Resolved mm-Wavelength Observations of the HD 181327 Debris Disk

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The presence of debris disks around young main sequence stars hints at the structure of hidden planetary systems, with any deviations from axisymmetry pointing toward interactions among planetesimals. Previous HST observations of the HD 181327 debris disk show an asymmetry in scattered light , which has multiple explanations that depend on the size of the grains in the asymmetry. We present ALMA 1.3 mm observations of HD 181327 that are sensitive to large grains and will allow us to discriminate between the possible explanations for the azimuthal variation.

Debris disks

Debris disks are analogous to the Solar System during the Late Heavy Bombardment. The disk is revealed in the spectral energy distribution (SED) by the presence of excess flux at long wavelengths (see Figure 1). Spatially resolved observations disambiguate the dust temperature and location, and can potentially reveal structures caused by dynamical processes involving planetesimals. Millimeter-wavelength observations probe large grains that are impervious to radiation pressure and are instead sensitive to gravitational forces. Thus, *these observations provide dynamical information.*

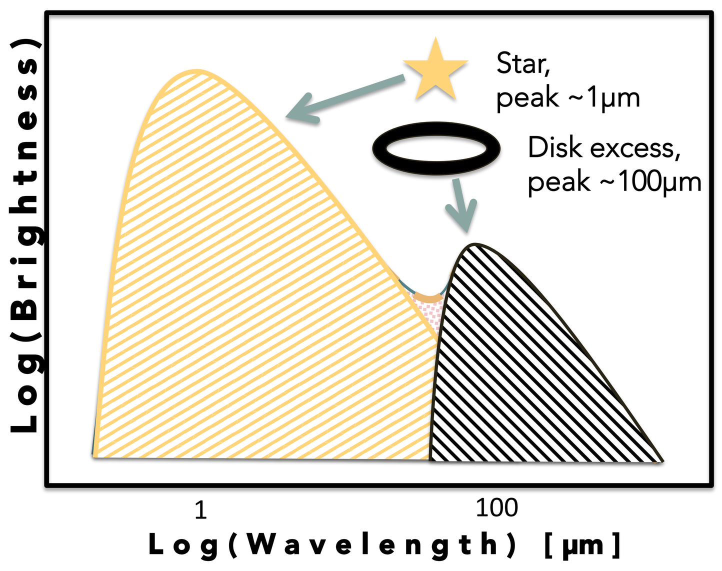


Figure 1: A representation of the spectral energy distribution of a star with a debris disk (log-log). The star's contribution to the brightness is shown in yellow, while the disk dominates at longer wavelengths, shown in brown.

The asymmetry of the HD 181327 disk…

…in scattered light.

HST STIS observations show an asymmetry in the HD 181327 disk. Extensive analyses showed that it was not caused by observational effects.

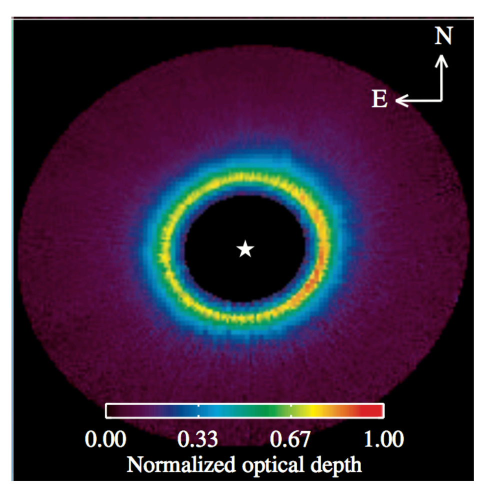


Figure 2: The normalized optical depth showing the scattered light asymmetry of HD 181327. The panel shows the illumination-corrected surface brightness divided by the best-fit scattering phase function map (Stark et al. 2014).

…at mm-wavelengths?

Do larger grains show the same asymmetry seen in the scattered light observation?

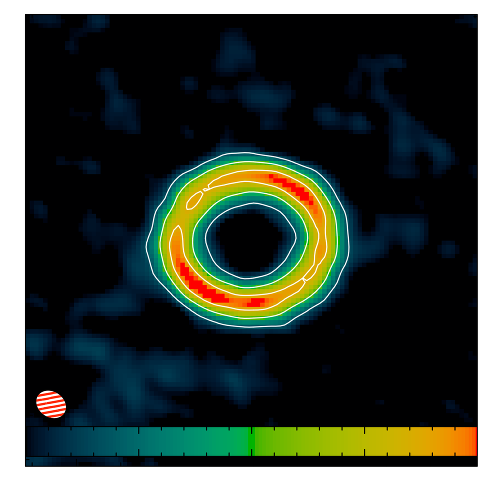


Figure 3: The ALMA 1.3 mm image of HD 181327. Contours are drawn at 3, 9, 15 x RMS (Jy/beam). The red dashed oval is the synthesized beam.

…and MCMC modeling.

To answer this question, we use ALMA data of the disk at 1.3 mm and model the visibilities with an axisymmetric disk.

Useful bits

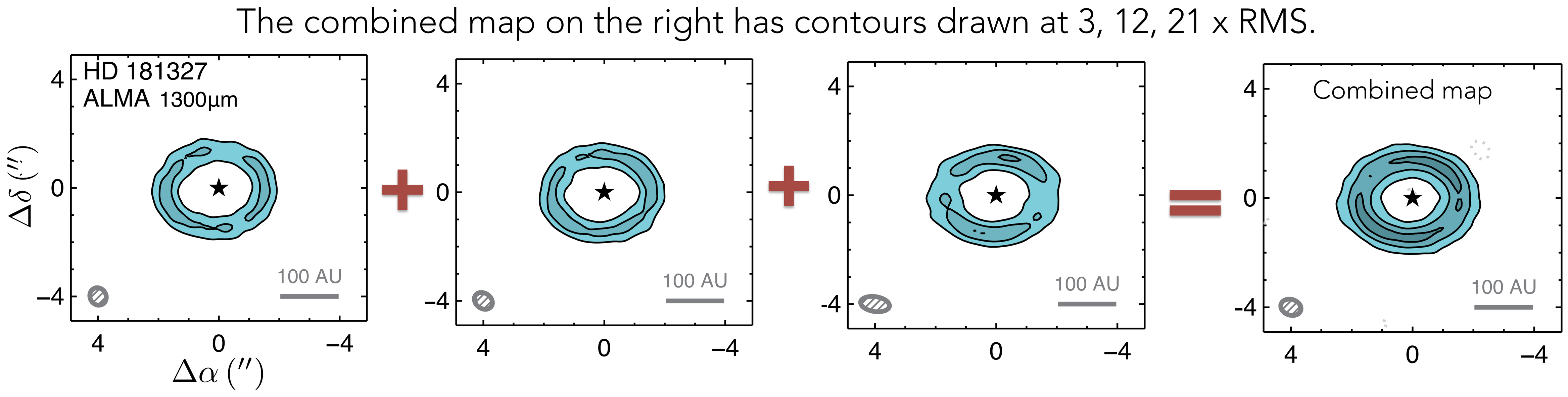
Axisymmetric – radial or rotational symmetry

– the synthesized beam shape, or the interferometer's response to a point source; like the PSF

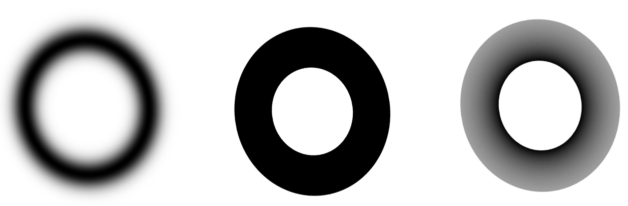
MCMC – Monte Carlo Markov Chain algorithm, i.e. a Bayesian method of fitting

The Data and Modeling

We show 3 observation blocks of the ALMA data of HD 181327 below. Contours are drawn at 5, 11, and 17 x RMS noise. The star displays the position of HD 181327. The oval shows shape of the synthesized beam. The combined map on the right has contours drawn at 3, 12, 21 x RMS.



Choose a model



Build a model disk at each step of MCMC and calculate χ^2

After finding a best fit, determine data – model and image residuals

HD 181327 stats

Spectral type	F5/6
Age	~23 Myr
Distance	51.8 pc
$L_{IR} / L_\star$	0.25%

Table 1: Properties of the debris disk host star.

Next Steps

We will model the dust distribution, quantify the degree of the asymmetry using a simultaneous SED + vis minimization approach (see Fig. 4), and finally, *determine what caused the asymmetry in the scattered light observations.* These steps will include a choice of grain composition and an exploration of 2-belt systems. Please stay tuned!

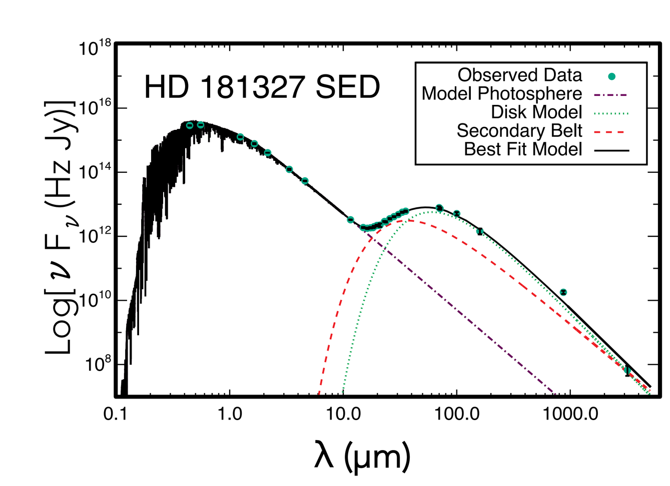
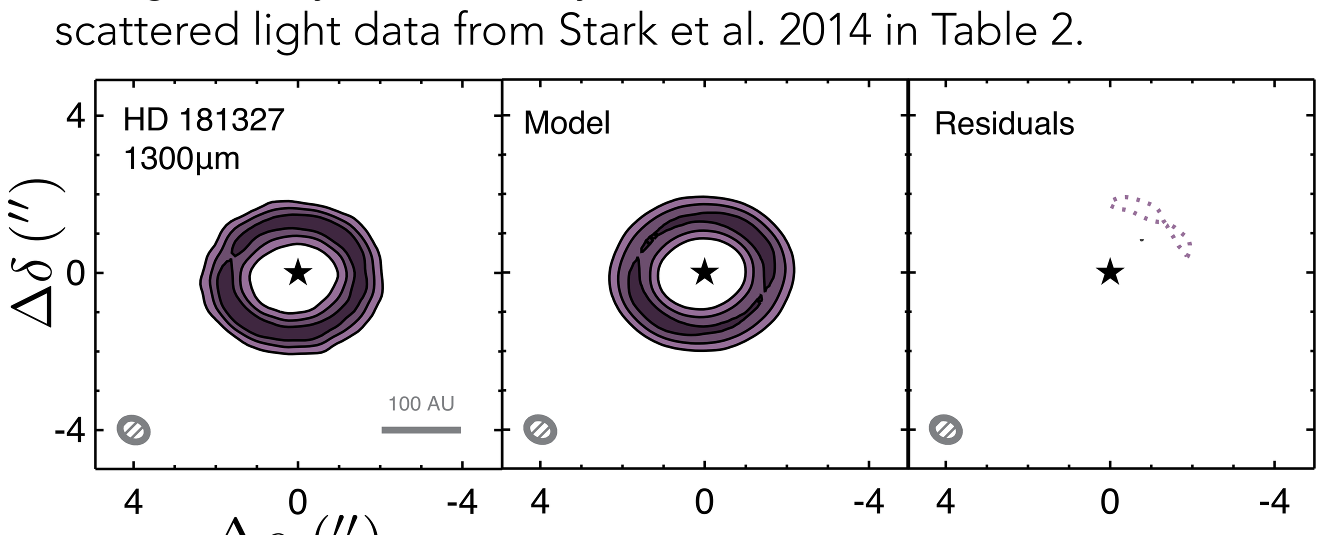


Figure 4: A first result of the SED + vis modeling on the SED.

Preliminary Results

We find that a constant surface density profile provides a good fit to the visibilities. The series of plots on the left show the data, model, and residuals (data – model), respectively, with a minimum contour at 5σ. We compare our preliminary fits of the geometry and density distribution of HD 181327 to the scattered light data from Stark et al. 2014 in Table 2.



Parameter	1.3 mm	Scattered light
R_{in} vs. a (AU)	67	82.3 ± 1.1
ΔR (AU)	40	–
PA (°)	77	98.5
inc (°)	30	30.3

Table 2: A preliminary comparison of the mm versus scattered light grain geometry. *The scattered light results are given for the innermost part of the ring. Additionally, we compare inner radius (mm) to the semimajor axis (scattered light).

Compared to the scattered light results, we find consistent inc angles, a slightly offset PA, and a smaller R_{in} (vs. semimajor axis), consistent with the presence of a 'birth ring'. Also, we do not see a strong asymmetry in the mm-data given our simple initial model.

References:
Steele et al. 2015, Stark et al. 2014, Mamajek et al. 2014, Lebreton et al. 2012, Schneider et al. 2006

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