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Submillimetre observations of Venus atmosphere using FLASH and CHAMP+ instruments on APEX

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Abstract

We report the ground-based carbon monoxide (CO), and other minor trace gases, observations of Venus middle atmosphere using submm heterodyne instruments named FLASH [1] and CHAMP+ [2] equipped at the Atacama Pathfinder Experiment (APEX) telescope. The high frequency resolution and multiple frequency bands observations of the Venus CO absorption lines are used to investigate the vertical profiles of temperature, CO, and wind velocity in the Venus middle atmosphere.

1. Introduction

More than a few questions still remain to be solved in the Venus middle/upper atmosphere (around 70–120 km). One of the most important issues is the vertical transient of the global dynamics i.e. the transition from the retrograde super-rotating zonal circulation (a.k.a "super rotation", hereafter abbreviated as RSZ) in the lower atmosphere to the very strong subsolar-to-antisolar flow (SS-AS flow) in the upper thermosphere. Compiling the currently available observational clues after Venus Express and several ground-based observations [e.g., 5–9], now there is no doubt about high importance of understanding the processes responsible for maintaining and driving the variations in the SS-AS and RSZ winds. It is believed that upward propagating gravity waves launched at cloud top level carry their momentum to Venus middle atmosphere where they break and provide a net drag force on the SS-AS wind pattern [3, 4]. Our early observations using the Heinrich Hertz Submillimeter Telescope (HHSMT) suggested that the large variability of the zonal winds around 100 km may be also attributed to the changing nature of this wave breaking [6, 7]. In fact, recent model simulations suggest that such a role of the gravity wave is very likely realistic [10], but still needs confirmation by more observations at various vertical levels in a wider range (~80–130 km), different latitudes, and different local times.

In order to have further observational constraints on the above mentioned mechanism, the best tracer to be observed is CO and its isotopes. By conducting the heterodyne spectroscopy of their rotational transitions at the submm domain, we can retrieve vertical profiles of CO, temperature, and, as the only method, winds at middle/upper atmosphere (as done in [5–9]): the depth and air-pressure broadened width of CO lines provide the information about CO abundance and temperature, and the Doppler shift of the line frequency gives the line-of-sight projection of wind velocity.

Another unexplained topic in the Venus middle atmosphere is the stability of CO_2 atmosphere. The CO_2 chemical-reaction cycle is one of the dominant chemical cycles in the Venus atmosphere. It involves the photodissociation of CO_2 on the dayside, production of O_2, and conversion of CO and O_2 into CO_2. However, since the direct reproduction of $CO+O \rightarrow CO_2$ is spin-forbidden, a certain catalytic chemical reactions are required in order to explain why there is so much CO_2 (96%) and so little CO (~ppmv) in the Venus atmosphere. Halogens are believed to be very important in this context and Cl*Ox* has been proposed to be one of the key catalyses [11], however due to lack of the observations details of such catalytic processes are not constrained yet.

Recently, HCl at 625 GHz was successfully observed by JCMT [12]. Their results showed that the abundance of HCl in Venus surprisingly drops at altitudes above 80 km which exhibits a clear conflict with photochemical model studies. This result implies several possibilities which can bring substantial impacts on the Venus photochemical understanding: such as much rapid photochemical destruction of HCl than the model assumptions and/or strong downward transport of HCl which removes it from the upper atmosphere.

2. Observations and data analysis

Our Venus observations were carried out on 06–07 and 14–15 July 2012 using the CHAMP+ and FLASH instruments, respectively. The apparent angular diameter of Venus was ~35–40″ at the observation dates. CHAMP+ provides the capability of observing double-sideband spectra at different frequency bands, 620–720 GHz and 780–950 GHz, simultaneously. The half-power-beam-widths (HPBW) of CHAMP+ are ~8.8″ and 7.7″ at 691 GHz and 806 GHz (the frequencies at which the submm rotational transitions of ^{12}CO are detected), respectively. For the FLASH observations, we used the 345-GHz band detector which employs a sideband separating receiver. The HPBW of FLASH345 is 18″ at 345 GHz. Both instruments were used with two Fast Fourier Transform Spectrometers with an instantaneous bandwidth of 2.5 GHz each.

The main observed species were ^{12}CO (3–2), (6–5), and (7–6), ^{13}CO (3–2), (6–5), and (8–7). The beam was positioned at several points on the Venus disk including the disk center and the limb of dayside and nightside (**Fig. 1**). In addition to the CO observations, we tried new observations of other tracer gases such as HDO, HCl, and ClO, which are the key species in the Venus atmospheric chemistry.

The data reduction and inversion analysis are currently in progress. In the presented contribution, the day and night differences of the vertical structure of the Venus middle/upper atmosphere will be discussed.

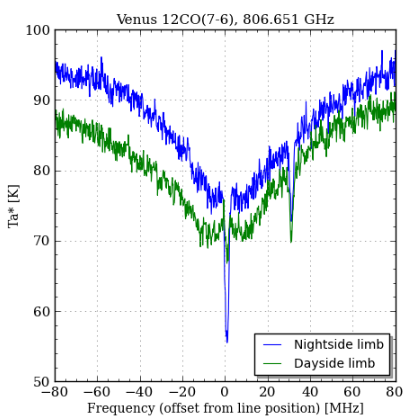

Figure 1: Examples of the Venus ^{12}CO (7–6) spectra observed by CHAMP+/APEX on 06 July, 2012. The spectra from dayside and nightside limbs are shown separately, where different line shapes at the core of absorption spectra indicate large variations in the temperature and CO concentration profiles between day and night. The weak absorption feature at +30 MHz is due to the terrestrial CO absorption.

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