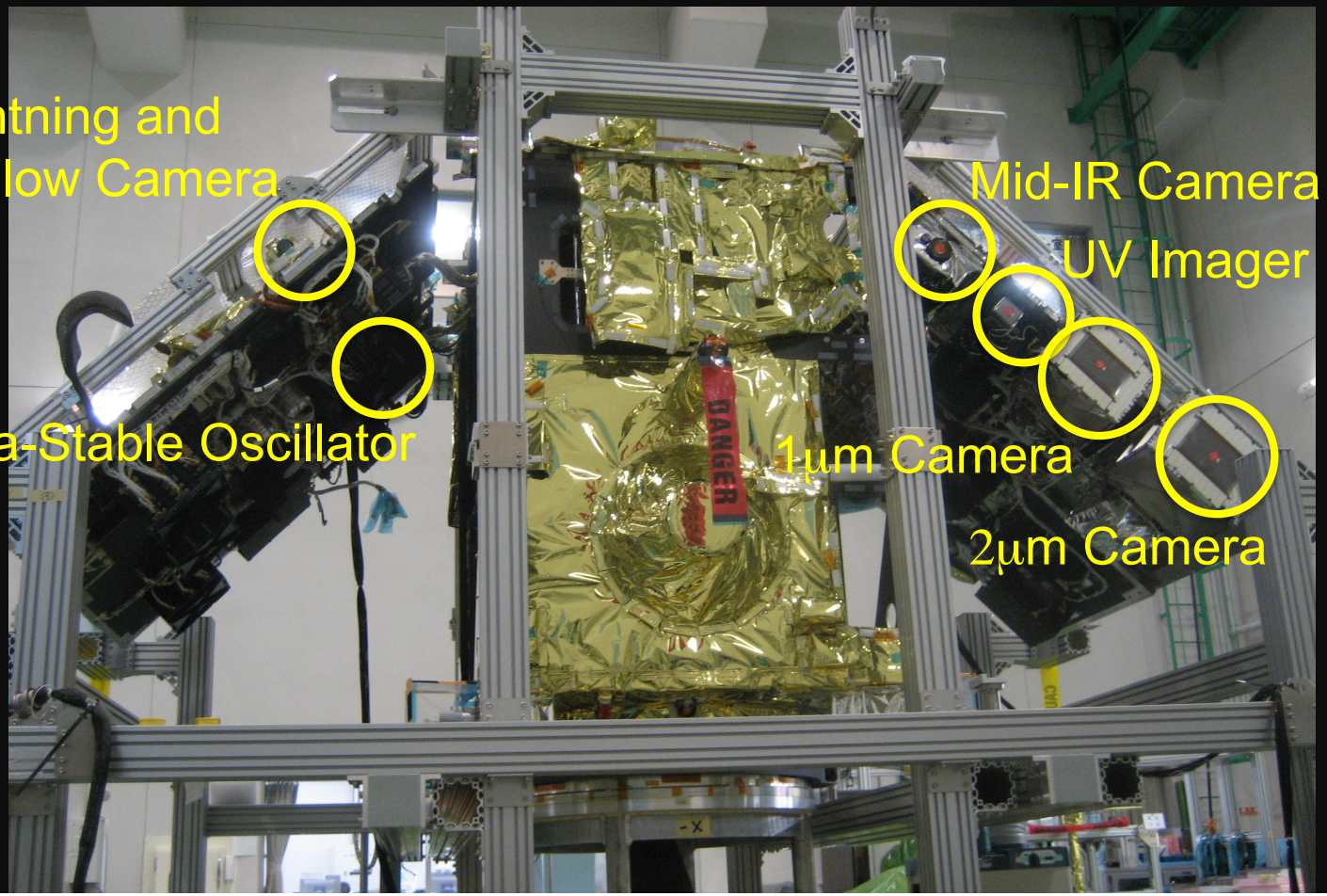
Toward Venus orbit insertion of Akatsuki

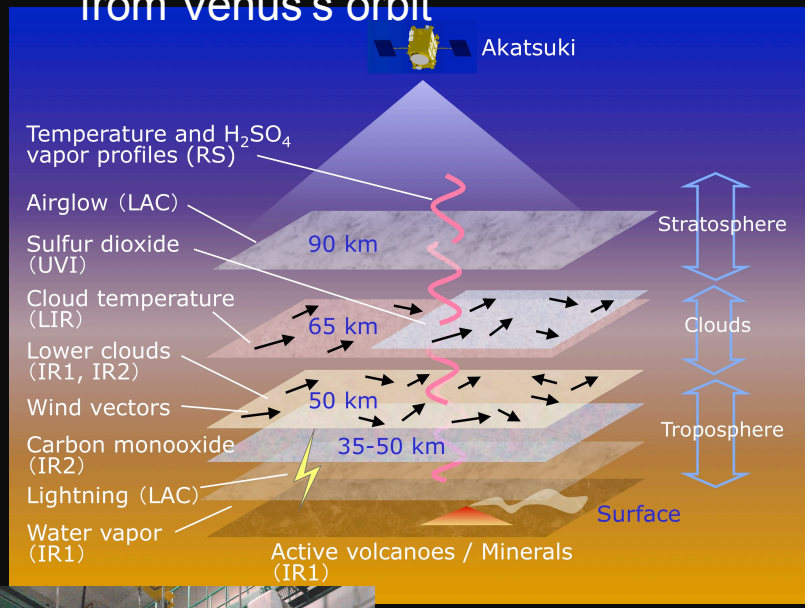
Takeshi Imamura (JAXA, Japan)

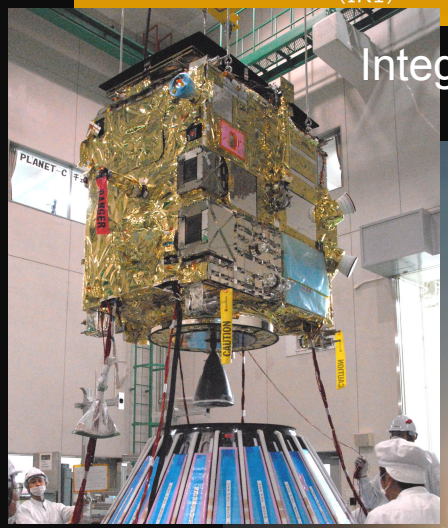


Development and launch

- Objective: Understanding the atmospheric dynamics and cloud physics of Venus
- Spacecraft
  - Designed for remote sensing from an equatorial, elliptical orbit
  - Mass: 500 kg (incl. fuel) Payload: 35 kg
  - Three-axis attitude control
- Science instruments
  - 1μm Camera (IR1)
  - 2μm Camera (IR2)
  - Longwave IR Camera (LIR)
  - Ultraviolet Imager (UVI)
  - Lightning and Airglow Camera (LAC)
  - Ultra-stable oscillator (USO)
- Launched in May 2010

3-D observation of the atmosphere from Venus's orbit



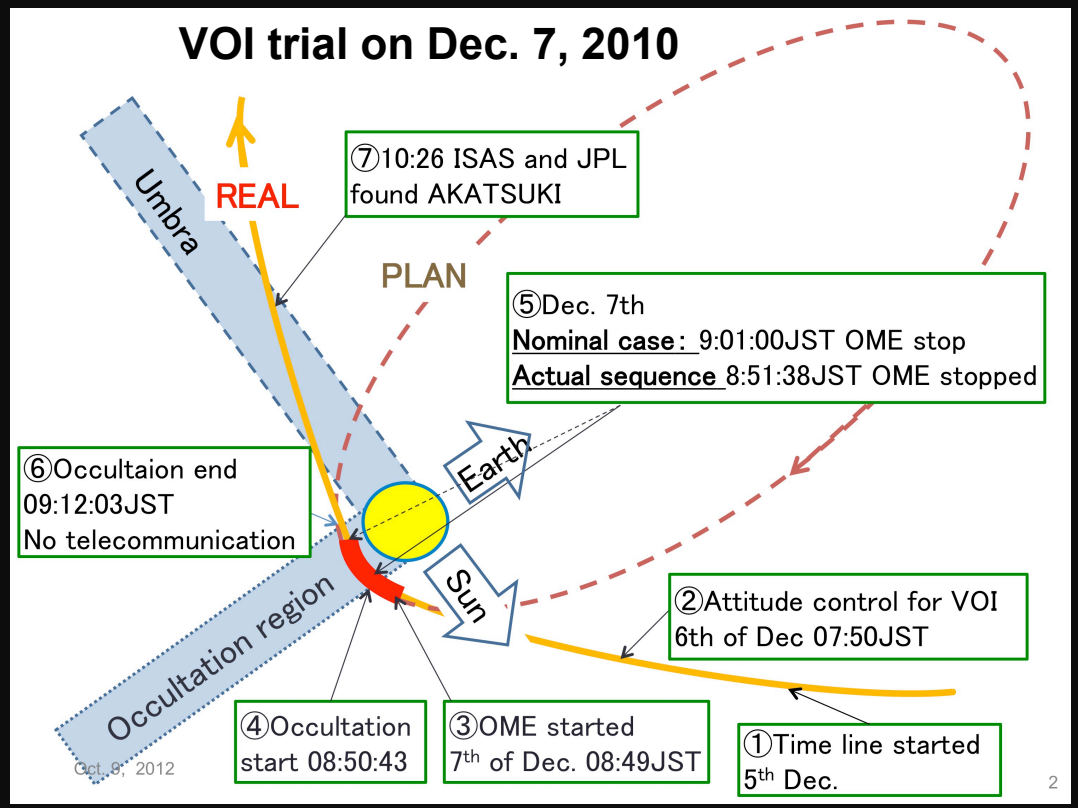


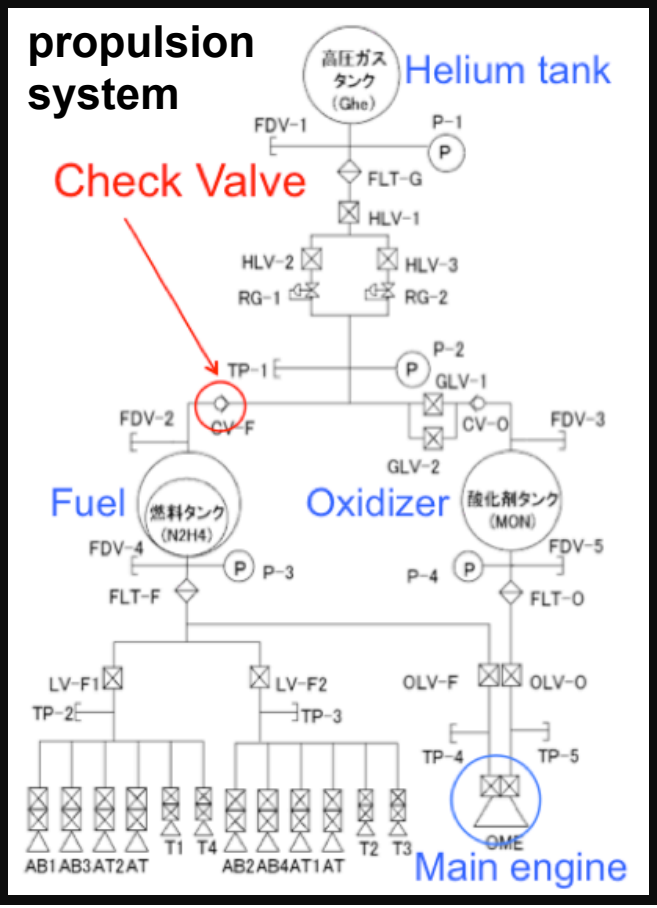
Integration at ISAS

Launch by H2A in May, 2010

Failure of Venus orbit insertion

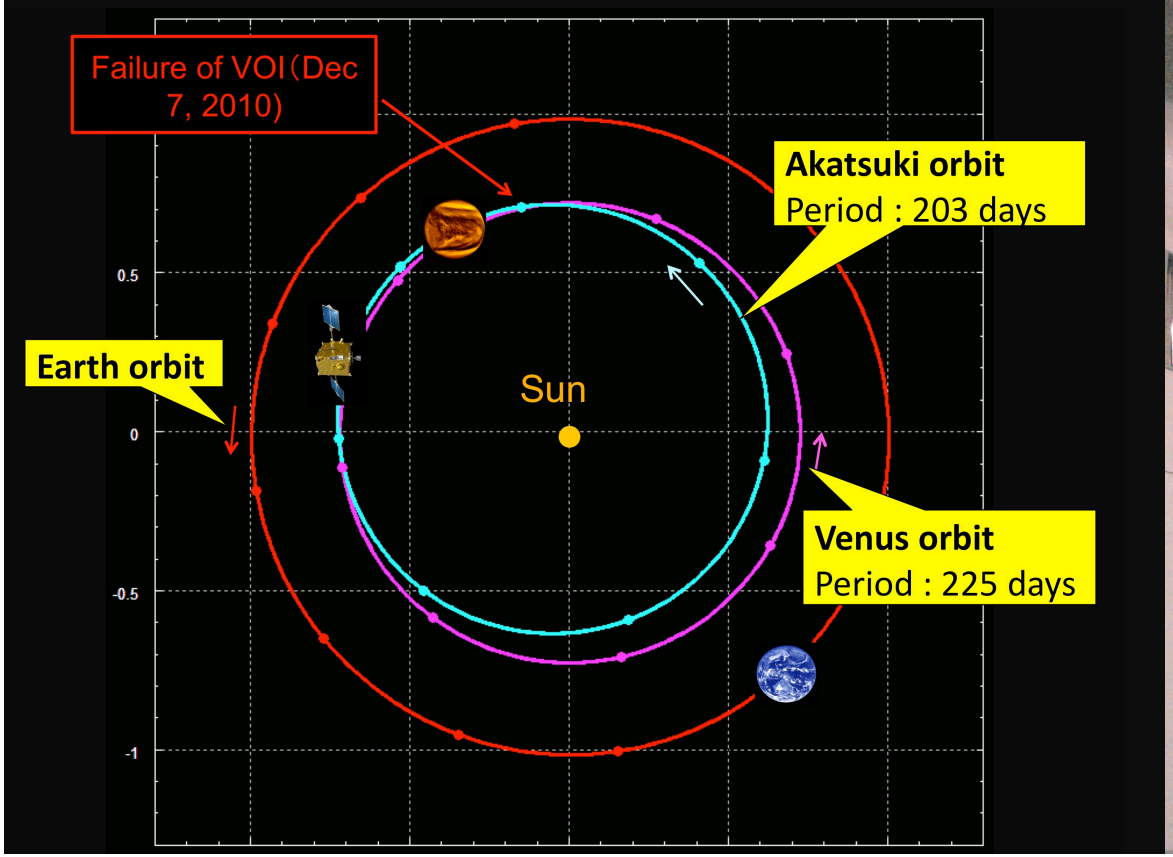
- The Venus orbit insertion (VOI) has failed on Dec 7, 2010 due to a malfunction of the propulsion system.
- The check valve between the helium tank and the fuel tank was blocked by an unexpected salt formation during the cruising from the Earth to Venus. As a result the orbital maneuvering engine (OME) became oxidizer-rich and fuel-poor condition, which led to an abnormal combustion in the engine with high temperature, and finally the engine was broken.



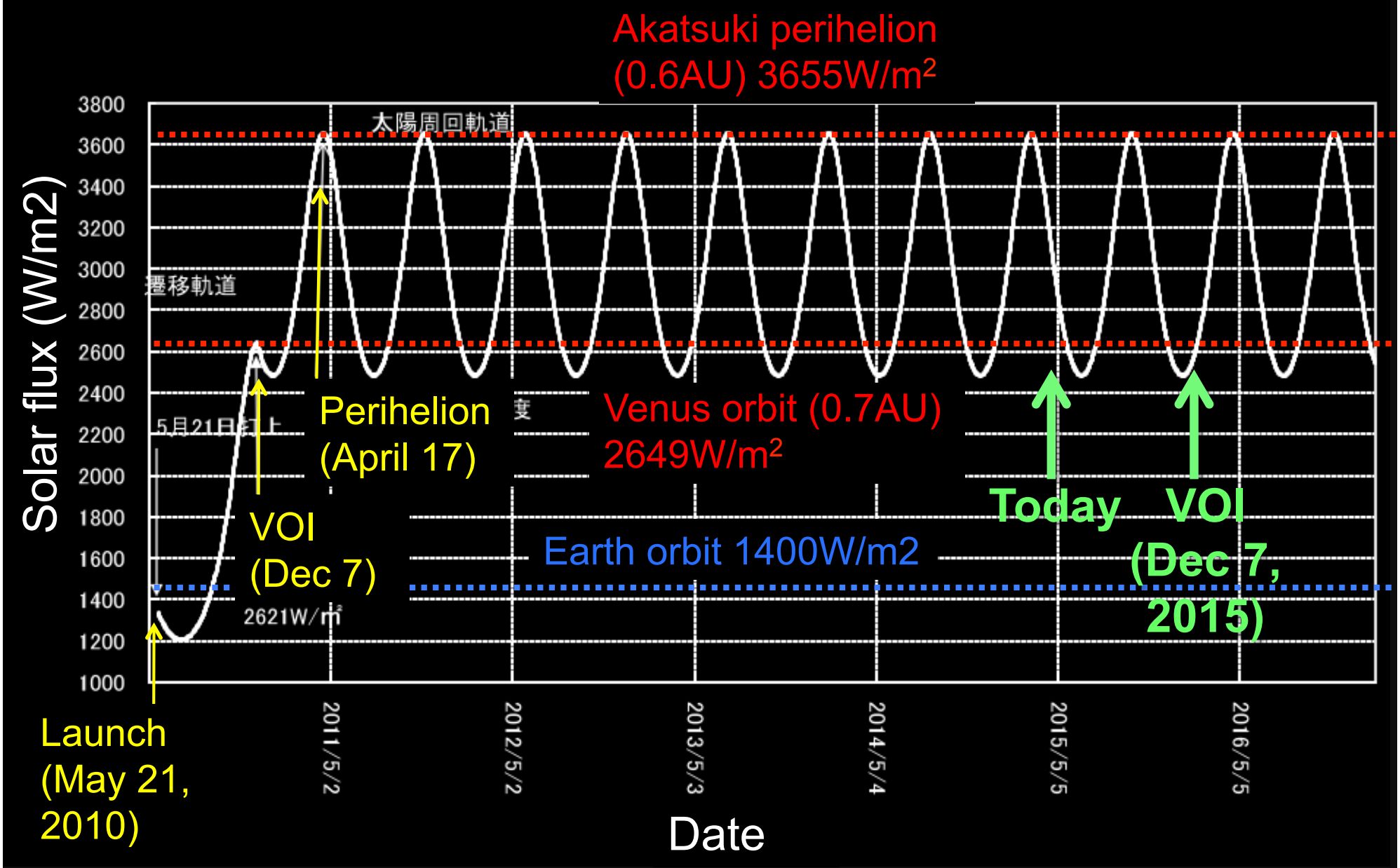


Toward the next VOI trial

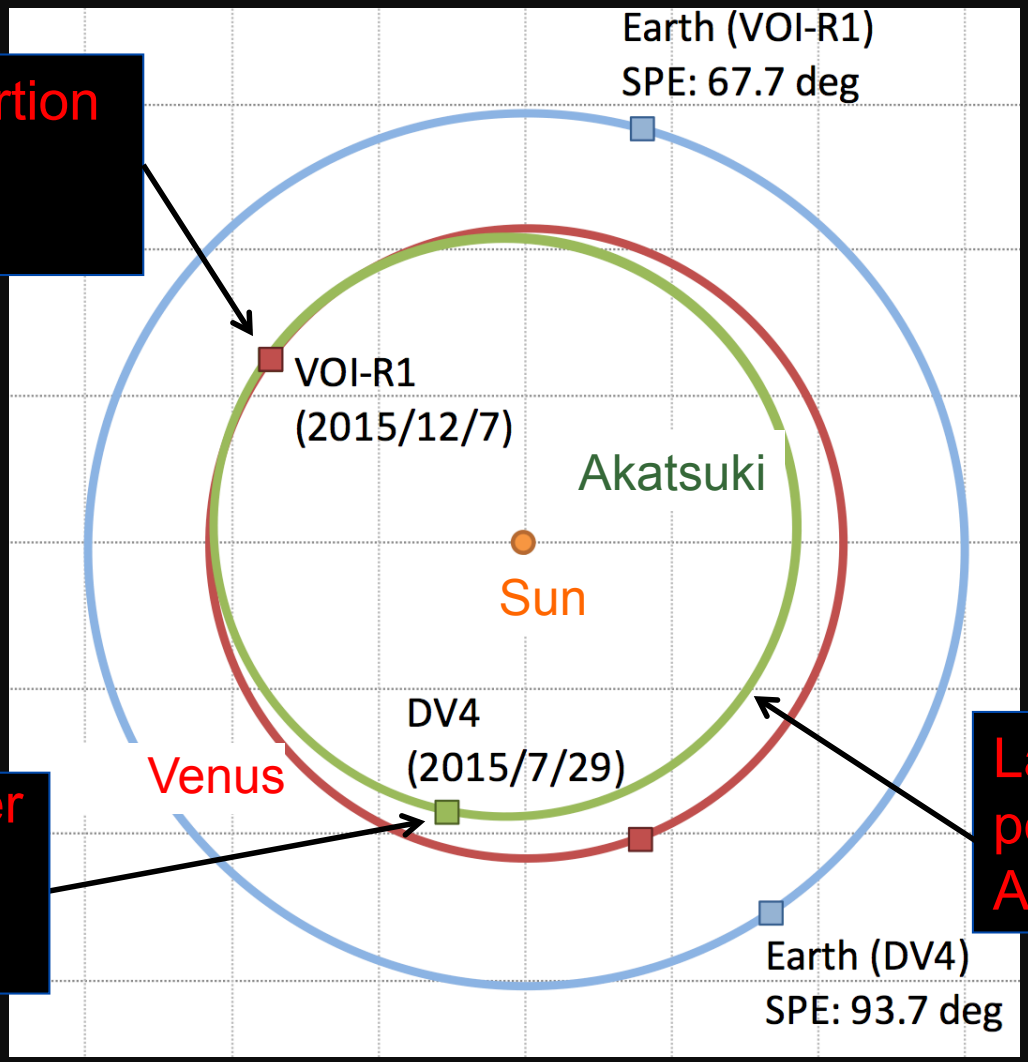
- Since the main engine (OME) was destroyed, we decided to use the attitude control thrusters (or reaction control system, RCS) for further orbit maneuvers. RCS does not require oxidizer, and we disposed the oxidizer of 65 kg in Oct 2011 to reduce the weight.
- An orbit control maneuver was conducted using RCS in Nov 2011. This operation enabled a Venus encounter in 2015.



Thermal condition



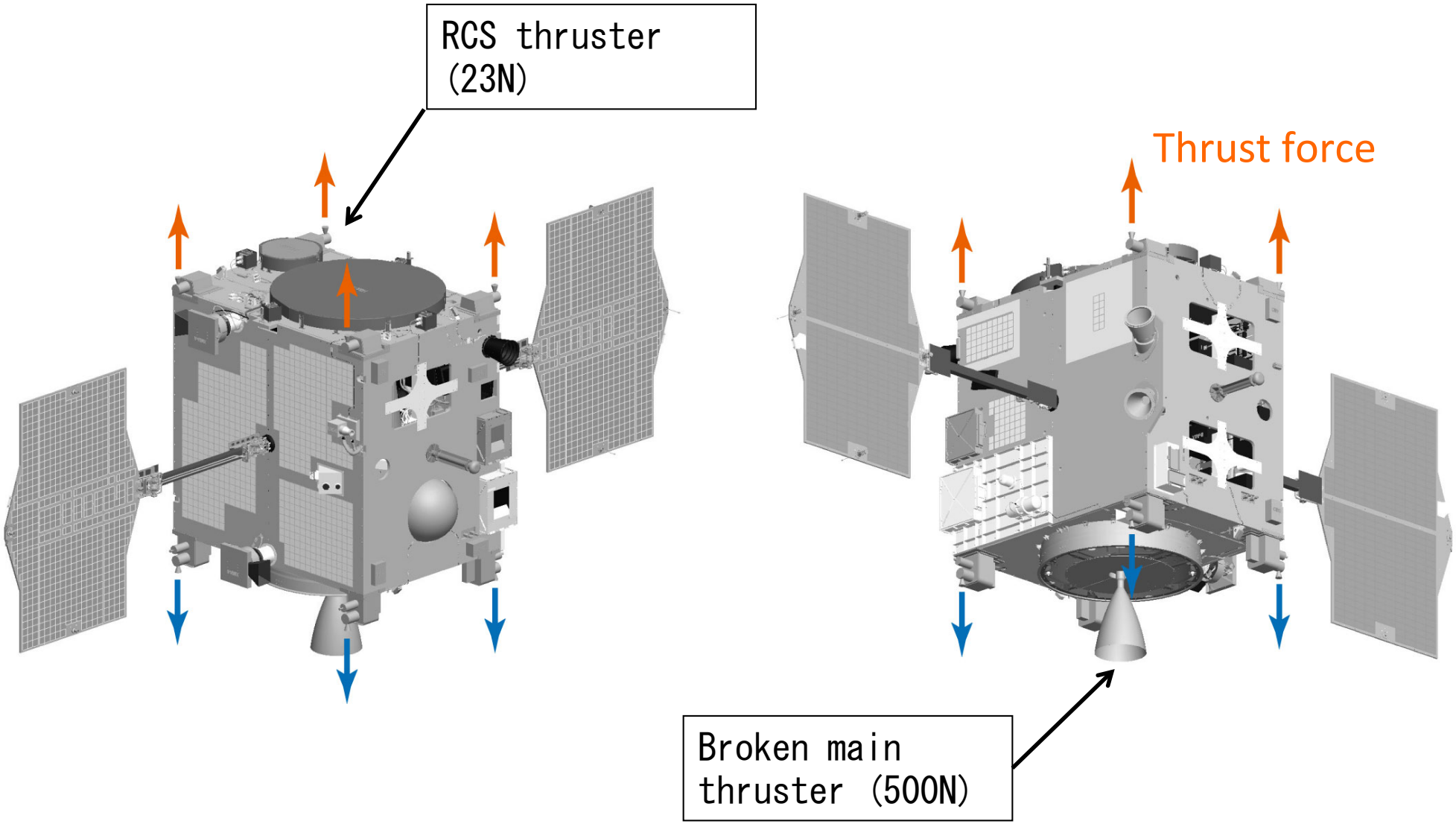
Venus orbit insertion
Dec 7, 2015
ΔV = 196 m/s



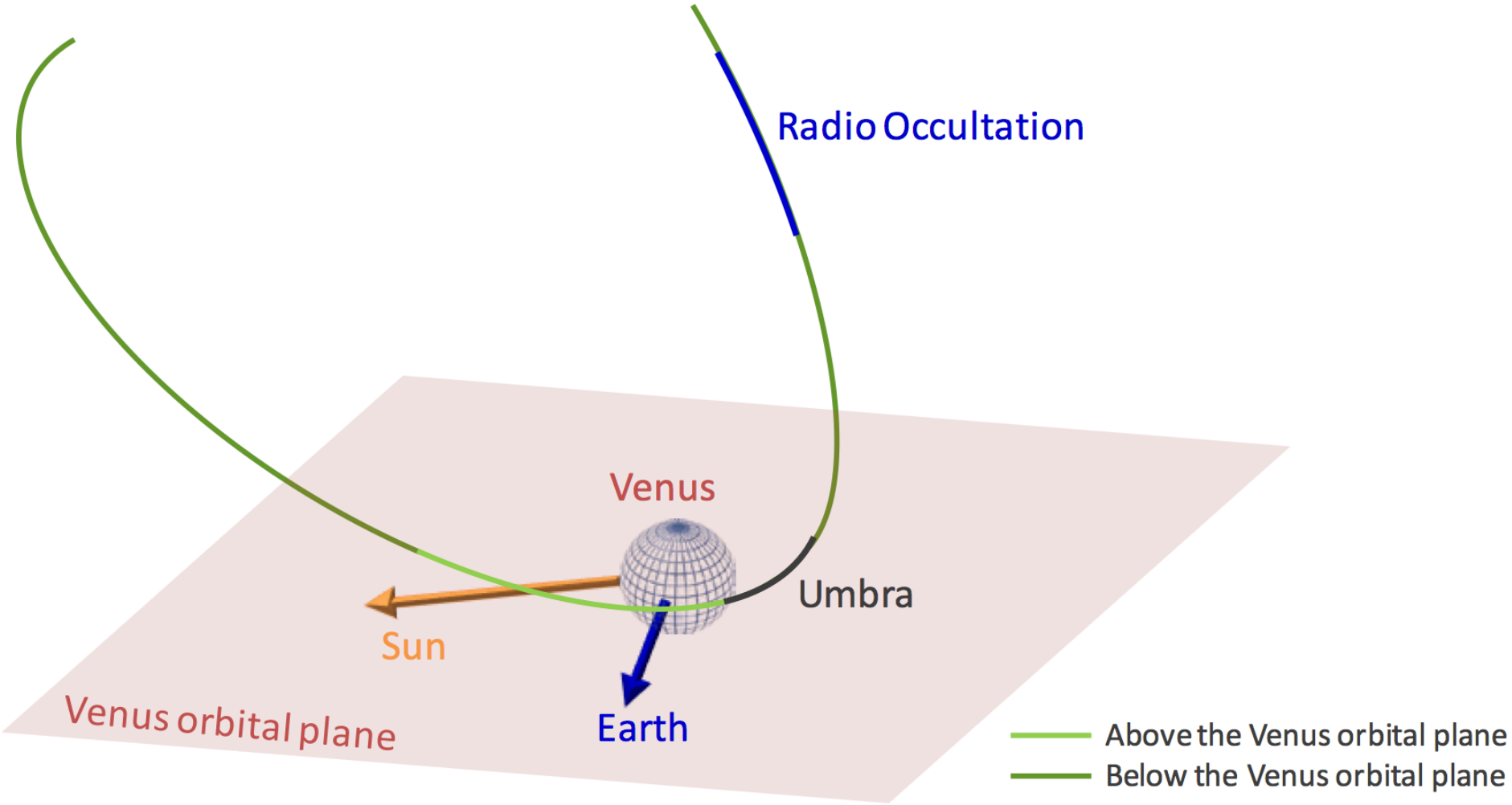
Orbital maneuver
Late July 2015
ΔV = 87 m/s

Last (9th)
perihelion passage
Aug 29, 2015

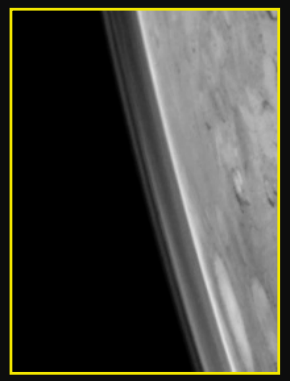
Event	Date	ΔV	Apoapsis	Period
DV4	late July, 2015	87 m/s		
VOI-R1	Dec 7, 2015	196 m/s	4.9×10^5 km	16.2 days
VOI-R2	Dec 7, 2015	3 m/s	4.7×10^5 km	15.3 days
PC1	Mar 25, 2016	32 m/s	3.2×10^5 km	8.7 days
PC2	Jun 14, 2017	2 m/s	3.1×10^5 km	8.4 days



The total power of 4 RCS thrusters is approximately 20% of the main thruster.

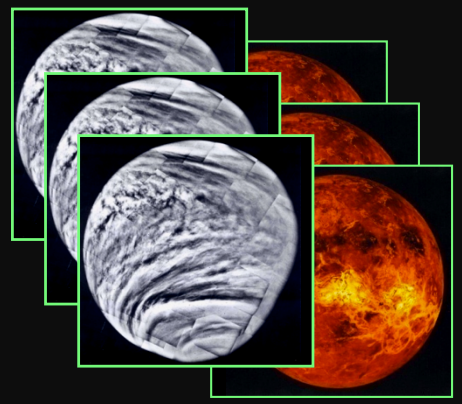

Radio Occultation
Venus
Umbra
Sun
Earth
Venus orbital plane
Above the Venus orbital plane
Below the Venus orbital plane

Observation plan in the new orbit



Limb images

Successive global images of atmosphere and ground surface (~9 days)

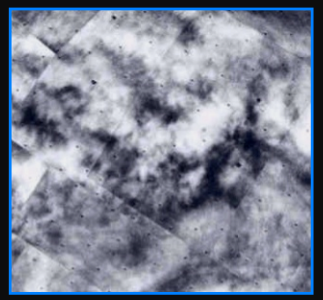


Orbital period ~ 9 days

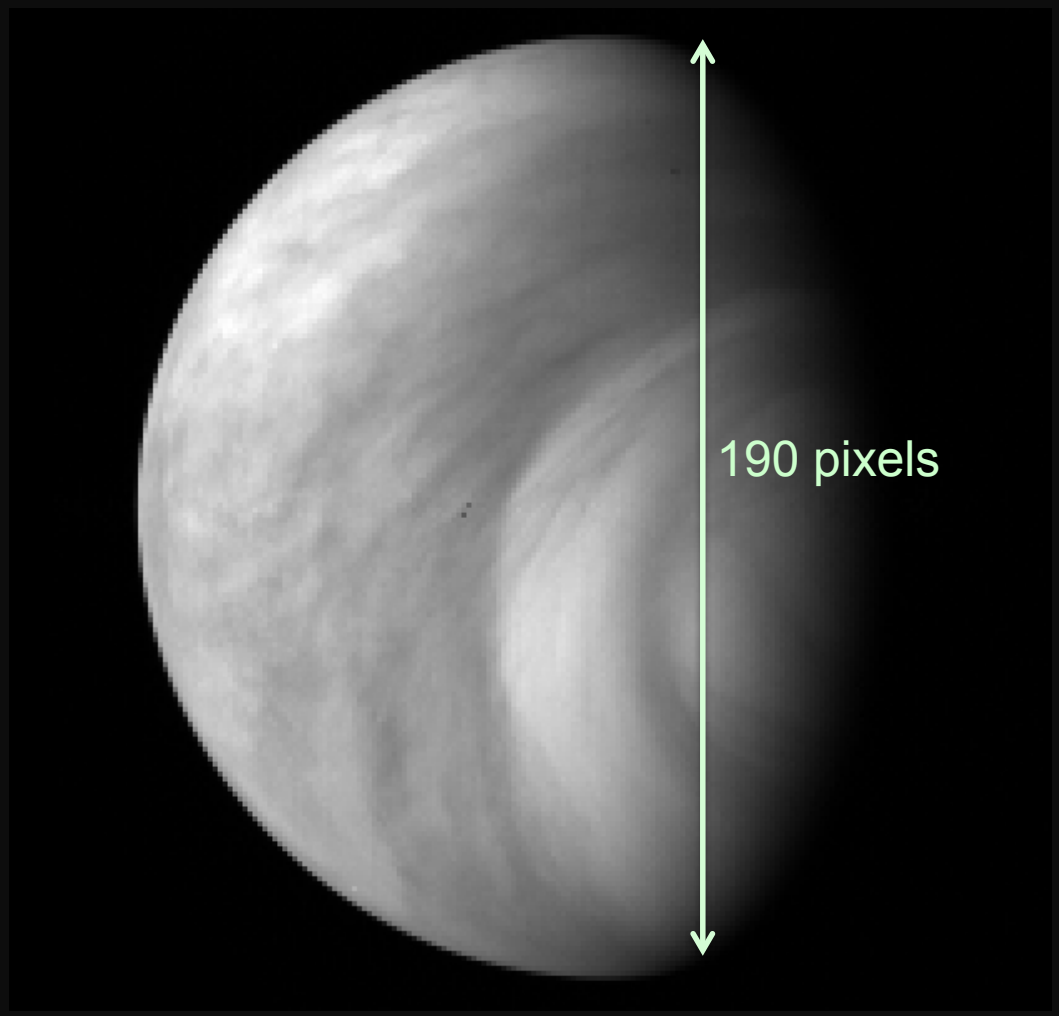
Ground station

Temperature / H_2SO_4 vapor / Ionosphere by radio occultation

- Close-up images
- Stereo viewing
- Lightning
- Airglow

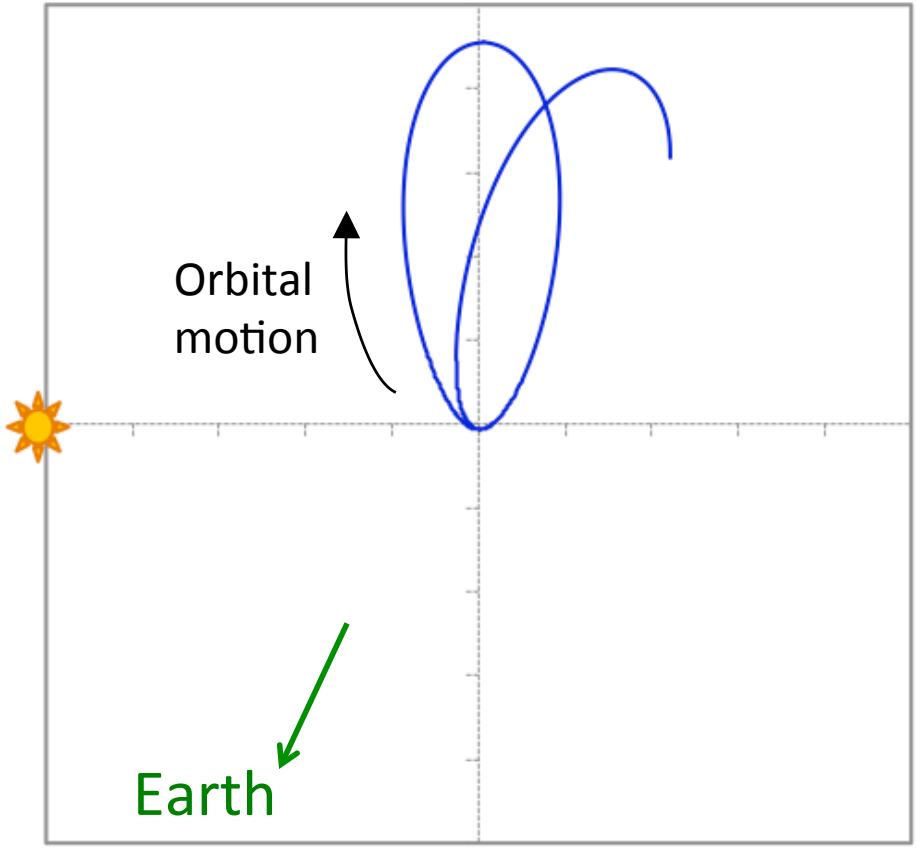


Venus to be seen from Akatsuki's apoapsis (an equivalent 2x2 binned VMC image)

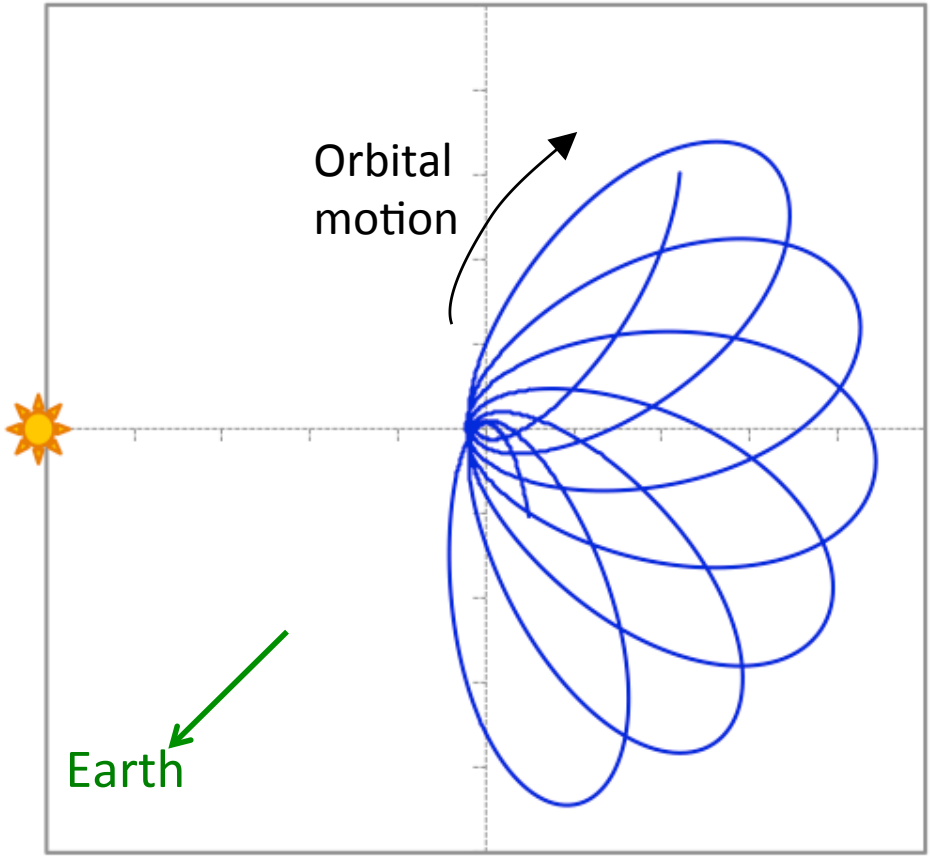


V0470_0048

Dec 7, 2015 (VOI) to Dec 31, 2015
Initial checkout



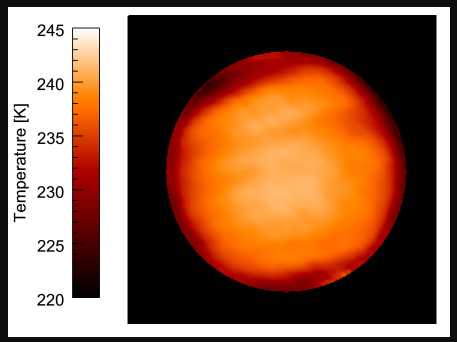
Jan 1, 2016 to Mar 31, 2016
Initial C/O → Regular obs



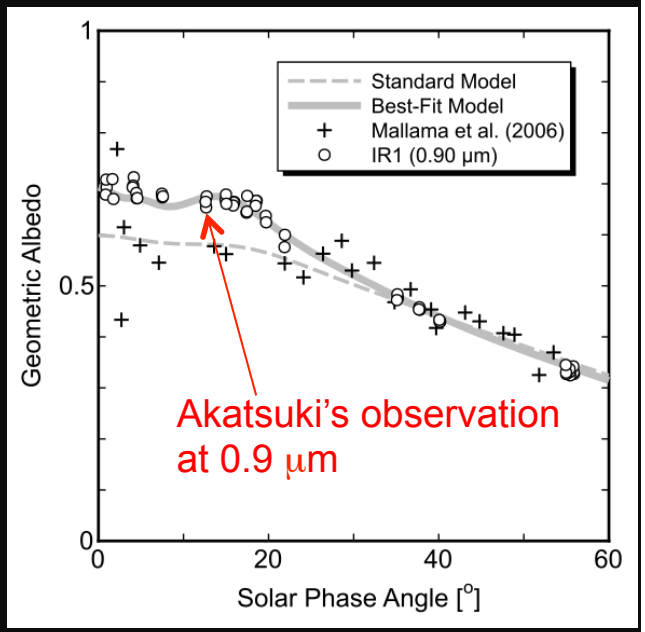
Trajectory of Akatsuki in a frame fixed to Venus and Sun
(Center: Venus)

Scientific observations during the cruise

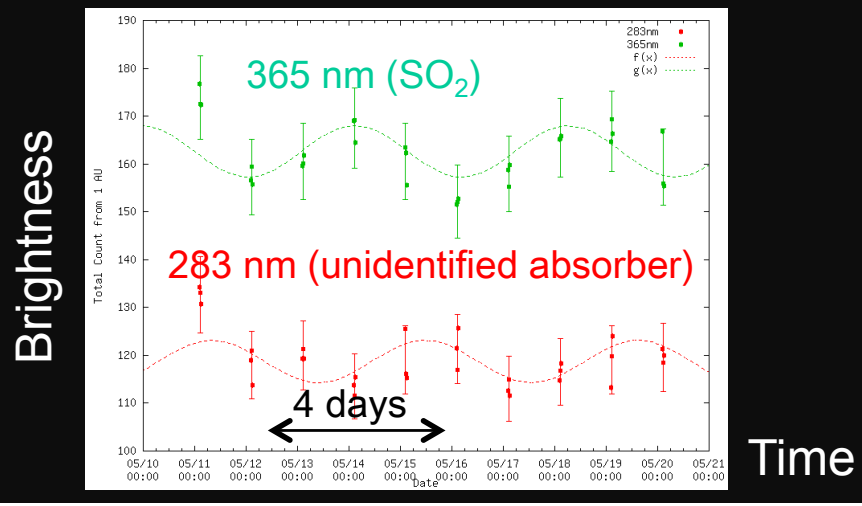
- Thermal images of Venus obtained by LIR two days after the failure of VOI revealed previously unknown structures in the cloud temperature distribution.
- Photometric observations of Venus at near-infrared wavelengths by IR1 and IR2 from distances of 10^6 km conducted in 2011 revealed existence of anomalously large particles near the cloud top during this period.
- Photometric observations of Venus at ultraviolet wavelength by UVI conducted during the same period discovered phase-shifted periodic variations of the amount of sulfur dioxide and unidentified UV absorber at the cloud top, providing clues of planetary-scale waves transporting these species.



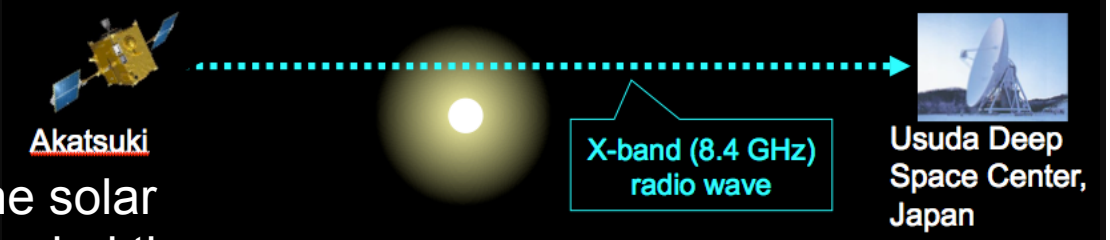
Temperature map obtained two days after the failure of VOI (Taguchi et al. 2012)



Scattering angle dependence of cloud albedo obtained from far distances (Satoh et al. 2014)

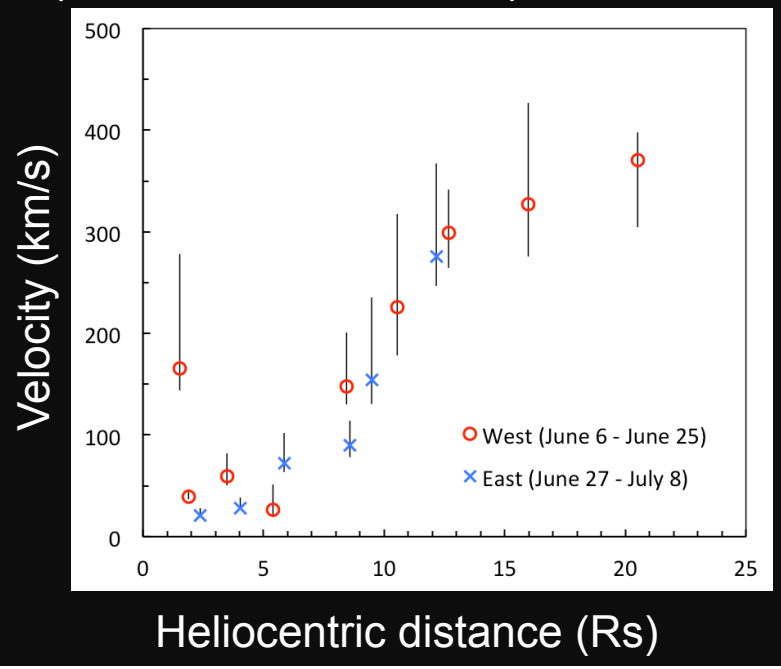


Scientific observations during the cruise

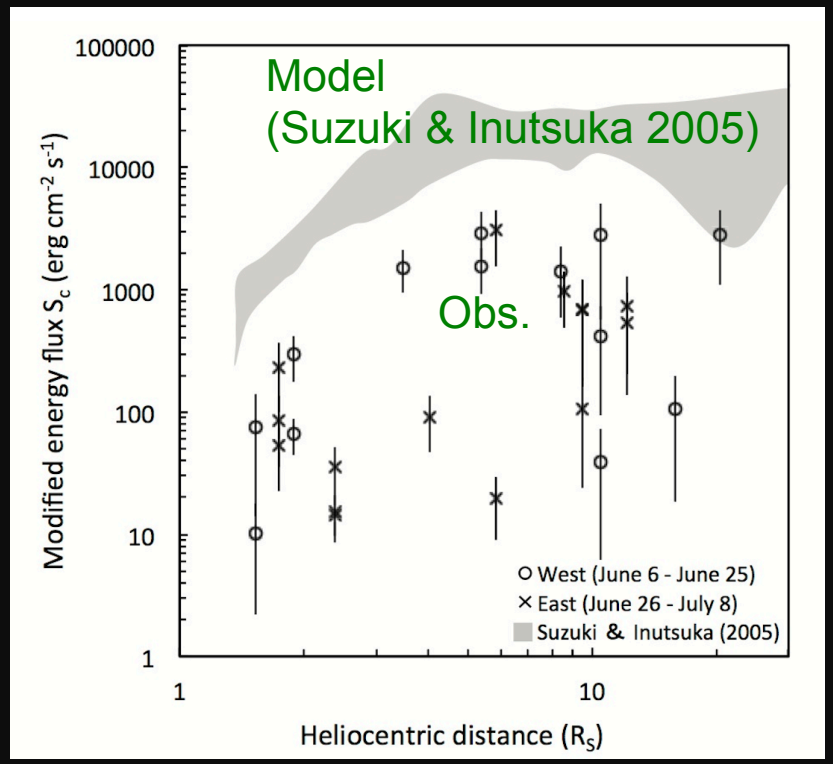


- Radio occultation observations of the solar corona conducted in June 2011 revealed the radial variations of the solar wind velocity and the energy flux of acoustic waves. The results constrain the coronal heating and acceleration mechanisms.

Radial variation of solar wind velocity (Imamura et al. 2014)



Radial variation of energy flux of acoustic waves (Miyamoto et al. 2014)



Summary and additional information

- We have developed a detailed VOI plan, in which the attitude control thrusters are used instead of the main thruster. The date of VOI is December 7, 2015.
- The spacecraft has passed through the perihelion 8 times, and the final perihelion passage is scheduled for August 29. We are carefully monitoring the change of the temperature of the spacecraft.
- NASA DSN support for orbital determination ongoing
- The new orbit around Venus is a long elliptical one with the orbital period of 8-16 days. The spatial resolution to be achieved around the apoapsis becomes worth as compared to the original orbit whose period is 30 hours, although we can get high-resolution images in close proximity of Venus.
- We are going to install an onboard software which extracts a portion of the image area containing Venus for observations from far distances. This enables increase of the number of images to be obtained.
- All of the science instruments have been switched off for more than three years due to thermal constraints. Some of them will be turned on before VOI.

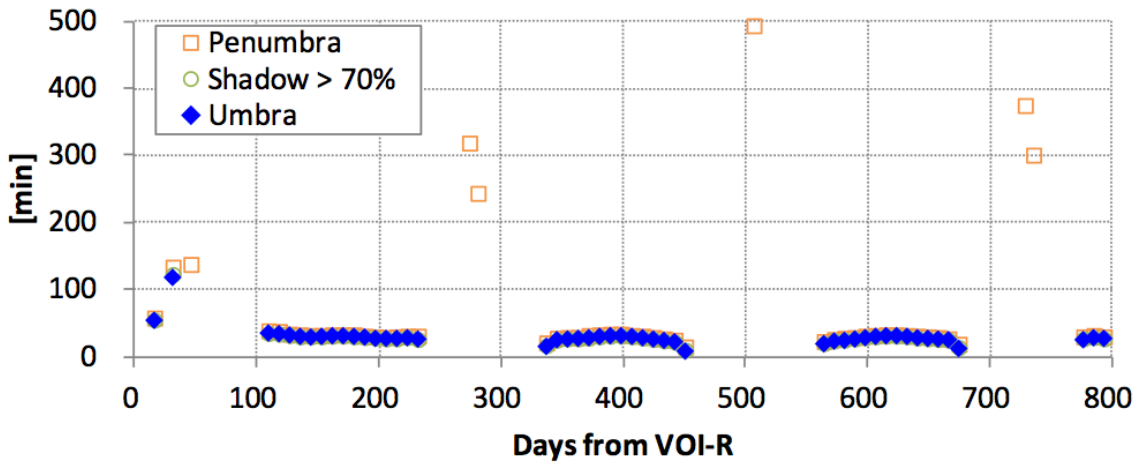


図 3.1.1　日陰時間

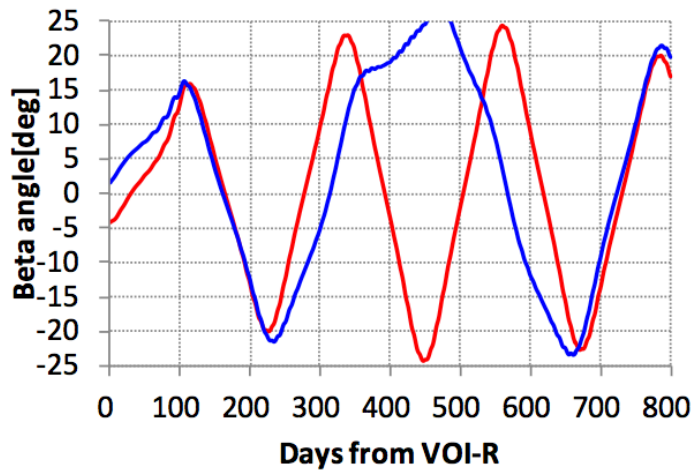


図 3.1.2　軌道面との成す角（太陽：赤／地球：青）

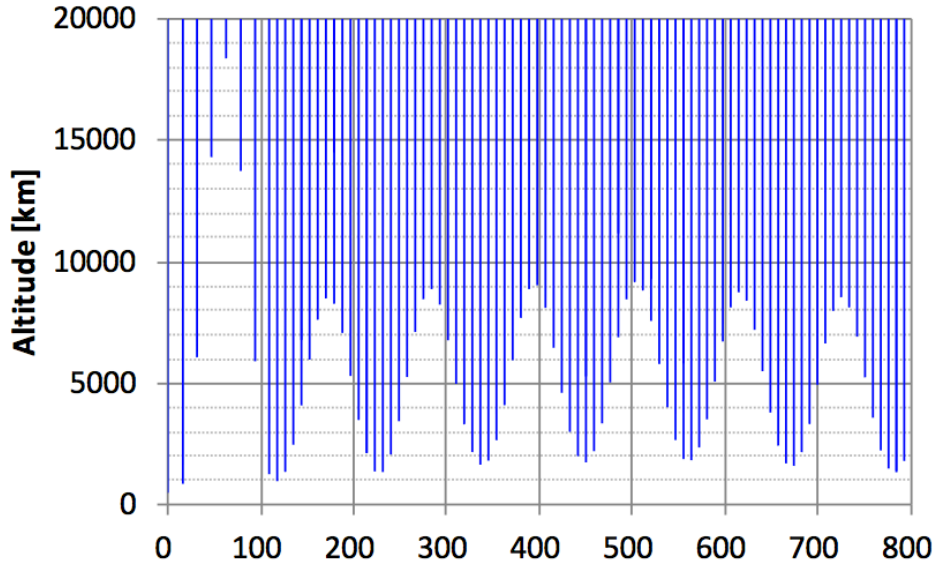


図 3.1.3　高度（近金点側）

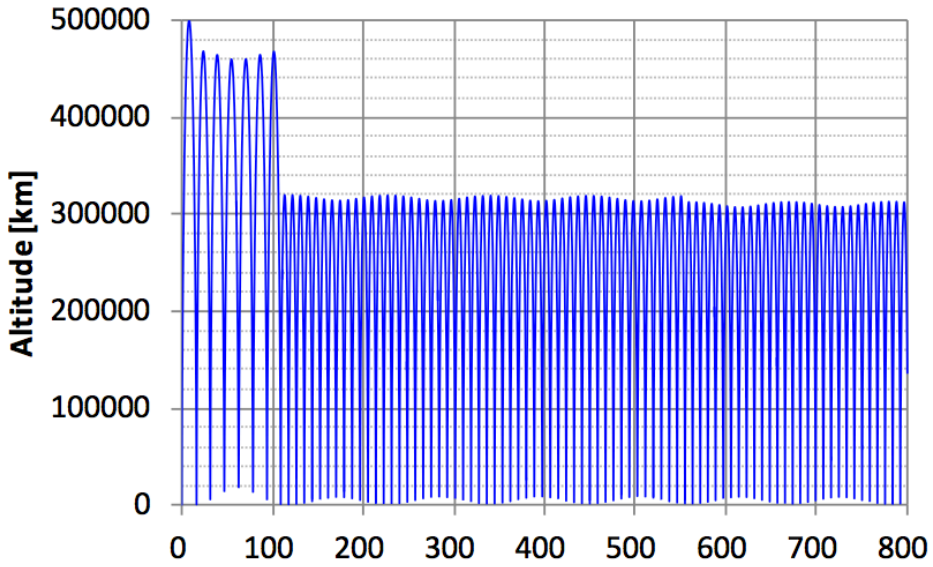
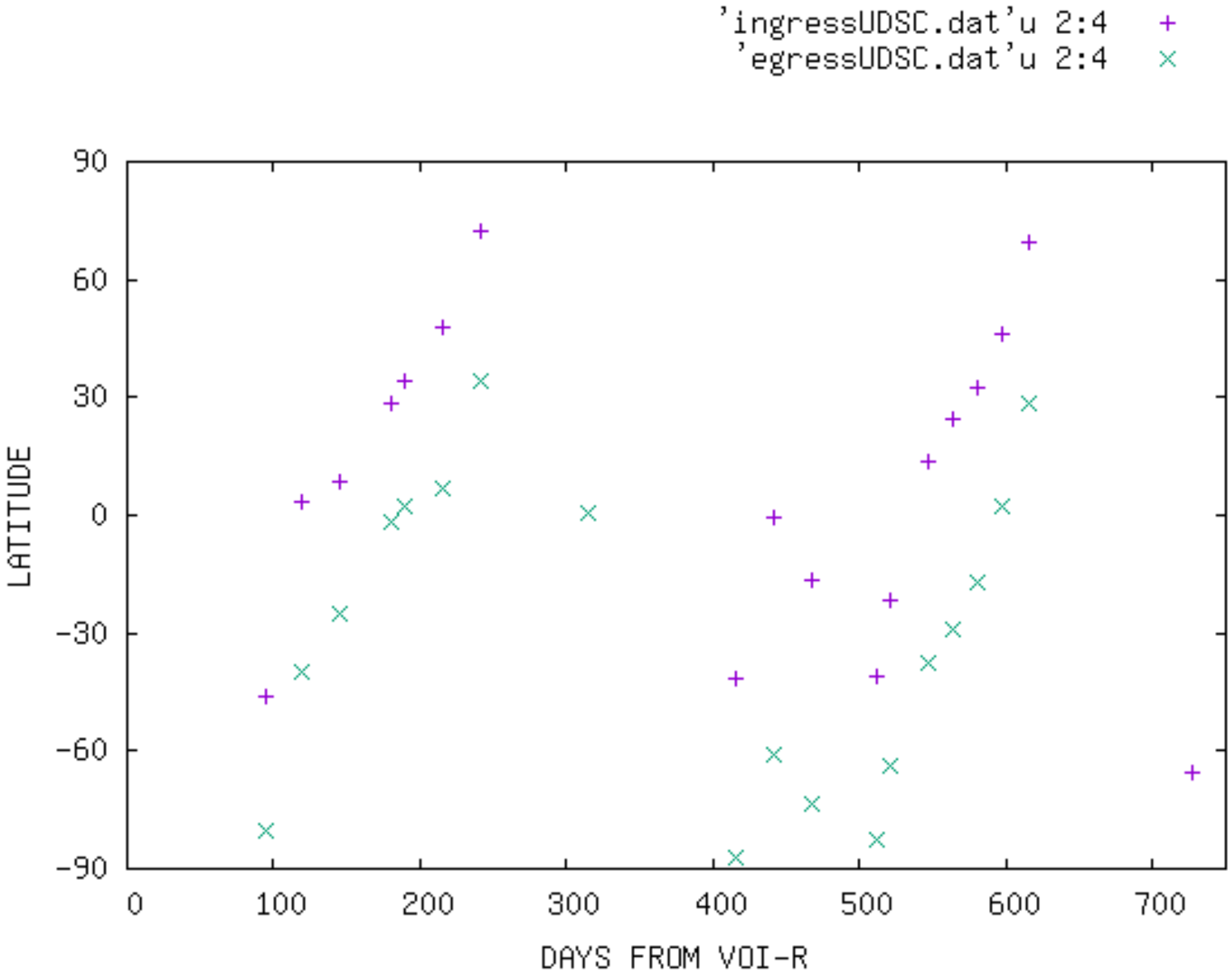


図 3.1.4　高度（遠金点側）

Latitudes to be observed (UDSC only)



Latitudes to be observed (UDSC+IDSN32)