

Dust Survival in Galactic Outflows

Insights from a New Suite of High-Resolution Simulations

Helena Richie & Evan Schneider, Pan Dust 2025, Nov. 14th, 2025



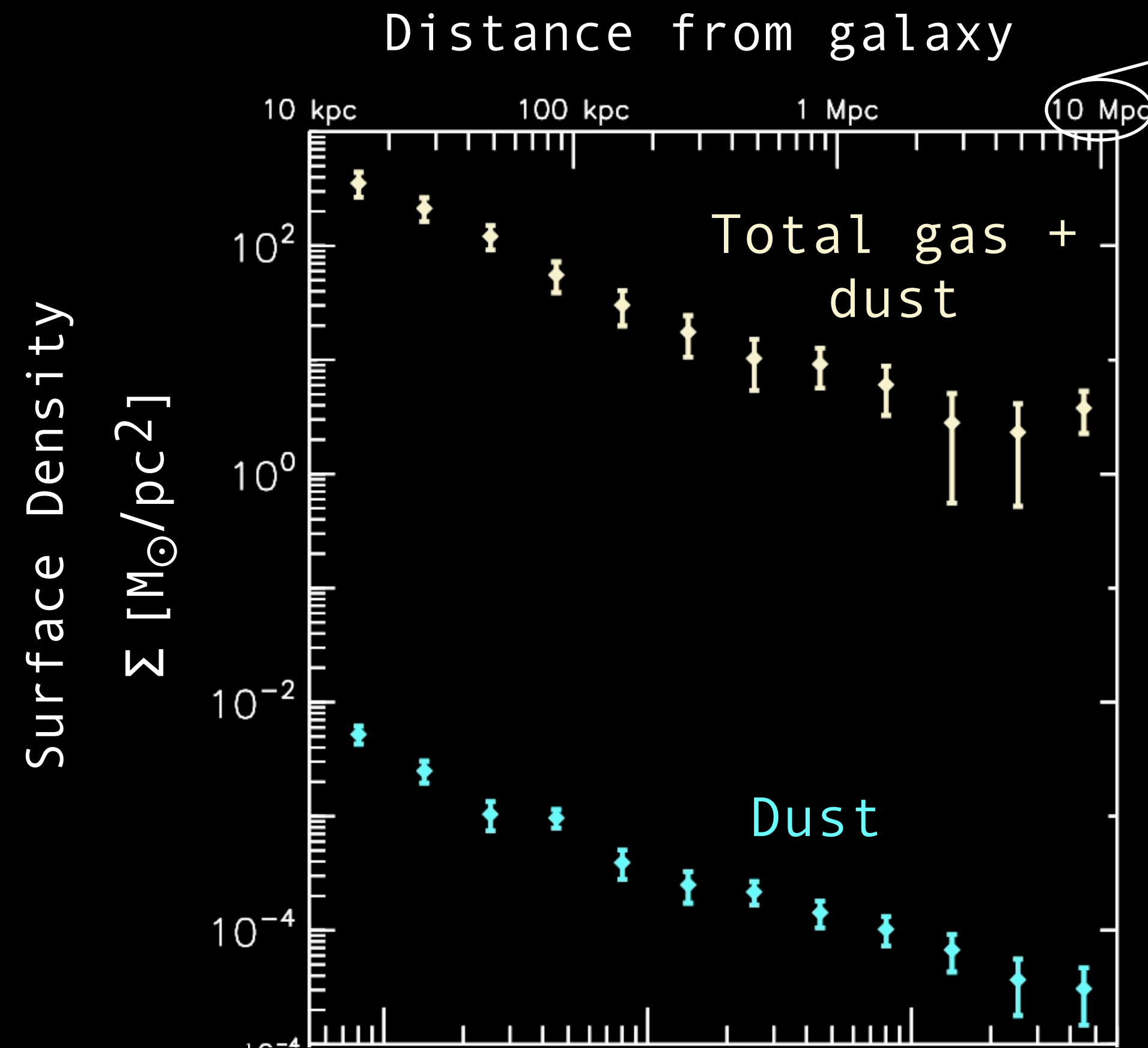
University of
Pittsburgh

Department of
Physics & Astronomy

Dust in the Circumgalactic Medium

10 Mpc !

CGM $\equiv$
circumgalactic
medium

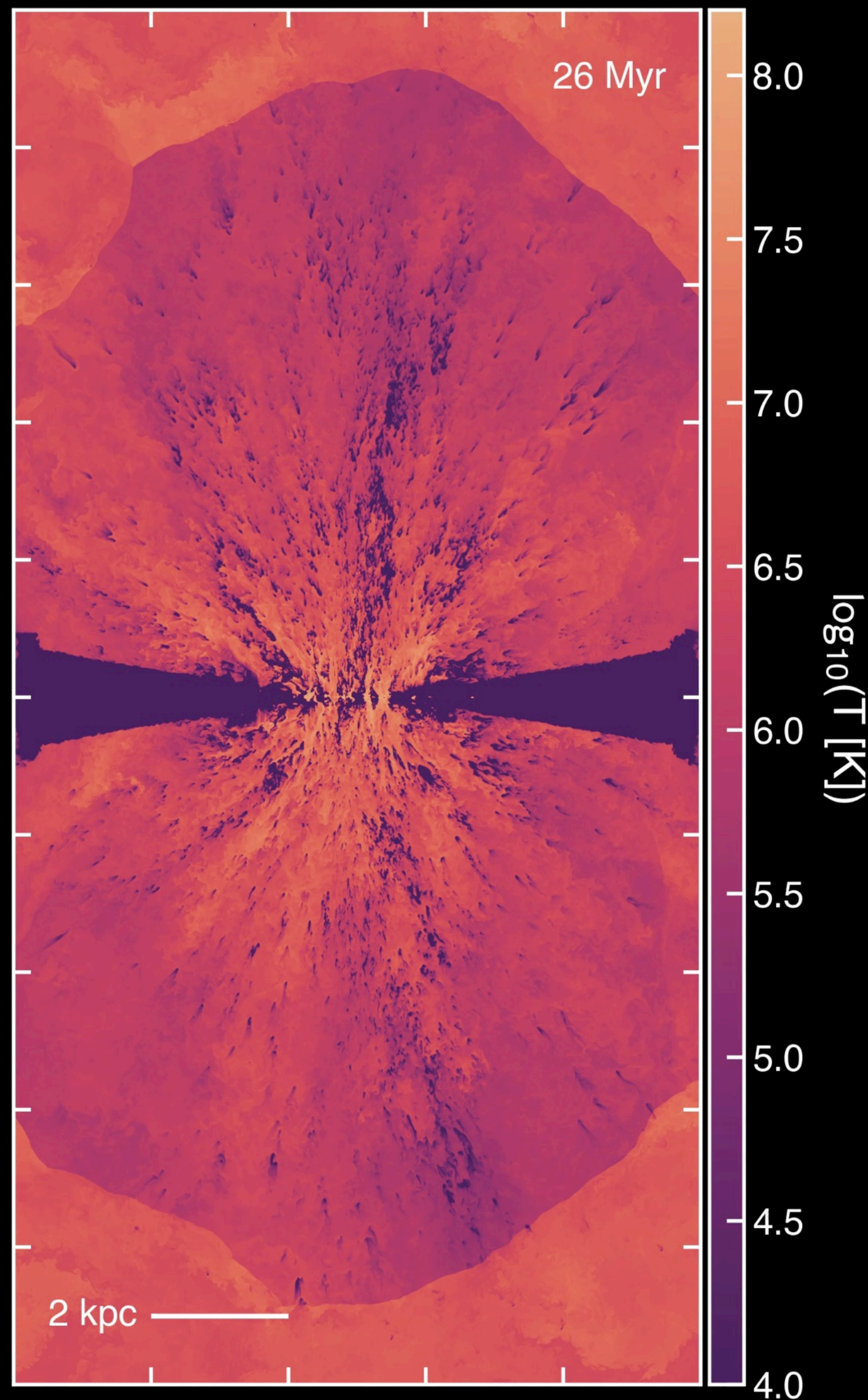


Mean surface density profiles
for galaxy halos at $z \sim 0.3$

These observations imply that the
mean halo cosmic dust density
(Ω_{dust}) is roughly equivalent (?!) to
the galactic Ω_{dust}

Ménard et al. (2010)

Gas Temperature Slice



Richie & Schneider (2025)

Multi-phase Galactic Outflows

hot supernova wind ($\sim 10^7$ K)

cool ISM clouds ($\sim 10^4$ K)

hydrodynamic
mixing

intermediate phase ($\sim 10^5$ K)

*Can outflows transport dust to the CGM
without destroying it?*

Sputtering: $t_{\text{sp}} \sim a \rho^{-1} T^{-2.5}$

Draine & Salpeter (1979);
Tsai & Mathews (1995)

For $a = 0.1 \mu\text{m}$ dust: $t_{\text{sp,hot}} \sim 10 \text{ Myr}$

$t_{\text{sp,cool}} > 10 \text{ Gyr}$

Dust in the Multi-phase Outflow of M82

PAH lifetimes in
supernova winds are
~1000 yr

(Micelotta et al. 2010)

See upcoming paper by
Serena Cronin et al. for
details on PAH evolution
in M82's outflow!

See also: Villanueva et al.
(2025), Lopez et al. (2025),
Fisher et al. (2024)



PAHs!

Spitzer: Engelbracht et al. (2006)

JWST: Bolatto et al. (2024)

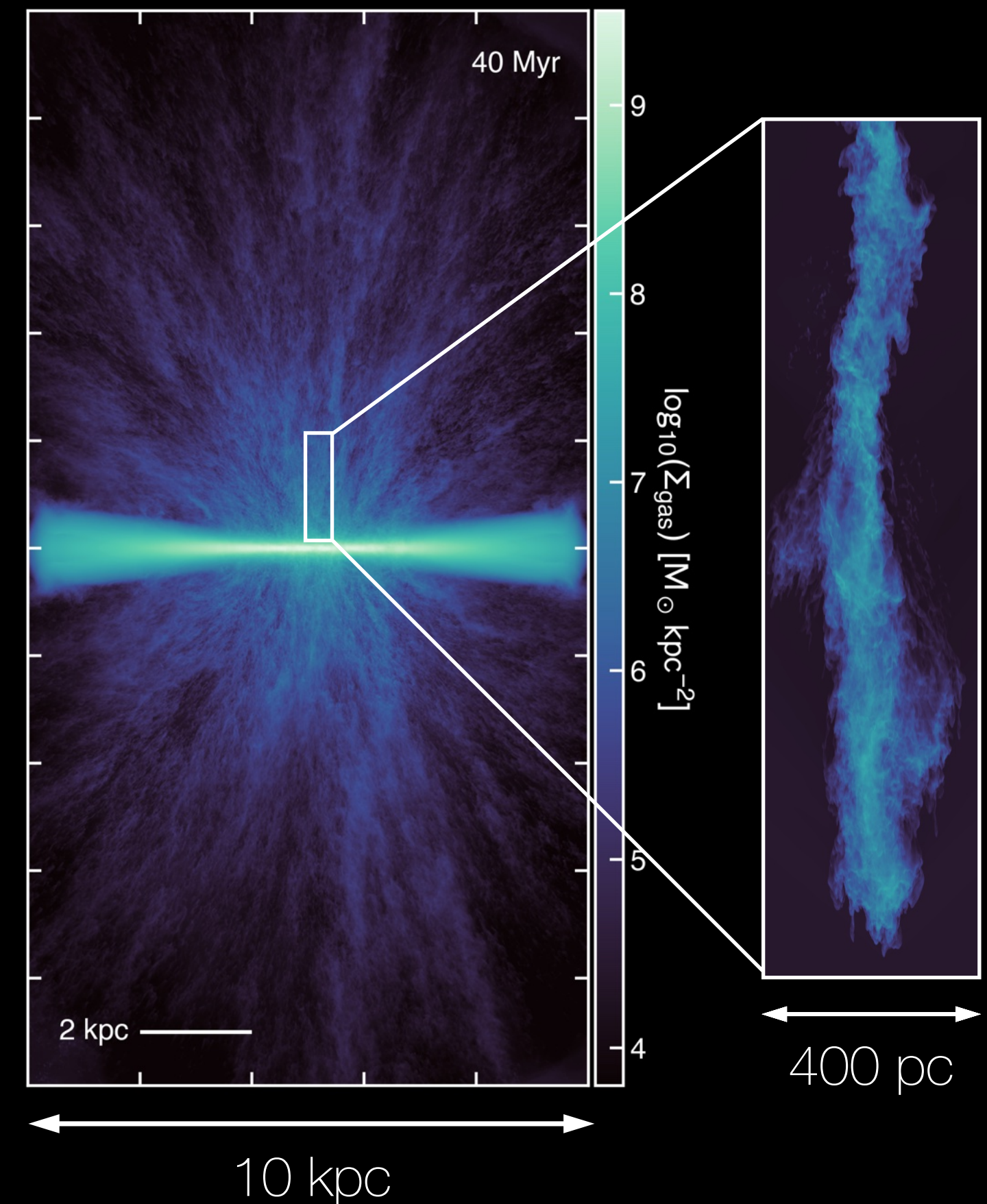
Using High Performance Computing to Tackle Outflow Simulations

Schneider & Robertson (2015) Dust model: Richie et al. (2024)

Cholla

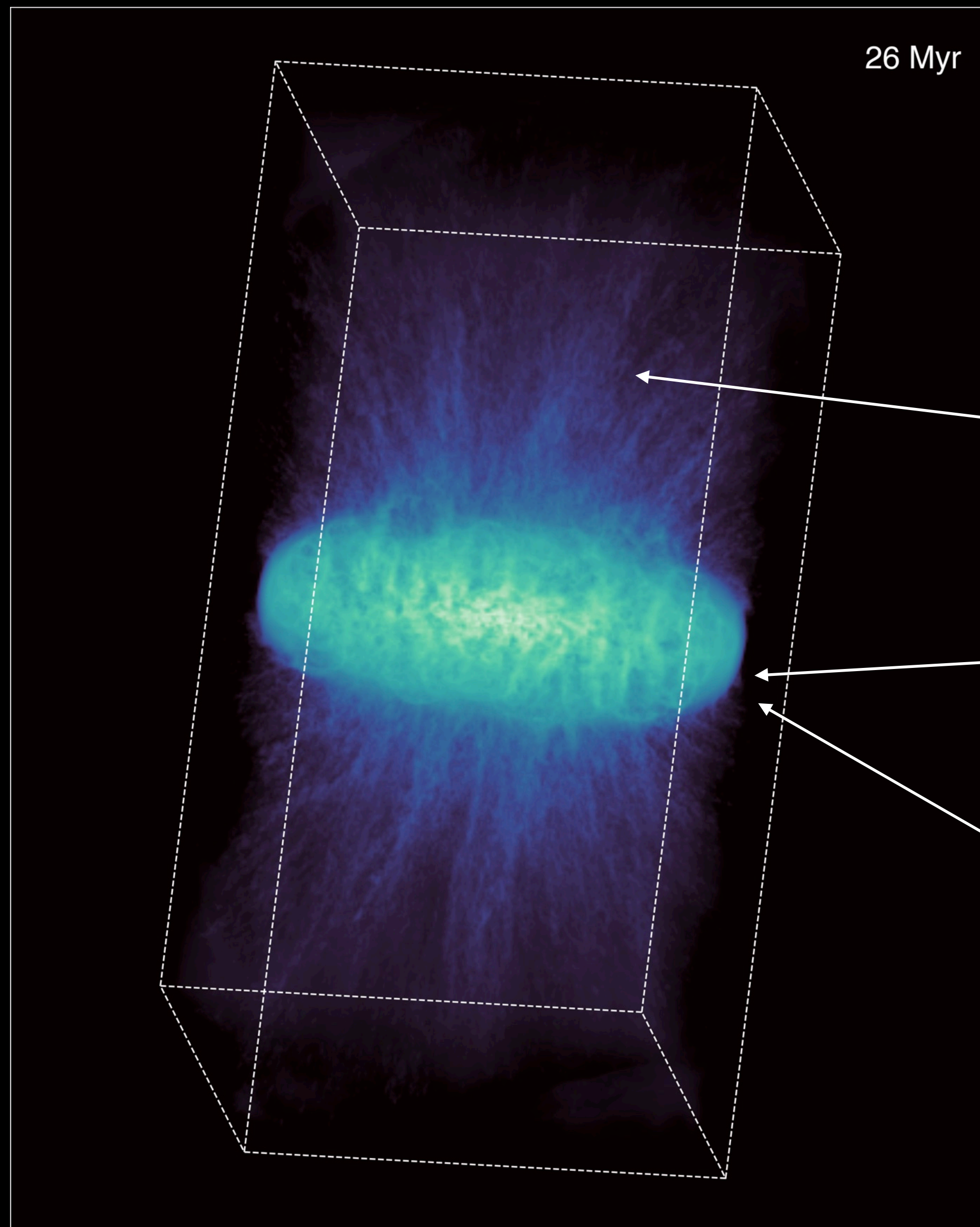
Computational **H**ydrodynamics **O**n
*para***LL**el **A**rchitectures:
a GPU-based hydrodynamics code

Richie & Schneider (2025)



This galaxy simulation uses **8192 GPUs** and takes ~5 hours to run.

Gas Density Projection



Global Galactic Outflow Simulations

Contains $\sim 10^5$ dusty clouds!

Initial hot, static halo, 10^6 K

10^4 K disk

Stellar mass: $10^{10} M_{\odot}$

$5 M_{\odot}/\text{yr}$ SFR

ISM dust-to-gas ratio: 0.01

we simulate four different grain sizes:
1, 0.1, 0.01, and $0.001 \mu\text{m}$

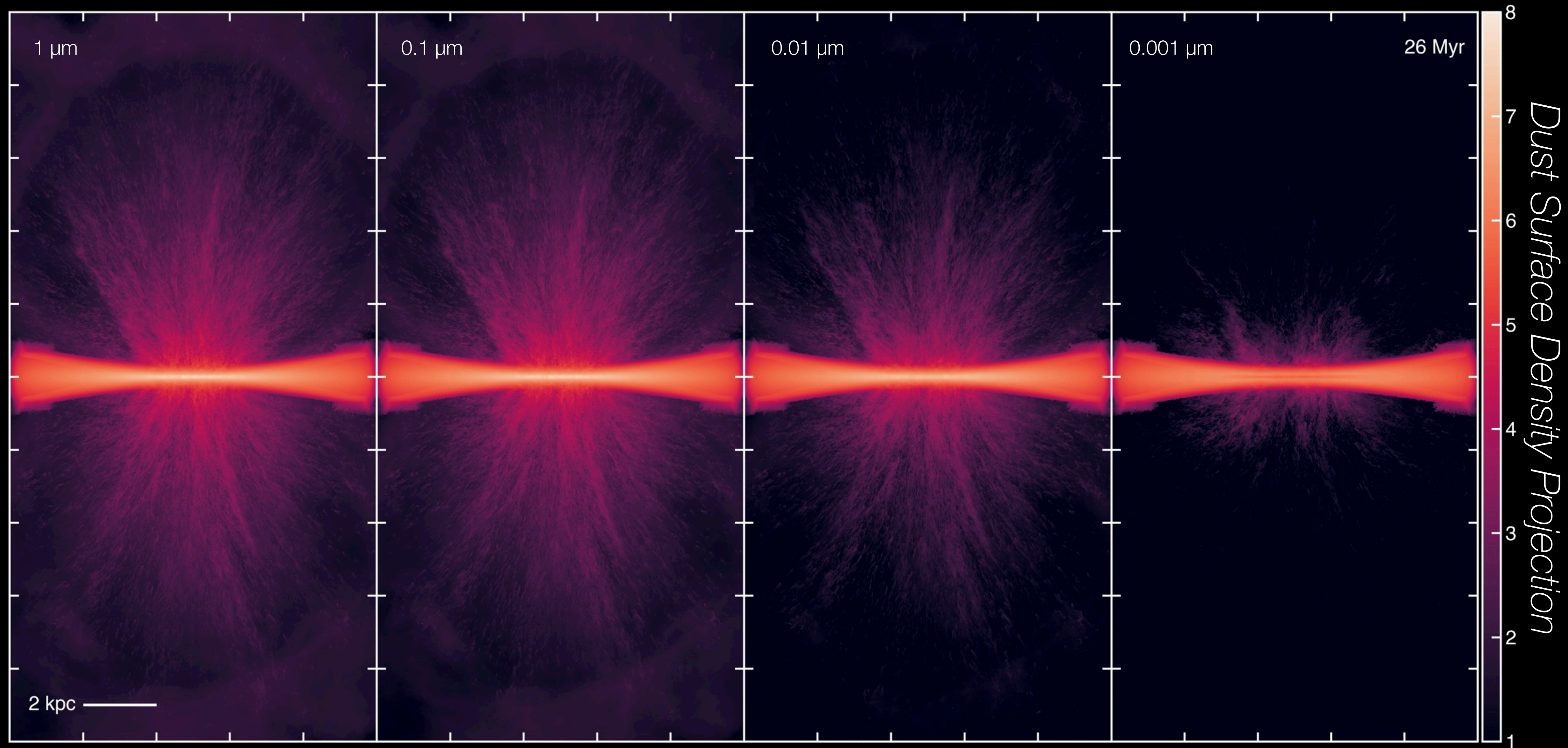
Box Dimensions

$10 \times 10 \times 20 \text{ kpc}^3$

$\Delta x = \Delta y = \Delta z = 4.9 \text{ pc}$

$2048 \times 2048 \times 4096$
(~17 billion) cells

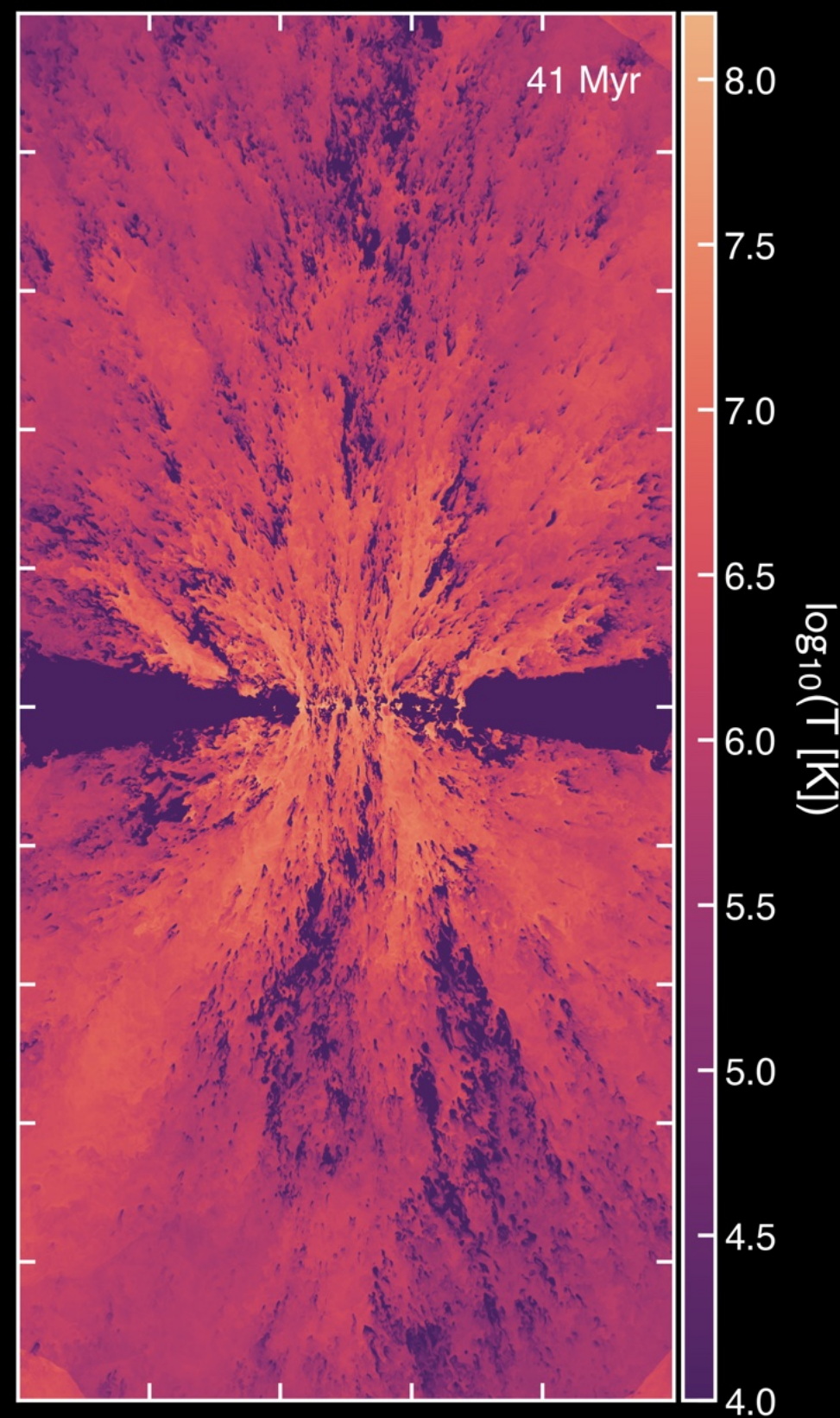
Richie & Schneider (2025)



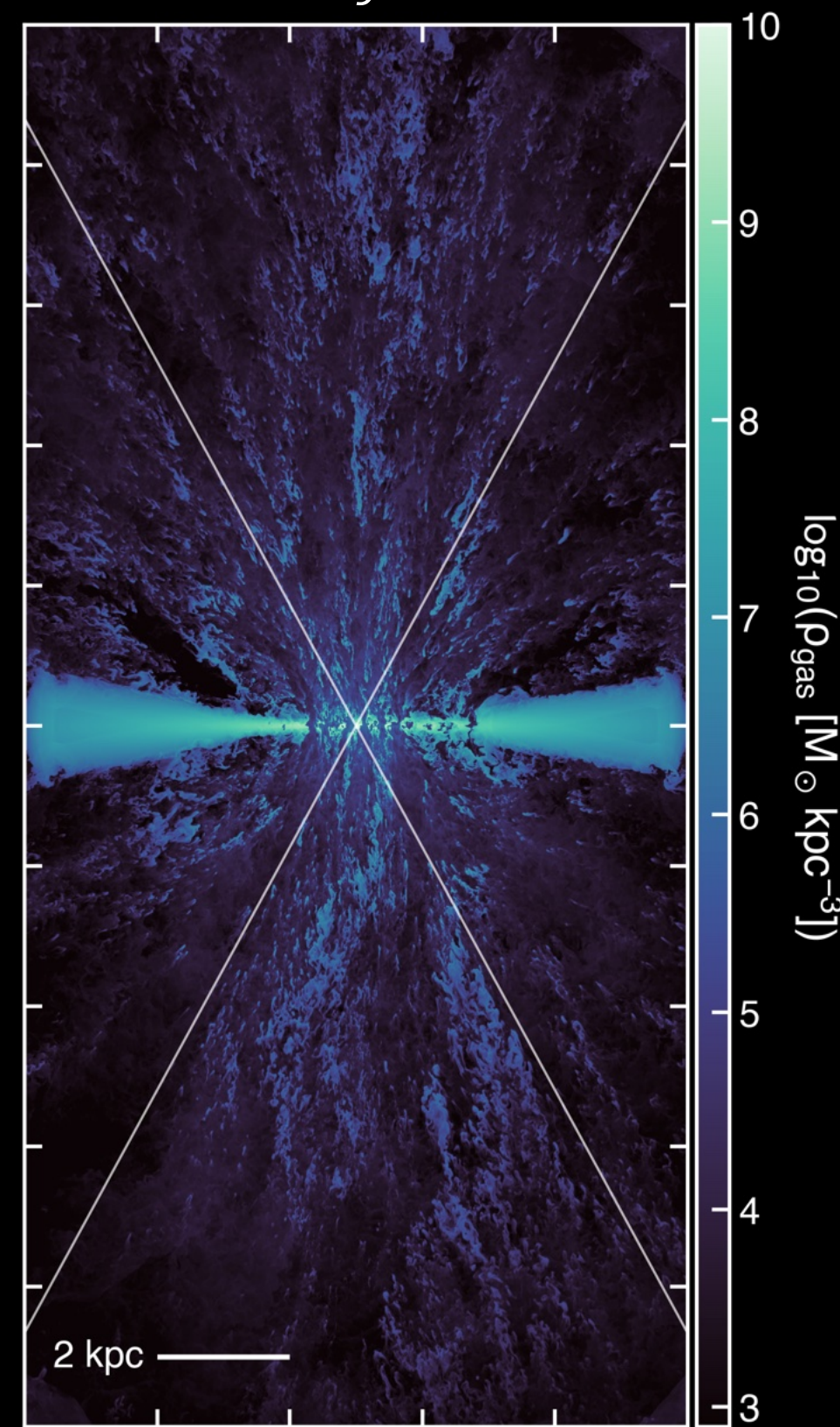
Richie & Schneider (2025)

Dust Survival in the Hot Phase

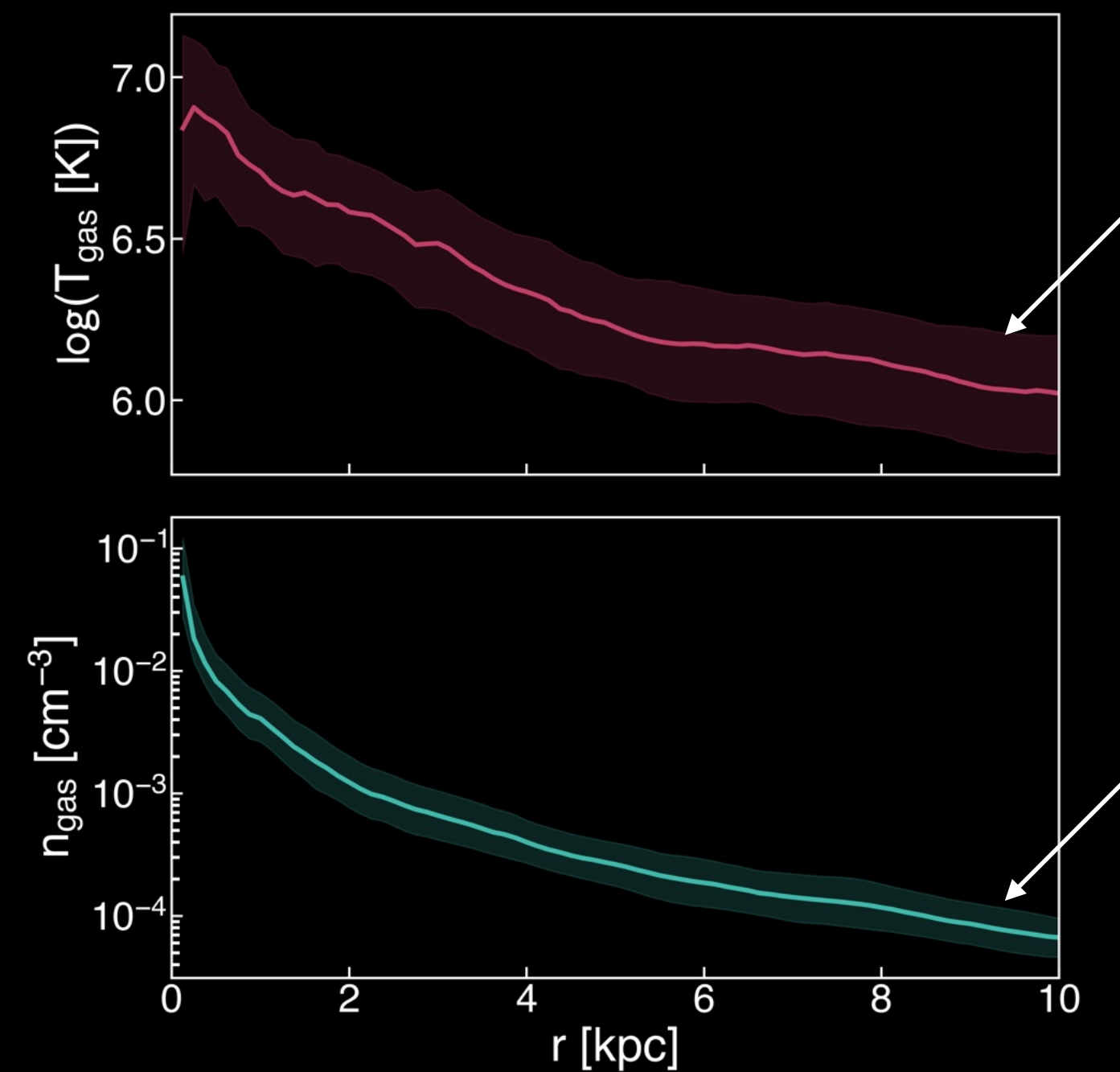
Temperature Slice



Density Slice



Median Hot Phase Profiles



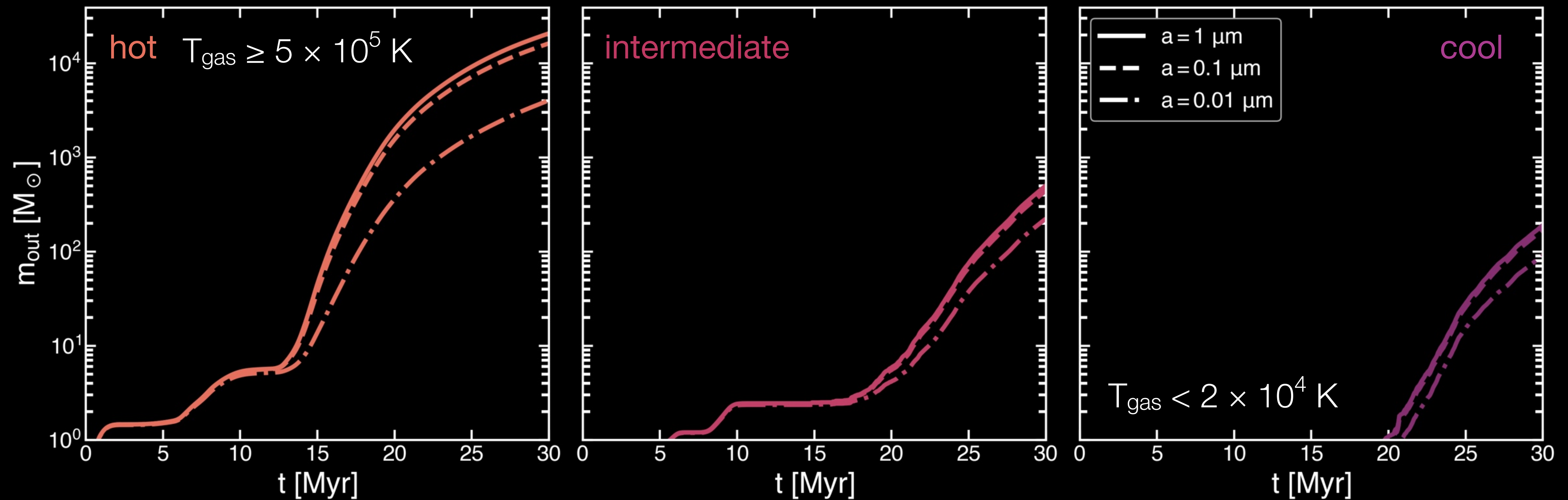
$a = 0.1 \mu\text{m}$ $t_{\text{sp,hot}}$ lengthens from
 $\sim 10 \text{ Myr}$ to $\sim 100 \text{ Myr}$

⇒ large grains can survive in the hot phase!

Richie et al. (2024)

How much dust survives?

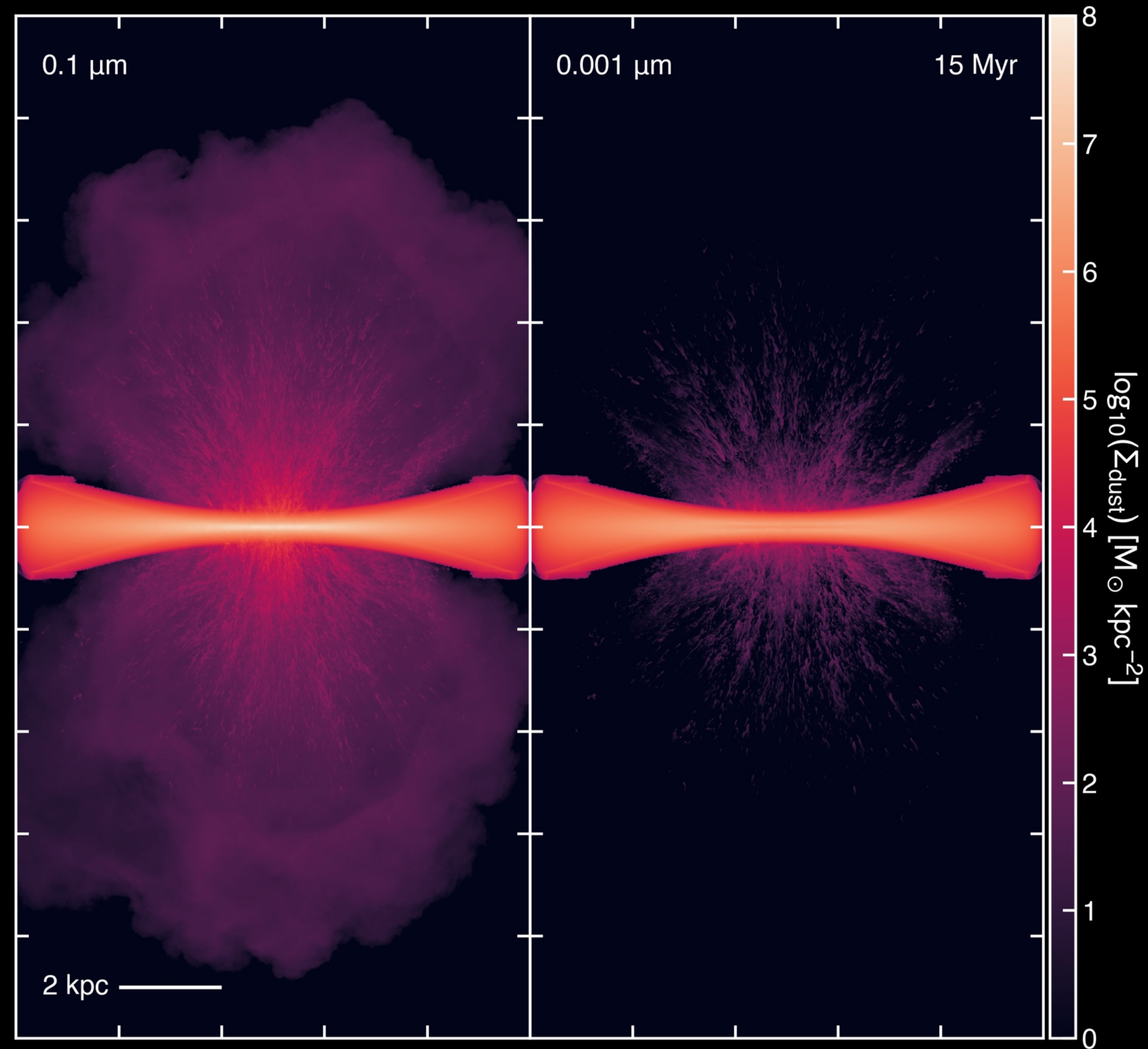
— : 98%
--- : 84%
- · - · - : 38%



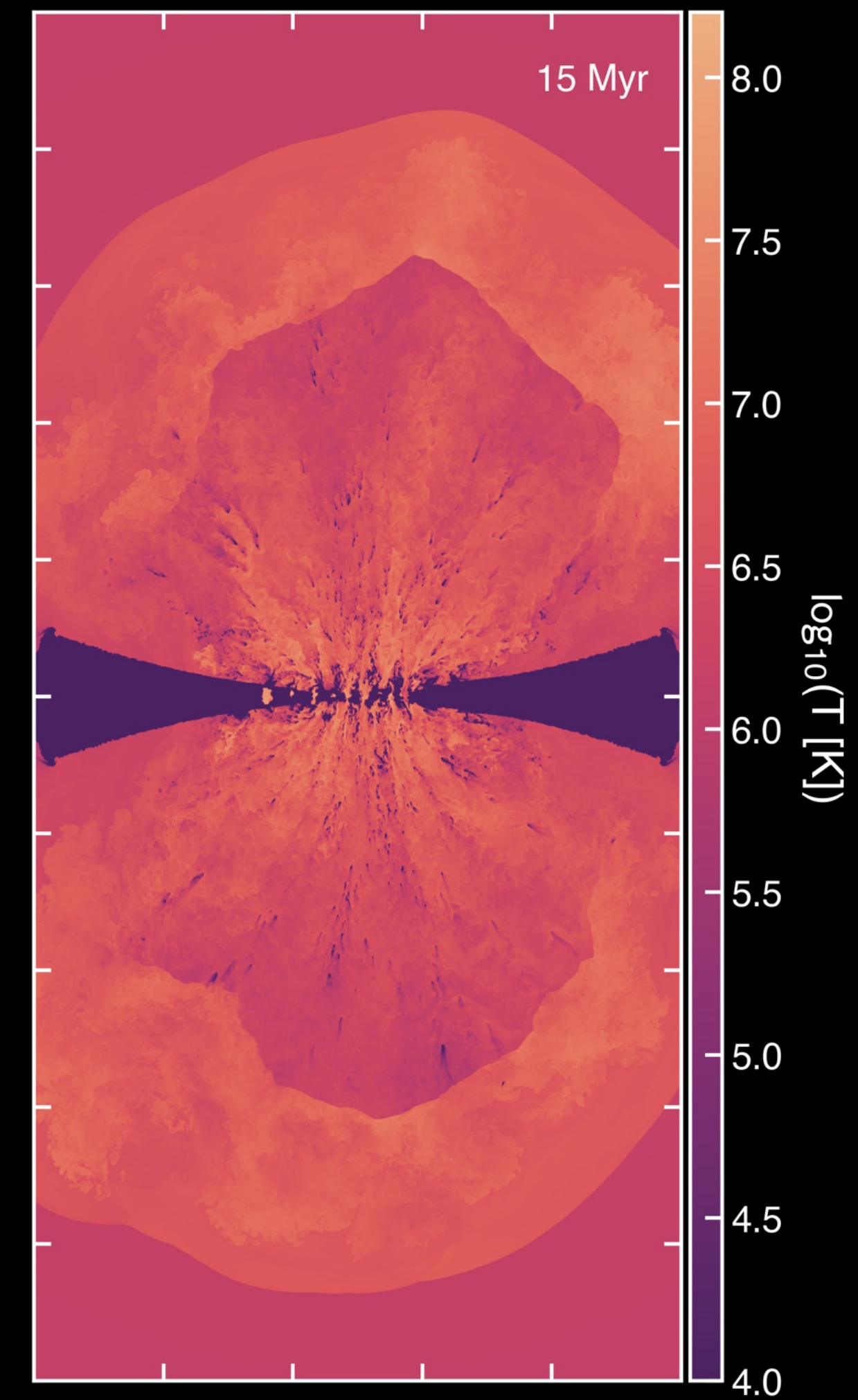
Richie & Schneider (2025)

Somewhat surprisingly, most dust leaves in the hot phase!

Dust Density Projection

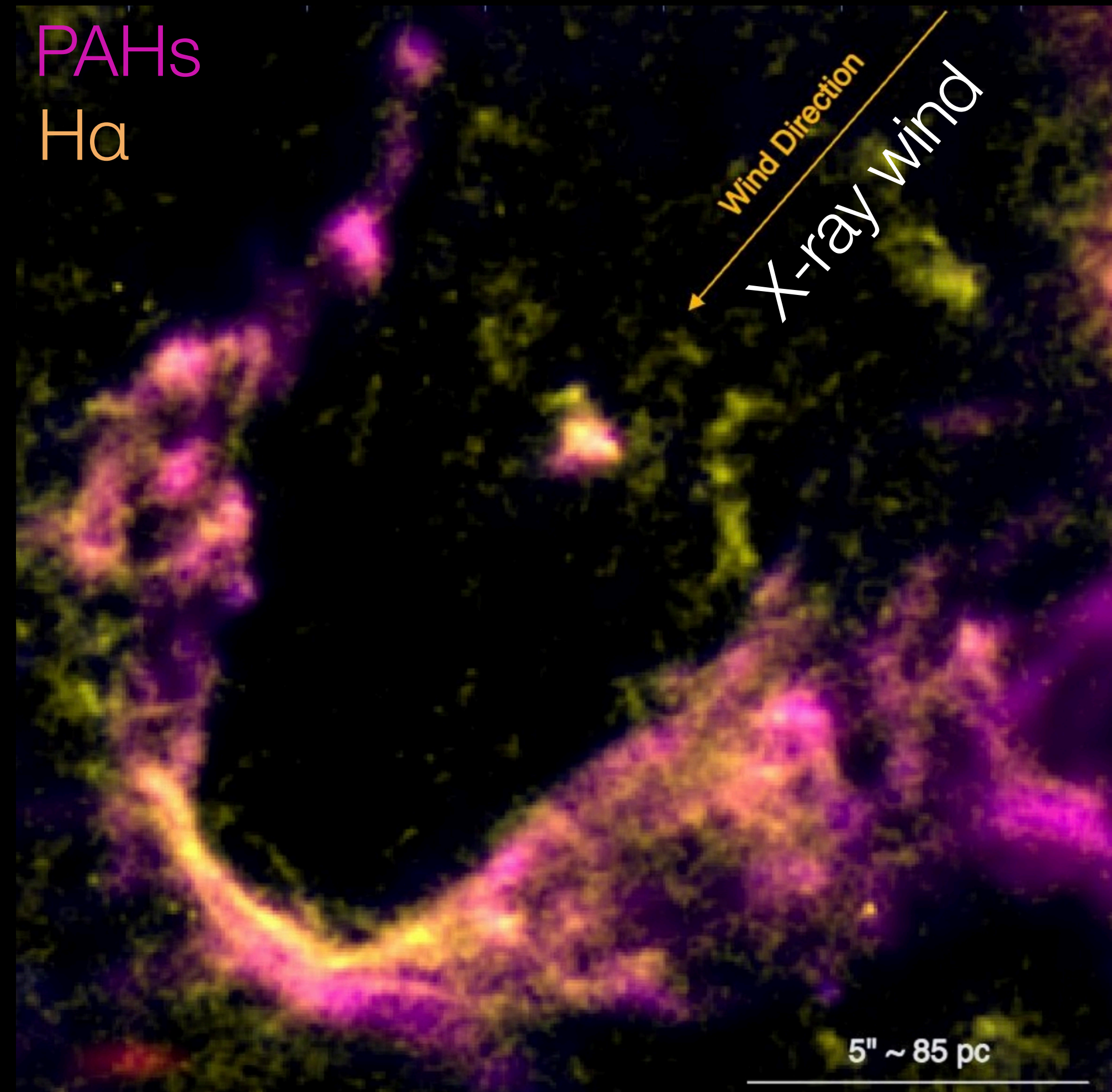


Gas Temperature Slice



Richie & Schneider (2025)

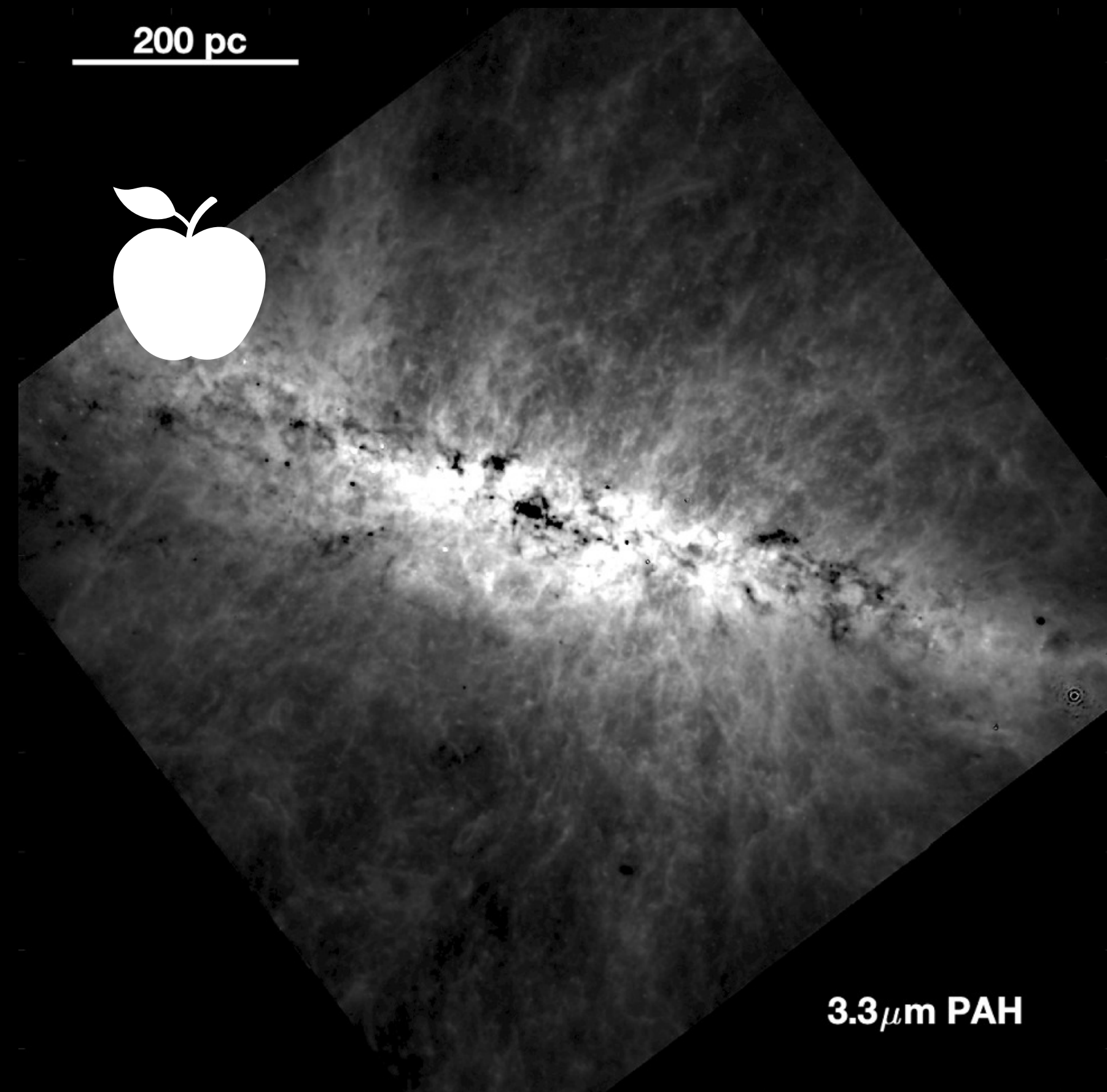
We see this in observations!



Lopez et al. (2025)

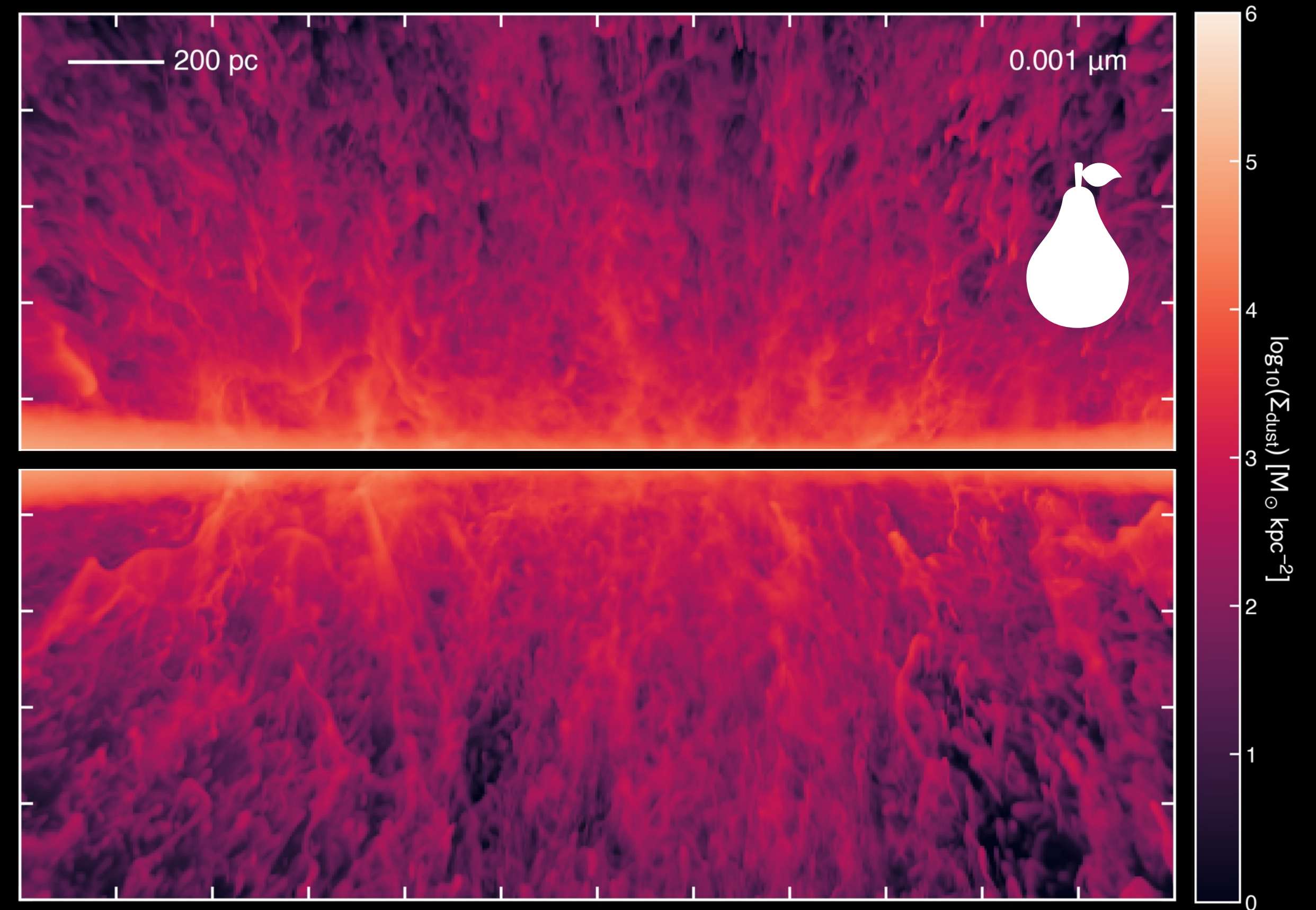
How can we make more direct comparisons?

Resolution: $\sim 1 - 2$ pc



Bolatto et al. (2024); Fisher et al. (2024)

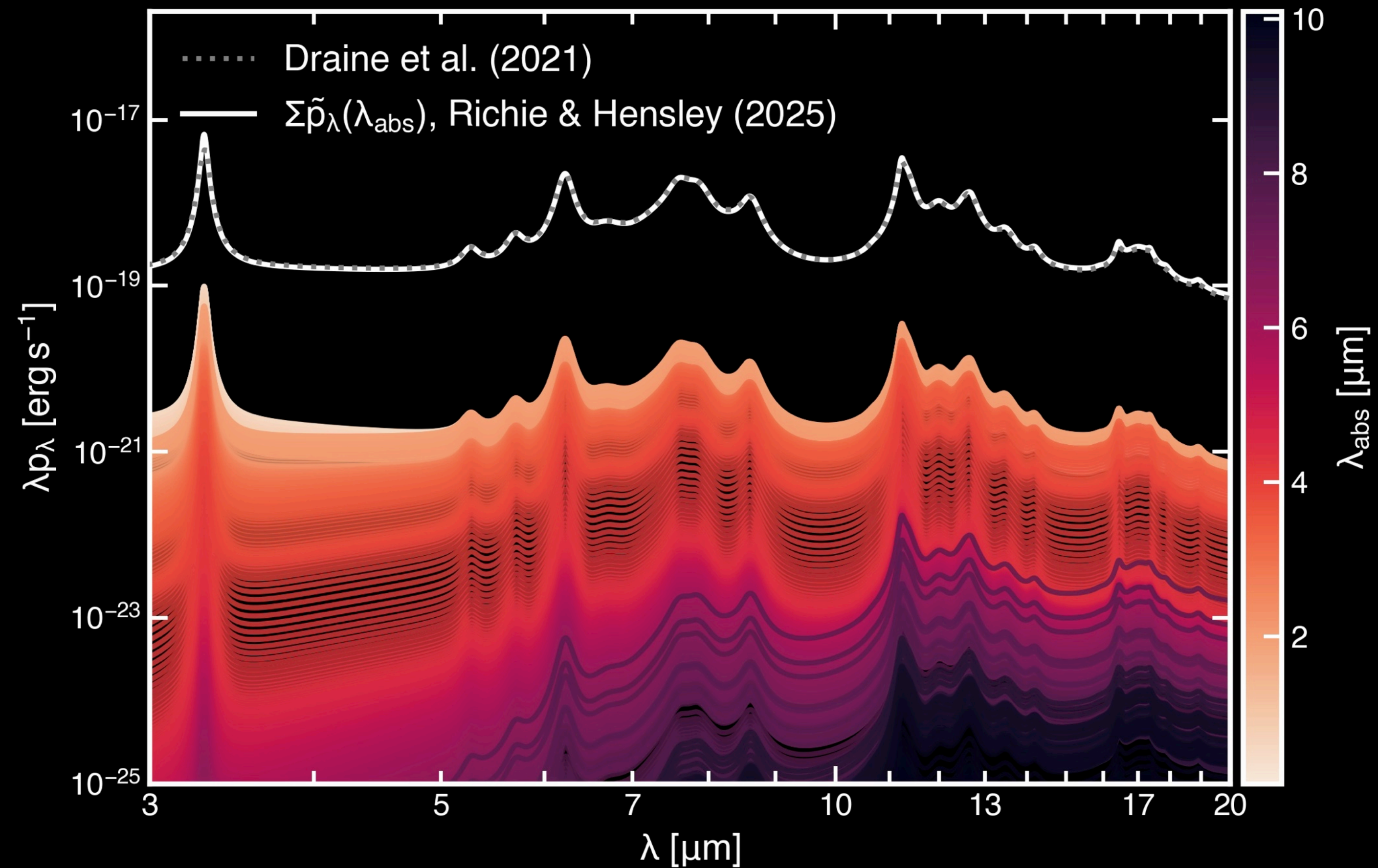
Resolution: 4.9 pc



Richie & Schneider (2025)

A New Method for Fast, Flexible Modeling of PAH Emission

With the “Single Photon Approximation”



Richie & Hensley (2025)

Takeaways

There's a lot of dust in the circumgalactic medium!

- Galactic outflows can efficiently transport large amounts of dust to the CGM
 - Large grains can survive in outflows in all gas phases
 - Small grains (PAHs) survive only in the cool gas
- We're working on comparing these simulations with cutting-edge observations of dusty outflows from JWST to learn more about their underlying PAH properties
- Cronin et al. (in prep.) find little PAH evolution in the inner ~ 2.5 kpc of the outflow, but what about the full outflow?

Movies at helenarichie.github.io

