Planet Formation with JWST

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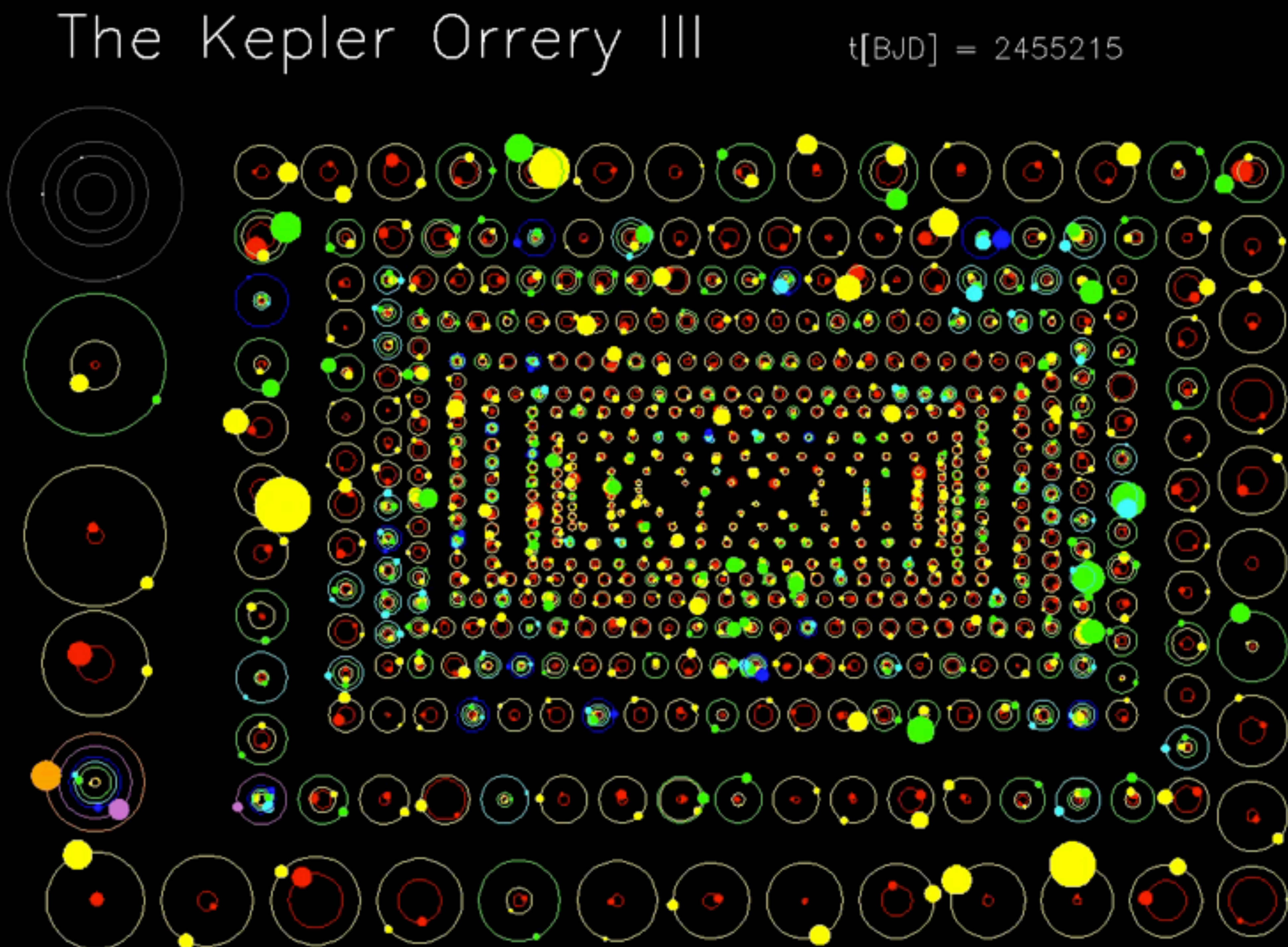
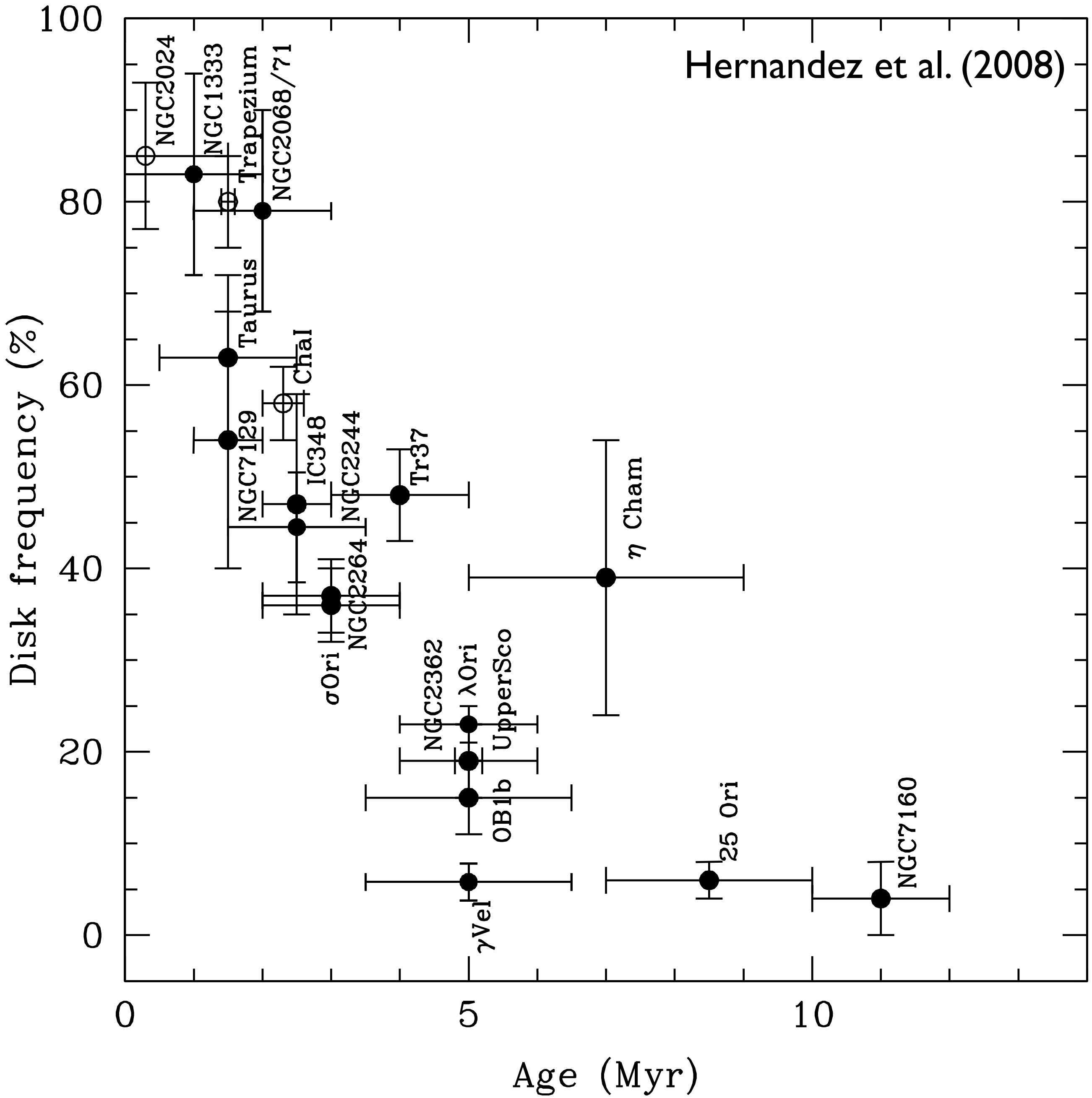


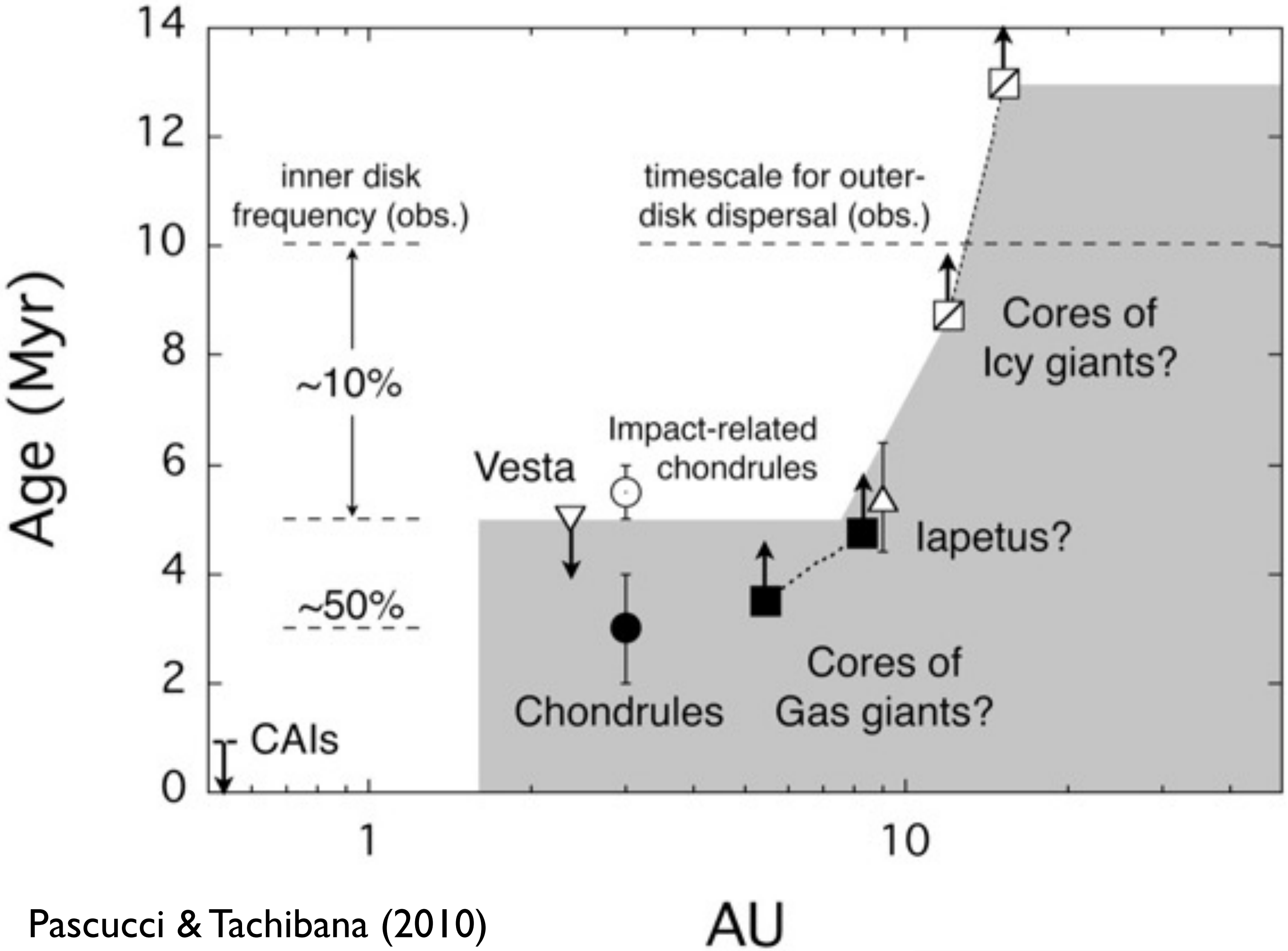
Credit: D. Fabricky

The lifetime of dust disks



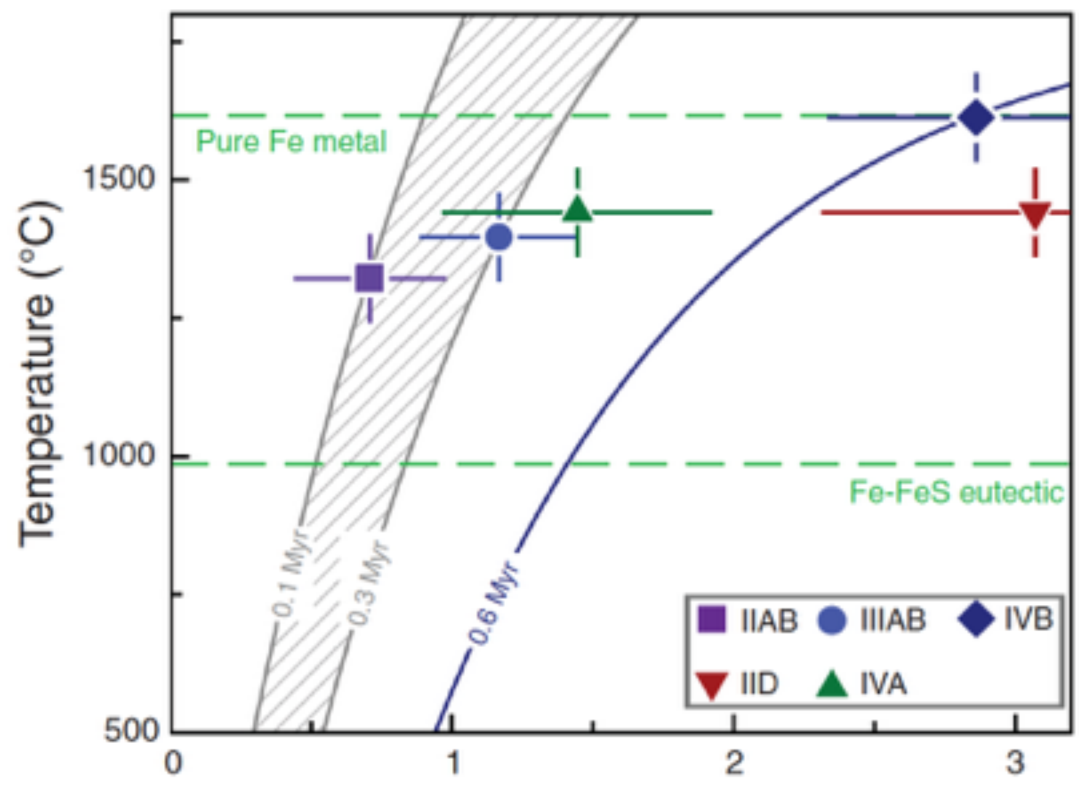
All stars are born with a circumstellar disk. The dust disk lifetime is ~3 Myr.

Disks – Solar System chronology



Pascucci & Tachibana (2010)

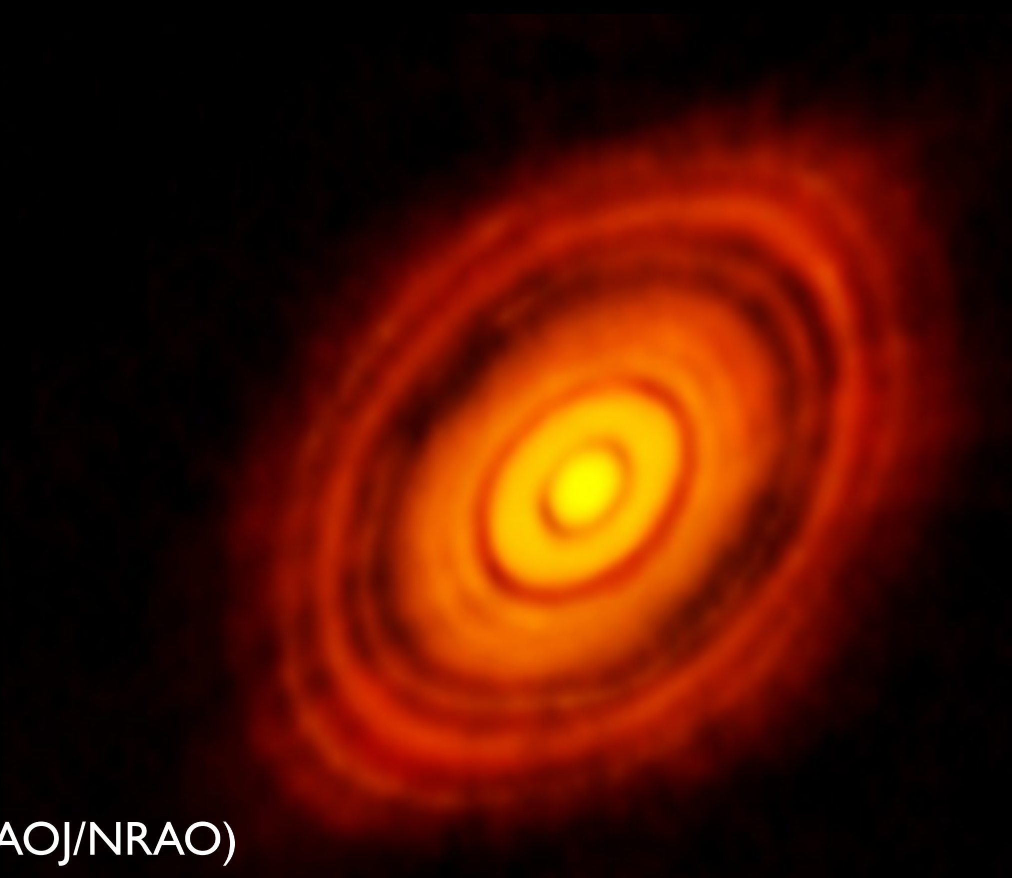
The evolution and dispersal of the dust in the solar nebula followed a similar path to that of dust in other disks



Kruijer et al. (2014)

Iron meteorite parent bodies accreted within ~0.5 Myr from CAIs

Structures may be due to rapid pebble accretion (Zhang et al. 2015) or embedded giant planets (Dipierro et al. 2015)



ALMA image of HLTau
Credit: ALMA (ESO/NAOJ/NRAO)

Main Open Questions

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- When and how do gaseous disks disperse?
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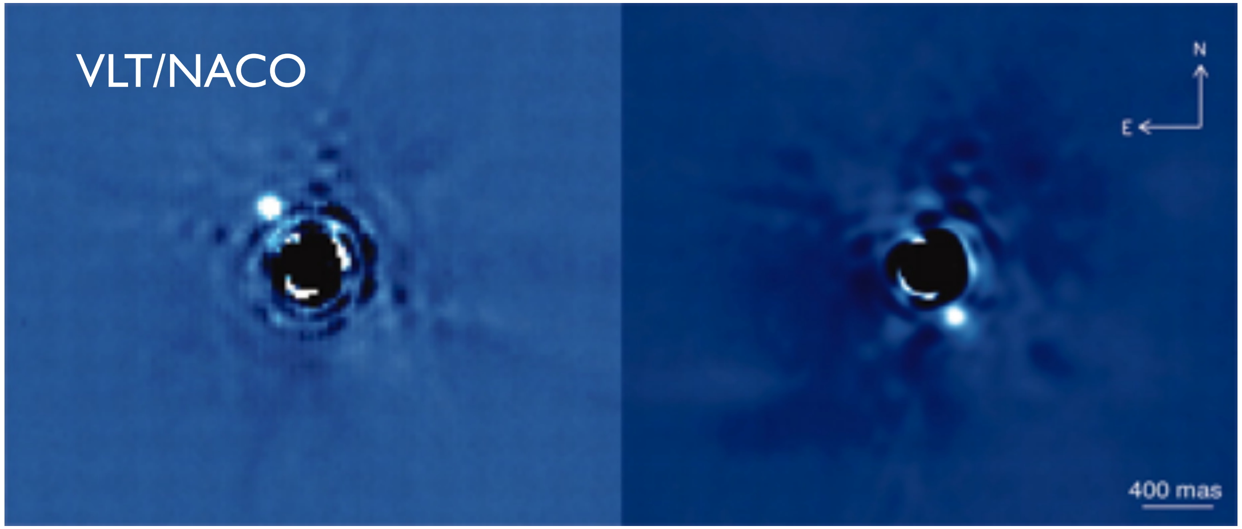
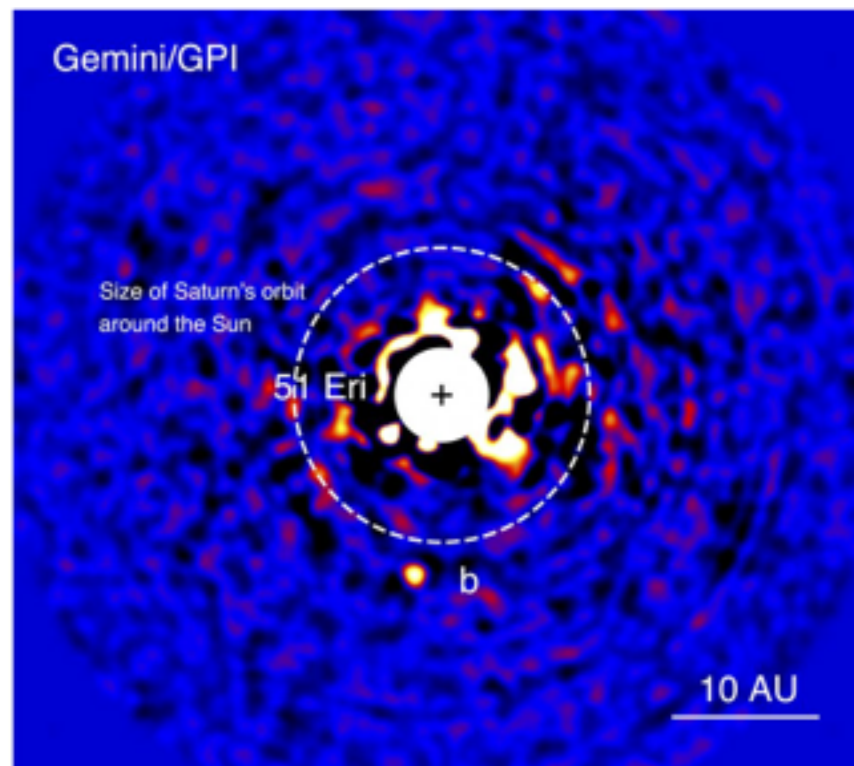
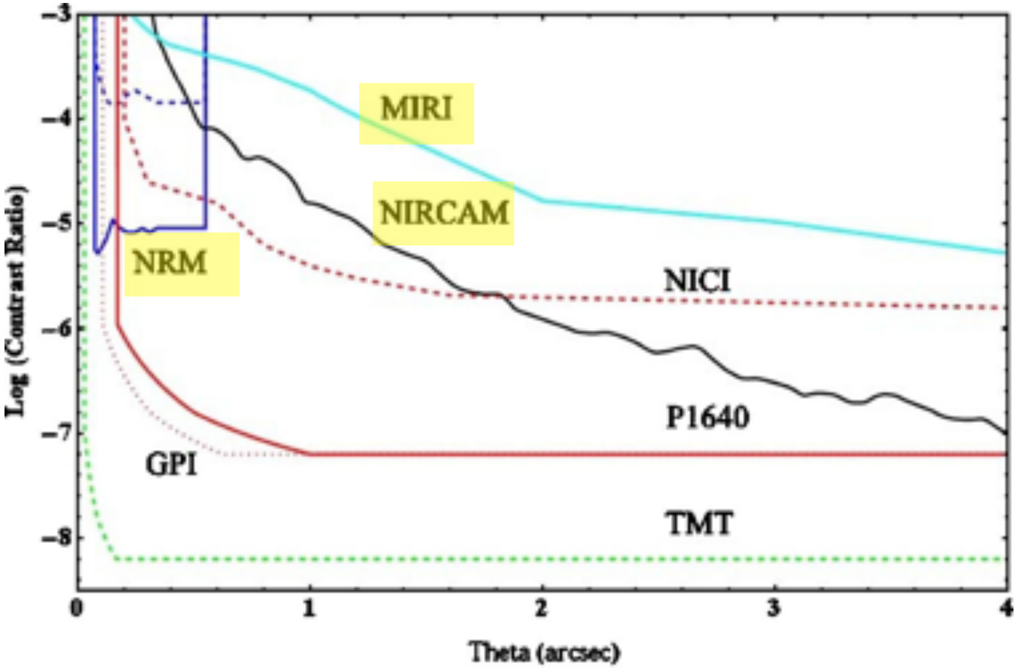


βPicb, a giant planet around a ~1.7M_{Sun} star that is ~10-20Myr old (Lagrange et al. 2010)

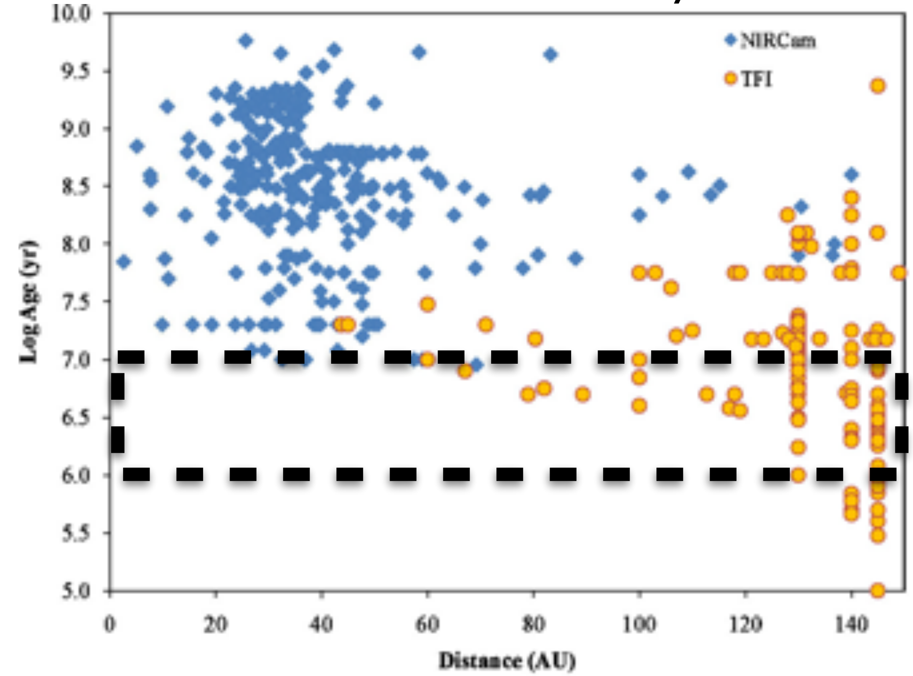


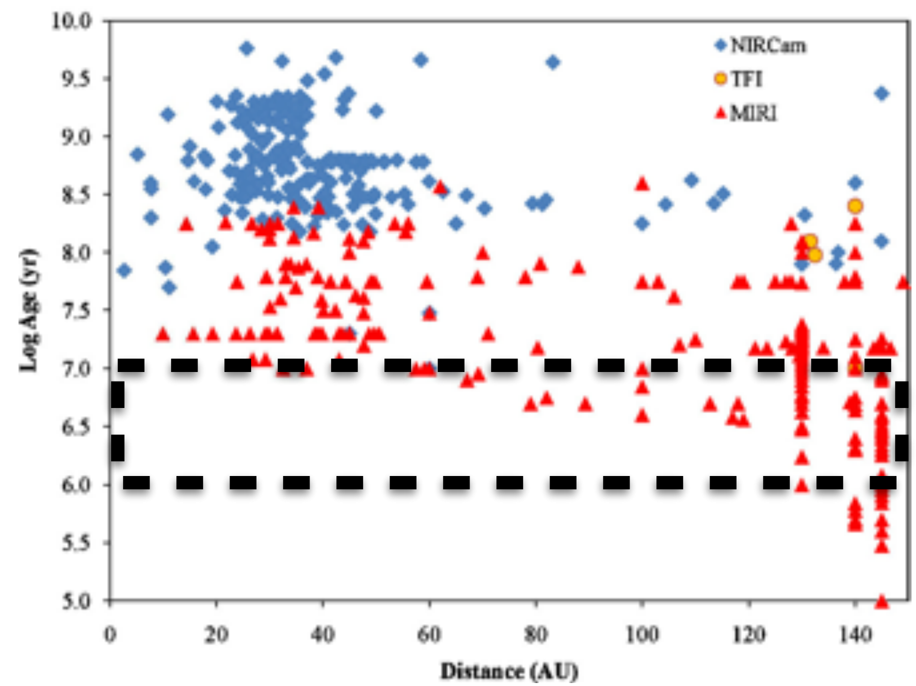
51 Eri b, a giant planet around a ~2M_{Sun} star that is ~20Myr old (Macintosh et al. 2015)

Beichman et al. (2010)



Planet detectability

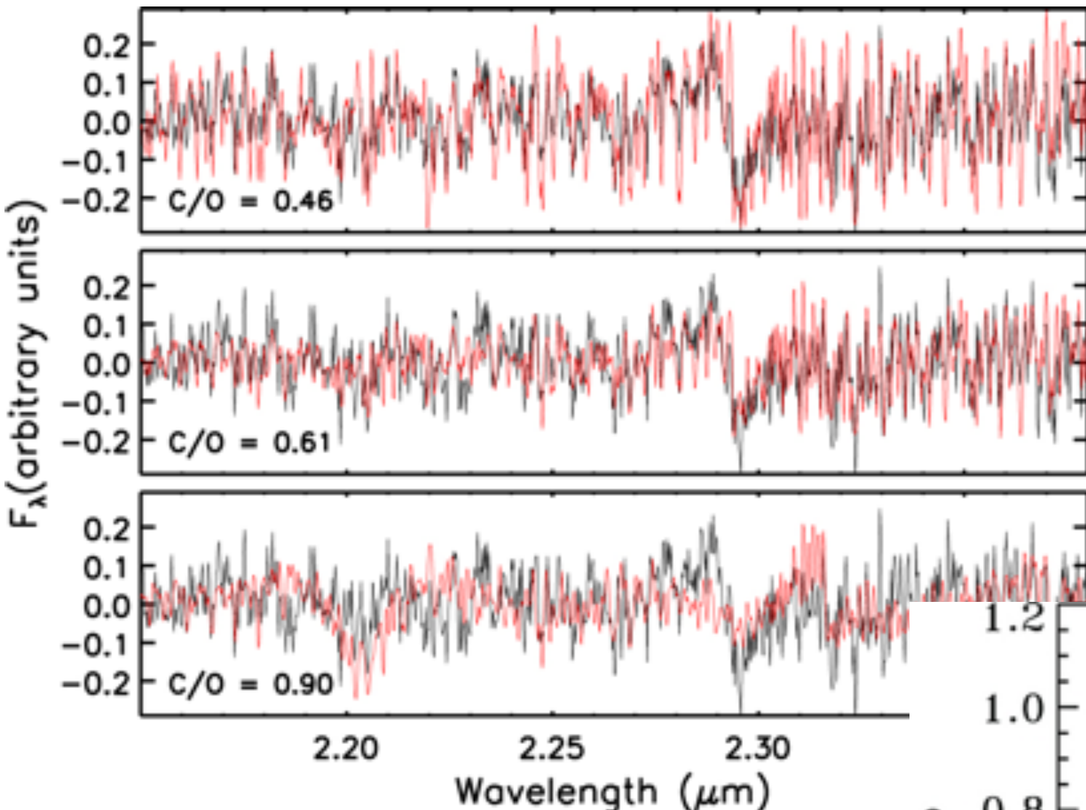




JWST can detect planets as small as $0.2\ M_{Jup}$ at large separations

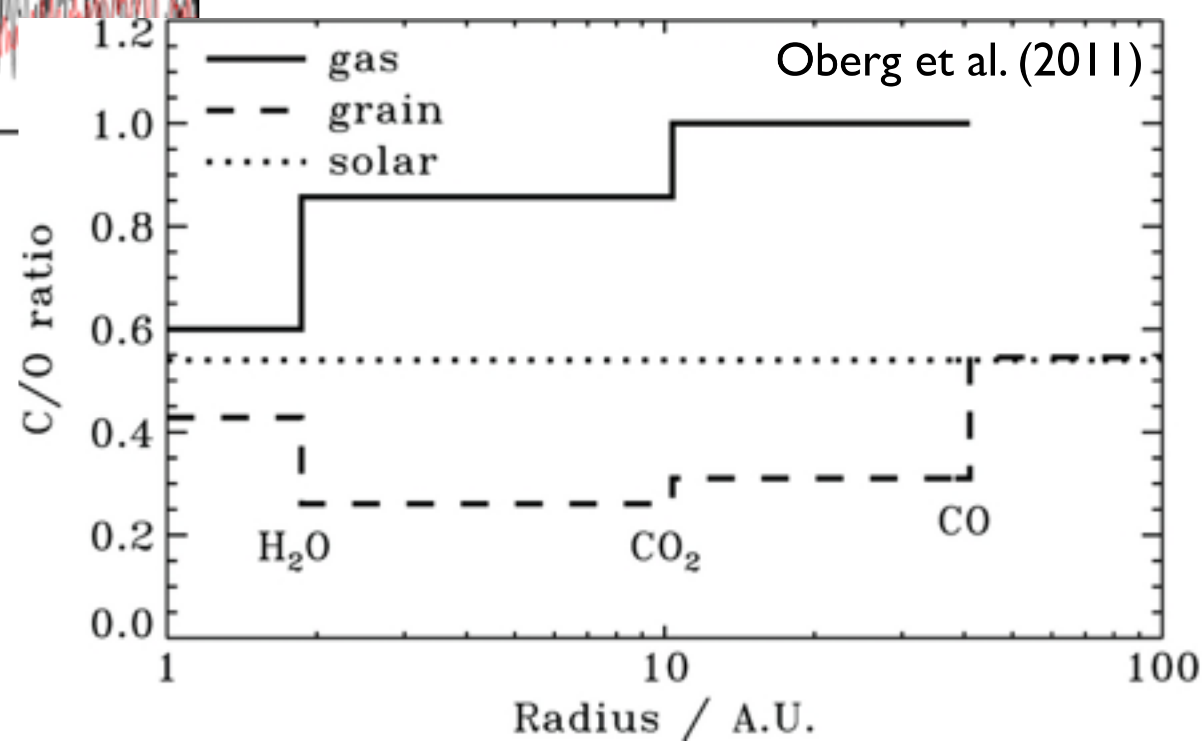
Sessions on Exoplanets
(this afternoon and Thursday)

C/O ratio: Linking giant planet composition to their formation site



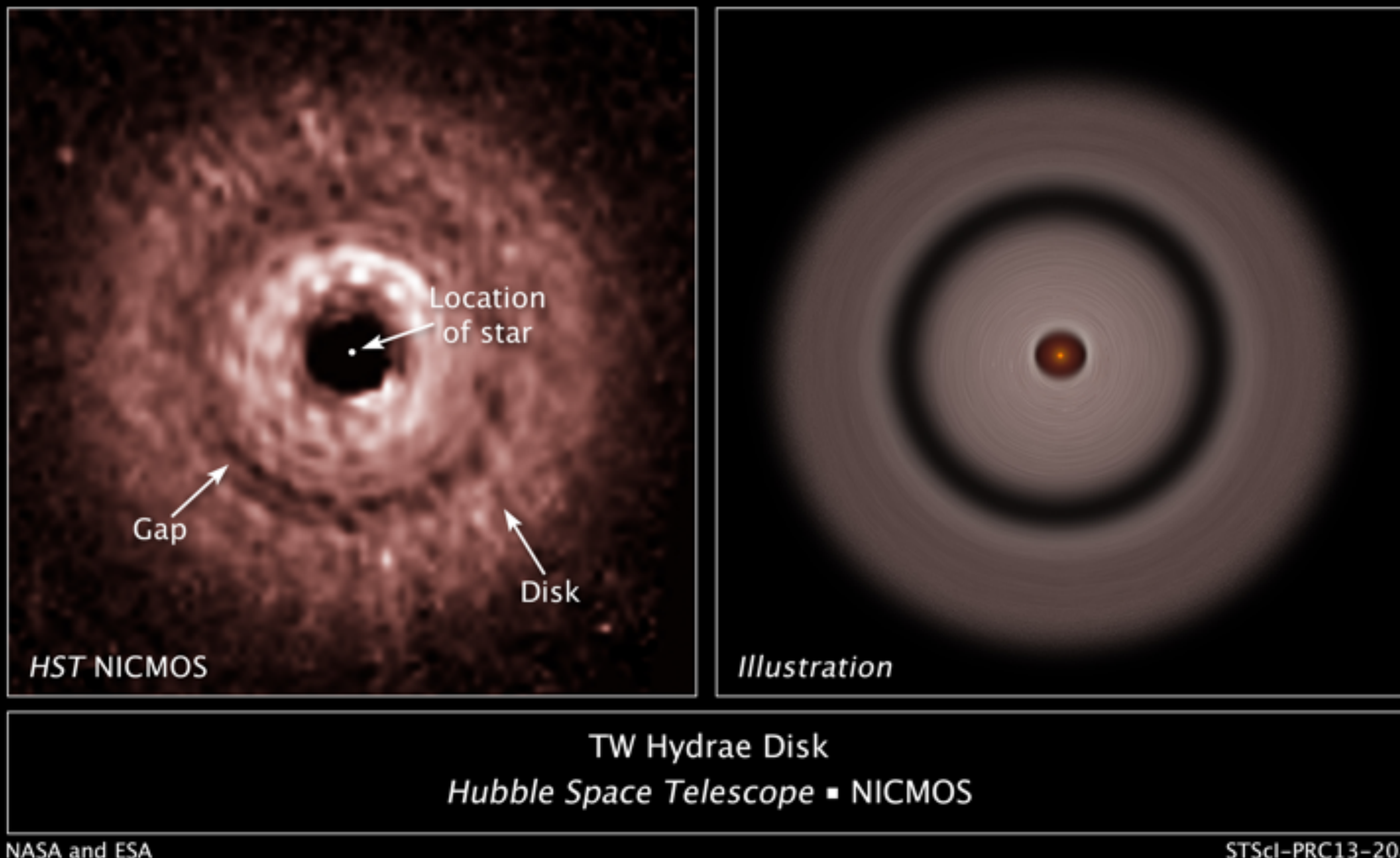
HR8799b, Barman et al. (2015)

Medium resolution spectra (R~600-2400) with JWST



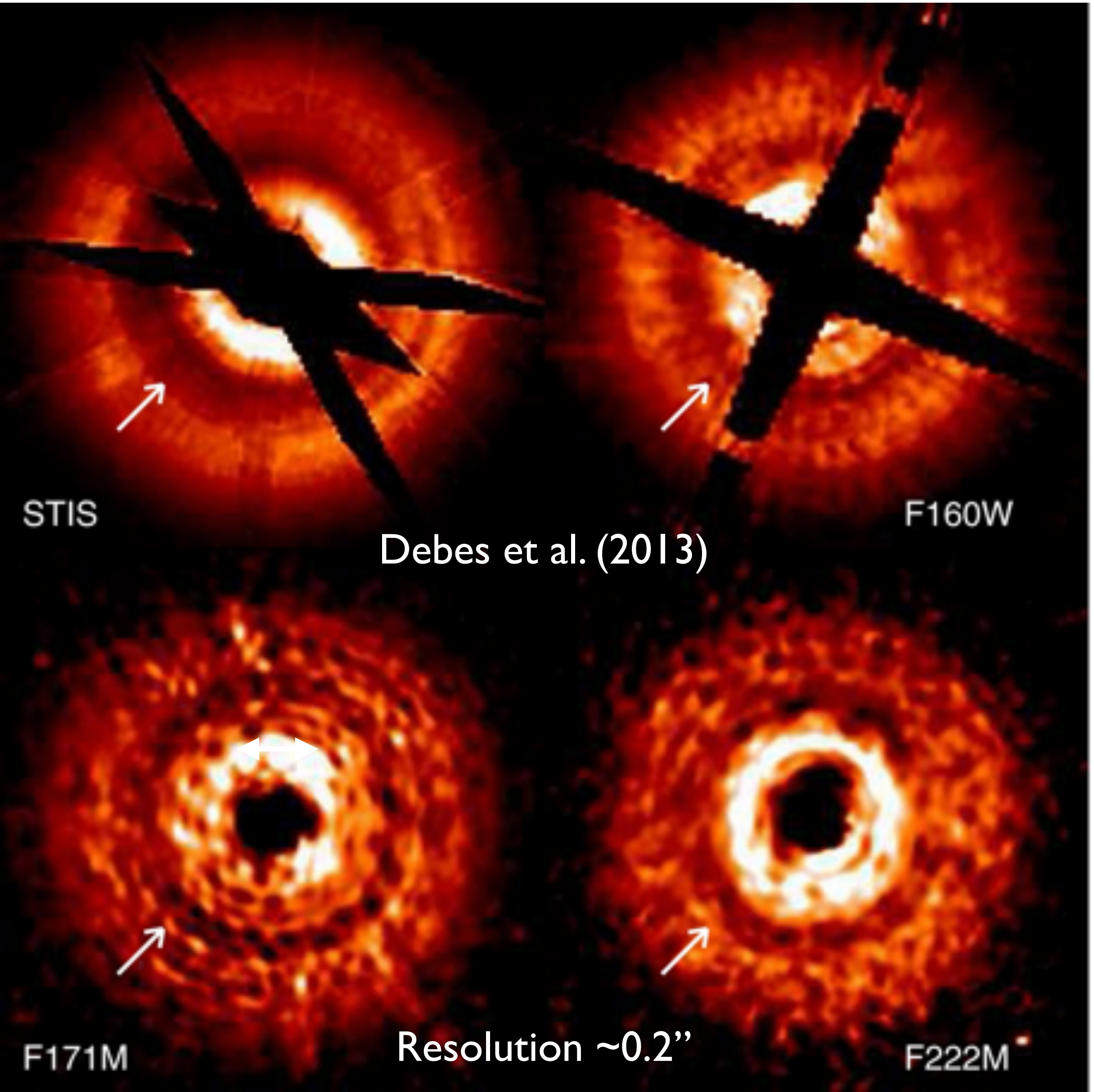
Indirect evidence of planets from the detection of narrow gaps in disks

The case of the ~10Myr-old star TWHya: a **6-28M$_E$** at ~80AU (Debes e al. 2013)

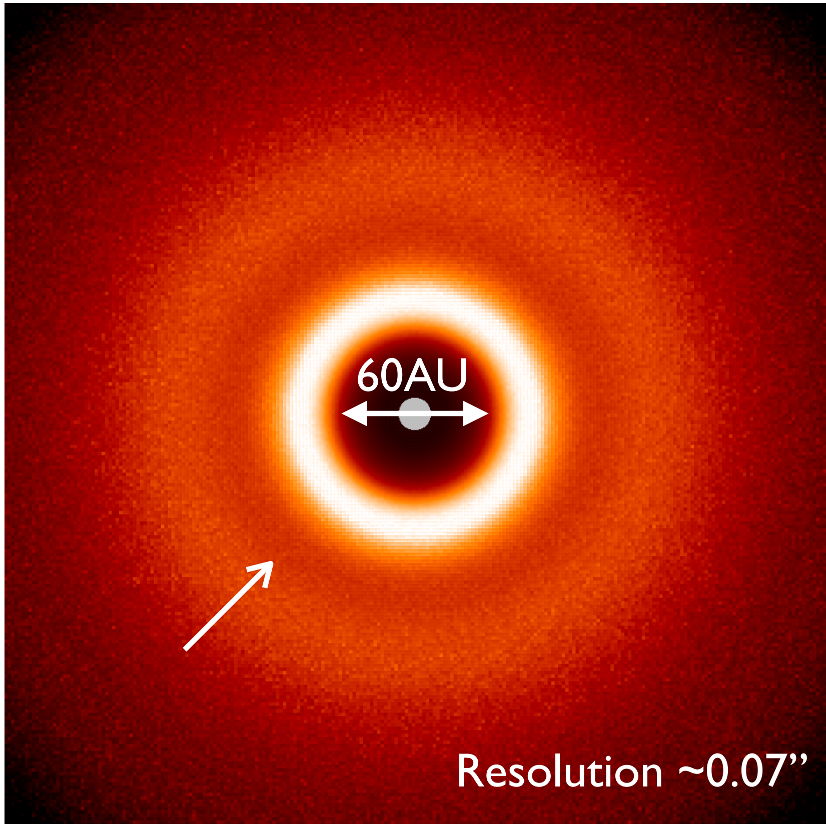


JWST will enable detecting structures closer to the star than HST and faint structures far out than what is possible with ground-based AO

HST images of the TWHya disk



Simulated NIRCAM image



Credit: H. Jang-Condell

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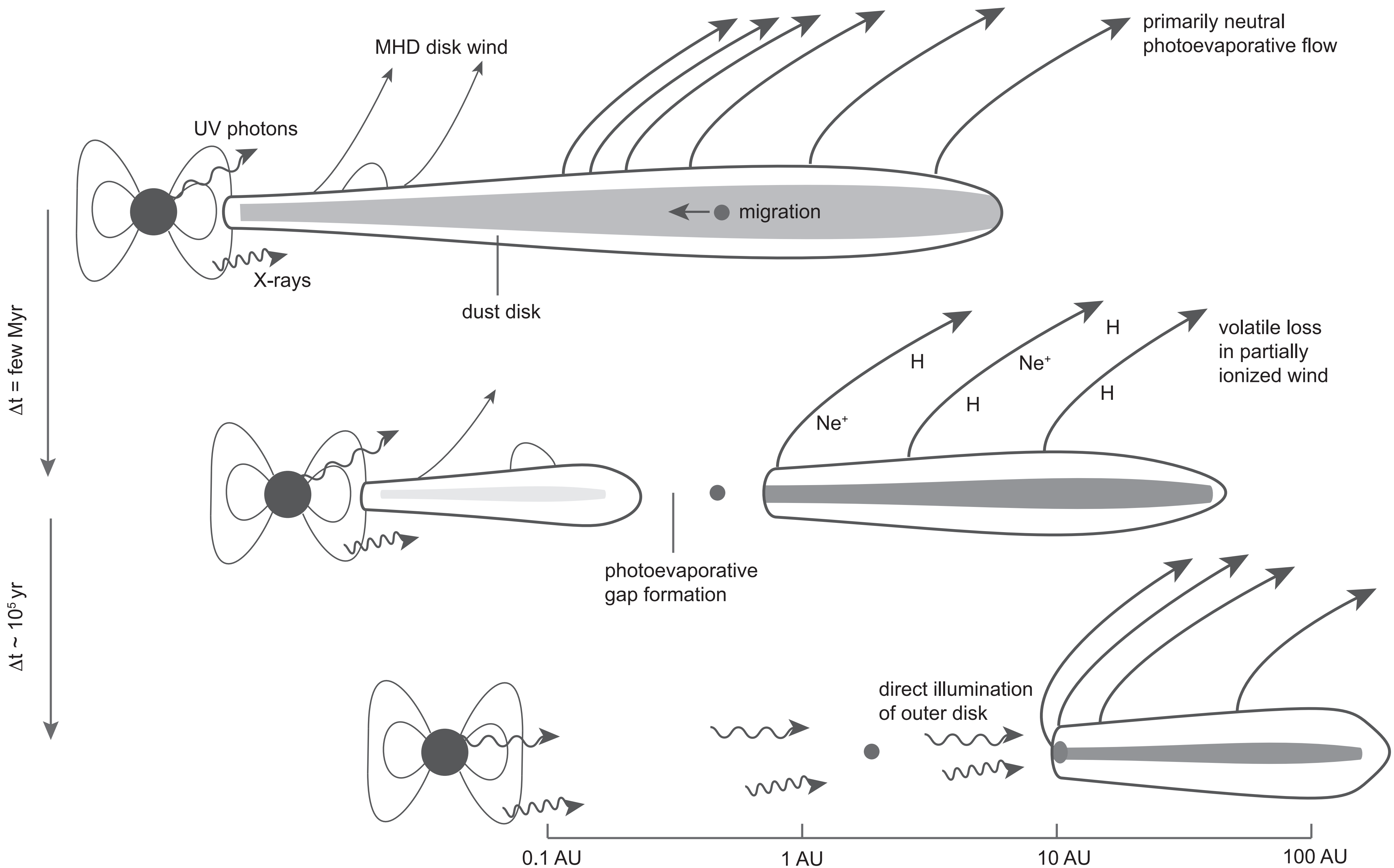
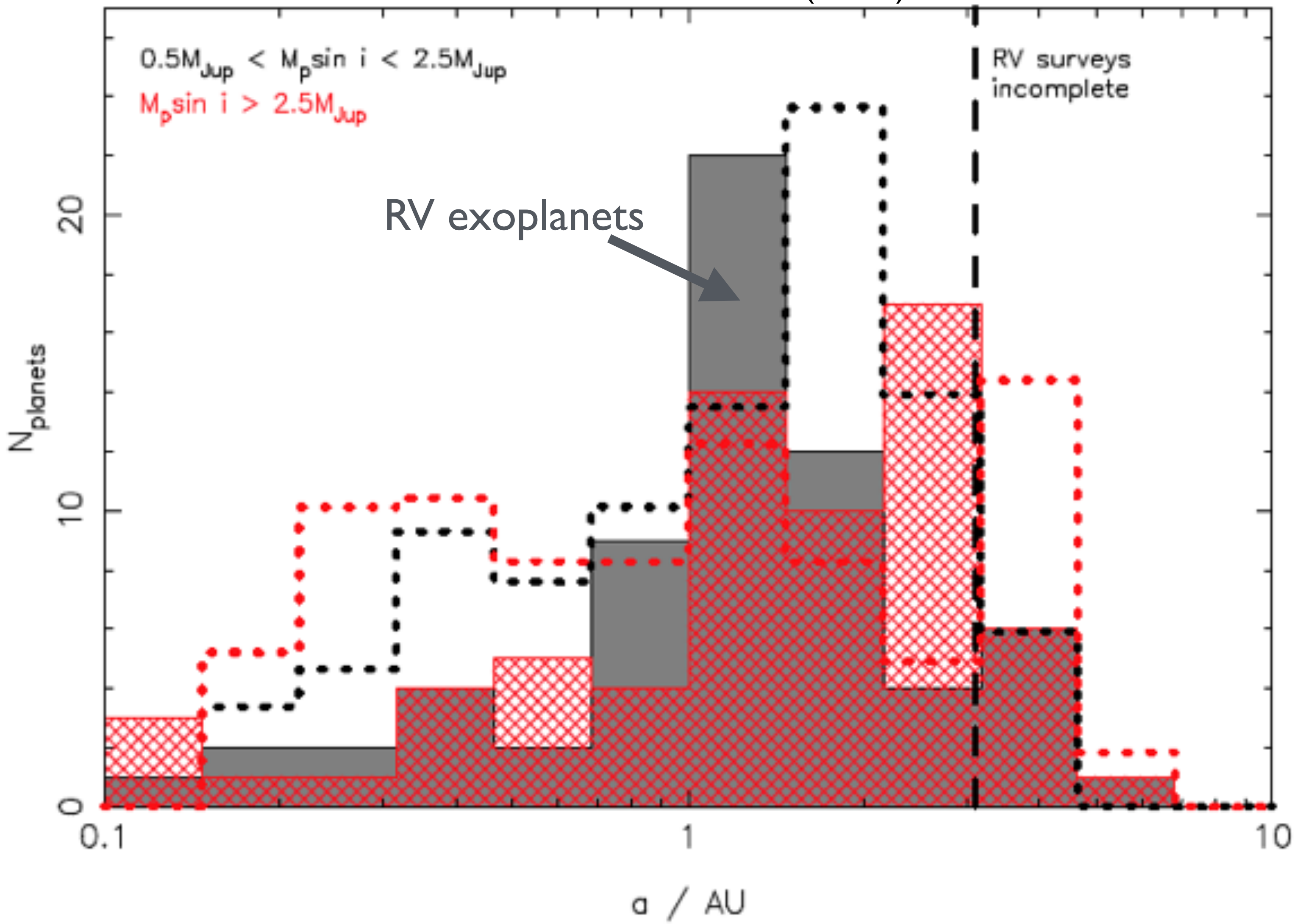
Schematic picture of disk evolution



from Alexander, Pascucci, Andrews, Armitage, Cieza 2014 (PPVI, review chapter)

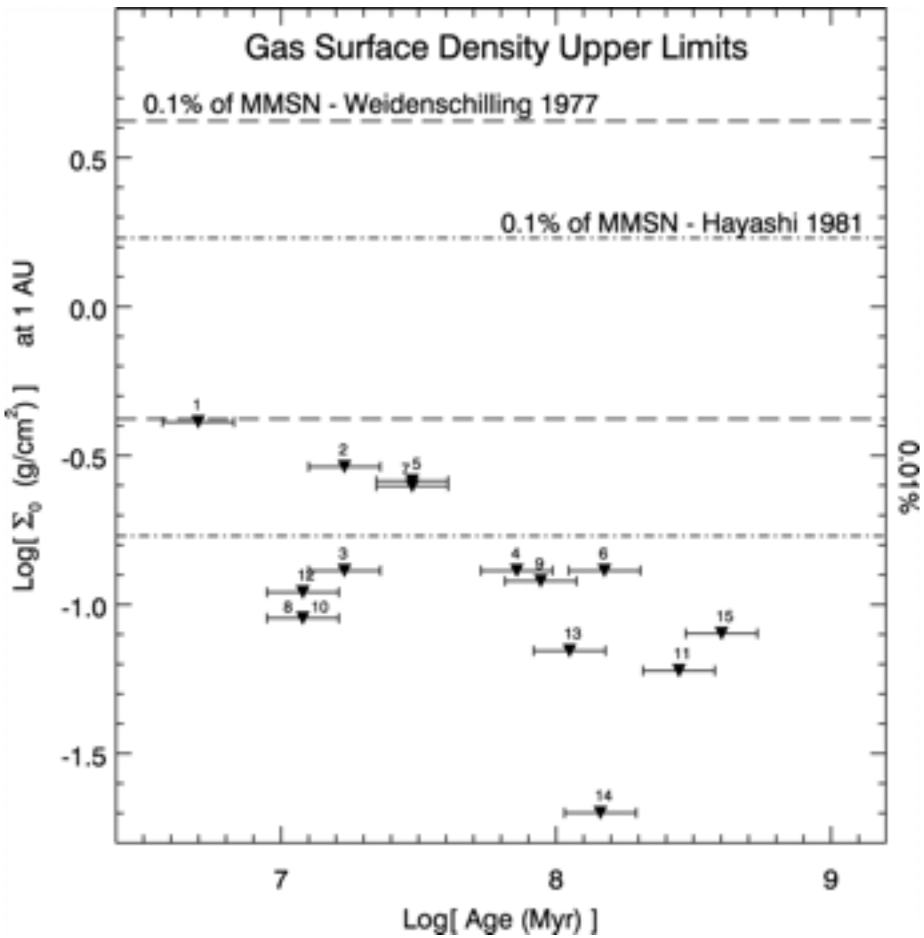
Deserts and pile-ups of giant planets

Alexander & Pascucci (2012)



See also Matsuyama et al. (2003), Hasegawa & Pudritz (2012), Moeckel & Armitage (2012), Ercolano & Rosotti (2015)

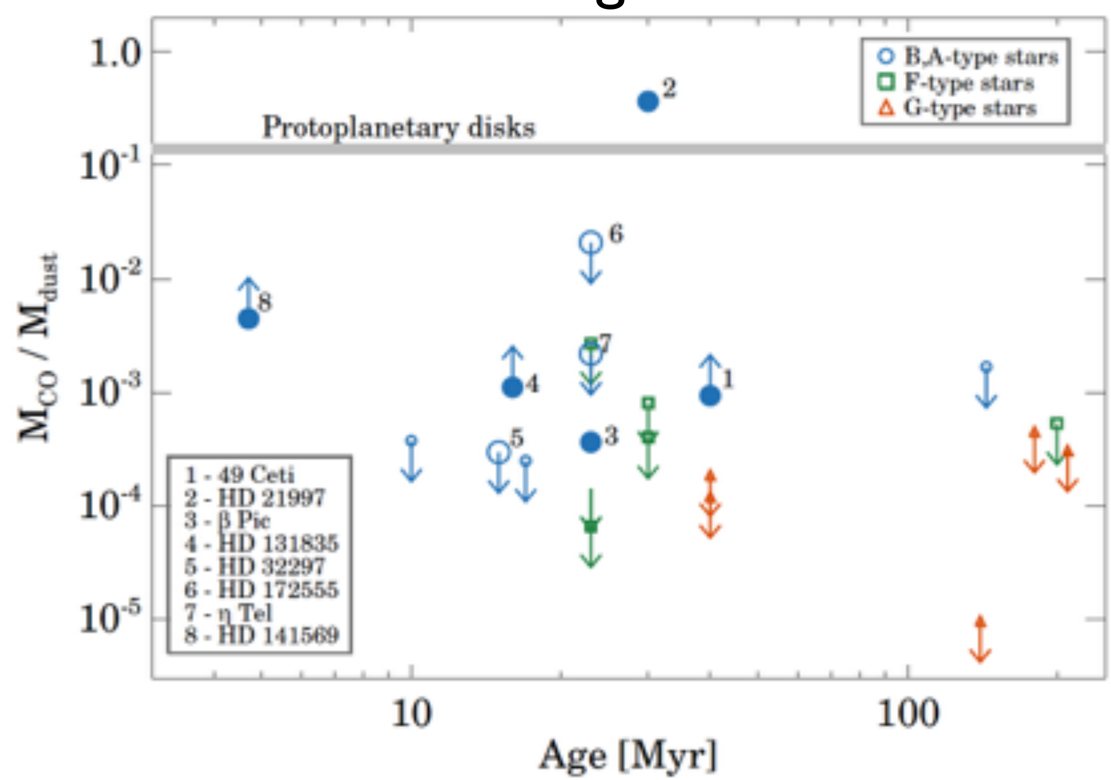
Solar-mass stars



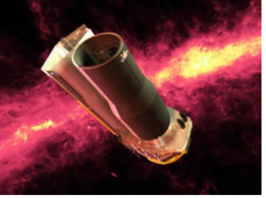
Pascucci et al. (2006)

Are accretion and photoevaporation always the main disk dispersal mechanisms?

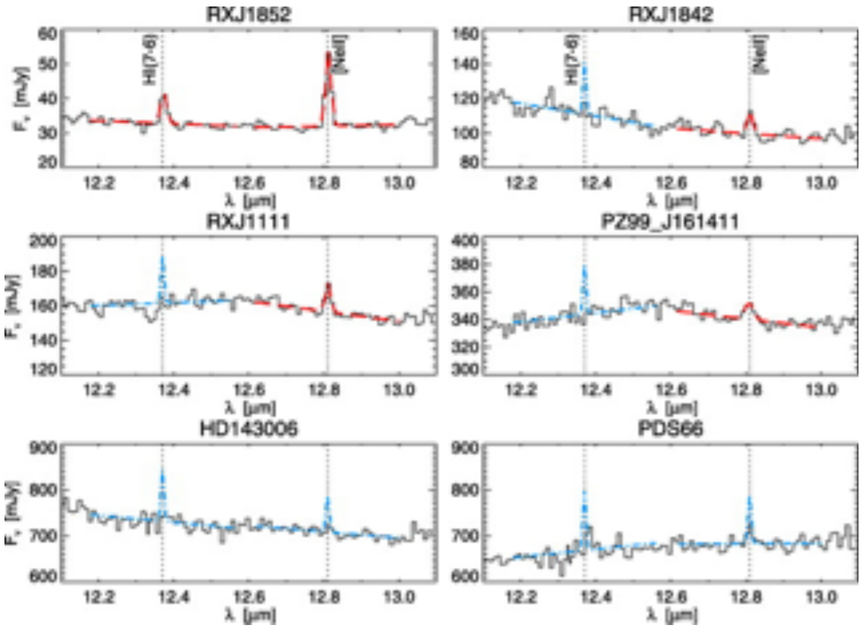
Herbig stars



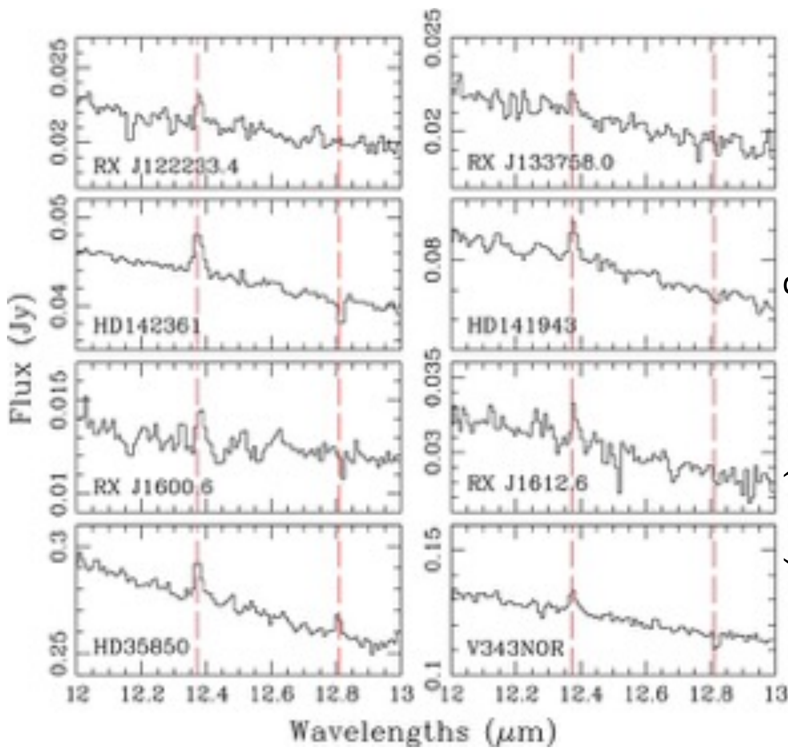
Moor et al. (2015)



Infrared lines tracing disk gas

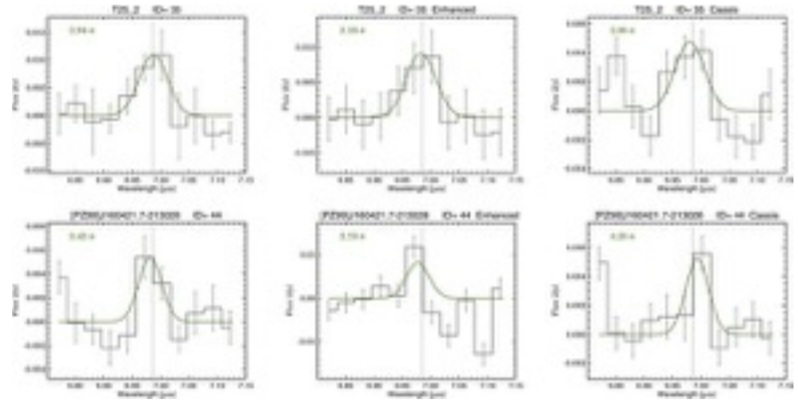


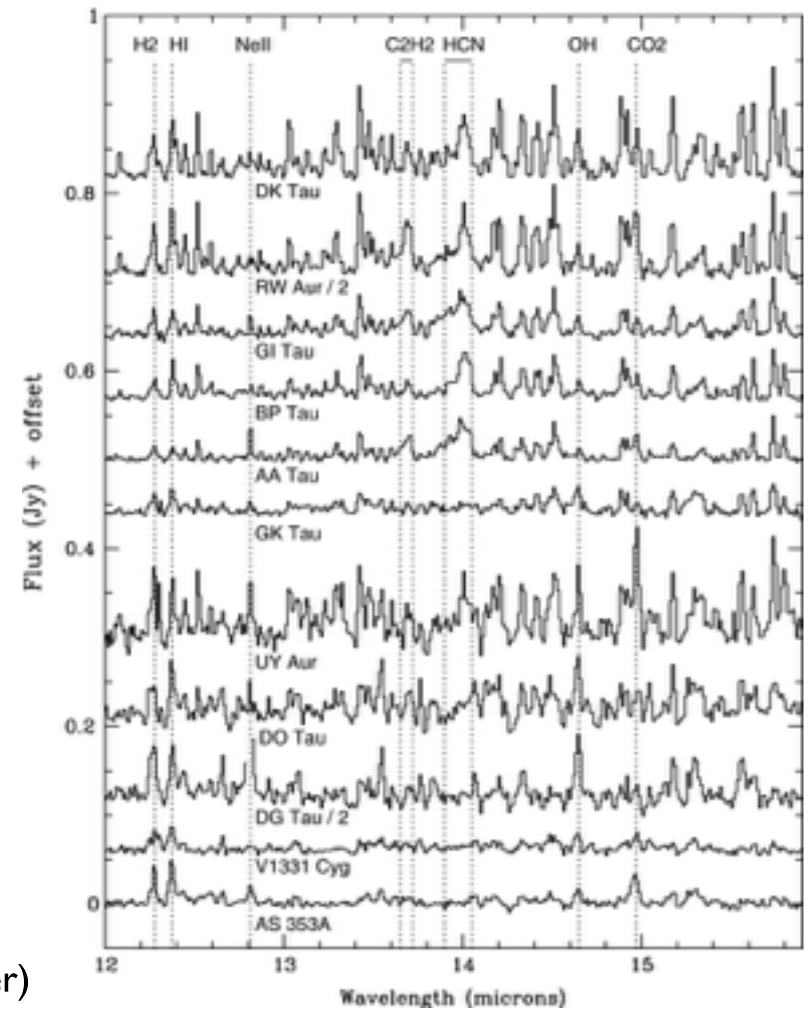
[NeII]–Pascucci et al. (2007)



HI–Rigliaco et al. (2015)

[ArII]–Szulagyi et al. (2012)

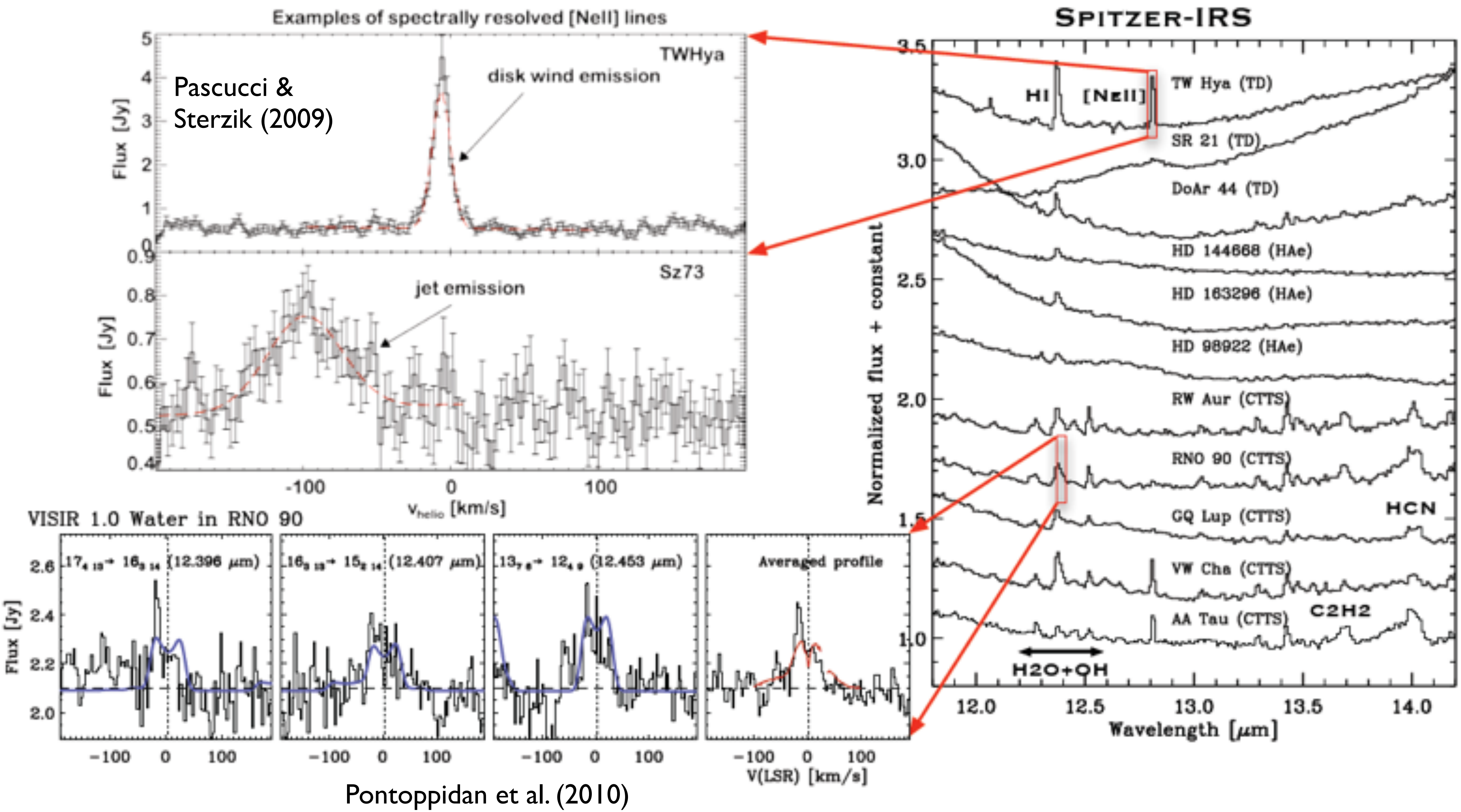




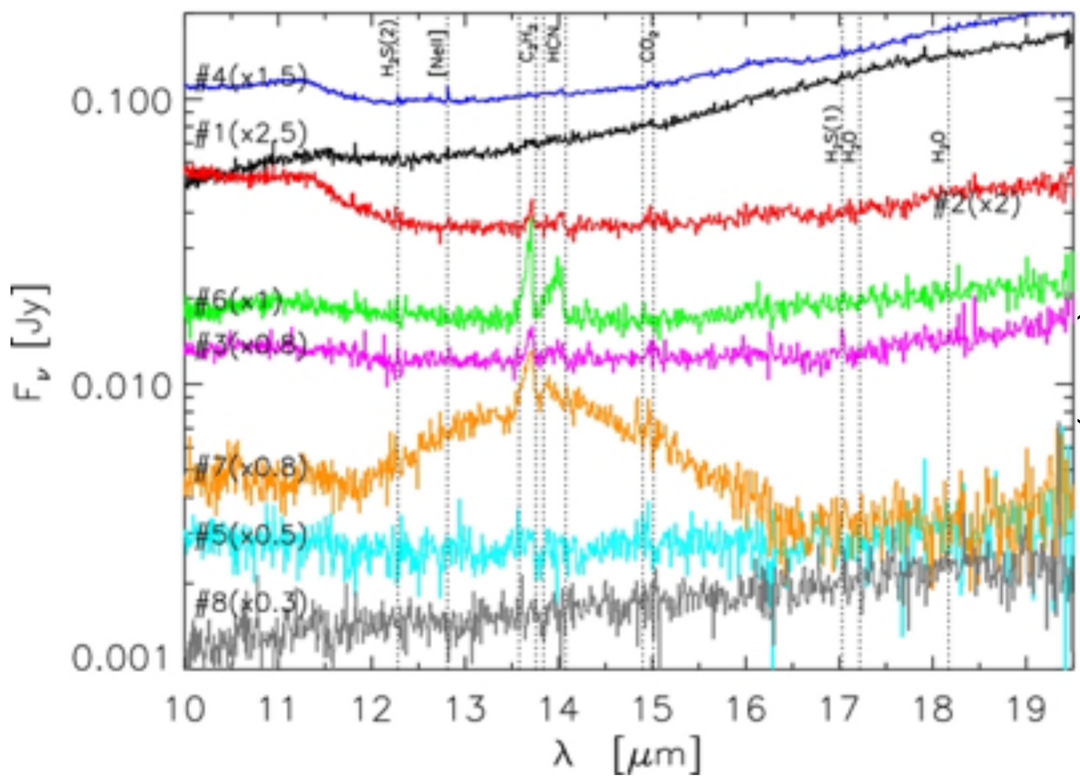
H_2O and organics–Carr & Najita (2011)

(poster by W. Fischer)

Complementarity between sensitive low-resolution space- and high-resolution ground-based spectroscopy



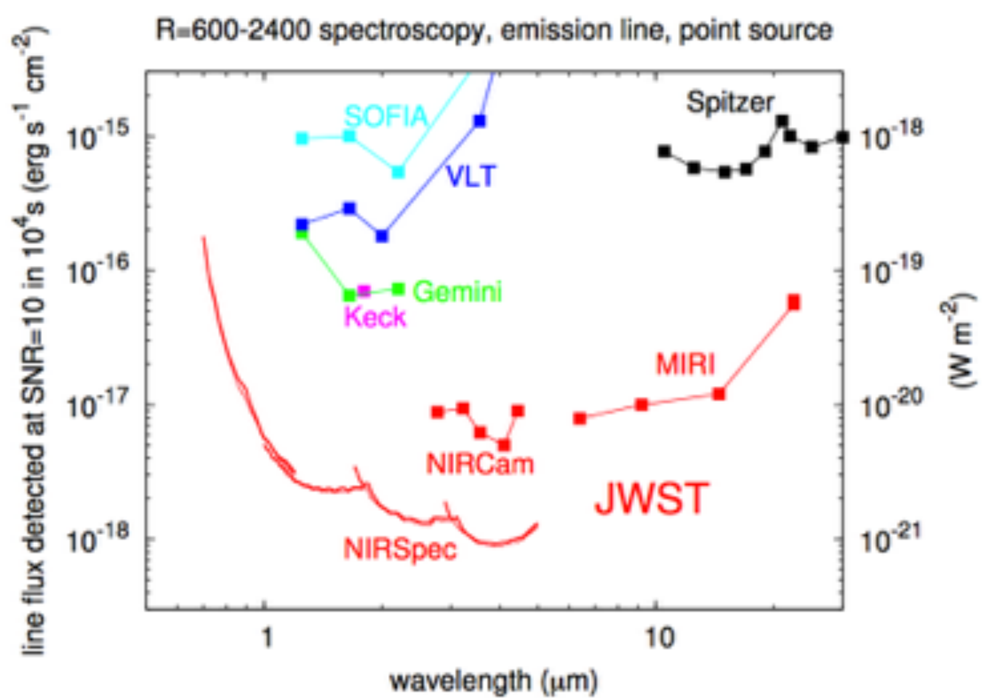
The faintest disks around young stellar/sub-stellar objects observed with Spitzer/IRS



Pascucci et al. (2013)

A few detections of [NeII], H_2, HCN, C_2H_2 lines. No water lines!
Fluxes ~10^{-18} W/m^2

MIRI has x100 better sensitivity than Spitzer/IRS



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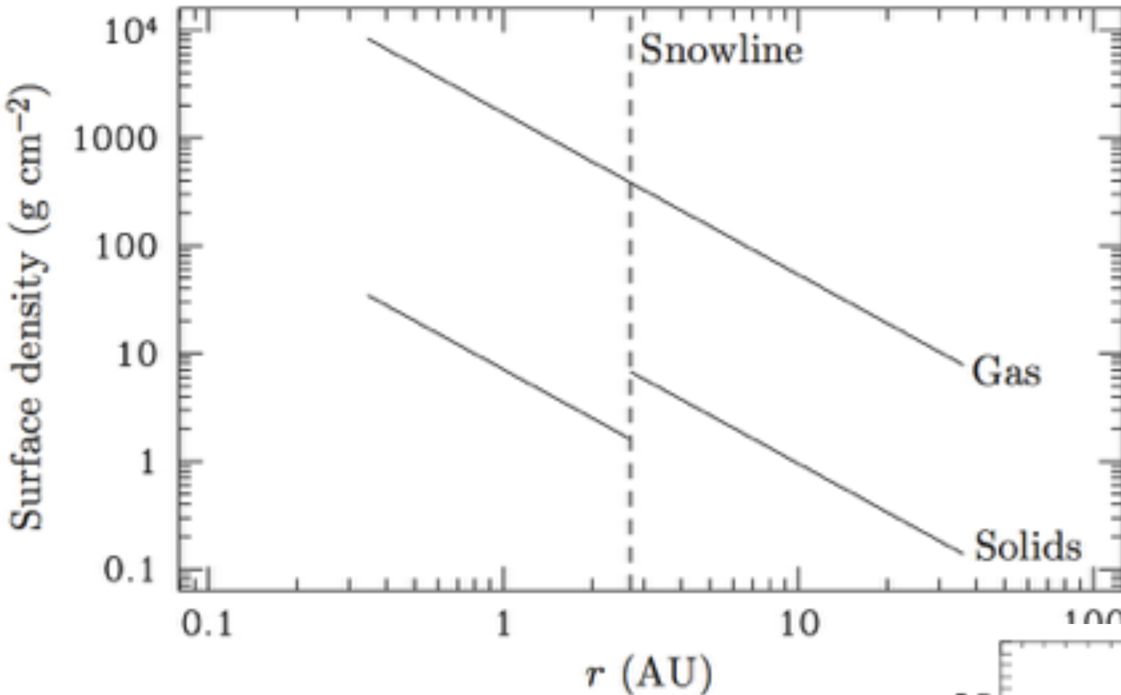
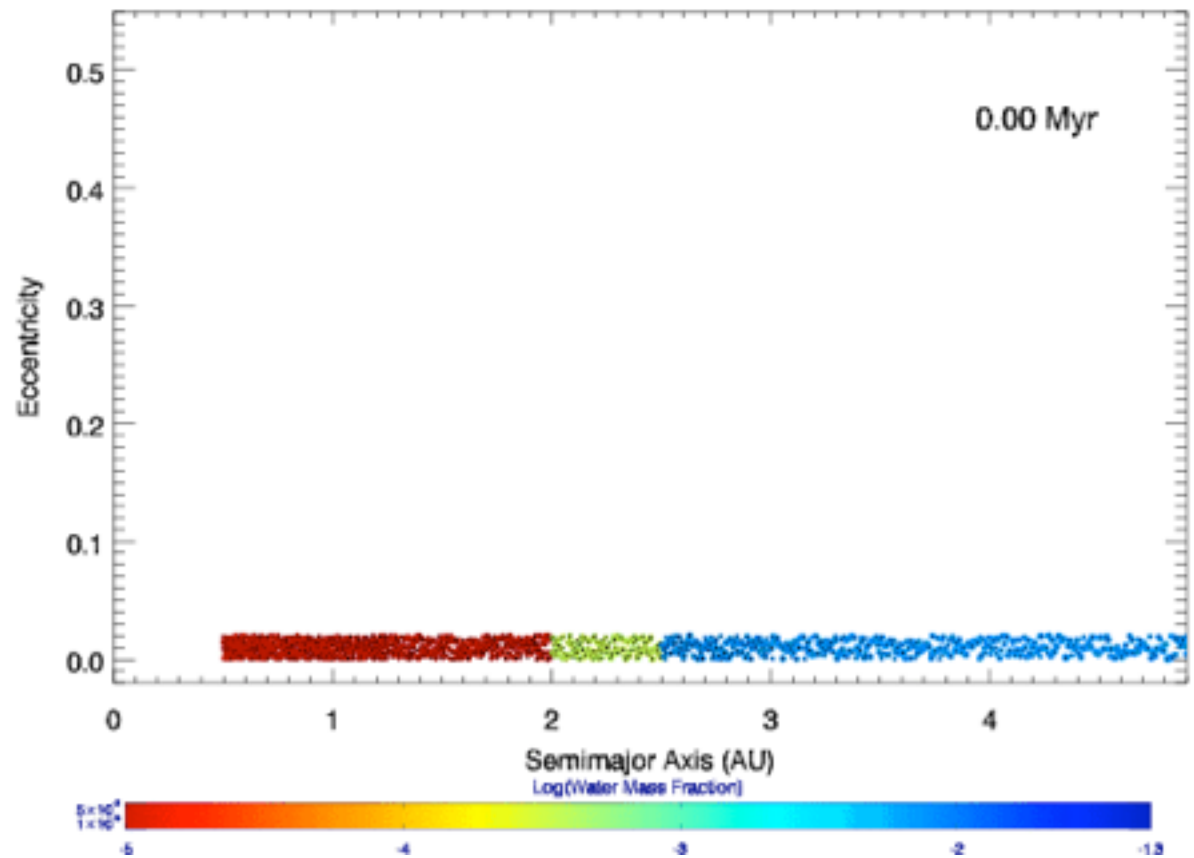
MMSN, Hayashi (1981)

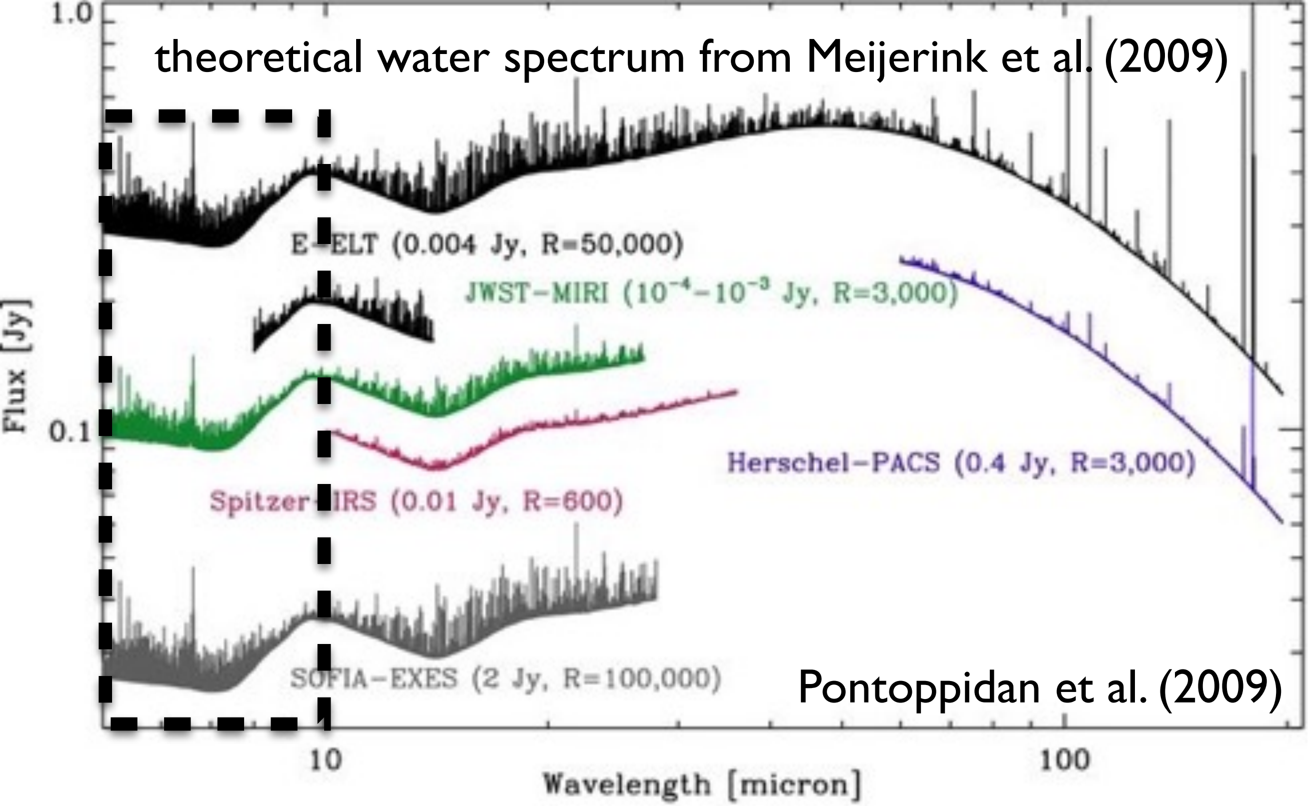


The location of the water snowline affects both giant planet formation and the delivery of water to rocky planets



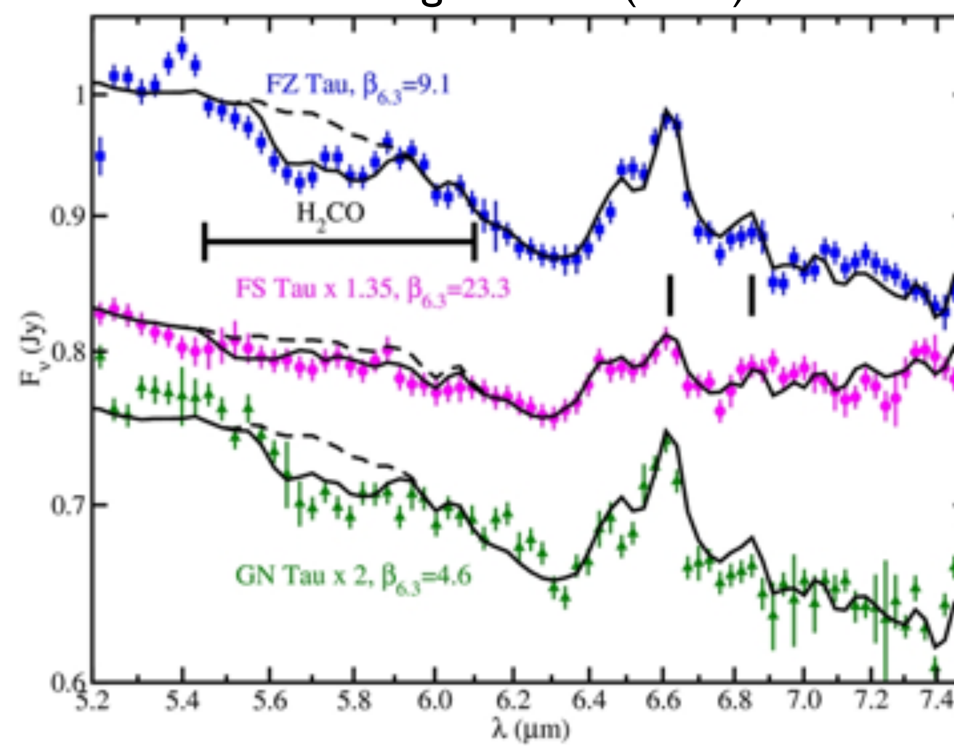
Credit: S. Raymond

JWST/MIRI spectroscopy

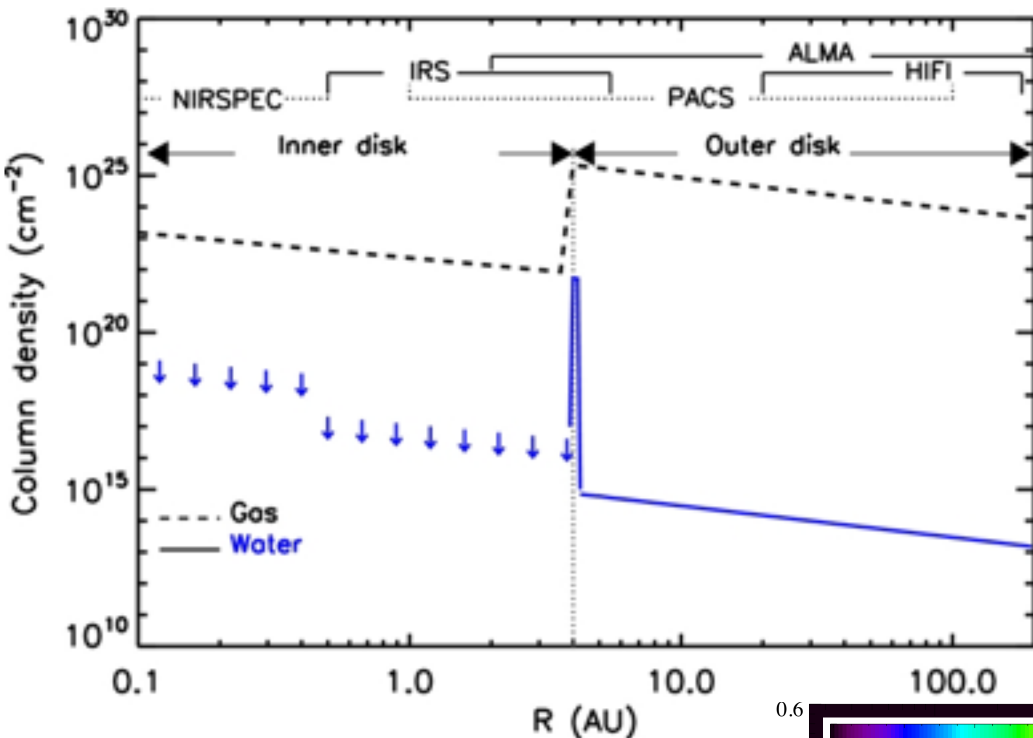


JWST/MIRI covers the ~6-10μm region and the spectral resolution is higher than Spitzer/IRS

Sargent et al. (2014)



Locating the water snowline in the disk of TW Hya

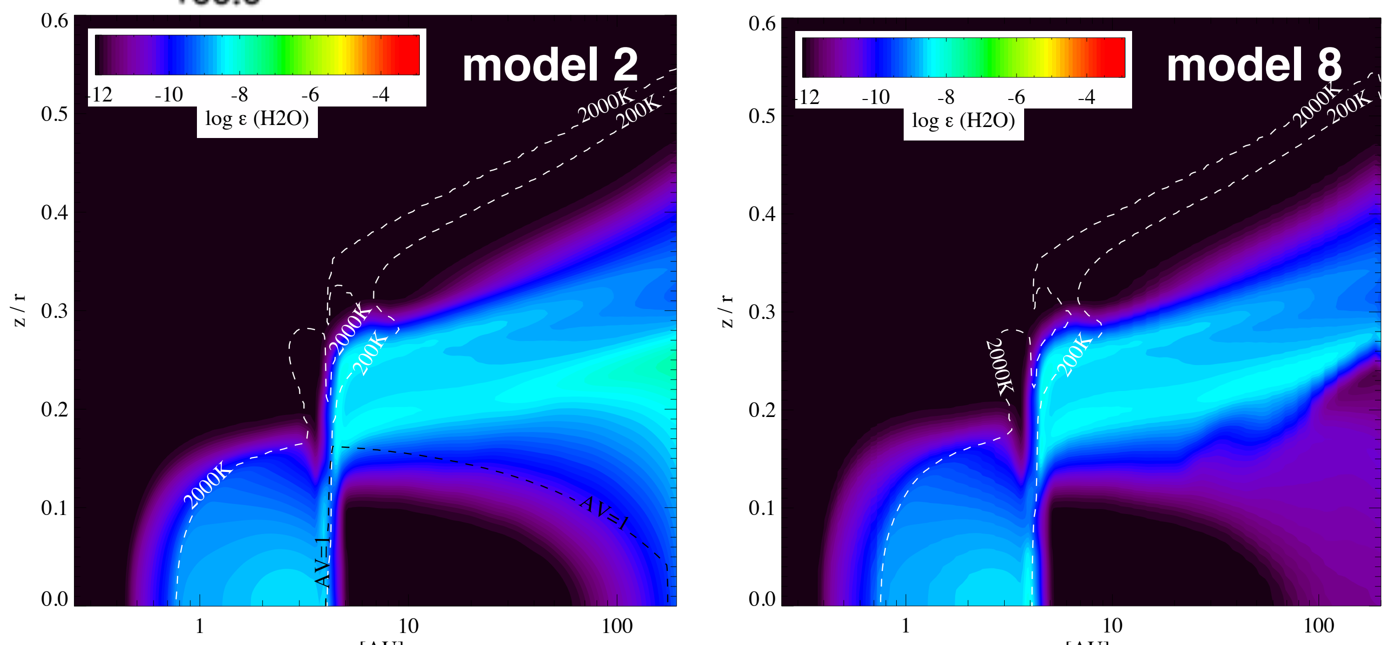


Zhang et al. (2013)

by modeling water emission lines covering a range of excitation energies

Note: several parameters affect the water line fluxes (Antonellini et al. 2015)

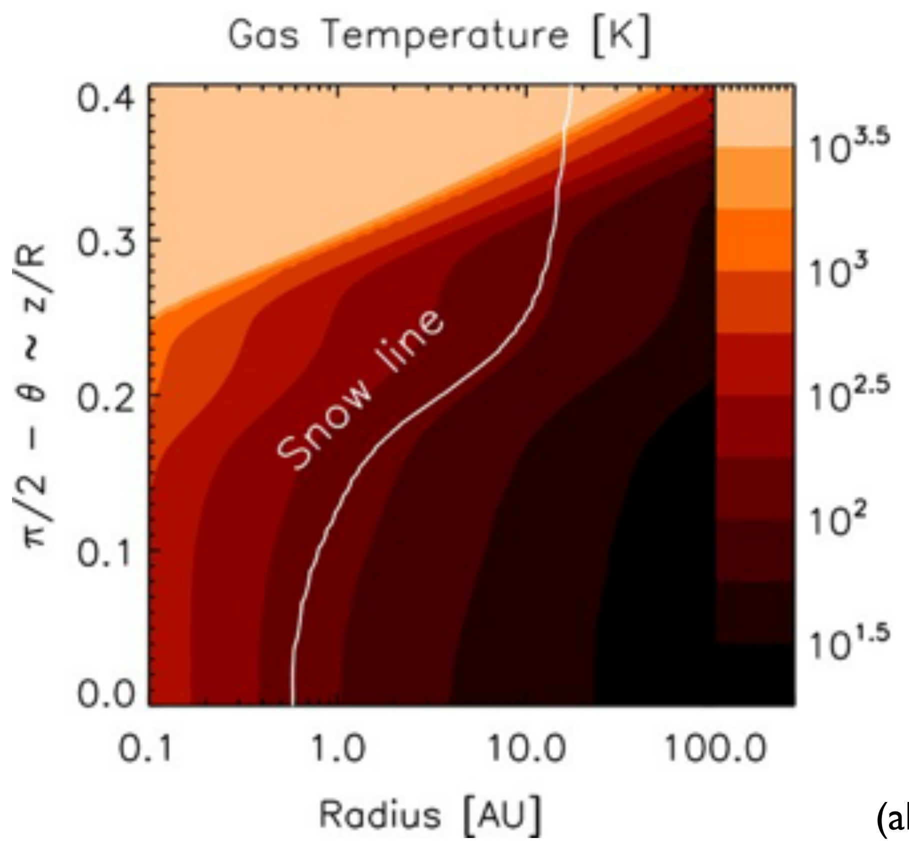
Kamp et al. (2013)



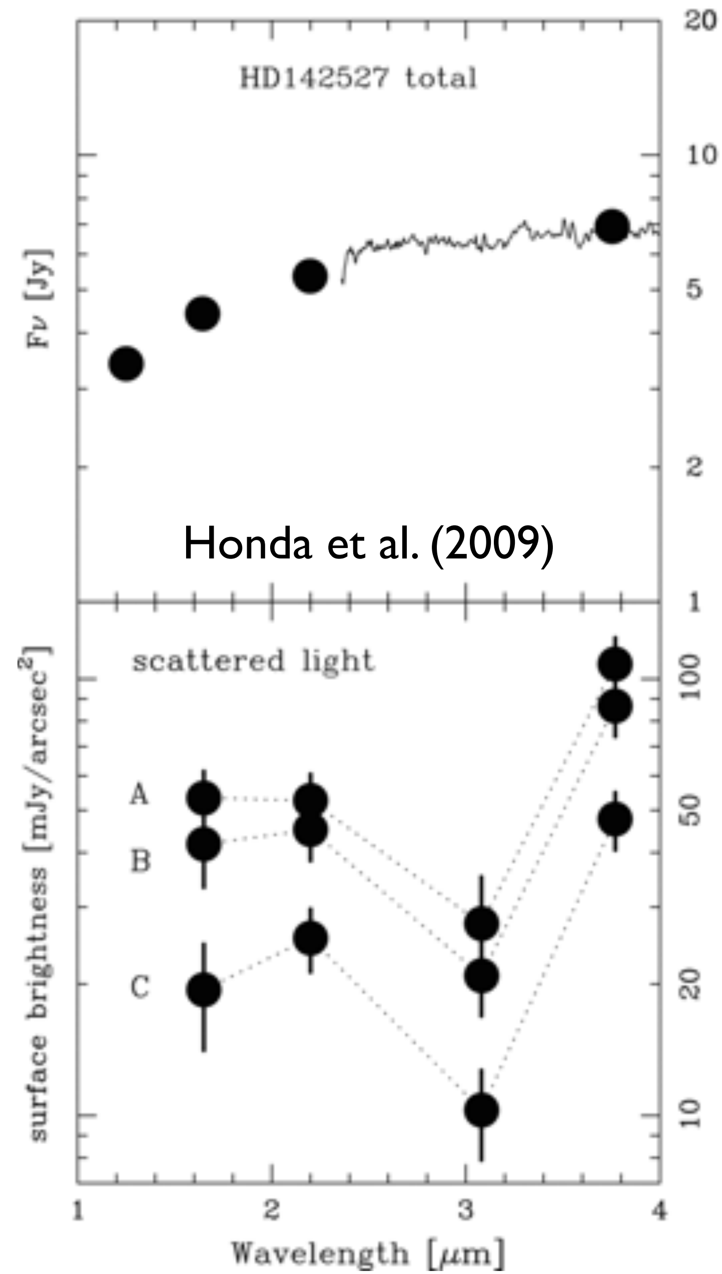
Detecting the surface water snowline in disks

(strong absorption features of water ice at 1.6, 2, and 3.1 micron)

JWST/NIRCAM coronagraphy or NIRSPEC (IFU)



Majierink et al. (2009)



Honda et al. (2009)

(also talk by H. Fraser)

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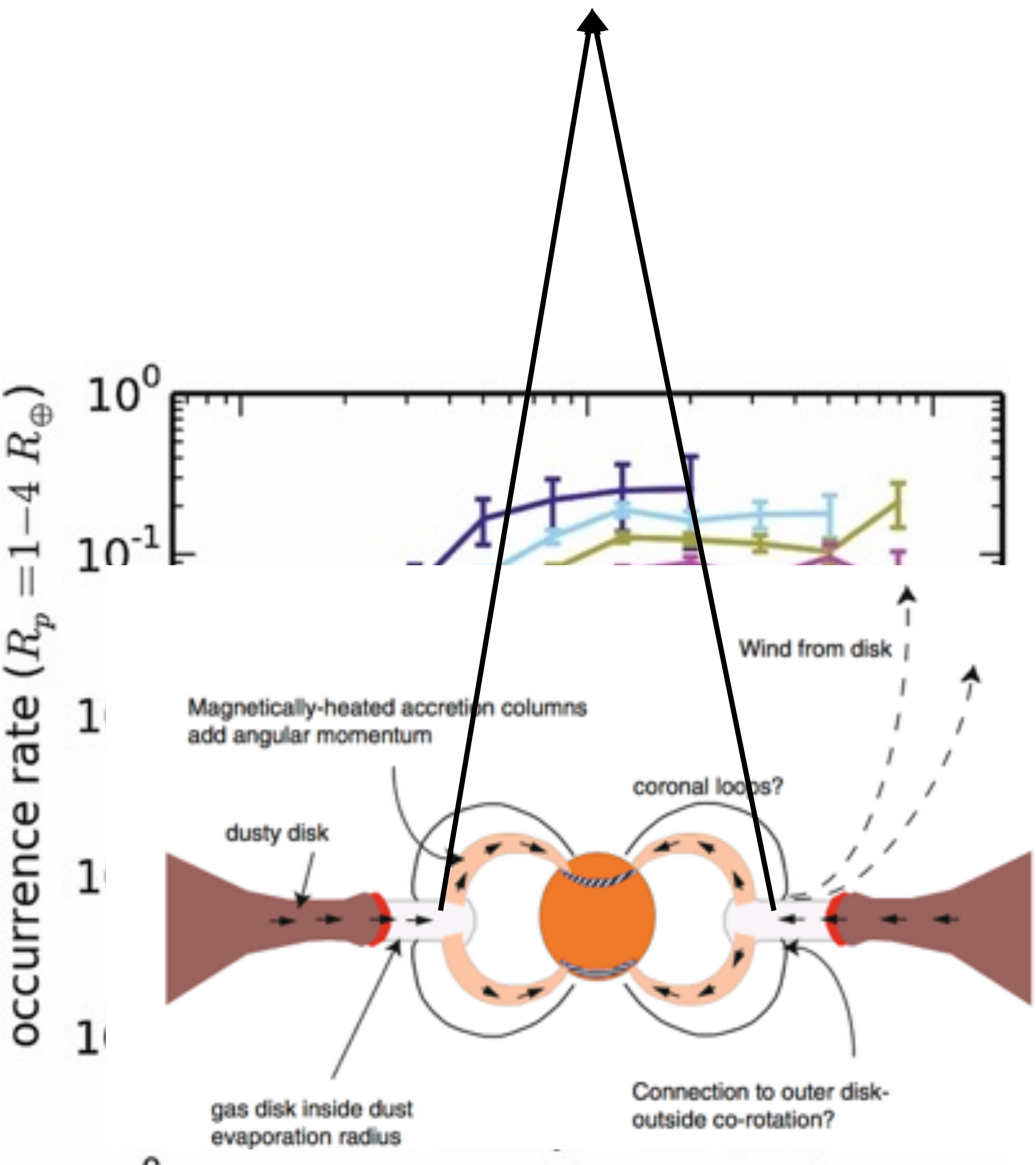
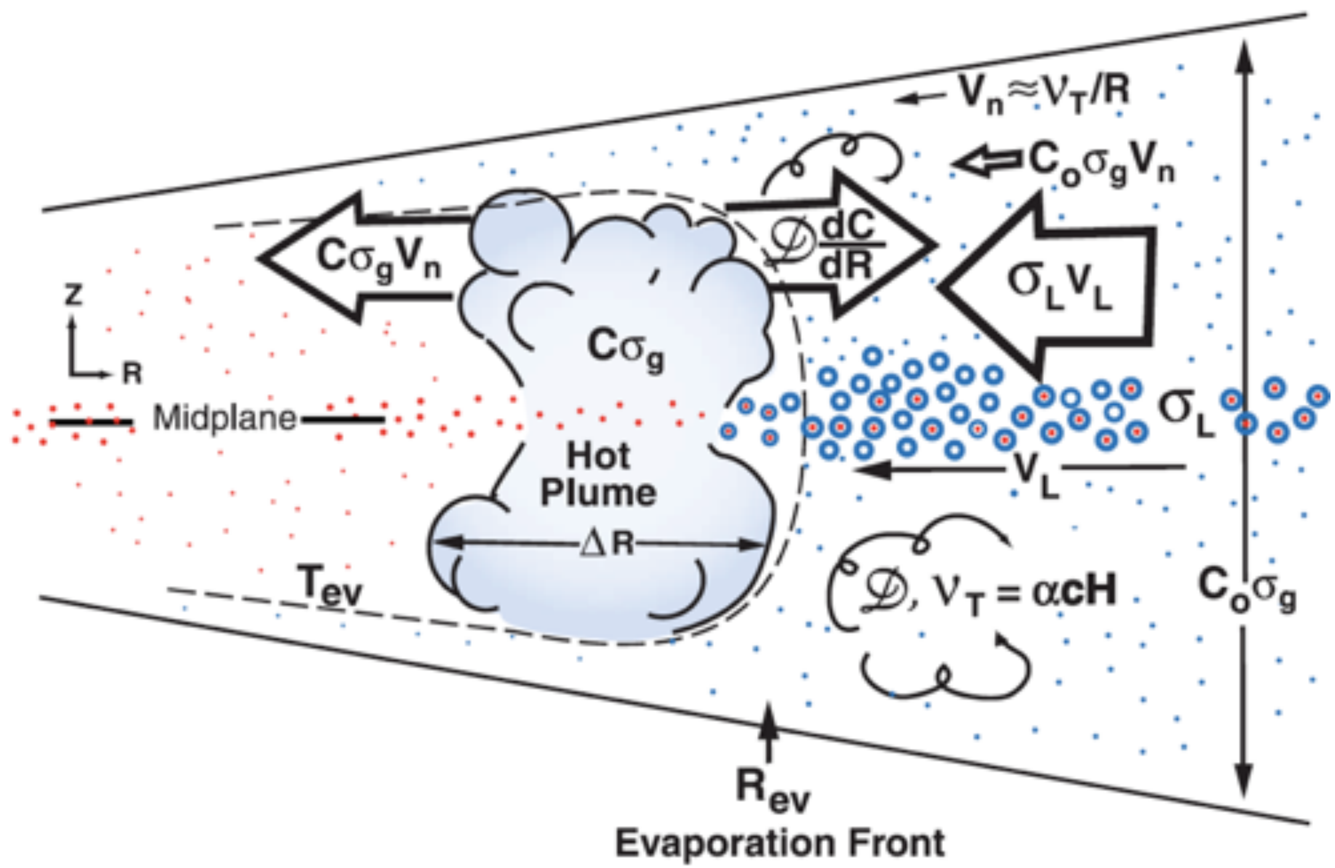


$a_{drop} \sim (M_{star})^{1/3}$

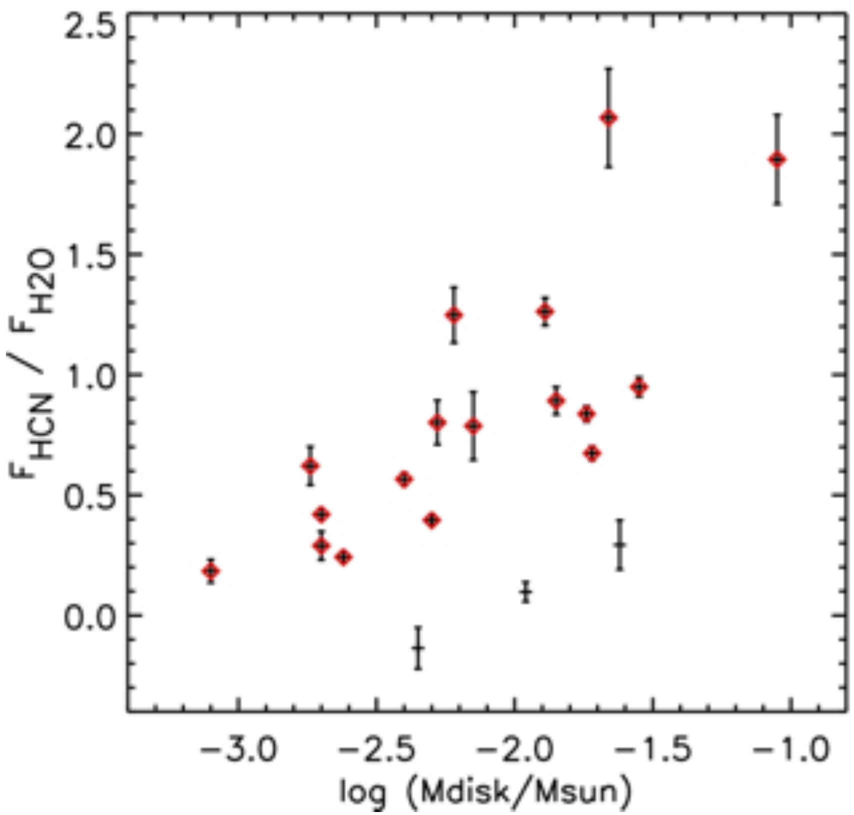
The relation between a_{drop} and M_{star} suggests that migration (either of fully formed planets or their building blocks) shaped the inner architecture of planetary systems

Mulders, Pascucci, Apai (2015)

Inward migration of solids ⇔ C/O ratio in the inner disk

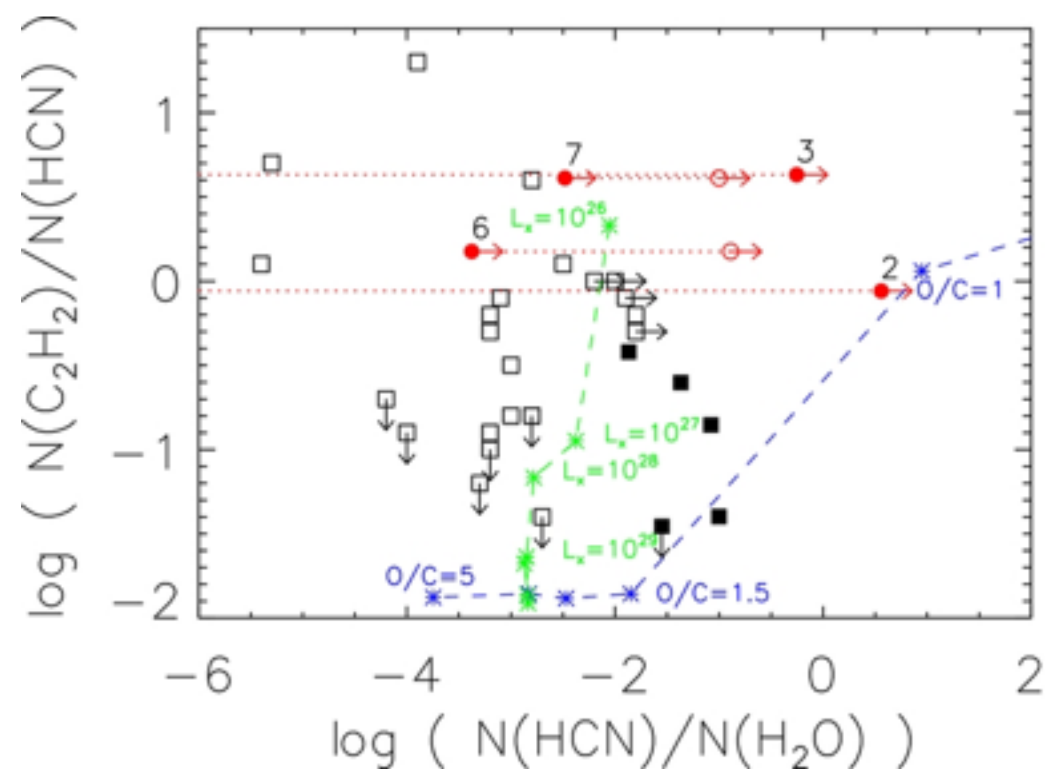


Neutral gas-phase chemistry is responsible for the warm inner water in disks (e.g. Woitke et al. 2009, Najita et al. 2011). The inward migration of icy solids can contribute to the water reservoir.

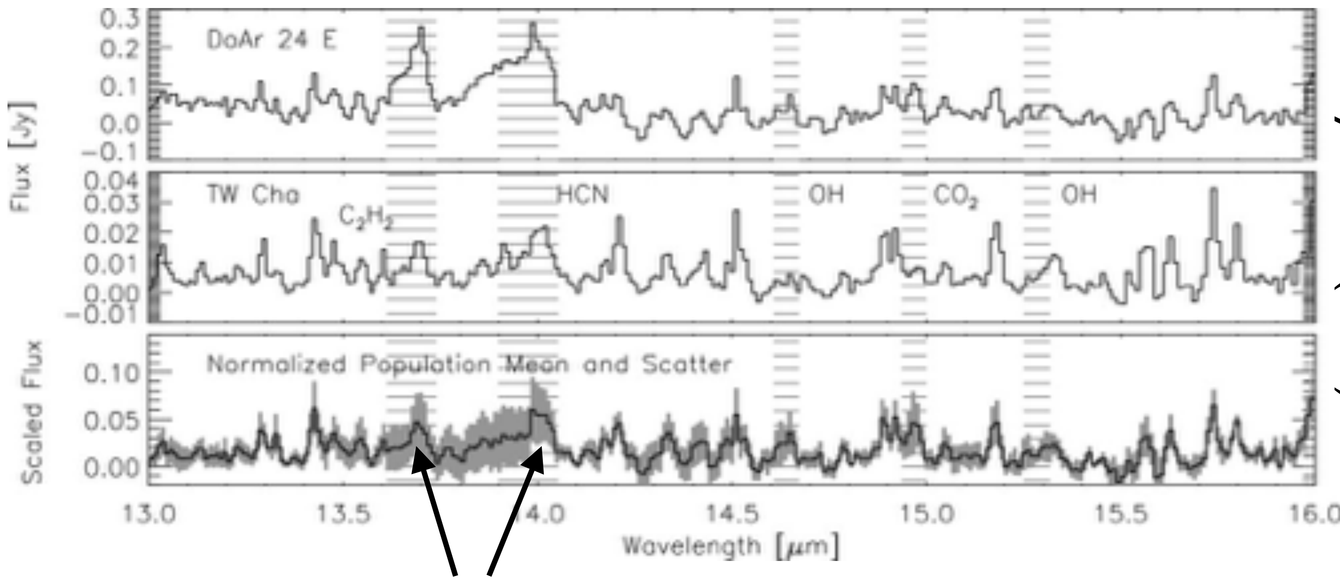


Najita et al. (2013): Large disks have formed planetesimals/ protoplanets that do not migrate inward (high C/O ratio)

Note: Need of detailed chemical models to disentangle the effect of different stellar irradiation (e.g. Walsh et al. 2015)



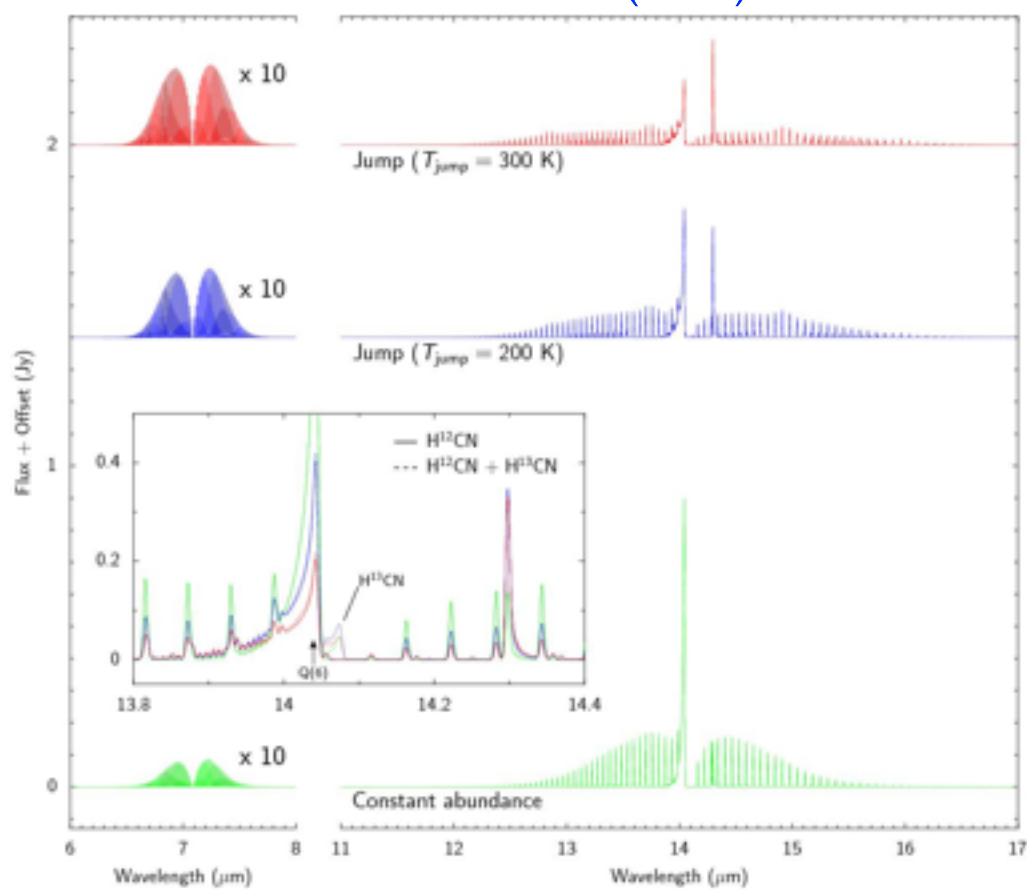
Pascucci et al. (2013): Enhanced carbon chemistry in disks around very low-mass stars



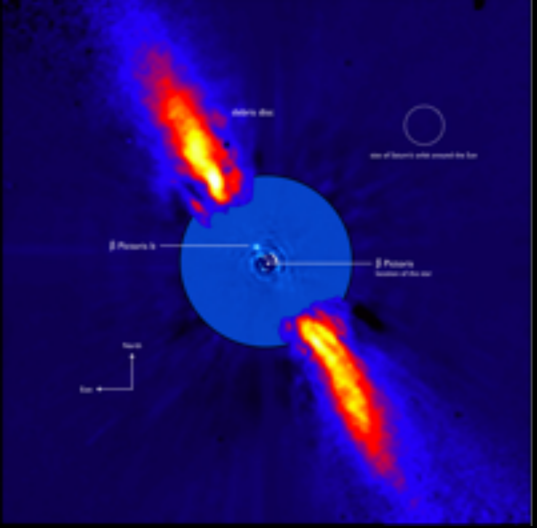
Salyk et al. (2011)

Q-branches

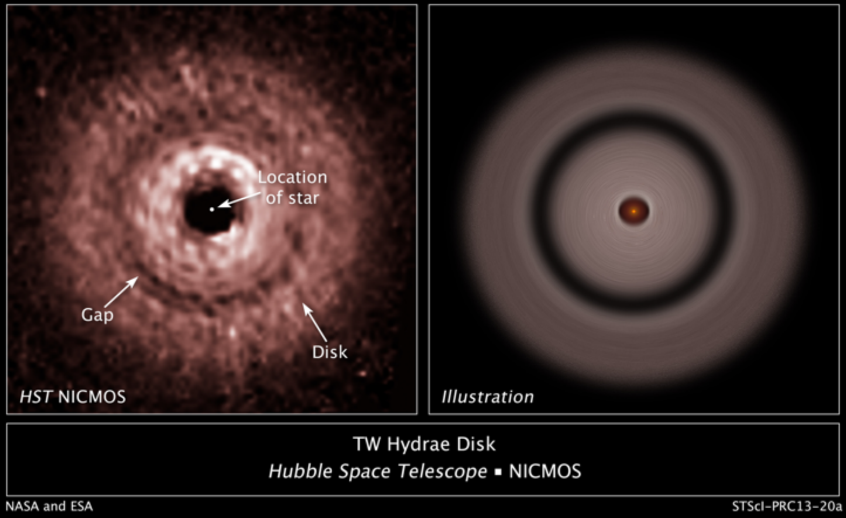
Bruderer et al. (2013)

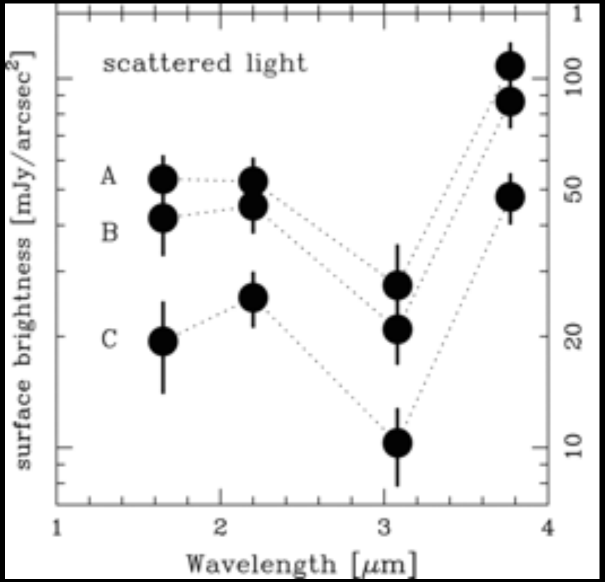


MIRI will enable detecting the 7 and 14μm P- and R-branches and thus identify different abundance structures.

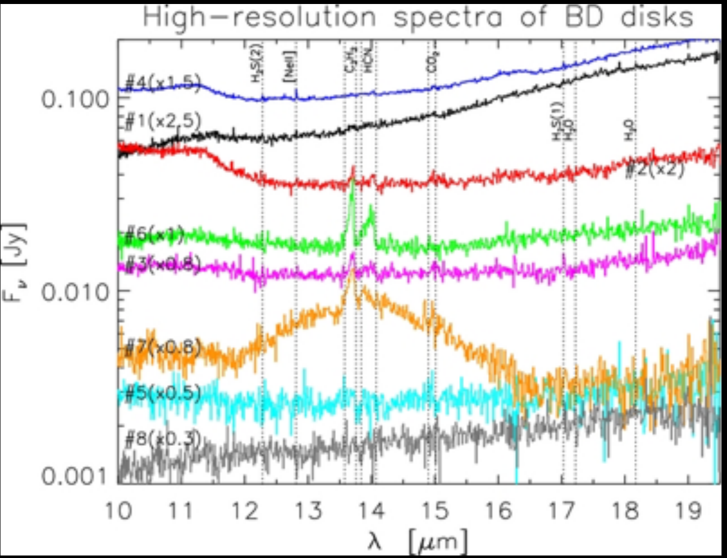


Planets directly and indirectly detected





Surface water snowline



Solids migration and disk dispersal