Herbig Ae Be Workshop - Santiago

Imaging the dust sublimation region of Herbig Ae/Be stars with VLTI/PIONIER

J. Kluska, F. Malbet, J.-P. Berger, J.-B. Le Bouquin, B. Lazareff, M. Benisty, J. Monnier, F. Baron, E. Thiébaut, F. Soulez, C. Dominik, A. Isella, A. Juhasz, S. Kraus, R. Lachaume, F. Ménard, R. Millan-Gabet, C. Pinte, M. Tallon, W.-F. Thi, G. Zins.

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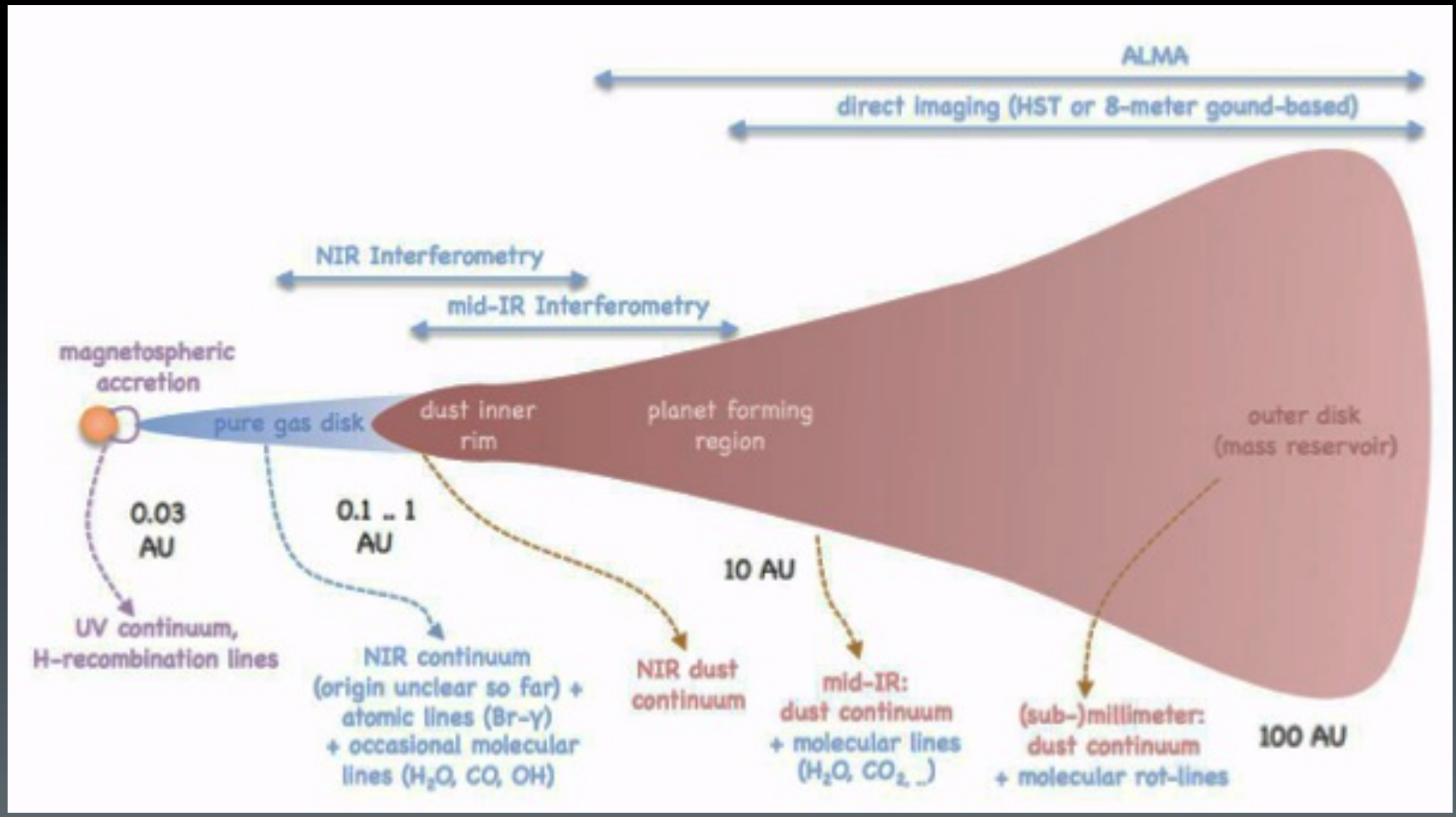
Outline

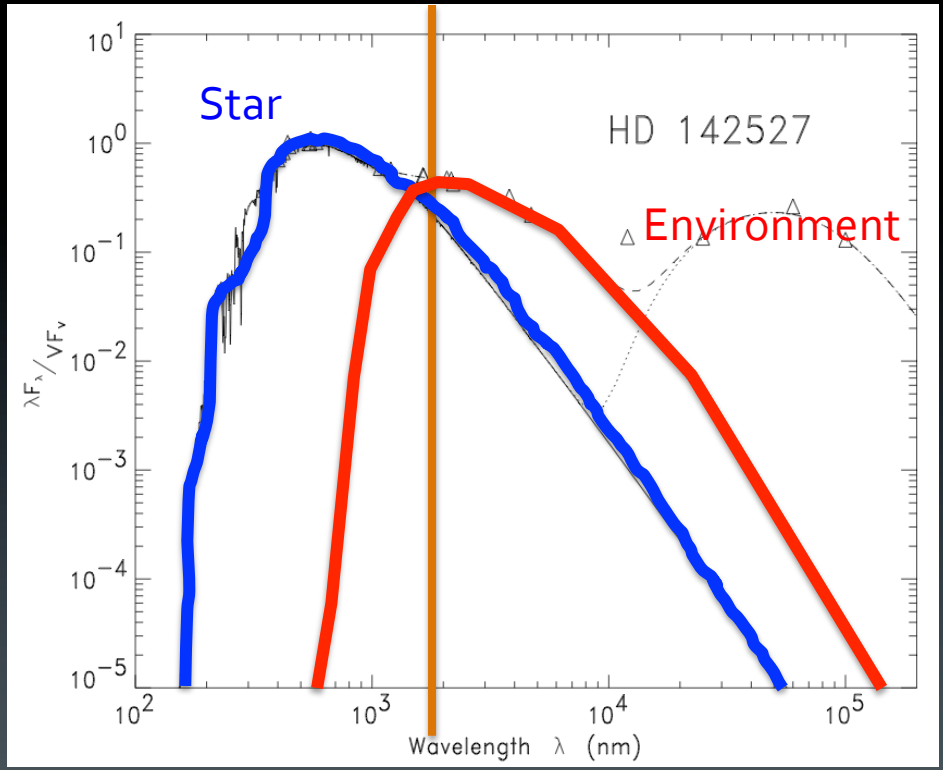
- Technical issue with astrophysical origin (chromaticity)
- Method of image reconstruction solving the problem
- Application on the VLTi/PIONIER Herbig Ae/Be Large Program

What do we want to image ?

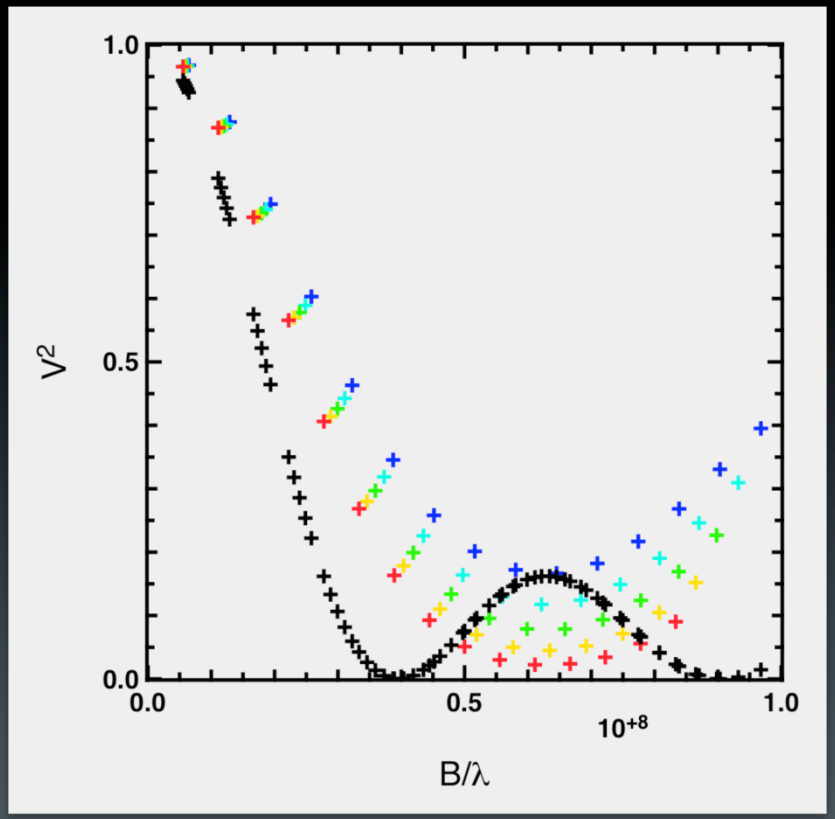


Dullemond & Monnier 2010

Chromaticity issue

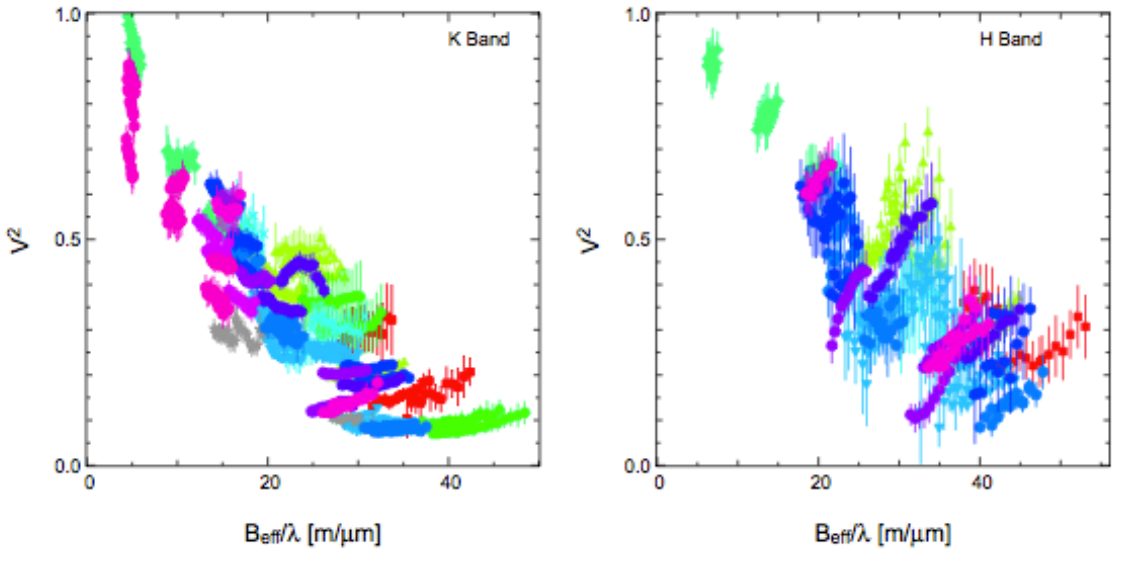


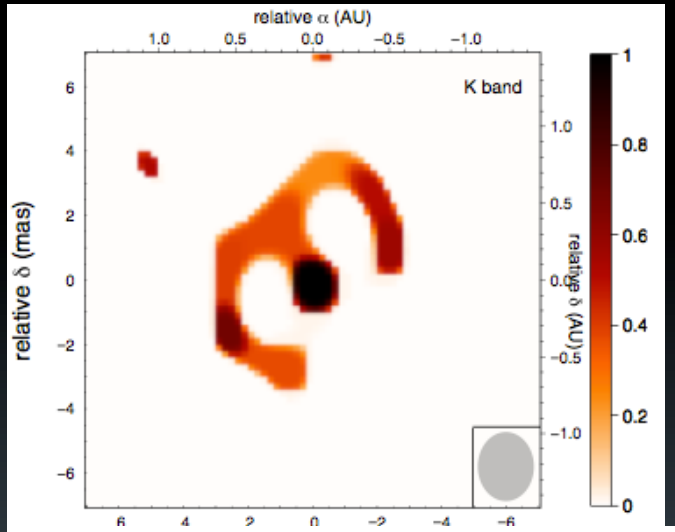
Malfait et al. 1998

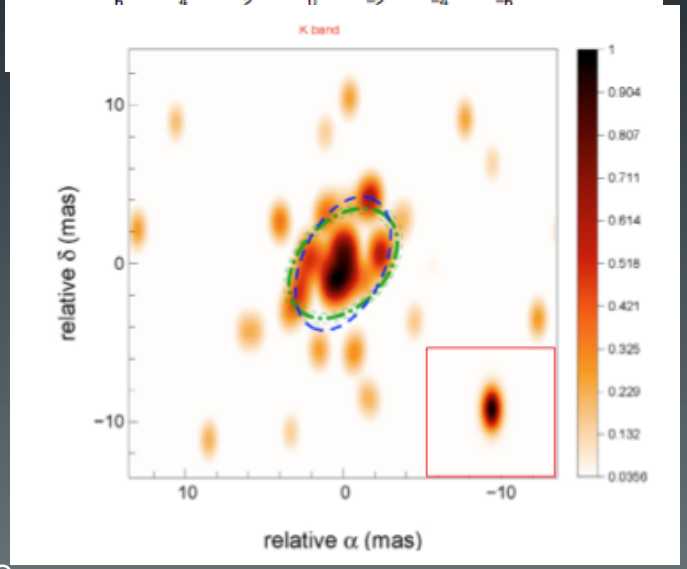


Monochromatic approach is not appropriate

Current images







Benisty et al. 2011

HD 163296
Renard et al. 2010

SPARCO : Semi-Parametric Approach for image Reconstruction of Chromatic Objects

Stellar model Image YSO

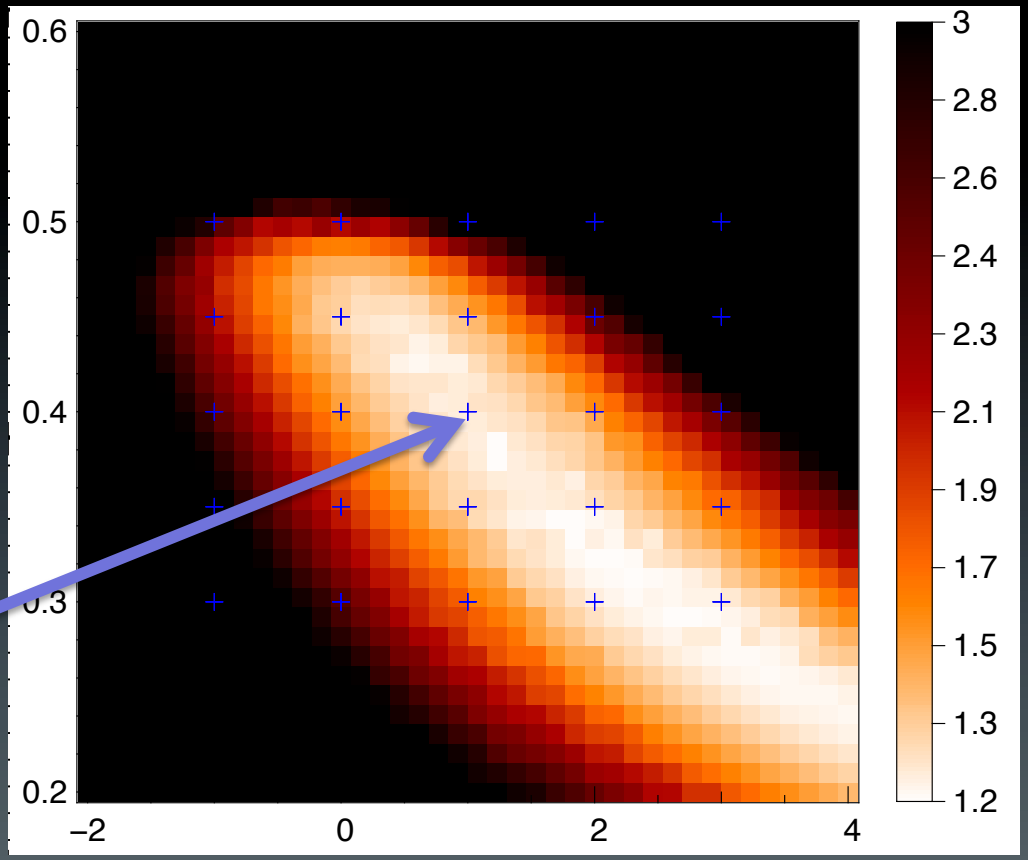
Flux : $F_s\,(\lambda / \lambda_0)^{-4}$ $(1-F_s)\,(\lambda / \lambda_0)^{d}$ F_{tot}

F_s : stellar-to-total flux ratio at λ_0

d_{env} : spectral index of the environment (temperature)

Kluska et al. 2014, A&A, in press, arXiv 1403, 3343.

Intrisic degeneracy



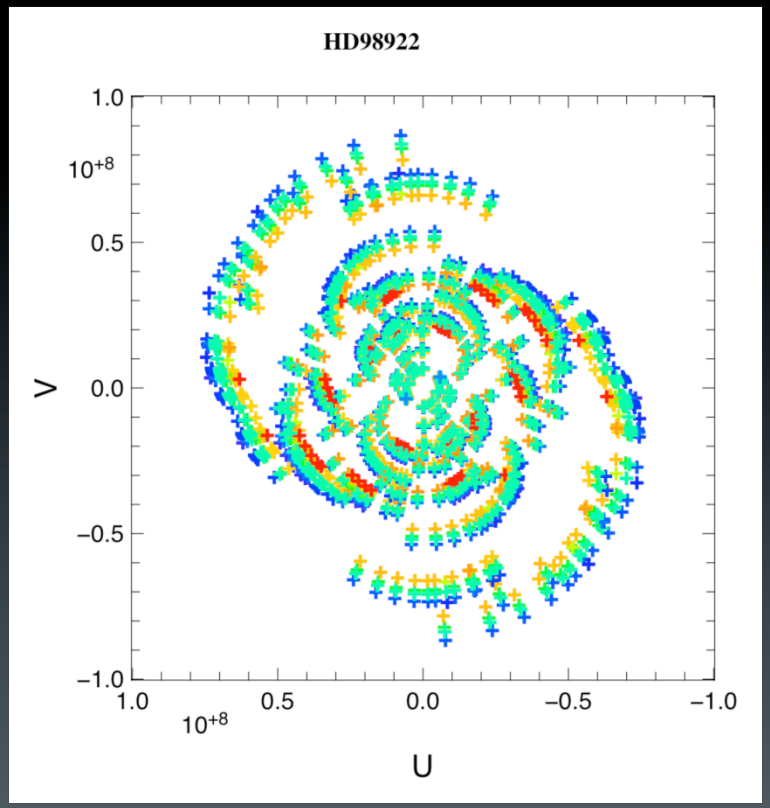
F_s

Real value

d_{env}

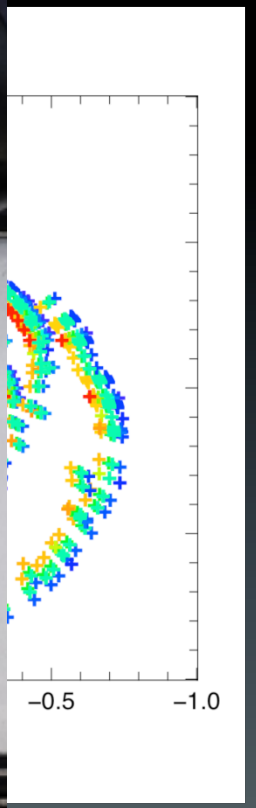
Images from PIONIER

- PIONIER survey of Herbig Ae/Be stars
- 31 nights of observation
- 55 stars observed
- ~12 imaging targets



Images from PIONIER

- PION
  Ae/B
- 31 ni
- 55 st
- ~12 i



Blind©, Lazareff

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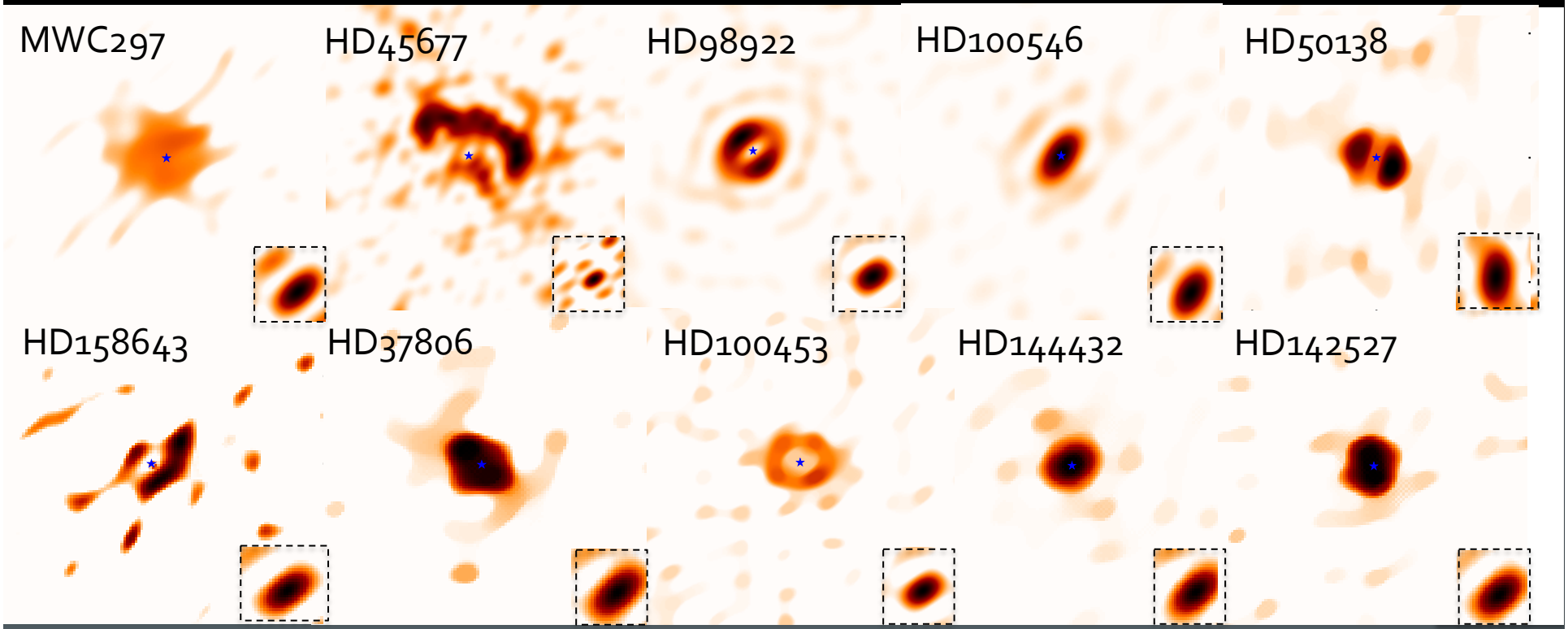
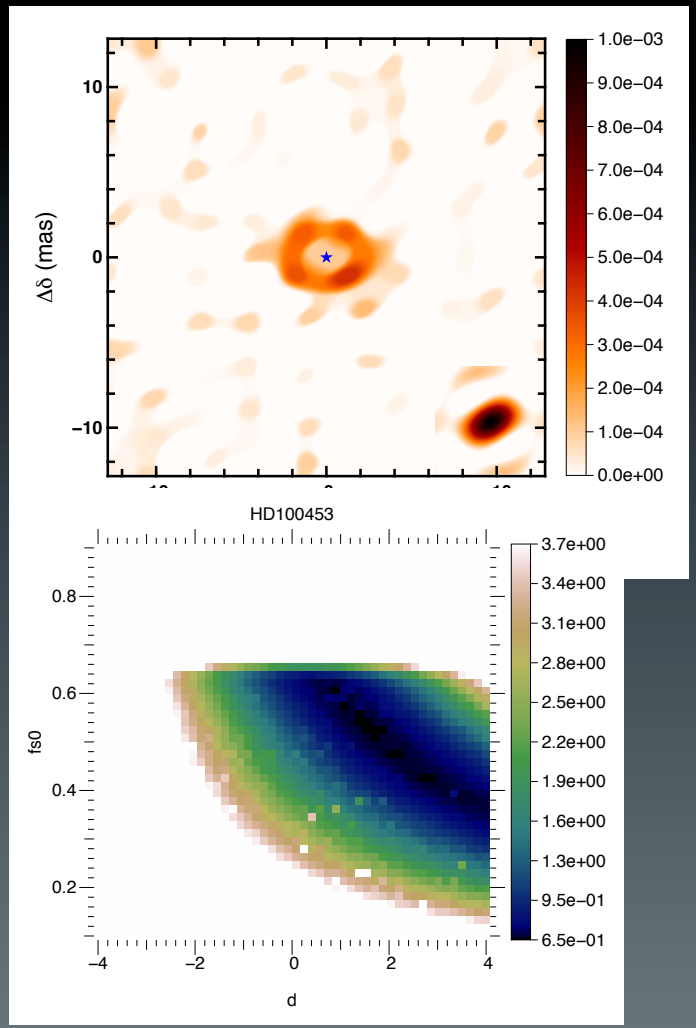
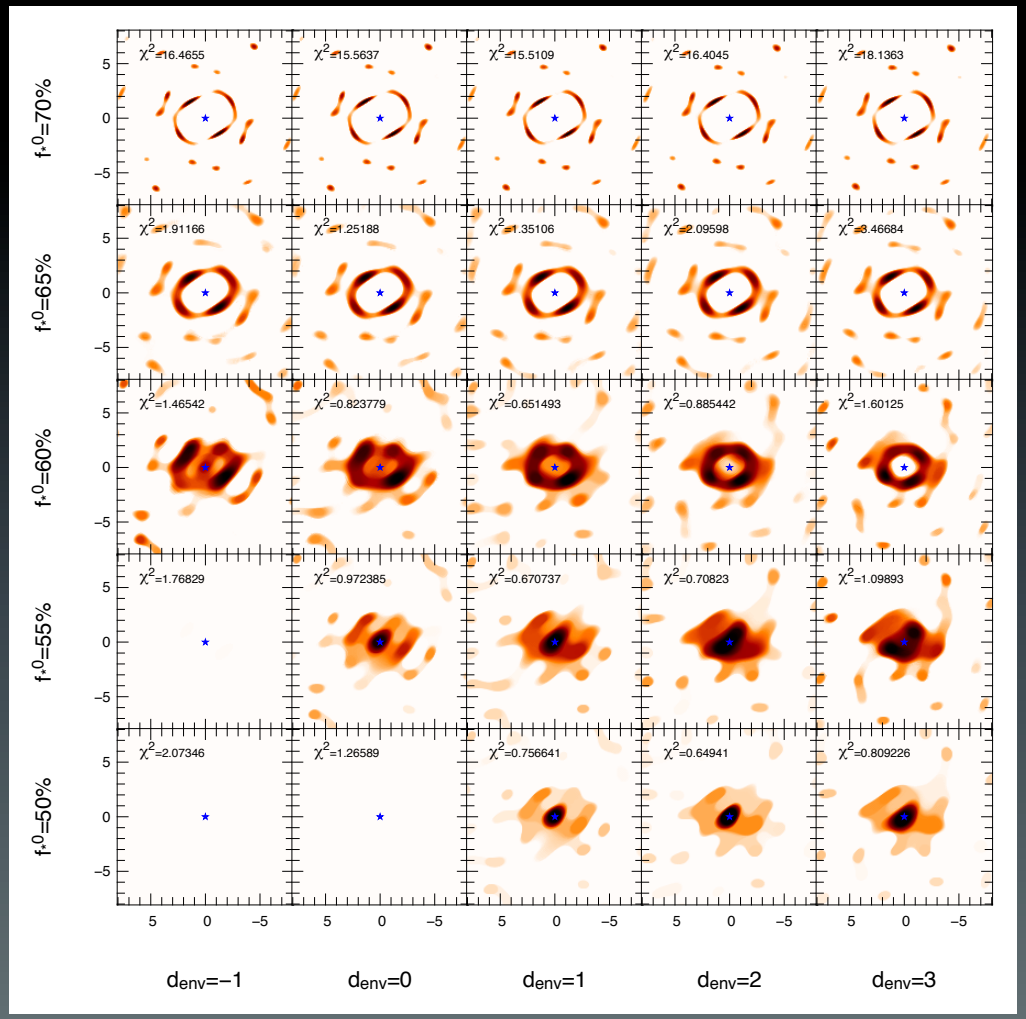
Images from PIONIER



Images from PIONIER

- HD100453





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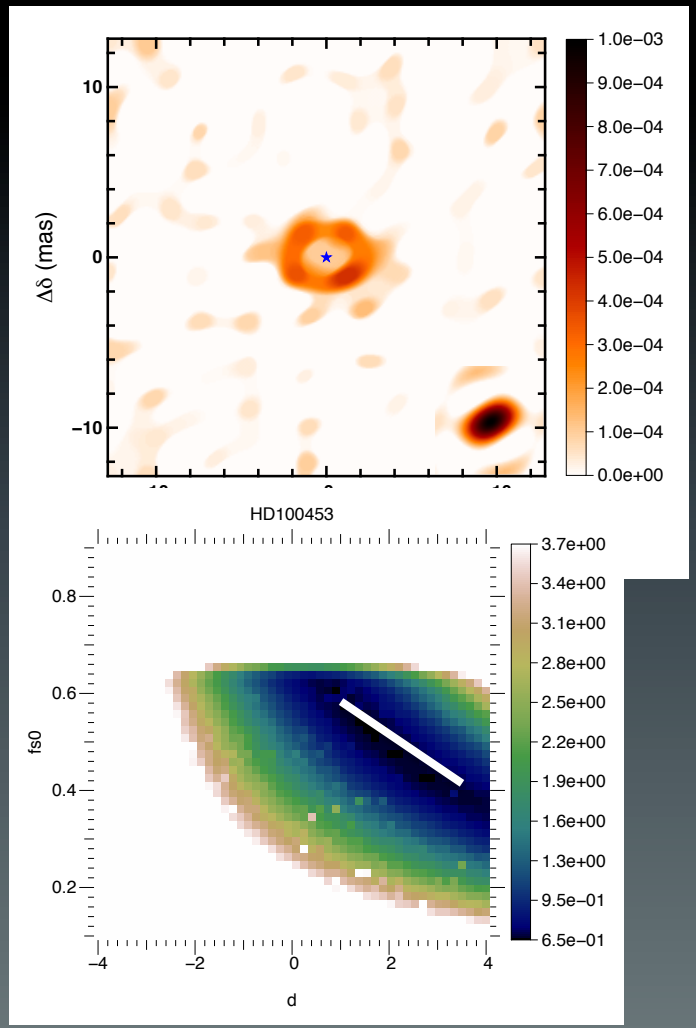

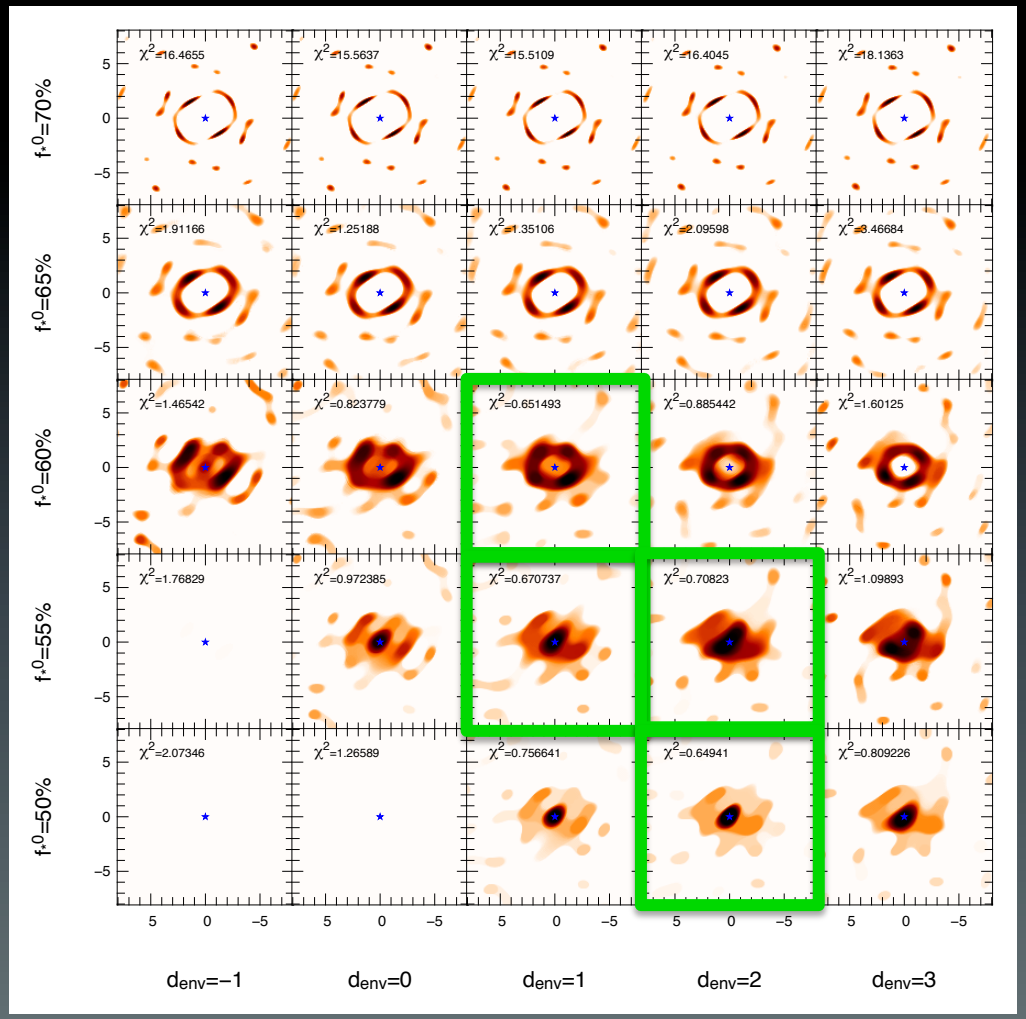

Images from PIONIER

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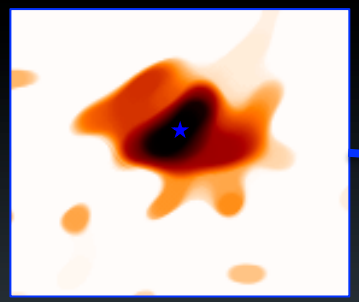

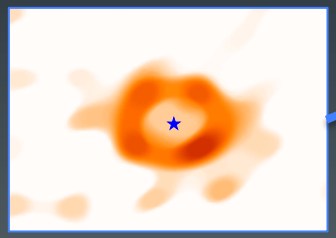

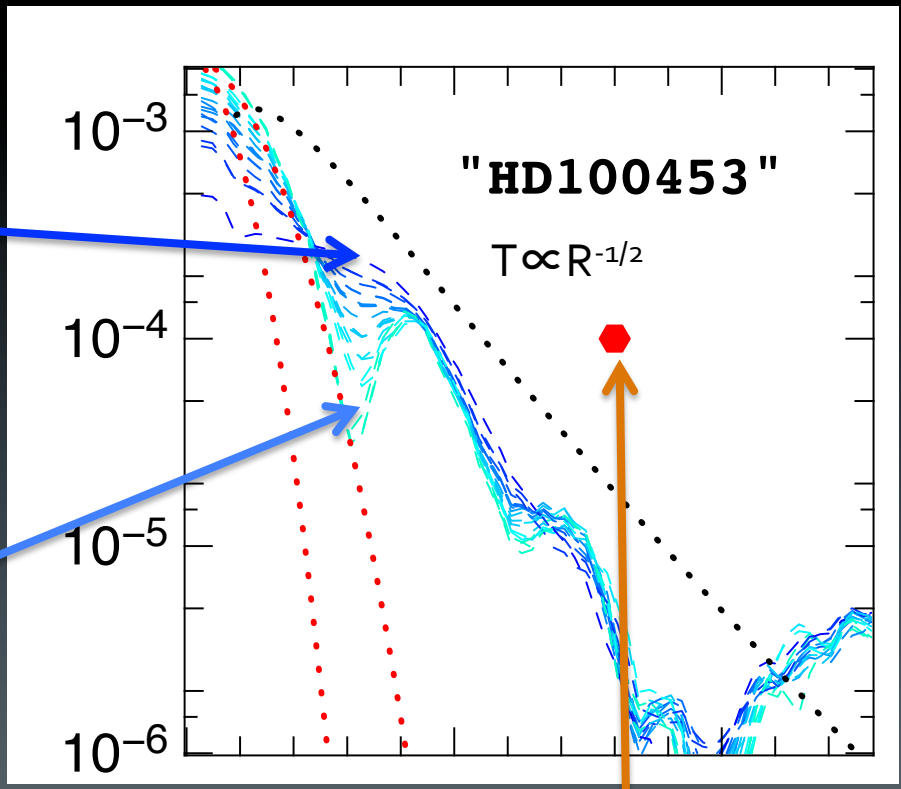

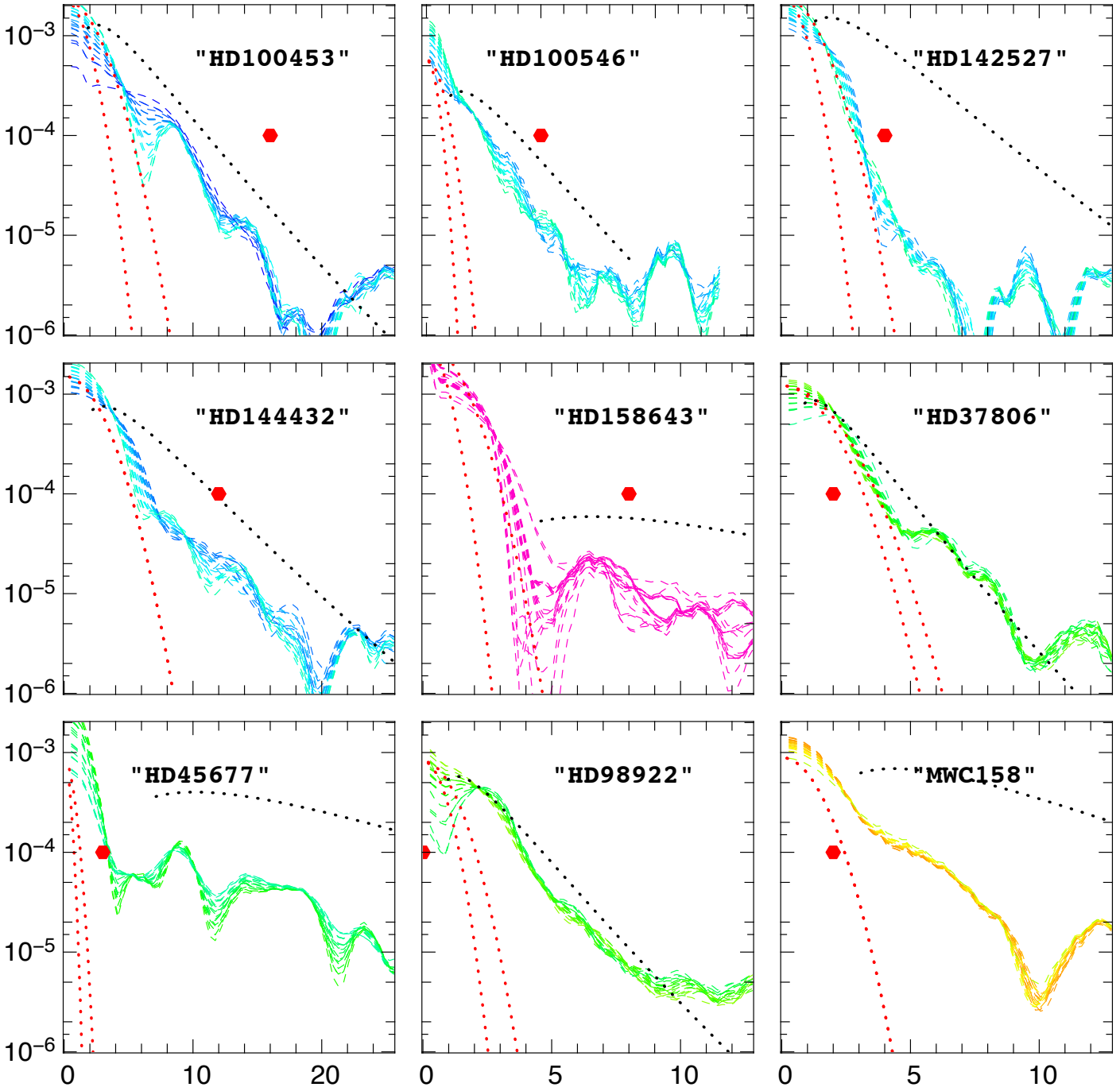
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"HD142527"
"HD144432"
"HD158643"
"HD37806"
"HD45677"
"HD98922"
"MWC158"
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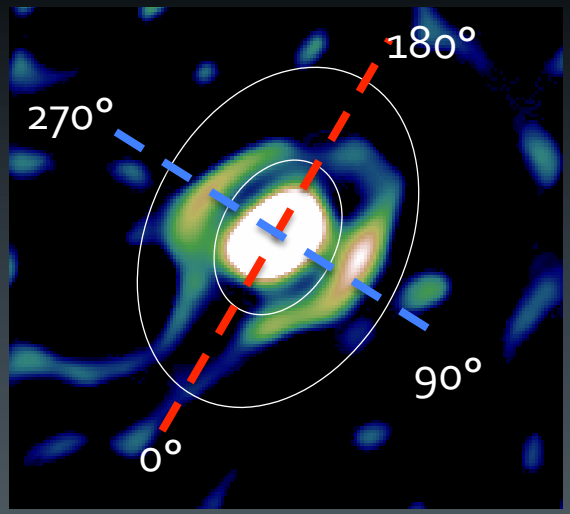
Images from PIONIER

- Azimuthal profile



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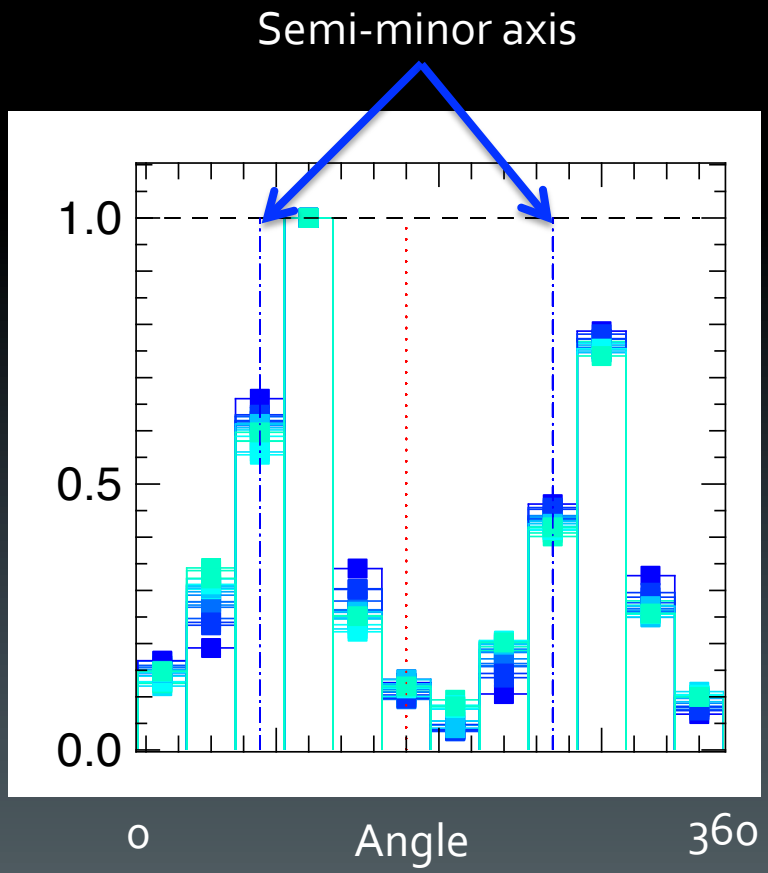

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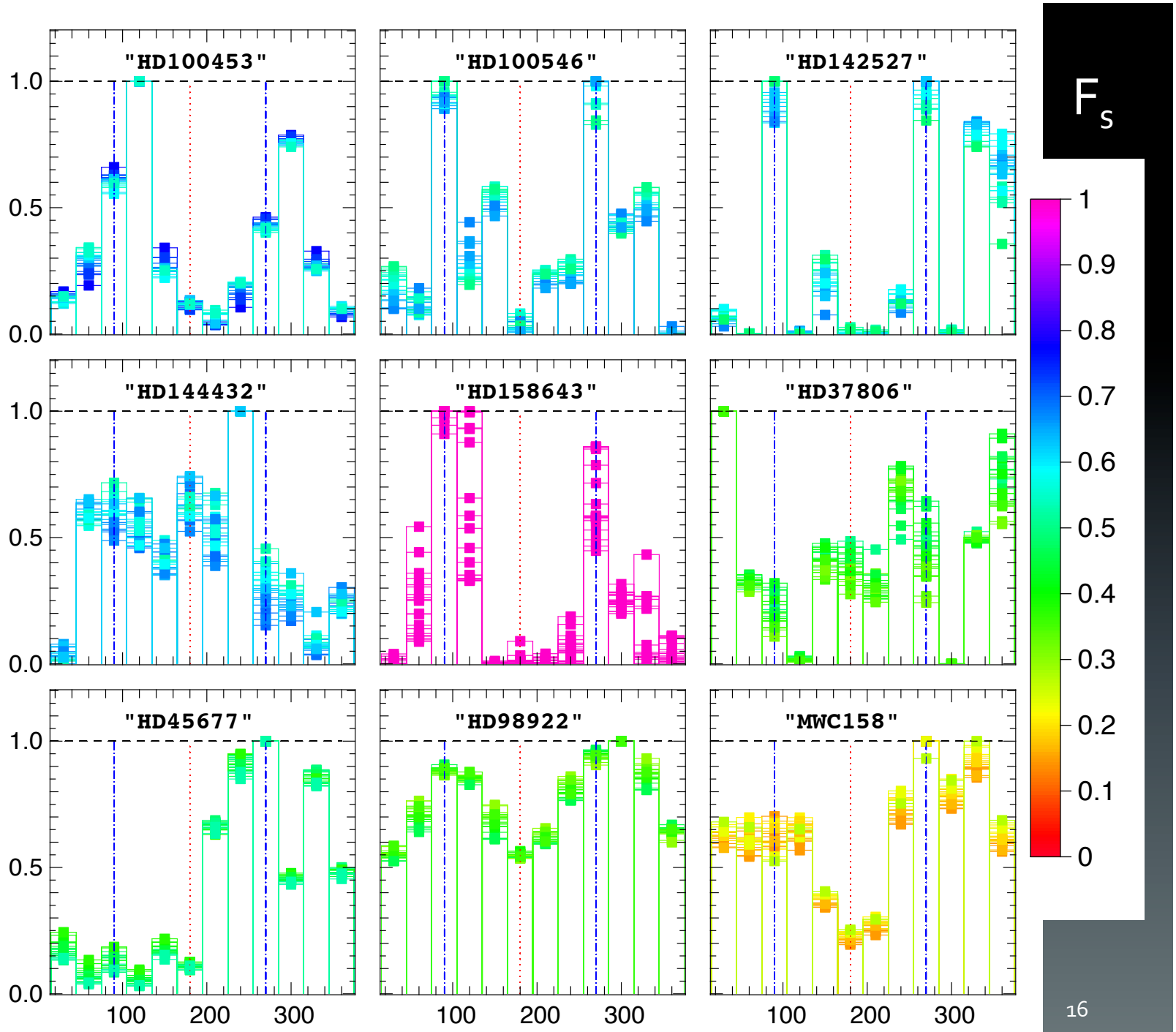
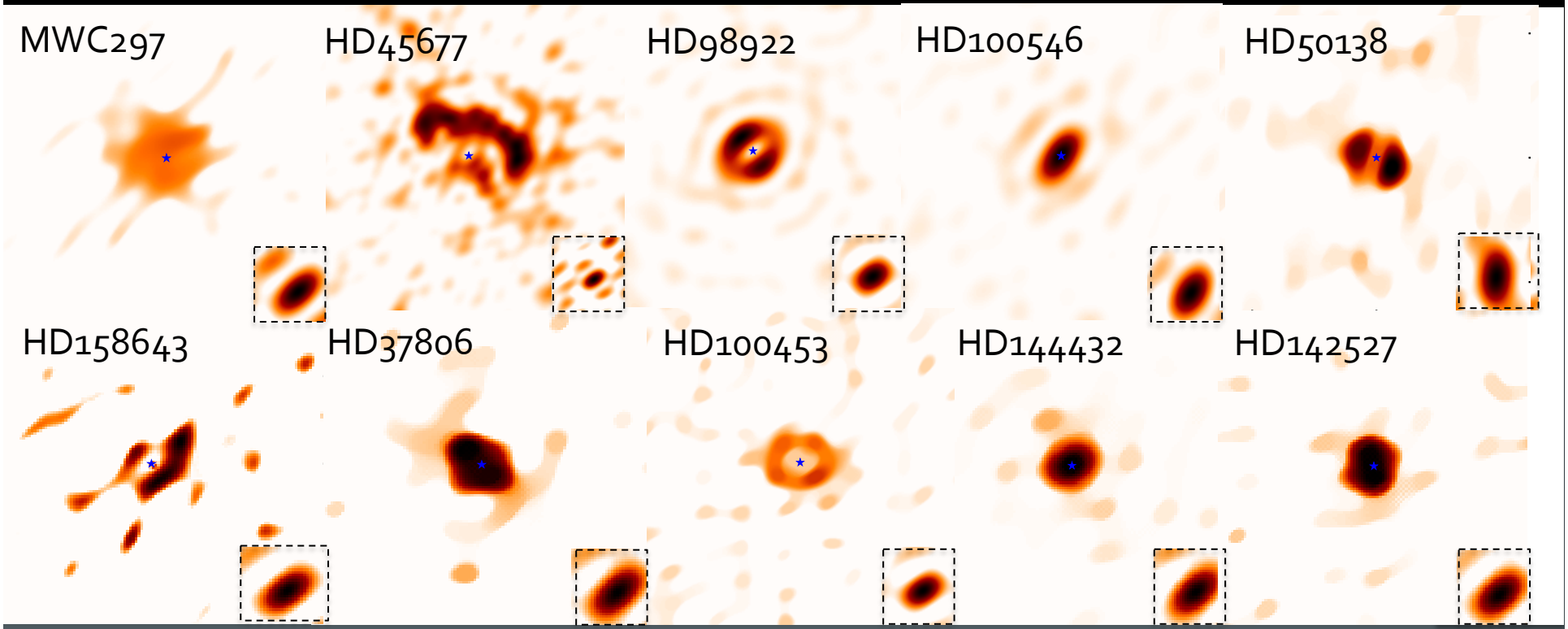
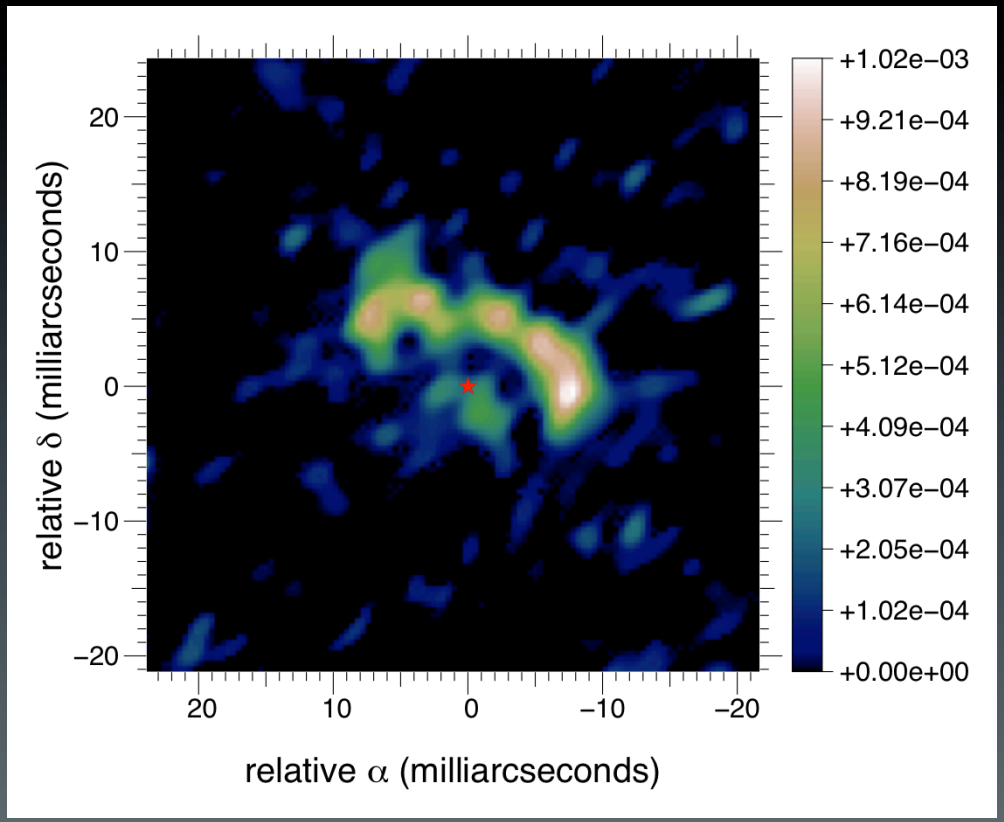


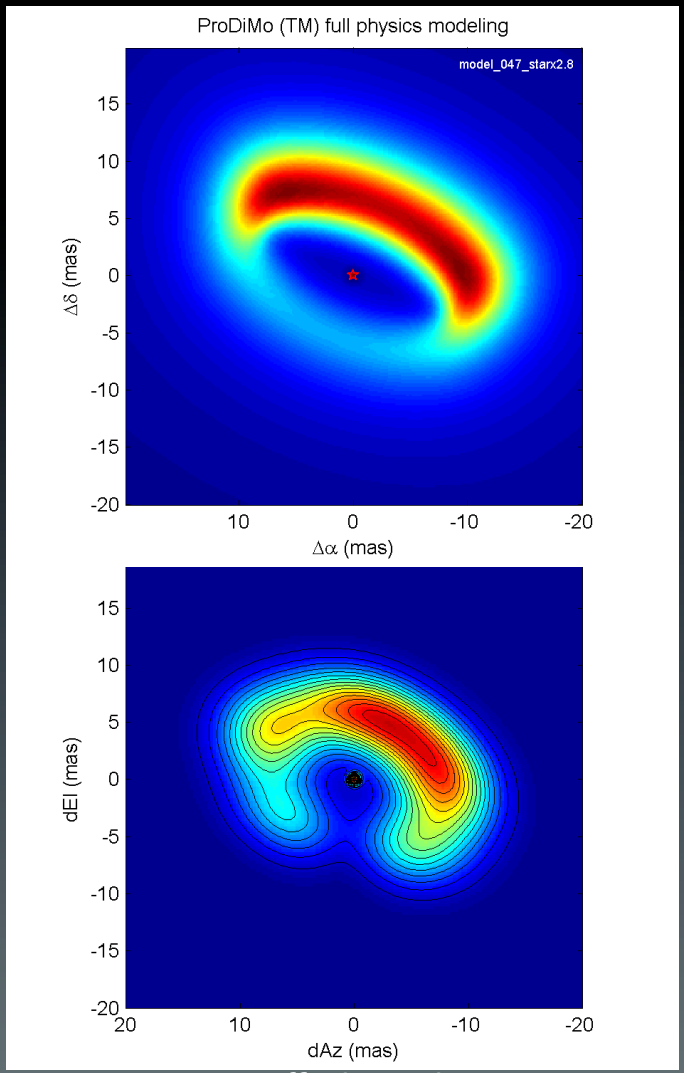
Images from PIONIER



Images from PIONIER

- HD45677





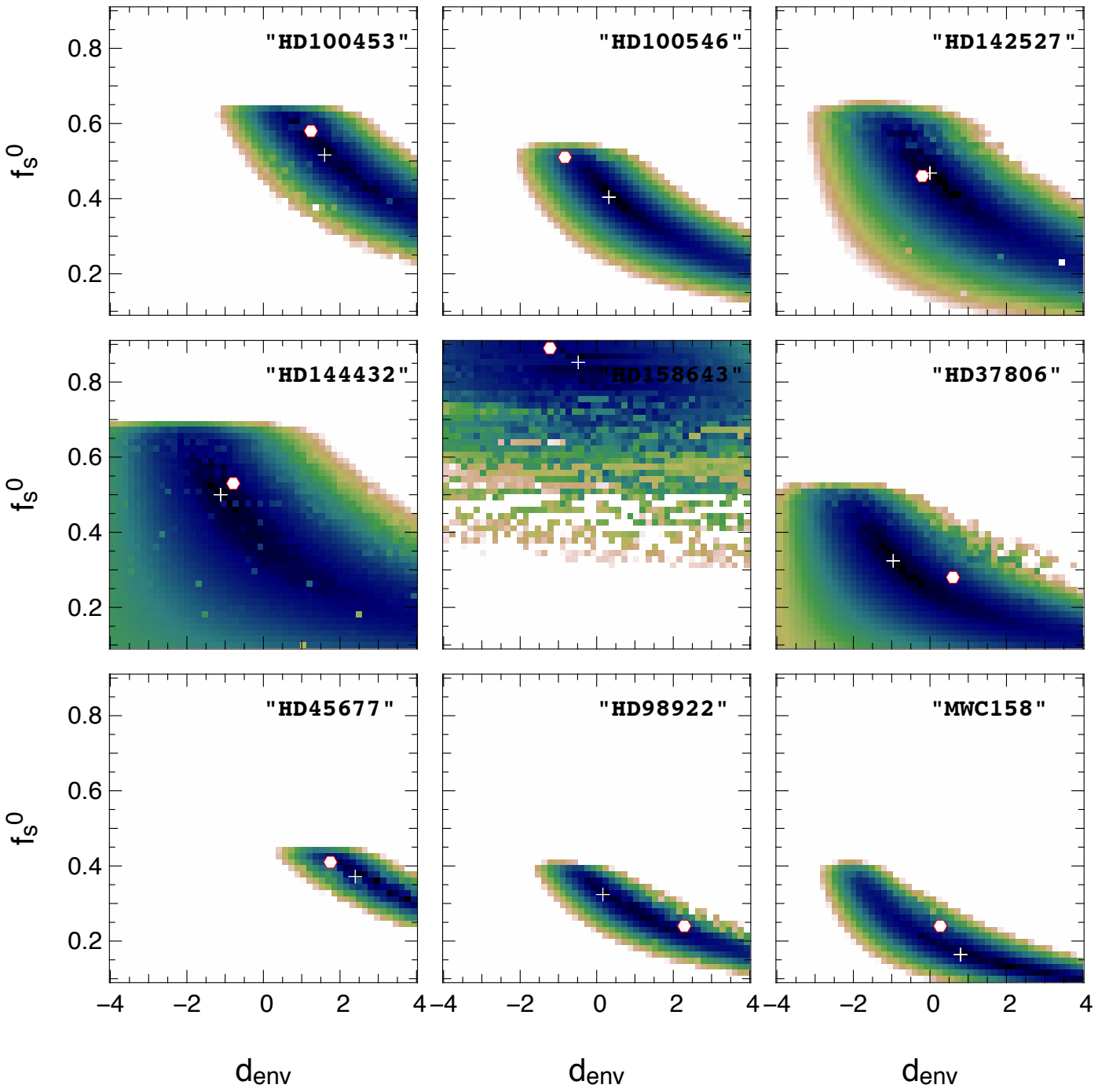
Lazareff, Thi et al. in prep.

To conlude…

- SPARCO method is helping to analyse interferometric dataset without strong constrains
- Analysis in the image space
- Need for simultaneous photometry
- Unresolved component ? (also seen by e.g. Eisner et al. 2007, Tannirkulam et al. 2008, Benisty et al. 2011)
  - Inner gazeous disk ? Refractory grains ?
- Azimuthal variations in the disk → Variability

Perspectives

- Follow-up observations on some variability suspected objects
- Comparing to RT models & adding other observations (spectroscopy, …)
- Image reconstruction (SPARCO + 3D) + lines
- Looking for a postdoctoral position to continue my work.


"HD100453"
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f_s^0
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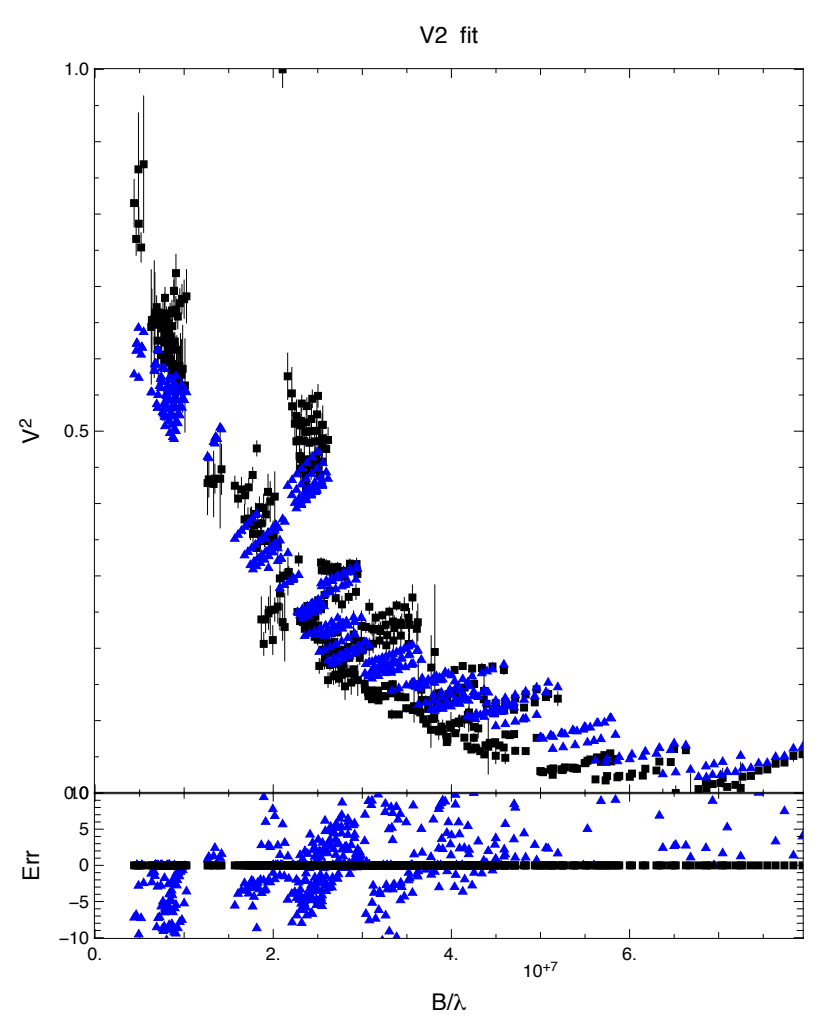
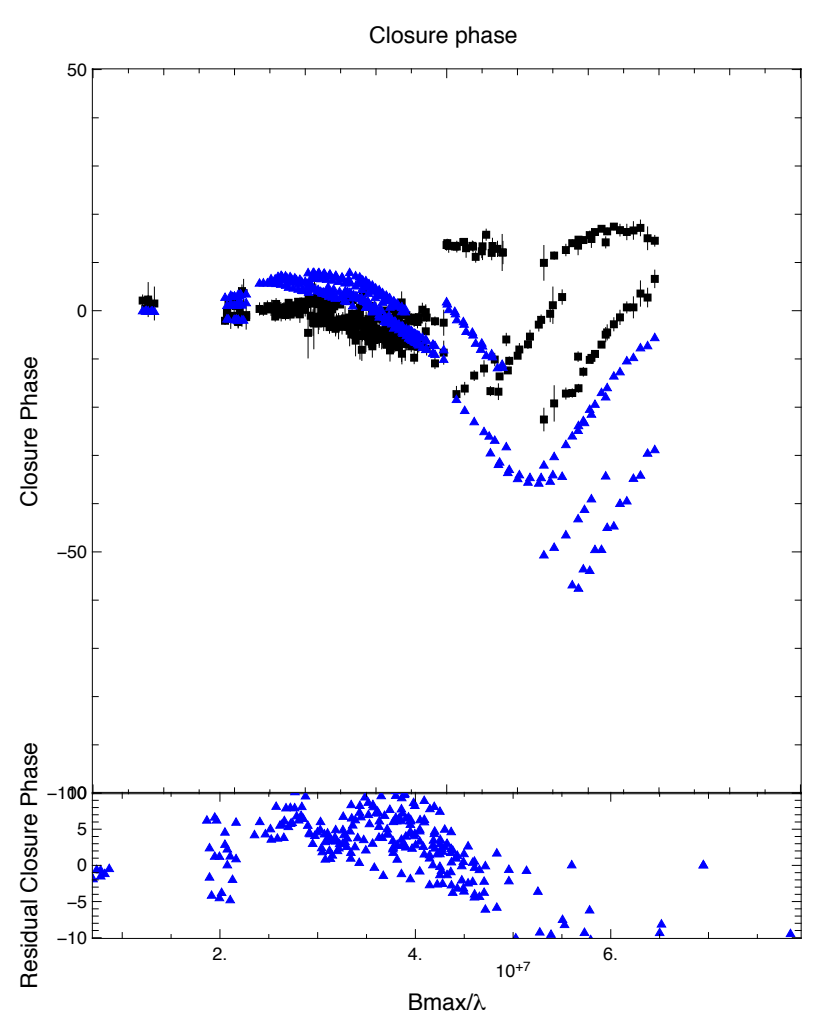
MWC158 (data epoch1, model LP)





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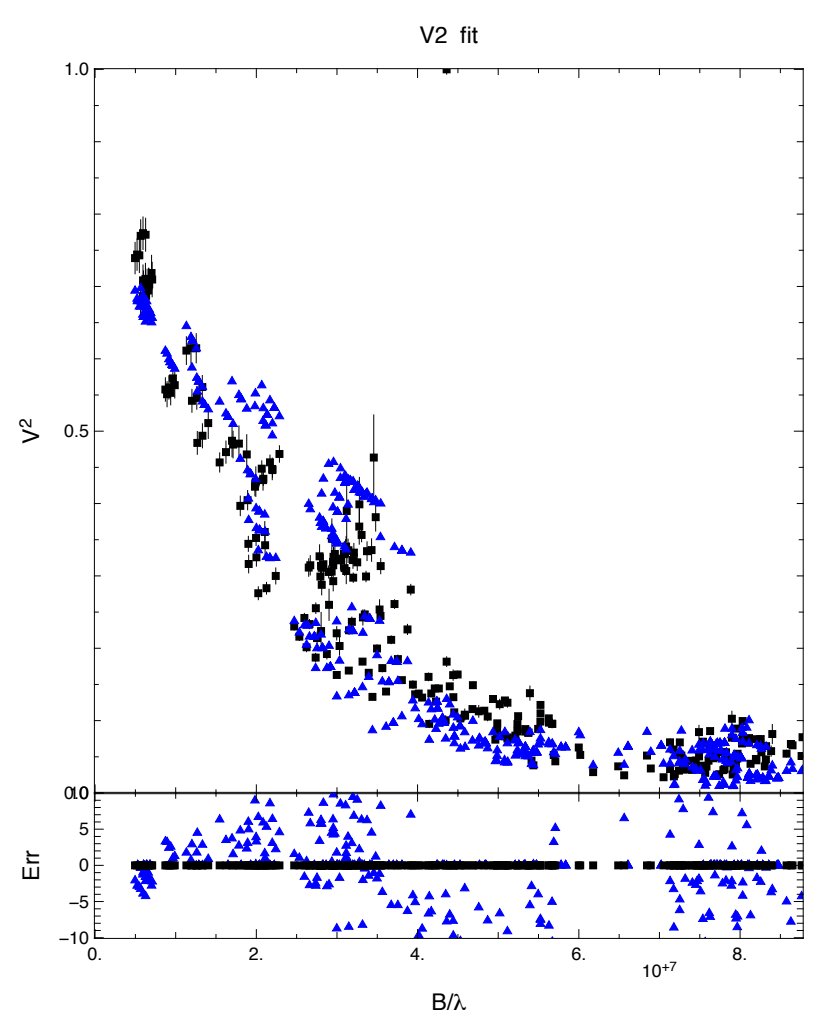
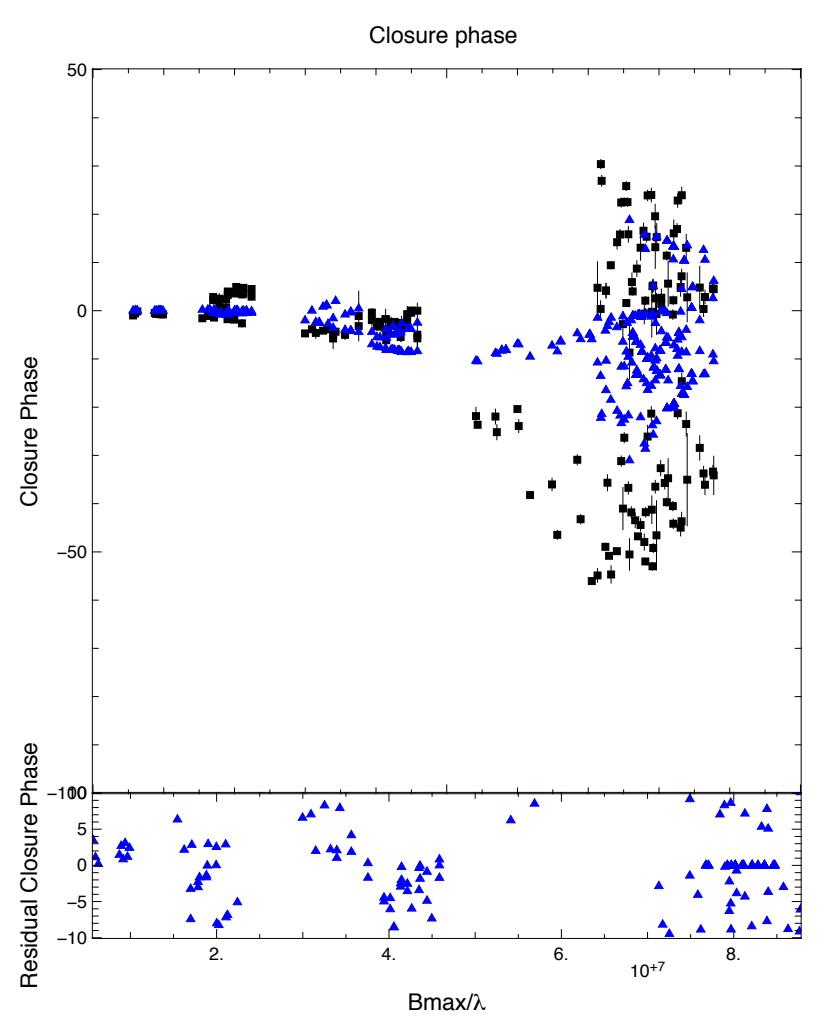
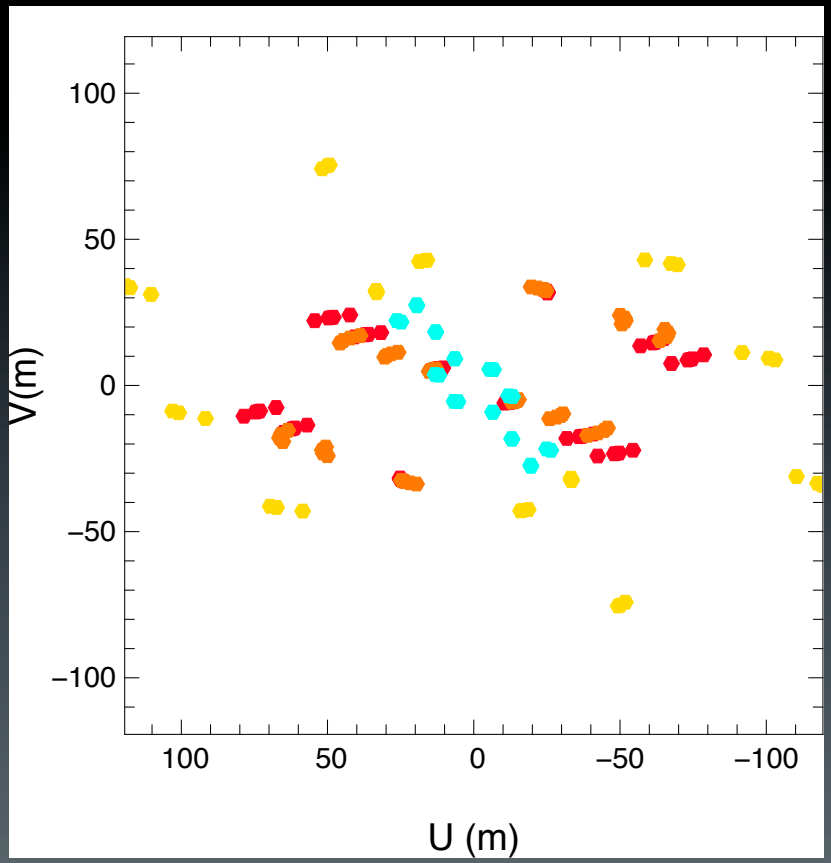
MWC158 (data LP - model epoch1)

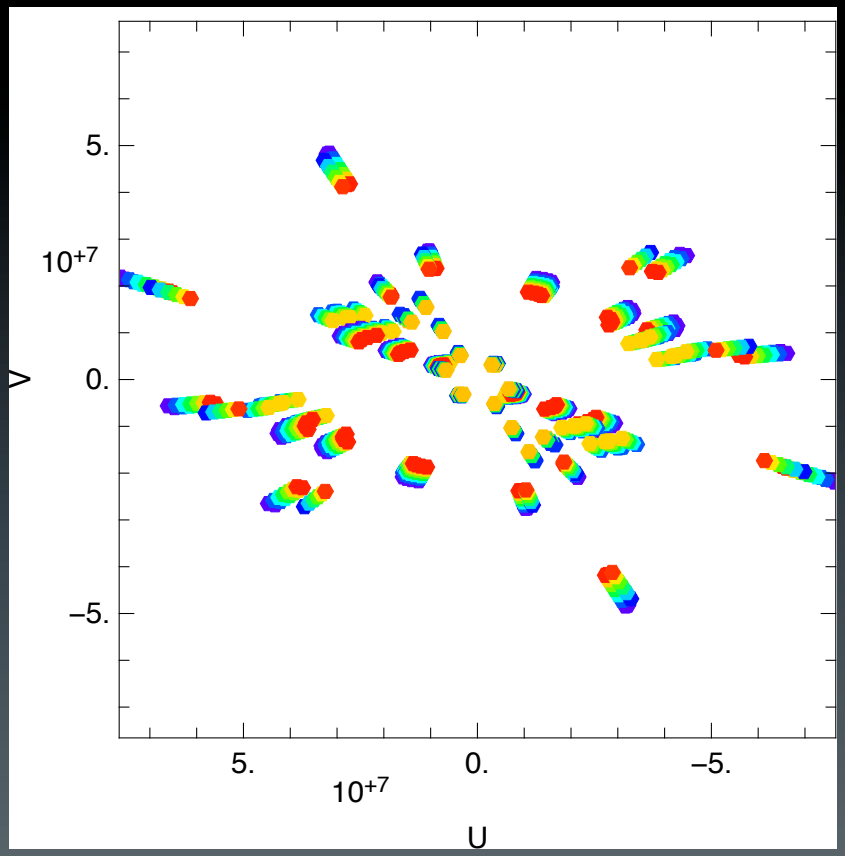




Chromaticity issue

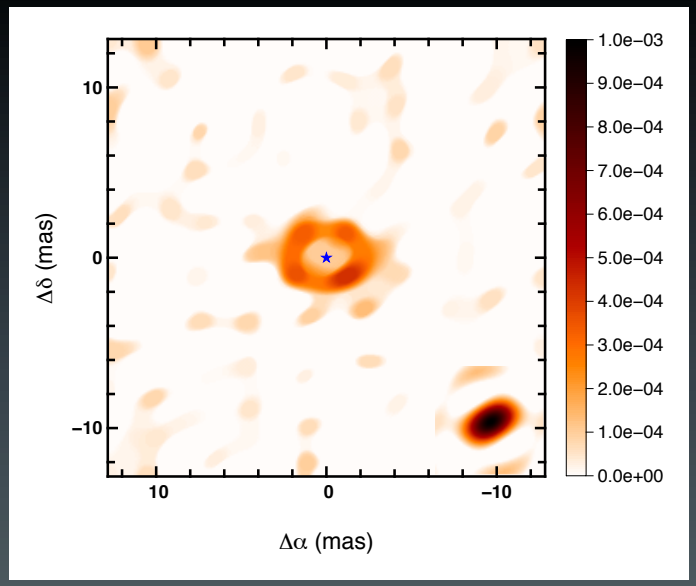


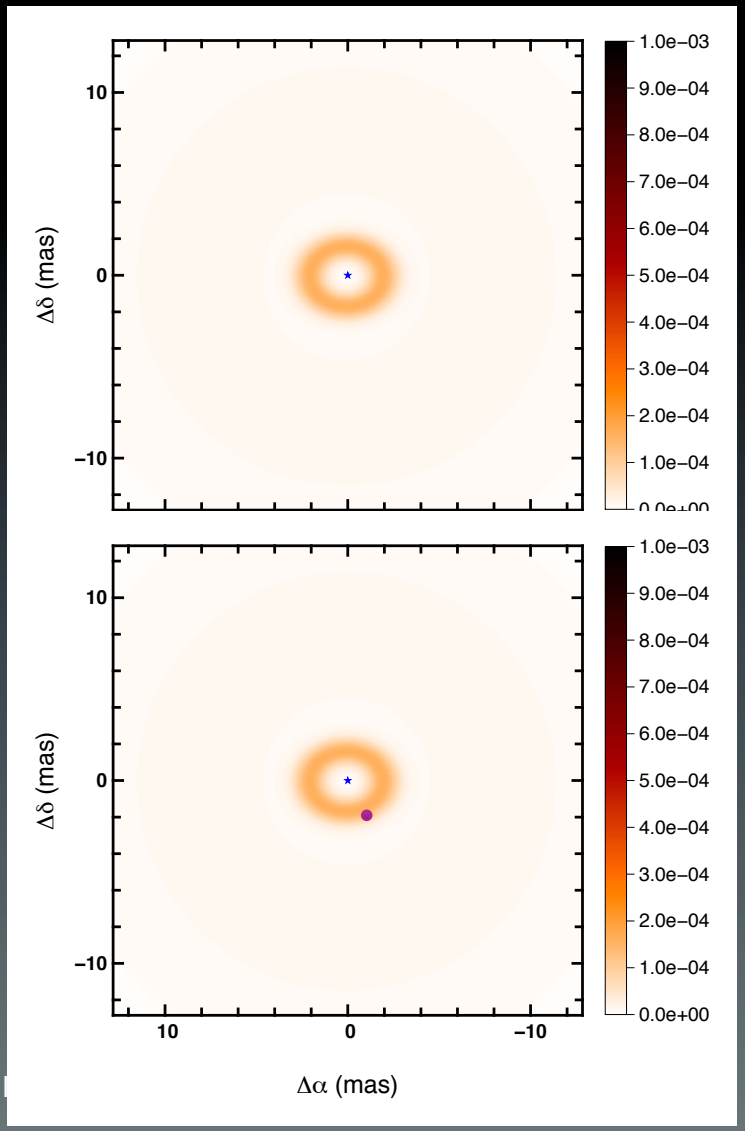
Chromaticity issue



Images from PIONIER

- HD100453





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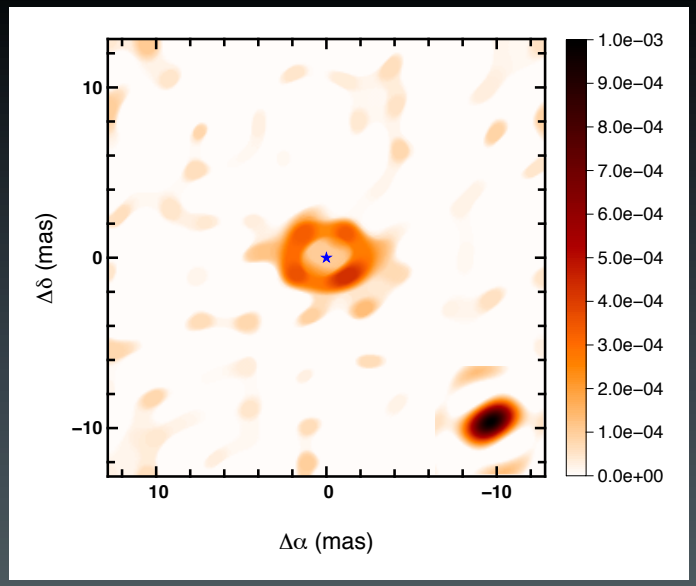
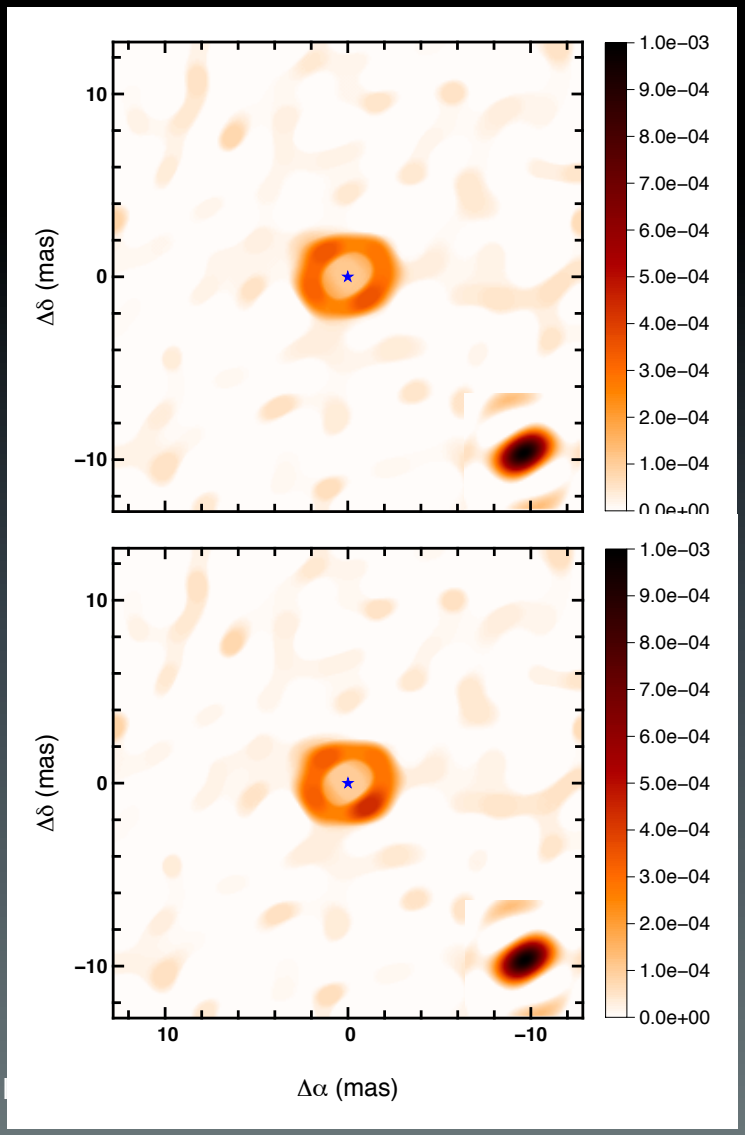
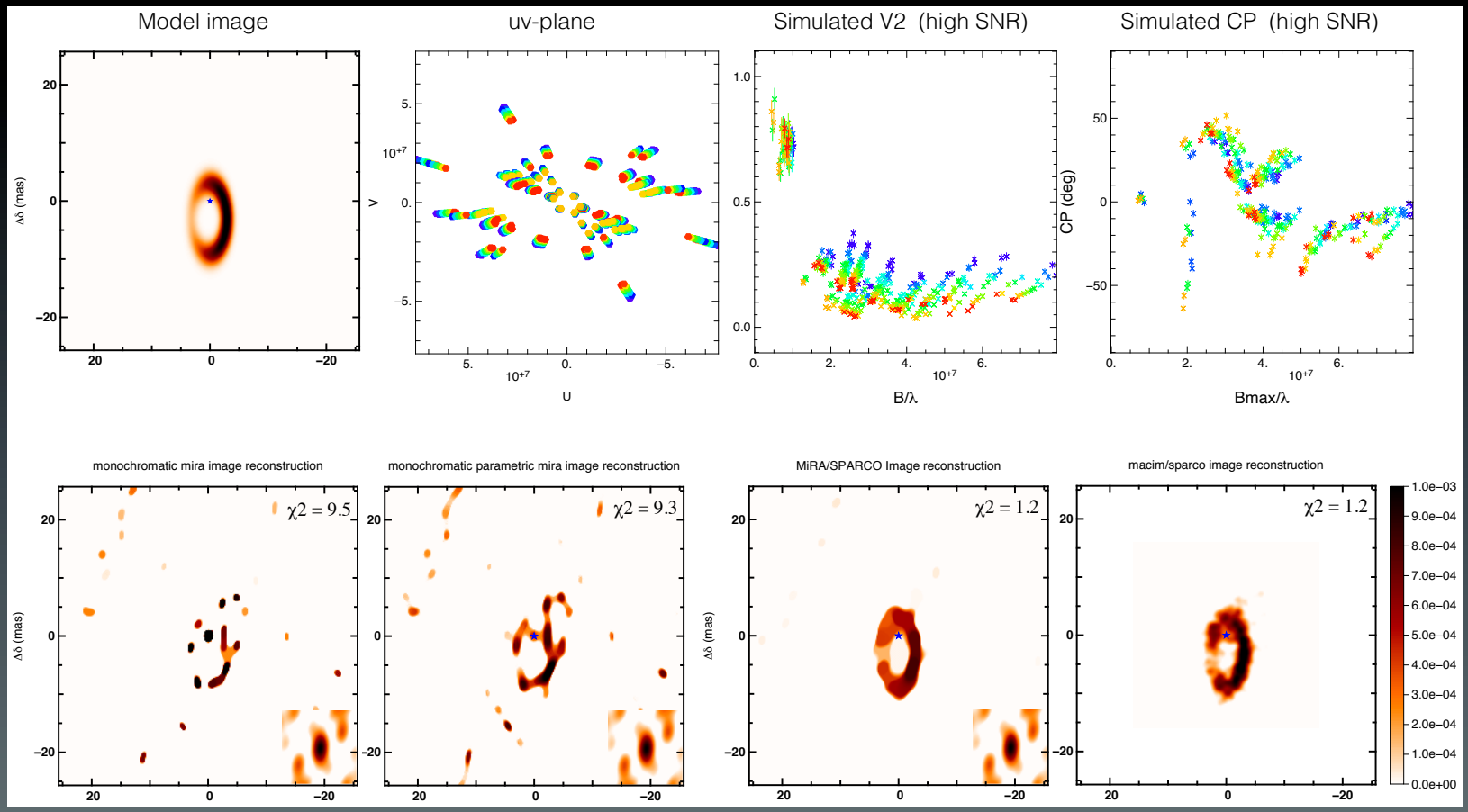


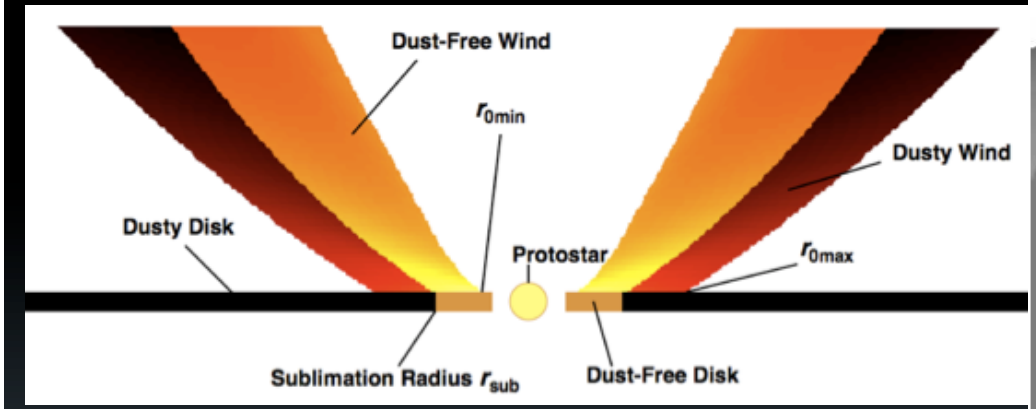


Chromatic image reconstruction

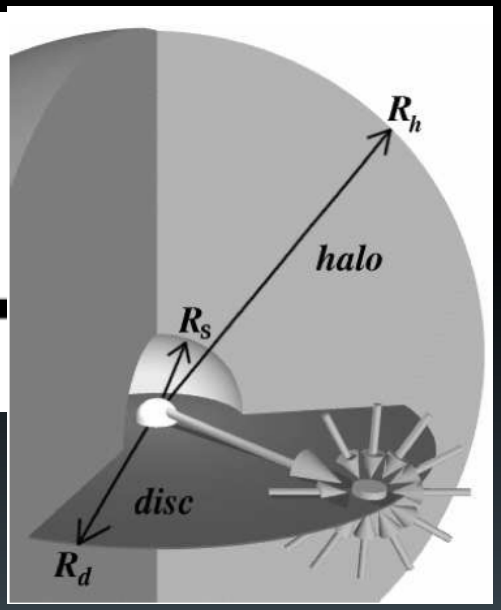


Kluska et al. (subm.)

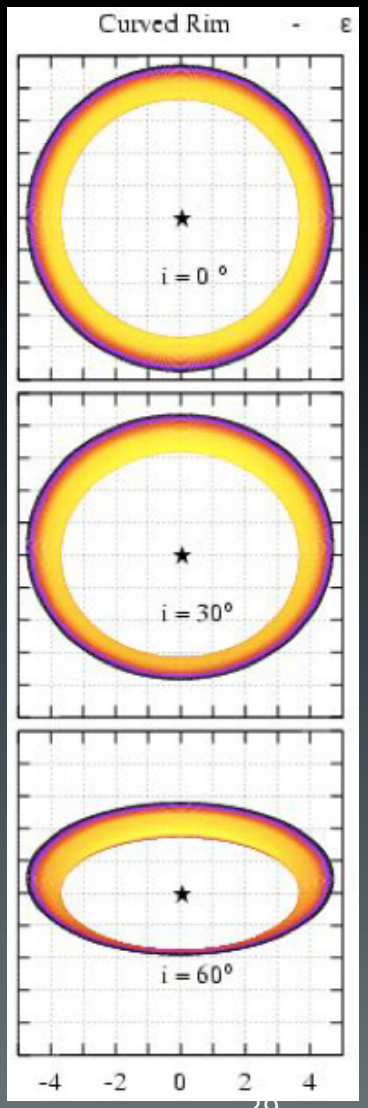
What do we want to image ?



Bans & Königl 2012



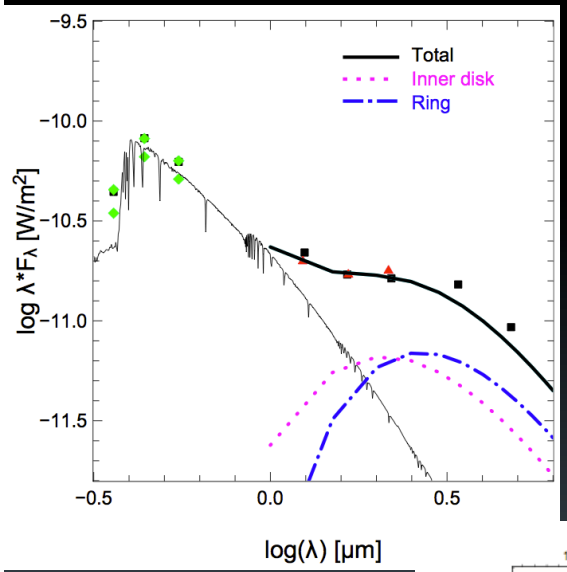
Vinkovic et al. 2003

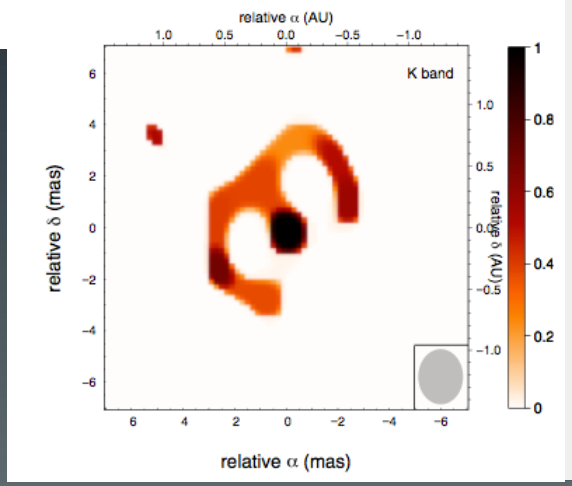


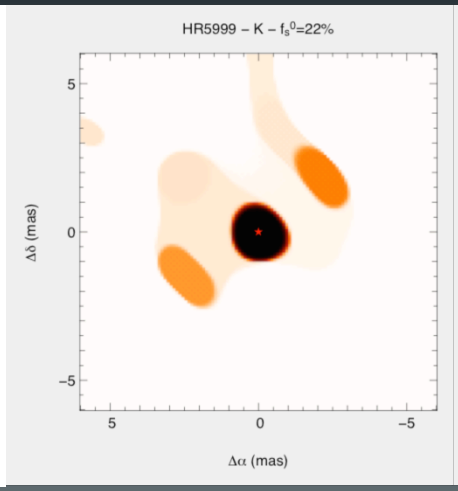
Isella & Natta 2005

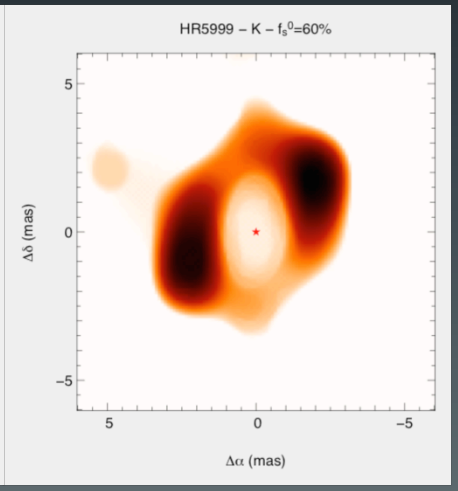
- Shape of the inner rim ?
- Asymmeties ?

Chromatic image reconstruction



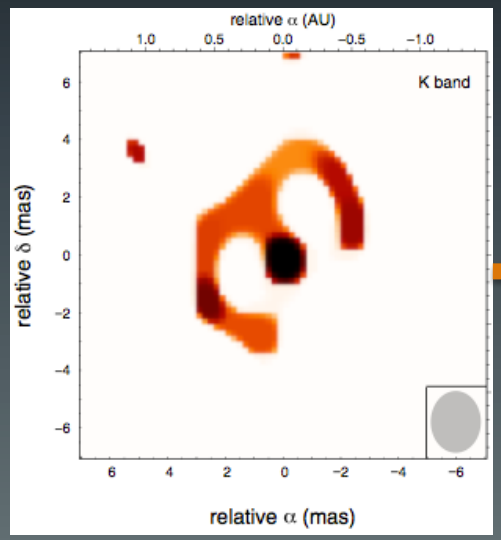


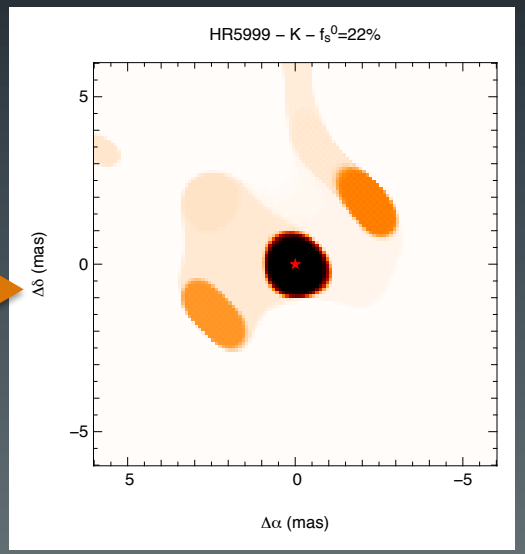




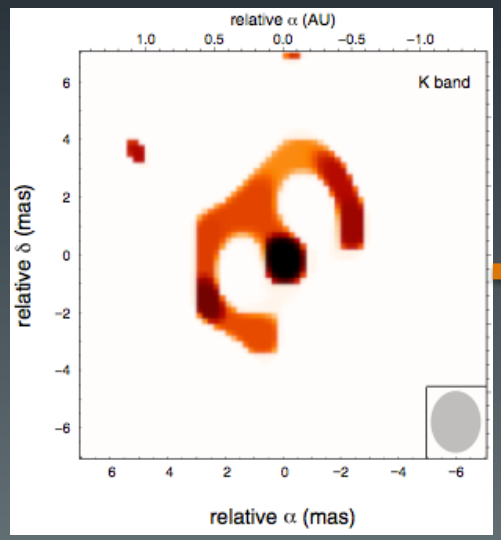
Chromatic image reconstruction

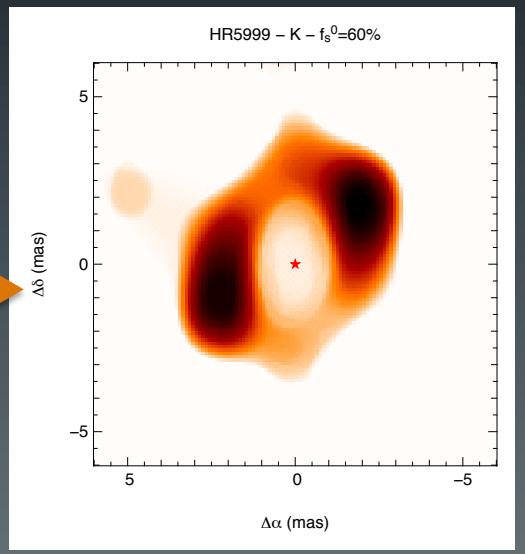
Stellar model | Image | YSO





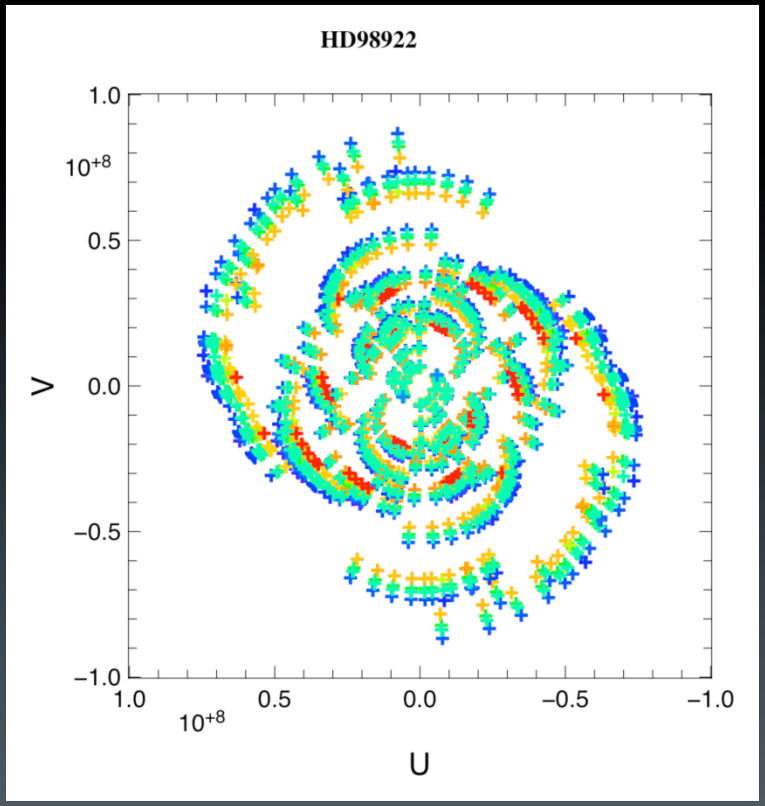
Chromatic image reconstruction





What are we imaging ?

- YSO :
  - Complex environment
  - Model independent
  - $H > 6$
- PIONER :
  - 4 Telescopes / 3 config.
  - Sensitive enough..
  - Spectral dispersion



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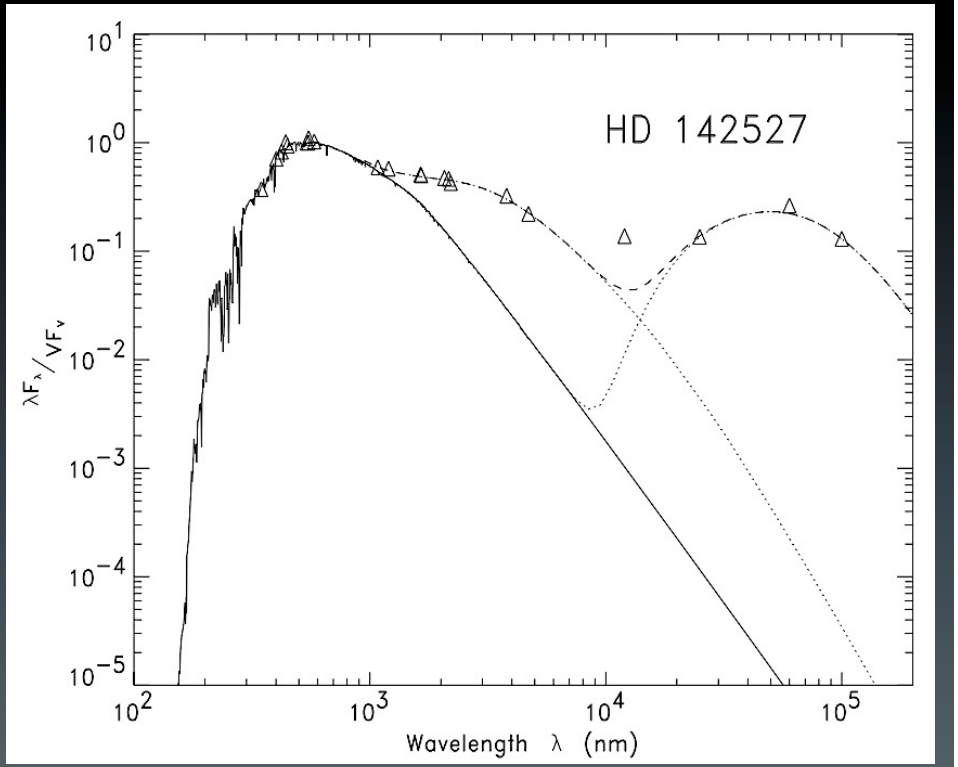
What are we imaging ?

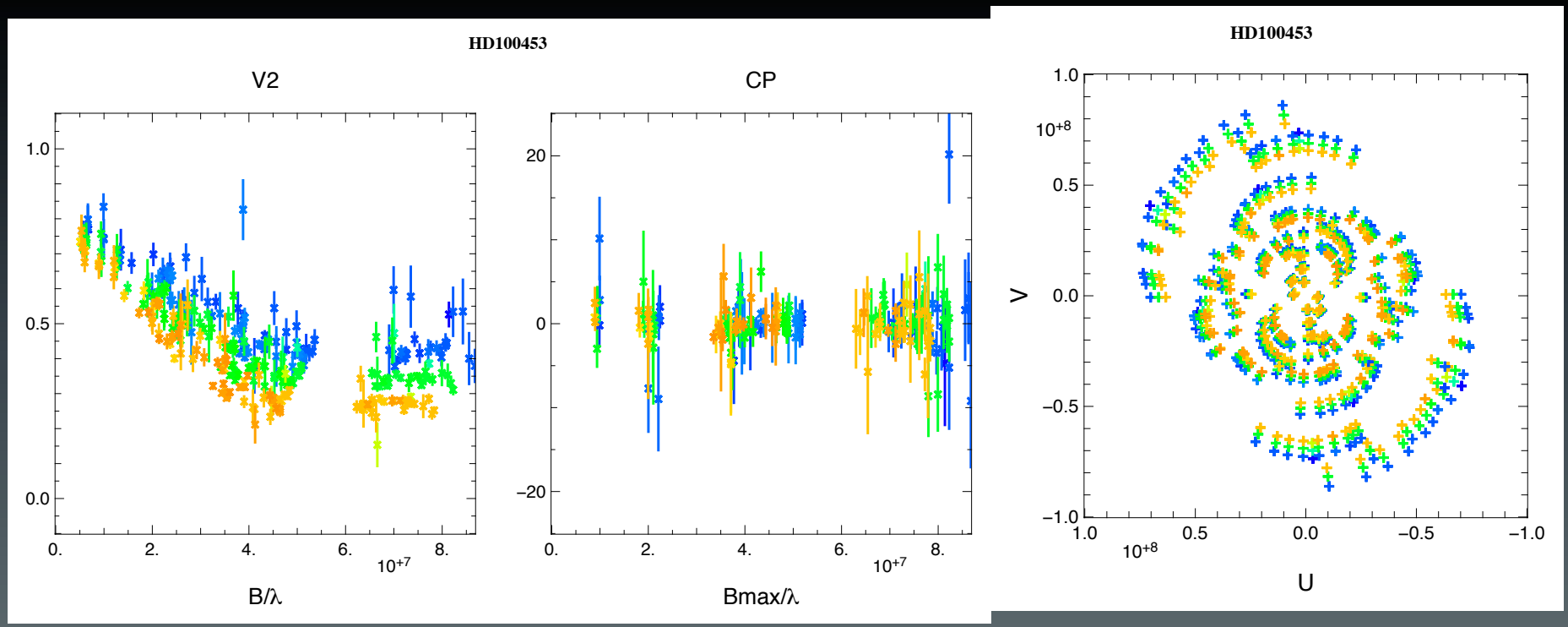
- YSO
- Near infrared
- Two components
  (at 1st order)



Malfait et al. 1998

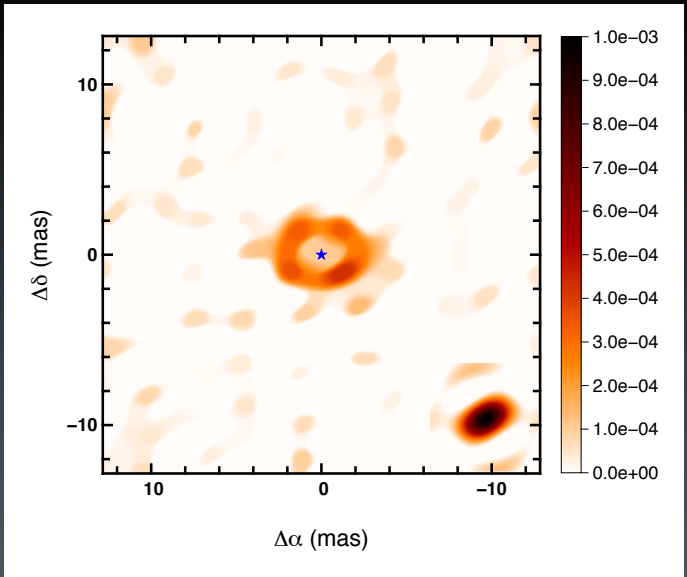
Herbig Survey

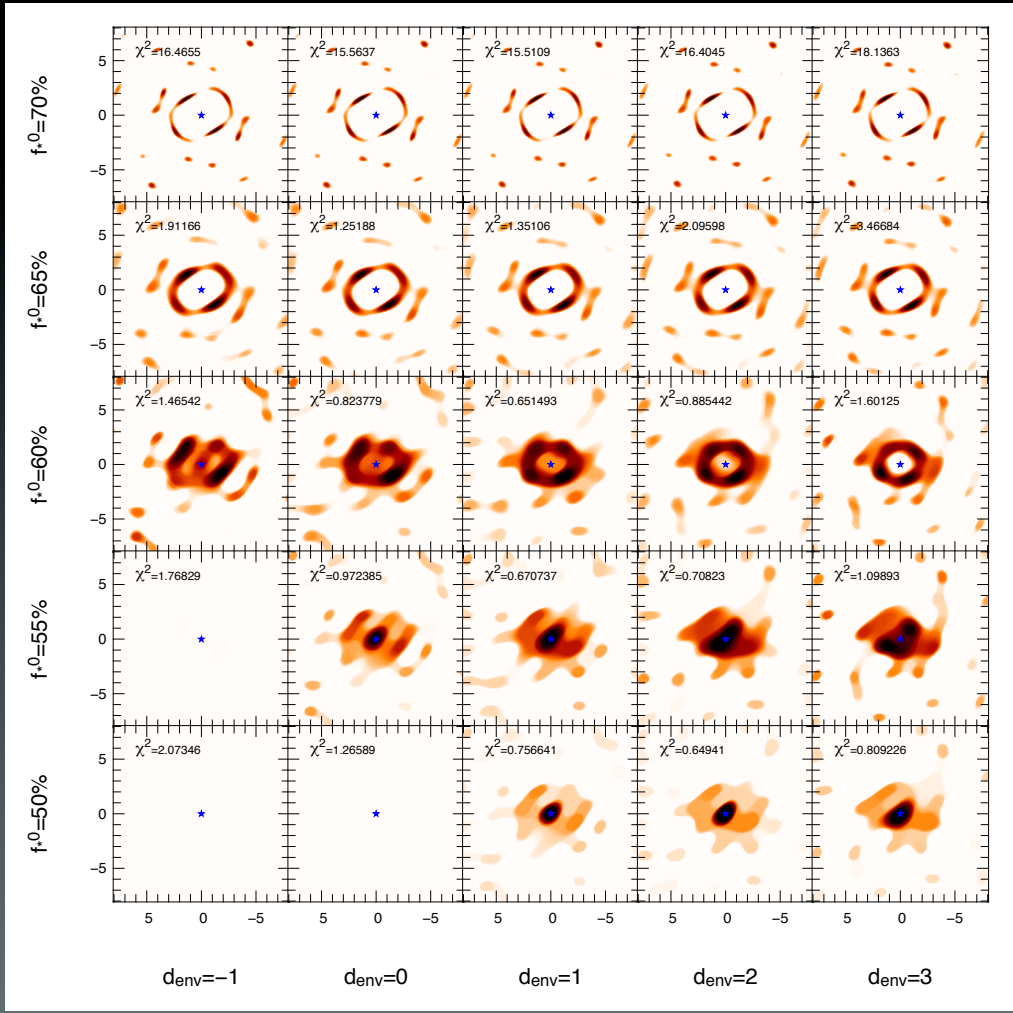
- HD100453



Herbig Survey

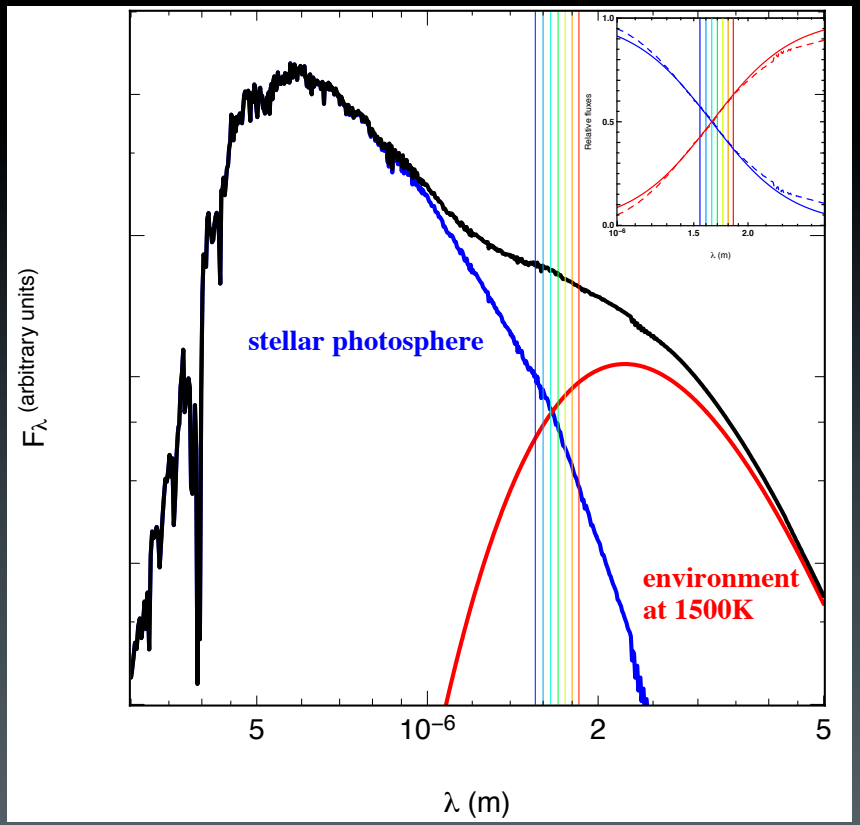
- HD100453





What are we imaging ?

- YSO
- Near infrared
- At least 2 components
  - The star
  - Its environment (~1500K)



Chromatic image reconstruction

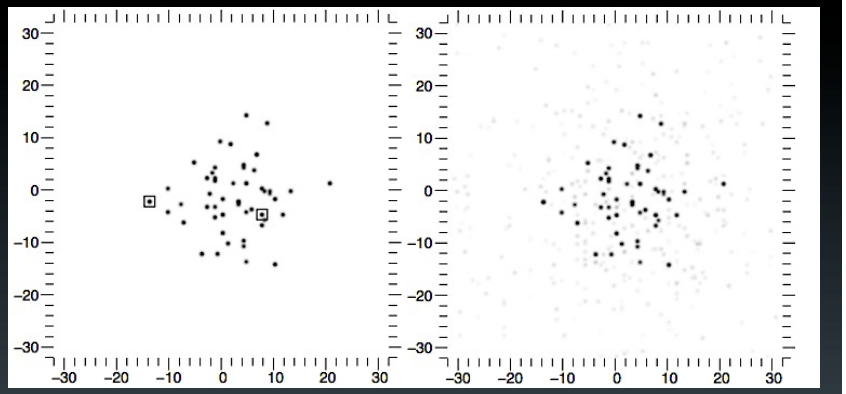
- 3D-approach (x,y,λ) :
  - MiRA-3D : Thiébaut & Soulez (2013)
  - Squeeze : Baron et al. (in prep.)

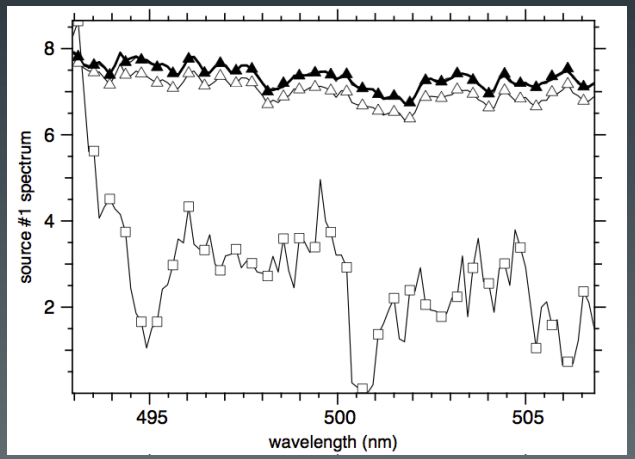
Model independent spectra

2 hyper parameters to tune

Sampling of the wavelengths :

- A lot of pixels
- Interpolation





Thiébaut, Soulez & Denis (2012)

Chromatic image reconstruction approaches

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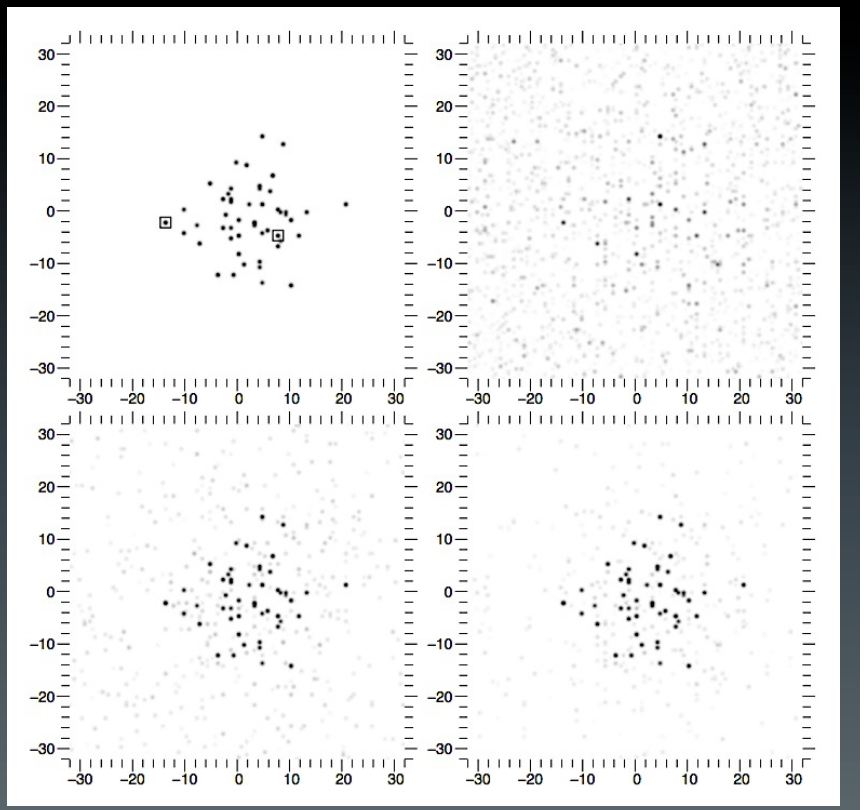
  - Squeeze : Baron et al. (in prep.)



Thiébaut, Soulez & Denis (2012)

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Model independent spectra

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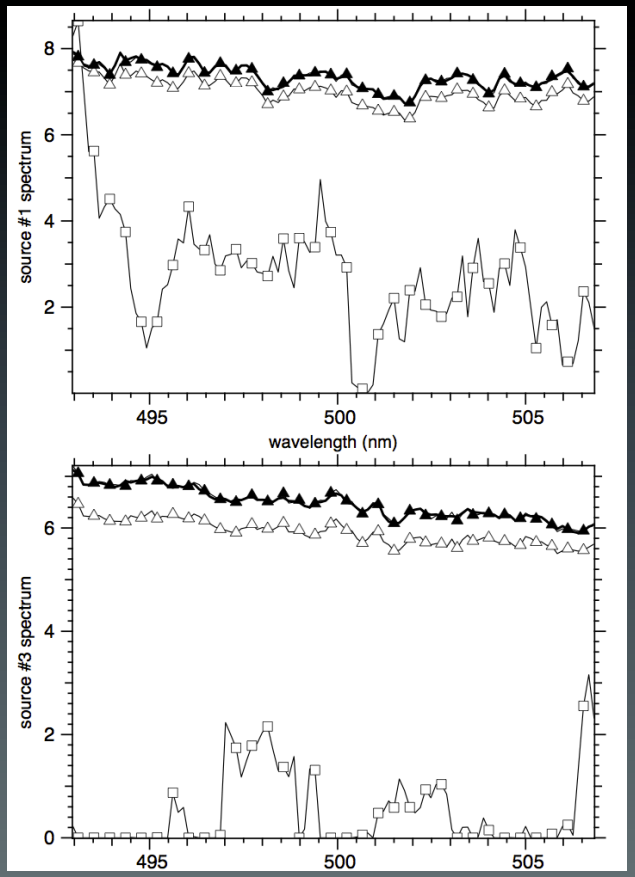

Thiébaut, Soulez & Denis (2012)

Chromatic image reconstruction

- SPARCO : Semi-Parametric Approach for imarge Reconstruction of Chromatic Objects (Kluska et al., subm.)
  - Adapted on MiRA, MACIM and Squeeze.

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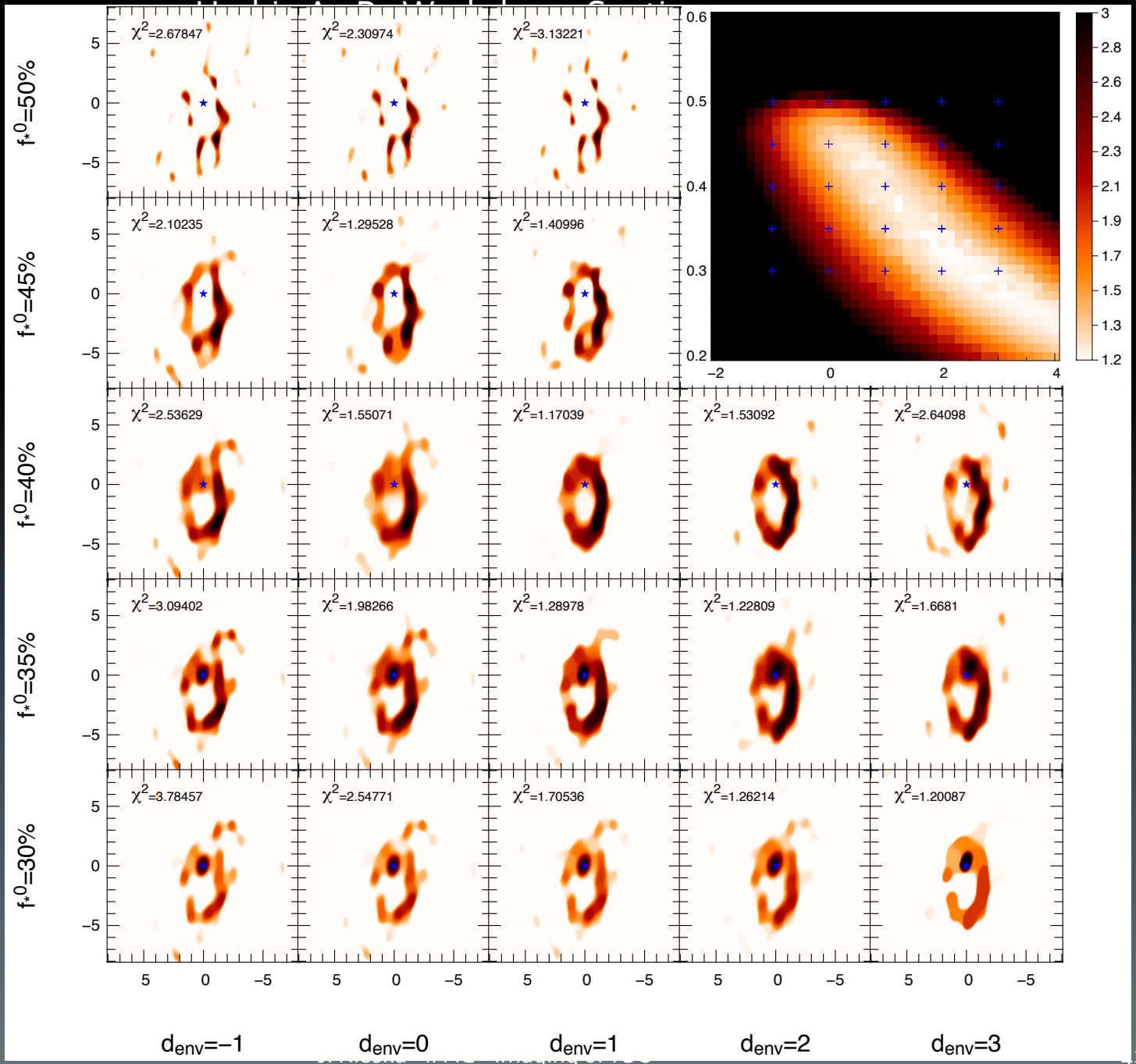
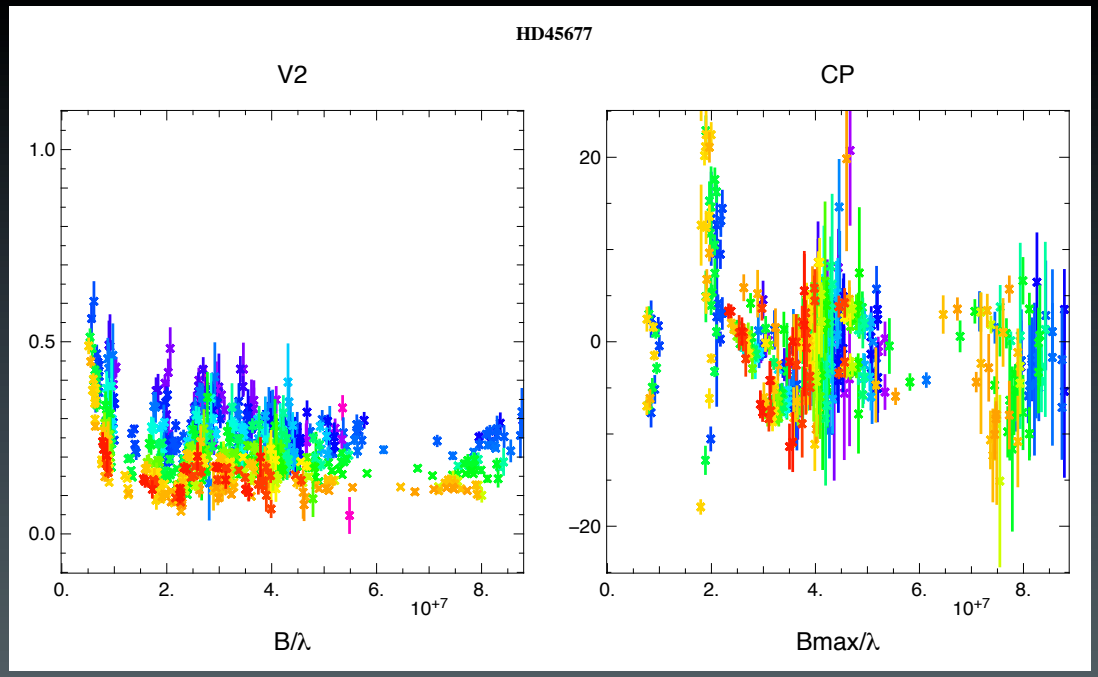
Institut de Planétologie et d'Astrophysique de Grenoble

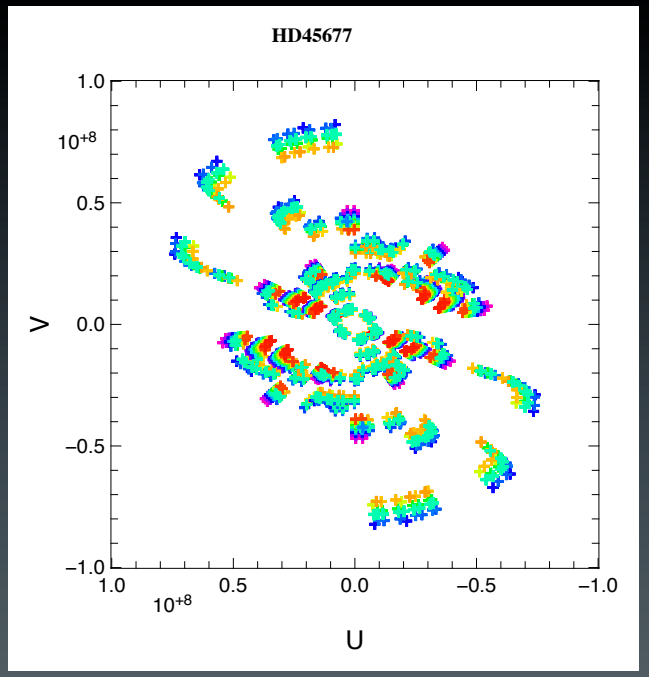


Kluska et al. in prep.

Herbig Survey

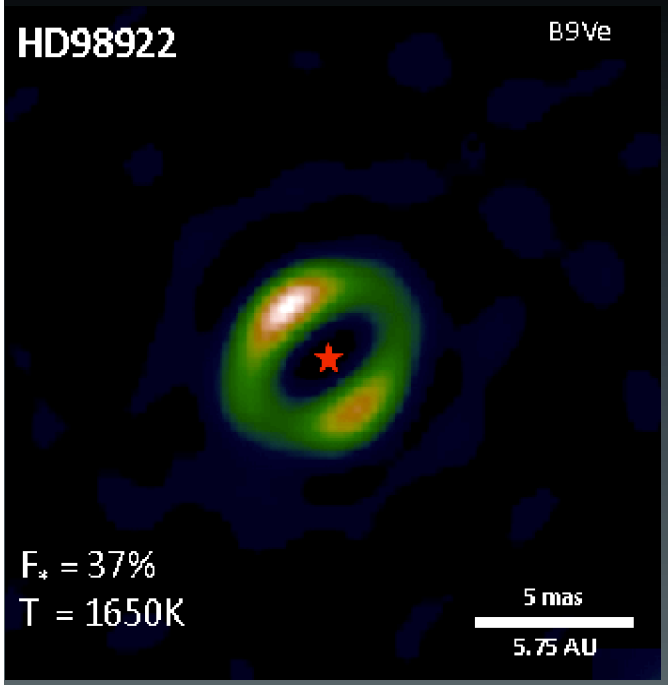
- HD45677

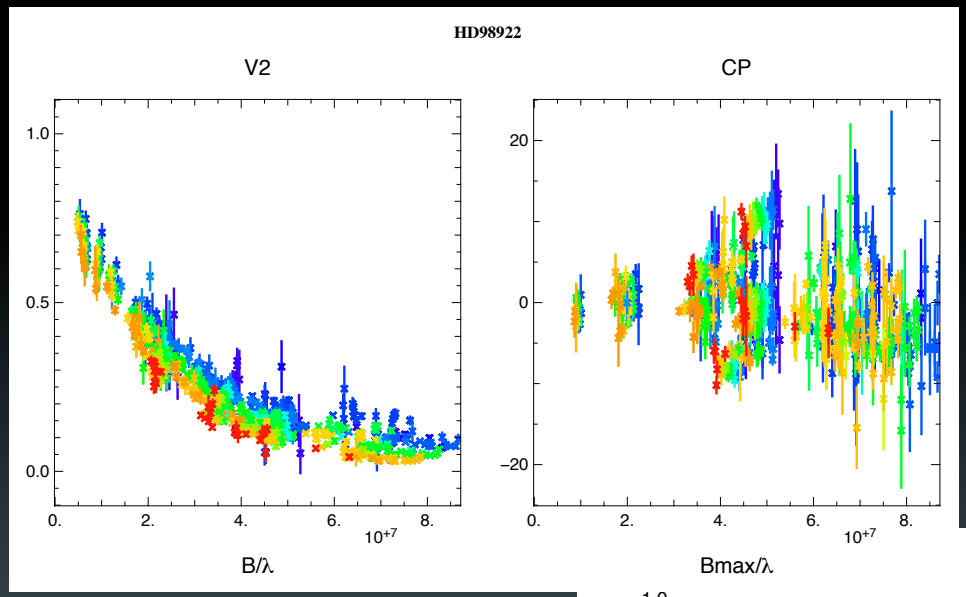


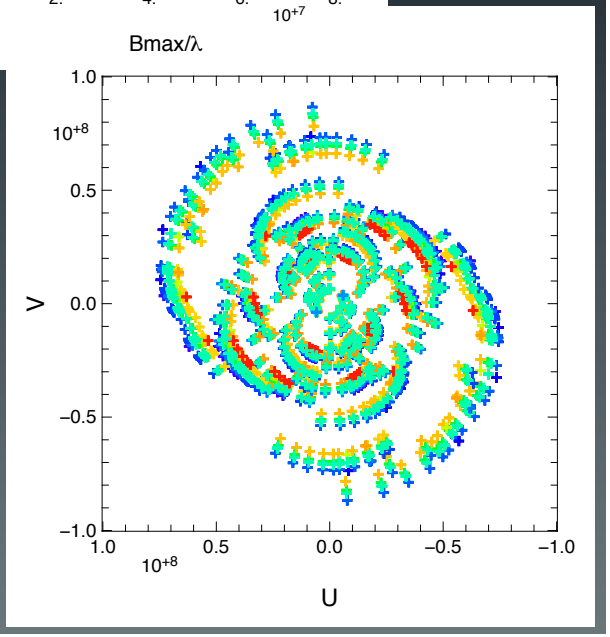


Herbig Survey

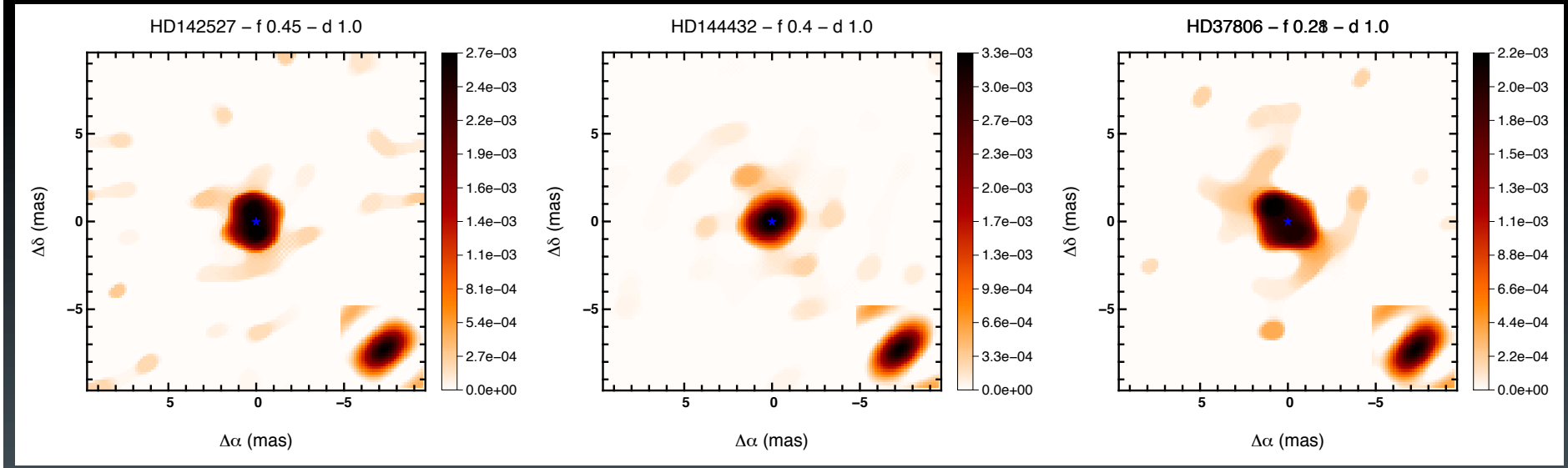
- HD98922





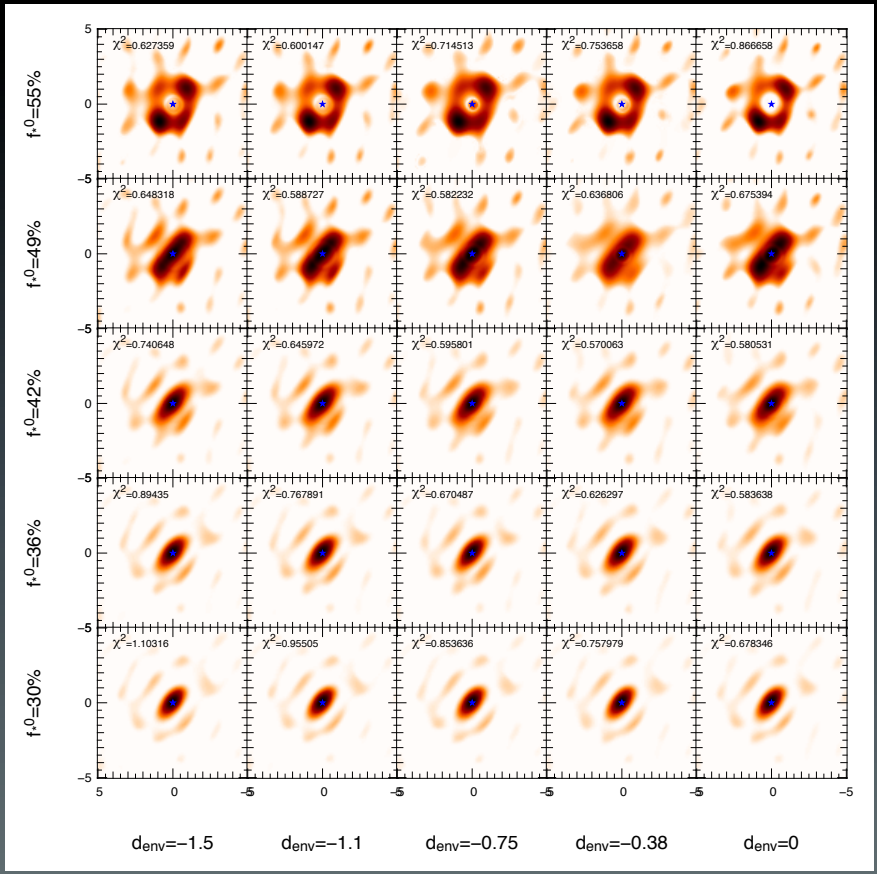


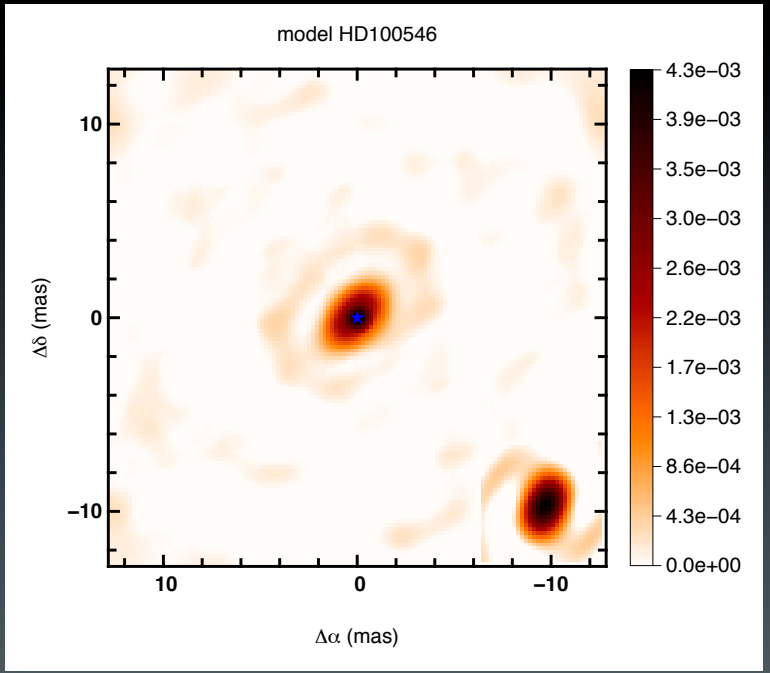
Herbig Survey



Herbig Survey

- HD100546





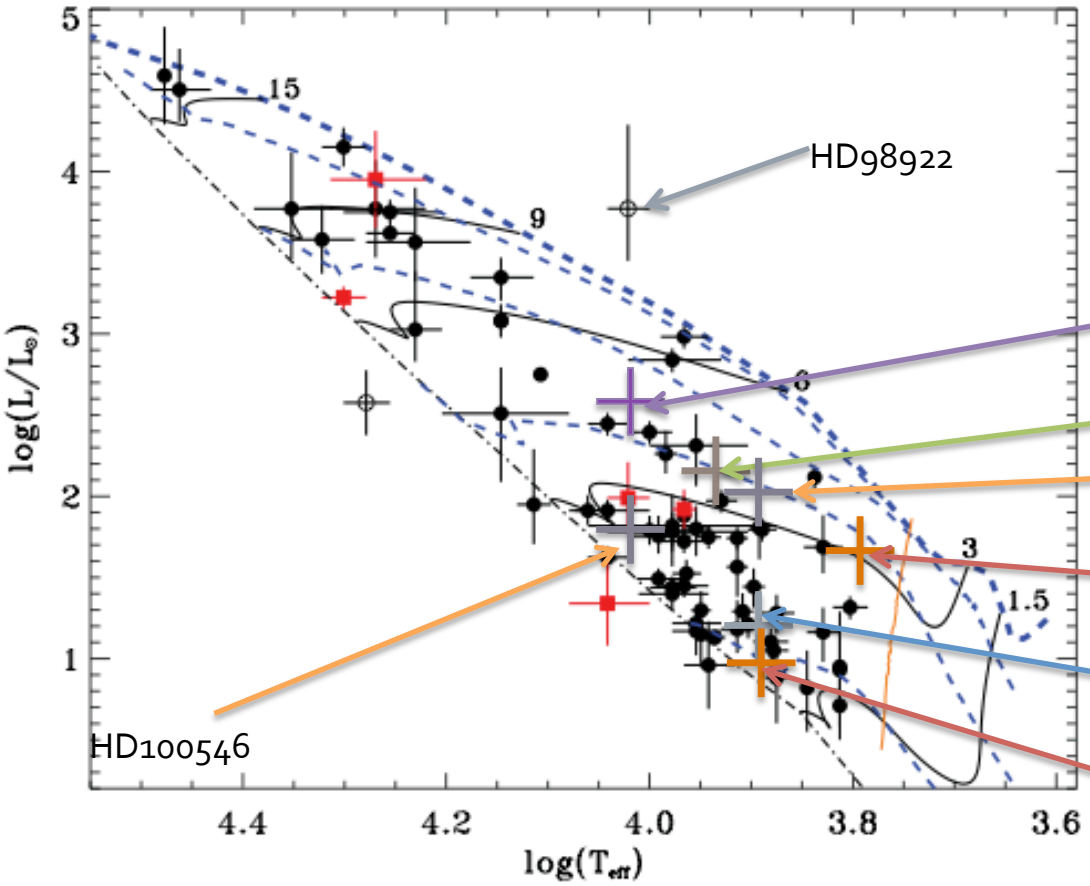


Figure 1. Magnetic (red squares) and non-magnetic (black points) HAeBe stars plotted in an HR diagram. The open circles correspond to HD 98922 (above the birthline) and IL Cep (below the ZAMS) that fall outside of the PMS region of the HR diagram, whose positions cannot be reproduced with the theoretical evolutionary tracks considered in this paper. The CESAM PMS evolutionary tracks for 1.5, 3, 6, 9 and 15 $M_{\odot}$ (black full lines), 0.01, 0.1, 1 and 10 Myr isochrones (blue thin dashed lines), and the ZAMS (black dot–dashed line) are also plotted. The birthline taken from Behrend & Maeder (2001) is plotted with a blue thick dashed line. The convective/radiative phase transition is overplotted with an orange triple dot–dashed line.

Alecian 2013

HD158643

HD37806

HD144668

HD142527

HD144432

HD100453