PROPOSITION DE THESE 2022

Ecole doctorale 560 Sciences de la Terre et de l'Environnement et Physique de l'Univers – Université de Paris

Nom des proposants : Andrea Goldwurm

Thèmes scientifiques : Astrophysique des hautes énergies. Accrétion et éjection dans les objets compacts et mécanismes de rayonnement à haute énergie. Analyse et interprétation de données d'astronomie X.

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Titre: Etude des processus d'accrétion et éjection dans les trous noirs variables ou transitoires en utilisant les données de la mission SVOM et les données multi-messager disponibles associés

Résumé

Les trous noirs actifs au centre des galaxies ou dans les systèmes binaires présentent une émission de haute énergie hautement variable et souvent de type transitoire. Ils seront des cibles prioritaires de la mission SVOM qui mettra en orbite, début 2023, plusieurs instruments X/gamma/optiques dédiés à l'étude des sursauts gamma (GRB) et d'autres sources célestes variables. Nous proposons une étude des phénomènes d'accrétion et éjection dans les trous noirs super-massifs des noyaux actifs des galaxies (AGN), et notamment des Blazars, et des trous noirs de type stellaire, notamment des binaires X galactiques de type transitoires (Novae-X), sur la base des observations du programme générale et du programme ToO de la mission SVOM, programmes en partie sous responsabilité du laboratoire APC. Une attention particulière sera donnée au contexte d'astronomie multi-messager de ces observations, avec la recherche des possibles émissions neutrinos, ondes gravitationnelles et rayons cosmiques associées aux évènements électromagnétiques variables étudiés avec SVOM.

Title: Study of accretion and ejection processes in variable black hole systems with SVOM

Abstract

We propose to carry out a study of accretion and ejection processes in black hole systems which are highly variable or transient emitters of high energy photons, by using the multi-wavelength data of the SVOM space mission and the relevant multi-messenger data that will be available to our laboratory.
The super-massive black holes located in galaxy centers, in particular those that generate the luminous Active Galactic Nuclei (AGN), or the stellar-mass black holes that evolve in bright X-ray close binary systems (XRB), show a high-energy emission (in X and gamma-rays) which is always variable and often transient. They will be priority targets for the Chinese-French space mission SVOM dedicated to the variable high-energy sky and that will be launched early 2023. SVOM will provide a large set of data from optical to gamma-ray wavelengths of high energy sources particularly those located at high galactic latitudes during the observations of the General Program (GP) of the mission. Galactic sources will be pointed instead mainly during Target of Opportunity (ToO) observations triggered by the appearance in the sky of a new transient source, for example of a BH X-ray Nova. APC has important responsibilities in these programs and it will be at the center of the scientific projects that will exploit these data. The thesis will focus on those programs dedicated to analysis and astrophysical interpretation of the mission data on BH systems, and will profit of, and contribute to, the large expertise in X/gamma-ray data analysis and in astrophysics of compact objects of the team. Particular attention will be dedicated to the multi-messenger astronomy context of the BH observations, with the search for possible neutrino, cosmic ray and gravitational wave emissions associated to the studied variable high-energy electromagnetic events.

Description of the subject:

Context

SVOM will fly four instruments, two narrow field telescopes, the visible telescope (VT) and the X-ray telescope (MXT), the large field X/hard-X -ray coded mask imaging system ECLAIRs and a non-imaging gamma-ray monitor (GRM). ECLAIRs will cover 90° × 90° field of view in the 4-150 keV range providing angular resolution of ~1.5° and location accuracy of few arcmin. It will be the main instrument to detect, locate and monitor variable high-energy sources providing both flux, temporal and energy data on their X-ray emission. Mainly dedicated to gamma-ray bursts (GRB) the mission will indeed actually monitor and study flaring activity of many other sources and in particular AGNs and galactic BH by combining ECLAIRs data with VT and MXT data of target sources collected during the planned observation program (GP). We expect that large part of the GP will be dedicated to the extremely variable Blazars, AGNs that point towards us their relativistic jets. The spectral density of their broad band emission is characterized by two large bumps, one peaking between the infrared and the X-ray ranges and the other in the high energy gamma-rays (> 10 MeV). The variability pattern shows a characteristic sequence (the BLZ sequence) where energy centroid of the bumps and their amplitude (therefore overall hardness and luminosity) are anti-correlated (for lower fluxes both bump peaks and the valley between them move to higher energies).

Subject

The SVOM multi-wavelength data will provide a solid base to study temporal-spectral variability of this class of super-massive BHs. In addition SVOM ToO observations will be triggered when some bright Blazar or XRB eruptions will be detected which will provide crucial measurements to get deep insights in the accretion-ejections processes at work in these luminous systems. One of the key questions on accreting BH systems (both AGN and BH-XRB) is the connection and interplay between processes occurring in the main active regions close to the BH that is the accretion disk, the hot corona and the relativistic jets. For the blazars case a crucial open question is whether the particle accelerations and interactions producing the bulk of gamma-ray emission (and luminosity) involve mainly hadronic or leptonic processes. This issue could be possibly resolved if a clear association with other messenger events then photons is established. For this reason particular attention will be dedicated to those sources recently considered counterparts of the high energy neutrino excess detected by the IceCube experiment, for example the Blazars TXS 0506+056 which was seen to flare in 2017 during the detection of a large neutrinos flux in the same area of the sky.

Methods and techniques

The candidate will work in close collaboration with the science and engineer teams of APC in charge of the development of the ECLAIRs data analysis pipeline (see below) in order to acquire full knowledge of the use and handling of the data analysis tools. Use of the in-flight calibration data, available since the first months of operations, will allow her/him to participate and contribute to the control and calibration of the pipelines. The candidate is expected also to participate to the analysis developments in particular to refine spectral and temporal analysis procedures of ECLAIRs data. The large amount of data that will be collected by SVOM during GP and ToOs will then provide then an extraordinary amount of original material to carry out the proposed astrophysics study. The exact topics and sources will be defined on the basis of the actual observations, the activity of the sources and the rapidly evolving scientific context of the time domain astronomy, in the frame of which this thesis will be carried out.

Required qualification

The candidate must possess a research Master diploma in astrophysics or in astro-particle physics and shall have a good knowledge of high-energy astronomy and related physical processes. Mastering techniques of statistical analysis and image processing (Fourier transform, convolutions/correlations, statistical tests, etc.) will be also an advantage because of the large part of data analysis of coded mask instrument data expected in this study. Our group will propose a subject for Master internship related to the preparation of SVOM observation program in particular on Blazars and galactic BHs. It is highly suggested to the candidate who is following the A&A Master in 2021-2022 to apply for this internship.

Direction, financing, collaborations and perspectives:

Direction

The work will be carried out at the APC-Paris laboratory (*Astrophysique de Haute Energie* group) and possibly, in part, at the DAp/CEA Saclay under the direction of Dr. Andrea Goldwurm, *Directeur de Recherche* at DAp/IRFU/CEA Saclay and at APC, avec *Habilitation à Diriger des recherches* (direction or co-dir. of 7 PhD, presently involved in co-direction of a PhD 2021-2024 at APC directed by S. Gabici).

Team

The candidate will join the APC SVOM science team that includes also the *Maîtres de Conferences (MCF)* at the *Université de Pari*s Cyril Lachaud and Alexis Coleiro along with a new MCF expected to join the team next year. This group has a large expertise in coded mask analysis systems (we participate to and we are now users of the INTEGRAL mission), has a deep knowledge of the SVOM mission and of the ECLAIRs instrument and already carried out several successful studies on compact objects and BH systems (including several PhD projects). APC built and delivered the coded mask of ECLAIRs, is in charge of the development of the ECLAIRs analysis pipeline within the mission French Science Center and has key responsibilities in GP and ToO programs of SVOM. APC is involved in TeV gamma-ray (HESS, CTA) and Gravitational wave (Virgo) observatories and in neutrino experiments (Antares, KM3NeT) and the team is therefore well positioned for leading the multi-messenger studies proposed for this thesis.

Financing

A CNES fellowship application with the associated request for CNRS/IN2P3 contribution has been submitted for this thesis. Applications to *Ecole Doctorale* ED560 and CEA/CFR will also be supported.

Collaborations

Include SVOM teams from France, in particular those of DAP/CEA Saclay and IRAP Toulouse, and SVOM teams from China and European countries. The student will integrate the High Energy Astrophysics group of APC and possibly the LEPCHE laboratory of the DAp/IRFU/CEA-Saclay.

Perspectives

At the end of the thesis the candidate will have acquired a large expertise in treatment and interpretation of astronomical X/gamma-ray data and will be able to integrate teams working in high-energy astronomy or astroparticle. The scientific preparation will also be appreciated in public or private sectors, other than astronomy, where statistical analysis techniques and/or scientific and rigorous methods of work are required.

References

1) The Deep and Transient Universe in the SVOM Era: New Challenges and Opportunities - Scientific prospects of the SVOM mission. Wei, J., et al. 2016, Proceedings of the Workshop held from 11th to 15th April 2016 at Les Houches School of Physics, France (arXiv: 1610.06892)
2) Multimessenger observations of a flaring blazar coincident with high-energy neutrino IceCube-170922Ab. IceCube Collaboration et al., 2018, Scie, 361, 6398

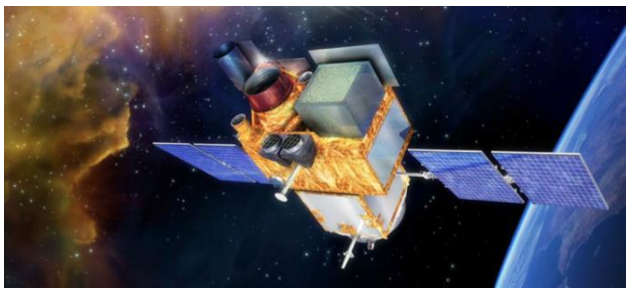
Additional material

Presentation of the thesis project for the M2 Astro Paris visit to APC / AHE group (01/10/2021).

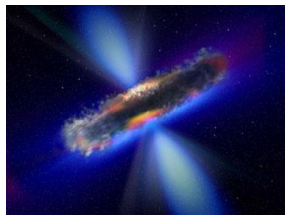
Links

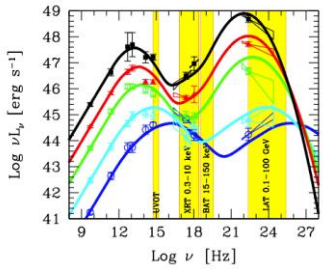
https://apc.u-paris.fr/APC_CS/fr/ahe
https://apc.u-paris.fr/APC_CS/fr/la-science-avec-svom-0
https://irfu.cea.fr/dap/Phocea/Vie_des_labos/Ast/ast_groupe.php?id_groupe=974

Figures

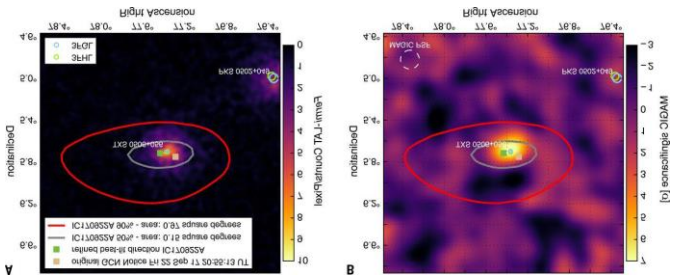


Artistic picture of SVOM

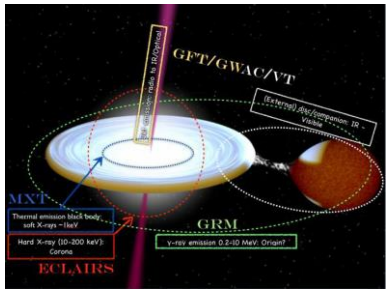




Artistic view of an AGN and the Blazar sequence: the Xrt-Bat energy ranges correspond to Mxt-Eclairs ones



Association of a Blazar flare detected by Fermi and Magic with the neutrinos event seen by IceCube (IceCube Collaboration et al. 2018)



Scheme of an XRB with the components that SVOM instruments will explore (Wei et al. 2016)