Progress on laboratory studies of sulfuric acid vapor opacity with application to Ka Band radio occultations of Venus.

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Introduction: Future missions to Venus will include radio occultation experiments operating in the Ka Band. Compared with prior radio occultation experiments operating at S and X Band, the use of Ka Band will enable finer vertical resolution for the retrieval of Venus atmospheric structure and composition. As with prior radio occultations, accurate retrievals of H_2SO_4 vapor abundance profiles from the attenuation of the radio signal will rely on models of the H_2SO_4 vapor opacity based on laboratory measurements under Venus conditions. Such measurements are currently underway at Georgia Tech.

Experimental Method: Fabry Perot-type microwave open resonators have been constructed using corrosion resistant materials to measure the pressure-broadened absorptivity and refractivity of H_2SO_4 vapor mixtures from 26-42 GHz. A gold-plated flat mirror and a curved mirror with a 40 cm radius of curvature (ROC) are oriented in 'semi-confocal' and 'parallel-plate' configurations. In the semi-confocal configuration, the mirrors are separated by close to half of the ROC, resulting in resonances with quality factors up to 12,000 at the upper end of the Ka Band. In the parallel plate configuration, the mirrors are separated by a shorter distance (~5 cm), resulting in resonances with a high signal to noise ratio evenly spaced in 4-5 GHz intervals across the entire band. Both configurations are housed in a borosilicate glass pressure vessel.

During a measurement cycle, the pressure vessel and an isolated flask containing a known volume of 98% sulfuric acid solution are placed in an oven and brought to a temperature of 565 K. When the resonator system achieves thermal stability, the valve connecting the flask and the pressure vessel is opened, introducing H_2SO_4 vapor into the resonator path. Measurements of the opacity of H_2SO_4 evaporates (H_2SO_4, SO_3, and H_2O) are made as well as mixtures with up to 3 bar of CO_2. The pressure-broadened opacity of the H_2SO_4 evaporates is isolated from that of the CO_2 by matching gas-induced shifts in resonant frequency using pure CO_2. Following the completion of a measurement, the system is allowed to cool to room temperature, and the remaining volume of H_2SO_4 solution is measured.

Prior Models: Prior radio occultation experiments have made use of the S and X Band H_2SO_4 vapor opacity models derived from the laboratory measurements of Kolodner and Steffes [1]. Akins and Steffes have also made measurements of the 2-4 millimeter absorption spectrum of H_2SO_4 vapor and developed a model based on the JPL millimeter line catalog [2]. Extrapolation of these models to Ka Band frequencies give conflicting interpretations of the attenuation that would result during a Venus radio occultation experiment. Measurements of the H_2SO_4 vapor opacity near 42 GHz are in relative agreement with the model of Akins and Steffes, and lower frequency measurements suggest that the transition region between models occurs between 30 and 40 GHz. In the JPL catalog (shown in Fig. 1), this range of frequencies represents a transition between the dominance of spectral features associated with elastic and inelastic collisions. Further measurements are underway to confirm the nature of the transition region and to determine if modifications to the lower frequency portion of the JPL catalog for H_2SO_4 can be used to model the opacity.

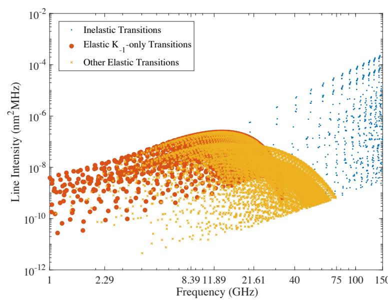

Fig 1. Line intensities for H_2SO_4 in the JPL Catalog

Implications for Dual Band Radio Occultations: In addition to measurement of the vertical profile of H_2SO_4 vapor at Venus, dual band X and Ka Band radio occultations are potentially capable of retrieving vertical profiles of other atmospheric constituents. Since the opacities of both the cloud and SO_2 increase with frequency, their effects on the downlink signal become more apparent at Ka Band. Subtraction of the H_2SO_4 vapor contribution (determined from X Band attenuation) from the Ka Band signal attenuation will result in residual attenuation, which can be interpreted as cloud or SO_2 opacity, depending on the height of the features. Accurate Ka Band opacity models for the cloud aerosols and SO_2 exist under Venus conditions [3,4].

References: [1] Kolodner, M. A. and Steffes, P. G. (1998) Icarus, 132, 151-169. [2] Akins, A. B and Steffes, P. G. (2019) Icarus, 326, 18-28. [3] Fahd, A. K. and Steffes, P. G. (1991) *JGR: Planets 96,* 17471–17476. [4] Fahd, A. K. and Steffes, P. G. (1992) *Icarus,* 97, pp. 200-210.