Roman Coronagraph School Europe 2026
– Debris Disks –

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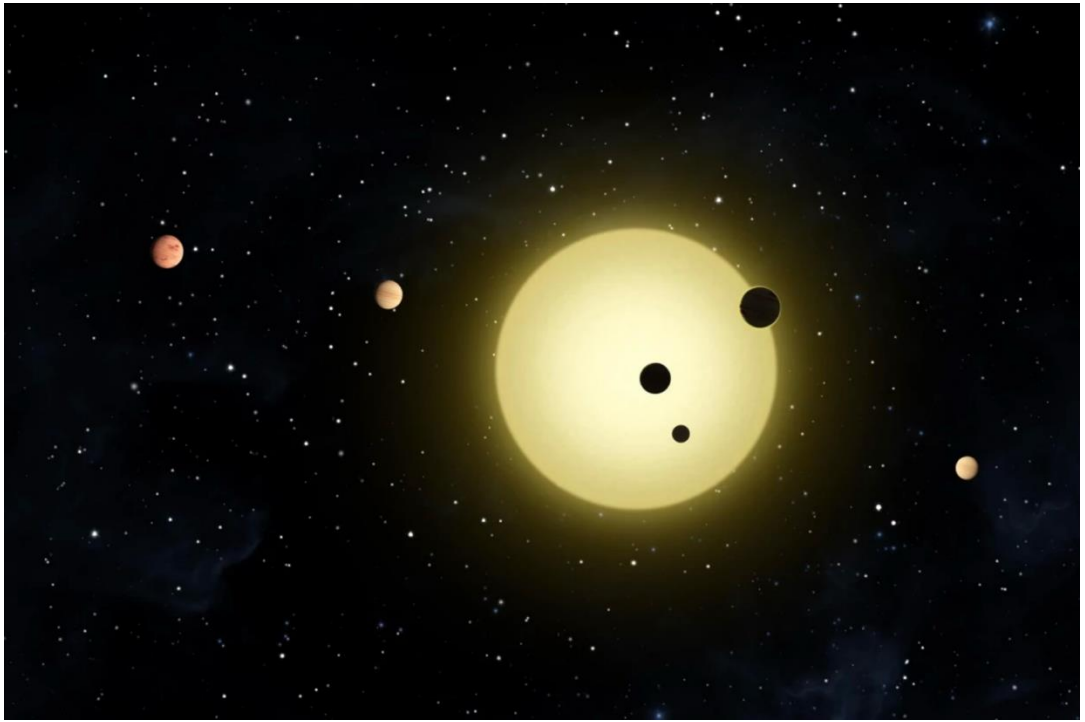
Session overview

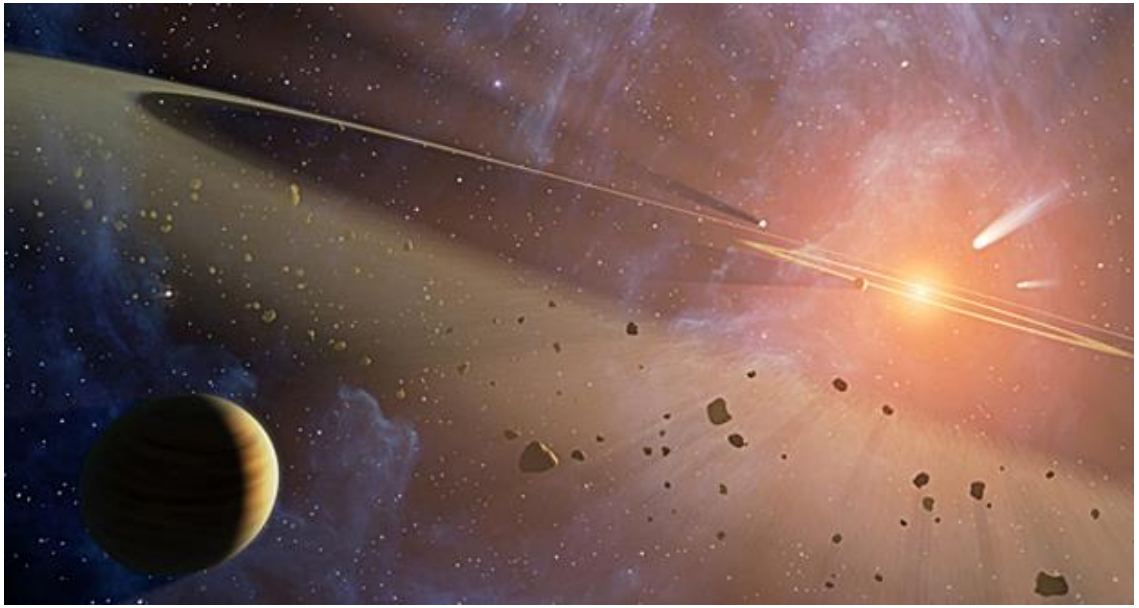
- Morning session (talk + google colab notebooks)
  - Debris disks theory (basics, history, components)
  - Observables (thermal, scattering)
  - Observing and analysis techniques (ADI, RDI)
  - Disks with Roman
- Afternoon session (hands-on)
  - Disk convolution with CorgiSim
  - Time series analysis

Disks basics



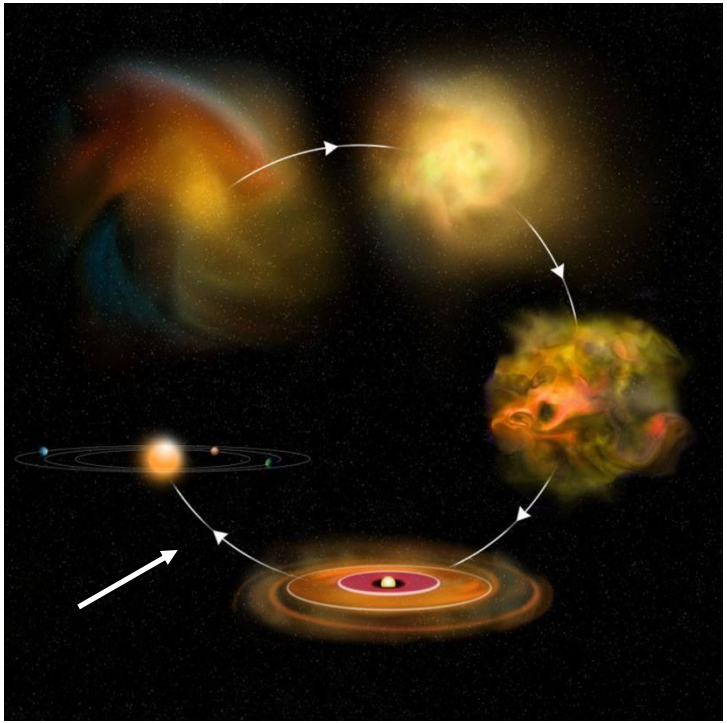
Planetary systems are not only formed by planets and star(s)!

Disks basics



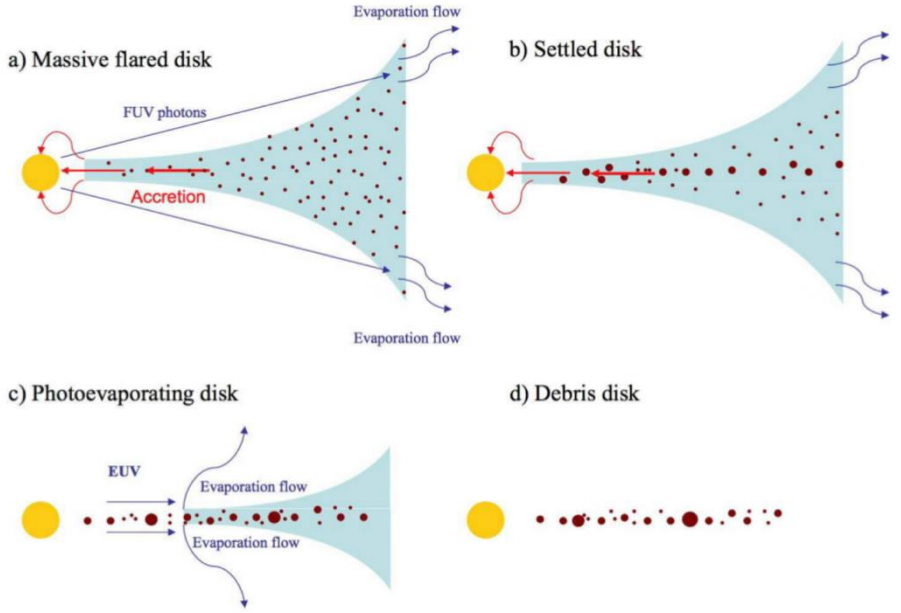
The dust and small bodies in them are relevant to their chemical and dynamical evolution.

Disks basics



- Planet formation process
  - Cloud collapse
  - Protoplanetary disk
  - Debris disk

Disks basics

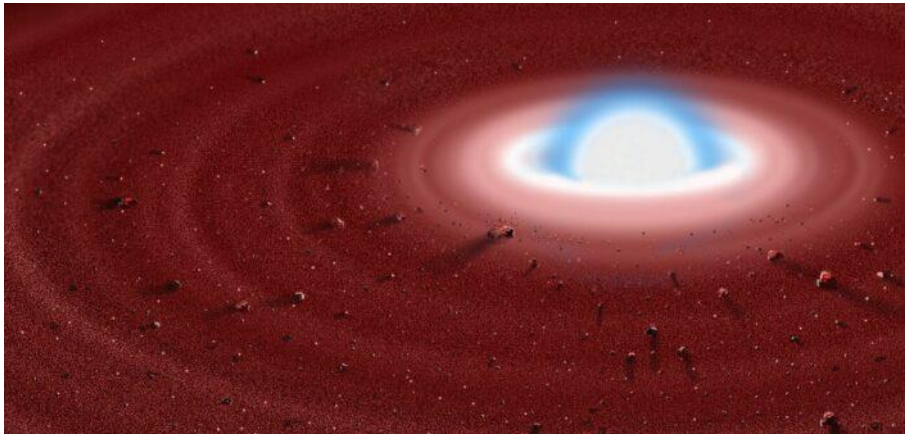


- Planet formation process
  - Cloud collapse
  - Protoplanetary disk
  - Debris disk
  - Mature planetary system
    - Kuiper & Asteroid belts

Disks basics

- Planet formation process
  - Cloud collapse
  - Protoplanetary disk
  - Debris disk
  - Mature planetary system
    - Kuiper & Asteroid belts
  - Zodiacal light -> signature of our own debris disk

Disks basics

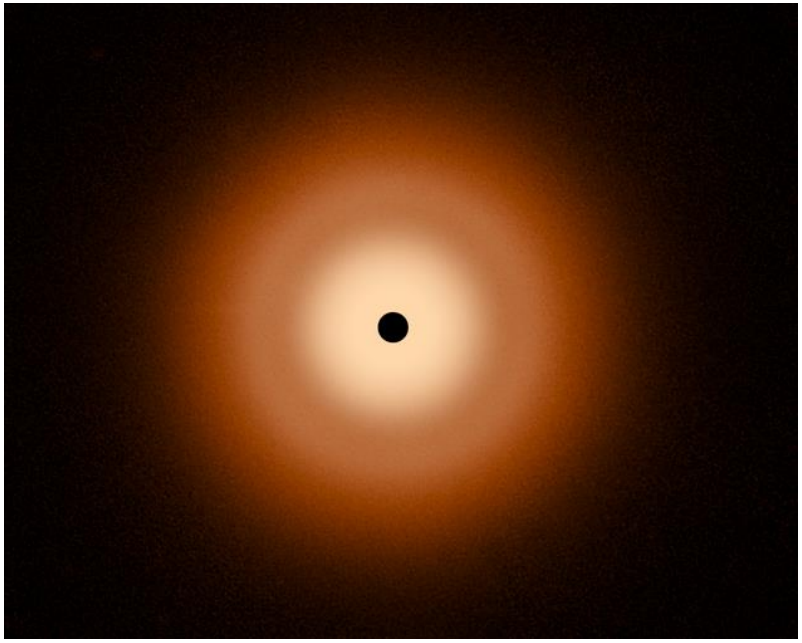


- Debris disks are not only a result of planet formation!

During stellar evolution, particularly at the last stages, the planetary system can suffer changes.

We can find debris disks around WD, meaning they originated from the *destruction* of a planetary system.

Disks basics

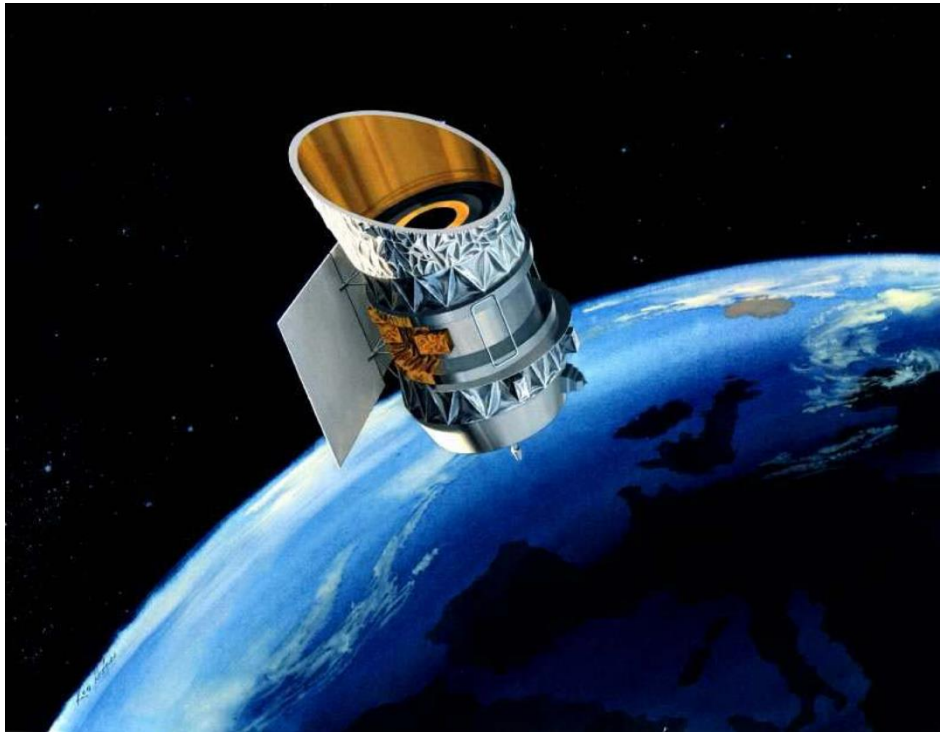


Vega disk with JWST

- So, debris disks are:
  - Made up of particles from km to µm
  - Not necessarily old *(depends on the environment and initial conditions)*
  - Optically thin ($\tau < 8 \times 10^{-3}$)
  - Low fractional luminosities:

    $f = L_{disk}/L_{*} < 10^{-3}$
  - Multiple morphologies possible

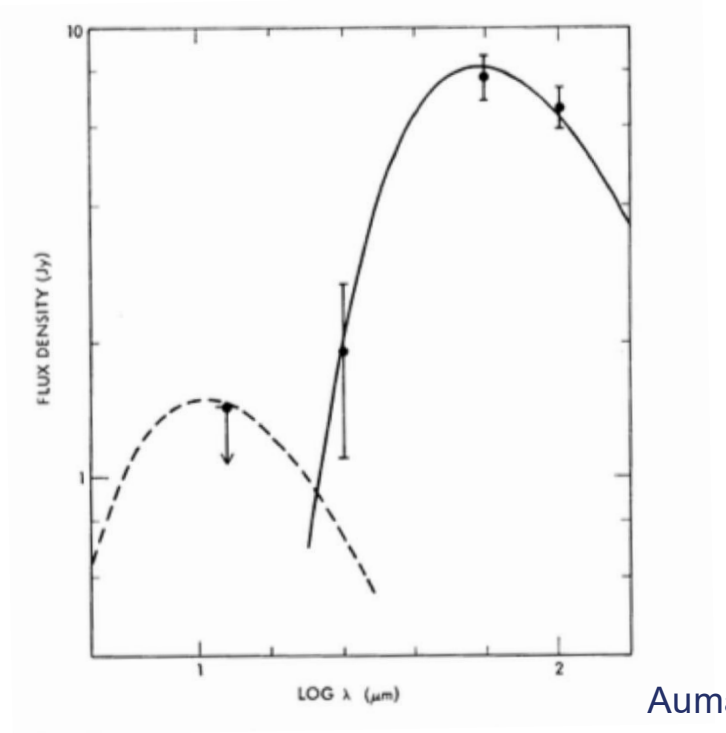
Disk history



IRAS – Infrared Astronomical Satellite

- 12, 25, 60 & 100 µm
- First survey telescope in IR

Disk history

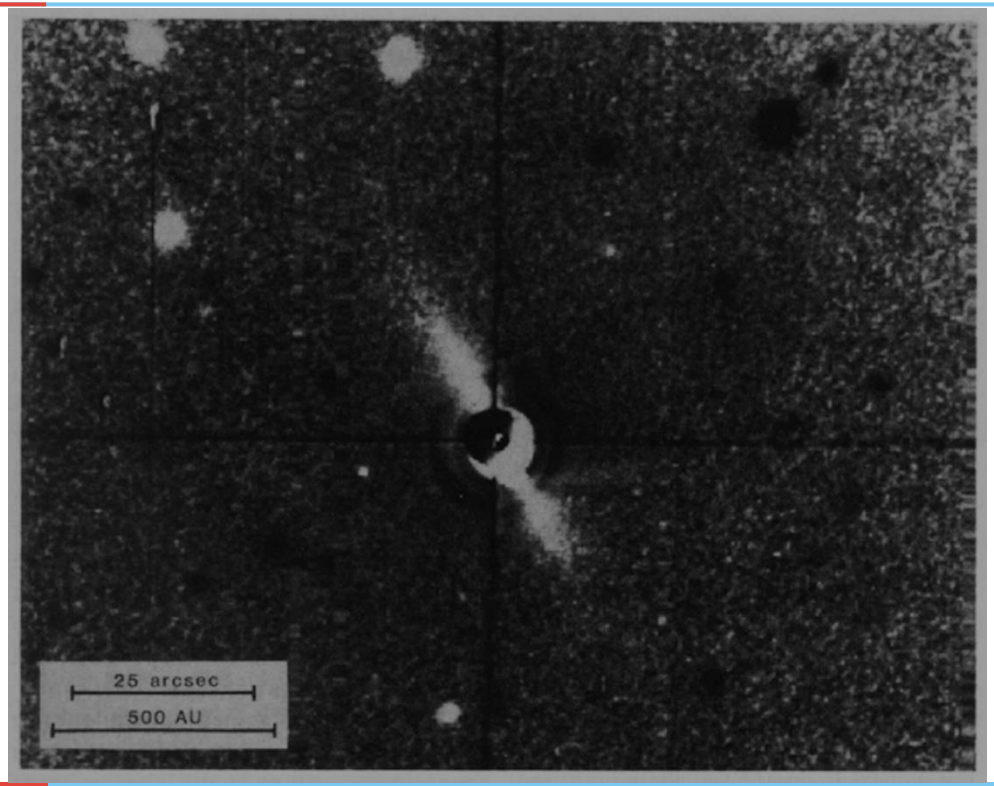


Aumann et al. 1984

IRAS – Infrared Astronomical Satellite

- 12, 25, 60 & 100 μm
- First survey telescope in IR
- First detection of IR excess around a star

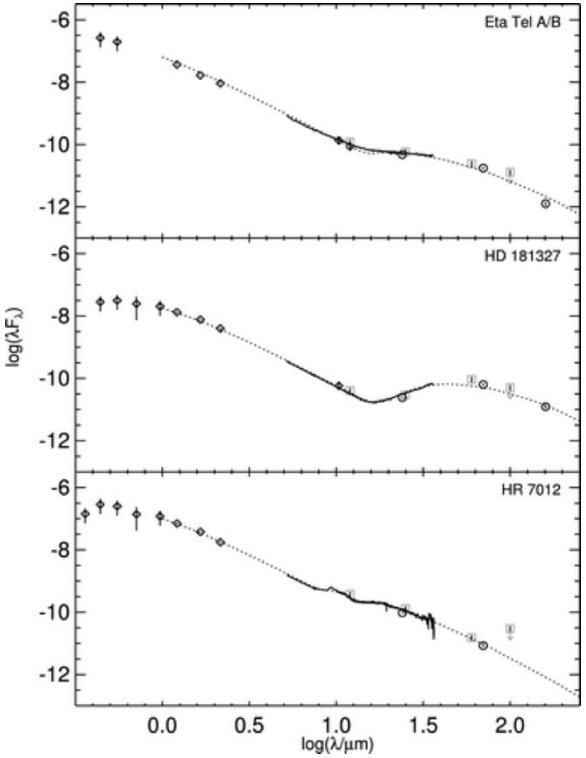
Disk history



Triggered the first high contrast imaging observations of a debris disk: **β Pic**

Smith & Terrile et al. 1984

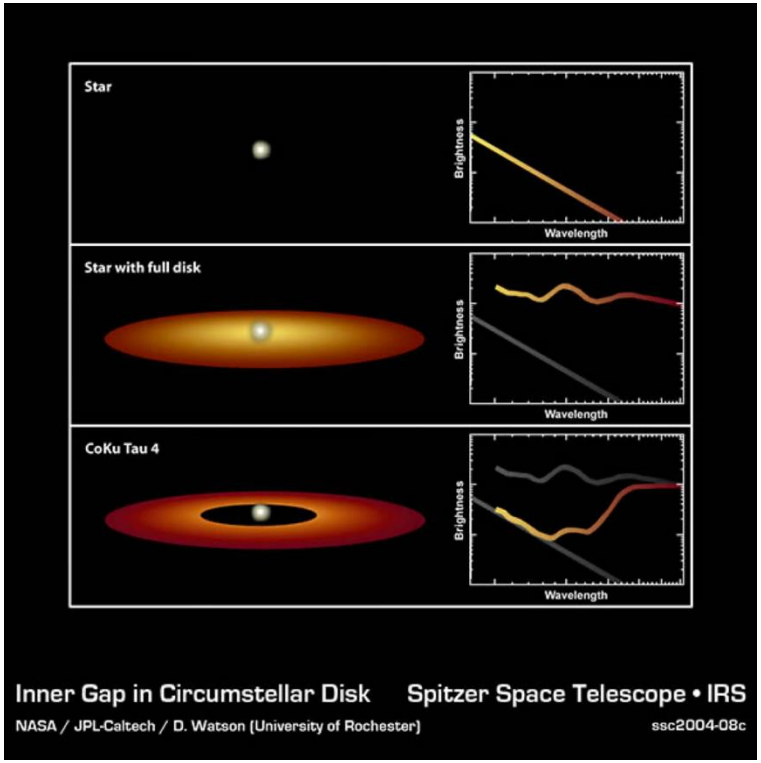
Disk history



Still, the main technique for disk detection remained the observations in IR.

Spectral Energy Distributions (SED)

Disk history



Still, the main technique for disk detection remained the observations in IR.

Spectral Energy Distributions (SED)

Disk history

Google Colab

Let's see an SED!

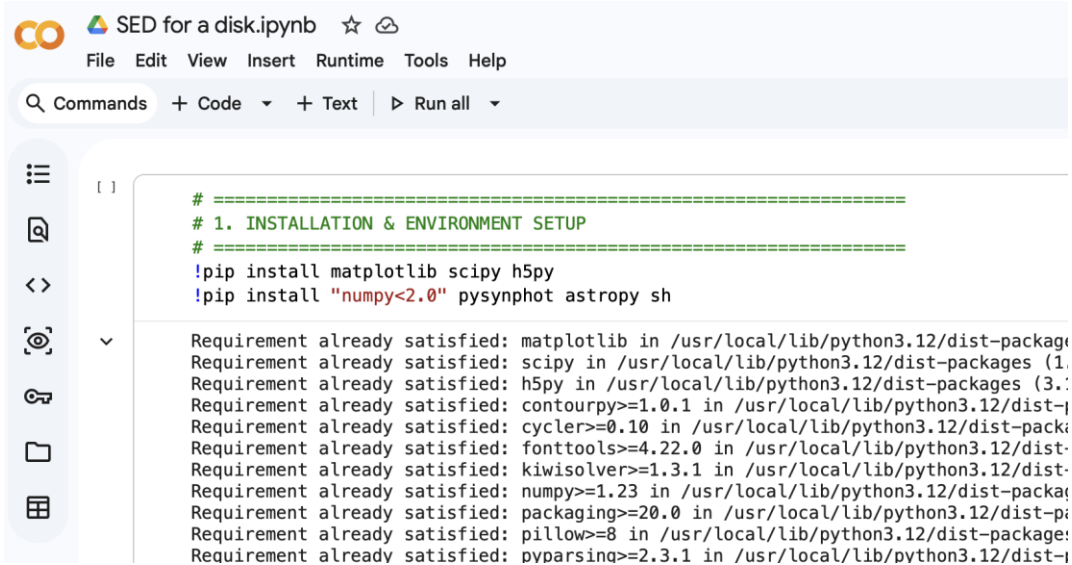
Roman_winter_school

↓

SED_disk

↓

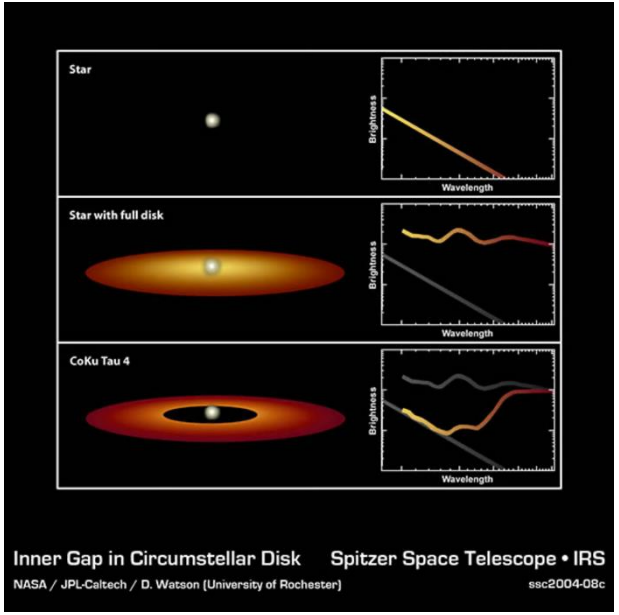
SED for a disk.ipynb



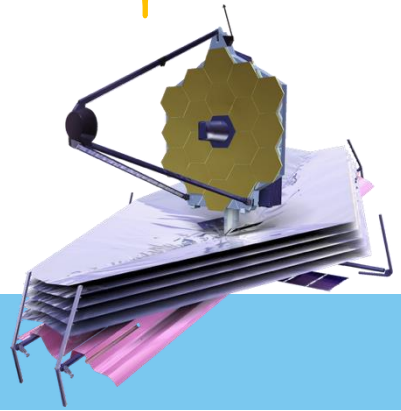
Disk history

Google Colab

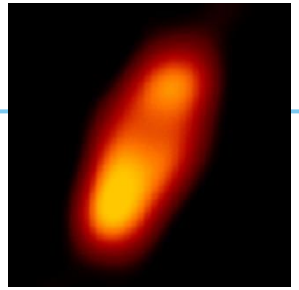
- What components show up in the SED?
- Based on the SED, which type of disk could it be?

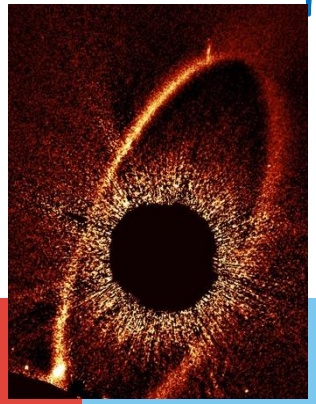


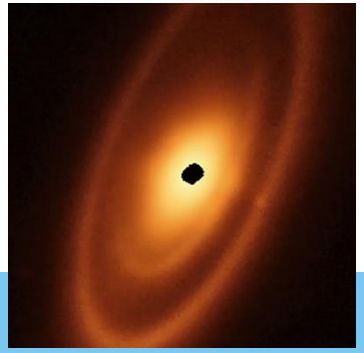
Disk history

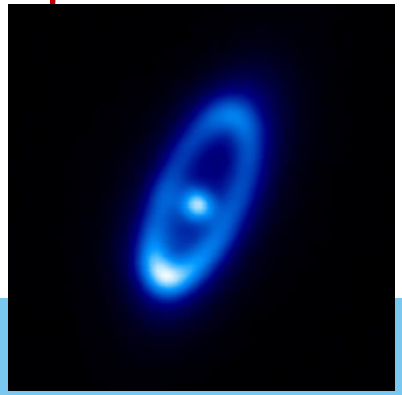


Disk history









Disk components

Historically, debris disks were supposed to have lost all primordial gas and are made up of just dust particles of different sizes.

The gas from the protoplanetary phase is lost!

Disk components

Why is the gas lost but not the dust?

- Collisional cascades
  - Collisional cascades produce a specific size distribution, that we use to model disks (Dohnanyi, 1969)

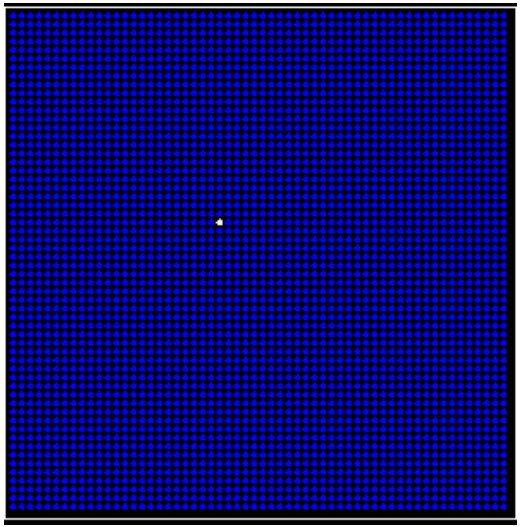
$$dN/da \propto a^{-3.5}$$

Disk components

Why is the gas lost but not the dust?

- Collisional cascades

- There is also gas production!



Disk components

Why is the gas lost but not the dust?

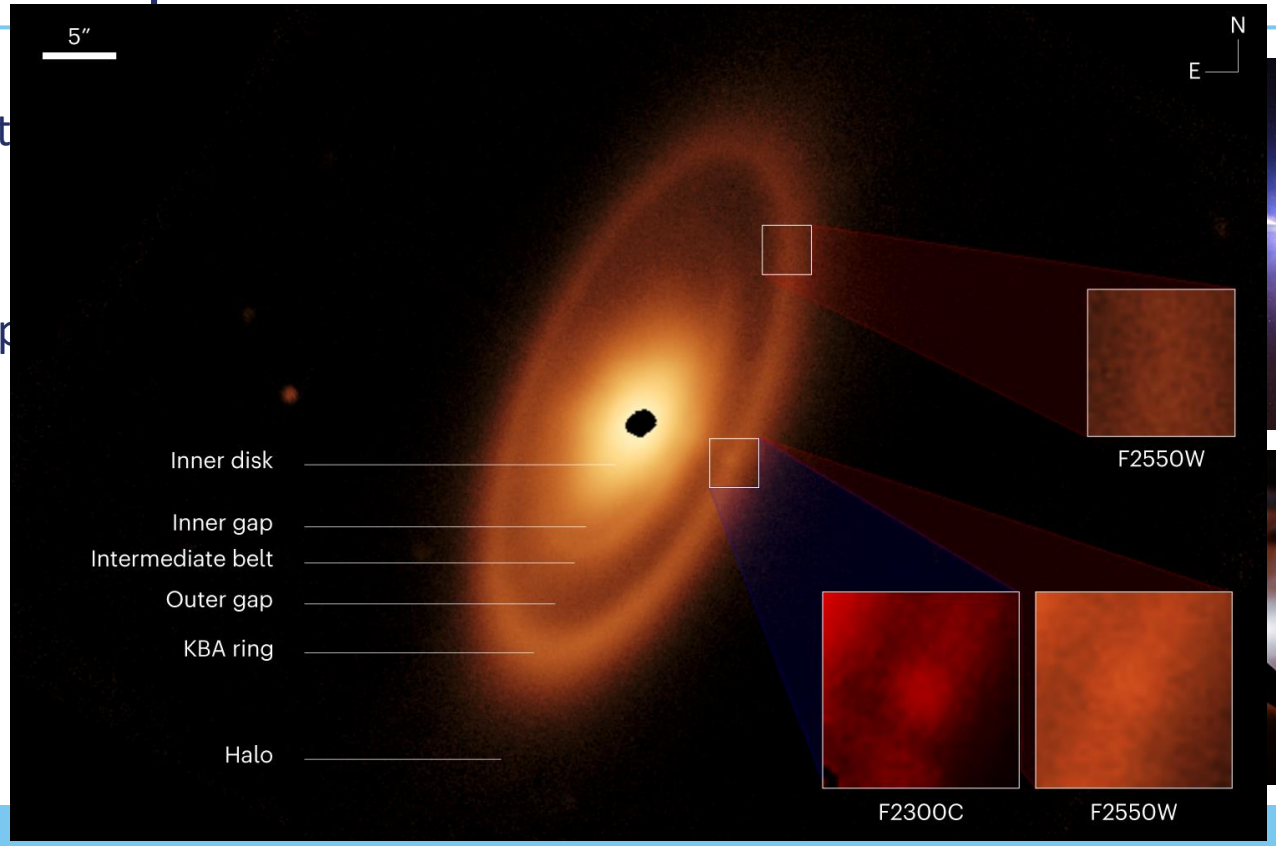
How are collisional cascades produced?

- Self-stirring
- Planet stirring
- Stirring by giant collisions

Disk components

Why is t

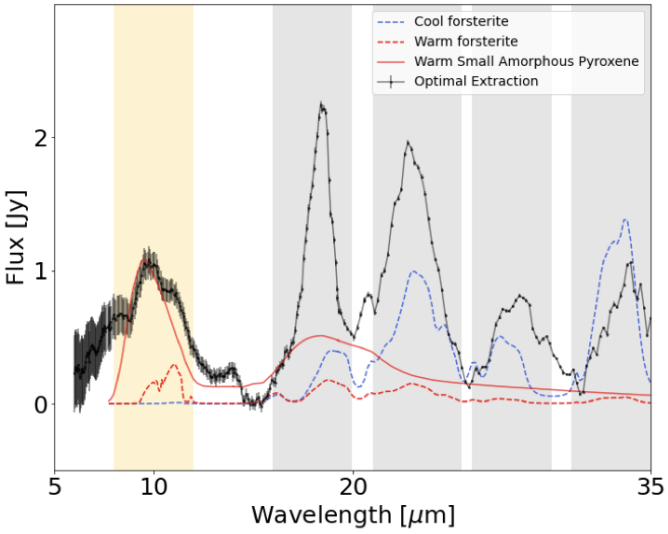
- Gas p
  -
  -



Disk components

Dust and gas composition

- Dust
  - Probed through spectral features (e.g. Silicates at ~10 µm)
  - Colors can usually differentiate between certain components (carbonaceous vs silicates)
  - Porosity is a big factor in the observed properties, but better determined from polarized light.
  - Usually minimum size > blowout size

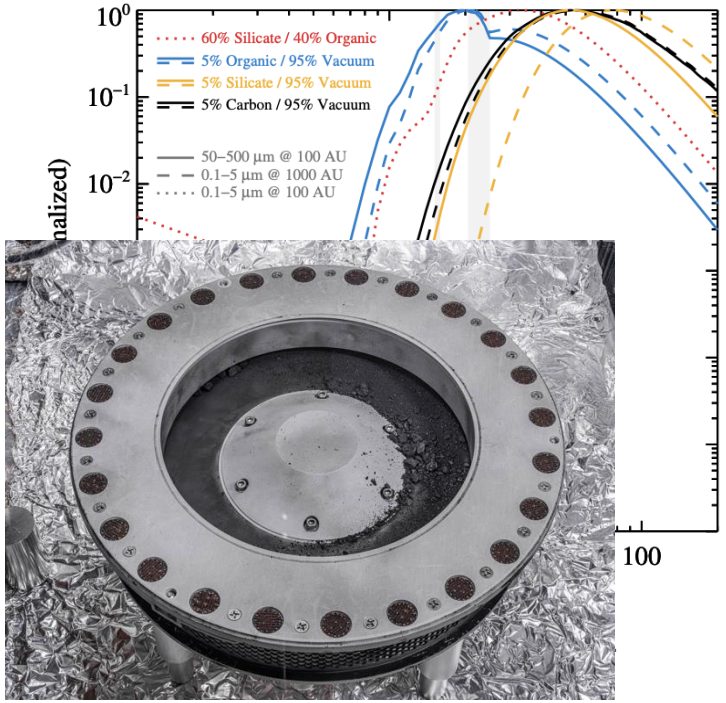


Lu et al. 2022

Disk components

Dust and gas composition

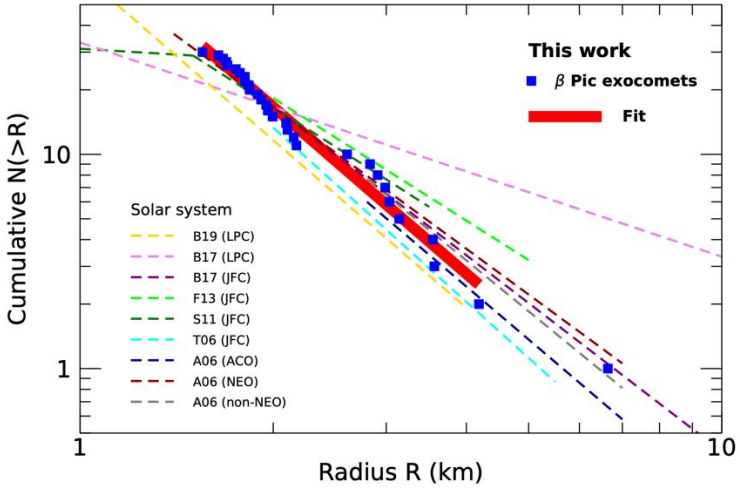
- Dust
  - Recent findings show that the composition can be similar to some solar system materials (Bennu sample)



Disk components

Dust and gas composition

- Dust
  - Recent findings show that the composition can be similar to some solar system materials (Bennu sample)
  - We also know that the size distribution of small bodies is similar to the solar system!



Lecavelier et al. 2022

Disk components

Google Colab

What is the effect of dust grain size in the SED?

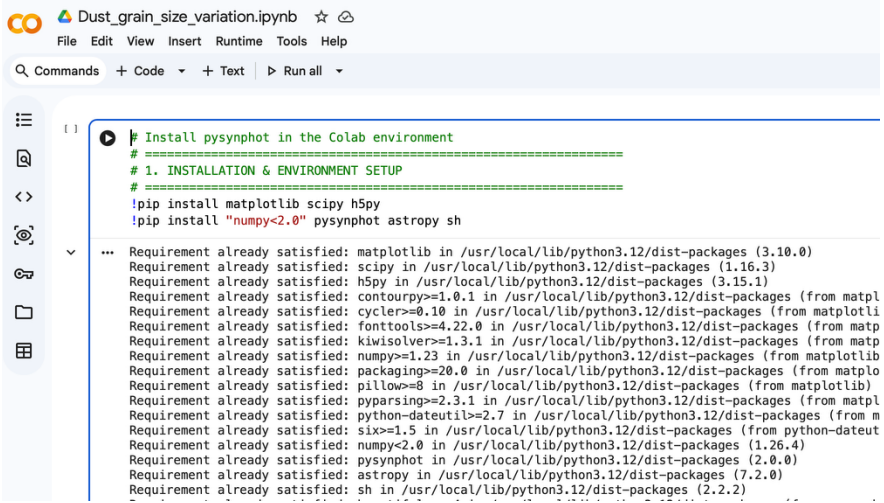
Roman_winter_school

↓

Dust_grain_sizes

↓

Dust_grain_size_variation.ipynb



Disk components

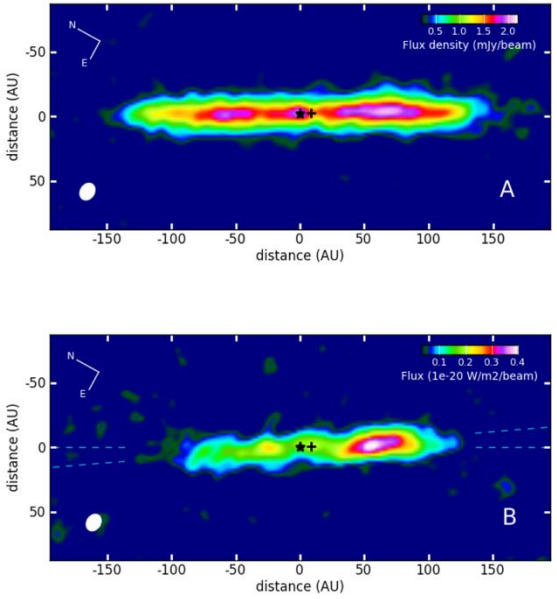
Google Colab

- Which were the biggest differences you observed in the SED?
- If a disk is “faint” in near-IR, is it more likely to have larger or smaller minimum grain size?
- Is an SED enough to say something about the composition?

Disk components

Dust and gas composition

- Gas
  - Mostly CO detected in sub-mm (C or O in a few cases)
  - Some refractory species observed in UV and optical spectroscopy (very high temperatures)
  - Variability observed (e.g. exocomets)

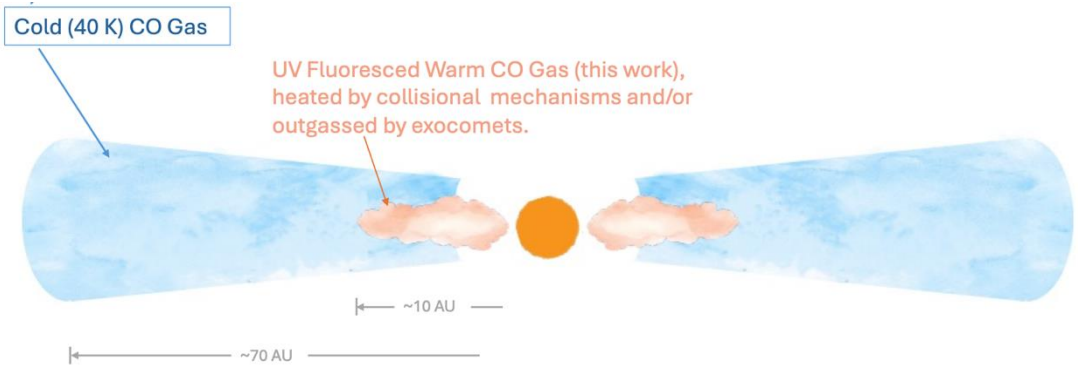


Dent et al. 2014

Disk components

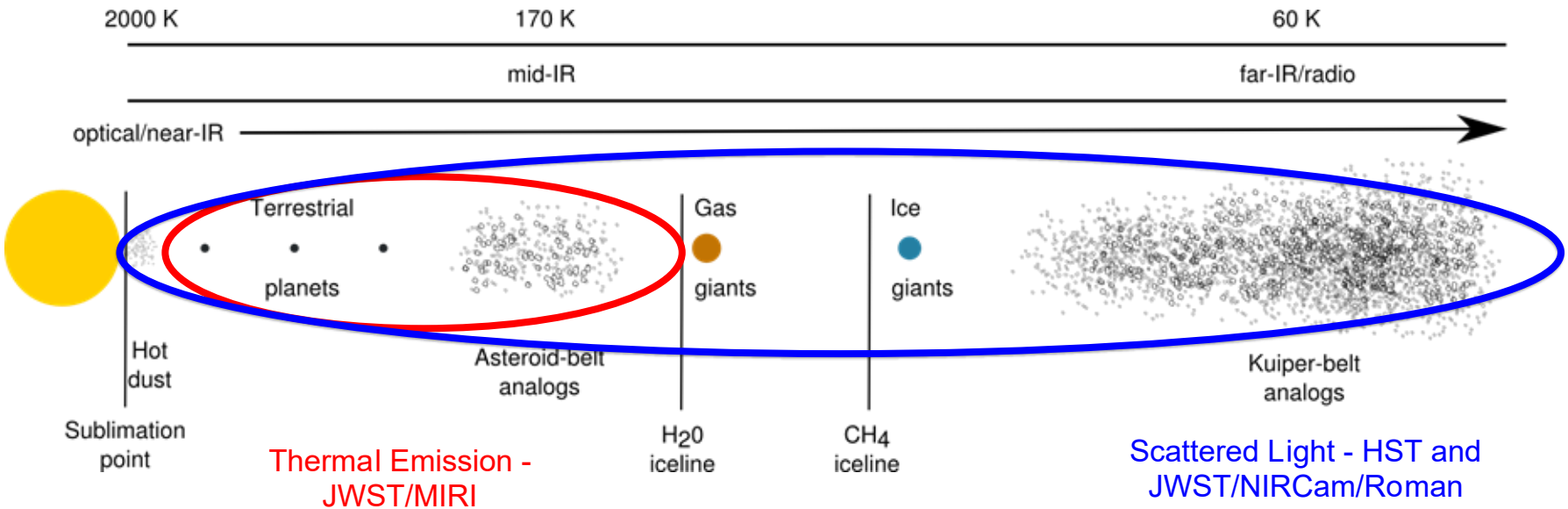
Dust and gas composition

- Gas
  - Gas is, mostly like dust, located at different distances from the star

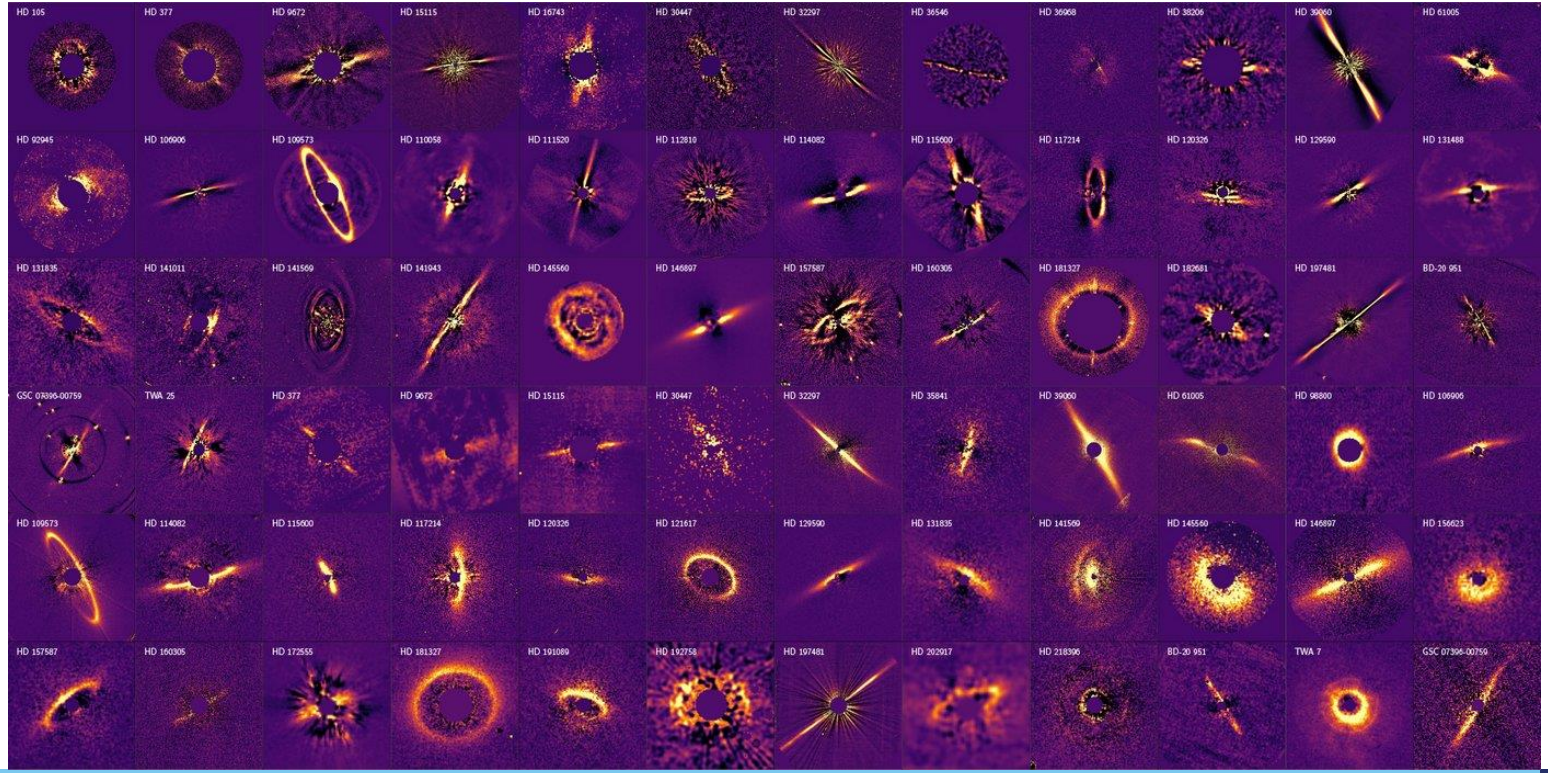


Lu et al. 2025

Disk components

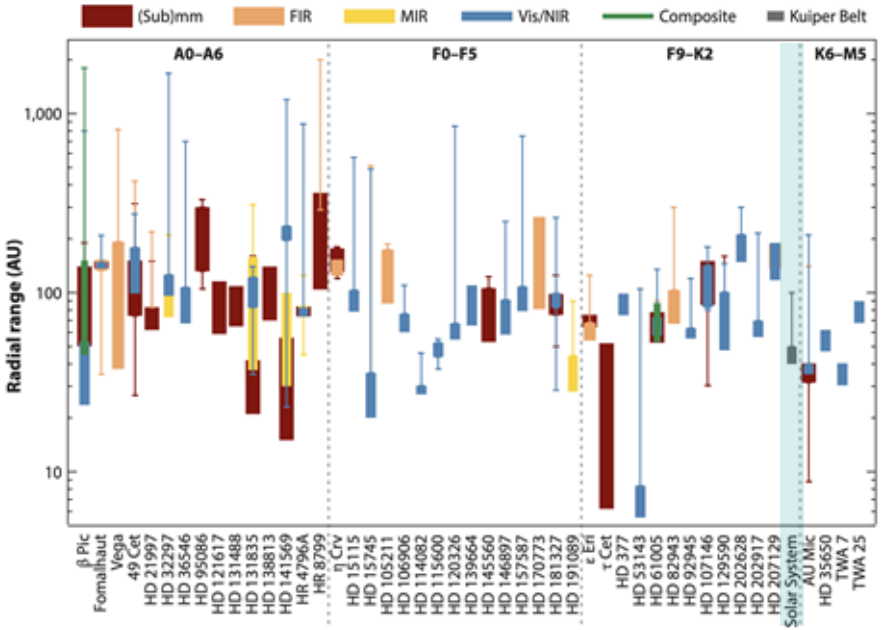


Disk components



Engler et al. 2025

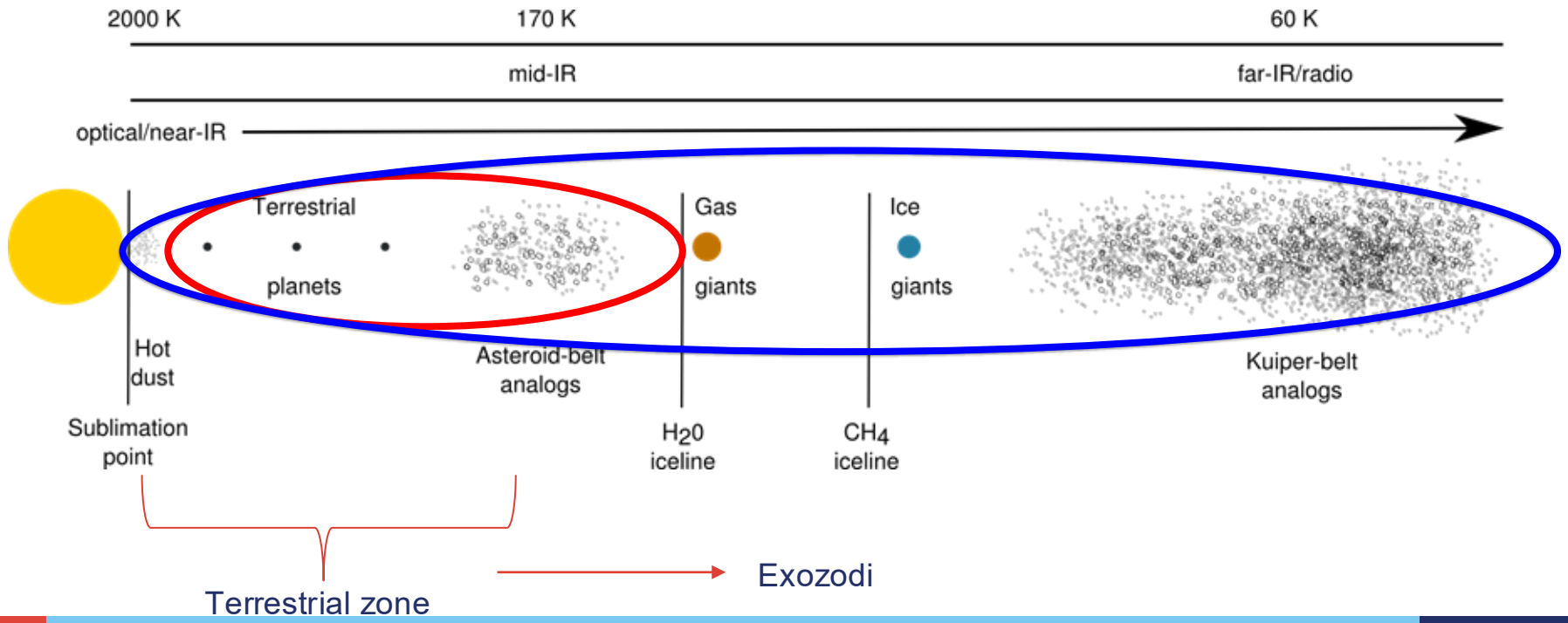
Disk components



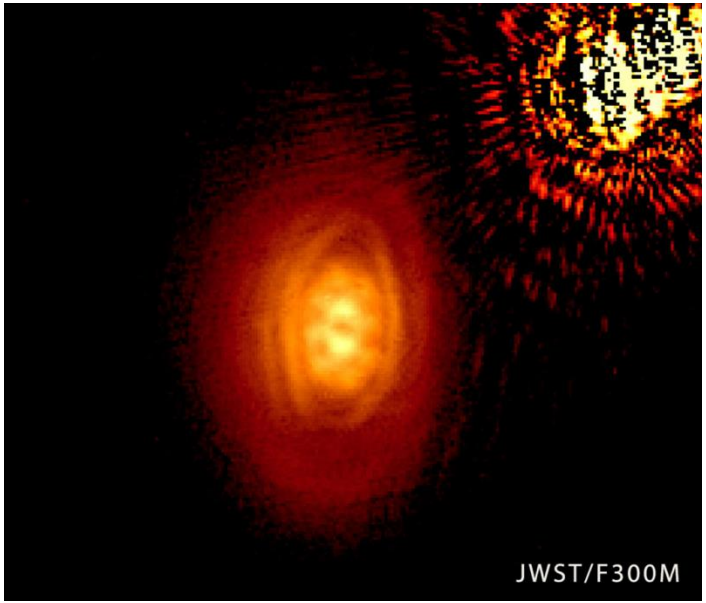
Hughes et al. 2018

No (clear) link between SpT and size of the disk

Disk components



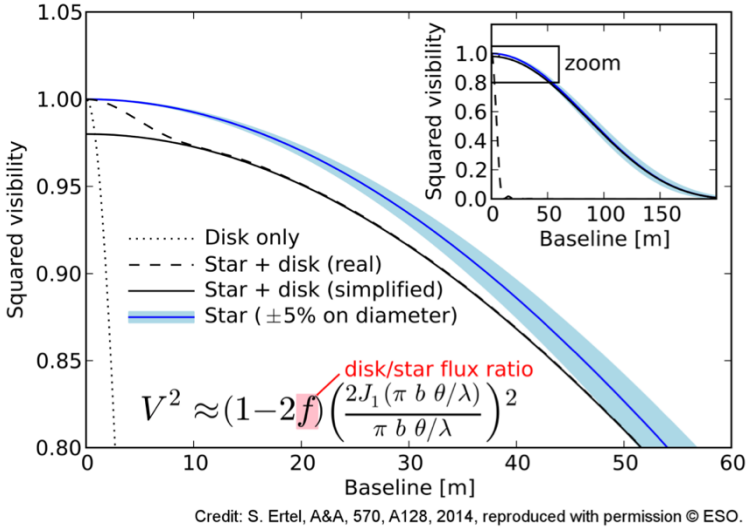
Disk components



Millar-Blanchaer et al. 2025

- Disks like HD 141569A (observed with JWST/NIRCam) shows a significant brightness in the inner region (also seen with MIRI)
- The habitable zone of planetary systems might be difficult to probe

Disk components

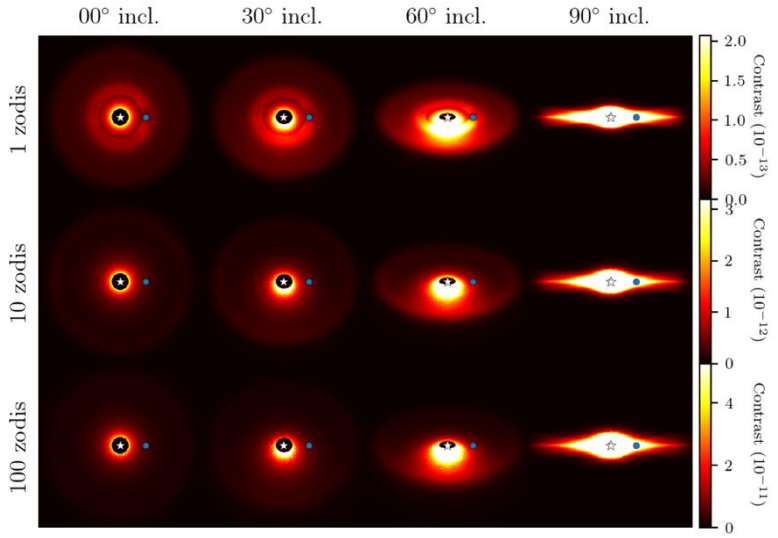


Credit: S. Ertel, A&A, 570, A128, 2014, reproduced with permission © ESO.

Ertel et al. 2025

- Exozodis are difficult to detect just from the SED

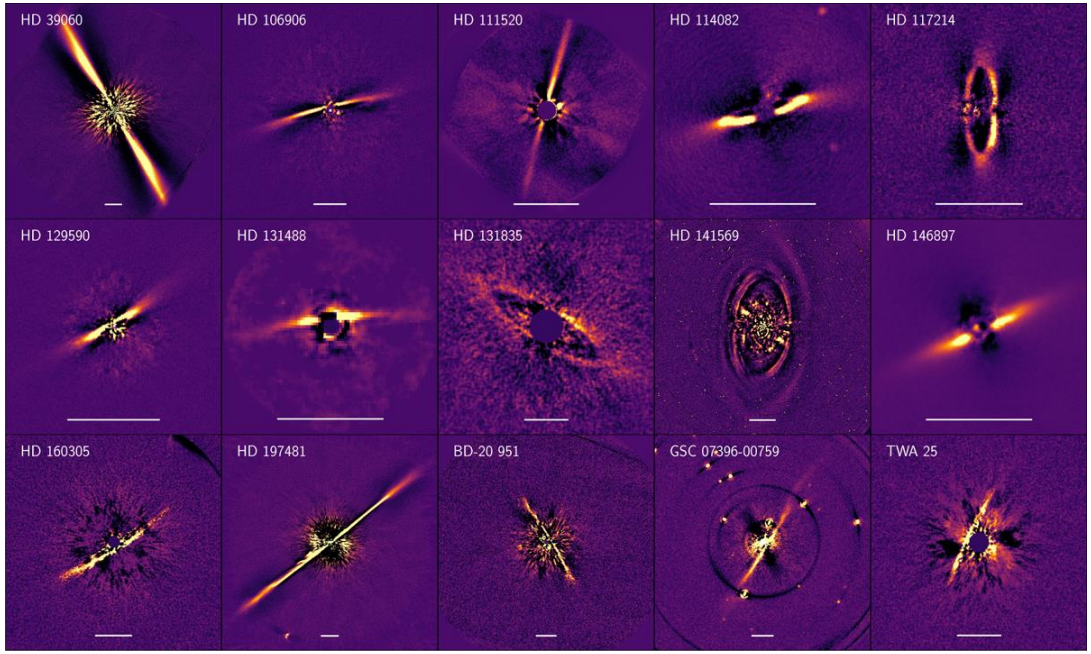
Disk components



Currie et al. 2023

- Exozodis are difficult to detect just from the SED
- Planets might cause effects in their shapes/dust distributions

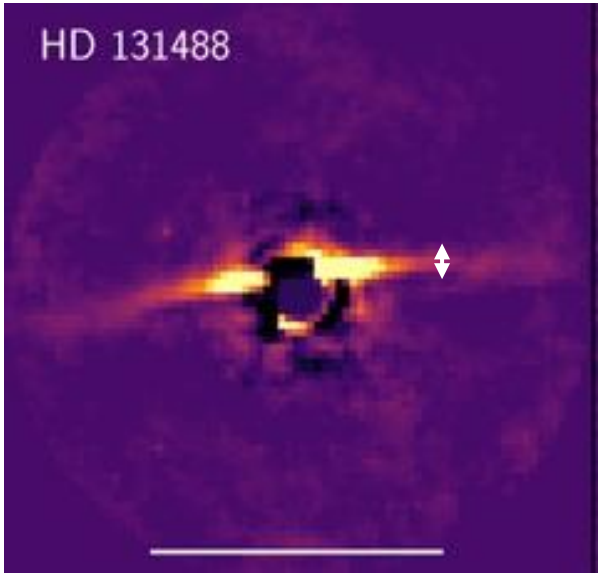
Disk components



Engler et al. 2025

What about scale height?

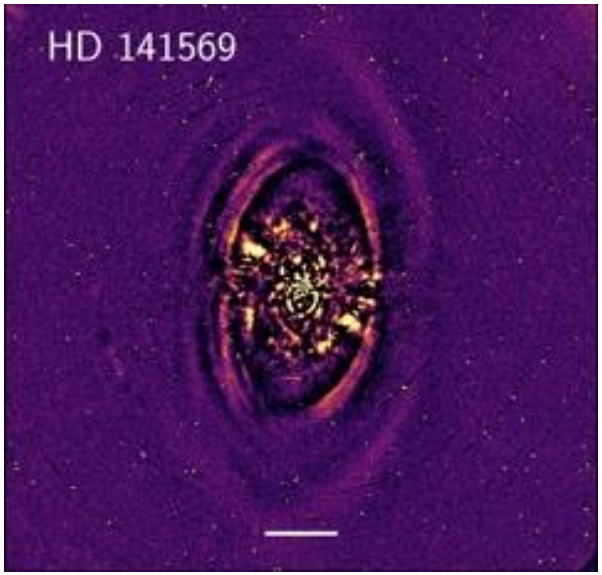
Disk components



Engler et al. 2025

What about scale height?

Disk components



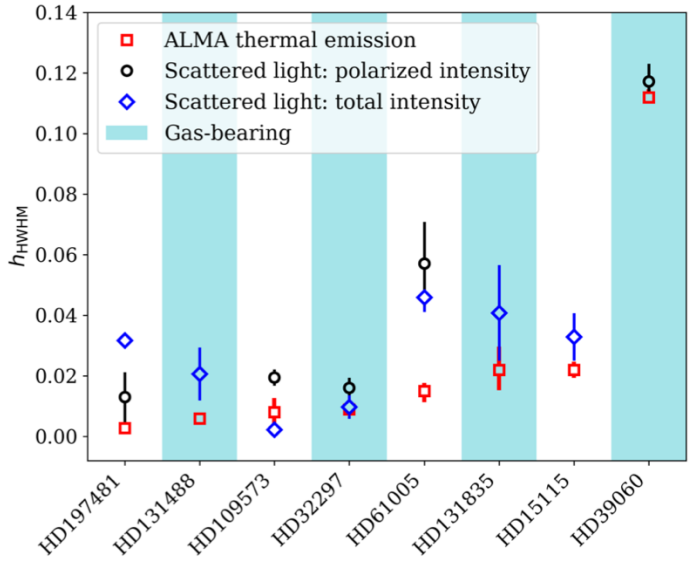
Engler et al. 2025

What about scale height?

What do we do if the disk is face on?

- Model!

Disk components

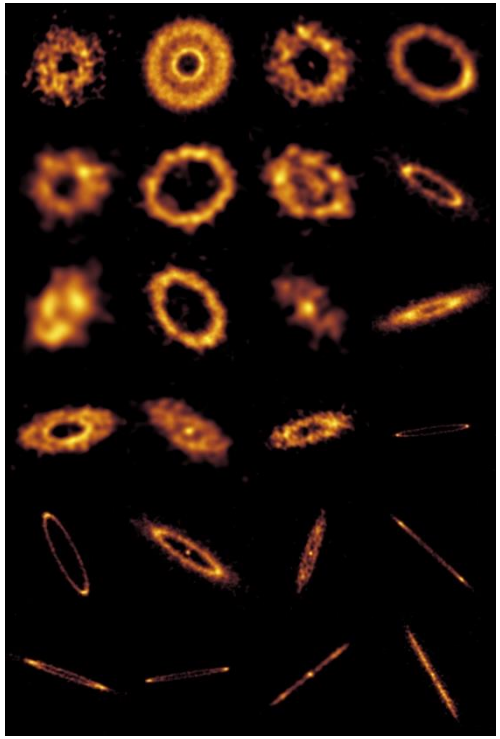


Zawadzki et al. 2025

What about scale height?

The scale height also changes with wavelength

Disk components



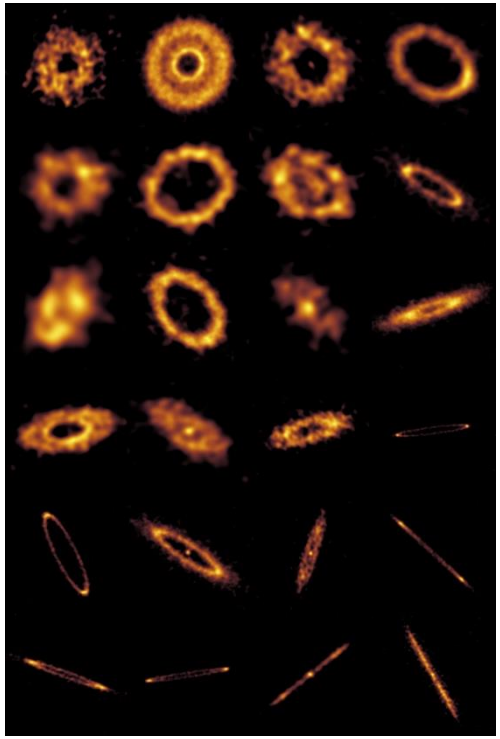
What about the dust mass?

- Based on the dust distribution, we can assume most of the mass is concentrated in larger particles (>1mm)
- We use long wavelength flux measurements to estimate the mass

$$M_d = \frac{F_\nu d^2}{B_\nu(T_{d,c})\kappa_\nu}$$

Marino et al. 2025

Disk components

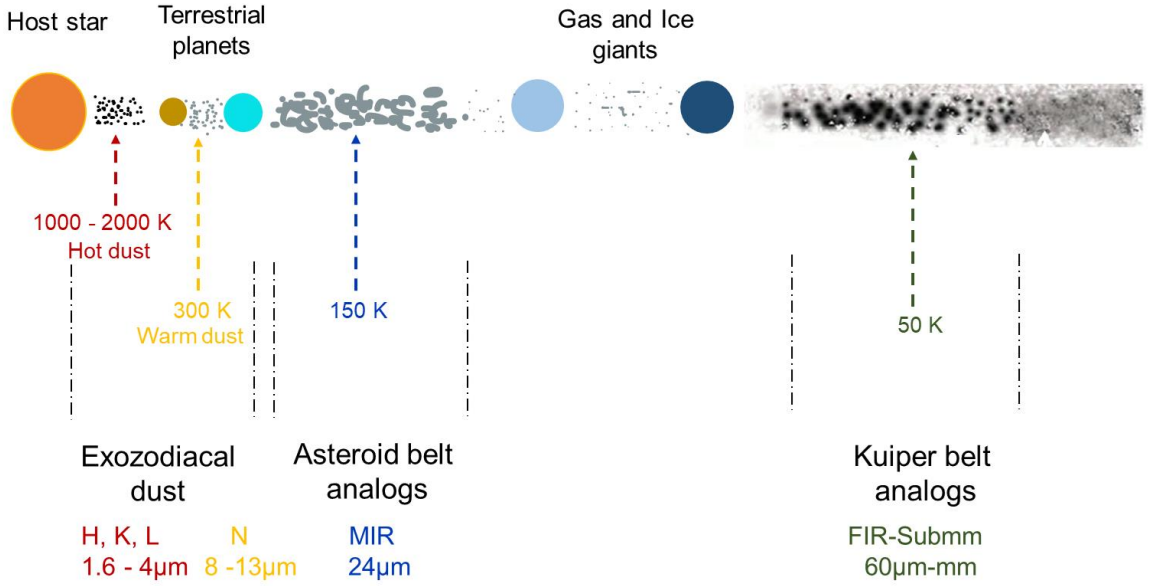


What about the dust mass?

- Mass is one of the big uncertainties in debris disks. It can be crucial for planet searches
  - Are morphological features caused by planets or self-stirring?
  - Is the disk mass enough to keep forming planets?

Marino et al. 2025

Disk components



How do we make out all these components?

Adapted from Gaspar et al. 2019; Youdin & Rieke 2015