

Tidal disruption events in real time: from Rubin/LSST alerts to TeV gamma rays with H.E.S.S. and CTAO, and a bridge to LISA

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Context

When a star passes too close to a supermassive black hole (SMBH), it is torn apart in a tidal disruption event (TDE). TDEs reveal otherwise dormant black holes, probe accretion physics under extreme conditions, and can launch relativistic jets in which particles may be accelerated to PeV energies. Hints of a link between TDEs and high-energy neutrinos make them prime targets for very-high-energy (VHE) gamma-ray astronomy, yet no TeV emission from a TDE has been detected so far. The Vera C. Rubin Observatory (LSST) is now turning TDEs from rare curiosities into a population of thousands of events, but only if candidates can be identified early, before peak brightness, and followed up quickly across all wavelengths and messengers.

This project is embedded in TRACER (TDE Real-time Alerts for Coordinated Electromagnetic Response), a multi-institute effort (IRFU, IJCLab, APC) that builds an end-to-end chain from LSST alerts, classified by the Fink broker, to coordinated follow-up managed through the Astro-COLIBRI platform. The PhD student will develop the gamma-ray branch of this chain and, in addition, open a new connection to the future space-based gravitational-wave observatory LISA.

Scientific objectives and work plan

- **1. From alerts to observations.** Integrate the Fink/LSST TDE stream into Astro-COLIBRI and build TDE-specific selection criteria, visualisation and scheduling tools that identify the rare candidates most promising for VHE emission (jetted or structured-jet events, nearby and bright nuclear transients). The student will help prioritise candidates using optical, X-ray (SVOM, Einstein Probe) and radio (MeerKAT) information.
- **2. VHE follow-up and physics.** Trigger, carry out and analyse TDE observations with H.E.S.S. (within the Transients Legacy Program led by the supervisor) and with the first CTAO telescopes. Combine the multi-wavelength data with emission models to detect, or constrain, particle acceleration in TDE jets and outflows, and contribute to the definition of a CTAO TDE Key Science program.
- **3. A link to LISA.** LISA will detect extreme-mass-ratio inspirals (EMRIs): stellar-mass compact objects (about 1–100 solar masses) spiralling into massive black holes of 10^5 – 10^7 solar masses, i.e. systems with a mass ratio of only about 10^{-7} – 10^{-4} , whose gravitational-wave signal accumulates over many thousands of orbits. EMRIs take place in the same galactic nuclei as TDEs, and some nuclear transients have been proposed to be linked to them. The student will (i) study which TDE-like nuclear transients could be jointly observable with LISA, and (ii) work on the definition of LISA alerts to be distributed through Astro-COLIBRI: which signals warrant an alert, on which timescales (LISA sources accumulate signal-to-noise over months to years, so early-warning and evolving sky localisations are central), with which thresholds, and how localisation regions can be turned into optimised follow-up schedules with our tilepy tool. EMRIs and TDEs serve as the guiding use case. This work is exploratory and simulation-based, and prepares the multi-messenger infrastructure ahead of LISA operations.

Astro-COLIBRI development and outreach

The student joins the Astro-COLIBRI team and contributes to the development of the web platform and smartphone apps (real-time alert display, observation planning, direct telescope triggers), to the definition of new alert streams, and, if interested, to outreach with the professional and amateur astronomy community (workshops, hackathons, citizen-science campaigns). This gives hands-on experience with cloud services, APIs, and software development beyond classical data analysis.

Tentative timeline

- **Year 1:** training on H.E.S.S./CTAO analysis and Astro-COLIBRI/tilepy tools; archival analysis of TDEs; first Fink–Astro-COLIBRI TDE integration; review of LISA source and alert concepts.
- **Year 2:** systematic LSST-triggered TDE campaigns with H.E.S.S., early CTAO data and multi-wavelength analysis; first paper; simulations of LISA (MBHB/EMRI) alerts and localisation, with mock data from the LISA community.

- **Year 3:** physical interpretation and modelling, CTAO TDE program, prototype of LISA alert handling in AstroCOLIBRI; second and third papers; thesis writing.

Environment and profile

The student will be a member of the H.E.S.S., CTAO and SVOM collaborations, with the possibility to take part in observation shifts in Namibia and on La Palma, and will work within the TRACER consortium with colleagues at IJCLab (Fink, LSST) and APC (multi-messenger and gravitational-wave astronomy). Regular participation in international conferences and collaboration meetings is foreseen. We look for a motivated candidate with a Master in astrophysics, astroparticle or high-energy physics, a good command of Python, and interest in both data analysis and software development. Prior experience with transient astronomy, gravitational waves or gamma-ray data is welcome but not required. The PhD is prepared at the doctoral school PHENIICS of Université Paris-Saclay.

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