Lamb-Dip and Two-Photon Absorption measurements using wave-modulated NICE-OHMS for Precision Spectroscopy on Water

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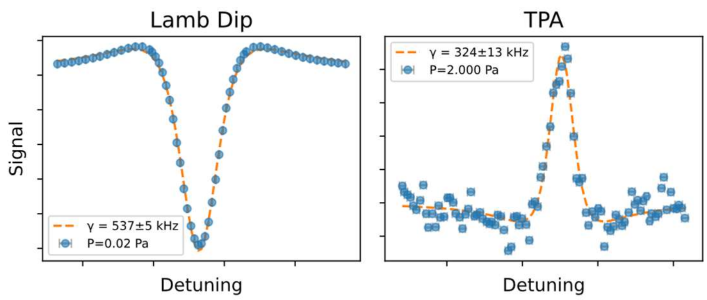
Water is a critical molecule in chemistry, radio astronomy and fundamental physics. This talk presents high-precision measurements of $H_2^{16}O$ using wave-modulated noise-immune cavity-enhanced optical heterodyne molecular spectroscopy (NICE-OHMS). Our instrument is used to perform Doppler-free measurements either through Lamb-dip saturation or two-photon absorption (TPA) measurements.

To enhance the accuracy of protected radio lines between 750 GHz and 3 THz, we performed high-precision Lamb-dip measurements of rovibrational lines in the 1.2-1.4 μm range. These measurements, featuring an accuracy of 2 kHz, were utilized within a spectroscopic network to improve 51 purely rotational microwave lines crucial for radio astronomy. The precision of these transitions, formerly at the 10-200 kHz level, has been improved to well below 10 kHz for all lines. This ensures that the frequency allocations defined by the International Astronomical Union are supported by unprecedented experimental precision.

Additionally, in this talk, we report several TPA transitions in $H_2^{16}O$ measured with kHz accuracy in the near infrared. This work marks the first TPA measurement in the water overtone range. By utilizing TPA's selectivity to disentangle dense state energies and reach high-parity levels, these results enable a precise metrological determination of overtone transitions.

TPA offers a unique probe for high-energy, same-parity states inaccessible via single-photon absorption. Combined, these methods provide a rigorous metrological characterization of water transitions, serving the needs of international astronomical bodies and advancing our understanding of molecular energy levels.



Examples of a scan on a Lamb Dip (left panel) and on a two-photon absorption (right panel).