Atmospheric science with the Venus transit

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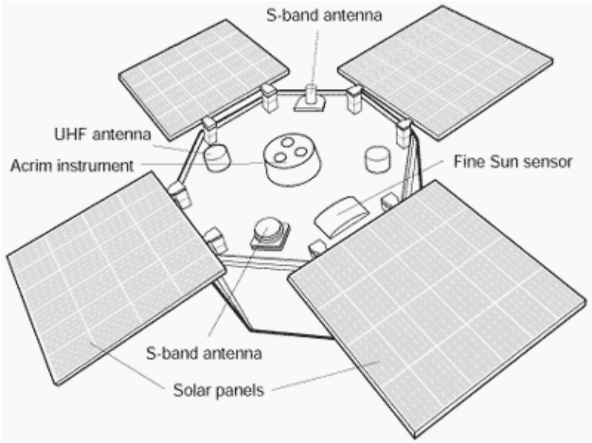
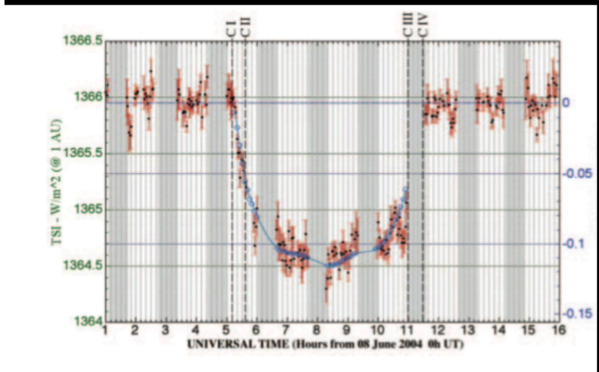
Paris Observatory

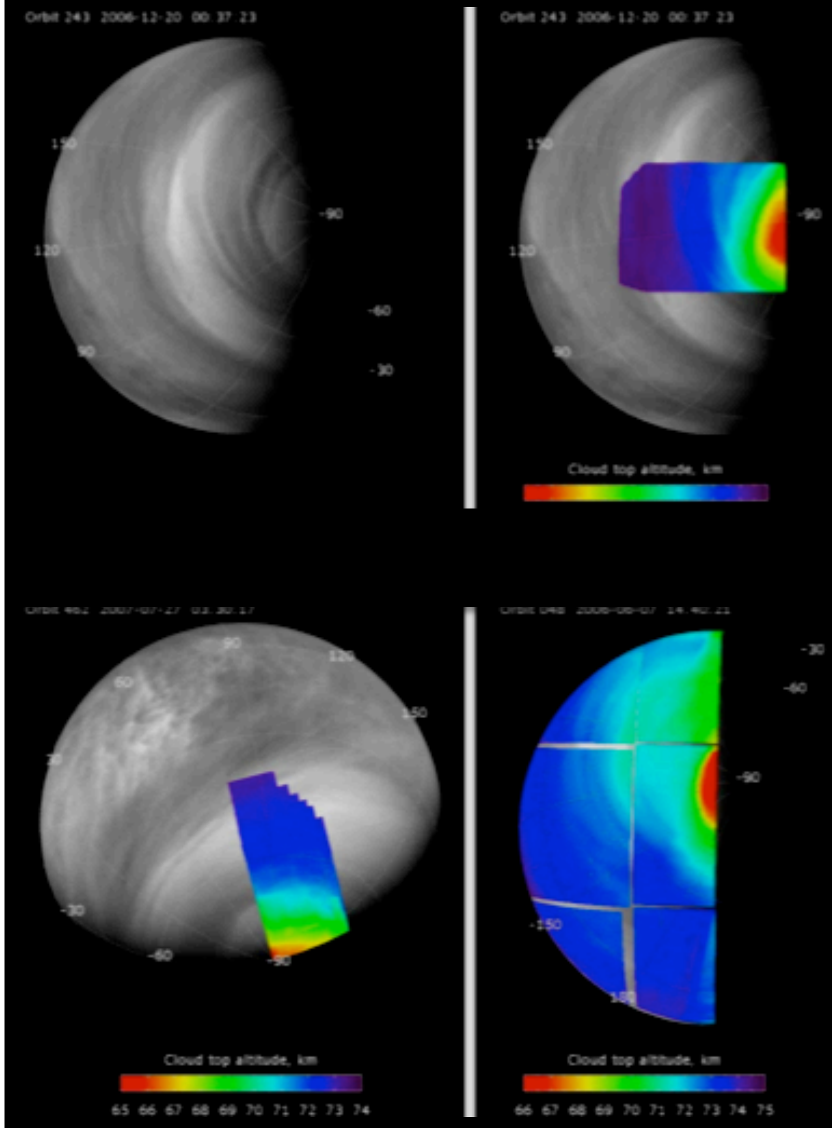


- Measurement of total solar irradiance (TSI) using ACRIM3 on board NASA's AcrimSAT, 2004 June 8 ToV

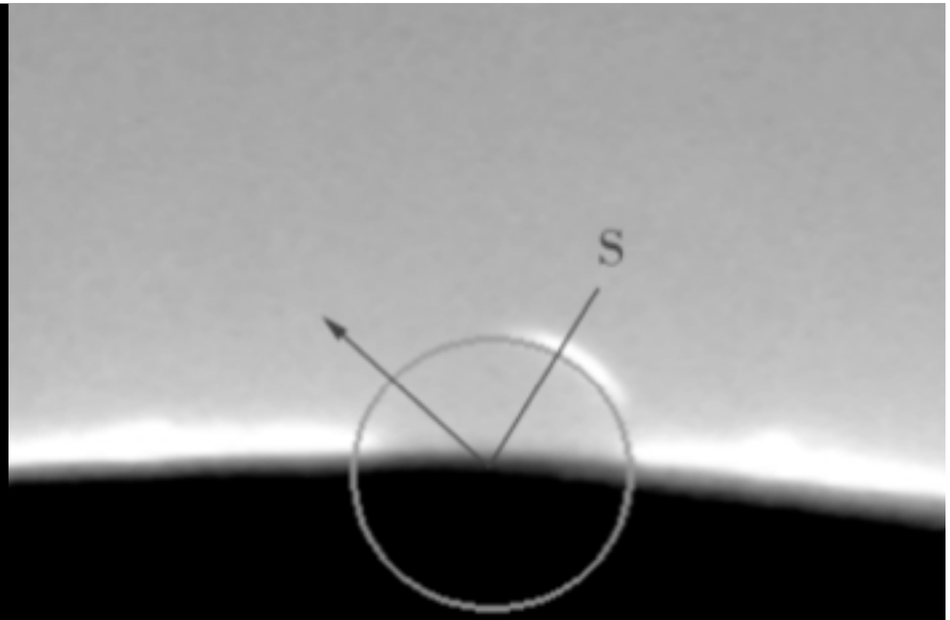


Schneider, Pasachoff, Willson 2006, ApJ 641, 565

- Aureole anisotropy



Ignatiev et al., 2009



- Brightening of transit aureole poleward of 55-60°N-S
- Matches VEx/VMC and VEx/VIRTIS cloud depression latitudinal extent in the South polar region (Ignatiev et al. 2009)

Model implementation

- Baum and Code (1953) – theory of refractive stellar occultations

A ray emitted by a surface element dS will reach the observer O after being refracted by an angle ω, at closest distance r_i.

- refraction angle ω is given by

$$\omega = -\nu\sqrt{2\pi r/H},$$

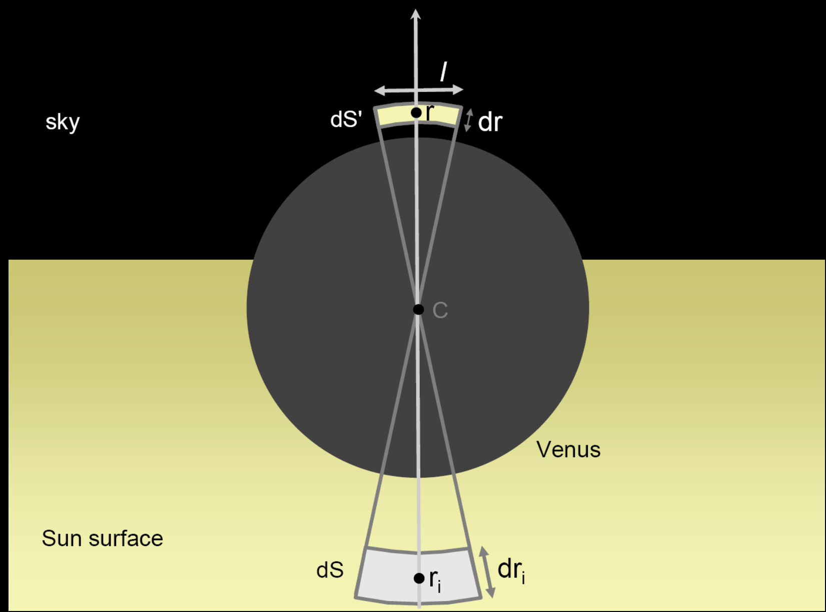
where ν is the gas refractivity.

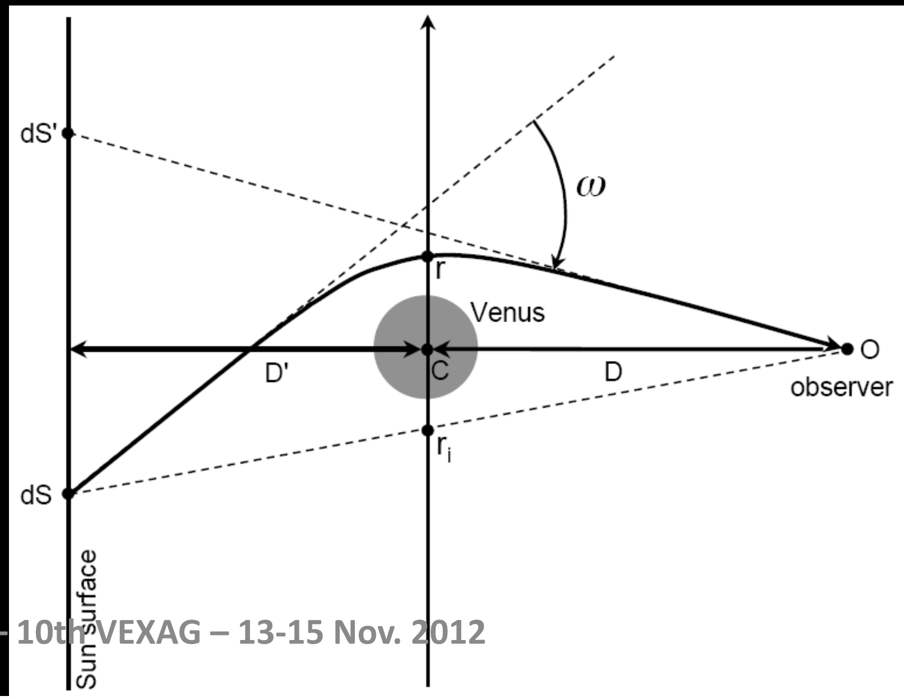
- A reference radius the closest approach distance $r_{1/2}$ corresponding to Φ = 0.5.

$$K \cdot n_{1/2} = \sqrt{H^3/\left(2\pi r_{1/2} D^2\right)}$$

where $n_{1/2}$ is the gas number density at $r_{1/2}$

$$\omega = -\frac{H}{D} \cdot e^{-\left(r-r_{1/2}\right)/H}$$





Tanga, Widemann et al., Icarus 218, 207-219, 2012

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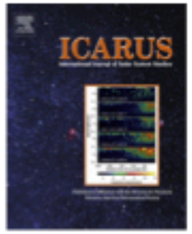

Sunlight refraction in the mesosphere of Venus during the transit on June 8th, 2004

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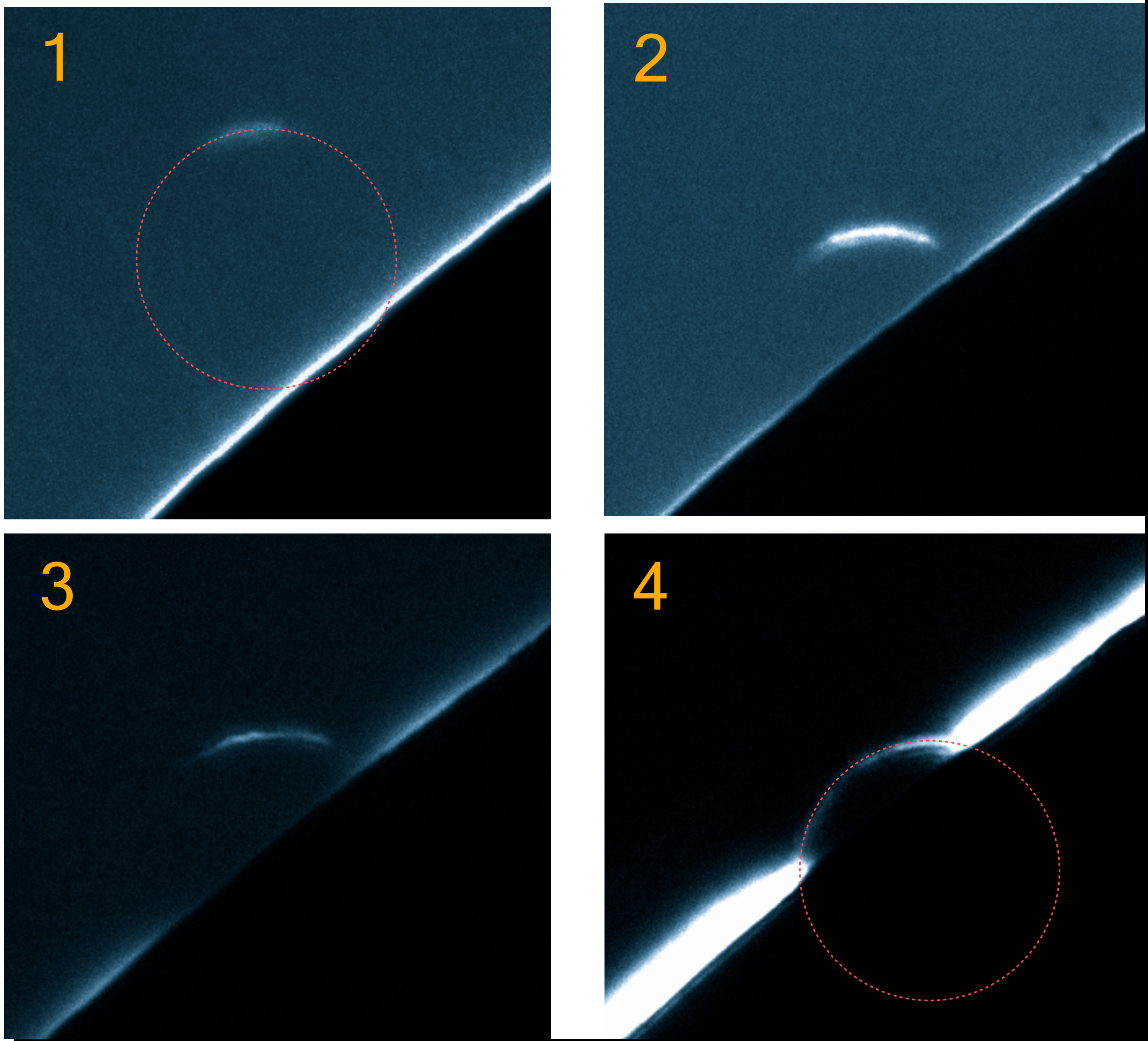
ABSTRACT

Many observers in the past gave detailed descriptions of the telescopic aspect of Venus during its extremely rare transits across the Solar disk. In particular, at the ingress and egress, the portion of the planet's disk outside the Solar photosphere has been repeatedly perceived as outlined by a thin, bright arc ("aureole"). Those historical visual observations allowed inferring the existence of Venus' atmosphere, the bright arc being correctly ascribed to the refraction of light by the outer layers of a dense atmosphere. On June 8th, 2004, fast photometry based on electronic imaging devices allowed the first quantitative analysis of the phenomenon. Several observers used a variety of acquisition systems to image the event – ranging from amateur-sized to professional telescopes and cameras – thus collecting for the first time a large amount of quantitative information on this atmospheric phenomenon. In this paper, after reviewing some elements brought by the historical records, we give a detailed report of the ground based observations of the 2004 transit. Besides confirming the historical descriptions, we perform the first photometric analysis of the aureole using various acquisition systems. The spatially resolved data provide measurements of the aureole flux as a function of the planetocentric latitude along the limb. A new differential

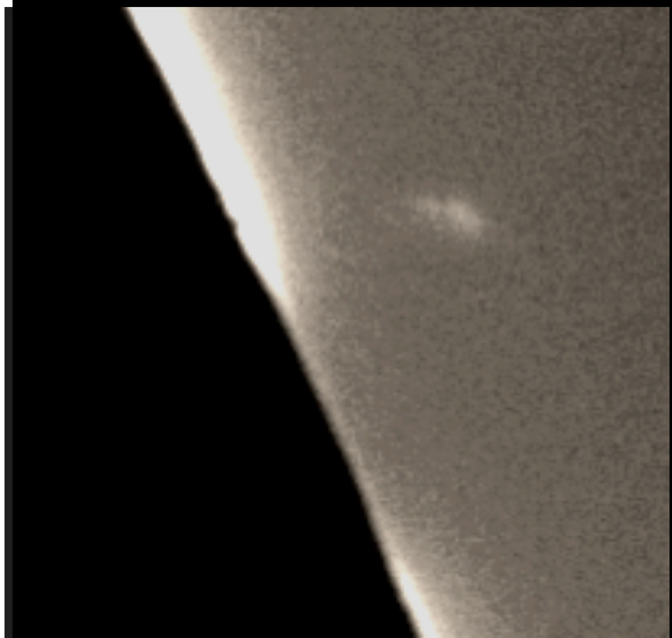
Aureole at ingress, on Ju



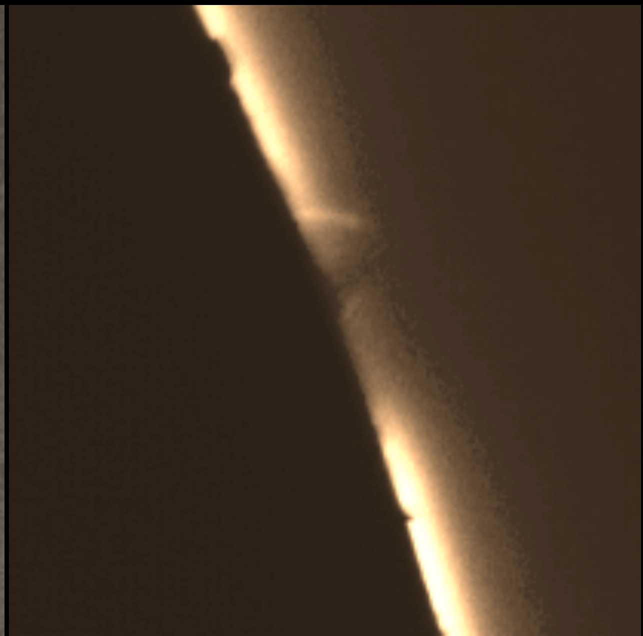
We designed (and built) ten « Venus Twilight Experiment »

-a 10-cm refractor
- an off-axis Lyot coronagraph

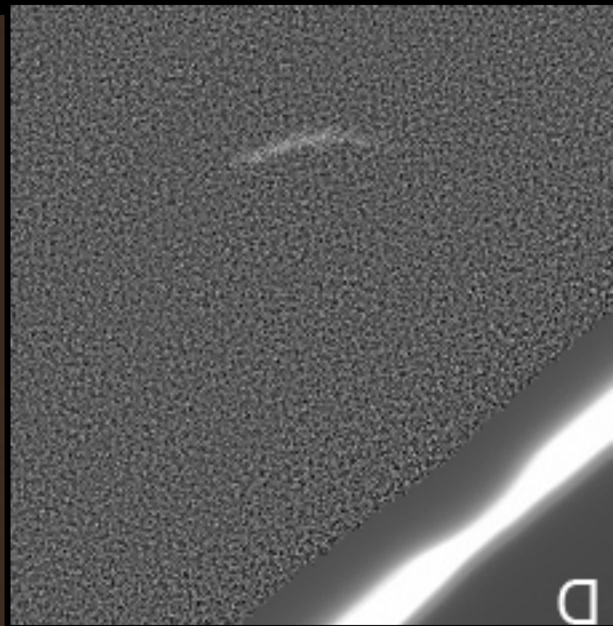
Lowell obs., 10-cm refractor + Paris-Nice coronagraph
Ingress – V-band (535 nm)



Longyearbyen, Norway
Egress – I-filter (760 nm)
T. Widemann



Mount-Isa, Australia
Egress – I-filter (760 nm)
F. Braga-Ribas

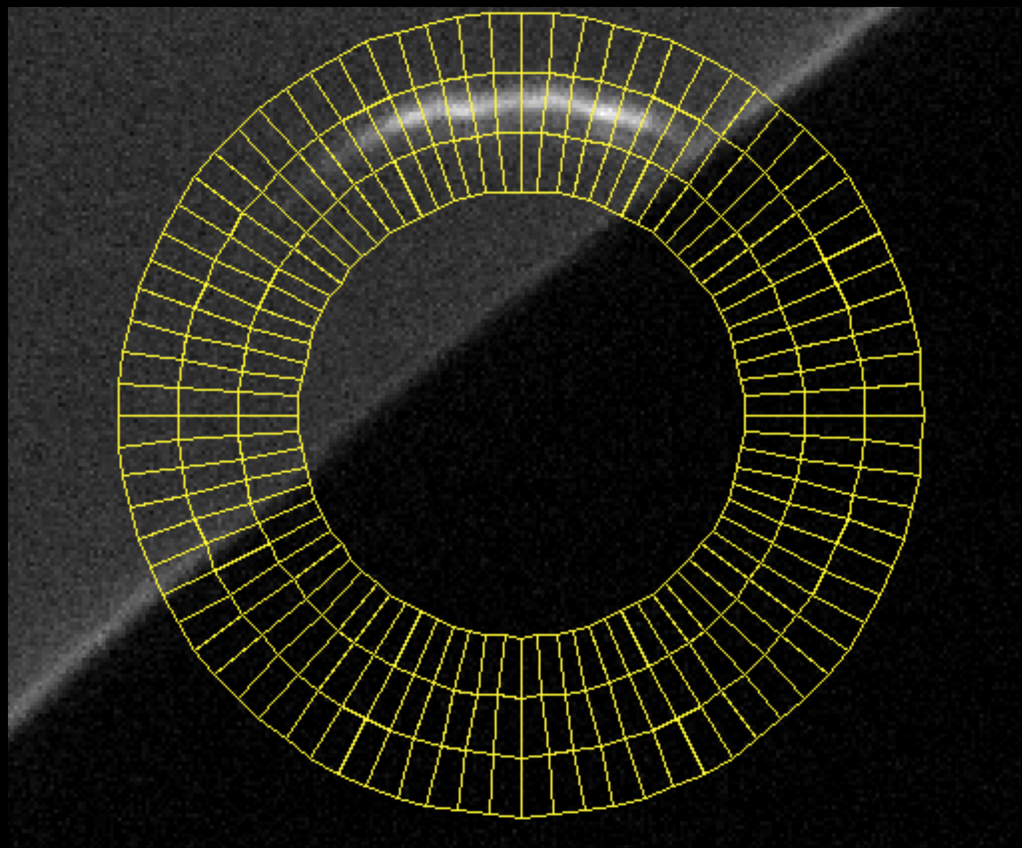


Haleakala, Maui
Ingress – B-filter (450 nm)
J. Pasachoff

Nayoro, Japan
Egress – V-filter (760 nm)

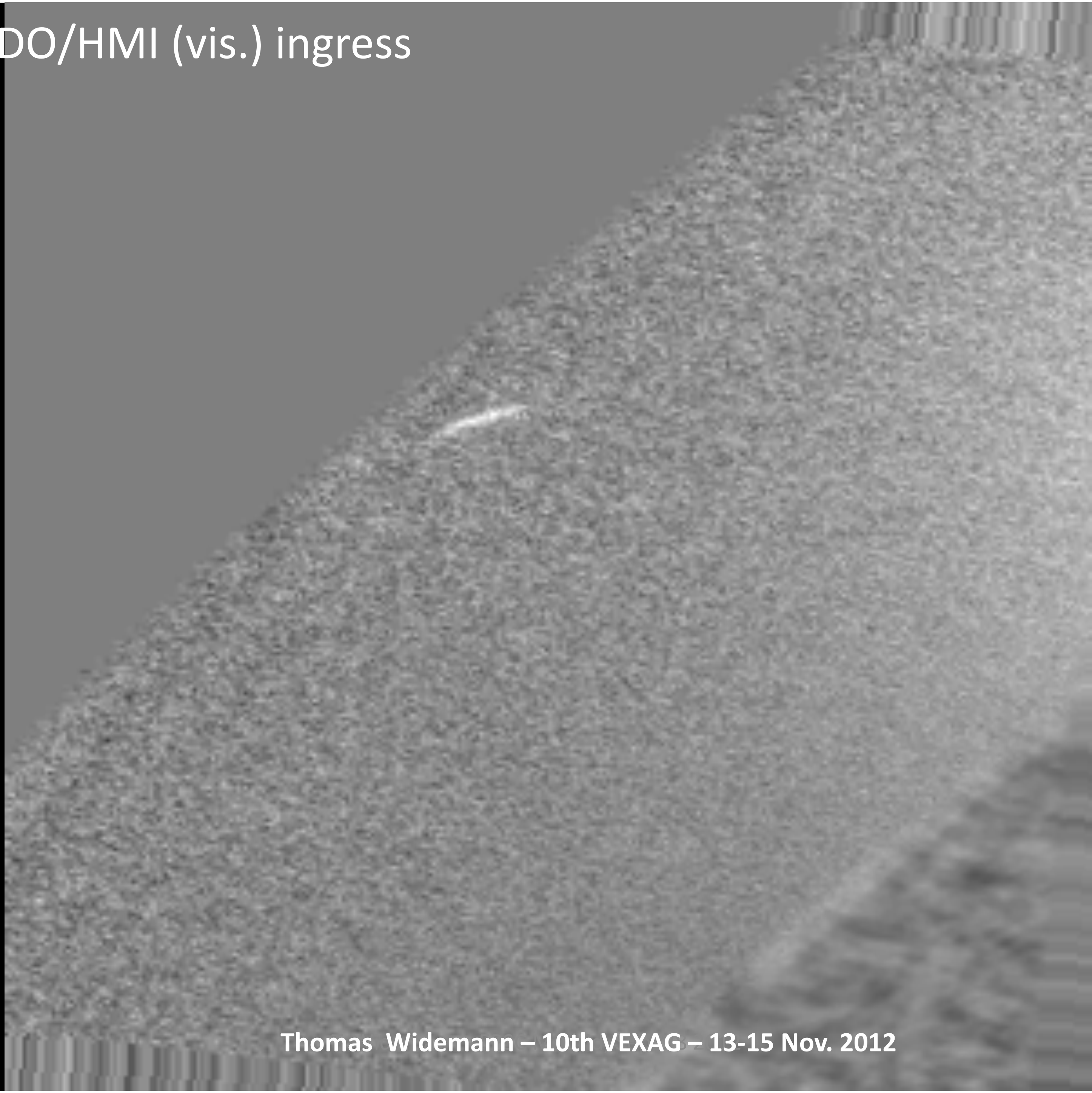
Tien Shan, Kazakhstan
Egress – B-filter (450 nm)

Udaipur, India
Egress – R-filter (607 nm)

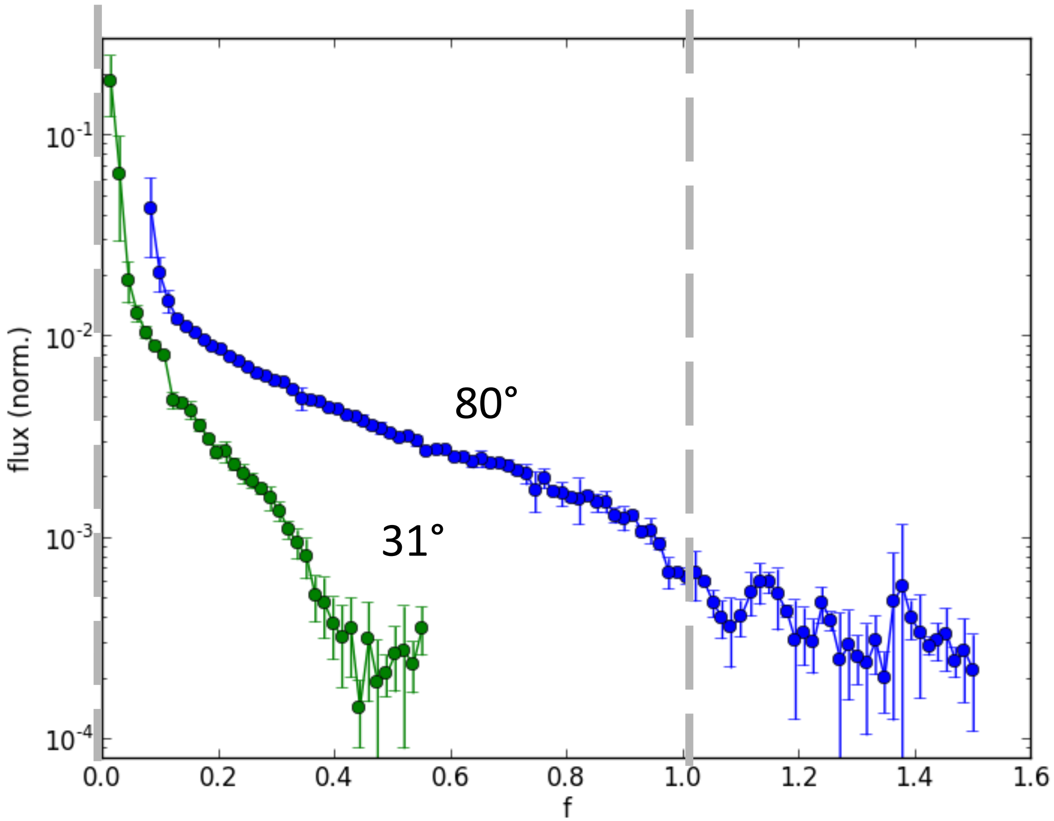


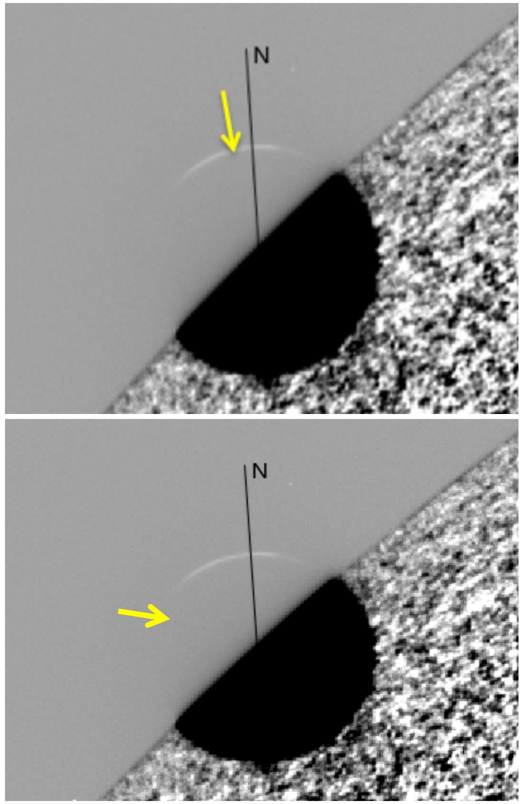
Lowell cor. – V band

• NASA SDO/HMI (vis.) ingress



Comparison, 80° vs 31°N – evening side





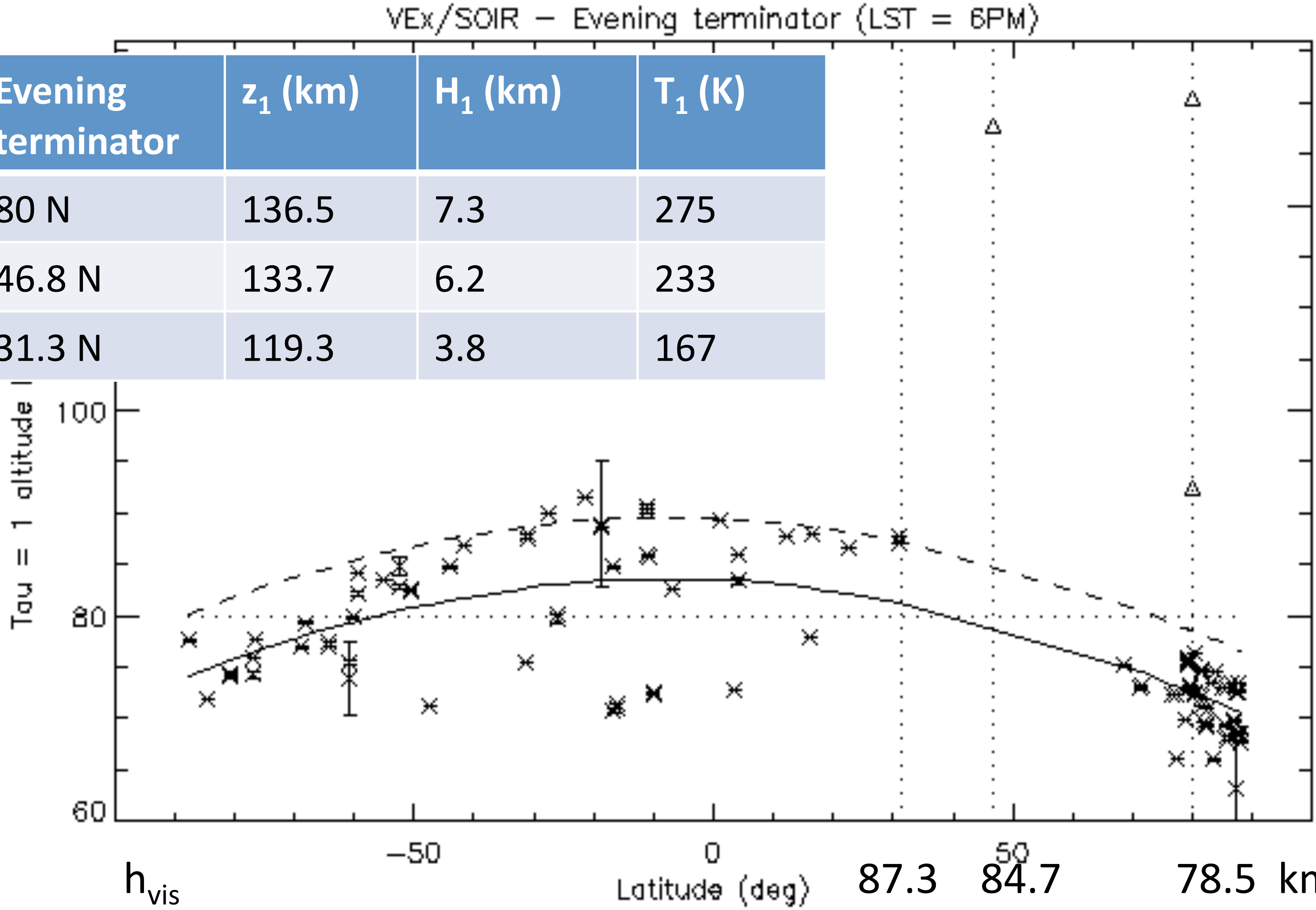
Upper haze $\tau = 1$ altitude level

2006-2010 (Wilquet et al. 2012)

Evening terminator 6PM

Evening terminator	z_1 (km)	H_1 (km)	T_1 (K)
80 N	136.5	7.3	275
46.8 N	133.7	6.2	233
31.3 N	119.3	3.8	167

31.3N 46.8N 80.0N



Δr = 58 km
H = 7.3 km

Δr = 49 km
H = 6.2 km

Δr = 32 km
H = 3.8 km

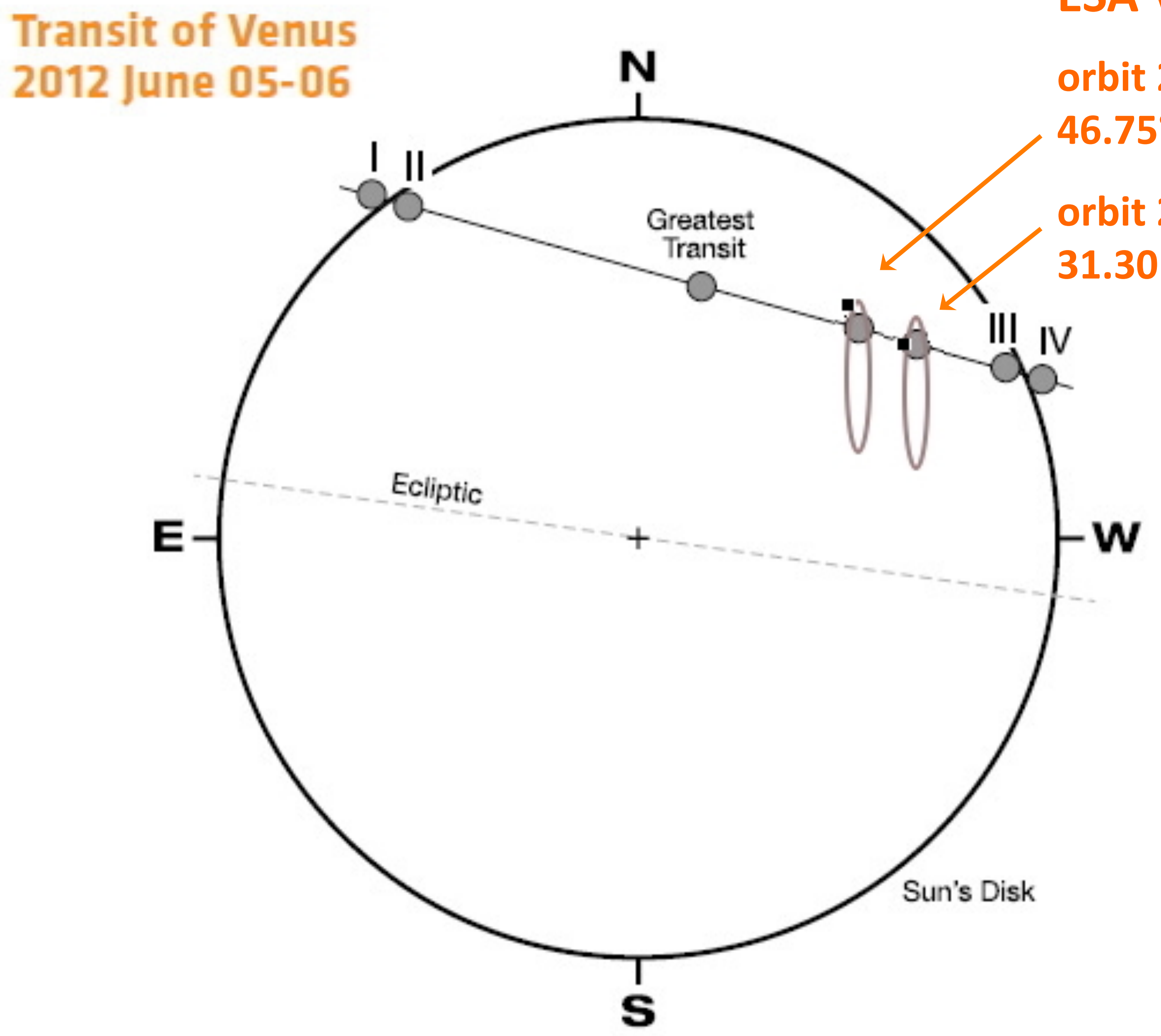
Δr = 20 km

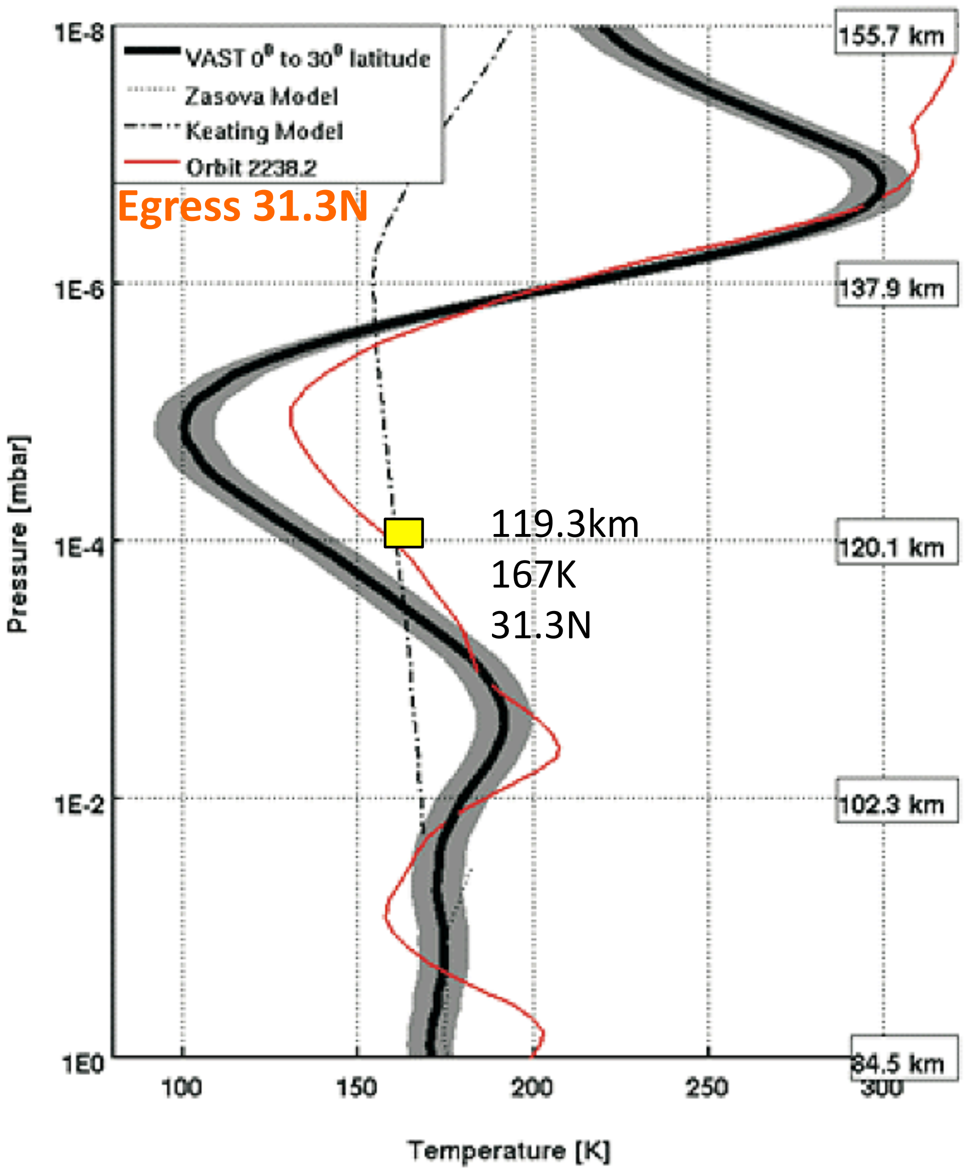
h_{vis}	87.3	84.7	78.5	km
$h_{3\mu}$	81.3	78.7	72.5	km

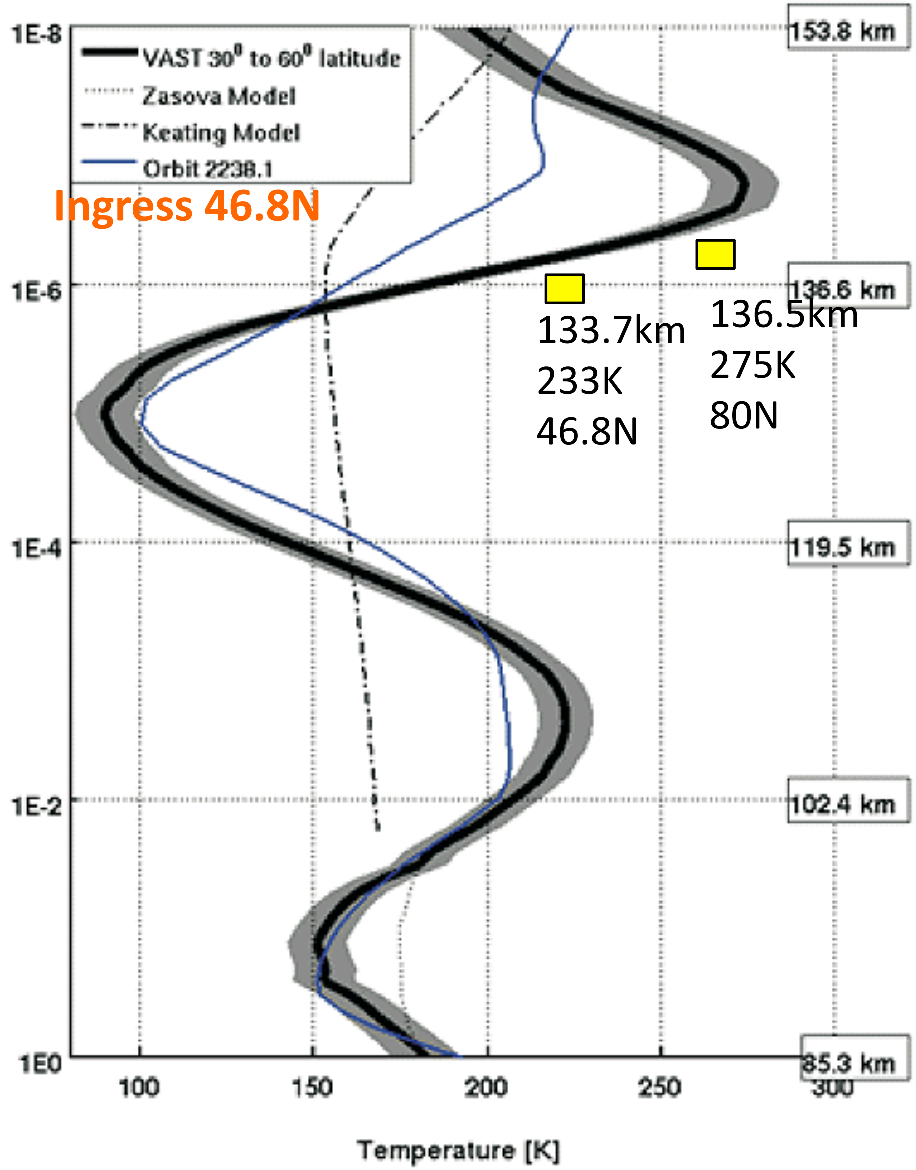
ESA Venus Express

orbit 2238.1 solar ingress
46.75°N – LST = 6.075PM

orbit 2238.2 solar egress
31.30N – LST = 6.047PM







Terminator, 0-30° Latitude

Terminator, 30-60° Latitude

Mahieux, Vandaele et al., Icarus, 2012

European Venus Explorer – where next?

An in-situ Venus explorer proposed in 2007 & 2010 as a Cosmic Vision M3 mission

Colin Wilson

Univ. of Oxford

EVE 2010

A balloon mission in the heart of the habitable layer

- **Helium superpressure balloon, 53-57 km float altitude.**
- **Benefit from benign climate: 10 – 50 °C, atmospheric densities like those found at 0 to 5 km altitude on Earth.**
- **Explore clouds of liquid water (albeit mixed with sulphuric acid).**
- **Use high winds of 200-250 km/h to circumnavigate the planet in 5-8 days.**

T. Balint

EVE 2010 vs. EVE 2007

- **2007 EVE proposal was for a large multinational ESA/IKI mission.**
  - Orbiter + Balloon + Lander
  - Russia was to provide launcher, lander, and EDLS components
  - mass & budget estimates were optimistic.

- **2010 EVE proposal was for an ESA-only balloon mission**
  - A more tightly focussed mission, achievable without non-ESA partners
  - A balloon element only
    - Cruise vehicle provides data relay during flyby
    - Thereafter, balloon communicates Direct-to-Earth
  - More robust treatment of mass, power, and cost.
  - detailed phase 0 mission study was carried out by CNES & Astrium
  - Highly ranked scientifically & technically, but did not make it to the final 4.

EVE III proposal?

- **A new Call for Ideas for Medium Class missions is expected from ESA.**
  - Issue date : ~ late 2013.
  - Submission date : ~ 2014.
  - Downselect to final mission choice : ~ 2016.
  - Launch date : ~ 2022-2025.
  - Cost cap around $500m

  An EVE proposal is foreseen. Current baseline is for a similar mission as proposed in 2010, but possible changes are now under discussion.

- **We look forward to discussing possible international architectures for Venus Exploration.**
  - *E.g. ESA in situ mission concurrent with NASA orbiter (& Russian lander?)*
  - *E.g. ESA orbiter concurrent with NASA in situ mission*
  - IVEWG is probably the best venue for this discussion.
  - Currently it is impossible to propose any sizeable NASA contribution to an ESA M-class mission, due to very different timetables of selection processes.
  - ***Are there clauses which we would like to see in the ESA Call for ideas, and/or the NASA Discovery AO, to make international collaborations easier to propose?***

Thanks for your attention

For further details:

C. Wilson et al., The 2010 European Venus Explorer (EVE) mission proposal, Experimental Astronomy, April 2012.

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