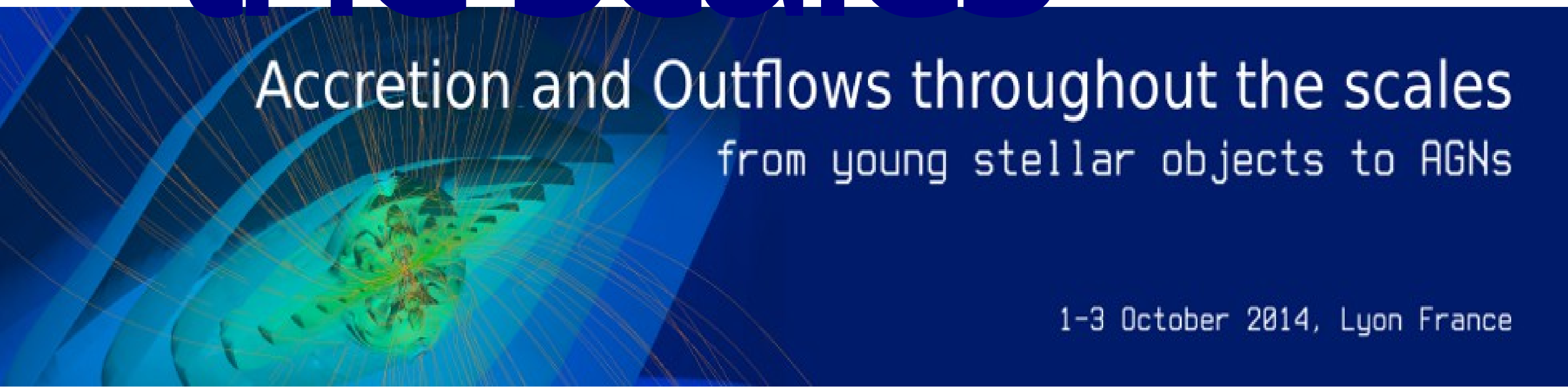
Accretion and Outflows throughout the scales



1-3 October, 2014
Centre Blaise Pascal, ENS Lyon, France

Program

Wednesday, October 1, 2014

TIME	EVENT
9:00 am - 9:05 am	Opening - Rolf Walder
9:05 am - 9:45 am	AGN outflows at parsec and sub-parsec scales - Yuri Kovalev
9:45 am - 10:25 am	Jet launching: MHD simulations of the accretion-ejection structure - Christian Fendt
10:25 am - 11:05 am	Numerical simulations of relativistic jets emission and dynamics - Peter Mimica
11:05 am - 11:30 am	Coffee break
11:30 am - 11:55 am	Can magneto-centrifugal outflows from accretion discs explain wind signatures/features in black hole X-ray binaries? - Susmita Chakravorty
11:55 am - 12:35 pm	The Importance of Accretion and Outflows for Young Star Spins - Sean Matt
12:35 pm - 2:30 pm	Lunch
2:30 pm - 3:10 pm	Outflows from young stellar objects and their impact on star formation - Robi Banerjee
3:10 pm - 3:35 pm	Non-ideal MHD consequences for the first Larson core - Jacques Masson
3:35 pm - 4:15 pm	Global MHD Simulations of Star-Disk Interaction - Kengo Tomida
4:15 pm - 4:45 pm	Coffee break
4:45 pm - 5:10 pm	Zooming in on proto-planetary disks - Åke Nordlund
5:10 pm - 5:35 pm	Constraints from zoom-simulation on accretion and outflow processes around solar mass stars - Michael Küffmeier
5:35 pm - 6:15 pm	Magnetic braking in collapsing dense cores - Patrick Hennebelle
6:15 pm - 7:30 pm	Cocktail

Thursday, October 2, 2014

TIME	EVENT
9:00 am - 9:40 am	A kinematic dynamo model for accretion disks around Kerr black holes - Luca Del Zanna
9:40 am - 10:05 am	MRI turbulence in accretion discs: angular momentum transport in the low Prandtl number limit - Heloise Meheut
10:05 am - 10:30 am	First steps toward 2D time implicit hydrodynamical simulations of accretion process in very young low mass star objects - Chris Geroux
10:30 am - 11:00 am	Coffee break
11:00 am - 11:40 am	On Vertically Global, Radially Local Models for Astrophysical Disks - Martin Pessah
11:40 am - 12:05 pm	Temperature Fluctuations driven by Magnetorotational Instability in Protoplanetary Disks - Colin McNally
12:05 pm - 12:30 pm	Variable accretion with episodic bursts - Eduard Vorobyov
12:30 pm - 12:55 pm	Pair Cascades in the Disk Environment of the Binary System PSR B1259-63/LS 2883 - Iurii Sushch
12:55 pm - 2:45 pm	Lunch
2:45 pm - 3:25 pm	Causality and stability of cosmic jets - Oliver Porth
3:25 pm - 3:50 pm	Jet launching from a circumplanetary disc embedded in an externally-ionised protosolar nebula - Oliver Gressel
3:50 pm - 4:15 pm	Transonic solutions of isothermal galactic outflows in gravitational potential of a dark matter halo and a super massive black hole - Asuka Igarashi
4:15 pm - 4:40 pm	Coffee break
4:40 pm - 5:05 pm	Rarefaction waves in magnetized astrophysical jets - Nektarios Vlahakis
5:05 pm - 5:30 pm	Variation of AGNs jets celerity due to Compton rocket effect in a complex photon field - Thomas Vuillaume
5:30 pm - 6:10 pm	Instabilities of Current-Carrying Relativistic Jets - Andrea Mignone
7:30 pm - 11:55 pm	Dinner

Friday, October 3, 2014

TIME	EVENT
9:15 am - 9:55 am	Radiative implications of obstacles embedded in microquasar and extragalactic jets - Valenti Bosch-Ramon
9:55 am - 10:20 am	Simulations of jet - environment interactions using the PLUTO code - Dimitrios Millas
10:20 am - 10:45 am	Simulations of stellar/pulsar-wind interaction along one full orbit - Maxim Barkov
10:45 am - 11:10 am	Coffee break
11:10 am - 11:50 am	Accretion-ejection in protostars: Observational constraints - Sylvie Cabrit
11:50 am - 12:20 pm	Mass outflows in interacting binaries of the Algol type - Romain Deschamps
12:25 pm - 2:20 pm	Lunch
2:20 pm - 3:00 pm	Relativistic modeling for precessing jets: the SS433 X-ray binary environment - Rony Keppens
3:00 pm - 3:40 pm	MRI driven outflows in accretion disks - Sébastian Fromang
3:40 pm - 4:20 pm	Relativistic Outflows from Compact Engines: from Pulsars to GRBs - Niccolò Bucciantini
4:20 pm - 4:25 pm	Closing Remarks - Benoît Commerçon
4:25 pm - 4:25 pm	Happy Hour

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Outflows from young stellar objects and their impact on star formation

Banerjee Robi [1]

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Jets and outflows are observed around young stellar objects over the whole stellar spectrum, from brown dwarfs to high-mass stars. Those outflows are most likely driven by the coupling of magnetic fields that thread the underlying accretion disc. If this is a universal mechanism, such a disc-wind configuration should be self-consistently build up during the collapse of individual cloud cores. Additionally, jets and outflows feed back energy and momentum to the ambient gas in star-forming regions. Yet, it is still controversial whether feedback from outflows are able to regulate star formation in molecular clouds.
In this talk, I will summarise recent results from numerical simulations on outflow launching during the birth of stars and their impact on star-forming regions based on sub-grid modells of outflows.

Simulations of stellar/pulsar-wind interaction along one full orbit

Barkov Maxim [1], Bosch-Ramon Valenti [,2], Perucho Manel [,3], Khangulyan Dmitry [,4]

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The winds from a non-accreting pulsar and a massive star in a binary system collide forming a bow-shaped shock structure. The Coriolis force induced by orbital motion deflects the shocked flows, strongly affecting their dynamics. We study the evolution of the shocked stellar and pulsar winds on scales in which the orbital motion is important. Potential sites of non-thermal activity are investigated. Relativistic hydrodynamical simulations in 2D and in 3D, performed with the code PLUTO and using the adaptive mesh refinement technique, are used to model interacting stellar and pulsar winds on scales ~80 times the distance between the stars. The hydrodynamical results suggest the suitable locations of sites for particle acceleration and non-thermal emission. In addition to the shock formed towards the star, the shocked and unshocked components of the pulsar wind flowing away from the star terminate by means of additional strong shocks produced by the orbital motion. Strong instabilities lead to the development of turbulence and an effective two-wind mixing in both the leading and trailing sides of the interaction structure, which starts to merge with itself after one orbit. The adopted moderate pulsar-wind Lorentz factor already provides a good qualitative description of the phenomena involved in high-mass binaries with pulsars, and can capture important physical effects that would not appear in non-relativistic treatments. Simulations show that shocks, instabilities, and mass-loading yield efficient mass, momentum, and energy exchanges between the pulsar and the stellar winds. This renders a rapid increase in the entropy of the shocked structure, which will likely be disrupted on scales beyond the simulated ones. Several sites of particle acceleration and low- and high-energy emission can be identified. Doppler boosting will have significant and complex effects on radiation.

Radiative implications of obstacles embedded in microquasar and extragalactic jets

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The interaction of microquasar and extragalactic jets with relatively small obstacles, such us stellar wind inhomogeneities, clouds, or stars, can lead to important consequences from the radiative point of view. Particles can be accelerated in the interaction region up to very high energies either through Fermi mechanisms or magnetic reconnection, and produce Doppler boosted emission in different energy bands. In this talk, I will overview some important aspects of the non-thermal phenomena related to the entrainment of obstacles in galactic and extragalactic jets.

Relativistic Outflows from Compact Engines: from Pulsars to GRBs.

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Compact rotating objects (BHs and Neutron Stars) are the engines of some of the most relevant phenomena in High Energy Astrophysics, from Pulsar (PSR) to GRB. Today, thanks to the development of numerical tools for GR-MHD we are able to models these systems and relate their observed properties to the otherwise unobservable engine. The observed features and dynamics in Pulsar Wind Nebulae (PWNe) can be directly related to the wind structure and ultimately to the PSR magnetosphere. The character of the prompt emission, of the afterglow, the presence of an associated supernova (SN), and the environment, all characterize and constrain the possible central engine of Long and Short Gamma Ray Bursts (GRBs). For GRBs the two leading models are the «collapsar» and the «millisecond proto-magnetar.» I will briefly review the various criteria that any model must satisfy, and I will illustrate the key ideas behind both the collapsar and millisecond magnetar, with their strengths and weakness, especially in the light of the recent observation of the so called "late activity".

Can magneto-centrifugal outflows from accretion discs explain wind signatures/features in black hole X-ray binaries?

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X-ray observations of black hole X-ray binaries (BHBs) suggest that disk winds occur in the softer (disk-dominated) states of the outburst and are less prominent or absent in the harder (power-law dominated) states, which are more characterized by radio-loud jets. We investigate the presence/absence and physical characteristics of disk winds in BHBs through the use of the magneto-hydrodynamic (MHD) solutions of Ferreira (1997). These models treat accretion and ejection self-consistently within a self-similar ansatz that allows to solve the full set of dynamical MHD equations without neglecting any term. As a consequence the ejection efficiency is no free parameter but depends on the global structure of the disk. By testing different sets of solutions with varying disk aspect ratio and ejection efficiency, we attempt to reproduce the observed state dependent prevalence of the winds. With no a priori theoretical assumption about the state of the black hole, we recover this observed bias of the winds for the softer states. In this talk I shall detail the methods employed by us, followed by the results.

Mass outflows in interacting binaries of the Algol type

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Algols are short period interacting binaries presenting an apparent paradox, as the most evolved star is also the less massive of the two. This implies that mass transfer has occurred, something known since the 1950's. Moreover, there is now gathering indirect evidence indicating that some Algols follow non-conservative evolutions but there is still no direct detection of large mass outflows. As a result, little is known about the eventual ejection mechanism. In order to reconcile stellar models with observations, we compute typical Algol models with the state-of-the-art binary star evolution code Binstar. We investigate systemic mass losses within the hotspot paradigm where large outflows of material form from the accretion impact during the mass transfer phase. We then study the impact of this outflow on the spectral emission density of the system with the radiative transfer codes Cloudy and Skirt. We found that depending on the hotspot temperature, these outflows may lead to the formation of either dust and therefore infrared excesses or highly ionised species and strong emission lines. Surprisingly, both characteristics are observed among Algols and related objects but were badly understood up to now. From this study, we also discovered many systems with strong and extended infrared emission that will surely help to better constrain systemic mass loss in short period binaries.

A kinematic dynamo model for accretion disks around Kerr black holes

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Ordered, large-scale magnetic fields are believed to be a fundamental ingredient in accretion processes that power the outflows and jets of AGNs and GRBs, especially in the Blandford-Znajek scenario where the central engine is a rotating black hole. However, the origin of such fields is still debated. A possibilty is a combination of the disk differential rotation and the likely presence of turbulence motions in the disk itself, which provides a mean-field alpha-Omega dynamo action, capable of enhancing any initial seed magnetic field. As a first astrophysical application of the ECHO code in its recent version supplemented by a generalized Ohm law, we present here a kinematic study of dynamo effects in thick accretion disks around Kerr black holes.

Jet launching: MHD simulations of the accretion-ejection structur

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I will present our recent MHD simulations treating the accretion-ejection structure. Our setup considers various approaches for a physical magnetic diffusivity that is essential for loading the accretion material onto the outflow. We find relatively high mass fluxes in the outflow, of the order of 20-40% of the accretion rate. We also consider simulations treating jet launching in a truly bipolar setup, thereby investigating the origin of an intrinsic jet-conter jet asymmetry. Simulations including a mean-field disk dynamo and launching outflows by a self-generated magnetic field will also be discussed.

MRI driven outflows in accretion disks

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Understanding the physical mechanisms driving angular momentum transport in accretion disks is a central question in modern theoretical astrophysics. In recent years, two processes have been proposed as efficient means of transport: magnetohydrodynamics (MHD) turbulence driven by the magnetorotational instability and magnetocentrifugally accelerated jets. These two mechanisms have been widely studied in isolation while they likely operate together in most accreting systems and possibly affect each other.
In this talk, I will review recent results that fill this gap and simultaneously consider MHD turbulence and magnetically driven disk winds. These results, based on local simulations of accretion disk, reveals the complexity of the flow but still suffer from numerical artefact associated with the simplified nature of the simulations themselves.
In the special case of protoplanetary disks, dissipative effects (ohmic dissipation, ambipolar diffusion and the Hall effect) are important and must be accounted for so that the dynamics can be properly understood. At 1 AU in a typical protoplanetary disks, recent simulations show that the flow structure is significantly altered when all three effects are included: the flow remains laminar in the bulk of the disk while significant magnetic torque efficiently drive angular momentum outward in the disk. Upon confirmation using more realistic simulations, these results could drive a change of paradigm regarding our understanding of angular momentum transport in protoplanetary disks.

First steps toward 2D time implicit hydrodynamical simulations of accretion process in very young low mass star objects.

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Recent calculations based on 1D stellar structure calculations have shown that episodic accretion can significantly affect the structure of very young low mass stars and impact their evolution even after a few Myr. Accretion effects can produce a spread in luminosity, as observed in young clusters and star formation regions, and explain various observational features (Baraffe et al. 2009, 2012). However, these conclusions depend on very simplified assumptions regarding the treatment of accretion in 1D stellar structure calculations, namely uniform redistribution of accreted mass and energy within the accreting object's interior. Seiss & Forestini (1996) and Siess et al. (1997) prescribe a more complex penetration function based on the Richardson criterion but it is unclear how much more correct these penetration functions are. We are now investigating the effects of accretion based on 2D time implicit simulations in order to better understand such effects on the structure on very young objects. One of the goals of such a study is to provide a better description of this process to be used in 1D stellar evolution code. Our simulations are based on a multi-dimensional fully compressible, time implicit hydrodynamical code (Viallet et al. 2011), using realistic stellar input physics (equation of state, opacities). I will present preliminary results of this exploration as applied to a young, one solar mass star which is almost fully convective, using as a first step a simple accretion outer boundary condition.

Effects of Turbulent Viscosity on A Rotating Gas Ring Around A Black Hole: Results of Numerical Simulation

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We present the time evolution of a rotationally axisymmetric gas ring around a non rotating black hole using two dimensional grid-based hydrodynamic simulation . We use the Shakura-Sunyaev ? viscosity prescription to estimate the turbulent viscosity. We in-vestigate how a gas ring which is initially assuemd to rotate with Keplerian angular velocity is accreted on to a back hole and hence forms accretion disc in presence of turbulent viscosity. Furthermore, we also show that increase of the ? coefficient increases the rate of advecation of matter towards the black hole. The density profile we obtain is in good quantitative agreement with that obtained from the analytical results.

Jet launching from a circumplanetary disc embedded in an externally-ionised protosolar nebula

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We perform adaptive-mesh, global resistive-MHD computer simulations of a protoplanetary disc (PPD) section with an embedded giant planet. The disc model assumes self-consistent and dynamically evolving Ohmic resistivity and ambipolar diffusion (AD), which are determined by a balance between external ionisation from X-rays, CRs and FUV photons, and absorption of free charges by gas-phase elements and on dust grains. Before the insertion of the planet core, the resulting configuration consists of a magnetically inactive dead zone and turbulent surface layers in the case of Ohmic resistivity alone. When considering the combined effect of AD and Ohmic dissipation, the magneto-rotational instability is supressed and a magneto-centrifugal wind is launched from the PPD instead.
When the embedded planet core of initially 100 earth masses has opened a gap in the disc, we study the ionisation structure and turbulent state of this region. By determining accretion rates and analysing the flow structure in the vicinity of the planet, we aim to address the important question of what limits the growth of gas giant planets in the classic core-accretion picture. Unlike in earlier 2D studies, and confirming previous 3D hydrodynamic models, we identify that the bulk of the mass accretion onto the core happens from high latitudes. This implies that mass transport through the circum-planetary disc (CPD) is negligible. At late times during the simulation, we observe the self-consistent emergence of a magnetically collimated outflow from the CPD, which had been predicted theoretically by Fendt.

Magnetic braking in collapsing dense cores

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I will discuss the role of magnetic field in transporting the angular momentum during the collapse of prestellar cores.

Transonic solutions of isothermal galactic outflows in gravitational potential of a dark matter halo and a super massive black hole

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We present fundamental properties of transonic galactic outflows in gravitational potential of a dark matter halo and a super-massive black hole assuming isothermal, steady and spherically symmetric state (Igarashi et al. 2014, arXiv:1405.3432). Transonic solutions of galactic outflows are classified according to the perspective of their topological features. We found that there are mainly two types of transonic solutions characterized by different locus of the transonic point; one transonic point is formed at a central region (100kpc). Because these two transonic solutions have substantially different mass fluxes and starting points, these solutions may have different influences on the evolution of galaxies and the release of metals into intergalactic space.
We have applied our model to the Sombrero galaxy and obtained a new type of the galactic outflow: a slowly accelerated transonic outflow through the transonic point at very distant region (126kpc). In this galaxy, previous works reported that although the trace of the galactic outflow is observed by X-ray, the gas density distribution is consistent with the hydrostatic state. We have clarified that the slowly accelerating outflow has a gas density profile quite similar to that of the hydrostatic solution in the widely spread subsonic region. Thus, it is difficult to distinguish the wide subsonic region from hydrostatic state. Such galactic outflows in quiescent galaxies with inactive star formation are different from the conventional supersonic outflows observed in star-forming galaxies.

Relativistic modeling for precessing jets: the SS433 X-ray binary environment

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We present numerical simulations to complement modern radio observations of the helical jets seen in association with X-ray binary SS433. Adopting a 3D relativistic hydrodynamic model, we go beyond the pure kinematic model frequently used to interpret the radio VLA views, pointing out that the gradual build-up of the full helical jet path naturally results in a somewhat decelerated propagation. Synthetic radio maps of the simulated, precessing jets confirm the basic scenario of an overdense jet injected at 0.26c, prevailing at the sub-parsec scale distances. Recent extensions to either larger simulated domains, or to closer in regions including time-variable ejection patterns, will be presented.

AGN outflows at parsec and sub-parsec scales

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The talk will present an overview of recent results achived by studies of AGN jets with ground-based and space Very Long Baseline interferometry.

Constraints from zoom-simulation on accretion and outflow processes around solar mass stars

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In the context of adaptive mesh refinement simulations of the collapse from pre-stellar cores ? simulated as part of giant molecular clouds ? to disks, I investigate in particular the role of the magnetic field and its impact on the accretion as well as the outflow processes. The simulations cover a range of nearly 9 orders of magnitude, from 40 pc to 0.015 AU, and are carried out using the adaptive-mesh-refinement code RAMSES (Teyssier 2002, Fromang et al. 2006). The strength of large-scale magnetic fields is shown to influence the accretion process dramatically, and is furthermore key to understand the launching of jets and outflows.

The magnetic field goes through a characteristic sequence of structure evolution during the accretion process, starting out with an approximate hour-glass shape in the earliest phases of evolution, then evolving into a structure that contains a central jet and a broader disk outflow. Late in the accretion process the magnetic field is mainly oriented along the direction of rotation. However, it remains non-stationarity, with strong fluctuations in time and space being characteristic throughout the entire process. Jets and outflows, for example, are seldom symmetric - more often one side or the other dominates, only to be replaced by the opposite sense of symmetry breaking.

The results presented in this poster thus demonstrate the variability of accretion processes due to stellar environment, and illustrate how this influences the formation of protoplanetary disks. Moreover, I show that accretion, jets and outflows are not distinct processes, but that they are rather tightly coupled to each other. With respect to computational aspect, an adequately large number of cells per level of refinement is crucial to be able to model the accretion process, and the jet launching semi-quantitatively. Insufficient refinement leads to lower mass disks which are lower in mass and more homogeneous, causing them being under resolved hence smearing out the influence of turbulence. The jets are weaker and of lower speed for under resolved cases since lower resolution causes a larger launching radii for the jet, corresponding to lower Kepler speeds.

Estimation of mass outflow rates from viscous, general relativistic accretion disc around black holes.

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We have studied advective accretion disc solutions by using relativistic equation of state (EoS) for multi-species fluid in full general relativity and estimated the mass outflow rate from such a disc around black holes. In our study we have used the viscosity prescription as have used by Peitz and Appl. For the multi-species fluids we have found all type of accretion solutions such as, Bondi like, ADAFs and shock solutions. We point out the regime of accretion solutions which may naturally produce bipolar outflows. Moreover , outflow rates vary with composition and viscosity of the disc. We have computed the dependence of mass outflow rates on viscosity parameter and discussed its implication in observations.

The Importance of Accretion and Outflows for Young Star Spins

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I will discuss theoretical models of angular momentum transport, due to both accretion and outflows, highlighting how they are helping us to understand the observed spin rates of pre-main-sequence and young stars.

Temperature Fluctuations driven by Magnetorotational Instability in Protoplanetary Disks

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The magnetorotational instability (MRI) drives magnetized turbulence in sufficiently ionized regions of protoplanetary disks, leading to mass accretion. The dissipation of the potential energy associated with this accretion is a component of the balance which determines the thermal structure of the disk. This is expected to be most significant in the inner regions, at the midplane inside the inner edge of the dead zone. To model the resulting thermal structure of the disk, it is critical to recognize that magnetized turbulence dissipates its energy intermittently in current sheet structures. I will discuss our recent study of this intermittent energy dissipation using high resolution numerical models including a constant resistivity and radiative thermal diffusion in an optically thick regime. Our models predict that these turbulent current sheets drive order unity temperature variations even where the MRI is damped strongly by Ohmic resistivity (McNally et al. 2014). I will discuss these temperature fluctuations, and the current sheets which drive them.

MRI turbulence in accretion discs: angular momentum transport in the low Prandtl number limit

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The mechanisms and rate of angular momentum transport in astrophysical discs is a central problem in accretion theory. Currently the most widely studied mechanism for this transport is the turbulence induced by the magnetorotational instability (MRI). However previous studies have proven that this transport decreases with a decreasing ratio of fluid viscosity to fluid resistivity, also called Prandtl number $Pm=\nu/\eta$. This questions the role of MRI turbulence in discs with very low Prandtl number such as protoplanetary discs.
In this context, we study the rate of angular momentum transport at low Prandtl number by the means of local simulations of MRI-driven turbulence at very high resolution. In this talk, I will present results showing a convergence of transport rate at low Pm for different magnetic field configurations and discuss the relevance of implicit Large Eddy Simulations (LES) for such a study.

Instabilities of Current-Carrying Relativistic Jets

Mignone Andrea [1]

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I discuss some recent results on the linear and nonlinear stability analysis of Newtonian and relativistic magnetized jets carrying helical magnetic fields.
Nonlinear evolution is investigated with the aid of three-dimensional numerical simulations using the PLUTO code.The role of Kelvin-Helmholtz, current- and pressure-driven instabilities and their impact on the jet morphology, jet braking and overall stability is analyzed.

Simulations of jet - environment interactions using the PLUTO code

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Jet - environment interactions can produce interesting astrophysical phenomena that may explain features in jets such as the HST-1 in M87. Using the PLUTO code (v4.0) by A. Mignone et al., we simulate the interaction between a relativistic, magnetized, axisymmetric jet with a selection of different environments, assuming that the poloidal component of the magnetic field is negligible in large distances from the source. Two different simulations are presented: the jet interacts with either a static atmosphere (first case) or with accreting material (second case). These interactions are explored by performing magnetohydrodynamic simulations of both the jet and the static atmosphere or the Bondi accretion. A transition in the shape of the jet from parabolic to conical near the Bondi radius was observed by Asada & Nakamura in the case of M87, which may be connected to pressure variations of the accreting material outside the jet. Consequently, the second case aims to examine whether such pressure variations may be produced by Bondi accretion and thus change the shape of the jet.

Numerical simulations of relativistic jets emission and dynamics

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In the recent decades simulations have become an indispensable tool for modeling and understanding many of the jet aspects. After introducing modern numerical methods used to perform relativistic jet simulations, I give an overview of selected topics where numerically computing an observational signature of a relativistic jet simulation is very important.

Zooming in on proto-planetary disks

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We use the adaptive mesh refinement computer code RAMSES to model the formation of protoplanetary disks in realistic star formation environments, with resolution scaling over 29 powers of two (nearly 9 orders of magnitude), covering a range from outer scales of about 50 pc to inner scales of less than 0.015 AU.
The simulations are done in three steps, with the first step covering 16 powers of two, following individual star formation in a 40 pc GMC model. In the 2nd step, the neighborhoods of several stars with a final system mass of 1-2 solar masses are followed during the accretion process, with a smallest mesh size of 2 AU, sufficient to follow the development of the large scale structure of their accretion disks and the accretion history over about 200 kyr. Finally, a selection of these disks are studied over shorter time intervals, of the order 100-1000 yr, with cell sizes ranging down to 0.015 AU, sufficient to resolve the vertical structure of a significant radius fraction of the disks.
The purpose of this procedure is to characterize the typical properties of accretion disks around solar mass protostars, with as few free parameters as possible, and to gather a statistical sample of such conditions, to quantify the extent of statistical variation of properties. This is a vast improvement over models where initial and boundary conditions have to be chosen arbitrarily. Here, the initial and boundary conditions follow instead from the statistical properties of the interstellar medium, which are reasonably well established, as per for example the Larson relations and the B-n relation, which provide typical values for the velocity and magnetic field RMS values on different scales.
As a byproduct of this type of modeling, which starts out from a supernova driven interstellar medium (no artificial forcing), we can follow the transport of short-lived radioactive nuclides (SLRs), from the time of ejection from supernovae and until they become part of the proto-planetary disks. The transport time is on average short enough to be consistent with initial abundance of 26Al in the Solar System derived from cosmochemistry.

On Vertically Global, Radially Local Models for Astrophysical Disks

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Astrophysical disks play a fundamental role in nature. They shape the evolution of planets, stars, and black holes by regulating the rate at which they acquire mass and exchange angular momentum with their environments. Unraveling the physical processes that govern these disks entails understanding the turbulent dynamics of magnetized plasma in the gravitational field of a central object. Fully global numerical simulations, while feasible, still remain very demanding. Therefore, there is great interest in devising local frameworks for studying the disk dynamics. During the last two decades, the framework known as the shearing box, has been extensively used for studying a small (in radius, azimuth, and height) volume around a fiducial location at the disk midplane. This framework is appropriate for studying barotropic disks, for which the pressure is only a function of the density and the angular frequency is independent of height. I this talk, I will introduce a new framework for developing vertically global, radially local models for non-barotropic disks, such as those with a non-trivial temperature structure, for which the angular frequency changes with height. I will illustrate the power and potential of this new framework with two prominent applications, namely the vertical shear instability and the magnetorotational instability. I will discuss the prospects of using this new framework to study a wide variety of astrophysical phenomena; including instabilities, convection, turbulent transport, as well as the structure and dynamics of disk coronae and winds, and the interstellar medium in galactic disks.

Causality and stability of cosmic jets

Porth Oliver [1], Komissarov Serguei

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Cosmic jets are able to transport energy over vast spaces which exceed by up to a billion times the size of their central engines. We propose that the reason behind this remarkable property is the loss of causal connectivity across these jets, caused by their rapid expansion in response to fast decline of external pressure with the distance from the "jet engine".
In order to verify this claim, we have carried out numerical simulations of moderately magnetized and moderately relativistic jets that expand and accelerate due to the decrease of ambient pressure. The results give strong support to our hypothesis and provide valuable insights on the mechanism of jet disruption. In particular, we find that the z-pinched inner cores of magnetic jets expand slower than their envelopes and become susceptible to instabilities even when the jet is stable on the global scale. This may result in local dissipation and emission without total disintegration of the flow. Cosmic jets may become globally unstable when they enter flat sections of external atmospheres. We propose that the Fanaroff-Riley morphological division of extragalactic radio sources into two classes is related to this issue. In particular, we argue that the low power FR-I jets become re-confined, causally connected and globally unstable on the scale of galactic X-ray coronas, whereas more powerful FR-II jets re-confine much further out, already on the scale of radio lobes, and remain largely intact until they terminate at hot spots.

Pair Cascades in the Disk Environment of the Binary System PSR B1259-63/LS 2883

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PSR B1259-63/LS 2883 is a very high energy (VHE; E > 100 GeV) ?-ray emitting binary consisting of a 48 ms pulsar orbitting around a Be star with a period of ? 3.4 years. The Be star features a circumstellar disk which is inclined with respect to the orbit in such a way that the pulsar crosses it twice every orbit. The circumstellar disk provides an additional field of target photons which may contribute to inverse Compton scattering and gamma-gamma absorption, leaving a characteristic imprint in the observed spectrum and light curve of the high energy emission. We study the signatures of Compton-supported, VHE gamma-ray induced pair cascades in the circumstellar disc of the Be star and their possible contribution to the GeV flux. We also study a possible impact of the gamma-gamma absorption in the disk on the observed TeV light curve.

Global MHD Simulations of Star-Disk Interaction

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In the final phase of star formation processes, gas accretes through circumstellar disks onto protostars, and the disk and the protostar interact each other via magnetic fields in the innermost region. The structure of the accretion flow in this region is determined by the strength of the stellar magnetic fields and the accretion rate, which depends on angular momentum transport by turbulence driven by the Magneto-Rotational Instability (MRI). Therefore, high resolution MHD simulations are required to study the structure of the accretion flow.
For this purpose, we have extended Athena MHD simulation code (Stone et al. 2008) by implementing a new MHD solver for spherical polar coordinates. We performed MHD simulations similar to Romanova et al. (2012) with sufficient resolution to resolve MRI within the disk. The properties of turbulent accretion disks with weak magnetic fields are similar to those obtained in local shearing box simulations. On the other hand, the magnetic interchange instability always persists in the visinity of the central star. When the stellar magnetic field is weak, the gas accretes directly onto the stellar surface through the disk. As the field strength increases, the interaction between the stellar field and disk makes the accretion strongly non-uniform.

Rarefaction waves in magnetized astrophysical jets

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Pressure variations in the environment of astrophysical jets induce rarefaction waves propagating inside the jet. Their implications on the jet dynamics will be discussed, focusing on the bulk acceleration and its efficiency in GRB and AGN jets.

Variable accretion with episodic bursts

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It has recently become evident from both numerical studies and, inderectly, from observations that accretion onto young protostars may have a highly variable character with episodic bursts revealing themselves as FU-Orionis-type and EX-Lupi-like eruptions. This newly emerging paradigm is beginning to supersede the classical Shu-Larson-Penston steady accretion model and this may have important consequences for the evolution of stars and planets. I will review the current status of the variable accretion paradigm, focusing on the disk gravitational instability and fragmentation model, in which accretion bursts are triggeredby fragements migrating onto the star. I will consider the implications of variable accretion and demonstrate that a similar mechanism can operate in primordial disks around the first stars. Finally, the possibility of variable accretion in AGN will also be discussed.

Variation of AGNs jets celerity due to Compton rocket effect in a complex photon field.

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Radio-loud AGN are among the most powerful objects in the universe. In these objects, most of the emission comes from the relativistic jet getting its power from accretion processes. However, despite many studies, the jets acceleration to relativistic speeds is still misunderstood. The bulk Lorentz factor characterizing the speed of these flows cannot be precisely measured and only limits have been established.
It is widely admitted that jets are composed of relativistic particles emitting light through several physical processes, one of them being the comptonization of photons coming from external sources to the jet. It has been shown that this emission can drive a group of highly relativistic leptons placed in an external photon field to relativistic bulk motions through the Compton rocket effect. In this work, we investigate this process and compute the resulting bulk Lorentz factor in the complex photon field of an AGN composed of several external photon sources.
To do so, we model the sources present in the inner parts of an AGN (the accretion disk, the dusty torus and the broad line region), taking precisely into account their geometry and anisotropy to numerically compute the bulk Lorentz factor of the jet at every altitude. The study, made for a broad range of parameters, investigates the patterns of the bulk Lorentz factor depending on the external sources which show some interesting and unexpected behaviours with natural acceleration and deceleration zones in the jet.

General relativistic radiation-hydrodynamics of accretion flows

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I will discuss recent progress in the numerical modeling of accretion flows made possible after solving the general relativistic radiation-hydrodynamics equations within the projected symmetric trace-free (PSTF) moment formalism. I will first present the necessary numerical tools for coping with the stiffness of the equations and for treating the intermediate regime between the optically thick and the optically thin. Then, I will show some applications to spherical accretion onto a black hole, supersonic Bondi-Hoyle accretion and some preliminary results about more realistic accretion discs.

Transient dynamics of perturbations in Keplerian discs using a variational approach.

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Since Keplerian discs are shear flows they are capable of a substantial transient effects in dynamics of perturbations. In this study we consider these effects employing a variational formulation of the optimisation problem which allows one to obtain an optimal initial perturbations that exhibit the highest possible growth at a specified time interval. First, we use this method to study a linear transient dynamics in a shearing sheet approximation. It is shown that the most rapidly growing shearing harmonic has azimuthal wavelength of order of the disc thickness. Moreover, its initial shape is always nearly identical to vortical perturbation having the same potential vorticity. Then we extend our study to a global spatial scale taking into account the background vorticity gradient and the disc cylindrical geometry. It is shown that global vortices with azimuthal wavelengths more than an order of magnitude greater than the disc thickness still are able to attain the growth of dozens of times in a few characteristic Keplerian periods. We estimate that if disc is already in a turbulent state with small effective viscosity these large scale vortices have the most favorable conditions to be transiently amplified before they are damped. At the same time, turbulence is a natural source of the potential vorticity for this transient activity. Thus, we conclude that transiently growing vortical structures on scales above the disc thickness should provide an additional angular momentum transfer in accretion discs and should affect their variability properties as well.

Non-ideal MHD consequences for the first Larson core

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We study the consequences of ambipolar diffusion for the first Larson core and its surroundings, namely the disk and the outflow. We show that the decoupling of neutral matters and magnetic fields due to ambipolar diffusion has strong consequences in the magnetic field topology and therefore on angular momentum repartition and the following properties of the disk (velocity field, beta plasma, aspect ratio)

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