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The Turbulence Spectrum of Molecular Clouds in the Galactic Ring Survey: A Density-Dependent PCA Calibration

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Turbulence plays a major role in the formation and evolution of molecular clouds. The problem is that turbulent velocities are convolved with the density of an observed region. To correct for this convolution, we investigate the relation between the turbulence spectrum of model clouds, and the statistics of their synthetic observations obtained from Principal Component Analysis (PCA). We apply PCA to spectral maps generated from simulated density and velocity fields, obtained from hydrodynamic simulations of supersonic turbulence, and from fractional Brownian motion fields with varying velocity, density spectra, and density dispersion. We examine the dependence of the slope of the PCA structure function, alpha_PCA, on intermittency, on the turbulence velocity (beta_v) and density (beta_n) spectral indexes, and on density dispersion. We find that PCA is insensitive to beta_n and to the log-density dispersion sigma_s, provided sigma_s < 2. For sigma_s>2, alpha_PCA increases with sigma_s due to the intermittent sampling of the velocity field by the density field. The PCA calibration also depends on intermittency. We derive a PCA calibration based on fBms with sigma_s<2 and apply it to 367 CO spectral maps of molecular clouds in the Galactic Ring Survey. The average slope of the PCA structure function, <alpha_PCA>=0.62\pm0.2, is consistent with the hydrodynamic simulations and leads to a turbulence velocity exponent <beta_v>=2.06\pm0.6 for a non-intermittent, low density dispersion flow. Accounting for intermittency and density dispersion, the coincidence between the PCA slope of the GRS clouds and the hydrodynamic simulations suggests beta_v~1.9, consistent with both Burgers and compressible intermittent turbulence.

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