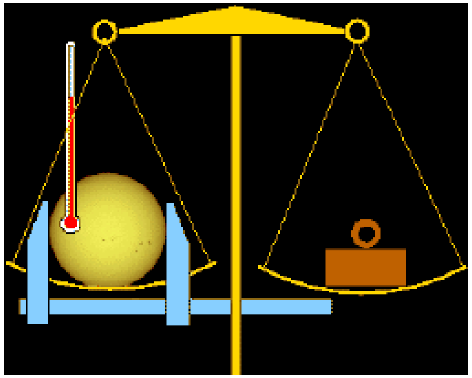
First science results with VEGA (I)

Fundamental parameters
Stellar activity

Karine Perraut and the CHARA/VEGA consortium

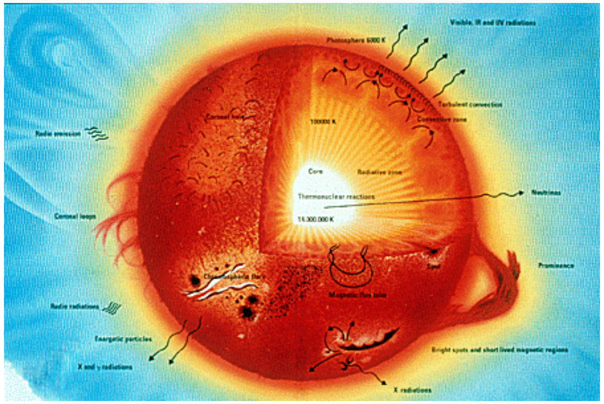
Science drivers



Physical processes working in the stellar interiors as well as the evolution of stars are based on **fundamental parameters** (**mass, radius, luminosity, abundances).**

The **effective temperature**, the **surface gravity** and the **mean density** are defined from these fundamental parameters.

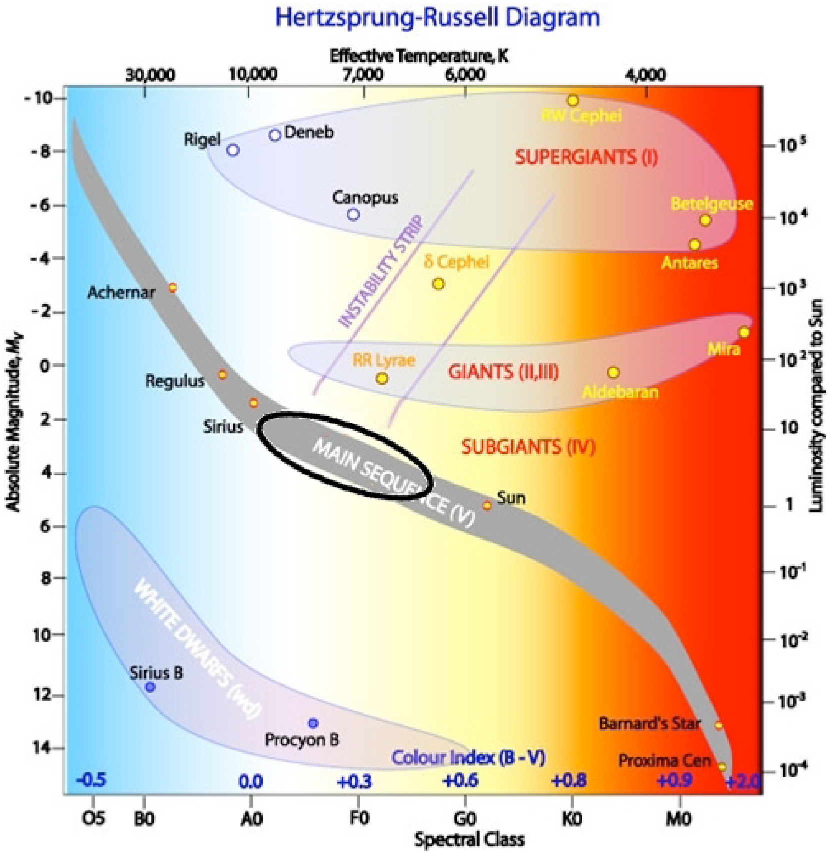
Mass loss rate, **pulsation period**, **rotation period** or **magnetic field** are also interesting for the study of peculiar evolutionary stage.



Comparing the observed location of a star in a H-R diagram and its location predicted by theoretical evolutionary tracks is a classical way to test the **stellar interior models.**

Outline

- **Fundamental parameters**
  - HAR (visible + long baselines) and High Spectral Resolution
    - Diameter measurement of an exoplanet host star
    - Diameter measurement of a roAp star γEqu
    - Limb-darkening of Sirius
- **Stellar activity**
  - High Spectral Resolution
    - Variability and wind of Deneb
    - Pulsations of δCep et βCep



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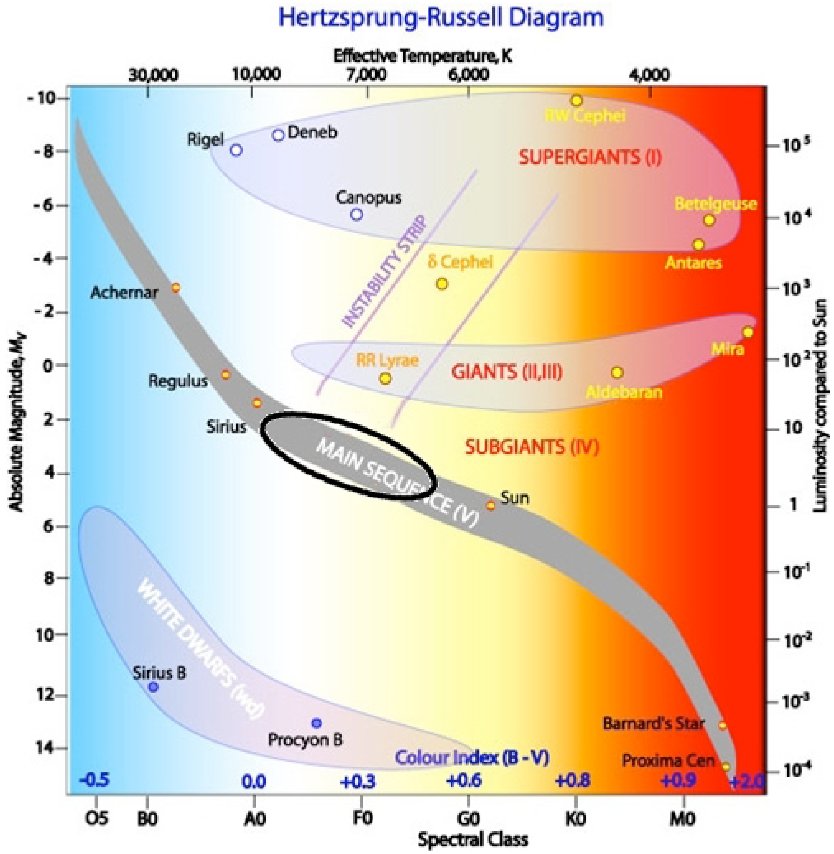

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  - High Spectral Resolution
    - Wind of Deneb
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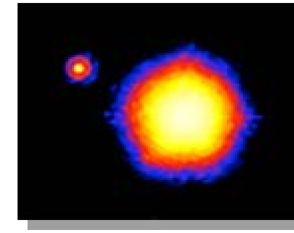
Diameter of exoplanet host stars



- Large pr... campanion detection... rs are followed in radial...
  - Detect... which radial velocit...
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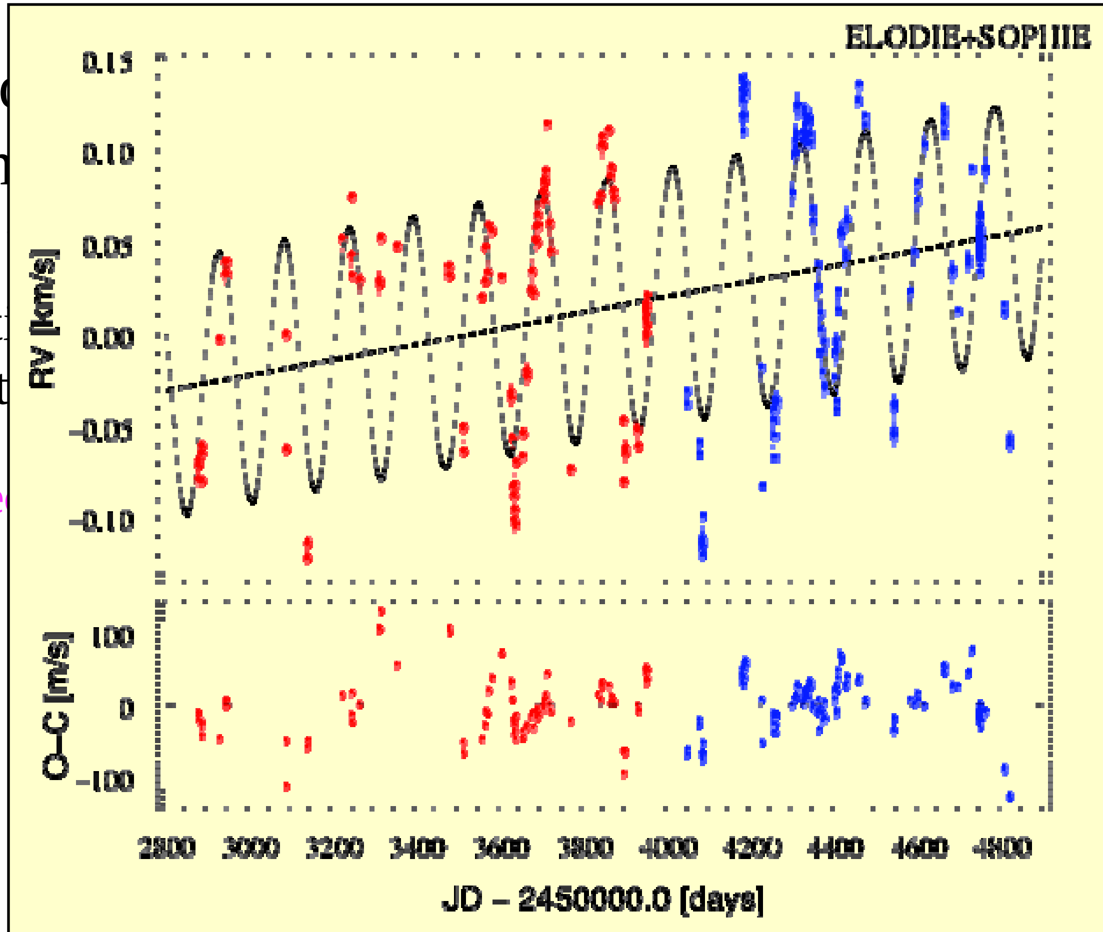
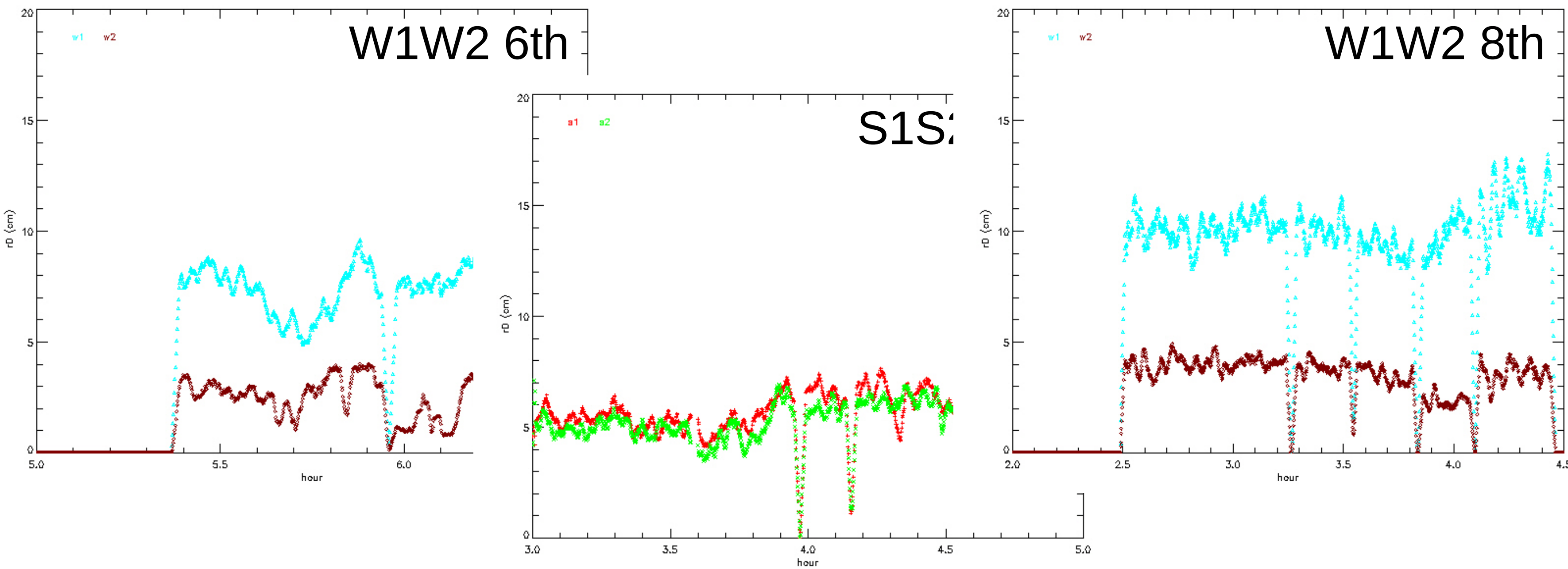
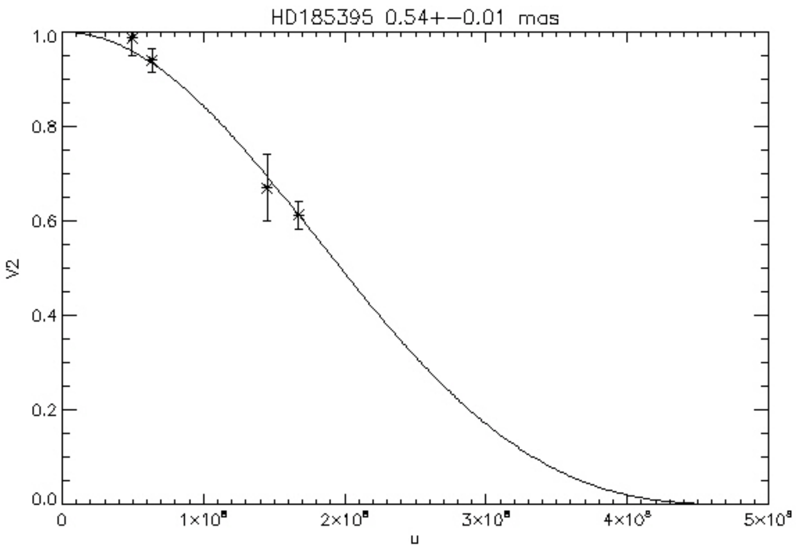


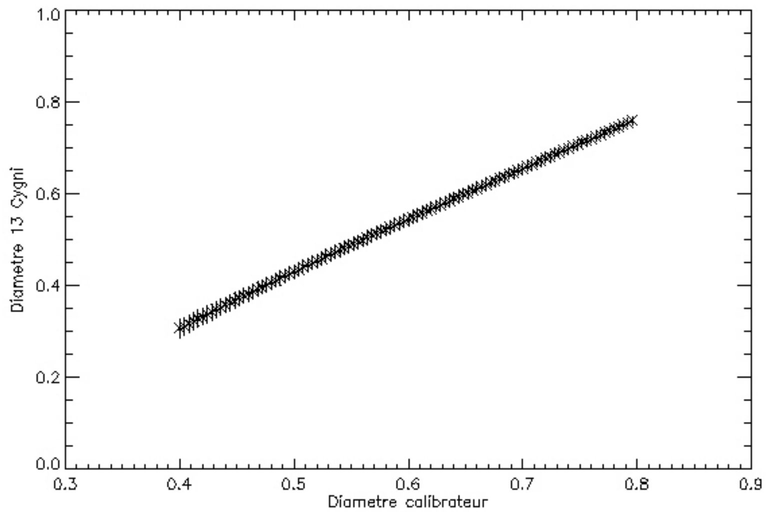
VEGA observations

- Observations on W1W2 (October 6th and 8th) and on S1S2 (October 7th)
  - Oscillations with W2 leading to low V^2
  - Good red and blue data on S1S2 (despite the lower seeing)



Results





1. The measured diameter **(0.54 ± 0.01 mas)** is smaller than the expected value of 0.8 mas (F4V star)
2. The measurement is strongly correlated to the calibrator diameter (the calibrator is larger than the star !)
3. We also attempted to check the effects of surface spots on V² (JMMC model fitting tool) but the data are too poor at that time to be constraining enough.

More measurements are necessary: longer baselines, other calibrators, 3T

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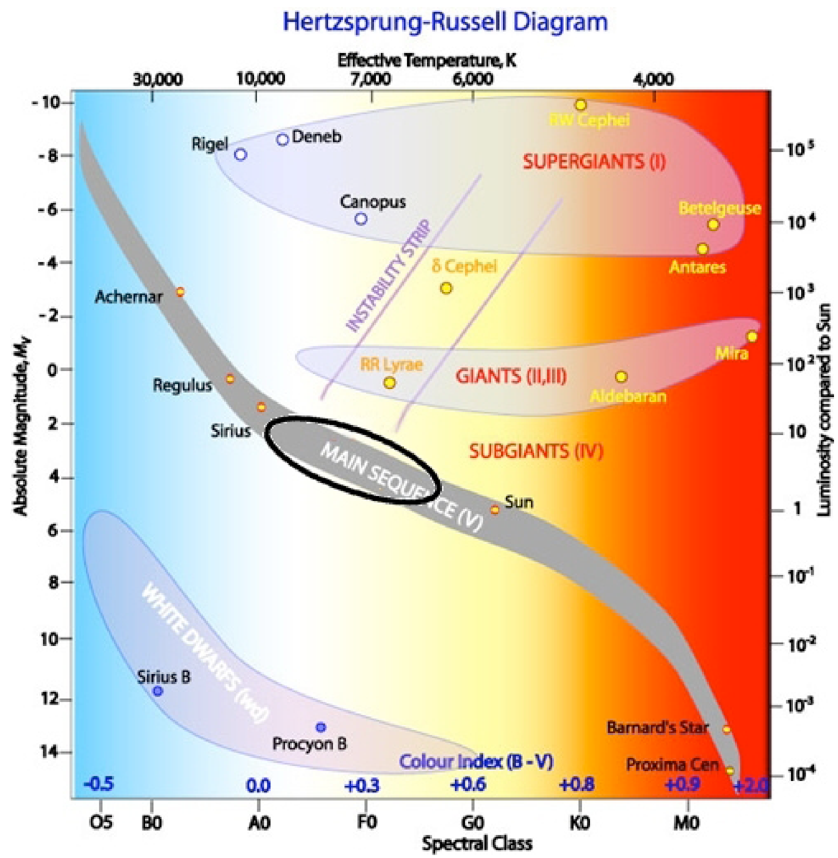
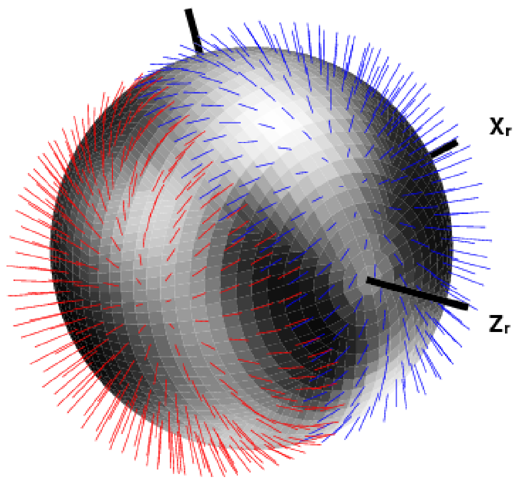
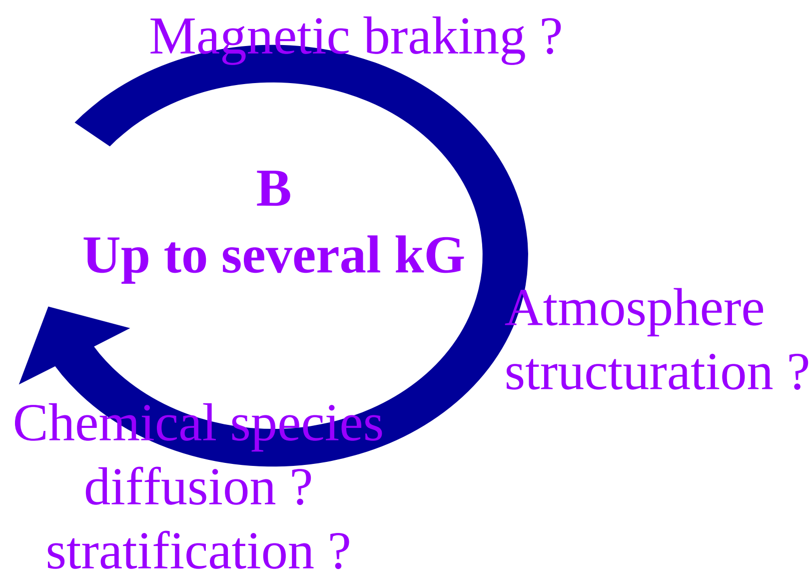


Diameter of a roAp star (γ Equ)

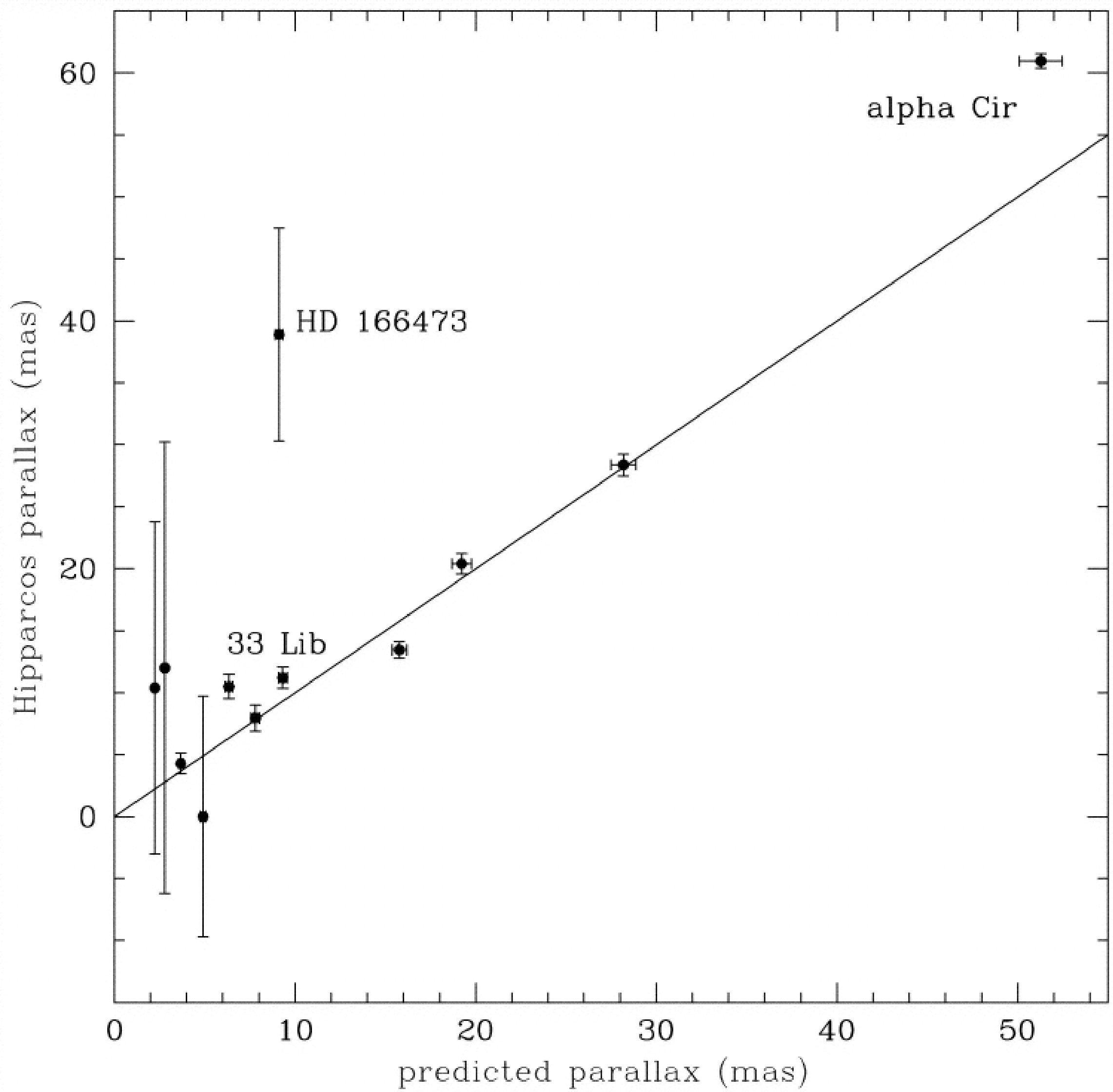
- Characteristics of Ap (or Chemically Peculiar) stars:
  - Strong and large-scale organized magnetic fields
  - Abundance inhomogeneities leading to spotted surfaces
  - Small rotational speeds
  - Pulsations with periods of a few minutes for roAp (rapidly oscillating Ap) stars.





Rationale

- roAp are br… …orders. Thus they are pa… …contribute in an uniqu… …ion of stars.
- However, t… …, the mixing length para… …eroseismic data should… *Cunha et al. 2003, MNR…*
- Diameter is… …fective temperature… determinati… This well known fact… and compromis… …rs.

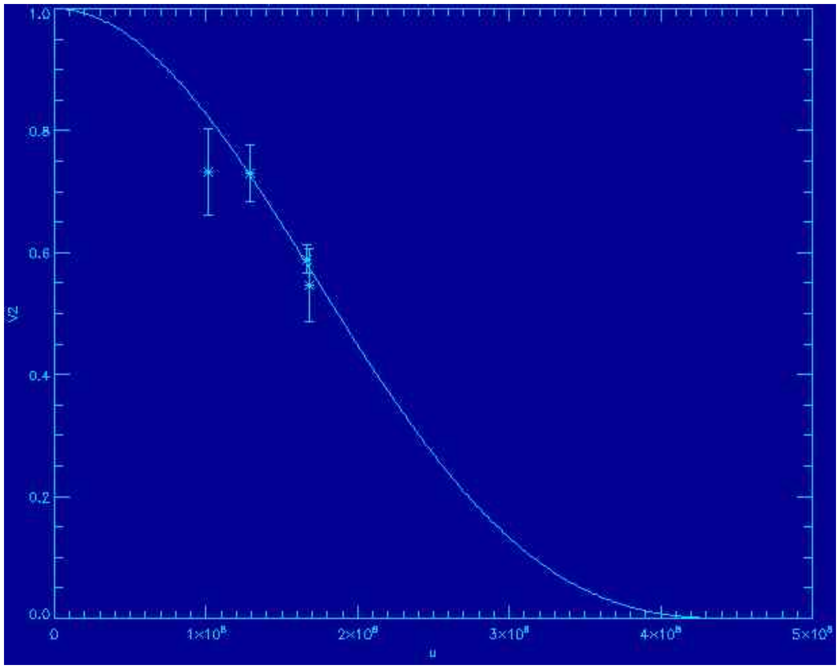


VEGA Observations

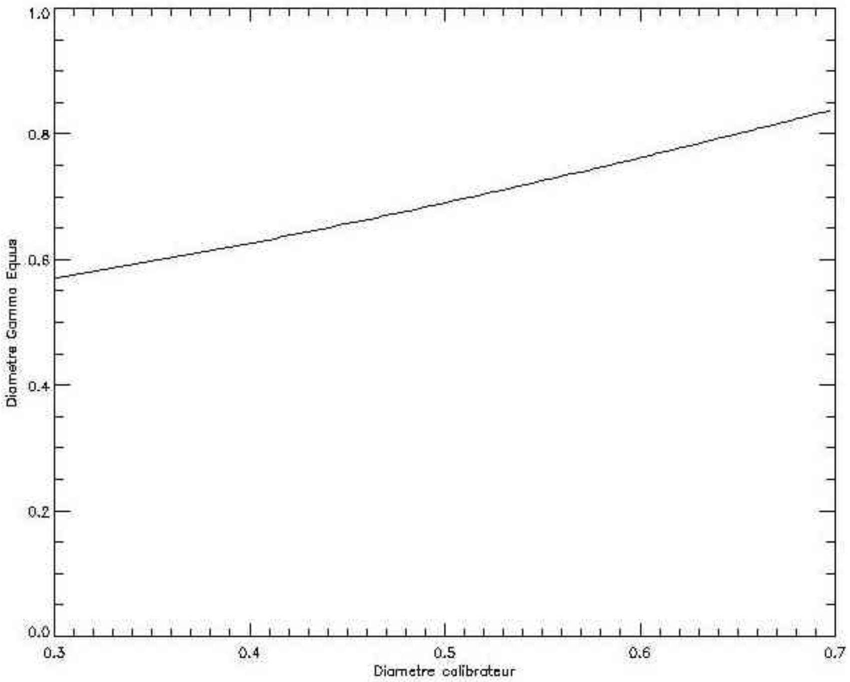
- **Baseline W1W2:**
  - 3 recordings on γEqu sandwiched by observations of the calibrator HD195810 on July, 29th and August, 3rd and 5th.
  - Blue and red cameras
  - For the red camera, λ_0 = 750 nm (July, 29th) or 640 nm (August, 3rd and 5th)

- Processing by **autocorrelation** with a spectral window of 6.5 nm
  - **Blue camera**:
    - only one calibrated point corresponding to the July, 29th
  - **Red camera**
    - Three calibrated points

γEqu results



Sensitivity to calibrator diameter



⇨ Diameter 0.56 ± 0.01 mas

φ = 0.301 mas (SearchCal)

Conclusion and perspectives

- **Accurate diameter measurement** of the roAp γEqu thanks to VEGA observations in blue and red cameras with the W1W2 baseline.
    - Accuracy of 1.8% on the angular diameter
- Collaboration with M. Cunha and I. Brandao (University of Porto) to determine the **effective temperature** from the angular diameter and the parallax (without using photometric and multiband spectroscopic observations)
    - *Cf. Analysis done on αCir (Bruntt et al., 2008, MNRAS, 386(4), 2039)*
- Interest to observe such a target in a 3-telescope mode

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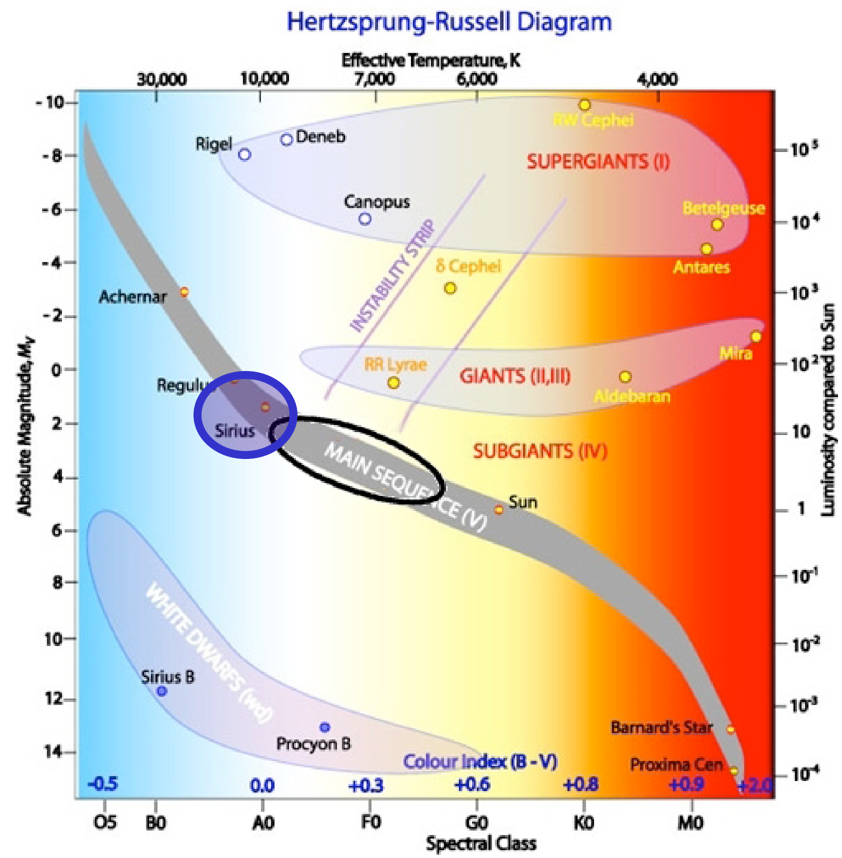
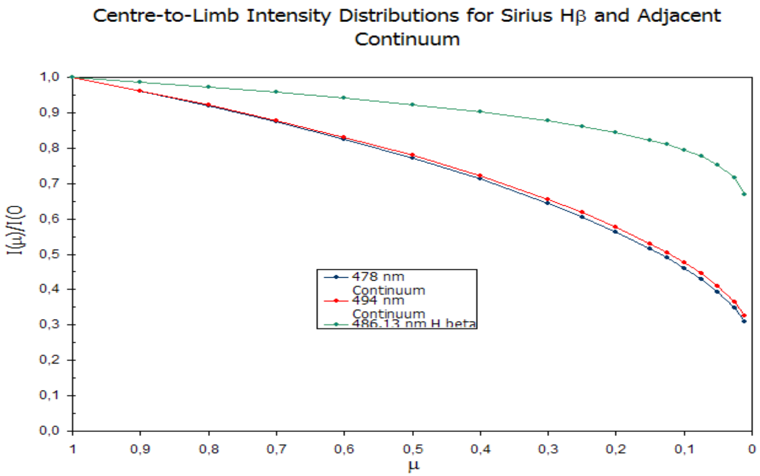
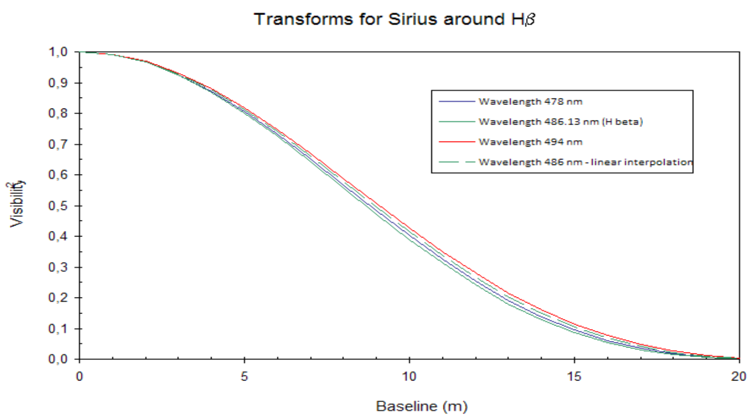


Limb-darkening of Sirius





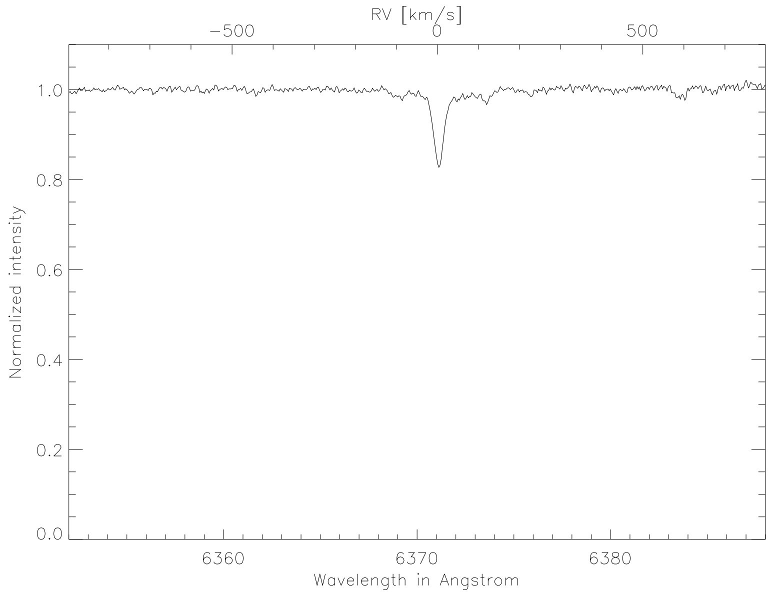
Simulations of centre-to-limb intensity for SIRIUS in Hβ (J. Davis et al.) & SUSI attempts (Hβ)

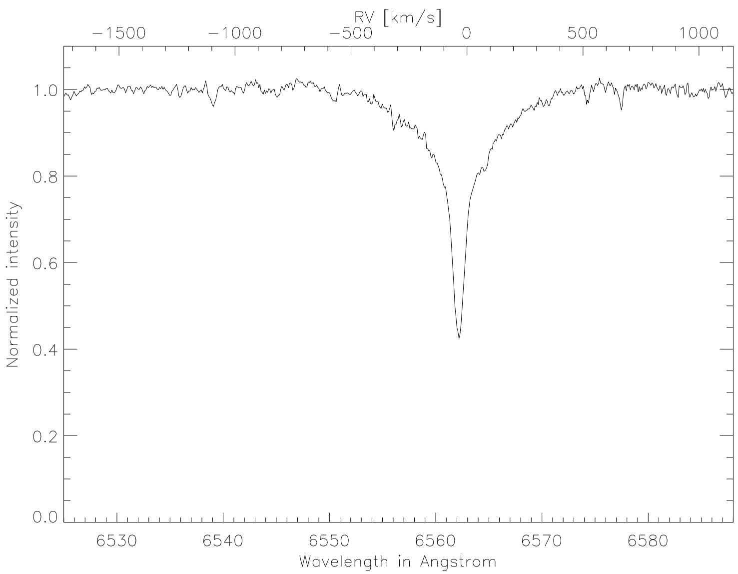
If the V² measurements are interpreted as Uniform-Disk diameters, then in the line, the diameter should be larger than in the surrounding continuum.

VEGA attempts in Hα and the High Spectral resolution

VEGA observations

- **Baseline S1S2:**
  - 1 recording on Sirius sandwiched by observations of the calibrator HD33904 on October 8th.
  - High Spectral Resolution
  - Blue and red cameras observing about 6 nm
  - For the blue camera, λ_0 = 637 nm For the red camera, λ_0 = 656 nm

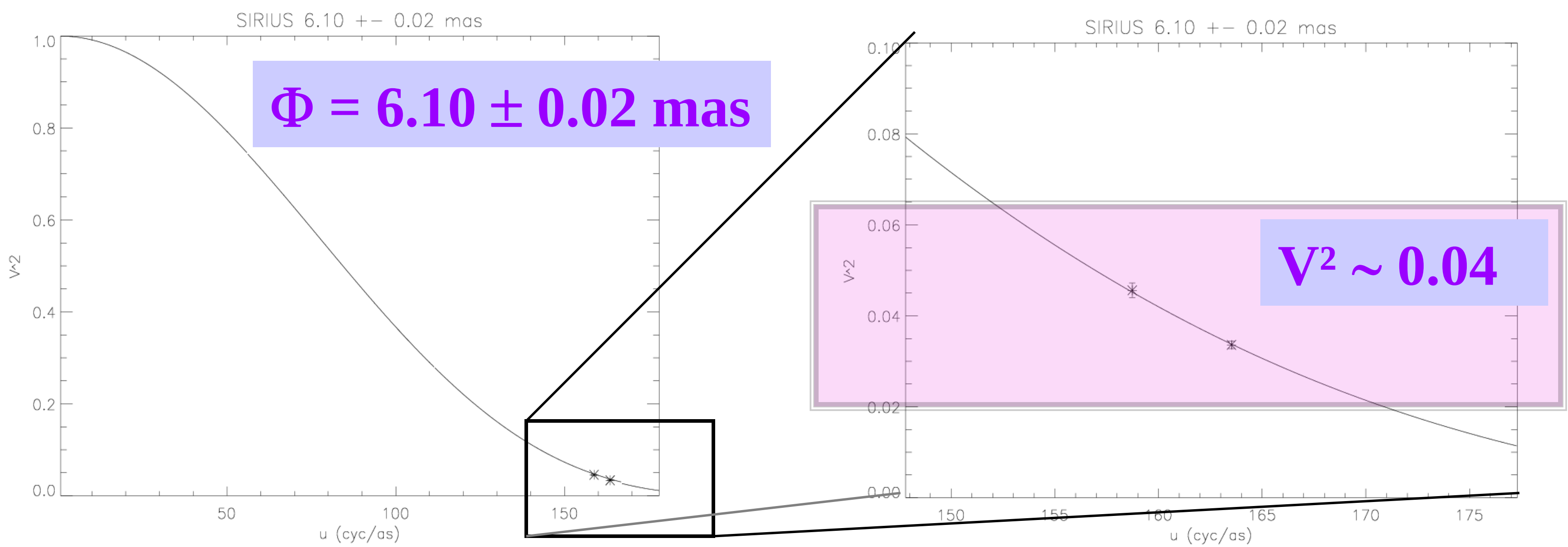




Sirius uniform disk result

- Data processed by autocorrelation calibrated by HD33904

(φ = 0.52 mas)



Differential Spectral Analysis

- Estimation of $V(\lambda)$ and $\varphi(\lambda)$, $\varphi(\lambda)$ the differential phase

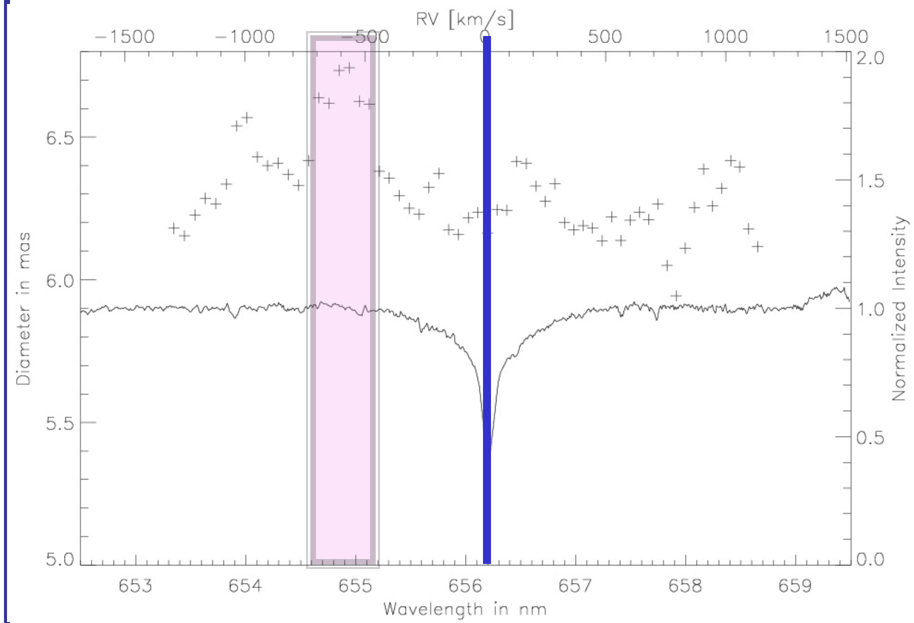
- The reference band is the same as the spectral band used for uniform disk analysis. The science band is 0.6 nm wide and moves over 6 nm by step of 0.1 nm.

- At each step, we measure $V_{ref} \times V_{sci}$ on SIRIUS and on the calibrator and we use our calibration process to deduce $V_{sci}(\lambda)$ *(Remember the Denis' talk).*

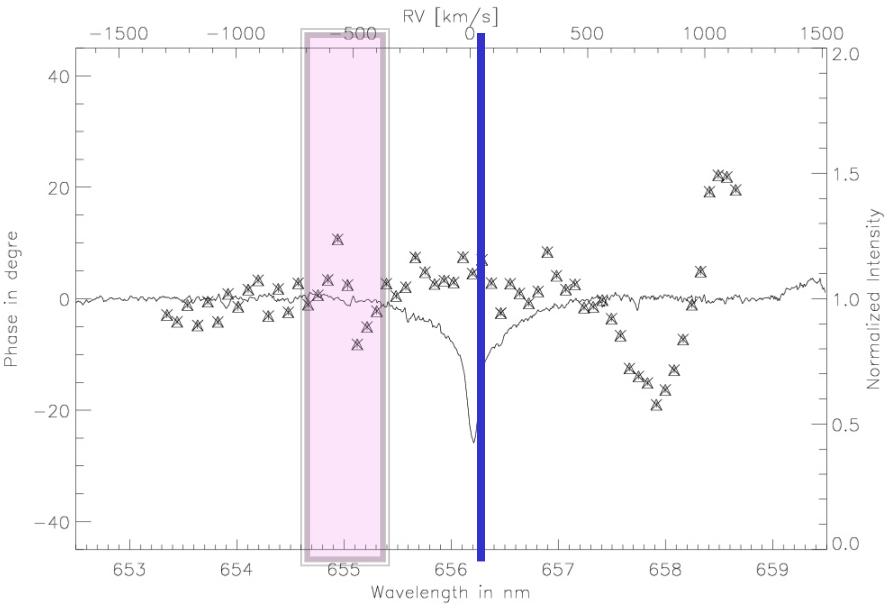
- We obtain a mean angular diameter of **Φ = 6.3 mas**, which is a little bit larger than the value obtained by autocorrelation (6.1 mas)

Results with AlgolR (1)

Angular diameter vs. λ



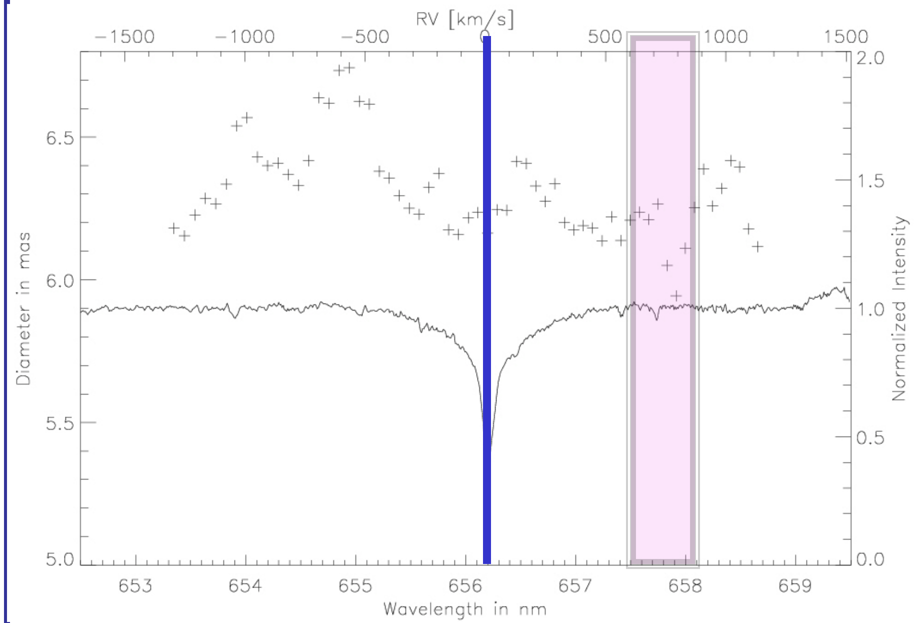
φ vs. λ



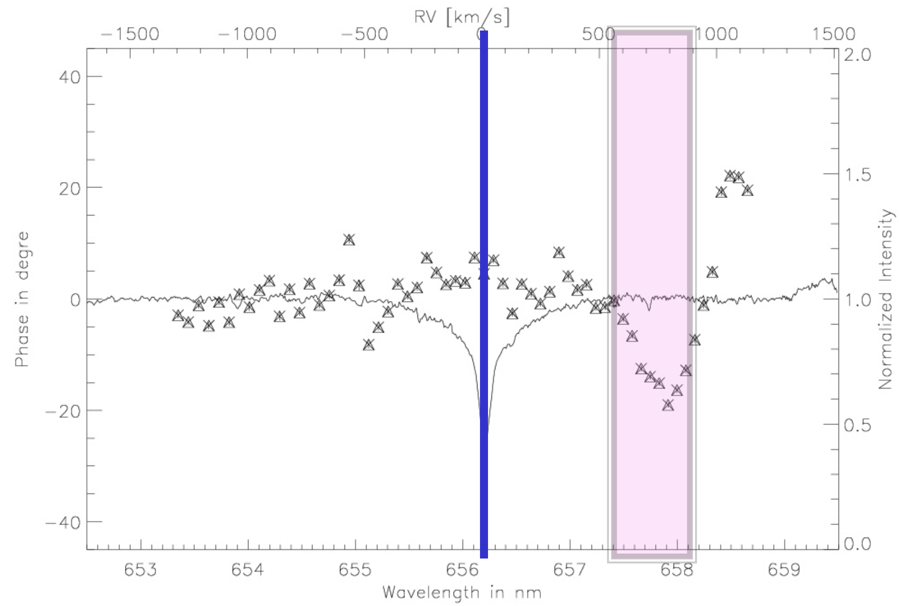
Around – 600 km/s, the diameter increases (6.3 to 6.7 mas) and the phase has a positive jump before a negative one (amplitude of 10°)

Results with AlgolR (2)

Angular diameter vs. λ

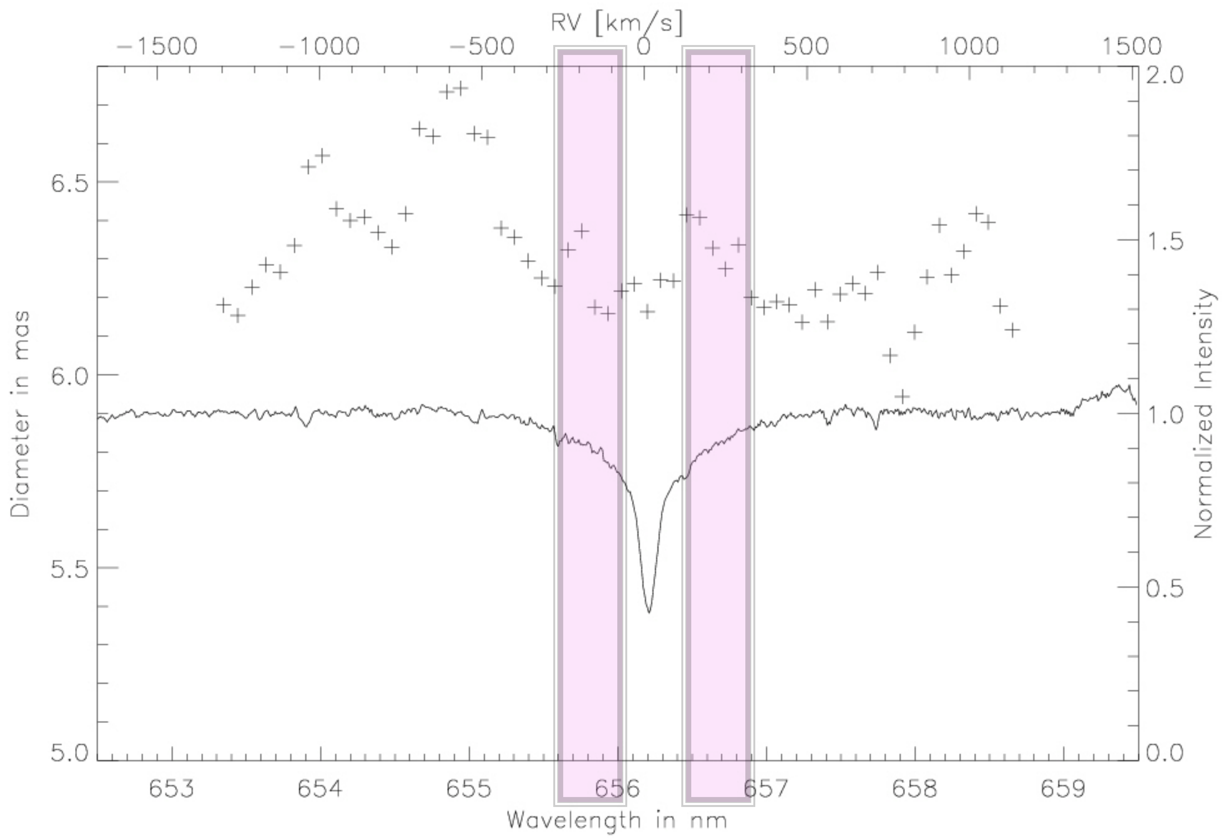


φ vs. λ



Around + 800 km/s, the diameter decreases (6.3 to 5.9 mas) and the phase presents a negative jump before a positive one (amplitude of 20°).

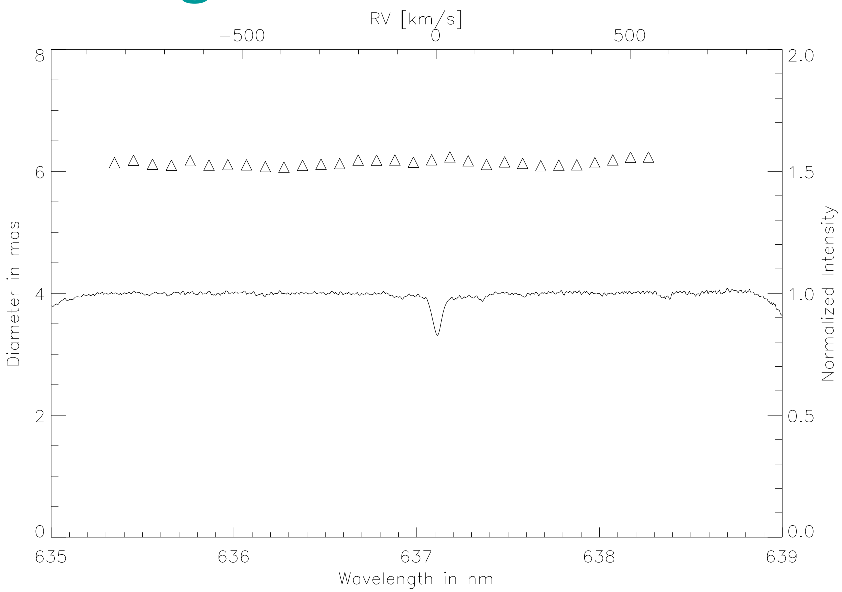
Results with AlgolR (3)



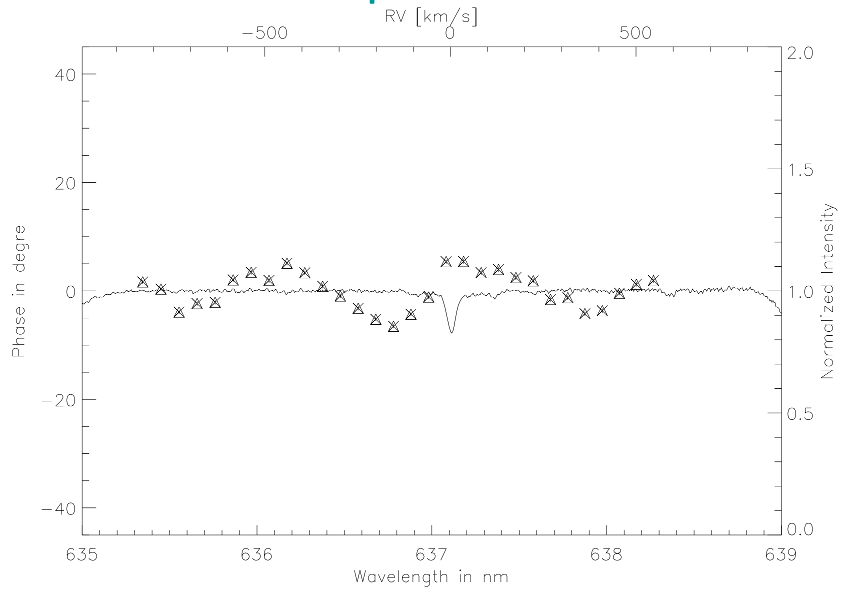
The diameter seems to be larger in the wings of the line (± 200 km/s) than in the core.

Results with AlgolB

Angular diameter vs. λ



φ vs. λ



The diameter is constant around $\lambda = 637$ nm and the differential phase too (with a fluctuation of 0.9° rms).

So diameter and phase variations around Hα are actual signals that have to be explained.

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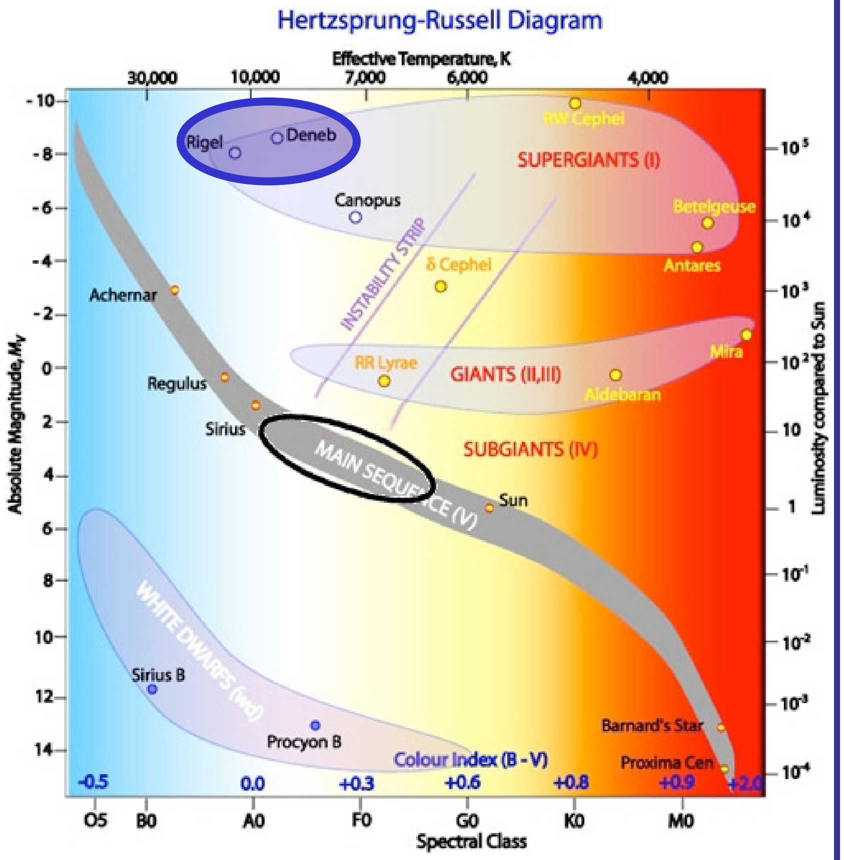
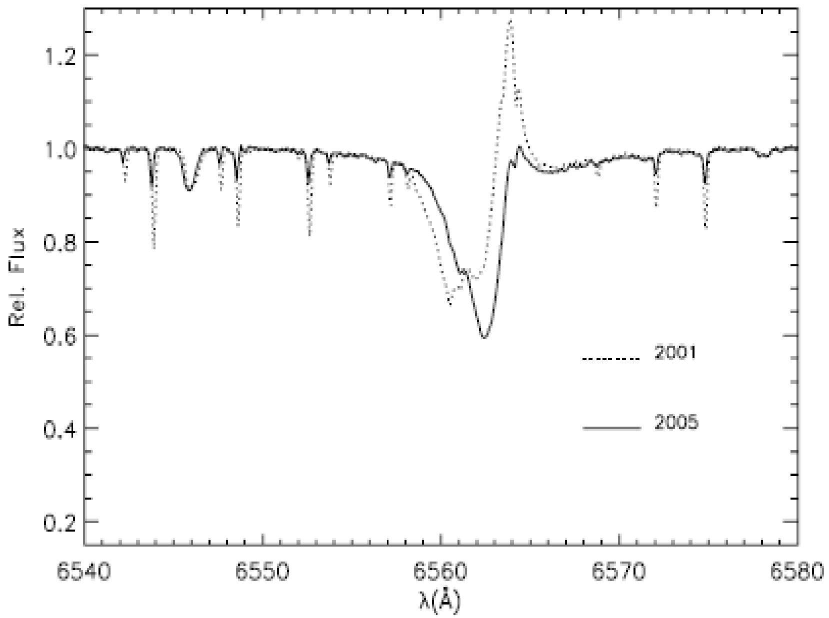


Variability and wind of Deneb

- A/B supergiants (e.g. Deneb A2Ia, and Rigel B8Ia) are among the brightest sources in the visible, used as stellar candles.

- Variability in Hα line is well known:
  - Sensitivity to mass-loss and its Perturbations
  - Timescale: weeks to months

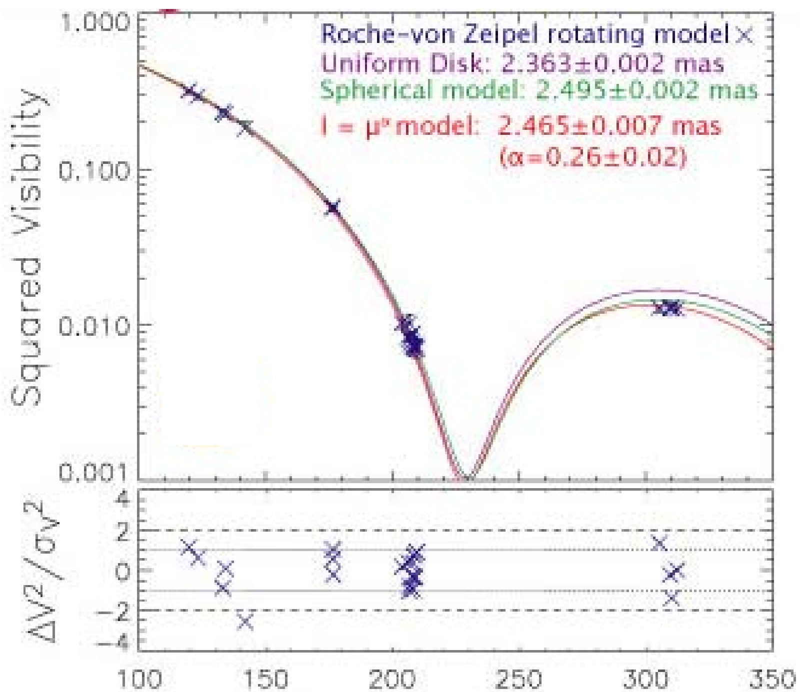
- Angular diameter constrained with FLUOR with a high accuracy



(Przybilla et al., 2008)

Rationale

- FLUOR measurements show that Deneb’s limb darkening is stronger than predicted by spherical, hydrostatic model atmospheres.

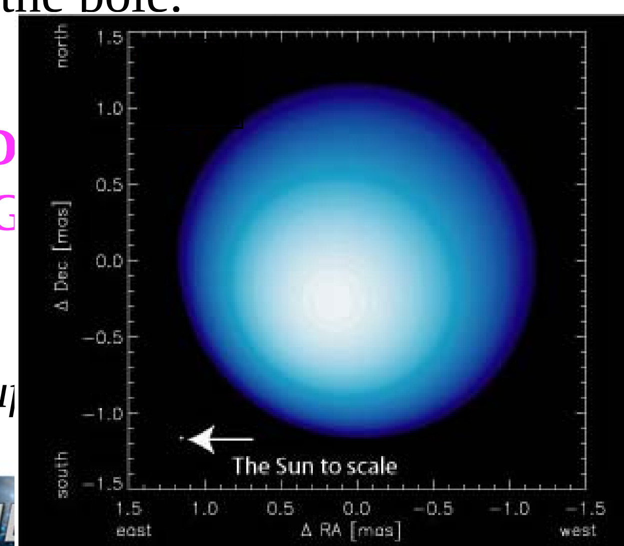


- signature of **asymmetry**. Deneb’ angle at a level of about 2%.
- ıcted Roche-Von Zeipel model tion angle of the pole.

⇨ **ıriability of D**
ıution of VEG

- *ıal ?*
- – *Is the wind structure latitude-dependant ?*

(Au



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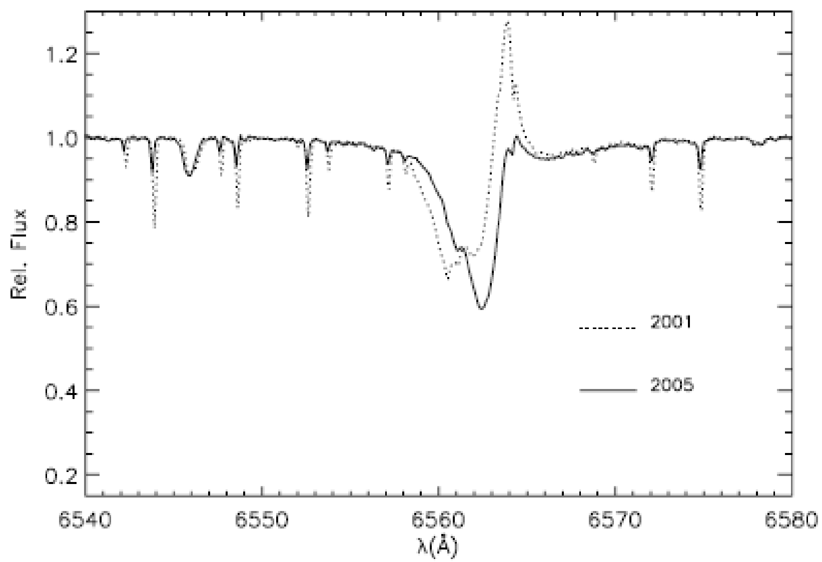
VEGA Observations

- Due to the large angular diameter (2.465 ± 0.007 mas), **only the S1S2 baseline** provides high enough visibility:
  - 3 recordings on Deneb on July 28th.
  - High Spectral Resolution (R ~ 30000) around Hα line
  - Baselines ranging from 20 to 24m
  - Position angles covering 60°
- Variability timescale from weeks to months is suitable for our kind of observations.
- Processing by a differential method.

VEGA spectrum

The VEGA spectrum is close to the 2005 ‘quiescent’ state.

(Schiller and Przybilla, 2008)



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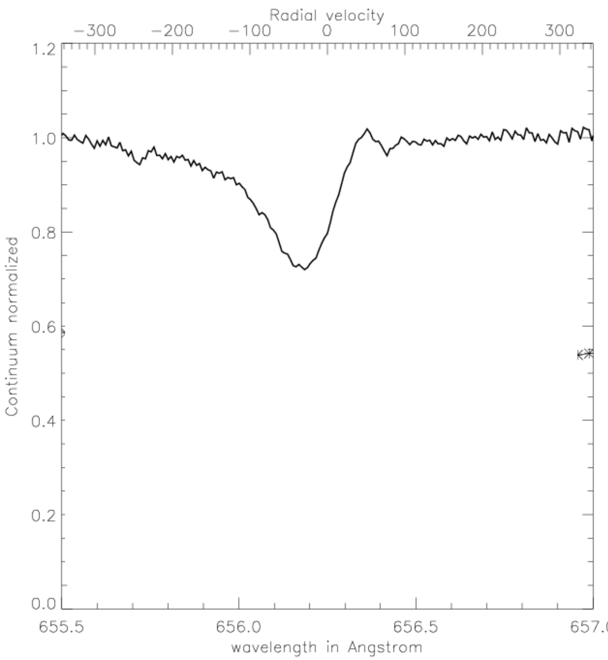
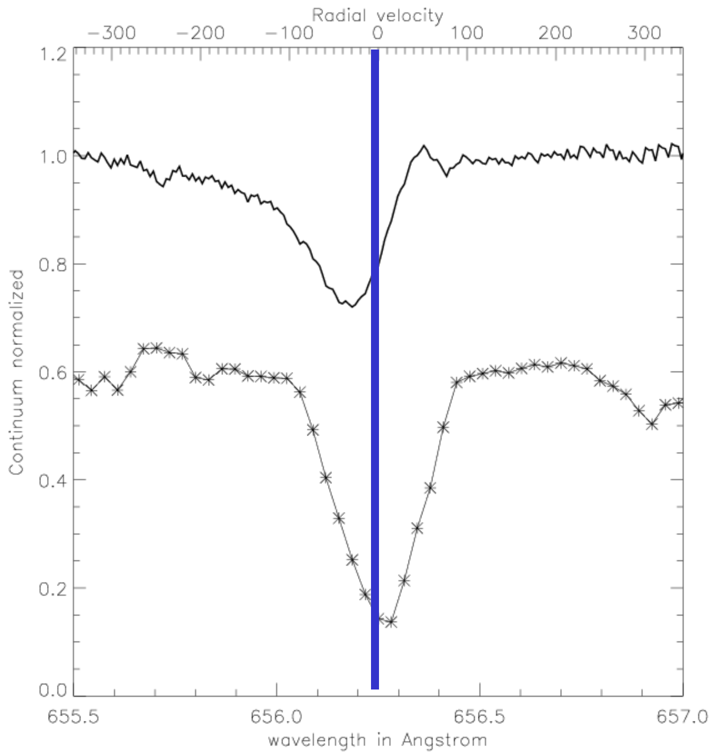


Results on visibility

- Deneb is strongly resolved in Hα. The preliminary estimation of the characteristic size leads to line forming regions at about **1.4 R_***.



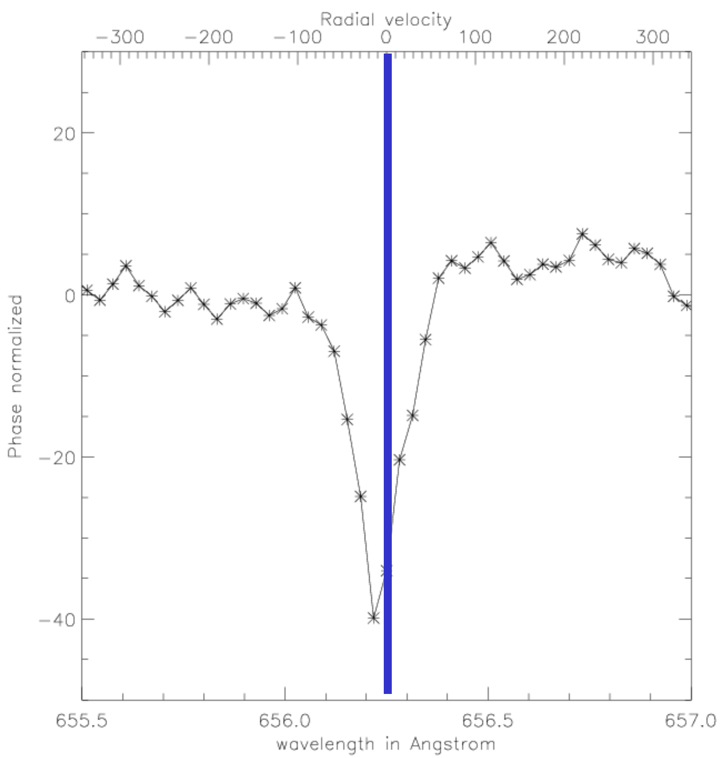
The shape of the visibility curve differs from the line profile.

The visibility minimum is close to the theoretical center of the line.

FWHM ~ 180-200 km/s

Results on differential phase

- A large phase effect (larger than 40°) is observed in the Hα line : **asymmetry**



The minimum of the differential phase is off-centred with respect to the theoretical center of the line.

FWHM ~ 140-170 km/s

Perspectives

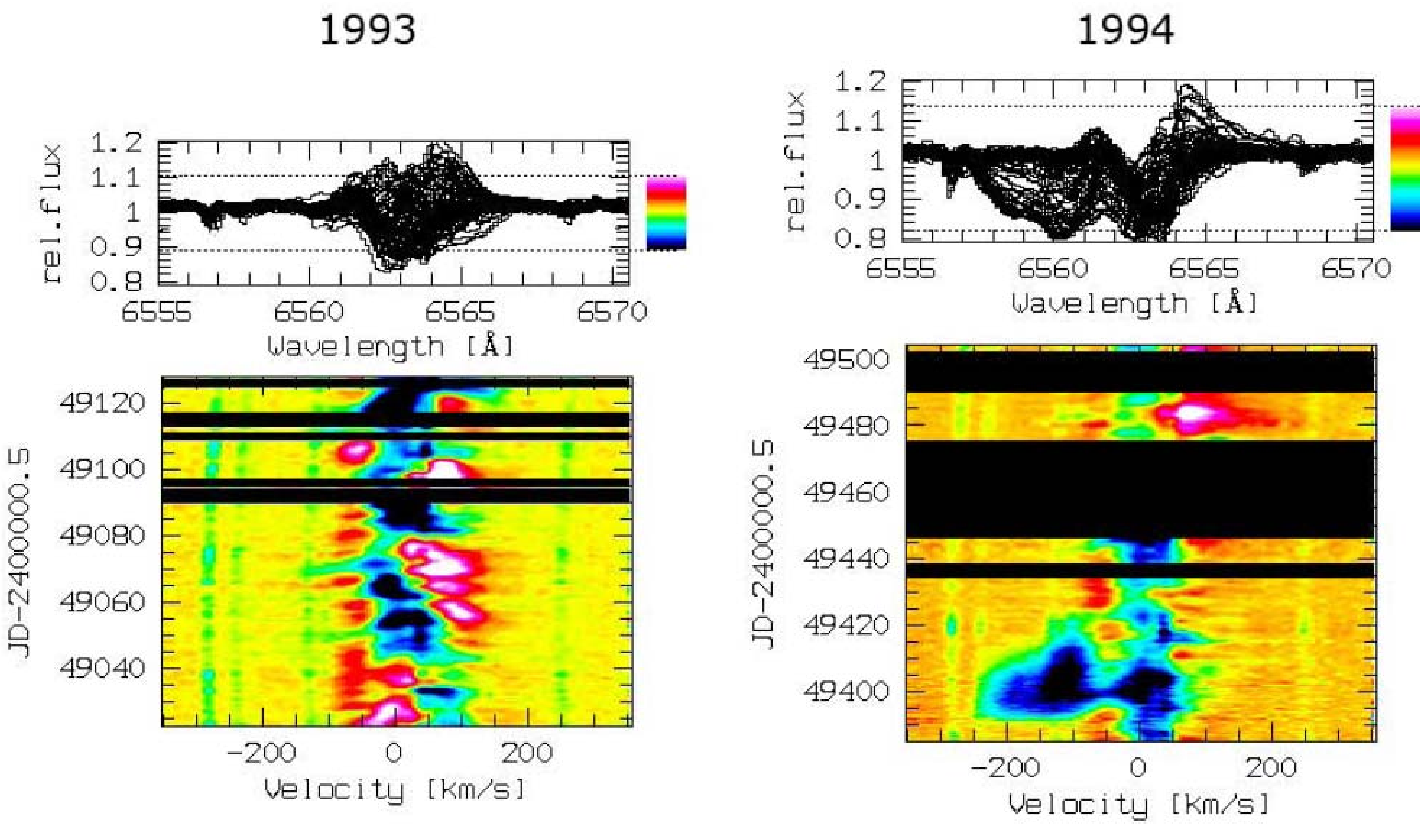
- Similar data have been recorded on Rigel and the same processing can be performed.

- A collabor
models for

- New VEG
variability

- Attempts c

- Interest of



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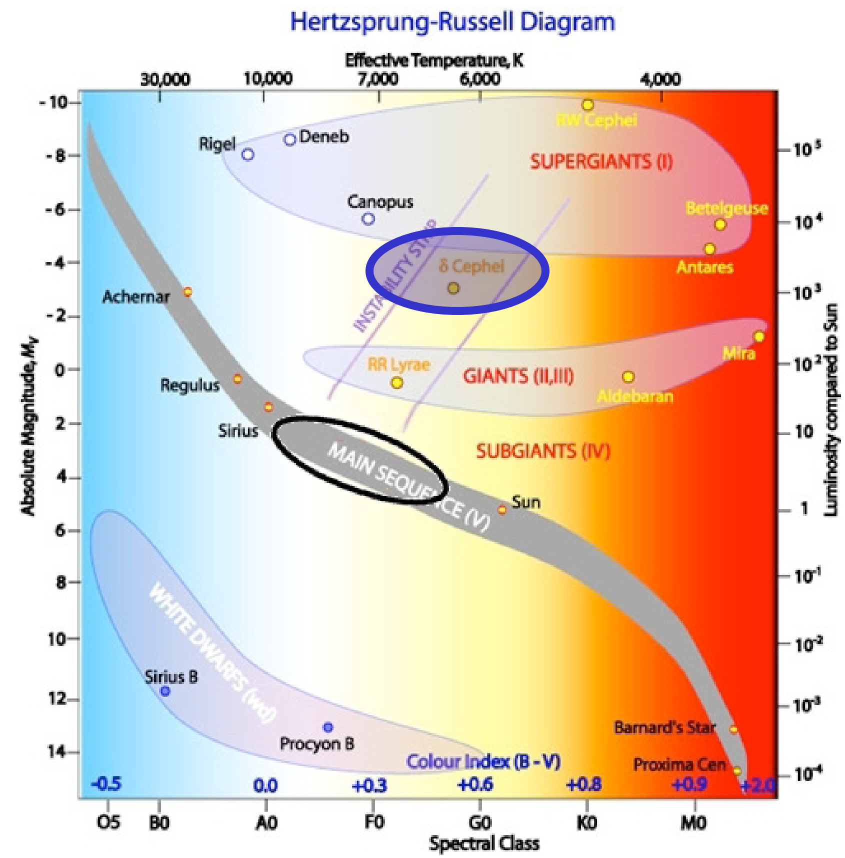


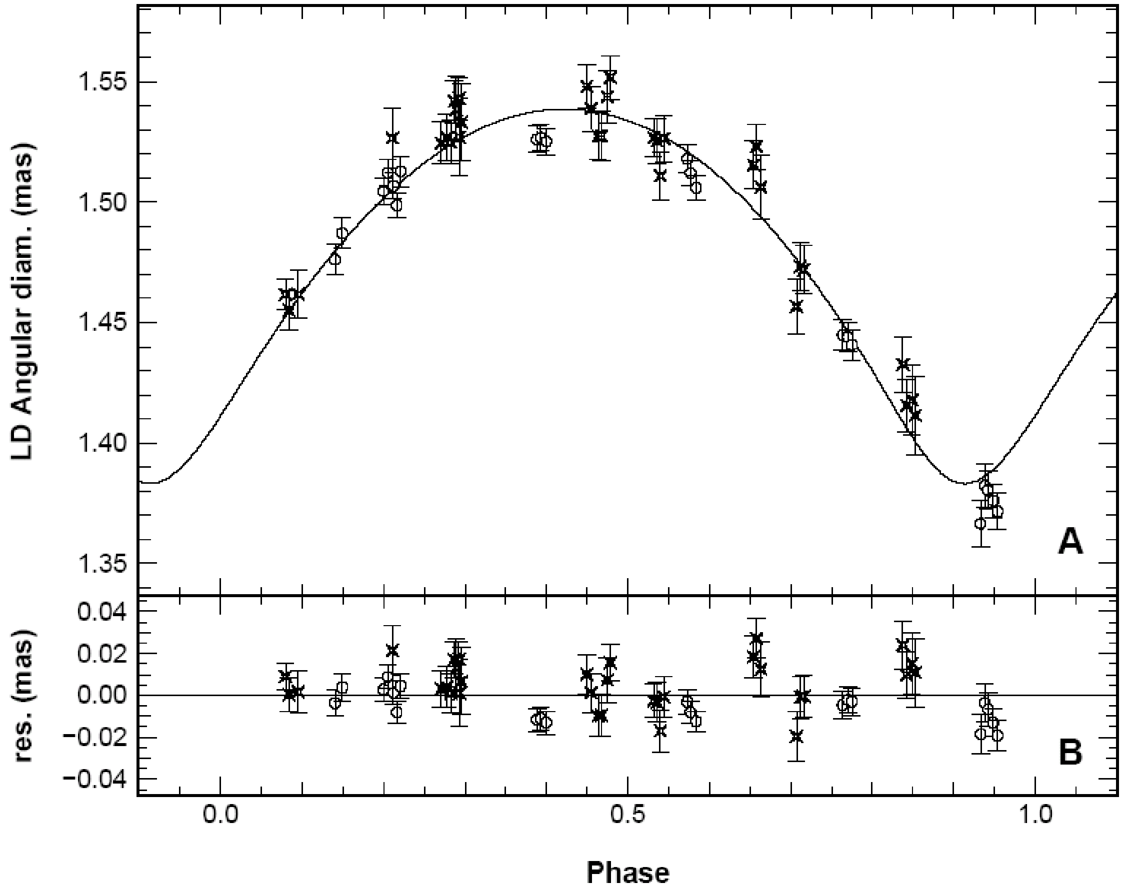
Pulsations of Cepheids

- Long-baseline i... ...cal way to **calibrate th...**

- Indeed it is now... ...s up to 1kpc with the I... ... 2004, Sasselov & Ka...

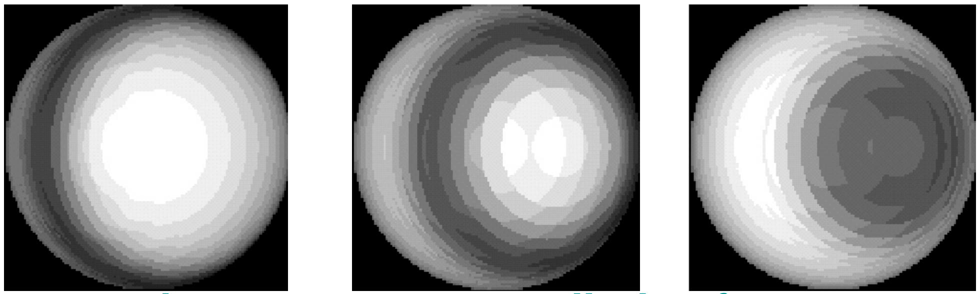
- Interferometric... ...er the whole pulsation... ...ed from the integra... ...profiles by the so-called...

- The visible ban... ...pheids performed in ne...



Rationale

- Study of the **dynamical structure of the atmosphere** and the circumstellar envelop



Atmosphere structure in a metallic line for various RV

(Nardetto et al., 2006, A&A, 454, 327)

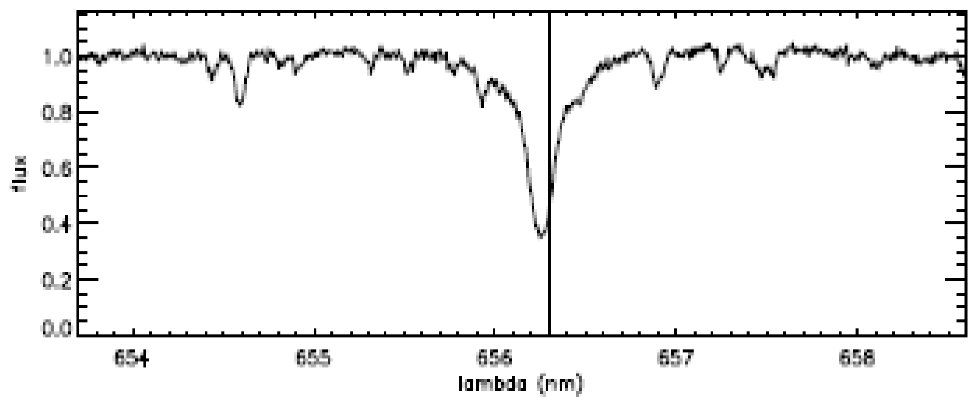
- Determination of **inclination axis** (to help mode identification)

- Resolve stellar surfaces to determine **high-degree modes** *(Kervella et al. 2003, A&A, 404, 1087)*

VEGA observations

- **δCep:**
  - Five recordings in High Spectral Resolution mode.
  - Data under processing

VEGA spectrum



- **[Notes: data on βCep]**
  - Five recordings in Medium Spectral Resolution mode.
  - Data are processed but need for more observations (in 3-telescope mode)

Conclusion and perspectives

- VEGA visibility accuracy allows 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** and **stellar activity** (stellar wind, spots, pulsations, …).

- We need to work on deep and careful data interpretation by means of realistic physical models and several collaborations are in progress.

- All these fields will take benefit from :
  - Simultaneous observations in visible and infrared ranges
  - The polarimetric mode SPIN of VEGA
  - the 3 and 4-telescope modes

… 09' runs will be very fruitful