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# Current Status of Venus Climate Orbiter Akatsuki

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## Abstract

Akatsuki is Japan's first mission to Venus with strong interest in its atmospheric dynamics. Launched in May 2010 but the orbit insertion in December 2010 failed. The healthy spacecraft will re-encounter Venus in late 2015 and another orbit insertion will be performed so as to achieve the originally planned science in orbit.

## 1. An overview of Akatsuki mission

Akatsuki, AKA as the Venus Climate Orbiter, is the 24th scientific space mission of ISAS, Japan. The mission, with strong support by international community, was proposed and approved in 2001. The Akatsuki mission has a close relationship with ESA's Venus Express as these are to date the only two active Venus missions since Magellan of the U.S.A.

### 1.1 Scientific objectives of Akatsuki

Akatsuki's primary mission is to understand the mechanism of peculiar atmospheric circulation of Venus (super rotation) which is 60 times faster (at ~70 km altitude) than rotation of the solid body. Such a strong shear should, sooner or later, be eliminated by friction if no maintenance mechanism works. Other targets of Akatsuki (ex. the mineralogy and possible volcanism on the ground and lightning) are thought to somehow contribute to drive the super rotation. The high-priority exploration of the Venusian meteorology would ultimately lead us to better understandings of planetary fluid dynamics.

### 1.2 Instruments on board Akatsuki

Akatsuki is a 3-axis stabilized spacecraft with 5 imaging instruments (Fig. 1), weighing some 500 kg including the fuel (almost 200 kg). The spacecraft and the orbit were so designed that Akatsuki performs just like a geo-stationary meteorological satellite but around Venus. The elongated 30-hour period orbit gives the spacecraft an angular velocity comparable to the super-rotating atmosphere in most places of the orbit (Fig. 2). Small-scale convections, disturbances, and waves, that may contribute maintenance of the super rotation, would be identified and tracked throughout the mission life of more than two Earth years.

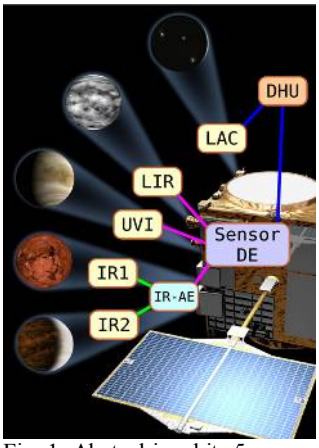

Fig. 1: Akatsuki and its 5 on-board sensors

Five on-board sensors will probe various depths of the atmosphere. UVI (Ultra-Violet Imager) images reflected sunlight in 2 wavelengths, sensitive to the cloud tops, $SO_2$ and unknown UV absorber. IR1 images reflected sunlight at 0.90 μm AND emissions from the deeper levels (originating almost from the ground surface) at 0.90, 0.97, and 1.01 μm on the night side of Venus. IR2 utilizes a similar technique in 1.73- and 2.3-μm windows. CO absorption (2.32 μm) and $CO_2$ absorption (reflected sunlight) at 2.02 μm are also the targets of IR2.

The Venus clouds are opaque in long-wavelength IR region in which LIR (8-12 μm camera) senses the

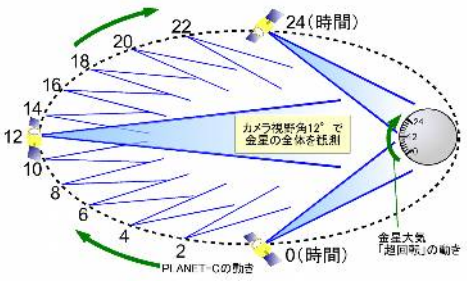

Fig. 2: Akatsuki's elongated 30-hour period orbit

temperature at the cloud top level. LAC (Lightning

and Airglow Camera) is unique because of its high-speed sampling (25,000 Hz). This should enable us to detect natural lightning events in Venus atmosphere, of which existence has been long controversial.High-resolution vertical profile of the atmosphere will also be acquired by the radio occultation, for which an Ultra-Stable Oscillator (USO) is on board Akatsuki. As the spacecraft will be in an equatorial orbit, equatorial and low-latitude regions (the strongest solar heating of atmosphere takes place) will be studied more extensively than before.

## 2. Launch, Cruising, and VOI-1

Akatsuki was successfully launched on 21 May 2010, by a H-II A 202 launcher, from the Tanegashima Space Center, Japan. The accuracy of the initial trajectory was excellent that eliminated the needs of orbit correction when the spacecraft came in the range of Usuda Deep Space Center half a day after the launch. All functions of the spacecraft were found good and three on-board cameras, UVI, IR1, and LIR, took snapshots of the earth (Fig. 3).

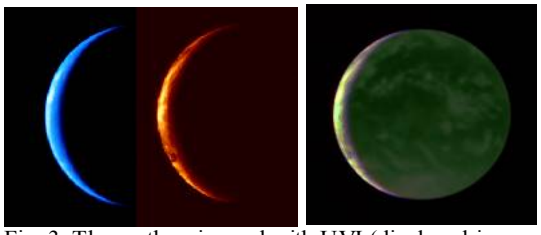

Fig. 3: The earth as imaged with UVI (displayed in blue), IR1 (red), and LIR (green). The UVI and IR1 images are composited to LIR image (right).

Akatsuki enjoyed a six-month smooth ride till it arrived at Venus in December 2010. While cruising, the orbital maneuvering engine (OME) with newly-developed ceramic thruster was successfully demonstrated for the first time. The science team carried out test observations: a zodiacal-light imaging with IR2 (in 1.65-μm H-band filter) in October 2010, imaging of the earth-moon system, and imaging of star fields with 4 cameras (UVI, IR1, IR2, and LIR).

During the attempt of insertion in Venus orbit (VOI) on 7 December 2010, however, a malfunction happened on the propulsion system. Premature engine shutdown prevented Akatsuki from being inserted in the Venus orbit. Akatsuki entered an orbit around the Sun with a period of 203 days, instead. The orbital maneuvering engine was found, after a test of the thruster on the orbit in September 2011, to be broken and unusable. Only 10% of expected thrust was obtained, clear indication of severe damage on the chamber throat.

## 3. Current Status and VOI-2

Although most of the fuel still remains, the 500-N thrust OME is no longer usable. Considering this, we decided not to use OME but to use the attitude control system (or the reaction control system, RCS) for further orbit maneuver. After finding out an alternate way of achieving orbit by using only RSC, three minor maneuvers were successfully done in November 2011. After this, Akatsuki has been on track to meet Venus again in 2015. We are considering and making trade-offs between several possible scenarios for VOI using only RCS.

## 4. Summary and Conclusions

Though the first attempt of VOI in December 2010 was not successful, Akatsuki is still healthy and careful operation continues. The spacecraft should meet Venus again in late 2015. We will do our best, with less-powerful but reliable RCS, to put Akatsuki in Venus orbit. As Venus Express is ending its mission, we hope Akatsuki will produce valuable data about the earth's twin planet for coming years.

## Acknowledgements

The team is grateful to the planetary science community of Japan, all support staff of JAXA, and manufactures of Akatsuki for their years of tireless works. International colleagues, especially the Venus Express team, supported us in planning and developing of mission and encouraged us after the disappointment. These altogether make it possible the mission being operated with lots of hope.

## References

[1] Nakamura, M., et al.: Return to Venus of the Japanese Venus climate orbiter AKATSUKI, Acta Astronautica, 93, 384-389, 2014..

[2] Nakamura, M., et al.: Overview of Venus orbiter, Akatsuki, Earth Planets Space, 63, 443-457, 2011.

[3] Svedhem, H., Titov, D., Taylor, F., Witasse, O., Venus as a more Earth-like planet, Nature, 450, 629-632, 2007.