

# Binary stars in moving groups

Rebecca Azulay (Univ. Valencia)

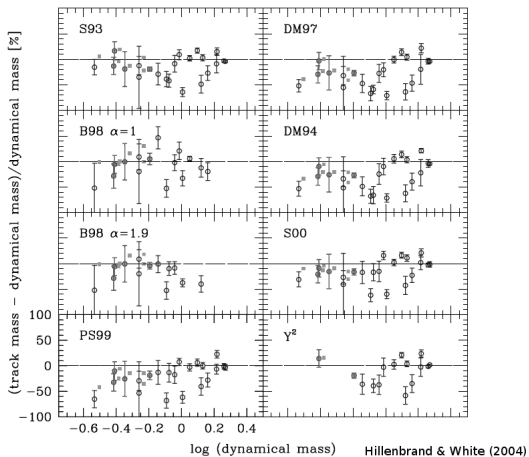
J.C. Guirado, J.M. Marcaide (Univ. Valencia)

E. Ros (MPIfR / Univ. Valencia)

I. Martí-Vidal (OSO, Sweden)

EVN Symposium 2014, Cagliari, Italy

# PMS stars: dynamical mass vs. evolutionary models

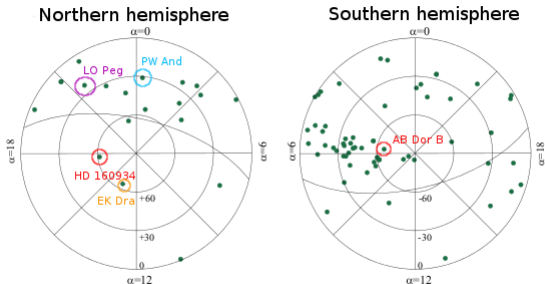


Evolutionary models systematically underpredict the dynamically determined masses by 10%–30%.

Binary stars in young nearby moving groups offer an opportunity to increase the number of PMS stars with dynamically determined masses. Several of these groups have been discovered:

- $\beta$  Pic
- Tucana-Horologium
- Columba
- Carina
- TW Hydrae
- $\epsilon$  Cha
- $\eta$  Cha
- Octans
- Argus
- AB Doradus

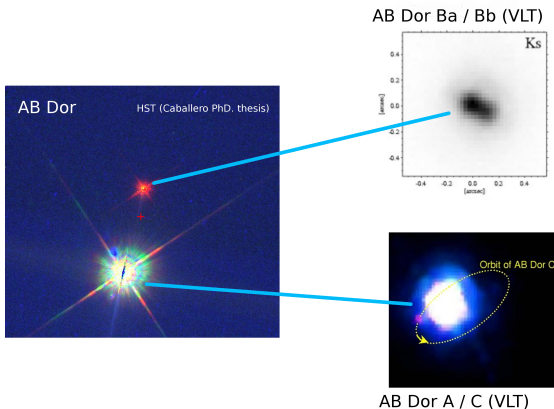
# AB Doradus moving group



- It is the closest moving group (mean distance to the Sun, 30 pc).
- Its age is reasonably well determined (50-120 Myr).
- It presents radio emission in some of its active members.



# AB Doradus stellar system

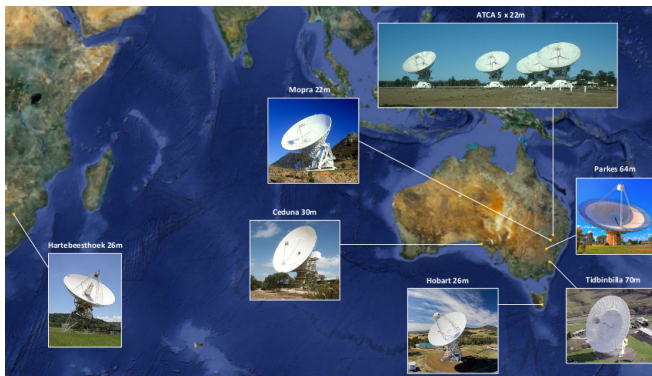


- The system has two pairs of stars separated  $9''$ : AB Dor A/AB Dor C and [AB Dor Ba/AB Dor Bb](#). It is placed at a distance of  $\sim 15$  pc.
- AB Dor Ba and AB Dor Bb are separated  $\sim 0.05''$ . The star has a high rotation rate and strong radio emission.

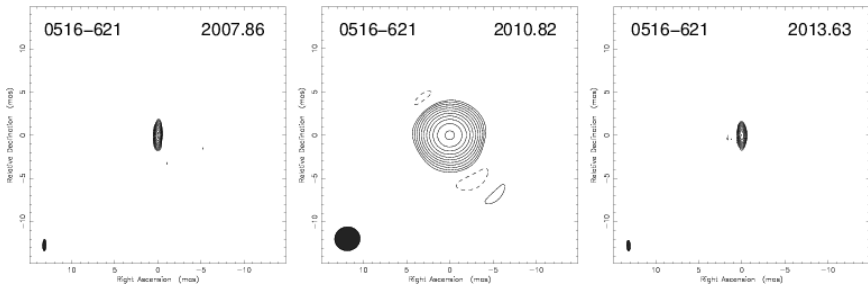
# AB Doradus B observations

We observed this target with the technique of phase-referencing (AB Dor B/0516-621, separated  $3.6^\circ$ ) in three different epochs with the **LBA** at 8.4 GHz:

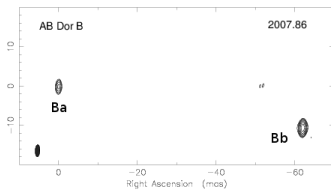
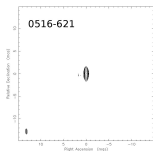
- 2007 november 11
- 2010 october 25
- 2013 august 16



- Calibrator: 0516–621

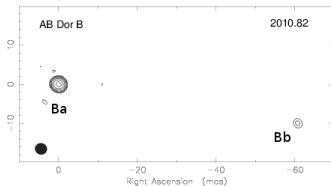


The source appears to be unresolved. The second epoch has only intra-Australian baselines. The flux of 0516-621 is [1.16 Jy](#).



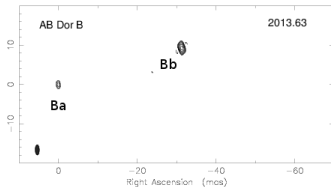
Flux Ba: 5.02 mJy

Flux Bb: 9.34 mJy



Flux Ba: 5.06 mJy

Flux Bb: 0.99 mJy



Flux Ba: 2.49 mJy

Flux Bb: 7.14 mJy

## Astrometric measures for relative orbit of AB Dor Bb respect AB Dor Ba

Instrument	Epoch	$\Delta x$ (mas)	$\Delta y$ (mas)	Reference
VLT (IR)	2004.098	$-56.3 \pm 1.8$	$-34.5 \pm 1.6$	Jason et al. (2007)
VLT (IR)	2005.019	$-54.8 \pm 3.5$	$-24.4 \pm 3.6$	Close et al. (2007)
LBA (radio)	2007.863	$-62.0 \pm 0.1$	$-10.5 \pm 0.1$	This work
LBA (radio)	2010.816	$-60.3 \pm 0.7$	$-9.7 \pm 0.7$	This work
LBA (radio)	2013.625	$-31.3 \pm 0.1$	$9.3 \pm 0.3$	This work

## Astrometric measures for the absolute orbits of AB Dor Ba and AB Dor Bb

Epoch	Component	RA (h min s)	Dec (° ' ")
2007.863	Ba	$5\ 28\ 44.57761 \pm 0.00008$	$-65\ 26\ 45.1002 \pm 0.0010$
	Bb	$5\ 28\ 44.56766 \pm 0.00008$	$-65\ 26\ 45.1107 \pm 0.0010$
2010.816	Ba	$5\ 28\ 44.61098 \pm 0.00009$	$-65\ 26\ 44.71316 \pm 0.0008$
	Bb	$5\ 28\ 44.60130 \pm 0.00014$	$-65\ 26\ 44.7229 \pm 0.0008$
2013.625	Ba	$5\ 28\ 44.63954 \pm 0.00005$	$-65\ 26\ 44.2920 \pm 0.0009$
	Bb	$5\ 28\ 44.63453 \pm 0.00013$	$-65\ 26\ 44.2827 \pm 0.0008$

# Determination of orbital parameters and masses

## Orbital parameters for AB Dor B

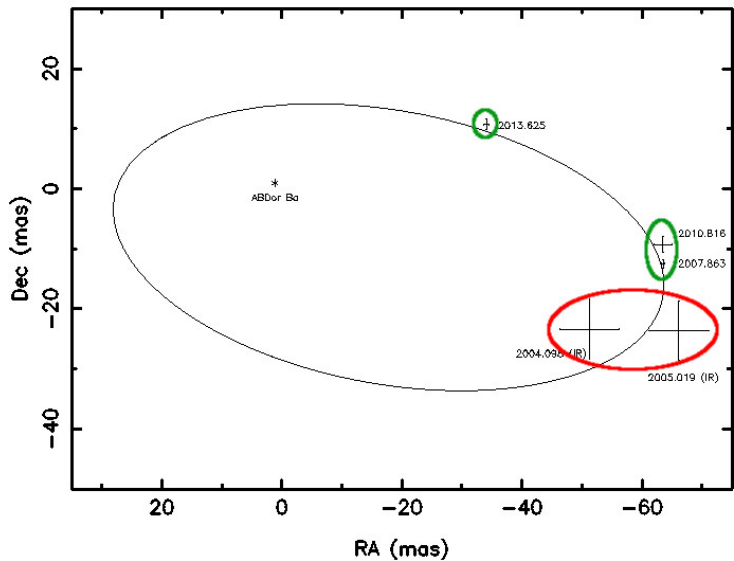
Parameter	
$P$ (yr)	$0.99 \pm 0.01$
$a$ (")	$0.049 \pm 0.001$
$a_1$ (")	$0.026 \pm 0.001$
$a_2$ (")	$0.023 \pm 0.001$
$e$	$0.5 \pm 0.1$
$\Omega$ ( $^\circ$ )	$85 \pm 5$
$i$ ( $^\circ$ )	$121 \pm 5$
$\omega$ ( $^\circ$ )	$40 \pm 20$
$T_0$ :	$2003.60 \pm 0.05$

The sum of the masses of both components is  $0.4 \pm 0.1 M_\odot$ .

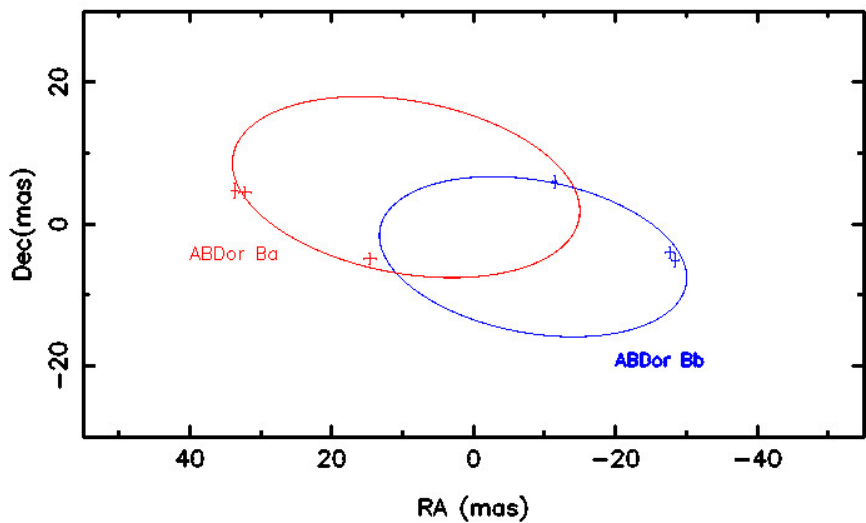
The mass of the component Ba is  $0.19 \pm 0.05 M_\odot$ .

The mass of the component Bb is  $0.21 \pm 0.05 M_\odot$ .

## Relative orbit ABDor Ba/Bb



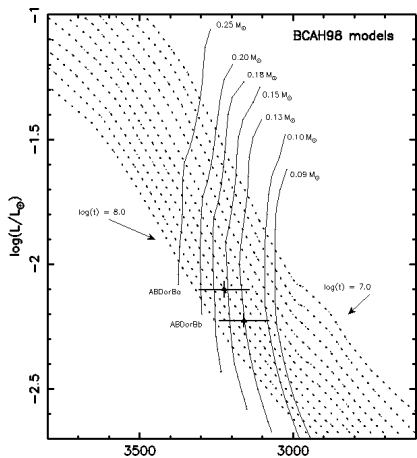
## Absolute orbits ABDor Ba/Bb





# Theoretical models

## BCAH98 models



Adapted from Janson et al. (2007)  $T_{\text{eff}}$  (K)

## Model masses

AB Dor Ba mass	0.13 – 0.20 $M_{\odot}$
AB Dor Bb mass	0.10 – 0.18 $M_{\odot}$

## Dynamical masses (our data)

AB Dor Ba mass	0.14 – 0.24 $M_{\odot}$
AB Dor Bb mass	0.16 – 0.26 $M_{\odot}$

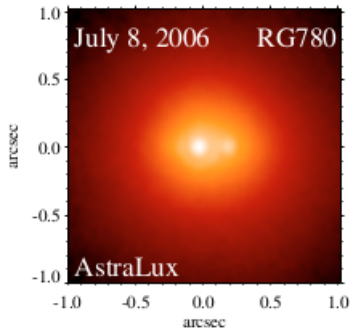
# HD 160934 stellar system

HD 160934 is a very active young star with spectral type K7Ve, placed at a distance of  $\sim 33$  pc with a high rotation rate.

It is a tertiary system:

- HD 160934 A
- HD 160934 B
- HD 160934 c

The components A and c are separated a distance of  $\sim 0.2''$ . HD 160934 B is at a distance of  $\sim 8.7''$  from the primary pair.



Hormuth et al. (2007)

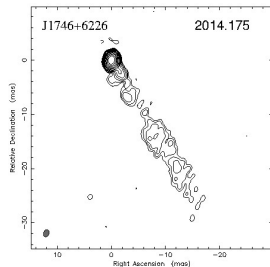
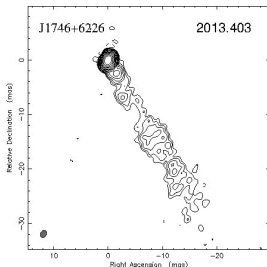
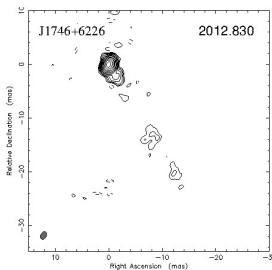
# HD 160934 observations

We observed this target with the technique of phase-referencing (HD 160934/J1746+6226, separated  $1.5^\circ$ ) in three different epochs with the EVN at 5 GHz.

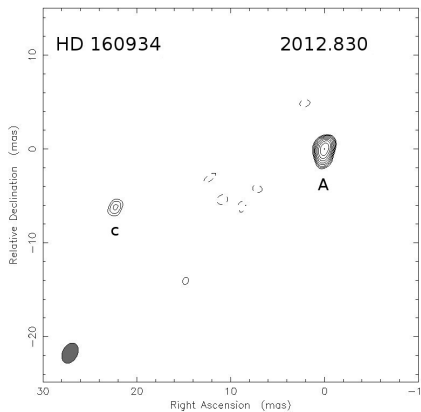
- 2012 october 30
- 2013 may 23
- 2014 march 5



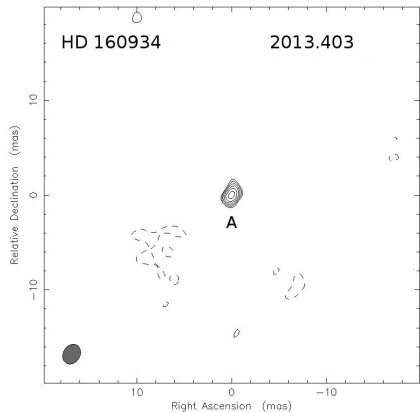
- Calibrator: J1746+6226



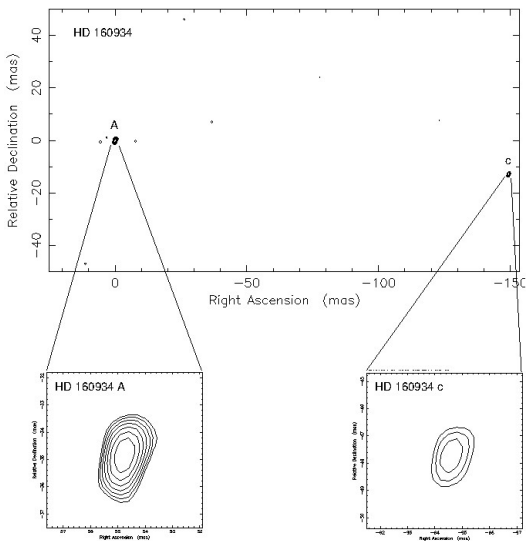
These are the maps of J1746+6226. This source has structure and a flux of **0.32 Jy**.



2012 october 30  
Flux A: 3.37 mJy  
Flux c: 0.71 mJy



2013 may 23  
Flux A: 3.19 mJy



2014 march 5; Flux A: 3.06 mJy, Flux c: 0.85 mJy.

## Astrometric measures for relative orbit of HD 160934 c respect HD 160934 A

Instrument	Epoch	$\Delta x$ (mas)	$\Delta y$ (mas)	Reference
AstraLux (IR)	1998.098	$-154.3 \pm 0.9$	$14.8 \pm 0.5$	Hormuth et al. (2007)
Gemini (IR)	2005.296	$-212.9 \pm 2.0$	$-5.6 \pm 2.6$	Lafrenière et al. (2007)
AstraLux (IR)	2006.518	$-214.9 \pm 1.0$	$3.4 \pm 1.0$	Hormuth et al. (2007)
Gemini (IR)	2006.712	$-217.9 \pm 2.0$	$4.9 \pm 2.6$	Lafrenière et al. (2007)
Palomar (IR)	2008.477	$-169.1 \pm 0.3$	$9.7 \pm 0.3$	Evans et al. (2012)
Keck (IR)	2010.318	$-64.6 \pm 0.3$	$23.5 \pm 0.3$	Evans et al. (2012)
Keck (IR)	2011.310	$6.3 \pm 0.3$	$18.9 \pm 0.3$	Evans et al. (2012)
VLBI (Radio)	2012.830	$22.27 \pm 0.09$	$-6.18 \pm 0.14$	Azulay et al. (2014)
VLBI (Radio)	2014.175	$-149.34 \pm 0.06$	$-12.87 \pm 0.08$	Azulay et al. (2014)

## Astrometric measures for the absolute orbits of HD 160934 A and HD 160934 c

Epoch	Component	RA (h min s)	Dec (° ' ")
2012.830	A	$17\ 38\ 39.59830 \pm 0.00016$	$61\ 14\ 16.6077 \pm 0.0010$
	c	$5\ 28\ 44.56766 \pm 0.00008$	$-65\ 26\ 45.1107 \pm 0.0010$
2013.403	A	$17\ 38\ 39.60667 \pm 0.00016$	$61\ 14\ 16.6865 \pm 0.0010$
2014.175	A	$17\ 38\ 39.61159 \pm 0.00016$	$61\ 14\ 16.6882 \pm 0.0010$
	c	$5\ 28\ 44.63453 \pm 0.00013$	$-65\ 26\ 44.2827 \pm 0.0008$

# Determination of orbital parameters and masses

Orbital parameters for HD 160934.

Parameter	
$P$ (yr):	$10.33 \pm 0.06$
$a$ ("):	$0.155 \pm 0.002$
$a_1$ (")	$0.067 \pm 0.002$
$a_2$ (")	$0.088 \pm 0.002$
$e$ :	$0.626 \pm 0.005$
$i$ ( $^\circ$ ):	$82.4 \pm 0.2$
$\omega$ ( $^\circ$ ):	$35 \pm 1$
$\Omega$ ( $^\circ$ ):	$85.9 \pm 0.3$
$T_0$ :	$2002.32 \pm 0.07$

The sum of the masses of both components is  $1.19 \pm 0.05 M_\odot$ .

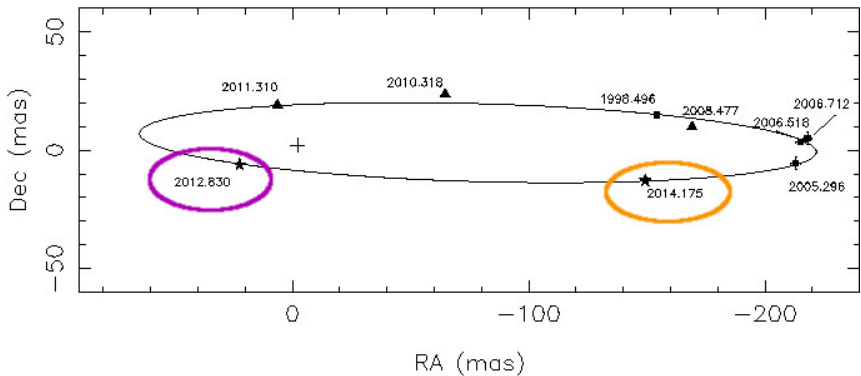
**Preliminary:**

The mass of the component A is  $\sim 0.68 M_\odot$ .

The mass of the component c is  $\sim 0.51 M_\odot$ .

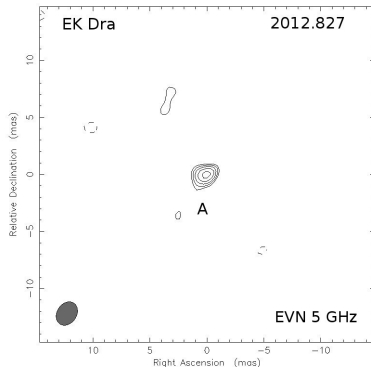
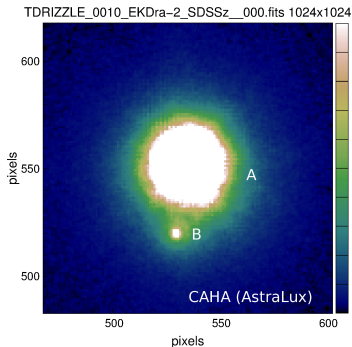


## Relative orbit of the binary HD 160934.



# Other stars: EK Draconis

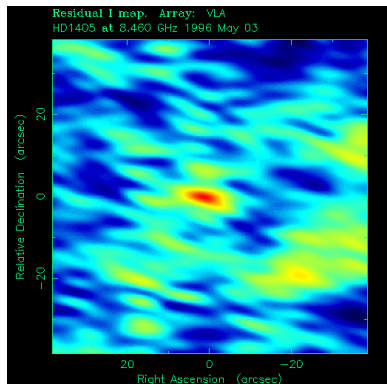
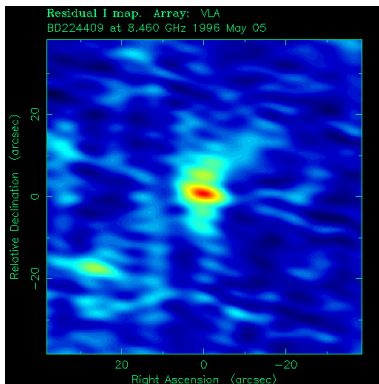
**EK Dra** is a young, active, nearby star with spectral type G1.5 V, placed at a distance of  $\sim 33$  pc.



It is a long period binary star (**EK Dra A / EK Dra B**; period of 45 yr) where the secondary is much fainter than the primary. Both components are separated a distance of  $\sim 0.74''$ .

## Other stars: LO Peg, PW And

We have EVN scheduled observations for days 23/10/2014 and 26/10/2014 for other two radio stars of the AB Doradus moving group: **LO Pegasus**, **PW Andromedae**.



- Status of the project

	Sum masses	Individual masses
AB Dor A/C	✓	✓
AB Dor Ba/Bb	✓	✓
HD 160934	✓	✓ (preliminar)
EK Draconis	in progress	in progress
LO Pegasus	observation scheduled	observation scheduled
PW Andromedae	observation scheduled	observation scheduled

The more dynamical masses we have, the better we can calibrate the theoretical models.