**DOCUMENT 1**

**START PAGE**

MARIE SkŁodowska-CURIE ACTIONS

**Individual Fellowships (IF)**

**Call:** **H2020-MSCA-IF-2016**

PART B

“TAcc-NeXB”

**This proposal is to be evaluated as:**

**[Standard EF]**

Part B - Page 1 of 23 **TABLE OF CONTENTS**

***In drafting PART B of the proposal, applicants must follow the structure outlined below.***

***DOCUMENT 1 (13-PAGE LIMIT APPLIED)***

**START PAGE (1 page)**

**LIST OF PARTICIPATING ORGANISATIONS**

**Start page count (MAX 10 PAGES SECTIONS 1-3)**

**1. EXCELLENCE**

**2. IMPACT**

**3. QUALITY AND EFFICIENCY OF THE IMPLEMENTATION**

**STOP page count (MAX 10 PAGES SECTIONS 1-3)**

***DOCUMENT 2 (NO OVERALL PAGE LIMIT APPLIED)***

**4. CV of the experienced researcher**

**5. Capacities of the PARTICIPATING ORGANISATIONS**

**6. Ethical aspects**

**7. Letter of commitment of PARTNER ORGANISATION (GF only)**

*Please note that:*

* *Applicants must ensure that document 1 does not exceed the total page limit of 13 pages. The Start Page must consist of 1 whole page. The Table of Contents must consist of 1 whole page. The List of Participating Organisations must consist of 1 whole page. Section 1 must start on page 4 of the document. Expert evaluators will be instructed to disregard any excess pages above the 10 page limit. Such excess pages will be watermarked.*
* *No reference to the outcome of previous evaluations of a similar proposal should be included in the text. Experts will be strictly instructed to disregard any such references.*

**List of Participating Organisations**

Please provide a list of all participating organisations (both beneficiaries and, where applicable, partner organisations[[1]](#footnote-2)) indicating the legal entity, the department carrying out the work and the supervisor.

If a secondment in Europe is planned but the partner organisation is not yet known, as a minimum the type of organisation foreseen (academic/non-academic) must be stated.

For non-academic beneficiaries, please provide additional data as indicated in the table below.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Participating organisations** | **Legal Entity Short Name** | **Academic** | **Non-academic** | **Country** | **Dept./**  **Division /**  **Laboratory** | **Supervisor** | **Role of Partner Organisation[[2]](#footnote-3)** |
| Beneficiary |  |  |  |  |  |  |  |
| Katholieke Universiteit Leuven | KU Leuven | X |  | Belgium | CmPA, Dept. of Mathematics | Rony Keppens |  |
| Partner Organisation |  |  |  |  |  |  |  |
| - NAME |  |  |  |  |  |  |  |

**Data for non-academic beneficiaries**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Name** | **Location of research premises**  **(city / country)** | **Type of R&D activities** | **No. of full - time employees** | **No. of employees in R&D** | **Web site** | **Annual turnover**  **(approx. in Euro)** | **Enterprise status (Yes/No)** | **SME status[[3]](#footnote-4) (Yes/No)** |
|  |  |  |  |  |  |  |  |  |

**Please note that:**

* Any inter-relationship between the participating organisation(s) or individuals and other entities/persons (e.g. family ties, shared premises or facilities, joint ownership, financial interest, overlapping staff or directors, etc.) **must** be declared and justified **in this part of the proposal**;
* The information in the table for non-academic beneficiaries **must be based on current data, not projections**.

**Start page count – MAX 10 PAGES**

**1. Excellence**[[4]](#footnote-5)

**1.1 Quality and credibility of the research/innovation action (level of novelty, appropriate consideration of inter/multidisciplinary and gender aspects)**

*You should develop your proposal according to the following lines:*

* *Introduction, state-of-the-art, objectives and overview of the action*
* *Research methodology and approach: highlight the type of research / innovation activities proposed*
* *Originality and innovative aspects of the research programme: explain the contribution that the action is expected to make to advancements within the action field. Describe any novel concepts, approaches or methods that will be employed.*
* *The gender dimension in the research content (if relevant)*
* *The interdisciplinary aspects of the action (if relevant)*
* *Explain how the high-quality, novel research is the most likely to open up the best career possibilities for the experienced researcher and new collaboration opportunities for the host organisation(s).*

In the 2000’s, simulations giving birth to wind-capture discs have been observed for symbiotic binaries, a family of binary systems where the two bodies are of stellar size and where the stellar wind is much slower than for massive stars (see eg Abate+13[[5]](#footnote-6)). Since the accretor is much larger than in X-ray binaries (where we deal with a 10kms neutron star), the scale discrepancy is small enough to grasp both the shock and the accretor within the same simulation space. Those simulations brought insightful comments concerning the long-puzzling formation of barium stars, the shaping of planetary nebulae and the evolutionary path to the progenitors of Type Ia supernovae.

I want to carry on a similar investigation but in Supergiant X-ray Binaries (SgXB) hosting a neutron star (NS) where the scale discrepancy is way more important. In those systems, the mass transfer proceeds through the intense wind of the evolved OB Supergiant : it is called wind accretion. Several authors considered either an anomalously fast wind (Lora-Clavijo+13[[6]](#footnote-7)) or an excessively large NS (Blondin+12[[7]](#footnote-8)) to bypass this numerical obstacle but none has designed a consistent scheme to connect the orbital and accreting scales (resp. 10 billions of kilometres and 10 kilometres in realistic X-ray binaries). This multi-scales monitoring is a necessary condition to disentangle the phenomena responsible for the impressive time-variability we observe in those systems : is the stellar wind homogeneous? What is the influence of the X-ray radiative feedback on the shock? Is the shock stable? Does the flow form a disc around the accretor in spite of its low angular momentum? If not, what is the geometry of the accreted flow once it enters the NS magnetosphere? As we study those physical questions, we bring up hints about observational unexplained features such as the origin of the log-normal distribution in time of the X-ray luminosity in X-ray binaries, the correlations between the spectral and photometric time-variability or the evolutionary tracks over secular time scales of those systems.

My approach is to identify the dominant physical ingredients at each scale : from the ballistic wind at the orbital scale to the neighbourhood of the NS, dominated by its magnetic and gravitational fields (with departures from the non-relativistic theory), the computational algorithms we must rely on evolve a lot in complexity. For the last three years, I have managed to cover the orbital and intermediate scales. For the latter, I characterized a test-case planar hydrodynamical (HD) shock and the properties pertaining to mass accretion with Fabien Casse (APC, FR) in El Mellah & Casse 2015[[8]](#footnote-9), using analytical predictions on the topology of the flow (Foglizzo+96[[9]](#footnote-10)) as guidelines to ensure the robustness of our mesh-based code, [MPI-AMRVAC](homes.esat.kuleuven.be/~keppens) (Porth+14[[10]](#footnote-11)). This study has relied on a grid specifically designed to uniformly span up to 5 orders-of-magnitude in space, equivalent to 17 levels of refinement in AMR (Adaptive Mesh Refinement). At a larger scale, I identified the structure of the stellar wind in a SgXB, its likelihood to form a disc and the essential parameters it depends on (El Mellah & Casse 2016[[11]](#footnote-12)) ; it enabled me to suggest self-consistent sets of observational parameters for several systems, such as the mass of the NS. The latter has been a long-standing question which connects to the still unknown equation-of-state of matter within those degenerated objects. Constrains on the maximum mass of a NS decide the viability of the models (relying on empirical coupling between General Relativity and Quantum Chromodynamics) and could lead to a major breakthrough in fundamental Physics.

I am now piping those results into 3D HD simulations of the NS vicinity to use physically-motivated sheared outer boundary conditions rather than a planar flow to monitor the accretion of angular momentum. Those demanding High Performance Computing (HPC) numerical simulations lie at the crossroad of :

* the modern international supercomputing facilities (organized in the PRACE – for Partnership for Advanced Computing in Europe),
* the on-going discoveries in Applied Mathematics (for the solving schemes of the underlying partial differential equations),
* the synthetic numerical models I design to save computing time while still retaining the essential physical features of the problem.

Since I was granted computing hours on the CINES supercomputers (part of the PRACE network) and that the MPI-ARMVAC code contains the most recent numerical solvers, the challenge is now to make an affordable numerical setup to address the flow within the shock. There, the flow (now a plasma due to photo-ionization) is likely to either form a disc or to couple to the NS magnetic field. To answer this question, I need to adapt the available magneto-HD (MHD) solvers to the multi-scales meshes I designed (see WP 3).

The plasma dynamics within the NS magnetosphere is a burning topic in high energy Astrophysics but the current numerical simulations focus on the innermost parts without coupling them with the upper scales, dominated by stellar physics. The approach I have undergone could enable to bridge the gap between the two communities and sparkle new interdisciplinary collaborations between high energy, stellar and plasma Astrophysics (the core domain of my host institution). In particular, I am willing to promote my results to the NS community and trace back the consequences of their fruitful though autonomous results to the orbital scale : given the coupling I will find between the scales, what is the expression at large scale of the instabilities they identified within the magnetosphere? How do they affect the flow upstream? Ultimately, this comprehensive sketch of wind accretion is prone to join the question of jet-launching conditions, a vastly explored and fertile ground of contemporary research with a wide range of career opportunities and applications (microquasars, active galactic nuclei, young stellar objects...).

**1.2 Quality and appropriateness of the training and of the two way transfer of knowledge between the researcher and the host**

*Describe the training that will be offered.*

*Outline how a two way transfer of knowledge will occur between the researcher and the host institution(s):*

* *Explain how the experienced researcher will gain new knowledge during the fellowship at the hosting organisation(s)*
* *Outline the previously acquired knowledge and skills that the researcher will transfer to the host organisation(s).*

*For Global Fellowships explain how the newly acquired skills and knowledge in the Third Country will be transferred back to the host institution in Europe (the beneficiary) during the incoming phase.*

Given its international renown, KU Leuven, and the Centre for mathematical Plasma Astrophysics (CmPA) in particular attract plenty of visiting scholars acknowledged for their major accomplishments. It is the occasion for many of them to provide advanced seminars and courses on specific techniques of direct use for my research. As an example, Prof. Paul Gibbon from the Jülich Supercomputing Centre, author of a reference book in plasma Physics[[12]](#footnote-13), is expected to give several sessions on particle-based parallel programming in late 2017. These methods could bring me tools to extend the scope of my simulations to other burning topics such as cosmic rays acceleration at shocks (Spitkovsky08[[13]](#footnote-14)) or Monte-Carlo monitoring of photons in optically thick environments (Commerçon+14[[14]](#footnote-15)). The Flemish Supercomputer Centre (VSC) also offers dedicated trainings I plan to attend on HPC and coding (Message Passing Interface language, code performance analysis tools, etc).

In addition of those formal courses, I will take advantages of the specific expertise of the CmPA which hosts, among other Prof. Stefaan Poedts, author of two reference books on MHD[[15]](#footnote-16),[[16]](#footnote-17). The CmPA division is among world leading institutes which pay specific attention to HD and plasma physical processes that work across many spatial and temporal scales, ranging from those encountered in laboratory, magnetospheric, solar, or heliospheric gases and plasmas, all the way to the more exotic physics found in eg pulsar winds or in connection with active galactic nuclei. I am willing to reinforce the capacity of the team to consistently deal with several scales in three ways :

* A numerical one, by coupling the multi-scales meshes I developed with the dynamical AMR option of the MPI-AMRVAC code. I will also consider the possibility to implement Adaptive Time Stepping (ATS) to make this code the optimal tool to explore multi-scales phenomena on a non-Cartesian mesh, a long-awaited tool within the Astrophysics community[[17]](#footnote-18).
* A computational one, by using the skills I have developed during my PhD to monitor CPU activity and optimize the computing performance of HPC simulations using advanced tools such as the Vampir profiler. Indeed, sophisticated hardware technologies require smart load balancing between processors and nodes to be used at their maximal capacity.
* A physical one, by identifying the relevant flow numbers and the self-similar scales and piping them to the scale-variant domains while still retaining the simple most physical framework. This skill I developed during my PhD already turned profitable when I proceeded in this way to design a synthetic model of wind accretion in SgXB (El Mellah & Casse 201611).

**1.3 Quality of the supervision and of the integration in the team/institution**

* *Qualifications and experience of the supervisor(s)*

*Provide information regarding the supervisor(s): the level of experience on the research topic proposed and their track record of work, including main international collaborations, as well as the level of experience in supervising researchers. Information provided should include participation in projects, publications, patents and any other relevant results.*

The supervisor for this project, Prof. Rony Keppens, has extensive experience in computational solar and astrophysics, and in participating in and managing research projects. His international career includes PhD research at the National Centre for Atmospheric Research (1991-1994, High Altitude Observatory, Boulder, US), postdoc experience at the Kiepenheuer Institute for Solar Physics (Freiburg, GR) and group leadership (2001-2005) in Numerical Plasma Dynamics at the FOM Institute for Plasma Physics Rijnhuizen (currently DIFFER, Eindhoven, NL). He held full professor level appointments at Utrecht University (NL) and as Astronome at Observatoire de Paris (FR), and has been a tenured professor at KU Leuven since 2006. He received a concurrent professorship (2013-2016) at Nanjing University (CN), enhancing Belgian-Chinese research efforts in solar and plasma physics. At KU Leuven, he has chaired the CmPA (about 35 researchers with 5 permanent staff members) since 2009. He has been involved in many national and international interdisciplinary research projects, and currently coordinates an Inter-University Attraction Pole network with 7 partners (IUAP FP7/08 CHARM 2012-2017, 3 Meuro). He acted as promotor for 8 completed PhDs, and currently supervises 5 ongoing PhDs and 5 postdocs. He contributed to over 200 scientific publications (ADS search on 10/8/2016 yields 202 entries, 2652 citations, H-index 30), among which a Cambridge University Press book on Advanced MHD (2010).

He is contact point and co-developer for the open-source MPI-AMRVAC code, used for massively parallel, grid-adaptive computations. With his team, he is actively researching plasma dynamics in astrophysical jets and accretion discs, studies solar prominences, coronal rain, and space weather phenomena, and has expert know-how on MHD waves and instabilities in plasmas and on state-of-the-art numerical algorithmic approaches.

* *Hosting arrangement*s[[18]](#footnote-19)

*The application must show that the experienced researcher will be well integrated within the team/institution in order that all parties gain the maximum knowledge and skills from the fellowship. The nature and the quality of the research group/environment as a whole should be outlined, together with the measures taken to integrate the researcher in the different areas of expertise, disciplines, and international networking opportunities that the host could offer.*

*For GF both phases should be described - for the outgoing phase, specify the practical arrangements in place to host a researcher coming from another country, and for the incoming phase specify the measures planned for the successful (re-)integration of the researcher.*

In the last decade, the CmPA has gained worldwide recognition for its pioneering role in HPC, with several PRACE funded projects running on Tier 0 platforms. A postdoctoral stay as a Marie Curie fellow at the KU Leuven CmPA will allow me to join and interact with the core developer team of the open source code effort MPI-AMRVAC. This software is ideally suited for high performance computing, and has a build-in versatility in its applications. This versatility has been key for my own PhD research, where I added functionalities that were not available in the public release such as customized user-defined grids. During my latest visit in April 2016 to the CmPA, we transferred this functionality to the public release, and can now fully exploit this feature in block grid-adaptive fashion. As a postdoc, I plan to make further improvements to the discretization schemes that are absolutely vital for my application on X-ray binary physics, such as encoding angular momentum conservation at machine precision, making Python tools for post-processing large data volumes, working with state-of-the-art visualization tools, etc.

The diversity in the plasma physical expertise of its 40 team members ranges from pure analytic modelling of wave and instabilities in especially solar contexts, to the study of winds and jets associated with massive stars or accreting configurations, over fundamental know-how on MHD descriptions of plasmas. The step to full scale MHD modelling of the X-ray binary accretion processes will thus fit seamlessly with the research ambitions of the division as whole, while it is as yet uncharted territory for the kind of numerical simulations I envision in this project. Close collaboration is foreseen with postdocs Chun Xia (general MPI-AMRVAC code development, specific attention to solar physics applications), Kirit Makwana (developing coupled fluid-kinetic treatments for reconnection physics), Matthieu Leroy (Hall-MHD applications, Earth magnetosphere physics) and Jannis Teunissen (FWO funded postdoc since summer 2016, focus on plasma discharges and coupled elliptic-hyperbolic problems on adaptive meshes).

**1.4 Capacity of the researcher to reach or re-enforce a position of professional maturity/independence**

*Applicants should demonstrate how the proposed research and training will contribute to the further professional development as an independent/mature researcher.*

*Describe* ***briefly*** *how the host will contribute to the advancement of the researcher's career.*

*Therefore, a complete* ***Career Development Plan should not be included in the proposal****, but it is part of implementing the action in line with the European Charter for Researchers.*

My academic accomplishments as a student (Ecole Normale Supérieure, ranked 2nd in 1,409 candidates at the Agrégation) have shown my ability to develop a clear and rigorous reasoning to address challenging questions. My research experience at MIT (US) on stellar binaries (S. Rappaport et al, 2013[[19]](#footnote-20)) and exoplanets (S. Rappaport et al 2012[[20]](#footnote-21), R. Sanchis-Ojeda et al 2014[[21]](#footnote-22)) has been a firm basis for my PhD that I have just finished and where I have taken the most of HPC simulations to tackle specific questions on X-ray binaries. I have delimited the two main regimes of mass transfer depending on the parameters of the system (El Mellah & Casse 201611) and I had previously characterized the shock produced by a gravitationally beamed planar flow (El Mellah & Casse 20158). I am now in a suitable position to pursue this journey towards the innermost regions of the accreted flow, in the neighbourhood of the compact object, provided I can join a team with the required numerical MHD skills. It is precisely the reason why I think the CmPA at KU Leuven is an ideal place to address the coupling between the plasma within the shocked region and the NS magnetosphere. Besides, the links with observers I have piled up during my year in the US can be reinforced thanks to the strong links of Rony Keppens with the astronomers of the Institute of Astronomy of KU Leuven (eg he co-supervises a postdoctoral position with Leen Decin).

**2. Impact**

**2.1 *Enhancing the potential and future career prospects of the researcher***

*Explain the expected impact of the planned research and training on the career prospects of the experienced researcher after the fellowship. Which new competences will be acquired?*

The research project I want to carry on in Leuven will make the most of the leading-edge skills gathered and improved at the CmPA. Few places in the world are so firmly turned towards the use of numerical simulations as a proper reasoning step in a scientific discussion as the CmPA. I personally advocated in favour of the rise of a computational epistemology in the introduction of my PhD manuscript ; it still requires to push HPC simulations to the limit, in particular in extreme physical environments such as X-ray binaries, planetary magnetospheres or the stellar corona, three topics addressed by the staff at the CmPA.

The competences I will acquire in this team (see section 1.2 and 1.3) will make me a decisive asset to tackle the question brought up by the observations made by the current (FERMI, INTEGRAL) and future (SVOM, LOFT, ATHENA) generations of satellites. The evolution of the data available over the last decade suggests an incoming inflation of the number of X-ray binaries as the sensitivity of the instruments rise (Walter+15[[22]](#footnote-23)). On the other hand, a selective pool of young numerical astrophysicists has been bred by a few precursors such as Rony Keppens. I am willing to fit my career into this promising track of explaining the plethora of available and incoming observational data with the numerical tool. If I was first introduced to HD and radiative simulations by Fabien Casse in Paris, I now plan to obtain reliable MHD simulations of the vicinity of a NS undergoing accretion thanks to Prof. Keppens’ expertise. Since I characterized the large orbital scale during my PhD (El Mellah & Casse 201611), it would make me one of the few able to bridge the gap between the stellar Physics which dominates the orbital dynamics and the NS magnetosphere. Teams such as Sera Markoff’s (University of Amsterdam, NL) or Alexander Tchekhovskoy’s (UC Berkeley, US) ones have been extensively exploring the latter and might take advantage of my unique profile to use a physically-motivated coupling with the large scale to orientate their research. I intend to set the conditions for this mutual feeding between NS studies and X-ray binaries models. On the other hand, the tools I will acquire thanks to my secondment will make it possible for me to characterize the instabilities and follow their growth (linear and non-linear), an ability more and more required as numerical simulations grow in complexity : being able to extract the physically meaningful information out of a seemingly cumbersome simulation is a precious prerequisite for the established instability community – Thierry Foglizzo (CEA, FR) and John Blondin (NC State University, US) for instance.

Aside of this core knowledge I wish to assimilate, the experience I will acquire in using the modern tools of HPC simulations analysis (eg parallel 3D visualization, selective post-processing to save memory) and communication tools (eg web interfaces as complimentary material to share results within the community, augmented reality in articles and posters) will boost my early career and highly participate in the multiplication of prospects I will be offered.

**2.2 *Quality of the proposed measures to exploit and disseminate the action results***

*Describe how the new knowledge generated by the action will be disseminated and exploited, e.g. communicated, transferred into other research settings or, if appropriate, commercialised.*

*What is the dissemination strategy - targeted at scientists, potential users and to the wider research and innovation community - to achieve the potential impact of the action?*

*Please make also reference to the "Dissemination & exploitation" section of the H2020 Online Manual[[23]](#footnote-24).*

*The following section of the European Charter for Researchers refers specifically to dissemination:*

***Dissemination, exploitation of results***

*All researchers should ensure, in compliance with their contractual arrangements, that the results of their research are disseminated and exploited, e.g. communicated, transferred into other research settings or, if appropriate, commercialised. Senior researchers, in particular, are expected to take a lead in ensuring that research is fruitful and that results are either exploited commercially or made accessible to the public (or both) whenever the opportunity arises.*

*Concrete planning for section 2.2 must be included in the Gantt Chart (see point 3.1).*

The dissemination strategy for my technical deliverables (code development, simulation data, visualisation tools…) is twofold :

- as an active member of the MPI-AMRVAC code community, I follow the philosophy of the group which is to make the code and its annual updates free, open (with source files easy to access via [GitLab](https://gitlab.com/mpi-amrvac/amrvac)) and well documented. A couple of my own code developments have been implemented in the official version (grid stretching and axisymmetric configurations)

- I also make my personal data and the [Spyre](https://github.com/adamhajari/spyre) web visualisation interface I developed available on demand or via my [personal webpage](http://www.apc.univ-paris7.fr/~elmellah/index.html) to further explore the results I describe in my articles. Access and re-use of the data, in agreement with the Horizon 2020 prioritites, are guaranteed thanks to the storage policies of the supercomputing facilities I work on (see sections 3.2 and 3.3).

Concerning the scientific conclusions I will draw from this raw material and technical tools, I will share different levels of details depending on the events I will attend and the documents I will rely on :

- two to three times a year, I will use the mobility grant of the Marie SKŁODOWSKA-CURIE EF to give seminars to specialists in the world leading laboratories in high energy and plasmas Astrophysics : Princeton University (US) with Jim Stone, UC Berkeley (US) with Eugene Chiang and Alexander Tchekhovskoy, the Max Planck Institutes for Astrophysics and Extreterrestrial Physics (DE) with Jason Dexter, the Niels Bohr Institute (DK) with Martin Pessah, the Observatory of Paris (FR) with Frédéric Vincent and the Observatory of Nice (FR) with Héloïse Méheut. During 30 to 50 minutes talks, I will discuss the precise aspects of the theoretical side of my research. On the other hand, I also intend, more sporadically, to present the sections of my work which are of direct use for observers such as Patrizia Romano’s team at the Institute of Astrophysics of Palermo (IT). Because the observers’ scientific interests orientate the fundings for new space missions, this step of my dissemination strategy will indirectly contribute to the technological innovation and economic growth at stake in any major Physics instrument.

- at an intermediate scale, I will attend local conferences and workshops to emphasize my main results to colleagues I still have to meet. It will be an occasion to enlarge my social scope and possibly to discover connected topics where my work could prove useful. In particular, I will be part of the InterUniversity Attraction Pole CHARM network (for Contemporary challenges for Heliospheric and AstRophysical Models) whose Prof. Keppens is a key member.

- to improve my visibility within the community as a whole, I will design oral presentations and posters for a broader audience. I will synthetize my results and apply to the main international conferences twice a year : the 44th European Physics Society conference on plasma Physics (June 2017, UK), the 29th Texas symposium on relativistic Astrophysics (December 2017, ZA), the 30th International Astronomical Union general assembly (August 2018, AT) and the 42nd COSPAR scientific assembly (2018).

***2.3*. *Quality of the proposed measures to communicate the action activities to different target audiences***

*Please make also reference to the guidelines* [*Communicating EU research and innovation guidance for project participants*](http://ec.europa.eu/research/participants/data/ref/h2020/other/gm/h2020-guide-comm_en.pdf)*[[24]](#footnote-25) as well as to the "communication" section of the H2020 Online Manual[[25]](#footnote-26).*

*Concrete planning for section 2.3 must be included in the Gantt Chart (see point 3.1).*

*The following section of the European Charter for Researchers refers specifically to public engagement:*

***Public engagement***

*Researchers should ensure that their research activities are made known to society at large in such a way that they can be understood by non-specialists, thereby improving the public's understanding of science. Direct engagement with the public will help researchers to better understand public interest in priorities for science and technology and also the public's concerns.*

Beyond the communication of my results within the scientific community, I am willing to devote part of my working time (10 to 15%) to teaching and public outreach. For the latter, I will apply to the Planetarium of Brussels which shares privileged links with KU Leuven 20kms away through the Belgium Federal Science Policy Office (BELSPO). There, I could either support the development of an exhibition or give a public talk on high energy Astrophysics (possibly in French, my native tongue). Another possibility is to give seminars at the Cozmix, the public observatory of Bruges, very active in promoting Science to a large and indiscriminate audience. Finally, KU Leuven sponsors the yearly Flemish Science Week which aims at introducing middle and high school students to specific problematics. I wish to present the didactical material I developed to explain the Roche formalism (a [Mathematica applet](http://demonstrations.wolfram.com/TrajectoryOfATestMassInARochePotential/) with 3D printed surfaces), as I did for the French Science festival in October 2015.

My academic accomplishments (see 1.4) and my experience (monitorat with ~100 hours per year during my PhD, private tutoring) have made me particularly fitted for higher education teaching. My future supervisor is in charge of two Master courses he is willing me to join as a teaching assistant :

* In the first semester, the course GOB30A – Computational Methods for Astrophysical application. Its aim is to introduce incoming graduate students to advanced numerical techniques to address problems of fluid dynamics, radiative transfers, etc. The second part of the course is made of hand-on sessions with the MPI-AMRVAC code.
* In the second semester, the course GOW48A – Research Projects in Theoretical Astrophysics (with Leen Decin from the Institute of Astronomy of KU Leuven). Students are driven in an investigation of an astrophysical contemporary problem through bibliographic work, reappropriation of the results and exploration of their own insights.

If the occasion presents, I would be glad to personally monitor an encouraging student for a pre-PhD internship over a few months.

**3. Quality and Efficiency of the Implementation**

***3.1 Coherence and effectiveness of the work plan***

*The proposal should be designed in such a way to achieve the desired impact. A Gantt Chart should be included in the text listing the following:*

* *Work Packages titles (for EF there should be at least 1 WP);*
* *List of major deliverables, if applicable;[[26]](#footnote-27)*
* *List of major milestones, if applicable;[[27]](#footnote-28)*
* *Secondments, if applicable.*

*The schedule should be in terms of number of months elapsed from the start of the action.*

Each of those WP will imply, as a main milestone, a submission to a peer-reviewed international journal (MNRAS, A&A, ApJ, etc).

WP 1 : The shock

The aim is to characterize the 3D structure of the shock around the accretor as a function of the Mach number of the incoming flow and to study its stability with Thierry Foglizzo (CEA, FR). In the 2000’s, T. Foglizzo et al showed that a resonant cavity can form between the shock and the sonic surface, the latter being typically 100 to 10,000 times closer from the accretor. The numerical study of this configuration has revealed how important this mechanism can be, with a possible application to the case of core-collapse supernovae. I plan to export this study to an axisymmetric configuration and monitor the non-linear growth and saturation of this advective-acoustic cycle. I also intend, with Allard Jan Van Marle (APC, FR), to evaluate the impact of self-ionization on the shock structure and the possibility for the shocked flow to form a disc-like structure around the accretor. The main deliverables are :

1. A first 3D multi-scales shock where numerical artefacts are under control.

2. X-ray luminosity diagram of the accreted flow, comparison to observations.

3. Characterization of a possible disc-like structure (poster).

4. Stability of the shock with respect to the advective-acoustic cycle and to the self-ionizing feedback.

WP 2 : A clumpy wind

The stellar wind itself is expected to display a certain level of inhomogeneity whose influence on the shock remains to be investigated. Ducci+2009[[28]](#footnote-29) carried on a statistical study of its average influence on the accretion process and I intend to use their results to represent the “clumps” in the wind and follow them as they get accreted. The main deliverables are :

1. X-ray luminosity diagram of the accreted flow.
2. Evaluation of the influence of a clumpy wind on the stability of the shock.

WP 3 : The NS magnetosphere

With Zakaria Meliani (ObsPM, FR) and Rony Keppens, I want to implement a static dipolar field to represent the NS magnetosphere and study the coupling with the flow. The main deliverables are :

1. First simulation where the magnetic field divergence is controlled using the constrained transport module developed by Fabien Casse (APC, FR).
2. Validation of the compatibility of the MHD simulations with the stretched grids on test-cases.
3. Produce X-ray light curves and spectra of the cyclotron emission to compare to the observations.

**Example Gantt Chart**

***Reflecting work package, secondments, training events and dissemination / public engagement activities***

Month#1 is fiducially set to April 2017. Deliverables are given in the order they are written in 3.1. Only the main international conferences have been specified (except the COSPAR scientific assembly whose date in 2018 is to be determined). The two-months periods in-between WP are to work on the communication and dissemination material (presentations, posters, web interfaces…), to write computing time proposals on supercomputers and to adapt to potential delays.

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| **Month** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** |
| ***Work package*** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| ***Deliverable*** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| ***Milestone*** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| ***Conference*** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| ***Workshop*** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| ***Seminar*** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| ***Dissemination*** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| ***Public engagement*** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

***3.2. Appropriateness of the allocation of tasks and resources***

*Describe how the work planning and the resources mobilised will ensure that the research and training objectives will be reached.*

*Explain why the amount of person-months is appropriate in relation to the activities proposed.*

I estimate the computing time (in CPU-hours) for the WP 1, 2 and 3 to respectively 500, 200 and 400 CPU-hours. The preliminary debugging work can be carried on local clusters at KU Leuven but the effective simulations must be performed on advanced facilities. Computing time is granted after applications are evaluated and I have been granted two times 300 CPU-hours on the national French supercomputer (CINES) for the last two years. I will participate again in the 2017 PRACE campaign to ask for 400 CPU-hours on the CINES and in parallel, I will ask 400 CPU-hours on the Jülich supercomputer, a privileged partner of the CmPA. It will cover my computing needs for the first year (600 CPU-hours) and I will repeat the applications for 2018.

In terms of working labour, I will be in the expert team for the code I use and I will be able to interact in a direct way on technical issues. For the physical problematics, Rony Keppens is acknowledged for his expertise in MHD and plasma Astrophysics (for the NS magnetosphere – WP 3) and Thierry Foglizzo is one of the world-leading experts in HD instabilities and shock Physics in Astrophysical context (for the study of the shock – WP 1).

***3.3 Appropriateness of the management structure and procedures,* including risk management**

*Describe the:*

* *Organisation and management structure, as well as the progress monitoring mechanisms put in place, to ensure that objectives are reached;*
* *Research and/or administrative risks that might endanger reaching the action objectives and the contingency plans to be put in place should risk occur.*

The environment of the CmPA is ideal for the scientific goals I set given its strongly interacting team composed of a core of 10 members whose Rony Keppens is a key-manager. Should an application to computing-time on the CINES or the Jülich supercomputer be discarded, I would apply to computing time on the Flemish VSC, use the local facilities and reapply to the mid-year offers.

***3.4******Appropriateness of the institutional environment (infrastructure)***

*The active contribution of the beneficiary to the research and training activities should be described. For GF also the role of partner organisations in Third Countries for the outgoing phase should appear.*

* *Give a description of the main tasks and commitments of the beneficiary and all partner organisations (if applicable).*
* *Describe the infrastructure, logistics, facilities offered in as far they are necessary for the good implementation of the action.*

The beneficiary will grant me access to the CmPA facilities at KU Leuven. The facilities I need on a weekly-basis (desktop, Ethernet connection, registration to the main scientific reviews, storage space, computing facilities, personal website hosting…) will be managed by the local administration, technical teams, etc. It will also let me participate as a teaching assistant to the courses mentioned in 2.3 and I will attend advanced courses displayed in the local facilities. Finally, the beneficiary will bring me its support to apply to computing-time, submit papers to peer-reviewed journals, find complementary fundings for the communication and dissemination of my results, etc.

**STOP page count – MAX 10 pages**

1. All partner organisations should be listed here, including secondments [↑](#footnote-ref-2)
2. For example hosting secondments, for GF hosting the outgoing phase, etc. [↑](#footnote-ref-3)
3. As defined in [Commission Recommendation 2003/361/EC](http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:124:0036:0041:en:PDF). [↑](#footnote-ref-4)
4. Literature should be listed in footnotes, font size 8 or 9. All literature references will count towards the page limit. [↑](#footnote-ref-5)
5. Abate C., Pols O. R. et al 2013, Astronomy & Astrophysics 552, A26 [↑](#footnote-ref-6)
6. Lora-Clavijo F. D. & Guzman F. S. 2013, Monthly Notices of the Royal Astro. Soc. 429, 3144 [↑](#footnote-ref-7)
7. Blondin J. & Raymer E. 2012, The Astrophysical Journal 752, 30 [↑](#footnote-ref-8)
8. El Mellah I. & Casse F. 2015, MNRAS 454, 2657 [↑](#footnote-ref-9)
9. Foglizzo T. & Ruffert M. 2013, Astronomy & Astrophysics 361, 22 [↑](#footnote-ref-10)
10. Porth O., Xia C. et al 2014, The Astrophysical Journal Supplement Series 214, 4 [↑](#footnote-ref-11)
11. El Mellah I. & Casse F. 2016, being reviewed [↑](#footnote-ref-12)
12. Short Pulse Laser Interactions with Matter : An Introduction, P. Gibbon, Imperial College Press [↑](#footnote-ref-13)
13. Spitkovsky A. 2008, ApJ 682, 8 [↑](#footnote-ref-14)
14. Commerçon B., Debout V. & Teyssier R. 2014, A&A 563, 11 [↑](#footnote-ref-15)
15. Principles of MHD, Goedbloeb J. P. & Poedts S., 2004, Cambridge University Press [↑](#footnote-ref-16)
16. Advanced MHD, Goedbloeb J. P., Keppens R. & Poedts S., 2010, Cambridge University Press [↑](#footnote-ref-17)
17. Cosmologists have developed their own multi-scales Cartesian codes for the last decade (see eg the [RAMSES code](http://www.ics.uzh.ch/~teyssier/ramses/RAMSES.html)) but it does not fit the Astrophysical needs, where systems are generally centred and non-isotropic, contrary to the Universe. [↑](#footnote-ref-18)
18. The hosting arrangements refer to the integration of the researcher to his new environment in the premises of the host. It does not refer to the infrastructure of the host as described in the Quality and efficiency of the implementation criterion. [↑](#footnote-ref-19)
19. Rappaport S., Deck K., Levine A., Borkovits T. et al 2013, The Astrophysical Journal 768, 33 [↑](#footnote-ref-20)
20. Rappaport S., Levine A., Chiang E., El Mellah I. et al 2012, The Astrophysical Journal 752, 1 [↑](#footnote-ref-21)
21. Sanchis-Ojeda R., Rappaport S., Winn J., Kotson M. et al 2014, The Astrophysical Journ. 787, 47 [↑](#footnote-ref-22)
22. Walter R., Lutovinov A., Bozzo E. & Tsygankov S. 2015, Astronomy & Astrophysics Rev. 23, 2 [↑](#footnote-ref-23)
23. <http://ec.europa.eu/research/participants/docs/h2020-funding-guide/grants/grant-management/dissemination-of-results_en.htm> [↑](#footnote-ref-24)
24. <http://ec.europa.eu/research/participants/data/ref/h2020/other/gm/h2020-guide-comm_en.pdf> [↑](#footnote-ref-25)
25. <http://ec.europa.eu/research/participants/docs/h2020-funding-guide/grants/grant-management/communication_en.htm> [↑](#footnote-ref-26)
26. A deliverable is a distinct output of the action, meaningful in terms of the action’s overall objectives and may be a report, a document, a technical diagram, a software, etc. Should the applicants wish to participate in the pilot on Open Research Data, the Data Management Plan should be indicated here.

    Deliverable numbers ordered according to delivery dates. Please use the numbering convention <WP number>.<number of deliverable within that WP>. For example, deliverable 4.2 would be the second deliverable from work package 4. [↑](#footnote-ref-27)
27. Milestones are control points in the action that help to chart progress. Milestones may correspond to the completion of a key deliverable, allowing the next phase of the work to begin. They may also be needed at intermediary points so that, if problems have arisen, corrective measures can be taken. A milestone may be a critical decision point in the action where, for example, the researcher must decide which of several technologies to adopt for further development. [↑](#footnote-ref-28)
28. Ducci L., Sidoli L. et al 2009, MNRAS 398, 2152 [↑](#footnote-ref-29)