VELOCITY COHERENCE IN DENSE CORES

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Abstract. By analyzing the dependence of line width on size in NH_3 maps of dense cores, and in $C^{18}O$ and OH maps of the gas around the cores, we find that: (1) on scales larger than the FWHM contour of an NH_3 core, line width is correlated with size such that $\Delta v \propto R^a$ where $a \sim 0.4$; and (2) within the cores themselves, the power-law slope of the line width-size relation goes to zero (i.e., line width is constant). We interpret this result as evidence for a breakpoint between "turbulent" self-similar molecular clouds and "velocity coherent cores" which can collapse to form individual stars or small groups of stars.

Low-mass ($\sim$ 1 to 10 $M_\odot$) dense cores appear to be relative islands of calm in a more turbulent sea. These cores, which are the birthplace of many of the stars in our Galaxy, have average densities $\sim 10^4$ cm^{-3}, sizes of approximately a few tenths of a parsec, and are characterized by very small internal velocity dispersions ($\sim$ several tenths of a km s^{-1}; cf. Benson & Myers 1989; Myers & Benson 1983) . In our recent work (Barranco & Goodman 1996; Goodman et al. 1996), high-sensitivity $C^{18}O$, OH, and NH_3 mapping of the cores and their environs have shown that the line width-size power-law scaling relation discovered more than a decade ago by Larson (1981) appears to have a break in slope at a size scale roughly comparable to the full-width-half maximum (FWHM) contour of an NH_3 map ($\sim$ 0.1 pc).

On scales larger than an NH_3 $(J,K) = (1,1)$ FWHM emission contour, extensive $C^{18}O$ and OH maps of core environs show a radial dependence of line width on size such that $\Delta v \propto R^a$ where a ~ 0.4. The left panel of Figure

Figure 1. Assuming that "size" scales as $1/T_A$, the implied line width–size scaling relation for the L1251A dark cloud environment *(left)* shows a "Larson's Law" dependence of line width on size, whilst observations of an individual dense core within the cloud *(right)* exhibit "velocity coherence" (i. e., virtually no dependence of line width on cloud size).

1 shows one example of this line width-size relation, for the region around the dense core designated L1251A. In practice, the "radial" dependence of line width is derived by approximating $R \propto 1/T_A$ and fitting a straight line to $\log(\Delta v)$ vs. $\log(T_A)$. Barranco & Goodman (1996) describe the fitting procedure in detail and provide empirical justification for the $R \propto 1/T_A$ approximation.

A demonstration of "Larson's Law" (left panel of Figure 1) is interesting on its own, since line width-size relations have rarely been studied in single-tracer maps of individual clouds. (Most studies use multiple lines and/or cloud-to-cloud comparisons (e.g. Fuller & Myers 1992; Larson 1981; Myers & Goodman 1988) . Nonetheless, the most interesting result of our analysis is a "coherence" effect associated with the cores. The NH_3 maps show that, within the cores themselves, Larson's Law effectively ends: the line width "inside" the core is constant to a very high degree of significance. This velocity "coherence" effect is illustrated by the nearly constant line width in the L1251A NH_3 data shown in the right-hand panel of Figure 1.

Since the measured velocity dispersion, σ, cannot go below the thermal velocity dispersion, $\sigma_{\rm T}$, (~ 0.07 km s^{-1} for NH_3 at 10 K), it is obvious that the Larson's Law correlation between line width and cloud size must end at some small size (i.e., line width cannot decrease interminably with cloud size). But, the velocity dispersion at which the cores become coherent is

always significantly above a purely thermal velocity dispersion. For L1251A, the $\sim$ constant "non-thermal" velocity dispersion is $\sigma_{\rm NT} = (\sigma^2 - {\sigma_{\rm T}}^2)^{0.5} = \Delta v_{\rm NT}/2.35 \sim 0.1$ km s^{-1}.

The size scale of the break in the line width-size scaling relationship we find in our molecular line data is just a few times larger than the size scale at which Larson (1995) has recently discovered a break in the power-law slope of the function describing the clustering of newly-formed stars in the ISM. The size scale of the break in the star-clustering power-law has been likened to a Jeans size by Larson. We expect that our result and Larson's are similar, in that we are finding the Jeans mass clumps with roughly constant line width, and he is studying the fruits of those clumps.

In summary, we find that line width decreases with cloud size as Larson's Laws would predict for size scales larger than the FWHM of an NH_3 core, but asymptotically approaches a constant value within the cores. We hypothesize that this effect results when the self-similar cascade that characterizes the larger-scale ISM effectively "ends" inside the dense cores, where self-gravity becomes a dominant force. It is possible that the location of the cores corresponds to what once were simply "eddies" or regions of reduced kinetic energy, in the larger-scale turbulent flow of the ISM. In such regions, gravity would gain the edge it needs over kinetic pressure support, in order to initiate a slow collapse.

References

Barranco, J.A. and Goodman, A.A. 1996, ApJ, in prep.
Benson, P.J. and Myers, P.C. 1989, Ap. J. Suppl., **71**, 89
Fuller, G.A. and Myers, P.C. 1992, ApJ, **384**, 523
Goodman, A.A., Barranco, J.A., Heyer, M.H. and Wilner, D.J. 1996, ApJ, in prep
Larson, R.B. 1981, MNRAS, **194**, 809
Larson, R.B. 1995, MNRAS, **272**, 213
Myers, P.C. and Benson, P.J. 1983, ApJ, **266**, 309
Myers, P.C. and Goodman, A.A. 1988, ApJ, **329**, 392