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A unique talent of MIDI: Discovering asymmetries in the first AUs of gapped protoplanetary discs

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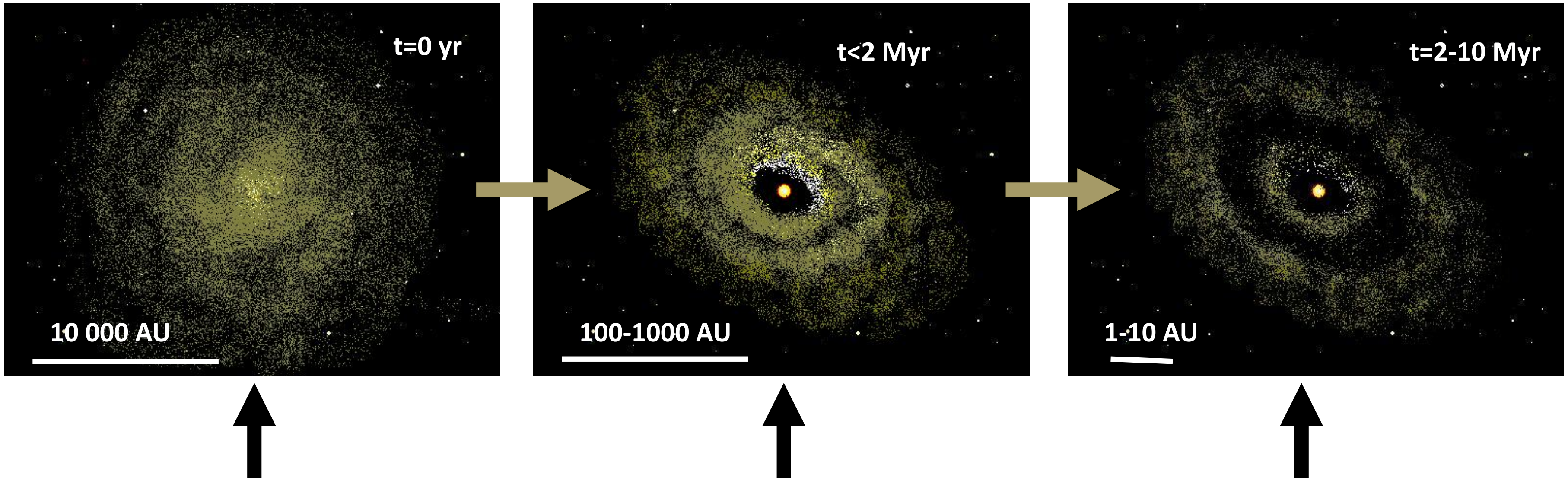
ESO Fellowship programme

Thank you, ESO!

Formation of low and intermediate-mass stars

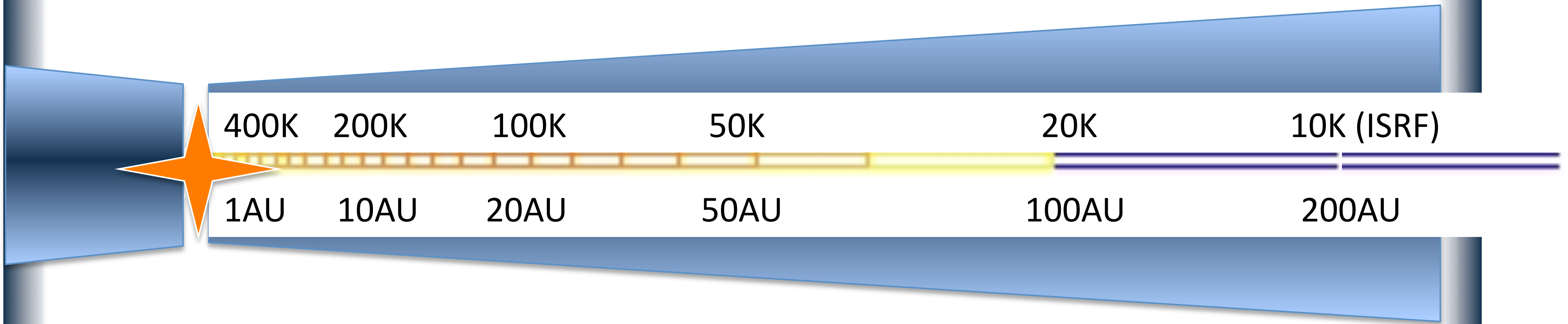


Star + disc formation

Planet formation in young gas rich accretion discs

Signatures of planets: gaps, cavities, spirals and other asymmetries

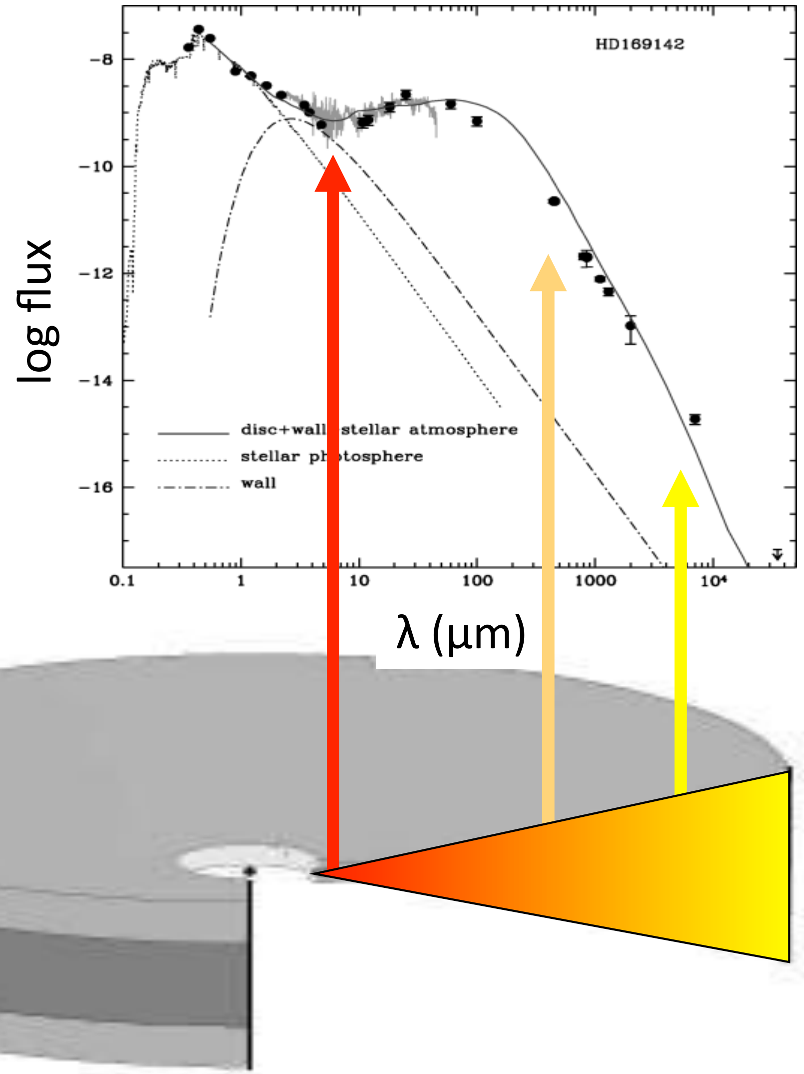
Disc structure: both hot and cold!



Dust component:

Only 1% of disc mass
but a wealth of information

(Chiang & Goldreich 1997,
D'Alessio 1998,
Robitaille et al. 2006,
d'Alessio et al. 2005,
Dullemond & Natta 2003,
Dullemond et al. 2001)

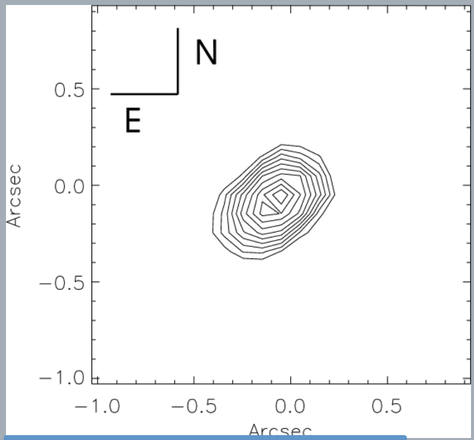


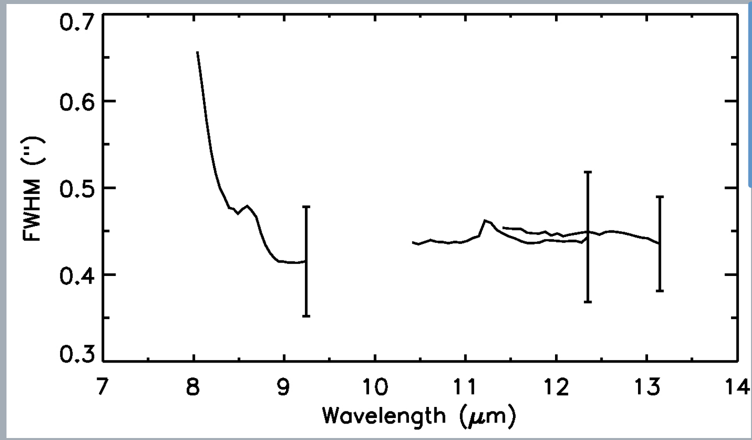
Images from:

Dullemond et al. (2006)

Dent et al. (2006)

HD 100546:
Multiwavelength observations with ESO instruments over the years

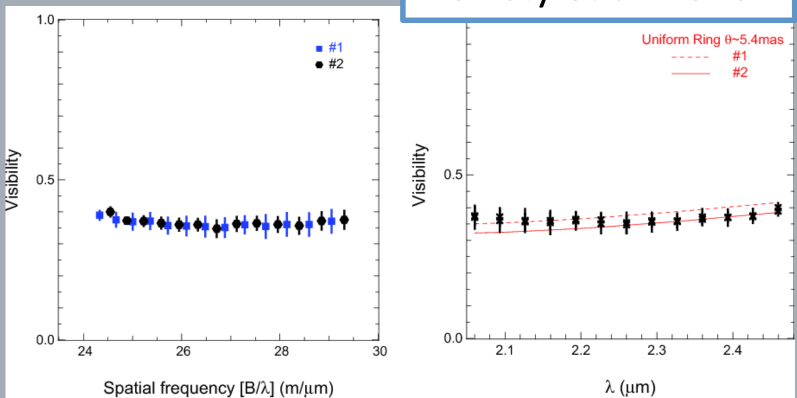




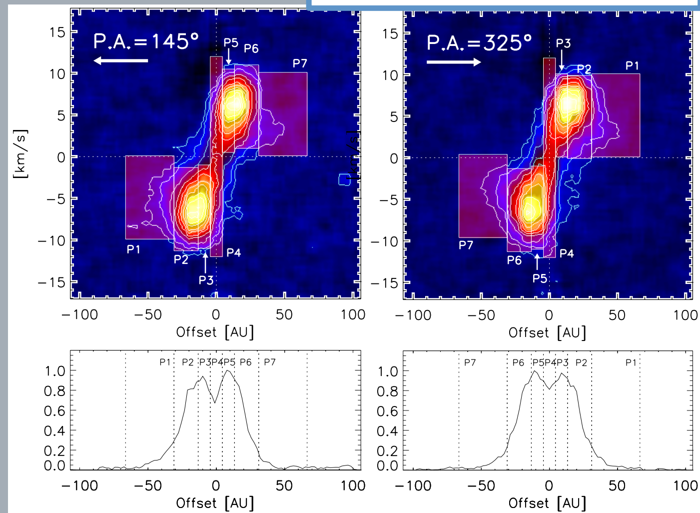
VISIR:
Verhoeff et al. 2009,
Panić et al. 2012, subm.

MIDI:
Leinert et al. 2004

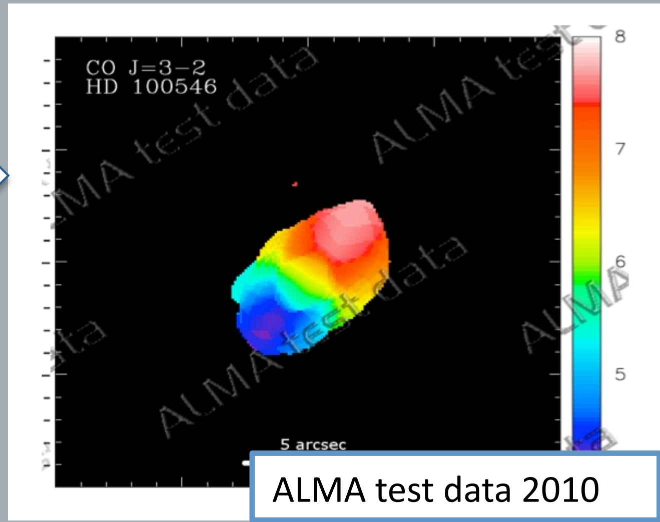
AMBER:
Benisty et al. 2010



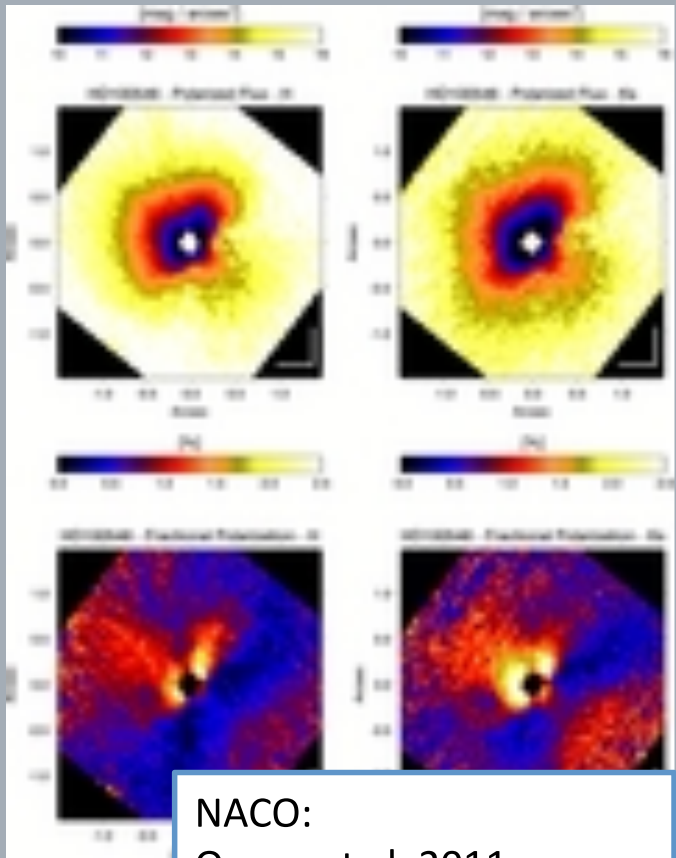
CRIRES:
Goto et al. 2012



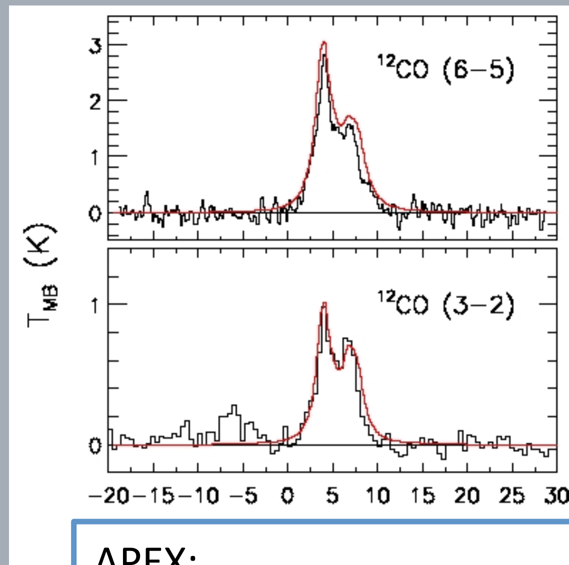
… with many Paranal instruments and more recently ALMA!



ALMA test data 2010

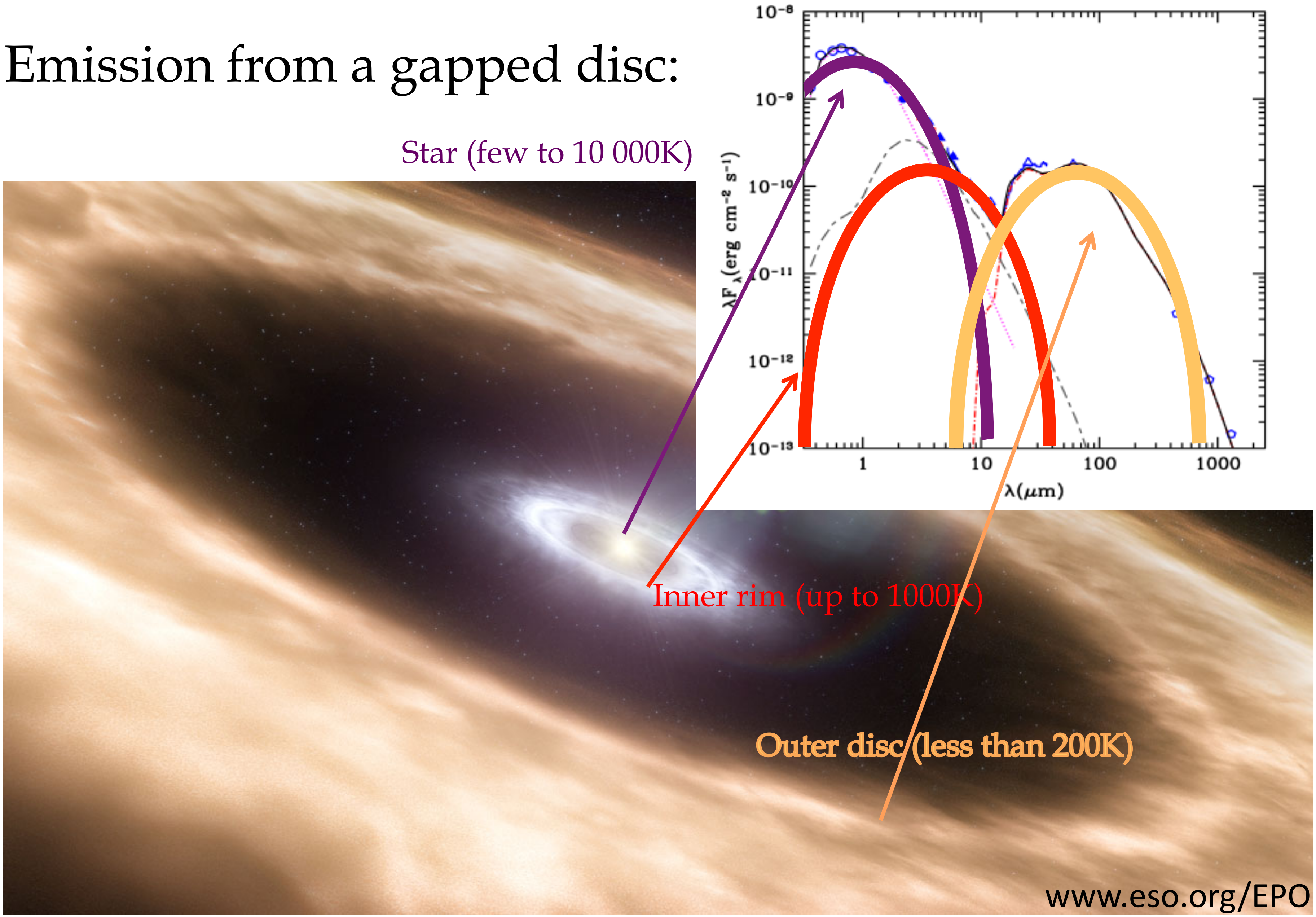


NACO:
Quanz et al. 2011



APEX:
Panić et al. 2010

Emission from a gapped disc:

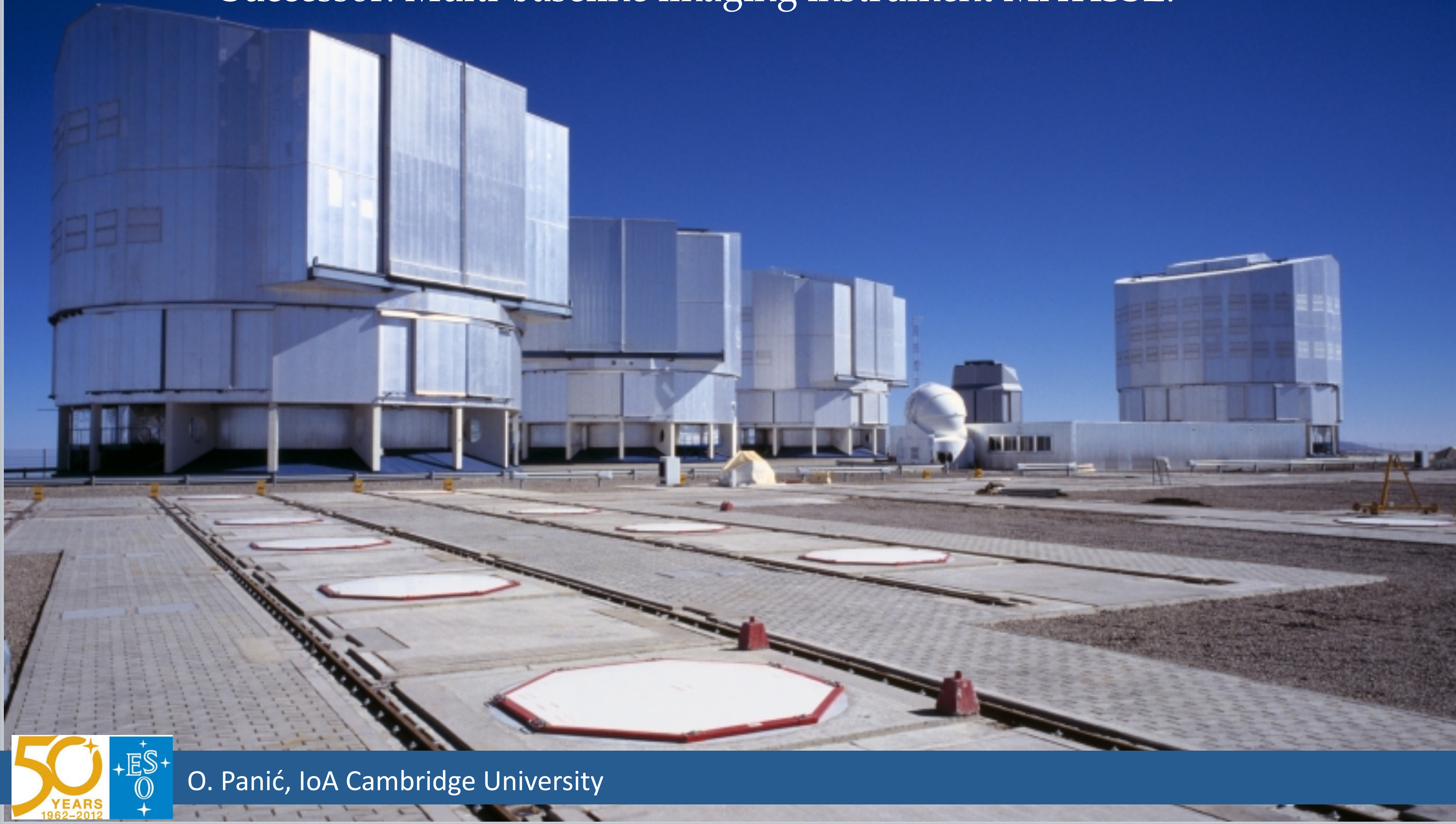


VLTI/MIDI instrument for N-band

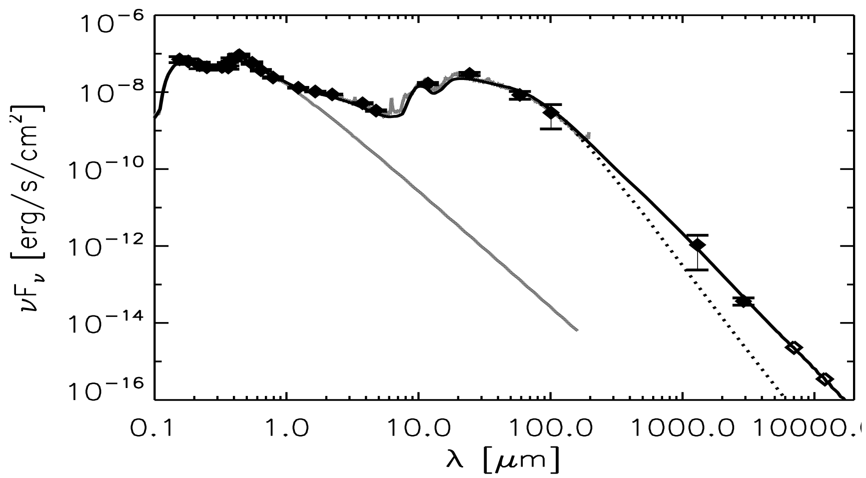
Interferes light on single baselines between UT or AT telescopes

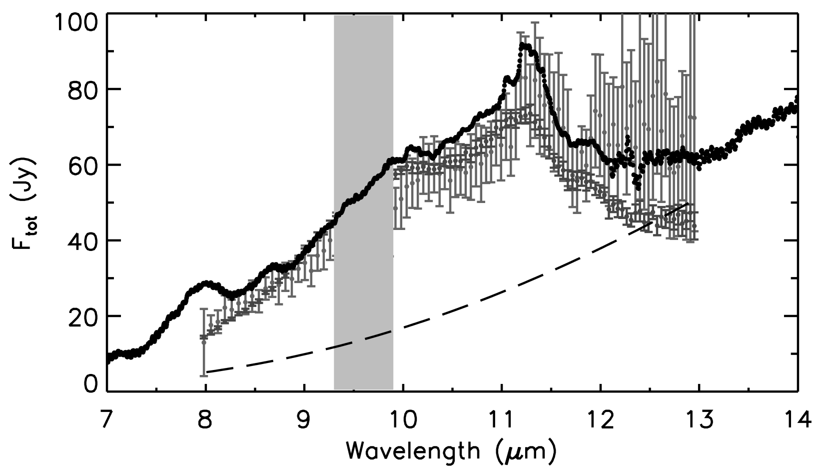
Baseline range: 10~100m.

Successor: Multi-baseline imaging instrument MATISSE.



Gapped disc around the Herbig Be star HD 100546:

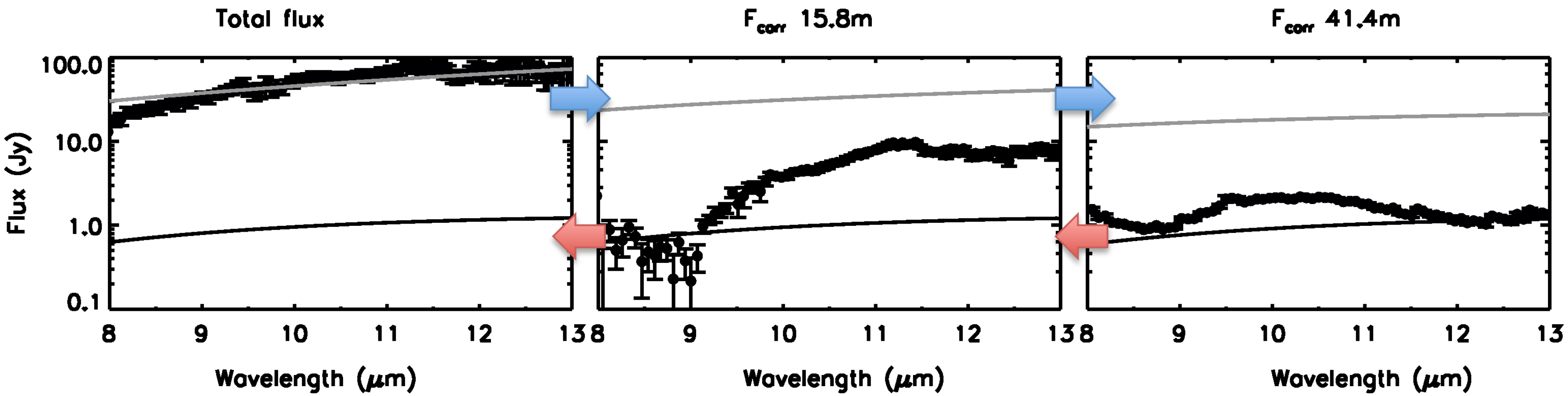




Bouwman et al. 2003, Benisty et al. 2010, Thi et al. 2010, Tatulli et al. 2011, Mulders et al. 2011, Panić et al. 2012 subm.

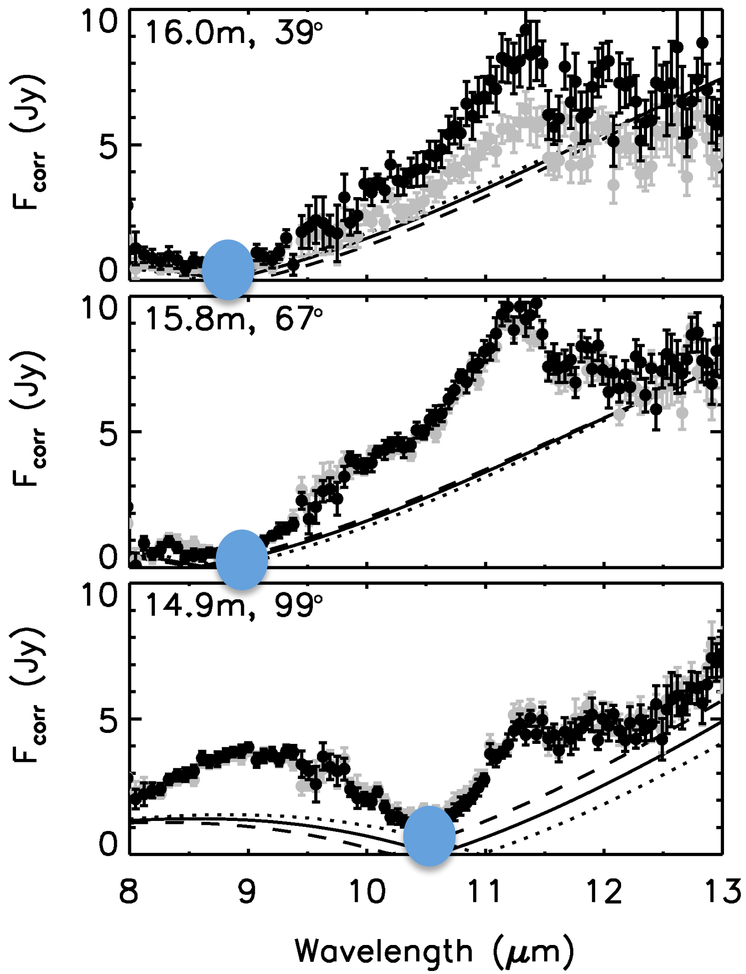
MIDI observations of HD 100546

… exclude continuous disc models,

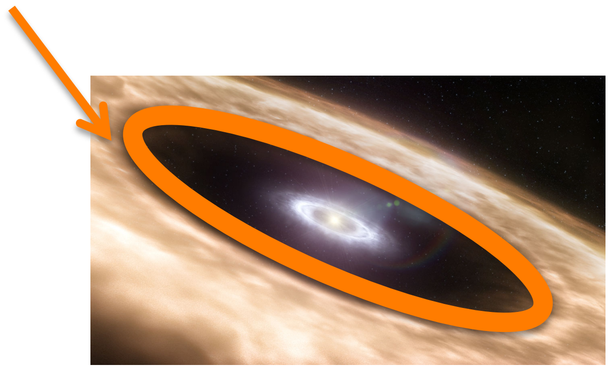


and effectively separate out the inner disc emission (~1% of total).

Correlated fluxes on 15m baselines (AT)

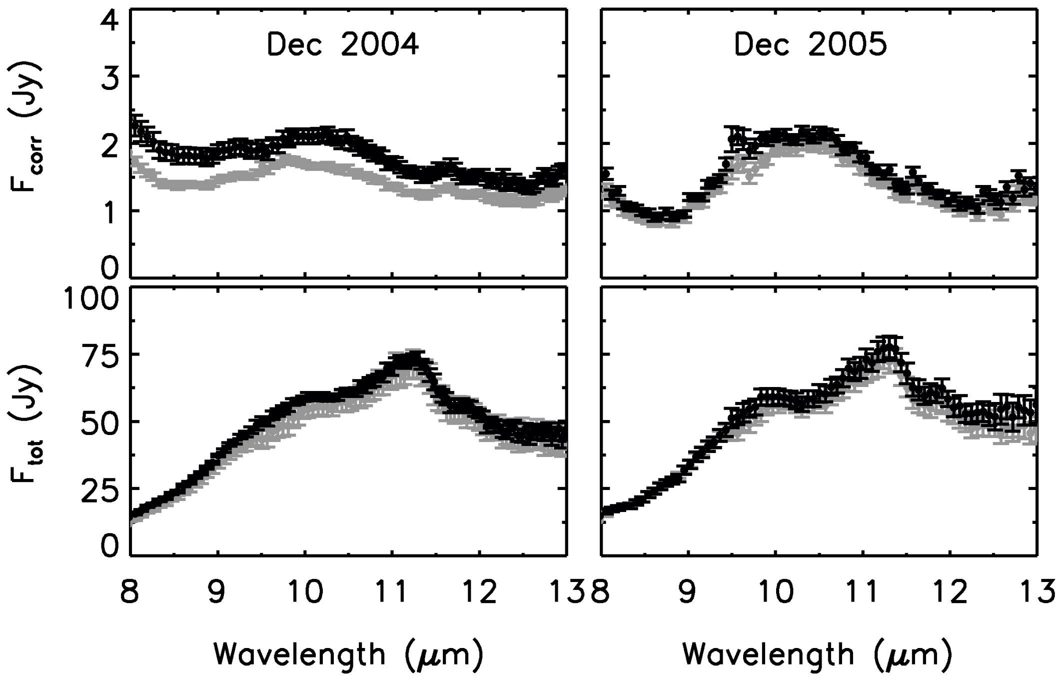


Existence of minima imply a sharp feature. This is due to the bright wall at 11AU.

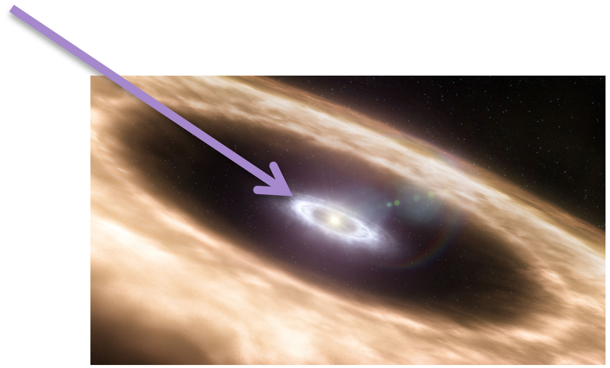


The position of the minima allow to derive disc inclination and position angle: i=53±8°, PA=145±5°.

Variability on the 40m baselines (UT)



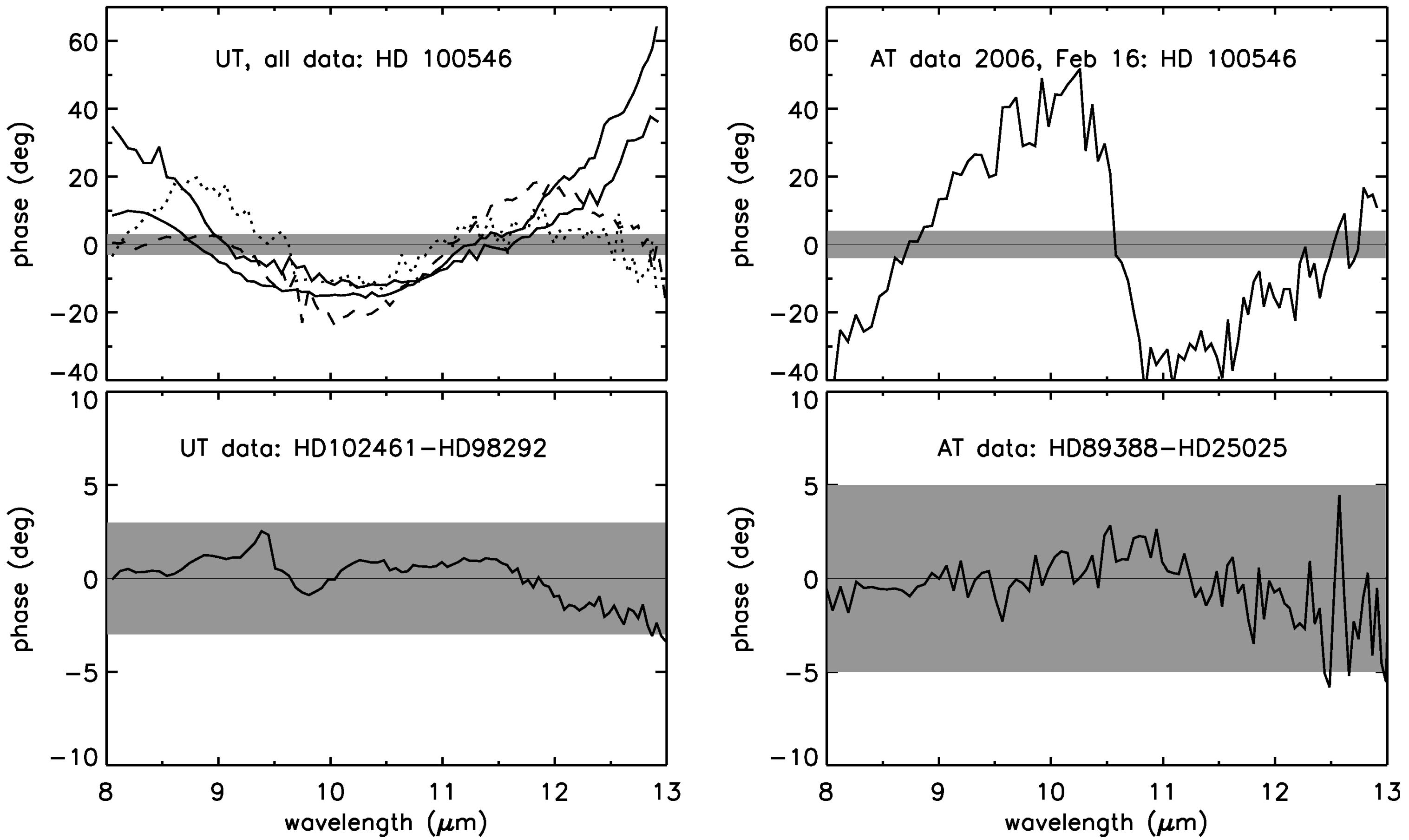
Correlated fluxes originate from the inner disc. They yield R<0.7AU.



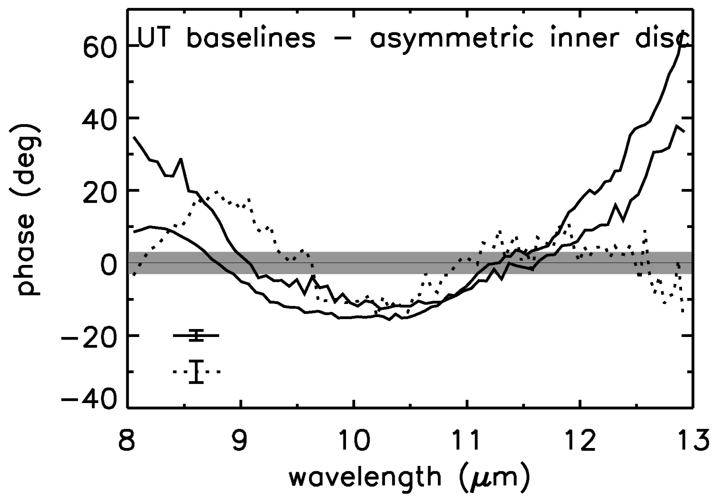
Also note:
Total fluxes do not vary with time.

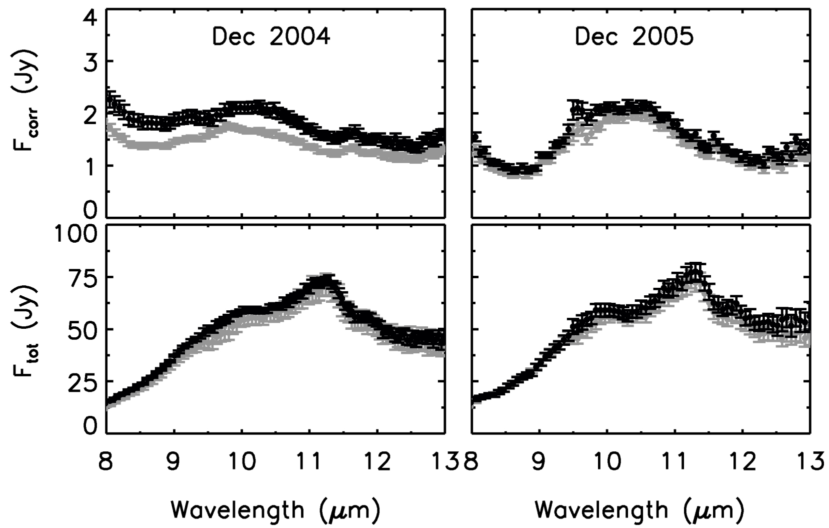
1 year is the orbital period at 1.3 AU. The inner disc (<0.7AU) CAN (r)evolve on this timescale.

Phase deviation - due to the disc and not atmosphere



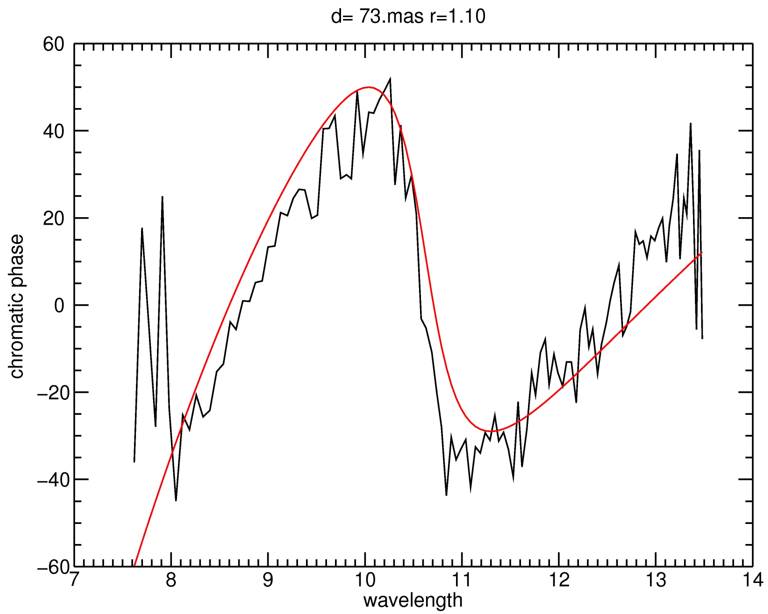
Asymmetry in the inner disc





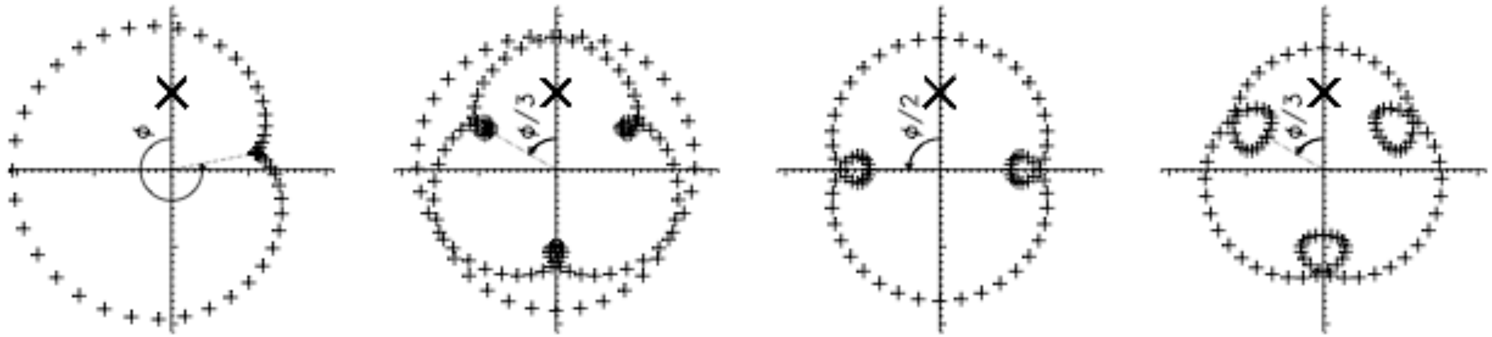
Asymmetry naturally explains variability of the correlated fluxes
– different orientations/projections of the bright structure 1 year apart.

Asymmetry in the outer disc



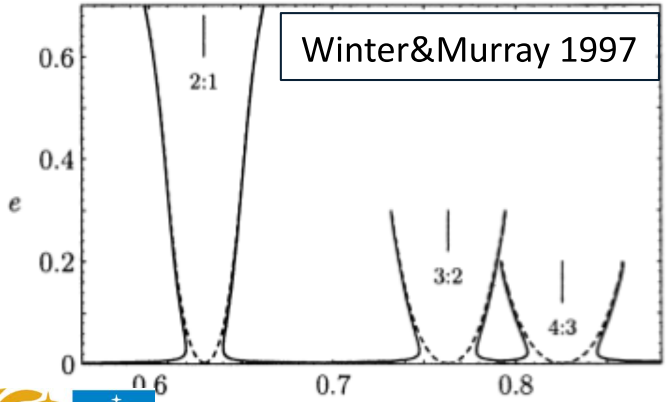
Asymmetry is also seen on short baselines (phase information) and could originate in asymmetry or eccentricity of the disc wall.

Planet as possible cause of asymmetry



2 : 1 5 : 3 3 : 2 4 : 3

Wyatt et al. 2003



Winter&Murray 1997

The 2:1 resonance is not point-symmetric, and is the most stable one.

Conclusions:

- MIDI is a valuable instrument to study symmetry and geometry of planet forming regions, e.g., HD 100546 shown here.
- MATISSE will allow much more – full imaging of these regions
- ALMA is already able to access the density and temperature of the dust at 0.2" scales (20AU), and will do even better in full operations – perfectly complementary to Paranal facilities