

Organic Composition of Comet C/2004 Q2 (Machholz)

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SUIA 2007

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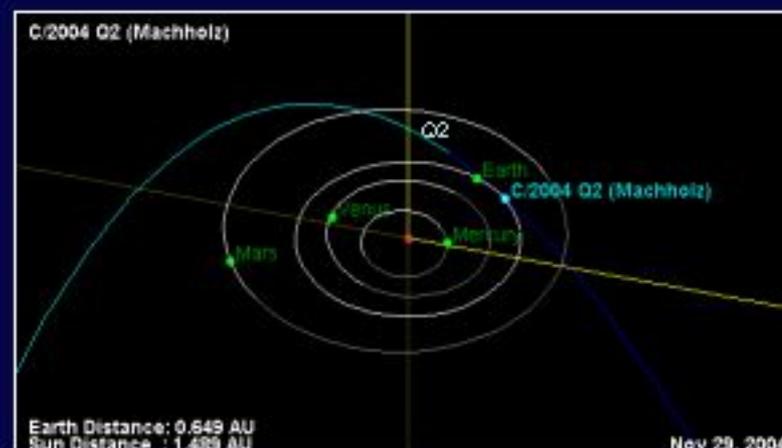
NASA GSFC

Astronomy, Biology, Comets ...

- **Astronomy** is about **Evolution** ...
 - “*birth*”, “*lifespan*”, “*death*” of stars ...
 - **formation of planetary systems** ...
- **Biology** is about **life** (as we know it) ...
 - requires presence of **Water**, **Pre-biotic organics** ...
- **Comets**
 - formed **early** in the history of the Solar system
 - might have delivered **Water and Pre-biotic organics to early Earth (???)**

C/2004 Q2 (Machholz)

- Newly discovered comet (2004)
- Two observing runs
 - November 28, 29, 2004
 - $\Delta = \sim 0.642$ AU
 - $R_h = \sim 1.48$ AU
 - January 19, 2005
 - $\Delta = \sim 0.377$ AU
 - $R_h = \sim 1.21$ AU
- Test of heterogeneity



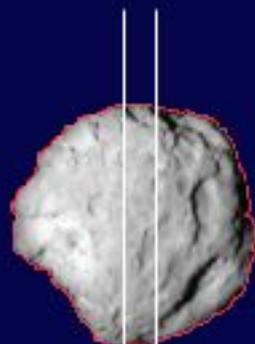
<http://ssd.jpl.nasa.gov/sbdb.cgi>

- Keck Observatory on Mauna Kea, Hawaii.
- NIRSPEC- Near Infrared Echelle Spectrograph
 - 1-5 μm (Many molecules emit in this region)
 - $\lambda/\delta\lambda \sim 25,000$ (Resolving Power)

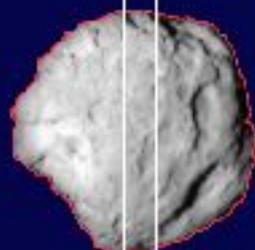


Mode of Observation

Spectrometer Slit



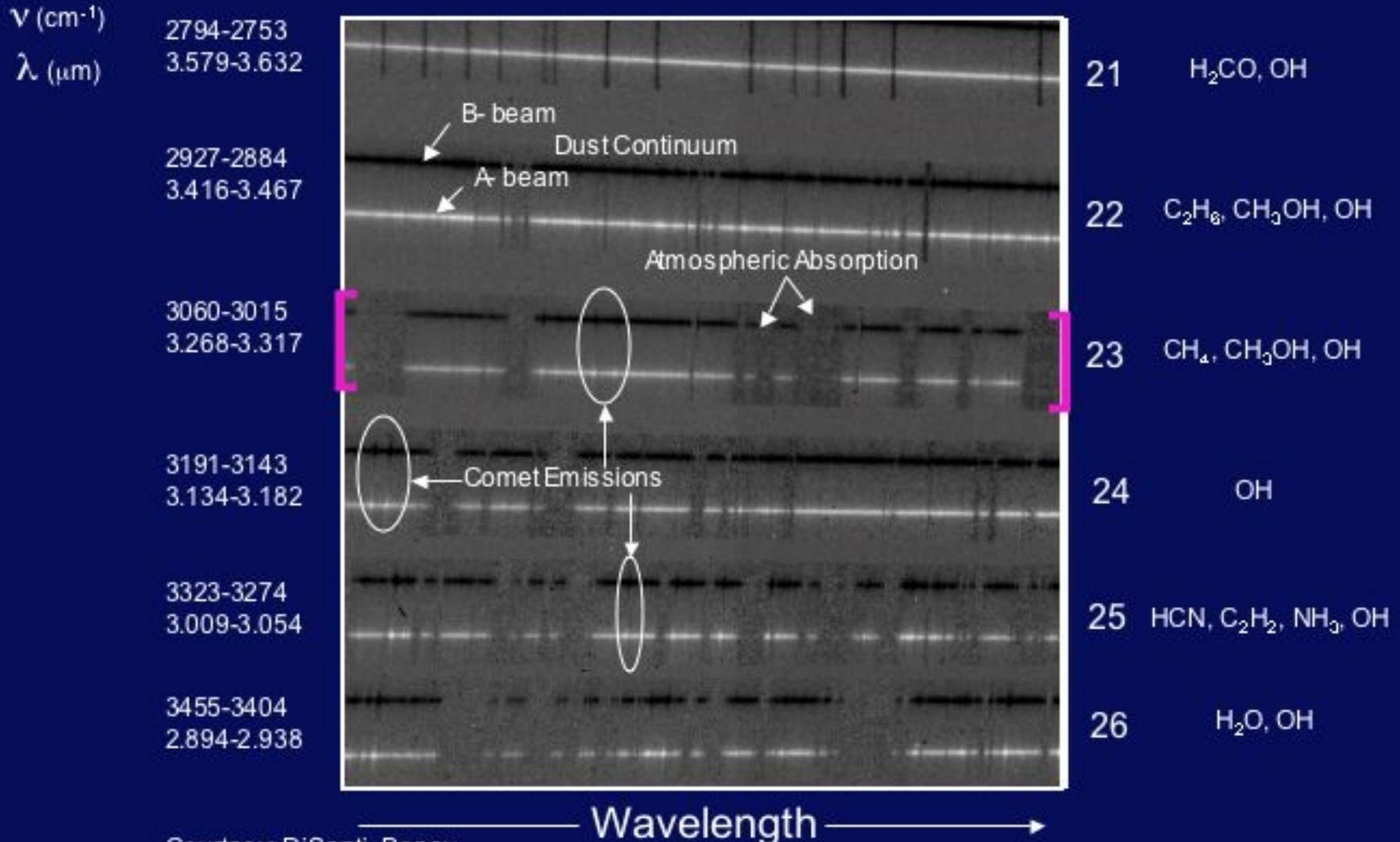
B-Beam Position



A-Beam Position

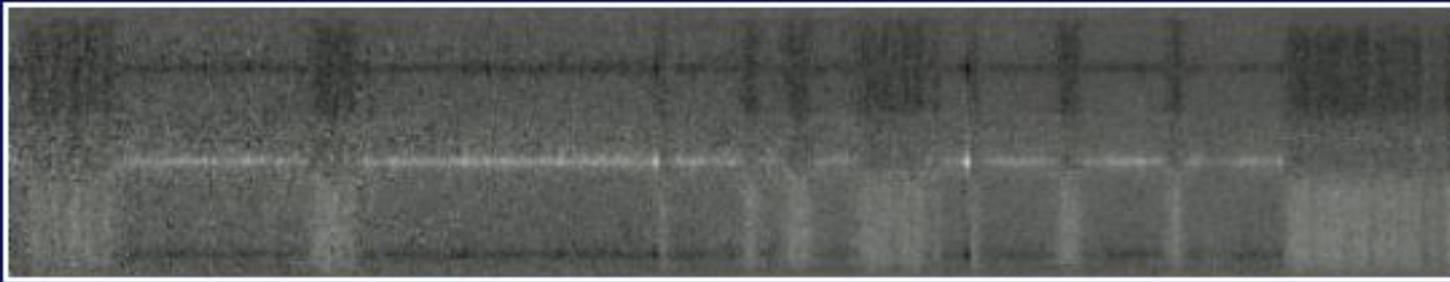
NIRSPEC Echellogram

C/2004 Q2 (Machholz) UT 2005 Jan 19, KL 2

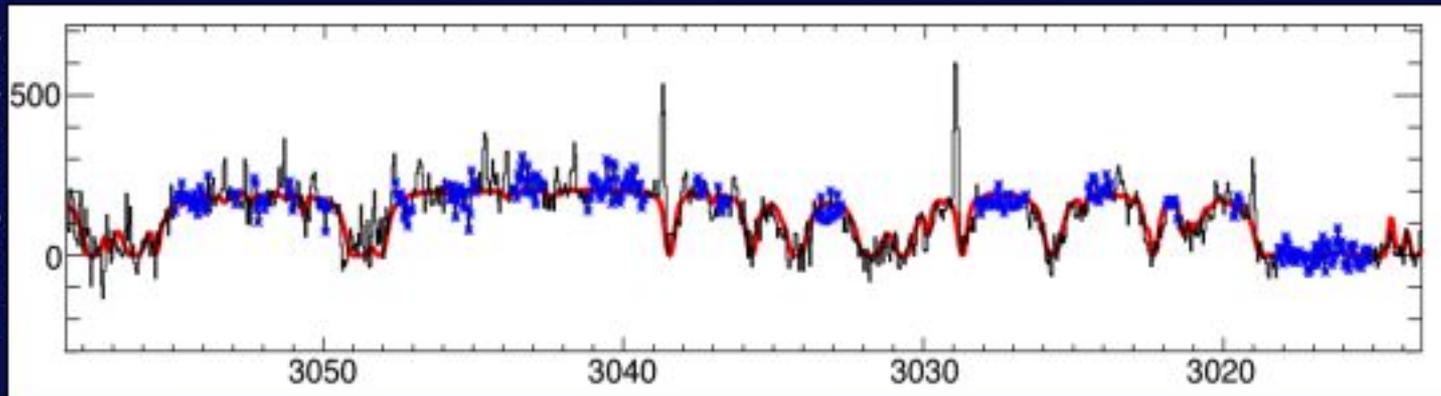


Courtesy: DiSanti, Bonev

Extracting a Spectrum



- Straightened spectral order



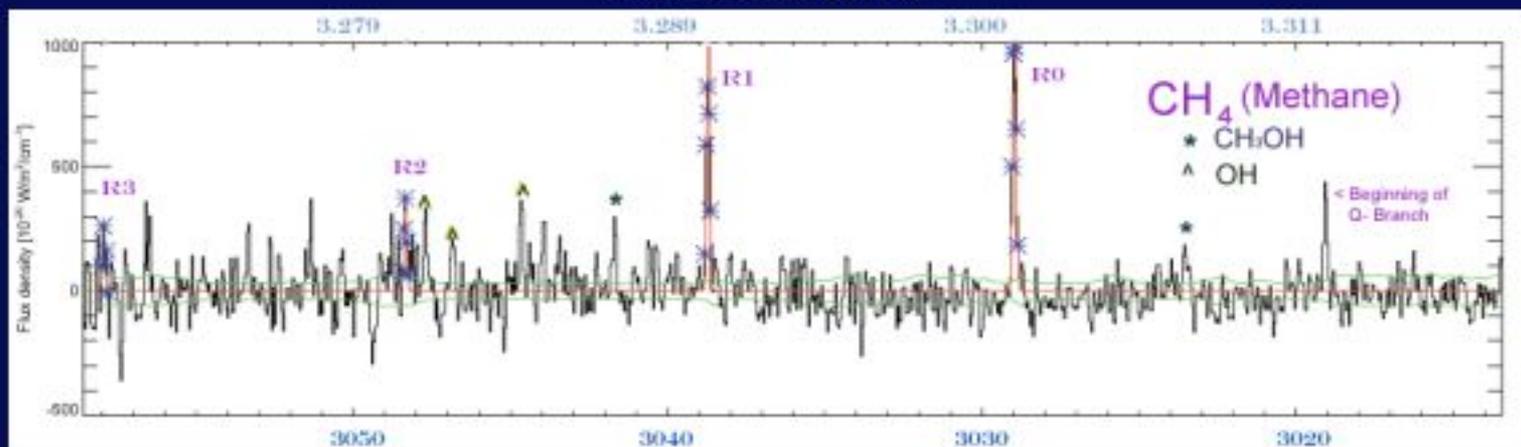
- Extracted spectrum with atmospheric absorbance model

Wavenumber (cm^{-1})

- Residual comet spectrum

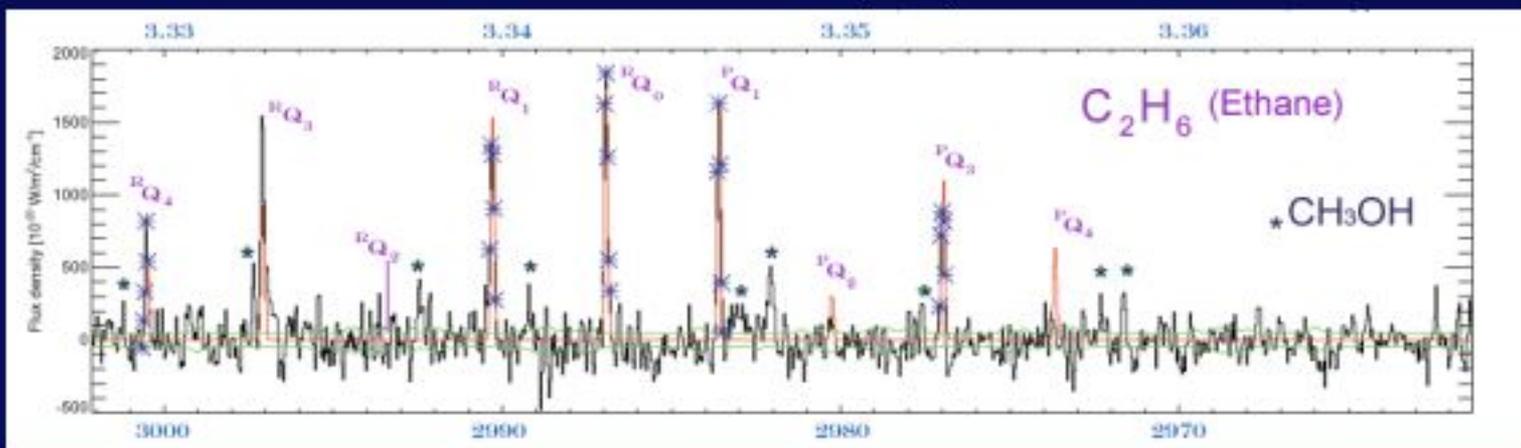
C/2004 Q2 (Machholz)- 28 Nov 2004, KL2 order 23

Wavenumber (cm^{-1})



Frequency (μm)

Wavenumber (cm^{-1})

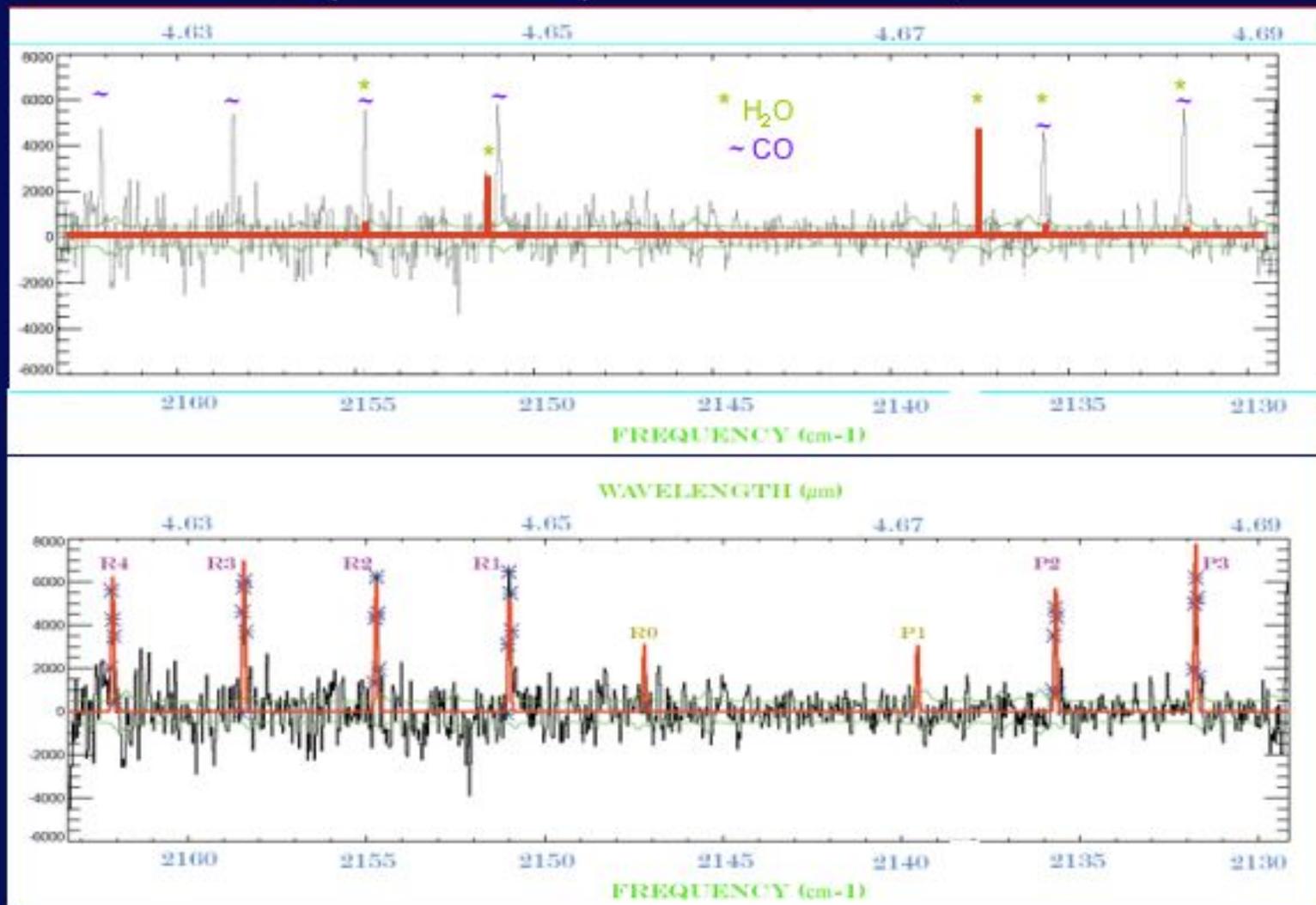


Frequency (μm)

C/2004 Q2 (Machholz)- 28 Nov 2004, KL1 order 23

Fluorescence Models

C/2004 Q2 (Machholz)- 29 Nov 2004, Order 16-Mide



Principle Measurements

- Rotational Temperature (T_{rot}) K
- Production Rate (Q) s^{-1}
- Mixing Ratio = $[Q_{\text{molec}}]/[Q_{\text{H}_2\text{O}}]\%$

C/2004 Q2 (Machholz)

28-29 November 2004

Molecule	T_{rot} (K)	Production Rate $\times 10^{27}$ (s^{-1})	Mixing Ratio $[Q/[Q_{\text{H}_2\text{O}}]]\%$
CH ₃ OH	75	3.58 ± 0.13	3.11 ± 0.27
C ₂ H ₆	80	0.90 ± 0.04	0.78 ± 0.07
H ₂ O (2.96 μm)	$115^{-17}/_{+22}$	115 ± 9.1	100
CH ₄	80	2.07 ± 0.06	1.54 ± 0.07
HCN	$73^{-7}/_{+8}$	0.23 ± 0.02	0.17 ± 0.02
C ₂ H ₂	80	0.19 ± 0.06	0.14 ± 0.05
H ₂ O (2.91 μm)	$102^{-3}/_{+2}$	134 ± 4.5	100
CO	$90^{-18}/_{+21}$	7.32 ± 0.39	4.72 ± 0.80
H ₂ O (4.66 μm)	90	155 ± 25	100

C/2004 Q2 (Machholz)

Mixing Ratios $[Q_{\text{molec}}]/[Q_{\text{H}_2\text{O}}]\%$

Molecule	Nov. 2004	Jan. 2005
CO	4.72 ± 0.80	-
CH ₃ OH	3.11 ± 0.27	-
C ₂ H ₆	0.78 ± 0.07	-
CH ₄	1.54 ± 0.07	$1.69 \pm 0.22^*$
HCN	0.17 ± 0.02	$0.16 \pm 0.01^*$
C ₂ H ₂	0.14 ± 0.05	$0.09 \pm 0.01^*$
Heliocentric Distance: ~1.49 AU		~1.21 AU

**November and January results
agree within 1 sigma**

**Implies that Q2's nucleus
is homogeneous.**

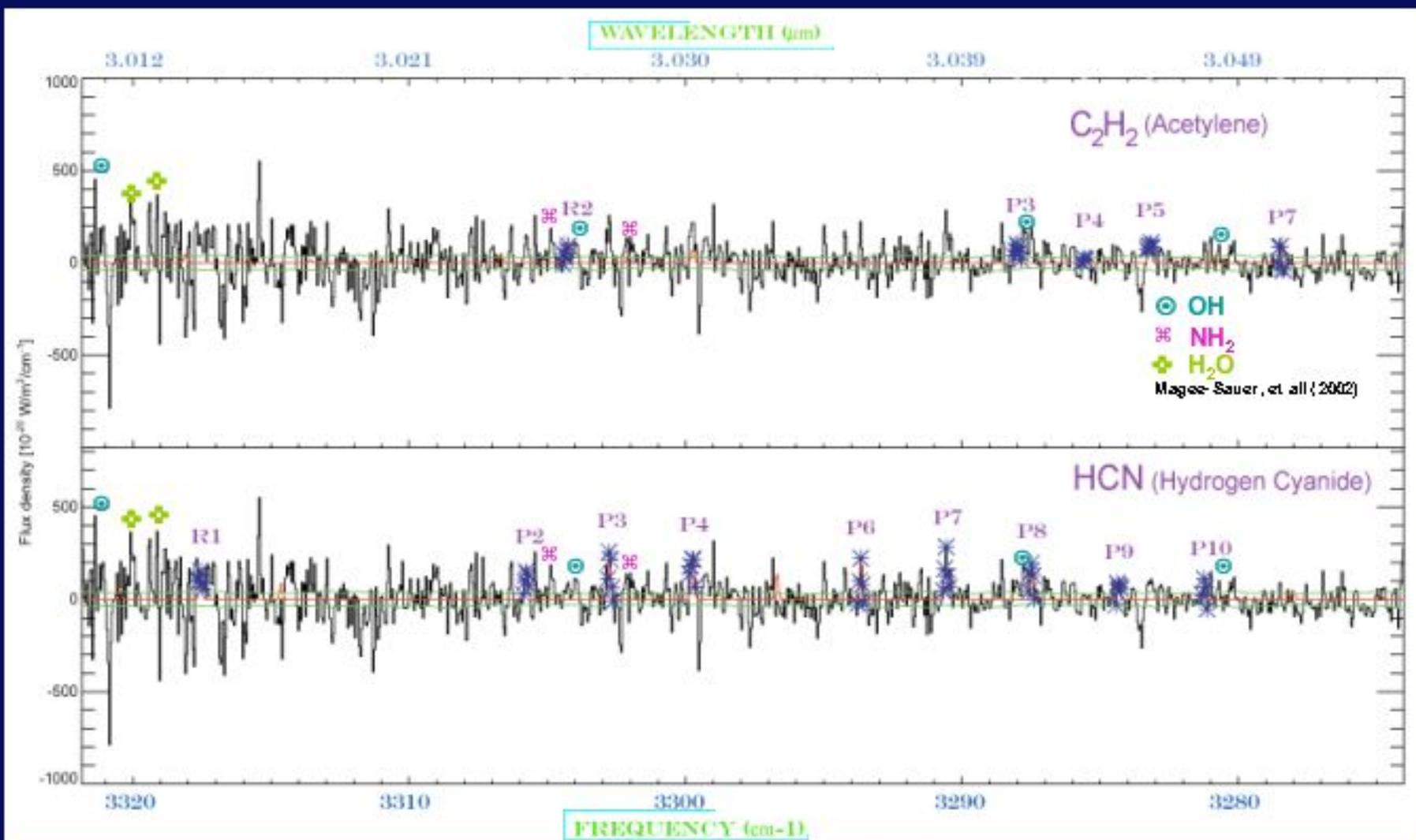
* Bonev, 2007

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- Justin Nuesma, SUIA 2007

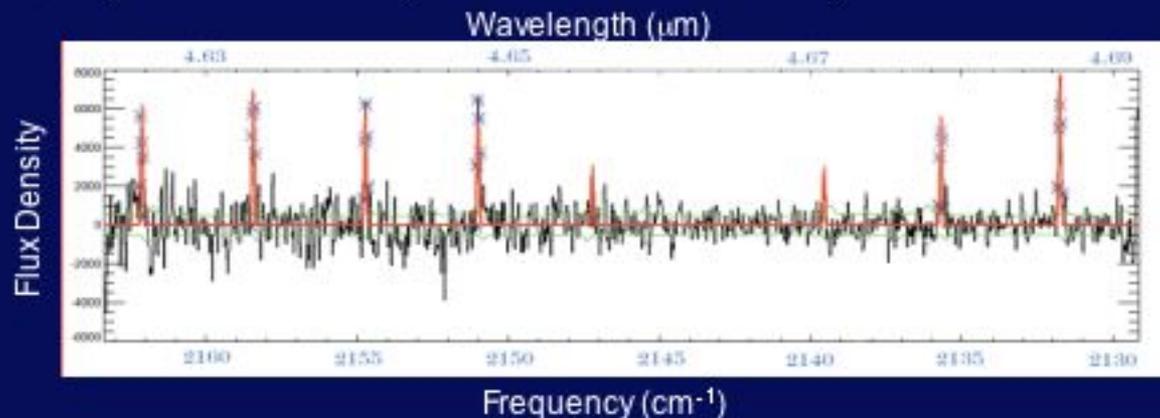
Additional Orders

C/2004 Q2 (Machholz)- 28 Nov 2004, KL2 order 25



Rotational Temperature

C/2004 Q2 (Machholz)- 29 Nov 2004, M-wide order16



- Observed line flux, F_{line} , is temperature dependent
- Fluorescent emission models, g-factors, (red line) at a range of temperatures are compared to observed lines
- At the best fit T_{Rot} , F_{line}/g is independent of temperature

C/2004 Q2 (Machholz) 29 Nov 2004

$$T_{\text{Rot}}(\text{CO}) = 90^{-18/+21} \text{ K}$$

Slope of F_{line}/g



Rotational Temperature (K)

Preparing Data for Analysis

- KL2 filter
 - Six orders, 40 cm^{-1}
- Crop
- Masks
 - Dark field subtraction
 - Flat fielding
 - Remove dead pixels and cosmic ray hits
- Spatial Alignment
- Spectral Alignment and Calibration

