Spatial distribution of warm dust around the Vega-type star HD 166191 after an asteroid collision

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& many others...

KONKOLY ESO MATISSE

Max-Planck-Institut für Radioastronomie · Astrophysik Kiel · Max-Planck-Institut für Astronomie Heidelberg · LAGRANGE

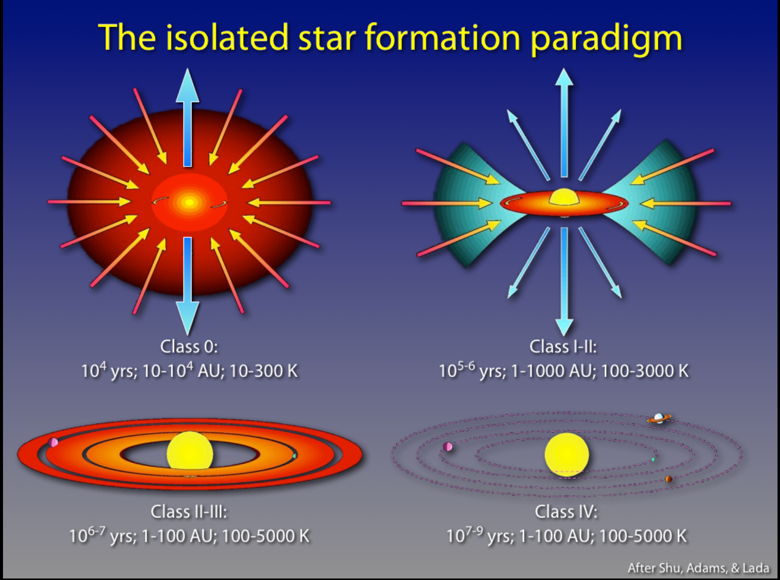


Figure Courtesy: Mark McCaughrean

Figure Courtesy: NASA/JPL-Caltech

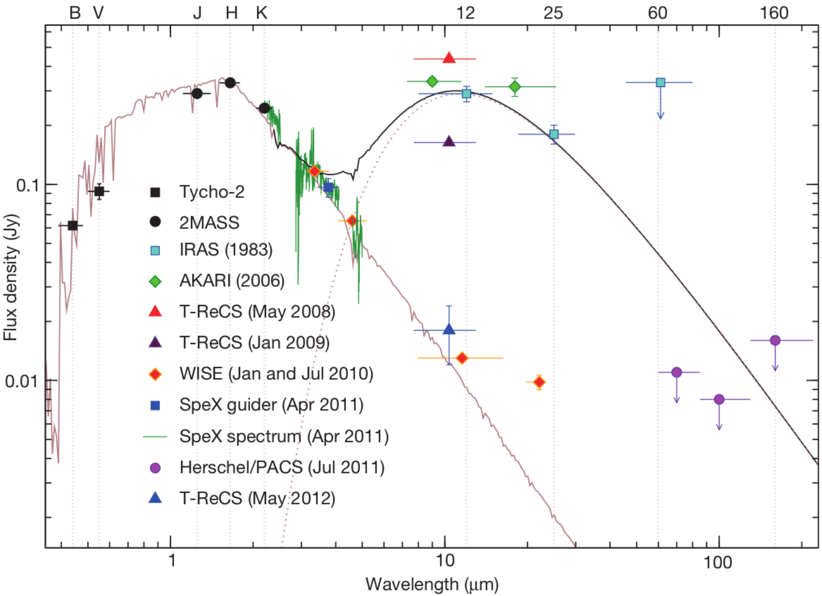
Giant impacts

- Giant impacts between the planetary embryos play an important role in rocky planet formation (e.g., Chambers & Wetherill 1998).
- A prominent example: The giant impact hypothesis of Moon formation (Canup 2004, 2012).
- Study of exosolar giant impacts helps in understanding the formation of planetary system like Solar system.

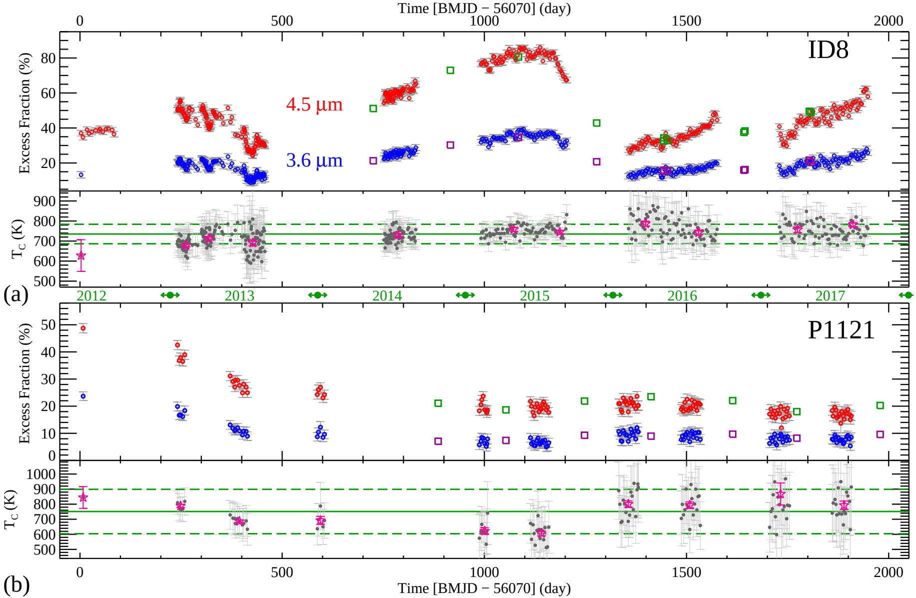
Figure Courtesy: NASA/JPL-Caltech

Extreme debris discs

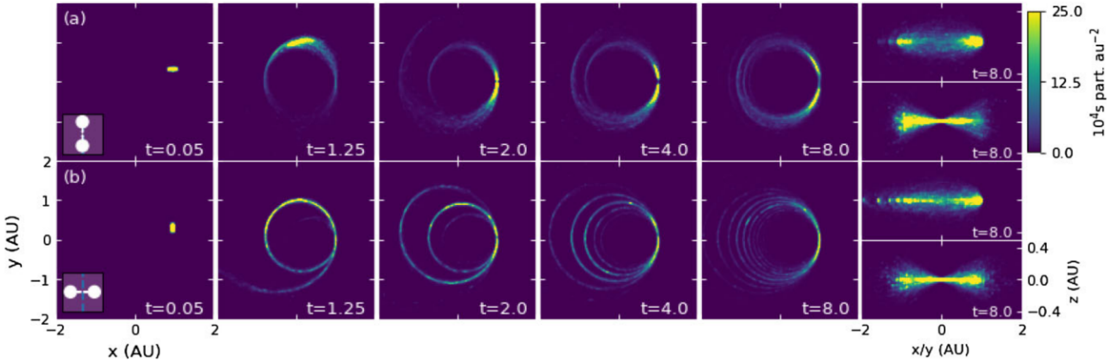
- $T > 400$ K
- $f_{\rm dust} > 1\%$
- Yearly variability (next page).
- Understood as secondary dust at $< \sim 1$ au.
- Analog to the hypothetical "giant impact" that creates the Earth-Moon system.
- Dust evolution within human timescale.



TYC 8241 2652 1 (Melis+ 2012)



ID8, P1121 (Su+ 2019)



Dust evolution after an impact event (Lewis+ 2023)

- Clump created in a impact event
- Azimuthal spreading due to velocity dispersion

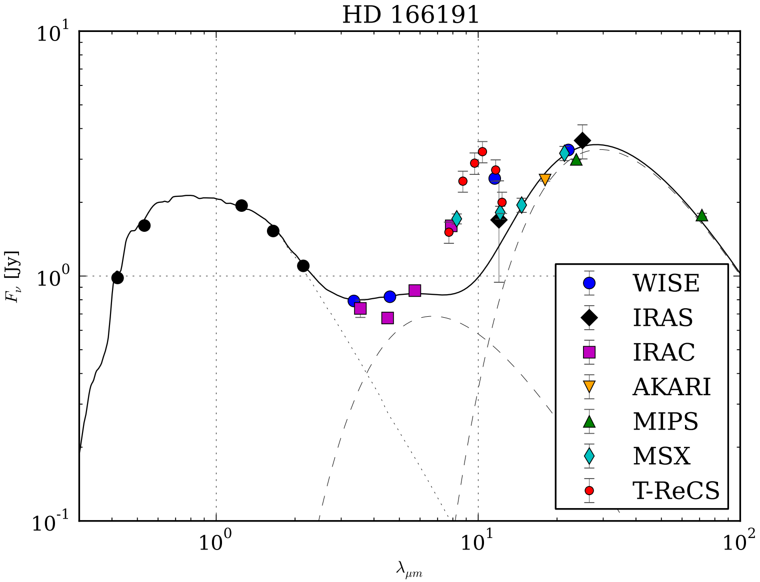
Here we report multi-epoch MATISSE observations of HD 166191, aiming at resolving the post-impact asymmetric dust distribution, and its temporal evolution.

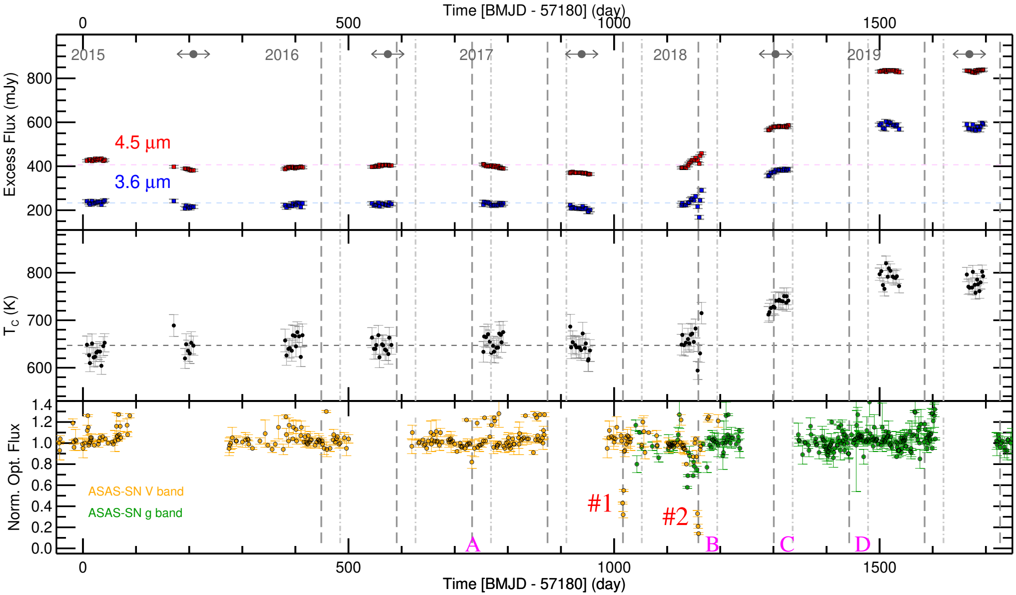
HD 166191

- Spectral type: F8
- $\sim$ 100 pc
- $\sim$10 Myr
- Double debris rings (Schneider+ 2013)
- warm dust at $\geq$0.3 au ($\geq$3 mas)
- Impact event in 2018!

A perfect target for post-impact study.

- Bright ($\sim$1 Jy in L band)
- Large angular size.





HD 166191: Brightening in Spitzer bands and in optical (Su+ 2022)

Su+'s interpretation: Asteroid collision at 0.6 au; clump on an edge-on orbit.

Aim of our MATISSE observations:

- Resolve the inner warm dust with L-band data.
- Constrain the size and inclination (the transits!)
- Detect the asymmetry
- Study the temporal evolution
- N-band data is “bonus”.

After the 2018-2019 brightening event of HD 166191 is reported (2019 Aug).

Epoch 1 2019-09-18 (DDT)
Closure phase signal!
Encouraging further observation.

Epoch 2 2021-08-23

Epoch 3 2023-03-15
(GTO; AT; GRA4MAT)

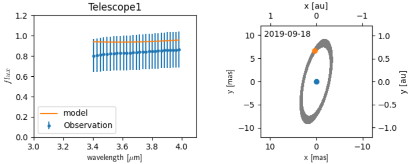
Epoch 4 2023-05-09 (GTO; UT)

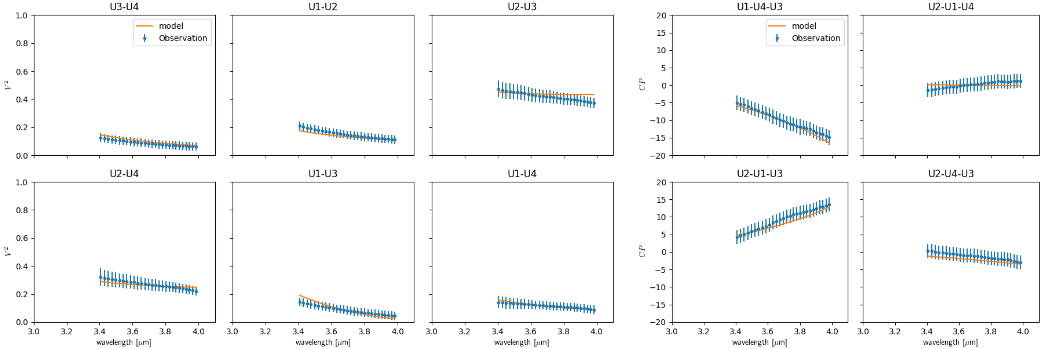
Epoch 5 2023-08-30

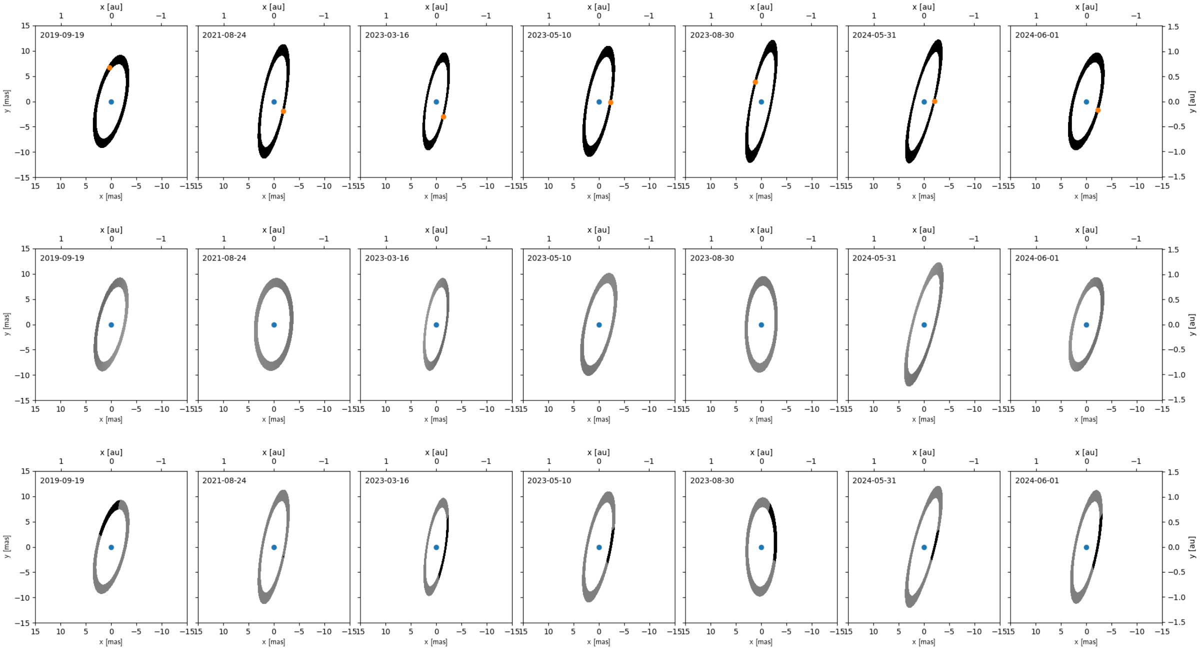
Epoch 6 2024-05-31

Epoch 7 2024-06-01

- Epoch 1 (2019 Sep).
- Obs in LMN bands. Only L-band shown here.
- Model includes: star + ring + clump.
  Other model types tried: star + modulated ring, star + ring + arc.







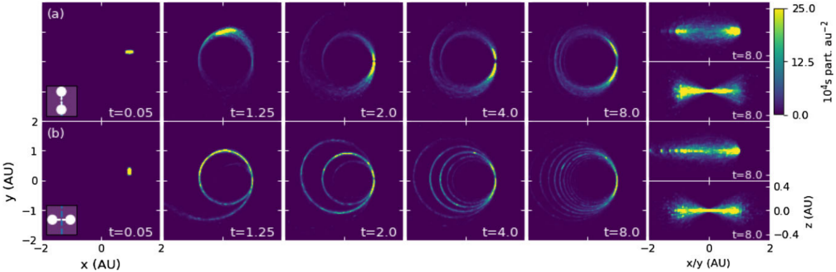
2019-09-19
2021-08-24
2023-03-16
2023-05-10
2023-08-30
2024-05-31
2024-06-01
x [au]
y [au]
x [mas]
y [mas]

Robust messages

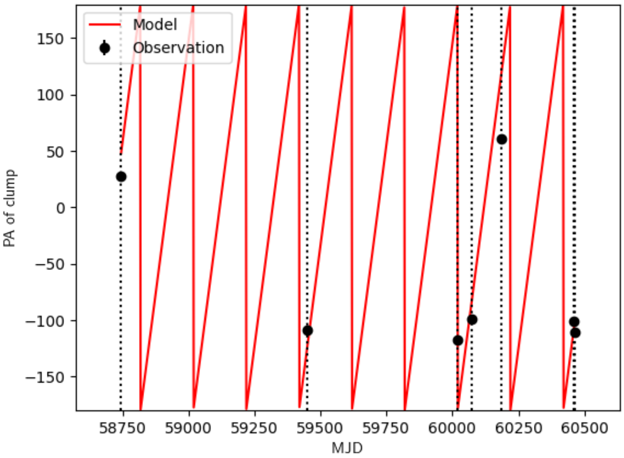
- Almost constant ring. With $r = 9$–10 mas, $i = 70$–$80°$, $PA = 75$–$85°$
- A "bright spot" with azimuthal motion.
- High inclination consistent with the transits.
- Large ring size → small grains.
- Asymmetry weakens fast → constraints on collision parameters.

Ambiguity/degeneracy in the modeling

- Cannot constrain the detail of morphology of the "bright spot". Is it a compact point-like source, or smoother, azimuthally extended?
- Related to the limited uv-coverage.
- We want imaging!

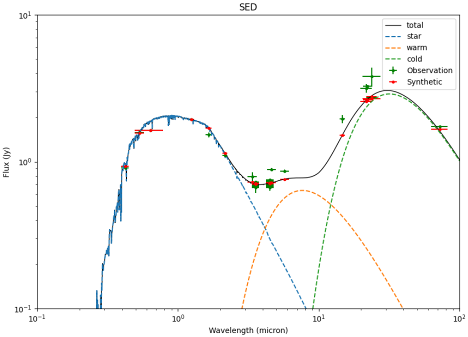


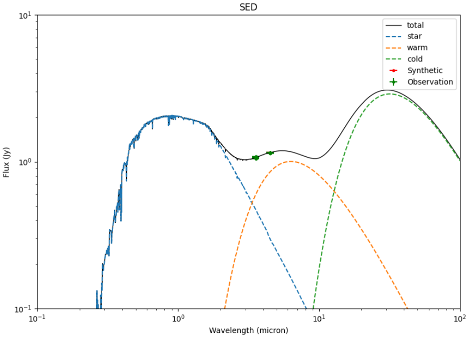
- Is the azimuthal motion of the "bright spot" consistent with Keplerian motion?
- Fitting of PA with a constant angular velocity: $P \sim 200$ d, counterclockwise. Not consistent with Keplerian velocity ($\sim$300 d).
- True distribution might be more complex: Combination of RT effect (stationary asysmmetry along minor axis) and dust asymmetry (moving), which could not be reliably modeled with our limited data set.
- RT effect for optically thick case (mentioned in several other talks): Asymmetric brightness distribution even when dust distribution is axis-symmetric.
  Is the warm dust opt. thick?



Pre-impact: $f_{\mathrm{warm}} = 3.4\%$.

Post-impact: $f_{\mathrm{warm}} = 6.5\%$.

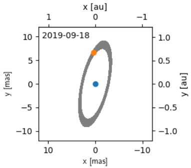


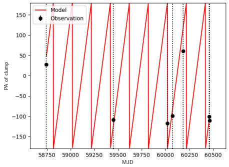


HD 166191 might have at least $\tau \sim 1$.

Take-away message

- Constant, inclined ring.
- Radius ~ 1 au
- Asymmetric and variable distribution.
- Constraints on collision parameter (via dynamical simulation)
- Multi-epoch interferometric observation has the potential of tracking the temporal change of dust distribution.





Outlook

- Imaging of HD 166191.
- Analysis of N-band data?
  Structure of outer disk.
  Minerology (inner and outer disk).
- While cold outer debris disk also has asymmetric, complex structure, they are roughly static on human timescale. Inner warm dust (extreme debris disks) might have dramatic change in spatial distribution in several years, providing an opportunity for study of structure evolution.
  $\rightarrow$ More observation on EDDs!

Thank you!