



Fundamental stellar parameters (Low mass stars and brown dwarfs)

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Introduction

- Stellar mass function is a very important constraint on star formation models
- Photometric luminosity function is being accurately determined by IR surveys (DENIS, 2MASS), down to the brown dwarfs domain
- But still biased by unknown multiplicity fraction
- Mass/Luminosity relation poorly constrained for low mass stars, especially below 0.2 Solar mass
- Search for brown dwarfs

M-dwarfs survey

- **Goals**
 - Derive masses with a few % accuracy
 - Detect nearly all stellar companions at all separations
- **Method**
 - Combine radial velocity and adaptive optics
 - Allow to explore the full range of separations for binary systems
 - AO + coronagraphy provides high angular resolution and high dynamic range

M-dwarfs survey

- **Sample**
 - 120 (200) M-dwarfs with $d < 9\text{pc}$ (12pc)
+ 30 from old programme (12 orbits) initiated with CORAVEL + IR speckle
- **Collaboration (1997-2003)**
 - LAOG: J.-L. Beuzit, G. Chauvin, X. Delfosse, A.-M. Lagrange, D. Mouillet, C. Perrier
 - CFHT: T. Forveille
 - Geneva: M. Mayor, D. Ségransan, S. Udry
 - Also: F. and C. Roddier, E. Martin

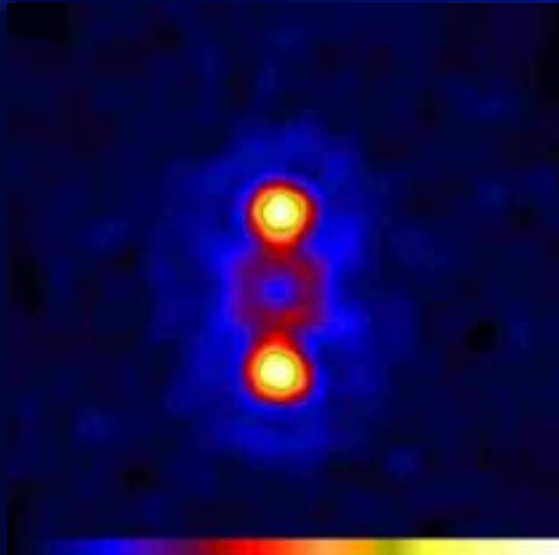
M-dwarfs survey

- **Instruments**
 - **ELODIE (OHP 1.93-m)**
 - 15 to 70 m/s; $V < 12$
 - Earlier results from CORAVEL (300 m/s)
 - **PUEO + KIR (CFHT)**
 - Down to 0.08'' separation (0.8 AU at $d = 10$ pc)
 - Lyot coronagraph with 1'' mask ($\Delta K = 13$ at 2'')
 - 1-5 mas accuracy in astrometry using WFS data reconstruction and AOPHOT (Véran & Beuzit, 98)
 - Earlier results obtained with ADONIS

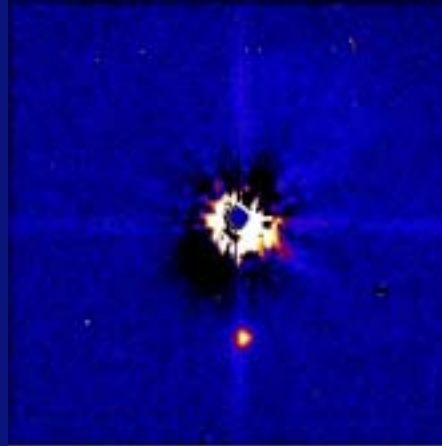
M-dwarfs survey

- **Instruments**
 - **NAOS + CONICA (July 2003...)**
 - Down to 0.03'' separation (0.3 AU at $d = 10$ pc)
 - Lyot coronagraph with 0.7'' mask ($\Delta K = 11$ at 1'')
 - New 4Q coronagraphic mode (2004)
 - Differential imaging mode (2004)
 - CIA coronagraph available 2005 ?
 - WFS reconstruction and/or deconvolution methods
 - MISTRAL (Fusco et al., 2002)

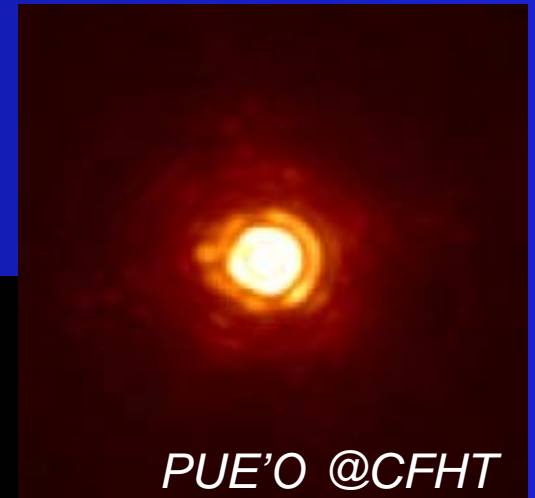
Observations



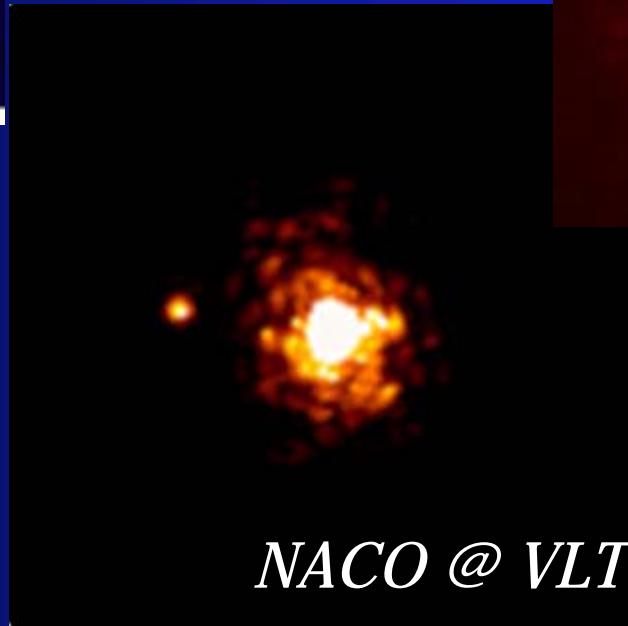
AIC on PUEO (2000)



Coronagraph on PUEO



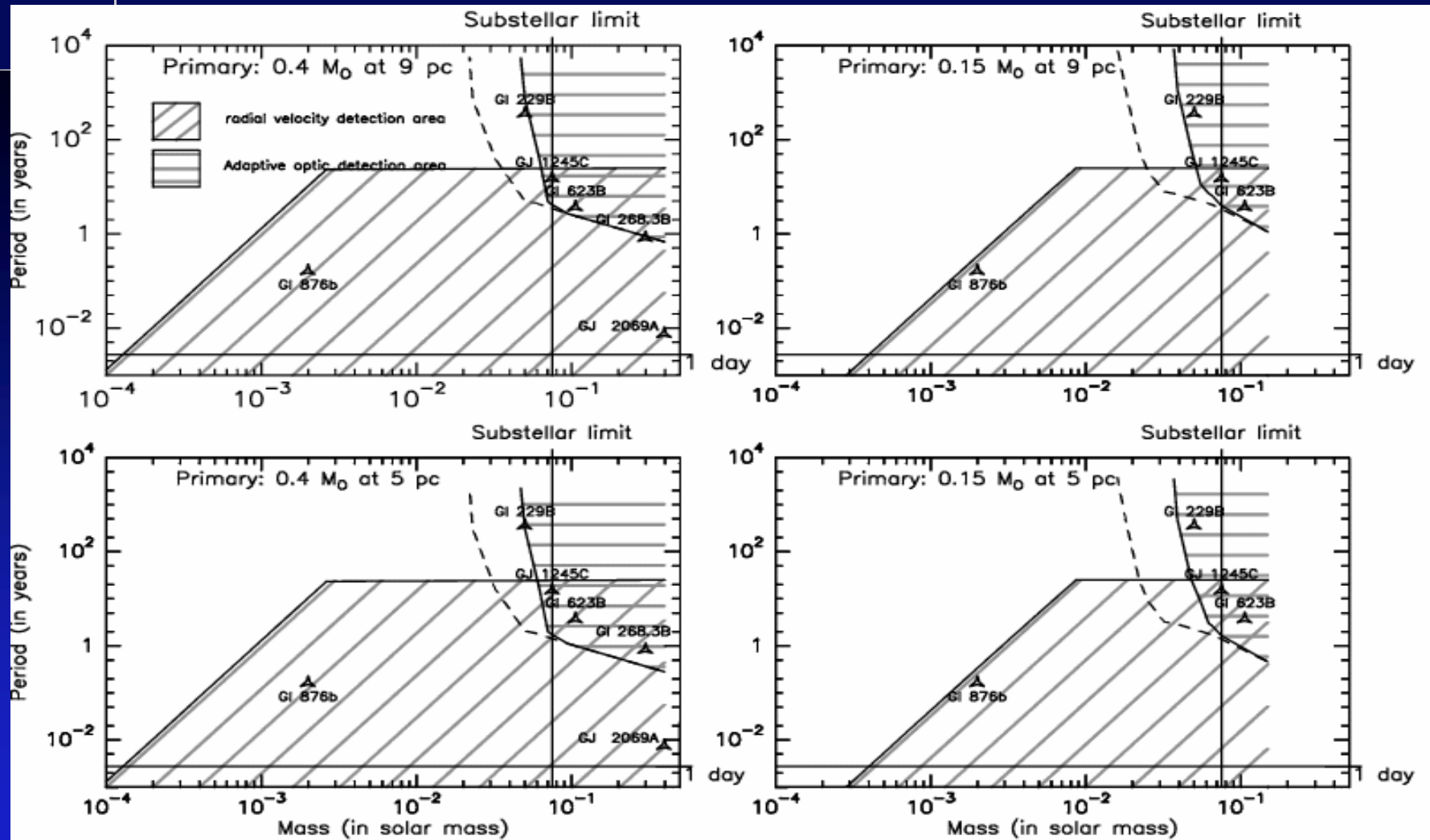
PUE'O @CFHT



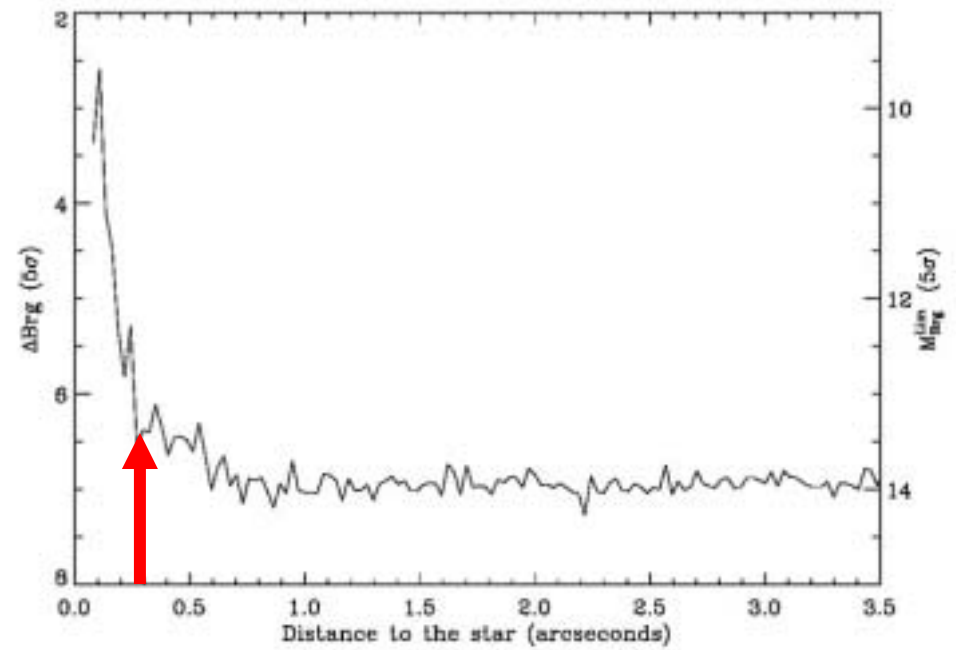
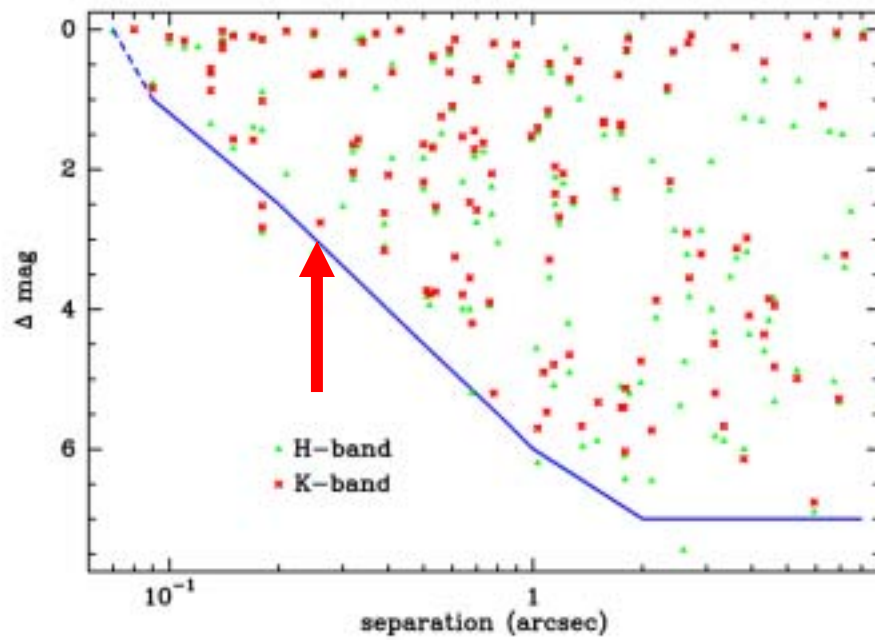
NACO @ VLT

$V = 10$
 $\Delta K = 4.2$
Brg . $t_{exp} = 10$ s

Detection limits



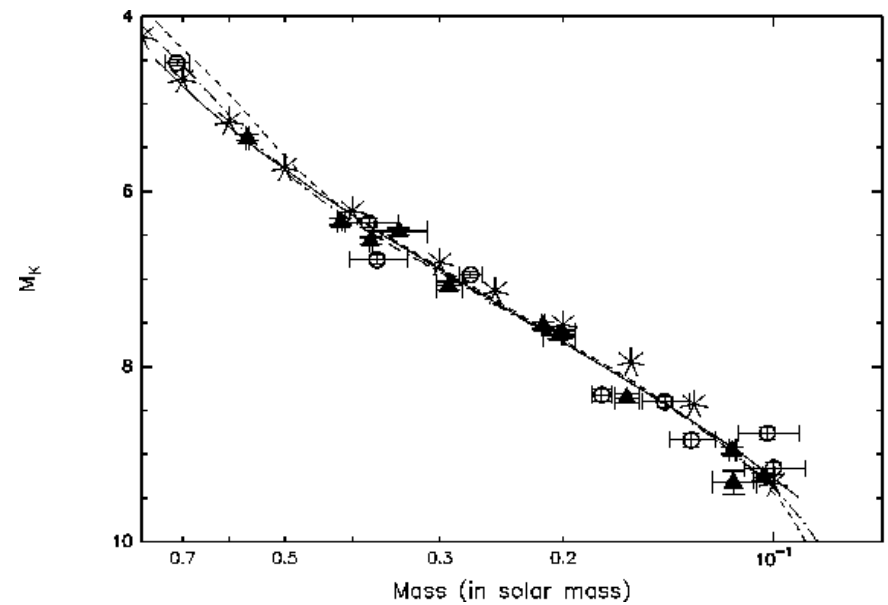
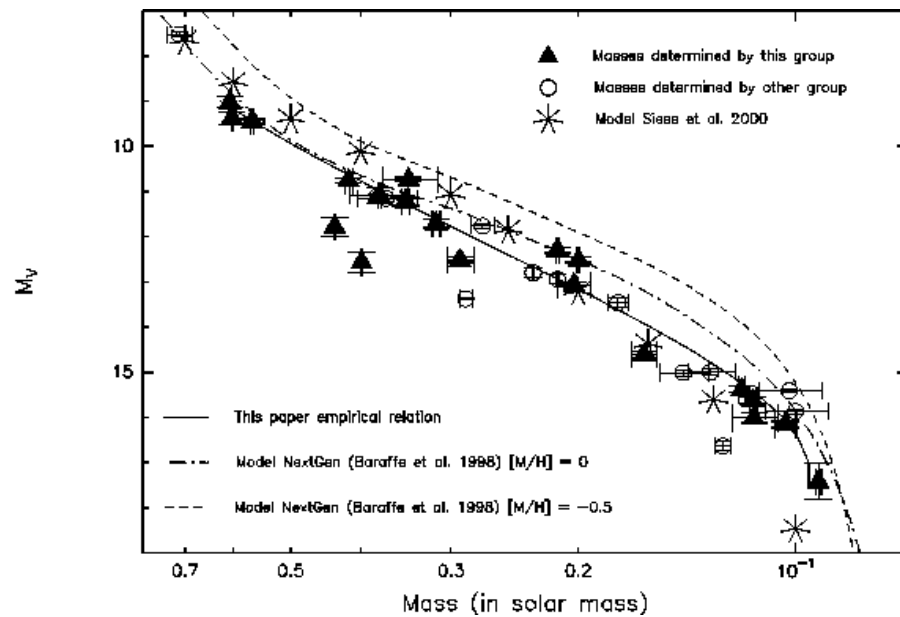
Detection limits



Mass-luminosity function

- **Improved mass/luminosity relation**
 - Only PUEO data at the moment: ~ 32 masses
 - NACO expected to provide new masses in the next 2 years (3 new resolved systems July 03)
 - Better accuracy needed at short wavelength
 - Effect of metallicity (at short wavelength)
- **Example of mass accuracy: Gl 570**
 - Mass A = 0.568 ± 0.012 Msun (2.2%)
 - Mass B = 0.382 ± 0.006 Msun (1.7%)

Mass-luminosity function

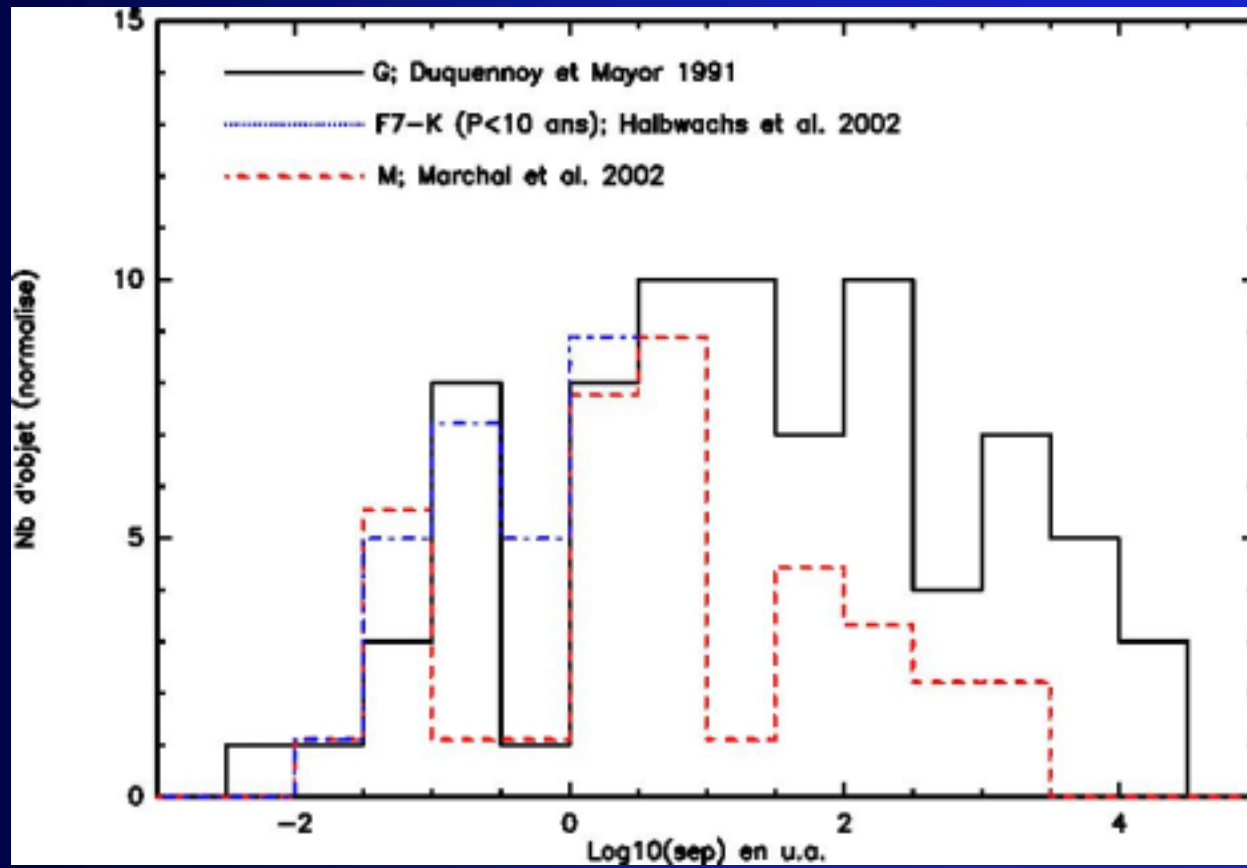


Delfosse et al., 2000

Multiplicity fraction

- Sub-sample of 94 M-dwarfs : $d < 9.25$ pc, $M_v < 15$ and spectral types from M0 to M6
- Multiplicity fraction of M-dwarfs = $25.7 \pm 3\%$
- Corrected from instrumental effects by Monte-Carlo simulations
- Multiplicity fraction decreases with mass of primary:
 - OB stars ~ 70%
 - G dwarfs ~ 57% (Duquennoy & Mayor, 1991)
- G and M dwarfs show very similar separation distributions at short periods
- Lack of companions around M-dwarfs at large periods

Multiplicity fraction



Remarks

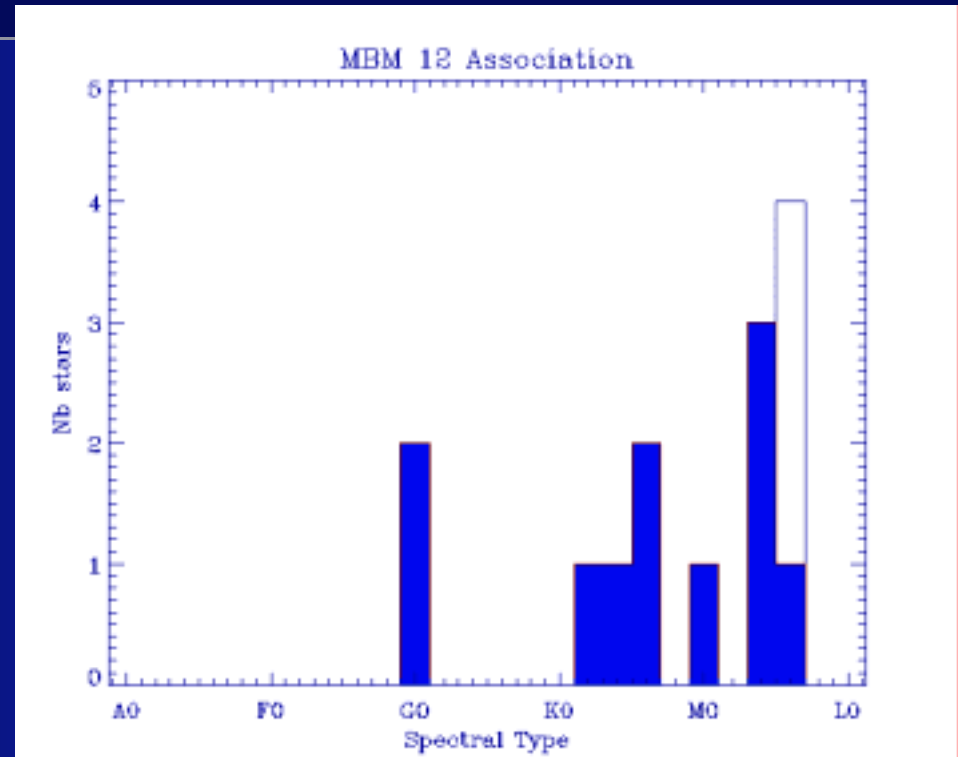
- No BD at $d < 3$ AU
- A lot of our targets have faint companions with $\Delta K > 8-9$ (follow-up observations in progress).
- New extra-solar planet around Gl 876 (ELODIE), only one around M-dwarfs

Conclusion and future

- Improved mass/luminosity relation for very low mass stars
- Close interaction with the Lyon group (Allard, Baraffe, Chabrier) to adjust models
- Multiplicity fraction of M-dwarfs = $25.7 \pm 3\%$
- Detailed analysis of systems parameters on-going
- New/improved masses expected from NACO soon
- Follow-up of observed faint companions on-going
- Program to be extended to L dwarfs on NACO + LGS (could be started with IR wavefront sensor ~ 30 targets)

Pueo/Kir AO observations of MBM 12

d = 65 (275)pc
Age = 2 Myr
14 stars known
(Hearty et al. 2000)
(Luhman 2001)

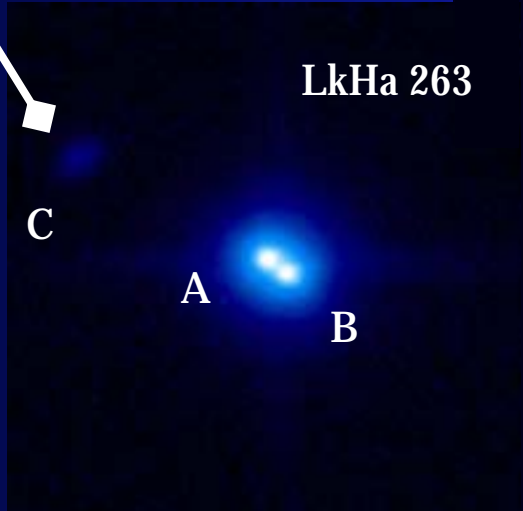


Observations of 11 members (Dec 2001)
Coronagraphy ($\varnothing = 0.9''$) coupled with
the AO system PUEO/KIR + GRIF (CFHT)
**Collaboration: G. Chauvin, A.-M. Lagrange, F.
Ménard, T. Fusco, J.-L. Beuzit, D. Mouillet, J.-C.
Augereau**

Seven binaries and a protoplanetary disk

Detection of seven close binaries unknown
Un uncertain wide binary around LkH α 264

A faint nebulosity close to LkH α 263 AB



E0255+2018

HD 17332

MBM 12-10

RX J0255.3+2005

S18

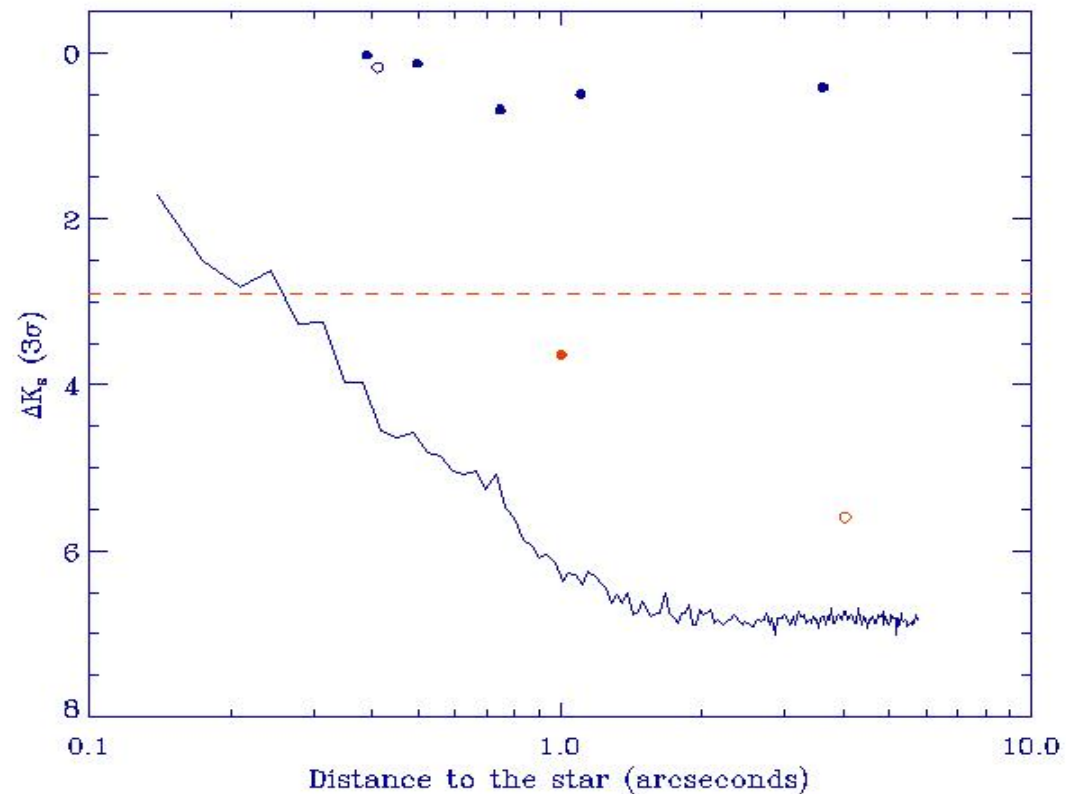
1''

RX J0255.3+1915

Study of the binarity fraction

Comparison with multiplicity of G-K field dwarfs and M field dwarfs

We considered : - same mass ratio $q=0.1$, i.e $\Delta K = 2.9$ according to BCAH98 model
- same physical separation range



Binarity excess in the MBM 12 association ?

Table 1: Binarity fraction results

Associations	Nobs	bf (%)	bf (MS) (%)	Age (Myr)	d (pc)
MBM12	11	54.	18.-23.	2	275
		-	22-28	-	65
TW hydrae	19	32.	19.-24	10-20	65
IC348		19.5		2	320

Binary Excess ?

Binary fraction: bf ~ 54%

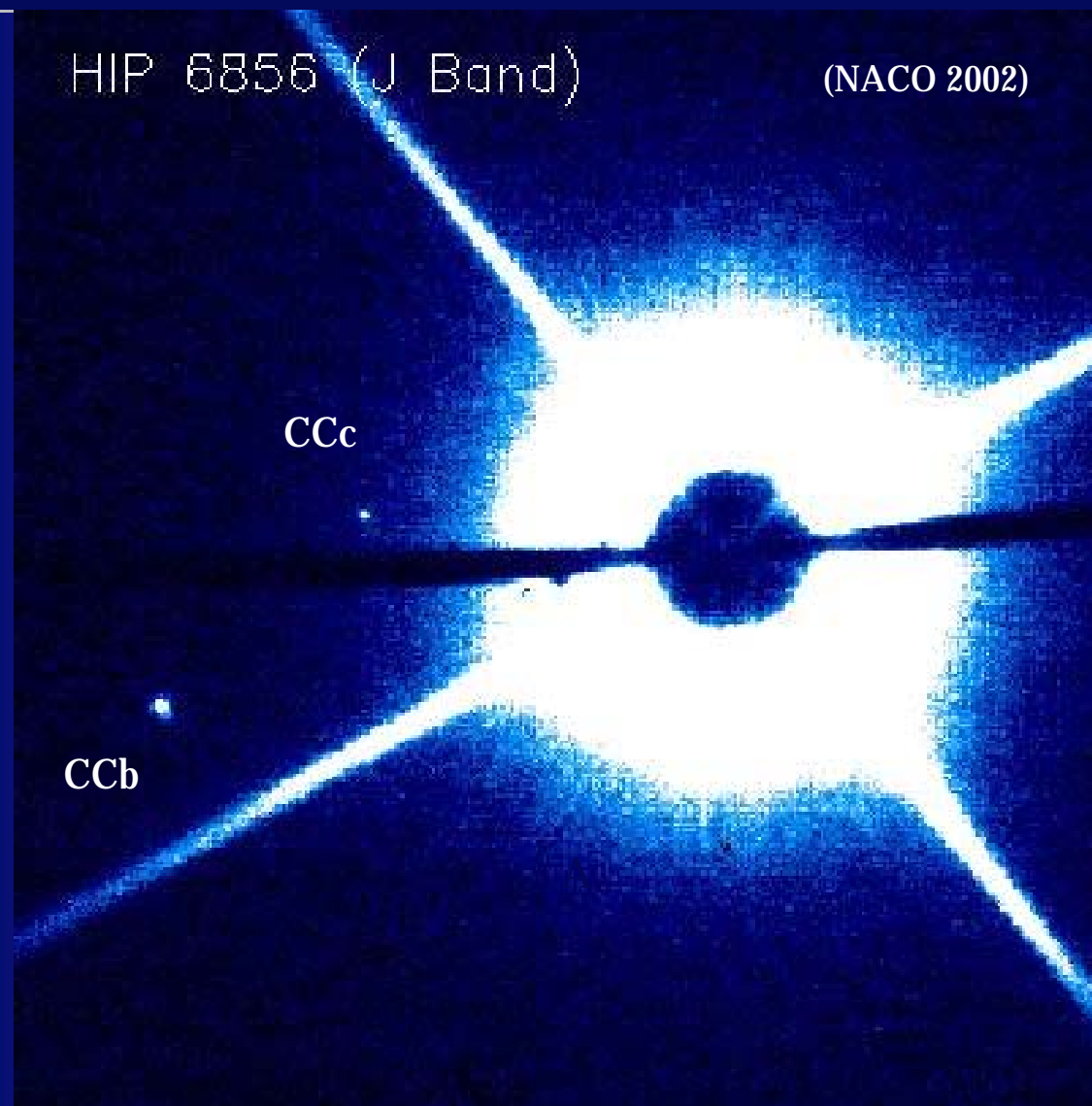
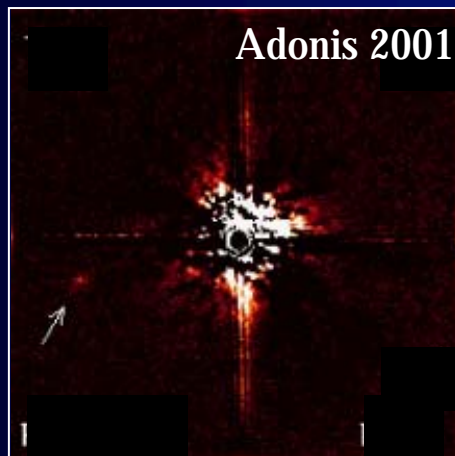
(19.5%, IC348; Duchêne et al. 99)

➤ *Binary fraction inversly correlated to the stellar density*

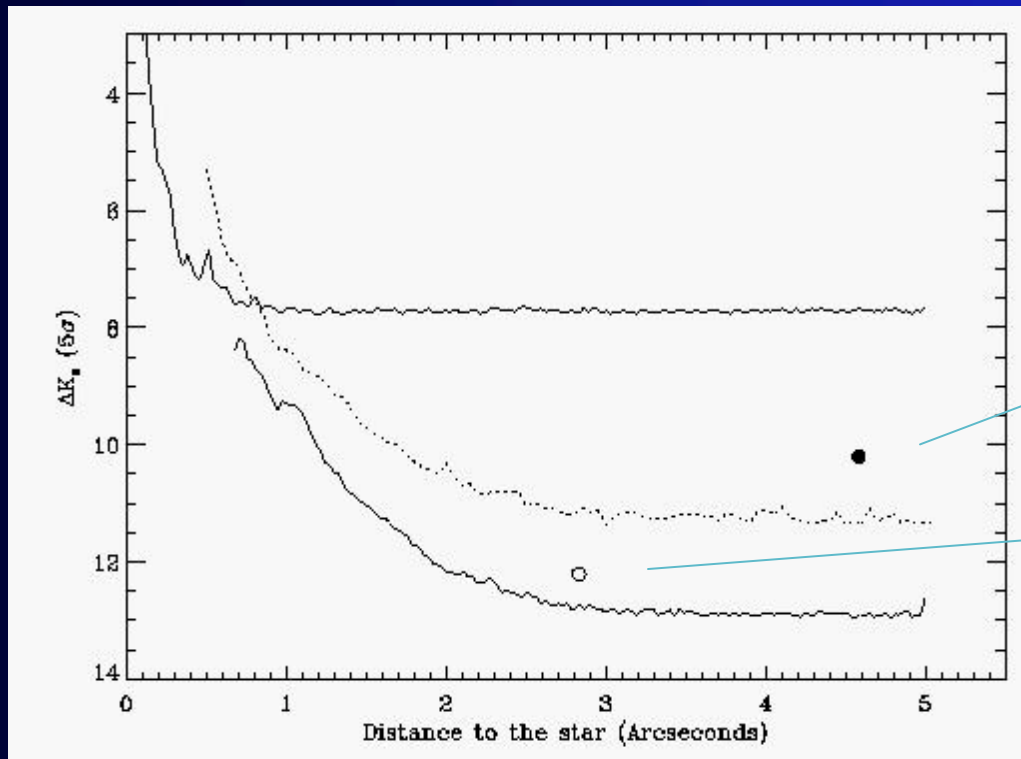
VLT/NACO observations of HIP 6856 A possible 3-5 Jup mass companion ?

Detection of 2 faint companions
with NACO in coronagraphic mode
Ks filter, Exp. Time = 150 s
Separations: CCB (4.8"); CCc (2.8")
 ΔK_s : CCB (10.25); CCc (12.2)

Astrometry needed to actually
discriminate between background
object and physical companion



VLT/NACO detection limits for HIP 6856



HIP 6856 CCb

HIP 6856 CCc

Detection limits (VLT-NACO)

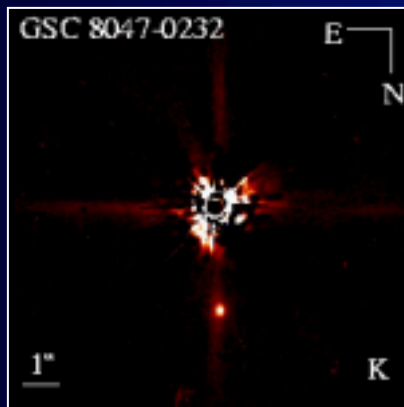
- upper curve: classical imaging
- lower curve: coronagraphic mode
- dotted: ADONIS coronagraphic mode

VLT/NACO observations of GSC8047-0232

A 20-30 Jup mass companion

VLT/NACO GTO 70
Dec. 2002

- Coronagraphy J, H and Ks
- Spectroscopy needed in Ks to confirm the sub-stellar nature of this object



First detection with ADONIS - 2001

GSC 8047-0232 (Ks Band)

B

A

1''

Ks filter, Exp. Time = 35 s
Sep. = 3.28'' ; $\Delta K = 8.5$

And Pueo Nui ?

- Only AO system accessible to French astronomers in the Northern hemisphere !
- Better resolution (diffraction-limit in R)
 - More objects with RV and AO data (more masses with very high accuracy)
- Better correction AND stability
 - New coronagraphic modes (AIC, 4-Q, etc.)
 - Differential imaging (Trident)
 - Improved deconvolution → astrometric accuracy
 - Extension to the visible : imaging and low-resolution spectroscopy