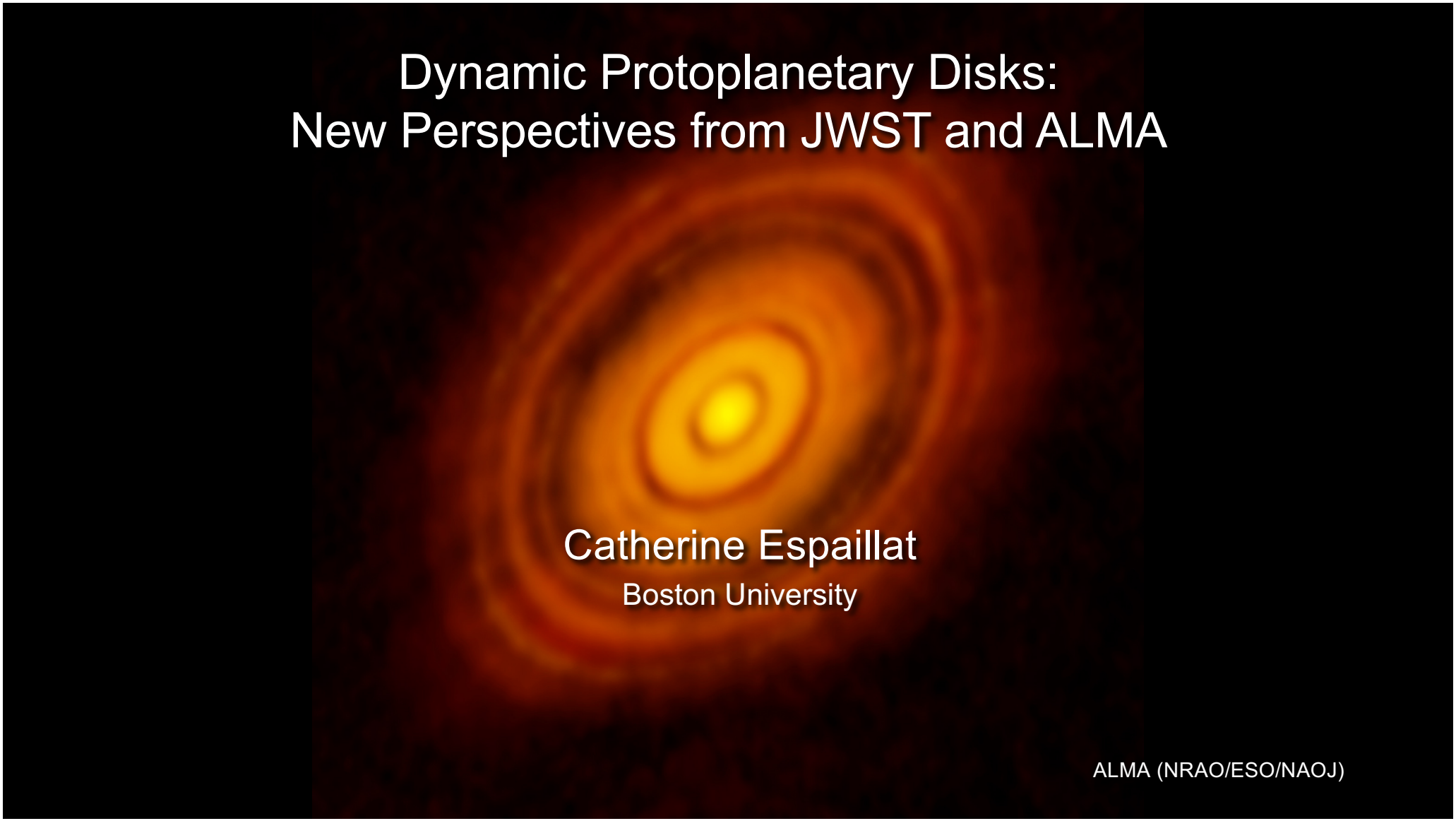
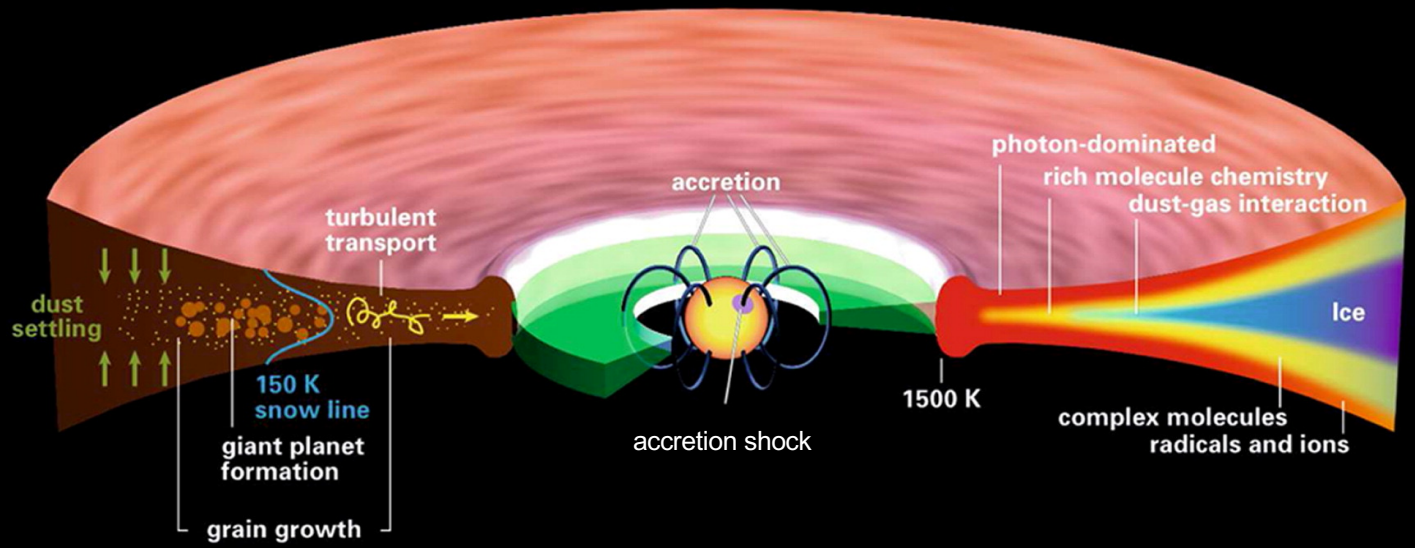
Dynamic Protoplanetary Disks: New Perspectives from JWST and ALMA



Catherine Espaillat
Boston University

ALMA (NRAO/ESO/NAOJ)

Protoplanetary disks have complex radial and vertical structure



Henning & Semenov 2014

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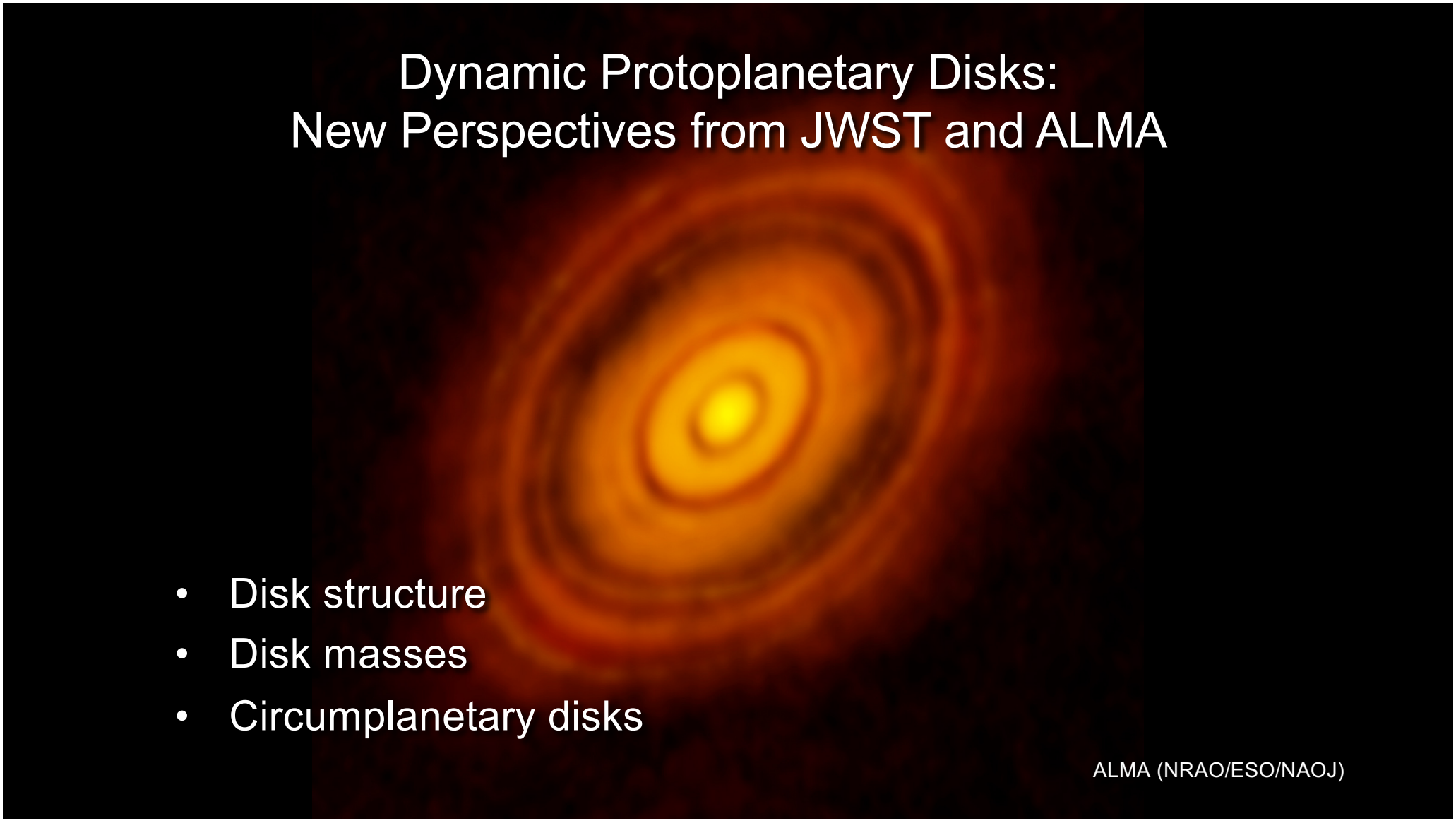
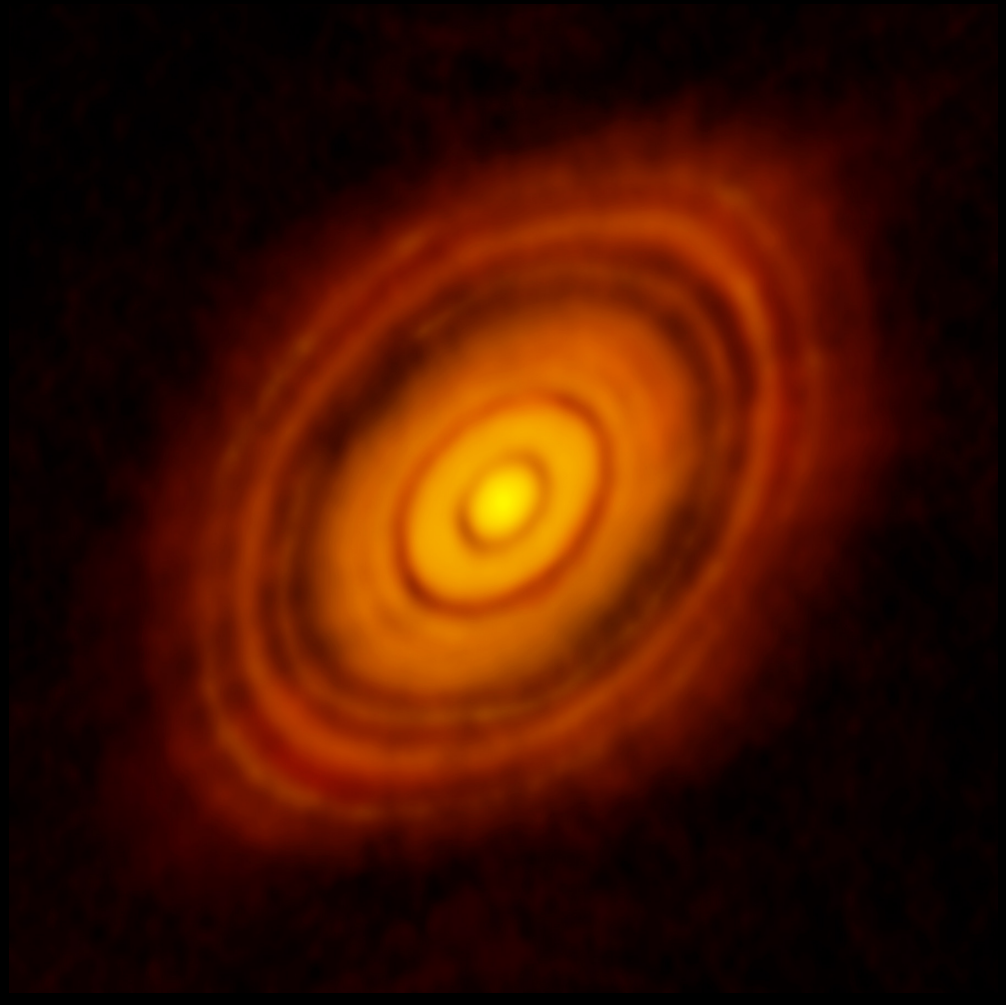


- Disk structure
- Disk masses
- Circumplanetary disks

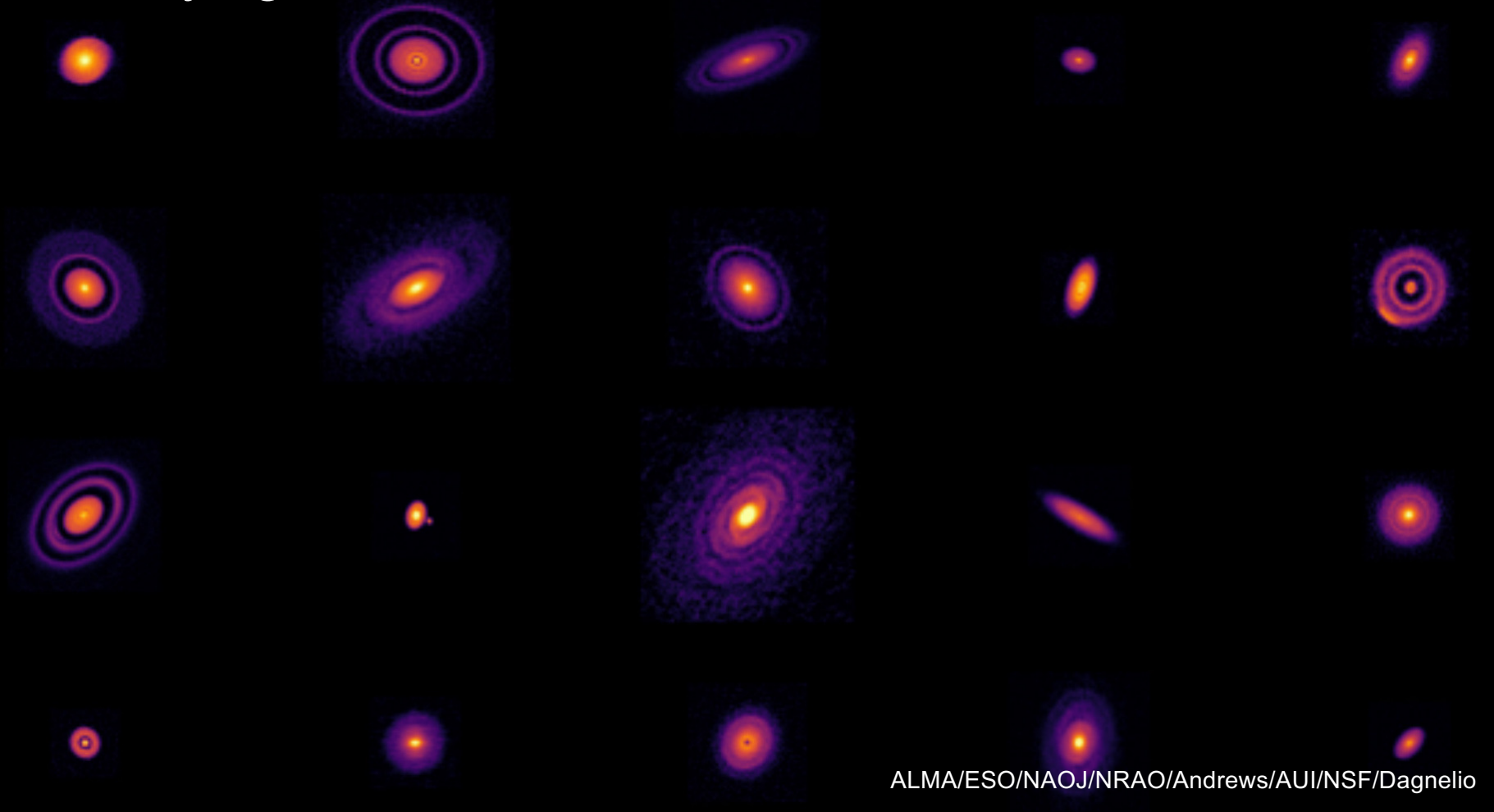
ALMA (NRAO/ESO/NAOJ)

ALMA revolutionized our understanding of disk structure



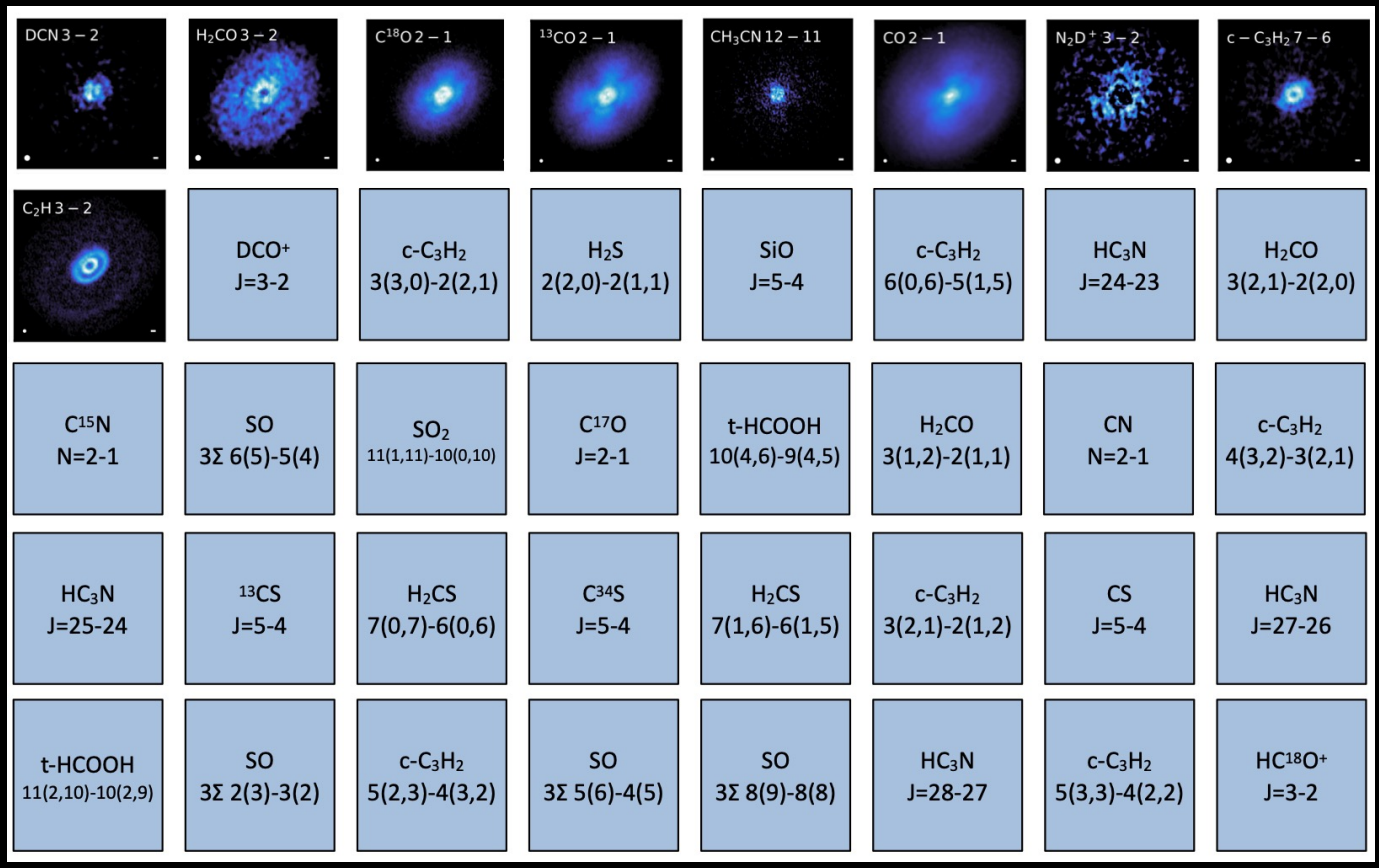
ALMA Partnership 2015

Surveying disk structure with ALMA



ALMA/ESO/NAOJ/NRAO/Andrews/AUI/NSF/Dagnelio

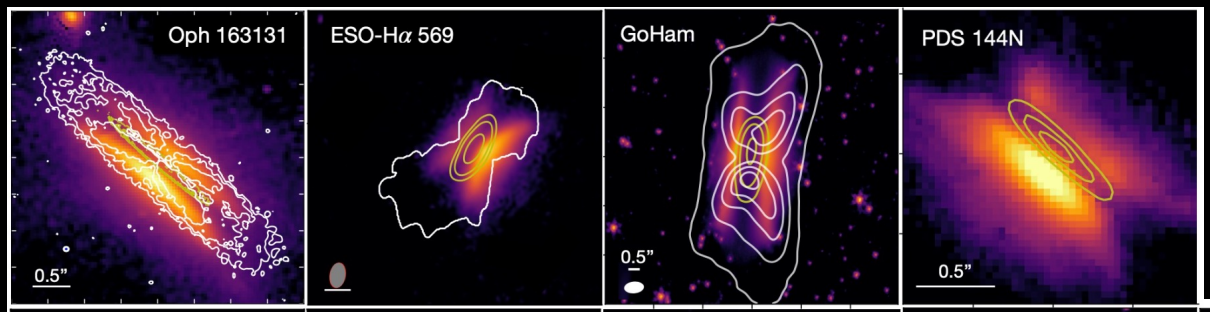
ALMA MAPS the chemical structure of disks



Oberg et al. 2021; figure from Carpenter et al. 2022

DiskStrat will explore the vertical dimension of disks with ALMA

PI: Le Gal; Co-PIs: Aikawa, Bergner, Espaillat, Menard

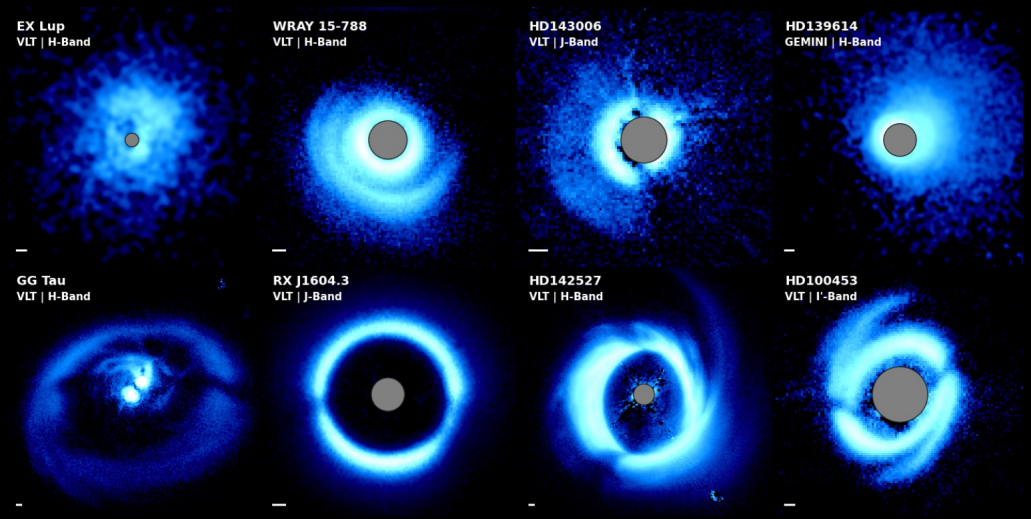


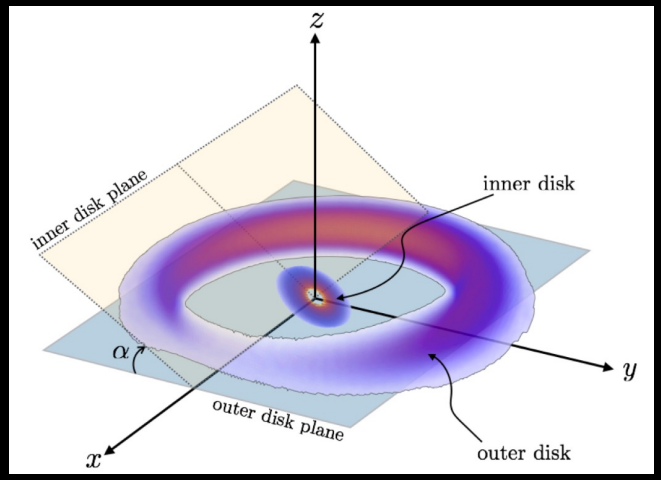
Molecular tracers
C_2H, HCN
^{12}CO, ^{13}CO, $C^{18}O$, CS
CO isotopologues, SO lines
HCO^+, $H^{13}CO^+$
C_2H, HCN, H_2CO, CH_3CN, CH_3OH, c-C_3H_2, H_2CS
C_2H+HCN+CO isotopologues; H_2S+CS+SO
DCN, $HC^{15}N$, $H^{13}CN$

Data from Villenave et al. 2020, 2022, & F. Menard

Disk structure variability is detected through shadows on the outer disk

The variability in some of the shadows is on the timescale of months to years, which points to precession of a misaligned inner disk.

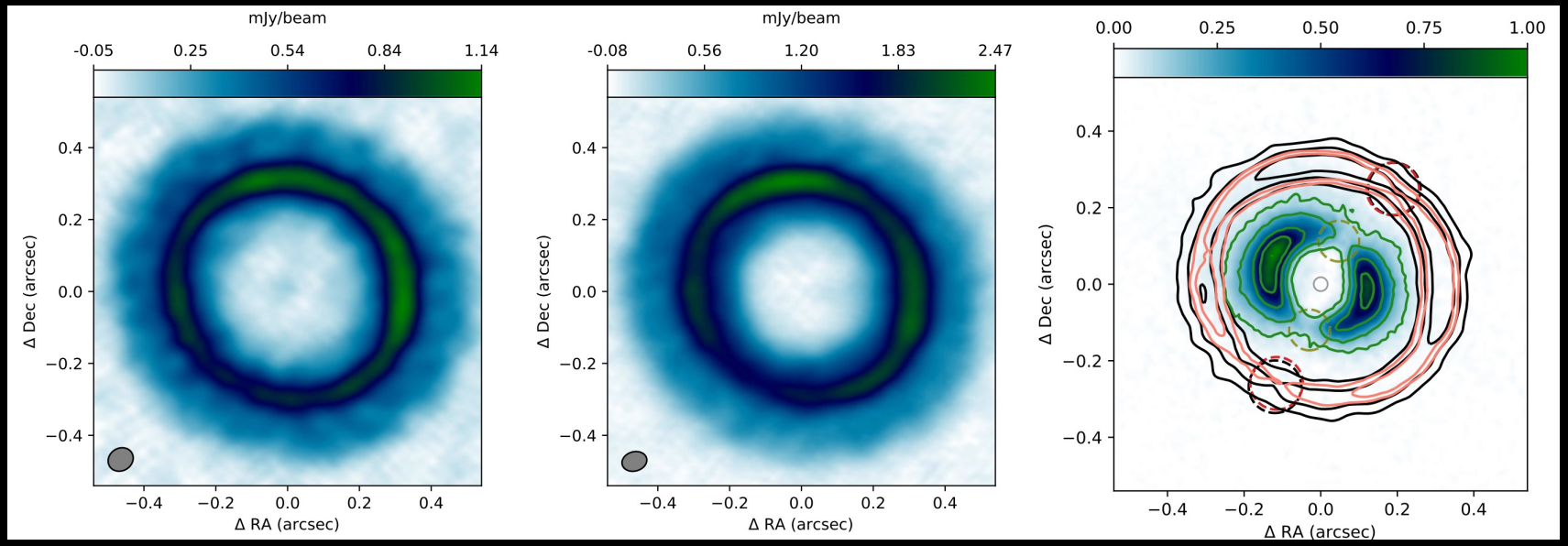




Benisty et al. 2023; Marino et al. 2018

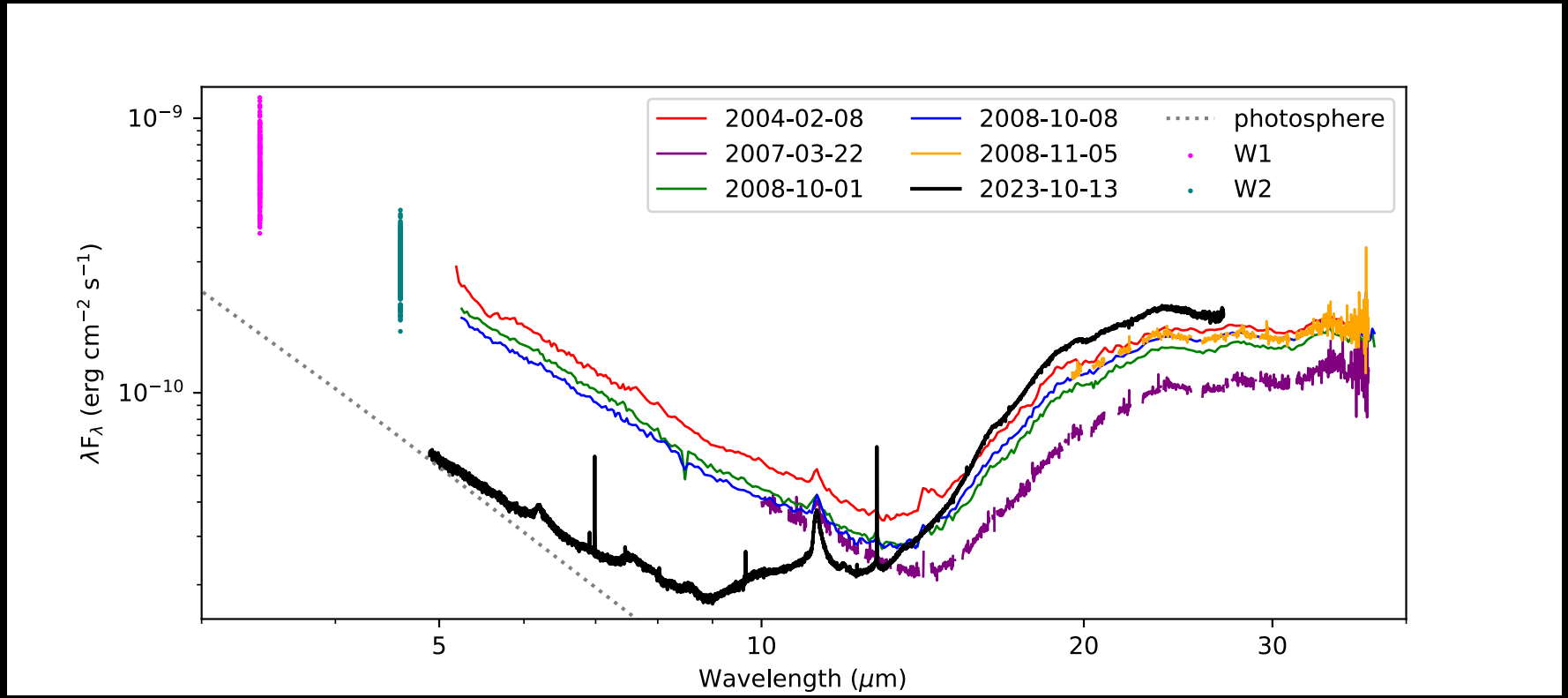
ALMA also detects shadowing on the outer disk

ALMA observations of DoAr 44 in the continuum at 230 and 350 GHz compared to SPHERE NIR scattered light images indicate dips which are most likely due to shadowing by a misaligned inner disk.



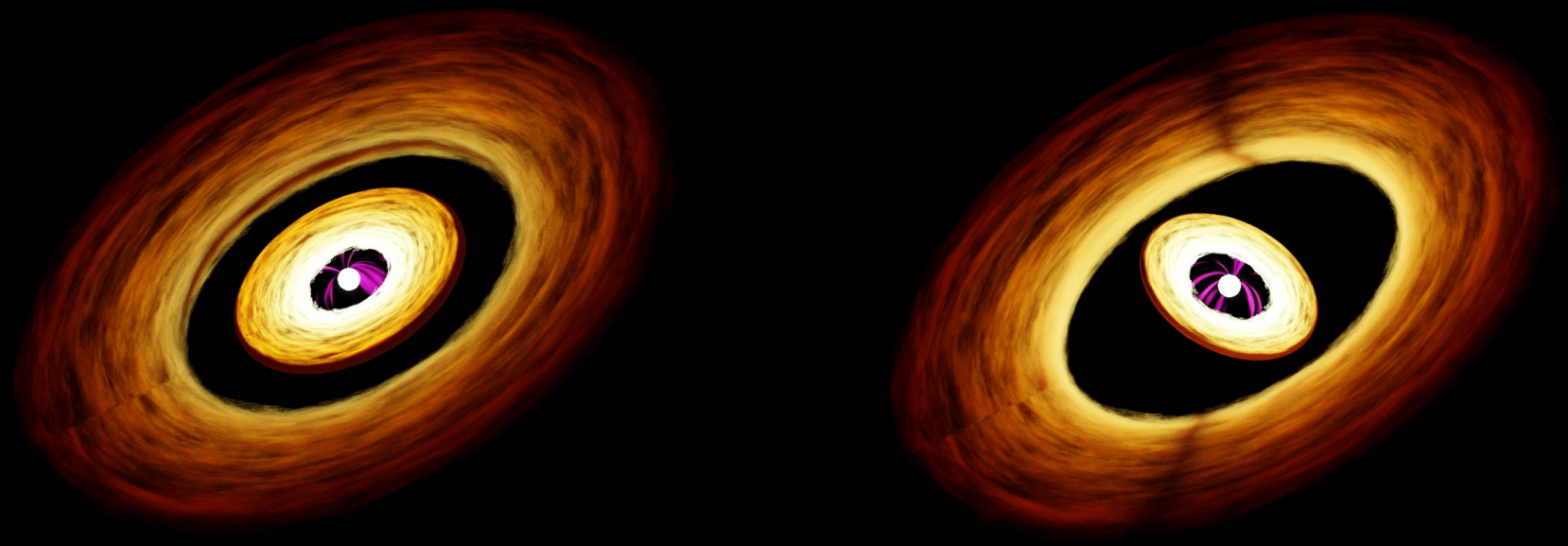
Arce-Tord et al. 2023

JWST can identify misaligned inner disks via MIR “seesaw” continuum variability



Espaillat et al. 2024

A misaligned inner disk will lead to variable shadowing on the outer disk as the inner disk precesses



Espaillat et al. 2024

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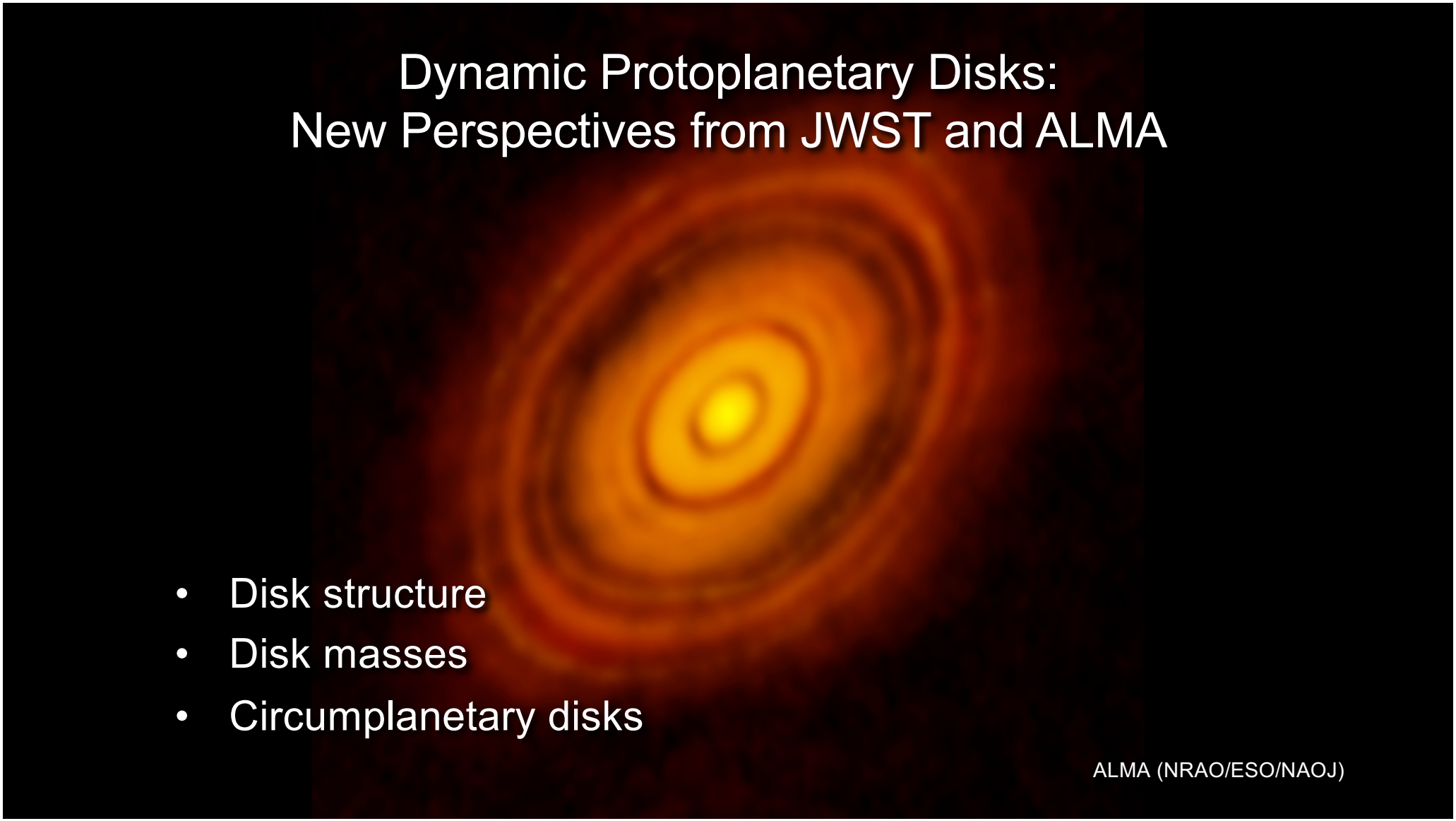

- Disk structure
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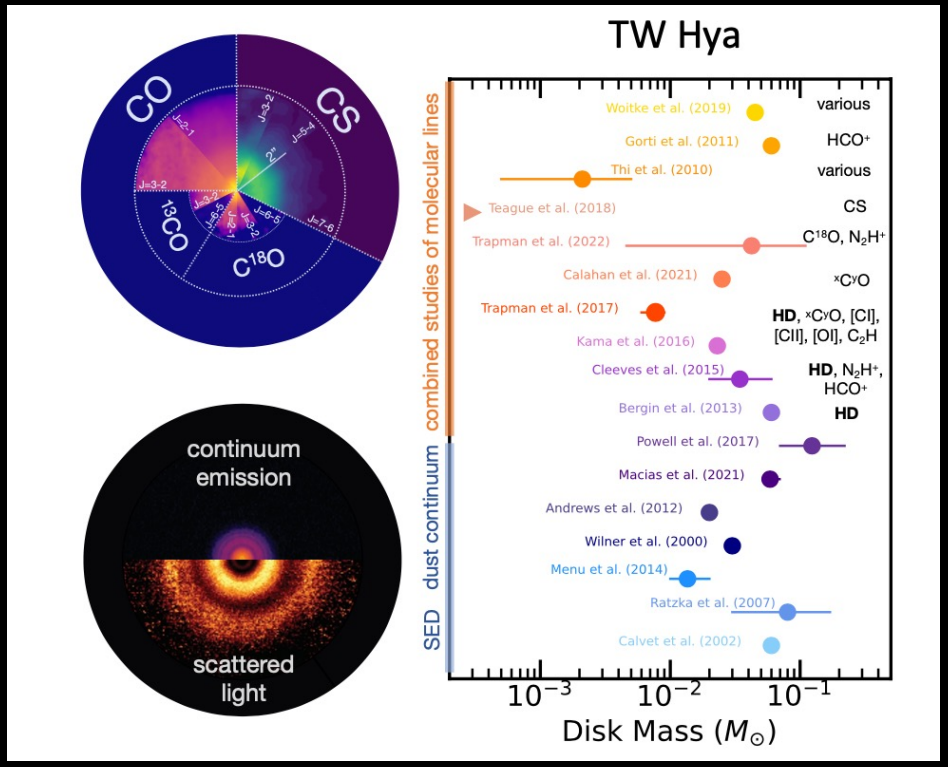
ALMA (NRAO/ESO/NAOJ)

Protoplanetary disk masses provide insight on when planets form

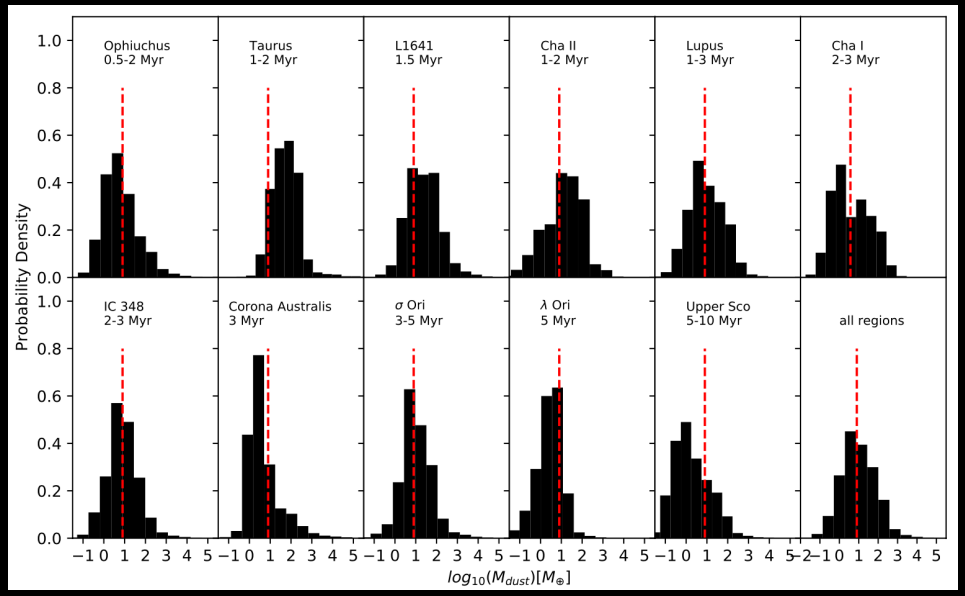
NASA/JPL-Caltech

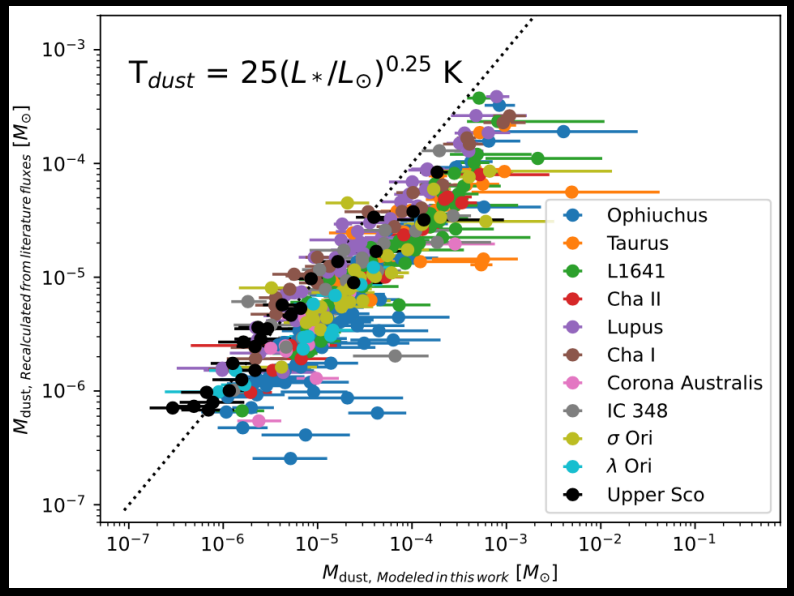
Different methods yield different disk masses



Miotello, et al. 2022

Disk dust masses measured using multiwavelength SED model fitting are 2-5x higher

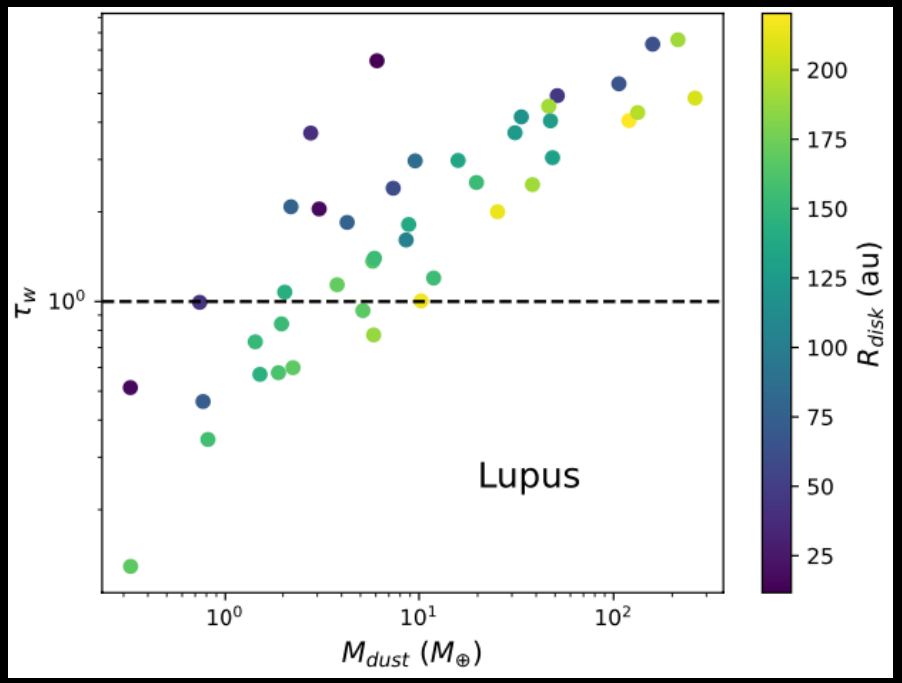




Rilinger, Espaillat et al, 2023; see also Ballering & Eisner 2019, Ribas, Espaillat et al. 2020

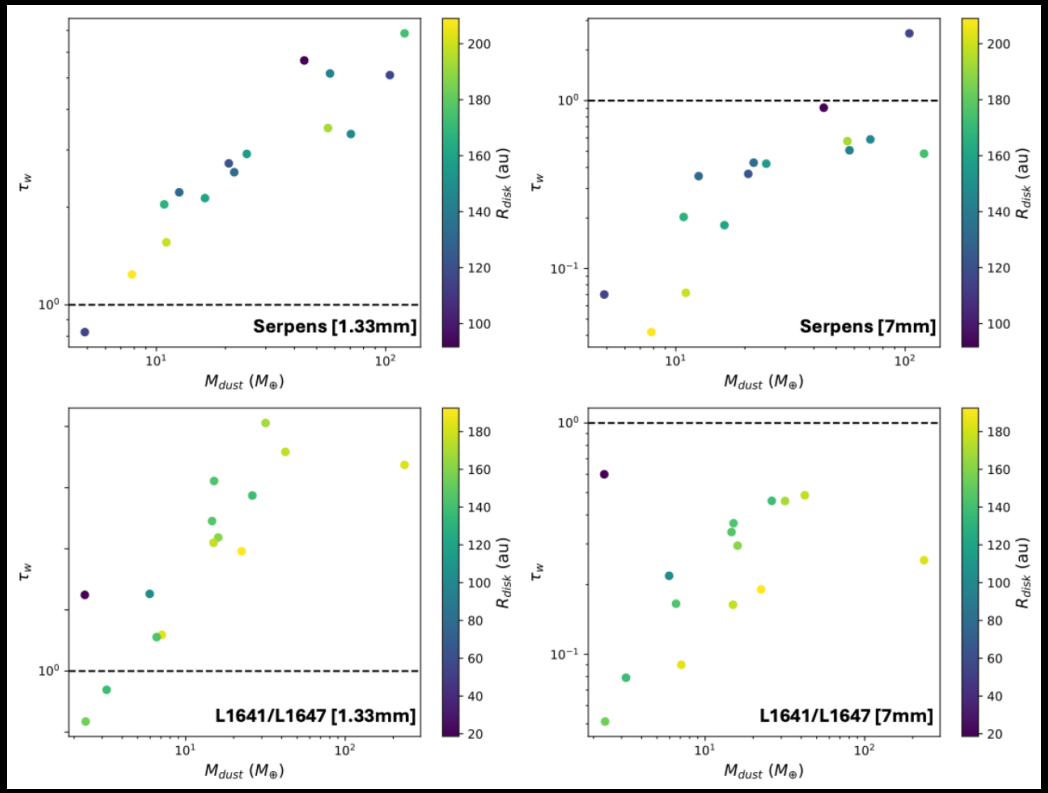
SED modeling can account for dust located in optically thick regions of disks

More than half of disks in Lupus are partially optically thick at 1.3 mm



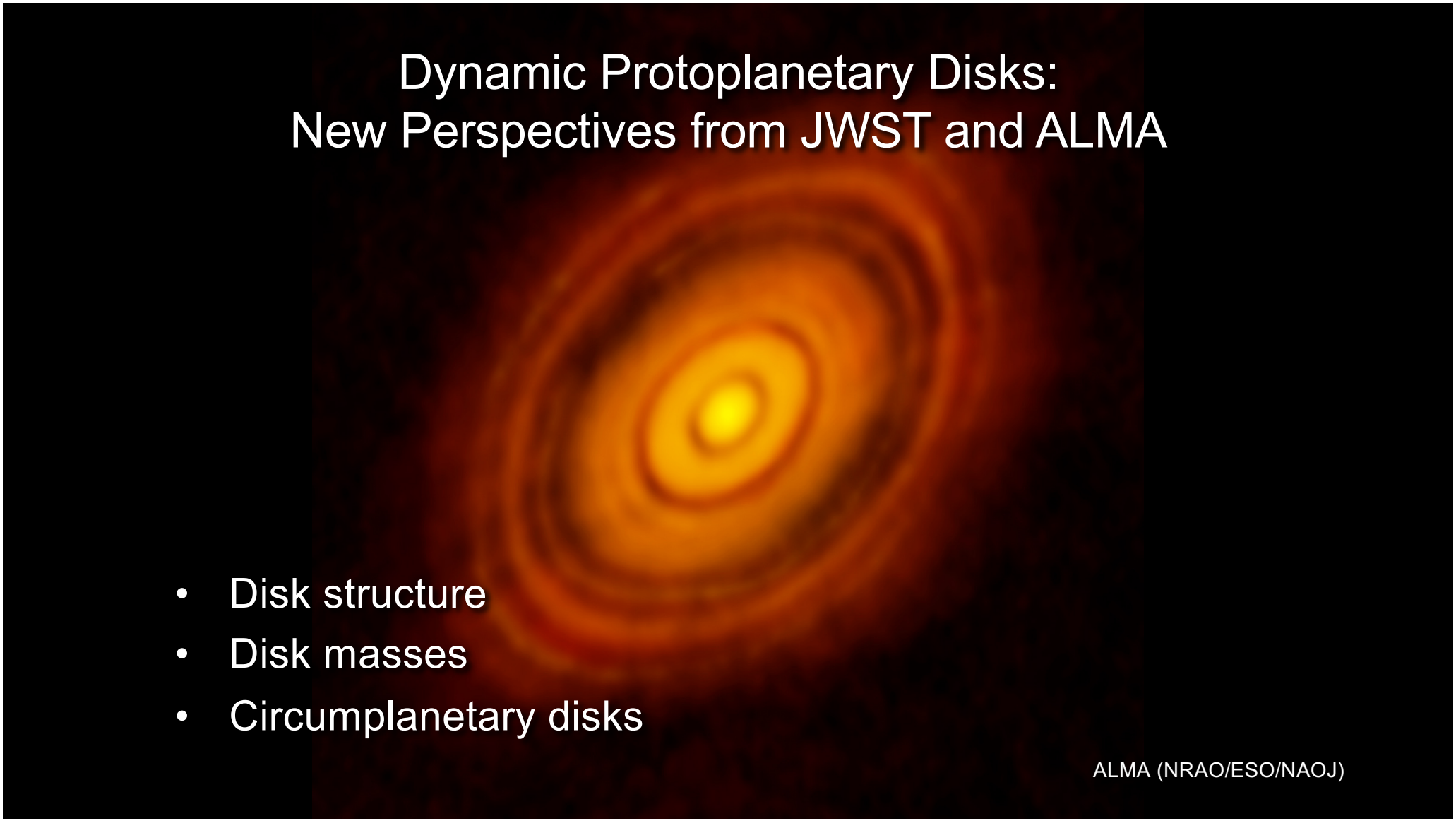
Rilinger, Espaillat et al, 2023; see also Tripathi et al. 2017

Models predict most disks are optically thin at 7 mm



Zamudio, Espaillat et al, in preparation

Dynamic Protoplanetary Disks: New Perspectives from JWST and ALMA



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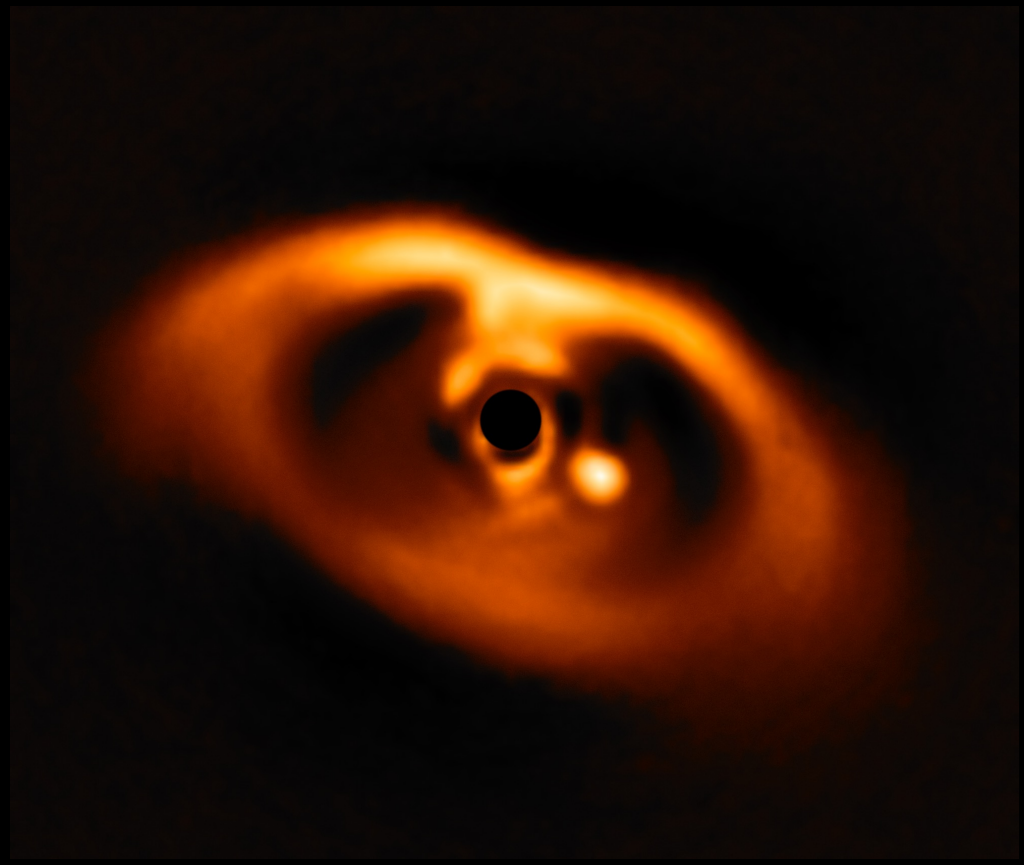
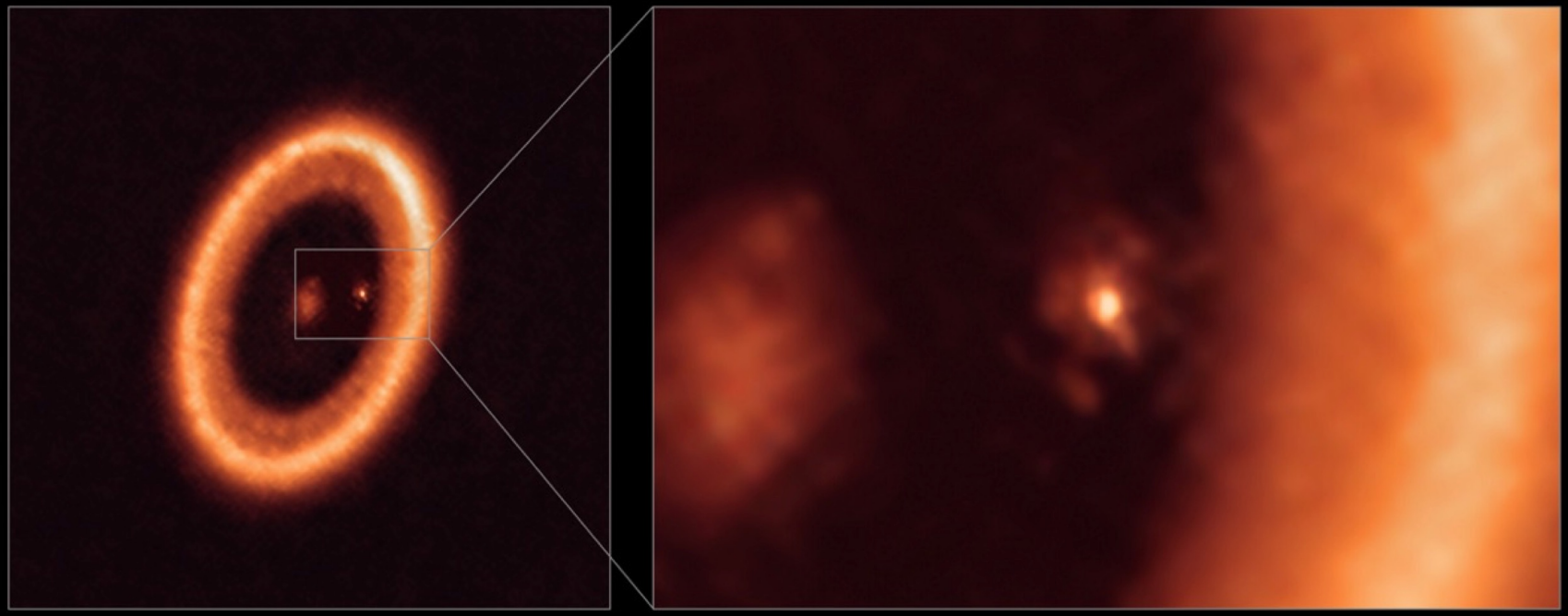
ALMA (NRAO/ESO/NAOJ)

PDS 70 contains a protoplanet within a large disk gap



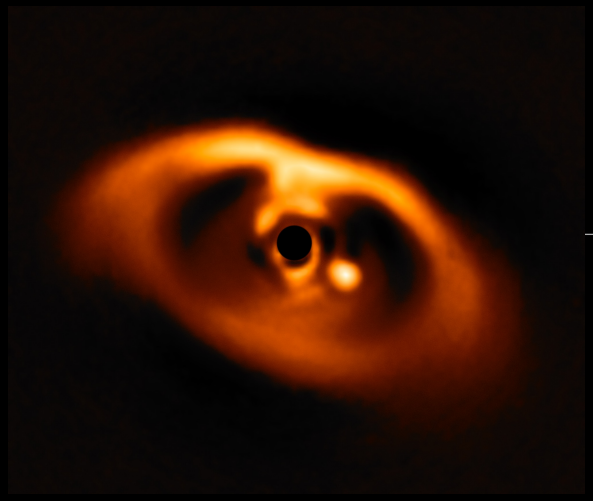
Keppler et al. 2018

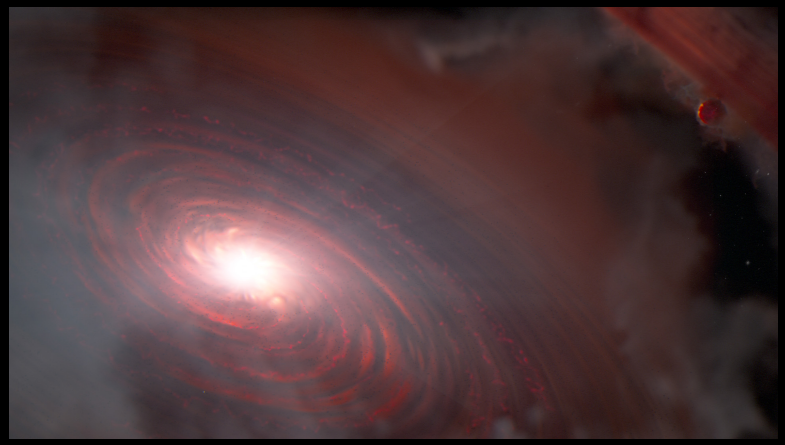
The PDS 70 protoplanet has a circumplanetary disk imaged by ALMA



Benisty et al. 2021

JWST has found water in the PDS 70 protoplanetary disk

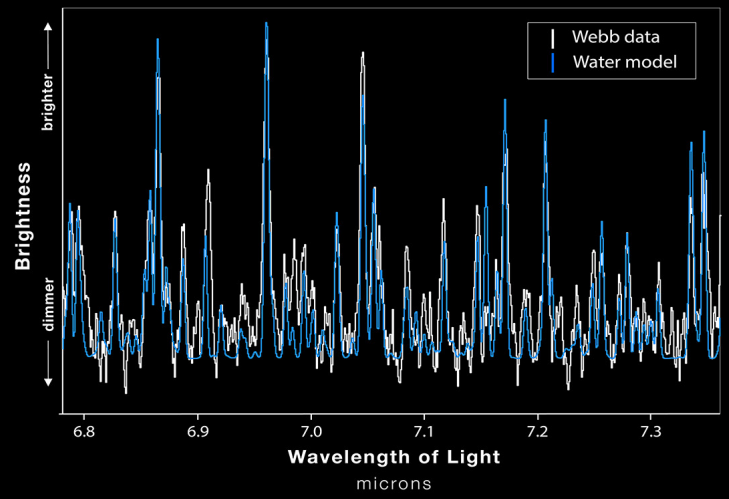




PDS 70 INNER DISK

EMISSION SPECTRUM

MIRI | IFU Medium-Resolution Spectroscopy



WEBB
SPACE TELESCOPE

Keppler et al. 2018; Perotti et al. 2023; NASA

Dynamic Protoplanetary Disks: New Perspectives from JWST and ALMA

- Disk structure: *complete surveys of the radial and vertical dust and gas distribution in disks, and sub(mm) variability*
- Disk masses: *accurate measurements of dust masses and the dust-to-gas ratio, and the total disk mass*
- Circumplanetary disks: *more robust detections*

ALMA (NRAO/ESO/NAOJ)