Impact of different radiative transfer prescriptions on the morphological structures of AGB outflows

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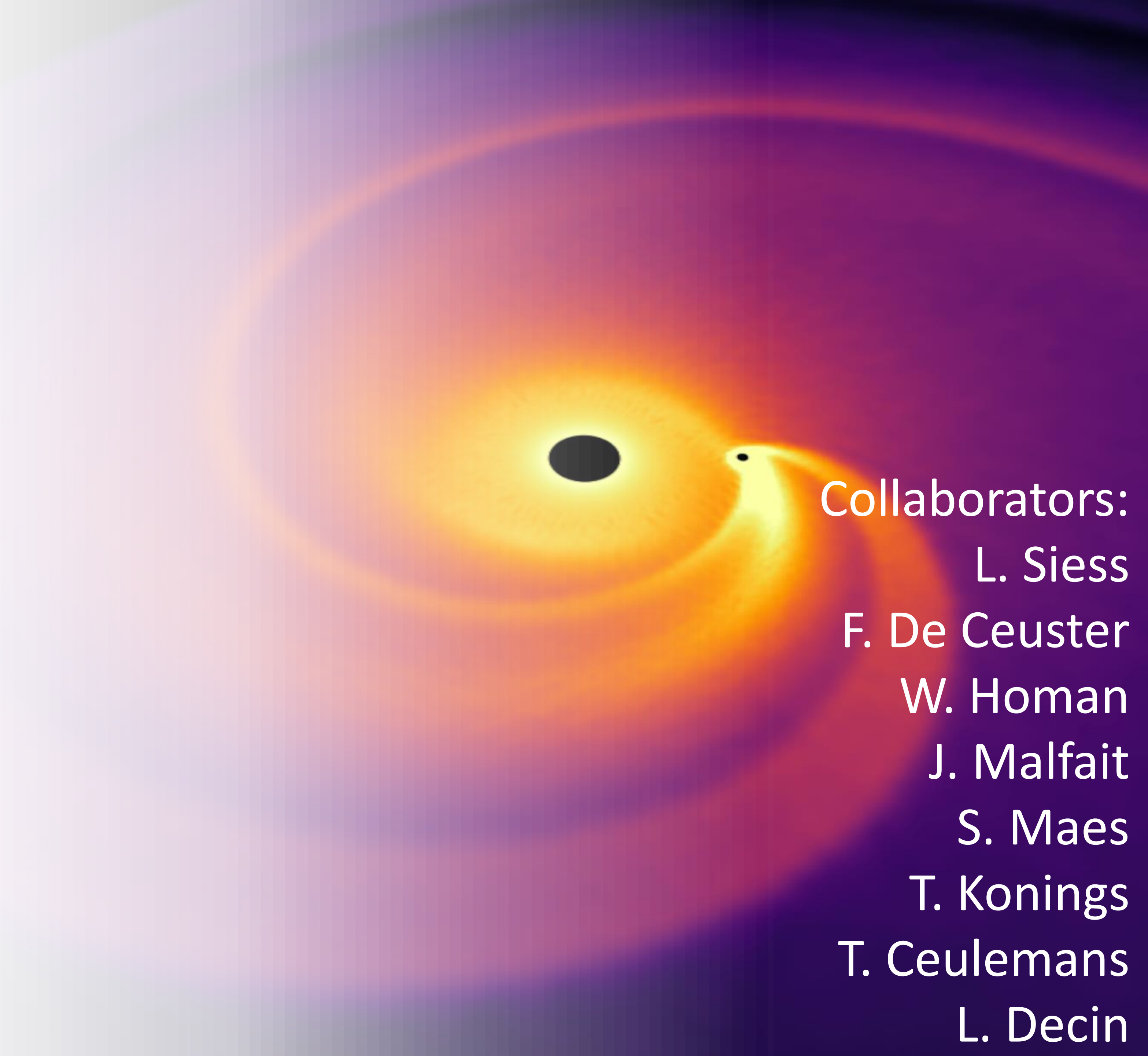

Collaborators:
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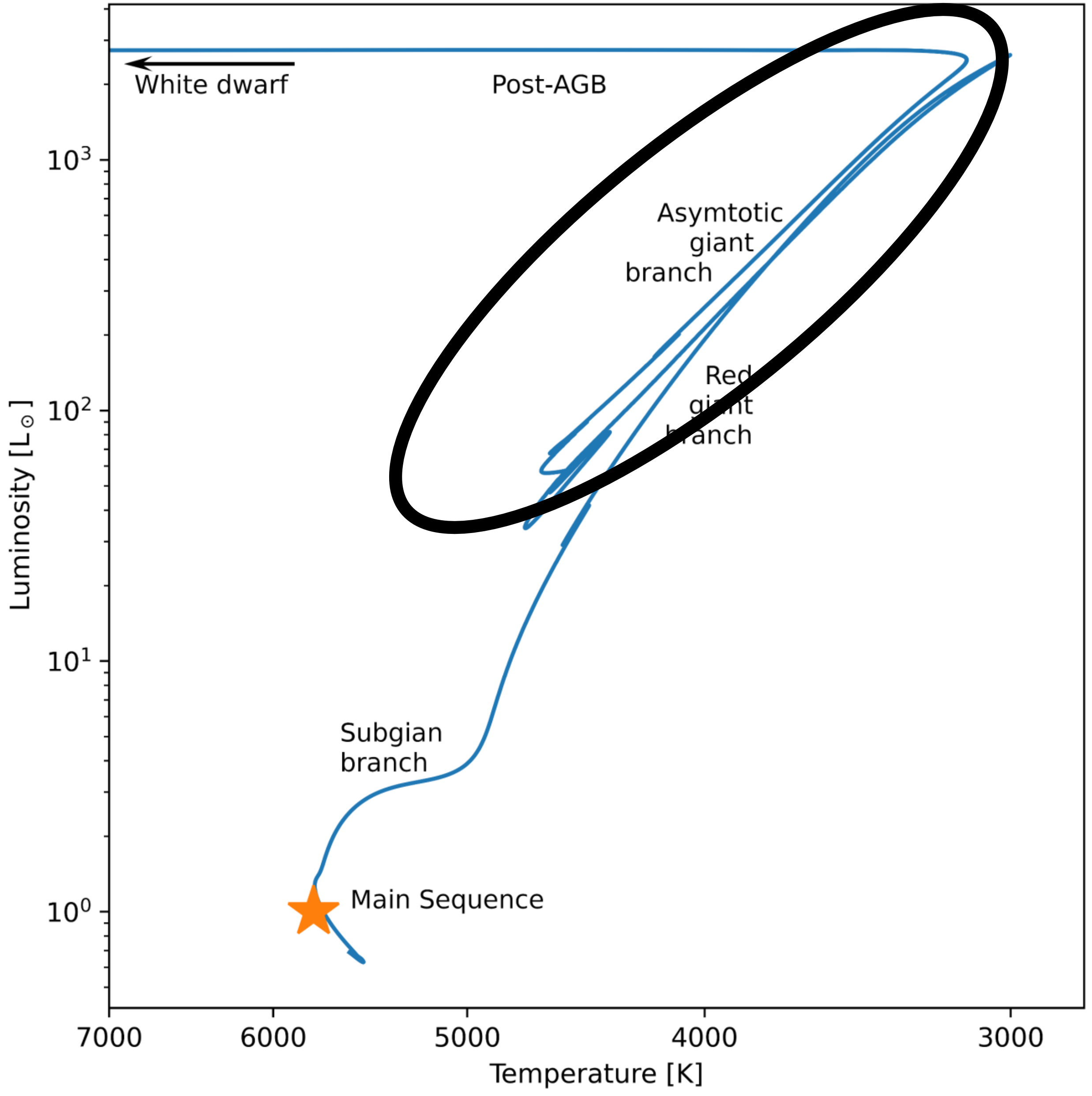
S. Maes
T. Konings
T. Ceulemans
L. Decin

AGB stars

- Low and intermediate mass
- $M_{ini} \in [0.8\ \mathrm{M_\odot}, 8\ \mathrm{M_\odot}]$

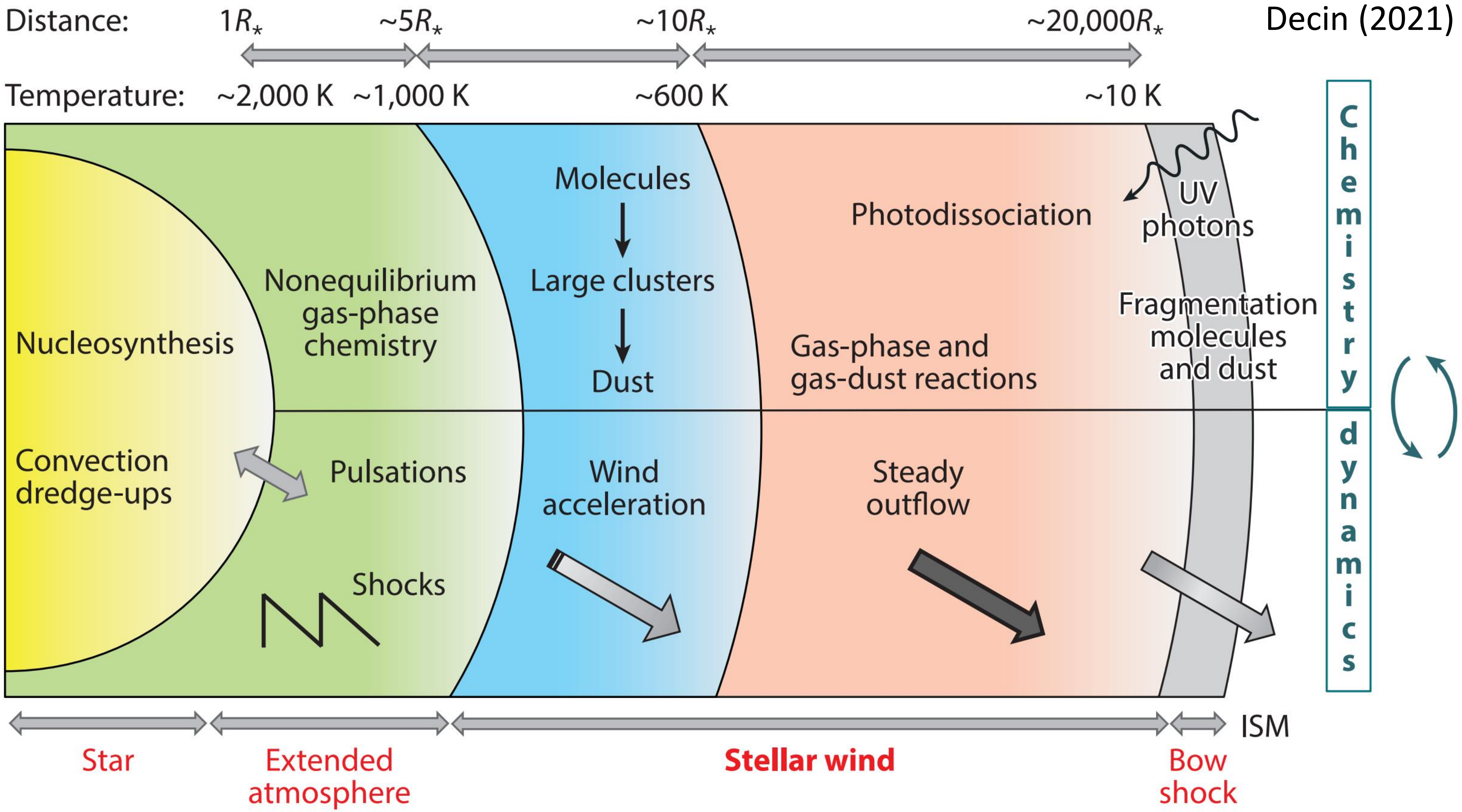
- Significant mass loss
  - $\dot{M} = 10^{-8} - 10^{-4}\ \mathrm{M_\odot/yr}$
  - $v_\infty = 5 - 25\ \mathrm{km/s}$
- Dust-driven wind

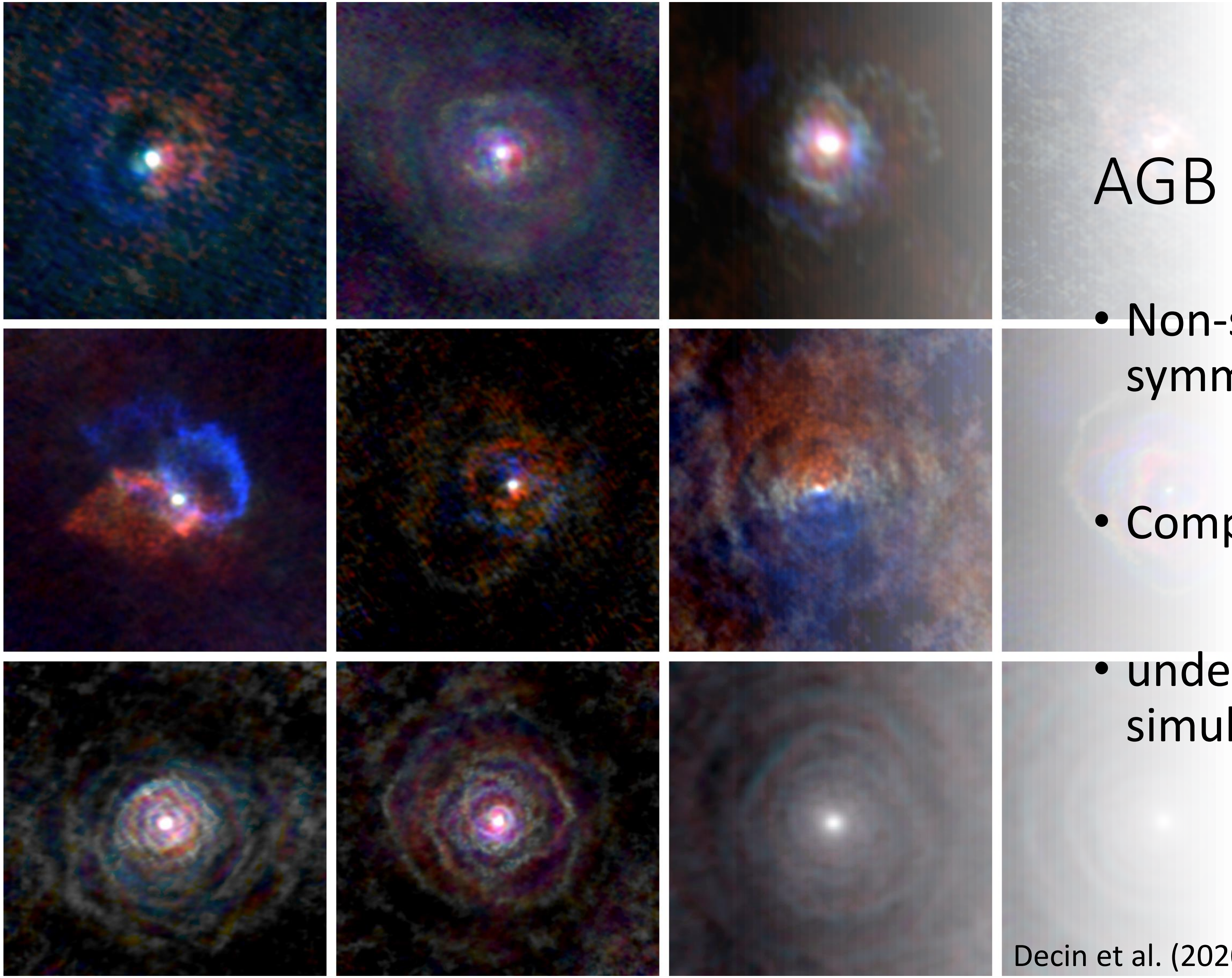
Evolution of 1 $\mathrm{M_\odot}$ star



AGB’s dust-driven wind

Decin (2021)





AGB outflows

- Non-spherically symmetric
- Companion perturbed
- understanding through simulations

Decin et al. (2020)

Hydrodynamic setup

- 3D Smoothed Particle Hydrodynamics (SPH)
- Phantom by Price et al. (2018), Siess et al. (2022)

- External acceleration
  - $\vec{a} = -\frac{GM_{AGB}}{r_1^2}(1-\Gamma)\hat{r}_1 \; - \; \frac{GM_{comp}}{r_2^2}\hat{r}_2$

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- Eddington factor: radiative acceleration
  - $\Gamma = \frac{\kappa F/c}{GM_{AGB}/r_1^2}, \quad \kappa(T_{eq}) = \frac{\kappa_{max}}{1+exp[(T_{eq}-T_{cond})/\delta]} + \kappa_g$

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Approximations

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Free-wind	$\Gamma = 1$	✗

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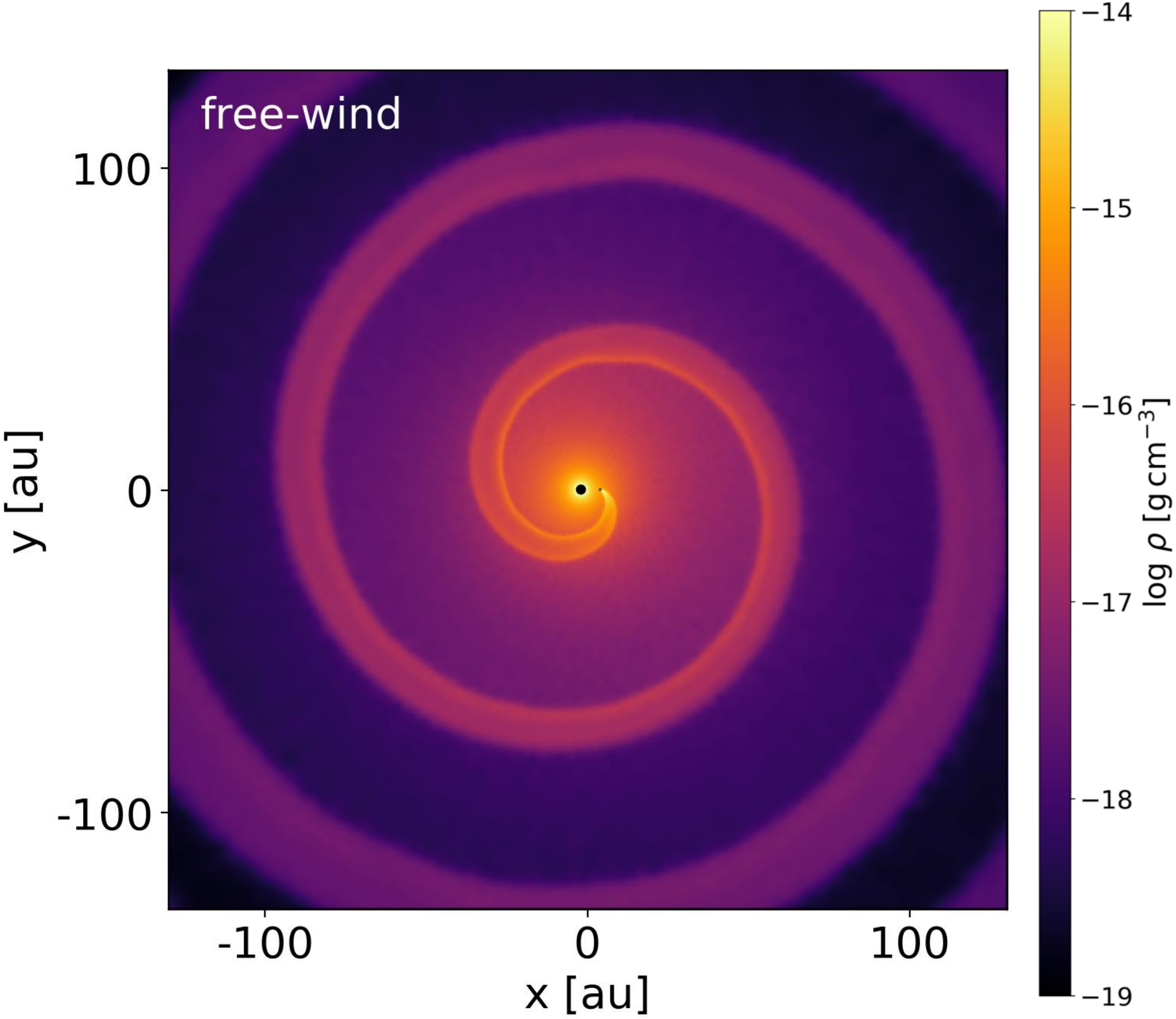
Attenuation	$\Gamma = \dfrac{\kappa L_{AGB}}{4\pi c G M_{AGB}} e^{-\tau}$	$T_{eq}^4 = \dfrac{1}{2}\left(1 - \sqrt{1 - \left(\dfrac{R_\star}{r}\right)^2}\right) e^{-\tau} T_\star^4$

Morphological structures

Parameter	Value	Unit
$\dot{M}_{\rm AGB}$	3×10^{-6}	$M_\odot\ yr^{-1}$
$M_{\rm AGB}$	1.02	$M_\odot$
$L_{\rm AGB}$	4384	$L_\odot$
$T_{\rm eff,AGB}$	2874	K
$R_{\rm AGB}$	1.24	au



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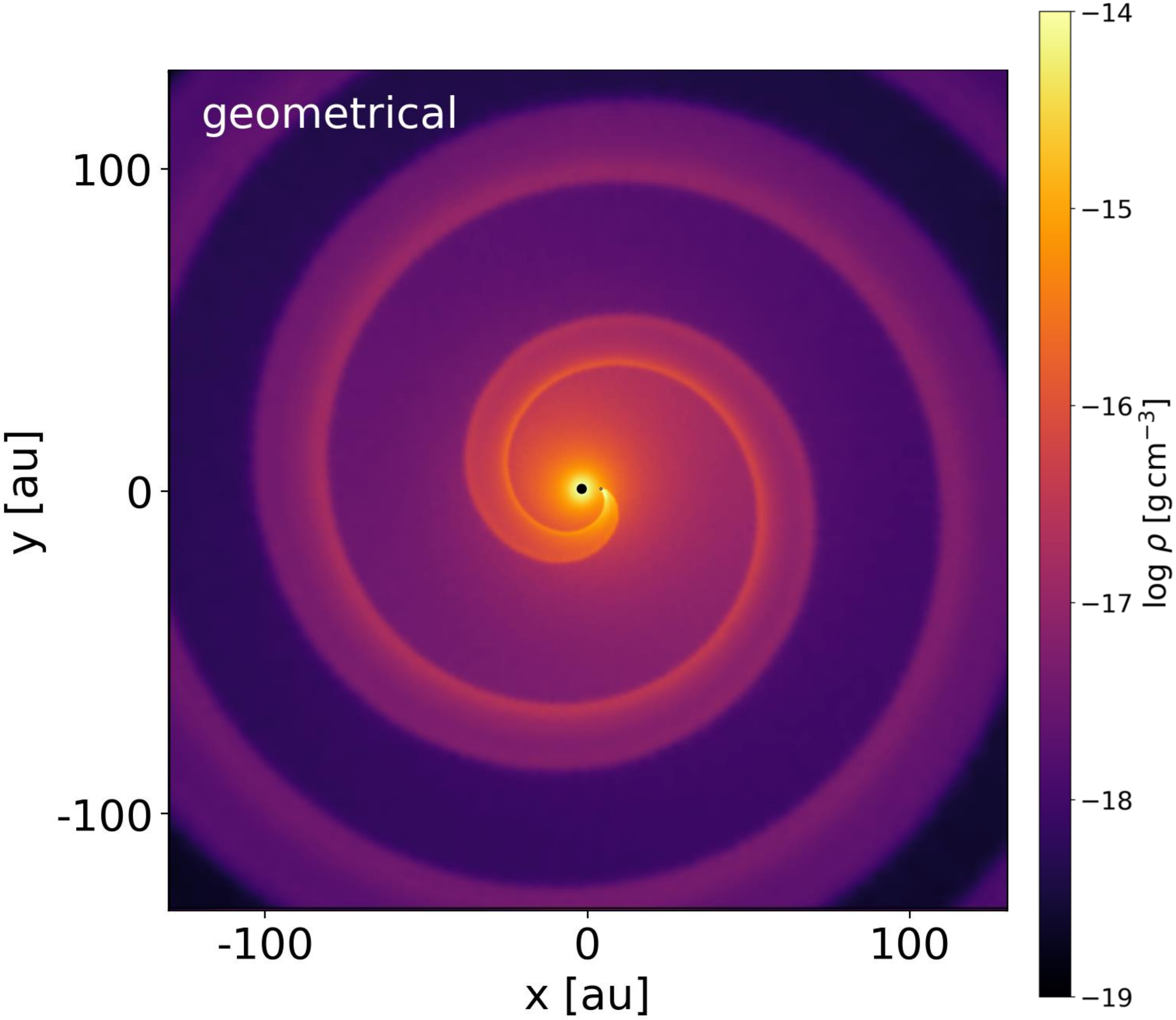

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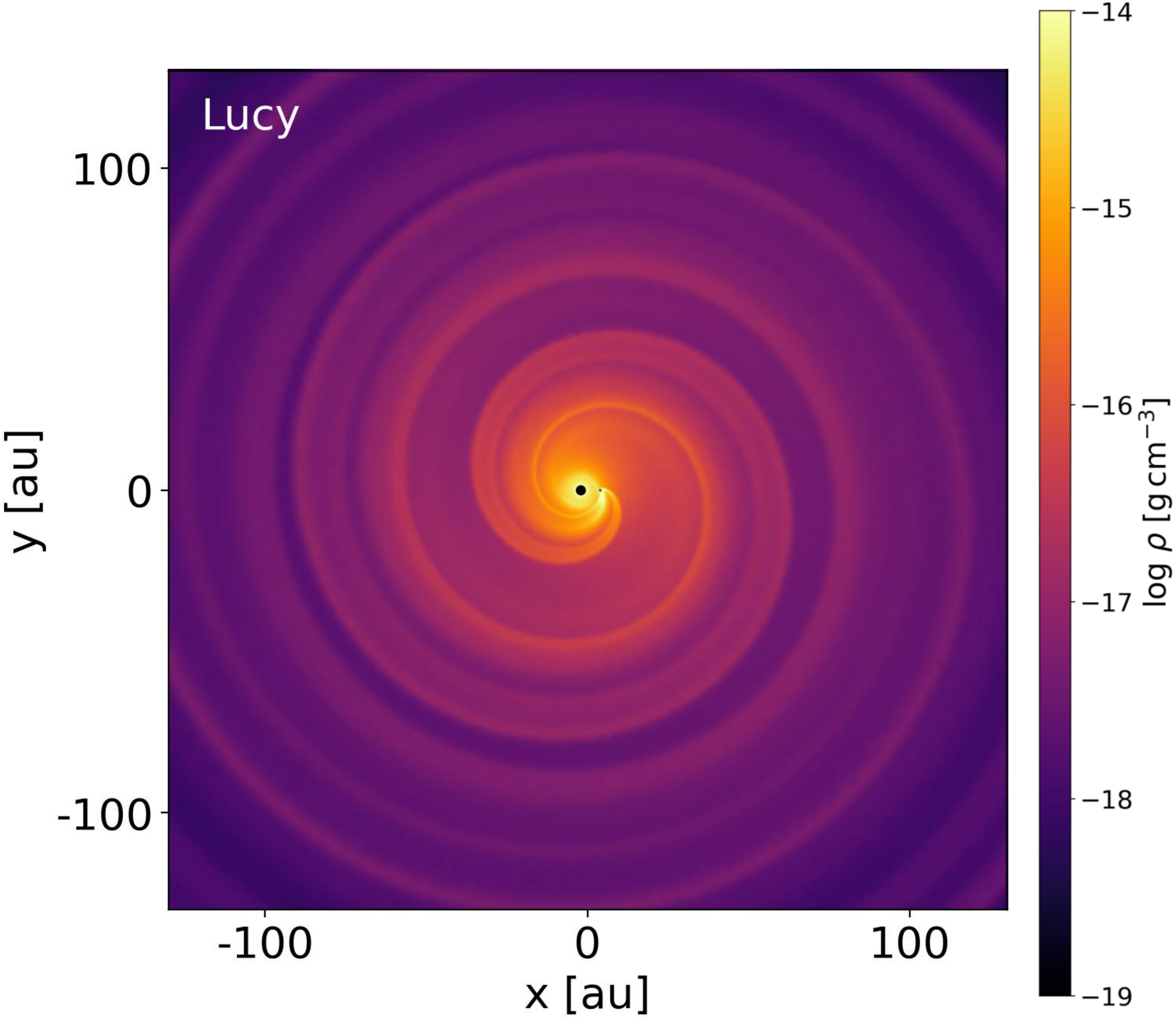
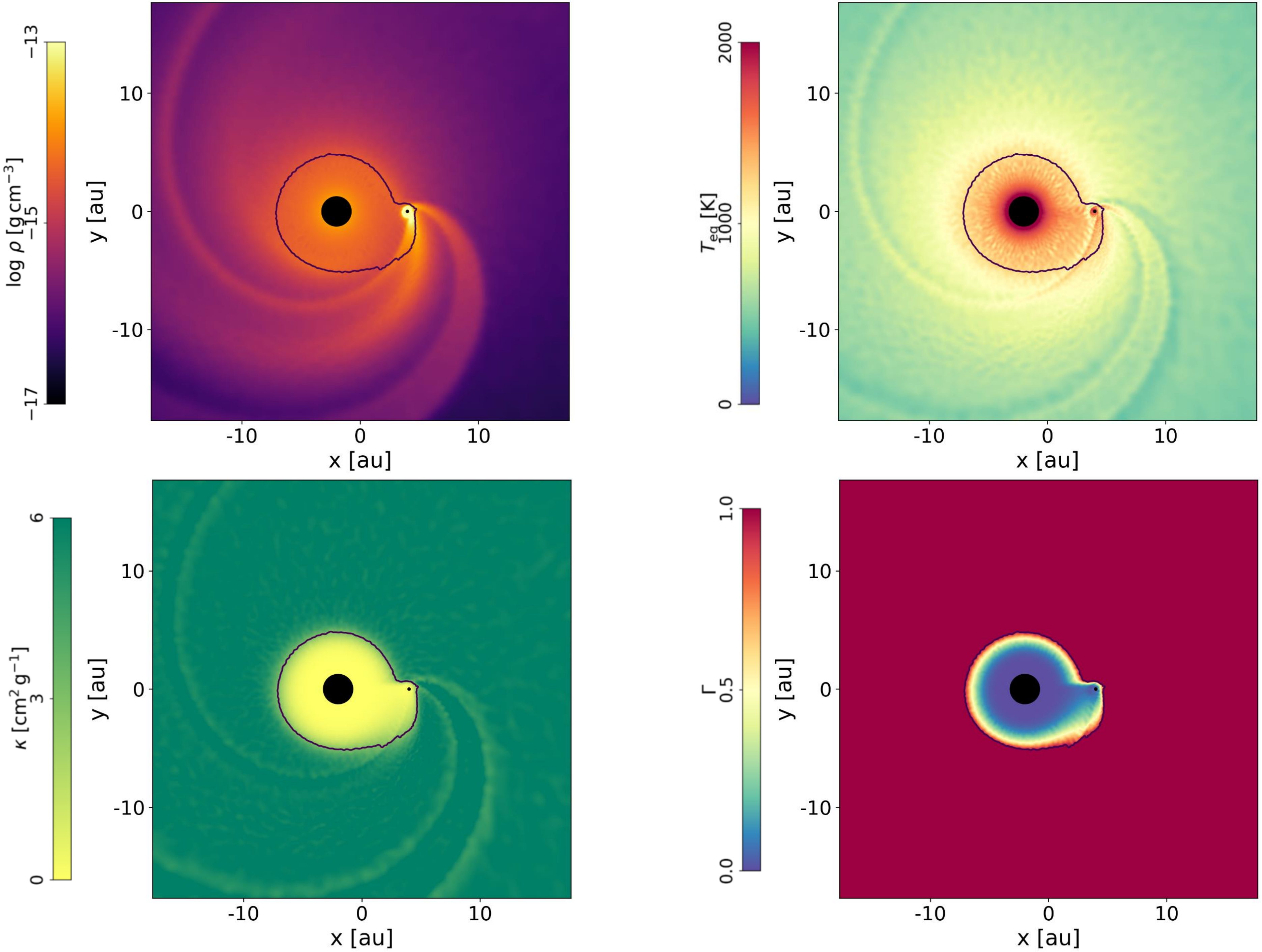


Lucy Approximation



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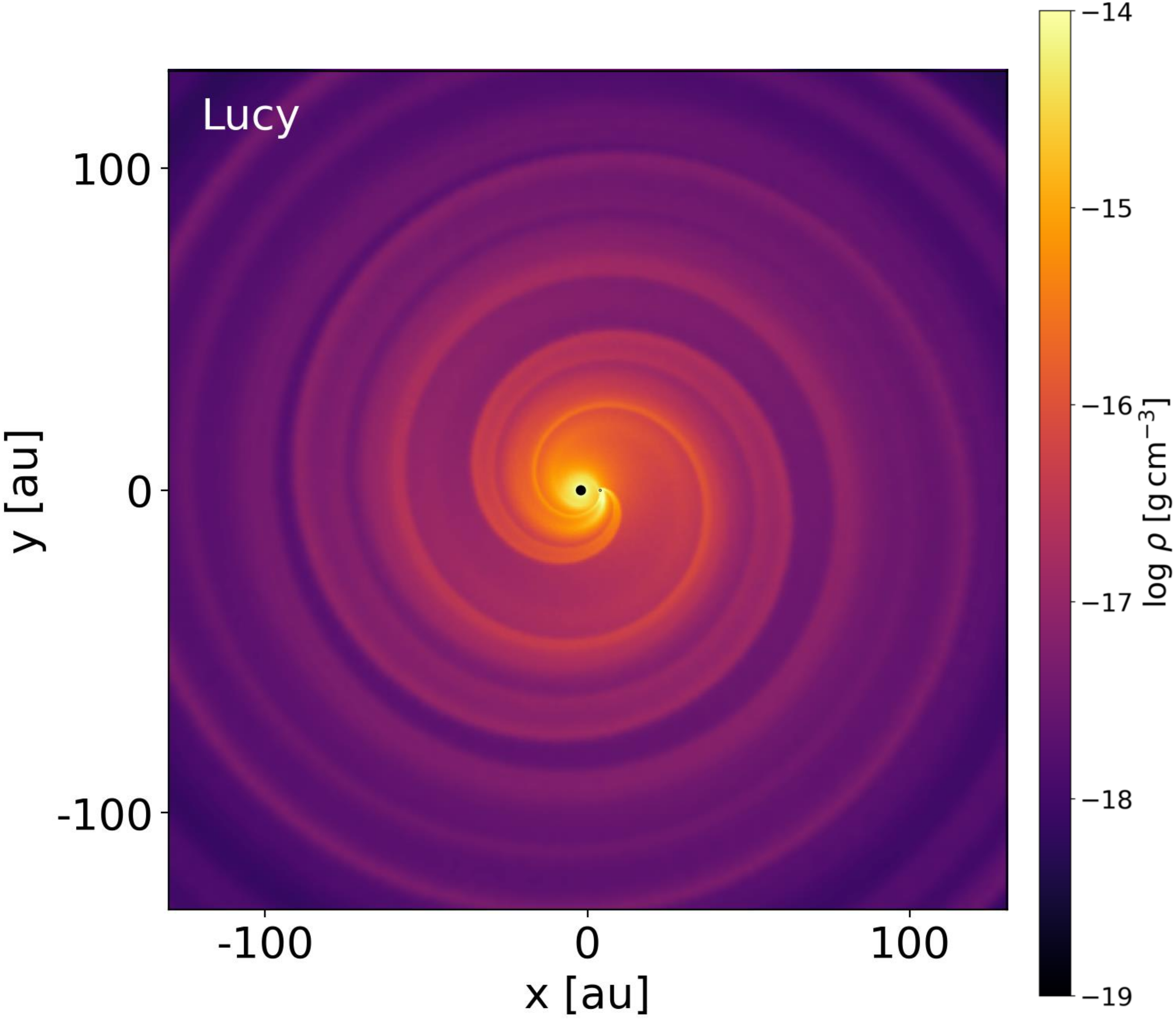

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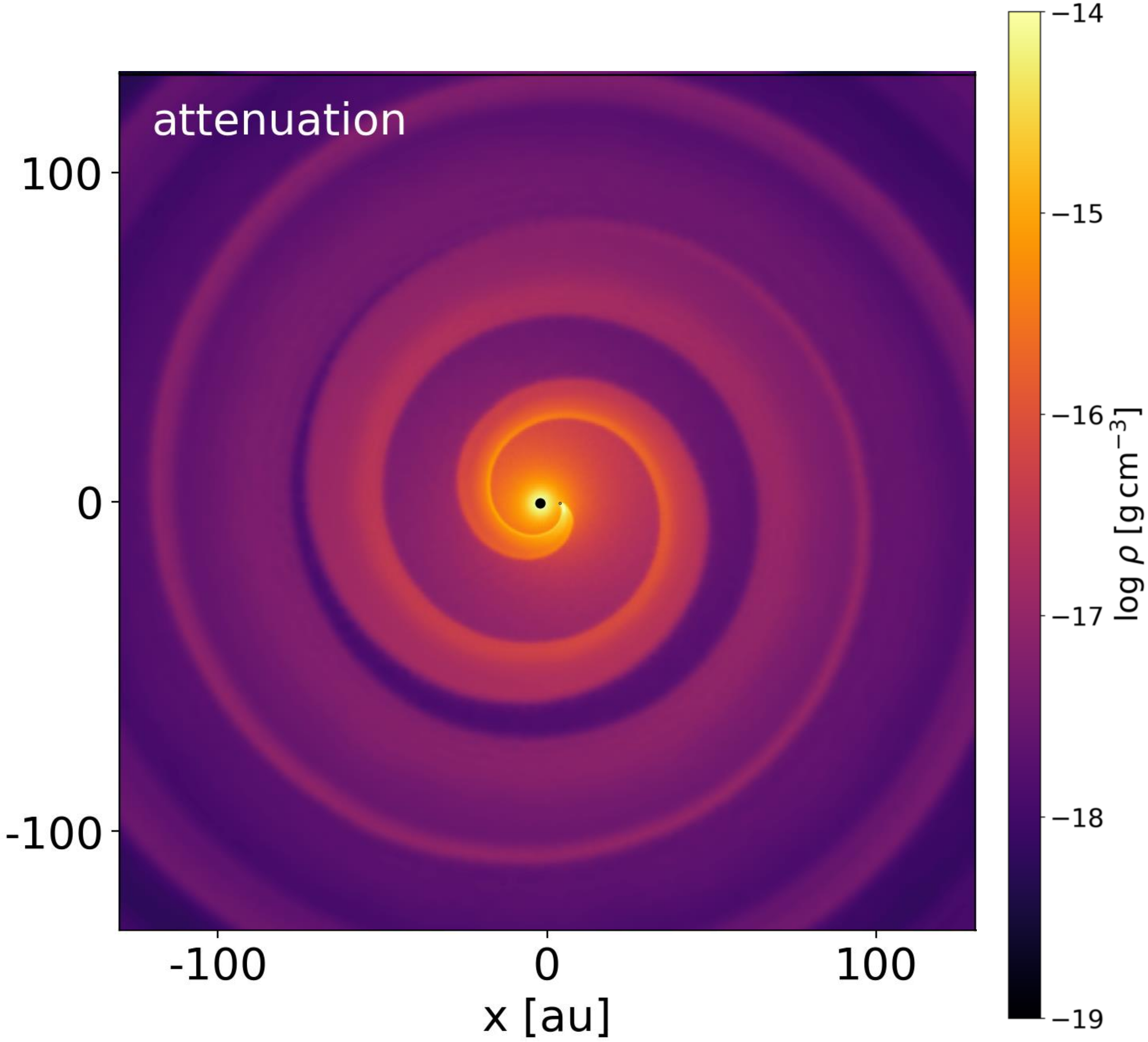
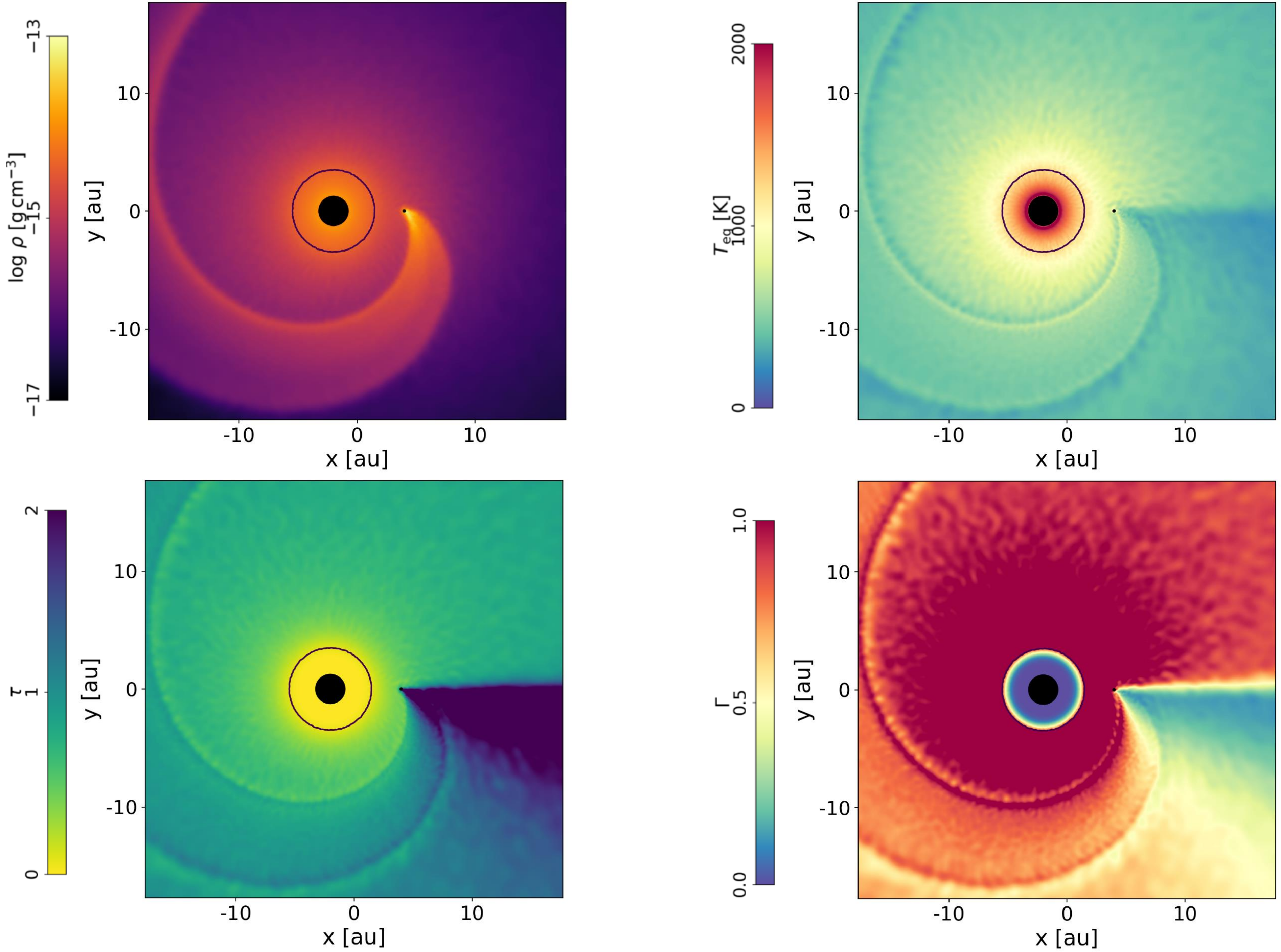


Attenuation Approximation



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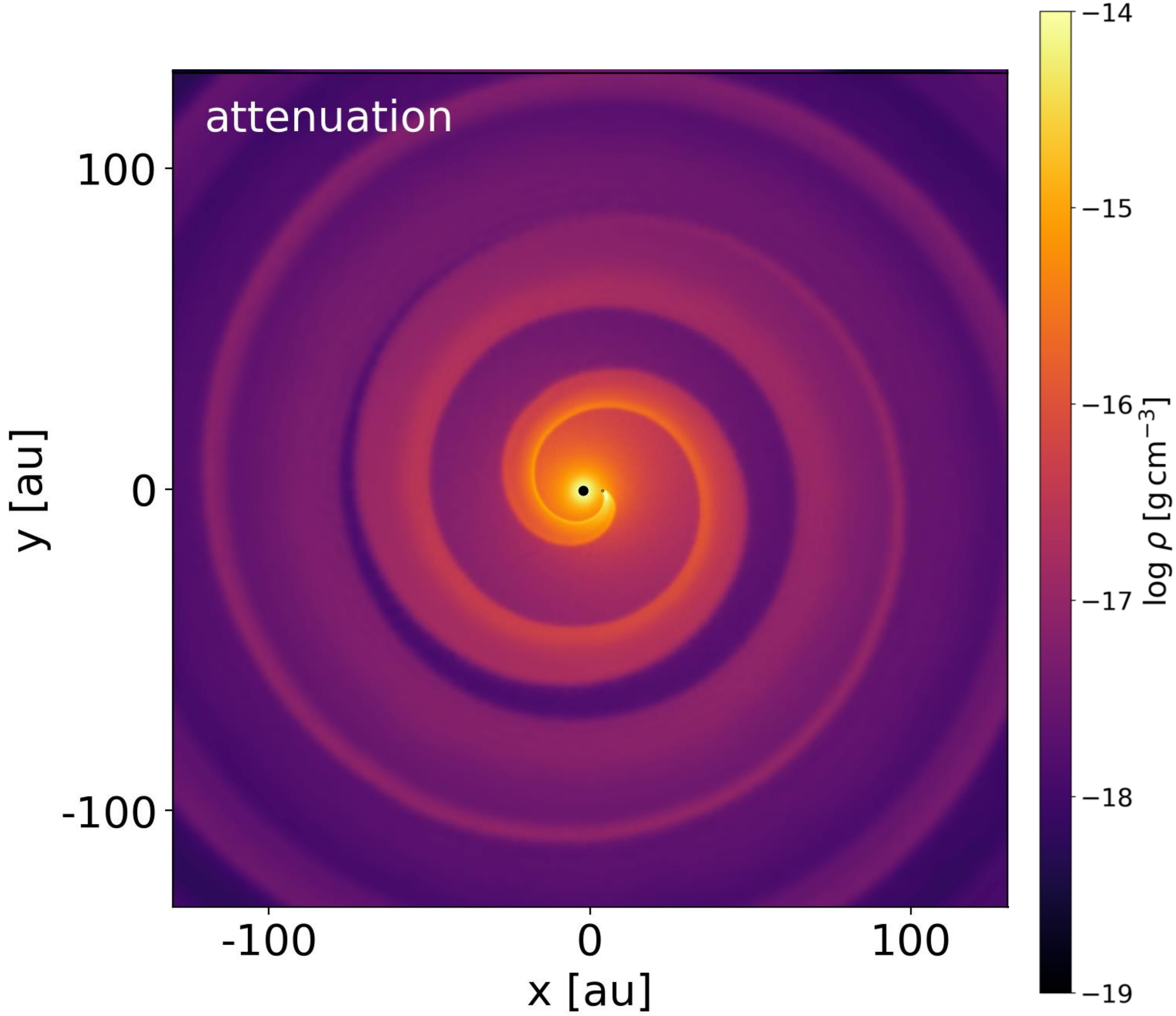

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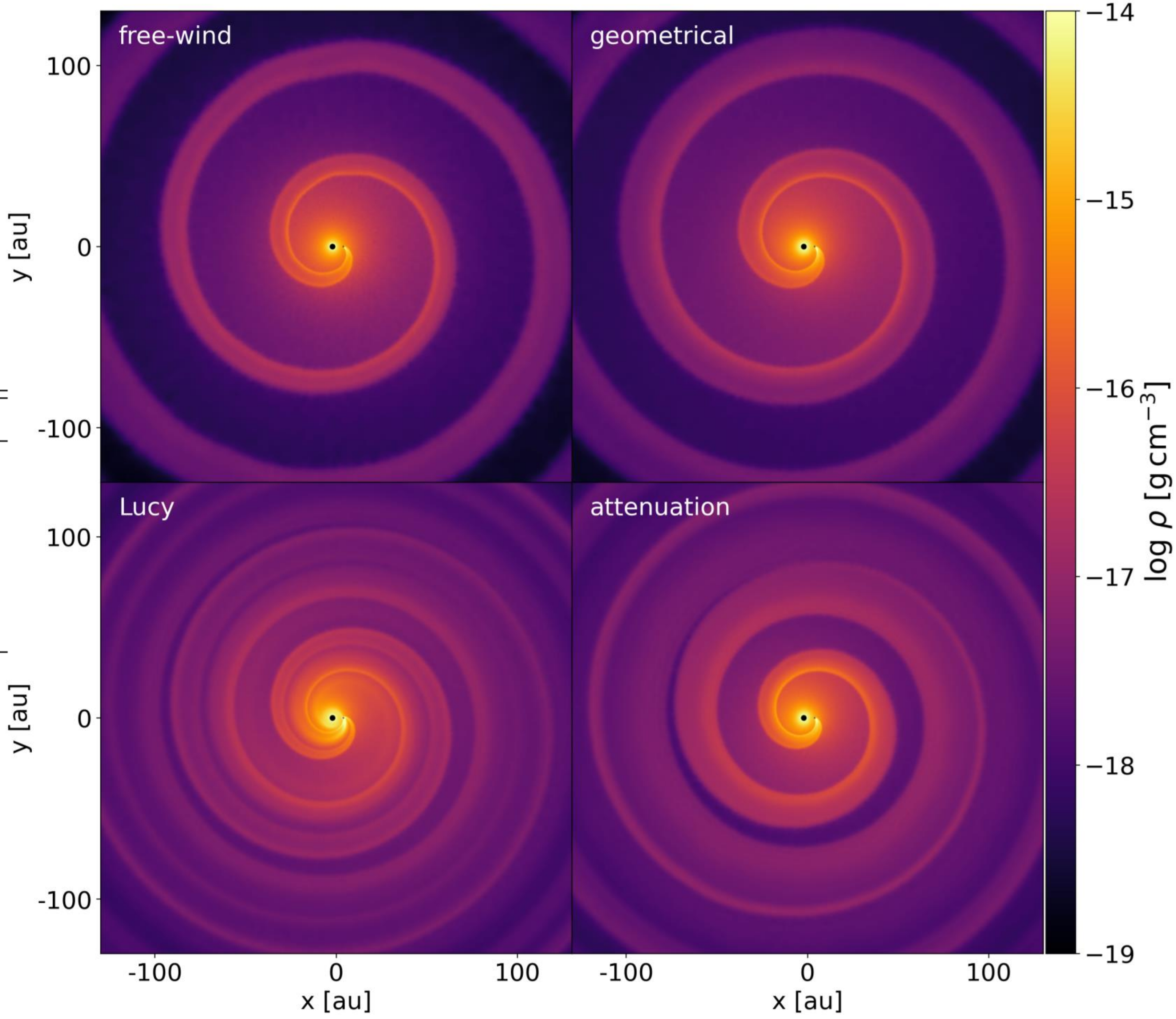
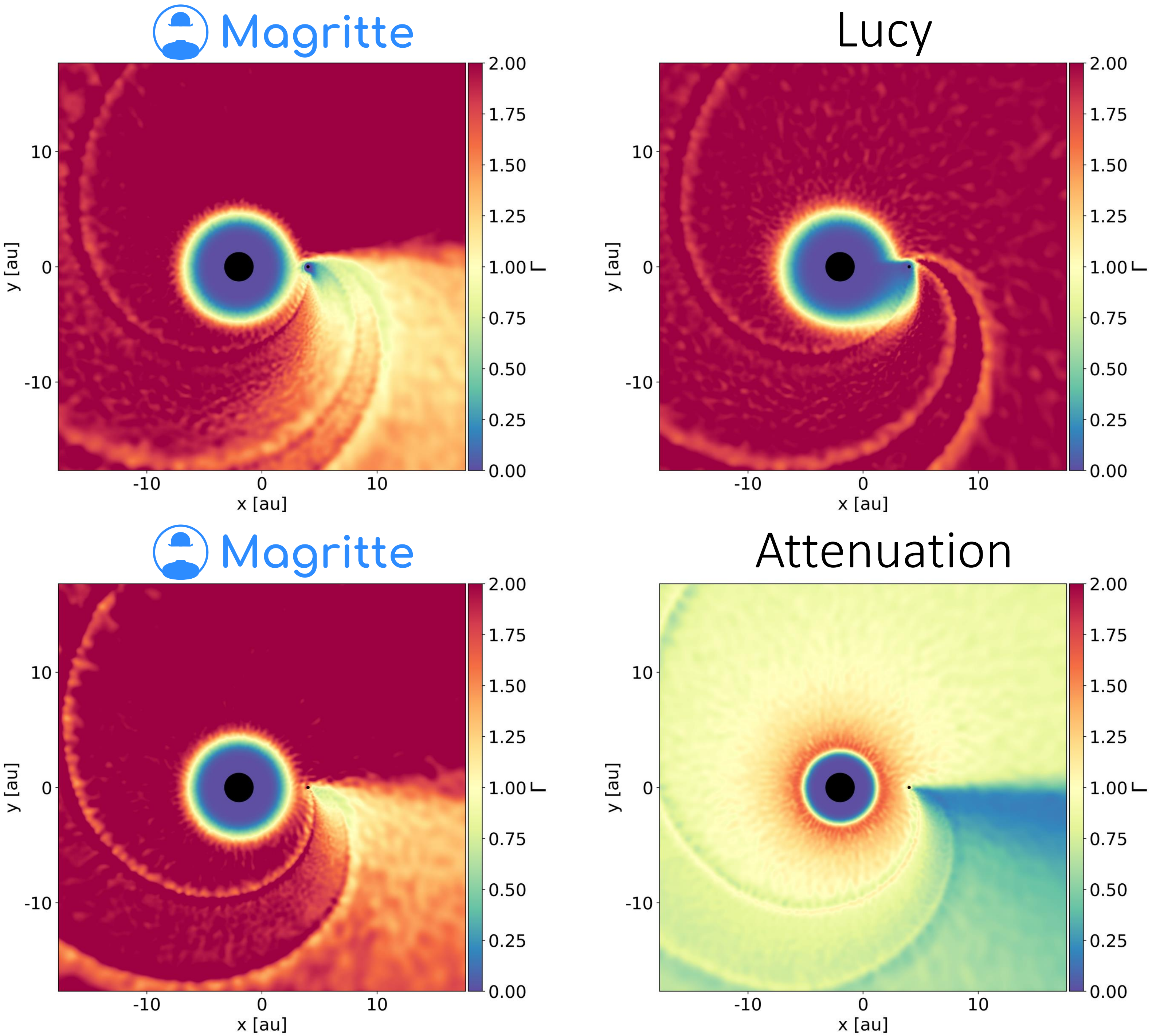


Validation Study

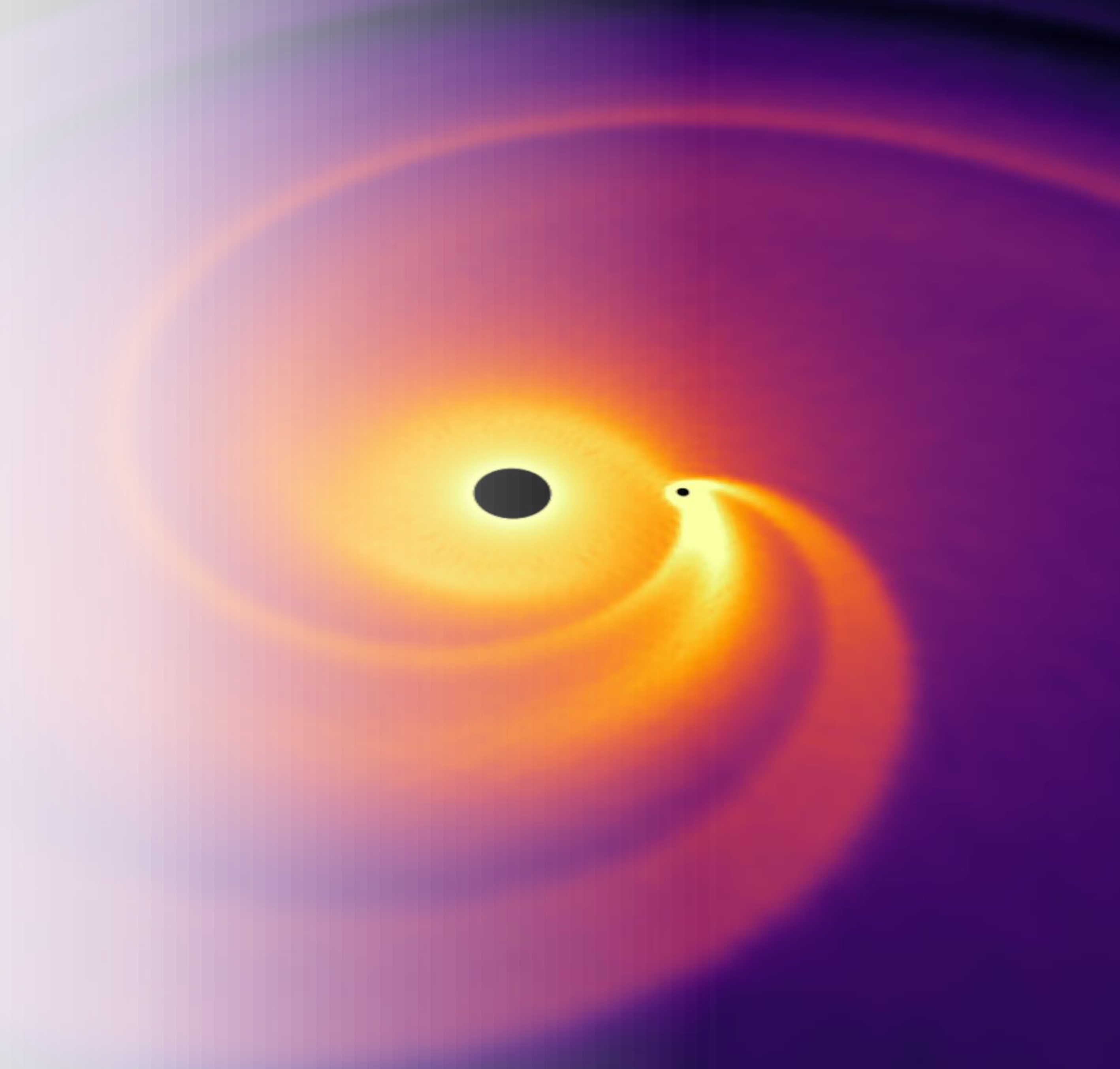
- Full 3D radiation transfer code Magritte

- Lucy approximation most accurate



Conclusions

- Dust formation and radiative transfer is crucial
- Different approximations can make significant changes
- Lucy approximation most accurate



Esseldeurs et al. (2023)