



From Core to Clouds: Laboratory Synergy within the EnVision's VenSpec Science Team

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The VenSpec Suite, aboard ESA's EnVision mission to Venus, is coordinated by a joint science team that ensures seamless integration and cooperation among the instruments [1]. Rather than organizing efforts by instrument channel, the science team is structured into interdisciplinary Working Groups (WGs) that leverage synergies across all channels and foster collaborations among researchers and institutions. Among them, the Laboratory Investigations Working Group (WG) plays a central role in supporting the VenSpec Suite's science objectives through laboratory experiments that simulate Venus' extreme surface and atmospheric conditions. The group unites a wide range of international laboratories and researchers. Their common goal is to provide essential reference data for instrument calibration, radiative transfer modelling validation, and interpretation of surface and atmospheric observations from the three VenSpec instruments: VenSpec-H (high-resolution IR spectrometer) [2], VenSpec-U (UV spectral imager) [3], and VenSpec-M (push-broom NIR multispectral imager) [1],

The Laboratory Investigations WG addresses a broad array of key scientific themes:

- **Venus surface composition, formation and evolution:** Ongoing studies include laboratory spectral investigations of analog materials spanning mafic to felsic compositions. Emissivity measurements at Venus surface temperatures are carried out at the Planetary Spectroscopy Laboratories (PSL) facility at the German Aerospace Center (DLR), providing high-temperature NIR spectra critical for interpreting VenSpec-M data. Current experiments include investigation of the influence of mineral mixtures (as both different particulated rocks or systematic mixing), grain size, and surface weathering, supporting the development of spectral libraries directly relevant to the VenSpec-M channel [e.g., 4].
- **Sample characterization:** The WG focuses on analyzing both natural rock and mineral samples. Comparisons between isolated mineral spectra and those embedded in rock matrices—highlighted by the PTAL database and Earth analogue studies—enhance our understanding of surface spectral variability and support the construction of relevant reference datasets.
- **Surface temperature studies:** Experimental campaigns aim to quantify the temperature dependence of emissivity, reflectance, and spectral contrast data. These measurements are essential for interpreting surface spectral signals in Venus' high-temperature environment and for applying atmospheric corrections to remote sensing data.
- **Surface/Atmosphere interactions:** Collaborative efforts, including those with the Hot Environments Lab (HEL) at NASA Goddard, investigate how Venus' atmosphere may chemically or physically alter surface materials and affect spectral signatures. These studies are vital for

disentangling surface and atmospheric contributions in observational data.

In the atmospheric domain, the WG contributes to:

- **Atmospheric investigations and aerosol Studies:** Several laboratories are equipped with innovative techniques - including Raman spectroscopy and micro-chamber setups - to simulate Venus conditions and characterize aerosol properties [e.g. 5]. These studies aim to constrain the scattering and absorption behavior of aerosol species and their role in radiative transfer processes, and monitor the chemical composition and heterogeneous reaction on the surface of the aerosol.
- **Gaseous (Photo) Chemistry:** The WG will explore photochemical reactions governing Venus' dense CO₂-rich atmosphere. These experiments feed directly into models of atmospheric composition, structure, and evolution, and inform the interpretation of trace gas observations from VenSpec-U and VenSpec-H.
- **CO₂ broadening and continuum spectroscopy:** Dedicated laboratory efforts will address pressure- and temperature-dependent absorption behavior of CO₂, the dominant atmospheric constituent. These measurements are essential for atmospheric modeling and retrievals from IR and UV spectral data.
- **Atmospheric Chemistry at High Temperature:** This WG explores the VUV-absorption cross-section of several atmospheric species such as CO₂, C₂H₂, NH₃, HCN, CH₃SH at relevant Venus atmospheric temperature [e.g., 6]. These measurements are essential for the interpretation of observations from VenSpec-U.

The Laboratory Investigations WG fosters the sharing of laboratory capabilities and facilities, promoting transparency and coordination among its members. The group will aim to compile a shared inventory of ongoing investigations, available samples, and experimental methodologies. This effort will help avoid duplication, identify knowledge gaps, and guide the prioritization of future work. Synergies with Earth-analogue field studies - such as NASA EMIT remote sensing observations of Venus-like regions - are also being investigated. Comparisons between remote and laboratory-acquired spectra aim to bridge differences in resolution and context, improving the relevance of terrestrial analogues for Venus science.

The WG maintains strong links with the Atmospheric Modeling and Radiative Transfer Working Groups. Key areas of joint focus include the correction of surface spectra for atmospheric effects and modeling of surface-emitted radiation as it propagates through the dense Venusian atmosphere. Overall, the activities of the Laboratory Investigations WG are developed in close synergy with the other WGs within the VenSpec science team [e.g., 7, 8]. This ensures optimal cross-investigation strategies and integrated science planning, helping to maximize the scientific return of the EnVision mission.

In summary, the Laboratory Investigations WG provides foundational, cross-disciplinary support to the VenSpec Suite through coordinated laboratory campaigns, targeted spectral measurements, and strong integration with the modeling and observational communities. Its work is essential to interpreting future EnVision data and unlocking new insights into Venus' geology, atmospheric chemistry, and evolutionary history.

References: [1] Alemanno et al. (2025, this meeting); [2] Robert et al. (2025, this meeting); [3] Marcq et al. (2025, this meeting); [4] Alemanno et al. (2024) EPSC2024-303, <https://doi.org/10.5194/epsc2024-303>, 2024. [5] Ubukata et al. (ACS Earth and Space Chemistry, 2025, under review). [6] Venot et al. (2018) Astronomy & Astrophysics, 609, A34. [7] Barraud et al. (2025, this meeting); [8] Hueso et al. (2025, this meeting)

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