Section B. Science and Measurement

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Section B Outline

- TIMED Science Objectives
- TIDI Measurements
- TIDI Measurement Techniques Overview
- TIDI Instrument Overview
- TIDI Coverage
- TIDI Requirement Summary

TIMED Science

- **Mission Science Objectives**
  - To investigate and understand the energetics of the mesosphere and lower thermosphere (MLTI)

- **Mission Goals**
  - To determine the pressure, temperature, density, and wind structure in the MLTI region, including seasonal and latitudinal variations.
  - To determine the relative importance of various radiative, chemical, electrodynamical, and dynamical sources and sinks of energy for the thermal structure of the MLTI.

TIDI

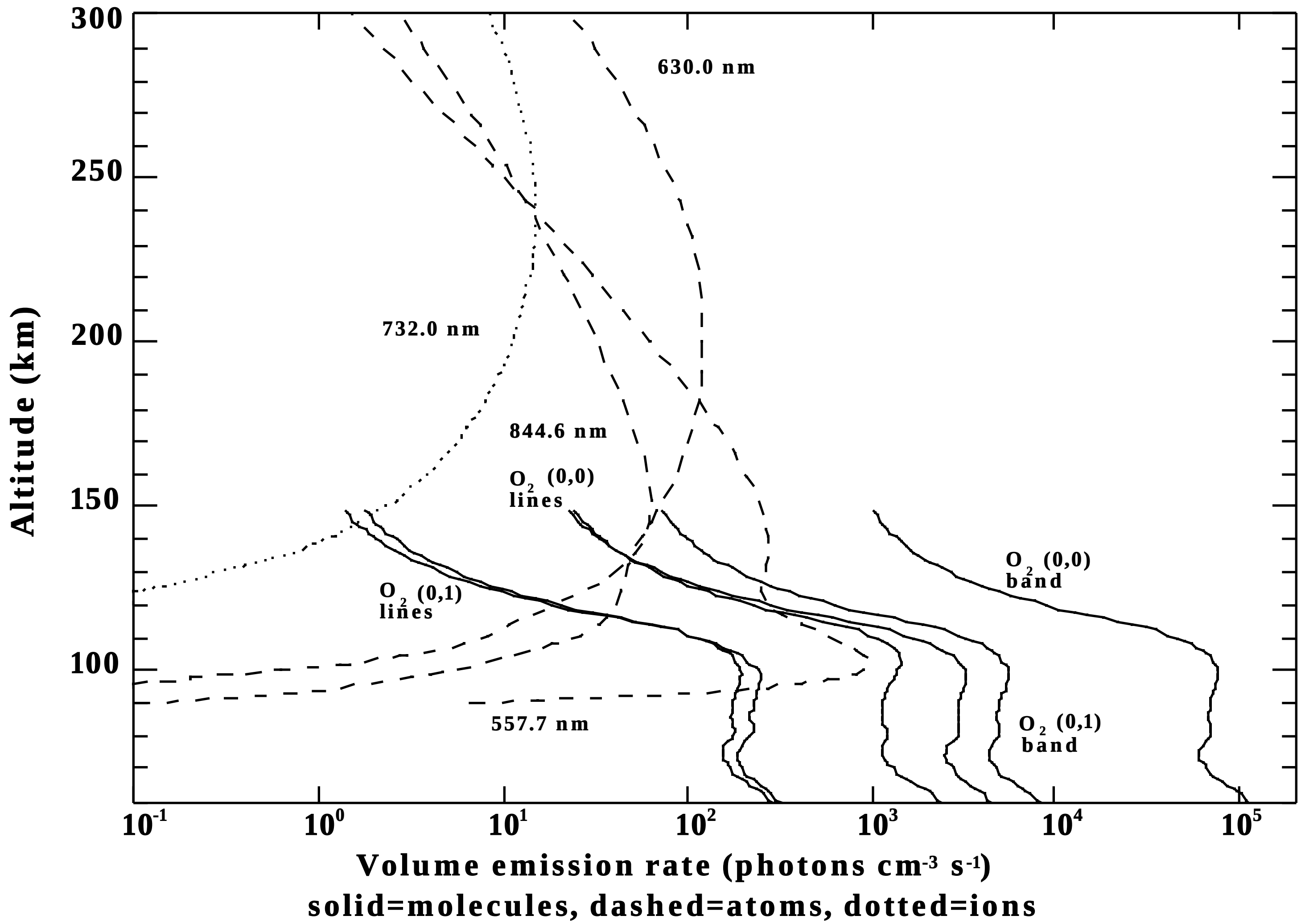
TIDI Measurement Goals

- **Obtain global wind measurements from 60 km to 300 km for at least 2 years with an accuracy of a few m/s.**
- **Obtain global measurements of temperature and specie volume emission rates (VER) in the MLTI region.**
- **Derive concentrations of important minor species, such as O, O_3, and $O(^1D)$.**

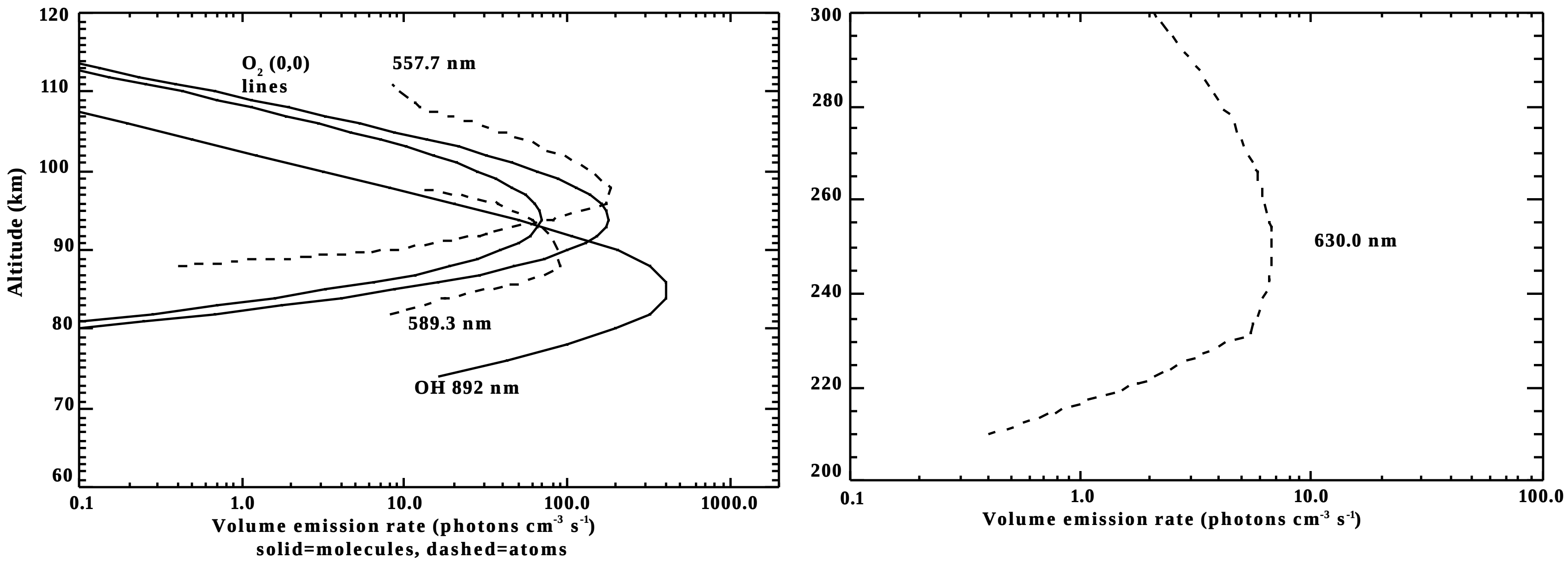
TIDI Measurement Method

- Use high-resolution spectrometry to look at atomic and molecular emission lines in the visible and near IR. Doppler shifts, widths, and intensities are measured.
- Perform limb measurements using movable telescopes to probe the atmosphere in altitude.
- Use multiple telescopes and the spacecraft movement to look at the same volume of space in order to derive wind vectors.

Typical Dayglow Volume Emission Rates



Typical Nightglow Volume Emission Rates



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Dayside Science

Measurement	Feature	Altitude Range	Statistical Uncertainty
Vector Wind	O_2 Atmosphere (0-1) P11	60 - 85 km	5 m/sec @ 85km
	O_2 Atmosphere (0-0) P9	85 - 120 km	1 m/sec @ 85km 4 m/sec @ 120km
	OI (557.7 nm)	90 - 250 km	4 m/sec @ 120km 6 m/sec @ 150 km
	OI (630.0 nm)	200 - 300 km	7 m/sec @ 150 km 13 m/sec @ 300 km
	OII (732.0 nm)	170 - 300 km	20 m/sec @ 250 km
Neutral Temperature	O_2 Atmosphere (0-1) P11 and O_2 Atmosphere (0-1) P7	60 - 85 km	15 K @ 60 km 12 K @ 85 km
	O_2 Atmosphere (0-0) P9 and O_2 Atmosphere (0-0) P15	85 - 120 km	2 K @ 85 km 7 K @ 120 km
	OI (557.7 nm)	100 - 150 km	5 K @ 120 km 30 K @ 150 km
	OI (630.0 nm)	200 - 300 km	40 K @ 150 km
O_2 Density	O_2 Atmosphere (0-0) Volume Emission Rate	~100 km	5 - 10%
	O_2 Atmosphere (0-1) and O_2 Atmosphere (0-0)	60 - 90 km	5% using self-absoprtion ratio
O Density	OII (732.0 nm) and OI (844.6 nm)	150 - 300 km	
O_3 and $O(^1D)$ density	O_2 Atmosphere Volume Emission Rate	70 - 95 km	

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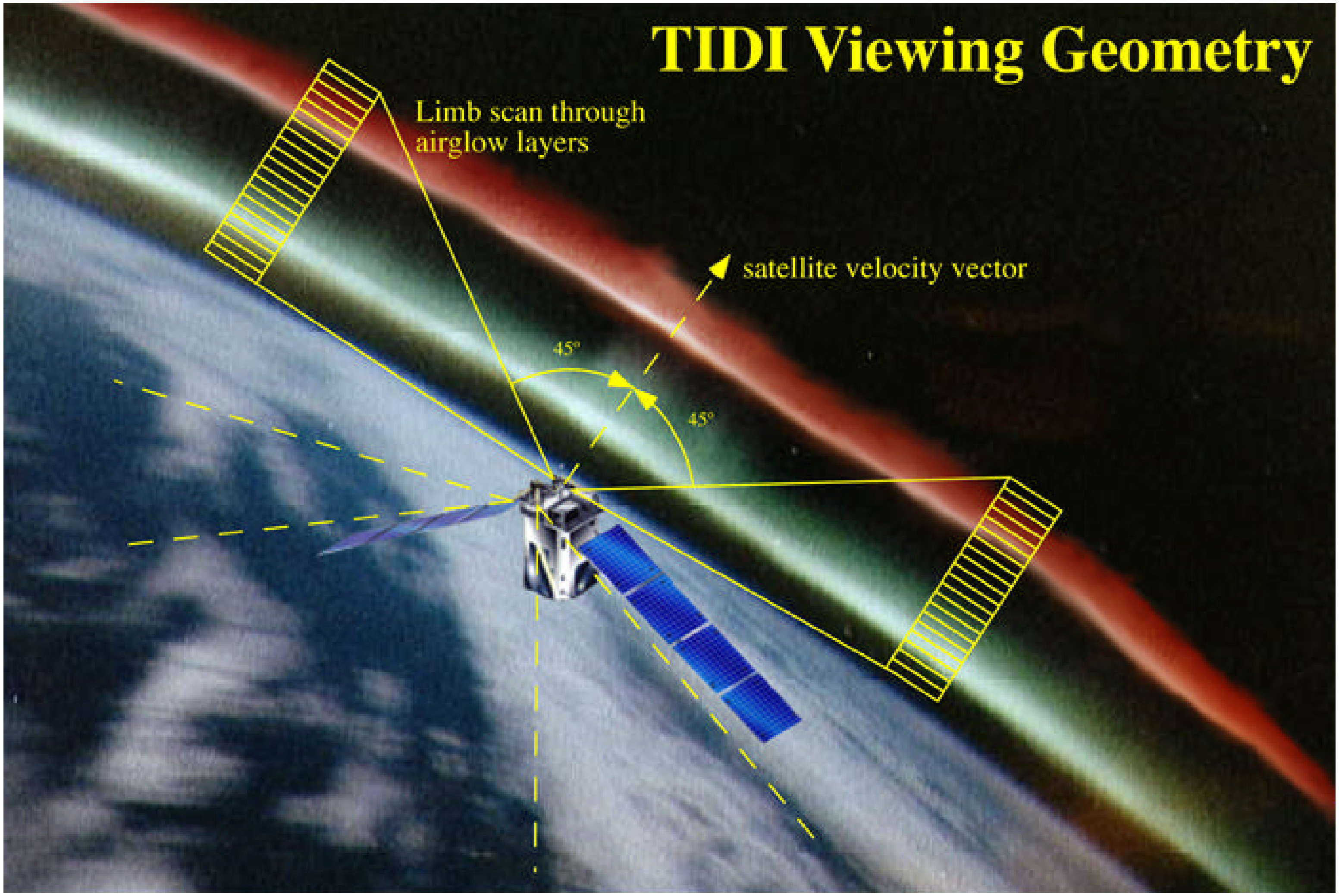
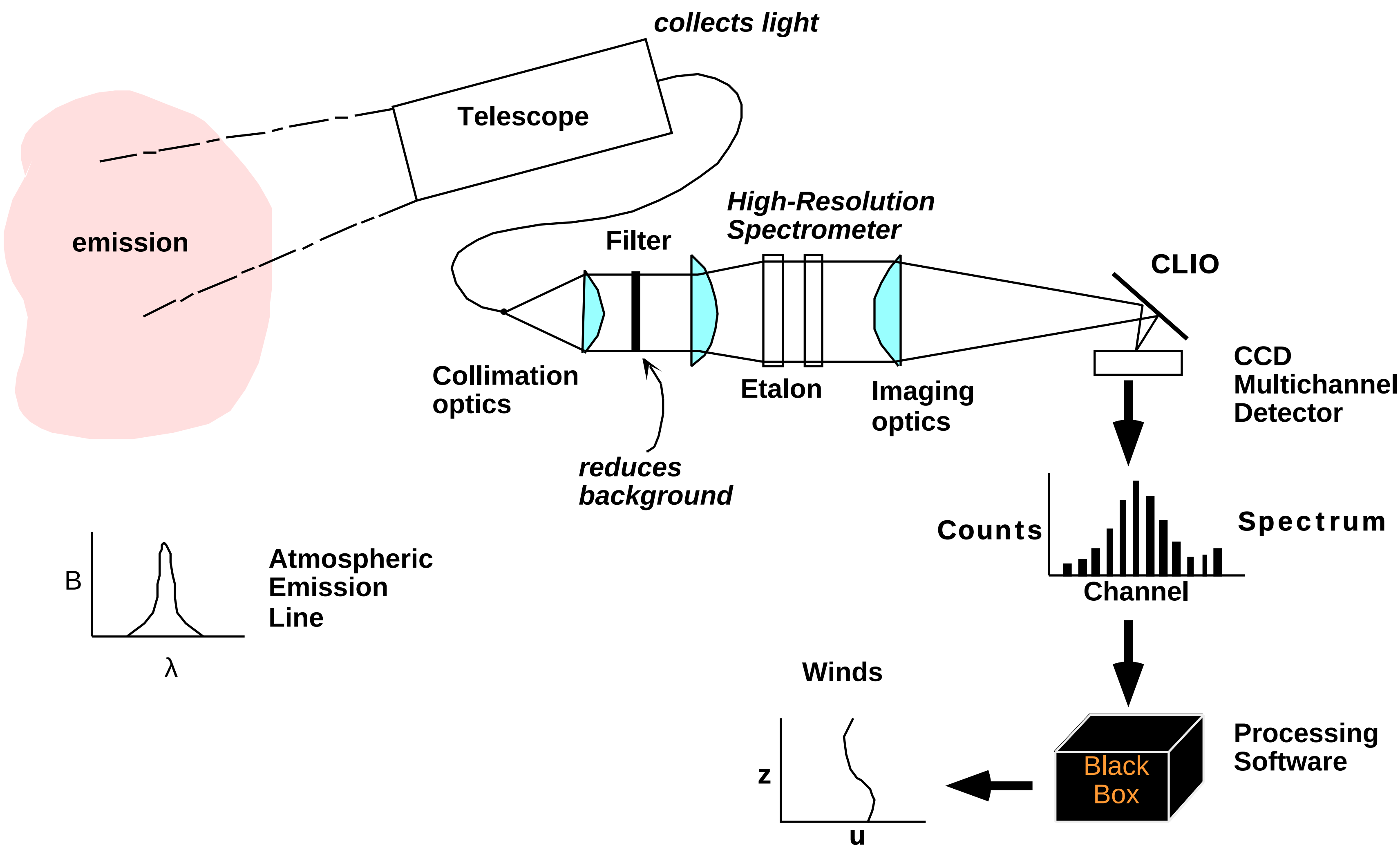
Nightside Science

Measurement	Feature	Altitude Range	Statistical Uncertainty
Vector Wind	OH Meinel (7-3)	80 - 90 km	5 m/sec @85 km
	Na D	85 - 95 km	11 m/sec @90 km
	O_2 Atmosphere (0-0) P9	85 -1 05 km	5 m/sec @95 km
	OI (557.7 nm)	95 -1 05 km	6.5 m/sec @95km
	OI (630.0 nm)	200 - 300 km	20 m/sec @230 km
Neutral Temperature	OH Meinel (7-3)	80 - 90 km	8 K @85 km
	Na D	85 - 95 km	12 K @90 km
	O_2 Atmosphere (0-0) P9 and O_2 Atmosphere (0-0) P15	85 -1 05 km	11 K @95 km
	OI (557.7 nm)	95 -1 05 km	9 K @95 km
	OI (630.0 nm)	200 - 300 km	
O Density	OH Meinel	80 - 95 km	
	O_2 Atmosphere	85 -1 00 km	
	OI (557.7 nm)	90 -1 05 km	

TIDI Viewing Geometry



Profiler Sampling



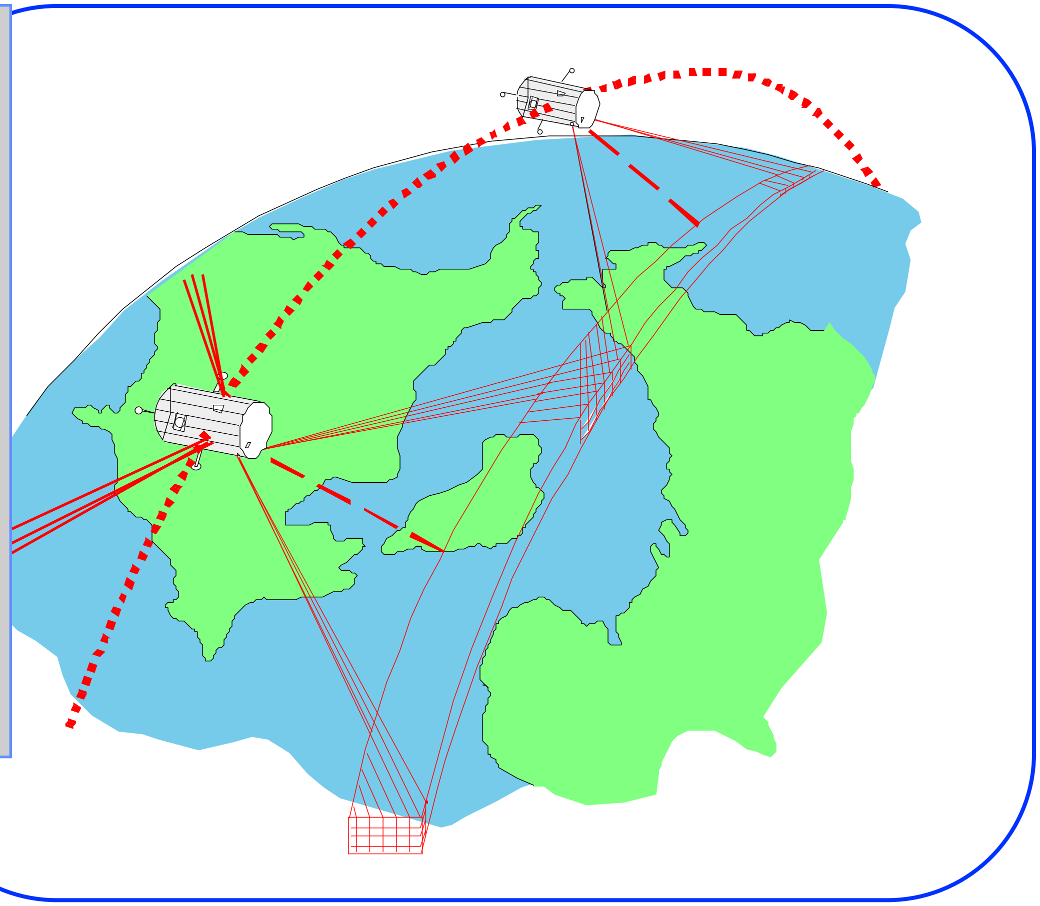
TIDI Wind Measurements

- **TIDI measures wind by measuring the Doppler shift of atmospheric emission features.**
  - **Doppler shifts are small; 10 m/s ~5 x 10^{-4} cm^{-1} ~ 2 x 10^{-5} nm, ~17 MHz**
  - **Accurate knowledge of pointing is required to compensate for satellite motion, ~7500 m/s**
  - **Two views of nearly the same volume from approximately orthogonal directions are required in order to form a wind vector. The two views are provided by two telescopes, one looking forward and one looking backward. The backward looking telescope sees the same volume as the forward looking one about 8 minutes later.**
  - **The telescopes' zenith angles are adjusted to look at different altitudes.**
  - **Different emitters are used at different altitudes to cover the regions of interest.**

The TIMED Doppler Interferometer

TIDI

- **TIDI performs a limb scan of the horizon to determine the vector-neutral wind, temperature, and selected constituent abundances**
- **Vector winds are built up by combining line-of-sight Doppler measurements in four orthogonal directions with the assumption of time invariance over a period of about 8 minutes**



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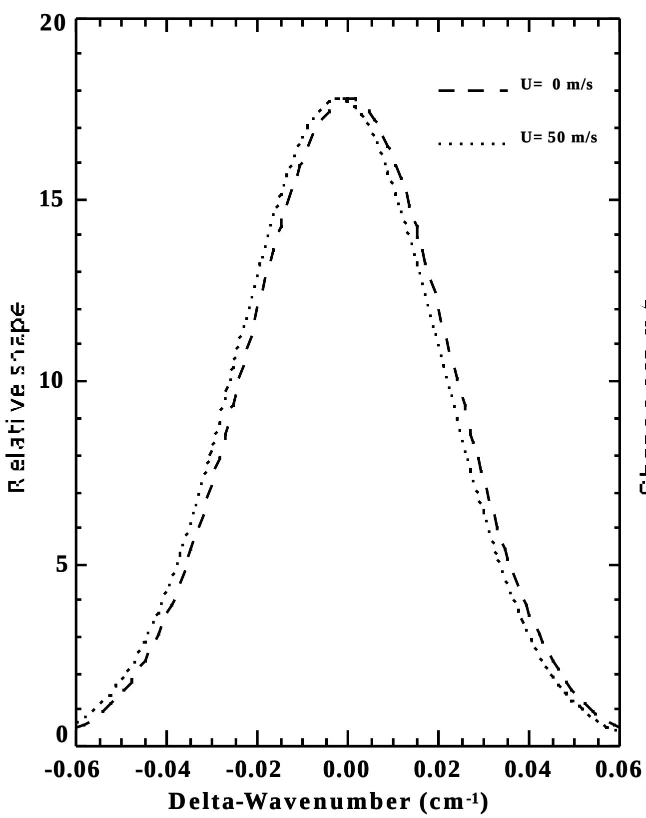
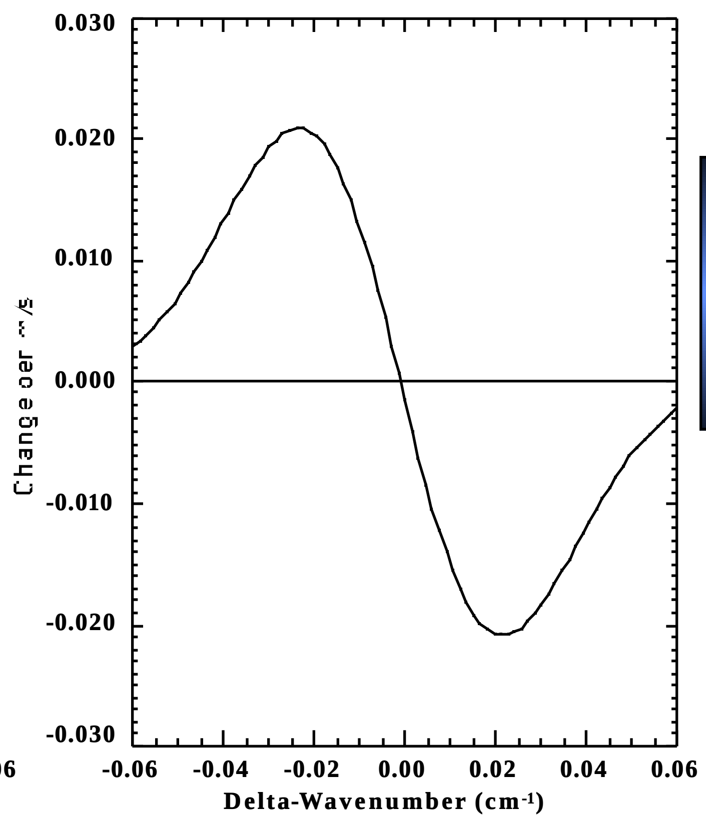
Effect of Wind on Emission Line



Spectra



Difference

$u = 1$ m/s
$\Delta\nu$ 5×10^{-5} cm^{-1}
2.2×10^{-6} nm
$= 1.5$ MHz

$$\Delta\nu = (\nu_0 u)/c$$

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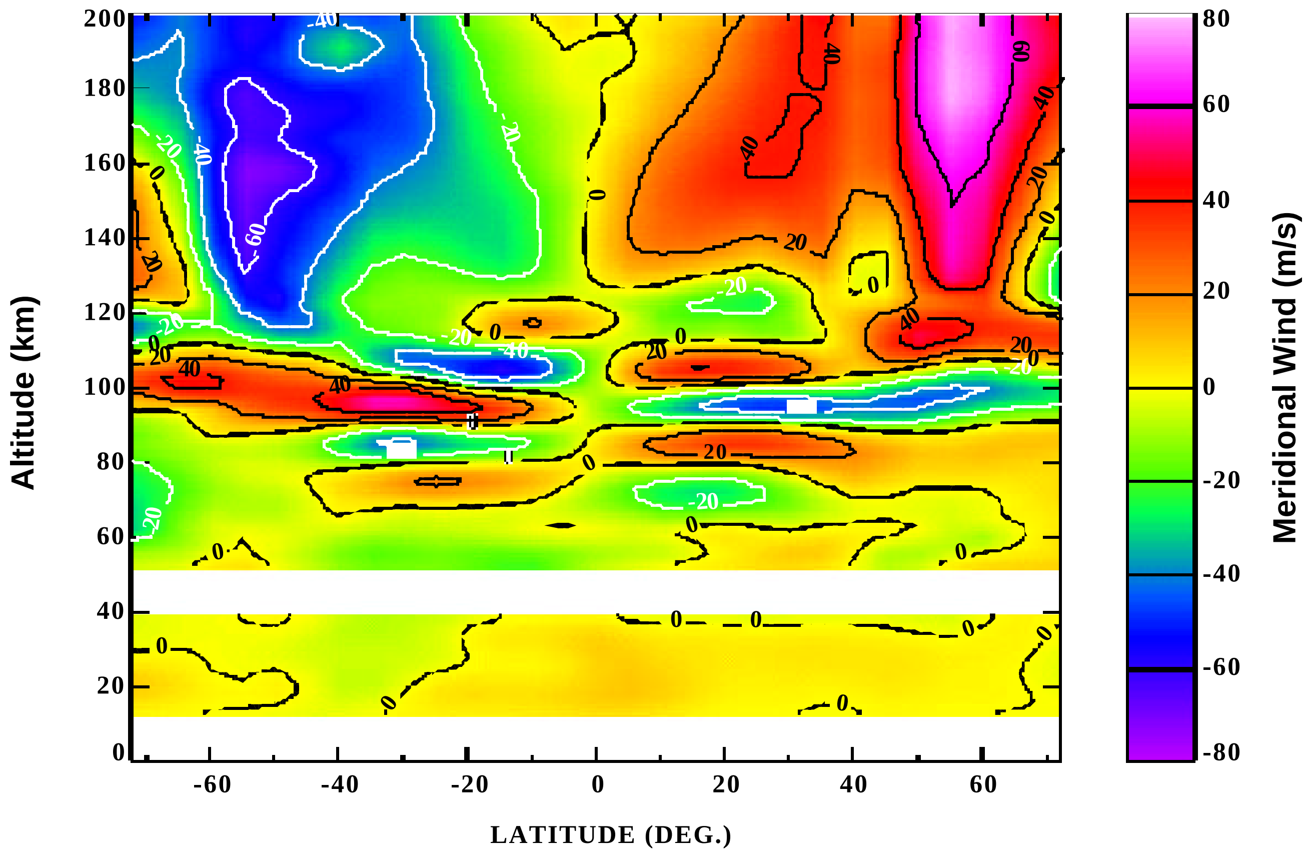
Example of Wind Measurement from UARS

Combined HRDI and WINDII meridional wind measurements. Monthly means from March 1993 and March 1994



Semidiurnal and diurnal tides are evident in these data HRDI below 110 km; WINDII above 110 km.

TIDI Temperature Measurements

- **TIDI can measure temperature in two ways:**
  - **<u>Doppler width</u>. The spectral width of emission line is proportional to the square root of the temperature.**
  - **<u>Rotational temperature</u>. The ratio of the brightness of two lines in a rotational band of a molecular emission is uniquely related to the temperature.**

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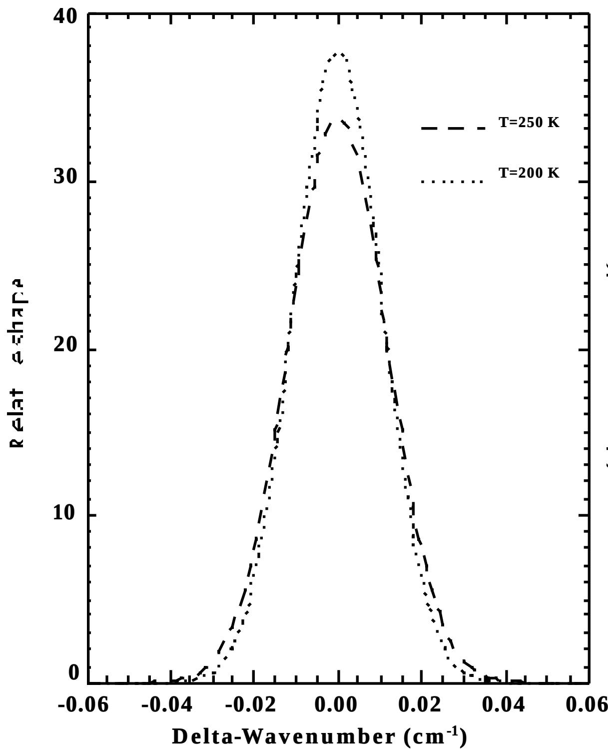
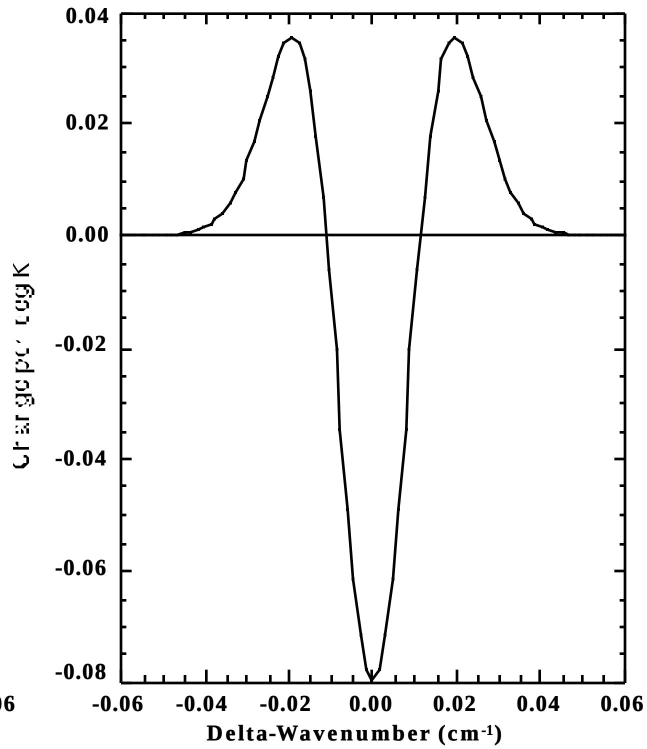
Effect of Temperature on Emission Line



Spectra



Difference

$$\Delta\nu = 4.30x10^{-7}\,\nu_0\sqrt{T/M}$$

			Width			
Emitter	M	T(K)	(cm^{-1})	(nm)	(MHz)	(m/s)
$O_2(^1\Sigma)$	32	200	0.014	8.2×10^{-4}	420	320
$O(^1S)$	16	200	0.027	8.5×10^{-4}	820	450
$O(^1D)$	16	1200	0.059	2.3×10^{-3}	1765	1100

Rotational Temperature Method

O_2 (0,0) Line Strength Change with Temperature

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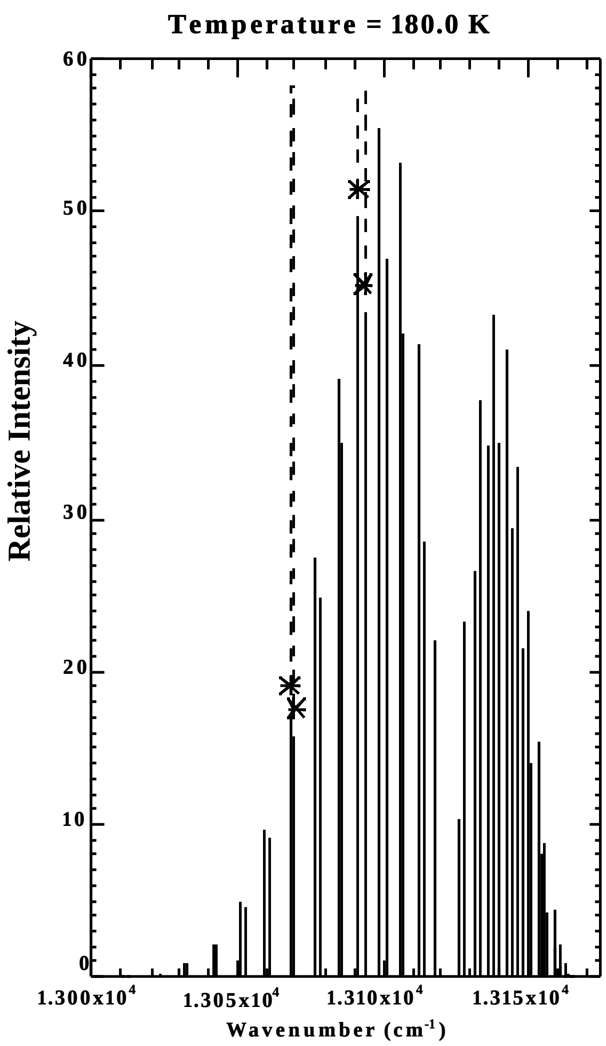

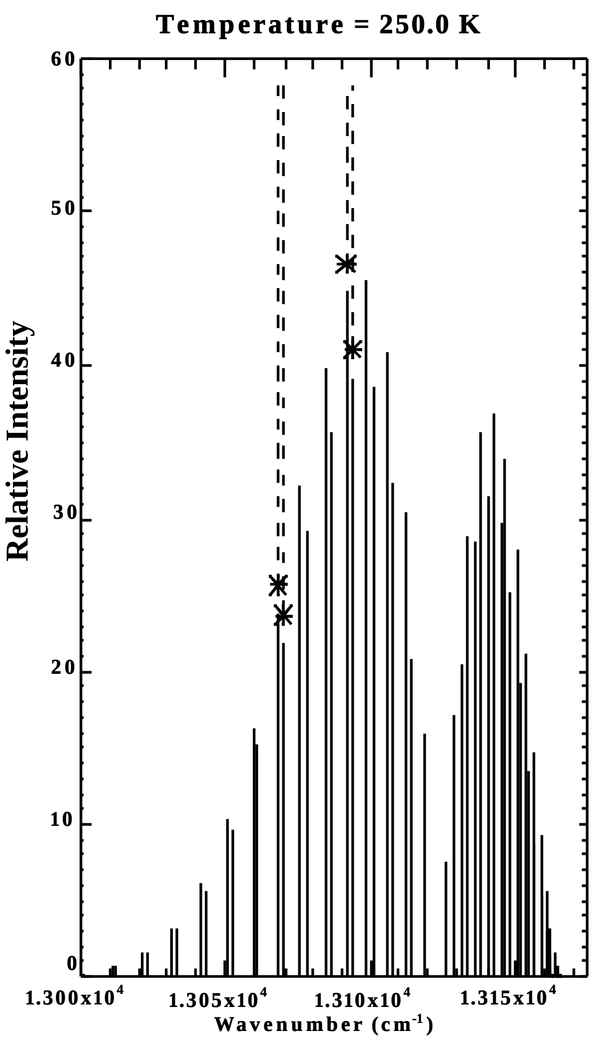

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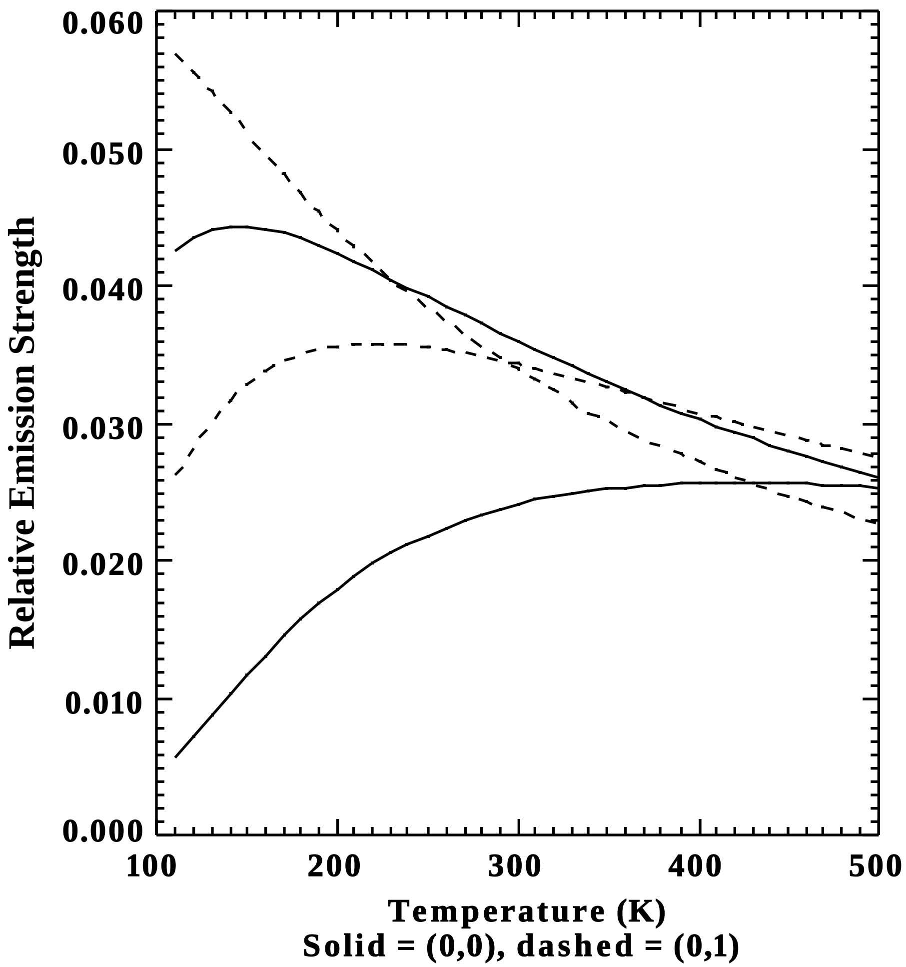
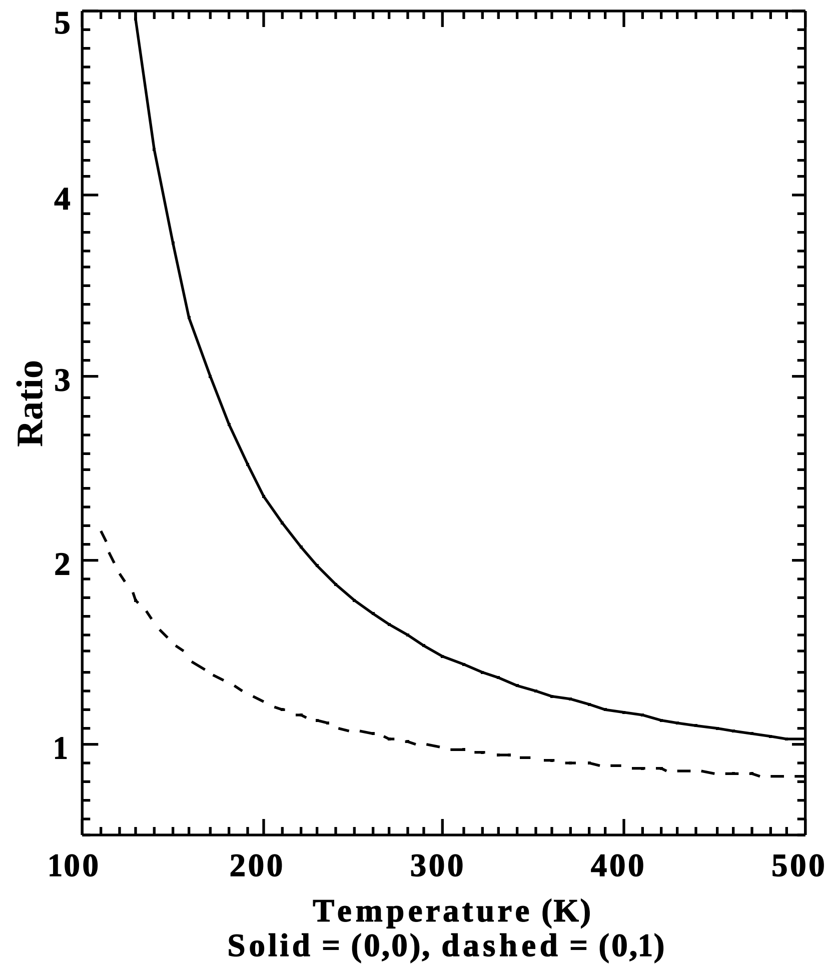
Rotational Temperature Method

Line Strengths and Ratio as Function of Temperature



O_2 Atmospheric Line Strength



Ratio of Line Strengths

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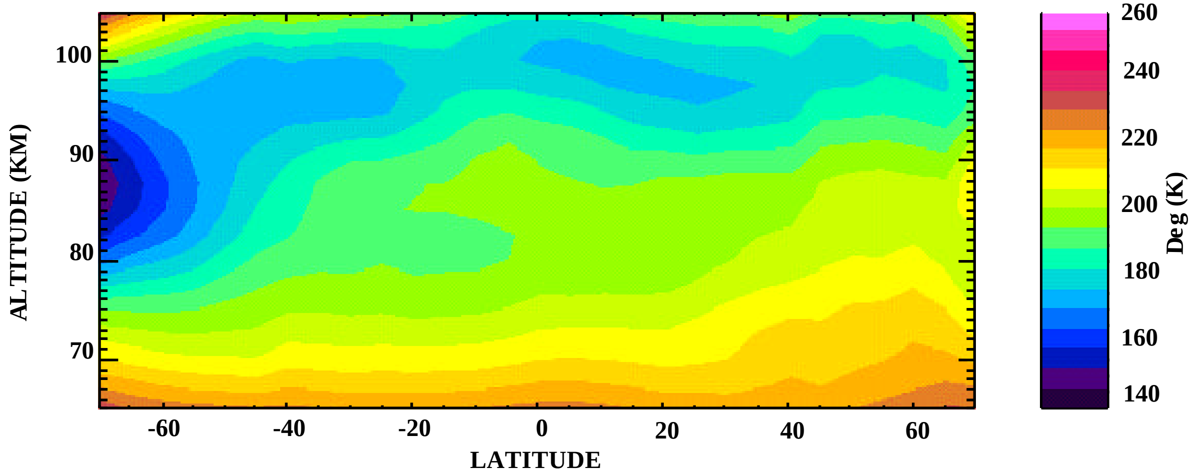
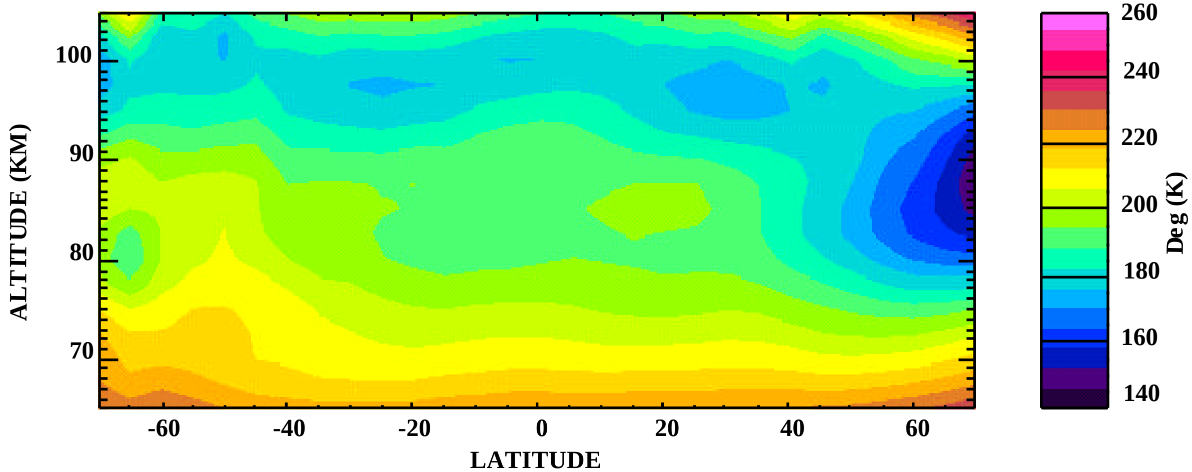
Example of Rotational Temperature Measurement from HRDI

HRDI Mean Temperatures for February



HRDI Mean Temperatures for August



Minor Species Density

- The volume emission rate is related to concentration of various components.
- A knowledge of the chemistry allows minor species density to be retrieved.
- The absolute sensitivity of the instrument must be known very well.
- Can recover O, $O(^1D)$, and O_3.

Example of Minor Specie Retrieval - HRDI Mesosphere Ozone