Scientific committee 2013-11-05/06

Proposal for the upgrade of the Exploratory Project E2 on "Impact of Black Holes on their Environment" to an Interface Project AIM-APC

I The proposed Interface project and strategy

I-1 Scientific aim of the project

The general aim of this project is to study properties, formation, evolution and cosmic feedback of black holes by exploring the interaction with their environment for specific cases which span from the micro-quasars of the dark ages to the supermassive black holes in the local universe. The science topics we identified for the first part of the project (the 2-yr exploratory phase) were: A) Micro-quasars in the re-ionization era; B) Feedback of supermassive black holes (SMBH) on galactic bulges in Active Galactic Nuclei (AGN); C) Impact of the Galactic Center (GC) SMBH on its close environment; D) Jets and outflows from stellar-mass compact objects in X-ray binary systems (**see original E2 proposal and updated introduction in the E2 UES Web page**s). In this second phase, as interface (I/F) project over 5 years, we intend to complete the planned exploratory studies and focus the research work on two axes that will include the four original topics: the axis on the **SMBH in the galactic nuclei that links topics B and C (SMBH axis)** and the axis on **microquasars that includes topics A and D (microquasar axis)**. With this additional research program on the BH impact on their environment we expect to provide new important contributions to the quest for a global scenario that can link and unify black hole behaviors over different scales (from stellar to supermassive sizes) and cosmic epochs (from the re-ionization era to the local universe).

I-2 From Exploratory to Interface

In the past two years, in spite of some delay in the setting-up of the program, our team has made remarkable progresses in all four project items, as described in the 2-year-report and in the E2 pages of the UES LabEx Web site. The team high-rate of publications directly related to the project topics is a strong indication of the intense activity of our group. We therefore propose now to extend, through the LabEx support as 5-yr I/F project, our research work in order to obtain new important results in this field. The strategy we adopt is to privilege in the first part (3 yr) of the I/F project the axis of research on SMBH in galactic nuclei, maintaining activity on the microquasar topics, and then select for the second part (2 yr) one topic of the research axis on microquasars. The I/F project will allow us, after one further year of exploratory consolidation and preparation (2014), to employ one postdoc for two years (2015-2016) on the first axis of research and then another postdoc (2017-2018) or a PhD thesis (2016-2018) for the 2nd axis. The exploratory work done on the Galactic Centre topic has demonstrated that the goal to extract the light curve of Sgr A* is potentially achievable and therefore we select this topic for the first 2-yr postdoc position of the I/F project. For the 2nd part, the exact subject on microquasar research will be selected in 2015, depending on the state of the art in that field at the time. We detail below the rationale of this strategy.

I-3 Program of work for the 1st part of the project (2014-2016): SMBH in galactic nuclei, the GC case

As explained in the E2 project report, major advances have been obtained by our team in this axis of research on the item of the past activity of the SMBH at the center of our own galaxy. After the first discovery in 2010 of rapid variability in the X-ray emission of molecular clouds surrounding the GC SMBH, Sgr A*, which was interpreted as reflected radiation bringing us the signature of an intense activity by Sgr A* in the past centuries (Terrier et al. 2010 ApJ 719 143, Ponti et al. 2010 ApJ 714 732), we launched with the support of the UES LabEx, a vast campaign of observations and collaborative work meant to confirm our findings and to further explore the past behavior of Sgr A*. The work performed in the last 2 yr using X-ray Chandra data has led to the astonishing conclusion that the molecular clouds are reflecting the radiation of two distinct outburst events of Sgr A*, one short (1-2 yr) and one long (10 yr) both involving peak luminosities up to 1 million times the present Sgr A* luminosity. These results, that have just been published in A&A (Clavel et al. 2013, A&A 558, A32) as a highlight paper in the 2013 October volume, modify the picture we originally proposed and at the same time give us confidence on the possibility to reach our final goal. We now know that thanks to the large program of future observations we have obtained to study this

phenomenon we should be able in the next 2-3 yr to draw the activity light curve of Sgr A* for the past 300-400 yrs. To reach this goal we need to perform the following tasks:

1) Complete analysis and publication of 2012 Galactic Center XMM Large Project Obs. (700 ks, PI Terrier) and of the 2013 XMM Obs. dedicated to the G2 object (see below) (150 ks, PI Ponti, co-I Goldwurm, Terrier et al.).
2) Carry out and analyze our approved 2014 Chandra Obs. of the GC molecular cloud Sgr C (100 ks, PI Soldi).
3) Carry out and analyze the associated 2014 observations at other wavelengths, like the approved mm CARMA observation of Sgr A MC (PI Clavel) and, if approved, the 30-m IRAM Obs. of Sgr B MC in molecular lines proposed along with our Spanish colleagues (PI Armijos-Abendano, co-Is Goldwurm, Terrier).
4) Run simulations and develop modeling of the reflection processes in the GC, in collaboration with our colleagues of the Dublin University, initiated with the Ulysses program (2013, PI Goldwurm and Chernyakova). This will be used to put constraints on the possible configurations of the past activity of SgrA*.
5) Put all results together in order to derive a model of the Sgr A* outburst activity and propose further tests of the model to be carried out with new instruments in X-rays (NuSTAR, Astro-H) and at other wavelengths.
6) Carry on the organization of the Scientific Event E1.2 (Galactic Centre) at the 2014 COSPAR Symposium in Moscow (PI: Goldwurm), participate and present there our results.

In addition to the above tasks, we plan to extend the research in the following two directions:

7) Study the interaction of the G2 cloud discovered through IR observation and seen to rapidly approach the GC SMBH (Gillessen et al. 2012 Nat 481 51). We are part of the collaboration that is monitoring the event with XMM and we will contribute to the study of the possible enhancement of X-ray emission or rate of X-ray flares that Sgr A* displays daily, during and after the periastron passage foreseen in spring 2014 (2014-2015).
8) Participate to the data analysis and interpretation of Astro-H data of the GC region. Astro-H is a Jaxa-NASA-ESA mission that will carry innovative instrumentation to study the X-ray sky, among them a bolometer for the high resolution spectroscopy of X-ray lines and a focusing hard X-ray telescope. Some of us are co-I of the mission and we intend to collaborate with our Japanese colleagues on the topics of the GC (2015-2016).

In addition, we want to study Sgr A* in comparison to extragalactic black holes and in particular low luminosity Seyfert galaxies as reported in the E2 2-yr report section IV-3 (AGN part of the SMBH in galactic nuclei research axis).

I-4 Program of work for the 2nd part of the project (2017-2018): Microquasars

For the Microquasar axis of research we intend to pursue the exploratory work phase in 2014-2016 as discussed in the E2 2-yr report Sect. IV-3 and then select by the end 2015 the exact topic for the 2-yr postdoc position (or 3-yr PhD thesis) that will make the 2nd part of the I/F project. Detailed tasks will be defined in 2015-2016.

II. Team, workplan and budget

The I/F project team in 2014 will be the same as the present E2 team, apart from two students that complete their thesis in 2013, and with an additional AIM member (O. Limousin) that will join the team to work on task 8) (Sect. I) as instrument specialist of Astro-H and formal co-I of the mission. The team 10 members beginning 2014 are:

APC: Andrea Goldwurm (**leader of the projec**t), Volker Beckmann, Philippe Laurent, Regis Terrier, Guillaume Trap, Maica Clavel (PhD), Simona Soldi (Postdoc)

AIM: Felix Mirabel (**co-leader of the project**), Sylvain Chaty, Olivier Limousin

We expect that new M2/PhD students (between 1 and 3) will join the team in 2014 or 2015. However the PhD thesis of M. Clavel and the CNES postdoc position of S. Soldi both dedicated to the Galactic Center topic will end by the end of 2014. In order to perform the tasks listed in Sect. I we therefore require a new 2-yr postdoc position financed by the I/F project to be opened no later than January 2015.

The work plan is as follow:

2014: Continue exploratory work on all the topics of the two axes of research. Work on tasks 1) 2) 6) of SMBH axis. Definition and candidate selection for the postdoc position on Galactic Centre SMBH to be started in 2015.

2015: 1st year LabEx postdoc position on Galactic Centre topic of the SMBH in galactic nuclei research axis: work on tasks 1) to 8) and AGN topic of SMBH axis. Continue exploratory work on microquasar research axis, decide postdoc vs. PhD thesis for 2nd part of I/F project. If PhD thesis, select exact topic (XRBs vs Cosmo-µQSO).

2016: 2nd year LabEx postdoc position on Galactic Centre topic of the SMBH in galactic nuclei research axis: work on tasks 1) to 8) and AGN topic of SMBH axis. Review the objectives of the Microquasars axis, decision on the exact topic (XRBs vs Cosmo-µQSO) and work plan for the postdoc position to be started in 2017.

2017-2018: Postdoc (or PhD thesis) work on the selected topic of the Microquasar research axis.

BUDGET FOR 2014-2016 (case of Postdoc position for the 2nd part of the I/F project)

Item description	2014	2015	2016	Justifications
Human ressources		52000 APC	52000 APC	2 yrs Postdoc (Jan 2015 – Dec 2016) on items C and B: Galactic Center and SMBH in AGNs
Consumables & missions	13000 APC 7000 AIM	10000 APC 8000 AIM	10000 APC 8000 AIM	Cospar 2014, conf. workshops, 2-3 visiting programs Conferences, workshops, 4 visiting programs
Equipment		5000 APC	5000 APC	Computer for Postdoc
TOTAL COSTS	20000	75000	75000	Total 170000 € over the 3 yr period (2014-2016)

BUDGET FOR 2017-2018 (case of Postdoc position for the 2nd part of the I/F project)

Item description	2017	2018	Justifications
Human ressources	52000 AIM	52000 AIM	2 yrs Postdoc (Jan 2017 – Dec 2018) on items A & D: Microquasars in the Ionization era and XRB environment
Consumables & missions	12000 APC 6000 AIM	12000 APC 6000 AIM	Conferences and workshops, 4 visiting programs: items B, C Conferences and workshops, 2-3 visiting programs: items A, D
Equipment	5000 AIM	5000 AIM	Computer and equipment for the Postdoc position on items A, D
TOTAL COSTS	75000	75000	Total 150000 € in 2 yrs period (2017-2018)

III Why in Labex UES: extend the research in a domain of excellence of AIM and APC

Research in black hole astrophysics is one of the excellence domains of the AIM and APC high-energy groups. Both labs build up today on the strong heritage of the activities developed in this field by the Service d'Astrophysique/CEA Saclay in the years 1990-2005, with the works on black-hole X-ray Novae (e.g. Goldwurm et al. 1992 ApJ 389 L79), the discovery of microquasars (Mirabel et al. 1992 Nat 358 215, Mirabel & Rodriguez 2004 Nat 371 46), their multi-wavelength (Chaty et al. 1996 A&A 310 825) and modeling (Laurent & Titarchuck 1999 ApJ 511 289) studies and with the setup of a large program on the high-energy activity of the Galactic Center (Goldwurm et al. 1994 Nat 371 589, 2003 ApJ 584 751). These works were based on high-energy space missions like SIGMA (1991-2007), XMM (since 1999) and INTEGRAL (since 2002) and associated multi-λ campaign projects (INTEGRAL-MINE). The two labs have since 2005 very successfully focused their BH research on one side (AIM) on microquasars and on the other (APC) on the SMBHs at the Galactic Centre and in AGN, also by extending their database to the American observatories SWIFT, Fermi, and Chandra. As a consequence AIM has today worldwide recognized expertise in microquasars and associated multi-λ research and APC in the GC, AGN and BH accretion modeling. Most of this research has been financed till now through projects (SIGMA, INTEGRAL, INTEGRAL-MINE). However such sources are not available anymore, and in order to maintain our expertise and leadership at international level, the new form of research funding shall support the AIM and APC new projects in such a competitive domain of modern astrophysics as the astrophysical BH research. Even if the two labs will maintain their respective expertise (GC and AGN for APC and microquasars for AIM) the collaborations and the interrelations allowed by the UES LabEx I/F project will favor our common search for a global picture that links BHs at different scales and cosmic epochs. Note that even if we will keep applying to other funding sources, the usual channels (ANR, ERC) do not always favor interface between laboratories and tend to privilege research in single topics. This is why our program on a diversity of items carried out in two Institutes best fit the LabEx concept of interface between laboratories. This is mainly an observational project (even if supported by theoretical modeling/simulation programs), based on space mission data (even if supported by multi-λ programs) on the very competitive domain of BH research, with topics fully consistent with core science of the High-Energy Astrophysics area of the LabEx UnivEarthS.