Searches for counterparts to gravitational waves with H.E.S.S. and CTA

Over the last two years the Imaging Air Cherenkov Telescopes (IACTs) H.E.S.S. and MAGIC were able to detect very-high-energy gamma-ray emission from gamma-ray bursts (GRBs). These breakthrough results have triggered renewed discussions of the particle acceleration and emission mechanisms that can be found in these violent explosions [1].

Complementing the detections of GRBs via X-ray satellites, the detection of gravitational waves allows to provide new and complementary insights into the pre-explosion phase, the initial conditions, the geometry of the system, and much more. The proposed thesis project will exploit the exciting possibilities of combining the detection of GWs and the detection of the resulting GRB by VHE gamma-ray observatories in truly multi-messenger observations and analyses.

The core of the proposed project will be H.E.S.S., currently the world's most sensitive gamma-ray instrument, and CTA, the next generation, global high-energy gamma-ray observatory. We'll also collaborate closely with partners from around the world including obviously the gravitational wave instrument Advanced VIRGO, the SVOM satellite to detect GRBs, various radio telescopes in Australia and South Africa, optical observatories, and many more. The group at IRFU, CEA Paris-Saclay is leading observations of transient phenomena by both H.E.S.S. and CTA and has long-standing experience with these challenging observations. The group is also driving changes and modernizations of the communication in the astroparticle community (e.g. via the Astro-COLIBRI web/smartphone application, [2]).

The PhD student will first have the opportunity to participate in the development and improvement of the framework that allows to optimize the schedule of follow-up observations of astrophysical transients. Some of the most interesting event are being detected only with large localization uncertainties (i.e. especially GWs, but also GRBs, neutrinos and others). We therefore need specialized tools and algorithms that allow to point the follow-up instruments like H.E.S.S. into the right direction to rapidly catch the associated emission [3]. A crucial observation period by the GW interferometers (called O4) is scheduled to start in spring of 2023. This timing is perfectly matching the PhD project presented here, as the selected student will have the opportunity to lead the H.E.S.S. and CTA/LST-1 follow-up observations searching for GRBs and other VHE gamma-ray counterparts to the GWs detected by LIGO/VIRGO/KAGRA during that period. A sizeable amount of observation time with both the H.E.S.S. and CTA/SLT-1 IACTs has been reserved for these exciting searches. We'll thus have ample opportunities to optimize our follow-up procedures, lots of data to analyze, results to present at international conferences, and papers to publish.

The core of the proposed thesis project will be the **real-time search for transient high-energy gamma-ray emission linked to the detection of a gravitational wave** (and other multi-messenger astrophysical transients like high-energy neutrinos, gamma-ray bursts, fast radio bursts, stellar/nova explosions, etc.). The **combined observations will unequivocally prove the existence of a high-energy cosmic ray accelerator** related to these violent multi-messenger phenomena and will allow to derive novel insights into the most violent explosion in the universe.

Left: The H.E.S.S. array of Cherenkov telescopes in Namibia. Right: The first CTA telescope on La Palma.

REFERENCES

[1] H.E.S.S. Collaboration: "Revealing x-ray and gamma ray temporal and spectral similarities in the GRB 190829A afterglow, Science, Vol. 372 (2021); access to the paper: ADS

[3] P. Reichherzer, F. Schüssler, et al. : "Astro-COLIBRI-The COincidence LIBrary for Real-time Inquiry for Multimessenger Astrophysics", ApJS 256 (2021); access to the paper: ADS

[2] H. Ashkar, F. Schüssler, et al. : "The H.E.S.S. gravitational wave rapid follow-up program", JCAP 03 (2021); access to the paper: ADS

ENVIRONMENT (COLLABORATIONS, INSTITUTE, THESIS DIRECTOR)

The PhD student will become a member of the H.E.S.S., CTA (and if interested SVOM) collaborations. He/she will participate and later lead the preparation of observations in close collaboration with external partners and will be in charge of the subsequent data analyses. Participation in the onsite operation of the experiments in Namibia and La Palma as well as the data calibration is possible. The student will have an extensive set of data analysis tools at his disposal but will also have the opportunity to develop novel methods and techniques taking full advantage of the information provided by multiple messengers. These novel techniques are being applied and tested to H.E.S.S. data before being transferred to CTA. Analysis of the first CTA physics data will conclude the thesis project opening multiple possibilities for further studies and employments.

The PhD student will evolve within the astroparticle physics group at Irfu/CEA-Saclay, which is one of the major groups within H.E.S.S. and CTA. Interaction with external partners and members of other collaborations (Desy-Zeuthen/Berlin, MPIK/Heidelberg, Univ. Alabama/US, etc.) as well as within the active astrophysics community of Paris-Saclay will allow the student to enlarge his horizon and become a key member of the new and rapidly growing multi-messenger community. The multi-messenger astroparticle group at IRFU embraces the opportunities enabled by bringing together people from a wide range and diversity of thought, culture, background, experience and identity.

The thesis director, Fabian Schüssler (fabian.schussler@cea.fr), is member of the H.E.S.S., CTA, ANTARES and SVOM collaborations. He is the official H.E.S.S. contact for multi-messenger studies, and is responsible for the H.E.S.S. science working group on transient phenomena and the related observation program. Fabian is leading several projects bringing the global multi-messenger and astroparticle physics together and is developing novel tools to manage the increasing flow of information about transient astrophysical events.

REQUIREMENTS

- Basic knowledge of astro/astroparticle physics
- Basic knowledge of programming (Python, C/C++, etc.)

OBTAINED KNOWNLEDGE AND EXPERIENCES

- Data analysis ("Big Data": large volumes of complex data)
- Software development (novel algorithms, machine learning, smartphone apps, etc.)
- Work in a competitive, international environment
- Synthesis of results and presentation at international conferences
- Scientific publications in international journals

CONTACT

Fabian Schüssler: fabian.schussler@cea.fr, Tel.: 01 69 08 30 20
Homepage: https://www.multimessenger-astronomy.com