Tracing Organic Chemistry in Primordial Disks Through High-Resolution Infrared Spectroscopy

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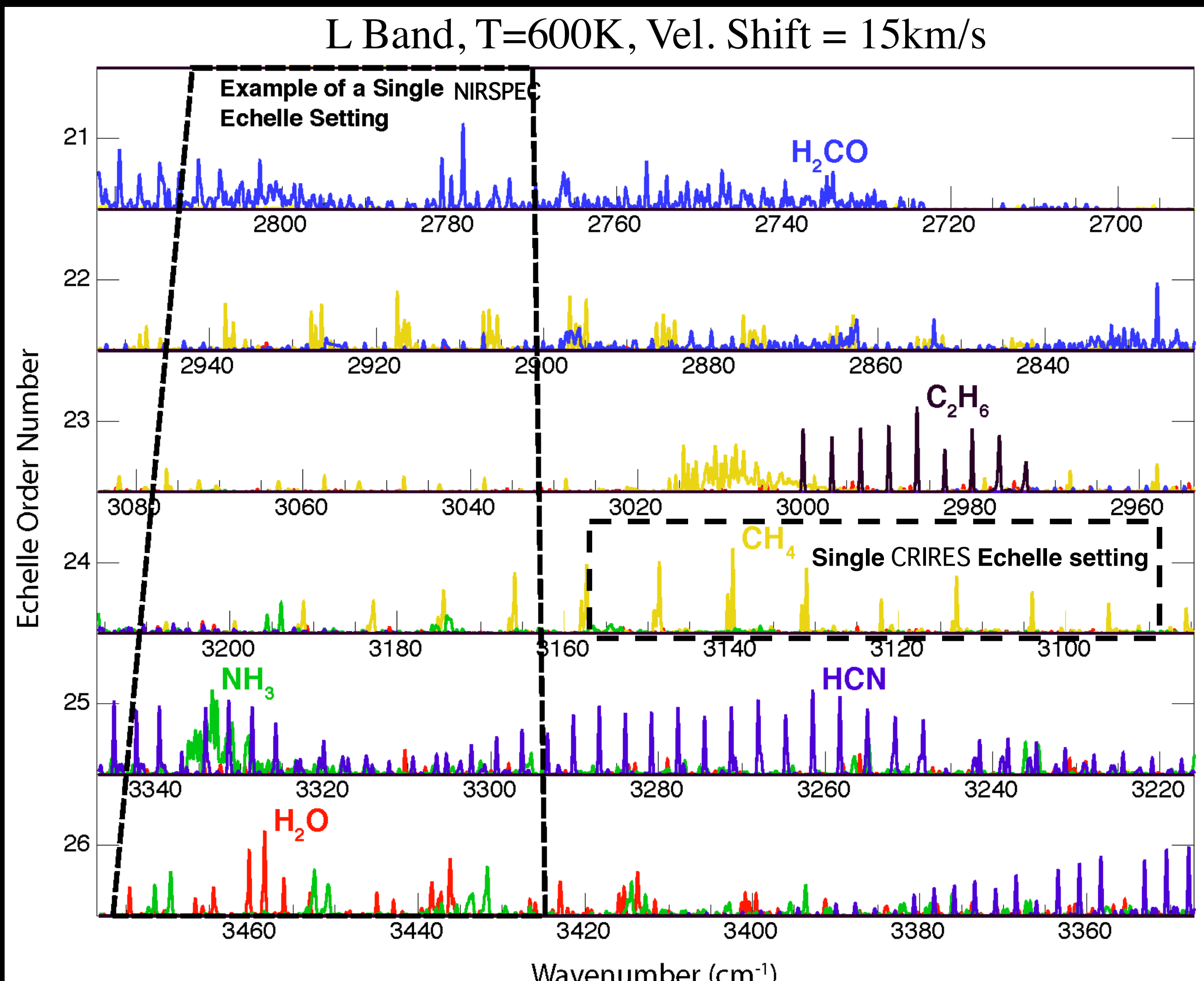
Introduction…

- Understanding the thermal and chemical structure of the gaseous component of circumstellar disks will allow us to better track volatile material through the evolution from dust to planets
- We are on the cusp of tracing out the major chemical gas species in the terrestrial-planet zone using high-resolution NIR spectroscopy

High-Resolution Spectroscopy at 3 - 4 µm:

Excellent Tracer of Warm Molecular Volatile Gases

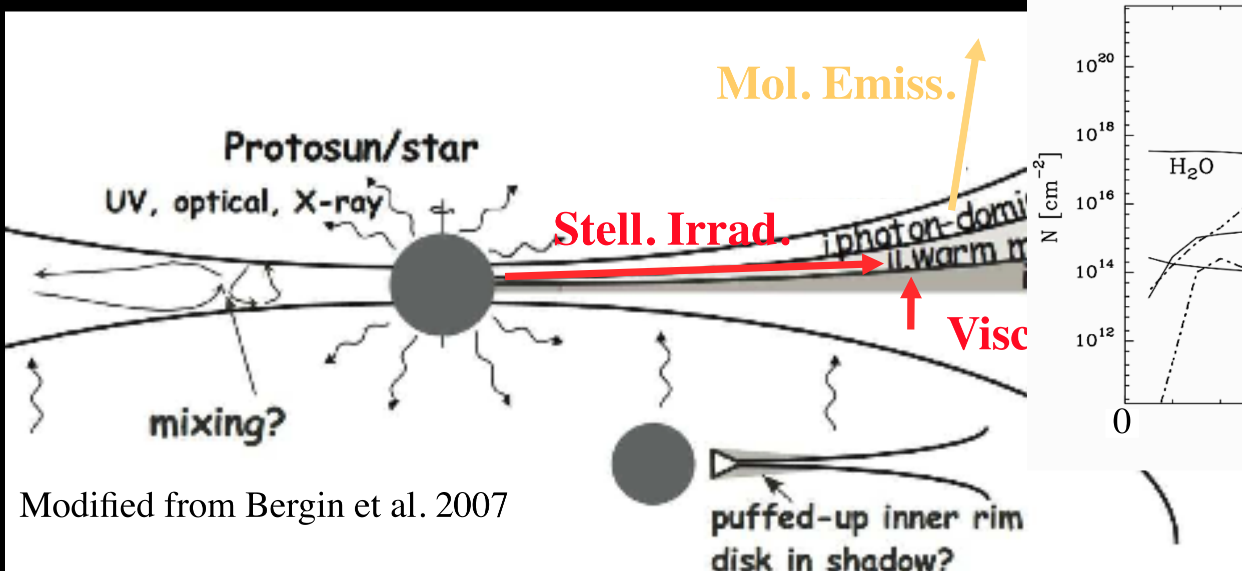


- Covers fundamental ro-vibrational bands for many simple volatiles and hydrocarbons

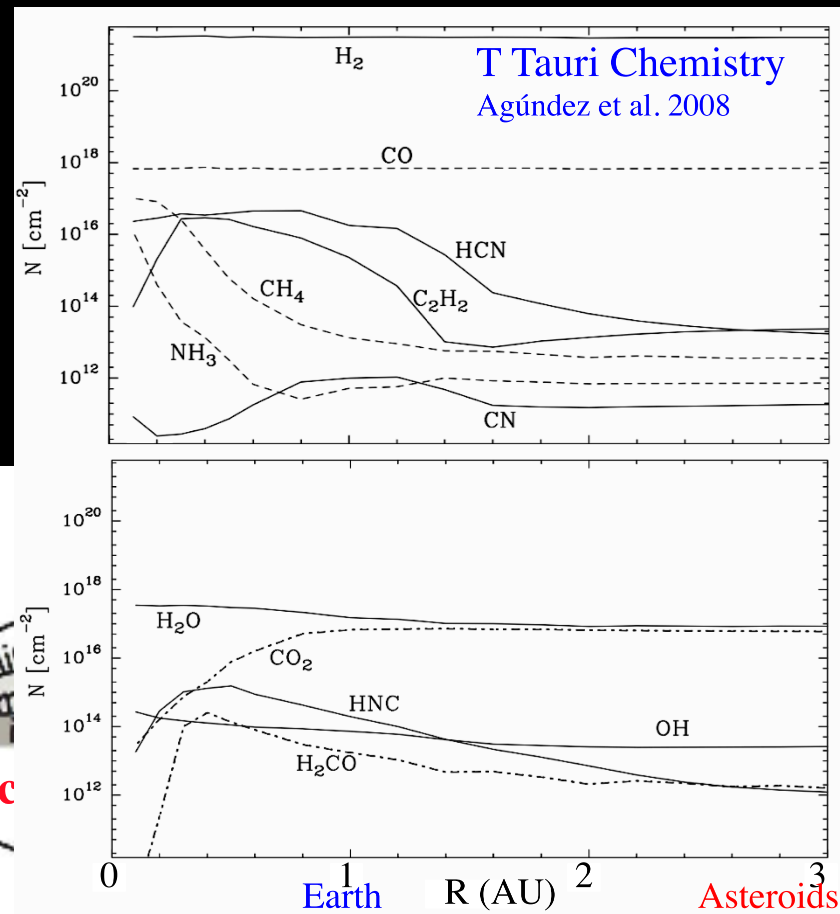
  → very sensitive to variations in temperature between 100K and 1000K, perfect for inner 5 AU of planetary systems

Chemistry in Warm Disk Surfaces

- NIR emission probes the warm gas-phase molecular chemistry just above the cold midplane
- Resolving powers for current echelle spectrographs go up to R ~ 100K → able to determine radial distributions on AU scales within 10 AU



Modified from Bergin et al. 2007



Comets ->

High-Resolution Spectroscopy at 3 - 4 µm:
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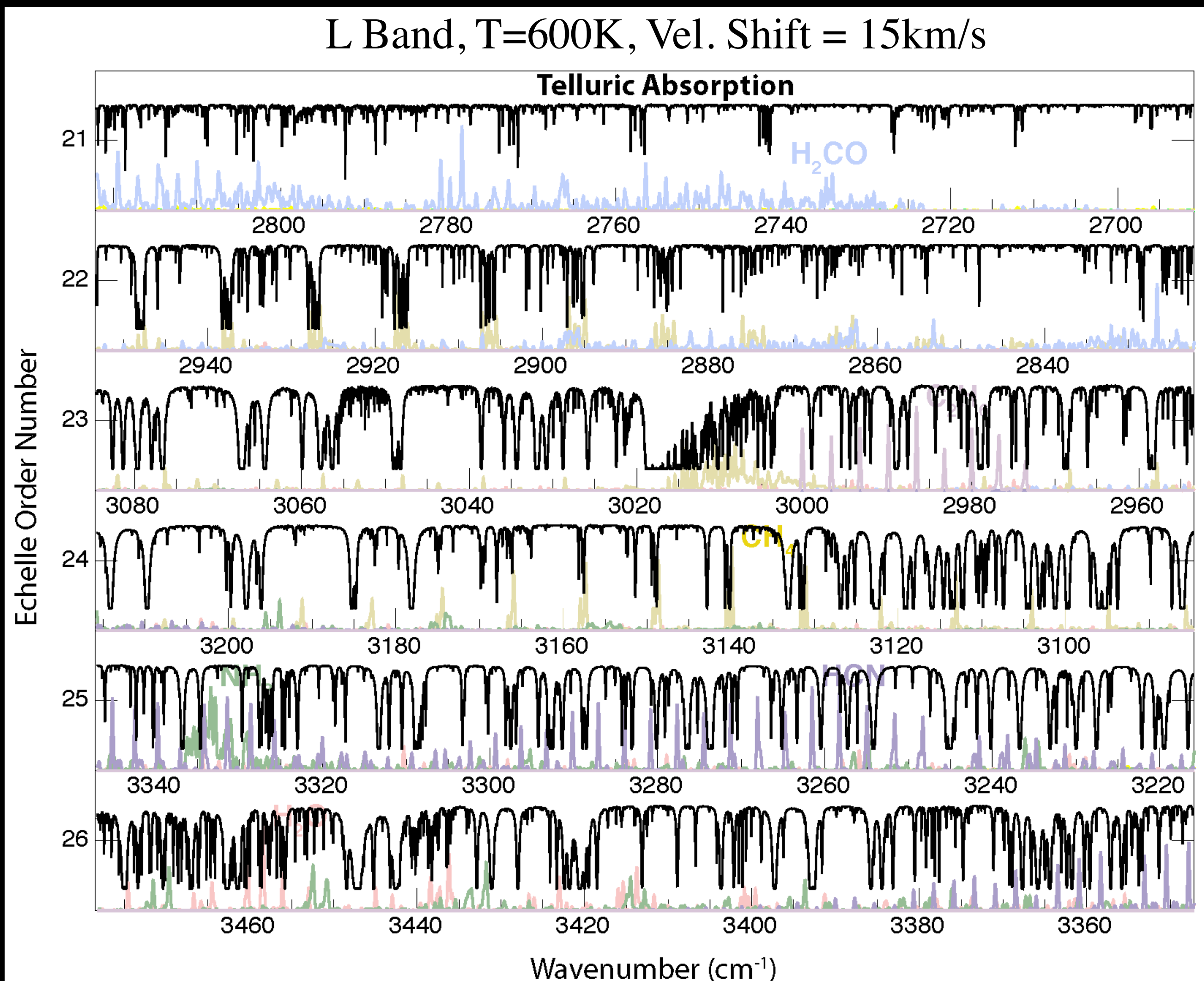

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- Major difficulty: accurately removing the signature of telluric absorption

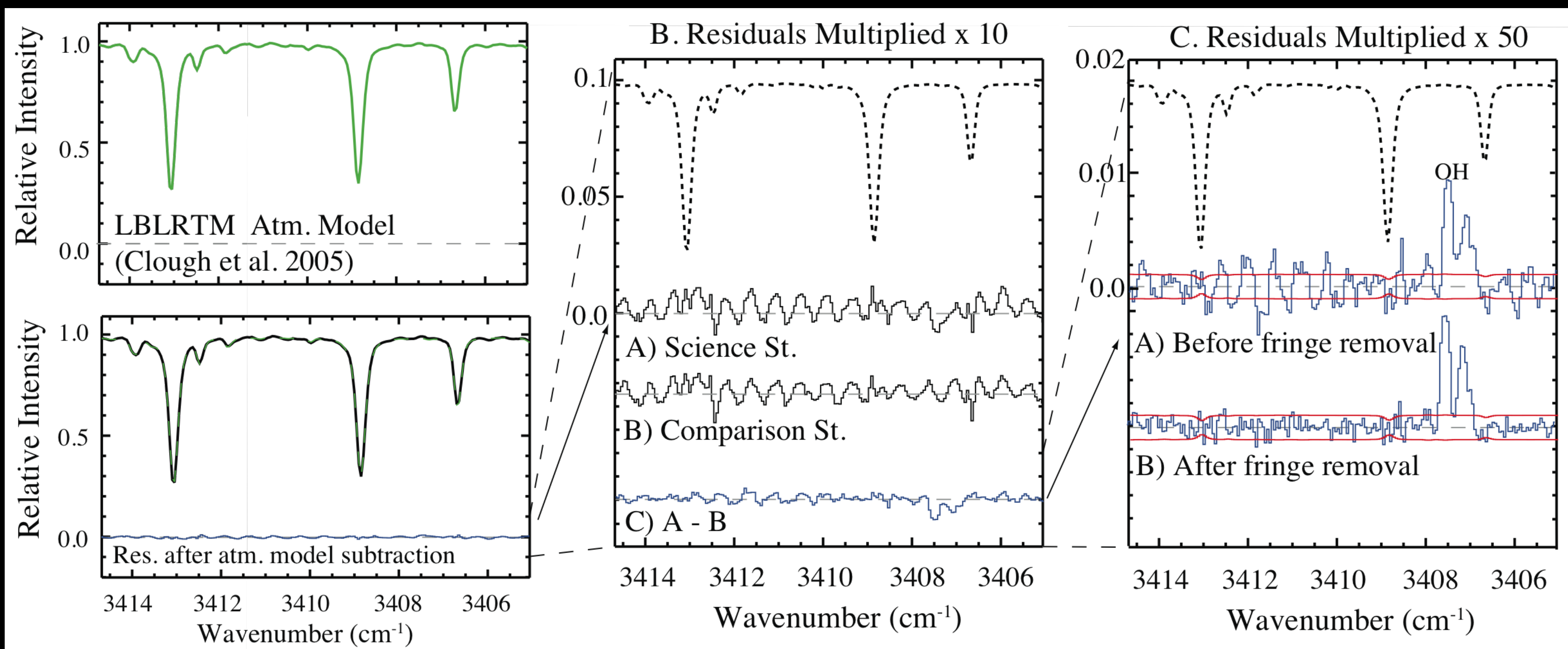
Innovations in Data Reduction:

Solving the Telluric Absorption Problem & Removing Instrumental Effects

A. Fit Atmospheric Models for for Science & Calibration Stars - Airmass, Molec. Abund., & Temp

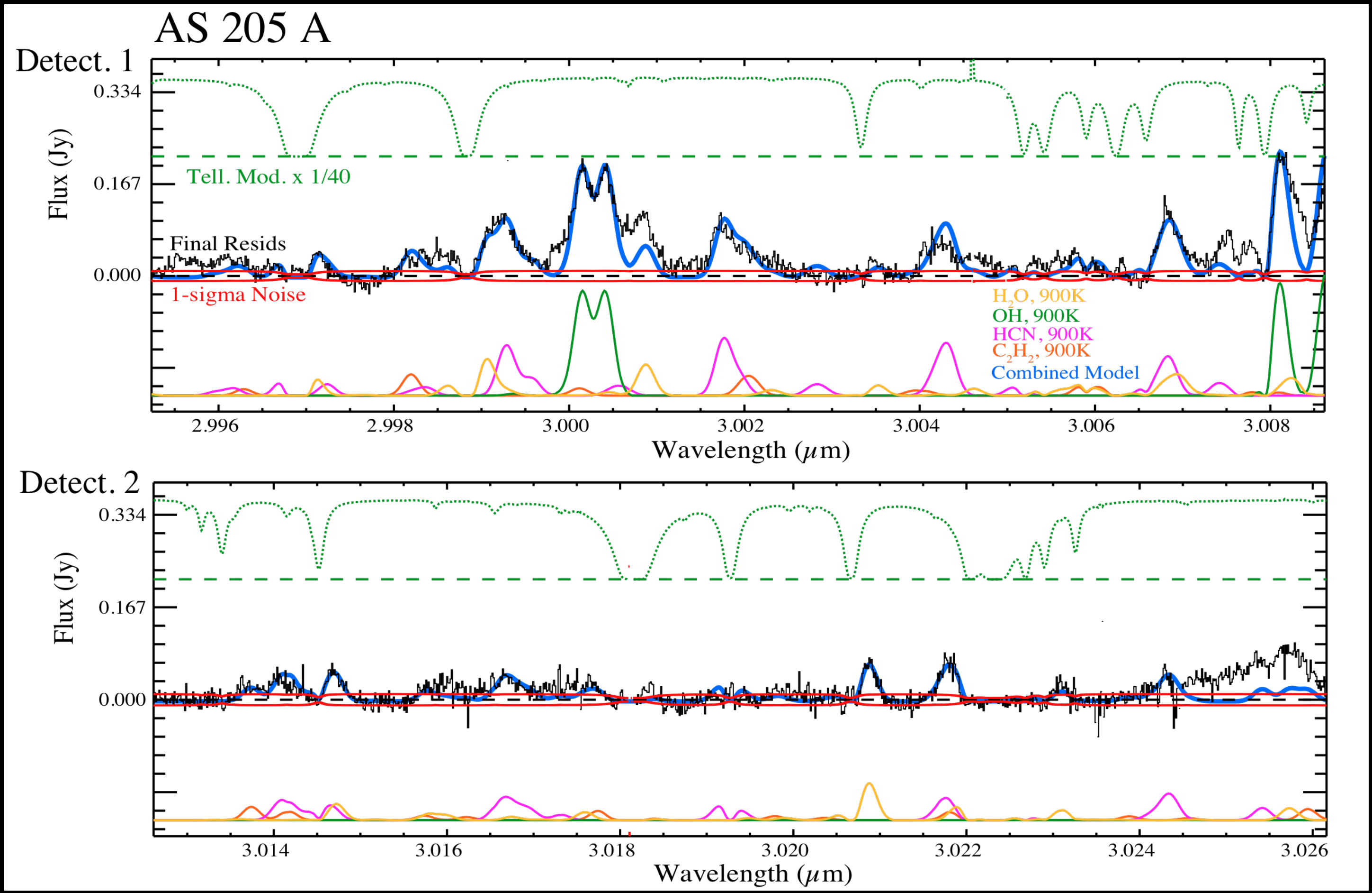
B. Subtract Calibr. Star residuals from Science Star residuals to remove remaining systematics

C. Use Fourier filter to remove remaining uncorrected fringing



Deep Search for Organics in T Tauri Stars

- Observed the bright TT stars AS 205 A and DR Tau with CRIRES on the VLT
- First detection of HCN and C_2H_2 at NIR wavelengths; upper limit for CH_4
- Improves upon spatial and thermal constraints from Spitzer



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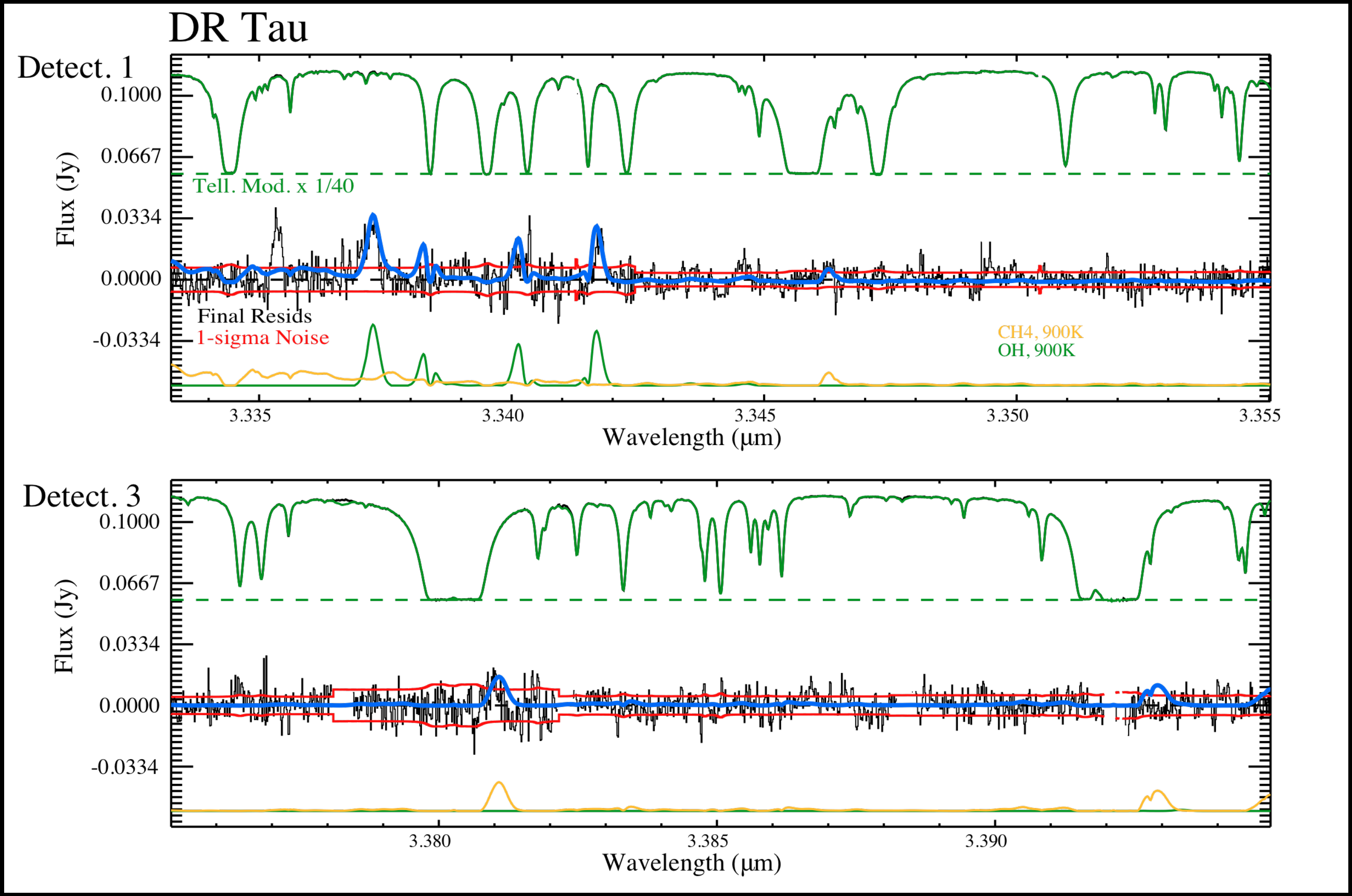
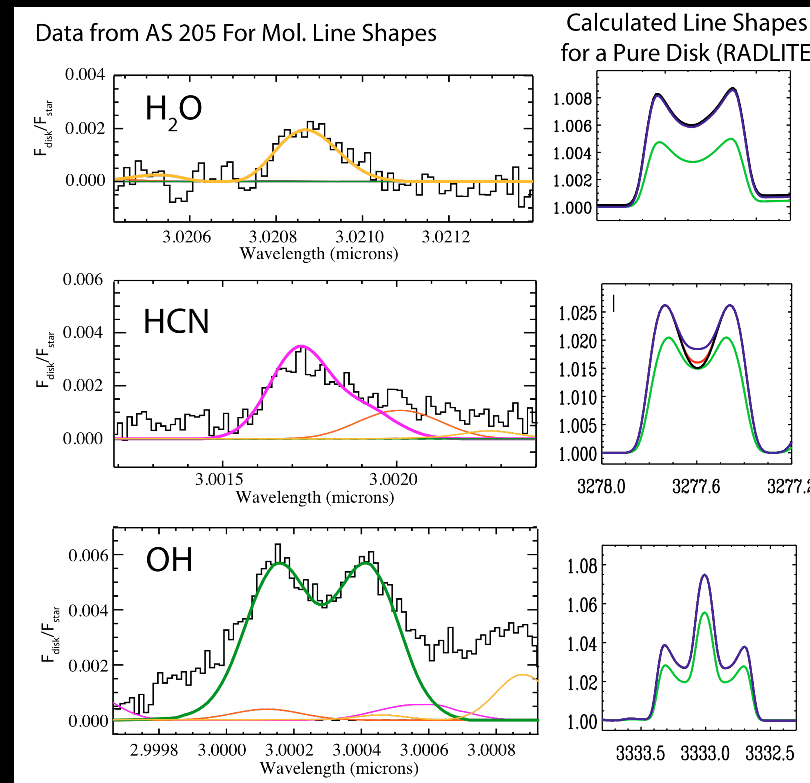
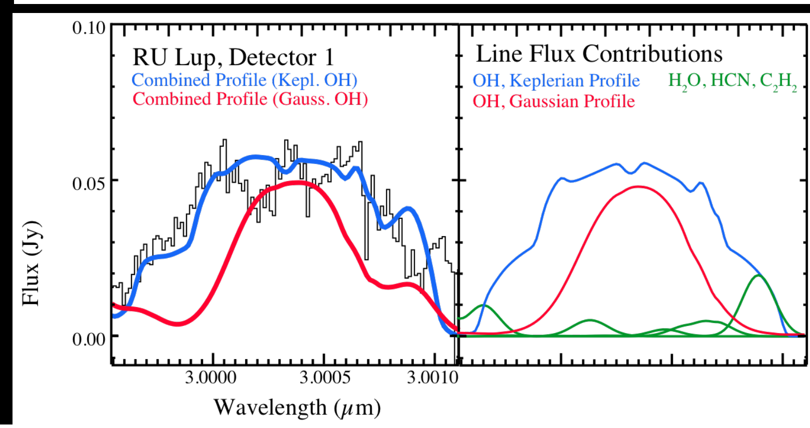


Deep Search for Organics in T Tauri Stars

- AS 205 Line Shapes: Centrally peaked, with evidence of broad wings
  - All the molecules appear to have a similar velocity broadening, yielding an inner radius of ~ 0.25 AU
  - Models of the expected line profiles from modeling using RADLITE (Pontoppidan et al. 2009)
- The one line that shows a deviation from the single-peaked profile is the OH line for RU Lup, which can be fit using a double-peaked Keplerian profile

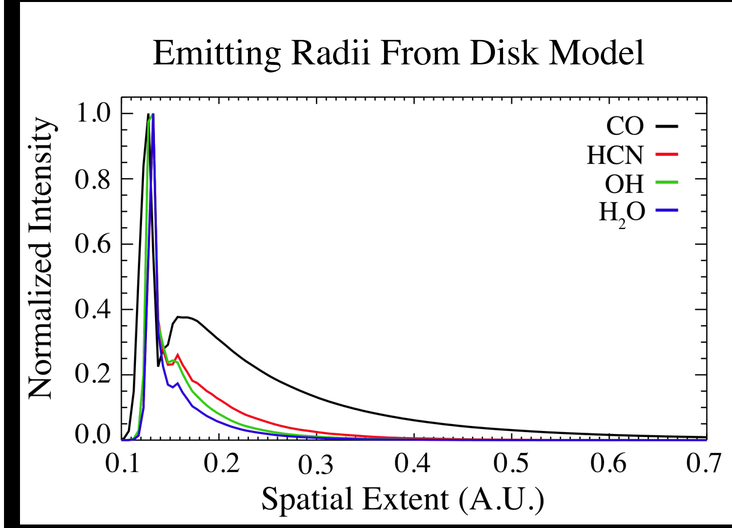


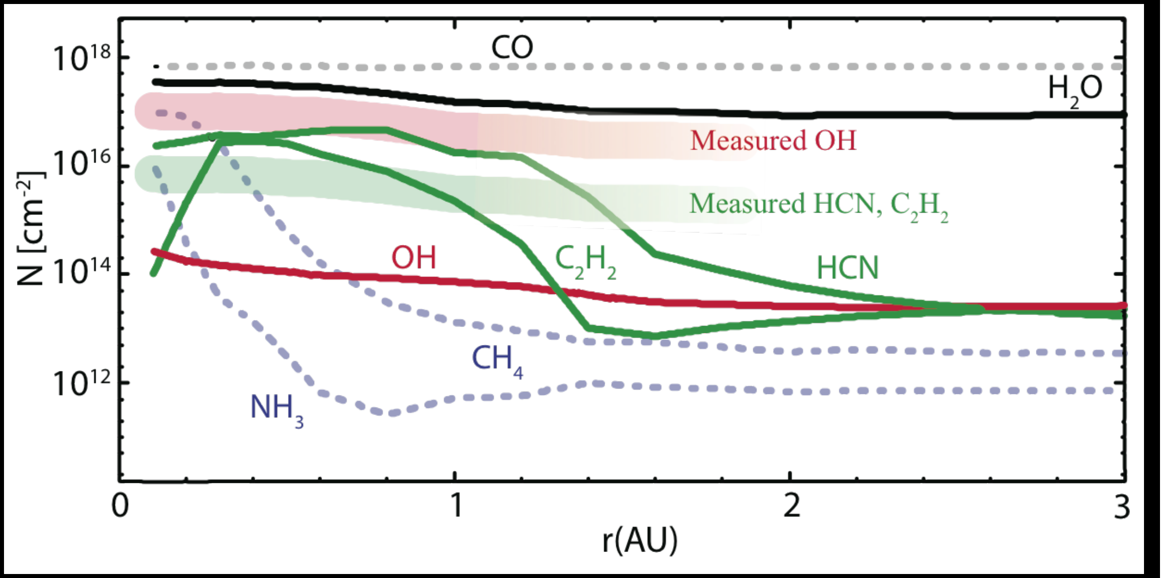


Deep Search for Organics in T Tauri Stars

- Results for mixing ratios based on two models: slab model and RADLITE/ RADMC disk model

Mixing Ratios (log10 (X/H2O))	Slab Model	Disk Model	Predictions from Agundez et al. 2008 (< 3 AU)
HCN (AS 205)	-1.22	-1.15	-3 (3AU) to -0.5 (0.8AU)
OH (AS 205)	-0.6	-0.7	-2.5 (0 – 3 AU)
C_2H_2 (AS 205)	-1.30	-	-1 (0.4 AU) to -4 (1.6 AU)
CH_4 (DR Tau)	< -1.15	< -1.04	0 (0.2 AU) to -4 (3 AU)

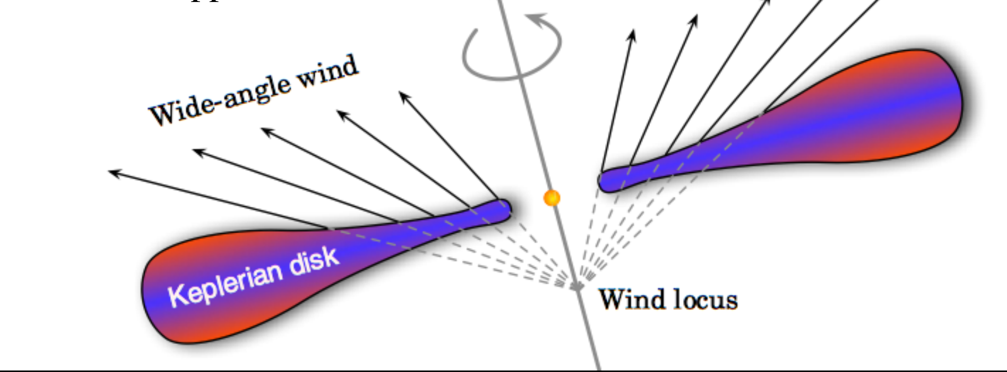


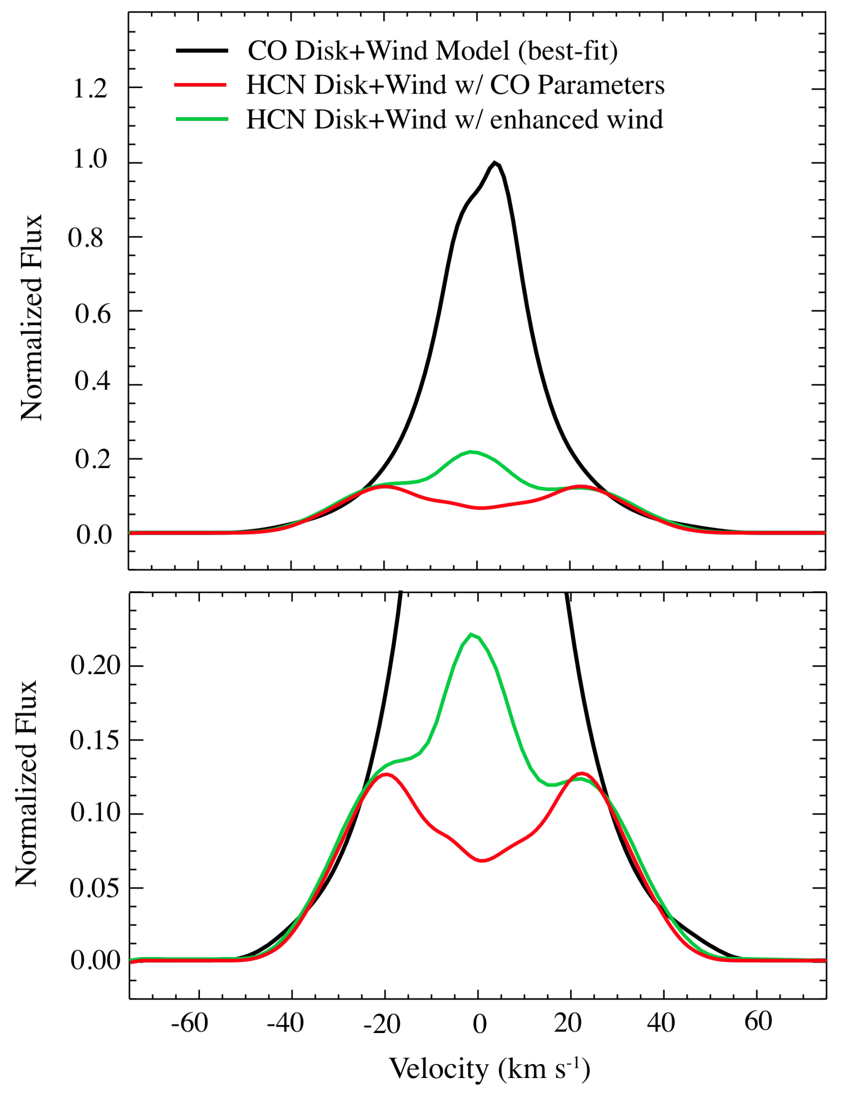


Deep Search for Organics in T Tauri Stars

- Line Shapes: Centrally peaked, with evidence of broad wings
  - Pontoppidan et al. (2011) fit the CO spectral and spectro-astrometric features for AS 205 with a Disk + Disk Wind model
  - Wind addition to RADLITE model only fits our lines with unphysical characteristics for the wind mass and temperature…

From Pontoppidan et al. 2011





Current and Future Work

Near-Term (Relatively…)

- Improve our disk modeling (is the wind interpretation correct?) to extract better constraints on spatial and thermal characteristics
- Broadening our surveys of molecular emission in the inner regions of both high- and low-mass stars to cover characteristics such as disk mass and age
- Applying improved non-LTE models to calculate more accurate temperatures and abundances

Long-Term

- Spectro-astrometry beyond CO – Can we get enough flux??
- Observations of cooler gas: mid-IR and (sub-)mm observations (condensation fronts!)

Additional Slides