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TURBULENCE PARAMETERS FROM STATISTICS OF SPECTRAL LINE DATA CUBES

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In a previous work, Lazarian & Pogosyan (2000) developed a technique to obtain information on interstellar turbulence by studying the emissivity statistics in velocity channel maps. Here we use MHD simulations to extend previous tests of the method and study anisotropies in two-point statistics, which reveal the direction of the magnetic field.

Turbulence is best described using statistical tools, such as the correlation function $\xi(\mathbf{r}) = \langle\rho(\mathbf{x})\rho(\mathbf{x}+\mathbf{r})\rangle$, where $\mathbf{x}$ is the spatial position, $\mathbf{r}$ a spatial separation (or "lag"), and the angle brackets denote average over all space. An alternate useful description is the power spectrum, $P_\rho(\mathbf{k}) = \int \mathrm{d}\mathbf{r}\, \mathrm{e}^{i\mathbf{k}\cdot\mathbf{r}}\xi(\mathbf{r})$. So far, studies of turbulence have been made using only density statistics, while velocity is a more useful quantity to study turbulence. In order to obtain velocity information we need spectral line data. However, in spectroscopic observations we do not observe the gas distribution in real coordinates, instead we have the intensity towards a certain position in the sky and a given velocity along the line of sight (LOS). Furthermore, both velocity and density fluctuations contribute to the statistics of emissivity fluctuations. The issue of disentangling the relative contribution of velocity and density fluctuations was addressed in Lazarian & Pogosyan (2000), hereafter LP00, where an analytical study of the 2-D power spectrum in velocity channels was made (using power-law statistics spectrum of density $P_n \sim k^{-n}$, velocity $P_v \sim k^{-\mu}$, and emissivity in velocity channels $P_\rho \sim k^{-\gamma}$), this technique is now termed "Velocity-Channel-Analysis" (VCA). In particular, LP00 found that for a steep density field ($n < -3$), when the channels are thin (thickness smaller than the turbulent dispersion at a given scale) the spectrum is dominated by the velocity, while for very thick channels the density dominates.

Here we used MHD simulations in a 216^3 grid, with a density spectral index of $-11/3$ and velocity indices of -3.1, -3.3, -3.5, $-11/3$, -3.8, and -4.0. With these we emulated spectroscopic observations (produced PPV cubes) and analyzed them using the VCA. Some of the measured and predicted indices are summarized in Table 1. We see a gradual steepening of the spectrum as we increase the thickness of the channels, and the emissivity in very thick channels match the predictions very well. However, the spectrum in thin channels keeps getting shallower past the asymptotic value predicted. We showed this problem is exclusive of the analysis with numerical simulations and is neither expected nor observed in real observations (Stanimirović & Lazarian 2001). With only 216 emitters along the LOS (where the number of emitters in real observations can be regarded as infinite), a large velocity resolution results in many empty channels, introducing noise, and making the spectrum shallower. A way around this is to use channels of thickness only enough to be considered thin, so the noise introduced is minimal.

TABLE 1

MEASURED SPECTRAL INDICES USING VCA

	Predicted spectral index (γ)					
	−2.95	−2.85	−2.75	−2.67	−2.6	−2.5
# vel.	Velocity index (μ)					
chnls.	−3.1	−3.3	−3.5	−3.67	−3.8	−4.0
25	−2.54	−2.54	−2.50	−2.47	−2.47	−2.44
15	−2.68	−2.74	−2.74	−2.74	−2.74	−2.74
10	−3.03	−3.01	−3.00	−2.99	−3.00	−3.02
5	−3.03	−3.13	−3.22	−3.29	−3.34	−3.44
1	−3.65	−3.65	−3.65	−3.65	−3.65	−3.65

The magnetic field sets a preferential direction for the motion of a turbulent plasma, making the cascade, and also the two-point statistics anisotropic. We calculated contours of equal cross-correlation in our simulated observations and they reveal an elongation with symmetry axis along the mean magnetic field. This method presents a technique to obtain the direction of the magnetic field where other data is not available (see Esquivel et al. 2003).

REFERENCES

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