Detailed Modeling of Dust Emission in the disk of HD 142527

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SUMMARY

Aim: The properties of dust grains in protoplanetary disks are underdetermined. As a case study, we aim at revealing the dust properties and distribution in the crescent disk surrounding HD 142527 by modeling.

Method: We use two-dimensional, axisymmetric disk models to reproduce the continuum emission at 890 μm from the disk of HD 142527 observed by ALMA during Cycle 0. Our model takes account of the dust scattering opacity and the disk geometry. We use two opacity models, **the conventional model** (conventional composition, homogeneous sphere, maximum grain size 1 mm) and **the reduced-scattering model**; the only different is **the latter being 90% smaller in scattering opacity**.

Results:

- The conventional model cannot reproduce the 890 μm continuum emission in the disk northwestern region; the model intensity reaches a ceiling lower than the observed value and it becomes insensitive to the increase in dust surface density due to the heavy scattering.
- With the reduced-scattering model, the emission is reproduced successfully in all azimuth direction, including the northwestern region.
- In the south region where the disk is optically thin, the best-fit parameters are found to be depending little on the scattering opacity.
- The contrast of dust surface density in the azimuth direction is derived to be about 40 in the reduced-scattering model, much smaller than that derived by the conventional model. which is 70 – 130.

Conclusion: The effective scattering might be lower than expected in protoplanetary disks.

Future Direction: Investigate the reason of low scattering, incorporate optical properties of porous dust aggregates, and perform multi-wavelength modeling.

1. INTRODUCTION

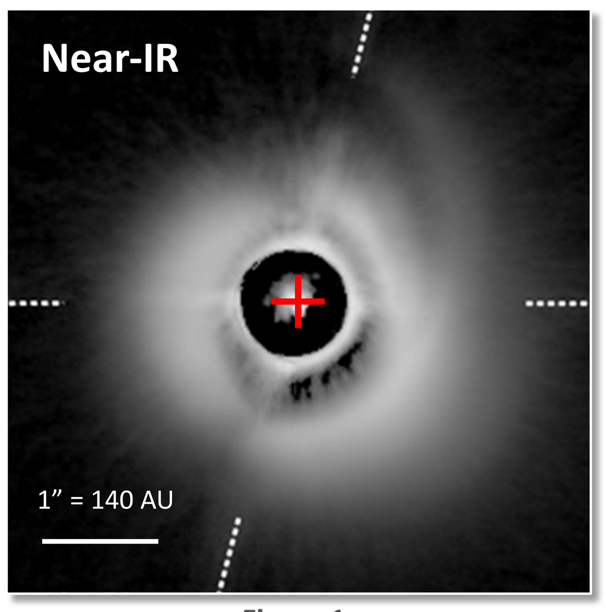

Figure 1:
1.6 μm, Fukagawa et al. 2006.

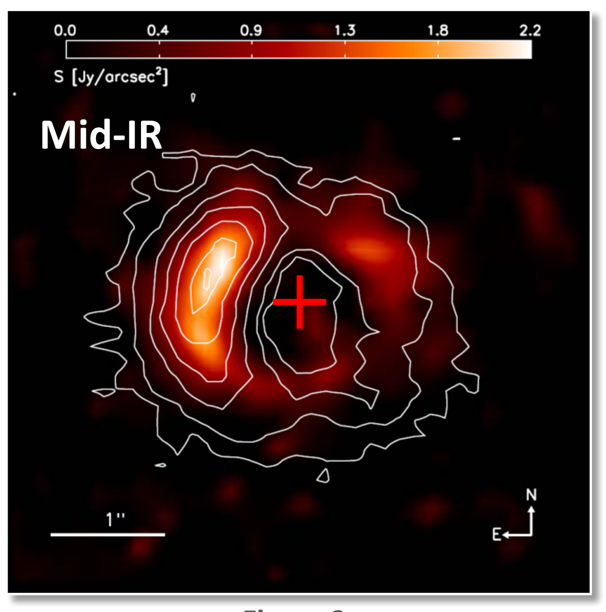

Figure 2:
18.72 μm (contour), 24.5 μm (color), Verhoeff et al. 2011.

- ❑ NE: far side, SW: near side
- ❑ Inclination: 27°
- ❑ Fit radial intensity profile with

$$I_{\rm obs}(r, PA') = I_{0,\rm obs} \exp\left[-\left(\frac{r_{\rm obs} - r_{0,\rm obs}}{w_{0,\rm obs}}\right)^2\right]$$

$$PA' = PA + 19°$$

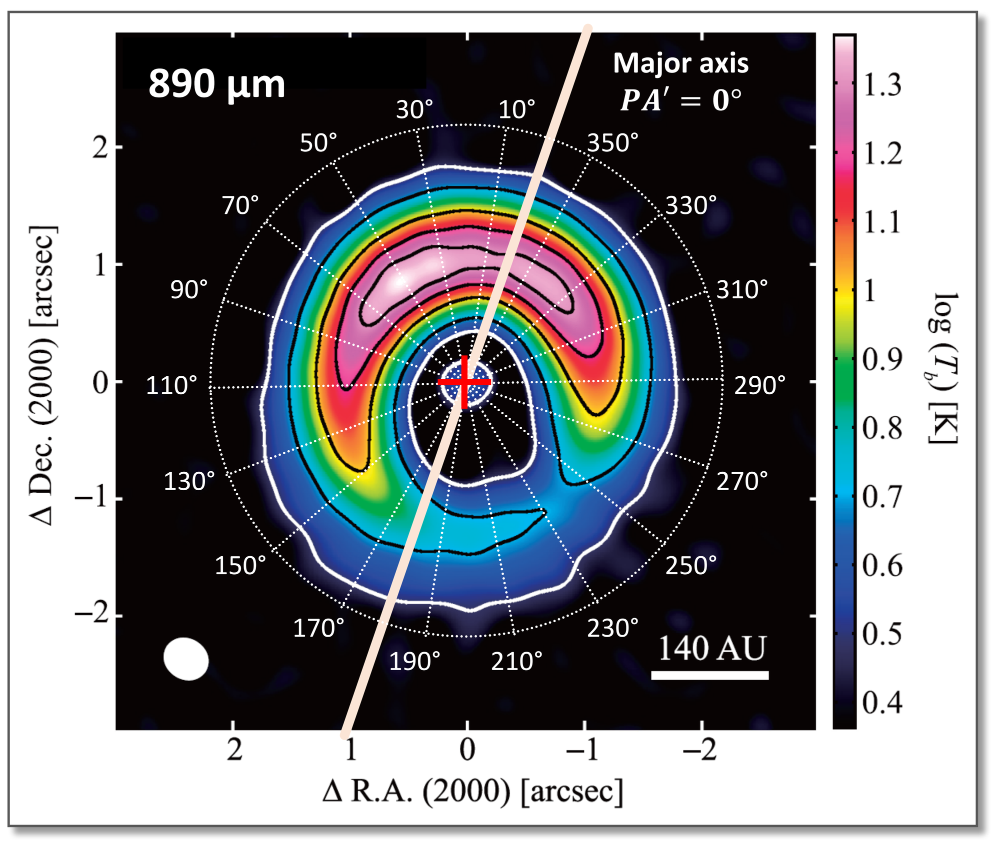

Figure 3:
890 μm continuum emission by ALMA Cycle 0, Fukagawa et al. 2013.

2. METHOD

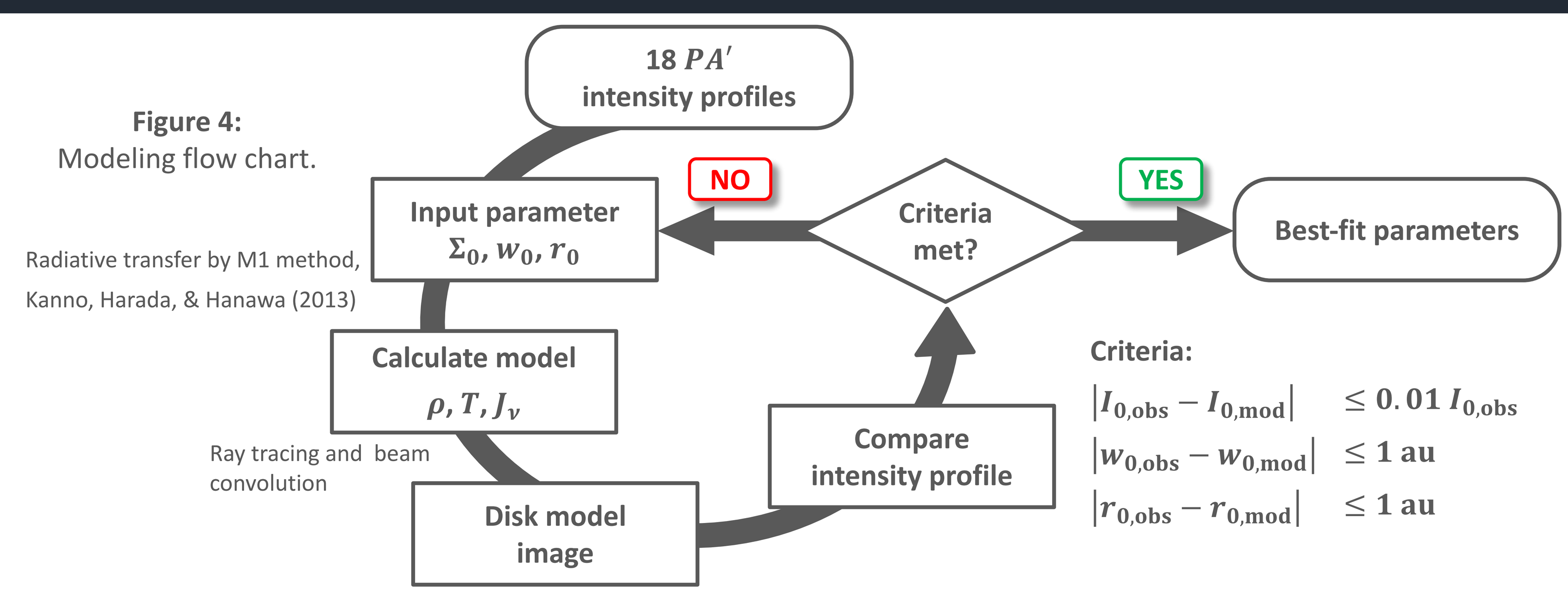

Figure 4:
Modeling flow chart.

Criteria:

$|I_{0,\rm obs} - I_{0,\rm mod}| \le 0.01\, I_{0,\rm obs}$

$|w_{0,\rm obs} - w_{0,\rm mod}| \le 1$ au

$|r_{0,\rm obs} - r_{0,\rm mod}| \le 1$ au

- ❑ 2D, axis and midplane symmetric, passive disk model in hydrostatic equilibrium
- ❑ Dust radial surface density:

$$\Sigma(r, PA') = \Sigma_0 \exp\left[-\left(\frac{r - r_0}{w_0}\right)^2\right]$$

- ❑ **Dust grains properties:**
  - compact sphere
  - silicate, carbonaceous compounds, water ice
  - solar elemental abundance
  - $n(a) \propto a^{-3.5}, a_{\rm max} = 1$ mm

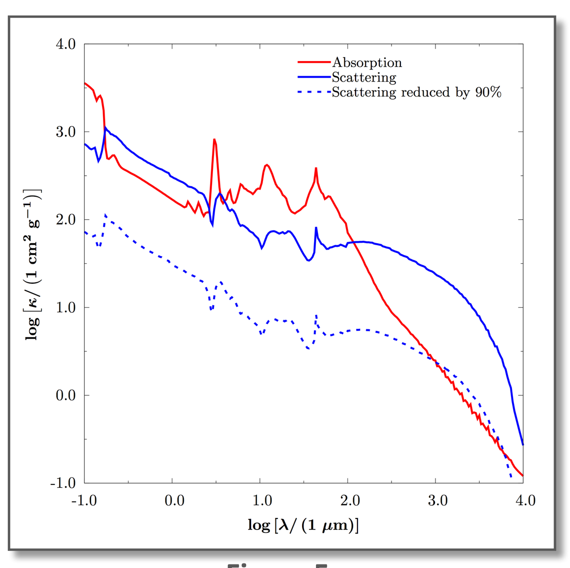

Figure 5:
Dust opacity, Aikawa & Nomura (2006).

$\Sigma_0 = 0.10$ g cm^{-2}
$w_0 = 27$ au
$r_0 = 175$ au
$\rho_0 = 1.3 \times 10^{-16}$ g cm^{-3}

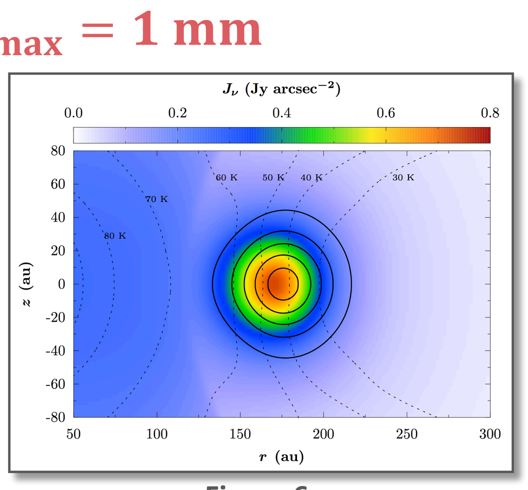

Figure 6:
Disk model example.

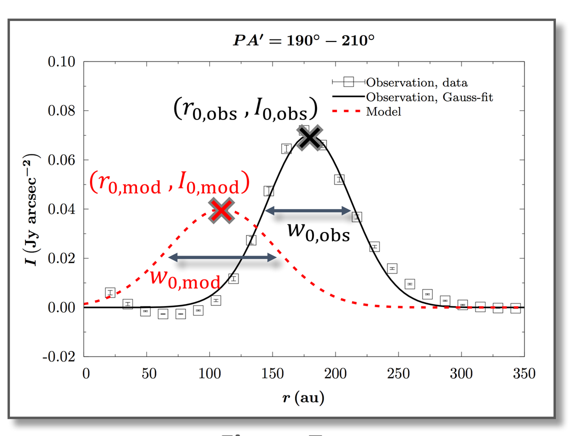

Figure 7:
Radial intensity profile example.

3. RESULTS

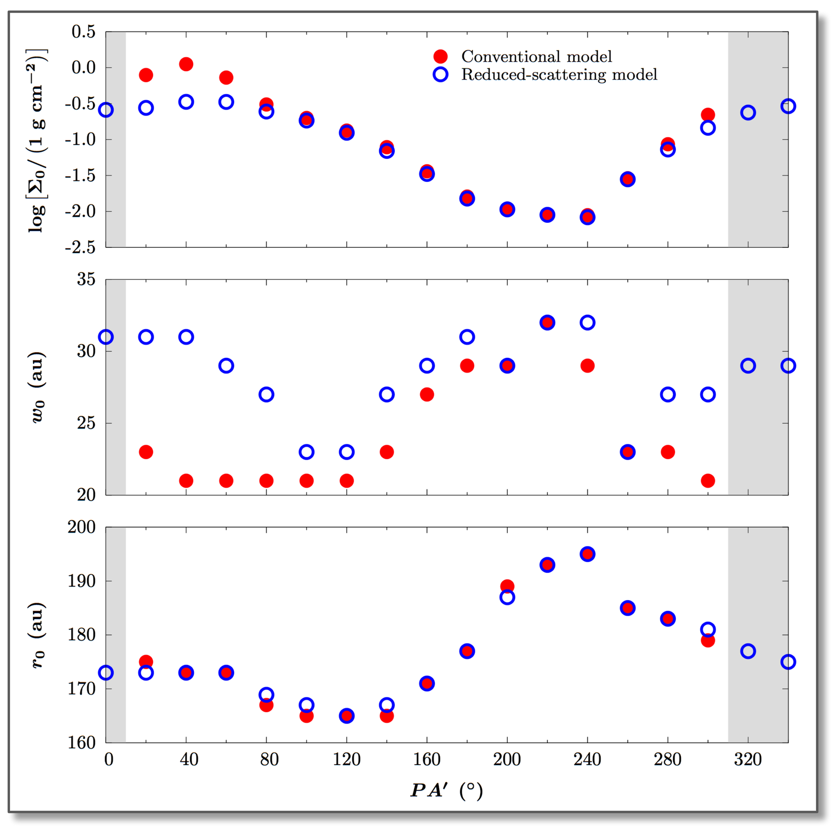

Figure 8:
Derived best-fit (Σ_0, w_0, r_0). The conventional model cannot reproduce the emission in $PA' = 310° - 10°$ (gray shaded region).

- ❑ **The conventional model cannot reproduce the intensity profiles in NW due to the heavy dust scattering.**
- ❑ The reduced-scattering model:
  - same κ_a, 90% smaller κ_s.
  - estimates smaller Σ_0, larger w_0 in optically thick northern region.

4. DISCUSSIONS

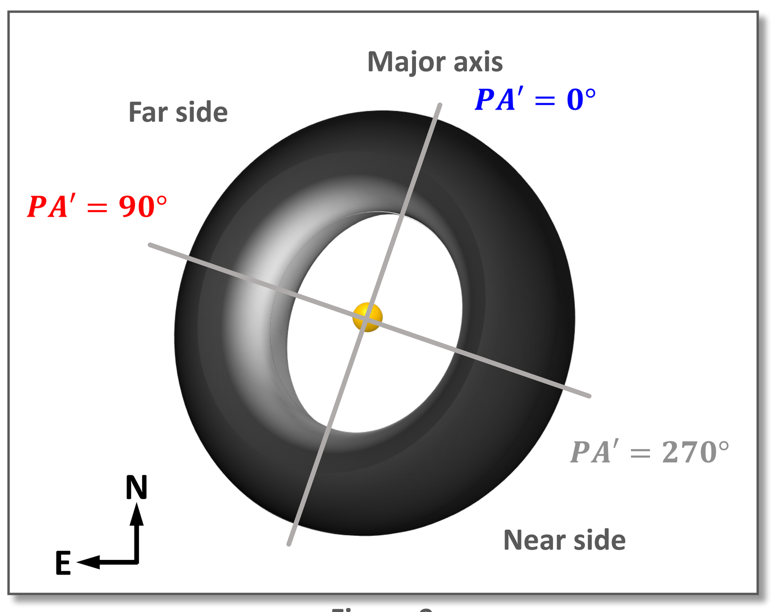

Figure 9:
Illustration of an axisymmetric, inclined, optically thick disk model.

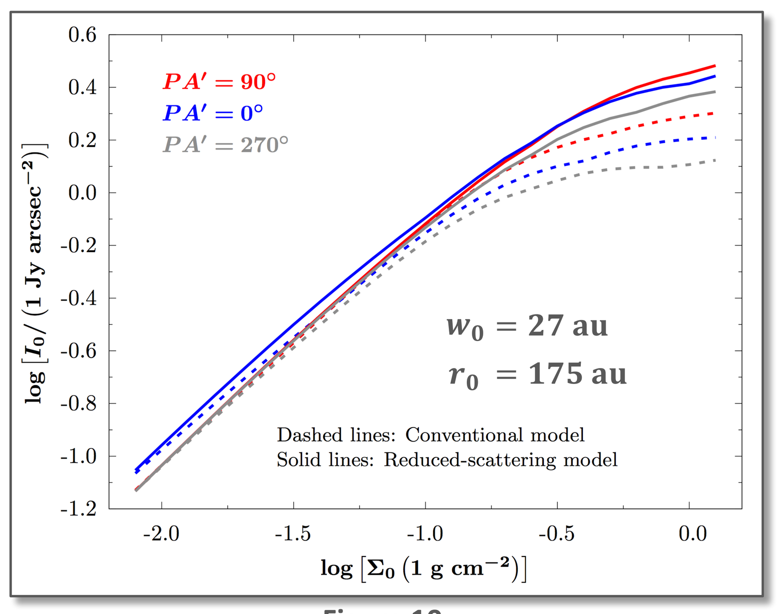

Figure 10:
Peak intensity against peak dust surface density, at different PA'.

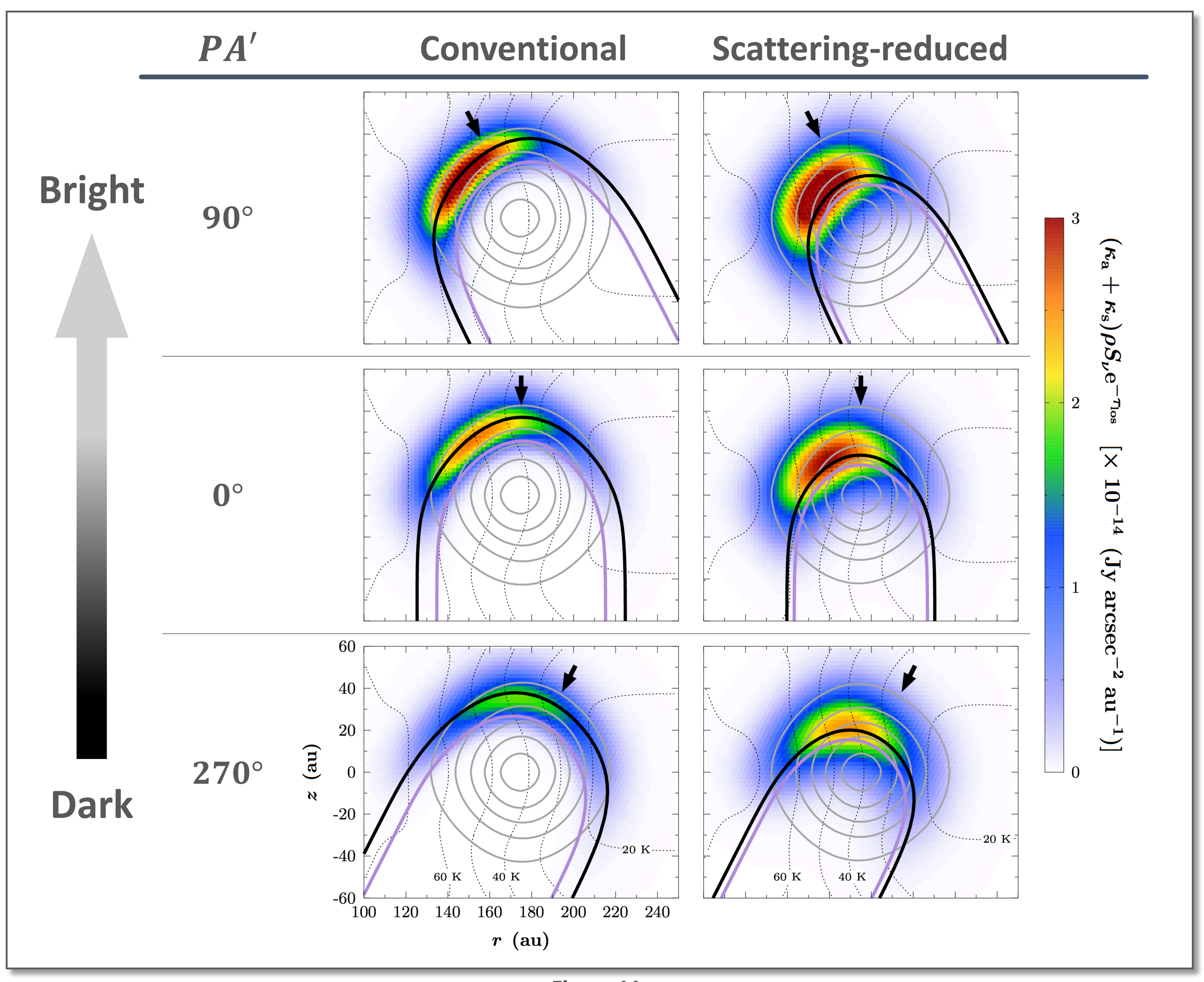

Figure 11:
The emission per unit length, $(\kappa_a + \kappa_s)\rho S_\nu \exp(-\tau_{\rm los})$. S_ν is the source function and $\tau_{\rm los}$ is the optical depth in the line of sight.

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