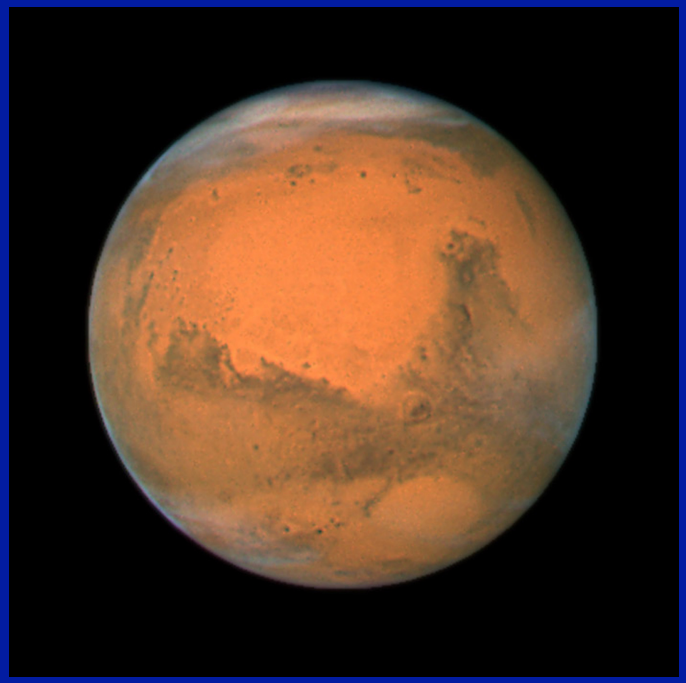
Future study of Mars' Atmosphere using the NASA-IRTF





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$O_2(a^1\Delta_g)$ Emission

$O_3 + h\nu \rightarrow O\,(^1D) + O_2\,(a^1\Delta_g)$ (90%)
$O_3 + h\nu \rightarrow O\,(^3P) + O_2\,(X^3\Sigma_g)$ (10%)

$O_2\,(a^1\Delta_g) \rightarrow O_2\,(X^3\Sigma_g) + h\nu$

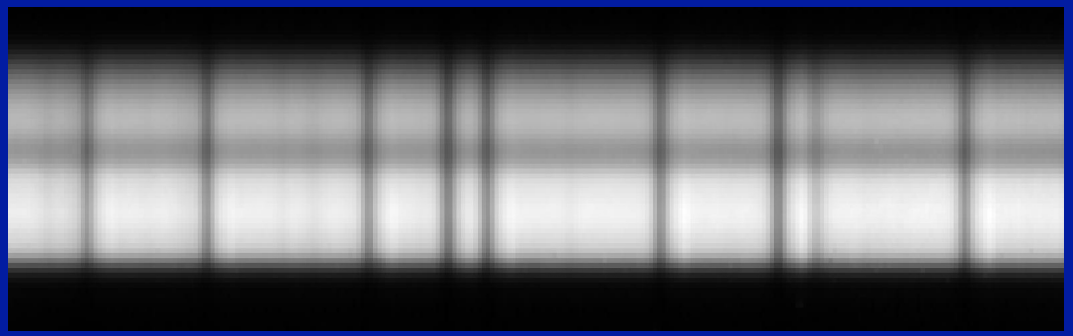
$O_2\,(a^1\Delta_g) + CO_2 \rightarrow O_2\,(X^3\Sigma_g) + CO_2$

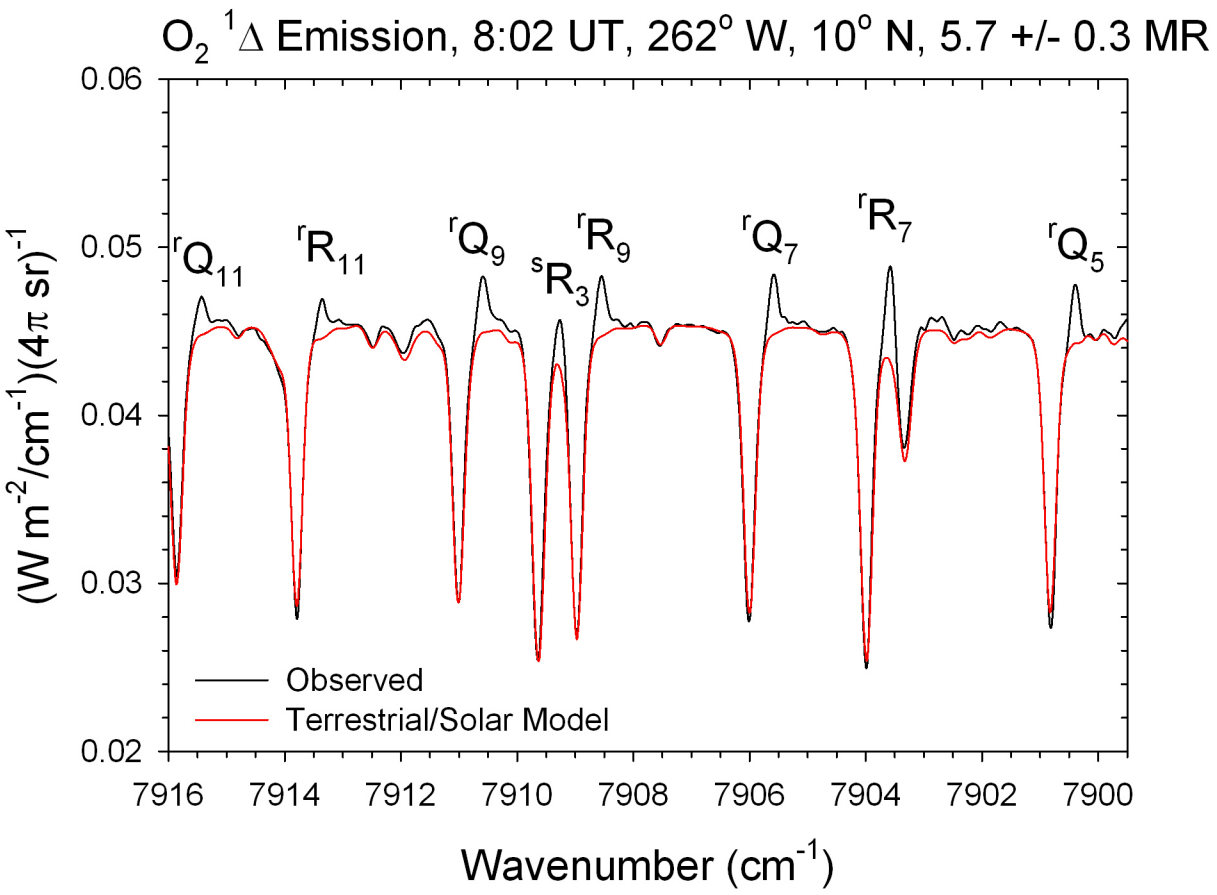
$\alpha_1[O_3] = \tau^{-1}[O_2\,(a^1\Delta_g)] + k_4[CO_2][O_2\,(a^1\Delta_g)]$

Altitudes > 20 km

$$\alpha_1[O_3] = [O_2\,(a^1\Delta_g)]/\tau$$

(Novak et al., *Icarus*, (2002), **158**,14-23)

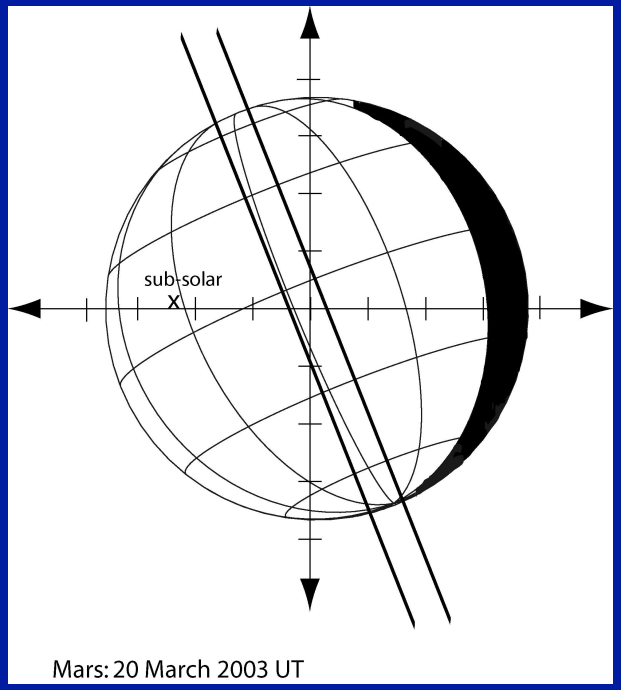


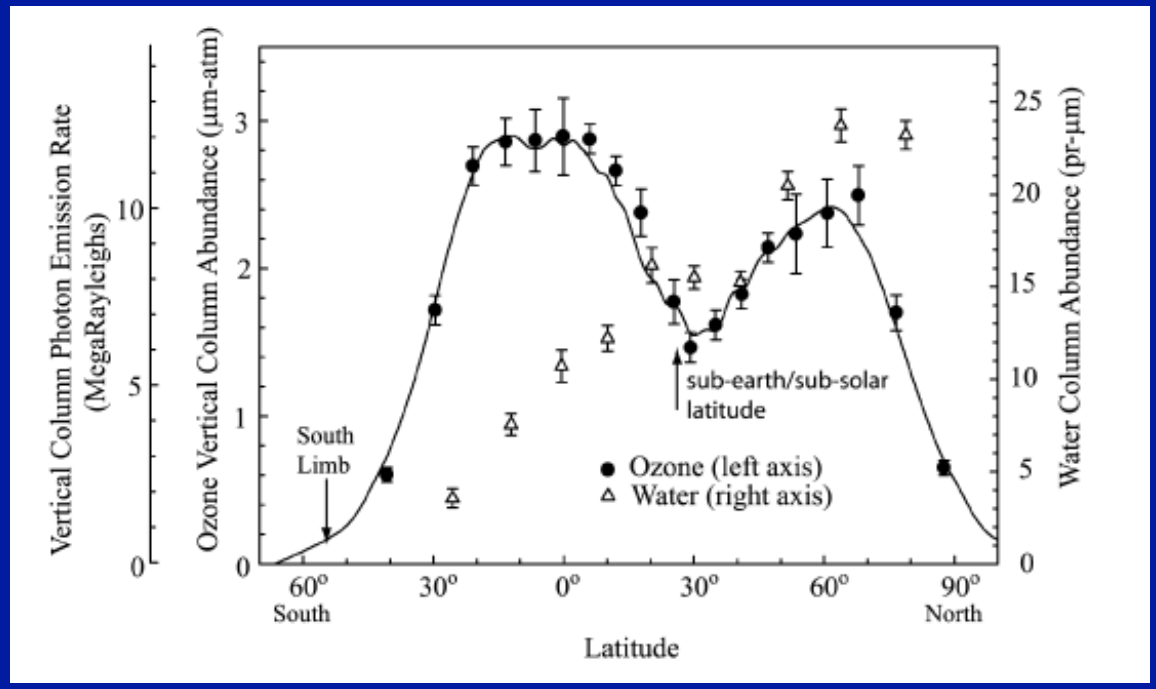

O2 1Δ Emission, 8:02 UT, 262° W, 10° N, 5.7 +/- 0.3 MR
(W m-2/cm-1)(4π sr)-1
0.06
0.05
0.04
0.03
0.02
rQ11
rR11
rQ9
sR3
rR9
rQ7
rR7
rQ5
Observed
Terrestrial/Solar Model
7916
7914
7912
7910
7908
7906
7904
7902
7900
Wavenumber (cm-1)

A. 1-D and 2-D Mapping of Molecules in Mars' Atmosphere

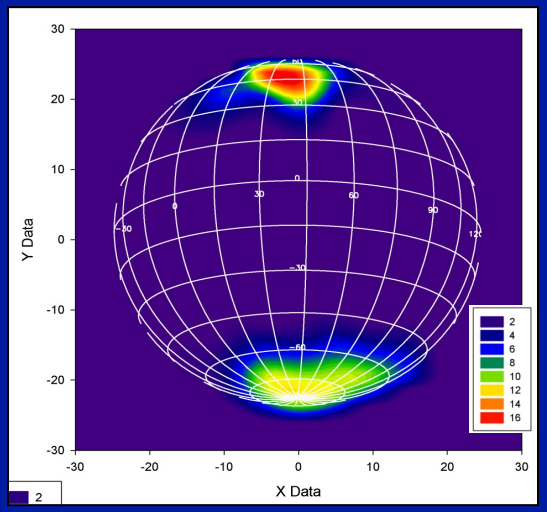
1-D Maps: Slit Positioned Across Mars

Ozone (O_2 ($^1\Delta$)), Water (based on HDO)

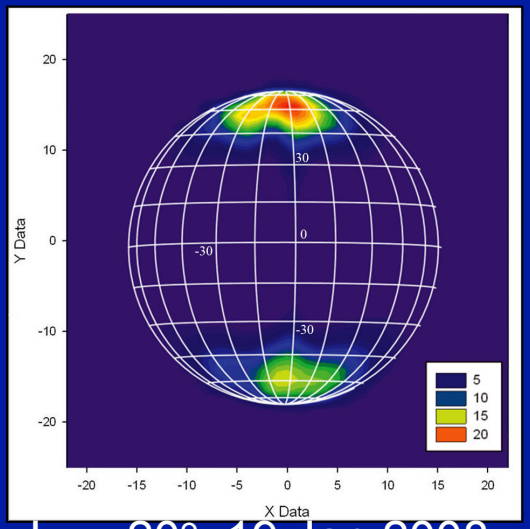




2-D Mapping, Step Slit Across Planet

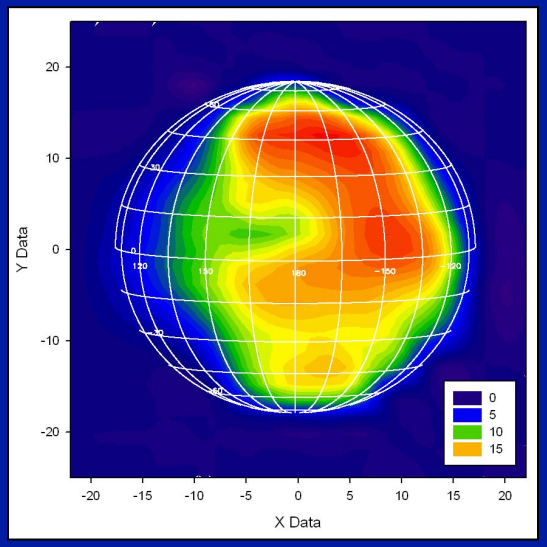


L_s = 357°, 06 Jan 2006
Before Vernal Equinox

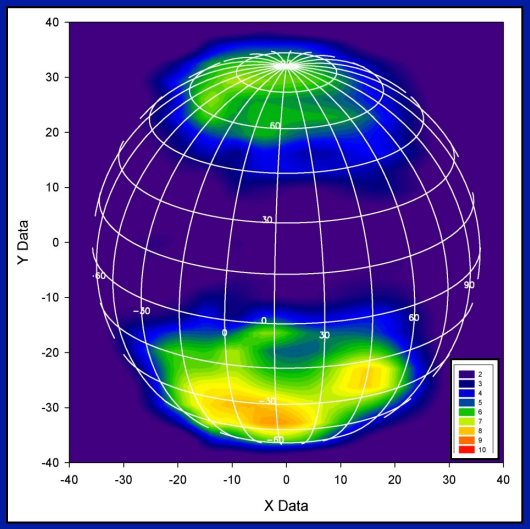


L_s = 20°, 19 Jan 2008
Early Northern Spring

Values in MegaRayleighs (10^{12} photon/(cm^2 s)



L_s = 50°, 25 Mar 2008
Mid-Northern Spring



L_s = 85°, 01 Mar 1997
Late Northern Spring

Sanstead, P, Bebawee, R., Novak, R., Mumma, M., Villanueva, G., Hewagama, T., (2009), "2-D Maps Of The $O_2(a^1\Delta_g)$ Emission During The Mars Aphelion Season," American Astronomical Society, DPS meeting #41, #49.10

Mapping by CSHELL and iSHELL

CSHELL: -Column Densities based on one order.
-Position of slit (often without guider) was checked before and after spectral image.
-Full Maps of one molecule took ~ three hours of clock time.

iSHELL: -Several orders appear simultaneously, more absorption or emission lines per order yield more precise data.
-Guider works simultaneously with taking of spectral image; works both in dark and daylight
-Recently (30 Jan 2018) 1-D and 2-D maps for $O_2(^1\Delta)$, H_2O, and HDO performed within an 8 hour session.

B. Search for trace gases in Mars' Atmosphere, iSHELL settings

iSHELL Setting	Trace gas
L1 (2.74-3.02 μm):	Nitrous oxide (2.88 μm)
	Hydroperoxy (2.93 μm)
L2 (2.96-3.24 μm):	Acetylene (3.035 μm)
	Hydrogen cyanide (3.042 μm)
L3 (3.20-3.48 μm):	Methane (3.33 μm) (already identified)
	Ethane (3.349 μm)
	Ethylene (3.347 μm)
	Methyl chloride (3.37 μm)
Lp1 (3.28-3.66 μm)	Formaldehyde (3.57 μm)
	Carbonyl Sulfide (3.42 μm)
	Methyl Chloride (3.37 μm)

Lp2 (3.57-3.95 μm) Hydrogen Sulfide (3.71 μm)

Lp3 (3.83-4.18 μm) Sulfur Dioxide (4.01 μm)

L3
Setting

30 Jan
2018
18:18 UT

Mars



Summary:

1. Mapping, 1-D (North/South, East/West)
   2-D (Step slit across planet)
   Guider enables more efficient 2-D maps

2. Search for trace gases:
   Gases with astrobiological significance
   Methane, ethane, propane, etc.
   Other gases may be identified
   Isotopologues (such as HDO/H_2O)