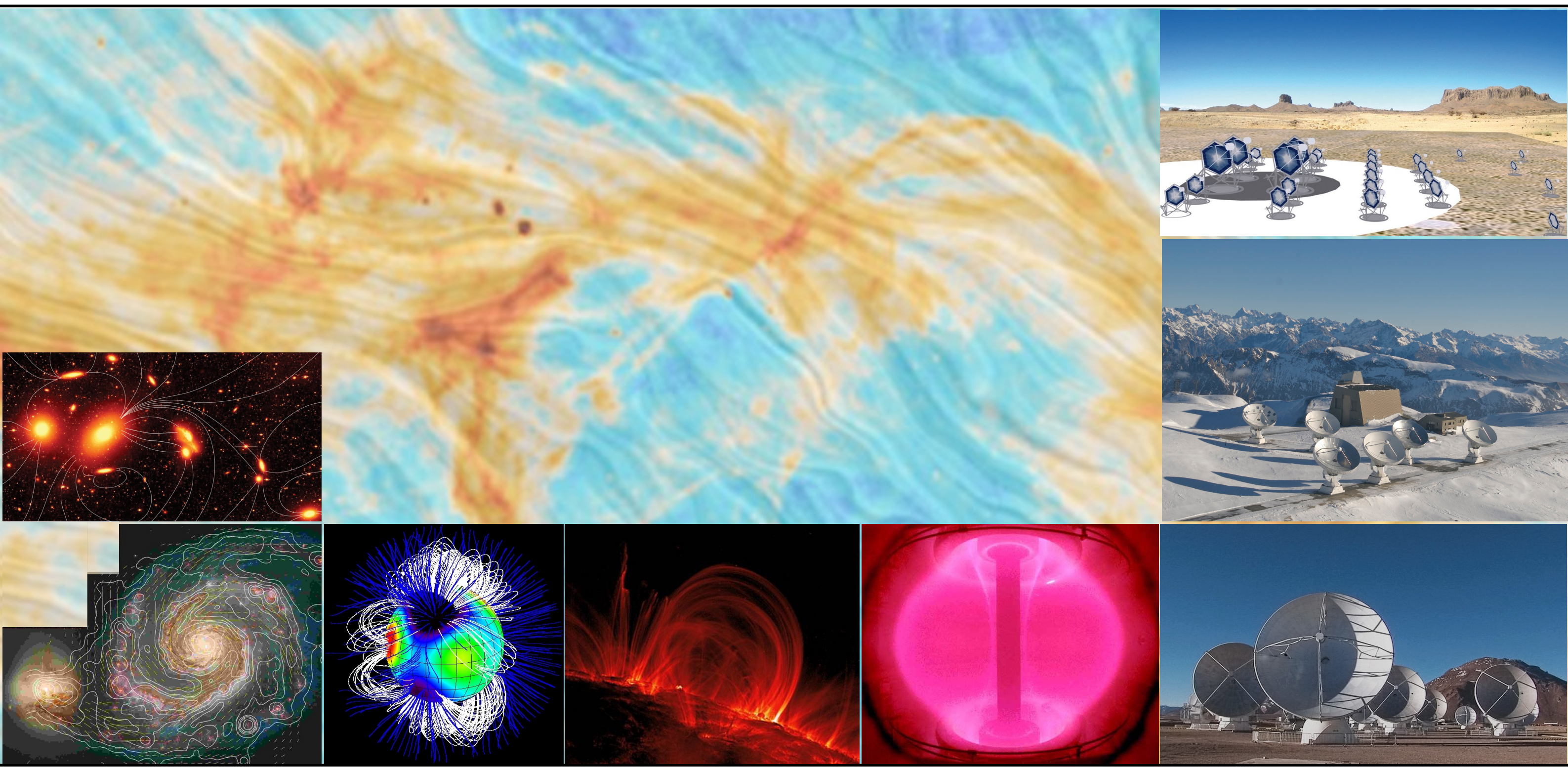
Magnetic Fields in the Universe V

From Laboratory and Stars to primordial Structures

Abstracts



October 5-9, 2015

Institut d'Etudes Scientifiques de Cargèse, Corsica, France

INVITED TALKS

Observations of solar wind turbulence

Olga Alexandrova
LESIA, Observatoire de Paris, PSL Research University, CNRS,
UPMC Université Paris 06, Université Paris-Diderot, 5 place Jules Janssen, F-92190 Meudon, France

Solar wind is probably the best laboratory to study turbulence in astrophysical plasmas. In addition to the presence of magnetic field, the differences with neutral fluid isotropic turbulence are: (i) weakness of collisional dissipation and (ii) presence of several characteristic space and time scales. I will discuss observational properties of solar wind turbulence in a large range from the MHD to the electron scales. At MHD scales, within the inertial range, turbulence cascade of magnetic fluctuations develops mostly in the plane perpendicular to the mean field, with the Kolmogorov scaling $k_{\perp}^{-5/3}$ for the perpendicular cascade and $k_{\parallel}^{-2}$ for the parallel one. Solar wind turbulence is compressible in nature: density fluctuations at MHD scales have the Kolmogorov spectrum. Velocity fluctuations do not follow magnetic field ones: their spectrum is a power-law with a $-3/2$ spectral index. Probability distribution functions of different plasma parameters are not Gaussian, indicating presence of intermittency. At the moment there is no global model taking into account all these observed properties of the inertial range. At ion scales, turbulent spectra have a break, compressibility increases and the density fluctuation spectrum has a local flattening. Around ion scales, magnetic spectra are variable and ion instabilities occur as a function of the local plasma parameters. Between ion and electron scales, a small scale turbulent cascade seems to be established. It is characterised by a well defined power-law spectrum in magnetic and density fluctuations with a spectral index close to -2.8. Approaching electron scales, the fluctuations are no more self-similar: an exponential cut-off is usually observed (for time intervals without quasi-parallel whistlers, which can be generated in the solar wind by the electron heat flux instability) indicating an onset of dissipation. The small scale inertial range between ion and electron scales and the electron dissipation range can be together described by $\sim k_{\perp}^{-8/3} \exp(-k_{\perp}\rho_e)$, with the curvature appearing at the electron Larmor radius ρ_e. The nature of this small scale cascade and a possible dissipation mechanism are still under debate.

Magnetorotational turbulence in protoplanetary discs

Steven Balbus
University of Oxford, Denys Wilkinson Building, Keble Road, Oxford OX1 3RH, UK

The conceptual framework for understanding protostellar/planetary disc dynamics has evolved from Lewis Models of local thermodynamic equilibrium to α Shakura-Sunyaev discs, to MHD physics. These gaseous systems are generally in a regime in which non-ideal MHD physics and non thermal processes are both of great importance, but are also very model- and parameter-dependent. The elucidation of PPDs will require not only careful modelling, but considerable observational input as well. ALMA promises to be a game-changer. In this talk, I will present an historical review of the topic and convey an idea of where our still tentative understanding of the subject lies, and what would be nice to know.

Topics in MHD Turbulence

Andrey Beresnyak

Laboratories for Computational Physics, Naval Research Laboratory

Code 6043 4555 Overlook Ave SW Washington, DC 20375, USA

The last decade saw a dramatic improvement in our understanding of the basics of MHD turbulence. While it has been known that the spectrum of the solar wind is anisotropic, the nature of this has been debated. The standard Goldreich-Sridhar model offered a qualitative critical balance argument, that lead to the k^{-2} parallel spectrum prediction, which was consistent with measurements and simulations. Recently, it became clear that the k^{-2} parallel spatial spectrum is simply the ω^{-2} Lagrangian frequency spectrum of strong turbulence. Another success story came from high resolution simulations with *Re* up to 36000, which started to show remarkably simple asymptotic behavior. In particular, the previously reported anomalous scaling of residual energy (magnetic minus kinetic) became more conventional (same scaling as total energy), various alignment quantities, reported to show slopes around 0.1-0.2 earlier, flattened out and became consistent with minor intermittency corrections (0.02-0.06), the scaling exponents for higher order moments became less anomalous. At the same time, our theoretical insight into the dynamics of imbalanced turbulence has been mostly supported by numerical simulations. This gives us an opportunity to look at the highly imbalanced solar wind and try to disentangle effects that are expected from theory of Alfvénic turbulence and other effects, that clearly are not part of the Alfvénic cascade paradigm. Given that the latter was a staple assumptions for the last few decades, this should renew interest in studying the dynamics of the solar wind plasma.

Fast Magnetic Reconnection in Astrophysical and Laboratory Plasmas

Amitava Bhattacharjee

Department of Astrophysical Sciences and Princeton Plasma Physics Laboratory, Princeton University, 100 Stellarator Road, Princeton, NJ 08543, USA

The problem of fast magnetic reconnection in high-Lundquist-number plasmas has been an active area of research for several decades. The main challenge is to explain why reconnection in natural or laboratory plasmas (including fusion devices) can proceed rapidly from a relatively quiescent state characterized by high values of the Lundquist number. Recent work has demonstrated that there is a fundamental shortcoming in the classical Sweet-Parker theory even within the framework of resistive magnetohydrodynamics (MHD). When the Lundquist number exceeds a critical value, the Sweet-Parker layer is unstable to a rapid tearing instability, hereafter referred to as the plasmoid instability. Numerical simulations, supported by heuristic scaling arguments, strongly suggest that within the framework of resistive MHD, the nonlinear reconnection rate mediated by the plasmoid instability becomes insensitive to the Lundquist number. Because the plasmoid instability can initiate a cascade to thin current sheets that are much thinner than the original Sweet-Parker layer, the so-called Hall current terms in the generalized Ohm's law become important, triggering the onset of Hall reconnection, which lead to higher reconnection rates. Recent results from the largest two-dimensional Hall MHD simulations to date will be presented that demonstrate the rich dynamics enabled by the interplay between the plasmoid instability and the Hall current. In three dimensions, the plasmoids evolve to form flux ropes that produce turbulence spontaneously, but the reconnection rate remains robustly at the two-dimensional value. Examples of applications will be drawn from heliophysical and magnetically confined laboratory plasmas.

Magnetic plasma turbulence: where theory meets observations

Stanislav Boldyrev

Department of Physics, University of Wisconsin, Madison,1150 University Avenue, Madison, WI 53706

Recent advances in numerical simulations and in in situ space observations allowed one to study plasma fluctuations with unprecedented resolution at scales comparable to the plasma microscales, such as particles gyroradii, inertial lengths, etc. These studies were able to probe fundamental effects in plasma turbulence, such as particle heating and acceleration, energy cascades and intermittency, self-organization and structure formation. The presentation will review recent observational and theoretical puzzles related to transition from magnetohydrodynamic to kinetic turbulence, energy cascades and intermittency at kinetic scales, and the role of plasma parameters in various turbulence regimes.

Magnetic field structure from Planck polarization observations of the diffuse Galactic ISM

François Boulanger, on behalf of the *Planck* Collaboration

Institut d'Astrophysique Spatiale, Université Paris-Sud, Bâtiment 120-121, 91405 Orsay Cedex, France

The *Planck* satellite has produced the first whole sky map of polarization at sub-mm and mm wavelengths. For the first time, we have the dust data needed to characterize the structure of the Galactic magnetic field in the diffuse interstellar medium (ISM) and its correlation with interstellar matter. I will present several results from the data analysis. I will describe the statistical properties of dust polarization at high and intermediate Galactic latitudes. I will quantify the correlation between the magnetic field orientation in the plane of sky, inferred from the polarization angle, with the filamentary structure of matter as traced by the total dust intensity. I will show how we may phenomelogically describe the structure of the magnetic field to account for the statistics of the polarization fraction and angle, and power spectra including cross-spectra betweeen the *Planck* dust and synchrotron polarization maps.

Cosmic rays in clusters of galaxies : relativistic particle acceleration

Gianfranco Brunetti
Istituto di Radioastronomia, INAF, Via P. Gobetti, 101 40129 Bologna, Italy

Cosmic rays can be accelerated in galaxy clusters by different mechanisms and remain confined in the cluster volume accumulating for cosmological times. This component generates non-thermal radiation from radio to gamma-rays through a variety of mechanisms. Mpc-scale synchrotron radiation from the inter-galactic-medium (ICM) is observed in a fraction of massive clusters and provides a unique probe of the complex interplay between magnetic fields and cosmic rays in these environments. In this talk I will focus on the generation of magnetic turbulence in galaxy clusters and on the physics of particle acceleration mechanisms in the turbulent ICM. I will outline the most important expectations of current models from radio to gamma-rays and the observational strategies with future observations.

Spatial gradients of polarization vector

Blakesley Burkhart
Harvard-Smithsonian Center for Astrophysics, 60 Garden St., Cambridge, MA 02139, USA

Magnetized turbulence is a ubiquitous physical process in the ISM of galaxies from scales of kpc to accretion disks. In general, quantitative studies of turbulence have been hindered in the past by our lack of theoretical understanding of MHD turbulence especially in the presence of observational constraints. However there has been a recent explosion of new techniques and diagnostics for measuring MHD turbulence in the multiphase ISM. In this talk I will discuss the utility of synchrotron intensity and polarization for measuring turbulent fluctuations in the ISM. In particular one can use polarization gradients and correlation function of synchrotron intensity to back out important flow parameters such as the sonic and Alfvén Mach numbers. This has particularly interesting consequences for measuring turbulence in the accretion disk of Sg A* using the Event Horizon Telescope.

Zeeman measurements of the Magnetic Fields in star forming regions

Richard Crutcher

Astronomy Department, University of Illinois, MC-221, 1002 W. Green Street, Urbana, IL 61801, USA

I will briefly review our current knowledge of Zeeman observations of magnetic fields in molecular clouds and the implications of these results for star formation. I will also present new observational data on Zeeman mapping of the $N = 2 \rightarrow 1$ transition of CN and discuss how these new data fit into the previous picture. I conclude with a brief discussion of possible future observations.

Magnetic fields in galaxy clusters: cosmological MHD simulations

Klaus Dolag

LMU, USM, Scheineerstr. 1, München, Germany

In galaxy clusters, non-thermal components such as magnetic field, turbulence and high energy particles keep a record of the processes acting since early times till now. These components play key roles by controlling transport processes inside the cluster atmosphere and therefore have to be understood in detail. However including them in cosmological simulations is extremely challenging as the structures in and around clusters are quite complex and span a very large dynamic range in scales. I will report the status of what can be achieved in numerical simulations of the formation of galaxies and galaxy clusters in cosmological context and our predictions for the magnetic field structure based on models of magnetic seeding directly coupled to the star-formation process. This allows to model the transport of heat coupled directly to the magnetic fields in galaxy clusters as well as the modeling of cosmic ray electrons powering the diffuse radio emission within galaxy clusters.

Dynamos in stars

Emmanuel Dormy

Institut de Physique du Globe de Paris, ENS Paris, 24 rue Lhomond, 75231 Paris Cedex 05

I will present direct numerical simulations of self excited dynamo action and discuss their applicability to dynamo mechanisms in stars. Particular attention will be given to the dynamo mechanisms and the resulting properties of the field. I will investigate the transition from steady dipolar to multipolar dynamo waves solutions varying different control parameters. I will discuss the relevance to stellar magnetic fields. I will also address the essential question of dynamo action with vanishing resistivity. I will show that even the classical ABC flow, which usually serves as a prototype for fast dynamo raises unexpected difficulties and that even at a resolution of 4096^3 the asymptotic behaviour is not yet reached.

Studies of the ISM magnetic field from anisotropies in synthetic PPV cubes

Alejandro Esquivel

Instituto de Ciencias Nucleares Universidad Nacional Autónoma de México

A. Postal 70-543, 04510, México D.F., Mexico

Turbulence in the interstellar medium is anisotropic due to the presence of magnetic fields. The anisotropy, which can be seen either in density or velocity depends on the strength of the magnetic field, and leaves a signature that can be found in spectral line maps. We construct synthetic spectral line observations from a grid of magnetohydrodynamic simulations to study this anisotropy under different turbulent regimes. We vary the velocity resolution on the simulations to change the relative contribution of the density and velocity fields in order to isolate the contribution of velocity. We found that with low velocity resolution the anisotropy depends strongly on the sonic Mach number. While, for high velocity resolution the anisotropy is less dependent to the sonic Mach number, thus more sensitive to the Alfvénic Mach number.

Polarization maps (Zeeman and dust emission) from MHD simulations

Diego Falceta-Gonçalves

EACH-Universidade de São Paulo, Rua Arlindo Béttio 1000, Ermelino Matarazzo, São Paulo, Brazil

In this work I will review the basic results from synthetic dust emission polarization maps based on MHD numerical simulations. Different turbulent regimes, ranging from weakly magnetized subsonic to strongly magnetized and supersonic flows, are explored. Self-gravity is also studied, adding another dimension to the problem. The spatial distribution of the gas density and the magnetic field geometry is tested in order to explain the observed statistics of the Stokes parameters. In addition, we present a comparative analysis of Zeeman broadening effect on the same simulations. The synthetic maps and measures are then compared to basic observational properties of the ISM.

Magnetic fields in the Galactic halo

Katia Ferrière
IRAP, Université de Toulouse, CNRS, 9 Avenue du Colonel Roche, BP 44346, Toulouse Cedex 4, France

Recent radio polarization observations of nearby edge-on spiral galaxies have revealed the presence of X-shape magnetic fields in their halos. Whether the halo of our own Galaxy also hosts an X-shape magnetic field is still an open question, as such a field would be very hard to detect from inside. In this talk, I will review the galactic magnetic configurations predicted by dynamo theory, and I will discuss the physical conditions leading to the emergence of X-shape magnetic fields in galactic halos. I will then propose a general mathematical description of X-shape magnetic fields, which I will apply to the halo of our Galaxy. I will present the resulting synthetic maps of synchrotron emission and Faraday rotation measures and show how their comparison with existing observational maps makes it possible to draw a number of conclusions on the presence and the likely characteristics of an X-shape magnetic field in the Galactic halo.

Cosmic Magnetism with the Square Kilometre Array and its Pathfinders

Bryan Gaensler

Dunlap Institute for Astronomy and Astrophysics, University of Toronto

50 St. George Street Toronto, ON M5S 3H4, Canada

The Square Kilometre Array (SKA) will be the largest and most powerful radio telescope ever constructed, and will answer fundamental questions in astronomy, physics and cosmology. One of the flagship science projects for the SKA is "The Origin and Evolution of Cosmic Magnetism", in which radio polarimetry will be used to reveal what cosmic magnets look like and what role they have played in the evolving Universe. Many of the SKA prototypes now taking data are also targeting magnetic fields and polarimetry as key science areas. In this talk, I will review the prospects for innovative new magnetism and Faraday rotation experiments with the SKA, and also with its precursor facilities including the MWA, LOFAR, ASKAP and MeerKAT. Sensitive wide-field polarisation surveys with these telescopes can provide a dramatic new view of magnetic fields in the Milky Way, in galaxies and clusters, and in the high-redshift Universe.

Particle Acceleration by Magnetic Reconnection

Elisabete de Gouveia Dal Pino
IAG-Universidade de São Paulo, Rua do Matão 1226, São Paulo, Brazil

Particle acceleration in magnetic reconnection discontinuities is currently regarded as an important mechanism to accelerate particles in a broad range of astrophysical sources and environments. In this talk, I will review this mechanism discussing both the first and second order Fermi acceleration processes, particularly in the framework of collisional fluids highlighting the differences with regard to collisionless ones. I will also discuss recent applications of this process to astrophysical fluids, like the surrounds of the black holes in binary systems (BHBs) and active galactic nuclei (AGNs), relativistic jets (of AGNs and GRBs) and the turbulent interstellar and intergalactic medium.

The LOFAR Multifrequency Snapshot Sky Survey

George Heald

ASTRON, Oude Hoogeveensedijk 4, 7991 PD Dwingeloo, The Netherlands

One of LOFAR's unique strengths is the capability to perform deep, wide area imaging surveys in a little-explored region of the radio spectrum. In this talk I will outline a comprehensive survey effort that is already underway. I will begin by focusing on a shallow commissioning survey, the Multifrequency Snapshot Sky Survey (MSSS), that has already generated a broadband source catalog of over 100,000 sources. I will review the survey's image and catalog data products, highlight the first discoveries and science results, and describe work toward producing high-level data products at higher angular resolution and in full polarization. I will then highlight scientific projects that are making use of MSSS data and deeper LOFAR imaging to study the properties of magnetic fields in the Milky Way, galaxies near and far, and the Universe.

Dust grain alignment by radiative torques

Thiem Hoang[1,2]

[1] Canadian Institute for Theoretical Astrophysics, University of Toronto, 60 St. George Street, Toronto, ON M5S 3H8, Canada

[2] Goethe University Frankfurt, Max-von-Laue-Str. 1, Room 2.143 D-60438 Frankfurt am Main, Germany

The alignment of interstellar dust is important for tracing magnetic fields in molecular clouds and for measuring CMB B-mode polarization signal, as recently revealed by *Planck* and BICEP results. In this talk, we will review different physical mechanisms proposed to explain the alignment of interstellar dust and show that classical textbook alignment mechanism based on paramagnetic relaxation is rather inefficient. We will show that interstellar grains having net helicity can be aligned efficiently by radiative torques (RATs) arising from the interaction of anisotropic radiation fields with the irregular grains. We will review our analytical model of RAT alignment and present theoretical predictions of resultant dust polarization both in absorption and emission for various environments. Numerous observational data from optical to submm wavelengths appear to be consistent with the predictions by RAT alignment, which consolidates the usage of dust polarization as a reliable tool for studying magnetic fields and star formation and allows for physically motivated modeling of dust polarization for CMB B-mode missions.

Polarized dust emission in the LMC/SMC

Annie Hughes, Jean-Philippe Bernard

IRAP, Université de Toulouse, CNRS, 9 Avenue du Colonel Roche, BP 44346, Toulouse Cedex 4, France

I will present the current results regarding dust polarization in the nearby Large and Small Magellanic Clouds (LMC and SMC) as observed with the *Planck* satellite. I will also discuss the importance of similar measurements towards other galaxies with future facilities allowing polarization measurements in the sub-mm, in particular NIKA2 on the IRAM 30m and ALMA. Finally, I will report on the performances of the PILOT balloon borne experiment, in particular from its first flight, which is scheduled in September this year.

Magnetic Reconnection: experiments and theory

Hantao Ji

Department of Astrophysical Sciences, Princeton University, Princeton, NJ 08540, USA

Frontiers of magnetic reconnection research will be discussed by highlighting a few recent achievements primarily from laboratory experiments but also from theory and numerical simulations. Of particular importance among these achievements is the development of a reconnection "phase diagram", in which different coupling mechanisms from the global system scale to the local dissipation scale are classified into different reconnection phases [1]. This progress motivated the major next-step laboratory device, called the Facility for Laboratory Reconnection Experiments or FLARE (flare.pppl.gov), which is currently under construction at Princeton. The goal of the FLARE project is to access reconnection regimes directly relevant to heliophysical and astrophysical plasmas. The currently existing small-scale experiments have been focusing on the single X-line reconnection process in plasmas either with small effective sizes or at low Lundquist numbers, both of which are typically very large in natural plasmas. The new regimes involve multiple X-lines are illustrated in the reconnection phase diagram. The design of the FLARE device is based on the existing Magnetic Reconnection Experiment (MRX) (mrx.pppl.gov). After a brief summary of recent laboratory results on the topic of magnetic reconnection, the motivating major physics questions, the construction status, and the planned collaborative research especially with heliophysics and astrophysical communities will be discussed.

[1] H. Ji & W. Daughton, Phys. Plasmas 18, 111207 (2011)

Magnetic fields in spiral galaxies

Marita Krause

Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69. D-53121, Bonn, Germany

Magnetic fields in the disk and halo of spiral galaxies can best be deduced from radio observations. With the increase of the sensitivity and bandwidth of the extended VLA (EVLA) including spectral polarimetry the observations could be significantly improved. I will present new EVLA results for the face-on galaxy M51 and of edge-on galaxies, obtained from the CHANG-ES survey. This is an EVLA survey of 35 edge-on galaxies observed in C- and L-band in three different configurations. Its aim is to study the origin of and physical conditions in galactic halos and its relation to e.g. star formation activity in the underlying disk, CR propagation and galactic wind. I will discuss the observations in terms of magnetic field strength and structure, radio scale heights and star formation.

Self-gravitating Magnetoturbulence

Alexei Kritsuk
Center for Astrophysics and Space Sciences, University of California San Diego
9500 Gilman Drive, Mail Code 0424 La Jolla, CA 92093-0424, USA

Highly compressible turbulence in magnetized self-gravitating ISM is regarded as a fundamental player regulating star formation processes in galactic disks and shaping the statistics of emerging stellar populations. Yet the statistics of turbulence are only loosely constrained observationally and its theoretical understanding remained elusive for quite some time. I will briefly review recent progress achieved in high dynamic range numerical experiments that stimulated new theoretical work and resulted in better understanding of energy cascades in compressible MHD. New exact scaling relations suggested a number of advanced turbulence diagnostics beyond routinely used density PDFs and power spectra and offered a new comprehensive approach to tackling turbulence, self-gravity and magnetic fields together in a common framework. I will also discuss the dependence of turbulence scaling on the nature of pumping mechanisms involved.

Reconnection in non-relativistic and relativistic turbulent astrophysical media

Alex Lazarian

Department of Astronomy, University of Wisconsin-Madison,

475 N. Charter Street, Madison, WI 53706, USA

I shall discuss magnetic reconnection at scales much larger than the typical plasma scales, i.e. at the scales that the MHD treatment of the process is appropriate. I shall show that MHD turbulence makes magnetic reconnection fast and provide the comparison of the predictions of the turbulent reconnection theory with numerical simulations. I shall demonstrate how the turbulent reconnection works when turbulence is externally driven and is driven by the reconnection process itself. The results for non-relativistic and relativistic reconnection will be presented. My message is that the MHD turbulent reconnection is the generic type of magnetic reconnection applicable to most of astrophysical situations and that the tearing reconnection is bound to transfer to the turbulent reconnection regime within 3D systems that are characterized by large Reynolds numbers. I shall discuss, if time permits, the applications of turbulent reconnection theory to star formation, cosmic ray acceleration and gamma ray bursts.

Intermittency in the magnetised interstellar medium

Pierre Lesaffre

LERMA / LRA - Ecole Normale Supérieure de Paris et Observatoire de Paris,

24 rue Lhomond 75231 Paris Cedex 05

I will first give a general introduction on intermittency. Regardless of the mechanisms which stir the interstellar gas, the damping of its turbulent motions must occur at much smaller scales, where microscopic dissipative processes such as viscous friction, Ohmic resistivity or ambipolar diffusion can take place. The resulting heating is therefore likely to be extremely localised and intense, thus highly susceptible to open new chemical routes. The chemical species produced in the wake of such hot spots should therefore help us to study observationally the turbulent dissipation mechanisms in the interstellar gas.

I will then present 3D numerical simulations of decaying MHD turbulence, where we strive to control the dissipation as best as we can. I will show how we can locally recover the dissipation due to the numerical scheme. I will discuss some properties of the dissipation field and show our attempts to discriminate observationally some of its characteristics.

Finally, I will briefly report small scale 2D hydrodynamic simulations of decaying turbulence in the diffuse interstellar medium including chemistry. In this 2D set up, highly dissipative structures are along ridges and we observe a strong molecular enhancement in their wake. I will show how we could use these numerical experiments to calibrate statistical models of chemistry induced by turbulence dissipation.

The link between magnetic fields and cloud and star formation

Hua-Bai Li

Department of Physics, The Chinese University of Hong Kong, Shatin, NT Hong Kong, China

Whether magnetic fields play an important role in cloud/star formation has been long debated. Recent observations revealed a simple picture of magnetic field morphologies that may greatly reduce the controversy: magnetic fields have a tendency to preserve their orientation at all scales that have been probed - from 100-pc scale inter-cloud media down to sub-pc scale cloud cores. This ordered morphology implies that both gravitational contraction and turbulent velocities should be anisotropic, due to the influence of dynamically important magnetic fields. Such anisotropy is now observed and will be reviewed in this talk.

Coupling PIC and MHD approaches

Alexandre Marcowith

Laboratoire Univers et Particules de Montpellier, Université Montpellier II,

Place E. Bataillon cc072 34095 Montpellier, France

High-energy cosmic rays (CRs) propagate through the interaction with long-wavelength electromagnetic perturbations well described by the magnetohydrodynamics (MHD) formalism. In many cases in astrophysics CR have a high pressure and are able to produce intense currents which can modified the magnetized fluid dynamics. As this interaction is non-linear, the development of numerical tools able to give a kinetic description of the CR distribution and to follow the fluid dynamics is highly necessary: this is the main purpose of the PIC-MHD (PIC for particles in cell). This short review describes first the principle of the PIC-MHD method. Then a couple of recent astrophysical applications are discussed: propagation of CR in MHD turbulence with application to the transport in the interstellar medium, acceleration of CRs around supernova remnant shocks and the problem of magnetic field amplification.

The Role of Magnetic Fields in Star Formation

Chris McKee

Physics Department, University of California at Berkeley, Berkeley CA 94720, USA

Magnetic forces in the diffuse interstellar medium are much greater than the forces due to self-gravitation, thereby precluding star formation there. Historically, it has been conjectured that ambipolar diffusion, in which neutral molecules contract relative to the magnetized ions, is essential for allowing gravitational forces to exceed magnetic forces in star-forming clouds. However, observations of magnetic field strengths in molecular cloud cores have failed to find evidence of cores that are magnetically dominated. Ideal magnetohydrodynamic (MHD) simulations of a region in a turbulent molecular cloud carried out in collaboration with PS Li and Richard Klein are in good agreement with the Crutcher *et al.* (2010) analysis of Zeeman observations of the line-of-sight magnetic field in molecular clouds. We show that the observed line of sight field in molecular clumps scales approximately as $n^{2/3}$ as inferred by Crutcher *et al.* for the total field; in addition, the total field in our simulation approximately obeys this scaling. The simulations show how tangling of the field lines reduces the field measured by the Zeeman effect. Comparing simulations with an initially weak field (initial Alfvén Mach number $M_A = 10$) to one with an initially moderate field ($M_A = 1$), we find that only the initially moderate field is in good agreement with the observations of magnetic field structure by H-B Li *et al.*. Finally, we find some evidence for turbulent reconnection in our ideal MHD simulation: ideal MHD in the presence of turbulence is not ideal.

The Faraday sky

Niels Oppermann
Canadian Institute for Theoretical Astrophysics, University of Toronto
60 St. George Street, Toronto, ON M5S 3H8, Canada

Faraday rotation is an observable that is sensitive to magnetic fields everywhere along the line of sight between a source and the observer. Thus, by observing far-away sources it is possible to obtain information on magnetic fields in a host of different environments: from the Milky Way's interstellar medium and the radio sources themselves all the way to cosmological scales. However, the information is presented in a highly entangled way and making sense of it requires careful statistical analysis. I will give an overview over recent ideas, show results pertaining to the Galactic interstellar medium, and discuss the possibility of constraining cosmic magnetic fields in low-density environments.

The Planck constraints on the primordial magnetic fields

Daniela Paoletti on behalf of the *Planck* Collaboration

Istituto di Astrofisica Spaziale e Fisica Cosmica, INAF, Via P. Gobetti, 101 40129 Bologna, Italy

Primordial magnetic fields (PMF) may provide a new window on the early universe physics and may represent a contribution to the generation of large scale magnetic fields observed in galaxies and galaxy clusters. The Cosmic Microwave Background (CMB) represents a unique opportunity to investigate the PMF characteristics and constrain their amplitude. In fact, PMF are an independent source of all kind cosmological perturbations -scalar, vector and tensor- and have an impact on the CMB anisotropy angular power spectrum. Together with this, PMF modelled as a stochastic background have also a non-Gaussian contribution which is responsible for a non-zero CMB anisotropy bispectrum and induce a Faraday rotation of the CMB polarization. These contributions can be used to derive upper limits on the amplitude of PMF with CMB data. The high quality of CMB data in temperature and polarization allows to constrain PMF with great accuracy. In particular, the recent release of the Planck 2015 data has lead to interesting constraints on PMF characteristics. I will present the constraints on PMF amplitude and spectral index derived with Planck data on the CMB anisotropies angular power spectra in temperature and polarization and the Planck non-Gaussianity measurements and bispectrum.

The VKS experiment and theory of magnetic field reversals

François Petrelis

LPS, Ecole Normale Supérieure de Paris, 24 rue Lhomond, 75231 Paris Cedex 05

In the last 15 years, three experiments have been able to generate a magnetic field by the dynamo instability. In the von Karman sodium experiment, a turbulent swirling flow of liquid sodium generates a magnetic field which behavior displays a variety of dynamical regimes such as random or periodic reversals. I will describe these behaviors and present a simple model that explains their origin. Its relevance for astrophysical objects will then be considered.

Cluster Magnetic Fields: Patterns and Puzzles

Lawrence Rudnick

Minnesota Institute for Astrophysics, University of Minnesota,

116 Church St. SE Minneapolis, MN 55455, USA

Cluster magnetic fields are illuminated by two particle populations – cosmic ray electrons which yield synchrotron radiation and thermal electrons which cause the Faraday rotation of polarized sources. The thermal electrons are directly observed in X-rays and the inverse Compton scattering of the CMB (S-Z effect). The cosmic ray electrons are found in radio galaxies, cluster-wide halos, and peripheral shock-related relics. I will highlight key parts of the current wisdom on the inferred cluster fields, and some of the puzzles that keep me up at night. I will show some recent results on Abell clusters 2255 and 2256, and, time permitting, take a glimpse of what's ahead with broadband polarization surveys.

Collisionless MHD turbulence in the inter-galactic medium

Reinaldo Santos-Lima

Department of Astronomy, Universidade de São Paulo, Rua do Matão 1226, São Paulo, Brazil

Turbulence develops in the magnetized plasma of the intracluster medium of galaxies (ICM) in scales (spatial and temporal) which are weakly collisional (with respect to the ion-ion collision frequency). Naturally, anisotropies in the ion thermal velocities distribution are locally developed due to the turbulence shear and compression. In its turn, high beta plasmas (like the plasma of the ICM) are subject to electromagnetic instabilities driven by temperature anisotropy. These instabilities produce anomalous collisionality via wave-particle scattering, then reducing the mean-free-path of the ions by several orders of magnitude. This reduction (i) affects directly the transport properties of the plasma, and (ii) decreases the pressure anisotropy level, bringing the large scale dynamics to behave similar to collisional MHD. In particular, it allows the turbulence to amplify the magnetic fields via the small-scale dynamo. Using the quasilinear theory, we calculate the scattering rate of ions due to the kinetic instabilities ion-cyclotron, mirror, and firehose. Using these results we estimate the average scattering rate of ions consistent with data cubes of high-beta MHD turbulence, which represent the intracluster medium.

Particle acceleration in relativistic magnetized shocks and reconnection

Lorenzo Sironi[1], Dimitrios Giannios[2], Maria Petropoulou[2], Anatoly Spitkovsky[3]

[1] Institute for Theory and Computation, Harvard University, 60 Garden St., Cambridge, MA 02138, USA

[2] Department of Physics and Astronomy, Purdue University, 525 Northwestern Avenue, West Lafayette, IN 47907, USA

[3] Department of Astrophysical Sciences, Peyton Hall, Princeton University, Princeton, NJ 08544, USA

We investigate the efficiency of particle acceleration in the relativistic jets of blazars and gamma-ray bursts, by means of first-principles particle-in-cell (PIC) kinetic simulations. Shocks and magnetic reconnection have long been considered as possible candidates for powering the jet emission. We find that in weakly magnetized or quasi parallel-shocks (i.e., where the magnetic field is nearly aligned with the flow), particle acceleration is efficient. However, most jet configurations result in strongly magnetized quasi-perpendicular shocks, where the level of self-generated turbulence is insufficient to accelerate the particles far beyond the thermal energy. So, shock models are unlikely to account for the jet emission. In contrast, we show that magnetic reconnection can deposit more than 50 per cent of the dissipated energy into non-thermal leptons as long as the energy density of the magnetic field in the jet flow is larger than the rest-mass energy density. With 2D and 3D PIC simulations, we show that magnetic reconnection in jets satisfies all the basic conditions for the emission: extended non-thermal particle distributions (with power-law slope between -2 and -1), efficient dissipation and rough equipartition between particles and magnetic field in the emitting region.

Prospects for CTA

Hélène Sol
LUTH, Observatoire de Paris, 5, place Jules Janssen, 92190 Meudon, France

The previous decade has demonstrated the richness of our cosmos when observed at very high energy (VHE) gamma-rays and has offered an initial picture of the "energy skeleton" of our universe up to a few tera-electron-Volt (TeV). The instruments of new generation in ground-based gamma-ray astronomy, especially the future Cherenkov Telescope Array (CTA), should provide unique tools to explore the turbulent, variable, energetic, non-thermal universe and to study extreme cosmic particle accelerators. Observation in the VHE range of galactic and extragalactic objects such as pulsar wind nebulae and supernova remnants, binary stellar systems, massive star clusters and diffuse interstellar medium, the Galactic Center, blazars, radiogalaxies and starburst galaxies can put significant constraints on the magnetic field inside the sources, through the analysis of particle acceleration and emission processes where magnetic effects are believed to play an important role. It will be also possible to use high-redshift active galactic nuclei as beacons of TeV gamma-rays to probe weak intergalactic magnetic field (IGMF). TeV photons propagating along the line of sight interact with the extragalactic background light (EBL) and produce electron-positron pairs. Through the inverse-Compton interaction mainly on the cosmic microwave background (CMB), these pairs generate secondary components possibly detectable as delayed "pair echos" in the GeV range for very weak IGMF (smaller than 10^{-16} G), or as a spatially extended gamma-ray emission or "pair halo" around the primary TeV source for higher IGMF values (larger than 10^{-16} G). Such gamma-ray method might constrain extremely tiny values of the IGMF, unreachable by other means.

Turbulent Dynamos

Ethan Vishniac
Department of Physics and Astronomy, Johns Hopkins University,
3400 Charles St. Baltimore MD 21210 USA

The analytic theory of large scale magnetic field generation is usually conceived as a process that relies on the fluid kinetic helicity, with the consequent accumulation of magnetic helicity on eddy scales as a process that limits and ultimately suppresses the dynamo. I will discuss an alternate approach, in which turbulence in a rotating and/or shearing flow leads to the spontaneous transport of eddy scale magnetic helicity. Its subsequent accumulation in a stratified background drives the dynamo process. The kinetic helicity is typically subdominant at all times. I will show that this leads to a prediction for the dependence of stellar magnetic field strengths on rotation speeds which is consistent with observations. I will also show a preliminary analysis of an MRI simulation which confirms the major points in this picture.

Polarized dust emission in massive star forming regions

Qizhou Zhang

Harvard-Smithsonian Center for Astrophysics, 60 Garden St., Cambridge, MA 02138, USA

Massive stars ($M > 8 M_{\odot}$) typically form in parsec-scale molecular clumps that collapse and fragment, leading to the birth of a cluster of stellar objects. We investigate the role of magnetic fields in this process through dust polarization at 870μ obtained with the Submillimeter Array (SMA). The SMA observations reveal polarization at scales of 0.1 pc. The polarization pattern in these objects ranges from ordered hour-glass configurations to more chaotic distributions. By comparing the SMA data with the single dish data at parsec scales, we found that magnetic fields at dense core scales are either aligned within 40 degrees of or perpendicular to the parsec-scale magnetic fields. This finding indicates that magnetic fields play an important role during the collapse and fragmentation of massive molecular clumps and the formation of dense cores. We further compare magnetic fields in dense cores with the major axis of molecular outflows. Despite a limited number of outflows, we found that the outflow axis appears to be randomly oriented with respect to the magnetic field in the core. This result suggests that at the scale of accretion disks (<1000 AU), angular momentum and dynamic interactions possibly due to close binary or multiple systems dominate over magnetic fields. With this unprecedentedly large sample of massive clumps, we argue on a statistical basis that magnetic fields play an important role during the formation of dense cores at spatial scales of 0.01 - 0.1 pc in the context of massive star and cluster star formation.

CONTRIBUTED TALKS

Magnetic fields and massive stellar feedback

Marta Alves

IRAP, Université de Toulouse, CNRS, 9 Avenue du Colonel Roche, BP 44346, Toulouse Cedex 4, France

Massive star formation is a very important phenomenon in the Galaxy due to its impact on the interstellar medium. When stars form they push back the surrounding material through the combination of thermal pressure from the warm ionised gas and radiation pressure due to starlight. Magnetic field lines are dragged with the gas due to flux freezing. We derived an analytical model that describes the magnetic field structure in a massive star forming region. We find that, due to the compression of the field lines by the expansion of the ionised gas, there is a local increase of the magnetic pressure in the neutral layer - photodissociation region (PDR) - that separates the ionised and molecular regions. This could play an important role in the evolution of PDRs. The magnetic field structure in a few PDRs close to the Sun (e.g.in the Ophiuchus region) was revealed, for the first time, by Planck dust polarised emission observations. I will present these PDRs and show their magnetic field configuration and I will discuss the dynamical importance of the magnetic field (e.g. its role in the total pressure balance) as well as the direction of the field lines with respect to the ionisation front.

The Global Magneto-Ionic Medium Survey (GMIMS): unveiling the Galactic magnetic field

Ettore Carretti, on behalf of the GMIMS consortium
Osservatorio Astronomico di Cagliari, INAF, Via della Scienza 5 09047 Selargius, Italy

It has been known since the 1950s that the Milky Way has a magnetic field, but much remains unknown about its structure and properties. While the field in the Galactic disk is well studied, the structure and major properties of the field above the disk and in the halo are still largely matters for speculation. The polarised radio emission from the interstellar medium is the tool with the highest information content on the magnetic field: the received signal carries information on the field at origin and the field along the propagation path through the magneto-ionic medium, and we can (potentially) generate a tomographic view of the entire Galactic field. Decoding and exploiting this information is the goal of GMIMS, and this is being done by mapping the diffuse polarised radio emission from the entire sky over the ultra broad frequency range of 300 to 1800 MHz in thousands of individual frequency channels. The task is split into six component surveys, three each in the Northern and Southern hemispheres, sub-dividing the frequency range. Observations are complete for three surveys, one from the DRAO 26-m Telescope (1300-1800 MHz) and two from the Parkes Telescope (300-900 MHz and 1300-1800 MHz). The first science papers are emerging, in particular two papers with results relevant to the large- scale structure of the Milky Way and its ordered field. In this talk we will present the survey, the technical challenges it faces, the results to date, and the work in progress.

Magnetised wind and synchrotron halo of IC10

Krzysztof Chyzy

Astronomical Observatory of the Jagiellonian University, ul. Orla 171 30-244, Kraków, Poland

We report our recent investigation of magnetic properties of IC10 the nearest starbursting dwarf galaxy, using multi-frequency interferometric (VLA) and single-dish (Effelsberg) observations. At higher frequencies and on the largest spatial scales, we find magnetic field structure dominated by the radial component, which resembles those usually observed in edge-on spiral galaxies with high star formation rates. At lower frequency (1.43 GHz) VLA observations reveal an extended synchrotron envelope, with an unusual pattern of polarised emission, strongly affected by the Milky Way foreground signal. The analysis of radio scale-heights and the cosmic rays bulk speed suggest that IC10 have strong and magnetised galactic-scale wind which blows up the extensive radio envelope and shapes the global structure of magnetic fields. Moreover, the magnetized plasma spread out of the galaxy can also seed the intergalactic medium with random and ordered magnetic fields. Having clumpy disc, large star-formation and significant feedback of magnetised plasma, IC10 gives us an unusual insight in processes expected to act in protogalaxies in the early Universe.

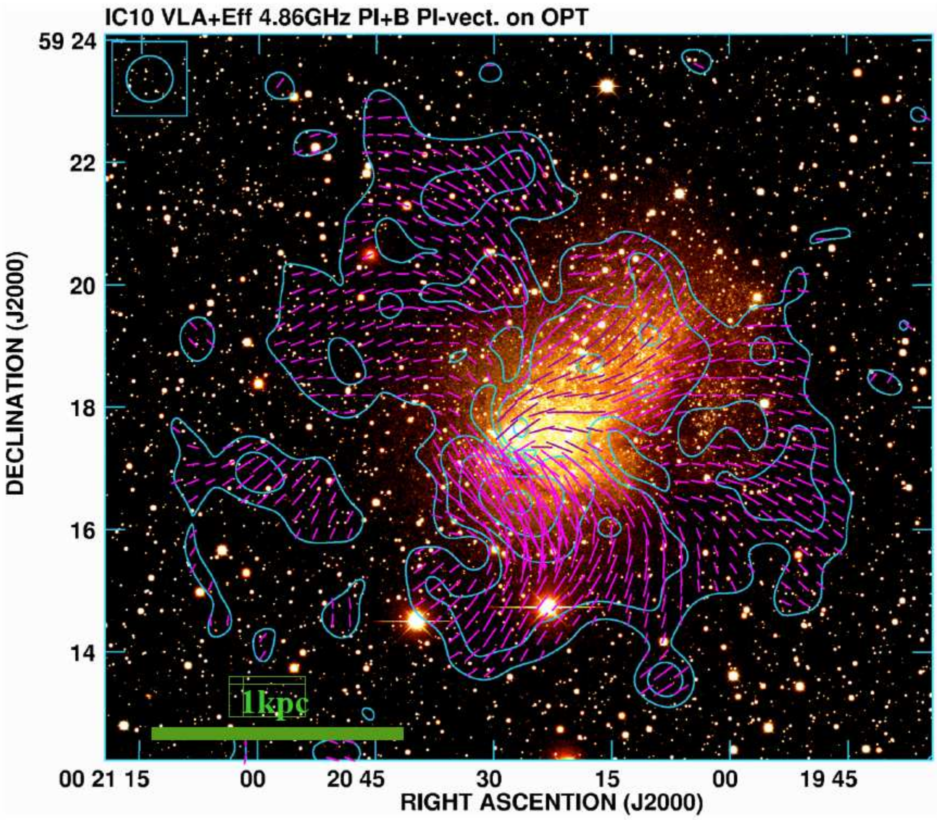


Figure 1: Contours and B-vectors of polarized intensity (from combined VLA and Effelsberg data) of IC10 convolved to the resolution of 45" at 4.86 GHz and superimposed on the true-color optical image (from P. Massey/Lo Observatory and K. Olsen/NOAO/AURA/NSF). The contour levels are (3, 6, 12, 24, 40) times 11 μJy/beam. A vector of 10" length corresponds to a polarized intensity of about 38 μJy/beam. The global structure of magnetic fields extending far away from giant star-forming regions in the galaxy disk is clearly visible.

Laboratory astrophysics with magnetized laser plasmas

Andrea Ciardi

LERMA, Observatoire de Paris, UPMC, ENS Paris, UCP, UMR 8112, 4 Place Jussieu, Paris, 75005, France

Plasmas generated by high power lasers offer the opportunity to study compressible, radiative magnetohydrodynamic flows under conditions relevant to certain astrophysical environments. Self-generated magnetic fields can be generated in laser-matter interactions and can serve to study phenomena such as Biermann battery in shocks or magnetic field reconnection. These intense fields are however confined to relatively small plasma volumes and often have short lifetimes, of the order of the laser pulse duration. Instead of relying on self-generated magnetic fields, recent experimental advances are now allowing allowing to couple laser produced plasmas with externally imposed steady-state homogenous magnetic fields with intensities up to 0.4 MG [1]. Here we will present on-going numerical and experimental work we are carrying out on astrophysical applications related to the collimation of jets [2,3], the dynamics of magnetized accretion columns and ion/ion electromagnetic streaming instabilities.

[1] Albertazzi, B., et al., "Production of large volume, strongly magnetized laser-produced plasmas by use of pulsed external magnetic fields", 2013, Review of Scientific Instruments, 84, 043505.

[2] Ciardi, A., et al., "Astrophysics of Magnetically Collimated Jets Generated from LaserProduced Plasmas", 2013, Physical Review Letters, 110, 025002

[3] Albertazzi et al., "Laboratory formation of a scaled protostellar jet by coaligned poloidal magnetic field", 2014, Science, Volume 346, Issue 6207, pp. 325-328

Magnetically Aligned HI and Dust: Measuring B-mode Polarization Foregrounds with Neutral Hydrogen

Susan Clark, J. Colin Hill, Joshua E. G. Peek, Mary E. Putman

Department of Astronomy, Columbia University, 550 West 120th Street, New York, NY 10027, USA

The Planck all-sky polarization maps provide key foreground information for studies of the polarized CMB, including the search for primordial B-mode polarization. However, the Planck 353 GHz polarization measurements lack the sensitivity at high latitudes to precisely describe the polarized dust foregrounds. We present the discovery that the orientation of neutral hydrogen (HI) structures traces the Planck 353 GHz polarization angle with surprising precision across a range of angular scales. This result demonstrates a deep connection between the structure of diffuse Galactic HI, Galactic dust, and the magnetic field. When combined with Planck 353 GHz and other data, this method will enable higher fidelity maps for foreground subtraction. As it is particularly powerful at high latitudes, this method may be the best tool yet developed for identifying the cleanest regions of high-latitude sky for CMB polarization experiments to target. We explore the physical properties of the HI structures, and the physical mechanisms responsible for their alignment with the magnetic field, by examining the HI structures across a range of densities and environments.

The Galactic Plane Infrared Polarization Survey (GPIPS)

Dan Clemens

Institute for Astrophysical Research, and Department of Astronomy, Boston University,
College of Arts and Sciences Building, 725 Commonwealth Avenue, Boston, MA 02215, USA

The Galactic Plane Infrared Polarization Survey (GPIPS) used near-infrared (H-band; 1.6 microns) background starlight polarimetry to reveal the plane-of-sky magnetic field in the first Galactic quadrant midplane. Using the Mimir instrument on the 1.8m Perkins Telescope, GPIPS detected one million stellar polarizations (4 stars per sq arcmin) within $l = 18°$ to $l = 56°$ and $b = -1°$ to $b = +1°$. These polarizations probe to 20-30 mag of visual extinction and distances of about 7 kpc. Initial magnetic field findings for the many size-scales spanned by GPIPS will be presented, including mean field orientation across this portion of the disk, spatial variations in the mean field and field dispersion properties, and measures of the effects of spiral arms on the observed polarization properties. All GPIPS data have been processed to science-quality catalogs, images, and figures and are publically available. GPIPS has been supported by NSF grants AST 06-07500, 09-07790, and 14-12269.

Clusters, radio haloes, and the evolution of the ICM magnetic field

Virginia Cuciti

University of Bologna, Istituto di Radioastronomia, INAF, Via P. Gobetti, 101 40129 Bologna, Italy

A fraction of massive and merging galaxy clusters host Mpc-scale Radio Halos (RH) generated by ultrarelavistic electrons in the magnetized Intra Cluster Medium (ICM). According to the currently prevailing view RHs arise from the acceleration of particles by turbulence generated during cluster mergers. This scenario predicts a strong connection between the RH properties and the mass and dynamics of the hosting cluster. Large massselected samples of galaxy clusters are necessary to test these expectations. I will present results recently published in Cuciti et al. (2015). In this work we compiled from the Planck SZ cluster catalogue an almost mass-selected sample of galaxy clusters with $M > 6\,10^{14}\,M_{\odot}$ and $z = 0.08 - 0.33$. We used the NVSS (plus the literature) at $z < 0.2$ and the Extended GMRT Radio Halo Survey at $z > 0.2$ to investigate the presence of RHs. We found evidence of a drop of the fraction of clusters with RHs at lower masses and confirmed that RHs are preferentially found in merging systems. I will show how these results can be used to put some constraints on the evolution of the magnetic field in the ICM.

Effects of the ICM on the magnetic field of a Virgo galaxy

Ancor Damas Segovia
Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany

Our knowledge of galactic magnetism lacks to explain important questions regarding the interaction between galaxies and their environment. Questions like how magnetic fields react to the action of ram-pressure by the intra-cluster (ICM) medium or how this interaction affects the evolution of galaxies themselves, are still under discussion. The Continuum HAlos of Nearby Galaxies - an EVLA Survey (CHANG-ES) project consists of a continuum survey of 35 nearby edge-on galaxies observed with the VLA interferometer using different configurations at two frequencies. The broadband receivers of the VLA offer a sensitivity never seen before, reaching rms values of a few μJy. The application of a powerful tool called rotation measure synthesis (RM-Synthesis) to the broadband data will disclose small rotation measures and thus probe the magnetized plasma at the lowest densities. In this talk I will present the effects of the ICM on the magnetic field of galaxies, focusing on the specific case of a Virgo galaxy. In this particular galaxy we have observed new features in the polarized radio emission of the halo. Models predict that the action of the ICM on this galaxy would remove extended radio features from the halo which contradicts what it is seen in the VLA data.

Can we observationally test the Dynamo model ?

Jamie Farnes

Sydney Institute for Astronomy, University of Sydney, Sydney, Australia

Observing magnetic fields in galaxies is a significant observational challenge, that is still being overcome with the new generation of radio instruments. While measurements of the "rotation measure" with a radio telescope give integrated magnetic field measurements along the line of sight, we typically have few constraints on whether we are truly tracing the same physical region of a background radio source. In a multi-wavelength study comprising both radio and optical data, we may indeed not be probing the same line of sight at all. Overcoming these obstacles requires significant samples of polarised spectral energy distributions, obtained over very large ranges in wavelength. If such observational challenges can be overcome, then together with the leap in sensitivity of newer instruments, it will be possible to provide the first measurements of the evolution of magnetic fields in a significant sample of normal galaxies at different redshifts. This will provide the first direct test of dynamo theory. I will present our recent progress in enabling this direct experimental verification of dynamo action in galaxies. This has been done by constructing the first catalogue of broadband polarised SEDs from 400 MHz to 100 GHz, allowing us to identify two distinct sub-populations in the depolarisation properties of extragalactic sources, and to increase the number of radio sources available for dynamo studies by an order of magnitude. Consequently, we have found an association bet ween magnesium-absorbing intervening galaxies and the rotation measure at the 3.5σ level. The redshift distribution of our sample suggests that magnetic fields have remained essentially unchanged over the last seven billion years. I will detail the observational campaign currently underway with the Karl G. Jansky Very Large Array - that will trace dynamo evolution in two distinct redshift bins . Furthermore, I will also demonstrate the even larger leap that can be achieved using the Very Large Array Sky Survey (VLASS) and the Square Kilometre Array (SKA) and its pathfinders and precursors - that promise to improve the number of sources available for such studies by a further factor of 10,000, in hundreds of redshift bins.

A model of the Galactic Magnetic Field

Glennys Farrar
Center for Cosmology and Particle Physics, New York University,
4 Washington Place, New York, NY 10003, USA

Jansson and Farrar (2012) developed a model of the Galactic magnetic field whose parameters were determined by fitting to all-sky Rotation Measures and the WMAP polarized Galactic synchrotron emission maps. The JF12 fit revealed a coherent, directed, spiraling poloidal component in the halo. I will discuss the features of the data which drive this conclusion, and describe subsequent studies which show why the deduced structure of the halo field is robust to uncertainties in the relativistic and thermal electron densities and possible foregrounds. I will also discuss what can be said about its origin.

E- and B-modes from the magnetized filamentary structure of the interstellar medium

Tuhin Ghosh, on behalf of the *Planck* collaboration

Institut d'Astrophysique Spatiale, Université Paris-Sud, Bâtiment 120-121, 91405 Orsay Cedex, France

The Planck survey has quantified polarized Galactic foregrounds and established that they are a main limiting factor in the quest for a B-mode imprint from primordial gravity waves on the cosmic microwave background (CMB). The necessity to achieve an accurate removal of foreground contributions binds the search of the signal from cosmic inflation to our understanding of the dusty magnetized interstellar medium. Planck has reported an asymmetry in power between the dust E- and B-modes for both the dust and synchrotron polarization. This result is revealing a new statistical information on the magnetic field toplogy that has yet to be spelled out. We will present an analysis of the Planck data characterizing the correlation between the filamentary structure of the dust intensity map and the magnetic field orientation, and showing that it may account for the observed E and B asymmetry. This interpretation could also apply to synchrotron polarization. Future models of Galactic foregrounds for CMB polarization studies will need to take into account the observed correlation between the magnetic field toplogy and the structure of interstellar matter. We will discuss how this may be done.

Non-Zeeman Circular Polarization of Molecular Spectral Lines in the ISM

Martin Houde

Department of Physics and Astronomy, University of Western Ontario

1151 Richmond Street, London, Ontario, N6A 3K7, Canada

In this presentation I will discuss the recent discovery of circular polarization signals in the rotational line profiles of molecules that are negligibly sensitive to the Zeeman effect. Our initial findings obtained for CO in the Orion KL star-forming region with the Caltech Submillimeter Observatory were recently followed with similar detections for two transitions of CO in an exhaustive study of the supernova remnant IC 443 (G) done with the IRAM 30m and APEX telescopes. These new results have clearly established that circular polarization arises, as predicted, from the conversion of linear polarization signals incident on the molecules responsible for the detected radiation. I will further show how the anisotropic resonant scattering model developed to explain these observations also naturally provides an answer to a long standing puzzle concerning the polarization characteristics of SiO maser lines in the circumstellar envelope of evolved stars. As this scattering model directly involves the ambient magnetic field, these results suggest the possibility of starting a whole new subfield of more incisive studies of magnetic fields in the interstellar medium.

Formation of proto-multiple systems in a magnetized, fragmenting filament

Chat Hull

Harvard-Smithsonian Center for Astrophysics, 60 Garden St, MS 42, Cambridge, MA 02138, USA

In just the past few years, it has become clear that filamentary structure is present in the star-formation process across many orders of magnitude in spatial scale, from the galactic scales probed by Planck and Herschel all the way down to the AU-scale structures that ALMA has revealed within protoplanetary disks. A similar story can be told of magnetic fields, which play a role in star formation across the same vast range of size scales. Here I will show filamentary structure near three protostars in the Serpens Main star-forming region, as seen with both CARMA (at 1000 AU scales) and ALMA (at 150 AU scales!). Even at such high resolution, these sources have a number of nearby, filamentary blobs/condensations/companions, which may be the beginnings of multiple star systems. Additionally, the filamentary structures along which these companions lie coincide in a tantalizing way with the magnetic fields we mapped with CARMA.

Filamentary structures in LOFAR observations of the interstellar medium

Vibor Jelić

Kapteyn Astronomical Institute, University of Groningen & ASTRON

Landleven 12 9747AD Groningen, The Netherlands

The low radio frequency observations are very sensitive to small column densities of the interstellar medium that are difficult to detect at higher radio frequencies. The wide frequency coverage and good angular resolution of the Low Frequency Array (LOFAR), make LOFAR an excellent instrument for studying Galactic polarized emission. In combination with the rotation measure (RM) synthesis, LOFAR observations allow us to study the relative distribution of synchrotron-emitting and Faraday-rotating regions at an exquisite resolution of 1 rad/m^2 in Faraday depth. Recent observations with LOFAR revealed diffuse polarization in several fields at high Galactic latitudes with interesting morphological features: i) a very long and straight filament, showing excess in RM comparing to the background emission and (ii) an interesting system of linear depolarization canals conspicuous in an image showing the peaks of Faraday spectra. During my talk I will present these observations, discuss general properties of detected structures and of underlying magnetic fields and show puzzling correlation with the Planck dust polarization data.

Generation and Saturation of Magnetic Fields in Turbulent and Multiphase ISM Regulated by Star Formation Feedback

Chang-Goo Kim, Eve C. Ostriker

Department of Astrophysical Sciences, Peyton Hall,

4 Ivy Lane, Princeton University, Princeton, NJ 08540, USA

The diffuse interstellar medium (ISM) is highly turbulent and strongly magnetized, and turbulent and magnetic energies are comparable with each other. The interplay between turbulence and magnetic fields naturally results in equipartition magnetic fields via smallscale turbulence dynamo. However, most numerical simulations to date are limited to the idealized driven turbulence in a periodic box. Here, we investigate the quasiequilibrium states of turbulent, magnetized, and multiphase ISM regulated by star formation feedback. We incorporate effects from massivestar feedback via timevarying heating rates and supernova (SN) explosions. In our models, turbulence driving by SN feedback and gas heating rate are directly related to the star formation rate (SFR), and the feedback terms mediate the SFR to give a right total pressure support against the vertical gravity. Thus, turbulence is selfconsistently regulated to balance driving and dissipation. Since smallscale turbulence dynamo is a rapid process, the turbulent magnetic fields generated by turbulence are also directly connected to the SFR and saturated to the equipartition level at all times. However, evolution of the mean (ordered) magnetic fields is much slower. Although we observe a converging signature, the growth process and saturation level are not complete within the time of our simulations (4 orbits). We discuss the effects of existing mean magnetic fields on the final SFR in the context of the thermal and dynamical equilibrium model.

The Importance of the Magnetic Field from an SMA-CSO-Combined Sample of Star-Forming Regions

Patrick M. Koch, Ya-Wen Tang, Paul T. P. Ho, SMA Polarization Legacy Team

Academia Sinica Institute of Astronomy and Astrophysics,

11F of Astronomy-Mathematics Building, AS/NTU No.1, Sec. 4, Roosevelt Rd, Taipei 10617, Taiwan

Magnetic fields are thought to be relevant for star formation. Measuring field strengths is, thus, paramount to make quantitative assessments of the role of the magnetic field. Observationally, it has been difficult to measure field strengths. Commonly used techniques provide either only one single averaged field strength for an entire observed region, or they provide only single isolated values, as e.g., in the case of Zeeman observations. We will introduce Submillimeter Array (SMA) dust polarization observations which have served as a testbed to develop a new method to measure the field strength. This new technique precisely addresses earlier shortcomings by yielding a field strength at every position of detected polarization. With the recent dedicated SMA polarization legacy program, we have further significantly increased the sample of high-resolution magnetic field observations. In combination with Caltech Submillimeter Observatory (CSO) data, we will present sample trends based on 50 sources that clearly reveal generic magnetic field features and quantify the magnetic field force versus gravity. In particular, we identify magnetic field morphologies that allow for collapse, and others where the magnetic field is resisting gravity leading to a largely reduced star-formation efficiency. We conclude by providing the statistical evidence - based on almost 4000 independent measurements from our SMA and CSO samples - that the prevailing magnetic field orientation in star-forming regions is one that prefers the magnetic field to be roughly perpendicular to a source major axis.

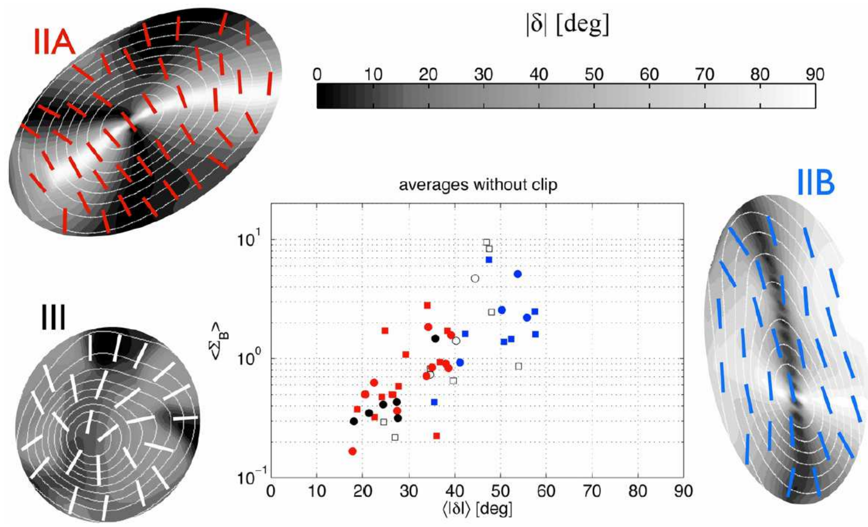


Figure 1: Source-averaged magnetic field tension-to-gravity force ratios, $\langle\Sigma_B\rangle$, versus source-averaged misalignment angles, $\langle|\delta|\rangle$, for the combined SMA (circles) and CSO (squares) samples of 50 star-forming regions. Schematic generic magnetic field configurations (segments) are illustrated as IIA (red), IIB (blue) and III (white). Contours show dust emission. The black-to-white color grading indicates the local misalignment angle $|\delta|$ between a magnetic field and a dust emission gradient orientation. $\langle\Sigma_B\rangle$ clearly depends on generic field configurations, discriminating between faster and slower/no collapse.

[1] Koch, P.M., Tang, Y.-W., Ho, P.T.P., Zhang, Q., Girart, J.M., et al., 2014, ApJ, 797, 99
[2] Koch, P.M., Tang, Y.-W., & Ho, P.T.P., 2013, ApJ, 775, 77
[3] Koch, P.M., Tang, Y.-W., & Ho, P.T.P., 2012, ApJ, 747, 79

Numerical simulations of magnetic reconnection in solar wind: collisional vs collisionless regime

Grzegorz Kowal[1], Diego Falceta-Gonçalves[2], Alex Lazarian[3]

[1] Center for Theoretical Astrophysics, University of Cruzeiro do Sul
Rua Galvão Bueno, 868, Liberdade CEP 01506-000, São Paulo, Brazil
[2] EACH-Universidade de São Paulo, Rua Arlindo Béttio 1000, Ermelino Matarazzo, São Paulo, Brazil
[3] Department of Astronomy, University of Wisconsin-Madison,
475 N. Charter Street, Madison, WI 53706, USA

Magnetic reconnection is an important process responsible for magnetic topology change and magnetic energy release in many astrophysical environments. It is a fundamental mechanism for the solar flares. It is also responsible for dynamics of the interplanetary plasma, magnetic dynamo in the interstellar medium. Very recent works demonstrate the important coupling between the reconnection and magnetized turbulence responsible for breaking of the flux-freezing condition. Finally, it might be responsible for acceleration of charged particles in relativistic diffusive plasmas resulting in ultra-high relativistic cosmic rays.

In this talk we present our recent results on the numerical studies of magnetic reconnection in solar wind. We directly compare two regimes of plasma, without and with collisionless effects, by applying standard MHD and kinetic CGL-MHD frameworks, respectively, applied to the same initial conditions. In the CGL-MHD framework we use the pressure anisotropy limits obtained from the solar wind observations. We demonstrate the growth of kinetic instabilities from the initial isotropic pressure configurations. We show how they affect the current sheet topology and the resulting reconnection rate. We compare the statistics of self-generated turbulence in both cases. Finally, we discuss the implications and compare our results with observations.

Statistical properties of polarized dust emission : lessons from a model of the turbulent and magnetized interstellar medium

François Levrier, Jérémy Neveu

LERMA / LRA - Ecole Normale Supérieure de Paris et Observatoire de Paris,

24 rue Lhomond 75231 Paris Cedex 05

The Planck satellite has mapped the polarized microwave sky (from 30 GHz to 353 GHz) with unprecedented sensitivity and angular resolution. This wealth of data yields the first complete map of polarized thermal emission from dust in our own Galaxy, shedding new light on the Galactic magnetic field. Within this data lie clues to the statistical properties of its turbulent component, in particular its spectral index across spatial scales. To extract these properties, a thorough understanding of how they translate into those of the polarized emission maps is necessary. We address this problem using a model of the turbulent and magnetized interstellar medium based on fractional Brownian motion fields. I will present simulated maps of polarized dust emission (Stokes Q and U) and show how various statistical observables depend on the model parameters. Within the framework of this model, I will show that the polarization angle dispersion function is unambiguously linked to the magnetic field spectral index, independently of the dust statistical distribution.

Energy dissipation in incompressible ambipolar diffusion magnetohydrodynamics

Giorgos Momferratos[1], Pierre Lesaffre[2], Edith Falgarone[2], Guillaume Pineau des Forêts[3,4]

[1] LERMA, Observatoire de Paris, UPMC, ENS Paris, UCP, UMR 8112, 4 Place Jussieu 75252 Paris cedex 05, France

[2] LERMA / LRA - Ecole Normale Supérieure de Paris et Observatoire de Paris, 24 rue Lhomond 75231 Paris Cedex 05

[3] Institut d'Astrophysique Spatiale, Université Paris-Sud, Bâtiment 120-121, 91405 Orsay Cedex, France

[4] LERMA, Observatoire de Paris, UPMC, ENS Paris, UCP, UMR 8112, 61 avenue de l'Observatoire, 75014 Paris, France

Turbulent energy dissipation is a key process in the cold interstellar medium (ISM), not only on the road to star formation but also as a source of suprathermal energy able to open new chemical routes, otherwise inactive at the low gas temperature. Such routes are required, though, to explain the high abundance of species such as CH^+ and SH^+ observed in the ISM. In this context, the space-time intermittency of energy dissipation is particularly relevant because it drives injection of suprathermal energy in the ISM locally far above the average level. The detailed characteristics of the spatial distribution and the geometrical properties of the energy dissipation rate can provide valuable inputs to chemical models. Our incompressible simulations show that ambipolar diffusion leads to forcefree magnetic fields at small scales. As a result, the typical scale of ion-neutral friction heating is displaced to large scales in the inertial range, much greater than dimensional analysis would predict. The structures of high dissipation are spatially coherent sheets, each with a single nature of dissipation (viscous, ohmic or ambipolar). We reveal their statistical scaling laws and compute their intermittency exponents.

Magnetic Field in the Outer Heliosphere and Beyond

Nikolai Pogorelov[1], Jacob Heerikhuisen[1], Ming Zhang[2]

[1] Department of Space Science, University of Alabama in Huntsville,

320 Sparkman Drive, Huntsville, AL 35805, USA

[2] Department of Physics and Space Sciences, Florida Institute of Technology,

150 West University Boulevard, Melbourne, FL 32901, USA

While there are a lot of heliospheric magnetic field measurements in the vicinity of Earth, Voyager 1 and 2 (V1 and V2) spacecraft are providing us with is situ measurements in the outer heliosphere – the region of the solar wind (SW) governed by its interaction with the local interstellar medium (LISM). The V1 and V2 spacecraft trajectories are in the northern and southern hemispheres, respectively. V2 is now approaching the heliopause, a boundary between the SW and LISM, measuring SW properties sometimes markedly different from those by V1 at the same heliocentric distance. In 2012, V1 crossed the heliopause, which turned out to be not a smooth tangential discontinuity, but rather a complicated transition region most likely affected by instabilities and magnetic reconnection. The interpretation of Voyager measurements in terms of the global SW-LISM interaction is very difficult, if possible, without numerical simulations. On the other hand, the heliospheric interface with the LISM is strongly dependent on the coupling between the heliospheric and interstellar magnetic fields (HMF and ISMF). We derive the ISMF direction and strength from the SOHO Solar Wind Anisotropy (SWAN) backscattered Ly-alpha emission experiment, which discovered a deflection of neutral H atoms in the heliosphere from their original direction in the unperturbed LISM, and by fitting a narrow "ribbon" of the enhanced energetic neutral atom flux discovered by the Interstellar Boundary Explorer (IBEX). We have developed an MHDkinetic model that reproduces the IBEX ribbon and therefore allows us to constraint the properties of the ISMF draped around the heliopause. Additionally, we have recently demonstrated that a distortion of the ISMF by the presence of the heliopause may be responsible for the small-scale anisotropy of TeV cosmic rays consistently measured by Tibet, Milagro Super-Kamiokande, IceCube/EAS-Top, and ARGO-YGB air shower observations. In this presentation, we tie up observational and simulation results to build a self-consistent picture of the HMF-ISMF coupling at the heliospheric interface and propose constraints on the LISM properties in the near vicinity (a few thousand AU) of the heliosphere.

Magnetic fluid-structure Dynamo

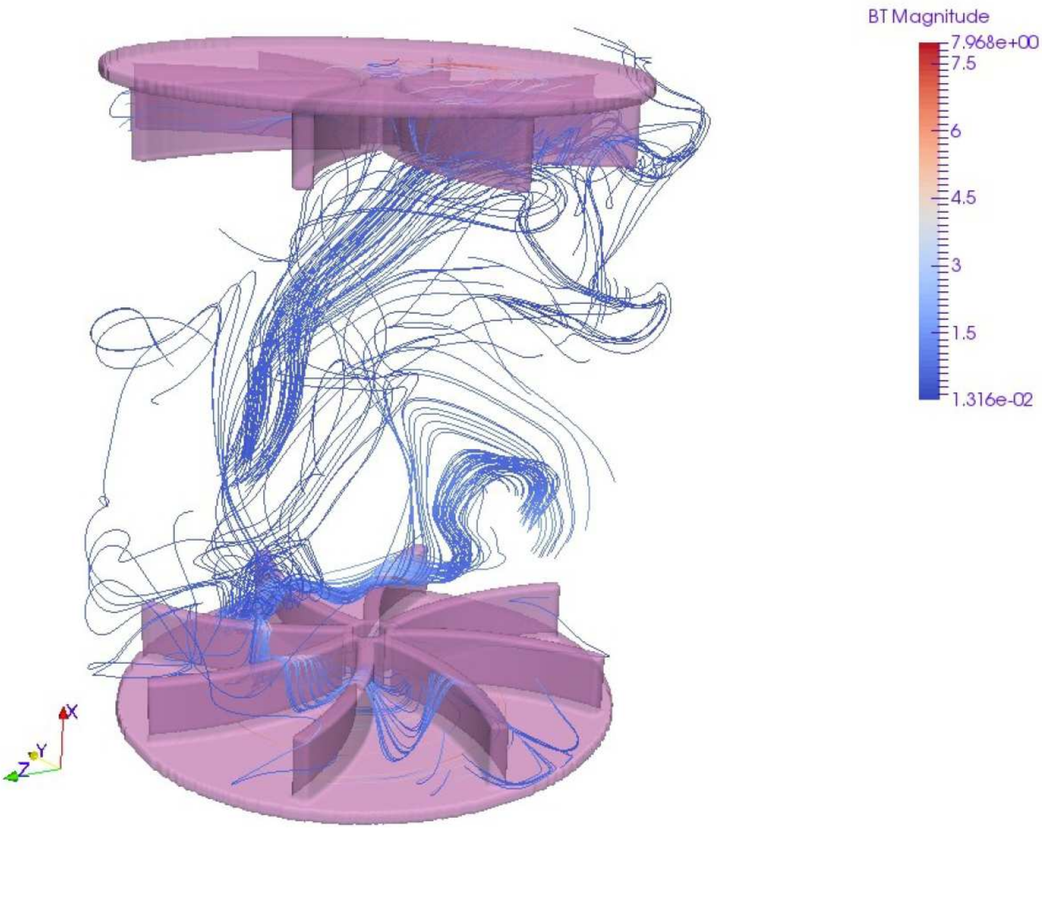
Yannick Ponty[1], Sebastian Kreuzahler[2], Nicolas Plihon[3],
Holger Homann[1], Rainer Grauer[2]

[1] Laboratoire J.-L. Lagrange, Observatoire de la Côte d'Azur, Université de Nice-Sophia, BP 4229, 06304 Nice Cedex 4, France

[2] Institut für Theoretische Physik I, Ruhr-Universität Bochum, 44780 Bochum, Germany

[3] Laboratoire de Physique, ENS de Lyon, 69007 Lyon, France

We present a direct numerical simulation (DNS) version the Von Karman flow, forced by two rotating impellers. The cylinder geometry and the rotating objects are modeled via a penalization method and implemented in a massive parallel pseudo-spectral Navier-Stokes solver. First, we present our hydrodynamic simulations and compare with a set of well documented water experiments. Secondly, we included the magnetic induction equation inside the fluid and solid system in order the study the dynamo effect. We will present several common features with the VKS dynamo experimental campaigns, as the observed magnetic mode ($m = 0$) and the variation with the magnetic permeability. The magnetic and current behaviors near and inside the impellers will be detail. Dynamic behaviors along the saturation regime will concluded this talk.



Magnetic Fields in Protostellar Disks: Current Status and the Upcoming ALMA Revolution

Ramprasad Rao[1], Josep M. Girart[2], Zhi-Yun Li[3]

[1] Academia Sinica Institute of Astronomy and Astrophysics, 645 N. Aohoku Pl., Hilo, HI 96720, USA

[2] Institut de Ciencies de l'Espai (CSIC-IEEC), Campus UAB Carrer de Can Magrans, S/N 08193 Cerdanyola del Vallès, Catalonia, Spain

[3] Department of Astronomy, University of Virginia, P.O. Box 400325, Charlottesville, VA 22904, USA

When and how large-scale rotationally supported disks form in magnetized dense cores remains hotly debated. One of the best ways to tackle this issue is via polarization studies of the emission from spinning dust grains in the presence of magnetic fields. Early observations with the SMA and CARMA imply a magnetic field that is mainly toroidal. However, it is important to have fields that are poloidal in order to launch jets and outflows perpendicular to the disk. I will discuss the current status of this emerging field, including our magnetic field measurements made by the SMA towards IRAS 16293B which is a disk that is almost face on. The field geometry appears to be azimuthal which is consistent with toroidal magnetic fields. In addition, CARMA observations of HL Tau, which is more edge on also reveals mainly toroidal fields. I will discuss how these observations will be improved by the approved ALMA Cycle 2 programs from both our group and others, which will revolutionize our understanding of the role of magnetic fields in disk formation and evolution.

Statistical properties of the polarized emission of Planck Galactic cold clumps

Isabelle Ristorcelli, on behalf of the *Planck* Collaboration

IRAP, Université de Toulouse, CNRS, 9 Avenue du Colonel Roche, BP 44346, Toulouse Cedex 4, France

The Galactic magnetic fields are considered as one of the key components regulating star formation, but their actual role on the dense cores formation and evolution remains today an open question. Dust polarized continuum emission is particularly well suited to probe the dense and cold medium and study the magnetic field structure. Such observations also provide tight constraints to better understand the efficiency of the dust alignment along the magnetic field lines, which in turn relate on our grasp to properly interpret the B-field properties. With the Planck all-sky survey of dust submillimeter emission in intensity and polarization, we can investigate the intermediate scales, between that of molecular cloud and of prestellar cores, and perform a statistical analysis on the polarization properties of clumps. Combined with the IRAS map at 100microns, the Planck survey has allowed to build the first all-sky catalogue of Galactic Cold Clumps (PGCC, Planck 2015 results XXVIII 2015). The corresponding 13188 sources cover a broad range in physical properties, and correspond to different evolutionary stages, from cold and starless clumps, nearby cores, to young protostellar objects still embedded in their cold surrounding cloud. I will present the main results of our polarization analysis obtained on different samples of sources from the PGCC catalogue, based on the 353GHz polarized emission measured with Planck. We have studied in particular the variation of the polarization fraction towards the clump and its surrounding environment, and relative orientation between the B-field and the clump main axis. The statistical properties are derived from a stacking method, using optimized estimators for the polarization fraction and angle parameters. These properties are determined and compared according to the nature of the sources (starless or YSOs), their size or density range. Finally, I will present a comparison of our results with predictions from MHD simulations of clumps including radiative transfer and the dust radiative torque alignment mechanism.

A New Multiscale Analysis of the Gradient of Linear Polarisation

Jean-François Robitaille
Jodrell Bank Centre for Astrophysics, School of Physics and Astronomy, The University of Manchester, Oxford Road, Manchester M13 9PL, UK

Previous power spectra analysis of the amplitude of the polarisation intensity vector *P* in the Galactic plane have shown evidence of large-scale structures in the Galactic magnetic field. The power-law behaviour of these spectra is expected to be related to the energy transfer from larger to smaller scales in the turbulent fluctuations of the magnetic field. However, the power spectrum of the amplitude of *P* alone is not sensitive to fluctuations of the polarisation angle which also show evidence of large-scale variations in the Galactic plane. For this reason, Gaensler et al. (2011) proposed calculation of the amplitude of the gradient of *P* as a new technique to measure variations of the vector *P* in the Stokes parameters *Q*-*U* plane. Acting as an edge detector in a map, the gradient of *P* highlights areas of sharp changes in the magnetic field and/or the free-electron density, which are most likely due to turbulent fluctuations or shock fronts in the ISM. Despite the fact that the gradient of *P* is only sensitive to the smallest scales, the analysis of this quantity allows a novel interpretation of linear polarisation images.

In this talk, I will present a new multiscale method to calculate the amplitude of the gradient of *P* using wavelet-based formalism (Robitaille & Scaife 2015). This new analysis technique reveals that different networks of filaments are present on different angular scales in the Galactic plane. The wavelet formalism allows us to calculate the power spectrum of the fluctuations seen in the gradient of *P* and to determine the scaling behaviour of this quantity. The gradient of *P* distributions show higher skewness on smaller scales than at larger scales. The spatial distribution of the outliers in the tails of these distributions creates a coherent subset of filaments correlated across multiple scales, which trace the sharpest changes in the polarisation vector *P* within the field. We suggest that these structures may be associated with highly compressive shocks in the medium.

Probing the role of the magnetic field in the formation of structure in molecular clouds using Planck

Juan Soler[1,2]

[1] Institut d'Astrophysique Spatiale, Université Paris-Sud, Bâtiment 120-121, 91405 Orsay Cedex, France

[2] DSM/IRFU/SAp CEA/Saclay, Bâtiment 709 Orme des Merisiers 91191 Gif sur Yvette Cedex, France

The Planck observations of intensity and polarization of thermal emission from Galactic dust over the whole sky, and down to scales that probe the interiors of nearby molecular clouds, constitute an unprecedented data set for the study of the morphology of the magnetic field. Within ten nearby (d < 450 pc) Gould Belt molecular clouds we evaluate statistically the relative orientation between the magnetic field projected on the plane of sky, inferred from the polarized thermal emission of Galactic dust observed by Planck at 353 GHz, and the gas column density structures, quantified by the gradient of the column density, N_H. The relative orientation is evaluated pixel by pixel and analyzed in bins of column density using the novel statistical tool called "Histogram of Relative Orientations". Within most clouds we find that the relative orientation changes progressively with increasing N_H from preferentially parallel or having no preferred orientation to preferentially perpendicular. In simulations of magnetohydrodynamic turbulence in molecular clouds this trend in relative orientation is a signature of Alfvénic or subAlfvénic turbulence, implying that the magnetic field is significant for the gas dynamics at the scales probed by Planck. We compare the deduced plane-of-the-sky magnetic field strength with estimates we obtain from the Davis-Chandrasekhar-Fermi method and with the line-of-sight magnetic field strengths derived from Zeeman splitting observations towards some of the studied regions. Finally, we discuss the implications of the Planck observations for the general picture of molecular cloud formation and evolution.

Dust polarization in the Infrared Dark Cloud G34.43

Ya-Wen Tang[1], Patrick M. Koch[1], Nicholas Chapman[2], Giles Novak[2]

[1] Academia Sinica Institute of Astronomy and Astrophysics,

11F of Astronomy-Mathematics Building, AS/NTU. No.1, Sec. 4, Roosevelt Rd, Taipei 10617, Taiwan, R.O.C.

[2] CIERA and Department of Physics & Astronomy, Northwestern University,

2145 Sheridan Road, Evanston, IL 60208, USA

Recent HERSCHEL observations reveal that filaments are likely the primary structures through which material accumulates under the influence of gravity and turbulence, and stars are formed within them. In order to study how stars form within filaments, the studies of the environment and structures of filaments in their early stages - typically as infrared dark clouds (IRDCs) - are essential. Within the well studied IRDCs, the G34.43 region appears particularly interesting due to the distributed low-mass stars along with massive stars at the center, suggesting a slow star formation process within the filament. In this paper, we report the magnetic field (B) traced with thermal dust polarization at 350 μm. The inferred B field is strong, being a few *m*G. The B field orientation is perpendicular to the long axis of the filament elongation, suggesting that the B field guides the material toward the filament. The B field appears to be conserved down to scales of tens of mpc. Toward the three densest cores in the filament, the fragmentation processes appear dramatically different, being clustered in MM3 while no fragmentation is resolved in MM1. Our results suggest that the B field plays an important role in the structure formation at scales of tens of pc, and it is also important in the fragmentation process on scales of tens of mpc.

Magnetic fields in the periphery of GMCs

Thomas Troland

Department of Physics and Astronomy, University of Kentucky,

505 Rose Street, Lexington KY 40506-0055, USA

We have conducted a survey of magnetic field strengths in galactic GMCs via the Zeeman effect in 18 cm (1665 & 1667 MHz) OH absorption lines against extragalactic continuum sources. These observations, obtained at Arecibo, sample relatively low column density molecular gas ($N(H) = 10^{21}$ to 10^{22} cm^{-2}; $Av = 0.5$ to 5 mag). We observed 38 OH absorption lines toward 21 sources. Previous Zeeman effect observations of HI absorption lines have sampled lower $N(H)$ diffuse gas. Likewise, previous Zeeman observations of OH emission lines have sampled higher $N(H)$ molecular cores. Therefore, the present Zeeman data set provides a bridge in the sampled $N(H)$ range between diffuse H0 gas and molecular cores. The present data strongly suggest that magnetic field strengths remain constant as a function of increasing $N(H)$ up to about 10^{22} cm^{-2}. This value is comparable to the column density at which 353 GHz Planck linear polarization data show that (1) molecular filaments change from lying statistically parallel to the plane-of-sky magnetic field to statistically perpendicular, and (2) the percentage linear polarization decreases sharply. As diffuse gas gathers into star-forming molecular gas, and $N(H)$ increases locally, the physics of the process evidently changes, and the role of the magnetic field may change as well once $N(H)$ exceeds 10^{22} cm^{-2}.

POSTERS

Influence of magnetic fields in the rotation curves of spiral galaxies

Eduardo Battaner, Beatriz Ruiz-Granados, Estrella Florido

Física Teórica y del Cosmos, Facultad de ciencias, Universidad de Granada, Edificio Mecenas. Avenida Fuentenueva sn. 19071 Granada, Spain

One of the most controversial hypotheses for explaining the flat rotation curve of spiral galaxies is the assumption that the rotation is magnetically driven. We here defend that magnetic fields are not ignorable, without excluding the effect of a dark matter halo. Two observational facts will be in particular discussed. First, several galaxies, including M31 and our own, present an increase of the rotation velocity at large radii after the broad interval where it is constant. This fact is difficult to explain with the dark matter hypothesis alone. Second, magnetic strengths in both the intergalactic and external galactic media have a similar order of magnitude. If magnetic fields are approximately constant at the rim of the galaxy, the Alfvén speed must exponentially increase until eventually reach values of the order of the rotation velocity.

A joint Herschel-Planck analysis: multi-scale observations of molecular cloud dynamics

Andrea Bracco[1,2]

[1] Institut d'Astrophysique Spatiale, Université Paris-Sud, Bâtiment 120-121, 91405 Orsay Cedex, France

[2] DSM/IRFU/SAp CEA/Saclay, Bâtiment 709 Orme des Merisiers 91191 Gif sur Yvette Cedex, France

The recent Planck results in polarization at sub-mm wavelengths allow us to gain insight into the Galactic magnetic field topology, revealing its statistical correlation with matter, from the diffuse interstellar medium (ISM) to molecular clouds (MCs) (Planck Intermediate Results XXXII, XXXIII, XXXV). This correlation carries a lot of information about the dynamics of the turbulent ISM, stressing the importance of magnetic fields in the formation of structures, some of which eventually undergo gravitational collapse producing new star-forming cores. Investigating the early phases of star formation has been a fundamental scope of the Herschel Gould Belt survey collaboration (http://gouldbelt-herschel.cea.fr), which, in the last years, has thoroughly characterized, at a resolution of few tens of arcseconds, the statistics of MCs, such as their filamentary structure and column density. Although at lower angular resolution, the Planck maps of dust emission at 353 GHz, in intensity and in polarization, show that all MCs are characterized by a non-trivial correlation between the magnetic field and their density structure. This result opens new perspectives on their formation and evolution, which we have started to explore. In this talk, I will present first results of a comparative analysis of the Herschel-Planck data, where we combine the high resolution Herschel maps of some MCs of the Gould Belt with the Planck polarization data. In particular, I will discuss the large-scale envelopes of the selected MCs, and, given the correlation between the magnetic field and the matter observed at the resolution of Planck, I will show how to make use of the high resolution information of the density structure provided by Herschel to account for the statistics of dust polarization in the Planck data.

The Magnetic Century Cloud Sample: A Statistical Study of Magnetic Fields in Molecular Clouds

Ren Cashman

Institute for Astrophysical Research, Boston University, College of Arts and Sciences Building, 725 Commonwealth Avenue, Boston, MA 02215, USA

Relatively few studies have been done of the magnetic fields in the cool, quiescent interstellar medium. We present preliminary results from the "Magnetic Century Cloud Sample" (MCCS), a new sample of 100 quiescent, diffuse molecular clouds. Galactic Ring Survey (GRS) ^{13}CO spectroscopic data are used to identify molecular clouds, find distances to the clouds, and reveal the nature of the gas. We use near-infrared (NIR) H-band (1.6 μm) background starlight polarimetry from the Galactic Plane Infrared Polarization Survey (GPIPS) to study the relationship between B-fields and cloud morphology. The environment and star-forming nature of each cloud are determined through use of Spitzer/GLIMPSE and Spitzer/MIPSGAL data. This new, powerful sample will characterize the distribution of B-field morphologies in molecular clouds and help constrain the role of B-fields in the formation of the clouds themselves.

Current Status of ALMA Polarization Capabilities

Paulo Cortes

NRAO/ALMA, Alonso de Cordova 3107 Vitacura Santiago, Chile

ALMA is now in the process of finishing the remaining commissioning items pending from the construction phase. In this talk, the current state of the ALMA polarization capabilities will be presented along with a brief description of the polarization science verification data on 3c286 and 3c138. The later obtained at high angular resolutions during the long baseline campaign.

Constraints on Polarization Efficiency in the Vela C Molecular Cloud: First Results from BLASTPol 2012

Laura Fissel
CIERA, Northwestern University, 2145 Sheridan Rd Evanston, IL, USA 60208

We present a study of submillimeter polarization observed in the nearby (d$\sim$700 pc) giant molecular cloud (GMC) Vela C, using data collected during the 2012 Antarctic flight of BLASTPol. This sensitive balloon-borne polarimeter observed Vela C for 57 hours from an altitude of 38 km, yielding the most detailed submillimeter polarization map ever made of a GMC forming high mass stars. Our 500 micron polarization map covers nearly the entire extent of this 30 by 10 pc cloud and has a spatial resolution of 0.5 pc. Statistical comparisons between submillimeter polarization maps and three dimensional numerical simulations of magnetized star-forming clouds are a promising method for constraining magnetic field strength, but uncertainty concerning how the dust polarization efficiency varies within the cloud can make such comparisons difficult. Previous work suggests that this uncertainty can be reduced by studying the dependence of observed polarization fraction (p) on column density (N). In Vela C, we find that most of the structure in p can be modeled by a power-law dependence on two quantities: the first is N and the second is the local dispersion in polarization angle (S). The decrease in p with increasing S is attributed to changes in the magnetic field direction within the beam. The decrease in p with increasing N can be explained by reduced polarization efficiency for deeply embedded dust grains, but might also be affected by increasing magnetic field disorder at high densities. Using a simple polarization efficiency model, we show that even if all of the decrease in p vs N is due to inefficient grain alignment at high densities, the BLASTPol map still traces the average magnetic field up to $A_V > 10$. Our power-law model for $p(N,S)$ provides new constraints for models of magnetized star-forming clouds and an important first step in the interpretation of the BLASTPol 2012 data set.

Complex magnetic fields threading high mass star forming cores: the effect of stellar feedback

Josep Girart

Institut de Ciencies de l'Espai (CSIC-IEEC), Campus UAB Carrer de Can Magrans, S/N 08193 Cerdanyola del Vallès, Catalonia, Spain

Recent work, on a statistically significant sample of massive star forming cores observed with the Submillimeter Array at 345 GHz, has shown that magnetic fields play an important role during the formation of dense cores at spatial scales of 0.01-0.1 pc in the context of massive star and cluster star formation (Zhang *et al.* 2014, see also invited talk by Q. Zhang). This work shows that at these scales the magnetic fields threading the cores tend to be more organized rather than chaotic. Here, we present three massive star forming regions where a complex magnetic field is observed. In the three cases we found that the magnetic field energy is probably overwhelmed by the stellar feedback (specially in two of the sources that already have an UCHII region).

Dust properties and gas dynamics in a magnetized prestellar core

Josep Girart[1], Felipe Alves[2], Pau Frau[3], Gabriel A. P. Franco[4],
Fabio P. Santos[5], Helmut Wiesemeyer[6]

[1] Institut de Ciencies de l'Espai (CSIC-IEEC), Campus UAB Carrer de Can Magrans, S/N 08193 Cerdanyola del Vallès, Catalonia, Spain

[2] Max-Planck-Institut für extraterrestrische Physik, Giessenbachstr. 1, 85748, Garching, Germany

[3] Instituto de Ciencia de Materiales de Madrid (CSIC), Sor Juana Inés de la Cruz 3, 28049, Madrid, Spain

[4] Departamento de Física-ICEx-UFMG, Caixa Postal 702, 30.123-970, Belo Horizonte, Brazil

[5] Department of Physics and Astronomy, Northwestern University, 2145 Sheridan Road, Evanston, IL, 60208, USA

[6] Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, 53121, Bonn, Germany

Prestellar cores are collapsing objects where gravity struggles against thermal pressure and magnetic fields in order to evolve and form a protostar. Observationally, this evolution may be traced by the gas kinematics and dust properties. In this work, we present recent results toward the object FeST 1-457, an evolved starless cores in the Pipe nebula. We report APEX dust polarization data and IRAM 30-m molecular line data toward this object. The polarization data reveal that the core is embedded in a very uniform magnetic field, and that the dust grains are aligned up to $\sim 10^4\,\mathrm{cm}^{-3}$. Our model predicts a polarization hole for higher densities, which is consistent with radiative torques grain alignment theory. We are currently inspecting molecular line data (N_2H^+ and NH_2D) in order to check for variations on the kinematics between ions and neutral species. Such a variation would strongly suggest that gas dynamics is affected by the magnetic field.

Magnetic field structures resulting from cosmic-ray driven dynamo

Michal Hanasz, Dominik Wóltański

Nicolaus Copernicus University, Centre for Astronomy, Faculty of Physics, Astronomy and Informatics

ul. Gagarina 11, 87-100 Torun, Poland

Cosmic-Ray-driven dynamos produce magnetic arms in galactic disks and large-scale helical magnetic fields in galactic halos. Relying on numerical models of hybrid N-body and CR-MHD simulations we are going to explain mechanisms of formation of those prominent structures. We shall discuss the relation of the 3D magnetic field structures with their counterparts in radio maps of synchrotron radio-emission from spiral galaxies.

GMIMS perspective on the Fan Region

Alex Hill

Department of Astronomy, Haverford College, 370 Lancaster Ave Haverford, PA 19003, USA

Diffuse polarized radio continuum emission provides information about the structure of the Galactic magnetic field. The Fan Region is one of the dominant features of the sky in polarized radio continuum, long thought to be a local (d < 500 pc) synchrotron emission feature. We present 1.5 GHz polarized radio continuum observations from the Global Magnetoionic Medium Survey (GMIMS). We find that the 1.5 GHz polarized radio emission is anti-correlated with Hα emission from the Perseus Arm, 2 kpc away. This indicates that ionized gas in the Perseus Arm depolarizes about 40% of the Fan Region emission, indicating that some of the Fan Region emission originates in or beyond the Perseus Arm. The synchrotron emission must therefore be produced along a large path length, suggesting the presence of a coherent magnetic field in the plane in the outer Galaxy. We argue that the polarized emission from the Fan Region is a consequence of the structure of the Galactic magnetic field and ISM. We model beam depolarization due to the ISM, finding that in the presence of depolarization the rotation measure measured from polarized emission is much lower than that measured towards background point sources, explaining an observed discrepancy between the GMIMS rotation measures and background rotation measures.

Tracing the Magnetic Fields of IRDCs using NIR Polarimetry

Sadia Hoq

Astronomy Department, Boston University, College of Arts and Sciences Building, 725 Commonwealth Avenue, Boston, MA 02215, USA

The role of the Galactic magnetic field in the formation of Infrared Dark Clouds (IRDCs) and their star formation is not well understood. We study the relationships between magnetic fields and cloud properties for 5 IRDCs in the first Galactic quadrant. To trace the plane-of-sky magnetic field in the vicinity of the clouds, we use near-infrared (NIR) shallow H-band (1.6 μm) and deep K-band (2.2 μm) polarimetric observations of background starlight observed using the Mimir instrument on the 1.8 m Perkins telescope. The Herschel Hi-GAL Survey was used to estimate the IRDC column densities, and ^{13}CO and NH_3 were used to reveal the cloud velocity information. We determine whether any correlations exist between magnetic field properties (direction, dispersion, strength) and IRDC properties, such as density and level of star formation activity.

The effect of turbulent magnetic field in cosmic ray propagation

Behrouz Khiali, Elisabete de Gouveia Dal Pino, Reinaldo Santos-Lima
IAG-Universidade de São Paulo, Rua do Matão 1226, São Paulo, SP, Brazil

Magnetic fields and turbulence are known to be present in astrophysical flows of every scale and cosmic rays (CRs) are deflected due to their interactions with turbulent magnetic field. Charged particles follow the turbulent magnetic fields and scatter. Pitch-angle diffusion is the key process in CR scattering in turbulent plasmas. In the present work we have determined numerically the pitch angle diffusion coefficients by injecting test particles both in pure MHD turbulence and also in large scale magnetic reconnection layers with embedded turbulence and then compared with analytical predictions from quasi-linear and nonlinear diffusion theories for particle transport in turbulent astrophysical medium and also with past numerical experiments.

Studies of the Galactic Magneto-Ionic Medium with the Canadian Galactic Plane Survey

Roland Kothes

Dominion Radio Astrophysical Observatory, NRC, P.O. Box 248, Penticton, BC V2A 6J9, Canada

The completion of the Canadian Galactic Plane Survey (CGPS) has given the astronomical community an incredibly broad view of the Interstellar Magneto-ionic Medium (MIM) while preserving its spectacular details. Here, I would like to give a summary of the results of recent studies with the CGPS 1420 MHz radio continuum and polarization data. A study of the effect of HII regions and supernova remnants on the background polarization signal gives a very detailed view of the "Polarization Horizon" and the relation between large-scale and turbulent magnetic fields. A rotation measure study of the smooth polarization features in the Inner Galaxy reveals details of the large-scale field reversal between the Orion Spur and the Sagittarius arm. And a comparison of pulsar dispersion measures and extragalactic rotation measures of CGPS sources provides information about the configuration of the Outer Galaxy large-scale magnetic field.

A Resonant MHD, Galactic Scale Instability

Marco Martos

Astronomia Extragalactica y Cosmologia, Instituto de Astronomia UNAM,
Apdo. Postal 70-264 Ciudad Universitaria Mexico, DF, 04510, Mexico

Confirmed via numerical simulations with the ZEUS MHD code, we show here that the galactic magnetized disk must be unstable to spiral and bar perturbations in the presence of a magnetic field of the currently observed intensity. The instability produces large scale MHD turbulence, and predicts a number of structural features that appear consistent with galactic measurements: local reversals and strong amplifications of the field, a truncation of the dense central disk, filamentary structure, and resonance-related structure that is expected from theory. The large scale four main gaseous arms are preserved for timescales of 10 Gy, as in the quasistationary picture of Lin & Shu.

Magnetic properties of low-mass protostellar cores: SMA and ALMA observations of polarized dust continuum emission in Class 0 protostars at scales 500AU

Anaëlle Maury[1], Josep M. Girart[2], Qizhou Zhang[3], Ramprasad Rao[4], Shih-Ping Lai[5], Eric Keto[3], Patrick Hennebelle[1]

[1] DSM/IRFU/SAp CEA/Saclay, Bâtiment 709 Orme des Merisiers 91191 Gif sur Yvette Cedex, France

[2] Institut de Ciencies de l'Espai (CSIC-IEEC), Campus UAB Carrer de Can Magrans, S/N 08193 Cerdanyola del Vallès, Catalonia, Spain

[3] Harvard-Smithsonian Center for Astrophysics, 60 Garden St., Cambridge, MA 02138, USA

[4] Academia Sinica Institute of Astronomy and Astrophysics, 645 N. Aohoku Pl., Hilo, HI 96720, USA

[5] Academia Sinica Institute of Astronomy and Astrophysics, Roosevelt Rd, Taipei 10617, Taiwan

The Class 0 phase represents a pivotal stage in star formation during which the "angular momentum problem" needs to be solved. The long-standing paradigm for the formation of solar-type protostars proposes that this is done through the fragmentation of the parental core in a multiple system and/or the formation of a protostellar disk. However, MHD simulations show that magnetic braking redistributes the angular momentum in the infalling envelope and might prevent the formation of close multiple systems and large circumstellar disks. Whether or not magnetic fields actually play a dominant role to shape the angular momentum transport in protostellar envelopes still has to be investigated from an observational perspective, in a statistical yet detailed fashion. We recently observed a sample of Class 0 protostars with both the SMA and ALMA interferometers, aiming at testing the efficiency of magnetic braking to regulate angular momentum transport. The submillimeter polarized dust continuum emission maps will be compared to molecular lines emission maps tracing the envelope kinematics at similar scales, and ultimately with predictions of MHD simulations. Here, we propose to present our dataset and provide a preliminary analysis looking for a correlation between the topology of magnetic field lines and the multiplicity, disk properties and envelope kinematics of these low-mass Class 0 protostars.

Magnetic Fields in Disk Galaxies: PEGS in the NIR

Jordan Montgomery

Department of Astronomy, Boston University, College of Arts and Sciences Building, 725 Commonwealth Avenue, Boston, MA 02215, USA

Our Polarization of Edge-on Galaxies Sample (PEGS) project has observed the magnetic (B) field in the cold, dusty interstellar medium (ISM) of 13 edge-on galaxies using near-infrared (NIR) H-band (1.6 microns) polarimetry. Observations were conducted from 2011 to 2015 on the Perkins 1.8 m telescope (Flagstaff, AZ). The selected galaxies span a wide range of star formation rates, masses, and Hubble types. These observations will reveal the large scale B-field geometry in the mid-plane of disk galaxies and will place constraints on α-ω dynamo models. A comparison of NIR and synchrotron polarimetry of these galaxies will reveal whether the B-field in the hot ISM and cold ISM are well aligned in disk galaxies. The NIR data will also be examined for correlation between departures from the median B-field direction and regions of active star formation, as traced by Spitzer 24 micron photometry.

GMF simulations based on the cosmic-ray driven dynamo

Natalia Nowak

Astronomical Observatory of the Jagiellonian University, ul. Orla 171 30-244, Kraków, Poland

We present a new three-dimensional model of the Galactic Magnetic Field (GMF). Our MHD numerical calculations of a large-scale magnetic field evolution provide results involving a cosmic-ray driven dynamo process that depends on star formation rates. We use more than thirty seven thousands rotation measures of extragalactic sources from Taylor 2009 to construct our GMF model. We compare our modelled results directly with observations, constructing models of high-frequency polarized radio emission and rotation measurement maps out of the simulated magnetic field in our modeled galaxy. We reproduced rotation curve of the gas for the Milky Way generated by sum of gravitational potential, which greatly compare with observational rotation curve. We construct realistic maps of rotation measure in the plane of the galaxy on the basis of the simulated magnetic field, which we compare directly with observations.

The effect of ambipolar diffusion on low-density molecular ISM filaments

Evangelia Ntormousi

DSM/IRFU/SAp CEA/Saclay, Bâtiment 709 Orme des Merisiers 91191 Gif sur Yvette Cedex, France

The filamentary structure of molecular clouds and its potential link to star formation have been recently brought into focus by high resolution observational surveys. An especially puzzling matter is that local interstellar filaments appear to have the same thickness, independent of their column density. This requires a theoretical understanding of the physics in their interior. Assuming that filaments are dissipative structures of the interstellar turbulence cascade, we suggest that a ambipolar diffusion is the diffusive process setting the characteristic thickness. This happens because the turbulence cascade through the propagation of MHD waves is cut off at a certain scale. We employ high-resolution, 3D MHD simulations, performed with the grid code RAMSES, to investigate non-ideal MHD turbulence as a filament formation mechanism. We focus the analysis on the mass and thickness distributions of the resulting filamentary structures. The simulations of driven and decaying MHD turbulence show that the morphologies of the density and the magnetic field are different when ambipolar diffusion is included in the models. In particular, the densest structures are broader and more massive as an effect of ion-neutral friction and the power spectra of both the velocity and the density steepen at a smaller wavenumber. The comparison between ideal and non-ideal MHD simulations points to ion-neutral friction as a good candidate for setting a characteristic scale.

Diffuse radio emission in CIZA-J0649.3+1803

Kamlesh Rajpurohit[1], Matthias Hoeft[1], Reinout J. van Weeren[2]

[1] Thüringer Landessternwarte (TLS), Sternwarte 5, D-07778 Tautenburg, Germany

[2] Hkarvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA

Galaxy clusters form through a sequence of mergers of smaller galaxy clusters and groups. During mergers large scale shocks are driven into the intracluster medium (ICM), these shocks accelerate electrons to relativistic speeds. Together with magnetic fields these electrons emit synchrotron radiation and may form so-called radio relics. Radio relics are elongated, peripheral, polarized, Mpc-scale diffuse synchrotron sources that appear to have magnetic fields at the micro-gauss level. Relics are generally found in a merging system supporting the scenario that they trace shock fonts. In present work Faraday Rotation Measure maps are developed in order to investigate the magnetic field in the galaxy cluster CIZA J0649+18. This cluster is known to possess diffuse emission in the peripheral region. By using Rotation Measure (RM) synthesis on multi-wavelength Westerbork Synthesis Radio Telescope (WSRT) observations (between 1159 to 1758 MHz), we aim for unveiling the nature of the diffuse emission by studying its Faraday spectra.

NIR Polarimetry of Molecular Cloud associated with IRAS 18236-1205

Devaraj Rangaswamy
Instituto Nacional de Astrofísica, Óptica y Electrónica, Puebla, Mexico

We present the Near-infrared polarimetric observations of the molecular cloud associated with the source IRAS 18236-1205 which is a region with earliest phase of star formation. Linear polarimetric observations were carried out in H-band with the POLICAN instrument operated at OAGH observatory in Cananea, Mexico. Our initial analysis of the region with GRS ^{13}CO ($J = 1-0$) line data has revealed the S-shaped morphology of the molecular cloud. The ATLASGAL dust clumps at 870 μm (beam size 19") are exclusively associated with the center and edges of the S-shaped cloud. The gas velocity dispersion values appear to be low towards these dense clumps, where the signatures of star formation are traced by the 6.7 GHz masers, outflows, and embedded infrared point sources. These results indicate that the turbulence is dissipated them. The diffuse emissions in Herschel Hi-GAL maps (70- 500 μm) are spatially seen towards the high values of gas velocity dispersion, where the ATLASGAL clumps are absent. The H-band polarization vectors representing the direction of magnetic field spatially appear to be less concentrated towards the dense regions in the cloud, where extinctions are higher, and/or outflow activities are present. These characteristics will enable us to infer the correlation of the turbulence, magnetic field, and rotation in the cloud. Subsequently it will allow to validate the predictions of numerical simulations of star formation.

Cosmic Rays in Turbulent Magnetic Fields

Amit Seta

School of Mathematics & Statistics, Newcastle University, Newcastle upon Tyne NE1 7RU, UK.

Cosmic rays play an important role in galaxy's dynamics as their average pressure is comparable to thermal, kinetic and magnetic pressure. They support the interstellar medium against gravity via their interaction with galactic magnetic fields. Cosmic rays scatter off Alfvén waves (a part of interstellar turbulence) giving rise to pitch angle diffusion, which in turn leads to diffusion in real space. As the average radius of gyration of these energetic particles is much smaller than the scale height of the galaxy, they are closely tied to the magnetic field lines and thus the configuration of galactic magnetic field is an important input to determine their propagation in the galaxy. We plan to study the propagation of cosmic rays in a realistic magnetic field configuration. To start with, we look at charged particles propagating in simple magnetic field configurations to confirm our expectations and also to test the accuracy of our code. The observations confirm that the galactic magnetic field have a significant random component and thus to understand the propagation of cosmic rays in random fields we extend our work for magnetic field generated by a fluctuation dynamo. In particular this will allow us to clarify at what scales can energy equipartition between magnetic field and cosmic rays can be considered and would also provide insight into behaviour of cosmic rays with respect to Fermi Bubbles (especially about their confinement within them).

High-precision Faraday rotation measures from LOFAR pulsar observations, towards reconstructing the 3-D Galactic magnetic field

Charlotte Sobey
ASTRON, Oude Hoogeveensedijk 4, 7991 PD Dwingeloo, The Netherlands

Observations of pulsars using next generation low-frequency radio telescopes, for example LOFAR (the Low Frequency Array), provide powerful probes of astrophysical plasmas. LOFAR's large fractional bandwidth and collecting area combine to produce the highest-quality polarisation profiles of pulsars below 200 MHz to date. These data are well suited for using the novel technique of RM-synthesis to achieve unprecedented precision on Faraday rotation measures (RMs). The time- and position-dependent ionospheric Faraday rotation is calculated and subtracted using a code that has been verified using long-track LOFAR pulsar observations. I will present a growing catalogue of over 130 precise RMs obtained using the LOFAR Cycle 1 Pulsar Census. Combining the accurate RMs and dispersion measures from LOFAR pulsar observations provides an efficient method to accurately reconstruct (and monitor) the 3-D Galactic magnetic field.

Turbulent Effects on Relativistic Magnetic Reconnection in Poynting-Dominated Plasmas

Makoto Takamoto

Department of Earth and Planetary Science, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo, Japan

In many high energy astrophysical phenomena with relativistic outflows, it is considered the outflows are initially Poynting energy dominated plasmas, and the Poynting energy will be converted into bulk kinetic and radiation energy at some stage. However the dissipation mechanism efficient enough to explain observations is still unknown. In this presentation, we report on our recent findings of the enhancement of the magnetic reconnection rate by turbulent processes in a Poynting-dominated plasma. We performed 3-dimensional relativistic resistive magnetohydrodynamics simulations, and found that reconnection rate becomes very fast and independent of the plasma resistivity due to turbulent effects. However, we also found that compressible turbulence effects modify the turbulent reconnection rate predicted in non-relativistic incompressible plasmas. We also discuss the relativistic effects and possible astrophysical applications.

Does the halo of our Galaxy possess an X-shape magnetic field?

Philippe Terral, Katia Ferrière

IRAP, Université de Toulouse, CNRS, 9 Avenue du Colonel Roche, BP 44346, Toulouse Cedex 4, France

The magnetic field is an important component of the interstellar medium. It plays a major role in a variety of physical processes in galaxies (hydrostatic balance, star formation, cosmic-ray acceleration and propagation...), but its properties remain poorly understood. Radio observations of nearby galaxies similar to the Milky Way reveal common features such as field lines with an "X-shape" structure in their halos. This finding quite naturally raises the question of whether the halo of our own Galaxy possesses an X-shape magnetic field. Here, we present a study in which we use analytical models of divergence-free, X-shape magnetic fields to simulate all-sky maps of the Galactic Faraday depth. The few free parameters of these models are adjusted to provide the best possible fit to the observational map, which is based on a large number of Faraday rotation measures of extragalactic sources. We also implement a statistical approach to estimate the uncertainty in the Faraday depth values arising from the turbulent magnetic field. This uncertainty, combined with the measurements errors, enable us to define the appropriate ... criterion to test our models. In this poster, we present our analytical models of the Galactic magnetic field, our reference map of the Galactic Faraday depth and finally we present our first results.

Simulation of polarised galactic dust

Flavien Vansyngel

Institut d'Astrophysique Spatiale, Université Paris-Sud, Bâtiment 120-121, 91405 Orsay Cedex, France

I will present a method to simulate the polarised dust emission of the interstellar medium at one frequency. The ingredients of the recipe is (1) an existing intensity galactic dust emission map (I map), (2) a model for mean and turbulent galactic magnetic field and (3) a set of relative amplitude between TT, EE, BB, TE dust power spectra. Maps of Stokes parameters Q/I and U/I are computed from a simulation of the magnetic field. The dust (I,Q,U) map is then post-processed in order to match the desired TE correlation and E-B asymmetry. Except for correlation with the B signal, any correlation structure at any scale is in principle achievable by tuning the model of the magnetic field and choosing adequate relative spectra amplitudes. In particular, the method is able to construct polarised dust map that reproduces the dust power spectra measured by the *Planck* collaboration. Since the method allows the simulation of numerous polarised dust maps, this method is of particular interest for cosmologists to simulate radio-microwave skies and e.g. forecast CMB B-modes detections for future CMB experiments. Together with the measured dust power spectra, this method is also useful to constrain the turbulent magnetic field. In addition, it provides an interpretation of the measured dust-synchrotron correlation.

Rotation measure study of disk-like galaxies at $z \sim 0.5$

Anna Williams

Astronomy Department, University of Wisconsin-Madison

2535 Sterling Hall 475 N. Charter Street Madison, WI 53706-1507, USA

Magnetic fields are ubiquitous in the universe. They accelerate cosmic rays, affect star formation, and regulate the redistribution of matter and energy within galaxies. Despite their prevalence, the origin and growth of magnetic fields is not well understood. We present the preliminary results of a Faraday rotation measure survey that aims to determine whether young, disk-like galaxies at redshift $z \sim 0.5$ contain large-scale magnetic fields. Our survey contains 38 quasars with SDSS identified MgII absorption systems at $z \sim 0.5$, and over 100 quasars that serve as controls to constrain the contributions from both the foreground rotation measure and the intrinsic rotation measure of the quasar. We utilize the broadband, polarization capabilities of the S-band receiver at the VLA to simultaneous observer Stokes I, Q, U, and V from 2-4 GHz. This large wavelength coverage allows us to use multiple methods of constrain the Faraday rotation, including rotation measure synthesis, and q- and u- model fitting. We present the initial results of the survey, including new rotation measures, our estimates of the foreground rotation measure, and the additional information we receive from the resolved sources in our study.

Formation of protostellar cores in magnetic interstellar clouds

Siyao Xu
Department of Astronomy, Peking University, Beijing, China

Initial conditions are the major concern for star formation physics. We probe the stability and density structure of interstellar molecular clouds, by means of both a linear analysis of magnetohydrodynamics (MHD) waves in the presence of self-gravity, and a nonlinear description of turbulence. It shows both magnetic field and turbulence are influential in fragmenting molecular clouds. Filaments form from a joint effect of the collapse along magnetic field lines and contraction across field lines which is enhanced by turbulence anisotropy and reconnection diffusion. The fragmentation scale of nascent cores is characterized by the neutral-ion decoupling scales of Alfvén and fast modes, where a localized isotropic collapse is triggered due to the evacuation of magnetic support. Direct comparison between the decoupling scales and sizes of infrared dark cloud cores shows a good consistency over a wide range of densities and core sizes.