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

Thu. Jun 3, 2021 9:00 AM - 10:30 AM JST | Thu. Jun 3, 2021 12:00 AM - 1:30 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:Kevin McGouldrick(University of Colorado Boulder)

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.

9:00 AM - 9:05 AM JST | 12:00 AM - 12:05 AM UTC

[PPS02-01] Introduction

9:05 AM - 9:20 AM JST | 12:05 AM - 12:20 AM UTC

[PPS02-02] Mission Concept Study for Japan’s Next Venus Exploration

*Ryoma Yamashiro[1], Masato Nakamura[1], Chikako Hirose[1], Nobuaki Ishii[1], Ryoh Nakamura[1], Takehiro Matsumoto[1], Yuuki Akiyama[1], Junichi Nakatsuka[1], Kenta Goto[1], Hiroyuki Toyota[1], Tomoaki Toda[1], Atsushi Yamazaki[1], Takehiko Satoh[1], Takumi Abe[1], Toru Kouyama[2], Masataka Imai[2], Hideo Sagawa[3], Mitsuteru Sato[4], Yukihiro Takahashi[4], Makoto Taguchi[5], Tetsuya Fukuhara[5], Takao M. Sato[6], Shin-ya Murakami[7], Yoshi-Yuki Hayashi[8], Takeshi Imamura[9] (1.Japan Aerospace eXploration Agency, 2.National Institute of Advanced Industrial Science and Technology, 3.Kyoto Sangyo Univ., 4.Hokkaido Univ., 5.Rikkyo Univ., 6.Hokkaido Information Univ., 7.Keio Univ., 8.Kobe Univ., 9.Tokyo Univ.)

9:20 AM - 9:45 AM JST | 12:20 AM - 12:45 AM UTC

[PPS02-03] Venus Atmospheric Structure Investigation (VASI) on the Proposed DAVINCI+ Probe

★Invited Papers

*Ralph Lorenz[1], James Garvin[2], Natasha Johnson[2], Stephanie Getty[2], Giada Arney[2], Francois Forget[4], Sebastien Lebonnois[4], Noam Izenberg[1], David Atkinson[3], David Crisp[3] (1.Johns Hopkins University Applied Physics Laboratory, 2.NASA Goddard SpaceFlight Center, 3.Jet Propulsion Laboratory, 4.LMD, Universite de Paris)

9:45 AM - 10:00 AM JST | 12:45 AM - 1:00 AM UTC

[PPS02-04] Venus cloud-aerosol observation using Life-signature Detection Microscope (Venus LDM)

*Satoshi Sasaki[1], Akihiko Yamagishi[2], Yoshitaka Yoshimura[3], Keigo Enya[4], Atsuo Miyakawa[2], Sosuke Ohno[5], Kazuhisa Fujita[4], Tomohiro Usui[4], Sanjay Limaye[6] (1.Tokyo University of Technology, 2.Tokyo University of Pharmacy and Life Sciences, 3.Tamagawa University, 4.JAXA, 5.Chiba Institute of Technology, 6.University of Wisconsin)

10:00 AM - 10:15 AM JST | 1:00 AM - 1:15 AM UTC

[PPS02-05] Venus, an astrobiology target

*Sanjay S Limaye[1] (1.University of Wisconsin Madison)

10:15 AM - 10:30 AM JST | 1:15 AM - 1:30 AM UTC

[PPS02-06] Discussion

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

[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:Kevin McGouldrick(University of Colorado Boulder)
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9:00 AM - 9:05 AM

[PPS02-01]Introduction

Mission Concept Study for Japan’s Next Venus Exploration

*Ryoma Yamashiro[1], Masato Nakamura[1], Chikako Hirose[1], Nobuaki Ishii[1], Ryoh Nakamura[1], Takehiro Matsumoto[1], Yuuki Akiyama[1], Junichi Nakatsuka[1], Kenta Goto[1], Hiroyuki Toyota[1], Tomoaki Toda[1], Atsushi Yamazaki[1], Takehiko Satoh[1], Takumi Abe[1], Toru Kouyama[2], Masataka Imai[2], Hideo Sagawa[3], Mitsuteru Sato[4], Yukihiro Takahashi[4], Makoto Taguchi[5], Tetsuya Fukuhara[5], Takao M. Sato[6], Shin-ya Murakami[7], Yoshi-Yuki Hayashi[8], Takeshi Imamura[9]

1. Japan Aerospace eXploration Agency, 2. National Institute of Advanced Industrial Science and Technology, 3. Kyoto Sangyo Univ., 4. Hokkaido Univ., 5. Rikkyo Univ., 6. Hokkaido Information Univ., 7. Keio Univ., 8. Kobe Univ., 9. Tokyo Univ.

Japan's Venus Climate Orbiter, AKATSUKI has been observing Venus since its orbital injection in 2015, and has made significant achievements in elucidating phenomena in the Venusian atmosphere, such as super-rotation and gravity wave. Recently, a mysterious flash has been detected which could be a promising sign of lightning strike. On the other hand, AKATSUKI is already in the late operation phase and the end of its operation is in sight. We are considering the next generation of Venus missions to continue to investigate this interesting and enigmatic neighboring planet and to understand its unknown phenomena.

As one such mission, we are considering a project to put small probes into orbit around the Lagrange points L1 and L2 of Venus, respectively, to observe both the day and night sides of Venus continuously and simultaneously. This project was named PLANET-D after PLANET-C, the name of AKATSUKI when it was planned, and the two probes were named PLANET-D1 and PLANET-D2 respectively. Under the plan, the two spacecraft will initially be carried as a single unit on the launcher, launched, and once in LEO, will be injected into the Earth-Venus transiting orbit on a kick stage located between the launcher and the spacecraft. The spacecraft will then be controlled by the propulsion system in the vicinity of Venus and will first enter the L1 Lissajous orbit of Venus. After that, PLANET-D1 and PLANET-D2 will separate on the Venus L1 Lissajous orbit, PLANET-D1 will keep the same orbit, and PLANET-D2 will transfer to the Venus L2 Lissajous orbit. Each spacecraft will control its own orbit to maintain its orbit, and continue observations of Venus from two directions via X-band using different stations or in the manner to halve a visibility for each spacecraft.

The Epsilon rocket, Japan's small solid rocket, was tentatively set as the launch vehicle, and the system design of the spacecraft was carried out using the technical results of AKATSUKI and HAYABUSA2, and the results of the subsystem study of the future mission, DESTINY+. The Orbital Maneuver Engine (OME) for planetary transit is mounted only on PLANET-D1, while PLANET-D2 has only a small propulsion system, the Reaction Control System (RCS), for transfer between Venus L1 and L2 and for maintaining and controlling its own orbit, Venus L2 Lissajous. Due to the difference of the propulsion system, the mass of PLANET-D1 and PLANET-D2 are different, 145 kg and 55 kg respectively. The timing of the launch is better in 2031 than in the Earth-Venus meeting cycle.

Currently, the science community is discussing what should be observed on Venus from the viewpoint of planetary science. In addition to the Venusian meteorology targeted by AKATSUKI, many new themes are proposed, such as atmospheric chemistry, atmospheric escape, and geologic processes. The detail design of PLANET-D will be revised and updated in response to a demand from the science community.

Keywords: Venus, Exploration, Lagrange point

Venus Atmospheric Structure Investigation (VASI) on the Proposed DAVINCI+ Probe

*Ralph Lorenz[1], James Garvin[2], Natasha Johnson[2], Stephanie Getty[2], Giada Arney[2], Francois Forget[4], Sebastien Lebonnois[4], Noam Izenberg[1], David Atkinson[3], David Crisp[3]

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Only a single near-surface profile exists of the atmosphere of our twin planet, that obtained in 1985 by the VEGA-2 lander. The handful of other probe missions have very limited vertical resolution, or sensor failures. Unlike altitudes above 40km, which have been relatively well-surveyed by radio occultation profiles from orbiter missions, the fine temperature structure of lowest part of the Venus atmosphere must be interrogated by direct measurement. This structure is important in several respects. First, the structure and composition reflects the interactions between surface and atmosphere of an ‘exoplanet in our back yard’ which may be much more typical than are those of Earth. Secondly, there are indications that particularly interesting phenomena may occur on Venus, not seen in the atmospheres of Earth, Mars or Titan (but analogous to aspects of ocean stratification on Earth) : the VEGA-2 profile is impossible to reconcile with a profile that is both convectively stable and compositionally uniform. A favored hypothesis is that the lowest few kilometers are compositionally denser (lower N2). The supercritical thermodynamics of carbon dioxide add to the rich possibilities in this region.

The exchange of angular momentum between the retrograde, slowly-rotating Venus and its dense atmosphere is reflected in the wind profile, which can now be interpreted by global circulation models. Again, while cloud-top (60-70km) winds are now well-known from Akatsuki and preceding missions, very little data exist on winds in the hidden lowest 40km. Doppler tracking, turbulence measurements, and trajectory reconstruction from descent imaging will shed unprecedented light on the lower atmospheric dynamics.

DAVINCI+ is presently concluding a Phase A study in NASA’s Discovery program, with possible selection in summer 2021 for flight in the latter half of this decade. This presentation will review how the VASI’s measurements of pressure, temperature and wind, far superior in resolution and/or quantity to those of previous missions, may improve our understanding of Venus and complement DAVINCI+’s composition measurements and imaging.

Keywords: Atmosphere, Venus, Convection, Wind, Turbulence

DAVINCI+

Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging Plus

Venus cloud-aerosol observation using Life-signature Detection Microscope (Venus LDM)

*Satoshi Sasaki[1], Akihiko Yamagishi[2], Yoshitaka Yoshimura[3], Keigo Enya[4], Atsuo Miyakawa[2], Sosuke Ohno[5], Kazuhisa Fujita[4], Tomohiro Usui[4], Sanjay Limaye[6]

1. Tokyo University of Technology, 2. Tokyo University of Pharmacy and Life Sciences, 3. Tamagawa University, 4. JAXA, 5. Chiba Institute of Technology, 6. University of Wisconsin

Much of the size and shape information about of Venus aerosols forming the haze and the cloud layer is obtained from indirect inferences from analysis of variation of polarization with phase angle and the glory feature from Venus images, together from nephelometers and particle spectrometers on descent probes. The particles are inferred to be spherical and it desirable to obtain the size/shape information about the particles, particularly the large particles (> 3 μm) whose shape is uncertain.

Microscopic imaging of Venus aerosols can be an attractive measure for the *in situ* particle characterization of Venus' cloud layer. Direct measurements with a fluorescence microscope can provide information on the biochemical characteristics, as well as morphology, density of the particles.

Recently, a fluorescence microscope system for life-signature detection on Mars surface (Mars LDM) has been designed and under development. Application of this system is promising to observe Venus cloud particles, upon overcoming several challenges including strong acidity and the corrosive effects of the sulfuric acid (~75%) of the aerosol.

Various aerial platforms for long duration sampling of the Venus clouds have been proposed or considered, and further technical development is needed. In addition, an aerosol collection system is needed for microscopic imaging. In this context, a fluorescence imaging approach is proposed in combination with a collector based on impactors for the Venus clouds. For the preparation of the system, we identify the following main challenges:

(1) What kind of microorganisms can be used as models for the instrument performance evaluation?

(2) What fluorescent stains can be used in the strong acidic condition?

(3) How can we interpret the fluorescence microscope images of the particles?

Discussions on these questions and proposal for approaches will be performed for an *in situ* bio/chemical and physical characterization system for Venus cloud particles based on fluorescence microscopy. We also identify the challenges and describe our approach to overcoming them for a fluorescence microscope based on an *in situ* bio/chemical and physical characterization instrument for use in the Venus clouds, using suitable aerial platform.

Keywords: life signature detection microscope, Venus cloud

Venus, an astrobiology target

*Sanjay S Limaye[1]

1. University of Wisconsin Madison

The interest in the possibility of life on Venus is driven not just by curiosity about life originating in another Earth-like environment, but because of the possibility that life may be playing a critical role in the planet's present, and possibly its past, atmospheric state. The brilliance of Venus in the night sky (as viewed from Earth) is due to its highly reflective cloud cover, about 28 km thick at the equator. Its spectral albedo is about 90% at wavelengths > 500 nm, but it drops gradually to about 40% around 370 nm before rising slightly at shorter wavelengths. This albedo drop is due to the presence of several absorbers in the atmosphere and the cloud cover. A very large fraction of the energy absorbed by Venus is at ultraviolet wavelengths with sulfur dioxide above the clouds contributing to the absorption below 330 nm; however, the identities of the other absorbers remain unknown. The inability to identify the absorbers that are responsible for determining the radiative energy balance of Venus over the last century is a major impediment to understanding how the planet "works", a major component of NASA's efforts in planetary exploration. Limaye et al. (*1*) presented a hypothesis suggesting that cloud-based microbial life could be contributors to the spectral signatures of Venus' clouds, building upon previous suggestions of the possibility of life in the clouds of Venus (*2-5*).

We suggest a set of four interconnected themes for the exploration of Venus as an astrobiology target –(i) investigations focused on the likelihood that liquid water existed on the surface in the past leading to the potential for the origin and evolution of life, (ii) investigations into the potential for habitable zones within Venus' clouds and Venus-like atmospheres, (iii) theoretical investigations into how active aerobiology may impact the radiative energy balance of Venus' clouds and Venus-like atmospheres, and (iv) application of these investigative themes towards better understanding the atmospheric dynamics and habitability of exoplanets. These themes can serve as a basis for proposed Venus Astrobiology Objectives and suggestions for measurements for future missions, as per the goals and objectives developed by the Venus Exploration Analysis Group (VEXAG), which is sponsored by NASA to plan for the future exploration of Venus. Similarly, they can inform laboratory work that can begin now in support of potential mission approaches and instruments and their required technical development. The scientific investigation of Venus has also been discussed in two recent reports - Search for Life across Space and Time (National Academies of Sciences and Medicine 2017) and "An Astrobiology Strategy for the Search for Life in the Universe" (National Academies of Sciences and Medicine 2019).

Additional information about the astrobiology interest in future exploration of Venus can be found in the Venus Collection to be published in Astrobiology in the coming months. This collection will include papers prepared following the first workshop, "Habitability of the Venus Cloud Layer" held in Moscow in October 2019 with support from the Russian Academy of Science and NASA.

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Keywords: Venus, Clouds, Habitability, Future exploration

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

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[PPS02-06]Discussion