

IRS Observations of Water Vapor (and other gas phase molecules)

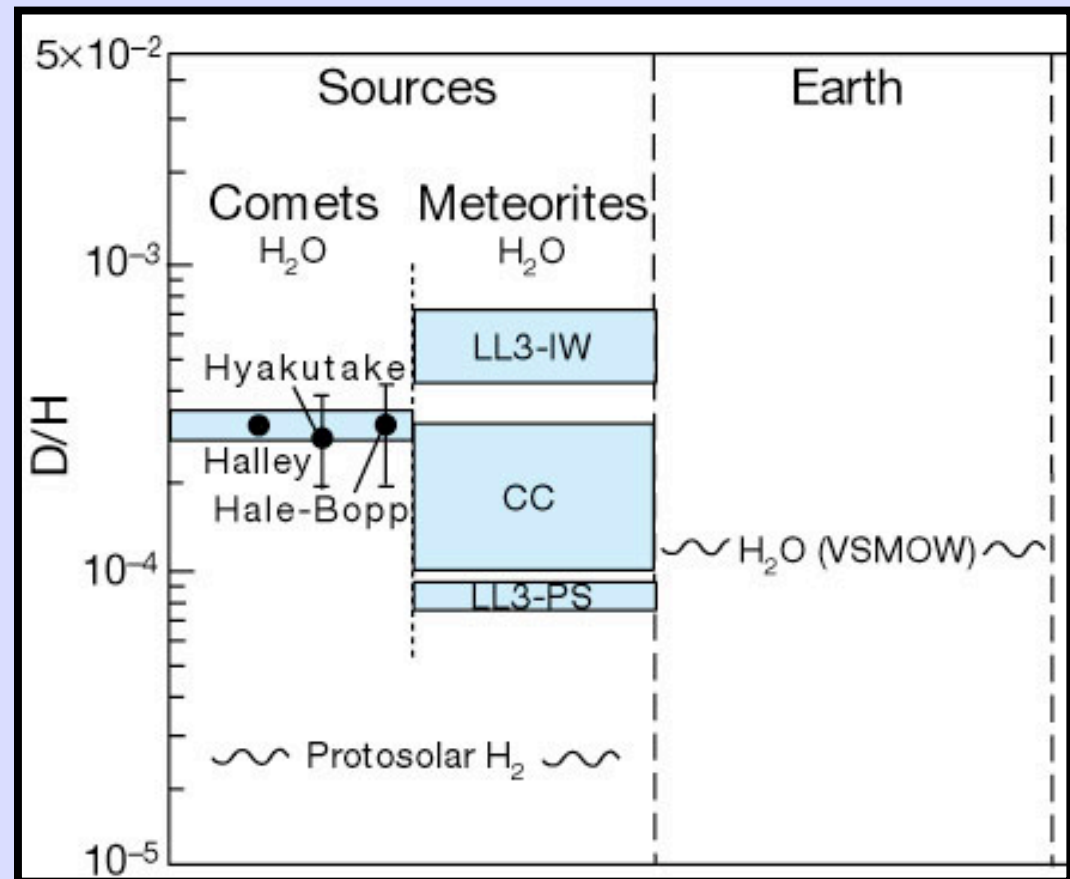
Colette Salyk

Geoffrey Blake, John Carr, Ewine van Dishoeck, Fred Lahuis,
Joan Najita, Klaus Pontoppidan, the c2d Legacy team

What is the source of Earth's water?

Primordial source ?

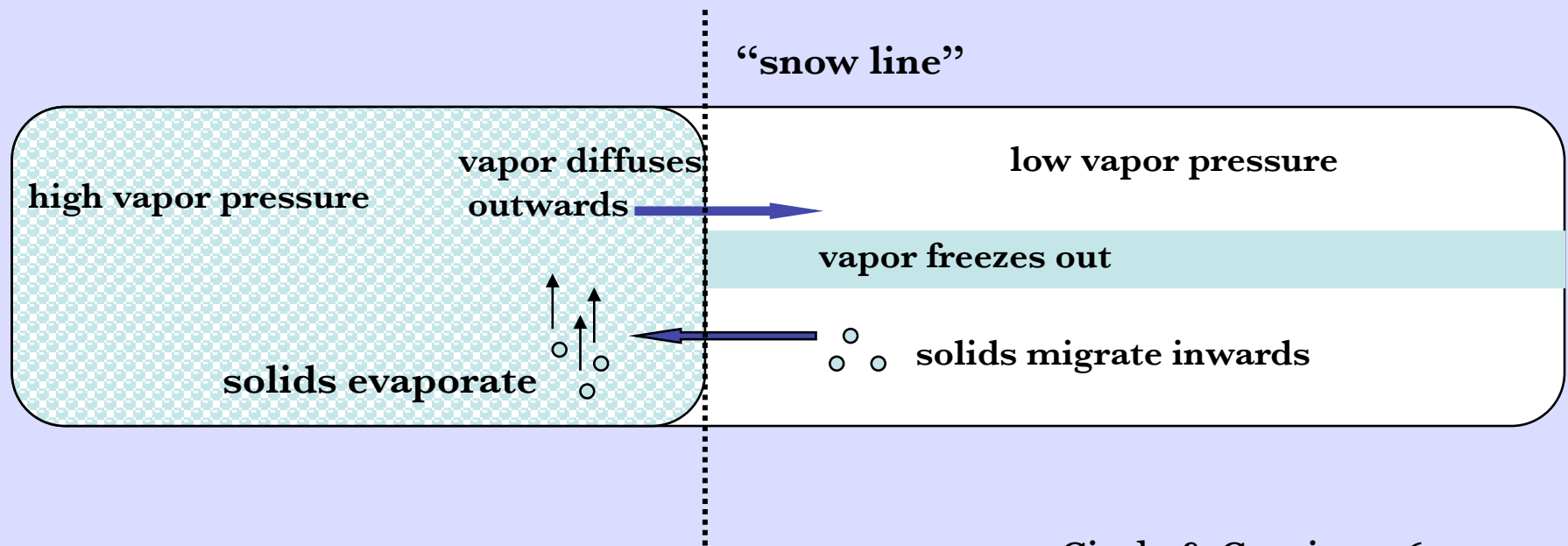
Delivery by comets or asteroids?



Drake & Righter 2002

Water vapor as a tracer of disk evolution

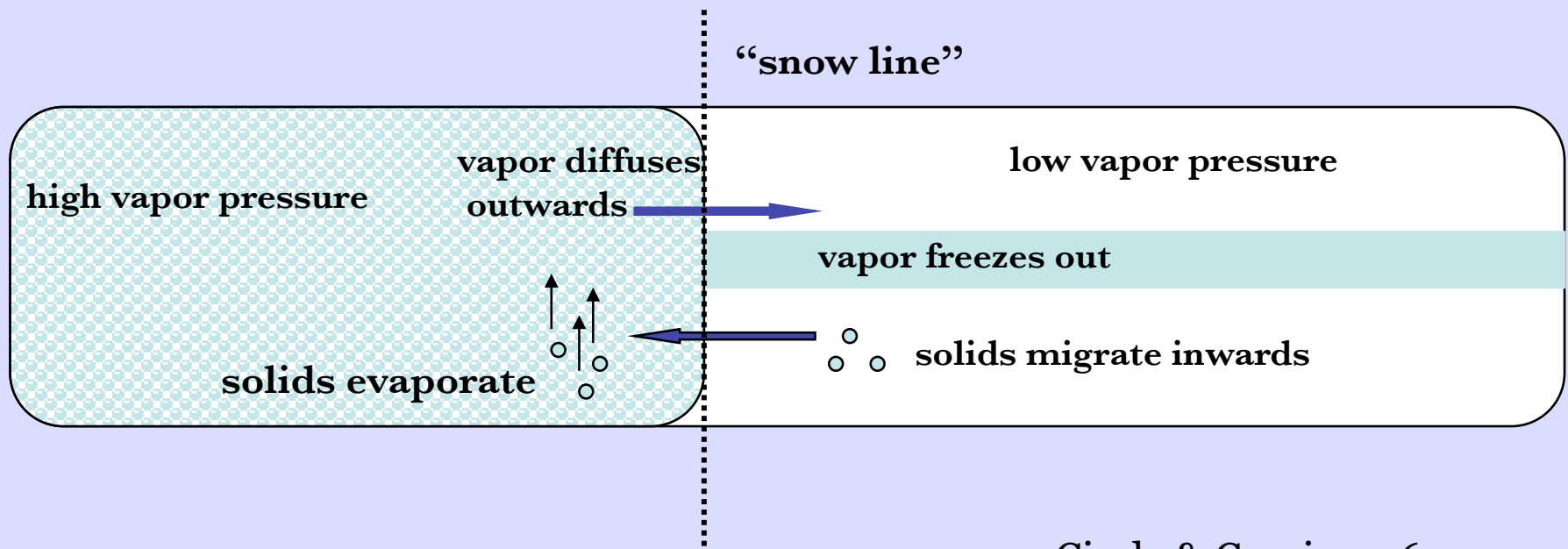
Water vapor contents may be set by a balance between vapor diffusion and icy planetesimal migration



Ciesla & Cuzzi 2006

Water vapor as a tracer of disk evolution

Water vapor contents may be set by a balance between vapor diffusion and icy planetesimal migration



Ciesla & Cuzzi 2006

Inner disk water vapor content may reflect disk evolution

Caveats for interpretation of emission spectra

To what extent do abundances depend on disk chemistry vs. disk transport?

Example: High UV fluxes may cause photodissociation of water at the disk surface

What are the line excitation mechanisms?

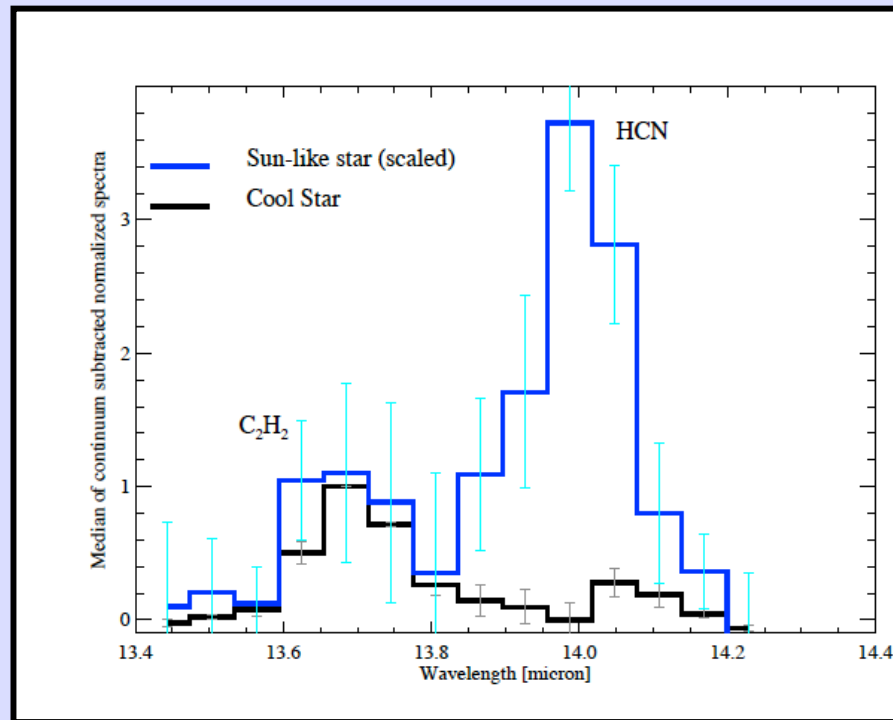
Example: Excitation models affect derived column densities

How are bulk disk properties expressed at the disk surface?

Example: Dust settling and growth may enhance molecular emission

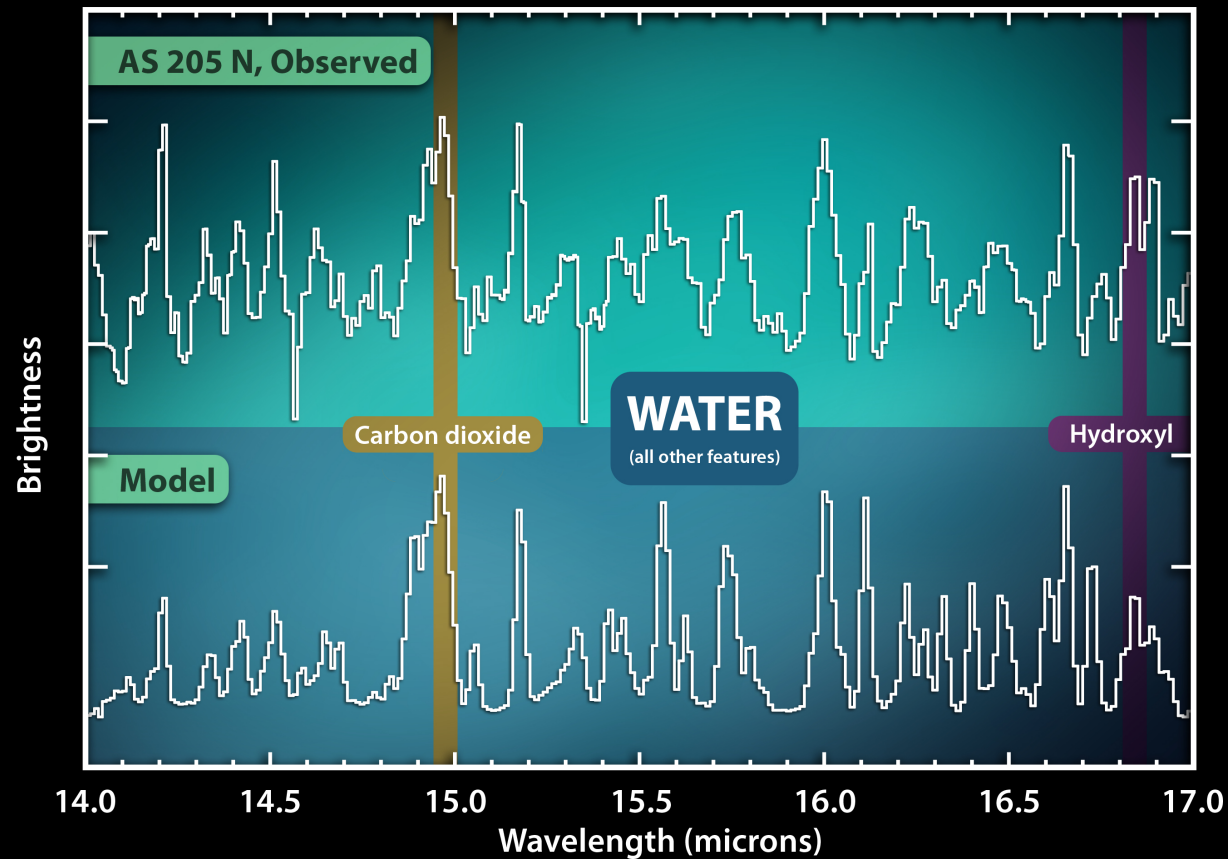
Caveats for interpretation of emission spectra

To what extent do abundances depend on disk chemistry vs. disk transport?



Pascucci et al. 2008

Discovery of water vapor in inner disks



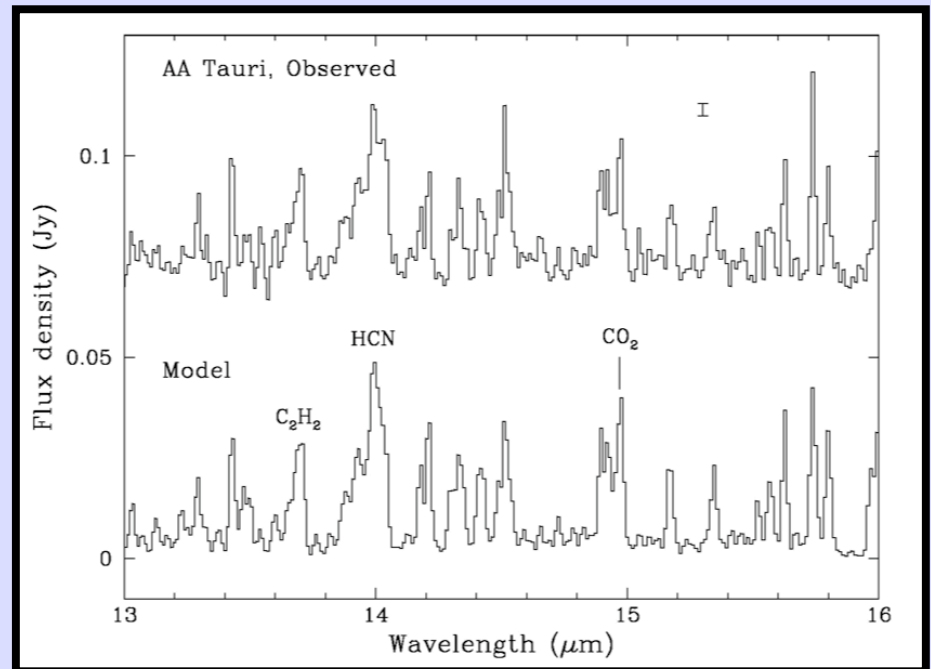
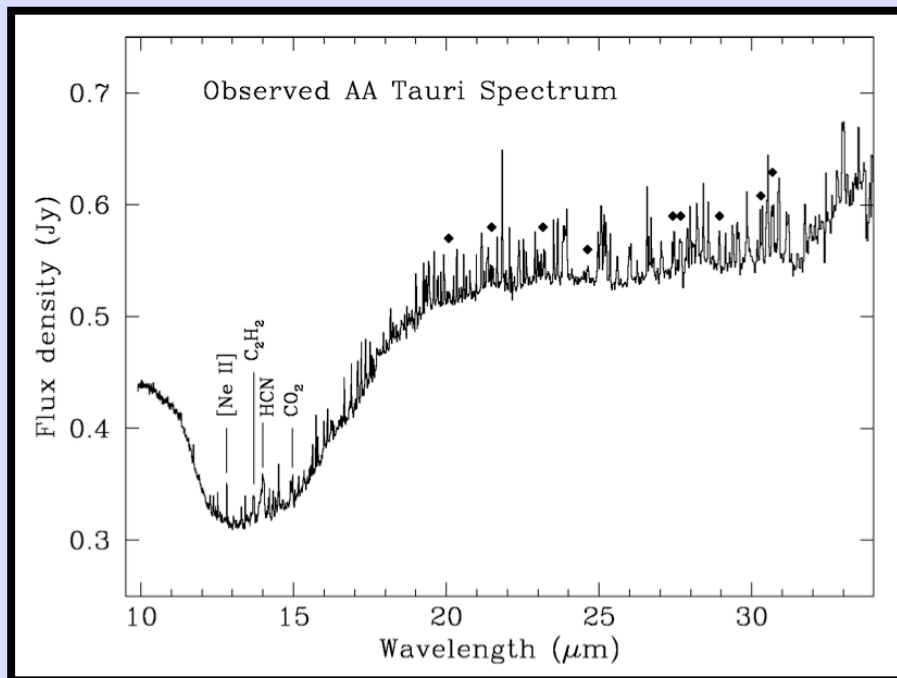
Water Vapor and Other Gases in AS 205 N

NASA / JPL-Caltech / C. Salyk (Caltech)

Spitzer Space Telescope • IRS

ssc2008-06b

Water (and other molecules) seen in many disks, with high enough S/N



Carr & Najita 2008

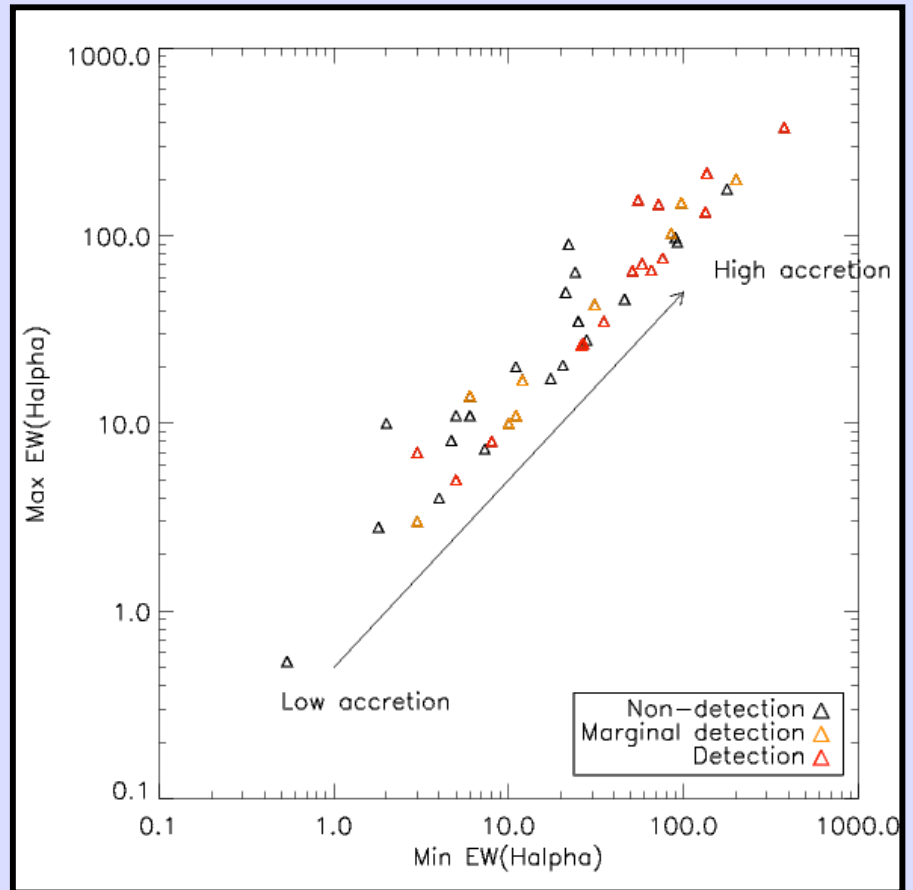
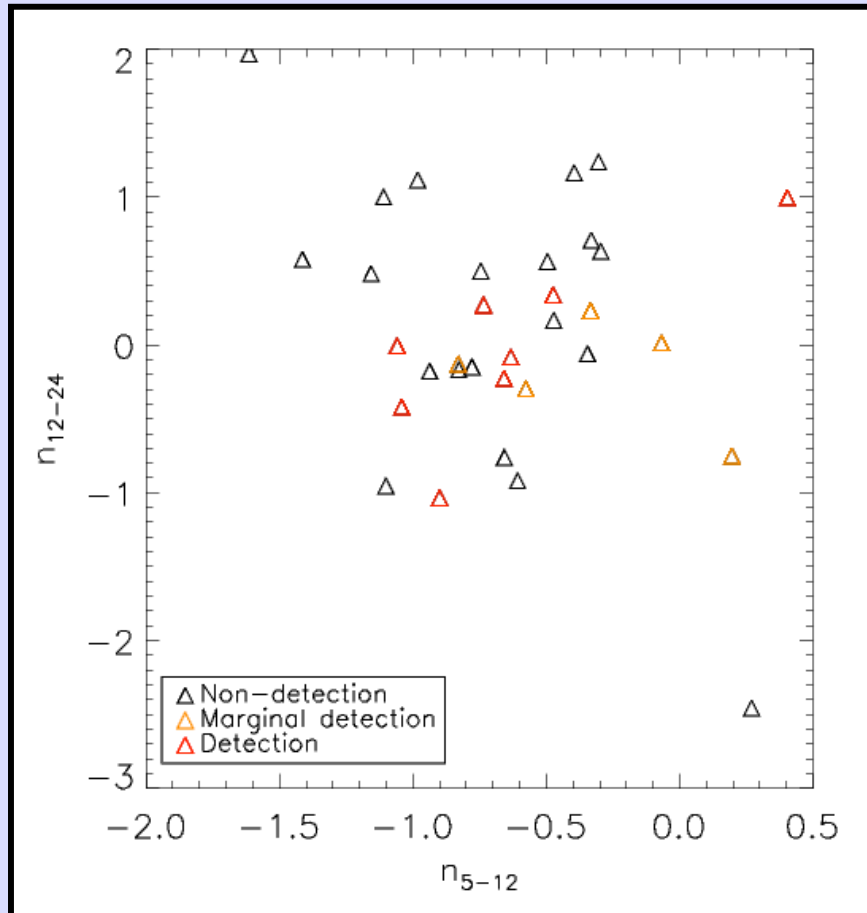
Molecular detections in c2d sources

Water vapor detected in 30-50% of cTTSs

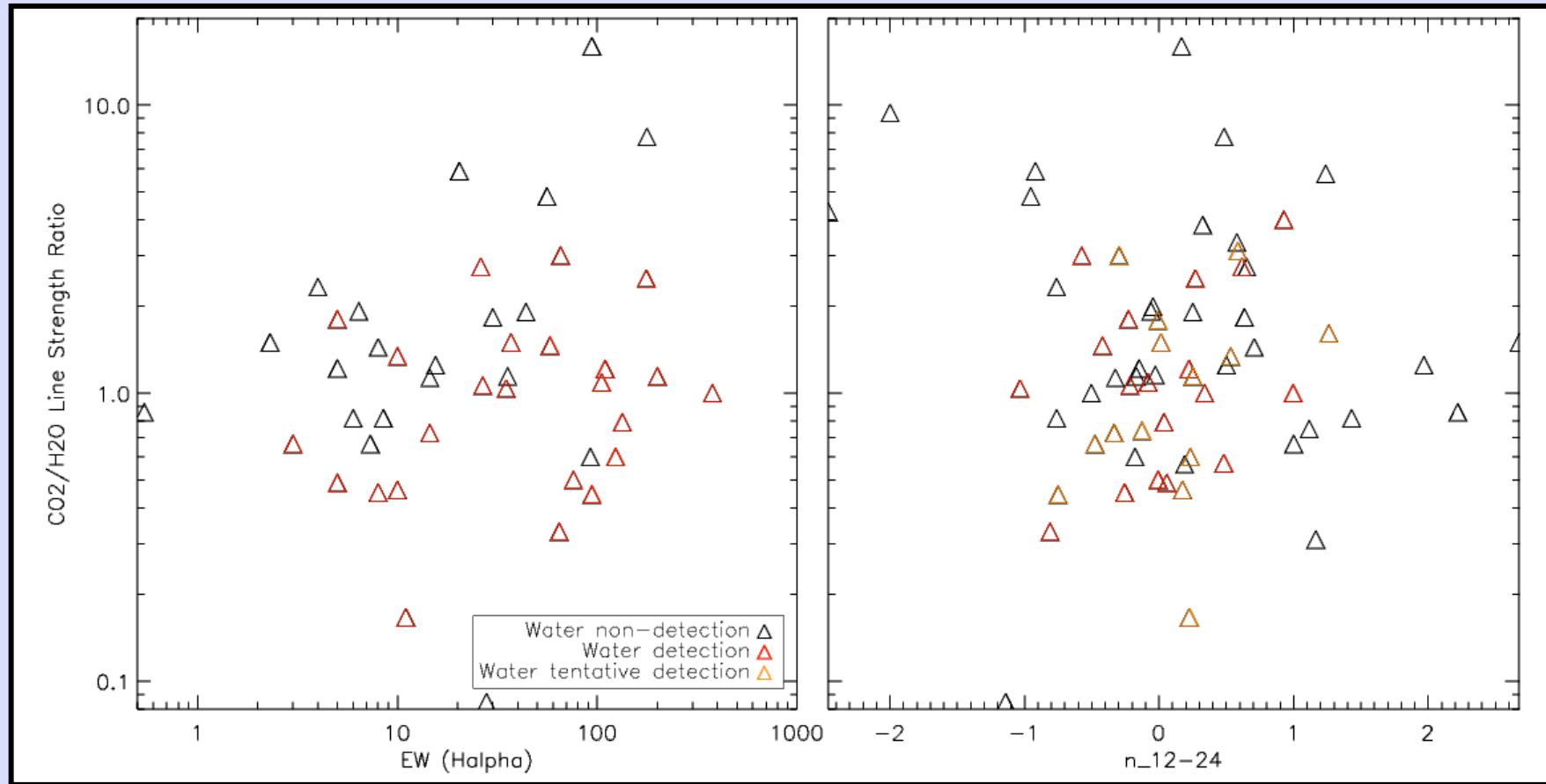
CO₂ detected in many sources, with a variety of CO₂/H₂O ratios (including sources with CO₂ but no H₂O)

Many tentative detections of HCN and OH

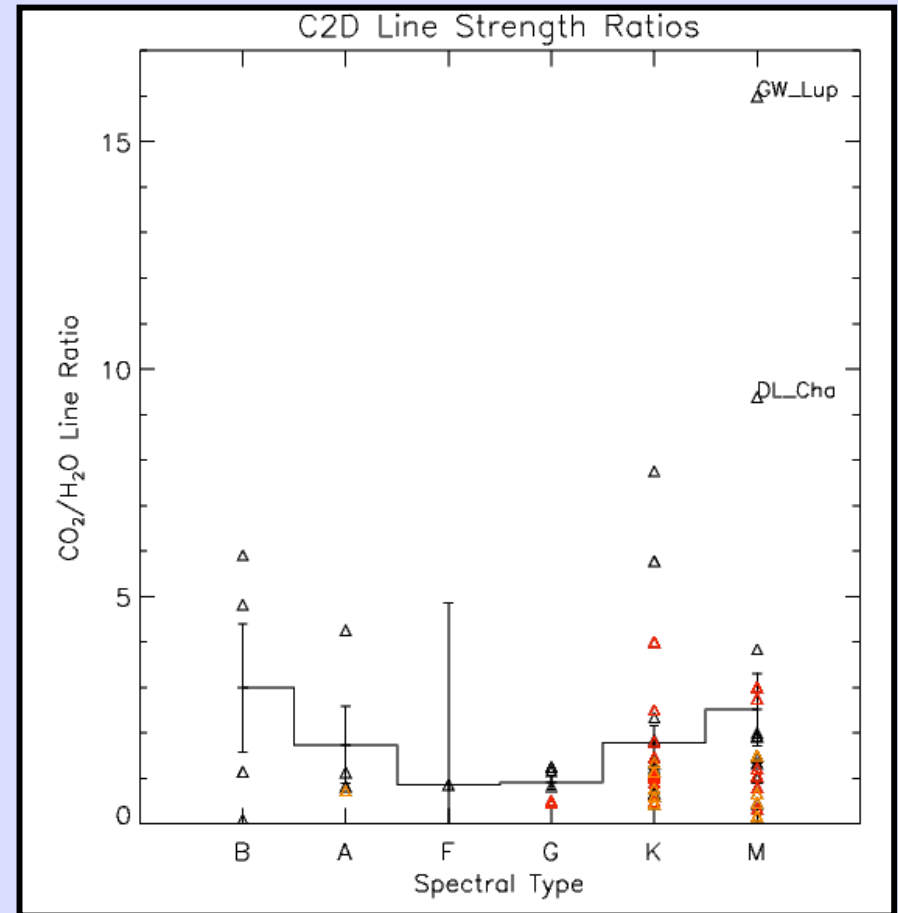
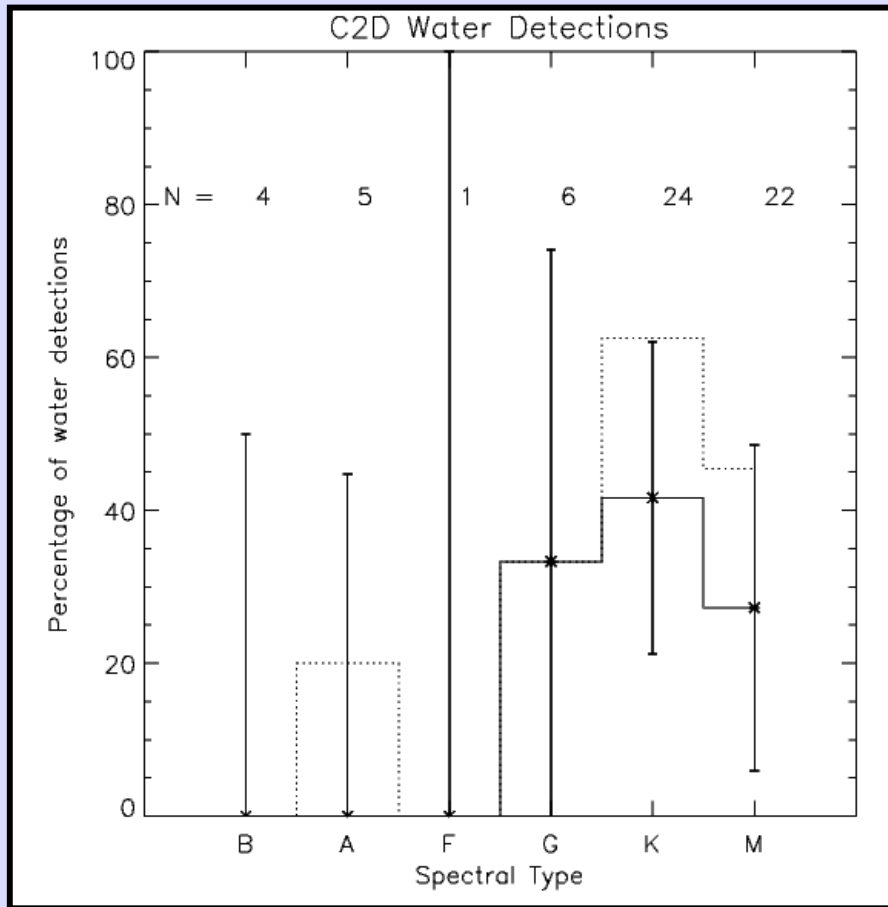
Water detections in c2d sources



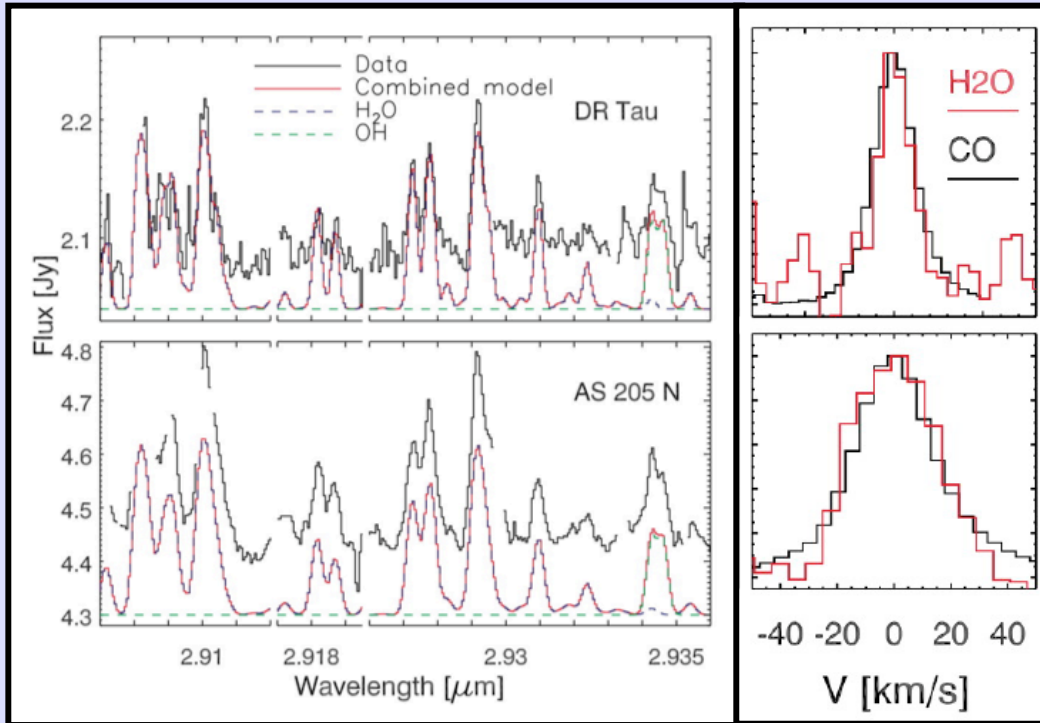
CO₂ detections in c2d sources



Spectral Type Dependencies

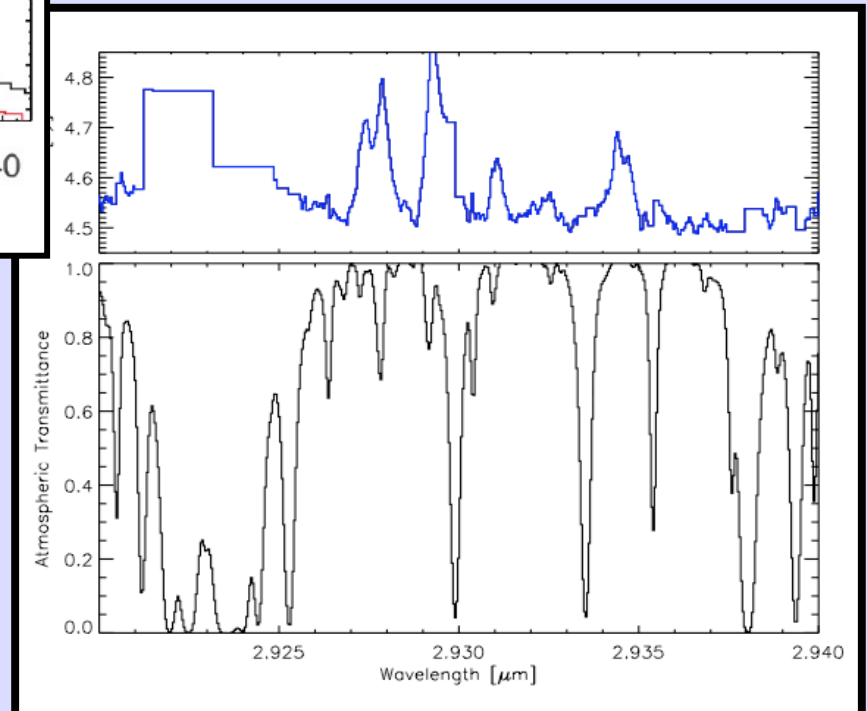


Follow-up spectroscopy with Keck-NIRSPEC ($R \sim 25,000$)

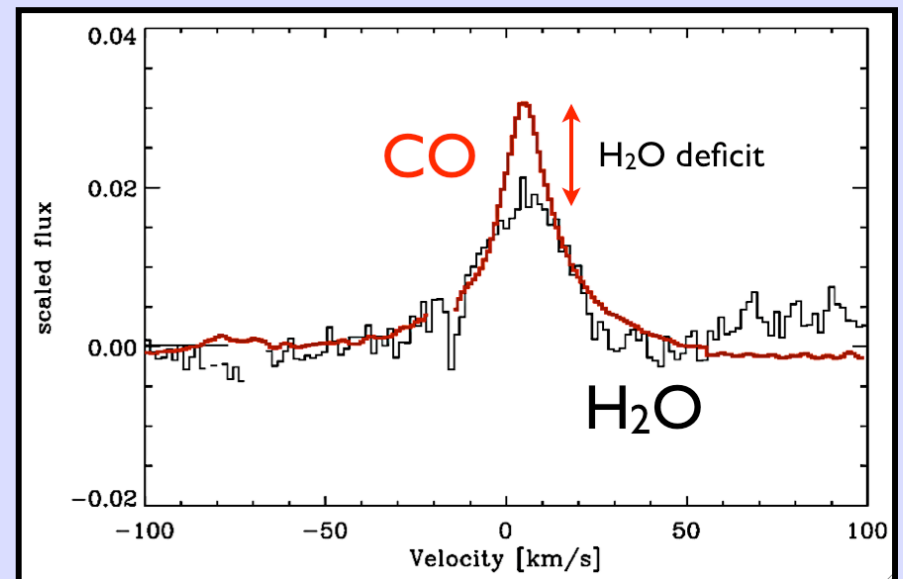
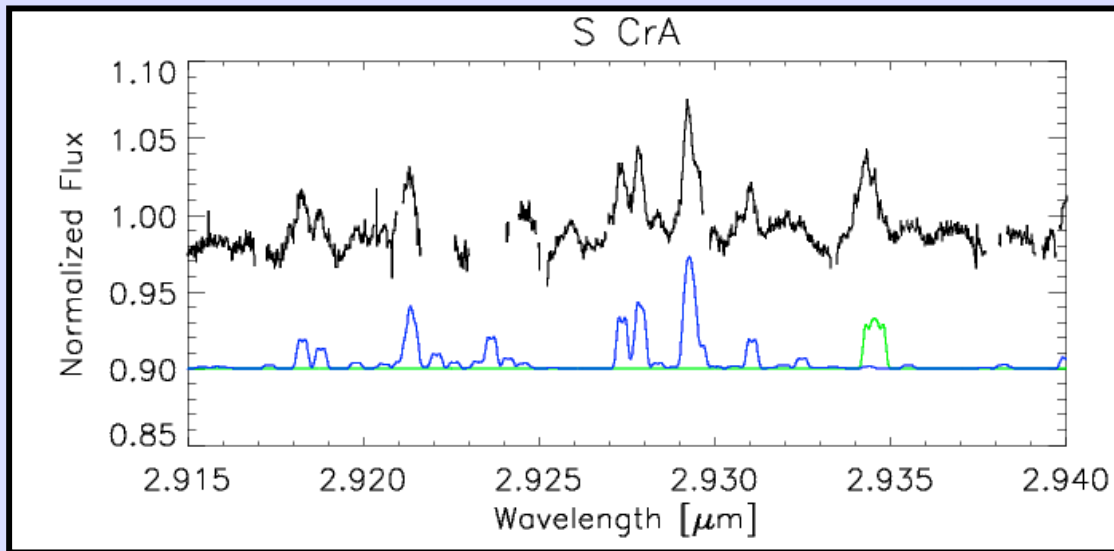


$r_{\text{in}} \sim 1 \text{ AU}$

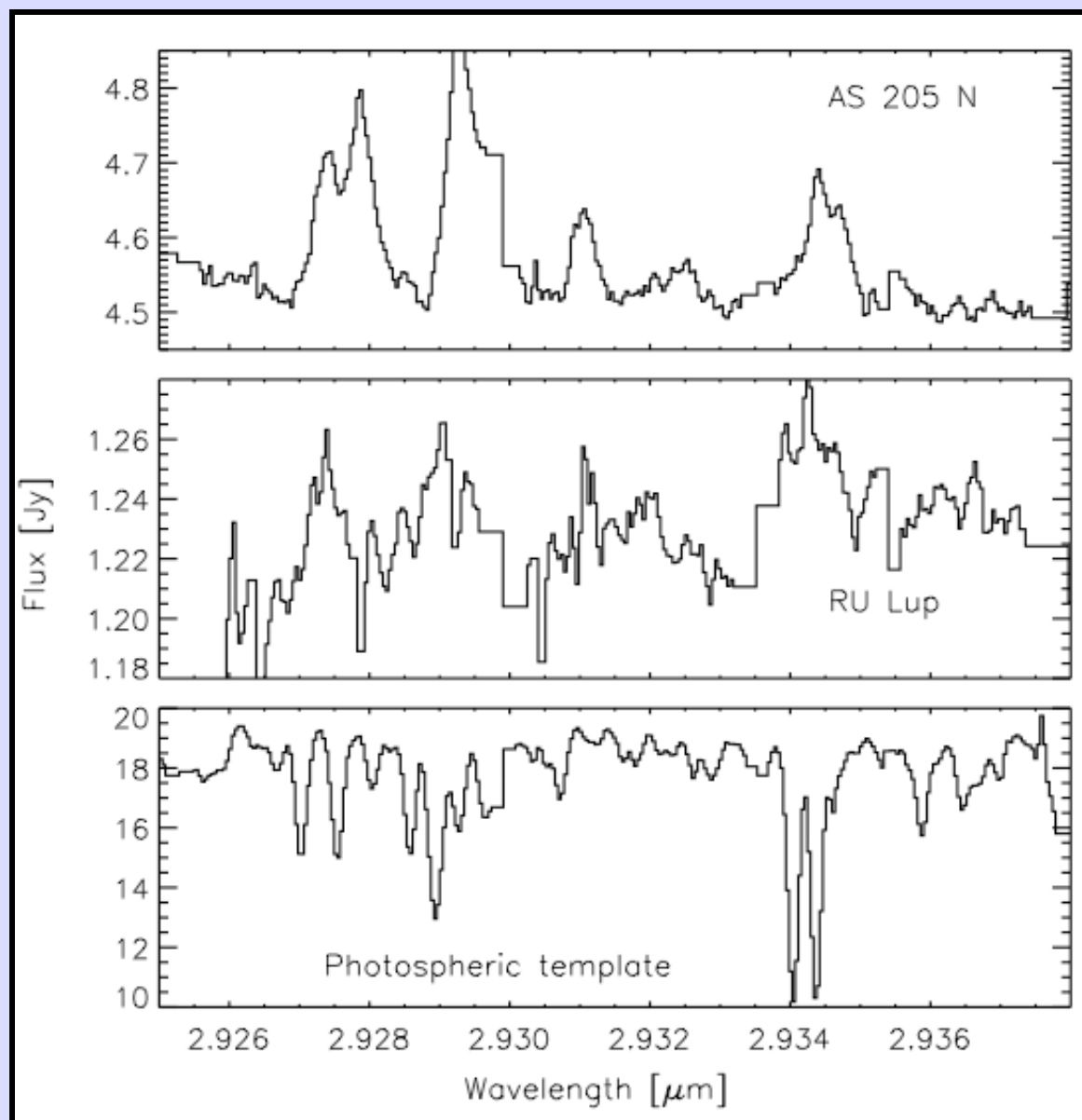
$T \sim 1000 \text{ K}$



Follow-up spectroscopy with VLT-CRIRES ($R \sim 100,000$)

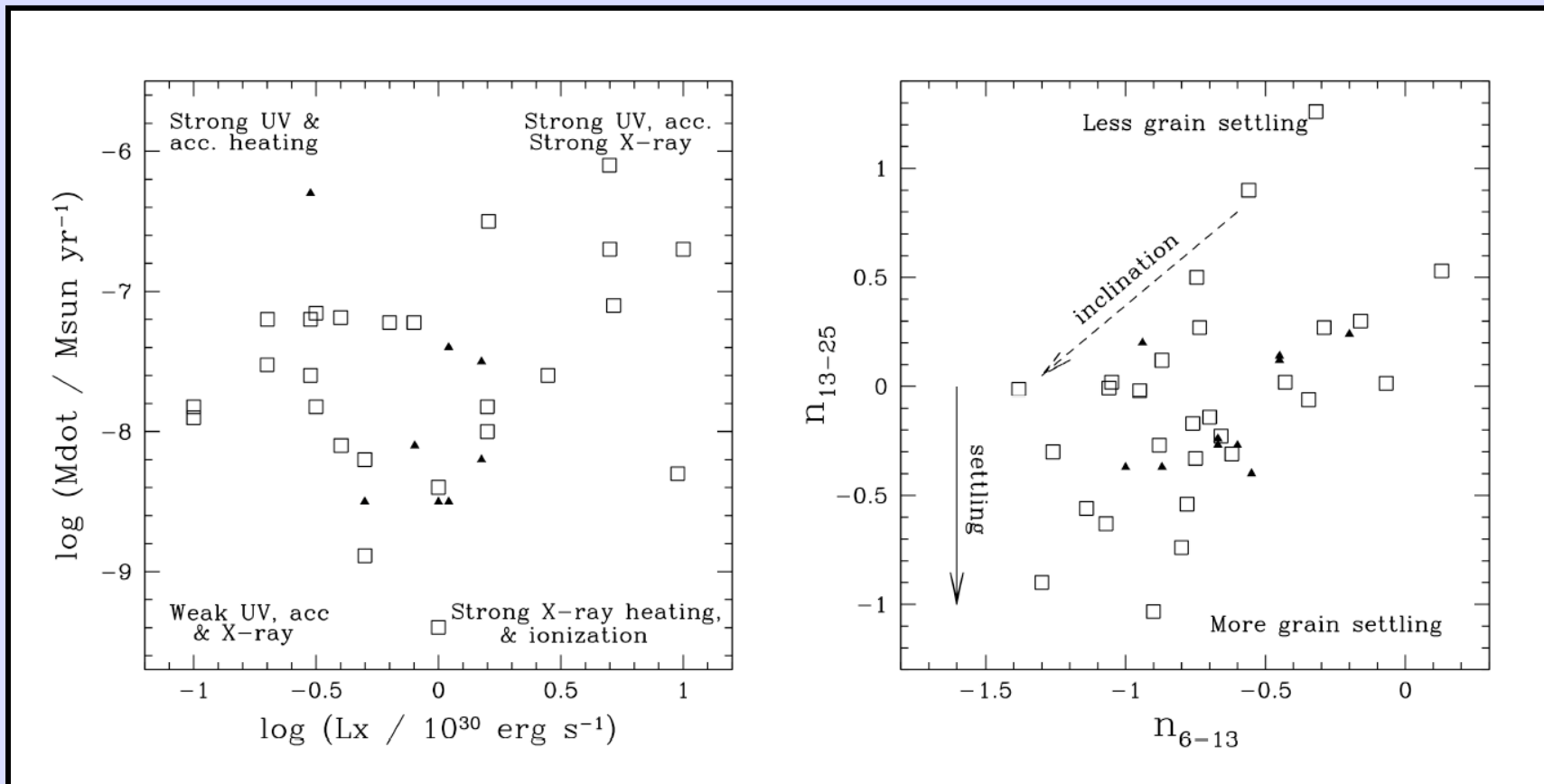


Follow-up spectroscopy: Effect of stellar photospheres

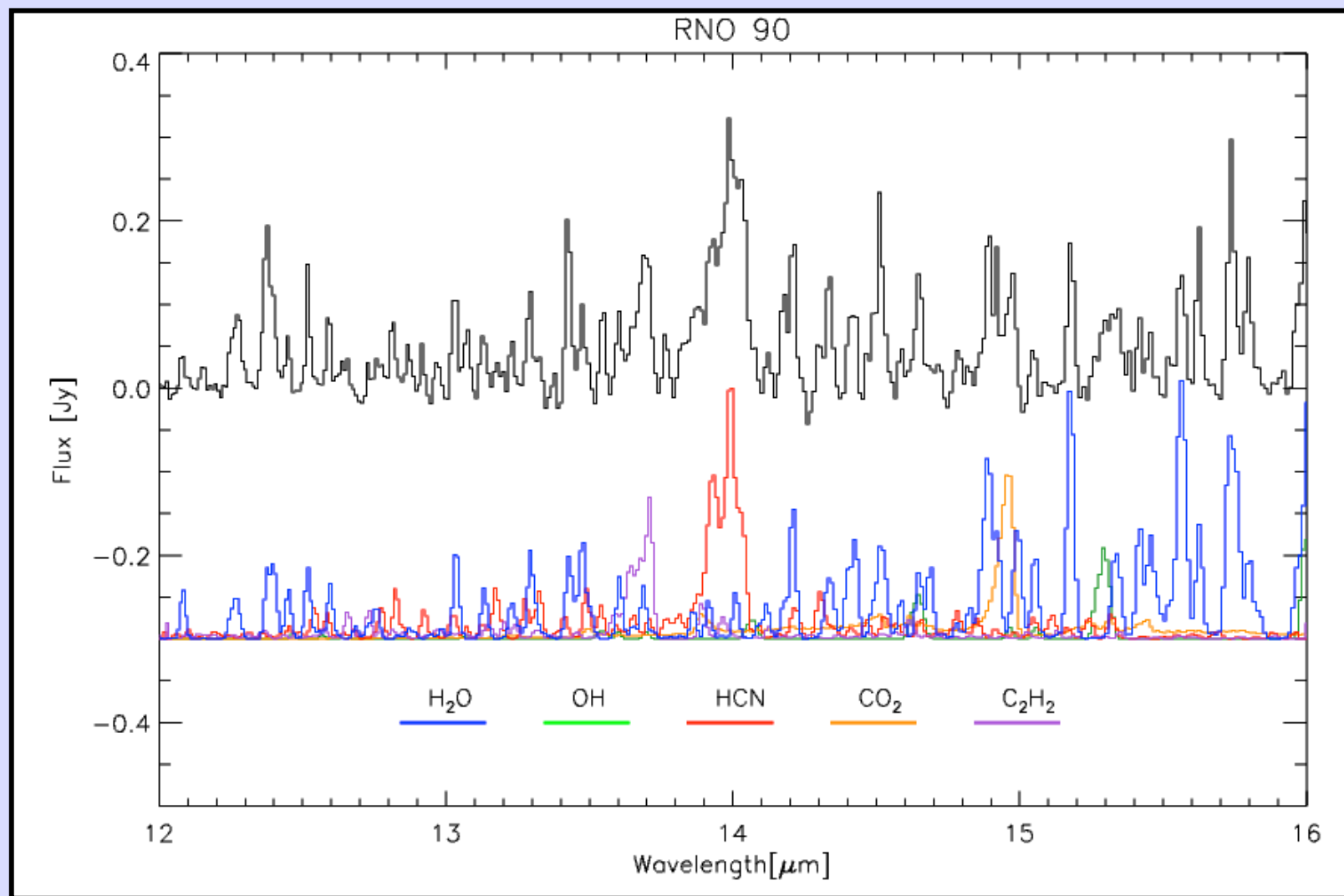


Work in progress: Spitzer cycle 5 observations

Survey of 41 disks in nearby star-forming regions



Work in progress: Spitzer cycle 5 observations



PID#50641, J. Carr, PI

Conclusions

Water vapor and other molecules common in IRS spectra. Emission lines tentatively more common for lower-mass stars.

High-resolution follow-up observations (NIRSPEC/CRIRES) suggest emission from small radii ($r < \text{a few AU}$).

A great variety of molecular ratios is seen, suggesting significant disk diversity . No trends observed just yet.

Cycle 5 high S/N spectra of 41 disks currently being processed. Most sources show rich molecular spectra; at least 80% show water emission.

Table 1: Fits to NIRSPEC data

	DR Tau	AS 205A
CO $v_{\text{in}}, v_{3\sigma}$ [km s ⁻¹]	27, 32	35, 40
CO $r_{\text{in}}, r_{3\sigma}$ [AU]	0.8, 0.6	0.5, 0.4
H ₂ O $v_{\text{in}}, v_{3\sigma}$ [km s ⁻¹]	24, 28	36, 42
H ₂ O $r_{\text{in}}, r_{3\sigma}$ [AU]	1.0, 0.7	0.4, 0.3
OH $v_{\text{in}}, v_{3\sigma}$ [km s ⁻¹]	28, 32	34, 39
OH $r_{\text{in}}, r_{3\sigma}$ [AU]	0.7, 0.5	0.5, 0.4
r [AU] ^a	3	3 ^b
σ [km s ⁻¹] ^a	2	2
M_{\star} [M_{\odot}] ^a	0.76	1.2
i [°] ^a	67	47
$\Omega_{\text{CO,H}_2\text{O,OH}}$ [sr]	2×10^{-16}	6×10^{-16}
$T_{\text{CO,H}_2\text{O,OH}}$ [K]	1000	1000
N_{CO} [cm ⁻²]	7×10^{18}	6×10^{18}
$N_{\text{H}_2\text{O}}$ [cm ⁻²]	8×10^{17}	6×10^{17}
N_{OH} [cm ⁻²]	2×10^{17}	2×10^{17}

Possible solutions

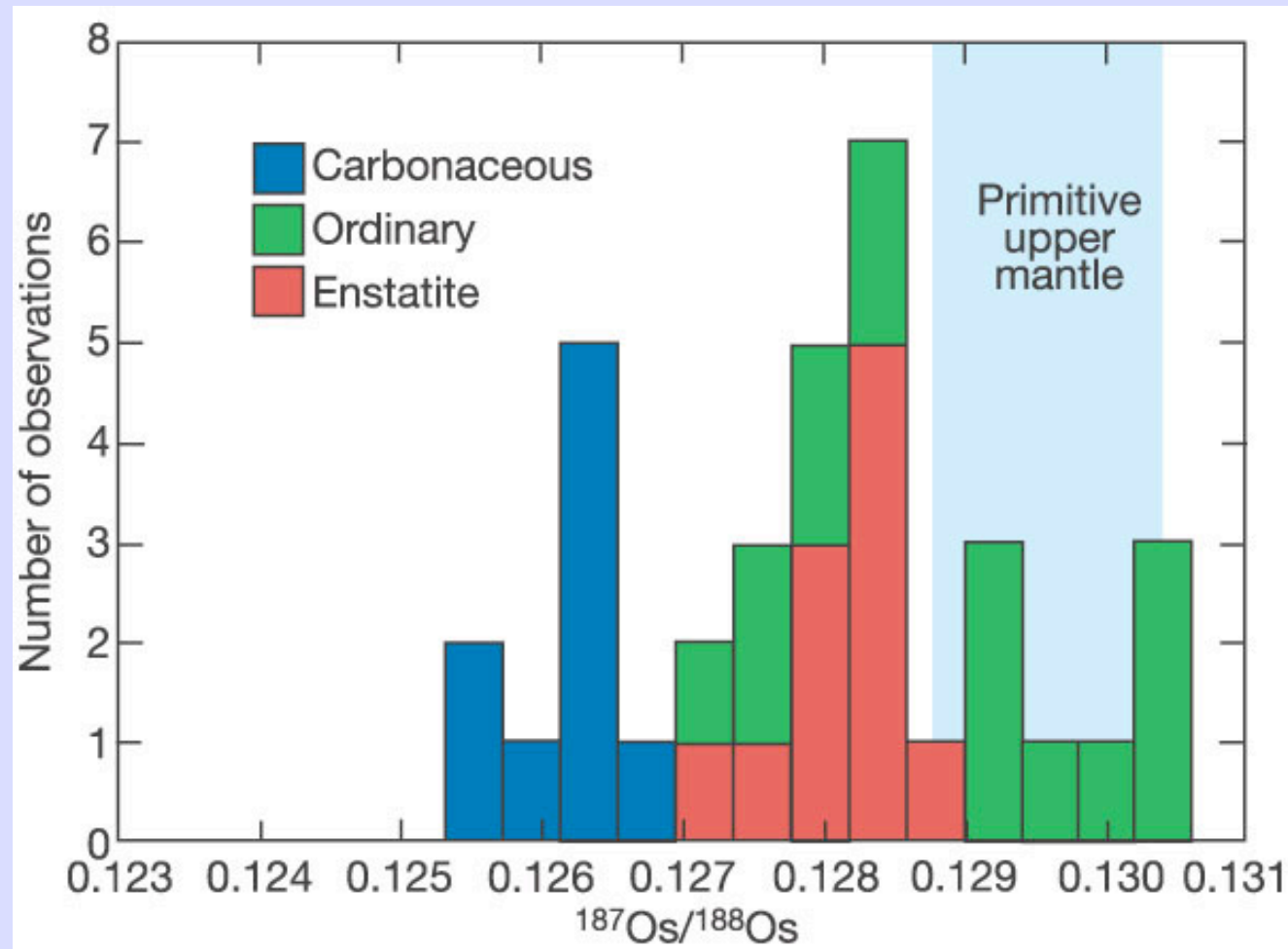
D/H ratios observed in comets do not represent the bulk of the comet (Podolak, Mekler & Prialnik 2002)

D/H ratios observed in comets are probing the wrong reservoir

Adsorption of water onto grains followed by 'wet' accretion (Drake 2005)

Evolution of D/H ratio in Earth's oceans (Genda & Ikoma 2008)

Problems with water delivery



Drake & Righter 2002