Starlight Reshapes Planetary Nurseries

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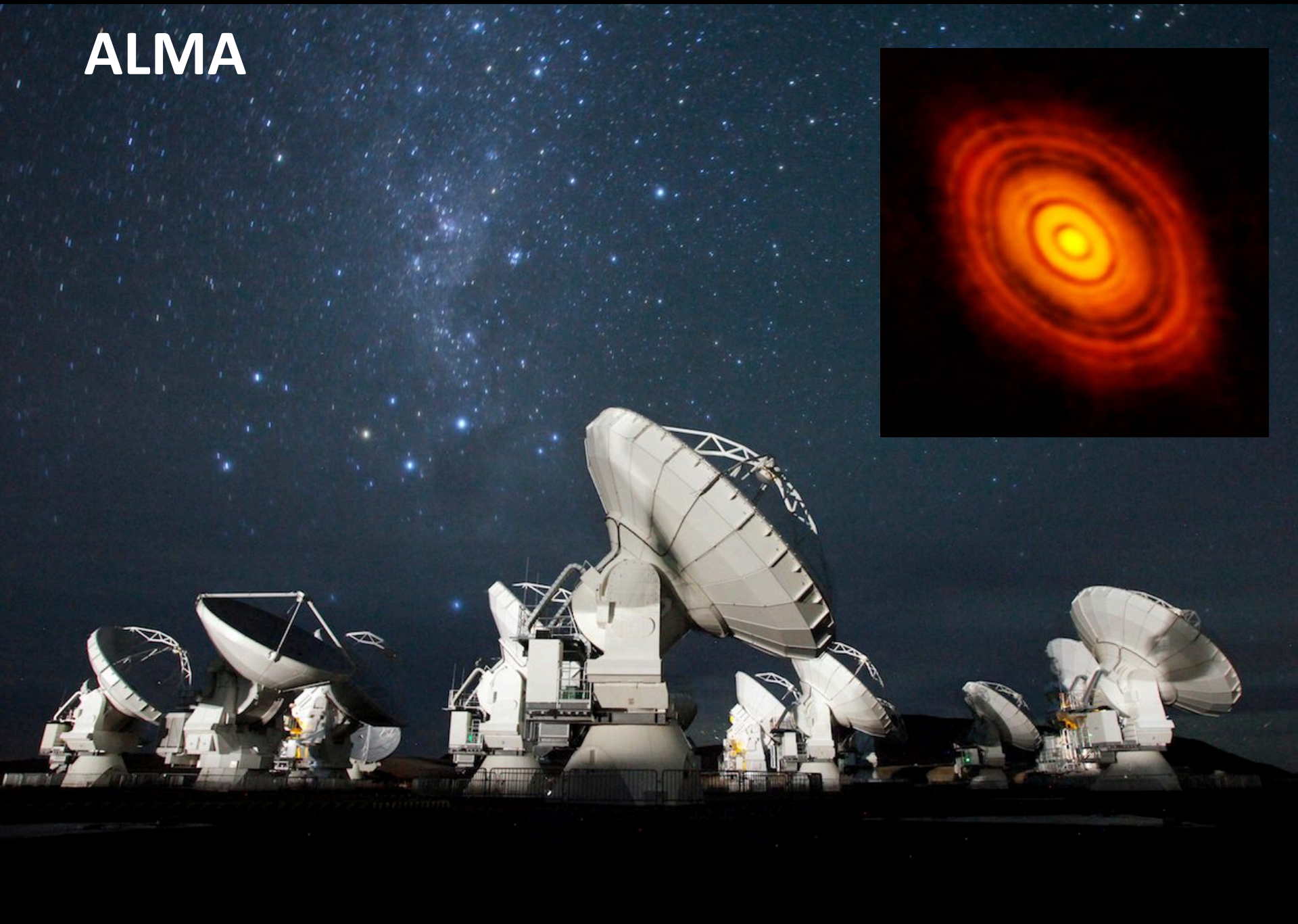
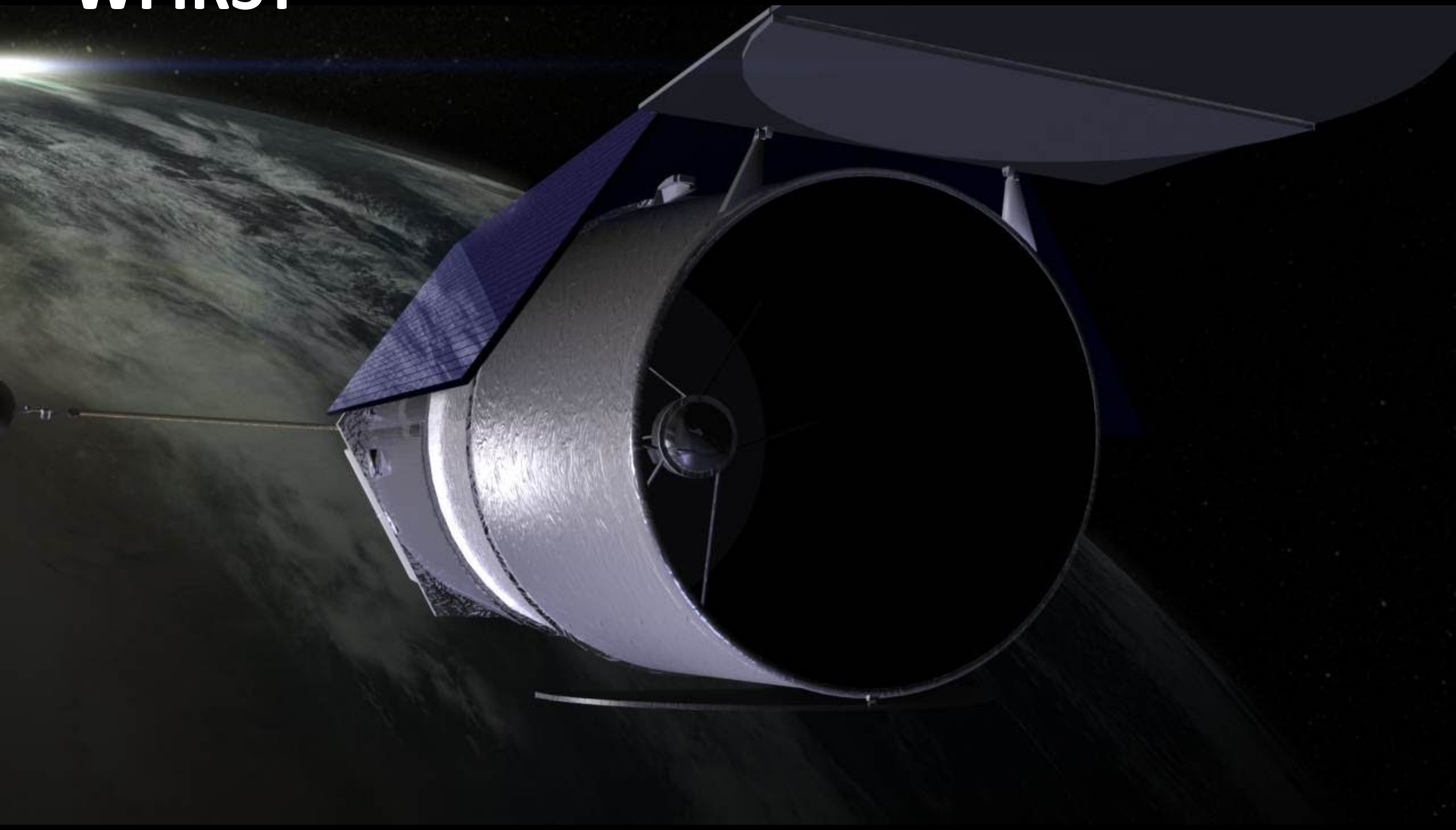
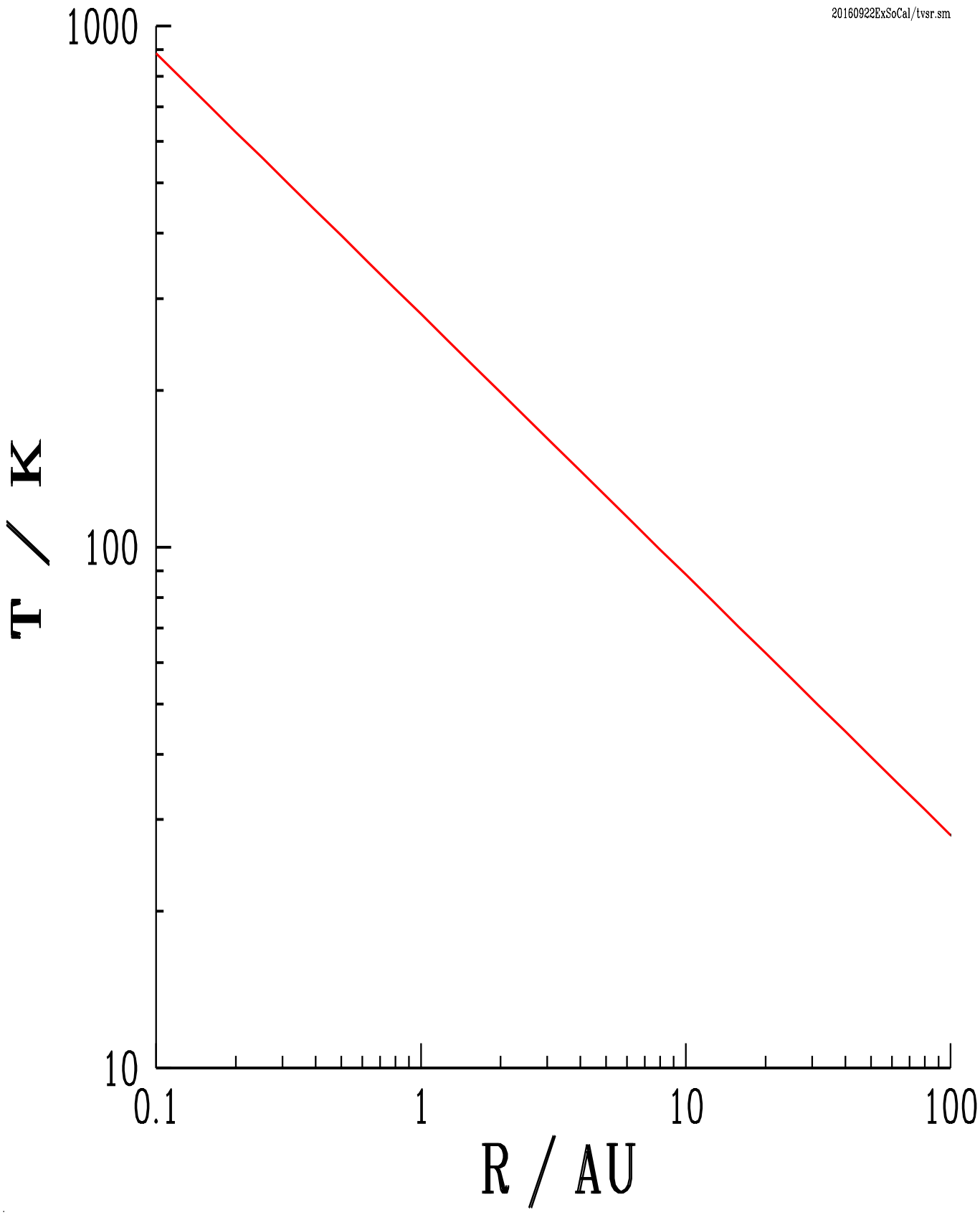
ALMA



WFIRST



Artwork by W. K. Hartmann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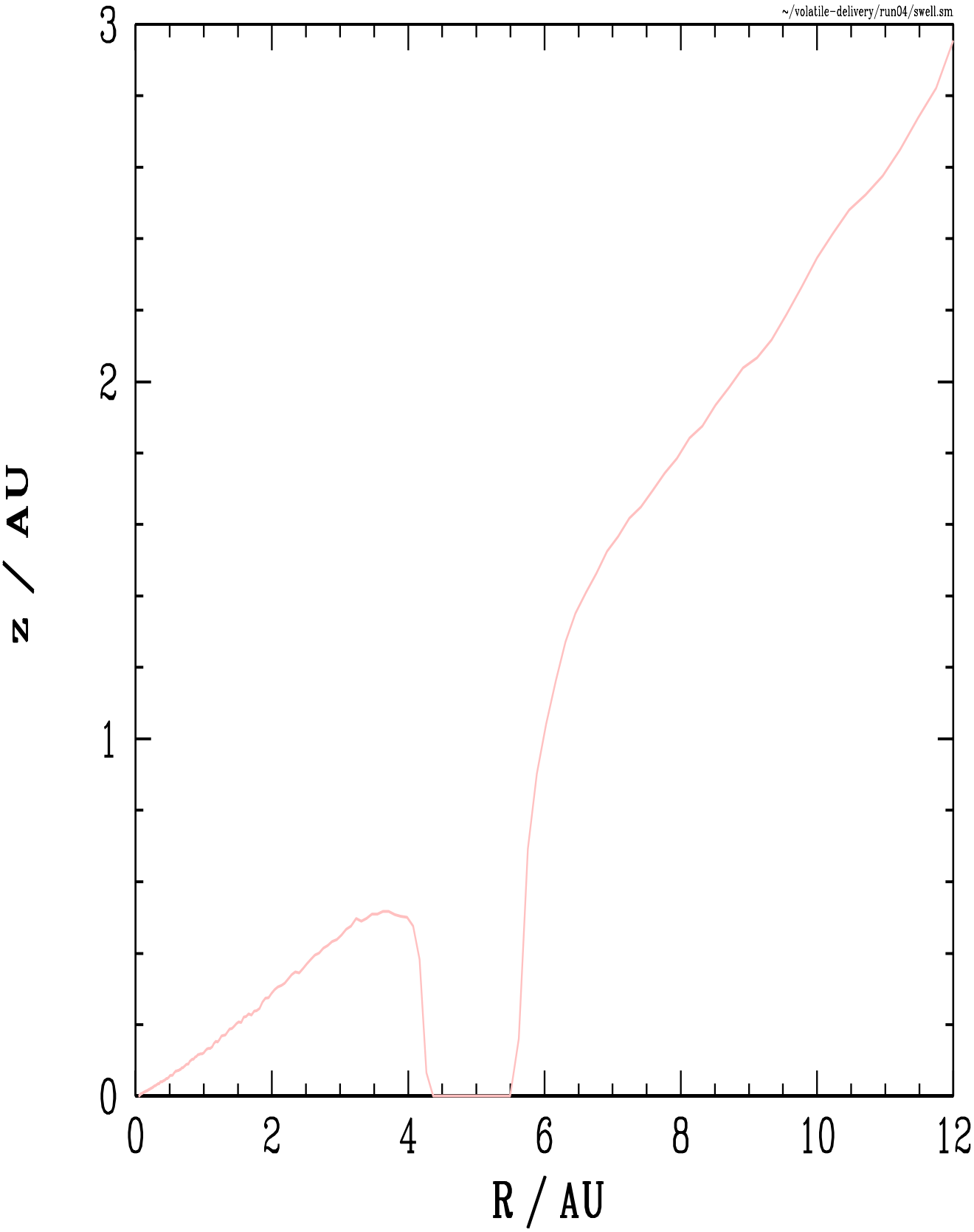
100
10
T / K
0.1
1
10
100
R / AU

Artwork by W. K. Hartmann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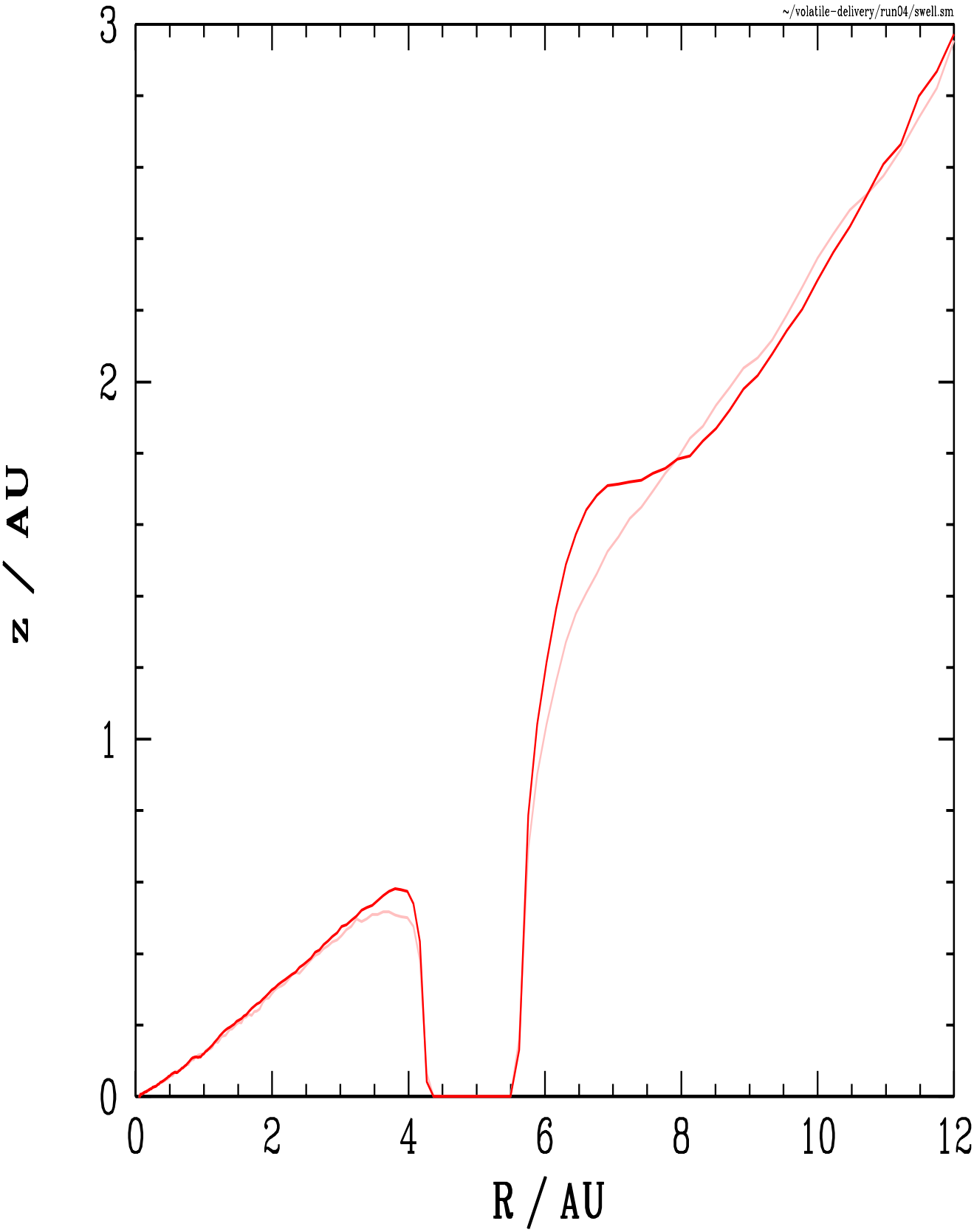
1
2
3
0
2
4
6
8
10
12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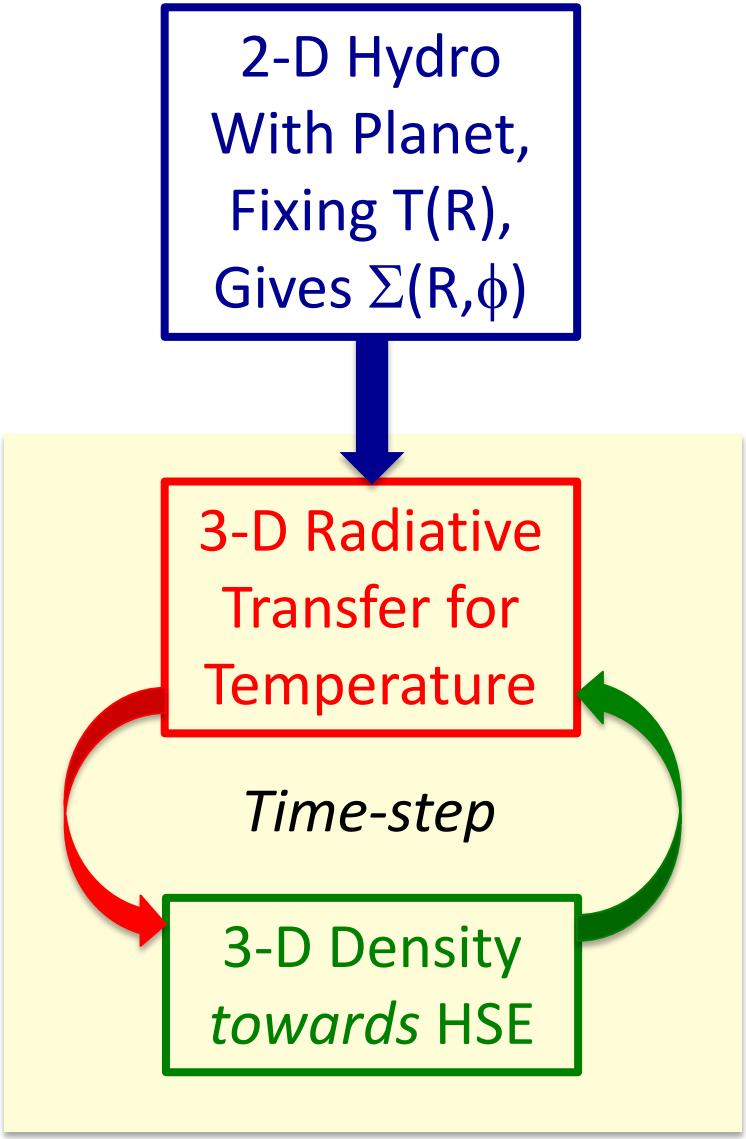
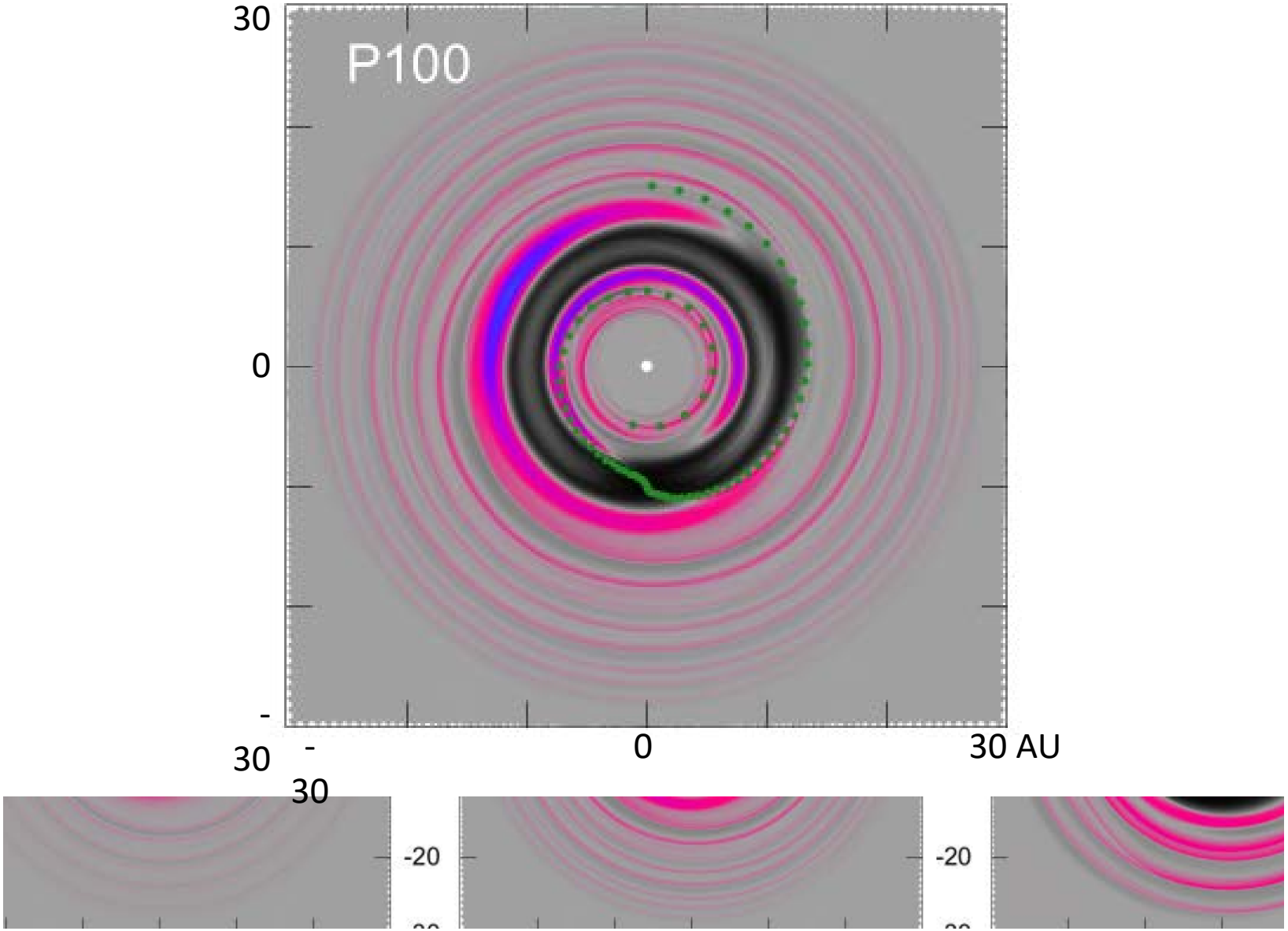
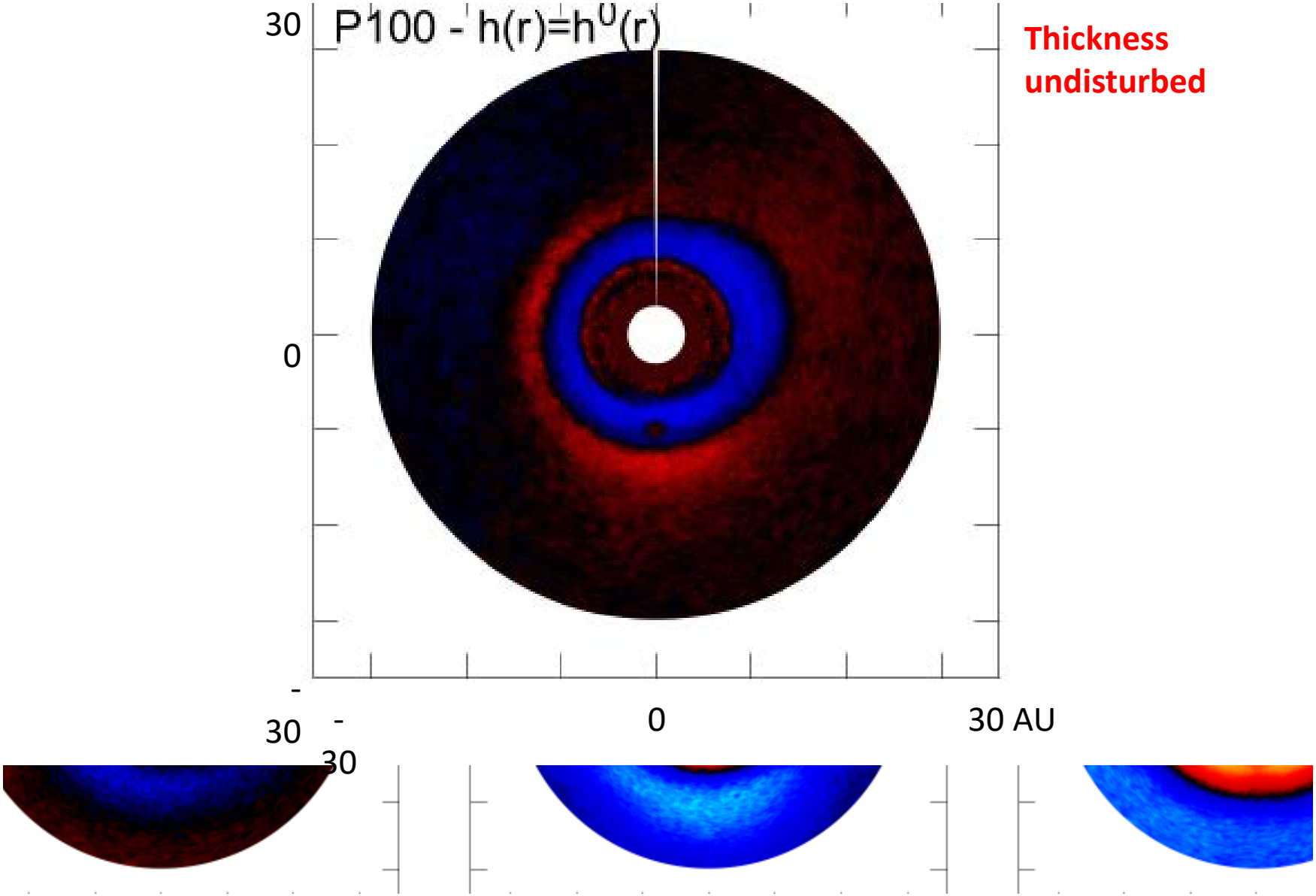

2-D Hydro
With Planet,
Fixing T(R),
Gives Σ(R,ϕ)
3-D Radiative
Transfer for
Temperature
Time-step
3-D Density
towards HSE

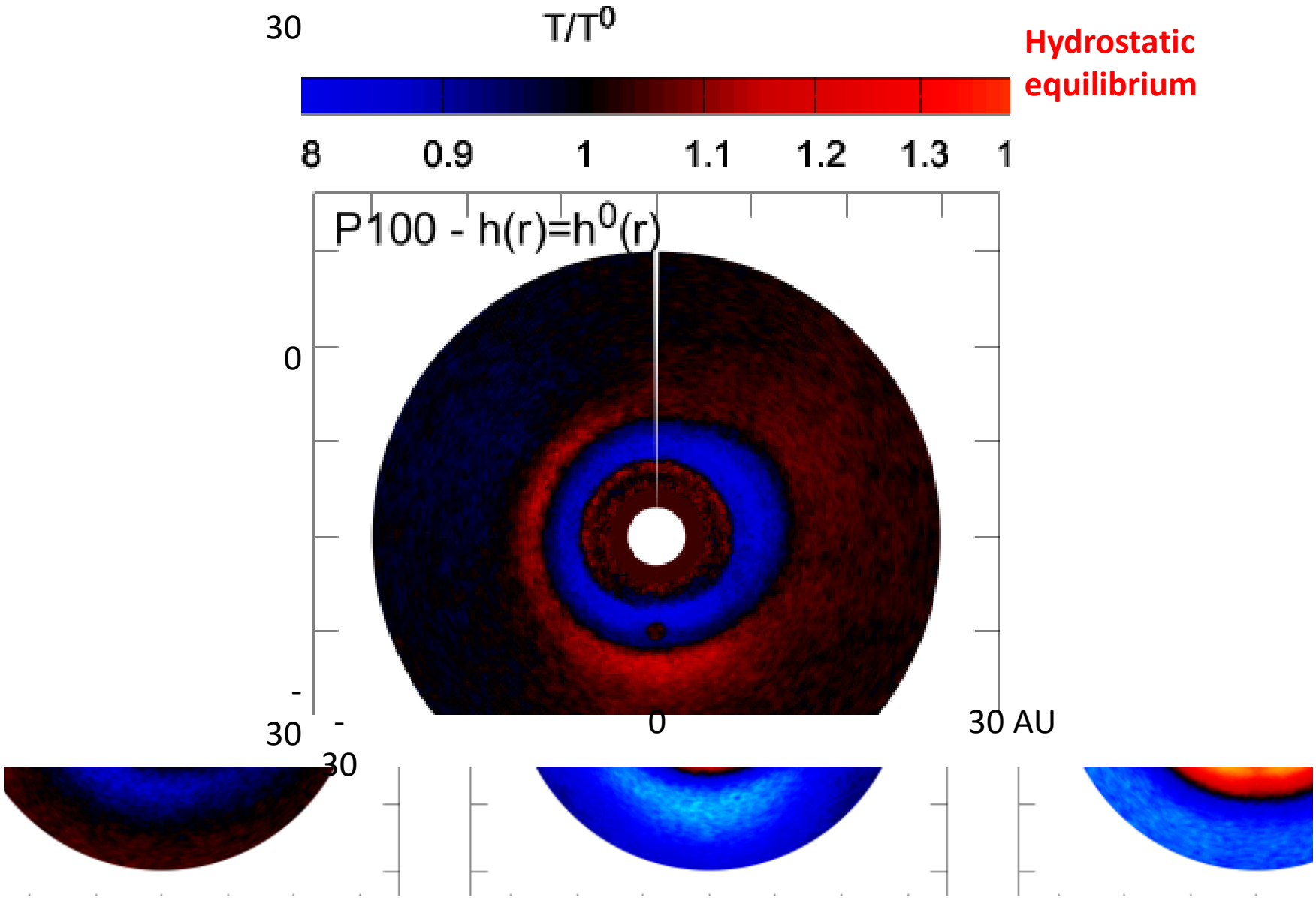
Surface Density Ratio With 100-Earth-Mass Planet



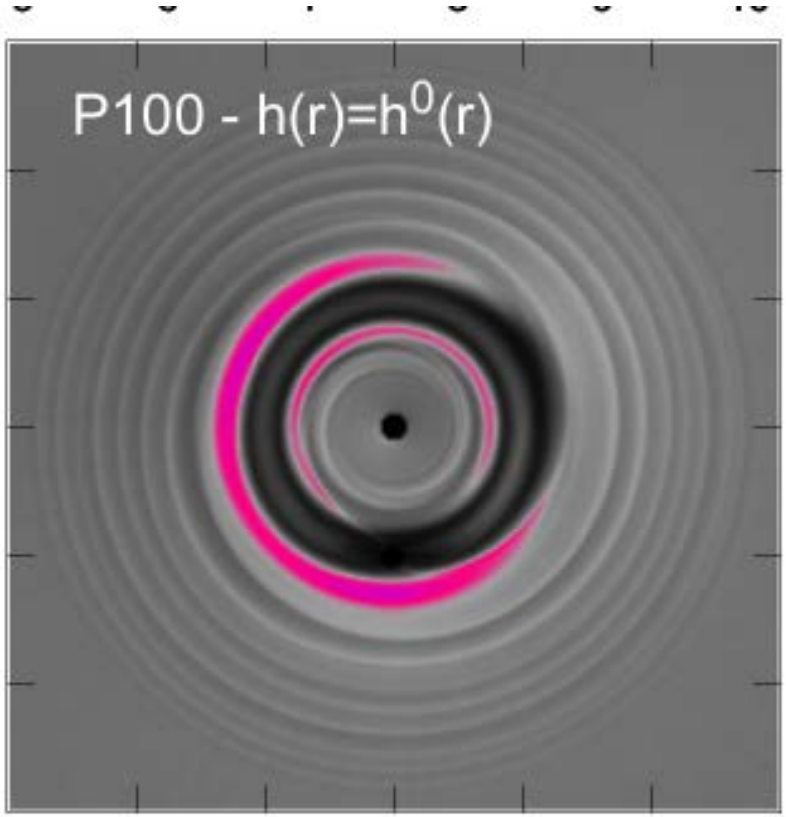
Midplane Temperature Ratio With 100-Earth-Mass Planet

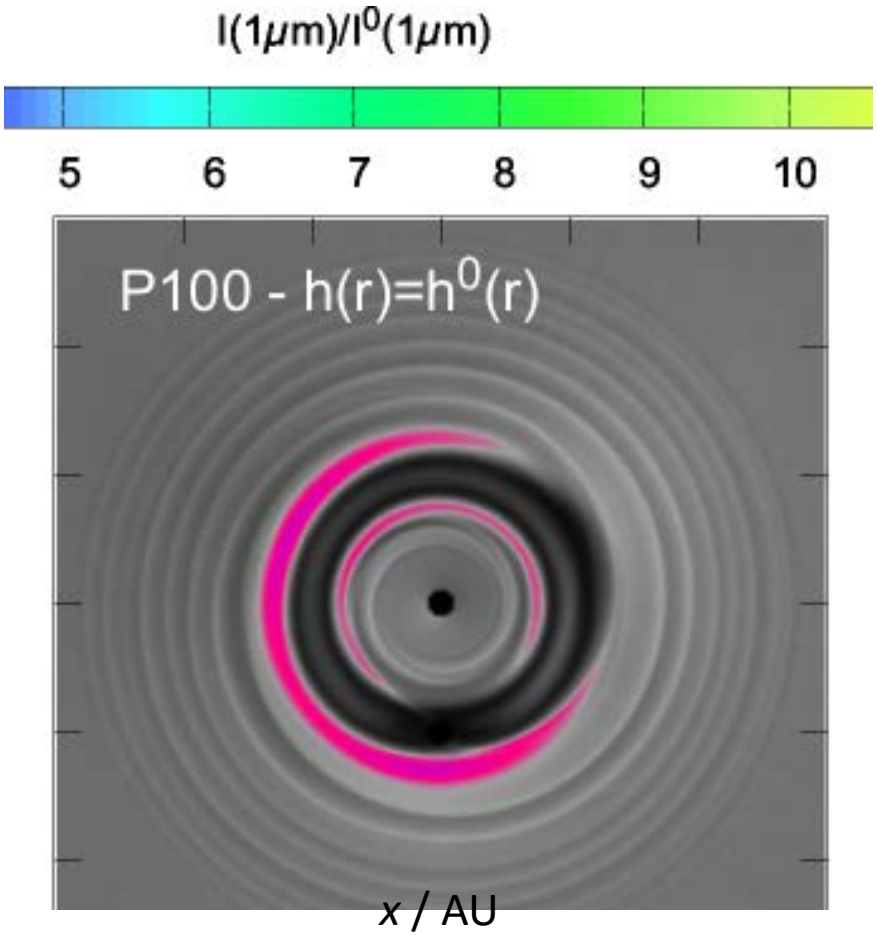


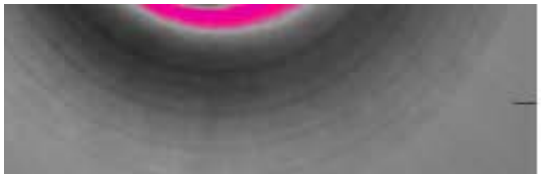
Midplane Temperature Ratio With 100-Earth-Mass Planet

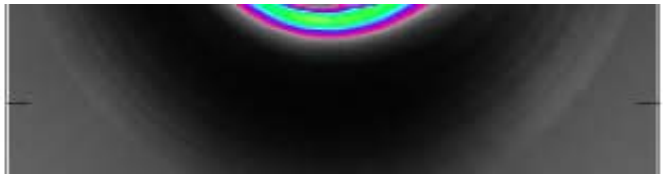


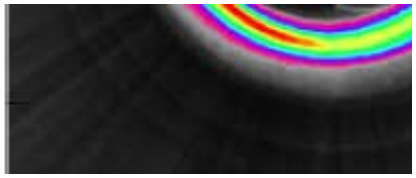
The disk's response to starlight heating drastically changes the appearance in scattered light!



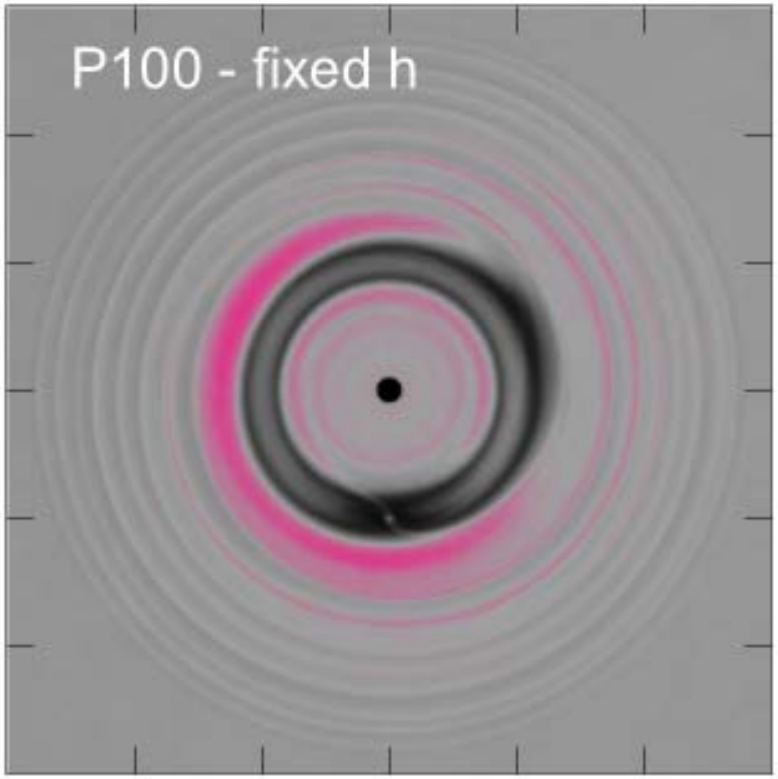


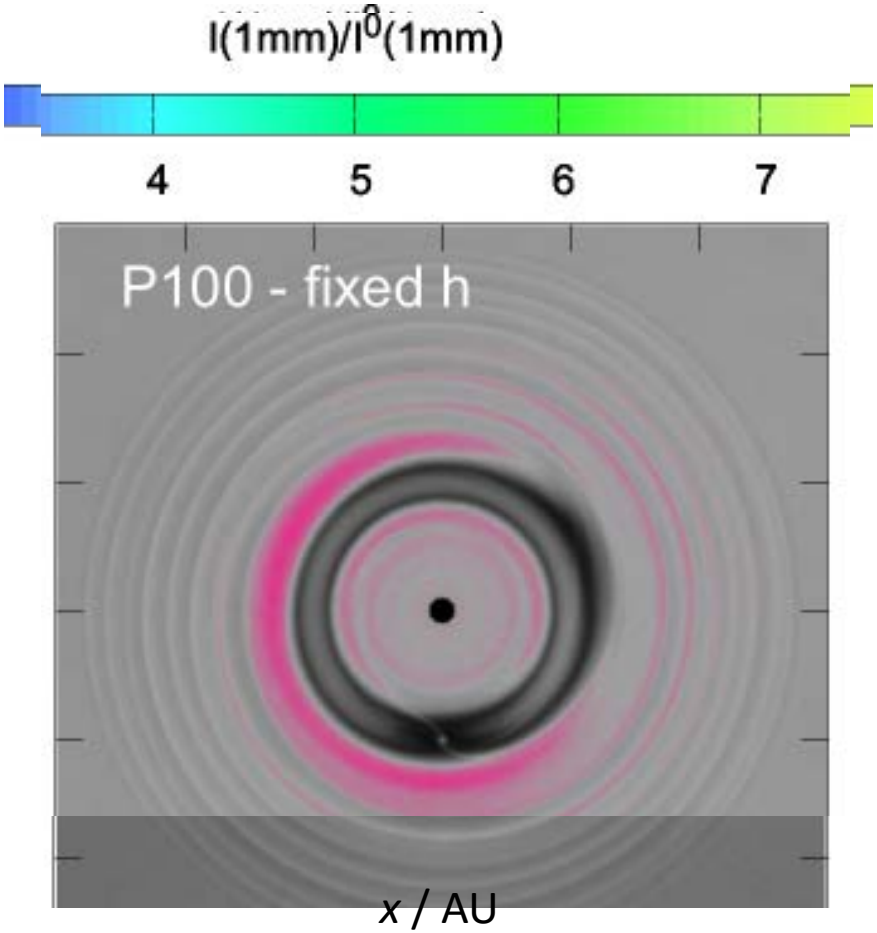


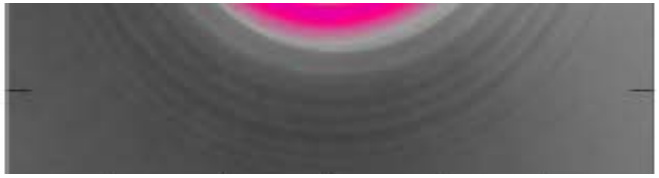


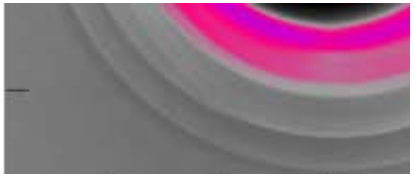


The disk's response to starlight heating somewhat changes the appearance in millimeter continuum.









Summary

Reliably predicting young planets' signatures requires treating disks' response to the starlight falling on the planet-raised features.

The equilibrium response:

- **Greatly increases the scattered-light contrast at the gap's outer edge.**
- **Reduces the outer spiral arm's brightness in scattered light.**
- **Reshapes the millimeter continuum emission.**

arXiv:1608.05123

Two Timescales

$$t_{dy} = \frac{2\pi}{\Omega} \propto r^{3/2}$$

$$t_{th} \approx \frac{c_s^2 \Sigma}{\sigma T^4} \propto r^{1/2}$$

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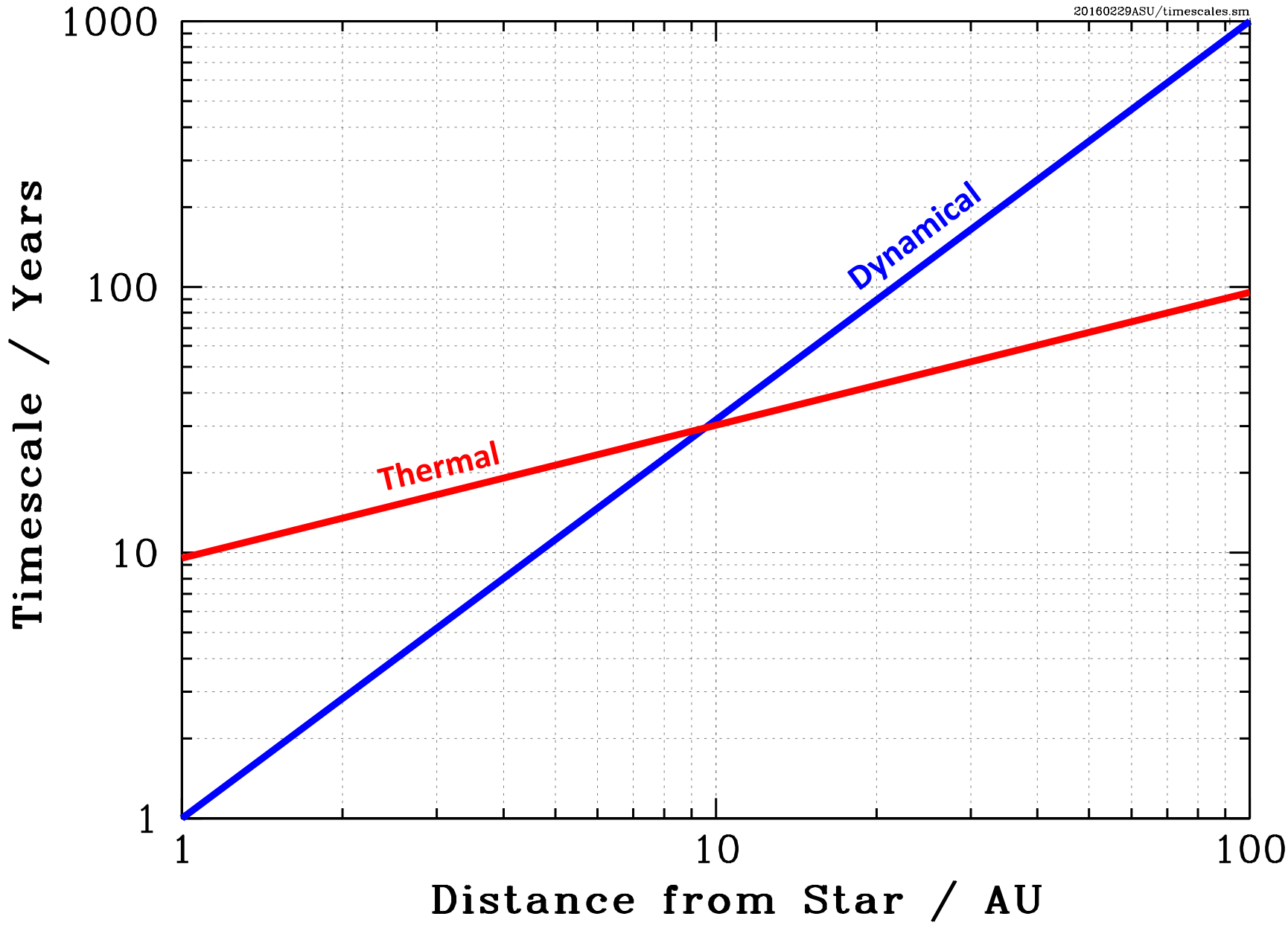
Watanabe & Lin 2008


20160229ASU/timescales.sm
1000
100
10
1
1
10
100
Timescale / Years
Distance from Star / AU
Dynamical
Thermal

Poor Man's Radiation Hydrodynamics

$$\Delta h = (h_{eq} - h)\frac{\Delta t}{\max\left(t_{dy}, t_{th}\right)}$$