Mass, age and metallicity of the central star of the multiple system HR8799

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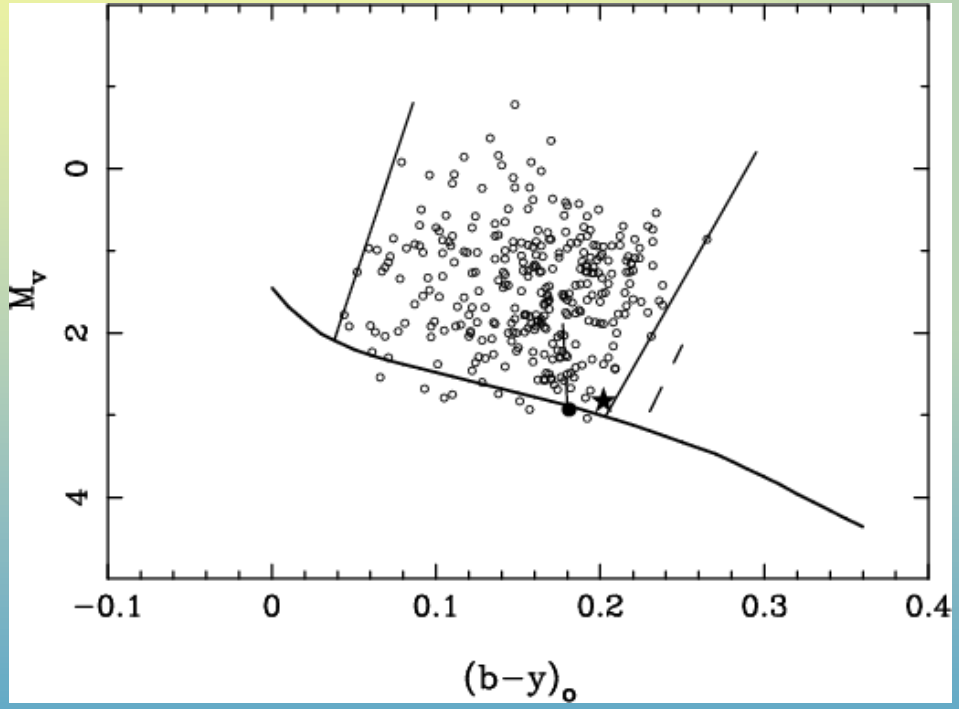
What is stellar seismology

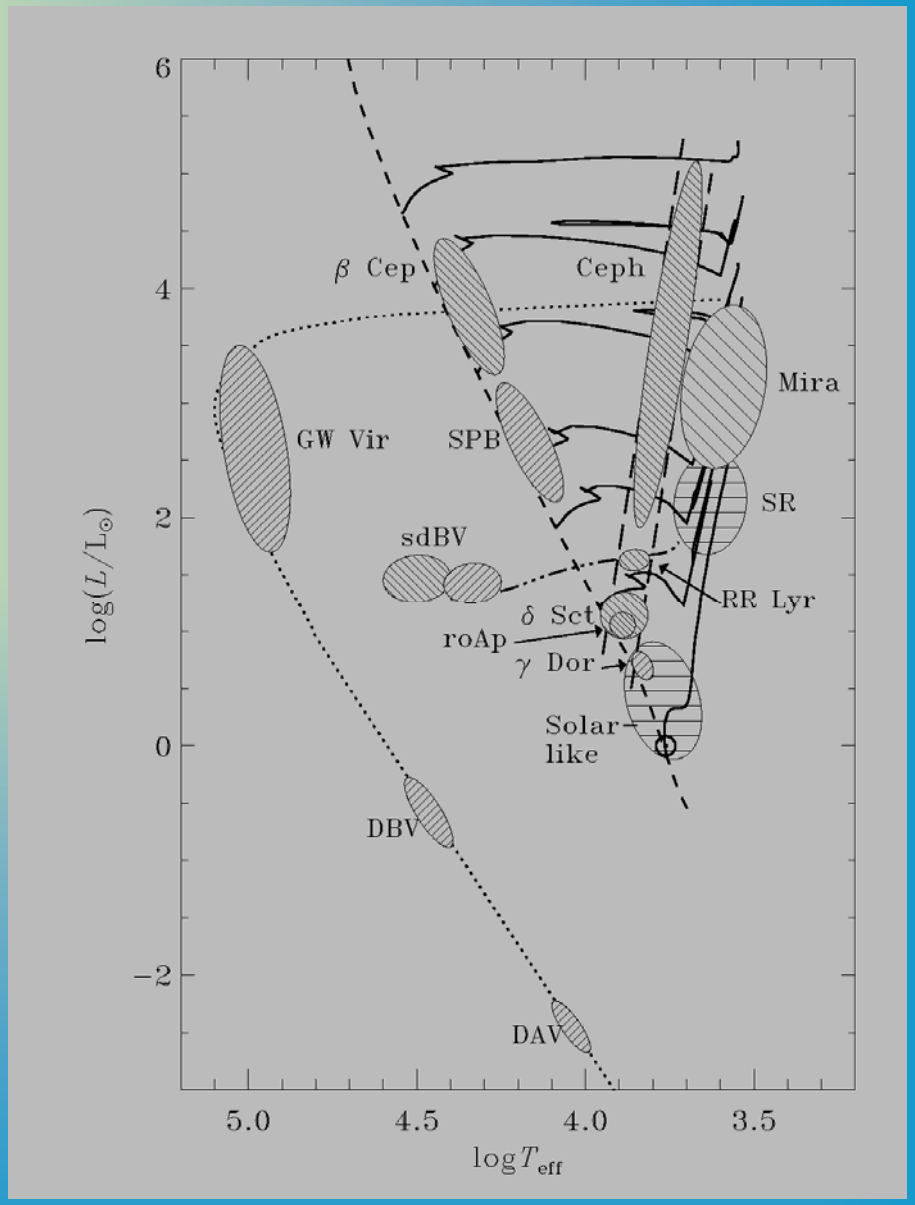
Determination of the mass, age and metallicity in the literature

Determination using asteroseismology

Planning

Locating HR8799 in the HR Diagram

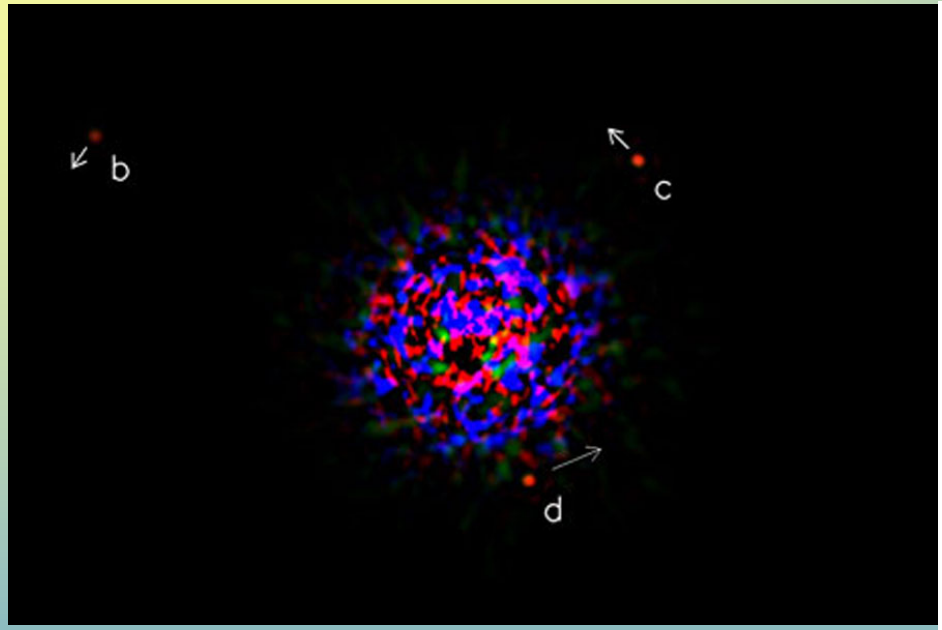




Physical characteristics of HR8799

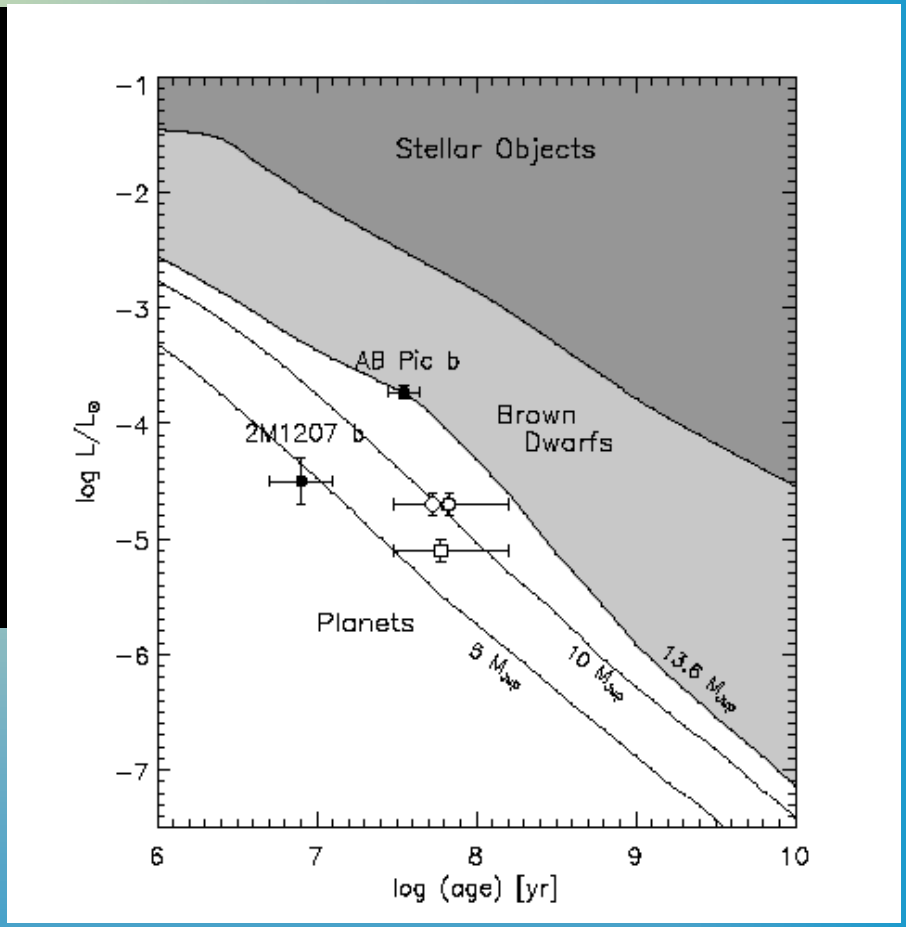
Detection of other orbiting objects

Take a picture of the system



Age determination necessary to estimate the mass of the objects

Mass determination necessary to estimate the gravitational stability of the system

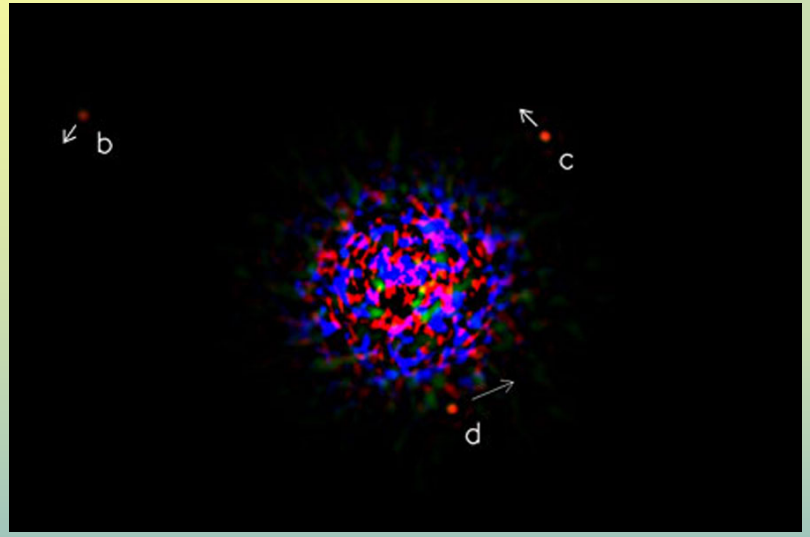


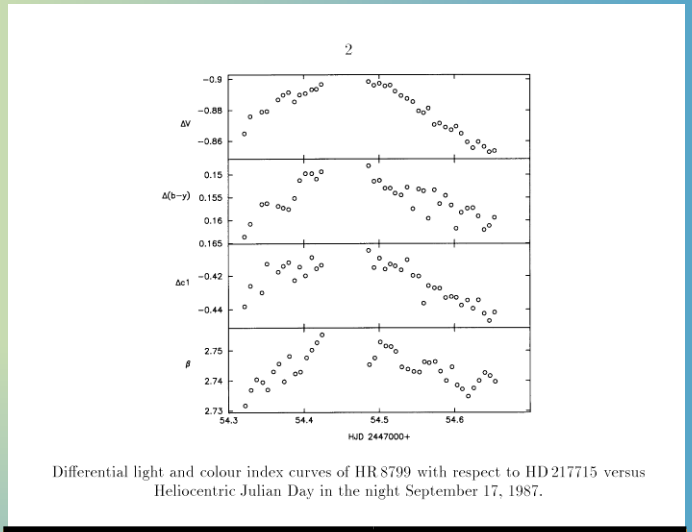
Metallicity determination necessary to estimate mass and age

Physical characteristics of HR8799

Pulsating stars harboring planets: γ Doradus

HR8799 (Moya, Amado et al.,MNRAS and MNRAS Letters 2010)





Differential light and colour index curves of HR 8799 with respect to HD 217715 versus Heliocentric Julian Day in the night September 17, 1987.

Pulsational frequencies, Zerbi et al. 1999

f_1	1.9791
f_2	1.7268
f_3	1.6498

Observational data

Gray & Kaye 1999

λ Bootis surface chemical peculiarities

T_{eff} (K)	7430±75
Log g (cm s^{-2})	4.35±0.05
M_V	2.98±0.08
R ($R_\odot$)	1.34±0.05
L ($L_\odot$)	4.92±0.41
v sin i (km s^{-1})	37.5±2
π (mas)	25.04±0.85

Physical characteristics of HR8799

Mass and age determination in the literature

Mass = $1.5 \pm 0.3 M_{\odot}$ (Gray & Kaye, 1999)

Method/s	Authors	Age in Myr
HRD position	Song et al. 2001	[50,1128]
Kinematics Isochrones	Marois et al. 2008 Zuckerman & Song 2004 Rhee et al. 2007	[30,160] 30 30
Kinematics	Móor et al. 2006	[20,150]
Kinematics Isochrones IR excess	Chen et al. 2006	[30,730]
Asteroseismology	Moya et al. 2010	[26,430]-[1123,1625]

Age determinations

1) Kinematics

Space motion with respect to the Sun:
UVW=(-11.9,-21.0,-8.8 km s^{-1})

Similar to:

1) Other stars with ages between TW Hydra association (8 Myr) and Pleiades (125 Myr)

2) Members of the 30 Myr old Columbia and Carina associations

3) The stars HD984 (30 Myr) and HD221318 (100 Myr)

"Of course, in this UVW range of young stars, there are also older stars with randon motions; so other, independent, methods must be employed to place limits/constraints on the age of HR8799"

Information taken from Marois et al. 2008

Age determinations

2) IR excess of the debris disk

"The measured infrared excess ratio of ~100 at 60-90 μm would be typical of a debris disk star of age ≤50 Myr (Su et al. 2006)"

"However, this argument is purely statistical and must be interpreted with caution" (Reidemeister et al. 2009)

The presence of planets can affect the disk, changing its properties. This can makes unreal any age determination based on the comparison of these characteristics with statistically inferred properties

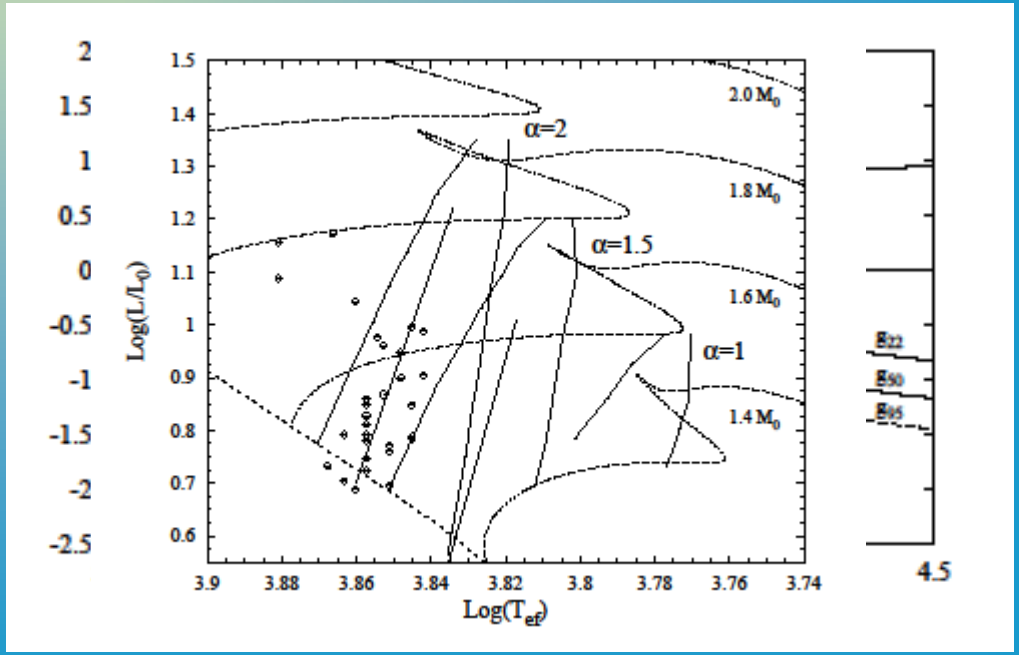
Age determinations

3) γ Doradus pulsator

“The γ Doradus class stars are probably young”

The γ Doradus excitation mechanism is related with the luminosity flux blocking at the bottom of the outer convective zone (Guzik et al. 2000, Dupret et al. 2004)

γ Doradus pulsations depends on the effective temperature and not on the age

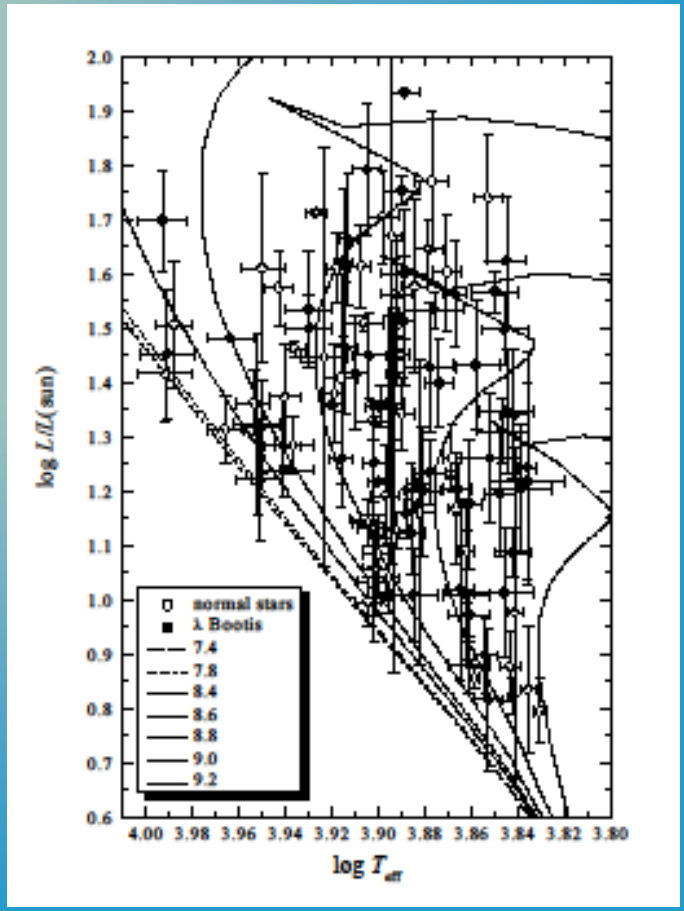


Age determinations

4) λ Bootis chemical peculiarities

"λ Bootis are generally thought to be young stars"

"The group of λ Bootis stars consists of true Population I type objects which can be found in the area of the whole main sequence. The age distribution has a peak at a rather evolved stage (≈1Gy)…"
Paunzen 2003



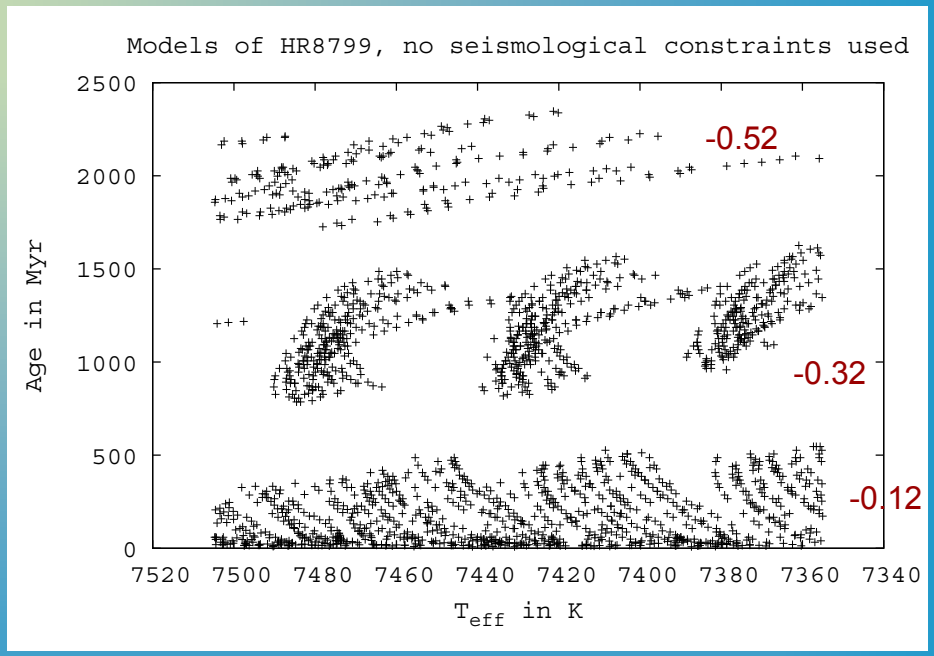
Age determinations

4) Position in the HR diagram

Observational data

T_{eff} (K)	7430±75
Log g (cm s^{-2})	4.35±0.05
M_V	2.98±0.08
R ($R_\odot$)	1.34±0.05
L ($L_\odot$)	4.92±0.41
v sin i (km s^{-1})	37.5±2
π (mas)	25.04±0.85

Due to the λ Bootis nature of the star, its metallicity is unknown, ranging between [-0.52,0.08]



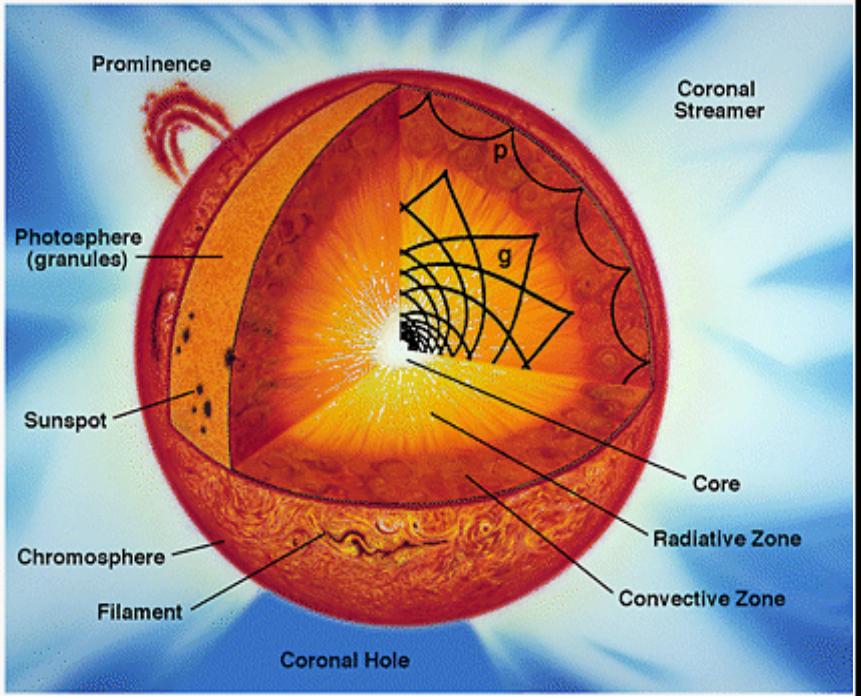
There are no models with solar metallicity fulfilling observations. We need a larger luminosity.

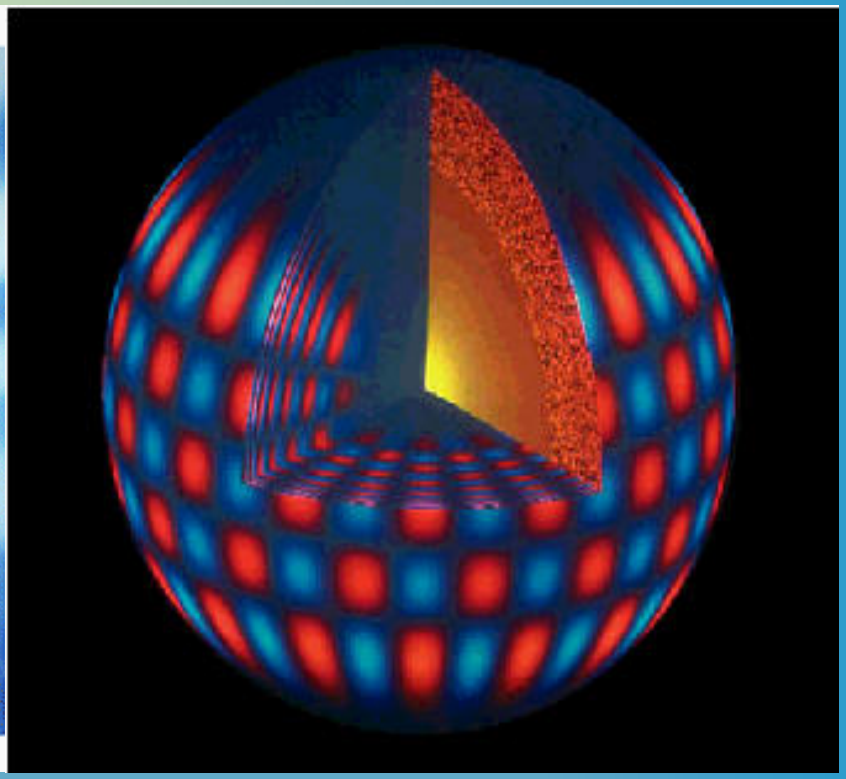
models in the range [30,160]Myr, 18%

Similar to that found by Song et al. 2001

Physical characteristics of HR8799

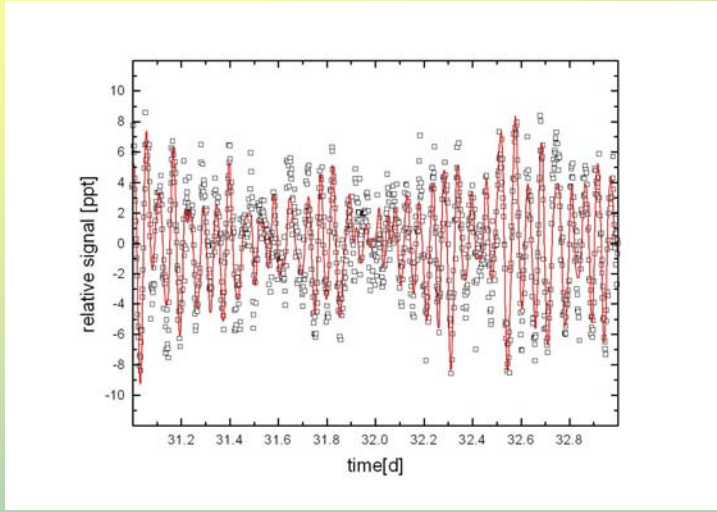
What is stellar seismology?

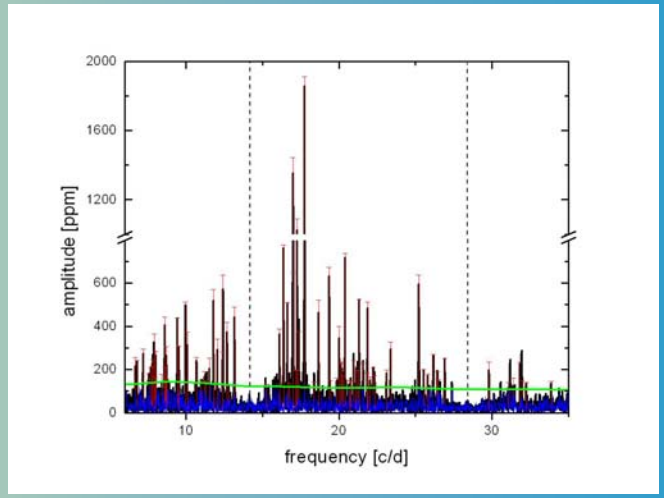




Physical characteristics of HR8799

What is stellar seismology?





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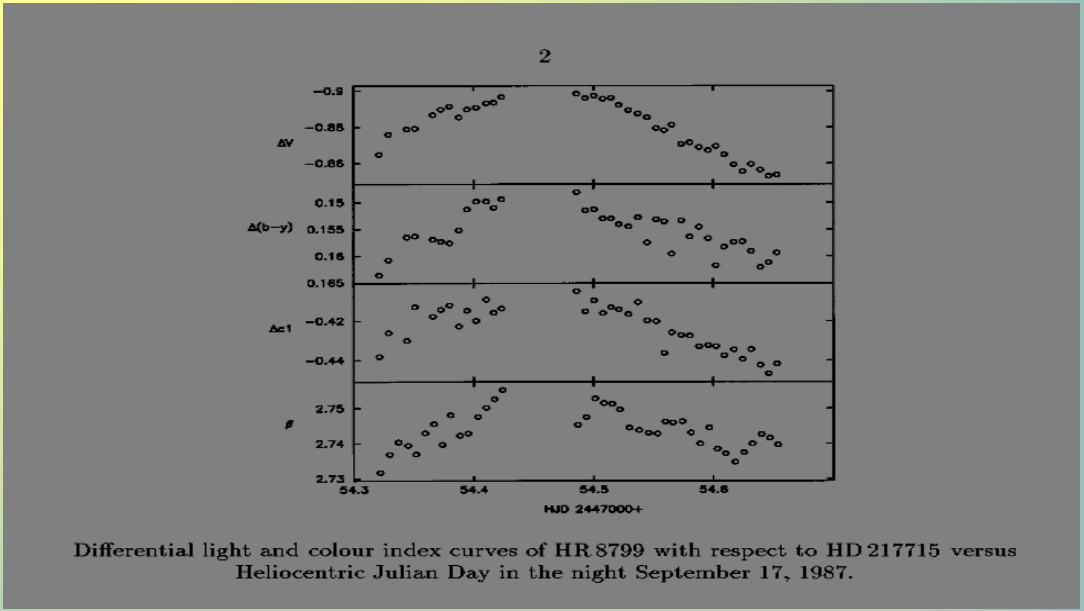
Stellar numerical models

Theoretical frequencies

Physical characteristics of HR8799

Pulsational data



Differential light and colour index curves of HR 8799 with respect to HD 217715 versus Heliocentric Julian Day in the night September 17, 1987.

Pulsational frequencies

f_1	1.9791 c/d
f_2	1.7268 c/d
f_3	1.6498 c/d

Multicolour Strömgren photometry observations.

This allows the application of:

1) Frequency Ratio Method (FRM)
2) Mode identification (multicolour photometry)
3) Instability analysis (Time Dependent Convection)

FRM is the only possible method with only 3 frequencies, and it has some limitations

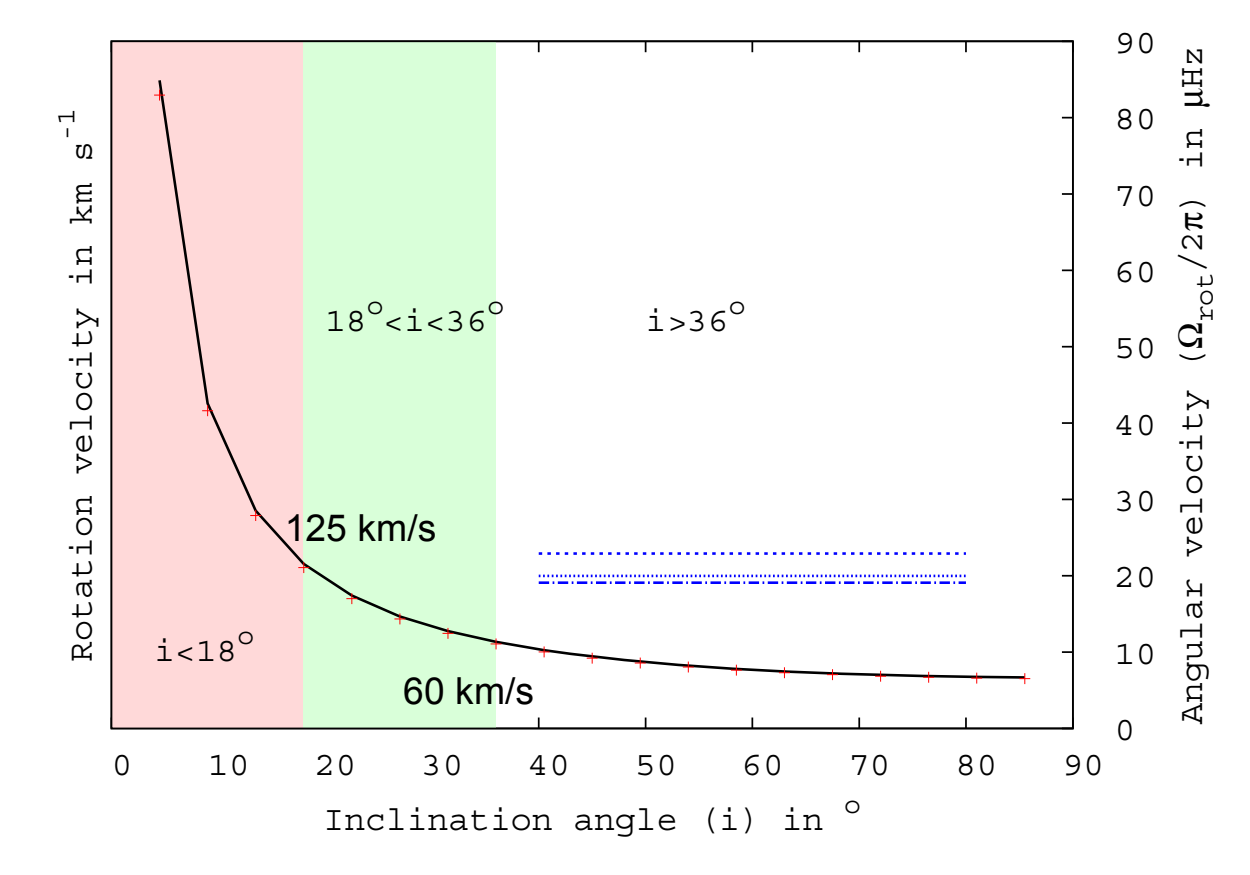
FRM limits

All the frequencies must have the same azimutal order *m*

The rotation velocity of the star must be limited to ≈ 60 km/s

Red= Limitation imposed by the λ Bootis nature of the star

Green= Rotation velocities where the FRM is inaccurate

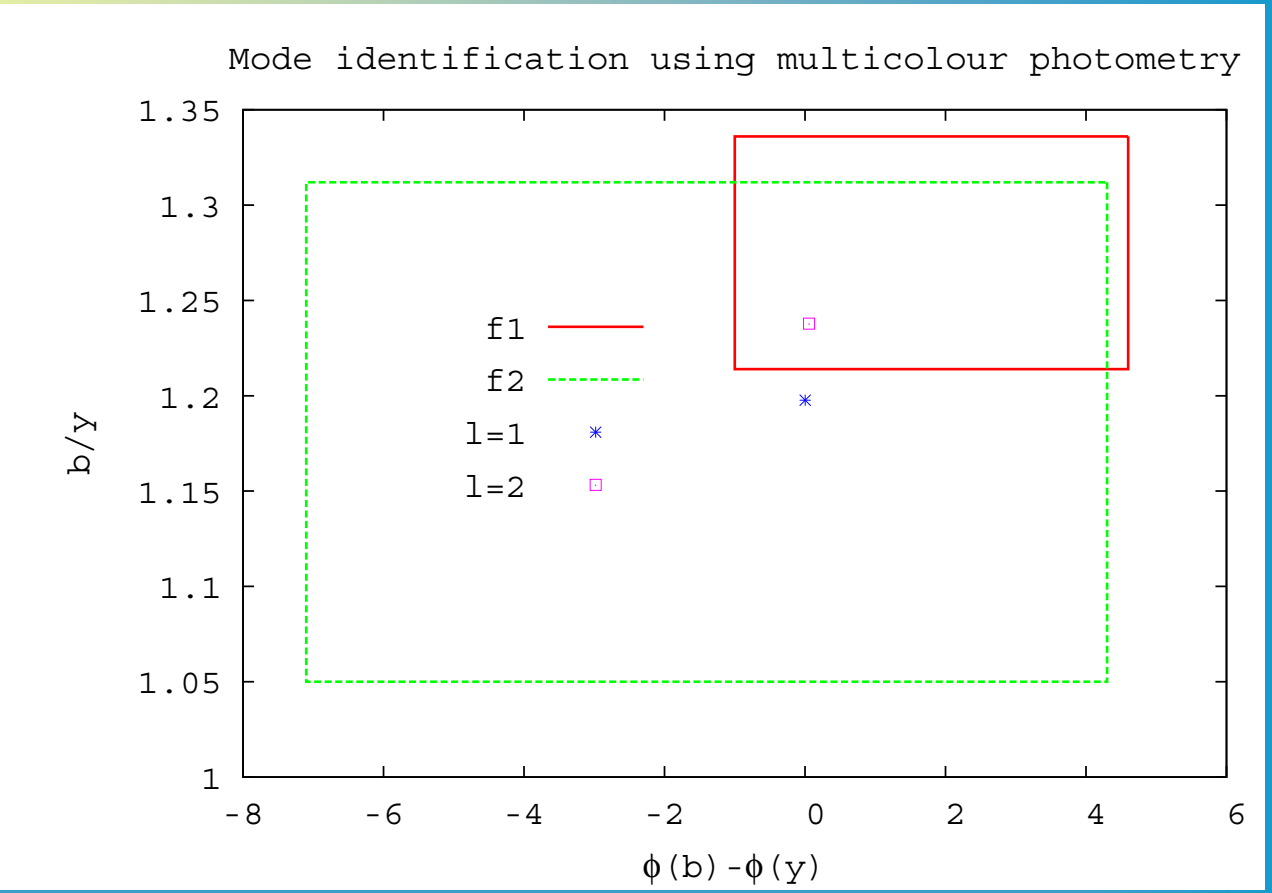


Mode identification using multicolour photometry

Comparing amplitude ratio and phase differences of the same mode observed in different filters

Theoretical predictions obtained with a non-adiabatic pulsational code.

This code also provides information about the energetic stability of the mode. A stable mode cannot be observed

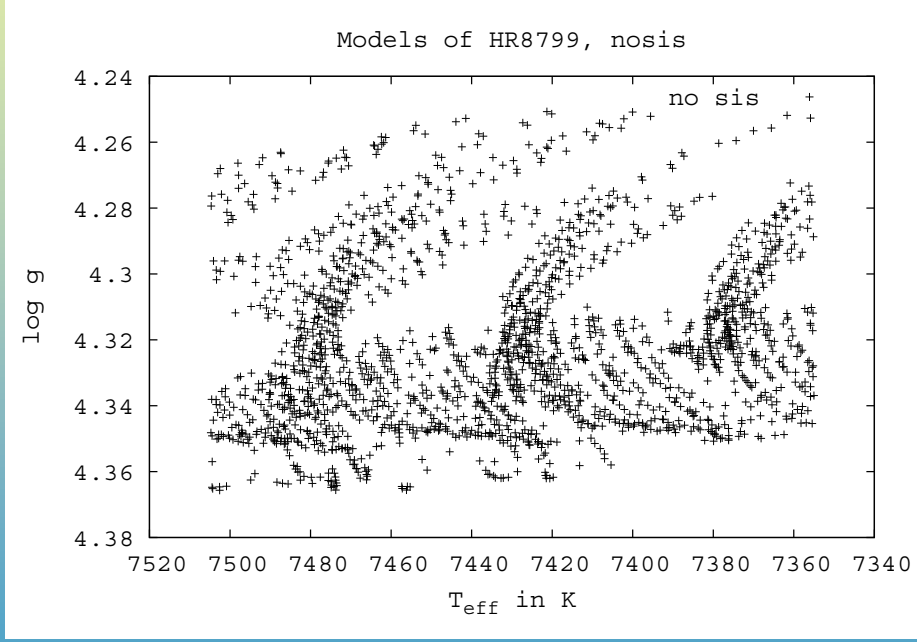


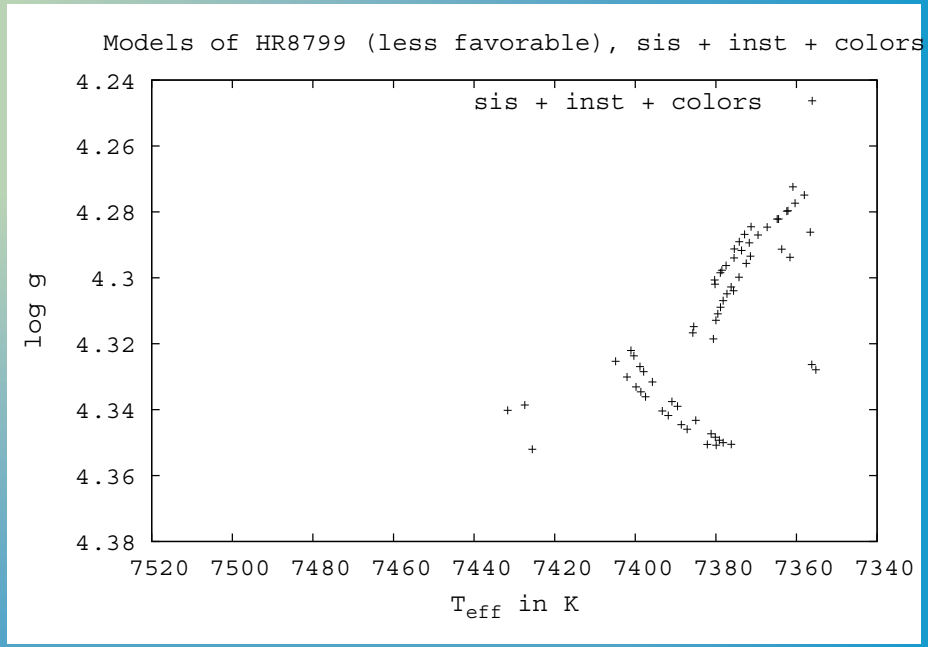
The benefit of using asteroseismology

HR diagram

Without seismology

With seismology





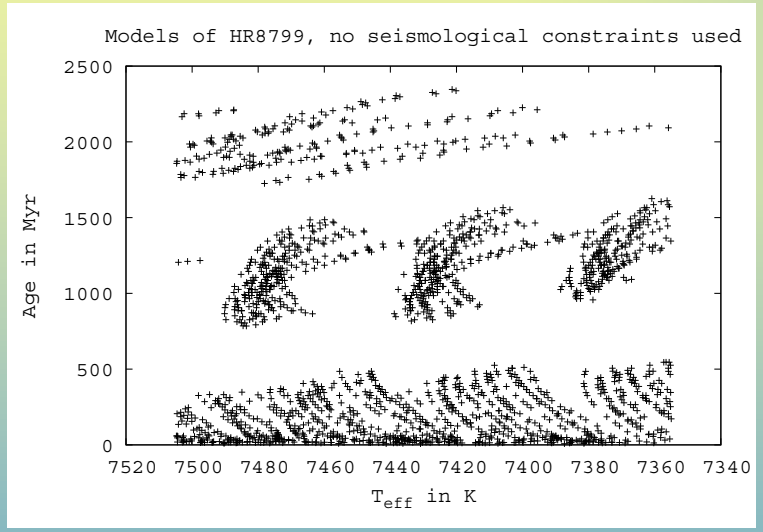
Stellar mass in the ranges [1.32,1.33] and [1.44,1.45] $M_{\odot}$

Physical characteristics of HR8799

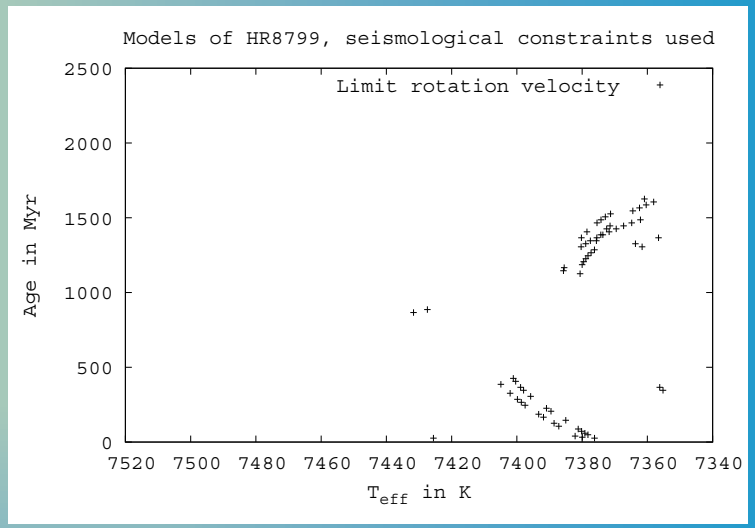
The benefit of using asteroseismology

T_{eff} – Age Diagram

Without seismology



With seismology



Stellar age in the ranges [26,430] and [1123,1625] Myr

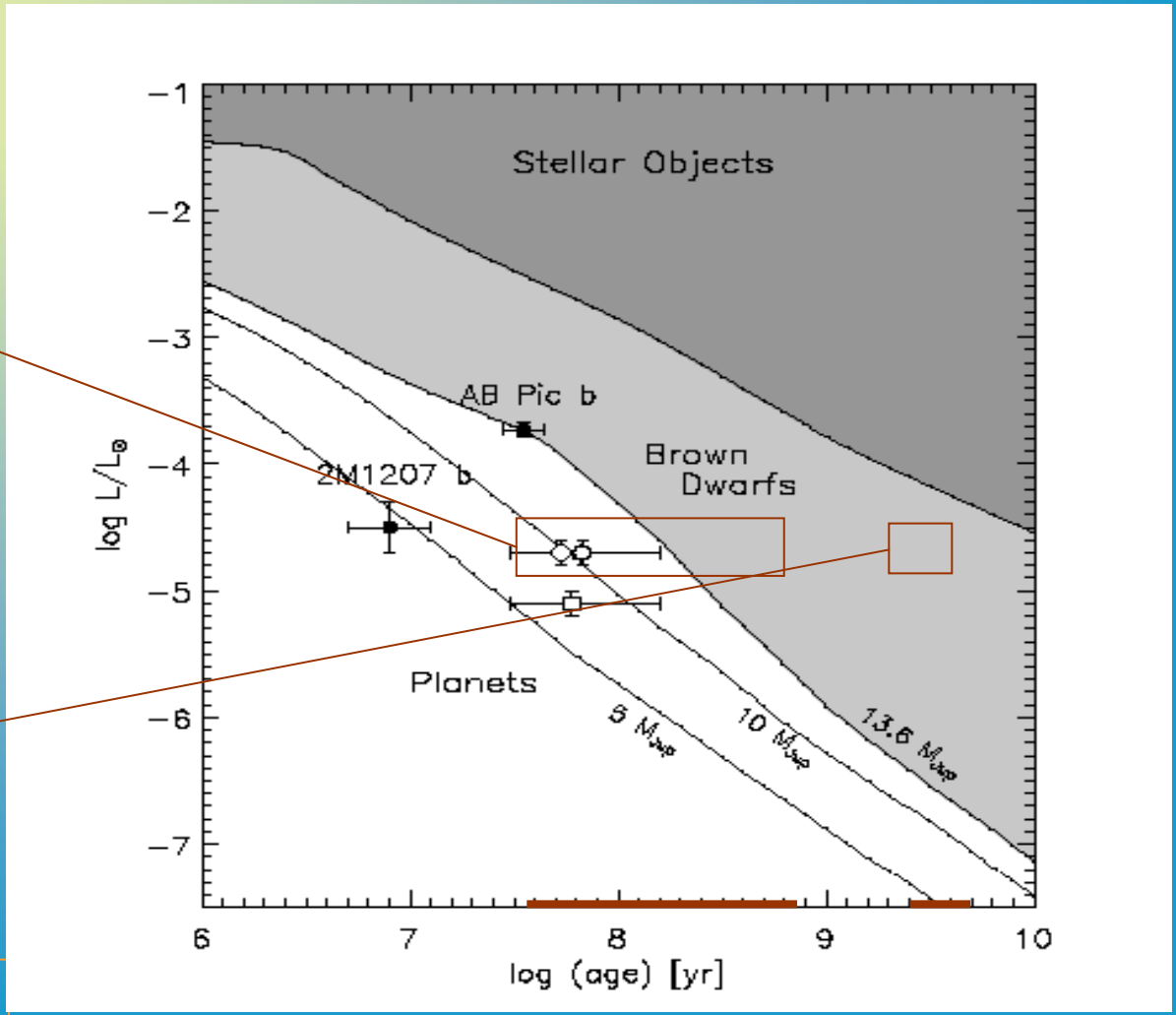
models in the range [30,160] Myr: 16.1%

Consequences on the determination of the mass of the accompanying objects

M=5-14 M_J

M=3-13 M_J

Brown dwarf



Conclusions

The age of the system HR8799 is not accurately known with conclusive arguments:

1) Proper motions is not a conclusive probe

2) We do not accurately know the influence of the planets in the IR excess of a debris disk for the age determination of the system

3) These two methods need the comparison with other stars with an accurate age determination. These determinations have been mainly done with the same methods…

4) The HR diagram position (and its comparison with isochrones, etc.) is not a good indication due to the λ Bootis nature of HR8799.

5) Asteroseismology can give an independent and self consistent (but model dependent) estimation of the age of the system. The problem is that the present amount of observational data is not enough for this purpose. Nevertheless asteroseismology can offer a rouge estimation with the present observational data.

Future plans

Improve the quantity and quality of the asteroseismic observational data:

1) More multicolour photometric observations for the mode identification of f_2

2) Spectroscopic time series to detect new pulsational modes and their mode identification

3) Space observations to obtain as much modes as possible.

4) HR8799 can be a δ Scuti – γ Doradus hybrid pulsator