Temporal variations of the Venus oxygen night airglow observed from ground

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O₂ airglow on Venus

1.27 µm (and 1.58 µm) night airglow

Main transition is O₂ (a¹Δg - X³Σg⁻).

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 $\mu$m (and 1.58 $\mu$m) night airglow

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).

[Allen et al., 1992]
## Observations

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

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>site</td>
<td>Okayama Astrophysical Observatory, Japan (seeing ~2.5′′)</td>
<td>Gunma Astronomical Observatory, Japan (seeing 2~3′′)</td>
</tr>
<tr>
<td>telescope</td>
<td>1.88m</td>
<td>1.5m</td>
</tr>
<tr>
<td>instrument</td>
<td>SuperOASIS MCT array 0.97′′/pix, 128×128</td>
<td>Infrared Camera MCT array 0.4′′/pix, 1024×1024</td>
</tr>
<tr>
<td>Resolution, range</td>
<td><strong>R~1,000</strong> 1.25~1.33 µm</td>
<td><strong>R~1,500</strong> 1.17~1.32 µm</td>
</tr>
</tbody>
</table>
Spectral analysis
Moderate resolution ($\lambda/\Delta\lambda \sim 1000$-$2500$)

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

The observed 1.3-$\mu$m spectra show
- the 1.27-$\mu$m 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 ($\lambda/\Delta\lambda \sim 1000-2500$)

**OAO**
11 Dec. 2002

**GAO**
11 May 2004
# Observations

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

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Site</td>
<td>InfraRed Telescope Facility, Mauna Kea, Hawaii (seeing ~1&quot;)</td>
</tr>
<tr>
<td>Telescope</td>
<td>3m</td>
</tr>
<tr>
<td>Instrument</td>
<td>CSHELL</td>
</tr>
<tr>
<td></td>
<td>InSb array</td>
</tr>
<tr>
<td></td>
<td>0.2&quot;/pix, 256×256</td>
</tr>
<tr>
<td>Resolution, range</td>
<td><strong>R~40,000</strong></td>
</tr>
<tr>
<td></td>
<td>1.264~1.267 (\mu\m)</td>
</tr>
</tbody>
</table>

High spectral resolution makes possible to conduct "daytime" observations!
Spectral analysis

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

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

14Dec. 2005

1. Bright region around anti-solar point
2. Streak like structure

Warmer region and cooler region

At the wavelength of $^3\!R(3)$

After 8x5 binning at the airglow layer

$T_{\text{rot}}$ [K]

Band Intensity [MR]

- 0
- 1
- 2

0
150
200
250
Temperature at 95 km

Rotational temperatures of O$_2$ airglow are higher than the temperature at this altitude expected from VIRA (168K at 95km).
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
2007/7/15

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

sub-earth

(\alpha, \beta)

anti-solar
Observations with VIRTIS-M

Nadir observation mode

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".