PROBING THE TEMPERATURE OF MARS' MESOSPHERE. T. A. Livengood[1], R. L. Smith[2], Th. Kostiuk[3], K. E. Fast[3], W. C. Maguire[3], and T. Hewagama[3,4], [1]USRA (USRA, NASA/GSFC, Code 693, Greenbelt, MD 20771, timothy.a.livengood@nasa.gov), [2]NPP (NPP, NASA/GSFC, Code 693, Greenbelt, MD 20771), [3]NASA/GSFC (NASA/GSFC, Code 693, Greenbelt, MD 20771), [4]UMCP (U. of MD, Dept. of Astronomy, College Park, MD 20742).

Introduction: Infrared emission by CO_2 forms in Mars' mesosphere at 9–10 µm wavelength and is observable from the Earth or in nadir viewing at spectroscopic resolving power $\lambda/\Delta\lambda \geq 10^6$. Emission also has been observed in limb-scanning at low spectroscopic resolution from the Mars Global Surveyor (MGS) TES instrument, at a tangent height of ~65–70 km. MGS/TES has provided new data on seasonal variability, altitude, and meridional distribution of this emission, which has reignited interest in remote spectroscopic investigations of the physics of the mesosphere. Infrared heterodyne spectroscopic measurements at resolving power $\sim 10^7$ have been acquired in August 2001; June 2003; and October 2008, exploring the variability in temperature and intensity of the mesospheric emission along the meridian and in different Mars seasons. These data make possible the exploration of the thermal profile from surface to the mesosphere.

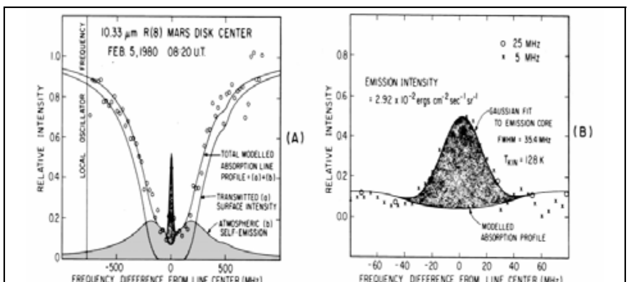

Figure 1: Infrared heterodyne spectra of Mars nonthermal emission with model, illustrating contributions to the observed spectrum. (A) Full line spectrum data at 25 MHz resolution and modeled components contributing to the observed spectrum: transmitted surface intensity, atmospheric LTE self-emission, and the narrow non-LTE emission core. (B) Non-LTE core measurement at 5 MHz resolution with fitted Gaussian function and retrieved kinetic temperature of 128 K.

Spectroscopy of the extremely narrow molecular features that form in the mesosphere probes processes leading to the nonthermal emission of CO_2 in the upper atmosphere of Mars [1] and helps to interpret and complement measurements made by the Mars Global Surveyor (MGS) Thermal Emission Spectrometer (TES) [2]. The mesospheric temperature also is related to the extent of the atmosphere encountered through spacecraft aerobraking. Molecular features formed at mesospheric temperature and pressure are of order a few tens of MHz in width, requiring resolving power $\lambda\Delta\lambda \sim 10^6$ for detection and approximately an order of magnitude greater resolving power to accurately characterize the emission line profile. These measurements can be accomplished using infrared heterodyne spectroscopy (IRHS), the technique that originally detected these emission features [3][4] and that was used to demonstrate that the emission undergoes modest gain-amplification and thus is a natural lasing phenomenon [5]. Since 2001, Mars' mesospheric CO_2 emissions have been observed at 10 µm wavelength using Goddard Space Flight Center's Heterodyne Instrument for Planetary Winds and Composition (HIPWAC).

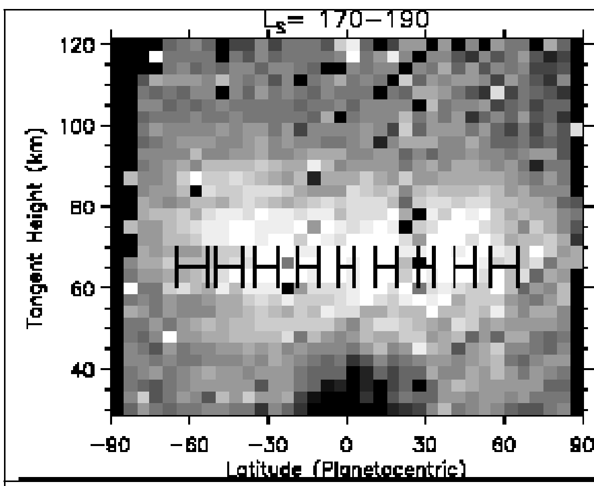

Figure 2: TES data mapping the meridional distribution and altitude distribution of CO_2 emission, from limb-scanning observations at the Mars season indicated. The bright region at 60–90 km tangent height is the region of non-LTE emission pumped by solar radiation. The meridional distribution of this emission has been observed to vary with Mars season. The overplotted bars indicate the range of latitude and approximate altitude region investigated by IR heterodyne observations. This particular map was prepared for the season and aspect geometry of August 2001; current conditions are slightly different.

The HIPWAC spectra include tropospheric and stratospheric features of normal-isotope carbon dioxide and carbon dioxide hot band transitions, as well as weak features resulting from CO_2 isotopologues. These features are analyzed by Smith *et al.* [6, this meeting].Removing these features, the remaining non-LTE emission features formed in the mesosphere can be modeled as a Gaussian emission-line profile whose width is controlled by Doppler line-broadening, yielding the kinetic temperature. Relative excitation of transitions with differing lower-state energy yields rotational temperatures.

MGS/TES limb scan measurements of Mars show 10µm hot band emission of CO_2 at ~65 km tangent height [2]. TES measurements have mapped the hot band emission intensity along the ~2 PM meridian, providing new information about the altitude region of the emission and its seasonal variability. Modeling the spatial, seasonal, and altitude distribution observed in the TES measurements [2] has been qualitatively successful. However, TES temperature retrievals from nadir and limb-scanning data combined are limited to below the ~65 km altitude needed for the model. IR heterodyne spectra from HIPWAC provide data to eliminate assumptions now required to extend the temperature profile above 65 km. Heterodyne measurements of the non-LTE/lasing transitions of CO_2 probe the 50–90 km altitude region on Mars, in which physical conditions can not readily be studied by other means ([7]; [1]).

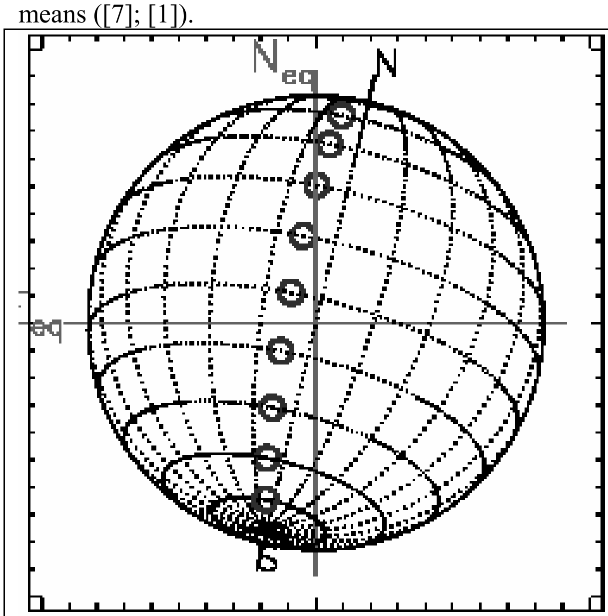

Figure 3: Meridional mapping of non-LTE CO_2 emission. Measurements near the polar limb are accommodated by our beam-integrated radiative-transfer software for spatially variable sources

TES measurements of the CO_2 10 µm emission show a strong seasonal/solar zenith angle variation. The meridional distribution of the non-LTE emission on Mars also has been mapped with HIPWAC for a comparison to TES to investigate the extent to which meridional seasonal variability is to variations in temperature and excitation rate.

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