[E] Oral | P (Space and Planetary Sciences)：P-PS Planetary Sciences

Thu. Jun 3, 2021 1:45 PM - 3:15 PM JST | Thu. Jun 3, 2021 4:45 AM - 6:15 AM UTC | Ch.02 Zoom Room 02

[P-PS02] Recent advances of Venus science and coming decades

convener:Takehiko Satoh(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Thomas Widemann(Observatoire de Paris), Kevin McGouldrick(University of Colorado Boulder), Hideo Sagawa(Kyoto Sangyo University), Chairperson:Hideo Sagawa(Kyoto Sangyo University)

Akatsuki, Japan's Venus Climate Orbiter, has been operational in the Venus orbit for more than 5 Earth years, advancing our knowledge mostly about the atmospheric dynamics by feature tracking in the high-resolution imagery. Together with 8 years of coverage made by ESA's Venus Express (2006 - 2014), including spectroscopic information plus plasma measurements, we are in another golden age of Venus science decades after the landing missions of the USA and the former USSR in the 1970's. In addition, the Venus community has been eager to realize next generation missions to Venus. This session will cover all aspects of science related to Venus, either by observationally (including future missions) or by theoretically, about the planet itself or its surrounding environment or even implications to the exoplanets. Contributions by experts and by early-career researchers are all welcome.

1:45 PM - 1:50 PM JST | 4:45 AM - 4:50 AM UTC

[PPS02-13] Introduction

1:50 PM - 2:05 PM JST | 4:50 AM - 5:05 AM UTC

[PPS02-14] Spatial distribution of HCl abundance at the cloud top of Venus retrieved from IRTF/iSHELL spectra

*Takao M. Sato[1], Hideo Sagawa[2] (1.Hokkaido Information University, 2.Kyoto Sangyo University)

2:05 PM - 2:30 PM JST | 5:05 AM - 5:30 AM UTC

[PPS02-15] Day-night contrast of the atmospheric circulation at the cloud top of Venus revealed by Akatsuki LIR

★Invited Papers

Kiichi Fukuya[1], *Takeshi Imamura[2], Makoto Taguchi[3], Tetsuya Fukuhara[3], Toru Kouyama[4], Takeshi Horinouchi[5], Javier Peralta[6], Masahiko Futaguchi[11], Takeru Yamada[3], Takao M. Sato[7], Atsushi Yamazaki[8], Shin-ya Murakami[10], Takehiko Satoh[8], Masahiro Takagi[9], Masato Nakamura[8] (1.Department of Earth and Planetary Science, The University of Tokyo, Japan, 2.Graduate School of Frontier Sciences, The University of Tokyo, Japan, 3.Rikkyo University, Japan, 4.Artificial Intelligence Research Center, National Institute of Advanced Industrial Science and Technology, Japan, 5.Faculty of Environmental Earth Science, Hokkaido University, Japan, 6.Instituto de Astrofísica e Ciências do Espaço, Portugal, 7.Space Information Center, Hokkaido Information University, Japan, 8.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, Japan, 9.Faculty of Science, Kyoto Sangyo University, Japan, 10.Research and Education Center for Natural Sciences, Keio University, 11.Omori Medical Center, Toho University, Japan)

2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC

[PPS02-16] Identification and characterization of quiescent cloud region "CALM" in the Akatsuki and Venus Express data

*Takehiko Satoh[1,2], Choon Wei Vun[3,2], Takeshi Horinouchi[4], Kevin McGouldrick[5], Takao M. Sato[6] (1.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 2.Dept of Space and Astronautical Science, SOKENDAI, 3.ZMP Inc., 4.Hokkaido University, 5.University of Colorado, Boulder, 6.Hokkaido Information University)

2:45 PM - 3:00 PM JST | 5:45 AM - 6:00 AM UTC

[PPS02-17] EnVision: Understanding why Earth's closest neighbour is so different

*Thomas Widemann[1], Richard Ghail[2], Colin Wilson[3], Dmitri Titov[4] (1.Observatoire de Paris, France, 2.Royal Holloway, U. of London, UK, 3.U. of Oxford, UK, 4.ESA-ESTEC, Noordwijk, Netherlands)

3:00 PM - 3:15 PM JST | 6:00 AM - 6:15 AM UTC

[PPS02-18] Discussion

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[P-PS02] Recent advances of Venus science and coming decades

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1:45 PM - 1:50 PM

[PPS02-13]Introduction

Spatial distribution of HCl abundance at the cloud top of Venus retrieved from IRTF/iSHELL spectra

*Takao M. Sato[1], Hideo Sagawa[2]

1. Hokkaido Information University, 2. Kyoto Sangyo University

The atmosphere of Venus can be divided into three altitudinal regions with different chemical conditions. High temperature and pressure and the absence of effective photolysis processes are dominant in the lower atmosphere up to 60 km where solar radiation longer than UV can reach. The middle atmosphere between 60 and 110 km is controlled by photochemistry driven by solar UV radiation. In the upper atmosphere above 110 km, dissociation, ionization, and ionospheric reactions are important processes. HCl is the primary chlorine reservoir in the Venus atmosphere bellow 110 km. Highly reactive chlorine species (ClO_x) is produced by solar UV photolysis of HCl and has been proposed to play an important role in catalysis of CO and O recombination to CO_2, thereby stabilizing the CO_2 atmosphere. Chlorine chemistry is also linked to sulfur chemistry and its understanding is necessary to explain the observed vertical distribution of SO_2.

Interestingly, there is a large inconsistency between the HCl abundances measured by spacecraft and ground-based telescopes. The SOIR instrument onboard Venus Express measured its abundance as less than ~50 ppb at the cloud top (~70 km) increasing to 1 ppm in the upper atmosphere (~110 km). Such a vertical trend conflicts with the vertically constant profile (up to ~80 km) reported by sub-mm ground-based observations. Near-infrared ground-based observations also showed the HCl abundance at the cloud top as ~500 ppb, which are nearly one order of magnitude larger than the SOIR results. The reason for this inconsistency has not been understood yet.

In order to re-examine HCl abundance at the cloud top, we carried out a high-resolution spectroscopy of Venus’ dayside at wavelengths of 3.580-3.934 μm with IRTF/iSHELL on August 5-7, 2018 and August 18-20, 2020 (UT). Taking the full advantages of its high spectral resolution of R ~ 75,000, iSHELL resolved individual HCl lines with sufficient separation from terrestrial lines. In this presentation, we will show spatial distribution of HCl abundance at the cloud top, retrieved from processed spectra and compare them with previous studies.

Keywords: Venus, atmosphere, HCl, ground-based observation, radiative transfer

Day-night contrast of the atmospheric circulation at the cloud top of Venus revealed by Akatsuki LIR

Kiichi Fukuya[1], *Takeshi Imamura[2], Makoto Taguchi[3], Tetsuya Fukuhara[3], Toru Kouyama[4], Takeshi Horinouchi[5], Javier Peralta[6], Masahiko Futaguchi[11], Takeru Yamada[3], Takao M. Sato[7], Atsushi Yamazaki[8], Shin-ya Murakami[10], Takehiko Satoh[8], Masahiro Takagi[9], Masato Nakamura[8]

1. Department of Earth and Planetary Science, The University of Tokyo, Japan, 2. Graduate School of Frontier Sciences, The University of Tokyo, Japan, 3. Rikkyo University, Japan, 4. Artificial Intelligence Research Center, National Institute of Advanced Industrial Science and Technology, Japan, 5. Faculty of Environmental Earth Science, Hokkaido University, Japan, 6. Instituto de Astrofísica e Ciências do Espaço, Portugal, 7. Space Information Center, Hokkaido Information University, Japan, 8. Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, Japan, 9. Faculty of Science, Kyoto Sangyo University, Japan, 10. Research and Education Center for Natural Sciences, Keio University, 11. Omori Medical Center, Toho University, Japan

In spite of the importance of elucidating the atmospheric circulation of Venus from the viewpoint of planetary meteorology, winds at the cloud top of Venus have been measured predominantly on the dayside. Prominent poleward drifts have been observed with dayside cloud tracking and interpreted to be caused by thermal tides and a Hadley circulation; however, the lack of nightside measurements over broad latitudes has prevented the unambiguous characterization of these components. Here, we obtain cloud-tracked winds at all local times for the first time using thermal infrared images taken by LIR onboard the Venus orbiter Akatsuki. To suppress the random noise and topography-related stationary features present in the original images, we applied a moving average in the time domain in a coordinate system that rotates with the superrotating background atmosphere, thereby highlighting drifting cloud patterns. The occurrence of prominent equatorward flows was found on the nightside, resulting in null meridional velocities when these are zonally averaged. The velocity structure of the thermal tides were unambiguously determined for the first time. The semidiurnal tide was found to have an amplitude large enough to contribute to the maintenance of the atmospheric superrotation. The weakness of the mean meridional flow at the cloud top implies that the poleward branch of the Hadley circulation exists above the cloud top and the equatorward branch in the clouds. The LIR data, combined with the analysis method developed in this paper, would enable characterization of various types of atmospheric motions including waves and the mean flow with emphasis on the localtime dependence.

Keywords: Venus, Akatsuki, atmosphere

Identification and characterization of quiescent cloud region "CALM" in the Akatsuki and Venus Express data

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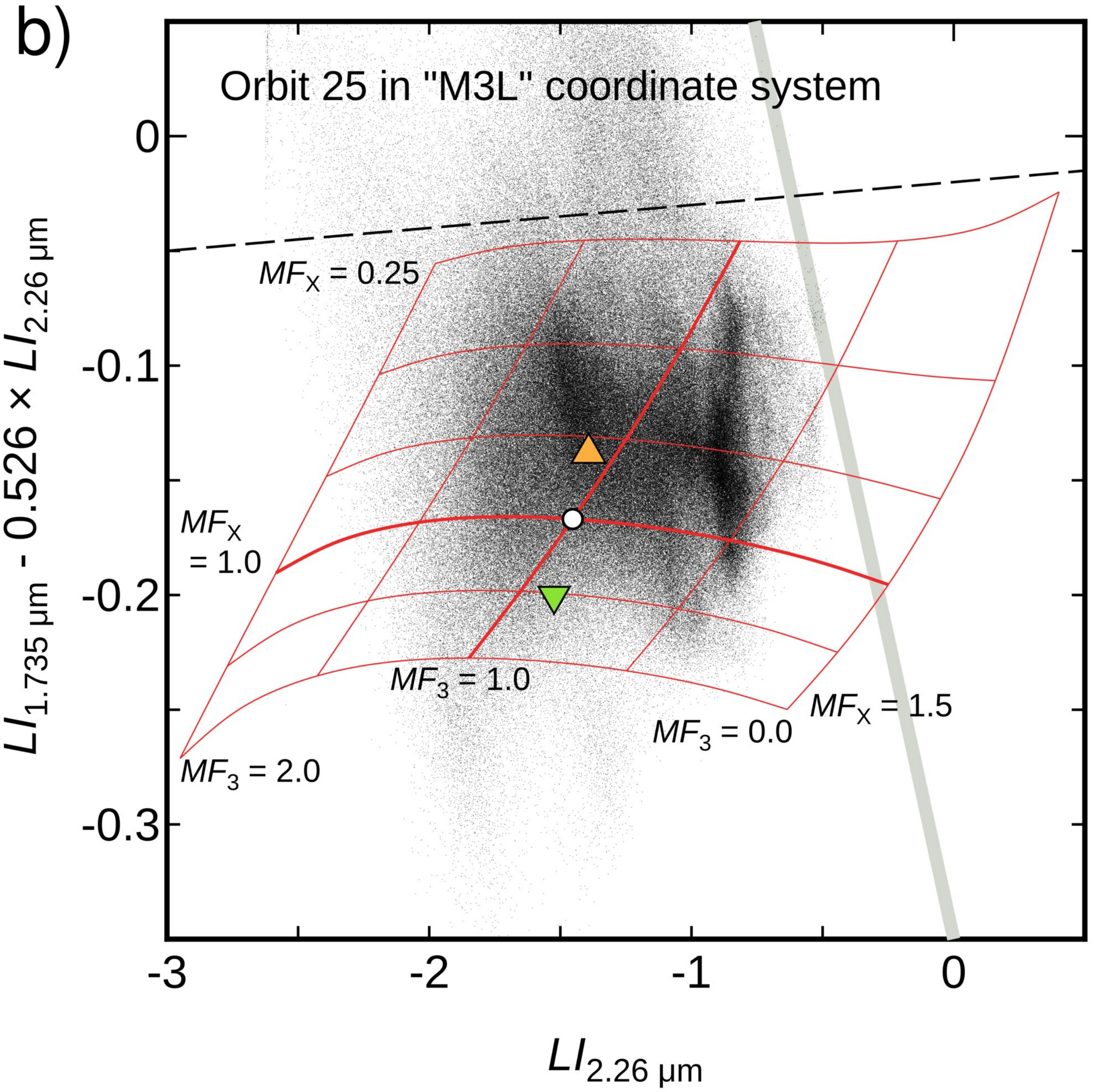
1. Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 2. Dept of Space and Astronautical Science, SOKENDAI, 3. ZMP Inc., 4. Hokkaido University, 5. University of Colorado, Boulder, 6. Hokkaido Information University

"CALM" was identified in the Akatsuki IR2 data acquired during Orbits 24 and 25 (August 2016) once data (in 2.26- and 1.735-um filters) were plotted in a special coordinates: the horizontal axis is logarithm of radiance at 2.26 um while vertical axis (basically logarithm of radiance at 1.735 um) has been sheared such that the curve corresponding to varying amount of Mode 3 particles becomes almost level (M3L = Mode 3 Leveled). CALM appears as a concentration of data points in this correlation plot (Clouds Aligned Linearly in M3L coordinates) and is interpreted as relatively quiescent region in which aerosol sizes are determined by equilibrium. Because IR2 stopped working in December 2016, the available data set is limited. To identify more CALM-like regions and to characterize them, we have examined the data acquired by VIRTIS-M onboard Venus Express. Examples of CALM-like regions in VEx/VIRTIS-M data will be presented along with physical insights obtained through comparison with Akatsuki/IR2 data.

Keywords: cloud, microphysics, sulfuric acid, Akatsuki, Venus Express


b)
Orbit 25 in "M3L" coordinate system
MF_X = 0.25
MF_X = 1.0
MF_X = 1.5
MF_3 = 1.0
MF_3 = 0.0
MF_3 = 2.0
0
-0.1
-0.2
-0.3
-3
-2
-1
0
LI_1.735 μm - 0.526 × LI_2.26 μm
LI_2.26 μm

EnVision: Understanding why Earth's closest neighbour is so different

*Thomas Widemann[1], Richard Ghail[2], Colin Wilson[3], Dmitri Titov[4]

1. Observatoire de Paris, France, 2. Royal Holloway, U. of London, UK, 3. U. of Oxford, UK, 4. ESA-ESTEC, Noordwijk, Netherlands

EnVision is a proposed orbiter mission aiming at determining the nature and current state of Venus' geological evolution and its relationship with the atmosphere, to understand how and why Venus and Earth evolved so differently. It is is one of two M5 mission concepts in Phase A study with a final down-selection expected in June 2021. EnVision’s overall science goals are

- to **characterise** the sequence of events that generated the regional and global surface features of Venus, and characterize the geodynamics framework that controls the release of internal heat over Venus history;

- to **search** for ongoing geological processes and determine whether the planet is active in the present era;

- to **characterise** regional and local geological units, to better assess whether Venus once had condensed liquid water on its surface and was thus perhaps hospitable for life in its early history.

EnVision will deliver new insights into geological history through complementary imagery, polarimetry, radiometry and spectroscopy of the surface coupled with subsurface sounding and gravity mapping; it will search for thermal, morphological, and gaseous signs of volcanic and other geological activity; and it will trace the fate of key volatile species from their sources and sinks at the surface through the clouds up to the mesosphere.

EnVision’s science payload consists of VenSAR, a dual polarization S-band radar also operating as microwave radiometer, three spectrometers VenSpec-M, VenSpec-U and VenSpec-H designed to observe the surface and atmosphere of Venus, and the Subsurface Radar Sounder (SRS), a High Frequency (HF) sounding radar to probe the subsurface. These are complemented by a radio science investigation which achieves gravity mapping and radio occultation of the atmosphere, for a comprehensive investigation of the Venusian surface, interior and atmosphere and their interactions.

Keywords: Venus, Planetary surface, Planetary Interior, Planetary Atmosphere

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[PPS02-18]Discussion