Small Scale Ionized and Neutral Structures in the Diffuse Interstellar Medium
Socorro, NM May 21-24, 2006

SUNDAY

08:00 - 09:30 – Breakfast & Registration
09:30 - 09:35 – K. Y. Lo/Jim Ulvestad Welcome
09:35 - 09:40 – LOC/SOC announcements

Observations of Small-scale Atomic Structures

Moderator: Michael Faison

09:40 - 10:20 Brogan (R) - Review of VLBA Observations of AU-Scale HI Structures
10:20 - 10:35 Stanimirovic - Properties of Cold Itsy-bitsy HI Clouds in the Diffuse ISM
BREAK 10:35 - 10:55
10:55 - 11:35 Weisberg (R) - Pulsar Studies of Tiny Scale Structure in the Neutral ISM
11:35 - 12:15 Lauroesch (R) - Optical Absorption Line Observations of Small Scale Interstellar Structure
LUNCH 12:15 - 13:30
13:30 - 13:55 Jenkins (I) - Fluctuations in ISM Thermal Pressures Measured from CI Observations
13:55 - 14:15 Gibson - Multiscale Structure in Cold HI
14:15 - 14:30 Naomi McClure-Griffiths - Thin Strands of Cold Hydrogen in the Riegel-Crutcher Cloud

Interpretation of Neutral Structures

Moderator: Don Cox

14:30 - 14:45 Heiles - Tiny Scale Atomic Structures as Discrete Structures
POSTER SUMMARIES 14:45 - 15:00
Faison - Probing the Cold, Neutral ISM on 100 Milliarcsecond Angular Scales with MERLIN
Minter - Limits on the Power Spectra of HI towards PSR B0329+54
Redfield - Reconstructing our Interstellar Past: A Look at the Small Scale Structure in the Direction of the Historical Solar Trajectory
Smoker - Small Scale Structure in the ISM Towards IC 2391 and NGC 6475
Welty - Variable Interstellar Absorption toward HD 219188
BREAK & POSTERS 15:00 - 15:45
15:45 - 16:10 Gwinn (I) - Optics Effects of Very Small Atomic Clouds
16:10 - 16:35 Deshpande (I) - The Small Scale Structure in the Interstellar HI: A Resolvable Puzzle
16:35 - 17:00 Slavin (I) - Evaporation and the Thermal Balance of Tiny HI Clouds
17:00 - 17:20 Nagashima - Evaporation Timescales of HI Clouds
17:20 - 17:40 Inoue - Structure and Stability of Phase Transitions in the Interstellar Medium

18:30 - Conference Dinner at 1211 Vista Drive (Drinks starting at 18:00)

MONDAY

BREAKFAST 08:00 - 09:00

Numerical Simulations of Neutral Structures

Moderator: Nissim Kanekar

09:00 - 09:25 Vazquez-Semadeni (I) - Numerical Simulations of Turbulence of the Neutral ISM

09:25 - 09:45 Hennebelle - On the Structure of the Atomic Interstellar Gas

09:45 - 10:10 Lazarian (I) - Turbulence from Spectral Lines

10:10 - 10:30 Kim - The Power Spectra and Probability Denisty Fluctuations of Density Fields in Isothermal Hydrodynamic Turbulent Flows

BREAK 10:30 - 11:10

Observations of Small-scale Molecular structures

Moderator: Nissim Kanekar

11:10 - 11:35 Heithausen (I) - Small-scale Molecular Structure in the Galaxy

11:35 - 11:55 Hily-Blant - Dissipative Structure of diffuse ISM Turbulence I - CO Diagnostics

11:55 - 12:15 Falgarone - Dissipative Structure of diffuse ISM Turbulence II - Chemical and H2 Line Excitation Diagnostics

12:15 - 12:30 Vladimir Strelnitski - Turbulent AU Structures in Outflows from YSOs as Revealed by Water and Methanol Masers

LUNCH 12:30 - 13:45

The Local ISM

Moderator: Toney Minter

13:45 - 14:10 Linsky (I) - Structure of the local ISM

14:10 - 14:30 Frisch - The Heliosphere Vantage Point: Uncovering the Secrets of Low Column Density ISM

14:30 - 14:45 Dave Meyer - Cold clouds in the Local Bubble

POSTER SUMMARIES 14:45 - 15:00

Gazol - High Pressure Regions in a Turbulent Bistable Gas

Hodge - HI Density Distribution Driven by Supernovae: A Simulation Study

Inutsuka - The Effect of Magnetic Field on Turbulence Driven by Thermal Instability

Dib - Detailed Virial Balance Analysis of Molecular Clouds in Three-Dimensional Numerical Simulations

Hennebelle - Influence of the magnetic field on the thermal condensation

Stanimirovic - B1849+00 probes the tiny-scale molecular gas ?

Ingalls - Molecular Cloud Structure from a CO Spectral Line: Interferometric Observations of MBM-12

BREAK & POSTERS 15:00 - 15:45

Ionized Medium on Larger Scales

Moderator: Scott Ransom

15:45 - 16:10 Cordes (I) - The Wavenumber Spectrum and Galactic Distribution of the Fluctuating Ionized ISM

16:10 - 16:35 Haverkorn (I) - Observations of Turbulence in the Magneto-Ionized ISM on Subparsec Scales

16:35 - 17:00 Wood (I) – the propagation of ionizing radiation through a clumpy (fractal) medium and the porosity of the interstellar medium

TUESDAY

BREAKFAST 08:00 - 09:00

Ionized Medium through Pulsar Scintillations

Moderator: Ron Reynolds

09:00 - 09:40 Stinebring (R) - Pulsar Scintillation Arcs and the Ionized ISM

09:40 - 09:55 Brisken - VLBI Observations of the Pulsar Scintillation Arc Phenomenon

09:55 - 10:15 Ransom - Parsec-scale Constraints on the ISM From the Millisecond Pulsars in Terzan5

BREAK 10:15 - 10:45

IDV Observations

Moderator: Ron Reynolds

10:45 - 11:10 Lovall (I) - The MASIV Survey

11:10 - 11:30 Bignall - Properties of the Scatterer in Front of Scintillation Quasar PKS 1257-326

11:30 - 11:55 De Bruyn (I) - A Remarkable Superposition of a Very Compact Quasar and a Fast-moving Very Local Turbulent Screen

LUNCH 11:55 - 13:30

Interpretation of Scintillations

Moderator: Dan Stinebring

13:30 - 14:10 Rickett (R) - What Do Scintillations Tell Us about the Ionized ISM

14:10 - 14:30 Macquart (I) - Variability in Radio Absorption Spectra Against Extragalactic Sources and Implications for the ISM

14:30 - 14:55 Walker (I) - Interpretation of Extreme Scattering Events and Pulsar Dynamic Spectra

POSTER SUMMARIES 14:55 - 15:10

Crossley - Echoes of Crab Pulsar Giant Radio Pulses

Hill - Density Enhancements in the WIM

Stinebring - Diffraction from 2d Gaussian Lenses in the ISM

Boldyrev - Dynamic Alignment and Exact Scaling Laws in MHD Turbulence

Lazarian - Formation of Tiny Scale Structures in Viscosity-Damped MHD Turbulence

BREAK & POSTERS 15:10 - 15:50

Ionized Medium – Theory

Moderator: J-P Macquart

15:50 - 16:30 Zweibel (R) – On plasma turbulence and dissipation scales in the ISM

16:30 - 16:55 Spangler (I) - The Propagation Distance and Sources of Interstellar Turbulence

16:55 - 17:20 Coles (I) - Evidence for Anisotropy and Intermittency in the Turbulent Interstellar Plasma

17:20 - 17:45 Boldyrev (I) - On Non-Gaussian Statistics of the Electron Density Distribution in the ISM

17:45 - 18:05 Mason - Spectrum and Small-scale Structures in MHD Turbulence

18:05 - 18:25 Palotti - Smale Scale Velocity and Density Structures Formed by Shear Flow

WEDNESDAY

Moderator: Miller Goss

BREAKFAST 08:00 - 09:00
09:00 - 09:30 Zwiebel – On Spitzer's ideas about the tiny-scale structure in the ISM
09:30 - 10:00 Heiles – Observational overview
10:00 - 10:30 Spangler – Theory overview
BREAK 10:30 - 10:45
10:45 - 12:15 - Panel Discussion
END

VLA Tour in the afternoon

Observations of Small-scale Atomic Structures

Crystal Brogan (National Radio Astronomy Observatory; cbrogan@nrao.edu)
W. Miller Goss (National Radio Astronomy Observatory)
T. J. Lazio (Naval Research Laboratory)

Presentation: invited-R (40)

VLBA Observations of AU-Scale Structure

Several recent VLBA studies of Galactic H I absorption toward background quasars have provided evidence that there are opacity changes in the neutral Galactic interstellar medium on size scales as small as a few AU. The nature of these opacity variations has remained a matter of debate, but could reflect a variety of physical processes, including changes in the H I spin temperature or gas density. As an example we will present results from three epochs of VLBA observations (1995, 1999, and 2002) of Galactic H I absorption toward the quasar 3C 138 with a resolution of 20 mas ($\sim$ 10 AU). We confirm the previously detected milliarcsecond scale spatial variations in the H I opacity at the level of $\Delta\tau_{max} = 0.50 \pm 0.05$. The typical size scale of the optical depth variations is $\sim$ 50 mas or 25 AU. In addition, for the first time we see clear evidence for temporal variations in the H I opacity over the seven year time span of our three epochs of data. We also attempted to detect the magnetic field strength in the H I gas using the Zeeman effect. From this analysis we have been able to place a 3 σ upper limit on the magnetic field strength per pixel of $\sim$ 45 μG. We also estimate the plane of sky covering fraction of the small scale H I gas of $\sim$ 10%. This small covering fraction suggests that the filling factor of such gas is quite low in agreement with recent optical observations. We also find that the line widths of the milliarcsecond sizescale H I features are comparable to those determined from previous single dish measurements toward 3C 138, suggesting that the opacity variations cannot be due to changes in the H I spin temperature. From these results we favor a density enhancement interpretation for the small scale H I structures, although these enhancements appear to be of short duration and are unlikely to be in equilibrium.

Snezana Stanimirovic (UC Berkeley; sstanimi@astro.berkeley.edu)

Presentation: talk (20)

Properties of Cold Itsy-bitsy H I Clouds in the Diffuse ISM

I will discuss properties of the tiniest H I clouds traced through time variability of H I absorption profiles against pulsars and very sensitive H I absorption observations of continuum sources. In particular, I will focus on two issues. First, what these measurements are telling us about the general turbulent spectrum in the interstellar medium. Second, how do observed cloud properties compare with predictions from recent numerical simulations of the condensation of the CNM out of the WNM, and the production of cold 'shreds' in cloud-shock interactions.

Joel M. Weisberg (Carleton college; jweisber@carleton.edu)
Snezana Stanimirovic (U. California, Berkeley)

Presentation: invited-R (40)

Pulsar Studies of Tiny-Scale Structure in the Neutral Interstellar Medium

Pulsars have provided unique contributions to studies of the tiny-scale structure in the interstellar medium (ISM. Being almost perfect point sources and moving at high speeds (10^{2-3} km s^{-1}), pulsars probe a tiny column that sweeps rapidly across the ISM. Hence a multiepoch set of pulsar signal propagation measurements provides a one-dimensional cut across the intervening ISM structures.

We will explain the multiepoch pulsar H I absorption technique and illustrate the delicacy of the required calibration. We will show that advances in the capabilities of spectrometers through the years have led to more robust results in recent times. We will summarize the results that have been obtained with this technique and compare them with multiepoch H I interferometry experiments. We will then emphasize what all these measurements are telling us about the general properties of the cold ISM.

Finally, we will discuss our recent extensions of these techniques to molecular gas via pulsar OH ISM studies.

J. T. Lauroesch (Northwestern University; jtl@elvis.astro.northwestern.edu)

Presentation: invited-R (40)

Optical Absorption Line Observations of Small Scale Interstellar Structure

Recent optical absorption line studies (primarily studying the NaI D lines) have provided convincing evidence for pervasive small-scale structure in the diffuse interstellar medium on scales of order 1000 AU through observations of members of multiple star systems and clusters. Such spectra reveal that absorption components change in strength, velocity, and even number from sightline to sightline. However, these variations do not imply that the interstellar medium consists of a multitude of very small cloudlets since the vast majority of components are seen toward multiple stars in a system. Instead it appears that these variations arise in sheets or filaments of gas within which the physical conditions vary. Using temporal variations in interstellar absorption lines it has been found that in some cases there can be significant structure on AU scales. Our survey of ∼40 stars suggests that this phenomenon is not as pervasive as the variations noted on larger (∼1000 AU) scales. While the majority of the known variable sightlines are associated with the Orion-Eridanus H I shell, this phenomenon is not limited to that region.

Edward B. Jenkins (Princeton University Observatory; ebj@astro.princeton.edu)

Presentation: invited (25)

Fluctuations in ISM Thermal Pressures Measured from C I Observations

The ground electronic state of C I is split into three fine-structure levels whose relative populations are determined by the balance between collisional excitations (and de-excitations) and radiative decay. High resolution absorption-line spectroscopy of stars in the ultraviolet reveal how much these populations vary with radial velocity and from one location to the next, which in turn indicate the magnitude of pressure changes and how they relate to the gas kinematics. Recently, Jenkins and Tripp have analyzed nearly all of the suitable high-resolution spectra in the HST archive, which has allowed a five-fold increase in the coverage beyond that of their original survey of 21 stars published in 2001 (ApJS, 137, 297). In the earlier work, they concluded that converging and diverging flows within a turbulent medium were responsible for the pressure changes. Moreover, they found that the effective gamma of the gas was higher than that based on predictions for thermal equilibrium. This near adiabatic behavior suggests that most of the pressure changes occur over small length scales where the characteristic times for such changes are much shorter than the thermal equilibration times. The raw results for measured pressures are weighted by the C I densities, which in turn are influenced by ionization equilibria. Thus, in order to obtain a pressure distribution function weighted according to H I , one must apply a correction that depends on the effective gamma of the gas. All of these issues will be now be revisited with the expanded set of data.

Steven J. Gibson (NAIC; gibson@naic.edu)

Presentation: talk (20)

Multiscale Structure in Cold HI

Neutral atomic gas features exhibit self-similar structure on a wide range of angular and physical scales. This structure is usually interpreted as tracing turbulent cascades, but it can be difficult to study over a significant dynamic size range for relatively unconfused sight lines. One case where the sight line geometry is reasonably well known is the Pleiades cluster, where dust grains in a passing interstellar cloud are illuminated as a reflection nebula. I will present power spectrum measurements of the optical nebulosity over five decades of angular size, from 0.1 arcsecond to a few degrees (roughly 10 AU to 5 pc) and compare this to cold H I 21cm line emission associated with the same grains. Closer to the Galactic plane, where dust and H I emission are more confused, HI self-absorption (HISA) may serve as a useful cold gas tracer. The Canadian Galactic Plane Survey has shown HISA with physical structure on scales of 100 pc down to as low as 0.1 pc. I will present an initial power spectrum analysis of CGPS HISA and discuss its implications.

Naomi McClure-Griffiths (ATNF; naomi.mcClure-griffiths@csiro.au)

Presentation: talk (20)

Thin Strands of Cold Hydrogen in the Riegel-Crutcher Cloud

We present new high resolution (1 arcminute) neutral hydrogen (HI) images of the Riegel-Crutcher cloud observed in self-absorption in the direction of the Galactic Center. The large nearby sheet of cold hydrogen is resolved into a network of dozens of thin (0.1 pc wide) hair-like filaments. Individual filaments are up to 17 pc long, presenting a remarkable aspect ratio of 170. The strands are reasonably cold, with spin temperatures of ∼40 K and in places have optical depths larger than one. Although on larger spatial scale, these strands seem to support the Heiles 1997 argument that TSAS is contained in curved sheets and filaments. Comparing the HI images with observations of stellar polarization we show that the filaments are very well aligned with the local magnetic field. We argue that the magnetic field provides the stability to contain these significantly over-pressurized filaments.

Interpretation of Neutral Structures

Carl Heiles (University of California, Berkeley; heiles@astron.berkeley.edu)

Presentation: talk (20)

Tiny-Scale Atomic Structure as Discrete Structures

The conventional interpretation of neutral SINS (i.e., SNS – Small Neutral Structures; also known as Tiny-Scale Atomic Structure, TSAS) involves individual discrete structures. This leads to conflicting constraints on temperature, pressure, molecular abundances, optical absorption lines, ionization degree, dust abundance, geometrical shapes, and the ubiquity of observed SNS structures. We review the basic astrophysics that leads to these difficulties. We illustrate them with recently observed neutral structures that seem directly related to SNS. We estimate the probability of seeing individual SNS structures with the conventional observational techniques, namely the ones that involve 21-cm and optical absorption lines.

Michael Faison (Yale University; faison@astro.yale.edu)
W. Miller Goss (NRAO Socorro)
Tom Muxlow (University of Manchester)

Presentation: Poster

Probing the Cold, Neutral ISM on 100 Milliarcsecond Angular Scales with MERLIN

Many previous absorption studies of the neutral, diffuse ISM on small scales have probed on angular scales of 1 to 100 milliarcseconds (mas), such as the VLBI and pulsar observations (Brogan et al., 2005 AJ , A; Stanimirovic et al., 2003 ApJ 598:L23), or on angular scales of a few arcseconds, through observations with the VLA and other connected-element interferometers (e.g., Deshpande, Dwarakanath, and Goss, 2000 ApJ 543:227). In order to build up a complete picture of the Tiny-Scale Atomic Structure of the ISM, it is necessary to image Galactic H I over as many angular scales as possible.

We have used the Multi-Element Radio Linked Interferometer Network (MERLIN), based in the United Kingdom, to image Galactic neutral hydrogen (HI) in absorption towards three moderately-resolved extragalactic sources close to the Galactic place: 3C111, 3C161, and 3C123. The typical angular resolution of our H I optical depth images is 100-400 milliarcseconds. All of these sources show some H I optical depth variations over scales from 100 mas to a few arcminutes. The results of this work will be presented and the implications for the structure function of the neutral ISM on these intermediate scales will be discussed.

Anthony Minter (NRAO Green Bank; tminter@nrao.edu)
Dana S Balser (NRAO Green Bank)

Presentation: Poster

Limits on the Power Spectra of H I towards PSR B0329+54

We discuss multi-epoch, GBT observations of H I absorption toward the pulsar PSR B0329+54 spanning approximately three years. Due to the sensitivity of the GBT, the brightness of PSR B0329+54 and the proper motion of PSR B0329+54 changes in the H I absorption can be detected on time scales of less than one day. The structure function of H I absorption variations has been computed and there is no evidence of any H I variations on time scales from hours to several years. We explore how false detections can arise from systematic errors in the baseline modeling. Finally, we discuss the merits of using structure functions to analyze H I absorption spectra.

Seth Redfield (University of Texas at Austin; sredfield@astro.as.utexas.edu)
John Scalo (University of Texas at Austin)
David S. Smith (University of Texas at Austin)

Presentation: Poster

Reconstructing our Interstellar Past: A Look at the Small Scale Structure in the Direction of the Historical Solar Trajectory

The properties (e.g., density, velocity, and morphology) of our local interstellar medium (LISM) directly influence the structure of the heliosphere, which via the modulation of Galactic cosmic rays, may have consequences for ozone layer chemistry, biological mutation rates, and climate. The presence of dense small scale structures in the LISM can have an important impact on the intensity and timing of heliospheric variation. We present high spectral resolution observations of 50 stars within 10 degrees of the direction of the historical solar trajectory. This densely packed collection of sightlines provide an opportunity to sample morphological length scales in the LISM down to <0.1 pc, as well as enable a reconstruction of the interstellar density profile encountered by the Solar System in our most recent past. This work could ultimately lead to a deterministic history of the cosmic ray flux at the top of Earth's atmosphere, and provide an empirical test of the LISM-Earth connection.

Jonathan Smoker (Queen's University Belfast; j.smoker@qub.ac.uk)
Francis Keenan (Queen's University Belfast)
Ian Hunter (Queen's University Belfast)
UVES POP team www.eso.org/uvespop (European Southern Observatory)

Presentation: Poster

Small Scale Structure in the ISM Towards IC 2391 and NGC 6475

We present optical spectroscopic observations in the Na, Ti, Ca, CH and K-lines towards 25 O and B-type stars in the open clusters IC 2391 and NGC 6475, obtained with the UVES echelle spectrometer as part of the Paranal Observatory Project. The signal-to-noise ratios per pixel are in the range 200-400. These data are used to probe the small-scale structure in the local interstellar medium in the relevant species.

Carl R. Gwinn (UC Santa Barbara; cgwinn@physics.ucsb.edu)

Presentation: invited (25)

Optics Effects of Very Small Atomic Clouds

Lenses change focal length when immersed in water; and interstellar scintillation changes when H I has small-scale structure. Lenses at optical wavelengths, and variations in electron density at radio wavelengths, introduce differences among path lengths. Paths of different lengths interfere to modulate intensity in the observer plane. The modulations represent focusing or defocusing for a lens, or interstellar scintillation for fluctuations in electron density. Interstellar atomic hydrogen changes path lengths, and opacity, near the 21-cm transition. If the 21-cm opacity or refractive index changes across the scattering disk, then the scintillation pattern in the observer plane will change rapidly with frequency, near the 21-cm line.

The Kramers-Kronig relations relate the maximum change in optical path length to the optical depth near the center of the absorption line. If the Doppler velocity of the 21-cm line shifts by a linewidth across the scattering disk, then a pulsar in strong scattering will change its scintillation pattern by about $\Delta I/<I>\sim 2\,\tau$ across the line. Smaller-scale variations in Doppler velocity can yield even stronger intensity variations. I will present observations of an HI-absorbed, scintillating pulsar, and resulting observational limits on small-scale structure of H I along the line of sight.

Avinash A. Deshpande (Raman Research Institute, Bangalore, India; desh@rri.res.in)

Presentation: invited (25)

The Small-scale Structure in Interstellar HI: A Resolvable Puzzle

During the past decade or so, measurements of Galactic HI absorption using VLBI against extra-galactic sources, as well as multi-epoch observations in pulsar directions, have detected small-scale transverse variations corresponding to tens of AU at the distance of the absorbing matter. Hitherto these measurements have been interpreted as small-scale structure in the H I distribution

with densities $n_{HI} \sim 10^4 - 10^5$ cm^{-3}, orders of magnitude greater than those of the parsec-scale structure. Naturally it is difficult to imagine how such structures could exist in equilibrium with other components of the ISM.

In this talk we show that structure on all scales contributes to the differences on neighboring lines of sight, and that the observed differences can be accounted for by a natural extension of the distribution of irregularities in the distribution of H I opacities at larger scales, using a single power law. Appreciating certain similarity of the contexts, we also examine if a suitable single power-law description of the electron density distribution in the ISM is consistent with the observations of the Extreme Scattering Events. In either cases, we find a) no compelling evidence for over-dense, over-pressured structures, and b) no surprise in these *apparent* density enhancements on small transverse scales.

Jonathan Slavin (Harvard-Smithsonian Center for Astrophysics; jslavin@cfa.harvard.edu)

Presentation: invited (25)

Evaporation and the Thermal Balance of Tiny H I Clouds

Among the mysteries of the very small neutral clouds is their creation and survival in the midst of various processes that could lead to their destruction. One of these processes is thermal conduction, which, if the clouds are embedded in hot gas and the conductivity operates at close to the Spitzer-Hrm value, leads to rapid evaporation of the clouds. This evaporation rate can be reduced by a number of effects including radiative cooling, saturation of the conduction, and magnetic shielding. The shielding of the cold, small clouds from the hot gas via a warm, lower density envelope might also help to prolong their lives, though then thermal conduction by neutral hydrogen must be considered. I will discuss thermal evaporation and thermal balance of tiny cold clouds and what their existence tells us about the diffuse interstellar medium.

Masahiro Nagashima (Kyoto University; masa@scphys.kyoto-u.ac.jp)
Hiroshi Koyama (Kobe University)
Shu-ichiro Inutsuka (Kyoto University)

Presentation: talk (20)

Evaporation Timescale of H I Clouds

We estimate the evaporation timescale for spherical HI clouds consisting of the cold neutral medium surrounded by the warm neutral medium. We focus on clouds smaller than 1pc, which corresponds to tiny H I clouds recently discovered by Braun & Kanekar (2005) and Stanimirovic & Heiles (2005). By performing one-dimensional spherically symmetric numerical simulations of the two-phase interstellar medium (ISM), we derive the timescales as a function of the cloud size and of pressure of the ambient warm medium. We find that the evaporation timescale of the clouds of 0.01 pc is about 1Myr with standard ISM pressure, $P/K_B \sim 10^{3.5}$ K cm^{-3}, and for clouds larger than about 0.1 pc it depends strongly on the pressure. In high pressure cases, there exists a critical

radius for clouds growing as a function of pressure, but the minimum critical size is ~ 0.03 pc for a standard environment. If tiny H I clouds exist ubiquitously, our analysis suggests two implications: tiny HI clouds are formed continuously with the timescale of 1 Myr, or the ambient pressure around the clouds is much higher than the standard ISM pressure. We also find that the results agree well with those obtained by assuming quasi-steady state evolution. The cloud-size dependence of the timescale is well explained by an analytic approximate formula derived by Nagashima, Koyama & Inutsuka (2005). We also compare it with the evaporation rate given by McKee & Cowie (1977).

Tsuyoshi Inoue (Kyoto University; tsuyoshi@tap.scphys.kyoto-u.ac.jp)
Shu-ichiro Inutsuka Kyoto University
Hiroshi Koyama Kobe University

Presentation: talk (20)

Structure and Stability of Phase Transition Layers in Interstellar Medium

We analyze the structure and stability of the transition layer (or front) that connect the cold neutral medium and warm neutral medium in the plane-parallel geometry. Such fronts appear in recent numerical simulations of thermally bistable interstellar medium. The front becomes the evaporation or condensation front depending on surrounding pressure. The physical properties of the front is important in the dynamics of the interstellar medium. The stability analysis was done by long and short wavelength approximations. We find that the plane-parallel evaporation front is unstable under the corrugational deformation, whereas the condensation front seems to be stable. The instability is analogous to the Darrieus-Landau instability of the combustion front. The growth rate of the instability is proportional to the evapolation flow speed and corrugation wavenumber for the modes with wavelength much longer than the thickness of the front, and it is suppressed at the scale approximately equal to the thickness of the front. The timescale of the instability is smaller than the cooling timescale of the warm neutral medium (1 Myr), and can be as small as the cooling timescale of the cold neutral medium (0.01-0.1 Myr). Thus, the instability should be one of the processes for driving the interstellar turbulence.

Numerical Simulations of Neutral Structures

Enrique Vazquez-Semadeni (Centro de Radioastronomia y Astrofisica, UNAM, Mexico; e.vazquez@astrosmo.unam.mx)

Presentation: invited (25)

Numerical Simulations of Turbulence in the Neutral ISM

Numerical simulations of turbulence in the neutral ISM suggest a scenario in which the various fields (density, temperature, pressure, velocity, and magnetic field) are highly transient, although

following well-defined statistical distributions (PDFs), which depend on the global parameters of the flow, in particular the rms Mach number M, and the mean magnetic field B. In general, the rms fluctuations of the various fields increase with increasing Mach number, and decrease with increasing magnetic field strength. The shape of the distributions depends on the effective behavior of the thermal pressure, which in turn depends on the competition between the turbulent crossing time and the cooling time. In the warm neutral medium, the cooling time is long enough that turbulence-induced density fluctuations behave in an intermediate manner between the thermal-equilibrium and the adiabatic regimes. This causes a population of fluid parcels that are out of thermal equilibrium, and occasionally have pressures over an order of magnitude larger than the mean ISM value. A population of transient, high-density, high-pressure structures also exists. The magnetic pressure shows little correlation with density at low and intermediate densities, but high-density structures tend to have larger-than-average field strengths. These results may shed some light on the nature of the very-small scale structures in the ISM, although global ISM simulations so far have not had enough resolution to resolve them.

Patrick Hennebelle (Observatoire de Paris; patrick.hennebelle@ens.fr)
Edouard Audit (Commisariat a l'energie nucleaire)
Thierry Passot (Observatoire de Nice)

Presentation: talk (20)

On the Structure of the Atomic Interstellar Gas

The physics of the thermally bistable atomic hydrogen involves very different spatial scales which must be accurately described in order to ensure a fair description of the dynamical processes taking place in the interstellar atomic gas.

In the talk, I will first address thoroughly this crucial issue. Then very high resolution, 2D and 3D, numerical simulations attempting to describe a turbulent flow of atomic interstellar hydrogen will be presented. I will show that transient, dense, small scale structures can be dynamically triggered and appear as a natural outcome of the physics of a two phases flow. Synthetic H I spectra will be presented and the effect of the magnetic field will be discussed.

Alex Lazarian (University of Wisconsin-Madison; lazarian@astro.wisc.edu)

Presentation: invited (25)

Turbulence from Spectral Line

Turbulence is a crucial component of dynamics of astrophysical fluids dynamics, including those of ISM, clusters of galaxies and circumstellar regions. Doppler shifted spectral lines provide a unique source of information on turbulent velocities. The problem that one faces dealing with astrophysical data, e.g. with 21cm emission of atomic hydrogen, is that no point-wise measurements are available. We discuss the techniques that make use of observations to determine the 3D velocity statistics, e.g. correlation functions of velocity fluctuations, spectra etc. The most promising of those are the Velocity-Channel Analysis (VCA) [1] and its offspring Velocity Coordinate Spectrum (VCS) [2] that are based on the analytical description of the intensity fluctuations in the Position-Position-Velocity (PPV) data cubes. Those cubes are available from observations. We stress that a great advantage of VCS is that it does not necessary require good spatial resolution. This means that turbulence spectra can be available from objects that are not spatially resolved. As the result an important insight is possible into turbulence within supernovae remnants, external galaxies, distant molecular clouds and star-forming regions. An additional advantage of the VCS is that it can be applied to studies of subsonic turbulence and separate potential and solenoidal parts of the velocity correlation tensor. We show examples of the application of the VCS to the Milky Way H I data and discuss its application to studies of turbulence with X-ray telescopes. We also demonstrate CO and H I data that support analytical predictions obtained for the VCA.

Jongsoo Kim (Korea Astronomy and Space Science Institute; jskim@kasi.re.kr)

Presentation: talk (20)

The Power Spectra and Probability Density Functions of Density Fields in Isothermal Hydrodynamic Turbulent Flows

In order to study the spectral and statistical properties of density fields, we perform three-dimensional, isothermal hydrodynamic, turbulence simulations with numerical resolutions up to 512^3. The covered range of root-mean-square Mach numbers is from 1 to 10. As the Mach number increases, the slope of the density power spectrum becomes shallower, which is the consequence of the dominant filament and sheet structures in density fields of highly supersonic flows. We also find that the probability density functions of isothermal gas densities in decay and driven turbulent flows are not necessary to follow a lognormal distribution, which is different from previous results. We will discuss the implications of our results on i) the observed spectral slopes of ionized and neutral gas components in the interstellar medium and ii) the theories of IMF and star formation.

Observations of Small-scale Molecular structures

Andreas Heithausen (University of Cologne; aheithau@uni-koeln.de)

Presentation: invited (25)

Small-scale Molecular Structure in the Galaxy

Small-area molecular structure resembling those clumpuscules, proposed by Pfenniger and Combes(1994) as candidates for baryonic dark matter, have recently been detected (Heithausen 2002, 2004) in an area where the shielding is too low for them to survive for a long time. I will sumarized the current information on those structures, based on a combination of low and high-angular resolution observations. I will show that such structures might be an abundant phenomenon in the interstellar medium, however so far not recognized as such due to their small sizes. While on smallest scales they may dominate the total gas amount, on larger scales they possibly form only a minor part of it.

Pierre Hily-Blant (IRAM, Grenoble, France; hilyblan@iram.fr)
Edith Falgarone (Ecole Normale Superieure (LERMA/LRA), Paris, France)
Jerome Pety (IRAM, Grenoble, France)

Presentation : talk (20)

Dissipative structures of diffuse ISM turbulence: I- CO diagnostics

We present ^{12}CO and ^{13}CO line observations at high-angular resolution of the parsec scale environment of a low-mass dense core located in a diffuse high latitude cloud. The gas surrounding the core is highly turbulent as shown by the ^{12}CO linewidths of several km s^{-1}. The statistical analysis of the velocity field reveals a new kind of filamentary small-scale structures that are the locus of the largest velocity shears in the field. They are spatially correlated with gas optically thin in the ^{12}CO(1-0) line, therefore gas warmer and more diluted than the bulk of the gas. The CO abundances derived from the observations is large and cannot be reproduced by steady-state models where the sole heating source for the gas is UV photons and cosmic-rays: an additional heating source is required, independent of UV photons and we propose that it is the dissipation of the turbulent energy. We compare our observations with 3-*d* magneto-hydrodynamic simulations (Padoan et al. 1998) of decaying turbulent flows, relevant to a scale of 5 pc and find marked differences.

Edith Falgarone (Ecole Normale Superieure (LERMA/LRA); edith.falgarone@lra.ens.fr)
Pierre Hily-Blant IRAM, Grenoble, France
Jerome Pety IRAM, Grenoble, France
Guillaume Pineau des Forets IAS, Orsay, France
Laurent Verstraete IAS, Orsay, France
Peter Schilke MPIfR, Bonn, Germany

Presentation : talk (20)

Dissipative structures of diffuse ISM turbulence: II- Chemical and H_2 line excitation diagnostics

The non-thermal energy of turbulence in the cold diffuse medium exceeds by far the gas thermal energy. Its dissipation is intermittent in space and time and locally deposits large amounts of non-thermal energy in the gas, modifying its subsequent thermal, chemical and dynamical evolution. Observations with the IRAM-Plateau de Bure Interferometer of a structure of extreme high-velocity shear (see Hily-Blant et al. abstract) suggest that dissipation may occur at scales $\approx$ 700 AU or smaller.

Recent attempts have been made at modeling the coupled impulsive heating and chemical enrichment in dissipation bursts followed by thermal and chemical relaxation of the gas. The signatures of such processes, although occurring in only a few percent of the diffuse gas, may have been observed in the excitation of the rotational levels of the H_2 molecule and the detection of large abundances of molecules, such as HCO^+, in diffuse molecular gas.

Vladimir Strelnitski (Maria Mitchell Observatory; vladimir@mmo.org)

Presentation: talk (20)

Turbulent AU Structures in Outflows from YSO~Rs as Revealed by Water and Methanol Masers

Water masers were historically the first understood indicators of powerful gas outflows from YSOs. Subsequent studies revealed definite signs of intermittent turbulent motion in these sources with a power-law (Kolmogorov) velocity spectrum and a fractal spatial structure. Recent computer simulations indicate that the observed water maser condensations are compact, physically isolated structures, not an optical effect of radiation propagation in a quasi-homogeneous medium with random velocity field. This makes H2O masers invaluable probes of highly supersonic, intermittent turbulence. The observed sizes of maser condensations are close to the dissipation scale of turbulence estimated from dimensional considerations, which may be a solution of the dissipation scale problem. The Class I methanol masers are also connected with the outflowing gas from YSO~Rs and they are often observed in the same general region as the H2O masers. However, they are considerably larger in size and demonstrate a drastically different structure of radial velocities. Possible reasons of these differences as well as possible computer simulations that may help better understand the nature of the masers and supersonic turbulence will be discussed.

The Local ISM

Jeffrey Linsky (JILA; jlinsky@jila.colorado.edu)

Presentation: invited (25)

Structure of the local ISM

This talk will summarize the work of our group and others concerning the physical properties and structure of warm interstellar clouds located in the Local Bubble. Absorption line studies with the high resolution spectrometers on HST and ground-based observatories have identified the Local Interstellar Cloud and a group of about a dozen warm clouds in the solar neighborhood. I will show their morphologies in Galactic coordinates and provide preliminary estimates of their temperatures and column densities. Comparisons will be made with the ionization equilibrium models of Slavin and Frisch.

Priscilla C. Frisch (University of Chicago; frisch@oddjob.uchicago.edu)

Presentation: talk (20)

The Heliosphere Vantage Point: Uncovering the Secrets of Low Column Density ISM

The Sun is embedded in a tenuous, low column density, partially ionized, rapidly moving interstellar cloud that provides insight into global low column density ISM. The surrounding cloud is observed both inside of the solar system, through partially ionized Ne, Ar, and He, and towards nearby stars. The surrounding cloud is warm, T∼6400 K, with $n(H)$ ∼0.3 cm^3, H I/H II∼2, V ∼17 km s^{-1} (LSR), and $N(HI) < 10^{18}$ cm^2. It is part of a cluster of local interstellar clouds (CLIC), that is turbulent, FWHM(V)∼10 km/s, and flowing past the Sun. The CLIC originated with star formation in the Scorpius-Ophiuchus Association. If viewed from elsewhere, the CLIC would appear to be either or both typical low column density H I gas or diffuse ionized gas, n(e)∼0.1 /cc. Radiative transfer models of the surrounding ISM indicate that this closest material is in photoionization equilibrium, offering insight into the formation of global tepid tenuous rapidly moving ISM (Slavin Frisch, 2002, 2006).

Dave Meyer (Northwestern; davemeyer@northwestern.edu)

Presentation: talk (20)

Cold clouds in the Local Bubble

The high-latitude Galactic H I cloud toward the extragalactic radio sources 3C 225 and 3C 237 is characterized by very narrow 21 cm emission and absorption indicative of an H I spin temperature of about 20 K. Through high-resolution optical spectroscopy, we have recently detected strong Na I absorption corresponding to this cloud toward a number of nearby stars. Assuming that the turbulent H I and Na I motions are similar, we derive a cloud temperature of 20 K and a turbulent velocity of 0.4 km s^{-1} from a comparison of the H I and Na I absorption line-widths. We can also place a firm upper limit of 45 pc on the distance of the cloud, which places it well within the Local Bubble in this direction.

Adriana Gazol (Centro de Radioastronomia y Astrofisica, UNAM; a.gazol@astrosmo.unam.mx)
Jongsoo Kim (Korea Astronomy ans Space Science Institute)
Enrique Vazquez-Semadeni (Centro de Radioastronomia y Astrofisica, UNAM)
Leticia Luis (Centro de Radioastronomia y Astrofisica, UNAM)

Presentation: Poster

High Pressure Regions in a Turbulent Bistable Gas

We will present results from two dimensional high resolution numerical simulations of a thermally bistable medium in presence of turbulent velocity fluctuations in a box with 100pc by side. In particular we will discuss the pressure distribution of the gas and the properties (pressure evolution, lifetimes, sizes) of the resulting high pressure regions.

Jacqueline Hodge (UC Davis; jackie.hodge@gmail.com)
Avinash A. Deshpande (Raman Research Institute, Bangalore, INDIA)

Presentation: Poster

H I Density Distribution Driven by Supernovae: A Simulation Study

We model the complex distribution of atomic hydrogen (HI) in the interstellar medium (ISM) assuming that it is driven entirely by supernovae (SN). We develop and assess two different models. In the first approach, the simulated volume is randomly populated with non-overlapping voids of a range of sizes. This may relate to a snapshot distribution of supernova-remnant voids, although somewhat artificially constrained by the non-overlap criterion. In the second approach, a simplified time evolution (considering momentum conservation as the only governing constraint during interactions) is followed as SN populate the space with the associated input mass and energy.

We describe these simulations and present our results in the form of images of the mass and velocity distributions and the associated power spectra. The latter are compared with trends indicated by available observations. In both approaches, we find remarkable correspondence with the observed statistical description of well-studied components of the ISM, wherein the spatial spectra have been found to show significant deviations from the Kolmogorov spectrum. One of the key indications from this study, regardless of whether or not the SN-induced turbulence is the dominant process in the ISM, is that the apparent non-Kolmogorov spectral characteristics (of H I and/or electron column density across thick or thin screens) needed to explain related observations may not at all be in conflict with the underlying turbulence (i.e. the velocity structure) being of Kolmogorov nature. We briefly discuss the limitations of our simulations and the various implications of our results.

Shu-ichiro Inutsuka (Department of Physics, Kyoto University; inutsuka@tap.scphys.kyoto-u.ac.jp)
Hiroshi Koyama (Department of Earth and Planetary System Science, Kobe University)

Presentation : Poster

The Effect of Magnetic Field on Turbulence Driven by Thermal Instability

Our understanding on the physical processes in the transition between warm neutral medium (WNM) and cold neutral medium (CNM) is dramatically increased in the last few years. In this paper we explain the basic property of thermal instability and the effect of magnetic field on it in terms of linear stability analysis. Then we analyze the propagation of a shock wave into WNM by taking into account radiative heating/cooling, thermal conduction, physical viscosity, and the magnetic field in one-, two-, and three-dimensional magnetohydrodynamical simulations. The results show that the thermal instability in the post-shock gas produces high-density cold cloudlets embedded in warm neutral medium. Here we emphasize the importance of ambipolar diffusion in producing tiny cold cloudlets. The dynamical evolution driven by thermal instability in the post-shock layer is an important basic process for the transition from warm gases to cold gases, because the shock wa! ves are frequently generated by supernovae in the Galaxy.

Sami Dib (Max-Planck-Institut fr Astronomie; dib@mpia.de)
Enrique Vazquez-Semadeni (Centro de Radioastronomia y Astrofisica, UNAM, Mexico)
Jongsoo Kim (Korea Astronomy ans Space Science Institute)

Presentation: Poster

Detailed Virial Balance Analysis of Molecular Clouds in Three-Dimensional Numerical Simulations

We analyse the virial balance of clumps and cores in a set of 3D, driven, isothermal, magnetohydrodynamical simulations of molecular clouds. We apply a clump finding algorithm based on a density threshold and a friend-of-friend approach to identify clumps and cores in the simulation box. For each object, we calculate all the terms that enter the virial equation in its Eulerian form (EVT). These terms include the thermal, kinetic and magnetic volume and surface energies (E_{th}, E_k, E_m, Γ_{th}, Γ_k, Γ_m, respectively), the gravitational term W, the second time derivative of the moment of inertia and the first time derivative of the flux of moment of inertia through the clump boundary. We also calculate, for each object, other stability indicators commonly used in observational and theoretical work such as the Jeans number J_c, the mass-to magnetic flux ratio (normalized to the critical value for collapse), μ_c, and the virial parameter α_{vir}. Our results show that: a) In general clumps and core are dynamical, out-of-equilibrium structures, but we also find some Barnard 68 like objects at the bottom of the turbulent cascade b) Surface energy terms are as important as volume terms in the overall energy balance, c) Not all clumps that have infall-like motions are gravitationally bound, d) The near equality of the temporal terms in the EVT enables the usage of the other terms as a stability indicator (gravity versus other energies), and e) We explore the relationships between the classical parameters J_c, μ_c, and α_c to their counterparts in the EVT (e.g., J_c is compared to $\mid W \mid / \mid E_{th} - \Gamma_{th} \mid$) with the aim of determining the stability of clumps based on observations of their combined dynamical, thermal and magnetic properties.

Patrick Hennebelle (Observatoire de Paris; patrick.hennebelle@ens.fr)

Presentation: Poster

Influence of the Magnetic Field on the Thermal Condensation

In the case of an initially uniform magnetic field our main conclusions are: (i) the magnetic pressure is able to prevent the thermal condensation if the angle between the converging flow and the magnetic field is too large; (ii) if the magnetic field and the initial converging flow are sufficiently aligned, the magnetic tension is capable of realigning the flow and the field and the condensation occurs along the field lines; (iii) the condensation is more easy to achieve in case of weak or strong fields and more difficult when the magnetic energy is comparable to the kinetic energy of the incoming flow; (iv)as a consequence the magnetic intensity is the same into the 2 phases

In the case when Alfven waves propagates we show that: (i)the waves stabilize efficiently the pertubations of large wavelength; (ii) they destabilize the pertubations of intermediate wavelengths; (iii) they do not affect the perturbations of small wavelengths; (iv) the waves tend to enhance the thermal fragmentation of the gas and can trigger very large density fluctuations.

Snezana Stanimirovic (UC Berkeley; sstanimi@astro.berkeley.edu)
Joel Weisberg (Carleton College)
John Dickey (University of Tasmania)
Anton de la Fuente, Katie Devine, Abby Hedden (Carleton College)
Stuart Anderson (Caltech)

Presentation: Poster

B1849+00 probes the tiny-scale molecular gas ?

We have detected deep and narrow absorption features against PSR B1849+00 in both OH mainlines using the Arecibo telescope. This is the first successful absorption measurement against any pulsar made in both OH mainlines. The absorption features are produced by small scale molecular structure along the line of sight. In addition, in the pulse-off spectrum, we see OH absorption against SNR G33.6+0.1 which is only 8 arcmin away from the pulsar and is partially covered by the Arecibo beam. It is intriguing that the absorption features seen against the SNR differ greatly from the tiny-scale features seen in the PSR-only absorption spectra! We investigate two possible explanations for this dramatic difference: (a) the PSR being more distant than the SNR; (b) the effect of clumping of molecular gas on very small spatial scales for the emission/absorption studies.

James G. Ingalls (SSC/Caltech; ingalls@ipac.caltech.edu)
W.T. Reach (SSC/Caltech)
T.M. Bania (Institute for Astrophysical Research, Boston University)
J.M. Carpenter (Caltech)

Presentation: Poster

Molecular Cloud Structure from a CO Spectral Line: Interferometric Observations of MBM-12

We present aperture synthesis images (linear resolution about 0.005 pc, or 1000 AU) of the CO(1–0) emission towards the edge of high latitude dark cloud MBM-12, made using the OVRO millimeter interferometer. The synthesized velocity channel maps and the directly measured visibility spectrum, both of which are primarily sensitive to brightness fluctuations, show significant emission at the wing velocities of the single dish line profile. We detected almost no fluctuations in the line core, however. The fact that we detected the line wings implies that the CO emission originates in a medium that is structured on milliparsec scales. The weakness of line core fluc-

tuations implies that the emitting material is surface-filling on scales of about 0.1 pc, and that it is probably locally opaque to CO(1–0) radiation. We estimate the physical properties of the underlying medium using models that posit the CO-emitting gas to be distributed in either (1) discrete clumps or (2) a continuously varying fractional brownian motion structure.

Ionized Medium on Larger Scales

James Cordes (Astronomy Department, Cornell University; cordes@astro.cornell.edu)
Joseph Lazio (Naval Research Laboratory)
Ramesh Bhat (Swinburne University)

Presentation: invited (25)

The Wavenumber Spectrum and Galactic Distribution of the Fluctuating Ionized Interstellar Medium

I will discuss constraints on the wavenumber spectrum obtained from radio scattering measurements, including angular broadening, pulse broadening, and scintillation arcs. The assumed form of the wavenumber spectrum is important in the modeling of the electron density in the NE2001 Galactic model for electron density and its fluctuations. I will discuss the features of the NE2001 model, including its strengths and weaknesses. The next version of the model, NE200X, will include new measurements and alternative model features, which I shall describe. Finally I will mention constraints on the intergalactic medium from radio-wave scattering of AGNs; their interpretation relies on the Galactic model in order to remove foreground scattering.

Marijke Haverkorn (NRAO/UC-Berkeley; marijke@astro.berkeley.edu)

Presentation: invited (25)

Observations of Turbulence in the Magneto-Ionized ISM on Subparsec Scales

Structure in the interstellar medium is present from scales of many parsecs down to AUs. Much of these fluctuations are thought to be caused by turbulence, which connects all these scales via cascades of energy to smaller scales. Therefore, in order to understand the structure at AU scales better, it is useful to also study the characteristics of turbulence on parsec scales.

I will discuss observations of structure in the magneto-ionized medium on scales that are large in the context of this workshop but small on Galactic scales, i.e. on parsec and subparsec scales. Statistical description of Faraday rotation in the Milky Way and modeling of depolarization of both Galactic and extragalactic radio synchrotron radiation allow study of the power spectrum and typical scales of structure in the magnetized ISM, with the goal of shedding light on turbulent processes in the interstellar gas.

Kenny Wood (St. Andrews; kw25@st-and.ac.uk)

Presentation: invited (25)

The Propagation of Ionizing Radiation Through a Clumpy (Fractal) Medium and the Porosity of the Interstellar Medium

I will show results from our three dimensional Monte Carlo photoionization code on the structure of 3D HII regions. A 3D ISM allows the propagation of ionizing radiation from midplane OB stars to high latitude diffuse ionized gas. Modeling of WHAM data on individual HII regions allows us to estimate the porosity of the ISM in these regions. I will discuss future steps to be taken in performing photoionization simulations in MHD simulations.

Ionized Medium Through Pulsar Scintillations

Dan Stinebring (Oberlin College; dan.stinebring@oberlin.edu)

Presentation: invited-R (40)

Pulsar Scintillation Arcs and the ionized ISM

I will review the observations and theory of pulsar scintillation, focusing on the phenomenon of scintillation arcs. It has been known since soon after the discovery of pulsars that dynamic spectra of the sources occasionally show pronounced fringing or crisscross patterns. It was a surprise, however, when the 2d Fourier analysis of these spectra showed faint, parabolic features in the secondary spectra. I will show evidence that the scintillation arc phenomenon is widespread and that it underpins many other scintillation phenomena. Furthermore, there is often pronounced substructure in the arcs, and it translates along the main arc in a manner that is determined by the proper motion of the pulsar. This substructure may be produced by lens-like features in the ionized ISM that are far out of pressure balance with the WIM. These may, in turn, be related to deterministic structures that cause extreme scattering events. Observations with this technique, which rely on a large flux density and/or a large collecting area, have an angular resolution of about a milliarcsecond. They often show features in the scatter broadened image out to 15 V 20 times this resolution, however. Thus, single-dish observations can study details in the scattering medium on AU-size scales while covering a relatively large field of view that scans the sky at the pulsar proper motion speed. We are still learning how to interpret the richly detailed scintillation arc pattern that results, and observational and interpretive surprises continue.

Walter Brisken (National Radio Astronomy Observatory; wbrisken@aoc.nrao.edu)
J-P Macquart (National Radio Astronomy Observatory)

Presentation: talk (20)

VLBI Observations of the Pulsar Scintillation Arc Phenominon

The secondary intensity power spectra of some pulsars exhibit arc-like structures that hint at complex scattering behavior. A favored model is the interference of several wavefields, each a copy of the pulsar's original emission transmitted through stationary phase points (SPP) in the scattering screen with a different delay and rate depending on the location of the SPP. We are testing this model by using VLBI to triangulate relative positions of the SPPs. Our technique allows us to extract information on interstellar turbulence over a large range of scales <1 to >100AU, including anisotropy, and even a superficial analysis indicates the presence of unusual features in the character of the interstellar turbulence on these scales. Current progress towards these goals will be presented.

Scott Ransom (NRAO; sransom@nrao.edu)
Vicky Kaspi (McGill University)
Jason Hessels (McGill University)
Ingrid Stairs (UBC)
Paulo Freire (Arecibo)
Fernando Camilo (Columbia University)

Presentation: talk (20)

Parsec-scale Constraints on the ISM From the Millisecond Pulsars in Terzan5

Over the past two years, we used a series of GBT observations to uncover at least 33 millisecond pulsars in the globular cluster Terzan 5 located in the Galactic bulge. We now have 32 timing solutions for the pulsars which give us precise positions and dispersion measures (DMs) and indicate that the DMs are dominated by variations in the integrated electron density along the slightly different sight lines towards the pulsars. At a distance of 8.7 kpc, angular separations between the pulsars range from $0.3" - 100"$ and correspond to projected physical separations of 0.01-4 pc, giving us a unique probe into the ionized ISM properties on these scales.

IDV Observations

Jim Lovell (ATNF; jim.lovell@csiro.au)
Dave Jauncey (ATNF)
Cliff Senkbeil (University of Tasmania)
Lucyna Kedziora-Chudczer (Sydney University)
J-P Macquart (NRAO)
Barney Rickett, et al (UCSD)

Presentation: invited (25)

The MASIV Survey

The Micro-Asrcsecond Scintillation-Induced Variability (MASIV) Survey is using the VLA to survey∼550 flat-spectrum radio sources to construct a sample of $\sim 100-150$ scintillating AGN. The sample as a whole will allow us to better understand the most compact AGN population. Studies of individual sources will allow ISM and AGN structures to be probed on the micro-arcsecond scale. I will present results from the first four epochs of the survey which has found over 100 new scintillators. We find that rapid, large amplitude variables such as PKS0405-385, J1819+3845 and PKS1257-326, are very rare, that the number of scintillating sources increases with decreasing flux density, and that the population is dominated by sources that scintillate for periods of several months rather than many years.

Hayley Bignall (Joint Institute for VLBI in Europe; bignall@jive.nl)
David L. Jauncey (ATNF, CSIRO)
Jean-Pierre Macquart (NRAO)
Lucyna Kedziora-Chudczer (University of Sydney)
Jim Lovell (ATNF, CSIRO)
Tasso Tzioumis (ATNF, CSIRO)

Presentation: talk (20)

Properties of the Scatterer in Front of Scintillating Quasar PKS 1257-326

PKS 1257-326 is a quasar showing extremely unusual, rapid interstellar scintillation (ISS), which has persisted for at least a decade. Only two other sources have been found to show similarly rapid ISS: PKS 0405-385 which shows short episodes of rapid ISS interspersed with long "quiescent" periods, and J1819+3845 which, similarly to PKS 1257-326, shows more persistent ISS. Observations with the VLA and ATCA have revealed some properties of the turbulent ionized medium responsible for the ISS of PKS 1257-326. The scattering occurs in an unusually nearby (∼10 pc), localized thin "screen". The turbulence is highly anisotropic, producing a highly elongated scintillation pattern with axial ratio ∼10:1. I will summarise recent findings for discussion in the broader context of what such observations can tell us about small-scale ionized structures in the ISM.

Ger de Bruyn (ASTRON (NFRA); ger@astron.nl)

Presentation: invited (25)

J1819+3845: a Remarkable Superposition of a Very Compact Quasar and a Fast-moving Very Local Turbulent Screen

The quasar J1819+3845 shows dramatic scintillation-induced intensity variations with a typical modulation index of 30% at a frequency of 5 GHz. The medium responsible for the scintillation is located at a distance of only a few parsec and has a transverse velocity of about 30 km/s. The source has now shown scintillations for more than 7 years, without interruption, setting a lower limit to the transverse size of the medium/screen of about 10^{15} cm.

The overall properties of J1819+3845 evolve slowly, on a years timescale. However, in recent years we have also seen power emerge at very fast temporal scales suggesting the emergence, and dissapearance, of faint ultracompact structure at 6cm. An explanation for the fast variations in terms of changes in the screen appears less likely. This structure may be related to the diffractive scintillations observed at 21cm.

We will present and discuss some of our intensive polarization monitoring providing differential polarimetric astrometry at the few microarcsecond level and conclude with our current state of knowledge about the source and medium.

Interpretation of Scintillations

Barney Rickett (University of California San Diego; bjrickett@ucsd.edu)

Presentation: invited-R (40)

What Do Scintillations Tell Us about the Ionized ISM?

Interstellar scintillations (ISS) has been studied since pulsars were discovered nearly 40 years ago. I will briefly review how these have been interpreted in terms of the wavenumber spectrum of the electron density in the ionized ISM. Within 1 kpc of the Sun, the results are consistent with a Kolmogorov power law over scales from about 100 km to a few AU. This describes a stochastic ionized medium, probably turbulent, which may be concentrated in one or more discrete regions along the line of sight, whose depths are very much larger than 3 AU - typically presumed to be more than a parsec.

However, over the years there have been several observed phenomena which show that some lines of sight have scattering from discrete regions as small as a few AU. Extreme scattering events are one example (Fiedler et al. 1987, Nature, 326, 675). Recently Hill, Stinebring et al. (2004, ApJ, 619, L171) reported ISS arcs from pulsar B0834+06 in which four isolated "reverse arcs" were observed which were caused by discrete AU-sized regions that survived for 20 days or longer. I will discuss possible explanations for these "tiny" ionized regions and how they may be related to the more pervasive turbulence in the ionized medium.

Jean-Pierre Macquart (NRAO; jmacquar@aoc.nrao.edu)

Presentation: invited (20)

Variability in Radio Absorption Spectra Against Extragalactic Sources and Implications for the ISM

I describe a mechanism by which interstellar scintillation can induce variability in any radio emission or absorption line. Scintillation acts like a high pass filter and responds to fine scale structure in the gas. In systems containing absorption at several velocities, lines can vary relative to one another if the spatial distribution of the material responsible for the individual lines differs. I will outline several simple models and apply them to the two systems in which H I variability is best documented: AO 0235+164 and PKS 1127-145.

Mark Walker (MAW Technology Pty Ltd; Mark.Walker@mawtech.com.au)

Presentation: Invited (25)

Interpretation of Extreme Scattering Events and Pulsar Dynamic Spectra

Several radio-wave scintillation phenomena exhibit properties which are difficult to accommodate in terms of distributed Kolmogorov turbulence in the ionised ISM. At least one of these ”anomalous” propagation phenomena – the ”Extreme Scattering Events” – requires discrete clouds with extraordinarily high electron densities. The Galaxy presumably contains a lot of these clouds, as there appear to be thousands of them per cubic parsec, locally. Despite this they are an ”uncatalogued” ISM component of which we know little. I will discuss the properties of the scattering/refracting clouds responsible for anomalous radio-wave propagation phenomena, including results from holography of these media.

Jared H. Crossley (New Mexico Tech; jaredc@nmt.edu)
Timothy H. Hankins (New Mexico Tech)
Jean A. Eilek (New Mexico Tech)

Presentation: Poster

Echoes of Crab Pulsar Giant Radio Pulses

We have detected short-lived ”echoes” of giant pulses from the Crab pulsar. We observed individual giant pulses with high time resolution, at 1.4 and 4.8 GHz. Over a course of several years, we saw the echoes on only two days (separated by 13 months), and only at the lower frequency. The echo emission follows the giant pulse primary emission by 40-100 microseconds. The peak flux of the echo component is consistently a factor of 10 less than that of the primary component. The echo widths are greater than the primary component widths. One of our two echo events lasted no more than four days. The frequency dependence and shorter echo lag time suggest that these echoes differ from those reported previously. We use simple models to investigate the possibility that the echoes are due to reflection from plasma structures close to the pulsar, possibly close to the interface between the pulsar wind and the outer synchrotron nebula.

Alex S. Hill (University of Wisconsin-Madison; hill@astro.wisc.edu)
Ronald J. Reynolds (University of Wisconsin-Madison)
Robert A. Benjamin (University of Wisconsin-Whitewater)

L. Matthew Haffner (University of Wisconsin-Madison)

Presentation: Poster

Density Enhancements in the WIM

The density structure of the Warm Ionized Medium (WIM) can be explored by studying the H-Alpha intensity distribution on the sky and by comparing emission measures (EM) along pulsar sightlines with pulsar dispersion measures (DM). After excluding sightlines associated with known classical H II regions, a histogram of the vertical component of emission measure, $EM\sin(|\ b\ |)$, reveals large scale enhancements ($EM \sim 3 \times 10$ cm^{-6} pc) within a more uniform plane-parallel emitting layer ($EM\sin(|\ b\ |) = 1.1$ cm^{-6} pc). The regions of enhanced emission measure subtend from one degree to tens of degrees on the sky and represent density enhancements within the more uniform ionized medium or regions with a higher flux of ionizing radiation. Comparisons of EM and DM indicate that within the more uniform WIM, the gas along lines of sight through the Galactic disk is clumped into regions that occupy about 20% of the interstellar volume with a mean density within the clumps of > 0.07 cm^{-3}.

Dan Stinebring (Oberlin College; dan.stinebring@oberlin.edu)
John Matters Oberlin College
Daniel Hemberger Oberlin College
T Joseph Lazio Naval Research Lab

Presentation : Poster

Diffraction from 2d Gaussian Lenses in the ISM

One explanation for extreme scattering events (quasar flux variations with ringing and an extended flux minimum lasting for weeks) is refraction by lens-like structures in the ISM. Prompted by this and intriguing features in pulsar scintillation arcs, we have used an e-m wave propagation code to explore the flux time signature expected for a 2d lens with a Gaussian column density profile. This builds on the work of Clegg, Fey, and Lazio (1998), but considers 2d rather than 1d lens structures and simulates the light curves with a wave optics approach. We find results that are consistent with CFL, but demonstrate a richer interference structure at entry and egress from the lens. We present preliminary results of the simulation and discuss the range of parameters needed to explain extreme scattering events or scintillation arc substructure with this model.

The simulation used in this research was developed by W. A. Coles, B. J. Rickett, and collaborators (UCSD!), and we thank them for permission to use it. This work was supported by the National Science Foundation. Basic research in radio astronomy at the NRL is supported by the Office of Naval Research.

Stanislav Boldyrev (University of Wisconsin-Madison; boldyrev@wisc.edu)
Joanne Mason (University of Chicago)
Fausto Cattaneo (University of Chicago)

Presentation: Poster

Dynamic Alignment and Exact Scaling Laws in MHD Turbulence

Kolmogorov theory of hydrodynamic turbulence has an exact relation for the third-order longitudinal velocity structure function, from which one infers the Kolmogorov energy spectrum $E(k) \sim k^{-5/3}$. In 1998 Politano and Pouquet found somewhat analogous relations for magnetohydrodynamic turbulence. This would suggest that the spectrum of MHD turbulence has the Kolmogorov scaling as well. However, recent high-resolution direct numerical simulations suggest that the spectrum is $E(k) \sim k^{-3/2}$. We propose that this apparent contradiction is resolved if one invokes the phenomenon of scale-dependent dynamic alignment of velocity and magnetic field polarizations, recently discovered in MHD turbulence [see the presentation by Joanne Mason, this meeting]. Possible astrophysical applications of this phenomenon are discussed.

A. Lazarian (UW-Madison; lazarian@astro.wisc.edu)

Presentation: Poster

Formation of Tiny Scale Structures in Viscosity-Damped MHD Turbulence

Both theory and numerical simulations show that MHD turbulence in the fluids with viscosity much larger than resistivity does not vanish at the viscous scale. Instead it protrudes to much smaller scales by forming magnetic filaments which transverse scales are much smaller than the viscous scale. The magnetic pressure within the filaments is balanced by the pressure of the gas outside the filaments. This causes the compression of the gas and formation of gaseous filaments. Is the viscosity-dominated regime is relevant to the ISM? I shall argue that this is very relevant to the partially ionized gas, where the viscosity by neutrals damps the turbulence at scales much larger than the scales at which the resistivity gets important. Moreover, one can speculate, that the anisotropic viscosity in the partially ionized gas makes the viscosity-dominated regime is also relevant to the fully ionized plasmas. Therefore, the viscosity-dominated turbulence has a potential to explain both neutral and ionized tiny-scale structures. I shall show that the necessary conditions for this involve the significant magnetic pressure in the medium (which is nearly always true for the ISM) and the existence of turbulent velocities at the scale of the viscous damping, that are larger or comparable with the Alfven velocity. The latter may be achieved either by the localized energy injection or by the decrease of the Alfven velocity due to the turbulent formation of clumps. This provides a viable explanation for the formation of tiny scale structures both in neutral and ionized gas. I shall discuss both the results from Lazarian, Vishniac Cho 2004 theoretical work, as well as new unpublished numerical simulations done with A. Beresnyak.

Ionized Medium – Theory

Ellen Zweibel (U. Wisconsin, Madison; zweibel@astro.wisc.edu)

Presentation: Review (40)

Turbulence and Dissipation Scales in the ISM

his talk will be primarily pedagogical. I will discuss a variety of processes for producing small scale structure in a turbulent medium, and how small scale structure is related to dissipation.

Steven R. Spangler (University of Iowa; steven-spangler@uiowa.edu)

Presentation: invited (25)

The Propagation Distance and Sources of Interstellar Turbulence

The phenomena responsible for "Tiny Scale Atomic Structures" and radioastronomical Extreme Scattering Events would seem to be a component of interstellar plasma turbulence, perhaps corresponding to large amplitude, solitary structures which arise in such turbulence. The point of this presentation is to emphasize a constraint on the properties and sources of all forms of interstellar turbulence by the dissipation due to ion-neutral collisional damping. The damping rate of MHD waves on neutral gas in the Diffuse Ionized Gas (DIG) component of the ISM is of order 8.3×10^{-10} Hz for 70% ionization fraction of hydrogen (Minter and Spangler ApJ 485,182,1997). With a corresponding Alfven speed of 23 km s^{-1} (Minter & Spangler 1997) interstellar turbulence should be strongly damped within a parsec of its sources. This conclusion should apply to both plane Alfven waves as well as the more realistic turbulence model of quasi-2D, vortex-like structures. This calculation is strongly discordant with the observation that turbulence in the DIG seems uniformly distributed and at locations far from obvious turbulence "generators" such as supernova remnants and star formation regions. The resolution of this question could provide important hints as to the generation of interstellar turbulence, and the medium through which it propagates. I will also discuss current knowledge on the kinetics of ion-neutral collisions in partially ionized plasmas.

William Coles (University of California, San Diego; bcoles@ucsd.edu)

Presentation: invited (25)

Evidence for Anisotropy and Intermittency in the Turbulent Interstellar Plasma

Density fluctuations in the interstellar plasma scatter radio waves from distant cosmic radio sources. Measurements of the effects of this scattering, loosely termed scintillation, provide a way of estimating some of the statistics of these density fluctuations. The spatial spectrum of these fluctuations has been found to follow a "Kolmogorov" power law, suggesting, but not proving, that the fluctuations are turbulent in origin. It is usually assumed that the scattering comes from a compact region (a "thin screen") and the turbulence is isotropic, but these assumptions have been made purely for analytical simplicity. In fact it is often very difficult to find analytical approximations for the statistics of the density fluctuations and these assumptions have been essential. However more recently evidence has been accumulating that scintillations really do often come from single compact region somewhere on the line of sight, so the first assumption is justified, but the spatial statistics often show signs of anisotropy indicating that the second assumption is not always justified. I will discuss the recent evidence and speculate, with vigorous handwaving, what this implies and doesn't imply about the interstellar plasma.

Stanislav Boldyrev (Department of Physics, University of Wisconsin-Madison; boldyrev@wisc.edu)

Presentation: invited (25)

On Non-Gaussian Statistics of the Electron Density Distribution in the ISM

Radio waves propagating from distant pulsars in the interstellar medium (ISM), are refracted by electron density inhomogeneities, so that the intensity of observed pulses fluctuates with time. The theory relating the observed pulse time-shapes to the electron-density correlation function has developed for 30 years, however, two puzzles have remained. First, observational scaling of pulse broadening with the pulsar distance is anomalously strong; it is consistent with the standard model only when non-uniform statistics of electron fluctuations along the line of sight are assumed. Second, the observed pulse shapes are consistent with the standard model only when the scattering material is concentrated in a narrow slab between the pulsar and the Earth. We propose that both paradoxes may be resolved at once if one assumes stationary and uniform, but non-Gaussian statistics of the electron-density distribution. Such statistics must be of Levy type, and the propagating ray should exhibit a Levy flight. We propose that a natural realization of such statistics may be provided by the interstellar medium with random electron-density discontinuities. In particular, we argue that such density structures could correspond to the ionized boundaries of molecular regions (clouds) and demonstrate that the power-law distribution of scattering angles that is required to match the observations arises naturally from the expected intersections of our line of sight with randomly distributed, thin, approximately spherical ionized shells of this type.

[1] Boldyrev, S. & Gwinn C. R., Phys. Rev. Lett. 91 (2003) 131101; ApJ 624 (2005) 213

[2] Boldyrev, S, & Konigl, A., ApJ. 640 (2006) 344

Joanne Mason (Dept. Astronomy & Astrophysics, University of Chicago; jmason@flash.uchicago.edu)
Fausto Cattaneo (Dept. Astronomy & Astrophysics, University of Chicago)
Stanislav Boldyrev (Dept. Physics, University of Wisconsin at Madison)

Presentation: talk (20)

Spectrum and Small-scale Structures in MHD Turbulence

I review a new theory for incompressible MHD turbulence in the presence of a strong mean-field, developed in [1,2,3]. There it is suggested that the turbulent eddies are locally anisotropic in the plane perpendicular to the large-scale magnetic field, with the magnetic- and velocity-field fluctuations aligning within the scale dependent angle $\theta \sim \lambda^{0.25}$ (so-called dynamic alignment). Here I present numerical results that support this theory. The results are of interest to turbulence in the interstellar medium and suggest that the spectrum of electron-density fluctuations is anisotropic with respect to the local magnetic field, and should scale as $=E(k) \sim k^{-3/2}$In this theory, the small-scale density structures take the form of sheets or ribbons elongated in the direction of the magnetic field, rather than filaments. This may provide a natural explanation for recent observations of interstellar scintillations of PSR 0329+54 and PSR J0437-4715 [4,5].

[1] Boldyrev, S. (2005). ApJ, 626, L37. [2] Boldyrev, S. (2005). Astro-ph/0511290. [3] Mason, J., Cattaneo, F. & Boldyrev, S. (2006). Astro-ph/0602382. [4] Shishov, V.I. et al. (2003). A&A, 404, 557. [5] Smirnova, T.V, Gwinn, C.R. & Shishov, V.I. (2006). Astro-ph/0603490.

Matthew Palotti (University of Wisconsin; mlpalotti@wisc.edu)
Ellen Zweibel (University of Wisconsin)
Fabian Heitsch (University of Michigan)

Presentation: talk (20)

Small Scale Velocity and Density Structures Formed by Shear Flow

The Kelvin Helmholtz Instability (KHI) arises at the boundary of a shear layer. In a purely hydrodynamical case, the KHI leads to a large-scale rotating eddy at the interface. However, when there is a weak magnetic field aligned parallel to the layer, the field will break up the large-scale eddy and lead to the formation of smaller-scale structures. We present results of 2D MHD numerical simulations, investigating the role of magnetic field strength in the formation of small scale velocity and density structures at the boundary of a shear flow.

Prelude to Panel Discussion

Ellen Zweibel (U. Wisconsin, Madison; zweibel@astro.wisc.edu)

Presentation: Review (30)

On Spitzer's Ideas about the Tiny-scale Structure in the ISM

One of the last things Lyman Spitzer worked on was small scale interstellar structure. He maintained a folder of correspondence with some of the scientists at this meeting, as well as their papers and notes of his own. I will describe his views, and comment on how they might have been impacted by recent results.

Carl Heiles (University of California, Berkeley; heiles@astron.berkeley.edu)

Presentation: Review (30)

Observational Review

Steve Spangler ((University of Iowa; steven-spangler@uiowa.edu)

Presentation: Review (30)

Theory Review