VENUS:
OBSERVE IT WHILE IT'S HOT!

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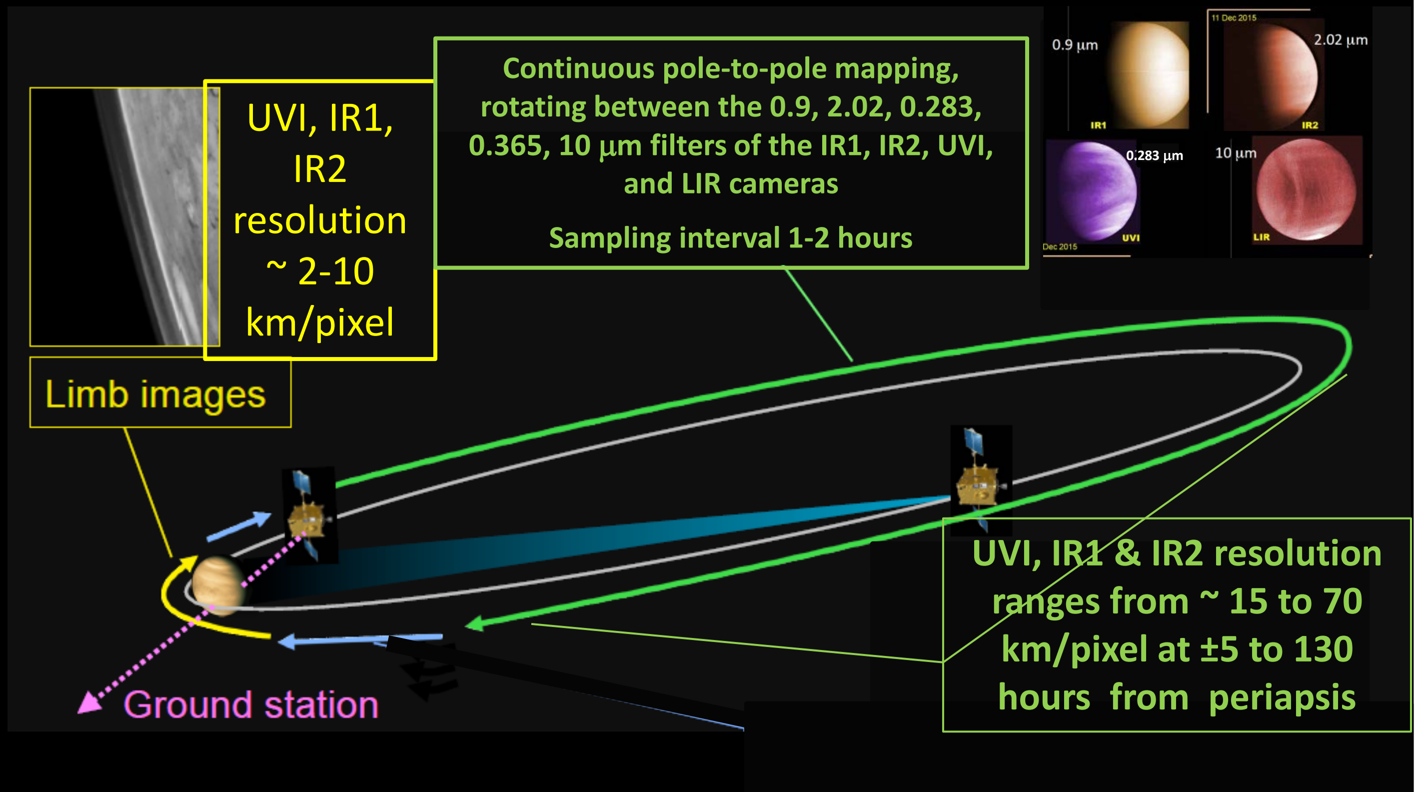
New Coordination Opportunities

- Akatsuki successfully achieved VOI Dec 7, 2015
- Akatsuki is operating in an long elliptical, equatorially centered orbit with a period of 10-12 days

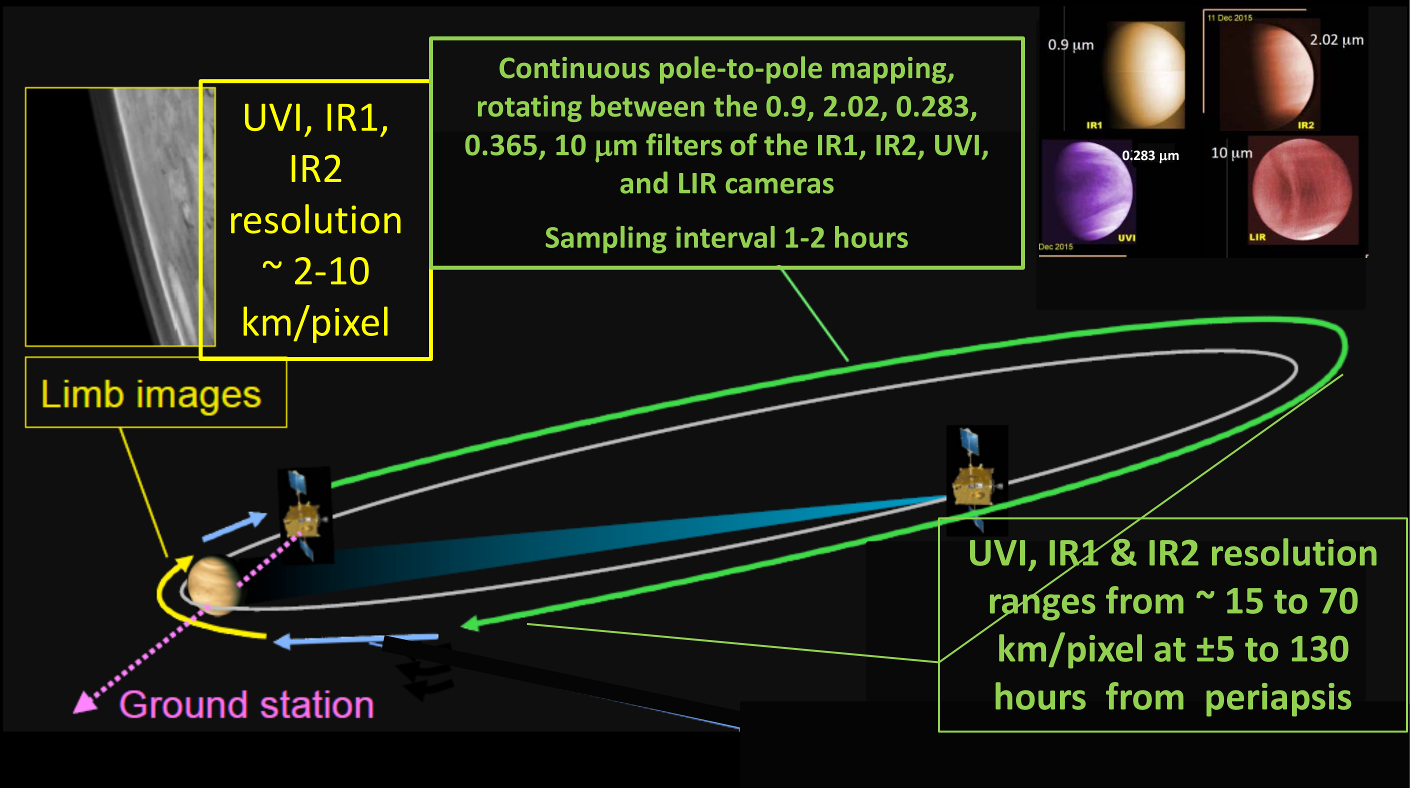


Akatsuki's 1-2 hour observing period and highly elliptical orbit provides ample opportunity to plan coordinated temporally coincident observation of Venus at multiple wavelengths from Earth based platforms

Two Key Akatsuki Observation Objectives:

1) Collect data to investigate via modeling the radiative deposition on Venus from equator to pole, and the resulting mass and energy transport

2) Collect data needed to investigate the sulfur chemistry cycling within Venus upper cloud deck

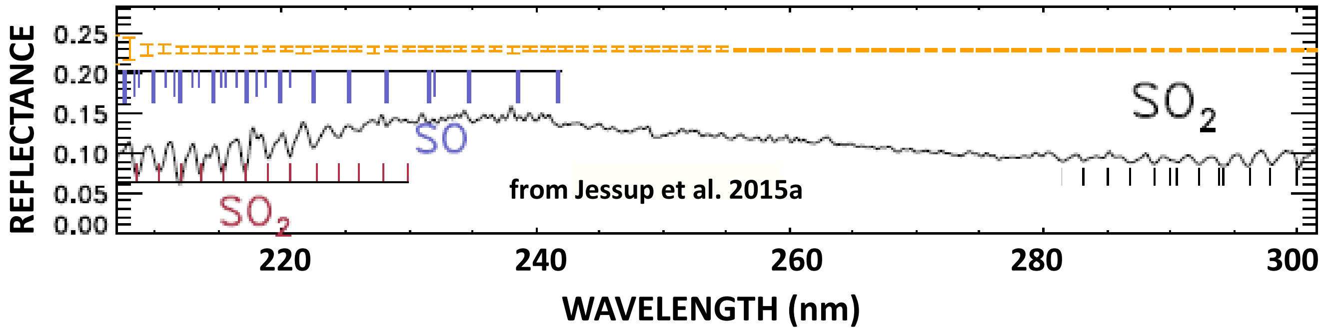


To advance Akatsuki's atmospheric chemistry objectives observations that uniquely capture mechanisms that drive sulfur cycle are needed

UV observing provides unique opportunities

Joint observation of SO_2 and SO gases key to tracing photochemistry

SO_2 and SO gas absorptions conspicuous between 200-300 nm



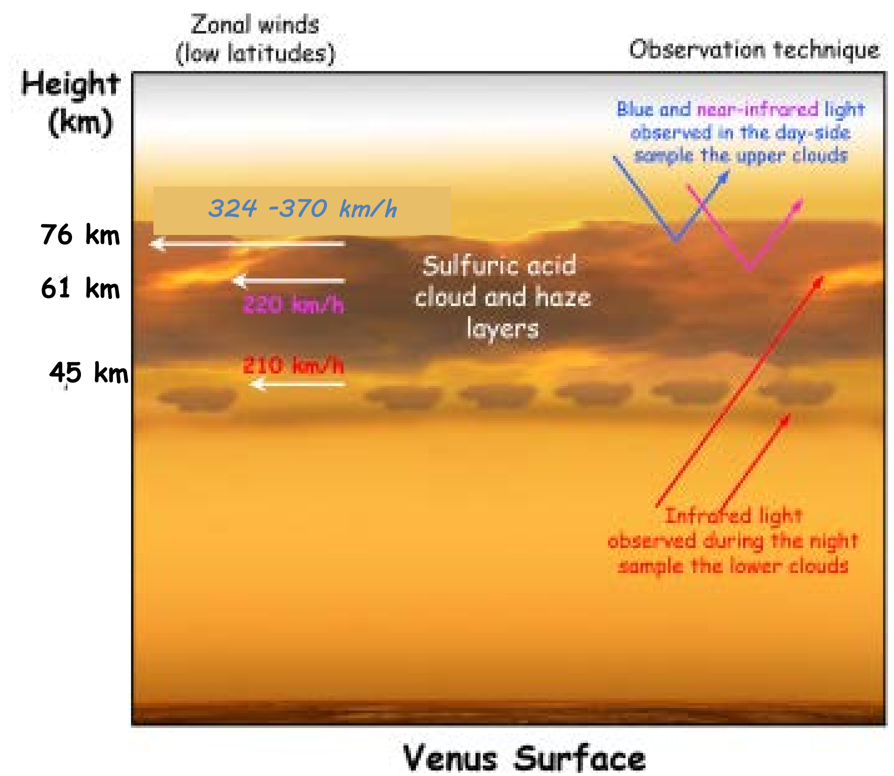
SO_x signatures not convolved with other prominent (or trace) Venus gases

Records SO_2 and SO gases absorption originating from between 70 and 80 km

When **photolysis products are mapped simultaneously as function of local time**

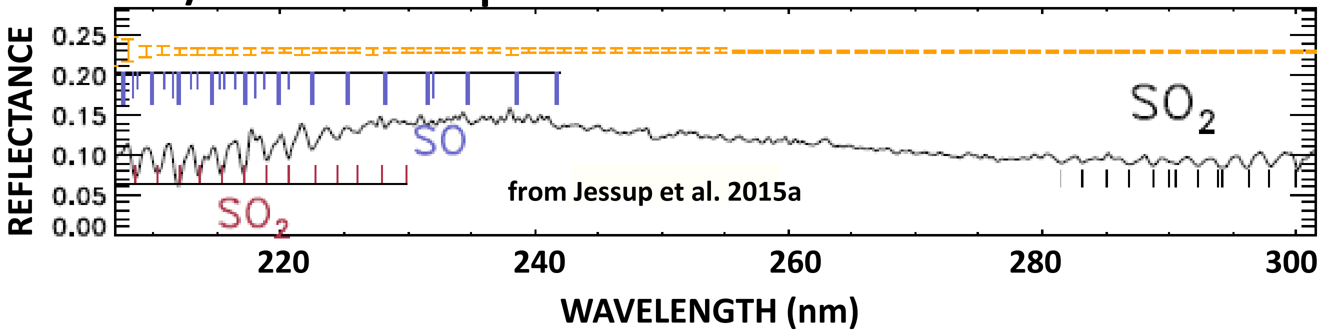
then

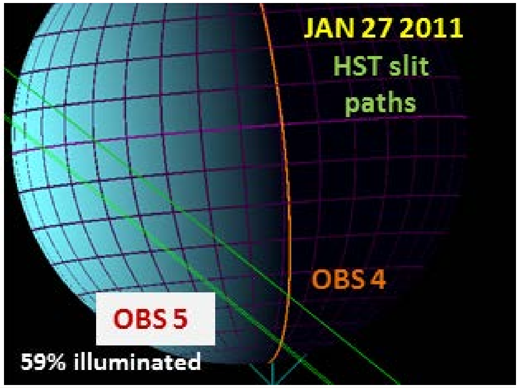
SO_2 and SO gas distribution can be used to define relative role of photochemistry and dynamics in progressing the sulfur cycle at the H_2SO_4 cloud altitude.



Why HST

HST/STIS G230LB spectrum:





0.1″ HST slit records gas signature between ~15 and 75±5° SZA with ~50 km/pixel spatial resolution

Currently HST is the ONLY:

- Earth-based Telescope has access to λ < 280 nm where both SO_2 and SO absorptions are seen

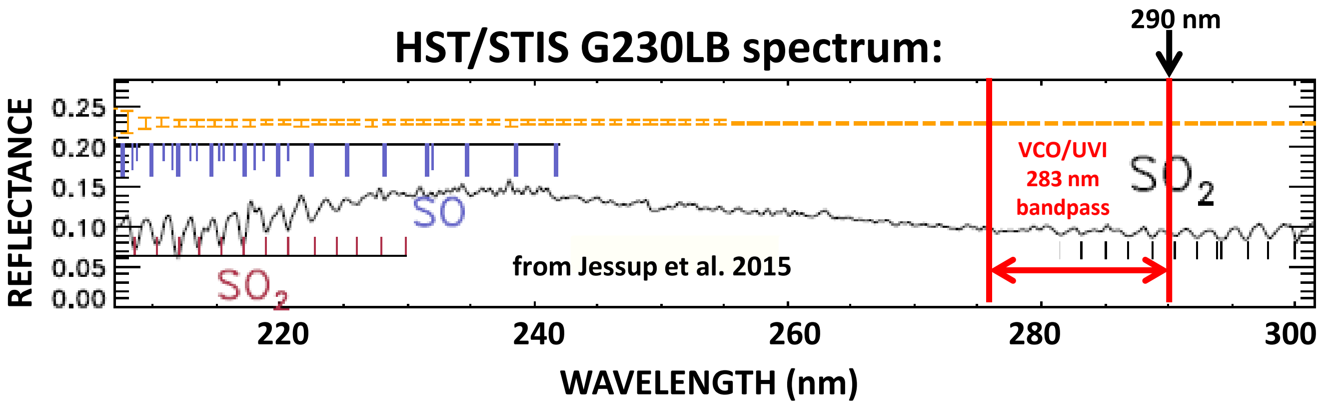
Currently ONLY HST :

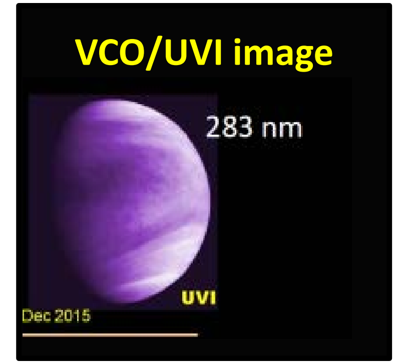
- Houses a UV spectrograph with spectral resolution required to make distinction retrievals of SO_2 and SO gases simultaneously.
- This means HST can **provide data needed to study (parameterize) the relative role of photochemistry, zonal and vertical transport between 70 and 80 km**

HST can map behavior at multiple local times and latitudes :

- The STIS long slit can document SO_2 and SO variation over ~60° SZA in a single exposure—so that instantaneous local time variation are mapped
- WFC3 has filters that allows mapping of UV signature in the SO_2 bands located at 200-240 nm& 280-290 nm, and the UV absorber at 395 nm ***expanding*** altitude range and the spatial coverage over which sulfur species distributions are mapped

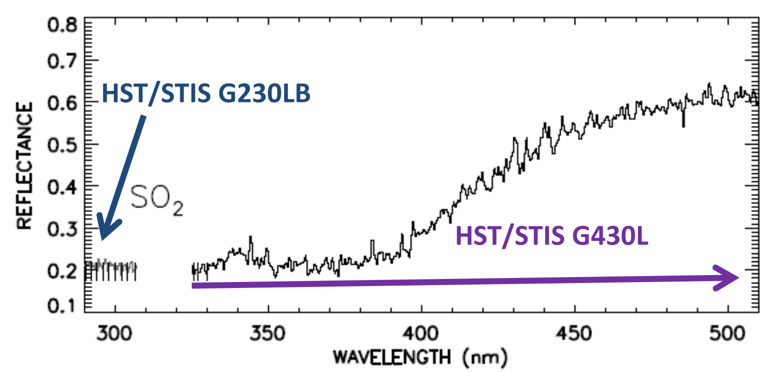
Benefits of Joint HST + AKATSUKI UV observations





Enhances calibration, validation & analysis of the data

- HST/STIS and HST/WFC3 calibration is well understood, coincident HST data will provide a powerful and needed tool to calibrate/validate VCO radiometry
- VCO/UVI 283 nm bandpass records signatures of the haze, unknown UV absorber and SO_2 gas, STIS spectral observations will be used to validate SO_2 retrievals
- HST/STIS can distinctly observe spectral signature of the unknown UV absorber this data is needed to accurately identify the composition and phase (gas/aerosol) of this enigmatic species



Joint HST + Akatsuki Observing Opportunities in 2017:

HST observations can only be made in specific windows that safeguard

- the telescope/baffling from overheating
- the telescope from stray light

In the HST observing windows only 50-60% of Venus is illuminated

Joint observation of Venus by HST and Akatsuki can occur between

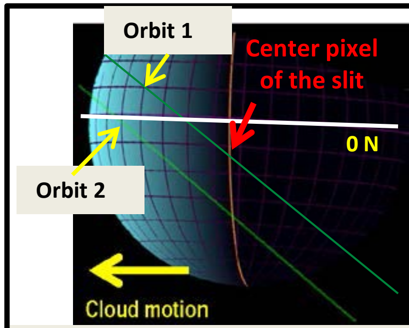
- **January 16- February 4, 2017 (p.m. quadrant observable)**
- **May 21-June 21, 2017 (a.m. quadrant observable)**

During these observing windows

- HST and Akatsuki will obtain simultaneous, spatially and temporally coincident images of Venus
- HST will obtain spectra of Venus that are simultaneous, spatially and temporally coincident with the Akatsuki imaging

Proposed HST Observation Plan:

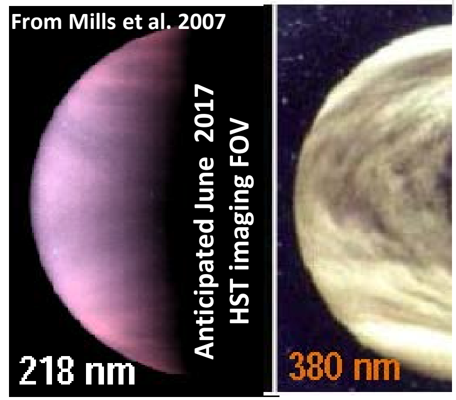
In 3 HST orbits (= 3 hr time period) we plan to obtain
200-1000 nm spectral imaging of Venus & 212-264 nm and 395±6 nm imaging of Venus



0.1″ STIS slit (green line) records gas signature from terminator (orange line) to sunlit limb with ~50 km/pixel spatial resolution

In orbits 1 & 2 HST/STIS exposures will be taken, placing the center of the slit at two distinct latitudes along the terminator for each exposure.

Orbit 3



WFC3 images sensitive to the SO_2 bands located at $\lambda <$ 240 nm or $\lambda >$290 nm and the UV absorber at 395 nm will be taken, recording cloud contrast similar to the examples displayed

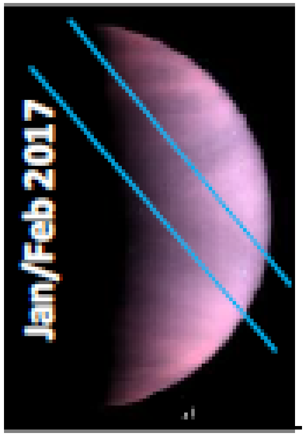
In 3 orbits, each exposure is separated by ≤ 1.5 hr
this is shorter than the photochemical or dynamical transport rates
Therefore, there will be no temporal confusion within the data.

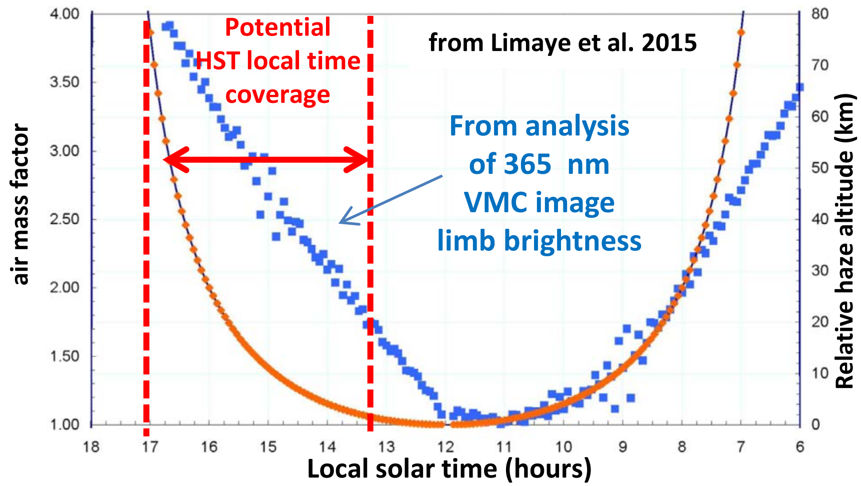
Given the 9 Earth-day Akatsuki Venus orbit pattern, our goal is to repeat the 3 orbit HST observing pattern on 3 specific dates, once every 4.4 Earth days so that

- **changes in the local time and latitude variability are tracked as a function of the cloud rotation period (assuming zonal wind velocity of ~ 100 m/s)**
- **Coincident HST spectral and Akatsuki imaging observations are obtained on three dates**

On dates when Akatsuki and HST observations are coincidentally obtained, HST spectral observations will be used to cross-calibrate the planned 283 nm and 365 nm Akatsuki imaging

P.M. Quadrant observing in January 2017





Local time asymmetry between the pre- and post-noon H_2SO_4 cloud haze density and winds have been observed.

The WFC3 images will provide detailed maps of Venus' 65-80 km SO_2 gas distribution as function of local time and latitude on the p.m. quadrant.

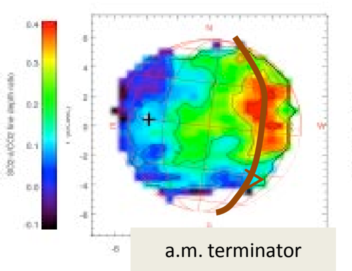
These observations will be *first* HST images ever recorded on the p.m. quadrant

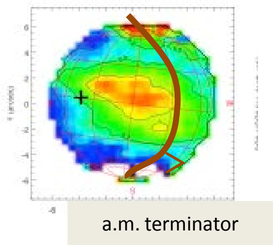
HST/STIS will provide *first* simultaneous measurement *of the p.m. quadrant* SO_2 and SO densities with both local time and latitude resolution without any temporal confusion

Coincident acquisition of the STIS+WFC3 images provides a way to generate a reasonable estimate of the pole to pole dayside SO gas distribution between 70 and 80 km

Joint HST-Akatsuki observations will provide needed insight into how chemistry and dynamics work together to support the observed trends.

A.M. Quadrant observing in June 2017

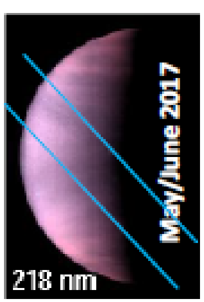




- VEx era observations made between 60 and 100 km indicate Venus' SO_2 gas density may be inflated on the a.m. terminator relative to what is observed at local times—**BUT** ***not always***

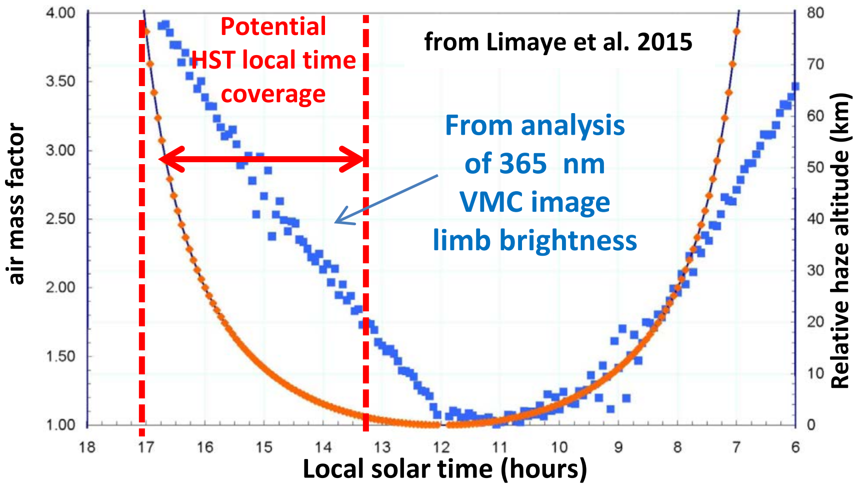
- transience in the near-terminator SO_2 inflation **cannot** be explained by photochemical processes
- The observed transience may be related to changes in vertical mixing and/or microphysical processing

The VEx-era results demand that NEW multi altitude, temporally coincident observations of the pole-to-pole SO_2 distribution are obtained

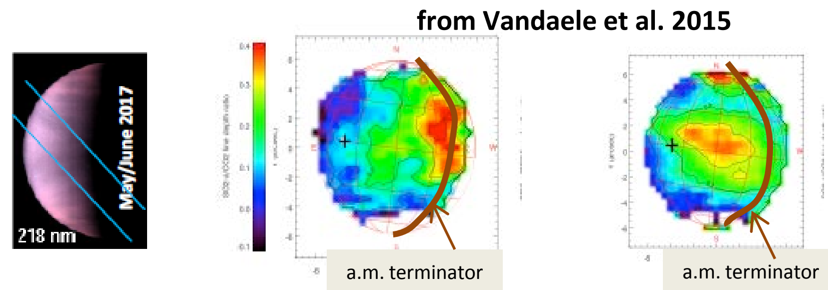


- Joint HST WFC3+VCO imaging will cover wavelengths from 200-300 nm, so that the dayside SO_2 is mapped from pole-to-pole between 65 and 80 km
- Acquisition of co-located coincident STIS spectra will validate the SO_2 retrievals
- The STIS spectral also provide a way to generate a reasonable estimate of the pole to pole dayside SO gas distribution between 70 and 80 km

Additional Ground based observing coordination welcomed



P.M. Quadrant observing in June 2017

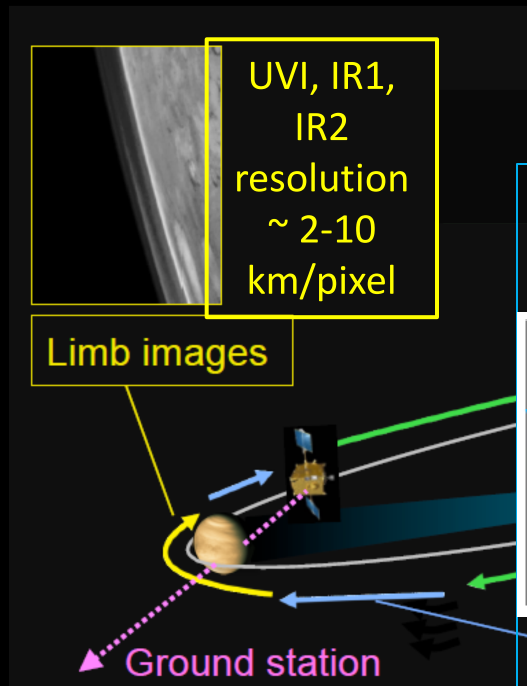


A.M. Quadrant observing in January 2017

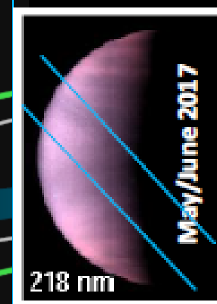
For either opportunity additional ground based observations taken at these times would only enhance the science return of the coordinated HST-Akatsuki observations

Unprecedented Opportunity for coincident detailed mapping of haze and chemistry

- Near-periapsis Akatsuki will take limb images from multiple vantage points in a 3 hour window
- As a result detailed haze properties will be recorded at multiple local times between the a.m. and p.m terminators



When Akatsuki is at/near periapsis HST will obtain:



- pole-to-pole 20 km/pixel images of Venus in the 225 nm and 290 nm filters
- 200-1000 nm limb to terminator STIS spectra

These observations will be sufficient to accurately map Venus' dayside SO_2 and SO behavior at multiple latitudes and local times while detailed haze properties are being recorded by VCO.

Additional coordinated observations taken in June/May 2017 and /or in Jan/Feb 2017 could provide additional data on the key tracers of the sulfur-oxide chemistry cycle while Akatsuki is getting detailed measurements of the haze properties

Great opportunity for coincident detailed mapping of sulfur species over a broad altitude range.

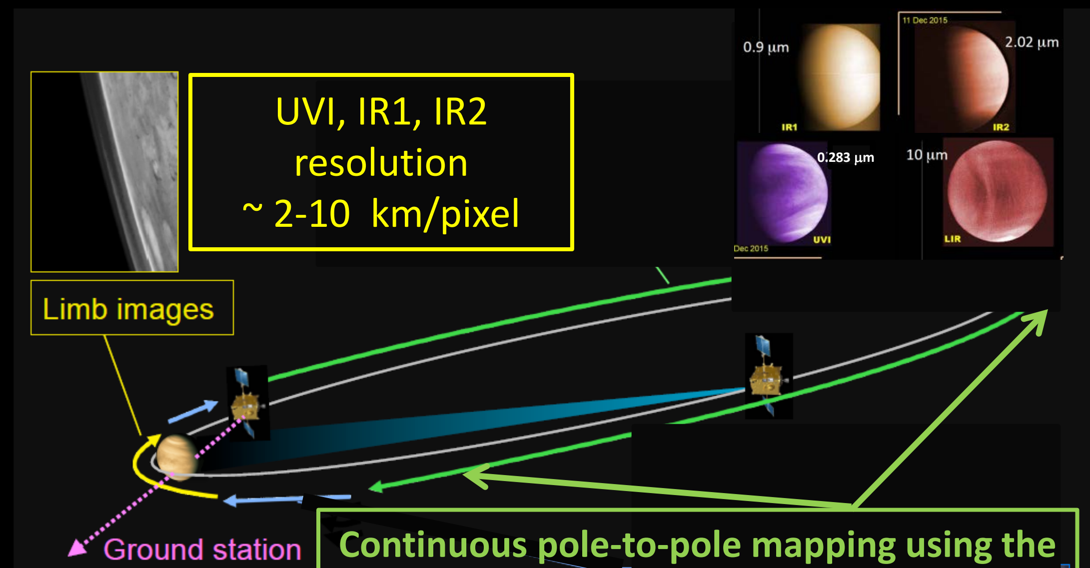
2017
Coordinated & Complementary HST Observations will provide:

50±5 km spatial resolution STIS spectra recording from the limb to terminator as function of local time and latitude the:

- SO_2 distribution at 65-80 km
- SO at 70-80 km
- unknown UV absorber signature at $\lambda > 350$ nm, near 60-70 km
- 240-260 nm cloud top albedo at 65-75 km

20±2 km/pixel spatial resolution WFC3 images providing pole-to-pole mapping of the dayside:

- SO_2 gas absorption signature & cloud top brightness at 70-80 km altitude at $\lambda < 240$ nm
- SO_2 gas absorption signature & cloud top brightness at 65-70 km altitude at $\lambda > 290$ nm
- cloud brightness levels & contrast at 65-80 km
- The distribution of unknown UV absorber signature near 60-70 km



Continuous pole-to-pole mapping using the IR1, IR2, UVI, and LIR cameras

Sampling interval 1-2 hours

UVI, IR1 & IR2 resolution ranges from ~ 15 to 70 km/pixel at ±5 to 130 hours from periapsis

additional ground based observations taken at these times would only enhance the science return of the coordinated HST-Akatsuki observations

For ground-based coordination go to https://www.cps-jp.org/~akatsuki/pub/for_observers/