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Angular Differential Imaging of Disks and application to β Pictoris

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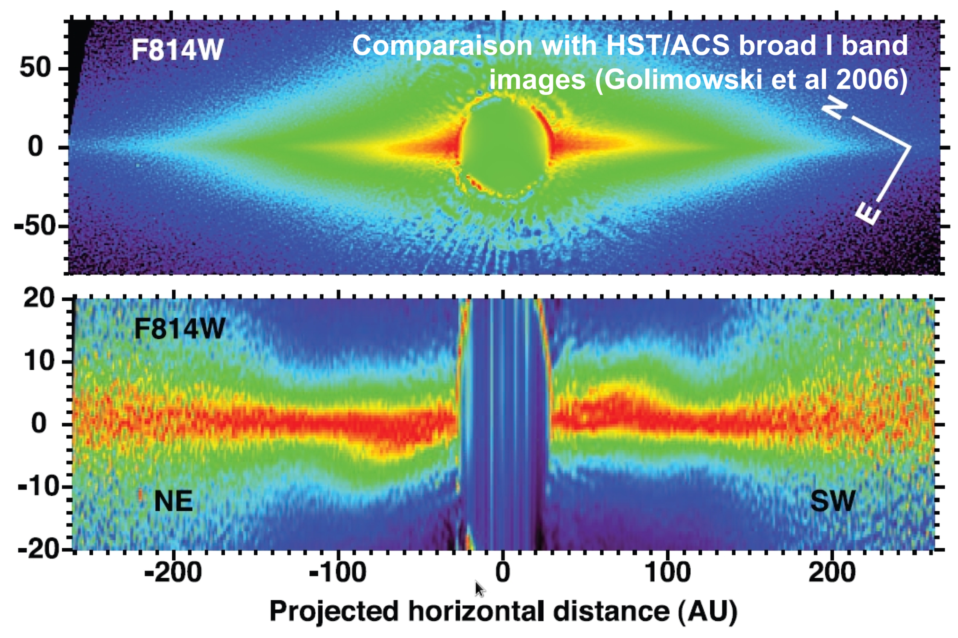
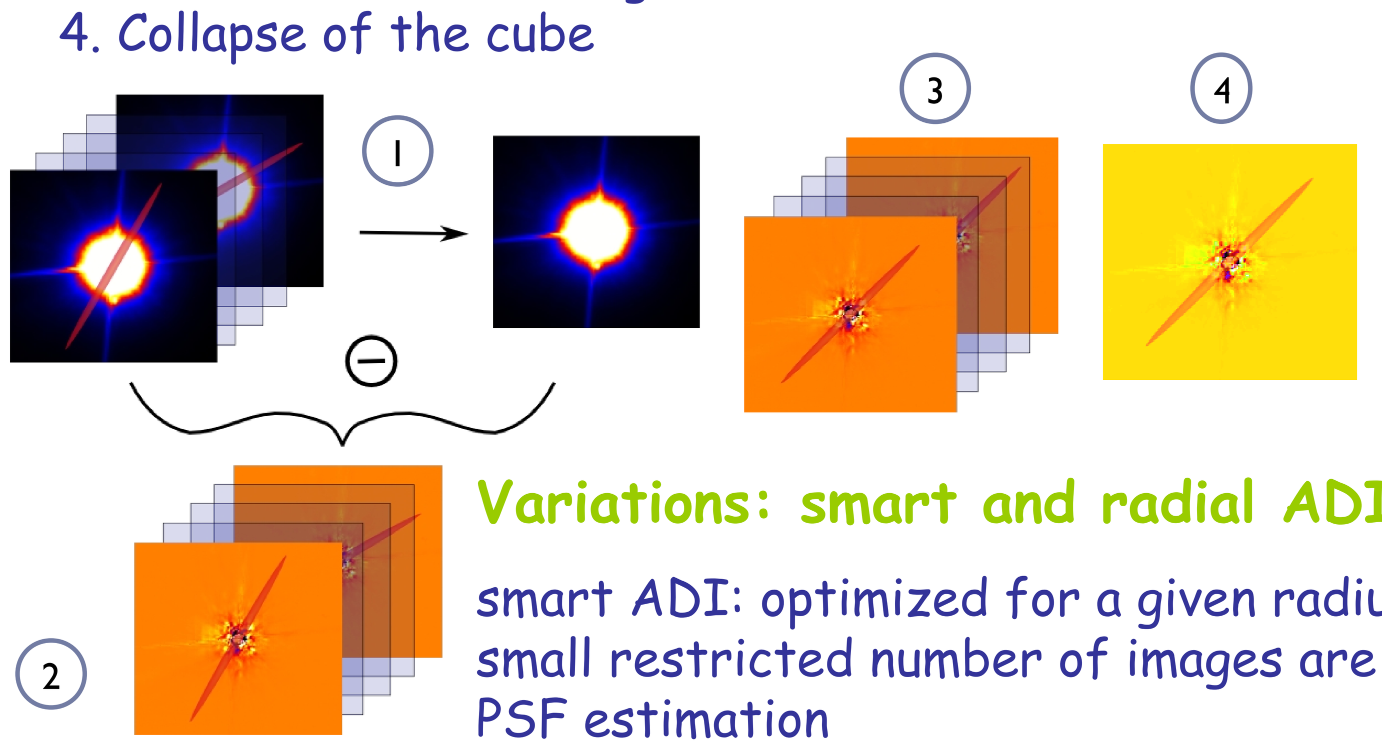


Imaging disks very close to the star, typically less than a few arcseconds, is very difficult a task. The contrast between the star and the tenuous disk is indeed high and quasi-static speckles from imperfect optics and diffraction artefacts prevail. This is however a region of great interest since it allows to study the relations between possible planets and disk structures.
In the case of point sources, an innovative way to estimate and subtract the stellar flux has been designed: Angular Differential Imaging (hereafter ADI) used in pupil- stabilized observing mode (Marois et al 2005). When applied to extended structures such as disks, it induces biases since the disk contaminates the point-spread function estimated in the ADI procedure.

Classic ADI in 4 steps

1. PSF estimation (mean or median combination)
2. PSF-subtraction to all images
3. De-rotation of all images
4. Collapse of the cube



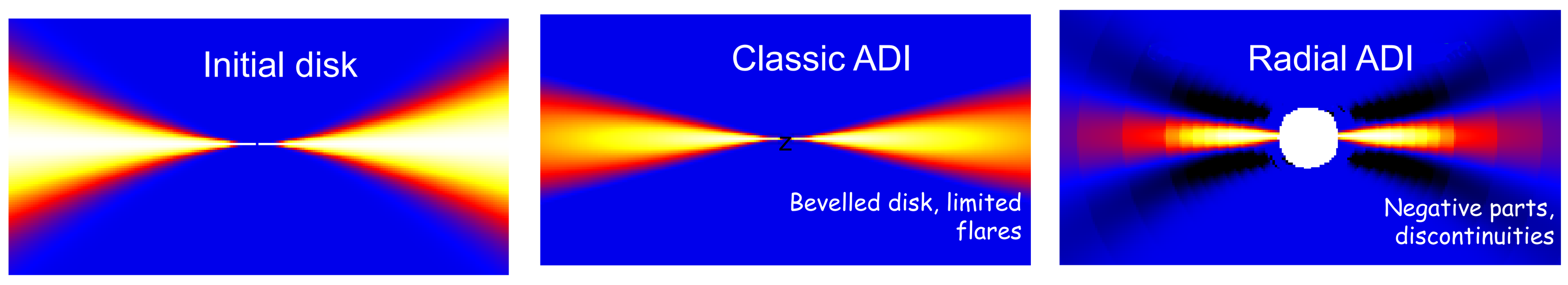
Variations: smart and radial ADI

smart ADI: optimized for a given radius, only a small restricted number of images are used for PSF estimation

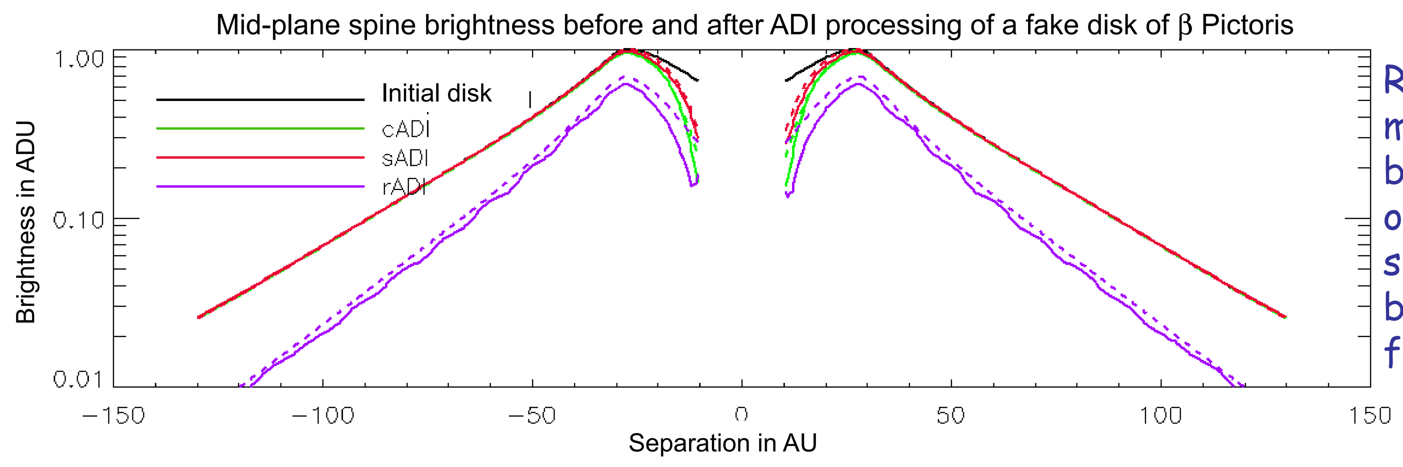
radial ADI: optimized for all radii, the PSF is evaluated in concentric rings

Key parameter: **Scale height of the disk vs amplitude of field rotation**. Flux losses due to disk self subtraction can be quantified using this key parameter.

Bias induced on a disk seen edge-on: self-subtraction

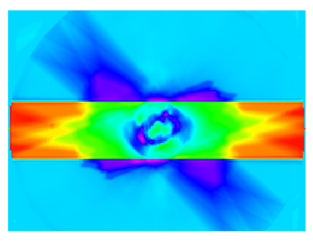


Edge-on disk	Restitution after classic-/smart-ADI	Restitution after radial ADI
Mid-plane centroïd positions	+ +	+
Mid-plane brightness	++ (if scale height < field rotation/2)	+ (if scale height < sep. criteria/2)
Scale height	- (can be accounted for, if no flux loss in the midplane)	- -



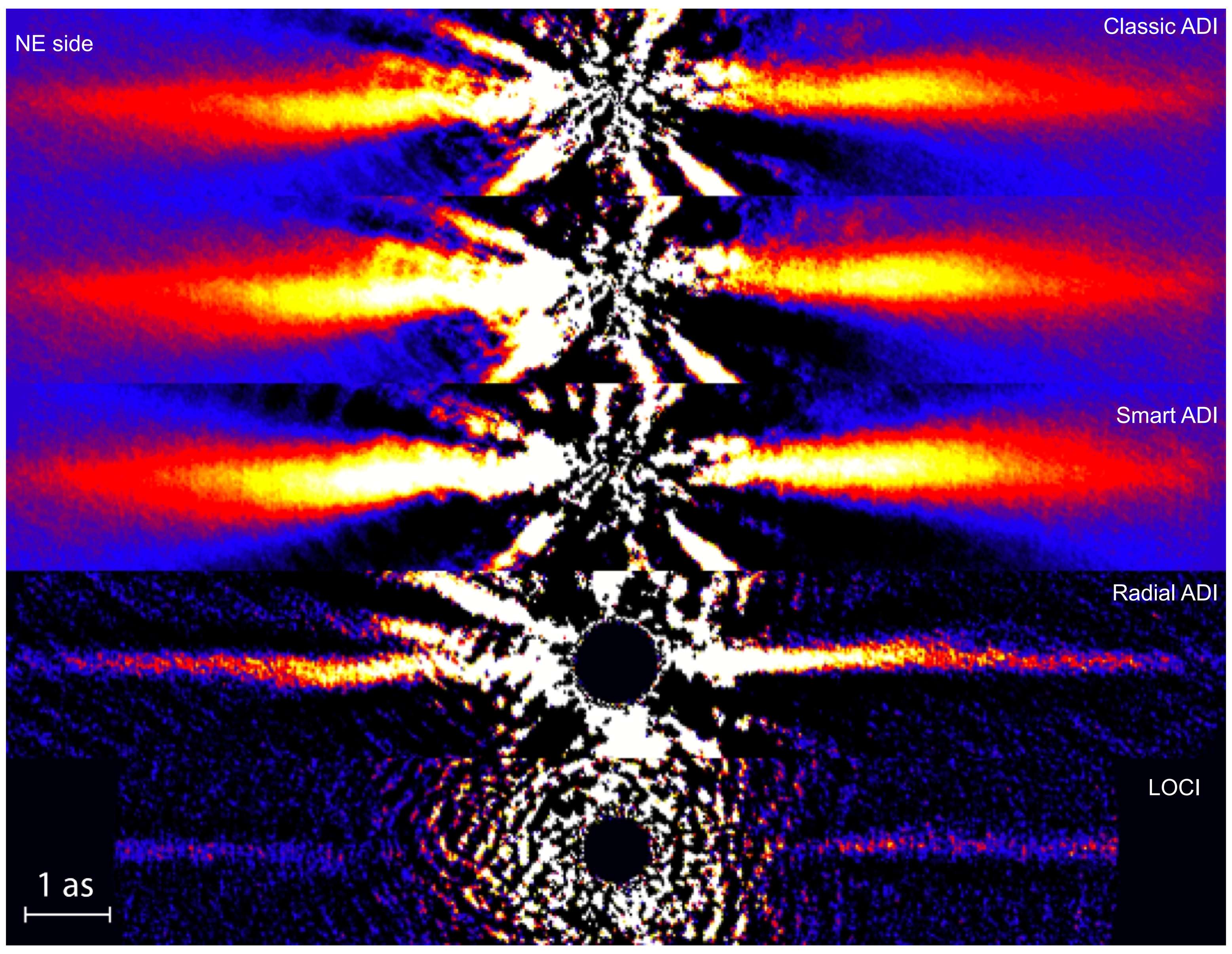
Radial ADI affect the most the radial brightness distribution of the disk. Classic and smart ADI are unbiased beyond 30 AU for a 35° field rotation.

Other biases: artificial structures created by position angle (PA) discontinuities or non-uniform PA evolution rate during the observing sequence



Probing the geometry of the β Pictoris disk with ADI

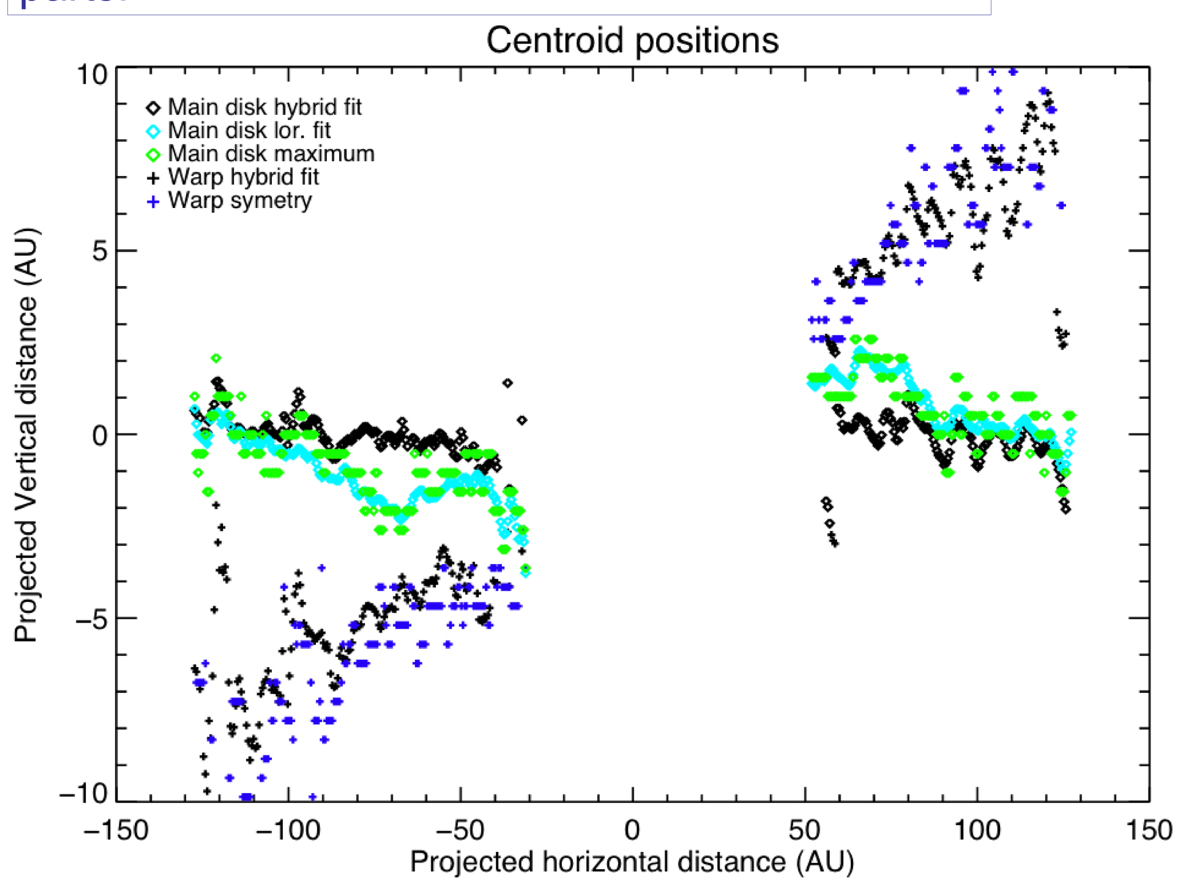
ADI has been successfully applied to the disk of β Pictoris to refine the structure of the disk and set constraints on the planet position relative to the disk (Lagrange et al 2011, submitted).



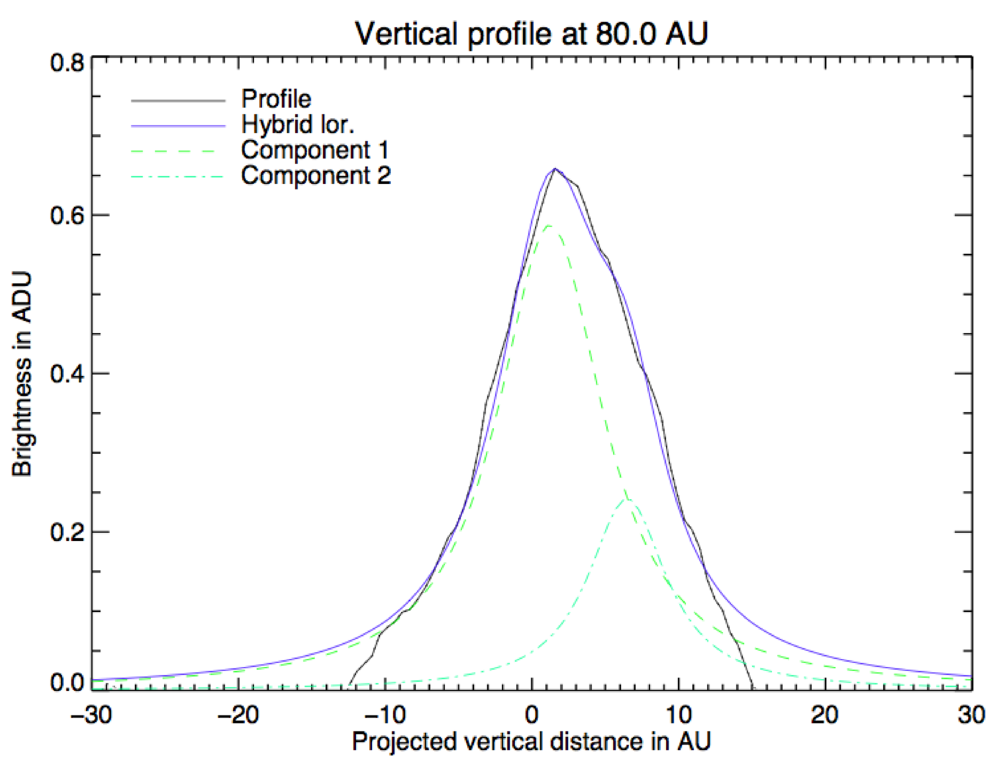
ADI images of β Pictoris in Ks band (2,2μm) with NACO/VLT. ADI reduction affects the geometry of the disk so accounting for biases is required to measure the geometry, ie the inclination of the 2 components of the disk

The object:
A5V star, 19,3pc, ~12Myrs
Planet detected, 8<a<15 AU, ~9M_{jup},(Lagrange et al 2009)
Disk detected with HST and ground-based AO systems (eg Mouillet et al 2009, Heap et al 2000, Golimowski et al 2006, Boccaletti et al 2009)
Peculiarities: warping of the inner part of the disk (r<80AU), asymmetries observed in external parts.

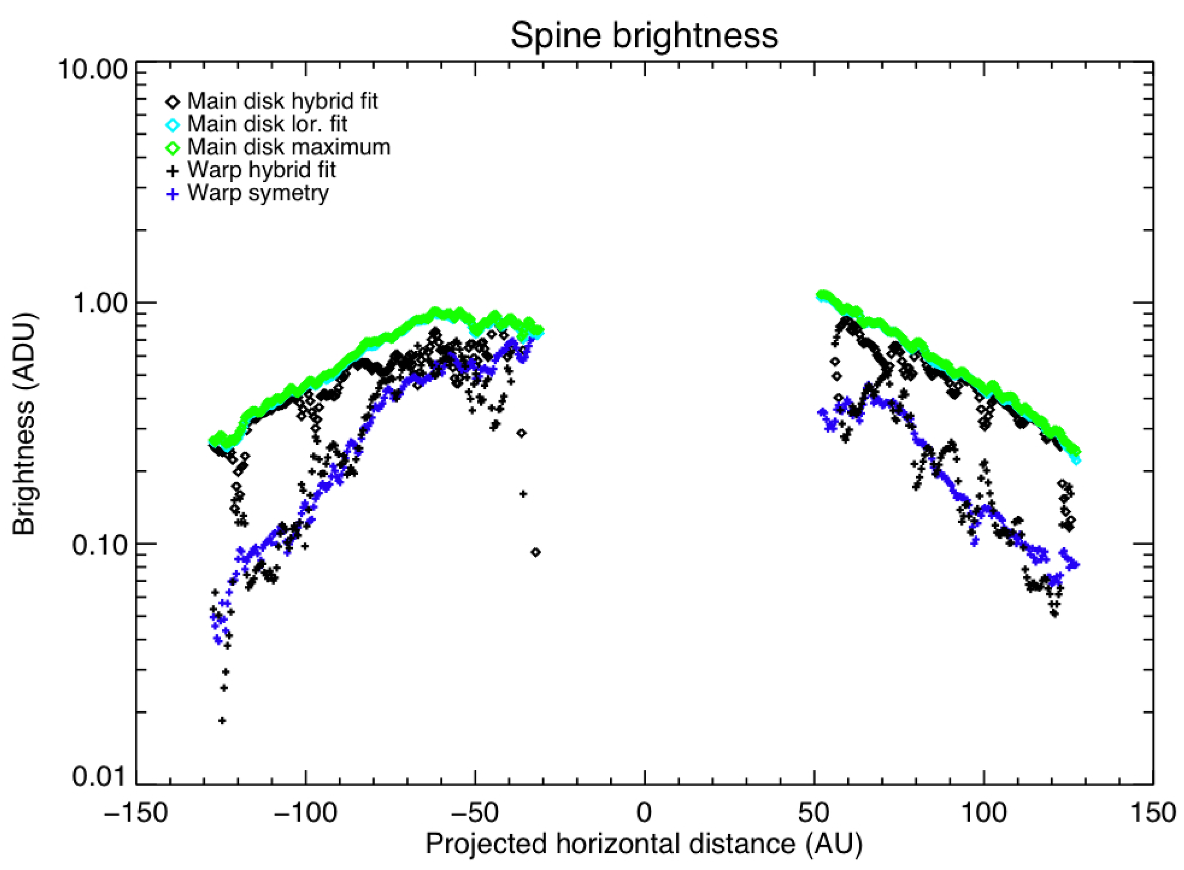
Analysis of images:
Disk detected up to 7" (entire FoV), no brightness asymmetry for r>2"
Disk PA measured (NE/SW) : 29.07/209.00 $\pm$0.2
Relative warped component inclination: ~4,5°



The inclination of the warped component of the disk (crosses) relative to the main component (circles) is computed using a hybrid lorentzian fit along the vertical profiles of the disk (see below) and a symmetrisation method.



Fit of a hybrid lorentzian function on a vertical profile to define the spine of the main and warped components of the disk.



- The spine brightness of the warped component significantly decreases beyond 80 AU.
- It turns out difficult to separate the warped and main component spine brightness at r<60UA for both methods →
How relevant is a 2-disk model vs a continuous dust distribution?
- The spine brightness on NE side plateaus around 50AU.
Is it a clue for an inner cavity or an artefact?