The size of ABDorA from VLTI/AMBER interferometry

(The size of ABDor A as an age indicator)

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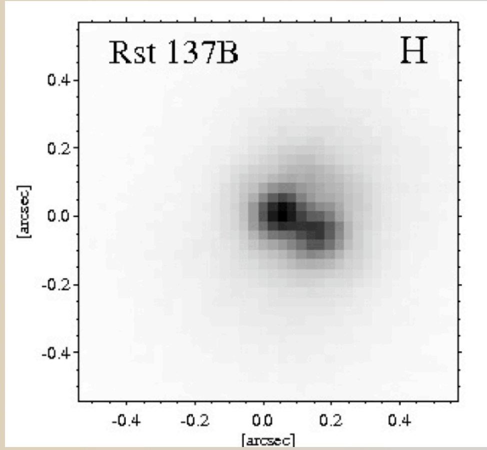
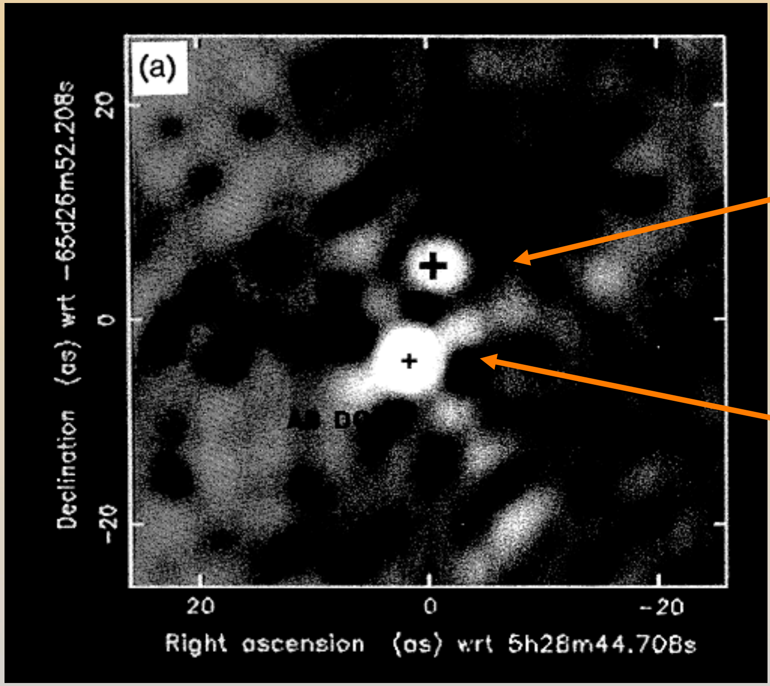
The AB Doradus system

- ABDorA (main component) is an intensively observed southern-hemisphere PMS star (m_V = 6.9).
- Quadruple system
- Fast rotator (0.5 days): Strong radio emission

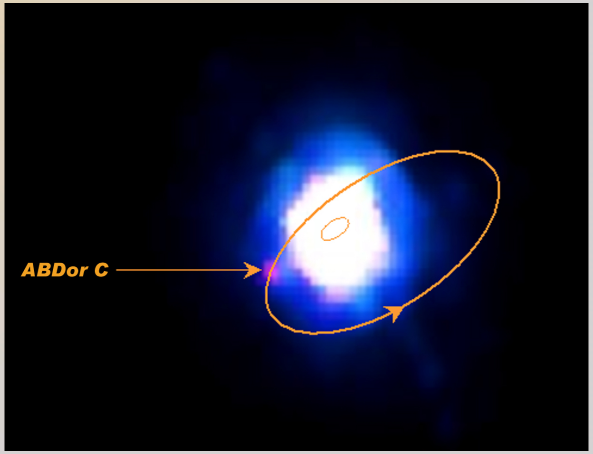


AB DorBa / AB DorBb

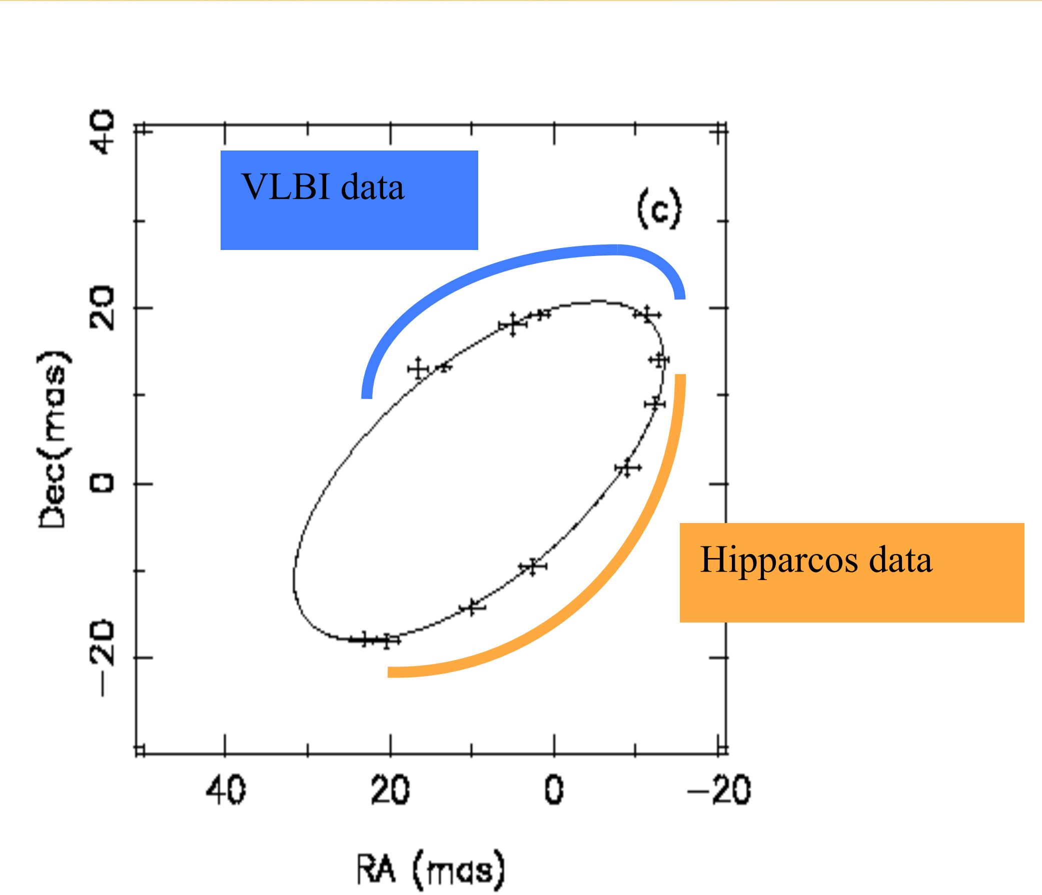
(a.k.a. Rst137B)



AB DorA / AB DorC



Reflex (ABDorA) Orbit / Mass of ABDorC



Guirado et al. ApJ 1997

- ABDorA was excluded from the Hipparcos link (acceleration)
- We discovered an unseen companion, ABDorC, with mass:

Mass estimate (ABDor C):

0.08 – 0.11 M⊙

THE ASTROPHYSICAL JOURNAL, 490:835–839, 1997 December 1

ASTROMETRIC DETECTION OF A LOW-MASS COMPANION ORBITING THE STAR AB DORADUS

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ABSTRACT

We report submilliarcsecond-precise astrometric measurements for the late-type star AB Doradus via a combination of VLBI (very long baseline interferometry) and *HIPPARCOS* data. Our astrometric analysis results in the precise determination of the kinematics of this star, which reveals an orbital motion readily explained as caused by gravitational interaction with a low-mass companion. From the portion of the reflex orbit covered by our data and using a revised mass of the primary star (0.76 $M_\odot$) derived from our new value of the parallax (66.3 mas $< \pi <$ 67.2 mas), we find the dynamical mass of the newly discovered companion to be between 0.08 and 0.11 $M_\odot$. If accurate photometric information can be obtained for the low-mass companion, our precise mass estimate could serve as an accurate calibration point for different theoretical evolutionary models of low-mass objects. This represents the first detection of a low-mass stellar companion using VLBI, a technique that will become an important tool in future searches for planets and brown dwarfs orbiting other stars.

Subject headings: astrometry — stars: individual (AB Doradus) — stars: kinematics — stars: low-mass, brown dwarfs — techniques: interferometric

From 1997 to 2004
VLT / SDI image of ABDorC

letters to nature

A dynamical calibration of the mass–luminosity relation at very low stellar masses and young ages

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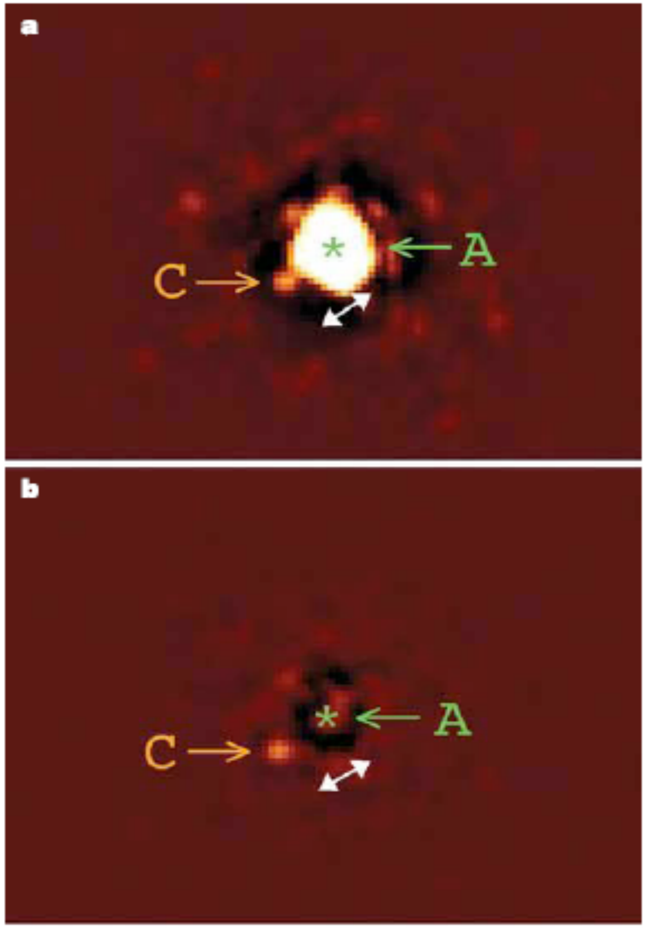
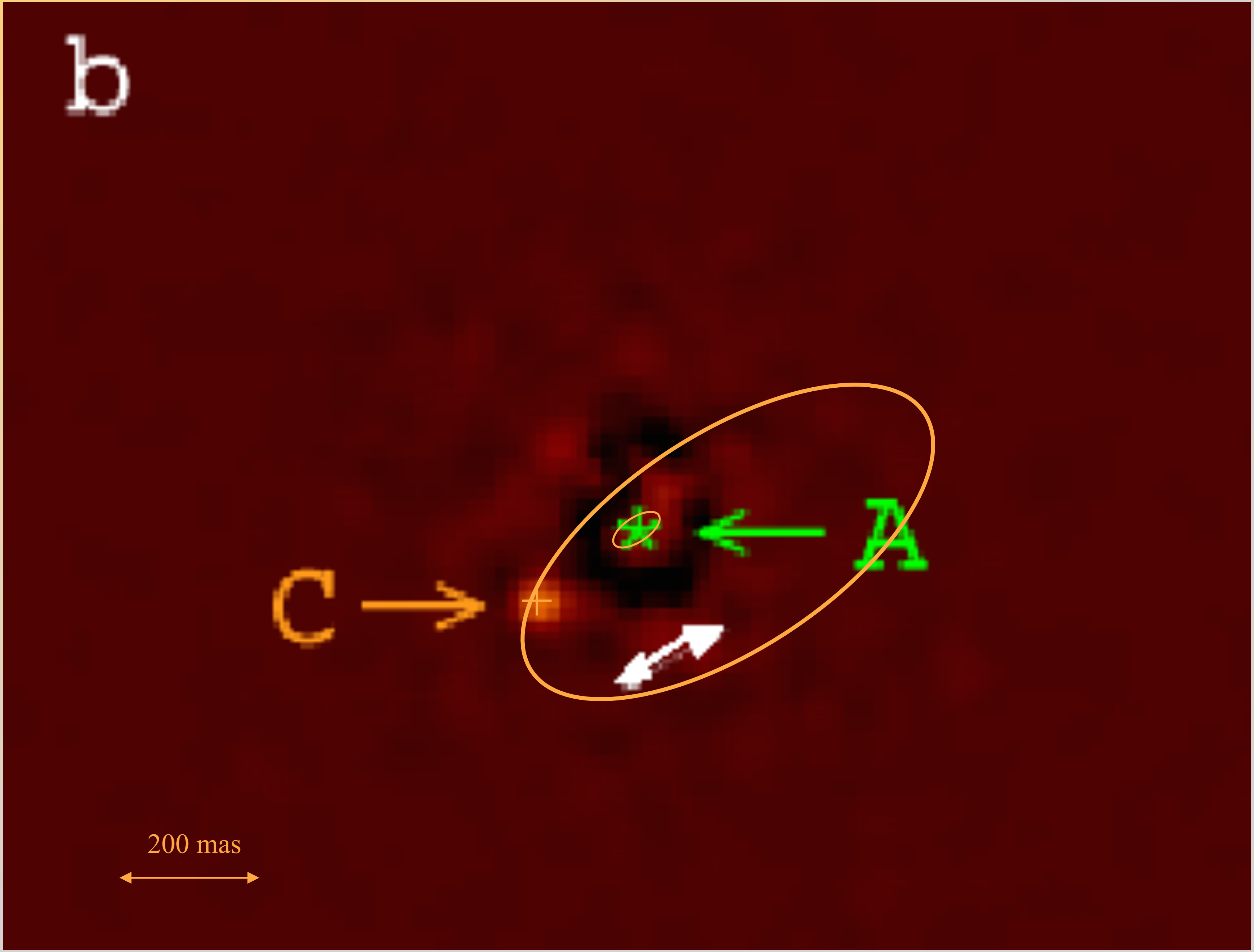
Mass is the most fundamental parameter of a star, yet it is also one of the most difficult to measure directly. In general, astronomers estimate stellar masses by determining the luminosity and using the 'mass–luminosity' relationship[1,2], but this relationship has never been accurately calibrated for young, low-mass stars and brown dwarfs[3]. Masses for these low-mass objects are therefore constrained only by theoretical models[1,2]. A new high-contrast adaptive optics camera[4–6] enabled the discovery of a young (50 million years) companion only 0.156 arcseconds (2.3 AU) from the more luminous (>120 times brighter) star AB Doradus A. Here we report a dynamical

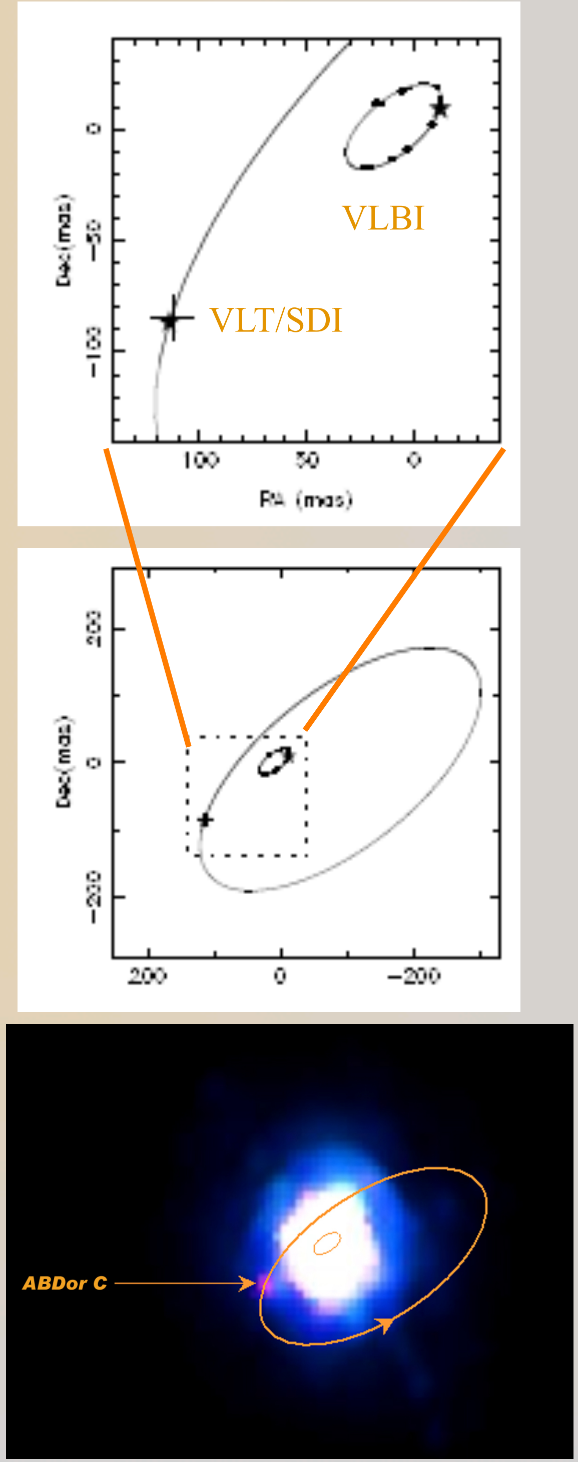



b
A
C
200 mas

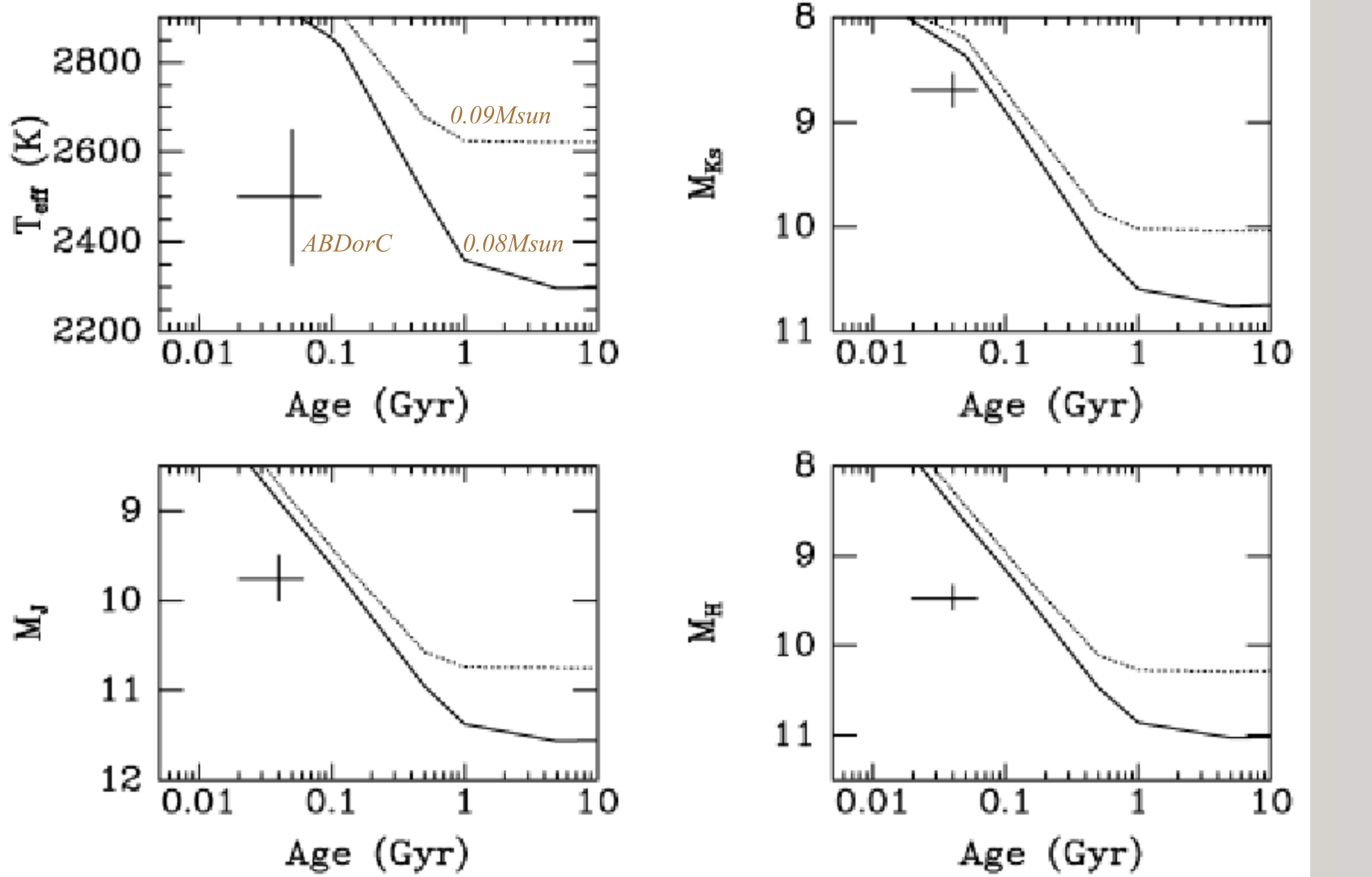
•Astrometric discovery of the VLM star ABDorC (0.09Msun) from VLBI observations (Guirado et al. AJ, 1997). **Dynamical mass of ABDorC.**

•VLT/SDI imaging of ABDorC (Close et al. Nature, 2005). **JHK photometry**

• ABDorC became one of the few low-mass stars with dynamical mass and photometry measured independently.

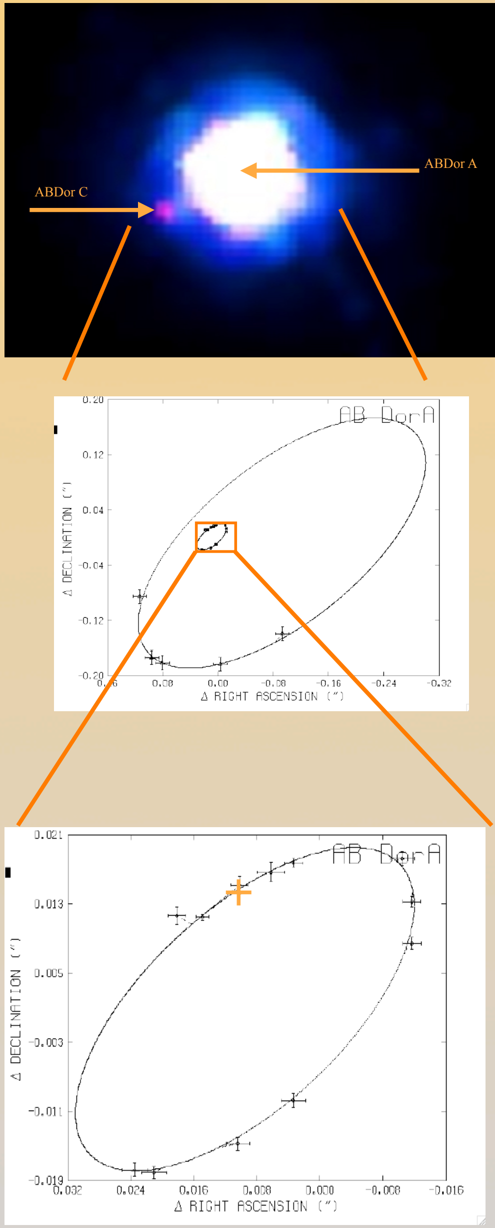


ABDorC: precise calibration for evolutionary models



Close et al. Nature, 2005

Some parameters of ABDorC were improved / revised



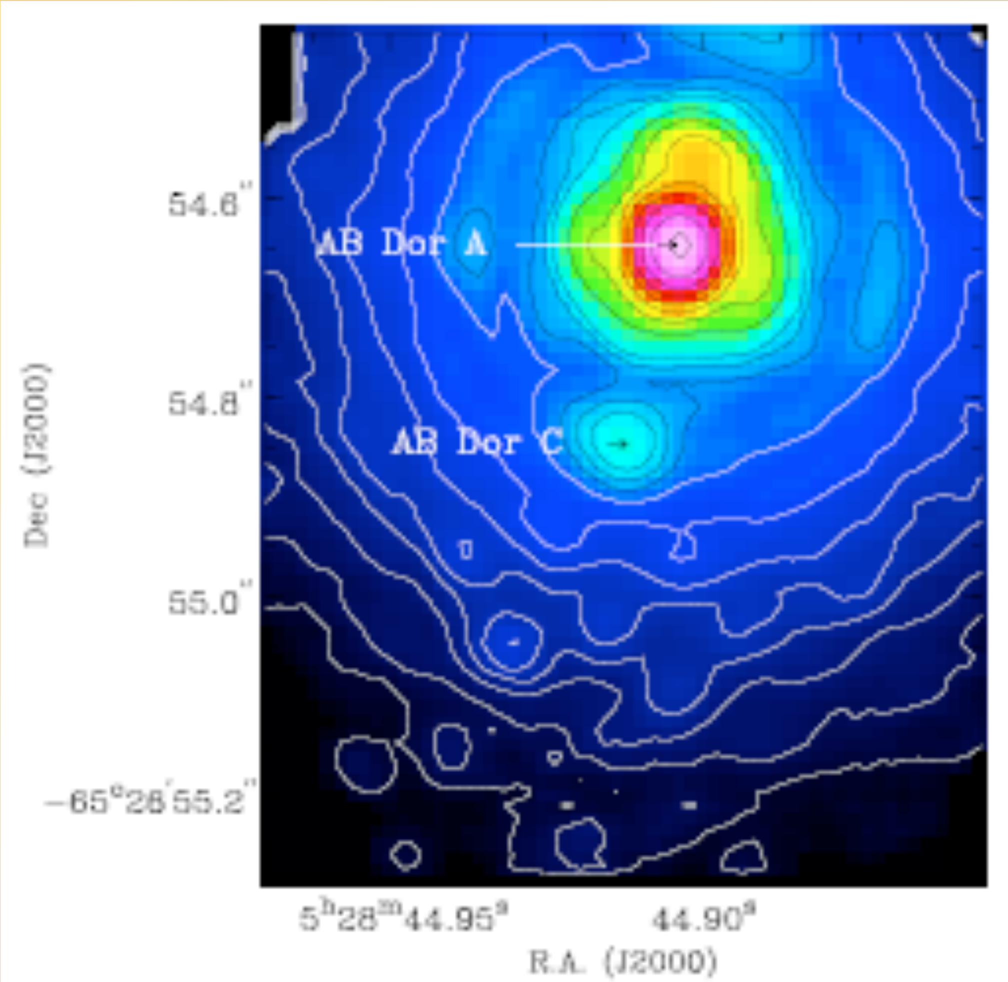
- *monitoring of ABDor/ABDorC relative orbit → m1+m2*
- *monitoring of ABDor reflex orbit → mass function*

Mass(ABDorC) = 0.089± 0.007 Msun

Mass(ABDorA) = 0.863 ± 0.050 Msun

Both dynamical

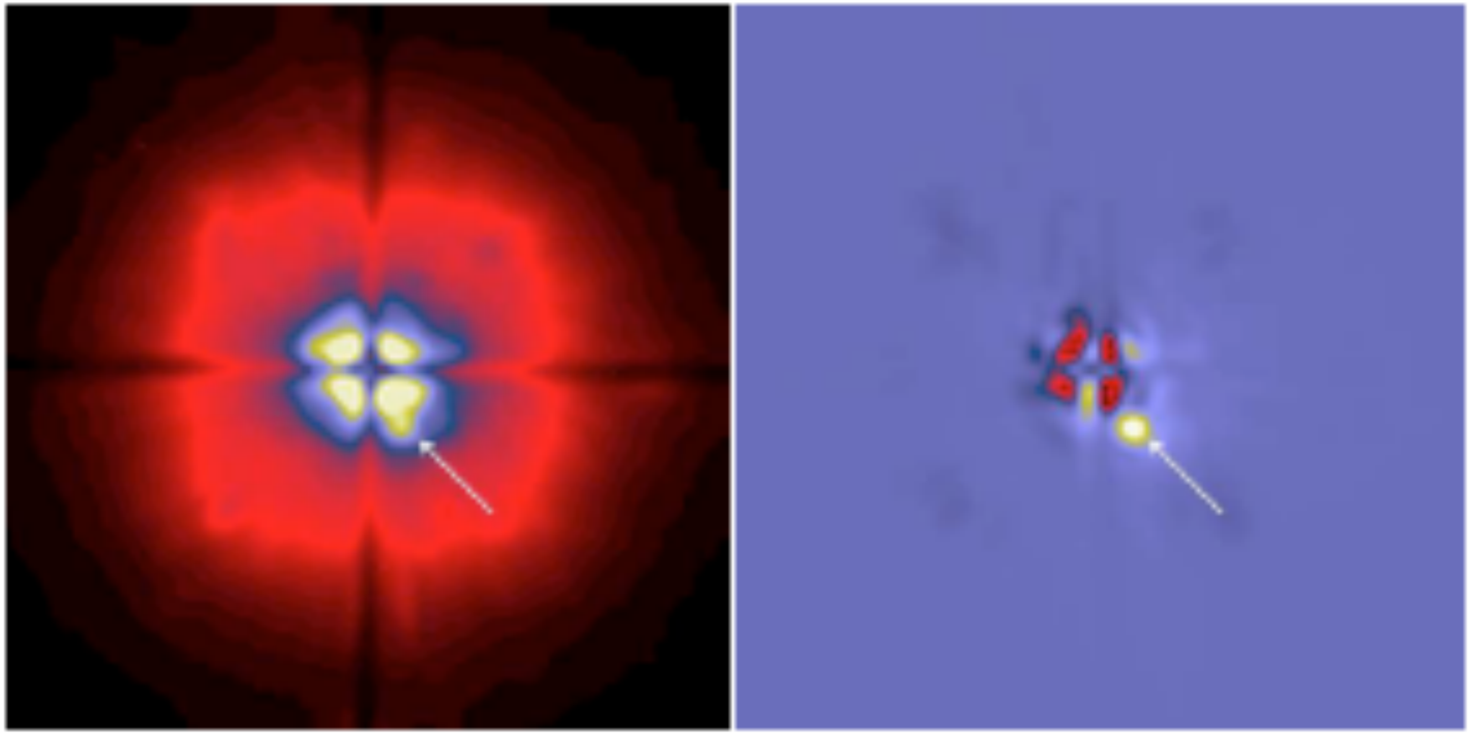
New photometry : VLT / SINFONI -



Thatte et al. 2007; Close et al. 2007

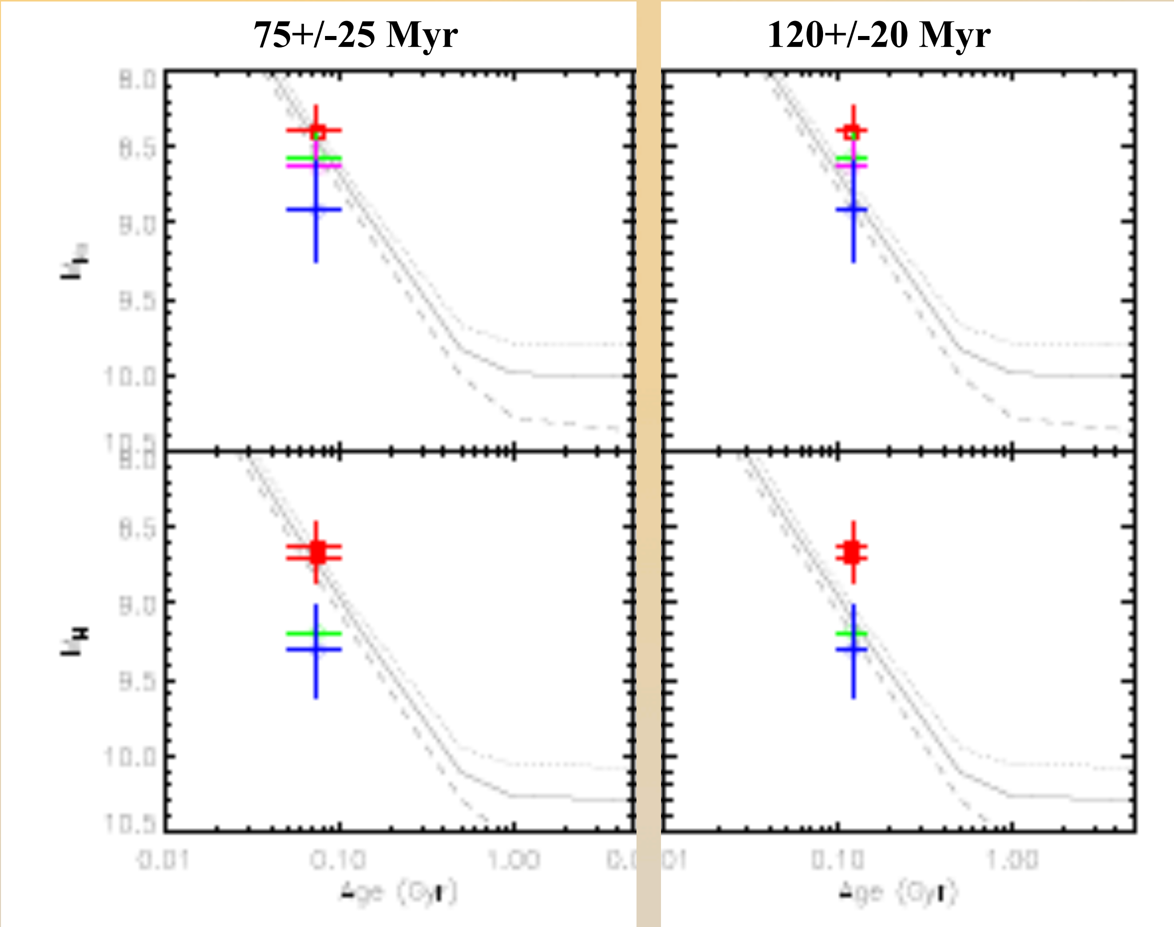
VLT / Coronograph

(Boccaletti et al. 2008)



VLT / Coronograph

(Boccaletti et al. 2008)



+ Bocaletti 2008 (coronograph)
+ Close et al. 2005 (SDI)
+ Close et al. 2007 (SINFONI)
+Luhman et al. 2006 (SDI)

Different age estimates for the system:

50 Myr (Zuckerman 2004, López-Santiago 2006—ABDor moving group)

75 Myr (Nielsen 2005, Janson et al. 2006, Boccaletti et al. 2008)

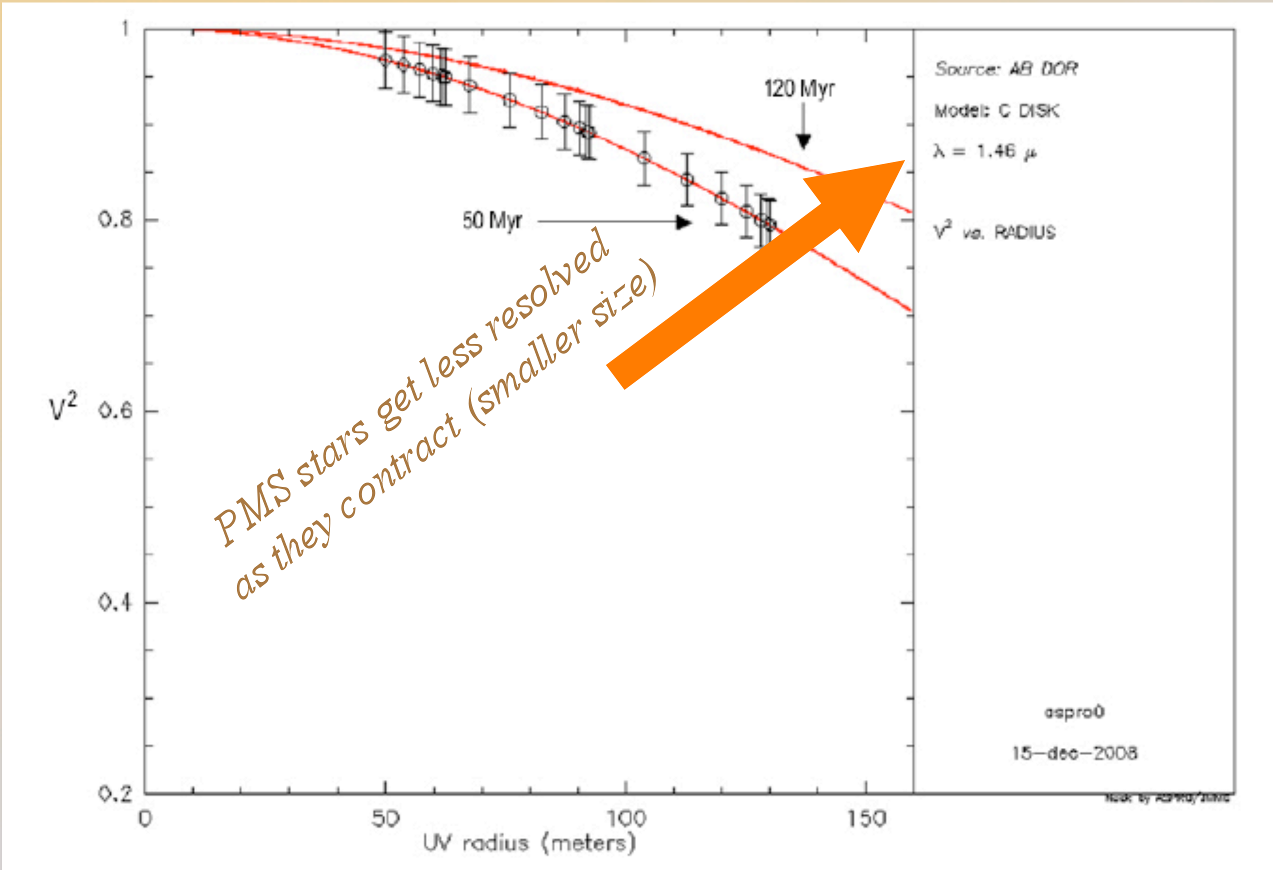
120 Myr (Luhman 2005, Ortega et al. 2007 –coeval with the Pleiades)

How interferometry can help?

- **Age range considered: 25 to 120 Myr**

- **The size of ABDorA can provide bounds to the age of the system, as it contracts towards the main sequence (provided A and C are coeval).**

- **Example: AMBER/VLTI, K-band, AT's with largest baselines**



How interferometry

- **Age range considered: 25 to 120 Myr**
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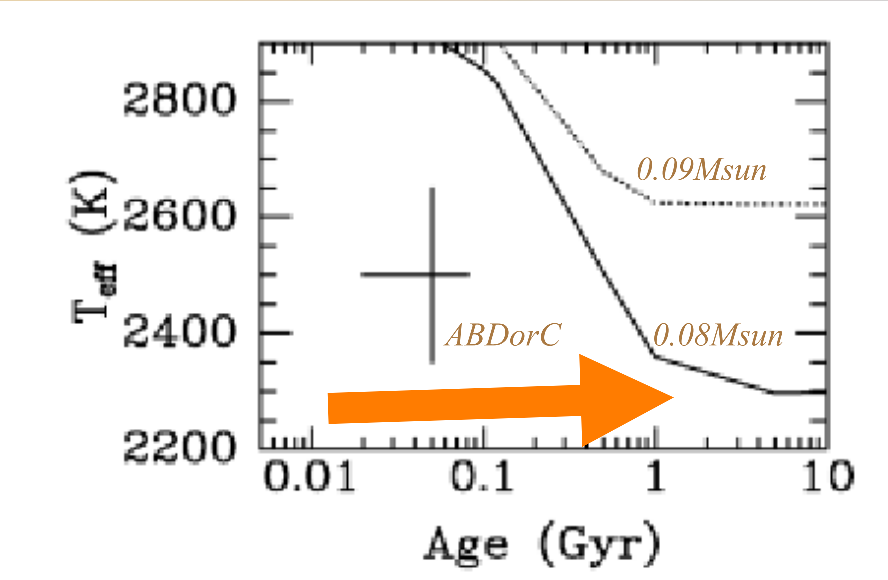
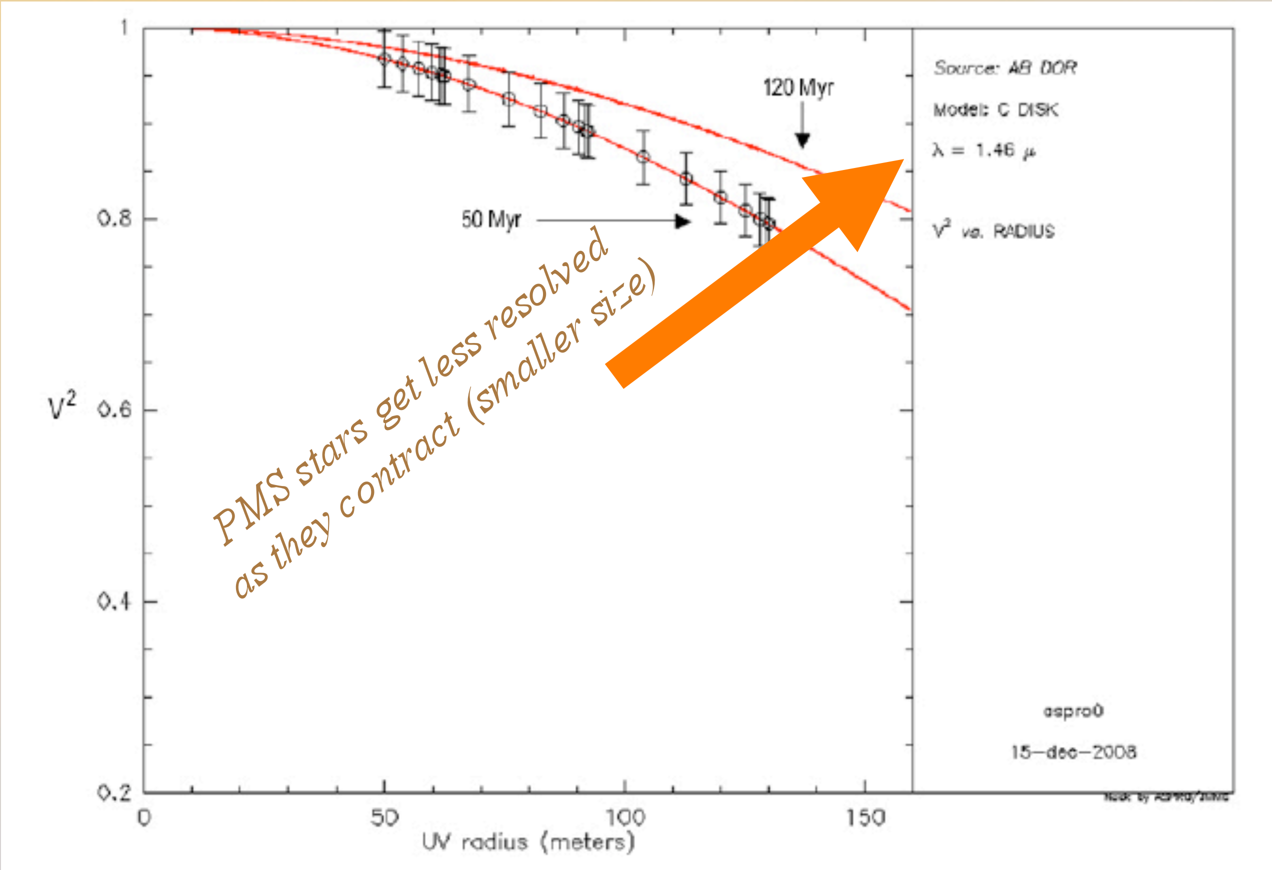
- **Example: AMBER/VLTI, K-band, AT's with**

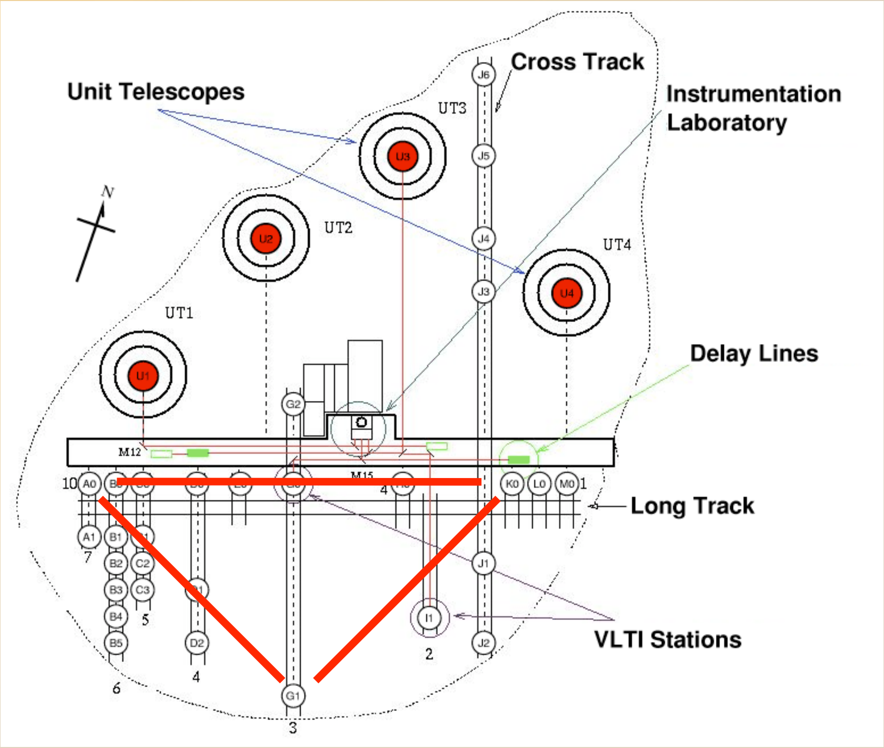




We observed ABDorA in P86

AMBER instrument LR-JHK

A0-K0-G1 (largest resolution in P86)



Time allocated: 10 hr, 25 December 2009

VISITOR mode

Some details of the observation

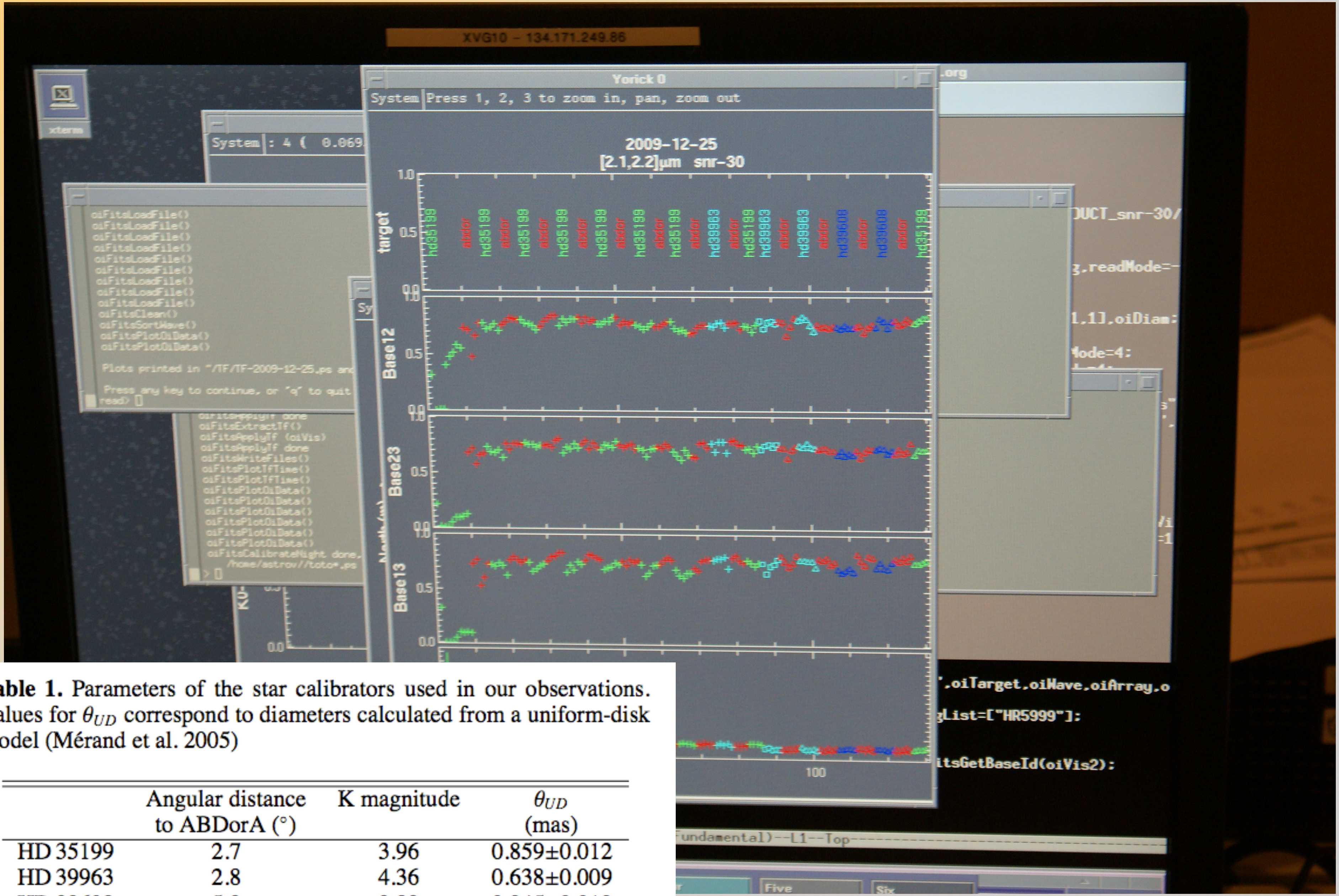


Table 1. Parameters of the star calibrators used in our observations. Values for θ_{UD} correspond to diameters calculated from a uniform-disk model (Mérand et al. 2005)

	Angular distance to ABDorA (°)	K magnitude	θ_{UD} (mas)
HD 35199	2.7	3.96	0.859±0.012
HD 39963	2.8	4.36	0.638±0.009
HD 39608	5.3	3.83	0.945±0.012

AMBER data reduction

HD35199: primary amplitude calibrator
HD39608, HD39963: secondary CALs

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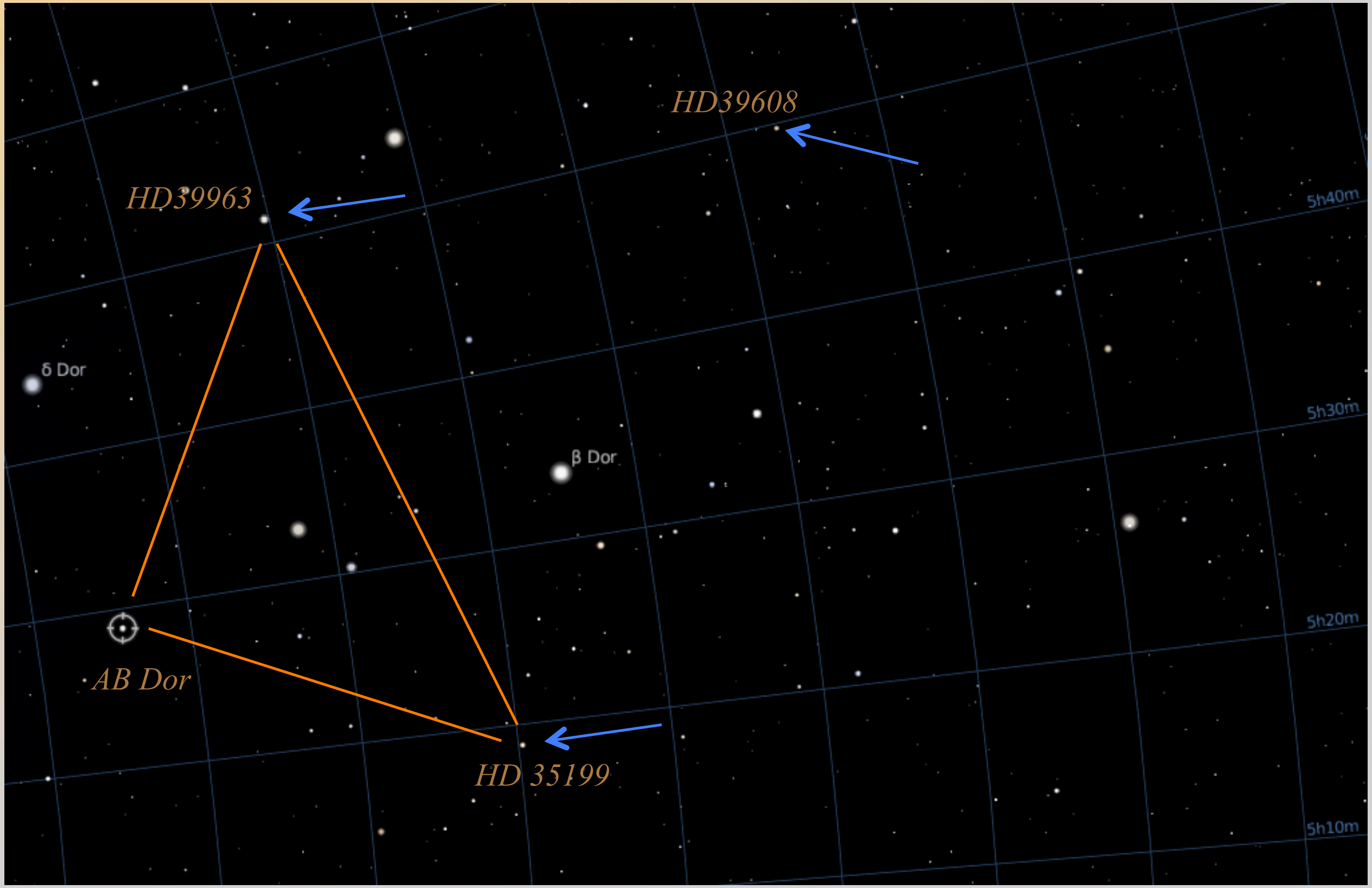
- **HD39963:**
ϑ_{UD} = 0.66+/.0.04 mas

- **HD39608:**
ϑ_{UD}= 0.95+/.0.04 mas

(both values with Merand et al. estimates)

The gains determined were applied to ABDorA raw visibilities



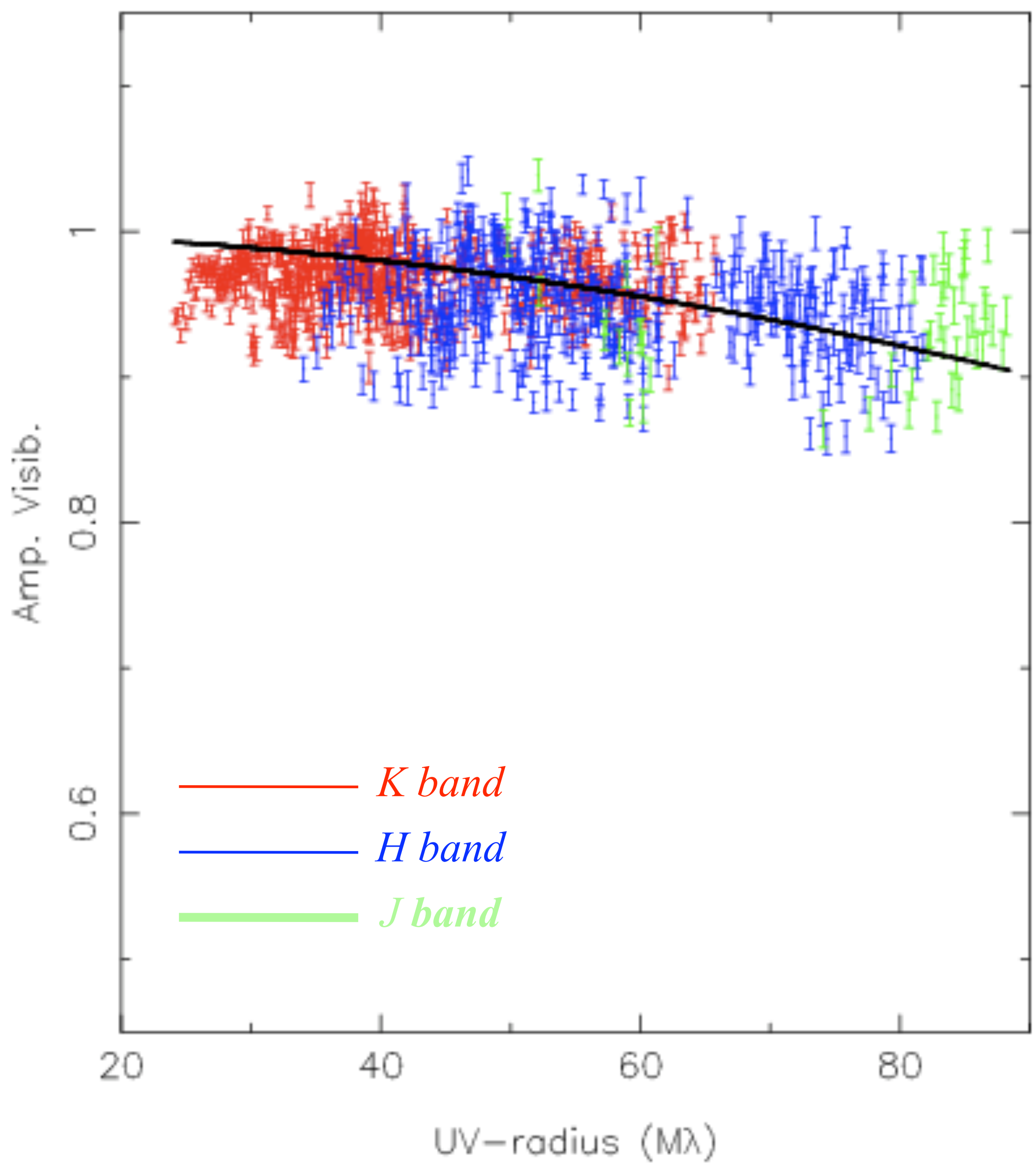
Size of ABDorA

ABDorA
UD-diameter = 0.62±0.04 mas

Limb-darkening correction:
LD-diameter = 0.60±0.04 mas

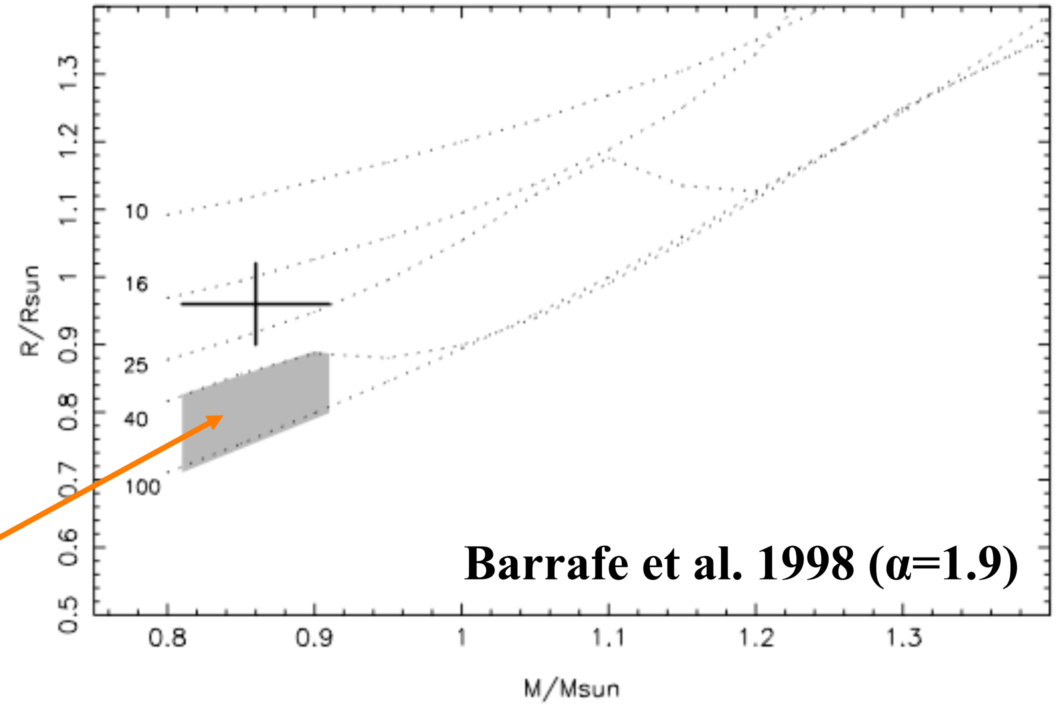
Distance: 14.9 ± 0.1 pc
(Hipparcos +VLBI series)

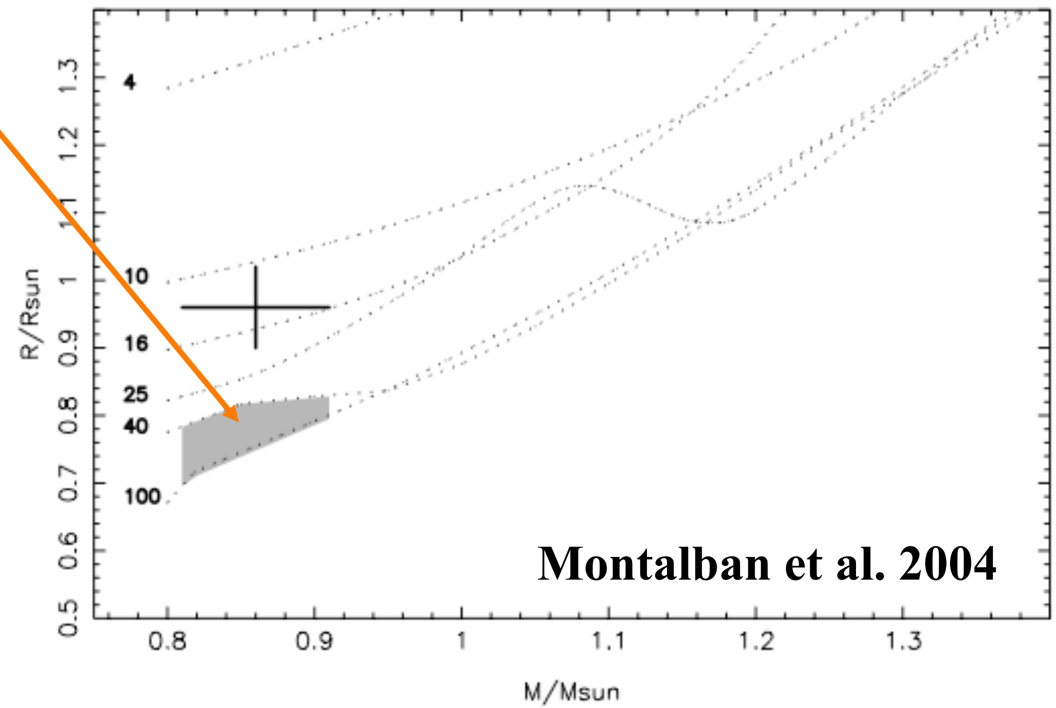
R = 0.96±0.06 R⊙



Comparison of measurements (M and R) with PMS models in the M-R plane

ABDorC age range 40-120 Myr

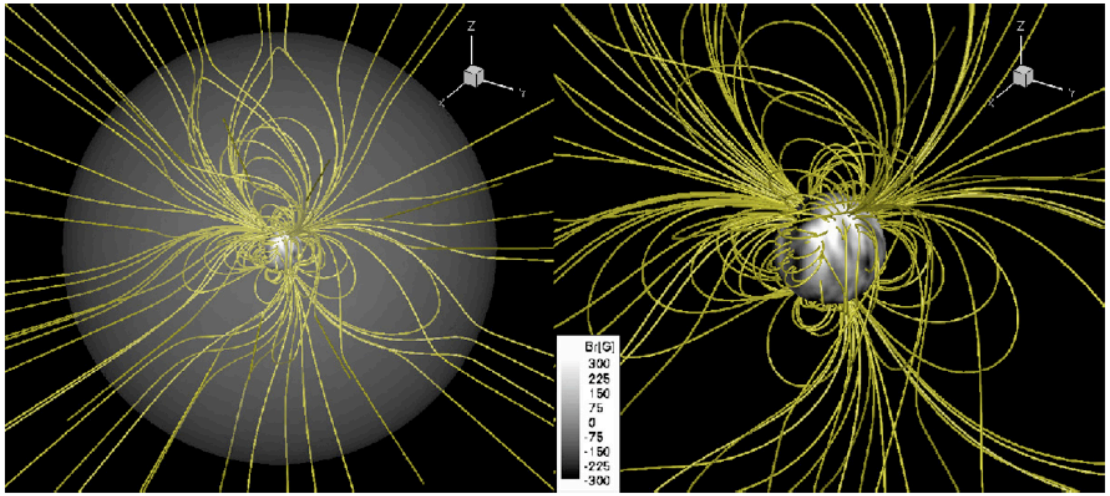




Magnetic field in ABDor

- **Strong magnetic field (≈200G)**
- **Fast rotator (12hr)**
- **Frequency and durations of sunspots**

Strong magnetic activity



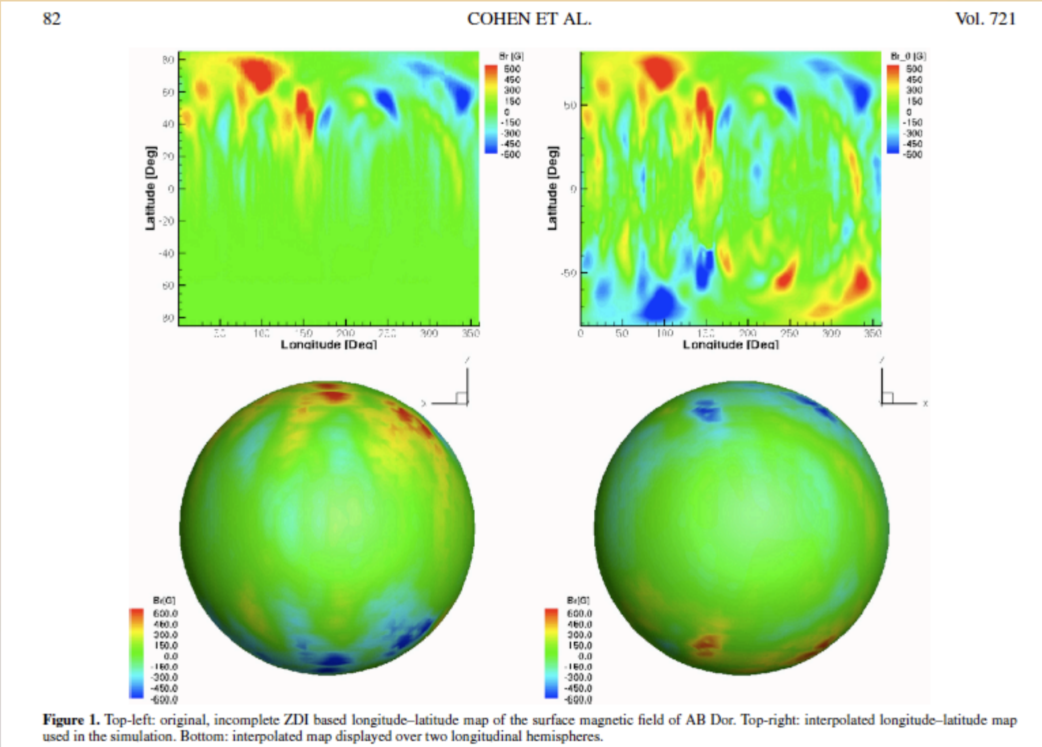

82 COHEN ET AL. Vol. 721

Figure 1. Top-left: original, incomplete ZDI based longitude–latitude map of the surface magnetic field of AB Dor. Top-right: interpolated longitude–latitude map used in the simulation. Bottom: interpolated map displayed over two longitudinal hemispheres.

- **There are previous evidences of a connection between magnetic activity and stellar size (Ribas et al. 2003; Torres et al. 2006).**
- **Loss of efficiency in convection, that leads to**

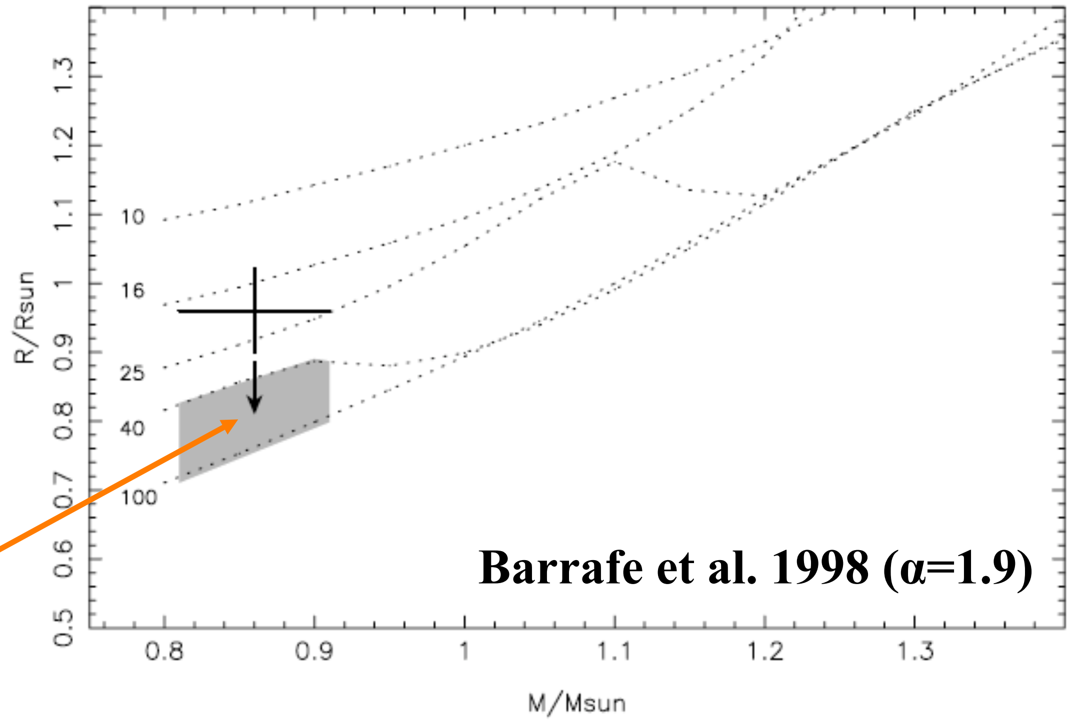
↓

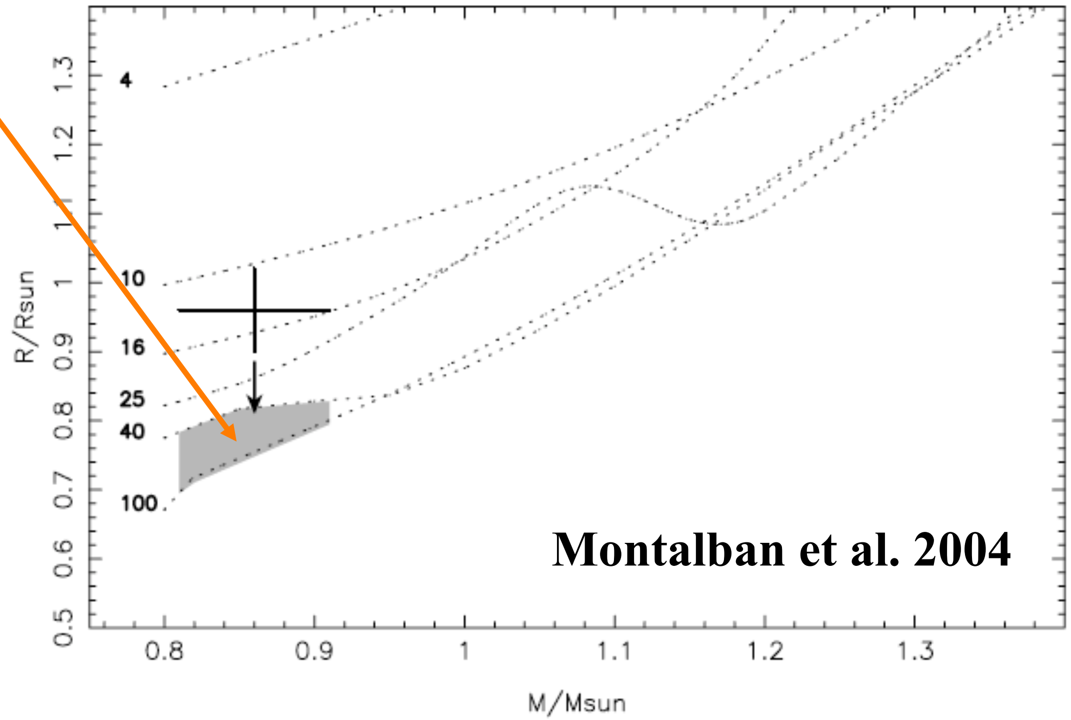
Larger radius

(10-15% than that expected in absence of magnetic activity)

Comparison of measurements (M and R) with PMS models in the M-R plane

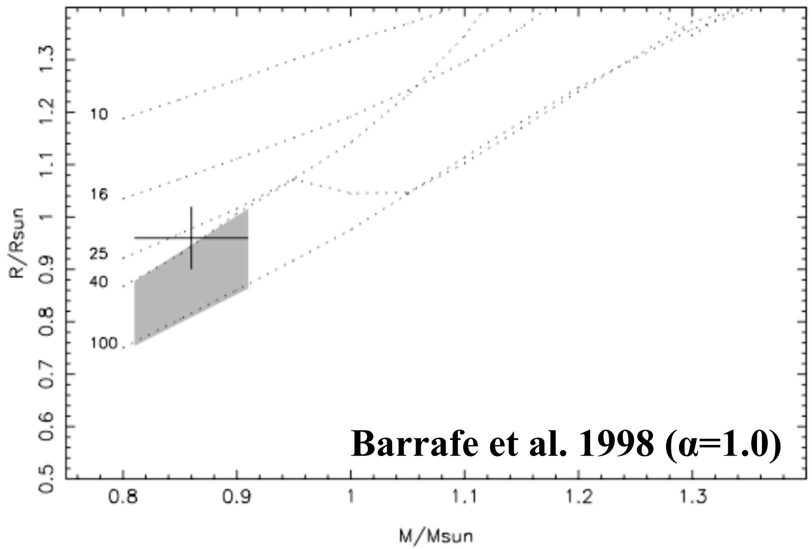
ABDorC age range
40-120 Myr

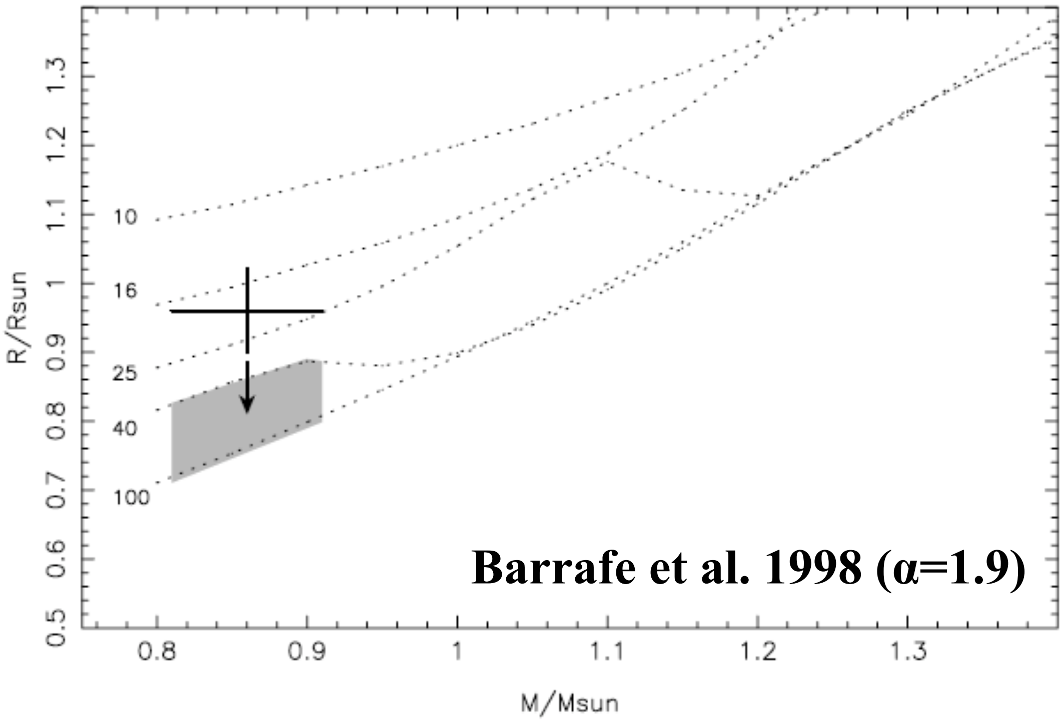


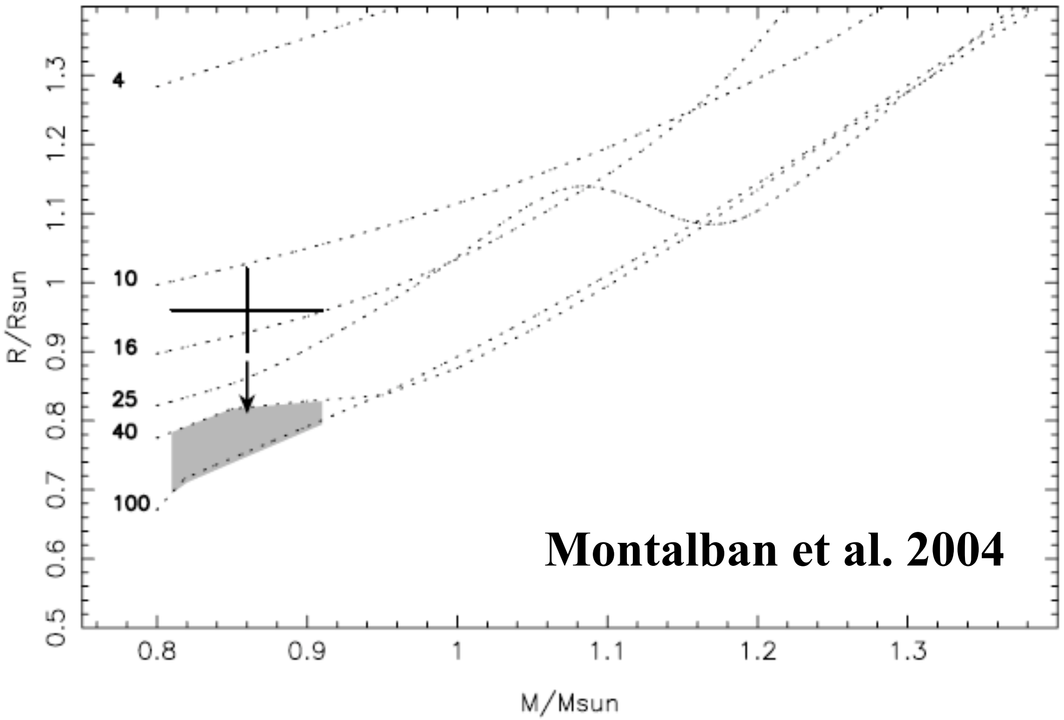


Arrows indicate correction (in radius) due to magnetic field effects. See previous slide.

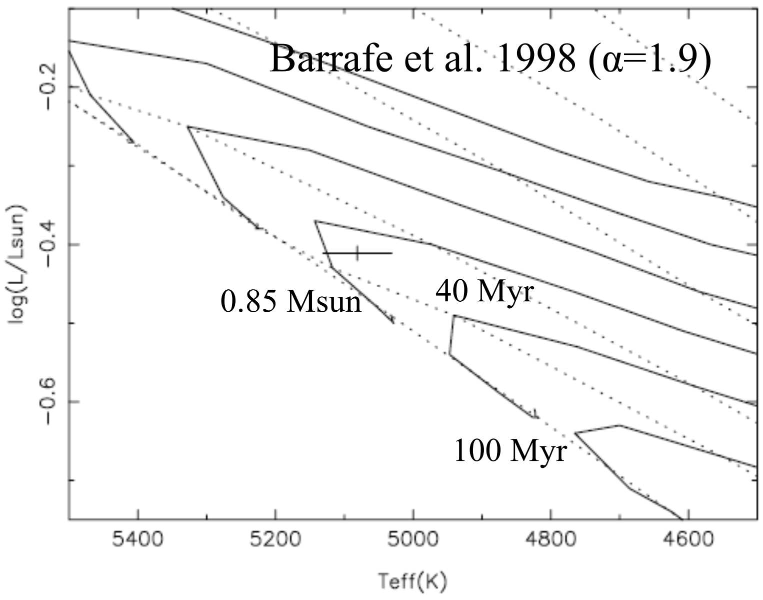
Comparison with PMS models M-R plane

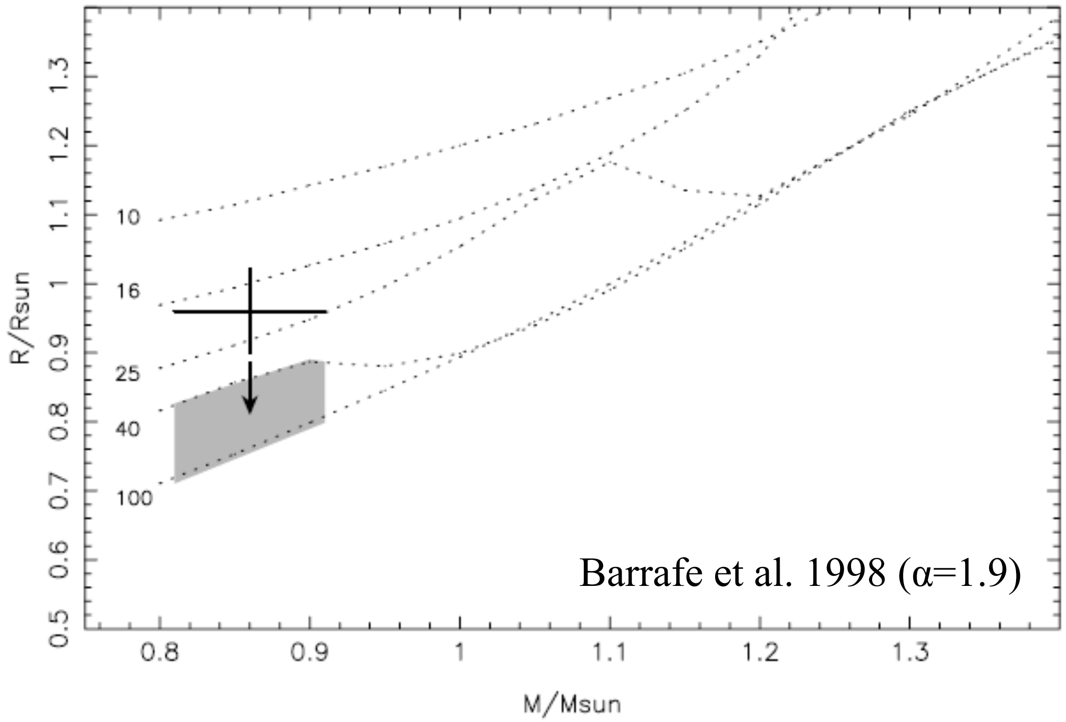


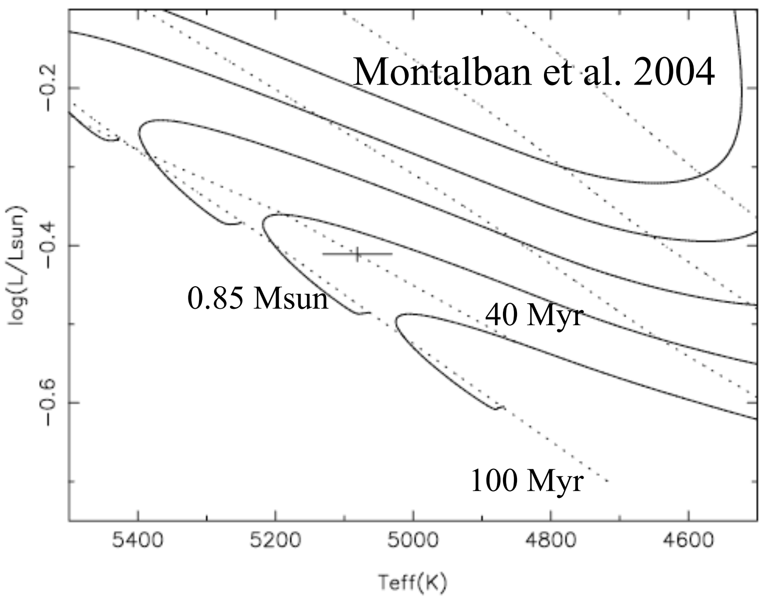


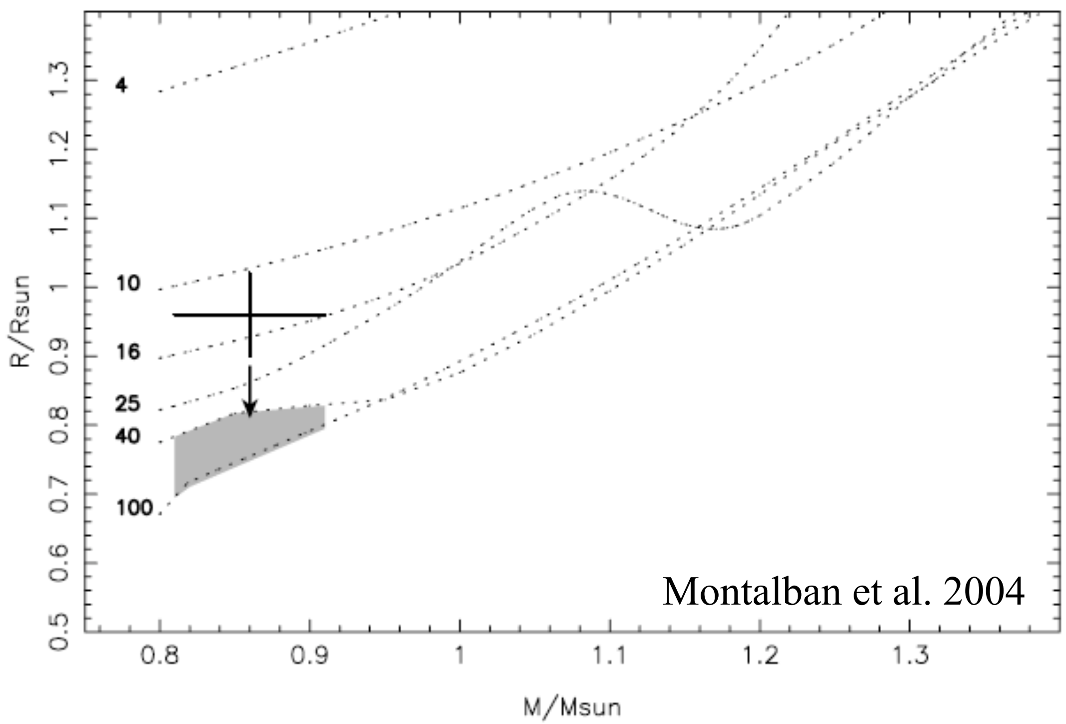


Comparison with PMS models
H-R diagram / M-R plane









Conclusions

- **We have determined the radius (UD model) of ABDorA: R = 0.96±0.06 $R_\odot$**
- **Comparisons of theoretical and measurement values in the M-R plane, and HR diagram show some discrepancies.**
- **Part of this discrepancy could be due to the strong magnetic activity in ABDorA, that may translate to a larger size.**
- **If this effect is taken into account PMS models favor an age for the ABDor system of 40-50 Myr, at the younger side of the range reported in the literature (younger than the Pleiades cluster).**

Ambiguities remaining in the system

- **Could be ABDorC a binary system?**
- **Starspots / fast rotation influence in the visibilities?**
- **Study of the secondary pair at 10” (components Ba/Bb) –if coeval with pair A/C**

Details in: Guirado et al. A&A, 2011, 533, A106