Mass-luminosity relation and multiplicity statistics of very low mass stars

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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 unkown 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

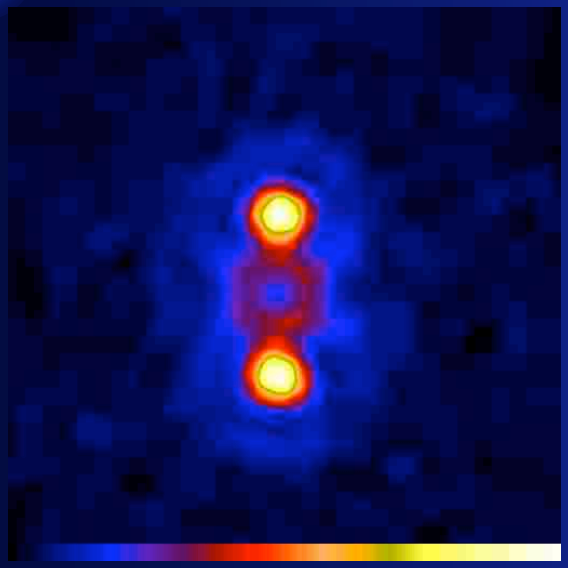
M-dwarfs survey

- 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'')
    - Astrometry/photometry using WFS data reconstruction and AOPHOT (Véran et al. 98)
    - Earlier results obtained with ADONIS

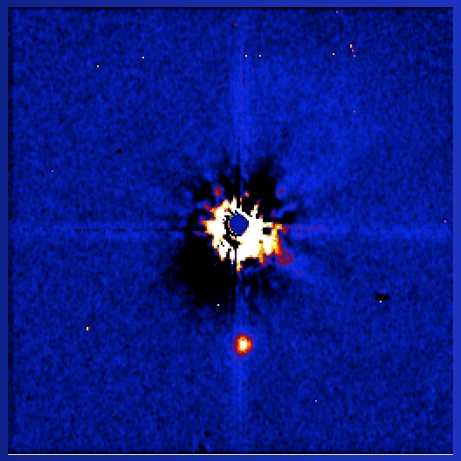
M-dwarfs survey

- Instruments
  - NAOS + CONICA (July 2003…)
    - Down to 0.03'' separation (0.3 AU at d = 10 pc)
    - Lyot coronagraph with 0.7" mask (ΔK = 11 at 1'')
    - New 4Q coronagraphic mode, SDI mode…
    - WFS reconstruction and/or deconvolution methods
      - MISTRAL (Fusco et al., 2002)

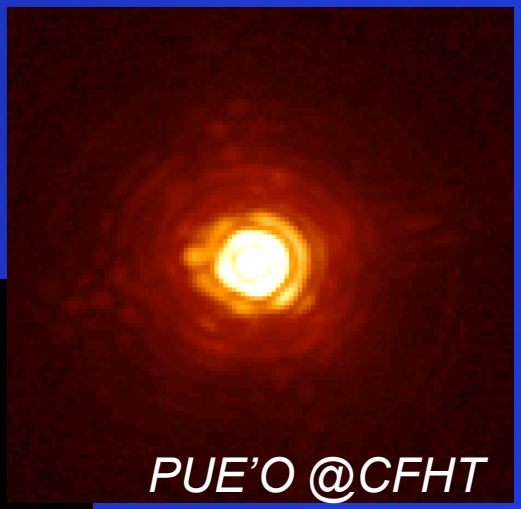
Observations

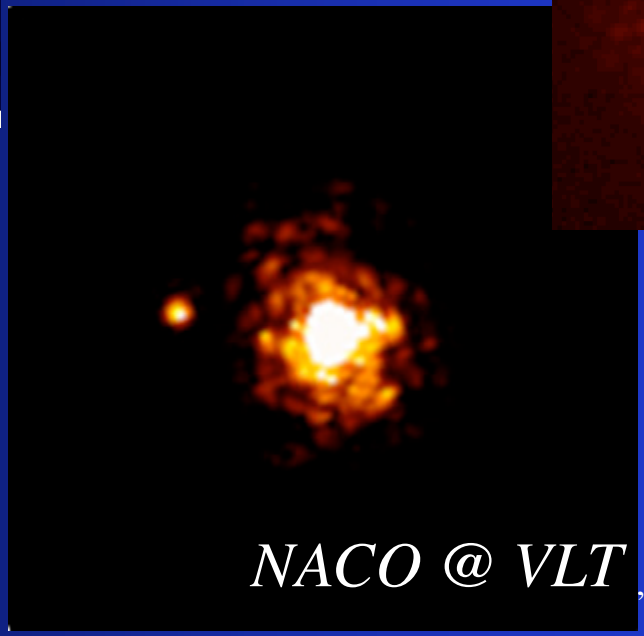


AIC on PUEO (2000)



Coronagraph on PUEO



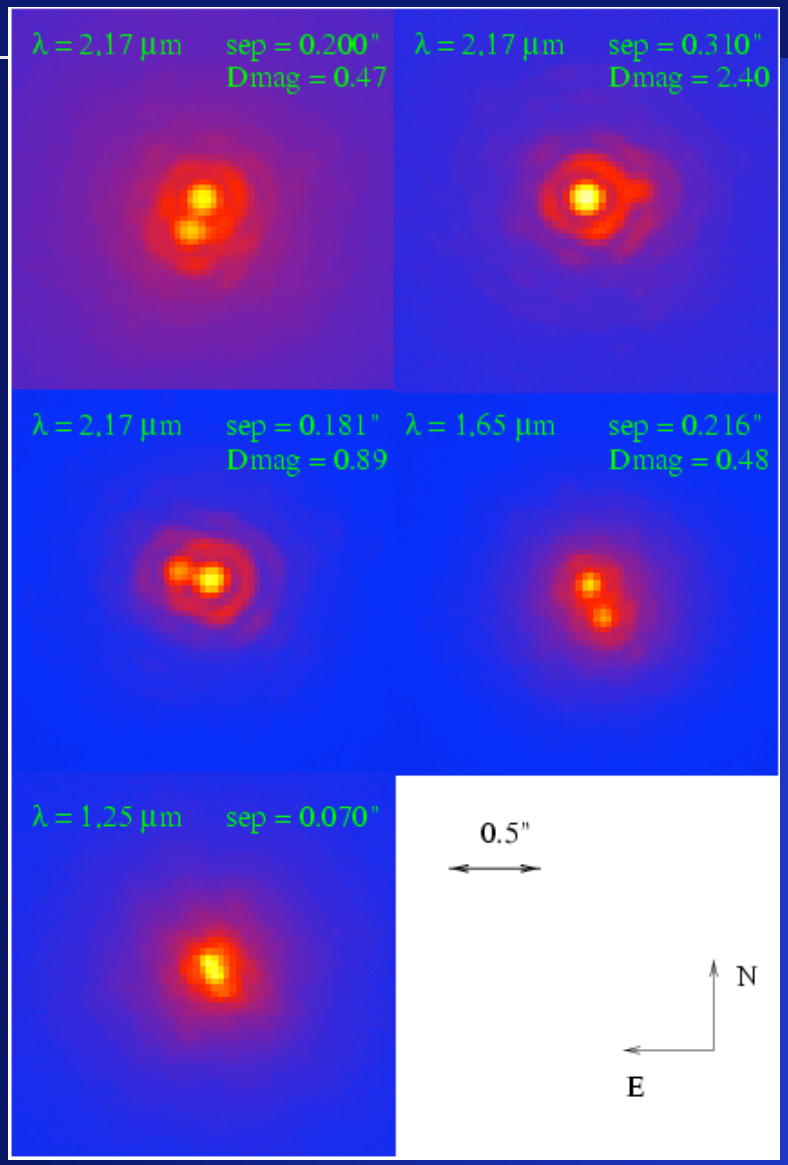


V = 10
ΔK = 4.2
Brg . t*exp* = 10 s

AO-PSF Reconstruction

, 10-12 May 2004

Observations



Reduction

- Deconvolution methods needed:
  - Resolution is ok (diffraction-limited core)
  - Extended halo (significant fraction of energy)

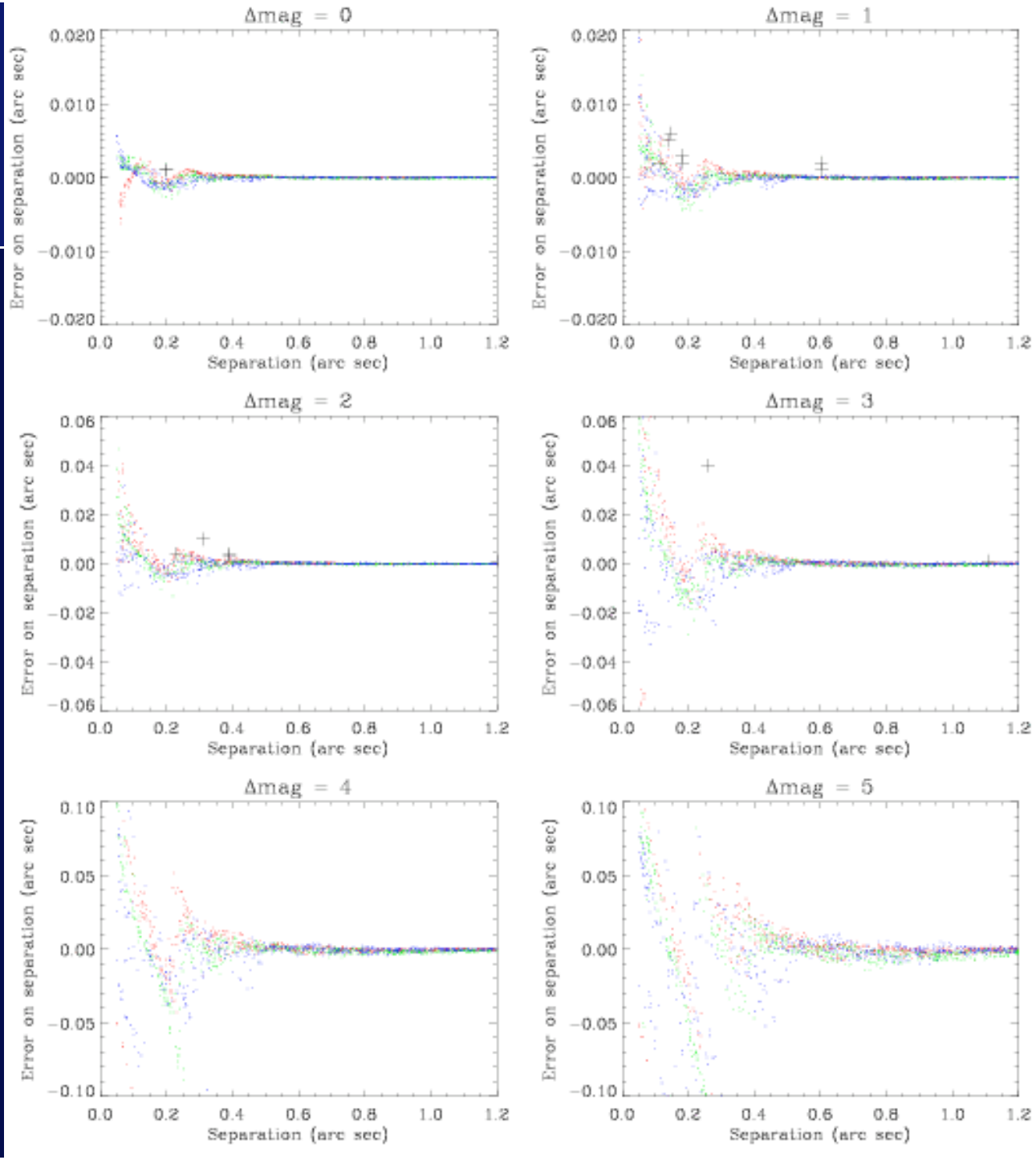
    ➔ Goal is to concentrate flux in central core
  - Allow accurate measurements (astrometry and photometry)
  - Allow better detection (better contrast)
- Accurate separation / magnitude difference of companions
- Approach
  - Classical deconvolution : estimate AO corrected PSF, then object
  - Blind deconvolution: estimate AO corrected PSF and object at the same time
  - Approach 1 is used for our program using AOPHOT (Véran, 98)

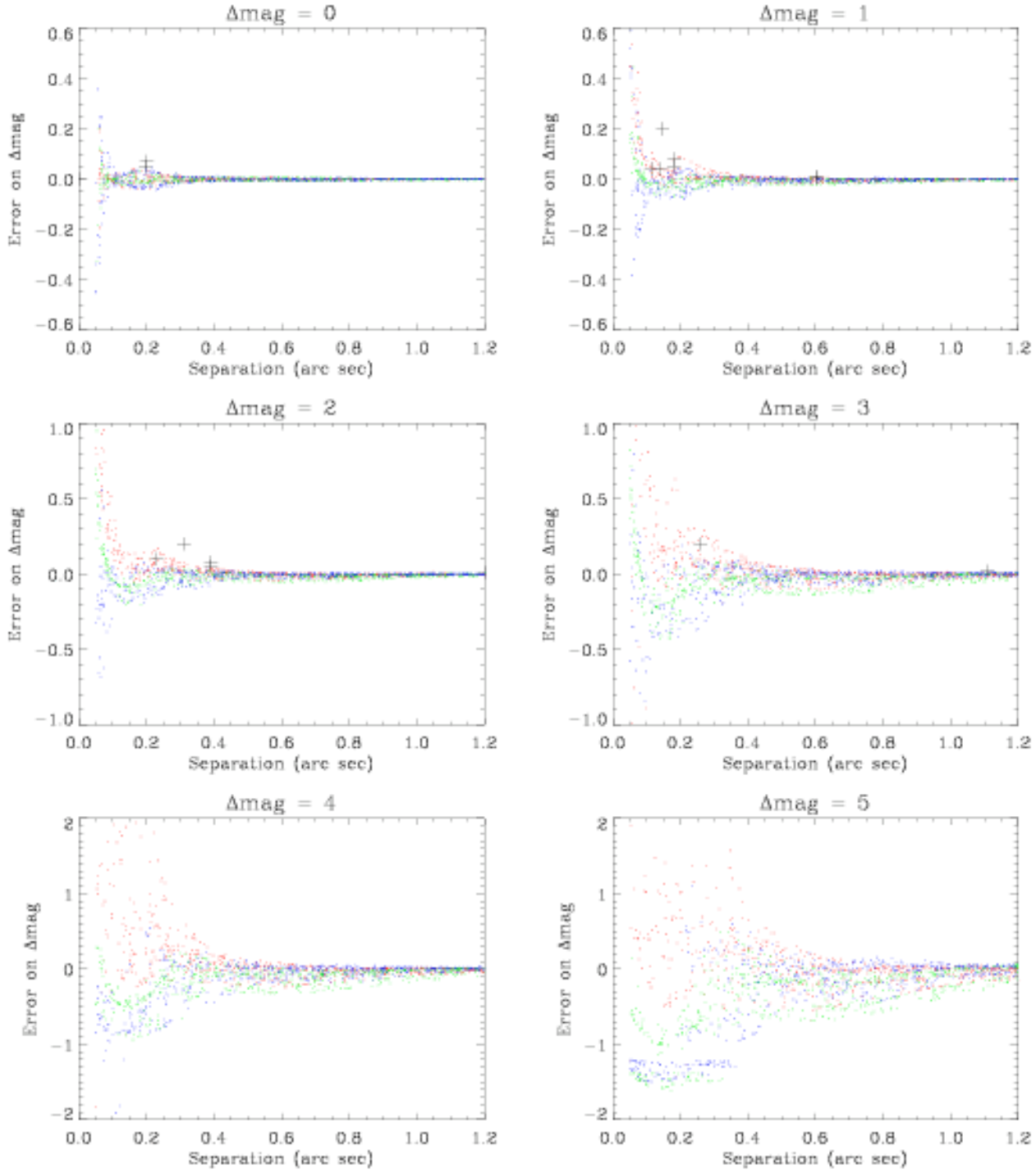
PSF Reconstruction with PUEO

- Tools to provide the AO corrected long exposure PSF in the direction of guide source if brighter than R ~ 13
- On-line computation (real-time)
  - Using WFS measurements and DM commands
  - Uncorrected atmospheric free seeing
  - AO corrected long-exposure PSF (perfect optics, Kolmogorov for high spatial frequencies)
- Off-line computation
  - Uncorrected non-common path aberrations
  - High spatial frequency not following Kolmogorov model (mirror seeing, etc.)
  - Considered as quasi-static effects and corrected using point-source images taken during the night
  - DPH2PSF package (CFHT web page)

PSF Reconstruction with PUEO

- For bright objects, accuracy limited by reconstructed PSF
- Accuracy of the AOPHOT method as a function of separation and magnitude difference ?
- Simulations and real data:
  - Use of real PSFs to generate binary systems with random parameters
  - Use of reconstructed PSFs with AOPHOT to measure parameters
  - Comparison with parameters derived from real data
  - Different seeing conditions
- For bright enough companions (5-10% of primary) and separation larger than ~0.4”:
  - Photometric accuracy ~ few %
  - Astrometric acuracy ~ 1 mas


Δmag = 0
Δmag = 1
Δmag = 2
Δmag = 3
Δmag = 4
Δmag = 5
Error on separation (arc sec)
Separation (arc sec)


Δmag = 0
Δmag = 1
Δmag = 2
Δmag = 3
Δmag = 4
Δmag = 5
Error on Δmag
Separation (arc sec)

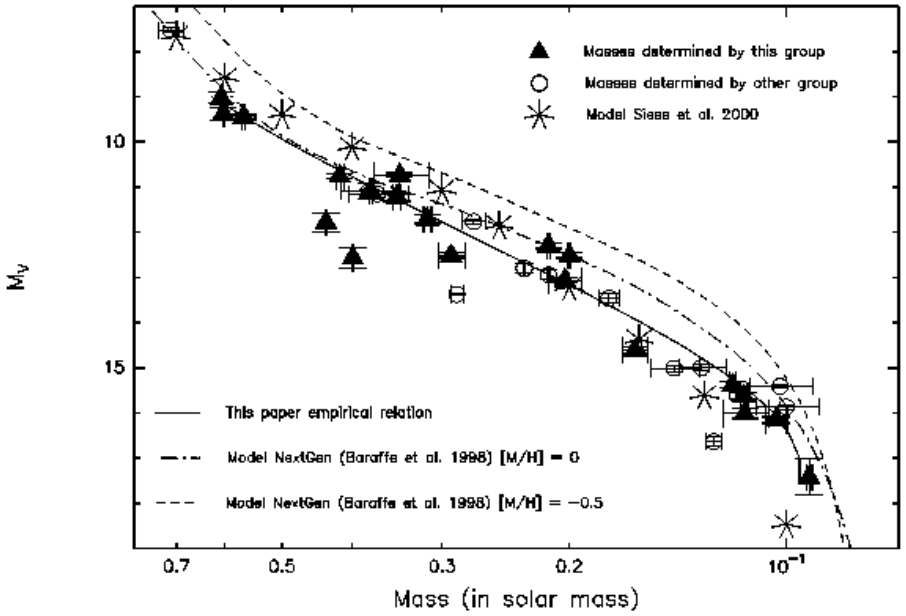
Mass-luminosity function

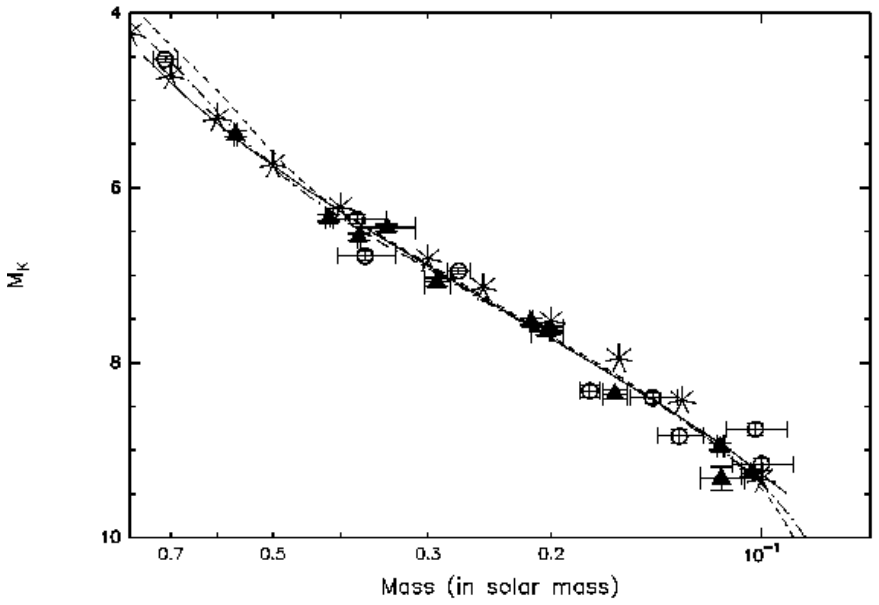
- Example of obtained accuracy (Gl 570)
  - Mass A = 0.568 +/- 0.012 Msun (2.2%)
  - Mass B = 0.382 +/- 0.006 Msun (1.7%)
  - Parallax = 0.1689 +/- 0.0008” (0.5%)
  - Magnitudes: _J = 1.19 +/- 0.03
- Other results
  - Mass A = 0.5425 +/- 0.0025 Msun (0.5%)
  - Mass B = 0.2650 +/- 0.0011 Msun (0.4%)

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 (7 new resolved systems)
  - Better accuracy needed at short wavelength

Mass-luminosity function





Delfosse et al., 2000

Conclusion

- Excellent results obtained so far on PUEO with AOPHOT
- We need even better on NACO !
- PSF reconstruction / Blind deconvolution