Ultra-cool dwarf binaries

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1./ Introduction: Context and motivations

2./ Statistical properties of binary ultra-cool dwarfs in different environments

- 2.1/ In the solar neighbourhood
- 2.2/ In a young open cluster: The Pleiades
- 2.3/ In SFR: Cha-I, R-CrA, USco
- 2.4/ Impacts on the models of formation

3./ Physical properties of binary ultra-cool dwarfs: Dynamical masses

- 3.1/ Current status
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- 3.3/ Planets around BD

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Context of the study: About the interest of ultracool binaries

Binaries as testimonies

How do brown dwarfs and VLMS form, how do they evolve ???

$\Rightarrow$ ***still few unanswered questions !***

Depending on the scenario of formation, the properties of multiple systems change !

Multiple systems provide valuable "tests" and important constraints for the models.

Binaries as scales

What about the Mass vs. Luminosity relation for BD and VLMS ???

$\Rightarrow$ ***Still needs to be calibrated !***

Binaries offer a unique opportunity to measure dynamical masses <u>independently</u> from any model.

Context of the study:
About the interest of ultracool binaries

Models of atmospheres:

In ONE shot, you can study the properties of TWO objects with different properties (masses, evolution, Teff, etc…)

Statistical Properties of binary ultracool dwarfs

In three different environments and ages

Statistical Properties of Binary Ultracool dwarfs

	Field (~1-5 Gyr)	**Pleiades** (~120 Myr)	**USco** (~5 Myr)
Number of binaries	~40	~5	3
Binary Fraction (>5 AU)	~15%	~10% (~ 50% photom.)	42±19%
Distrib. Sep.	<20 A.U Max~4-8 AU	<20 A.U	<18 A.U
Distrib. Mass Ratios	Q>0.5	Q>0.5	Q>0.5

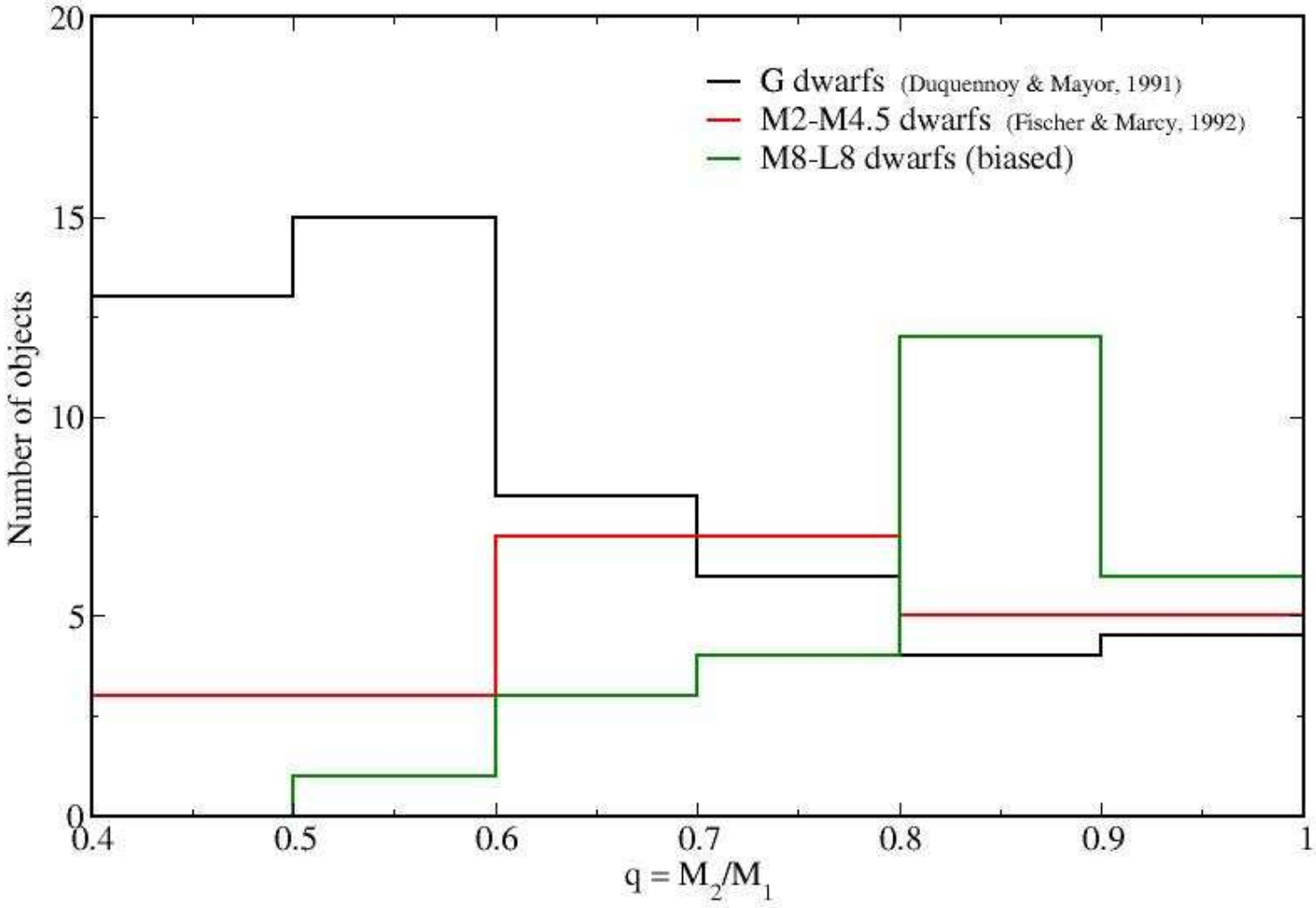
Statistical Properties of Binary Ultracool dwarfs

Distribution of Mass Ratios:

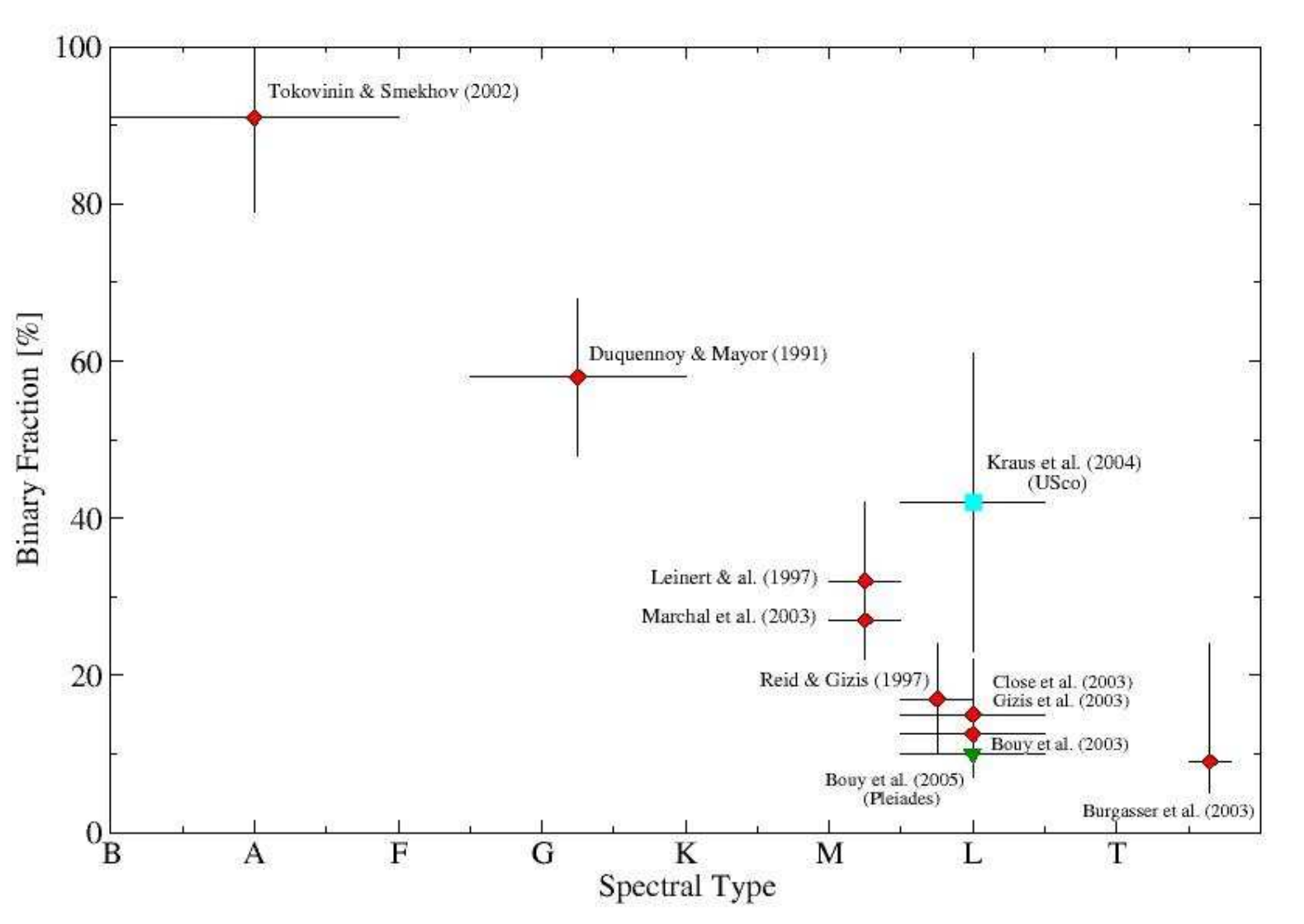
Lack of small Mass ratios ???

(might be Biased)

Inversion of the trend for Later SpT ???



Statistical Properties of Binary Brown dwarfs In the Pleiades (~120 Myr)



Discussion:
Impacts on the models of formation and evolution

1./ Star Like model #1:

BD form like stars from the fragmentation and collapse of small molecular clouds.

	Consistent with model's predictions ?
Binary Freq.	YES
Distrib. Sep.	NO

Credits: J. Alves

Discussion:
Impacts on the models of formation and evolution

1./ Star Like model #2:

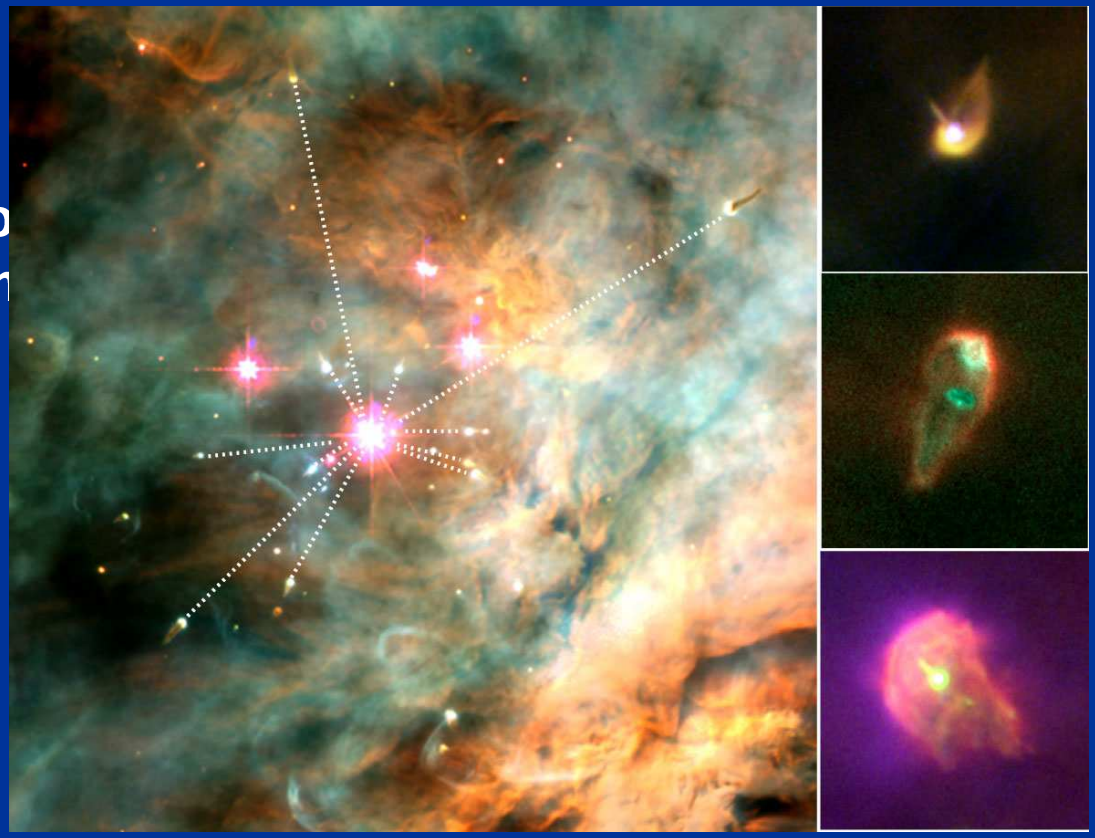
BD form like stars as ejected stellar embryos in multiple proto-stellar systems.

	Hydrodynamical simulations #1 (Bate et al. 2002)	Hydrodynamical simulations #2 (Delgado Donate et al. 2002, 2004)	Dynamical simulations (Sterzik & Durisen, 2003 Umbreit et al., 2005)
Binary Freq.	NO	YES (if…)	YES
Distrib. Sep.	N/A	YES (if…)	YES

Discussion:
Impacts on the models of formation and evolution

1./ Star Like model #3:

BD form via the Photo-evaporation o stellar embryos in th vicinity of bright massive stars

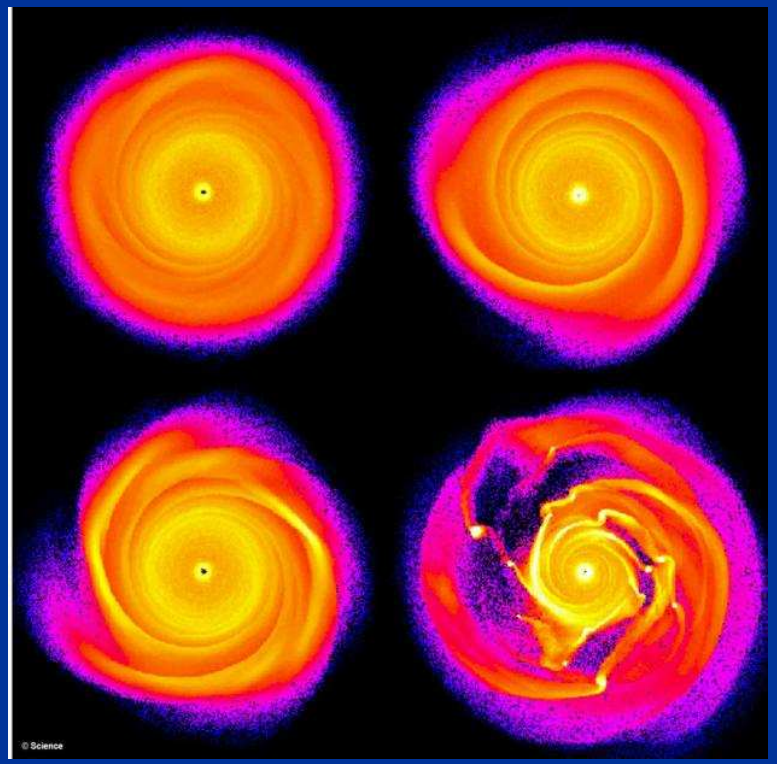


(credits: STSci)

Discussion:
Impacts on the models of formation and evolution

Planet-like models

BD may form like planets in disks surrounding stars

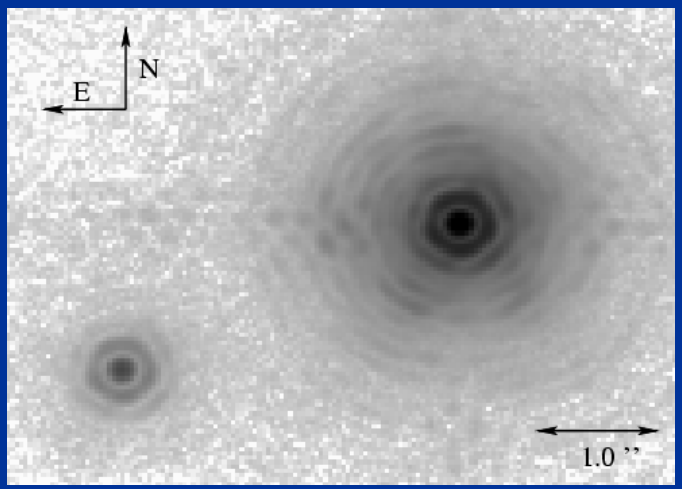


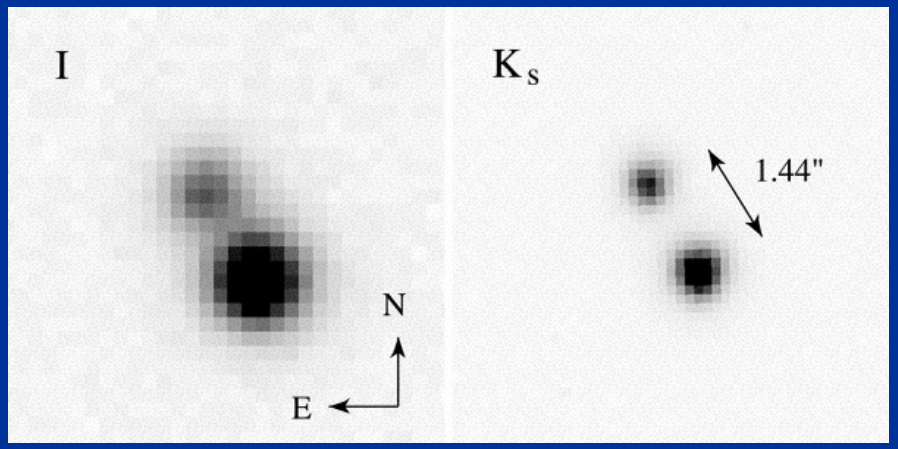
(Mayer et al. 2003)

Some wide binaries…

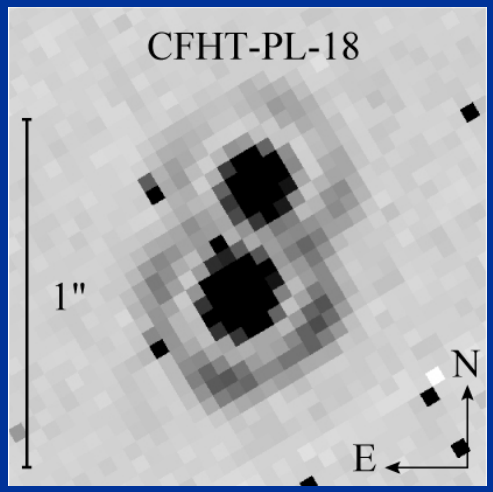
Interesting but do not change the previous conclusions…

(Forveille et al. 2004
Golimowski et al., 2004
30 A.U)





(Luhman et al. 2004, 240 A.U)



(Martin et al. 1998, 30 A.U)

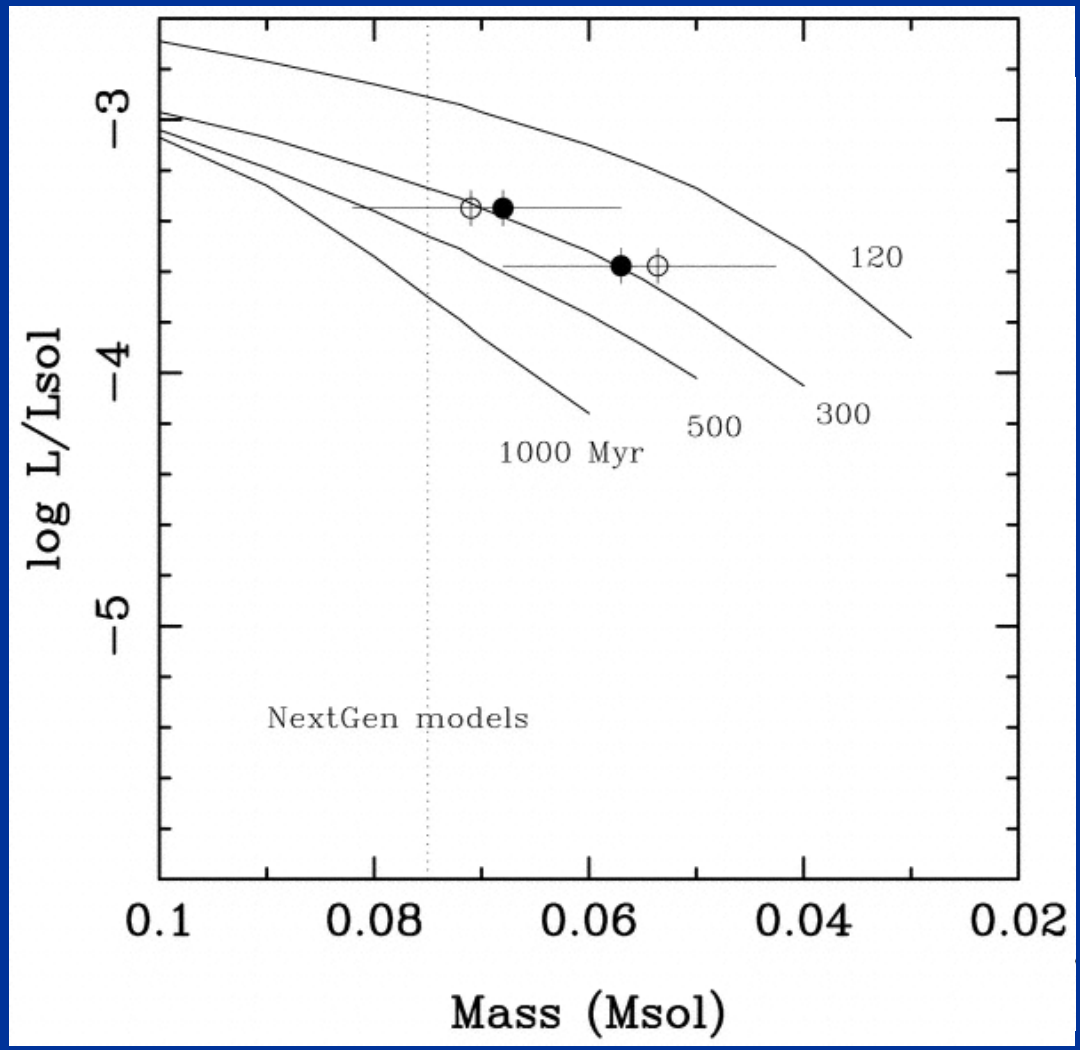
Physical Properties of binary ultra-cool dwarfs:
Dynamical masses

Gl 569Bab

Zapatero-Osorio et al., 2004

M1 = 0.034-0.070 Msun (M8.5)

M2 = 0.055-0.087 Msun (M9)

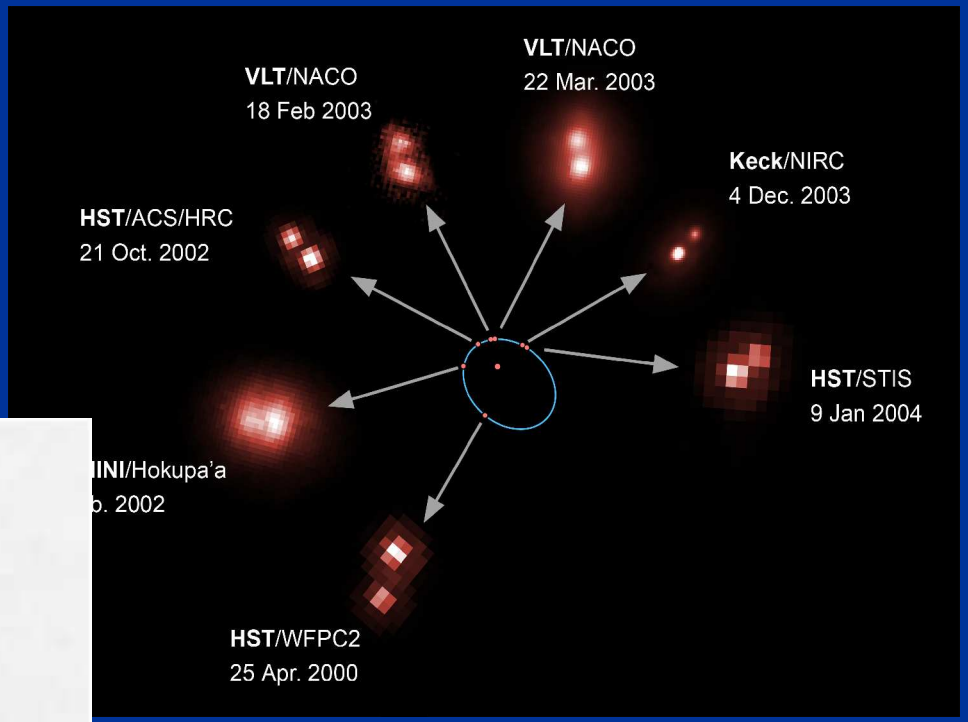


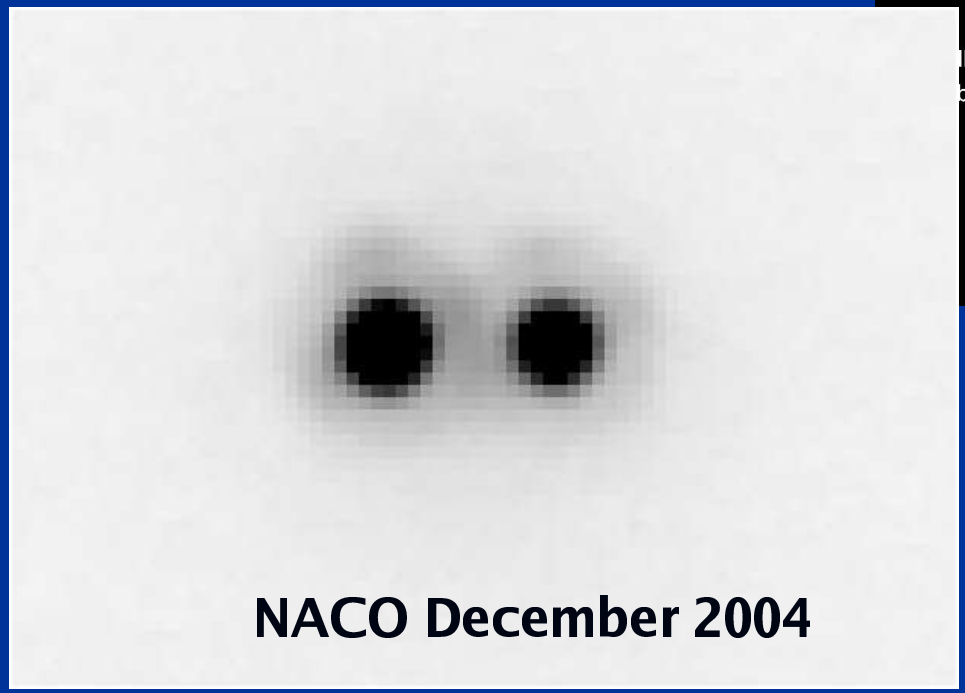
2MASSW J0746425+200032

Bouy et al., 2004

M1 + M2 = 0.146 **Msun**

M1 = 0.075-0.095 Msun (L0)
M2 = 0.055-0.100 Msun (L1.5)





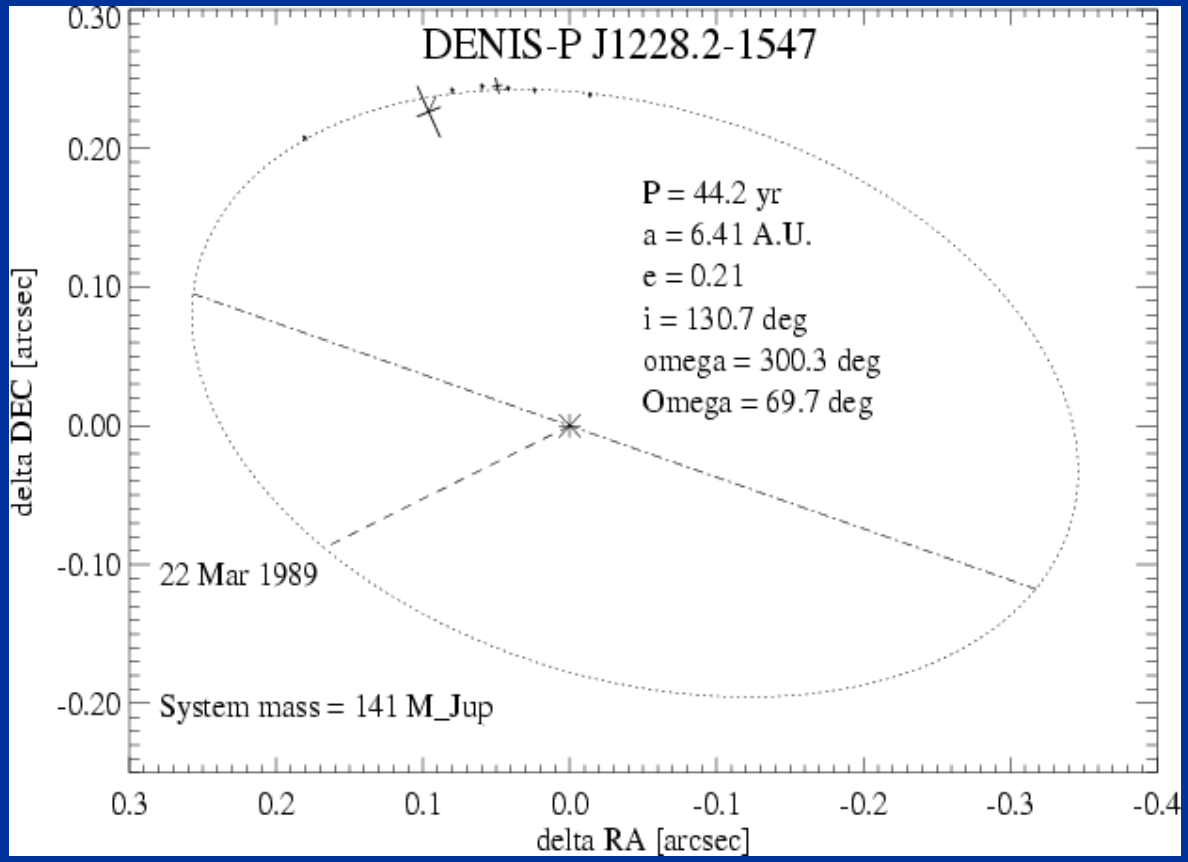
NACO December 2004

DENIS-P J1228.2-1547

Brandner et al., 2004

P ~ 45 yrs

M1 + M2 = 0.141 **Msun (L5)**



On-going work:

1./ By our group:

Object	HST Obs.	NACO Obs.	Gemini Obs.	TOTAL:
DENIS1228.2-1547	6	0	0	6
2MASS0850+1057	3	0	0	3
2MASS0920+3517	3	0	0	3
2MASS1426+1557	3	2	1	6
2MASS1311+8032	3	0	0	3
2MASS2206-2047	1	4	0	5
2MASS2331-0406	1	1	1	3
2MASS1146+2230	6	0	0	6
DENIS0357-4417	3	0	0	3
DENIS1004-1146	3	0	0	3
DENIS0205-1159	8	0	0	8
DENIS1441-0945	8	0	0	8
HD130948	1	0	2	3
LHS2397a	2	1	0	3
GJ569B	+1	0	0	9

On-going work:

HST proposal for cycle 15:

Object	SpT	Period [yrs]	Orbit coverage
DENIS0205-1159	L5	8	58-71 %
2MASS1534-2952	T5.5	5	97-117 %
2MASS0920+3517	L6.5	7	77-91 %
DENIS0357-4417	L3	10.5	40-50 %
2MASS1728+3948	L7/T	14	35-42 %

On-going work:

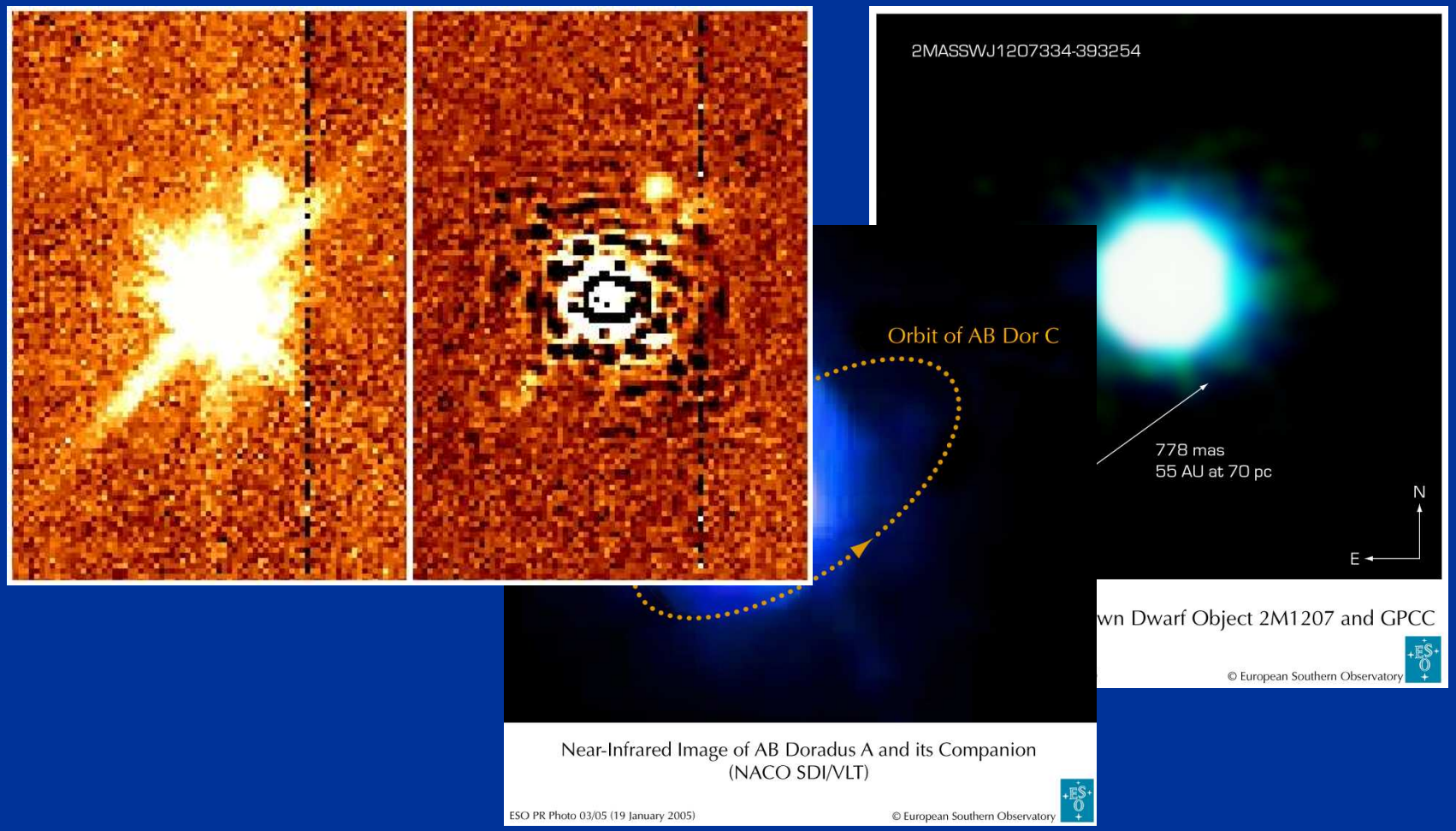
2./ By other teams:

(list probably uncomplete…)

Object	Team	Instr.
ε-Indi B	Close et al.	NACO
HD130948	Potter et al.	HST, Gemini
LHS102B	Golimowski et al.	HST, NACO

Planets around BD

A new domain of research ! Direct imaging/spectroscopy of planets around



Conclusions

Very active field of research !

Many interesting results coming in the next few months

Still a lot of work required:
- on the theoretical side
- on the observational side

The study of binarity should be complemented by:
- study of the IMF
- study of disks
- study of kinematics