Companions to A-F type stars

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I. Context

1. Search for giant exoplanets (GPs):

- Most of exoplanets found around Solar-mass stars

2. A-F type stars:

- **Stellar mass** : a key parameter to understand planetary formation and evolution

- Radial velocity surveys of A-F Main Sequence stars with Harps and Sophie :

    - several planetary and/or brown dwarfs candidates

    - in most cases : only the **close separations** are investigated   (**P** < a few hundreds days ; **a** < 1-2 AU)

    (Lagrange et al. 2009, Lagrange et al. 2013)

3. Young stars:

- Stars in young associations : more favorable to the search for GPs than older stars thanks to a lower contrast.

- Complementarity between RV and Direct Imaging.

exoplanet.eu, 2014-1-12

Stellar mass (in Solar mass)
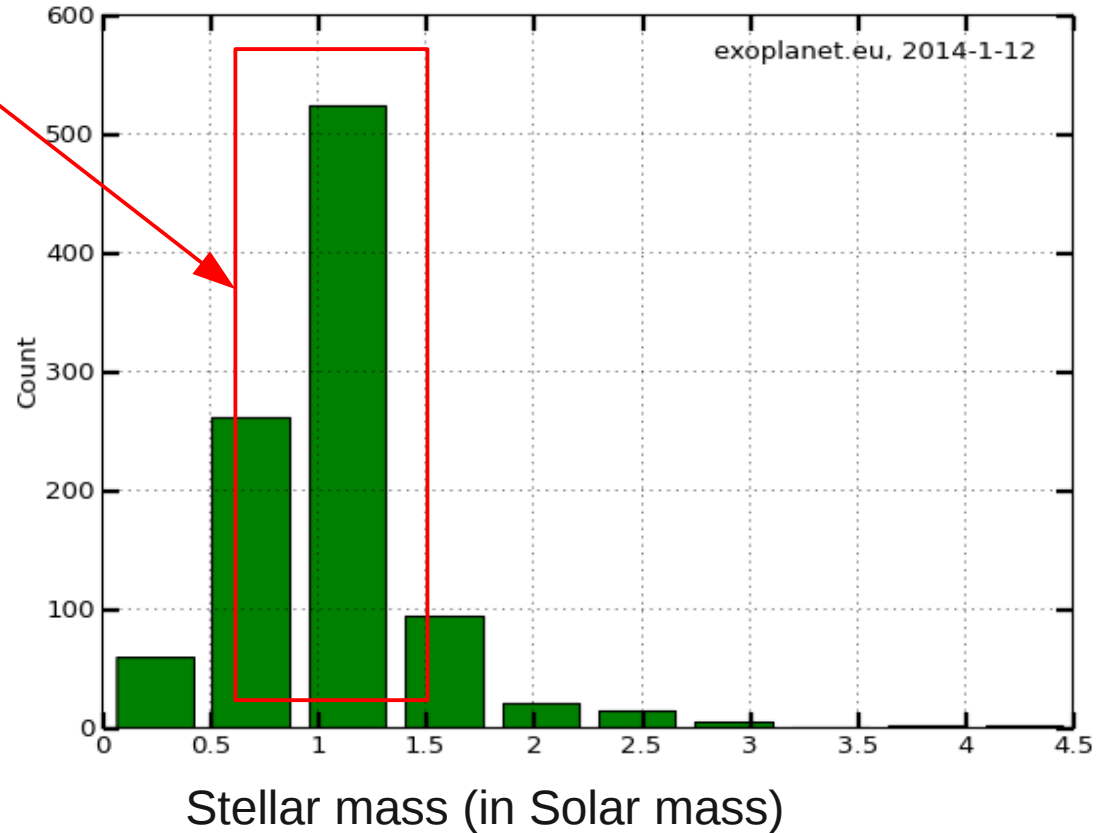
(From exoplanet.eu)

Contribution of interferometric observations

- Improving the coverage of longer orbital periods

- Ruling out unknown stellar / BD companions as possible source of RV variations

- Improving RV detection limits in the BD domain for very early type stars and/or fast rotators

Interferometric detection limits
(Pionier/VLTI)

Radial velocity detection
limits
(Harps/La Silla)

Direct imaging detection
limits
(Naco, SPHERE/VLT)

VLTI/PIONIER

SAM

NACO

RV/HARPS

SPHERE

M (/Mjup)

Semi-major axis (AU)
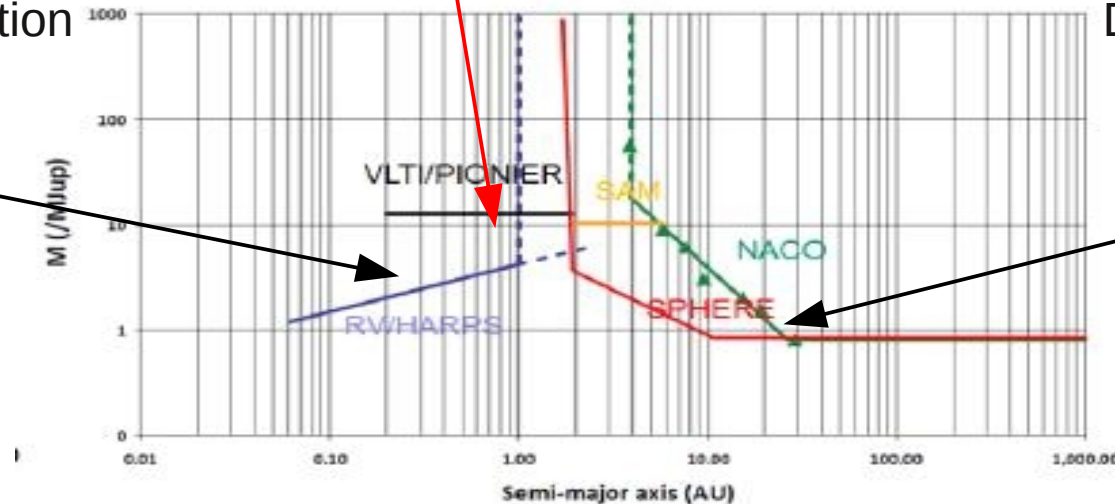
Schematics of achievable detection limits in the case of Beta Pictoris

# II. Method : searching for companions with Pionier

- Strategy described in *Absil et al. 2011* :

    - closure phase as main interferometric observable

    - not affected by atmospheric turbulence

    - sensitive to off-axis companions

- 3-4h integration time -> highest possible dynamic (1:200 -> 1:500)

- Fit of obs. data with binary models (χ^2 minimization)

- Comparison of the best fit to single-star model

- Detection at 3σ level

- In case of non-detection : computation of sensitivity limits

    (2d-map of 3σ upper limits on flux ratio ; 1d diagram of flux ratio versus angular distance)
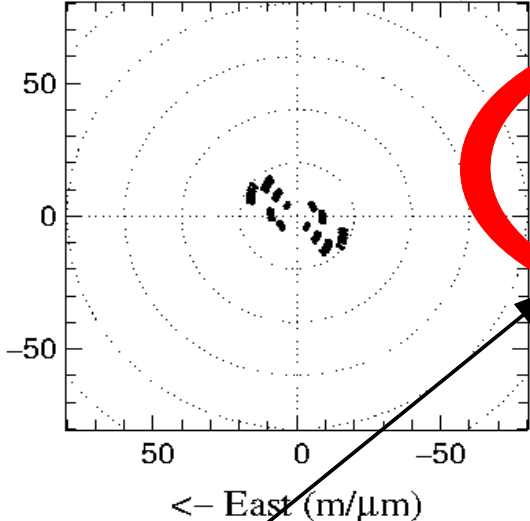
III. Detail of the sample

Star HD	Star HIP	Spectral type	Association or age
203 (*)	560	F3V	B Pic
15115 (*)	11360	F2V	B Pic
29391	21547	F0V	B Pic
31746	22844	F5V	1.4 Gyr
39060 (*)	**27321**	**A6V**	**B Pic**
60532	**36795**	**F6V**	**2.6 Gyr**
109573 (*)	61498	A0V	TWA
146624	79881	A0V	B Pic
164249 (*)	88399	F6V	B Pic
172555 (*)	92024	A7V	B Pic
174429	92680	G9IV	B Pic
181327 (*)	95270	F6V	B Pic
191089 (*)	99273	F5V	30 Myr
197481 (*)	102409	M1V	B Pic
207575 (*)	107947	F6V	TucHor
218396 (*)	**114189**	**A5V**	**Col**
224392	118121	A1V	TucHor

IV. A possible close low-mass stellar companion around the young A-type star **HD224392**

- HIP 118121 – eta Tuc

- Spectral type : A1V

- Member of Tuc Hor assoc. (30 Myr)

- D = 48.7 pc

- mH = 4.95

- Fast-rotator (vsini = 190 km/s)

- Harps RV data (*Lagrange et al. 2009*) : no detection

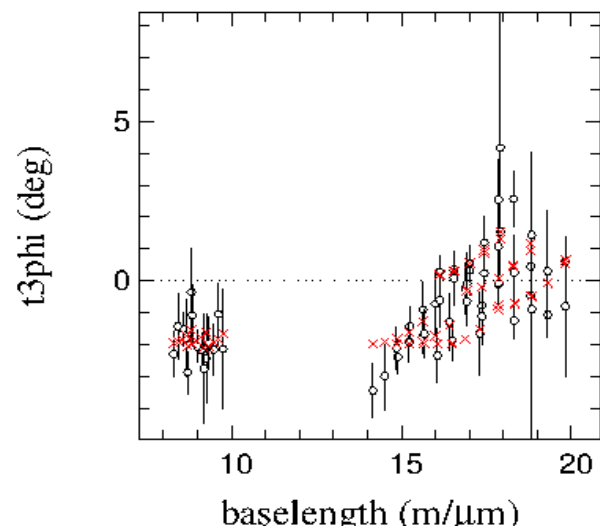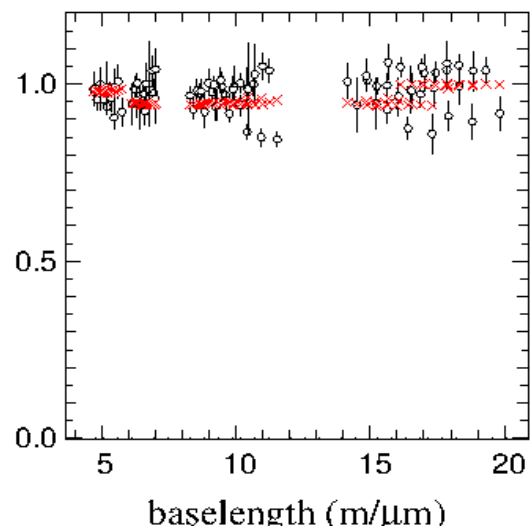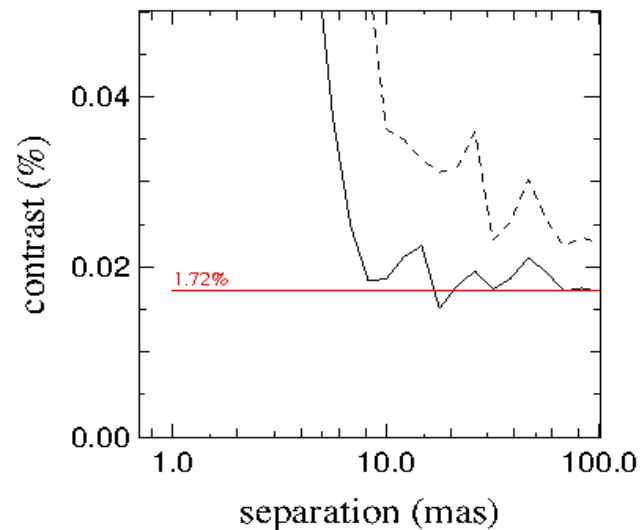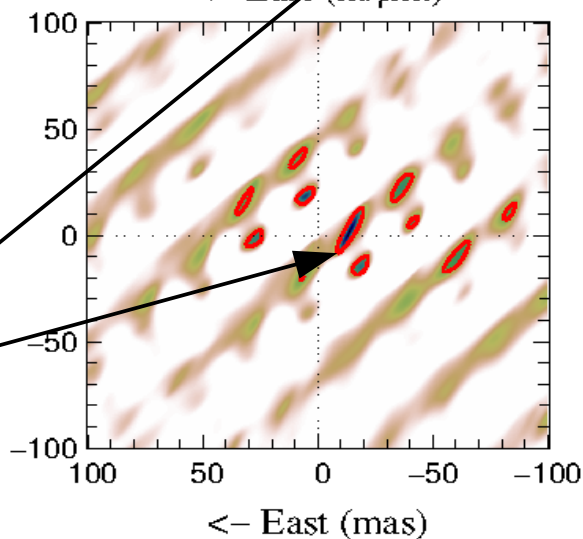- NaCo direct imaging (*Ehrenreich et al. 2010*) : no detection at sep. > 7 AU.

Harps – HD224392 – A1V – $v \sin i = 190$ km s^{-1}

Radial Velocity [m s^{-1}]

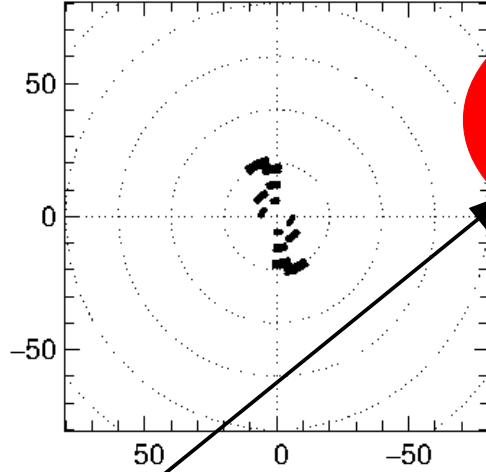Julian Day – 2453000
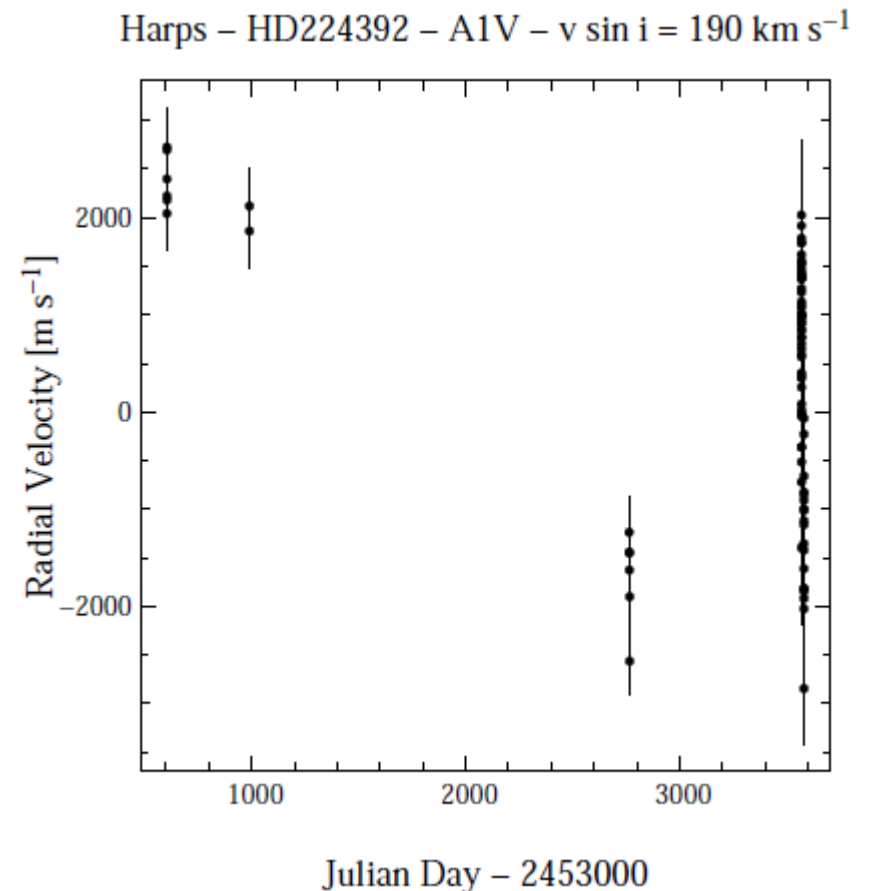
August 2012 :
- bases :A1-B2-C1-D0

X2single=3.98
P1 = 9.23e-08%   P0= 3.8e-21%

X2bin=0.75
1.58% (-13.89,2.13)mas

- $P_0 \sim 0$;
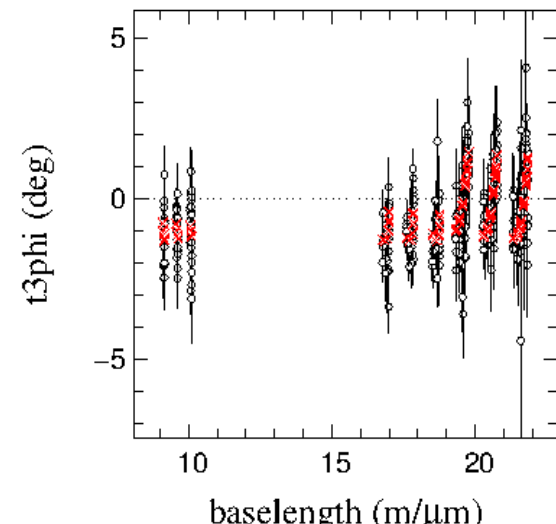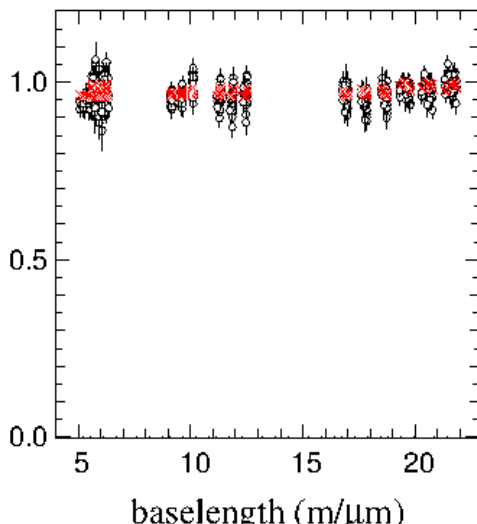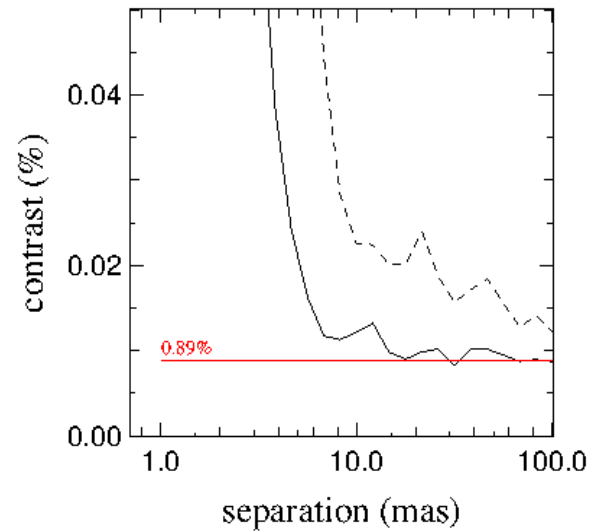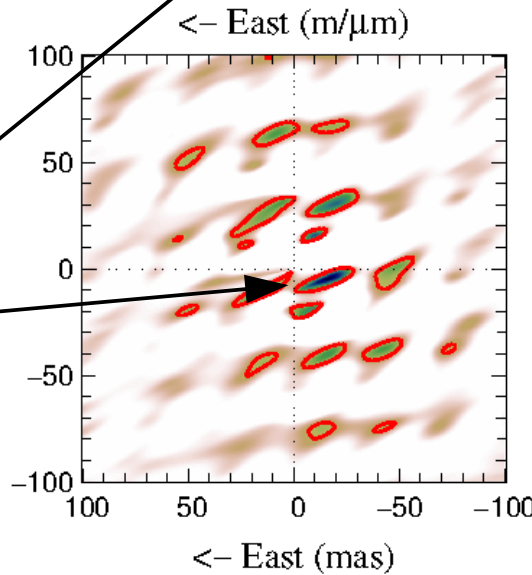- Contrast 1.58 %
- Best-fit position :
(-13.89,2.13) mas

September 2013 :
- bases :A1-B2-C1-D0

X2single=2.70
P1 = 3.59e−33%   P0= 7.38e−56%

X2bin=0.88
1.04% (−16.40,−4.63)mas

- $P_0 \sim 0$;
- Contrast 1.04 %
- Best-fit position :
(-16.40,-4.63) mas

Preliminary characterization of HD224392 possible companion

- Using 2012 and 2013 data :

  - separation between 0.65 and 0.8 AU.

  - contrasts of 1.58 – 1.04 % -> $\Delta H = 4.5 – 4.95$.

  - Companion : $H = 6.0 – 6.5$ ($mH = 9.45 – 9.9$)

- First estimation of the mass of the companion :

  - using various evolutionary models (*Allard et al. 1998*, *Chabrier et al. 2000*, *Baraffe et al. 2003*)

  - mass between **0.15 and 0.35 solar mass**.

- Not detectable with AO.

- Remarks :

    - detection still uncertain (see talk of O.Absil)

    - could still be due not to a companion but to an asymmetric disk.

Typical detection limits : example of AU Mic

M1V; member of Beta Pic moving group (~21 Myr); d=9.91 pc
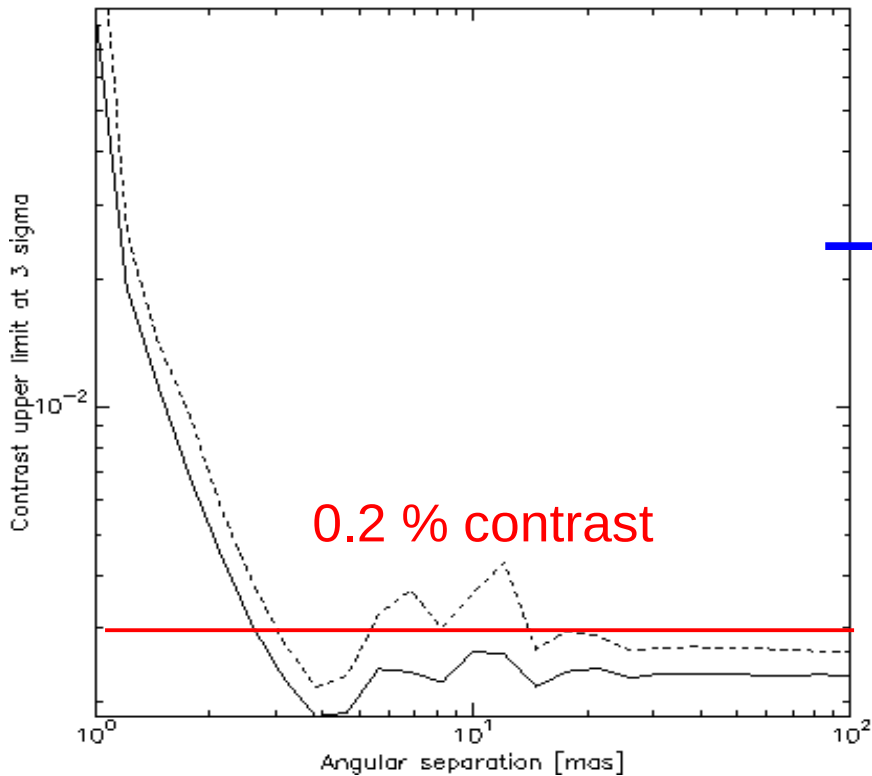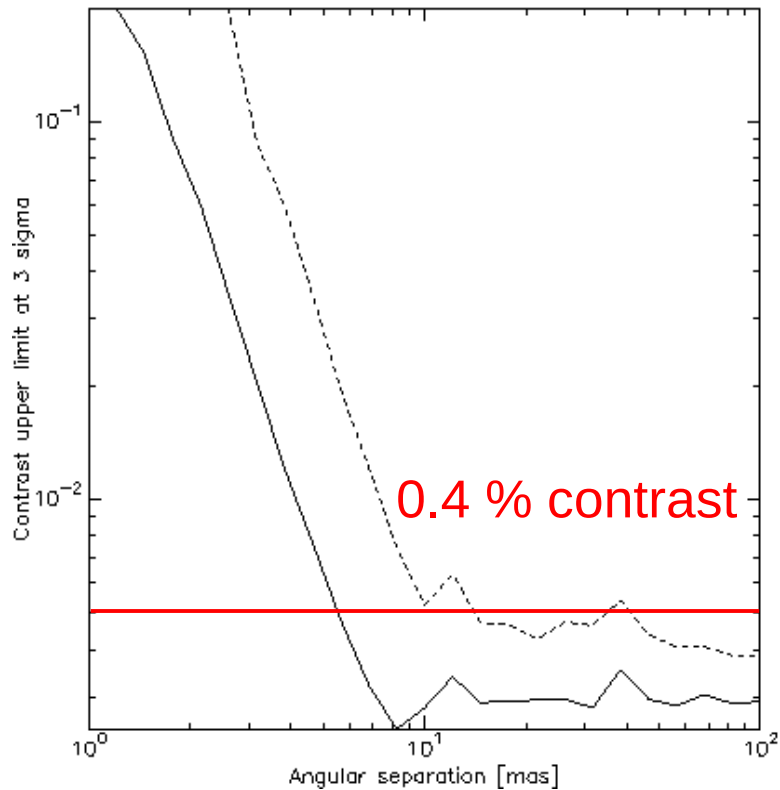
Stellar H, d, age and COND_03 ev. model
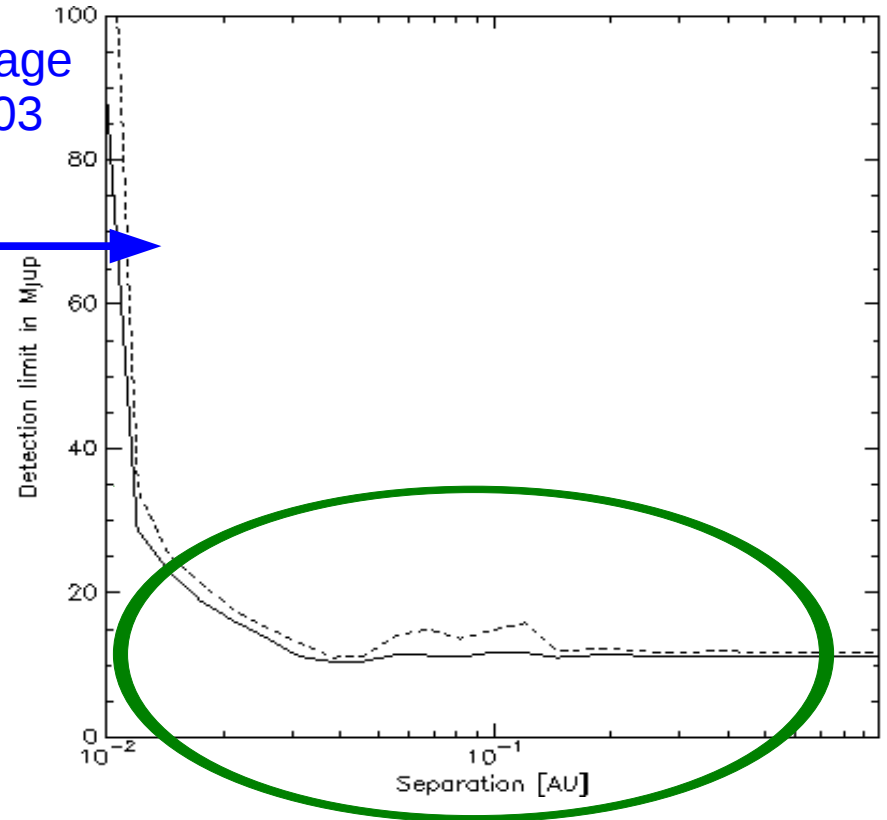
0.2 % contrast

Sensitivity function of angular separation for two levels of completness (plain – median and dotted – 90% completness)
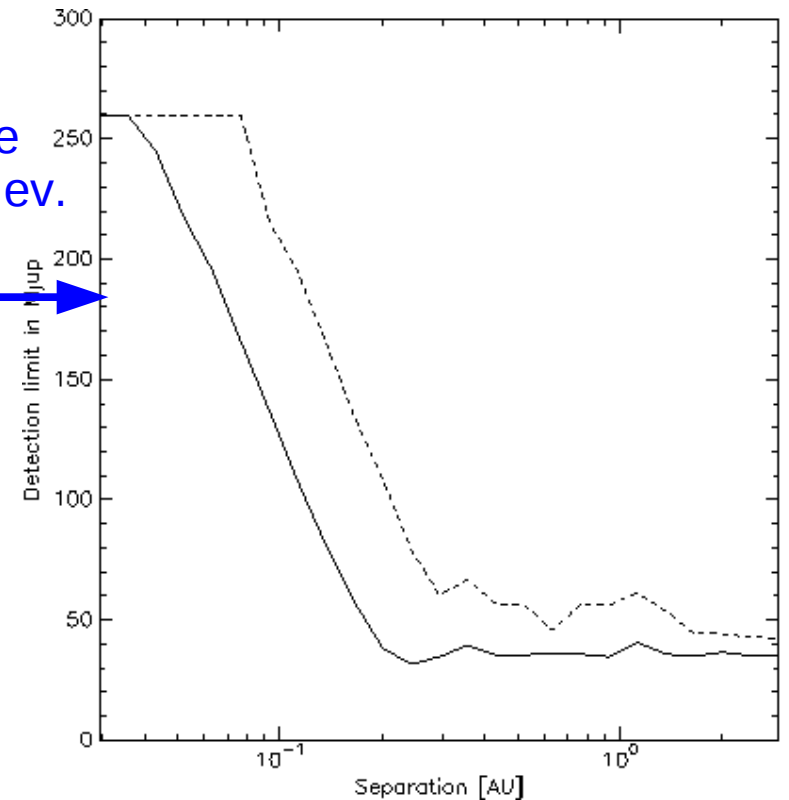
Detection limit (in Mjup) function of separation

Typical detection limits : example of HIP21547

F0V; member of Beta Pic moving group (~21 Myr); d=29.43 pc

Stellar H, d, age and COND_03 ev. model

0.4 % contrast

Sensitivity function of angular separation for two levels of completness (plain – median and dotted – 90% completness)

Detection limit (in Mjup) function of separation

Conclusions and perspectives

- Validation and full characterization of HD224392 companion (if real)

- Potential contribution to evolutionary models calibration

- Combination of radial velocity (Harps), interferometric (Pionier) and future SPHERE detection limits

- Potential extension to other young, nearby stars (depending on Pionier future):

  - new Harps survey of young, nearby stars, started in 2013.