An Empirical Model for Methanol (CH_3OH) in Comets

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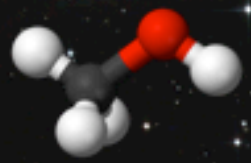

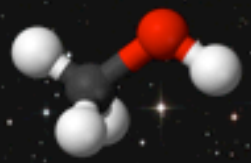

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The Goddard Center for Astrobiology
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Introduction

- Ultimate Objective: to better understand the composition of the early solar system
- Immediate Objective: to better characterize methanol in comets

1) Developed empirical fluorescence model for ν_3 band
2) Calculated fluorescence g-factors for features in ν_2 and ν_9 band region

Comets

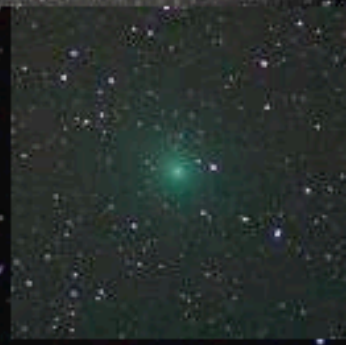
Tuttle (52K)

C/2001 A2 (100K)

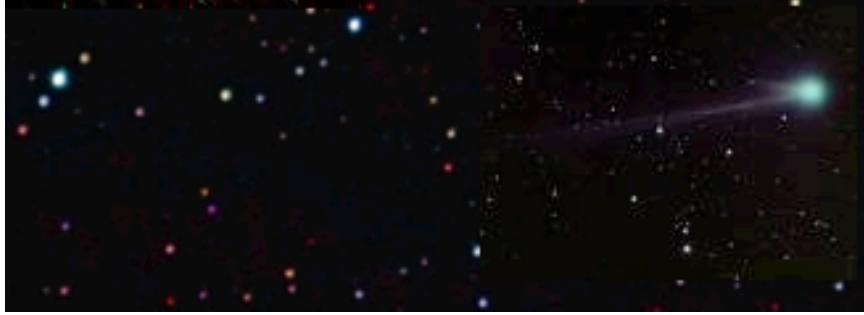
C/2007 Lulin (68K)

C/2004 Q2 (95K)

McNaught-Hartley (70K)



Boattini (85K)

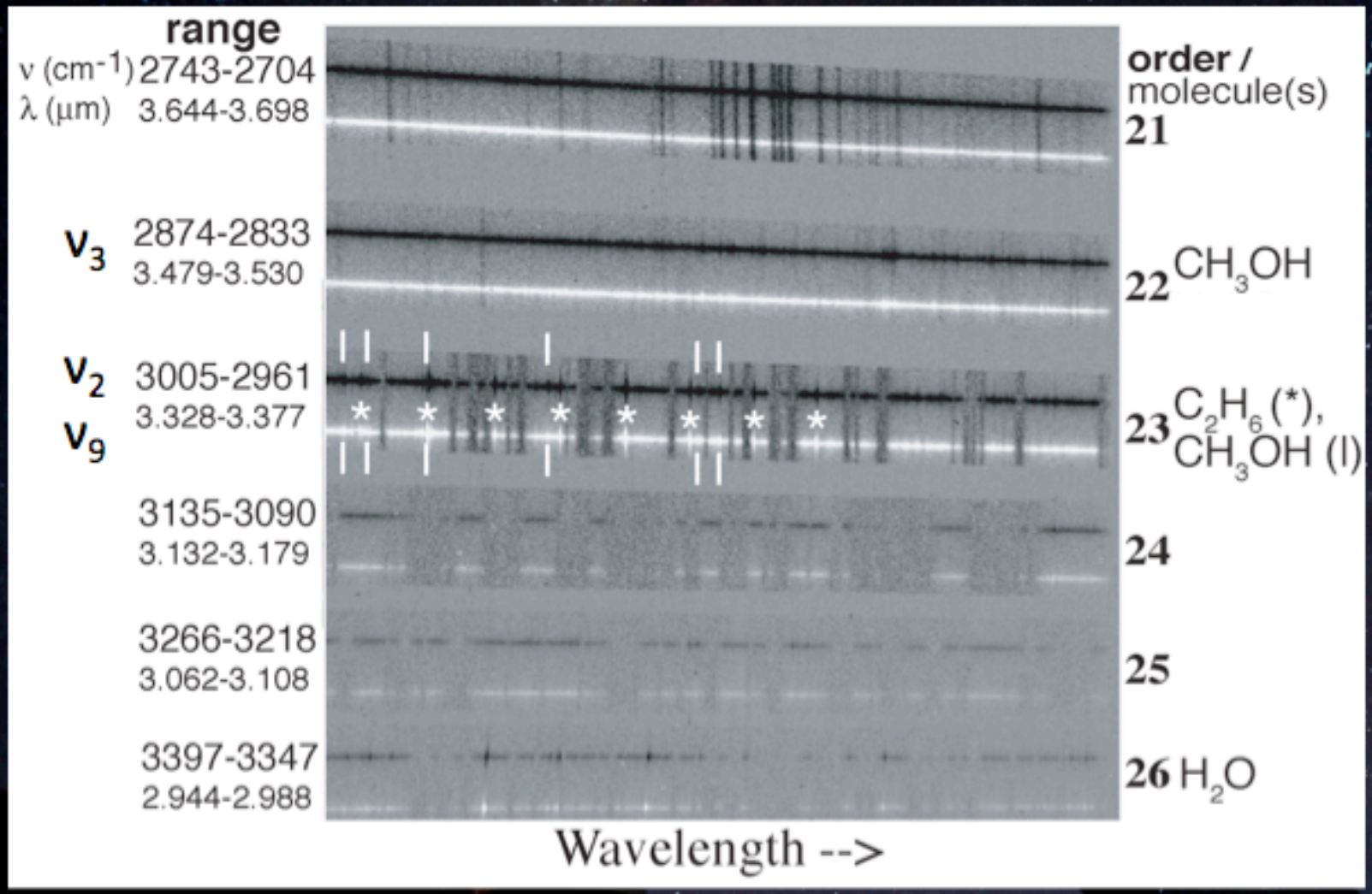


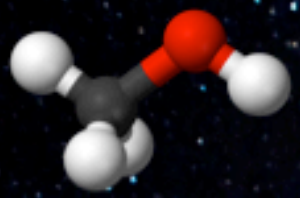
K4 Linear (75K)

NIRSPEC

- High-resolution $\lambda/\Delta\lambda \approx 40{,}000$ [I used 25,000]
- Sensitive to $\lambda \approx 1\text{-}5\mu m$ [I used 3.33-3.53μm]
- Large simultaneous wavelength coverage

NIRSPEC Echellogram





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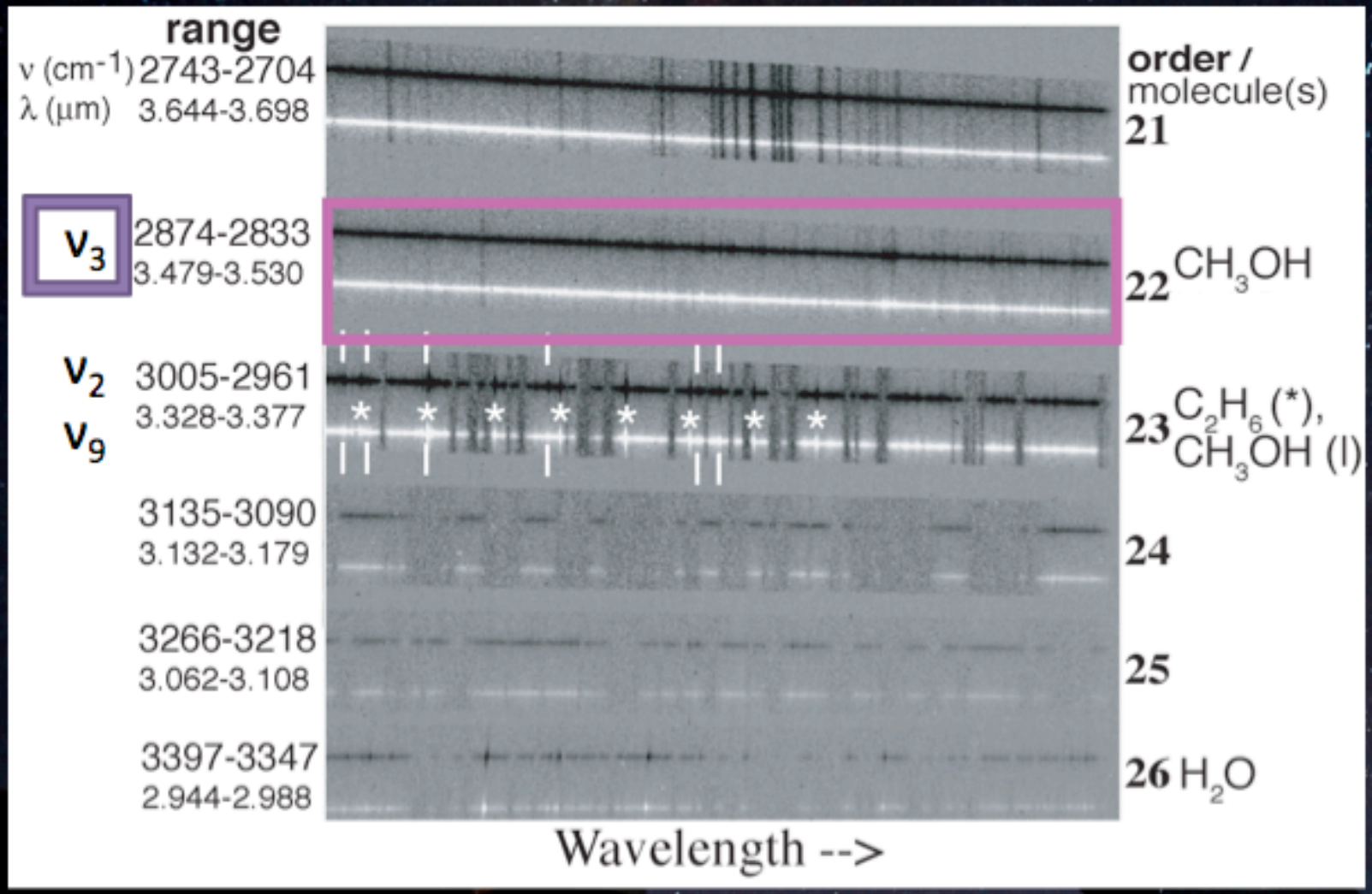

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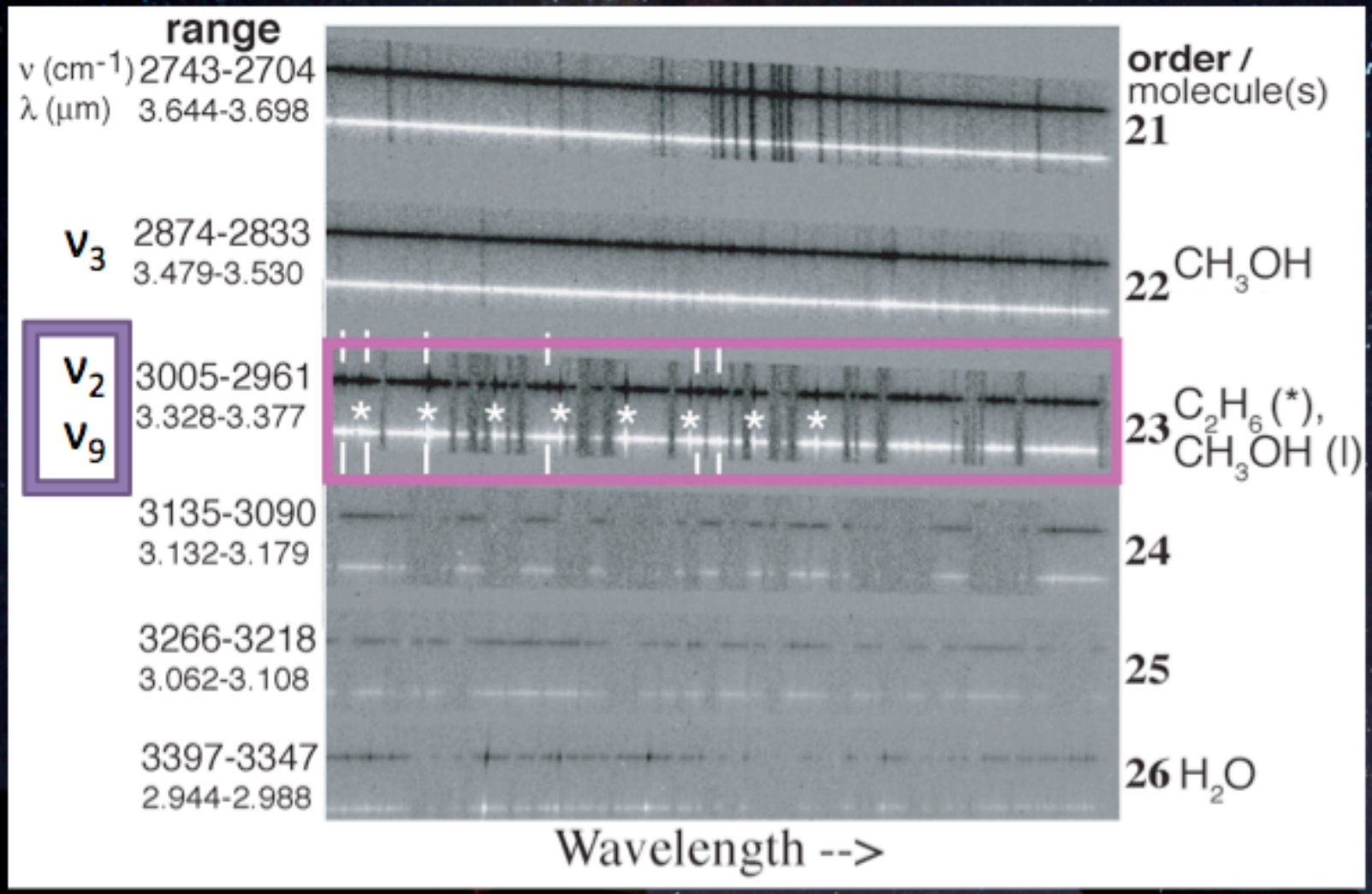
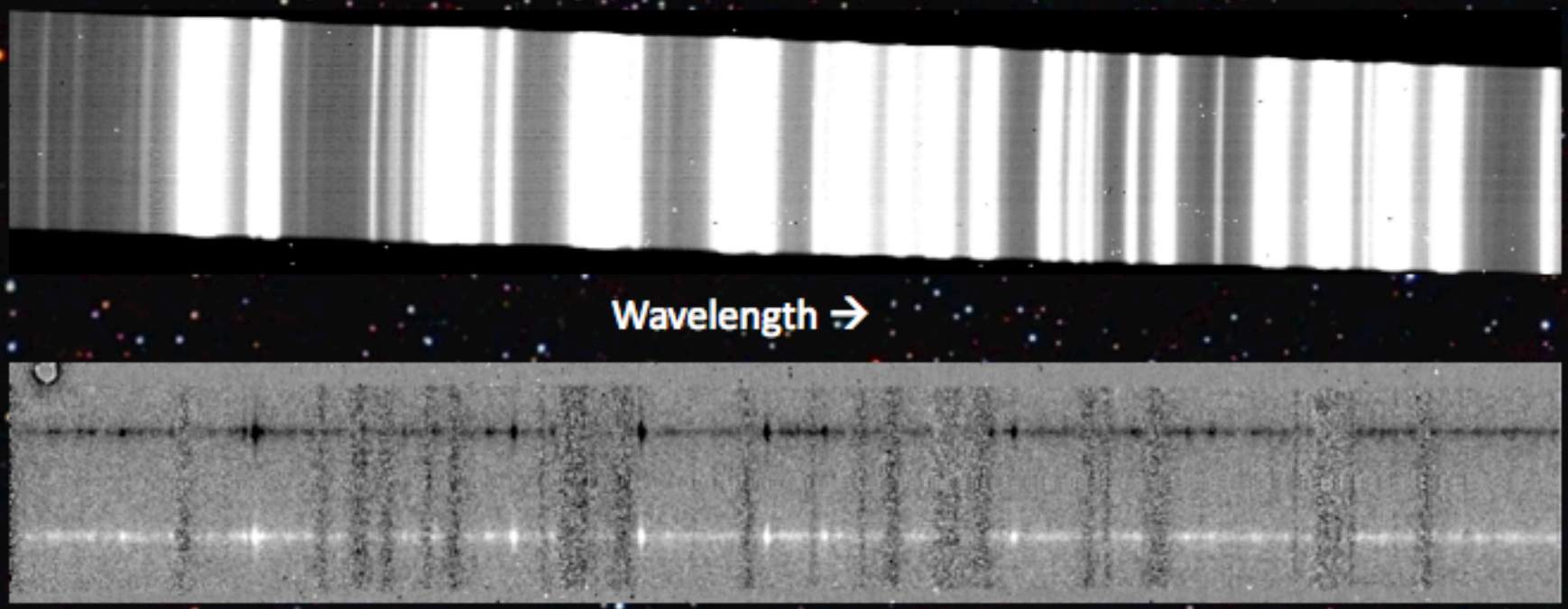


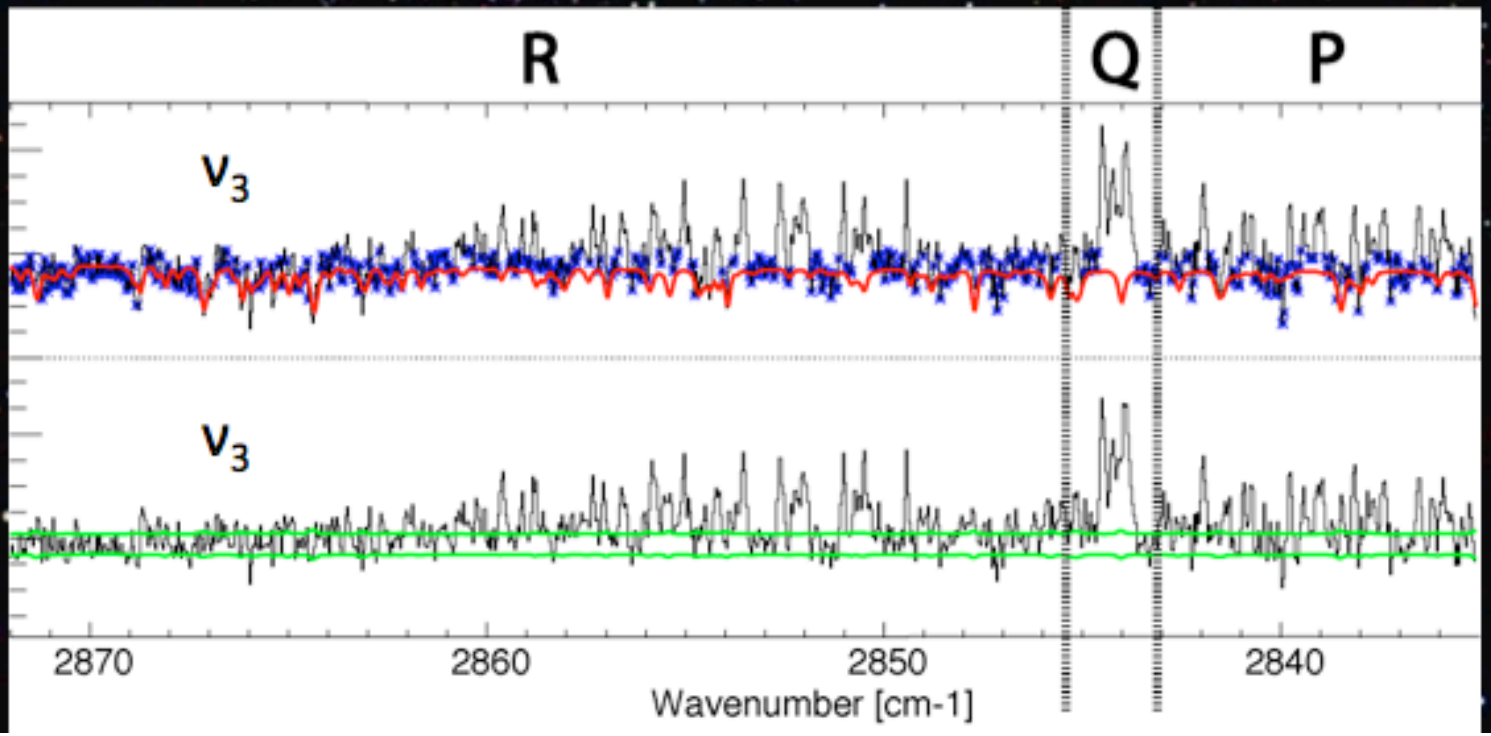
Order Processing

- Removing hot pixels
- Spatial straightening
- Spectral straightening



Residuals

- Combine A and B beams
- Remove the cometary continuum
- There remains associated stochastic error



Production Rate and Line Intensity

$$Q = w * F_{Line} / g_{Line}$$

Q : production rate (molecule/second)

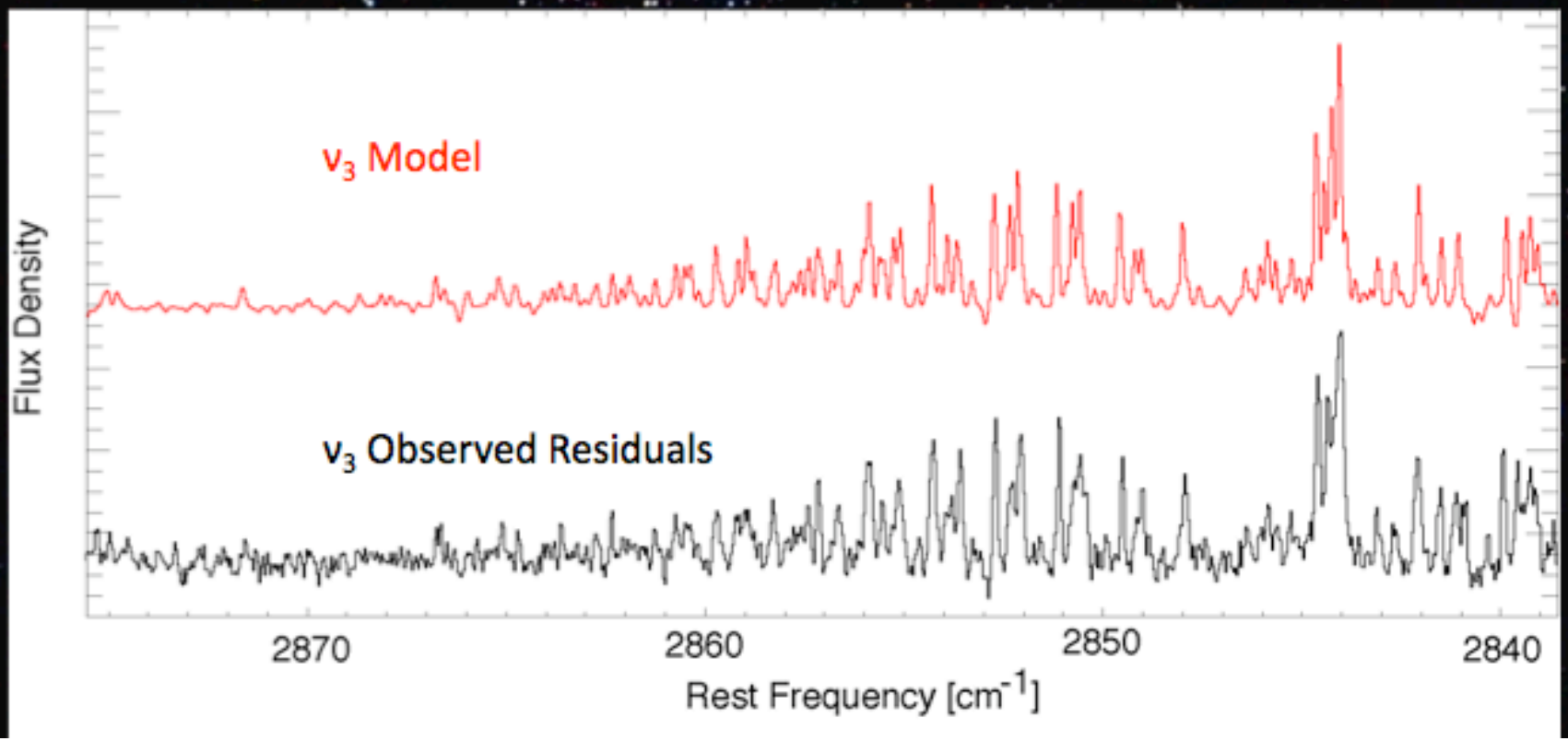
w : conversion constant

F_{Line} : line flux (watts/meter^2)

g_{Line} : g-factor (photon/second/molecule)

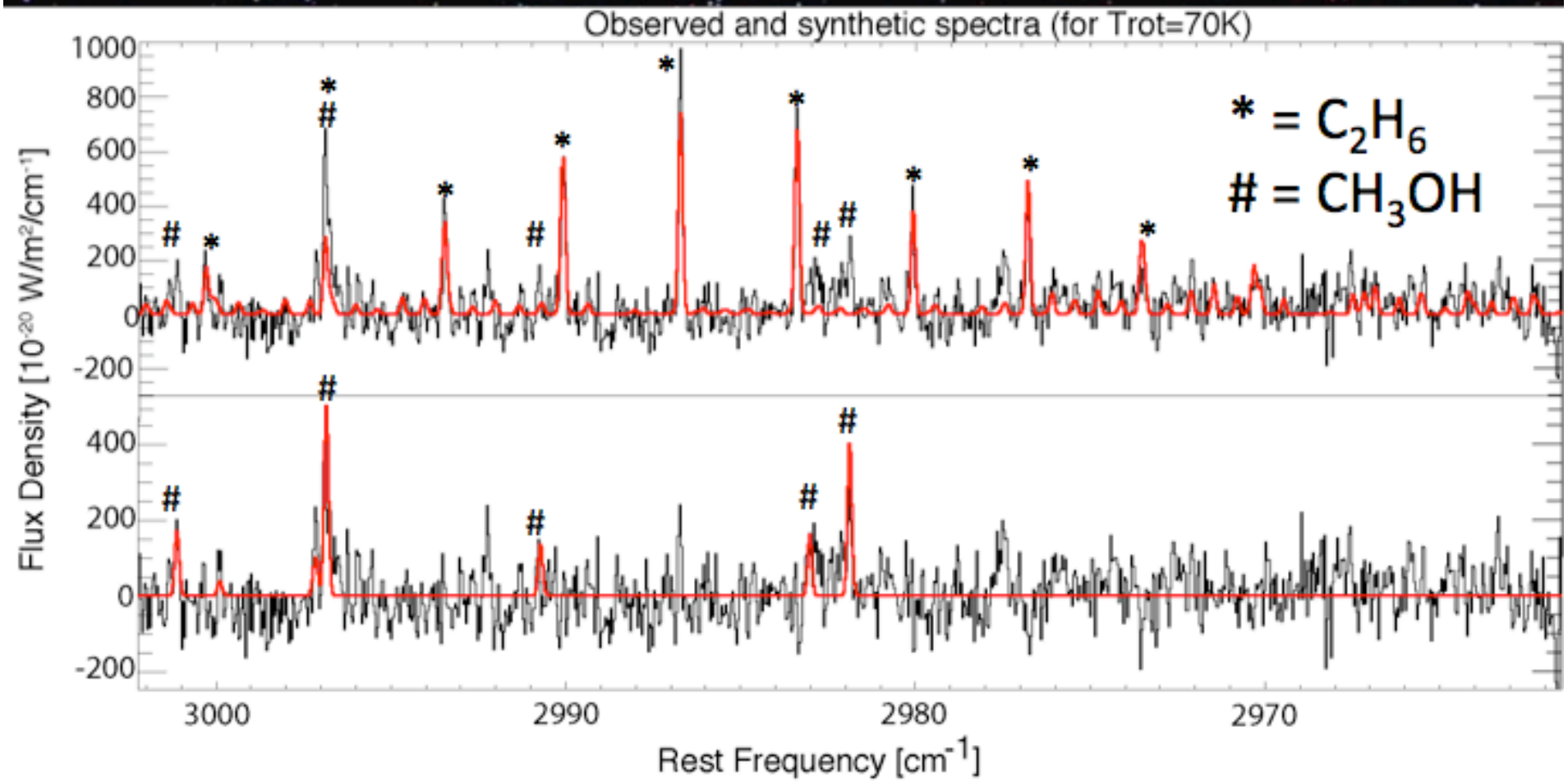
ν_3 Band Empirical Models

- Sample bins of 3 – 5 pixels
- Find average wave number, intensity, and error
- Apply model to residuals to obtain production rate



ν_2, ν_9 Band Region

- Subtracted contribution from ethane



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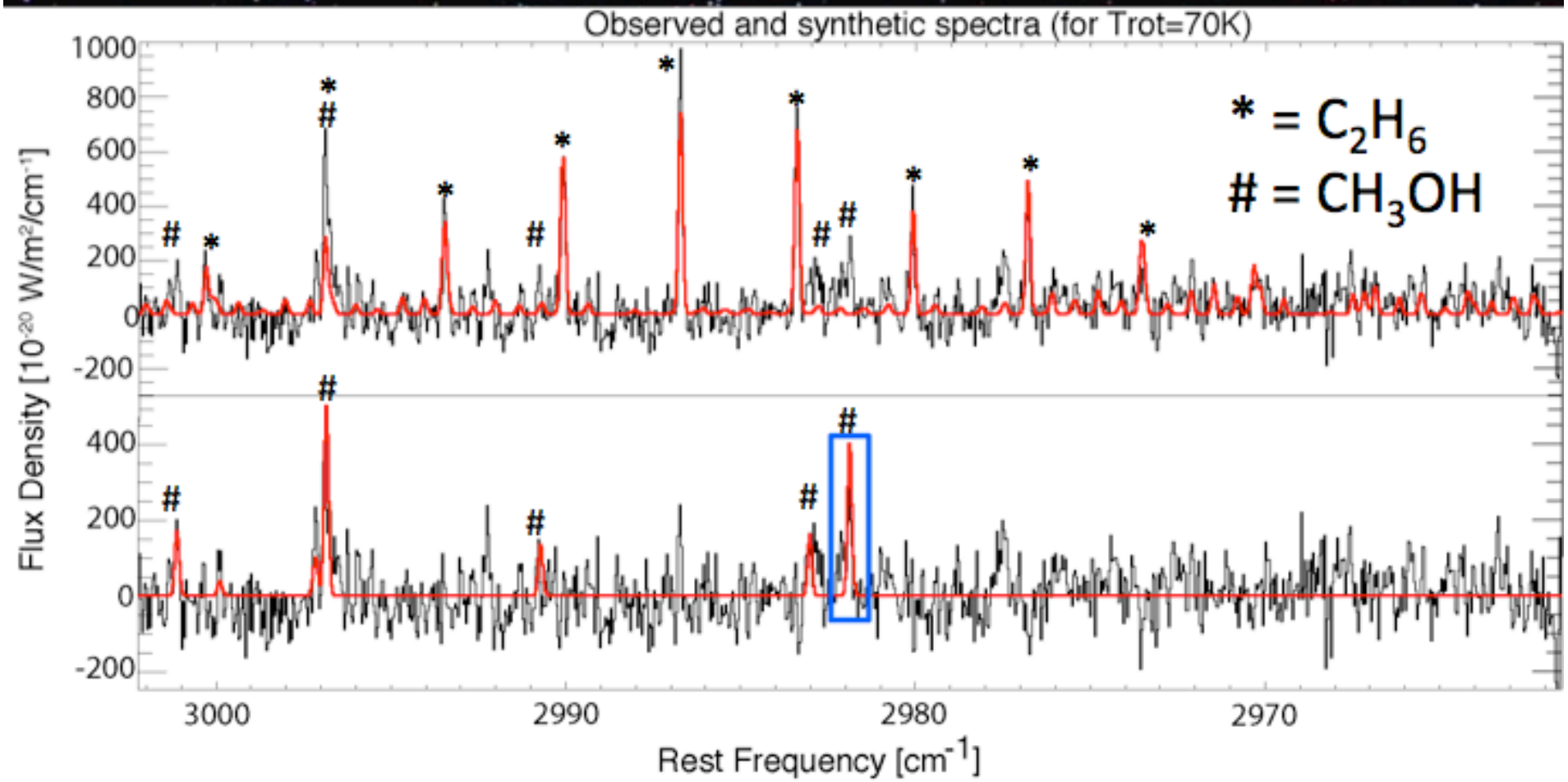
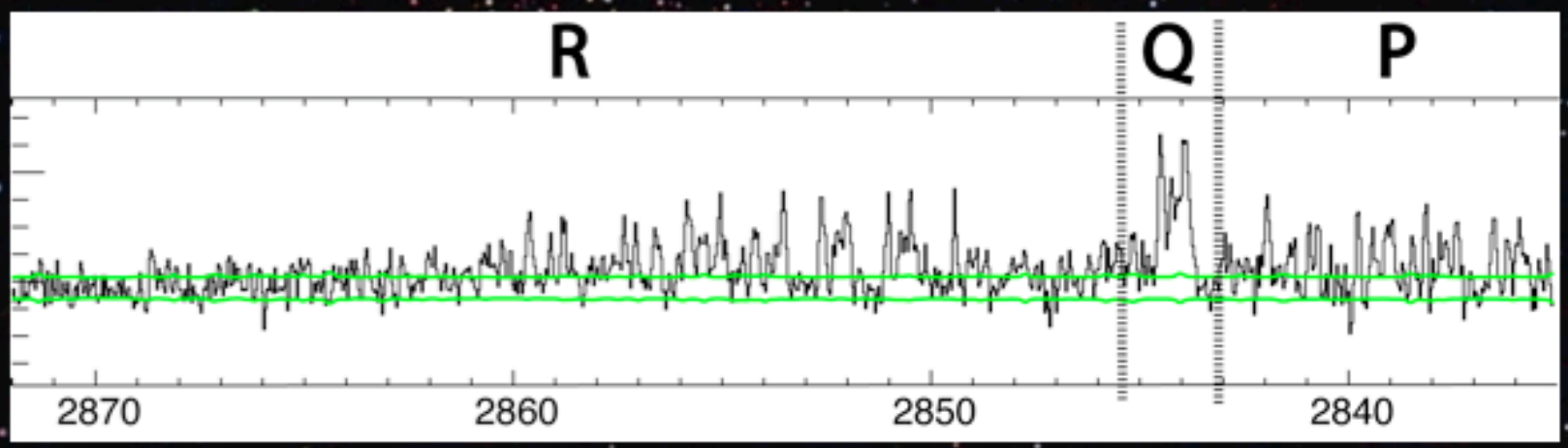


ν_2, ν_9 Band Region g-factors

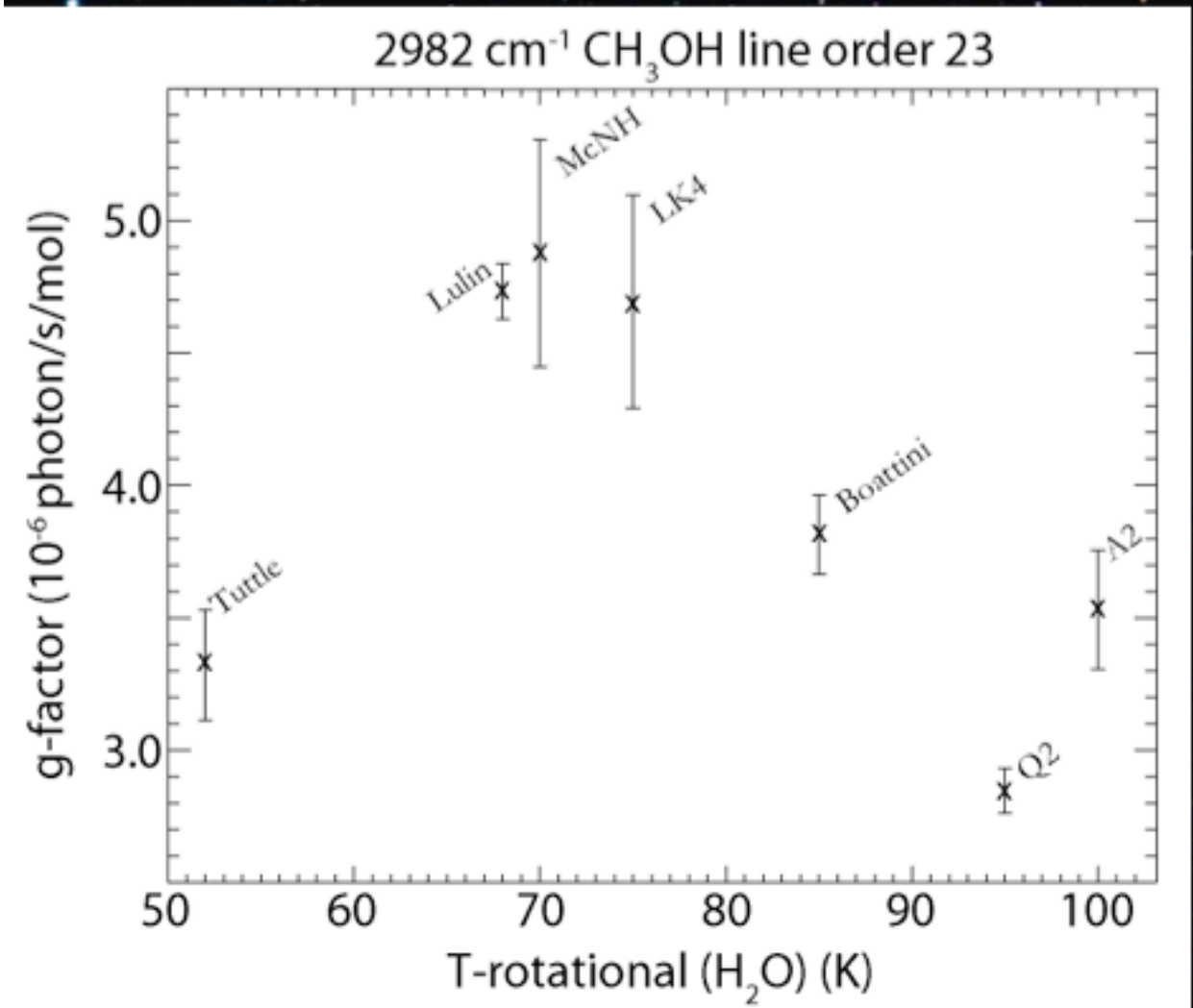
- Establish line-by-line g-factors based on empirical model
- Calibrate to production rate based on ν_3 Q-branch



- Apply to methanol feature at 2982cm^{-1}

g-factor Dependency

- g-factors at 2982 cm^{-1} exhibits T_{rot} dependency



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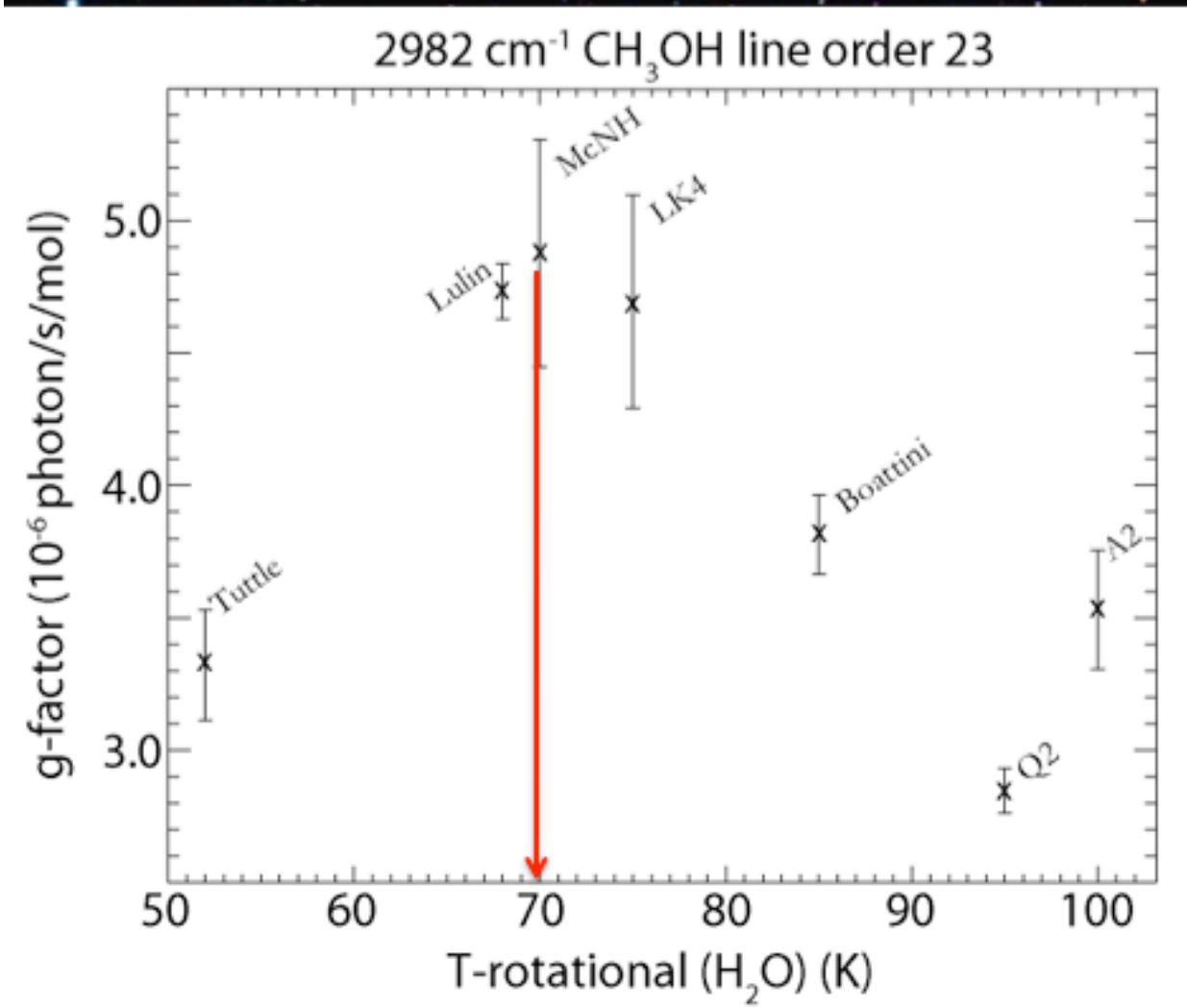

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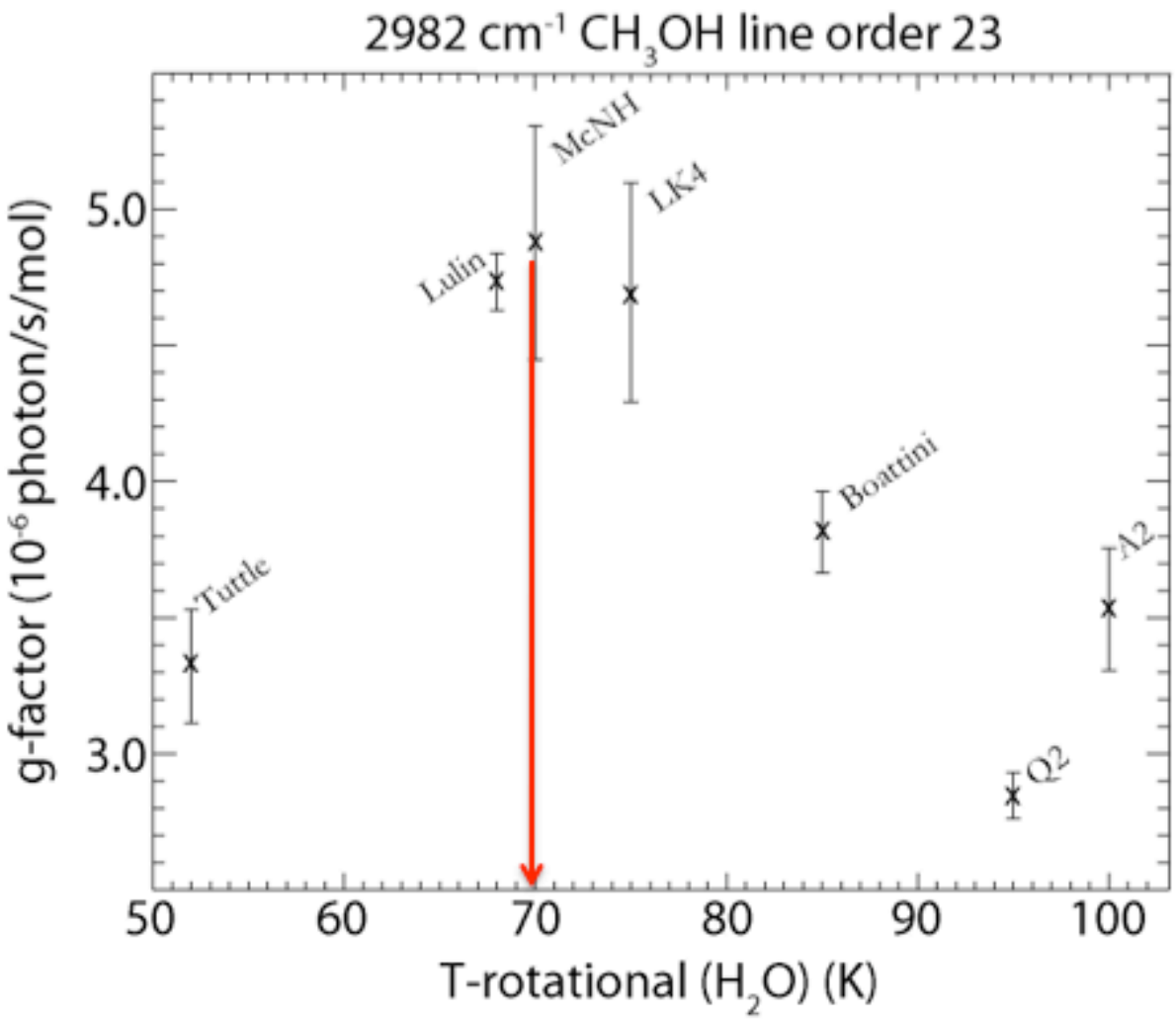

$\langle E \rangle \approx c_2 T_{rot}(\max g_{Line})$

$T_{rot} \approx 70K$

$\langle E \rangle \approx 50\ cm^{-1}$

Conclusions and Extensions

- Empirical approach is viable means of characterizing methanol
- Use of comets as natural, low temperature laboratories to test quantum mechanical models
- Application to additional comets to generate a more comprehensive database

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