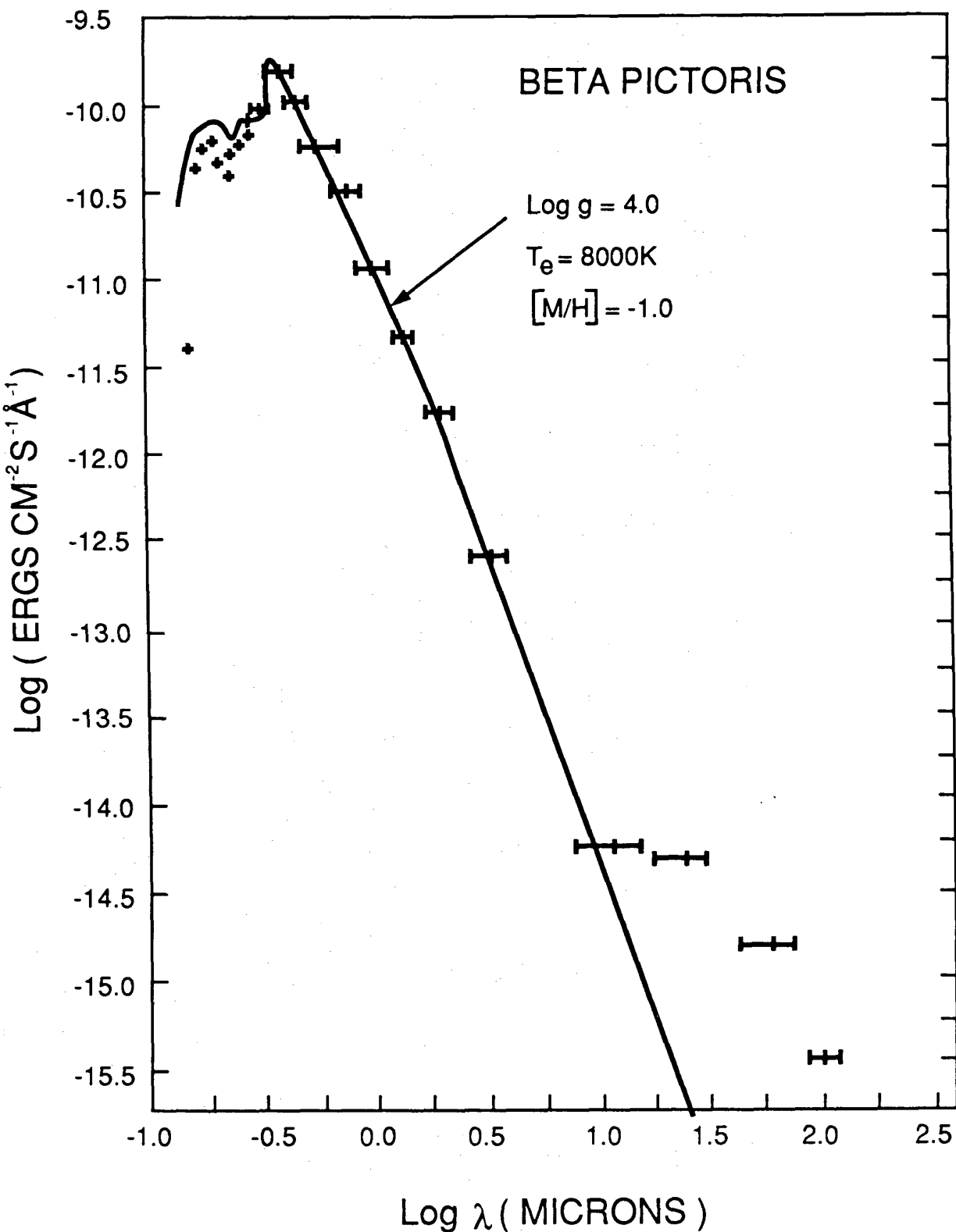


# *Properties of $\beta$ Pictoris seen as a “regular” star*

# Issue with the luminosity?



A5V

$v \sin i = 120 \text{ km/s}$   
underluminosity

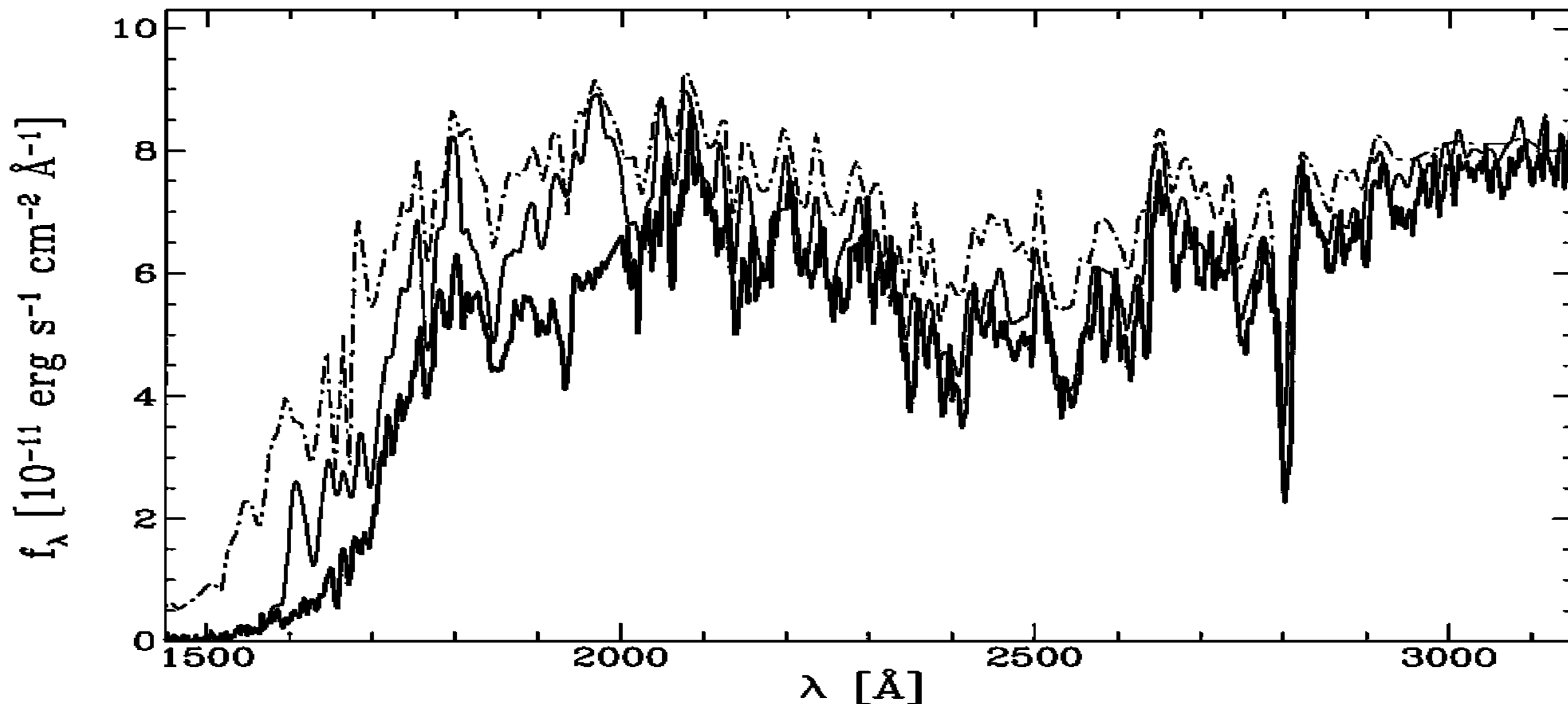
metal deficient  $[M/H] \sim -0.6 \pm 0.3$

Yale isochrone  $Y=03$   $Z=0.004$   
ZAMS age  $\sim 10^8$

# What UV tells

GHRs spectra:  $T_{\text{eff}} \sim 8200$  K  
solar composition

— solar metallicity  
- - 1/4 solar metallicity



Lanz et al., 1995

# In the HR diagram

BASIC PARAMETERS OF THE  $\beta$  PICTORIS SYSTEM

Parameter	Adopted Values	Geneva <sup>a</sup>	Strömgren <sup>a</sup>
	Star		
Temperature.....	$T_{\text{eff}} = 8200 \pm 150 \text{ K}$	8150 KN <sup>a</sup>	8240 MD
Surface gravity.....	$\log g = 4.25 \pm 0.1$	4.20 KN	4.28 MD
Metallicity.....	$[\text{Fe}/\text{H}] = -0.02 \pm 0.15$	-0.09 B -0.16 KN	+0.05 B
Mass .....	$M = 1.8 \pm 0.1 M_{\odot}$	...	...
Luminosity.....	$L_{\text{bol}} = 11.3 \pm 3.5 L_{\odot}$	...	...
Distance.....	$d = 16.4 \text{ pc}$	...	...
Rotational velocity.....	$V \sin i = 100 \text{ km s}^{-1}$	...	...

Geneva and Strömgren photometry

$T_{\text{eff}} = 8200 \pm 150 \text{ K}$

age:

ZAMS [0.3,0.5Gyr]

**pre-MS 12 Myr**

$L_{\text{bol}} = 6.88 L_{\odot}$

$M_{\text{bol}} = 2.63$

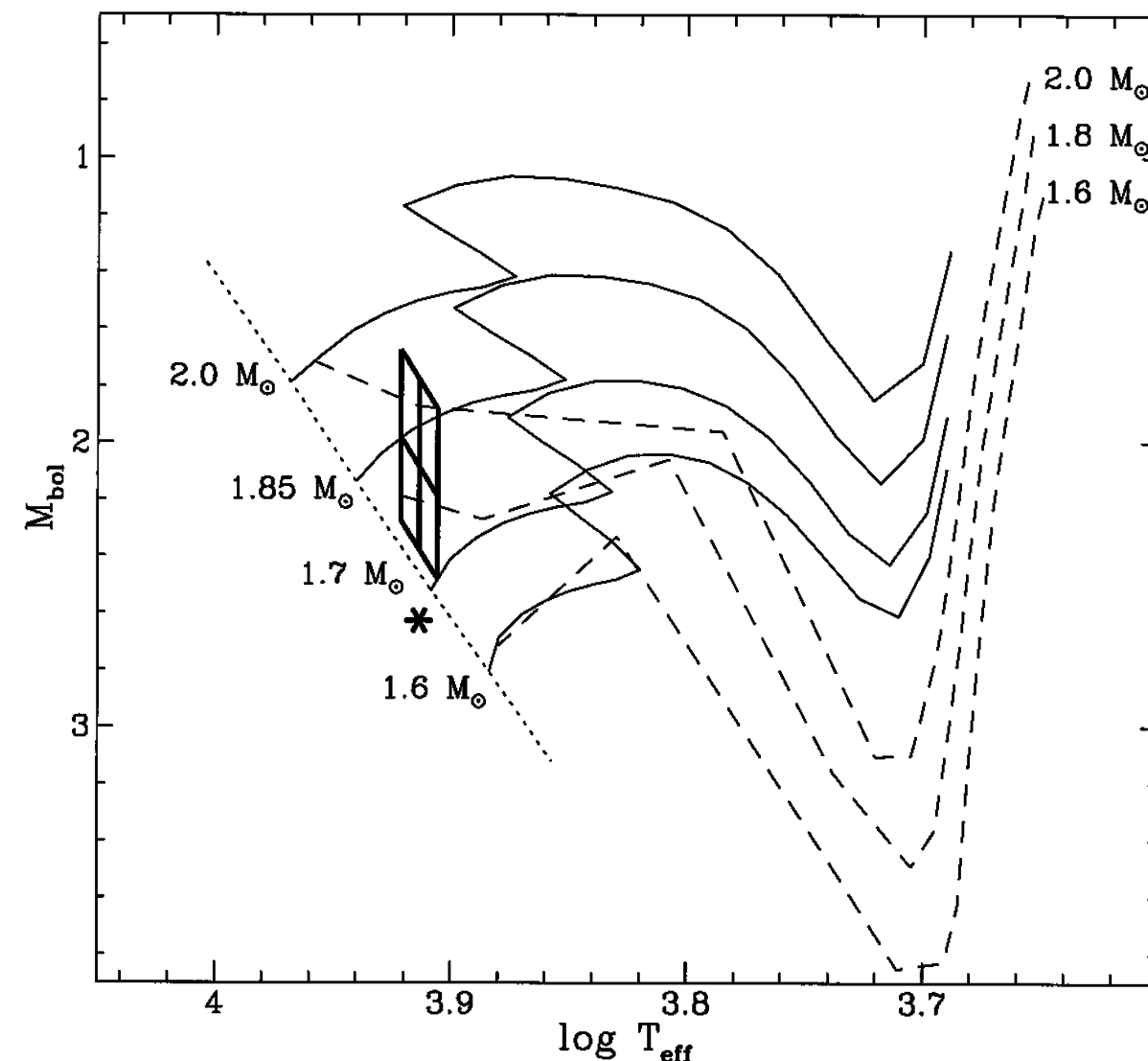
Typical A5V on the ZAMS

$L_{\text{bol}} = 8.2 L_{\odot}$

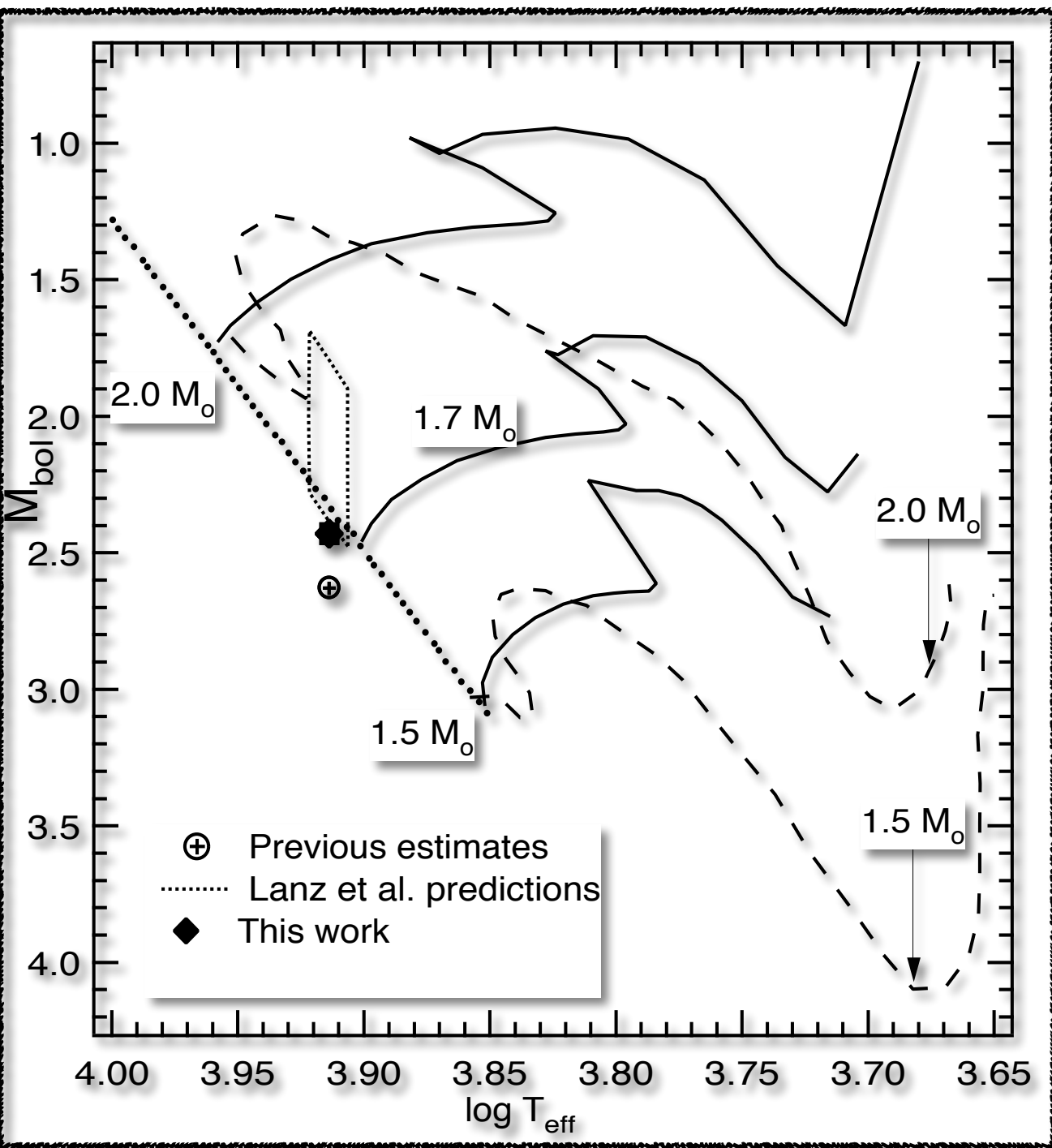
$M = 1.72 M_{\odot}$

$\log = 4.37$

Lanz et al., 1995



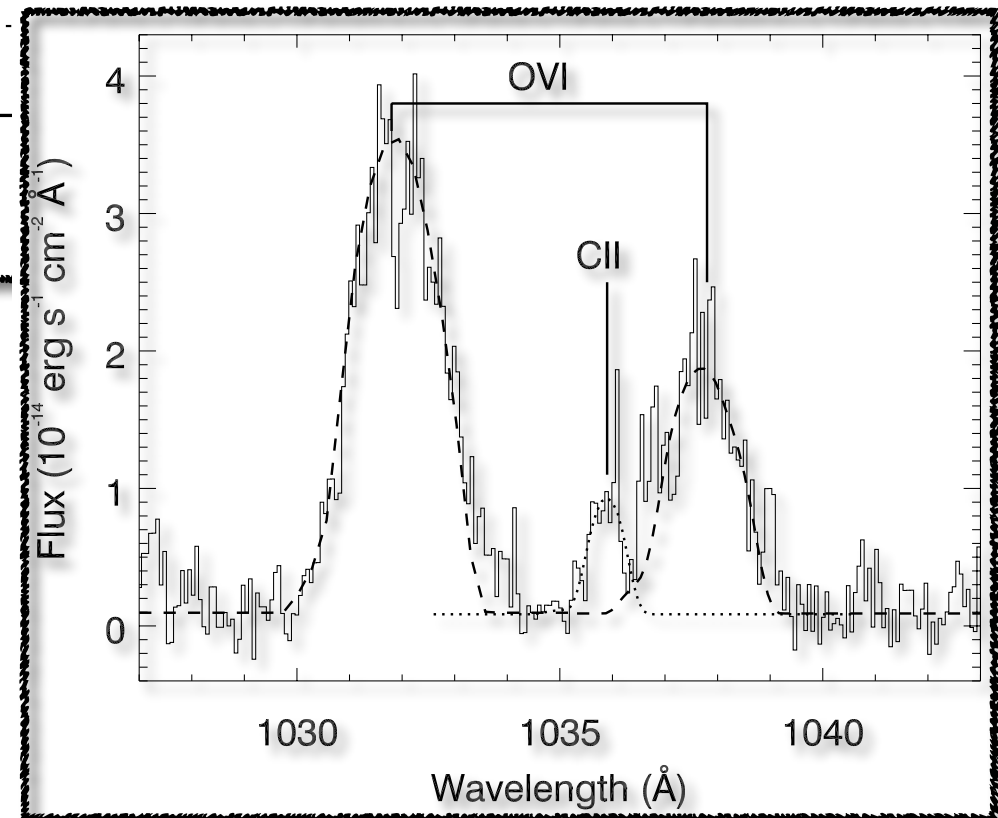
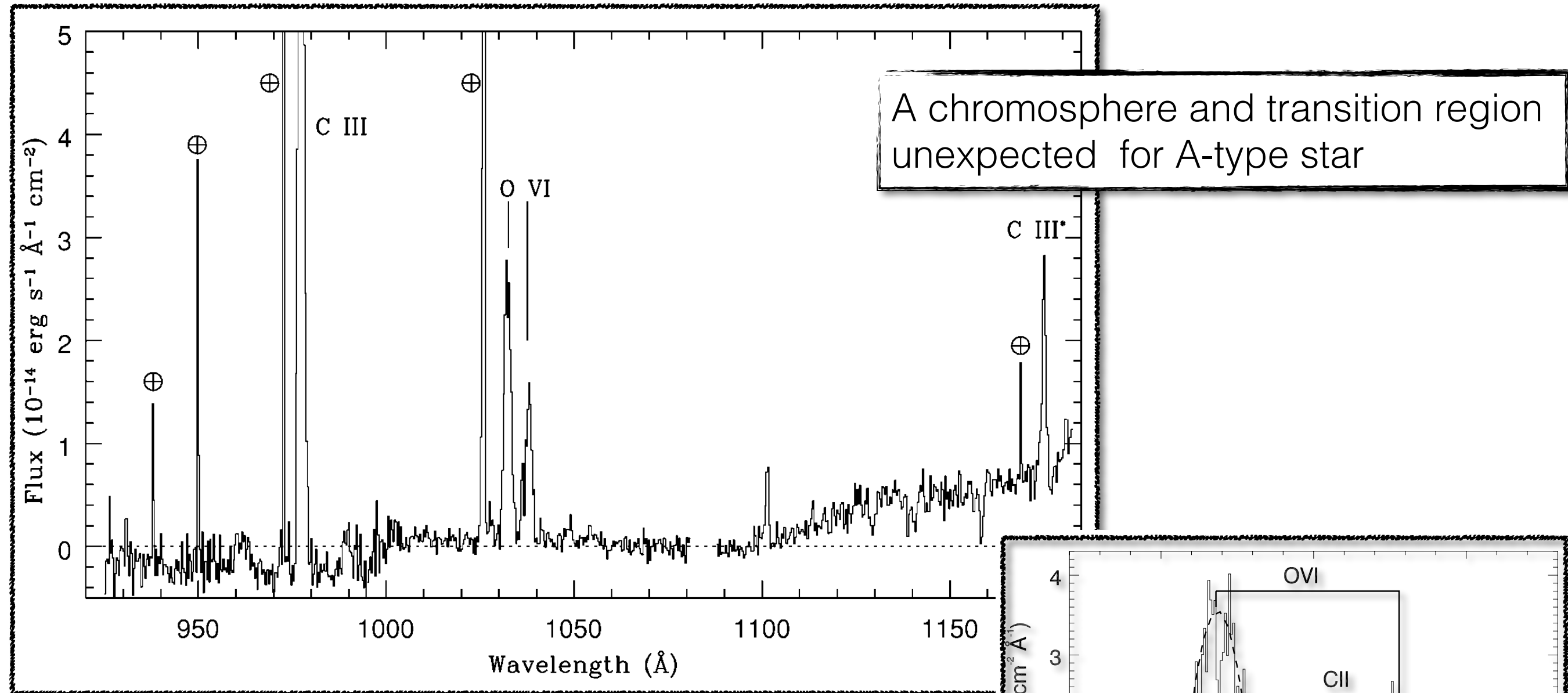
# HIPPARCOS FIXES THE LUMINOSITY ISSUE



$d = 19.28 \pm 0.19$  pc  
 $L_{\text{bol}} = 8.7 L_{\odot}$   
 $M_v = 2.42 \pm 0.03$   
 $M_{\text{bol}} = 2.43$   
 $T_{\text{eff}} = 8200$  (adopted)  
 $\log g = 4.38$  (from  $L$ )  
 on the ZAMS or very close to  
 at least 8 Myr  
 extinction no longer needed

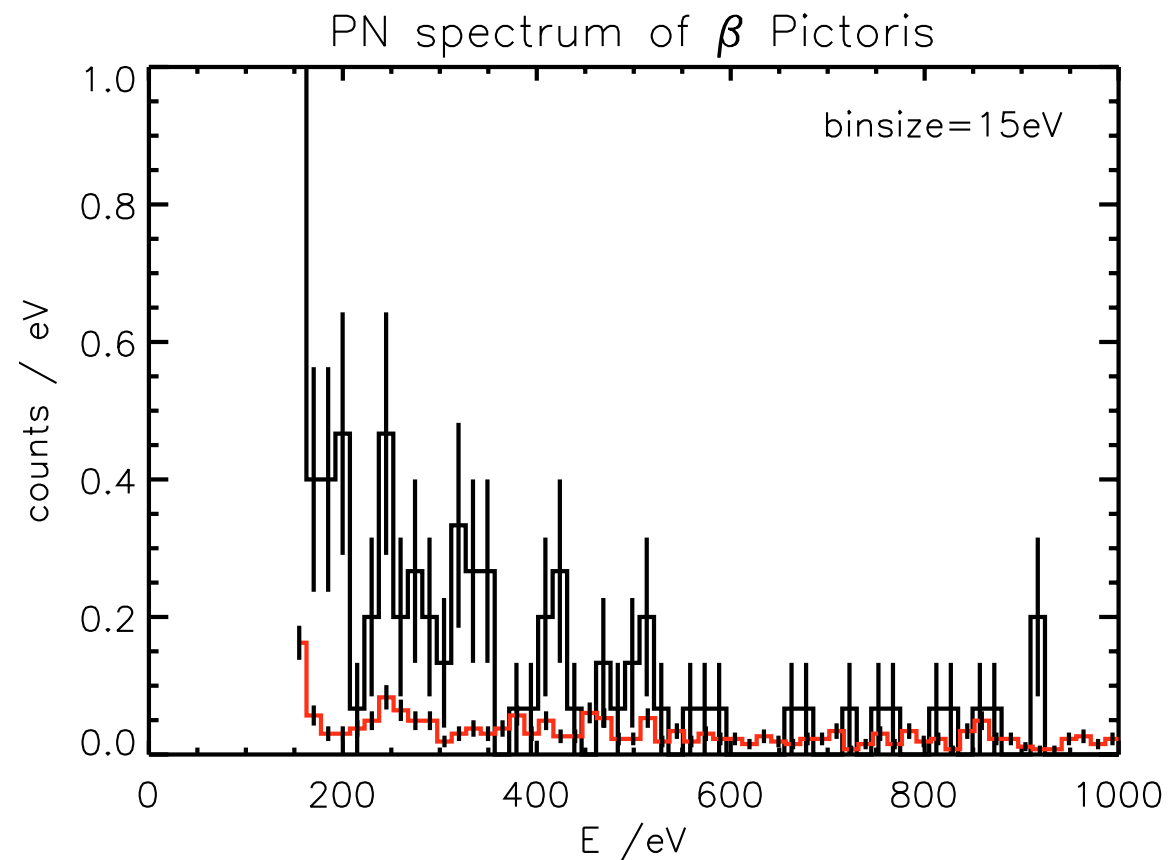
Authors	$\pi$ mas	$\sigma_{\pi}$ mas	d pc	$M_v$
VA 95	60.1	10.6	$16.6^{+3.6}_{-2.5}$	$2.74^{+0.36}_{-0.42}$
Lanz	61		16.4	2.78
Hipp	51.87	0.51	$19.28^{+0.19}_{-0.19}$	$2.42^{+0.03}_{-0.02}$

# Stellar activity



Deleuil et al., 2001  
Bouret et al., 2002

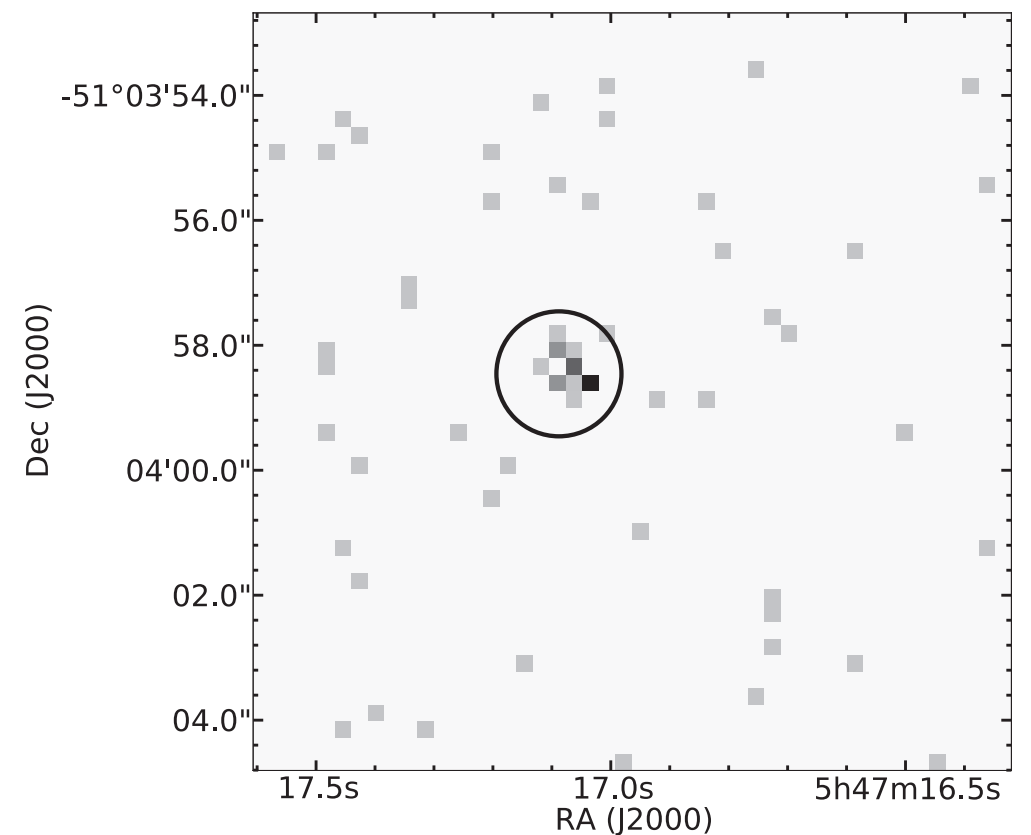
# and a corona..



XMM : Hempel et al., 2005

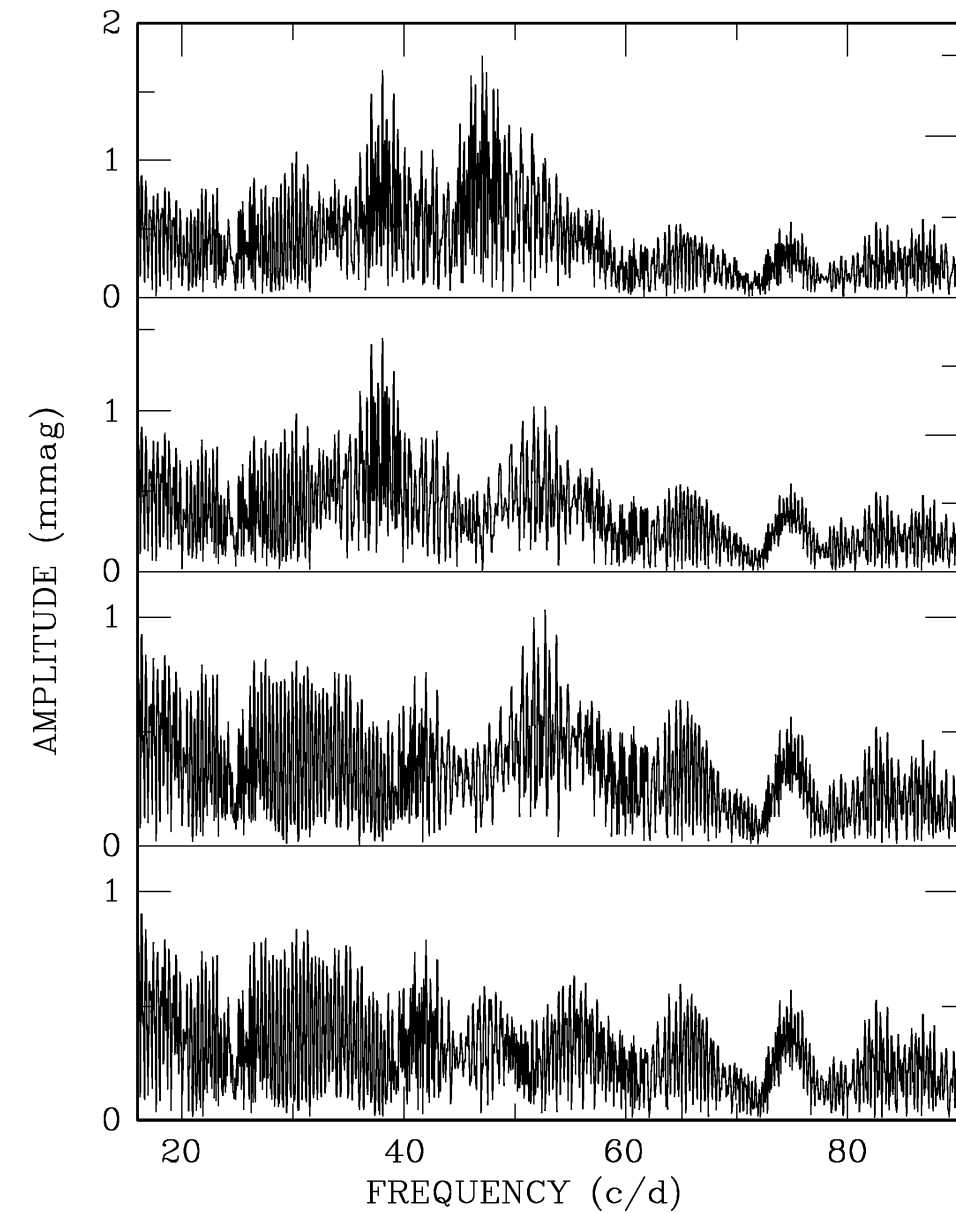
very cool and dim corona as have  
cool stars

$$\log L_X / L_{\text{bol}} = -8.2 \text{ (0.2--2.0 keV)}$$

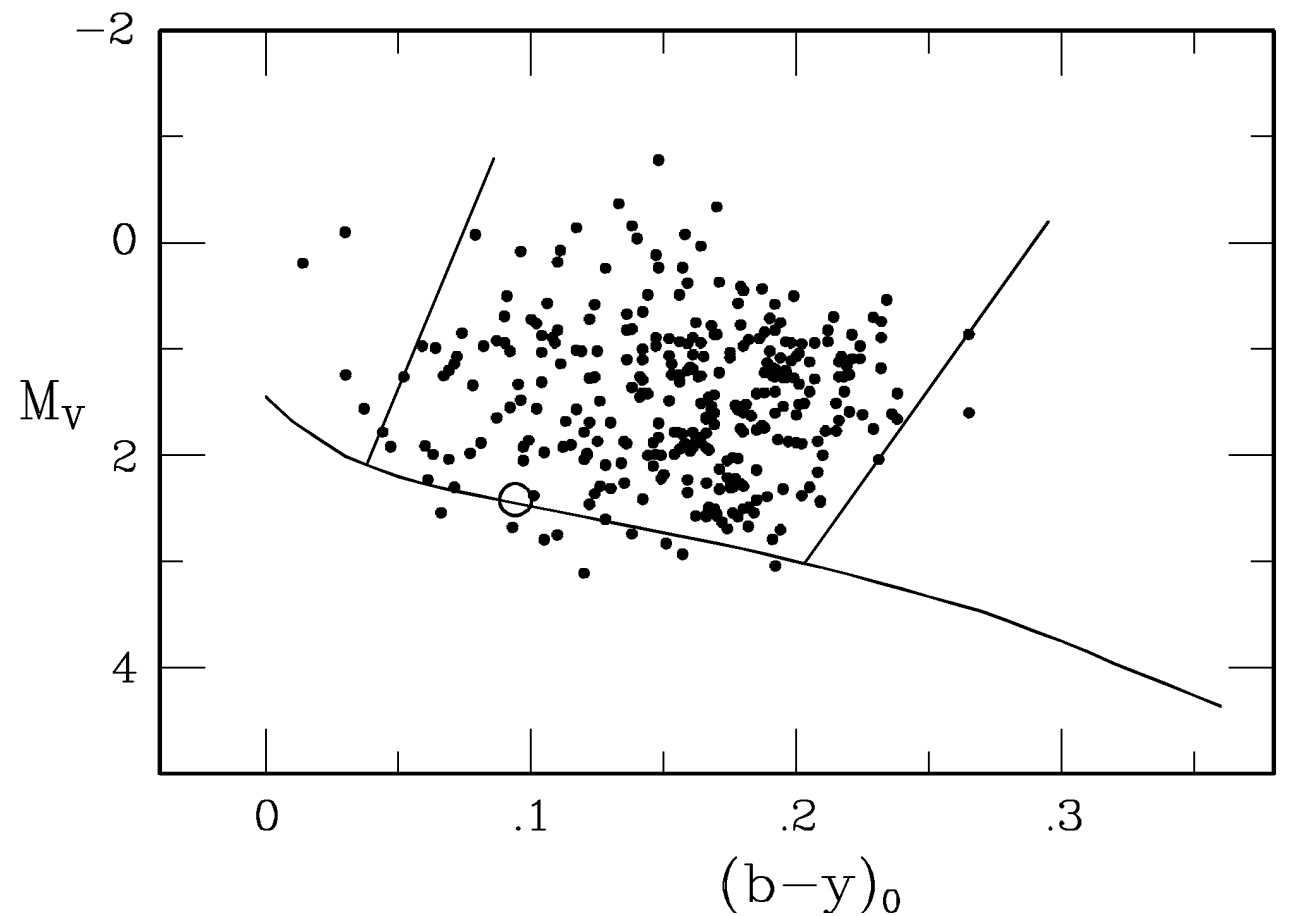


Chandra/HRC-I:  $9 \pm 2 \times 10^{-4}$  count/s  
Gunther et al., 2012

# Photometry: pulsations!



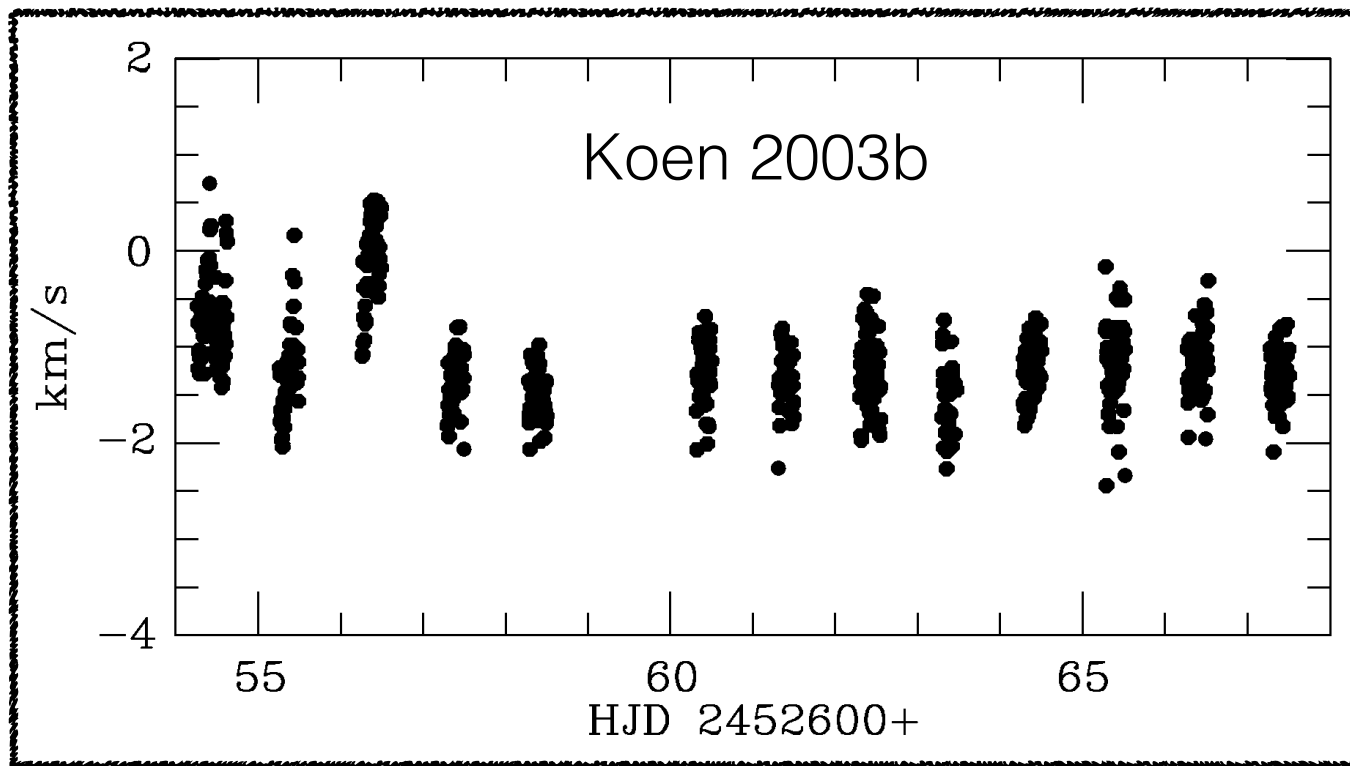
Frequency (d <sup>-1</sup> )	Period (d)	Amplitude (mmag)	Pulsation constant $Q$
47.055(3)	0.021 252(1)	1.63(7)	0.014
38.081(3)	0.026 260(2)	1.50(7)	0.017
52.724(4)	0.018 967(2)	1.07(7)	0.012



Koen 2003a

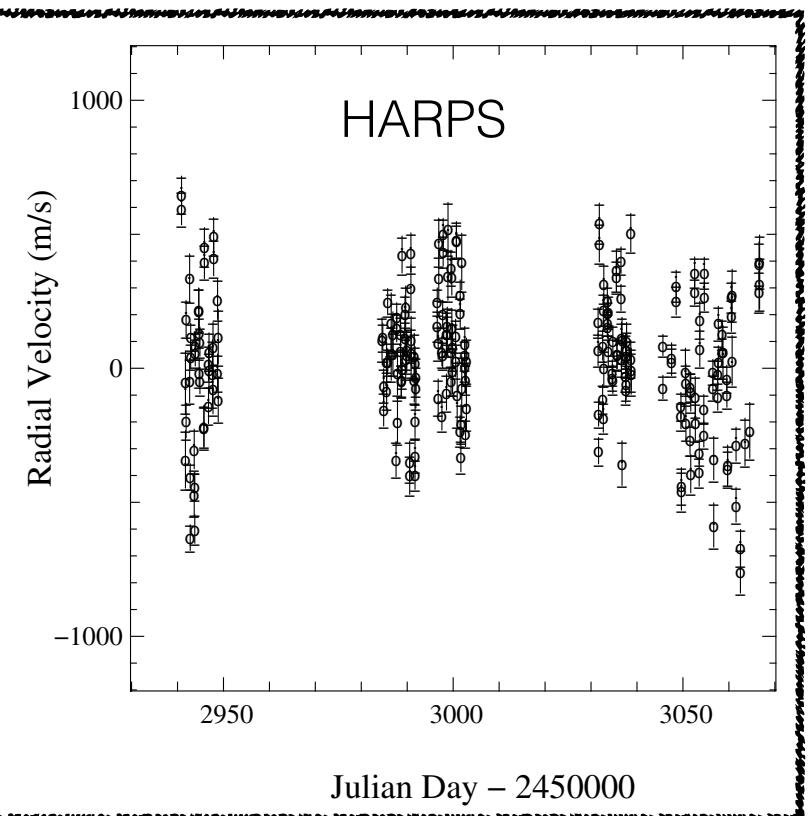
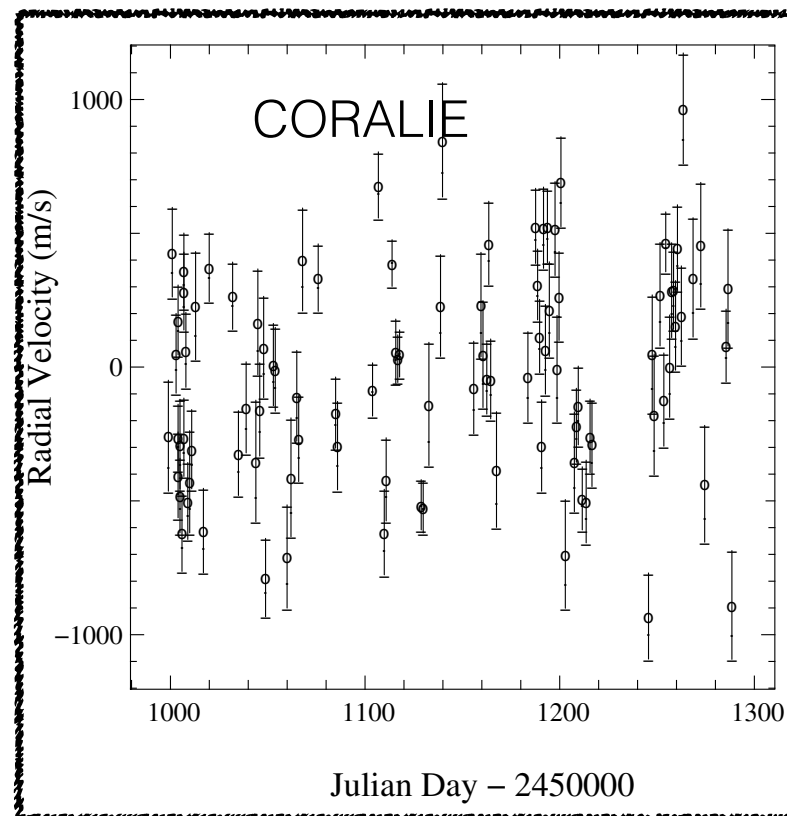


# Spectroscopy: pulsations

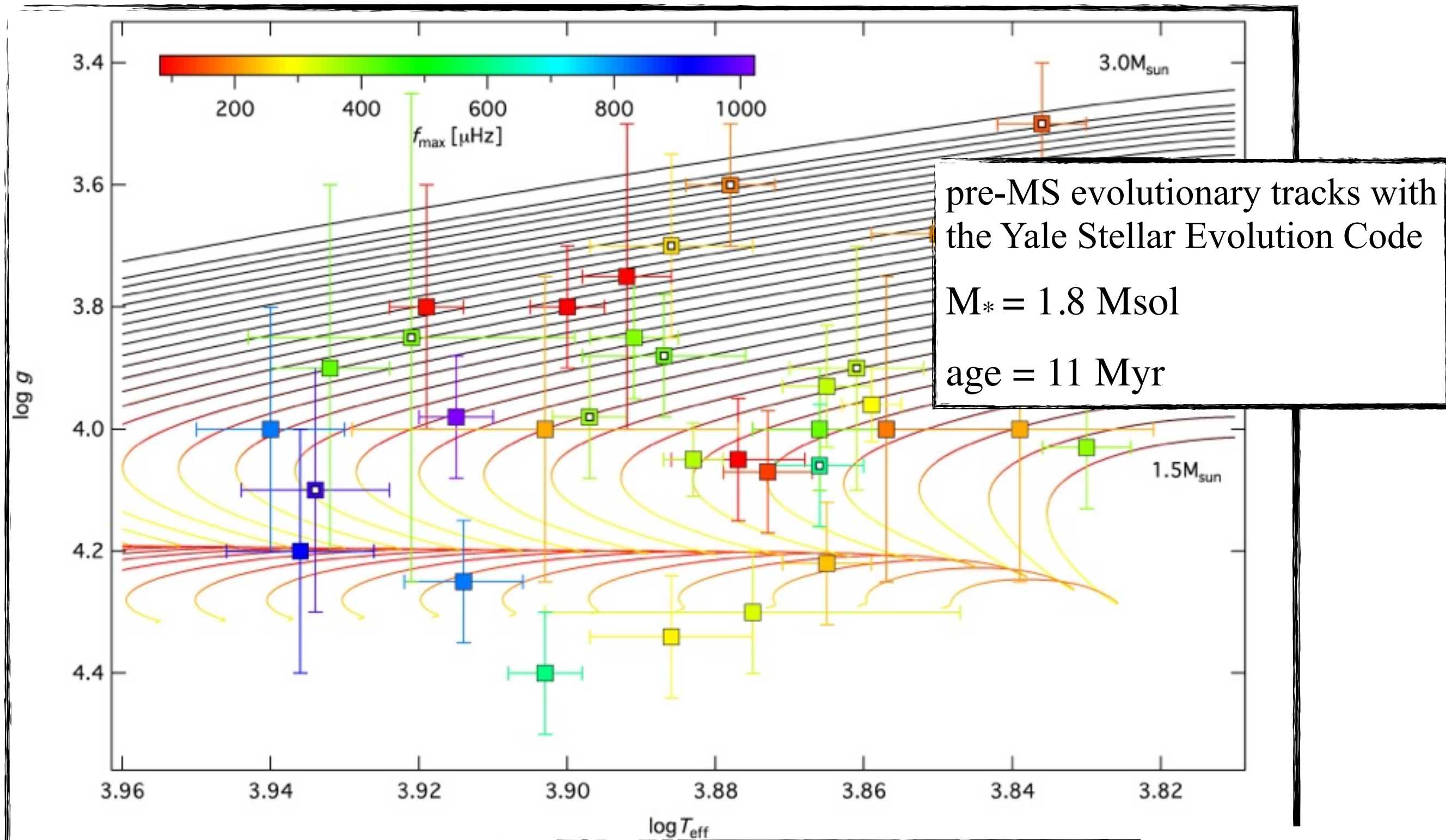


18 frequencies  
high-degree, non-radial pulsation modes.

Galland et al., 2006



# $\beta$ Pic is a PMS $\delta$ scuti



Zwintz, 2008

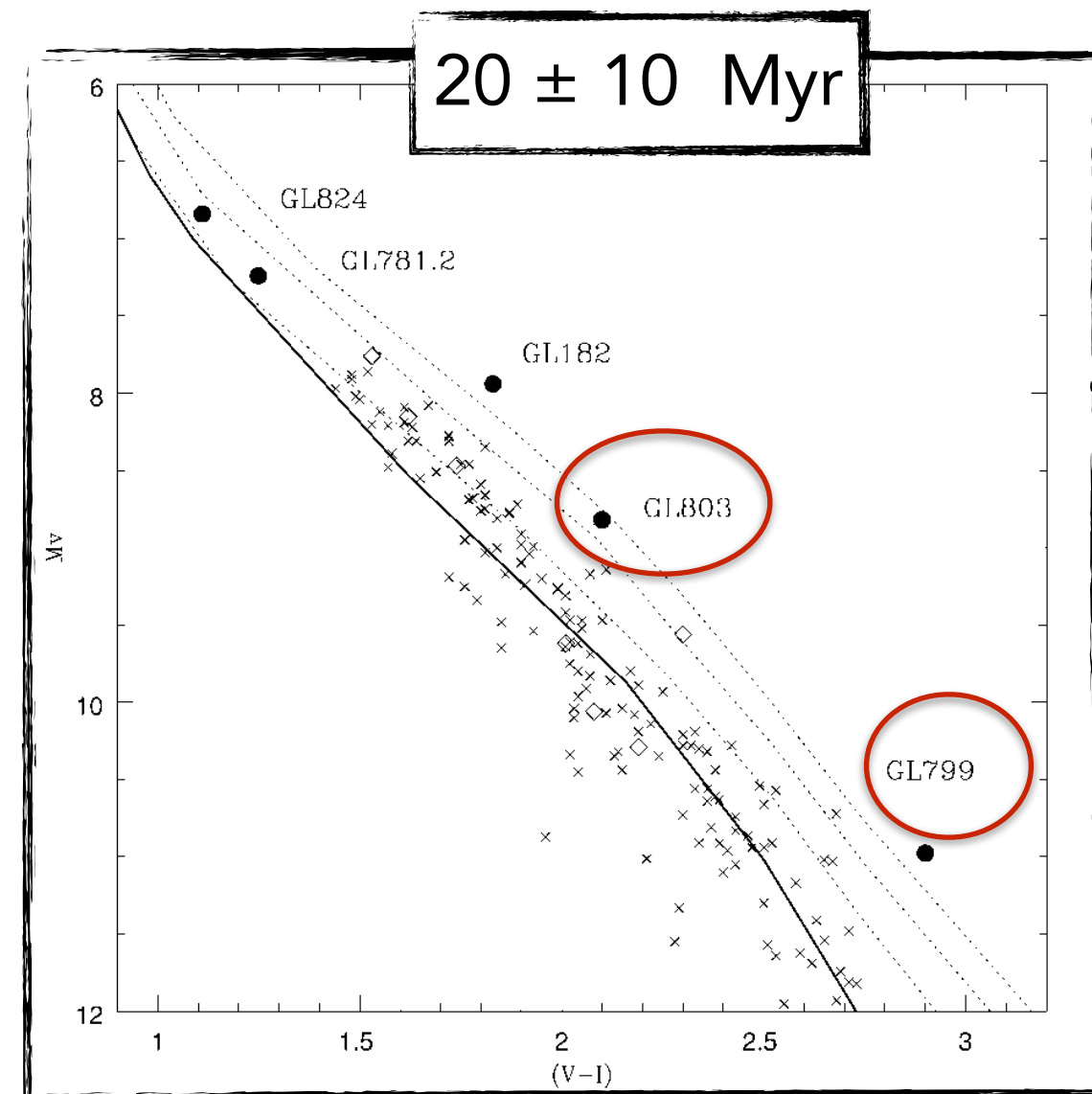
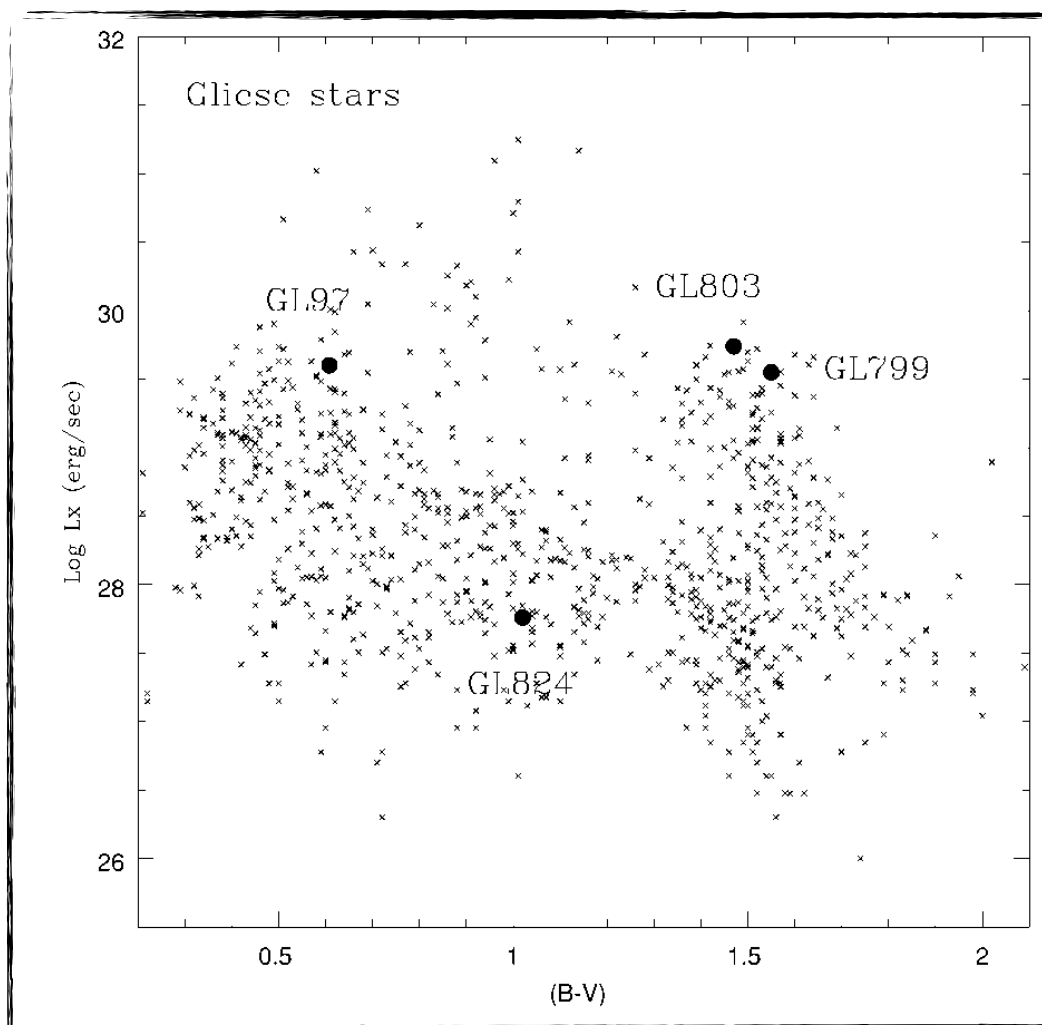
Zwintz et al., 2014

# The $\beta$ Pic comoving group

Membership: common origin based on equatorial coordinates, parallaxes, proper motions and radial velocity

youth indicators: chromospheric and coronal activities

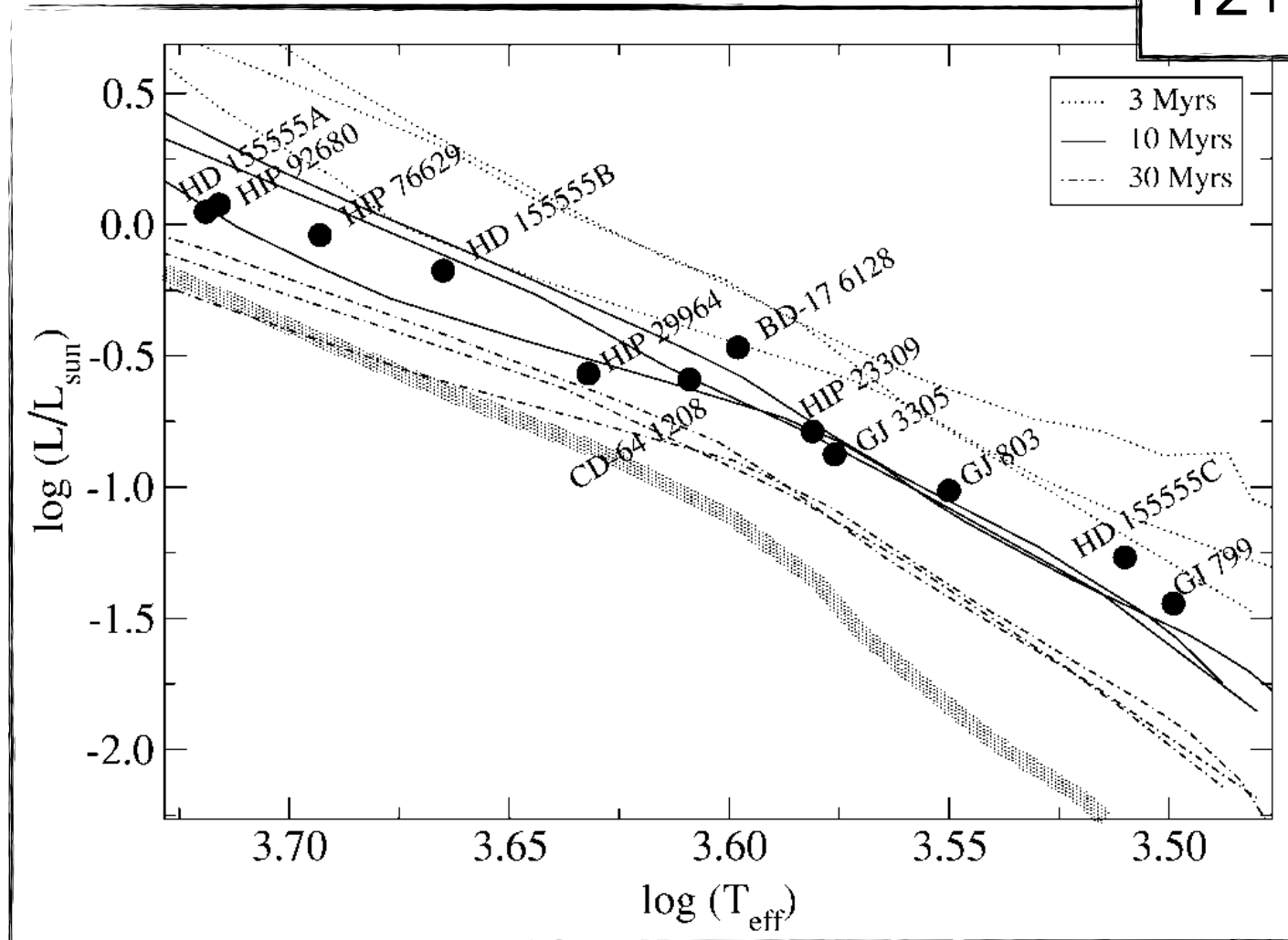
pre-MS tracks



# Isochronal age of $\beta$ Pic MG

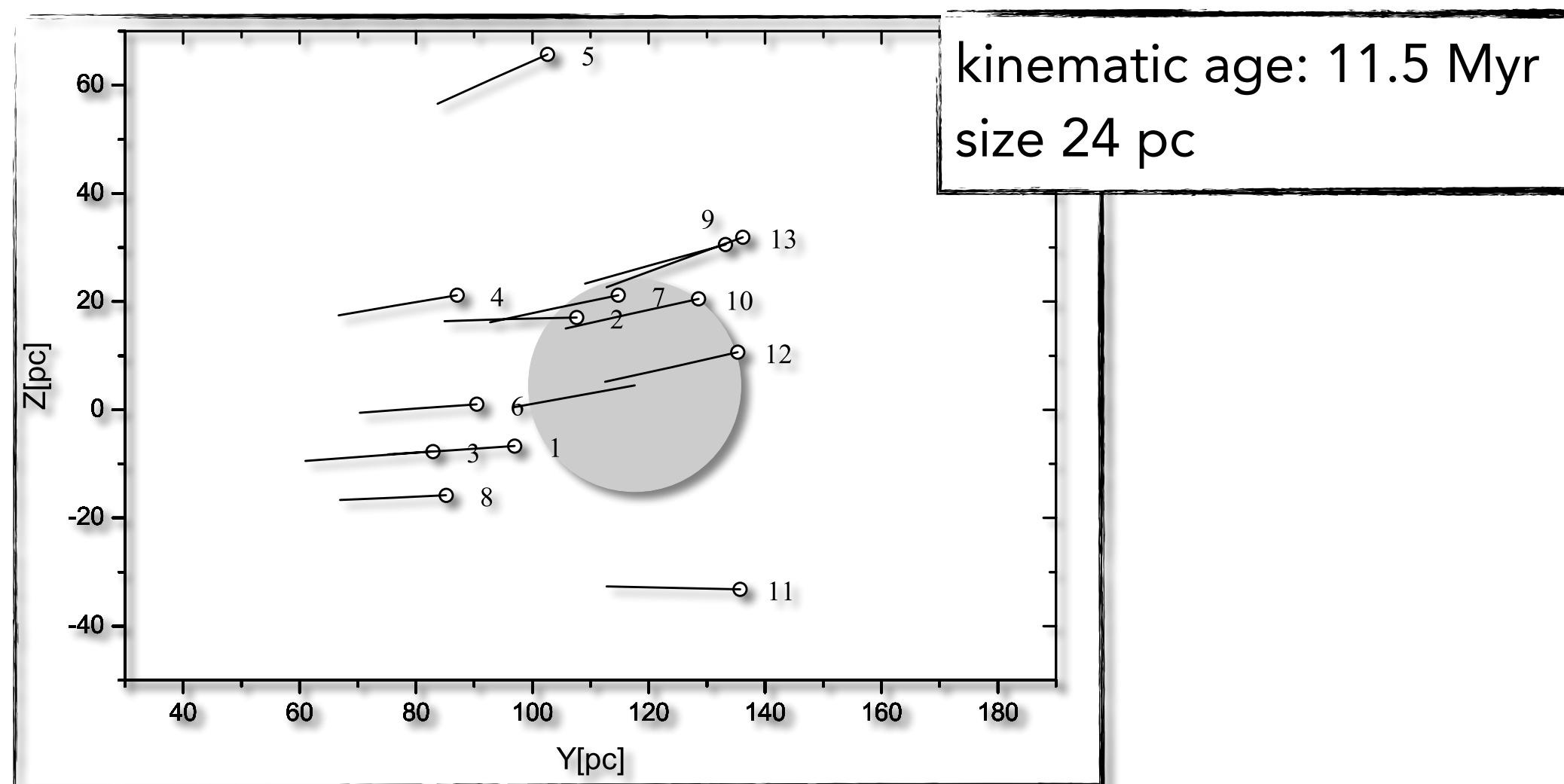
BPMG: 17 members

isochronal age from late K and M stars:  
12+8/-4 Myr



Zuckerman et al. (2001)

# Kinematic age



Ortega et al. 2002

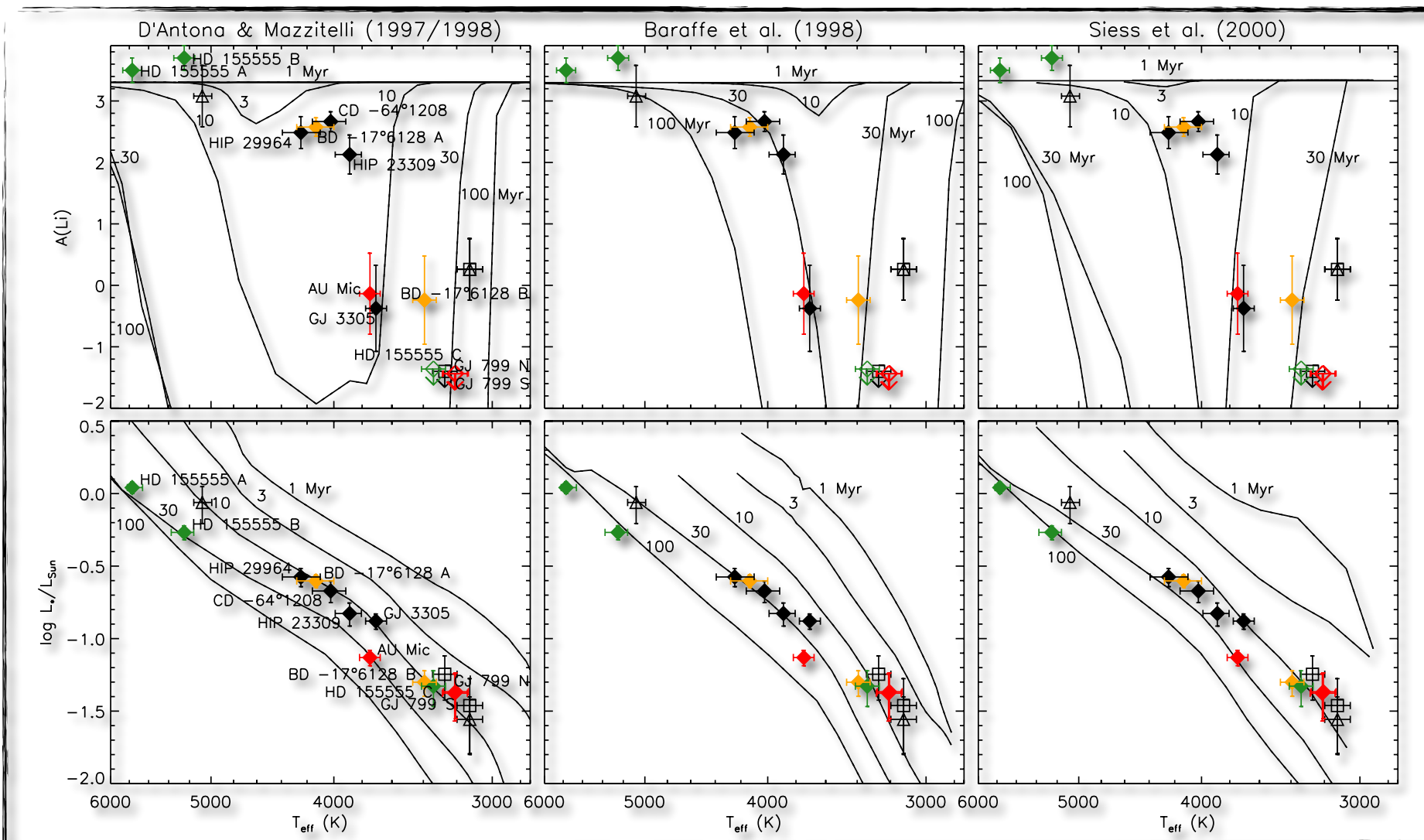
Ortega et al., 2004

Song et al. 2003

time of closest approach for pairs of  
BPMG members of  $22 \pm 12$  My  
(Makarov, 2007)

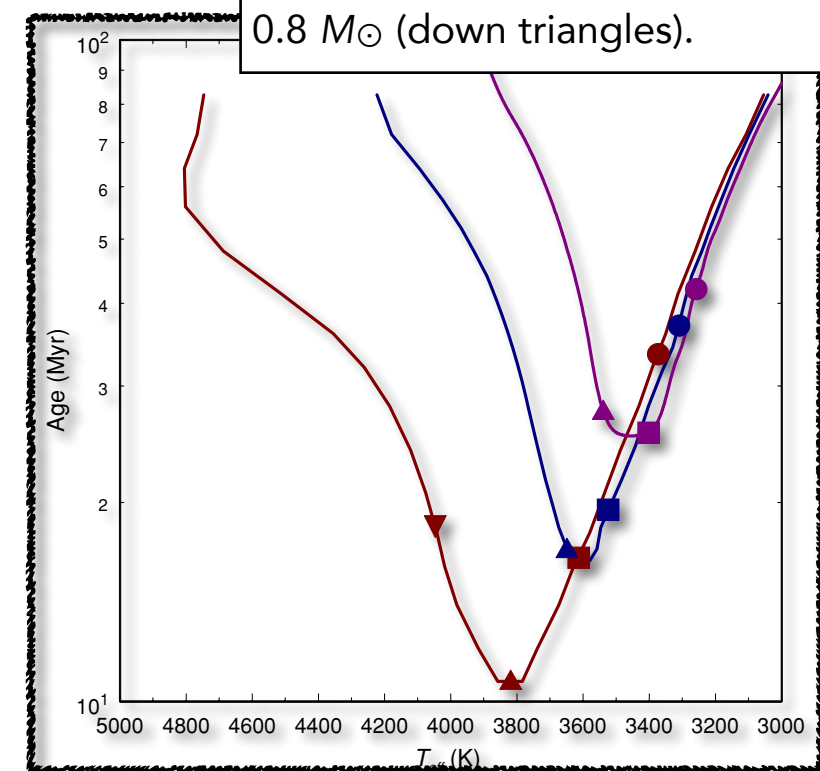


# Lithium derived age



Li isochronal age  
 $\approx 30 \text{ Myr}$

magnetic inhibition parameter  
 $\delta = 0$  (red)  
 $\delta = 0.01$  (blue)  
 $\delta = 0.02$  (magenta)  
 $0.2 M_{\odot}$  (circles)  
 $0.4 M_{\odot}$  (boxes)  
 $0.6 M_{\odot}$  (up triangles)  
 $0.8 M_{\odot}$  (down triangles).

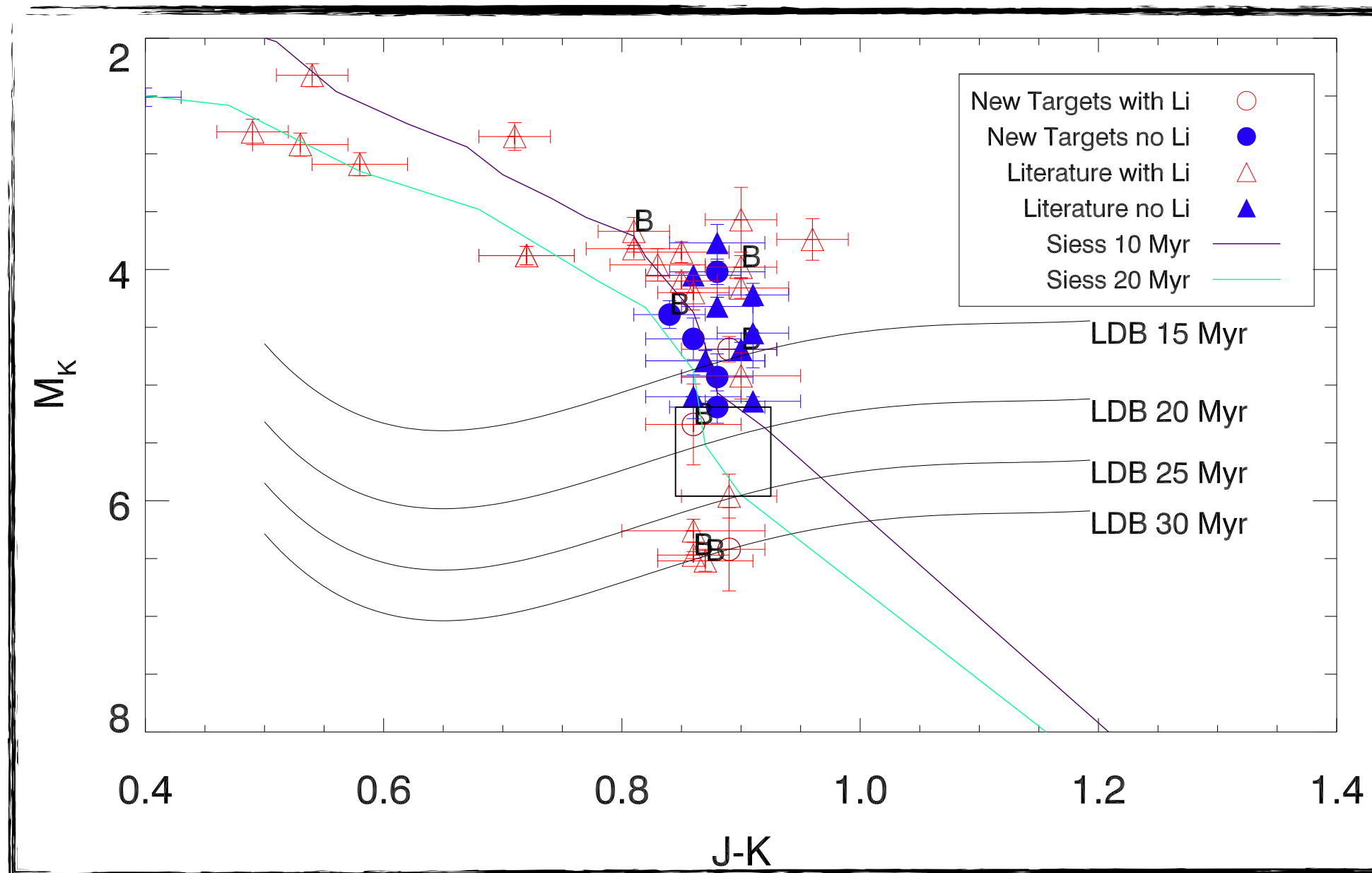


Yee & Jensen, 2010

Song et al., 2002

- stellar radii under predicted by models of MS M stars
- effect of magnetic field (MacDonald & Mullan, 2010)

# Lithium Depletion Boundary



age =  $21 \pm 4$  Myr

# Conclusions

$\beta$  Pic is a PMS  $\delta$  scuti star.

$T_{\text{eff}} = 8200 \pm 150 \text{ K}$ ; (1995)

$[\text{Fe}/\text{H}] \sim 0.0$

$L_*$  from Hipparcos

presence of a chromosphere and a cool corona

current age estimate: 11 Myr

Comoving group:

- kinematic age: 11.5 Myr
- isochronal age:  $12.8^{+8}_{-4}$  Myr
- Lithium Depletion Boundary:  $21 \pm 4$  Myr

Spectra : To be re-analyzed - improved opacities, models ... revise the  $T_{\text{eff}}$  and  $[\text{Fe}/\text{H}]$

Magnetic field to be looked for?

Isochronal age :

- new models (inclusion of the rotation)
- MCMC or other statistical techniques to get better estimate of the error