**WHY WOULD WE SEE 2-D TURBULENCE IN INTERSTELLAR GASES?**

*Anthony H. Marker (NRAO)*

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**ABSTRACT**

Neutral gas in the galaxy traced through the H I 21 cm line and the CO (J = 1-0) line, as well as the ionized gas seen in the radio and reionization lines have power spectra of density fluctuations that are consistent with 2-Dimensional turbulence on large spatial scales ($\geq 0.01$ kpc). We show, however, that in situ measurements of the turbulence in the Milky Way show that the turbulence is likely 3-Dimensional. A method has been devised to make "observable" models of the density and velocity fields of a turbulent gas. The derived power spectra (density and velocity) are the only inputs into the model. These models have been used to study how propagation effects and the various modes of observation can change the 3-Dimensional turbulence into the observed 2-Dimensional turbulence. The following effects can make the observed turbulence appear 3-Dimensional: 1) if the turbulence is contained in a thin filament or shell; 2) if the medium has a high optical depth; and 3) if many methods of observation are combined. A simple model of turbulence is used which effectively limits the emission from the medium under study to a thin slab, for example, by assuming an individual channel map. A straightforward analysis of data leads to misleading or incomplete results if these effects are not taken into account.

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**WHY NOT 3-D TURBULENCE**

- Derivation of turbulence in the ISM are 3-D.
- Turbulent structure exhibits a change from 3-D to 2-D for $l > l_{gam}$.
- For large times, the turbulent structure is random.
- Can test this hypothesis with models.

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**OBSERVATIONS OF 2-D TURBULENCE IN THE GALAXY**

**H I 21 cm observations with interferometers**

- Measure line of sight density power spectrum directly.
- $n = 23 \pm 2$ (Kolmogorov turbulence has $n = 5/3$).
- $0.01 < l < 0.1$ pc.
- CO (J = 1-0) single dish maps.
- Measure line of sight density power spectrum through structure function.
- $n = 23 \pm 2$.
- $0.01 < l < 0.1$ pc.

- Diurnal mean gas observed in H I
- Density proportional to EM $n \propto EM$.
- Measure line of sight density power spectrum through EM structure function.
- $n = 23 \pm 2$.
- $0.01 < l < 0.1$ pc.
- $l_{gam} = 10$ cm.

**Velocity correlation fluctuations are consistent with 2-D velocity fluctuations on the same scales for all observations.**

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**TURBULENCE MODEL**

- Singleton (in time).
- Define power spectrum (slope, level, mean and outer scale).
- Use power spectra of density and velocity.
- Let $\Delta n \sim n_{0}/l$, $\Delta c \sim c_{0}/l$.
- 5th model.
- Use sample variance and random phase to determine $N$ and $l$.
- FFT $N \rightarrow r$ and $V \rightarrow v$.
- Integrate along z-axis including "radial transfer" to reproduce observations.

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**RESULTS**

What causes the observed 2-D turbulence?

- Emission from thin sheets or filaments.
- Openly.
- Sense channel maps limiting to be from thin slabs of space.
- Incompleteness or misleading results can be obtained if one does not take into account any effect which changes the observed turbulent characteristics from 3-D to 2-D.

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**Theory**

In general, we will assume that the observed turbulence is related to the column density of the neutral gas integrated to some depth $l$ into the medium. The value of $n$ can be a free parameter for the observed maxima assuming that the Parker rotation curve can be convolved into a density, velocity correlation function. It can be made finite by the opacity of the medium or it can be finite due to the turbulent gas being contained in a thin filament or shell with a size $l$. We can write the column density as $N = n_{0}/l$, where $n_{0}$ is the column density at the filament or shell and $l$ is the size of the filament or shell. We will assume that the turbulence is random and isotropic. The free parameter $l$ gives the gas length scale in the medium as observed for visual field of view. The power spectrum of the turbulent fluctuations is related to the Parker rotation curve, $P(k) \propto k^{-5/3}$, where $k$ is the wave number, $k = 2\pi/l$. The length scale is given by the length scale of the turbulence, $l_{gam} = (v_{turb}^{2}/g) (l_{turb}^{2}/g)$, where $v_{turb}$ is the turbulent velocity and $g$ is the acceleration due to gravity. The power spectrum of the turbulent fluctuations, $P(k) \propto k^{-5/3}$, defines the relationship between the 3-D and 2-D turbulence. A general physical model is used to describe the turbulence.

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**Figure 1.** Image of "observable" flux from a gas whose emission is contained to a single channel map and its corresponding structure function. The channel map is an equivalent width of 10 pixels. The outer scale of the turbulence is 200 pixels and is shown by the solid line in the left. It is clearly seen that there is a transition from 3-D turbulence to 2-D turbulence on the size scale of 10 pixels.

**Figure 2.** Image of "observable" flux from a gas which is optically thick and its corresponding structure function. The outer scale of the turbulence is 128 pixels and is shown by the solid line on the left. The optical depth at ten pixels is $r = 1$. It is clearly seen that there is a transition from 3-D turbulence to 2-D turbulence around an optical depth of $r \sim 1$. 

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**Figure 3.** Image of "observable" flux from a gas which the full data cube is sampled and its corresponding structure function. The outer scale of the turbulence is 100 pixels. It is easily seen that 3-D turbulence is observed on all relevant size scales. The outer scale for the turbulence is 30 pixels and is shown by the solid vertical line.