Scientific committee 2013-11-05/06

ANNUAL WORK-PACKAGE REPORT

WP Exploratory Project E2 (AIM/APC)
Impact of Black Holes on their Environment

I- PERMANENT (bold) & NOT-PERMANENT (not-bold) PERSONNEL

Position	Name / surname	Laboratory Name	Grade, employer
WP leader	**Goldwurm Andrea (AG)**	**APC**	**Research Director, CEA**
WP co-leader	**Mirabel, Felix (FM)**	**AIM**	**Research Director, CEA**
WP member	Beckmann Volker (VB)	APC	Post-Doc, CNRS
WP member	**Chaty Sylvain (SC)**	**AIM**	**Professor, Univ. Paris Diderot**
WP member	Clavel Maica (MC)	APC	PhD Student, Un. Paris 11
WP member	Coleiro Alexis (AC)	AIM	PhD Student, Un. Paris Diderot
WP member	De Jong Sandra (SDJ)	APC	PhD Student, Un. Paris Diderot
WP member	**Laurent Philippe (PL)**	**APC**	**Research Director, CEA**
WP member	Soldi Simona (SS)	AIM, APC since Dec 2012	Post-Doc CNES, CNRS
WP member	**Terrier Regis (RT)**	**APC**	**Researcher, CNRS**
WP member	**Trap Guillaume (GT)**	**APC**	**Palais de la Decouverte, coll. APC, CEA**

II- 2013 FINANCIAL REPORT

Item description	initial budget	commitment costs *(2013/08/30)*	Justifications (see details in: http://univearths.in2p3.fr/en/content/e2-impact-black-holes-their-environment)
Human ress. & Equip.	0	0	
Consumables and missions costs	24100	17100	7 Visiting programs: 6 at APC or AIM and 1 at MPE-Garching Support participation to 10 conferences or workshops
TOTAL COSTS	24100	17100	7000 left (6000 AIM, 1000 APC) to be reported to 2014

III- BUDGET FOR 2014-2015

Item description	2014	2015	Justifications
Human ressources		50000 (APC)	1st yr PostDoc from Jan 2015 for item C/B (Interface Project proposal TBC)
Consumables and missions costs	13000 (APC) 7000 (AIM)	10000 (APC) 10000 (AIM)	Cospar 2014, other conf., 2-3 visiting programs (e.g. Morris) Visiting Programs: T. Tauris, G. Romero, V. Douna, L. Pelizza.
Equipment costs		5000 (APC)	Computer for Postdoc (I/F project proposal TBC)
TOTAL COSTS	20000	75000= 20000 + 55000	Total 95000 in 2 yrs out of the 170000 over the 3 yr period (2014-2016) we will ask in our I/F program proposal (TBC)

IV- SCIENTIFIC REPORT

The aim of this project is to study properties, formation, evolution and cosmic feedback of black holes by exploring their interaction with the environment for specific cases which span from the micro-quasars of the dark ages to the supermassive black holes (SMBH) of the local universe. The specific science topics are: A) Micro-quasars in the re-ionization era; B) Feedback of SMBH on galactic bulges in Active Galactic Nuclei; C) Impact of the Galactic Center SMBH on its close environment; D) Jet and outflows from stellar-mass compact objects in X-ray binary systems.

IV-1. Work expected to be carried out after the last Scientific Committee (2012, December)

Topic C: Analysis and interpretation of all Chandra data (> 1 Ms) of the Galacic Center molecular clouds.
Topic A: Start the simulation program collaboration on the role of microquasars in the reionization era.
Topic B and D: Pursue specific studies of Active Galactic Nuclei (AGN) and galactic X-Ray binary systems (XRB)

IV-2. Main results achieved since the beginning of the program (2012 and 2013)

One axis of the E2 scientific program concerns the **supermassive black holes (SMBH) in the center of galactic nuclei**. The closest of such objects is obviously the SMBH in our own Galactic Center (GC) , associated to the presently-very-weak source Sgr A* **[topic C].** In 2010, after our discovery of strong variability in the X-ray emission of the molecular clouds of the GC region, we launched a vast reasearch program to explore, with X-ray data but also data at lower energies and theoretical calculations, whether such studies could lead to new results on the past behavior of Sgr A*. Our succesfull observation proposals allowed us to offer a PhD thesis (M. Clavel since Oct 2011) and to obtain a CNES PostDoc position (S. Soldi since Dec 2012) on this topic. The observational program we set up and carried out in order **to study the past activity of the Supermassive Black Hole of the Galactic Center (GC), Sgr A*, from the echos produced in the molecular clouds (MC) of its close environment**, has led recently to new crucial results. Our tourough analysis of the GC X-ray data collected with the X-ray Chandra observatory over the period from 2000 to 2011, has now shown that the apparent superluminal variability of the MC X-ray emission located about 15' east of Sgr A* is due to echoes of multiple X-ray outbursts of the central black hole, that took place in the past few hundred years. In particular we identified in certain clouds a linear increase behaviour that spanned over 10 years along with a comparable decrease phase on 10 yr and a linear profile. On the other hand a more peaked emission profile on a timescale of only 2-3 yr is seen propagating in other molecular structures. These results change deeply the picture we tentatively proposed in 2010 when we first discovered, using XMM and INTEGRAL, the large X-ray variability of the GC MCs (Terrier et al. 2010, Ponti et al. 2010, 2013). At that time we proposed that a single 300 yr long past outburst of Sgr A* that terminated 100 yr ago could explain all data. Even though the short timescale spikes of emission identified thanks to the Chandra angular resolution can still be superposed on a general increase of past activity over a longer period, the time characteristics of these events that peak at 10^{39} ergs/s i.e. 10^{6} times the present Sgr A* X-ray luminosity, is now clearly established and shall be accounted for in future models of the overall process. These results are in press (Clavel et al. 2013) and will be presented at the 2013 October IAU conference on the Galactic Center along with several other contributions of our group. Meanwhile the complete survey of the central molecular zone (CMZ) of the Galaxy with XMM (700 ks Obs of the central 1°x2° of the Galaxy) has been proposed and then performed by our group in 2012. The preliminary work on the reflection features with these data shows that new important results will be obtained and their comparison with the Chandra-based local model will validate and/or extend the picture of Sgr A* past activity. In order to converge to a global model of the reflection process in the CMZ we have also initiated, with our Irish colleagues, a project of detailed numerical simulation of the reflection process. This program progresses well and we expect it to provide in the next 1-2 years a complete global model of Sgr A* past activity and of reflection features observed today in the GC. This will prepare our activity on Astro-H data of the Galactic Center that we expect to be able to start in late 2015.

In the larger context of **super-massive black holes [topic B]** we studied the variability of these sources in the X- and gamma-rays by using the multi-year light-curves from the Swift/BAT and Fermi/LAT instruments. The study shows that intrinsically the different classes of non-beamed active galactic nuclei (AGN) seem to host the same type of central engine, as there is no difference in their respective behavior (Soldi et al. 2013). At the same time we investigated the class of radio galaxies which appear as gamma-ray emitters. Apparently, gamma-ray emission can be produced in these sources although the jet is not pointed towards the observer. The fact that only certain radio galaxies are Fermi/LAT sources, cannot be explained by proximity or other parameters connected to the AGN, but

radio galaxies seem to undergo also duty cycles, with short active gamma-ray bright periods over long in-active time scales (de Jong 2013, Beckmann et al. 2013). In this respect Sgr A* appears simply a dormant version of an AGN.
The other axis of the E2 program concerns **stellar-size black holes in X-ray binary systems (XRB) micro-quasars**. Here we explore the physical processes of accretion/ejection at work in XRBs **[topic D]** and then study the role of micro-quasars in the universe re-ionization phase **[topic A].** After having discussed, in the seminal paper by Mirabel et al. 2011, the basic idea for which micro-quasars, as strong sources of X-rays and jets of relativistic particles, can ionize their environment and therefore contribute to the re-ionization of the universe, we worked with Dr. Mark Djikstra from MPA Garching to better quantify together the effect of the X-rays in this contest. A work to develop a Monte Carlo simulation of the impact of jets in universe re-ionization has also been started in collaboration with Dr. L. Pelizza and PhD student V. Douna, from IAFE of Buenos Aires. An existing simulation code of our group will be adapted by our Argentinian colleagues in order to compute the path of jet particles in the intergalactic medium and then determine the ionization rate. Both projects will be continued in 2014, thanks to preliminary studies by V. Douna that provide in coherent way the number of micro-quasars and their properties at a given cosmological red-shift and sky region. For the galactic XRBs **[topic D]**, we are carrying out studies of the hydrodynamic and radiation processes in collaboration with Prof. Titarchuk (Italy) and we have also worked on their distribution in our Galaxy by computing all distances of galactic XRB, and showing that all the binaries containing a massive companion star are clustered around a stellar forming complex. With the measured accurate positions, we were able to derive the birth location of all XRB in our Galaxy, taking into account the rotation of Galactic arms (Coleiro & Chaty 2013)

IV-3. Summary of the project objectives for 2014-2015

Our work program on the Galactic Center SMBH is very large and extends now over the next 3-4 years. It includes: **1)** Complete analysis and publication of 2012 Galactic Center XMM Large Project Obs. (700 ks), carry out and analyze our approved 2014 Chandra Obs. of the molecular cloud Sgr C (100 ks). **2)** Analysis and publication of associated 2014 Obs. at other wavelength (i.e. sub-mm CARMA obs. of Sgr A MC). **3)** Simulations and data modeling of the reflection process in the CMZ (initiated with the Ulysses program). **4)** Possible use of Astro-H data. **5)** Scientific Event E1.2 (Galactic Center) at 2014 COSPAR Assembly in Moscow: organization (chair: Goldwurm) and presentation of our results. In addition, we want to study Sgr A* in comparison to extragalactic black holes. Here the main focus will be the question on which accretion modes are dominating which types of objects. While for bright AGN accretion through a disk is the commonly accepted model, in the fainter AGN and in Sgr A* an advection dominated accretion flow (ADAF) is present. In this context we will study on a statistical basis, which parameters determine at what point an AGN accretes through a disk, and when an ADAF type accretion sets in. Here again the hard X-ray selected AGN are an interesting sample, as they include both efficiently and non-efficiently accreting AGN.

For the micro-quasar topics we intend to pursue the simulation program described above. We recently obtained new observations of micro-quasars with the VLT (ISAAC PI Chaty, X-shooter PI Goldwurm) and with the Herschel satellite. VLT ISAAC IR photometric + spectroscopic data will allow us to identify new sources and micro-quasar candidates, while VLT X-shooter IR spectroscopic data will reveal the close surroundings of the companion star (atmosphere, envelop). With Herschel photometric data, we will examine the broad environment of XRBs in the far-IR, with the aim of detecting the triggering of stellar formation, due to jets and outflows colliding with the surrounding interstellar medium. Computational work will allow us to determine population synthesis evolution of XRBs hosting massive companion stars, and compare these computations with observational output. To carry out this ambitious, but feasible, program we will submit a proposal to transform the Exploratory Project E2 into an Interface Project.

IV-4. Indicators (Jun2011–2013) (http://univearths.in2p3.fr/en/content/e2-impact-black-holes-their-environment)

Papers published in peer review journals: 19 (7 directly financed by E2); in conference proceedings: 13 (7 d.f.E2). Invited talks in international conferences: 8 (3 d.f.E2). PhD Thesis in progress: 3 (2 defended in Sep 2013).