Direct Wind Measurements in the Atmospheres of Mars, Earth and Venus

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Introduction: Infrared heterodyne spectroscopy offers the capability to resolve single molecular transition features by providing ultra high resolving power of $>10^7$. Thus, it is a very sensitive tool to study the dynamics of planetary atmospheres.

The Cologne Tuneable Heterodyne Infrared Spectrometer (THIS) enables ground-based measurements of those transitions and provides direct line-of-sight wind velocities from their Doppler shift [1]. Its tunability offers the possibility to probe targets throughout a wide range of the mid-infrared regime (8-13µm).

Method & Observations: Non local thermodynamic equilibrium (non-LTE) emission of CO_2 around 10 µm occurs due to solar radiation at low pressure levels in the mesospheres of Mars, Earth and Venus. On Mars, the 10 µbar level of the mesosphere can be found at approximately ~80 km altitude, whereas on Venus it is located at around ~110 km. By means of the precise frequency information of the CO_2 emission, the Doppler shift can be directly deduced from the measured spectra and a statement on the predominant wind speeds can be given.

Various observations of the dynamics in the Venusian and Martian atmosphere took place in recent years at the McMath-Pierce Solar telescope on Kitt Peak, Arizona [2][3]. The telescope provides a field of view of 1.7 arcsec, yielding an adequate spatial resolution to determine longitudinal and latitudinal variations. Wind speeds up to approximately 100 m/s on Mars and 150 m/s on Venus were measured with an accuracy of 10 m/s.

On Earth, CO_2 non-LTE emission can not be observed from the ground. Here, stratospheric Ozone can be probed to determine wind velocities at ~32 km altitude. Telluric ozone is detected in absorption using the sun as background emitter. First observations were performed in Cologne, Germany in January 2010.

Results: A great variability of the zonal wind velocities in the atmosphere of Mars was determined during the last 6 years. Mainly seasonal variability was expected and explained by general circulation models.

On Venus the wind contributions need to be distinguished between the zonal super-rotational component and the sub-solar to anti-solar flow which is predominant in high altitudes. It was found, that the wind velocity decreased unexpectedly towards the equatorial region from its maximum in mid-latitudes of around 30 m/s. The sub-solar to anti-solar flow however reached an expected maximum of 150 m/s at the terminator. Variability of a few 10 m/s was found on various time scales.

The telluric ozone observation provided a wind field with a velocity of about 88 m/s with an east-west orientation.

Outlook: Future observations of the dynamics in the atmospheres of Mars and Venus will be performed using the Cologne heterodyne spectrometer. Longtime investigations of the mesospheric winds shall provide more information on the variability and help to understand and outline the differences between our neighbor planets and Earth and to develop more sophisticated circulation models, especially for the Venusian atmosphere.

Stratospheric winds in the Earth atmosphere shall be determined in specific periods during the next years to learn more about dynamical properties and behavior.

References:

[1] Sonnabend, G. et al.: Ultra high spectral resolution observations of planetary atmospheres using the Cologne tuneable heterodyne infrared spectrometer; *JQSRT 109* (2008), 1016-1029

[2] Sornig, M. et al.: Venus upper atmosphere winds from ground-based heterodyne spectroscopy of CO_2 at 10µm; *PSS 56* (2008), 1399-1406

[3] Sonnabend, G. et al.: Mars mesospheric zonal wind around northern spring equinox from infrared heterodyne observations of CO_2; *ICARUS 217* (2012), 315-321