Feeding the spinning top
Spin evolution of accretion-powered pulsars in high-mass X-ray binaries

Team leader: I. El Mellah, KU Leuven, Belgium

Abstract

High-mass X-ray binaries (HMXBs) represent an ephemeral albeit critical phase in the evolution of massive binaries. They are a likely formation channel for the mergers we now observe through gravitational waves, when two compact objects coalesce. HMXBs contain a massive star in orbit with a compact object, generally a young and highly magnetized neutron star (NS), which taps a fraction of the intense radiation-driven stellar wind. As it accretes material to its magnetic poles, the neutron star spins up or down, depending on the properties of the accretion flow when it couples to the extended NS magnetosphere, a few hundreds Schwarzschild radii away from the NS surface. Once the accreted material enters the NS magnetosphere, it is funneled towards the magnetic poles where it produces X-ray bright spots precessing around the NS spin axis, which manifest as periodic X-ray pulses. For decades, the spin periods of NSs in many HMXBs have been monitored and show episodes of steady spinning up/down, separated by sudden torque reversals whose origin remains unknown. Contrary to predictions, the evolution of the NS spin and of the X-ray luminosity are not correlated. We still lack a unified model to understand how the wind couples to the magnetic field, penetrates the magnetosphere and spins up or down the NS.

In a joint effort, observers and theorists from the X-ray and the wind of massive stars communities recently agreed on a comprehensive framework to understand how the NS could be used as an X-ray probe to sample the micro-structure of the wind in HMXBs (Martínez-Núñez et al. 2017). Meanwhile, significant progress have been made in numerical simulations of the coupling between the plasma and the magnetosphere of highly magnetized pulsars in idealized environments. New observations unveiled the presence of a disk-like structure beyond the NS magnetosphere in several HMXBs, in agreement with numerical simulations.

With this proposal, we propose to gather a team of theorists, observers and computational astrophysicists during 2 one-week ISSI meetings in Bern in order to bring new insights on the coupling between the wind-captured disk and the NS magnetosphere in HMXBs and draw a consistent model of accretion-induced spinning up/down. It will be the occasion to use and develop state-of-the-art numerical techniques, conjointly with new diagnostics tools which will prove decisive to interpret the data provided by the existing and upcoming X-ray satellites. We are now in a position to bridge the gap between the orbital and magnetospheric scales in order to compute consistent spin-up/down rates for the accreting NS in HMXBs, with dramatic consequences on the long-term evolution of the whole system.

1 Scientific rationale

Two years ago, the discovery of a gravitational wave signal from two colliding NSs revived the interest of the community for the evolution of binaries containing massive stars (The LIGO/Virgo Collaboration 2017). Progenitor candidates of merging compact objects are HMXBs where the intense outflow of an evolved massive star is partly captured by an orbiting wind-fed compact companion, typically a NS. This loosely constrain wind accretion mechanism is one of the main responsible for the large uncertainties on the double compact object merger rates since it plays a role in the shrinking of the orbital separation, indispensable to bring the two final compact remnants close enough to spiral-in and merge within a Hubble time.

1.1 Current picture of wind accretion in HMXBs

At the bottom of the theory of wind accretion onto highly-magnetized NSs in HMXBs lies the wind launching mechanism of hot stars. It involves the resonant line-absorption of UV photons by thousands of transition between excitation levels of metal elements. By solving the statistical equations of population numbers in non-local thermodynamical equilibrium, an ab initio wind acceleration profile was first computed by Sander et al. (2017) for the archetypal HMXB Vela X-1, accounting for the X-ray ionizing feedback from the NS. The inhomogeneous structure of radiatively-driven winds has also been characterized by Sundqvist et al. (2018) in 2D radiative-hydrodynamics simulations. These results have been used in full 3D simulations of HMXBs: in spite of the absence of stellar Roche lobe overflow, the captured material was shown to circularize, in some cases, into a disk-like structure before reaching the extended magnetosphere of the accreting

NS (El Mellah et al. 2019, 2018). Subsequent observations identified a transient wind-captured disk in Vela X-1 (Liao et al. 2020).

On the other hand, in the immediate vicinity of the spinning NS, the plasma is channeled to the surface by the magnetic field lines into narrow accretion columns which emit most of the X-rays we observe (Arons & Lea 1976; Elsner & Lamb 1977). In many HMXBs, the hard X-ray emission, hardly absorbed, contains a periodic component believed to be due to the precession of the magnetic axis around the misaligned spin axis of the pulsar. It grants us access to the spin period of NSs in HMXBs, which have been monitored for decades (see right panel in Figure 1). Recent X-ray timing analysis focused on the evolution of the spin over much shorter lapses of time and found important variations over a few hours which had been overlooked until now (Martin-Carrillo 2020). The behavior of the spin of accretion-powered pulsars is dictated by the torques applied at the outer edge of the magnetosphere by the ionized material supplied by the stellar wind. **In order to connect these observations to the properties of the flow upstream, we need to determine how the accreted fraction of the wind couples to the magnetosphere and how angular momentum is transferred.**

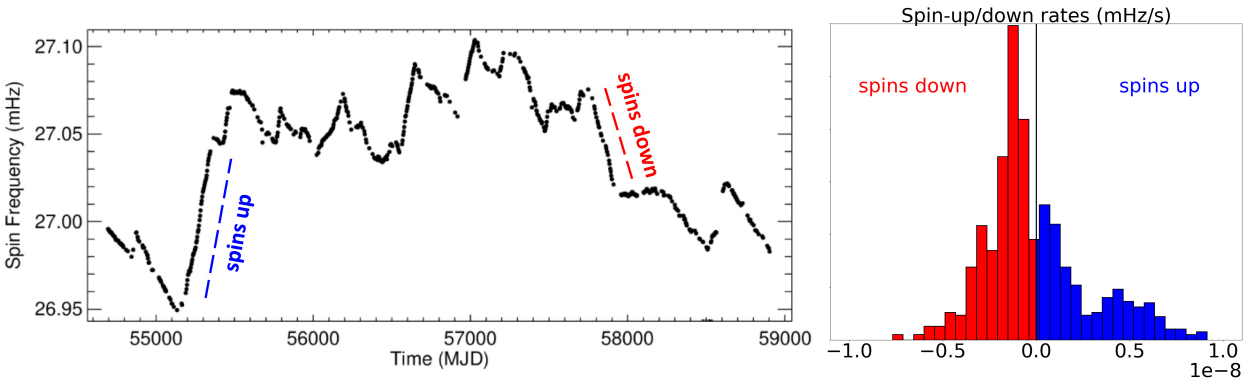

Figure 1: *(left panel)* Evolution of the NS spin frequency as a function of time from 2008 to today in the HMXB OAO 1657-415, with several torque reversals visible (data from the Fermi GBM database). *(right panel)* Corresponding frequency histogram of spin-up/down rates obtained by a simple local slope estimate from the NS spin evolution, with a hint in favor of a bimodal behavior, still to be explained.

1.2 Diving into the neutron star magnetosphere

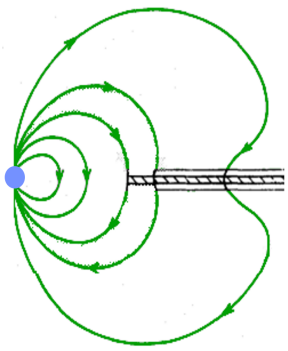

Figure 2: Accretion disk at the outer edge of the pulsar magnetosphere.

A seminal model of accretion-induce torques was introduced by Ghosh & Lamb (1979) for a prograde geometrically thin and optically thick accretion disk coupled to an aligned magnetospheric dipole anchored in a NS (see Figure 2). It predicts torque variations around zero, positively correlated to the mass accretion rate (with positive torques spinning-up the NS). Despite undeniable successes, it fell short at explaining the behavior of the spin of the NS in several HMXBs and in particular the sudden torque reversals between month to year-long episodes of steady spinning-up or down (Nelson et al. 1997). Chakrabarty et al. (1993) highlighted that the abrupt transitions between spin-up and spin-down states in the HMXB OAO 1657-415 are not compatible with the Ghosh & Lamb model (right panel in Figure 1). Discontinuous changes of the mass accretion rate onto the NS magnetosphere can be provoked by the capture of an overdense region in the wind (Ducci et al. 2009) but with coherence time scales of the order of an hour at most (Grinberg et al. 2017). In addition, the X-ray flux, indicative of the mass accretion rate, is comparable between spin-up and spin-down episodes (Baykal 1997; Jenke et al. 2012). The same absence of apparent correlation is observed in the HMXB Centaurus X-3 where the torques present a bimodal distribution and where a disk is known to exist around the NS (Bildsten et al. 1997). The wind-fed NS in the HMXB 4U 1538-52 presents a secular spin-down together with a persistent X-ray emission, in contradiction with the propeller regime when the NS spins down while the magneto-centrifugal barrier inhibits accretion (Illarionov & Sunyaev 1975). In Vela X-1, spin-up and spin-down episodes are observed, possibly consistent with a random walk (Fürst et al. 2010).

Our understanding of plasma-magnetosphere coupling is incomplete when it comes to HMXBs. It has been

proposed that the prograde thin disk geometry the Ghosh & Lamb model relies on was the main culprit. In HMXBs, the mass accretion rate is low and so is the specific angular momentum: when they form, wind-captured disks do not efficiently radiate and retrograde disks or quasi-spherical geometries must also be considered (Bozzo et al. 2008; Shakura et al. 2012).

1.3 The numerical tool: magneto-hydrodynamics simulations

Considerable progresses have been made within the last years in the numerical modeling of plasmas in highly magnetized environments. Particle-in-cell simulations provided new insights on the micro-Physics at stake during magnetic reconnection and provided reliable proxies for global magneto-hydrodynamics (MHD) simulations to work with realistically small resistivities (Che 2017). Thanks to adaptive mesh refinement, current sheets where magnetic reconnection occurs can be resolved at an affordable computational cost (Ripperda et al. 2019). Constrained transport, magnetic field splitting and other techniques, already partly implemented in the codes familiar to the participants, ensure robust and accurate solutions (see e.g. Xia et al. 2018).

Several MHD simulations of interest for the present project have already been performed by some of the team members. Zanni & Ferreira (2009) and Zanni & Ferreira (2013) considered accretion disks around T Tauri star which have a dipolar magnetosphere. Čemeljić (2019) performed a systematic parameter study of torque acting on a central dipolar magnetosphere using 2D axisymmetric star-disk simulations. Unprecedented 2D general relativistic MHD simulations by Parfrey & Tchekhovskoy (2017) investigated the different disk accretion regimes around highly magnetized rapidly rotating NSs, each regime displaying different torques and mass accretion rates. These closely related numerical studies will serve as references to explore accretion onto NSs in HMXBs.

1.4 Scientific goals

A team has emerged, with the required expertise to address the question of magnetospheric plasmas around accreting NSs. The team members have been chosen for their knowledge in the different domains involved in this investigation such as MHD modeling of the flow-magnetosphere coupling and pulse timing analysis. The scientific goals are split depending on the methodological viewpoint which needs to be adopted to fulfill them. We believe that this workload distribution makes the most of each team members' skills while guaranteeing a coordinated effort to tackle the question lying at the core of this workshop proposal: **how does the plasma penetrate within the magnetosphere and which net torque does it exert on the accreting NS?**

Observational

The experienced observers forming part of the team are familiar with the limitations and possibilities given the facilities at our disposal. Some of them are experts in X-ray timing analysis: we will be able to provide accurate NS spin periods by processing archival and unpublished data obtained thanks to successful observing proposals across many observatories. The observational milestones we foresee are:

1. A compilation of reduced datasets to compute instantaneous torques over time lapses much smaller than before, of the order of a few hours per bin.
2. A comparison of the obtained distribution of spin-up/down rates in different HMXBs (see proof-of-concept in right panel in Figure 1).
3. An analysis of the correlation with the pulse X-ray flux to identify representative behaviors.

These results will be made public to the community via **an online catalog** similar to the Fermi GBM one.

Theoretical

In parallel of the data analysis, the different scenarios proposed over the last decades to compute accretion torques onto NSs in HMXBs will be discussed and confronted with each other. In particular, we will proceed to:

1. An identification among each model of the characteristic signatures, the qualitative smokeguns to look for in the data.
2. Given realistic uncertainties on the input parameters, an estimate of the predicted accretion-torques

and of their time evolution given variable mass accretion rates.
3. A characterization of the possible correlation between torques and mass accretion rates.

We will summarize our results in **an organized review of semi-analytic predictions for different HMXB sources**. These steps will be followed by a comparison to the reduced observational data jointly obtained while numerical simulations will provide synthetic evolution of NSs spin as a function of time beyond the theoretical prescriptions.

Numerical

A decisive asset to ensure the fulfillment of our scientific goals is the wide numerical expertise available in the team, with 4 MHD codes represented: HARMPI (A. Tchekhovskoy), Pluto (J. Ferreira and M. Čemeljić), VH-1 (A. Manousakis) and MPI-AMRVAC (I. El Mellah). All these codes are public and so will be the numerical setups developed for the purpose of this research project. They are all grid-based codes which, on one hand, share enough similarities to ensure a seamless communication between their users and, on the other hand, contain complementary features. The numerical support will articulate around the following aims:

1. Simulations of plasma-magnetosphere coupling for representative morphologies (e.g. quasi-spherical, prograde or retrograde disks).
2. A study of the response of the computed accretion torques to mass accretion rates whose variability is motivated by the results obtained at the orbital scale (see Section 1.1).

These simulations will provide a key-deliverable of this project: **synthetic spinning-up/down light curves to be confronted to the observed ones**.

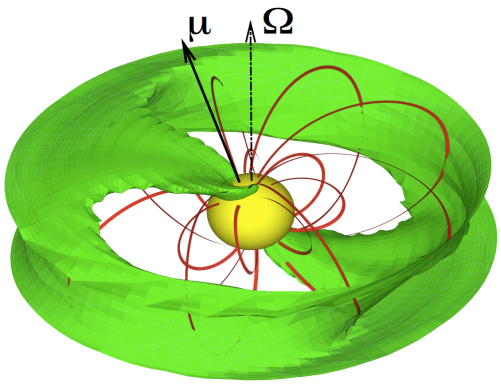

Figure 3: 3D MHD simulation of magnetospheric accretion from a disk onto a magnetic dipole μ (Romanova et al. 2014). In the accretion regime represented here, the plasma is funneled towards the magnetic poles of the accretor, forming two hot spots at the surface whose precession around the spin axis $\mathbf{\Omega}$ is responsible for the pulsar phenomenon. Other regimes can be unstable or produce outflows at the disk-magnetosphere boundary.

The poorly understood interactions between the plasma and the NS magnetosphere hampers progress on our understanding of the long term evolution of binary massive stars. Bringing answers to this question will be of tremendous importance to recount the troubled history of the merging double compact objects we are now in a position to detect thanks to the current and upcoming gravitational wave instruments. In addition, this work could bring a new light on the mechanism responsible for spinning-up/down of pulsars accreting at super-Eddington rates in ultra-luminous X-ray binaries (Bachetti et al. 2014) like NGC 7793 P13, currently the object of a long monitoring campaign (Fürst et al. 2018).

1.5 Timeliness of the project

Individual publications of the team members for the last years, along with the newly born gravitational wave astronomy, have enhanced the general interest in HMXBs which led, for instance, to a dedicated IAU symposium "High-mass X-ray binaries: illuminating the passage from massive binaries to merging compact objects" (Vienna, August 2018). A first meeting in 2021 would be well timed to push further and include new elements into our research. The confluence of the large number of modeling efforts and an extensive lineup of X-ray observatories make such a meeting very timely. In addition to the fleet of existing X-ray satellites, a new generation of instruments is on the way that will widen the parameter space for studies and comparison with models. Examples include XRISM (2022) for high-resolution spectroscopy, EinsteinProbe (late 2022) for sensitive long-term lightcurves and further in the future, the ESA mission Athena. Should this program be granted by ISSI, we will be able to take better advantage of the present momentum and widen the international participation in this research.

Name	Expertise
Enrico Bozzo	Theory of accretion onto highly magnetized NSs, X-ray observations
Felix Fürst	X-ray & γ-ray observations, orbital & long-term variability
Peter Kretschmar†	X-ray & γ-ray observations, accretion mechanisms, variability
Antonios Manousakis	Hydrodynamic simulations, stellar winds, accretion, X-ray observations
Silvia Martínez Núñez	Stellar winds, X-ray & optical counterpart
Ileyk El Mellah	Theory and simulations of wind accretion onto compact objects
Victoria Grinberg	Stellar winds, time-resolved X-ray spectroscopy
Abigail Stevens	X-ray spectral-timing, accretion onto compact objects in X-ray binaries
Alexander Tchekhovskoy	Theory and simulations of disk accretion onto compact objects
Antonio Martin-Carrillo	Data analysis, pulsar timing variability, X-ray binaries
Konstantin Postnov	Theory of quasi-spherical accretion onto NSs, radiative cooling
Miljenko Čemeljić	Magneto-hydrodynamics simulations & modeling of accretion disks
Jonathan Ferreira	Theory of disk accretion onto NSs, magnetically-driven outflows

† Self-supported as 'External Expert'

2 List of confirmed participants

Given their past achievements and the interest they showed at achieving the new goals set by the present proposal, we gathered the 13 members listed in the table hereafter (including a self-funded expert), all committed to participating in this project. The collaboration is composed of theorists, modelers and computational astrophysicists, along with observers whose work brings decisive constrains on the magnetic field of the NS, on the pulse period and on the variability of the mass accretion rate. Should our proposal be successful, we will add 20% of young scientists as suggested by the ISSI call guidelines.

3 Schedule and outputs

We foresee the first one-week meeting early 2021 to identify and distribute the work tasks, with a first collection of results and proofs-of-concept submitted to peer-reviewed journals late 2021 / early 2022 and presented at international conferences, possibly the EAS meeting and/or the IAU general assembly in 2022. The second one-week meeting, late 2022, will aim at discussing the perspectives open up by our findings for the community and drawing new research tracks accordingly. The content of a review summarizing our main conclusions will also be discussed, along with the observational campaigns suitable to confront our new predictions. The main scientific outputs, detailed in section 1.4, are:

- advanced MHD models and simulations of accretion-torques onto pulsar magnetospheres in HMXBs.
- synthetic spinning up/down light curves to be confronted to observed ones.
- a catalog of instantaneous torques distribution with the corresponding X-ray luminosity.

4 Added value of ISSI

Observers and theorists of HMXBs have few opportunities to meet and discuss at scientific conferences because these have been historically separated communities. Furthermore, the X-ray binary community is not always fully familiar with the knowledge developed by experts on the accretion process itself, which often takes place very close from the accreting compact object, six orders of magnitude smaller than the orbital separation. From our personal experience, the format the ISSI workshops offer is ideal to discuss modeling approaches and comparison with observation in much more detail than other scientific meetings. It provides a suitable environment for intense and productive exchanges which enormously foster collaborations and are crucial to address the new challenges of our proposed program. The topic does not overlap with on-going ISSI-sponsored teams. Finally, the central location in Europe and the provision of accommodation greatly simplify travel arrangements for all members.

5 Required facilities and financial support

The project will require and make full use of the standard facilities available at ISSI Bern. We request the regular ISSI funding support (per diem, accommodation and travel fees for the team leader).

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Curriculum Vitae — Alexander Tchekhovskoy

Education

- PhD, Astronomy, 2010, Harvard University (Cambridge, MA, USA)
- A.M., Astronomy, 2007, Harvard University (Cambridge, MA, USA)
- M.S., Applied Physics and Mathematics, June 2004, Moscow Institute of Physics and Technology (Moscow, Russia)
- B.S., Applied Physics and Mathematics, June 2002, Moscow Institute of Physics and Technology (Moscow, Russia)

Employment History

- 09/2017 – till now: Assistant Professor of Physics and Astronomy, Northwestern University (Evanston, IL, USA)
- 09/2016 – 08/2017: Theoretical Astrophysics Center Fellow, UC Berkeley (Berkeley, CA, USA)
- 09/2013 – 08/2016: NASA Einstein Fellow, UC Berkeley and LBL (Berkeley, CA, USA)
- 09/2010 – 08/2013: Center for Theoretical Science Fellow, Princeton University (Princeton, NJ, USA)

Research Interests

Numerical simulations of accretion and outflows, and their interactions with the environment, in a wide range of astrophysical settings.

Accepted proposals

- 01/2019 – 12/2019: PI on DOE INCITE allocation of 5.1 million GPU-hours on the world's fastest supercomputer Summit
- 05/2018 – 04/2019: PI on NSF PRAC grant OAC-1811605 of 5 million GPU hours on the Blue Waters supercomputer
- 01/2019 – 12/2019: PI on 6 million CPU-hour DOE NERSC allocation m2401

Publications

52 refereed publications, 11 as first author. 10 conference proceedings. 4397 citations. h-index: 33. i10-index: 49.

Especially relevant publications:

- Parfrey, K., **Tchekhovskoy**, A., 2017, General-relativistic Simulations of Four States of Accretion onto Millisecond Pulsars, ApJ Letters, 851, L34
- **Tchekhovskoy**, A., Spitkovsky, A., & Li, J. 2013, Time-Dependent 3D Magnetohydrodynamic Pulsar Magnetospheres: Oblique Rotators, MNRAS, 435, 1
- Fernandez, R., **Tchekhovskoy**, A., Quataert, E., Foucart, F., & Kasen, D. 2019, Long-term GRMHD Simulations of Neutron Star Merger Accretion Disks: Implications for Electromagnetic Counterparts, MNRAS, 482, 3373
- Bromberg, O., **Tchekhovskoy**, A., et al. 2018, The gamma-rays that accompanied GW170817 and the observational signature of a magnetic jet breaking out of NS merger ejecta, MNRAS, 475, 2971
- Liska, M., **Tchekhovskoy**, A., Quataert, E. 2019, Large-Scale Poloidal Magnetic Field Dynamo Leads to Powerful Jets in GRMHD Simulations of Black Hole Accretion with Toroidal Field, MNRAS, submitted, arXiv180904608

Curriculum Vitae — Abigail Stevens

Education

- PhD in Astronomy, April 2018; Anton Pannekoek Institute, University of Amsterdam (Netherlands). Thesis title: "New Techniques for Understanding X-ray Variability from Compact Objects" (Advisor: Phil Uttley)
- MSc in Astrophysics, August 2013; University of Alberta (Edmonton, Canada). Thesis title: "Understanding Parameter Degeneracies in Neutron Star X-ray Light Curves" (Advisor: Sharon Morsink)
- BA in Physics, May 2011; Bard College (Annandale-on-Hudson, New York, USA) Thesis title: "A Mathematical Exploration of Low-Dimensional Black Holes" (Advisors: Peter Skiff, Greg Landweber)

Employment History

- Since Sept 2018: NSF Astronomy and Astrophysics Postdoctoral Fellow, Michigan State University (East Lansing, Michigan, USA) and the University of Michigan (Ann Arbor, Michigan, USA)
- May–August 2018: postdoctoral researcher with Jay Strader - Michigan State University

Research Interests

Compact objects in X-ray binaries, accretion, general relativity, time-domain astronomy and X-ray variability, quasi-periodic oscillations (QPOs), X-ray burst oscillations, time series and spectral-timing analysis, signal processing with Fourier techniques, statistical methods, optimization algorithms, open-source research software • *NICER* science team, *STROBE-X* steering committee

Accepted proposals

- 2 as PI: *NICER-NuSTAR* joint Guest Observer proposal "Comparing emission mechanisms of low-frequency QPOs in black holes and neutron stars", Google Summer of Code 2018 mentor via the Open Astronomy organization
- 3 as Co-I: two *NICER* proposals "A spectral-timing study of GX 5–1"(PI: Homan) and "Jet-launching in Sco X–1" (PI: Homan), one Lorentz Center workshop for Python in Astronomy 2017
- Scientific Organizing Committee member for The Future of X-ray Timing (Oct 2019), Python in Astronomy (July 2019, May 2017), EWASS session on astronomy research software (June 2017), EWASS 2017 Hack Day, AAS 229 Hack Together Day (Jan 2017)

Publications

6 refereed publications, 3 as first author. 41 citations. h-index: 4. i10-index: 2.

Especially relevant publications:

- *A NICER Discovery of a Low-Frequency Quasi-Periodic Oscillation in the Soft-Intermediate State of MAXI J1535–571*
  A.L. Stevens, P. Uttley, D. Altamirano, et al. 2018, ApJL, 865, L15, 7pp.
- *Neutron Star Mass-Radius Constraint using Evolutionary Optimization*
  A.L. Stevens, J.D. Fiege, D.A. Leahy, and S.M. Morsink 2016, ApJ, 833,244, 13pp.
- *Phase-Resolved Spectroscopy of Type B QPOs in GX 339–4*
  A.L. Stevens and P. Uttley 2016, MNRAS, 460, 2796, 14pp.

Curriculum Vitae — Victoria Grinberg

Education

- PhD astrophysics 12/2013, Friedrich-Alexander-University Erlangen-Nuremberg, Germany
- Diploma physics, 2010, Ludwig Maximilians University Munich, Germany

Employment History

- since 7/2018: Margarete von Wrangell habilitation fellow, University of Tübingen, Germany
- 12/2016 – 6/2018: ESA research fellow, ESA/ESTEC, Noordwijk, The Netherlands
- 12/2013-11/2016: postdoctoral associate, Cambridge, MA, USA

Research Interests

Accretion and ejetion processes in X-ray binaries; high mass X-ray binaries as probes for stellar winds of massive stars; wind accretion processes; X-ray variability studies, including fast variability (timing); X-ray instrumentation and systematic influences of calibration uncertainties on scientific results.

Accepted proposals

PI of several accepted *Chandra*, *XMM*-Newton, *NuSTAR*, *Suzaku* and *INTEGRAL* proposals; Co-I of numerous further proposals. DLR funding proposals.

Publications

42 refereed publications, 5 as first author. 13 conference proceedings. 902 citations. h-index: 17. i10-index: 24.

Especially relevant publications:

- *The clumpy absorber in the high mass X-ray binary Vela X-1*
  V. **Grinberg**, N. Hell, I. El Mellah, J. Neilsen, A.A.C. Sander, M. Leutenegger, F. Fürst, D.P. Huenemoerder, P. Kretschmar, M. Kühnel, S. Martínez-Núñez, S. Niu, K. Pottschmidt, N.S. Schulz, J. Wilms, M.A. Nowak, 2017 A&A 608, A143
- *Chandra X-Ray Spectroscopy of the Focused Wind in the Cygnus X-1 System III. Dipping in the Low/Hard State*
  M. Hirsch, N. Hell, **V. Grinberg**, R. Ballhausen, M. A. Nowak, K. Pottschmidt, N. S. Schulz, T. Dauser, M. Hanke, G. V. Brown, J. Wilms, subm. to A&A
- *Evidence for an Evolving Cyclotron Line Energy in 4U 1538−522*
  P.B. Hemphill, R.E. Rothschild, F. Fürst, **V. Grinberg**, D. Klochkov, P. Kretschmar, K. Pottschmidt, R. Staubert, J. Wilms, 2016, MNRAS 458, 2745

Curriculum Vitae — Konstantin Postnov

Education and employment history

1983, graduated from Physical Department of Moscow State University

1983-1986, post-graduate study at Sternberg Astronomical Institute, Moscow State University

1987, PhD in astrophysics and radioastronomy, "Evolution of magnetized compact stars in binary systems" (supervisor – Prof. D.Ya. Martynov)

1987-1995, assistant professor, Faculty of Physics, Moscow State University

1995-1998, associate professor, Faculty of Physics, Moscow State University

1998, Doctor Thesis in astrophysics and stellar astronomy, "Astrophysical sources of gravitational waves"

1999-, professor, Faculty of Physics, Moscow M.V. Lomonosov State University,

2000-, senior researcher, Sternberg Astronomical Institute

2016- Deputy Director, Sternberg Astronomical Institute of Moscow State University

2018 – Acting Director, Sternberg Astronomical Institute of Moscow State University

Research Interests

Binary star evolution; astrophysics of neutron stars and black holes; accretion processes; X-ray pulsars; microquasars; gravitational waves; relativistic astrophysics

Accepted proposals

Co-I of accepted/executed INTEGRAL, XMM, NuSTAR, VLT proposals. Member of INTEGRAL TAC (2000-2004, 2008-2010, 2019-). Member of the SOC/LOC of various international conferences, including the European Astronomical Society meeting JENAM-2000, the annual High Energy Astrophysics meeting at the Space Research Institute (IKI) (2006-2018), INTEGRAL Workshops, International conference "Physics of Neutron Stars" (1992, 1995, 1997, 1999, 2001, 2005, 2008, 2011, 2014, 2017) . Chair of Sci. Programme Committee of International Conference "Modern cosmology and gravitational-wave astronomy" (Moscow, November 2016). Member of the Scientific Group of the international SRG-eROSITA mission.

Publications

188 refereed publications, 68 as first author. 3356 citations. h-index: 30. i10-index: 91.

Especially relevant publications:

Postnov, K., Oskinova, L., Torrejon, J. M. 2017. A propelling neutron star in the enigmatic Be-star gamma Cassiopeia. Monthly Notices of the Royal Astronomical Society 465, L119-L123.

Postnov, K. A., Gornostaev, M. I., Klochkov, D., Laplace, E., Lukin, V. V., Shakura, N. I. 2015. On the dependence of the X-ray continuum variations with luminosity in accreting X-ray pulsars. Monthly Notices of the Royal Astronomical Society 452, 1601-1611.

Postnov, K. A., Gornostaev, M. I., Klochkov, D., Laplace, E., Lukin, V. V., Shakura, N. I. 2015. On the dependence of the X-ray continuum variations with luminosity in accreting X-ray pulsars. Monthly Notices of the Royal Astronomical Society 452, 1601-1611.

Shakura, N., Postnov, K., Sidoli, L., Paizis, A. 2014. Bright flares in supergiant fast X-ray transients. Monthly Notices of the Royal Astronomical Society 442, 2325-2330.

Shakura, N., Postnov, K., Kochetkova, A., Hjalmarsdotter, L. 2012. Theory of quasi-spherical accretion in X-ray pulsars. Monthly Notices of the Royal Astronomical Society 420, 216-236.

Curriculum Vitae — Miljenko Čemeljić

Education and employment history

- 1996 graduated from Physics Department of University of Zagreb, Croatia;
- 2005 PhD at the University of Potsdam, Germany

Employment History

- Jan 1997–Jun 1999 Research Assistant, Polish Academy of Science, Nicolaus Copernicus Astronomical Center, Warsaw, Poland,
- Dec 1999–Jul 2003 Research Assistant & PhD student Astrophysikalisches Institut Potsdam
- Mar 2005-Sep 2005 TIARA Postdoctoral Fellow, ASIAA, Academia Sinica,Hsinchu, Taiwan
- Oct 2005-Feb 2007 Marie Curie RTN Senior Postdoctoral Fellow in JETSET network, IASA & University of Athens, Greece
- Feb 2007-Dec 2008 TIARA Visiting Scholar, ASIAA, Academia Sinica,Hsinchu, Taiwan
- Feb 2009-Jun 2009 Visiting Researcher, IASA& University of Athens, Greece,
- Aug 2009-May 2014 TIARA Visiting Scholar, ASIAA, Academia Sinica, Taipei, Taiwan
- June 2014-September 2015 Postdoctoral Researcher, CEA Saclay, LDEE/Sap, Paris, France
- October 2015-current Postdoctoral Researcher, Nicolaus Copernicus Astronomical Center,Polish Academy of Sciences, Warsaw, Poland

Research Interests

Accreting young stellar objects and accreting compact stellar objects - Accretion disk and magnetospheric star-disk interaction - Outflows and jets - X-ray binaries: high mass X-ray binaries - Neutron stars: millisecond pulsars - Methods: numerical simulations, modeling, theory

Publications

12 refereed publications, 6 as first author. 8 conference proceedings. 107 citations. h-index: 6. i10-index: 2.

Especially relevant publications:

- Cemeljic, Miljenko; Bulik, Tomasz; The Influence of Reprocessing in the Column on the Light Curves of Accretion Powered Neutron Stars, 1998, AcA, 48, 65
- Fendt, C.; Čemeljić, M., Formation of protostellar jets - effects of magnetic diffusion, 2002, A&A, 395,1045
- Čemeljić, M.; Shang, H.; Chiang, T.-Y.,Magnetospheric Accretion and Ejection of Matter in Resistive Magnetohydrodynamic Simulations, 2013, ApJ, 768, 5
- Čemeljić, Miljenko, "Atlas" of numerical solutions for star-disk magnetospheric interaction, 2019, A&A forthcoming articles https://doi.org/10.1051/0004-6361/201834580

Curriculum Vitae — Ileyk El Mellah

Education

- September 2016 : PhD with Fabien Casse & Andrea Goldwurm on Wind accretion onto compact objects - Paris Diderot University
- 2012-2013 : Master degree in Astrophysics - Paris Observatory
- 2008-2011 : Ecole Normale Supérieure of Cachan

Employment History

- Since June 2017 : FWO [Pegasus]^2 Marie Skłodowska-Curie fellow with Rony Keppens - KU Leuven
- 2016 - 2017 : post-doctoral scholar with Rony Keppens - KU Leuven
- 2013 - 2016 : PhD candidate - Paris Diderot University

Research Interests

Accreting stellar-mass compact objects - Accretion regimes: Roche lobe overflow, wind accretion - Accretion disks and wind-captured disks - Outflows and jets - Stellar winds: line-driven winds - X-ray binaries: high mass X-ray binaries - Binary systems: symbiotic, cataclysmic variables - Neutron stars: pulsars, magnetars - Magneto-hydrodynamical shocks - Plasma-neutron star magnetosphere interactions - Methods: numerical simulations, modeling, theory

Accepted proposals

- PI for computing time on the Flemmish VSC Tier-1 supercomputer : 2.5Mh·CPU
- PI for computing time on the French CINES Tier-1 supercomputer : 600kh·CPU
- co-PI for the XMM-Newton proposal "Mapping the wind and accretion in Vela X-1" (PI: Victoria Grinberg)

Publications

11 refereed publications, 5 as first author. 4 conference proceedings. 317 citations. h-index: 6. i10-index: 5.

Especially relevant publications:

- El Mellah I., Sundqvist J. O. & Keppens R. - Wind Roche lobe overflow in high mass X-ray binaries - A&A 2019
- El Mellah I., Sander A. A. C., Sundqvist J. O. & Keppens R. Formation of wind-captured disks in Supergiant X-ray binaries - A&A 2019
- El Mellah I., Sundqvist J. O. & Keppens R. - Accretion from a clumpy massive-star wind in Supergiant X-ray binaries - MNRAS 2018
- El Mellah I. & Casse F. - A numerical investigation of wind accretion in persistent Supergiant X-ray Binaries - MNRAS 2017
- El Mellah I. & Casse F. - Numerical simulations of axisymmetric hydrodynamical Bondi-Hoyle accretion on to a compact object - MNRAS 2015

Curriculum Vitae — Enrico Bozzo

Education

- PhD in Astronomy, University of Rome Tor Vergata (Italy), Thesis title: "Theory and Observations of Neutron Star X-ray Binaries: from wind to disk accretors" (Supervisor: Pr. L. Stella, Prof. R. Buonanno), 27.02.2009.
- Degree in Physics (summa cum laude), University of Rome Tor Vergata (Italy), Thesis title: "Interaction processes between neutron star magnetospheres and accretion disks" (Supervisor: Pr. L. Stella, Prof. R. Buonanno), 27.05.2005.

Employment History

- JEM-EUSO, ATHENA, XIPE, THESEUS, Euclid Project Manager & INTEGRAL Operations Coordinator, University of Geneva, Switzerland (02.2014 to present)
- LOFT Project Manager & INTEGRAL Operations Coordinator, University of Geneva, Switzerland (01.2012-02.2014)
- Postdoctoral Research Scientist & INTEGRAL Operations Coordinator, University of Geneva, Switzerland (04.2009-01.2012)
- Postdoctoral Research Scientist, Observatory of Rome, Italy (10.2008-04.2009)
- Visitor Scientist, University of Colorado, United States (01.2007-05.2007)
- PhD Student, University of Tor Vergata (Rome), Italy (10.2005-10.2008)

Research Interests

Accretion phenomena in Galactic and extragalactic X-ray sources; Theoretical modeling of disk and wind accretion onto neutron stars and black holes; Plasma-magnetic field interactions, shocks, magnetohydrodynamics instabilities; X-ray data analyisis and interpretation of X-ray binaries, magnetars, pulsar wind nebulae, Active Galactic Nuclei; Development of space missions for X-ray astronomy: technology (Silicon Drift Detectors, Micropore optics, coded masks) and ground segment operations.

Accepted proposals

Principal investigator of several XMM-Newton, INTEGRAL, Swift, RXTE proposals. Co-Is of numerous XMM, Swift, Chandra, INTEGRAL proposals.

Publications

281 publications, out of which 40 in refereed journals (14 as a first authors).

Especially relevant publications:

1. Bozzo, E. et al. 2013, "XMM-Newton and Swift observations of XTE J1743-363", A&A, 556, A30.
2. Bozzo, E. et al. 2012, "IGR J18179-1621: an obscured X-ray pulsar discovered by INTEGRAL", A&A, 545, A83.
3. Bozzo, E. et al. 2012,"XMM-Newton observations of four high mass X-ray binaries and IGR J17348-2045", A&A, 544, A118.
4. Bozzo, E. et al. 2011, "XMM-Newton observations of IGR J18410-0535: the ingestion of a clump by a supergiant fast X-ray transient", A&A, 531, A130.
5. Bozzo, E. et al. 2008, "Are There Magnetars in High-Mass X-Ray Binaries? The Case of Supergiant Fast X-Ray Transients", A&A, 683, 1031.

Curriculum Vitae — Felix Fürst

Education

Dec 2011	PhD in astrophysics (Dr. rer. nat.), Dr. Karl-Remeis Observatory. ECAP, Bamberg, Uni Erlangen-Nürnberg, Germany, grade: magna cum laude. Title: "Galactic Windmills: Spectroscopical and Timing studies of three X-ray binaries"
May–Nov 2009	stay in the US, University of California, San Diego (UCSD). Goddard Space Flight Center (GSFC), Greenbelt (per DAAD funding for PhD students)
Oct 2008	diploma in physics, Uni Erlangen-Nürnberg, Germany, grade: 1,27. Title of thesis "Investigations of the SAA and the long-time behavior of Vela X-1"

Employment, teaching, and research

since April 2019	XMM-Newton Research Scientist at ESA/ESAC for Quasar Ltd. User support, scheduling and calibration of the XMM-Newton observatory. Scientific analysis and interpretation of X-ray data of accreting objects.
Nov 2016–March 2019	Research Fellow at the European Space Astronomy Centre (ESAC) of ESA in Madrid, Spain. Data analysis and interpretation of data from XMM-Newton and INTEGRAL, as well as support of the INTEGRAL SOC.
June 2012–Oct 2016	post-doctoral scholar, California Institute of Technology, Pasadena. member of the NuSTAR science team, analyzing NuSTAR data, supporting the NuSTAR community, assisting in the instrument calibration
Oct 2008–May 2012	scientific employee, Dr. Karl-Remeis Observatory, Bamberg. Analyzing data of the X-ray satellite XMM-Newton as well as analysing and extracting data from the satellites RXTE, Suzaku, INTEGRAL, Swift and RHESSI

Research Interests

My main research interest lies in the analysis and understanding of accreting binary systems. Utilizing all modern X-ray telescopes, I investigate the behaviour of matter under the influence of strong gravitation, magnetic fields, and radiation. By using tracers like the variability of fluorescence lines and variations in X-ray flux the structure and physical state of the accreted matter becomes visible. I apply the models and lessons learned from binaries also to other accreting sources, like Ultra-luminous X-ray sources and Active Galactic Nuclei.

Publications

129 refereed papers (18 as first author), h-index 28.

Especially relevant publications:

1. Fürst F., Falkner S., Marcu-Cheatham D., et al., 2018, Multiple cyclotron line-forming regions in GX 301-2, A&A, 620, A153
2. Brightman M., Harrison F.A., Fürst F., et al., 2018, Magnetic field strength of a neutron-star-powered ultraluminous X-ray source. Nature Astronomy, 2., 312-316
3. Fürst F., Kretschmar P., Kajava J.J.E., et al., 2017, Studying the accretion geometry of EXO 2030+375 at luminosities close to the propeller regime, A&A, 606, A89
4. Brightman M., Harrison F.A., Fürst F., et al., 2018, Magnetic field strength of a neutron-star-powered ultraluminous X-ray source. Nature Astronomy, 2, 312–316
5. Fürst F, et al., 2014, "NuSTAR Discovery of a Luminosity Dependent Cyclotron Line Energy in Vela X-1". Astrophys. J., 780, 133.
6. Fürst F., et al., 2011. "Study of the many fluorescent lines and the absorption variability in GX 301−2", A&A, 535, A9.
7. Fürst, F., et al., 2010, "X-ray variation statistics and wind clumping in Vela X-1", A&A 519, A37.

Curriculum Vitae — Peter Kretschmar

Education and Employment History

Jul 2017 –	XMM-Newton Mission Manager
Oct 2009 – Jun 2017	Integral Mission Manager
Jan 2007 – Dec 2017	Integral Science Operations Manager
Jan 2005 – Dec 2006	Operations Scientist & Deputy Project Scientist for the Integral Mission.
Jan 2001 – Dec 2005	Post-Doc at MPE Garching, delegated to Integral Science Data Centre, Versoix.
Apr 1996 – Jan 2001	Post-Doc at IAA Tübingen, delegated to Integral Science Data Centre, Versoix.
Apr 1996	Ph.D. in Physics and Astronomy, Univ. Tübingen "Hochenergieröntgenspektren der akkretierenden Röntgenpulsare Vela X-1 und A 0535+26" *(Hard X-ray spectra of the accreting X-ray pulsars Vela X-1 and A 0535+26)*
May 1992	University diploma in physics (Dipl. phys.) "Kalibration von Hochenergieröntgendetektoren am Spektrum des Crab-Nebels und Untersuchungen am Röntgenpulsar A 0535+26" *(Calibration of hard X-ray detectors using the spectrum of the Crab Nebula and studies of the X-ray pulsar A 0535+26)*

Research Interests

High-energy observations of accreting X-ray pulsars and the comprehension of these systems at all scales, from the systems as a whole and their accretion mechanisms down to details of the radiation processes in the accretion column. High-energy radiation processes. High-energy satellite instrumentation.

Memberships

International Astronomical Union; European Astronomical Society; Sociedad Española de Astronomía; Swiss Society for Astrophysics and Astronomy

Publications

129 refereed publications, 261 non-refereed contributions.

Especially relevant publications:

1. Schönherr, G., Schwarm, F.-W., Falkner, S., et al., 2014, "Formation of phase lags at the cyclotron energies in the pulse profiles of magnetized, accreting neutron stars", A&A, 564, L8

2. Martínez-Núñez, S., Torrejón, J.M., Kühnel, M., et al., 2014, "The accretion environment in Vela X-1 during a flaring period using XMM-Newton", A&A 563, A70

3. Fürst, F., Kretschmar, P., Kajava, J.J.E., et al., 2017, "Studying the accretion geometry of EXO 2030+375 at luminosities close to the propeller regime", A&A, 606, A89

4. Martínez-Núñez, S., Kretschmar, P., Bozzo, E., et al., 2017, "Towards a Unified View of Inhomogeneous Stellar Winds in Isolated Supergiant Stars and Supergiant High Mass X-Ray Binaries", Space Sci Rev, 212:59

5. Sander, A.A.C., Fürst, F., Kretschmar, P., et al., 2018, "Coupling hydrodynamics with comoving frame radiative transfer. II. Stellar wind stratification in the high-mass X-ray binary Vela X-1", A&A, 610, A60

Curriculum Vitae —Antonios Manousakis

Education

- Ph.D. in Astronomy & Astrophysics, December 2011. Department of Astronomy. University of Geneva, Geneva, Switzerland. Thesis: Accretion in High Mass X-ray Binaries Advisor: Dr. Roland Walter.
- Degree in Physics, November 2006. Department of Physics. University of Crete, Heraklion, Greece. Thesis: Identification of optical counterparts to High-Mass X-Ray Binaries through Optical Photometry and Spectroscopy. Advisor: Dr. Pablo Reig and Prof. Nikolaos D. Kylafis.

Employment History

Sept. 2018–now	Assistant Professor, University of Sharjah, Sharjah, UAE
Feb. –Aug. 2018	Visiting Research. University of Crete, Herkalion, Greece
Jan.2017–Jan.2018	Visiting Faculty. Sultan Qaboos University, Muscat, Oman
Oct.2012–Dec.2016	Postdoctoral Fellow. Copernicus Astronomical Center, Warsaw, Poland.
Jan.2012–Aug.2012	Postdoc. ISDC Data Center for Astrophysics, Geneva, Switzerland.
Sep.2007–Dec.2011	Ph.D. Candidate. ISDC Data Center for Astrophysics, Geneva, Switzerland.

Research Interests

Accretion onto compact object (Neutron stars and Black Holes), stellar winds, General Relativistic (Magneto-) Hydrodynamic simulations; X-ray and γ-ray and, optical-IR observations; High Mass X-ray Binaries.

Memberships

International Astronomical Union (IAU), European Astronomical Society (EAS), Swiss Society for Astrophysics and Astronomy (SSAA/SGAA), Helennic Astronomical Society (HelAS)

Publications

Total Publications: 55. Refereed Publications: 19.

Citations (total/refereed.): 350/250. h-index (total/refereed.): 12/10.

Especially relevant publications:

1. Mishra, B., Vincent, F. H., Manousakis, A., et al., Quasi-periodic oscillations from relativistic ray-traced hydrodynamical tori, 2017, MNRAS, 467, 4036
2. Bozzo, E., Bhalerao, V., Pradhan, P., et al., Multi-wavelength observations of IGR J17544-2619 from quiescence to outburst, 2016, A& A, 596, A16
3. Parthasarathy, V., Manousakis, A., & Kluźniak, W., Quasi-periodic oscillations of perturbed tori, 2016, MNRAS, 458, 666
4. Manousakis, A., & Walter, R., The stellar wind velocity field of HD 77581, 2015, A& A, 584, A25
5. Manousakis, A., & Walter, R., Origin of the X-ray off-states in Vela X-1, 2015, A& A, 575, A58
6. Manousakis, et al., 2012, "Neutron star masses from hydrodynamical effects in obscured supergiant high mass X-ray binaries", A&A, 547, A20.
7. Bozzo, E. et al. 2012, "IGR J18179-1621: an obscured X-ray pulsar discovered by INTEGRAL", A&A, 545, A83.
8. Manousakis, A.; Walter, R., 2011, "X-ray wind tomography of the highly absorbed HMXB IGR J17252-3616", A&A, 526, A62.

Curriculum Vitae — Silvia Martínez-Núñez

Education

- PhD in Astrophysics, University of Valencia. March 2005. "INTEGRAL view of High Mass X-ray Binaries" (Supervisors: Peter Kretschmar, Víctor Reglero, Pablo Reig).
- Degree in Physics - University of Valencia, 1993-1998.

Employment history

- 2016-now: Post-doc researcher at Institute of Physics of Cantabria (IFCA), Santander, Spain.
- 2013-2016: Scientific collaborator at X-ray Astronomy Group. Alicante University, Alicante, Spain.
- 2007-2013: Post-doc researcher at Alicante University, Alicante, Spain.
- 2004-2007: Researcher at the Astrophysics and Space Research Group of Valencia University, Valencia, Spain.

Research Interests

High mass X-ray binaries; wind accretion processes; X-ray spectral variability studies; stellar wind characterization; simulations of *Athena* mission.

Accepted proposals

Team-leader of the "Unified View of Stellar Winds in Massive X-ray Binaries" and "A Comprehensive View of Stellar Winds in Massive X-ray Binaries" ISSI international teams.

Publications

16 refereed papers, 4 as first author. 29 international meetings contributions. 777 citations. h-index:14. i10-index: 16. Especially relevant publications:

1. Martínez Núñez, S., et al., 2017,"Towards a Unified View of Inhomogeneous Stellar Winds in Isolated Supergiant Stars and Supergiant High Mass X-Ray Binaries", Space Science Reviews, Volume 212, Issue 1-2, pp. 59-150.
2. Giménez-García, A., et al., 2016, "Measuring the stellar wind parameters in IGR J17544-2619 and Vela X-1 constrains the accretion physics in supergiant fast X-ray transient and classical supergiant X-ray binaries", A&A, 591, A26.
3. Martínez Núñez, S., et al., 2015, "The donor star of the X-ray pulsar X1908+075", A&A, 578, A107.
4. Martínez Núñez, S., et al., 2014, "The accretion environment in Vela X-1 during a flaring period using XMM-Newton", A&A, 563, A70.

Curriculum Vitae — Antonio Martin-Carillo

Education and Employment History

20XXX XXX
XXX

Research interests

XXX

Accepted proposals

XXX

Membership

XXX

Publications

XXX refereed papers, XXX as first author. XXX international meetings contributions. XXX citations. h-index:XXX. i10-index: XXX. Especially relevant publications:

Especially relevant publications:

1.
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Curriculum Vitae — Jonathan Ferreira

Education

- Habilitation from University Grenoble Alpes, July 2007
- PhD in Astrophysics, 1994, Paris VII University
- M.S. in Astrophysics, June 1990, Paris XI University
- Magistere in Fundamental Physics, June 1990, Paris XI University
- B.S in Fundamental Physics, June 1988, Paris XI University

Employment History

- 10/2012 - till now: Full Professor of Physics at University Grenoble Alpes (France)
- 09/2005- 09/2012: Associate Professor of Physics at University Joseph Fourier (Grenoble, France)
- 09/2003-08/2005: On leave at the CNRS (French National Center for Scientific Research)
- 11/1996-08/2003: Associate Professor of Physics at University Joseph Fourier (Grenoble, France)
- 10/1994-10/1996: Postdoc with Max Camenzind at the Landessternwarte Königstuhl, Heidelberg (Germany)
- 09/1993-09/1994: Assistant Professor of Physics at University Joseph Fourier (Grenoble, France)

Research Interests

Plasma dynamics, Magnetohydrodynamics, theory of accretion-ejection in compact objects (X-ray binaries, AGN) and young stars, synthetic observations of jets (YSO) and disks (YSO and XrB), jet collimation, analytical support of numerical simulations, star-disk interaction

Accepted proposals

Manager of the Work-Package "Theory" of the FP6 Marie-Curie network JETSET (2005-2009). Co-I of several successful ANR (French National Research Agency) projects, co-organizer of the conference "From Quiescence to Outburst : when microquasars go wild", september 2017.

Publications

65 refereed publications, 12 as first author. 41 conference proceedings. 2866 citations. h-index: 27.

Especially relevant publications:

- *Magnetically-driven jets from Keplerian accretion disks*, **Ferreira J.**, 1997, A&A, 319, 340
- *Accretion funnels onto weakly magnetized young stars*, Bessolaz N., Zanni C., **Ferreira** J., Keppens R., Bouvier J. 2008, A&A 478, 155
- *MHD simulations of accretion onto a dipolar magnetosphere I. Accretion curtains and the disk-locking paradigm*, Zanni C., **Ferreira** J., 2009 A&A, 508, 1117
- *MHD simulations of accretion onto a dipolar magnetosphere II. Magnetospheric ejections and stellar spin-down*, Zanni C., **Ferreira** J., 2013, A&A, 550, 99
- *A unified accretion-ejection paradigm for black hole X-ray binaries III. Spectral signatures of hybrid disk configurations*, Marcel, G.; **Ferreira**, J.; Petrucci, P.-O.; Belmont, R.; Malzac, J.; Clavel, M.; Henri, G.; Coriat, M.; Corbel, S.; Rodriguez, J.; Loh, A.; Chakravorty, S. 2018, A&A, 617, 46