

# Observations of Venus Night-Side by CO<sub>2</sub> Absorption Features

## Ground-based Observations in the Mid-infrared

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### Instrumentation:

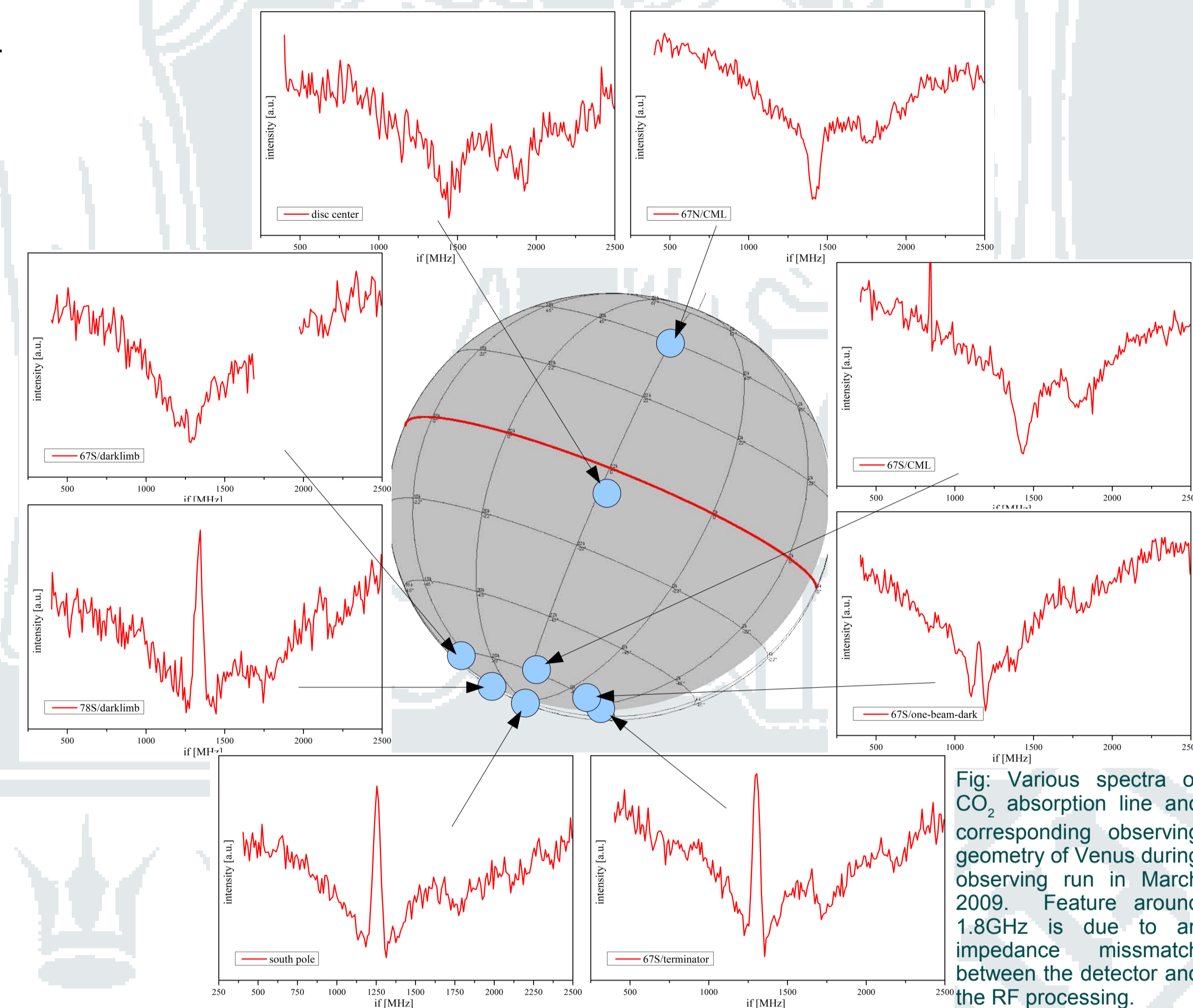
**THIS** (Tuneable Heterodyne Infrared Spectrometer)<sup>[1]</sup>  
**HIPWAC** (Heterodyne Instrument for Planetary Winds And Composition)

#### Heterodyne Technique:

- Superimposing Signal + Local Oscillator (LO)
  - all spectroscopic information preserved
- Ultra High Resolution ( $R > 10^7$ )
  - fully resolved lines
  - sensible for dynamics down to m/s
- Local Oscillator:
  - **THIS**: Quantum Cascade Lasers (QCL)
    - tuneable, emitting around 10 $\mu$ m
  - **HIPWAC**: CO<sub>2</sub> Laser
    - very stable, emitting at exact rest frequency of transition

### Method and Motivation:

- Observations of strong absorption features on Venus night side in recent years
- Variation of line shape along planetary disc
- Low Signal to Noise Ratio
  - detailed observations needed
- Analysis of line width yields
  - information about temperature
  - molecular abundances



### Observation of CO<sub>2</sub> Absorption Features:

- Pressure broadened CO<sub>2</sub> absorption features
  - origin between ~60 km and ~95 km
  - induced by thermal emission from the cloud level and above
- Observations
  - March 2012 at McMath-Pierce Solar Telescope at Kitt Peak National Observatory, AZ using **THIS**
  - May 2012 at NASA Infrared Telescope Facility at Mauna Kea Observatory, HI using **HIPWAC**

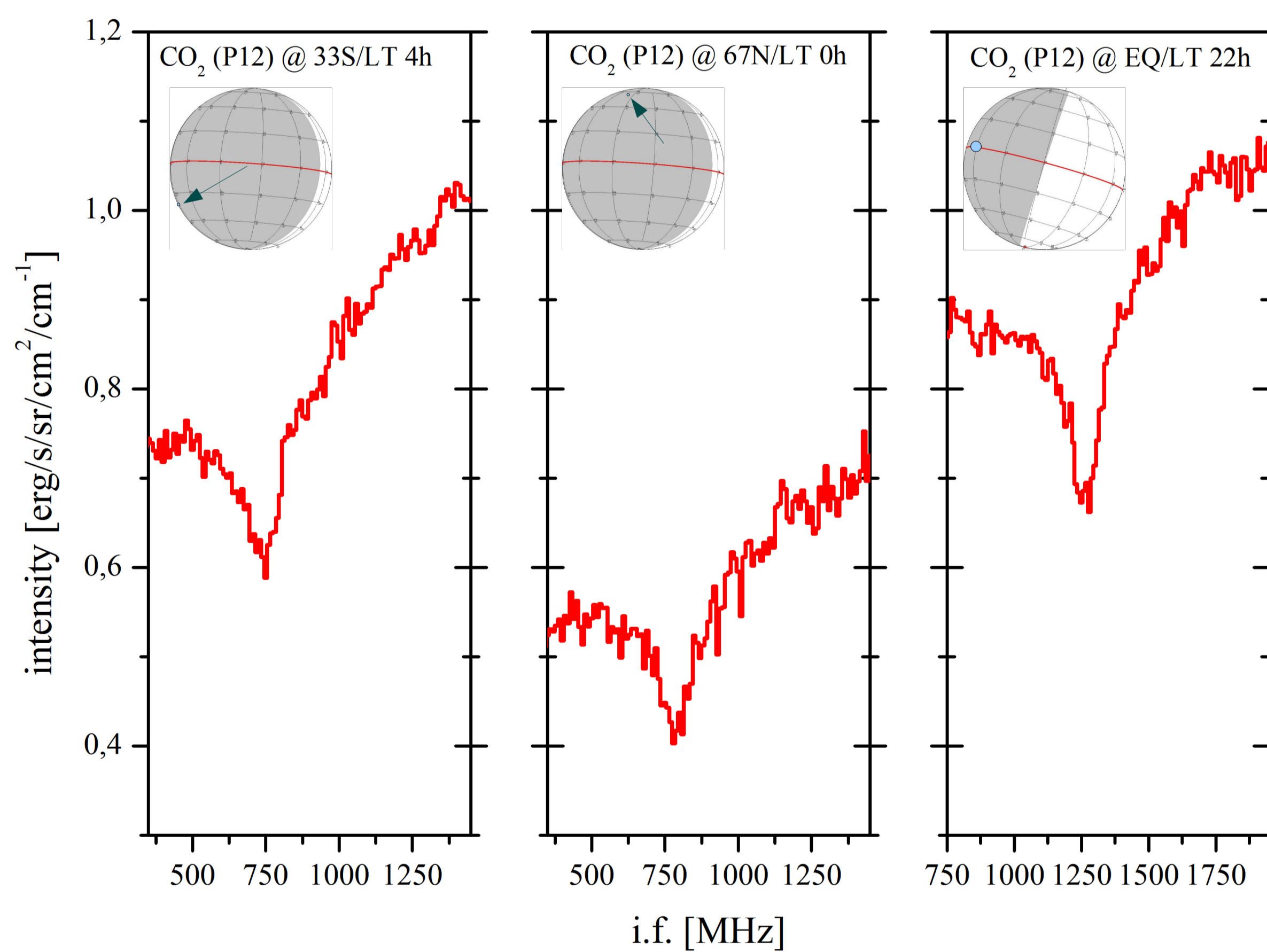


Fig. 5: CO<sub>2</sub> P(12) absorption feature observed at 33°S 4:00 Venusian local time (LT) (left), at 67°N 0:00 am LT (center) in May 2012 and at Equator 22:00 LT (right) in March 2012. The difference in frequency positions of the absorption peak is caused by varying radial velocity between Venus and Earth.

#### • Three Double Side Band (DSB) spectra at different positions and Venusian local time

- variation of signal level
  - dependence on background temperature
- variation of absorption depth and width
  - dependence on temperature/pressure profile

#### • Varying integration time:

$$\tau_{33S/LT4} = 160 \text{ min} \quad \tau_{67N/LT0} = 96 \text{ min} \quad \tau_{EQ/LT22} = 480 \text{ min}$$

### Temperature Distribution in Venus Upper Atmosphere:

- Observation of 33°S Local Time 4h
- Performed in May 2012
- CO<sub>2</sub> P(12) transition @ 951.1923 cm<sup>-1</sup>
- SNR of ~7.5
- Slope due to terrestrial transmission
- Atmosphere probed between 64 km and 94 km altitude
- **First vertical temperature profile from ground-based observations in the mid-infrared**

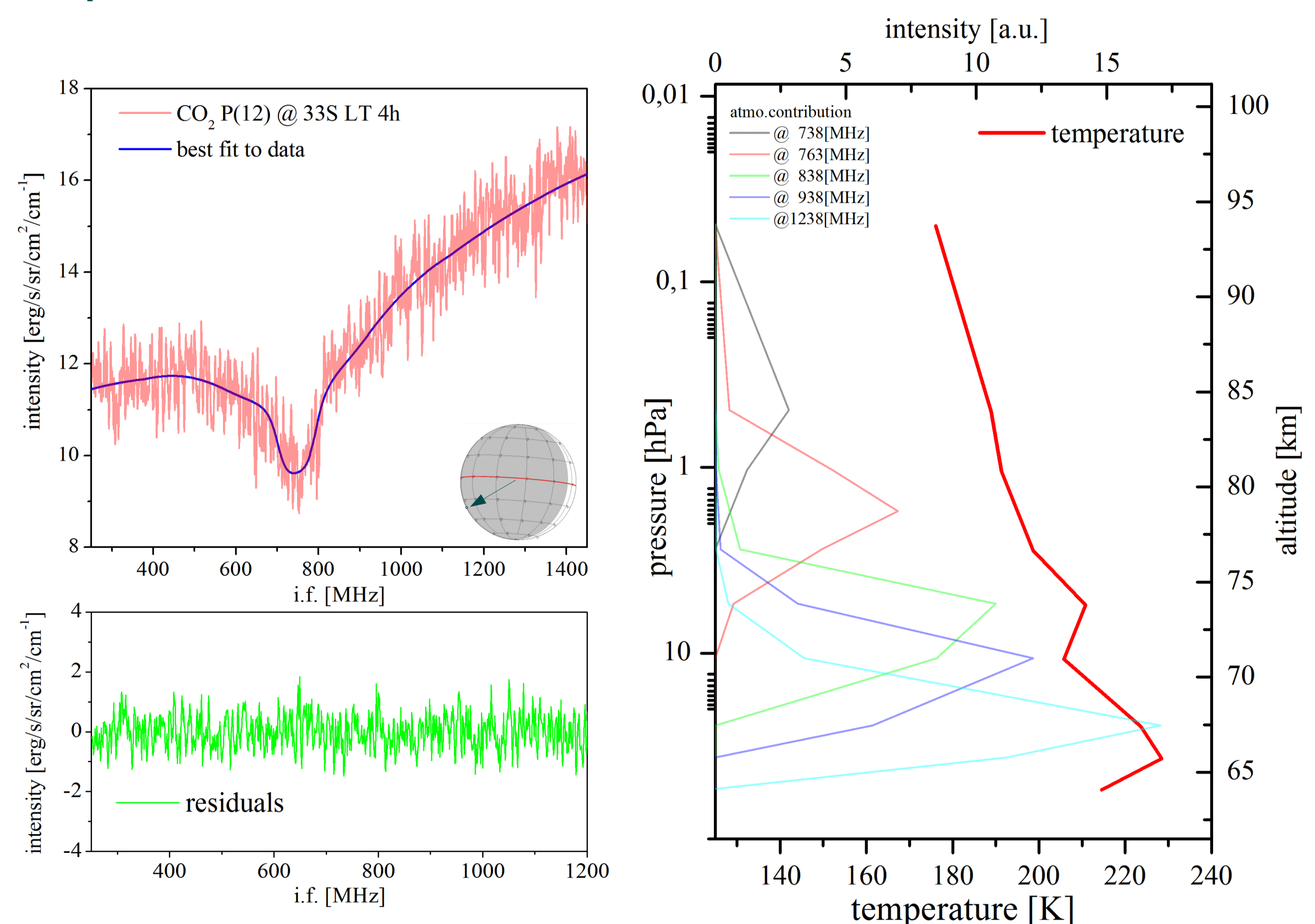


Fig. Left Top: DSB spectrum of the CO<sub>2</sub> P(12) transition at 951.192 cm<sup>-1</sup> (red) acquired with HIPWAC at the NASA Infrared Telescope Facility at Mauna Kea Observatory, HI, USA in May 2012 and computed DSB spectra (blue) using the radiative transfer model CODAT [3] on the basis of the vertical temperature profile shown in the right hand figure.  
Fig. Left Bottom: Residuals (green) between data (red) and fit (blue) in top figure.  
Fig. Right: Vertical temperature gradient (solid red) on the Venusian night side as observed with ground-based heterodyne technique. Dim solid lines represent the contribution of the atmospheric layers to different segments of the retrieved DSB spectrum.

### Comparison to VEX VeRa Profiles:

- Cross-analysis of IR-Het and Venus Express Radio Science Experiment<sup>[2]</sup>
- Simultaneous measurements at 33°S/LT4h
- IR-Het:
  - data acquisition between 19<sup>th</sup> and 21<sup>st</sup> of May
  - higher temperatures from 73 km to 85 km altitude
  - cold upper atmosphere: 176 K @ 94 km
- VeRa:
  - profiles not reliable above ~90 km
  - dependent on upper boundary

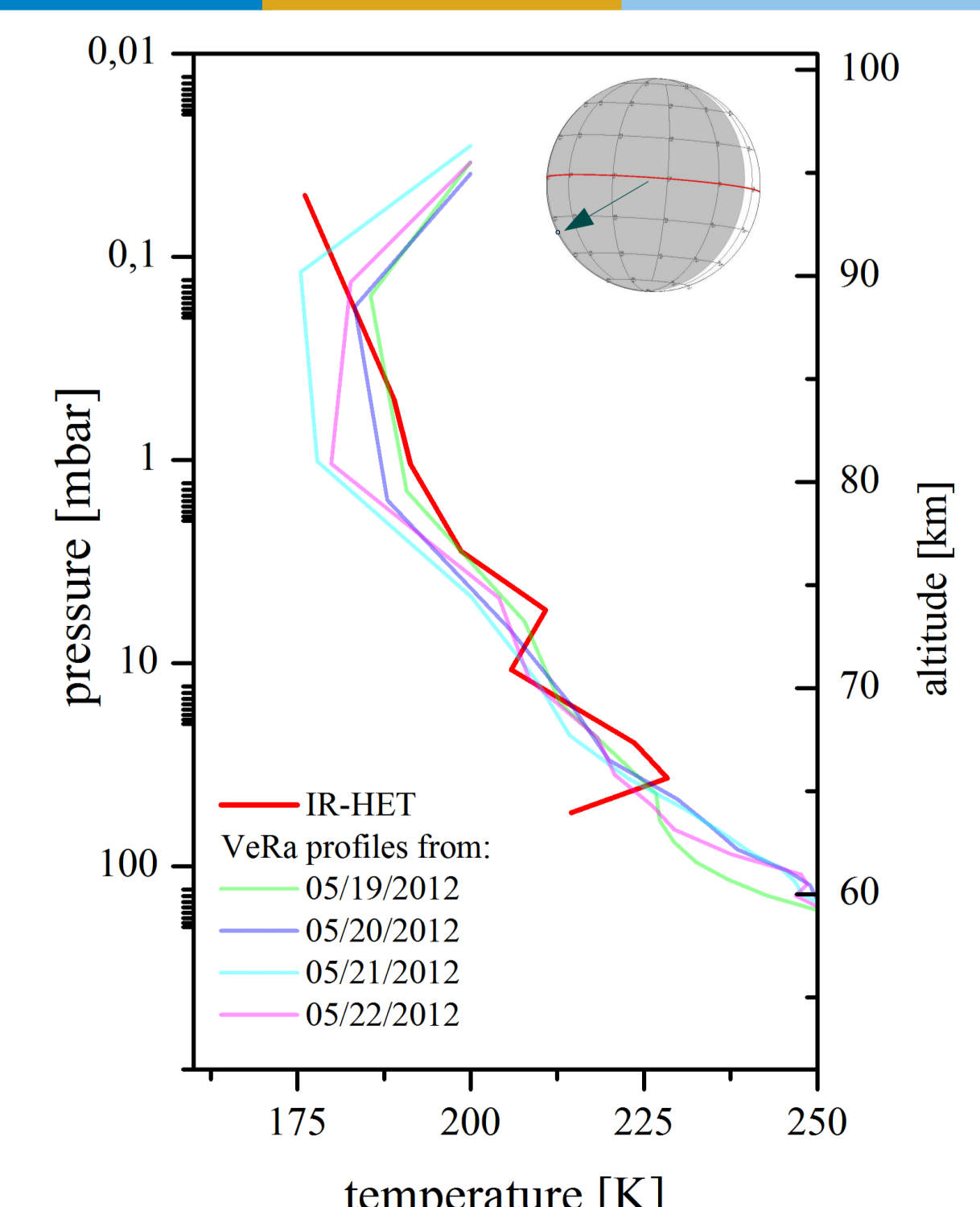


Fig. 7: vertical temperature profiles in the Venus atmosphere as observed by IR-Het and VeRa at around 33S/LT4h

### References:

- [1] Sonnabend, G., Sornig, M., Krötz, P., Stupar, D., Schieder, R.: Ultra high spectral resolution observations of planetary atmospheres using the Cologne tuneable heterodyne infrared spectrometer. *J. of Quantitative Spectr. & Rad. Transfer*, Vol.109, pp.1016 (2008)
- [2] Tellmann, S., Pätzold, M., Häusler, B., Bird, M.K., Tyler, G.L.: Structure of the Venus neutral atmosphere as observed by the Radio Science experiment VeRa on Venus Express. *J. Geophys. Res.*, Vol.114, pp.19 (2009)
- [3] Hewagama, T., Goldstein, J., Livengood, T.A., Buhl, D., Espenak, F., Fast, K., Kostjuk, T., Schmüling, F.: Beam integrated high-resolution infrared spectra: Accurate modeling of thermal emission from extended clear atmospheres. *J. of Quantitative Spectr. & Rad. Transfer*, Vol.109, pp.1081 (2008)