Magnetic Fields in the Universe III: from Laboratory and Stars to Primordial Structures

Abstract book

Zakopane
21-27 August 2011

Part I

Abstracts
Invited talks

James Anderson

MPIfR, Germany

Title: The Cosmic Magnetism KSP of LOFAR

The Cosmic Magnetism key science project of LOFAR aims to measure the properties of magnetic fields in the nearby universe, from our own Milky Way to the interstellar fields of other galaxies, to hopefully the magnetic fields between galaxies and clusters of galaxies. LOFAR is a new radio telescope, currently its commissioning phase, that will be able to observe the low frequency sky between 10 and 240 MHz with good sensitivity and approximately sub-arcsecond resolution. The Cosmic Magnetism KSP will use LOFAR to measure magnetic fields through the total and polarized emission of particles interacting with the magnetic fields, as well as the technique of rotation measure synthesis to study the Faraday rotation of polarized emission caused by the magnetic fields. The Cosmic Magnetism KSP will study a range of astronomical targets, including pulsars, supernova remnants, young stellar objects, nearby spiral and dwarf galaxies, and AGNs, to learn about the magnetic fields both within those objects and within the intervening plasmas between the objects and ourselves.

Rainer Beck

MPIfR, Germany

Title: Observations of Cosmic Magnetic Fields with the SKA and its Precursors

The origin of magnetic fields in the Universe is an open problem in astrophysics and fundamental physics. Polarization observations with the forthcoming large radio telescopes will open a new era in the observation of magnetic fields and should help to understand their origin. Low-frequency radio synchrotron emission, to be observed with LOFAR, MWA and the Square Kilometre Array (SKA), traces low-energy cosmic ray electrons and allows us to map the structure of weak magnetic fields in the outer regions and halos of galaxies, in halos and relics of galaxy clusters and in the Milky Way. Polarization at higher frequencies (1-10 GHz), to be observed with the SKA and its precursors ASKAP (Australian SKA Pathfinder) and MeerKAT (Karoo Array Telescope), will trace magnetic fields in the disks and central regions of galaxies and in cluster relics in unprecedented detail. All-sky surveys of Faraday rotation measures towards a dense grid of polarized background sources with ASKAP (project POSSUM) and SKA are dedicated to measure magnetic fields in distant intervening galaxies, clusters

and intergalactic filaments, and will be used to model the overall structure strength of the magnetic fields in the Milky Way. "Cosmic Magnetism" is key science for LOFAR, ASKAP and SKA.

Andrey Beresnyak

Ruhr-University Bochum, Germany

Title: Basic MHD Turbulence

A well-conductive turbulent plasma amplifies its ambient magnetic fields. On scales smaller than driving scale the spectrum is steep, which is characteristic for strong turbulence, and anisotropic. This is known as critically balanced strong MHD turbulence. In many circumstances, near sources of perturbations, such as the Sun in solar wind, MHD turbulence is imbalanced or cross-helical, which is known from observations and expected from theory. The standard Goldreich-Sridhar model of balanced MHD turbulence does not apply in this case. The keys to understand energy cascades in the imbalanced case are the anisotropies of the Elsasser fields which are notably different. I will outline theoretical predictions and compare them with some of the highest-resolution MHD numerical simulations ever performed.

Alfio Bonanno

INAF - Catania Astrophysical Observatory, Italy

Title: Stellar Dynamo Theory: new insights from the Kepler Mission

Magnetic fields appear to be ubiquitous in almost all types of stars but the underlying generation mechanism can be very different across the HR diagram. In this talk I will review the most plausible dynamo actions and illustrate the role that high-quality photometric data provided by the Kepler mission can make in addressing the most challenging issues. In particular, recent results of spectroscopic and photometric analysis of young active stars in the field of view of the Kepler space telescope will be presented.

Gianfranco Brunetti

INAF-IRA, Italy

Title: Particle acceleration and non thermal emission in galaxy clusters

Mpc-scale diffuse synchrotron emission from galaxy clusters (Giant radio halos) probe particle acceleration in turbulent regions. Shocks and turbulence are driven in the inter-galactic-medium (IGM) during clusters mergers and may have a deep impact on the non-thermal properties of galaxy clusters. I will discuss relevant aspects of cosmic ray physics and turbulence in galaxy clusters and the (re)acceleration of cosmic rays by compressible MHD turbulence. The expected non-thermal broad band emission is in very good agreement with present radio and gamma ray data and model expectations can be tested with future radio telescopes and high energy experiments. In general turbulent (re)acceleration is an important process in diffuse relativistic plasma, I will briefly discuss a few examples in addition to the case of galaxy clusters.

Jungyeon Cho

Chungnam National Univ., Korea

Title: Magnetic turbulence as a foreground for CMB studies

Present-day cosmicmicrowave background (CMB) studies require more accurate removal of theGalactic foreground emission. In this talk, we consider a method for filtering out the diffuse Galactic fluctuations on the basis of their statistical properties, namely, the power-law spectra of fluctuations. We focus on the statistical properties of two major Galactic foregrounds that arise from magnetized turbulence, namely, the diffuse synchrotron emission and the thermal emission from dust, and describe how their power laws change with the Galactic latitude. We attribute this change to the change in the geometry of the emission region and claim that the universality of the turbulence spectrum provides a new way of removing Galactic foregrounds. For the Galactic synchrotron emission, we mainly focus on the geometry of the synchrotron emitting regions, which will provide useful information for future polarized synchrotron emission studies. For thermal emission from Galactic dust, we discuss general properties of a publicly available 94 GHz total dust emission map and explain how we can obtain a polarized dust emission map. Based on a simple model calculation, we obtain the angular spectrum of the polarized dust emission. We discuss and demonstrate how we can make use of our findings to remove Galactic foregrounds using a template of spatial fluctuations. In particular, we consider examples of spatial filtering of a foreground at small scales, when the separation into CMB signal and foregrounds is done at larger scales. We demonstrate that the new technique of spatial filtering of foregrounds may be promising for recovering the CMB signal in a situation where foregrounds are known at a scale different from the one being studied. It can also improve filtering by combining measurements obtained at different scales. We also discuss how to remove foreground signals from the redshifted 21-cm observations.

Richard Crutcher

University of Illinois, USA

Title: Testing Ambipolar Diffusion Driven Star Formation Theory

One theoretical model for star formation calls for clouds to be initially magnetically subcritical (magnetic fields sufficiently strong to prevent gravitational contraction). Cloud evolution and star formation proceeds due to neutrals contracting through the magnetic field and the ions until a magnetically supercritical core is formed, which can then form stars. I will review evidence from observations of magnetic fields in molecular clouds and evaluate this theory of star formation against the observational results.

Elisabete de Gouveia Dal Pino

IAG – Universidade de São Paulo, Brazil

Title: Magnetic Braking Catastrophe in Protostellar Disk Formation

Circumstellar disks play a fundamental role in the late stages of star formation and also in planet formation. However, the mechanism that allows their formation and the decoupling from the surrounding molecular cloud core progenitor is still not understood. Former studies have shown that the observed embedded magnetic fields in molecular cloud cores are high enough to inhibit the formation of rationally supported disks during the main protostellar accretion phase of low mass stars under ideal MHD conditions. This has been known as the *magneticbrakingproblem*. Proposed mechanisms to alleviate this problem and help removing the excess of magnetic flux during the star formation process include non-ideal MHD effects such as the Hall effect, ambipolar diffusion (AD), or an anomalous hyper -resistivity of unknown nature. The first two mechanisms have been shown to be not sufficient to weaken the magnetic braking enough, at least at this stage of the disk formation. In this work, motivated by recent results that revealed an efficient removal of magnetic flux due to turbulent magnetic reconnection from collapsing clouds, we investigate this mechanism during the later phases of the protostellar disk formation. By means of fully 3D MHD simulations, we show that turbulent magnetic reconnection diffusivity is able to transport magnetic flux to the outskirts of the disk progenitor at time scales compatible with the collapse, allowing the formation of a rotationally supported disk around the protostar of dimensions ~ 100 AU, with a nearly Keplerian profile. This mechanism produces similar effects as those when an artificial hyper-resistivity about 10^3 orders larger than the Ohmic resistivity is applied to the disk. Since MHD turbulence is expected to be present in these magnetic cores, turbulent reconnection arises as a natural mechanism for removing magnetic flux excess and allowing the formation of these disks.

Klaus Dolag

University Observatory Munich, Germany

Title: Magnetic Fields, Turbulence and Cosmic Rays in Galaxy Clusters

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. Although including them in simulations is extremely challenging as the structures in and around clusters are quite complex and span a very large dynamic range in scales, it allows us to put constrains on turbulence and the presence of cosmic rays in galaxy clusters by comparing in detail the induced radio emission in these simulations with observations.

Alejandro Esquivel

ICN-UNAM, Mexico

Title: Statistical studies of magnetic fields from observations

We use MDH simulations to produce synthetic observations and test some of the statistical methods that are useful to study magnetic turbulence in the ISM from observations. The simulations cover a wide range of turbulence regimes, ranging from sub-sonic to super-sonic as well as sub-Alfvnic and super-Alfvnic. We focus in particular in the probability distribution function and the anisotropy of maps of column density and velocity centroids. We found that the maps of velocity centroids are a promising tool to gauge the magnetization in the ISM.

Diego Falceta-Goncalves

EACH - Universidade de São Paulo, Brazil

Title: Recent achievements on KMHD and applications: from accretion disks to IGM

Collisionless plasmas are ubiquitous in the Universe. In general full kinetic equations are needed for a correct description of the physics in such environments. Fluid approximations are, at some special cases, valid. In this work we will present few applications of the CGL approximation for anisotropic pressure plasmas based on numerical simulations of turbulence, as well as cosmic ray acceleration.

Edith Falgarone

Paris Observatory & Ecole Normale Supérieure, France

Title: Magnetic fields and turbulence in molecular clouds

Molecular clouds are turbulent with very high Reynolds numbers. Observations carried out over a broad range of scale-sizes and in different large-scale environments are mandatory to provide useful insights into cloud turbulence. In particular, the turbulent velocity field of molecular clouds exhibits the statistical properties of space-time intermittency. New observational results will be discussed. They reveal the coupling between scales, the existence of coherent structures of intense velocity-shear and their link with the topology and intensity of the magnetic field. Their role in the formation of dense structures will be addressed.

Mario Flock

MPIA Heidelberg, Germany

Title: Accretion and Outflows in MRI turbulent Accretion Disks

The Magneto-rotational Instability is the most prominent process to enable viscous accretion of matter onto the star. We present full 2π 3D global stratified MHD proto-planetary disk models calculated with the Godunov code PLUTO. This state-of-art global simulation presents the physical properties which can be found primarily in ionized disks regions. In our zero-net flux magneto driven turbulent disk we show good agreement with the radial mass accretion flow with the standard viscous disk evolution. In our simulations we find no trace of meridional flows. We also present how to define the radial dependence of alpha stress and show indications for an MRI driven outflow.

Gustavo Guerrero

NORDITA, Sweden

Title: Current status in solar dynamo modeling

In this talk I will briefly review the current status of modelling of the solar dynamo. Pros and cons of the two different approaches for dynamo simulations - mean-field models and direct numerical simulations, in global or local domains will be discussed. Recent achievements in the understanding of the quenching mechanism and its relation with the magnetic helicity conservation, and also the possible role of phenomena like magnetic buoyancy or turbulent magnetic pumping in the solar dynamo will also be presented.

Michał Hanasz

Centre for Astronomy, Nicolaus Copernicus University, Poland

Title: Cosmic-Ray driven dynamo in galaxies

I am going to review recent developments of local and global, galactic-scale numerical models, of the Cosmic-Ray-driven dynamo, which was originally proposed by Parker (1992). The concept of Cosmic-Ray driven MHD dynamo relies on buoyancy forces induced by the presence of cosmic rays in the interstellar medium. The CR-driven dynamo models are realized by means of direct CR-MHD numerical simulations of the dynamics of interstellar medium, composed of gas, magnetic-field, and Cosmic Rays. It is assumed that Cosmic Rays are accelerated in randomly distributed supernova remnants, and that supernovae deposit small-scale, randomly oriented, dipolar magnetic-fields into the ISM. Numerical experiments show that galactic magnetic fields are amplified to the equipartition values on timescales comparable to the rotation period of the galaxy. The amplification process is associated with efficient conversion of small-scale magnetic fields of SN-remnants into the galactic-scale magnetic fields. The resulting magnetic field reveals a spiral structure in face-on views, and it resembles the observed X-shaped magnetic fields in edge-on galaxies.

Carl Heiles

University of California, Berkeley, USA

Title: The Fifth Phase of the Interstellar Medium as revealed by Faraday Rotation

The current view of the diffuse Interstellar Medium recognizes four major phases, two of which are almost fully ionized and two almost neutral. However, there lurks a fifth phase, which is partially ionized. It is not widely recognized, mainly because it's presence is hard to establish observationally. It is well represented by the Local Interstellar Clouds (LIC), which lie in the immediate vicinity of the Sun. With its partial ionization, the fifth phase can have a fairly large electron column density, and in combination with a typical interstellar magnetic field it can produce observable Faraday rotation. We show that in high-latitude regions, the Faraday Rotation Measures are dominated by morphological structures seen in interstellar gas, many of which seem to be this fifth phase.

Martin Huarte-Espinosa

University of Rochester, USA

Title: Laboratory experiments on jets

Astrophysical jets have been studied with observations, theoretical models and numerical simulations for decades. Recently, supersonic magnetized jets have been formed in laboratory experiments of high-energy density plasmas. I will review these studies and discuss the experimental setup that has been used to form millimeter-scale jets which are driven by strong toroidal magnetic fields in a MAGPIE generator. The extreme physical conditions of these experiments are such that they can be scaled to astrophysical scenarios. These laboratory jets can provide fundamental insights on the physics of magnetized plasma jets as well as constraints on current models of astrophysical jets. I also will discuss the connection between the laboratory jets and recent 3D-MHD numerical simulations of cooling Poynting flux dominated jets.

Tsuyoshi Inoue

Aoyama-Gakuin University, Japan

Title: Generation Turbulence and Magnetic Field Amplification behind Shock Wave in the ISM

It is widely known that the interstellar medium is a multi-phase medium with various densities. In this talk, based on the results of 3D MHD simulations by Inoue et al. (2009, 2011), it is shown that the propagation of a shock wave in such a multi-phase medium causes turbulence behind the shock wave. The turbulence is driven by so-called Richtmyer-Meshkov instability that is induced by the interaction between the shock and density inhomogeneity. In addition, the generated turbulence amplifies magnetic field through the action of turbulent dynamo. Such a generation of turbulence can be an origin of supersonic turbulence ubiquitously observed in interstellar clouds, and the magnetic field amplification by turbulence can explain strong magnetic field observed in a young supernova remnant RX J1713.7-3946 that is suggested to be interacting with molecular clouds.

Tess Jaffe

IRAP Toulouse, France

Title: The Magnetic Field in the Plane of the Galaxy

Studying the magnetic field in the plane of our own Galaxy has long been difficult due to degeneracies and a lack of data. This situation is now changing rapidly due to new ground- and space-based observations. I will describe how a combination of observations from radio to gamma-ray frequencies now allows us to perform more realistic modeling than has previously been possible of both the large-scale structure of the magnetic field and its small-scale turbulence. Current and future projects such as Fermi, Planck, and the SKA will give us an unprecedented opportunity to test theories of magnetic field generation in our own Galaxy.

Mika Juvela

University of Helsinki, Finland

Abstract Cold Cores as seen with Planck and Hershel

I will review the results from the ongoing programme Galactic Cold Cores where Planck and Herschel satellite data are being used to study the initial stages of the star formation process. I will also discuss the Planck potential for observations of polarized dust emission from these objects.

Michael Kachelriess

Dept. of Physics, NTNU, Norway

Title: Limits on the IGMF from observations of TeV blazars

I review different approaches to infer the properties of the intergalactic magnetic field (IGMF) from gamma-ray observations of blazars. In particular, I discuss the constraints on the IGMF resulting from the non-observation of certain sources by Fermi-LAT which show that a relatively strong magnetic field fills more than 60% of space, favouring the primordial origin of the IGMF. Finally, I review briefly how these results affect different generation mechanisms from particle physics.

Grzegorz Kowal

University of Sao Paulo, Brazil

Title: Particle Acceleration in Magnetic Reconnection and Turbulent Sites

The magnetic fields can change their topology through a process known as magnetic reconnection. This process in not only important for understanding the origin and evolution of the large-scale magnetic field, but is seen as a possibly efficient particle accelerator producing cosmic rays mainly through the first order Fermi process. In this work we study the properties of particle acceleration inserted in reconnection zones and show that the velocity component parallel to the magnetic field of test particles inserted in magnetohydrodynamic (MHD) domains of reconnection without including kinetic effects, such as pressure anisotropy, the Hall term, or anomalous effects, increases exponentially. Also, the acceleration of the perpendicular component is always possible in such models. We find that within contracting magnetic islands or current sheets the particles accelerate predominantly through the first order Fermi process, as previously described, while outside the current sheets and islands the particles experience mostly drift acceleration due to magnetic fields gradients. Considering two dimensional MHD models without a guide field, we find that the parallel acceleration stops at some level. This saturation effect is however removed in the presence of an out-of-plane guide field or in three dimensional models. Therefore, we stress the importance of the guide field and fully three dimensional studies for a complete understanding of the process of particle acceleration in astrophysical reconnection environments.

Alex Lazarian

UW Madison, USA

Title: Power of Magnetic Reconnection

Astrophysical fluids are generically turbulent and this turbulent state induces fast magnetic reconnection. I shall discuss the theory and implications of reconnection for astrophysical fluids from interstellar medium to those in solar atmosphere. I shall show that accounting for magnetic reconnection changes major astrophysical paradigms including that of star formation. In particular, magnetic diffusion induced by reconnection, termed "reconnection diffusion", induces efficient removal of magnetic flux from star forming cores as well as heat advection in magnetized plasmas. At the same time, magnetic field lines shrinking after reconnection accelerate energetic particles. These manifestations of reconnection explain a number of existing

astrophysical puzzles, but should be treated as only initial attempts to explore the vast field of the reconnection implications.

Antonio Mario Magalhaes

IAG - Univ. Sao Paulo, Brazil

Title: Optical/near-IR observations and the connection to sub-mm Surveys

We will discuss results of optical/NIR starlight polarization data in several environments, as well as point out the interrelation between such data and those of past, current and upcoming sub-mm observations.

We first explore the relationship between the magnetic field in the local Interstellar Medium (ISM) and the heliosphere. We then discuss the potential for optical/NIR and sub-mm data for exploring the magnetic field structure in the Galaxy at small and large scales and at high Galactic latitudes. We also discuss the nature of the SMC dust and the magnetic field structure of the Galaxy. We then look into intriguing data concerning the relationship between the ambient magnetic field direction and that of disks around young stars in the Galaxy.

We conclude by describing SOUTH POL, an upcoming optical imaging polarimetry survey of the southern sky.

Katarzyna Otmianowska-Mazur

Astronomical Observatory of the Jagiellonian University, Poland

Title: Cosmic ray driven dynamo in barred and dwarf irregular galaxies. 3D numerical global simulations

We present three-dimensional global numerical simulations of the cosmic ray driven dynamo in barred and dwarf irregular galaxies. In both types of galaxies the radio observations show the presence of the ordered magnetic fields around several mG. We study the evolution of the interstellar medium of the barred galaxy in the presence of non-axisymmetric components of the gravitational potential, i.e. the bar. In the case of irregular galaxy we adopt the slow rotation curve of 25km/s. The three main component of the interstellar medium, i.e. magnetic fields, gas and cosmic rays are dynamically coupled. The magnetohydrodynamical dynamo is driven by cosmic rays, which are continuously supplied to the disk by supernova (SN) remnants. Additionally each SN explosion is a localized source of magnetic vector potentials. In all models we assume that 10% of 1051erg of SN kinetic energy output is converted into CR energy, while the thermal energy from SNe explosions is neglected. The simulations are performed with the GODUNOV code. To compare our results directly with the observed properties of galaxies we construct realistic maps of high-frequency (Faraday rotation-free) polarized radio emission on the basis of the simulated magnetic fields. The model entertain for the effects of projection and limited resolution.

The main result is that CR driven dynamo can amplify weak magnetic fields up to several mG within few Gyr in barred galaxies. Additionally, the modeled magnetic field configuration resembles maps of the polarized intensity observed in barred galaxies, explaining additionally the process of shifting of magnetic arms into inter-arm regions.

In the case of dwarf irregular galaxies despite the adverse conditions (low mass, slow rotation) the dynamo can operate. Observations and numerics show some indication for some dynamo thresholds - needs further deep investigation. SFR/SNR is the key parameter, but to high destroys the rotation: but we need both to operate the large scale dynamo. Possible magnetization of the IGM.

Dmitri Pogosyan
University of Alberta, Canada

Title: Magnetic turbulence from synchrotron intensity fluctuations

In this talk I will discuss how synchrotron emission reflects the statistically anisortropic nature of the magnetic turbulence and what we can be learn about the turbulence from studying correlation features of synchrotron intensity fluctuations in detail.

Alessandro Retinò

Laboratoire de Physique des Plasmas - CNRS, France

Title: In situ measurements of magnetic reconnection in the near-Earth space

Magnetic reconnection is a universal process occurring at current sheets forming in astrophysical plasmas, where small-scale changes in the topology of the magnetic field lead to large-scale plasma transport, acceleration of plasma jets, plasma heating and non-thermal particle acceleration. Reconnection is observed in the solar corona, in the solar wind, in planetary magnetospheres and is considered to play an important role in distant objects such as the interstellar medium and accretion disks. Despite of many observations, however, a number of key issues of reconnection are yet poorly understood. Among them, the microphysics, the mechanisms of non-thermal particle acceleration and the relationship with turbulence are some of the most important. Solving such issues requires in situ observations of particle distributions functions and electromagnetic fields in reconnection regions, that are only possible in the solar system through spacecraft measurements. Here we present some recent examples of in situ observations, focusing on the near-Earth space where multi-point measurements are available.

Dominik Schleicher

University of Goettingen, Germany

Title: On the effects of magnetic fields on the EoR and protogalaxies

The high-redshift Universe provides a potentially relevant probe regarding the origin of magnetic fields. If strong primordial fields were present, they had a significant influence on reionization and the formation of the first structures. Based on the observed reionization optical depth and the Gunn-Peterson troughs, one can thus establish an upper limit of a few nG (co-moving) for the primordial field strength. In the opposite limiting case of initially weak fields, rapid amplification is possible in the presence of turbulence. Using numerical MHD simulations including self-gravity, we demonstrate that the turbulent dynamo works even during gravitational collapse. As a result, magnetic fields are likely to be important already during primordial star formation.

Reinhard Schlickeiser

Ruhr-University Bochum, Germany

Title: Cosmic ray propagation in nonuniform turbulent magnetic fields

The derivation of the cosmic ray Fokker-Planck transport equation in turbulent nonuniform magnetic fields is reviewed, explaining the physical assumptions underlying the derived Fokker-Planck coe cients and relating the basic assumptions of linear and nonlinear transport theories. The non-uniformity of the large-scale guide magnetic fields provides via the mirror force additional adiabatic focusing of particles in position and momentum space. The diff usion approximation in the weak adiabatic focusing limit yields the modified diff usion-convection transport equation with new convection terms in the 4-dimensional momentum-position (p, X, Y, z) space. The geometry and nature of the MHD fluctuations determine the individual transport terms. Particularly important is the knowledge of the cross helicity state of MHD turbulence in cosmic sources.

The modified diff usion-convection transport equation is more general than transport equations solved by the GALPROP or other cosmic ray transport codes. In particular, it implies new physical processes such as focused acceleration/deceleration and charge-sign dependent perpendicular convective and diffusive spatial transport terms. Focused acceleration/deceleration could enhance/prevent diff usive shock acceleration in a diverging upstream magnetic field, depending on the generation of upstream MHD turbulence.

Kazunari Shibata

Kwasan and Hida Observatories, Kyoto University, Japan

Title: Solar and Stellar Flares - from nanoflares to superflares

Recent space solar observatories such as Hinode, Stereo, SDO are revealing ubiquitous nanoflares, waves and jets in the solar atmosphere. Though physics of smallest nanoflares are still puzzling, it has been found that unified model of flares based on reconnection mechanism can be applied to wide range of flares from nanoflares to the largest flares on the Sun. Stellar observations revealed "superflares" which are much more energetic than the largest solar flares on solar type stars. Here we will discuss recent observations of superflares and their physics, and impact on the planets as well as the Earth.

Marian Soida

Astronomical Observatory of the Jagiellonian University, Poland

Title: Observations of magnetic fields in galaxies

The easiest way to obtain information of magnetic field in the interstellar medium is to detect the synchrotron radiation of cosmic-ray electrons spiraling around magnetic field lines. Measurements of total nonthermal flux of radio emission gives the total magnetic field strength. The polarized part of that emission determines the ordered magnetic field in scales larger than the resolution of observations. Rotation measure determination allow us to estimate the regularity of the magnetic field, and provide information of the field component along the line of sight. Spiral galaxies are reach of cosmic ray electrons, and the interstellar medium is magnetized. The average total magnetic field strength reaches a few tens of micro G, its regular (in kiloparsec scale) component reaches 10 micro G. Magnetic field of similar order is detected also in flocculent, dwarf, and some irregular galaxies. Its regularity in such galaxies requires an amplification mechanism working effectively in such objects. Studying magnetic field distribution and configuration in perturbed galaxies allows us to discriminate between various interaction scenarios. The observations of polarized radio emission is also a very effective tool to detect even weak interaction.

Fabrizio Tavecchio

INAF-Oss. Astron. di Brera, Italy

Title: IGM magnetic field measurements from FERMI data

I will give a review of the current status of the estimates of the IGMF using TeV blazars, discussing several critical issues related to the method.

Enrique Vazquez-Semadeni

Centro de Radioastronomia y Astrofisica, UNAM, Mexico

Title: Molecular Cloud Evolution IV. Magnetic Fields and Ambipolar Diffusion

We investigate the formation and evolution of giant molecular clouds (GMCs) by the collision of convergent warm neutral medium (WNM) streams in the interstellar medium, in the presence of magnetic fields and ambipolar diffusion (AD), focusing on the evolution of the star formation rate (SFR) and efficiency (SFE), as well as of the mass-to-magnetic-flux ratio (M2FR) in the forming clouds. Our main results are: 1) A suite of simulations with global M2FRs 1.4, 0.9 and 0.7 spans a continuum of SFEs ranging from 35to 3%. 2) The moderately subcritical run with M2FR=0.7 entirely shuts off its star formation activity after 4 Myr. 3) The fragmentation of the cloud by the combined action of thermal, gravitational, and nonlinear thin-shell instabilities produces dense clumps of high M2FR and low density patches of low M2FR. Thus, the M2FR is a highly fluctuating function of position, with the 3-sigma range spanning over one and a half dex in the M2FR. 4) We report the occurrence of an unexpected phenomenon of buoyancy of the low-M2FR regions within the gravitationally-contracting clouds.

Hoang Thiem

University of Wisconsin-Madison, USA

Title: Mapping Magnetic Fields Using Aligned Grains

Studies of magnetic fields with starlight polarization and emission from aligned grains provide one of the major sources of the information about magnetic fields in star formation regions and in the diffuse ISM. I shall discuss the quantitative theory of alignment based on radiative torques. In particularly, I discuss a simple analytical model (AMO) that can reproduce well generic properties of radiative torques obtained for irregular shapes using Discrete Dipole Approximation code. I shall show that RATs induce alignment with grain longer axes perpendicular to ambient magnetic field, similar to Davis-Greenstein paramagnetic mechanism, though RATs does not involve paramagnetic dissipation. I shall discuss the RAT alignment by complex radiation interstellar field and provide the comparison of the theoretical predictions with observations. I shall show how the new theory can be used to improve the reliability of the polarimetric studies of magnetic fields.

Huirong Yan
KIAA, Peking Univ., China

Title: Cosmic Ray transport and acceleration in MHD turbulence

Cosmic ray (CR) transport and acceleration is essential for many astrophysical problems, e.g., CMB foreground, ionization of molecular clouds and all high energy phenomena. Recent advances in MHD turbulence call for revisions in the paradigm of cosmic ray transport. We use the models of magnetohydrodynamic turbulence that were tested in numerical simulation, in which turbulence is injected at large scale and cascades to to small scales. I shall address the issue of the transport of CRs, both parallel and perpendicular to the magnetic field and show that the issue of cosmic ray subdiffusion is only important for restricted cases when the ambient turbulence is far from that suggested by numerical simulations. I shall demonstrate compressible fast modes are dominant cosmic ray scatterer from both quasilinear and nonlinear calculations. I also shall discuss the nonlinear growth of kinetic gyroresonance instability of cosmic rays induced by large scale compressible turbulence. This feedback of cosmic rays on turbulence was demonstrated an important scattering mechanism in addition to direct interaction with the compressible turbulence. The feedback on large scale turbulence shall be also addressed. Implications for solar flares and supernova resonants are discussed.

Part II

Abstracts
Contributed talks

Takuya Akahori

Research Institute of Basic Science, Chungnam National University, Republic of Korea

Title: Faraday Rotation Measure due to the Intergalactic Magnetic Field

The nature and origin of the intergalactic magnetic field (IGMF) are an outstanding problem of cosmology, yet they are not well understood. We investigated the Faraday rotation measure (RM) due to the IGMF in filaments of galaxies, using a model IGMF based on the small-scale turbulence dynamo. As the RM due to the IGMF in filaments has not yet been detected, our model predicts that the root mean square value of RM across single filament in the present-day local universe would be ~ 1 rad m^{-2} and the RM would reach up to several rad m^{-2} against radio sources of redshift z=5. We also found that the probability distribution function of —RM— follows the log-normal distribution. The power spectrum has a broad plateau over angular scales of ~ 1–$0.1°$ with a peak around $\sim 0.15°$, and the second order structure function has a flat profile in angular separations of $> 0.2°$. These results could be tested with the Square Kilometer Array (SKA) and SKA pathfinders. We also present the Galactic foreground of the RM based on a model incorporating the magnetohydrodynamic turbulence in the Galactic halo. We finally demonstrate how we can separate the Galactic foreground from the extragalactic RM using a filtering technique.

Felipe Alves

Argelander-Institut für Astronomie - Universität Bonn, Germany

Title: Infrared and Optical Polarimetry around the Low-mass Star-forming Region NGC 1333 IRAS 4A

We performed J- and R-band linear polarimetry with the 4.2 m William Herschel Telescope at the Observatorio del Roque de los Muchachos and with the 1.6 m telescope at the Observatório do Pico dos Dias, respectively, to derive the magnetic field geometry of the diffuse molecular cloud surrounding the embedded protostellar system NGC 1333 IRAS 4A. We obtained interstellar polarization data for about three dozen stars. The distribution of polarization position angles has low dispersion and suggests the existence of an ordered magnetic field component at physical scales larger than the protostar. Some of the observed stars present intrinsic polarization and evidence of being young stellar objects. The estimated mean orientation of the interstellar magnetic field as derived from these data is almost perpendicular to the main direction of the magnetic field associated with the dense molecular envelope around IRAS 4A. Since the distribution of the CO emission in

NGC 1333 indicates that the diffuse molecular gas has a multi-layered structure, we suggest that the observed polarization position angles are caused by the superposed projection of different magnetic field components along the line of sight.

Robi Banerjee

University of Hamburg, Germany

Title: Molecular cloud formation out of magnetized ISM

We report on the results from our numerical simulations of molecular cloud formation by colliding streams of warm neutral gas. We find that super-critical streams proceed directly to collapse, while sub-critical streams first contract and then re-expand, oscillating on the scale of tens of Myr. Our simulations with various initial magnetic field strengths show that only supercritical or marginal critical streams lead to reasonable star forming sites. This result is not altered by ambipolar diffusion.

Jonathan Braithwaite

University of Bonn, Germany

Title: Why do massive stars have such weak magnetic fields?

In the ISM from which stars form, magnetic energy is comparable to thermal and kinetic. Once a star has formed, however, the magnetic energy is many orders of magnitude below equipartition with the gravitational, thermal and usually also the rotational energies. I present a natural explanation for this in terms of magnetic helicity conservation during core collapse, while magnetic energy and flux can be destroyed. In addition, I touch on processes such as meridional circulation and their likely influence on what magnetic field is left over from formation.

Blakesley Burkhart

UW Madison, USA

Title: Measureing MHD Turbulence in Polarization Maps

We studied images of linearly polarized radio emission from the interstellar medium (ISM) by taking the gradient of the linear polarization (Stokes P) maps of both observational data from the Southern Galactic Plane Survey (SGPS) and isothermal simulations of MHD turbulence. In both the observations and simulations, a complex network of filamentary canals are observed, which could be due to shock fronts or turbulent fluctuations in the magnetic field or electron density along the LOS. We show that the canals can be produced by both shocks and random subsonic fluctuations of MHD turbulence, however they show different distributions as well as different morphology. In order to characterize these differences we use the topology tool known as a Genus curve as well as PDF descriptors such as skewness and kurtosis. We find that higher skewness and kurtosis correspond to cases of ∇P with larger Mach numbers, even when convolved with the telescope beam. The topology of supersonic filaments observed in ∇P is more swisscheese like compared to subsonic cases. We apply these techniques to 1.4Ghz data of the Southern Galactic Plane Survey (SGPS) and find that the structures here match subsonic to transsonic type turbulence, which confirms past studies on the warm ionized and neutral interstellar medium.

Julius Donnert

Max Planck Institute for Astrophysics, Germany

Title: CR Reacceleration in Cluster Simulations

Radio Halos are Mpc sized diffuse objects commonly found in merging clusters. Their size poses the problem on maintaining a cluster-wide CR electron population, while injection from shock and galacitic outflows is localised. Hadronic models solve this problem with in-situ injection of CR electrons through hadronic interactions of long lived CR protons with the ICM. Over the past years it has become clear that these models are disfavoured by observations. Reacceleration models are predicted to elegantly solve many problems encountered with other models, at the cost of increased complexity.

We use a novel implementation of a Fokker-Planck solver to follow the reacceleration of CR electrons in postprocessing to a direct simulation of a cluster merger. We use hadronic injection of CR electrons to seed the population. We find that this mechanism does not only produce a bimodality, but also gives flatter surface brightness profiles, broken radio spectra and CR proton densities compatible with recent gamma-ray observations.

Robert Drzazga

Astronomical Observatory of the Jagiellonian University, Poland

Title: Magnetic field evolution in interacting galaxies

Violent gravitational interactions can change morphologies of galaxies and by the way of merging, transform them into elliptical galaxies. We investigated how such interactions affect the evolution of galactic magnetic fields.

For this purpose we selected 16 systems of interacting galaxies with available VLA radio data. Their radio emission and estimated magnetic field strengths were estimated and compared in systematic manner with the star-forming activity, far-infrared emission, and the stage of tidal interaction.

Interestingly enough, the mean of total magnetic field strength is larger for our sample of interacting galaxies than for the non-interacting objects, and this seems to be caused by enhanced production of random magnetic fields.

For the first time, we show a global evolution of magnetic fields with the advance of interaction process. According to our study the main production of magnetic fields terminates somewhere close to the nuclear coalescence, after which magnetic field diffuses. We found that the magnetic field strength for whole galaxies is weakly affected by the star formation rate.

Moreover, we show that the morphological distortions visible in the radio total and polarized emission do not depend statistically on the global or local SFRs, while they do increase (especially in the polarization) with the advance of interaction. The radio-far-infrared relations that we constructed for interacting and non-interacting galaxies display similar balance of the generation of cosmic rays and magnetic fields with the production of the thermal energy and dust radiation.

In my talk I will also show that the polarized emission could be yet another indicator of an ongoing galaxy merging process. I will discuss the role of interacting objects in magnetization of intergalactic medium as well as the connection of mergers with observed ultra high energy cosmic rays (UHECRs).

Detlef Elstner

Leibniz Institut für Astrophysik Potsdam, Germany

Title: The role of starformation for the galactic dynamo.

Magnetic field amplification by a dynamo seen in direct local box simulations of SN driven turbulence in the ISM agree very well with a mean field description. We derive scaling laws for the turbulent transport coefficients in dependence of the SN rate, density and rotation. This gives the input for global simulations of regular magnetic fields in galaxies within a mean field model. Using a Kennicutt-Scmmidt relation between starformation and density we can reduce the free parameters for global models to the prescription of density and rotational velocity. Simulations of mean magnetic field for different rotation curves and radial density distributions will be presented.

Natalie Gandilo

University of Toronto, Canada

Title: The Balloon-borne Large Aperture Submillimeter Telescope for Polarimetry

The Balloon-borne Large Aperture Submillimeter Telescope for Polarimetry (BLAST-Pol) is a 1.8-m telescope that observes polarized dust emission at 250, 350, and 500 microns, with a resolution of 30" at 250 microns. BLAST-Pol was designed to map magnetic fields over entire Giant Molecular Clouds, with sufficient resolution to trace these fields into cloud cores and dense filaments. In January 2011, BLAST-Pol completed a successful 9.5-day flight over Antarctica. Eight science targets were observed, and data analysis is under way. BLAST-Pol maps will provide an excellent dataset for studying the role of magnetic fields in star formation.

Joern Geisbuesch

HIA-DRAO, Canada

Title: Studying the Galactic Magnetic Field with the CGPS Survey

The Canadian Galactic Plane Survey (CGPS) is a major effort to study and understand the Magnetic Field and Interstellar Medium in our Galaxy. The CGPS covers nearly the entire Galactic plane visible from DRAO (DEC

¿ 19 degrees) at arcminute resolution in the radio. The Milky Way is mapped in continuum and polarized emission at 1420 MHz. Thus the CGPS and its (recent) extensions are highly valuable for determining the structure of the Galactic Magnetic Field over a large range of spatial scales. The CGPS allows us to study magnetic fields in discrete Galactic objects as well as the Milky Way's diffuse synchrotron emission. We present the latest results from the CGPS. Some of these are obtained from previous observations by improved data analysis. Also ongoing and planned extensions and their preliminary results are shown.

Hans (J.P.) Goedbloed

FOM-Institute for Plasma Physics, the Netherlands

Title: MHD instabilities of accretion disks and jets – a new spectral theory of rotating plasmas –

The theory of magnetohydrodynamic stability of rotating plasmas, such as accretion disks and jets about compact objects, has severely suffered from the wide spread belief that this theory necessarily involves non-self adjoint operators. In the new textbook on Advanced Magnetohydrodynamics [1], and a review paper on the topic [2], it is shown that, on the contrary, the physics just involves operators that are self-adjoint, viz. the generalized force and the Doppler–Coriolis shift operator. The central problem is that these operators occur in a *quadratic eigenvalue problem*, with complex eigenvalues. Exploiting energy conservation, this problem is solved by first constructing the *solution paths* (curves in the complex ω-plane on which the eigenvalues must be situated), and next computing the complex modes on them by means of monotonicity of the *alternator* (a powerful new way of counting in the complex plane).

Thus, for the first time, knowledge of the full complex spectrum of modes together with a connecting structure is obtained. This theory is applied to compute the complete spectrum of waves and instabilities of a thin accretion disk. This includes not only the magneto-rotational instabilities but also intricate new instabilities in the frequency range of the Alfv'en and slow magneto-sonic continua. The stability of rotating magnetized jets is studied by the same method, obtaining specific stability criteria in terms of the helicities of the magnetic field and of the flow velocity that may be compared with observable parameters of the jets.

[1] Hans Goedbloed, Rony Keppens and Stefaan Poedts, *Advanced Magnetohydrodynamics* (Cambridge University Press, 2010), Chaps. 12 and 13.

[2] J. P. Goedbloed, *Plasma Phys. Contr. Fusion*, to appear (2011).

[Special issue: Invited papers from the ICPP-LAWPP, 8–13 August, 2010, Santiago de Chile.];

Uli Klein

AIfA, Germany

Title: A New German Research Unit: Magnetisation of Interstellar and Intergalactic Media The Prospects of Low-Frequency Radio Observations

I will brief report on the Research Unit entitled "Magnetisation of Interstellar and Intergalactic Media. The Prospects of Low-Frequency Radio Observations", which is being funded since mid 2010. In this joint effort, astrophysicists from eight German research institutes investigate magnetic fields on scales from supernova remnants to clusters of galaxies. While on the observational side these efforts are strengthened by penetrating into the low-frequency radio regime, with LOFAR playing a crucial role. The projects are backed-up by theoretical studies involving in particular numerical MHD simulations.

Patrick Koch

ASIAA, Taiwan

Title: Magnetic Field Strength Maps for Molecular Clouds: A New Method Based on a Polarization - Intensity Gradient Relation and its Implications on Mass-to-Flux Ratio and Star Formation Efficiency

The magnetic field directions derived from the thermal dust polarization emission in molecular clouds tend to align with the dust emission gradient directions. We propose a new method, which – in the framework of ideal magneto-hydrodynamics (MHD) – connects the measured angle between magnetic field and emission gradient directions to the field strength. In particular, this method leads to maps of position-dependent magnetic field strength estimates. As a further important outcome of this technique, the local significance of the magnetic field force compared to the gravity force can be quantified in a model-independent way, from measured angles only. The technique is applied to a sequence of increasingly higher resolution data from JCMT, BIMA and SMA in the high-mass star formation region W51. These data trace the fragmentation process from the largest parent cloud ($\sim$ 2 pc) down to the collapsing core e2 ($\sim$ 60 mpc). All three data sets clearly show regions with distinct features in the field-to-gravity force ratio. Azimuthally averaged radial profiles reveal a transition from a field dominance at larger distances to a gravity dominance closer to the emission peaks. Normalizing these field-to-gravity force ratios to a characteristic core scale demonstrates self-similar scalings in the fragmentation from the initial parent cloud to the large-scale envelope and to the collapsing core. Furthermore, the polarization intensity-gradient method is linked to the mass-to-flux ratio, providing a new approach to estimate the latter one without mass and field strength inputs. A transition from a magnetically supercritical to a subcritical state is found. Finally, based on the measured radius-dependent field-to-gravity force ratio we derive a modified star formation efficiency with a diluted gravity force. Compared to a standard (free-fall) efficiency, the observed field is capable of reducing the efficiency down to 10% or less.

(Patrick M.Koch, Ya-Wen Tang & Paul T.P.Ho; ApJ, 2010,2011)

Krause Marita

MPIfR, Germany

Title: Magnetic fields and star formation as seen in edge-on galaxies

The observational results of the magnetic field structure in edge-on galaxies will be summarized, including recent results for NGC4631. I will discuss the possible influence of star formation on the magnetic field strength, uniformity and structure and then focus on the interplay of galactic wind, magnetic field and dynamo action.

Shih-Ping Lai

National Tsing Hua University, Taiwan

Title: Discovery of Toroidal Magnetic Fields around Protostars in NGC1333 IRAS 4A from Dust Polarization Measurements

We present the first map of the toroidal magnetic field structure in a disk around protostars. The magnetic field in the low-mass protostellar core NGC1333 IRAS4A (hereafter IRAS4A) have an hourglass morphology in the scale of few thousands AU (Girart et al. 2006, Science). Here we further explore the magnetic field structure within the central 200 AU region of

IRAS4A with the sub-arcsecond resolution dust polarization SMA data at 345 GHz. Our results reveal that except for the regions perpendicular to the center of IRAS4A1, the magnetic field appears to be parallel to the disk that contains the protostellar binary, IRAS4A1 and IRAS4A2, and perpendicular to the large scale hourglass structure. This field geometry is in agreement with the expectation of star formation models with ideal MHD condition; that is, if the magnetic field were frozen in the accreting material, it would be dragged into the direction parallel to the disk around the protostar by the rotation of the disk.

Marcia Leao

IAG-USP, Brazil

Title: Diffusion of magnetic fields in molecular clouds by turbulent reconnection

It is well known that star formation occurs in dense globule-like regions inside giant molecular clouds (GMC's, Blitz (1993); Williams et al. (2000)). The formation of structures appears to be related to compression caused by the continuous injection of turbulent energy in the clouds by internal or external sources (e.g., Leão et al. 2009). Even if the turbulence is **globally** strong enough for supporting the cloud against gravity (Klessen et al. 2000; Mac Low & Klessen 2004; Vázquez-Semadeni et al. 2005), it could cause the collapse in small scales, by generating high density regions in both magnetized (Heitsch et al. 2001; Nakamura & Li 2005) and non-magnetized medium (Klessen et al. 2000; Elmegreen & Scalo 2004). In this work, we are investigating the injection of turbulent energy in molecular clouds and globules, without specifying the type of physical mechanism responsible for this turbulence. The **aim** of this study is to analyze the conditions under which a cloud or globule supported against gravity by magnetic field and MHD turbulence can be led to the collapse. For the collapse to occur, there must be an efficient diffusion of the magnetic field **to outside of** the cloud, otherwise this can prevent the collapse. **In this study** we verify the efficiency of the mechanism of diffusive transport of magnetic flux by turbulent fast magnetic reconnection originally proposed by Lazarian (2005) and successfully tested numerically Santos-Lima et al. (2010) **for cylindric clouds without self-gravity**. **In this work, we performed** three-dimensional simulations of spherical clouds with self-gravity and an external gravitational potential due to embedded stars, initially immersed in a uniform magnetic field. We employed a grid based Godunov-MHD code (Kowal et al. 2007) and started with clouds out of the equilibrium with the external gravitational field. Then turbulence was injected in the system and it was left to evolve. We found that for typical conditions of the molecular clouds, transonic and super-Alfvenic turbulence can induce turbulent reconnection transport of magnetic field to the outskirts of the cloud, therefore decoupling the magnetic flux from the inner denser regions of the cloud and allowing the gravitational collapse of its core.

Mami Machida

Department of Physics, Kyushu University, Japan

Title: Quasi-periodic Galactic Dynamo obtained from 3D MHD simulations

We present the results of global three-dimensional magnetohydrodynamic simulations of dynamo activities in galactic gas disks. The simulation model is the same as that in Nishikori et al. (2006) except that new simulations do not assume equatorial symmetry. We obtained numerical results indicating the growth of non-symmetric structure with respect to the equatorial plane. As the magneto-rotational instability (MRI) grows, averaged magnetic fields are amplified until the magnetic pressure becomes as large as 10% of the gas pressure. The dynamo activity is driven by the buoyant escapes of the magnetic flux from the gaseous disk, which takes place when the plasma $\beta(\beta = p_{gas}/p_{mag})$ becomes less than 5. The timescale of the magnetic field flotation is about 10 rotation period at that radius which corresponded to the growth timescale of MRI. Numerical results indicate that the azimuthal magnetic fields change direction quasi-periodically and that the disk changes between symmetric state and anti-symmetric state. The equatorial symmetry changes due to the topological change of magnetic fields between the dipole magnetic fields and quadrupole magnetic fields. We also reproduced the sky distribution of the Rotation Measures (RMs) obtained from numerical results. The all-sky distribution of RMs seems to be consistent with observation.

Guillaume Molodij

Observatoire de Paris, France

Title: Multi-wavelength observations to understand the solar magnetic activity and its feedback on the interplanetary medium

Violent phenomena resulting from the magnetic activity of the Sun are responsible for non-recurrent disturbances in the interplanetary medium and interact with the Earth magnetosphere to cause severe geo-effective storms. During the last maximum of the Solar Cycle (23), active regions produced large numbers of X-class flares and coronal mass ejections. Multi-wavelength observations show that those events are associated to magnetic cloud formation in the interplanetary medium. In particular, the Halloween active region NOAA 10501 was associated to the most geo-effective magnetic cloud of the cycle. To understand the underlying process, a detailed multi-wavelength analysis is performed to precisely identify the solar sources of coronal mass ejections and magnetic clouds, and to derive the continuous emerging magnetic flux coming from the active region that shows complex topology with multiple domains of different magnetic helicity. A possible interpretation is that the emergence of the new flux with a large twist has injected magnetic helicity in the complex active region to induce shearing and stress in the magnetic field. This consequently drives a large-scale instability of the magnetic configuration leading to flares, filament eruptions, coronal mass ejections (CMEs), and then interplanetary coronal mass ejections (ICMEs).

David Mulcahy

MPIfR, Germany

Title: Searching for Magnetic Fields at Low Frequencies: Early Observations with LOFAR on M51 and NGC4631

This talk will highlight the recent progress made by the LOFAR Magnetism Key Science Project (MKSP) team whose objective is to study galactic and extragalactic magnetic fields through observing total and polarized radio synchrotron emission at low frequencies. Results of recent observations of M51 and NGC4631 with LOFAR HBA (110MHz-250MHz) will be presented as well as results from the observation of the pulsar PSR J0218+4232 where polarization was detected.This is important as polarimetry with LOFAR will allow the investigation of very small Faraday rotation measures and therefore very weak magnetic field strengths.

Maxim Reshetnyak

PhD., D.Sc., Russia

Title: Compressibility and helicity in geodynamo

Planetary magnetism is a subject of the dynamo theory. Specific of planetary dynamo is a strong nonlinearity caused with a high ratio of the magnetic to kinetic energies. The reason of the observed superequipartition state is a magnetostrophic balance, which proposes importance of the Coriolice and Lorentz forces. The first successful geodynamo models [1] included induction equation for the magnetic field as well as the Boussinesq-like equations for the thermal convection. The incompressible assumption was supported by the fact, that for the liquid iron core density drop in the radial direction is known to be of order 20%. These models describe many observed features of the planetary magnetic field. The further step to take into account compressibility of the core improved our understanding of the thermodynamics of the core [2] and started new generation of the geodynamo models. However, up to know these sophisticated models are not too popular because the resulted magnetic field at the surface of the Earth is very similar to that one in the Boussinesq models. Even it is not true it is not obvious what is the reason of this difference. At the same time it is clear that assumption on incompressibility prohibits generation of the mean kinetic helicity, which is responsible for existence of the large-scale magnetic fields, in a traditional in astrophysics way [3]. It appears, that cyclonic convection in the Earth's core [4] produces different helicity distribution compared to that one in the Parker'scenario. Here we extrapolate results of the 3D simulations to the Earth's parameters and show, that compressibility of the liquid core can be quite important for the magnetic field generation.

[**1**] Glatzmaier, G.A. Roberts, P.H. A three-dimension self-consistent computer simulation of a geomagnetic field reversal. Nature. 1995. **377**. 203–209.

[**2**] Glatzmaier, G.A. Roberts, P.H. An anelastic evolutionary geodynamo simulation driven by compositional and thermal convection. Physica D. 1996. **97**. 81–94.

[**3**] Parker, E. N. Hydromagnetic dynamo models. Astrophys. J. 1955. **122**. 293–314.

[**4**] Busse, F. H. Generation of planetary magnetism by convection. Phys. Earth Planet. Int. 1976. **12**. 350–358.

Reinaldo Santos Lima

University of Sao Paulo, Brazil

Title: Simulating the evolution of magnetic fields in the intra-cluster and intergalactic medium using a Kinetic MHD model

Estimates based on observational data reveal that the gas of the intergalactic (IGM) and intra-cluster medium (ICM) is weakly collisional. Therefore, using the standard magnetohydrodynamic (MHD) model for describing these kind of environments is poorly justified. In collisionless plasmas, the microscopic velocity distribution of the particles is not isotropic, and it gives rise to kinetic effects on the dynamical scales. These kinetic effects can have important effects on the turbulence and structure formation both in the IGM and ICM, as well as on the amplification and maintenance of the cosmic magnetic fields. It is possible to formulate fluid models for collisonless or weakly collisional gas by introducing modifications in the MHD equations. These models are often referred as kinetic MHD (KMHD). Using a KMHD model based on the so called CGL-closure, which allows the adiabatic evolution of the two components of the pressure tensor (i.e., the parallel and the perpendicular components with respect to the local magnetic field), we performed 3D numerical simulations of forced turbulence in the ICM in order to study the amplification of an initially weak seed magnetic field. We have found that a necessary condition for the magnetic field amplification to work is to impose limits to the anisotropy of the pressure. We have also found that the growth rate of the magnetic energy by the turbulence is comparable to that of the ordinary MHD turbulent dynamo, but the magnetic energy saturates at a level which is much smaller than that of the MHD case. In the case of an isothermal KMHD approach the success of the turbulent dynamo amplification depends critically on the regime of anisotropy. These results indicate that the amplification of magnetic fields in the ICM and IGM by turbulence is very limited when kinetic effects are important.

Ya-Wen Tang

Laboratoire d'Astrophysique de Bordeaux, France; CNRS, France

Title: Thermal Dust Polarization Toward Star Formation Regions – An Evolving Role of the Magnetic Field from Large to Small Scales from High Angular Resolution Observations

Authors: Ya-Wen Tang, Paul T. P. Ho and Patrick M. Koch (ApJ 2009, 2010)

The influence of the magnetic (B) field in star forming molecular clouds is not well understood because of the limitations of observational methods and instruments. One of the methods to probe the morphology of the B field projected in the plane of sky (B_bot) is through polarization of thermal dust continuum. The dust grains are believed to align with the B fields with their minor axes in most of the cases. In the submillimeter regime, the emission is optically thin and is able to trace the properties of the dense regions. We will present our observational results in two massive cores, Orion BN/KL and W51 e2/e8, with angular resolutions up to 1". In the closest massive star forming core Orion BN/KL, we find that the B field lines have an azimuthal symmetry with its center 2.5" west to the origin of the large scale ($\sim$ 0.2 pc) explosive outflows. This suggests that the B field lines in Orion BN/KL might be correlated with the explosive event. On a larger 0.5 pc scale, the B field is found to be uniform and dominant over turbulence. Such differences in the B field morphologies between small and large scales are also found in the massive core W51 e2/e8. Here, we find that the B field lines are shaped locally in the dense cores e2 and e8 at a 0.05 pc scale but remain uniform on a 0.5 pc scale. Based on the comparison of the B_bot at different scales, our results seem to suggest an evolving role of the B field from large to small scales.

Part III

Posters

- Luiz Andrade
  Galactic dynamo seeds from QED in torsioned spacetime
- Alexander Beck
  Cosmological evolution of magnetic fields during halo formation
- Florian Buerzle
  Studies in Star Formation using Smoothed Particle Magnetohydrodynamics
- Miljenko Cemeljic
  Magnetospheric launching in resistive MHD simulations
- Krzysztof Chyzy
  Magnetic fields and star formation in Magellanic type galaxies
- Robert Drzazga
  Seeking large-scale magnetic fields in pure-disk dwarf galaxy NGC 2976
- Lauranne Fauvet
  Expected constraints on the Galactic magnetic field with Planck
- Kotaro Fujisawa
  Stationary and Axisymmetric Magnetized Barotropic Stars with Various Field Configurations
- Avijit Kumar Ganguly
  Effect of Scalar Electromagnetic field Coupling and on light propagation in Astrophysical Environments.
- Annette Geng
  Magnetic fields in galaxy mergers
- Philipp Girichidis
  Importance of the initial conditions for star formation
- Noémie Globus
  Modeling astrophysical jets from Young Stars to Black Holes
- Carl Heiles
  An Arecibo survey of the polarization and Zeeman splitting of OH Megamasers
- Talayeh Hezareh
  Observational determination of turbulent ambipolar diffusion scale and magnetic field strength in molecular clouds
- Martin Huarte-Espinosa
  Interaction of Fanaroff-Riley class II radio jets with a randomly magnetised intra-cluster medium

- Martin Huarte-Espinosa
  Modeling Poynting flux vs. kinetic-energy dominated jets
- Luís H.S. Kadowaki
  Magnetic reconnection in accretion disks
- Aiara Lobo Gomes
  The Magnetic Field Structure at the Small Magellanic Cloud
- German Lugones
  Light
- Kenji Nakamura
  2D MHD Simulations including heat conduction of protostar flares
- Maria Soledad Nakwacki
  KMHD versus MHD turbulence in the intracluster medium: statistical numerical tools and simulated Faraday rotation maps
- Fábio Pereira Santos
  NIR Photometry and Optical/NIR Polarimetry Toward the RCW41 Star-Forming Region
- Helen Popova
  The regime of two off-phase dynamo waves in a solar cycle and predictions of Parker dynamo
- Helen Popova
  The nonlinear small mode model of Parker dynamo with the meridional circulation
- Amrita Purkayastha
  Low Frequency Observations of the Dwarf Galaxy NGC1569
- Gustavo Rocha da Silva
  Magnetic Field Amplification in Gamma-Ray Bursts due to Non-Thermal Relativistic Shocks
- Ilan Roth
  Magnetic Reconnection Structures over Electron Scale – Prerequisite to Jets?
- Klara Schure
  Cosmic ray streaming instabilities amplifying magnetic fields in the long-wavelength limit
- Hubert Siejkowski
  Cosmic-ray driven dynamo in the interstellar meduim of irregluar galaxies

- Federico Stasyszyn
  MRI with Smooth Particle Hydrodynamics

- Federico Stasyszyn
  Star formation in MHD cosmological simulations

- Ya-Wen Tang
  Thermal Dust Polarization Toward Star Formation Regions – An Evolving Role of the Magnetic Field from Large to Small Scales from High Angular Resolution Observations

- Dominik Wóltański
  Cosmic-ray driven dynamo in spiral galaxies

- Huirong Yan
  A new diagnostics of interplanetary magnetic field

Part IV

List of participants

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Kazunari Shibata (Japan)
Jim Stone (USA)
Marek Urbanik (Poland)

Local Organizing Committee

Joanna Kozakiewicz
Szymon Lichawski
Katarzyna Otmianowska-Mazur (chair)
Beata Pasternak
Hubert Siejkowski
Marian Soida
Marek Urbanik