University of Leicester PhD studentship

Funding Source: CENTA DTP

Proposed start date: 23rd September 2024

Closing date for applications: See our web page

Eligibility: UK/International

Department/School: Physics

Supervisors: **PI:** Dr Jeremy Harrison (University of Leicester, email: jh592@leicester.ac.uk)

Co-I: Prof John Remedios (NCEO)

Project Title: Carbonyl sulfide (COS) as climate diagnostic: re-evaluating the infrared spectroscopy used for remote sensing of the Earth's atmosphere.

Project Description):

Project Highlights:

- A complete laboratory re-evaluation of the infrared spectroscopy of carbonyl sulfide (COS)
- Production of a new COS linelist to improve remote-sensing observations of COS
- The opportunity to work with retrieval scientists and investigate COS as a climate diagnostic

Overview:

Planet Earth has a number of natural climate-regulating mechanisms, including the biospheric uptake of carbon by vegetation and the abundance of stratospheric sulfate aerosols (SSA). The former directly removes some carbon dioxide (CO_2) emissions from the atmosphere, while the latter have a cooling effect on climate. Both mechanisms are intrinsically linked to the trace gas carbonyl sulfide (COS or OCS).

COS is the most abundant sulfur-containing molecule in the atmosphere. The dominant source is biogenic activity in the oceans, while the sinks are due to uptake by vegetation (by the same initial pathway as CO_2) and destruction in the stratosphere (SSA formation). Despite this importance, its atmospheric sources and sinks are not well quantified. There is a growing recognition that COS can be used as a climate diagnostic, and that a better understanding of its atmospheric variations will lead to a deeper understanding of CO_2 uptake and SSA formation, and the responses of these to our changing climate. Remote-sensing observations have a crucial role to play in this respect since they provide a global view of COS that is not otherwise possible.

Observations of COS are made from a number of satellite instruments using different infrared bands: the Atmospheric Chemistry Experiment Fourier transform spectrometer (ACE-FTS; limb) which utilises the strongest ν_3 band at 2062 cm^{-1}, the Michelson Interferometer for Passive Atmospheric Sounding (MIPAS; limb) instrument which utilises the weaker ν_1 band at 858 cm^{-1}, and the Infrared Atmospheric Sounding Interferometer (IASI; nadir) instruments which utilise the ν_3 band. Additionally, ground measurements as part of the Network for the Detection of Atmospheric Composition Change (NDACC) utilise the ν_3 band, as does the balloon-borne JPL MkIV interferometer which also uses the weaker $\nu_1+\nu_3$ and $2\nu_3$ bands for the lowest altitudes.

HITRAN contains a COS linelist that has been utilised for all these remote-sensing observations. In order to improve these observations, we require reference COS spectroscopy that is accurate and robust. However, the HITRAN linelist has a number of deficiencies that urgently need to be resolved. Uncertainties in the line intensities can vary from 5% to 20%; this needs to be reduced to under 1%. This work will be the first detailed laboratory study of COS lineshape parameters and their temperature dependences. They will directly improve the observational data products.

Methodology:

In this project, the student will perform a complete re-evaluation of the IR spectroscopy of COS. This will involve utilising a state-of-the-art Bruker IFS 125HR Fourier transform spectrometer at the new National Centre for Earth Observation (NCEO) SPectroscopy for ENvironmental SEnsing Research (SPENSER) laboratory at Space Park Leicester. Infrared spectra will be recorded for both pure and air-broadened COS over a range of temperatures and pressures. These will be analysed to produce a robust COS linelist that will provide a more accurate basis for COS retrievals from remote-sensing observations.

We will collaborate with the ACE-FTS and MIPAS (IMK-KIT) retrieval teams to investigate how the new linelist improves the retrievals and resolves observed biases. We will also implement the new spectroscopy within the NCEO-Leicester IASI COS retrieval scheme, building on the work of a previous PhD student. These IASI satellite observations are a key part of the NCEO's national capability International Science programme which runs until March 2026. The student will have the opportunity for their work to feed into this programme, in particular into global COS inversions in collaboration with NCEO-Leeds.

References:

Glatthor et al.: Global carbonyl sulfide (OCS) measured by MIPAS/Envisat during 2002–2012, Atmos. Chem. Phys., 17, 2631–2652, https://doi.org/10.5194/acp-17-2631-2017, 2017.

Ma et al.: Inverse modelling of carbonyl sulfide: implementation, evaluation and implications for the global budget, Atmos. Chem. Phys., 21, 3507–3529, https://doi.org/10.5194/acp-21-3507-2021, 2021.

Sung et al.: Line strength measurements of carbonyl sulfide ($^{16}O^{12}C^{32}S$) in the $2\nu_3$, $\nu_1+2\nu_2+\nu_3$, and $4\nu_2+\nu_3$ bands, JQSRT, 110, 2082-2101, https://doi.org/10.1016/j.jqsrt.2009.05.013, 2009.

Whelan et al.: Reviews and syntheses: Carbonyl sulfide as a multi-scale tracer for carbon and water cycles, Biogeosciences, 15, 3625–3657, https://doi.org/10.5194/bg-15-3625-2018, 2018.

Funding details:

NERC CENTA studentships are for 3.5 years and are funded by NERC. In addition to the full payment of your tuition fees, you will receive the following financial support:

- Annual stipend, currently set at £18,622 (2023/4 – new figures to be confirmed spring 2024)

- Research training support grant £8,000 (RTSG)

If you are not eligible for UK Fees the University of Leicester will fund the difference between UK and International fees for the duration of your studies

For more details of the CENTA consortium please see the CENTA website: www.centa.org.uk.

Entry requirements:
Applicants are required to hold/or expect to obtain a UK Bachelor Degree 2:1 or better in a relevant subject.

The University of Leicester English language requirements apply where applicable.

Application advice:

To apply please refer to our web page for further information and read carefully the How to Apply section before submitting your application
https://le.ac.uk/study/research-degrees/funded-opportunities/centa-phd-studentships

In the funding section please specify that you wish to be considered for Ref CENTA2-PHYS2-HARR

In the proposal section please provide the name of the supervisors and project title (a proposal is not required)

Project / Funding Enquiries to: CENTA@le.ac.uk or jh592@leicester.ac.uk

Application enquiries to pgradmissions@le.ac.uk