

ϵ Indi Ba, Bb

Astrometric Study

Cátia Cardoso

Supervisor: Mark McCaughrean

Palermo 20th May 2009
CONSTELLATION X-Ray School

UNIVERSITY OF
EXETER



- ϵ Indi A: K5V star
- ϵ Indi B discovered by Scholz et al. (2003)
- Resolved as a binary by McCaughrean et al. (2004)

ϵ Indi Ba, Bb

- Closest known brown dwarfs to Earth, at 3.6224 pc [1]
- 1500AU from ϵ Indi A [2]
- Proper motion ~ 4.7 arcsec/year [2]
- T1 and T6 [3]
- Age $\sim 0.8 - 2.0$ Gyrs, but kinematics indicators of > 7.4 Gyrs [4]

[1] Van Leeuwen (2007); [2] Scholz et al. (2003); [3] McCaughrean et al. (2004); [4] Lachaume et al. (1999)

Cátia Cardoso

20th May 2009

UNIVERSITY OF
EXETER

Benchmark Object

- Orbits a K5V star:
 - Very well constrained distance
 - Well constrained metallicity
 - Reasonably constrained age
- Closest brown dwarf binary to Earth:
 - Very bright objects
 - AO system
 - Absolute motion of barycentre against a network of background stars
 - Short period ~ 10 years
 - Well resolved

Cátia Cardoso

20th May 2009

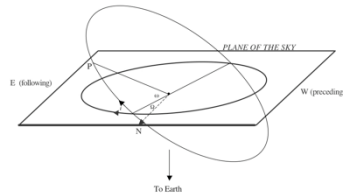
UNIVERSITY OF
EXETER

Relative Astrometry

- 3rd Kepler Law
 - Period
 - Semi-major axis

$$m_1 + m_2 = (4\pi^2 a^3) / (GP^2)$$

- Remove tilt



Credit image: www.astro.uvic.ca/~tanm/celmechs/celm17.pdf

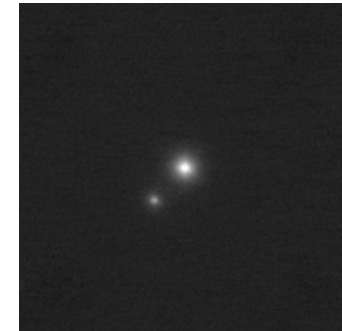
Cátia Cardoso

20th May 2009



Relative Astrometry

- ESO VLT NACO adaptive optics data in J, H, K_s bands
- Total 25 epochs between May 2004 and December 2008
- Observations continuing through periastron



ESO VLT NACO adaptive optics J, H & K composite image. McCaughrean et al., A&A (2004)

Cátia Cardoso

20th May 2009



Relative Astrometry

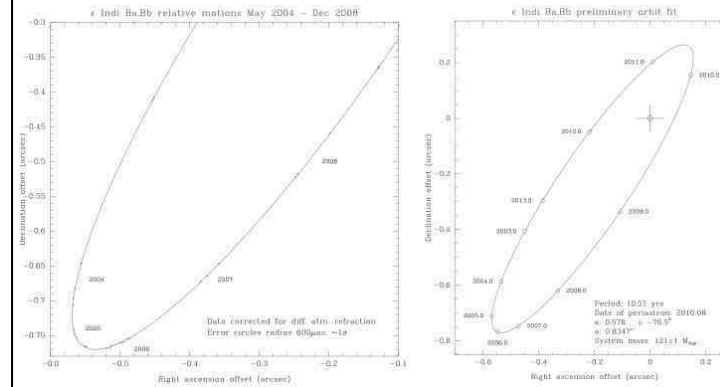
- Observed the binary: HD208371/2 to calibrate:
 - Image scale
 - Rotation variations with band and time
- Atmospheric dispersal correction
- Orbit fit with 3 different codes:
 - Non Linear Reduced χ^2 (D. Gudehus 2001)
 - Minimum χ^2 in grid search (R. Köhler 2008)
 - Markov Chain Monte Carlo (Q. Konopacky)
- All give consistent results

Cátia Cardoso

20th May 2009



Relative Astrometry



Cátia Cardoso

20th May 2009



Relative Astrometry

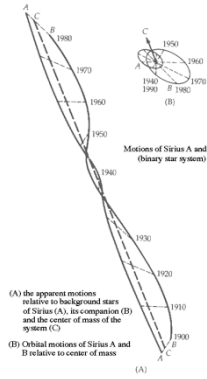
Period (years)	10.51	+ 0.34 / - 0.31
Periastron Passage	2010.08	+ 0.27 / - 0.30
Semi-major axis (mas)	643.7	± 14.3
Eccentricity	0.576	± 0.030
Inclination (deg)	76.49	+ 0.44 / - 0.48
System mass (M_{\odot})	0.1148	± 0.0009
System mass (M_{Jup})	120.3	± 0.9

Cátia Cardoso

20th May 2009

EXETER

Absolute Astrometry

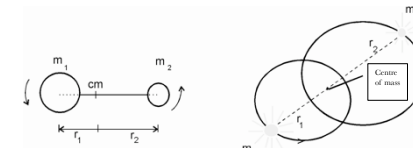


Credit image: Zelik & Smith

Cátia Cardoso

- Definition of centre of mass:
 $m_1 d_1 = m_2 d_2$
- To have the individual masses:

$$m_1/m_2 = (a_2 \sin i) / (a_1 \sin i)$$



Credit image: www.astron.iag.uq.edu.au/~jane/aga215/auis08/cap8.htm

20th May 2009

EXETER

Absolute Astrometry

- ESO VLT FORS2 data in I – band
- Total of 33 epochs between May 2005 and October 2008
- FORS2 field of view: 8.6 x 8.6 arcmin

Cátia Cardoso

20th May 2009

EXETER

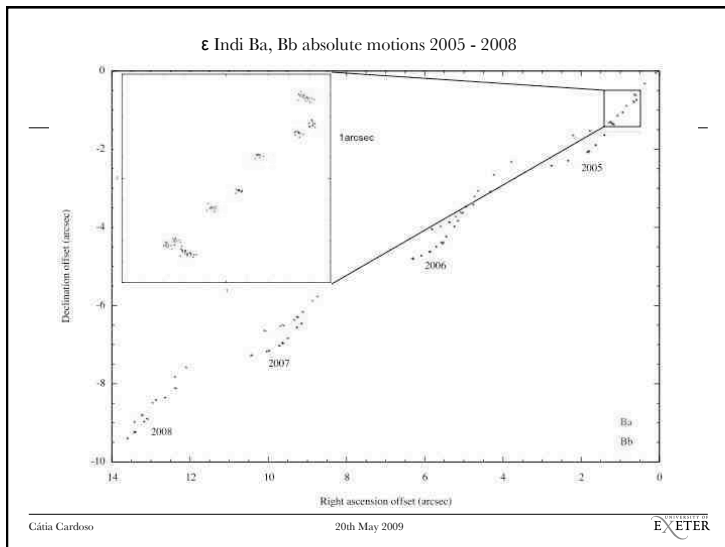
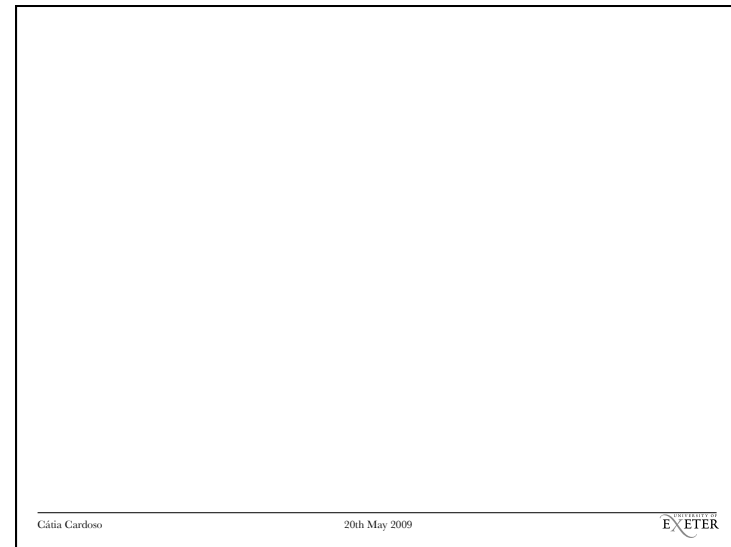
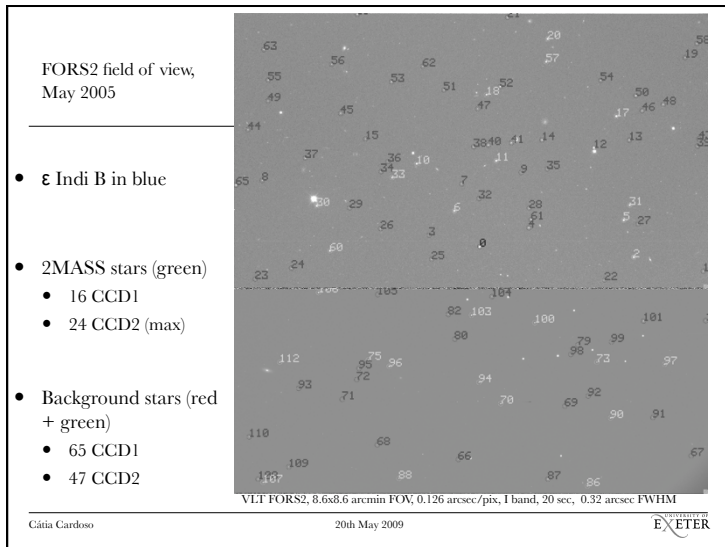
Absolute Astrometry

- PSF fitting
- Astrometric solution
 - Finding the gap between CCD's
 - 112 background stars for astrometric solution (max)
- Atmospheric dispersal correction

Cátia Cardoso

20th May 2009

EXETER



Results

- System mass = $120.3 \pm 0.9 M_{Jup}$
- Constrained ratio of $\sim 70:50$
- Possible error of $\sim 1 - 2 M_{Jup}$ in individual masses
 $\sim 0.5 M_{Jup}$ on the system mass
- Model independent \longrightarrow Calibrate evolutionary models and atmospheric models of T dwarfs

Cátia Cardoso 20th May 2009 EXETER

Future Work

- Asteroseismology study of ϵ Indi A for better constraint on age
- Create a reduced χ^2 parameter search routine for the absolute astrometric data
- Continue to obtain data until Bb rounds NW end of projected orbit in 2011

catia@astro.ex.ac.uk

- This work is funded by the E.C. Sixth Framework Program Marie Curie Research Training Network CONSTELLATION (MRTN-CT-2006-035890).

