Giant planets

NO GAP BUT LOCAL MINIMA

Brown dwarfs

Maddalena Reggiani

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Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

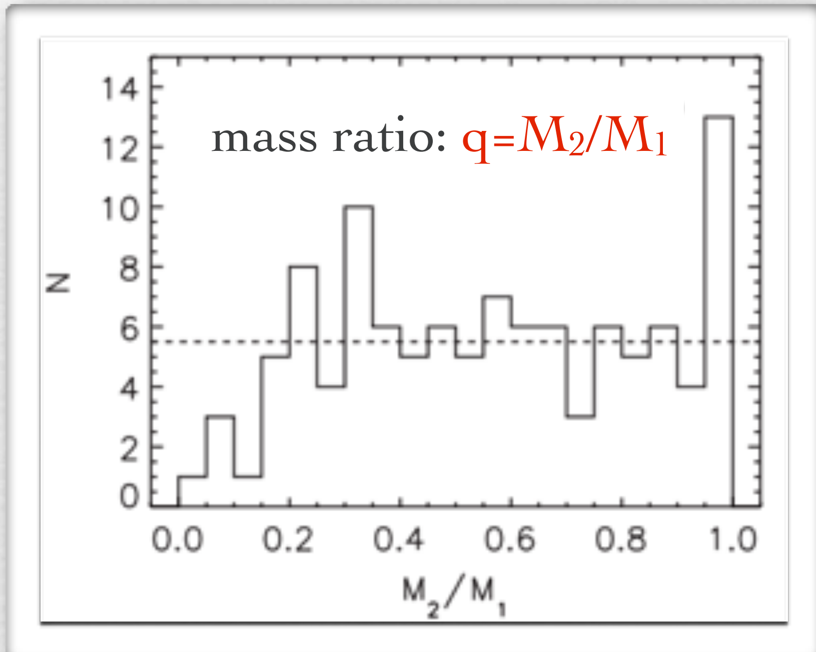
Credit: ESO

What's the problem?

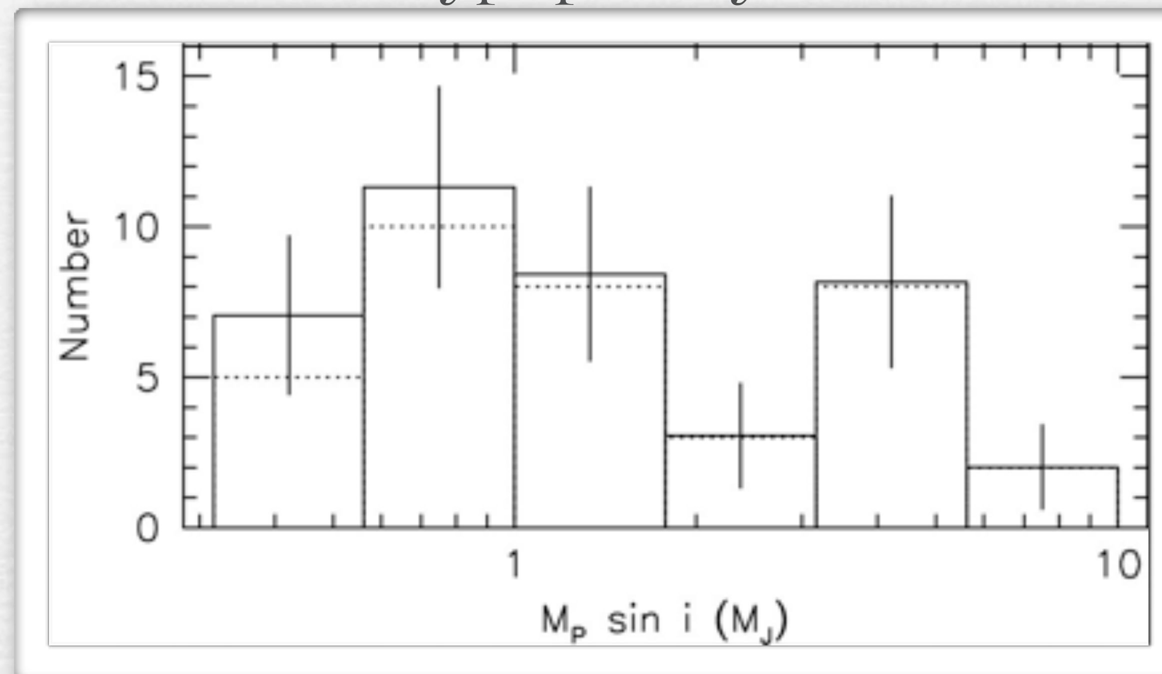
STELLAR COMPANIONS

PLANETS

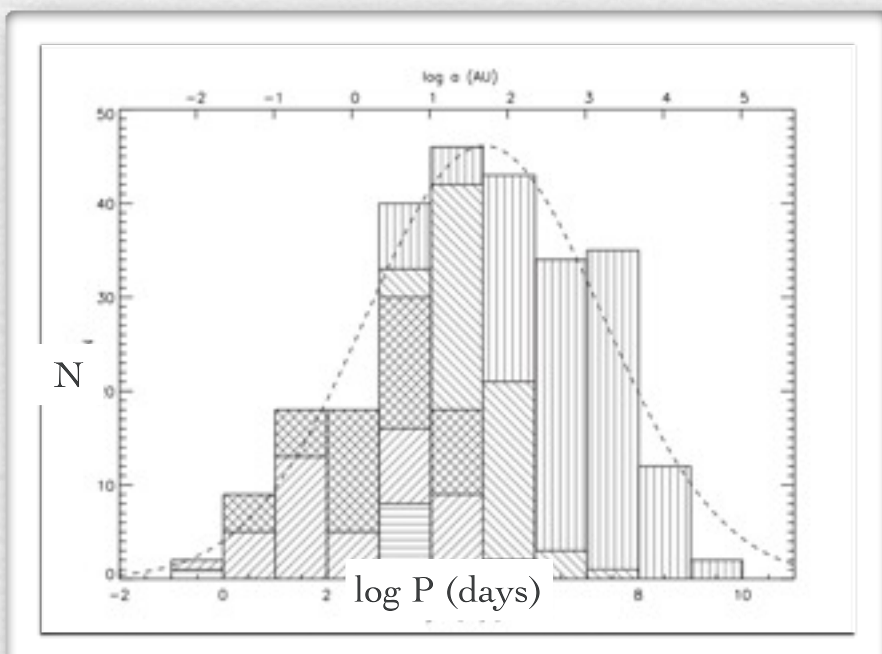
Solar-type primary CMRD



Solar-type primary CMF



Period distribution



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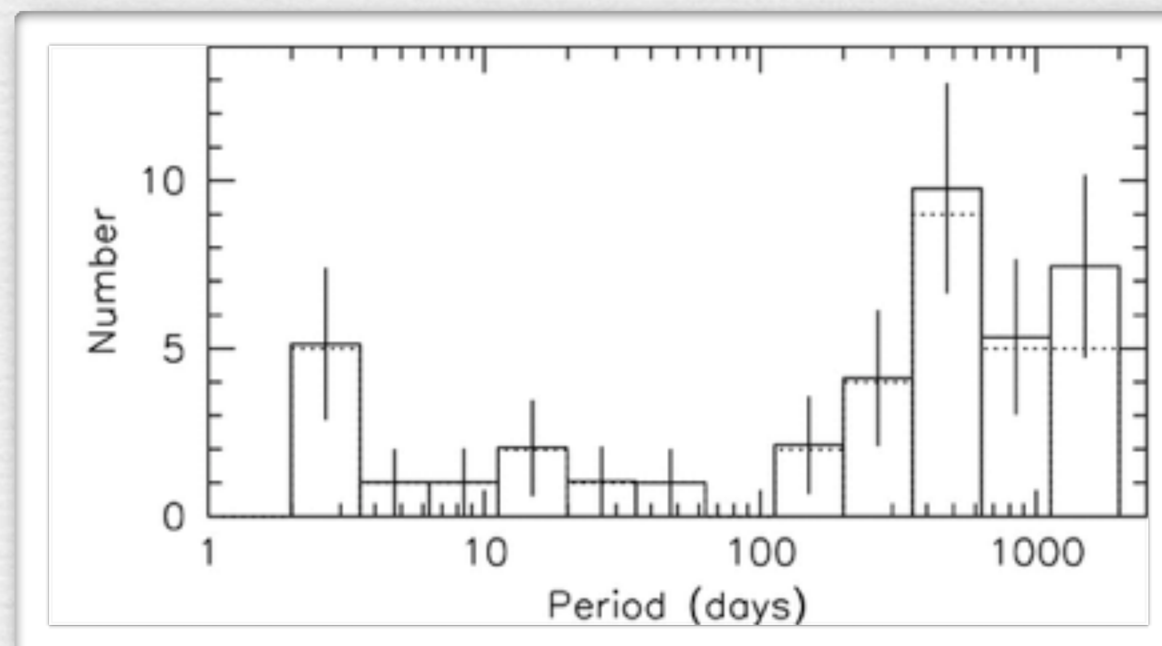

(Raghavan et al. 2010)

(Cumming et al. 2008)

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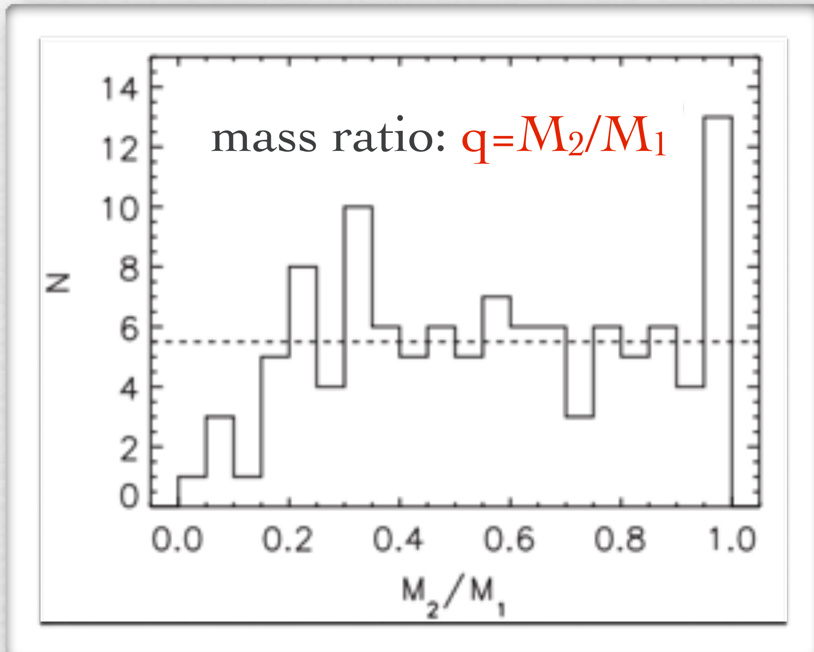

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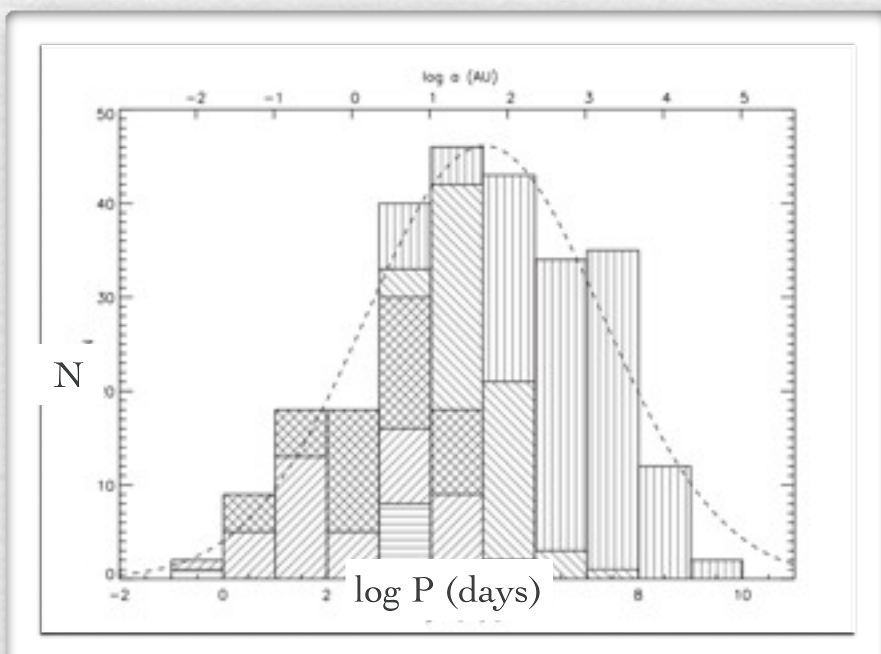

(Raghavan et al. 2010)

?

... and BDs?

PLANETS

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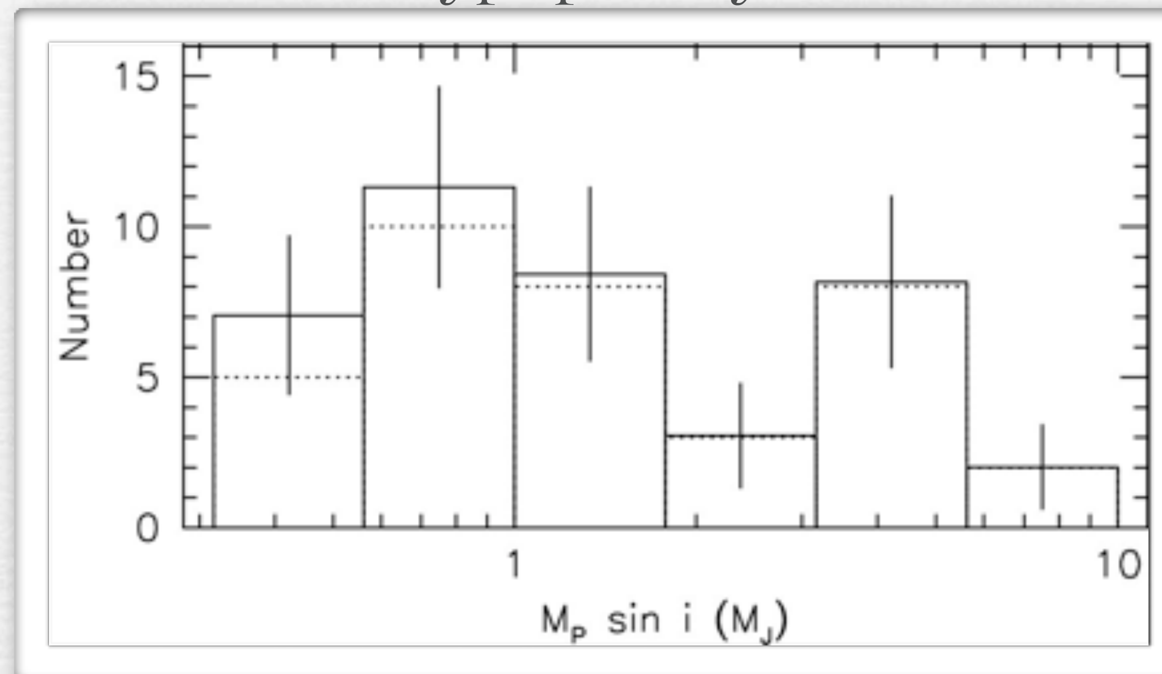

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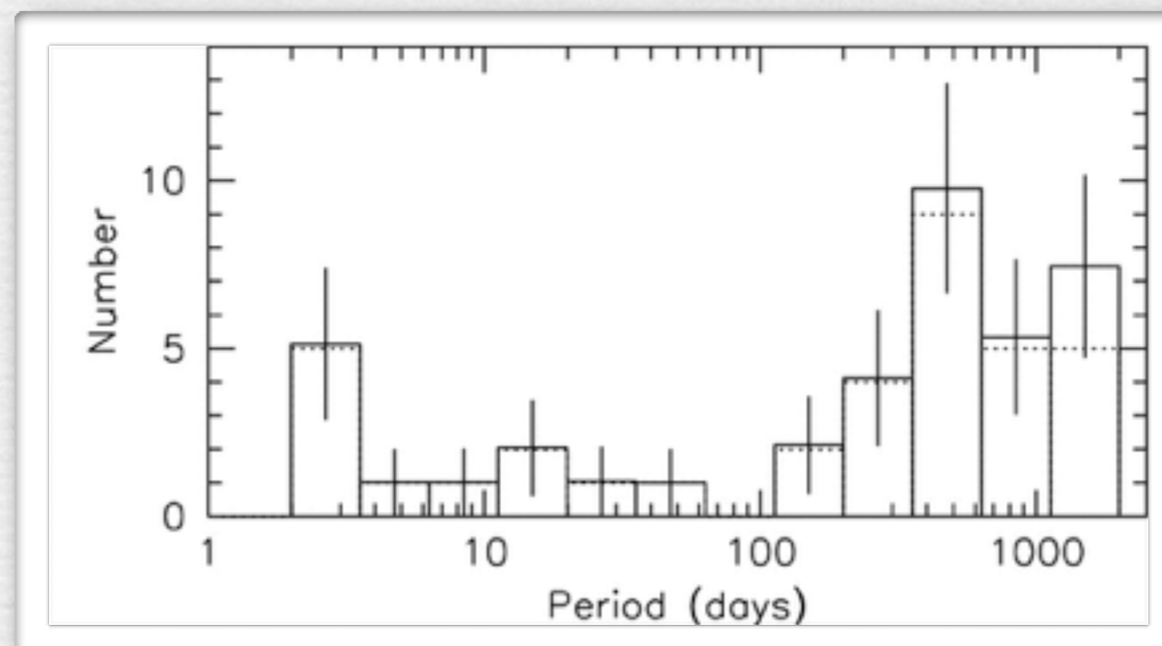

(Cumming et al. 2008)

Why do we care?

Different star/planet formation mechanisms predict different companion properties

STELLAR REGIME

TIDAL CAPTURE	M_2 is chosen randomly from the IMF ***(McDonald & Clarke 1993)***
CORE FRAGMENTATION	Accretion tend to equalize masses ***(Bonnel 1994, Whitworth et al. 1995, Bate 2000)***
CAPTURE IN DISPERSING CLUSTERS	Different CMRD for wide binaries ***(Kouwenhoven et al. 2010, Moeckel & Bate 2010)***

SUB-STELLAR REGIME

CORE FRAGMENTATION	$0.01/0.003 < q < 1$ ***(Boss 1988, Boyd & Whitworth 2005)***
DISK FRAGMENTATION	$0.001 < q < 0.2$ ***(Stamatellos et al. 2011)***
CORE ACCRETION	$q < 0.001$ ***(Kley 2000)***

The CMF as a function of primary star mass and separation is key to a complete understanding of star, BD and planet formations.

Stellar CMRD

- the CMRDs for M, G, A primaries are inconsistent with the IMF
- they are consistent with each other
- no evidence of dependence of the CMRD on separation

Evidences for a “universal” CMRD

(Reggiani & Meyer 2011)

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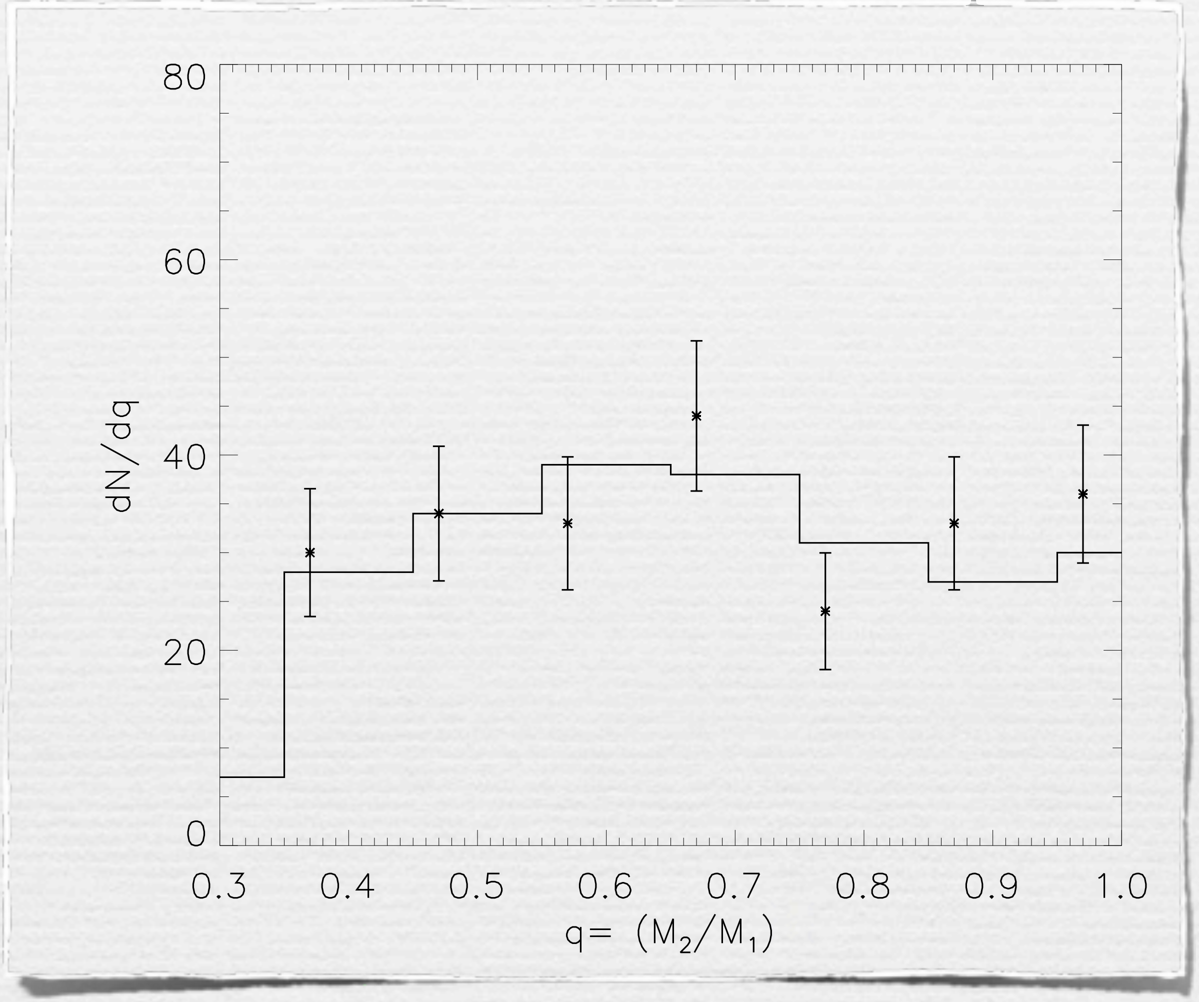
Combined CMRD for M, G, and A primaries



Maximum likelihood fit:

$\partial N/\partial q \propto q^{\alpha}$ with α=0.25±0.29

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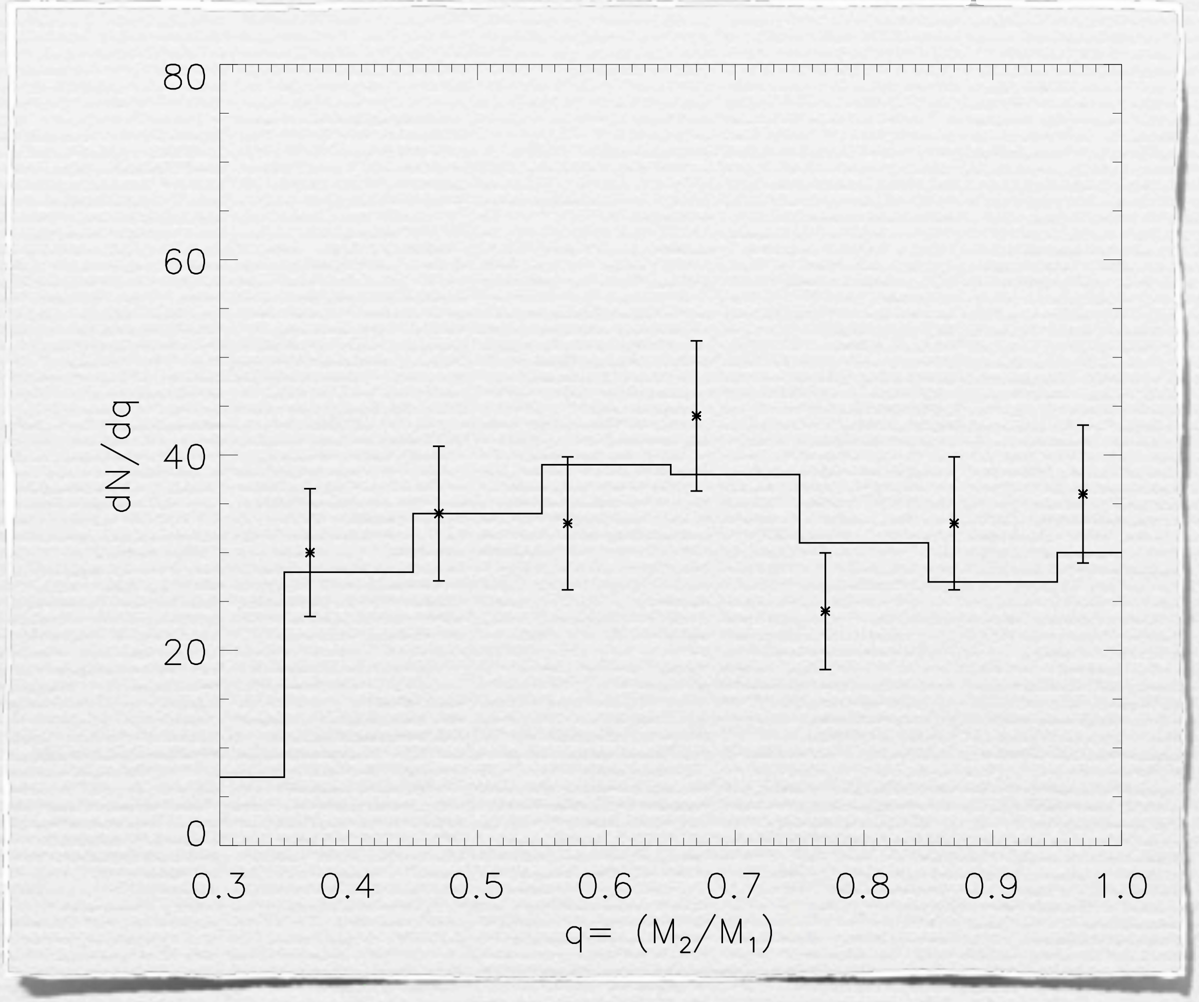

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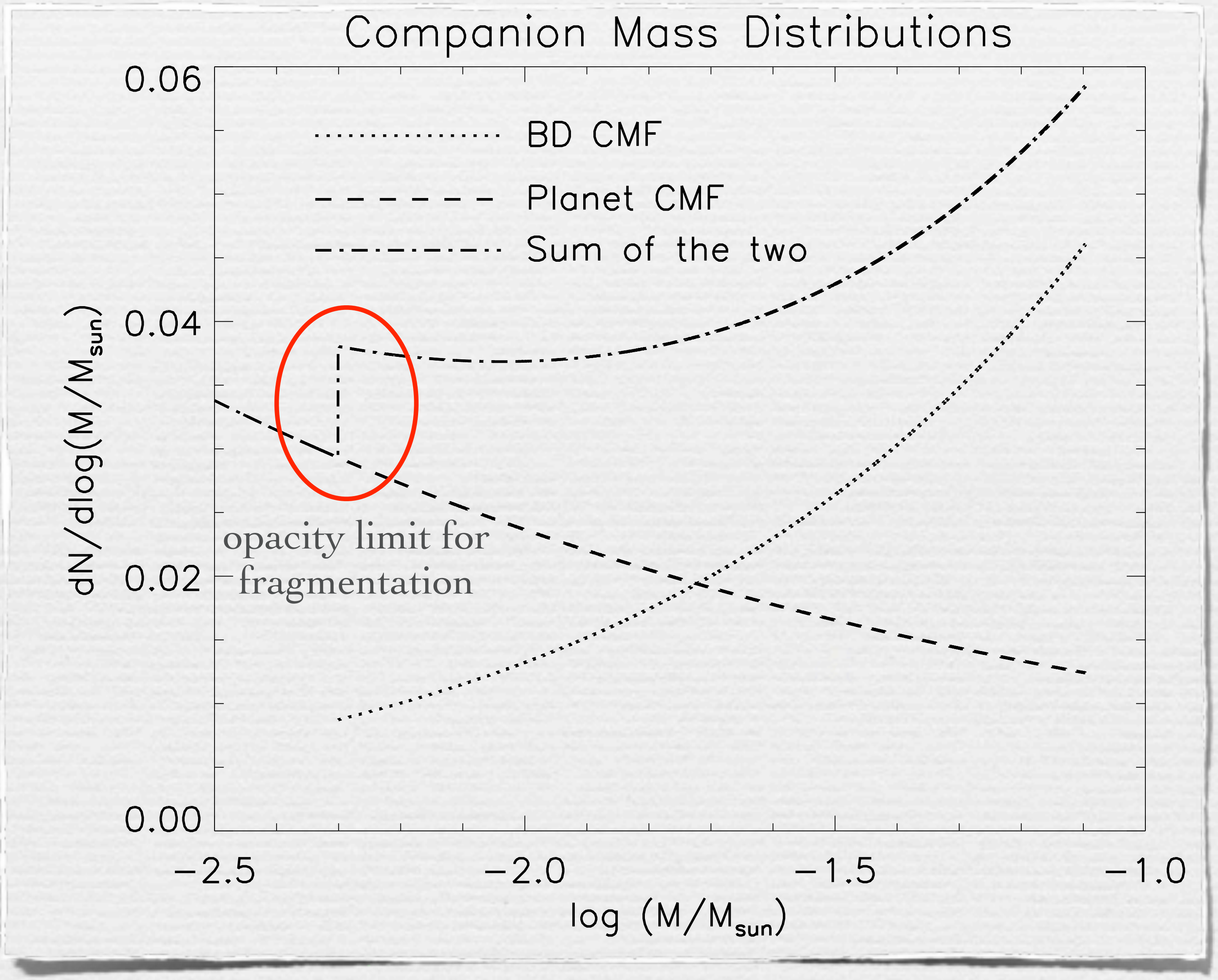
Can we extrapolate it into the BD regime?

A simple model for the sub-stellar CMF

MASS and SEPARATION DISTRIBUTIONS:

$$dN = C_0\, q^{\alpha 0,1}\, a^{\beta 0,1}\, \mathrm{dlog}\, q\ \mathrm{dlog}\, a$$

	BDs	planets
max mass	80 M_J	0.1 M_{star}
min mass	5 M_J	---
max separation	10000 AU	outer cutoff
min separation	0.1 AU	---
$\alpha_{0,1}$	1.25	-0.31
$\beta_{0,1}$	1	0.39



NORMALIZATIONS:

0.032 [12-72 M_J] - [28-1590 AU]

(Metchev & Hillenbrand 2009)

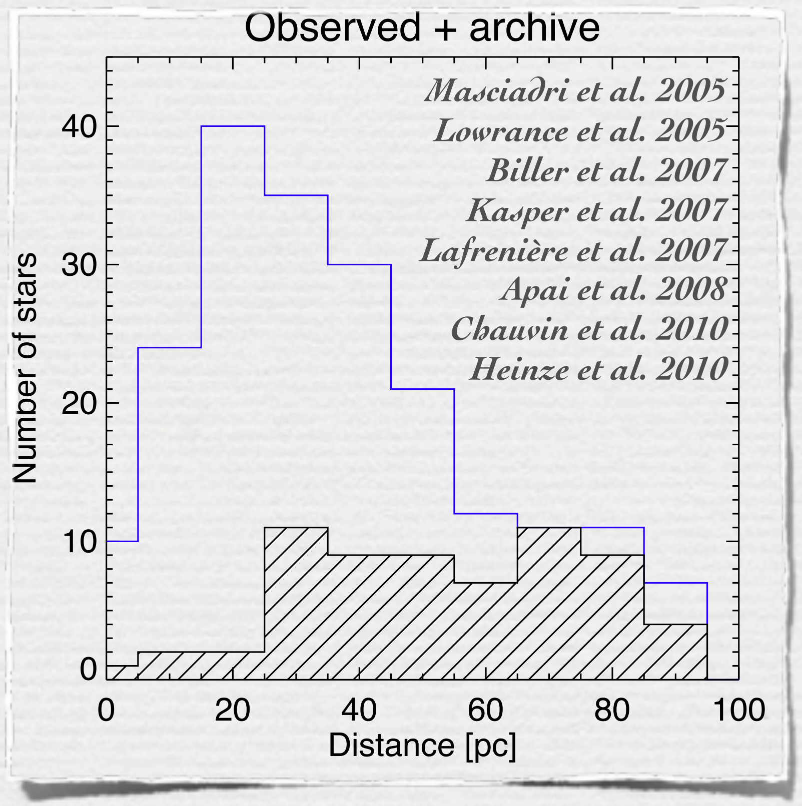
0.032 [1-13M_J] - [0.3-2.5 AU]

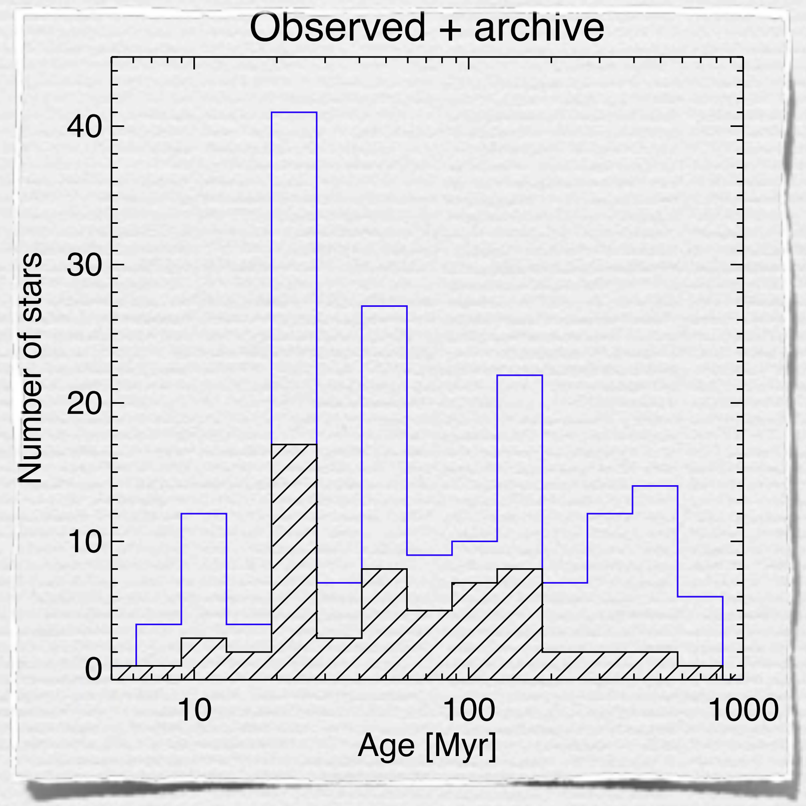
(Heinze et al. 2010)

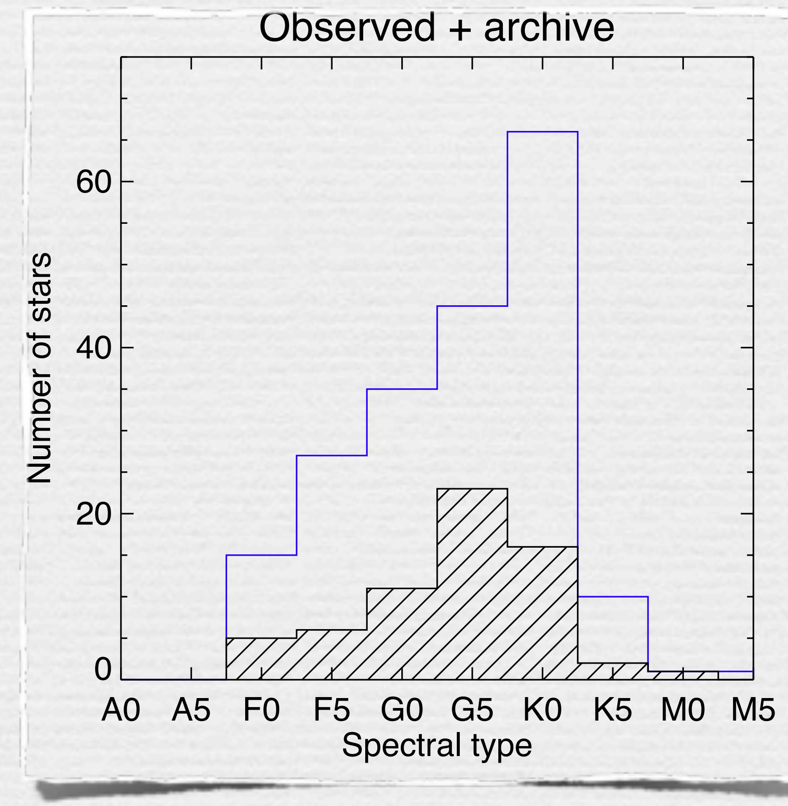
NaCo-LP: the test case

NaCo-LP started in 2008-2009 in preparation to SPHERE to study the occurrence of planets and BD at wide-orbits (50-500 AU) around solar-type stars.

- H-band
- 18 nights
- 110 targets
- selection criteria: dec < 25 deg, age < 200 Myrs , d < 100 pc, R < 9.5 mag







(Survey description and statistical analysis in ***Chauvin et al.*** and ***Vigan et al.*** in preparation)

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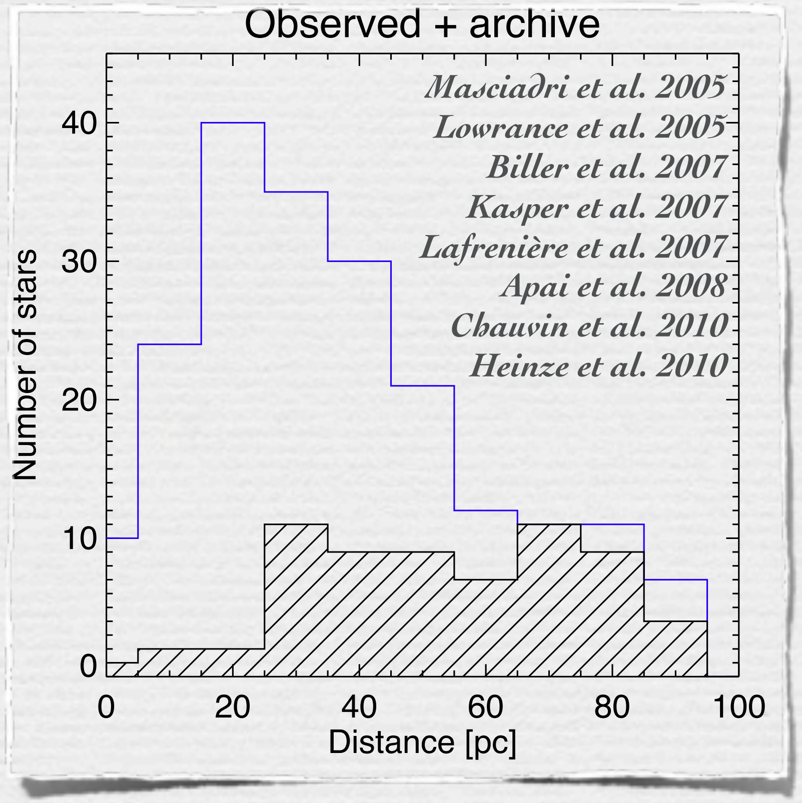

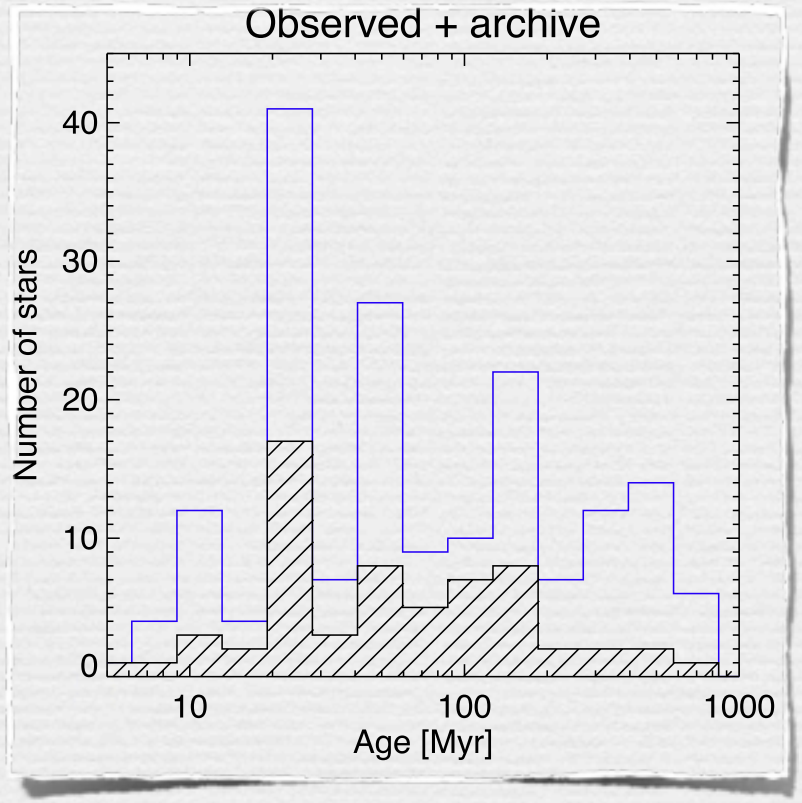

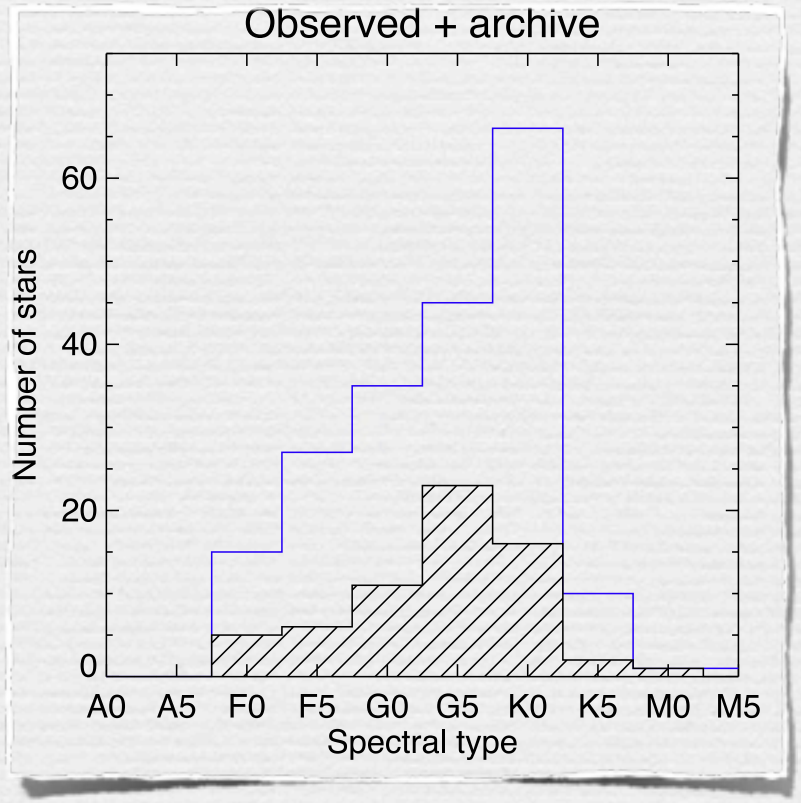

no detection of substellar companions

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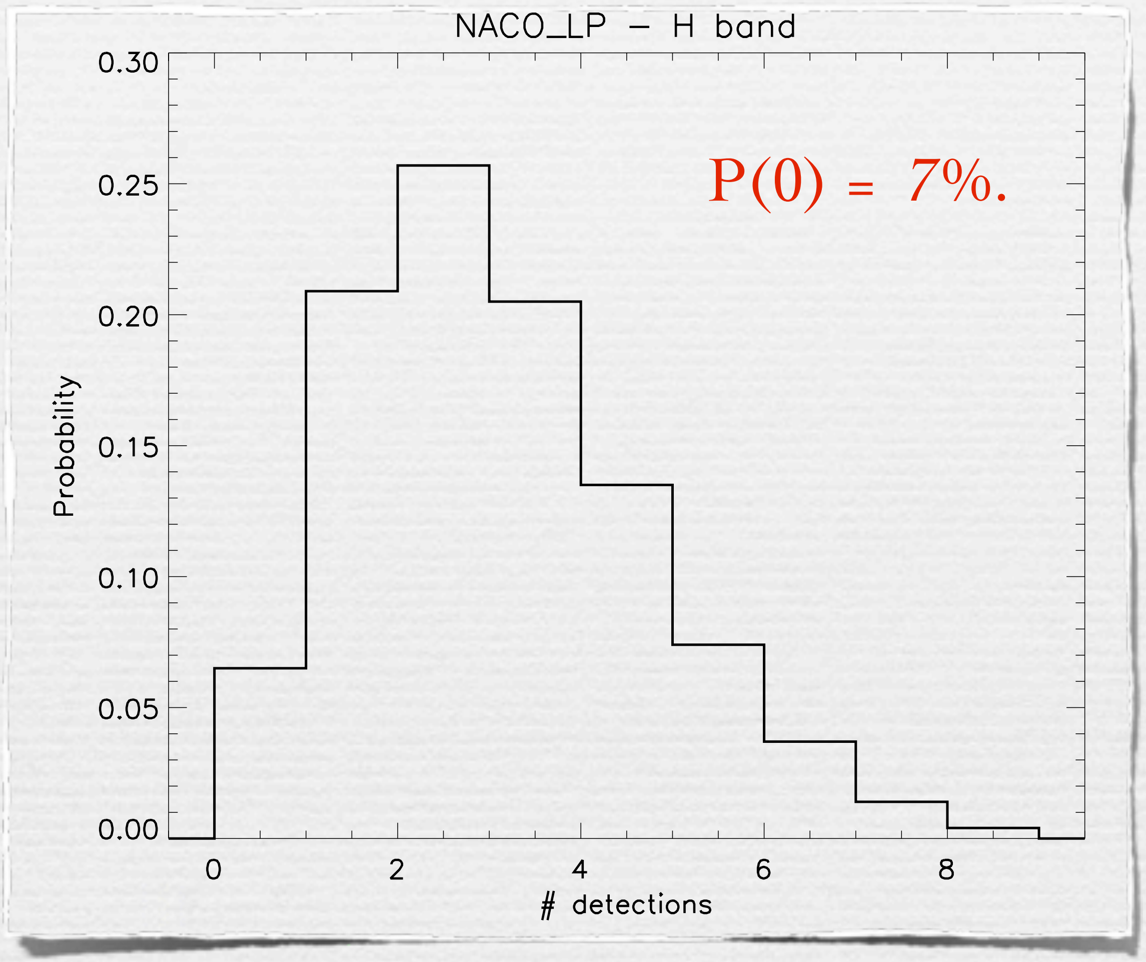

ASSUMED MODEL: $dN = C_0\, m^{\alpha_{0,1}}\, a^{\beta_{0,1}}\, d\log m\, d\log a$

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We will explore different combinations of β_1 and outer truncation radius.

(Reggiani et al., in preparation)

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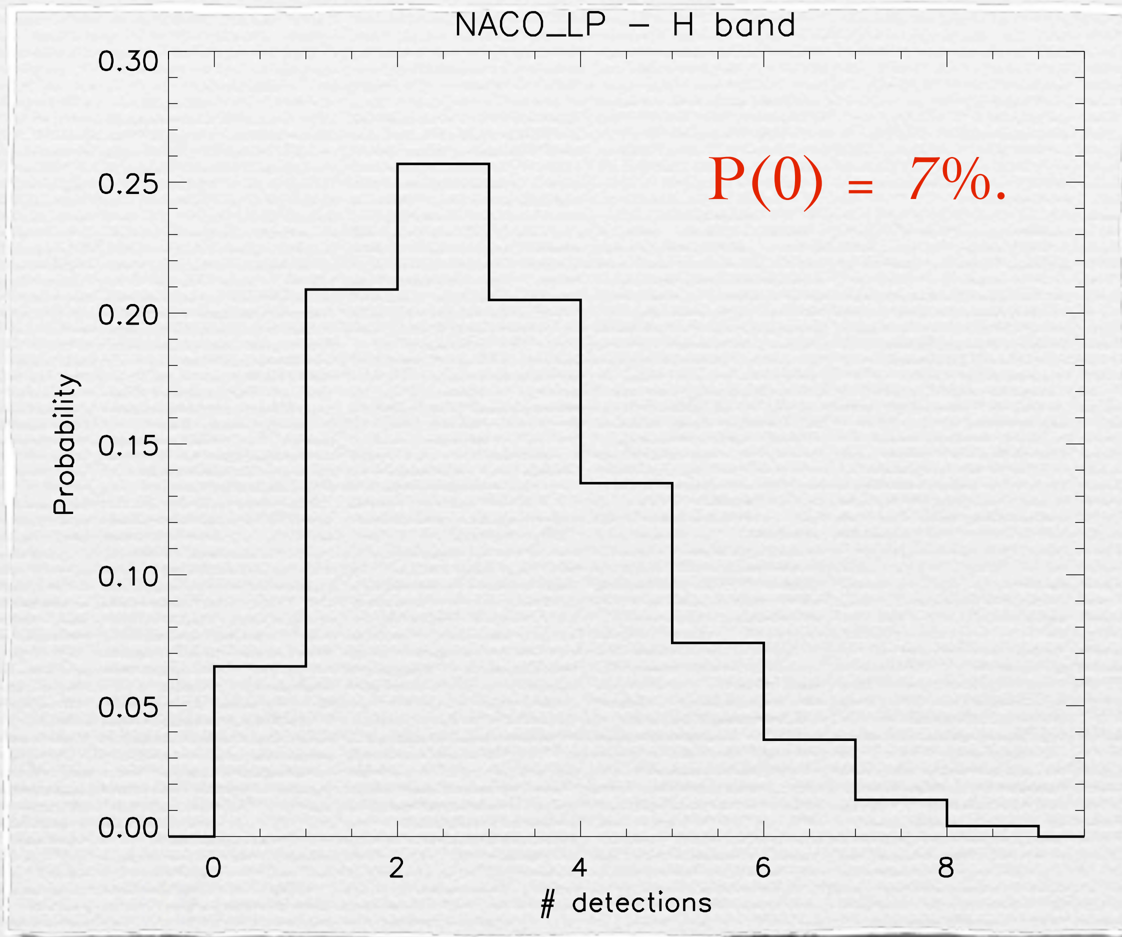

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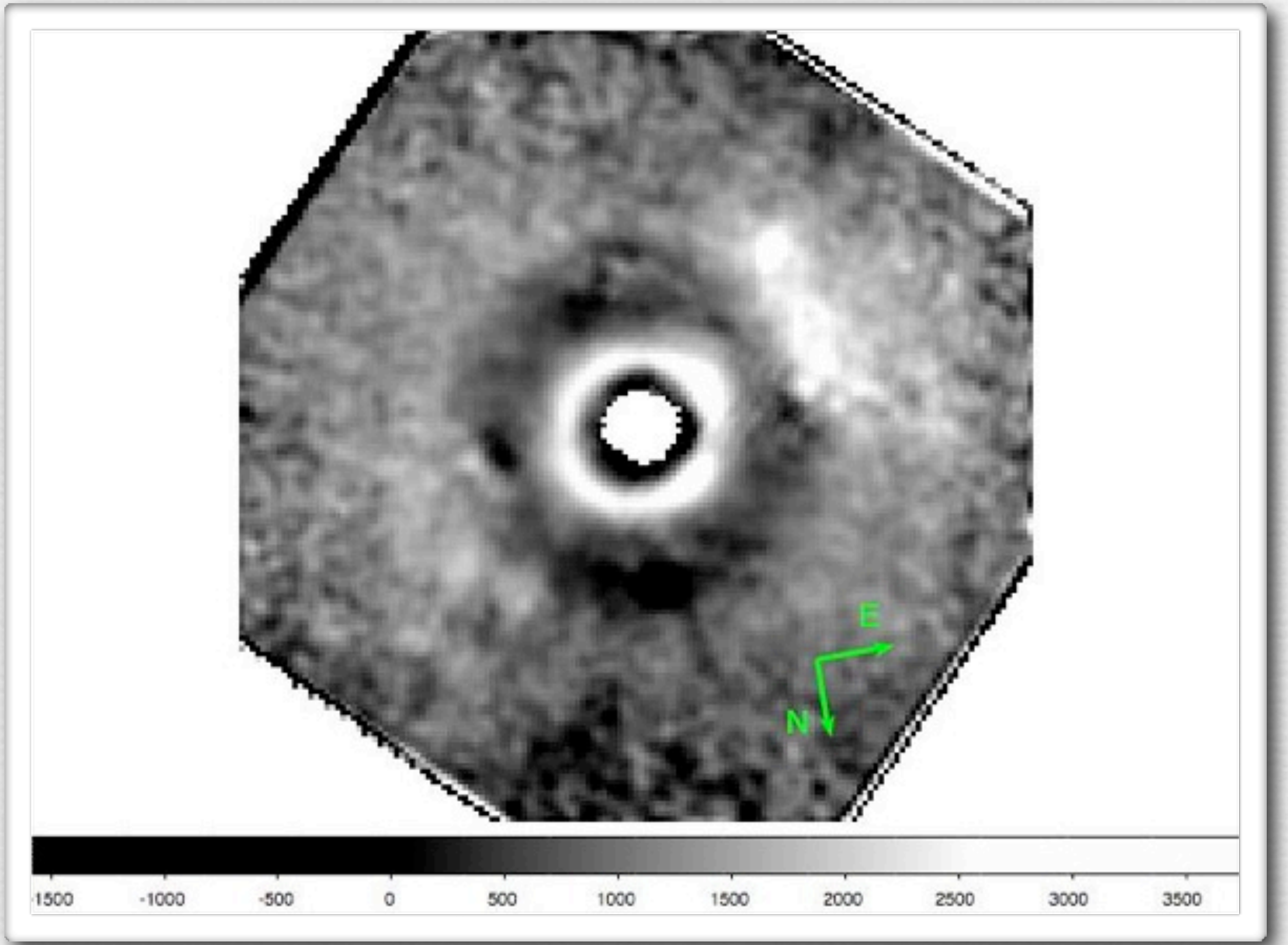
We will explore different combinations of β_1 and outer truncation radius.

(Reggiani et al., in preparation)

- The observations do not rule out our simple model.
- They are consistent with a minimum in the substellar CMF *(see also Sahlmann et al. 2011b; 25-45 M_J)*
- BD contribution to the CMF cannot be neglected!

HD169142: the best example

- Herbig Ae/Be star (L' = 5.7 mag, *Gezari et al. 1999*)
- 1-12 Myrs *(Guimarães et al. 2006; Blondel & Djie 2006)*
- 145-150 pc *(Sylvester et al. 1996, Blondel & Djie 2006)*
- NaCo/PDI H-band observations: resolved disk structures *(Quanz et al. 2013)*



HD169142: the best example

- DDT time (2 hours) in June 2013
- NACO L'-band images with AGPM vector vortex coronograph ***(Mawet et al. 2013)*** in ADI mode
- Data reduction package **PYNPOINT** ***(Amara & Quanz 2012)***

PYNPOINT

Creates a set of basis to reproduce stellar PSF with PCA methods
(Jee et al. 2007)

Fits the stellar PSF to the individual frames with chosen # of PCAs

Corrects for the PSF

Averages over all frames to improve the S/N

Returns the residual image

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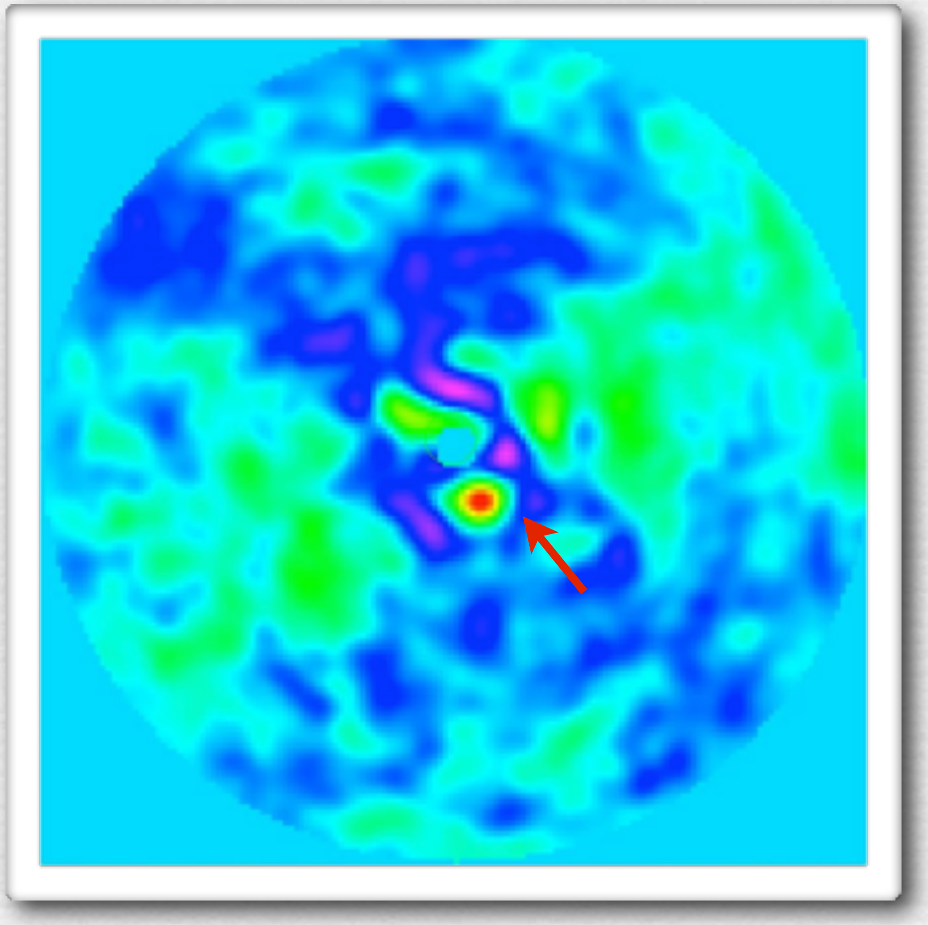
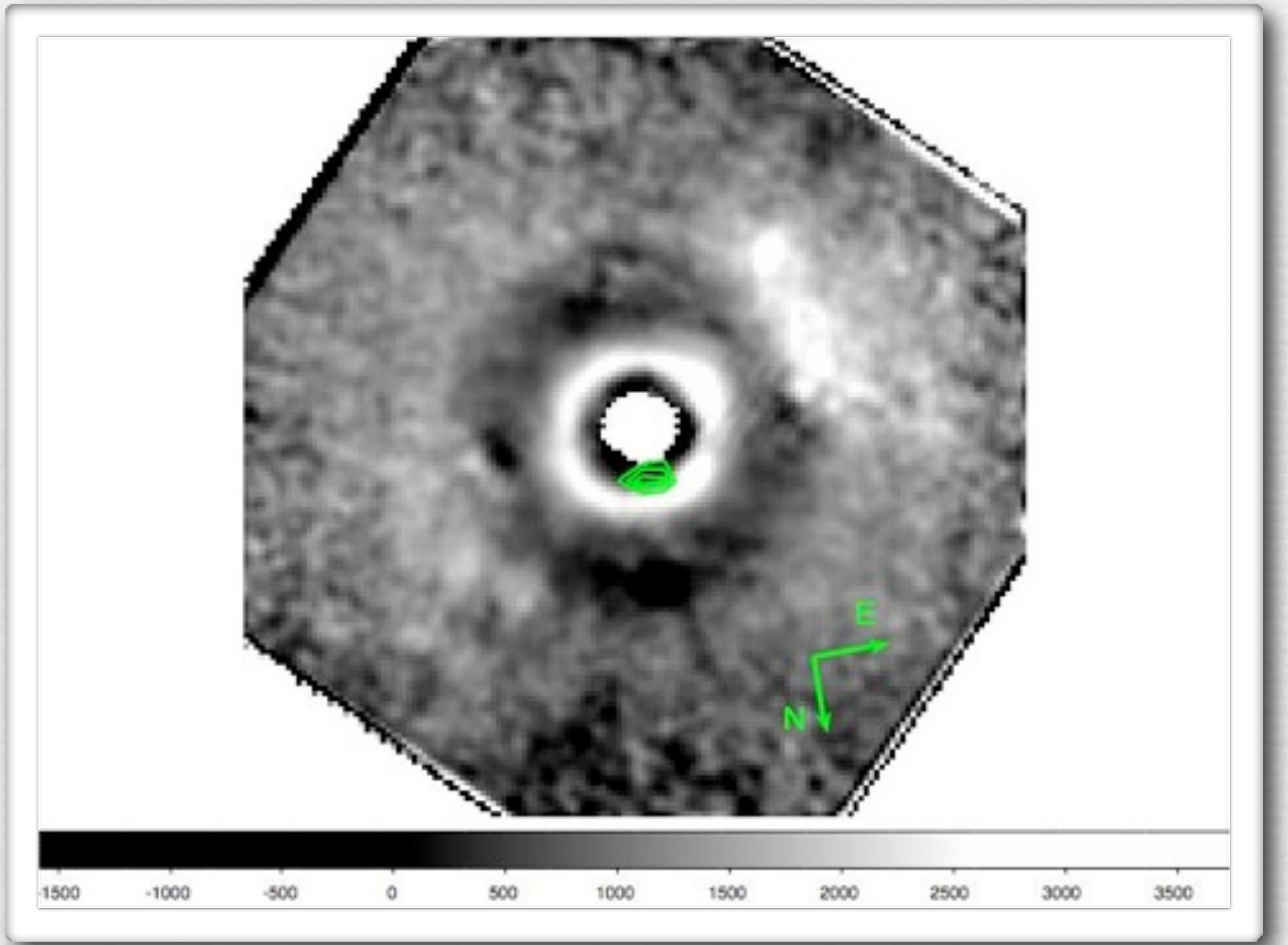


@ 22 AU (0.15")
res with 80 PCAs



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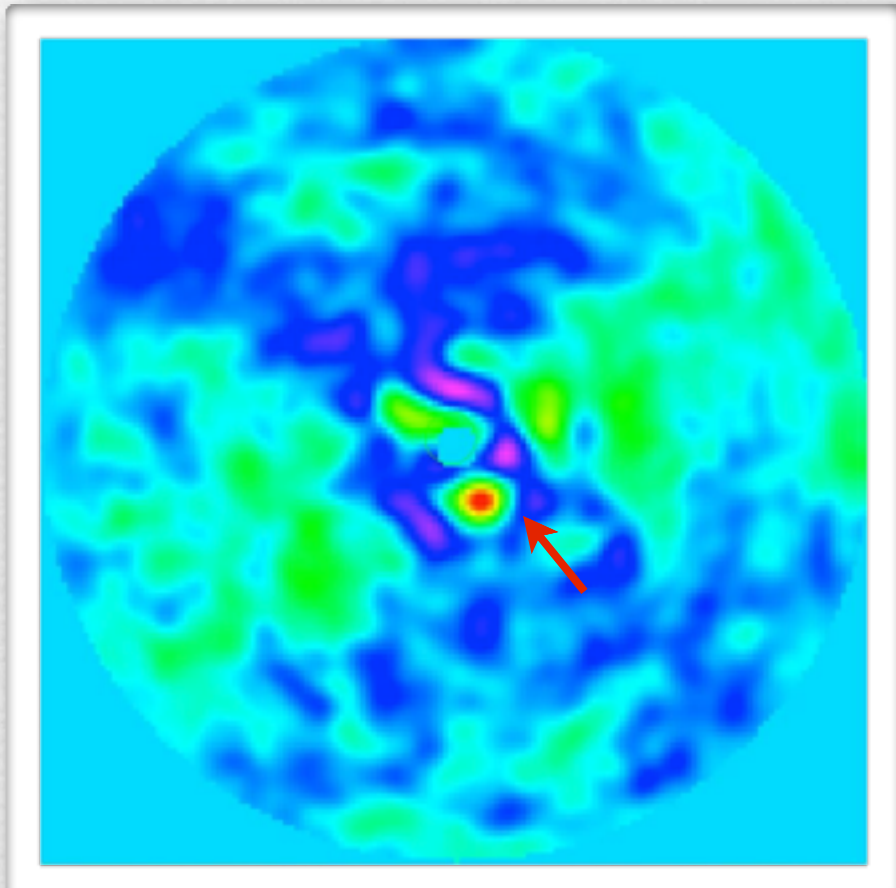

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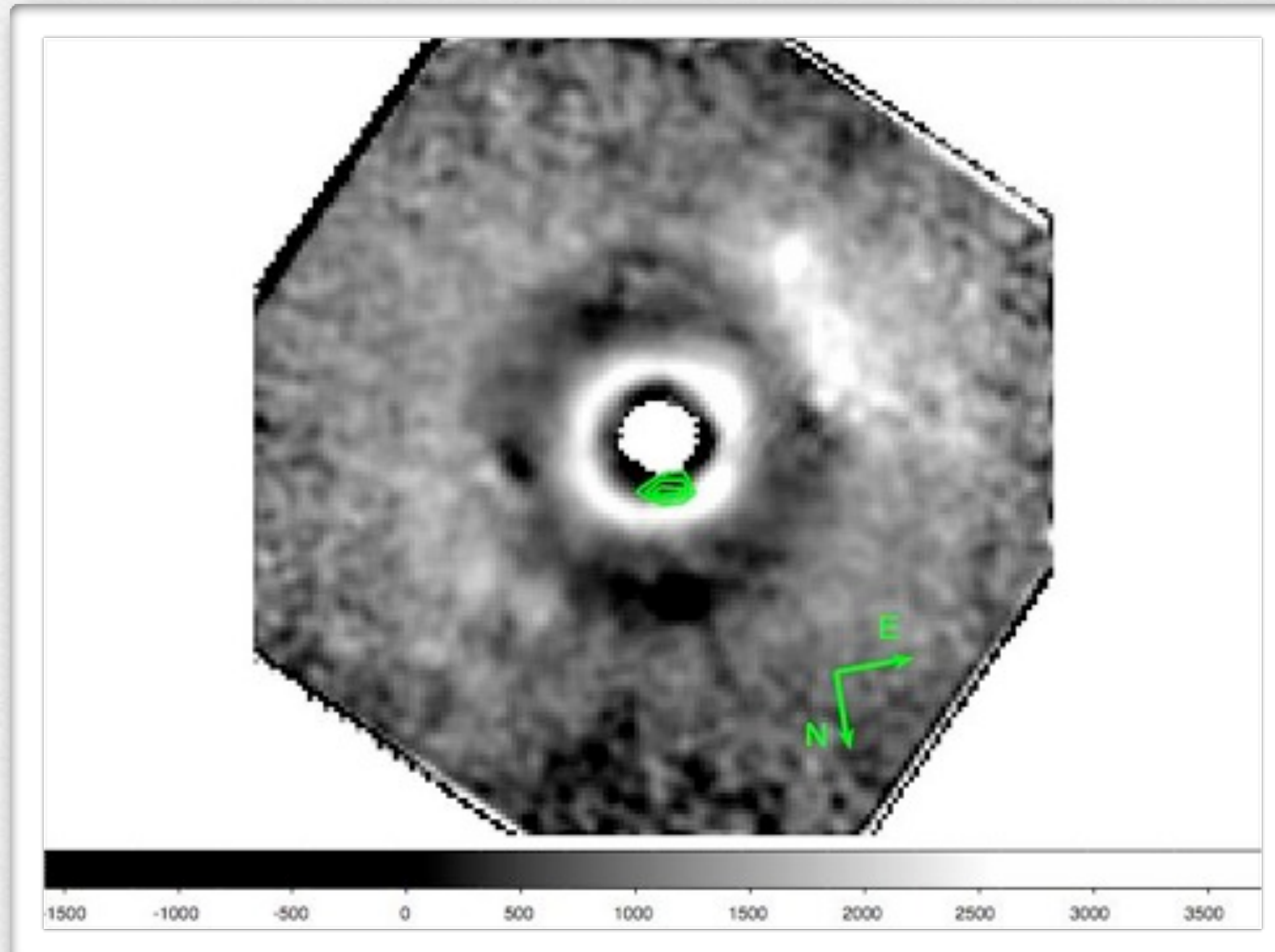

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L' ~ 12 mag @ ~145 pc @ ~5 Myr ➡ ~40 M_J (COND models)

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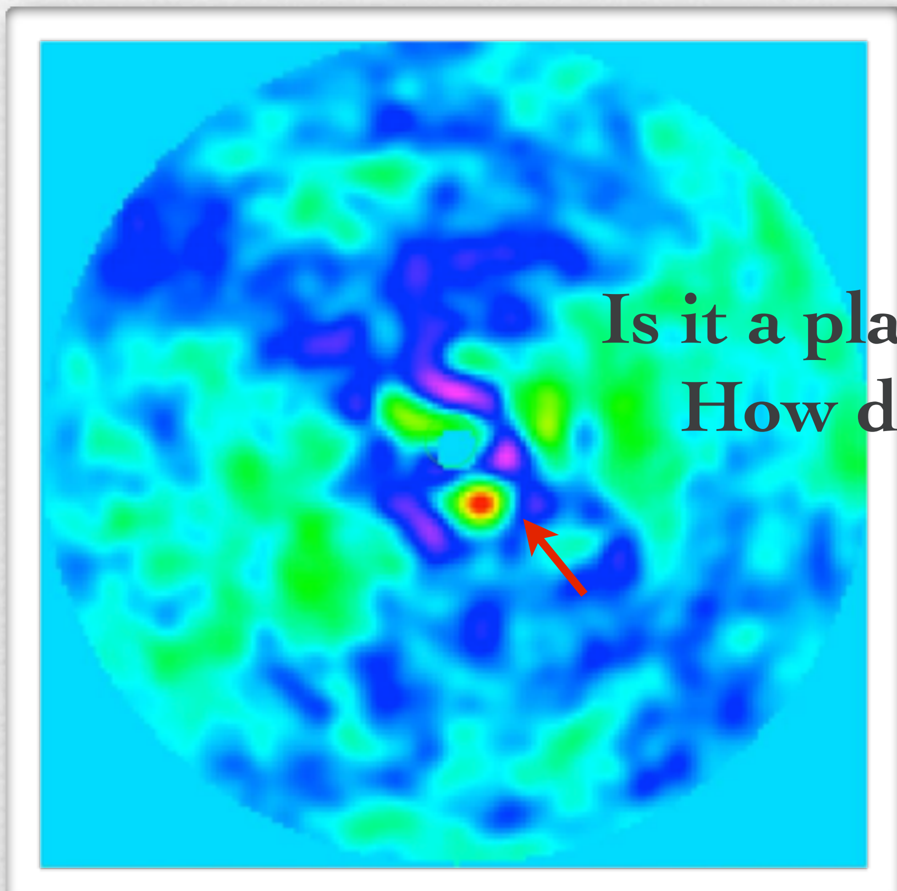

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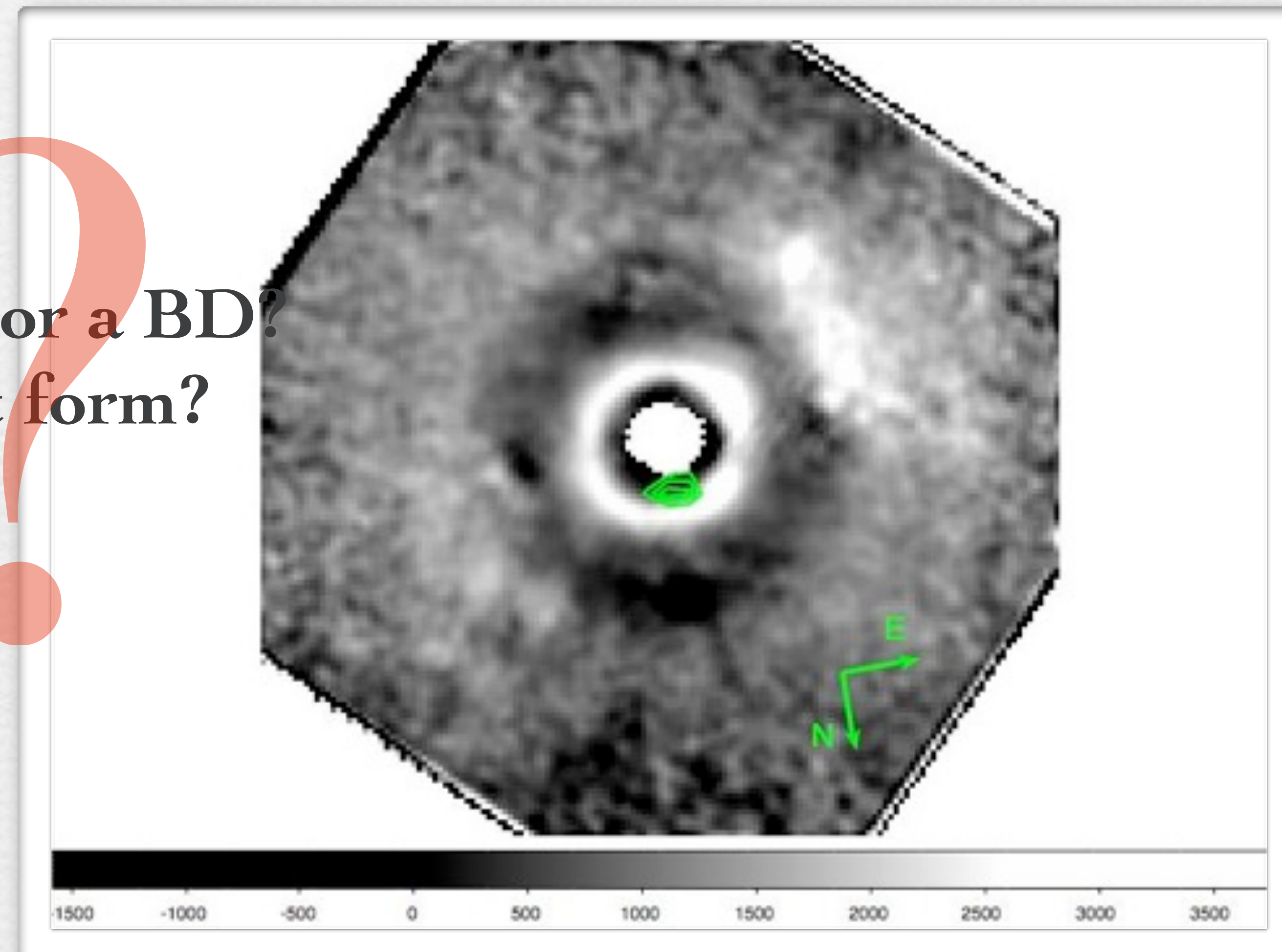
Is it a planet or a BD?
How did it form?



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Conclusions

- Current observations are consistent with a mass continuum in the substellar CMF.

- There seems to be a minimum in the substellar CMF between 10-30 M_J at large separations, consistent with results from Sahlmann et al. 2011 (25-45 M_J) for smaller separations (<10 AU).

- The BD contribution to the substellar CMF cannot be neglected.

- HD169142b: planet or BD? The only way of answering this question would be to know how it formed.