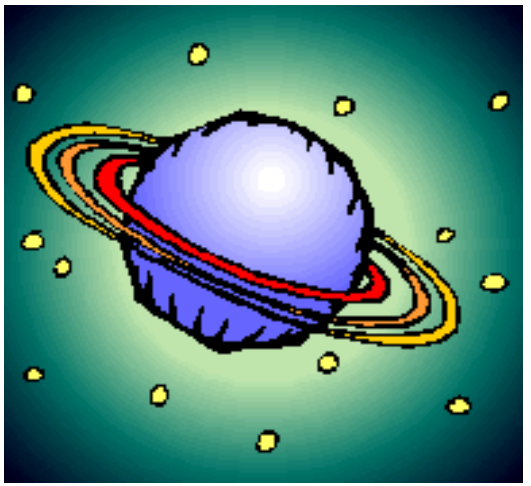

Observational Studies of Gas in Protoplanetary Disks with high resolution infrared spectroscopy

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and

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GAS 99%

mostly H_2

dust
1%

Important questions

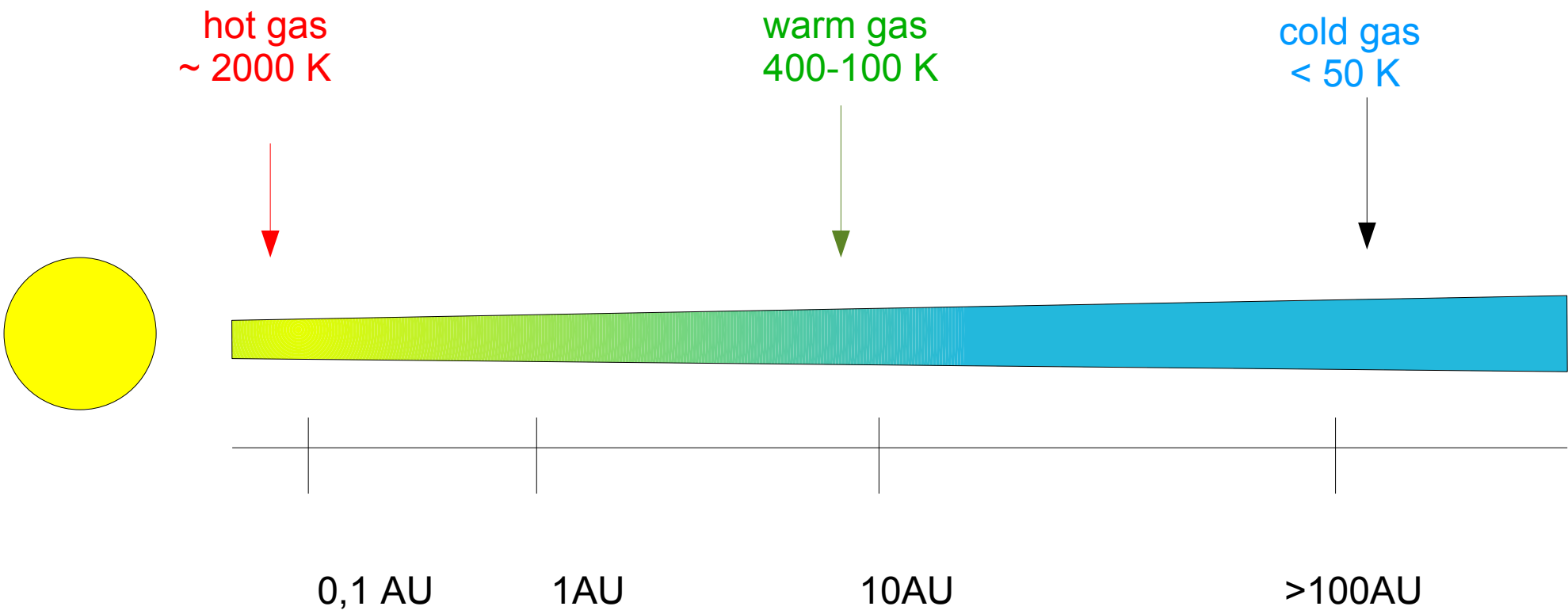
1 What is the mass of the disk ?

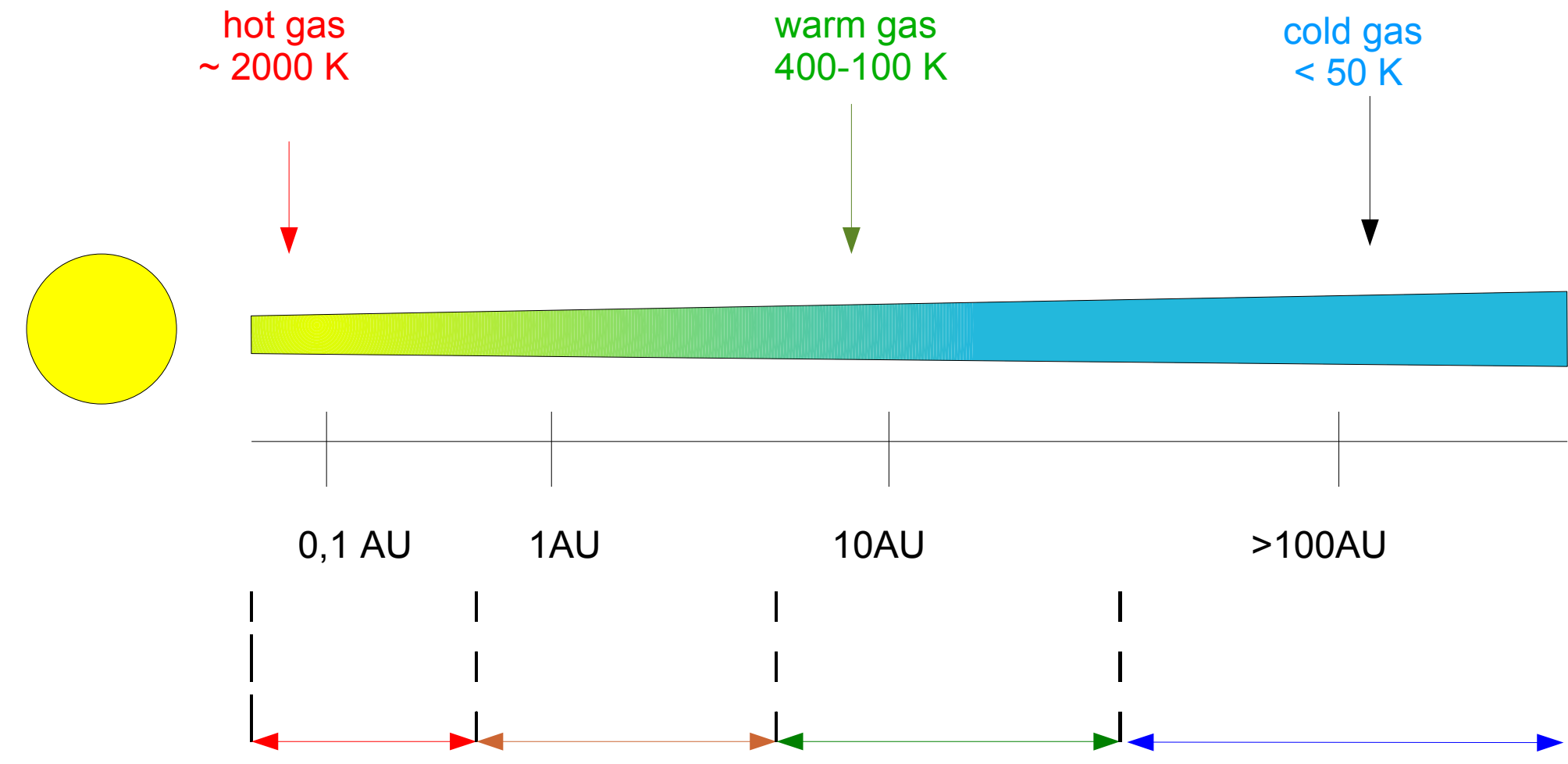
2 When does the disk disappear ?

3 What are the disk dynamics?

Molecule	Abundance [x 10^{-9}]*
H2	1000000000
CO	80000
OH	300
NH3	20
HCO+	8

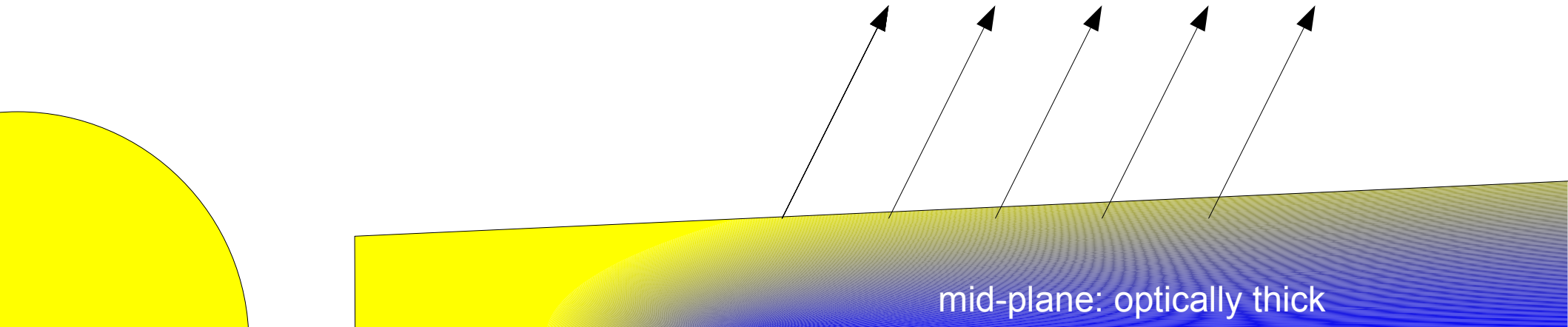
*TMC-1 core Stahler & Palla 2004


hot gas
~ 2000 K
warm gas
400-100 K
cold gas
< 50 K
0,1 AU
1AU
10AU
>100AU

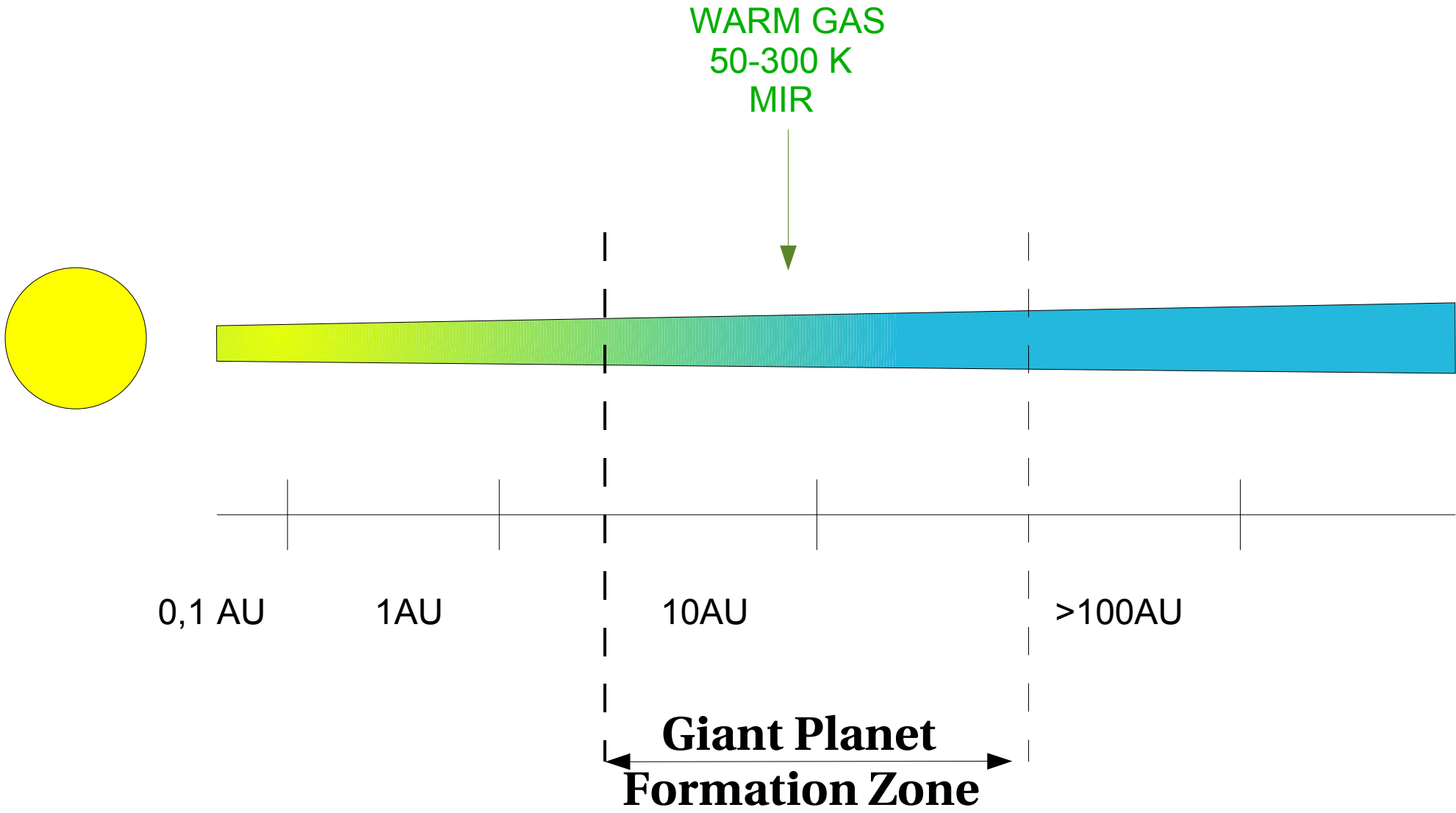

hot gas
~ 2000 K
warm gas
400-100 K
cold gas
< 50 K
0,1 AU
1AU
10AU
>100AU
H2 UV
H2 NIR (2.12 μm)
CO band-head (2.3 μm)
CO 4.7 μm
H2 MIR
28.21 μm
17.03 μm
12.27 μm
CO sub-mm
Na I D optical

We are interested in studying gas molecular lines

Upper layer (optically thin)



WARM GAS:
MIR H2 rotational emission at 12 and 17 micron

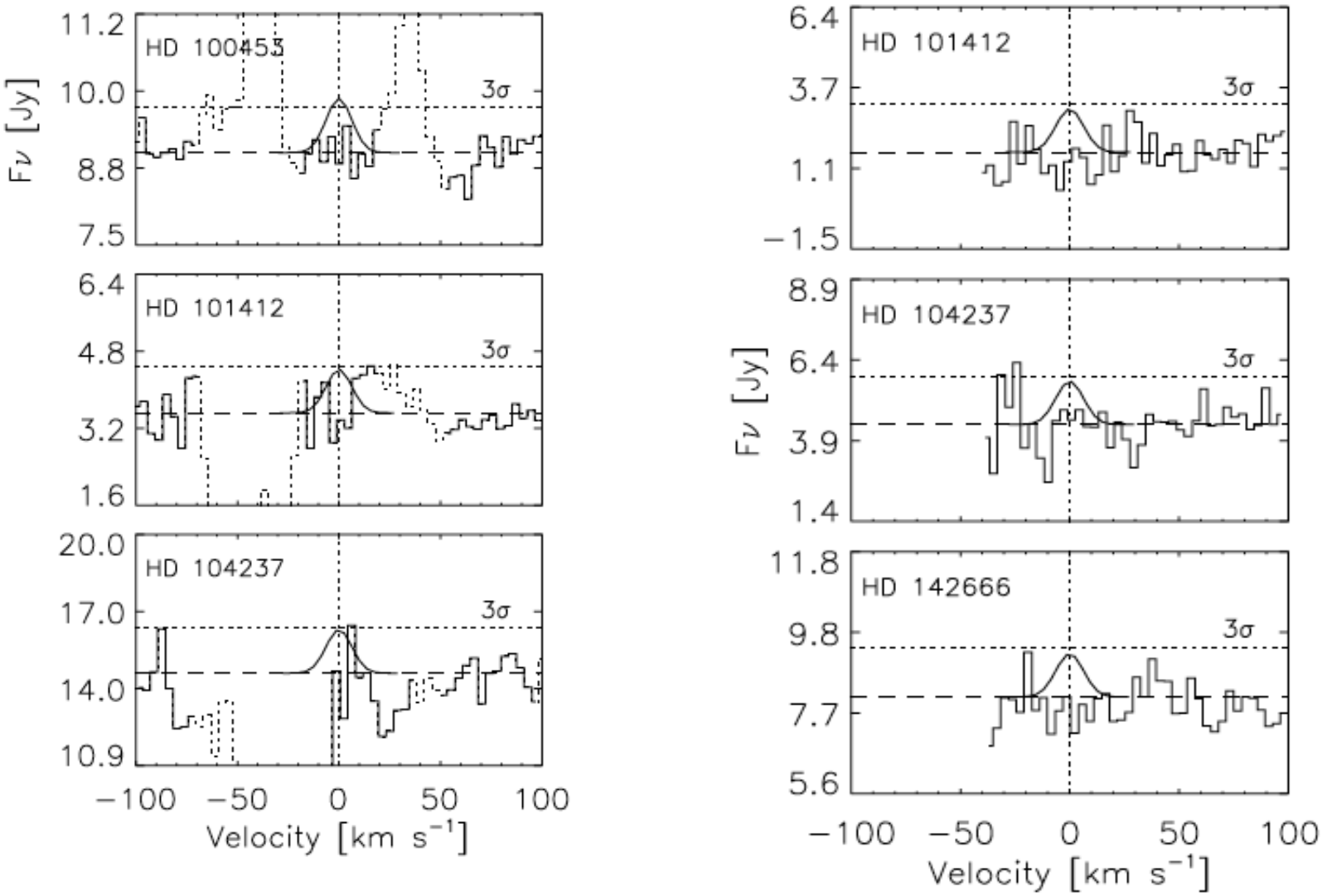


Searching for H2 emission at 12 and 17 micron from protoplanetary disks

Observations:

- ☆ VISIR (high resolution MIR spectrograph at ESO-VLT
- ☆ R = 20000 ~ 15 km/s
- ☆ 6 nearby HAeBe stars with GAS DISK RESERVOIRS

None of the targets exhibit H2 emission at 12 or 17 μm



☆ **Targets have less than**

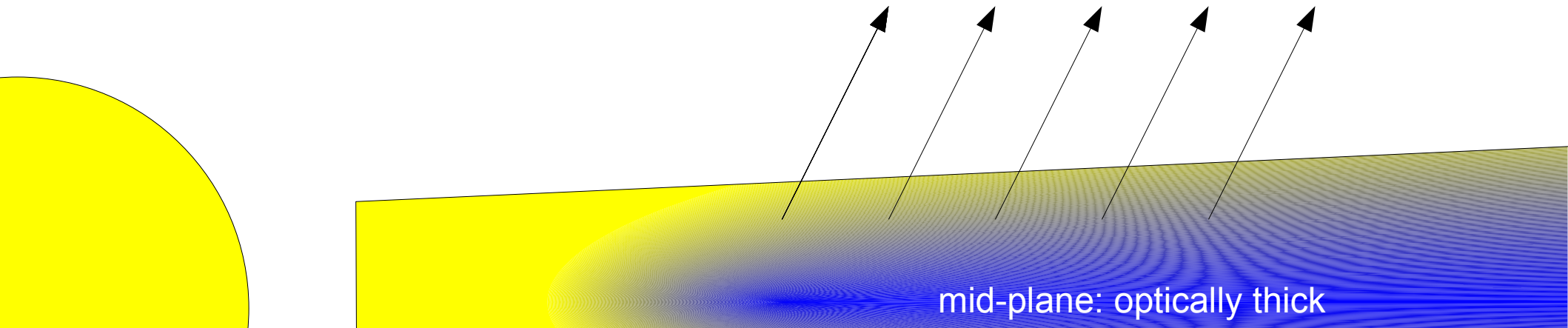
< 0.5 MJ of optically thin warm gas at 150 K

< 5 M⊗ of optically thin warm gas at > 300 K

Why ?

Do you remember ?

Upper layer (optically thin)



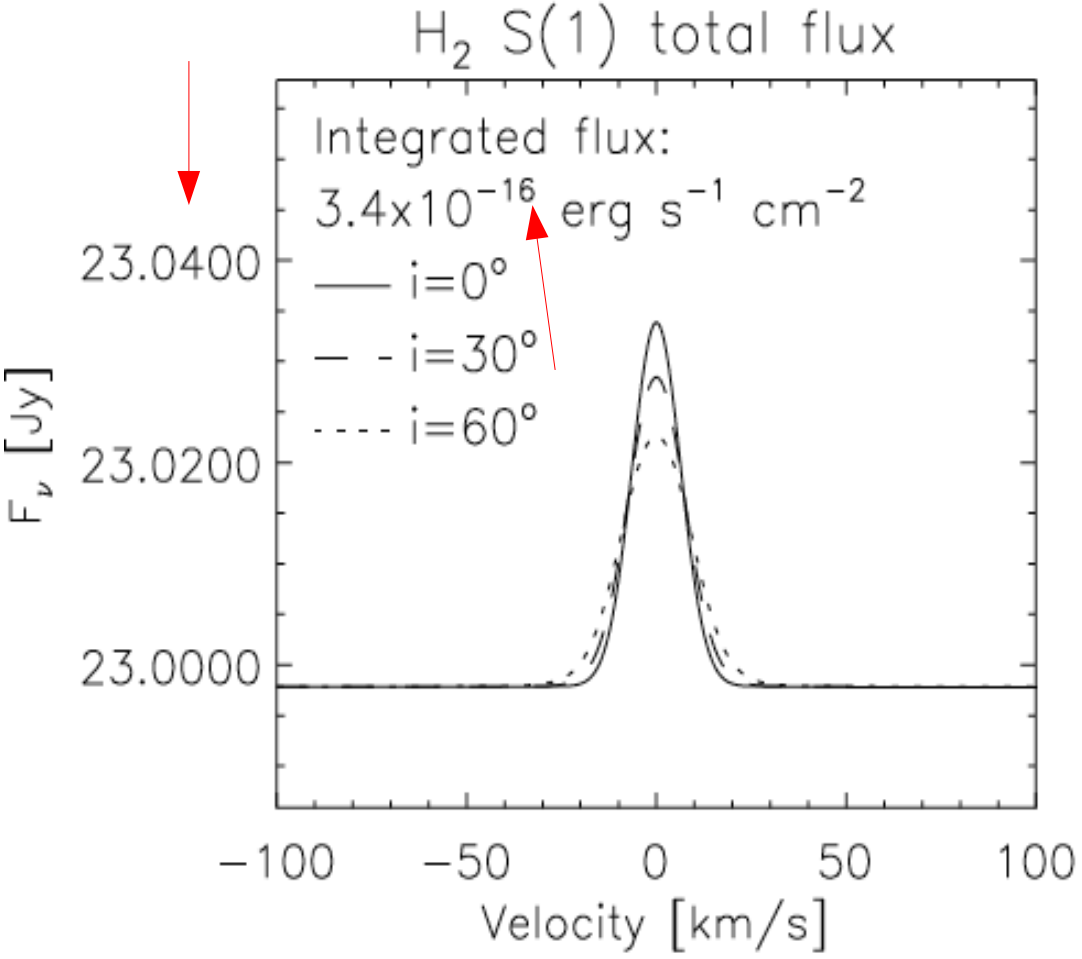
warm thermal H2 emission from an OPTICALLY THICK disk is very weak

Method:

- ☆ **Calculating the H2 emission from a two-layer CG 97 disk.**

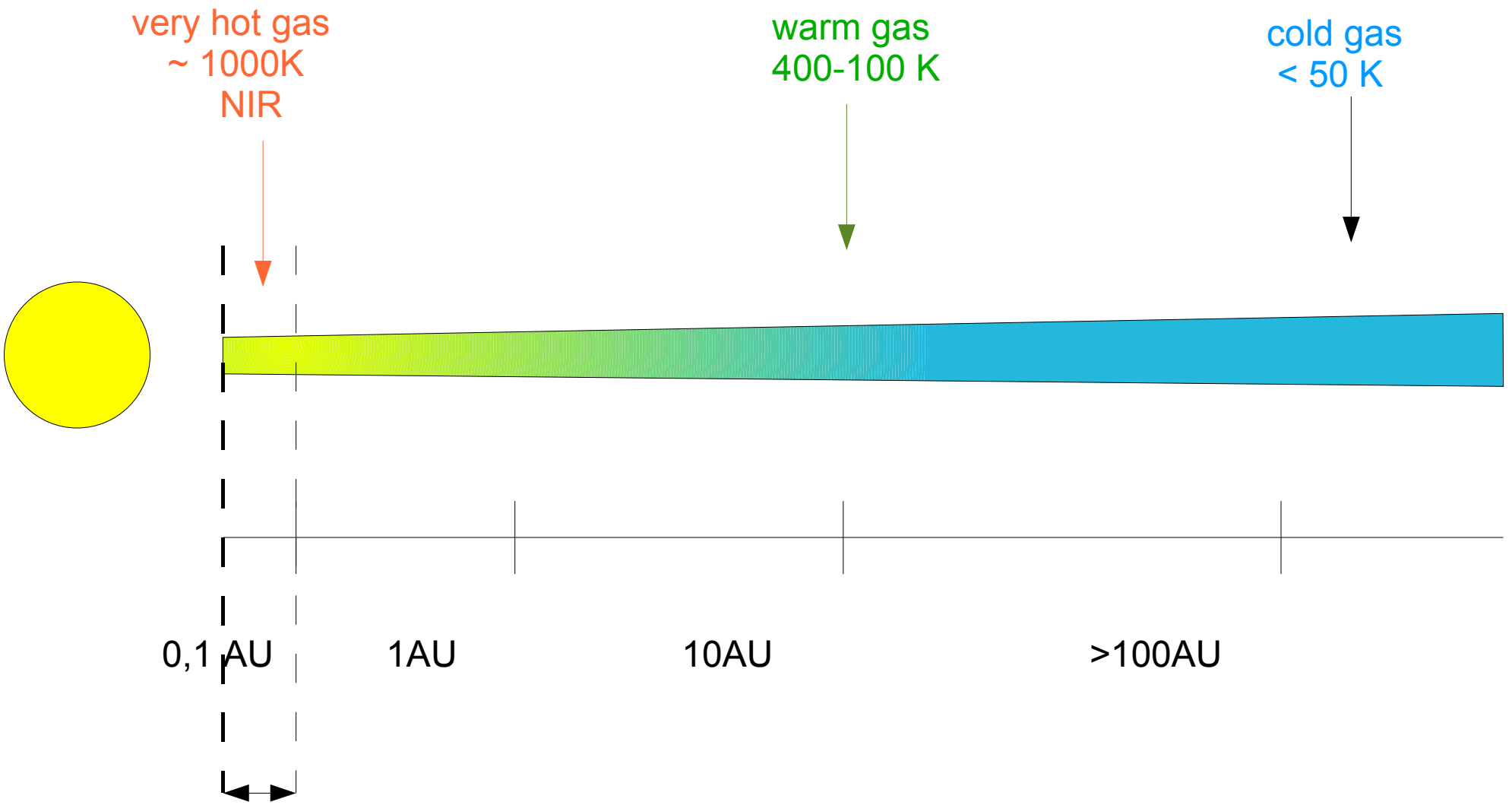
Result:

- ☆ **Emission is two orders of magnitude fainter than the sensitivity limits**



observational limit
0.5 x 10 $^{-14}$ erg /s /cm^2

NIR: UV or X-ray excited emission of VERY HOT GAS



Probe of the innermost region: after the dust sublimation radius T > 1500 K

Searching for H2 emission at 2.2 micron from protoplanetary disks

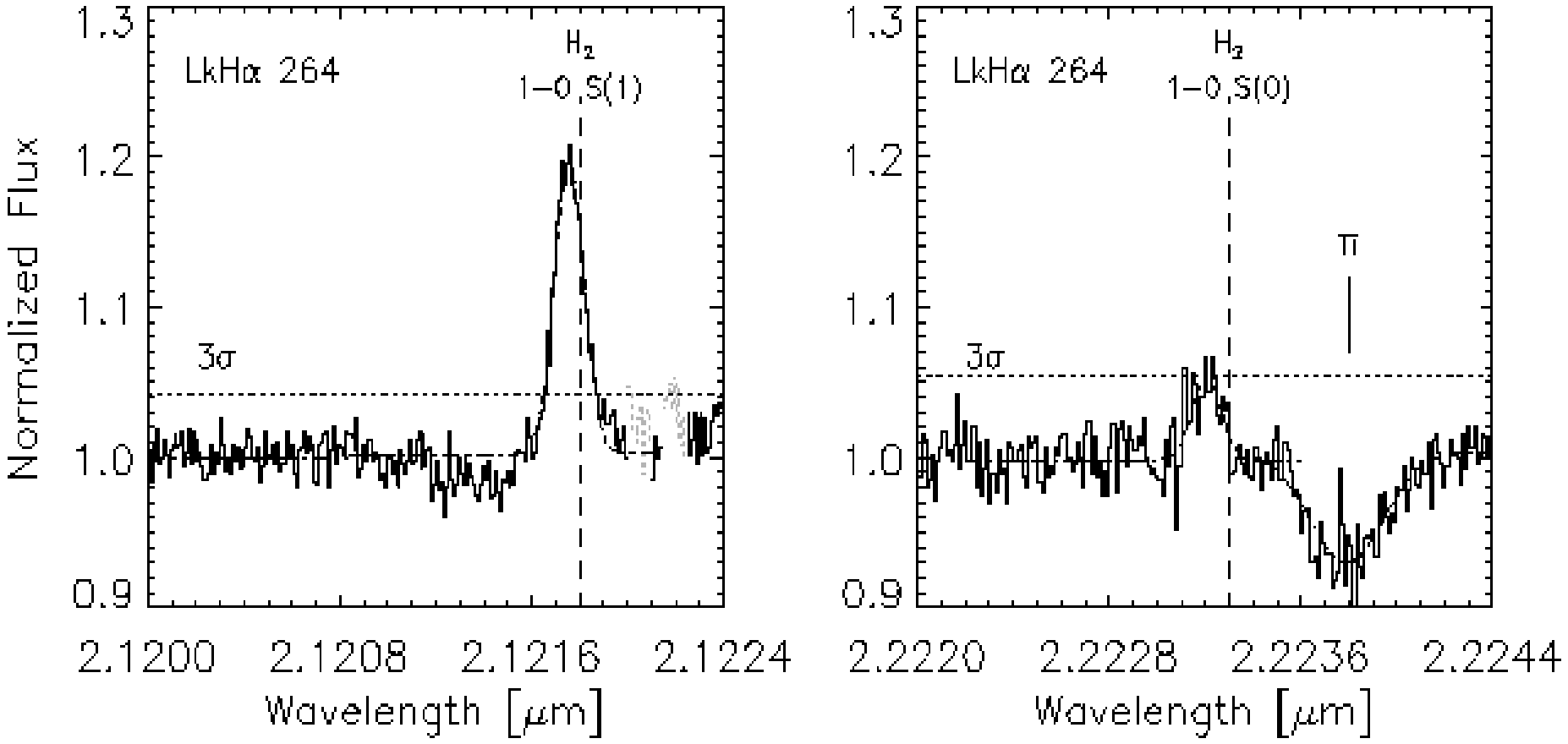
Observations:

- ☆ CRIRES high resolution NIR spectrograph at ESO-VLT
- ☆ R = 45000 ~ 15 km/s

- ☆ LkHa 264 (Classical T Tauri star)

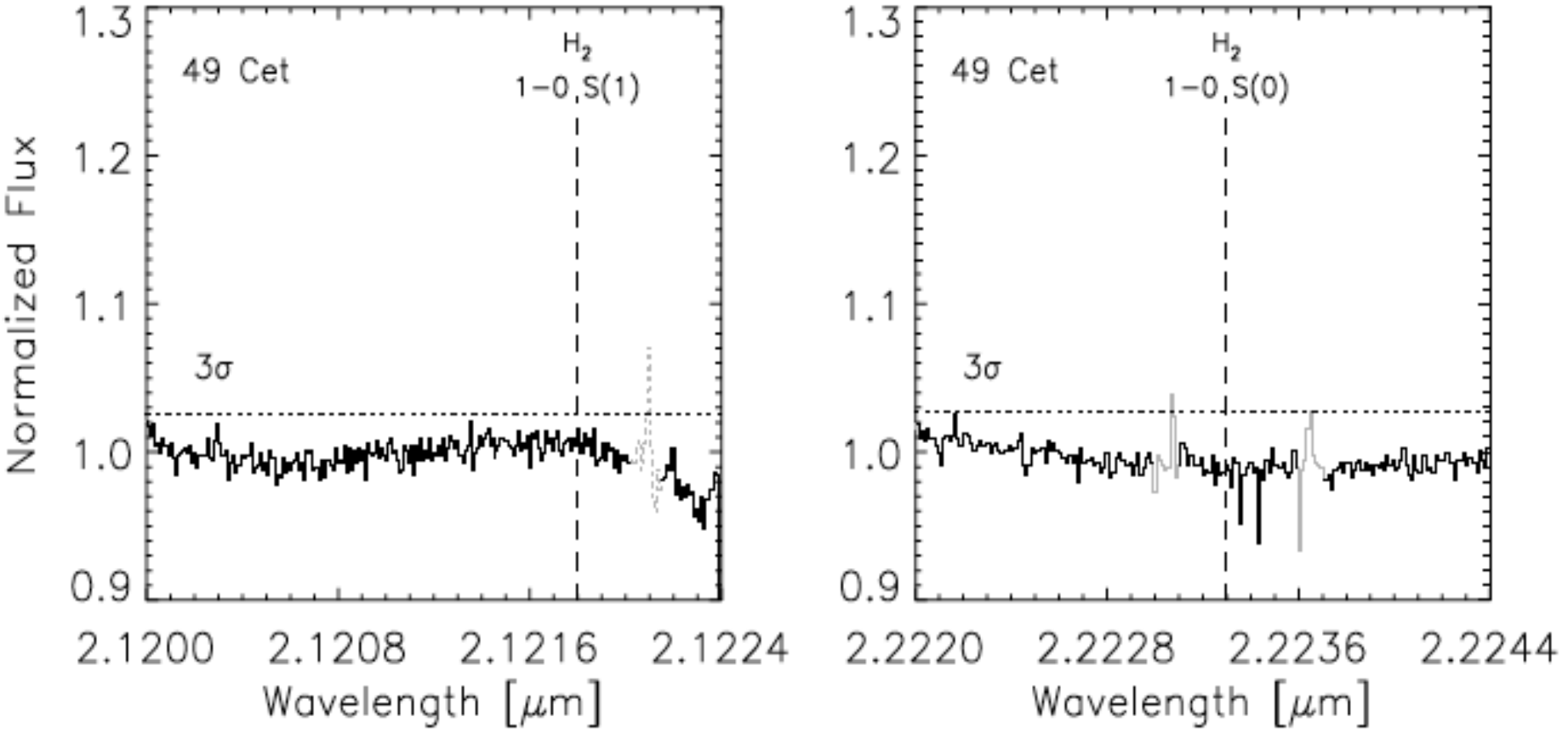
- ☆ 49 Cet debris disk with
  CO detected in the sub-mm -> (gaseous outer disk)

NIR H2 emission detected in LkHa 264



- ☆ Disk inclination < 35°
- ☆ The line ratios constrain the gas T to < 2000K
- ☆ The emission is thermal

NIR H2 emission non-detected in 49 Cet



- ☆ There is less than a few lunar masses of hot H2 inside 10 AU of 49 Cet
- ☆ The disk has a inner hole in the gas

- From our observations (detections and non-detections), important constraints on the physical properties are derived:
  - Mass,
  - Temperature,
  - Excitation mechanism,
  - Inclination.

- High-resolution infrared spectroscopy is a crucial tool for future studies of the structure of protoplanetary disks.