P-20

The CPS International School of Planetary Sciences

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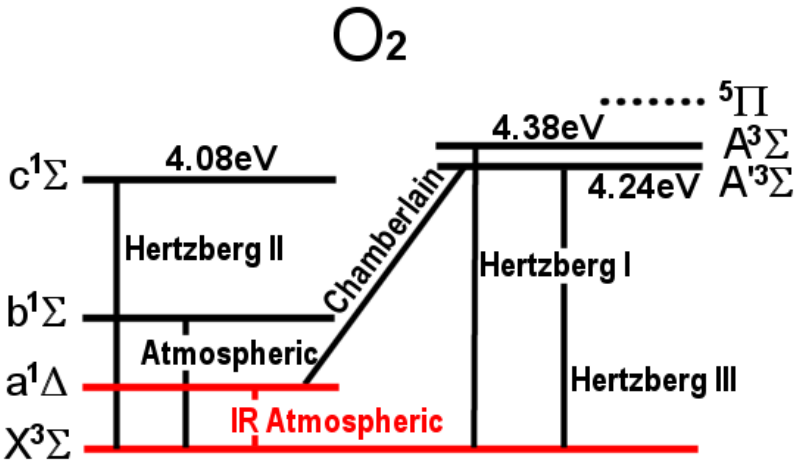
Temporal variations of the Venus oxygen night airglow observed from ground

Shoko OHTSUKI (ISAS/JAXA)

Naomoto Iwagami (Univ. of Tokyo)

O_2 airglow on Venus

1.27 μm (and 1.58 μm) night airglow



Main transition is O_2 ($a^1\Delta_g$ - $X_3\Sigma_g^-$).

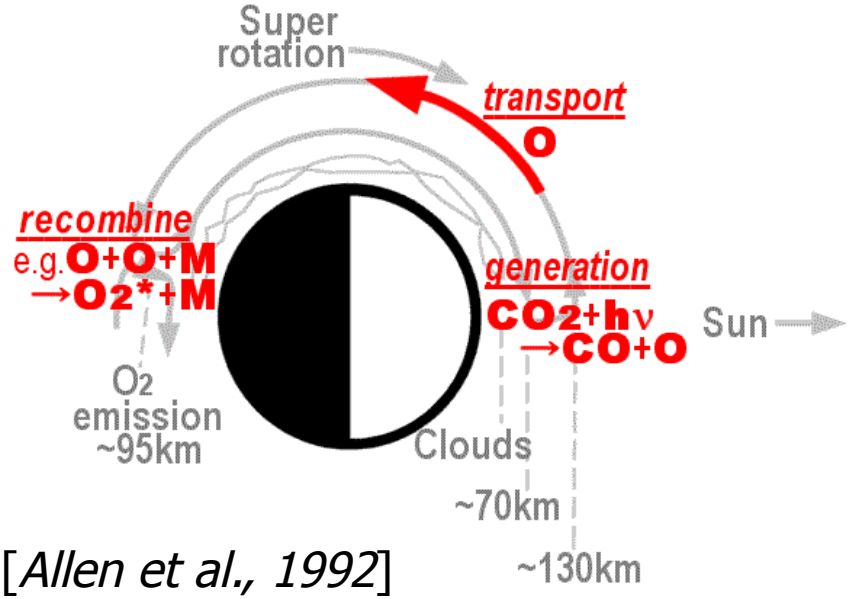
Emission at 1.27 μm is its (0-0) band and the brightest airglow on Venus.

It is detected on both the nightside and dayside of Venus by ground-based observation (Connes et al., 1979)

Currently (0-1) band emitting at 1.58 μm has been observed for the first time with VIRTIS on Venus-Express spacecraft.

O_2 airglow on Venus

1.27 μm (and 1.58 μm) night airglow



[*Allen et al., 1992*]

Observations in 1990's

(Allen et al., 1992; Crisp et al., 1996):

The brightest patch exists around anti-solar point.

The spatial structure is complex and varies dramatically.

O_2 airglow can be used as a probe of chemistry & dynamics around the emitting layer (90~115km).

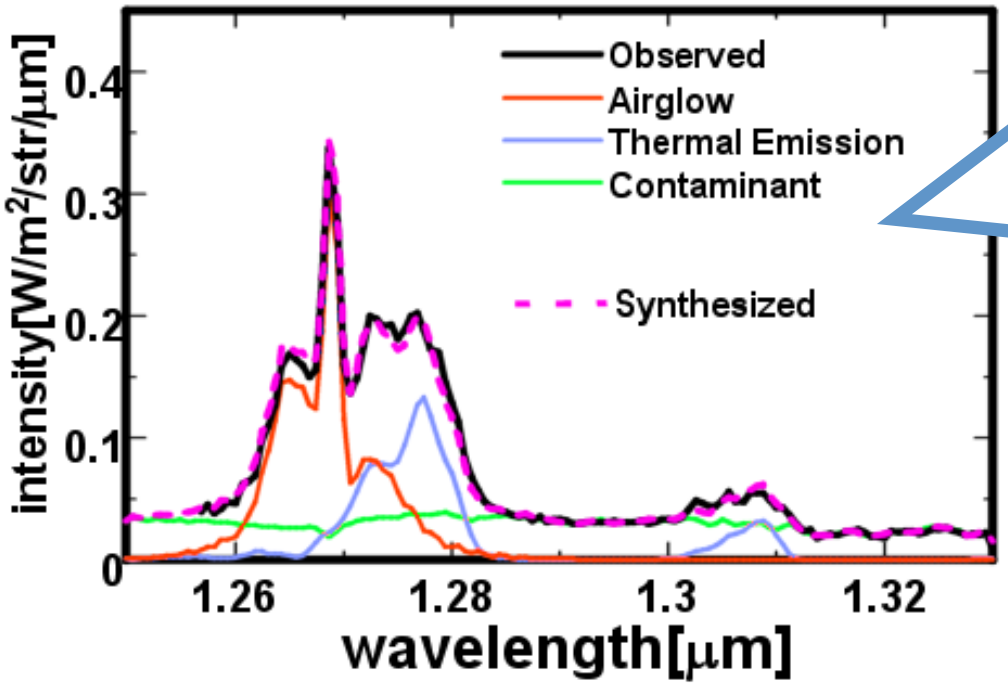
Observations

Moderate resolution ($\lambda/\Delta\lambda$~1000-2500)

date	11/Dec/2002	11/May/2004
site	**O**kayama **A**strophysical **O**bservatory, Japan (seeing ~2.5″)	**G**unma **A**stronomical **O**bservatory, Japan (seeing 2~3″)
telescope	1.88m	1.5m
instrument	SuperOASIS MCT array 0.97″/pix, 128×128	Infrared Camera MCT array 0.4″/pix, 1024×1024
Resolution, range	**R~1,000** 1.25~1.33 μm	**R~1,500** 1.17~1.32 μm

Spectral analysis

Moderate resolution ($\lambda/\Delta\lambda$~1000-2500)



- Molecular absorption line database **HITRAN** & **HITEMP**,
- Atmospheric model of Venus **VIRA1985**,
- Atmospheric model of Earth **U.S. Standard Atmosphere** (1966) or **MSIS-90**,

Fig. An example of observed and synthesized spectra(Dec. 11, 2002)

The observed 1.3-μm spectra show
- –the 1.27μm **airglow** feature of O_2 IRA (0,0) band,
- –the **thermal emission** from the lower atmosphere,
- –stray light from bright **dayside**.

Intensity and Temperature

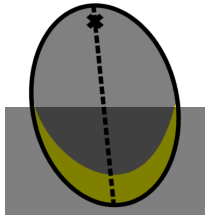
Moderate resolution ($\lambda/\Delta\lambda$~1000-2500)

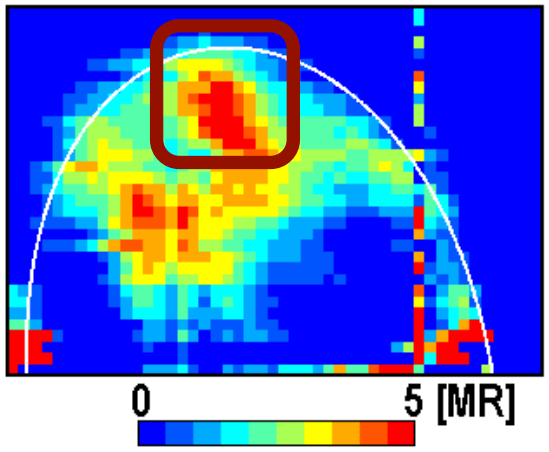
Band intensity

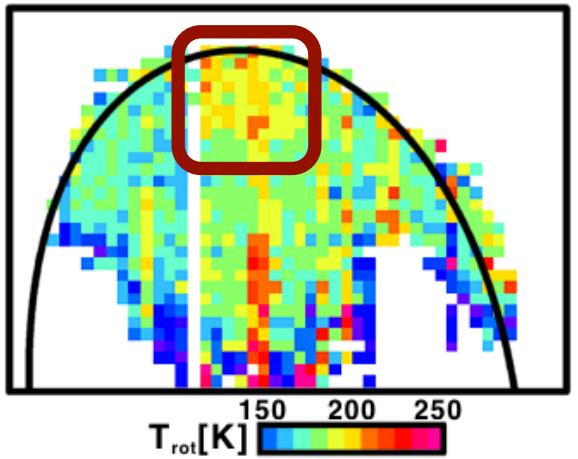
Rotational temperature

OAO

11Dec. 2002

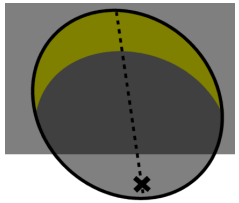


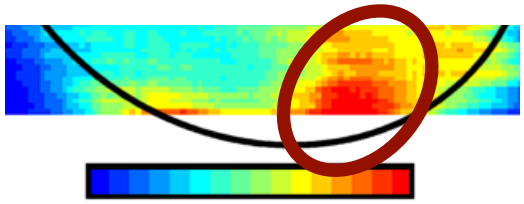


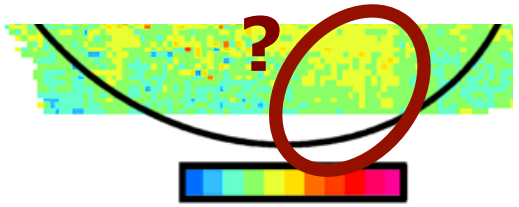


GAO

11May 2004







Observations

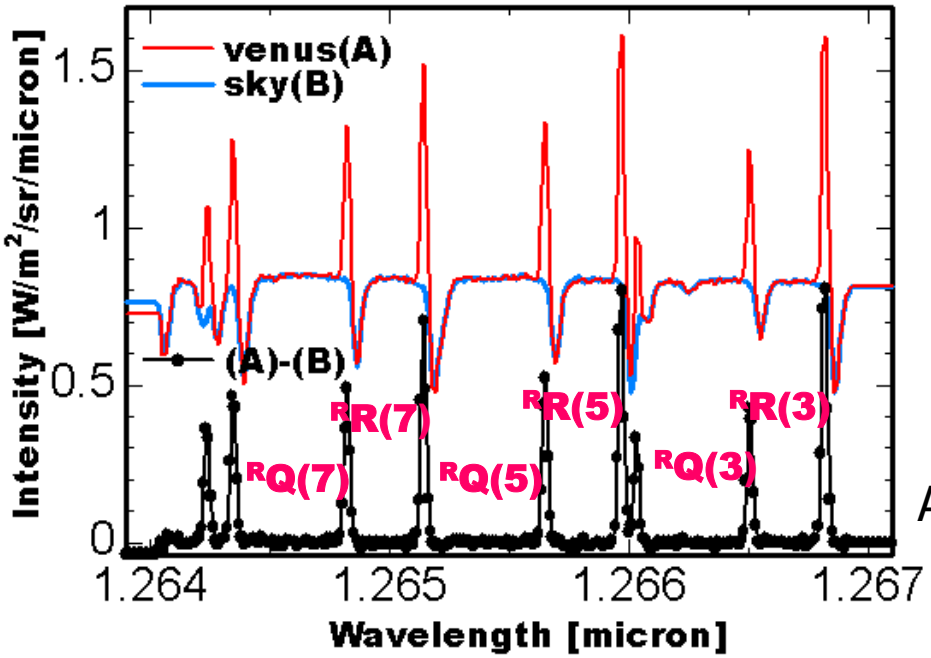
High resolution ($\lambda/\Delta\lambda$~40,000)

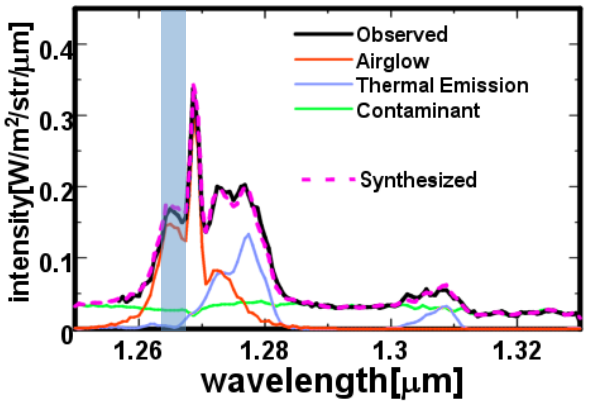
date	14/Dec/2005, 17-18/Feb/2006, 13-15/Jul, 22-24/Sep/2007
site	**I**nfra**R**ed **T**elescope **F**acility, Mauna Kea, Hawaii (seeing ~1″)
telescope	3m
instrument	CSHELL InSb array 0.2″/pix, 256×256
Resolution, range	**R~40,000** 1.264~1.267 μm

High spectral resolution makes possible to conduct "**daytime**" observations!

Spectral analysis

High resolution ($\lambda/\Delta\lambda \sim 40000$)





Average of 40 spectra

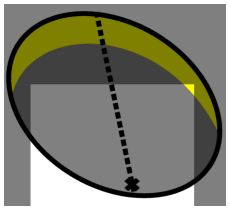
Because of daytime observation,

Observed = Venus **airglow** + **sky** (+ stray light from dayside)

- Each emission line in R-branch of O_2 ($a^1\Delta_g$ - $X_3\Sigma_g^-$) (0-0) band is resolved.
- Thermal emission from lower atmosphere is negligible weak.

Intensity and Temperature

High resolution (λ/Δλ~40000)

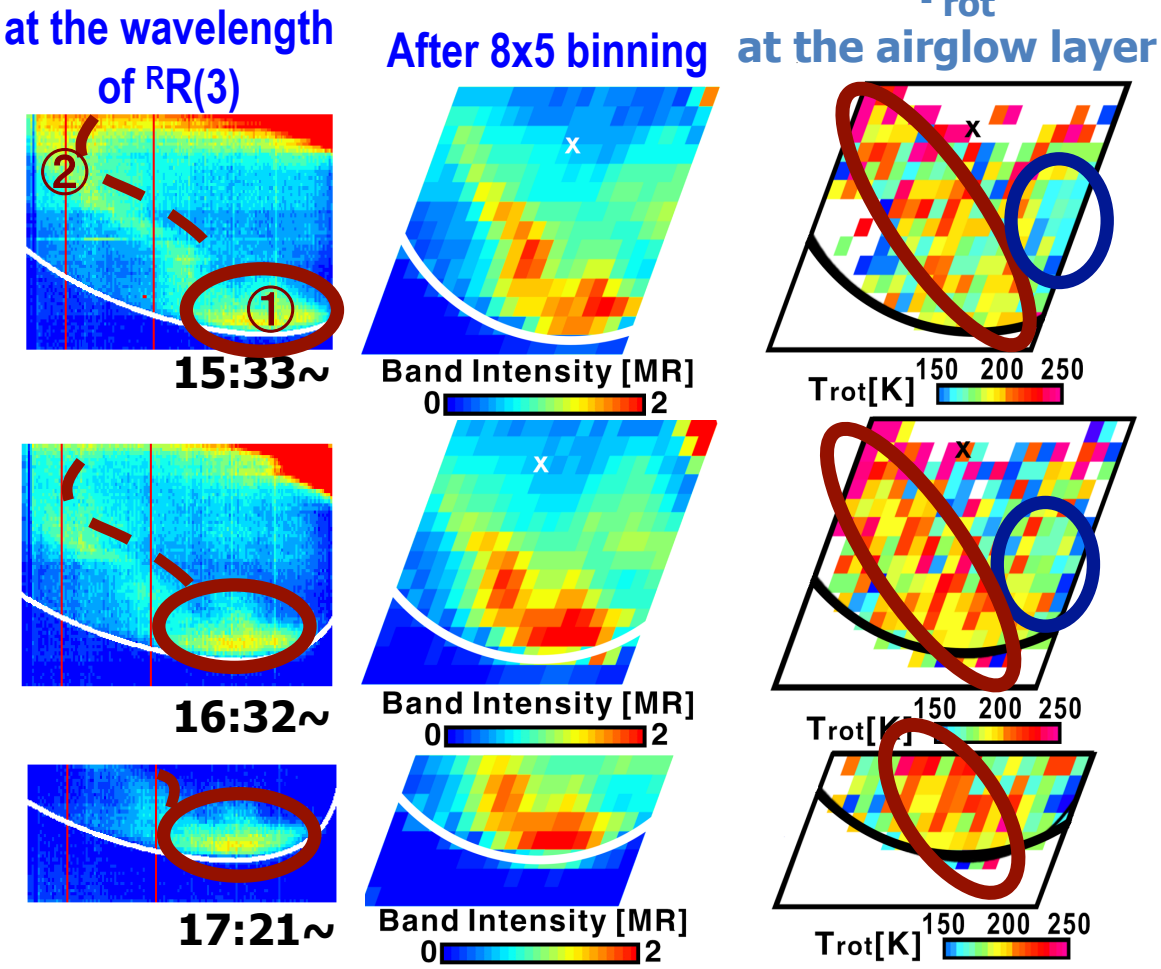


14Dec. 2005

① Bright region around anti-solar point

② Streak like structure

◆ Warmer region and cooler region



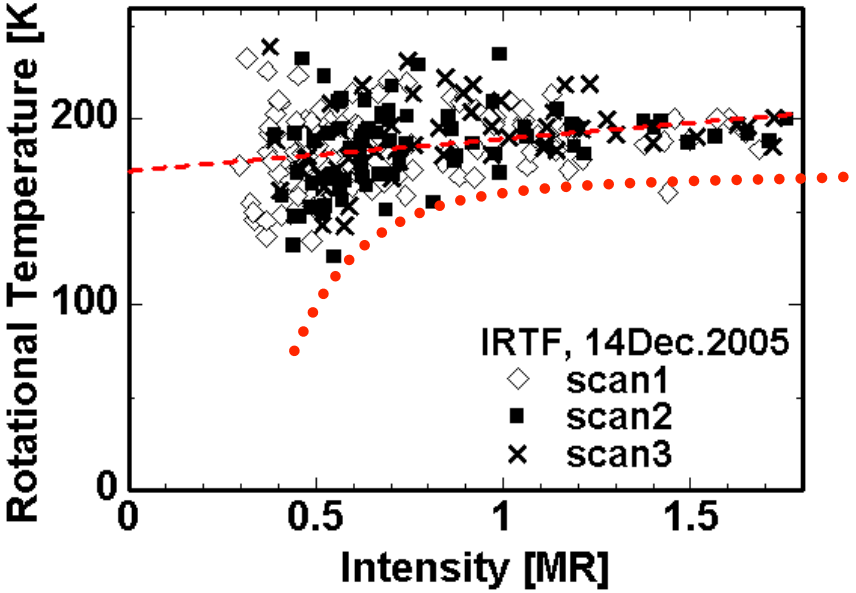
Temperature at 95 km

Method	Temperature (K)	Reference
1.27 μm O_2 airglow	185 ± 15	Connes et al. (1979)
Pioneer Venus night probe deceleration	167.2	Seiff and Kirk (1982)
Pioneer Venus OIR	170–175	Schofield and Taylor (1983)
VIRA (based on OIR and probe deceleration)	168	Seiff et al. (1985)
CO mm lines	165–210	Clancy and Muhleman (1991)
1.27 μm O_2 airglow	186 ± 6	Crisp et al. (1996)
CO mm lines	165–178	Clancy et al. (2003)
1.27 μm O_2 airglow	193 ± 9	Ohtsuki et al. (2005)
Venera 15 IR Fourier spectrometer	166.4	Zasova et al. (2006)
SPICAV Stellar occultation	194–240	Bertaux et al. (2007)
1.27 μm O_2 airglow	181–196	This work
(intensity weighted mean)		**Bailey et al. (2008)**

Rotational temperatures of O_2 airglow are higher than the temperature at this altitude expected from VIRA (168K at 95km).

Airglow and temperature

Heating associated with downward flow



[Ohtsuki et al., 2008]

- Calculated T_{rot} in the bright region were higher and low T_{rot} in the dark region.

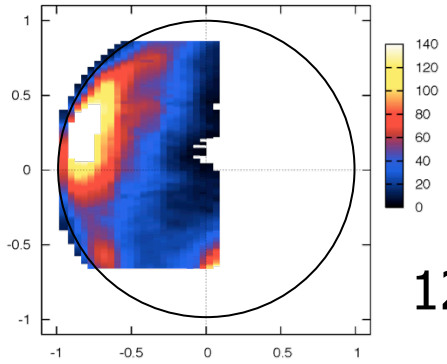
➔ T_{rot} have a weak correlation with the airglow intensity. [Ohtsuki et al., 2005,2008]

- "Warm layer in cryosphere" at altitudes 90-120km was detected by recent VEX/SPICAV observation.[Bertaux et al.,2007]

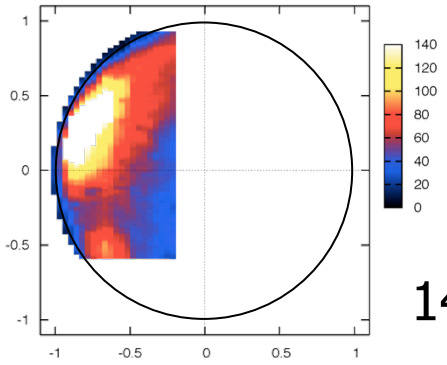
Temperature in bright region of the O_2 airglow is thought to be higher than other region, due to **adiabatic heating** associated with strong downward flow in solar-antisolar circulation.

Intensity maps

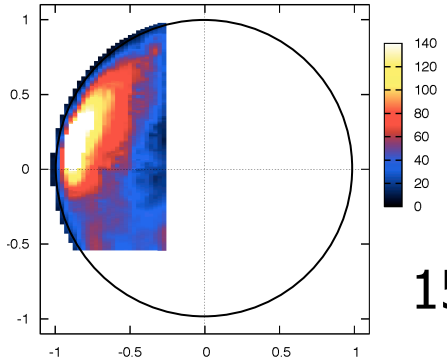
2007/7/13



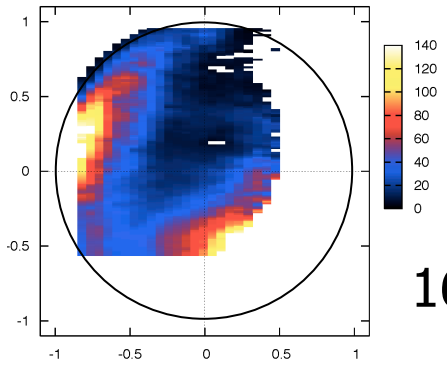
12:54-13:25 HST



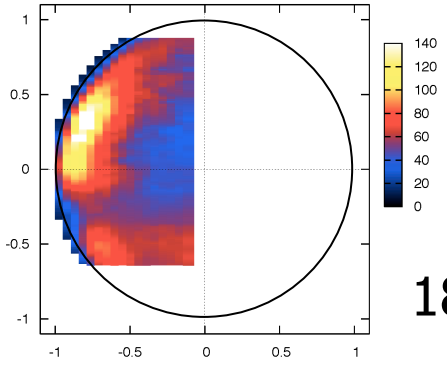
14:28-15:00 HST



15:45-16:20 HST



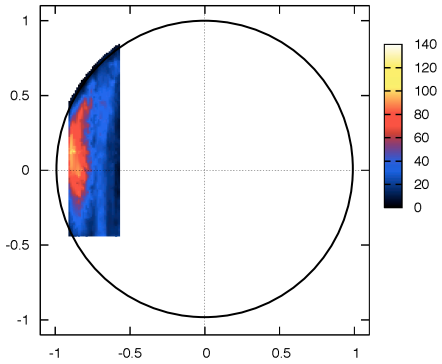
16:48-17:22 HST



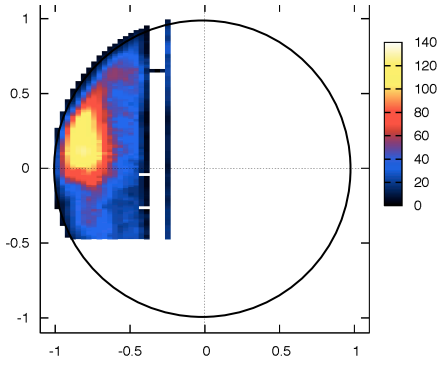
18:10-18:37 HST

Intensity maps

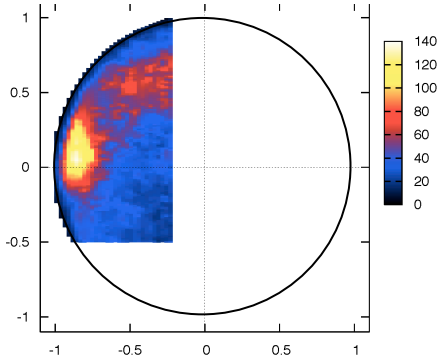
2007/7/14



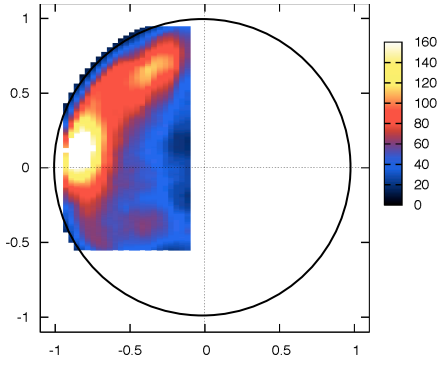
11:35-12:15 HST



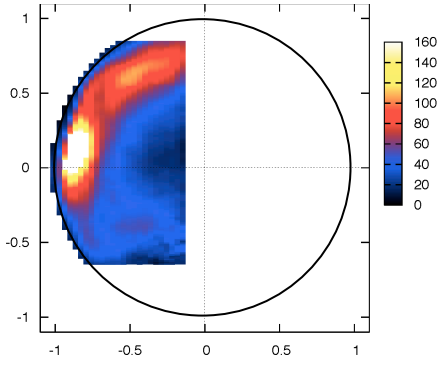
12:50-13:15 HST



14:12-14:43 HST



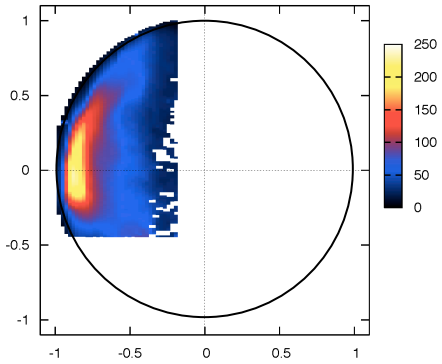
17:12-17:45 HST



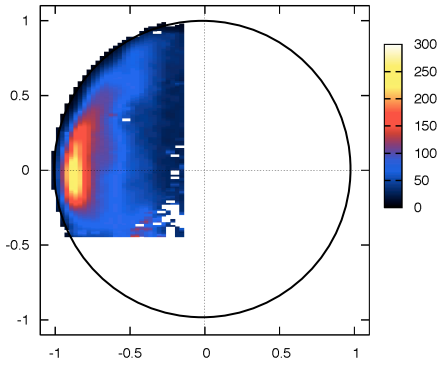
18:13-18:46 HST

Intensity maps

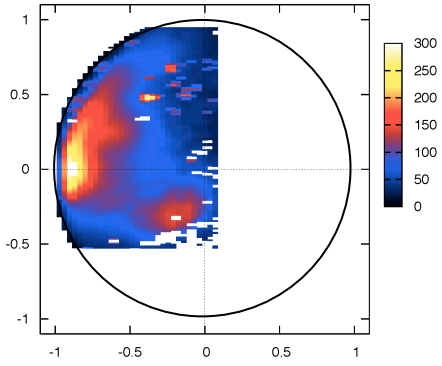
2007/7/15



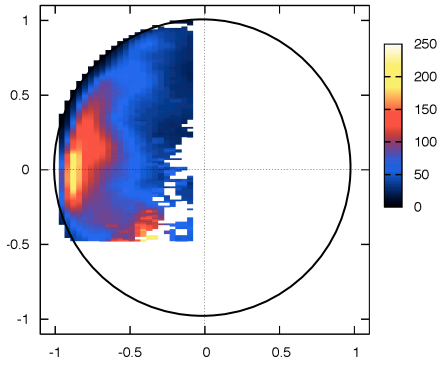
12:19-13:00 HST



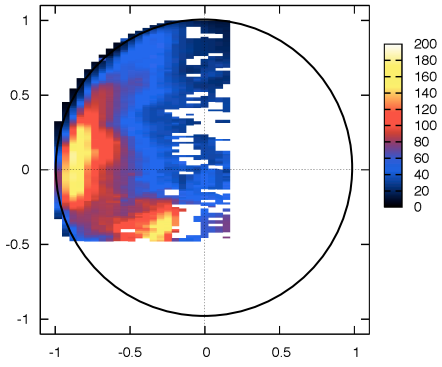
13:30-14:10 HST



14:52-15:32 HST



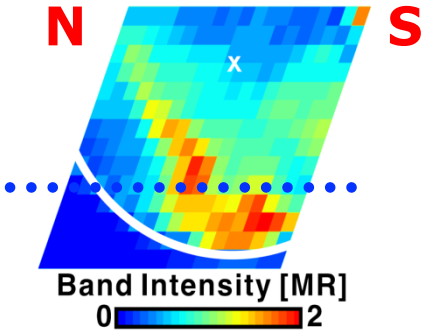
15:58-16:30 HST

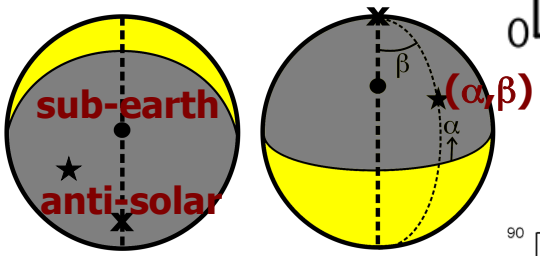


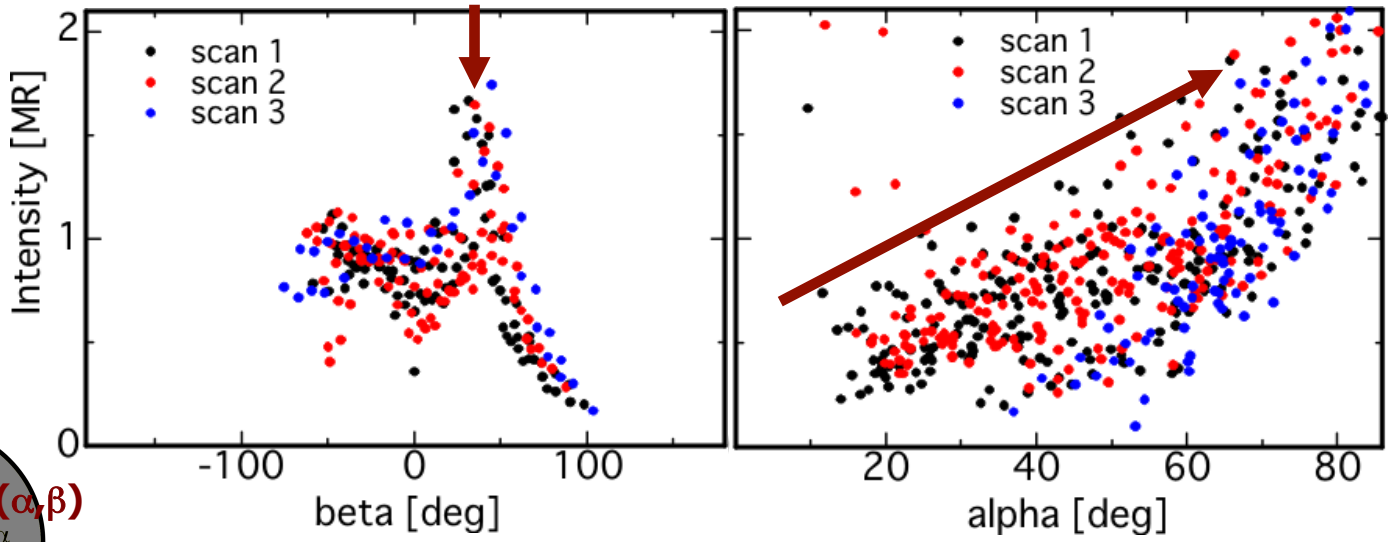
16:50-17:20 HST

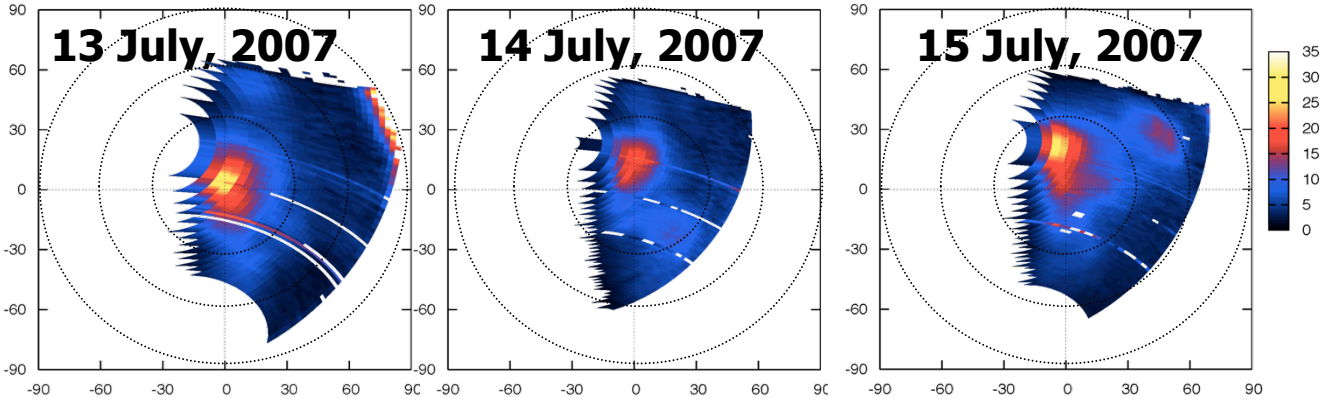
Polar plot at anti-solar point

14Dec. 2005



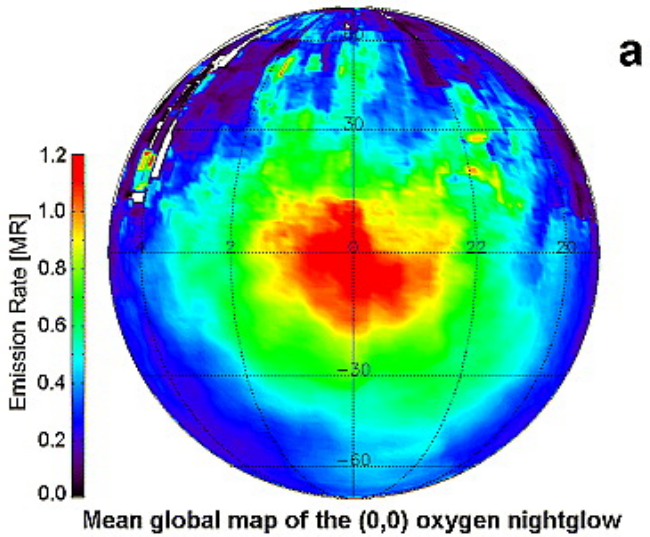




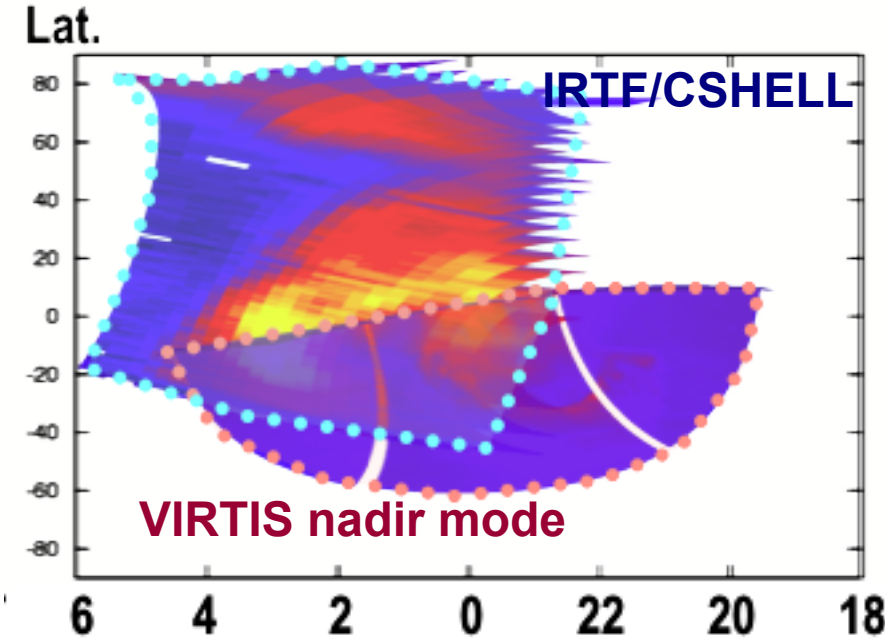


Observations with VIRTIS-M

Nadir observation mode



[Piccioni et al., 2009]



Many horizontal distributions of O2 emission are observed.

- Mean global map (over 880 orbits data are averaged) is shown.
- Region of maximum emission, 1.2MR, is near Anti-Solar point.

➔ Coordinated observations can cover wider range of night hemisphere!

Summary

- In this 10 years many ground-based observations of O_2 airglow were conducted.
  - Rotational temperature of O_2 airglow is derived.
  - A local temperature enhancement is found.

  ➔Adiabatic heating due to downwelling may produce a local warmer region.
  - High spectral resolution of CSHELL allows to observed O_2 airglow in daytime.

  ➔Temporal variation of the airglow around the anti-solar point were monitored.

AKATSUKI Message Campaign

We will deliver your message to the bright star Venus !!

JAXA would like to enhance people's interest in space and the Earth by holding a "message campaign" in which we invite people to send us messages that will be printed in fine letters on an aluminum plate and placed aboard the Venus Climate Orbiter "AKATSUKI".