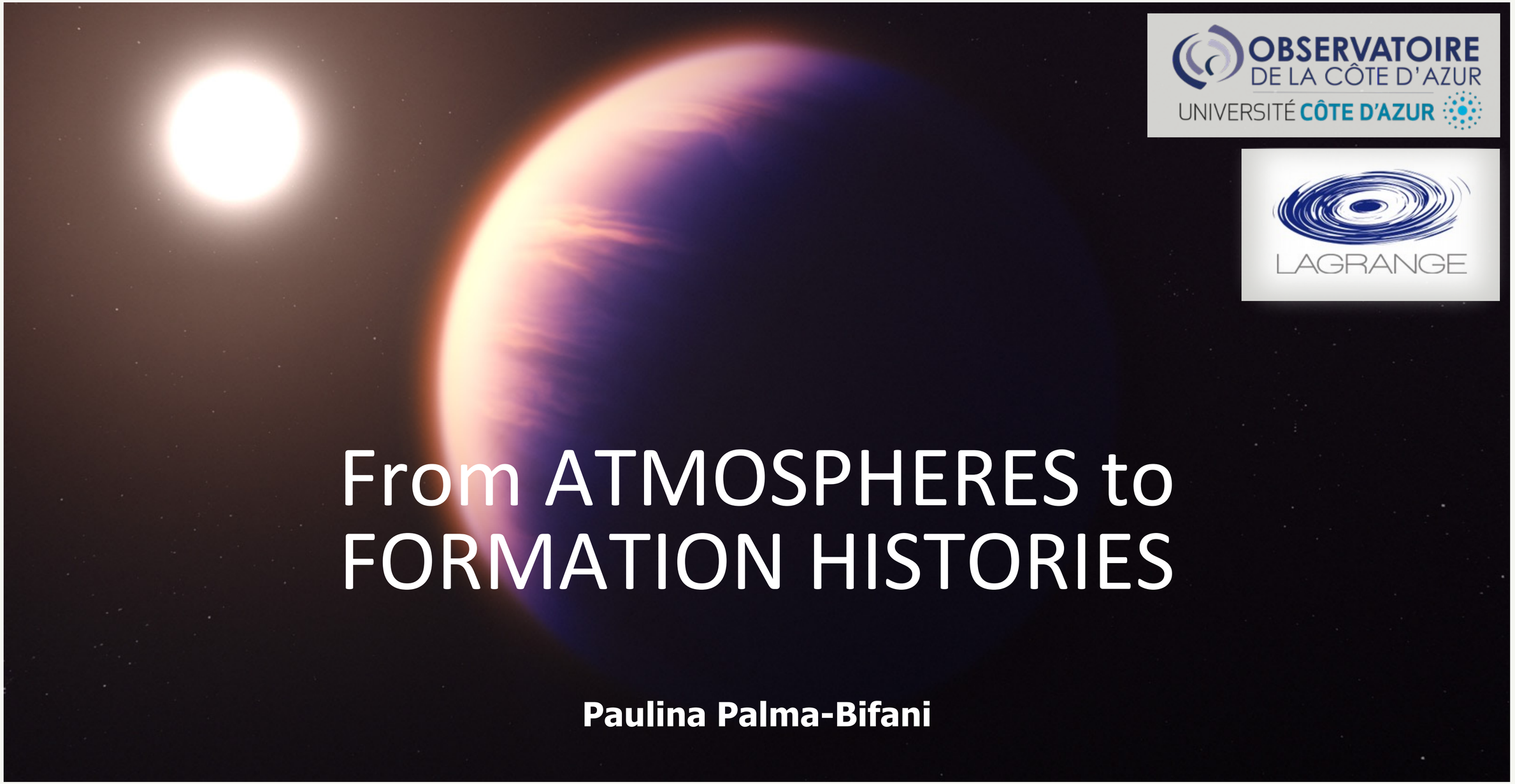
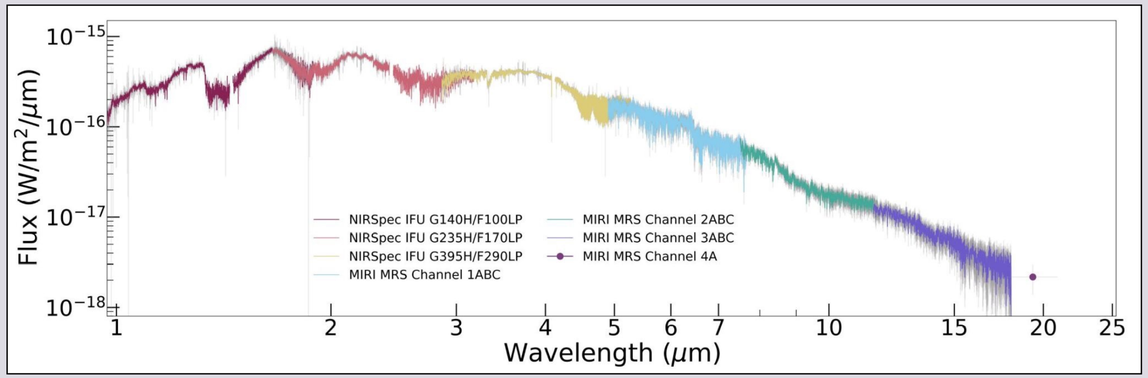
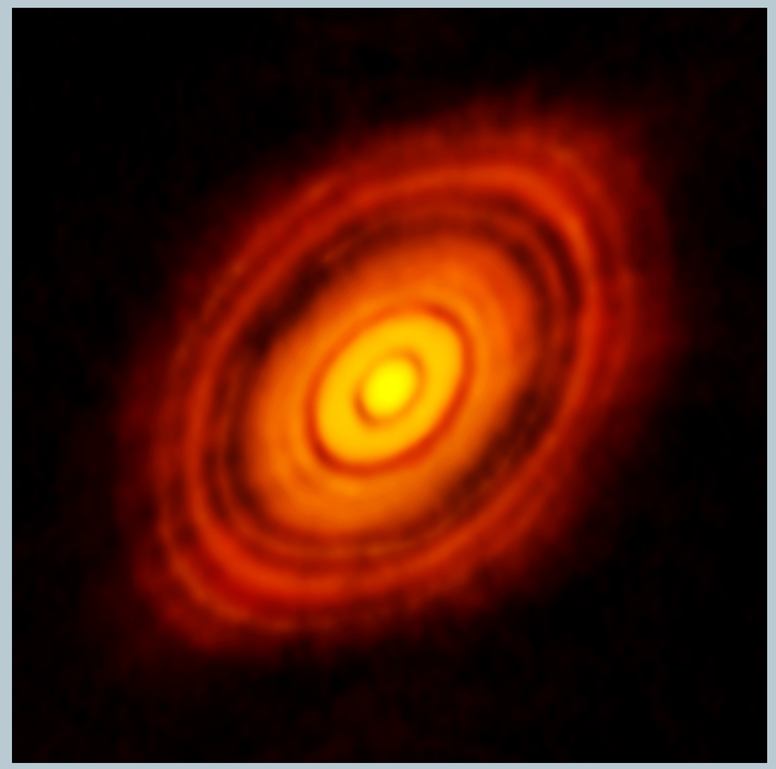


From ATMOSPHERES to FORMATION HISTORIES

Paulina Palma-Bifani

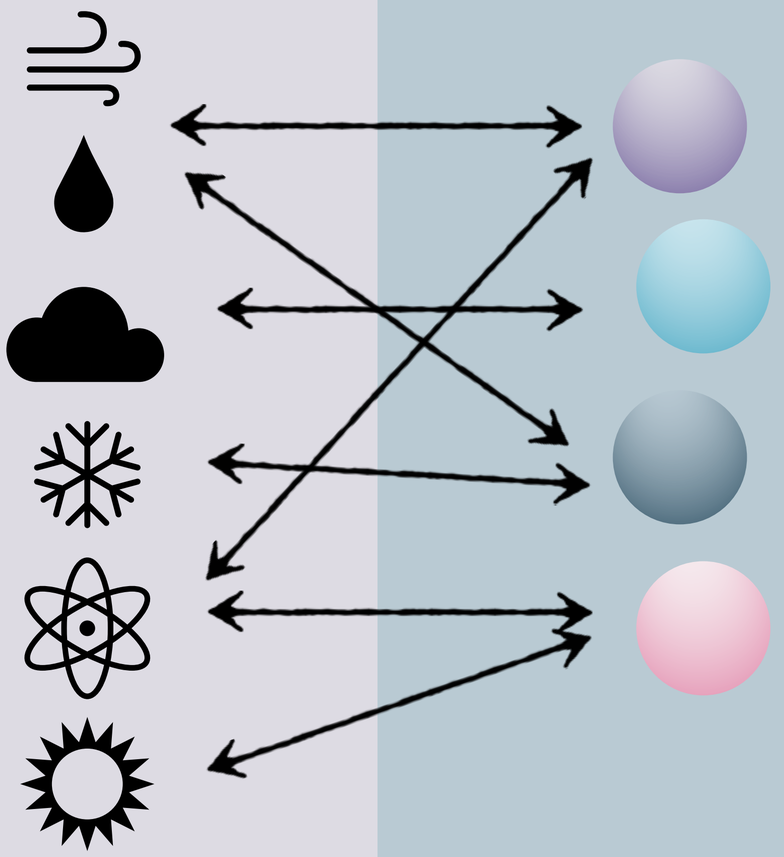
Atmospheres





Formation Mechanisms

Atmospheres



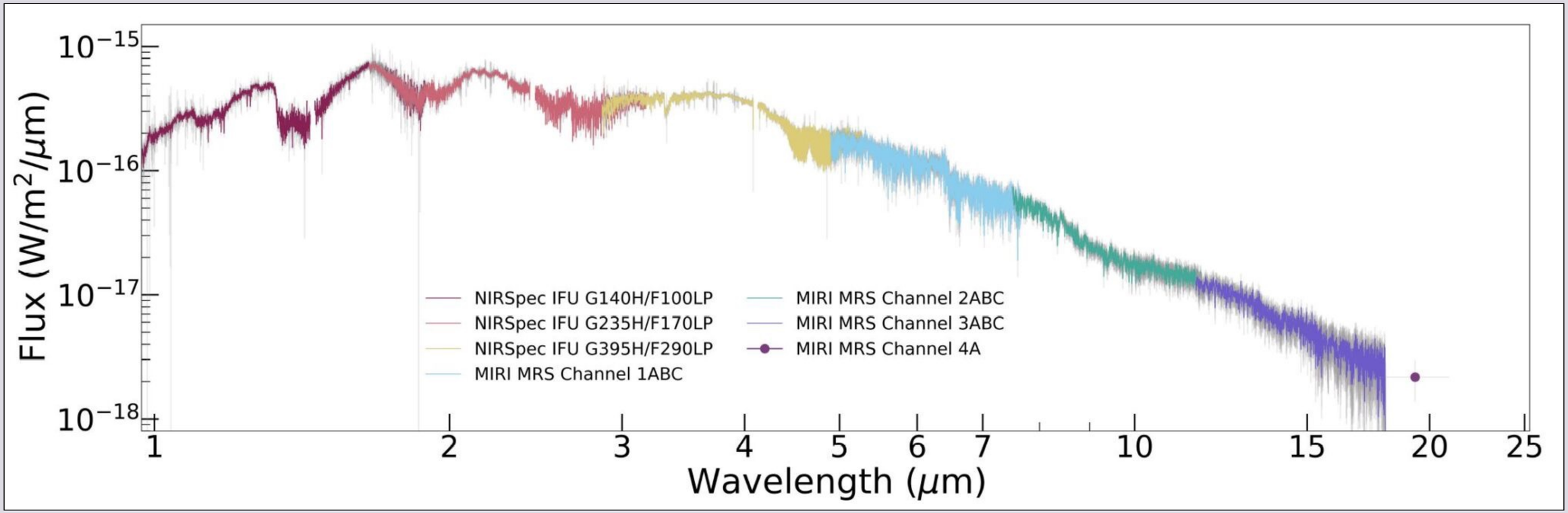
Formation Mechanisms

Atmospheres

Atmospheres

Miles et al. 2022

JWST - VHS 1256 b



Atmospheres

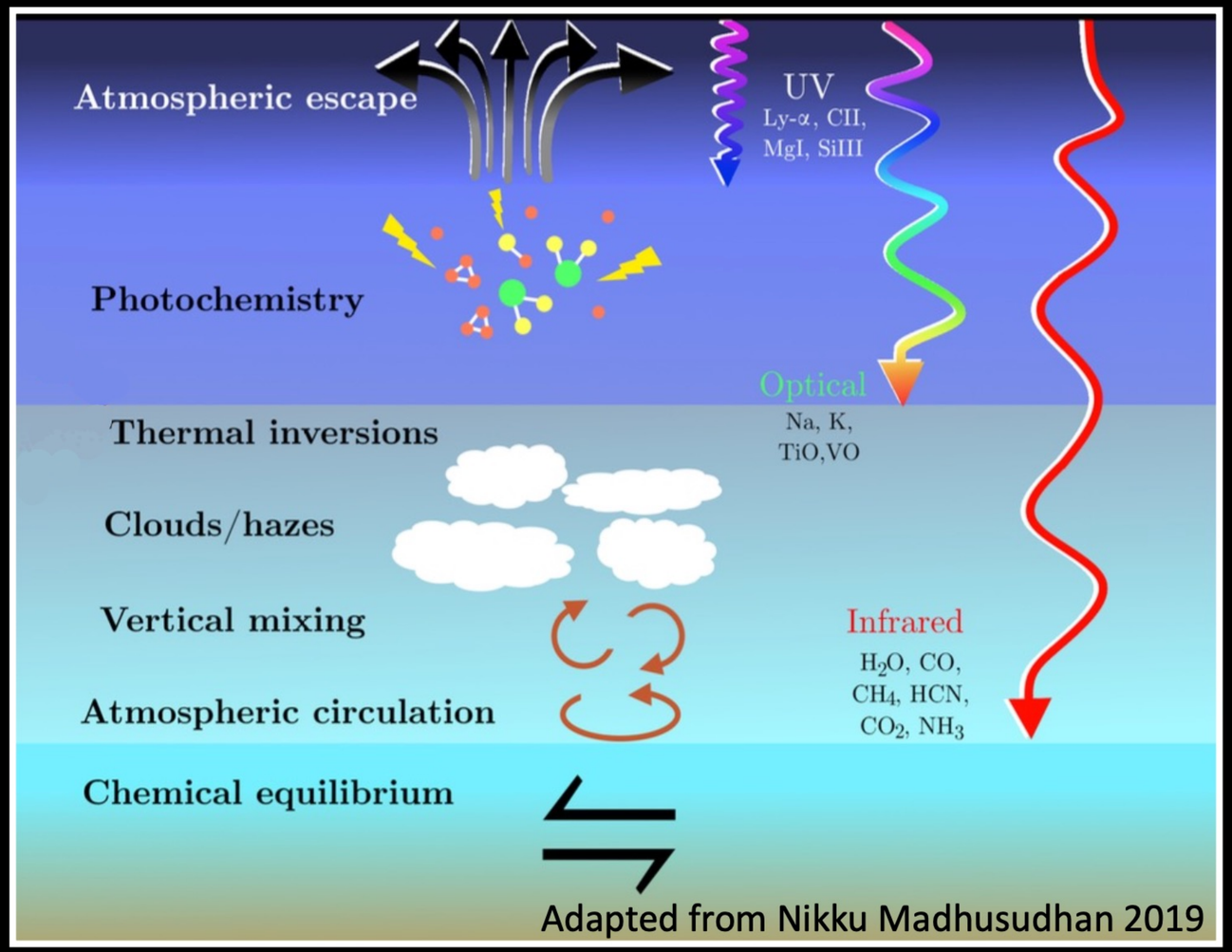
T_{eff}

$\log(g)$

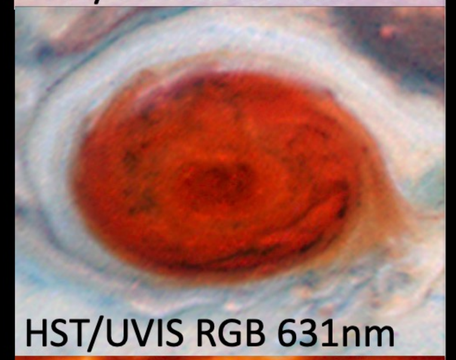
$[M/H]$

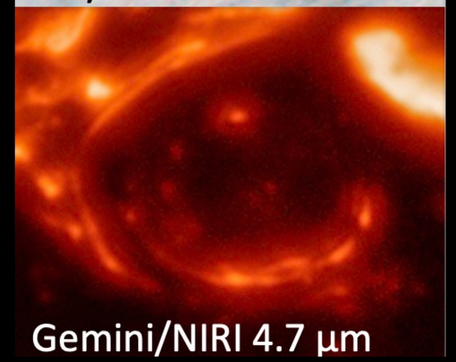
C/O

...



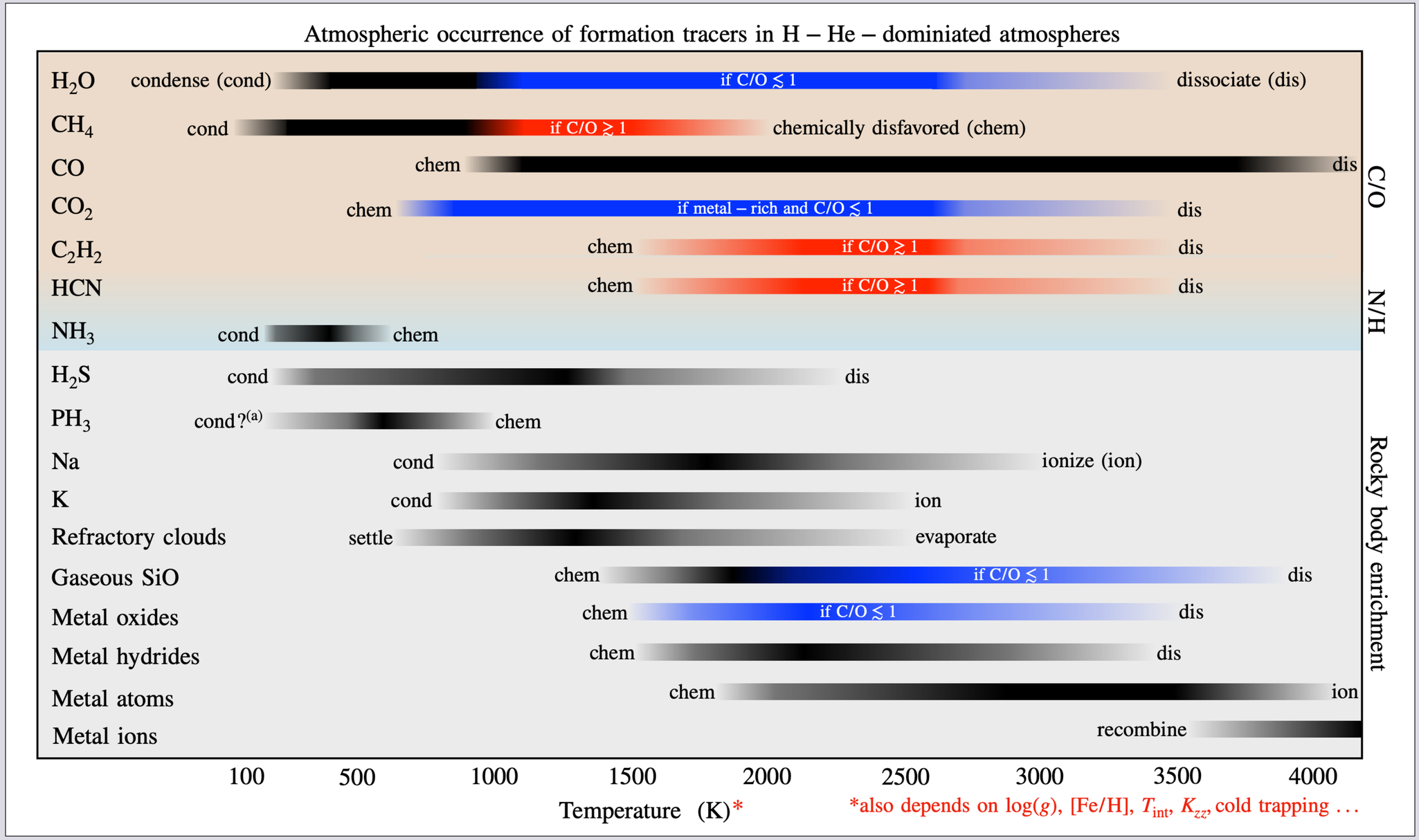

HST/UVIS ultraviolet


HST/UVIS RGB 631nm


Gemini/NIRI 4.7 µm

Atmospheres

Mollière et al. 2022



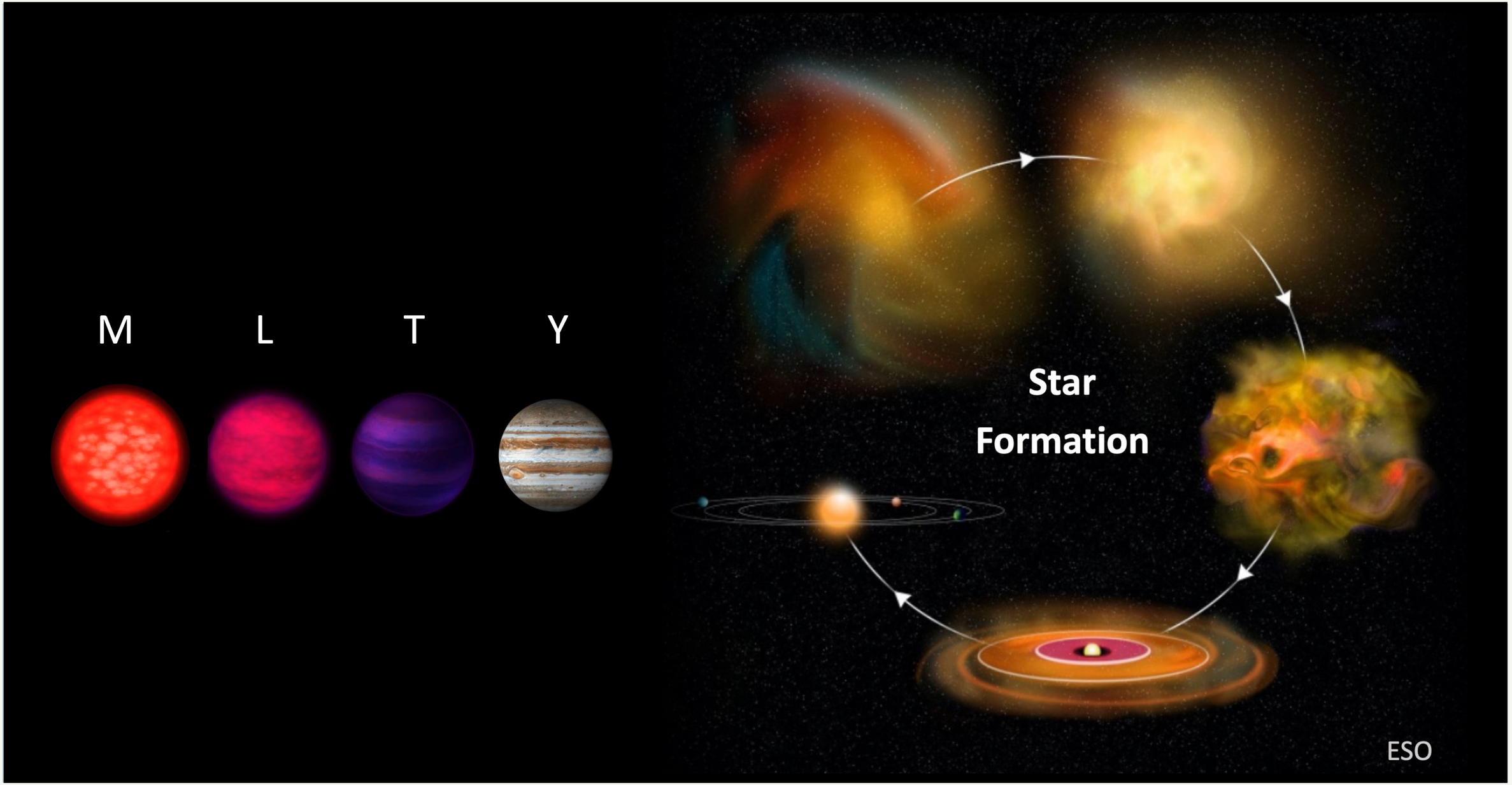
Atmospheres

Formation Mechanisms

Formation Mechanisms

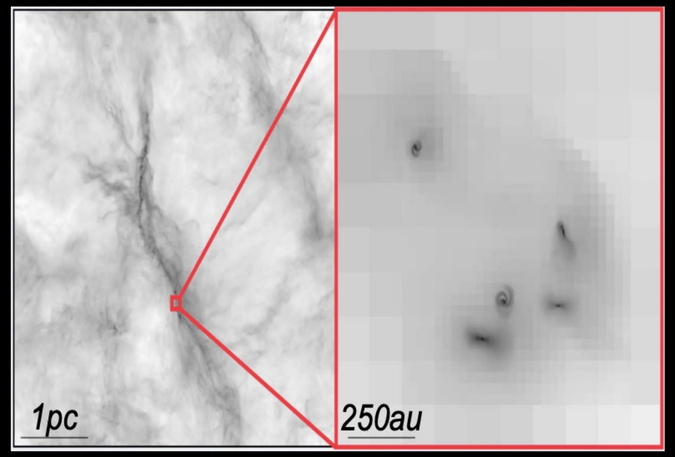
For Gas Giants (at wide orbits)

Formation Mechanisms

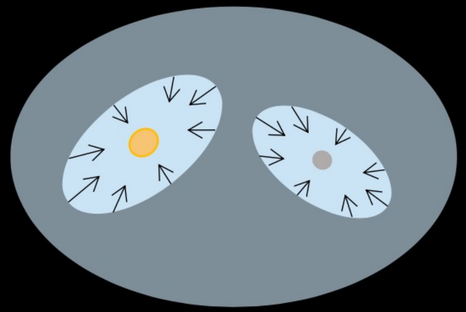


Formation Mechanisms

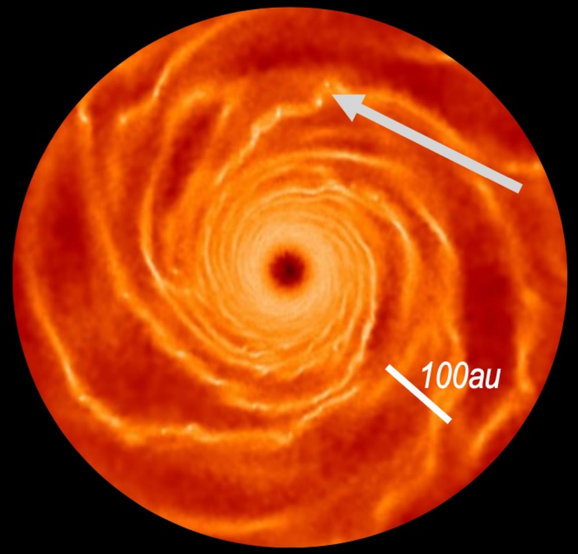
Gravoturbulent Fragmentation



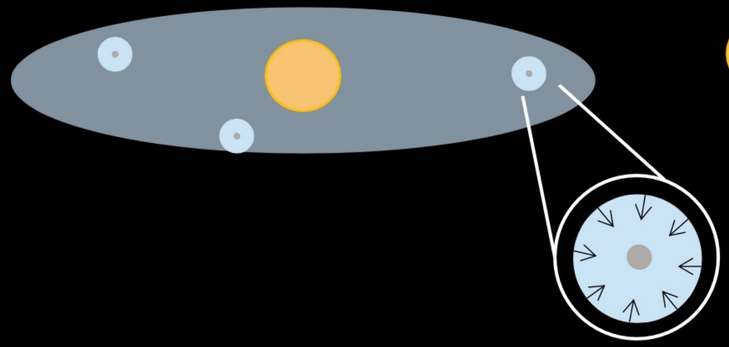
Padoan & Nordlund 2005



Gravitational Instabilities

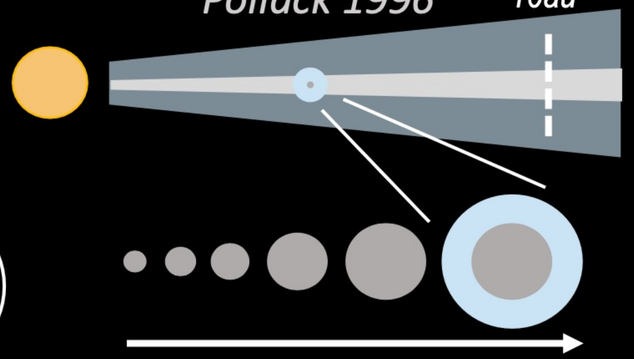


Boss 1997



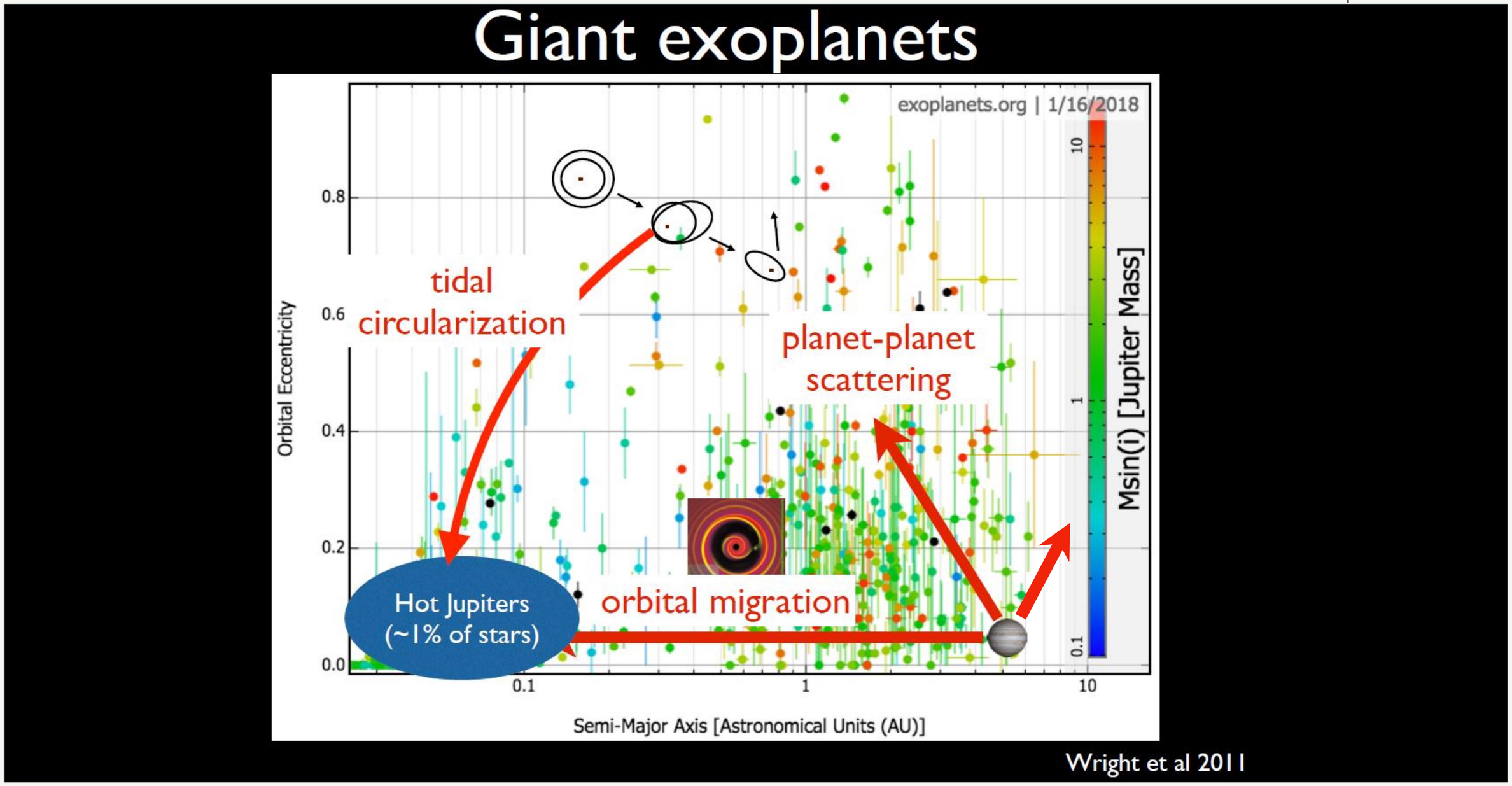
Core (Pebble) Accretion

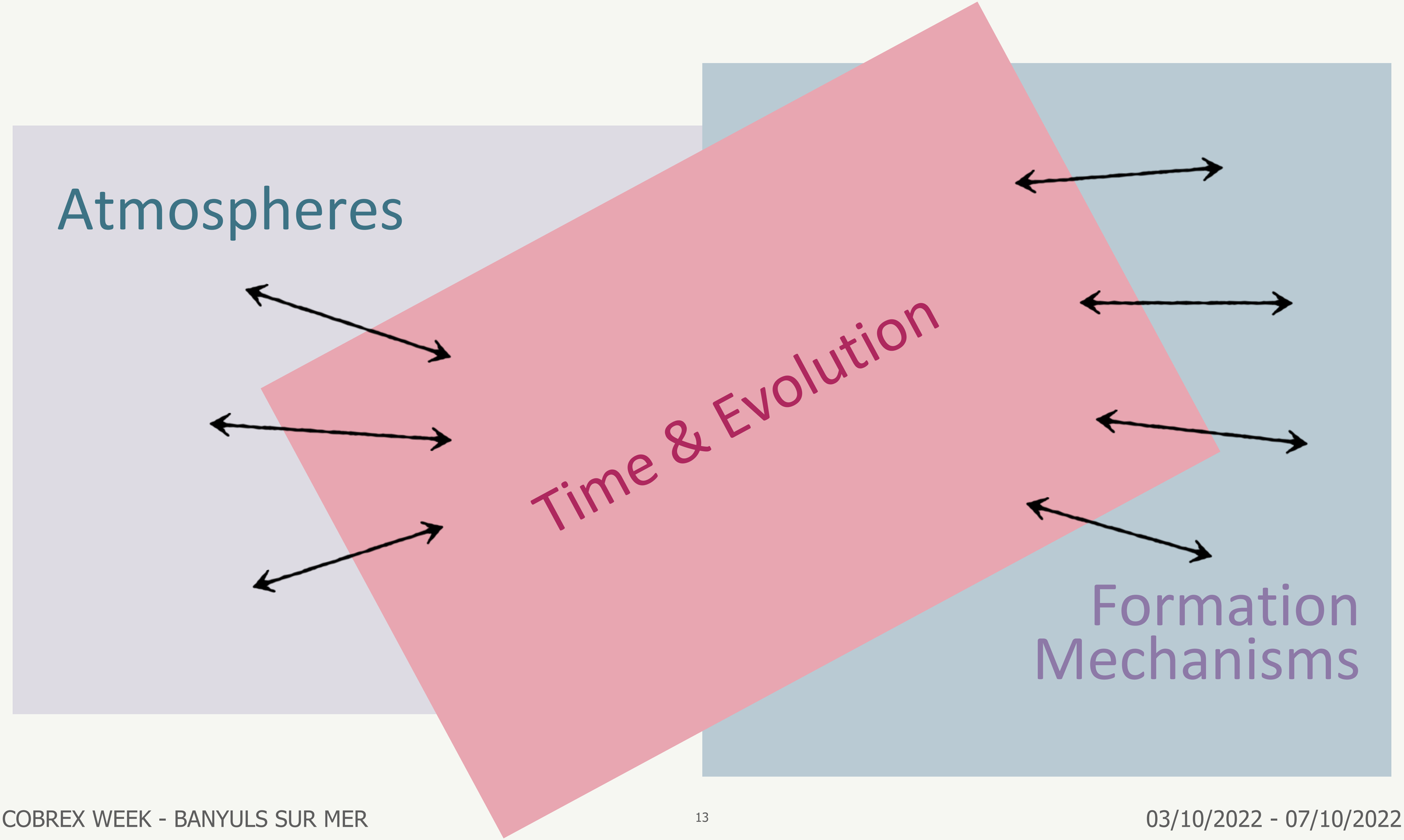
Pollack 1996



9

Formation Mechanisms




Atmospheres
Time & Evolution
Formation Mechanisms

Time & Evolution

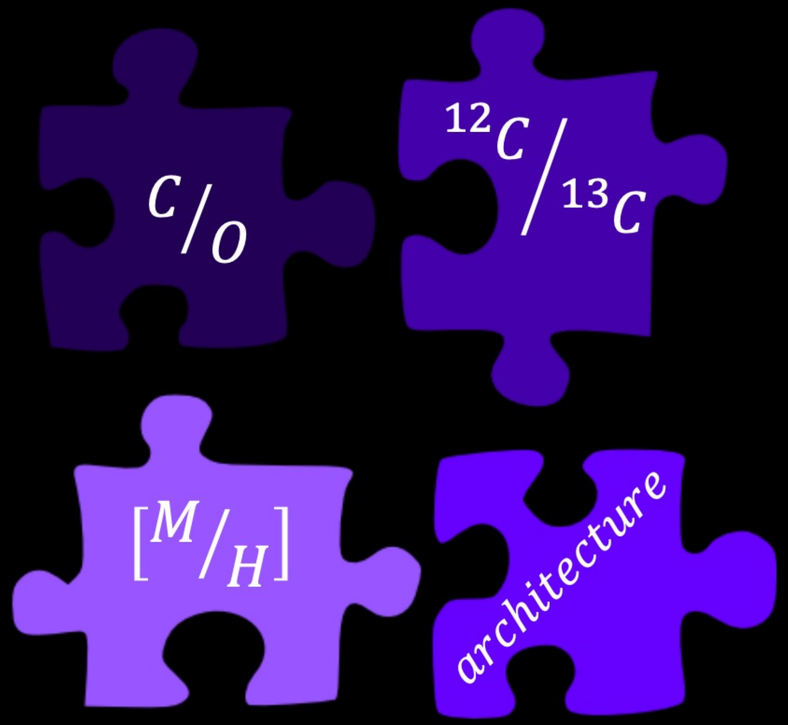
How do the formation environment and evolution history impact the atmosphere and spectral signatures?

Location of formation

Accretion of (other) solids

Accretion of solids

Dynamical interactions



Time & Evolution

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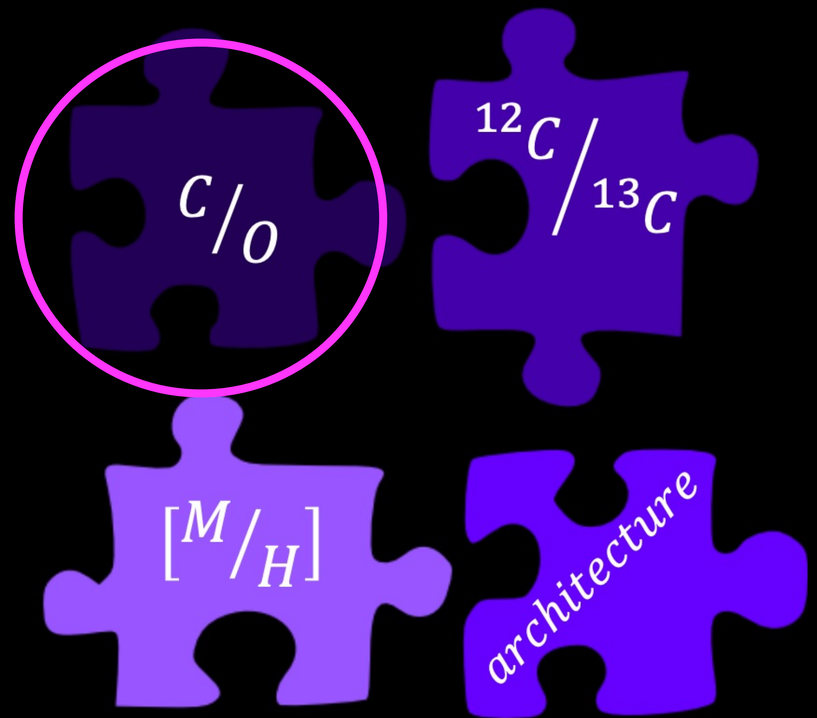
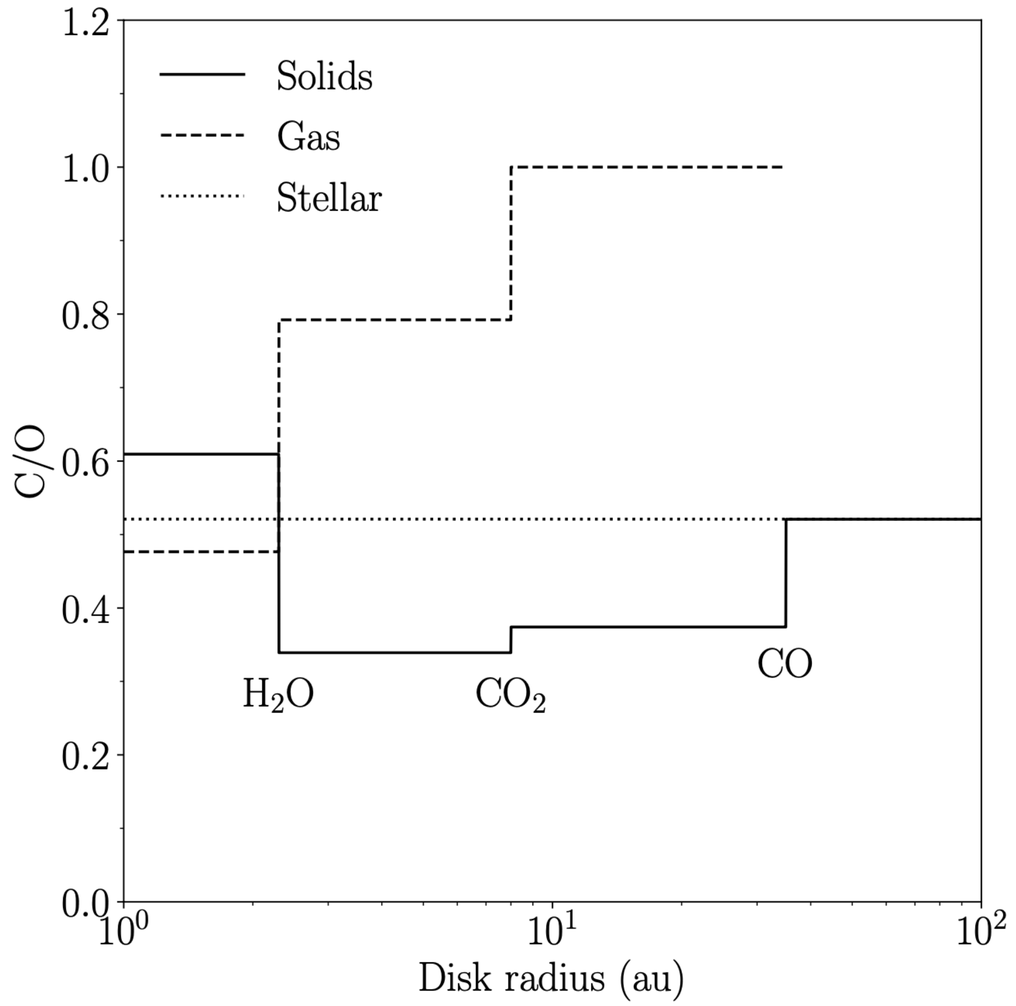


Accretion of (other) solids

Dynamical interactions

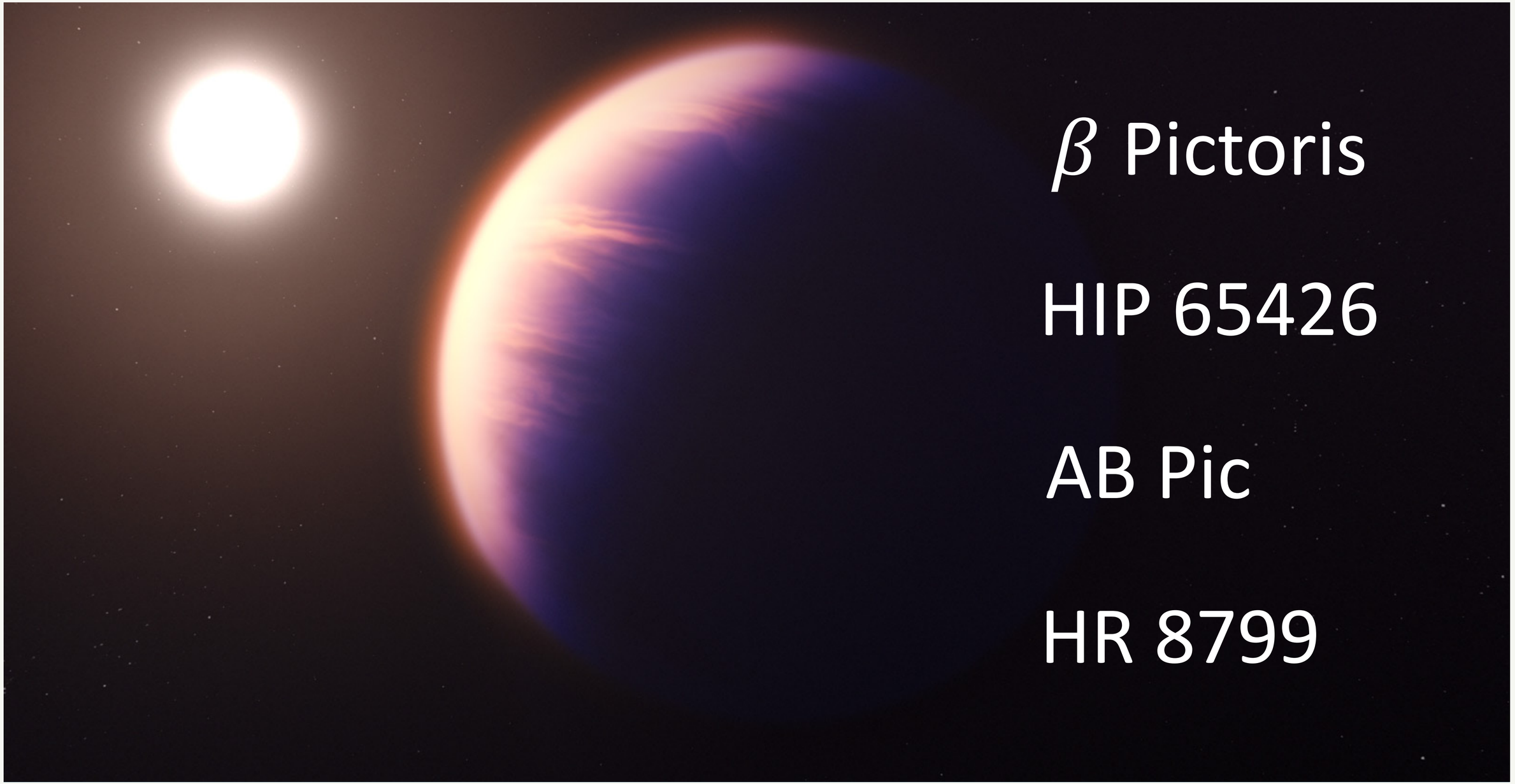
Time & Evolution

Mollière et al. 2022



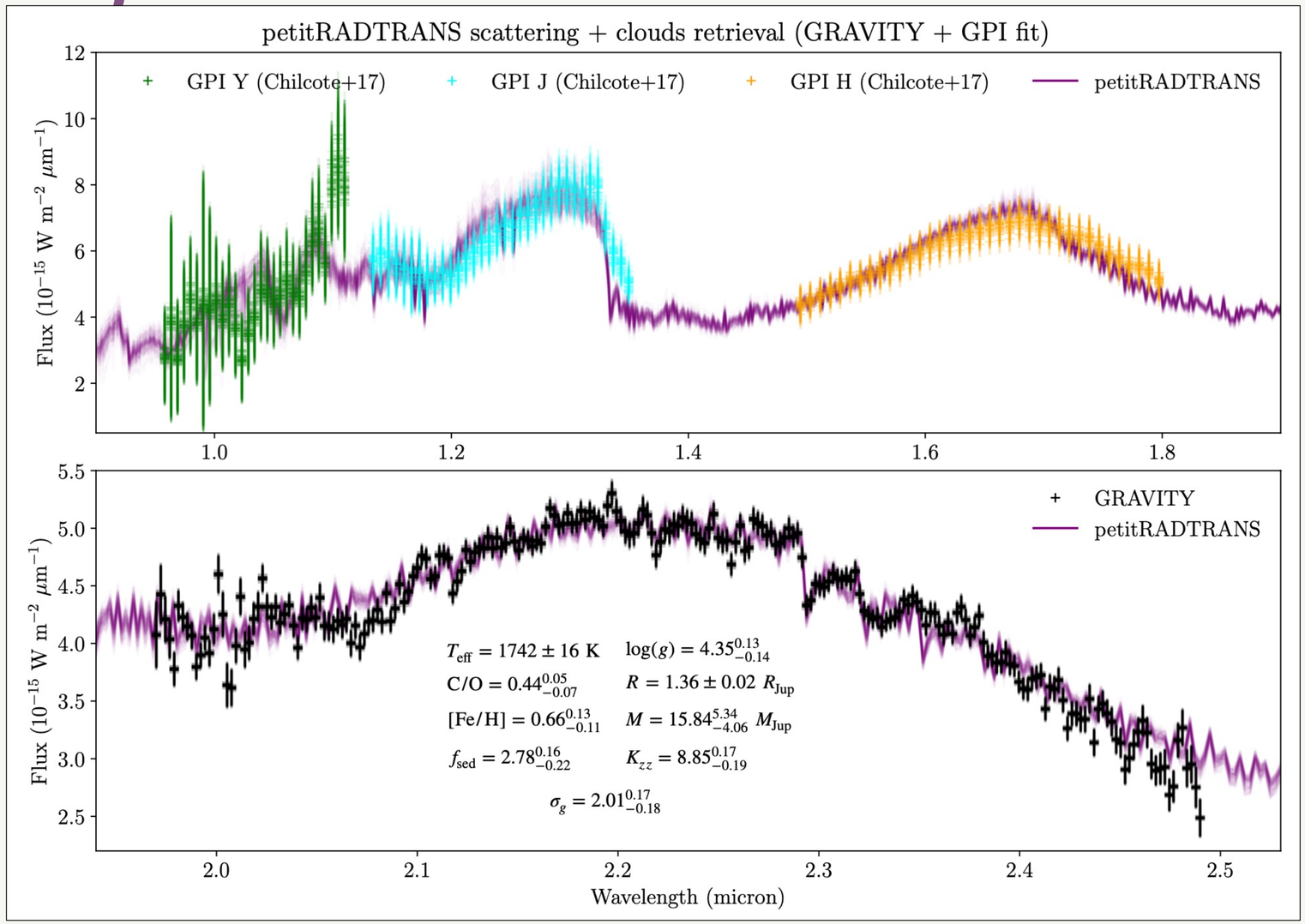
Oberg et al. 2011 Picture


Few examples …


β Pictoris
HIP 65426
AB Pic
HR 8799

β Pictoris b

GRAVITY Collaboration: M. Nowak et al. 2020



Parameter	Value
C/O	0.44
Distance	11 au
T_{eff}	1700 K
$\log(g)$	4.3 dex
ecc	0.15

β Pictoris b

GRAVITY Collaboration: M. Nowak et al. 2020

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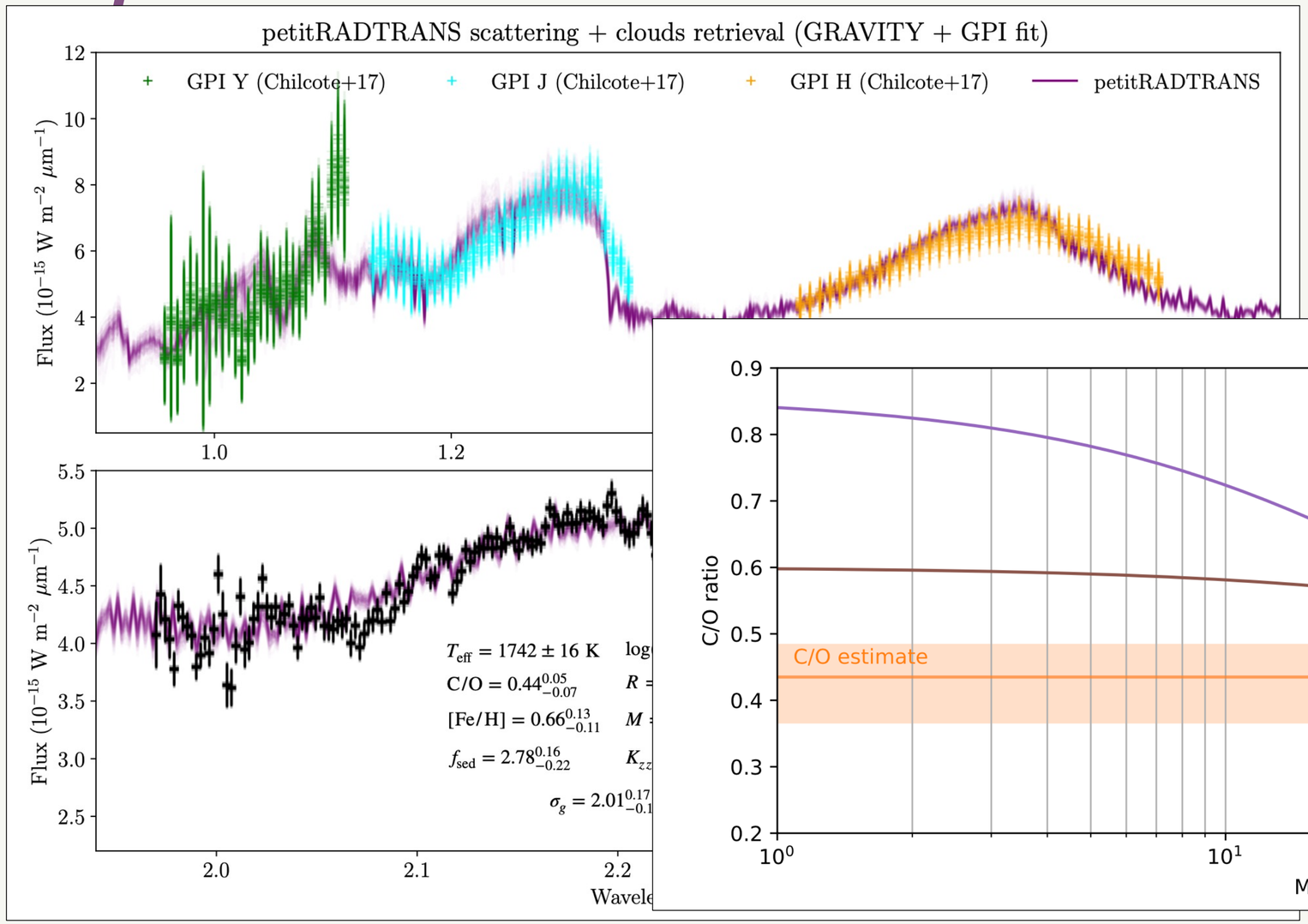
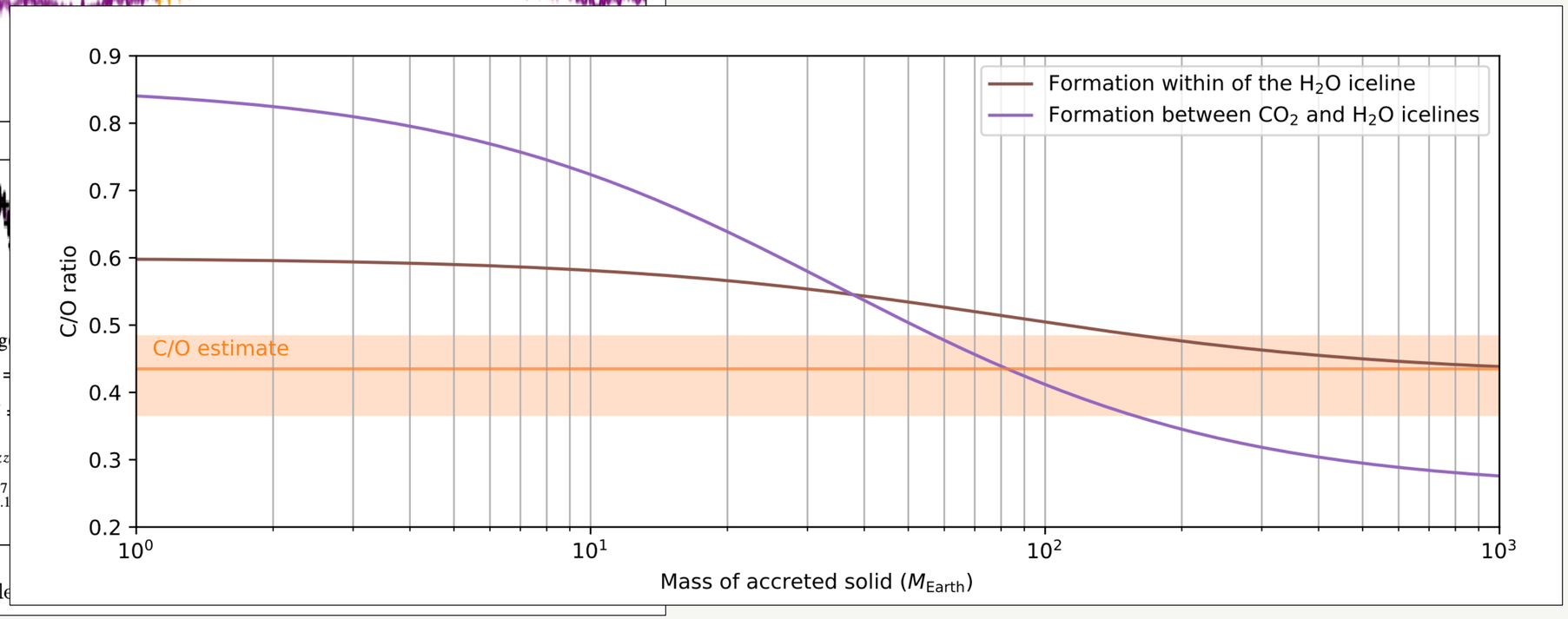
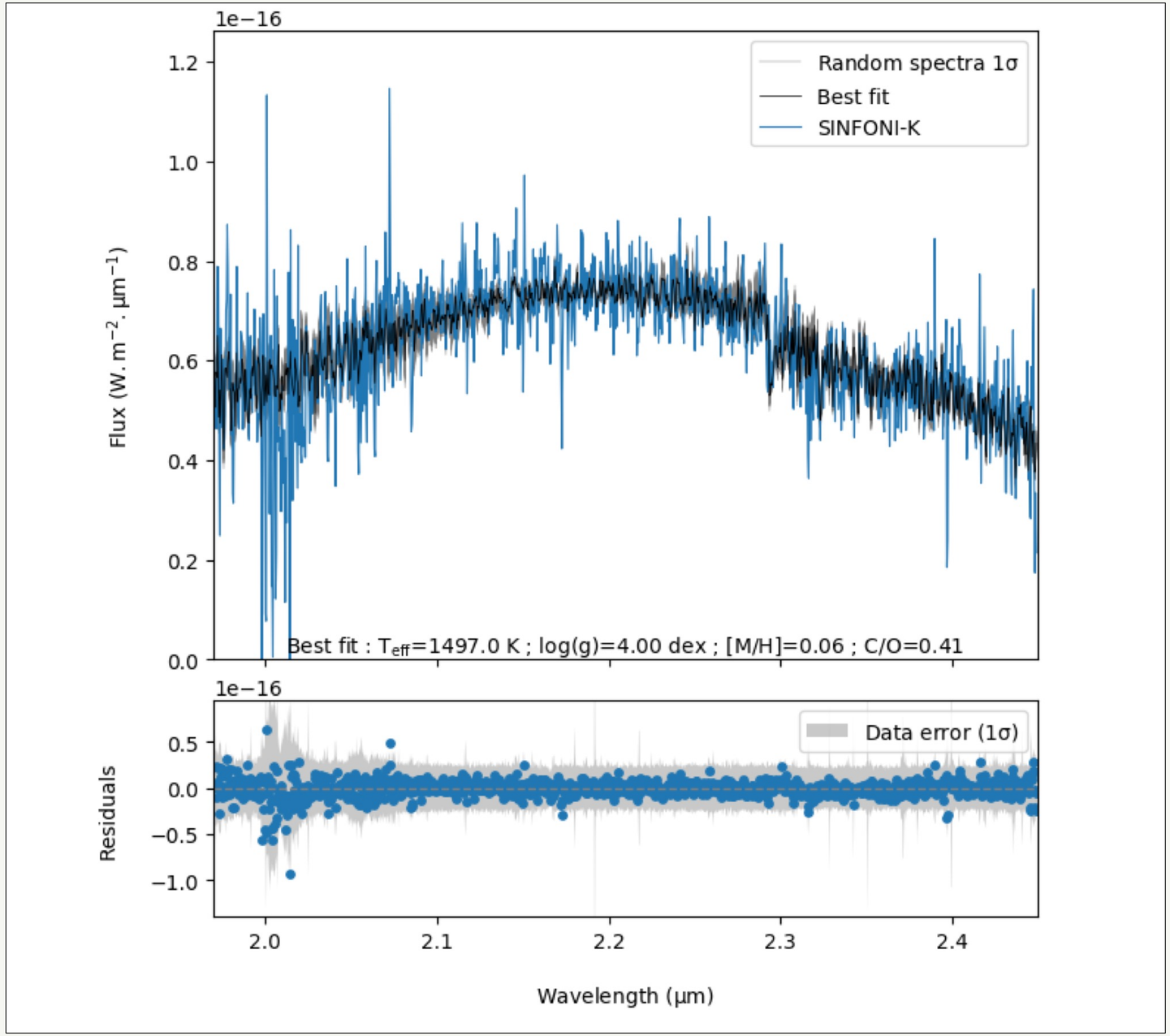




HIP 65426 b

Parameter	Value
C/O	< 0.55
Distance	92 AU
T_{eff}	1560 K
$\log(g)$	4.4 dex

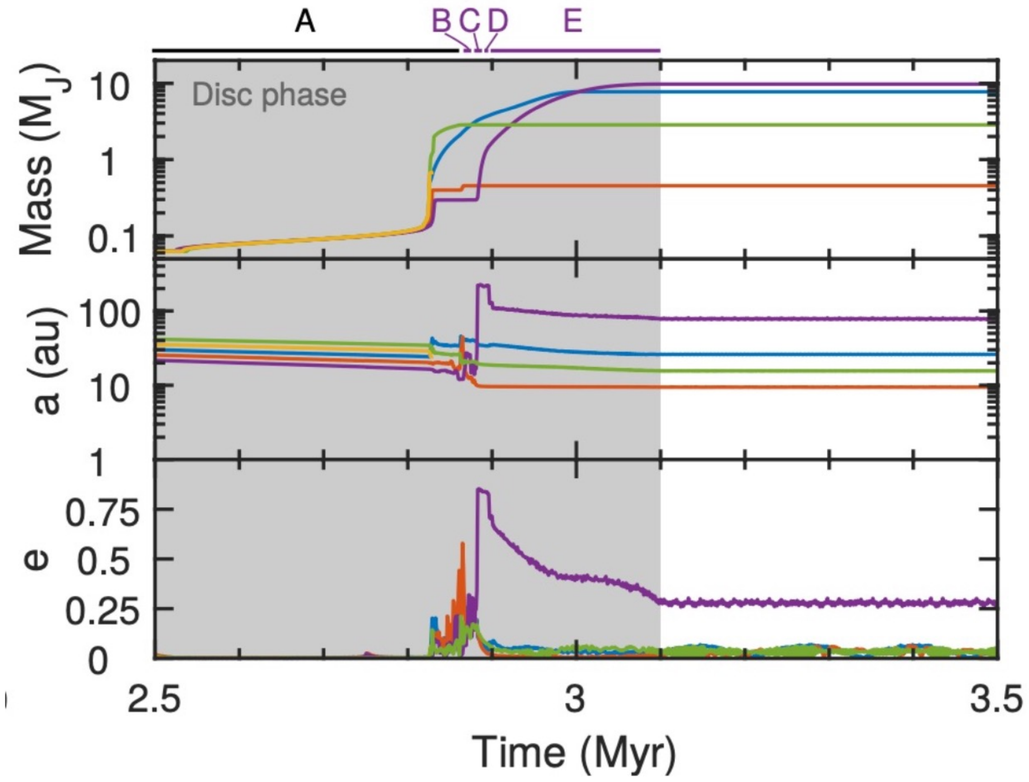
S. Petrus et al. 2020



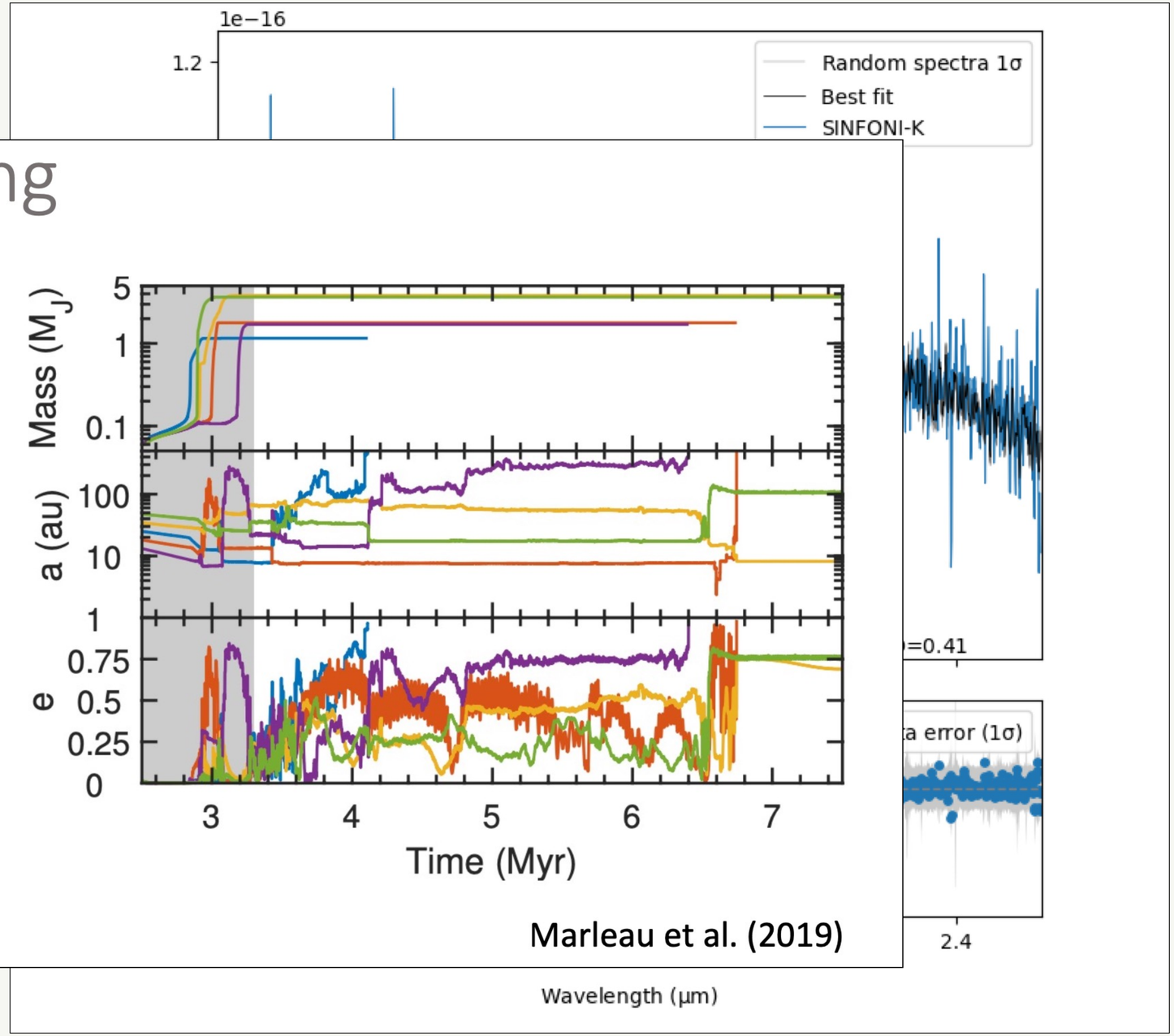
S. Petrus et al. 2020

HIP 65426 b

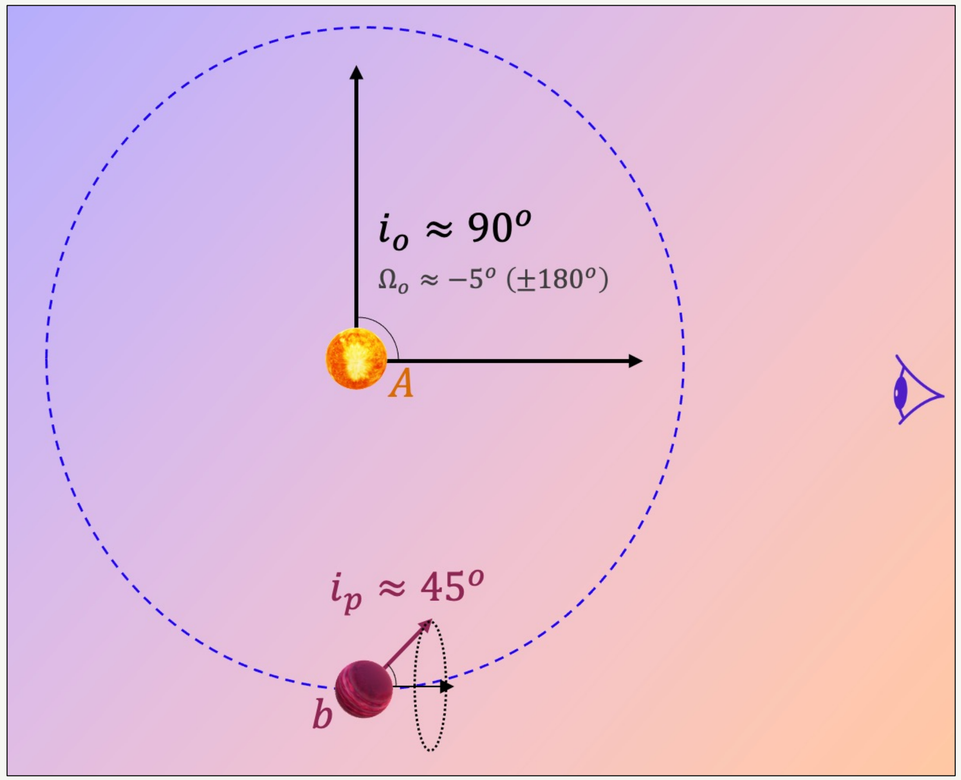
Planet-Planet Scattering

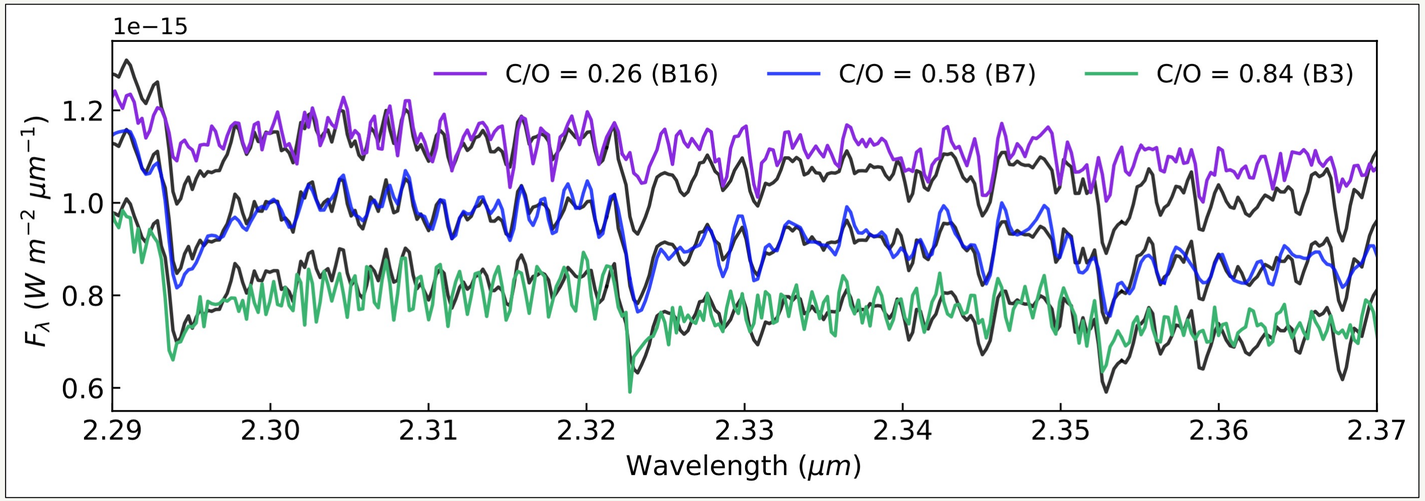


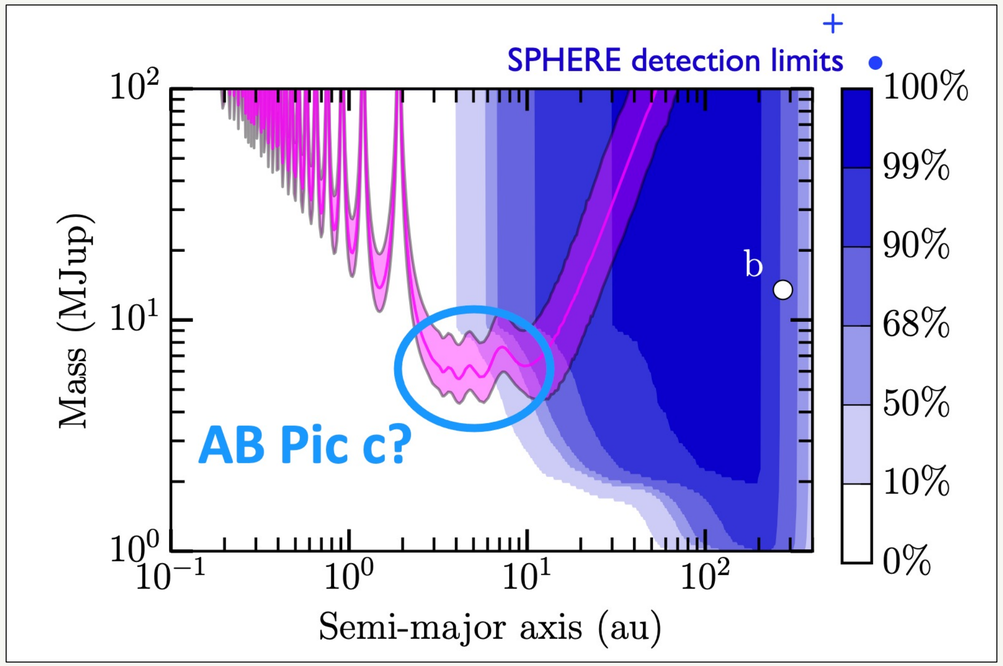
Marleau et al. (2019)



AB Pic b

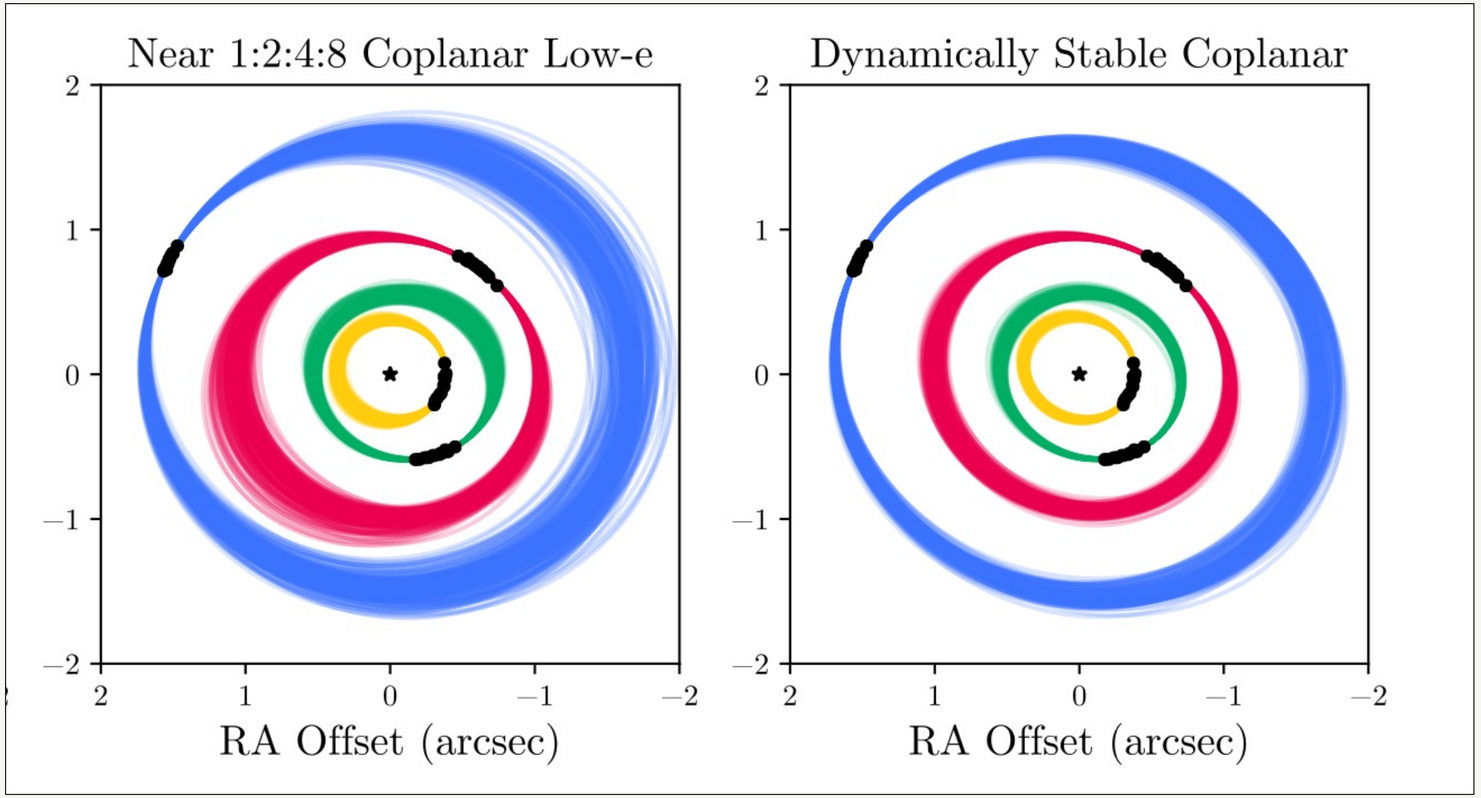

$i_o \approx 90^o$
$\Omega_o \approx -5^o\ (\pm 180^o)$
A
$i_p \approx 45^o$
b


1e−15
C/O = 0.26 (B16)
C/O = 0.58 (B7)
C/O = 0.84 (B3)
F_λ ($W\ m^{-2}\ \mu m^{-1}$)
1.2
1.0
0.8
0.6
2.29
2.30
2.31
2.32
2.33
2.34
2.35
2.36
2.37
Wavelength (μm)


SPHERE detection limits
Mass (MJup)
10^2
10^1
10^0
10^{-1}
10^0
10^1
10^2
Semi-major axis (au)
b
AB Pic c?
100%
99%
90%
68%
50%
10%
0%

HR 8799 bcde

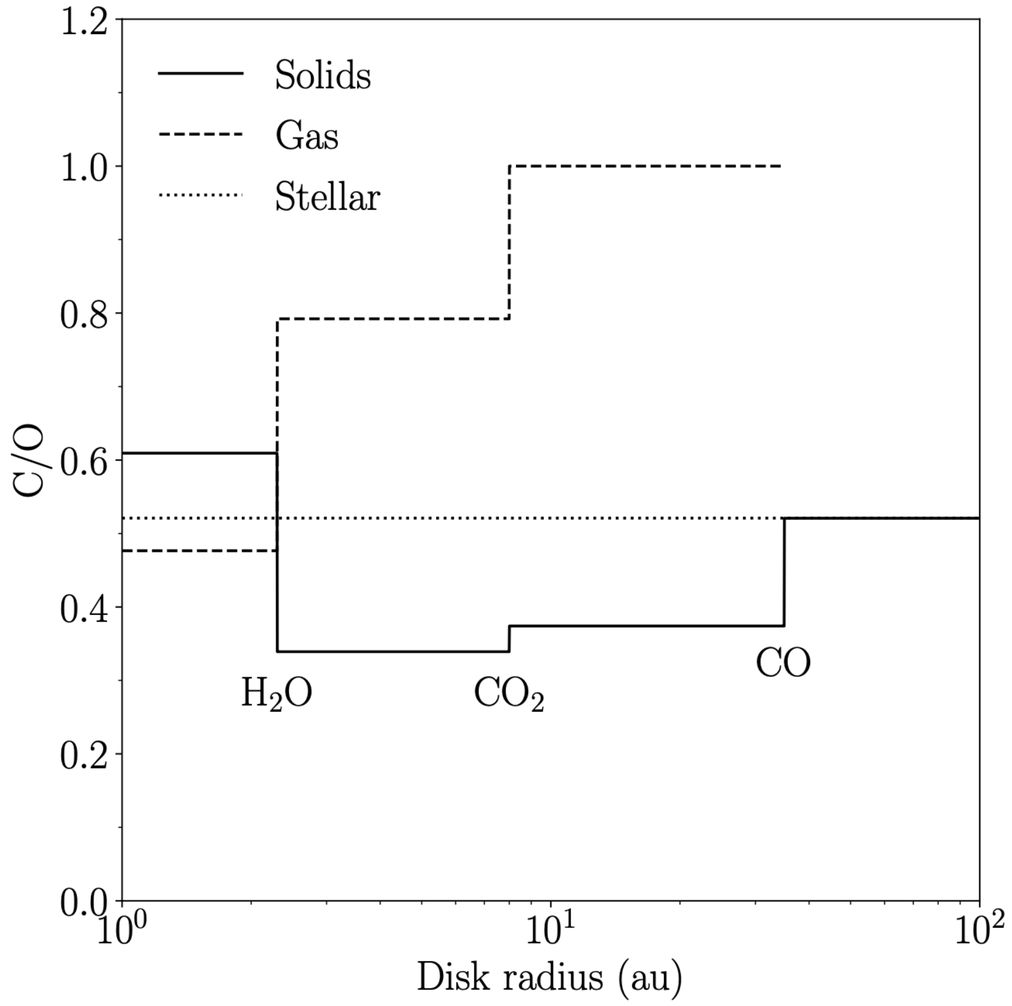
Wang et al. 2018



Parameter	b	c	e
C/O	0.61	0.65	0.6
Distance	69.5 au	37.6 au	15.3 au
$Mass$	5.8 M_{Jup}	7.2 M_{Jup}	7.2 M_{Jup}
[M/H]	-	-	0.48

Time & Evolution

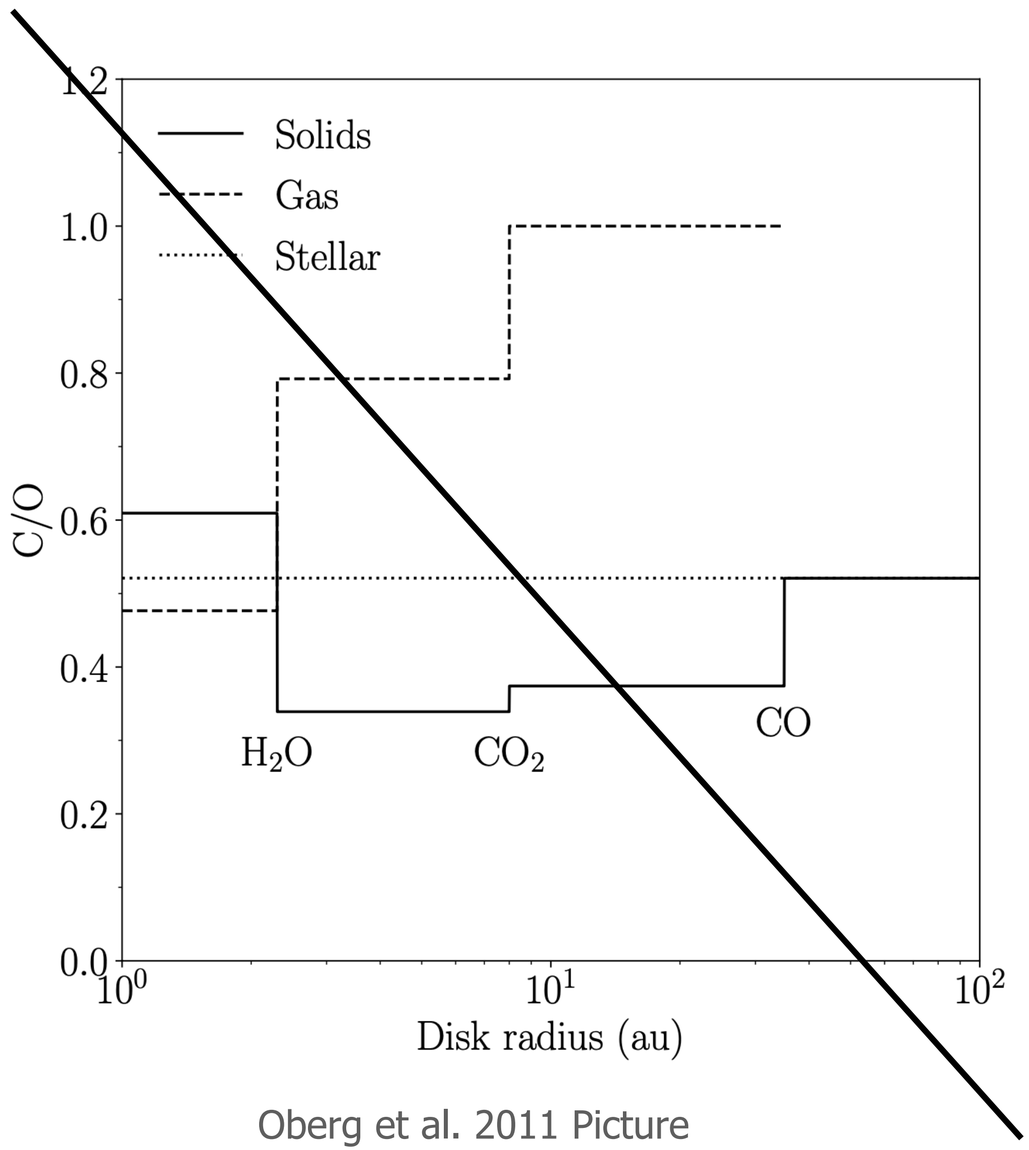
Mollière et al. 2022



Oberg et al. 2011 Picture

Time & Evolution

Mollière et al. 2022



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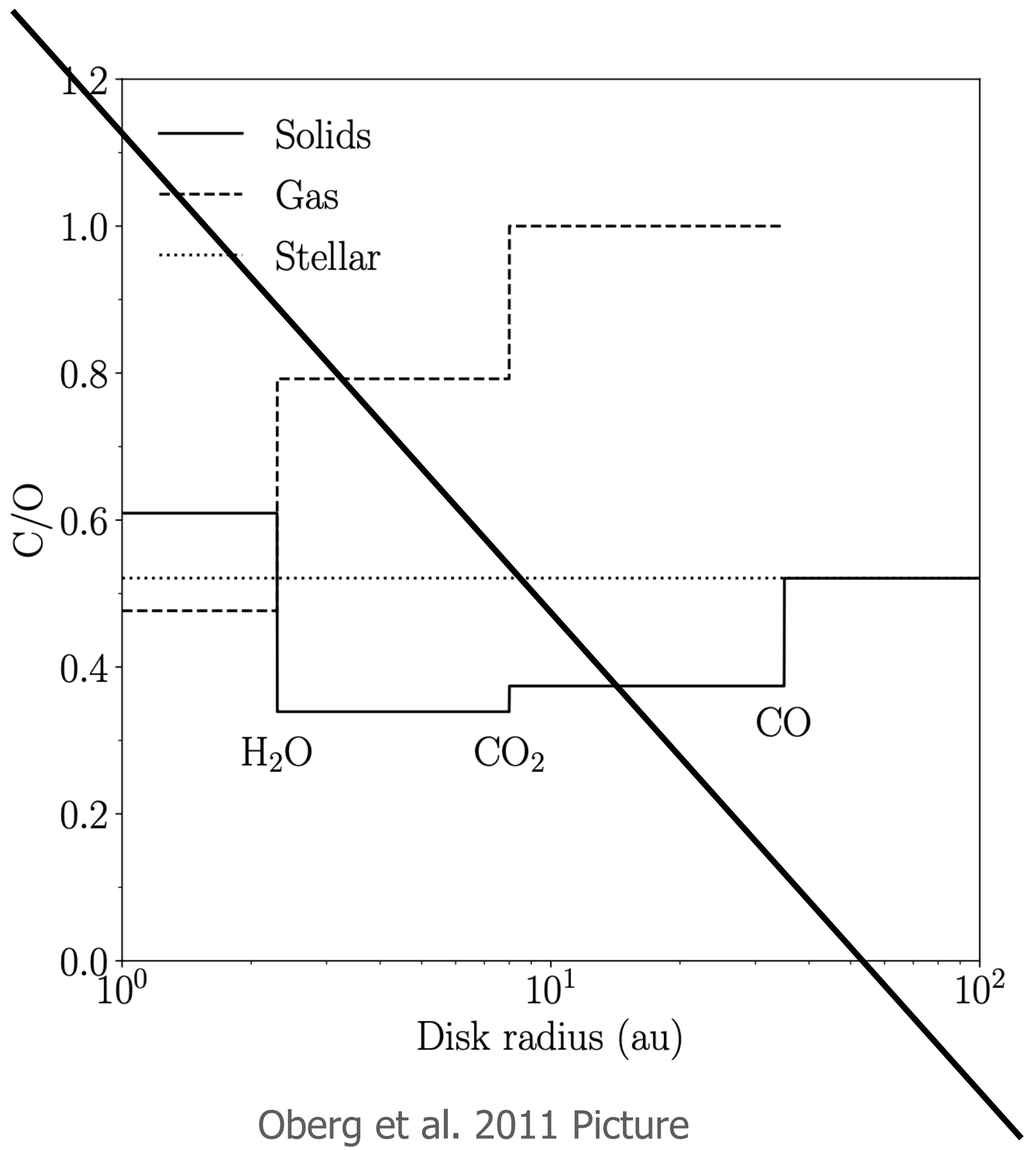
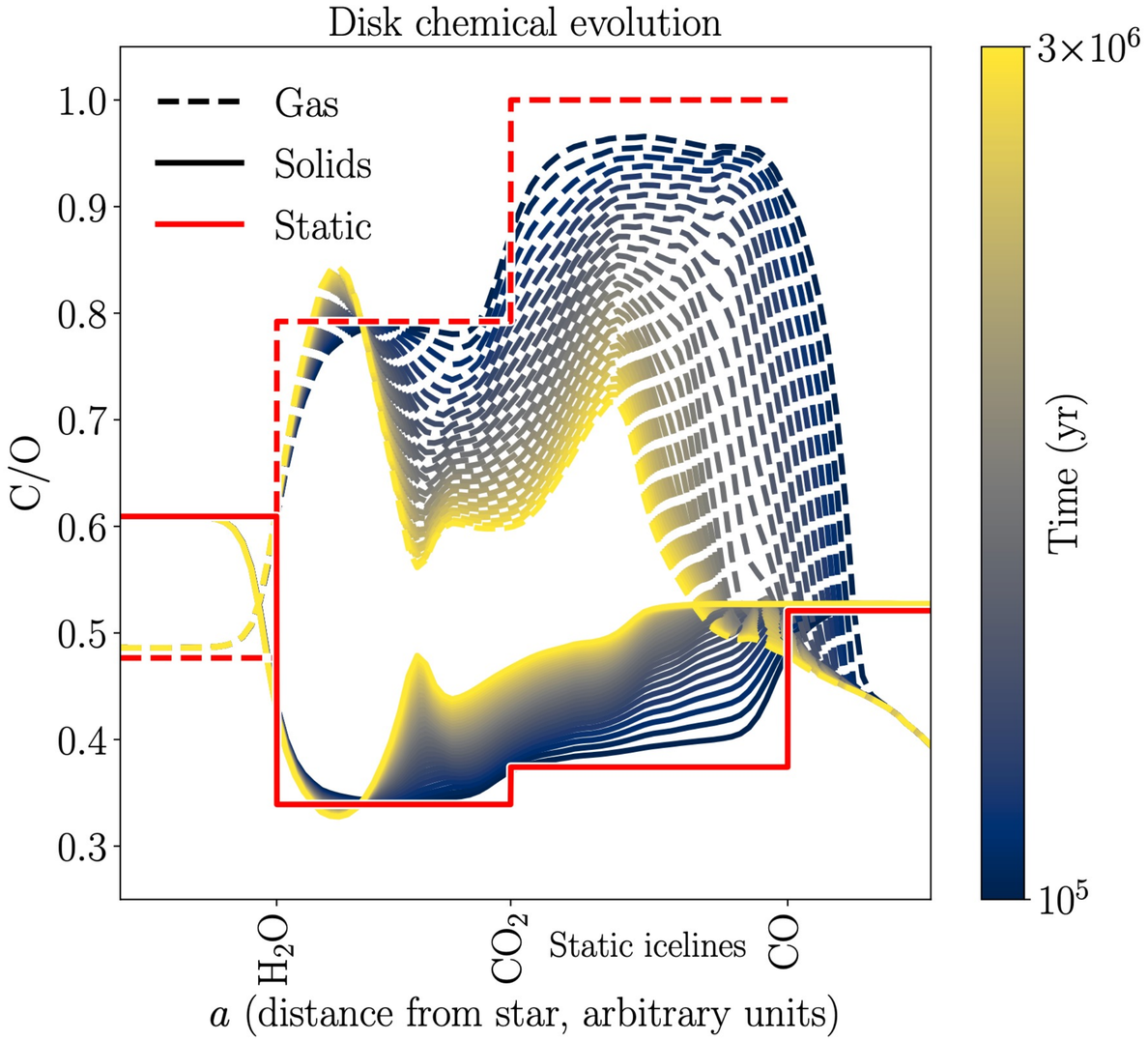
Time & Evolution

Mollière et al. 2022

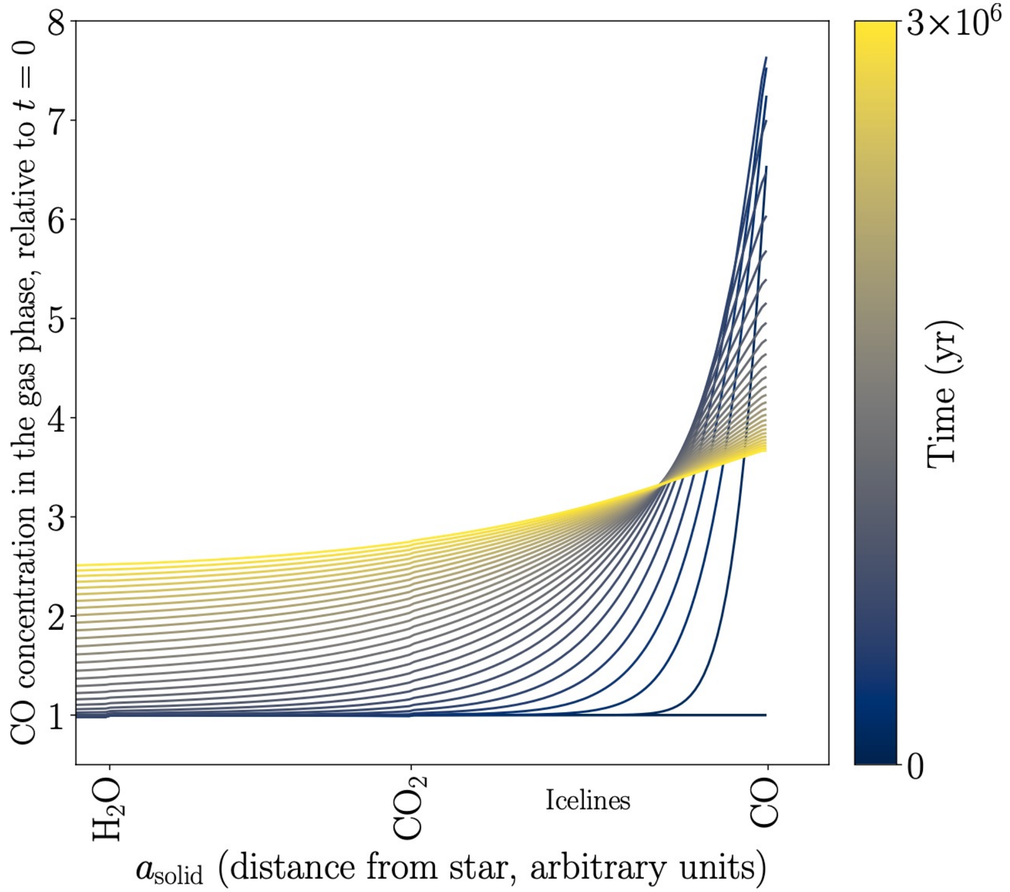


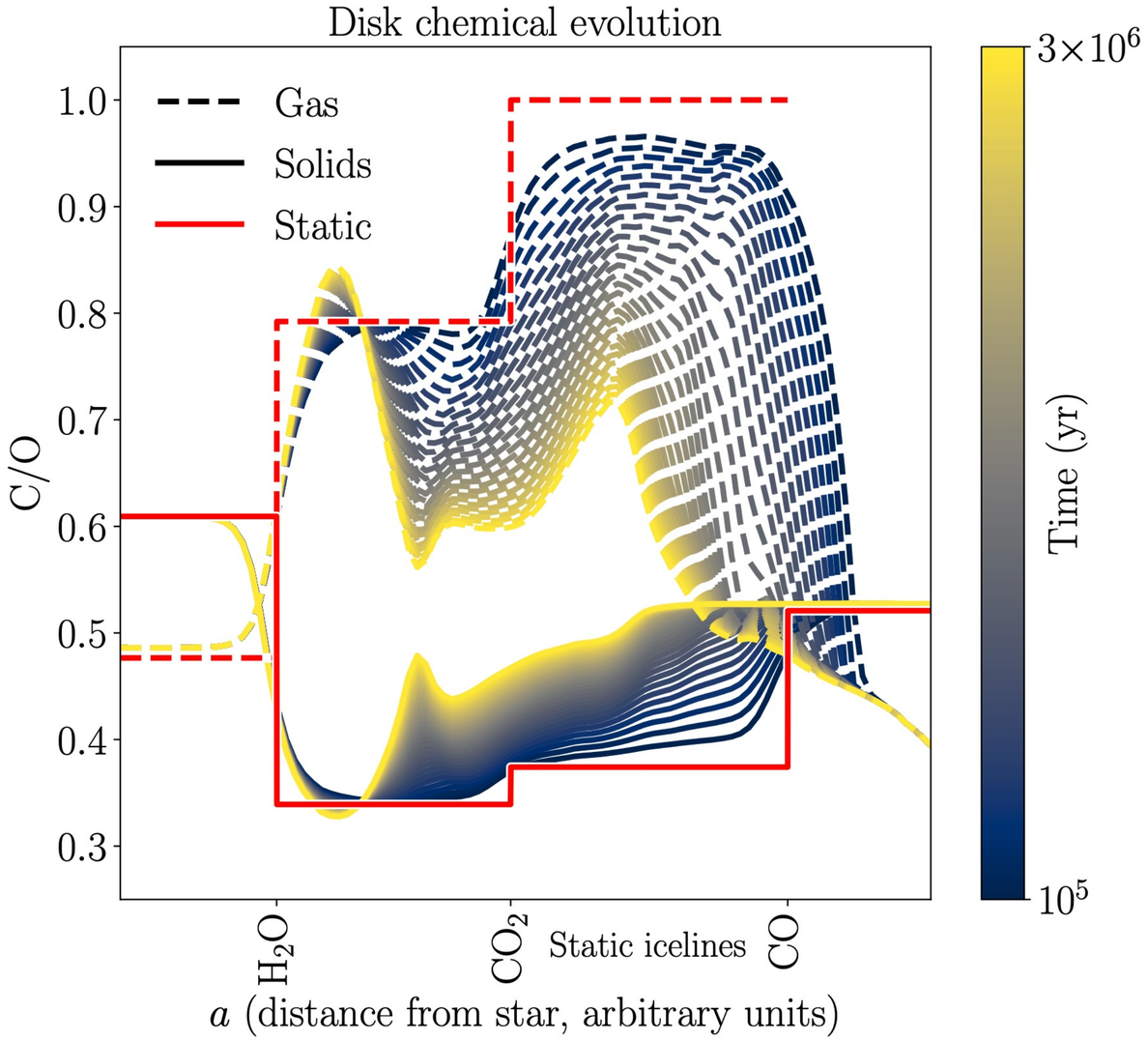
Oberg et al. 2011 Picture



Time & Evolution

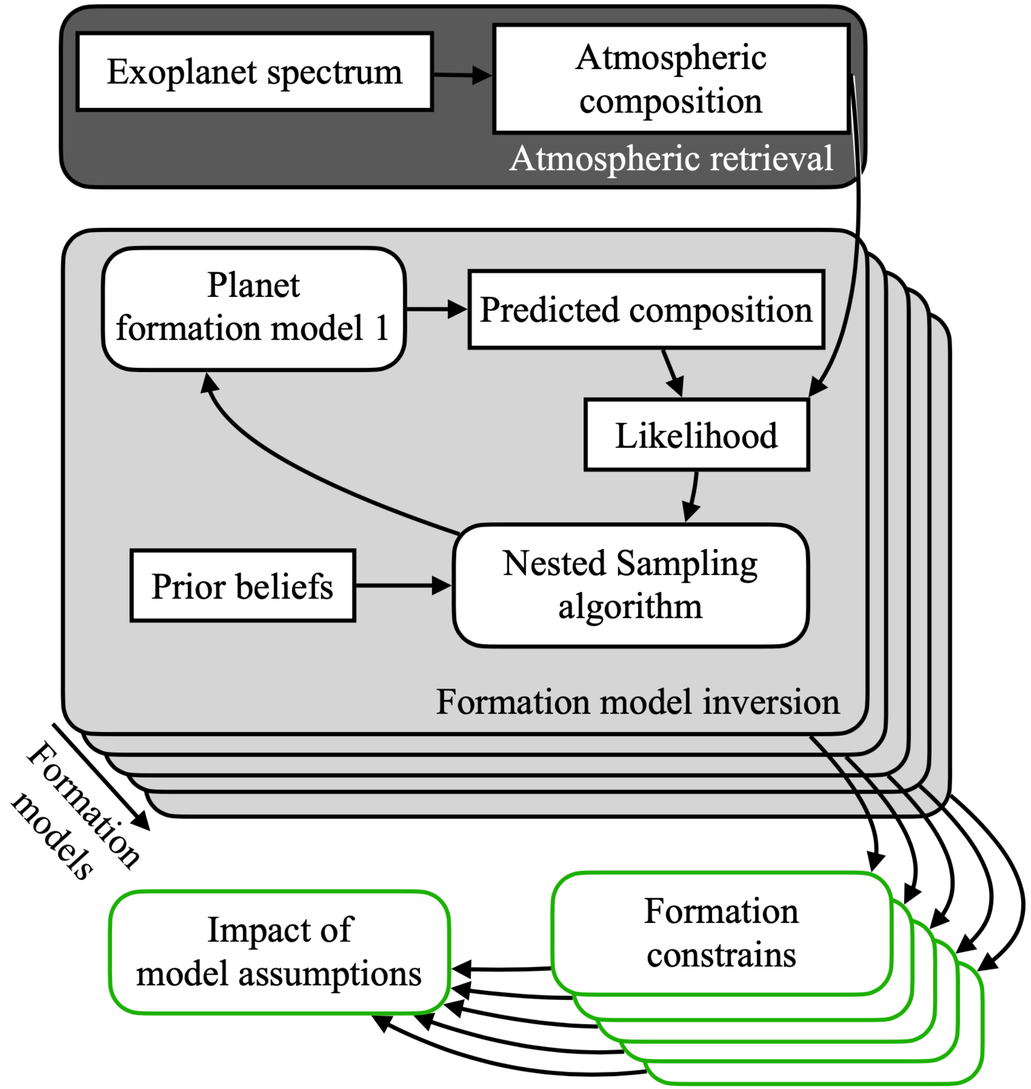
Mollière et al. 2022





Time & Evolution

Mollière et al. 2022



Composition

$$\mathcal{C} = (\mathrm{O/H}, \mathrm{C/H}, \mathrm{N/H}, \mathrm{Fe/H}, \mathrm{Si/H}, \mathrm{P/H}, \mathrm{S/H}, ...)$$

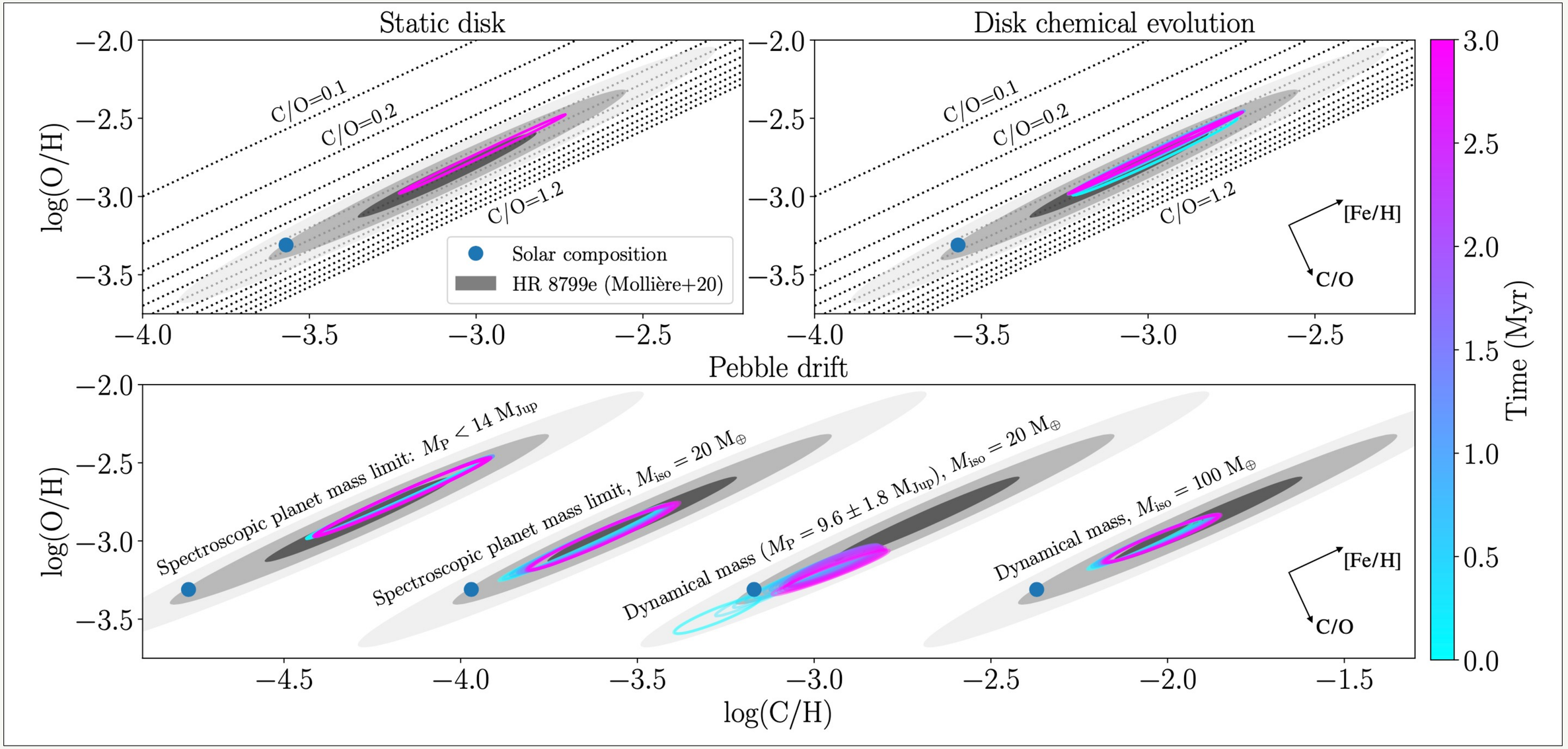
Formation parameters

$$P(\vartheta|\mathcal{C},\mathcal{M}) = \frac{P(\vartheta|\mathcal{M})P(\mathcal{C}|\vartheta,\mathcal{M})}{P(\mathcal{C}|\mathcal{M})}$$

Model

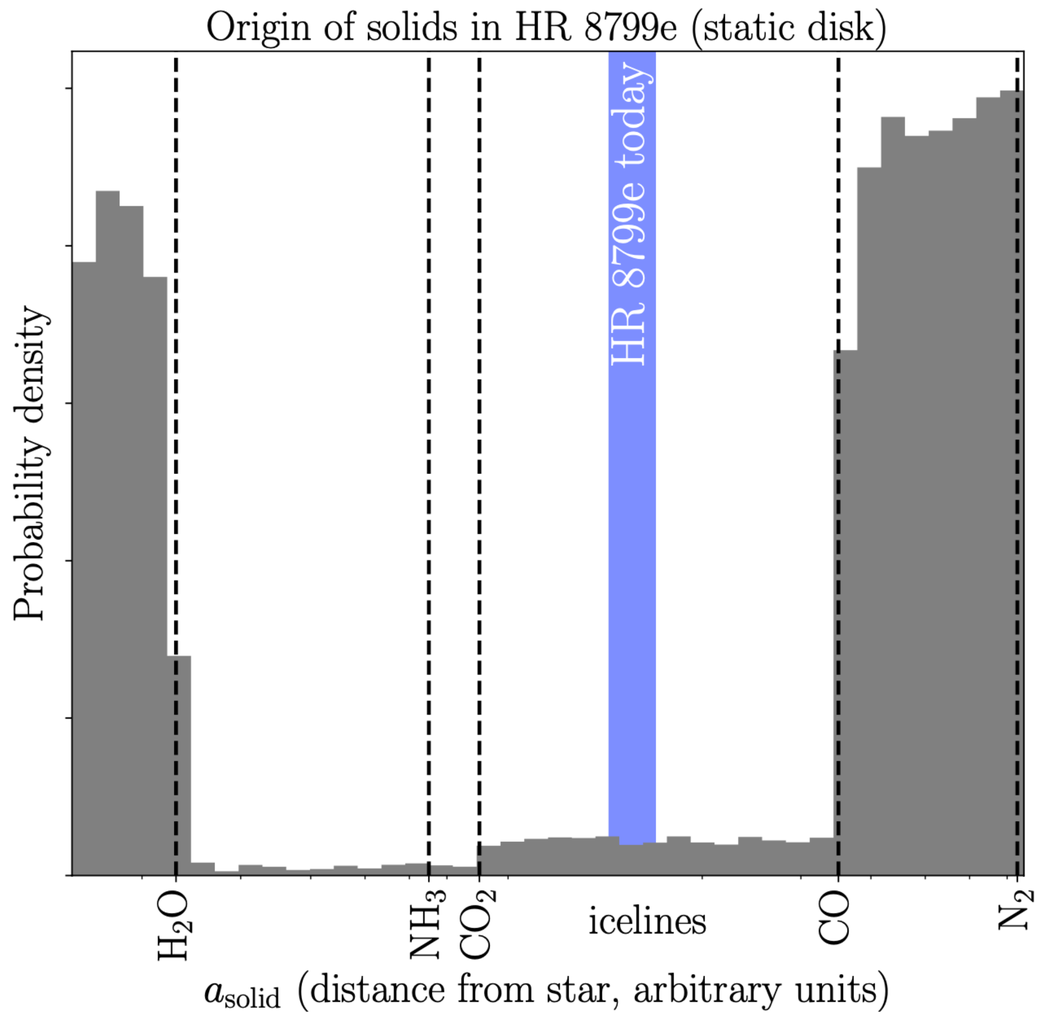
Mollière et al. 2022

HR 8799 e



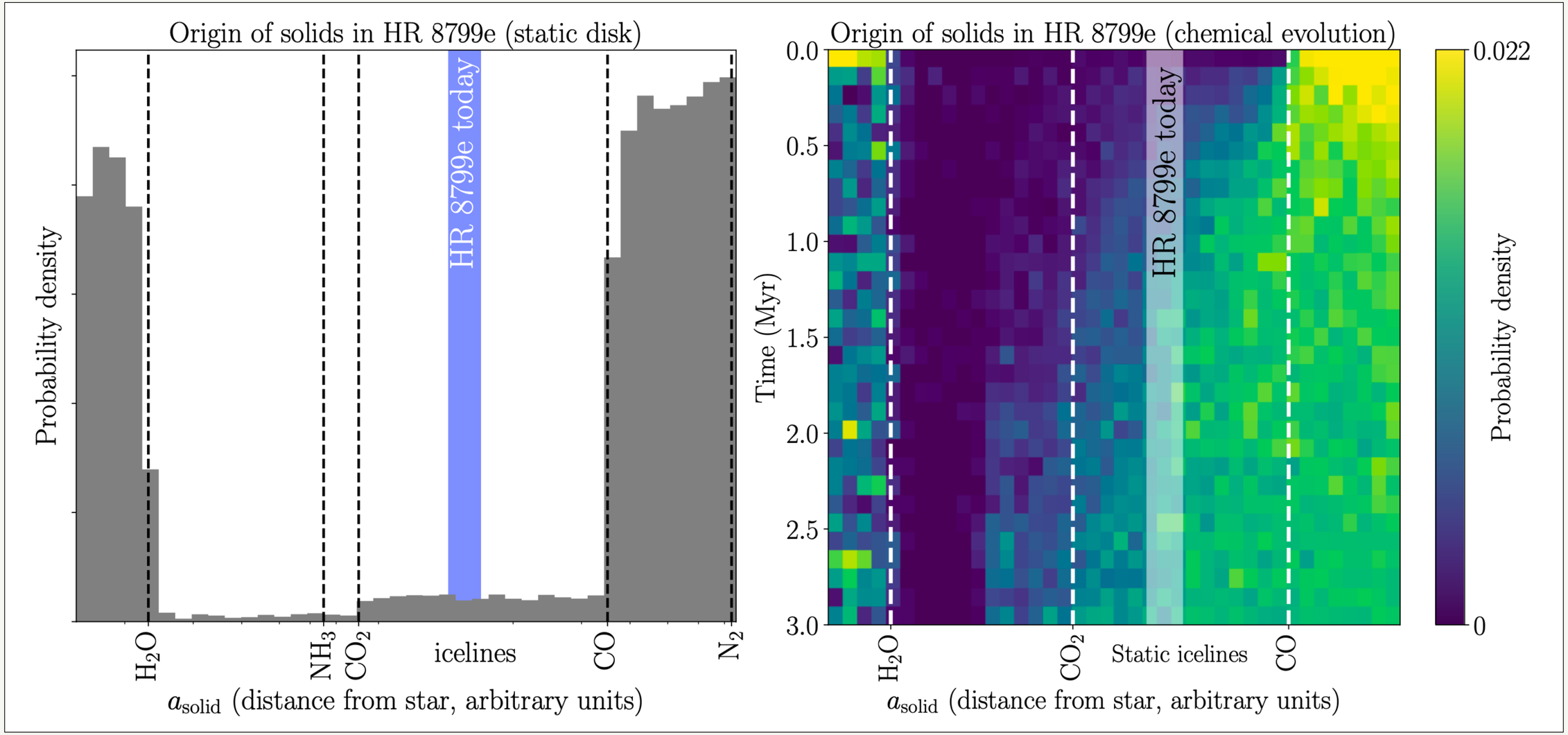
HR 8799 e

Mollière et al. 2022



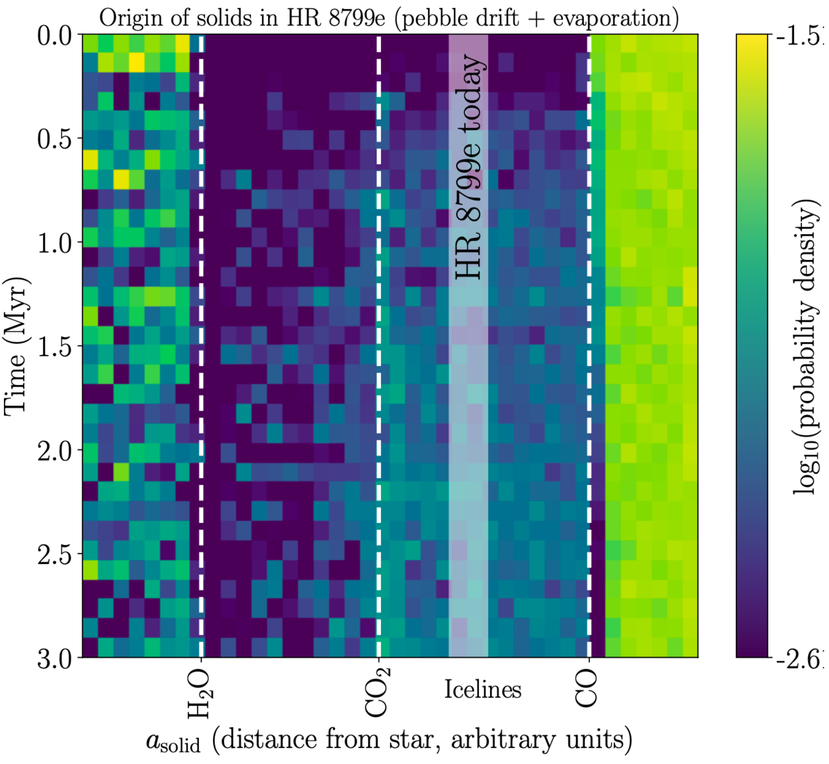
Mollière et al. 2022

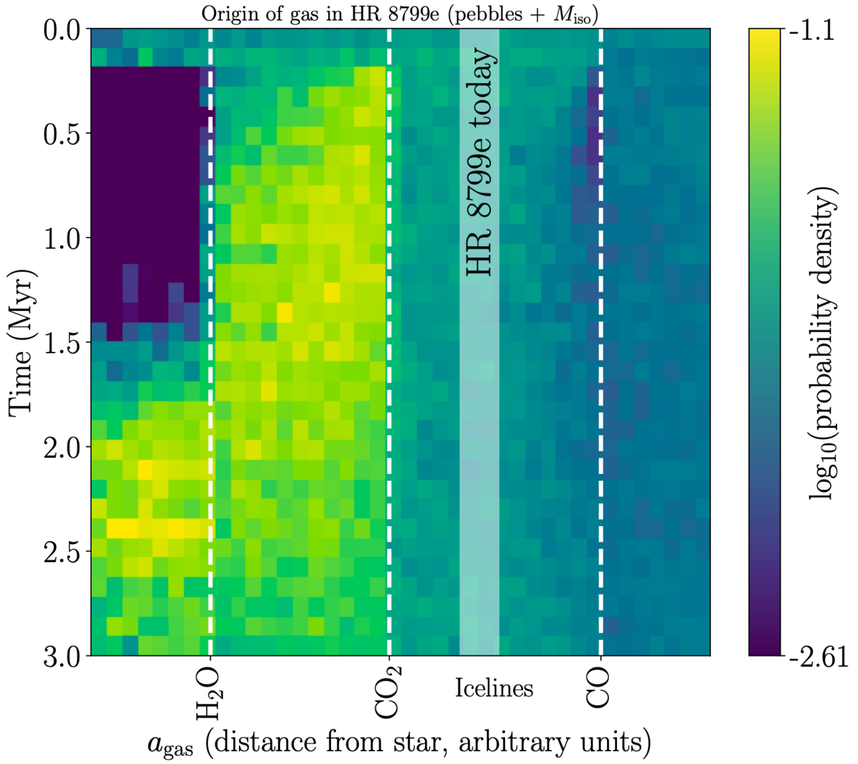
HR 8799 e

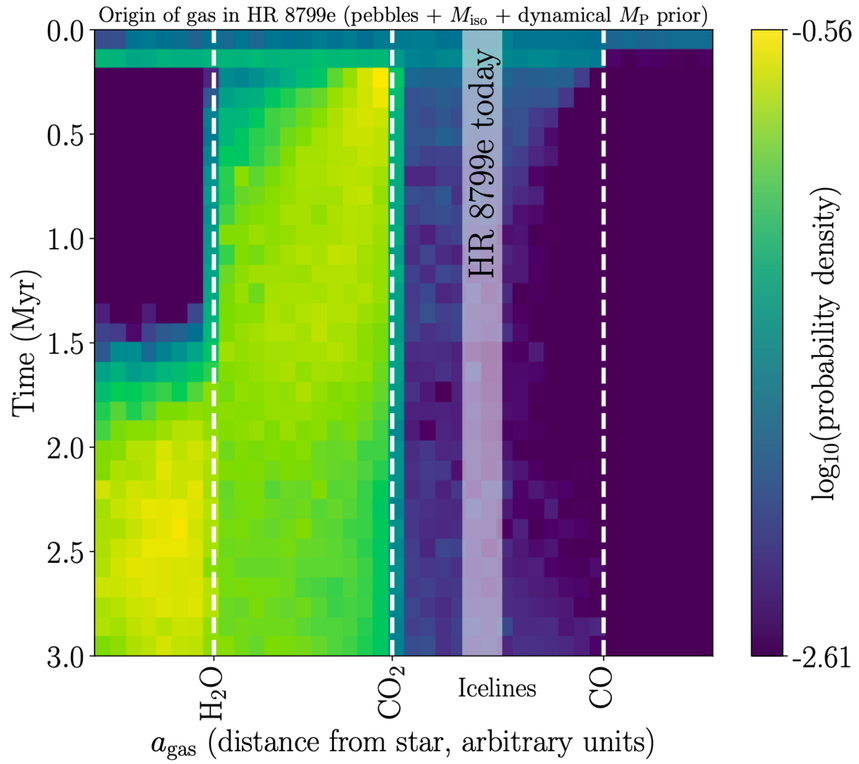


HR 8799 e

Mollière et al. 2022







Time & Evolution

Mollière et al. 2022

Disk composition and structure
Unknown disk elemental abundances
Available solid reservoir
Disk (thermal) structure
Planetary back-reaction on disk
Include pebble drift & evaporation at icelines

Planet bulk – atmosphere coupling
Metallicity gradient inside planet

Atmospheric evolution
Evaporation
Infall of comets / asteroids

Disk chemistry
Chemical evolution of disk
Inherited or 'reset' disk abundances
Cosmic ray ionization and stellar irradiation
Refratory carbon depletion in inner disk

Planet formation
Pebble and planetesimal accretion
3-d planet accretion
Planet migration
Leveraging full complexity of formation models
Planet formation by gravitational instability

Time & Evolution

Mollière et al. 2022

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Planet bulk – atmosphere co
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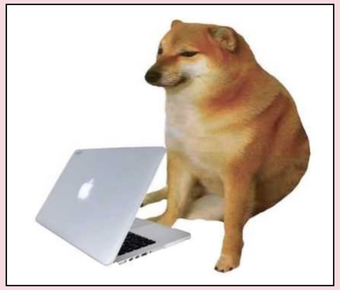
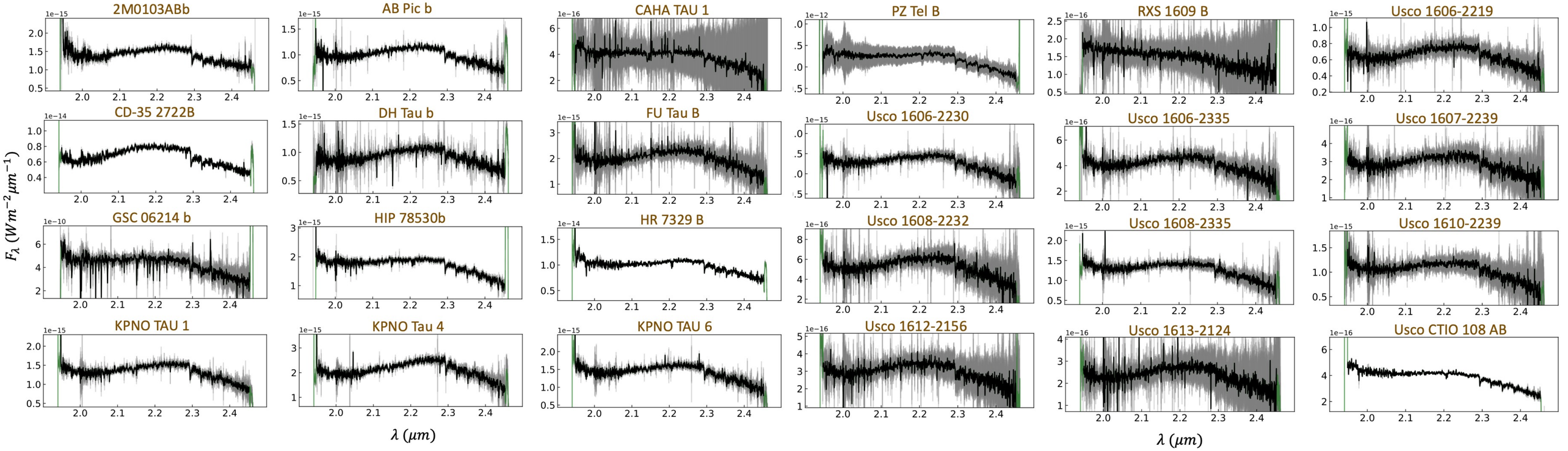
Atmospheres

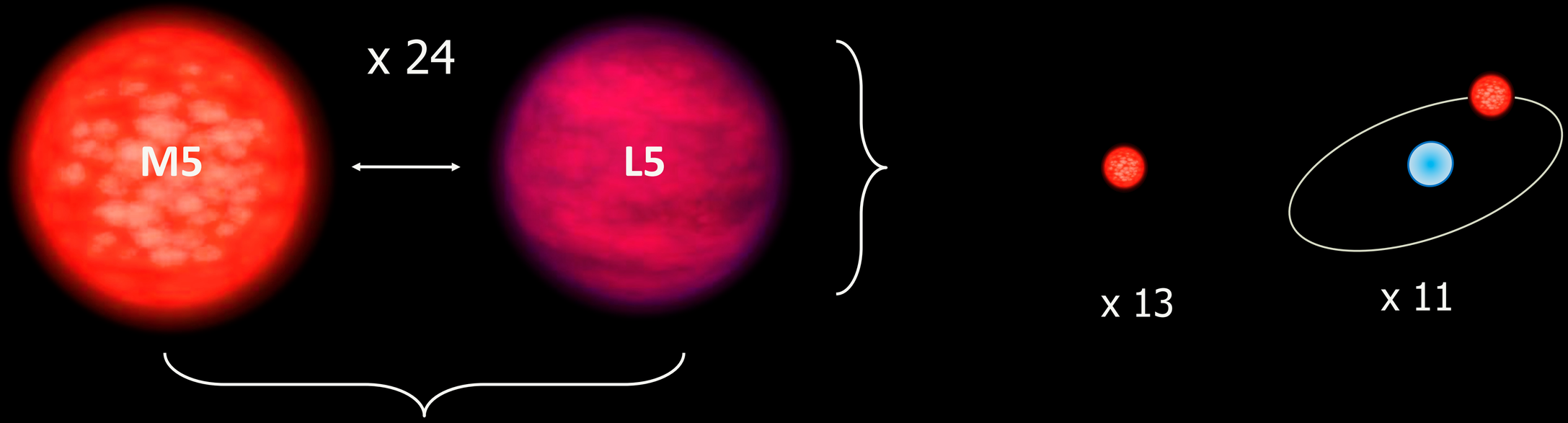


Formation Mechanisms


The SINFONI Library
& others…

The SINFONI Library





Ages: 1 - 30 Myr

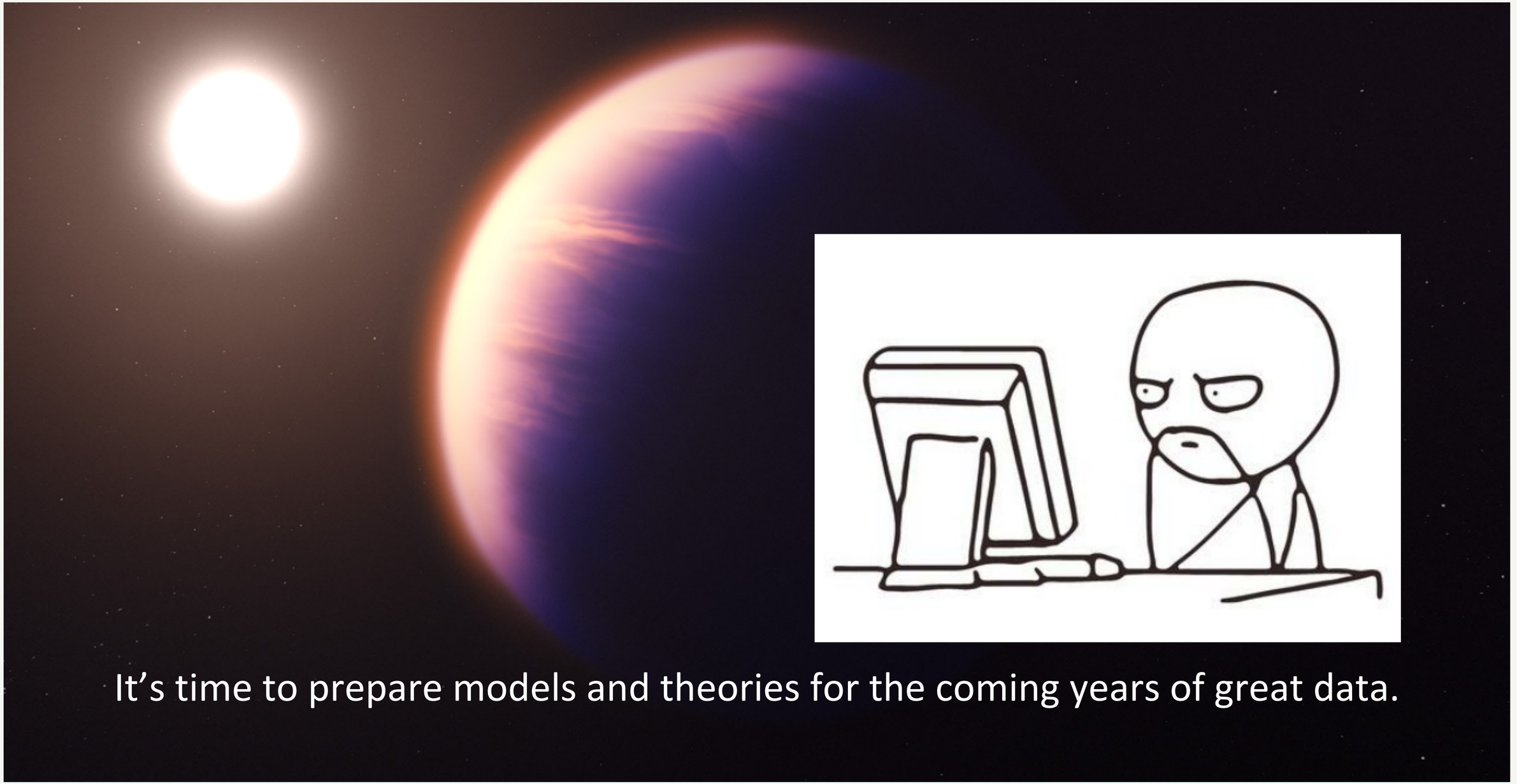
T_{eff} : 1500 - 2500 K

Masses: 5 - 70 M_{jup}

Distance: < 150 pc

AB Doradus, β Pic, Carina, Taurus,

Tucana & Upper Scorpius



It’s time to prepare models and theories for the coming years of great data.