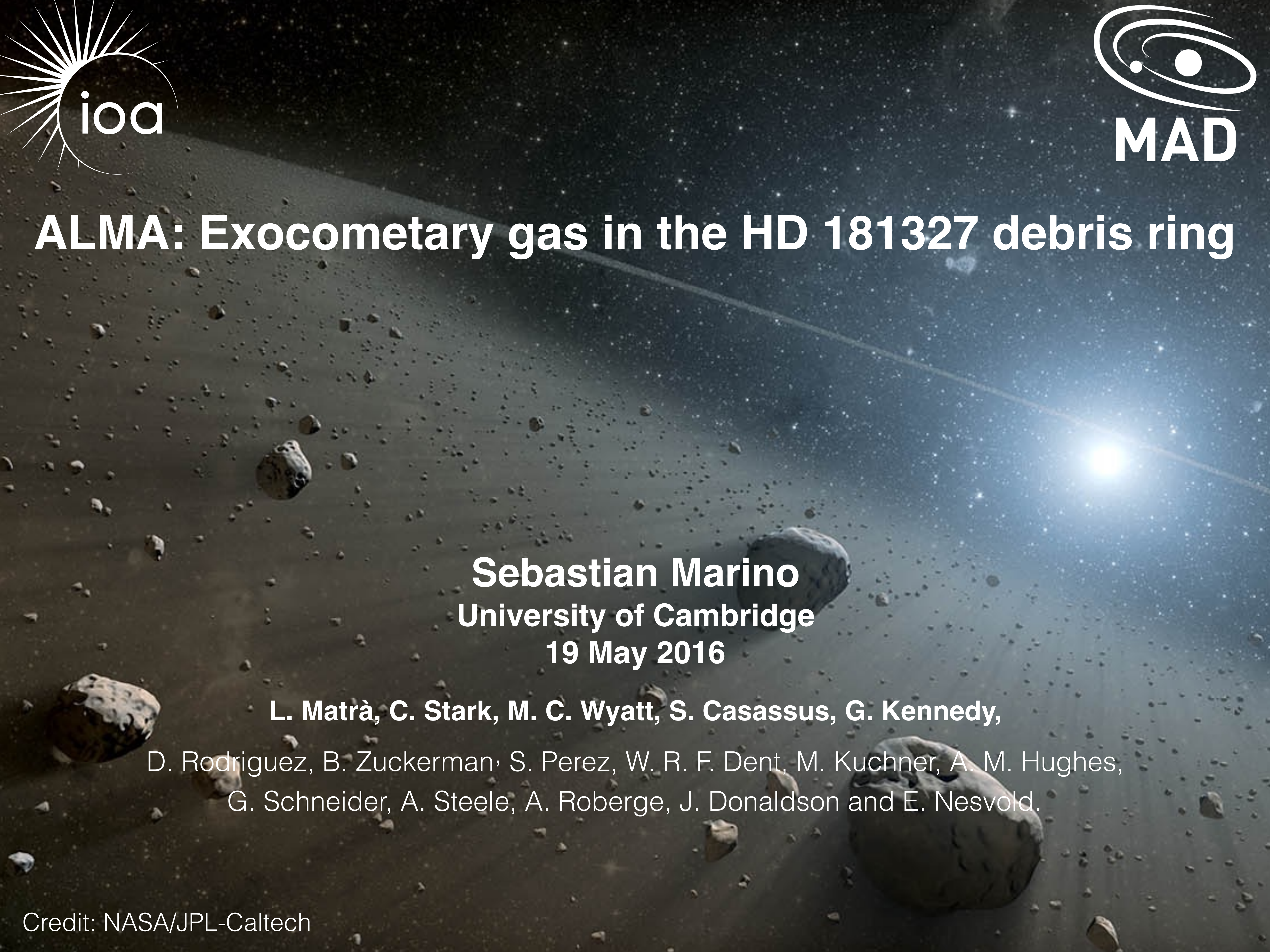

ALMA: Exocometary gas in the HD 181327 debris ring

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G. Schneider, A. Steele, A. Roberge, J. Donaldson and E. Nesvold.

Credit: NASA/JPL-Caltech

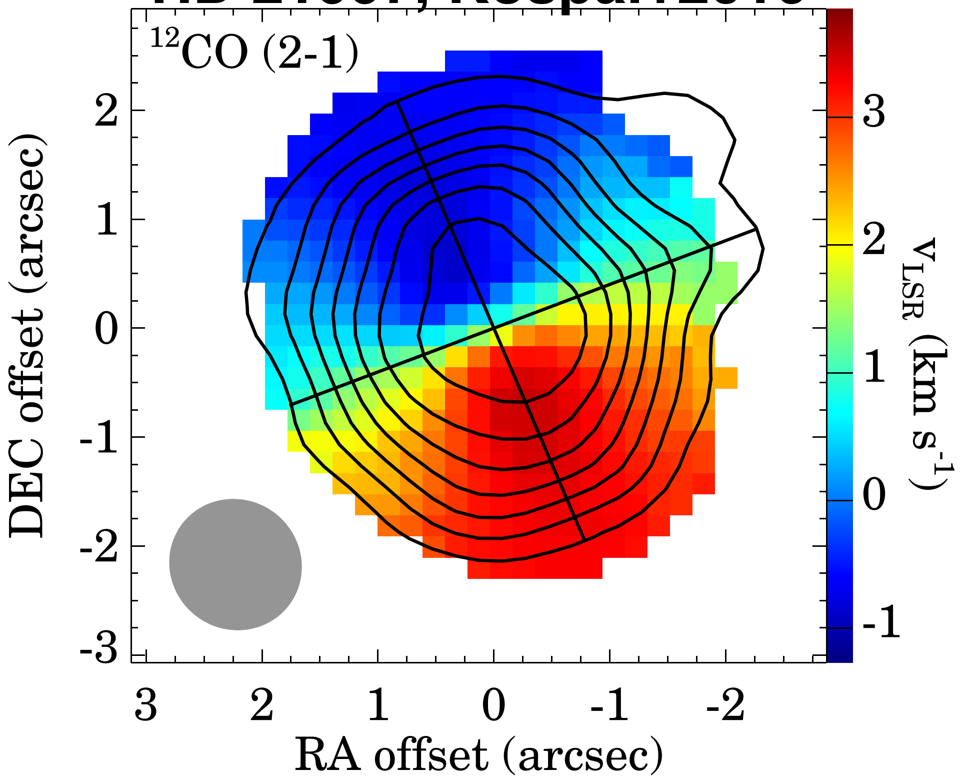
Debris disks and gas

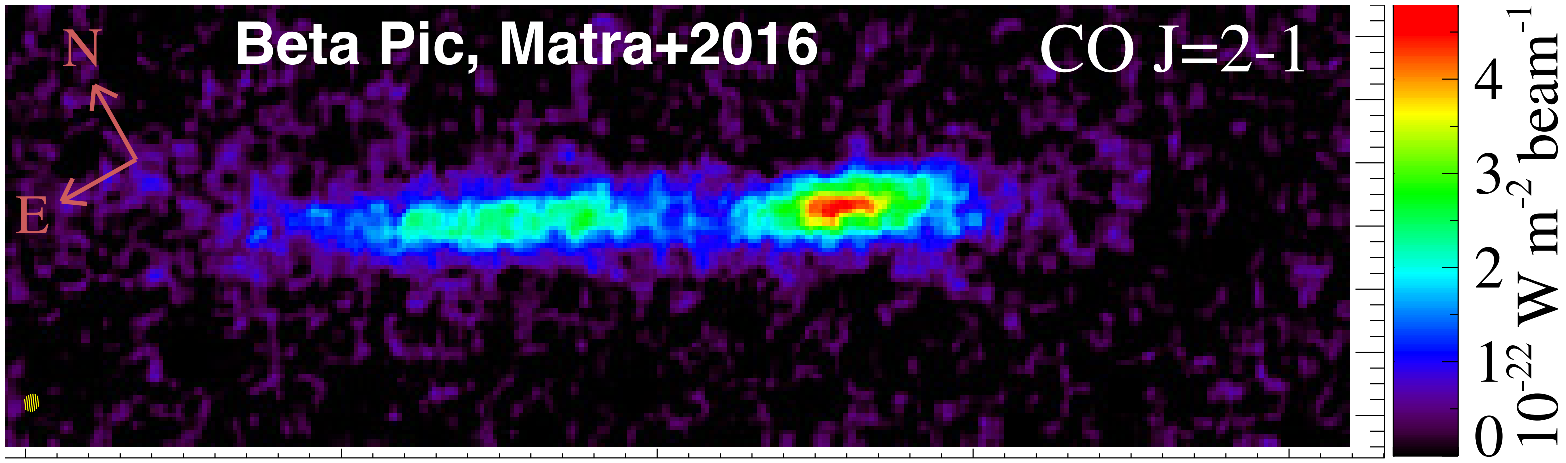
- **Byproduct of planet formation**
- Collisional cascade between **um- to km-sized bodies** (see Wyatt 2008)
- Kuiper belt analogues present in at least 20% of FGK stars (e.g. Eiroa+2013)
- ~8 gas detections (4 CO) until now, but **only around young A stars** (Moor+2015).
- Ongoing debate about gas origin: **Primordial or secondary?**

Primordial?

Secondary?

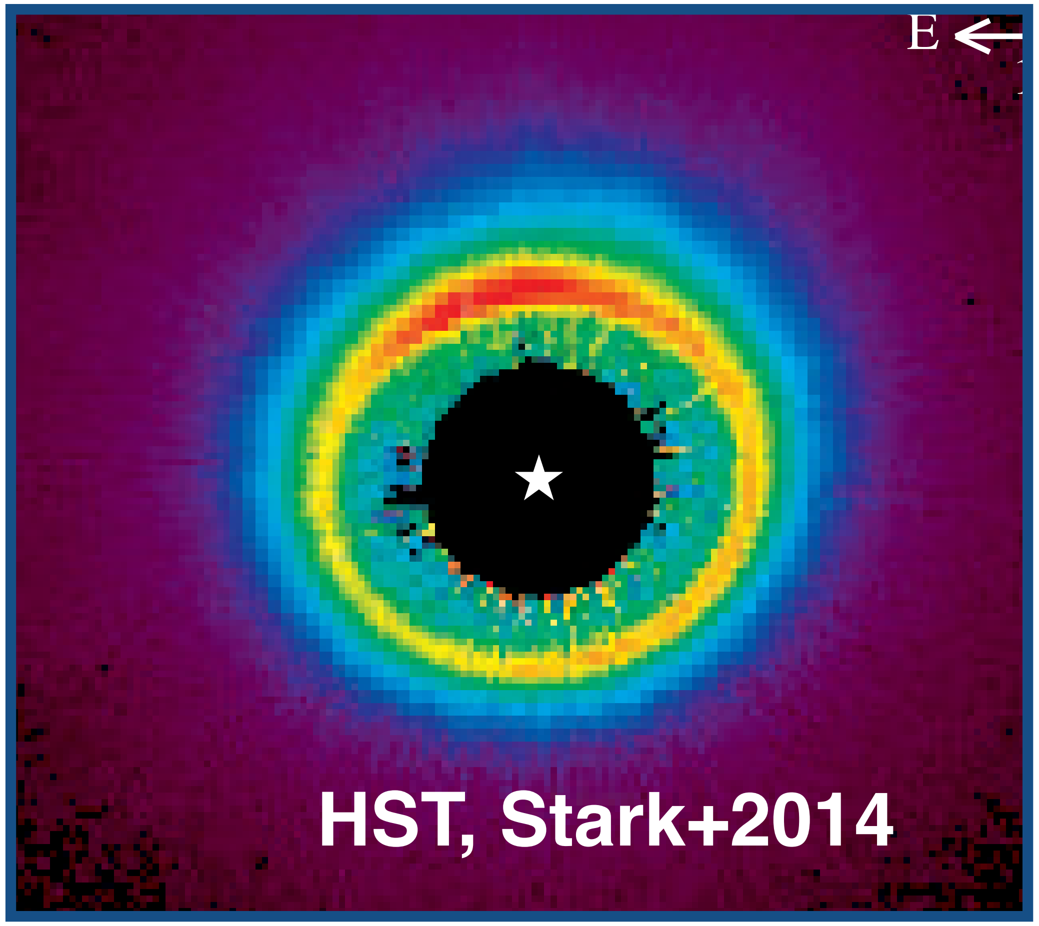
HD 21997, Kospal+2016



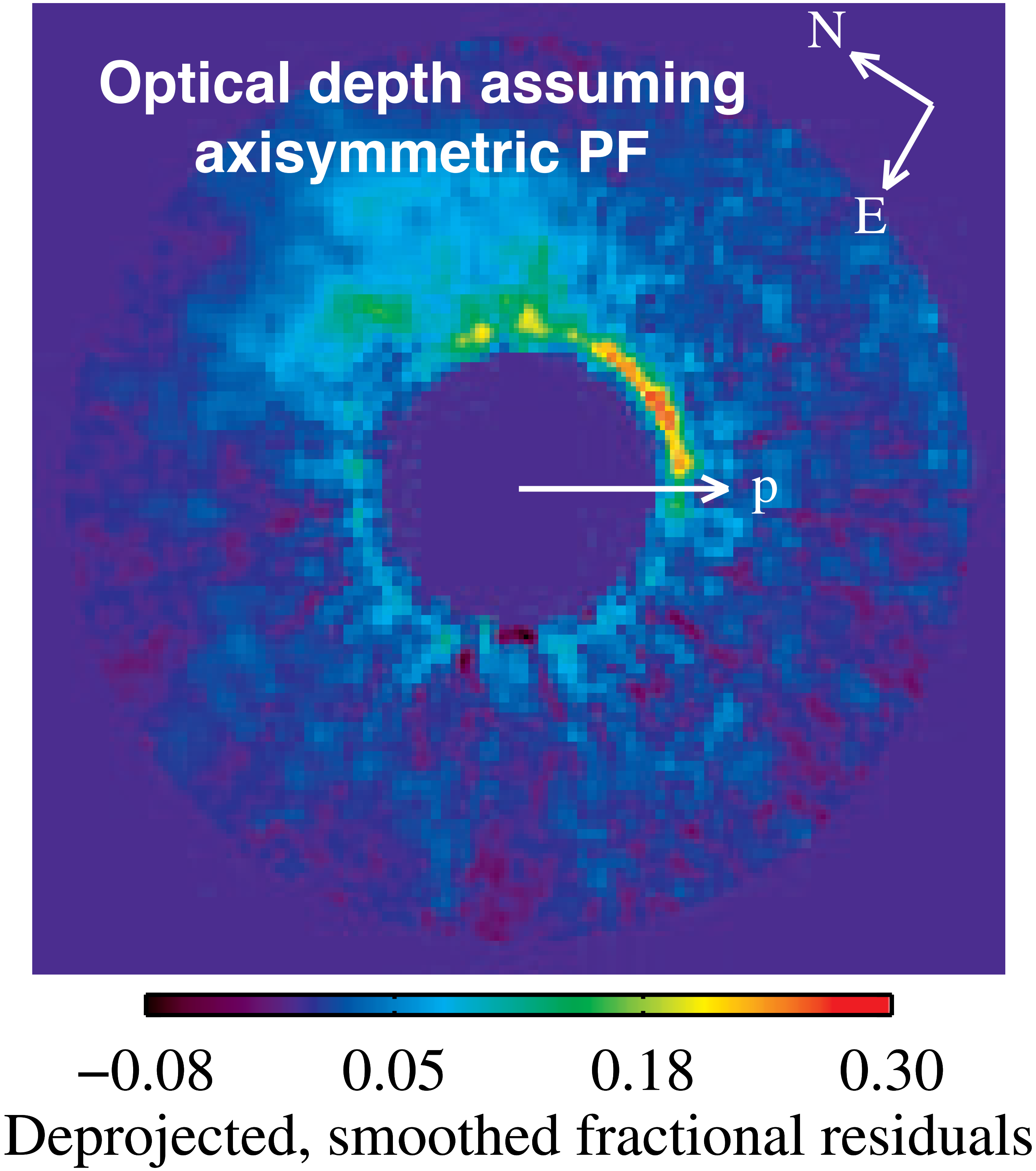


HD 181327 debris disk

- F6V ~23 Myr old star
- Debris disk of radius 90 AU
- e ~ 0.02
- Asymmetric in scattered light:
  - Giant collision
  - or warping by ISM

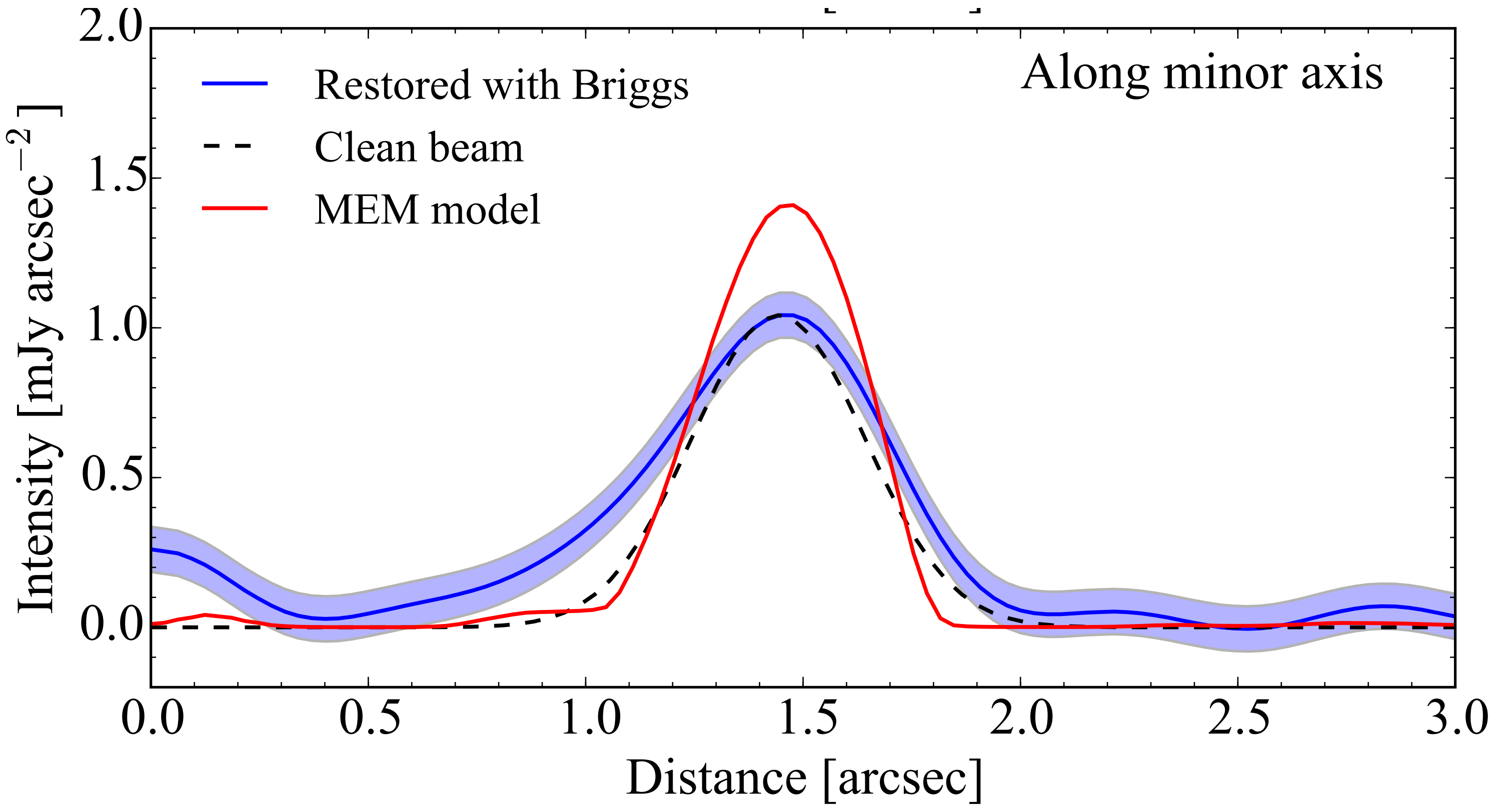


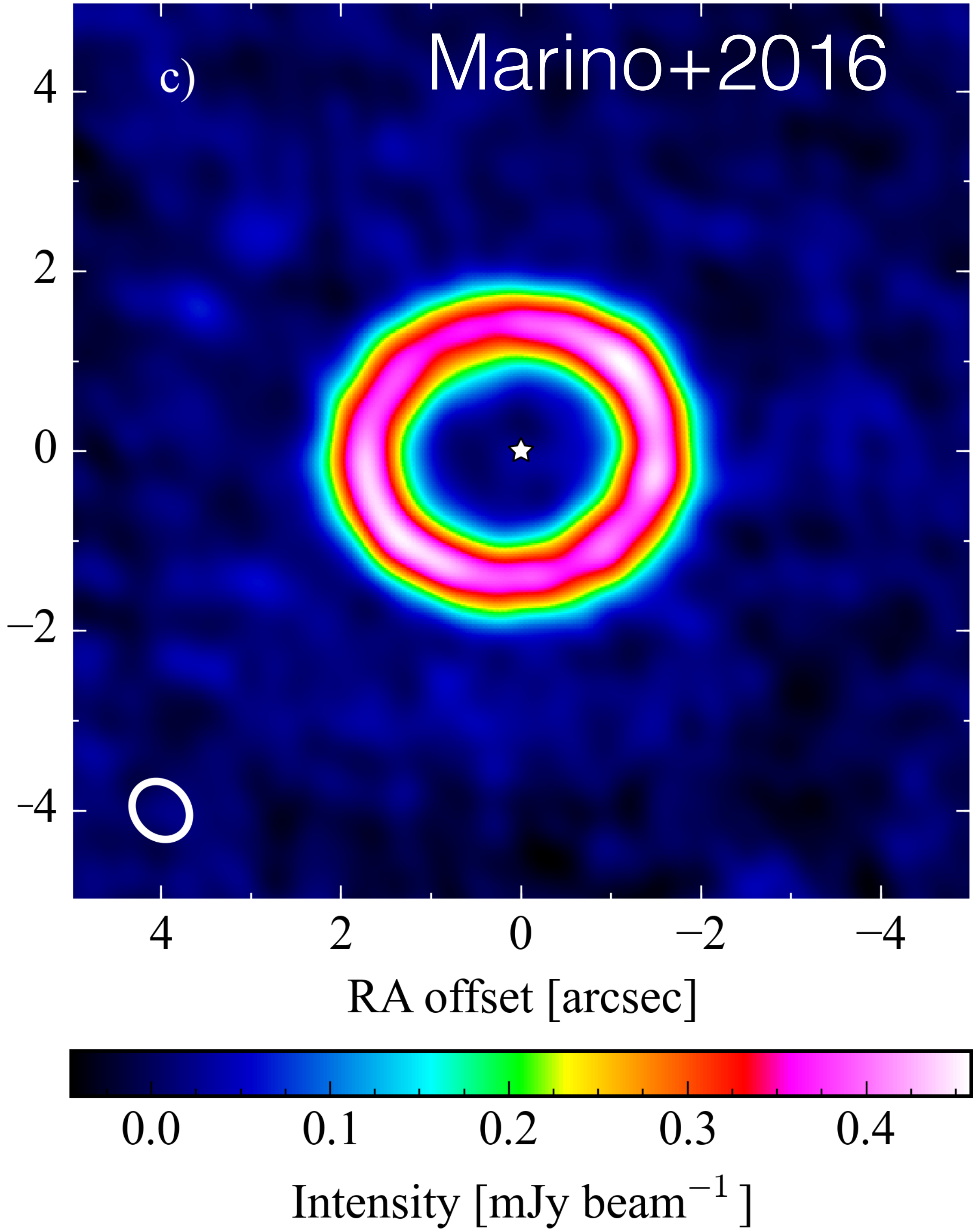
HST, Stark+2014


Optical depth assuming axisymmetric PF

ALMA: dust continuum

- Band 6 (1.3 mm)
- S/N ~ 30
- Radius ~90 AU
- Axisymmetric
- Width of ring marginally resolved:





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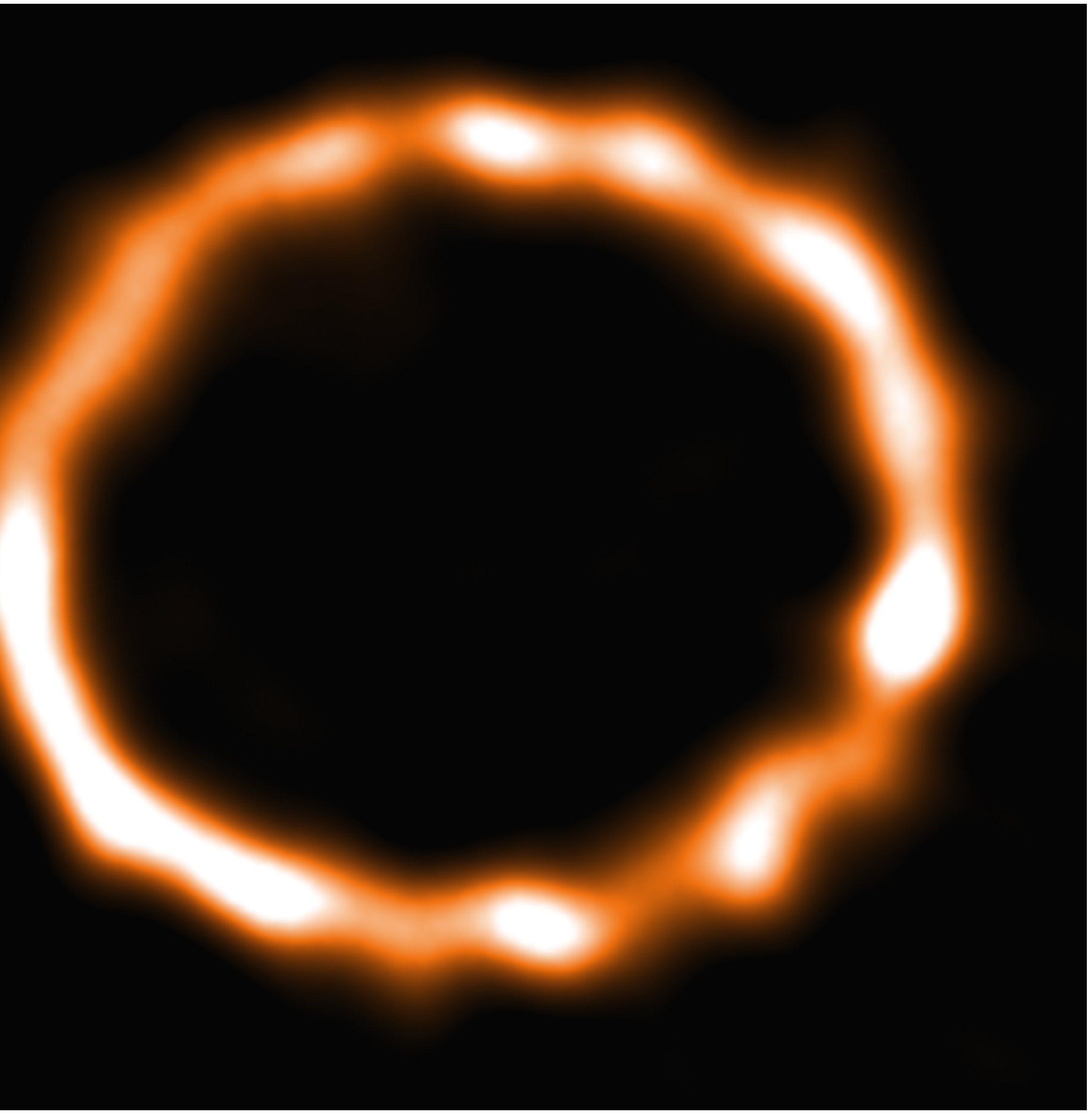
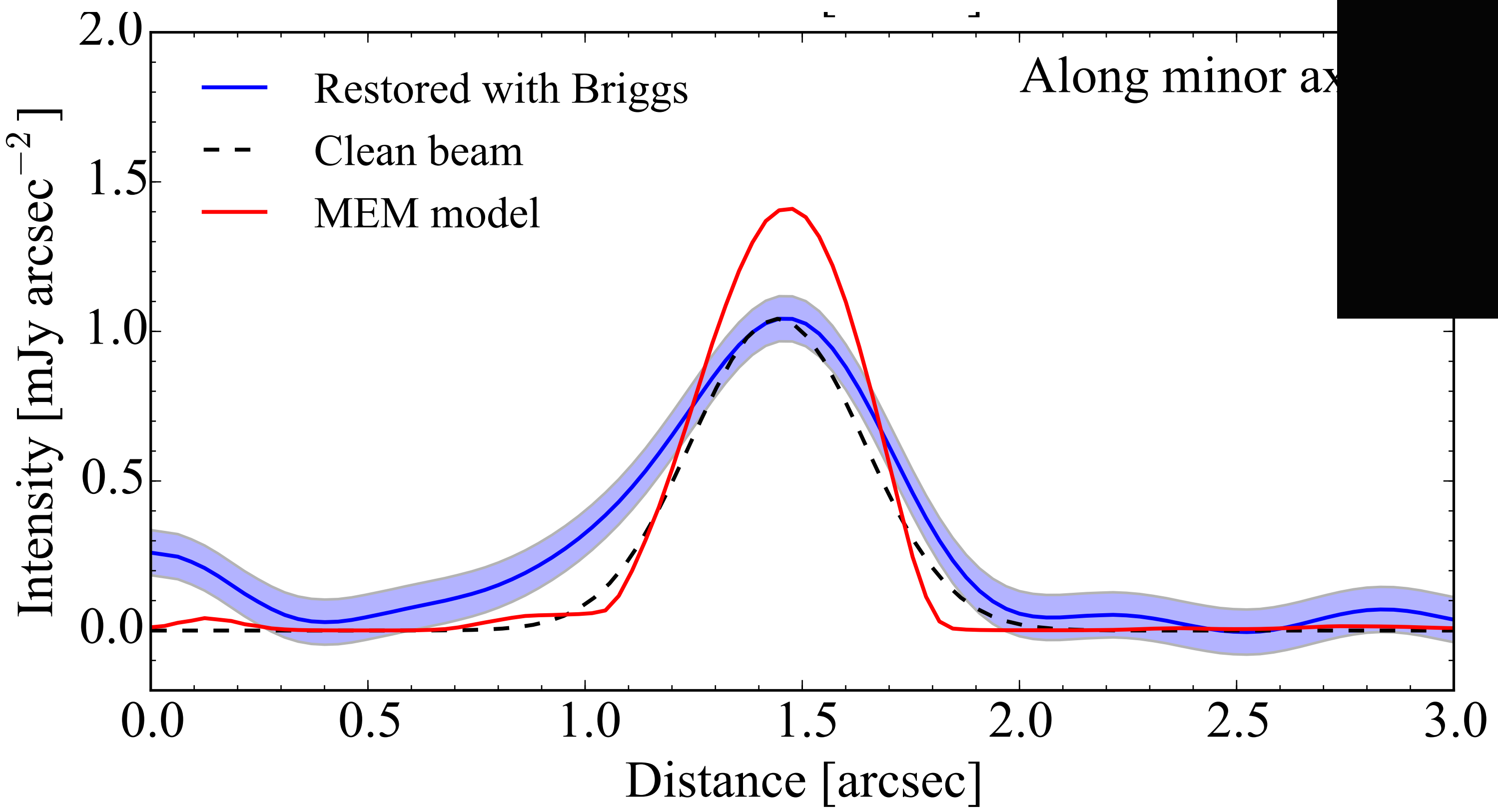
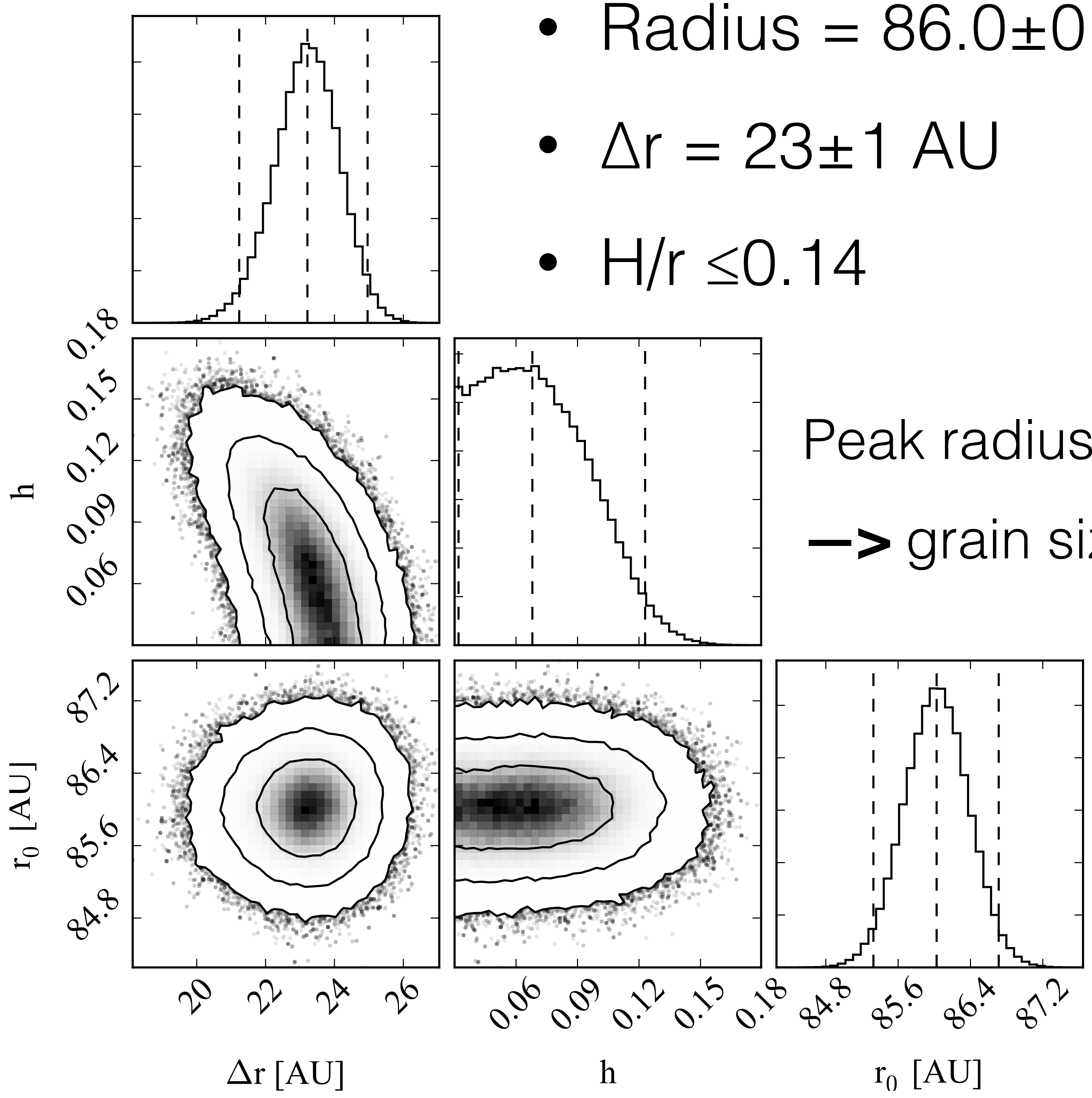




Dust continuum modeling

- MCMC+RADMC fitting in visibility space
- Radius = 86.0±0.4 AU
- Δr = 23±1 AU
- H/r ≤0.14

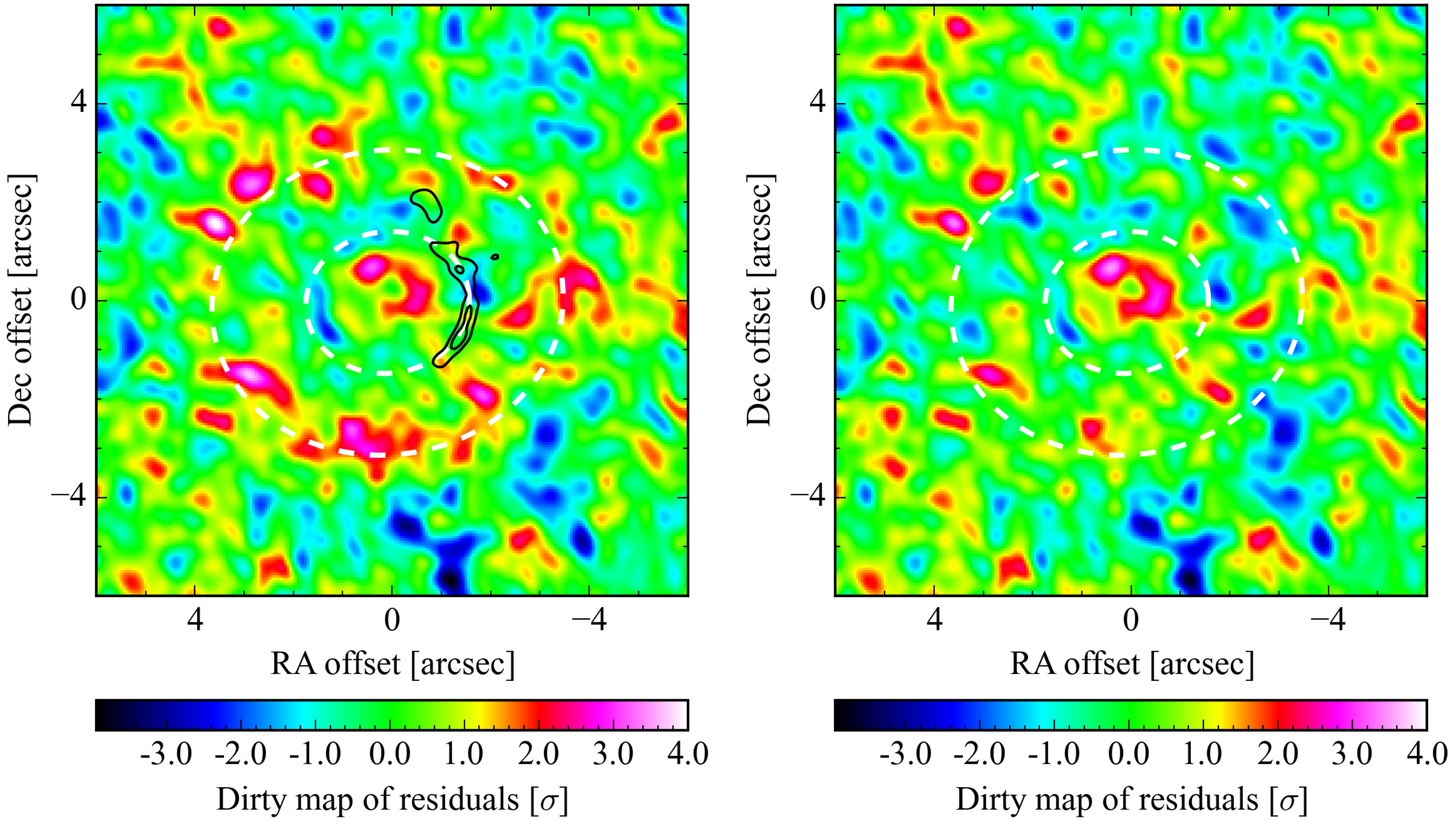


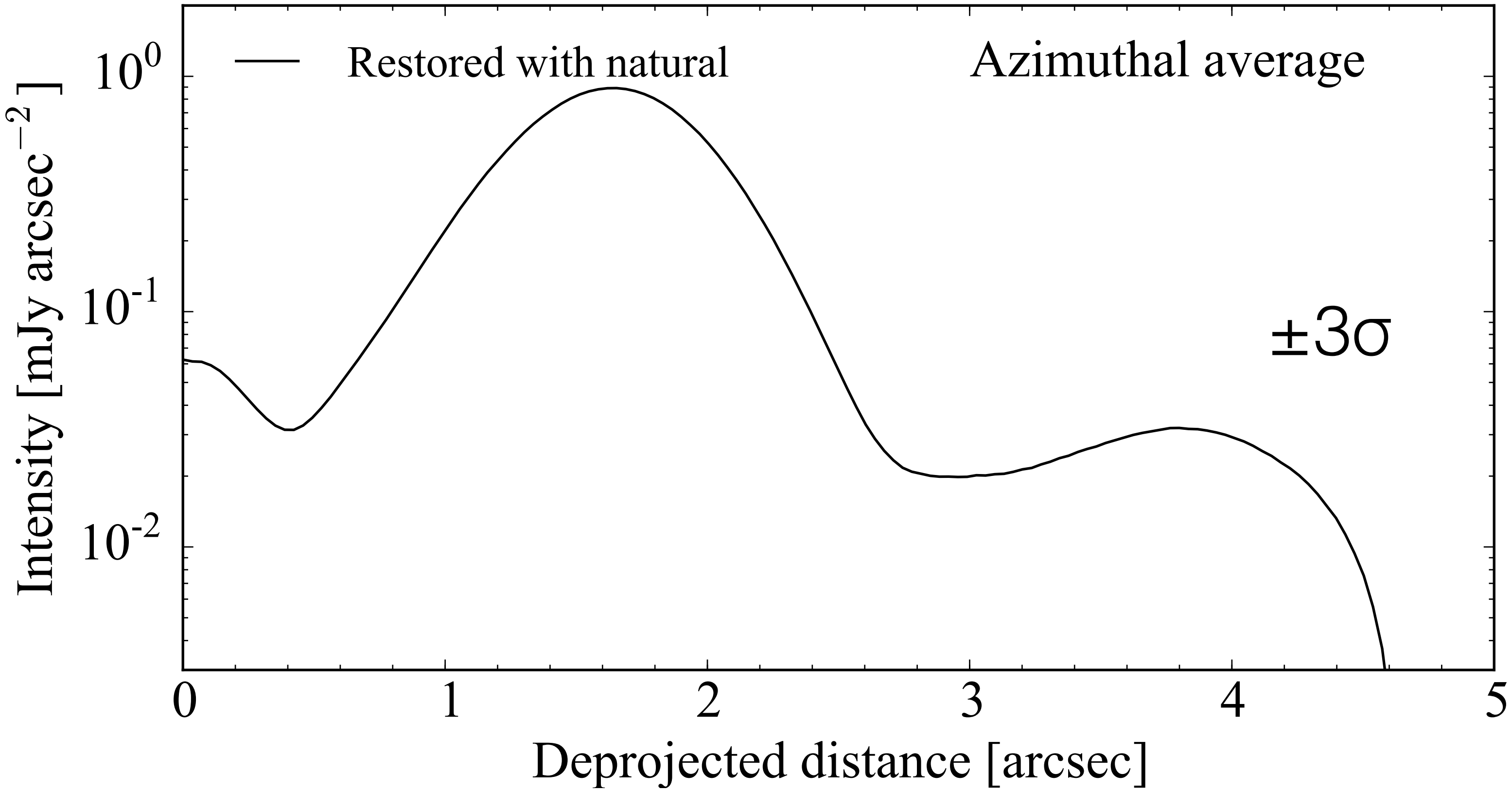
Peak radius smaller than in scattered light

—> grain size segregation?

Double ring?

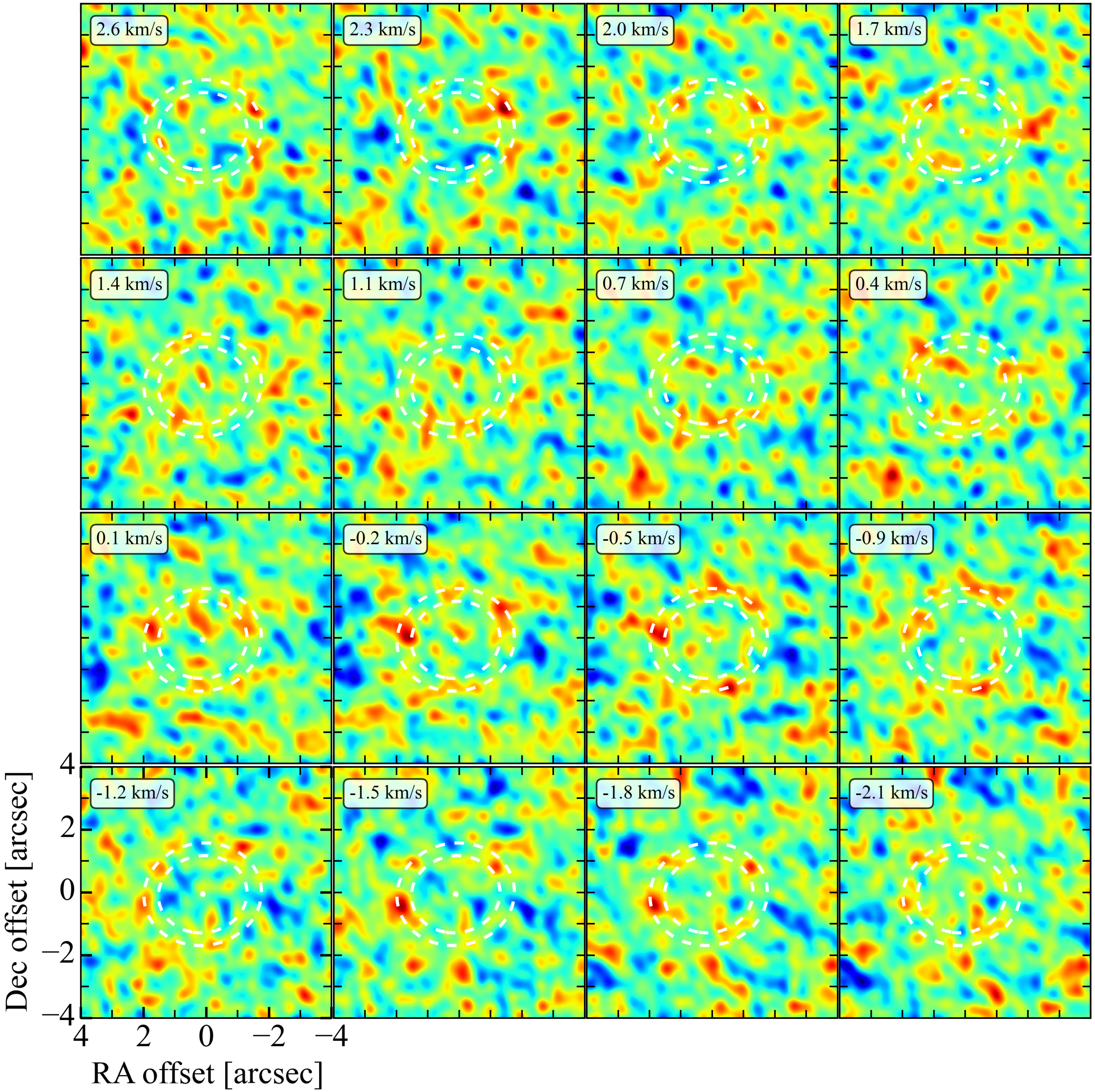
- No significant asymmetries
- Significant residuals at R~200 AU
- Visible in azimuthal average
- Origin:
  - Dust/planetesimals in eccentric orbits?
  - Gap?
  - Planet disk secular interactions? (Pearce & Wyatt 2015)





CO gas

CO (2-1)
Clear detection?



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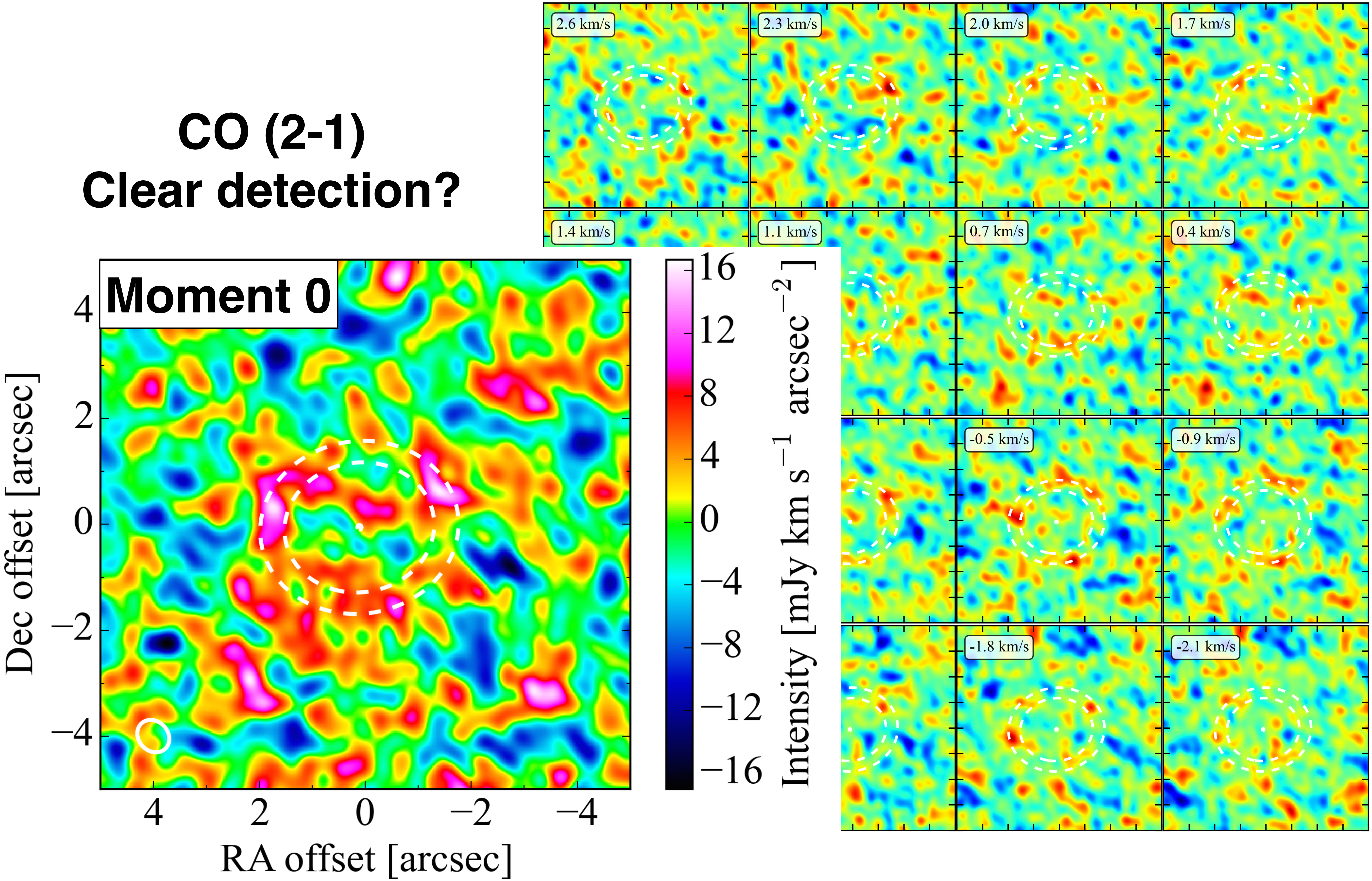
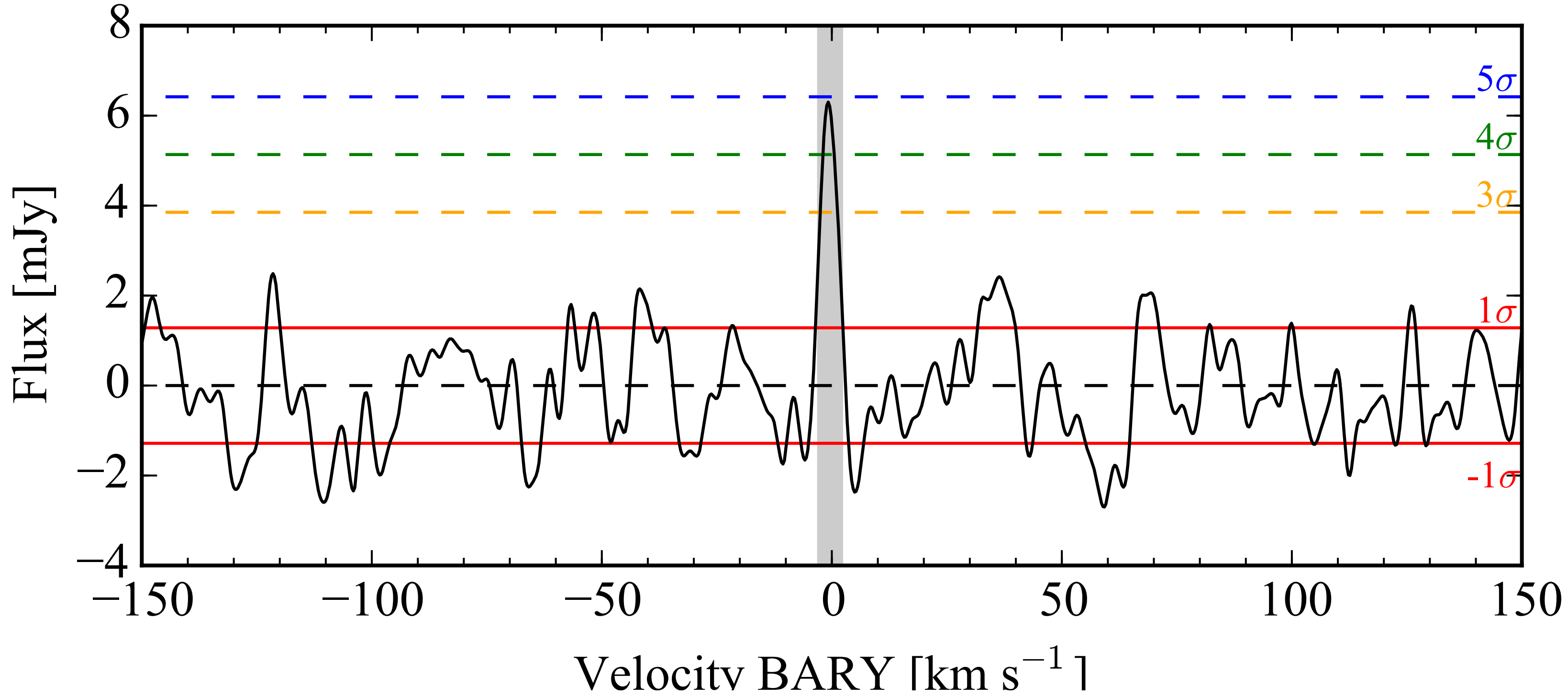
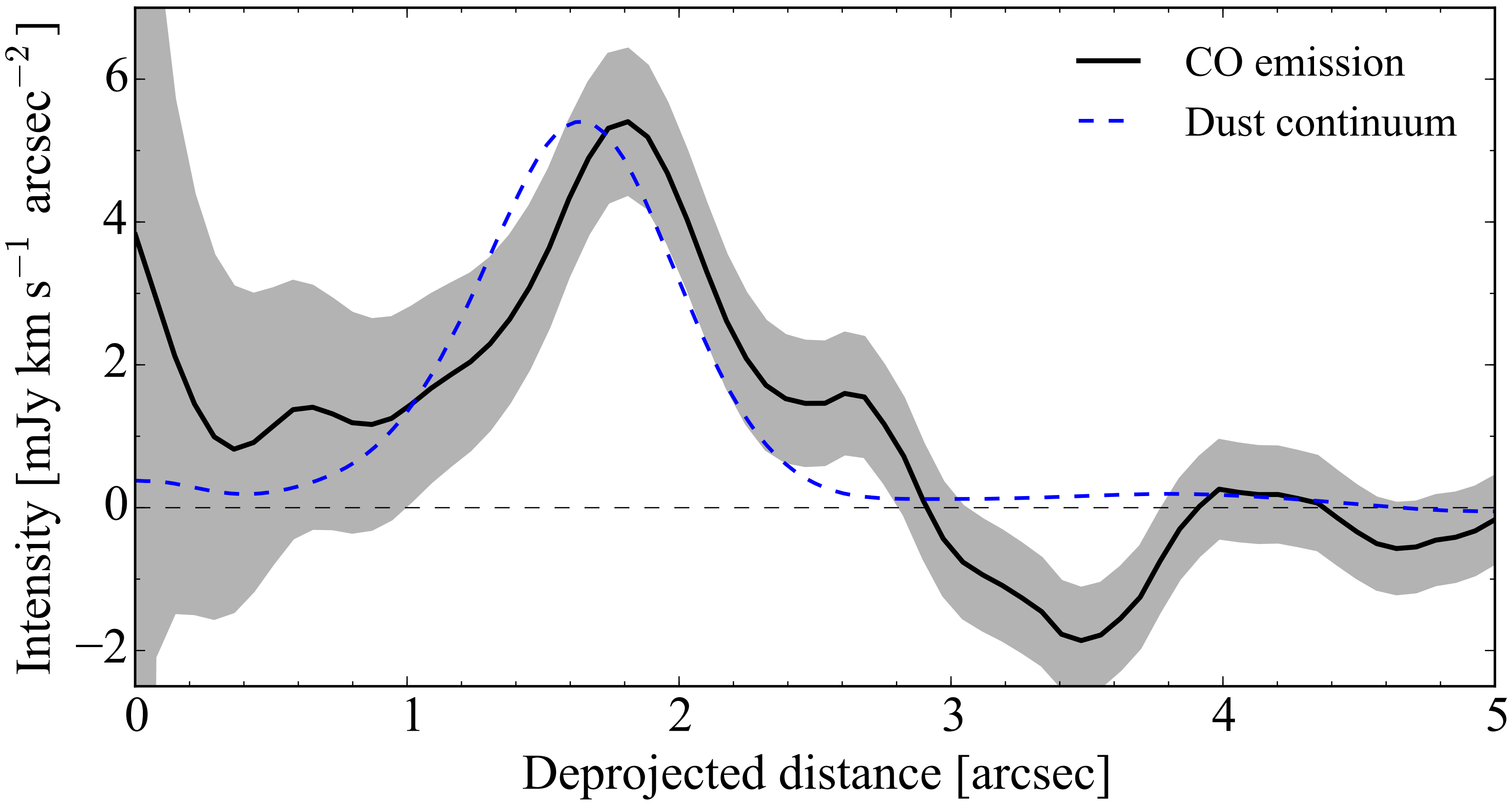


CO gas

Azimuthally averaging:

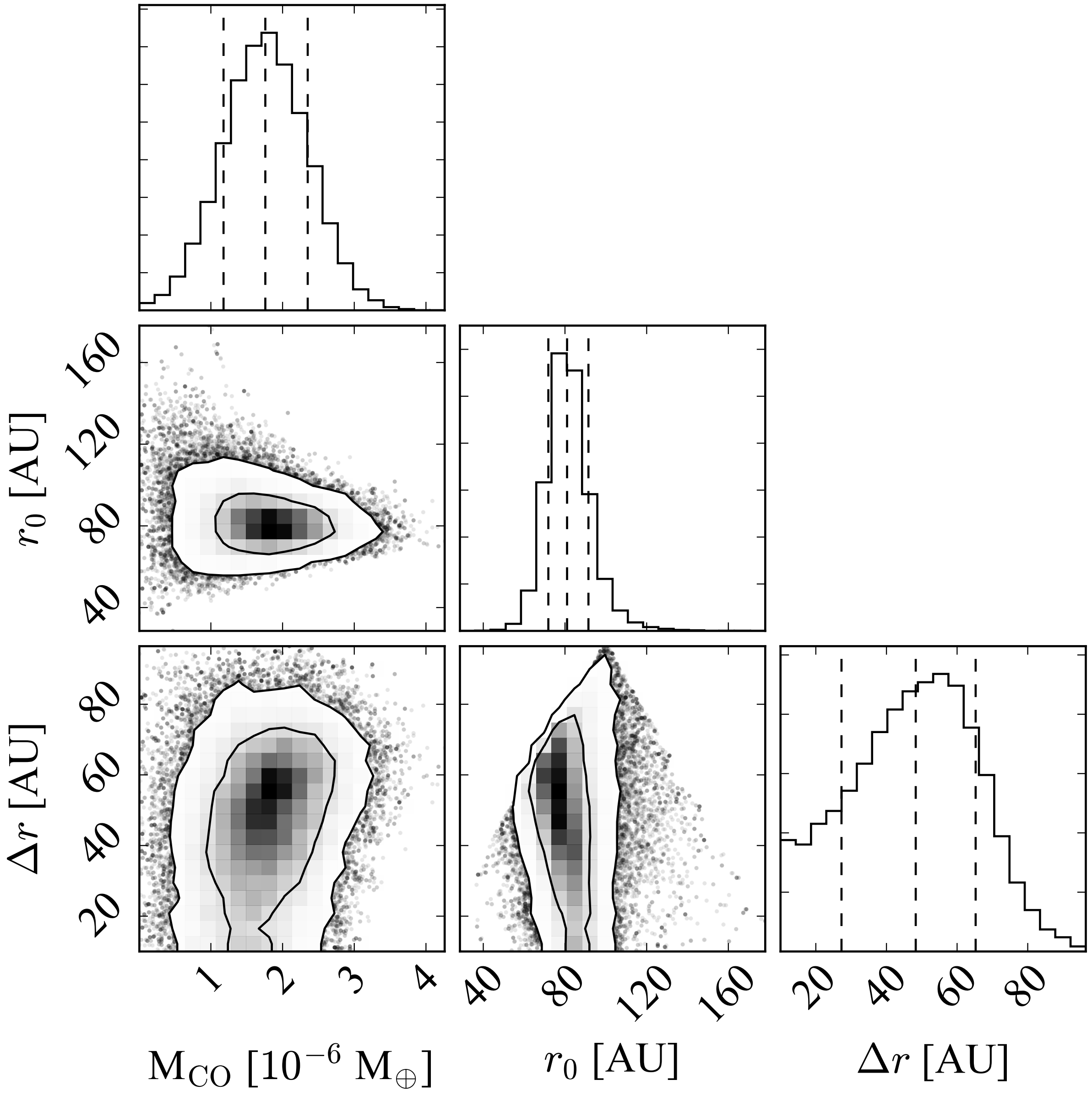
- F_{CO} = 30.1 ± 5.4 mJy km/s
- No signs of asymmetries
- Gas co-located with dust

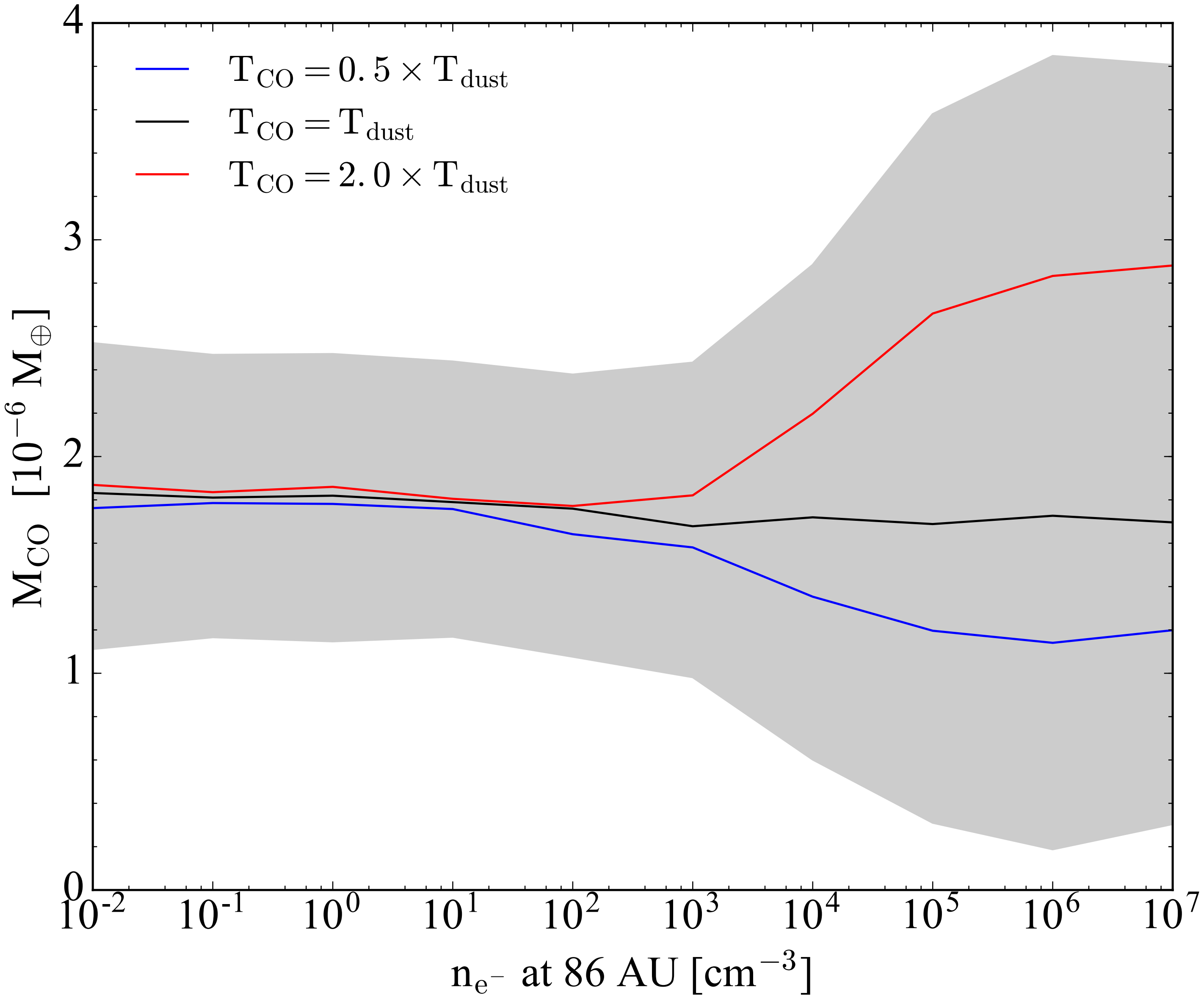




Constrains on the CO gas mass

- MCMC+RADMC+non-LTE CO fitting
- $M_{CO} \sim 1.2\text{-}2.9 \times 10^{-6}\ M_{\oplus}$, $r_{CO}=81 \pm 10$ AU
- Gas co-located, but Δr unconstrained
- CO/dust ratio 2 orders of magnitude lower than in ß Pic at the same age !!

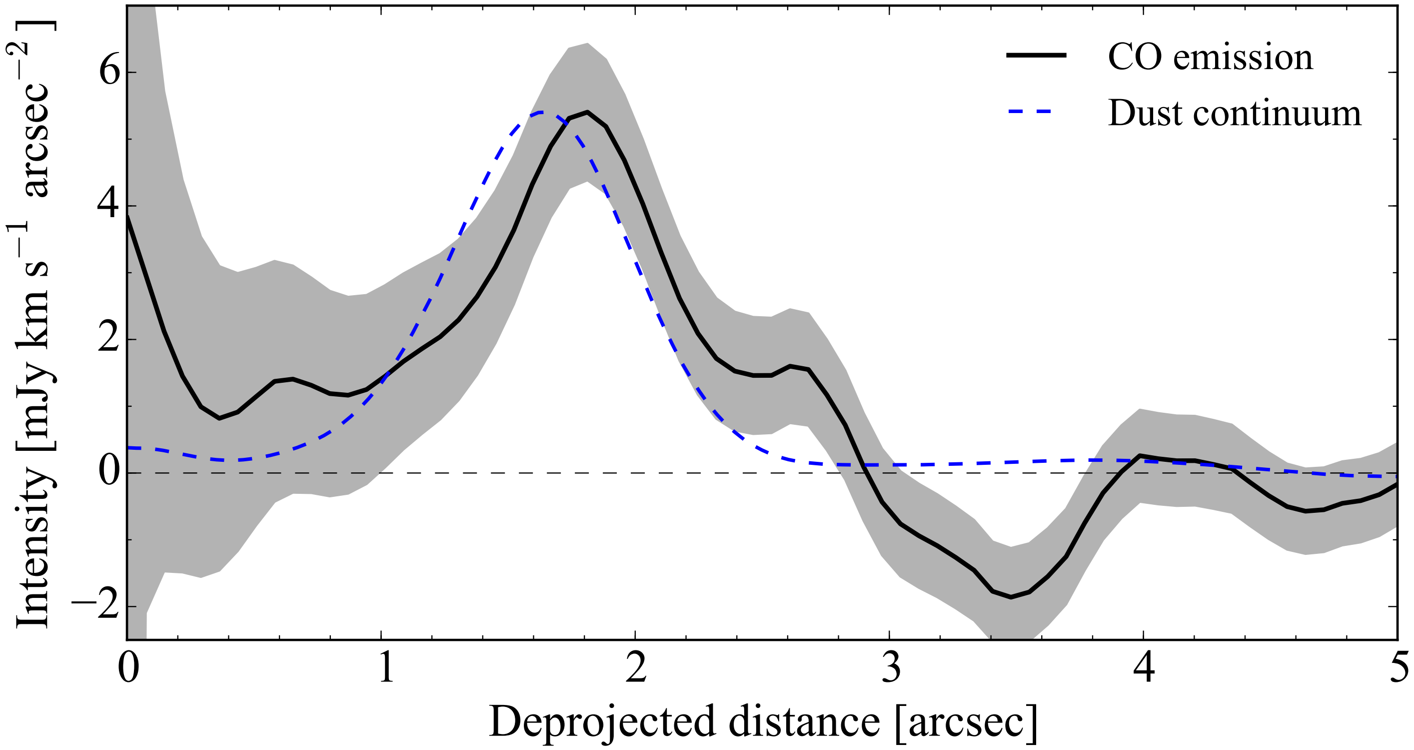




CO origin

- **Gas co-located with dust and planetesimals**
- N_{CO} (+ N_{H2} if primordial) —> photodissociation timescale ~150-200 yr

  —> secondary origin
- CO gas must be released from:
  - Icy bodies in collisions
  - Through photodesorption
  - Product of CO_2 photodissociation (~30 yr)



CO Cometary composition

- CO production rate determined by Mass loss rate of planetesimals.
- Then in steady state:

$$\dot{\mathrm{M}}_{\mathrm{co}}^{+} = f_{\mathrm{CO}} \times \dot{\mathrm{M}} = \frac{\mathrm{M}_{\mathrm{CO}}}{\tau_{\mathrm{co}}} = \dot{\mathrm{M}}_{\mathrm{co}}^{-}$$

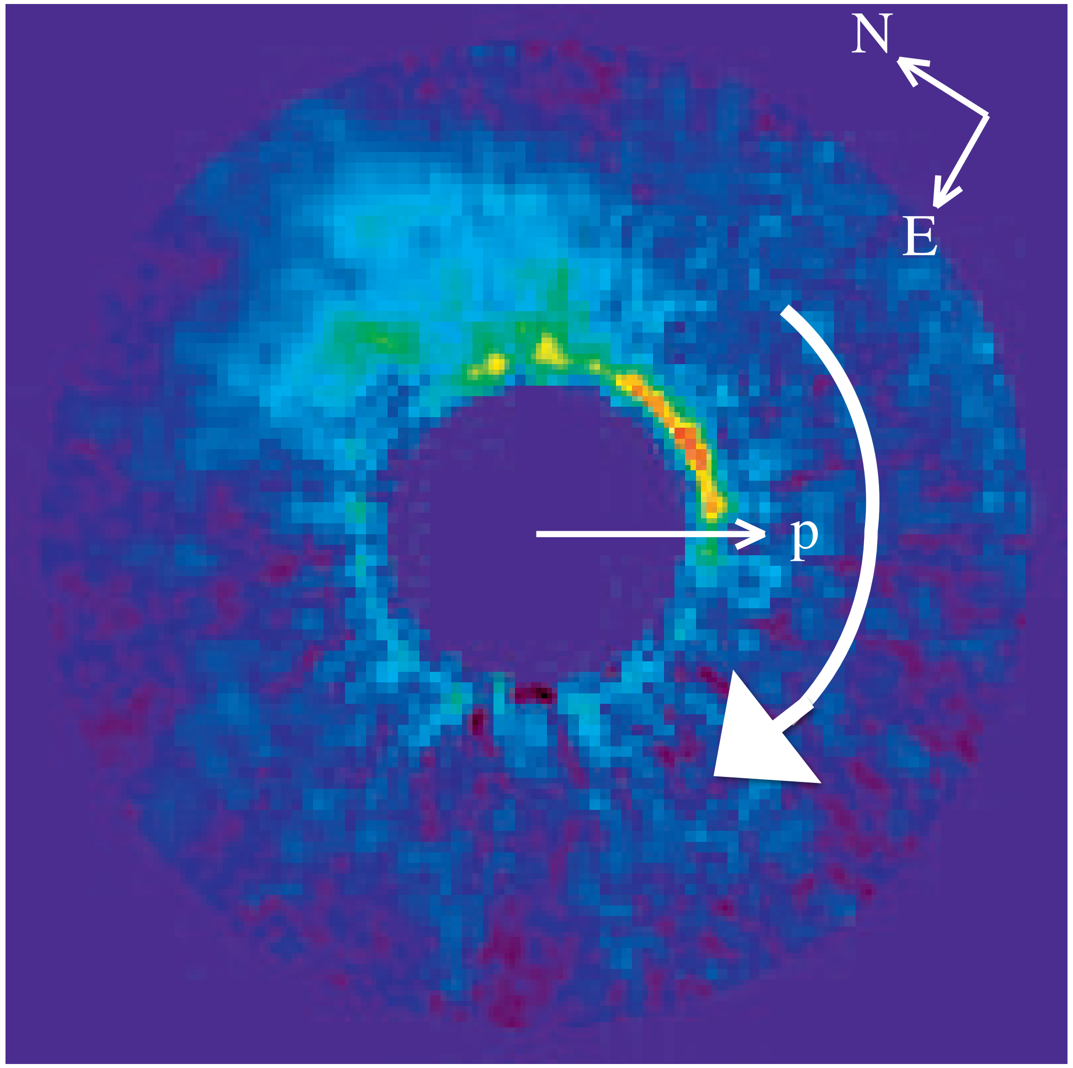
  - **—>** fco ~ 0.3%-11% given all the uncertainties in M_{CO} and dM/dt.
- Solar system comets have fco~ 0.3-16% (Mumma & Charnley 2011)
- It is roughly consistent with Solar system comets, despite the age difference.

Scattered light asymmetries?

- The asymmetry can be explained by
  - Very recent giant collision (<5 orbits)
  - Big body releasing small dust

However, no counterpart in mm-sized dust or in the CO distribution.

  - PF effect caused by a warp?



Summary and Conclusions

- Ring of planetesimals at 86 AU and Δr = 23 AU.
- No signs of a giant collision. —> warped disk?
- CO gas co-located with dust. CO mass ~10^{-6} $M_{\oplus}$.
  - CO/dust mass << ß Pic (F vs A star?).
- Gas is of secondary origin.
- CO ice fraction consistent with Solar System comets.

Thanks!

Gas - dust interactions

Total gas mass assuming:
- gas composed by CO+H_2O+photodissociation products
- CO/H_2O in comets
- C/CO in ß Pic

$$\tau_{\rm fric} \simeq 3\times10^{3}\ \left(\frac{\rm M_{gas}}{0.04\ \rm M_{\oplus}}\right)^{-1}\ \left(\frac{a_d}{1\ \rm mm}\right)\left(\frac{T_k}{50\ \rm K}\right)^{-1/2}\Omega_K^{-1}$$

$$\tau_{\rm coll} \simeq 200\ \left(\frac{a_d}{1\ \rm mm}\right)^{1/2}\Omega_K^{-1}$$

—> It is unlikely that dust distribution is shaped by gas (Lyra & Kuchner 2013)

CO as a result of CO2

CO_2 photodissociates in ~30 yr << τ_{CO}

—> N_{CO} traces primordial $N_{CO}+N_{CO2}$

—> $(N_{CO}+N_{CO2})/N_{H2O}$ ~ 0.4 -18%

Consistent with Solar system comets (2-27%)