宇宙航空研究開発機構
Japan Aerospace Exploration Agency

AKATSUKI Updates

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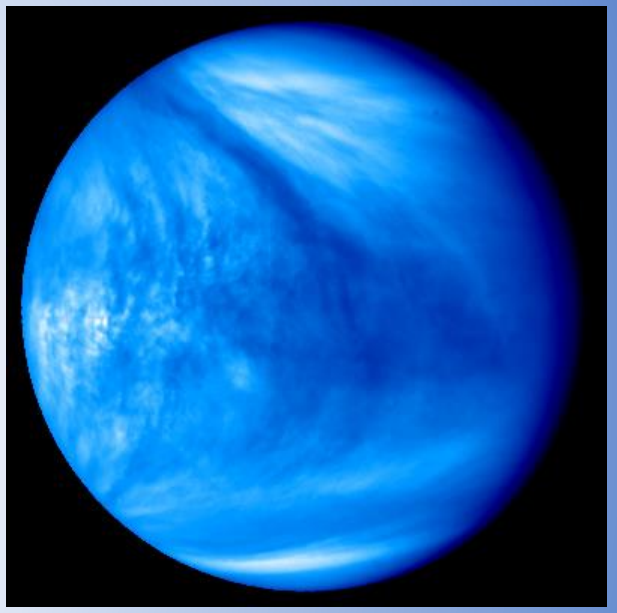
on behalf of the entire AKATSUKI team

Recent Activities of AKATSUKI and the Team

- SWT #14 in **February 2020**.
- Possible detection of “Venus lightning” by LAC in **March 2020**.
- New NASA Participating Scientists selected in **April 2020**.
- SWT #15 (Virtual) in **June 2020**.
- Co-hosted an on-line conference “Venus Science Today” in **August 2020**.
- Slight orbit adjustment (PC2) on **7 Oct 2020** to avoid prolonged umbrae.
- Coordinated Venus observations with BepiColombo (flyby on **15 Oct 2020**) and HISAKI (space EUV spectroscopic telescope).
- SWT #16 (Virtual) in **November 2020**.
- 5th anniversary in the Venus orbit on **7 December 2020**!!
- Coordinated radio occultation study with BepiColombo in **March 2021**.
- Current mission extension will end in **March 2021** (renewal under review).



Long Umbrae and the PC2 Operation

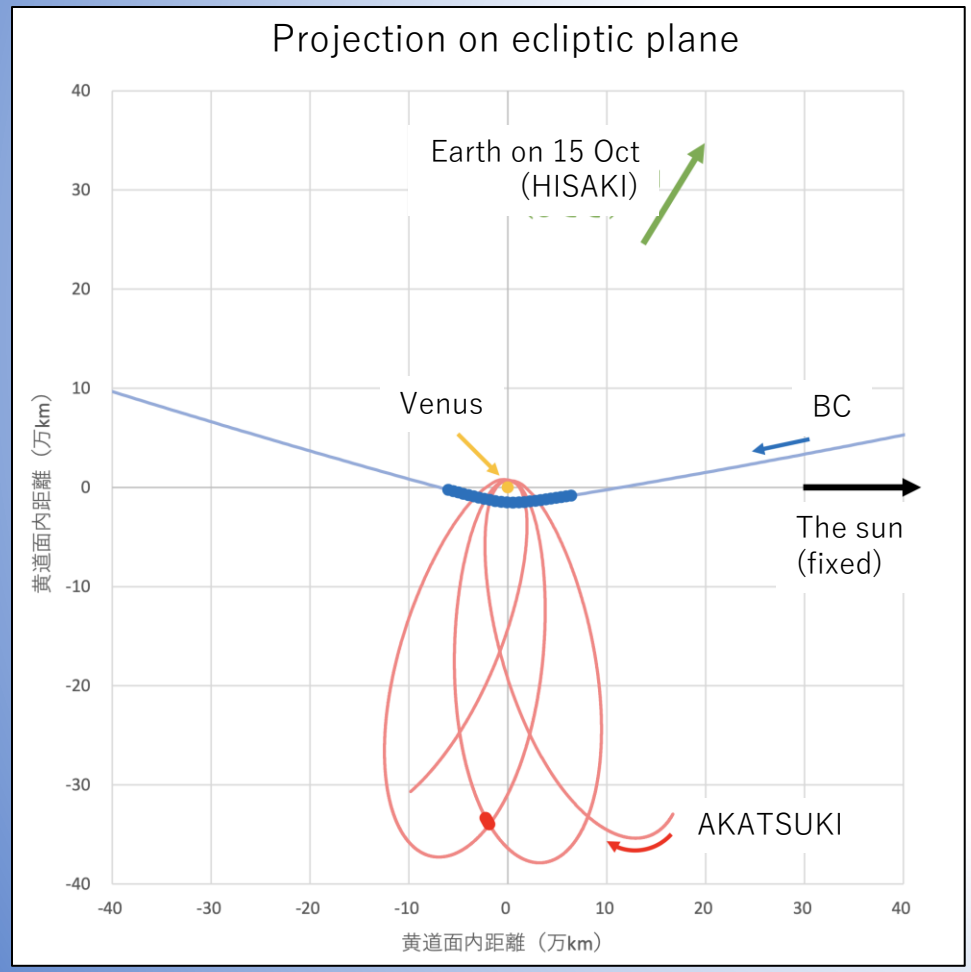
- The longest umbra that AKATSUKI could survive is 259 minutes (experienced on 30 Jan 2019, including “deeper than 40 %” penumbra), beyond which the spacecraft may not be able to survive due to limitation of battery (Lion) capacity to warm the spacecraft.
- The long-term orbit calculation predicted several prolonged umbrae (300-500 minutes) from February 2022 onwards. In order to avoid these, the Phase Control ΔV (PC2) was performed at 21:22:00 on October 7, 2020 (JST). Just 4.000 s of thrust (RCS) planned with expected ΔV of 0.531 m/s. Orbital analyses after PC2 indicated that the achievement was 98.4 %.
- This pushes the first “longer than 259 minutes” umbra away to 2035. Therefore, we do not anticipate any additional ΔV.
- The remaining fuel would enable operation of AKATSUKI for several more years (the median of estimates) with possibility of shorter lifetime (but likely 2 years or longer).

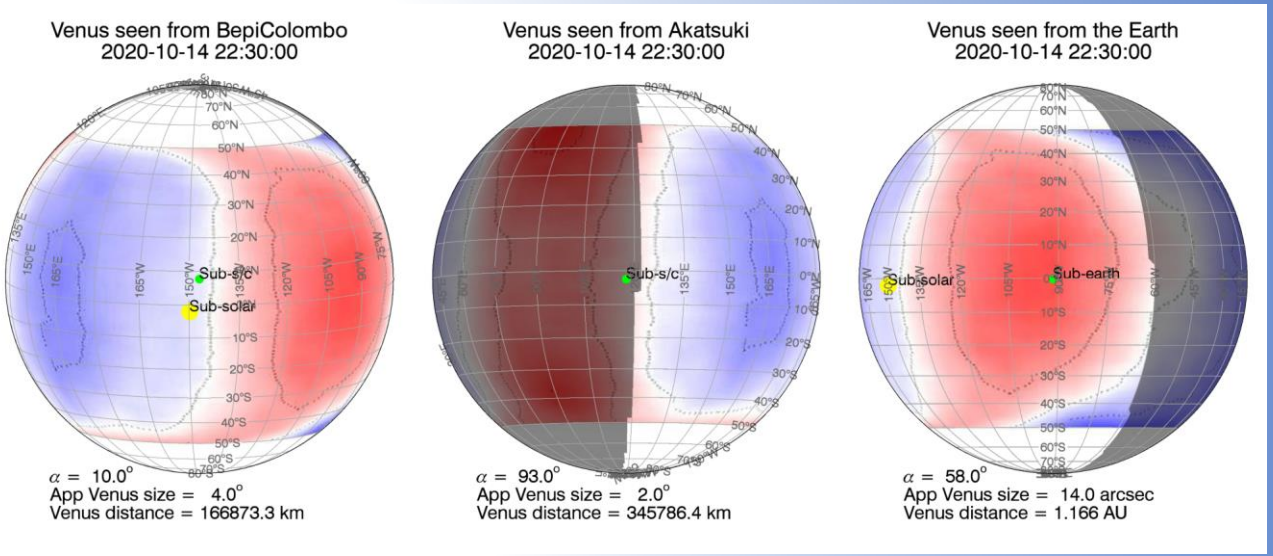
Long umbra（without ΔV）			Long umbra（with ΔV）		
	Umbra(min.)	Penumbra(over 40%)（min.）		Umbra(min.)	Penumbra(over 40%)（min.）
2022.02.11	232	333	2022.02.05	210	248
2022.09.28	231	453	2024.01.05	202	251
2023.05.14	249	489	2025.02.16	132	215

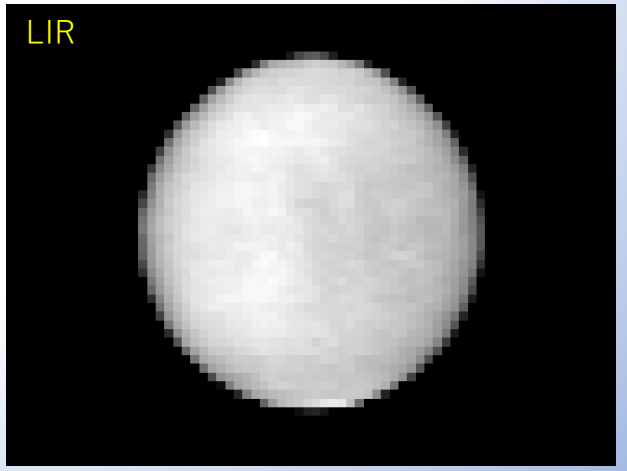
*1 Longest ever umbra @ 2019.01.30: main shade 199 minutes, half-shade (40% or more) 259 minutes 2 Past (previous) ΔV (PC1): 2.241 m/s (about 15 seconds x 4 units) on April 04, 2016 3 Estimated remained propellant volume: approx. 1,000 g (as of March 31, 2020)

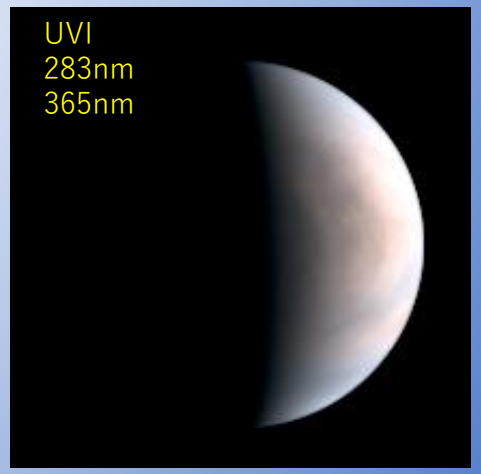
Tri-spacecraft Campaign Observation of Venus

- Tri-spacecraft (AKATSUKI, BepiColombo, and HISAKI) observations of Venus successfully carried out on 15 October 2020.

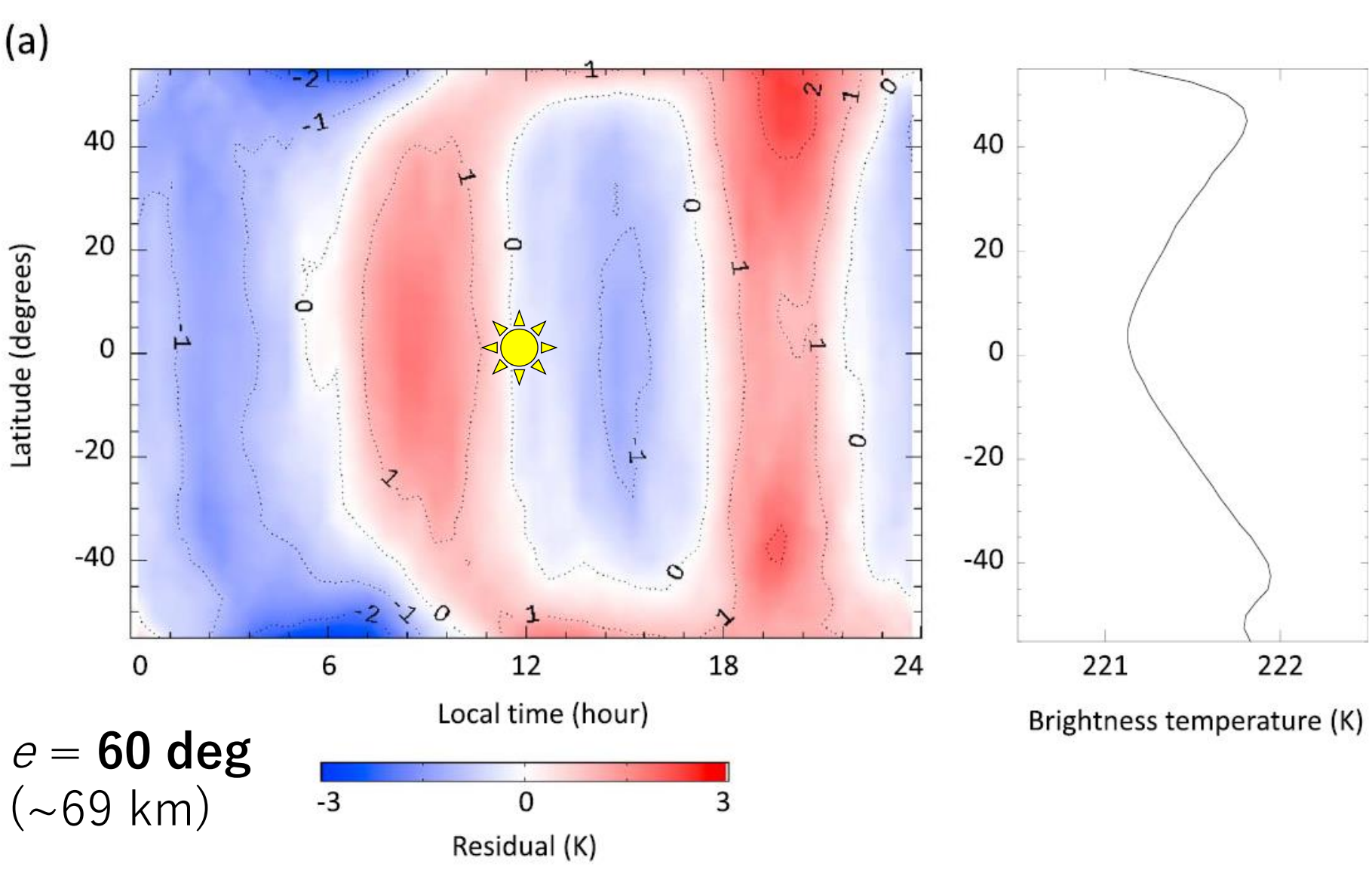




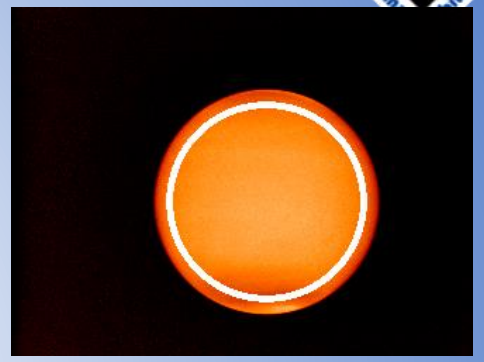




Global Structure of Thermal Tides from Observations



$e =$ **60 deg**
(~69 km)

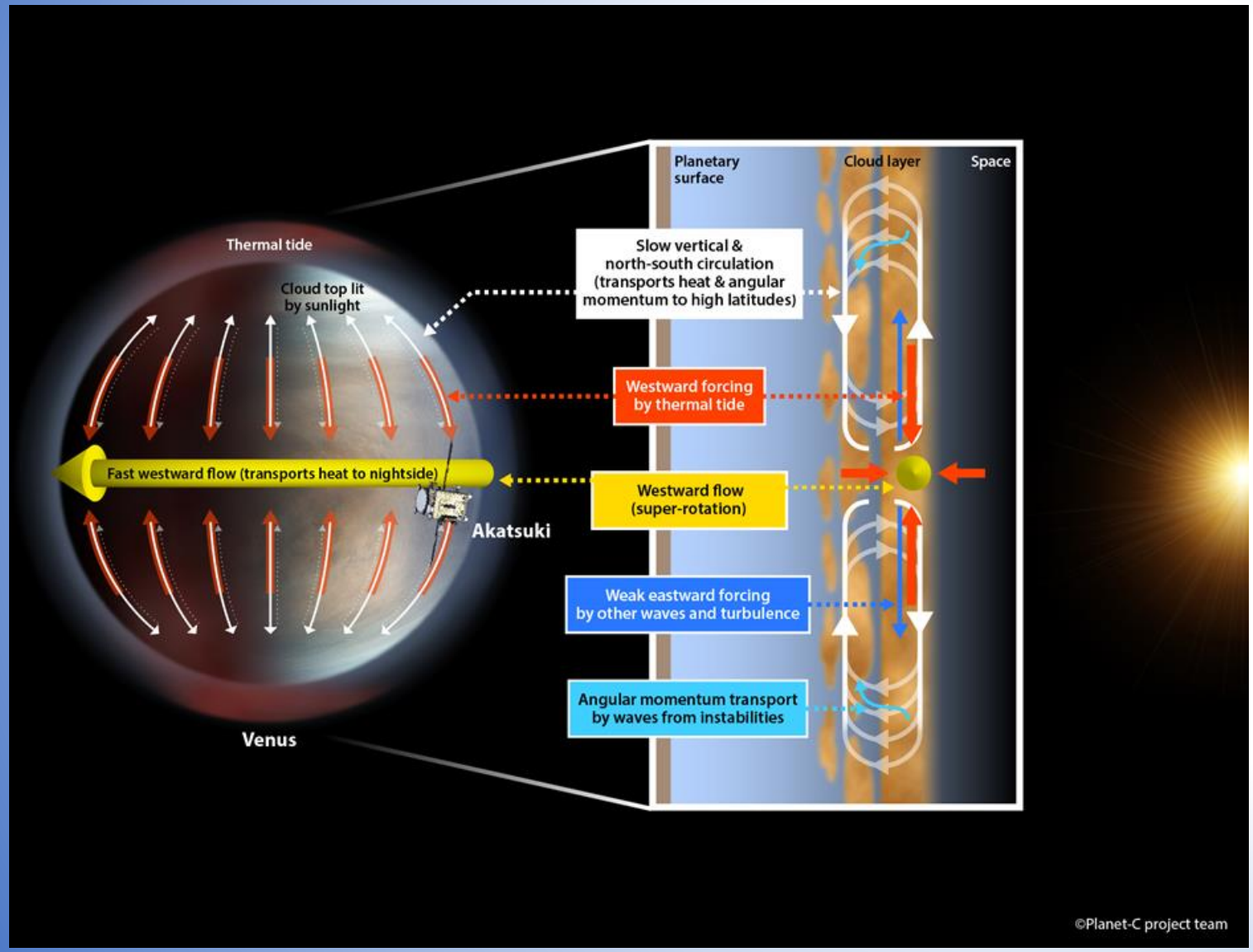


Time-averaged thermal tide structure over three Venusian years by LIR

First observational result of revealing the global structure of thermal tides at the cloud top

[Kouyama et al., 2019]

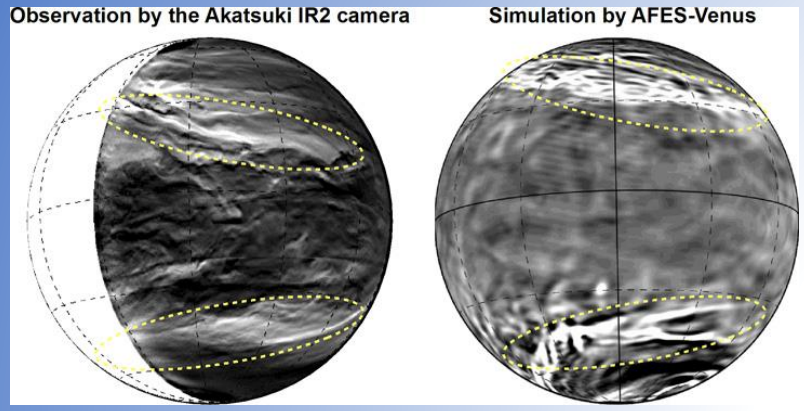
Super-Rotation Maintained by Thermal Tides

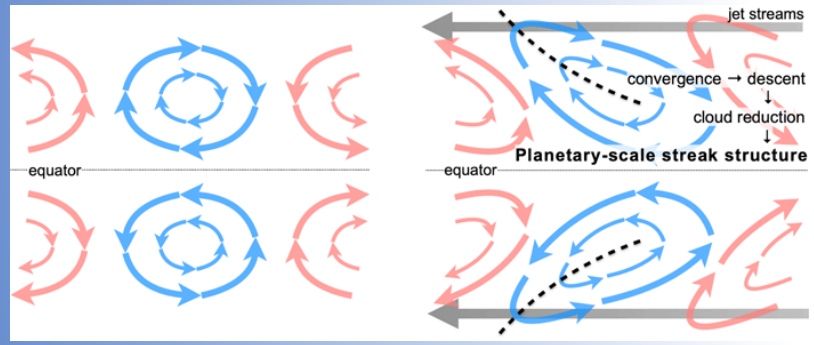


- Careful cloud-tracking analysis indicates that the super-rotation is maintained by the thermal tides (red arrows), while other waves and turbulences actually work to weaken the SR (blue arrows) in the equator to low latitudes.
- In the middle to high latitudes, however, other waves possibly work to maintain the SR (light blue arrows).
- “True” meridional motion should be very small (of the order of a few m/s) and difficult to determine only from the day-side (UV) measurements. Need higher precision night-side measurements.

Horinouchi et al., 2020

Planetary-Scale Streaks: Computed and Observed

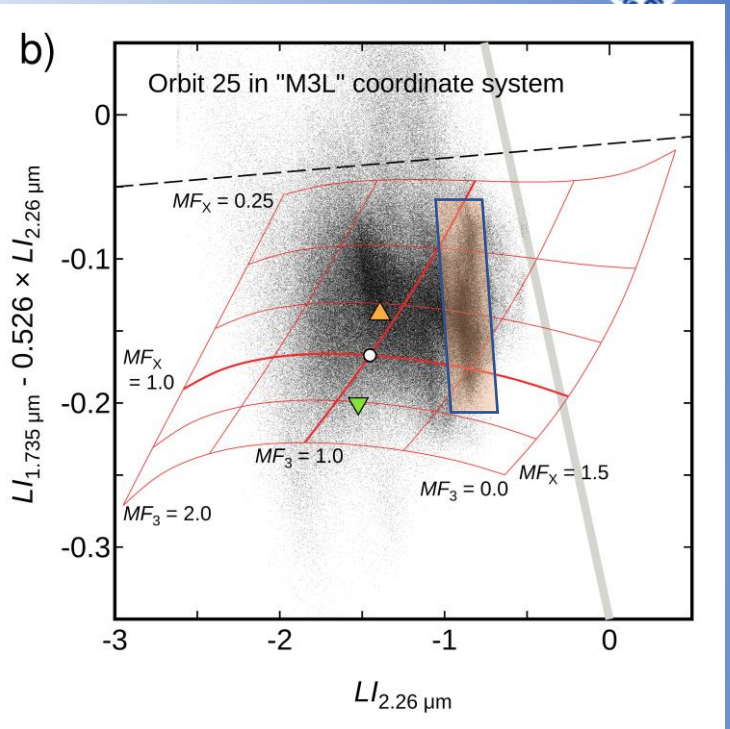


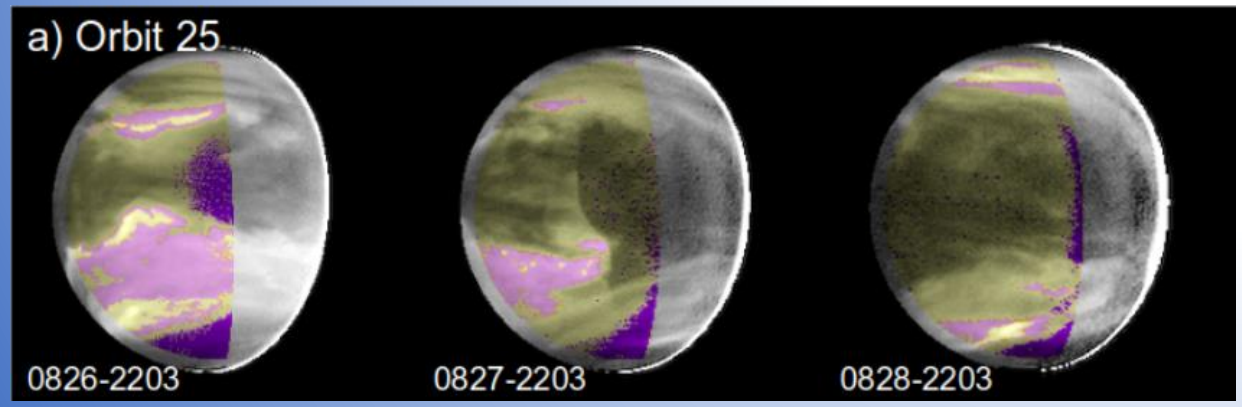


The planetary-scale streaks in the mid-to-high latitudes (bright in the IR2 2.26-μm image) are reproduced by AFES-Venus simulations (left). The bright parts in the simulation correspond to the strong downwelling regions.

Large vortices, subtending from the equator to ~60º latitudes get distorted by the high-latitude jets. Resultant convergence regions yield forced downward flows (dashed curves in the left figure).

Kashimura et al., 2019





The correlation plot of IR2 data (2.26 vs. 1.735 μm in Orbit 25) in the new M3L coordinates show confined data points, named CALM (above right). These data appear “pink” regions in the original images (left) but do not include the mid-latitude streaks. This suggest that CALM is equilibria-dominated quiescent region while the streaks are dynamically disturbed as indicated by the numerical simulations.

Satoh et al., 2020 (in press)

AKATSUKI Data Archives

- The 2020-06-01 public release has been delayed due to the Covid-19 situation. It is planned to release the data up to Orbit 133 (acquired on 4 Dec 2019) by the end of 2020. The data (PDS3 compliant) are available on both NASA PDS and ISAS DARTS.

- Updating to “PDS4 compliant” is under consideration. We expect the works will start in the spring of 2021.

Rel. date	Instruments	Levels	Obs. Period
2019-12-01	UVI, LIR	L1b, geo, L2b/c	2018-06-03 to 2018-12-07
2019-06-01	UVI, LIR	L1b, geo, L2b/c	2010-05-21 to 2018-06-03
2019-03-05	VCO	SPICE	
2018-12-01	UVI, LIR	L1b, L2b/c	2010-05-21 to 2017-12-10
	UVI, LIR	L3b/c	2010-12-09 to 2017-12-10.
	RS	L2, L3, L4	2016-03-03 to 2017-08-11
2018-10-01	UVI, IR1, IR2, LIR	L3b/c	2010-12-09 to 2017-06-06
2018-05-21	UVI, LIR	L1b, L2b/c	2010-05-21 to 2017-06-06
2018-05-01	VCO	SPICE	

Summary of AKATSUKI

- Successfully operated in the Venus orbit for 5 years (as of 7 December 2020). The success of PC2 operation (on 7 October 2020) ensures the safeness of the spacecraft from prolonged umbrae until 2035. Remaining fuel would be the critical factor to the lifetime of the mission.
- The team is proposing the second term of extended mission (from April 2021 to March 2024) which is under review at ISAS.
- A possible **lightning** event finally recorded in March 2020 (manuscript in prep.).
- It is identified that **the thermal tides** are the primary agent to maintain the super-rotation (SR) in the equator to low latitudes. Other waves work opposite but they may likely work to maintain the SR in the middle to high latitude regions.
- To quantitatively study **the meridional circulation**, more measurements (especially in the nigh-side with higher precision) are definitely needed. 3-D views of this is essential to evaluate other hypotheses for the SR.
- AKATSUKI data have been utilized in both observational and numerical studies.