PERSEE & hyperspectral imaging

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B. Lopez, J.-L. Menut, A. Marcotto, P.
Girard, etc, etc.

LAGRANGE

Observatoire de la CÔTE d'AZUR

Thèse « Imagerie hyperspectrale / PERSÉE »

- Objectifs
  - Structure spatio-spectrale de la lumière exo-zodiacale
    - Détectabilité d'exoplanètes
    - Informations sur la formation planétaire
  - Imagerie hyperspectrale
    (grande couverture spectrale et peu de télescopes)
  - Potentiel et performances des modes d'un interféromètre spatial « simplifié »
  - Validation en laboratoire sur le banc PERSÉE
    - Utilisation de la source complexe étoile + planète + exozodi
    - Introduction dans PERSÉE des pertubations modélisées de FKSI
- Sujet pré-séléctionné par le CNES en 2011, 2012
- Co-financement CNES / OCA

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The PhD thesis

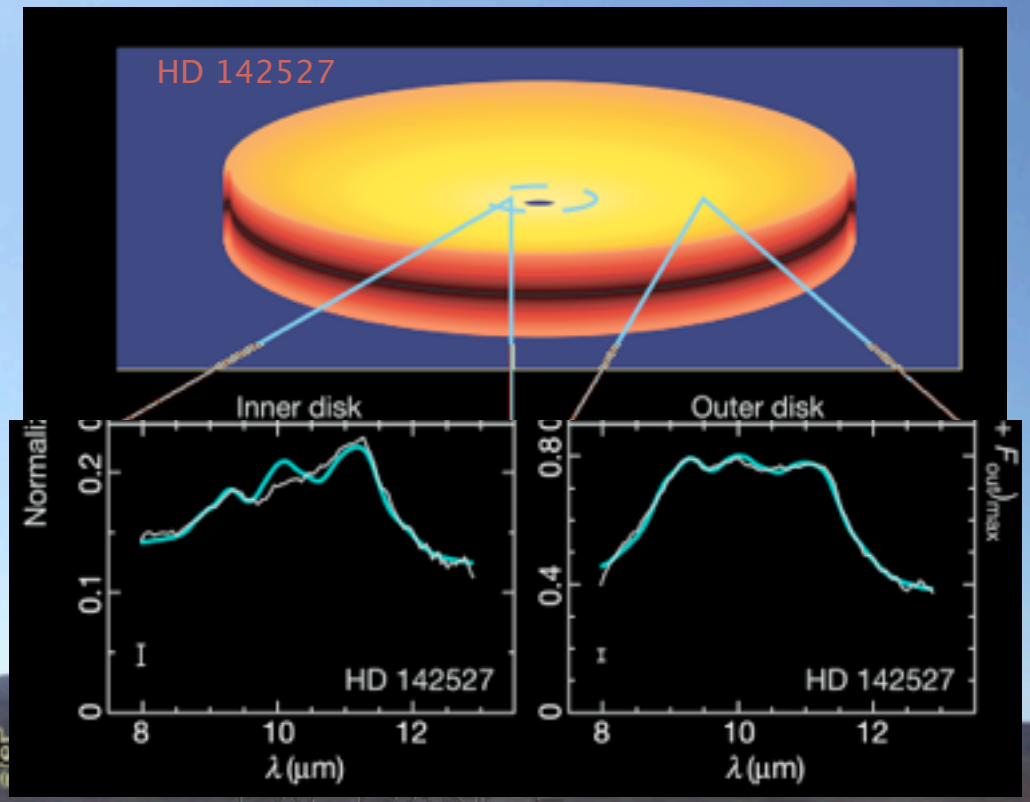
- Hyper(spectral)
  - Create abundance maps of components in a given system
- (Hyper)spectral
  - Use of spectral information to fill the UV coordinates + gain in « image » quality.
- Imaging
  - A nuller is an interferometer: it can potentially get images of the source. What are the nuller limits to get an actual « image »?
- Exozodis
  - we are not interested by point-sources only! The idea is to be able to reconstruct maps of the zodis & potential inhomogeneities.

Space interferometry: detection & characterization of exoplanets

- Space missions horizon 2020-2030
  - DARWIN, TPF-I, objectifs extrêmement ambitieux
    - Extinction étoile centrale $<10^{-6}$ dans l'infrarouge thermique (6-20 μm)
    - Égalisation des OPD à mieux que 1 nm
- Précurseurs
  - PEGASE
  - FKSI

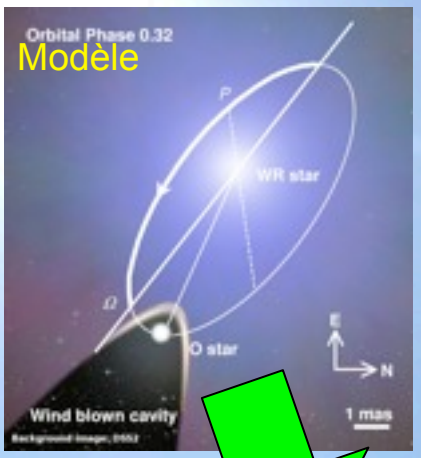
Examples of hyperspectral analysis with interferometry

- Characteristic features in the spectrum
  - @2μm: Hydrogen / metallic lines + CO lines
  - @10μm: Silicates dust features

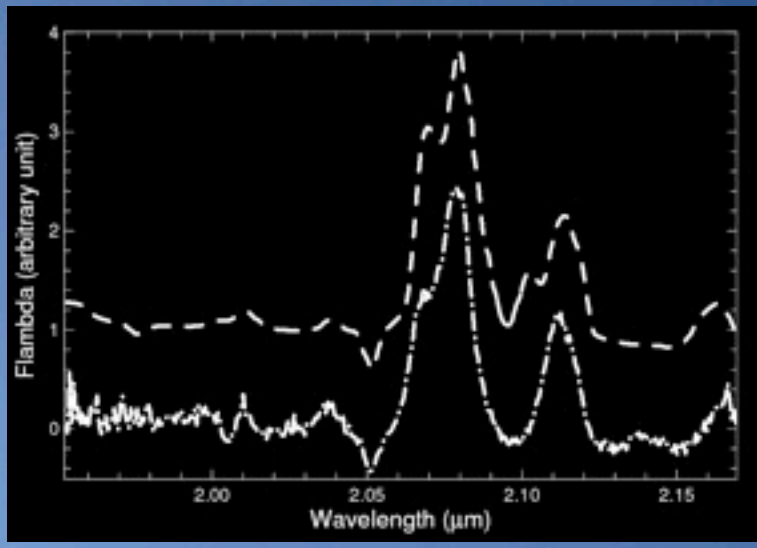


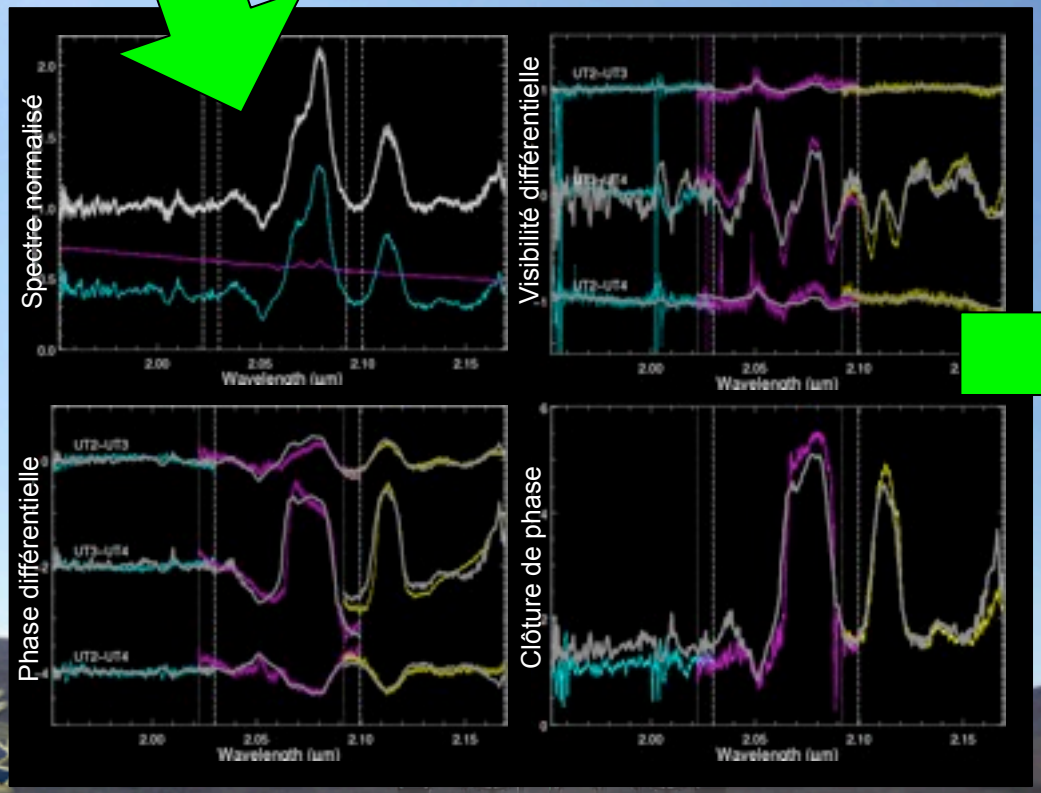
Van Boekel et al. 2004

Hyperspectral analysis of γ^2 Vel (2)



Étoile WR + O
+
Collision vent-vent
+
Poussière ?



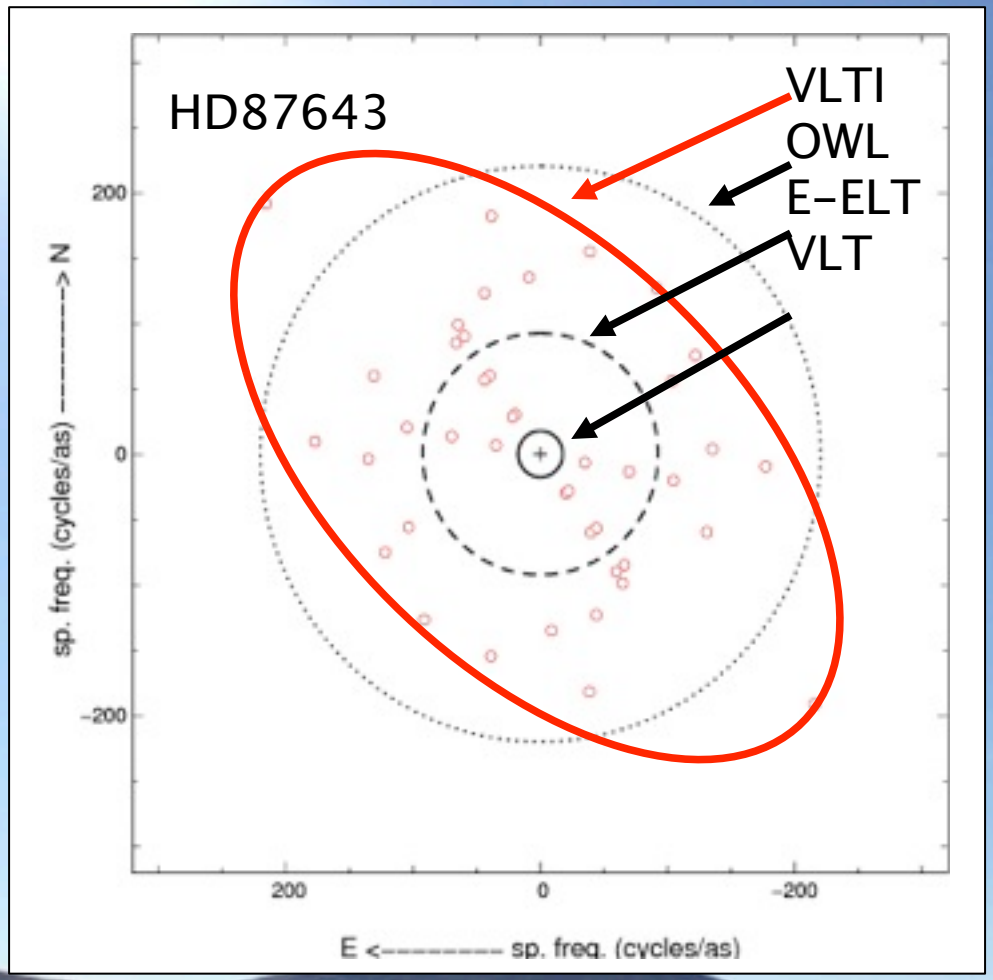


Séparation des spectres
+
Détection
3ème structure ?
+
Mesure astrométrique

$D_{AMBER} = 368^{+38}_{-13} pc$

$D_{hipparcos} =$

Complex structures: imaging



- Inner circle = **VLT today** (NACO ~ 1-2 **hours**)
- Dashed circle = **E-ELT** (42m). (1 hour?, ready in 5? years)
- Dotted circle = **OWL** (100m) (Not available)
- Red dots = **AMBER today** (1.5 **nights)**

Main characteristics:

- Low efficiency
- Low limiting magnitude
- « weak-phase » interferometry

Aperture synthesis

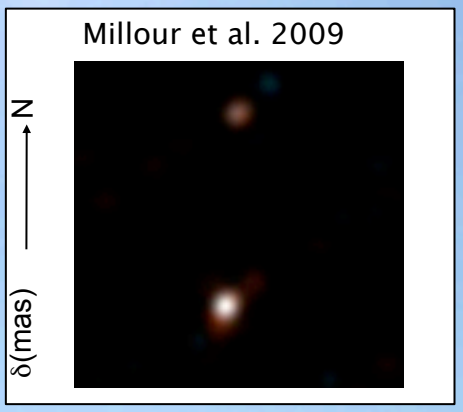
- **Squared visibiity (V^2)**
- If N_{tel}>3
  Phase closure

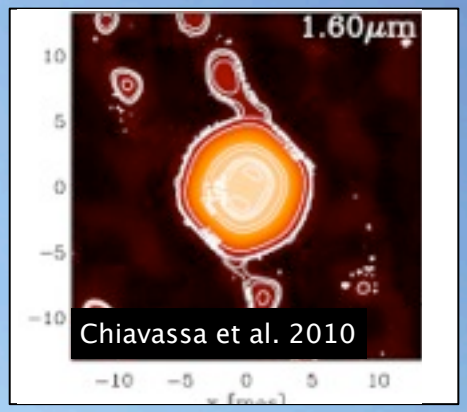
If spectrograph
Spectrum,
Différential phase,
Différential visibility

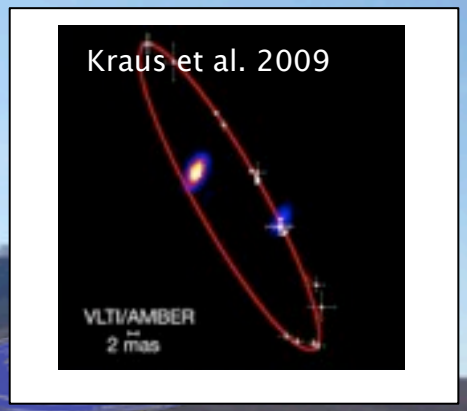
If N_{tel} > 4
Closure amplitude

If UV plane well sampled
Imaging

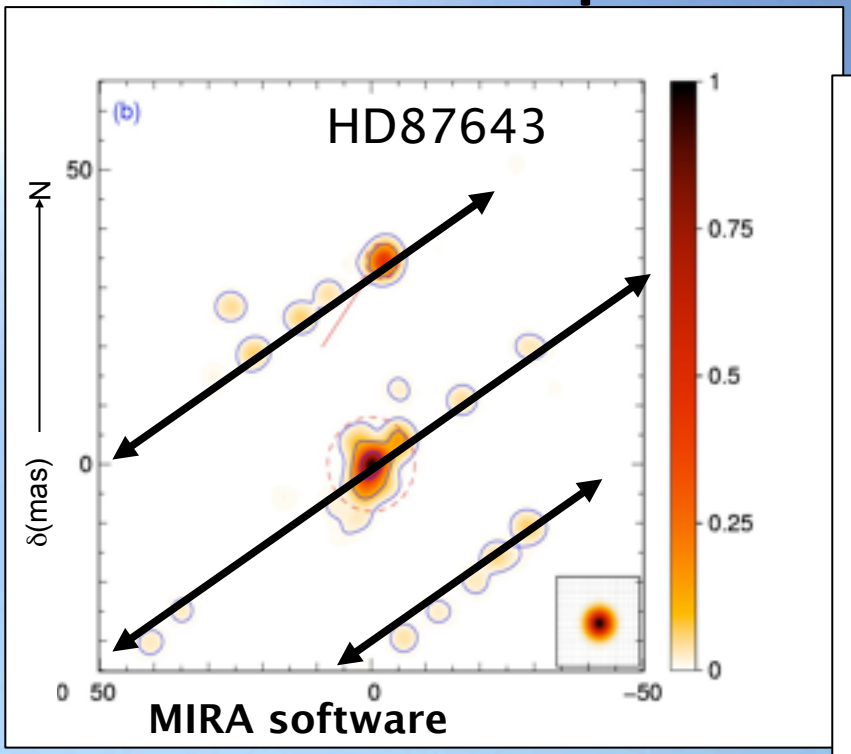
If many telescopes, phase reference
Direct imaging

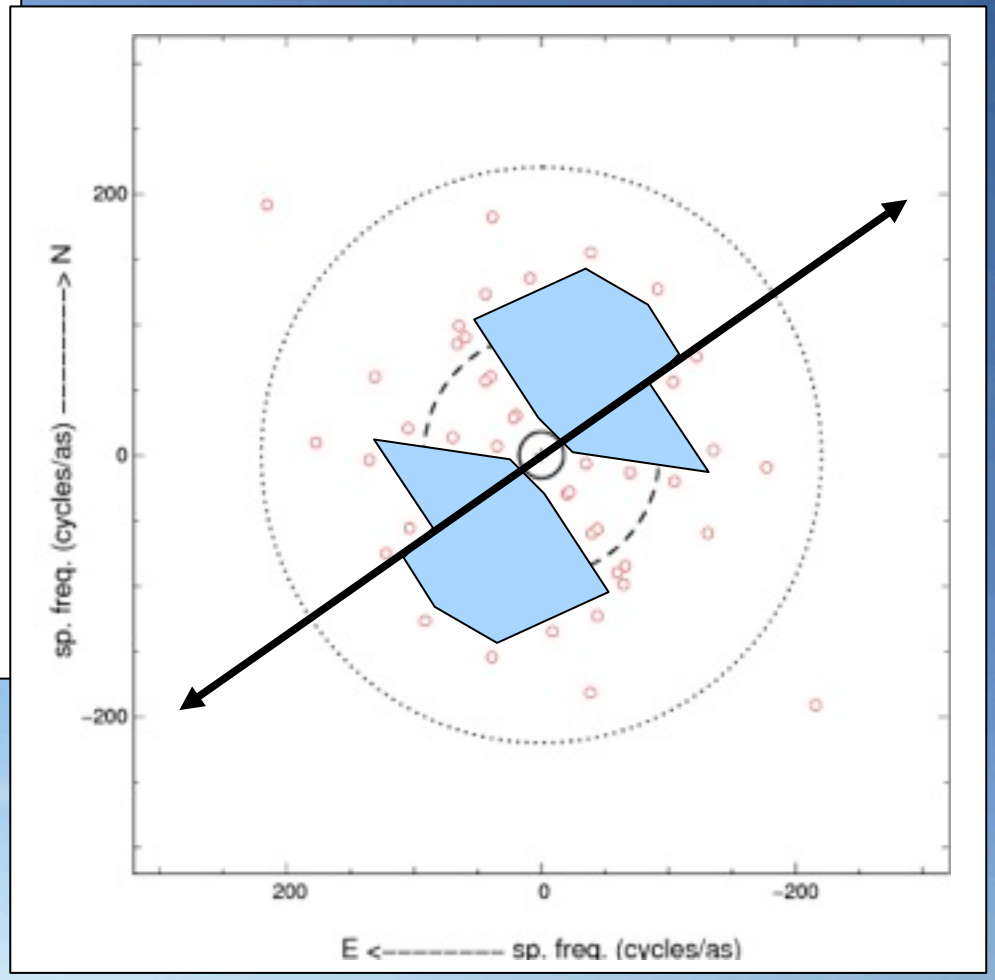






Aperture synthesis





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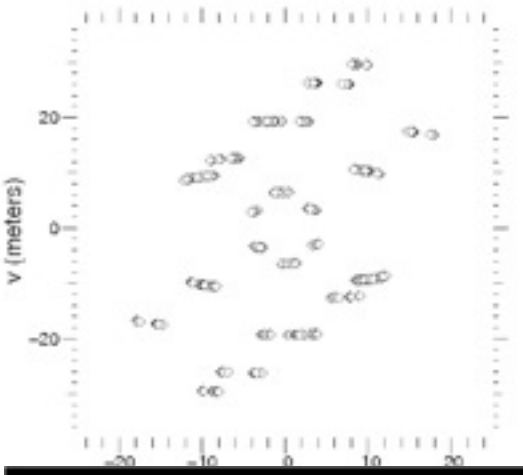
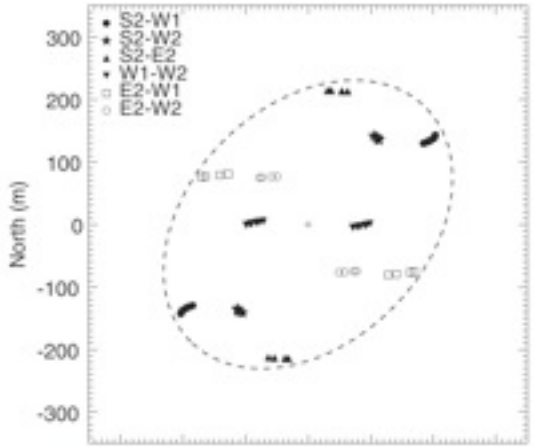
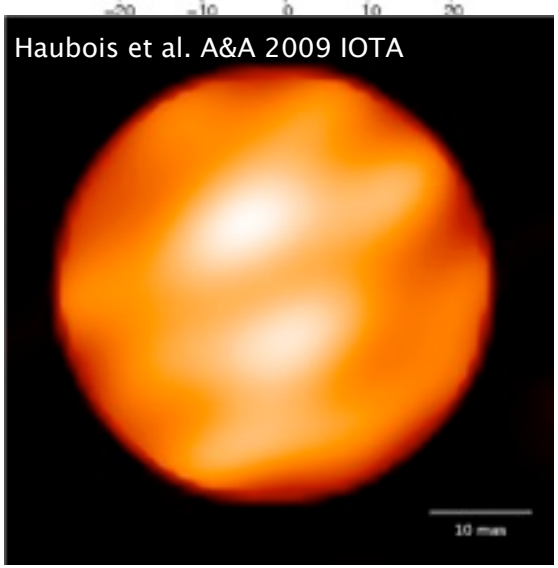
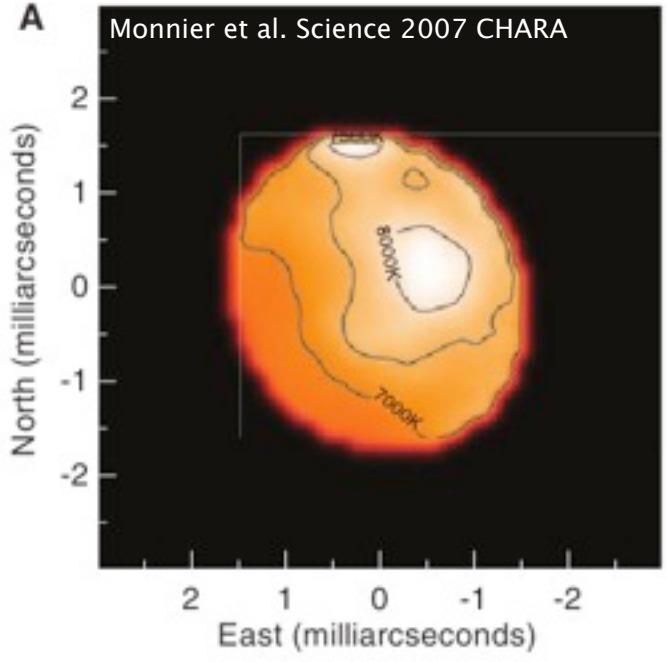
Improving image quality: limiting the

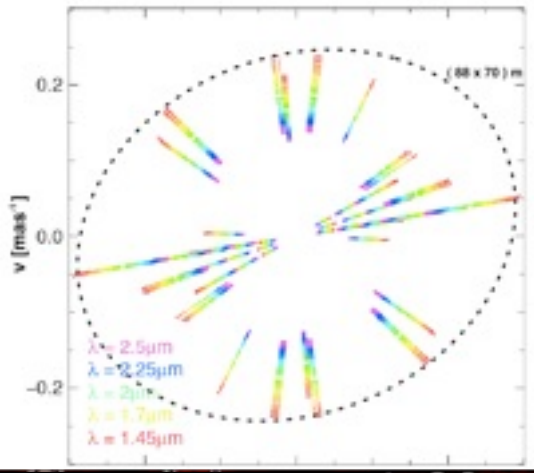


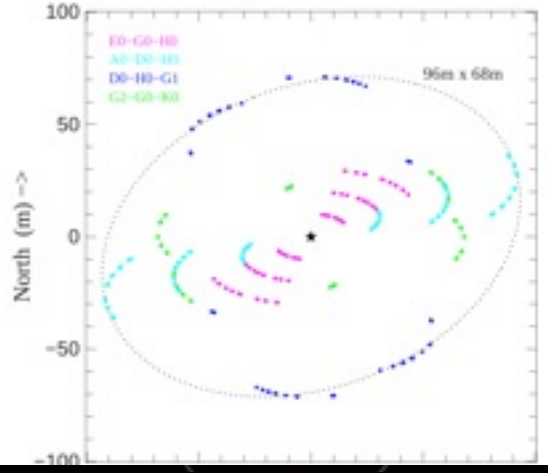




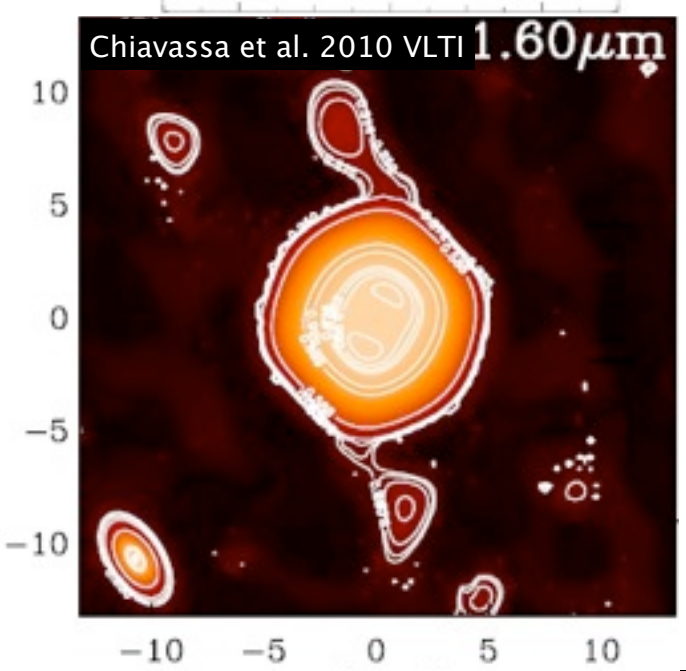


Improving image quality: using symmetries

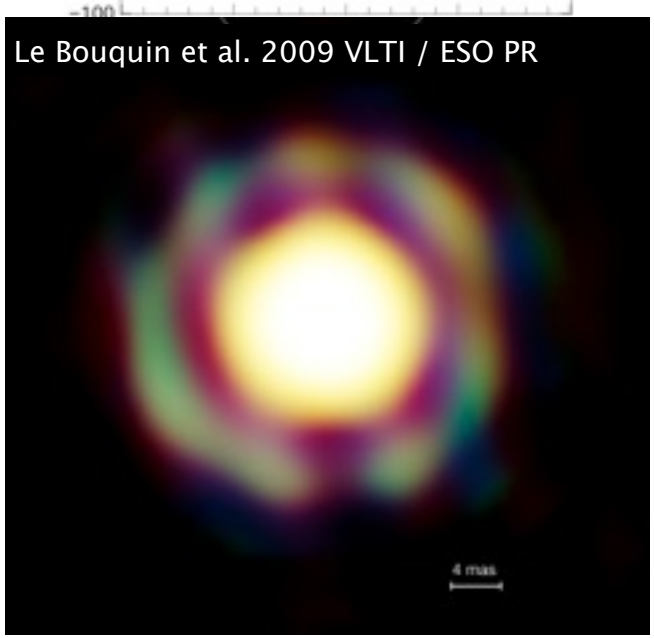




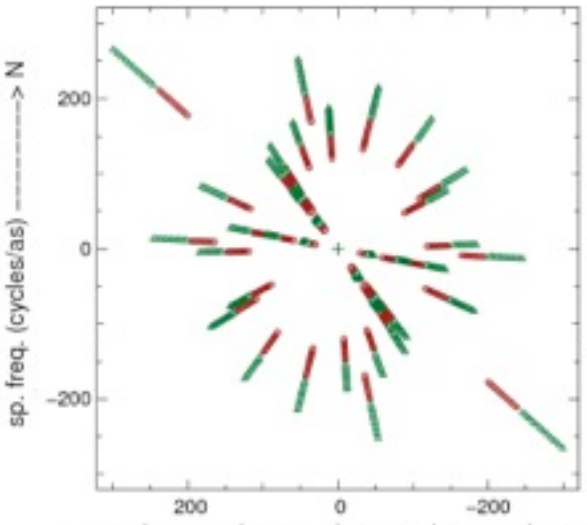
Chiavassa et al. 2010 VLTI

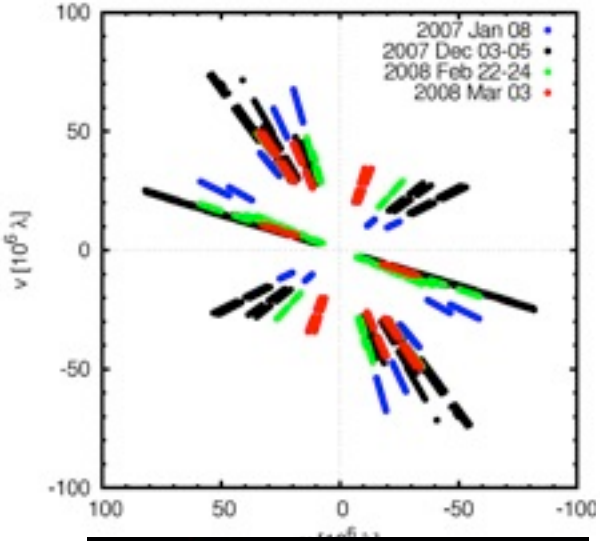


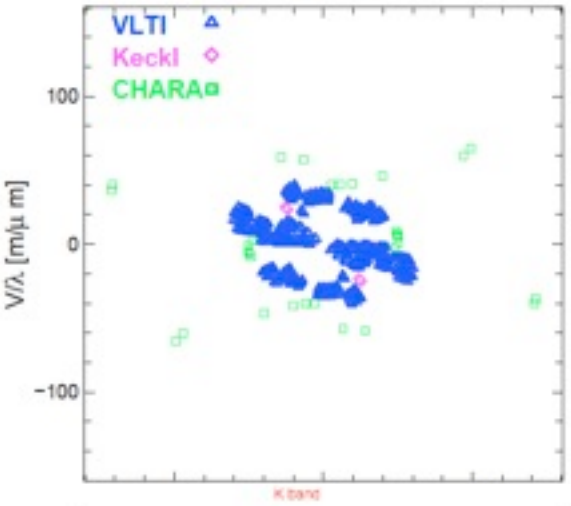
Le Bouquin et al. 2009 VLTI / ESO PR

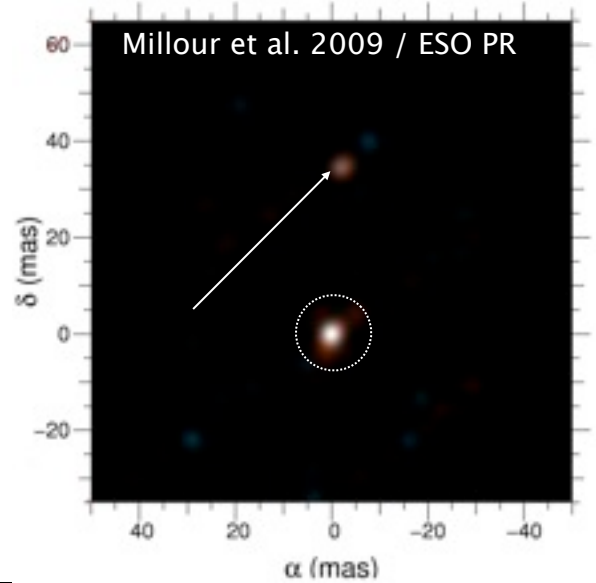


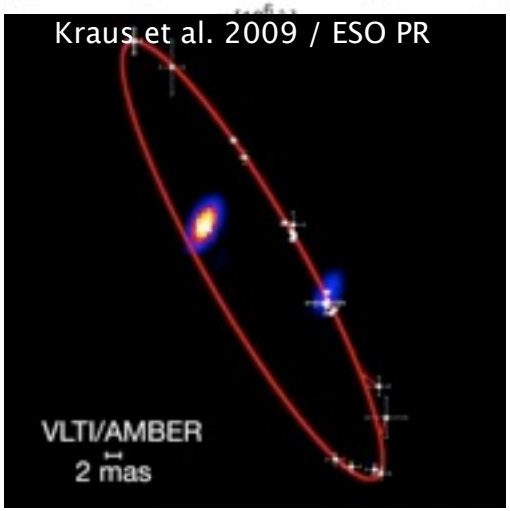
Improving image quality: Using spectral coverage

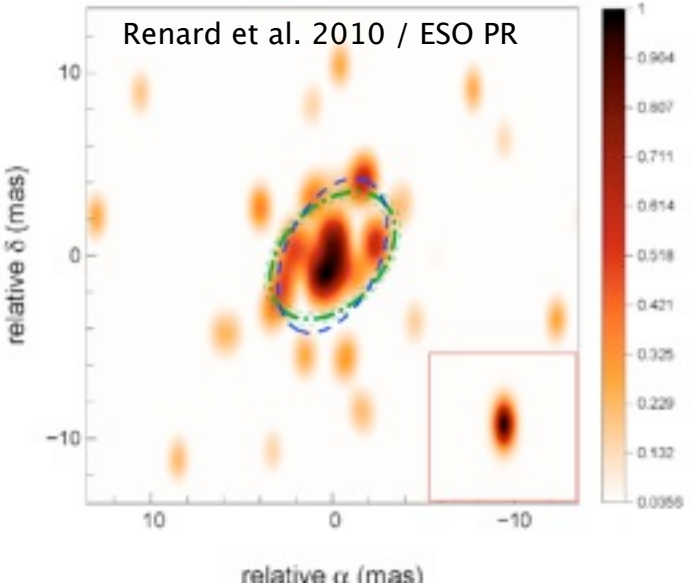




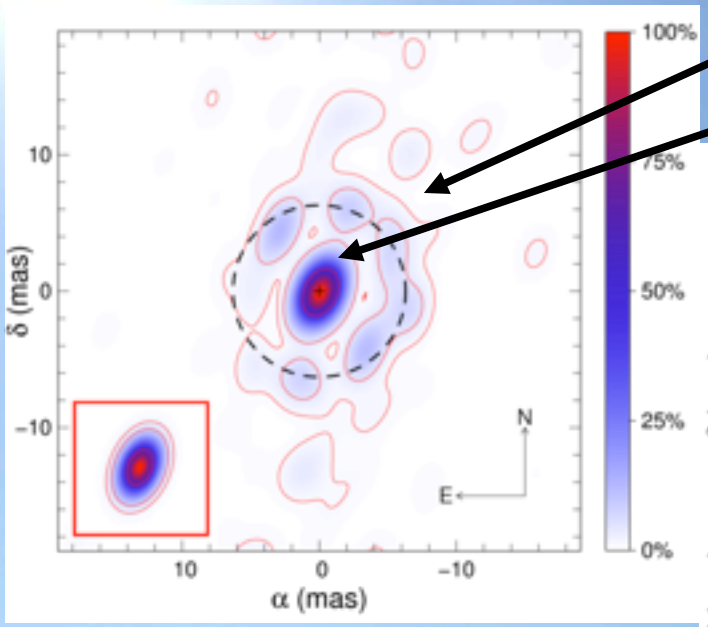






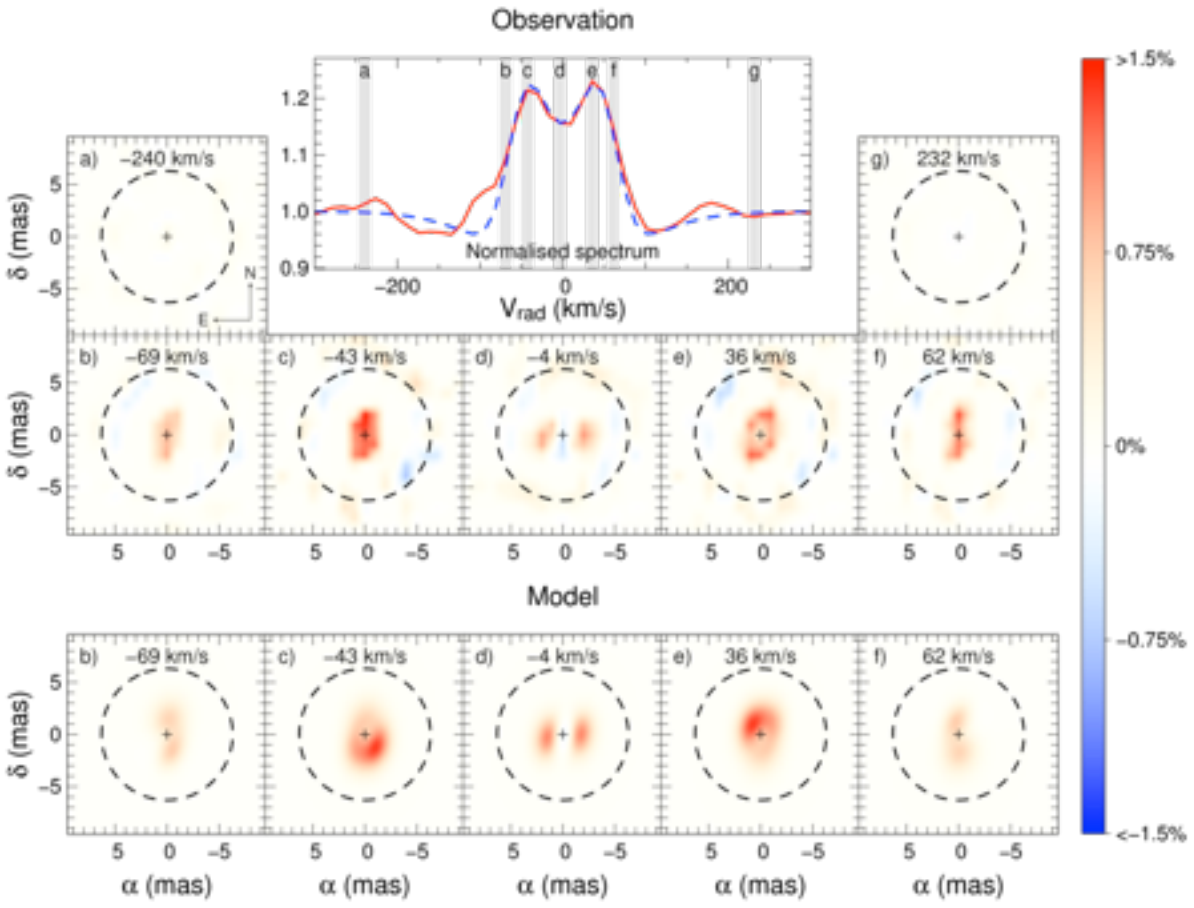


Improving image quality: Using spectral information



- Dust (sublimation inner rim)
- Gaz (rotating disk near the star)

Detection of gaz and dust in the system



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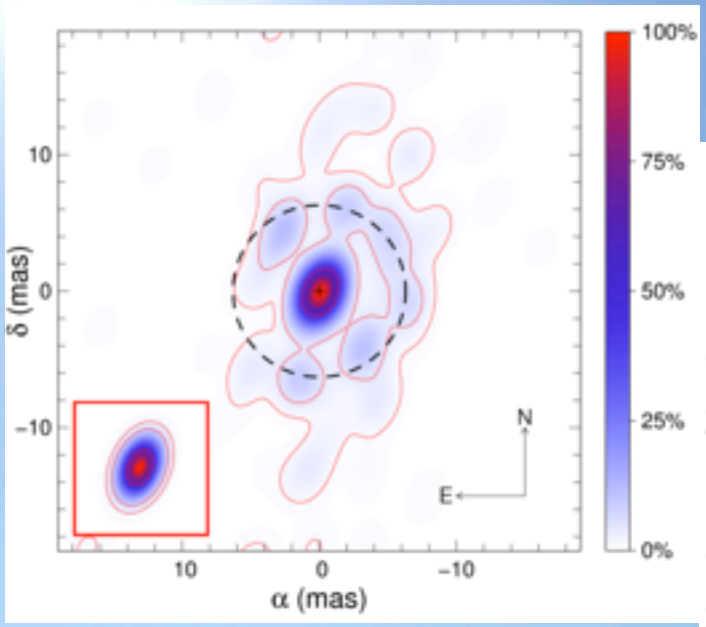
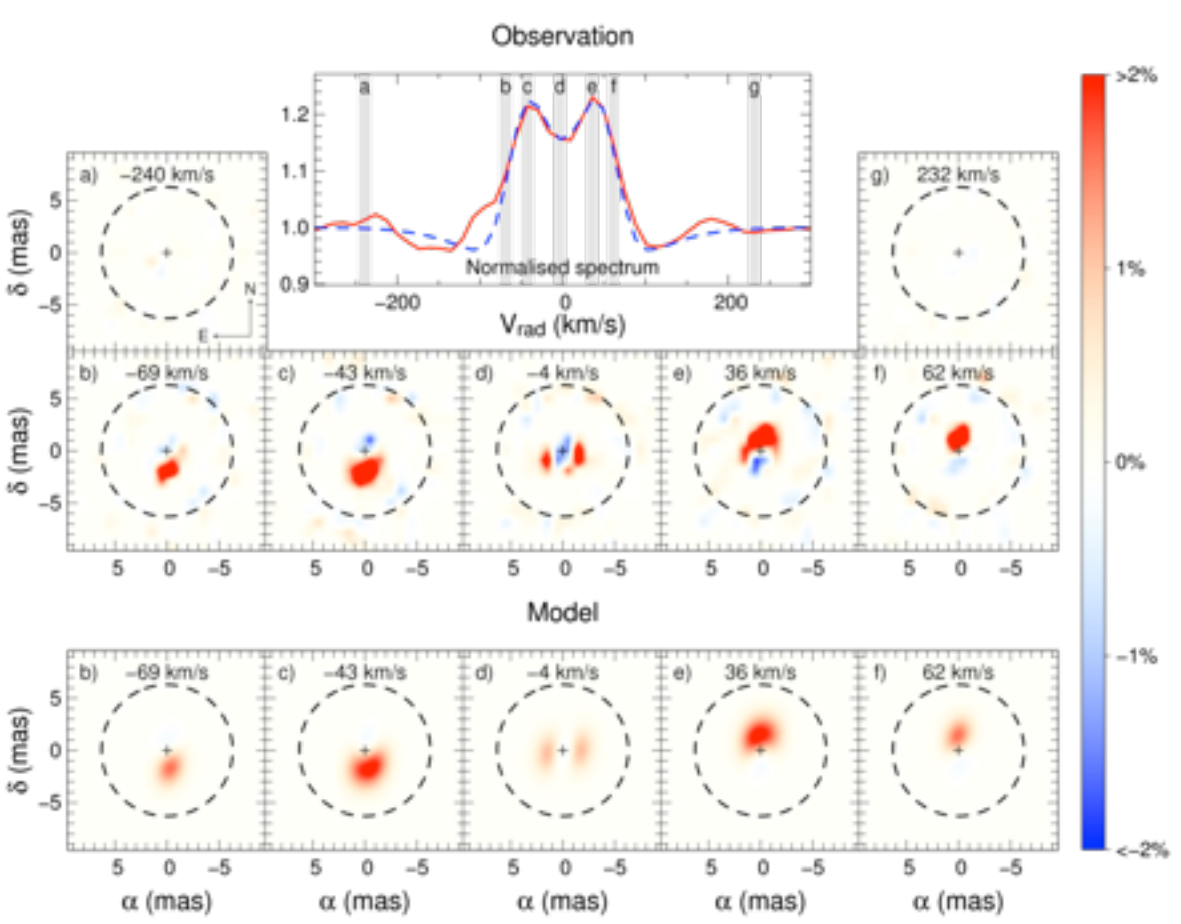


Gaz and dust kinematics

"self-cal" : differential phases taken into account in image restoration

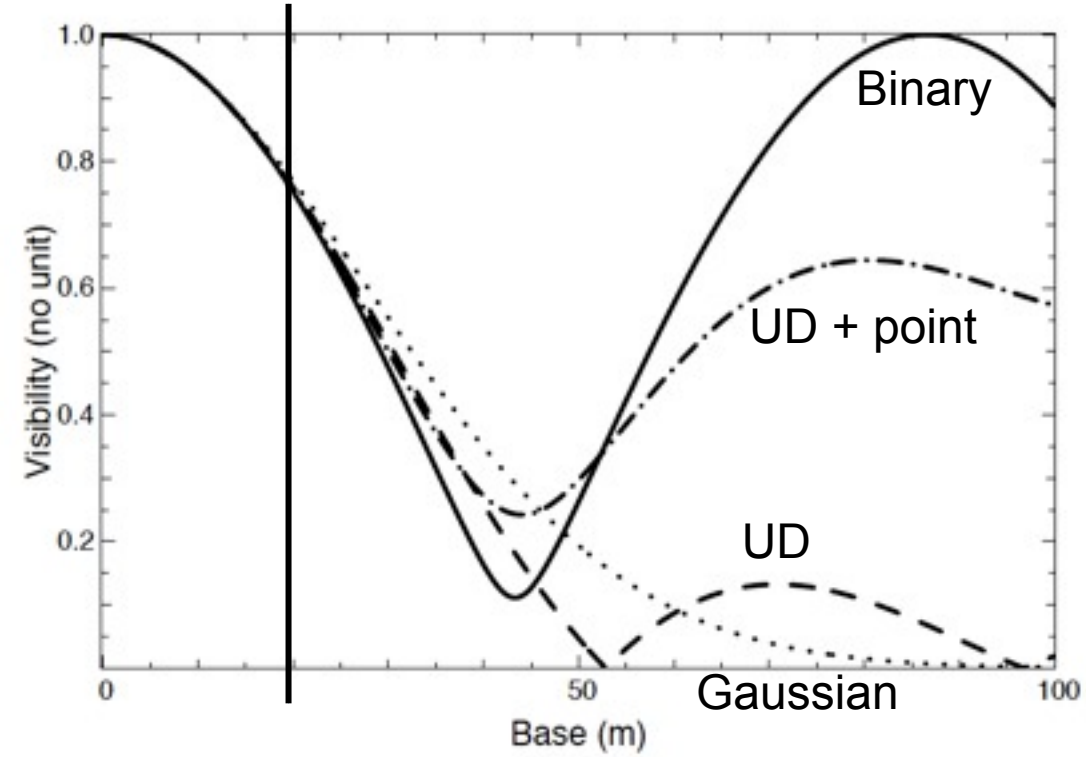


Millour et al. 2011

What is "visibility" ?

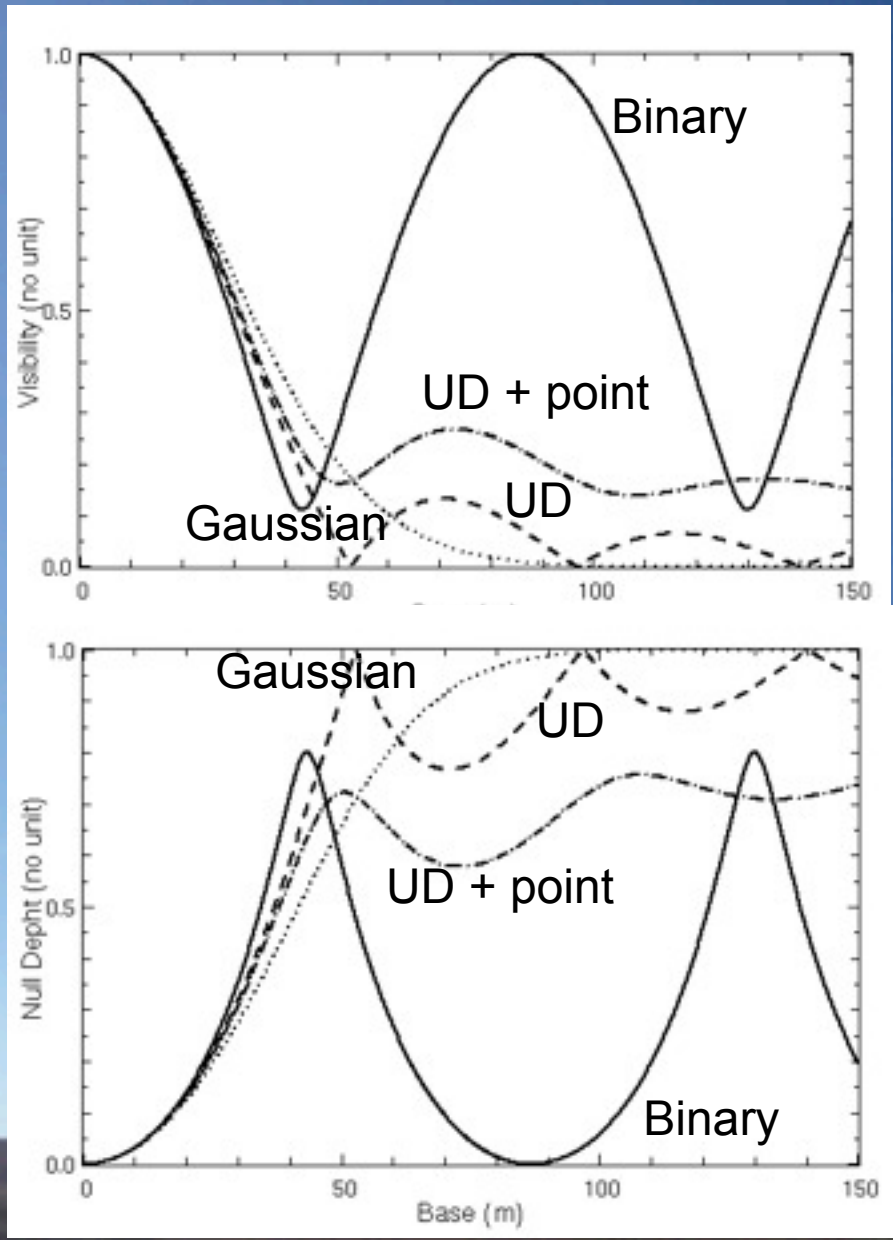
An effective application of the Van-Cittert / Zernike theorem

- V = **<u>Fourier transform of object's brightness distribution</u>**
- V close to 1: « unresolved » object
- V close to 0: « resolved » object



What is « Null »?

- Null depht
  - N = (1-V) / (1+V)
  - Directly related to visibility (the core observable)
- « Null phases » ?
  - How can a Nulling interferometer measure phases?
- Depht + phases = images?
- What dependence of Null depht wrt baseline?



The PERSÉE complex source

- Idea: model a realistic scene « as observed » by a spacecraft
  - Star
  - Planet
  - Exozodi

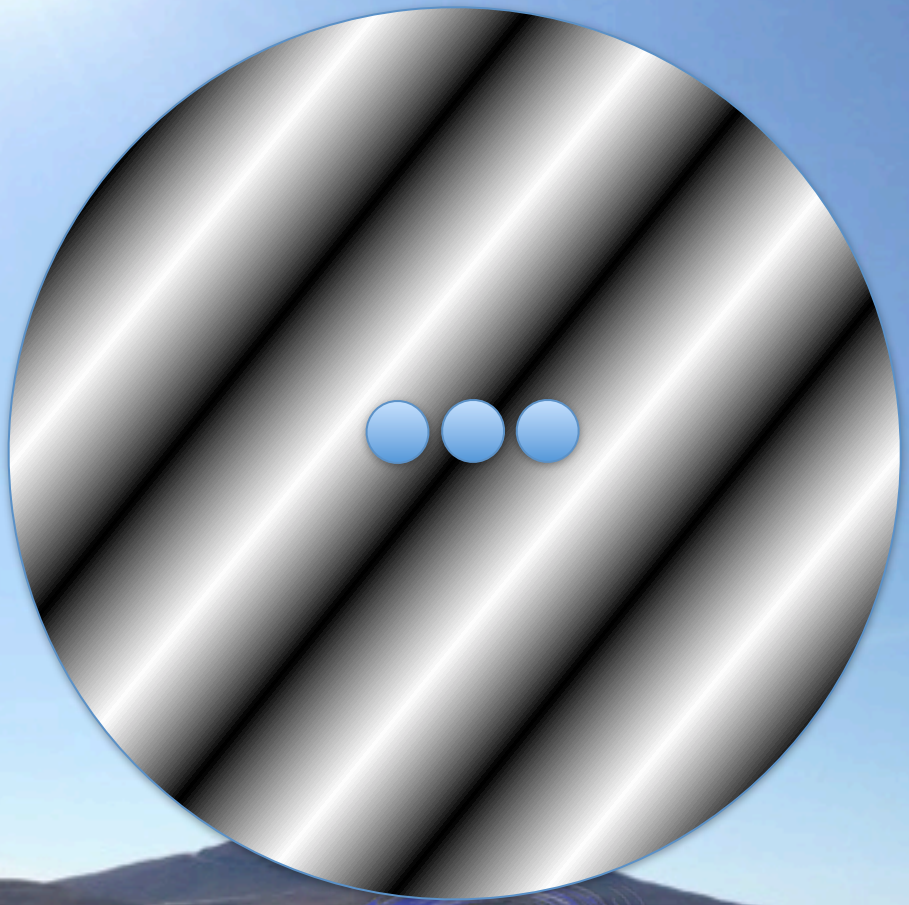
- Problem: the « exozodi » part of the source is hard to manufacture, or even to specify

The PERSÉE complex source

Null function

Source apparence

Fiber aperture



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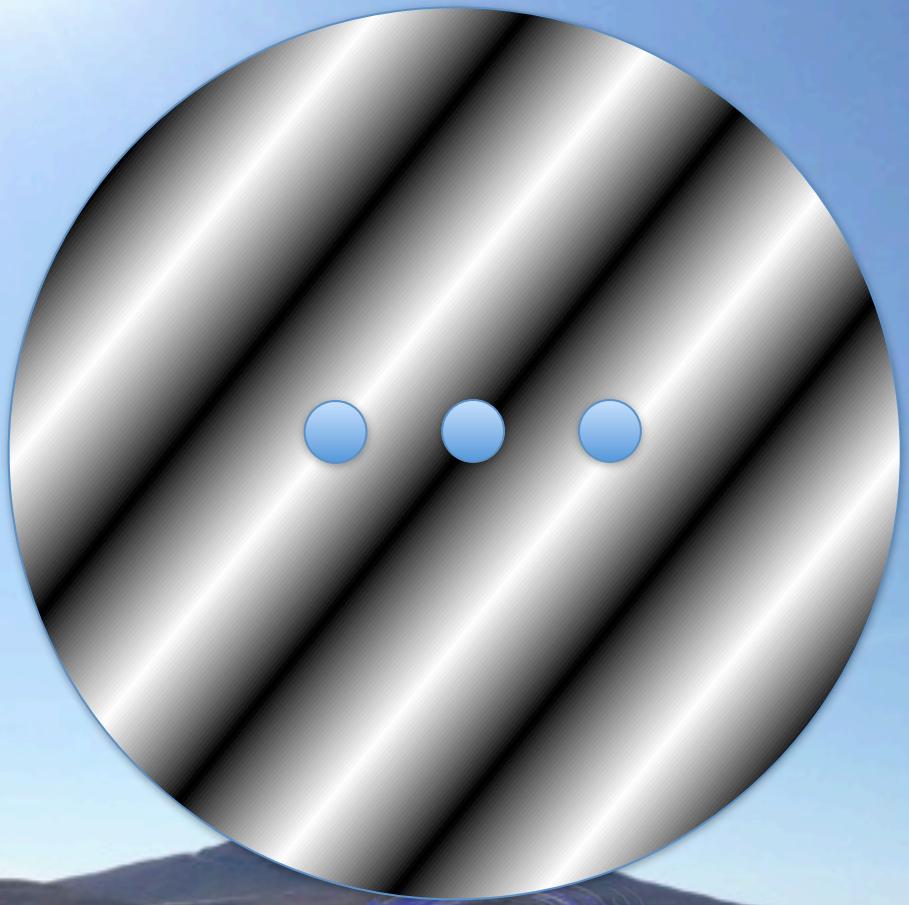

The PERSÉE complex source

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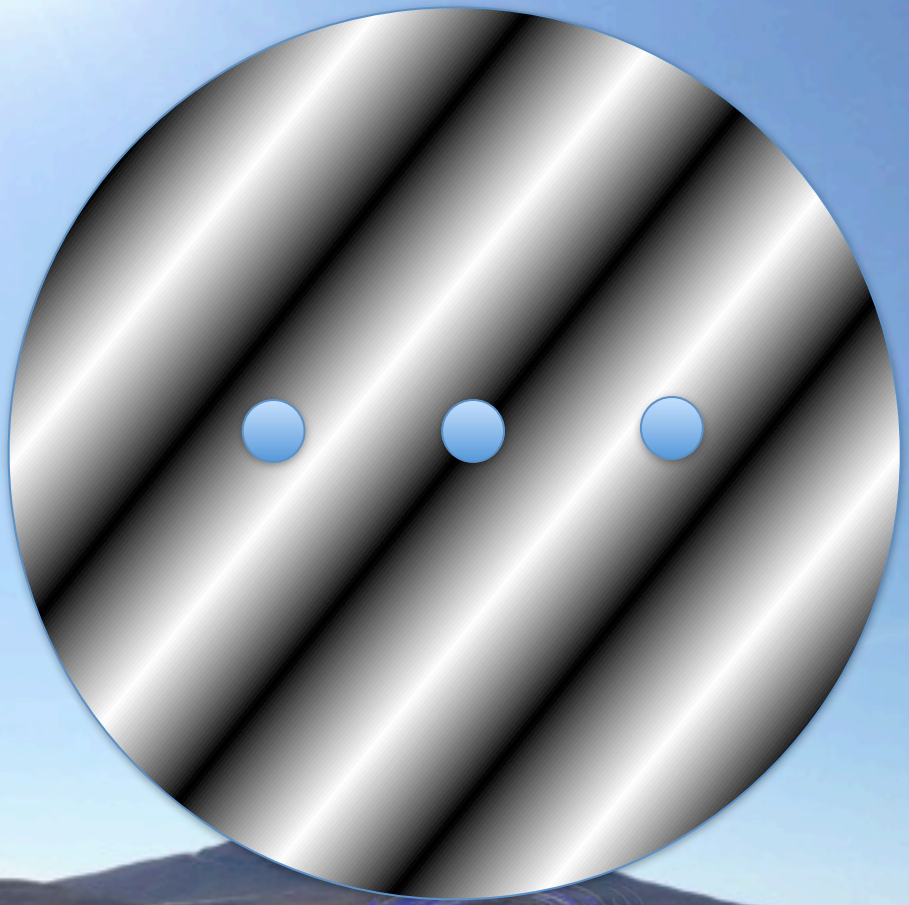

The PERSÉE complex source

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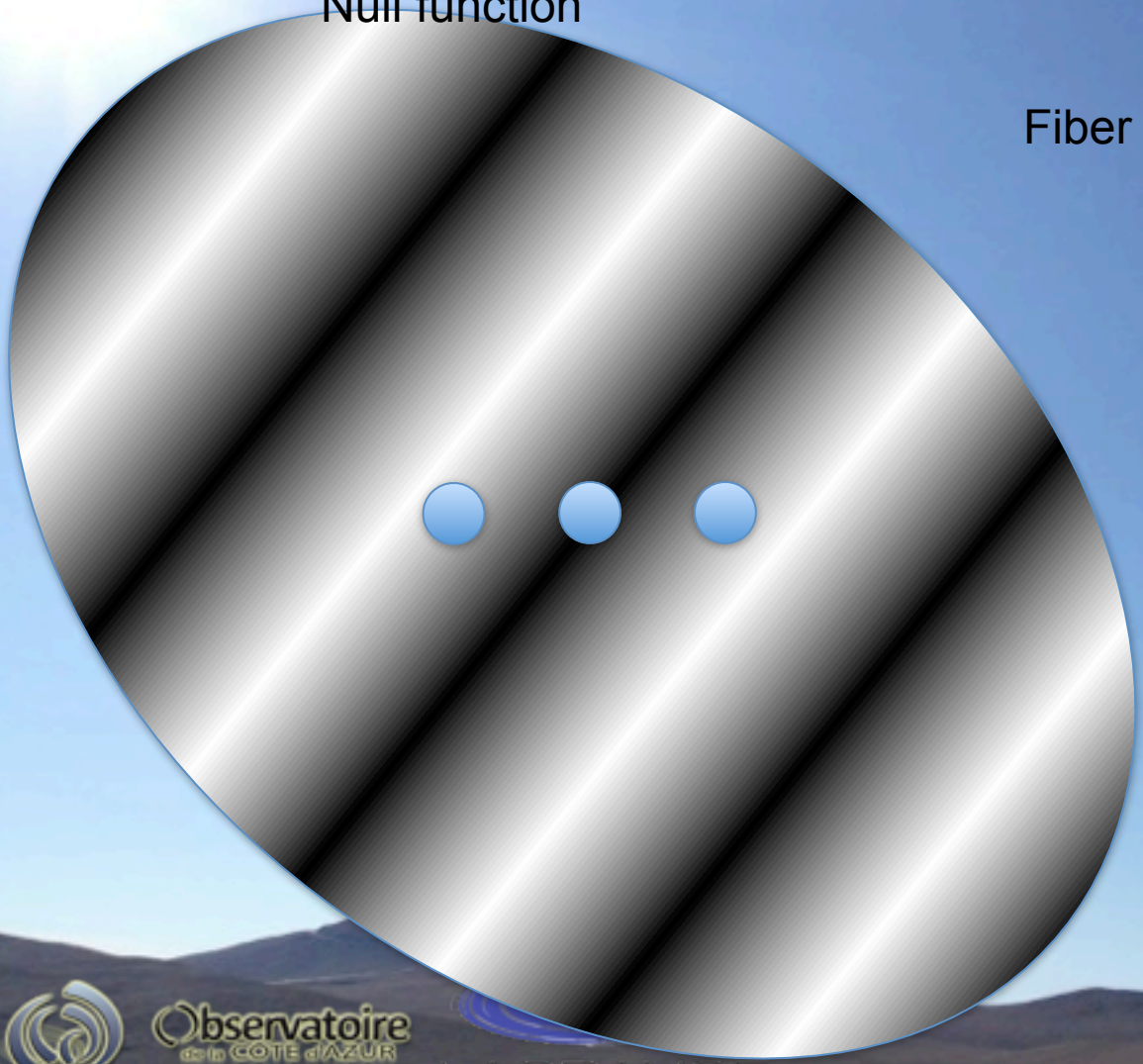

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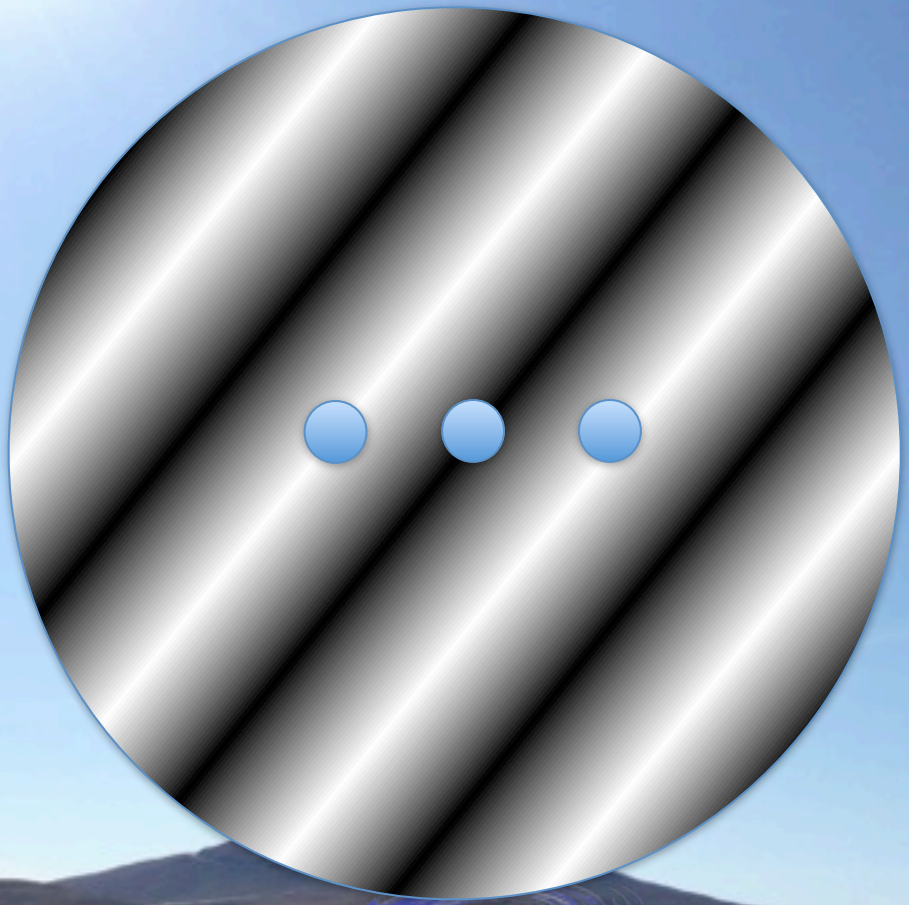

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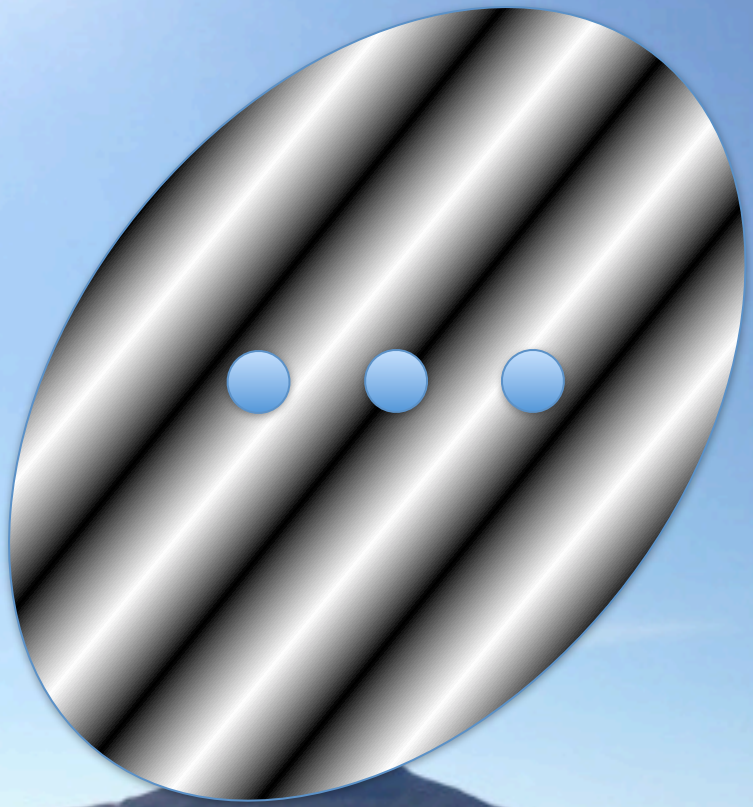

PERSÉE + planet

- The idea: in fact the exozodi is not necessary to map the transfer function of the nuller
- BUT: many open questions
  - Transfer function = null depht as a function of position in the field of view?
  - What defines the position?
    - position of planet??
    - position of barycenter??
  - How to use that transfer function in simulations

Questions (mainly to myself)

- Nulling SNR vs OLBI SNRs?
- Impact of (astrophysical) phases to null depht?
- Motorisation XY
- Send PERSÉE to Nice ?