

7<sup>th</sup> August, 2018

Dear Professors,

I am a [Pegasus]<sup>2</sup> Marie Skłodowska-Curie fellow in KU Leuven, at the Center for mathematical Plasma Astrophysics (CmPA), working in Computational Astrophysics with Rony Keppens. I joined the CmPA in October 2016 after defending my PhD on *Wind accretion onto compact objects*, under the supervision of Andrea Goldwurm and Fabien Casse. I apply to the Junior Professor position in Theoretical Astrophysics at the University of Potsdam for I believe my profile could match the expected requirements and since it would be a valuable asset to pursue and develop further my emerging academic career.

After my undergraduate studies at the Ecole Normale Supérieure, I volunteered to join the Kepler satellite data analysis effort under Saul Rappaport's lead at MIT. There, I was introduced to stellar evolution and binary systems and took an active part in the discovery and characterization of the first disintegrating exoplanet in 2012. My involvement also contributed to the identification of 30 new triple star systems and to a detailed analysis of the shortest-period exoplanets, those right in the spotlight of their host star. This seminal long term experience in Research laid the foundations of my scientific program : a better understanding of stellar objects and their compact remnants in interaction with their environment.

As I started my PhD, I turned to numerical tools to complement the analytical skills I had acquired during the previous years and model the turbulent twilight of binary systems, the X-ray binaries. I got familiar with advanced techniques such as solvers for hyperbolic partial differential equations and parallel computing, in the context of the finite volume MHD code MPI-AMRVAC. With several successful proposals on Tier-1 clusters and the code development I carried out, I could run the widest dynamics simulations of wind accretion onto compact objects.

By the end of my first postdoctoral year in KU Leuven, I was granted a 3-years [Pegasus]<sup>2</sup> Marie Skłodowska-Curie fellowship. I also joined a collaboration with Lida Oskinova, Silvia Martínez-Núñez and Peter Kretschmar to gather observers and theoreticians from the X-ray binaries and massive stars winds communities. It enabled me to design and confront simulations of the accretion process in Supergiant X-ray binaries to the most recent observations of Vela X-1. Thanks to simulations of the internal shocks and stratification in the wind of isolated massive stars by Andreas Sander, Jon Sundqvist and collaborators, we could evaluate the impact of the wind micro-structure on the time variability of the mass accretion rate onto the neutron star.

Beyond my research activity, I also proved my teaching abilities first in 2011 by passing the French Agrégation in Physics where I ranked second in 1,500 candidates. Since then, I regularly volunteered to be granted teaching responsibilities in a wide range of contexts. The present position is a unique occasion for me to fulfill my will to practice research jointly with teaching.

I am now willing to extend my investigations to deepen our understanding of the wind structure using the orbiting accretor as a probe. The expertise already available at the University of Potsdam in the domain would be a decisive asset to pursue this goal. May you judge my application admissible, I remain fully available to bring further information you might need.

Sincerely,

Ileyk El Mellah

A handwritten signature in black ink, consisting of a large, stylized 'E' followed by a series of loops and a long horizontal stroke at the bottom.

**Ileyk El Mellah**  
born on 5<sup>th</sup> April, 1989  
French citizen

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## Education

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|---------|--|
| 2013-16 | <b>PhD supervised by Fabien Casse &amp; Andrea Goldwurm on</b><br><i>Numerical simulations of wind accretion onto compact bodies</i><br>AstroParticule & Cosmology laboratory (APC) – Univ. of Paris 7 Diderot |
| 2012-13 | <b>Master degree in Astrophysics</b> – Observatory of Paris<br>Obtained with distinction   |
| 2010-12 | <b>Normalien at the <i>Ecole Normale Supérieure</i> of Cachan</b>  |
| 2011-12 | <b>Research internship and graduate courses</b> – MIT, Cambridge   |
| 2010-11 | <b>French <i>Agrégation</i> of Physics &amp; Chemistry</b> – ENS of Cachan, FR<br>Rank : 2 <sup>nd</sup> in 1,409 candidates   |
| 2008-10 | <b>Bachelor degree in Fundamental Physics</b> – ENS / Paris 6 University<br>Obtained with honours  |
| 2006-08 | <b>Preparatory classes to <i>Grandes Ecoles</i></b> – Lycée Janson-de-Sailly, Paris  |

## Research

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| Since 2016 | <b>FWO [Pegasus]<sup>2</sup> Marie Skłodowska-Curie fellowship</b><br><b>under the supervision of Rony Keppens</b><br>Center for mathematical Plasma Astrophysics – KU Leuven  |
| 2013-16    | <b>PhD thesis supervised by Fabien Casse &amp; Andrea Goldwurm on</b><br><i>Numerical simulations of wind accretion onto compact bodies</i><br>APC – Univ. of Paris 7 Diderot  |
| 2011-12    | <b>One-year internship supervised by Saul Rappaport on</b><br><i>Monitoring of close-in binary stars and short period exoplanets</i><br>Data analysis and models of light curves from the Kepler satellite<br>Kavli Institute for Astrophysics – MIT |
| Ap–Ag 2010 | <b>Internship supervised by Jean-François Lestrade on</b><br><i>Gravitational perturbations of debris discs by a passing-by star</i><br>LESIA – Paris Observatory  |
| Jn–Jl 2009 | <b>Internship supervised by Gérard Belmont &amp; Patrick Robert on</b><br><i>Resampling of the CLUSTER satellites data</i><br>Plasma Physics Laboratory – Vélizy   |

## Communications

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### Peer-reviewed publications

- [1] El Mellah I., Sundqvist J. O. & Keppens R.  
*Accretion from a clumpy massive-star wind in Supergiant X-ray binaries* (2017)  
MNRAS
- [2] Grinberg V., Hell N., El Mellah I., Neilsen J., Sander A. A. C., Leutenegger M. A.,  
Fürst F., Huenemoerder D. P., Kretschmar P., Kühnel M., Martínez-Núñez S.,  
Niu S., Pottschmidt K., Schulz N. S., Wilms J. & Nowak M. A.  
*The clumpy absorber in the high mass X-ray binary Vela X-1* (2017) - A&A
- [3] Xia C., Teunissen J., El Mellah I., Chané E. & Keppens R.  
*MPI-AMRVAC 2.0 for solar and astrophysical applications* (2017) - ApJ Supplement Series
- [4] El Mellah I. & Casse F.  
*A numerical investigation of wind accretion in persistent Supergiant X-ray Binaries  
I - Structure of the flow at the orbital scale* (2016) - MNRAS
- [5] El Mellah I. & Casse F.  
*A numerical simulations of axisymmetric hydrodynamical Bondi-Hoyle accretion  
on to a compact object* (2015) - MNRAS
- [6] Sanchis-Ojeda R., Rappaport S., Winn J., Kotson M., Levine A., El Mellah I.  
*The shortest-period planets found with Kepler* (2014) - ApJ
- [7] Rappaport S., Deck K., Levine A., Borkovits T., Carter J., El Mellah I., Sanchis-Ojeda R.,  
Kalomeni B.  
*Triple-star candidates among the Kepler binaries* (2013) - ApJ
- [8] Rappaport S., Levine A., Chiang E., El Mellah I., Jenkins J., Kalomeni B., Kite E. S.,  
Kotson M., Nelson L., Rousseau-Nepton L., Tran K.  
*Possible disintegrating short-period super-Mercury orbiting KIC 12557548* (2012) - ApJ

### Proceedings and PhD manuscript

- [9] El Mellah I., Sundqvist J. O. & Keppens R.  
*Clumpy wind accretion in Supergiant X-ray binaries* (2017) - SF2A
- [10] El Mellah I.  
*Wind accretion onto compact objects* (2017) - PhD manuscript
- [11] El Mellah I. & Casse F.  
*Numerical simulations of Bondi-Hoyle accretion onto a compact object* (2015) - SF2A

## Communications

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### Oral contributions<sup>a</sup>

Jl 2018	Caltech – seminar*
Ja 2018	Laboratoire Univers et Particules de Montpellier – seminar*
Dc 2017	Radboud University Nijmegen – seminar*
Nv 2017	ESAC (Madrid) – seminar*
Sp 2017	Observatory of Paris – seminar*
Sp 2017	KU Leuven – Frontiers of Astrophysical Modeling
Ag 2017	Köln – Numerical techniques in MHD simulations
Jl 2017	Paris – Journées de la SF2A
Mr 2017	Brussels Royal Observatory – CHARM meeting
Sp 2016	Arbatax – Super-Eddington accretion on compact objects
Sp 2016	Aarhus University – seminar*
Ap 2016	Paris 7 University – seminar*
Ap 2016	KU Leuven – seminar*
Oc 2015	AIM laboratory (CEA, Paris) – Computational Astrophysics meeting
Jn 2015	Toulouse – Journées de la SF2A
Mr 2015	Ecole des Houches – Turbulence, magnetic fields and self organization

### Posters

Jn 2017	<b>Clumps and shearing in Supergiant X-ray binaries</b> COSPAR 42 <sup>nd</sup> Scientific Assembly – Pasadena
Jn 2017	<b>Clumpy wind accretion in Supergiant X-ray binaries</b> EWASS – Prague
Dc 2015	<b>Numerical simulations of wind accretion onto compact objects</b> Texas symposium – Geneva
Nv 2014	<b>Numerical simulations of wind accretion undergoing flip-flop instability</b> IAP – Paris

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<sup>a</sup>The stars indicate an invited talk.

## Teaching & outreach

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### Teaching

2018-19	Computational methods for Astrophysics, 5 <sup>th</sup> year – KU Leuven
2017-18	Linear Algebra, 1 <sup>st</sup> year – KU Leuven
2016-17	Computational methods for Astrophysics, 5 <sup>th</sup> year – KU Leuven
2014-16	Classical Mechanics, 1 <sup>st</sup> year – Univ. of Paris 7 Diderot
2013	Physics for Medical studies, 1 <sup>st</sup> year – Univ. of Paris 7 Diderot
2013	Deterministic systems and signals, 4 <sup>th</sup> year – Univ. of Paris 7 Diderot
2012-13	Private lessons with the company <i>Cours Thalès</i> – Paris
2011	French <i>Agrégation</i> of Physics & Chemistry
2009-10	Teaching assistant at the high school Gustave Eiffel – Cachan

### Outreach

Oc 2017	Radio show <i>Faconde</i> on scientific outreach – Brussels
Ap–Nv 2015	Community manager of the Young Physicists Meeting – Paris
Oc 2015	Festival of Science – Univ. of Paris 7 Diderot
Sp 2015	Wolfram demonstration on the ballistic motion in a Roche potential and 3D-printing of the corresponding surfaces – APC
2013	Java applet on Turing theory of morphogenesis – Paris Observatory

## Grants & awards

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2017	Computing time on the Tier-1 VSC cluster : 1 Mh·cpu
2016	3-years FWO [Pegasus] <sup>12</sup> Marie Skłodowska-Curie fellowship
2016	Computing time on the CINES cluster : 300 kh·cpu
2015	Computing time on the CINES cluster : 300 kh·cpu
2013	3-years PhD fellowship from the Ecole Normale Supérieure of Cachan
2013	3-years teaching assistant grant from the Université of Paris 7 Diderot
2012	1-week observing time at the Mont Mégantic Observatory (Canada)
2011	French <i>Agrégation</i> of Physics and Chemistry - Rank : 2 <sup>nd</sup> / 1,409
2010	2-years fellowship from the ENS of Cachan as a <i>normalien</i>

## Selected skills

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### Programming languages

Fortran, C, C++, **Python**, Idl, Java, Perl, xML, Csh, Bash, **HTML**, **CSS**, JavaScript, CoffeeScript, HTML5

### Codes & softwares

MPI-AMRVAC, Mathematica, VisIt, Paraview, Vampir, VampirTrace, Atom, Emacs, Pyke, Inkscape, Gnuplot, DS9

### Data analysis

Extended Fourier and wavelet analysis, resampling and interpolation of time/space series

### Languages

French (native), English (fluent), Italian (B1)





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# Research statement

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El Mellah Ileyk

X-ray emitting binary systems host a compact object – a neutron star (NS) or a black hole (BH) – orbiting a stellar companion whose gas is accreted by the former. Since the discovery of the first extrasolar X-ray source in the early sixties (Giacconi et al. 1962), continuous observations of those systems have revealed a broad range of spectral and photometric behaviors with a special emphasis on their incredible time variability : flares, hysteresis loops in hardness–luminosity diagrams, off-states, quasi-periodic oscillations... all this on time scales ranging from milliseconds to years, fully within the scope of observational missions lifetimes (XMM-Newton, Chandra and Integral today, SVOM, LOFT and Athena tomorrow). The complex Physics at stake behind the scenes has long been beyond our reach due to limited observational data and numerical capacities. Those intrinsically intertwined systems require multi-scales approaches to fully appreciate the turbulent flow, from the Dantean stellar surface up to the magnetic vicinity of a NS, if not the relativistic surroundings of a BH. Game changing high performance computing technologies have ushered in a gold rush to design coupled semi-analytical models supported by numerical simulations to account for time variability in X-ray binaries. Once pie in the sky, a consistent overview of the accretion process is now within our grasp.

## Past activity

### PhD research activity

During my 3 years of PhD, I concentrated on mass transfer in binaries via wind accretion, the low angular momentum counterpart of the more comprehensively understood Roche lobe overflow (RLOF) mechanism. Supergiant X-ray binaries (SgXB), where a compact object (generally a NS) orbits an evolved O/B supergiant, are the ideal stage for wind accretion to occur. Indeed, the latter displays intense outflows, a fraction of which being captured by the NS. The rapid increase since the late 2000's in the number of SgXB (Walter et al. 2015) and the ambiguous status of the newly discovered SFXTs (Negueruela et al. 2006) only increased the appeal of this burning topic.

In a first attempt to better understand the wind accretion process, I confronted the analytical prescriptions given by Bondi, Hoyle and Lyttleton (BHL, Hoyle & Lyttleton 1939, Bondi & Hoyle 1944) to a hydrodynamical (HD) representation of the flow. To do so, I used and developed the explicitly flux-conserving finite volume transport code MPI-AMRVAC, a code whose origins trace back to the mid 90's when Gábor Tóth and Rony Keppens first tackled the question (Tóth 1996, Tóth et al. 1998). The new version I contributed to now addresses hydrodynamical or magneto-hydrodynamical problems, in Cartesian, cylindri-

cal or spherical geometry, with or without polytropic prescriptions, source terms, etc (Xia et al. 2017). For wind speeds similar to the ones observed in SgXB ( $\sim 1,000 \text{ km} \cdot \text{s}^{-1}$ ), the main challenge is the contrast between the scale at which the gravitational beaming of the fast inflow by the accretor becomes significant (the accretion radius) and the size of the compact accretor, typically 4 to 5 orders of magnitude smaller. Since most of the emitted light comes from the immediate vicinity of the accretor, it is important to follow the flow through these scales. To uniformly resolve the incoming planar flow, I implemented a radially stretched grid in a 2D spherical geometry. With suitable boundary conditions, I reached a numerically relaxed state and spanned the 5 required orders of magnitude thanks to the computing time I was granted on the CINES Tier-1 cluster (see Figure 1). In El Mellah & Casse (2015), I characterized the structure of the flow, which forms a stable detached bow shocked as it is beamed towards the wake of the accretor, and the dependence of the mass accretion rate on the Mach number of the inflow. For the first time, we monitored the flow deep enough to also confirm the analytical prediction by Foglizzo & Ruffert (1997) concerning the topology of the inner sonic surface (where the shocked flow becomes supersonic again) which has to be anchored into the accretor.

In a realistic SgXB though, the incoming wind is not planar due to the orbital effects. It carries a non-zero angular momentum which could, in some cases, lead to the formation of a wind-capture disc. To identify the favorable configurations, I designed a model of supersonic line-driven wind propagation in SgXB, coupling the stellar, orbital, wind and accretion parameters (El Mellah & Casse 2016). I identified the minimal set of dimensionless degrees of freedom of the problem to optimally explore the space of parameters. This investigation showed how sheared and beamed the wind is when it enters the region around the accretor where the shock is expected to develop – i.e. where the ballistic assumption breaks up and where HD simulations similar to the ones above are required. The need to connect the orbital scale motion, essentially ballistic, and the accretion region, centered on the compact object, became apparent.

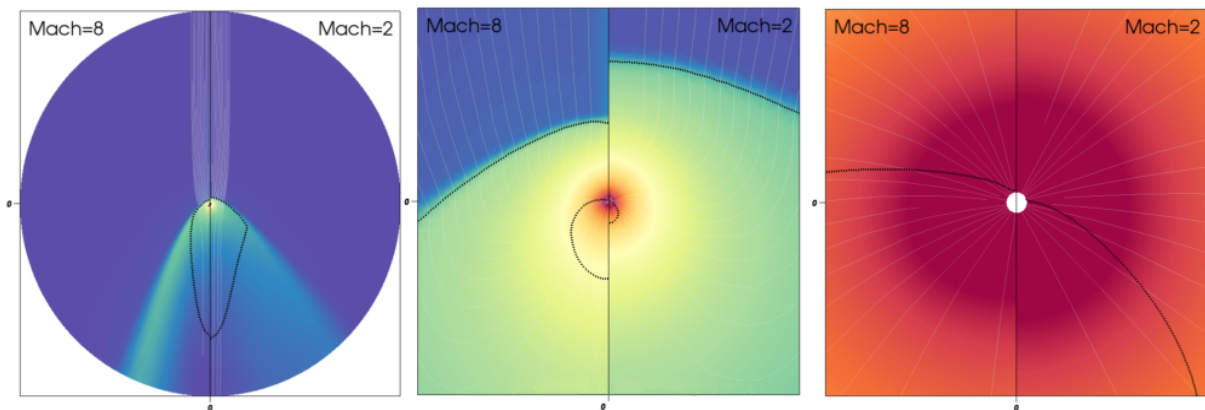


Figure 1: Successive zoom in on the innermost parts of a planar flow (coming from the top) being deflected by a central accretor for different Mach numbers at infinity. In white are represented the streamlines while the dotted black lines represent the Mach=1 surfaces.

## Postdoctoral research activity

Since the beginning of my postdoctoral activity one year ago, I started to consider more realistic internal structure for the incoming wind in SgXB than the uniform flow I had worked with during my PhD. Indeed, the line-driven winds of massive stars are notoriously inhomogeneous, due to the line-deshadowing instability (Owocki & Rybicki 1984) which leads to the formation of internal shocks. The serendipitous accretion of these overdense regions, or clumps, has been suggested as a possible explanation to the time variability of the X-ray luminosity in SgXB, of the order of 100 peak-to-peak. Using a two-dimensional pseudo-planar grid sampling a restricted angular region, Sundqvist et al. (2017) recently managed to compute the micro-structure of the wind and by then, the dimensions of the clumps, for an isolated massive stars. To evaluate the impact of clumps on the accretion process, I plunged a compact object in the wind ("CO" in the left panel in Figure 2), at different orbital separations, and injected the corresponding wind computed by Sundqvist et al. (2017) within the simulation space (right panel in Figure 2). By coupling the stretching of the mesh to the Adaptive Mesh Refinement (AMR) of MPI-AMRVAC, I could design 3D spherical setups spanning several orders of magnitude at an affordable computational cost and resolve small scale off-centered features like clumps injected from the upstream hemisphere. In El Mellah et al. (2017), we were able to follow the clumps as they cross the shock and to monitor the time variability at the inner border of the simulation space, corresponding approximately to the dimensions of the NS magnetosphere. With this work, we discovered how tempering the shock could be, which led to variations of the inner mass accretion rate an order of magnitude smaller than the observed variations of the X-ray luminosity in these systems. Thus, if the stochastic variations at low X-ray luminosity seem to match the variability induced by the clumps alone, the high luminosity levels can only be reached due to other underlying mechanisms, possibly within the NS magneto-

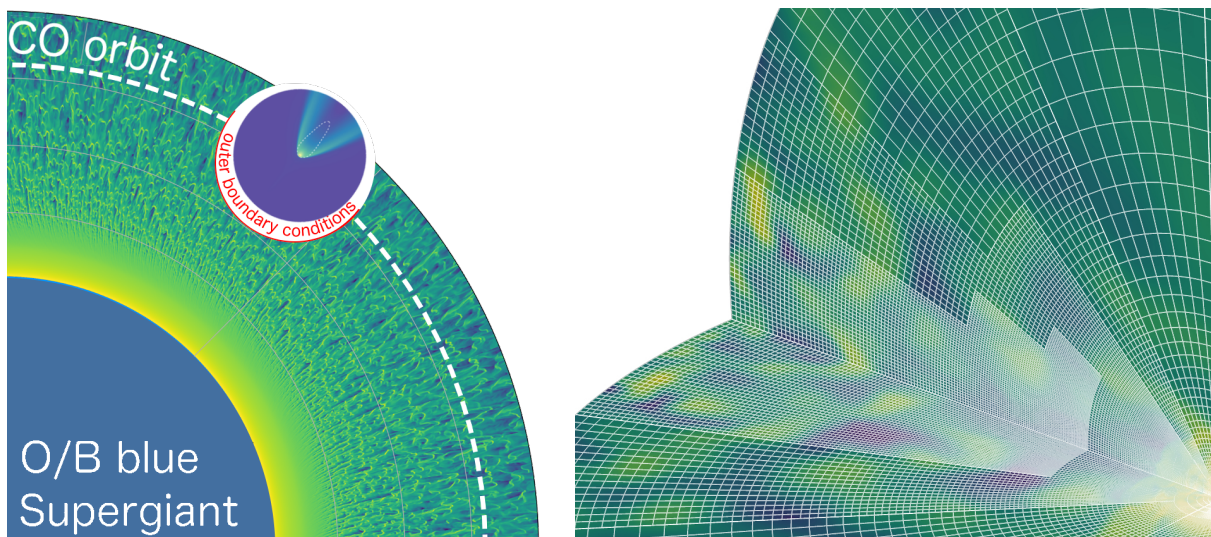


Figure 2: *(left)* Principle of the clumpy wind accretion simulations : we inject into the simulation space (upper right insert) a wind whose micro-structure has been computed out of radiative HD simulations by Sundqvist et al. (2017). *(right)* Two-slices representation of the upstream hemisphere of the simulation space, with the wind coming from the upper left. We overlaid a logarithmic density map to show the typical size of the inhomogeneities to resolve. The accretor lies in the bottom right corner.

sphere (eg the propeller effect, Bozzo et al. 2016). Concerning the column density levels, we retrieve average values compatible with what has been observed recently in Vela X-1 by Grinberg et al. (2017). However, in the latter paper, I evaluated the time variability associated to unaccreted clumps passing by the line-of-sight and concluded that this type of micro-structure within the wind can not explain by itself the variations in column density observed by Grinberg et al. (2017).

In Xia et al. (2017), I carried out a numerical validation of the stretched grid implementation I had made during my PhD by confronting quantitative simulation results of Bondi spherical accretion to the analytical expectations on the mass accretion rate and the location of the sonic point for different adiabatic indexes. We also studied the propagation of a trans-Alfvénic wind from the solar surface to the Earth orbit to validate the compatibility of the stretched grid with the magneto-HD solver and Powell’s method for the cleaning of the divergence of the magnetic field.

## Project outline

In X-ray binaries, the challenge of scales can be alleviate thanks to the different dominant physical effects at stake at different scales. For instance, the magnetic field has generally little influence at the orbital scale but is decisive to fully appreciate the conditions in which the accreted flow emits most of the light we observe. Besides, in SgXB, the magnetic field dominates the last phase of accretion possibly through magnetic gating. It is also a key-ingredient of the ejection mechanisms responsible for self-collimated jets we often observe in accreting systems.

## RLOF discs

To guarantee that we work with physically consistent accretion discs, I am now performing numerical simulations of RLOF configurations where the expanded atmosphere of the donor star is channeled into the Roche lobe of the accretor through the first Lagrangian point. This model includes a proxy on viscosity, similar to the one introduced by Shakura & Sunyaev (1973), and energy losses through radiative cooling. The former stands for the turbulent viscosity associated to the magnetic rotational instability (Balbus & Hawley 1991). Together with spiral shocks, they participate to the evacuation of angular momentum which makes the accretion possible. The ballistic solution is then superseded by the actual formation of a disc around the accretor. Since the plasma largely



Figure 3: Isodensity surface of a 3D flow from a stellar companion (upper right) to an accretor, 1,000 times smaller than the orbital separation between the two bodies.

exceeds 10,000K during the accretion process, a significant fraction of the elements is ionized. We make use of the SPEX cooling tables for solar abundances to compute the cooling function (van Marle & Keppens 2011), which yields cooling rates large enough to impact the thickness of the flow. However, the numerically convenient optically thin assumption we currently make breaks up in the disc and must be complemented with a flux-limited diffusion method I plan to implement in MPI-AMRVAC. These improvements could first lead to insights concerning the origin of negative superhumps in cataclysmic variables (CV, Murray & Armitage 1998). Replacing the inner accretor with a BH or a lowly magnetized NS, the wrapping of the disc could also be studied and numerical results obtained in the context of Smooth Particle Hydrodynamics simulations could be confronted (Foulkes et al. 2006). If the disc turns out to be misaligned with the orbital plane, it could have a serious impact on jet-launching conditions since a misalignment with the BH spin is likely to induce a precession of the jets Liska et al. (2017).

### Diving into the magnetosphere

Once I obtain a satisfying self-generated RLOF disc, I will use it as a fruitful landscape to explore two kinds of systems. First, with Zakaria Meliani, we wish to make this setup a scaled up version of a NS accretor in a Low Mass X-ray binary. A magnetized white dwarf (WD) in a CV intermediate polar alleviates the contrast between the orbital separation and the size of the compact object, while still retaining most of the geometry of the system: a RLOF donor star feeding a disc truncated in its innermost regions by the magnetic field of the accretor (Ghosh et al. 1977). Until now, the studies which have been carried on make an adiabatic assumption to bypass the question of cooling (Ju et al. 2017). Working with a physically-motivated vertical profile of the disc, we think we can shed light on the question of the spin-down efficiency of the accretion process on the WD. We would also be in possession of a reliable tool to elucidate the disc reformation during the afterglow phase of novae (Ness et al. 2012). With U Scorpii expected to go off in a couple of years, we started to collaborate with Jan-Uwe Ness to provide the modeling support for observer proposals.

This twofold setup also serves another purpose : diving into the magnetosphere of an accreting NS. Numerically, we recently implemented and validated a method of magnetic splitting generalized to non-potential fields (Xia et al. 2017). It enables us to handle more accurately the magnetic field evolution, in particular in low- $\beta$  shock-dominated plasmas, and to clean more easily the non-zero divergence. With this new feature available, we want to study how the innermost parts of the wind accreted flow derived in El Mellah et al. (2017) behave. Is the angular momentum carried by the clumps large enough to form a transient disc-like structure or does the NS magnetic field come into play before they can do so? The possible magnetic gating undergone by the innermost parts of the flow has never been explored with physical inputs accounting for the upper scales. Hence, it has produced fruitful results but ambiguous since the prescriptions employed have been independent from the large scale parameters (such as the stellar ones). We also want to address the case where the NS magnetospheric radius is much larger, of the order of the accretion radius. How does it alter the shock?

To conclude, the numerical expertise I have developed in Computational Astrophysics enables me to make the most of the high performance computing technologies available. They have ushered in a particularly exciting period to address a wide range of questions pertaining to accretion in X-ray binaries. To progress on these questions, I need to keep connecting with observers and modelers in this field, both communities being represented in Potsdam : with researchers from the Max Planck Institute for Gravitational Physics, I could reinforce the modeling of the relativistic surroundings of the accretor, where the X-rays we observe are produced, while the expertise in stellar Astrophysics at the Institut für Physik und Astronomie would provide a more realistic representation of the stellar wind which feeds the accretor. The conjunction of these two features supplies a unique opportunity to bridge the gap between the stellar and wind properties on one hand, and the high energy phenomena at stake near the compact object on the other hand. High energy Astrophysics is also a domain of interest of the Leibniz Institute for Astrophysics where quasars, a type of supermassive black holes undergoing an intense accretion phase, are under investigation. I already showed my capacity to obtain external fundings and do intend to raise the funds necessary to such a project with applications to ERC grants and to programs sponsored by the Deutsche Forschungsgemeinschaft. Beyond their autonomous requirements and satisfactions, I also expect my teaching duties to be opportunities to arouse the interest of the students in pursuing in this research domain. Should it be the case, I would gladly mentor them, as I have been mentored on my way to the endlessly mesmerizing field of Astrophysics.

## References

- Balbus, S. A. & Hawley, J. F. (1991), *Astrophys. J.* **376**, 214.
- Bondi, H. & Hoyle, F. (1944), *Mon. Not. R. Astron. Soc.* **104**, 273.
- Bozzo, E., Oskinova, L., Feldmeier, A. & Falanga, M. (2016), *Astron. Astrophys. Vol. 589, id.A102*, 11 pp. **589**.
- El Mellah, I. & Casse, F. (2015), *Mon. Not. R. Astron. Soc.* **454**(3), 2657–2667.
- El Mellah, I. & Casse, F. (2016), *Mon. Not. R. Astron. Soc.* **467**(3), 2585–2593.
- El Mellah, I., Sundqvist, J. O. & Keppens, R. (2017), *MNRAS* .
- Foglizzo, & Ruffert, (1997), *Astron. Astrophys.* .
- Foulkes, S. B., Haswell, C. A. & Murray, J. R. (2006), *Mon. Not. R. Astron. Soc.* **366**(4), 1399–1409.
- Ghosh, P., Pethick, C. J., Lamb, F. K. & Pethick, C. J. (1977), *Astrophys. J.* **217**, 578–596.
- Giacconi, R., Gursky, H., Paolini, F. R. & Rossi, B. B. (1962), *Phys. Rev. Lett.* **9**(11), 439–443.
- Grinberg, V., Hell, N., El Mellah, I., Neilsen, J., Sander, A. A. C., Leutenegger, M. A., Fürst, F., Huenemoerder, D. P., Kretschmar, P., Kühnel, M., Martinez-Nunez, S., Niu, S., Pottschmidt, K., Schulz, N. S., Wilms, J. & Nowak, M. A. (2017), *MNRAS* .
- Hoyle, F. & Lyttleton, R. A. (1939), *Math. Proc. Cambridge Philos. Soc.* **35**(03), 405–415.
- Ju, W., Stone, J. M. & Zhu, Z. (2017), *Astrophys. J.* **841**(1), 29.
- Liska, M., Hesp, C., Tchekhovskoy, A., Ingram, A., van der Klis, M. & Markoff, S. (2017), *eprint arXiv:1707.06619* 5(November), 1–5.
- Murray, J. R. & Armitage, P. J. (1998), *Mon. Not. R. Astron. Soc.* **300**(2), 561–566.
- Negueruela, I., Smith, D. M., Reig, P., Chaty, S. & Torrejón, J. M. (2006), *Proc. X-ray Universe 2005 (ESA SP-604)*. 26–30 Sept. 2005 .
- Ness, J. U. U., Schaefer, B. E., Dobrotka, A., Sadowski, A., Drake, J. J., Barnard, R., Talavera, A., Gonzalez-Riestra, R., Page, K. L., Hernanz, M., Sala, G. & Starrfield, S. (2012), *Astrophys. J.* **745**(1).
- Owocki, S. P. & Rybicki, G. B. (1984), *Astrophys. J.* **284**, 337.
- Shakura, N. I. & Sunyaev, R. a. (1973), *Astron. Astrophys.* **24**, 337–355.
- Sundqvist, J. O., Owocki, S. P. & Puls, J. (2017), (2).
- Tóth, G. (1996), *Magnetodynamic Phenom. Sol. Atmos. prototypes stellar Magn. Act. Proc. 153rd Colloq. Int. Astron. Union, held Makuhari, near Tokyo, May 22–27, 1995* **471**, 471.
- Tóth, G., Keppens, R., Botchev, M. A., Toth, , Keppens, & Botchev, (1998), *Astron. Astrophys.* **332**, 1159–1170.
- van Marle, A. J. & Keppens, R. (2011), *Comput. Fluids* **42**(1), 44–53.
- Walter, R., Lutovinov, A. A., Bozzo, E. & Tsygankov, S. S. (2015), *Astron. Astrophys. Rev.* **23**(1), 2.
- Xia, C., Teunissen, J., El Mellah, I., Chané, E. & Keppens, R. (2017), *submitted* .





# R É P U B L I Q U E F R A N Ç A I S E

Ministère de l'enseignement supérieur, de la recherche et de l'innovation

UNIVERSITE SORBONNE PARIS CITE

## DOCTORAT

Vu le code de l'éducation, notamment ses articles L.612-7, L.613-1, D.613-3 et D.613-6 ;

Vu le code de la recherche, notamment son article L.412-1 ;

Vu les pièces justificatives produites par M. ILEYK EL MELLAH, né le 5 avril 1989 à MEAUX (077) en vue de son inscription au Doctorat ;

Vu le procès-verbal du jury attestant que l'intéressé a soutenu le 7 septembre 2016 une thèse portant sur le sujet suivant : Accrétion par vent sur objet compact préparée au sein de l'école doctorale SCIENCES DE LA TERRE ET DE L'ENVIRONNEMENT ET PHYSIQUE DE L'UNIVERS, PARIS, devant un jury présidé par STEPHANE CORBEL, PROFESSEUR DES UNIVERSITES et composé de FABIEN CASSE, MAITRE DE CONFERENCES, GUILLAUME DUBUS, DIRECTEUR DE RECHERCHE, THIERRY FOGLIZZO, INGENIEUR, ANDREA GOLDWURM, ASTROPHYSICIEN, RONY KEPPENS, PROFESSEUR, MAXIMILLIAN RUFFERT, PROFESSEUR ;

Vu la délibération du jury ;

Le diplôme de **DOCTORAT** de physique de l'Univers préparé au sein de l'UNIVERSITE PARIS 7  
*mention très honorable*

est délivré à M. ILEYK EL MELLAH

au titre de l'année universitaire 2015-2016  
et confère le **grade de docteur**,  
pour en jouir avec les droits et prérogatives qui y sont attachés.

Fait le 28 juin 2017

Le titulaire

Le président de l'Université Sorbonne Paris Cité

François HOULLIER

La Présidente de l'Université Paris 7

Christine CLERICI

Le Recteur d'Académie,  
Chancelier des universités

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