

Return to Venus of AKATSUKI

An artistic rendering of the AKATSUKI spacecraft in orbit around Venus. The spacecraft is shown in the foreground, with its gold-colored body and various instruments visible. It has two large solar panel arrays extended. In the background, the reddish-brown surface of Venus is visible, showing some cloud patterns. A bright sun is in the upper left corner, creating a lens flare effect.

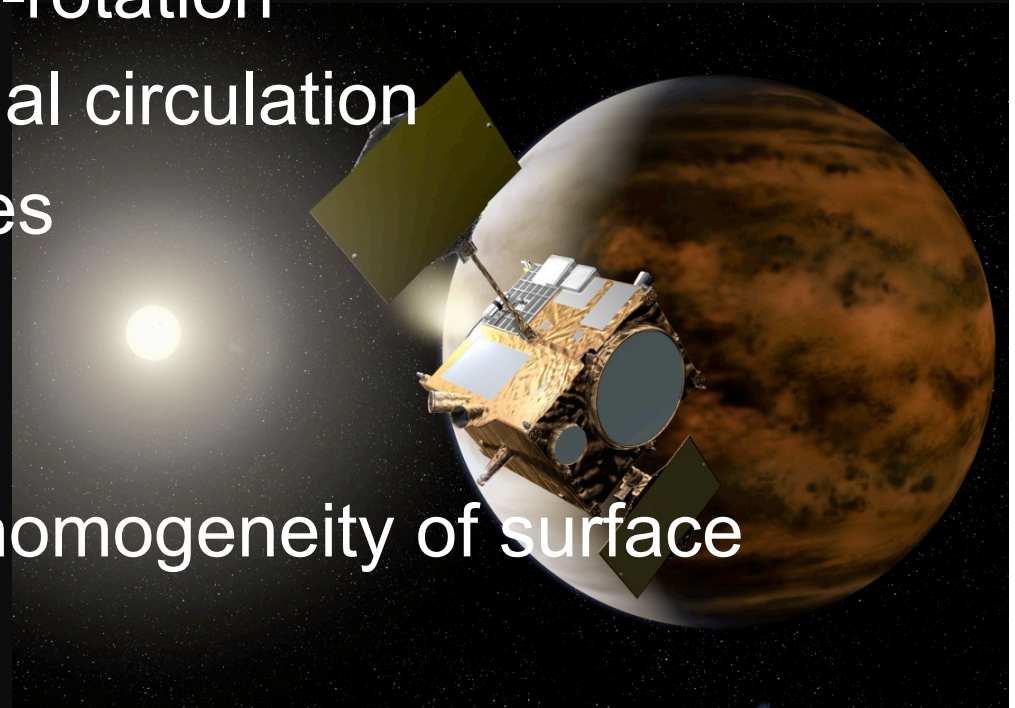
Masato Nakamura (ISAS)
AKATSUKI Project Team

Akatsuki project

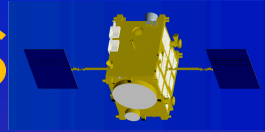
- Akatsuki was proposed in 2001 with strong support by international Venus science community and approved as an ISAS mission soon after the proposal.
- Akatsuki and ESA's Venus Express complement each other in Venus climate study. Various coordinated observations using the two spacecraft have been planned.
- Participating scientists from US have been selected.
- Akatsuki was launched in May 2010.
- The Venus orbit insertion scheduled for December 2010 has failed. Now Akatsuki is orbiting the Sun. ISAS is examining the possibility of conducting Venus orbit insertion again several years later.

Venus orbiter AKATSUKI

- Science target : **‘Weather of Venus’**
 - Mechanism of ‘super-rotation’
 - Structure of meridional circulation
 - Meso-scale processes
 - Formation of clouds
 - Lightning
 - Active volcanism, inhomogeneity of surface material
- Mission life : More than 2 Earth years in Venus orbit



3D observations



Akatsuki

Temperature and H_2SO_4
vapor profiles (RS)

Airglow (LAC)

Sulfur dioxide
(UVI)

Cloud temperature
(LIR)

Lower clouds
(IR1, IR2)

Wind vectors

Carbon monoxide
(IR2)

Lightning (LAC)

Water vapor
(IR1)

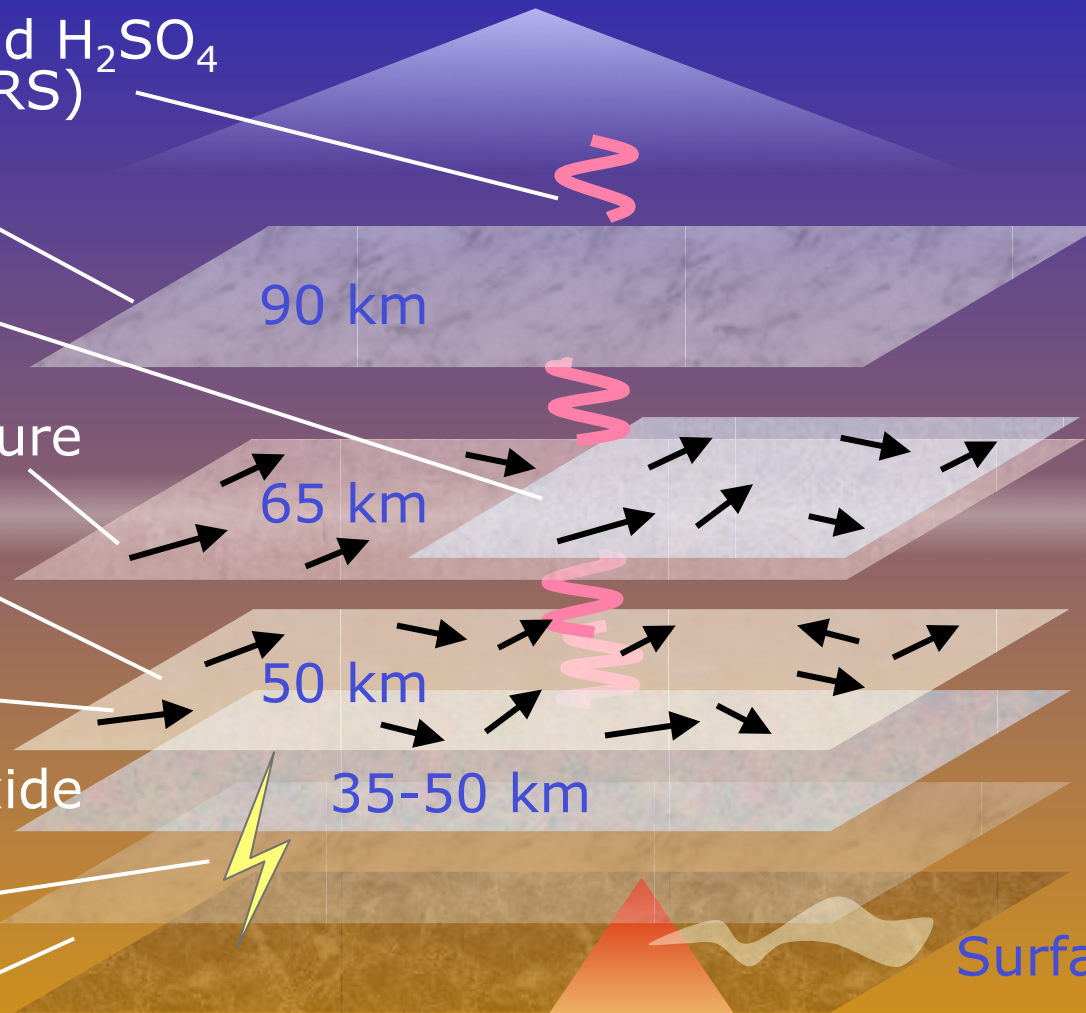
Active volcanoes / Minerals
(IR1)

Stratosphere

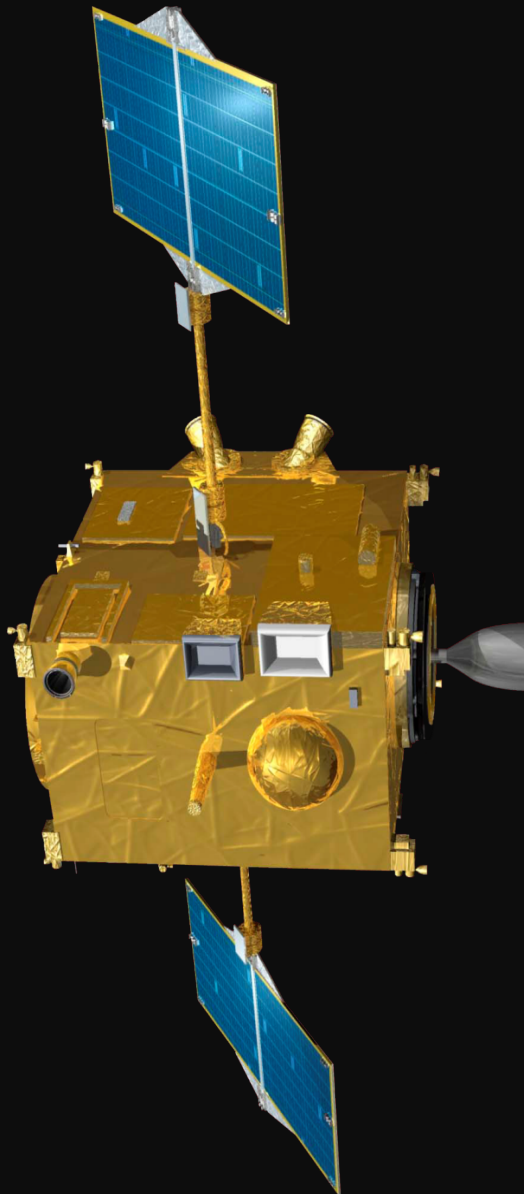
Clouds

Troposphere

Surface



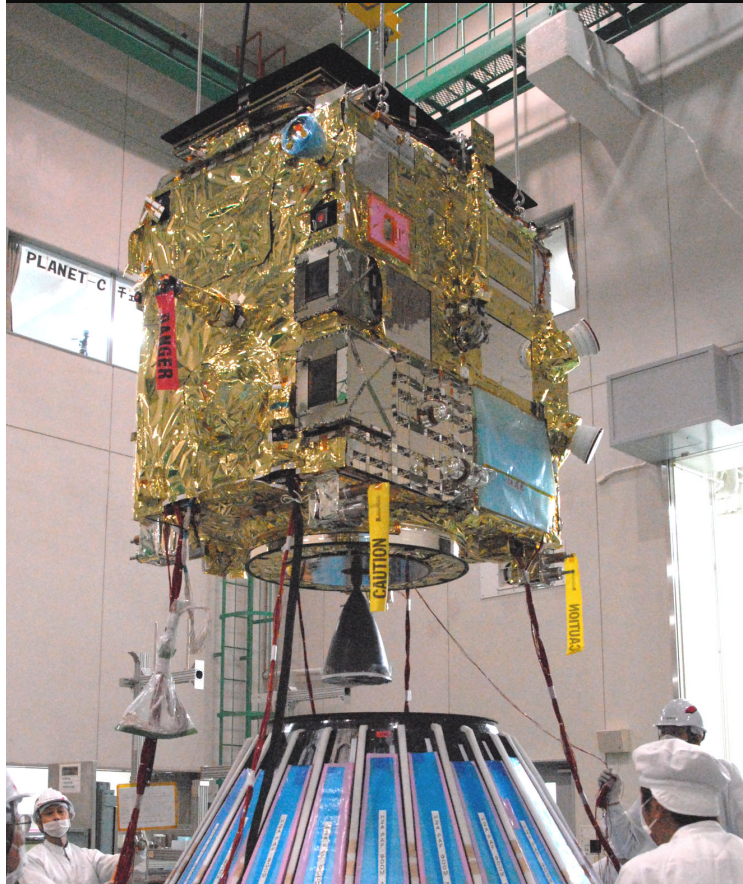
Spacecraft Configuration



PLANET-C "Akatsuki" Spacecraft

Shape and Size	Box-shaped with Solar Array Paddles and Orbital Maneuver Engine (1.04m x 1.45m x 1.40m)
Scientific Instruments	1 μ m Infrared Camera (IR1) 2 μ m Infrared Camera (IR2) Near Infrared (10 μ m) Camera (LIR) Ultra Violet Imager (UVI) Lightning and Airglow Camera (LAC) Ultra Stable Oscillator (USO)
Planned Orbit about Venus	Elliptic Orbit about Venus Periapsis Altitude : 550km Apoapsis Altitude : 80,000 km Orbital Period : 30 hours Orbital Inclination : 172 degrees
Mission Life	Two Earth years in the Venus orbit
Weight (wet)	518 kg (including 196 kg fuel) at launch
Power Supplied by Solar Paddles	More than 500 W at Venus orbit at the end of the mission life

Akatsuki launch: May 21, 2010



Integration

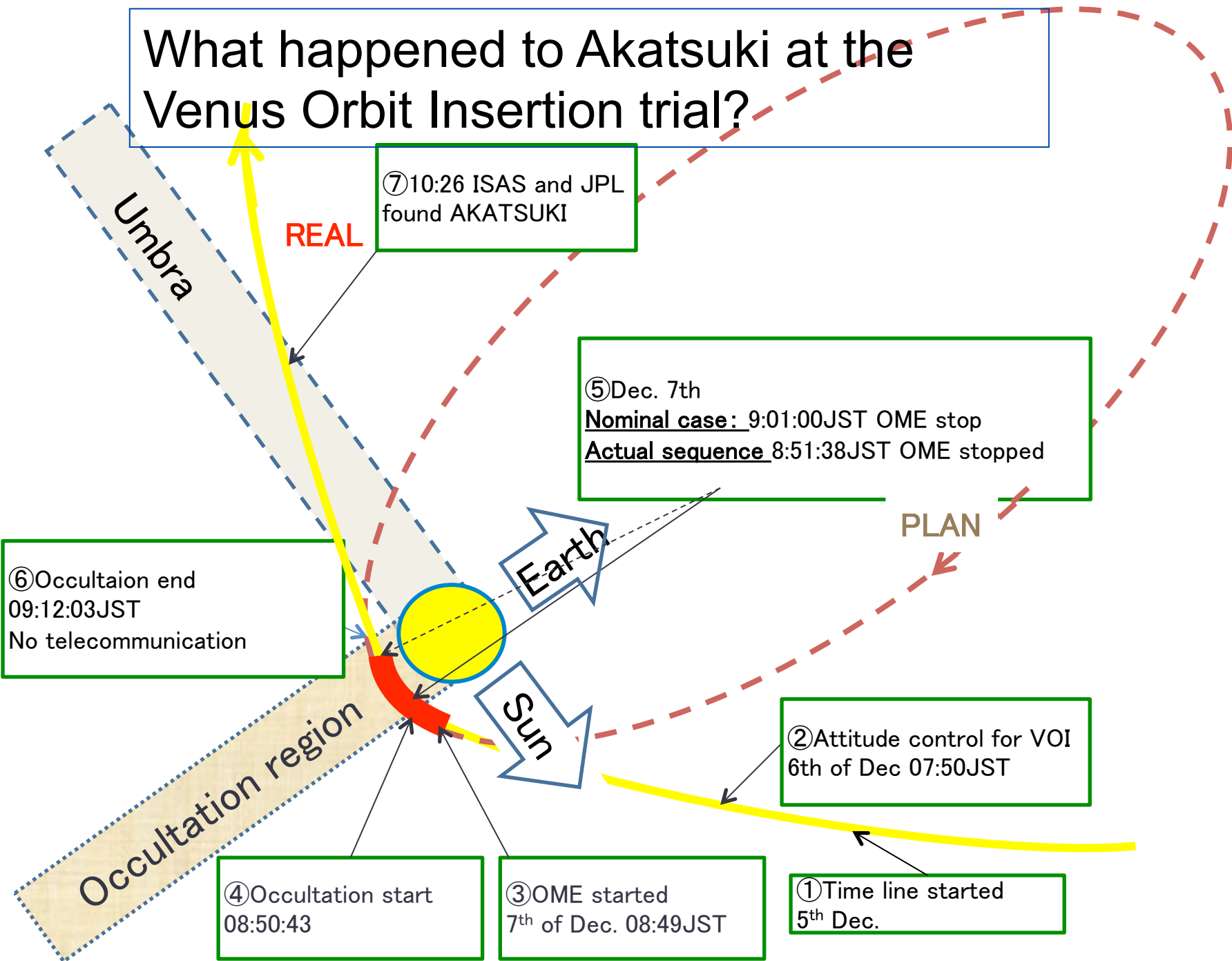


Separation from
H-IIA

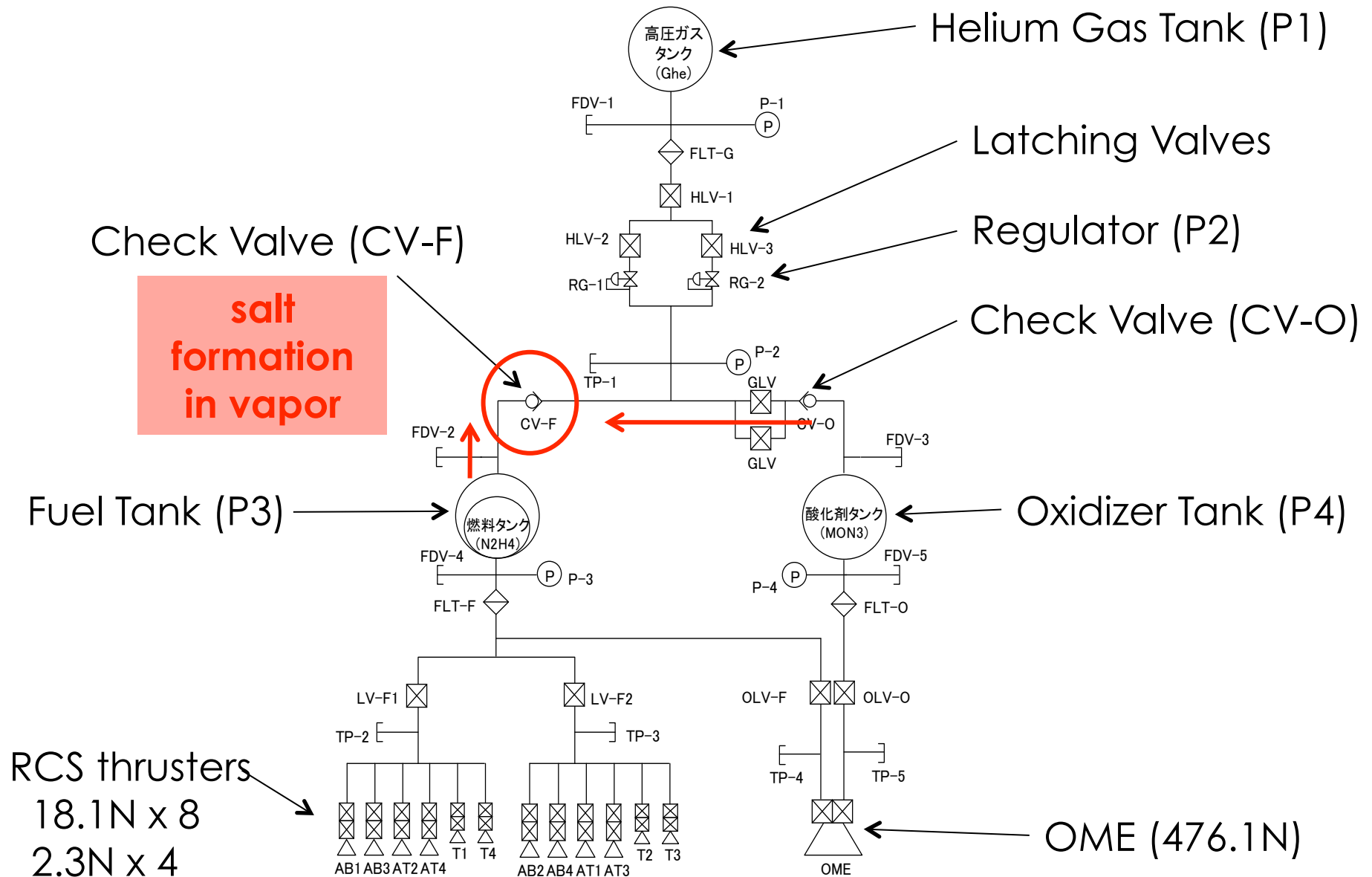


Launch by H-IIA from Tanegashima Space Center

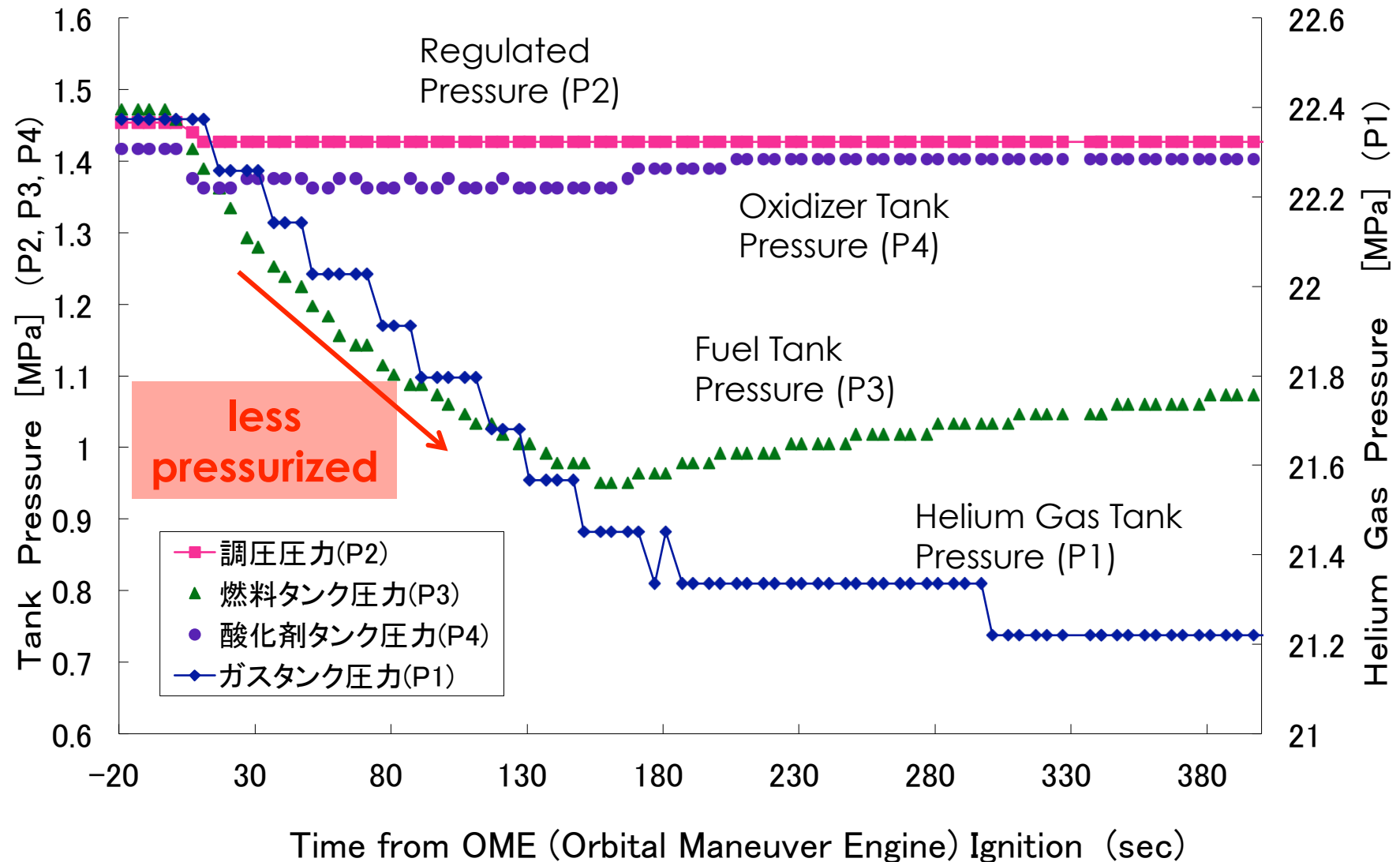
What happened to Akatsuki at the Venus Orbit Insertion trial?



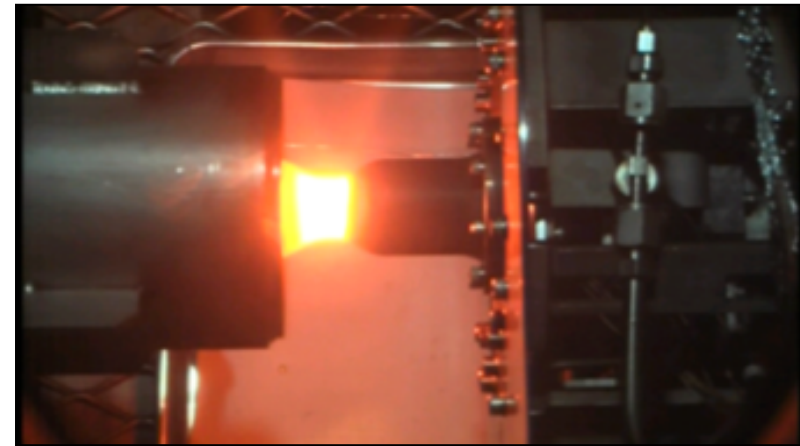
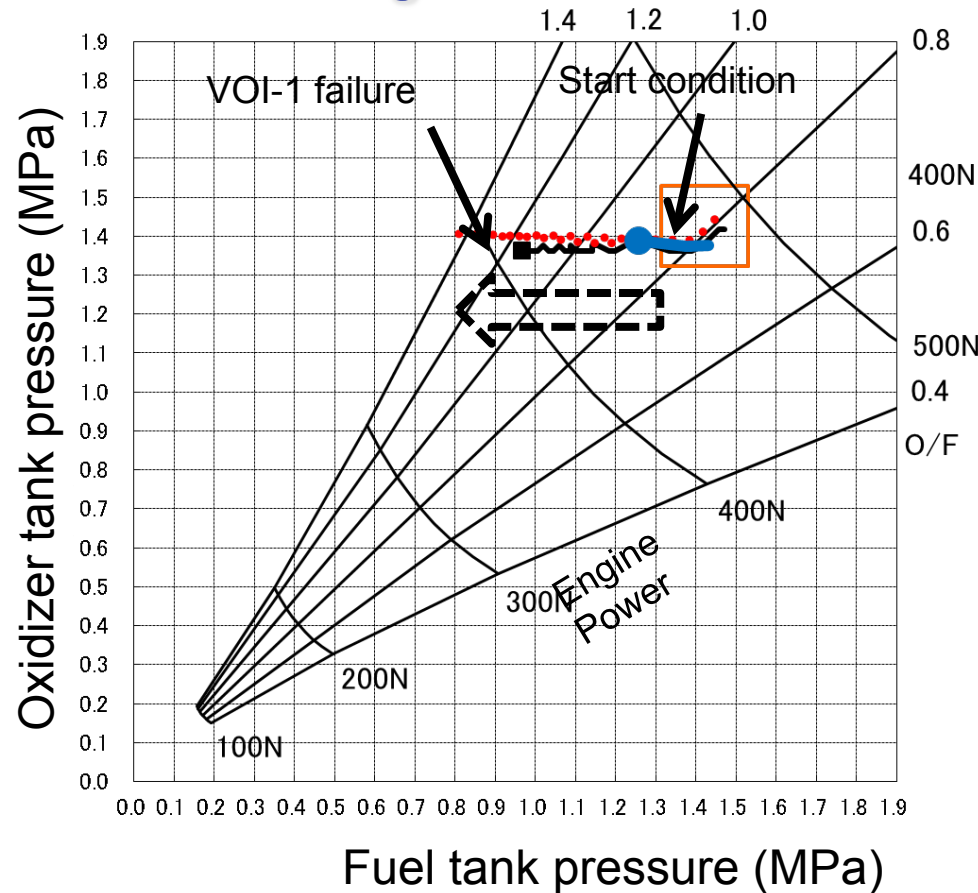
Block Diagram of Propulsion System



Profile of Pressures of Propulsion System



Orbital Maneuver Engine (OME) Burn on the ground simulating VOI-1



Ground test

Gas pressure to push oxidizer was properly controlled

- **Gas pressure to push the fuel was decreased**

→ **O/F increased → Temperature in the combustion chamber increased
and OME was Destroyed**

Possible Scenario of VOI-1 Failure

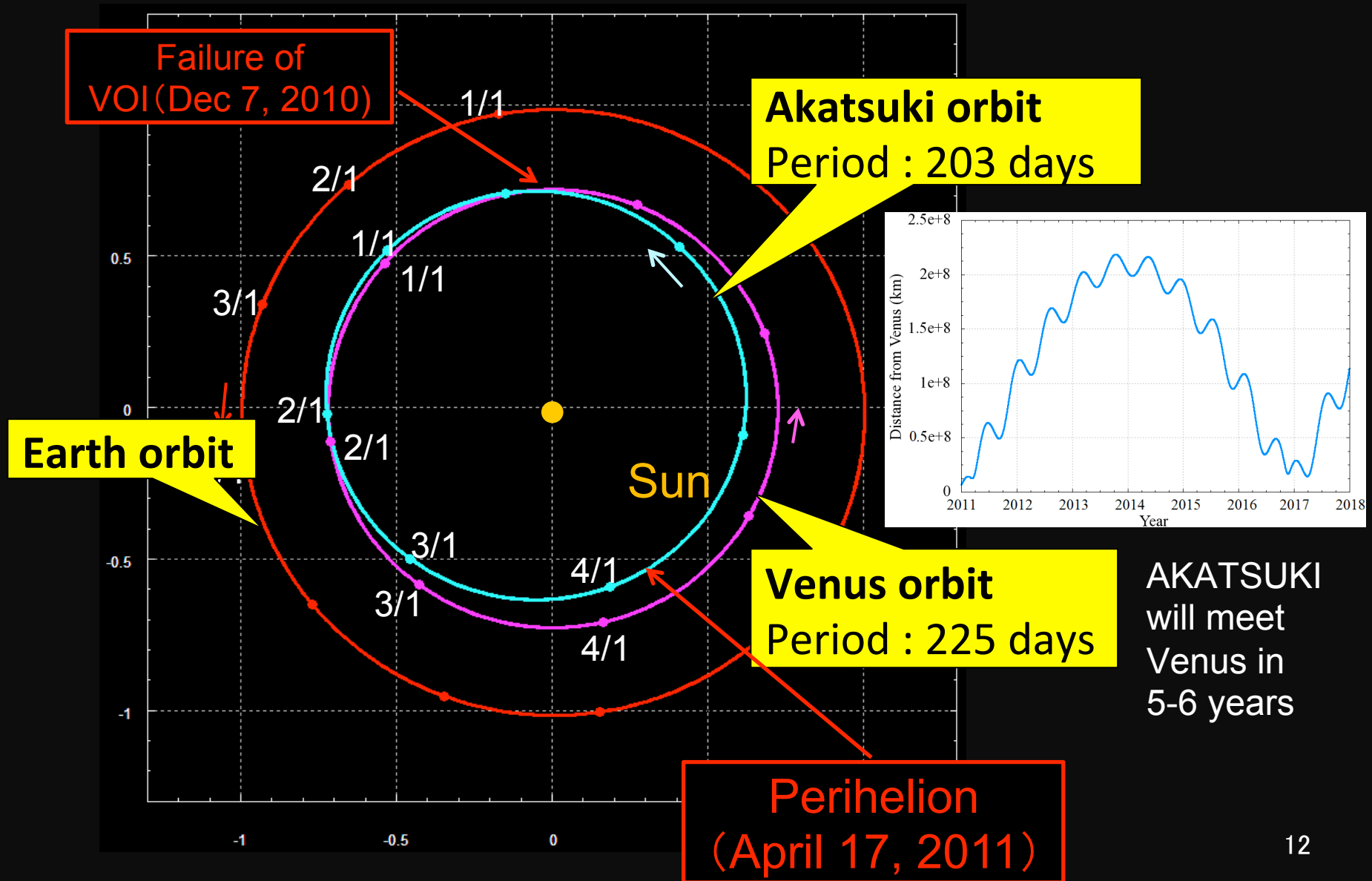
- AOCS (Attitude and Orbit Control System) sent an abort command due to the sudden attitude disturbance at 158 sec after VOI-1 start
 - OME (Orbital Maneuver Engine) induced unexpectedly large side forces at 152 sec
 - Fuel was less pressurized and mixture ratio of fuel/oxidizer was abnormal
 - Gas flow was obstructed at a check valve of fuel tank, which could be caused by
 - (1) Salt formation in fuel/oxidizer vapor
 - (2) Contamination in the check valve



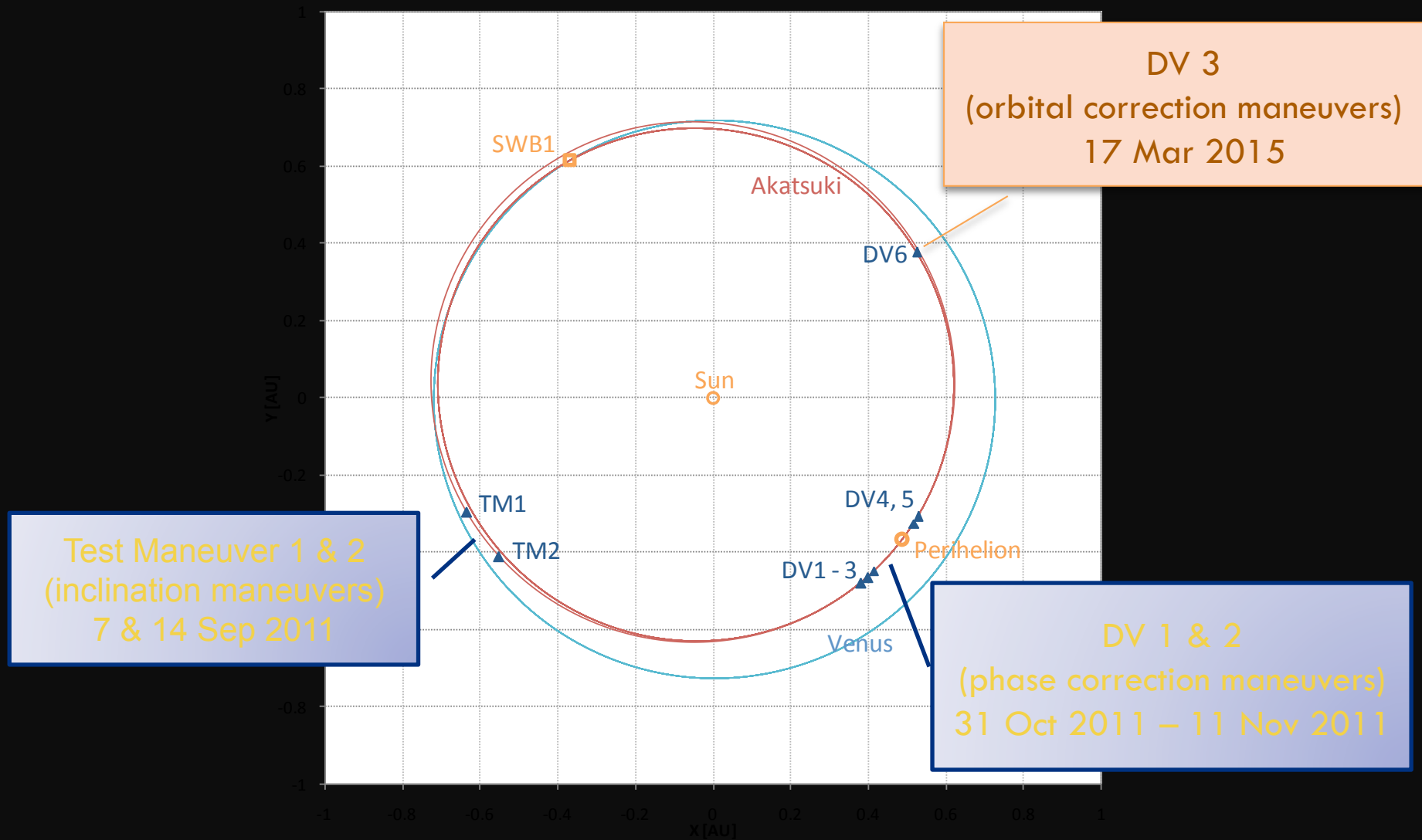
After ground test operation



AKATSUKI's orbit in present



Orbit maneuver plans trajectory to meet Venus



Possible Strategies of Venus Insertion

Current Orbit
(Period : 203 days)

+50 m/s
at first perihelion

Venus Encounter Orbit-1
(Period : 204 days)

Jan.27, 2017
(11:10)

-70 m/s
at first perihelion

Venus Encounter Orbit-2
(Period : 202 days)

Jun.21, 2016
(10:9)

-300 m/s
at first perihelion

Venus Encounter Orbit-3
(Period : 200 days)

Dec.02, 2015
(9:8)

Venus Encounter

Direct Capture(insertion)

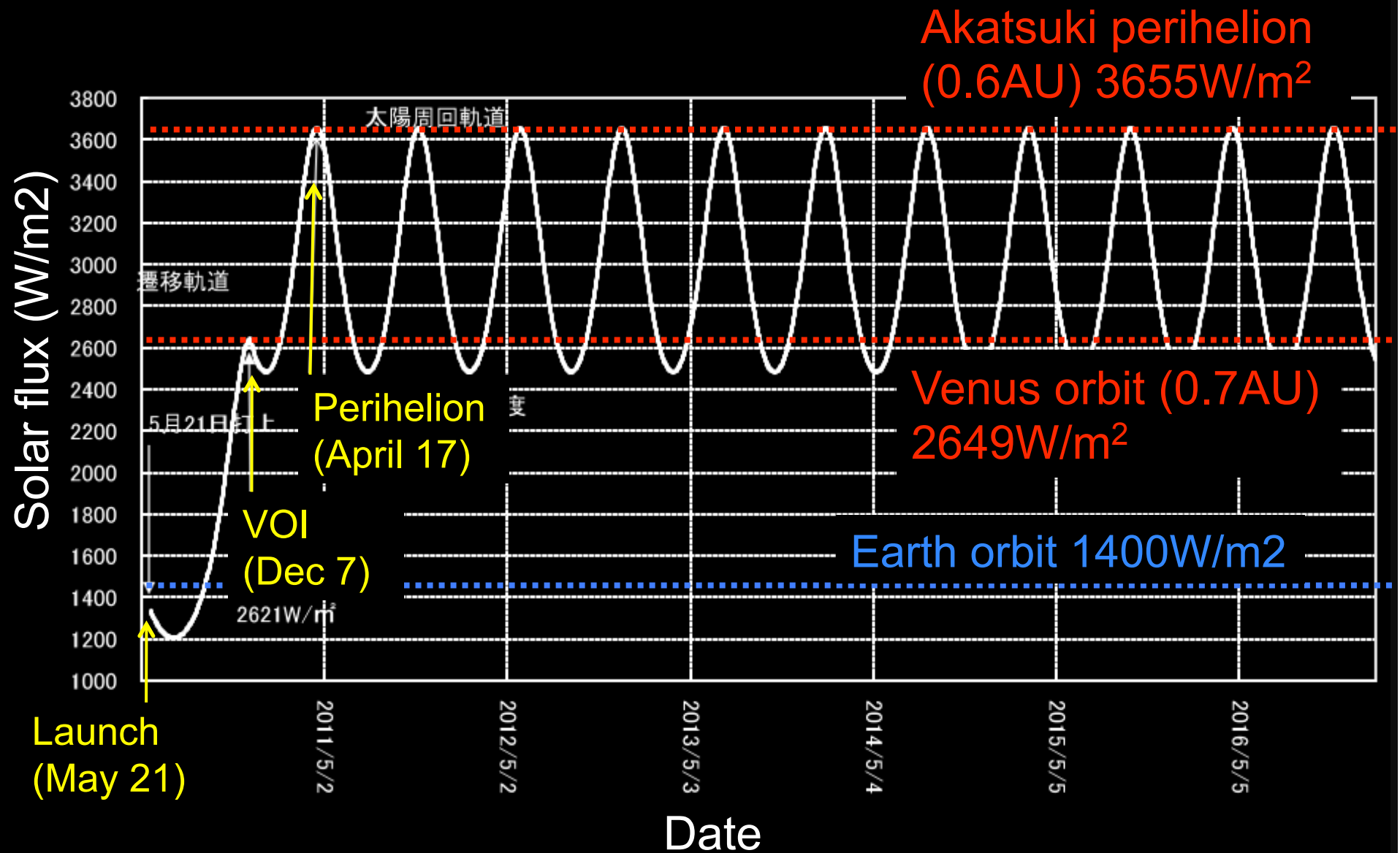
Venus Swing-by

Venus Insertion

Return to Venus?

- Most of the fuel still remains.
- AKATSUKI will encounter Venus in 2015 - 2017 depending on the orbit correction plan.
- The condition of the propulsion system is unclear. JAXA is examining various scenarios of second Venus orbit insertion depending on the conditions of the check valve and the main thruster.
- Thermal condition during the extended cruise phase is another problem.

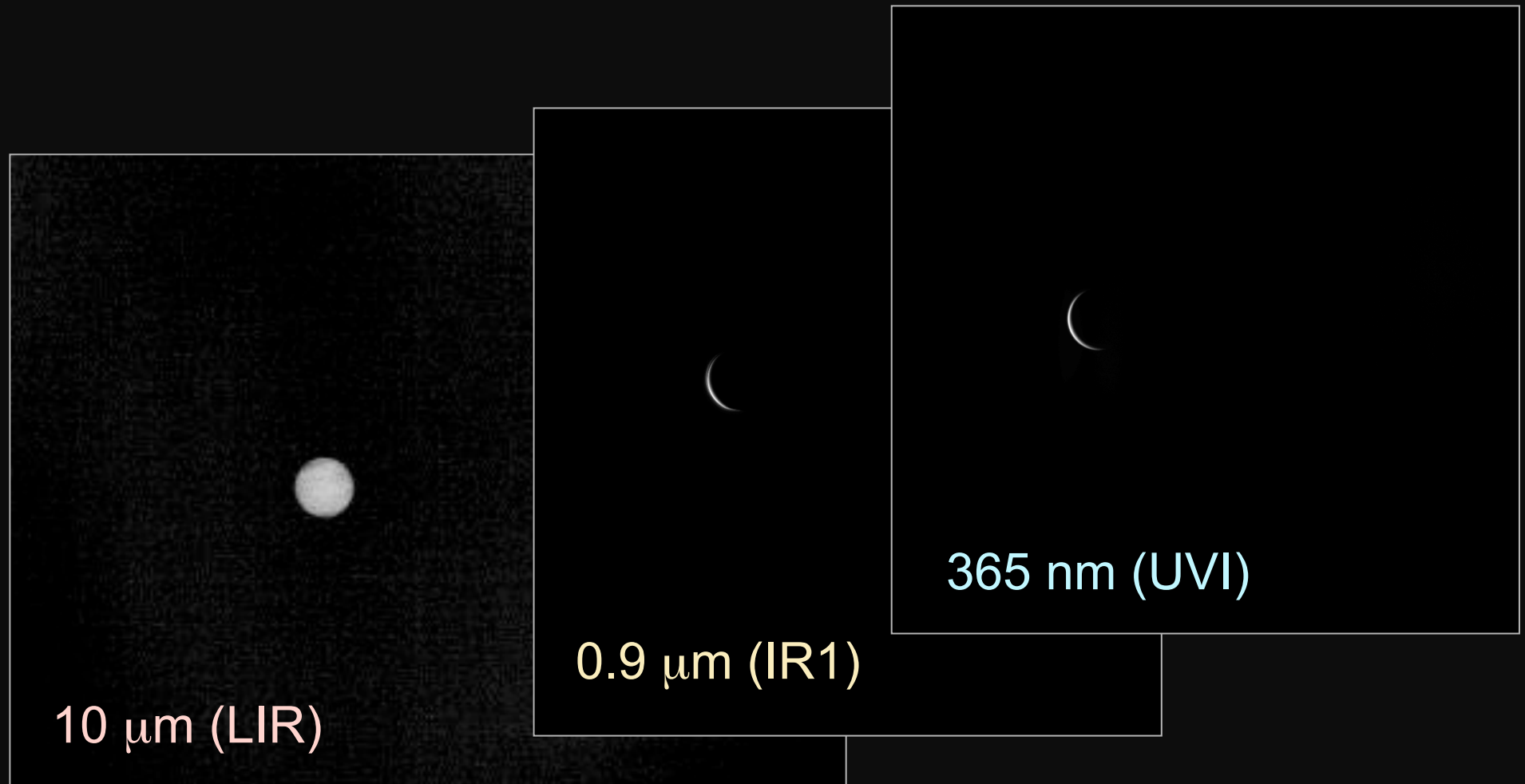
Thermal condition in the next 6 years



Thermal condition

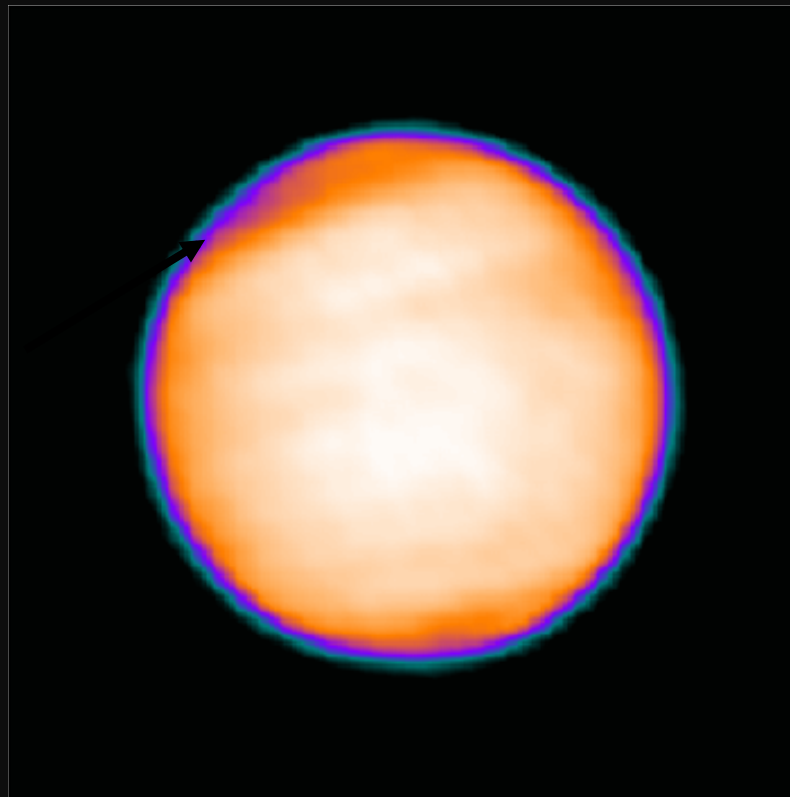
- The temperatures of the instruments exposed to space are gradually increasing as the spacecraft approaching the perihelion at 0.6 AU. We tried to minimize the number of instruments whose temperatures exceed the allowed upper limits by letting a certain side of the spacecraft face to the sun.
- After passing the perihelion every instruments are working normally.
- The degradation of the reflectivity of the outer film (MLI) during the extended cruise may influence the temperature tendency. Laboratory tests to evaluate the degradation are ongoing.

Venus seen from Akatsuki 2 days after the failure of Venus orbit insertion

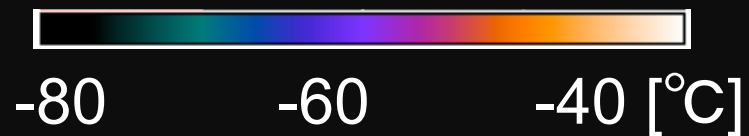


Distance : 600,000 km

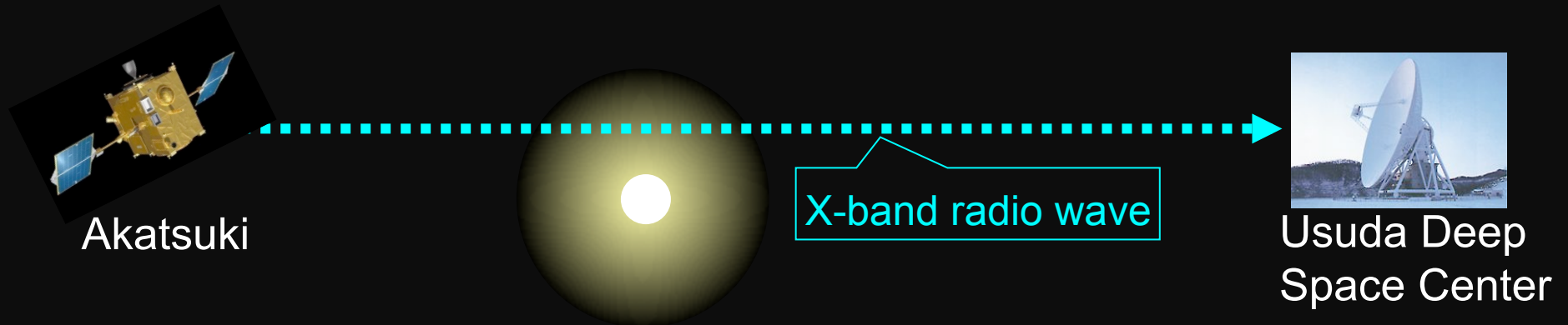
Venus thermal Image taken by LIR (Corrected)
December 9th (09:00JST)
600,000km away from Venus



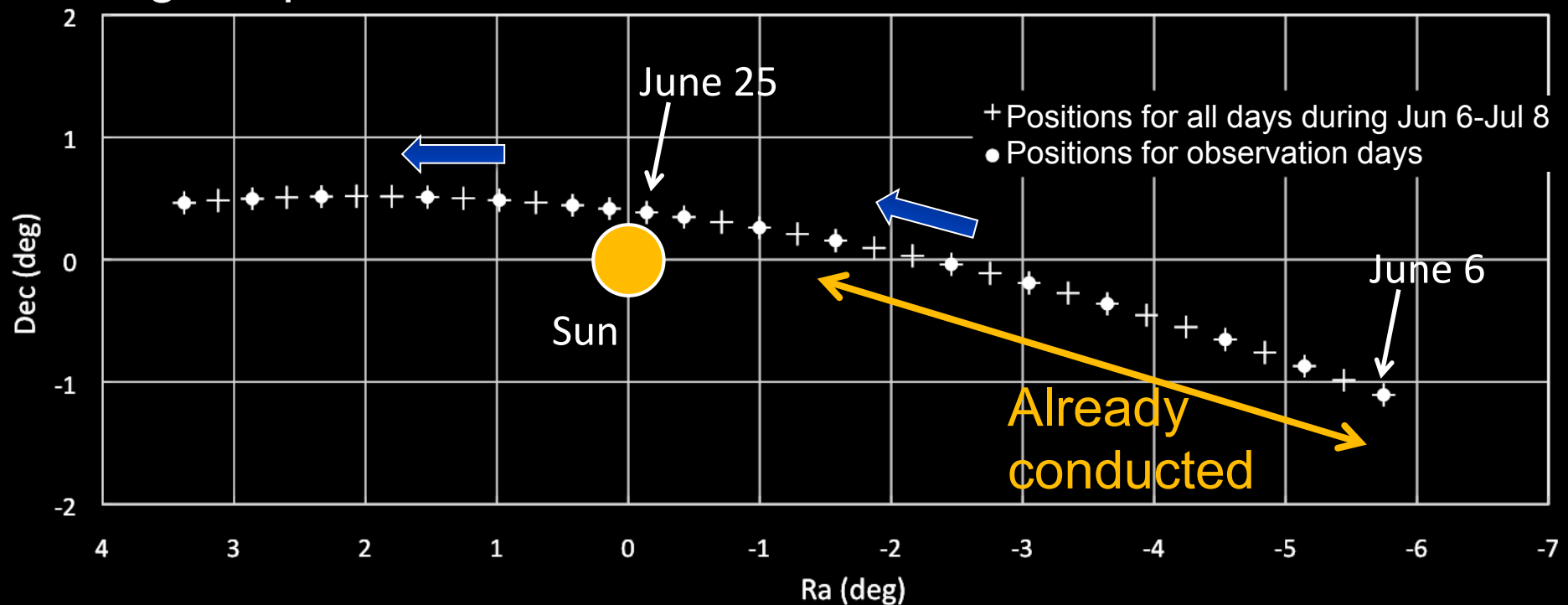
Improvement of the spatial resolution of the LIR 10 μ m image by using multiple frames taken under varying spacecraft attitude.



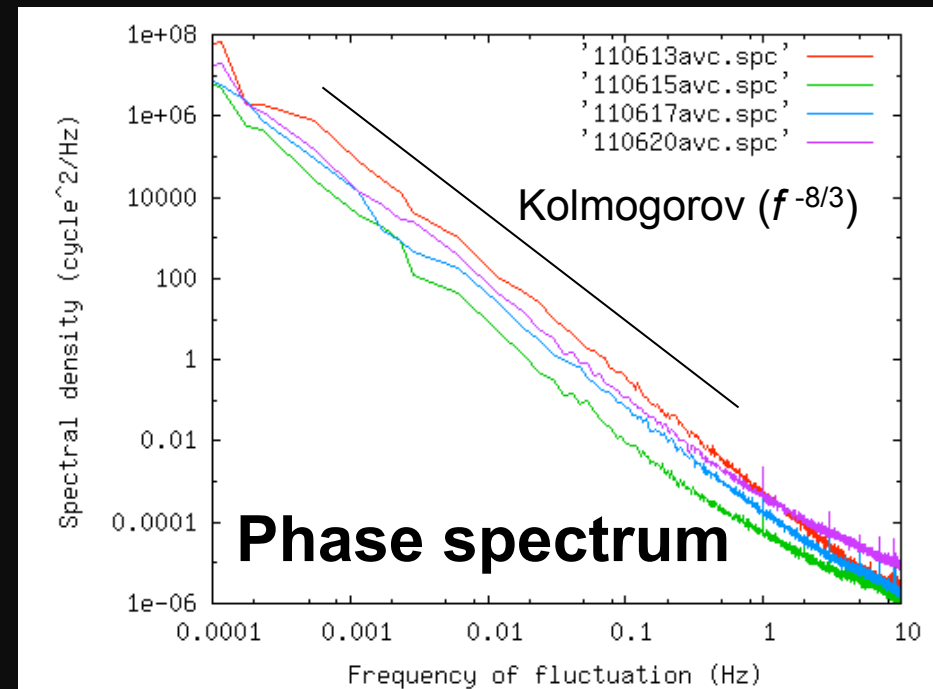
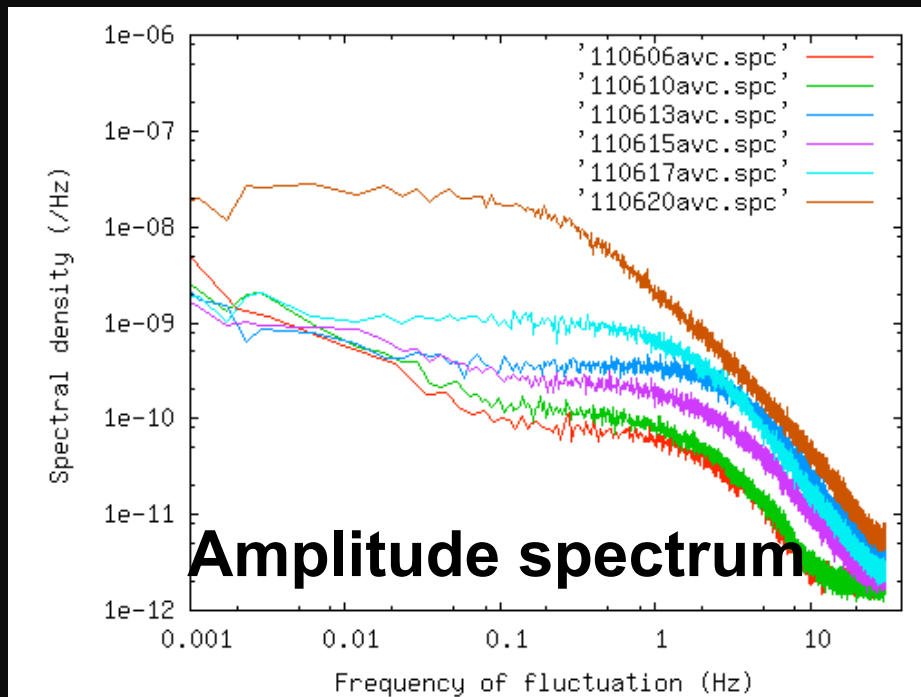
Radio occultation of solar corona (June 2011)



Angular position of Akatsuki relative to Sun as seen from Earth



Preliminary results for 6-21 solar radii



- Amplitude → Solar wind velocity, Power-law of turbulence
- Phase → Density fluctuation, Power-law of turbulence

Simultaneous observations with JAXA's solar observation satellite 'Hinode' are planned for 1.5 - 2.3 solar radii.



Road map to Return to Venus

We will conduct critical operation for PLANET-C Venus encounter

- Test maneuvers of OME will be performed on 7 Sep (TM1) and 14 Sep (TM2) 2011.
 - TM1 (2 sec): to see if the disturbance torque is much bigger than expected. (e.g. 50Nm) Transferring to Safe Hold Mode should be avoided at TM1.
 - TM2 (20 or more sec): to estimate the disturbance torque and attitude control algorithm. Transferring to Safe Hold Mode is acceptable.
 - In case when OME failures, multiple Venus swing-by's are our option.
- Orbit maneuvers (DV1 & 2) will be performed in the end of October to the beginning of November 2011.
- Venus encounter will be scheduled in November 2015 with multiple powered swing-by's.
- Venus Orbit Insertion (VOIR1) will be achieved in 2015 in the shortest case. The longest case will be in 2018.