National Aeronautics and Space Administration

FY24 Strategic University Research Partnership (SURP)

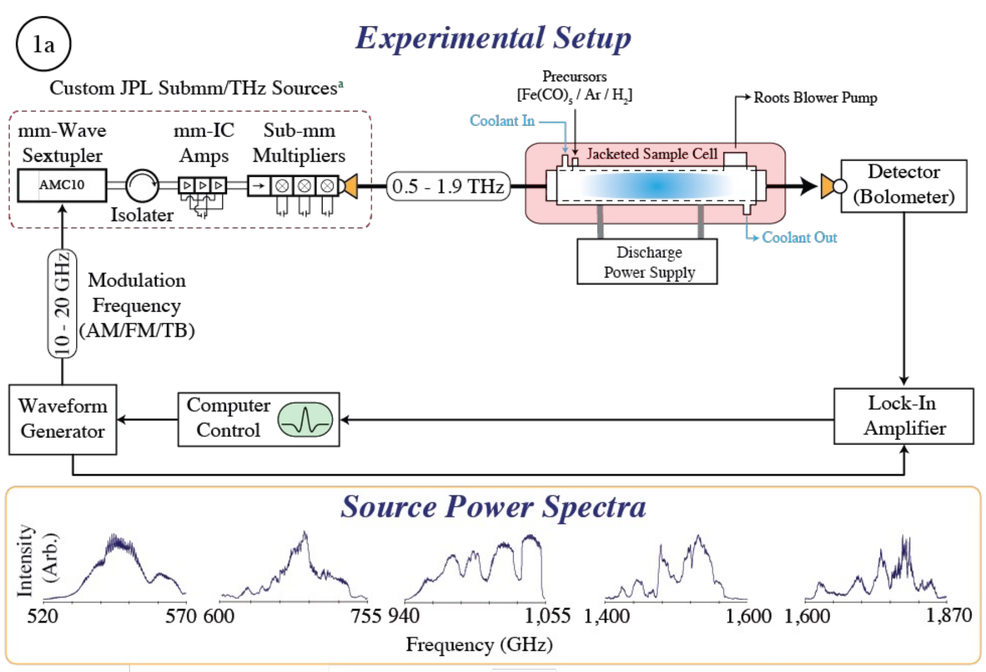
Terahertz Spectroscopic Investigations of Diatomic Transition Metal Hydrides in Support of Next Generation Space/Balloon Borne Observatories

Principal Investigator: Deacon Nemchick (329)**; Co-Investigators:** Brian Drouin (320), Lucy Ziurys (University of Arizona); Graduate Student Participants: Tyler Herman (UA) and Ambesh Singh (UA)

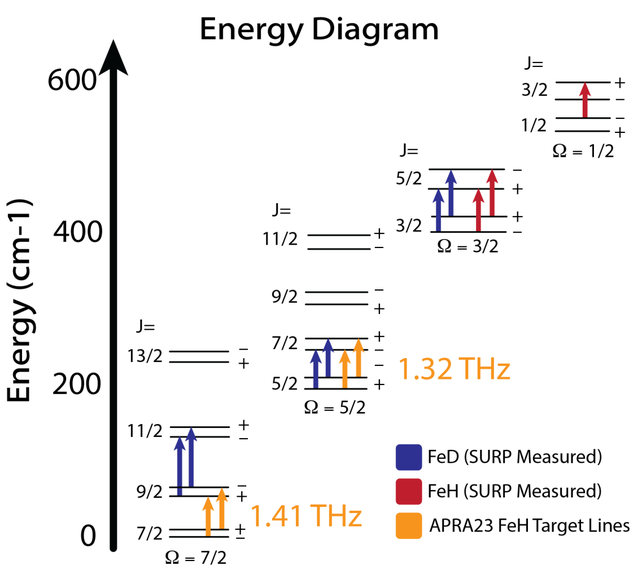
Objectives: The primary objective of this strategic partnership effort is to execute frequency modulated direct absorption measurements of astrophysically relevant transient metal hydrides in the terahertz region (0.7 – 2 THz) of the electromagnetic spectrum in pursuit of observational quality rest frequencies. Experimental efforts in this spectral region are challenged by both the rare nature of tuneable narrow linewidth radiation sources and the large search bandwidths associated with the targeted transient species that lack direct laboratory observation. Such work is necessary; however, to facilitate new observational discoveries in the ISM and circumstellar environments. This technical effort requires both the custom glow discharge cells native to the Ziurys laboratory to generate these exotic transient species, and the high frequency source hardware of the JPL laboratory used to collect their rotational spectra in this valuable spectral region. The collected data is then analyzed with custom least-squares Hamiltonian software to allow for extraction of structural and electronic parameters and quantum assignment. These results along with observed rest frequencies are then made available to astrophysics research communities through publication in peer reviewed journals and cataloging in the JPL public access database.

Approach and Results: SURP efforts focused on the acquiring the first direct absorption laboratory measurements of FeH and FeD in 1-2 THz spectral region. Execution of these challenging measurements require combining the highly specialized laboratory capabilities and institutional knowledge associated with the Ziurys research group at the University of Arizona and the High-Resolution Molecular Spectroscopy Laboratory at JPL. Multiple Herschel era GaAs-based cascaded multiple chain sub-mm and THz sources still maintained by group 329H and a collection of ancillary hardware were then transferred to UA to be interfaced with specialized AC/DC glow discharge cells native to the Ziurys Group at UA. The first in class direct absorption measurements of FeH and FeD in the 0.7 to 1 THz region are shown below.

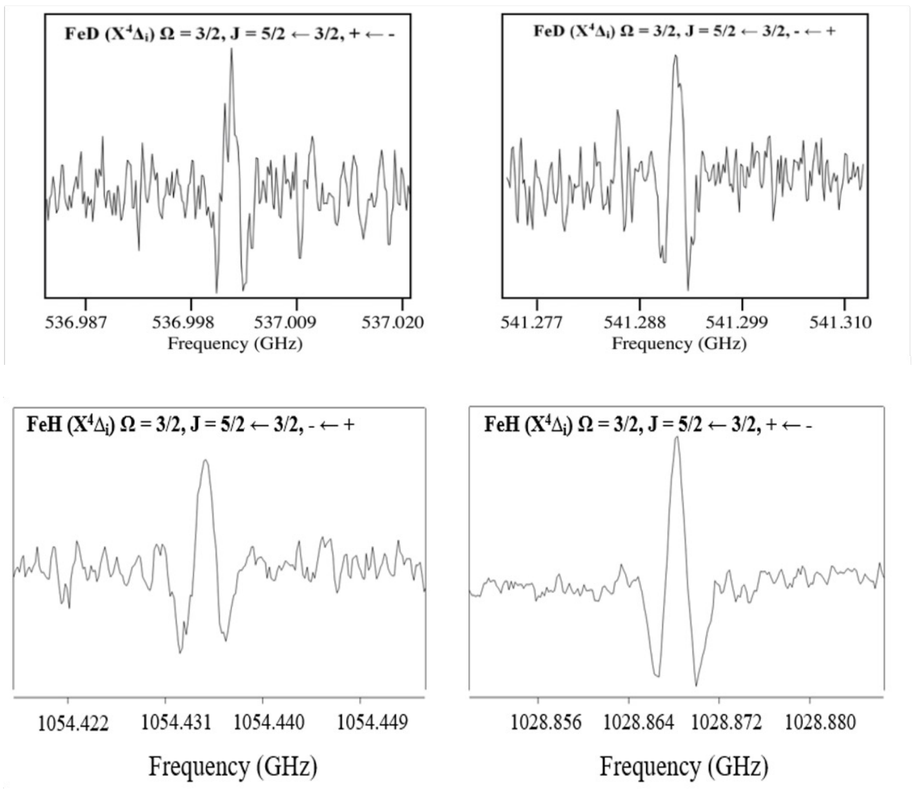
Significance/Benefits to JPL and NASA: Science associated with molecular astronomy has long been a Caltech/JPL hallmark, culminating in the highly capable Herschel/HIFI instrument which has left an unmatched legacy of THz hardware immediately useful for scientific research that supports the furthering of astronomical detections. Further explorations of interstellar and circumstellar chemistry are limited due to observational constraints including atmospheric opacity and state populations, leading to a need for additional space (Herschel 2.0) and balloon (ASTROS-like) missions. Strategic support of new characterizations of relevant molecular spectra thus, by proxy, also strategically supports future mission concepts. This collaboration will continue thanks to newly acquired APRA23 NASA ROSES funding.



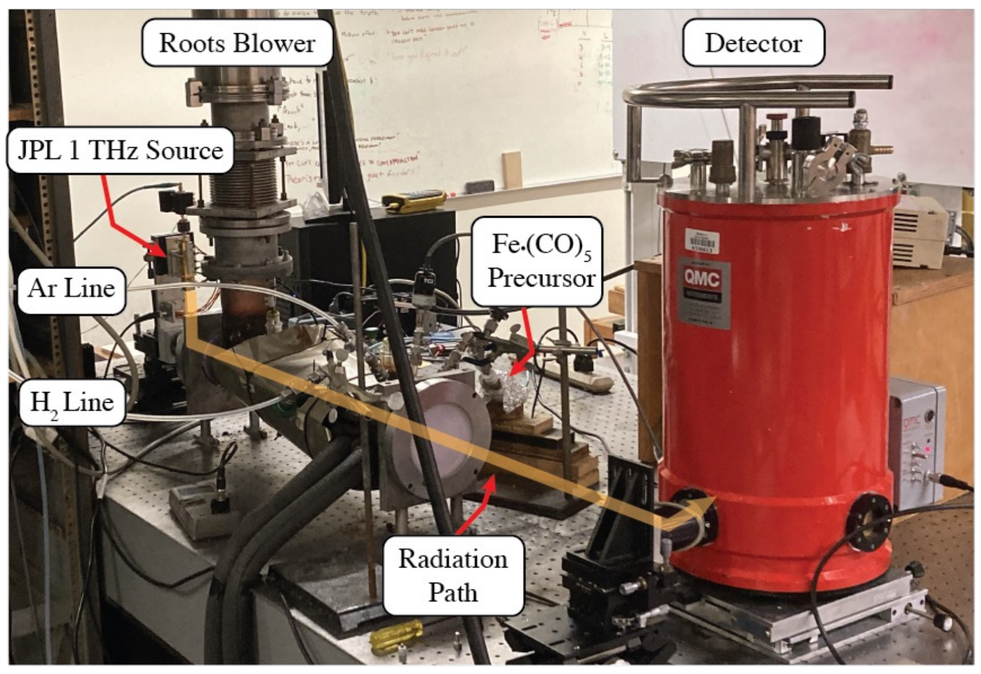
Experimental setup used for frequency modulated direct absorption of transient metal hydrides in block diagram format (1a). The THz radiation sources deployed are supplied by JPL (1b) and interfaced with custom AC/DC glow discharge cells maintained by the Ziurys Group at the University of Arizona (1c).



Energy level diagram for FeH including all direct absorption lines measured at the University of Arizona as part of SURP experimental efforts. The highly desirable FeH transitions in the omega=7/2 and 5/2 ladders to be targeted with newly acquired APRA23 funding.



First in class frequency modulated direct absorption measurements of FeH and FeD in the omega = 3/2 and omega = 3/2 ladder.



Photograph of the actual experimental setup at the University of Arizona in the Ziurys group research laboratory after the JPL source hardware was transported and installed. Terahertz radiation is columnated with an off-axis parabola and directed through the discharge cell before detection with a liquid helium cooled bolometer detector.

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Poster: Ambesh Singh, Tyler Herman, Deacon Nemchick, Brian Drouin, Lucy Ziurys, 'First Direct THz Measurement of FeH and FeD', 28th Austin Symposium on Molecular Structure and Dynamics

Contributed Talk: Ambesh Singh, Tyler Herman, Deacon Nemchick Brian Drouin, Lucy Ziurys, 'Direct Terahertz Rotational Measurements of FeH and FeD, 76th International Symposium on Molecular Spectroscopy

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