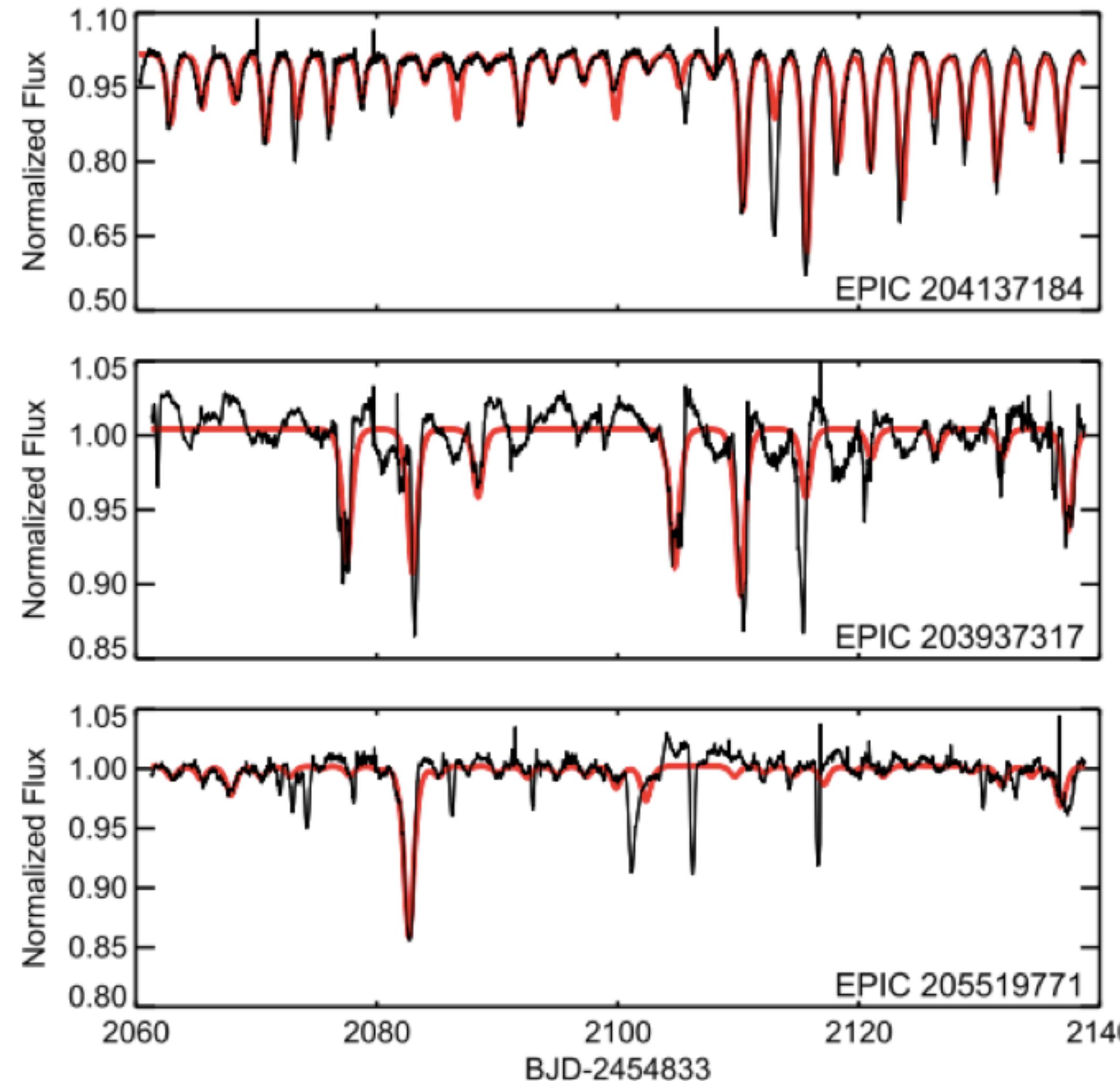


Misaligned Protoplanetary Disks: the mm perspective

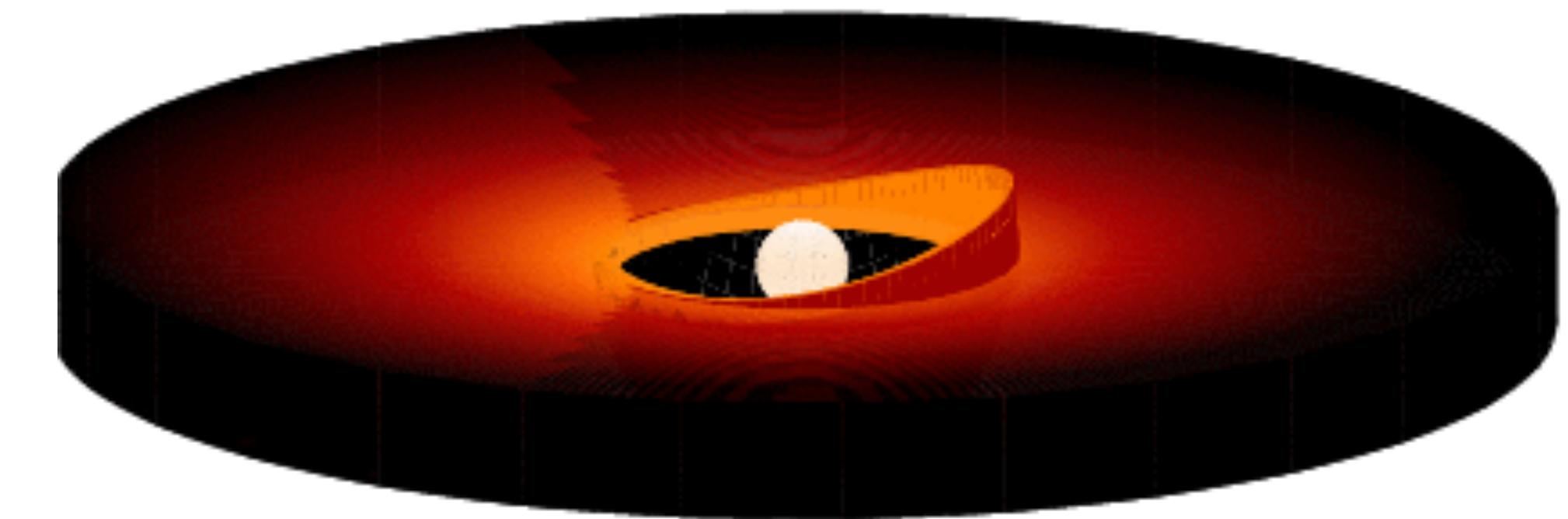
Ryan A. Loomis (NRAO)

Collaborators: S. Andrews (CfA), M. Ansdell (UC Berkeley), M. Benisty (U. Chile),
I. Czekala (UC Berkeley), S. Facchini (ESO), M. MacGregor (Carnegie DTM), K.
Öberg (CfA), P. Pinilla (U. Arizona)

‘Dipper’ systems: ~20% of YSOs, inner disk viewed edge-on

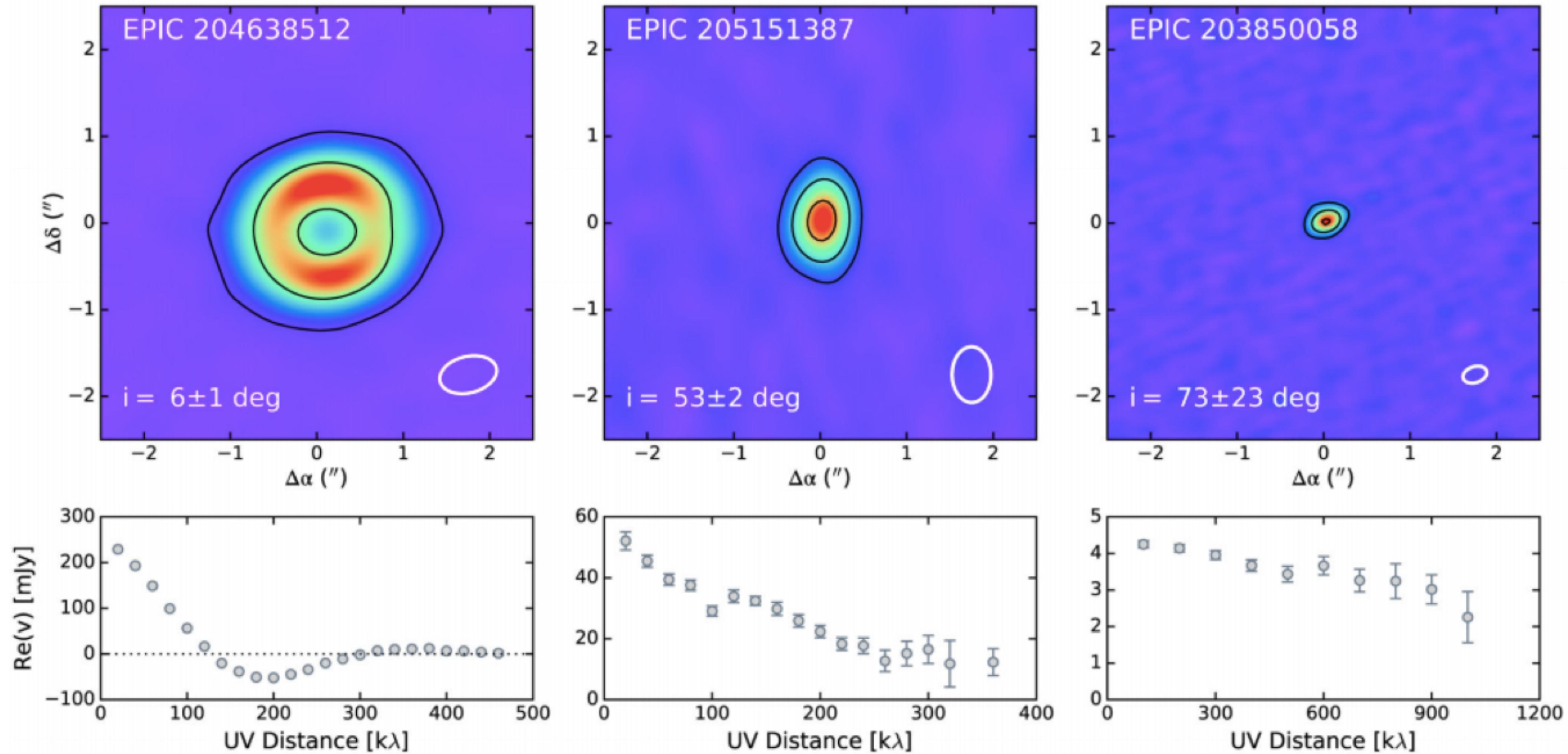


[Ansdell + 2016a]



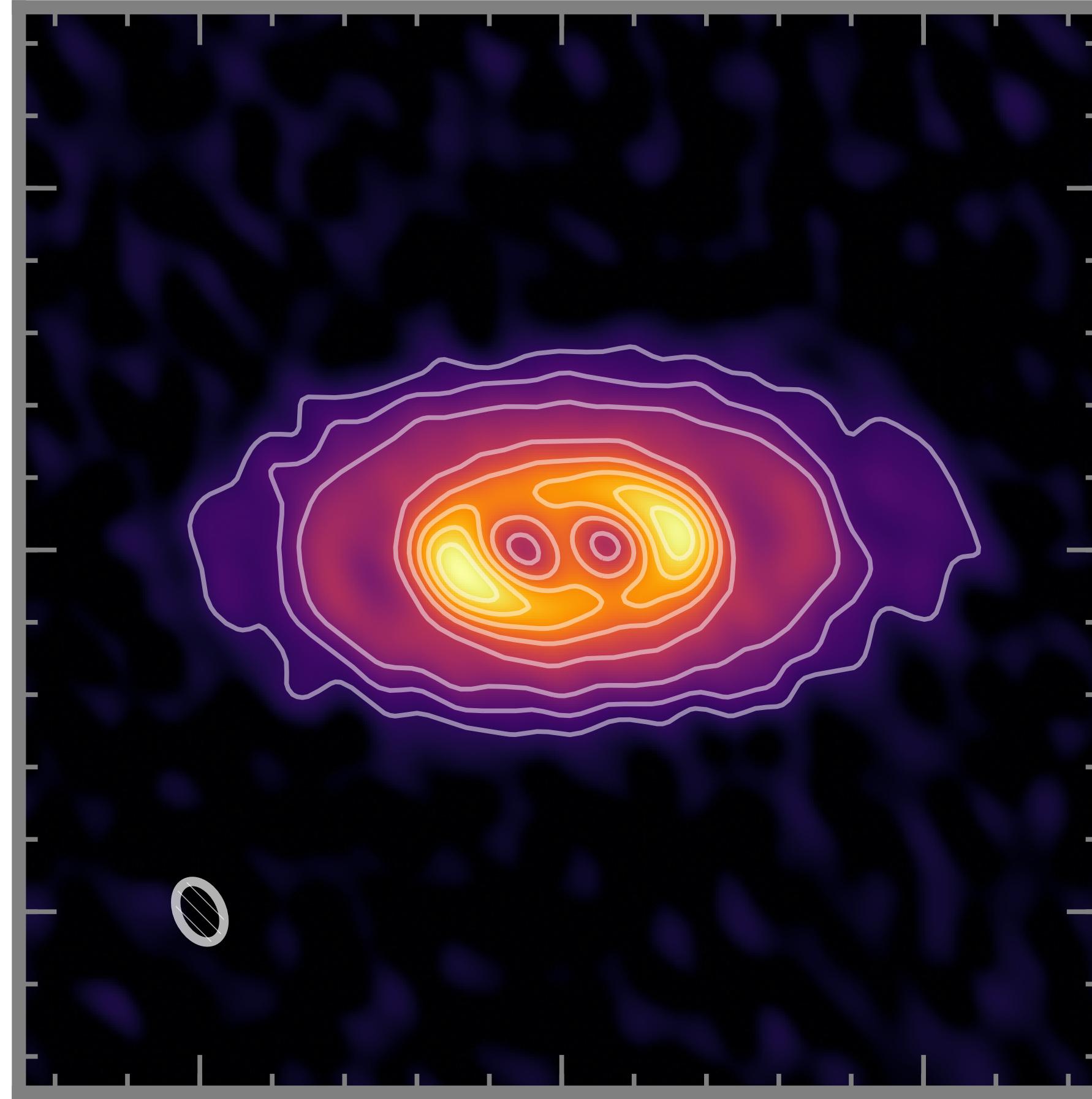
[Bouvier + 1999]

Dipper systems are not all edge-on: evidence for misalignments?

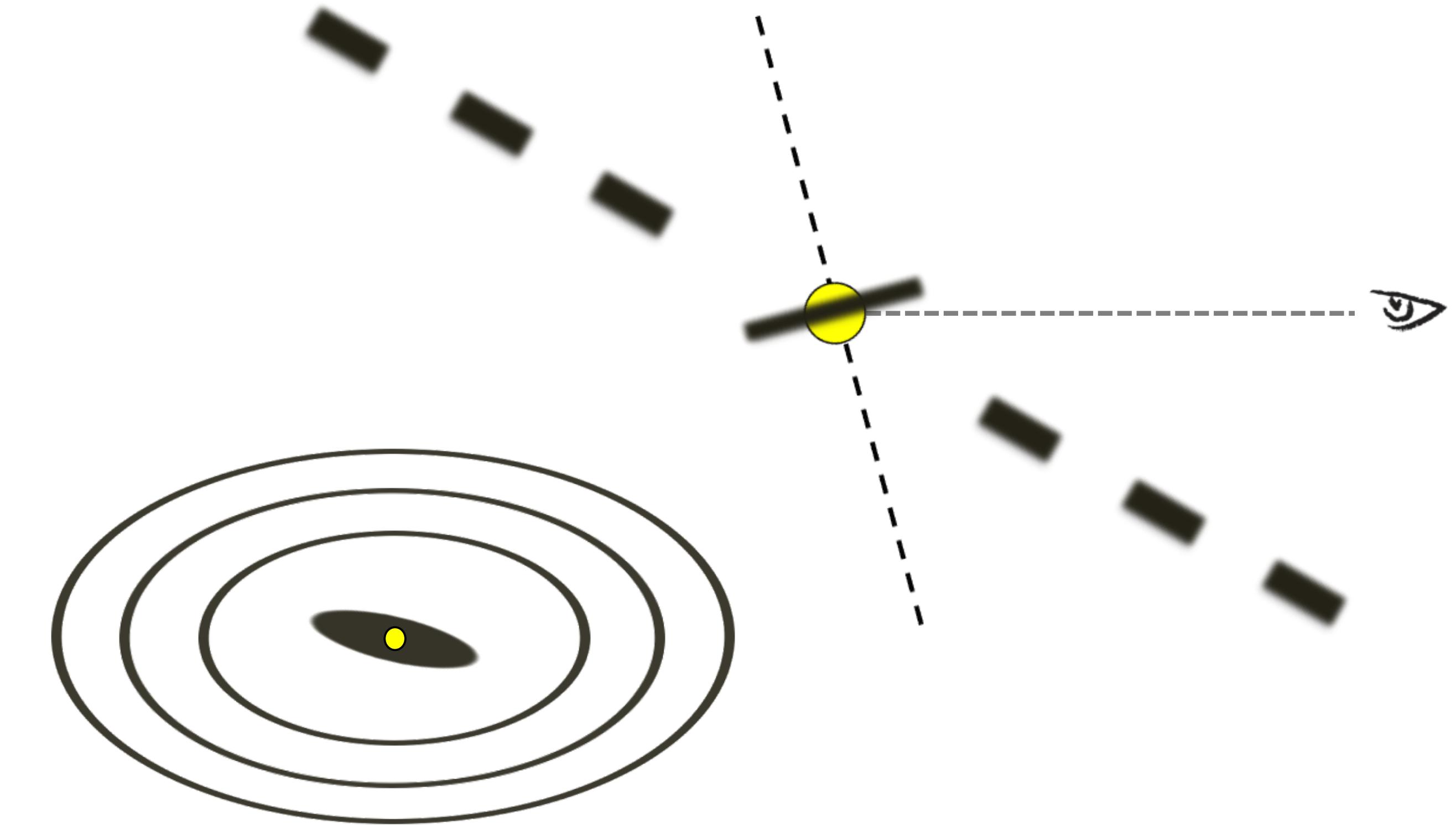


[Ansdell + 2016b]

AA Tau: the archetypical dipper is modestly inclined (59°)



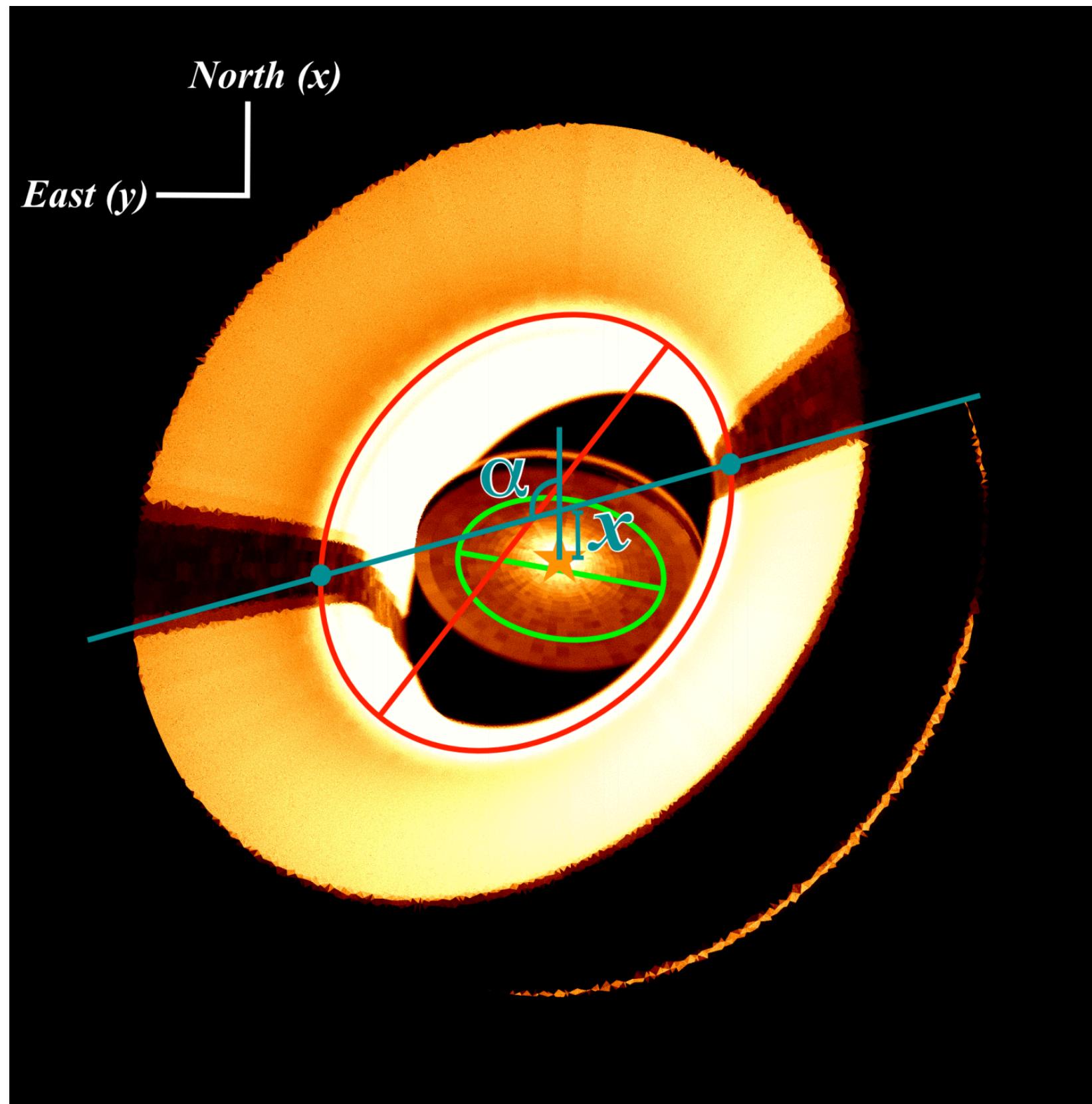
Proposed system geometry



[Loomis + 2017]

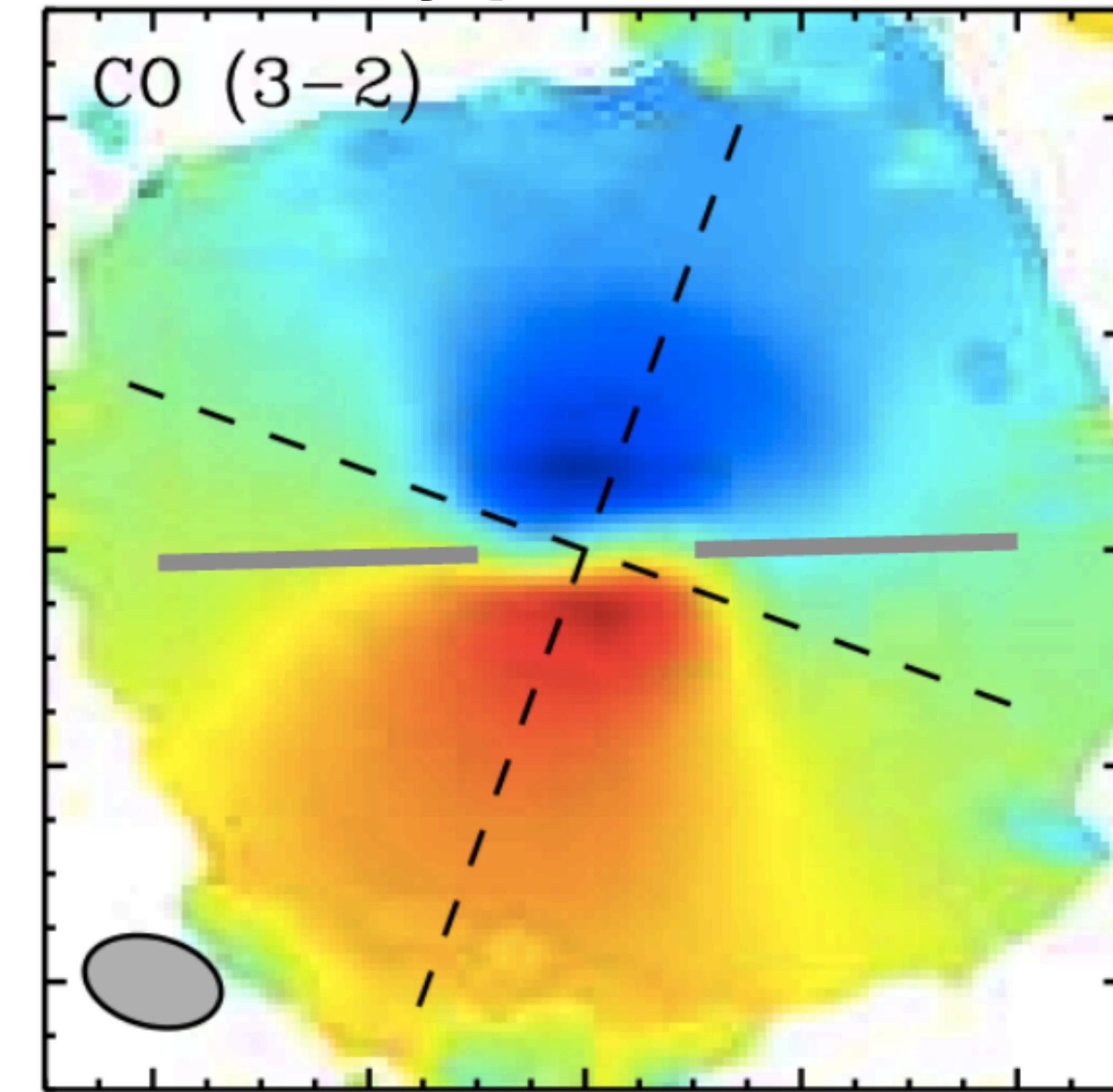
Signatures of misalignment in disks

Shadowing



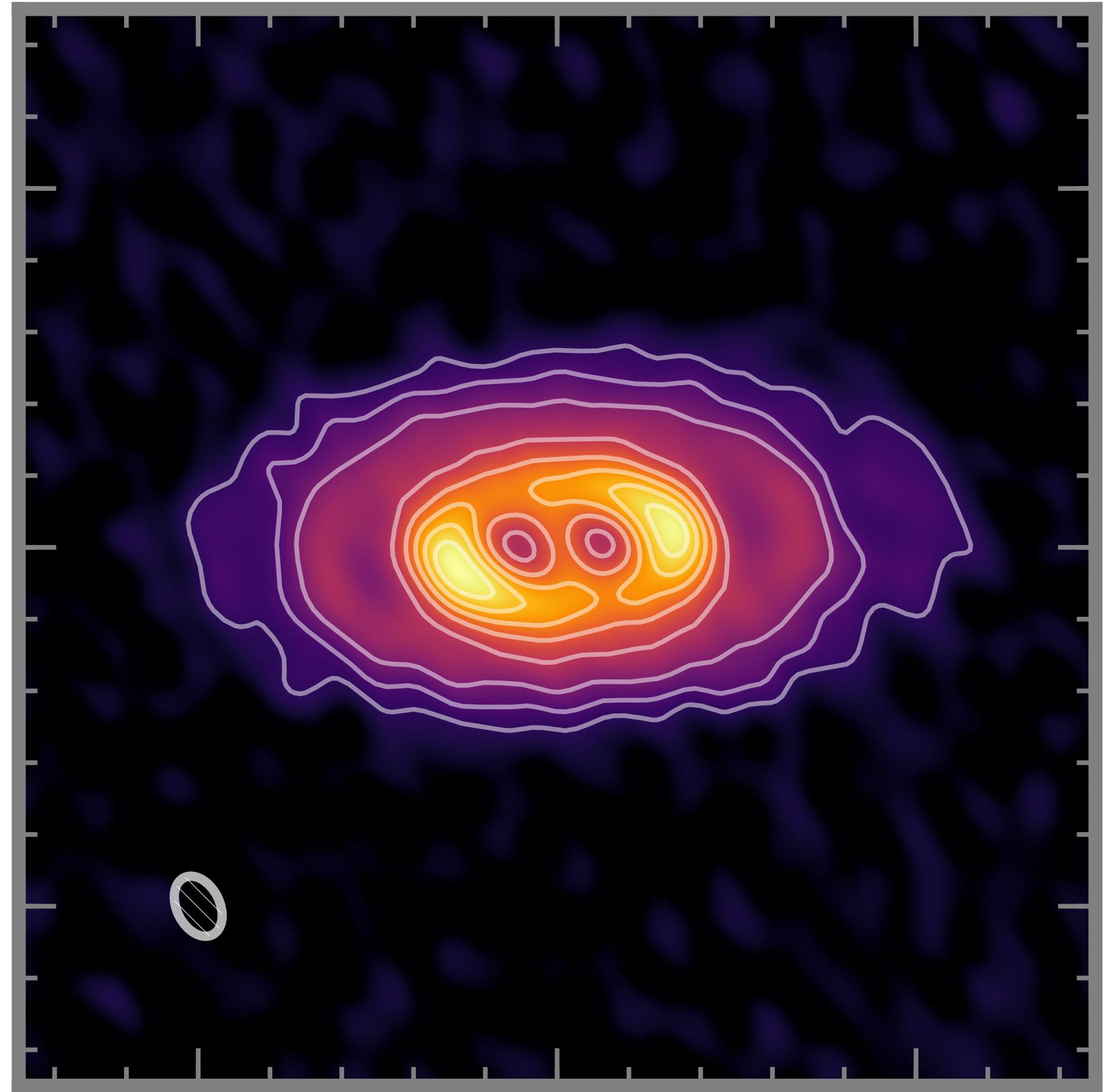
[Min + 2017]

Velocity perturbations

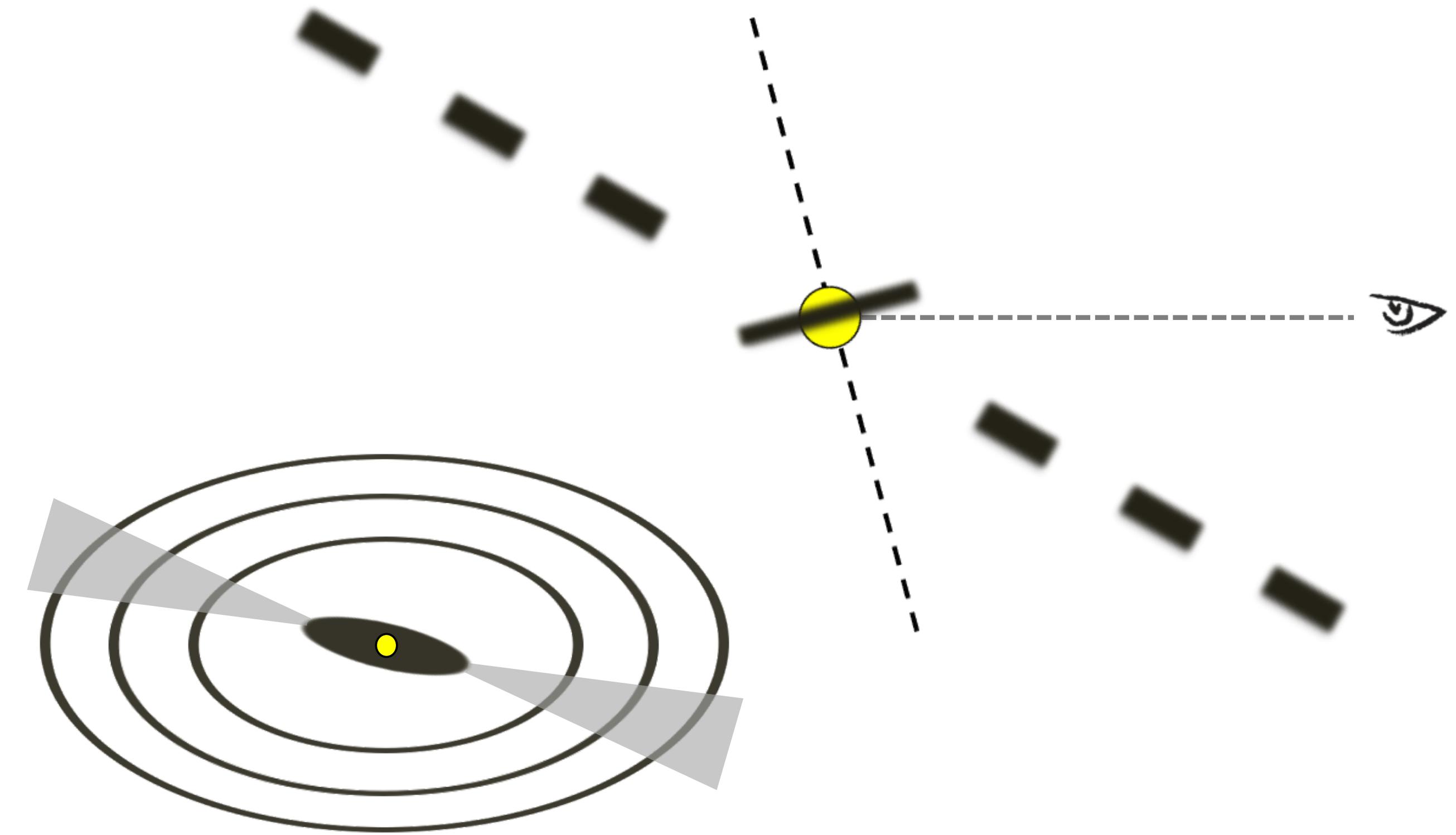


[Rosenfeld + 2013]

AA Tau: the archetypical dipper is misaligned with shadows

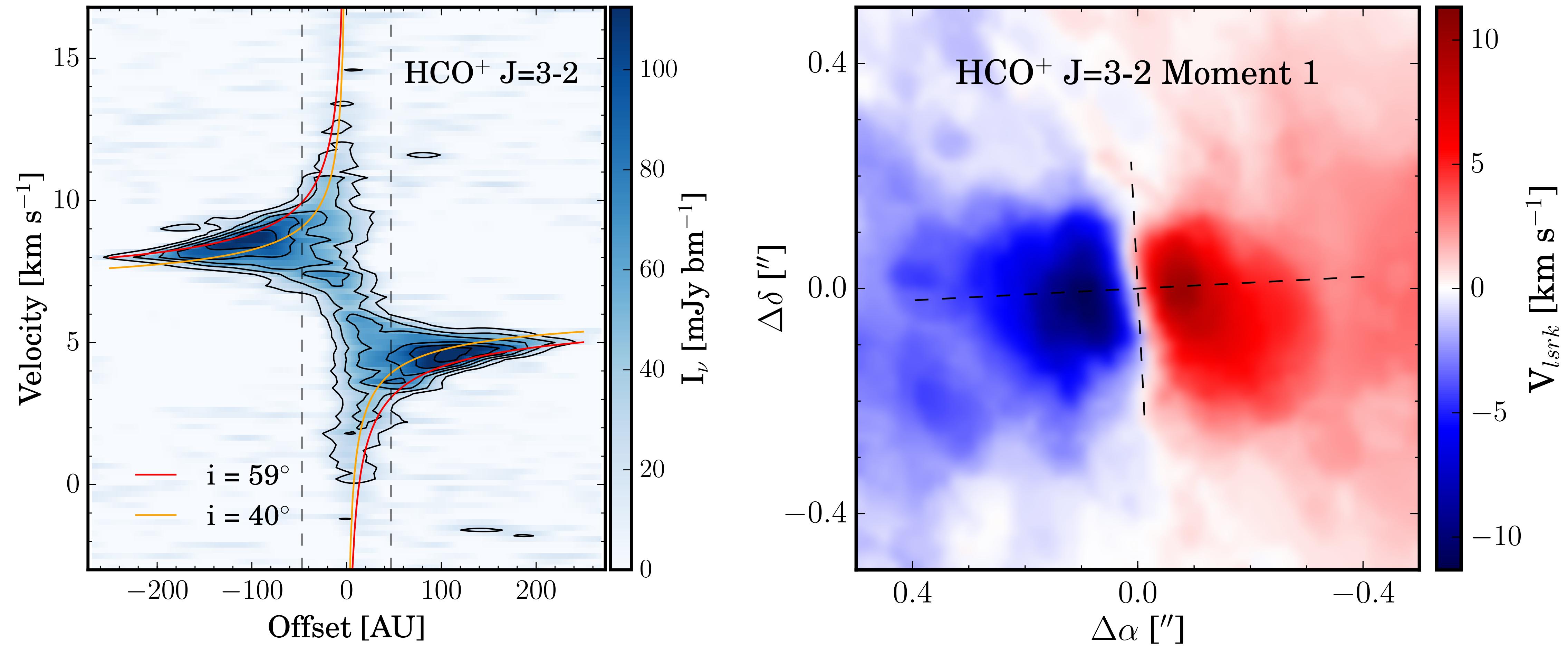


Proposed system geometry



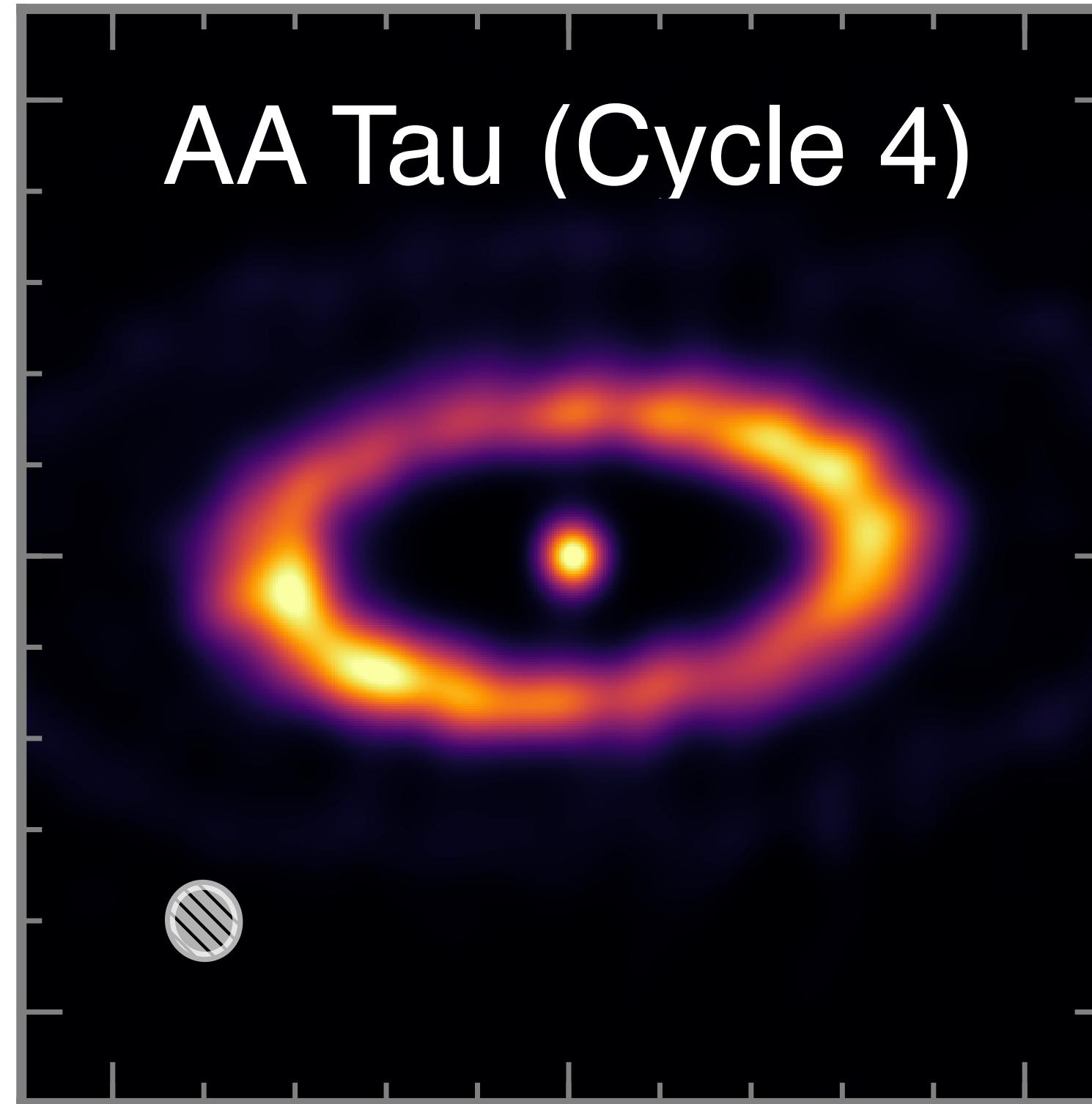
[Loomis + 2017]

AA Tau: the archetypical dipper has a kinematic warp



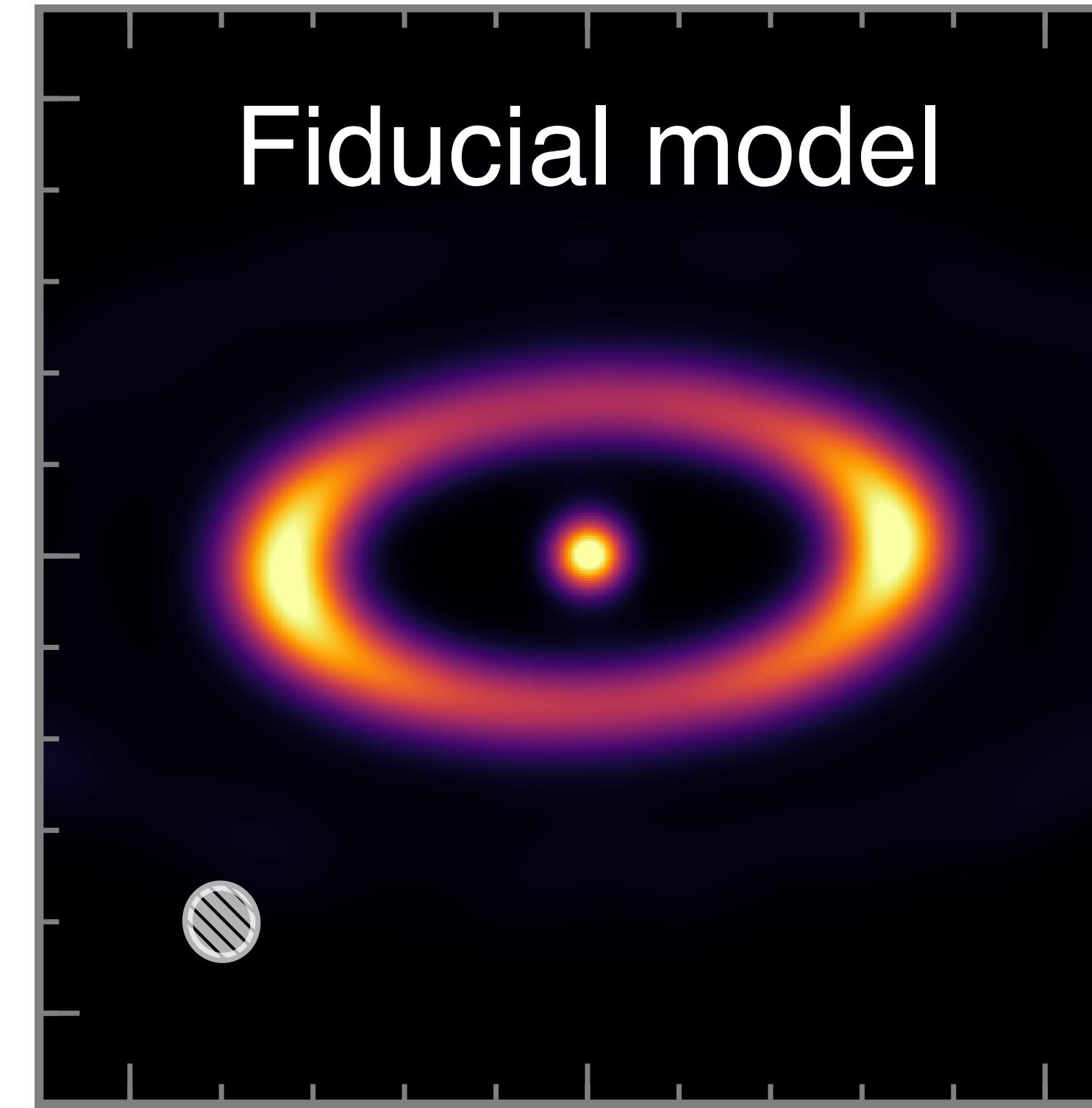
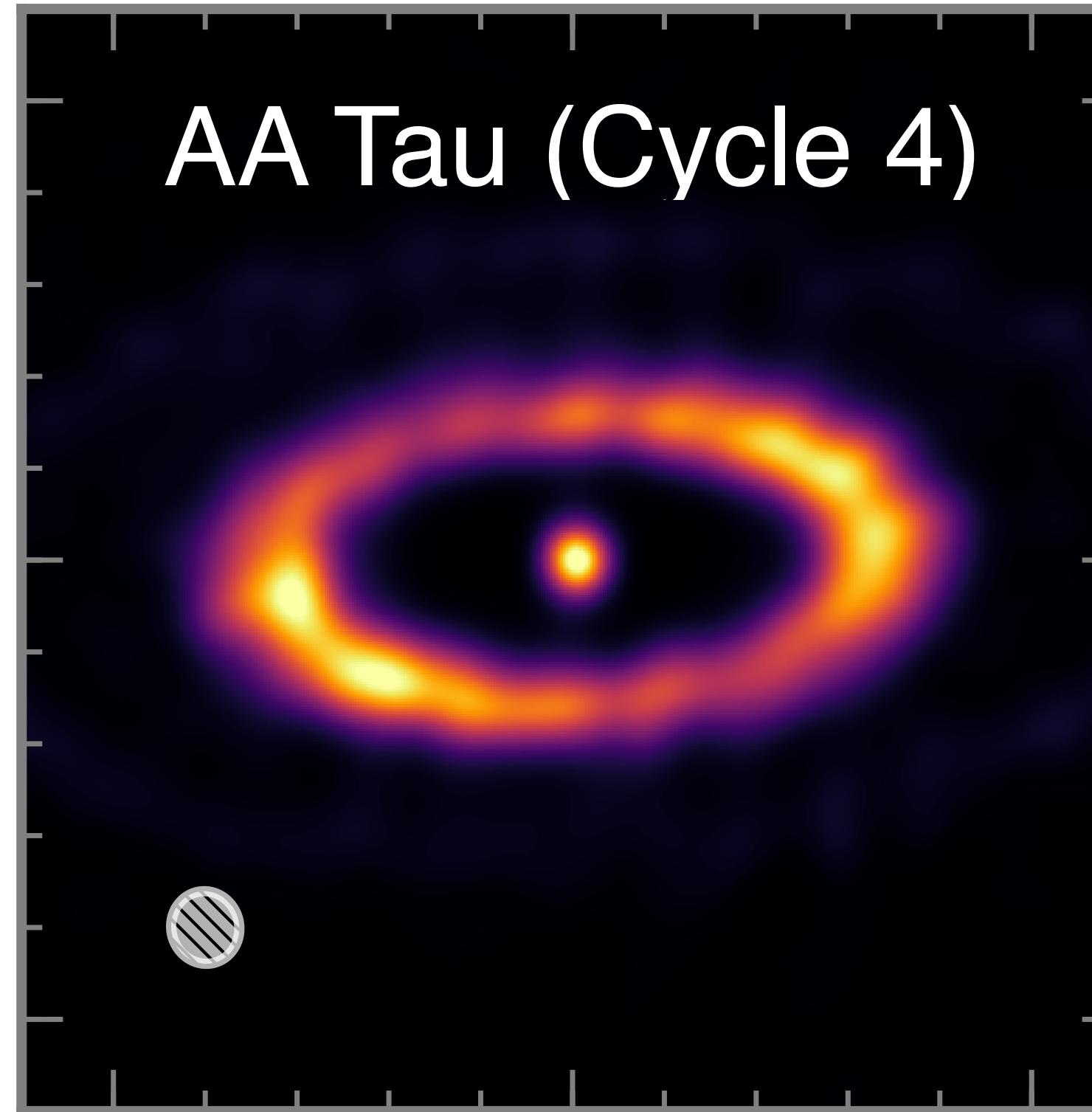
[Loomis + 2017]

High resolution observations match predictions from a misaligned inner/outer disk model



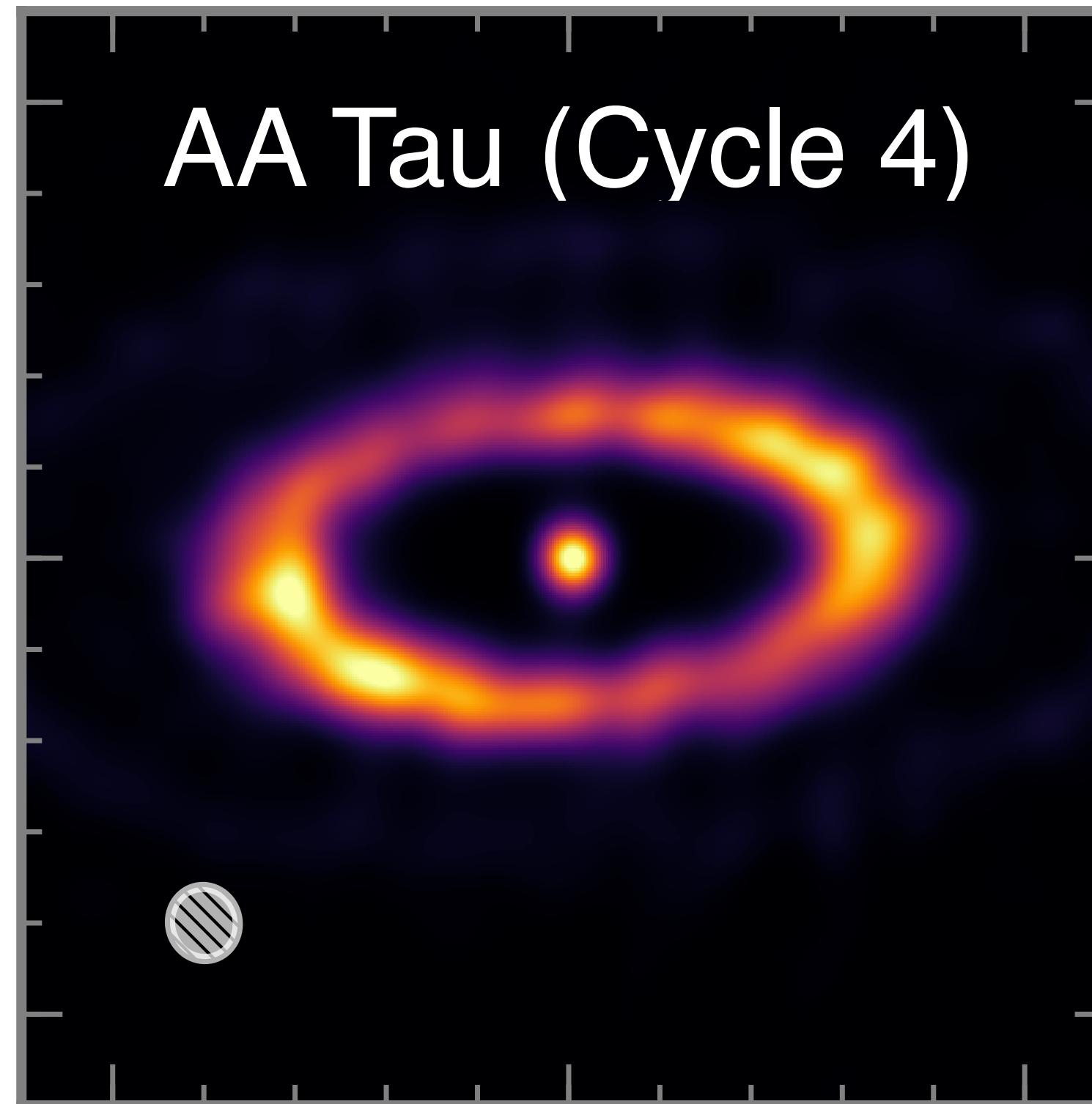
[Loomis + in prep]

High resolution observations match predictions from a misaligned inner/outer disk model

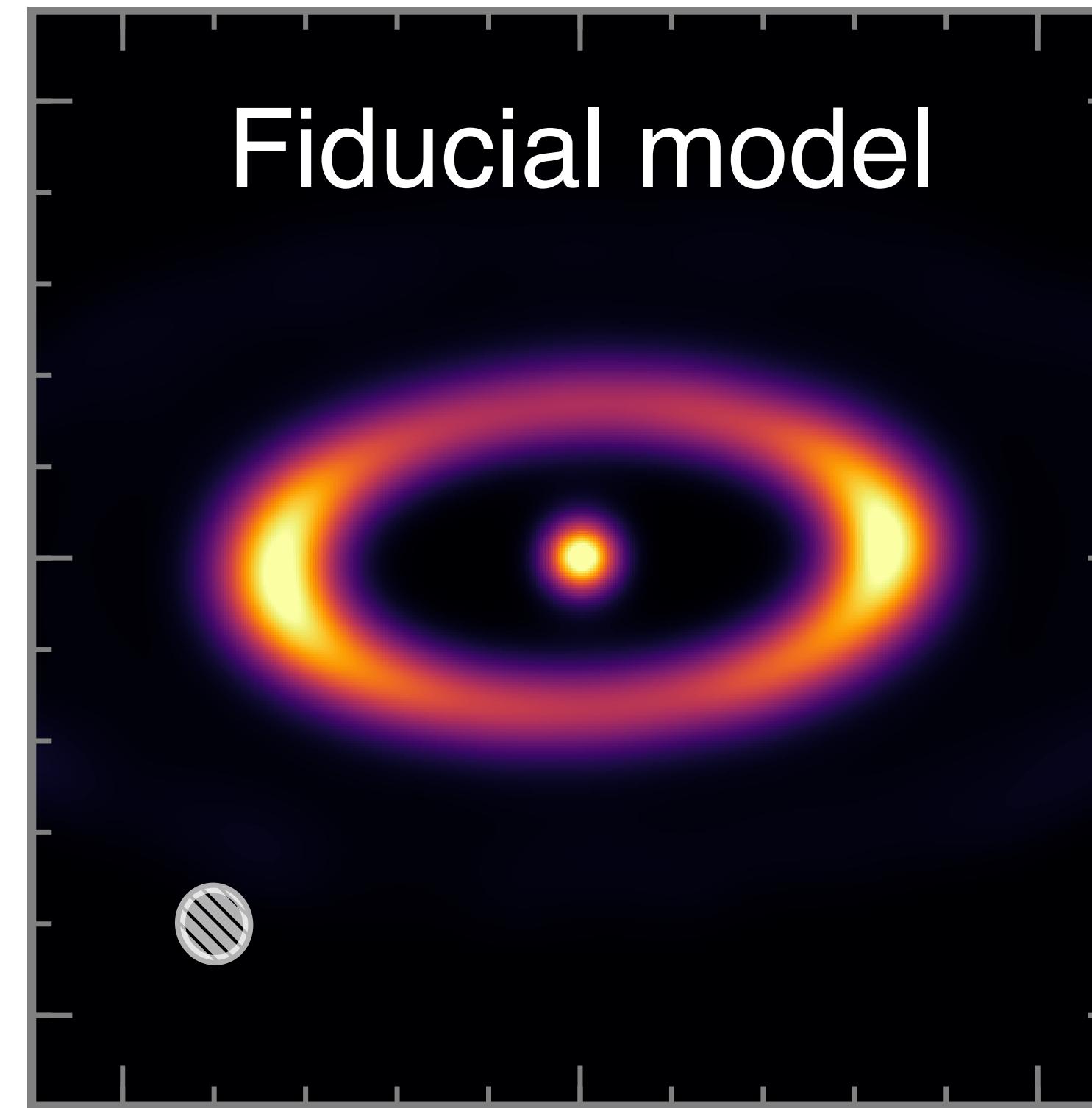


[Loomis + in prep]

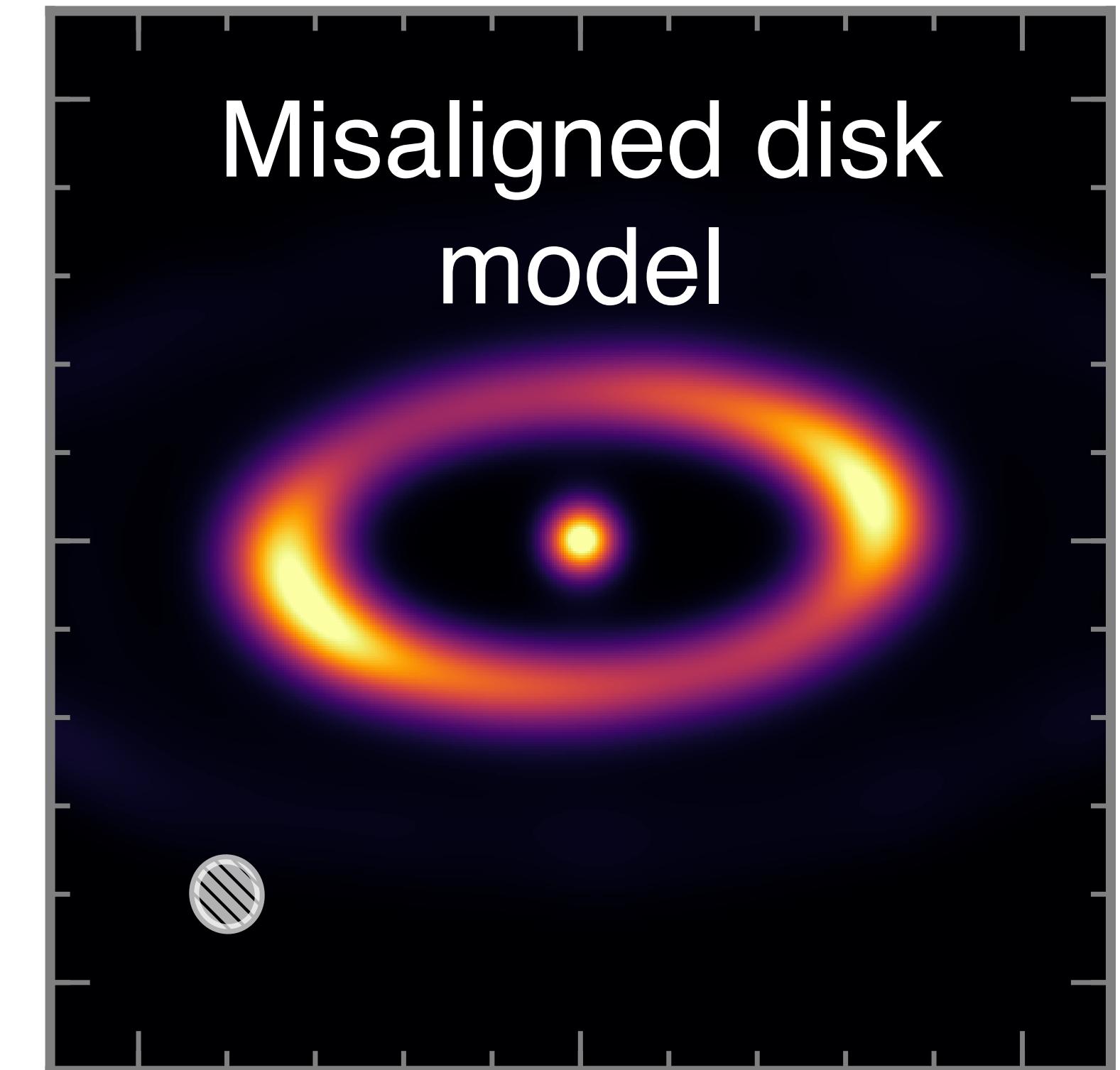
High resolution observations match predictions from a misaligned inner/outer disk model



AA Tau (Cycle 4)



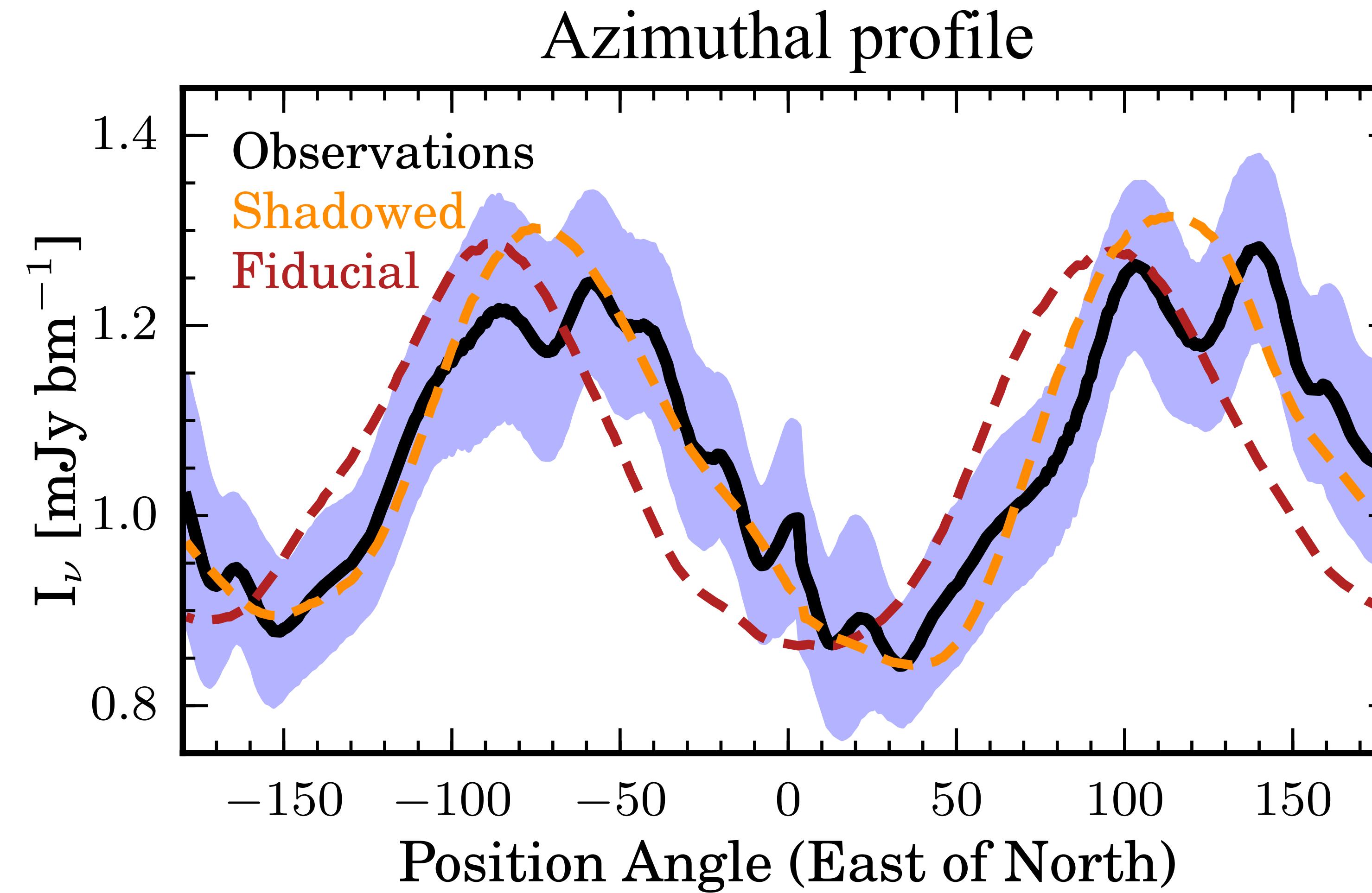
Fiducial model



Misaligned disk
model

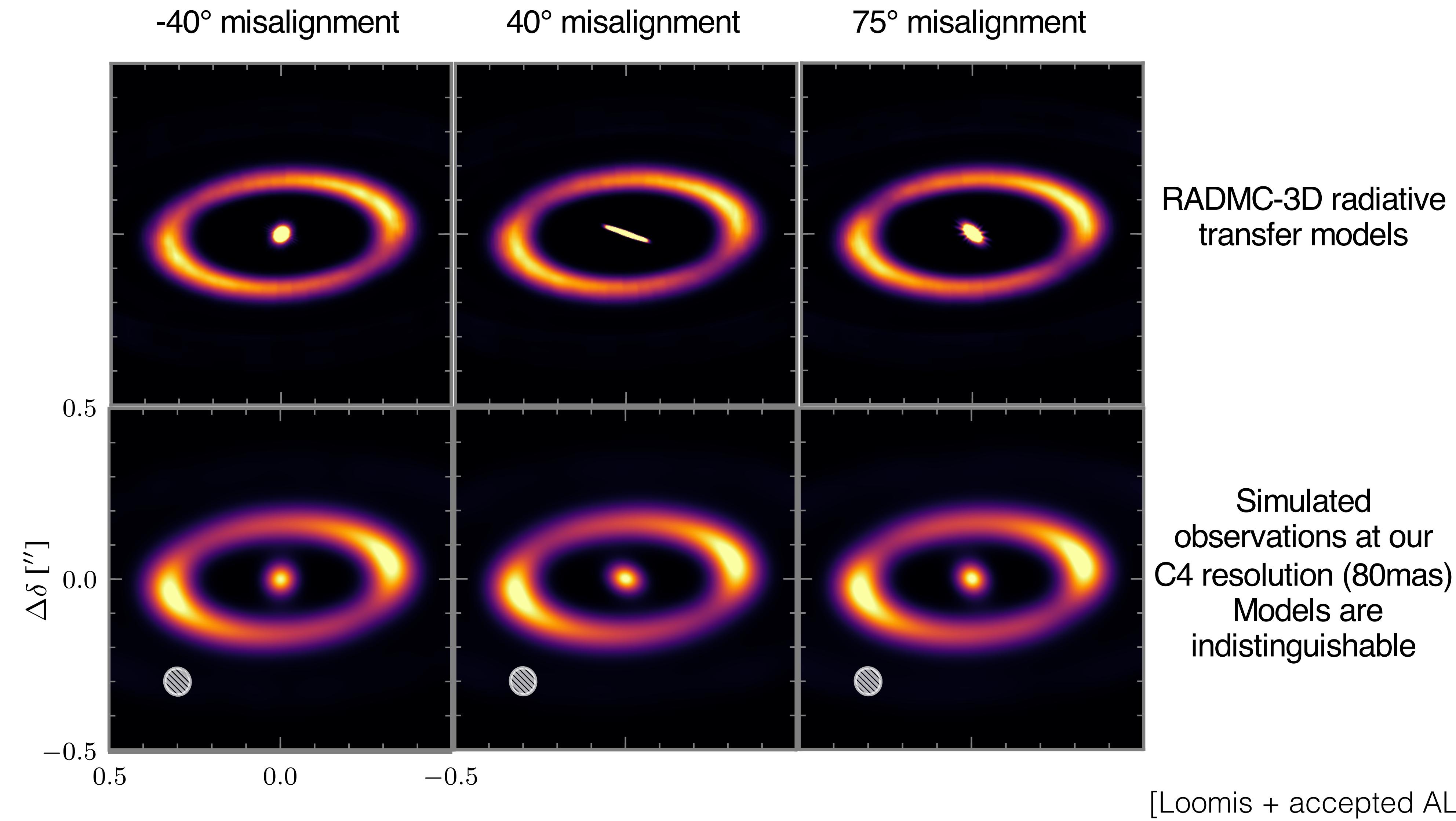
[Loomis + in prep]

High resolution observations match predictions from a misaligned inner/outer disk model

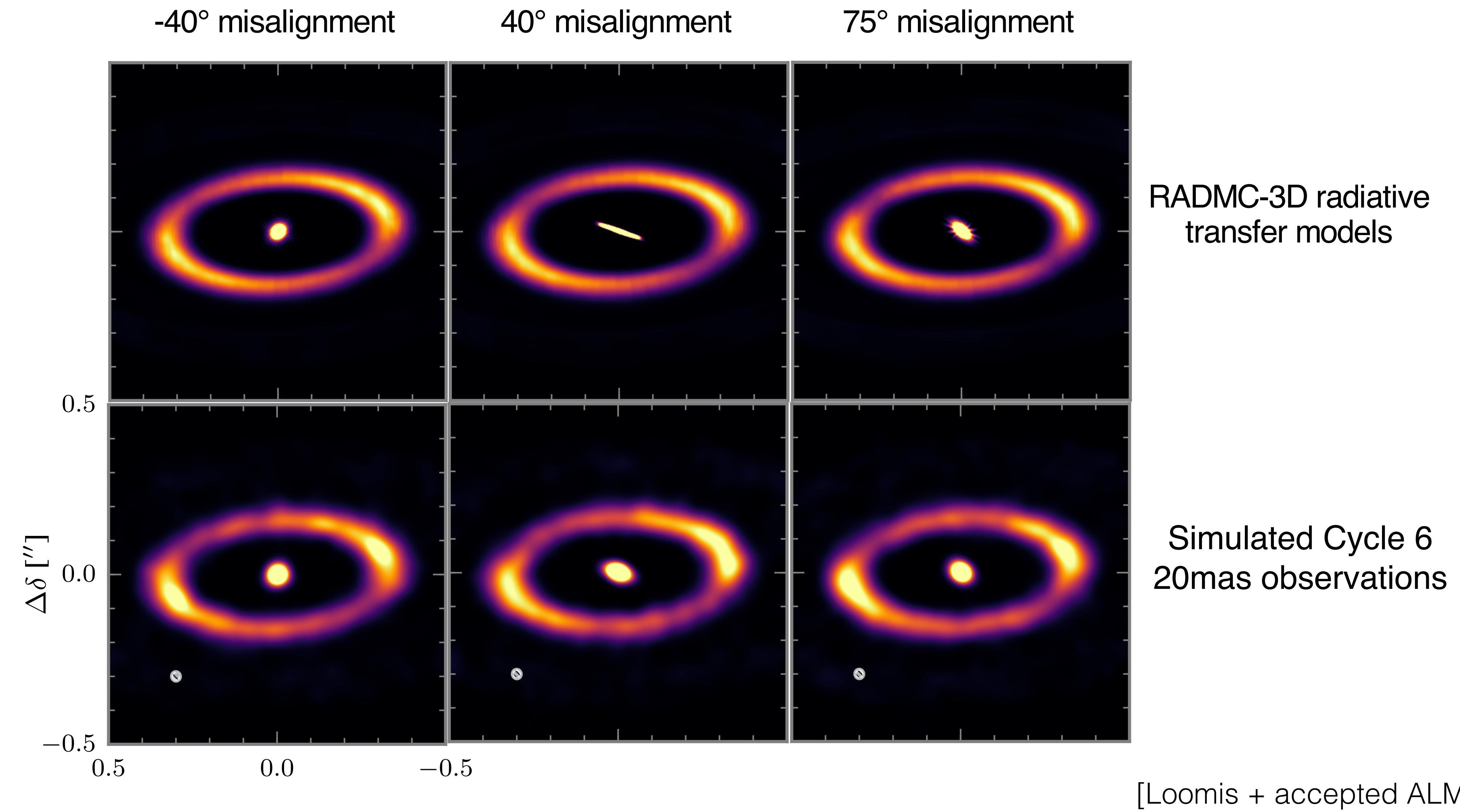


[Loomis + in prep]

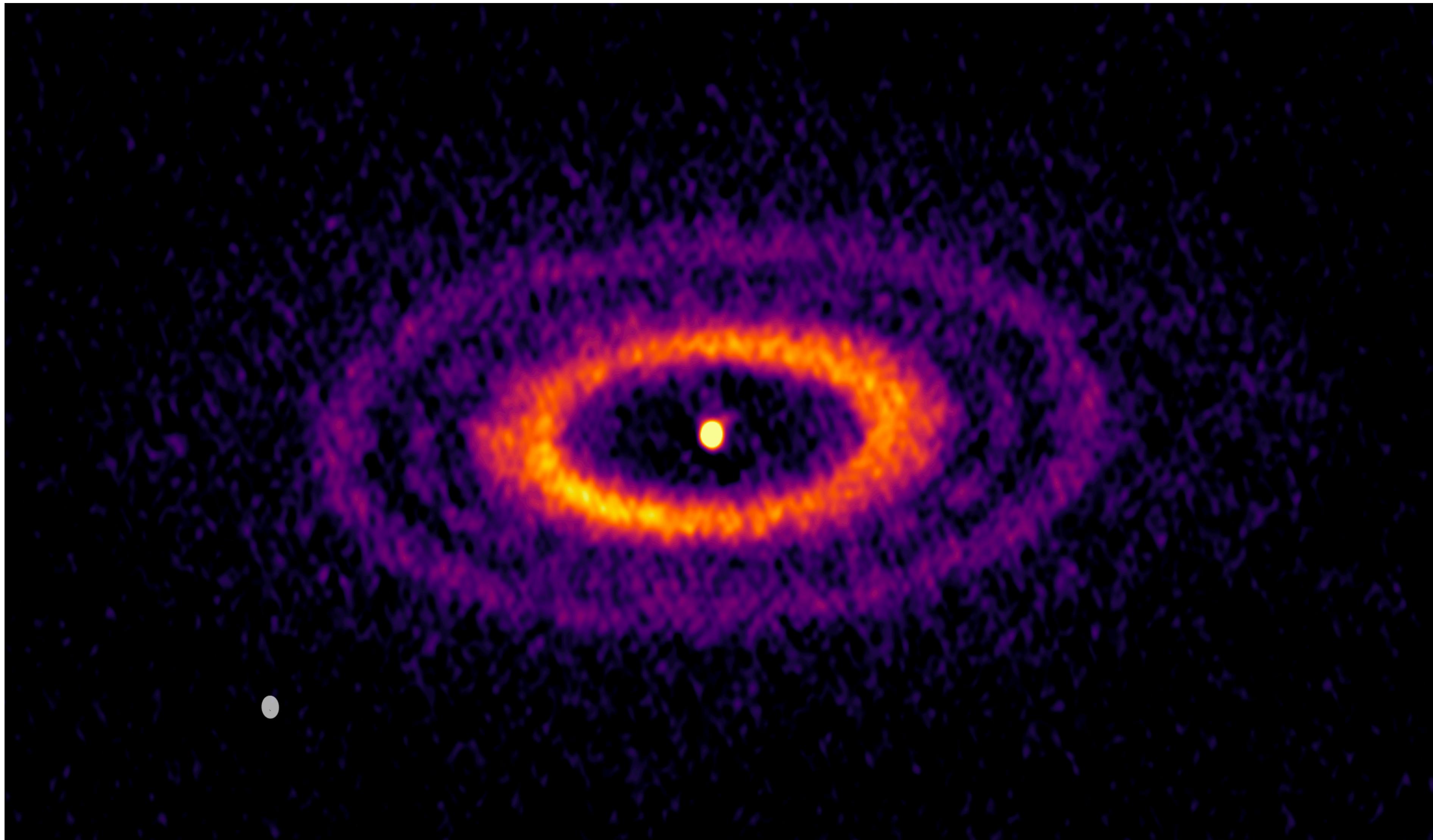
Higher resolution imaging needed to constrain misalignments



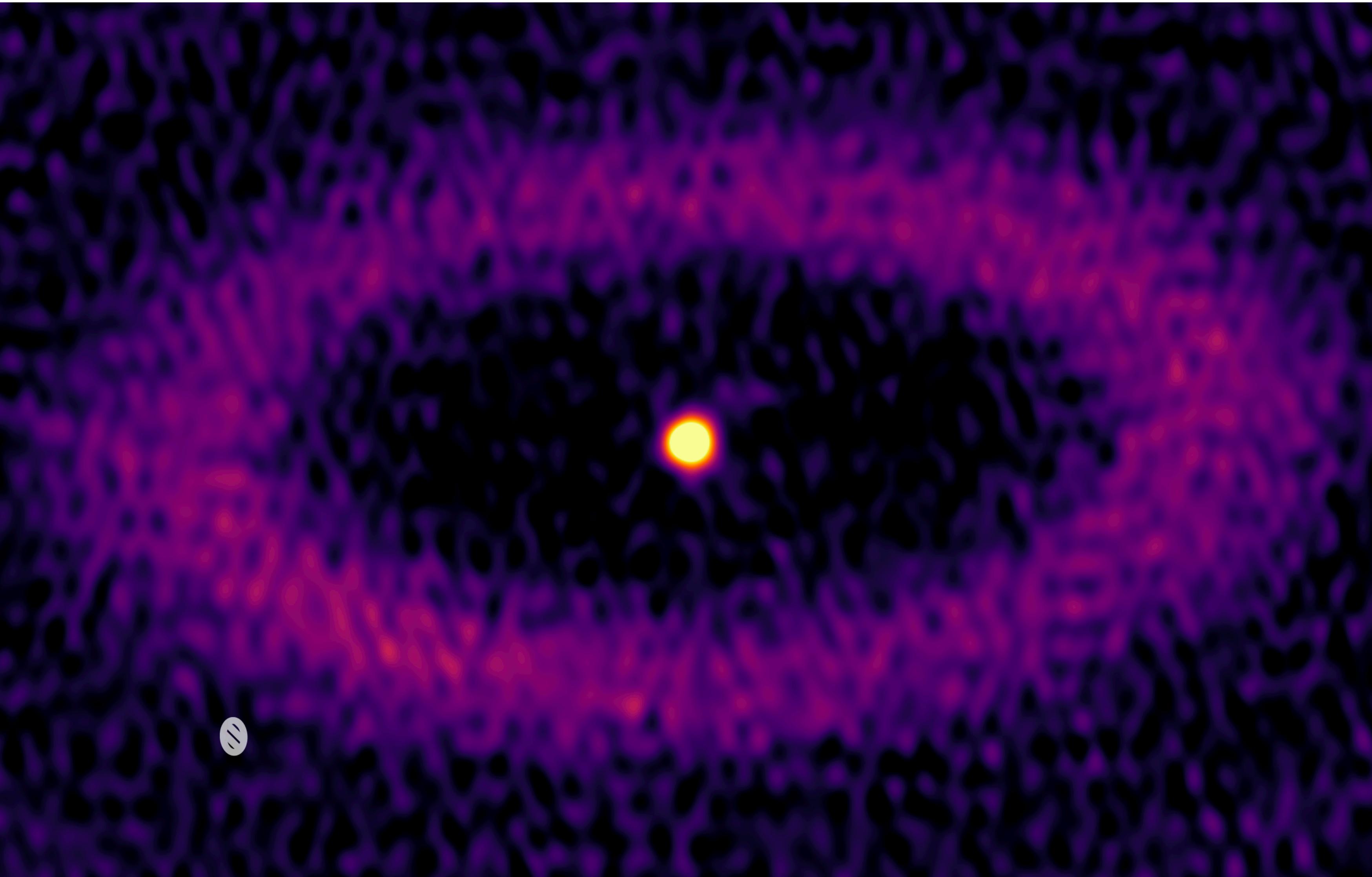
Higher resolution imaging needed to constrain misalignments



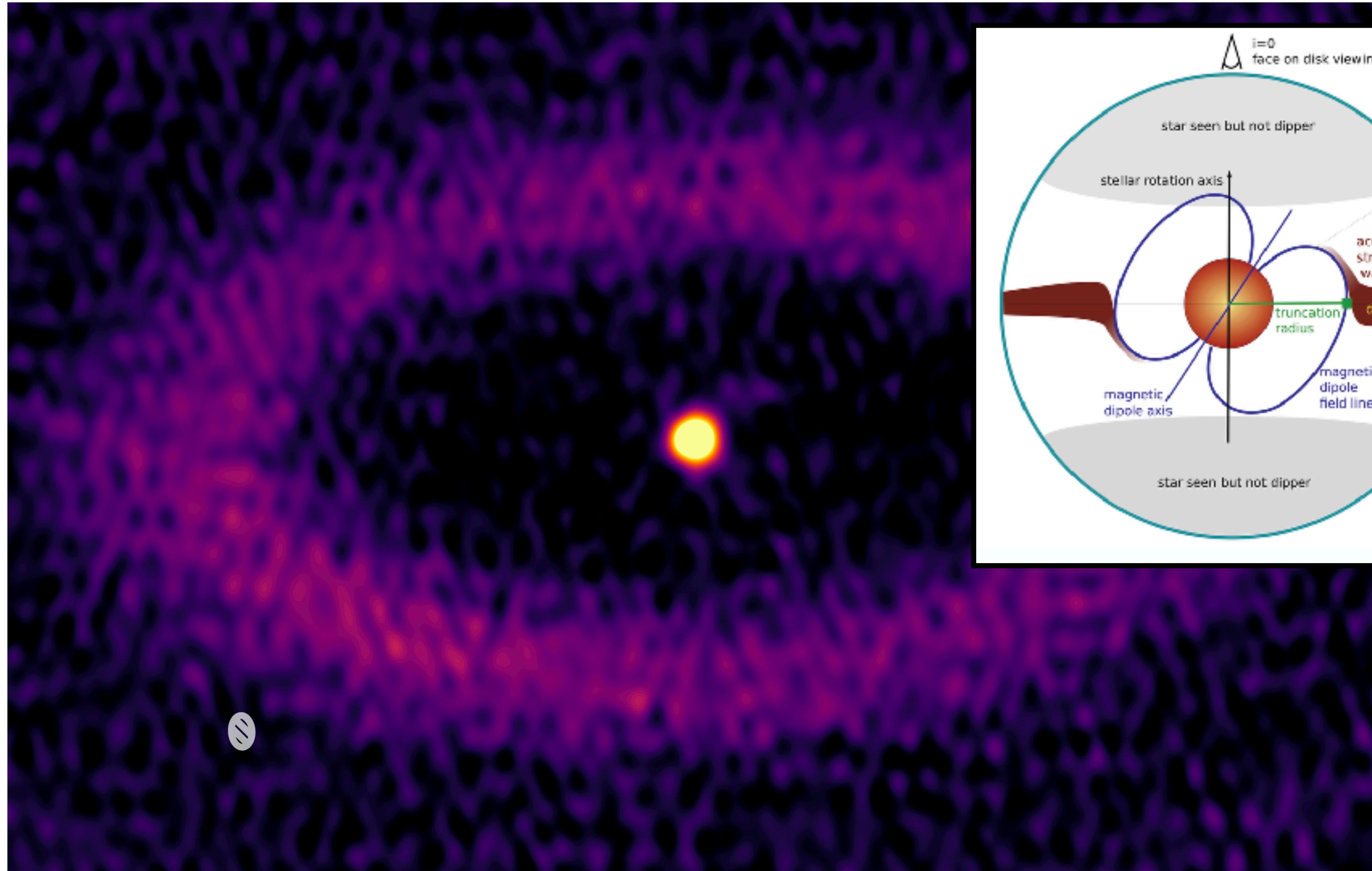
Cycle 6 results: inner disk is small and **not** edge-on



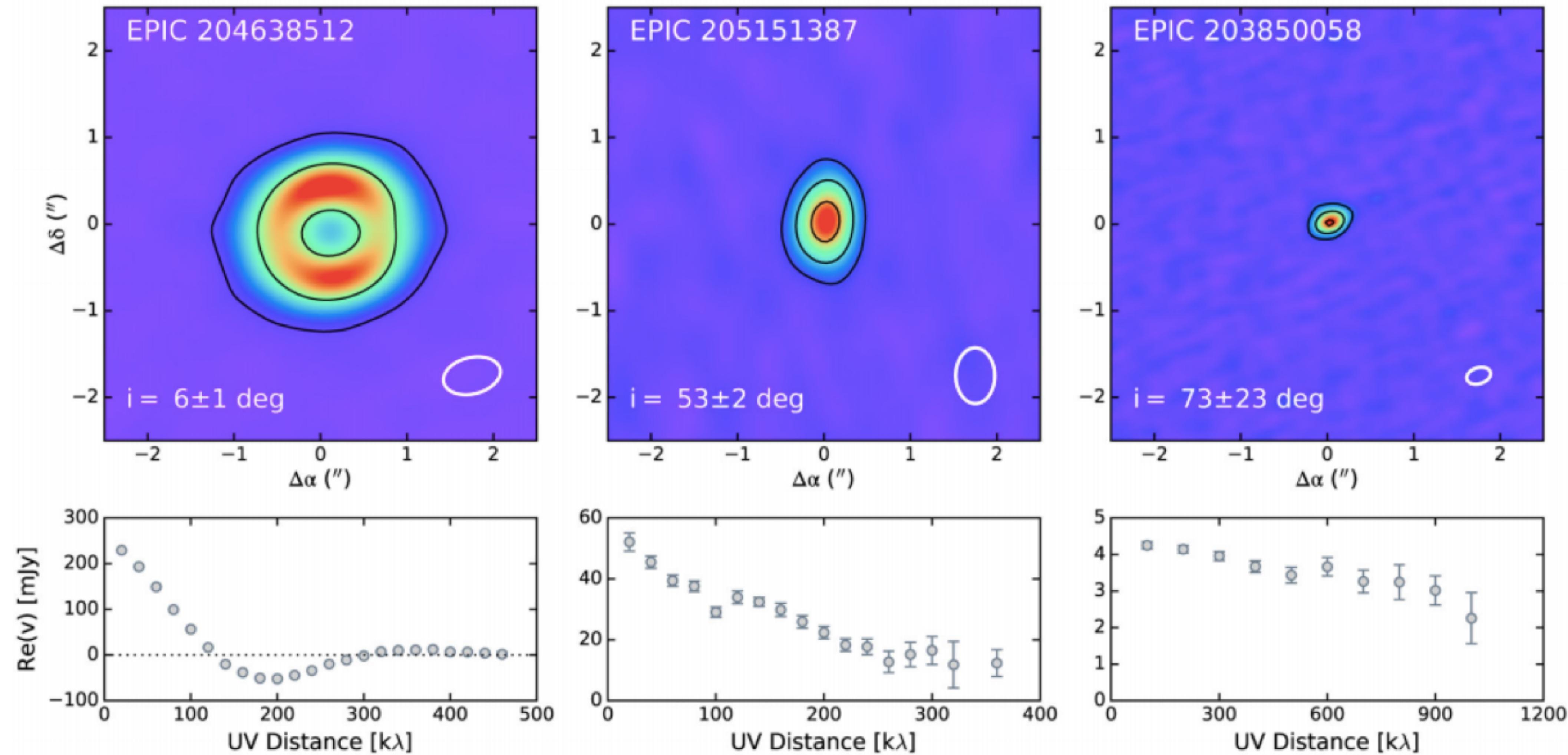
Cycle 6 results: inner disk is small and **not** edge-on (~30 deg)



What does this mean for assumed dipper mechanism?

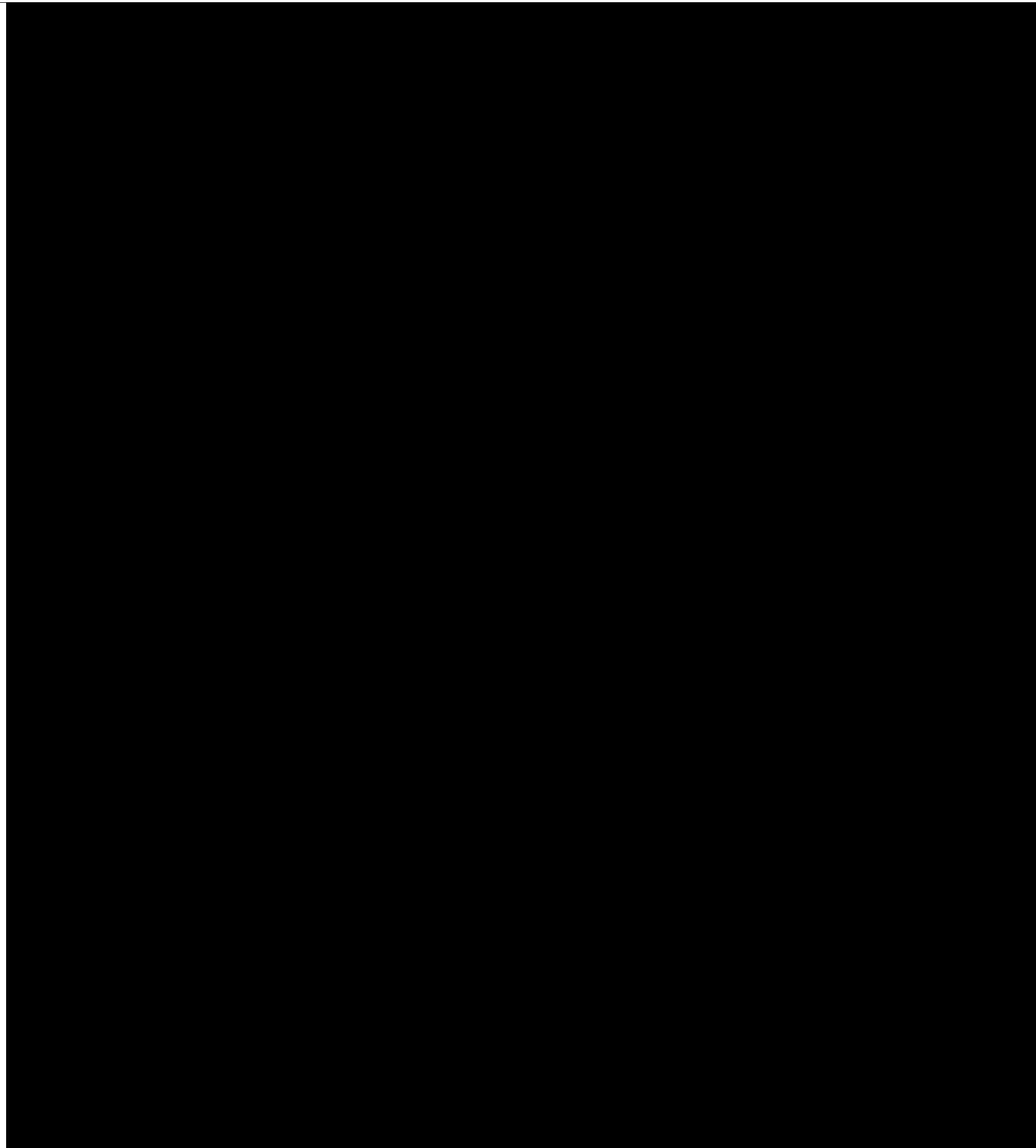
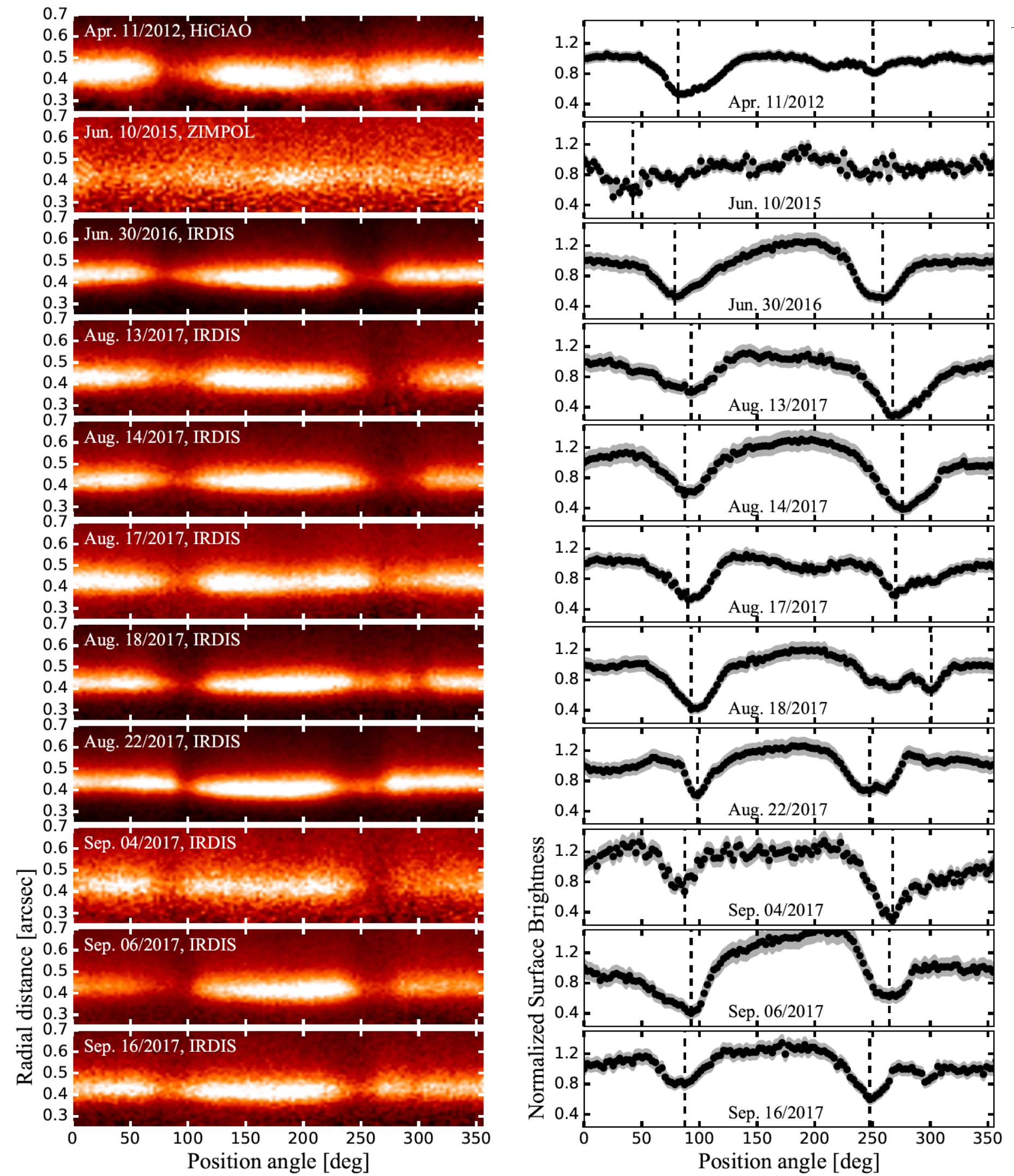


Dipper systems are not all edge-on



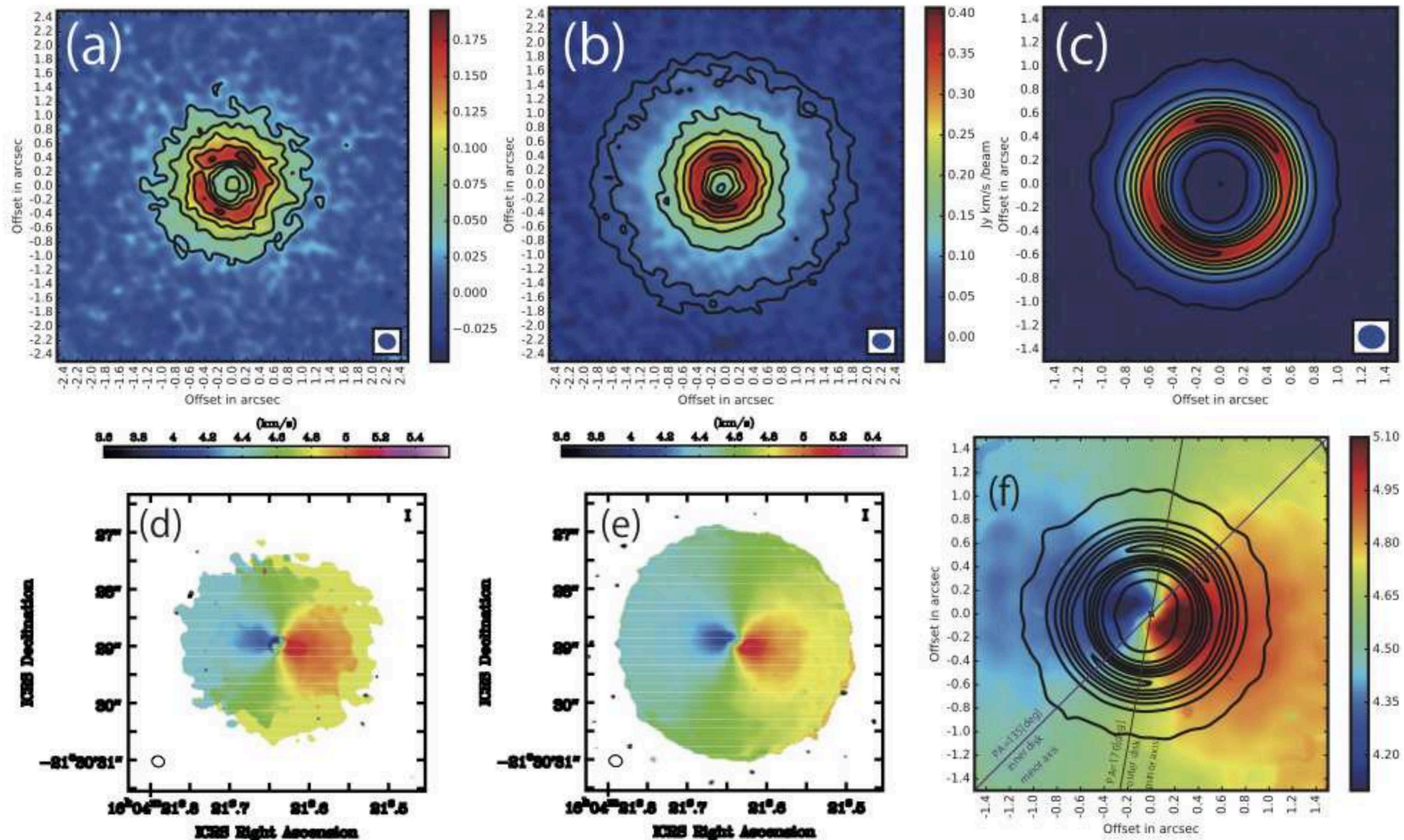
[Ansdel + 2016b]

SPHERE observations of J1604 in scattered light

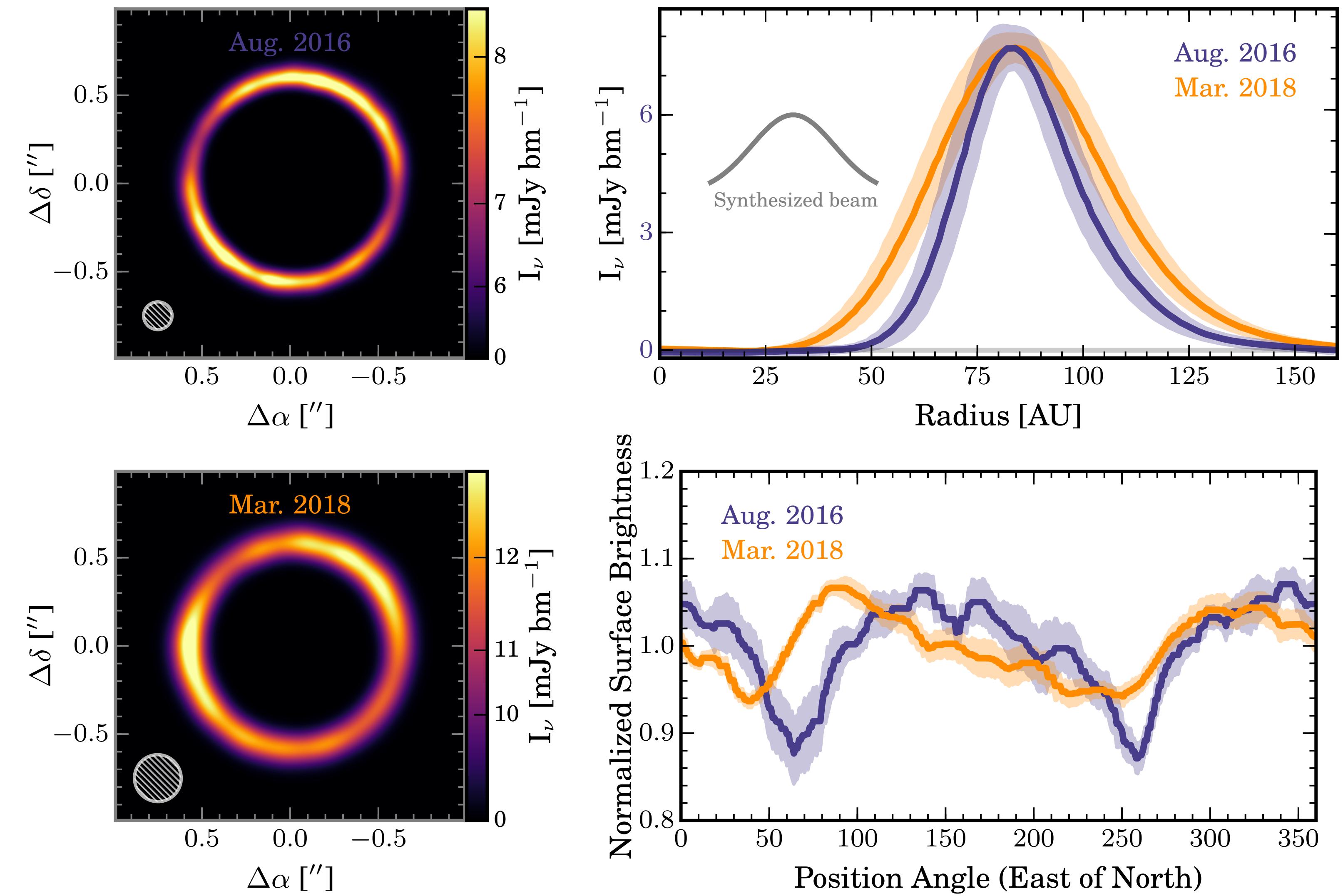


[Pinilla + 2018]

ALMA observations of J1604 mm continuum emission

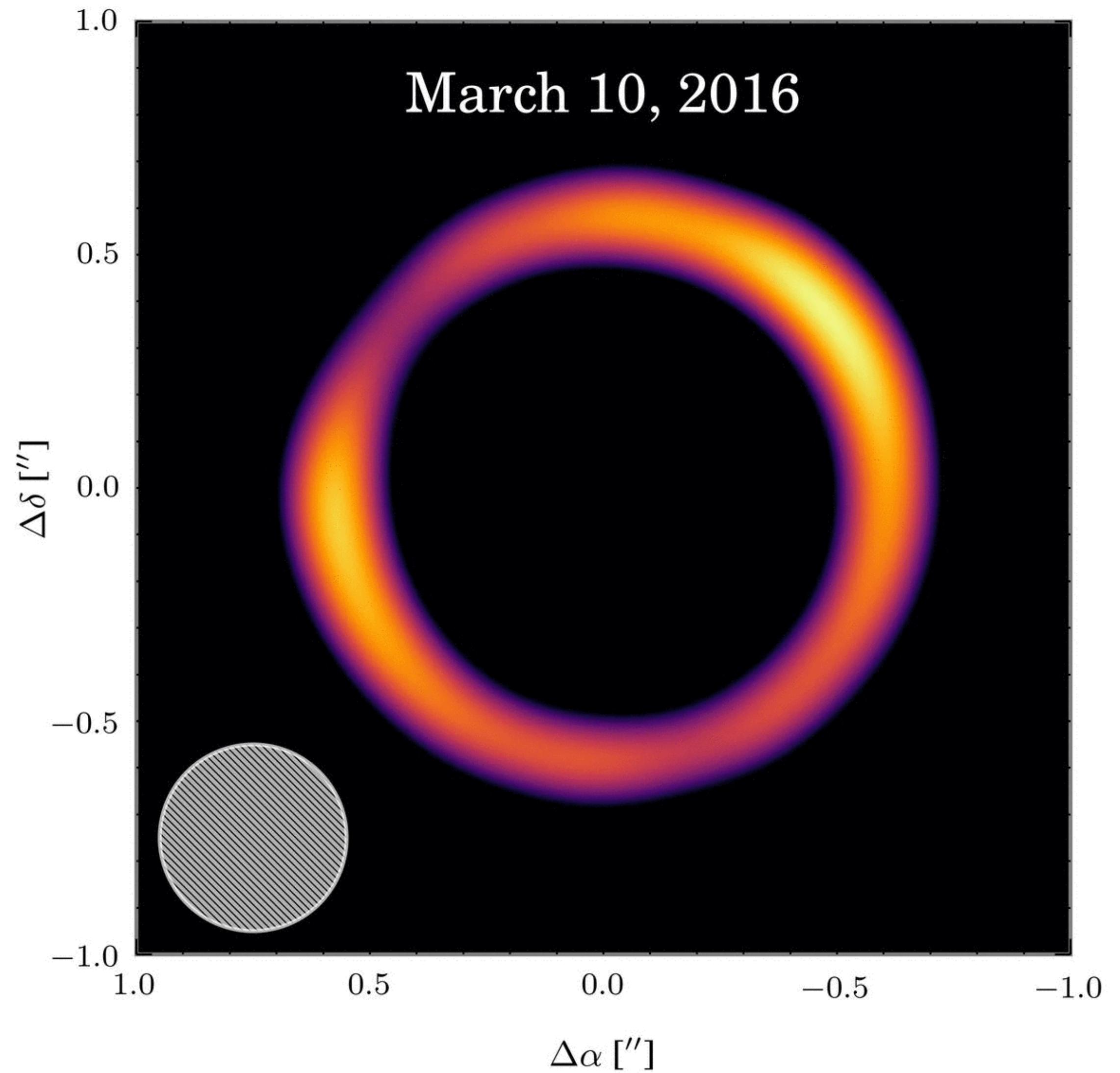


Multi-epoch ALMA observations of J1604



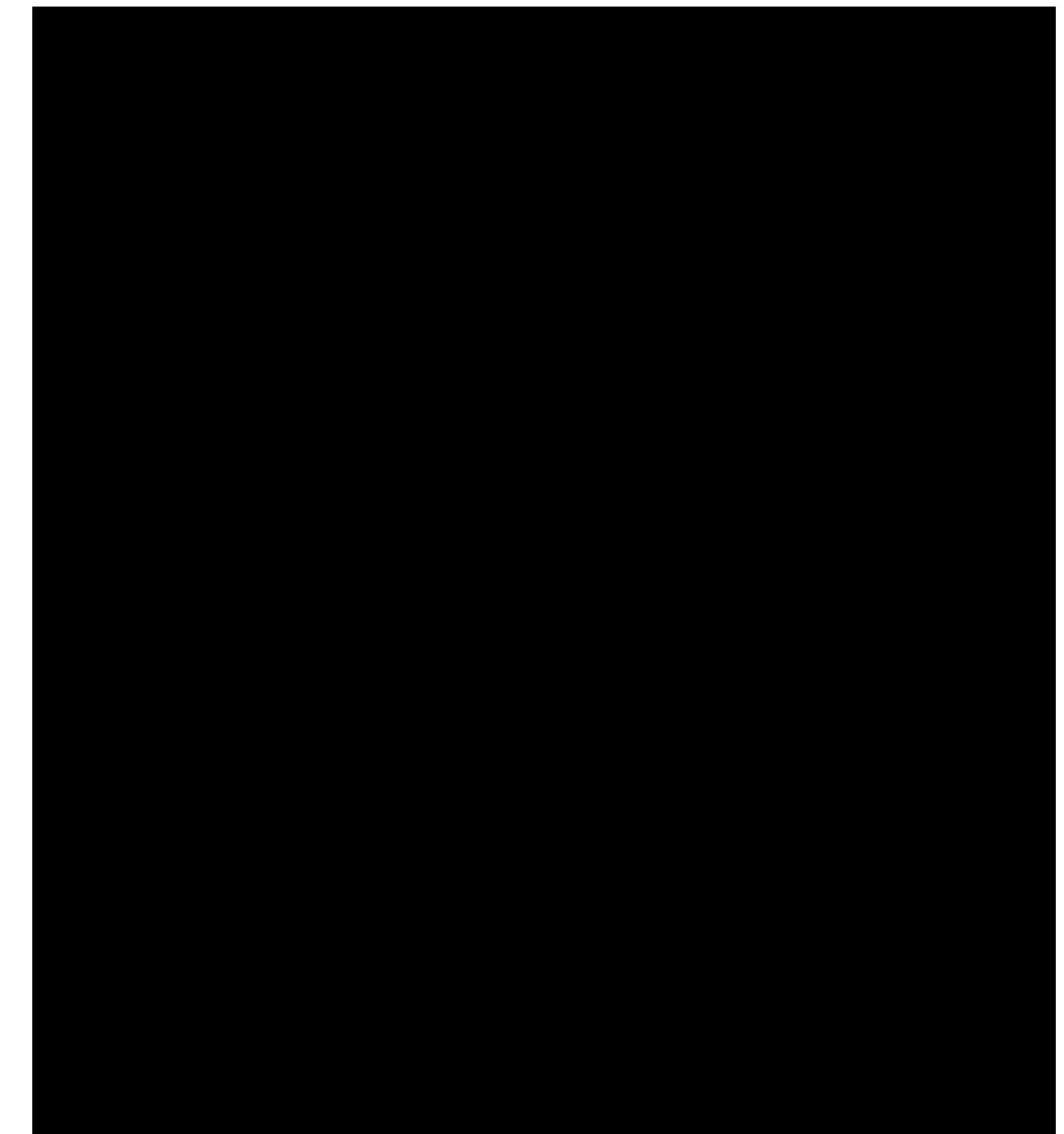
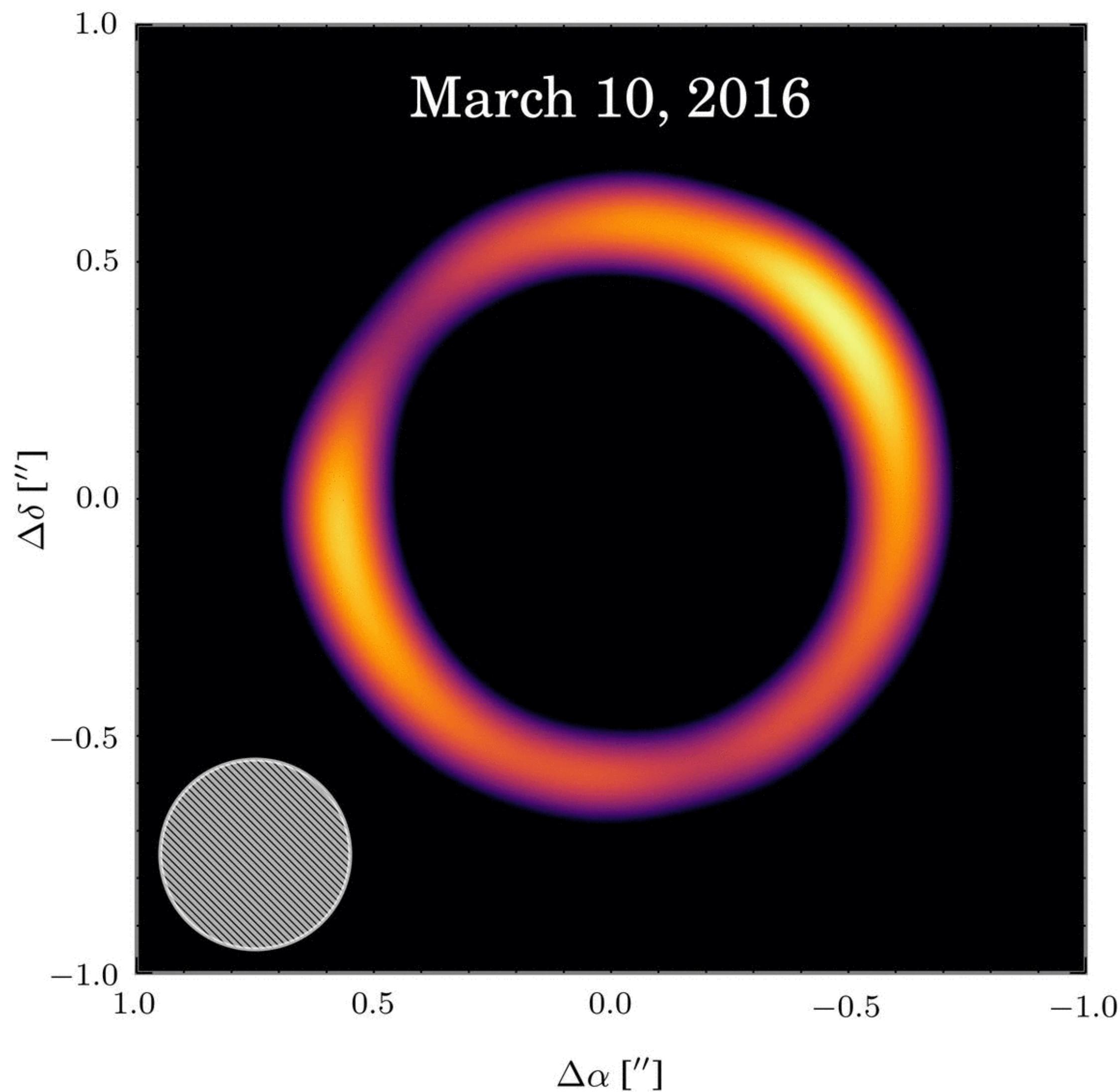
[Loomis + in prep]

Multi-epoch ALMA observations of J1604



[Loomis + in prep]

Comparison of mm and NIR shadows - cooling timescales?

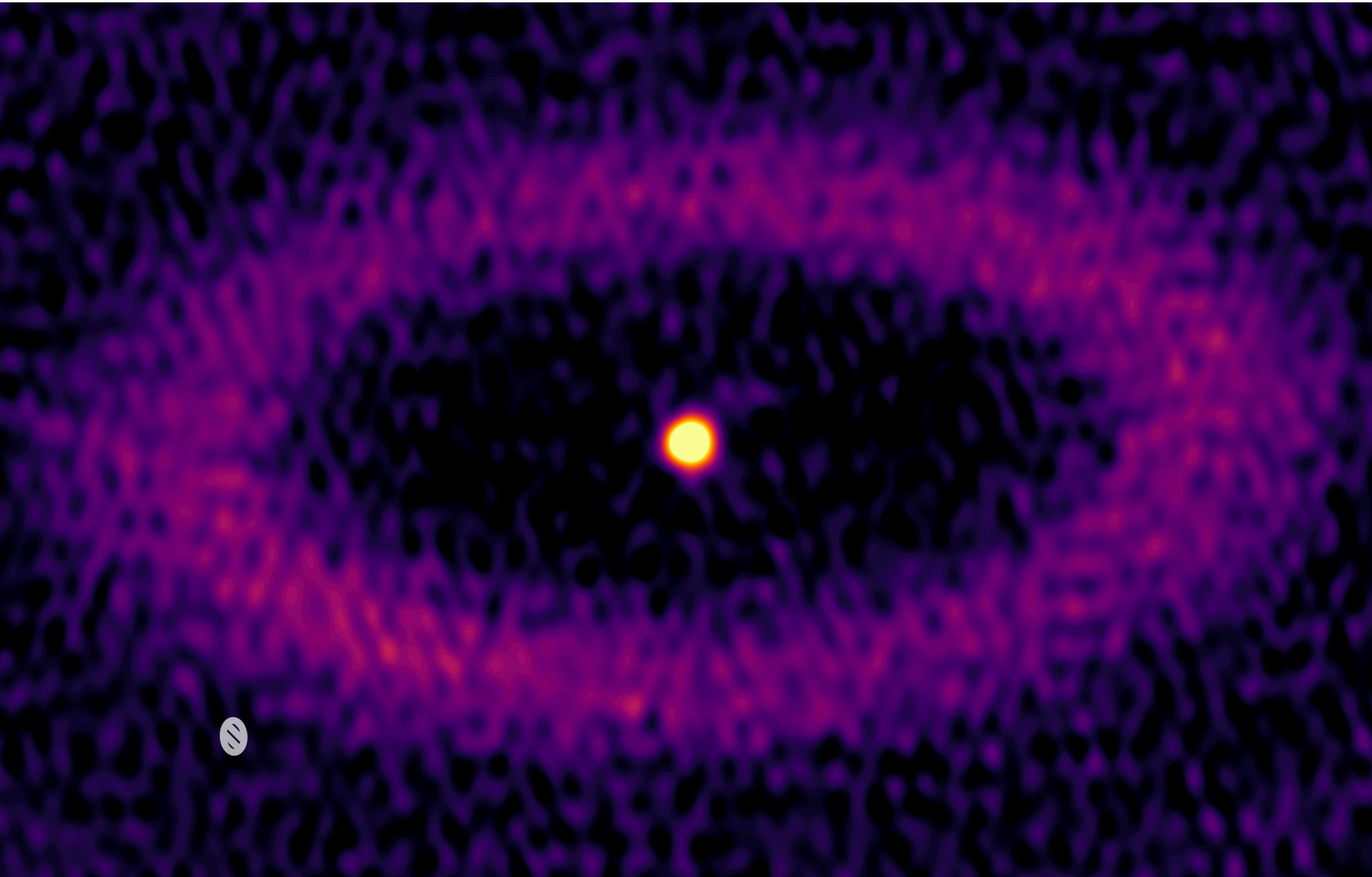


[see e.g. Casassus + 2019]

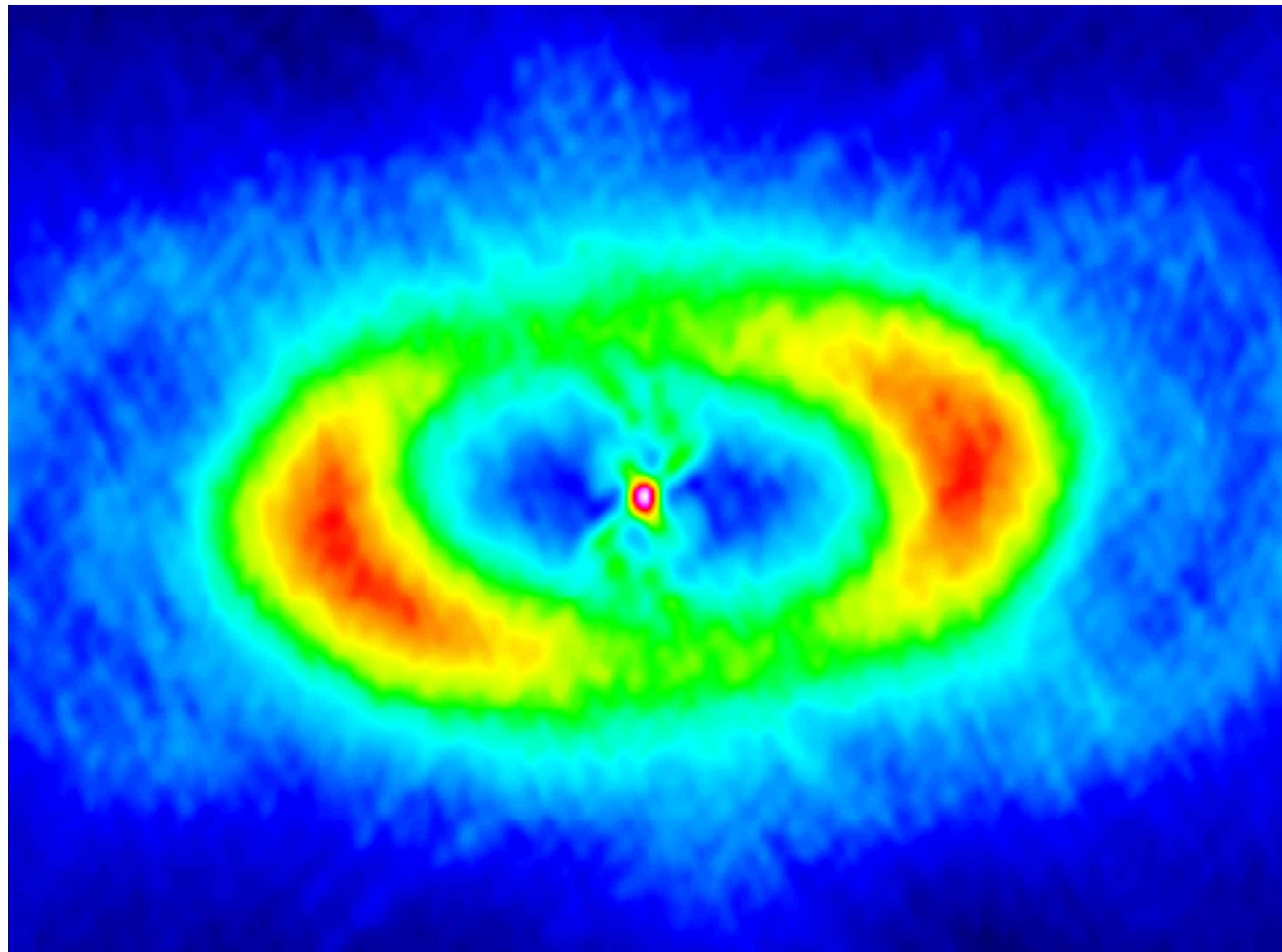
Brief technical digression



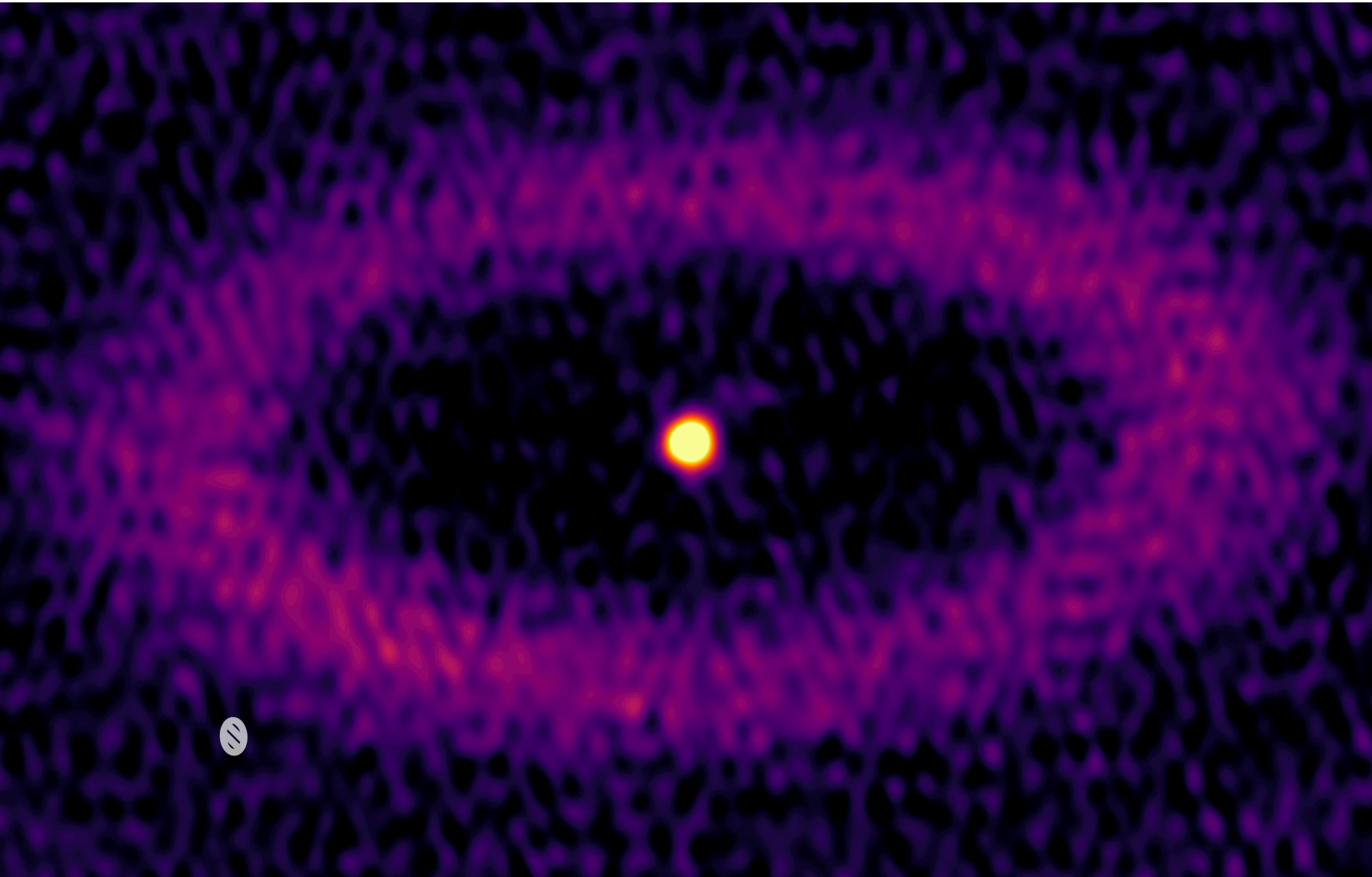
Brief technical digression - HDR imaging in cavities



Brief technical digression - HDR imaging in cavities



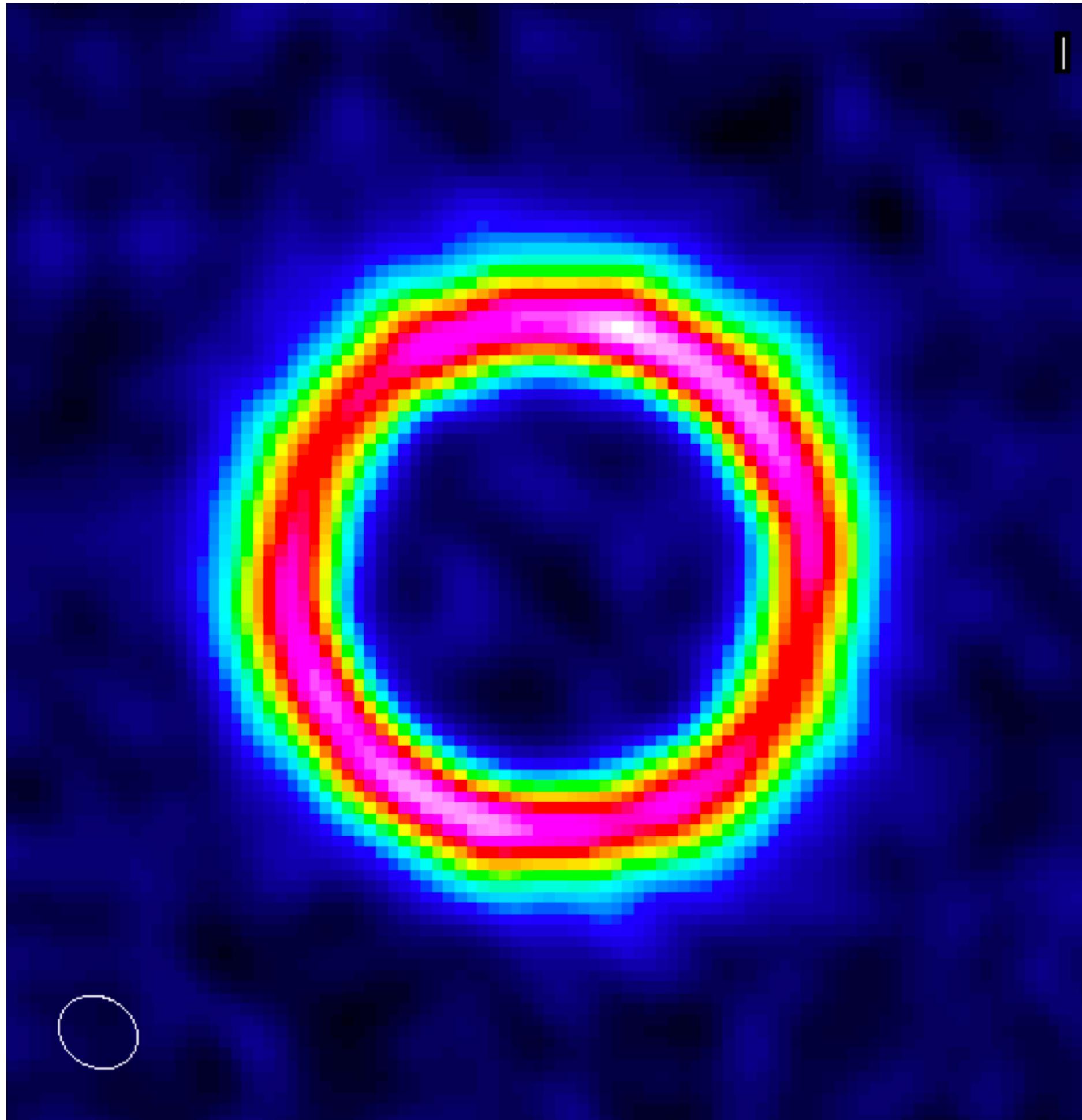
Brief technical digression - HDR imaging in cavities



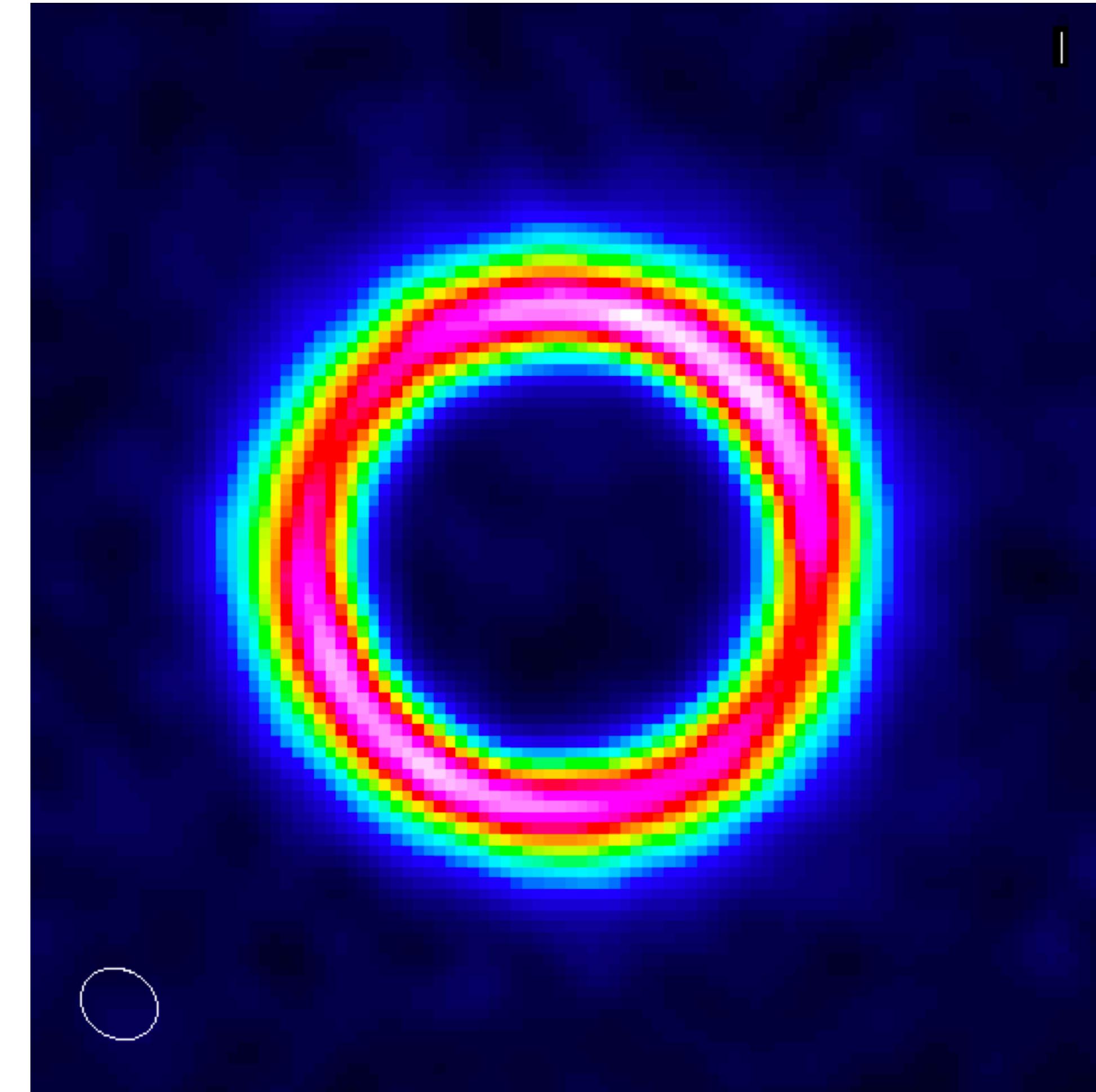
Brief technical digression - effects of gain on imaging cavities



Gain = 0.1 (default)



Gain = 0.02



Summary / Questions

Single T-Tauri stars AA Tau and J1604-2130 host misaligned inner disks

- Inner disks are casting shadows onto the outer disk
- Temperature structures are affected by shadows (e.g. Casassus + 2019)

The inner disk of AA Tau is **not** edge-on, closer to ~30deg

- What does this mean for interpretation of dippers??

The mm shadows in J1604 show time variability, similar to the scattered light

- Not aligned with scattered light shadows

Some technical points:

- Circularized beams are necessary to accurately measure shadows
- Our imaging cases are rapidly becoming very difficult for clean - high dynamic ranges, bright point sources, and cavities ~ sidelobe size scale
- Keep gains low and go slow