Thermospheric/Mesospheric Temperatures on Venus: Comparison between Ground-Based High-Resolution Spectroscopy of CO_2 and other Techniques

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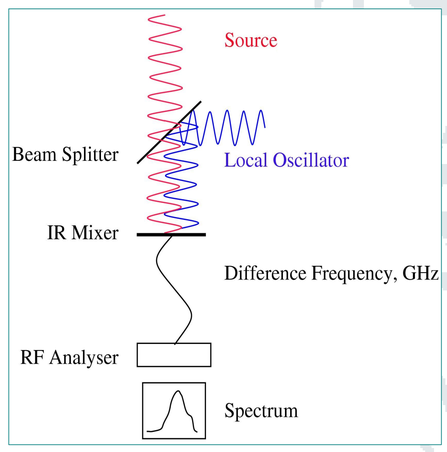
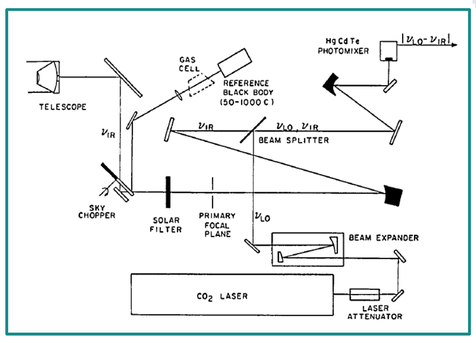
Heterodyne Technique:

- Superimposing source signal and local oscillator laser at ~10 mu
- Mixing two IR signals yields the frequency difference (intermediate frequency, IF)
- Radio frequency signal is detected and analyzed in great spectral detail
- R~10^7



The Instrument:

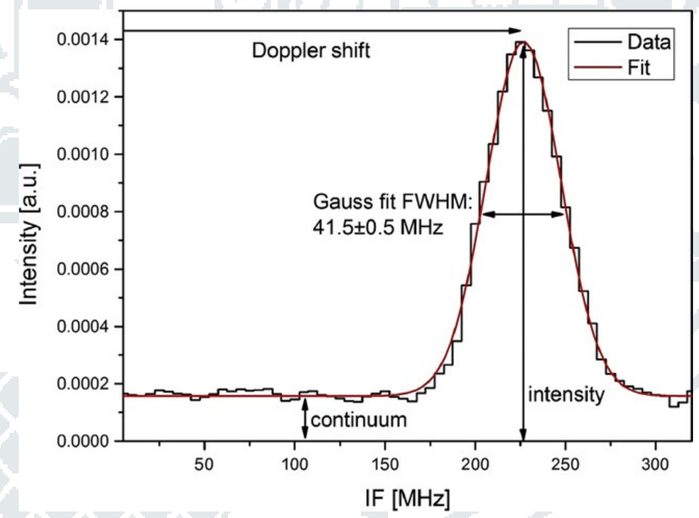
- Data were taken with the NASA instrument IRHS at the IRTF telescope on Mauna Kea, Hawaii
- Detecting the 10µm Non-LTE lines of carbon-dioxide
- Precise frequency determination (<2m/s) due to Lamb-dip stabilization



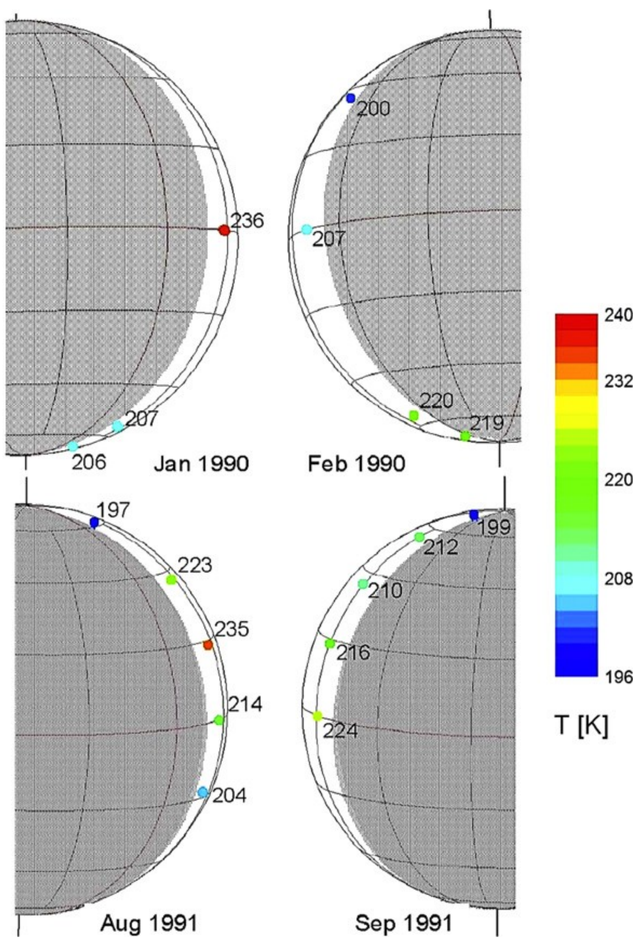
Temperature retrieval from observations of molecular features

- Infrared Heterodyne Spectroscopy allows observation of fully resolved molecular lines
- Non-LTE features from ~110km
- induced by solar irradiation
- Lines are Doppler broadened
- Linewidths corresponds to kinetic gas temperature

Typical spectrum of an IRHS observation observed on January 4 1990 at Equator and 70 West of the central meridian longitude. Shown is the measured emission core of the R8 line of the 10.4 mu band of CO_2. The spectral resolution is 5 MHz. IF corresponds to the difference frequency with respect to the laser local oscillator and the frequency of the range of the tunable high resolution filterbank. The line is fitted by a Gaussian profile. The width of the Gaussian of 41.5 ± 0.5 MHz directly yields a temperature of 244 ± 5 K of the emitting gas

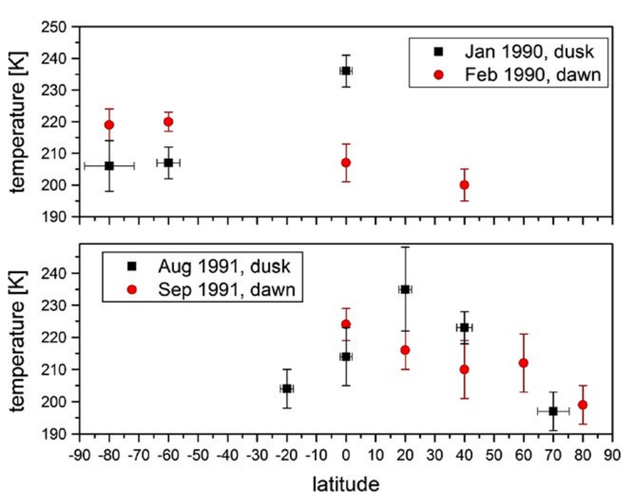


Infrared heterodyne observations from 1990 and 1991 and comparison to 2009

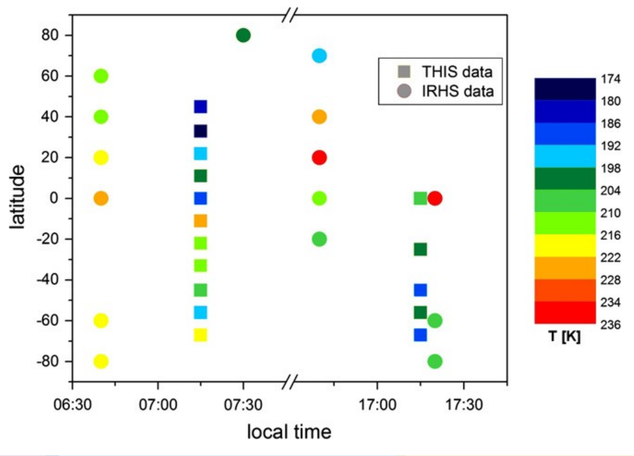


- Retrieved temperatures above VIRA reference model
- Uncertainties usually < 10K
- Temperatures decrease from low latitudes to poles with exception of Feb 1990
- Retrieved temperatures are higher than in similar observations in 2009 obtained with the same technique
- Possible influence of solar cycle?

All IRHS measurements of 1990 and 1991. The sizes of the colored dots relative to the size of the apparent disk of Venus correspond to the telescope FOV of 0.9 arcsecs.



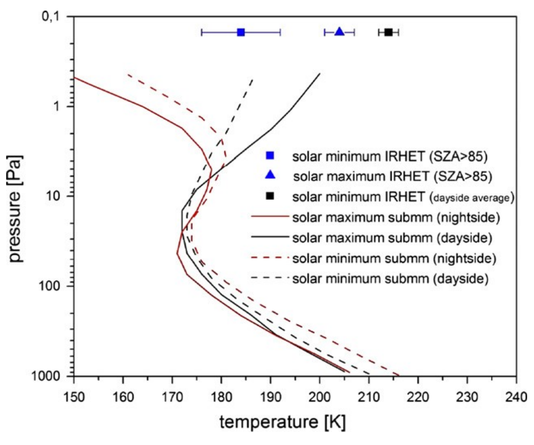
Temperatures vs. latitude for the four IRHS runs. Black indicates dusk, red dawn observations. In January 1990 and both runs in 1991 the warmest temperatures are seen at low latitudes with a decrease towards the poles. Only in the February 1990 case the observed values increase to higher latitudes with unusual high temperatures near the South Pole.



Comparison of IRHS and THIS (Tuneable Heterodyne Infrared Spectrometer, 2009) data. Plotted are the observed latitudes vs. local time. THIS data is adopted from Sonnabend et al. (2010). The color codes for the symbols represent the observed temperatures. IRHS was observing higher temperatures than THIS. See text for discussion.

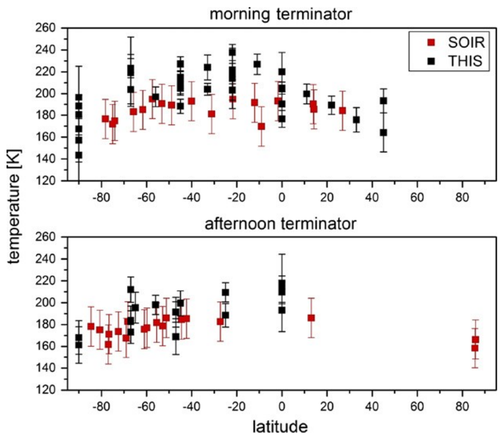
Comparison to sub-mm observations

Comparison to sub-mm observations is difficult due to different observing geometries, comparison of averaged values yields qualitative agreement



Comparison of IR het and sub-mm temperatures. Shown are averaged profiles from Clancy et al. (2011) for different solar activity conditions (solar maximum 2000–2002, solar minimum 2007–2009). In addition, averaged values for IR het observations are given for SZA > 85 for different solar activities in 1990/91 and 2009 (in blue) as well as a day side average for 2009 observations (in black).

Comparison to SOIR profiles



IR het observations are in agreement with space observations from SOIR

Comparison of IR het and SOIR temperatures from March 2009 (IR het) and January 2009 to February 2010 (SOIR, occultation seasons 10–13, Mahieux et al. (2011)). Shown for SOIR are retrieved values for 110 ± 3 km. Values are separated for morning and afternoon terminator. Error bars for SOIR are estimated to be in the order of 15 K, THIS uncertainties are usually on the order of 10 K with some exceptions due to lower signal-to-noise of the acquired data. Since SOIR observes at the terminator we only include IR het observations within 1.5 h local time around the terminator.

Literature:

Sonnabend, G, et al, 2010. Direct observations of Venusupper mesospheric temperatures from ground based spectroscopy of CO_2. J. Geophys. Res. Lett. 37, L11102.

Clancy, R.T., et al, 2011. Thermal structure and CO distribution for the Venus mesosphere/lower thermosphere: 2001–2009 Inferior conjunction sub-millimeter CO absorption line observations. Icarus, in press

Mahieux, A. , et al, 2011. Densities and temperatures in the Venus mesosphere and lower thermosphere retrieved from SOIR on board Venus EXpress. Part II. CO2 densities and temperatures. J. Geophys. Res., in preparation

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