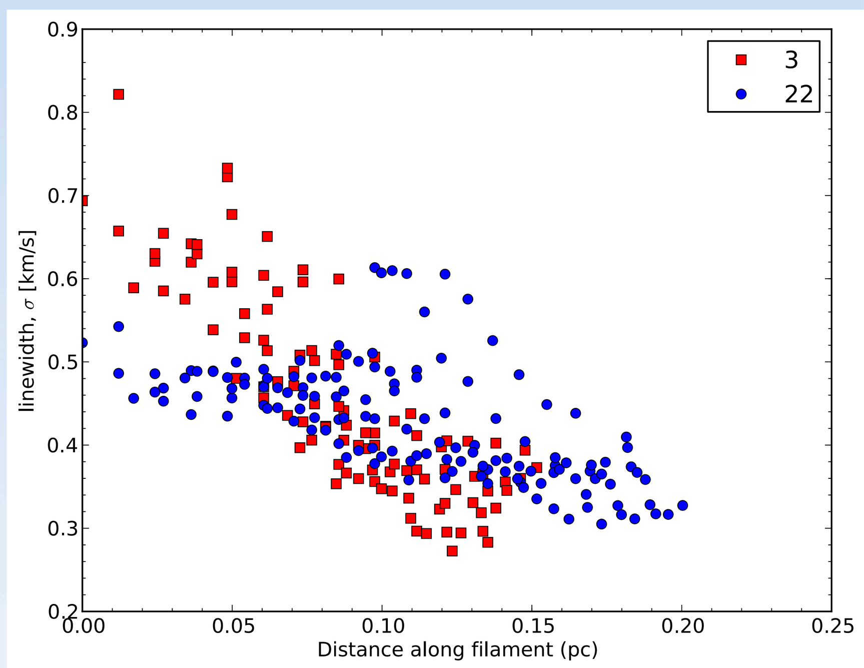


Fig. 5 (left) shows the variation in linewidth along the length of the filaments for 2 of the most quiescent filaments. Both filaments are aligned north-south, and the velocity dispersion decreases along the filament to the north.

length, L [pc]	<N(H_2)> [x10^{21} cm^{-2}]	mass per unit length, M_L [$M_\odot$ /pc] (ΣM/L)	σ_{tot} [km/s]	c_s [km/s]	T_{ex} [K]	virial parameter α	thermal virial parameter α_{therm}
0.42	36.2	117	0.85	0.41	52	5.5	1.2

Filament properties

The table (below) summarises average filament properties using a filament width of 0.1pc, which contains 37% of the total cloud mass. A width of 0.06pc contains 20% of the cloud mass. Virial parameters are calculated assuming cylindrical geometry with critical mass per unit length, $M_{crit} = 2c_s^2/G$ and virial mass per unit length, $M_{vir} = 2\sigma^2_{tot}/G$. There are then two measures of the virial stability, $\alpha_{therm} = M_{crit}/M_L$ and $\alpha = M_{vir}/M_L$. 80% of the filaments have α_{therm} <2, while 20% have α<2 .

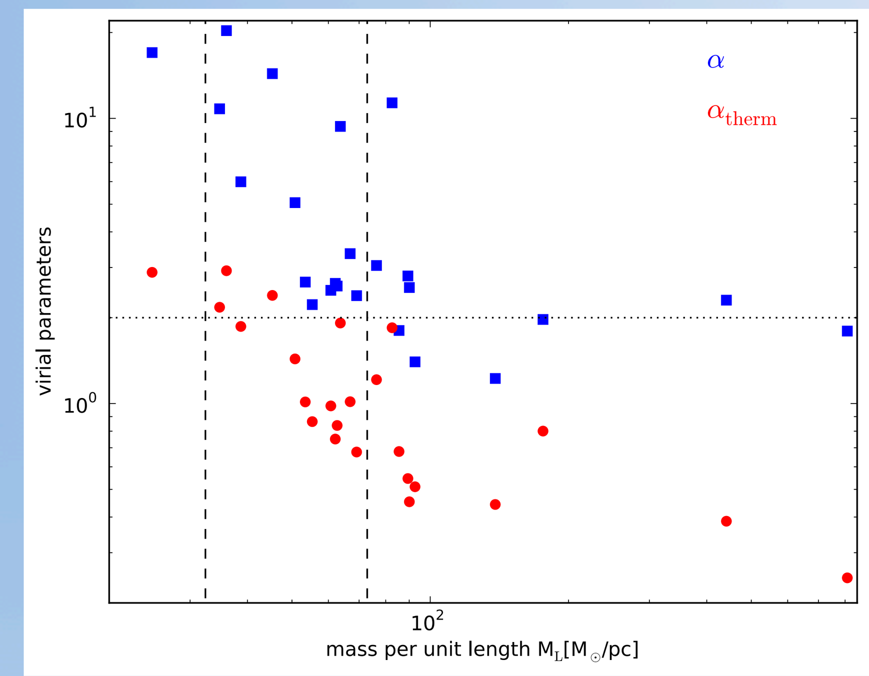
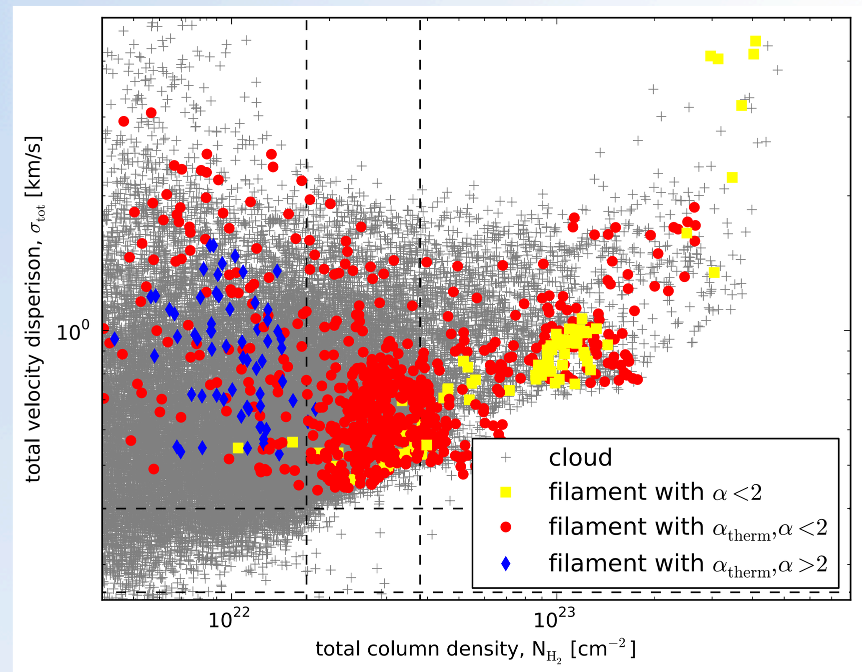


Figure 6 (left) shows the virial parameters α and α_{therm} against mass per unit length, M_L, for the filaments in Orion A. Dashed vertical lines show the critical mass per unit length, M_{crit}, for T_{ex}=20K and 45K. The dotted horizontal line shows α=2

Both virial parameters α and α_{therm} decrease with increasing M_L for low values of M_L. Near values where $M_L \approx M_{crit}$, the slope changes, and both virial parameters show little variation with increasing mass per unit length. For many filaments in Orion A, energetic outflow sources result in large linewidths, even in $C^{18}O$, leading to values of $M_{crit} >> M_{vir}$.

Fig. 2 (below) shows $N(H_2)$ against σ_{tot} for all detected emission in Orion A. Coloured markers show points along the filament spines, coded according to values of the virial parameters of the filament. Dashed lines show c_s and equivalent $N(H_2)$ at 20K and 45K. Between these dashed lines, corresponding mass per unit lengths are approximately equal to the critical mass per unit length for temperatures in the Orion A filaments.

The filaments with α and/or α_{therm} <2 have velocity dispersions which increase with increasing column density, whereas filaments with α and/or α_{therm} >2 have velocity dispersions which slightly decrease with column density.



- ❑ the filaments are warm, with median T_{ex}=45K
- ❑ 80% of the filaments have α_{therm} <2, suggesting they are self-gravitating, bound structures
- ❑ 20% of the filaments have α <2. This low percentage is likely a result of the energetic outflows leading to large total velocity dispersions as measured in $C^{18}O$ emission.
- ❑ all filaments with α_{therm} <2 have average $N(H_2) > 1.3 \times 10^{22}$ cm^{-2}.