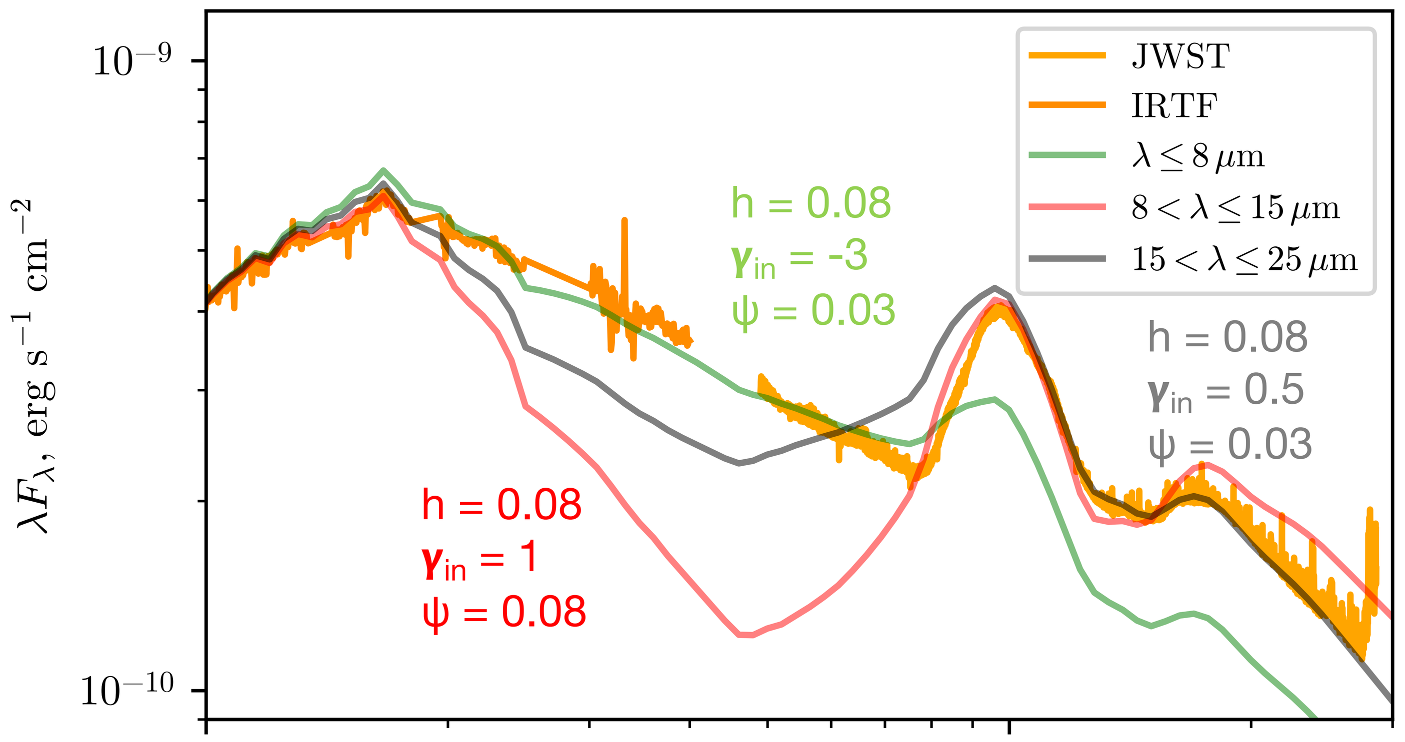
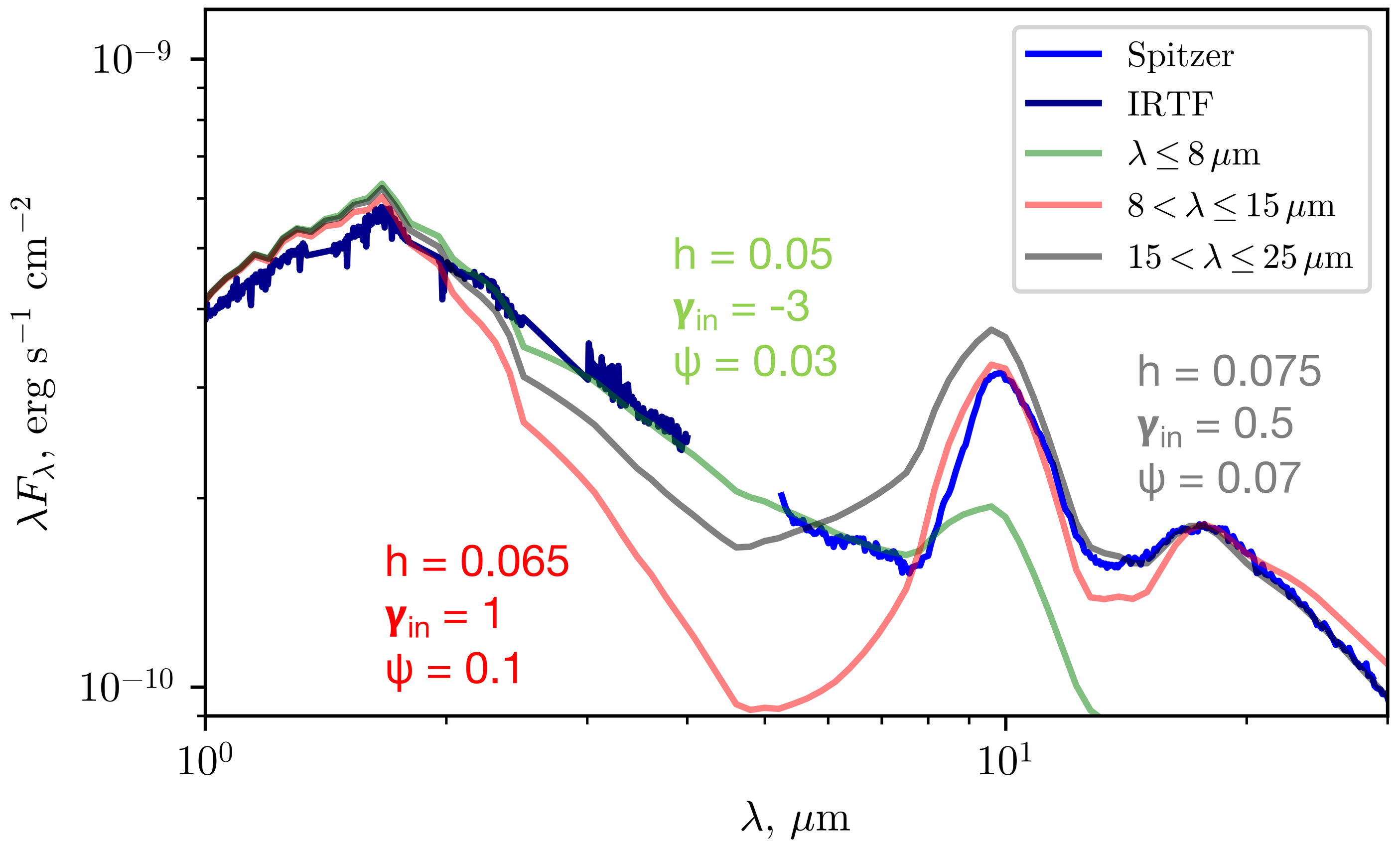
Radiative transfer modelling of dynamic inner disks of T Tauri stars with mid-infrared variability

Lis Zwicky[1,2], Péter Ábrahám[1,3], Ágnes Kóspál[1]
(they/them) (he/him) (she/her)

1 Konkoly Observatory, HUN-REN CSFK, Budapest, Hungary
2 Eötvös Loránd University, Budapest, Hungary
3 University of Vienna, Austria

V1279 Sco





We run a grid of simple vertical structure models:

$$\rho = \rho_0 \exp\left(-\frac{z^2}{2H^2}\right)$$

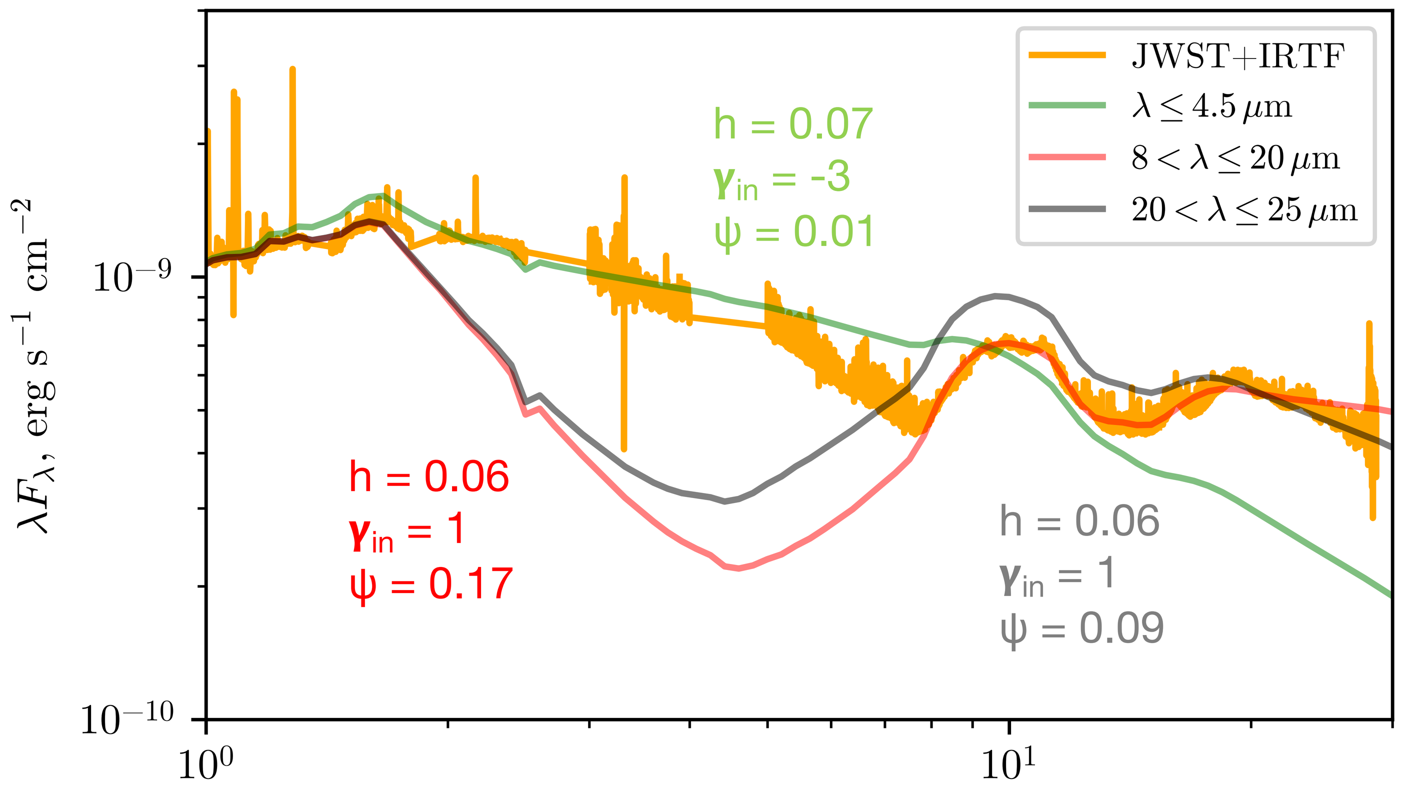
$$H = hR\left(\frac{R}{R_c}\right)^{\psi}$$

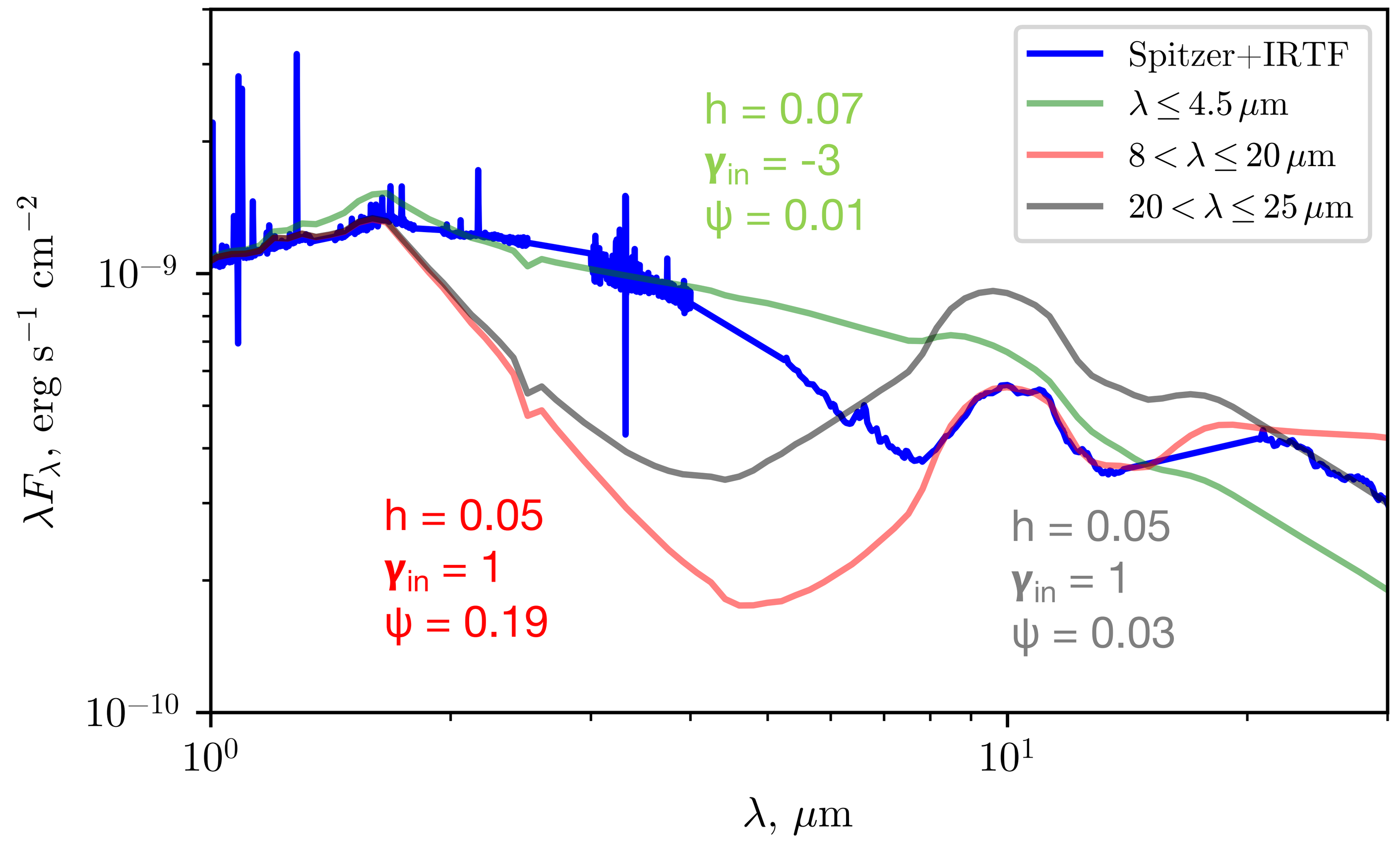
The inner disk is smoothed with exponential taper:

$$\Sigma \propto \exp\left[-\left(\frac{R_{c,in}}{R}\right)^{2-\gamma_{in}}\right]$$

$R_{c,in}$ is calculated from R_{min} where density drops to 10^{-24} g/cm^3. R_{min} is a model parameter, and we choose it to be near sublimation radius. For V1279 Sco $\boldsymbol{R_{min}}$ **= 0.1 au**. For RU Lup $\boldsymbol{R_{min}}$ **= 0.15 au**.

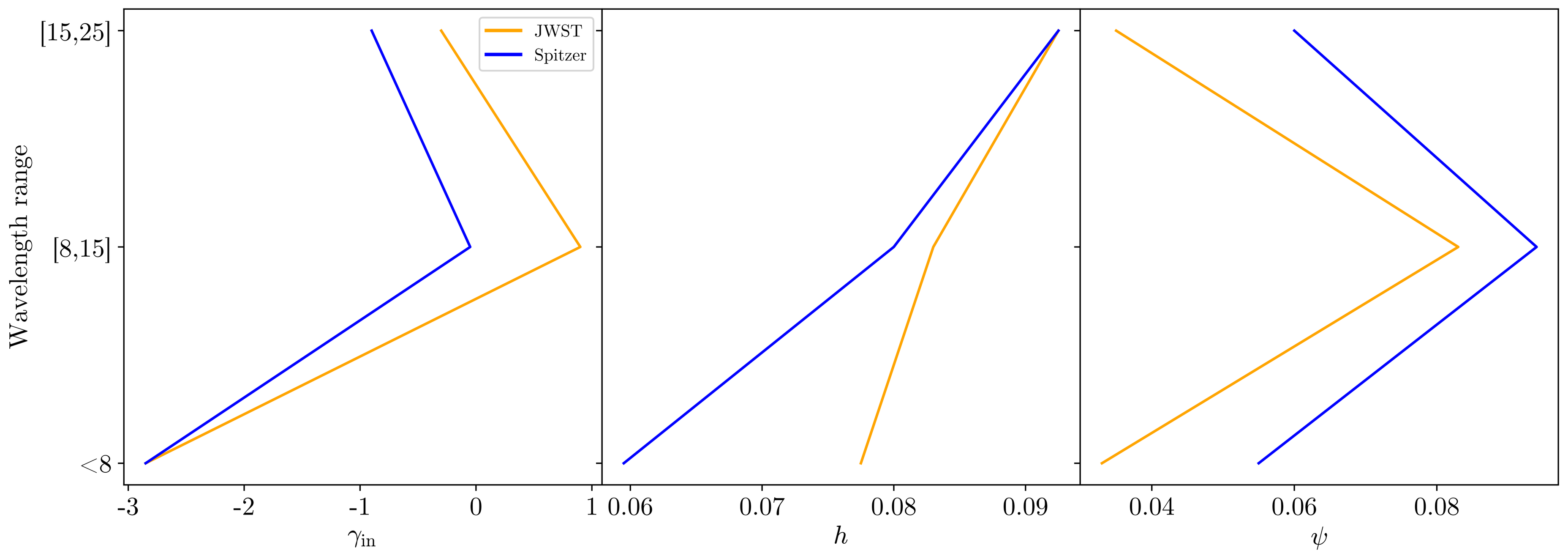
RU Lup





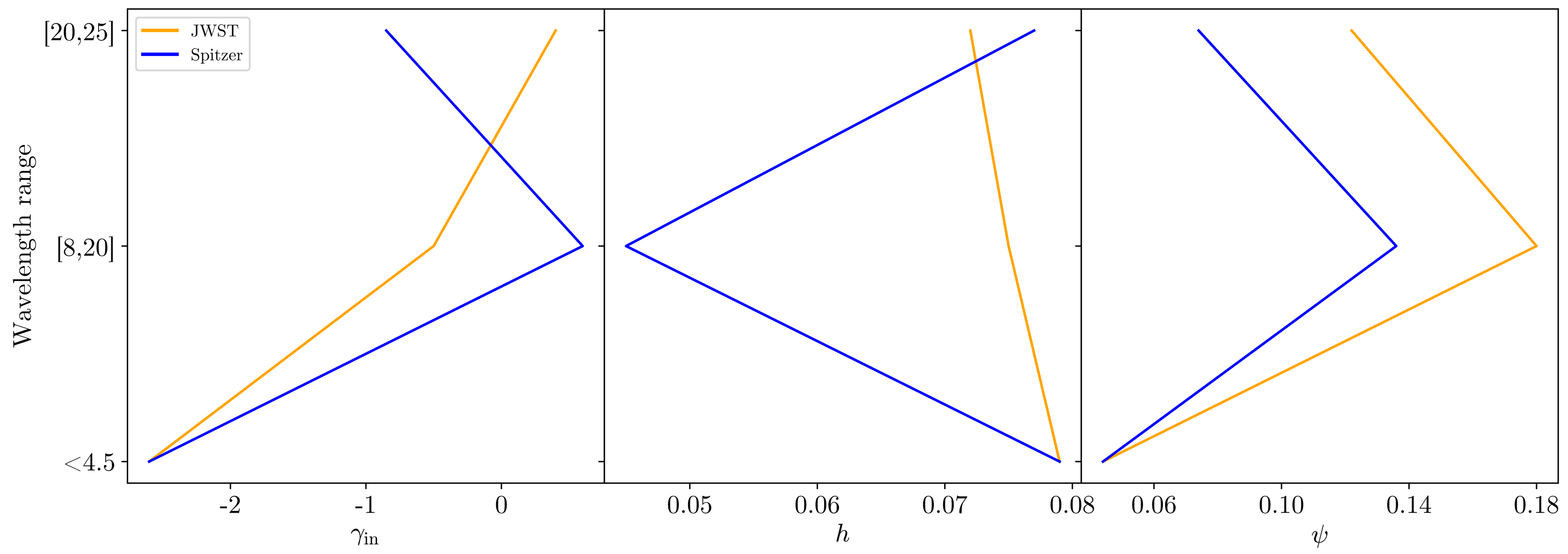
For V1279 Sco, we find that for both epochs we cannot fit the mid-IR spectra with simple vertical structure. We do find, however, that they can reproduce well parts of the spectra. As different wavelengths trace different parts of the disk, such fitting allows us to understand how these parameters vary with radius. The main difference between fits for two epochs lies in the inner disk: the Spitzer epoch requires lower scale heights with scale height difference increasing towards the star. The outer disk is the least affected. The Spitzer fit preference for higher flaring angles also comes from the need for lower scale height (from equation above).

Below are parameter values averaged over the top 10 best fit models for their wavelength ranges.



The case of RU Lup is more complex as we cannot find a fit for 5-8 μm range which could be due to this star being a strong accretor, requiring a special structure close to the star. This structure also should not change between the epochs. The main difference is in the 10 μm silicate feature: at the Spitzer epoch it has a significantly lower scale height, however the shape itself does not change. The outer disk can be fitted by many models which is why the averaged parameter values bend back for this range in the plot below. However, if we fix the $\boldsymbol{\gamma_{in}}$, the fit requires lowering the scale height and flaring compared to JWST too, suggesting increased shadowing.

Below are parameter values averaged over the top 10 best fit models for their wavelength ranges.



Abstract

Multi-epoch Spitzer observations of T Tauri stars revealed variability in the mid-infrared wavelength range on yearly and, in some cases, weekly timescales. A fraction of these stars exhibited a "seesaw" behavior, with anti-correlated variations at shorter and longer wavelengths, suggesting that structural changes within the inner disk drive this variability. Following the launch of JWST, numerous young stars previously observed by Spitzer were reobserved, demonstrating a diverse range of time-dependent behaviors – from changes at only the shortest or longest wavelengths to self-similar and seesaw variations.

The goal of this work is to find out which changes in physical disk properties could explain observed variability of two such stars with radiative transfer modelling.

YSO parameters:

V1279 Sco

d = 156.2 pc (Gaia)
A_V = 2.19 mag
R_c = 148 au (Long+2022)
M_{dust} = 120 $M_\oplus$ (Xin+2023)
i = -47.1° (Ansdell+2018)

RU Lup

d = 157.5 pc (Gaia)
A_V = 0.9 mag
R_{disk} = 62 au (Xin+2023)
M_{dust} = 159 $M_\oplus$ (Xin+2023)
i = 0° (Ansdell+2016)

Stellar spectra of both: XShooter + IRTF + BTSettle (Allard 2014)

Dust sublimation per Flock+2019

Dust opacities:

(approximate, we do not fit the feature here)

optool (Dominik+2021)

↓

Parametric disk setup:

DiskCheF (on GitLab)

↓

Radiative transfer:

RADMC-3D (Dullemond+2012)

Acknowledgements

This work was supported by the NKFIH NKKP grant ADVANCED 149943 and HKFIH OTKA project no. K-147380.