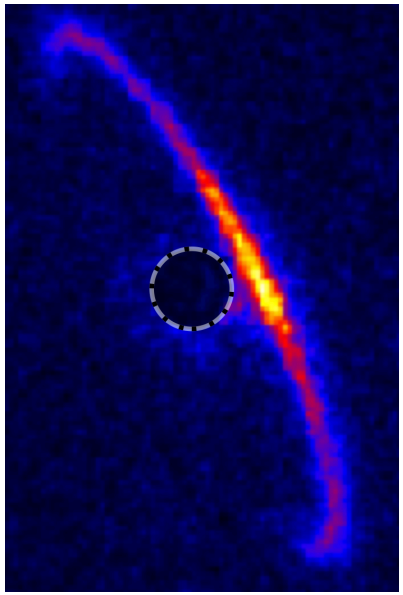
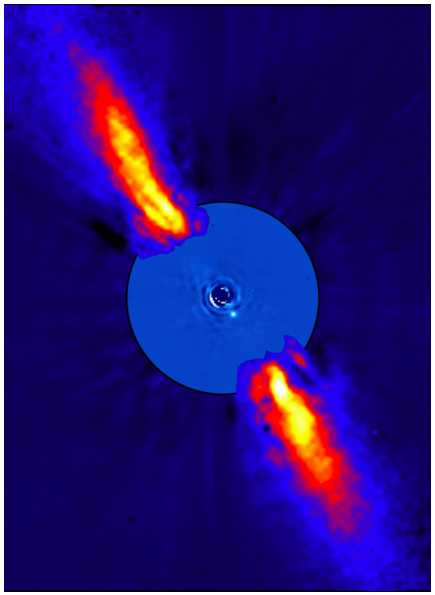
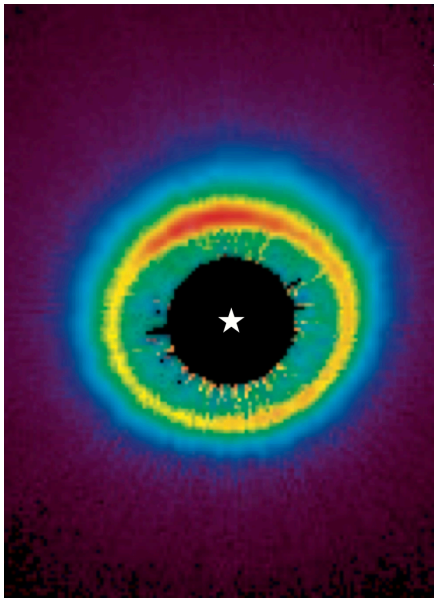




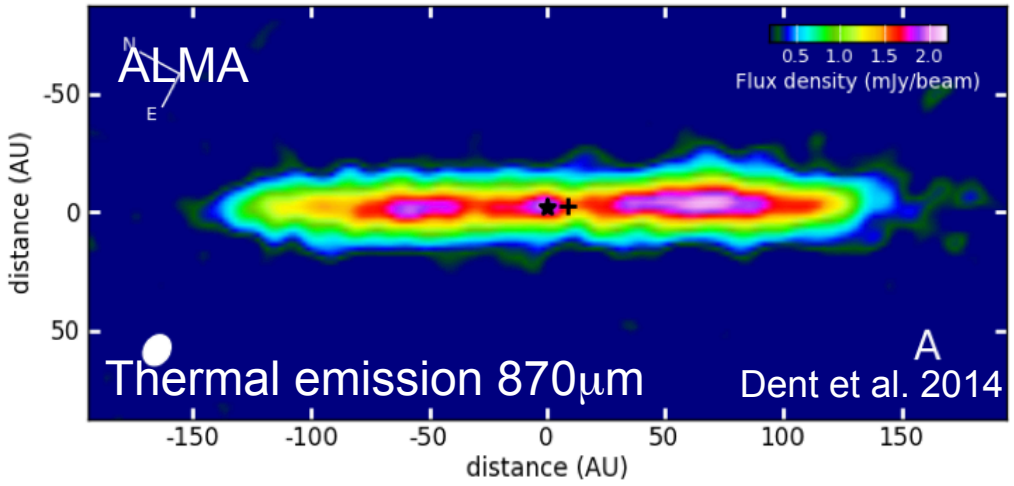
What can Kuiper belt analogs tell us about the underlying planetary systems ?

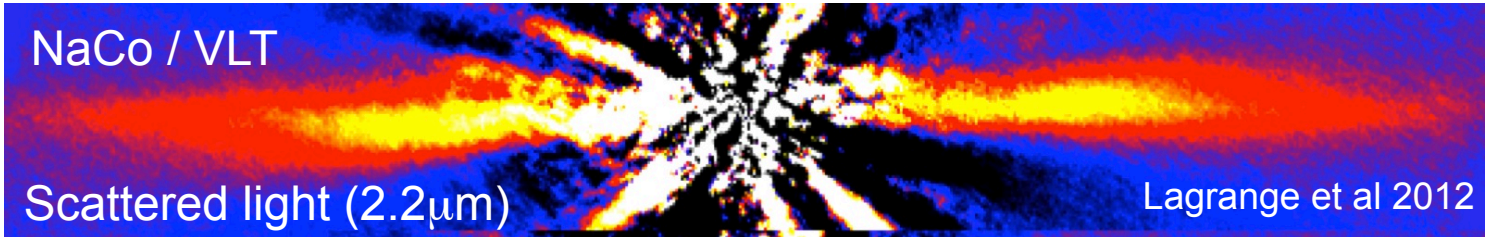
Julien Milli ESO Santiago

In collaboration with A.M. Lagrange, D. Mouillet, D. Mawet, J.C. Augereau, C. Pinte

PansSTARRS (C/2014 Q1)

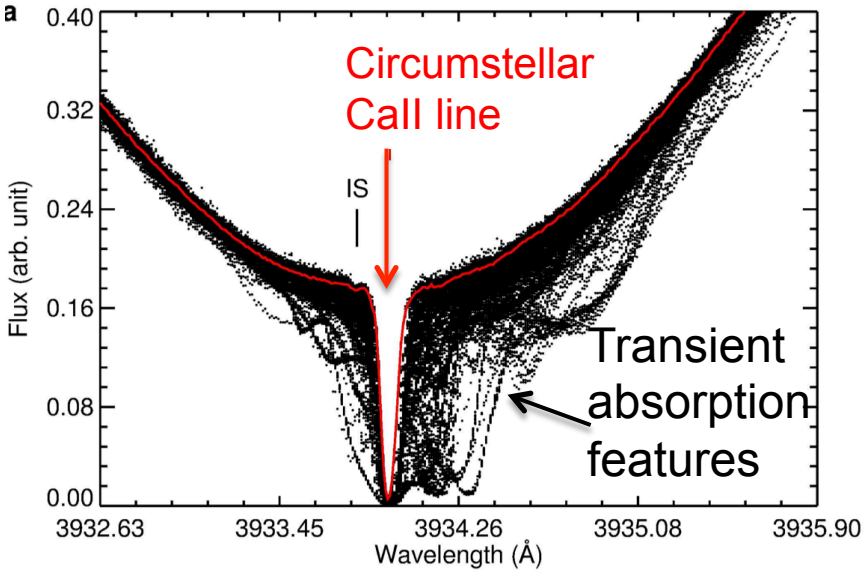
β Pictoris: a giant cometary reservoir





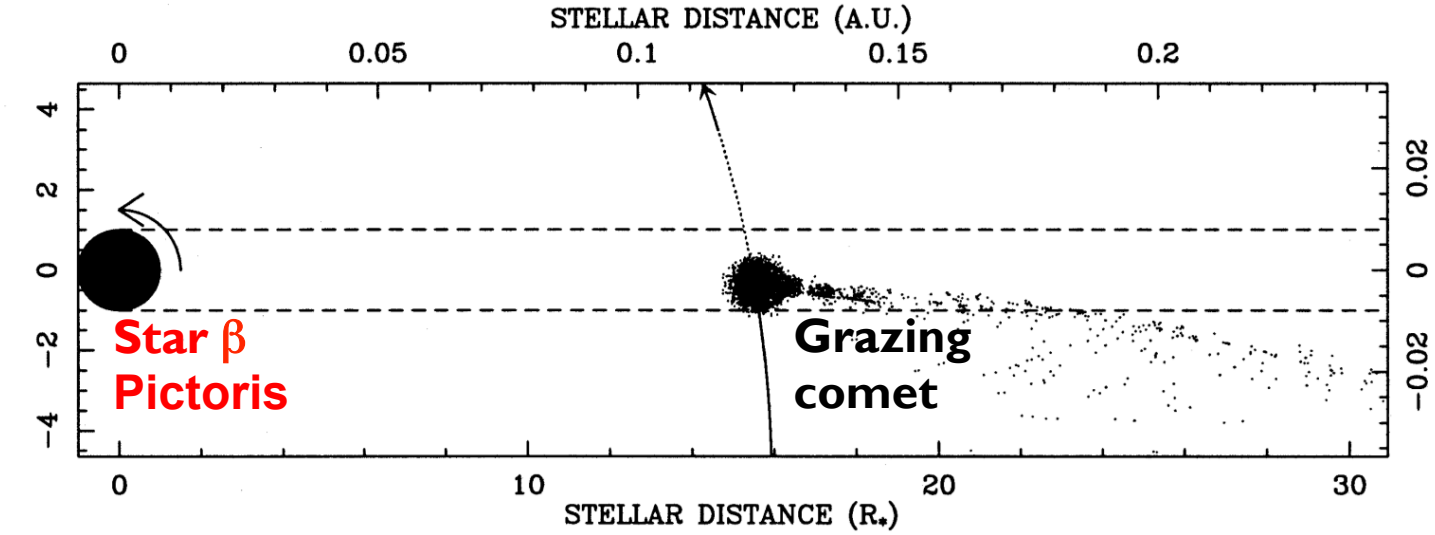
The β Pictoris debris disc

The signature of exocomets



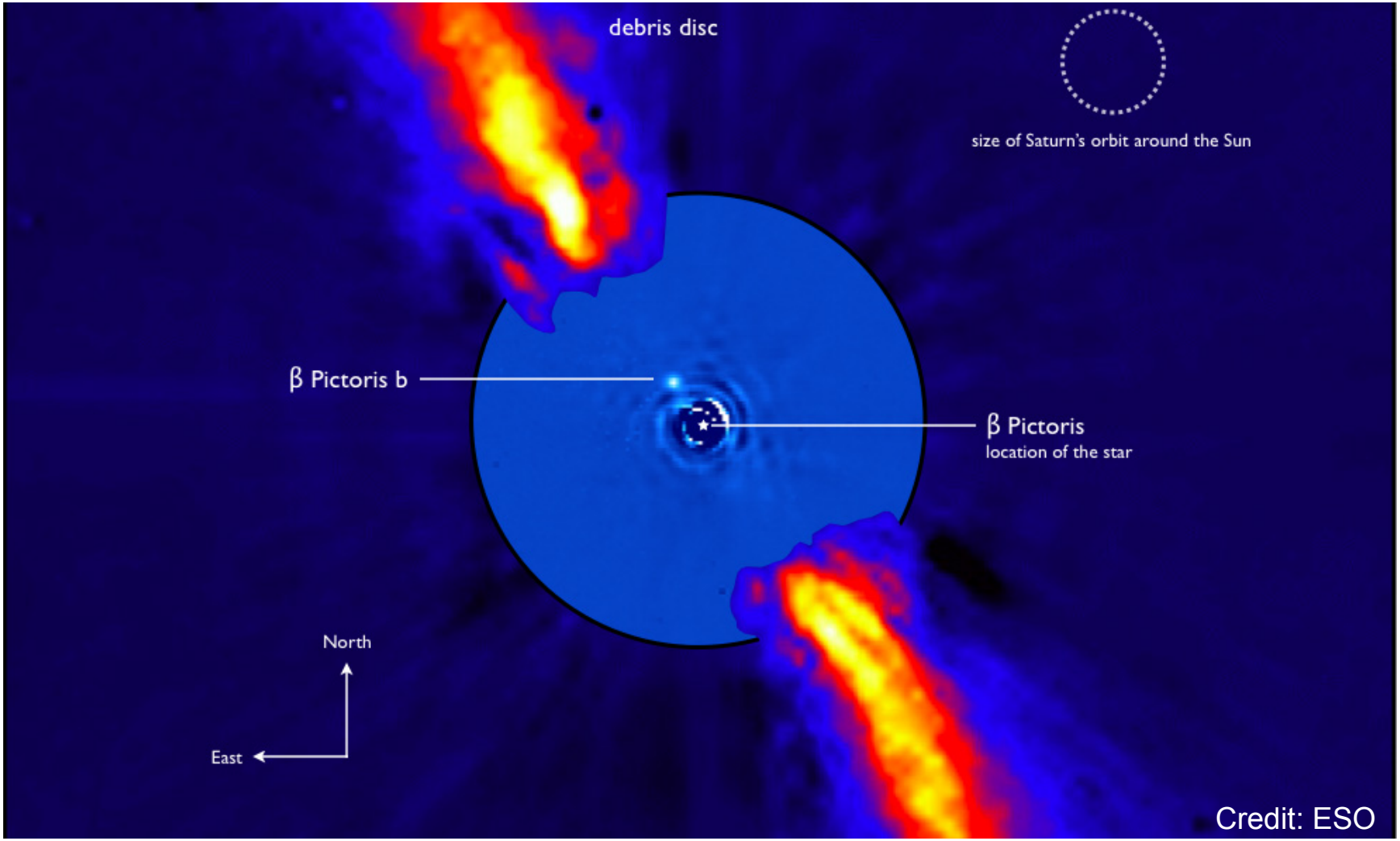
Kiefer et al. 2014

First evidence of exocomets through absorption spectroscopy of β Pictoris (Vidal-Madjar et al. 1986)



Beust et al. 1995

And one giant planet inside the ring



Content

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II. The dust properties

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Debris discs: circumstellar material around a main-sequence star

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Zodi

Asteroid belt

Kuiper belt

< 1 au

~2-3 au

~60 au

>200 au

Debris discs: circumstellar material around a main-sequence star

Zodi

Asteroid belt

Kuiper belt

< 1 au

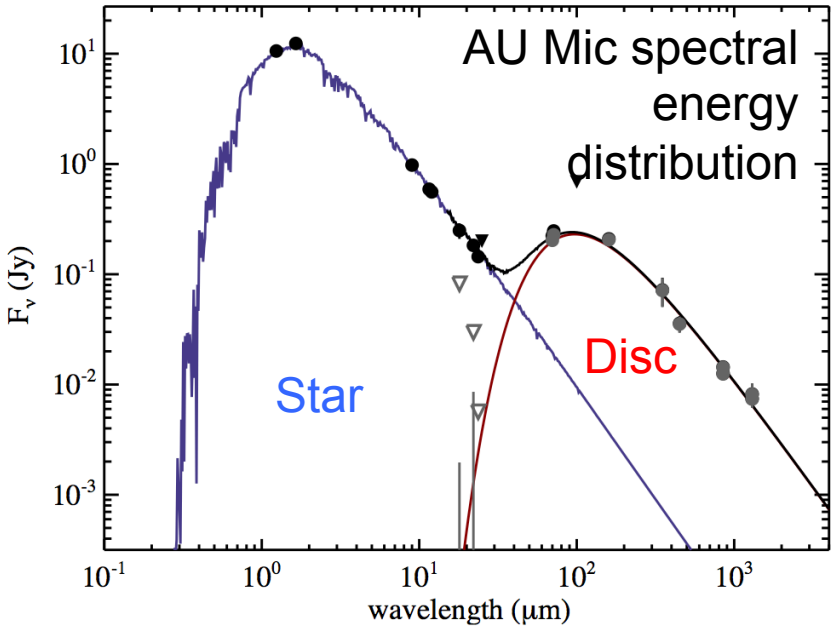
~2-3 au

~60 au

>200 au

They represent a common phenomenon (10-33% of AFGK stars, Matthews et al.2014).

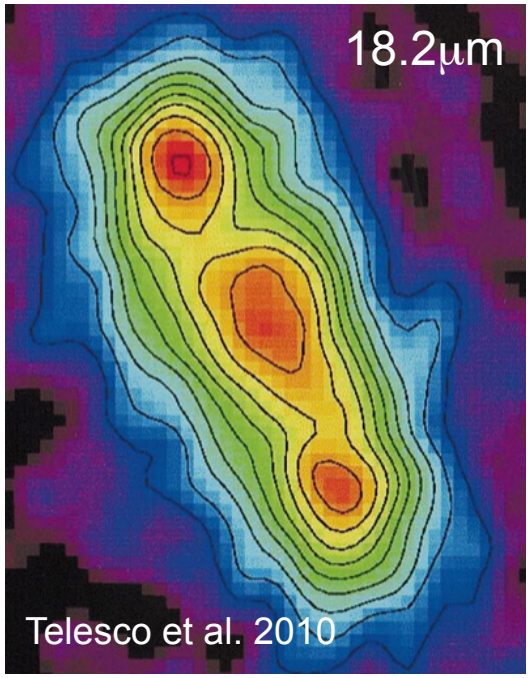
Debris discs are primarily detected through the infrared excess of the star.

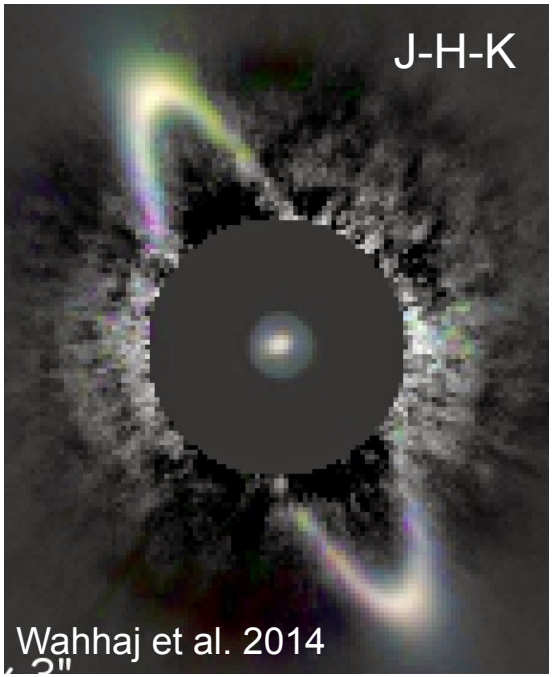


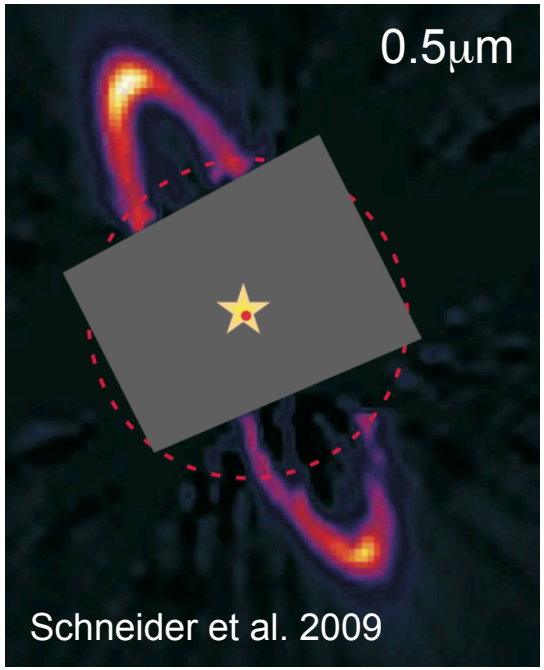
Matthews et al. 2015

The architecture of debris discs

The power of direct imaging to constrain the underlying planetary system





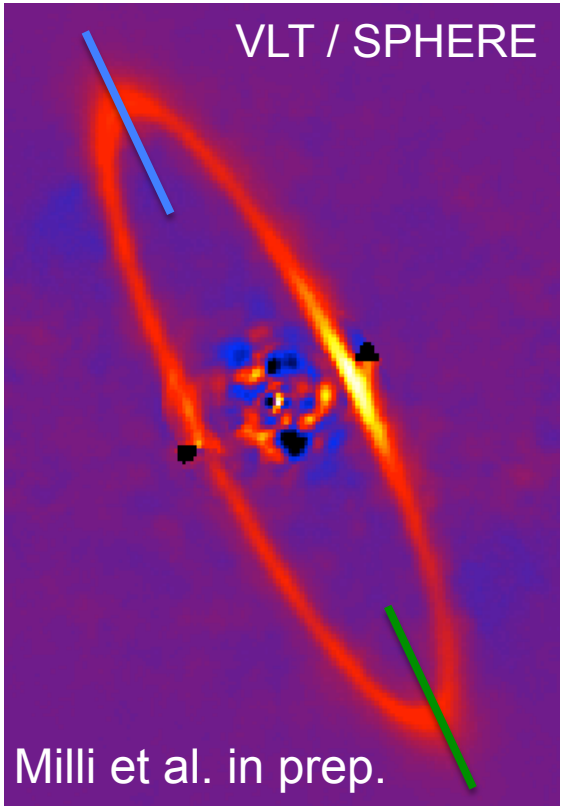


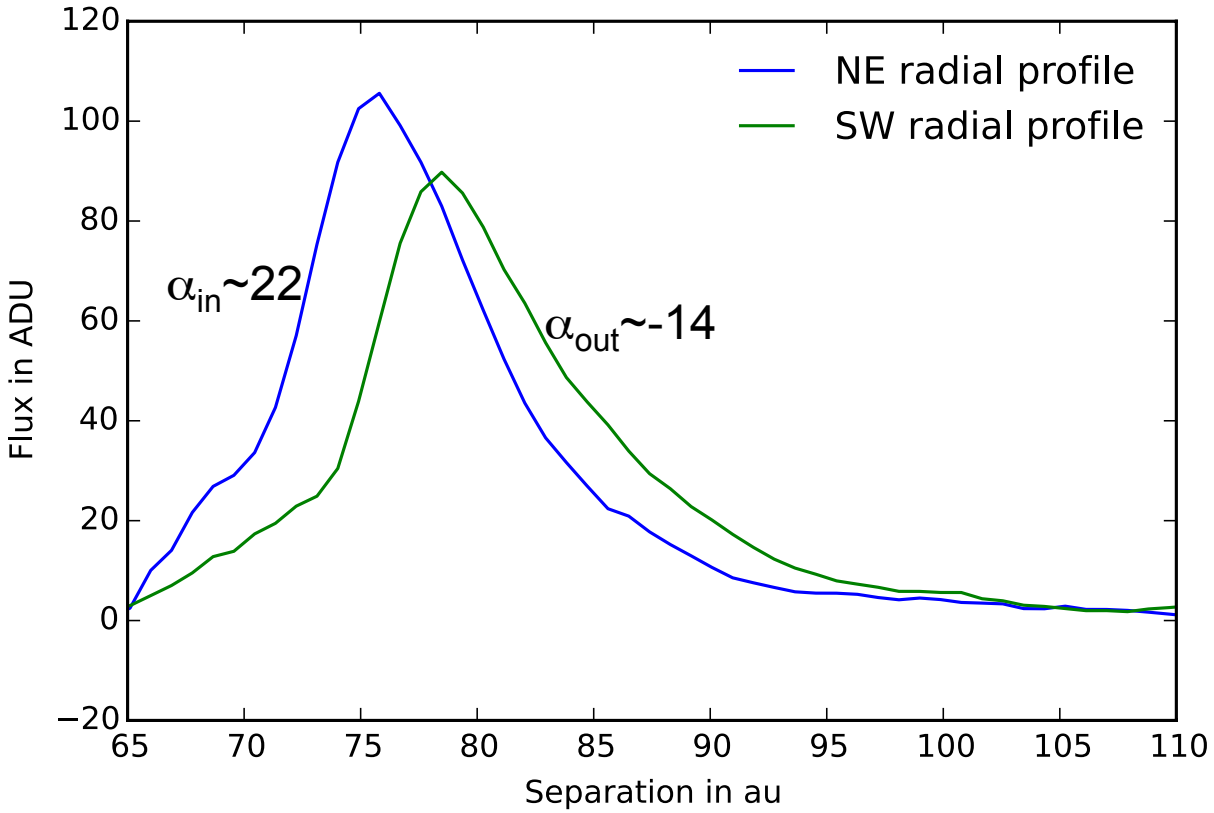
1”

73 AU

HR4796: a very narrow ring with steep edges and center offset

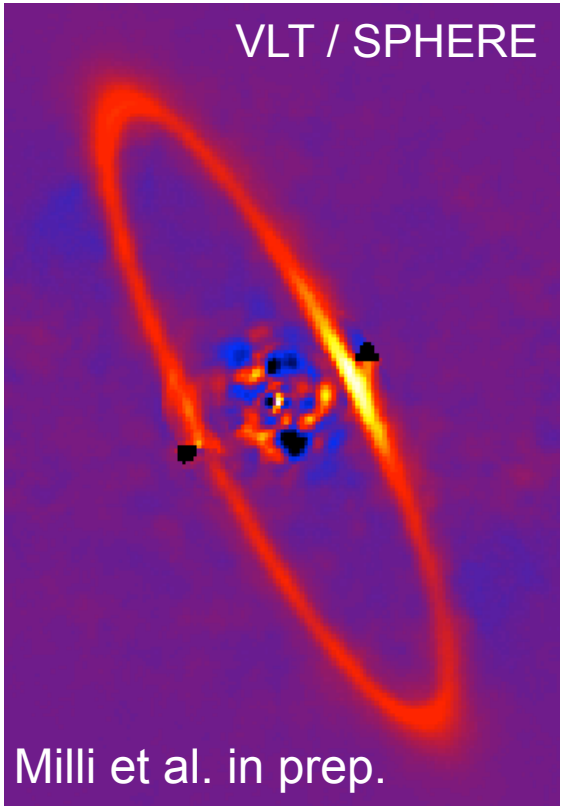
Measuring the morphology of the ring

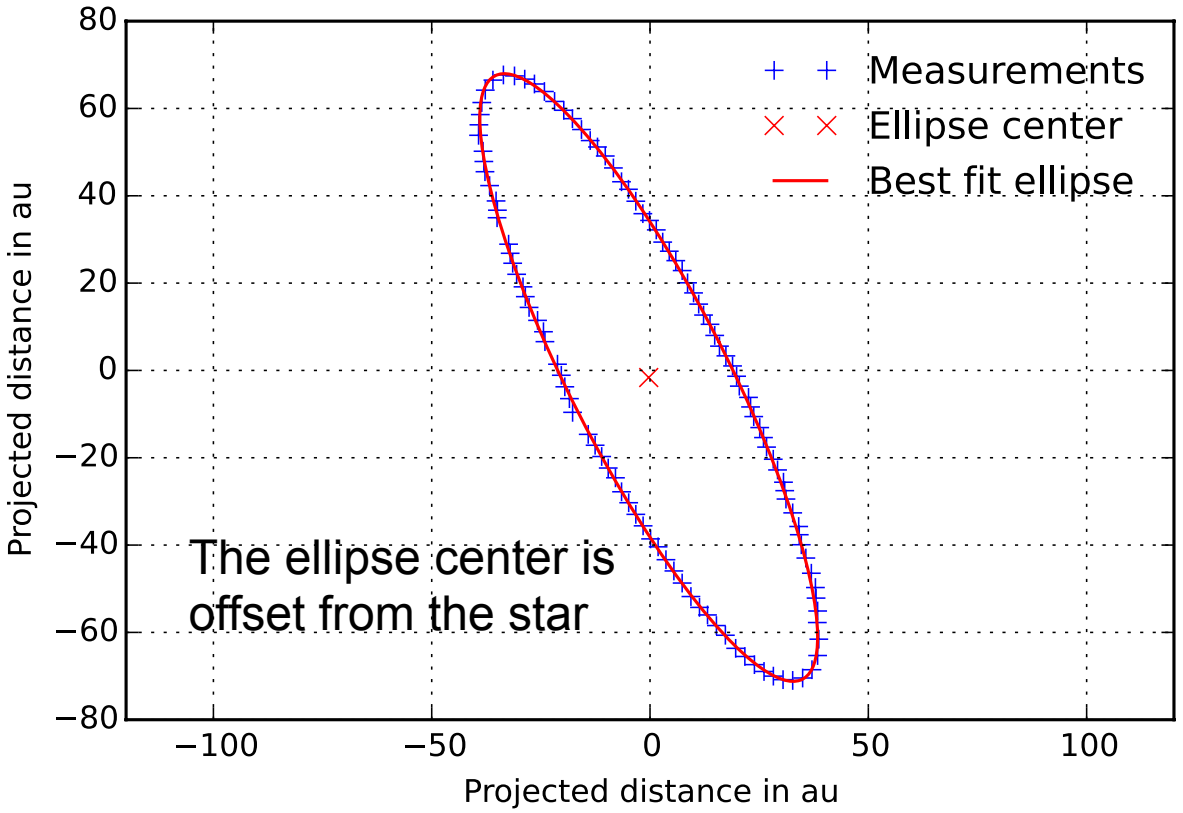




Binary component: no (Thebault et al. 2010)
Presence of gas in the system ? (Lyra & Kouchner 2012)
Inner / outer companion shaping the ring ? (Lagrange et al. 2012)

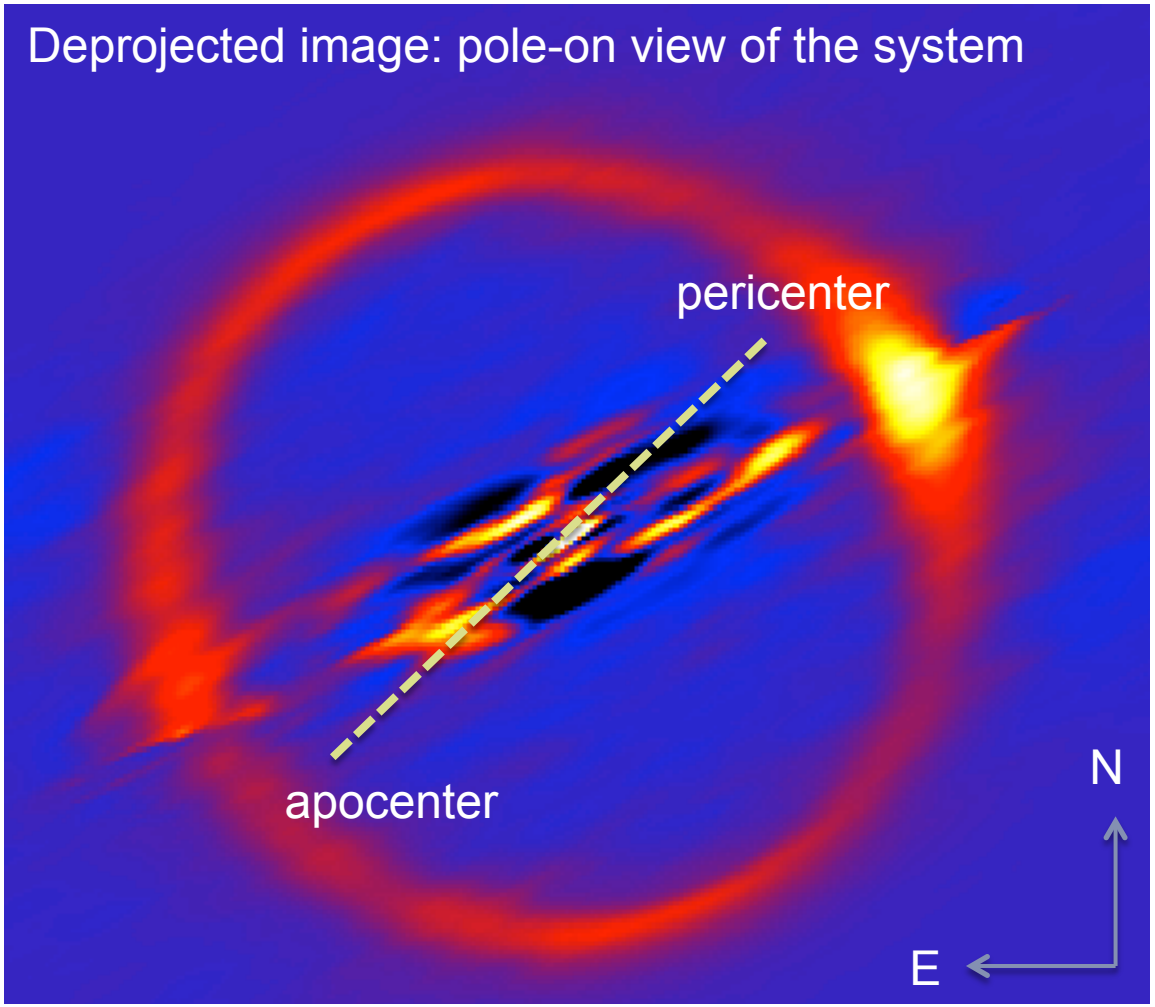
Measuring the morphology of the ring



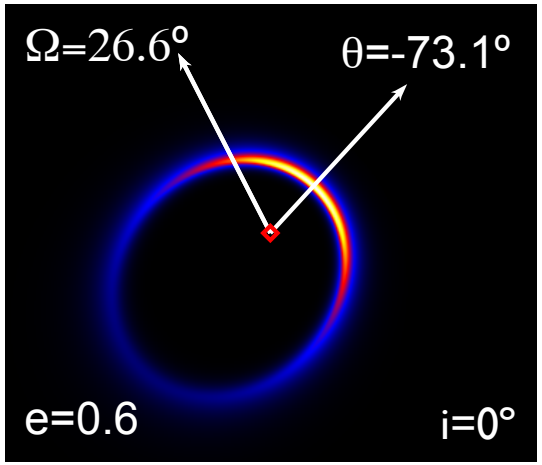


The ring is eccentric

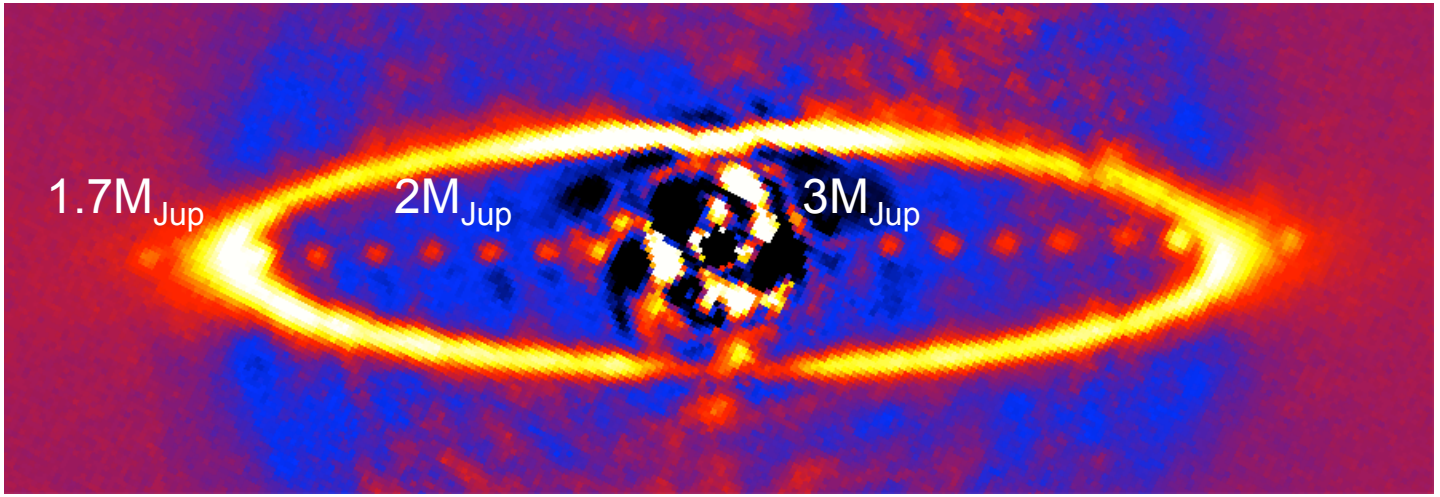
An eccentric ring



Eccentricity 10 times larger



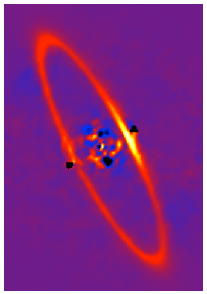
The origin of eccentricity: where is the planet ?



Fake planets illustrating the sensitivity reached (believing evolutionary models)

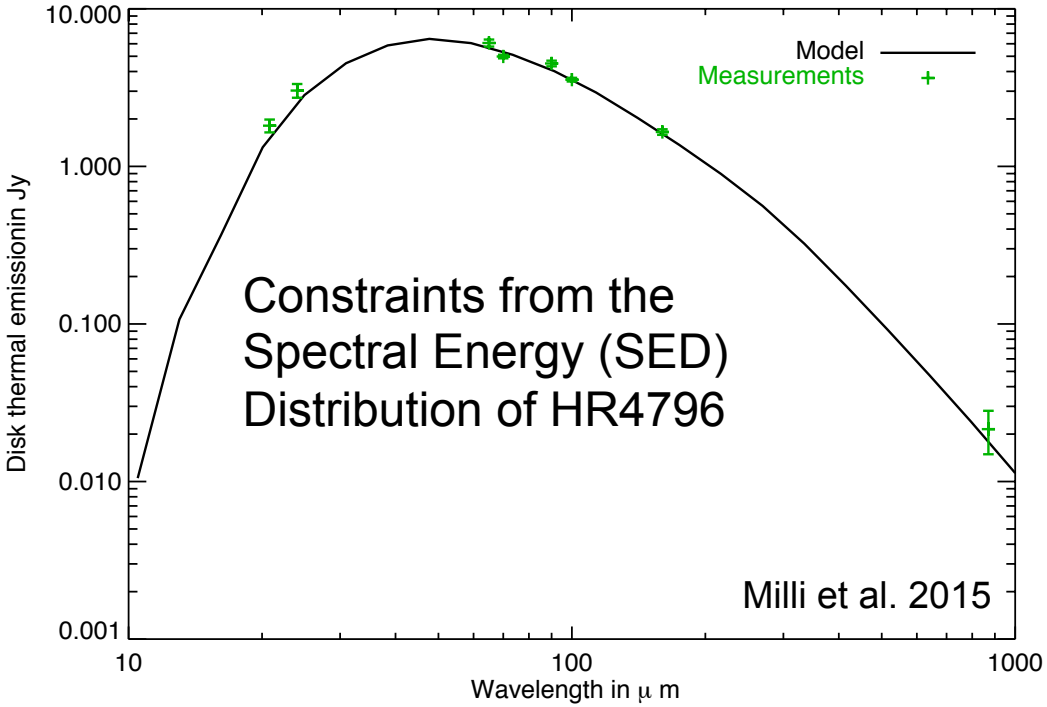
1-2 M_{Jup} planets can still hide in the image and carve the inner edge of the ring.

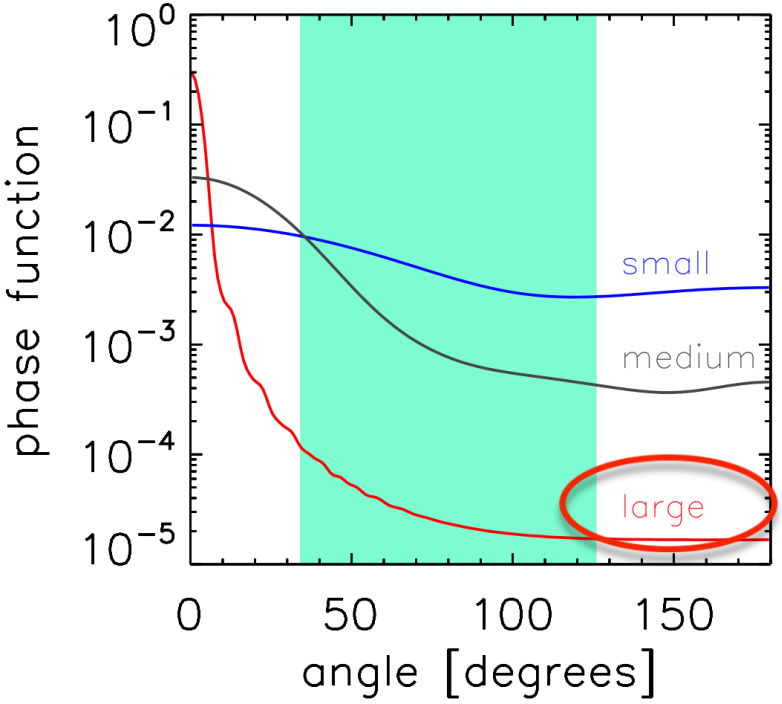
II. The dust properties of debris discs



Large (>1μm) icy grains are needed to reproduce the SED

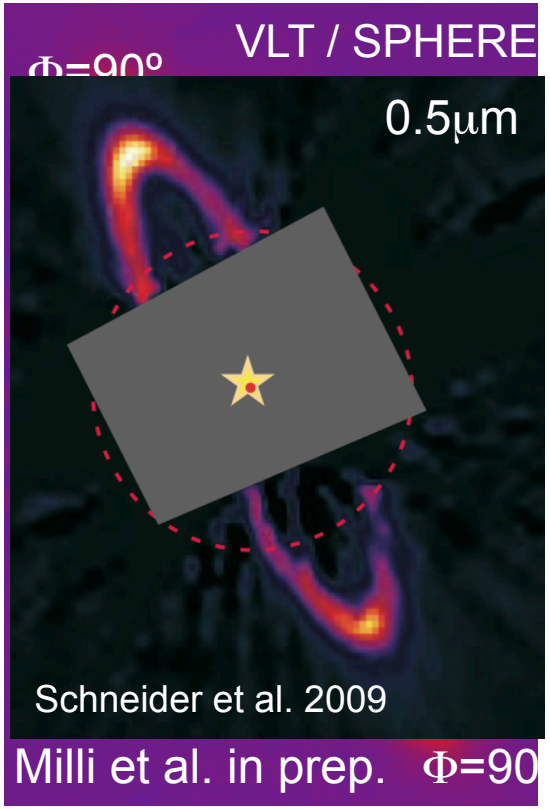
Strong forward scattering is predicted

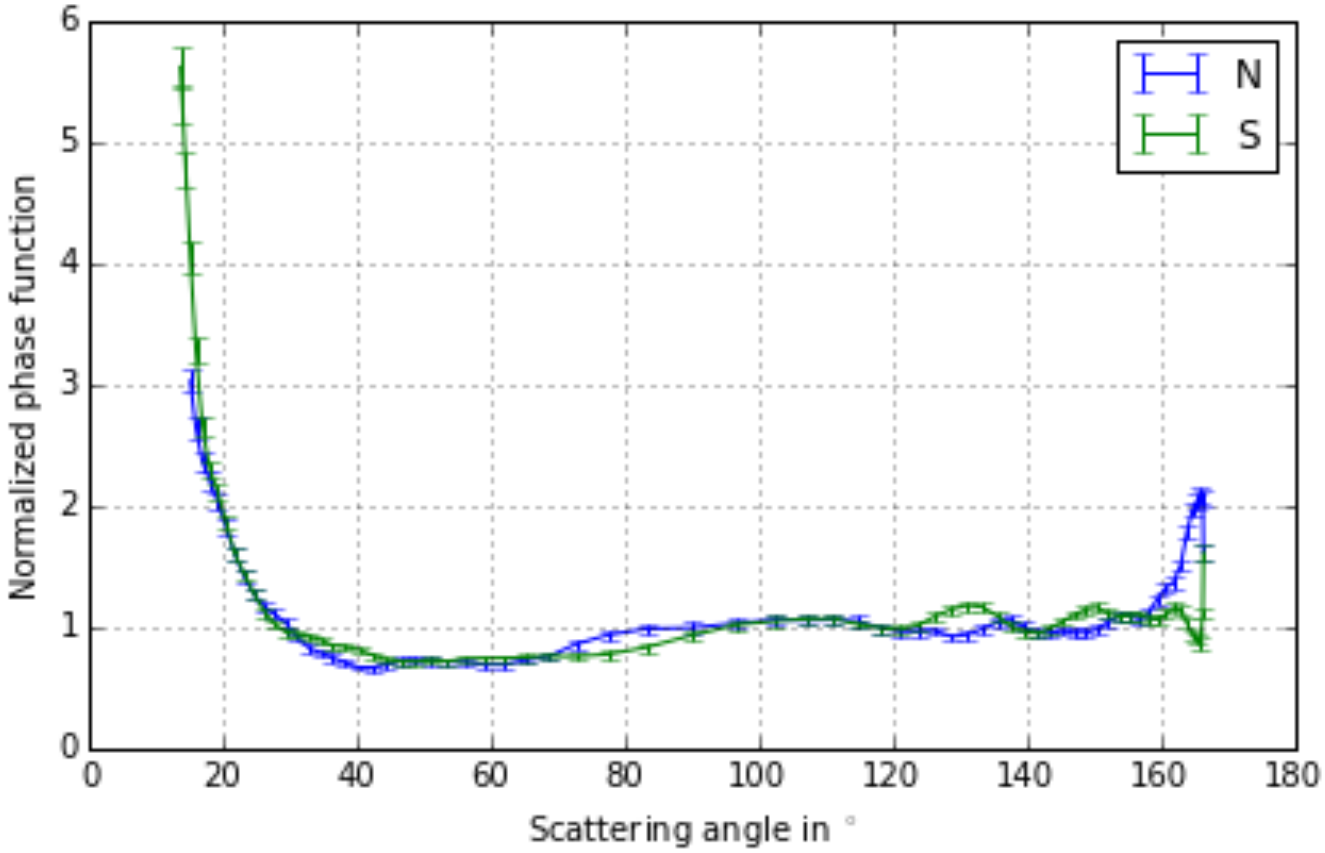




Mulders et al. 2012

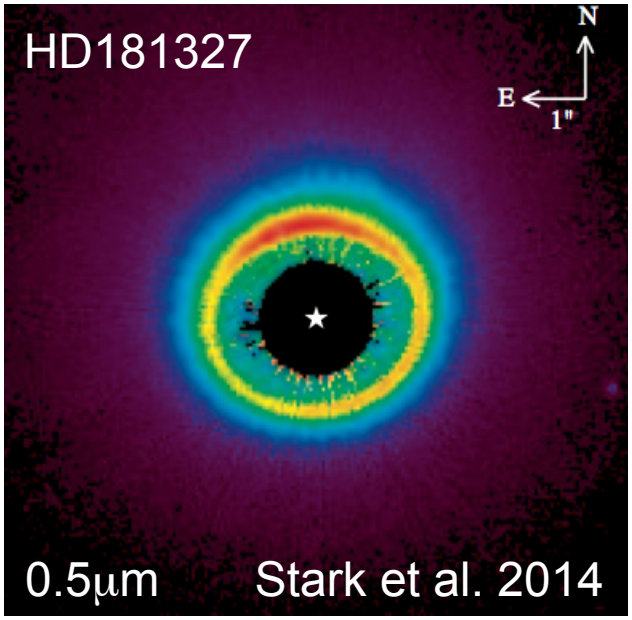
What can the phase function tell us on dust grains

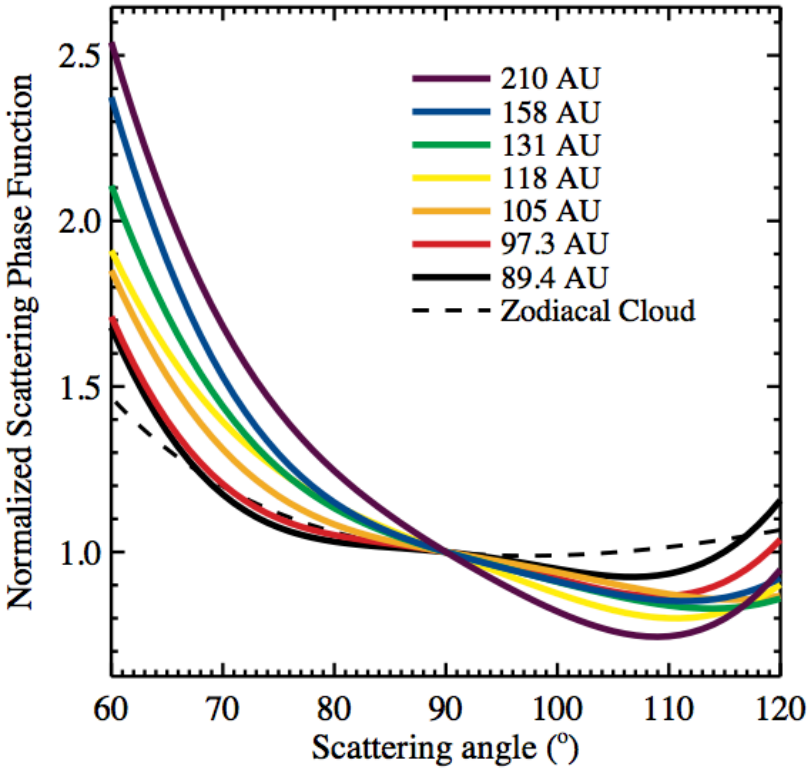




The predicted peak of forward scattering is indeed there !

Size segregation in wider debris discs

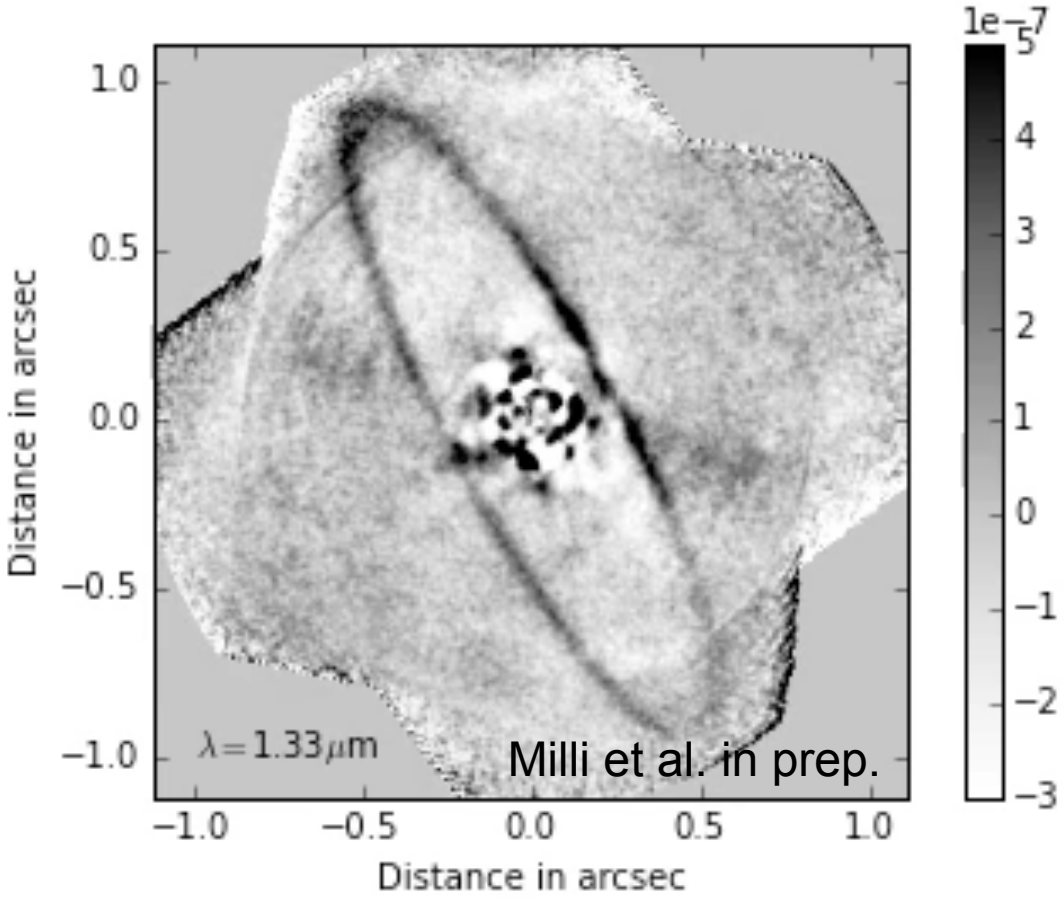




Observations consistent with decreasing grain sizes with orbital radius, as expected for grains subject to radiation pressure.

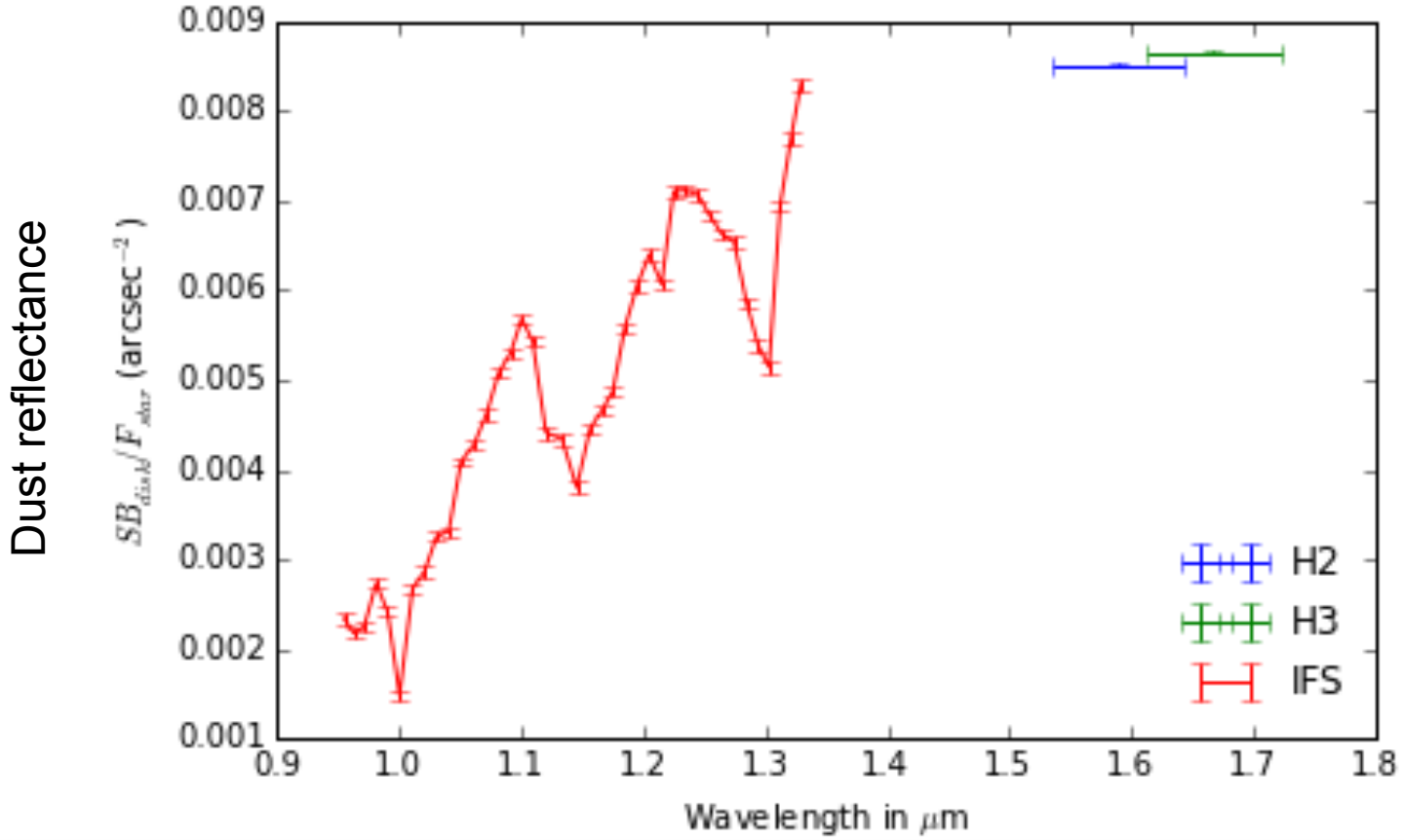
The reflected spectra of dust from 0.95μm to 1.3μm

VLT / SPHERE
Integral Field
Spectrograph



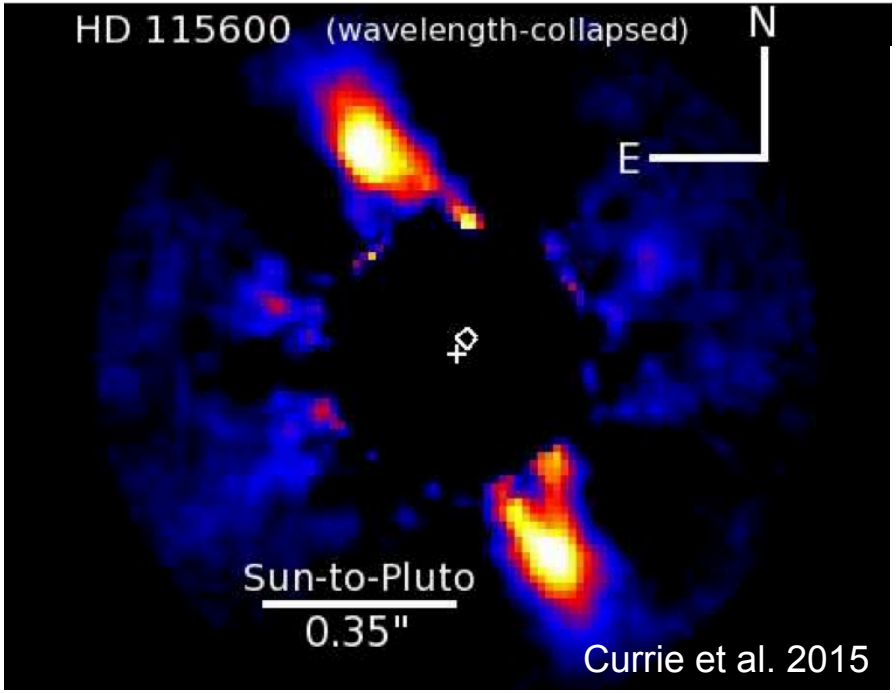
Wavelength dependance of the reflectance and phase function

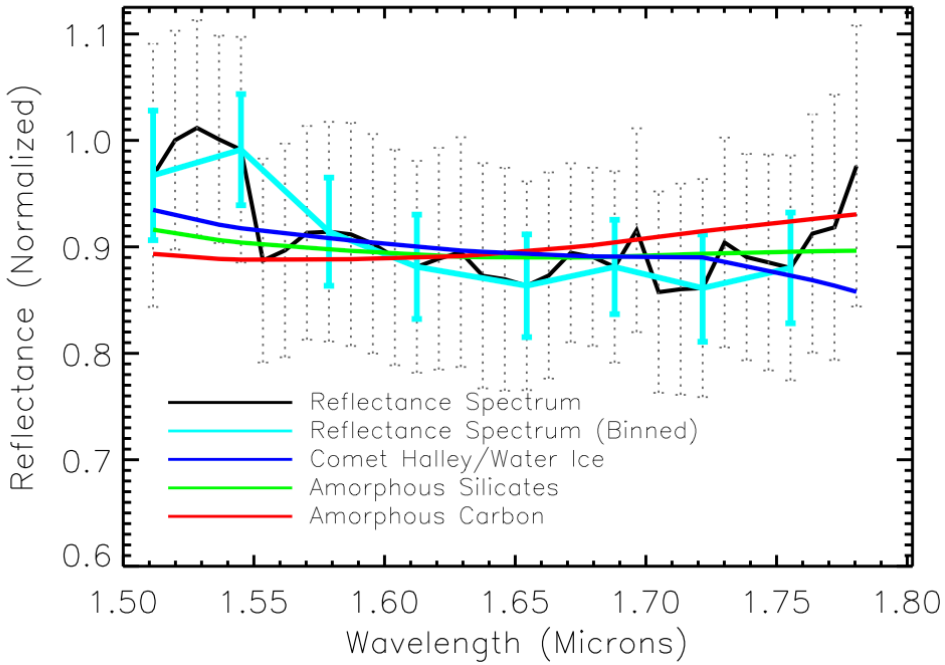
Dust reflectance



The dust has a red color, as previously reported (Debes et al. 2008, Rodigas et al 2014), confirming the grains are large. Tentative confirmation of tholins, also present among solar system bodies

Reflectance spectroscopy of Kuiper belt dust: a new science area

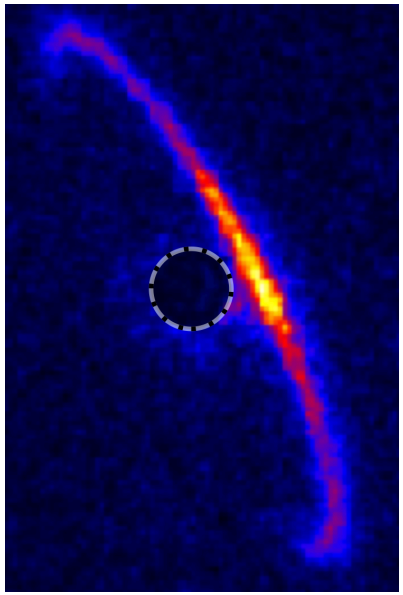


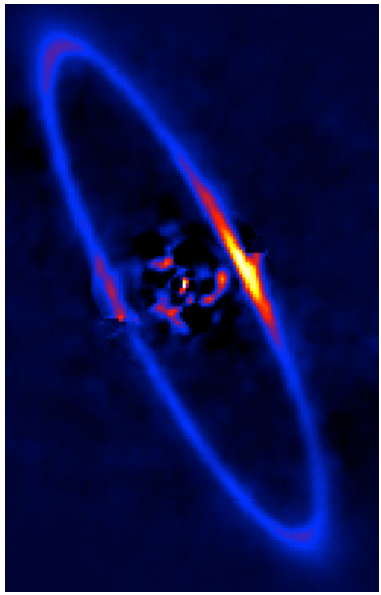


Slightly blue to gray disc color, consistent with major Kuiper belt chemical constituents

Conclusion and perspectives

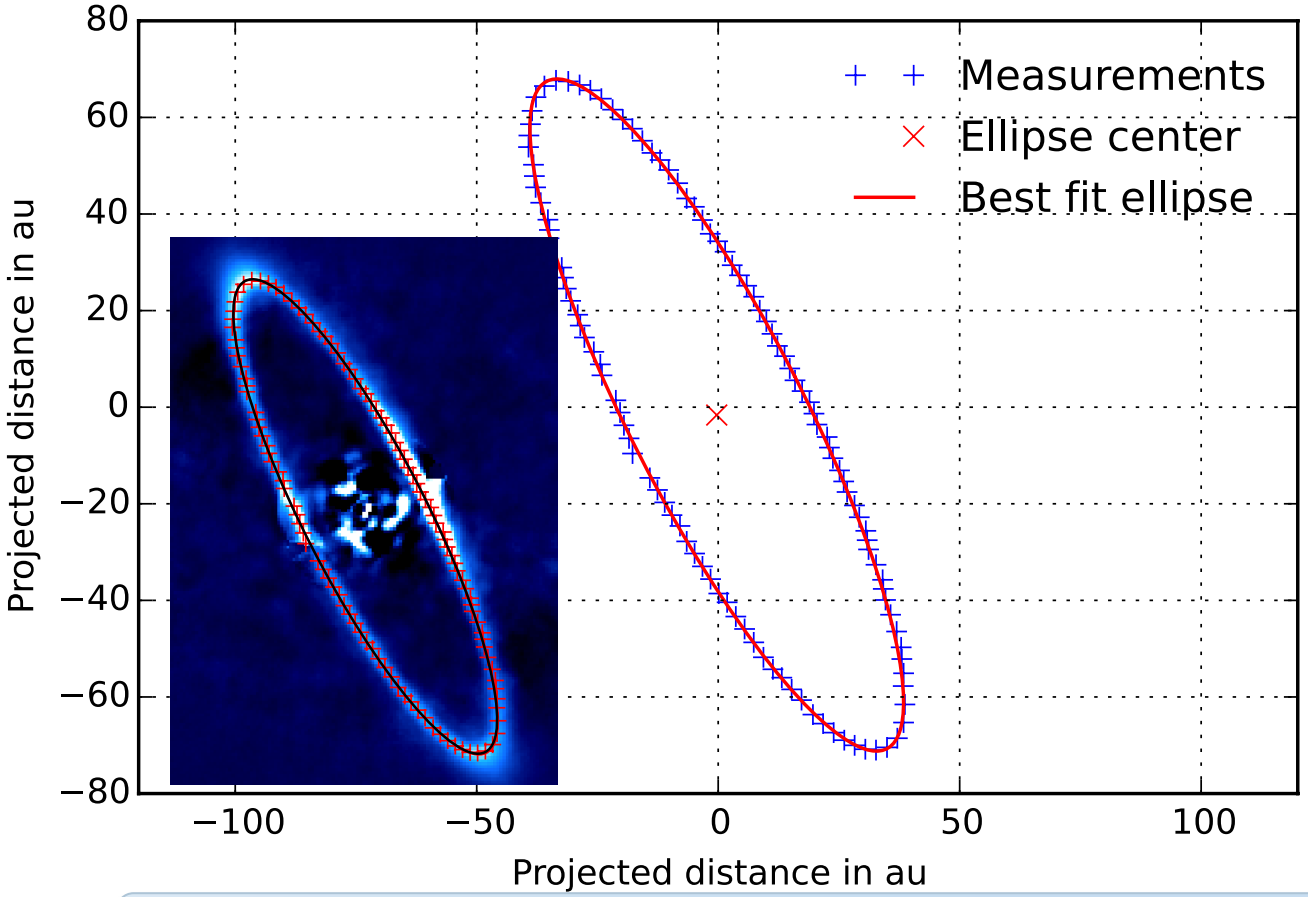
- High resolution direct imaging brings critical constraints for the architecture and dust properties of debris discs:
  - Morphology
  - Phase function
  - Reflected spectrum
- Comparison with solar system bodies is key to understand the diversity of systems
- Perspectives :
  visible polarisation and sub-mm observations bring precious complementary information

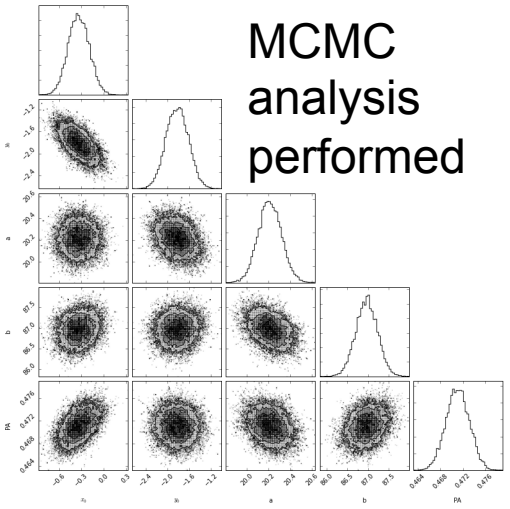




Backup slides

The offset of the ring





MCMC analysis performed

Projected ellipse parameters:

a = 77.6 au $^{+/-0.5}$

e = 0.02

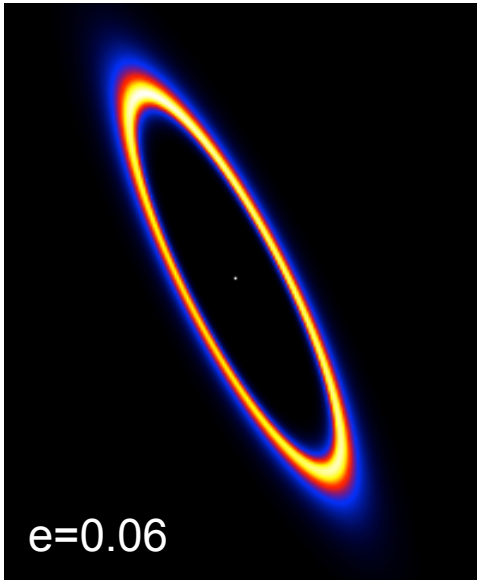
Offset of 1.6 $^{+/-0.5}$ au

i=76.9º $^{+/-0.1º}$

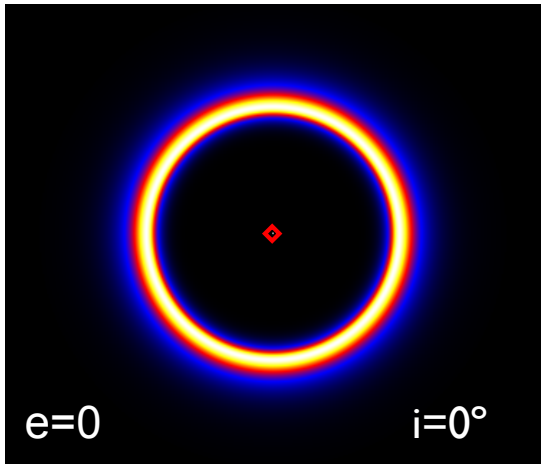
Results compatible with previous studies (Perrin 2015, Rodigas 2014, Wahhaj 2014, Schneider 2009)

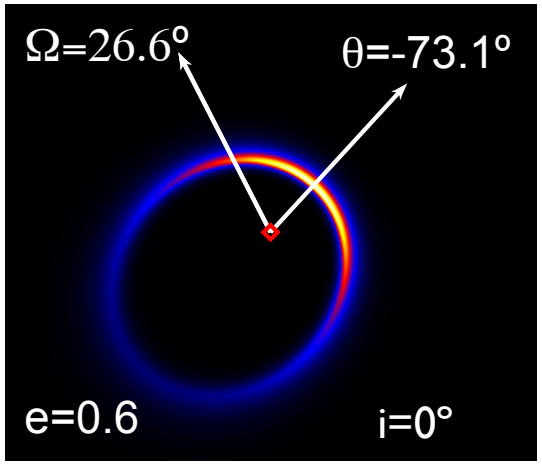
The deprojection of the ring

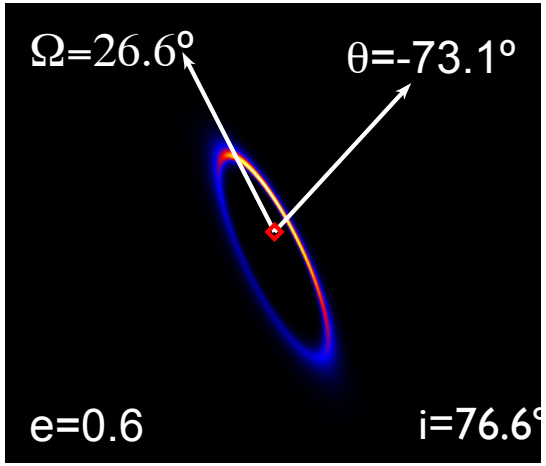
Deprojected ellipse parameters:
a = 77.6 au
e = 0.06
PA of ascending node Ω=26.6º
Argument of pericenter θ=-73.1º
Inclination i=76.6º



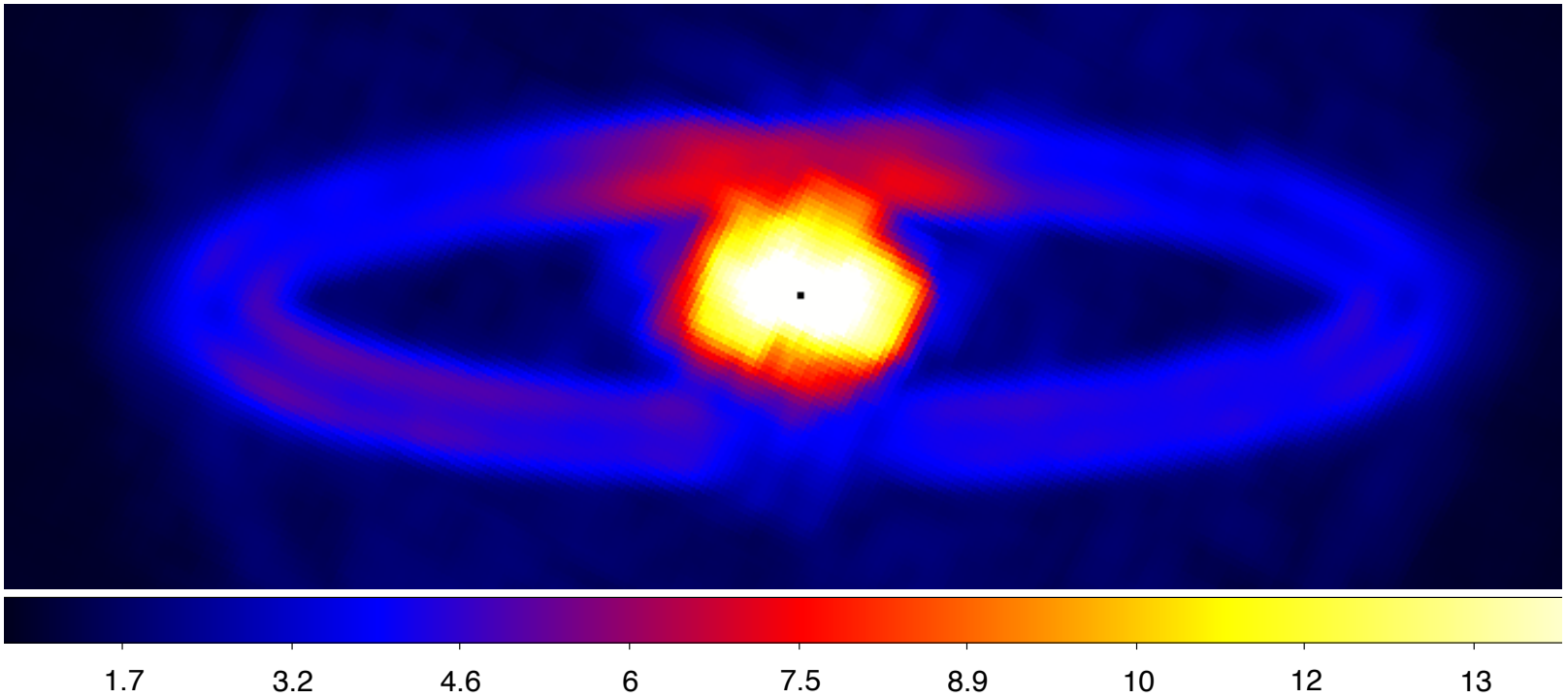
Isotropic model





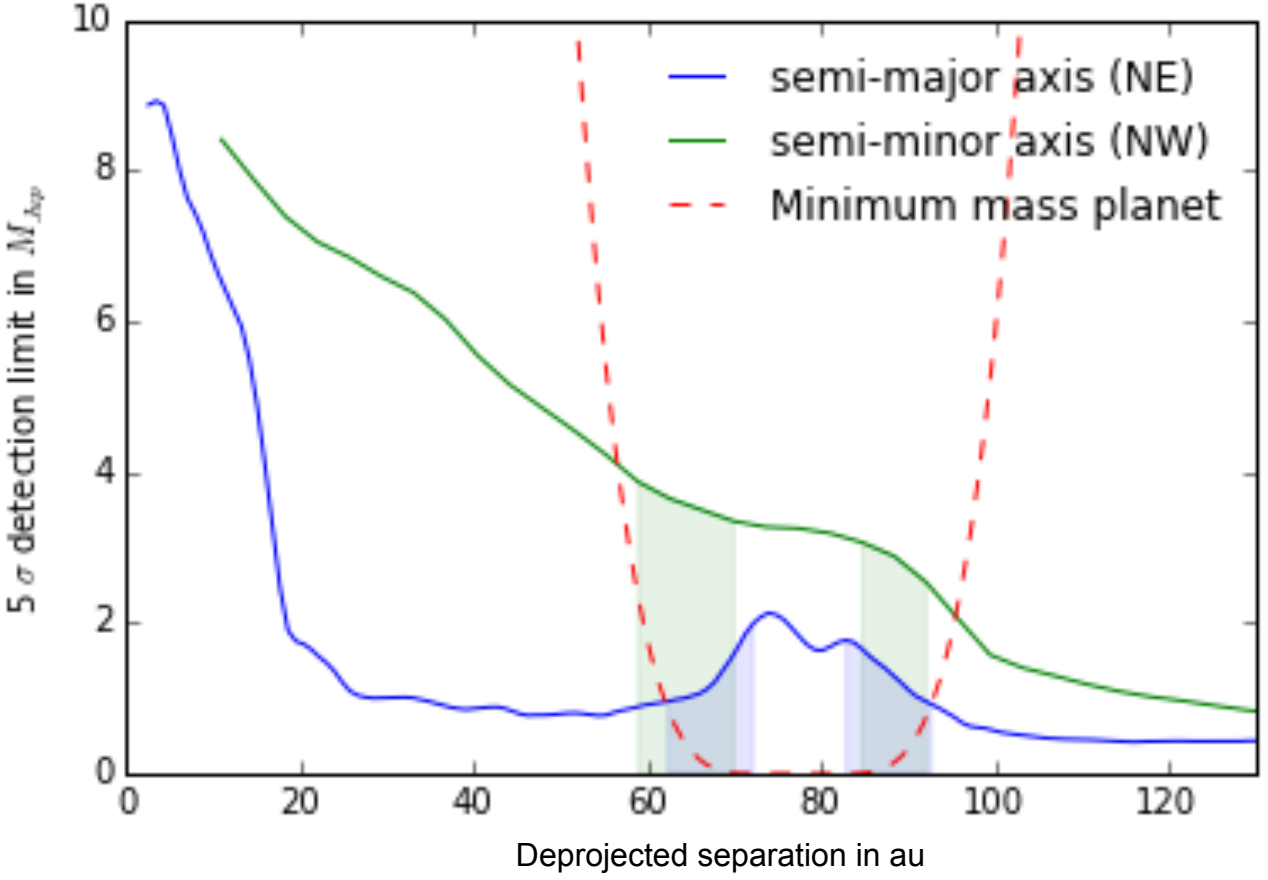


Constraints on planets



5σ detection limit converted in Jupiter mass using AMES/Cond

Planets shaping the ring



$$\frac{\delta a}{a} = 1.3\left(\frac{M_{planet}}{M_{star}}\right)^{2/7}$$

Wisdom 1980
Mustill & Wyatt 2011

No planet > 4 M_{jup} is scultping the ring