SUJET DE THÈSE PROPOSÉ AU LLR

A study of cosmological background photon fields using extragalactic gamma rays observed with the HESS and Fermi telescopes.

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Context:

Gamma-ray astronomy is a relatively new field of study that arose from applying particle-physics detector technologies to study the deep and enduring mysteries of the origin of the cosmic rays. Since its origins the field has advanced rapidly through numerous space and ground-based experiments, culminating in the latest-generation Fermi and HESS telescopes.

The extragalactic gamma-ray sky between 100 MeV to 10 TeV is dominated by a population of extremely energetic sources, thought to be galaxies in which powerful non-thermal emission is created by accretion of material onto a super-massive black hole. These objects are also among the best candidates of being the origin of the most energetic cosmic rays. Gamma rays are produced in relativistic jets of plasma which are launched from close to the black hole. Observationally, these so-called *active galactic nuclei* (AGN) are characterized by broad-band emission from radio to gamma-ray energies, variability timescales as short as a few minutes, and a double-peaked energy spectrum which is attributed to synchrotron and inverse Compton emission from charged particles in the jet. Extragalactic gamma rays are attenuated by interactions with cosmological infrared and optical photon fields (denoted “EBL”) which trace the history of stellar activity in the universe over the last 10 billion years. Observations in the GeV and TeV energy regimes have the potential to reveal the densities of these diffuse photon fields.

Gamma rays are detected when they initiate cascades of charged particles, either directly using space-based particle detectors or indirectly by large ground-based optical telescopes using the atmospheric Cherenkov technique. The astrophysics group at LLR is a member of international collaborations that have built and operate both types of instrument, namely the Fermi large-area space telescope and the HESS array of five telescopes in Namibia. In particular LLR has played a large role in the construction of the HESS-II instrument, the largest gamma-ray telescope in the world, which was commissioned in September 2012 and promises to detect gamma rays from ever most distant AGN.

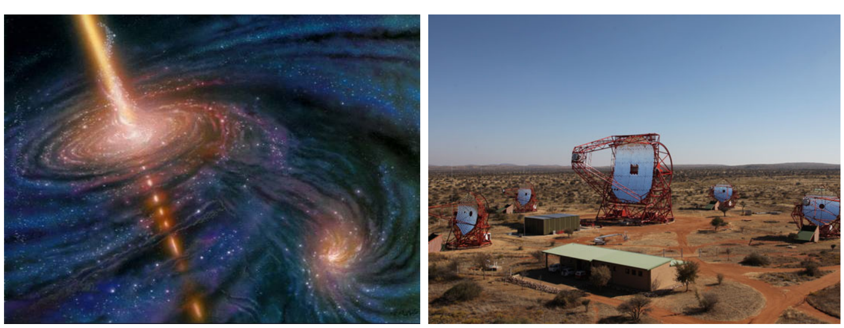

Figure 1: Left, artistic impression of jets in AGN. Right, the HESS array in Namibia.

Project outline:

A motivated PhD student wishing to join the LLR astrophysics group would have the opportunity to work with two world class gamma-ray detectors. He or she would develop new and novel analysis algorithms that combine observations from both instruments with the aim of increasing sensitivity to objects detected by both instruments, of measuring the spectra of temporal variability in AGN and of measuring the density of the EBL field in the universe.

This project has two major aims: the first is to improve our understanding of the cosmic infrared and optical background fields through gamma-ray observations with Fermi and HESS. The second aim of the project is to study the acceleration mechanisms powering the emission of gamma rays from super-massive black holes. These two branches of the project are complementary, and the student can proceed along either or both according to his/her interests.

Measurement of the EBL from observations with gamma-ray telescopes is in its infancy. Fermi has detected a large number of distant sources but the imprint of the EBL is small and only visible at the highest energies accessible to the instrument. HESS, on the other hand, has detected a smaller number of closer sources, in an energy range where the impact of the EBL is larger, and hence easier to detect. The newly-commissioned 28m HESS telescope will allow more distant sources to be detected in this waveband, iincreasing the range of distance and energy over which the EBL can be measured.

The study of temporal variability with Fermi and HESS provides an important window on the mechanisms of particle acceleration in AGN. Fermi has a large field of view but modest effective area allowing it to measure the full gamma-ray sky between 100MeV and 300GeV every 3 hours with (relatively) low sensitivity, while HESS has a small field of view and large effective area allowing it to make sensitive dedicated observations of single objects at energies larger than 50GeV. By combining observations with both instruments the variability spectrum of objects can be measured on timescales from years to minutes, which set strong constraints on the properties of the underlying emission mechanism.

The student would be expected to attend twice-yearly international collaboration meetings and to take an observation shift at the HESS telescope array in Namibia.

References:

"Fermi Observations of TeV-Selected Active Galactic Nuclei" http://arxiv.org/abs/0910.4881
"Evidence for a cosmological effect in γ-ray spectra of BL Lacs" http://arxiv.org/abs/1303.5923
The HESS telescope array: http://www.mpi-hd.mpg.de/hfm/HESS/
The Fermi telescope: http://fermi.gsfc.nasa.gov/
The astrophysics group at LLR: http://astrollr.in2p3.fr/