Science from the Venus night side:
Nightglow & lightning

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ESAC, Villanueva de la Cañada, Spain, 25th April 2013

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Dayglow, nightglow & aurora

- Atmospheric luminescence
- Defined by their excitation mechanisms

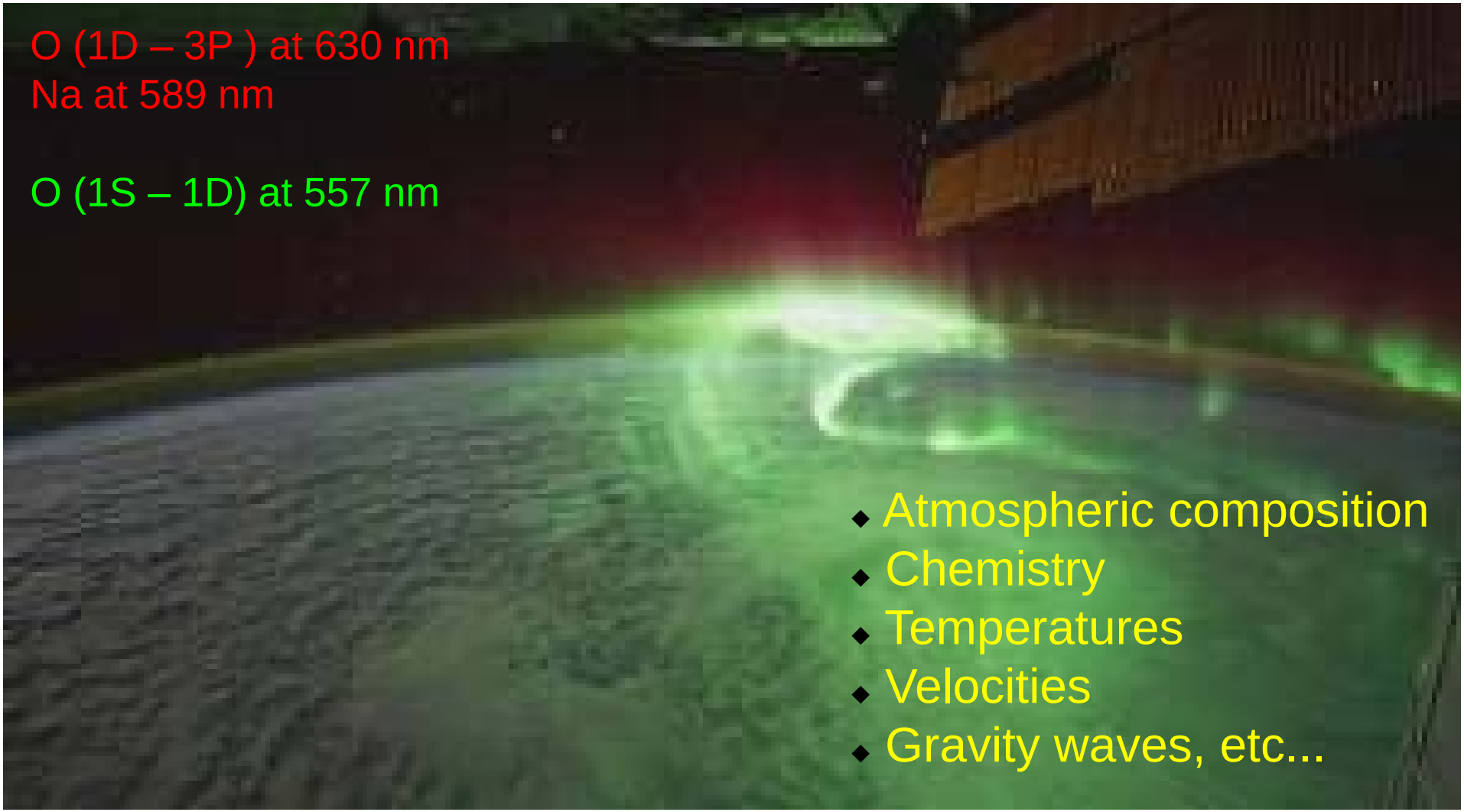
- Dayglow: (Nearly)-direct solar-photon interaction,
  e.g. CO_2+photon → CO(a) + O
- Aurora: Extra-atmospheric particles,
  e.g. CO_2+e → CO(a) + O

- Nightglow: Exothermic chemical reactions.

$$A + B \rightarrow C + D^*$$

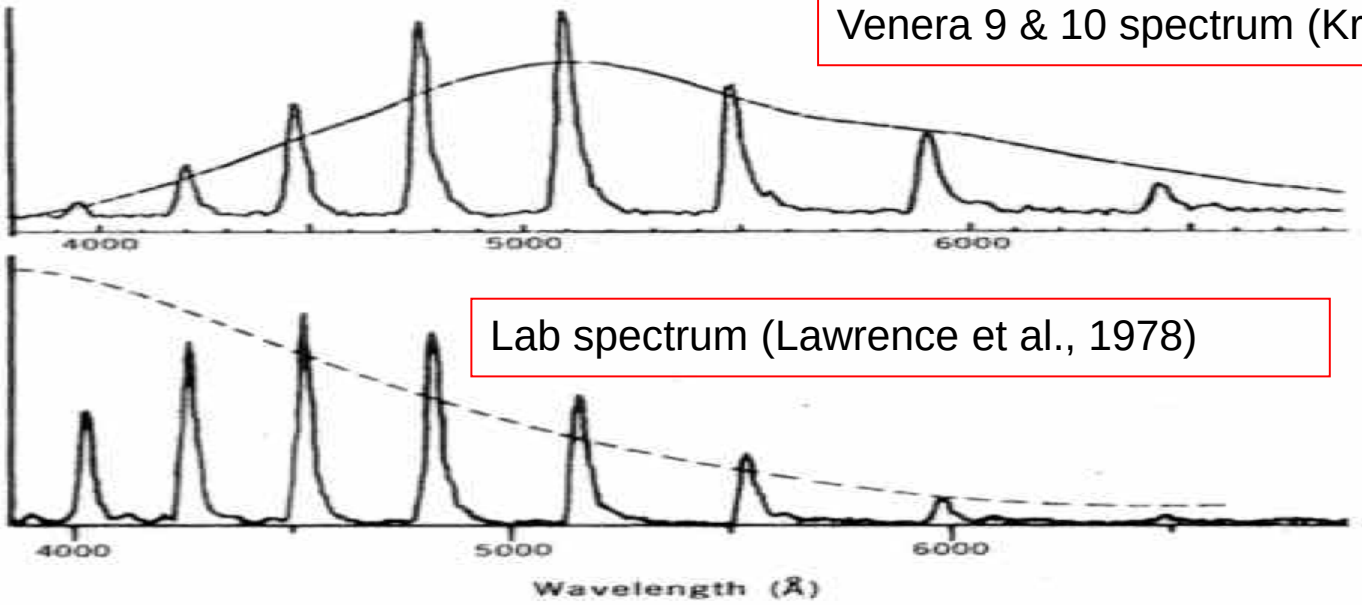
$$D \rightarrow E + \text{photon}$$

Nightglow. Usefulness.



Venus nightglow. 1st evidence.

- Venus nightglow spectrum:



Venera 9 & 10 spectrum (Krasnopolsky et al. 1978)

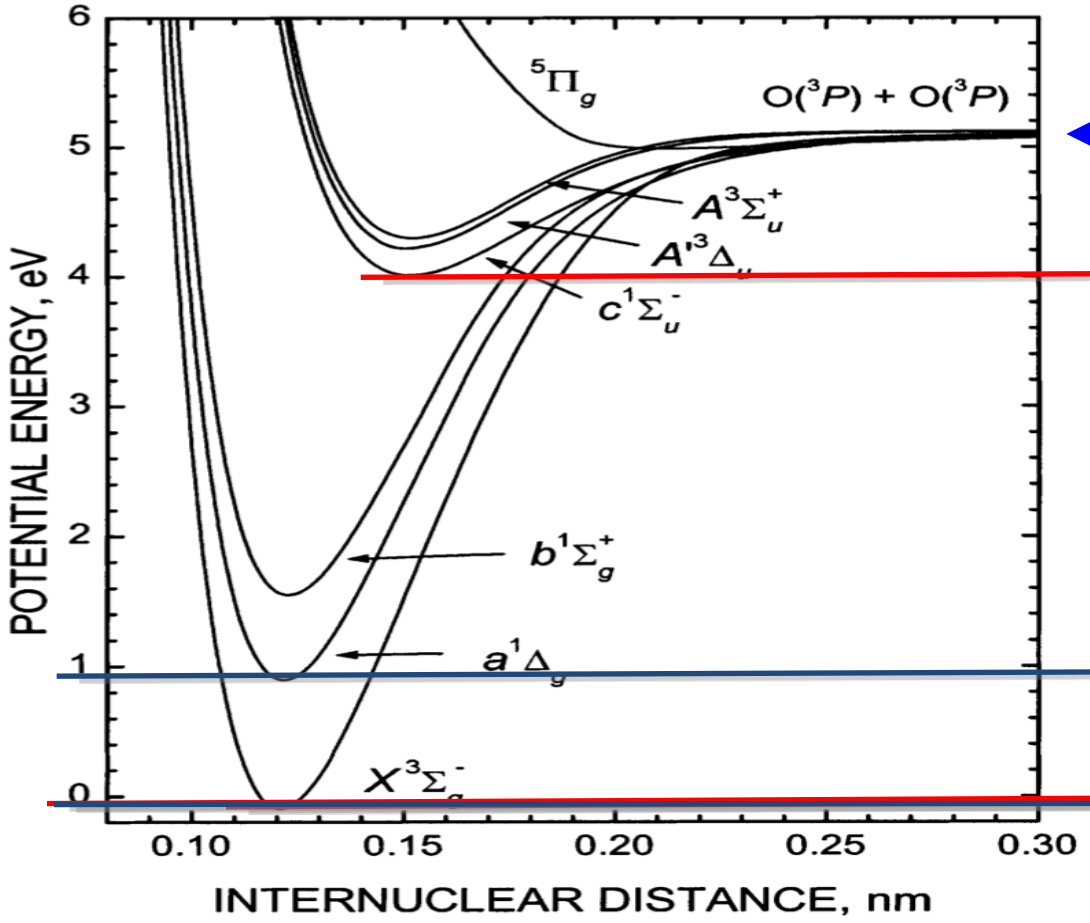
Lab spectrum (Lawrence et al., 1978)

Fig. 1. Herzberg II ($c^1\Sigma_u^- - X^3\Sigma_g^-$) bands of molecular oxygen. (Top) Venus night airglow as observed from Venera 9 (*1*). (Bottom) Venus night airglow as produced in laboratory afterglow. Dashed lines through each of the spectra show the relative sensitivities of the two spectrometers.

Observed on Earth (N_2/O_2), Venus and Mars (CO_2)

$$O + O + M(=CO_2) \rightarrow O_2^* + M;$$
$$O_2^* + M \rightarrow O_2^{**} + M$$
$$O_2\ (c,v=0) \rightarrow O_2\ (X,v'') + \text{photon (400-700 nm)}$$

O_2 nightglow excitation



ure 1. Bound states of O_2 arising from $O(^3P) + O(^3P)$
ts.

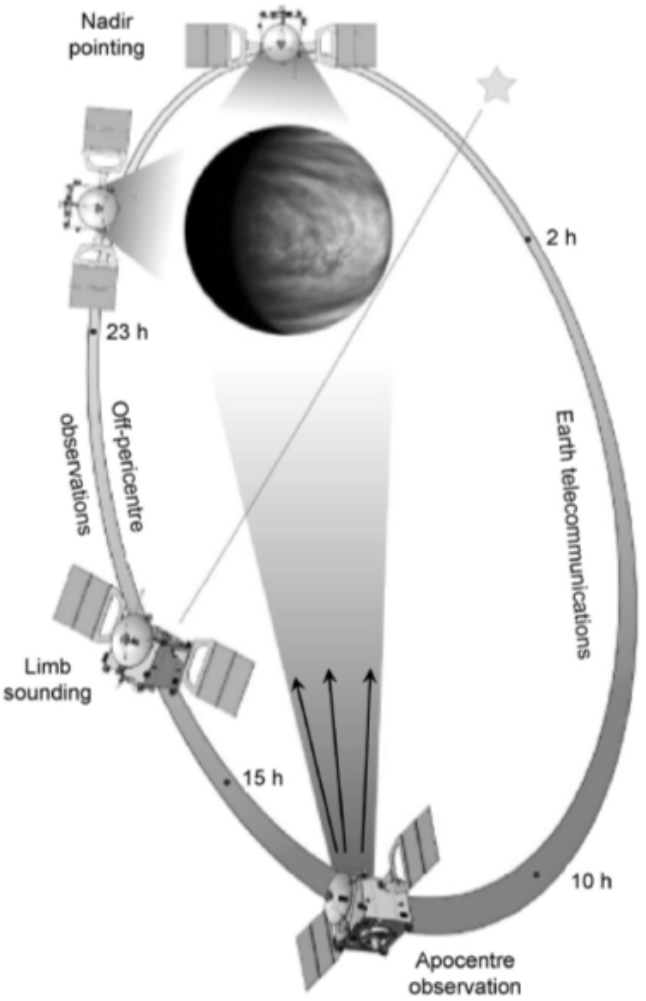
$O+O+M \rightarrow O_2+M$

Herzberg II system, 400-800 nm

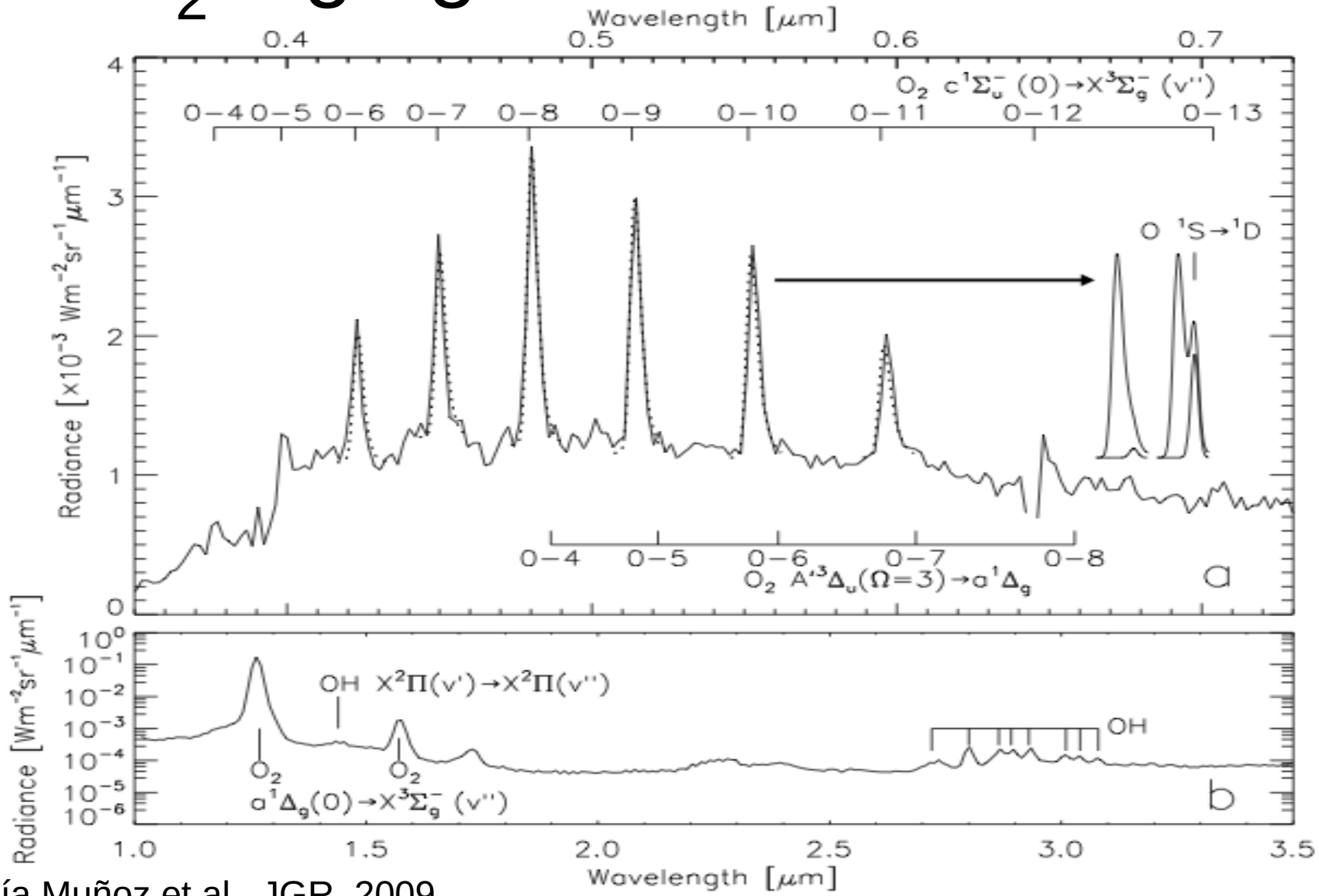
IR Atmospheric band at 1.27 μm

VIRTIS on Venus Express

- Visible and IR spectrometer.
- PI's: G. Piccioni & P. Drossart.
- Spectral coverage: 0.4-5 μm.
- Off-pericenter: nadir looking.
- Near-pericenter: limb-viewing



O_2 nightglow with VEx/VIRTIS



García Muñoz et al., JGR, 2009

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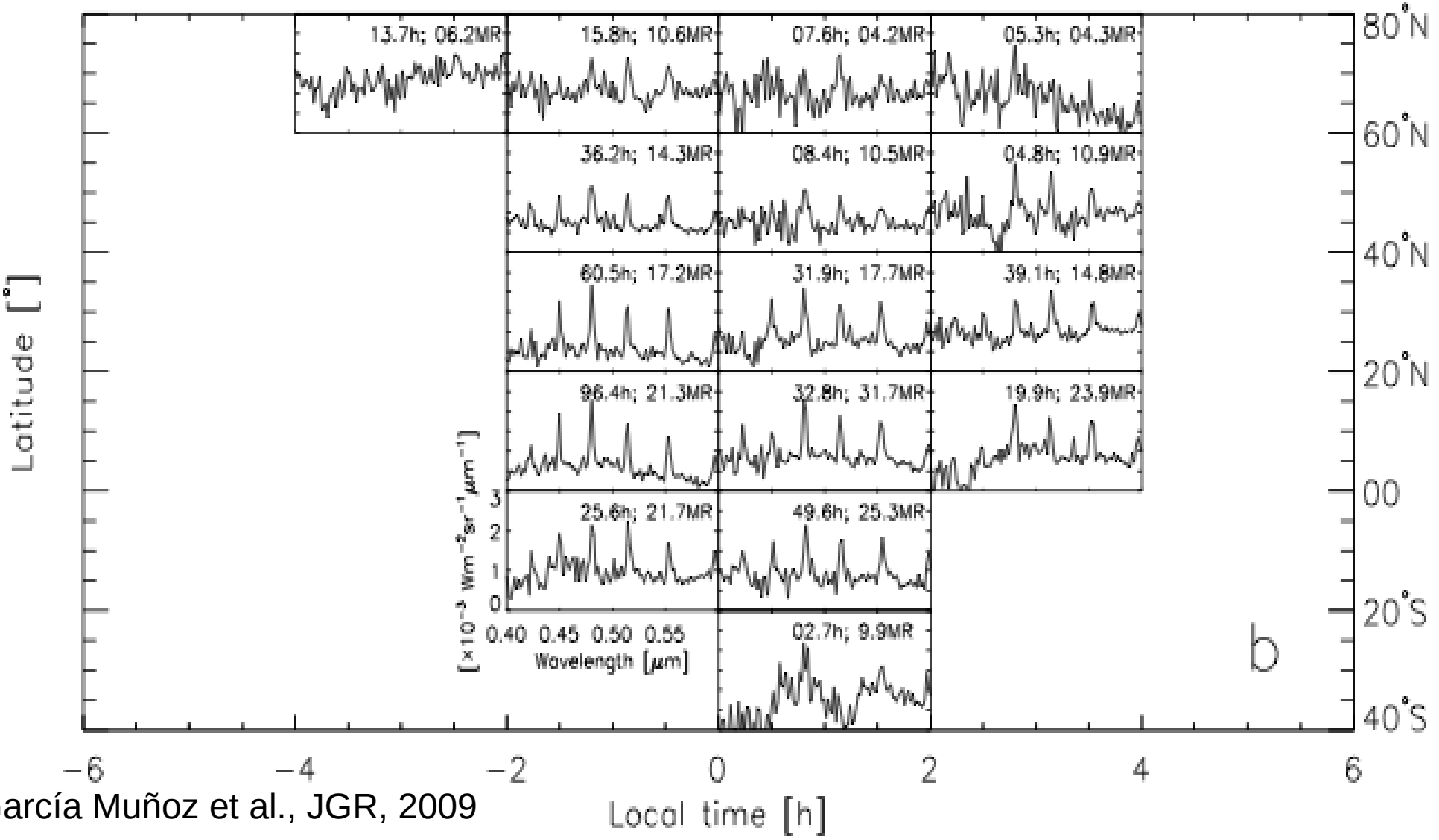

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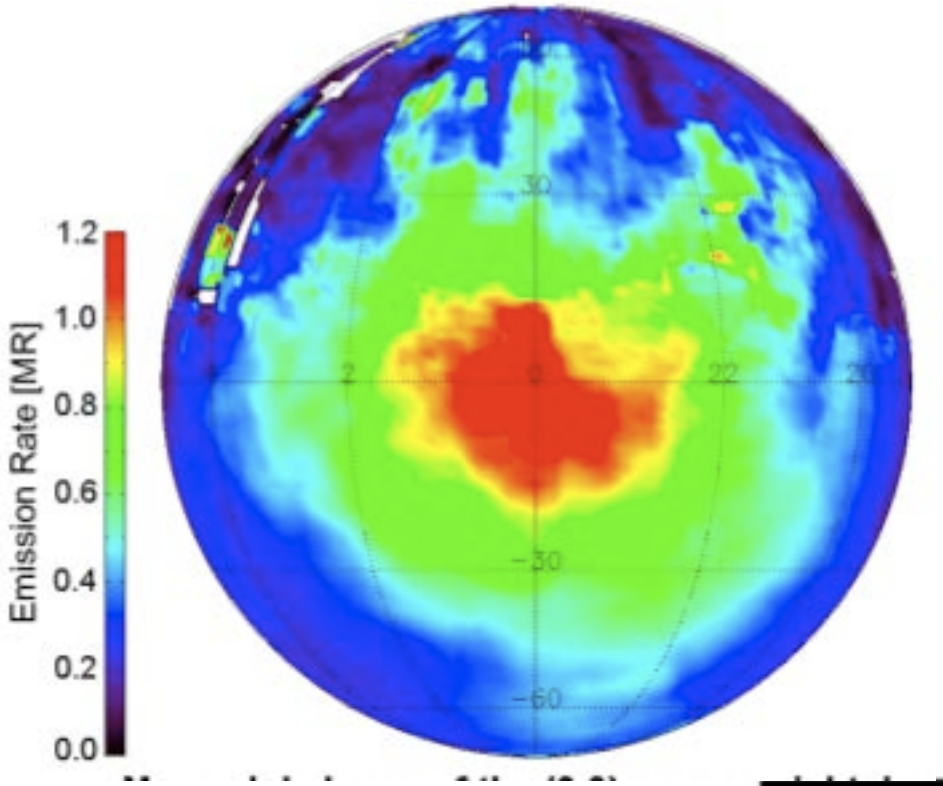
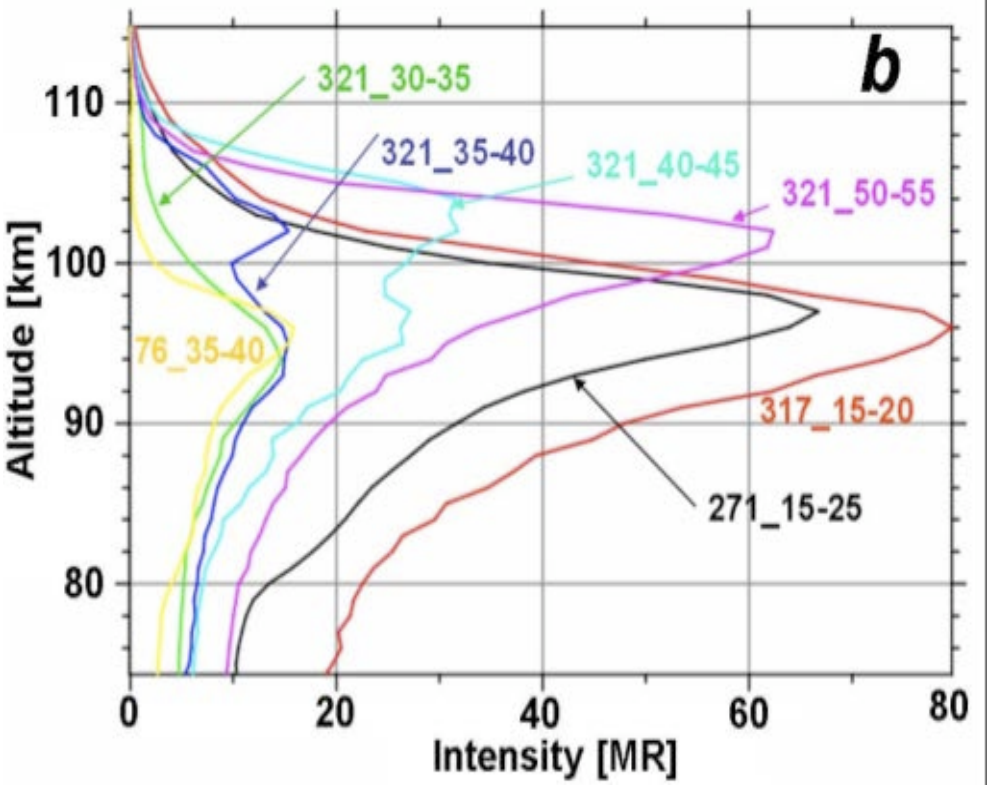
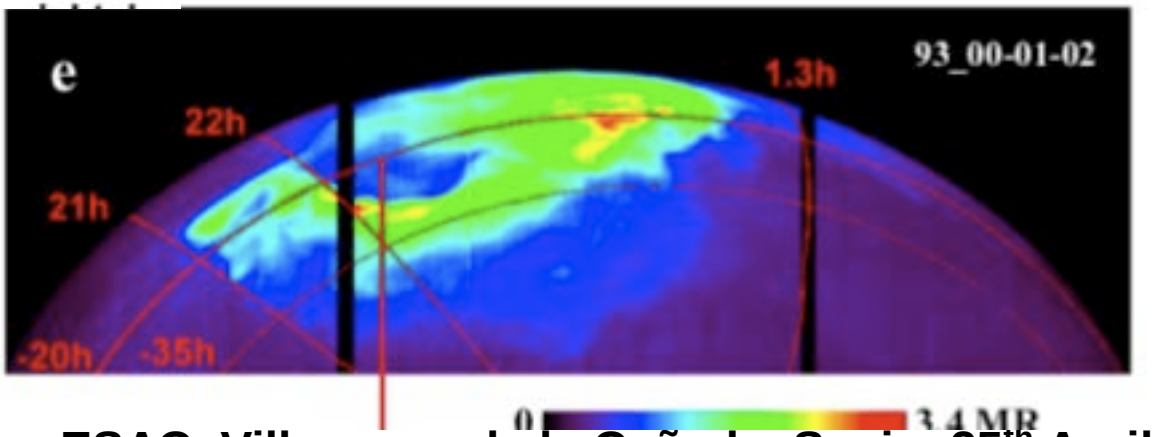
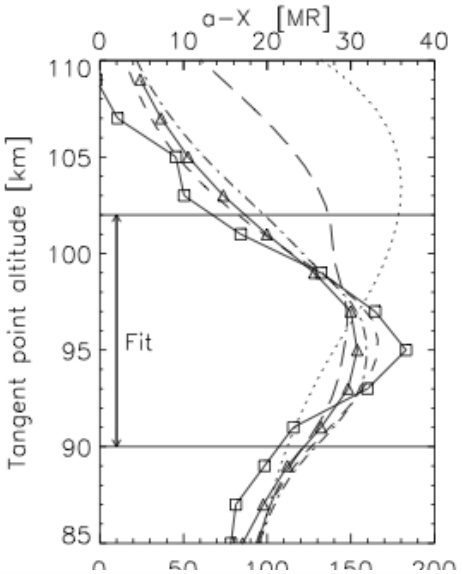


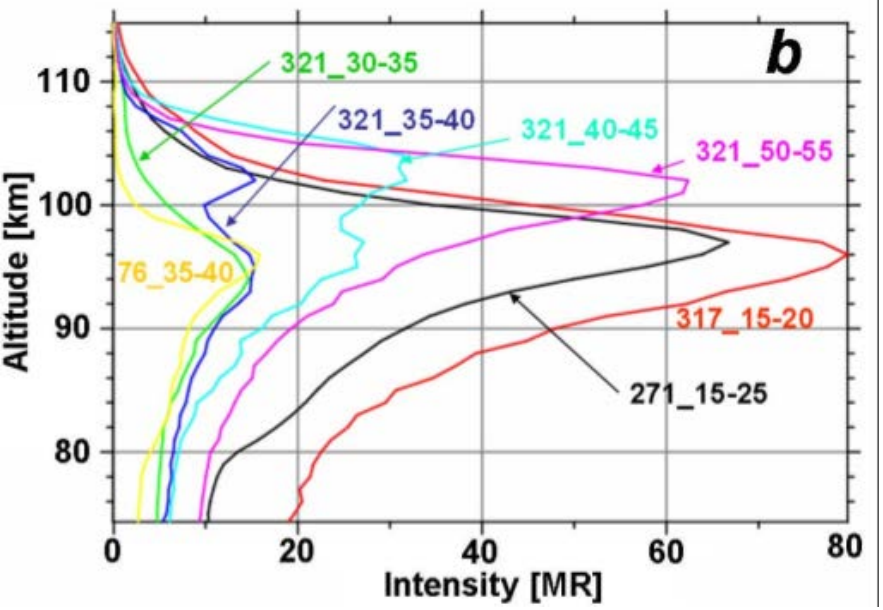


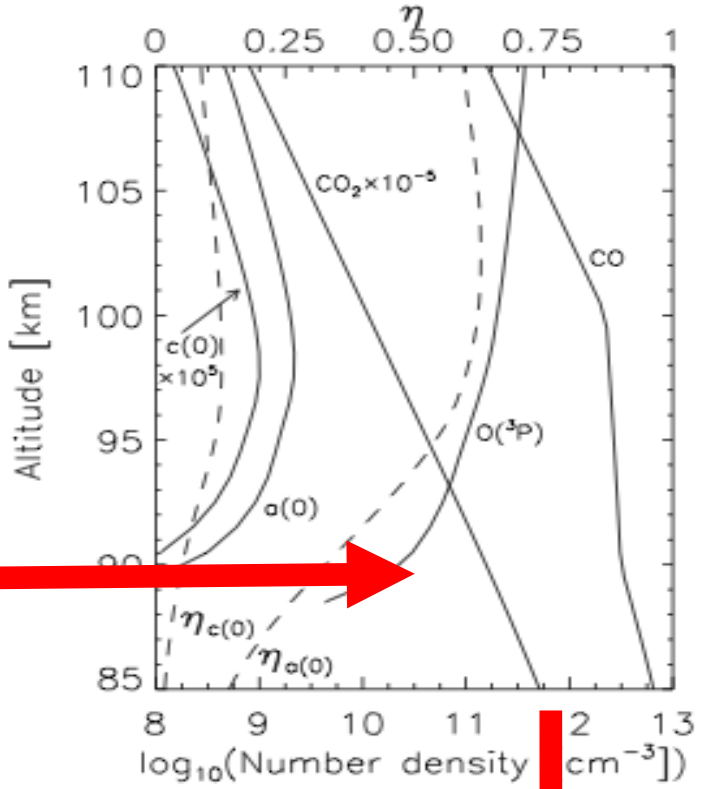
Piccioni et al., JGR, 2009



O_2 nightglow with VEx/VIRTIS

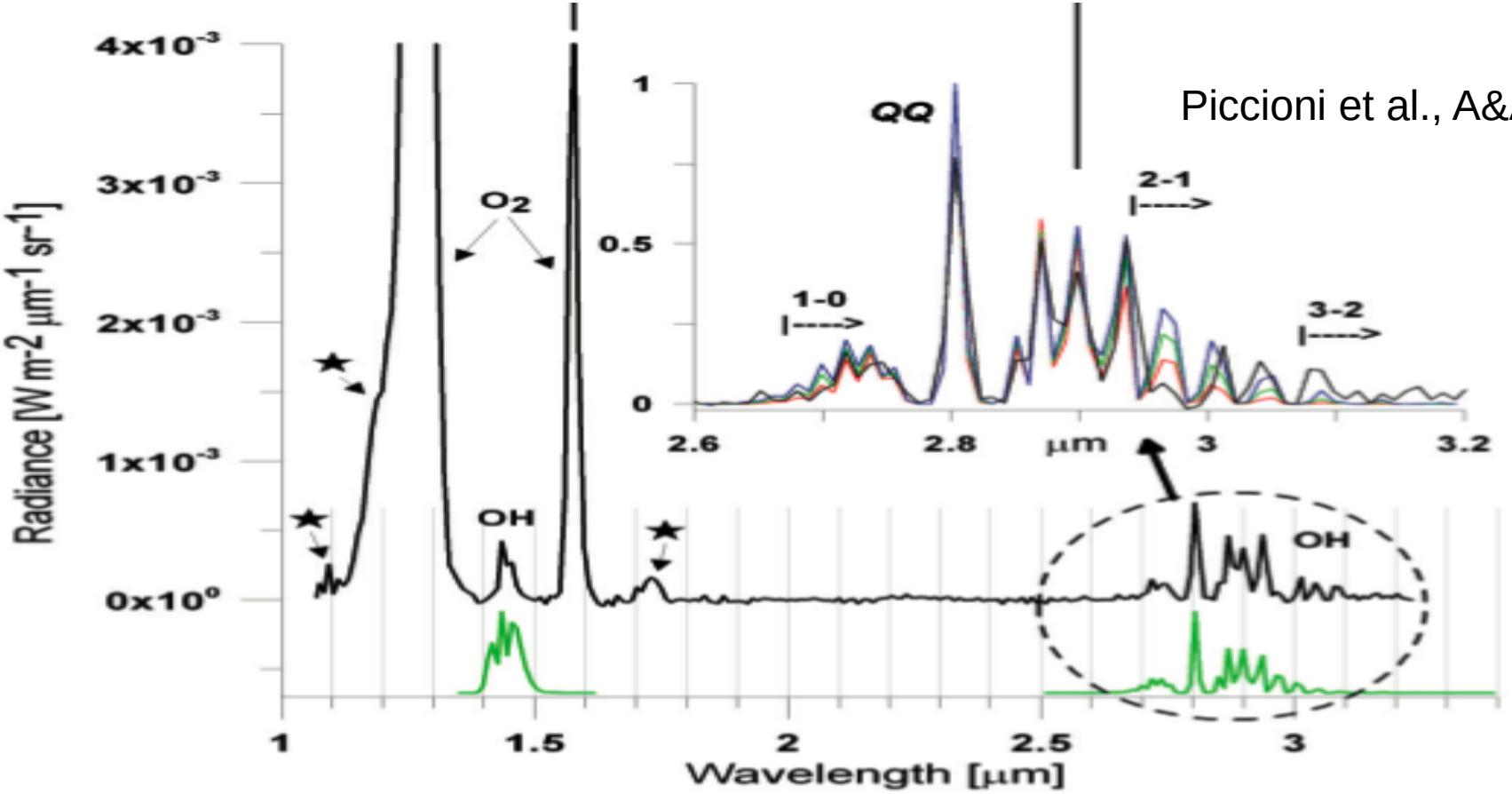






O(3P) profiles are directly comparable to photochemical model outputs

OH Meinel bands with VEx/VIRTIS



Piccioni et al., A&ALs, 2008

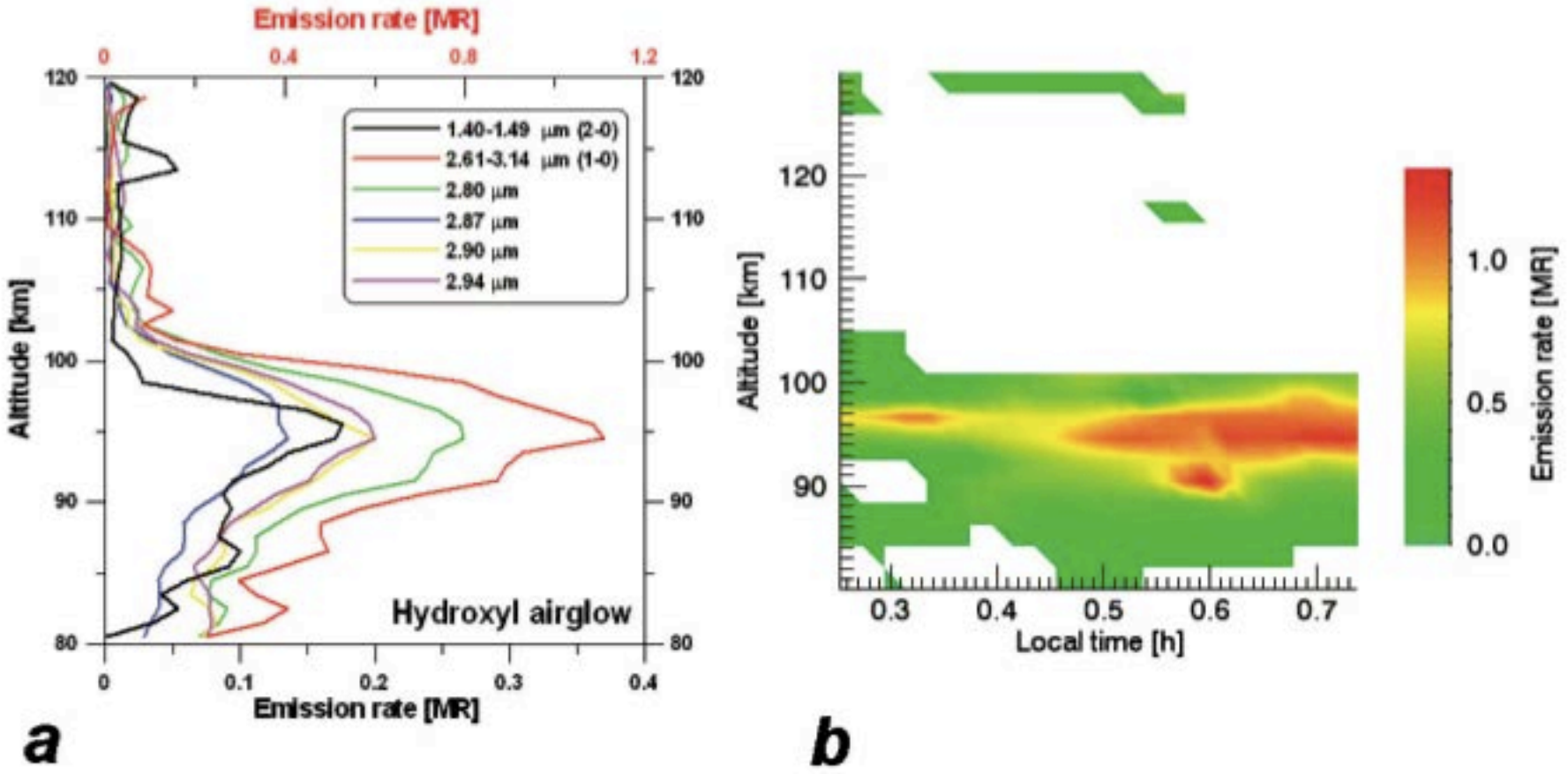
Bates-Nicolet: $H+O_3 \rightarrow OH^*(X,v'=6\text{-}9) + O_2$

$OH(v') \rightarrow OH(v'') + photon$

$OH(v') + CO_2 \rightarrow OH(v''') + CO_2$

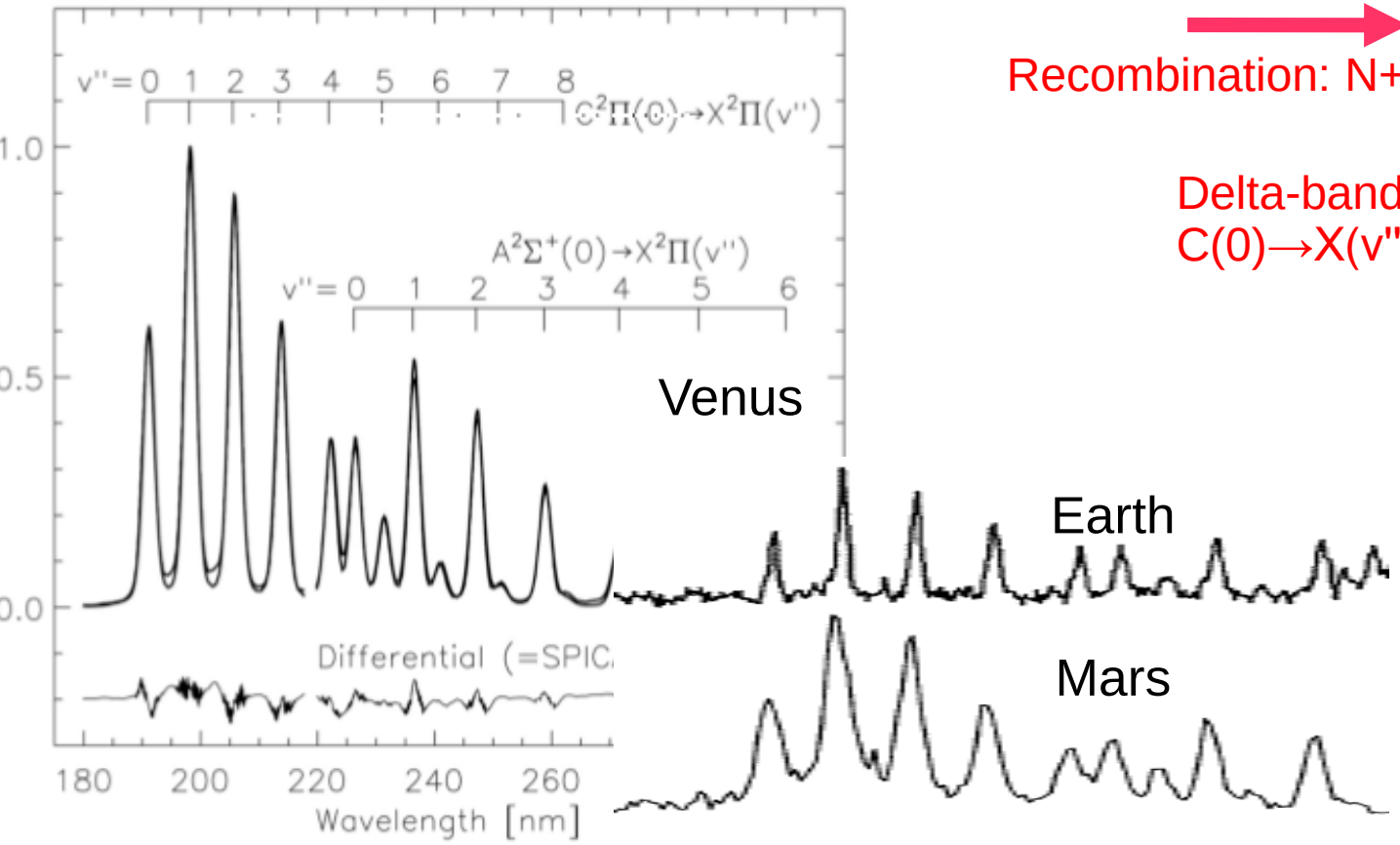
OH nightglow with VEx/VIRTIS

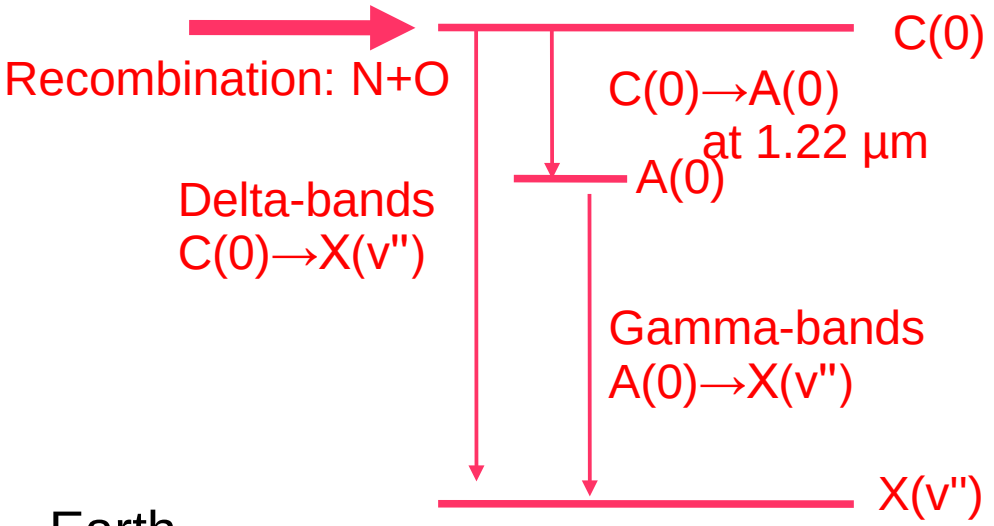
Piccioni et al., A&ALs, 2008



OH Meinel bands recently discovered on Mars!!
Clancy et al. (*submitted)*

NO nightglow with VEx/VIRTIS





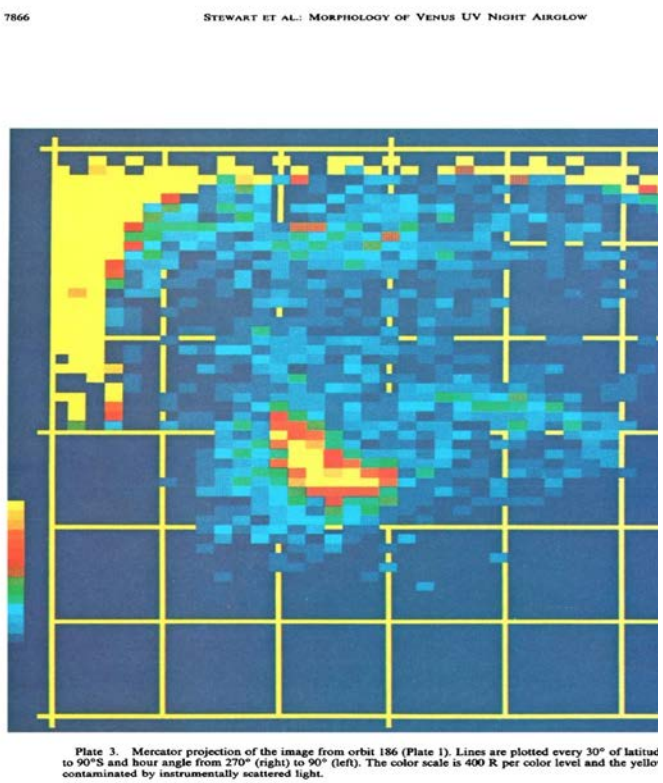
Recombination: N + O → NO (*C*)

UV emission: NO (*C, A)* → NO (*X*) 180-300 nm

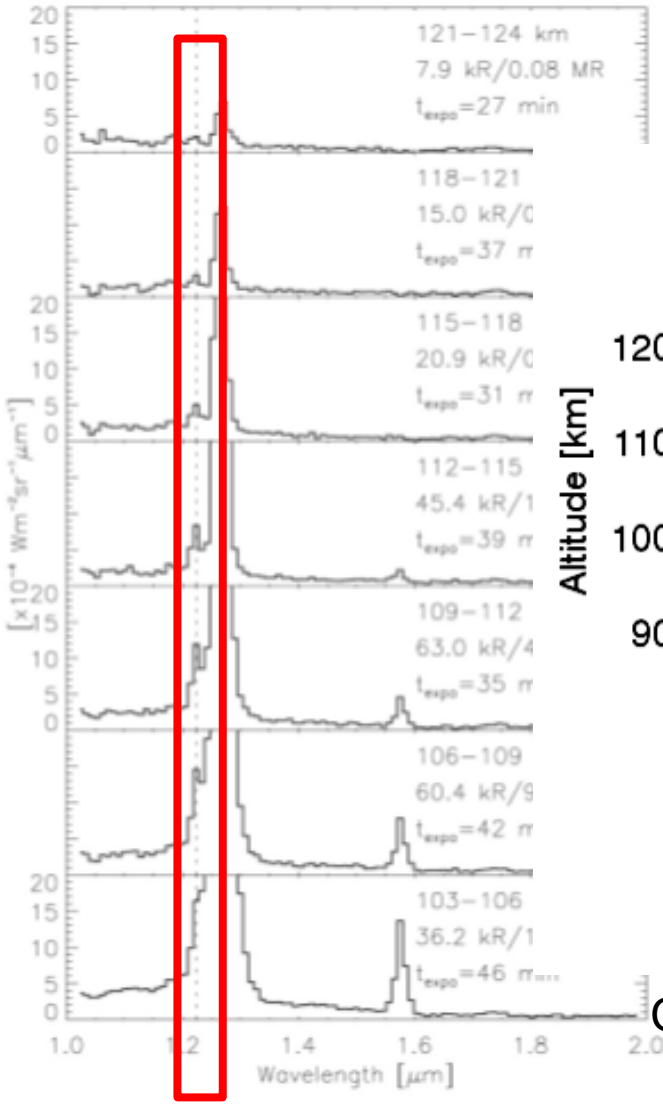
NIR emission: NO (*C*) → NO (*A*)

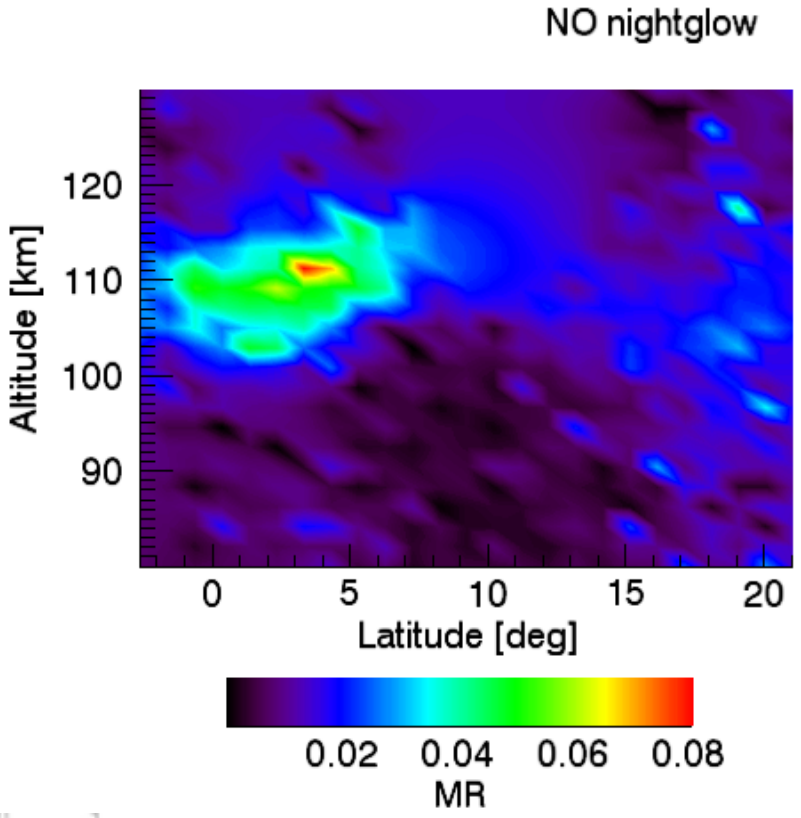
1.22 µm

NO nightglow with VEx/VIRTIS



PVO UV measurements
Stewart et al., (1980)

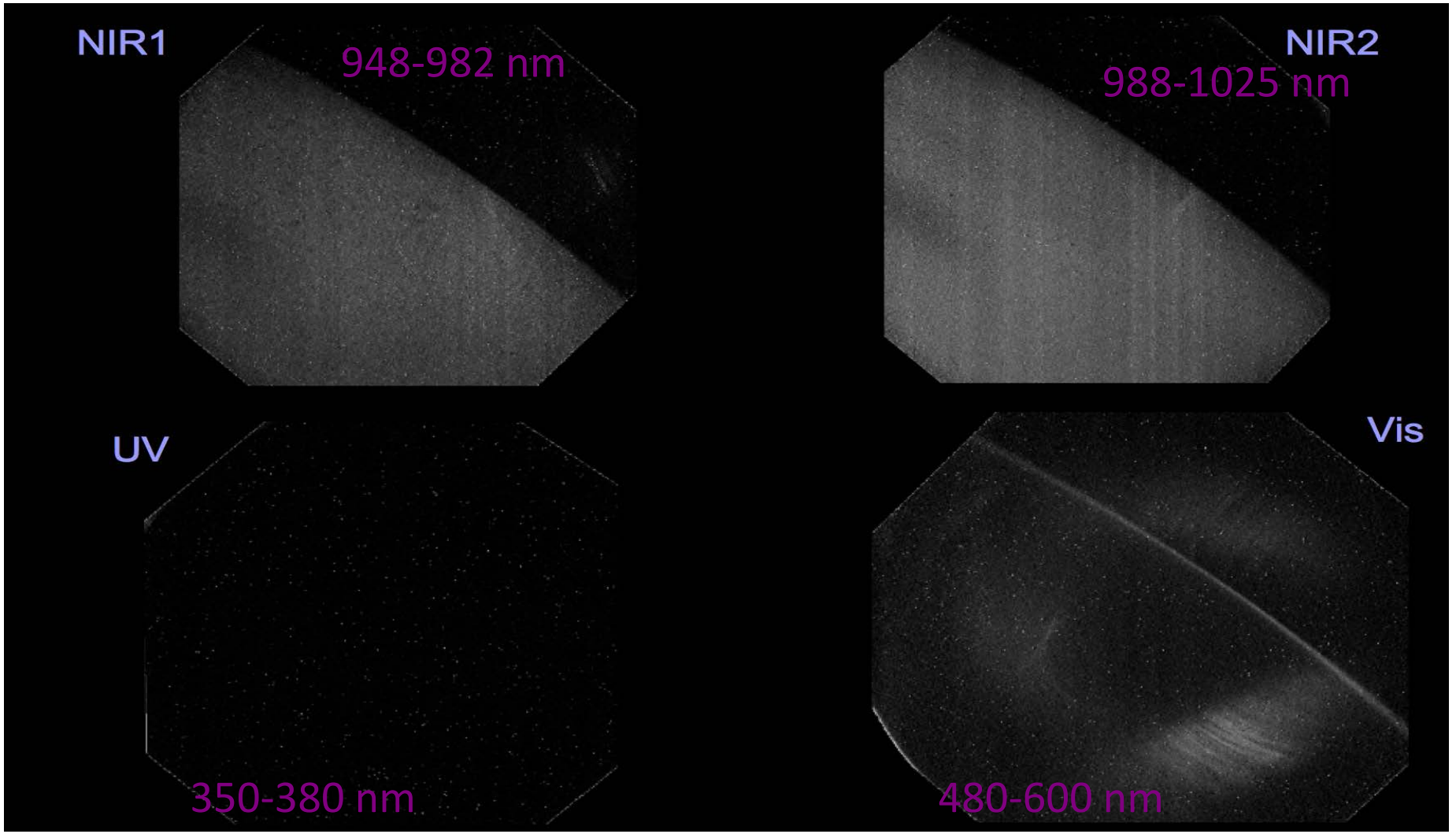




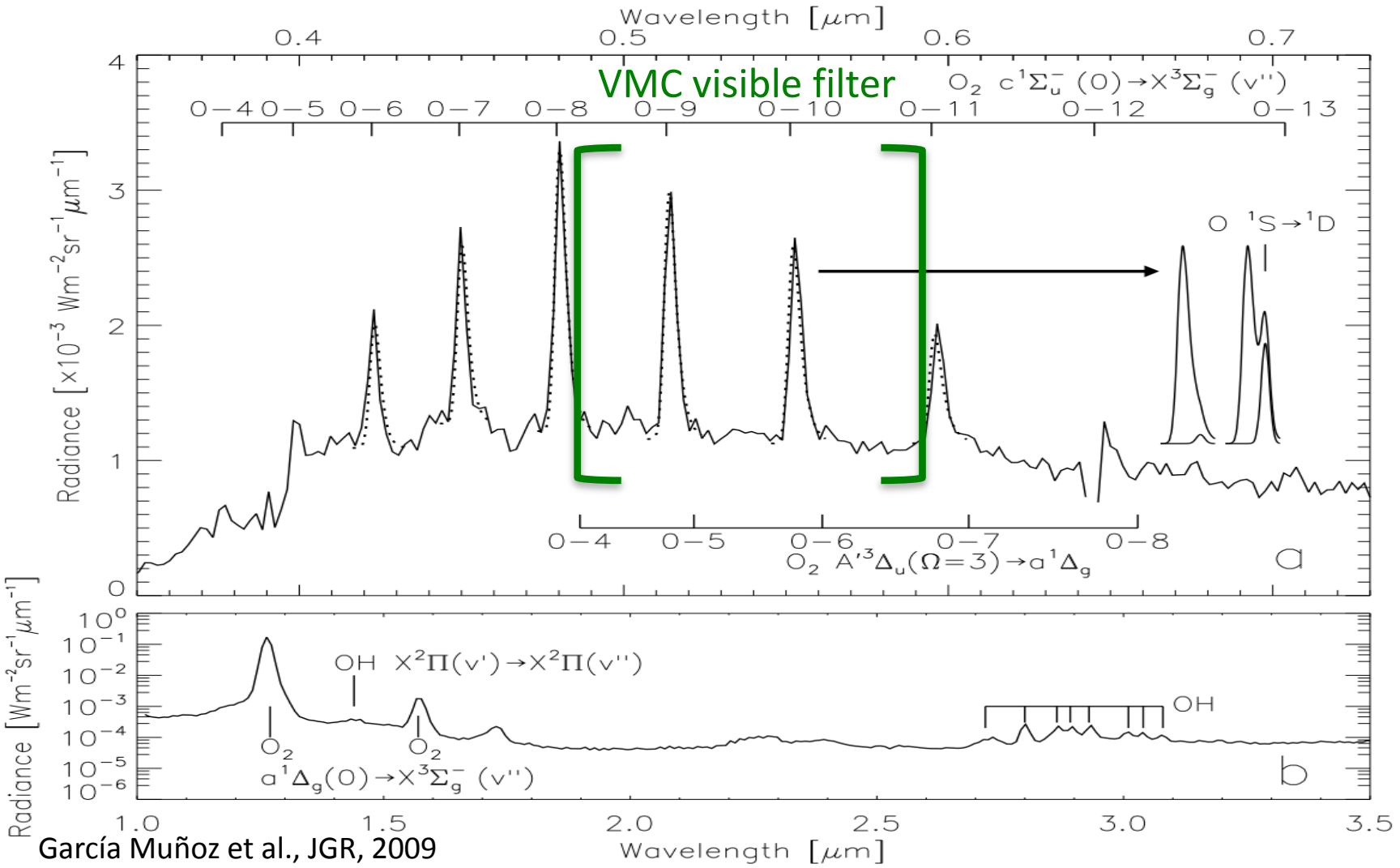
García Muñoz et al., PNAS, 2009

O_2 nightglow with VEx/VMC

Venus Monitoring Camera (VMC), PI: W.J. Markiewicz
Pupil < 1 cm, 17º FOV



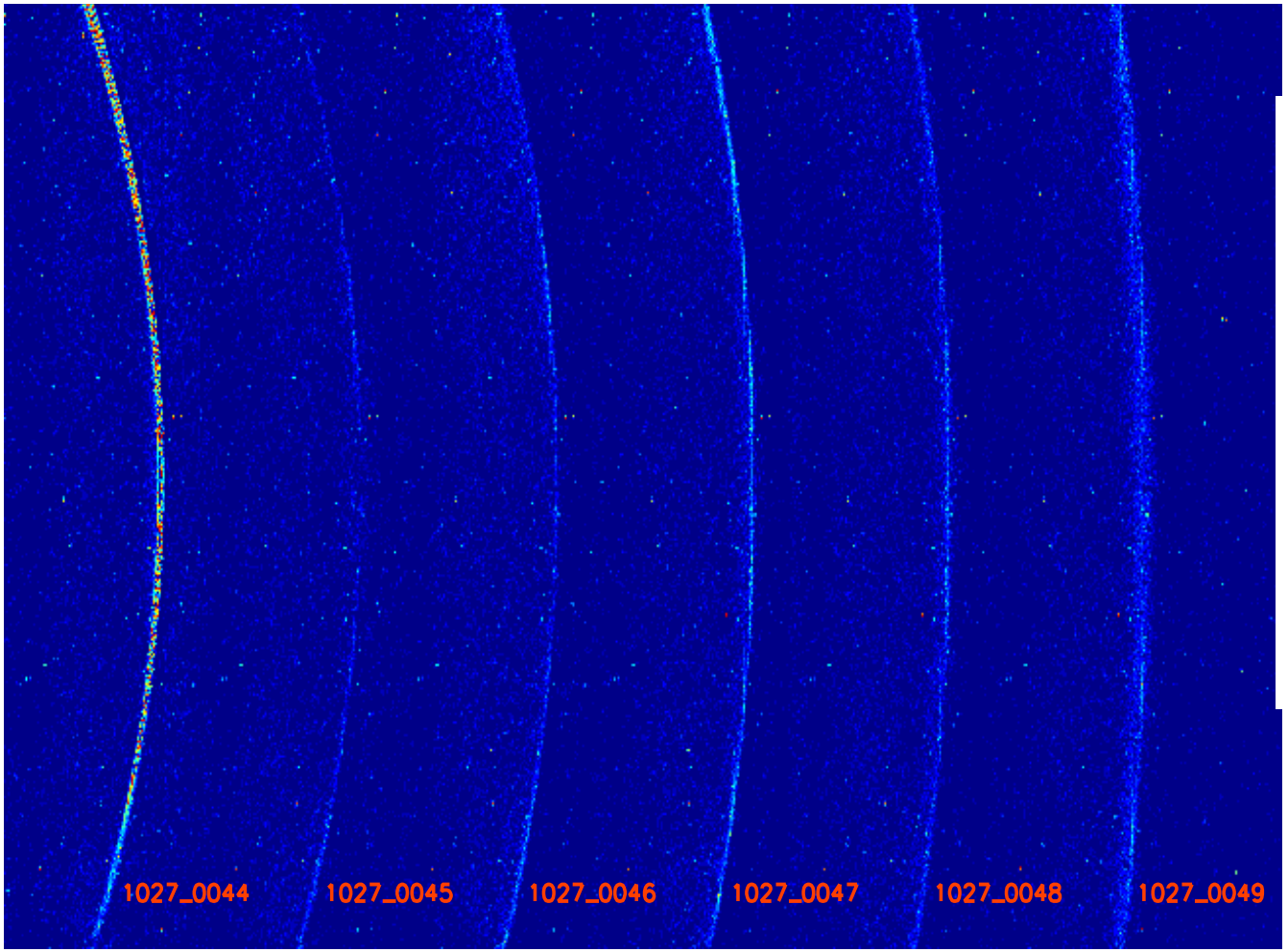
O_2 nightglow with VEx/VMC

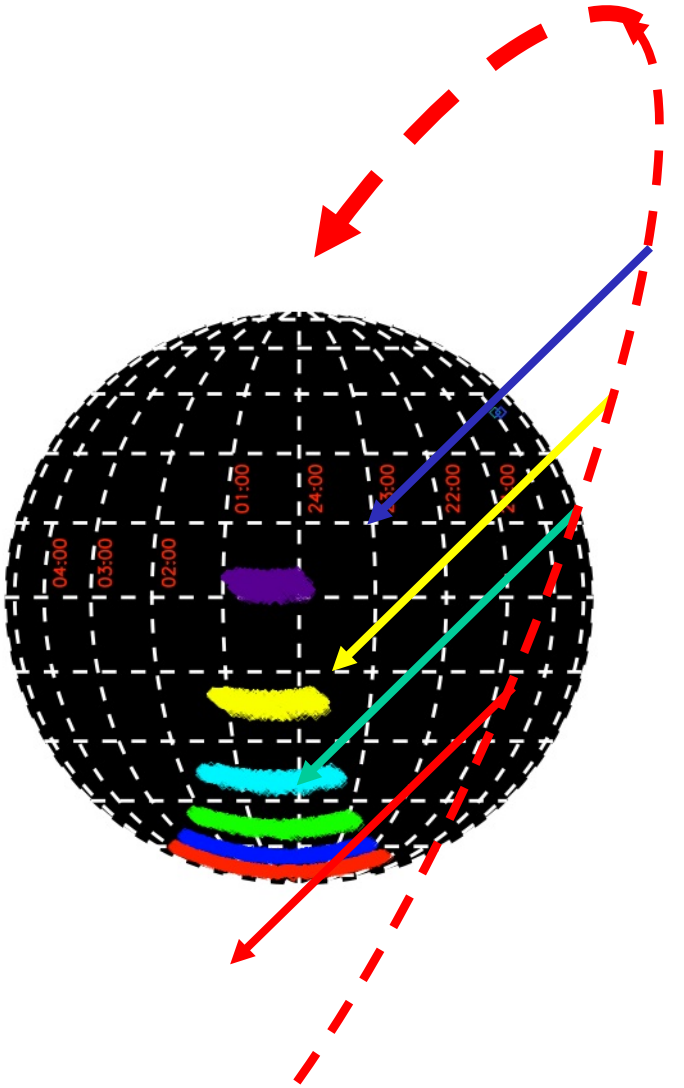


García Muñoz et al., JGR, 2009

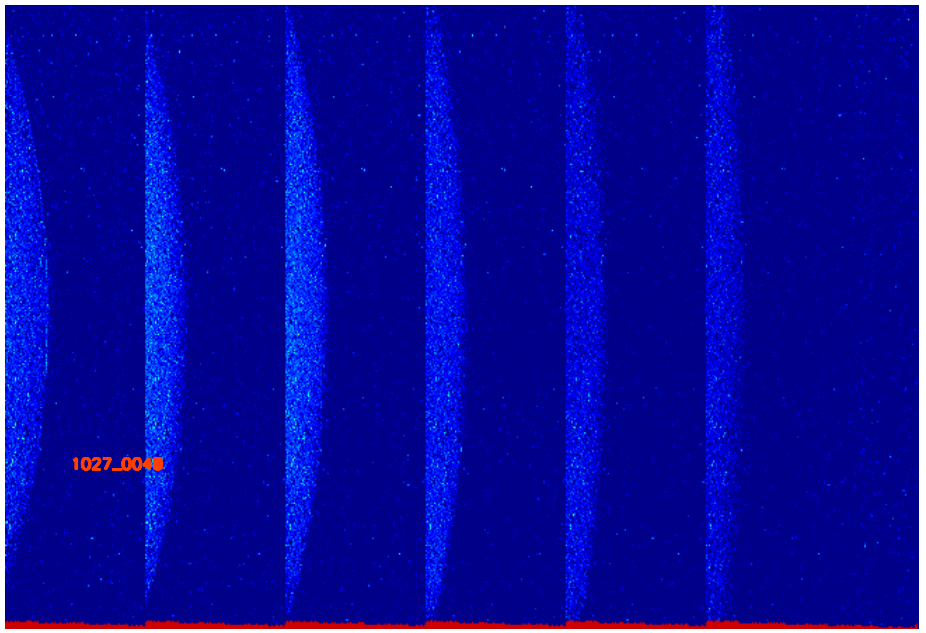
VMC O_2 nightglow images

Orbit 1026; 10 February 2009
1 image every 5 min; Pre-periapsis sequence



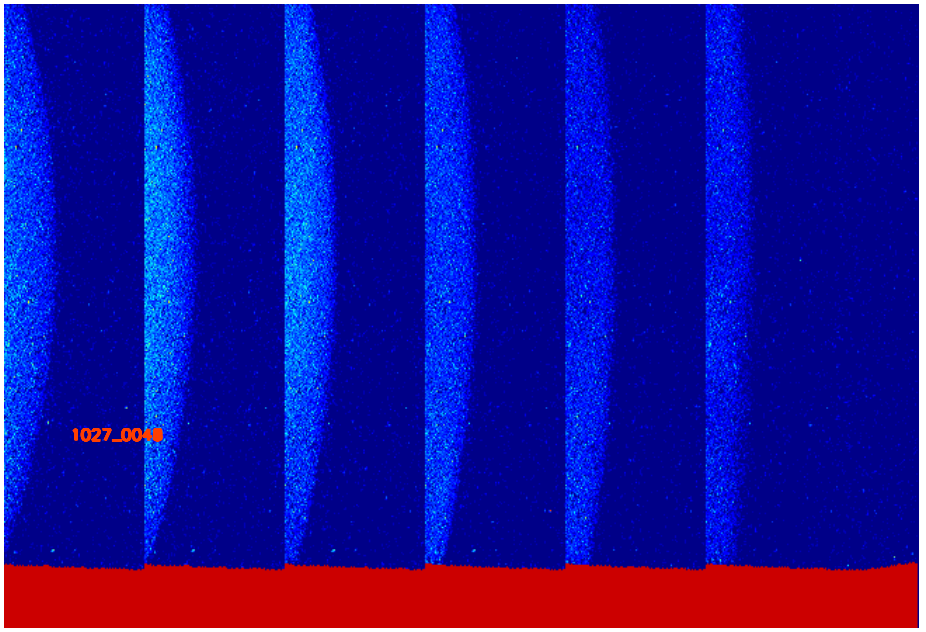


VMC NIR1 and NIR2 images



NIR1: 948-982 nm

NIR1: 988-1025 nm



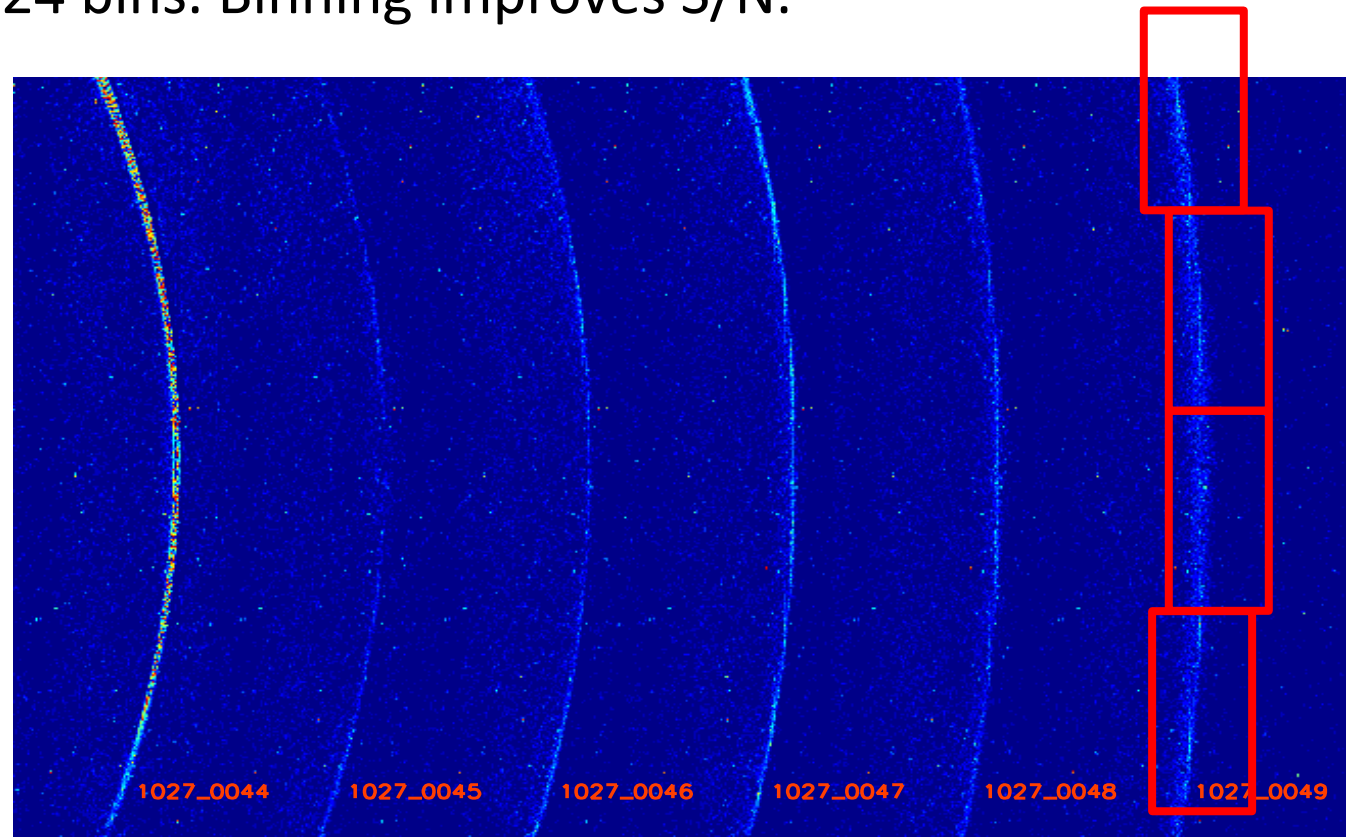
Selection and treatment of images

- Full public archive of VMC images in the VIS channel.
- Considered orbits 24 (May 2006) to 2099 (Jan 2012).
- Viewing: limb (airmass x 50), nightside, t_{expo}=30 secs

- Images with *acceptable* quality (i.e. w/o much astray light).
- Images were cleaned and radiometrically calibrated.
- For scientific analysis: 114 images from 36 orbits.

Selection and treatment of images

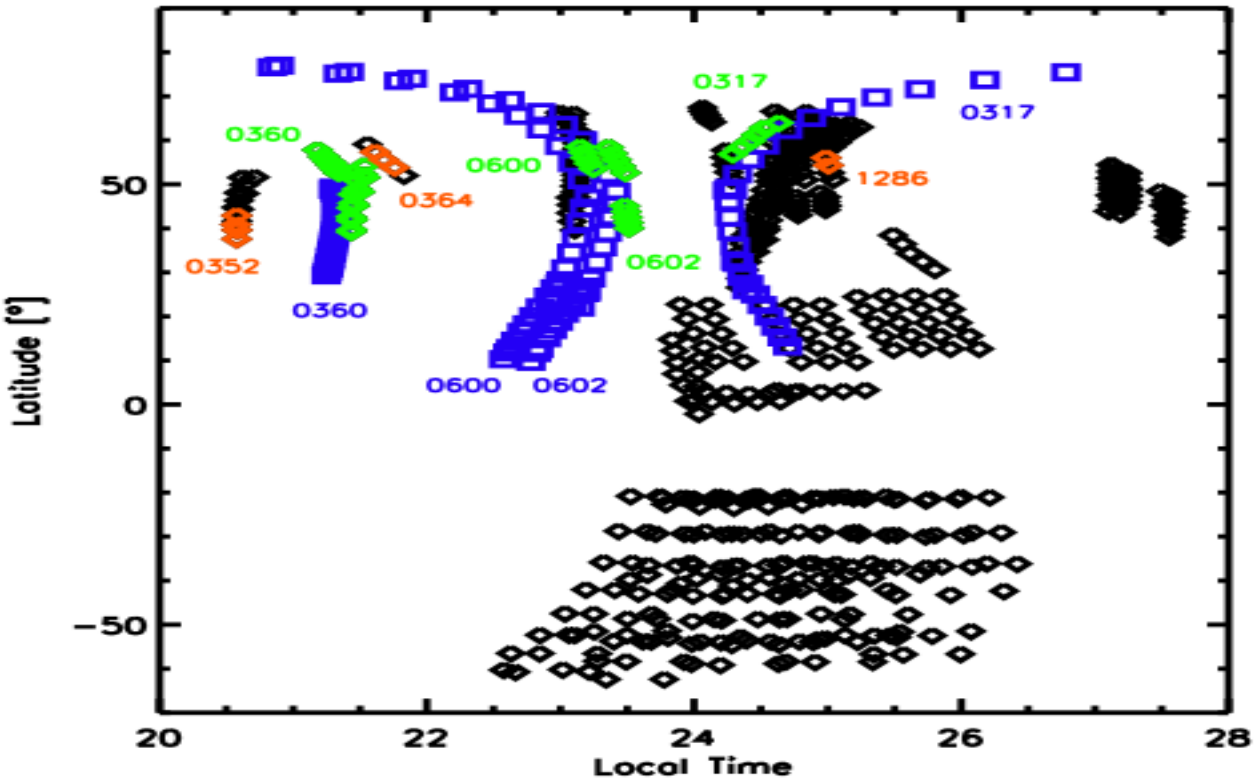
- For scientific analysis: 114 images from 36 orbits.
- 524 bins. Binning improves S/N.



- VMC coverage expands on Venera and PVO efforts,

either in temporal coverage or vertical resolution

Spatial coverage of bins



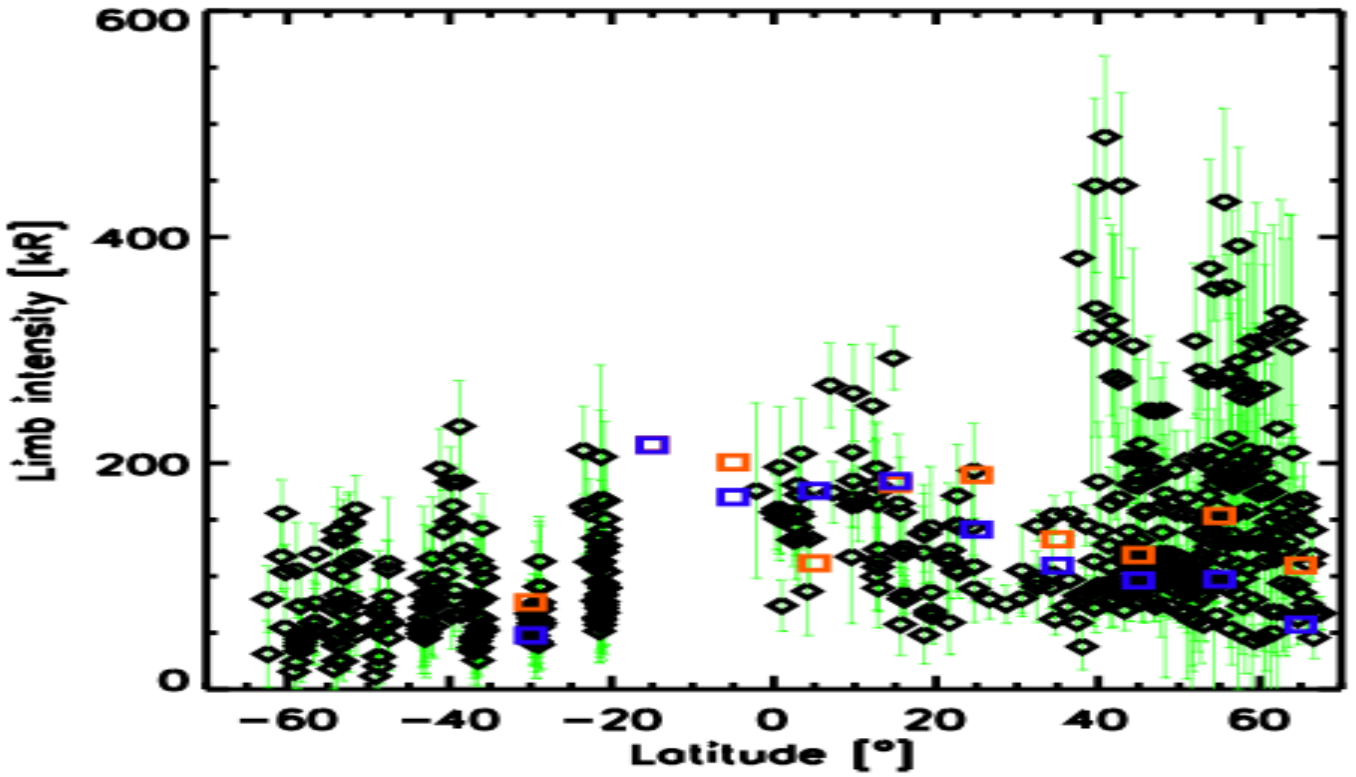
Non-blue: VMC bins

Blue: simultaneous VIRTIS data

Northern/southern hemispheres,

mostly within 2 hours from midnight

Visible nightglow intensity vs. latitude



Black: VMC bins

Blue: 1-year average of VIRTIS data at 1.27 µm (scaled by 1/200)

Red: 1-year average of VIRTIS visible data

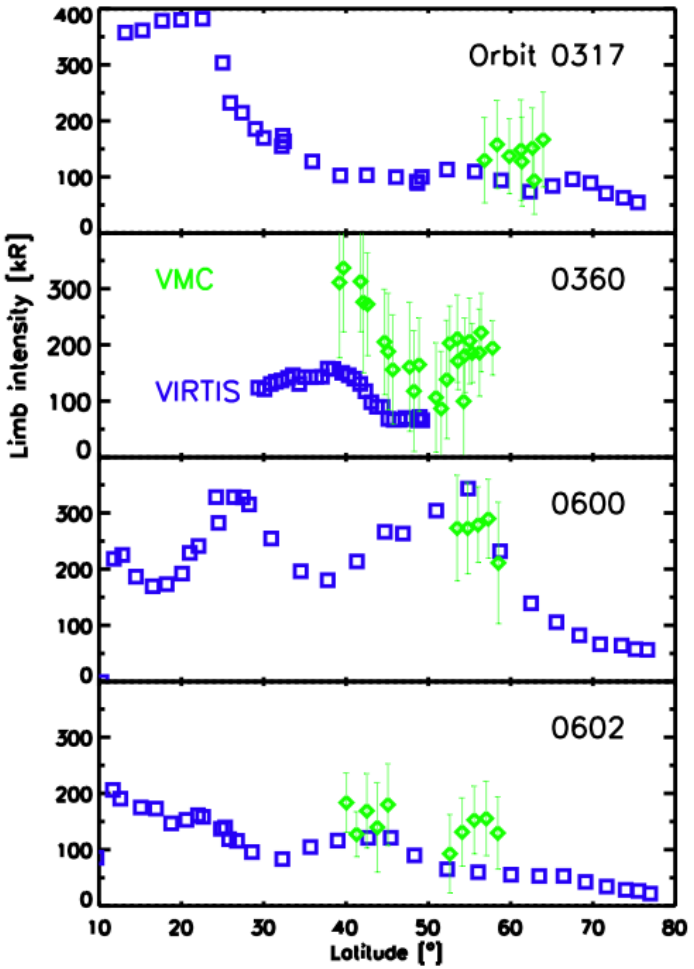
Interpretation:

1) General decay polewards from equator (≈150 kR).

2) Mild North/South background bias likely due to spatial resolution.

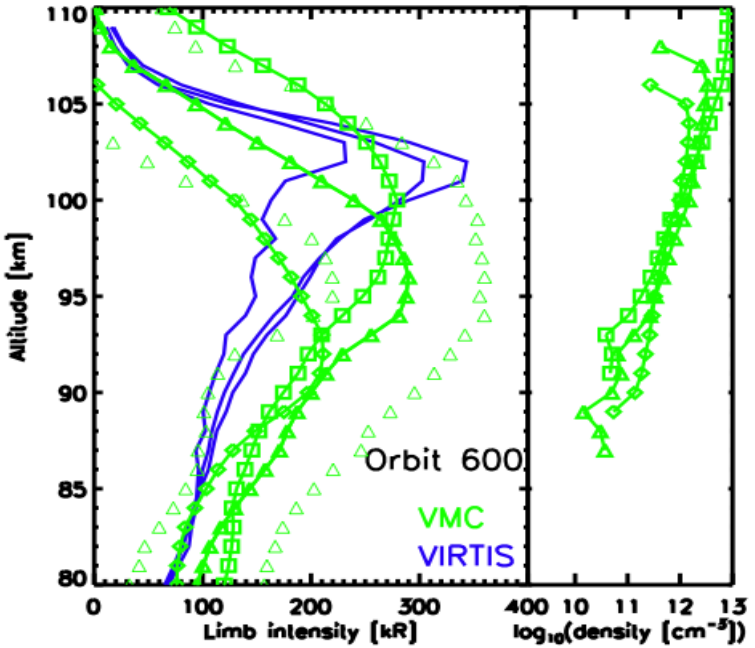
3) Events of high intensity (≈500 kR)

Simultaneous, co-located VMC & VIRTIS data



Limb emission profile

[O] vertical profile



Interpretation:

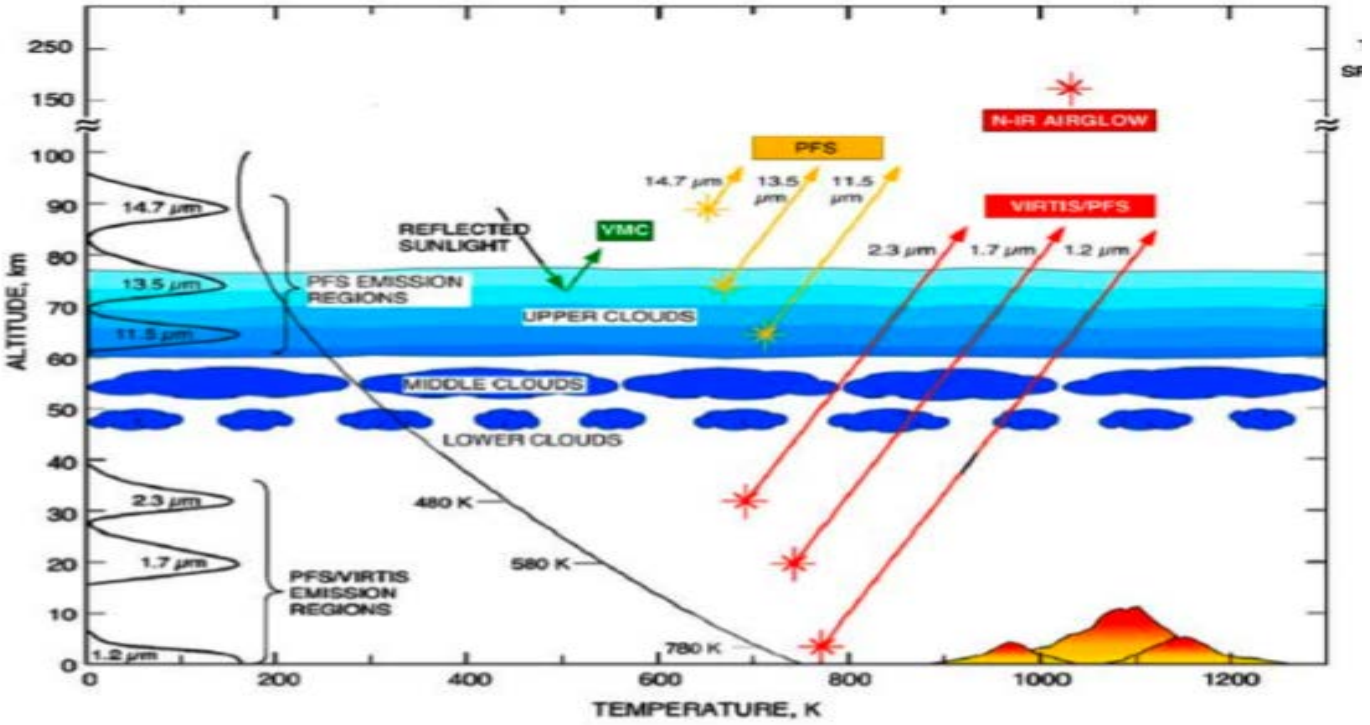
Visible (VMC) and NIR (VIRTIS) emissions

(scaled by 1/200) ***seem*** correlated

Lightning on Venus

Lightning in context: Solar System & beyond

Relevance: Fundamental, chemistry, ...



More likely:
intra-cloud

Definite answer on Venus remains controversial

Electromagnetic pulses

- Venera 11-14 (10-80 kHz),
  Generated by the craft?
- PVO (0.1-30 kHz) @ 100 Hz (whistler modes?),
  Correlation with topography?
- Galileo (0.1-5.7 MHz),
  Too remote observation?

- ***Cassini flybys (0.125-16 MHz): no detection,***
  but detection at Earth

- VEx magnetometer: '*clear*' evidence, terrestrial frequency, high dayside activity, whistler modes,...
  ...still controversial though...

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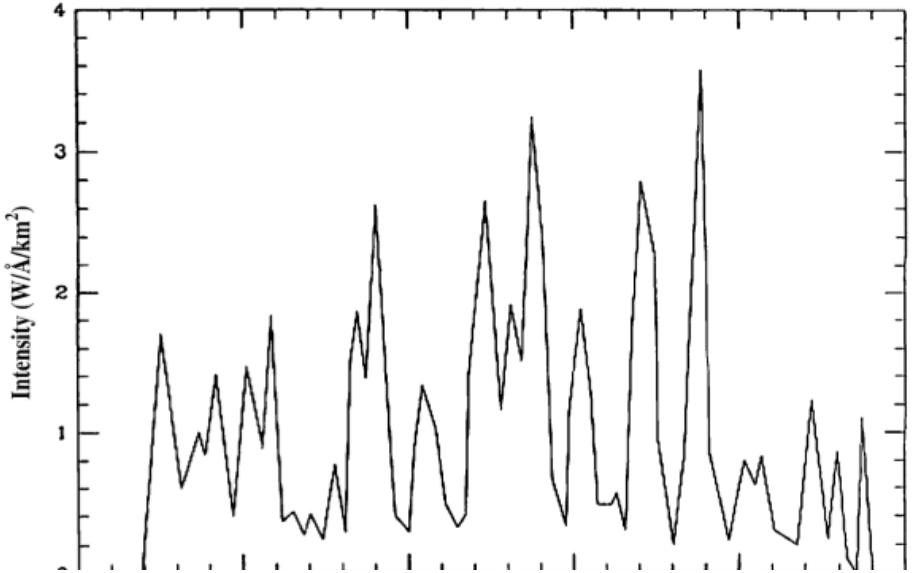
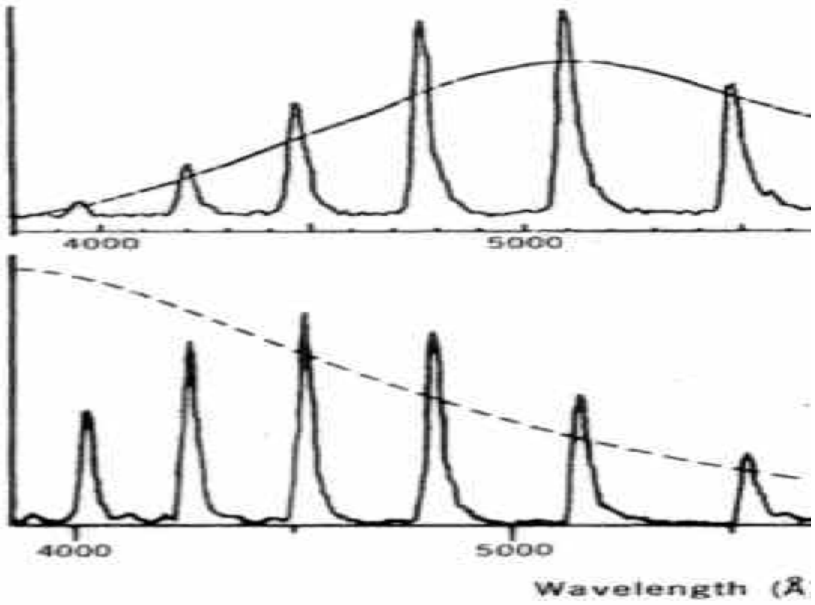
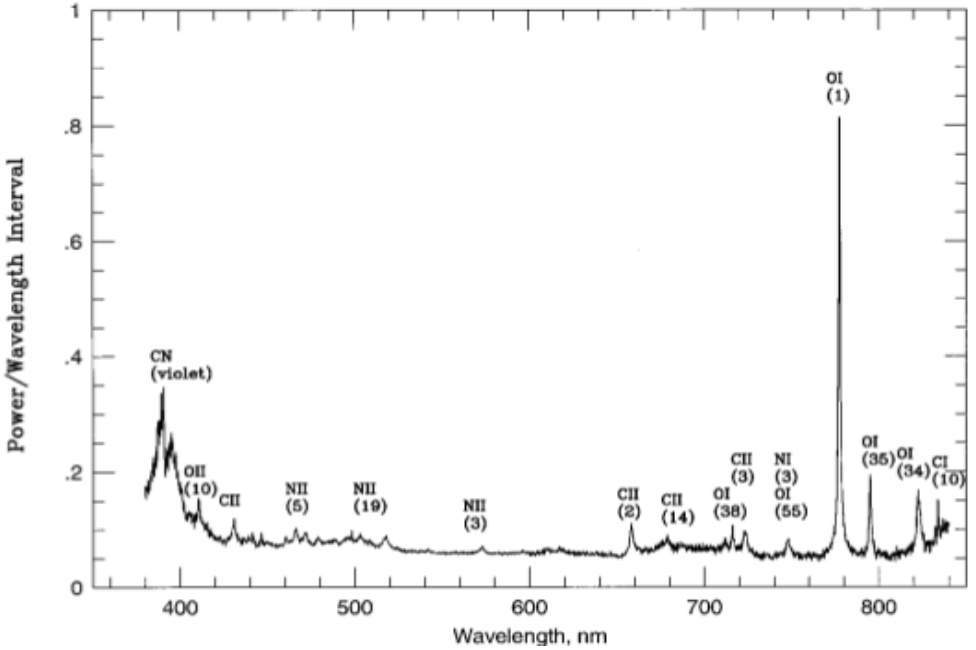
Optical observations

Venera 9-10



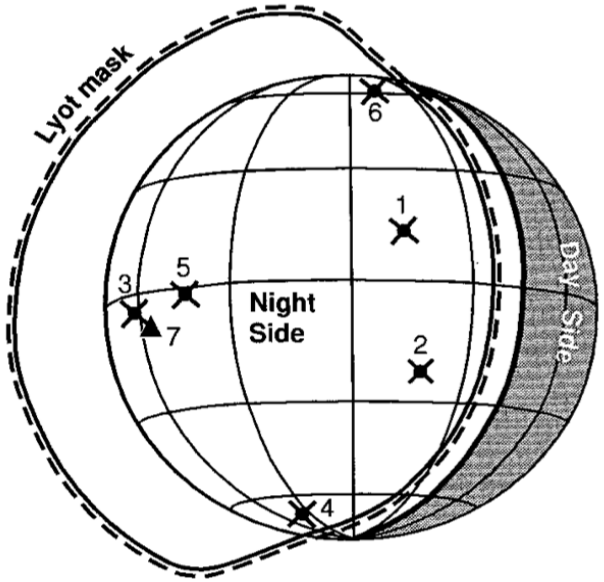


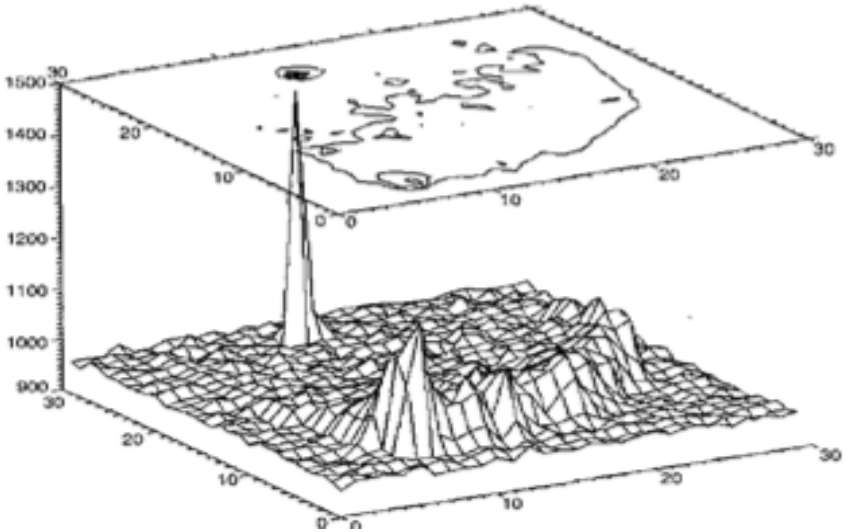


Optical observations

PVO: star tracker, broad band photometry
However, viewing geometry was not ideal

Ground based observations: Hansell et al. 1995





Myself at Calar Alto & La Palma

VEx contribution??

Mission planning: VIRTIS/VMC might contribute

Huge database of night-time observations

Enough sensitivity to capture flashes

Appropriate spectral coverage in the visible

- VIRTIS, with spectral resolution.
- VMC, with broadband filters.

...just started...