Program of the CoCoNuT 2019 workshop

Time/Date	Wednesday (18/09)	Thursday (19/09)	Friday (20/09)
9:30-10:30	K. Kiuchi	I. Kovalenko	B. Mueller
10:30-11:00	Coffee Break	Coffee Break	Coffee Break
11:00-11:30	M. Oertel	D. Alina	A. Torres-Forne
11:30-12:00	A. Sourie	B. Shukirgaliyev	H. Andresen
12:00-14:00	Lunch	Lunch	Lunch
14:00-15:00	T. Foglizzo	Collaboration/ Excursion	K. Boshkayev
15:00-15:30	Coffee Break		Coffee Break
15:30-16:00	R. Kazeroni		A. Pascal
16:00-16:30	J. Novak		ECL Lab tour

Venue: Nazarbayev University, block C4, room 268.

The workshop dinner will take place on Thursday, September 19, at 18:30 in the Uzbek restaurant Z-1 (14r Qonayev St.). The bus to the restaurant will leave the hotel at 18:00 and stop by at campus at 18:05 before heading for the restaurant. The dinner will be followed with some walking and sightseeing in the city center.

Kenta Kiuchi (9:30-10:30, 18/09)

Title: Recent progress of a numerical modeling of binary neutron star mergers in numerical relativity.

Abstract: Binary neutron star mergers are one of the most exciting targets for the multimessenger astrophysics. Building a reliable theoretical model is a challenging and exciting research theme and numerical relativity is a unique method to accomplish it. In this talk, I'll give a current status of a numerical modeling of binary neutron star mergers. In particular, I'll focus on a recent progress of CRA-YITP group.

Micaela Oertel (11:00-11:30, 18/09)

Title: Neutrino-nucleon interactions in dense and hot matter

Abstract: Neutrinos play an important role in compact star astrophysics: neutrino-heating is one of the main ingredients in core-collapse supernovae, neutrino-matter interactions determine the composition of matter in binary neutron star mergers and have among others a strong impact on conditions for heavy element nucleosynthesis and neutron star cooling is dominated by neutrino emission except for very old stars. Many works in the last decades have shown that in dense matter medium effects considerably change the neutrino-matter interaction rates, whereas many astrophysical simulations use analytic approximations which are often far from reproducing more complete calculations. In this talk I will present a scheme which allows to incorporate improved rates into simulations and show as an example some results for core-collapse supernovae.

Aurelien Sorie (11:30-12:00, 18/09)

Title: Constraining the equation of state of dense matter using tidal deformability and oscillations of neutron stars.

Abstract: In this talk, I will present two new projects developed at ULB, which aim at constraining the equation of state (EoS) of dense matter from gravitational-wave observations of neutron stars. First, I will discuss the role of the symmetry energy and the neutron-matter stiffness on the tidal deformability of a cold nonaccreted neutron star, using the thermodynamically-consistent BSk EoSs. Then, I will focus on our very first results concerning the modelling of neutron-star oscillations using spectral methods.

Thierry Foglizzo (14:00-15:00, 18/09)

Title: The impact of precollapse perturbations and rotation on the explosion of massive stars

Abstract: I will first discuss the magnitude of pressure perturbations produced during the infall of precollapse asymetries, distinguishing the contributions of entropy and vorticity perturbations. These results have been obtained using perturbative methods. I will also indicate some perspectives to address this problem experimentally using the shallow water analogy. In a second part I will describe the effect of rotation on the instability of the accretion shock using 2D equatorial simulations in cylindrical geometry. I will discuss some shortcomings of our theoretical understanding of the low T/W instability in an accretion flow.

Remi Kazeroni (15:30-16:00, 18/09)

Title: The coupling between neutrino-driven convection and pre-collapse perturbations in the gain layer of core-collapse supernovae.

Abstract: In the first part, I will introduce a toy model used to study the growth conditions of turbulent motions in the gain region of core-collapse supernovae where convection can be

linearly stabilized by advection. The numerical simulations of the model show that a single perturbation can trigger self-sustained convection only if the flow is linearly unstable. The 3D nature of the flow induces an efficient mixing which enhances the heating efficiency. This effect that could ease the onset of the explosion is absent in 2D.
In the second part, I will focus on the additional turbulence generated by parametrized density perturbations accreting through the gain layer where convection is already fully turbulent. The 3D simulations suggest that the turbulent kinetic energy of the flow scales like A/l where A is the amplitude of the perturbation and l its dominant azimuthal mode. The coupling is maximized when the temporal frequency of the perturbation matches the convective turnover frequency of flow. An analytical estimate is tested favorably against the simulations and indicates that the additional turbulence results mainly from the action of buoyancy which converts gravitational potential energy into kinetic energy over a length-scale inversely proportional to l. These results confirm that only large scale pre-collapse perturbations may provide favorable conditions to facilitate the shock revival.

Jerome Novak (16:00-16:30, 18/09)

Title: Magnetic field distribution in neutron stars

Abstract: We perform a numerical study of the magnetic field configurations in non-rotating neutron stars. We find that the monopolar part of the norm of the magnetic field can be described by a single profile, that we fit by a simple eighth-order polynomial, as a function of the star's radius. This new generic profile applies remarkably well to all magnetized neutron star configurations built on hadronic equations of state. We then apply this profile to build magnetized neutron stars in spherical symmetry, using a modified Tolman-Oppenheimer-Volkov system of equations.

Ilya Kovalenko (9:30-10:30, 19/09)

Title: Convection-driven turbulence in gas-dust optically thick interstellar clouds

Authors: I. G. Kovalenko, V. V. Korolev, E. V. Zhukova, A. M. Zankovich
(Volgograd State University, Volgograd, Russia)

Abstract: We study the effectiveness of one of the potentially most common mechanisms for generating undamped turbulence in the interstellar medium, including the conditions under which turbulence can exist as supersonic. Convective instability in an optically dense stratified gas-dust medium is considered as a mechanism for maintaining turbulence.

We consider stationary and non-stationary two-dimensional models of a self-gravitating gas-dust cloud with stellar radiation sources in its center. The material of the cloud is considered as a two-component, generally two-speed continuous medium. The first component, gas, is transparent for stellar radiation, and the second one, dust, is assumed to be an optically dense

medium, carried by the pressure of stellar radiation outward to the periphery of the cloud. The dust is specified as a set of spherical grains of a similar size (we made calculations for dust particles with radii of 0.05, 0.1, and 0.15 μm). The processes of scattering and absorption of UV radiation by dust particles followed by IR reradiation, with respect to which the medium is considered to be transparent, are taken into account. Dust-driven stellar wind sweeps gas outwards from the center of the cloud, forming a cocoon-like structure in the gas and dust. For the radiation flux corresponding to a concentration of one star with a luminosity of about 5×10^4 L_{\odot}$ per square parsec on the plane of sources, sizes of the gas cocoon are equal to 0.2–0.4 pc, and for the dust one they vary from tenths of a parsec to six parsecs. Gas and dust in the center of the cavity are heated to temperatures of about 50–70 K in the model with graphite particles and up to 40 K in the model with silicate dust, while the background equilibrium temperature outside the cavity is set equal to 10 K.

We present the results of numerical two-dimensional simulation of convective instability developing in such a cloud in the framework of radiative hydrodynamics. Convection arises in the inverse density distribution layer in the form of small-scale vortices. The sizes of vortices with time reach values of the order of $\sim (0.05-0.1) \lambda_J$ (λ_J is the Jeans length), and the flow becomes turbulent throughout the entire thickness of the cloud. Advance stage of turbulence takes on a transonic character with maximum Mach numbers up to 1.2, however, supersonic regions occupy a small part of the cloud volume. Modeling shows that the proposed mechanism can explain the turbulence observed in clouds at parsec and subparsec scales.

D. Alina (11:00-11:30, 19/09)

Title: On the relative orientation between magnetic fields, filaments and Galactic Cold Clumps

Abstract: It is now commonly accepted that magnetic field is one of the principal actor in the evolution of interstellar filaments and in the process of star formation along with gravity and turbulence. Polarimetric data of dust emission polarization is well suited to probe magnetic field structure in dense, cold interstellar medium and to provide hints on dust physics through the efficiency of grains alignment with respect to the magnetic field lines. Analysis of relative orientation between filamentary structures and magnetic fields is one of the methods to reveal the role of the magnetic field in the evolution of these structures.

I will present a statistical analysis of the relative orientation between the plane-of-sky magnetic field and the filaments associated with the Galactic Cold Clumps. We extracted 90 filaments from the Planck 353 GHz data all over the sky using the Rolling Hough Transform. We inferred magnetic field orientations within filaments using optically thin medium assumption and compared the orientation of the hosting filaments and embedded clumps with respect to both the background and inner magnetic fields and compared background and inner magnetic field orientations. We find different behaviours in terms of relative orientation depending on the environment density, and on the density contrast between the filaments and their environment.

In particular, filaments located in high background column density regions do not exhibit preferential orientation with respect to background magnetic field while those located in low background column density regions are aligned parallel to the field with the exception of highly contrasted filaments that are mostly perpendicular to it. We also reveal differences in the alignment of the clumps with respect to the filaments' magnetic field depending on the column density contrast of the hosting filaments: we observe a bimodal distribution of the relative orientations in highly contrasted filaments. I will discuss these findings in the frame of evolution and environment of the filaments (based on Alina et al. 2019).

B. Shukirgaliyev (11:30-12:00, 19/09)

Title: Studying the evolution of star clusters from birth to dissolution with a new approach.

Abstract: We study the evolution of star clusters in the Galactic tidal field starting from their birth in molecular clumps. Our model clusters form according to the local-density-driven cluster formation model in which the stellar density profile is steeper than that of gas. As a result, clusters resist the gas expulsion better than predicted by earlier models.

We vary the impact of the Galactic tidal field lambda, considering different Galactocentric distances (3-18 kpc), as well as different cluster sizes. Our model clusters survive the gas expulsion independent of \lambda.

We investigated the relationship between the cluster mass at the onset of secular evolution and their dissolution time. The model clusters formed with high star-formation efficiency (SFE) follow a tight mass-dependent dissolution relation, in agreement with previous theoretical studies. However, the low-SFE models present a shallower mass-dependent relation than high-SFE clusters, and most dissolve before reaching 1 Gyr (cluster teenage mortality).

Bernhard Mueller (9:30-10:30, 20/09)

Title: Turbulent flow in core-collapse supernovae from collapse to shock break-out

Abstract: Fluid instabilities play a central role in supernova explosions of massive stars from the final death throes of convective core and shell burning, through shock revival, and until shock breakout. Historically, the various phases of the (pre-)supernova evolution have been investigated separately. In this talk, I will present our efforts to move towards an integrated modelling pipeline of these different stages using supernova simulations with CoCoNuT as the critical link between 3D progenitor modelling and simulations of mixing instabilities in the envelope. I will focus in particular on highly dynamical phenomena like shell mergers and shell ignition seen in recent models of shell burning, and discuss the problem of wave excitation at convective boundaries. In the second part of the talk, I will address the long-term evolution of the explosion with a view to observable asymmetries, stressing the potential of stripped-envelope supernovae as a diagnostic for the global asymmetries seeded during the early explosion phase.

Alejandro Torres-Forne (11:00-11:30, 20/09)

Title: Universal Relations Of Core-Collapse Supernova With Gravitational Waves

Abstract: We will present the derivation, based on numerical simulations, of the universal relations that relate the frequencies of the most common oscillation modes of the proto-neutron star observed i.e. g-modes, p-modes and the f-mode, with the properties of the system, such as the surface gravity of the proto-neutron star or the mean density in the region enclosed by the shock. We show that the relations do not depend on the equation of state or progenitor star and hence are universal, and, therefore, these relations can be used to build methods to infer proto-neutron star properties from gravitational-wave observations alone.

Haakon Andresen (11:30-12:00, 20/09)

Title: Analytical GW signals, a test case for numerical integration routines

Abstract: Many core-collapse simulations are performed in either a waveless approximation of general relativity, such as the conformally flat approximation, or in the post-newtonian framework. In both cases, it is necessary to use the quadrupole formula to extract the gravitational wave signals. Several decades ago, a lot of work was done to circumvent the second-order time derivative that appears in the original formulation. However, one additional problem remains unexplored in the literature. When calculating the signal one has to perform a volume integral over chaotic and highly variable functions, which can cause severe problems if not handled correctly. Those who deal with such integrals regularly understand how to correctly perform, but no standardised test cases exist. I have developed such a test case and I will present it in my talk. I will show how one can construct mock data, from analytical functions, that mimics hydro data from real numerical simulations. I will show how these analytical signals can be integrated to provide a test case against which numerical integration schemes can be tested. The goal of this work is to provide a test case for new routines. I will also give some recommendations on how to calculate the volume integral.

K. Boshkayev (14:00-14:30, 20/09)

Title: SGRs and AXPs as fast rotating highly magnetized massive white dwarf stars

Abstract: The physical characteristics of SGRs and AXPs are investigated within the magnetar model and white dwarf model. Both models are compared and contrasted. The main advantages and drawbacks of the models are discussed in details.

Aurelien Pascal (15:00-15:30, 20/09)

Title: Modeling the cooling phase of proto neutron stars.

Abstract: The modelisation of proto neutron stars cooling is still a computational challenge due to the very different physical processes and timescales at stake, such as acoustic oscillations, hydrodynamic convection, neutrino transport and Kelvin-Helmholtz contraction.
In order to deal efficiently with these various timescales, we need to use a set of consistent approximations such as a succession of hydrostatic equilibrium, a stationary radiation transfert and find a way to model the convective motion without being limited by the acoustic timescale.
In this talk I will make a brief review of previous works focused on PNS cooling. Then I will introduce the model that I am developing and the current state of my work.