PIPA2016: PARTIALY IONISED PLASMAS IN ASTROPHYSICS

Monday 29 August – Friday 2 September, 2016
Hotel Nivaria, La Laguna (Tenerife)

ABSTRACTS

SESSION 1 Fundamental physical processes in partially ionised plasmas

Title: Partially Ionized Plasma in the Solar Wind and Its Interaction with the Local Interstellar Medium
Author(s): Nikolai Pogorelov
Session: S1/IT

Abstract: This presentation focuses on the physical processes occurring in the outer heliosphere, especially at its boundary called the heliopause, and in the local interstellar medium. The importance of magnetic field, charge exchange between neutral atoms and ions, and solar cycle on the heliopause topology and observed heliocentric distances to different heliospheric discontinuities are discussed. It is shown that time-dependent, data-driven boundary conditions are necessary to describe the heliospheric asymmetries detected by the Voyager spacecraft. We also discuss the structure of the heliopause, especially due to its instability and magnetic reconnection. It is demonstrated that the Rayleigh--Taylor instability of the nose of the heliopause creates consecutive layers of the interstellar and heliospheric plasma which are magnetically connected to different sources. This may be a possible explanation of abrupt changes in the galactic and anomalous cosmic ray fluxes observed by Voyager 1 when it was crossing the heliopause structure for a period of about one month in the summer of 2012. This talk also discusses the plausibility of fitting simulation results to a number of observational data sets obtained by in situ and remote measurements (IBEX, SOHO, HST). Additionally, it is shown that the presence of the heliosphere may be an explanation of the observed anisotropy of multi-TeV comic rays observed in a number of air shower experiments throughout the world. In particular, the topology of the heliotail and the distribution of magnetic field in the bow wave are important for quantitative fitting of observed and simulated TeV cosmic ray anisotropy. The distribution of magnetic field in the vicinity of the heliopause is discussed also in the context of Voyager measurements. We argue that a classical heliospheric current sheet formed due to the Sun\'s rotation is not observed by in situ measurements and should not be expected to exist in numerical simulations extending to the boundary of the heliosphere. Finally, we will show simulations results that demonstrate the importance of treating pickup ions as an entity separate from the thermal plasma.

Title: Multi-component Plasma Modeling and Dynamics in the Presence of a Suprathermal Non-equilibrated Ion Population
Author(s): G.P. Zank, P. Mostafavi, P. Hunana
Session: S1/ST

Abstract: Suprathermal energetic particles, such as solar energetic particles (SEPs) in the inner heliosphere and pickup ions (PUIs) in the outer heliosphere and the very local interstellar medium, often form a thermodynamically dominant component in their various environments. In the supersonic solar wind beyond some 10 AU, in the inner heliosheath (IHS), and in the very local interstellar medium (VLISM), PUIs do not equilibrate collisionally with the background plasma. Similarly, SEPs do not equilibrate collisionally with the background solar wind in the inner heliosphere. In the absence of equilibration between plasma components, a separate coupled plasma description for the energetic particles is necessary. Using a collisionless Chapman-Enskog expansion, we derive a closed system of multi-component equations for a plasma comprised of thermal protons and electrons, and suprathermal particles (SEPs, PUIs). The energetic particles contribute an isotropic scalar pressure to leading order, a collisionless heat flux at the next order, and a collisionless stress tensor at the second-order. The collisionless heat conduction and viscosity in the multi-fluid description results from a non-isotropic energetic particle distribution. A simpler single-fluid MHD-like system of equations with distinct equations of state for both the background plasma and the suprathermal particles is derived. We note briefly potential pitfalls that can emerge in the numerical modeling of collisionless plasma flows that contain a dynamically important energetic particle component. We conclude with some results related to the structure of shocks in the presence of a suprathermal component.

Title: Overview of multi-fluid equations and transport effects
Author(s): Manuel Collados
Session: S1/IT

Abstract: n this contribution, the equations that govern the behaviour of a multi-component plasma will be presented in a consistent way. Special attention will be given to the collisional terms that couple the different species and to the matter-radiation interaction terms. Characteristic plasma parameters will be defined and compared to determine typical values in different physical situations, which can lead to variations by many orders of magnitude. The two- and one-fluid simplification approaches will be discussed, emphasizing their main assumptions and restrictions. The application to different astrophysical scenarios will be discussed.

Title: Transport properties for magnetized sun chromosphere based on the Chapman-Enskog expansion
Author(s): Wargnier Quentin, Alvarez Laguna Alejandro, Magin Thierry, Massot Marc
Session: S1

Abstract: Currently, non-ideal MHD models can represent the sun atmosphere and solar flares. However, that such simulations are still not able to provide a predictive tool and do not capture the proper dynamics of the system . The origin of this problem can be related to the incorporation of consistent dissipative phenomena related to interspecies. A non-equilibrium model based on the model theoretically derived from kinetic theory by M. Massot et al (2009), which is general, for every range of temperature, and a large range of magnetic field, is going to be presented. The development of the system of equations has been developed by linearizing Boltzmann equations using the Chapman Enskog method, based on non-dimensional parameters (such as the Knudsen number, the mass ratio parameter between electron and heavy particles and the Hall parameter). The set of equations can be used both for partially and fully ionized plasmas. The spectral Galerkin method based on Laguerre Sonine approximation has been used for the development of the transport properties. Anisotropies transport systems with two temperatures have been obtained. The transport properties have been compared with the usual model of Braginskii, for values that can be found in the chromosphere of the sun.

Title: Ambipolar diffusion regulated collapse of filaments threaded by perpendicular magnetic fields
Author(s): Sven Van Loo, Christina Burge, Sam Falle and Tom Hartquist
Session: S1

Abstract: In giant molecular clouds the fractional ionisation is low enough that the neutral and charged particles are weakly coupled and ion-neutral drift, or ambipolar diffusion, becomes important. In this talk, we aim to elucidate the effects of ambipolar diffusion on the evolution of infinitely long filaments and the effect of decaying turbulence on that evolution. We numerically reproduce the density profiles for filaments that are in magnetohydrostatic and pressure equilibrium with their surroundings obtained by Tomisaka (2014) and show that these equilibria are dynamically stable. If the effect of ambipolar diffusion is considered, these filaments lose magnetic support initiating cloud collapse. The filaments do not loose magnetic flux. Rather the magnetic flux is redistributed within the filament from the dense centre towards the diffuse envelope.
The rate of the collapse is inversely proportional to the fractional ionisation and two regimes for the collapse are observed as predicted by Mouschovias & Morton (1991). For high values of the ionisation coefficient, i.e. X ≥ 10^-7, the gas is strongly coupled to the magnetic field and the Jeans length is larger than the ambipolar diffusion length scale.
Then the collapse is regulated by magnetically-driven ambipolar diffusion and the diffusion of the magnetic field is due to the gradients of the magnetic field. The gas collapses at velocities much lower than the sound speed. For X ≲ 10^-8, the gas is weakly coupled to the magnetic field and the magnetic support is removed by gravitationally-driven ambipolar diffusion. Here, neutrals and ions only collide sporadically, i.e. the ambipolar diffusion length scale is larger than the Jeans length, and the gas can attain high collapse velocities. When decaying turbulence is included, additional support is provided to the filament. This slows down the collapse of the filament even in the absence of a magnetic field. When a magnetic field is present, the collapse rate increases by a ratio smaller than for the non-magnetic case. This is because of a speed-up of the ambipolar diffusion due to larger magnetic field gradients generated by the turbulence and because the ambipolar diffusion aids the dissipation of turbulence below the

ambipolar diffusion length scale. The highest increase in the rate is observed for the lowest ionisation coefficient and the highest turbulent intensity.

Title: Observational evidence of the heliosphere-interstellar medium interaction obtained from neutral atom imaging with IBEX and pickup ion observations

Author(s): Eberhard Möbius (On behalf of the IBEX and Pickup Ion teams)

Session: S1/IT

Abstract: The heliosphere and interstellar medium are two partially ionized plasmas that interact strongly influenced by charge exchange and pickup ion processes. Enabled by these processes, the Interstellar Boundary Explorer (IBEX), launched October 19, 2008, takes global images of the solar system boundary using two energetic neutral atom (ENA) cameras. They provide us with valuable information about region where the solar wind slows down in response to the surrounding interstellar medium and the interactions that shape the heliosphere. Most unexpectedly, the images show a bright and persistent "Ribbon" across the sky, which provides a marker for the direction of the interstellar magnetic field, but the processes leading to the bright ENA emission are still being investigated. The IBEX-Lo camera also catches the interstellar wind of neutral H, He, O, and Ne atoms that blows through the solar system with a speed of ≈26 km/s as the accessible part of the surrounding partially ionized medium. The wind speed arises from the motion of the Sun relative to the local interstellar gas cloud (LIC). The observed gas flow is an excellent probe of the state of the LIC and shows clear signatures of the slowdown, heating and deflection of the interstellar plasma at the heliospheric boundary. For a quantitative evaluation of these processes a precise determination of the interstellar neutral (ISN) flow direction is important. IBEX measurements provide a very precise relation between ISN flow longitude and speed via the hyperbolic trajectory equation, but they contain larger uncertainties along the parameter tube defined by this relation. Complementary to this result, the observation of pickup ions, which are a natural product of the interaction of partially ionized plasmas, provide a high-precision determination of the flow longitude.

Title: Godunov-type numerical methods for magnetohydrodynamics

Author(s): K. Murawski

Session: S1

Abstract: We review shock-capturing schemes for solving MHD equations. This review covers explicit schemes in which adaptive mesh refinement is adopted. As these schemes are based on Riemann solvers, they are well suited for strong shocks and other discontinuities. We adopt these schemes to study wave phenomena in the solar atmosphere.

Title: Ionospheric Electrodynamics - Basic Physics and Field-Aligned Currents

Author(s): Antonius Otto

Session: S1/IT

Abstract: Ionospheres provide the basic interface between the typically fully ionized magnetospheric plasma and the neutral atmosphere for all gaseous planets. This interaction is facilitated through a partially ionized plasma where the plasma-neutral interaction provides new physics that is much richer than in a fully ionized environment. On macro-scales the dominant physical transport mechanisms are friction and resistivity, both of which can provide effective dissipation of flow and magnetic energy, however, with very different scaling laws. An important element of ionosphere-magnetosphere coupling is the formation and presence of strong magnetic field-aligned currents. These currents carry information, momentum, and energy and are typically formed through Alfven waves originating in the magnetosphere. However, it is illustrated that strong ionospheric conductance gradients can have a major impact on the current structure and evolution. The presentation will provide a systematic discussion of basic ionospheric electrodynamics, and of the influence of ionospheric conductance gradients on field-aligned current structure and geometry. Results are be compared to other environments with partially ionized plasma such as the solar atmosphere.

Title: Charge exchange reactions at interfaces between neutral gas and plasma: Dynamical effects and X-ray emission
Author(s): Izmodenov Vladislav
Session: S1

Abstract: Charge exchange is the main process linking neutral and charged particles in the interaction regions of neutral (or partly ionized) gas with a plasma. I will illustrate the importance of charge exchange with respect to the dynamics and the structure of neutral gas-plasma interfaces. The following phenomena will be considered: (1) the heliospheric/astrospheric interfaces - regions where the solar/stellar wind plasma interacts with the partly-ionized local interstellar medium (LISM) and (2) neutral interstellar clouds embedded in a hot, tenuous plasma such as the million degree gas that fills the so-called ``Local Bubble\". In (1), several effects in the outer heliosphere caused by charge exchange of interstellar neutral atoms and plasma protons will be discussed. In (2) the role of charge exchange in the formation of a transition region between the cloud and the surrounding plasma based on a two-component model of the cloud-plasma interaction wiil be discussed. In the model the cloud consists of relatively cold and dense atomic hydrogen gas, surrounded by hot, low density, fully ionized plasma. The structure of the cloud-plasma interface and the effect of charge exchange on the lifetime of interstellar clouds will be discussed. Charge transfer between neutral atoms and minor ions in the plasma produces X-ray emission. The X-ray emissivity consecutive to the charge transfer reactions has been estimated.

SESSION 2 Waves and instabilities in partially ionised plasmas: theory and observations

Title: Waves and instabilities propagation in solar plasmas
Author(s): Roberto Soler
Session: S2/IT

Abstract: Observations show that propagating waves and plasma instabilities as, e.g., Kelvin-Helmholtz and Rayleigh-Taylor instabilities, are frequent phenomena in the solar atmospheric plasma. The study of waves and instabilities in the solar corona is usually based on the ideal MHD theory for a fully ionized plasma. However, the plasma in the photosphere, chromosphere, and prominences is partially or even weakly ionized. In partially ionized plasmas, ion-neutral collisions can modify the behavior and properties of the classic MHD waves and instabilities. In this talk, I will review recent theoretical advances on the study of waves and instabilities in the solar plasma that take partial ionization effects into account.

Title: Role of waves in the dynamics of planetary magnetospheres and ionospheres
Author(s): Vytenis M. Vasyliunas
Session: S2/ST

Abstract: A planetary magnetosphere is formed by the interaction between the solar wind and the magnetic field generated within the interior of the planet. The solar wind is in motion relative to the planet and is furthermore highly variable, hence the interaction proceeds by waves that propagate back and forth between the two media; the distribution and properties of the waves substantially determine the interaction. The degree of ionization varies drastically across the interaction region, from the solar wind and the outer magnetosphere (fully ionized, for all practical purposes), to the inner magnetosphere (partially ionized, but effectively no coupling of plasma and neutrals), to the upper ionosphere (weakly ionized, weak coupling of plasma and neutrals), to the lower ionosphere (very weakly ionized, strong coupling of neutrals with ions but not with electrons), to the (nearly non-ionized) atmosphere, to the (non-ionized but electrically conducting) interior. Describing how a disturbance propagates through such an inhomogeneous region is a formidable problem, to date solved mostly by the approximation of ascribing sharp boundaries to the inhomogeneities which reflect and transmit waves. Aspects of the interaction which can be usefully discussed in terms of waves include the nature of the magnetopause and other boundaries in a magnetically open magnetosphere, the process by which solar wind flow establishes magnetospheric convection flow in the magnetosphere and ionosphere (in particular at low latitudes), and the influence of atmospheric motions on the magnetosphere. Of the latter, establishment of corotation has long been the most widely discussed instance, but interest in other possible effects has been motivated by more recent observations of seemingly rotational modulation of plasma and magnetic fields in the magnetosphere of Saturn, despite the fact that the planet\'s rotational and magnetix axes are (within observational uncertainties) completely aligned.

Title: High frequency waves in the presence of a null point: resonant cavity?
Author(s): Irantzu Santamaria, T. van Doorsselaere, E. Khomenko, M. Collados
Session: S2

Abstract: The null points have been for years one of the most intriguing structures in solar physics. The main reason for this is that they have never been observed. Nevertheless, theoretical and numerical studies predict these prominent discontinuities to be ubiquitous almost everywhere in the solar chromosphere and corona. The null points lead to reconnection events that can dissipate energy into heat, contributing to the chromospheric and coronal heating. Furthermore, the magnetic reconnection can also lead into very strong phenomena in the corona, such as, solar flares. In addition, wave propagation in the presence of a null point changes drastically compared to their behaviour in the absence of those discontinuities. As the Alfvén speed is zero, the null points cannot be crossed by pure Alfvén waves, being these waves guided outwards the null point along the field lines. Additionally, fast magnetic waves are refracted around null points due to the strong gradient in the Alfvén speed. Therefore, the only waves that can physically cross the discontinuities are the acoustic-like or slow magneto-acoustic waves. In this work we study the shock waves interaction with a null point. In particular we analyze the interaction between hydrodynamic shock waves, developed in the chromosphere, and a null point, that results on a jet-like phenomenon. This phenomenon is periodic, resulting in a high frequency region around the null

point. The frequency pattern of the waves changes with the equilibrium atmosphere. This fact suggests that the null point might be acting as a resonant cavity.

Title: Instabilities in Accretion Disks
Author(s): Mark Wardle
Session: S2/IT

Abstract: TBD

Title: Numerical Simulations of the Wardle Instability
Author(s): Sam Falle
Session: S2

Abstract: In dense interstellar clouds, the ionisation fraction is so low that the material may be considered to be made up of two fluids: a perfectly conducting fluid consisting of the ions and electrons and a neutral fluid consisting of atomic hydrogen. These interact via collisions, but the imperfect coupling leads to a finite resistivity, which is usually called ambipolar diffusion. Under these conditions, there exist shock structures, called C-shocks, in which the dissipation is due to resistivity rather than viscosity (Draine 1980). Since the thickness of such shocks is several orders of magnitude greater than that of a viscous shock, it is possible for the gas to remain cold, which in turn permits the survival of molecules that would be destroyed by the heating in a viscous shock.
Wardle (1990, 1991a,b) showed that C-shocks with Alfven Mach numbers greater than ~ 5 are subject to a transverse corrugation instability and nonlinear calculations have shown that this leads to the formation of dense fingers of neutral gas (Toth 1995a,b; Neufeld & Stone 1997; MacLow & Smith 1997). This has several consequences: the emission from an unstable shock is very different from that of a steady shock; the shock transition may no longer be smooth enough to prevent the destruction of molecules; the instability might play a role in the generation of the observed density inhomogeneities in dense clouds.
However, the instability relies on a separation between the conducting fluid and the neutral fluid, which does not occur if timescale for ionisation equilibrium is short compared to the flow time through the shock structure. The ionisation fraction is then simply a function of neutral density and our simulations show that this does indeed suppress the instability. Since the timescale for ionisation equilibrium is always short compared to the flow time in dense clouds, the instability does not occur unless charged grains play a significant role. Instability is possible in this case because a fluid composed of charged grains does undergo separation from the neutrals and the grain mass fraction influences the ionisation fraction. We use the multi-fluid code described in Falle (2003), which includes the grain fluid, to show that the instability can occur in such cases., with interesting consequences.

Title: Rayleigh-Taylor instabilities with sheared magnetic fields in partially ionised plasmas: High-beta approximation
Author(s): Michael Ruderman
Session: S2

Abstract: We consider the Rayleigh-Taylor instability of a magnetic interface. The plasma parameters and magnetic field are constant above and below the interface. The field direction is different below and above the interface. The plasma below the interface is fully ionised, while the plasma above the interface is only partly ionised. Hence, the plasma motion below the interface is described by the ideal MHD equations, while its motion above the interface is described by the MHD equations with the account of ambipolar diffusion. We derived the dispersion equation governing the interface stability. This equation is investigated in the approximation of large plasma beta. The solution to the dispersion equation is searched for in the form of expansion with respect to the inverse plasma beta. The first order approximation corresponds to the approximation of incompressible plasma. In this approximation the ambipolar diffusion does not affect the interface stability. The effect of ambipolar diffusion appears in the next order approximation. This effect is studied for various values of the equilibrium parameters.

Title: Kinetic plasma instabilities in weakly collisional ionospheric plasmas
Author(s): Wojciech Miloch, Miroslav Horky
Session: S2

Abstract: Dynamics of weakly collisional, magnetized plasmas are studied in ExB fields within parameter ranges relevant for ionospheric conditions. Collisional interactions with a neutral background can lead to distorted velocity distributions. In the case of charge-exchange collisions, we observe the formation of ring-shaped velocity distributions for ions, which becomes unstable and results in increased fluctuations in the electric potential. In the saturated stage of the instability, nonlinear three-wave interaction is observed. For elastic ion-neutral collisions the ion velocity distribution is distorted and broadened, but remains stable. Mixed conditions are also considered, and implications on ionospheric plasma phenomena are discussed. The study is carried out with the self-consistent particle-in-cell simulations with DiP3D code.

Title: Onset of the Kelvin-Helmholtz instability in partially ionized magnetic flux tubes
Author(s): David Martínez Gómez, Roberto Soler, Jaume Terradas
Session: S2

Abstract: Observations of solar prominences show the presence of turbulent flows that may be caused by Kelvin-Helmholtz instabilities (KHI). However, the observed flow velocities are below the classical threshold for the onset of KHI in fully ionized plasmas. We investigate the effect of partial ionization on the onset of KHI in dense and cool cylindrical magnetic flux tubes surrounded by a hotter and lighter environment. We use the linearized governing equations of a partially ionized two-fluid plasma to describe the behavior of small-amplitude perturbations superimposed on a magnetic tube with longitudinal mass flow. We perform a normal mode analysis to obtain the dispersion relation for linear incompressible waves. We focus on the appearance of unstable solutions and study the dependence of their growth rates on various physical parameters. In addition, we give an application of this model to solar prominence threads. We find that the presence of a neutral component in a plasma may contribute to the onset of the KHI even for sub-Alfvénic longitudinal shear flows. We also find that collisions between ions and neutrals reduce the growth rates of the unstable perturbations, but cannot completely suppress the instability. We conclude that turbulent flows in solar prominences with sub-Alfvénic flow velocities may be interpreted as consequences of KHI in partially ionized plasmas

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Title: Large-Amplitude Oscillations in Prominences
Author(s): Manuel Luna
Session: S2

Abstract: Large-amplitude oscillations in prominences are among the most spectacular phenomena of the solar atmosphere. Such an oscillations involve motions with velocities above 20 km/s, and large portions of the filament that move in phase. These are triggered by energetic disturbances as flares and jets. The AIA/SDO instrument offers an unprecedented view of the processes that trigger the oscillations and the subsequent dynamics. These oscillations are an excellent tool to probe the not directly measurable filament morphology. In addition, the damping of these motions can be related with the process of evaporation of chromospheric plasma associated to coronal heating and also strongly influenced by ion-neutral effects.

Title: The role of Alfvén wave heating in solar prominences
Author(s): Roberto Soler, J. Terradas, Ramón Oliver, J. L. Ballester
Session: S2

Abstract: Energy balance in prominences is a long-standing problem. It is generally accepted that incident radiation provides most of the heating. Nevertheless, radiative equilibrium models indicate that an additional, non-negligible source of heat may be necessary to compensate radiative losses and reproduce the observed temperatures in prominence cores. Here we suggest that this extra energy supply can be provided by externally-driven Alfvén waves impinging on the prominence. We consider that the prominence plasma is partially ionised and that wave energy dissipation is caused by collisions between different species. In our model, we find that wave heating strongly depends upon the wave period. Only waves with periods smaller than 100 s can transfer energy to the prominence. The presence of cavity resonances, associated with nearly standing waves in the prominence, is responsible for efficiently channeling wave energy. Then, ion-neutral friction in the partially ionised plasma converts this incoming energy into heat. We estimate that wave heating may compensate for about 10% of radiative losses of the prominence plasma.

Title: Observations of apparent superslow wave propagation
Author(s): Jo Raes, T. Van Doorsselaere, M. Baes, A. N. Wright
Session: S2

Abstract: Phase mixing of standing continuum Alfvén waves and/or continuum slow waves in atmospheric magnetic structures such as coronal arcades can create the apparent effect of a wave propagating across the magnetic field (Kaneko et al., 2015). We observe a prominence with SDO/AIA on 2015 March 15 and find the presence of oscillatory motion. Measuring the apparent velocity, we prove that interpreting this motion as fast magnetosonic waves is faulty as the propagation is slower than expected for even slow MHD waves for those circumstances. We also connect the decrease of the apparent velocity over time with the phase mixing process, which depends on the curvature of the magnetic field lines. We fit our observations of the superslow propagation to the frequency change in a modified Kippenhahn-Schlueter prominence model.

Title: Shock waves in partially ionised plasmas
Author(s): Istvan Ballai
Session: S2

Abstract: We investigate the nature and properties of shock waves propagating in an oblique direction to the ambient magnetic field in a partially ionised plasma modelling the plasma of solar prominences (or possible other partially ionised environments). The formation and propagation of shocks is described within the framework of single-fluid MHD and the evolutionary equation is obtained using a multiple-scaling technique. The coefficients of this equation depend on the propagation angle of shock waves, plasma-beta and the ionisation degree of the plasma. In particular, we investigate how the structure of the shock and the critical time required to shocks to form vary with the ionisation degree of the plasma. We also analyse the observational signature of these shocks and determine how our results can explain the recent observations of propagating bright blobs in solar prominences.

Title: Multifluid simulations of driven slow and fast magnetosonic waves in the solar chromosphere
Author(s): Yana G. Maneva, Alejandro Alvarez Laguna, Andrea Lani and Stefaan Poedts
Session: S2

Abstract: The photosphere and the lower chromosphere are weakly ionized and strongly dominated by neutrals. Hence studying the effects of partial ionization and the ion-neutral interactions there is of crucial importance for a proper treatment of the plasma heating and the properties of acoustic and MHD wave propagation. In this study we present the results from 2D multi fluid simulations with MHD electrons and protons and a separate fluid describing the neutral population. The momentum and energy transfer are governed by the viscous shear stress tensor, anisotropic heat conductance, elastic collisions, pressure gradients, resistive electromagnetic fields and gravity. Our model also includes inelastic collisions, caused by impact ionization and radiative recombination. We investigate the propagation of slow and fast magnetosonic waves driven by photospheric velocity and magnetic field drivers at the foot-points of the magnetic field in a chemically reactive gravitationally stratified partially ionized plasma. We study the waves generated by vertical and horizontal velocity drivers, as well as initial magnetic field perturbations, and follow their properties as they propagate outward through the partially ionized photospheric and chromospheric regions. We observe formation of shocks and related plasma heating, as well as additional heating at the boundary of the magnetic flux tube related to partial ionization effects. Plasma expansion due to advection in the upper chromosphere leads to cooling and density depletion inside the flux tube. We study the energy balance, the ionization changes and the deviation from the initial chemical equilibrium induced by the photospheric drivers.

Title: The Physical Processes in the Chromosphere: From a View of Partially Ionized Plasma Physics
Author(s): Paul Song
Session: S2

Abstract: The solar chromosphere is formed because of the existence and the dissipation of the mechanical energy in the photosphere, which is undergoing a cooling process due to the loss of energy via radiation. The photospheric temperature can support only weak ionization. Because of the existence of the solar magnetic field, the energy associated with the horizontal motion in the photosphere, which is abundant, can propagate upward and dissipate in the partially ionized plasma through Joule heating and frictional heating. The dissipated energy tends to raise the temperature of the medium and results in more radiative losses, so that the medium reaches a radiative equilibrium temperature. Because the heating process depends importantly on the magnetic field strength with more dissipation in the lower chromosphere in the weaker field region, whereas more in the upper chromosphere in the strong field region, two circulation cells are formed, of the size of supergranules. Near the upper boundary of the chromosphere, or the transition region, the upper-cell circulation is driven by the upwelling of hotter flow in the strong field region, spreads toward the weaker field region while cooling down, and then sinks near the end of the supergranule. In this process, the magnetic field is pushed away from the strong field region and spreads into the weaker field region, forming the canopy in the upper chromosphere. The flow returns at the mid-altitudes toward the strong field region. As the heating is stronger, the medium becomes buoyant forming the upwelling. In the lower chromosphere, on the other hand, a lower circulation cell is driven by the upwelling in the weaker field region and it converges in the mid-altitudes toward the strong field region. The flow pushes the magnetic field toward the strong field region, reinforcing a core of strong field. As the flow cools down during the circulation, it sinks down to the photosphere along the strong magnetic field. In this description, with semi-quantitative estimates to be consistent with empirical models, all processes are classical: no anomalus process is invoked. Heating by shocks or turbulence may play only secodnary roles.

Title: Mode conversion and wave heating in solar partially ionized atmosphere
Author(s): Elena Khomenko
Session: S2

Abstract: Wave transfer energy over the solar atmosphere and couple all its layers. High resolution observations reveal that wave properties such as their dominant periods, propagation speeds and directions are intimately related to the topology and strength of the magnetic field. Rich physics emerges when considering waves in partially ionized solar plasma, since partial ionization effects provide new mechanisms for the interaction of different wave modes, and also provide efficient ways of the wave dissipation. In this talk I will discuss the recent developments in the field of modeling of waves in complex solar magnetic structures with a special emphasis on the aspects involving partial ionization in the photosphere and chromosphere of the Sun.

Title:
Author(s): James Mather
Session: S2

Abstract:

SESSION 3 Turbulence, dynamo and non-linear processes

Title: Turbulence in Weakly Ionised Astrophysical Plasmas
Author(s): Turlough Downes
Session: S3/IT

Abstract: We review some general considerations in the study of turbulence in weakly ionised plasmas. The impacts of these considerations on two particular systems - molecular clouds and proto-planetary discs - are discussed, focusing in particular on the behaviour of the power spectra, probability density functions and dissipation regions of these systems. Some local and global implications of the effects of the weak level of ionisation are discussed.

Title: Ionization state and MHD effects in accretion disks of young stars
Author(s): Sergei Khaibrakhmanov, Alexander Dudorov
Session: S3

Abstract:
Ionization state and magnetic field in accretion disks of young stars are investigated. We consider such non-ideal magneto-hydrodynamic (MHD) effects as Ohmic diffusion and magnetic ambipolar diffusion. Role of the Hall effect is also investigated. Ionization fraction is calculated taking into account ionization by cosmic rays and X-rays, recombinations on dust grains radiative and dissociative recombinations, grain charging. We consider conditions of plasma decay in accretion disks. Influence of MHD effects on «dead» zones characteristics and planet formation conditions is discussed. *Acknowledgements. Work is supported by Russian science foundation (project 15-12-10017).*

Title: Introducing a new explicit scheme into Mancha3D code for overcoming the time step limitations in simulations of partially ionised solar plasma
Author(s): Pedro Gonzalez-Morales
Session: S3

Abstract: When we consider dissipation effects into the induction equation as the Ambipolar or the Hall diffusion terms, the time step given by the Courant-Friedrich-Levy (CFL) stability condition would become small and then the computational cost of solving the non-ideal MHD equations increase. In this talk we present the implementation of two numerical schemes into the code Mancha3D to overcame those limitation. The first of them is kwon as Super Time-Stepping (STS) and is design to overcome the limitations imposed when the Ambipolar term becomes large. The second one is called Hall Diffusion Scheme (HDS) and it is used when the Hall term becomes important. Those two numerical techniques can be use together by means of the Strang operator splitting.

Title: "Dynamos in Turbulent Accretion Disks"
Author(s): Oliver Gressel
Session: S3/IT

Abstract: A wide range of astrophysical objects harbour rotationally supported accretion disks around them during at least parts of their lifetime. It is widely believed that the redistribution of mass (moving inward) and angular momentum (moving outward) is mediated by magnetic forces - be it in form of a system-scale magnetocentrifugal wind, or conversely by non-vanishing turbulent correlations acting as an effective friction between neighbouring disk annuli. In both paradigms, it is moreover crucial to understand the long-term evolution (and amplification) of the entrained large-scale magnetic flux since it determines the geometry of outflows and jets, on one hand, and provides favourable conditions for the magnetorotational instability to operate, on the other. In turbulent regions, fluctuations become anisotropic (due to rotation and shear) and inhomogeneous (due to stratification) and hence contribute to the transport coefficients as well as the mean electromotive force. A complete theory of turbulent accretion disk should ultimately encompass all relevant aspects, such as eddy viscosity/diffusivity, diamagnetic pumping and mean-field dynamo effects.

Title: Two-fluid simulations of waves and reconnection with Mancha code
Author(s): Beatrice Popescu
Session: S3
Abstract:

Title: Angular momentum transport in weakly ionised protoplanetary disks
Author(s): Donna Rodgers-Lee
Session: S3

Abstract: The dusty disks surrounding protostars, so-called protoplanetary disks (PPDs), encompass a variety of physical conditions. These extreme conditions result in rapid changes of the ionisation fraction and necessitate the inclusion of all three non-ideal magnetohydrodynamic effects, namely Ohmic dissipation, ambipolar diffusion and the Hall effect. The upper layers of PPDs are thought to be fully ionised but towards the disk midplane the ionisation fraction decreases such that the plasma is very weakly ionised. One of the main focuses of PPDs studies is to investigate the mechanism responsible for angular momentum transport which allows accretion onto the protostar to occur. The magnetorotational instability (MRI) is thought to operate in certain regions of PPDs and redistribute angular momentum transport via the development of turbulence. A global picture of angular momentum transport including the influence of all non-ideal effects on MRI-driven turbulence is still missing though. The simulations I will discuss are some of the first to study the global nature of PPDs including all three non-ideal effects in a region where the Hall effect is dominant. We found that the Hall effect allows accretion to occur in regions where MRI-driven turbulence would otherwise be damped by Ohmic dissipation and ambipolar diffusion. We compare our results using a multifluid approach with those of the single fluid approximation and find that the results should be comparable.

SESSION 4 Magneto-convection, flux emergence and reconnection in partially ionised plasmas

Title: Magneto convection and partial ionization
Author(s): Juan Martinez-Sykora
Session: S4/IT

Abstract: The complexity of the chromosphere is due to various regime changes that take place across it. Consequently, the interpretation of chromospheric observations is a challenging task. It is thus crucial to combine these observations with advanced radiative-MHD numerical modeling. Because the photosphere, chromosphere and transition region are partially ionized, the interaction between ionized and neutral particles has important consequences on the magneto-thermodynamics of these regions. I am going to review the work done on self-maintined radiative magneto-convection simulations including the lower solar atmosphere. I will focus more on the work done with the Bifrost code (Gudiksen et al. 2011). We implemented in the code the effects of partial ionization using the generalized Ohm's law. This code also solves the full MHD equations with non-grey and non-LTE radiative transfer and thermal conduction along magnetic field lines. The ion-neutral collision frequency is computed using recent studies that improved the estimation of the cross sections under chromospheric conditions (Vranjes & Krstic 2013). The implementation of partial ionization effects impact our modeled radiative-MHD atmosphere, such as producing chromospheric heating and diffusion of magnetic field into the upper-chromosphere among others. We will describe, in detail, the importance on the physical processes and chromospheric synthetic observations from simulations of the ion-neutral interaction effects.

Title: Reconnection in partially ionised plasmas and its application to solar physics
Author(s): Vyacheslav S. Lukin
Session: S4/ST

Abstract: This talk will provide a brief overview of the impacts partial ionization and consequent non-equilibrium balancing of ionization, recombination, thermal, and convective plasma transport processes can have on the dynamics of magnetic reconnection. Recently published results [1-3], including development of secondary instabilities and the impact of the Hall physics on magnetic reconnection in a weakly ionized plasma, will be discussed.
[1] Leake, Lukin, Linton, and Meier, \"Multi-fluid simulations of chromospheric magnetic reconnection in a weakly ionized reacting plasma,\" ApJ 760 (2012), p. 109.
[2] Leake, Lukin, Linton, \"Magnetic reconnection in a weakly ionized plasma,\" PoP 20 (2013), p. 061202.
[3] Murphy, Lukin, \"Asymmetric magnetic reconnection in weakly ionized chromospheric plasmas,\" ApJ 805 (2015), p. 134.
*[Any opinion, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.]

Title: Photospheric Current Spikes as Possible Predictors of Flares
Author(s): Michael L. Goodman, Chiman Kwan, Bulent Ayhan & Eric L. Shang
Session: S4

Abstract: Flares involve generation of the largest current densities in the solar atmosphere. This suggests the hypothesis that prior to a large (M,X) flare there are related changes in the photospheric current distribution, and hence in the resistive heating rate in neutral line regions (NLRs). If this is true, these changes might be useful predictors of flares. Evidence supporting this hypothesis is presented. Results from a data driven, near photospheric, 3D magnetohydrodynamic type model suggest the model might be useful for predicting M and X flares several hours to several days in advance. The model takes as input the photospheric magnetic field observed by the Helioseismic & Magnetic Imager (HMI) on the Solar Dynamics Observatory (SDO) satellite. The model computes quantities in every active region (AR) pixel for 14 ARs, with spurious Doppler periods due to SDO orbital motion filtered out of the time series of the magnetic field for each pixel. Spikes in the model predicted NLR resistive heating rate Q, appearing as increases by orders of magnitude above background values in the time series of Q occur. There appears to be some correlation between spike times and the occurrence of M or X flares a few hours to a few days later. The subset of spikes analyzed at the pixel level are found to occur on HMI and granulation scales of

1 arcsec and 12 minutes. Spikes are found in NLRs with and without M or X flares, and outside as well as inside NLRs, but the largest spikes are localized in the NLRs of ARs with M or X flares, and associated with horizontal magnetic field strengths ~ several hG, and vertical magnetic field strengths several orders of magnitude smaller, suggesting that the spikes are associated with current sheets.

Title: Star formation mediated by reconnection diffusion
Author(s): Alexandre Lazarian
Session: S4/IT

Abstract: Turbulence induces fast reconnection and the process termed "reconnection diffusion". As turbulence is ubiquitous in astrophysical environments, so is reconnection diffusion. The latter process changes the dynamics of star formation. I shall discuss the implications of reconnection diffusion on the formation of magnetized cores, clumps and accretion disks.

Title: Computational Multi-Fluid Model for Partially Ionized and Magnetized Plasma
Author(s): Alejandro Alvarez Laguna, Andrea Lani, Yana Maneva, Nataly Ozak,Stefaan Poedts
Type of contribution: Poster
Session: S4

Abstract: In the present work, we present a computational model for studying reactive and partially ionized plasmas in thermo-chemical nonequilibrium under the effect of electromagnetic fields, such as in astrophysics or fusion-related applications. In order to tackle the non-equilibrium effects present in such a plasma, we adopt a multi-fluid formulation including electromagnetic effects. Multi-fluid equations consider each species within the mixture as behaving as different fluids, interacting among each other by means of collisions and chemical reactions. In the present poster, we will present a two-fluid model, accounting for ions and neutral species. The model includes chemical reactions for characterizing ionization, recombination and charge exchange collisions and accurate transport fluxes, obtained through the Grad's method and considering the anisotropy introduced by the magnetic field in the ionized species. The resulting equations are coupled to the full Maxwell's equations in order to capture phenomena such as electromagnetic waves or charge separation effects, neglected in standard magnetohydrodynamics (MHD) simulations. Our computational model will be used to simulate magnetic reconnection testcases which have been proposed in recent literature and for which reference numerical simulations are available with more simplified models (including our recently published two-fluid model).

Title: Realistic 3D simulations of the solar photosphere with the MANCHA code
Author(s): Nikola Vitas, Khomenko, E.; Collados, M.; de Vicente, A
Session: S4

Abstract: Over the last decade, realistic 3D radiative-MHD simulations became dominant theoretical model for understanding the polarization of the solar photosphere. We developed a new code (MANCHA) that solves coupled system of time-dependent equations on 3D Cartesian grid (single fluid quasi-MHD equations, radiative transfer equation and equation of state). The code has already been used for a variety of idealized numerical experiments (wave propagation, Rayleigh-Taylor instability, oscillations in prominences). Now for the first time we apply the code to simulate realistic solar near-surface convection in 3D. Here we present the results for different initial magnetic field configurations.

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