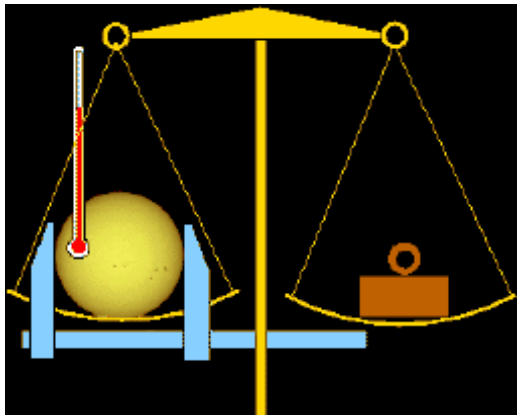
VEGA science update: Fundamentals parameters

Nicolas Nardetto

- Angular diameters (13 Cyg, γ Equ)
- Separations (β Cep, 48 And)
- Rotation (α Cep)
- Perspective on static and pulsating stars



Nicolas NARDETTO
Philippe Berio, Omar Delaa, Denis Mourard, Karine Perraut
and the VEGA and CHARA Teams

Pasadena, 11th of March 2010

Science drivers

angular
diameter
separation
(binarity)

VEGA LR

distance

mass (1-2%)
radius (1-2%)

mass loss
pulsation period
rotation period
magnetic field

VEGA MR/HR

effective temperature (+/-50K)
luminosity (5-10%)
surface gravity
mean density
abundances

Physics of stars
Evolution Models

Position in HR diagram

Overview

- Angular diameters:

13 Cyg : F4V (Exoplanets)

γ Equ : A9p (RoAp)

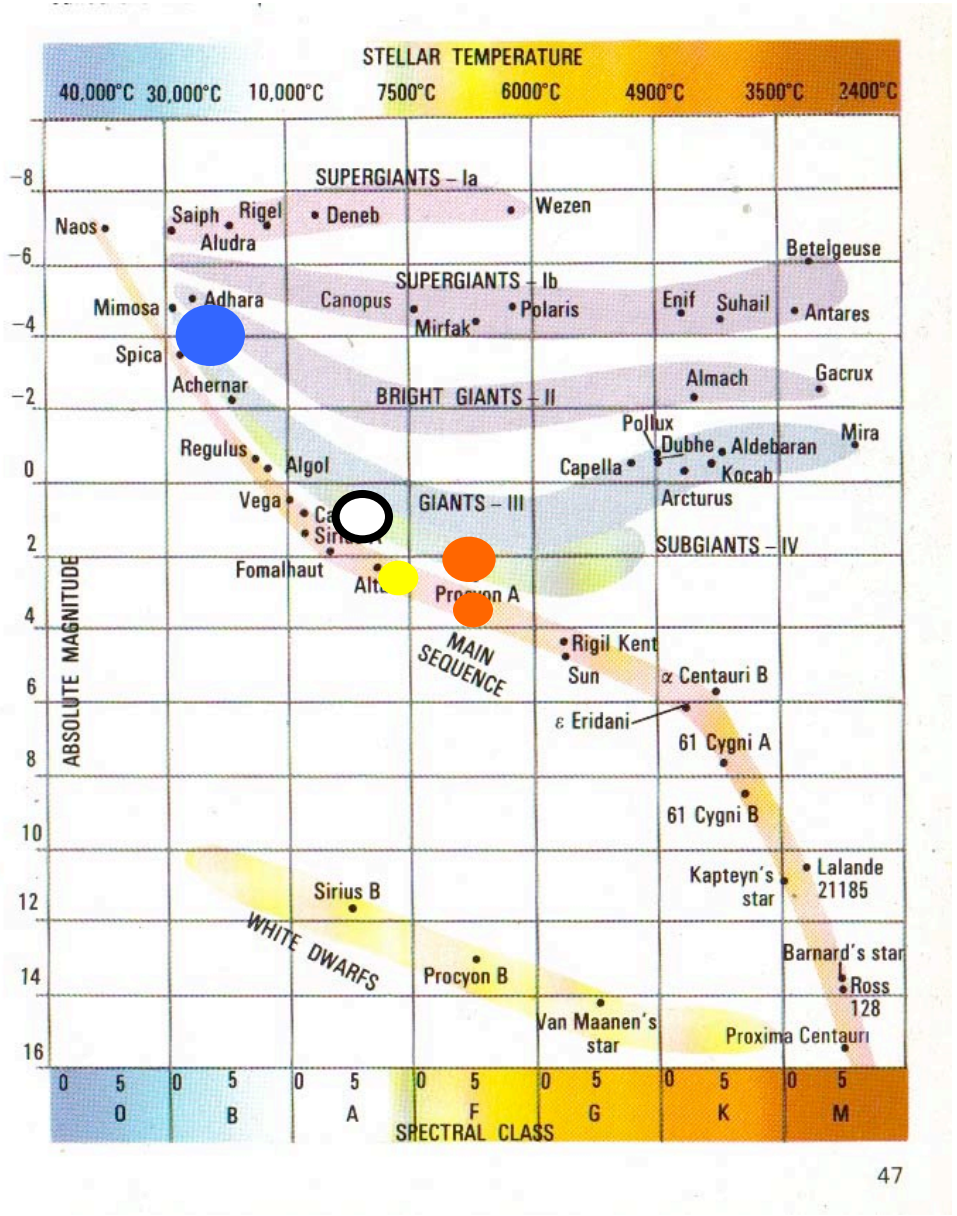
- Mass

β Cep : B2IIIev (pulsating binary)

48 And : F5IVe (sub-giants)

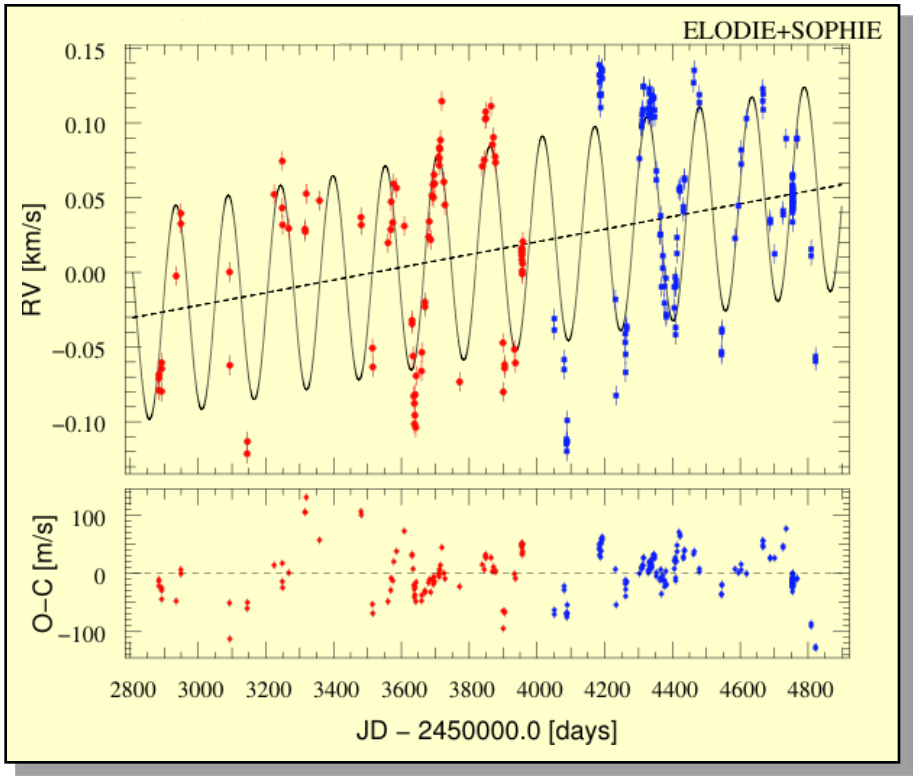
- Rotation

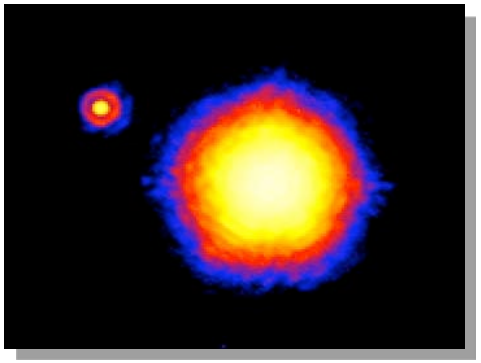
α Cep : A7IV (fast rotator)



Diameter of exoplanet host stars (13 Cyg)

Scientific justification (PI : A. M. Lagrange) : Large programs dedicated to companion detection around A and F stars. **Need for accurate diameter measurements to constrain complex models with multiple planets.**

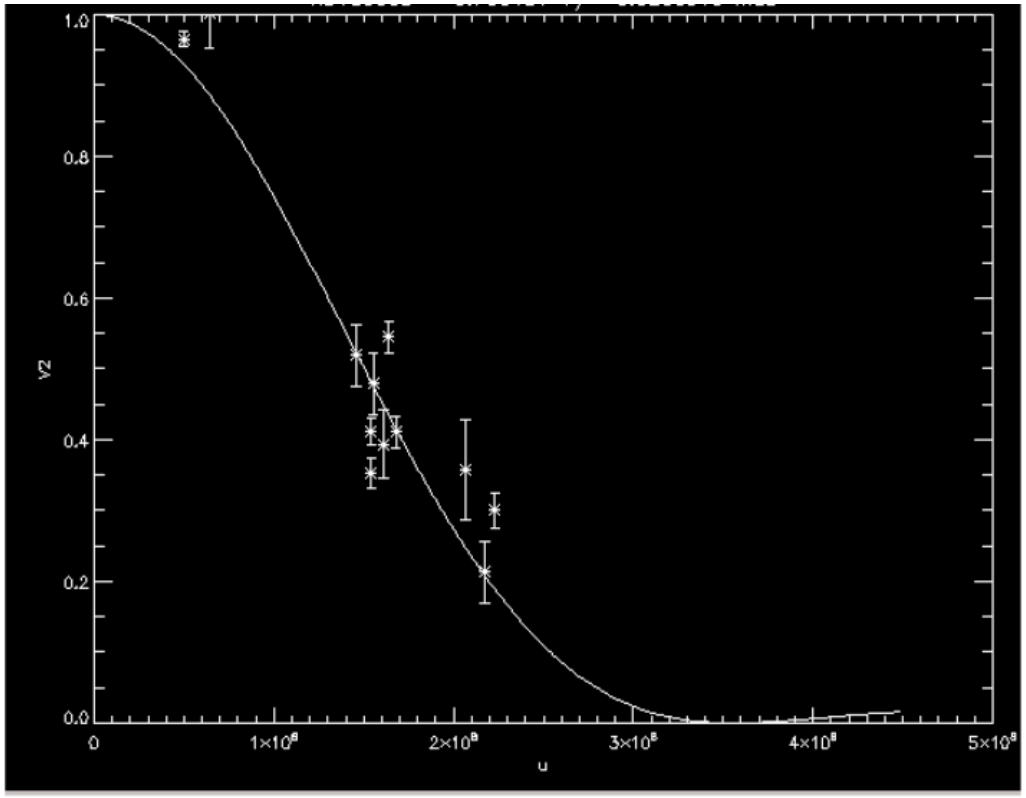




Observations:
W1W2 : 6&8/10/08, 6/7/09, 17/06/09
S1S2 : 7/10/08
W1E1 : 1/8/09
W2E2 : 1/8/09, 3/08/09

VEGA observations (13 Cyg)

We had to calibrate the HD184006 Search Cal Calibrator (old version) θ=0.84+-0.05mas instead of 0.59



Result: θ=0.696+-0.016mas relative precision of 1.5%

Perspective : input for the exoplanets model (limb-darkening, spots)

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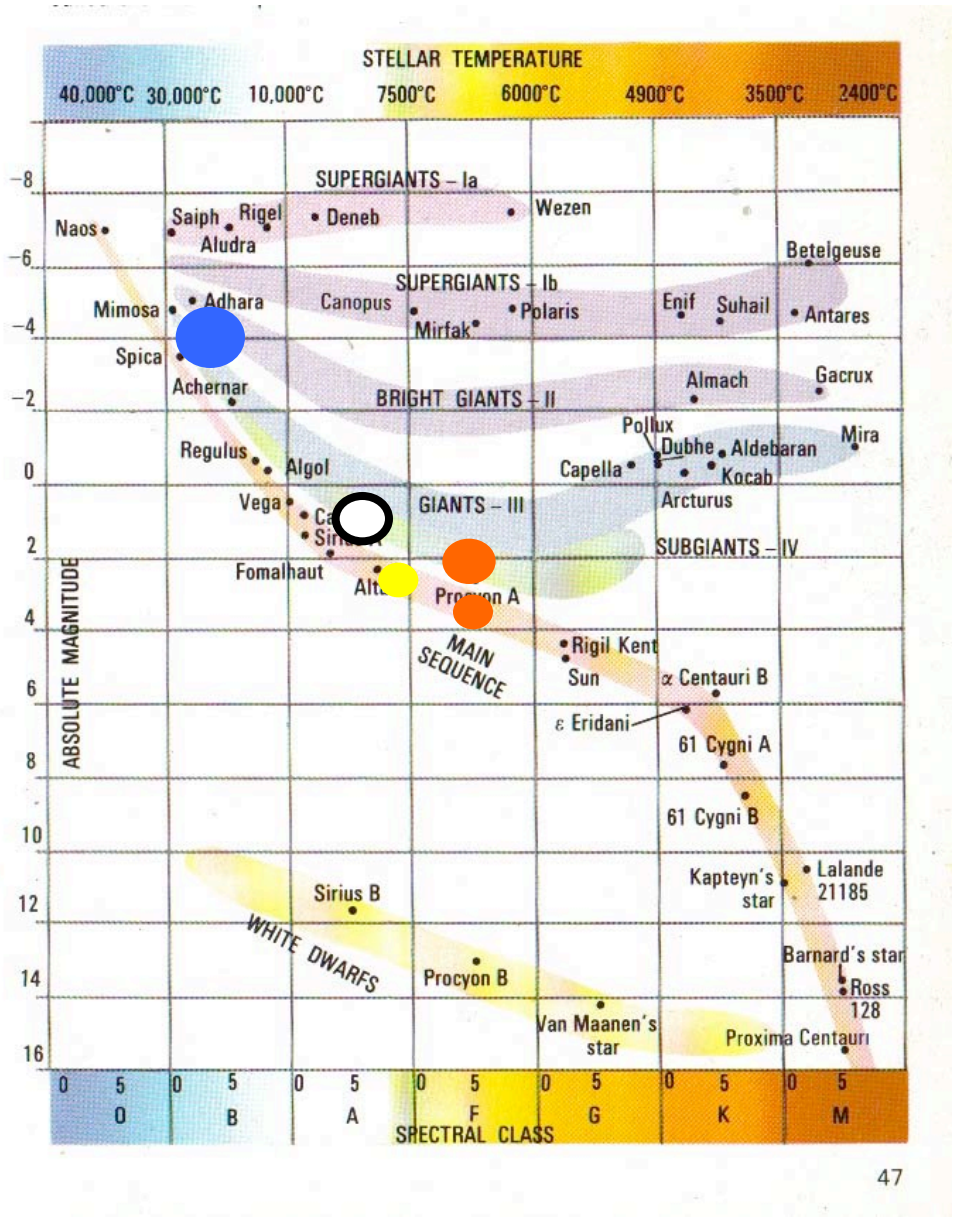
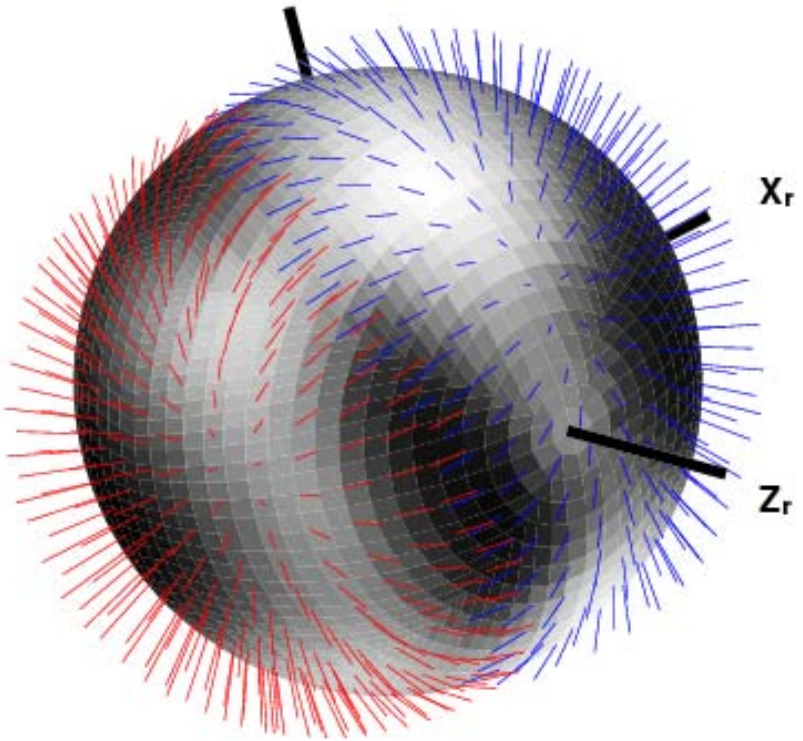


Diameter of a roAp star (γ Equ)

Scientific justifications (PI : K. Perraut):
RoAp are bright, pulsate with large amplitudes and in high radial orders. They have strong and large-scale organized **magnetic fields.** To put constraints on the interior chemical composition, the mixing length parameter and the amount of convective overshooting, asteroseismic data should be associated with **high precision stellar diameter** (*Cunha et al. 2003, MNRAS, 343, 831*).

This is very challenging due to the small angular diameter (< 1 mas) of these stars.



VEGA Observations (γ Equ)

- **2008. Baseline W1W2:**
  - **3 recordings** on γEqu sandwiched by observations of the calibrator HD195810 on July, 29th and August, 3rd and 5th.
  - **Observations at different wavelength**: 640 nm (August, 3rd and 5th) and at 590 nm and 750 nm (July, 29th)

- **2009. Baselines W1W2 and S2W2**
  - BUT problem of tracking requiring a temporal processing (to be done)
  - Need for an unbiased estimation of V^2 for the smallest visibilities (S2W2)

The angular diameter of 0.56 ± 0.01 mas obtained from the 2008' data has to be confirmed with the 2009' data

Modelling γ Equ

- **Collaboration between the VEGA consortium and M. Cunha & I. Brandao (University of Porto)**
  - Collection of photometric and low resolution spectroscopic data
  - Use of Kurucz models for UV and IR parts of the spectrum
    - ⇨ **Bolometric flux**
  - From the bolometric flux and the angular diameter determined with CHARA/VEGA observations :
    - ⇨ **Effective temperature**
  - From the bolometric flux, the angular diameter, and the parallax :
    - ⇨ **Radius and luminosity = position in the HR diagram**

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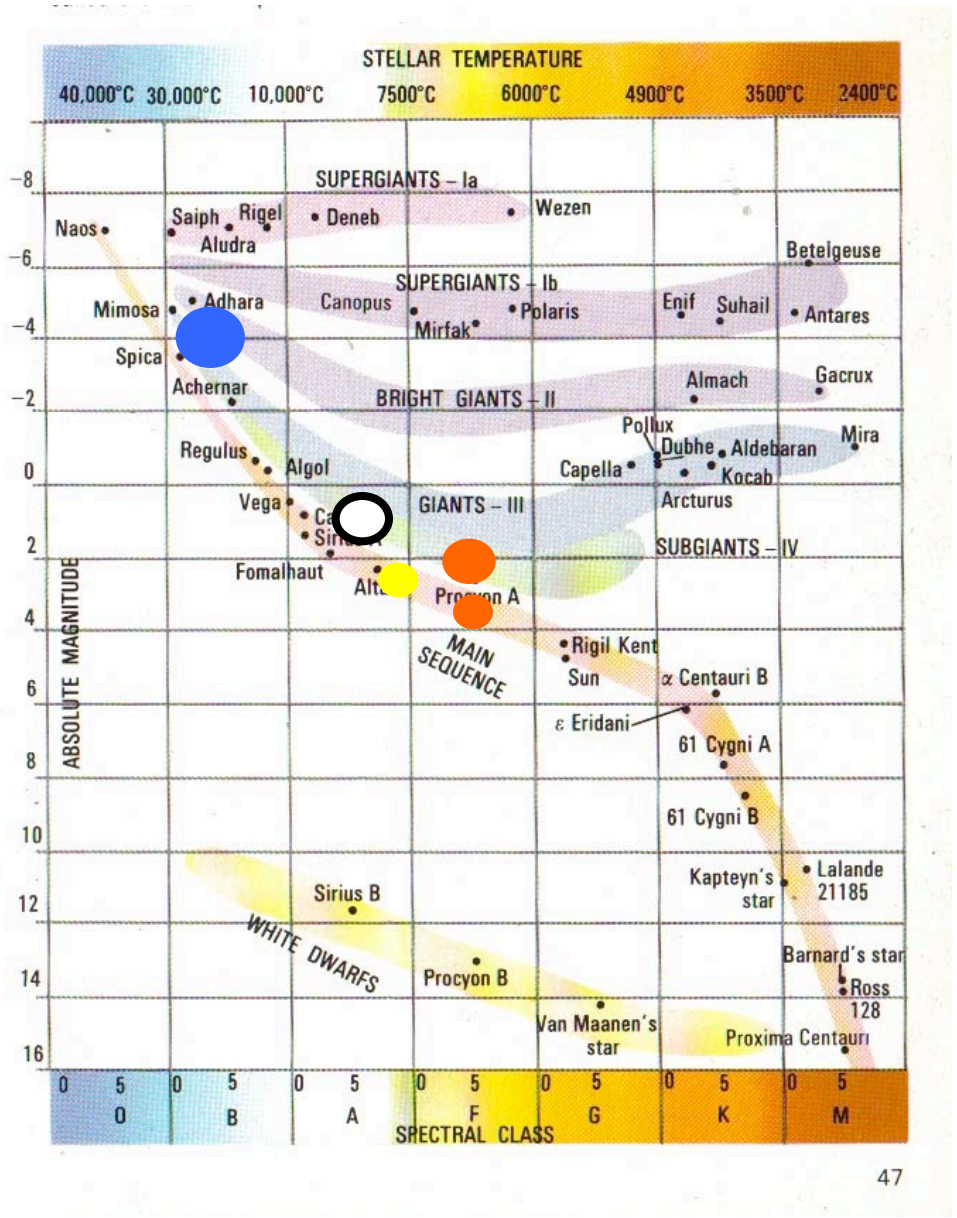


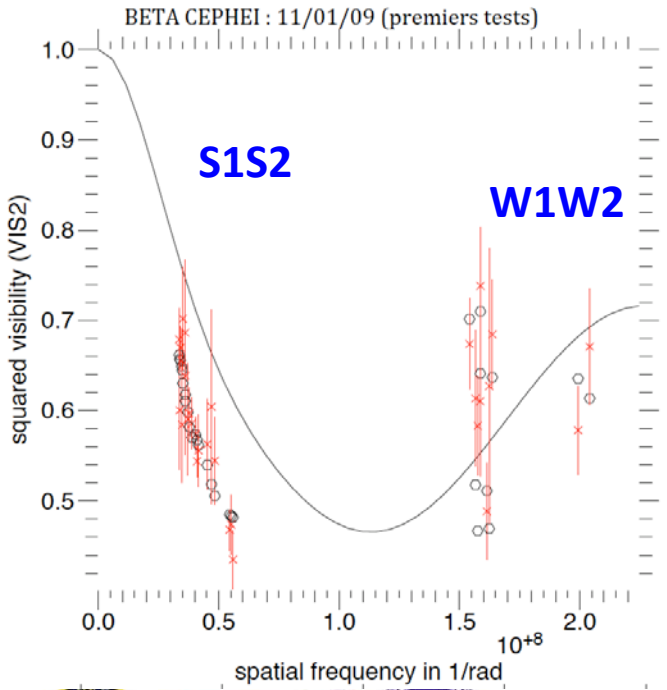
β Cep : binarity and CSE

Scientific justifications (PI: P. Mathias): Characterization of β Cep for asteroseismology. Anisotropic features at the limit of the resolution (Labeyrie et al. 1974) and a companion detected at 250 mas (Labeyrie et al. 1974, Wheelwright et al. 2009).

Date	Quality	Telescopes	Spectral Resolution
31/07/08	high	W1W2	MR
08/10/08	high	W1W2	MR
08/10/08	high	S1S2	MR
22/11/08	low	S1S2	MR
23/11/08	high	W1W2	MR
23/11/08	high	S1S2	MR
04/07/09	low	S1S2	MR
06/07/09	low	S1S2	MR
28/07/09	low	S1S2	MR
26/08/09	high	S1S2	MR

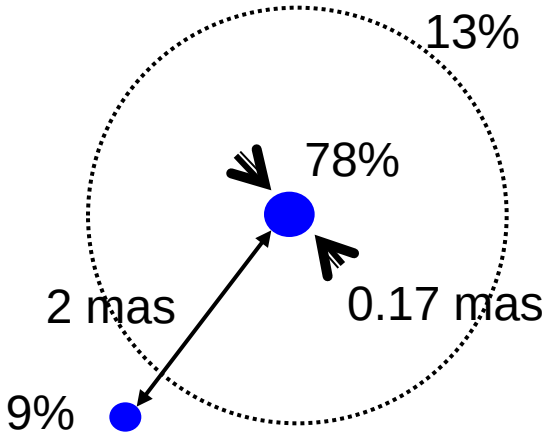
Attempts to find the 250 mas companion unsuccessful (orbital period=100y.)

Processing strategy: for the good nights estimation of V^2 in three spectral bands of 20nm (in red) and three spectral bands of 15nm (in blue)



β Cep : binarity and CSE

Model Fitting Strategy (JMMC tool): models with 6 parameters fitted : flux of the star (fixed angular diameter of 0.17mas), flux and size of a Gaussian centred on the star, flux and position (x, y) of a close companion.



Results:

name	value	standard deviation(+/-)	prev_val	vmin	vmax	scale	fixed	units
diameter1	0.17			0	0.5	AUTO	1	mas
flux_weight1	0.77756	0.14245	0.782667	0		AUTO	0	
flux_weight2	0.0890652	0.0201183	0.092013	0		AUTO	0	
flux_weight3	0.133374	0.0308341	0.12532	0		AUTO	0	
fwhm1	3.30187	0.504782	3.37757	0		AUTO	0	mas
x1	0					AUTO	1	mas
x2	0.888807	0.039244	0.880816			AUTO	0	mas
x3	0					AUTO	1	mas
y1	0					AUTO	1	mas
y2	-1.71876	0.110116	-1.71447			AUTO	0	mas
y3	0					AUTO	1	mas

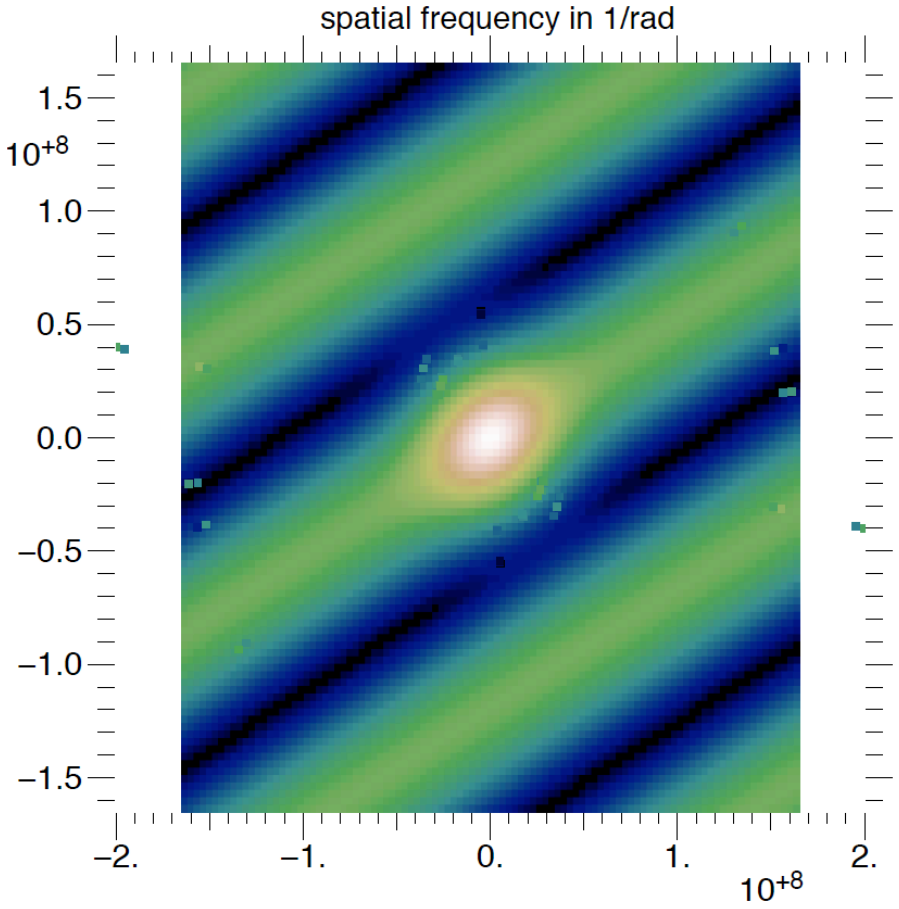
Chi2

Initial Chi2 = 24.0602 - Final Chi2 = 23.7342
Initial reduced Chi2 = 1.0025083333333333 - Final reduced Chi2 = 0.988925

Correlation between parameters:

	flux_weight1	flux_weight2	flux_weight3	fwhm1	x2	y2
flux_weight1	1	-0.249923	-0.177772	0.0156803	0.0500442	-0.105094
flux_weight2	-0.249923	1	0.530459	-0.0252773	-0.131208	0.202388
flux_weight3	-0.177772	0.530459	1	0.0238814	-0.335309	0.108447
fwhm1	0.0156803	-0.0252773	0.0238814	1	0.819255	0.746496
x2	0.0500442	-0.131208	-0.335309	0.819255	1	0.348573
y2	-0.105094	0.202388	0.108447	0.746496	0.348573	1

β Cep : binarity and CSE

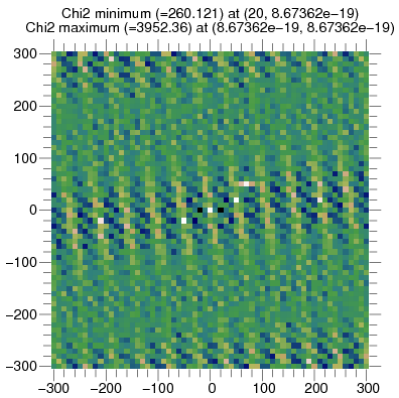


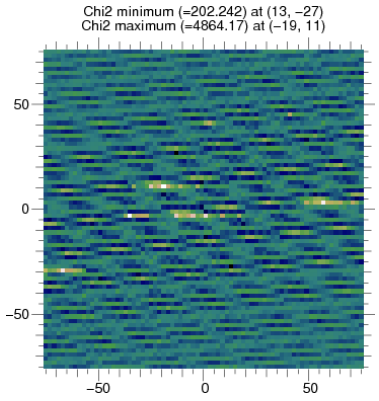
Results (continued):

- d=188+-18pc (hipparcos) give Porb=73 days
- observations at ϕ=0.0, 0.95, 1.60, 5.40!
- No detection of a companion by spectroscopy corresponding to such orbital period.

Perspectives

- more S1S2 observations (to confirm the CSE!)
- more W1W2 observations at different orbital phases to confirm the close binarity
- Differential interferometry in Hα





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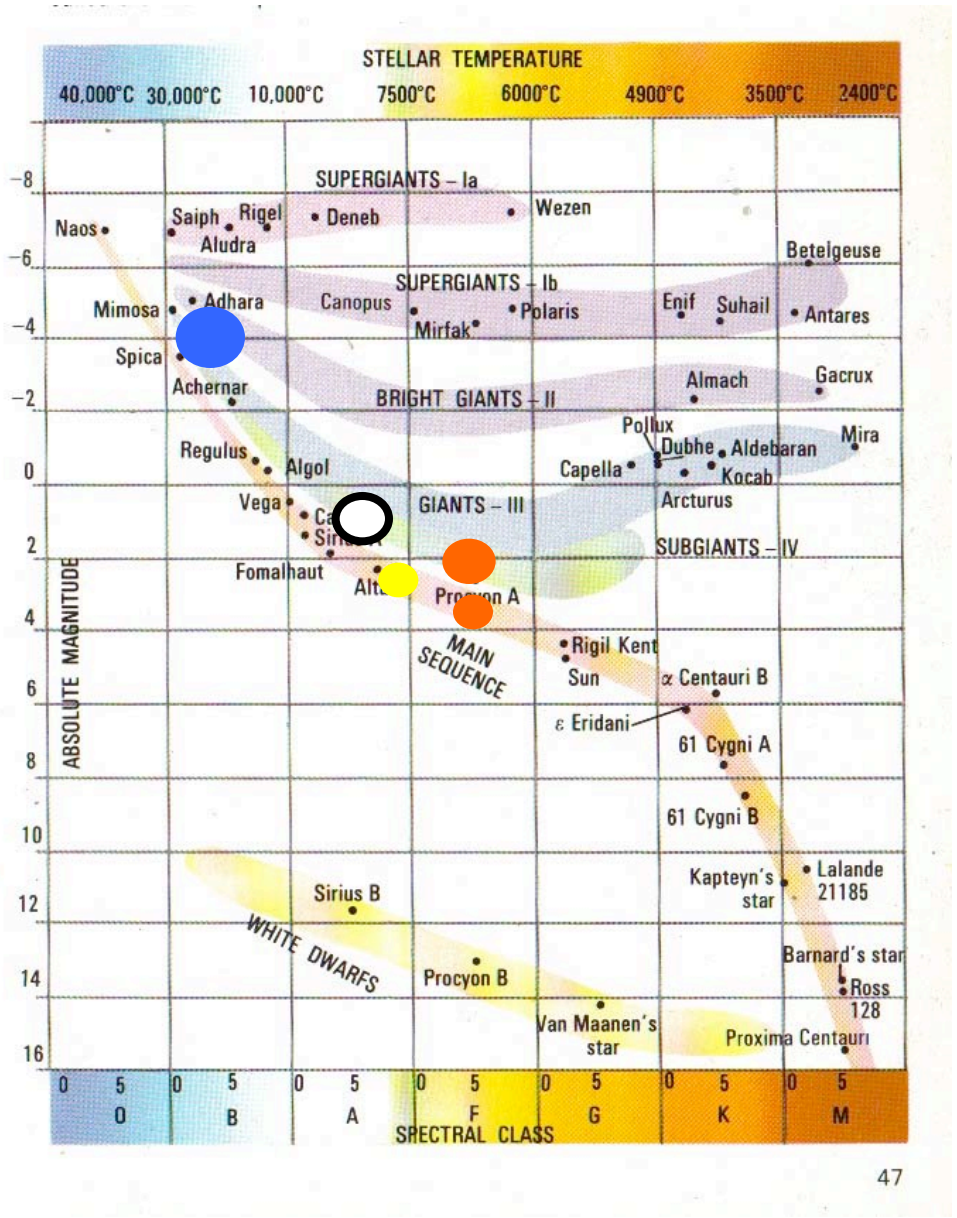


Observations of the binary system : 48 And

Scientific justifications (PI: C. Farrington): Exploring the fundamental parameters of the subgiant branch

Date	Time	Star	Telescopes	Spectral Resolution
23/11/2008	07:40	48 AND	S1S2	MR
24/11/2008	05:10	48 AND	S1S2	MR
24/11/2008	05:51	48AND	S1S2	MR
24/11/2008	06:12	48AND	S1S2	MR
01/10/2009	06:58	48AND	S1S2	MR
24/10/2009	04:35	48AND	S1S2	MR
24/10/2009	05:08	48AND	S1S2	MR
24/10/2009	06:02	48AND	S1S2	MR
26/10/2009	08:52	48AND	S1S2	MR
26/10/2009	09:29	48AND	S1S2	MR
17/11/2009	03:20	48AND	S1S2	LR
18/11/2009	01:58	48AND	S1S2	LR
18/11/2009	03:01	48AND	S1S2	LR

In blue, observations of good quality used in the model fitting process

Processing Strategy:

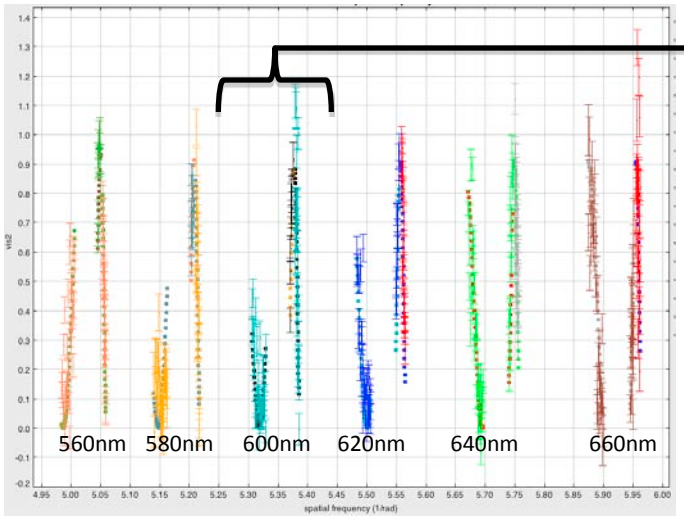
- in MR: Estimation of V^2 each 20s in 4 spectral bands of 10nm centered at 655, 665 ,675 and 685nm
- in LR: Estimation of V^2 each 20s in 6 spectral bands of 20nm centered at 560, 580, 600, 620, 640 and 660nm

Model Fitting Strategy (JMMC tool):

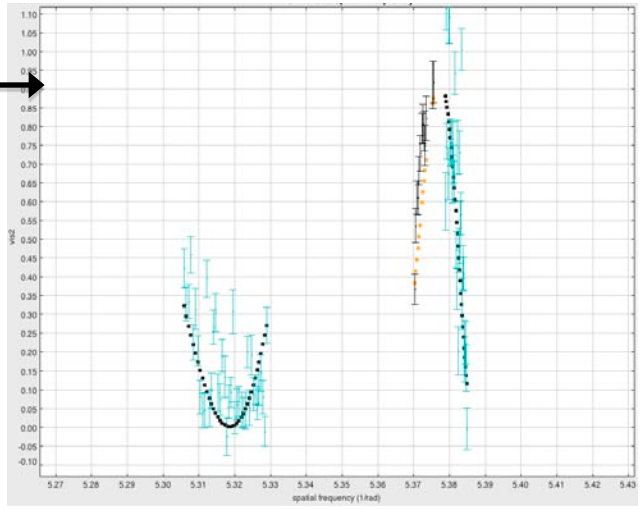
- 2 Uniforms Disks
- Fixed parameters : flux ratio=1, ϕ_1=0.82mas and ϕ_2=0.5mas
- Free parameters: Δx and Δy

Observations of the binary system : 48 And

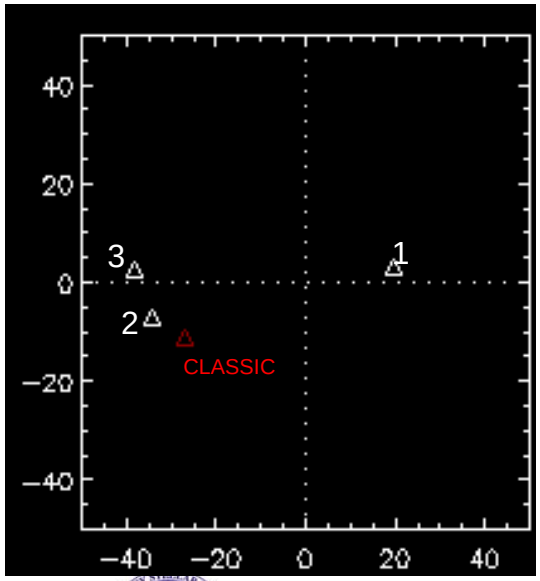
17/11/2009 and 18/11/2009 LR



Zoom λ=600nm



Date	Δx (mas)	Δy (mas)	Quality	N°	Orbital Phase (P=200j)
23-24/11/2008	19.6+/-0.1	3.1+/-0.05	Strong correlation	1	0
~10/10/2009	-26.7	-1.3		CLASSIC	1.6
24/10/2009	-34.2+/-0.08	-7.2+/-0.03	good	2	1.67
17-18/11/2009	-38.6+/-0.09	2.4+/-0.02	good	3	1.8



Conclusion : interpretation?

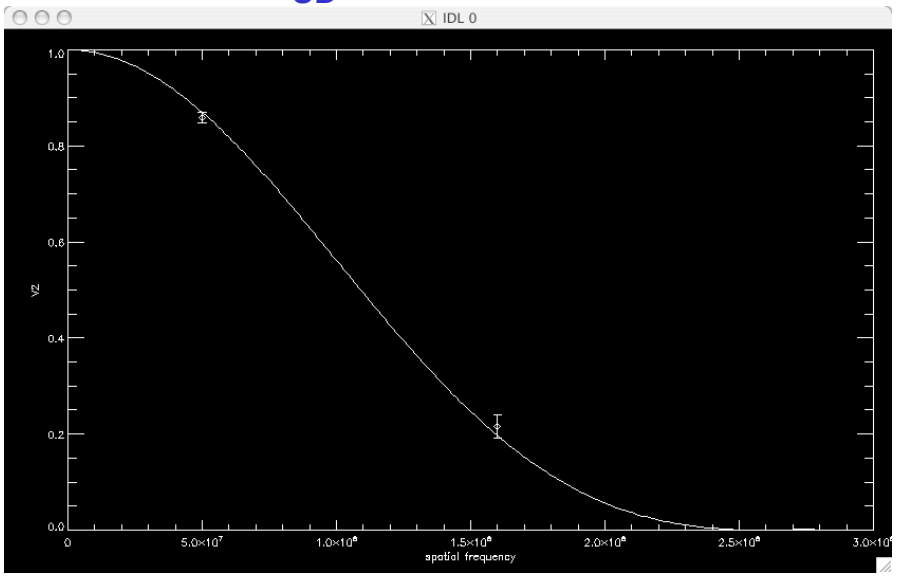
SubGiants (PI: C. Farrington)

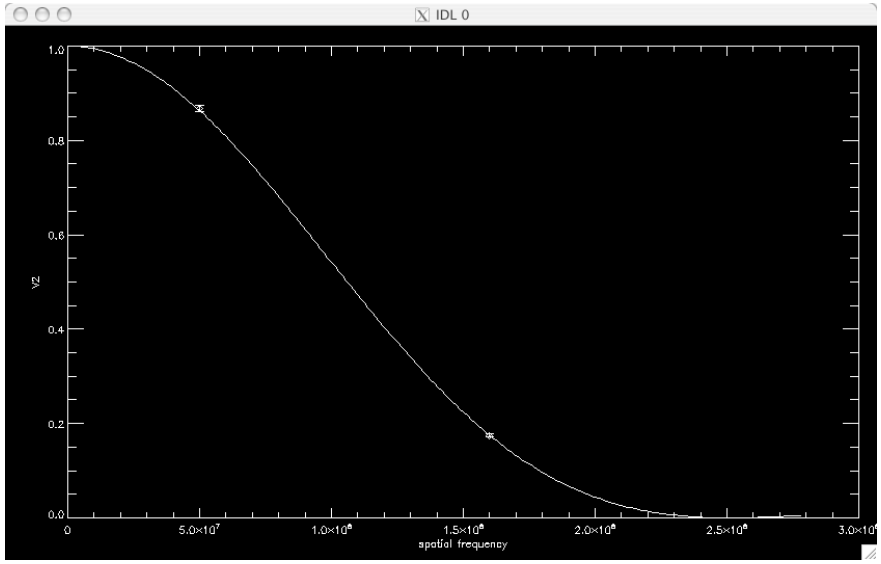
Current sample:

HD216385(F7IV) – HD220657(F8IV) – HD202444(F0IV) – HD211336(F0IV)

Analysis done for HD220657:

$\theta_{UD}=0.97\pm0.05$ (old method)





$\theta_{UD}=1.00\pm0.01$ (new method)

Photon centroiding hole correction may introduce a bias on V^2 at low level
(not fully validated at that time)

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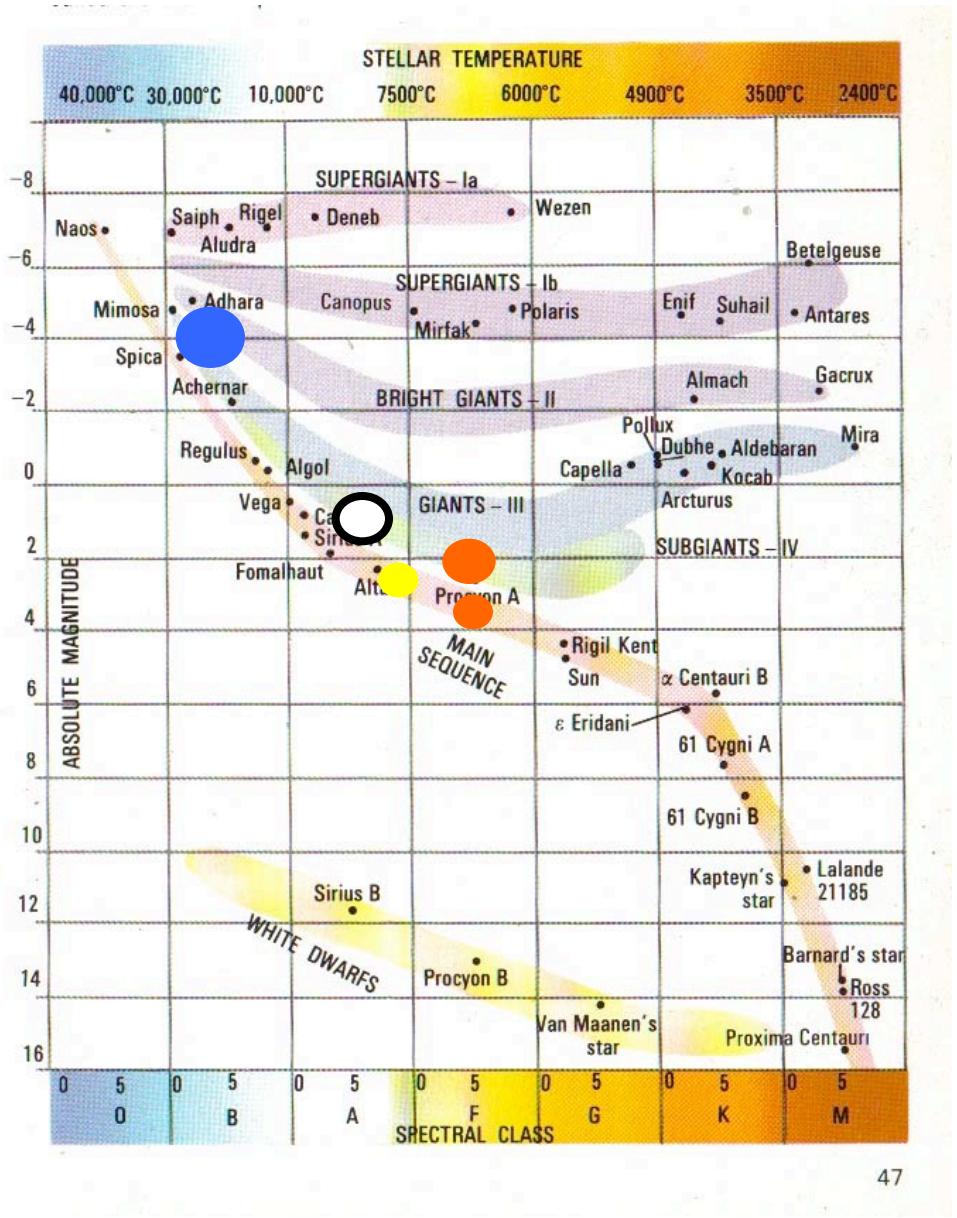
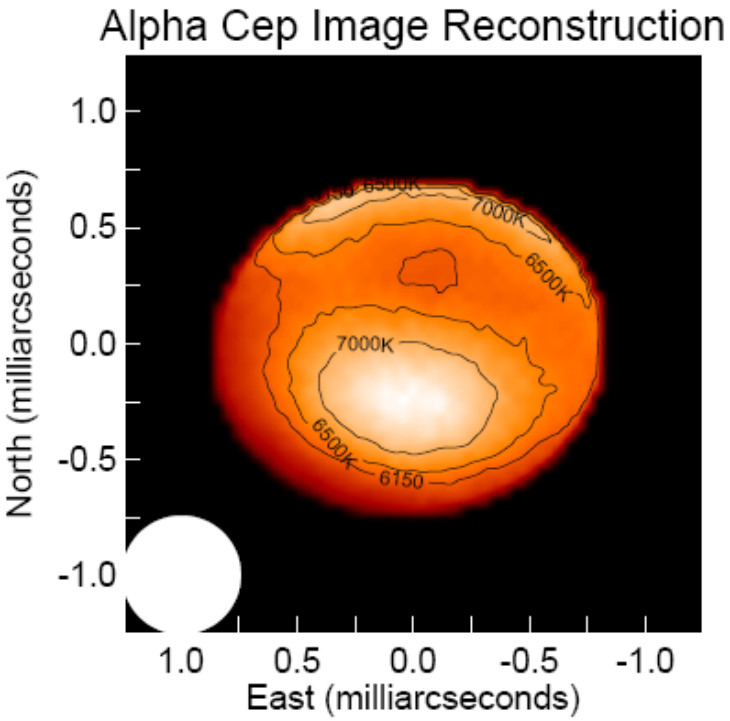


The fast rotator αCep

Von Zeipel effect
(PI: K. Perraut, A. Domiciano):

- Photosphere distorsion due to the centrifugal force ⇨ **oblateness**
- The equatorial temperatures are predicted to be much cooler than the polar ones: **"Gravity Darkening"**

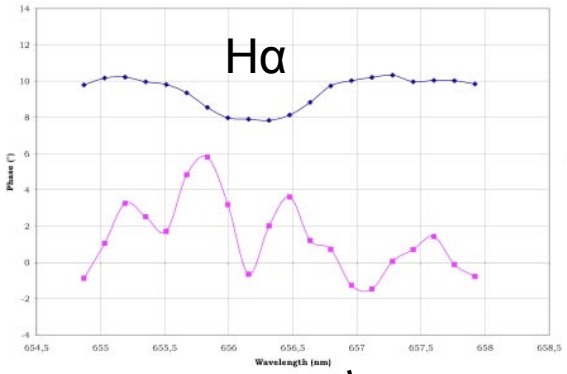
(Zhao et al.)



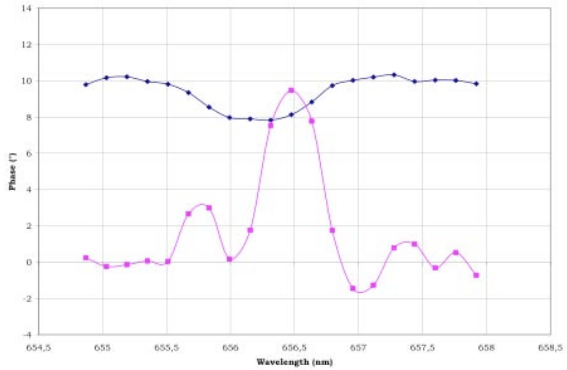
i (°) = 55.70 ± 6.23
PA (°) = -178.84 ± 4.28
Tpol (K) = 8588 ± 300
Rpol (R⊙) = 2.162 ± 0.036
Teq (K) = 6574 ± 200
Req (R⊙) = 2.740 ± 0.044

VEGA Observations (α Cep)

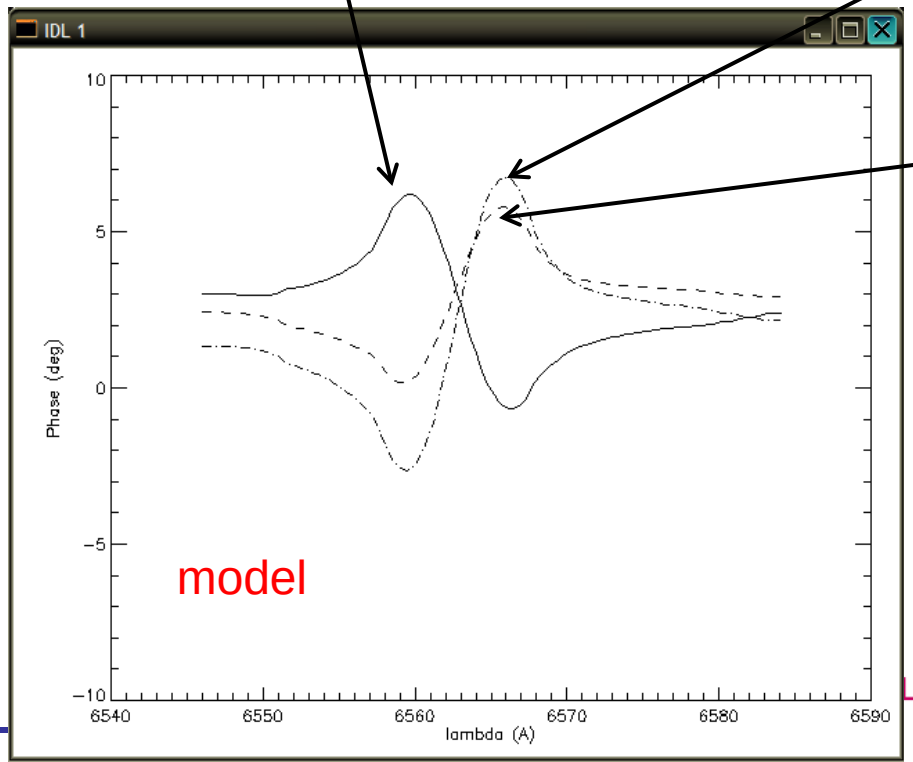
B = 28.4 m / PA =



B = 29.3 m / PA = -20.1°



B = 26.4 m / PA = -42.1°



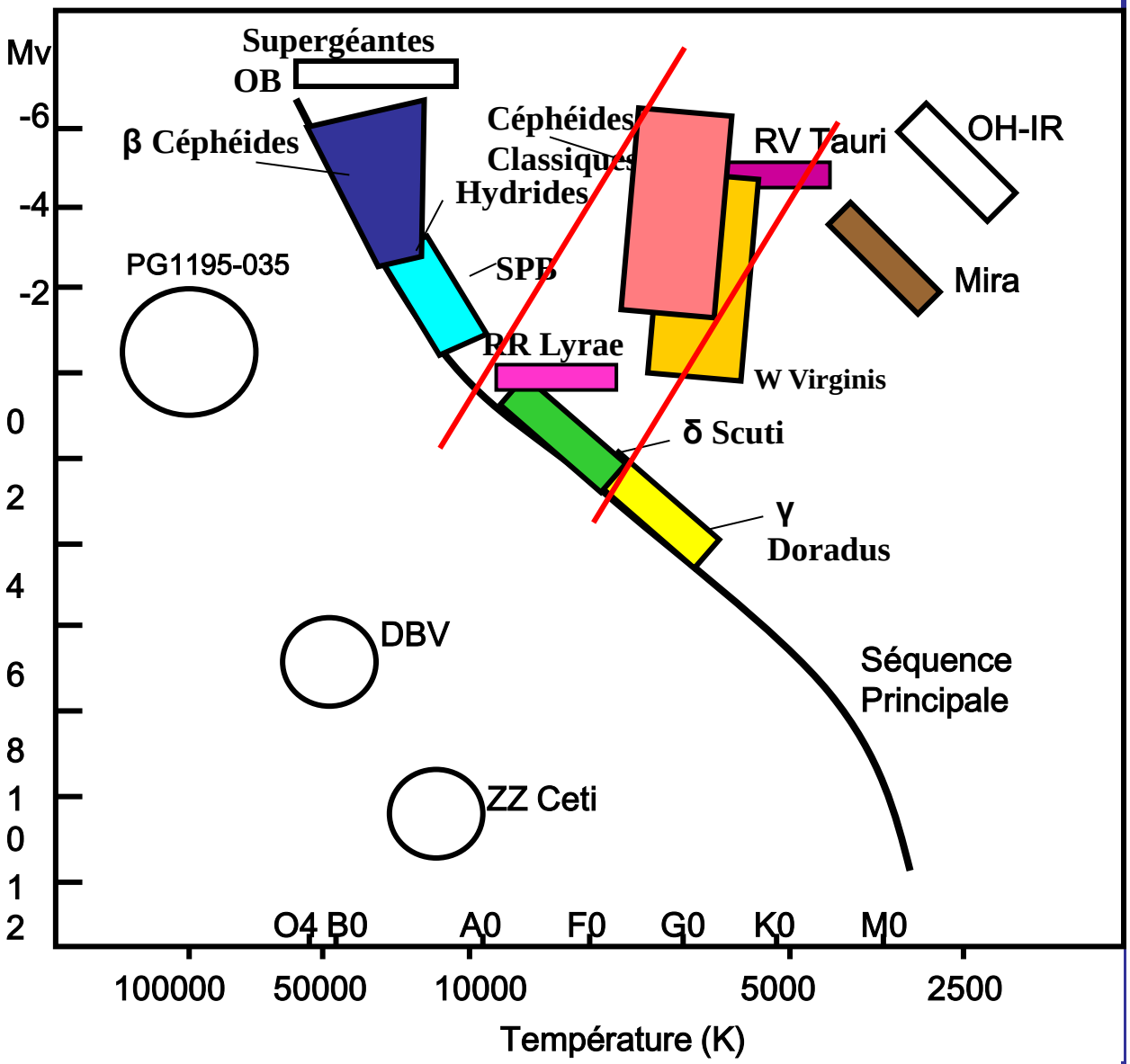
Prospective

Static stars:
1/ angular diameter

Pulsating stars:
1/ angular diameter variation (distances):
Cepheids (PL1)
W Vir /RR Lyrae/High-Amplitude δ Scuti (PL2)

2/mean angular diameter (asteroseismology) : β Cep, SPB, δ Scuti, γ Dor, RoAp

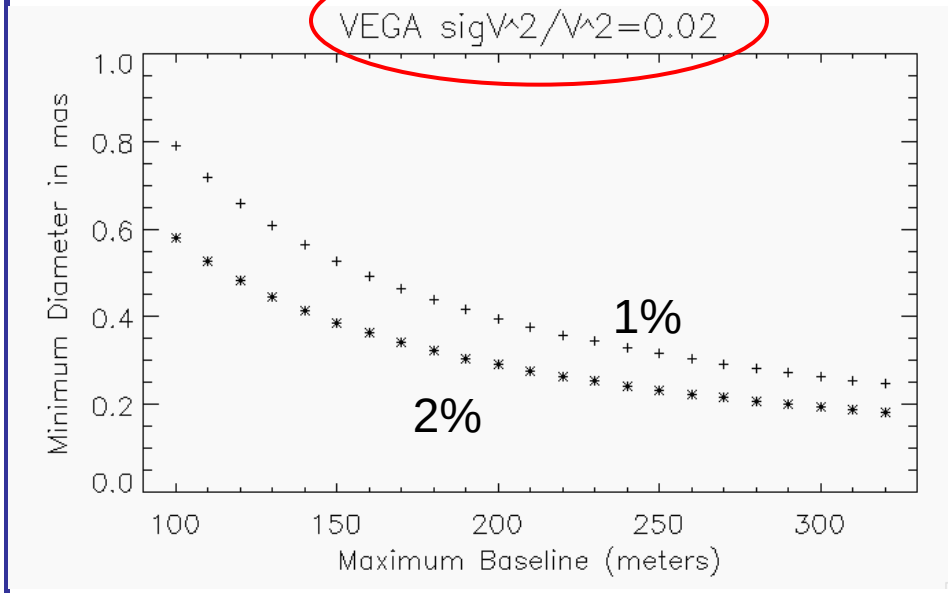
3/ masses (binaries)

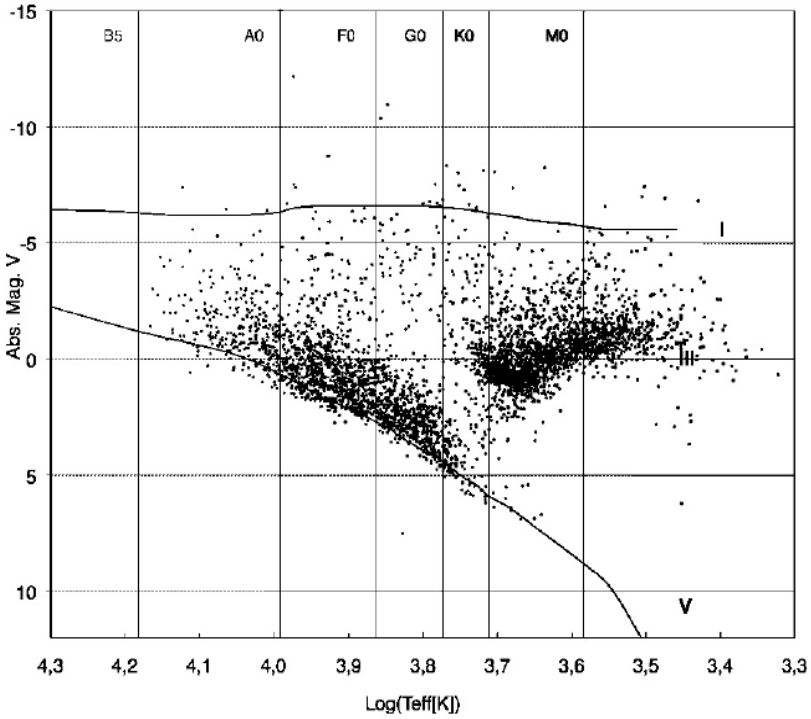


Static stars (see Mourard et al. 2009):

1/ Mean angular diameter

External Fringe tracker





4000 stars brighter than mV=6.5 that can be detected by VEGA with accuracy better than 2% ⇨ constraints on models (Creevey et al. 2007, Kervella et al. 2008)

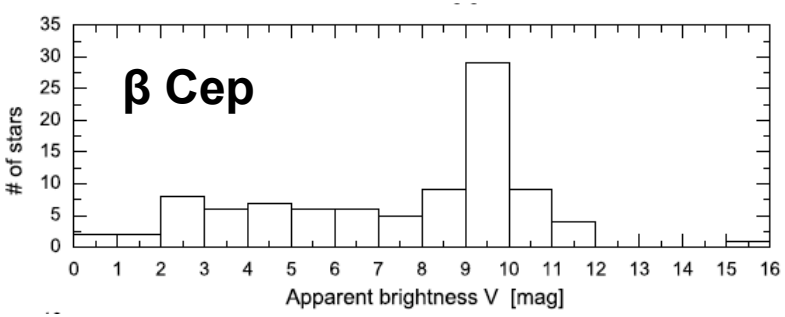
Pulsating stars (need AOs + external fringe tracker):

1/ angular diameter variation (distances): 2/mean angular diameter (asteroseismology) :

	Magnitude	V<7	V<9	
PL1	Cepheids	20	40	θ>0.3mas
PL2	W Vir	0	?	
	RR Lyrae	0	?	
	HADS	0	3	θ>0.2mas (variation?)

(δ > -30°)

Fernie et al. 1995
MacNamara et al. 1997



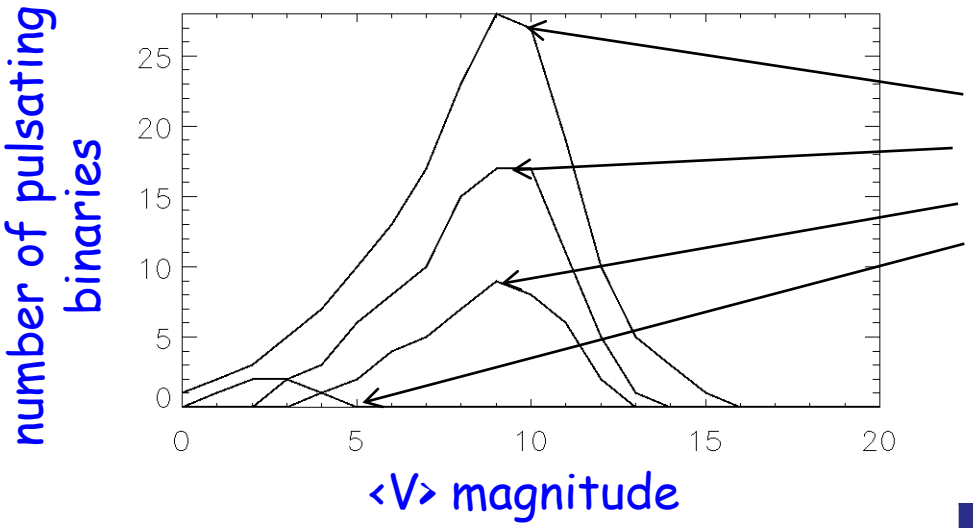
Magnitude	V<7	V<9	
β Cep	15	15	θ>0.2mas
δ Scuti	110	140	θ tbd
γ Dor	11	35	θ tbd
RoAp	5	9	θ < 1 mas

Precision and exactitude of 0.01 on the PL relations (5% on Ho)

Garcia et al. 1995
Stankov et al. 2005
Matthews et al. 1999
CGVC

Pulsating Binaries (need AOs + external fringe tracking)

3/ masses (binaries)



Zhou 2010 (δ > -30°)

182 : total of pulsating binaries

100 : Cepheids

49 : δ Scuti

10 : β Cephei

3 : SPB

12 : DBV

4 : "Solar Like" Pulsators

4 : γ-Dor

Magnitude	V<7	V<9
Pulsating Binaries	45	85

Bias by flux ratio and separation

Note : eclipsing binaries are now used to determine the distance of LMC. VEGA can calibrate the method observing Galactic eclipsing binaries (programs in progress)

Conclusion and perspectives

- **VEGA visibility accuracy and sensitivity** allow us to lead observing programs dedicated to fundamental parameter measurements.
- **VEGA high spectral resolution mode** opens a field of investigation in the area of fundamental parameters (rotation, pulsation, mass loss, magnetism).
- Interpretation needs **models**. Collaboration are in progress.
- All these fields will take benefit from :
  - **V+IR observations**
  - **The polarimetric mode SPIN of VEGA**
  - **3T and 4T**

… papers soon!

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β Cep	15	15
δ Scuti	110	140
γ Dor	11	35
RoAp	5	9