Characterizing the initial planet assembly with James Webb Space Telescope

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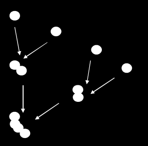
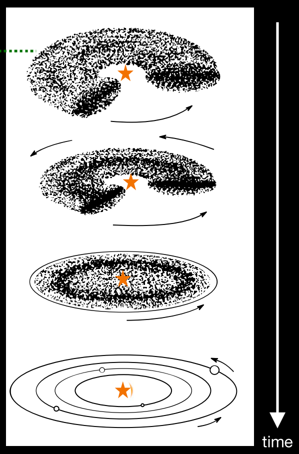
JWST's view on the birthplace of planets

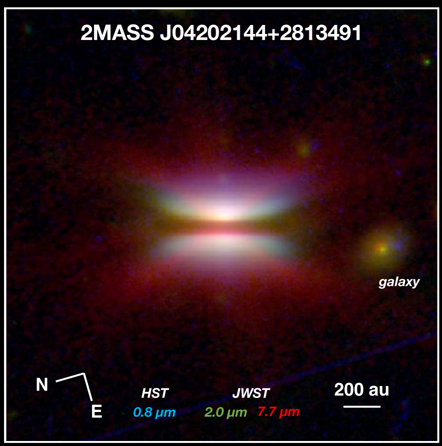
A swarm of µm-sized grains



*Grain clumping is the first step in planet formation, **but we still don't know HOW it happens.***



Credit: Til Birnstiel



Duchêne, … RT et al. (2023, arXiv:2309.07040)

The left image shows the birthplace of planets (the protoplanetary disk around Tau 042021) as observed by

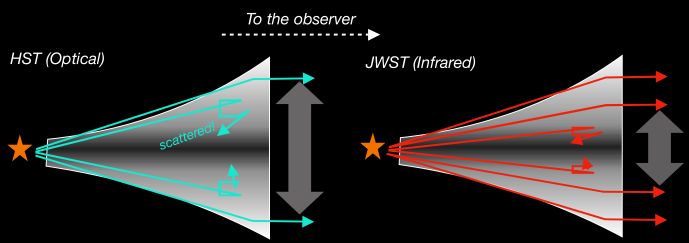
- *Hubble Space Telescope (0.8 µm)*
- *James Webb Space Telescope (JWST) with NIRCam (2.0 µm) and MIRI (7.7 µm)*

The disk is viewed from the side, which allows to learn crucial information about how planet formation begins:

- *How is "a dust swarm" distributed along the vertical and radial directions?*
- *How large are the dust particles?*
- *What is the morphology of the particles?*

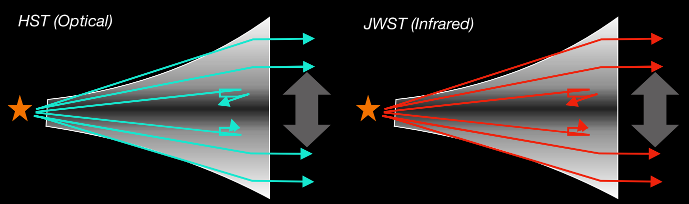
How to measure the particle size?

Small grains (grain size < λ; Rayleigh scattering)



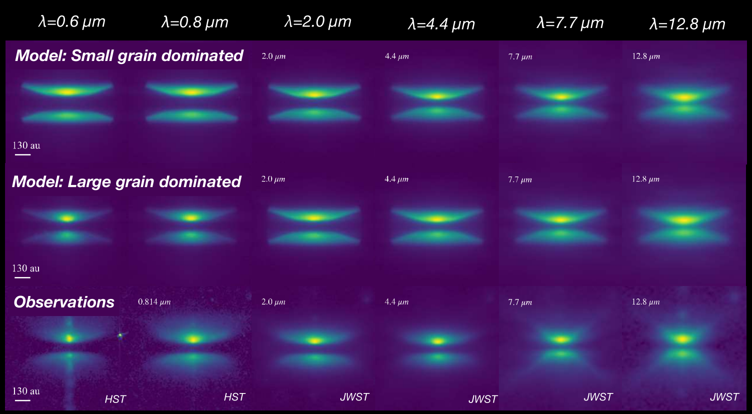
The disk will appear thicker for shorter wavelengths.

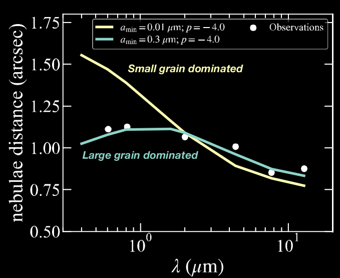
Large grains (grain size > λ; Geometrical optics)



The disk will have the same thickness regardless of λ.

Numerical simulations

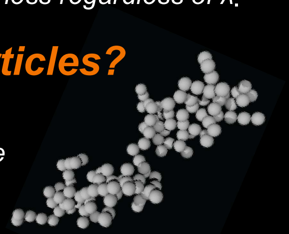




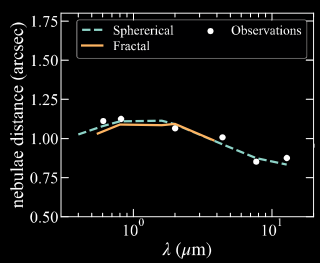
- *The data shows that the disk thickness remains almost constant at λ=0.6–2.0 µm*
- *The disk surface must be dominated by large grains!* (see also Duchêne+2023)
- *One possibility is the lack of very small grains (<0.3 µm).*

Evidence for fluffy particles?

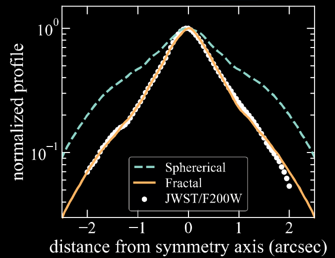
A better fit to the observations is obtained when the particles have a fractal structure (frac dim ≈ 1.9) consisting of 0.4-µm subgrains.



Dark lane thickness



Brightness distribution



Summary and future prospect

- *Thanks to the high spatial resolution and exquisite sensitivity of JWST, we start to obtain observational evidence for how planet formation begins.*
- *From the data we obtained in the Cycle 1 GO program, we showed that the surface region of the Tau 042021 disk is likely dominated by larger grains, perhaps with a fluffy structure.*
- *Our Cycle 2 proposal for JWST has been approved !*
- *Full Cycles 1 and 2 survey will cover 4+13 edge-on protoplanetary disks and enable comparative studies.*

Acknowledgment

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