High-Finesse Cavity Spectroscopy as a Tool for Astronomical Detection

Encadrants Français:

Bérenger GANS
CRCN
Institut des Sciences Moléculaires d'Orsay (ISMO)
Université Paris Sacaly
HDR rattaché à l'EDOM
berenger.gans@cnrs.fr

Ugo Jacovella
CRCN
Institut des Sciences Moléculaires d'Orsay (ISMO)
HDR rattaché à l'EDOM
ugo.jacovella@cnrs.fr

Encadrant Ecosse:

Ewen K. Campbell
School of Chemistry, The University of 511 Edinburgh, Edinburgh EH9 3FJ Scotland, U.K.
e.k.campbell@ed.ac.uk

PhD project:

The diffuse interstellar bands (DIBs), which are observed in the visible and near-infrared range (400–1500 nm), have been a well-established feature of interstellar extinction curves for over a century. While the identity of the carrier responsible for most of these bands remains elusive, C60+ has been identified as the carrier for only a small fraction of the more than 600 DIBs cataloged to date. The identity of the molecular ions responsible for the remaining absorptions is still unknown. A plausible hypothesis is that these DIBs arise from molecular ions that are challenging to detect in the laboratory due to their low densities.

To address this, cavity ring-down spectroscopy (CRDS) offers a solution by enabling measurements along kilometer-long absorption paths. This technique allows for extremely precise detection of absorption features, where the rate at which photons escape from the optical cavity is directly related to the absorption cross-section and the density of the molecules under investigation.

As part of this PhD thesis, the candidate will focus on recording the electronic spectra of molecular ions using CRDS at the exit of a supersonic expansion coupled with an electric discharge at ISMO (University Paris-Saclay). Another aspect of the project will involve recording similar spectra using CRDS in a cryogenically cooled ion trap at Edinburgh, in collaboration with the group of E. Campbell. The candidate will be expected to apply advanced concepts from molecular physics and quantum chemistry to analyse the electronic spectra obtained in the laboratory.

In addition, these laboratory measurements will be compared with astronomical data recorded by both ground-based and space-based telescopes. This will involve direct collaboration with astronomers and may include requests for new observation time based on the insights gained from the laboratory work.

This PhD project will thus span a range of interdisciplinary fields, bridging molecular physics, astrochemistry, optics, and astronomy, offering a unique opportunity to contribute to our understanding of the molecules responsible for DIBs and their role in the interstellar medium.

explicitation des complémentarités entre co-encadrants:

The two teams are experts in ion spectroscopy of astrophysically relevant species, each employing complementary approaches. The group in Edinburgh specializes in spectroscopy within cryogenic ion traps, utilizing a He-tagging technique. Meanwhile, the team at ISMO has strong expertise in molecular ion spectroscopy within a molecular beam, using a high-finesse cavity.

description des moyens mis à disposition:

The experimental setups in France and Scotland are fully operational and already generating data. They can be used with minimal operational costs, which are covered by grants secured by both groups. These funds will cover not only the operational costs of the experimental setup but also enable the PhD student to participate in at least two international conferences per year and attend NanoSpace meetings.

explicitation du caractère « 3i »

The supervisors of this project—Ugo Jacovella, Bérenger Gans, and Ewen K. Campbell—recently launched an international collaboration supported by the **European COST Action NanoSpace**. The complementary experimental setups used in each group, along with their shared objective of detecting new molecules in space through spectral fingerprints in the visible domain, naturally led to this partnership. Initiated in 2023, the collaboration quickly yielded success with the publication of a joint paper in ACS Earth and Space Chemistry on a topic central to the present PhD project. (Douglas-Walker, T. E.; Campbell, E. K.; Daly, C. F.; Douin, S.; Gans, B.; Jacovella, U.; Maurice, C.; Odant, R.; Palotas, J. Ion spectroscopy in the context of the diffuse interstellar bands: A case study with the phenylacetylene cation. ACS Earth and Space Chemistry, (Accepted in November 2024).)

expérience d’encadrement

Bérenger GANS received his HDR in 2021 and (co-)supervised 5 PhD thesis. He is currently (co-)supervising two PhD students (Hai Linh LE and Corentin Rossi) who will defend their thesis in 2025 and 2026.

Ugo Jacovella received is HDR in 2023 and is currently the main superviser of a PhD student (Corentin Rossi).

Ewen Campbell is a Senior Lecturer at the School of Chemistry, University of Edinburgh. He has graduated 2 PhD students as main supervisor since establishing a new group in 2018. His group currently comprises 1 Postdoc and 3 PhD students (in 1st, 2nd and 3rd year of study)