

Methane and Water on Mars

Maps of Active Regions and their Temporal Variability

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Washington DC, USA



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New Rochelle, NY, USA

The questions

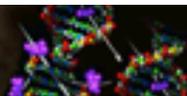
- **Where is methane and water being released?**
- **Is methane being co-released with water?**
- **Are these releases seasonal or sporadic?**

This talk

- **We present data taken from 1999-2006 taken with three telescopes, consisting of more than 100,000 raw spectra.**

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 - b) Maps of the D/H ratio of water***
 - c) Current observational campaign***
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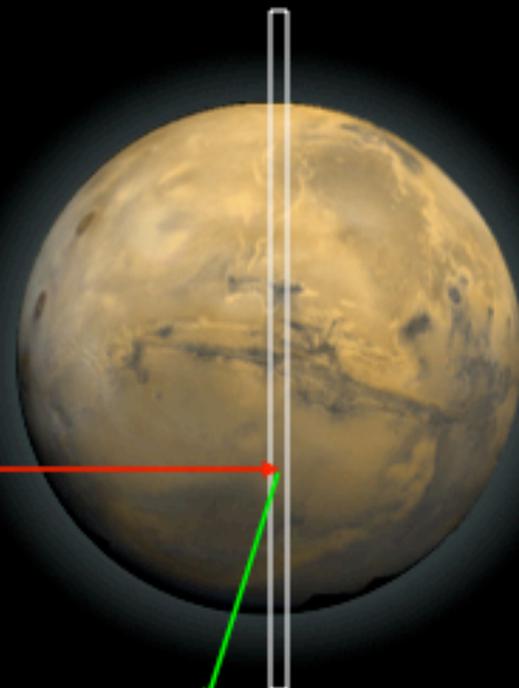
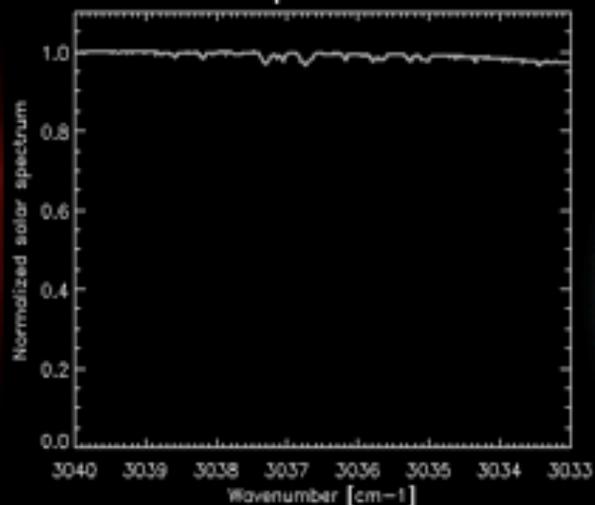
1. Mapping methodology

Methane and Water on Mars

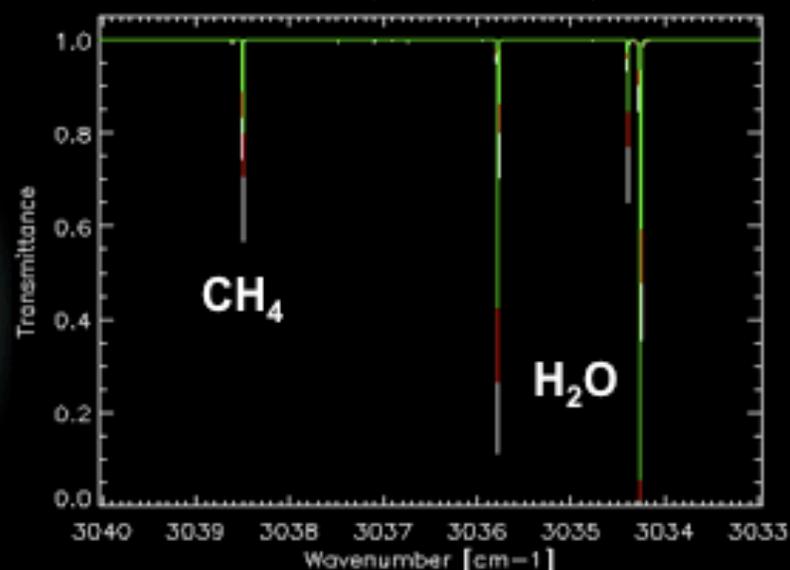
Methane Workshop, Frascati Italy, Villanueva et al. 2009



Solar Spectrum



Sun-Mars, Mars-Earth, Total



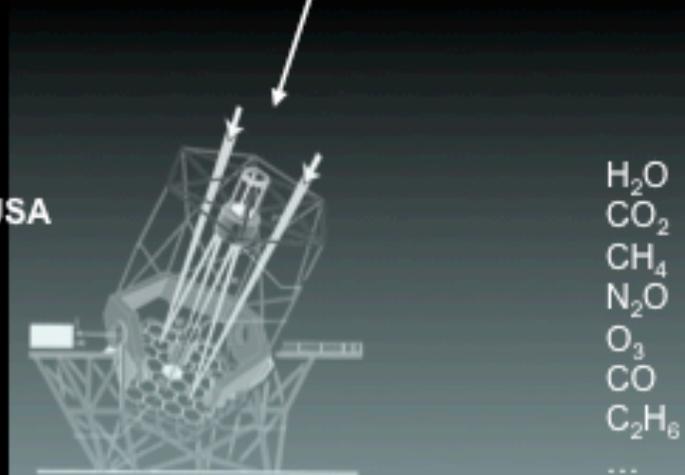
Keck II, Hawaii, USA
10m Telescope



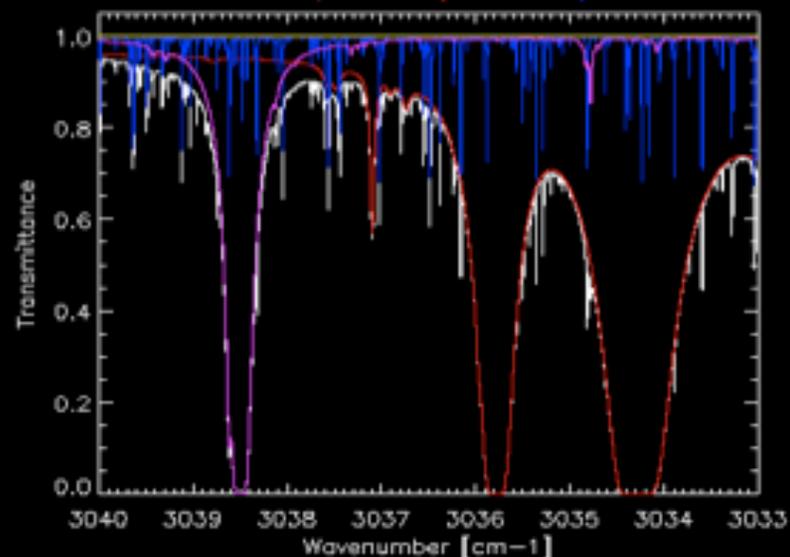
NASA-IRTF, Hawaii, USA
3m Telescope



GEMINI-South, Chile
8m Telescope

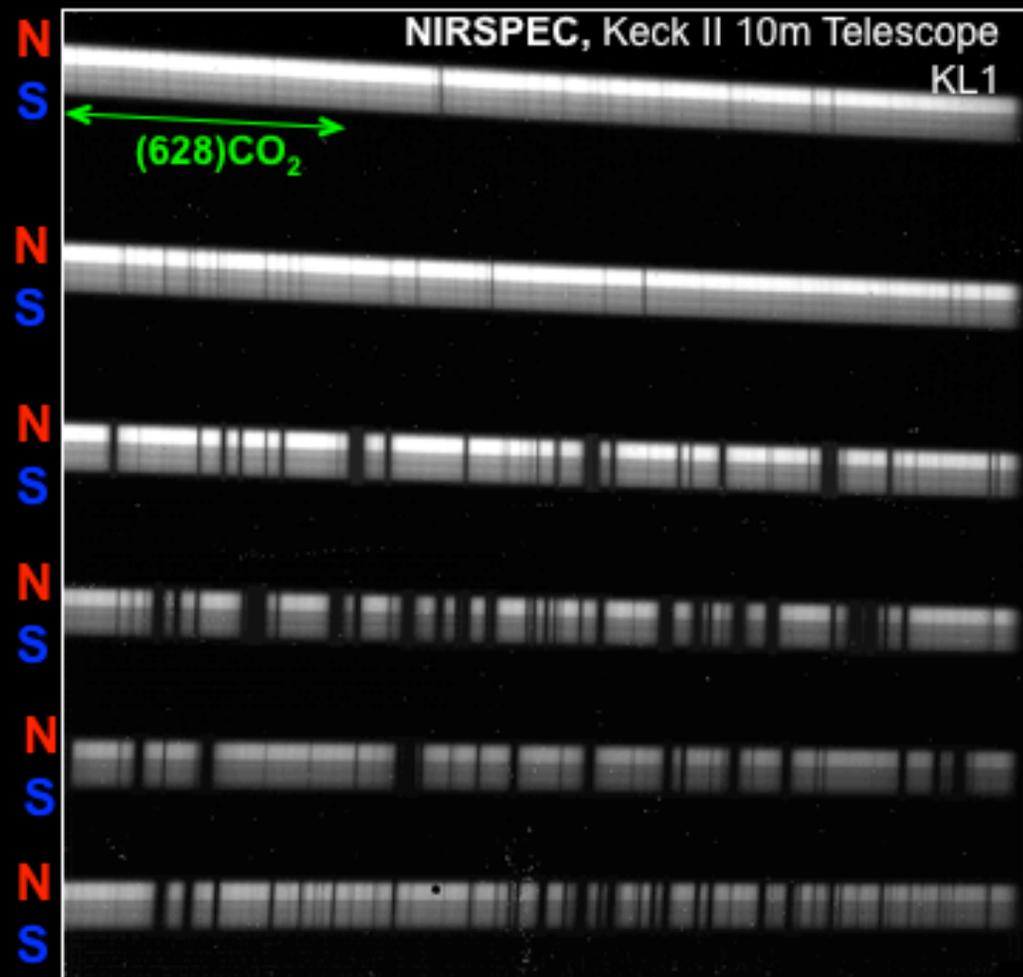
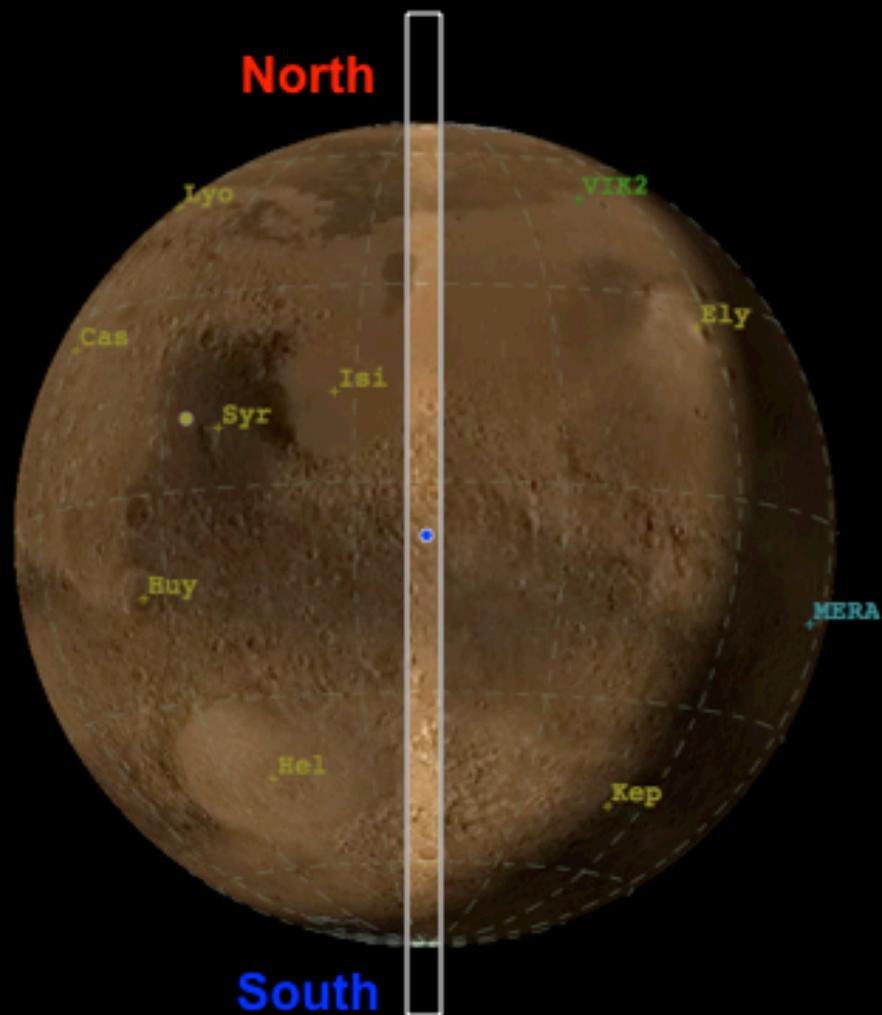


Methane, Water, Ozone, Total



Mapping technique #1 – Central Meridian

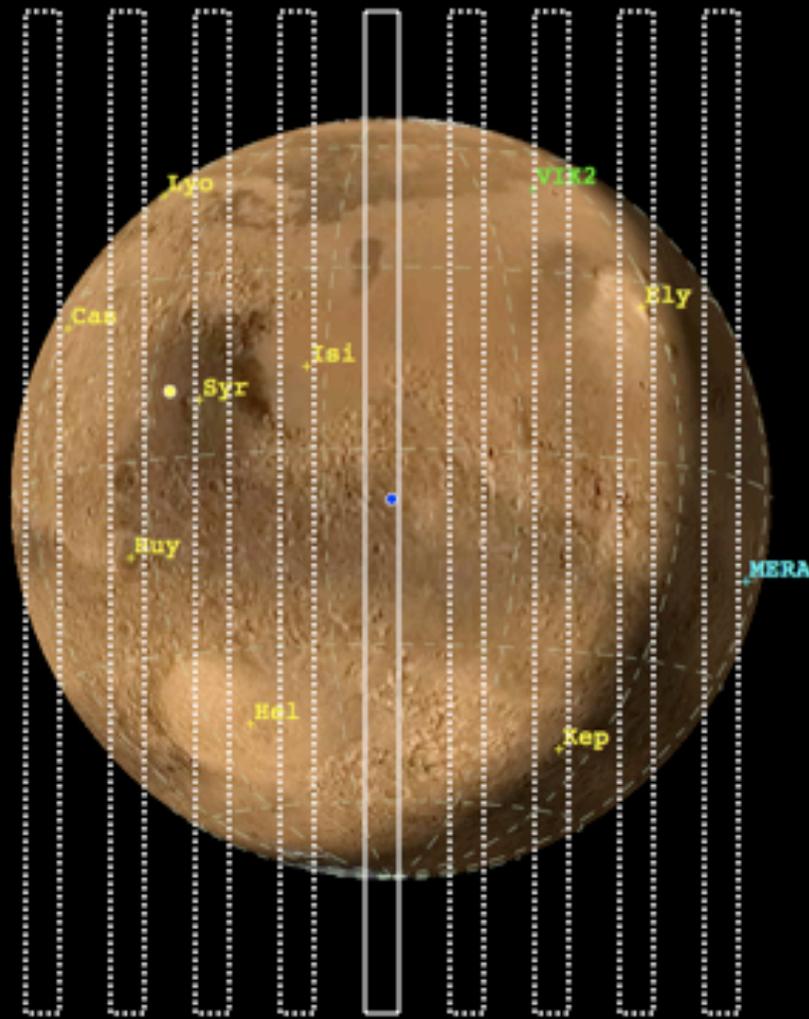
- Maximum spatial resolution
- Constant local time



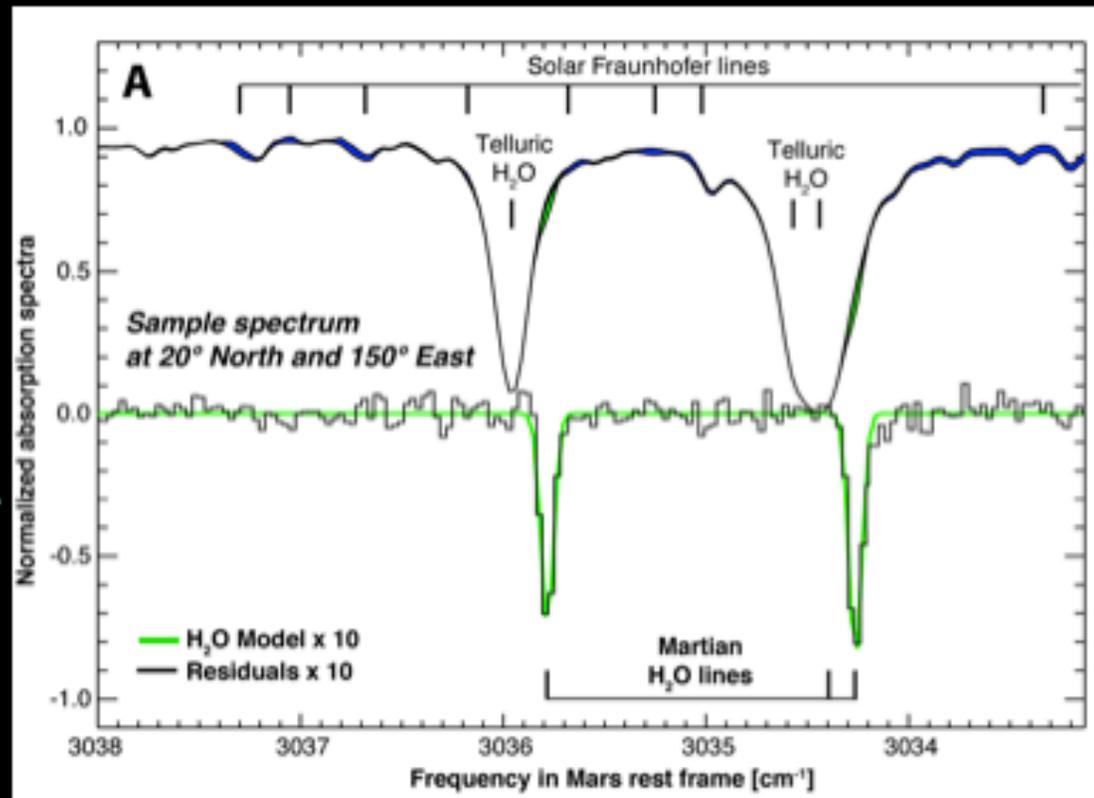
Frequencies between 2700-3400 cm^{-1} (3.7-2.9 μm)

Mapping technique #2 – Disk coverage

- Full disk coverage
- Sample of different local times



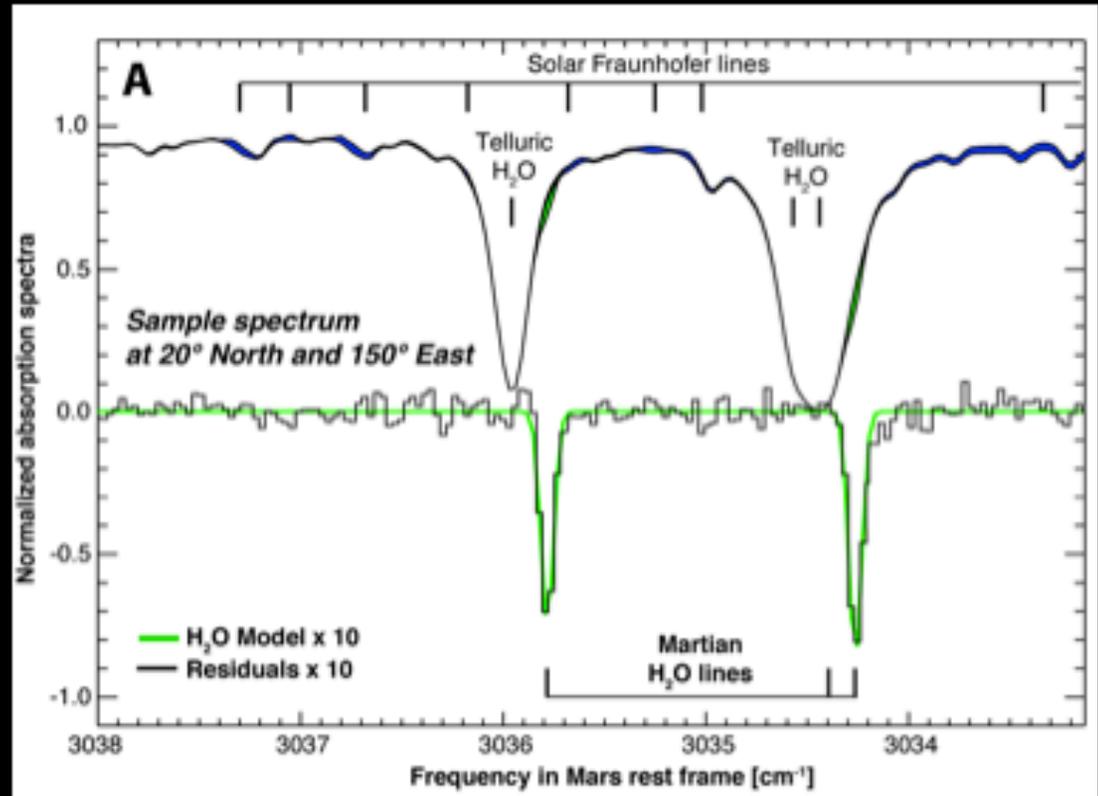
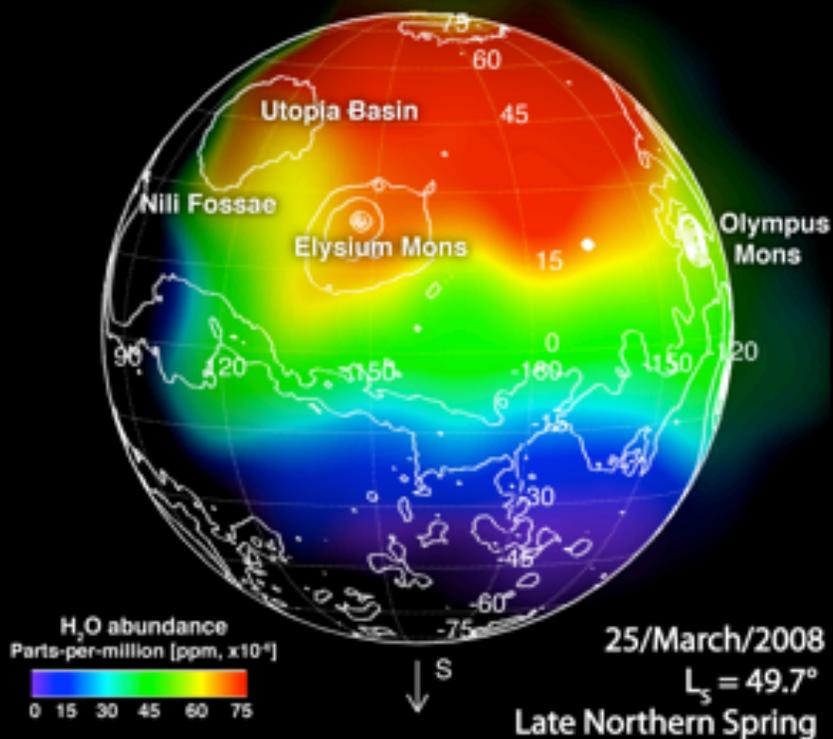
9 slit positions
across the planet

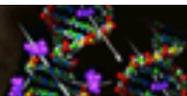


Mapping technique #2 – Disk coverage

- Full disk coverage
- Sample of different local times

B Water Vapor (H₂O) abundance





2. Spectral database



Keck II 10m Telescope

NIRSPEC, cross-dispersed spectrometer (R=40,000)



NASA-IRTF 3m Telescope

CSHELL, cryogenic echelle spectrometer (R=40,000)

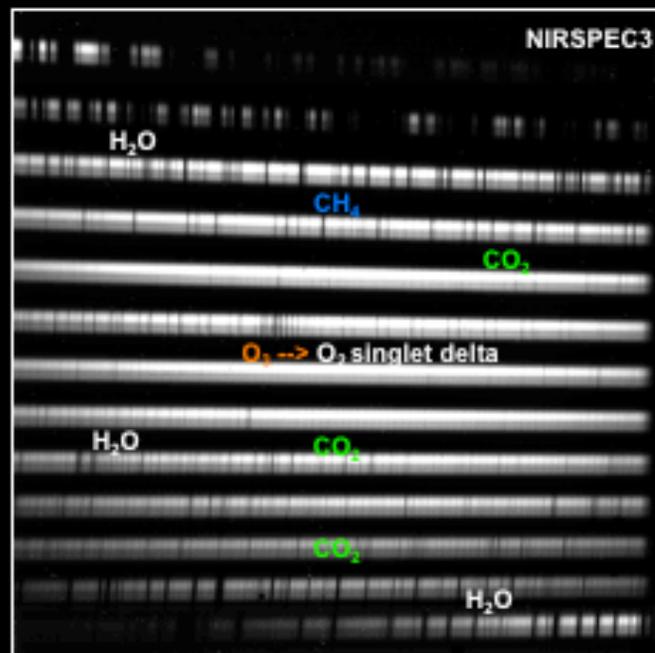


GEMINI-South, 8m Telescope

PHOENIX, high-resolution infrared spectrograph (R=65,000)

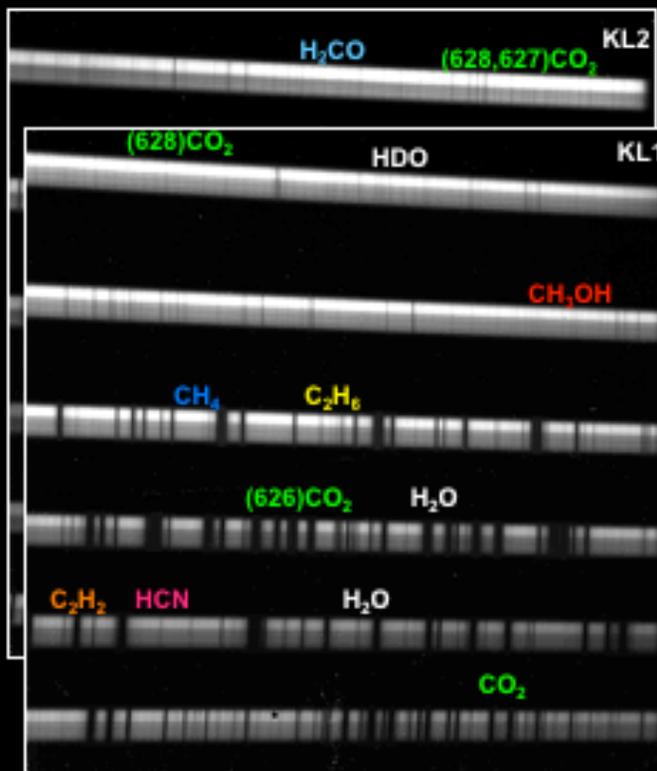
NIRSPEC3 setting

Range: 7200-8800 cm^{-1} (1.1-1.4 μm)



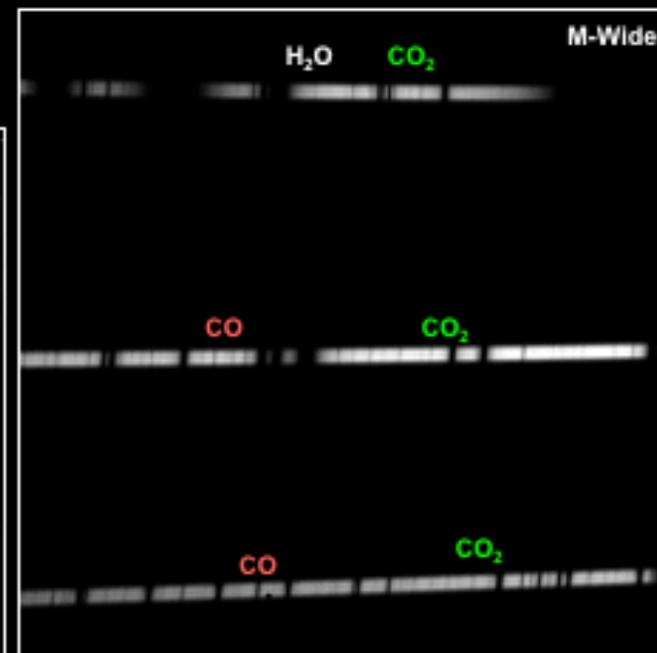
KL1 & KL2 settings

Range: 2700-3400 cm^{-1} (2.9-3.7 μm)



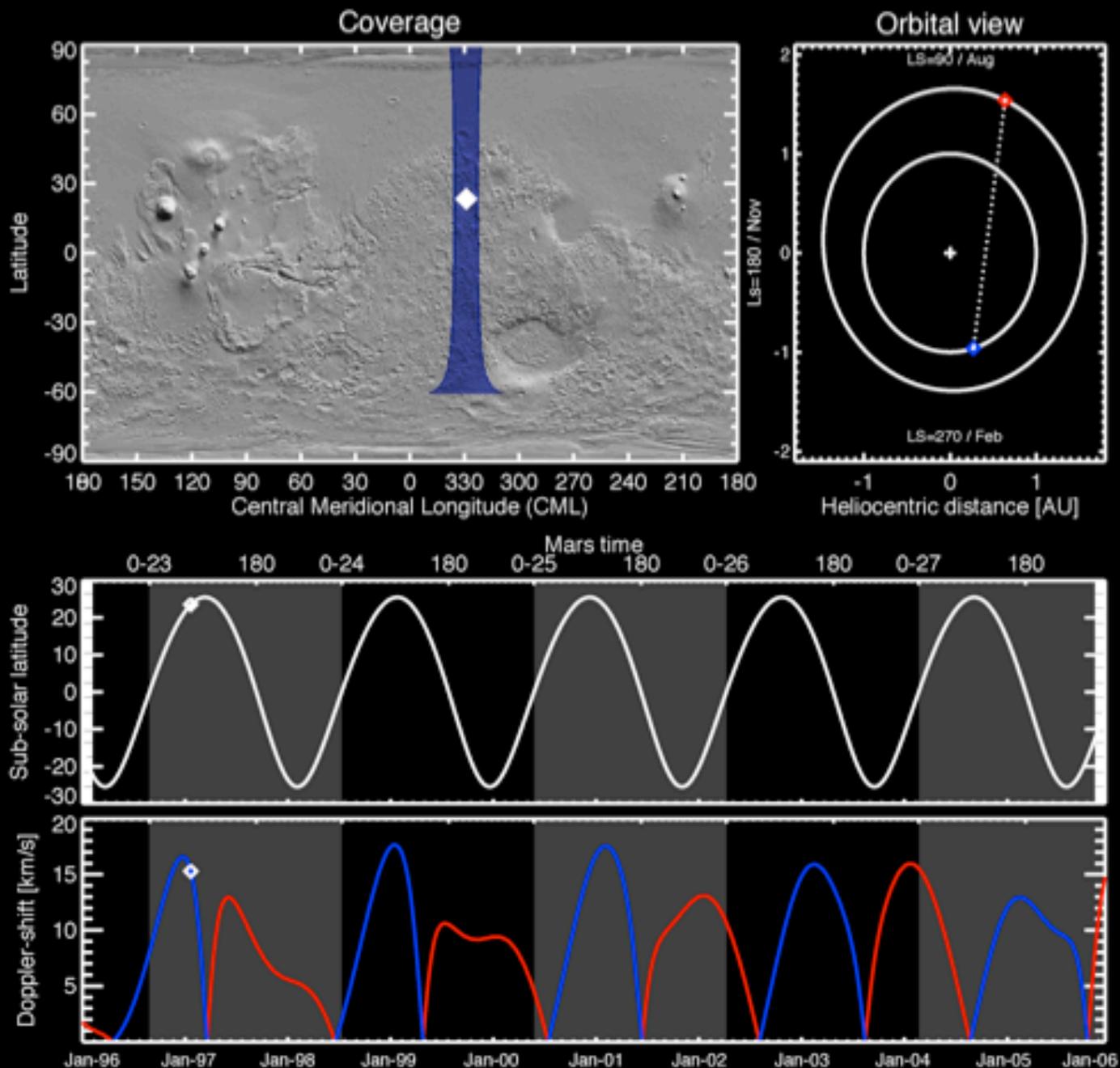
M-Wide setting

Range: 1800-2200 cm^{-1} (4.6-5.4 μm)



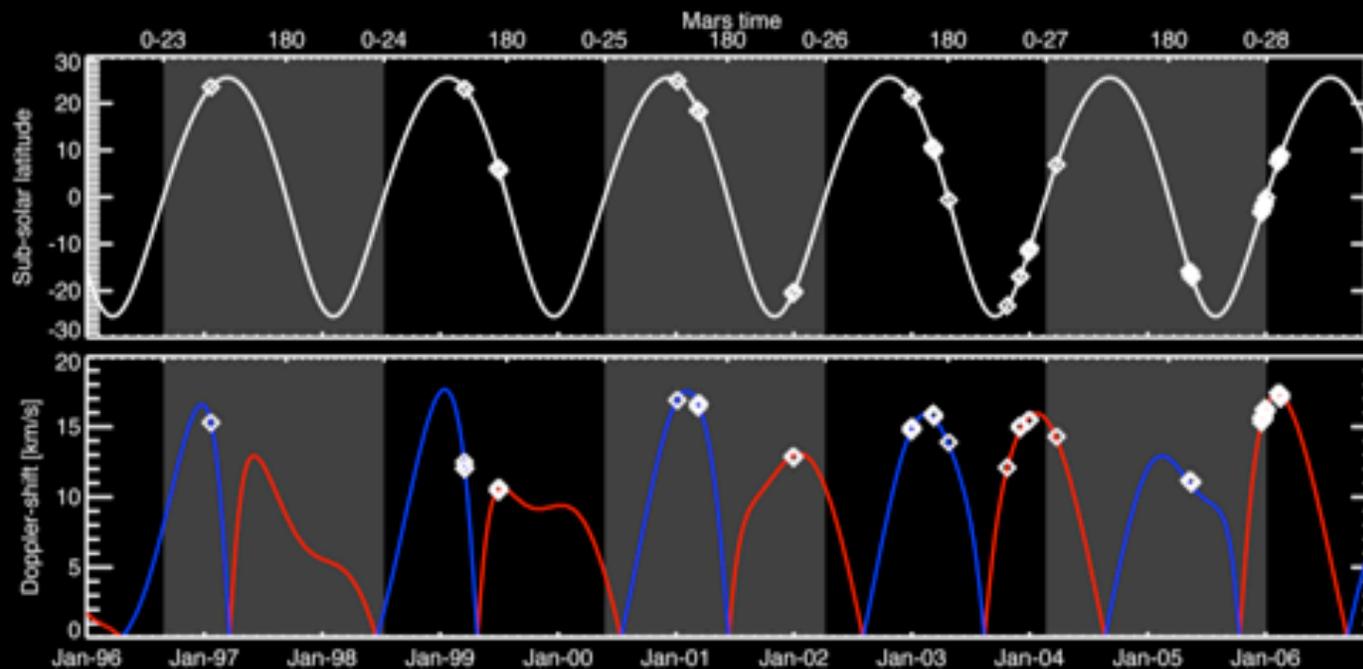
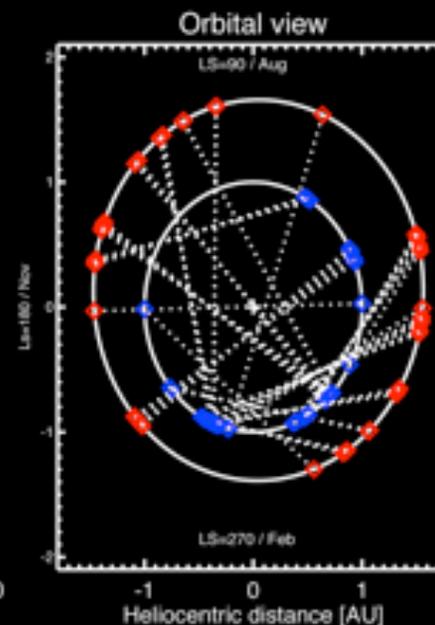
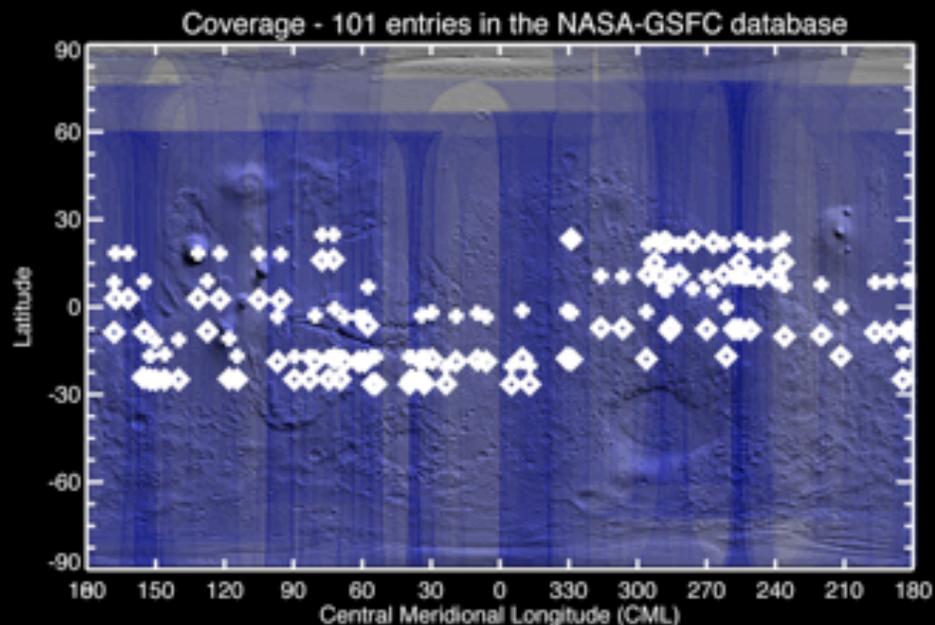
Methane and Water on Mars

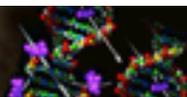
Methane Workshop, Frascati Italy, Villanueva et al. 2009



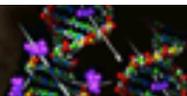
Methane and Water on Mars

Methane Workshop, Frascati Italy, Villanueva et al. 2009





3. Extraction of Mars Residuals

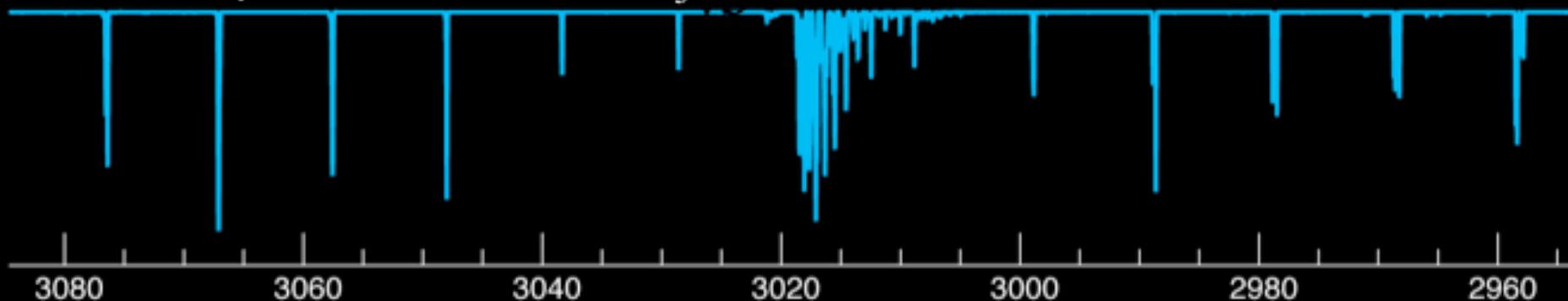


R-Branch

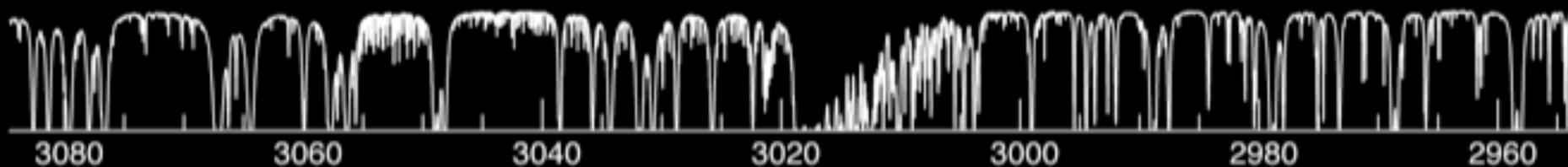
Q-Branch

P-Branch

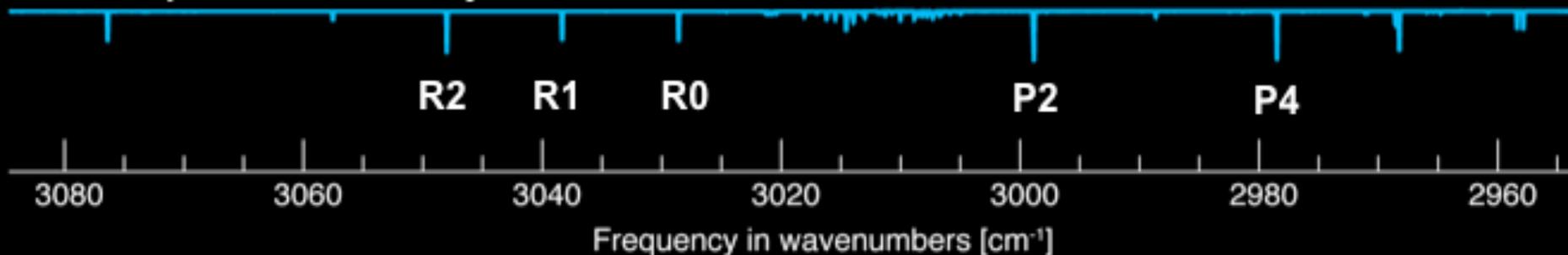
Simulated spectrum of Mars methane ν_3



Simulated terrestrial extinction

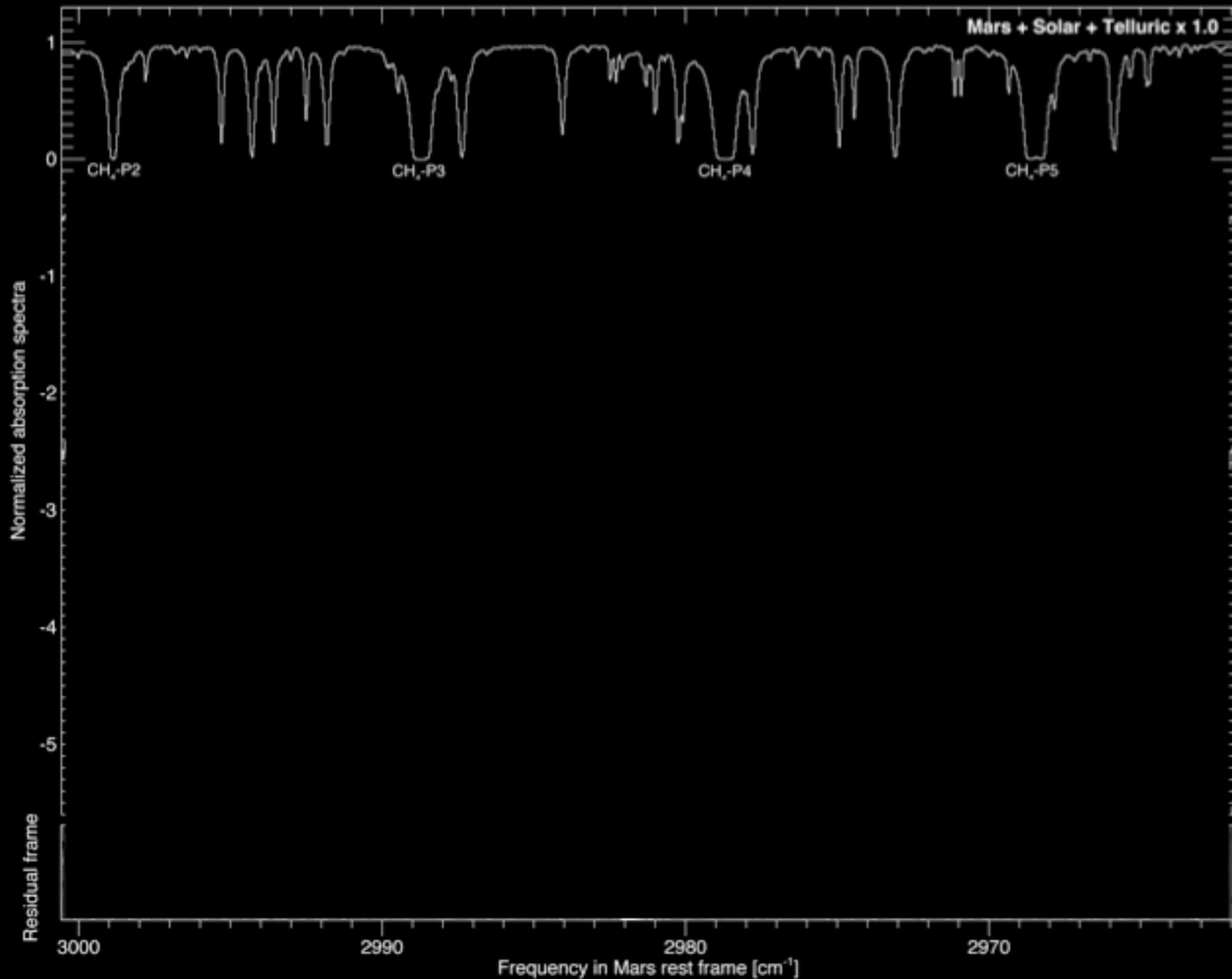
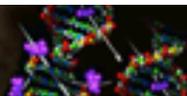


Mars spectrum affected by terrestrial extinction

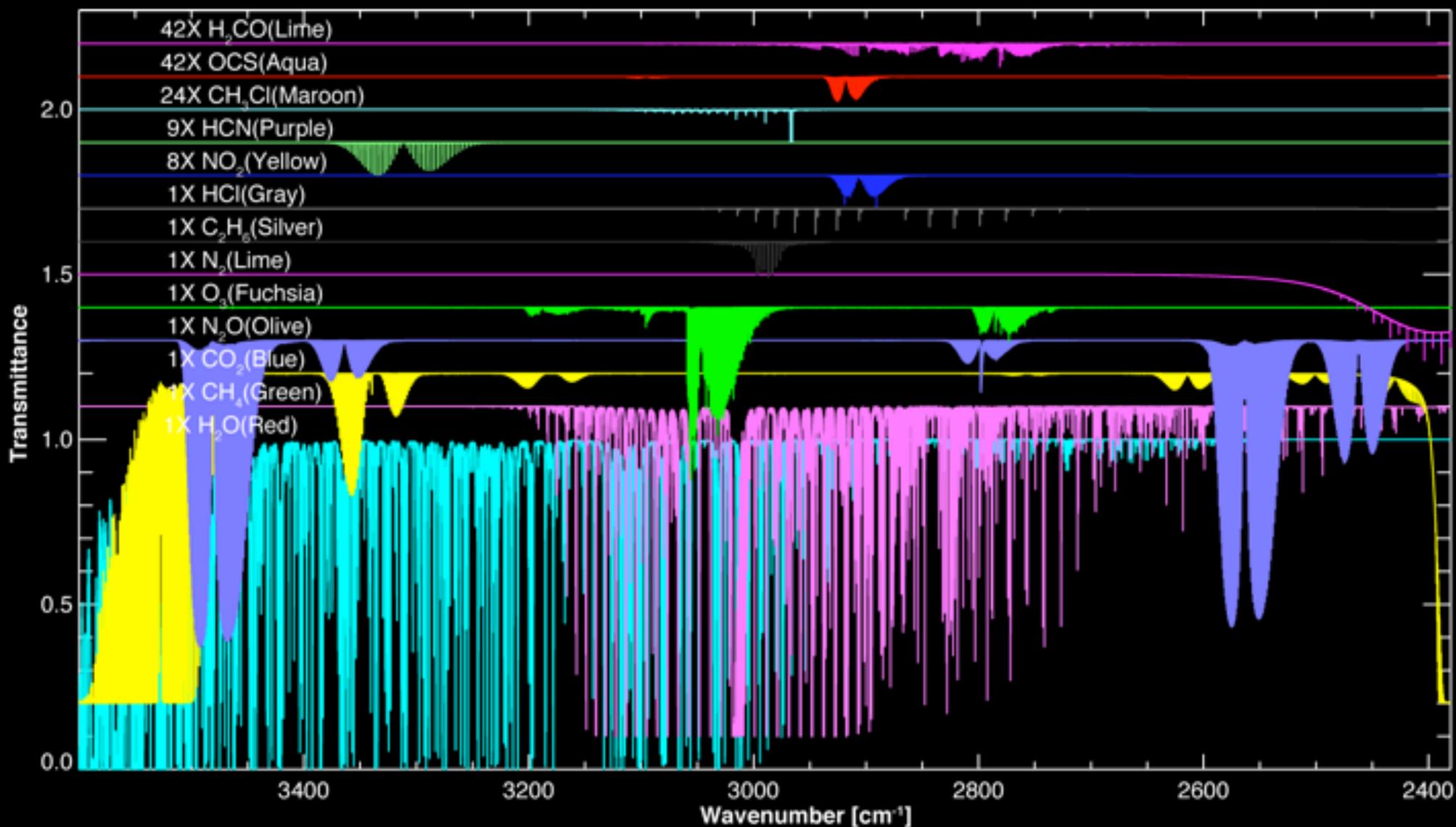


Methane and Water on Mars

Methane Workshop, Frascati Italy, Villanueva et al. 2009

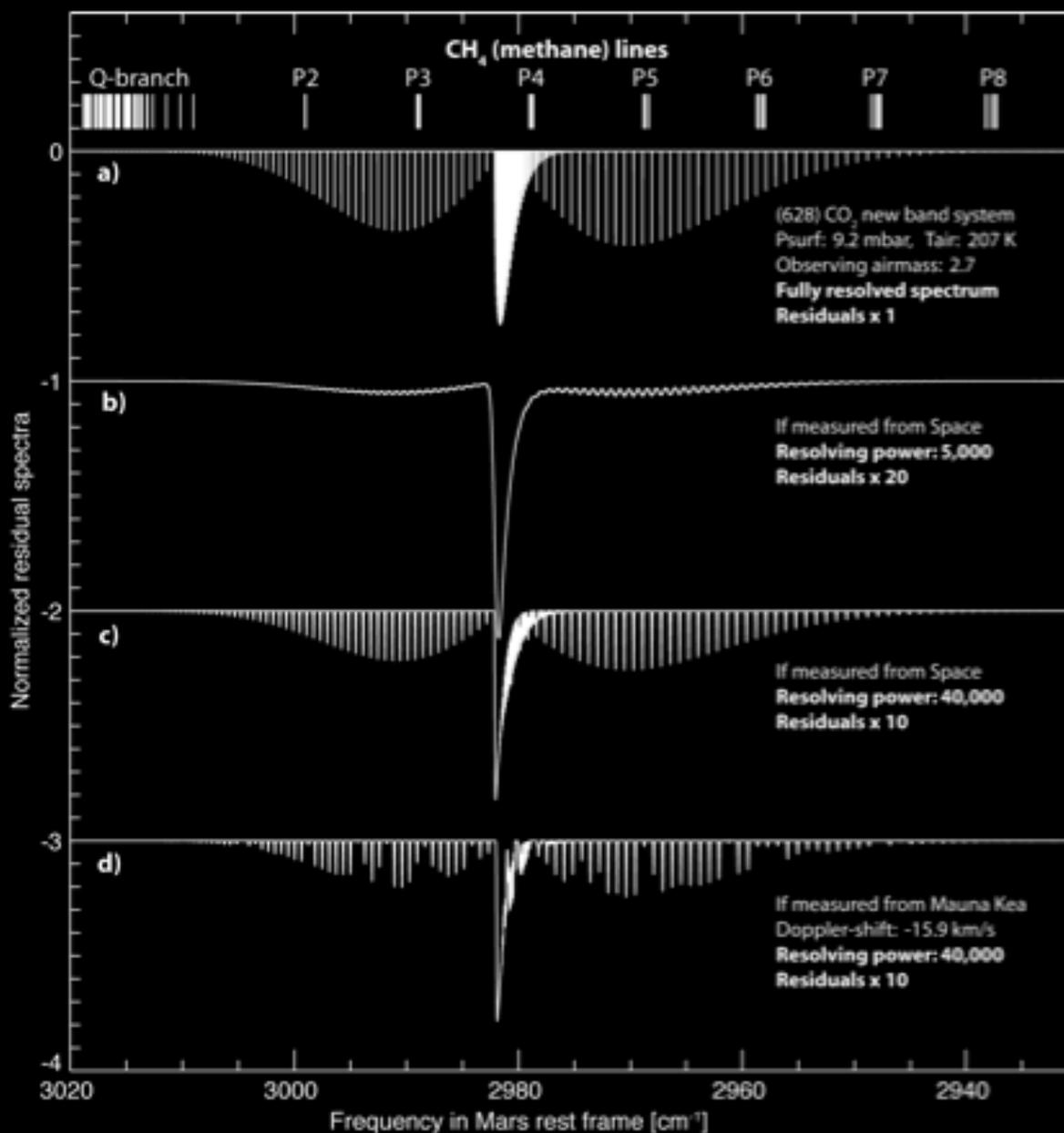


New terrestrial transmittance model LBLRTM (Line-By-Line-Radiative-Transfer-Model)

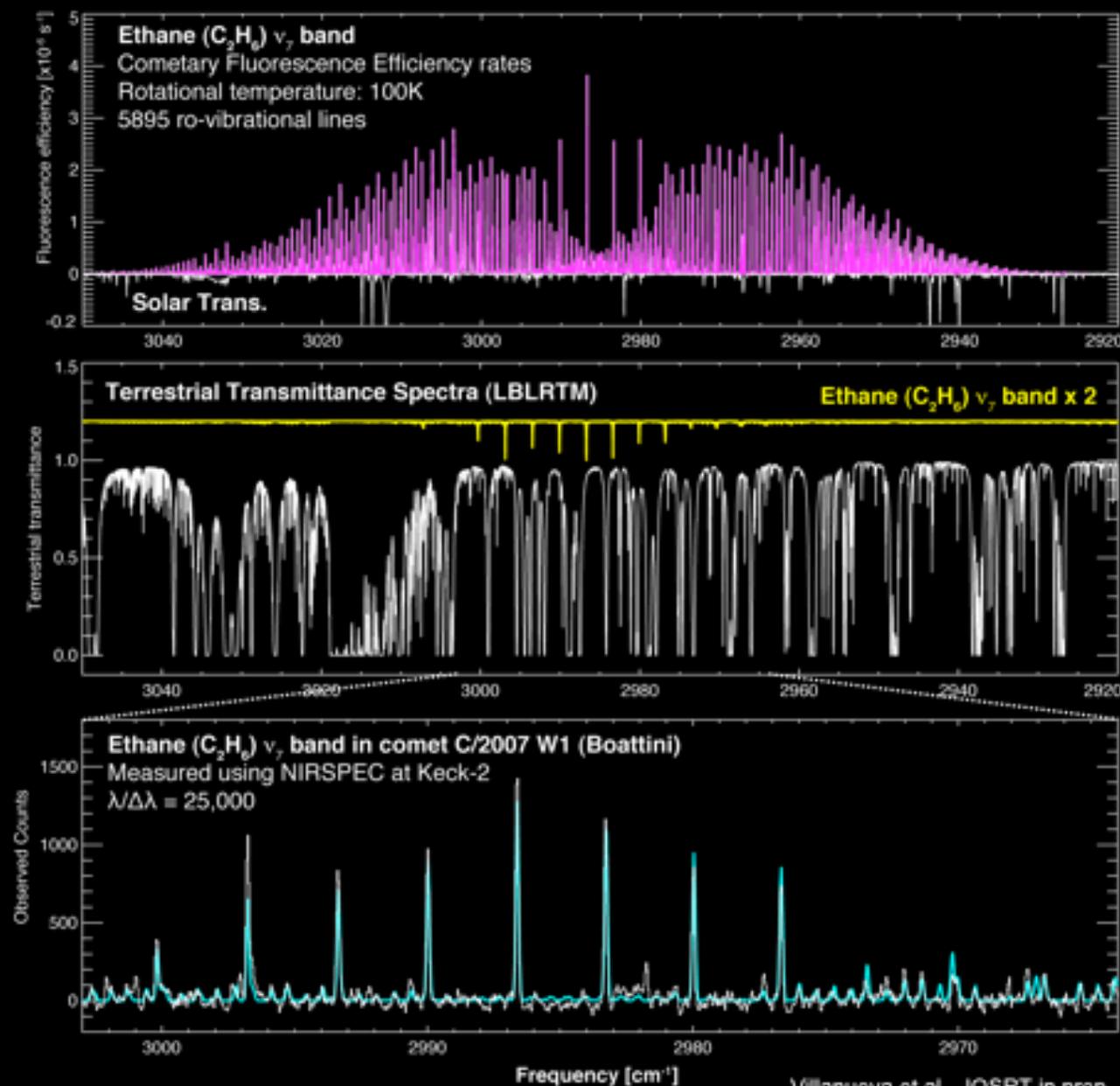


New isotopic bands of carbon dioxide (CO₂) – 5 bands

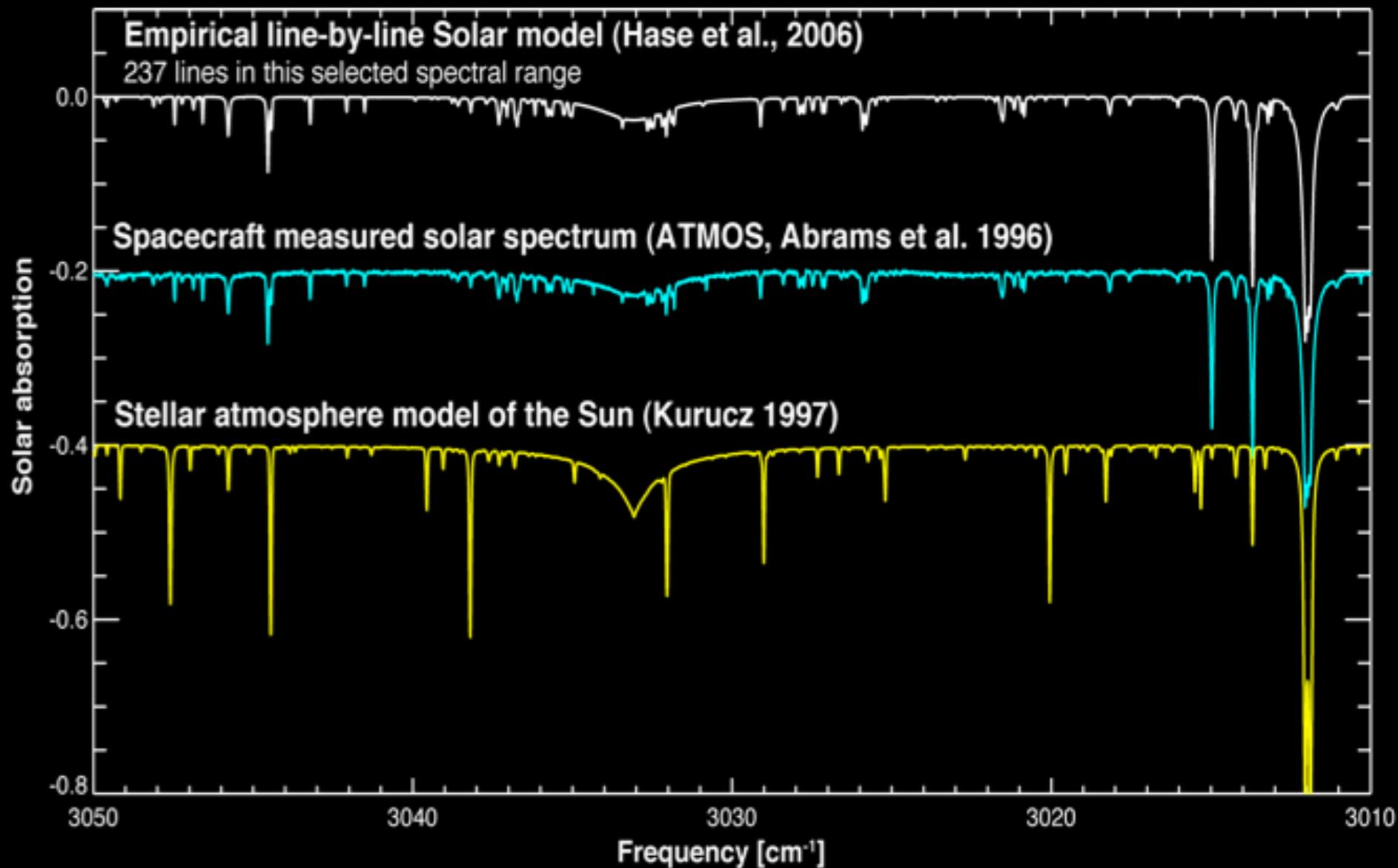
Villanueva et al. (2008 Icarus & JQSRT, and in prep.)



New ethane (C_2H_6) ν_7 terrestrial model Improving the CH_4 P-branch spectral region

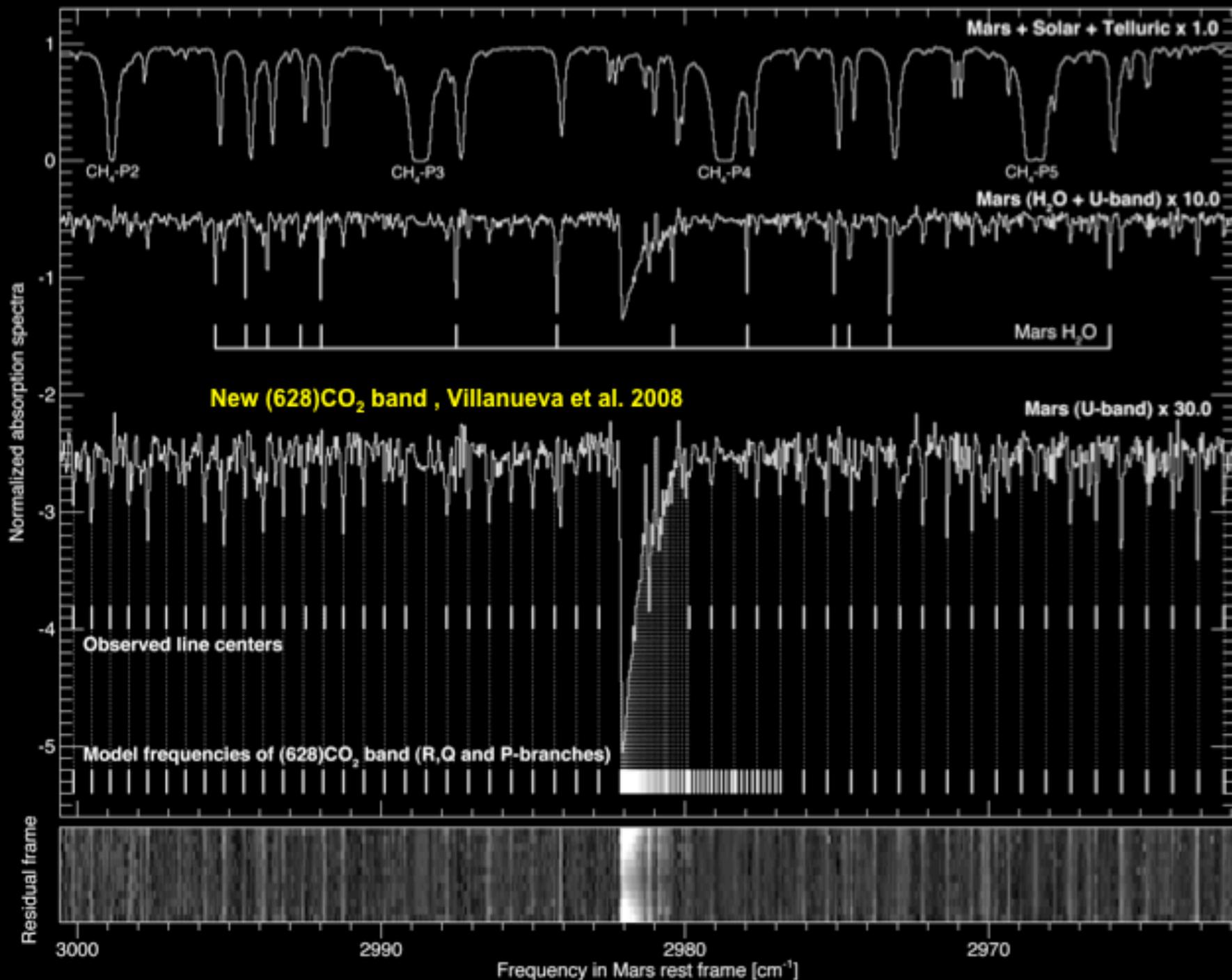
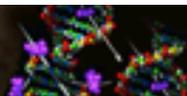


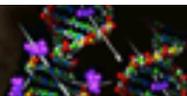
New solar spectrum



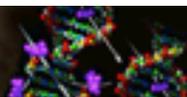
Methane and Water on Mars

Methane Workshop, Frascati Italy, Villanueva et al. 2009

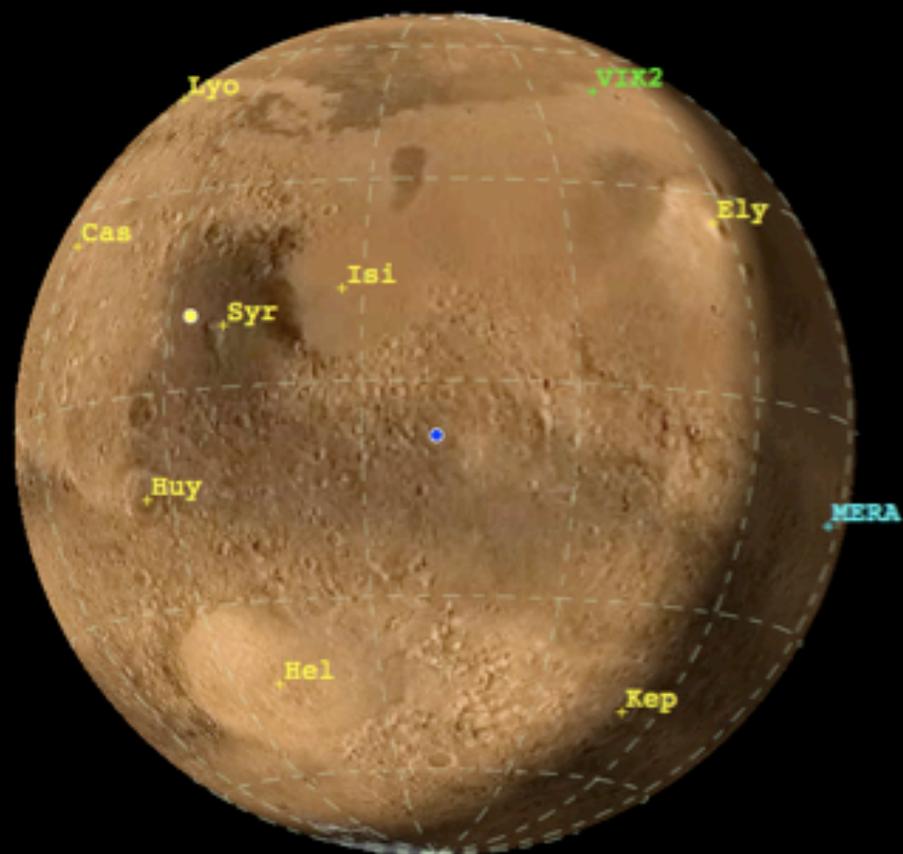




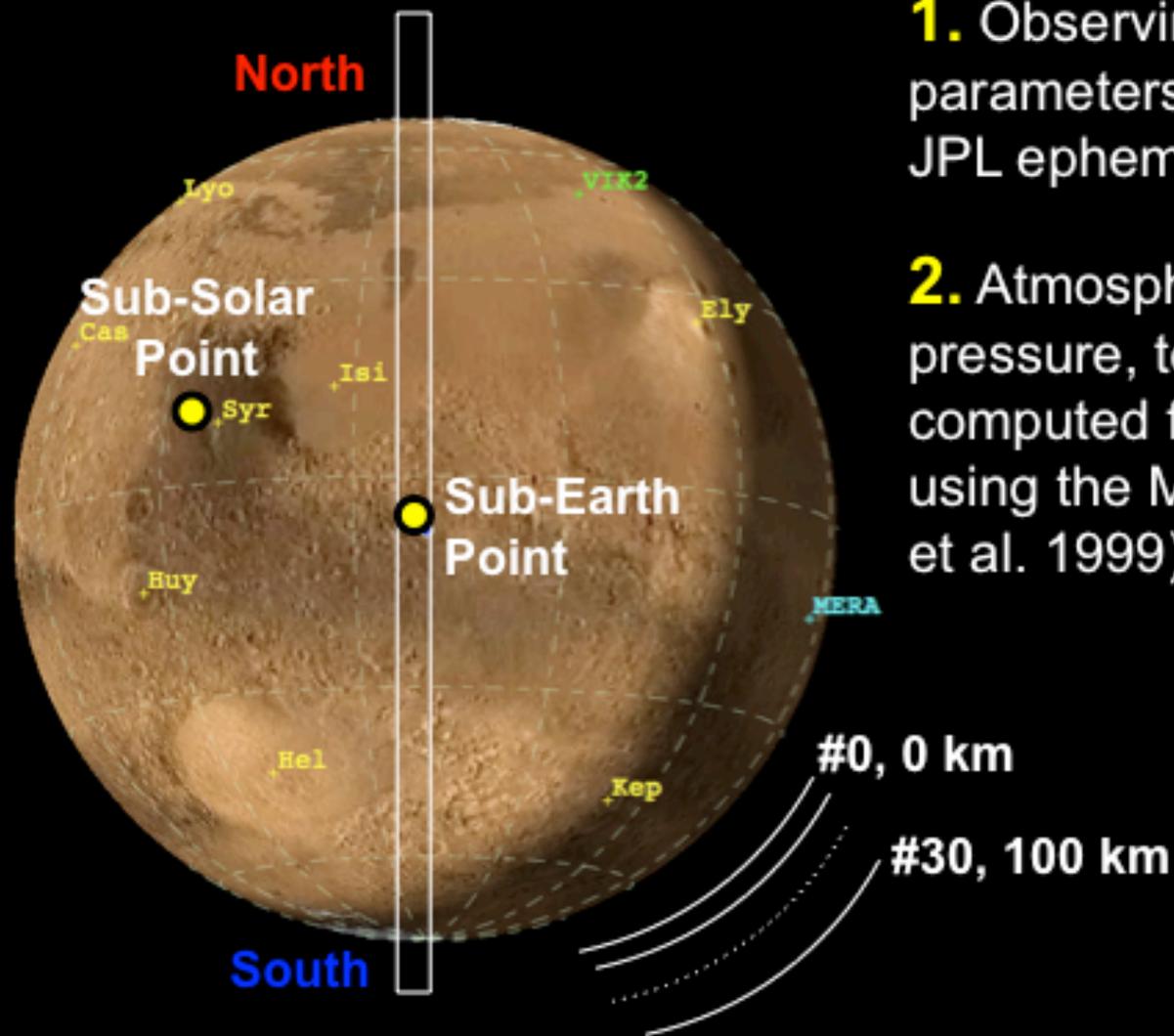
4. Retrieval of molecular abundances



Retrieval parameters



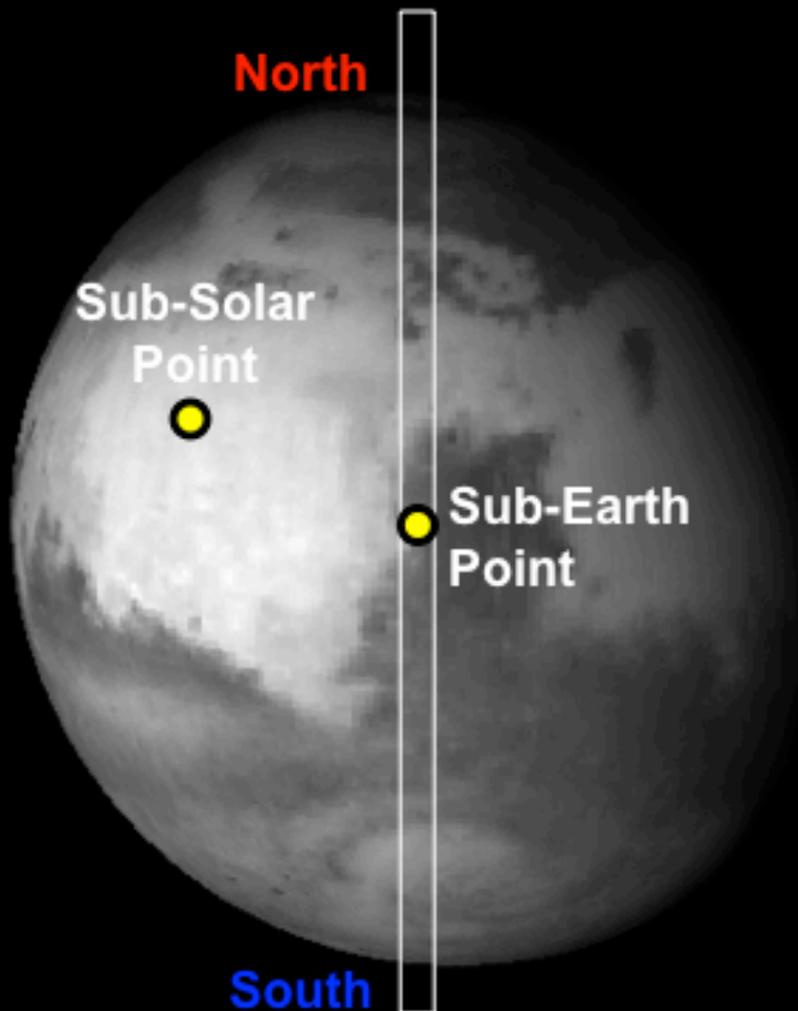
Retrieval parameters



1. Observing geometry and orbital parameters are obtained using NASA-JPL ephemeris generator (Horizons).

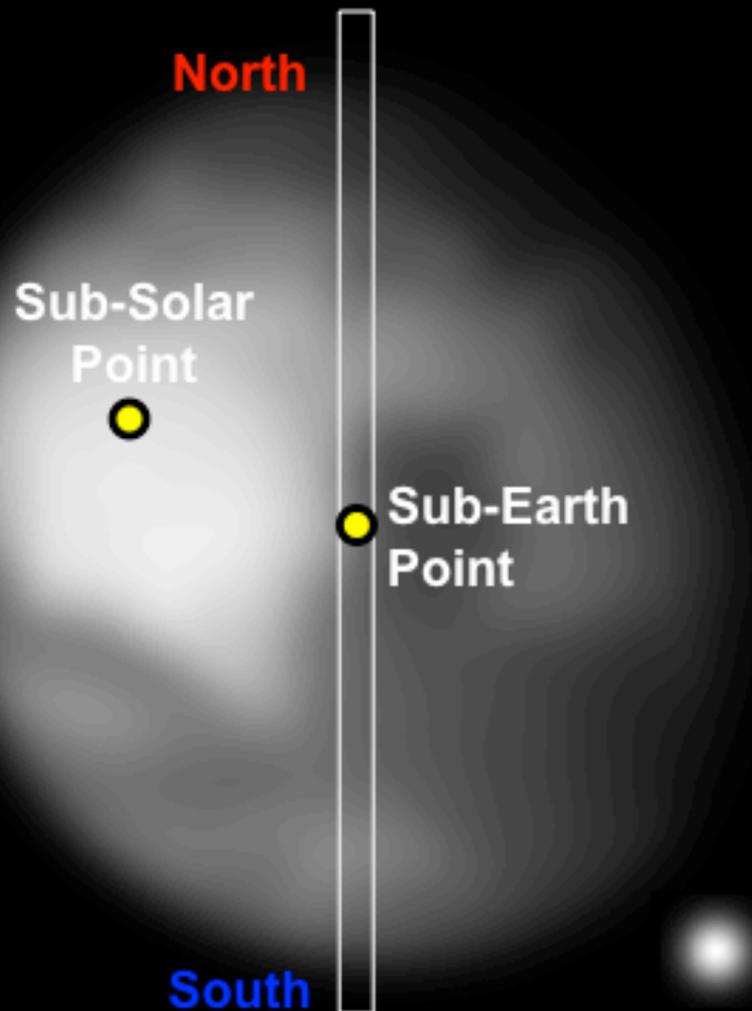
2. Atmospheric parameters (surface pressure, temperature, and 30 layers) are computed for the observational period using the Mars Climate Database (Forget et al. 1999)

Retrieval parameters



- 1.** Observing geometry and orbital parameters are obtained using NASA-JPL ephemeris generator (Horizons, ref.).
- 2.** Atmospheric parameters (surface pressure, temperature, and 30 layers) are computed for the observational period using the Mars Climate Database (Forget et al. 1999)
- 3.** Surface emission flux is calculated using albedo maps and considering a Lambertian surface.

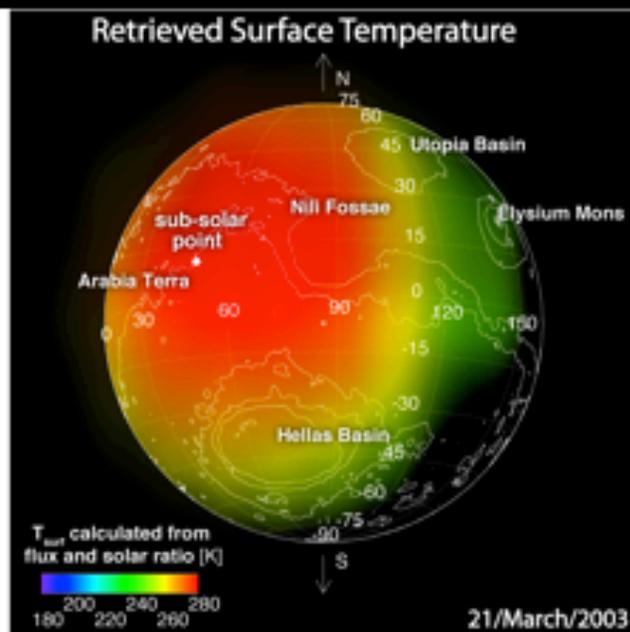
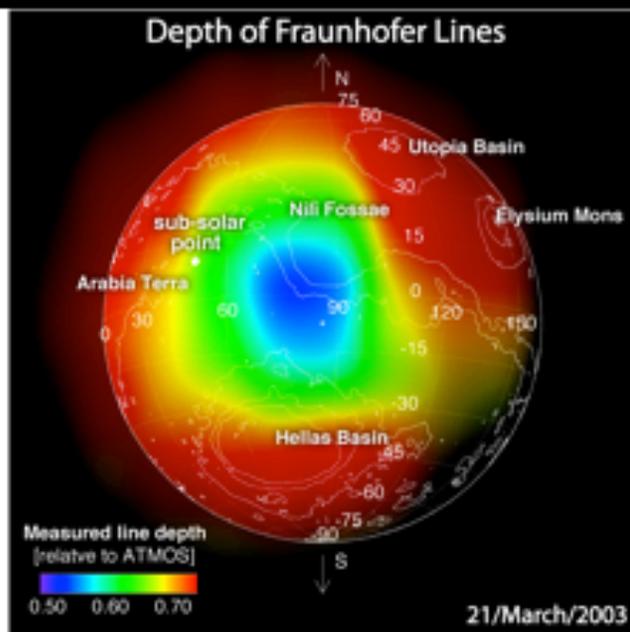
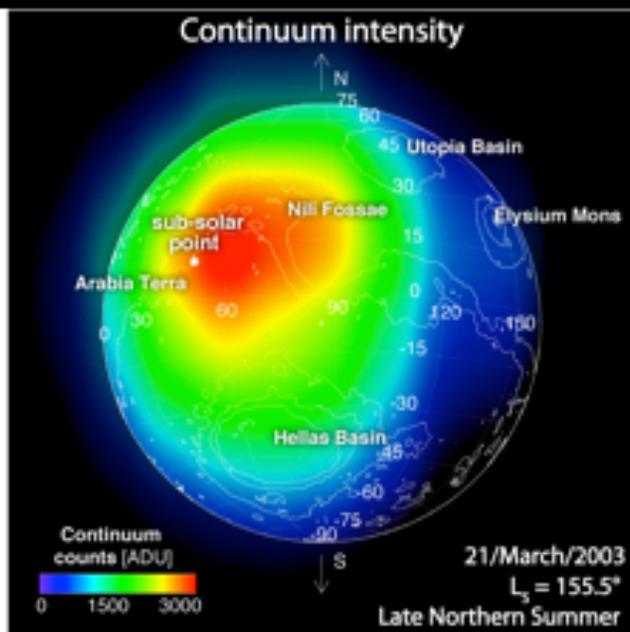
Retrieval parameters



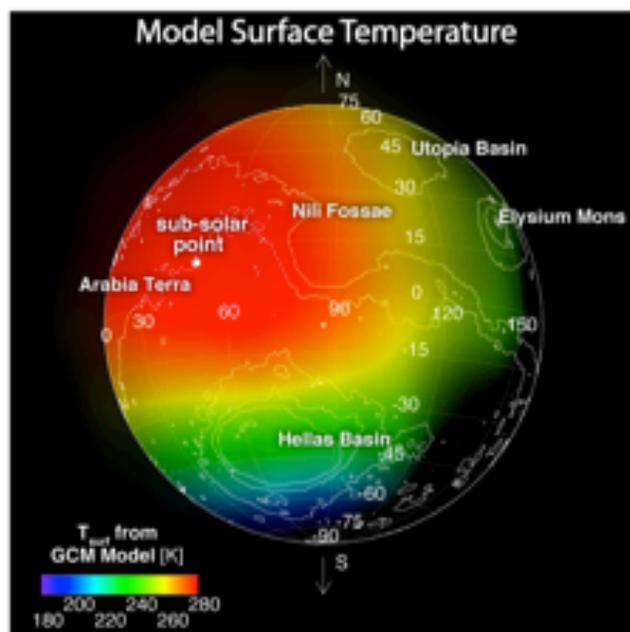
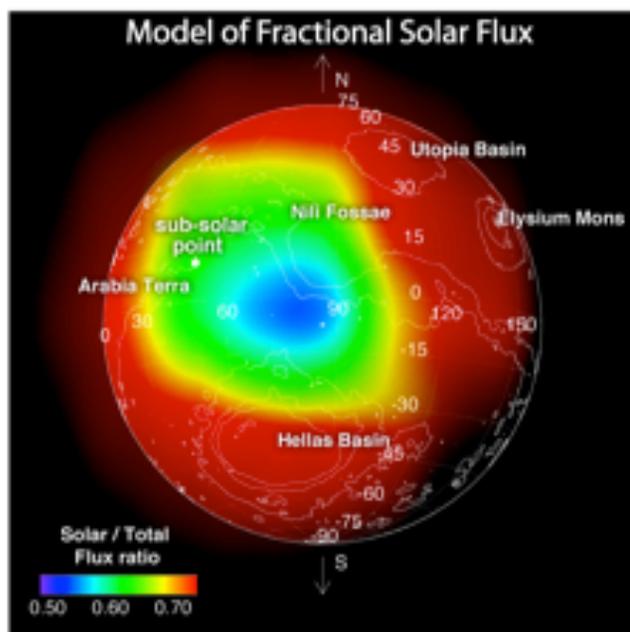
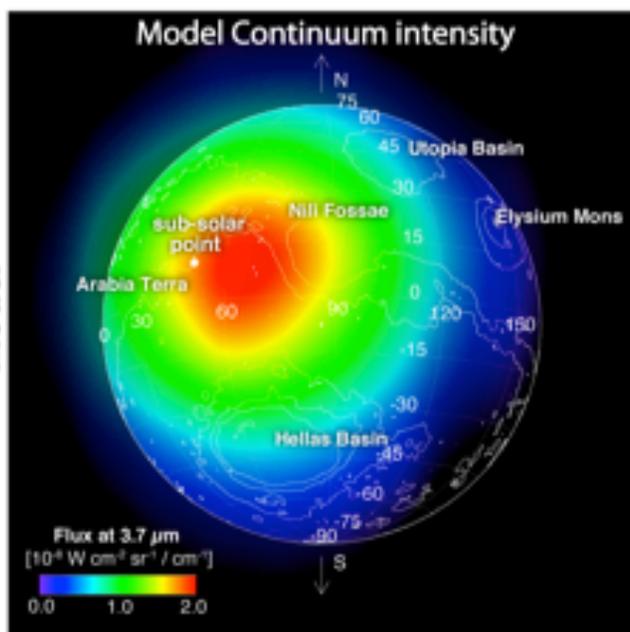
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- 3.** Surface emission flux is calculated using albedo maps and considering a Lambertian surface.
- 4.** The effects of atmospheric seeing are included (typical 0.6 arcsec).

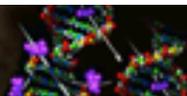
Comparison of Data vs. Model (GCM + Radiative Transfer)

Observed



Model



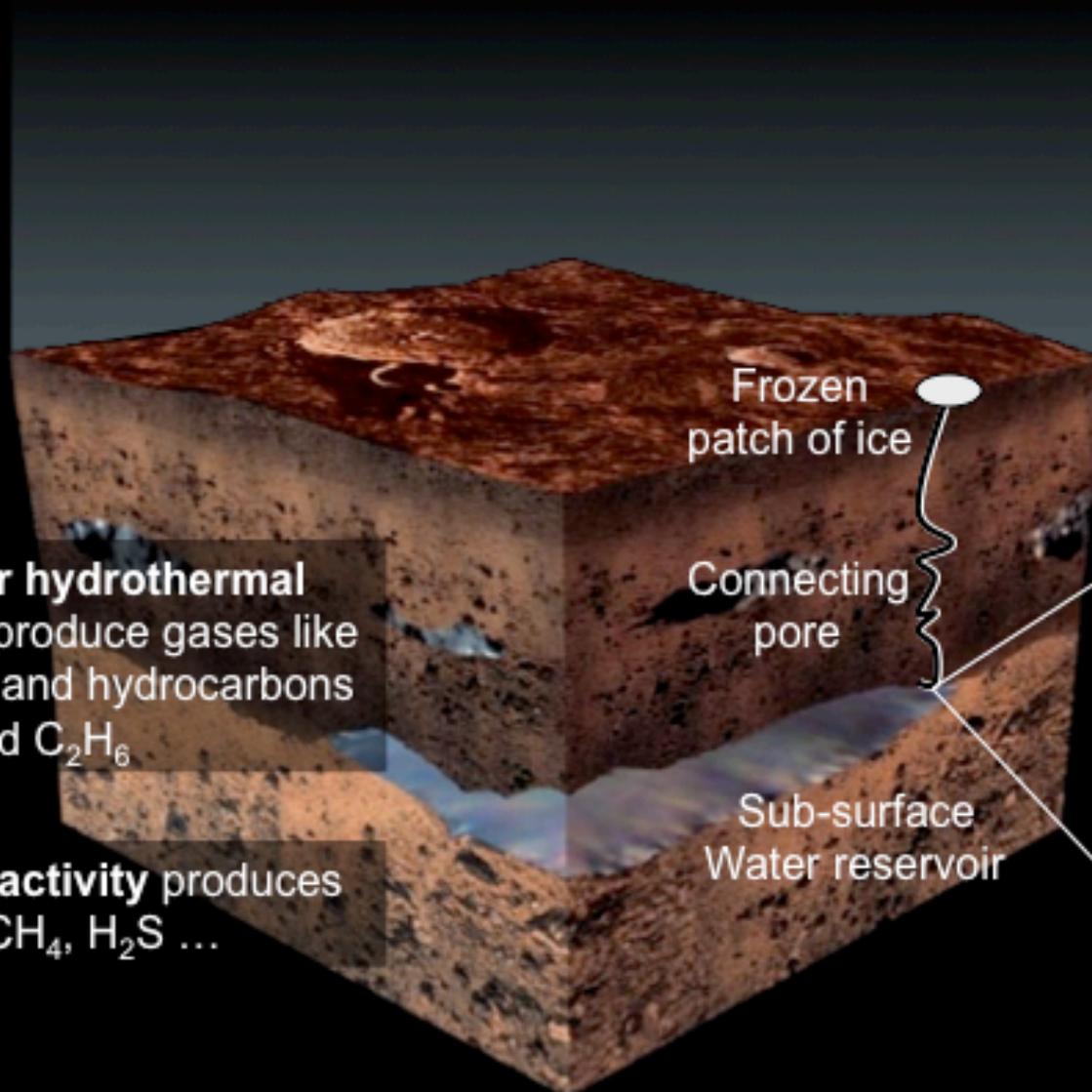


Latest results

5a. Maps of methane and water

Methane and Water on Mars

Methane Workshop, Frascati Italy, Villanueva et al. 2009



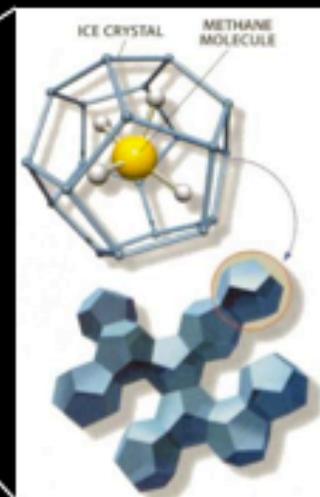
Methane could be stored in the form of clathrates

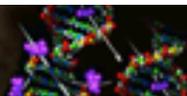


Volcanic or hydrothermal processes produce gases like SO_2 , CO_2 ,... and hydrocarbons like CH_4 and C_2H_6

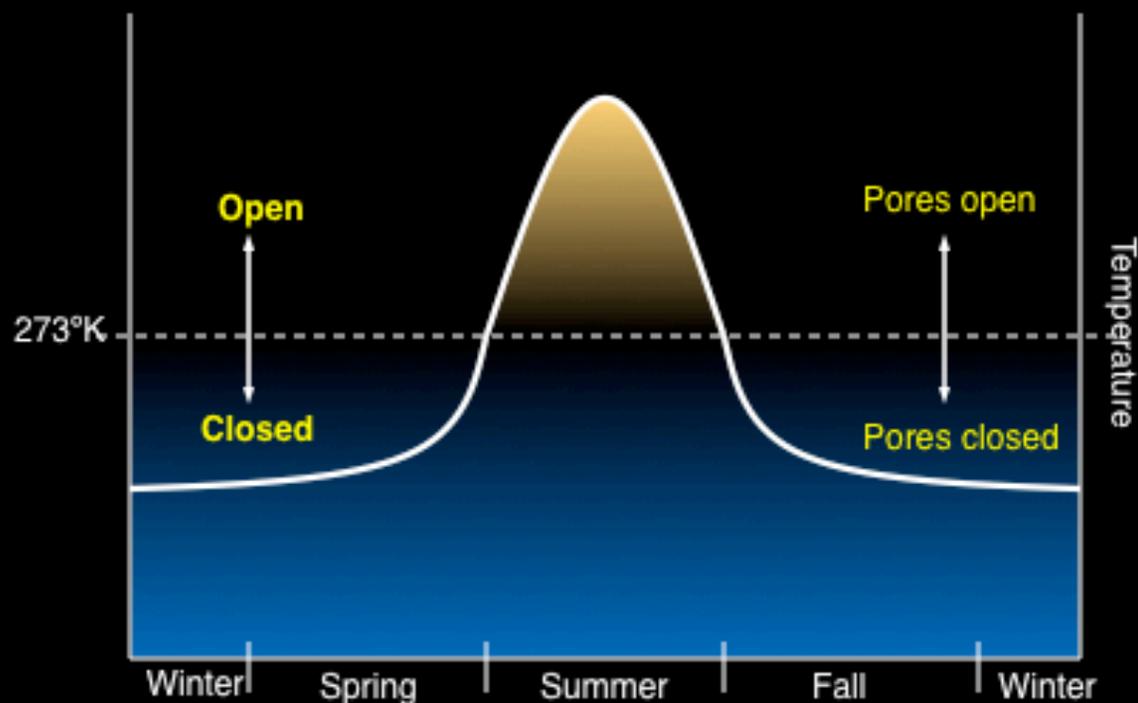


Biological activity produces gases like CH_4 , H_2S ...



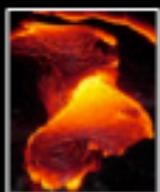
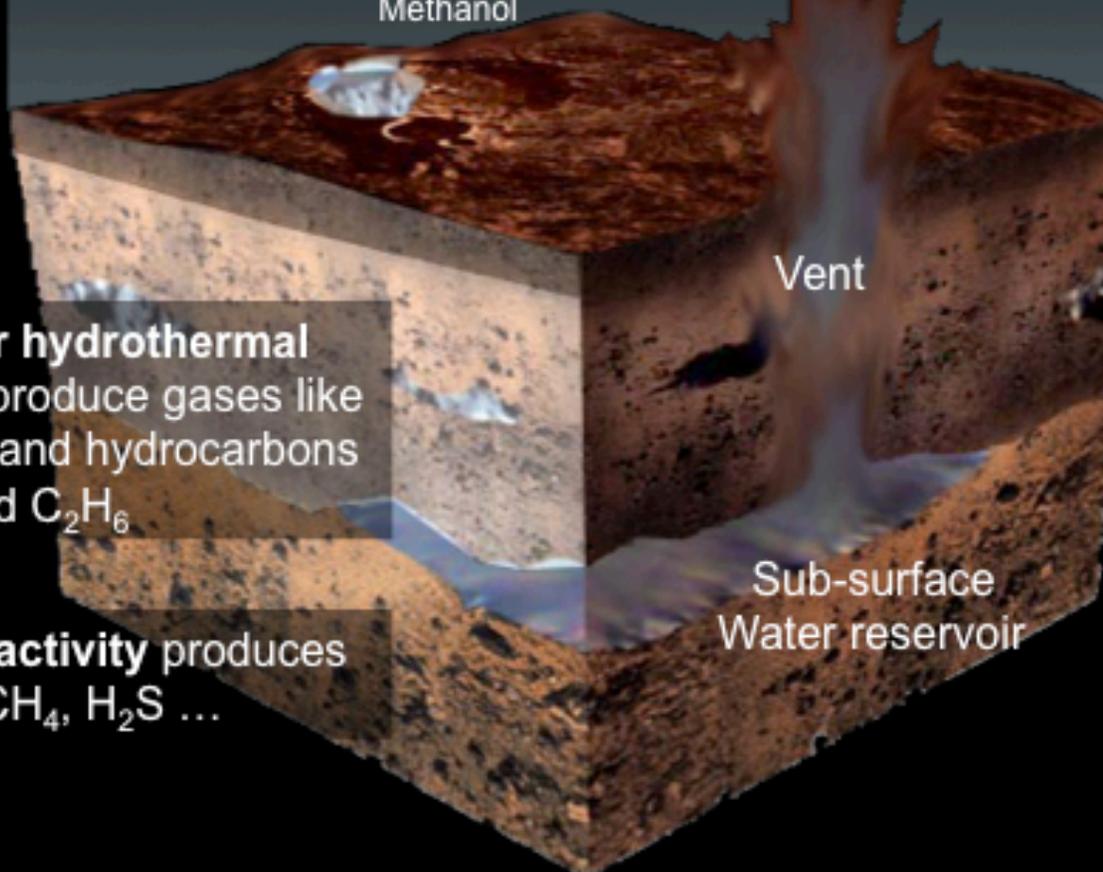
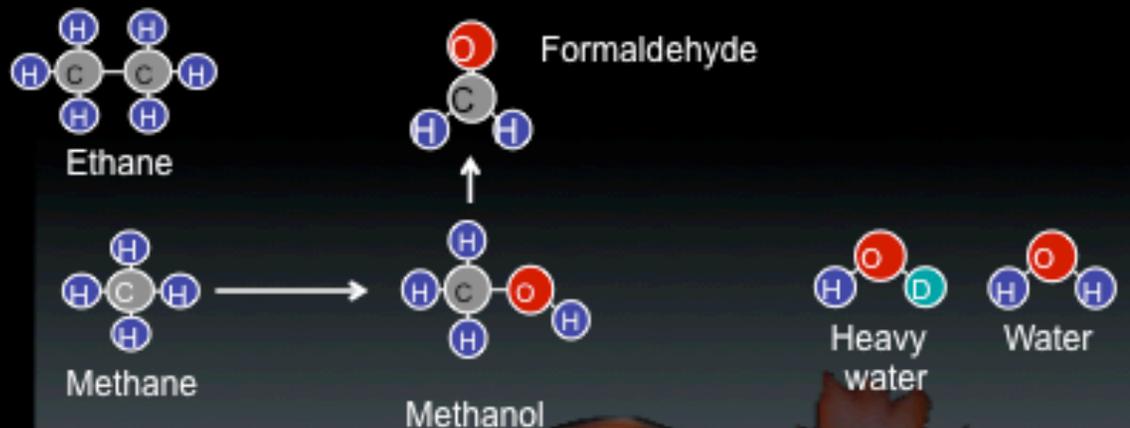


Vaporization of surface ices and Seasonal release of gases



Methane and Water on Mars

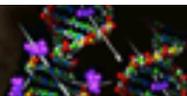
Methane Workshop, Frascati Italy, Villanueva et al. 2009



Volcanic or hydrothermal processes produce gases like SO_2 , CO_2 ,... and hydrocarbons like CH_4 and C_2H_6



Biological activity produces gases like CH_4 , H_2S ...



Latest results

5b. Isotopic Fractionation of Water (D/H)

$$(D/H)_{H_2O} \sim 5.5E$$

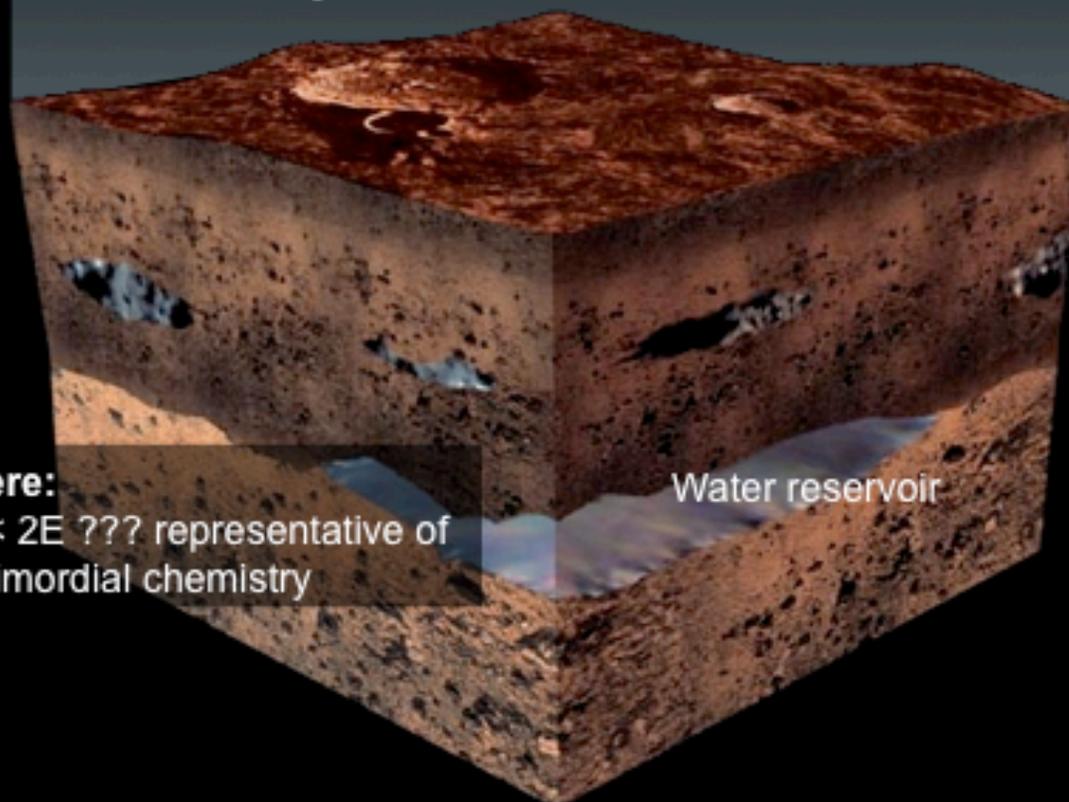
Thermal escape
of lighter isotope



Sublimation
condensation



Surface water ice
& regolith



Cryosphere:
 $(D/H)_{H_2O} < 2E$??? representative of
a more primordial chemistry

Water reservoir

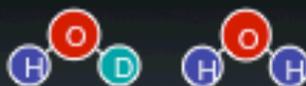
E: Terrestrial value
VSMOW

Adapted from ESA-Medialab image

$$(D/H)_{H_2O} \sim 5.5E$$

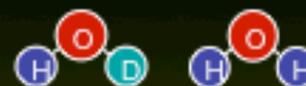
$$(D/H)_{H_2O} < 2E$$

Thermal escape
of lighter isotope

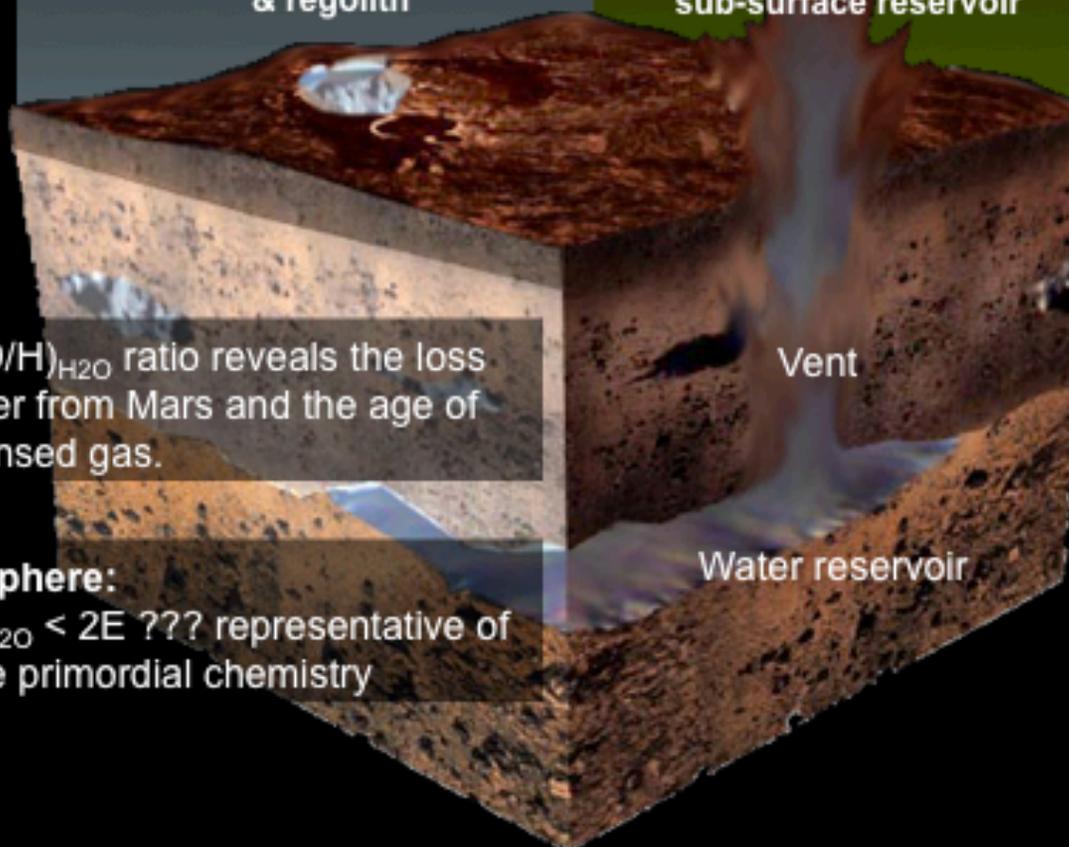


Sublimation
condensation

Surface water ice
& regolith



Release from
sub-surface reservoir



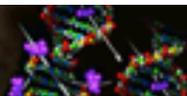
The $(D/H)_{H_2O}$ ratio reveals the loss of water from Mars and the age of the sensed gas.



Cryosphere:
 $(D/H)_{H_2O} < 2E$??? representative of a more primordial chemistry

E: Terrestrial value
VSMOW

Adapted from ESA-Medialab image

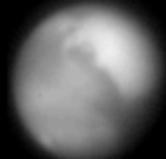


Latest results
5c. 2009 observational campaign

Mars as Observed with NIRC2

on the Keck II telescope using Adaptive Optics (AO)
June 8th 2009, 15:15 UT, $L_s = 281^\circ$ (Early SH Summer)

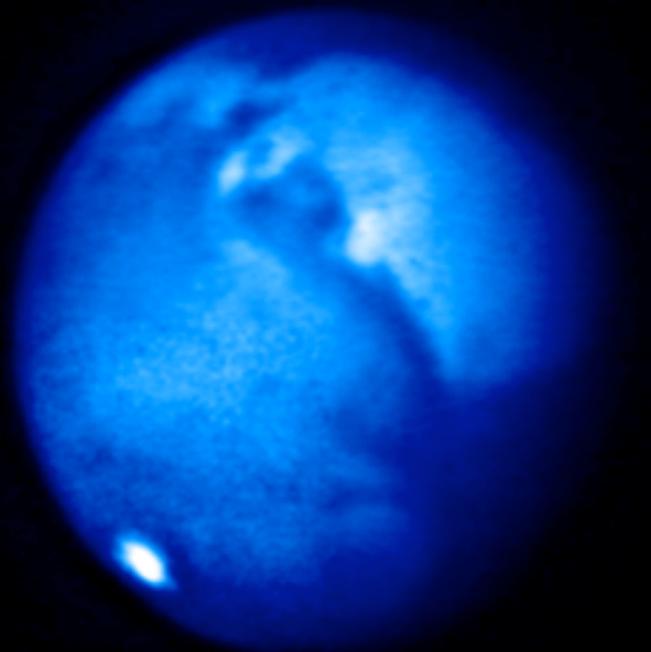
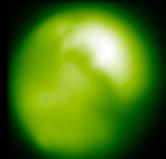
2.15-2.18 μm



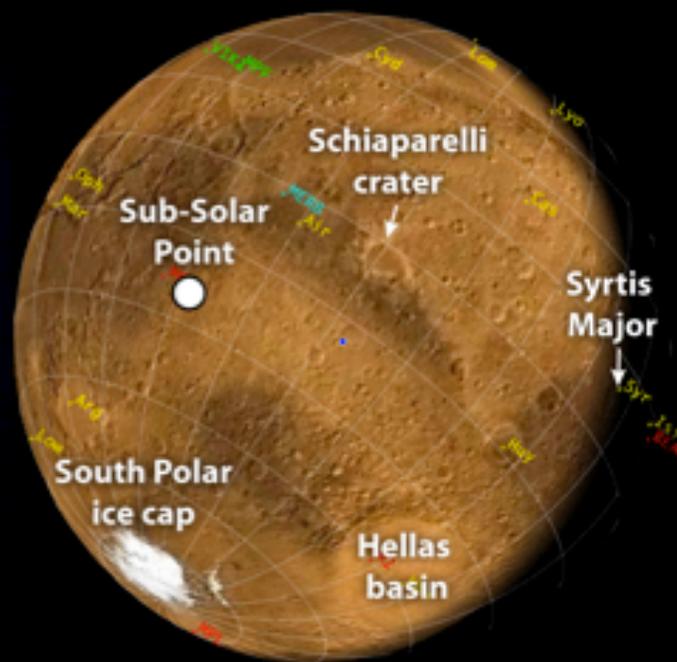
1.57-1.59 μm



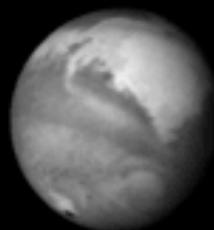
1.53-1.66 μm



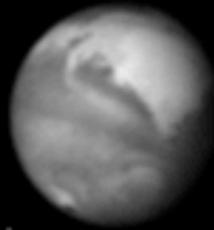
Water filter (2.986-3.14 μm)



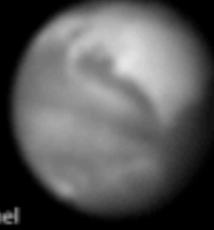
Mars24 image



Synthetic image
Fully Resolved
Mars diameter: 4.7"



Kernel
Convolved
with a 0.1" (FWHM) PSF



Kernel
Convolved
with a 0.2" (FWHM) PSF



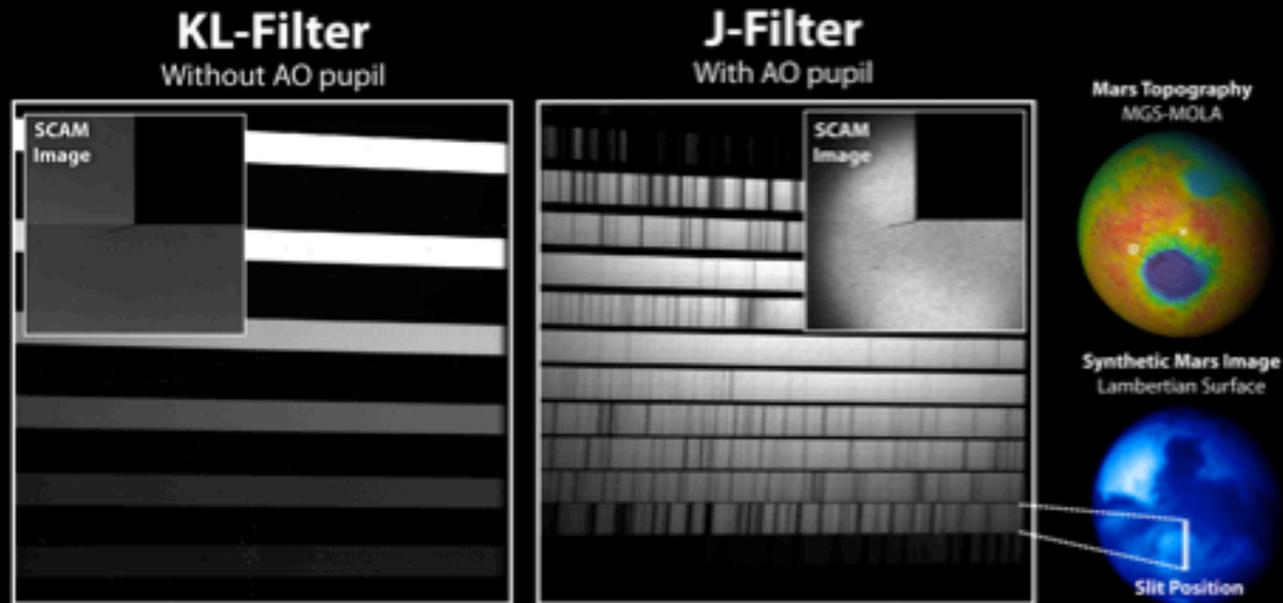
Kernel
Convolved
with a 0.4" (FWHM) PSF

Data Processing: G. L. Villanueva, M. J. Mumma (NASA-GSFC)

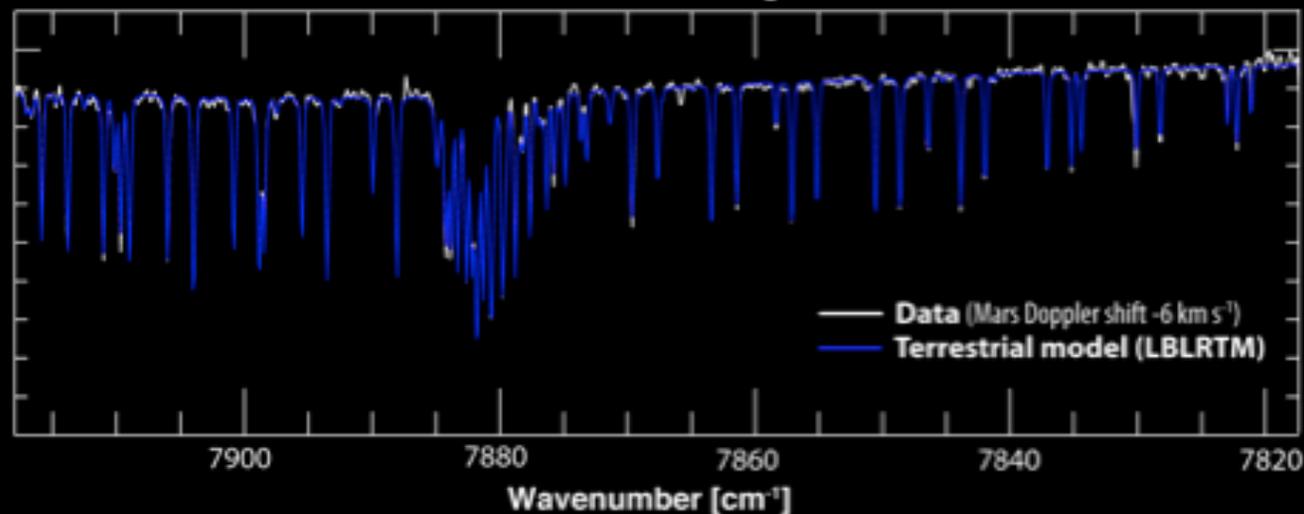
Observations: A. R. Conrad, R. C. Campbell, J. Lyke (W. M. Keck Observatory)

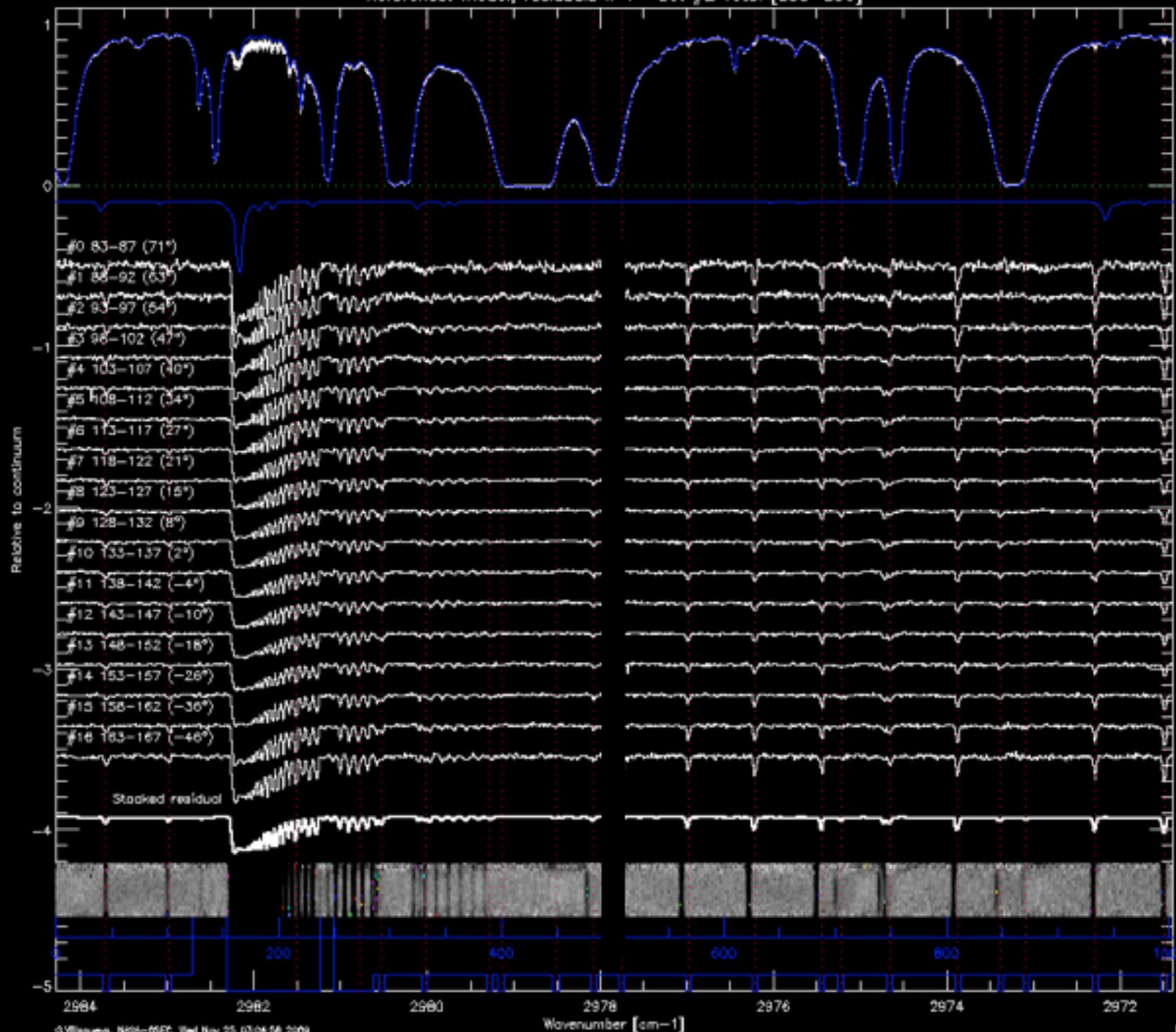
Mars as Observed with NIRSPA0

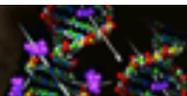
on the Keck II telescope using Adaptive Optics (AO)
June 13th 2009, 14:55 UT, $L_s = 284^\circ$ (Early SH Summer)



Order 60 - J-Filter - O₂ band







6. Conclusions

Some preliminary answers

- **Where is methane and water being released?**

Regions of high methane are observed normally over ancient terrain. We observe a water vapor polar plume in Northern Summer with no associated methane release.

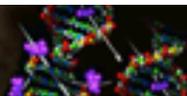
- **Is methane being co-released with water?**

Both gases are depleted at vernal equinox but are enhanced in warm seasons (spring/summer) though often with dissimilar spatial distributions.

- **Are these releases seasonal or sporadic?**

Further observations are required to answer this.

Preliminary data reductions of 2008 data in mid Northern Spring ($L_S=50$) show no indication of methane.



Thank you