Dust and Gas in the HD 95086 Planetary System

Mark Booth
Friedrich Schiller Universität, Jena

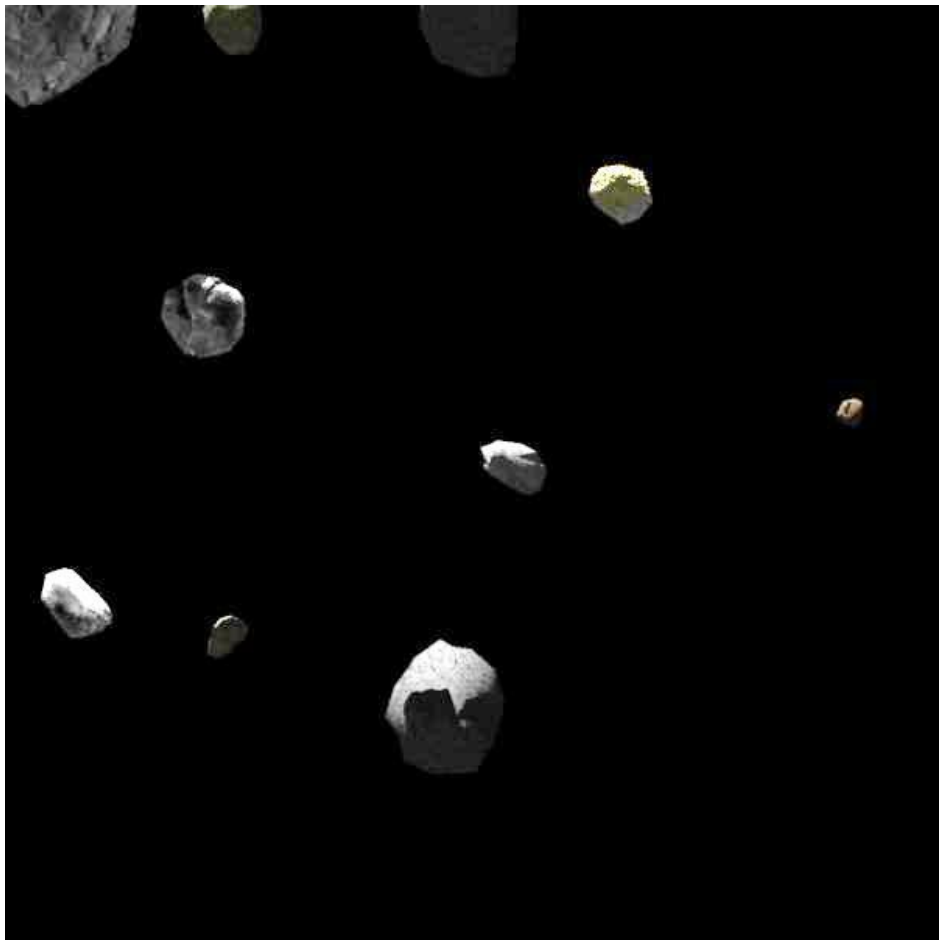
Collaborators: **Kate Su, Meredith Macgregor, David Wilner, Luca Matrà, Kevin Flaherty, Meredith Hughes, Neil Phillips, Renu Malhotra, Antonio Hales, Sarah Morrison, Quentin Kral, Steve Ertel, Brenda Matthews, William Dent, Simon Casassus**

Continuum observations: Su et al. (2017)
Gas observations: Booth et al. (in prep.)

DFG

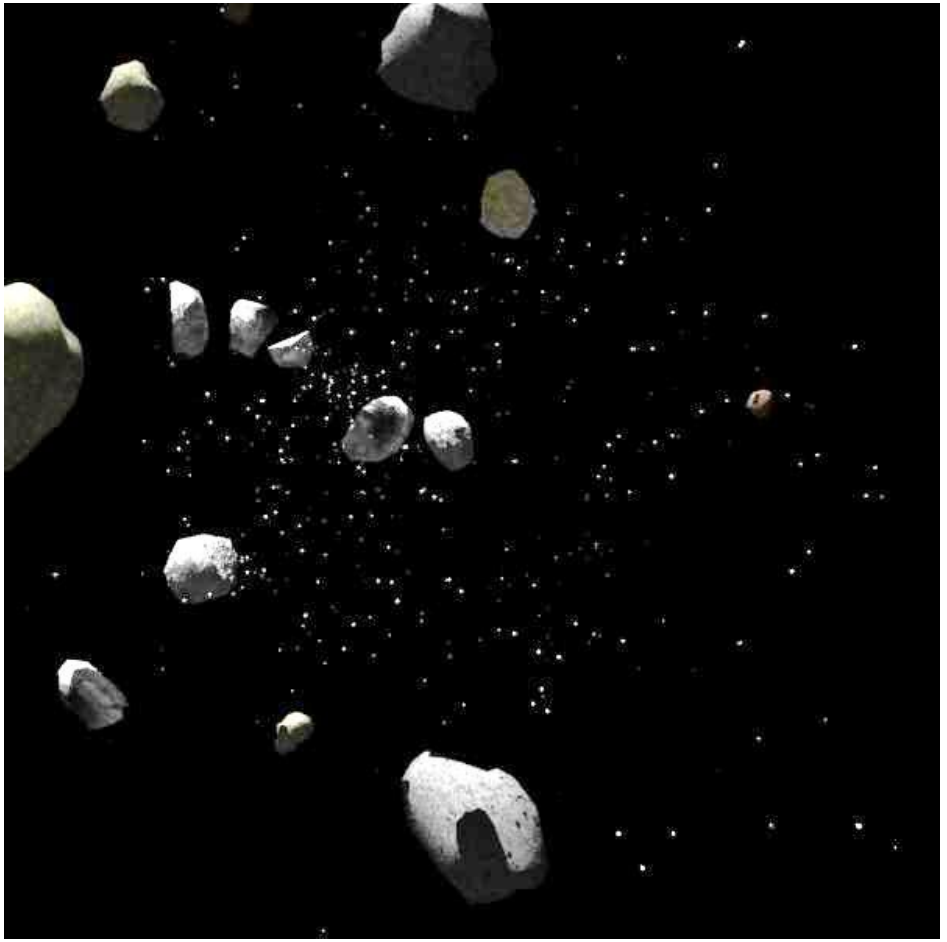
FRIEDRICH-SCHILLER-UNIVERSITÄT JENA

What is a Debris Disc?



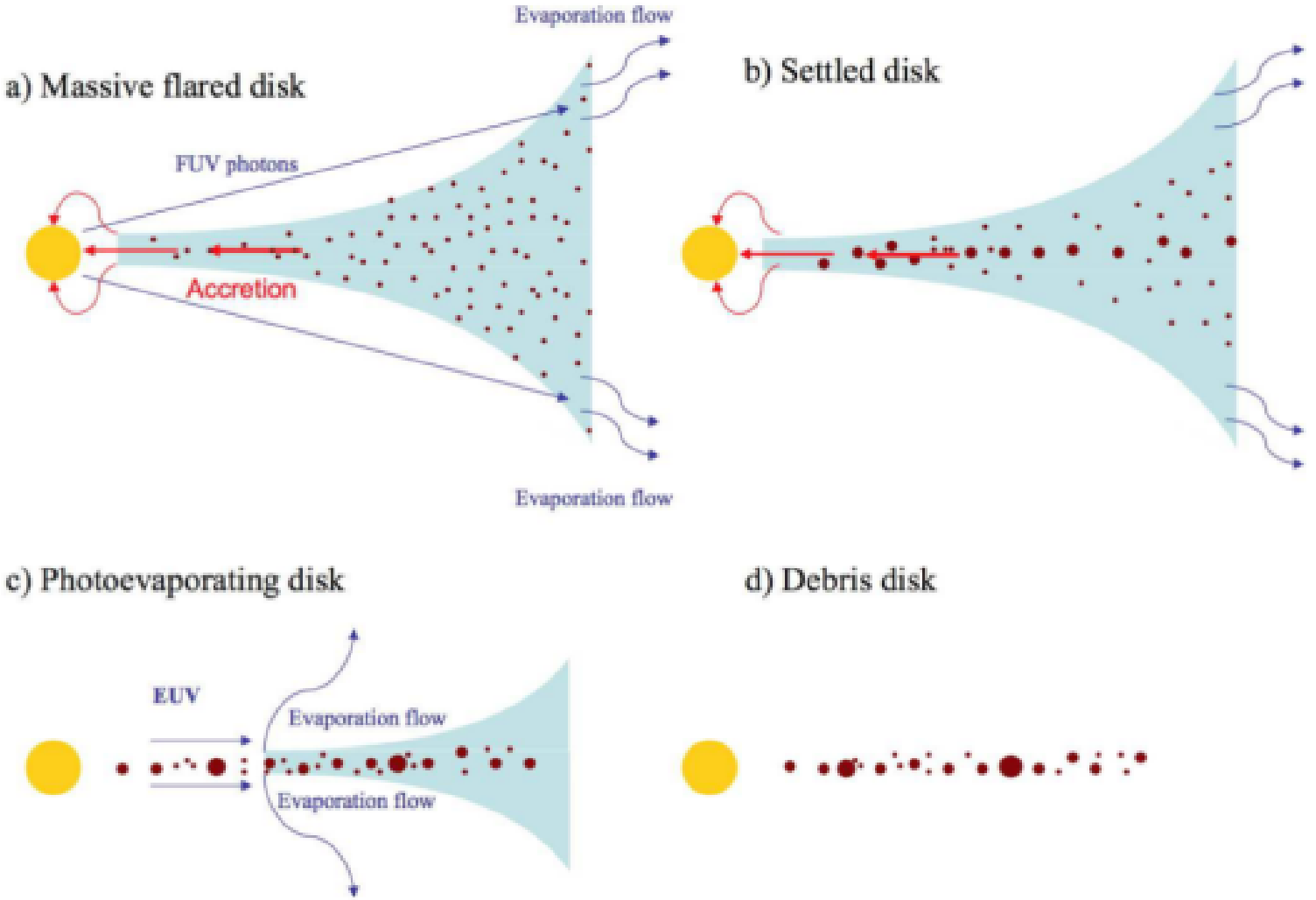
- Other stars are surrounded by planetesimals similar to our asteroids, KBOs and comets.

What is a Debris Disc?



- Other stars are surrounded by planetesimals similar to our asteroids, KBOs and comets.
- Collisions between planetesimals create dust.

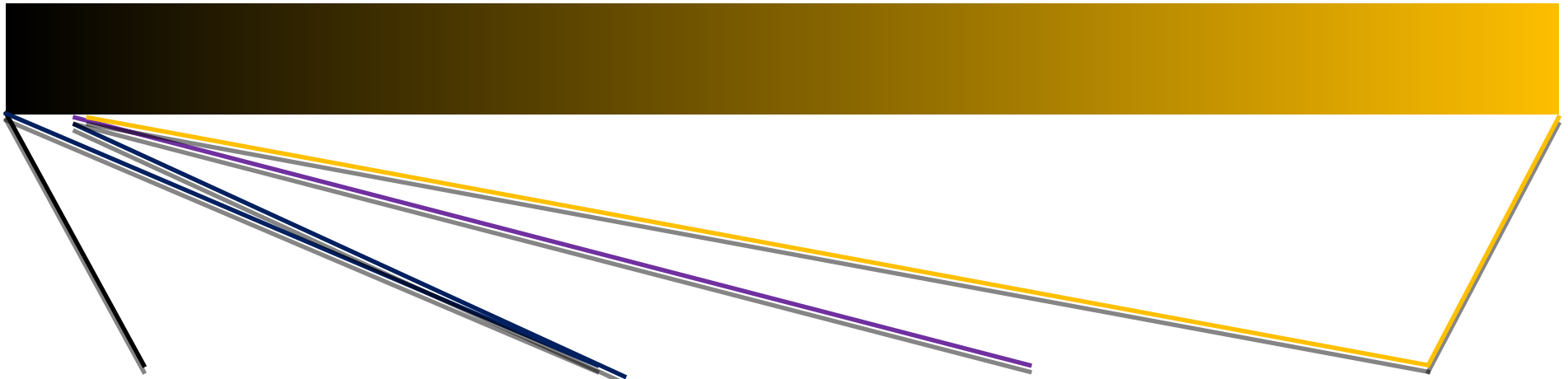
From Protoplanetary to Debris Discs



Williams & Cieza 2011

From Protoplanetary to Debris Discs

0 Myr 3-10 Myr A few Gyr

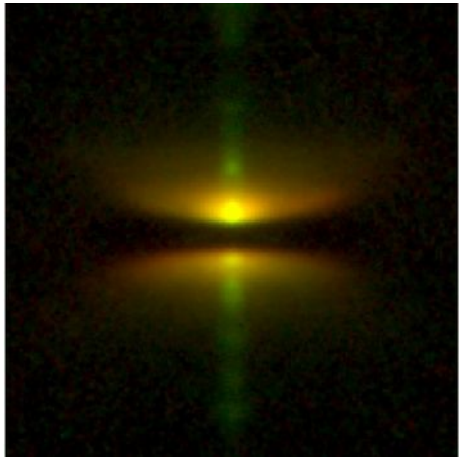


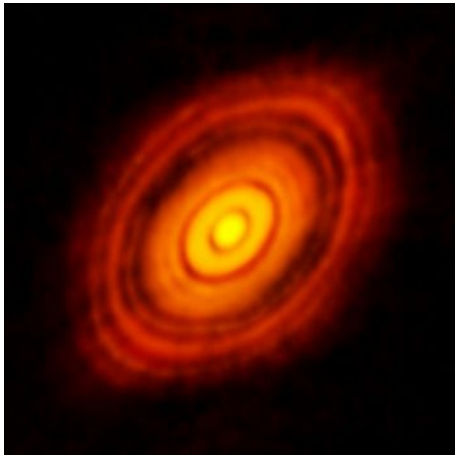
Flared disc

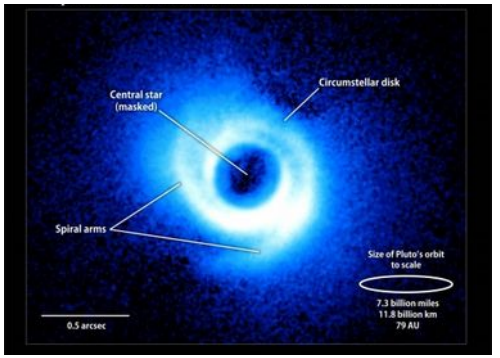
Protoplanetary disc

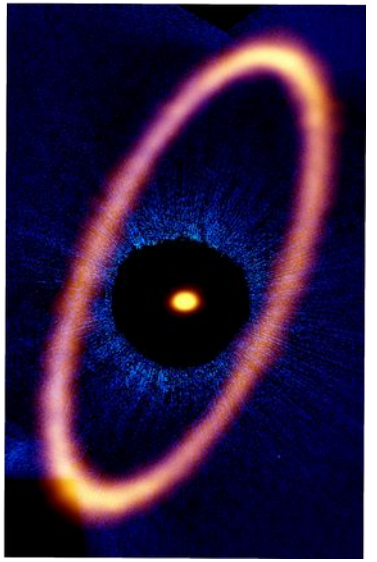
Transition disc

Debris disc

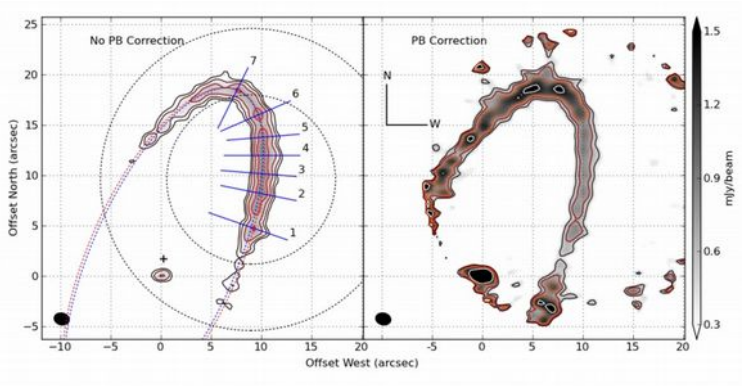




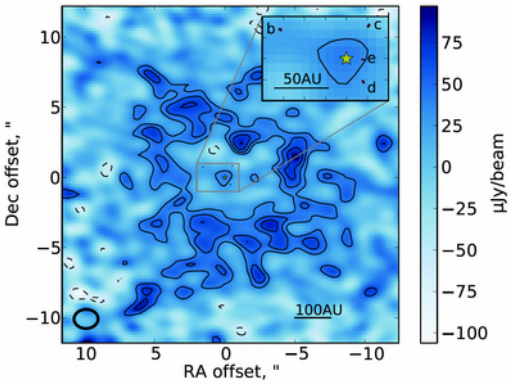




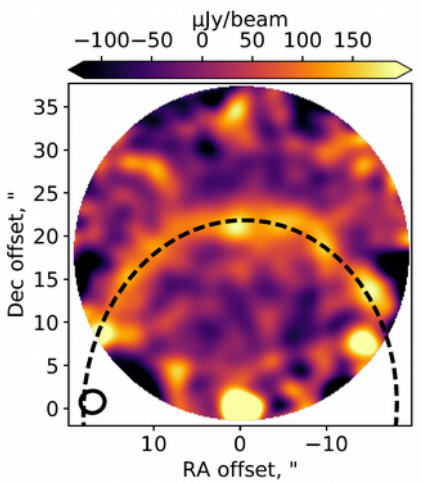
Fomalhaut
Boley et al.
2012



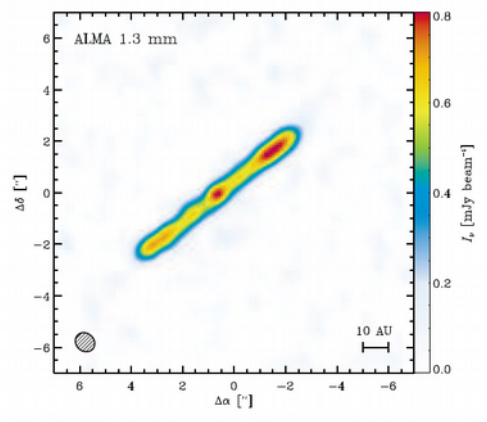
HR 8799
Booth et al. 2016



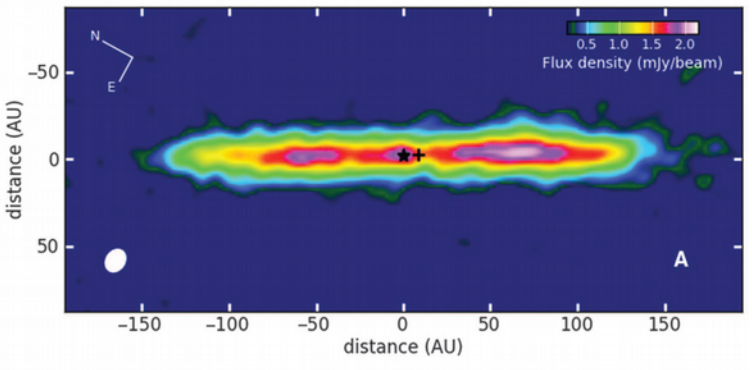
epsilon Eridani
Booth et al. 2017



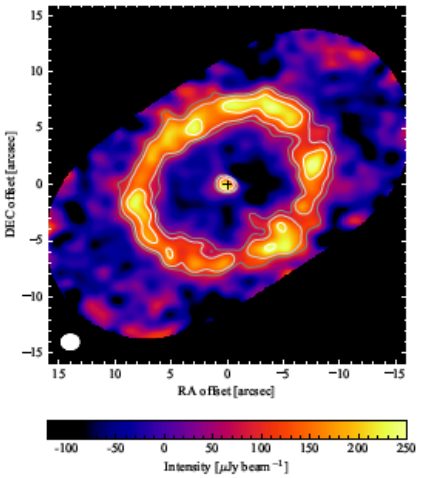
ALMA Debris Disc Observations



AU Mic
Macgregor et al. 2013



Beta Pic
Dent et al. 2014

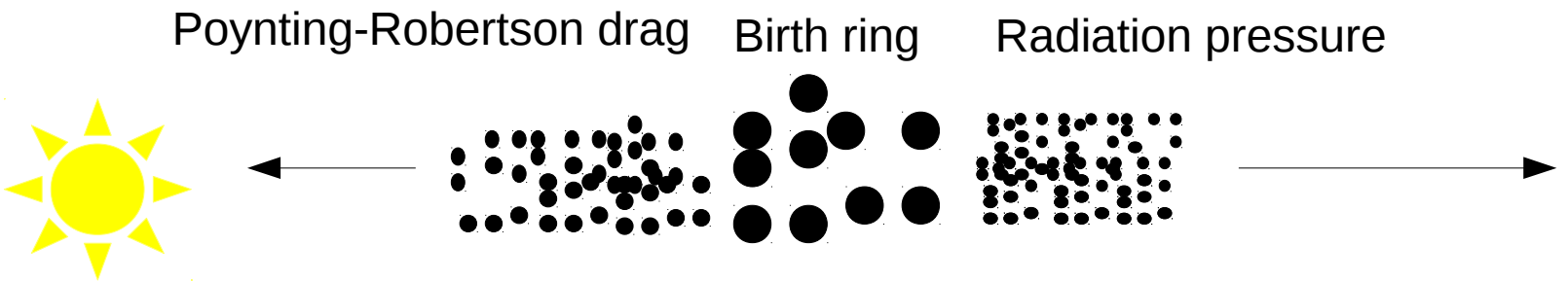


eta Corvi
Marino et al. 2016

See also talks by S. Marino and Z. Berdiñas

ALMA Debris Disc Observations

- ALMA gives us unprecedented resolution and sensitivity in the (sub-)mm regime.

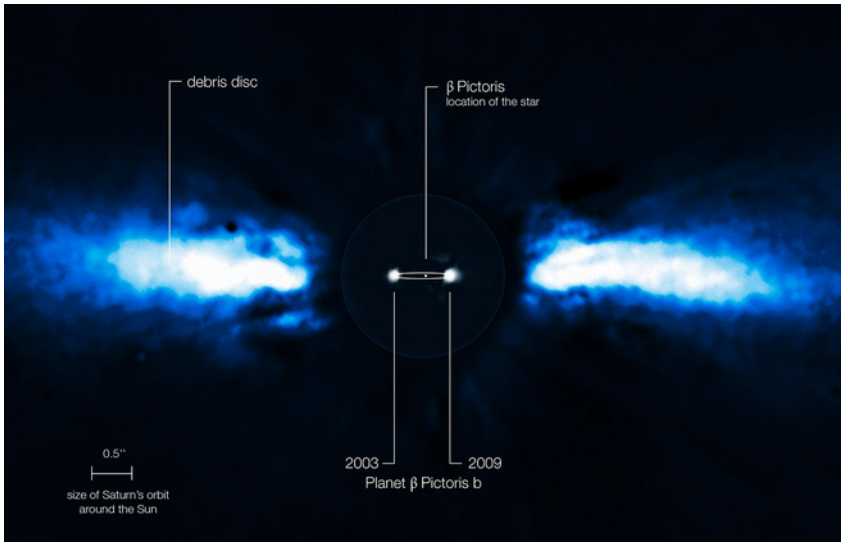


ALMA

SPHERE
Spectro-Polarimetric
High-contrast
Exoplanet REsearch

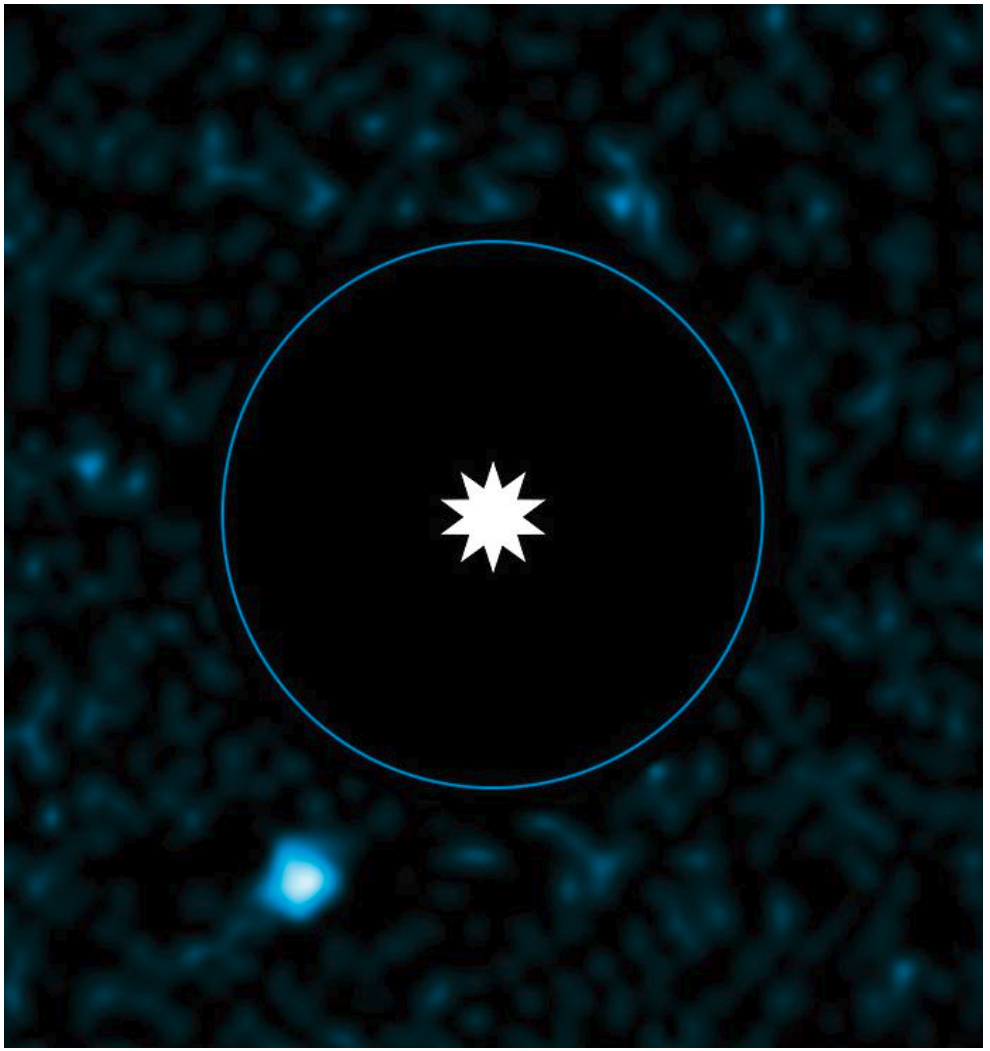
Finding Planets with Resolved Observations

- Considering dynamical interactions between planets and discs allows us to predict the locations of unknown planets and constrain the properties of any known planet.
- E.g. beta Pic b was predicted by asymmetries in the disc (e.g. Mouillet et al. 1997)



See also talk by C. Lazzoni

HD 95086



ESO/J. Rameau

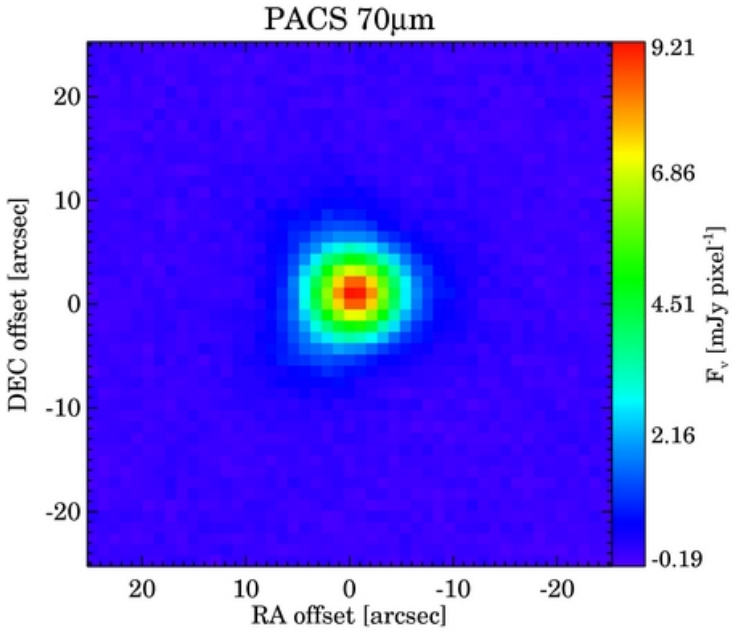
- A8 spectral type
- Lower Centaurus Crux
- 17 Myr
- Infrared excess detected by IRAS
- 4.4 M_J planet discovered through direct imaging

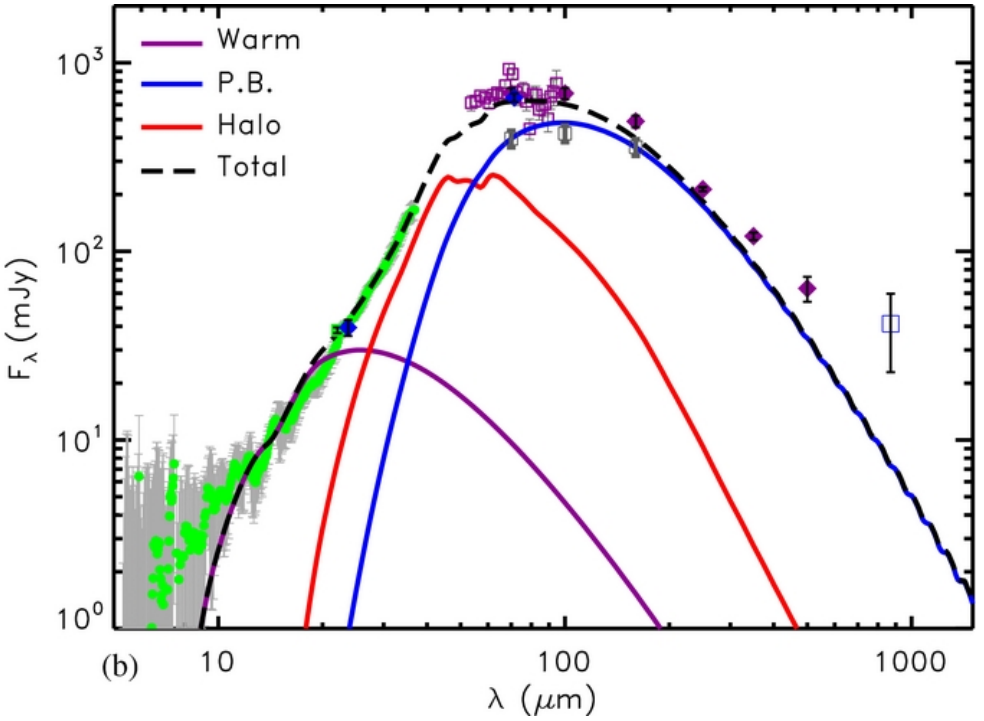
(de Zeeuw et al. 1999, Rhee et al. 2007, Rameau et al. 2013, 2016, Meshkat et al. 2013, de Rosa et al. 2016)

Herschel Observations

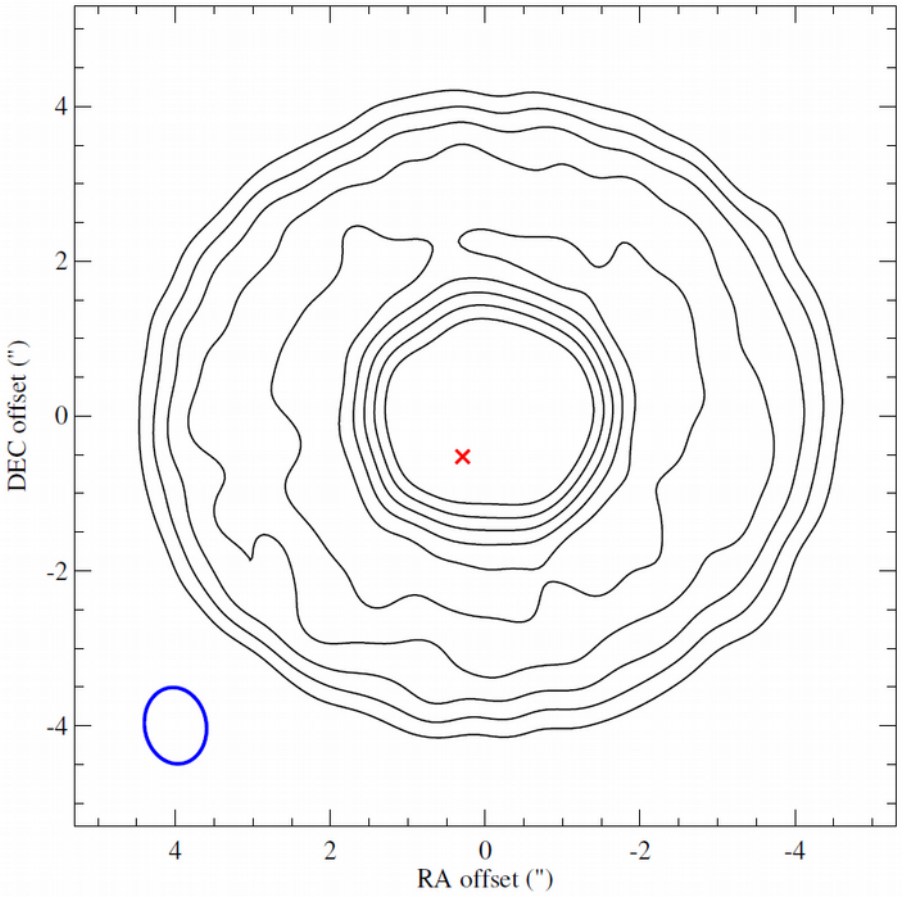
(Móor et al. 2013a, Su et al. 2015)

- Probably a three component disc
  - Warm component at around 7 AU
  - Cold component at 63-190 AU
  - Halo of blowout grains extending out to ~800 AU





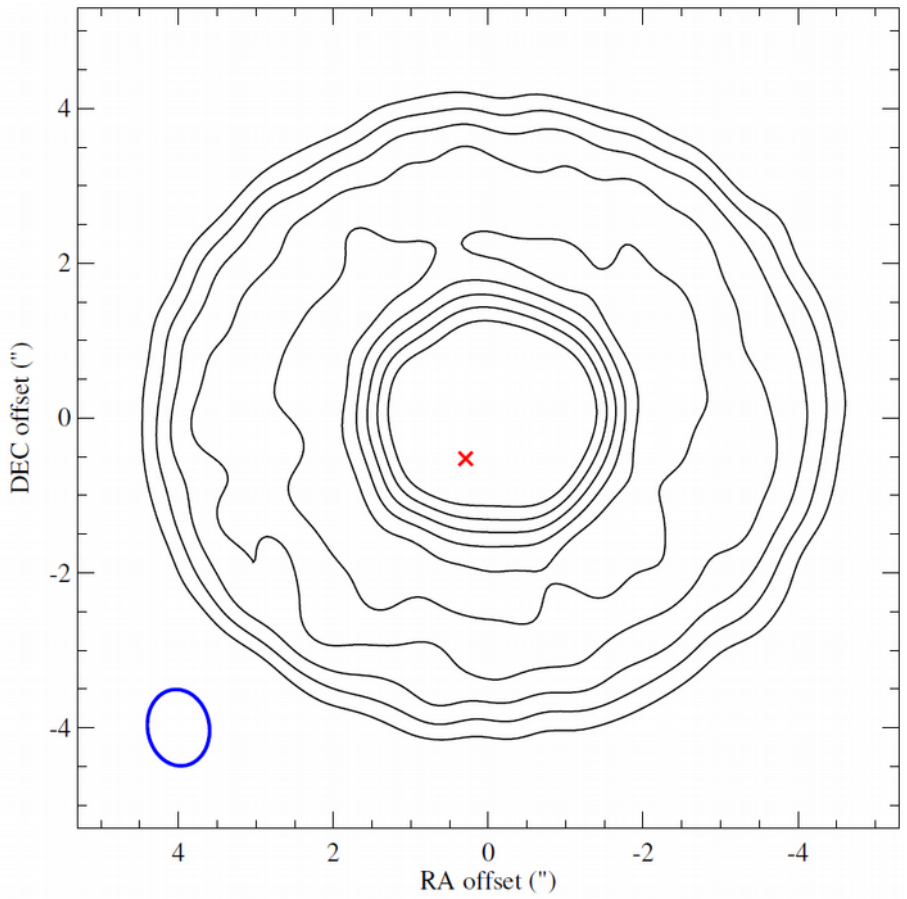
ALMA Observations



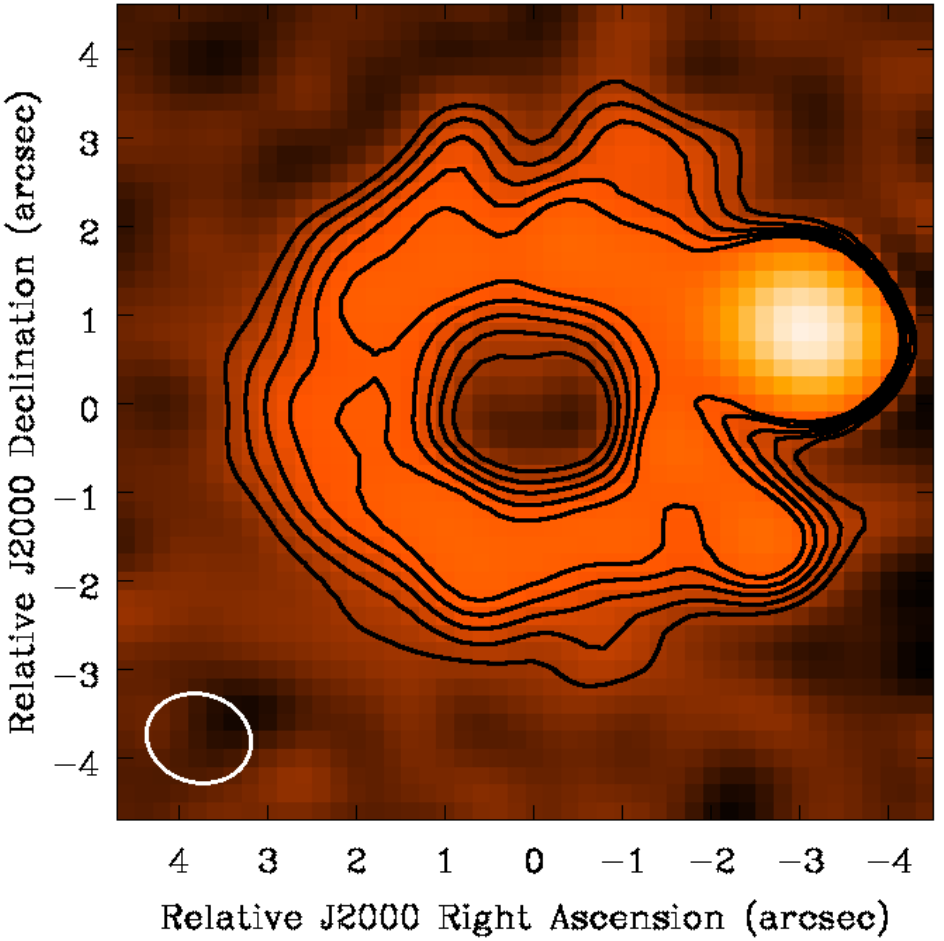
- Band 6 (1.3mm)
- 4.5 hours on source
- 1.2x1.0” beam

Prediction from Booth et al.
ALMA cycle 2 proposal

ALMA Observations



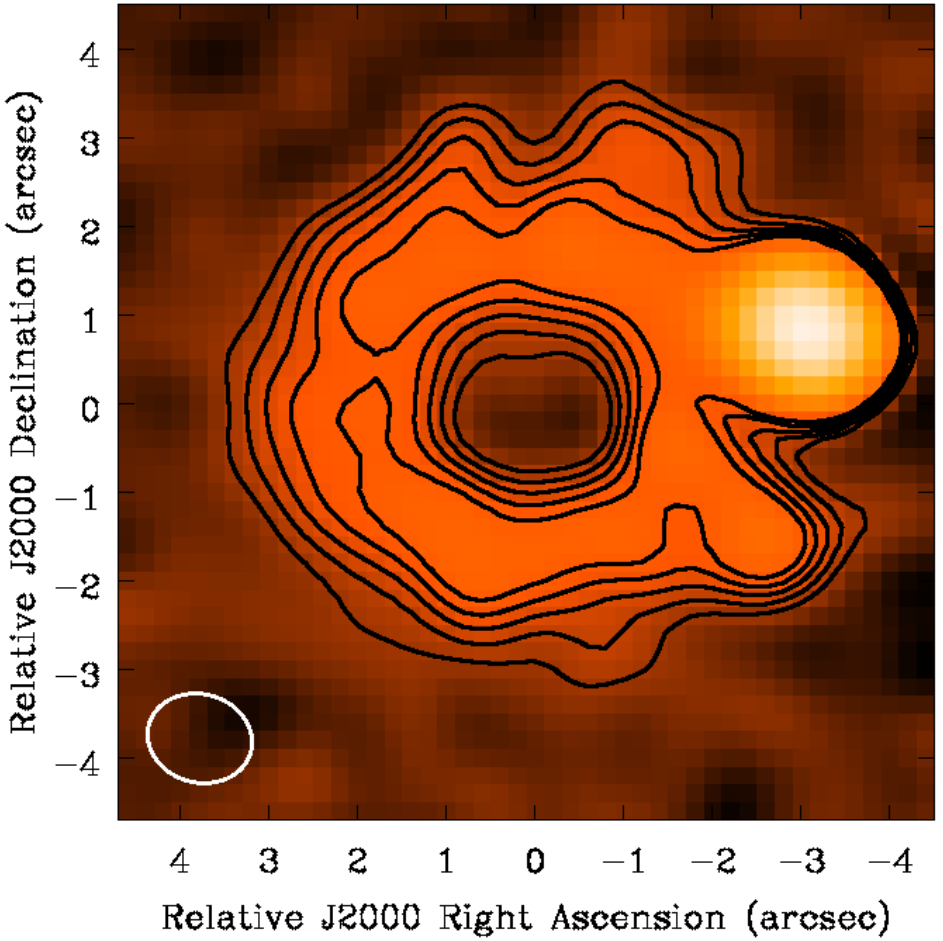
Prediction from Booth et al.
ALMA cycle 2 proposal



ALMA cycle 2 observation
Su + Booth data

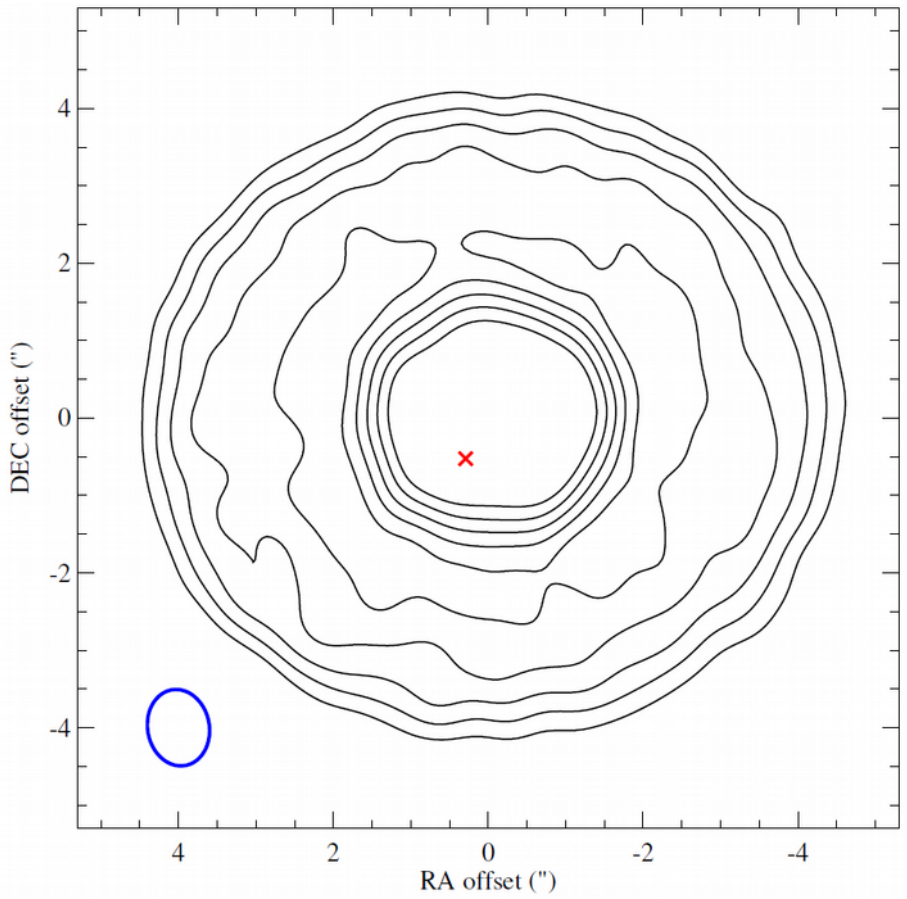
ALMA Observations

- Total flux density at 1.3 mm = 2.57 mJy
- 28° inclination
- 97° position angle
- 110-310 AU belt
- Inner edge is consistent with shaping by the known planet

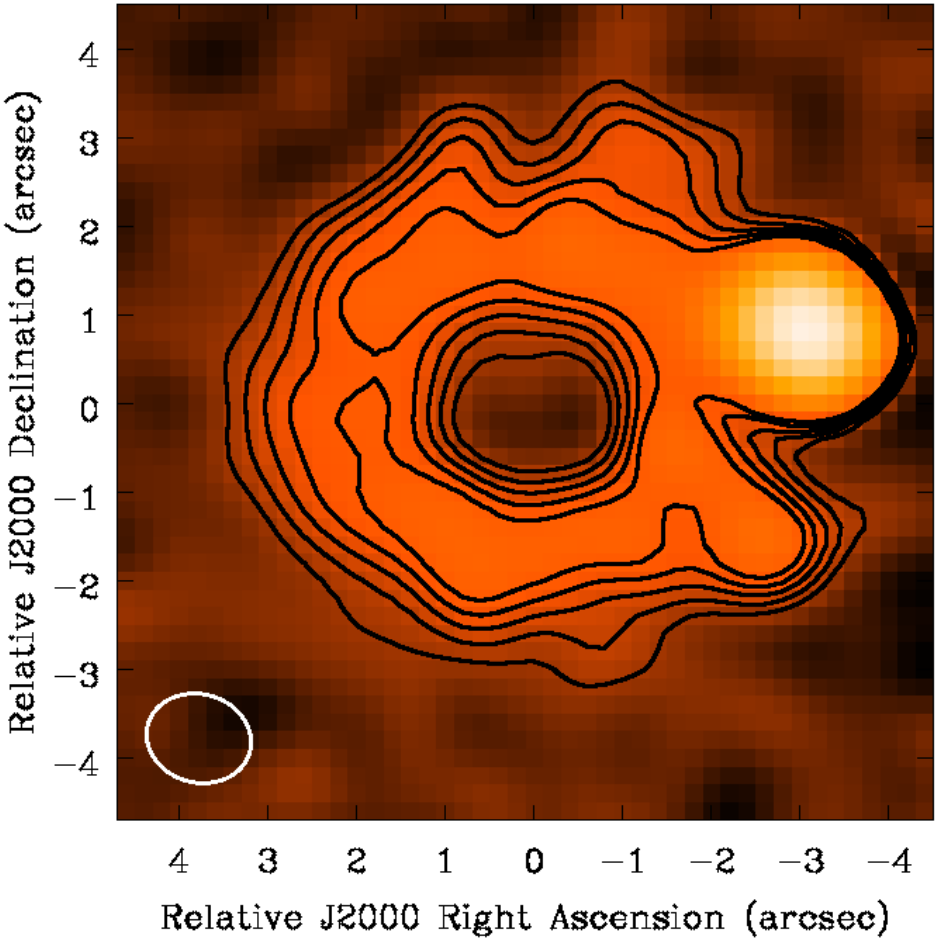


ALMA cycle 2 observation
Su + Booth data

ALMA Observations

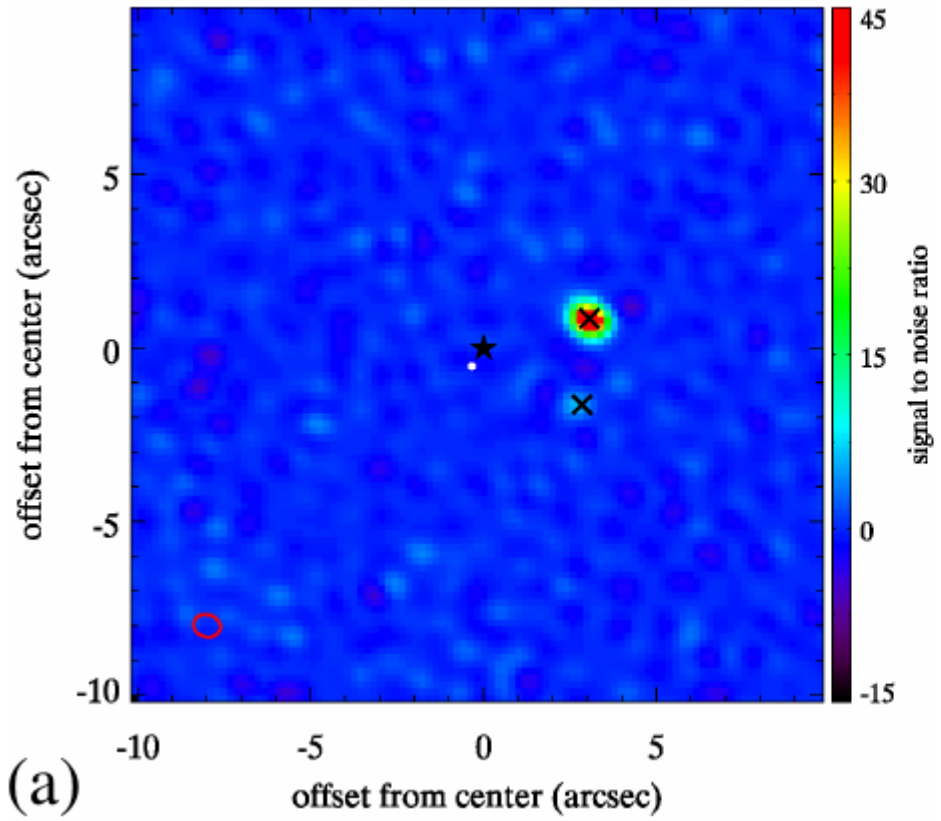


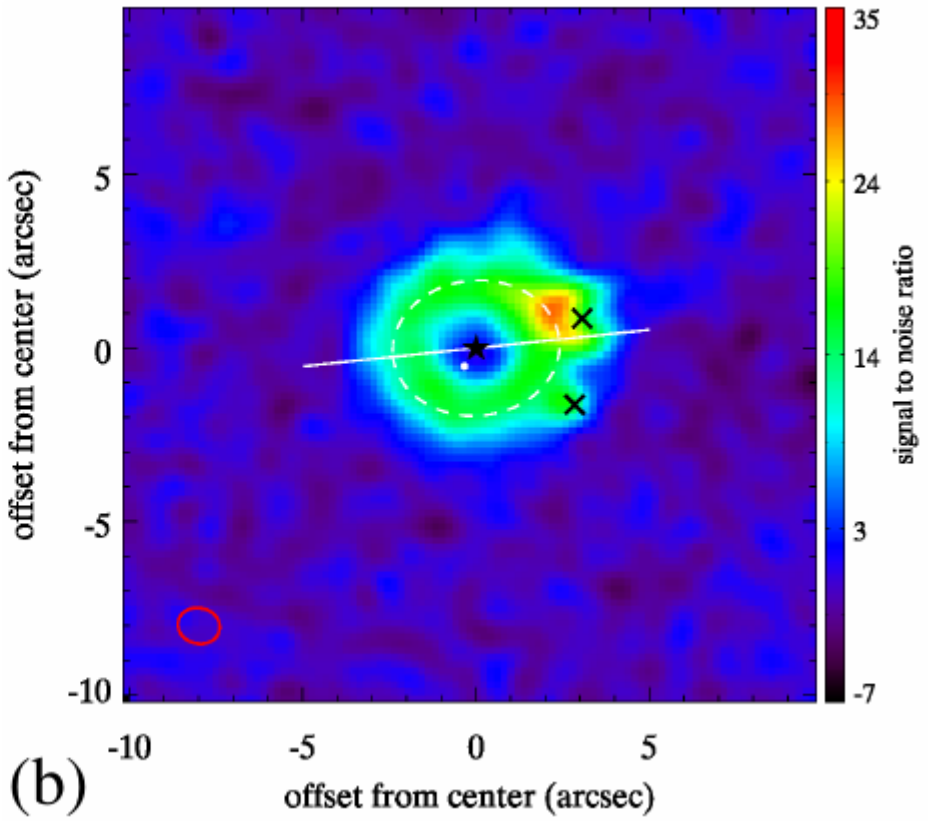
Prediction from Booth et al.
ALMA cycle 2 proposal



ALMA cycle 2 observation
Su + Booth data

Not point sources

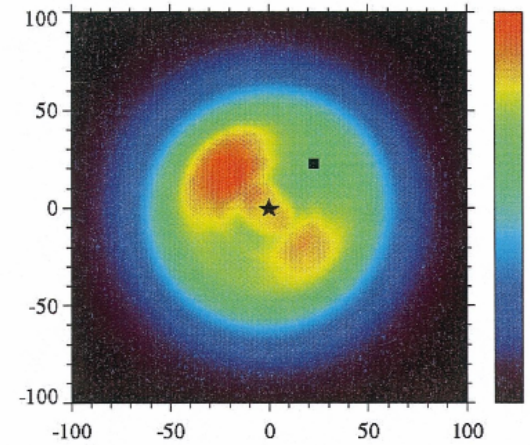




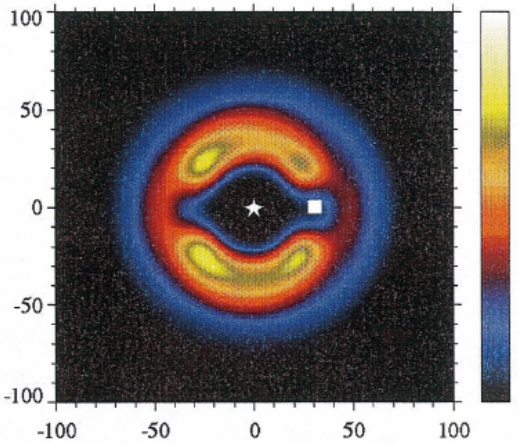
Long baseline data only shows two point sources.

Removing these doesn't completely remove the contamination.

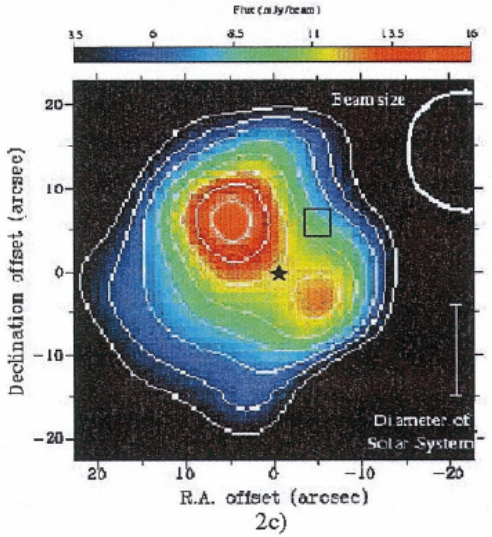
Clumps?



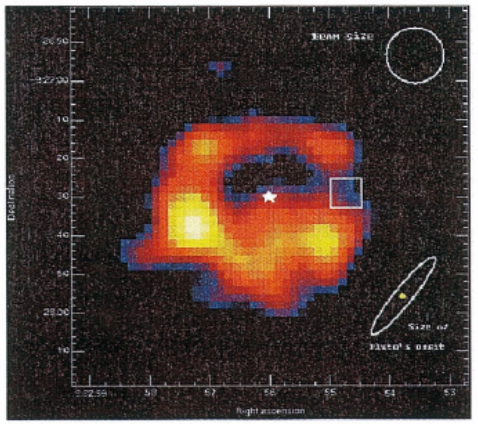
2a)



2b)



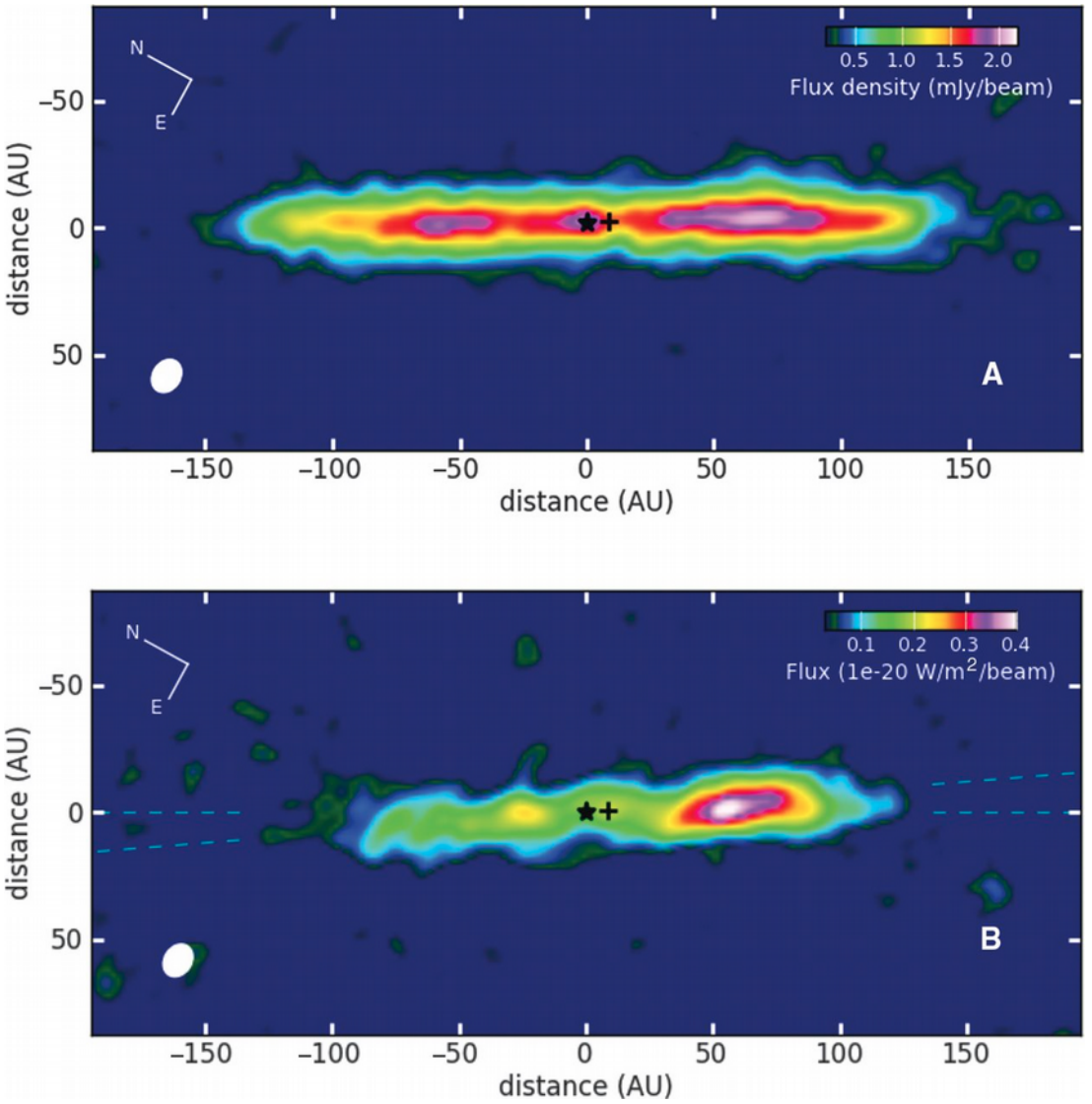
2c)



2d)

- Ozernoy et al. 2000 (see also Quillen & Thorndike 2002, Wyatt 2003...)
- Planets can trap planetesimals and dust in resonances

Clumps?



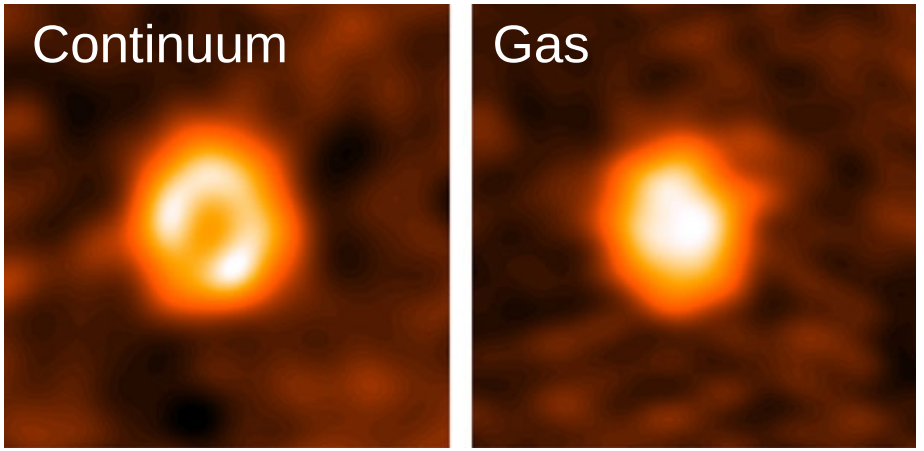
- Could we be seeing clumps in the disc produced by a massive collision like in beta Pic?

Dent et al. 2014

Gas in Debris Discs

- Presence of gas has often been used as a way to define the difference between protoplanetary and debris discs, but a growing number of debris discs have been found to have gas.
- Debris discs with detected CO gas tend to be very dusty and around high mass stars.

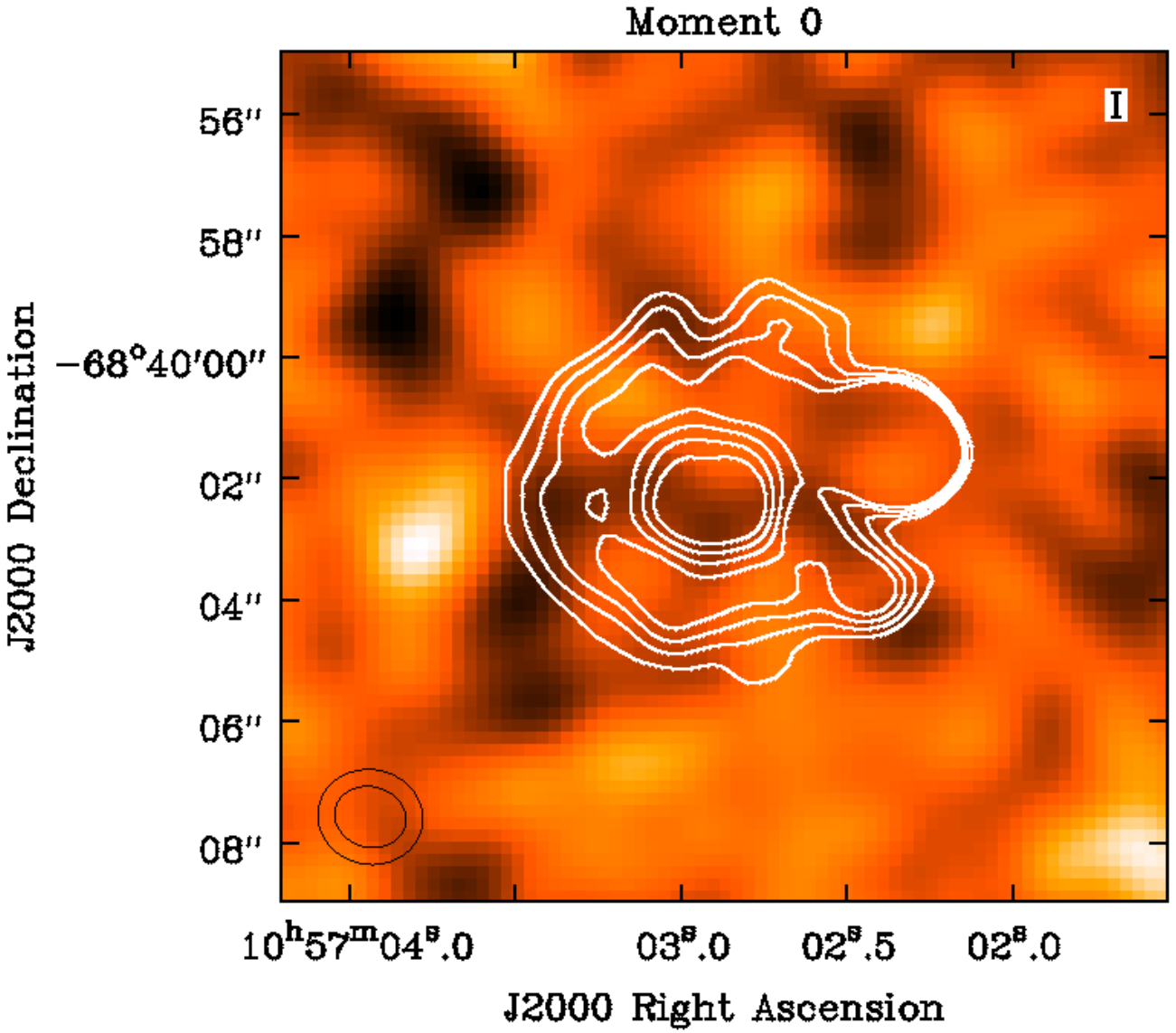
HD 21997



Moór et al. 2013b, Kóspál et al. 2013

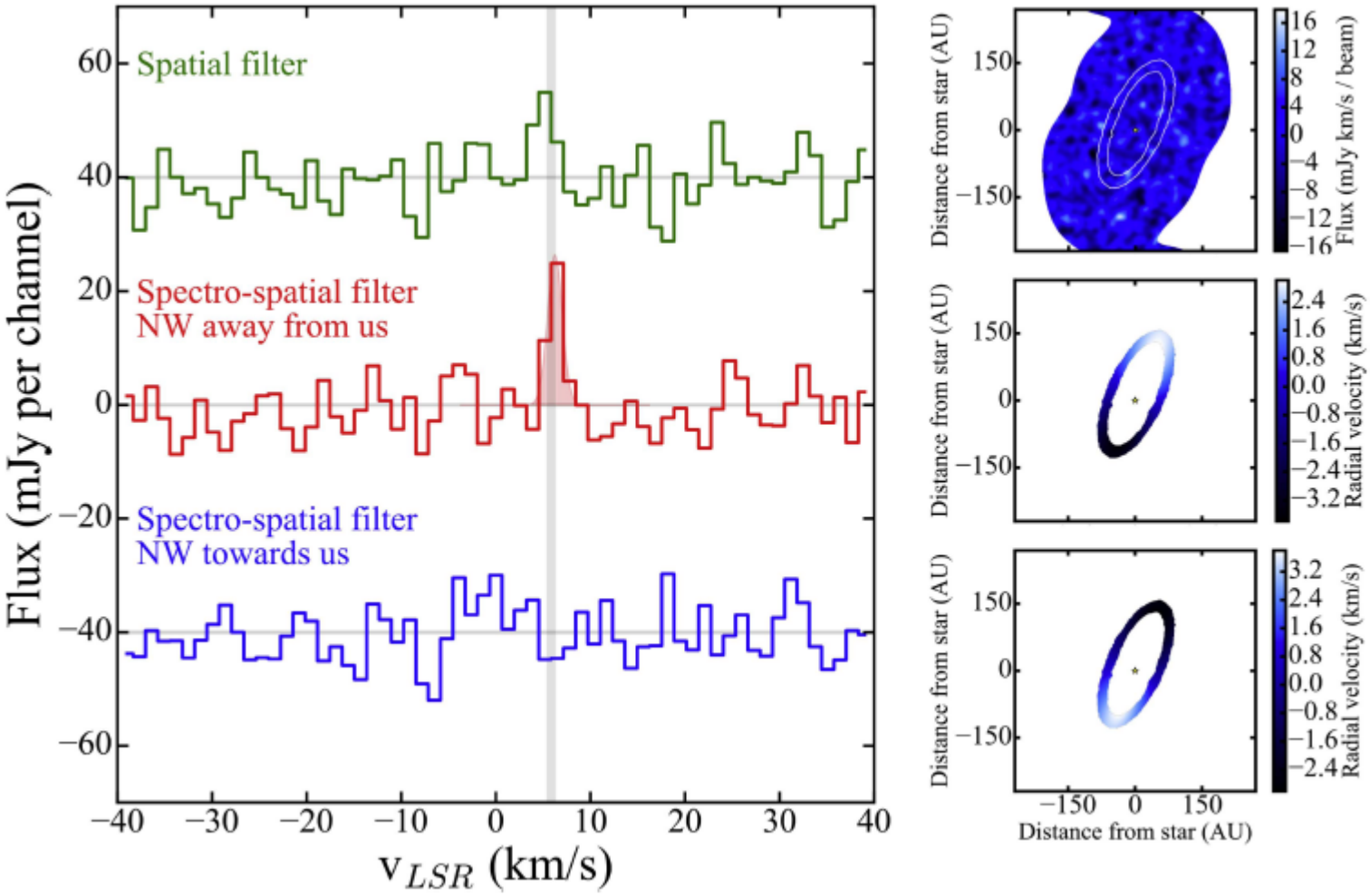
For gas absorption in debris discs see talks by I. Rebollido Vázquez and D. Iglesias

Gas in HD 95086



- No strong signal of CO J=2-1
- But maybe we can dig a little deeper to find some?

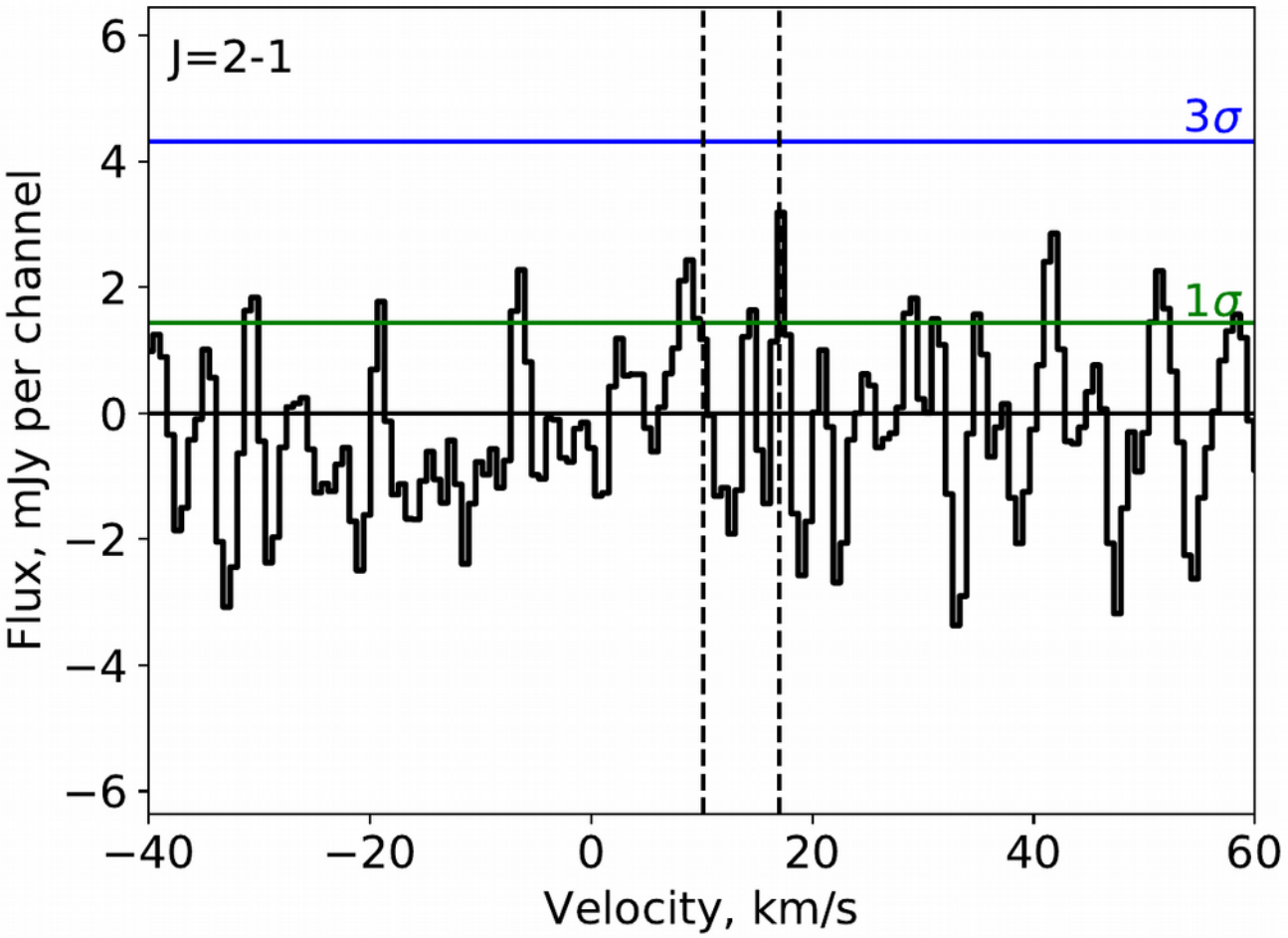
Spectro-spatial Filtering



Fomalhaut, Matrà et al. 2017

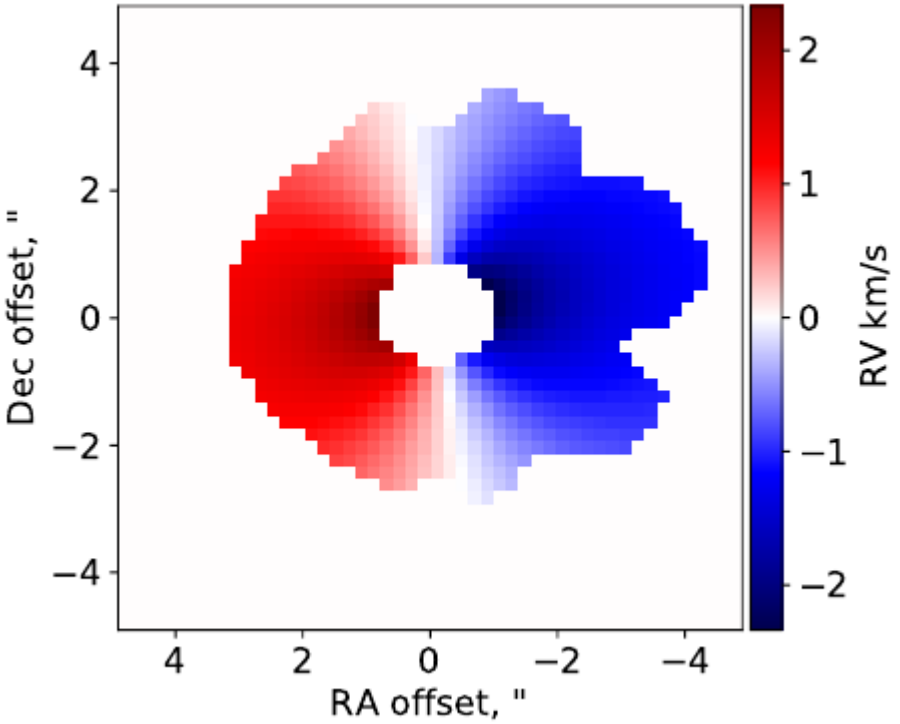
Spatial Filter

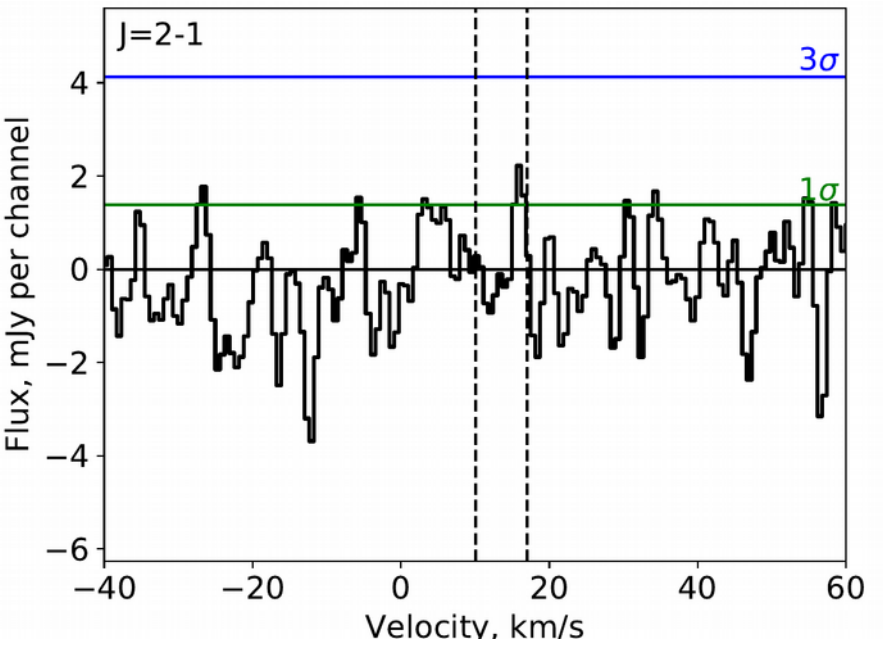
- Integrating across the disc shows nothing significant.



Spectro-spatial Filter

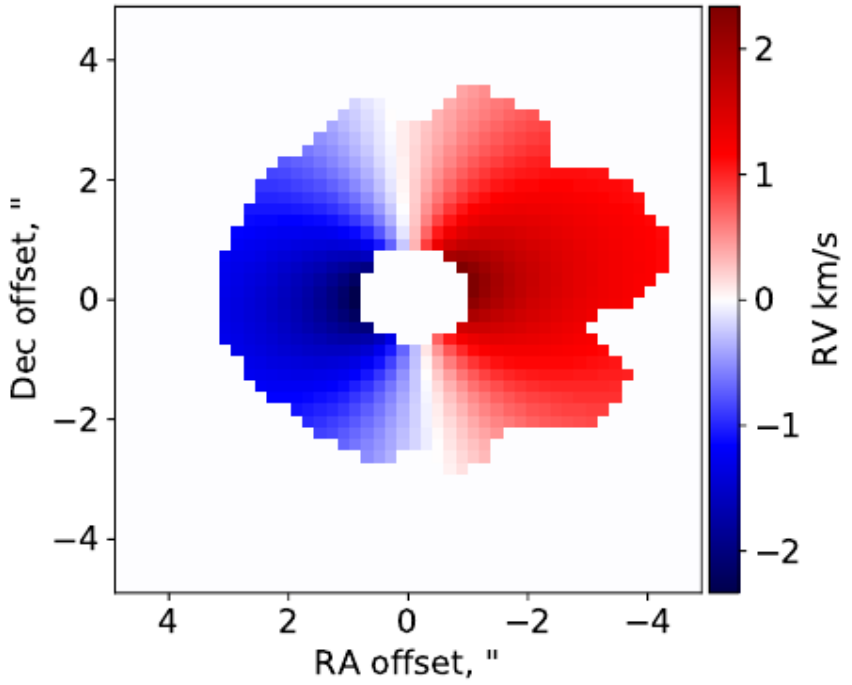
- If we assume the gas on the East side is moving away from us then we don't see any signal.

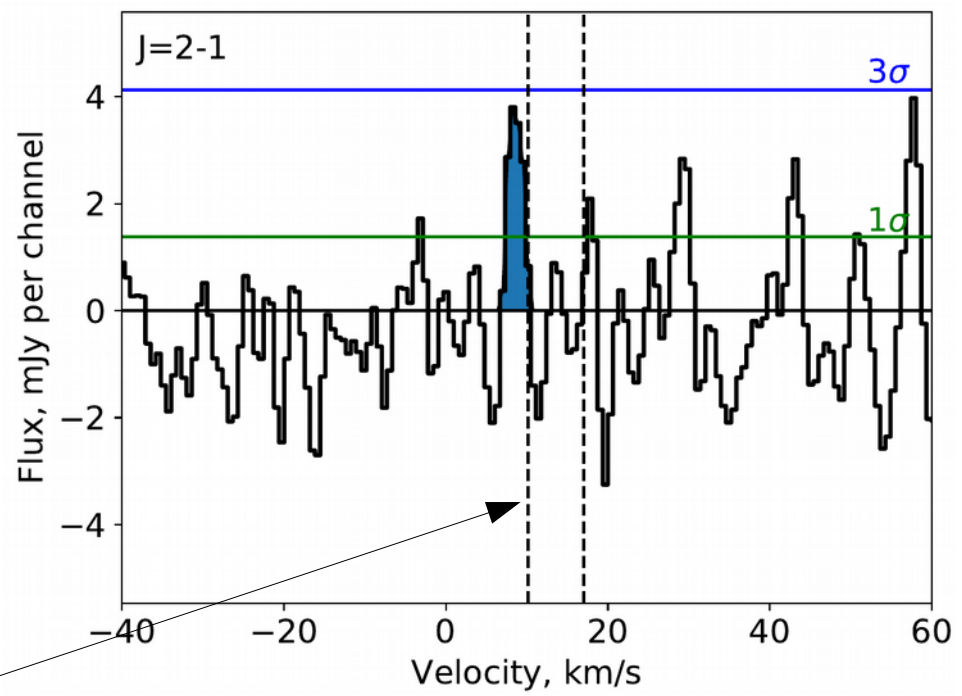




Spectro-spatial Filter

- If we assume the gas on the East side is moving towards us then we do see an unresolved spectral line centered at 9.5+/-0.4 km/s with a peak 4.3+/-1.5 mJy/channel.

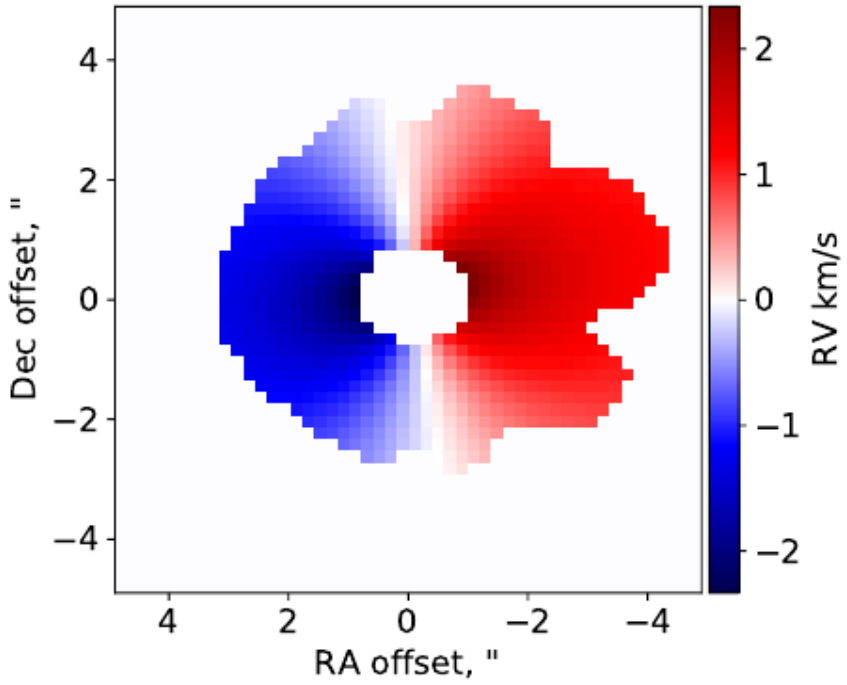


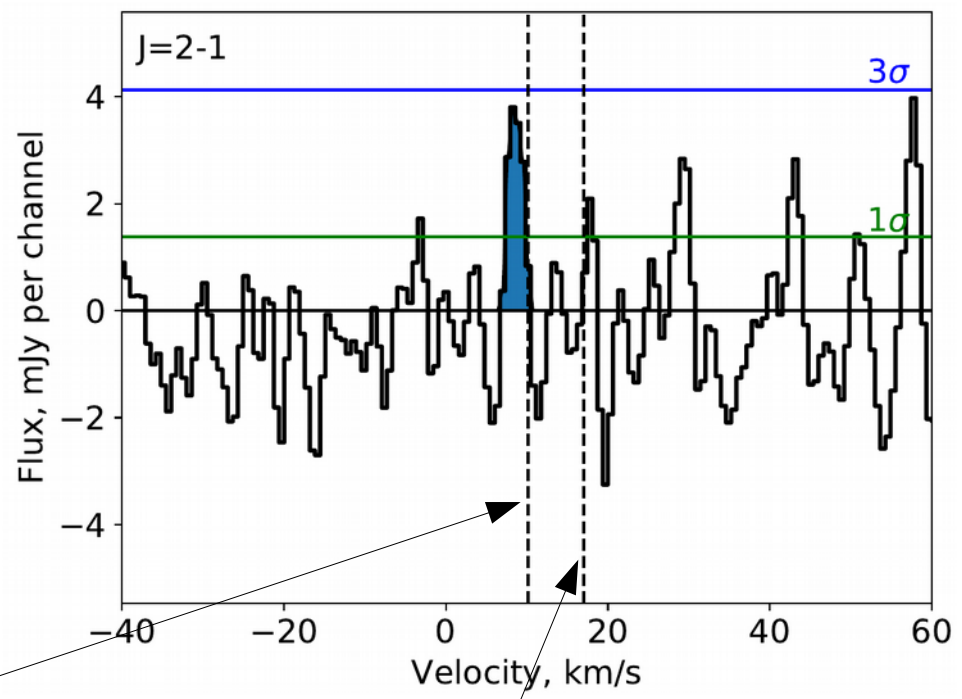


RV of the star = 10.1+/-1.2 km/s according to Madsen et al. 2002

Spectro-spatial Filter

- If we assume the gas on the East side is moving towards us then we do see an unresolved spectral line centered at 9.5+/-0.4 km/s with a peak 4.3+/-1.5 mJy/channel.

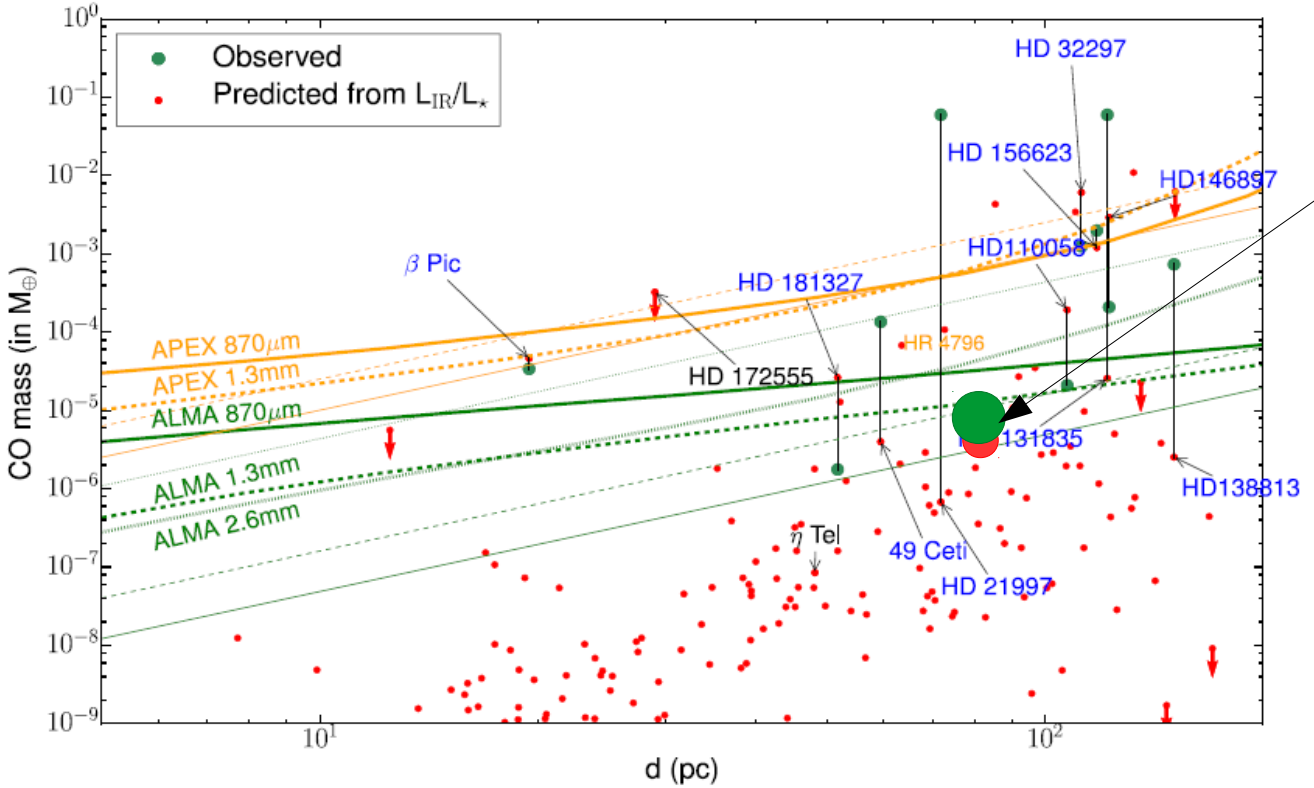




RV of the star = 10.1+/-1.2 km/s according to Kharchenko et al. 2007
Although Móor et al. 2013 find it to be 17+/-2 km/s

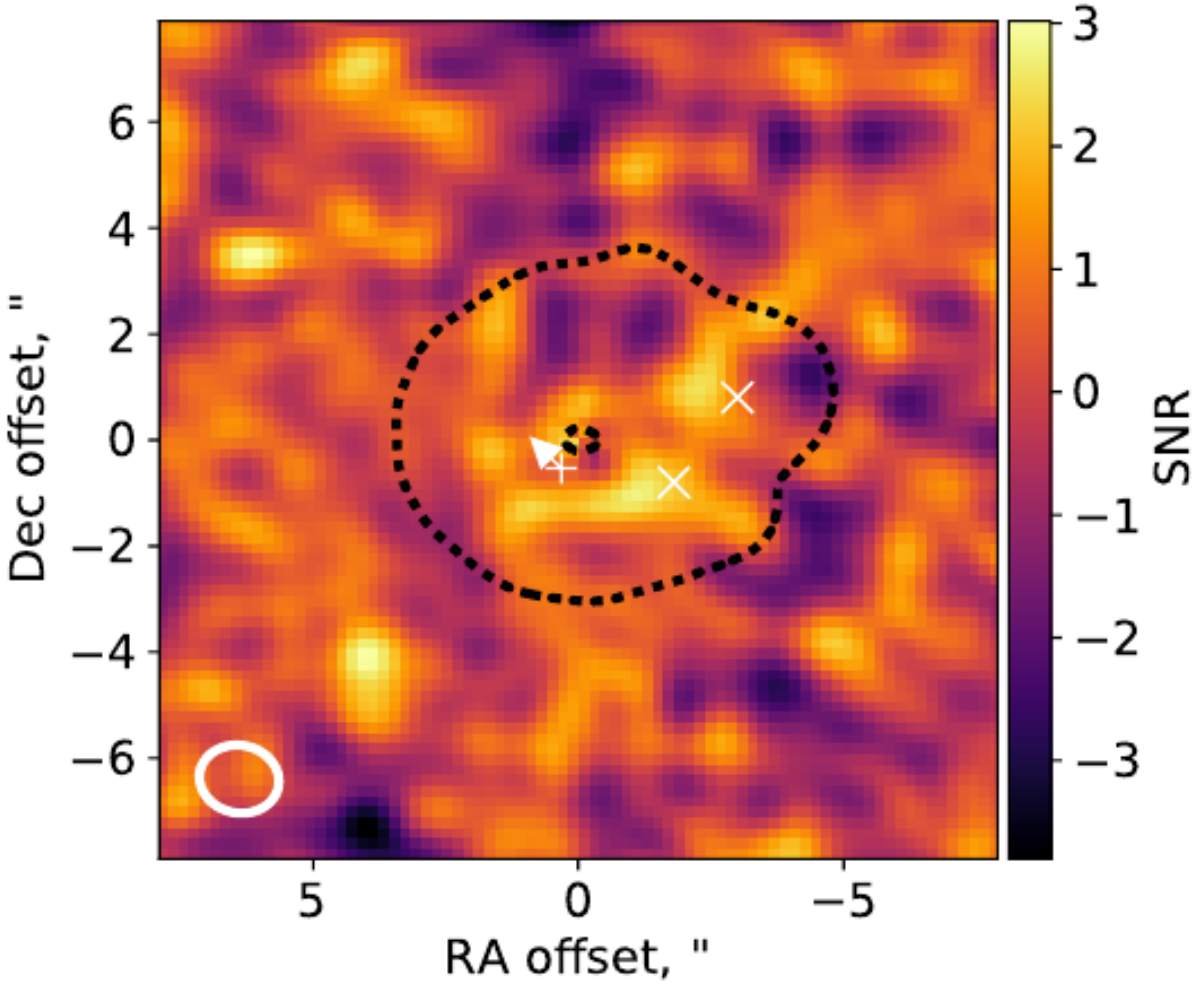
In Context

- Integrated CO flux is (5.0 +/- 2.8)x10^{-23} W/m², which equates to (7.5 +/- 4.2)x10^{-6} Mearth. Third lowest CO gas mass so far detected after Fomalhaut and HD 181327.



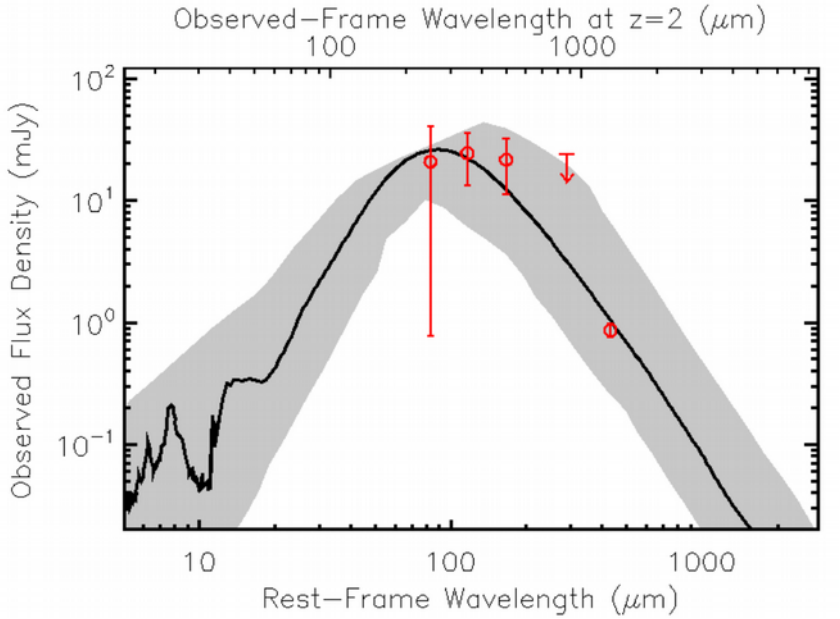
Predictions based on second generation production in a collisional cascade. Kral et al. 2017

Integrated CO 2-1 Image

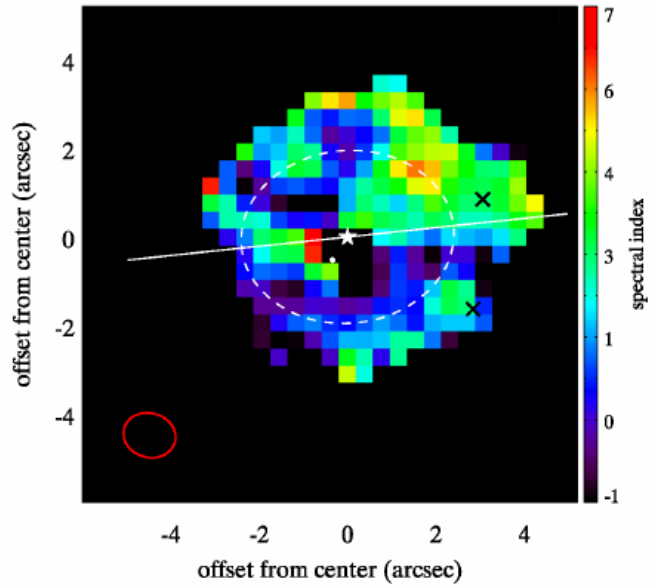


- No strong concentration of gas coincident with the 'clumps'.

Galaxies?

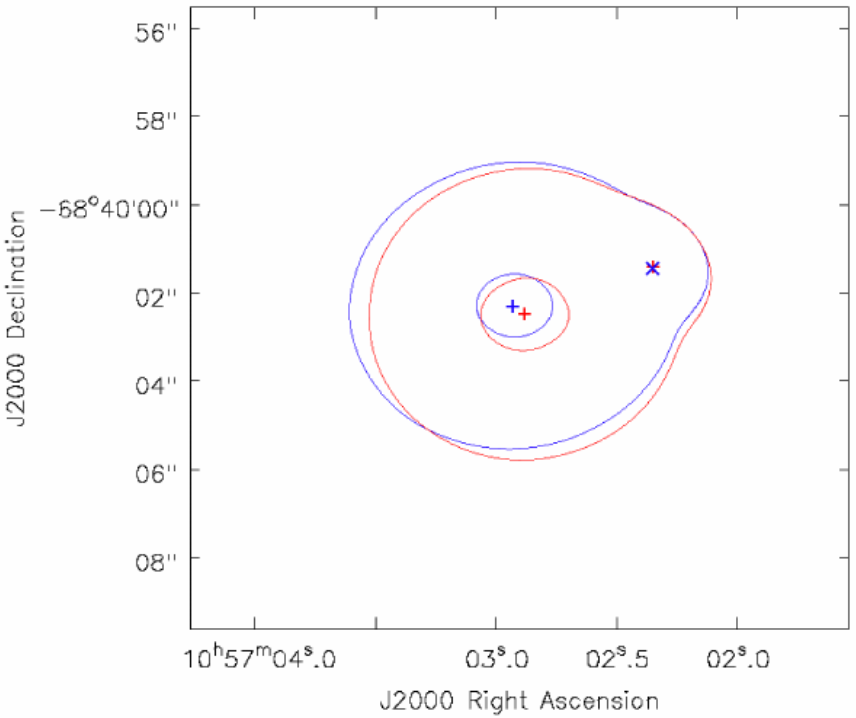


- SED is consistent with a z~2 galaxy.



- Spectral index for the bright source is also much steeper than the rest of the disc.

Galaxies?



Zapata, Ho & Rodríguez 2018

- Follow-up observations in band 7 suggest that the bright source is not co-moving.
- Chance of a galaxy brighter than 0.9 mJy being within the primary beam ~5%, but if both sources are unrelated galaxies then chances of them both being within the disc is 0.06%.

Conclusions

- HD 95086 hosts a bright, broad disc very similar to that around HR 8799.
- Inner edge is consistent with the known planet.
- As well as the disc, the continuum observations show two bright sources.
- The brightest should show up in CO if it is related to the disc, but it does not.
- It is consistent with a background object, although the chances of a galaxy coinciding with the disc are small.