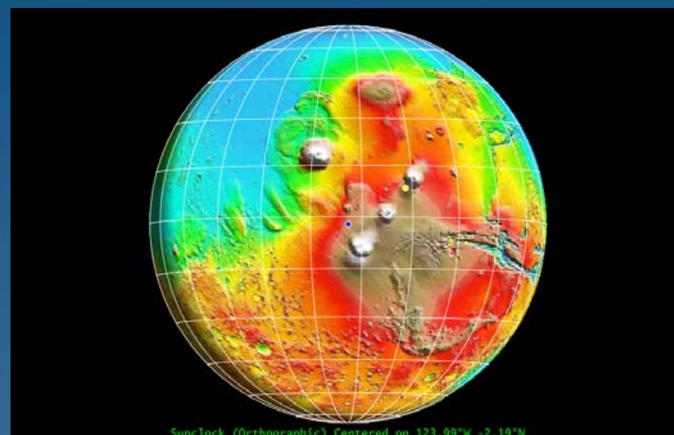
Measurement of the Isotopic Signatures of Water on Mars; Implications for Studying Methane



Robert Novak[1], Michael J. Mumma[2], Geronimo Villanueva[3]

1.Iona College, New Rochelle NY USA, 2. NASA-Goddard Space Flight Center, Greenbelt, MD USA, 3. NASA-GSFC, Catholic University of America, Washington DC USA

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Related Talks:

Michael J. Mumma: Absolute Measurement of Methane on Mars

Geronimo Villanueva: Methane and Water on Mars: Maps of Active Regions and their Seasonal Variability

Outline:

- $[HDO]/[H_2O]$

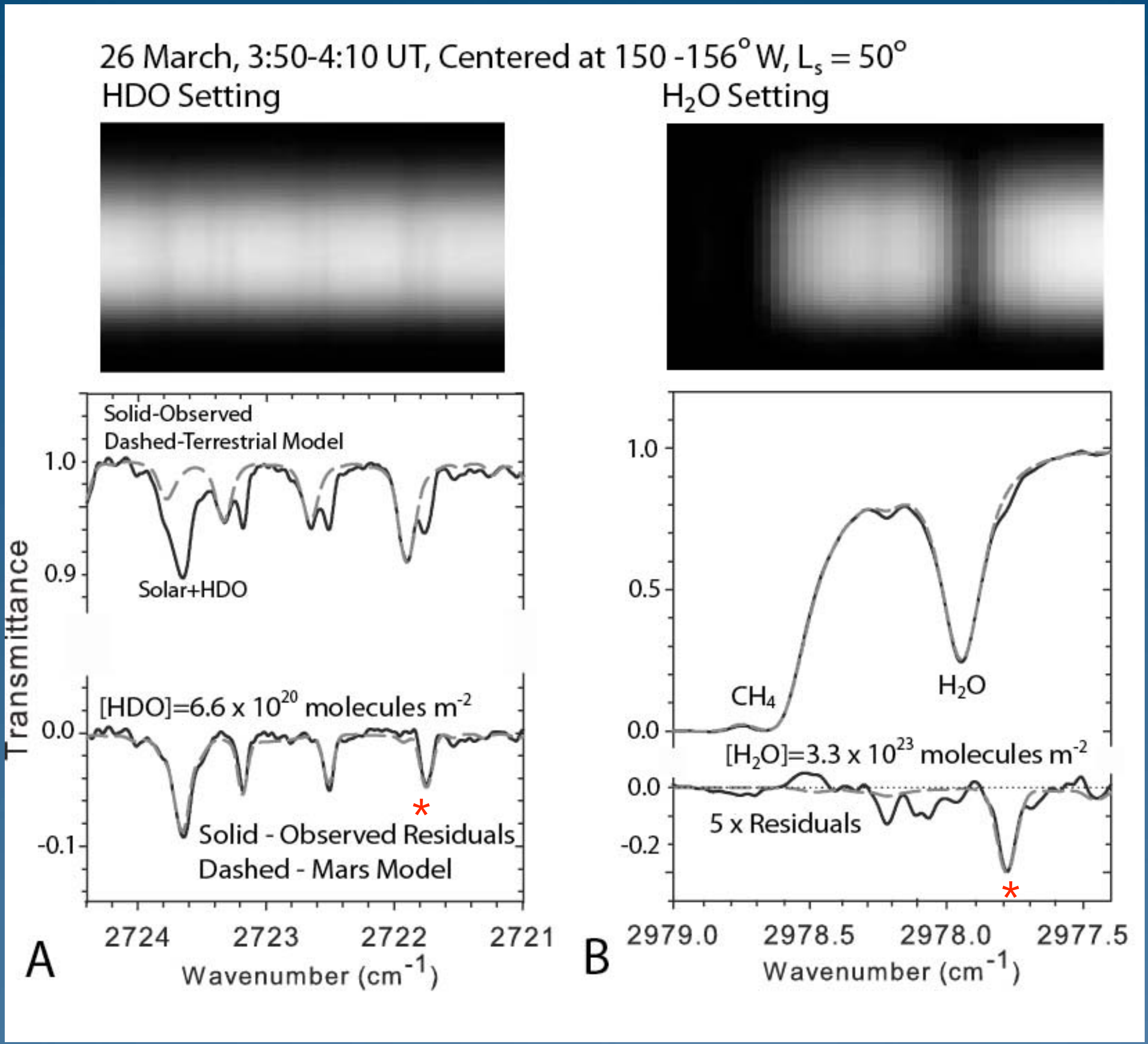
- Isotopologues of Methane

- Model to Predict measurement of $[^{13}CH_4]/[^{12}CH_4]$

- Considerations for the future

Measurements of [HDO]/[H_2O] on Mars

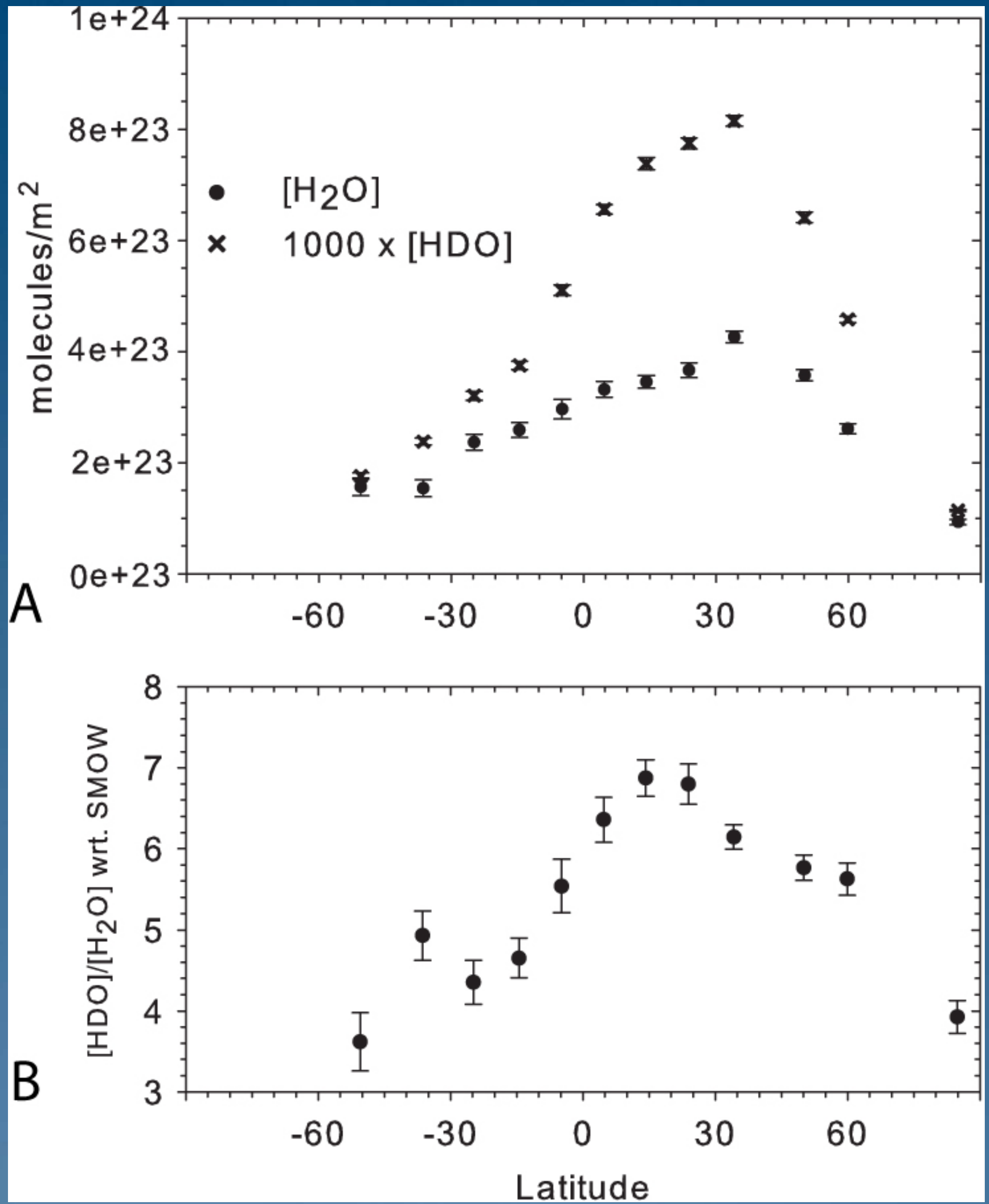
*
Eq. Width
= 0.0050 cm^{-1}
Noise
= 0.0002 cm^{-1}



*
Eq. Width
= 0.0041 cm^{-1}
Noise
= 0.0002 cm^{-1}

3 row extracts, 4.6°N, 26 March 2008

Column Densities
Of HDO and H_2O
150°-156° W



[HDO]/[H_2O]
wrt. SMOW

SMOW ratio
= 0.312 x 10^{-3}

Isotopic Signatures of Methane
in the Earth's Atmosphere:

$^{12}CH_4$	0.99827
$^{13}CH_4$	0.01110
$^{12}CH_3D$	0.00062

from HITRAN

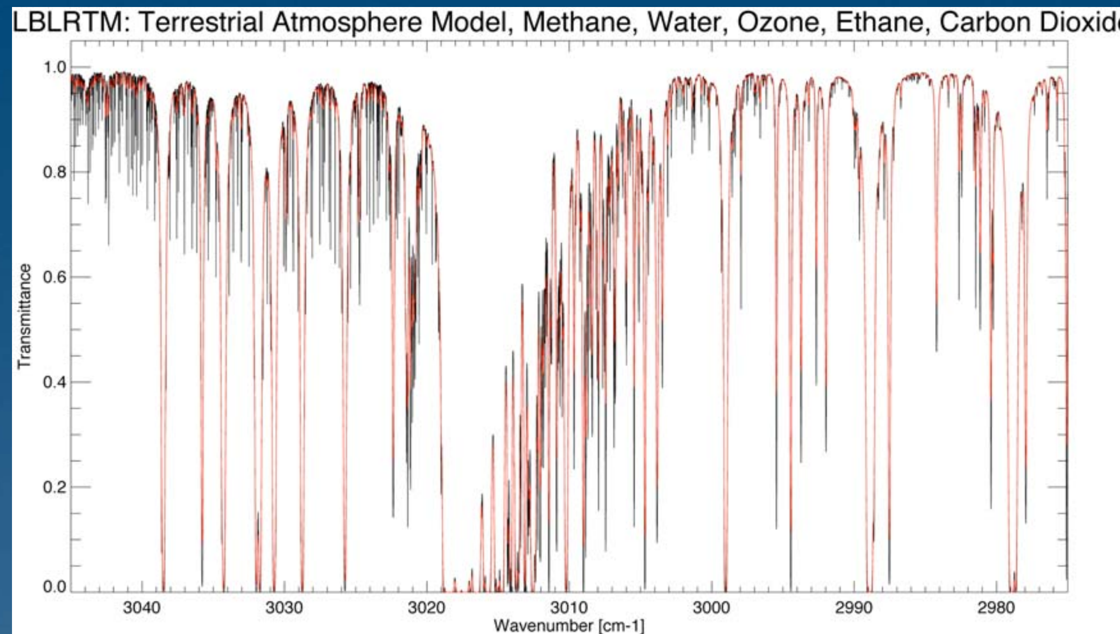
Variations of this ratio provide insights into
the origins of Methane, whether abiotic or microbial.

Sherwood Lolar B, et al. (2008), *Geochim. Cosmochim. Acta*., *72*, 4778-4795.
Onstott T.C. (2006), *Astrobiology, 6*, 377-395.

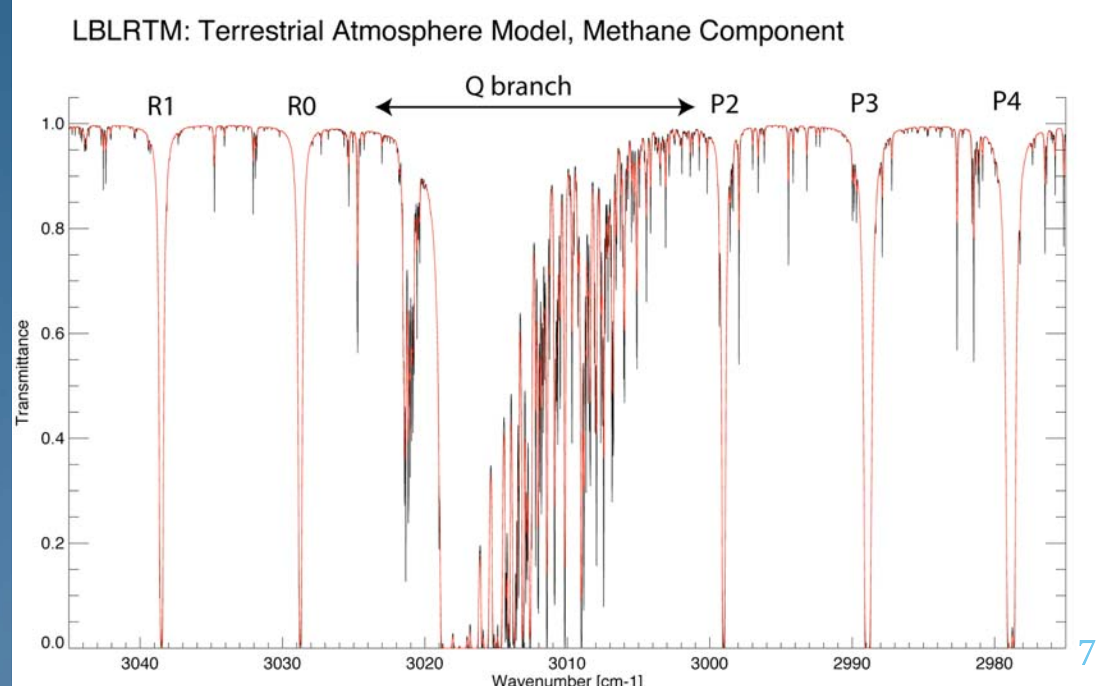
Models of Earth's atmosphere for measured conditions above Mauna Kea.

Line By Line Radiative Transfer Model (Clough et al. (2005), *JQSRT, 91*, 233-244.

A. Methane, Water, Ozone, Ethane, Carbon Dioxide.



B. Methane



Targeted Methane Transitions:

(from JavaHAWKS/HITRAN)

P4 Region (~ 2978.6 cm^{-1}, T=210K

Isotopologue	Wavenumber (cm^{-1})	Intensity
$^{12}CH_4$	2978.6505	9.784E-20
$^{13}CH_4$*	2978.6926	1.769E-21
$^{13}CH_4$*	2978.8083	1.058E-21
$^{12}CH_4$	2978.8481	6.564E-20
$^{13}CH_4$*	2978.8932	1.061E-21
$^{12}CH_4$	2978.9201	9.83E-20

(Wn.)/(Δ Wn.) = 70904

$I(^{13}CH_4)/I(^{12}CH_4)= 0.018$

Transitions in Red are Being compared.

* P5 transition

P2, ~2998.9 cm^{-1})

Isotopologue	Wavenumber (cm-1)	Intensity
$^{12}CH_4$	2998.9939	7.15E-20
$^{12}CH_4$	2999.0602	4.77E-20
$^{13}CH_4{}^*$	2999.0634	3.13E-22

(Wn.)/(Δ Wn.) > 900000

$I(^{13}CH_4)/I(^{12}CH_4) = 0.0066$

* P3

R0

Isotopologue	Wavenumber (cm-1)	Intensity
$^{12}CH_4$	3028.7523	1.53E-19
$^{13}CH_4{}^*$	3028.8519	1.60E-21

(Wn.)/(Δ Wn.) = 30400

$I(^{13}CH_4)/I(^{12}CH_4) = 0.011$

*R1

R1

Isotopologue	Wavenumber (cm-1)	Intensity
$^{12}CH_4$	3038.4984	1.445E-19
$^{13}CH_4{}^*$	3038.6144	1.968E-21
$^{13}CH_4{}^*$	3038.6285	1.312E-21

(Wn.)/(Δ Wn.) = 26000

$I(^{13}CH_4)/I(^{12}CH_4) = 0.023$

*R2

Summary:

Transition	(Wn.)/(Δ Wn.)	$I(^{13}CH_4)/I(^{12}CH_4)$
P4	70904	0.018
P2	> 900000	0.007
R0	30400	0.011
R1	26000	0.023

R1 is the targeted transition.
$^{13}CH_4$ (R2) is to the blue side of $^{12}CH_4$ (R1)
Del dot 0f -16.0 km/sec shifts wavenumber by .16 cm^{-1}
- Best transition to retrieve $^{13}CH_4$ through the Earth's Atmosphere from those listed here.

Components of Atmospheric Model Used to Retrieve Gas Column Densities on Mars:

- Solar Model (based on Hase et al., *JQRST*, 102, (2006), 450-463)
- Mars Atmosphere Model*, Incoming (LBLTRM model)
- Surface Blackbody Component
- Mars Atmosphere Model*, Outgoing (LBLTRM model)
- Earth Terrestrial Model (LBLTRM model)

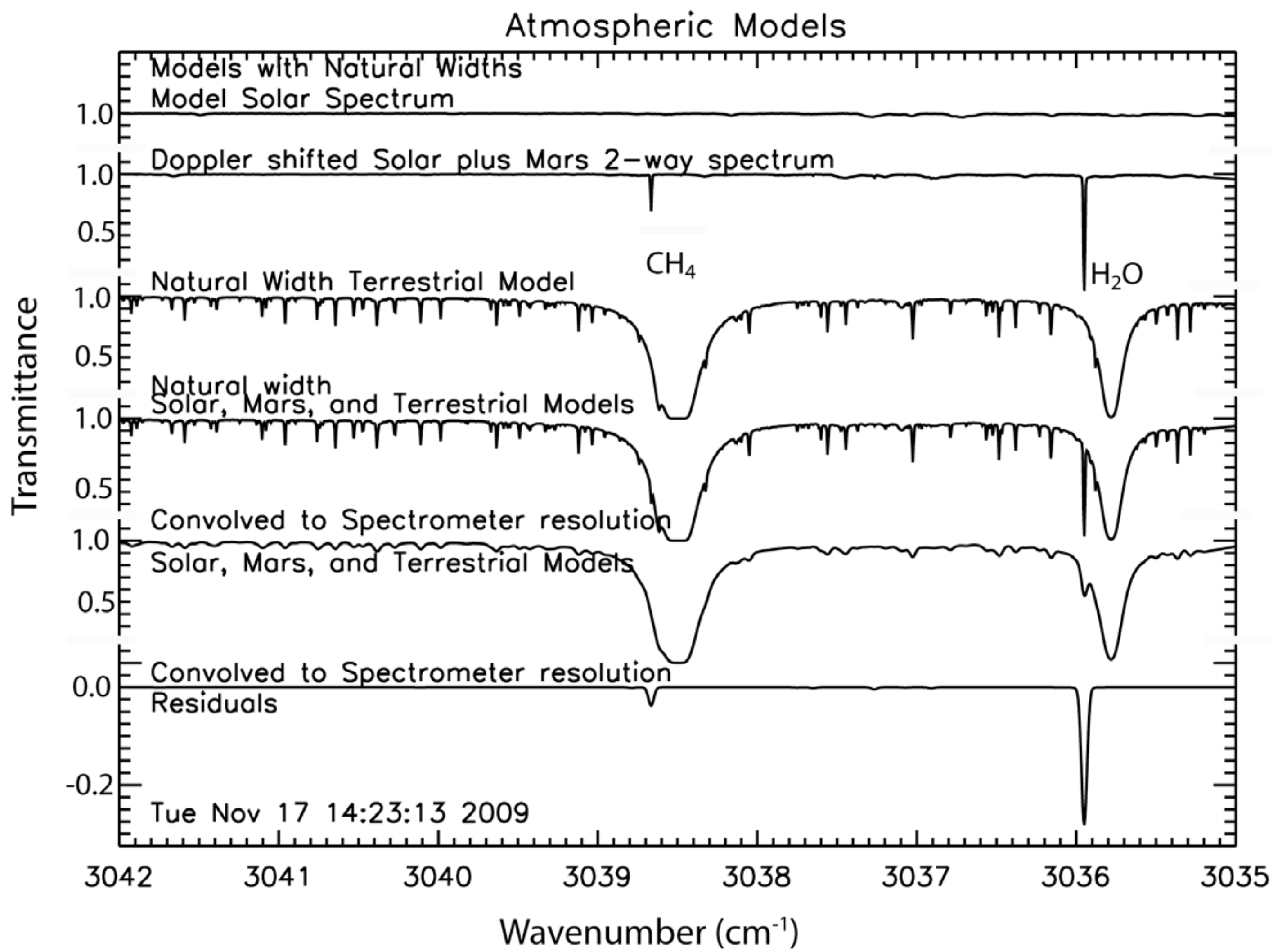
- Doppler shift between Sun and Mars (r dot)
- Doppler shift between Mars and Earth (del dot)

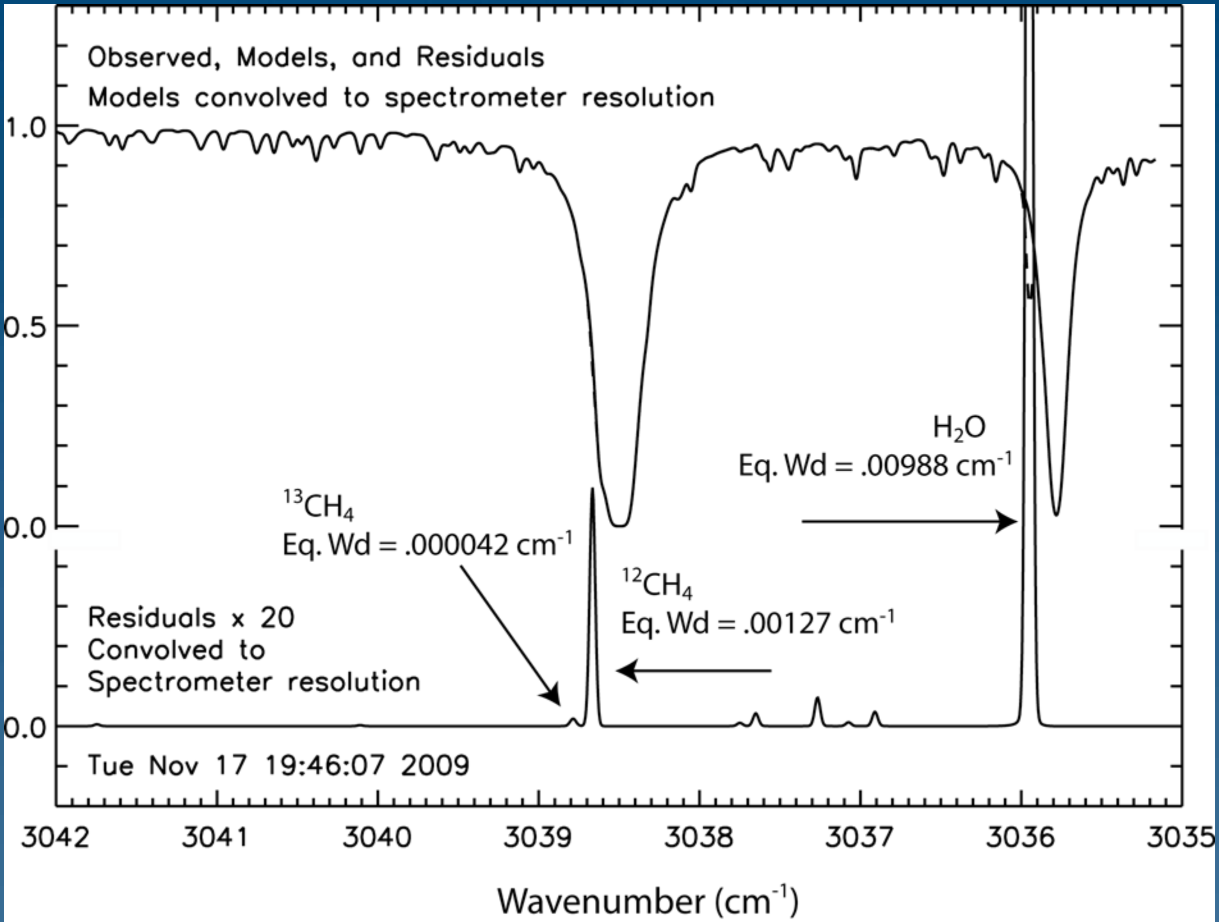
* 10 pr-microns H_2O, 40 ppb CH_4

[CH_4] = 40 ppb

Resolution = 75000

Relative velocity = -16.5 km/sec





Using noise = 0.0002 cm-1

$S/N(H_2O) = 49.4$

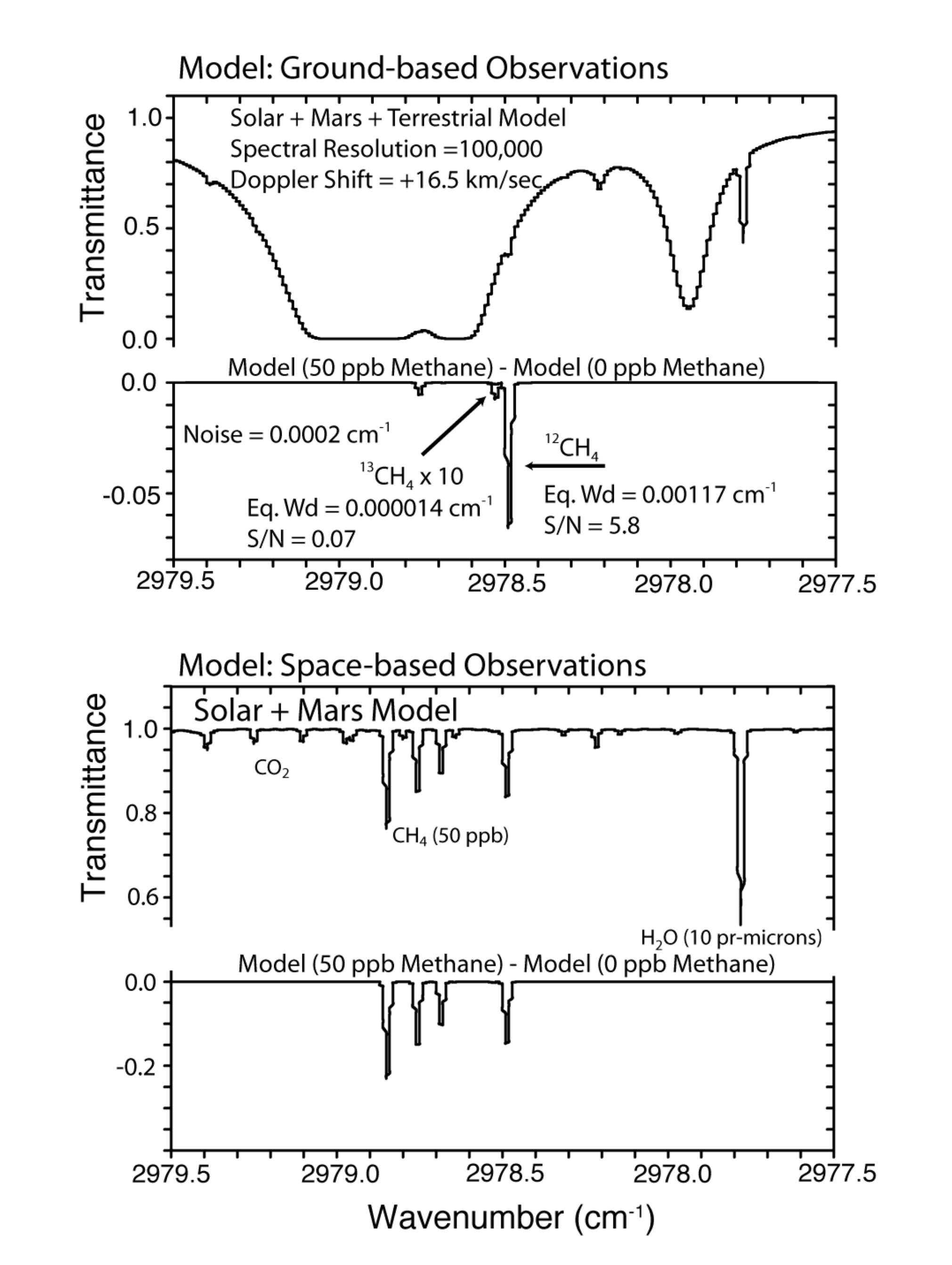
$S/N(^{12}CH_4) = 6.4$

$S/N(^{13}CH_4) = 0.2$

Model
P4 Transition

Ground-based:

Space-based:



Ground-Base Measurements of $^{13}CH_4/^{12}CH_4$:

- High Spectral Resolution (> 75000)
- Sufficient Doppler Shift (> 15 km/sec)
- Better S/N
  * Measure and Add Multiple Absorption Lines Simultaneously
  * More sensitive detectors

Possible Near Future Measurements:

- CRIRES on VLT
  * R > 100000
  * Altitude ~ 2600 m
  * precipitable terrestrial Water Vapor ~ 3.0 mm
  * Multiple lines of Methane

- iSHELL on NASA-IRTF (funded proposal)
  * R ~ 70000
  * Altitude ~ 4200 m
  * precipitable terrestrial Water Vapor ~ 1.0-2.0 mm
  * Cross disperse Spectrograph
    - Multiple Lines.

Suggested Future Work:

- High Resolution Space Based Near IR Spectrograph

- Detection/Models for $^{12}CH_3D$