I review recent results derived from numerical simulations of the turbulent interstellar medium (ISM), in particular concerning the nature and formation of turbulent clouds, methods for comparing the structure in simulations and observations, and the effects of projection of three-dimensional structures onto two dimensions. Clouds formed as turbulent density fluctuations are probably not confined by thermal pressure, but rather their morphology may be determined by the large-scale velocity field. Also, they may have shorter lifetimes than normally believed, as the large-scale turbulent modes have larger associated velocities than the clouds’ internal velocity dispersions. Structural characterization algorithms have started to distinguish the best fitting simulations to a particular observation, and have opened several new questions, such as the nature of the observed line width-size relation and of the relation between the structures seen in channel maps and the true spatial distribution of the density and velocity fields. The velocity field apparently dominates the morphology seen in intensity channel maps, at least in cases when the density field exhibits power spectra steep enough. Furthermore, the selection of scattered fluid parcels along the line of sight (LOS) by their LOS-velocity inherent to the construction of spectroscopic data may introduce spurious small-scale structure in high spectral resolution channel maps.

1 Introduction

Turbulence is a prime example of a chaotic system, and the interstellar medium (ISM) is most probably a prime example of a turbulent medium. A discussion of interstellar turbulence thus befits this volume. Although chaos theory generally refers to systems with only a few degrees of freedom while turbulent flows have in general an extremely large number of them, both types of systems share the properties of sensitivity to initial conditions and the resulting practical unpredictability, as a consequence of the nonlinear couplings between the relevant variables. Furthermore, interstellar turbulence is much more complex than natural terrestrial and laboratory turbulence because the former is magnetized, and, in cloudy regions, highly compressible and strongly self-gravitating, thus not expected to Kolmogorov-like except possibly in the diffuse gas.

In recent years, many reviews covering various aspects of interstellar and
molecular cloud turbulence have appeared in the literature. Compressible
turbulence basics and self-similar models are discussed by Vázquez-Semadeni. A compendium of a wide variety of interstellar turbulence aspects is given in the volume Interstellar Turbulence, including in particular turbulence in the HI gas and in the diffuse ionized component. A thorough review of the implications of compressible MHD turbulence for molecular cloud and star formation is presented in Vázquez-Semadeni et al. The present paper may be regarded as a companion to the latter reference, as it includes a number of topics not covered there. After reviewing the scenario of interstellar clouds as turbulent density fluctuations and some of its implications (sec. 2), I discuss the comparison of the structural properties of simulated clouds with those derived observationally for real clouds (sec. 3; see also Ossenkopf et al., this volume, for a discussion from a more observationally-oriented perspective), and on the effects of projecting three-dimensional (3D) data onto two dimensions, the latter point being important for the interpretation of observational data, which necessarily are projections on the plane of the sky (sec. 4).

2 Interstellar Clouds as Turbulent Density Fluctuations

A fundamental problem in the understanding of star formation is how the gas transits from a low-density diffuse medium to a comparatively enormously denser star. An intermediate step in this process is the formation of what we may generically refer to as interstellar clouds, including structures that span a wide range of physical conditions, from large diffuse HI clouds of densities a few \( \times 10 \) cm\(^{-3} \) and sizes up to hundreds of parsecs, to molecular cloud cores with densities \( \gtrsim \) \( 10^4 \) cm\(^{-3} \) and sizes of a few \( \times 0.01 \) pc. The process of cloud formation quite possibly involves more than a single mechanism, including the passage of spiral density waves and the effects of combined large-scale instabilities operating preferentially in the formation of the largest high-density structures, and the production of smaller density condensations by either swept-up shells or by a generally turbulent medium. In the remainder of this section we focus on the latter process.

An important question is whether structures formed by either turbulent compressions or passages of single shock waves can become gravitationally unstable and collapse. This depends crucially on the cooling ability of the flow, which, as a first approximation, can be parameterized by an effective polytropic exponent \( \gamma_{\text{eff}} \) such that the pressure \( P \) behaves as \( P \propto \rho^{\gamma_{\text{eff}}} \), where \( \rho \) is the fluid density. Note that in this description both the “cooling” and the “pressure” can be generalized to refer to non-thermal energy forms, such
as magnetic and turbulent.

The production and statistics of the density fluctuations in polytropic turbulence has been investigated recently by various groups. Passot and Vázquez-Semadeni have found that the probability density function (PDF) of the density fluctuations depends differently on the Mach number and on $\gamma_{\text{eff}}$. By means of a simple phenomenological model, these authors find that, for isothermal flows ($\gamma_{\text{eff}} = 1$), the PDF is lognormal, as a consequence of the Central Limit Theorem and of the accumulative and multiplicative (additive in the log) nature of the density jumps caused by shocks. Increasing the rms Mach number only increases the width of the lognormal PDF and shifts its peak towards smaller densities. Instead, varying $\gamma_{\text{eff}}$ changes the form of the distribution, which develops a power law tail at large densities for $0 < \gamma_{\text{eff}} < 1$, and at small densities for $\gamma_{\text{eff}} > 1$. This effect is a consequence of the modification of the lognormal by the local variation of the sound speed, which in the general polytropic case varies with the density as $\rho(\gamma_{\text{eff}} - 1)/2$. Essentially, in the power-law side of the PDF the density fluctuations are dominated by the nonlinear advection term in the momentum equation, with an increasingly negligible contribution from the pressure at increasingly large ($\gamma_{\text{eff}} < 1$) or small ($\gamma_{\text{eff}} > 1$) densities, due to the decreasing sound speed, while on the opposite side of the PDF the pressure dominates, impeding large excursions of the density. A concise discussion of the mechanism can also be found in Vázquez-Semadeni and Passot.

The stability of fluid parcels compressed in $n$ dimensions by shocks or turbulence requires $\gamma_{\text{eff}} > \gamma_{\text{cr}} \equiv 2(1 - 1/n)$. For three-dimensional compressions, the minimum Mach number $M_0$ necessary to induce collapse by the velocity field has been computed by several authors as a function of $\gamma_{\text{eff}}$ and the mass $m$ of the cloud in units of the Jeans mass. It is found that $M_0 \propto \ln m$ for the isothermal ($\gamma_{\text{eff}} = 1$) case, $M_0 \propto m(\gamma_{\text{eff}} - 1)/(4 - 3\gamma_{\text{eff}})$ for $4/3 > \gamma_{\text{eff}} > 1$, and $M_0 \geq \sqrt{10/(3(1 - \gamma_{\text{eff}}))}$ for $0 < \gamma_{\text{eff}} < 1$.

A relevant implication is that clouds formed by turbulent compressions are by necessity of a dynamical character, and are expected to either collapse, if the conditions described in the previous paragraph are satisfied, or else should reach some maximum density and then “rebound” as the external compression subsides (since the turbulent motions are chaotic, a compression will in general last a finite time only). This result has interesting implications on two “canonical” concepts of interstellar dynamics, as recently discussed by Ballesteros-Paredes et al. First, it may be that clouds in the ISM may not be pressure-confined as in popular models of the ISM, but rather in a highly dynamic and transient state, except if they become strongly gravitationally bound. An interesting corollary of this scenario occurs for regimes in...
which the \(\gamma_{\text{eff}} \sim 0\) (i.e., a nearly isobaric behavior), as is indeed the case for the ISM between densities \(\sim 0.1 \text{ and } 10^2 \text{ cm}^{-3}\). In this case, the thermal pressure remains nearly constant, regardless of the density structures formed by the turbulence. However, while traditionally this near pressure constancy has been regarded as a pressure balance condition that provides confinement for clouds, in the turbulent-cloud scenario it is only a relatively irrelevant consequence of the medium being maintained at nearly constant thermal pressure by the prevailing cooling processes as it is compressed by the turbulent motions.

Secondly, it appears difficult to produce the quasi-hydrostatic clumps which are the commonly assumed to be the initial conditions of many models of star formation. Their formation within a globally gravitationally stable region by a turbulent compression requires, as described above, that \(\gamma_{\text{eff}} < \gamma_{\text{cr}}\). However, this sets them in a state of gravitational collapse. To then form a hydrostatic structure, a change in \(\gamma_{\text{eff}}\) is required during the collapse, in order for \(\gamma_{\text{eff}}\) to now become \(\geq \gamma_{\text{cr}}\), so that the pressure may now overcome the ongoing gravitational compression, and ultimately halt the collapse. Such change in \(\gamma_{\text{eff}}\), at least from thermal contributions alone, is not expected until very high densities (\(\gtrsim 10^8 \text{ cm}^{-3}\)) are reached.

Another implication of the turbulent density fluctuation scenario for the clouds is that the time scales associated to clouds may be smaller than those derived from their sizes and internal velocity dispersions. If the cloud is made by the collision of large-scale streams, the time scale for its formation is the crossing time through its size \(L\) at the velocity difference between the turbulent scales larger than cloud (the colliding streams). For turbulence with a (normal) spectrum that decays with wavenumber \(k\), the characteristic velocity difference increases with separation, and thus the crossing time scale for the cloud is smaller than that derived from its internal velocity dispersion. Indeed, the line widths from the HI envelopes of molecular clouds are generally larger than the line widths in the molecular clouds themselves. This result has been proposed as a possible solution to the absence of post-T-Tauri stars in the Taurus region, since the region may be younger than the age derived from its internal velocity dispersion.

3 Comparisons Between Simulations and Observations

In recent years, numerical simulations of interstellar turbulence have advanced to the point that statistical comparisons with observational results have be-
come possible. This is a crucial task because it allows an iterative procedure in which simulations may be constrained as models of the ISM and interstellar clouds by comparison of their morphological, topological and statistical properties with their observational counterparts. Once the best-fitting set of parameters is found for a certain type of system, the simulations may then be used as highly complete models of such system to improve our understanding of the physical processes occurring within them. However, it should be pointed out that this is a difficult task, because the natures of the observations and of the simulations are quite different. While simulations are performed on a regular grid, with well-defined boundaries, observations refer to regions of space for which the size along the line of sight is not constant. For example, for HI observations, the path length through the disk decreases with Galactic latitude, while for molecular line observations, the observed objects in general may have different extents along the LOS over their projected area. Also, linear sizes perpendicular to the LOS increase with distance. In spite of these difficulties, however, several first steps have been taken in this direction.

3.1 Scaling Relations

One basic question is whether the clouds in the simulations reproduce the well-known Larson relations (see also the review by Blitz for a more recent account) $\Delta v \propto R^{1/2}$ and $\langle \rho \rangle \propto R^{-1}$, where $\Delta v$ is the velocity dispersion in the cloud, $\langle \rho \rangle$ its mean density, and $R$ its characteristic size. In an analysis of two-dimensional MHD simulations of the ISM including self-gravity and stellar-like driving, Vázquez-Semadeni et al. found that, although with much scatter, a Larson-like velocity dispersion-to-size scaling of the form $\Delta v \propto R^{0.4}$ is observed for clouds defined as the connected regions in the flow with densities above a given threshold. This result is roughly consistent with observational surveys giving scaling exponents between 0.4 and 0.7. However, the density-size relation is not verified in the simulations. Instead, small clouds with low densities, which are transient and not gravitationally bound, are formed in large quantities in the simulations. Rather than being satisfied by all clouds, the Larson density-size relation appears to be an upper bound to the region populated by the clouds in a $\rho$-$R$ diagram. The same trend was observed in a sample of objects away from map intensity maxima. This supports suggestions that the density-size relation may be an artifact of the limitations on integration times of observational surveys, and that the $\Delta v$-$R$ relation, satisfied by all clouds, may originate from the Burgers-like

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*a*But note that modeling of individual objects is not feasible because of the sensitivity to initial conditions of turbulent flows.
spectrum of molecular cloud turbulence. In this scenario, only those clouds which become sufficiently self-gravitating and are not strongly disturbed (i.e., in near virial equilibrium), satisfy the density-size relation.

3.2 Synthetic Line Profiles

Another important means of comparison between simulations and observations are the spectral line profiles, since their shapes (generally characterized by their first few moments) reflect the velocity structure of the flow in the observed regions. Line profiles from the simulations are constructed as density-weighted velocity histograms along each LOS.

Falgarone et al. compared the line spectra produced in a high-resolution 3D simulation of weakly compressible turbulence with observational data, concluding that both sets of spectral lines are very similar, in terms of the range of values of the variance and the kurtosis they present. The similarity is greater in this case than that achieved by other models of clouds (constructed with random uncorrelated velocity fields or with isolated clumps in an interclump medium) which do not account for the spatial correlations derived from the continuum nature of fluid turbulence. Similar results have been obtained from randomly generated flows with an imposed Kolmogorov spectrum. However, a more recent study based on the PDFs of the velocity centroids, rather than on the line profiles, suggests that in turn nearly incompressible turbulence fails to capture some features of the centroid PDFs of both molecular and HI regions, which exhibit a larger degree of non-Gaussianity than those derived from incompressible or weakly compressible turbulence.

Line profiles from simulations of strongly compressible MHD turbulence, including radiative transfer, as well as other diagnostics, have recently been compared to molecular line data by Padoan and coworkers to support their suggestion that molecular clouds may actually be in a super-Alfvénic regime, rather than a sub-Alfvénic one, as generally believed. Their tests were based on two 3D simulations of MHD isothermal turbulence without self-gravity, one super-Alfvénic, the other sub-Alfvénic. First, they noted that simulated line profiles from the super-Alfvénic run seem to reproduce the observed growth of line width with integrated antenna temperature better than those from the sub-Alfvénic run. Secondly, the super-Alfvénic run seems to better match the observed trend of magnetic field strength vs. gas density. Finally, the super-Alfvénic simulation also more closely reproduces the observational trend of the dispersion of extinction vs. mean extinction along selected lines of sight. However, one caveat remains before the super-Alfvénic model can be accepted: the simulations lacked self-gravity, which could have pushed the
results of the sub-Alfvénic simulation closer to the observational results, and the super-Alfvénic run away from them. Therefore, similar experiments are needed with self-gravitating runs in order to confirm this possibility.

3.3 Higher-Order Statistics and Fractality Analyses

The methods described in the previous section have taken into account only the velocity information in the spectral data “cubes”. We now briefly discuss methods that have tried to take spatial information into consideration as well.

Spatial structure is often described by means of the autocorrelation function (ACF), which measures the probability of finding equal values of a given physical variable at two different positions in space, as a function of their separation. Early studies in this direction measured the ACF of column density and of the line velocity centroids, attempting to determine whether characteristic lengths exist in the ISM, with mixed results. Recently, a variant of this approach termed the Spectral Correlation Function (SCF) has been introduced. The SCF measures the quadratic difference between line spectra (on a channel-by-channel basis) at different positions on a spectral-line map, in an attempt to include spectral as well as spatial information in the statistical description. So far, the method has been used to measure the angle-averaged correlation between the spectrum at a given position in a map and at its nearest neighbors, allowing the characterization of the small-scale variability of the spectra, and a comparison between CO maps and simulations of isothermal turbulence under various regimes (purely hydrodynamic, MHD, and self-gravitating). In that work, differences between the values of the SCF for weakly compressible purely hydrodynamic turbulence and for the Ursa Major molecular cloud indicate that simulation is not as accurate a model for the Ursa Major cloud as previously claimed by Falgarone et al. on the basis of line profile shapes (see sec. 3.2). Comparison of HI data with non-isothermal simulations has proven more difficult, because the thermal broadening of the warm gas swamps the velocity structure of the cold gas.

The recognition that the structure of the ISM may have a turbulent origin has also prompted searches for fractal properties of interstellar clouds (although see the contribution by Combes, this volume, for an alternative scenario originating the fractal structure). Early studies in this direction started by measuring the fractal dimension of the clouds in column density or intensity maps of selected regions, by means of the area-perimeter scaling

\[^b\]However, it has been pointed out by Scalo and Houlahan that one limitation of the ACF is that it cannot distinguish between hierarchically nested or randomly distributed structure.
in the projected clouds, finding dimensions near 1.4. Recent measurements of their area-perimeter relation in 2D simulations find similar values. However, these values are surprisingly close to the projected fractal dimensions of clouds in the Earth’s atmosphere, suggesting that the fractal dimension may be a significantly degenerate diagnostic which may not be capable of distinguishing between different physical regimes. Indeed, a more recent study by Chappell and Scalo has shown that the column density maps of various regions actually have a well-defined multifractal structure, so that attempting to measure a single fractal dimension for the clouds in the maps may erase much of the structural information. Furthermore, these authors emphasize that the methods used to determine fractal dimensions of clouds rely on the definition of “clouds” by means of some rather arbitrary criterion (such as thresholding the column density field), while the multifractal spectrum determination uses the structural information of the whole field. The multifractal spectrum of the regions studied appears to correlate fairly well with the geometric forms seen visually, potentially providing a means for quantitative structure classification schemes. The multifractal properties of numerical simulations of ISM turbulence are currently being investigated.

A method for determining the line width-size scaling of spectral maps independently of any specific definition of “clouds” in a spectral map has been introduced recently by Heyer and collaborators. The method uses the statistical technique known as Principal Component Analysis (PCA) to define a set of spectral profiles (eigenvectors) which form a “natural” basis for the spectral maps (in the sense that it reflects the main trends of the intensity data among the velocity channels). Eigenimages, which represent the intensity structures as “filtered” by the basis spectra, are generated by projecting the original spectra onto the eigenvectors. By then measuring the ACF of the eigenvectors and of the eigenimages, the relationship between the magnitude of velocity differences and the spatial scales over which these differences occur can be extracted. In order to “calibrate” the expected value of the exponent $\alpha$ in this relation (such that $\Delta v \propto R^\alpha$, where $\Delta v$ is the velocity difference and $R$ is the size), “pseudo-simulations” of fractional Brownian noise with a prescribed spectrum were produced and “observed” using a radiative transfer simulator. It was found that the scaling exponent is related to the spectral index $\beta$ by $\alpha = \beta/3$. Recent calibrations with actual hydrodynamic and MHD simulations in 3D are roughly consistent with this result, although the resolutions available in 3D simulations are still insufficient to develop clear power-law turbulent spectra, so the results are not conclusive. Tests with higher resolution 2D simulations apparently produce a different calibration, $\alpha = \beta/4$. 
The origin of these scalings is not well understood yet. In fact, they suggest that the very nature of the line width-size relation derived through PCA is unknown, since it does not follow the same scaling as, say, the second-order structure function, defined as $F_2(r) = \langle [u(x) - u(x + r)]^2 \rangle$, where the brackets denote a volume average. This function gives the mean quadratic velocity difference between positions separated a distance $r$. Yet, $F_2$ is related to the energy spectrum by

$$F_2(r) = 4 \int_0^\infty E(k) \left(1 - \frac{\sin kr}{kr}\right) dr,$$

so that, if $E(k) \propto k^{-\beta}$, then $F_2(r) \propto r^\eta$, with $\eta = (\beta - 1)/2$. $\eta$ is thus not functionally related to $\beta$ in the same manner as $\alpha$. The discrepancy is probably related to the fact that the above scaling refers to the structure function of the actual 3D velocity field, while in spectroscopic data every velocity interval contains the contribution of many fluid parcels (possibly far apart from each other), and only one of the three velocity components is observed. Thus, the true nature of the spatial and velocity increments in spectral data cubes remains unknown.

Finally, a method for structure analysis similar to the power spectrum, but using a wavelet rather than a Fourier basis is described in the contribution by Ossenkopf et al. (this volume).

4 Effects of Projection on Morphology

One advantage of 3D simulations is that they contain more structural information than even spectroscopic data “cubes”. While the latter only refer to two spatial and one velocity dimensions, 3D numerical simulations provide information on the 3D structure of all physical variables. (Of course, their downside is that they are necessarily limited in resolution and in the number of physical processes that can be included.) This allows an investigation of the 3D structures that generate the patterns observed in the position-position-velocity (PPV) space of the spectroscopic channel maps. To this end, channel maps are constructed from the simulations by integrating the density field along one direction (the line of sight, or LOS), and then selecting the contribution of each parcel along the LOS by its LOS-velocity. This is equivalent to constructing density-weighted velocity histograms (the “line spectra”) at each position in the plane perpendicular to the LOS.

A rather unexpected result has recently been found independently, using different approaches, by several groups. It appears that, at least under certain conditions, the projected spatial structure in the channel maps is dominated
by the spatial distribution of the velocity field, rather than by the 3D density field. Pichardo et al. have shown this in a 3D simulation of the ISM at intermediate scales (3–300 pc) by noting that the pixel-to-pixel correlation between channel maps and thin slices of the 3D velocity field tends to be larger on average than the correlation between channel maps and slices of the 3D density field. Independently, Lazarian and Pogosyan have shown analytically that, for cases with an underlying one-to-one mapping between the position along the LOS and the LOS-velocity (as for an expanding universe or the HI gas distribution in the Galaxy), and with uncorrelated random density and velocity fields with well-defined spectral indices, the power spectrum of the projected density field is dominated by the spectrum of the velocity field for density spectral indices steeper than $-3$, unless the velocity channels are very wide (as is clearly the case in the limit of a single velocity channel, in which the velocity dependence is integrated out). Finally, Heyer and Brunt have noticed that, in their pseudo-simulations (cf. sec. 3.3 above), channel maps and PCA-derived $\Delta v$-$R$ relations produced with and without density-weighting are notoriously similar, suggesting that the effect of the density weighting is relatively minor. A similar effect was noticed by Falgarone et al. about the shapes of synthetic line profiles. In summary, it appears that the spatial structure of the velocity field is at least as important as that of the density field in determining what is observed in projection on the plane of the sky.

A related effect has been observed by Pichardo et al. The morphology observed in the channel maps appears to contain much more small-scale structure than either the density or the velocity 3D fields. This is reflected in the power spectra of the channel maps and of 2D slices through the 3D density and velocity fields, the latter two having steeper slopes and falling off much more rapidly than the former. This phenomenon has been interpreted by those authors as a consequence of a pseudo-random sampling of fluid parcels along the LOS by the velocity selection performed when constructing a channel map. This introduces an additional ingredient of variability between neighboring LOSs, which causes artificial small-scale variability in the channel maps.

It can be concluded from this section that, for a fully turbulent ISM, the structure seen observationally, through spectroscopic observations, may differ from the actual 3D structures present in the medium. In particular, this suggests that structure-finding algorithms operating on spectroscopic data cubes may not identify exactly the same structures than would be obtained on the actual 3D spatial data, as already pointed out by various authors. These effects may be decreased, however, in cases when the observed regions contain well-defined “objects” which may be picked out by the observing process, such as shells, bipolar flows, etc.
In this review I have discussed recent results from numerical simulations of turbulence in the ISM. I first reviewed the scenario of interstellar clouds as turbulent density fluctuations. Work on the production of gravitationally bound structures in globally stable media by turbulent compressions was summarized, in particular the necessary Mach numbers (for 3D compressions) and the constraints on the effective polytropic exponent $\gamma_{\text{eff}}$ for $n$-dimensional compressions. Three implications were then discussed. First, the near thermal pressure balance observed in the ISM (except for molecular clouds) may not be a confining agent for clouds, but rather a relatively fortuitous consequence of the prevailing heating and cooling mechanisms, which render the medium nearly isobaric, in the presence of turbulence-induced density fluctuations. Second, it appears unlikely that nearly hydrostatic cores may be produced within the turbulent ISM unless some very specific variations in $\gamma_{\text{eff}}$ occur during a gravitational contraction induced by the turbulence. Third, the time scales associated with clouds may be smaller than those estimated from the clouds’ characteristic dimensions and their velocity dispersions, since the relevant velocities may instead be those of the larger, external flow streams that produced the clouds at their collision interfaces.

I then proceeded to review recent results from various attempts to relate numerical simulations to observational data, from early qualitative comparisons of spectral line profiles and surveys of clouds in 2D simulations (which suggested the existence of a whole population of low-column density clouds that do not satisfy Larson’s density-size relation), to recent approaches using more sophisticated statistical techniques such as the Spectral Correlation Function, Principal Component Analysis, and fractal dimensions and multifractal spectra, mostly aiming at characterizing the morphology of interstellar structures in a statistically meaningful way, and determining whether the structures developing in turbulence simulations reproduce their properties. Some of these methods are only being developed now, but they are already providing a quantitative method for discriminating between turbulence simulations with different parameter choices as the most suitable models for specific interstellar regimes, as well as providing a basis for interpreting observational data in terms of the simulations.

Finally, I discussed the relationship between the actual 3D spatial structure of the density and velocity fields, and that of the projected “intensity” field in channel maps. Recent works, using various approaches, suggest that the structure, both morphological and statistical (power spectrum) of the 2D intensity field is dominated by the velocity field, rather than by the
density. Additionally, since the total intensity in every LOS of a channel map is constructed by “selecting” scattered fluid parcels (on the basis of their LOS velocity) along the LOS, spurious small-scale variability is introduced into the structure seen in the channel maps, as the set of sampled parcels varies from one LOS to the next. These results suggest that the structure in channel maps bears a very complex and non-trivial relationship to the structures actually existing in the ISM. Further work in this area is likely to produce numerous unexpected and exciting results in the near future.

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References

1. D.S. Adler and W.W. Roberts, Jr. *Astrophys. J.* **384**, 95 (1975).
2. J. Arons and C.E. Max *Astrophys. J.* **196**, 77 (1975).
3. J. Ballesteros-Paredes, *Ph.D. Thesis*, Inst. de Astronomia, UNAM (1999).
4. J. Ballesteros-Paredes, E. Vázquez-Semadeni and J. Scalo *Astrophys. J.* **515**, 286 (1999).
5. J. Ballesteros-Paredes, L. Hartmann and E. Vázquez-Semadeni *Astrophys. J.*, in press (1999).
6. J. Ballesteros-Paredes, E. Vázquez-Semadeni and A.A. Goodman, in preparation (1999).
7. L. Blitz in *Protostars and Planets III*, eds. E.H. Levy, J.I. Lunine (University of Arizona Press, Tucson, 1993), 125.
8. C. Brunt, *Ph.D. Thesis*, Astr. Dept., The Univ. of Massachusetts, Amherst (1999).
9. R. Braun, in *Interstellar Turbulence*, eds. J. Franco and A. Carramiñana (Cambridge Univ. Press, Cambridge, 1999), 12.
10. D. Chappell and J. Scalo *Astrophys. J.*, submitted (1999).
11. W. Chicana and E. Vázquez-Semadeni, in preparation (1999).
12. J. Cordes in *Interstellar Turbulence*, eds. J. Franco and A. Carramiñana (Cambridge Univ. Press, Cambridge, 1999), 33.
13. R.L. Dickman and S.C. Kleiner *Astrophys. J.* **295**, 479 (1987).
14. J. Dubinsky, R. Narayan and T.G. Phillips *Astrophys. J.* **448**, 226 (1995).
15. B. Elmegreen in *Protostars and Planets III*, eds. E. H. Levy & J. I. Lunine (University of Arizona Press, Tucson, 1993), 97.
16. B. Elmegreen *Astrophys. J.* 419, 29L (1993).
17. B. Elmegreen in *Molecular Clouds and Star Formation*, eds. C. Yuan and J. You (World Scientific, Singapore, 1995), 149.
18. B.G. Elmegreen and D. M. Elmegreen, *Astrophys. J.* 220, 1051 (1978).
19. E. Falgarone, T.G. Phillips and C.K. Walker *Astrophys. J.* 378, 186 (1991).
20. E. Falgarone, J.L. Puget and M. Pérault *Astron. Astrophys.* 257, 715 (1992).
21. E. Falgarone, D.C. Lis, Pillips, T.G., Pouquet, A., Porter, D.H. and Woodward, P.R. *Astrophys. J.* 436, 728 (1994).
22. G.B. Field, D.W. Goldsmith and H.J. Habing *Astrophys. J.* 155, 149L (1969).
23. M.H. Heyer, J.M. Carpenter and E.F. Ladd *Astrophys. J.* 463, 630 (1996).
24. M.H. Heyer and F.P. Schloerb *Astrophys. J.* 475, 173 (1997).
25. M.H. Heyer and C. Brunt in *New Perspectives on the Interstellar Medium*, eds. A.R. Taylor, T.L. Landecker (Astron. Soc. of the Pacific, San Francisco, 1999), in press.
26. M.H. Heyer, C. Brunt, B. Pichardo and E. Vázquez-Semadeni, in preparation.
27. P. Houlahan and J. Scalo *Astrophys. J. Suppl.* 72, 133 (1990).
28. J.H. Hunter, Jr. *Astrophys. J.* 223, 946 (1979).
29. J.H. Hunter, Jr. and R.C. Fleck *Astrophys. J.* 256, 505 (1982).
30. J.H. Hunter, Jr., M.T. Sandford, II, R.W. Whitaker, R.I. Klein *Astrophys. J.* 305, 309 (1986).
31. *Interstellar Turbulence*, eds. J. Franco and A. Carramiñana (Cambridge Univ. Press, Cambridge, 1999).
32. W.H. Kegel *Astron. Astrophys.* 225, 517 (1989).
33. S.C. Kleiner and R.L. Dickman *Astrophys. J.* 286, 255 (1984).
34. S.C. Kleiner and R.L. Dickman *Astrophys. J.* 295, 466 (1985).
35. R.B. Larson *MNRAS* 194, 809 (1981).
36. A. Lazarian and D. Pogosyan *Astrophys. J.* , in press (1999).
37. M. Lesieur, *Turbulence in Fluids*, 2nd. ed. (Kluwer, Dordrecht, 1990).
38. S. Lovejoy *Science* 216, 185 (1982).
39. C.F. McKee, E.G. Zweibel, A.A. Goodman and C. Heiles in *Protostars and Planets III*, eds. E.H. Levy & J.I. Lunine (University of Arizona Press, Tucson, 1993), 327.
40. M.S. Miesch, J. Scalo and J. Bally *Astrophys. J.* 524, in press (1999).
41. P.C. Myers Astrophys. J. **225**, 380 (1978).
42. A. Nordlund and P. Padoan, in *Interstellar Turbulence*, eds. J. Franco and A. Carramiñana (Cambridge Univ. Press, Cambridge, 1999), 218.
43. P. Padoan and A. Nordlund, in *Interstellar Turbulence*, eds. J. Franco and A. Carramiñana (Cambridge Univ. Press, Cambridge, 1999), 248.
44. P. Padoan, M. Juvela, J. Bally and A. Nordlund Astrophys. J. **504**, 300 (1998).
45. T. Passot and E. Vázquez-Semadeni Phys. Rev. E **58**, 4501 (1998).
46. B. Pichardo, E. Vázquez-Semadeni, A. Gazol, T. Passot and J. Ballesteros-Paredes Astrophys. J. , submitted (1999).
47. D.H. Porter, A. Pouquet and P.R. Woodward Phys. Fluids A **6**, 2133 (1994).
48. E.W. Rosolowsky, A.A. Goodman, D.J. Wilner and J.P. Williams Astrophys. J. , in press (1999).
49. J. Scalo Astrophys. J. **277**, 556 (1984).
50. J. Scalo in *Interstellar Processes*, eds. D.J. Hollenbach and H.A. Thronson, Jr. (Reidel, Dordrecht, 1987), 349.
51. J. Scalo in *Physical Processes in Fragmentation and Star Formation*, eds. R. Capuzzo-Dolcetta, C. Chiosi and A. di Fazio (Kluwer, Dordrecht, 1990), 151.
52. F.H. Shu, F.C. Adams and S. Lizano Ann. Rev. Astron. Astrophys. **25**, 23 (1987).
53. S. Spangler in *Interstellar Turbulence*, eds. J. Franco and A. Carramiñana (Cambridge Univ. Press, Cambridge, 1999), 41.
54. J.E. Tohline, P.H. Bodenheimer and D.M. Christodoulou Astrophys. J. **322**, 787 (1987).
55. E. Vázquez-Semadeni Astrophys. J. **423**, 681 (1994).
56. E. Vázquez-Semadeni, in *Millimeter & Submillimeter Astronomy: Chemistry and Physics in Molecular Clouds*, eds. W. F. Wall, A. Carraminana, L. Carrasco, and P. F. Goldsmith (Kluwer, Dordrecht, 1999), 143.
57. E. Vázquez-Semadeni, J. Ballesteros-Paredes and L.F. Rodríguez Astrophys. J. **474**, 292 (1997).
58. E. Vázquez-Semadeni, E.C. Ostriker, T. Passot, and J. Stone, in *Protostars and Planets IV*, eds. V. Mannings, A. Boss and S. Russell (Tucson: Univ. of Arizona Press, 2000), in press.
59. E. Vázquez-Semadeni, T. Passot and A. Pouquet Astrophys. J. **473**, 881 (1996).
60. E. Vázquez-Semadeni and T. Passot in *Interstellar Turbulence*, eds. J. Franco and A. Carramiñana (Cambridge Univ. Press, Cambridge, 1999), 223.
61. E.T. Vishniac *Astrophys. J.* **274**, 152 (1983).
62. E.T. Vishniac *Astrophys. J.* **428**, 186 (1994).
63. R. Walterbos, in *Interstellar Turbulence*, eds. J. Franco and A. Carramiñana (Cambridge Univ. Press, Cambridge, 1999), 20.
64. M.G. Wolfire, D. Hollenbach, C.F. McKee, A.G. Tielens and E.L. Baker *Astrophys. J.* **443**, 152 (1995).