SPIRou, CRIRES+, VISIR, JWST

Perspectives pour l'étude de la structure, chimie et évolution des disques protoplanétaires avec la spectroscopie IR

Andrés Carmona

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SPiRou

Protoplanetary disks

Observational understanding

- What are the gas and dust physical and chemical structures in disks ?
- How do these structures evolve with time ?

Physics/Chemistry understanding

- What physical/chemical processes are taking place?

Connexion Solar System & Exoplanets

- How these processes can lead to the diversity of planets known?
- How can we capture signatures of planets in the making?

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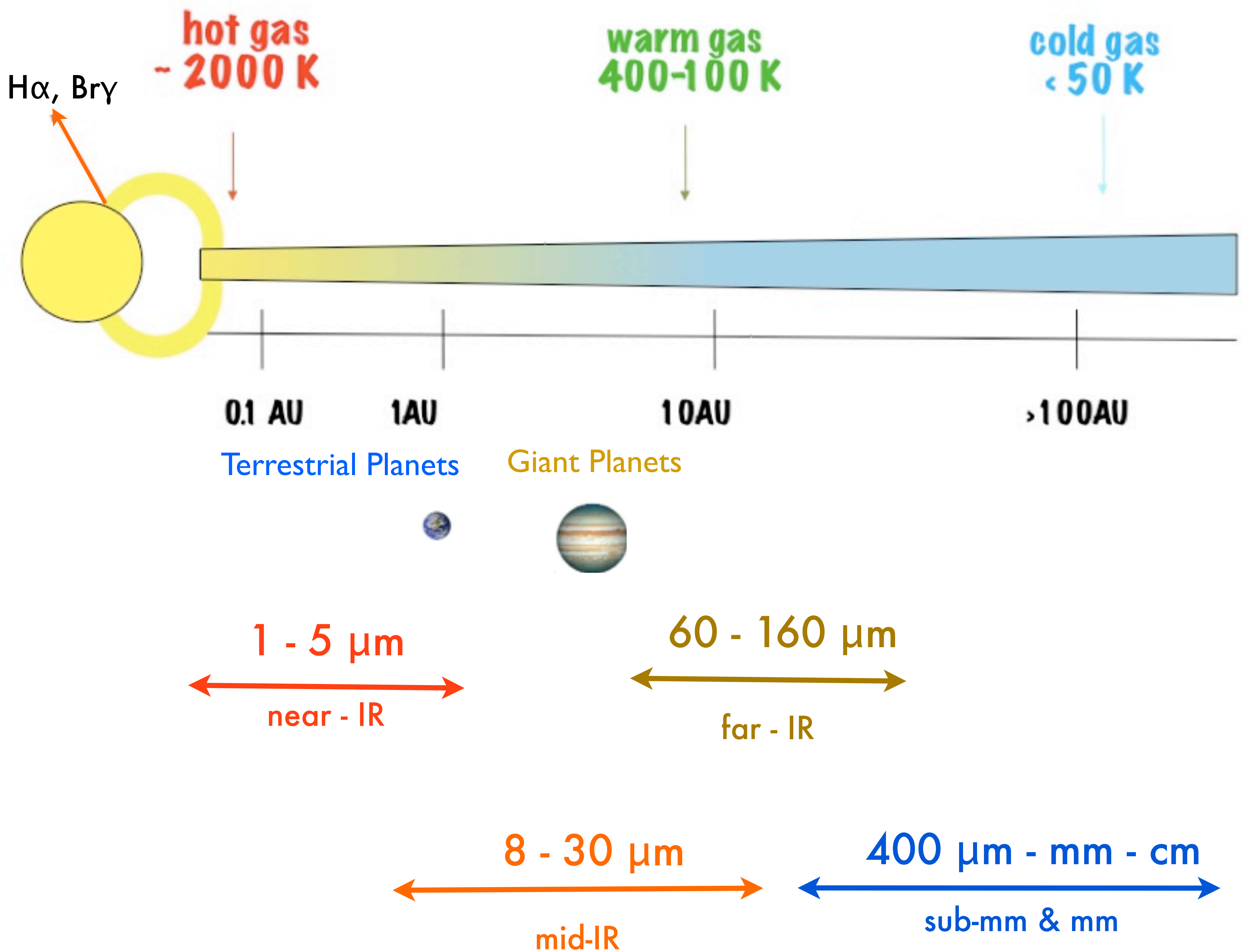
Complementary Instrumentations



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SPIRou @ CFHT

instrument performances

main science requirements

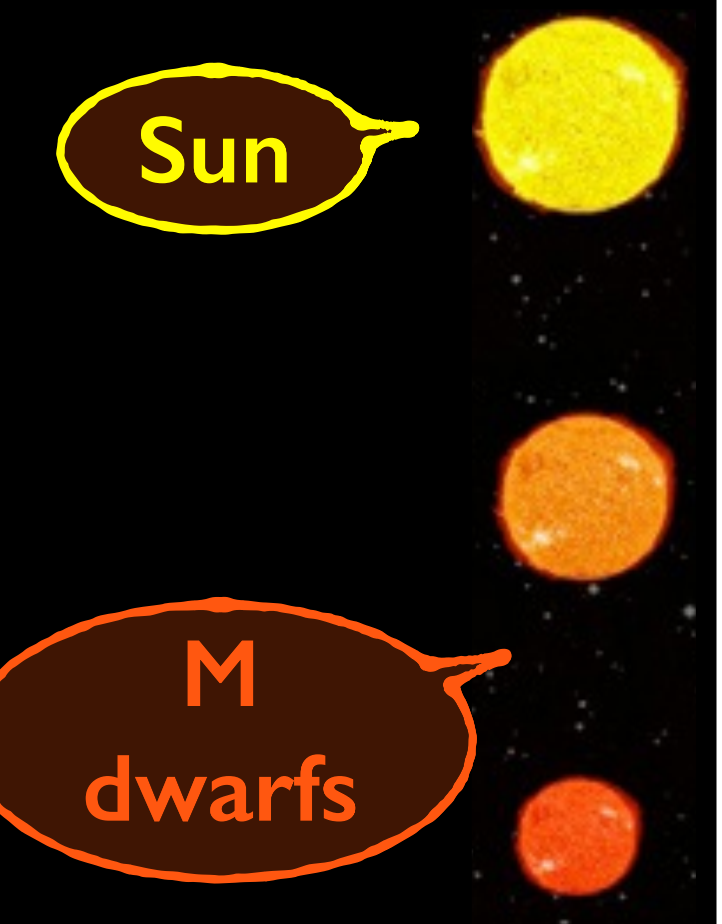
simultaneous wavelength domain: 0.98 - 2.35 µm (YJHK bands)
spectral resolution: 75 000 / RV precision: 1 m/s
circular & linear achromatic polarimetry
S/N~100 (per 2.3 km/s bin) @ H~11.0 in ~1 hr exposure

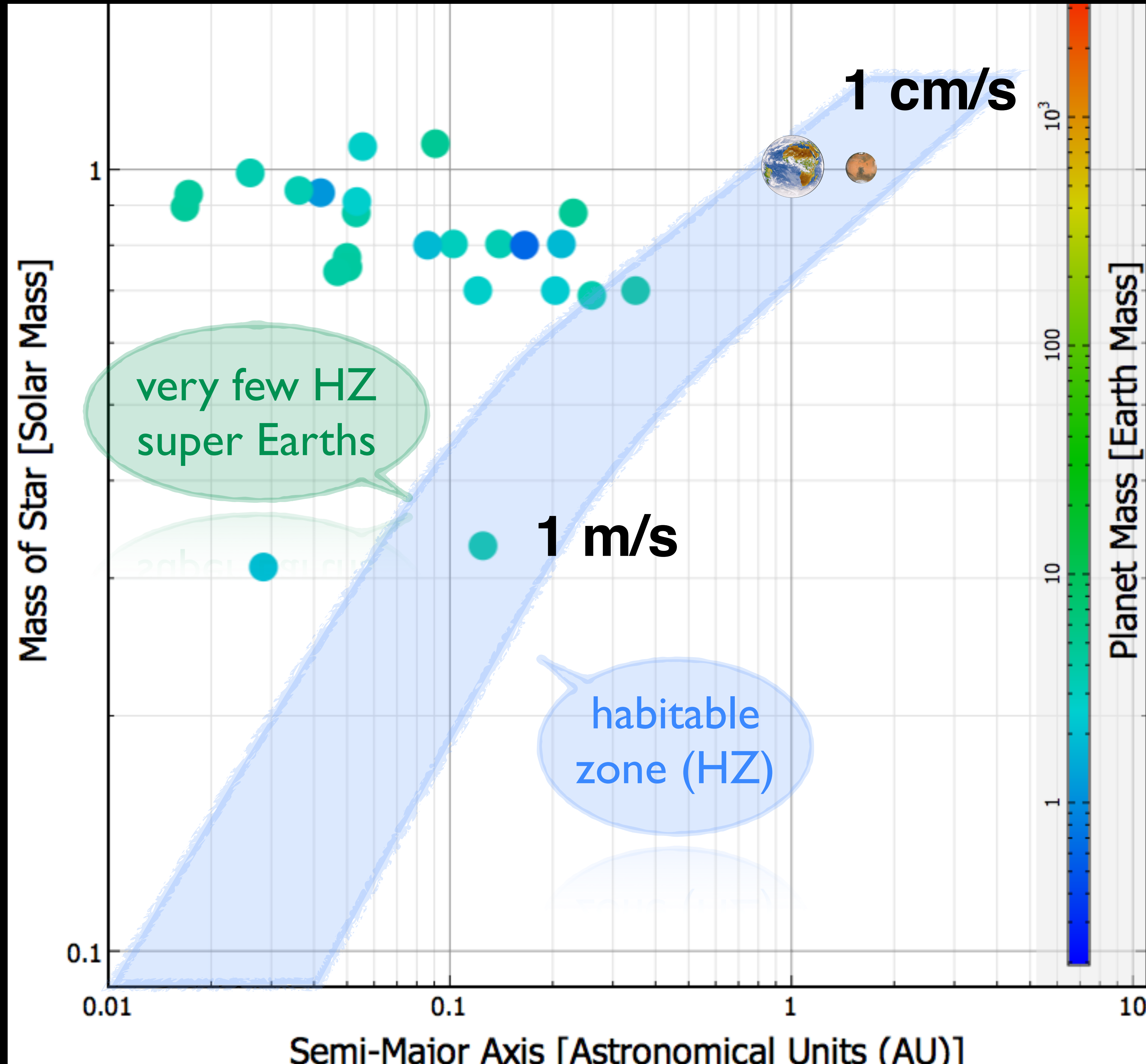
High-precision Velocimeter and Polarimeter in the near-IR

CRIRES (VLT)	**: 0.08 µm coverage, no polarimetry**
Carmenes (Calar Alto)	**: YJH bands, no polarimetry**

Canada France Hawaii Telescope (3.6 m)

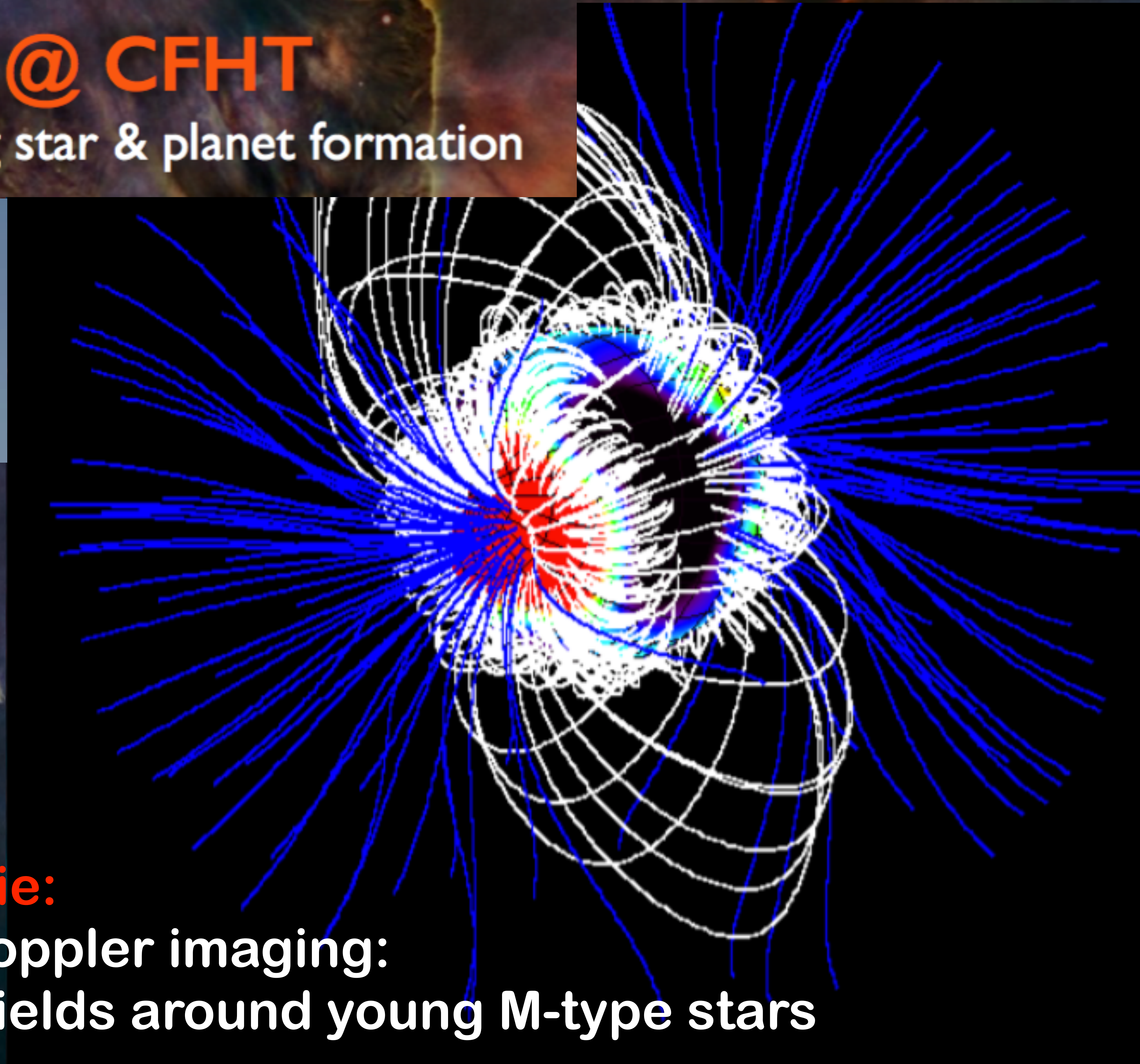
Earth-like planets around M-stars





SPIRou @ CFHT

investigating star & planet formation



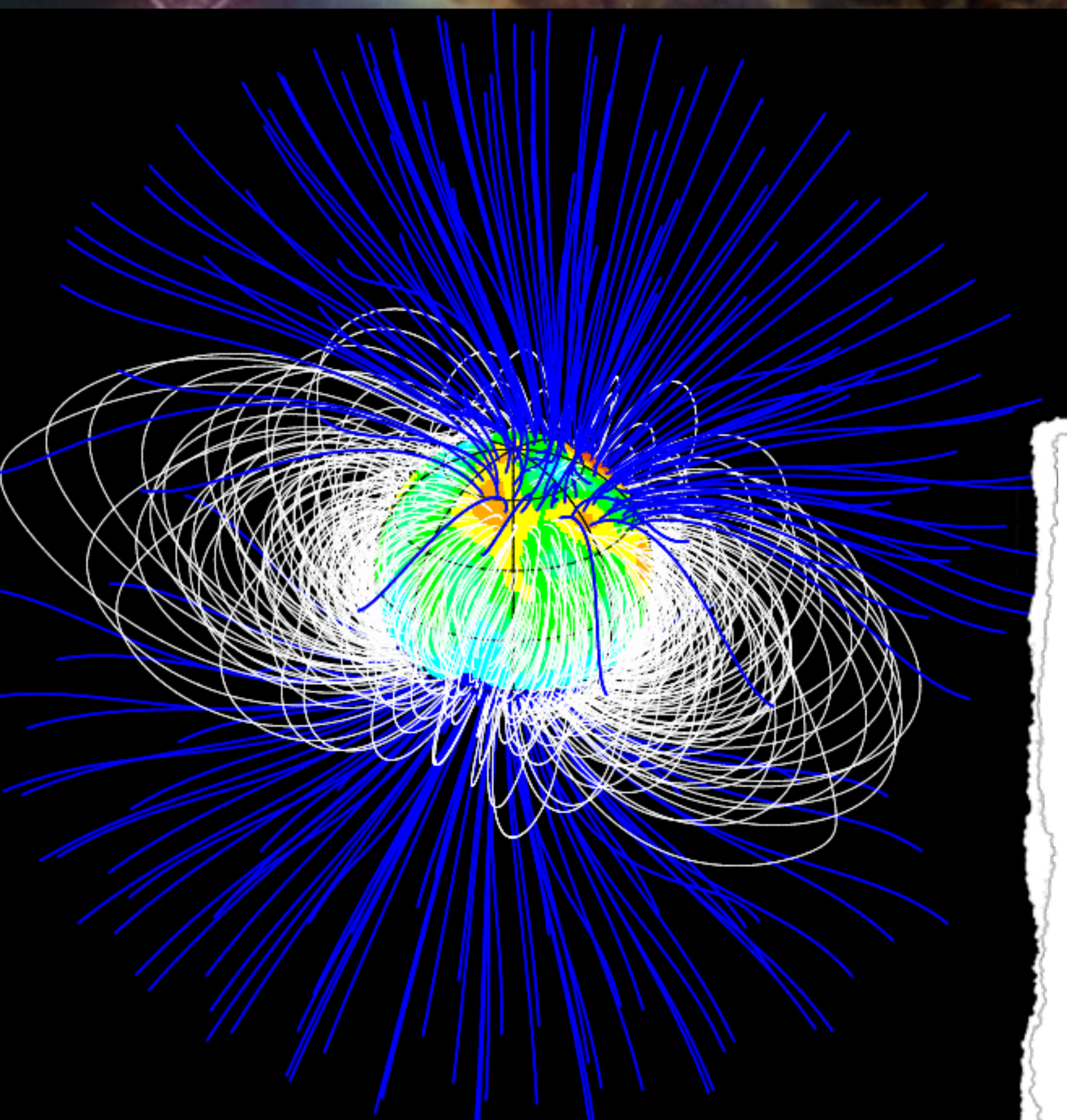
Polarimetrie:

Zeeman Doppler imaging:

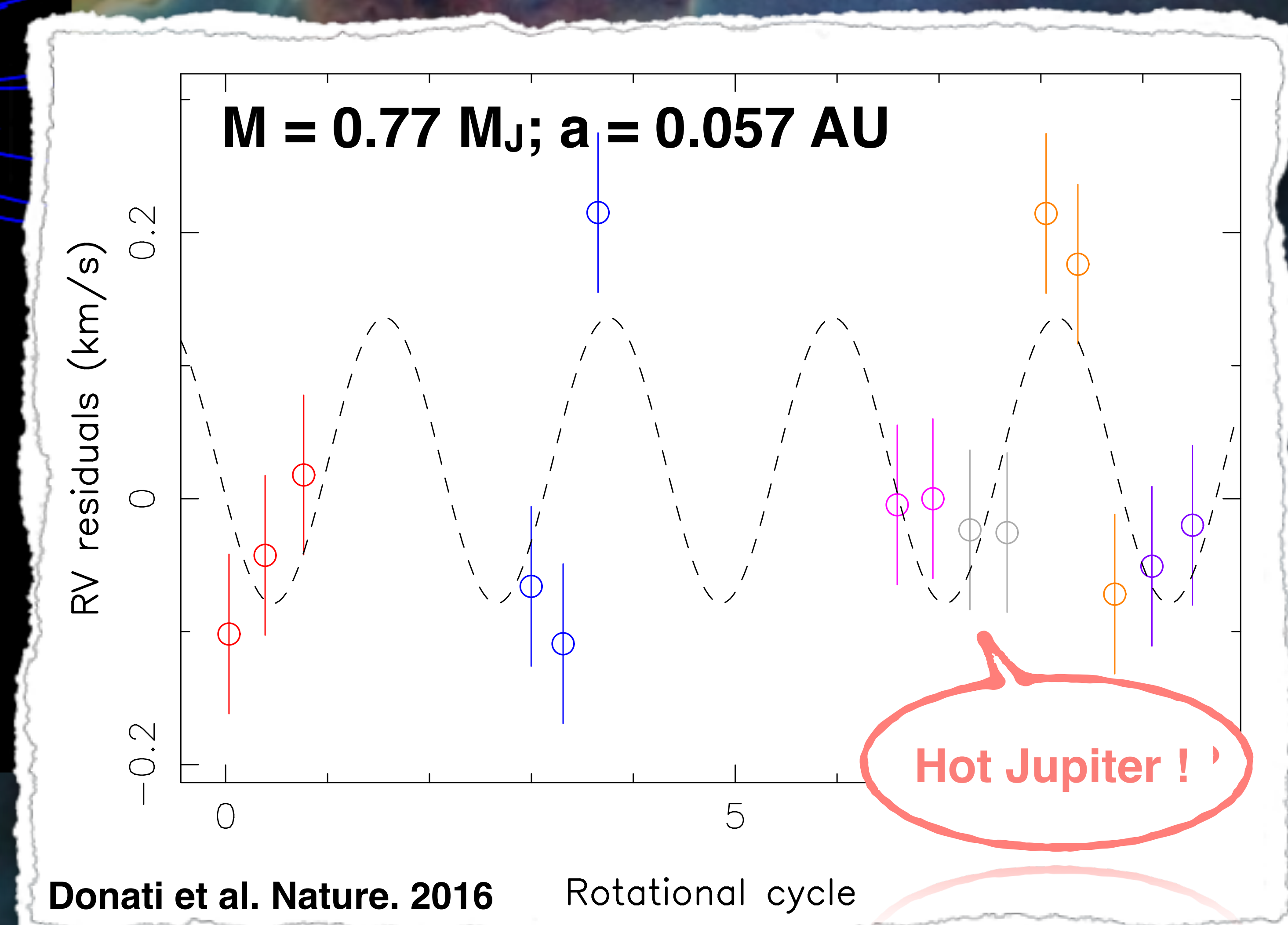
Magnetic fields around young M-type stars

hot Jupiters around young Suns

modeling the activity & RV curves of T Tauri stars



V830 Tau
<2 Myr

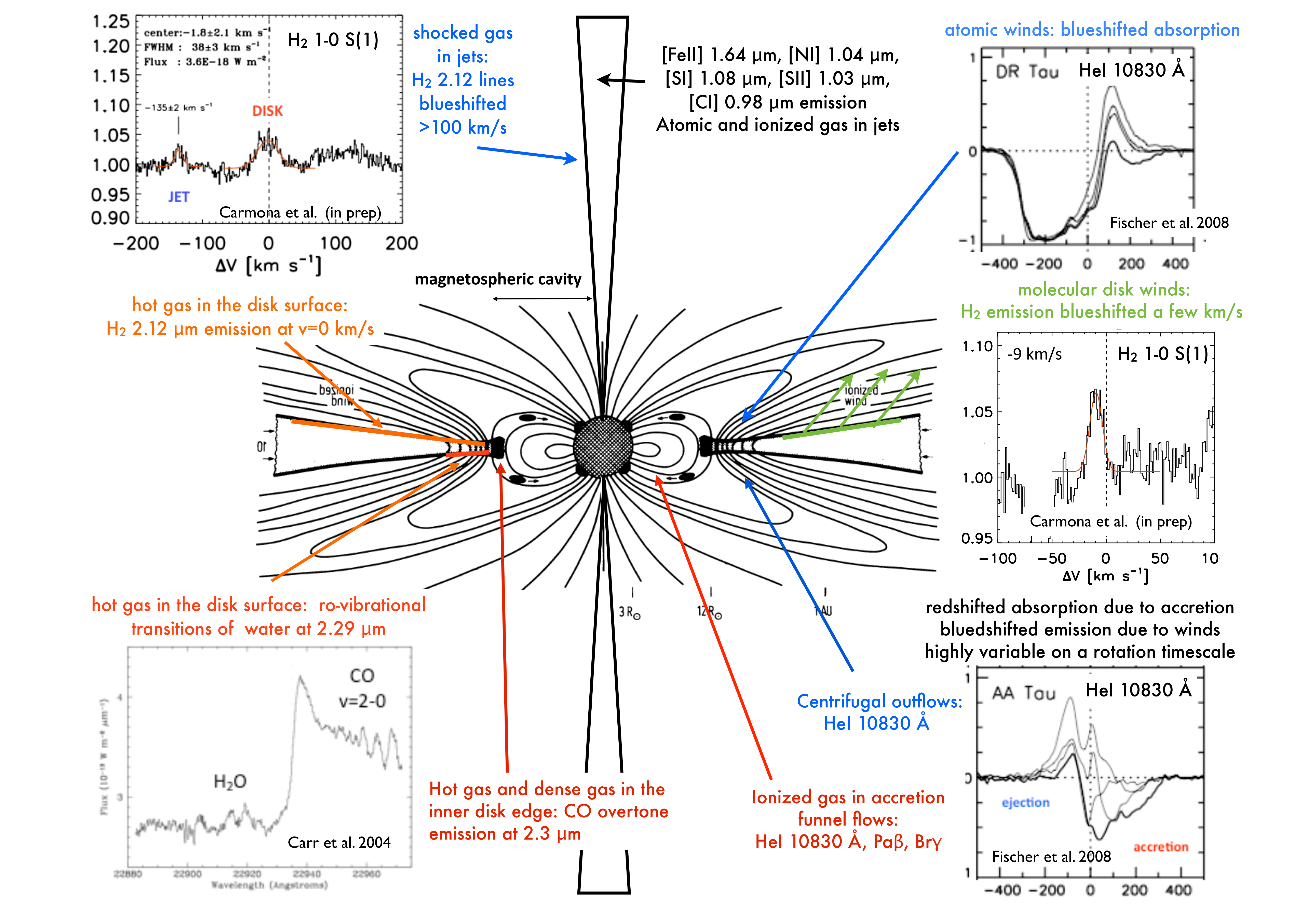


Perspective

WTTS → Transition Disks

SPiRou

accretion/ejection in TTauri stars

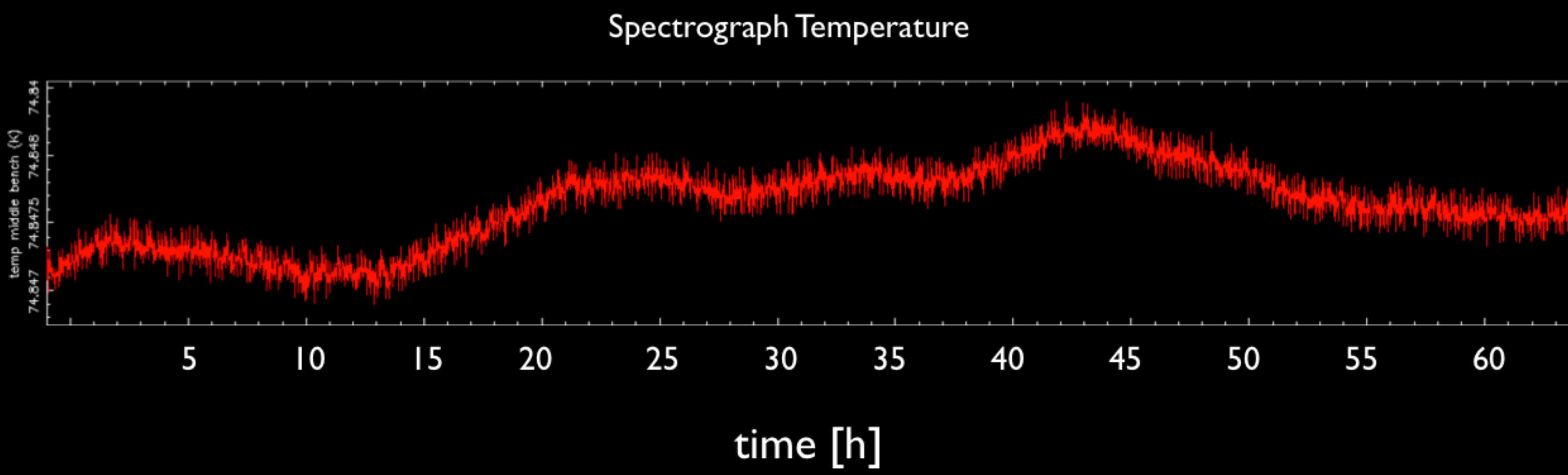


Carmona+ 2013

adapted from Camenzind

Validation tests: Jun - Nov 2017

stability 0.3 mK rms (!)



74.8475 K

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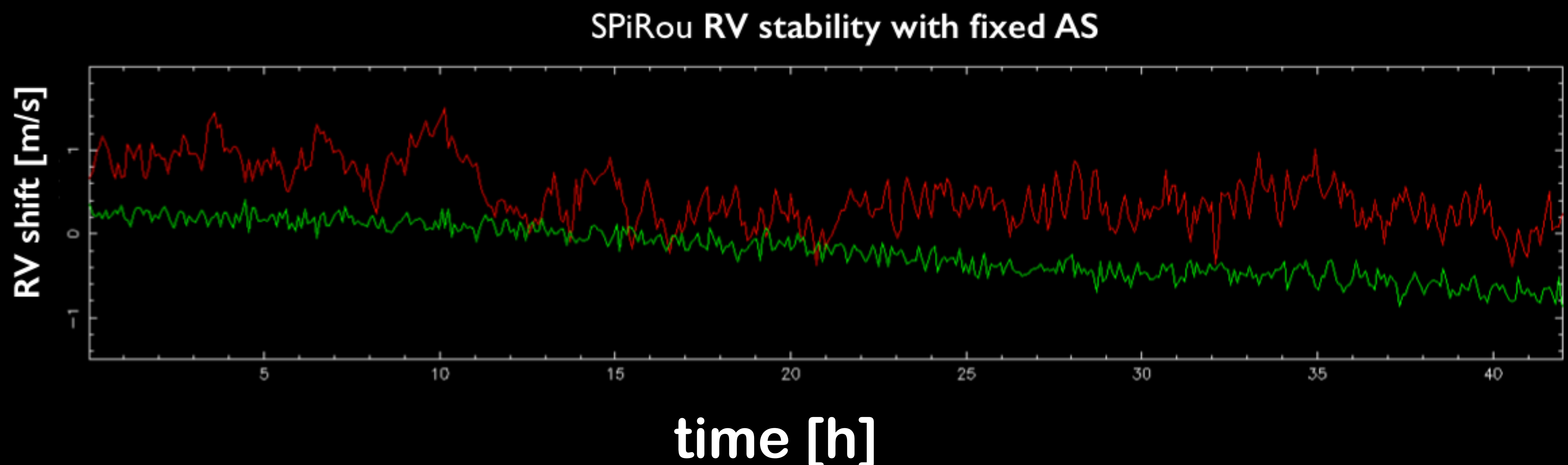
Radial Velocity stability 0.2 m/s !



Relative RV drift (science - calibration channel)

Absolute RV drift

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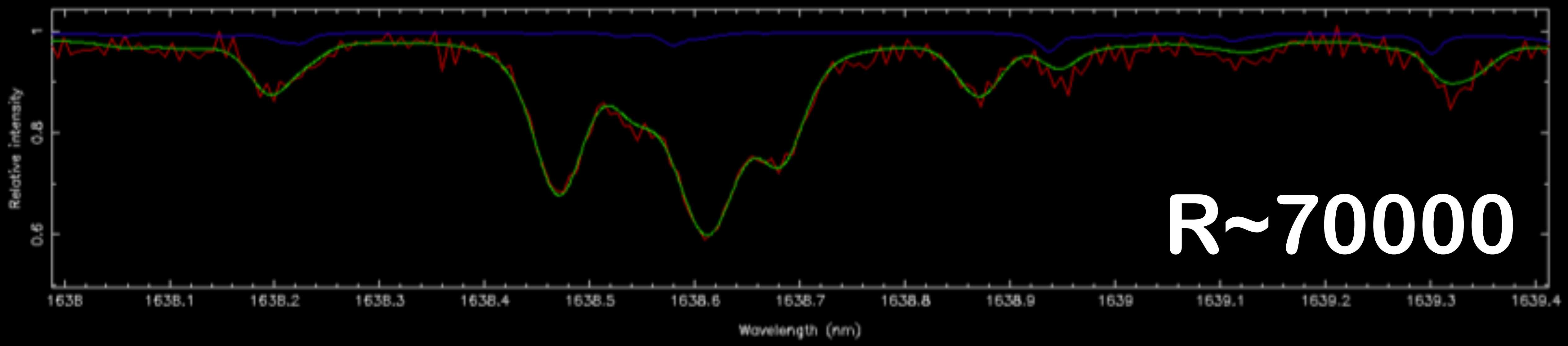
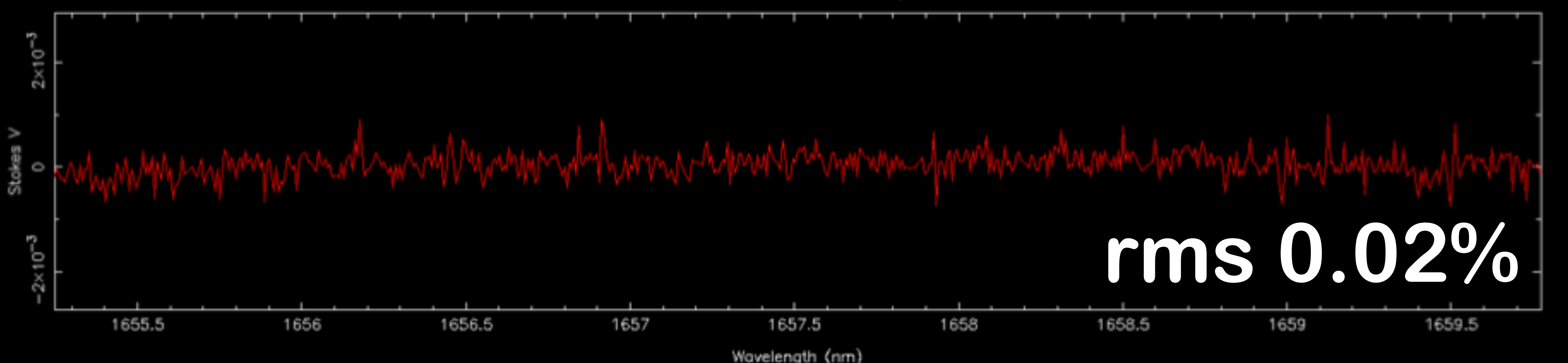
Solar Spectrum

SPiRou spectrum vs Solar atlas at 70K resolution & telluric spectrum



SPiRou Stokes V solar spectrum



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Acceptance November 2017

Crates arrived to Hawaii in January

SPiRou

LE SPECTROPOLARIMÈTRE INFRA ROUGE

Alignment 01/2018

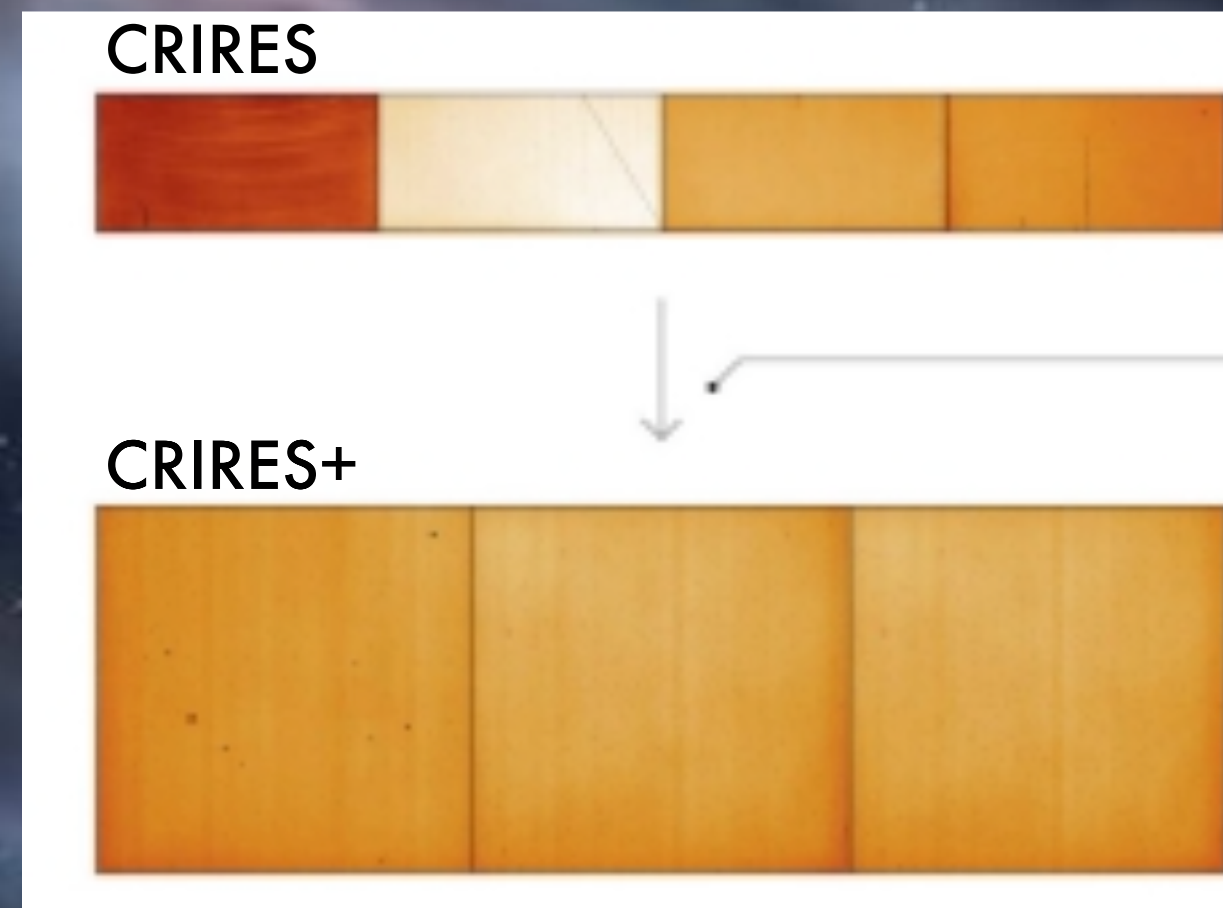
Technical data 27/02

We installed the H4RG (friday!), commissioning summer!! Beginning of operations in autumn !

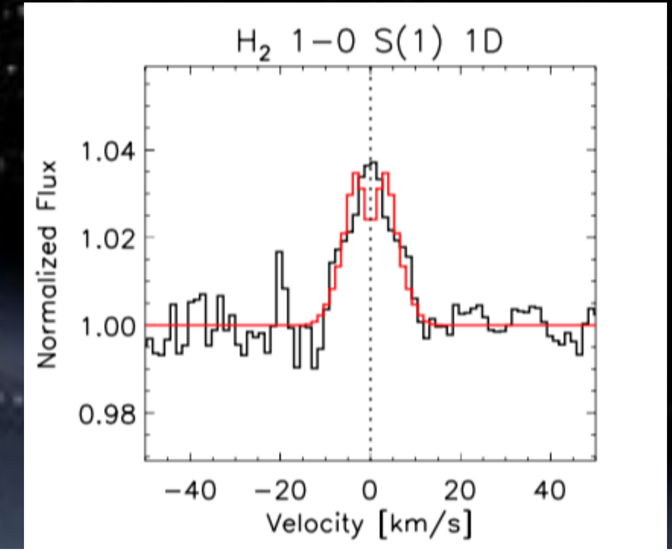
CRIRES+ 2019

Near-IR slit high-resolution spectrograph with AO

- 0.9 - 5.3 µm
- R~90 000
- CRIRES 0.08 µm ➜
  CRIRES+ :
  Y-band 1 exp.
  J or H-band : 2 exposures
  K-band: 3 exposures
- Polarimetry
- AO: 0.2″ resolution
  (28 au @ 140pc)
- Sensitivity: 10^{-15} erg/s/cm^{2}

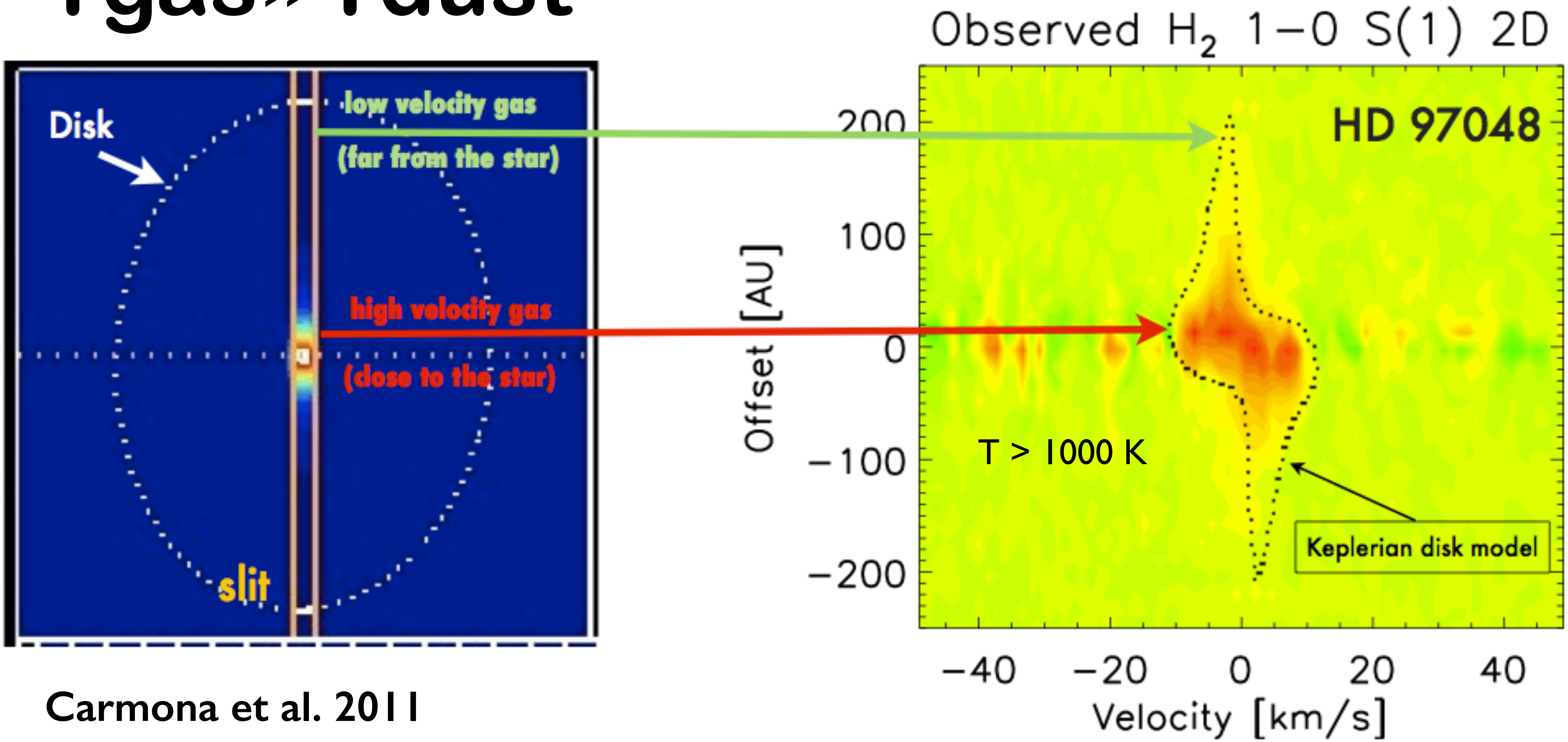


Slit observations + AO = Spatial information



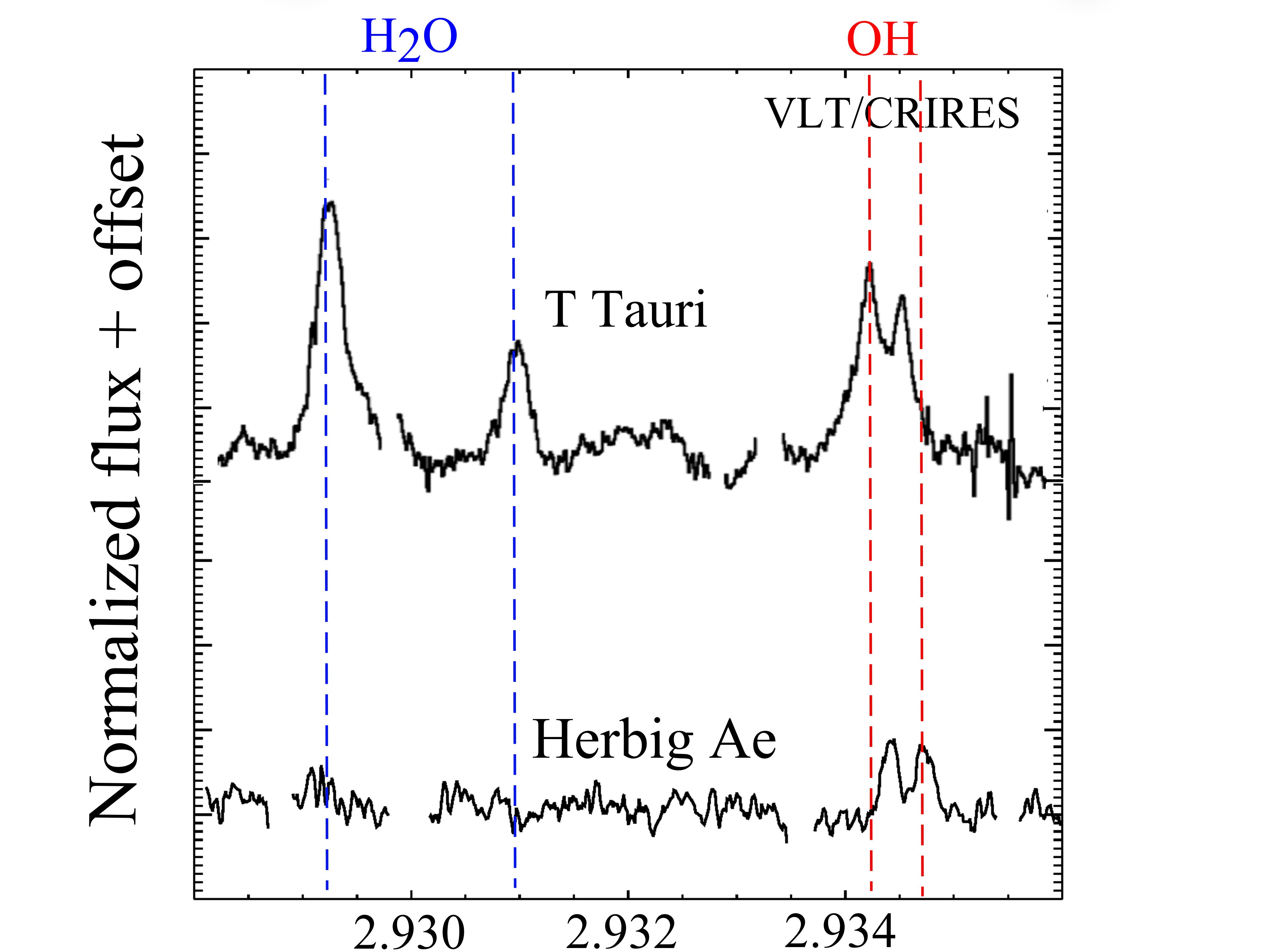
Tgas≫Tdust

CRIRES data



Carmona et al. 2011

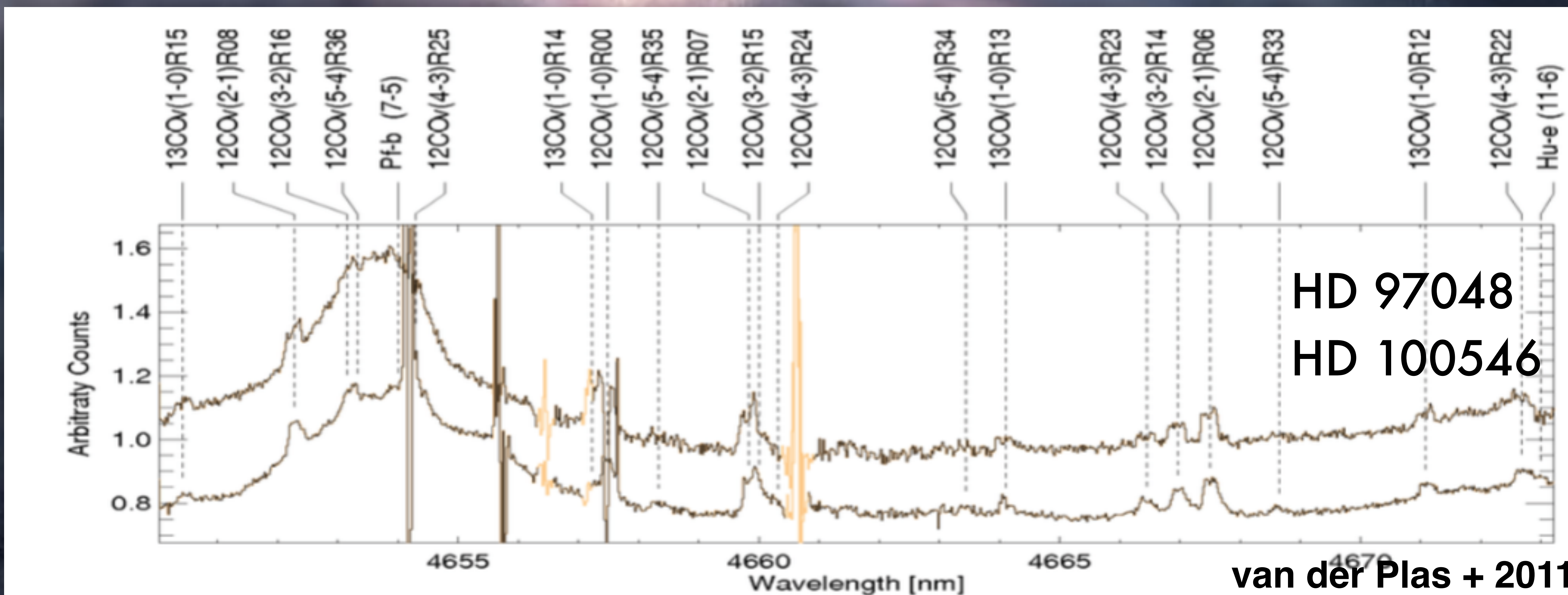
water, OH 2.9 & 3.3 µm



Fedele+ 2013

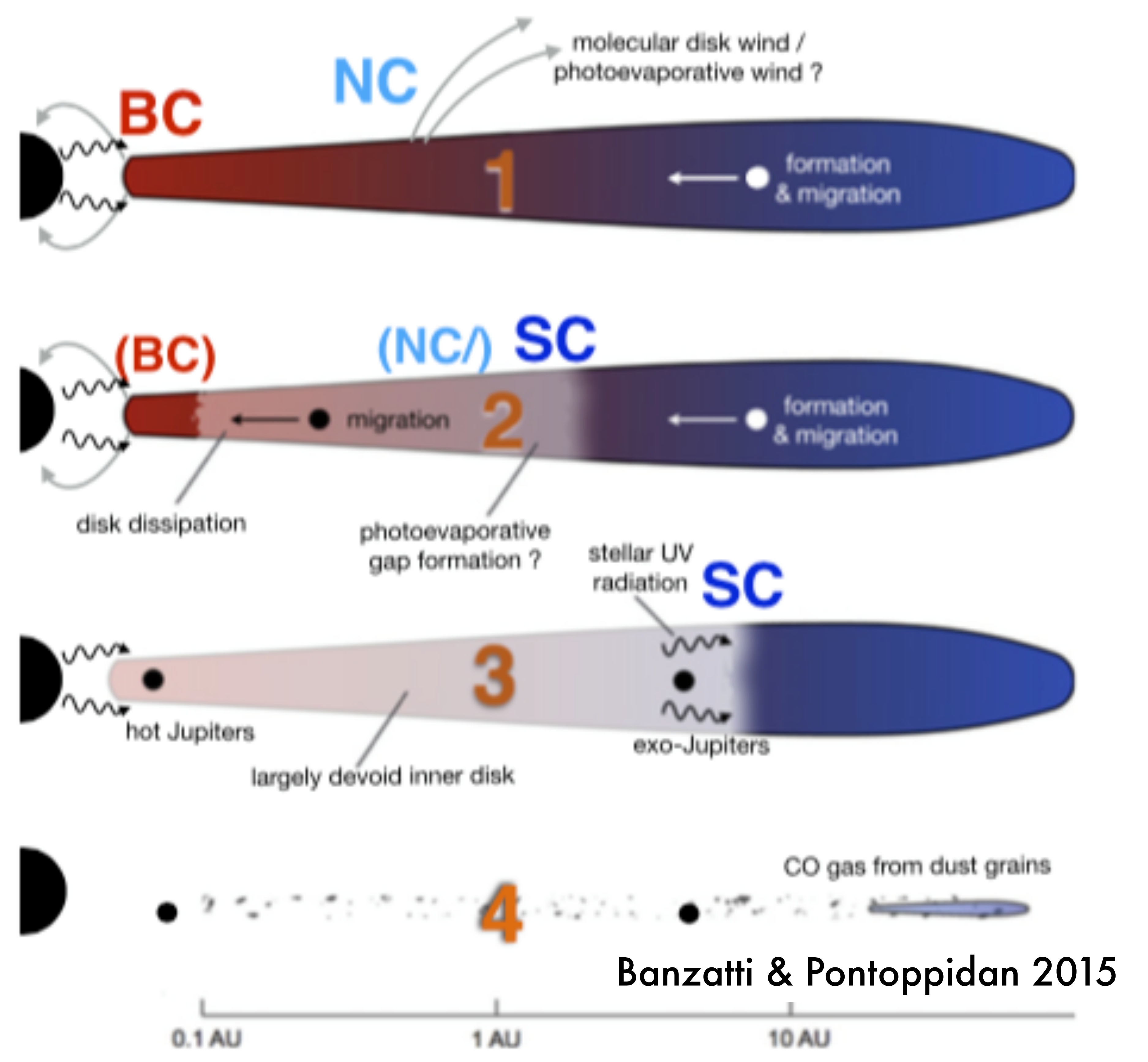
- Water and simple organics in the terrestrial planet region

CO 4.7 micron
best tracer of 300-1500 K gas



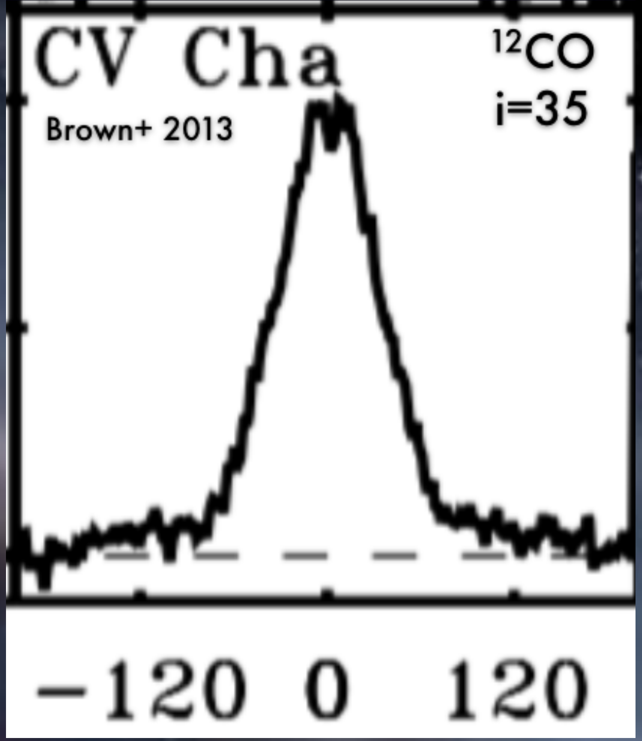
- Temperature in the disk surface layer
- Disk evolution tracer !

Statistically CO 4.7 μm is narrower in TD (few CO gas at R< few au)

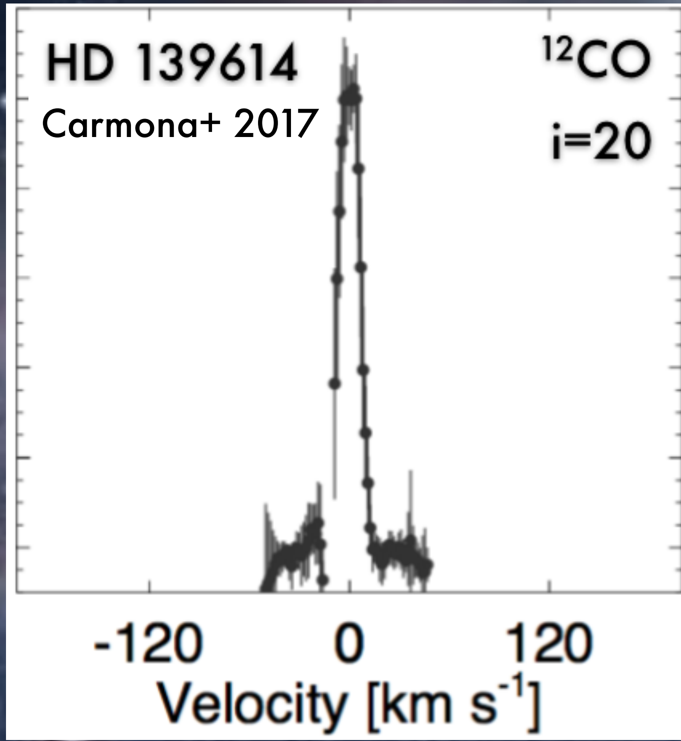


Banzatti & Pontoppidan 2015

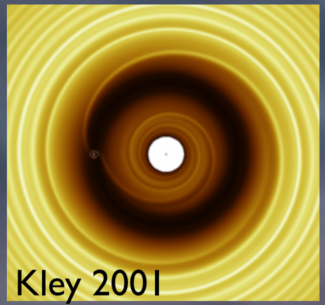
Primordial Disk

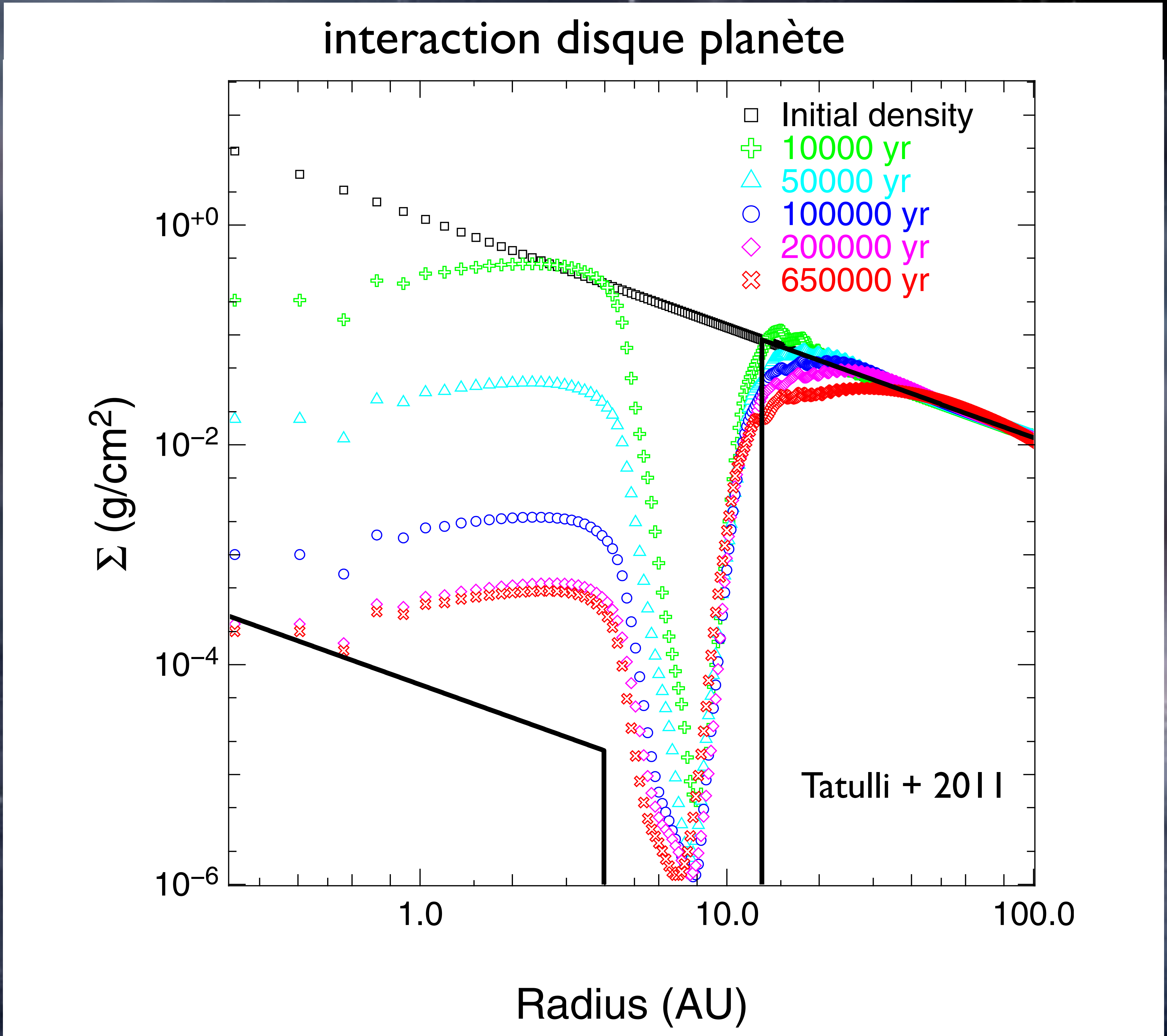


Transition Disk



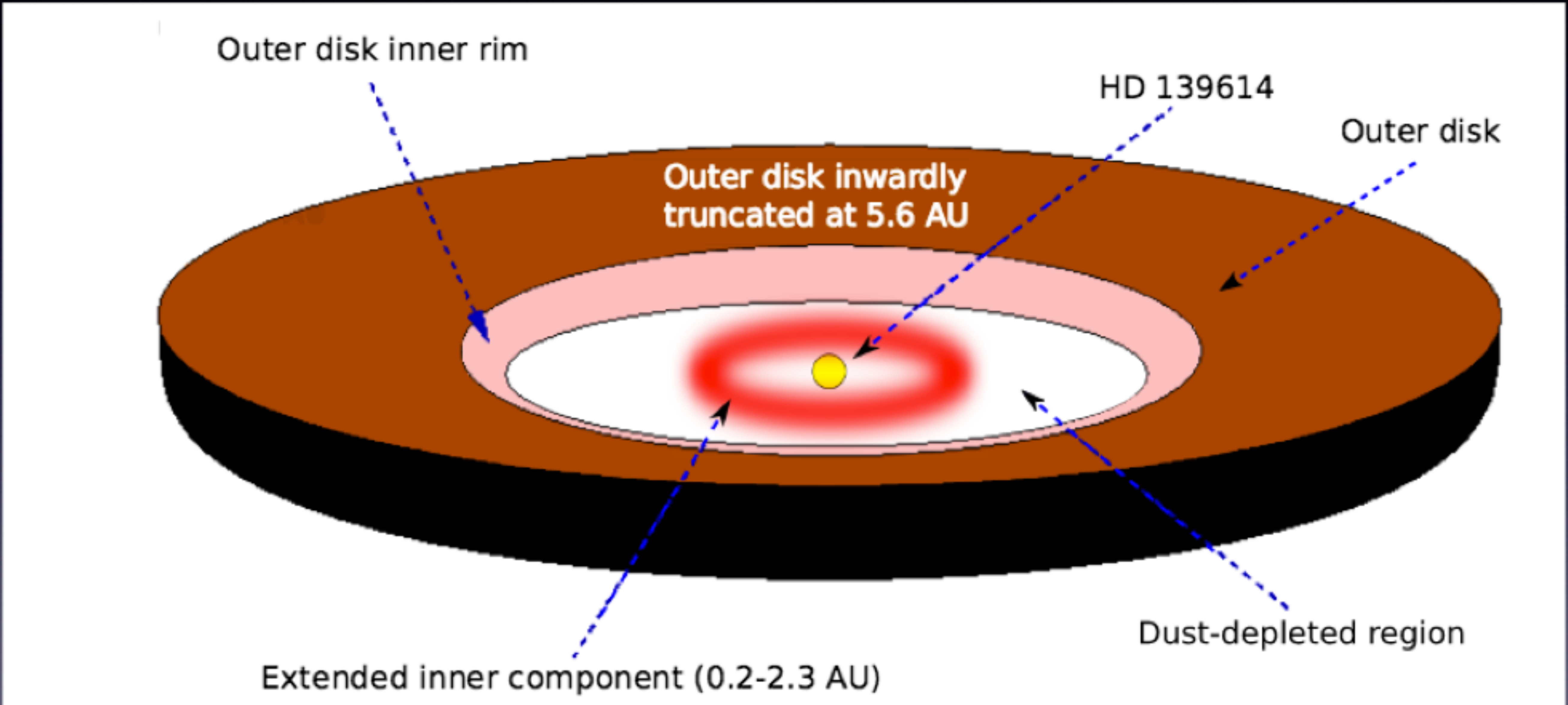
Profile de surface densité du disque & planète





HD 139614 dust disk

a transition disk with a dust gap of 3.5 AU width



VLTI near & mid-IR interferometry (PIONIER, MIDI) Matter et. 2014 & 2016

A7Ve, d= 140 pc, age: 9 Myr;
accretion rate=10^{-8} $M_{\odot}$/yr, L_X=10^{29} erg/s

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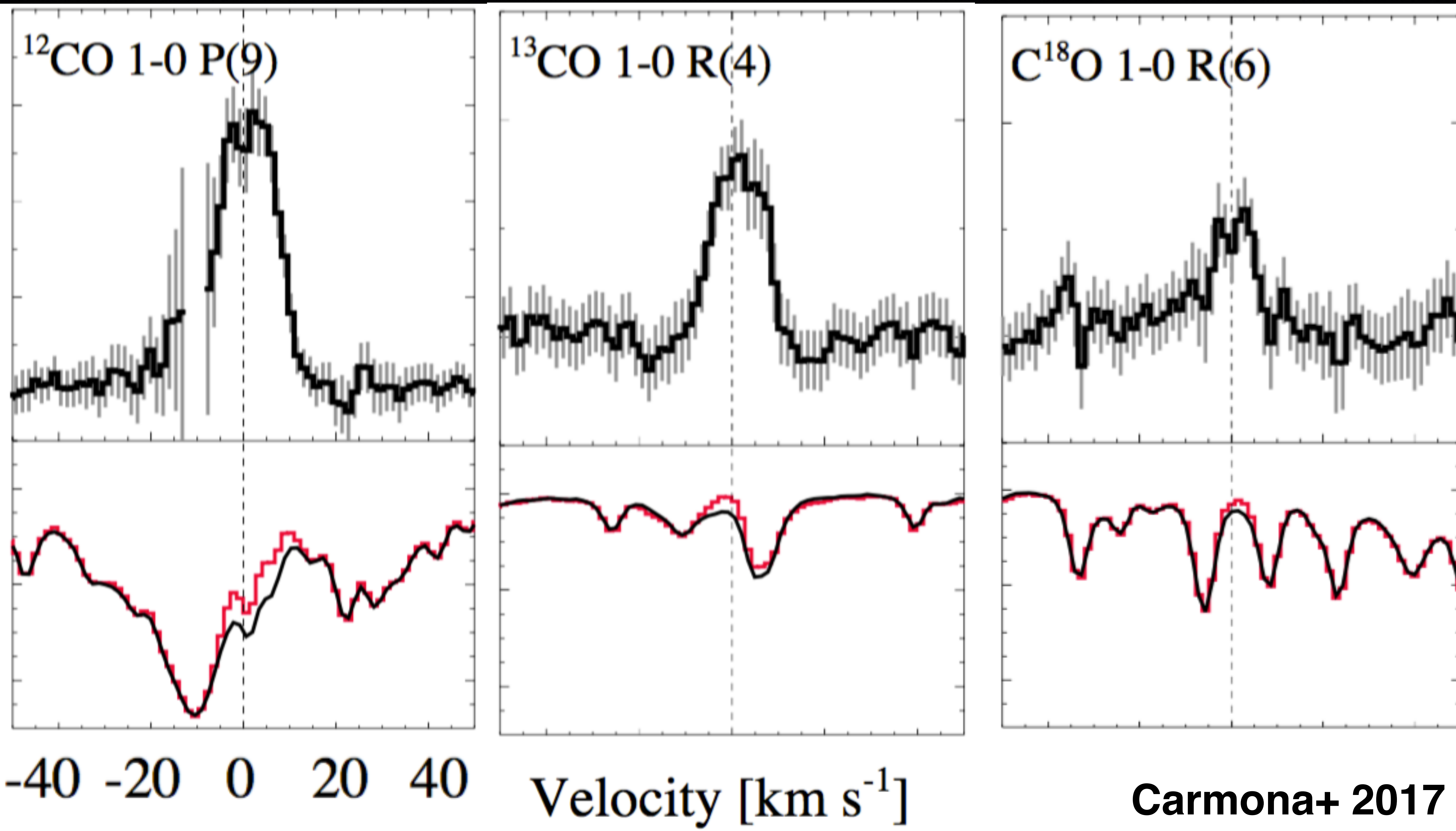
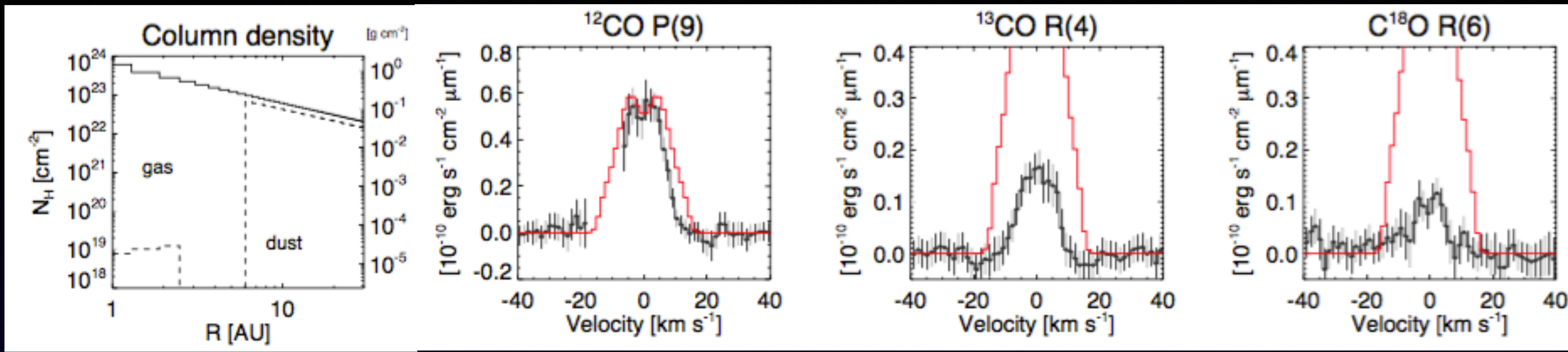
CRIRES HD 139164

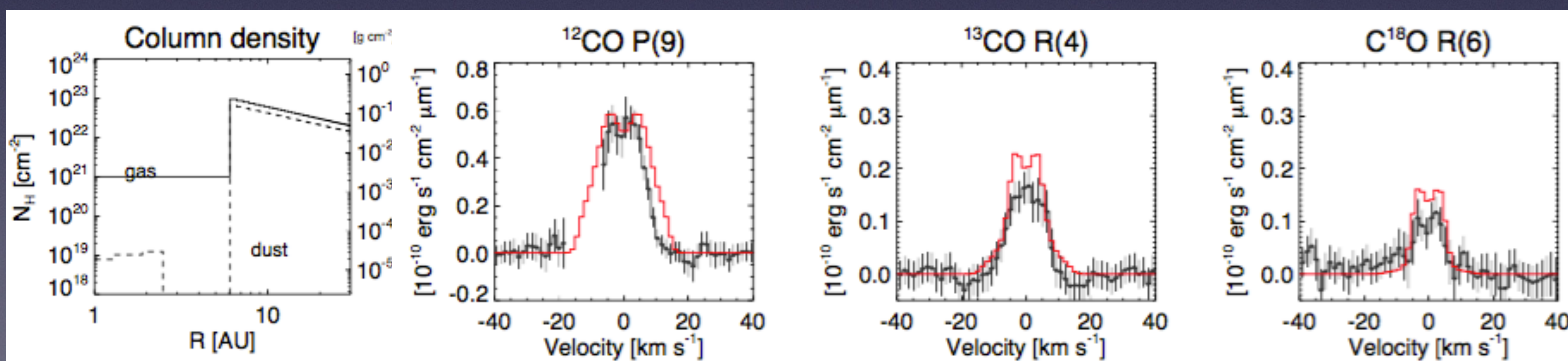


Carmona+ 2017



Gas density drop at R<6 au

N_H(R<6au) 10^{-3} g/cm^2, δgas =10^{-2}

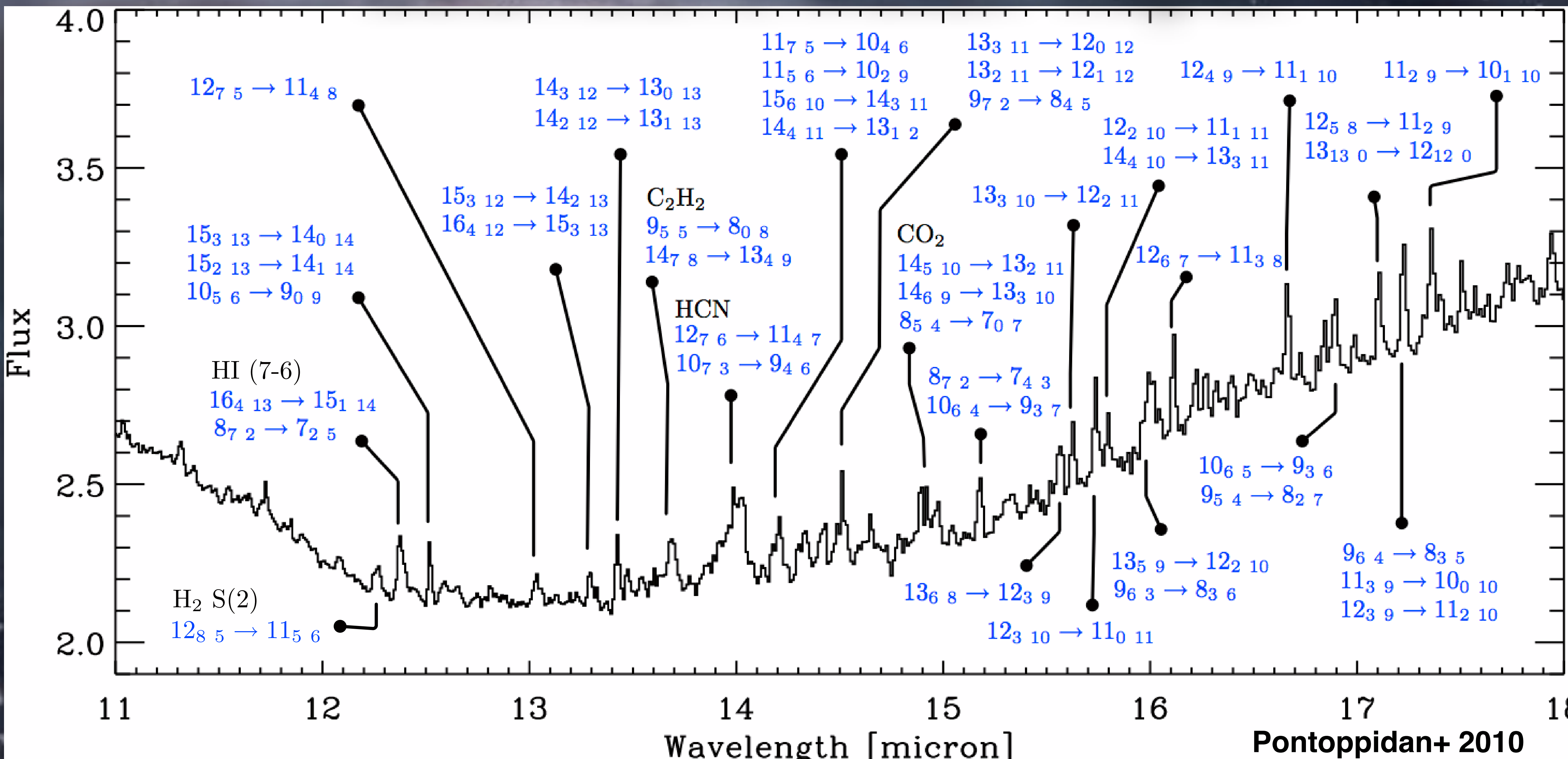


Tracing gas in regions not probed by ALMA

Carmona+ 2017

MID-IR spectroscopy

SPITZER
the inner disk of T Tauri stars has abundant water vapor



abundance H_2O ~10^{-4} (~CO)

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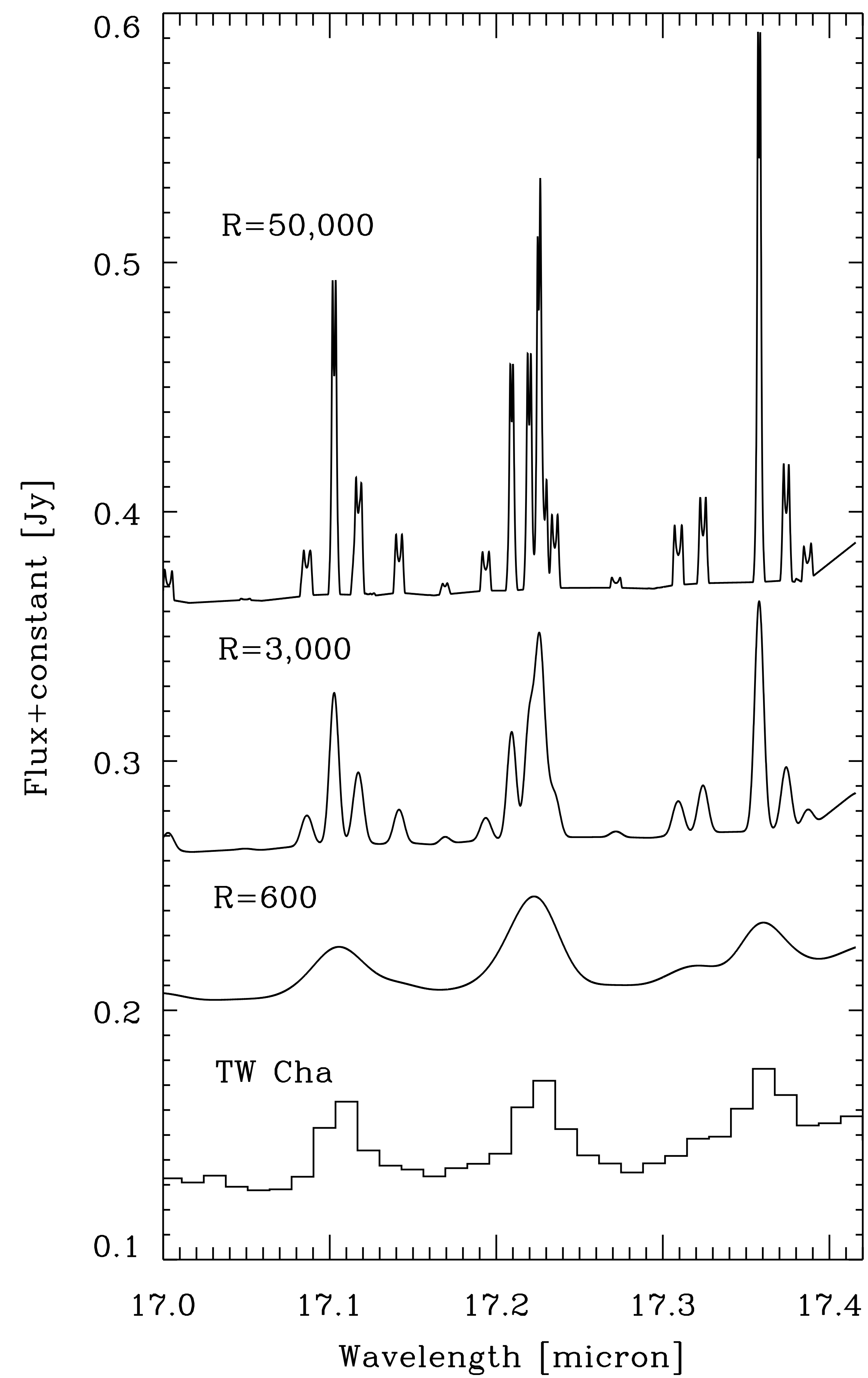
SPITZER R ~ 600

- **Abundances are uncertain**
- **Where is the slab in the disk located?**
- **What is the contribution of jets?**
- **Link to other observations**



Pontoppidan+ 2010

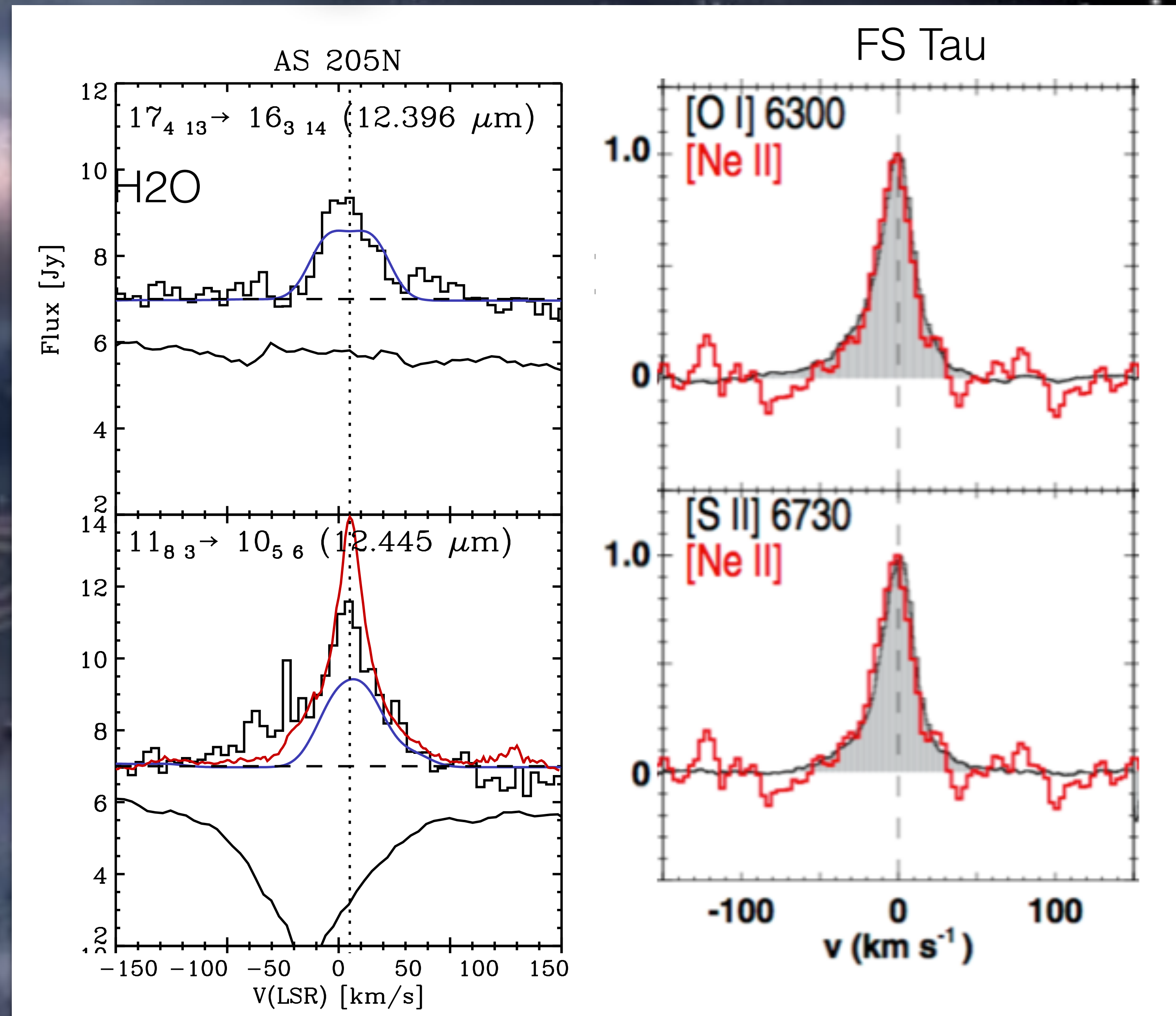
VLT/VISIR 12 micron R~17000 Spectrally resolving the emission

WATER

- Disk emission
- 0.4 to 1 AU
- T = 540 - 600 K
- O/P = 4 (gas chemistry)

[Ne II]

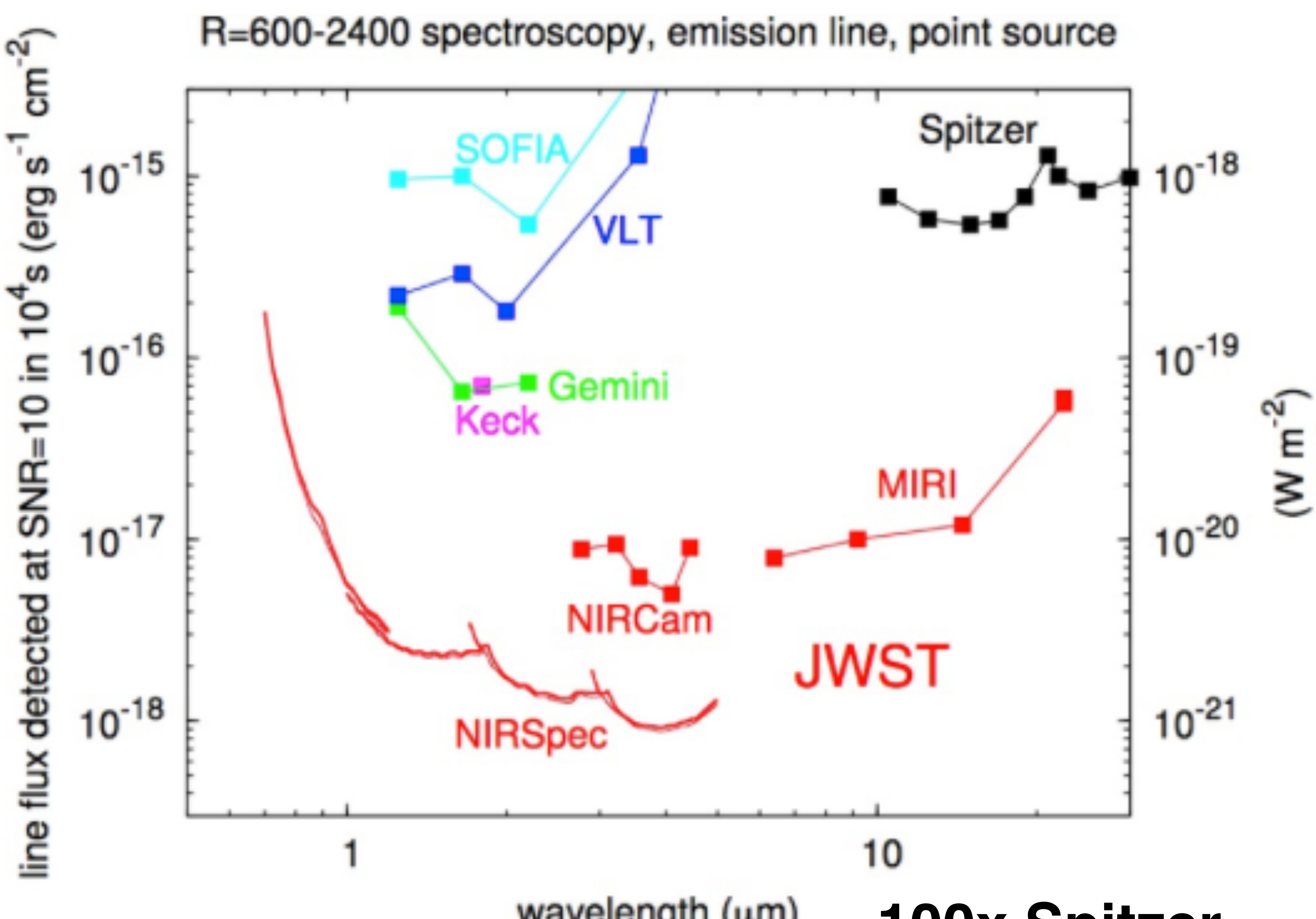
- Disk Winds
- Jet



Pontoppidan+ 2010b **Baldovin-Saavedra+ 2012**

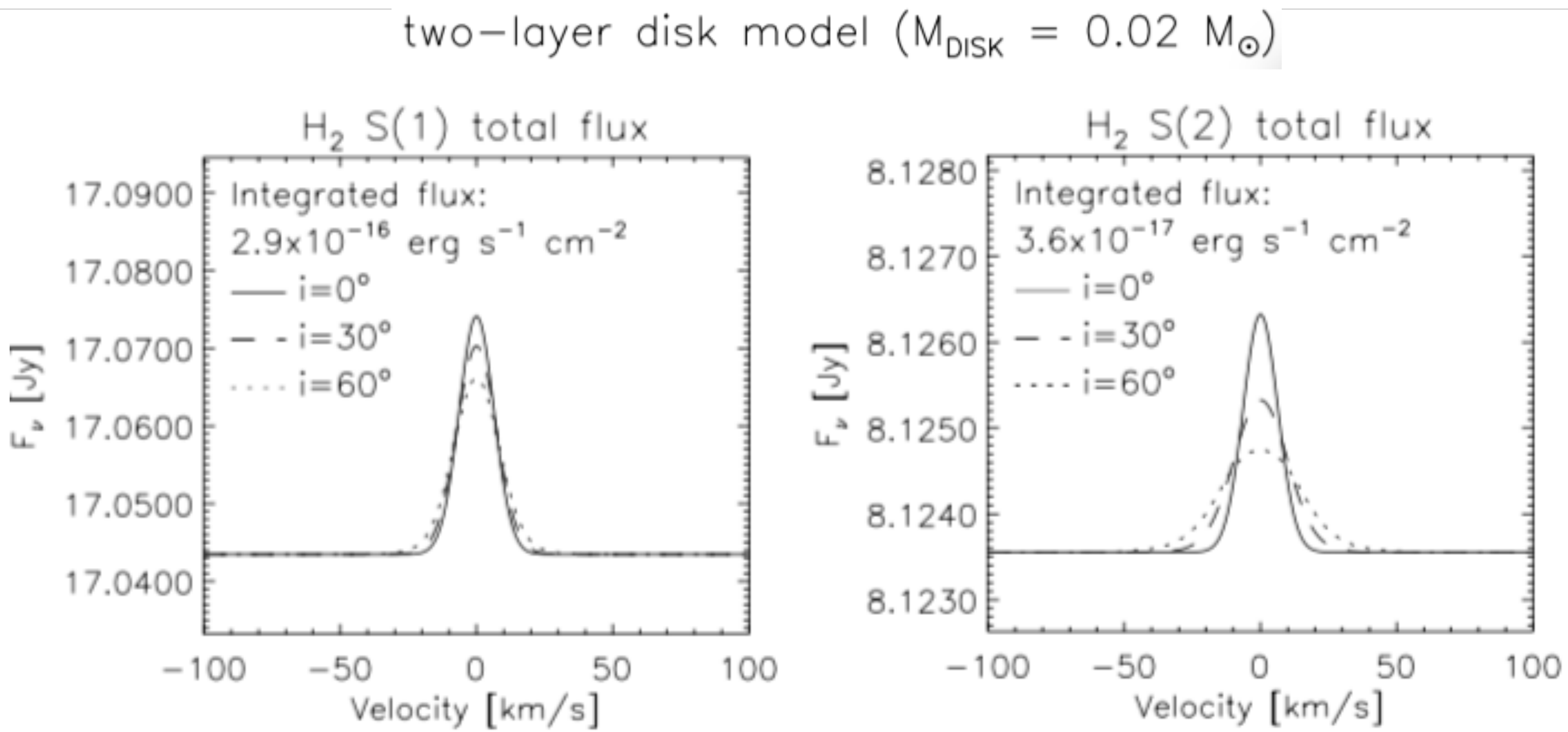
VISIR up-graded:
improved sensitivity ON-GOING LARGE PROGRAM

JWST (R=600 -2400)



100x Spitzer

JWST: Finally detect H_2 mid-IR emission from disks?



Carmona et al. 2008

line fluxes: 10^{-17} - 10^{-16} erg/s/cm^2
10^{-20} - 10^{-19} W/m^2

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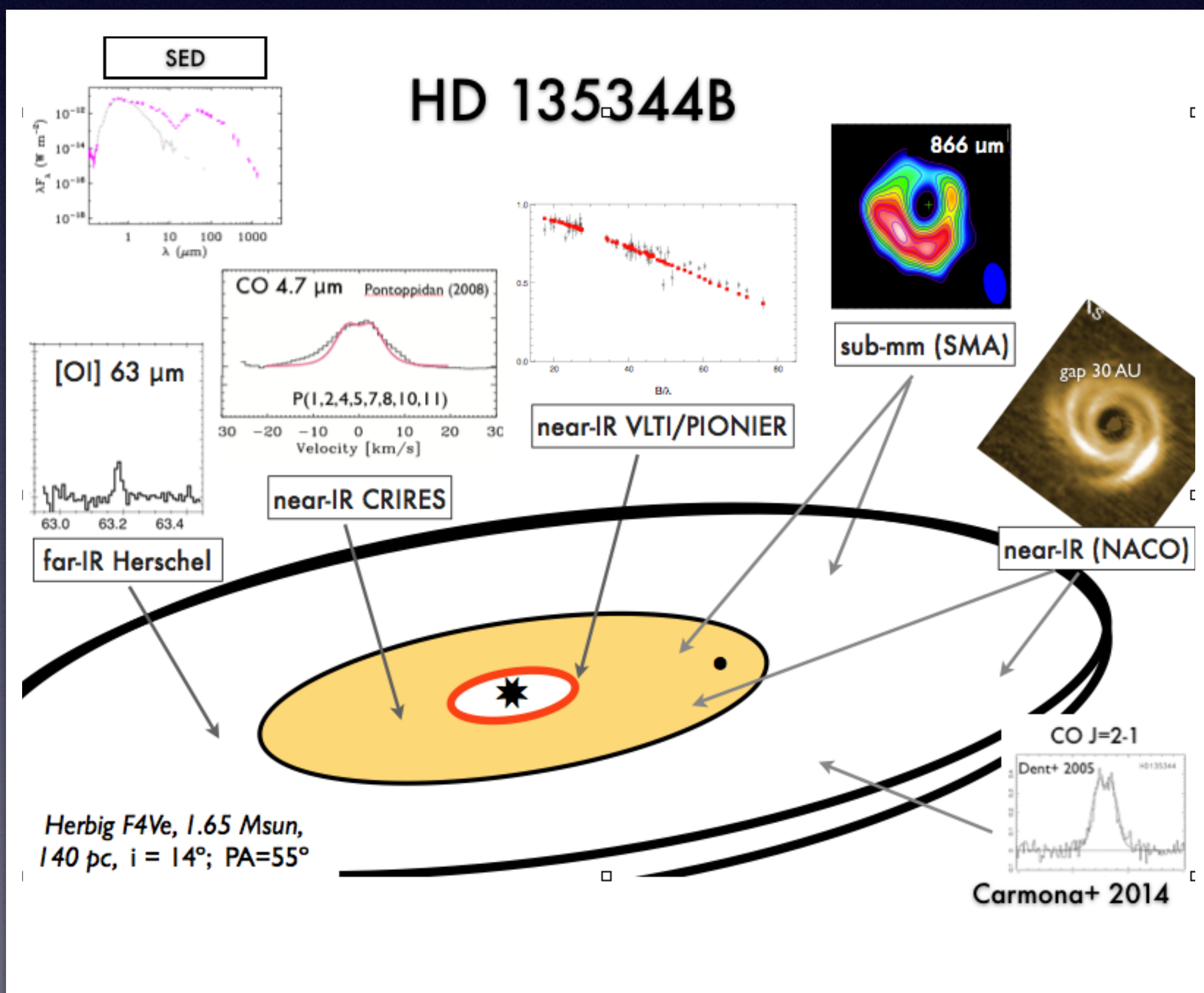
JWST: H_2 S(0) 28 μm line

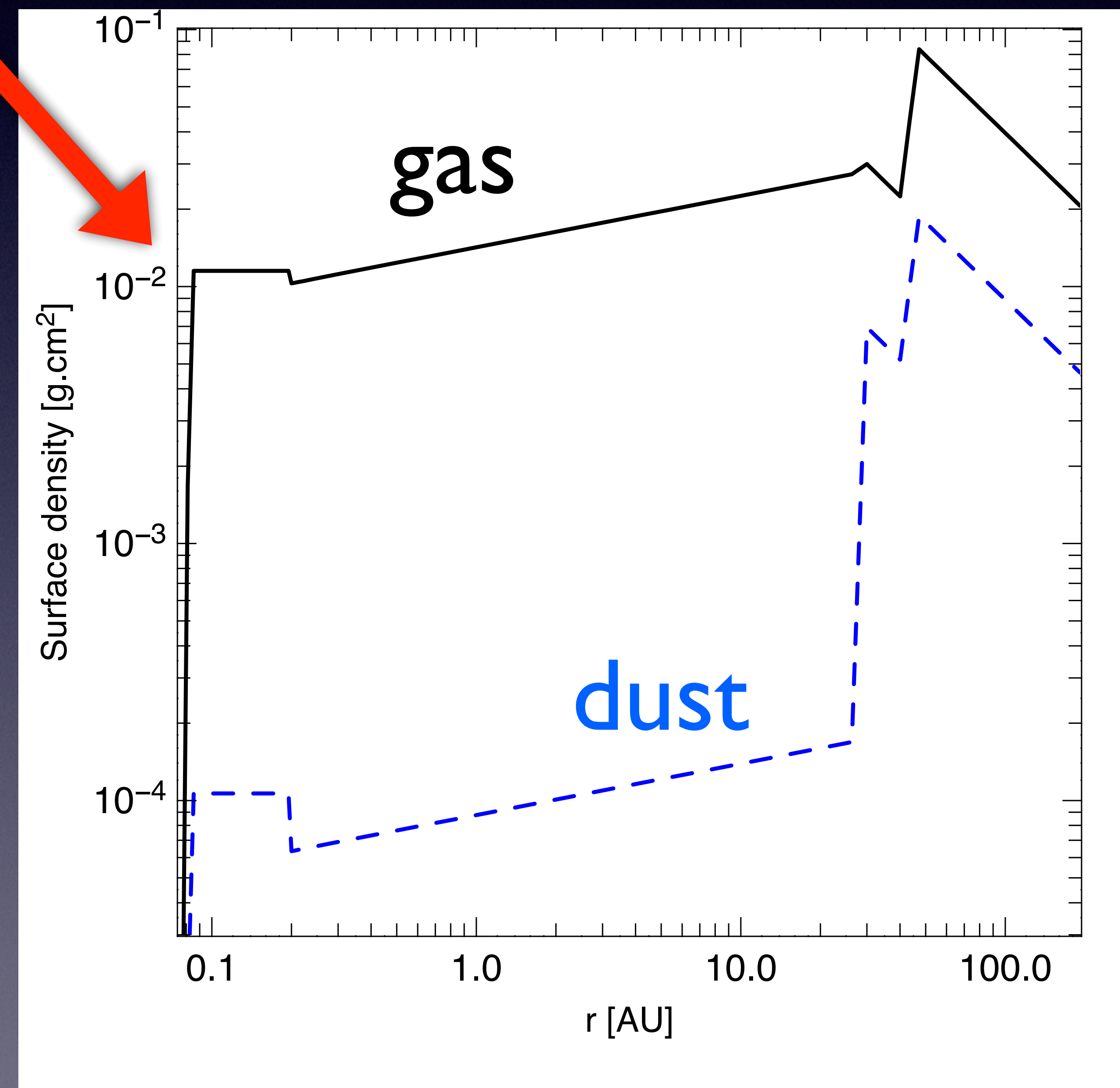
Present: r&z thermochemical parametric models

Full multi-wavelength gas +dust radiative transfer modeling (Carmona+ 2014)

10^{-2} g/cm²

HD 135344B





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+ [OI] 63 μm+ CO J=3-2 870μm + CO J=2-1 1.3mm

Future: 2D/3D hydro + dust + chimie + RT

Perspectives

★ SPIRou:

- Study the magnetic field of M-dwarf disks.
- Search for exoplanets in T Tauri stars (e.g. transition disks).
- Monitoring of the accretion/ejection and hot gas in the disk

★ CRIRES+:

- Gaz surface density in transition disks at R< 10au
- Disk temperatures at R<10 au
- Disk winds in primordial disks

★ VISIR:

- Spectrally resolving the water lines detected by Spitzer
- Study of disk dissipation using [NeII] lines

★ JWST:

- Water and simple organic molecules in a large sample of disks
- H_2 S(0), S(1) measurement in transition, primordial, and debris disks


Thank you