Magnetohydrodynamic (MHD) Turbulence at high Galactic latitudes

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Abstract: We performed statistical analysis of HI column density on a high Galactic latitude cloud, MBM16 (Figure 1), to investigate the charactistics of turbulence. We derived the HI column density map using data from the Galactic Arecibo L-Band Feed Array HI (GALFA-HI) Survey. We developed a code to generate the 3rd and 4th moment maps and derived the sonic Mach number (M_s) map (Figure 2) based on the relation between higher order moments and a level of turbulence, purely derived from theoretical MHD simulations. The derived M_s map allows us to investigate turbulence across the cloud at a resolution of ~0.7 pc. We found that HI in MBM16 is subsonic or transonic and this result is consistent with an independent estimate of turbulence based on the slope of spatial power spectrum. Our study is the first attempt for the Milky Way to study the spatial distribution of turbulence and will be extended to other clouds cataloged in the GALFA-HI data.

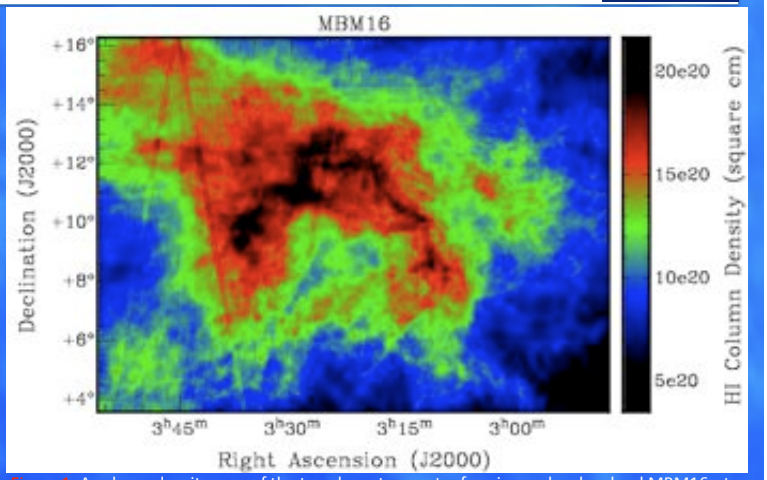

Figure 1: A column density map of the translucent, non-star forming molecular cloud MBM16 at a distance of ~80 pc.[2]

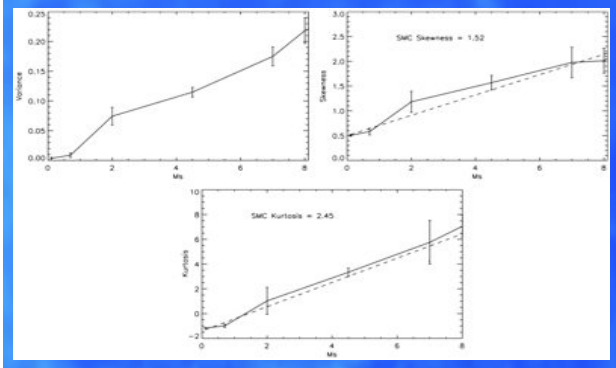

Figure 2: Taken from Burkhart et al. 2010[1]. These relationships were derived from analyzing how the statistics of numerical isothermal simulations of HI column density distributions behaved relative to a change in M_s.

We first obtain an HI column density map (Figure 1) using data from the GALFA-HI survey (Peek et al. 2011[4]). In order to estimate Ms, we adopt the following procedures:

1. Construct a box kernel that begins its convolution in the lower left corner, and is multiplied by a gaussian function to minimize edge effects.
2. Trace out a circular kernel that is 35 pixels to maximize signal-to-noise[1] in radius from the center pixel of the box. Any pixel within this circular kernel will have its value considered part of the distribution.
3. The 3rd and 4th statistical moments (skewness and kurtosis) are calculated using the data points in the circular kernels.
4. When the 3rd and 4th moment maps have been generated, we derive a sonic mach number map (Figure 3) by adopting the equation M_s=(Kurtosis+1.44)/1.05), derived from theoretical MHD simulations (Figure 2).

Conclusions:

We compare our results for MBM16(no stars) with the results for the SMC from Burkhart et al. 2010. We find MBM16 to be less turbulent than the SMC, which confirms the notion that stars are prominent drivers of interstellar turbulence. With a power spectrum slope of -3.9[3] for our region, we should–and do– see Mach numbers mostly below 2 (Figure 4). We do not expect to see much small scale structure across MBM16 because of the low mach numbers.

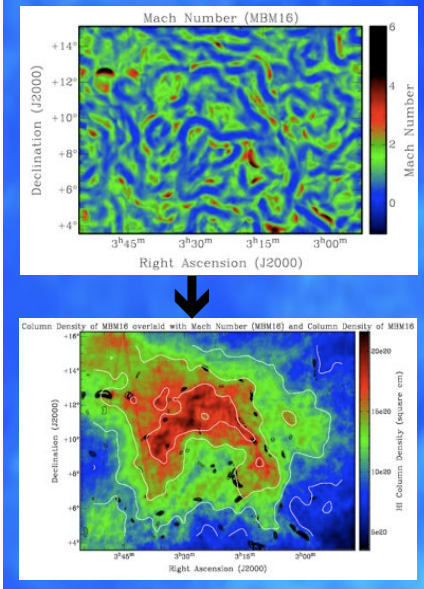

Figure 3: The Mach number map of MBM16 (top) with the column density map (bottom) overlaid with smoothed HI contours (white) and the highest levels of mach numbers (black). These highlight the most turbulent regions.

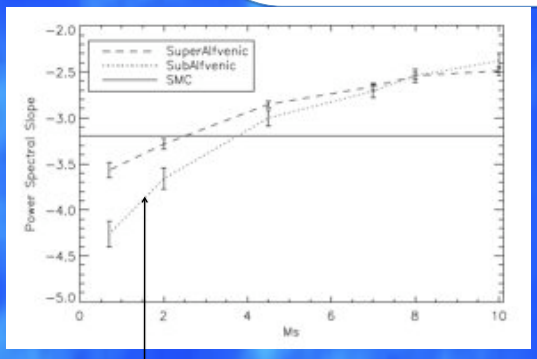

Figure 4: Taken from Burkhart et al 2010. Power spectral slope vs. Mach numbers of MHD simulations.

References:

1. Burkhart, B., Stanimirovic, S., Lazarian, A., & Kowal, G. 2010, ApJ, 708, 1204.
2. Hobbs, L.M. et al. 1988, ApJ, 327, 356
3. Chepurnov, A., Lazarian, A., Stanimirovic, S. , Heiles, C., & Peek, J.E.G., 2010. ApJ, 714, 1398
4. Peek J.E.G., Heiles, C.,Douglas, K.A., et al. 2011 ApJS, 194,20

M_s	SMC	MBM16
0-1	45%	55%
1-2	45%	39%
>2	10%	6%

Table 1: Comparison of turbulence across the of MBM16 and the SMC as a percentage of mapped area.