The variable inner disk of DG Tau

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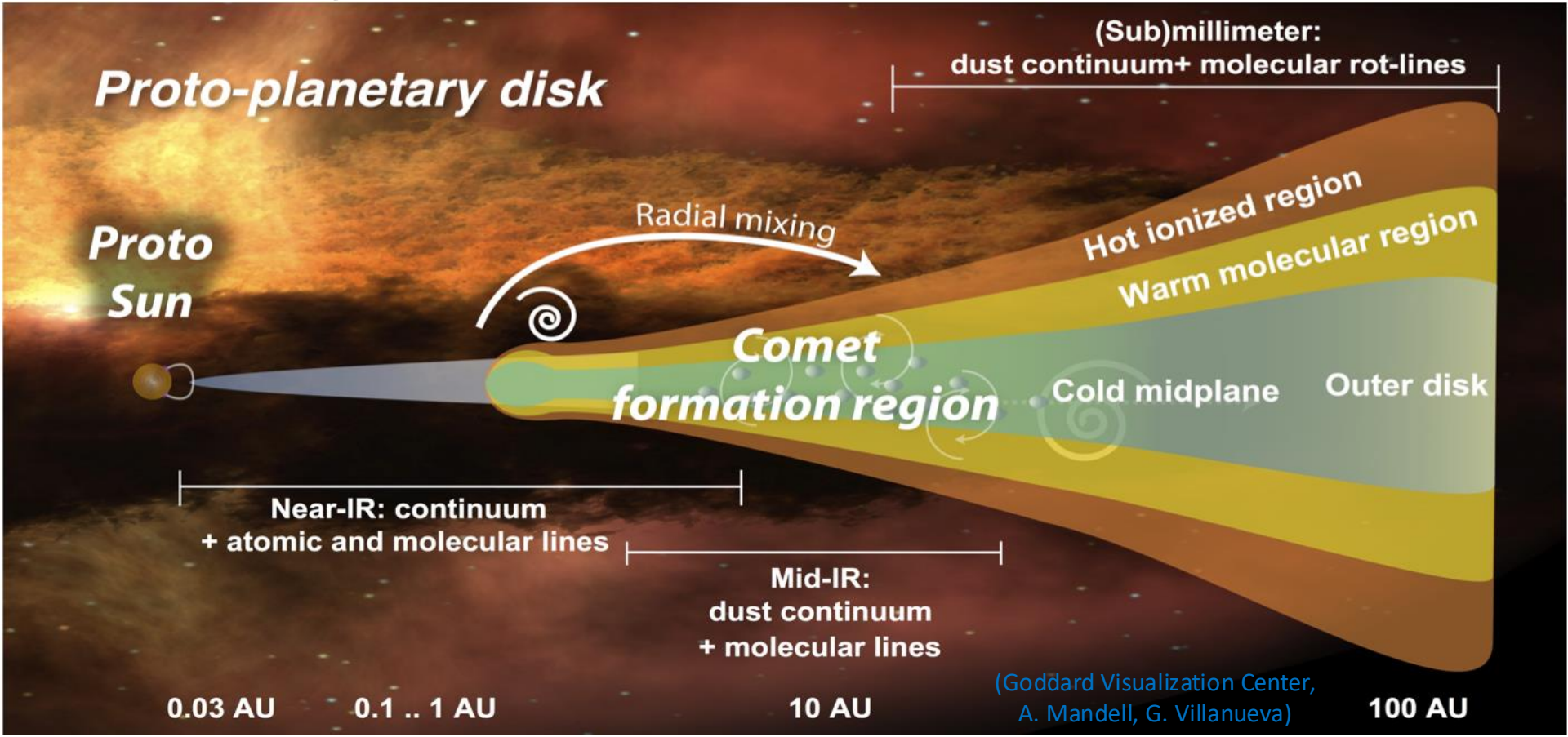
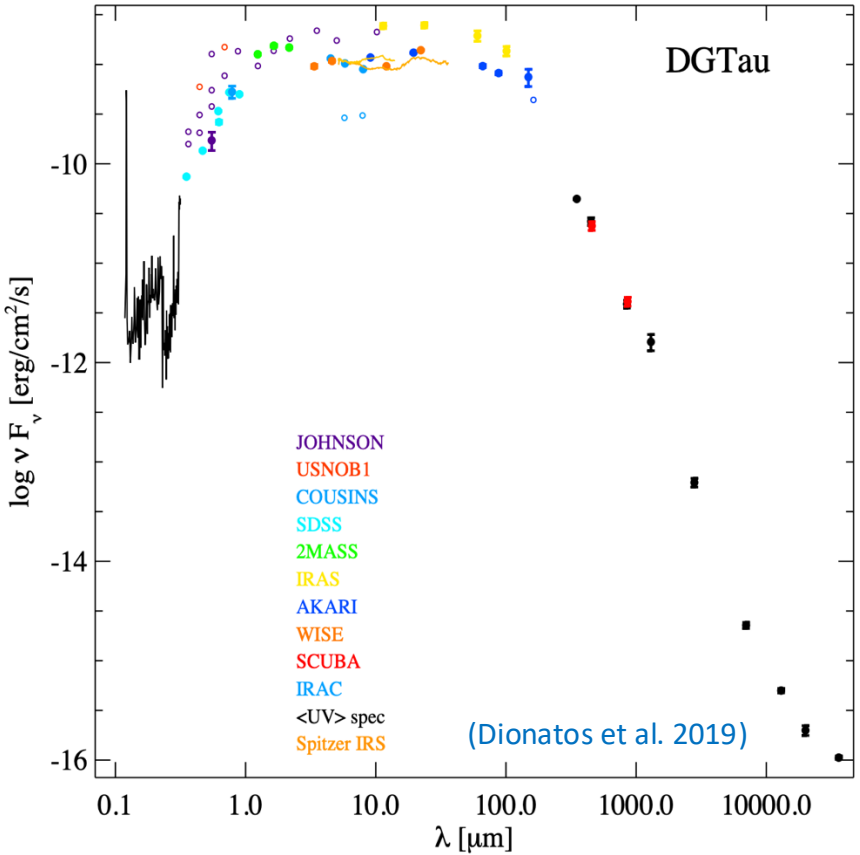
Overview of this talk

- Motivation
- Our target: DG Tau
- The interferometric view of DG Tau's disk
- Variability of the inner disk

Why do we care about the inner disk?



Our target: DG Tau

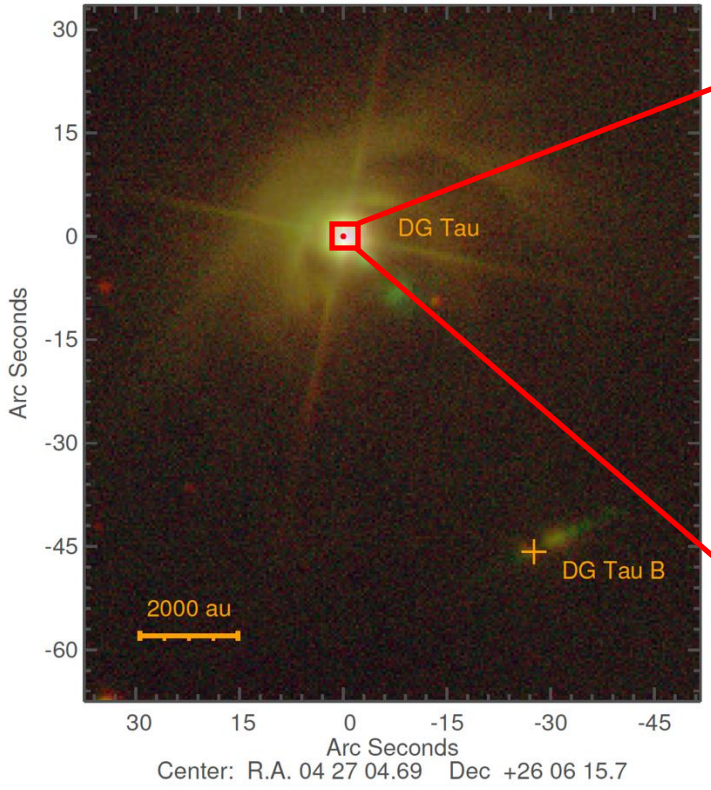


- Distance: d = 130 pc
- Spectral type: K6
- $M_\star = 0.7\ M_\odot$ (low-mass)
- $L_{bol} = 4.7\ L_\odot$
- $A_V = 1.4$ mag (moderate)
- $\dot{M} = (1 - 5) \times 10^{-7}\ M_\odot/yr$ (high)
- $i = 37.3 \pm 0.2°$
- Flat spectrum source (transition between Class I and Class II objects

(Ohashi et al. 2023, Varga et al. 2017, Güdel et al 2018, Carr et al. 2011, Eislöffel & Mundt 1998, Testi et al. 2002, Podio et al. 2013, Purser et al. 2018)

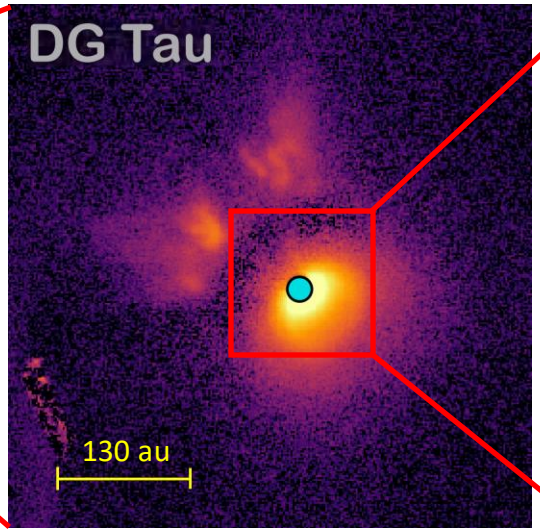
Our target: DG Tau

SDSS optical



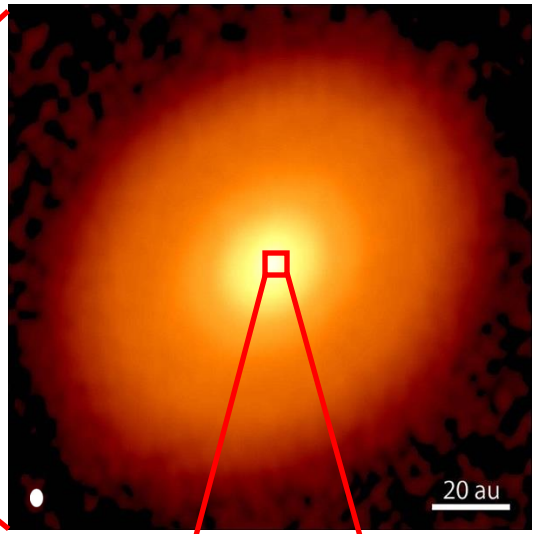
(Varga et al. 2017)

SPHERE near-infrared



(Garufi et al. 2024)

ALMA millimeter



(Ohashi et al. 2023)

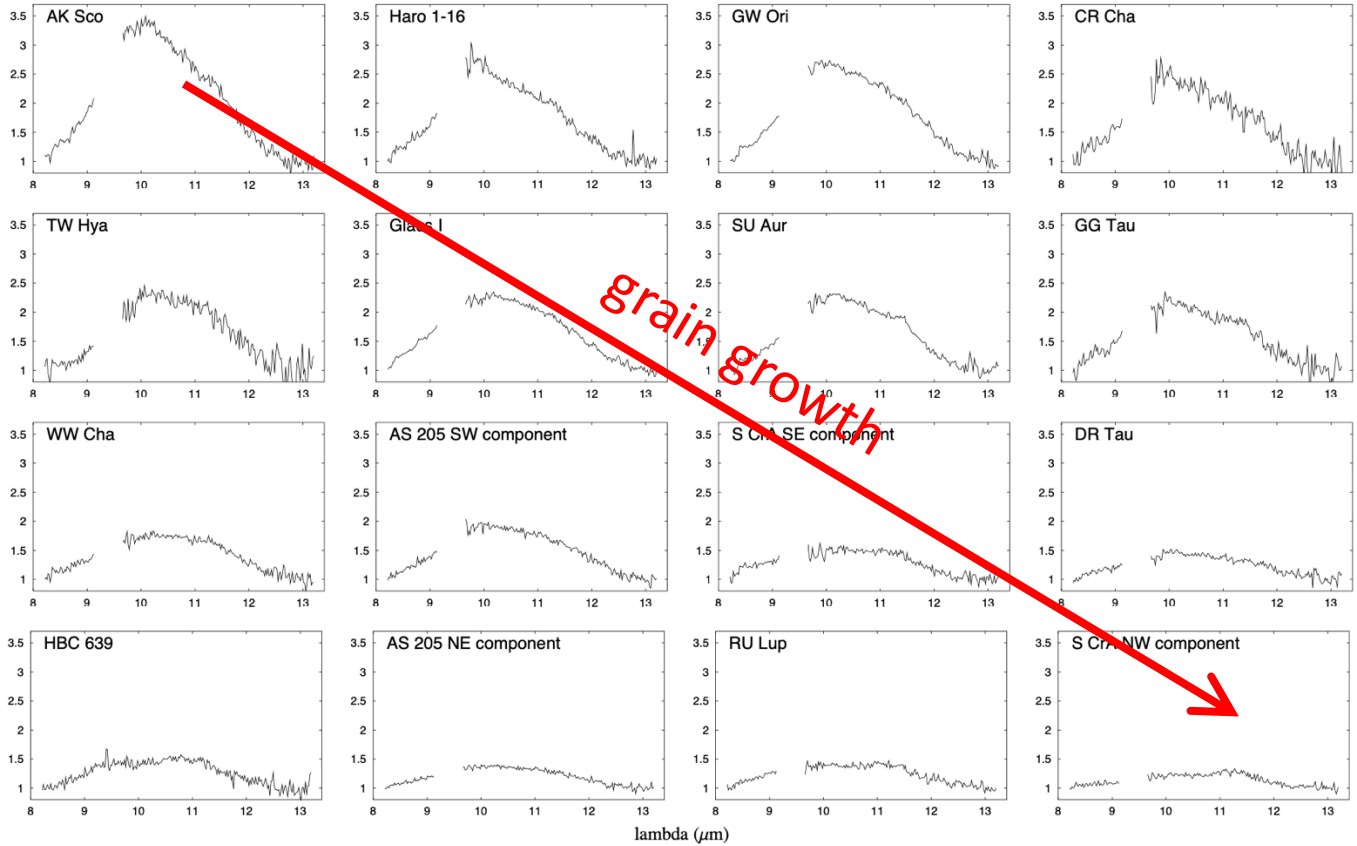
- What does the inner disk look like at au scale?

?????????

The JWST view of the DG Tau disk

(M. Güdel and the MINDS team, in prep.)

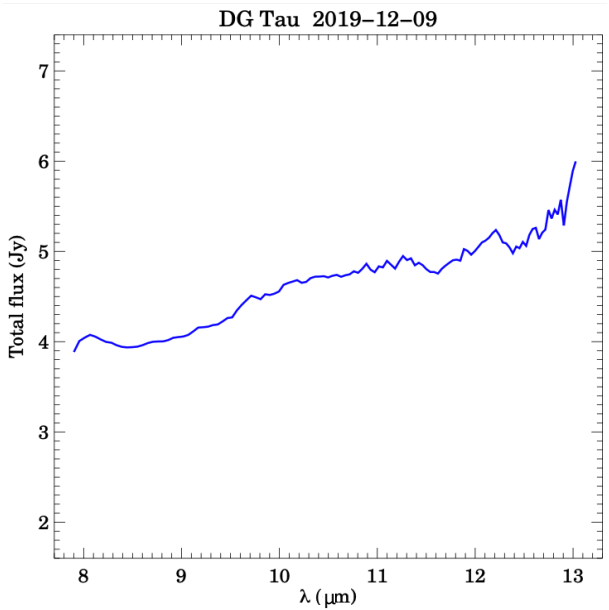
The JWST view of the DG Tau disk

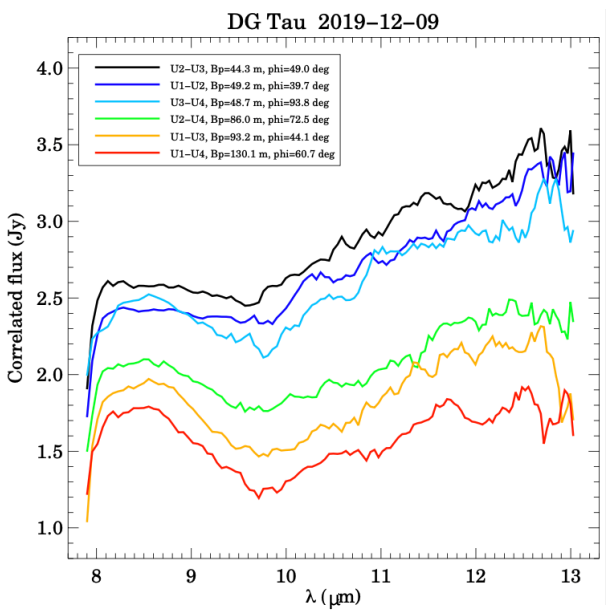


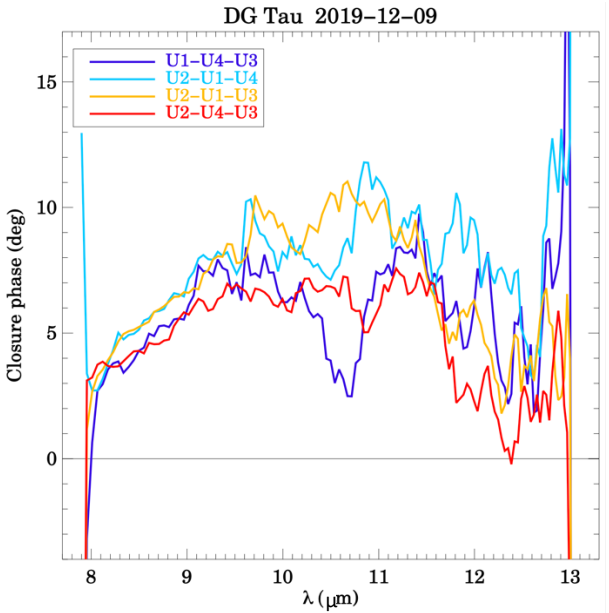
(Przyggoda et al. 2003)

Spatially resolved data on the 10 µm feature

MATISSE GTO observations with 4 UT telescopes on December 9, 2019





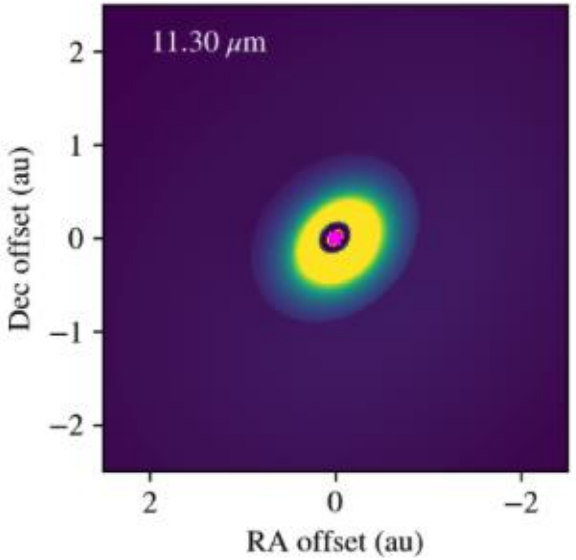


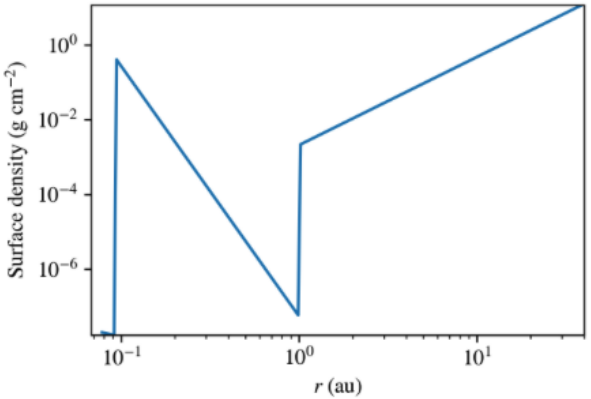
Total flux
emission

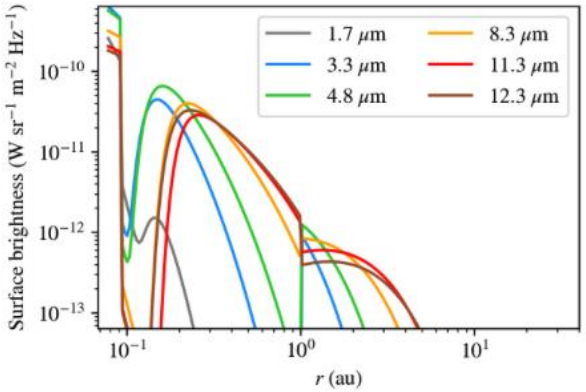
Correlated flux
absorption

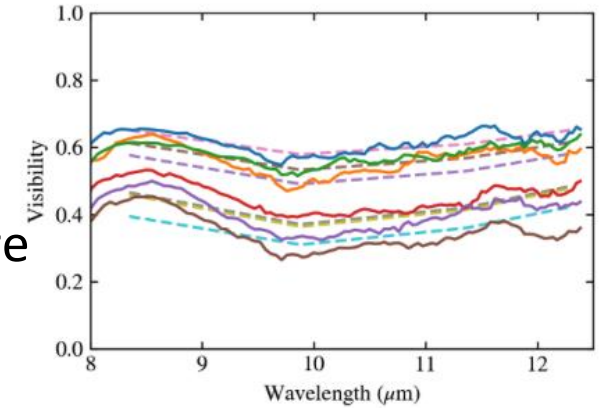
Closure phase
azimuthal asymmetry

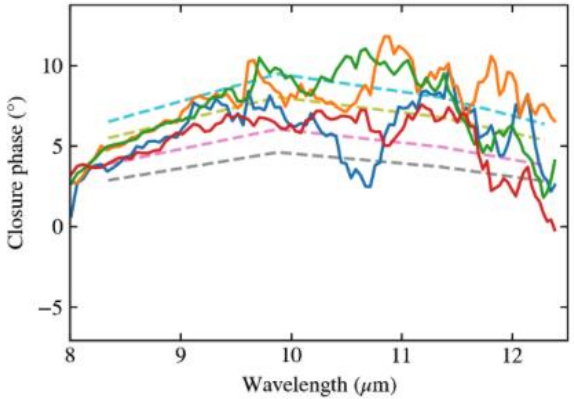
Three-zone thermal gradient model







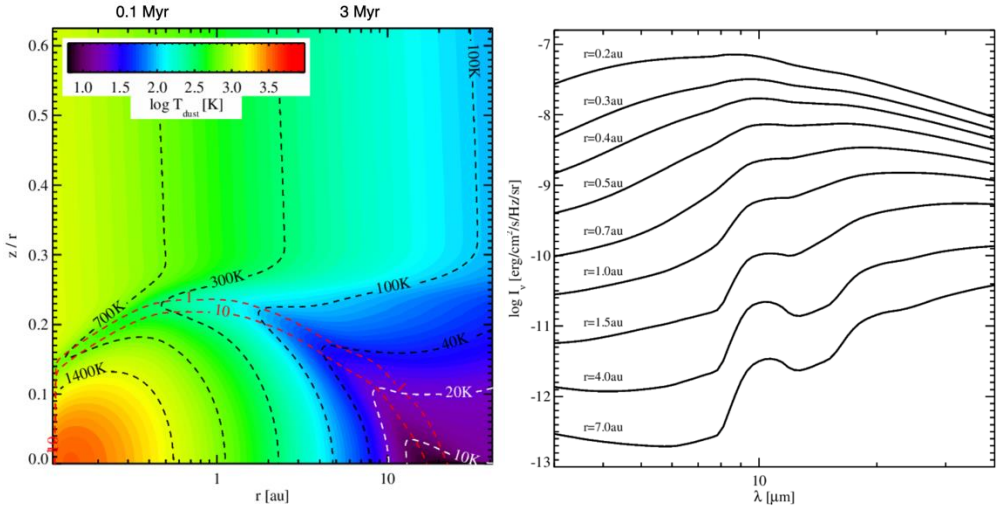


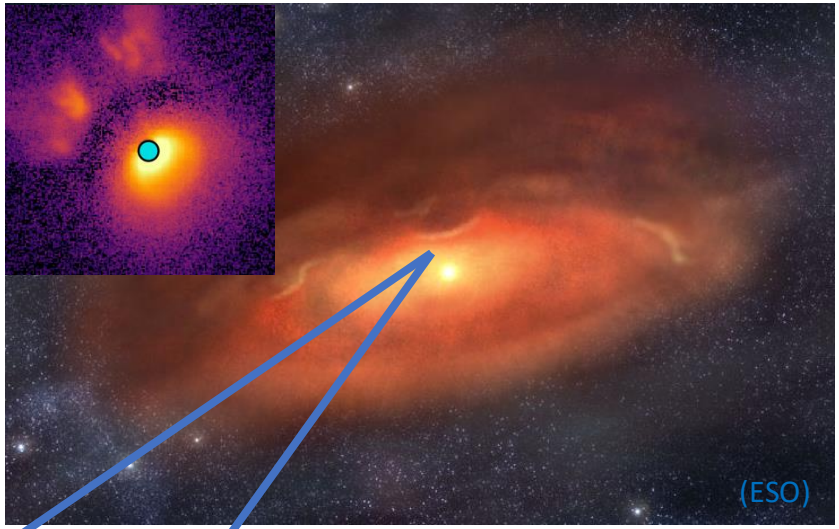


- **Inner zone**: amorphous silicates, absorption feature
- **Outer zones**: crystalline silicates, emission feature

(Varga et al. in prep.)

Origin of absorption in the inner zone

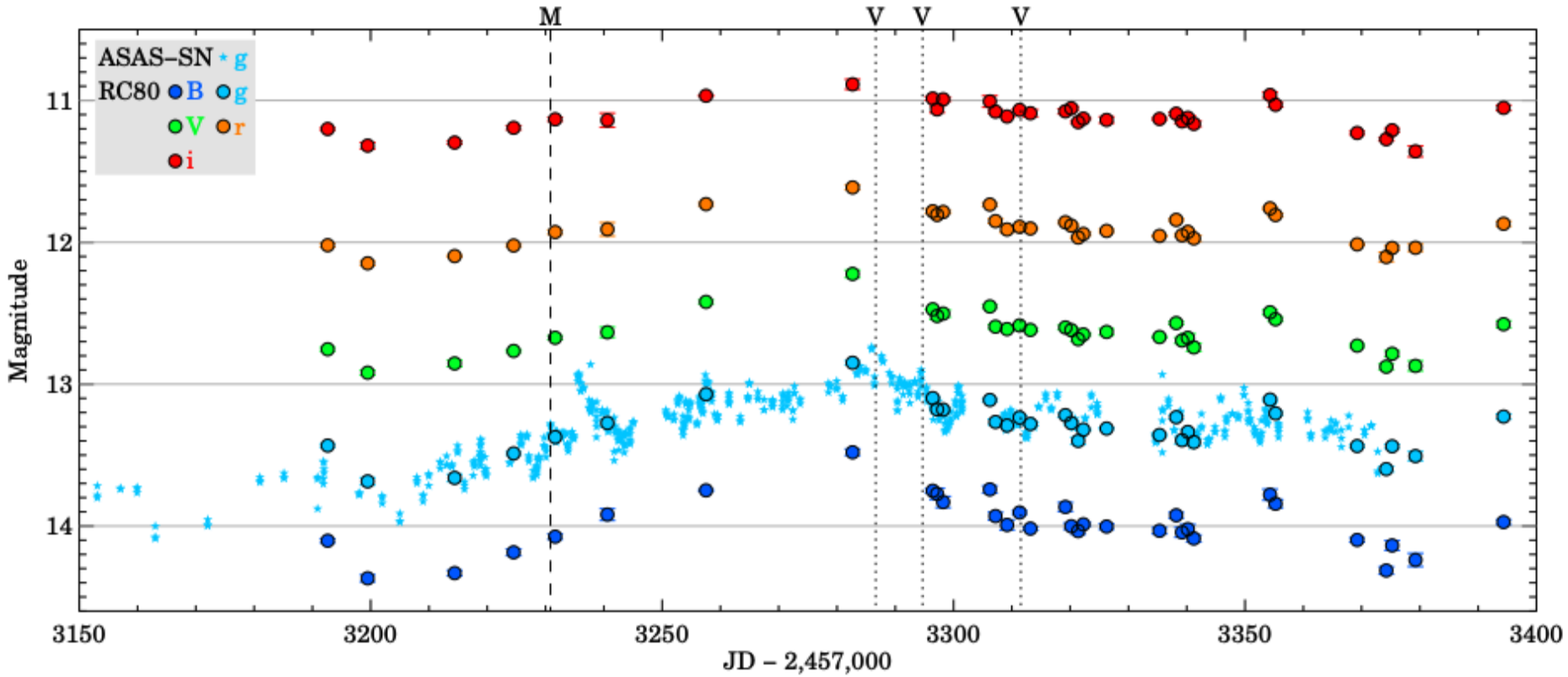




Temperature inversion: hotter midplane, colder disk surface (P. Woitke ProDiMo modeling)
→ no absorption

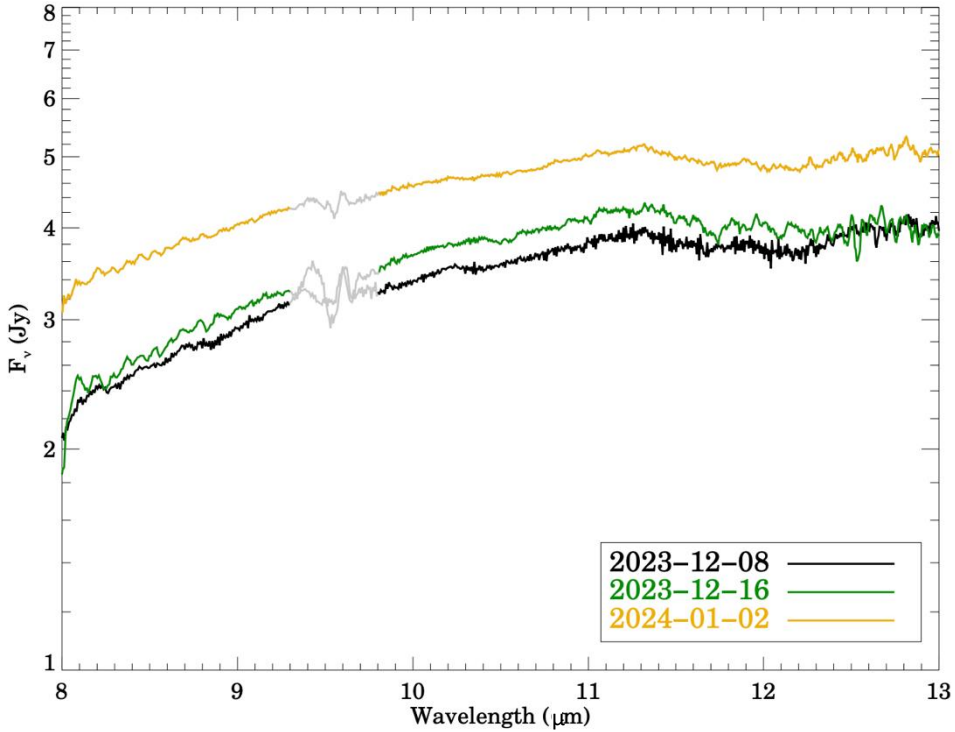
Dust cloud: obscures the 10 μm-emitting region but not the star (otherwise we would see A_V > 10 mag)

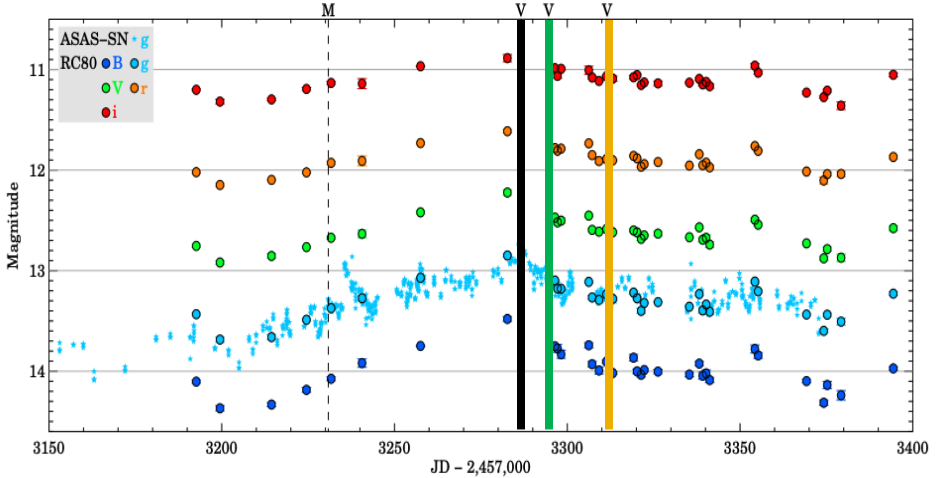
Optical variability of DG Tau



Infrared variability of DG Tau

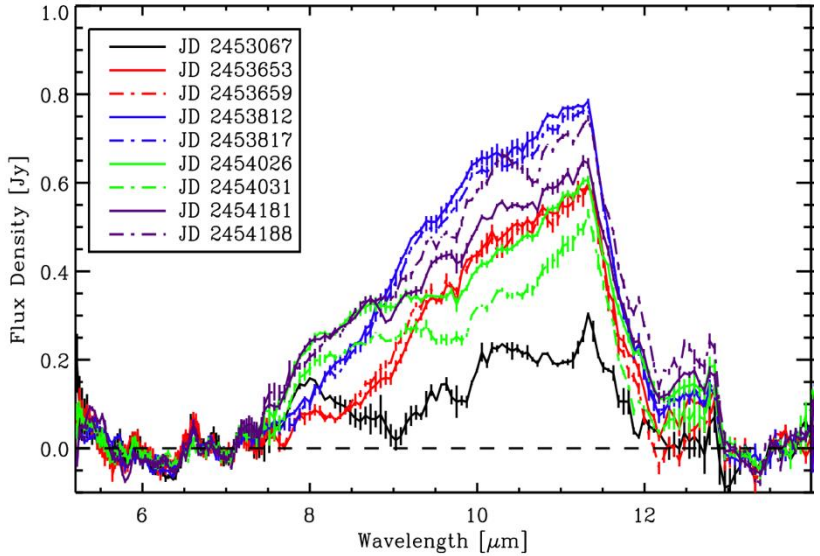
VLT/VISIR monitoring in 2023 Dec – 2024 Jan



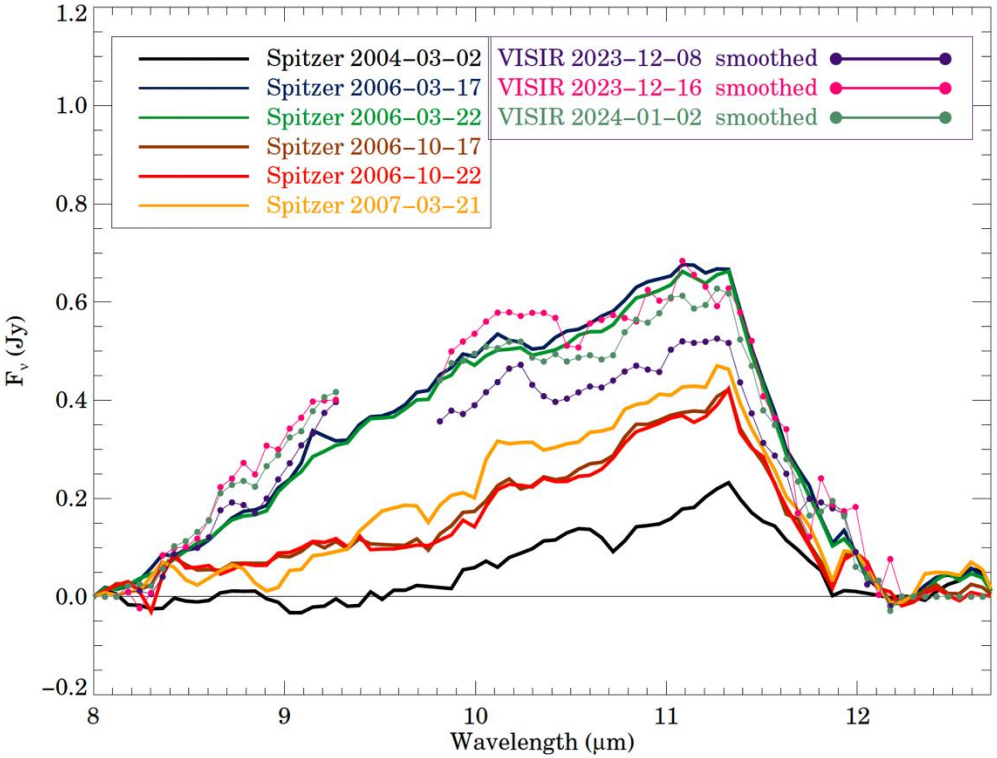


- **Large 10 μm variability**
- **Anti-correlation** between optical and 10 μm flux variability → shadowing?

Infrared variability of DG Tau



(Bary et al. 2009)

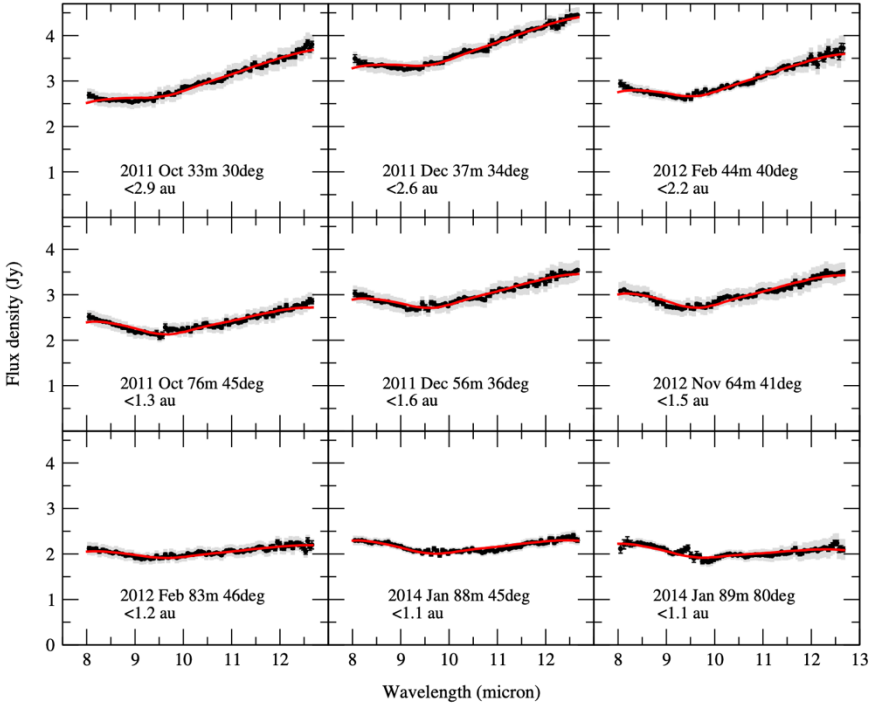


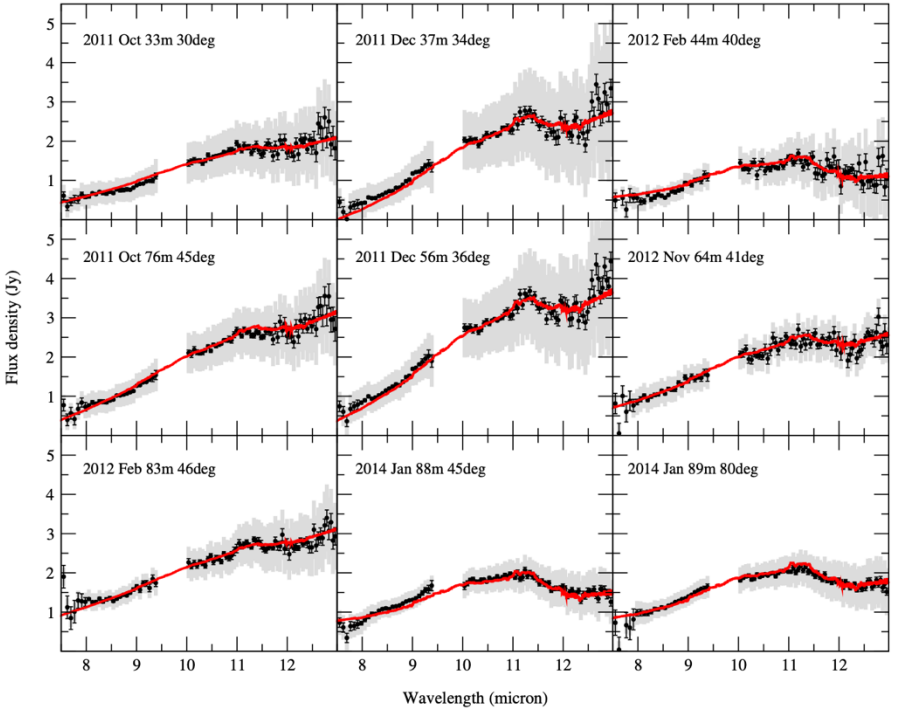
(Varga et al. in prep.)

- Highly variable strength of the 10 μm silicate feature

Multi-epoch interferometric observations

VLTI/MIDI monitoring in 2011 – 2014 (Varga et al. 2017)



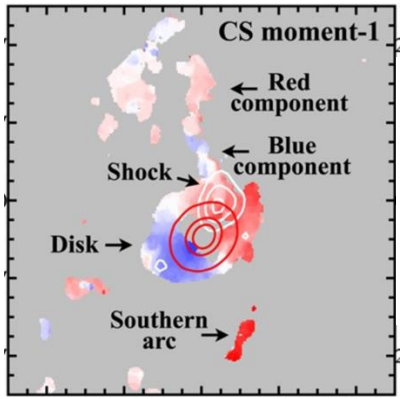


- Correlated flux: inner < 5 au region
- Approximately constant

- Uncorrelated flux: 5 – 10 au region
- Highly variable

Summary and future perspectives

- **Spatial structure:**
  - highly flared disk, MIR central absorption, crystalline ring
- **Spatially variable:**
  - density (3-zone model)
  - mineralogy (amorphous vs. crystalline)
- **Time variable:**
  - obscuring structures toward the star
  - variable illumination/shadowing of the disk
- **What are the connections between these structures?**
- **DG Tau** may become a laboratory for dynamical processes in planet-forming disks
- **Monitoring with VLTI/MATISSE would be very interesting!**



Hanawa et al. 2024: Cloudlet capture model for the accretion streamer onto the disc of DG Tau

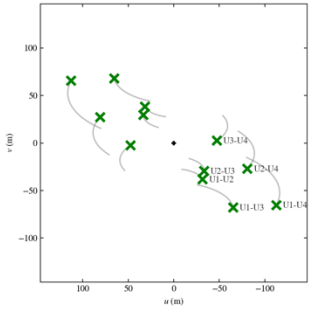
Spare slides

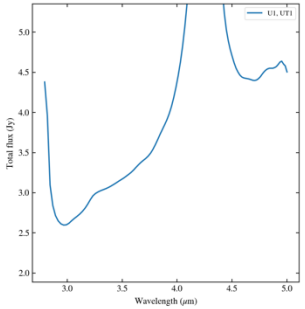
L – M bands

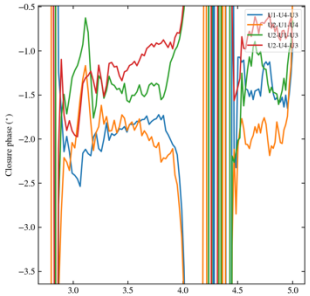
DG_Tau
date: 2019-12-09T05:53:12.1386
TPL start: 2019-12-09T05:33:52
SCI LM LOW -
U1-U2-U3-U4

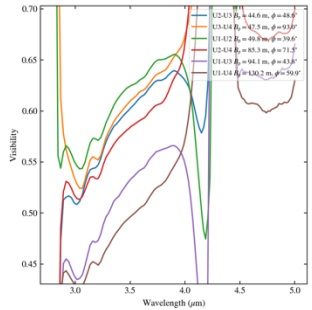
$\alpha = 66.7706^\circ$
$\delta = 26.1044^\circ$
MJD obs = 58826.24528
Seeing = 0.51″
τ_0 = 3.45 ms
PWV = 1.81 mm
Airm = 1.87
DIT = 111.00 ms

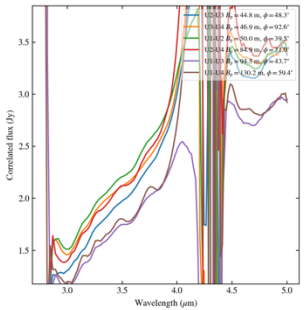
Cal. name : HD27482
Cal. Seeing = 0.40″
Cal. τ_0 = 3.38 ms
Cal. PWV = 2.25 mm
Cal. Airm = 2.21
Cal. TPL start : 2019-12-09T06:05:04
Cal. diameter = 2.28 mas
Cal. database : calib_spec_db_v10_supplement.fits

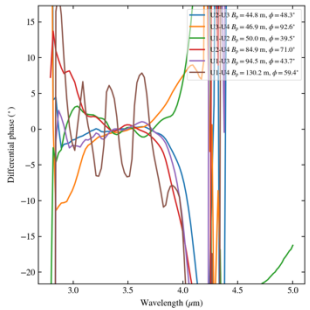


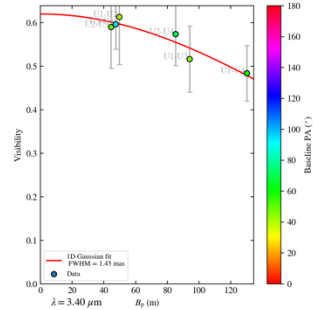


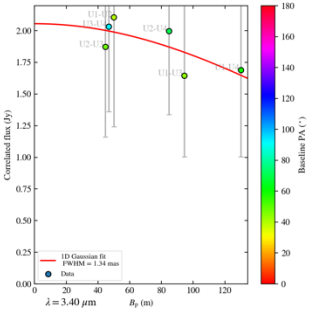










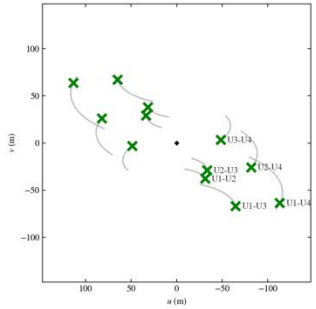


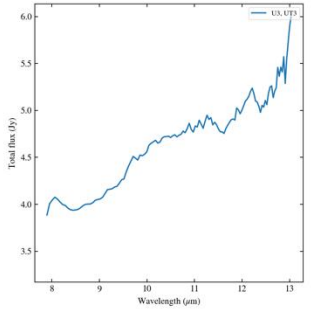
N band

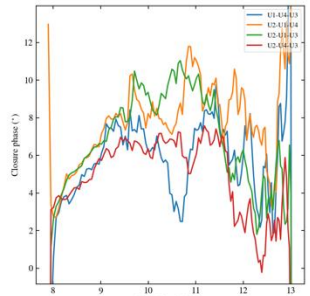
DG_Tau
date: 2019-12-09T05:41:42.2146
TPL start: 2019-12-09T05:33:52
SCI N LOW -
U1-U2-U3-U4

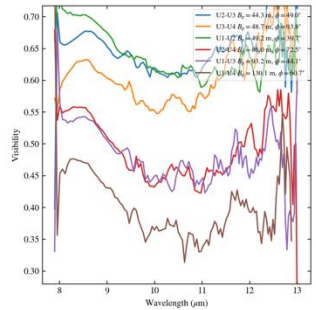
$\alpha = 66.7706^\circ$
$\delta = 26.1044^\circ$
MJD obs = 58826.23729
Seeing = 0.52″
τ_0 = 3.71 ms
PWV = 1.78 mm
Airm = 1.81
DIT = 20.00 ms

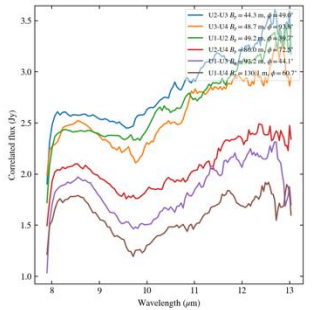
Cal. name : HD27482
Cal. Seeing = 0.46″
Cal. τ_0 = 5.69 ms
Cal. PWV = 1.83 mm
Cal. Airm = 1.76
Cal. TPL start : 2019-12-09T05:04:34
Cal. diameter = 2.27 mas
Cal. database : vBoekelDatabase.fitsold

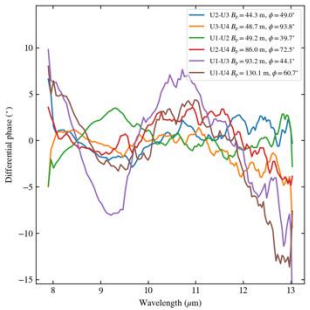


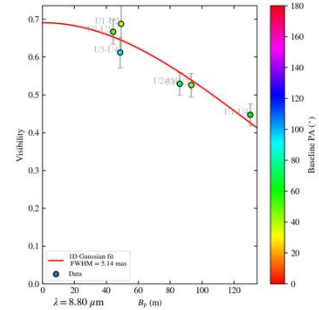


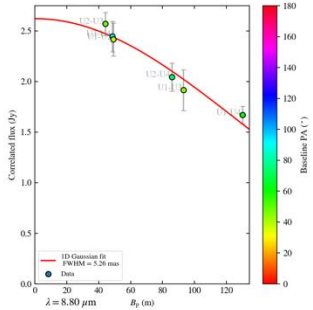




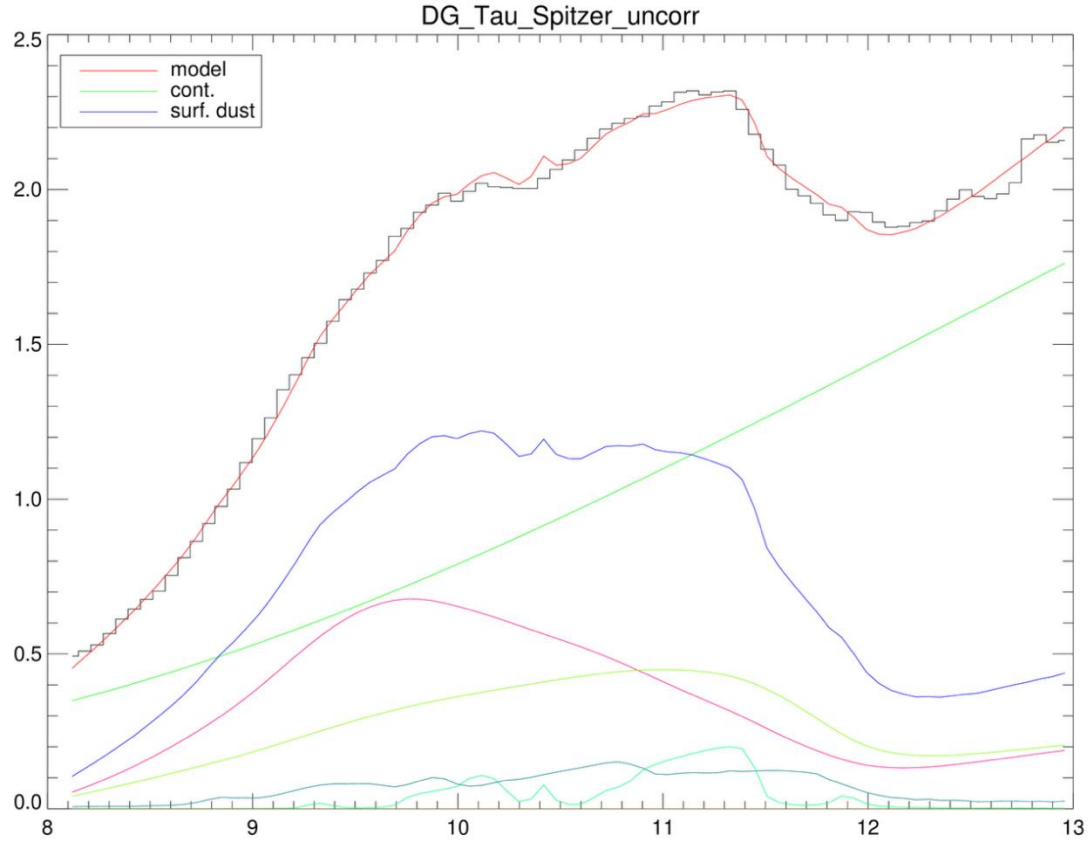








Mineralogical decomposition



SILICATE EMISSION

Amorphous silicates

Olivine 2.0 micron (4%)

Pyroxene 0.1 micron (46%)

Pyroxene 2.0 micron (37%)

Crystalline silicates

Forsterite 0.1 micron (4%)

Enstatite 2.0 micron (9%)

High crystallinity fraction!