VEGA: Status Report and Future Plans
march 2009, Nice

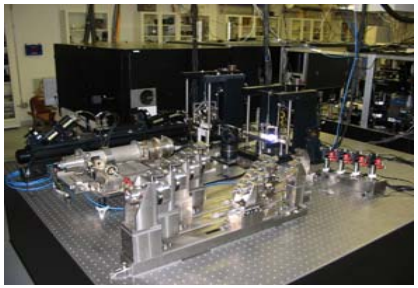
VEGA and CHARA teams

Grasse-Nice, Lyon, Grenoble

Mt Wilson

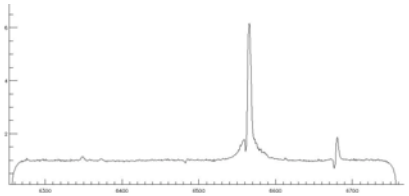
Outline

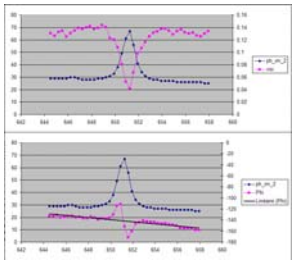
- Reminders about VEGA
  - Principle of the spectrograph
  - Observing, processing
- Data Reduction Software
  - Differential mode
  - V² mode
  - 3T mode
- The situation of the 2008 data
- Preliminary results on faint objects
- Feedback on VEGA and CHARA
- Future plans

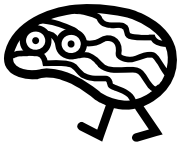


$$\left\langle \left|\tilde{I}\right|^2 \right\rangle \Rightarrow \left\langle V^2\left(\frac{B}{\lambda}\right)\right\rangle_{\left[\frac{B-D}{\lambda},\frac{B+D}{\lambda}\right]} + V^2(f) \text{ with } f \in \left[\frac{B-D}{\lambda};\frac{B+D}{\lambda}\right]$$

$$\left\langle \tilde{I}_1 \tilde{I}_2^* \right\rangle \Rightarrow |V_1 V_2| + \left(\arg(V_1) - \arg(V_2)\right)$$

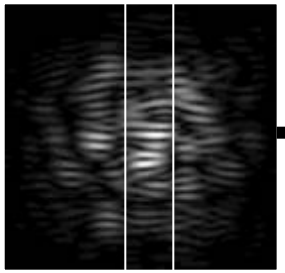


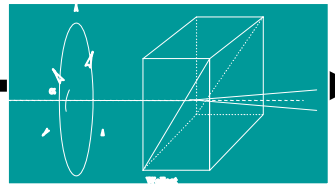




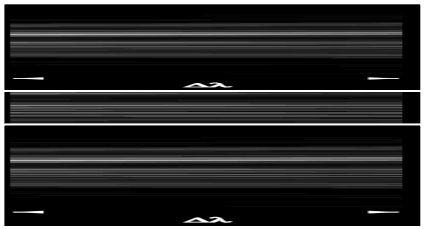
Principle of the VEGA Interferometric Spectrograph

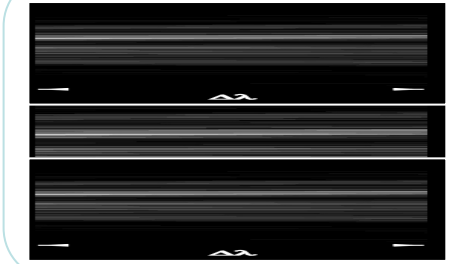
Dispersion

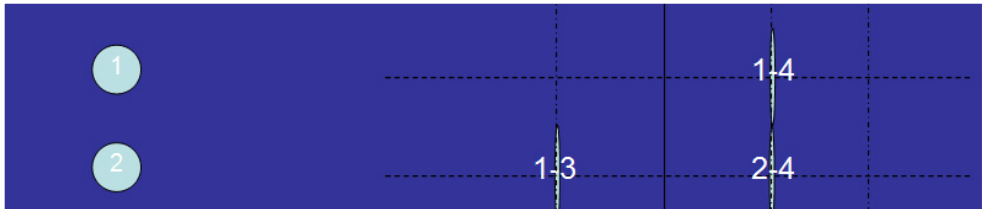




SPIN

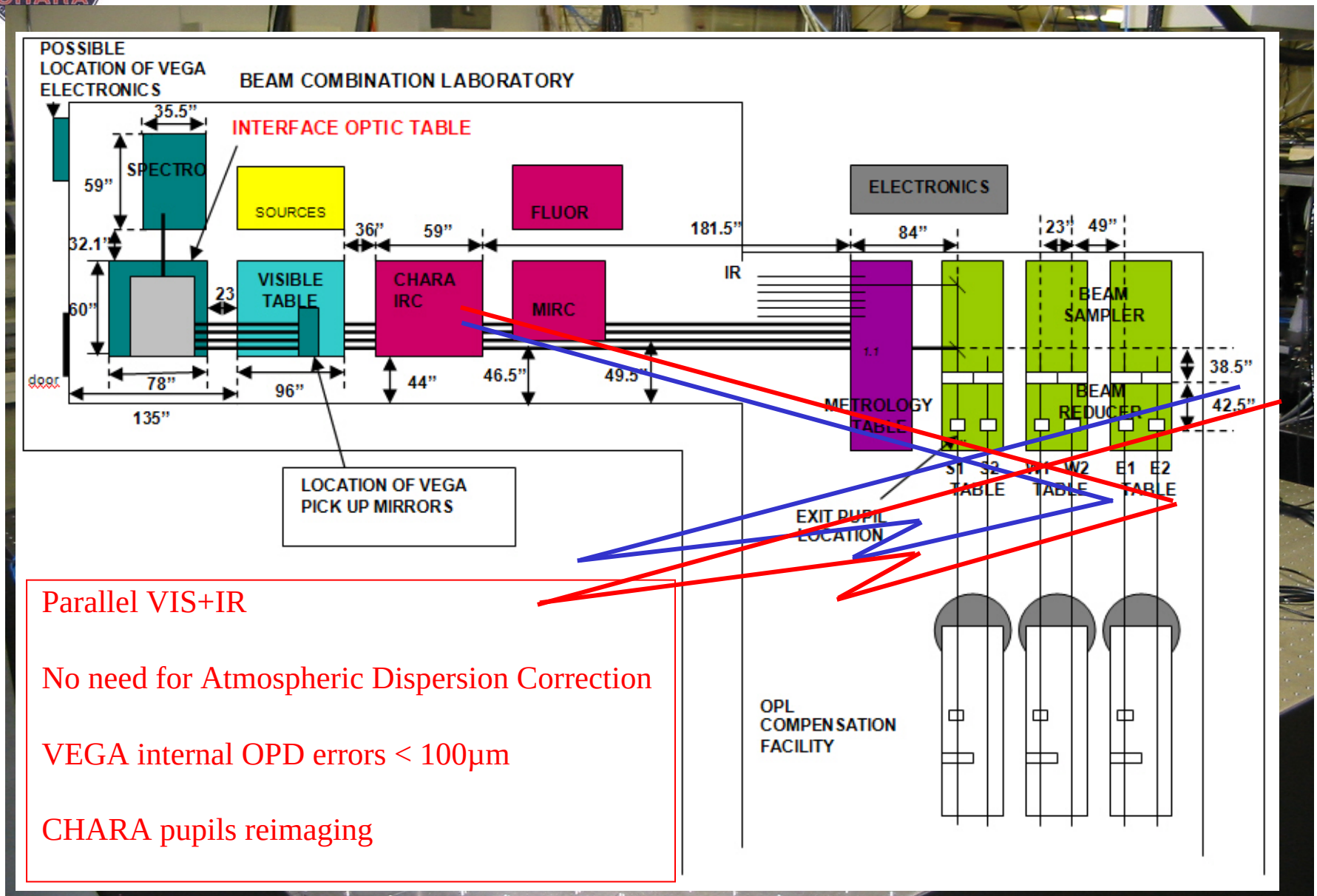






Grating	R	$\Delta\lambda$ (Blue)	$\Delta\lambda$ (Red)	$\lambda_R - \lambda_B$
R1: 1800gr/mm	30000	5 nm	8 nm	20 nm
R2: 300gr/mm	5000	30 nm	45 nm	145 nm
R3: 100gr/mm	1700	100 nm	150 nm	not possible

VEGA – CHARA Interface



Parallel VIS+IR

No need for Atmospheric Dispersion Correction

VEGA internal OPD errors < 100µm

CHARA pupils reimaging

Multimode interferometry

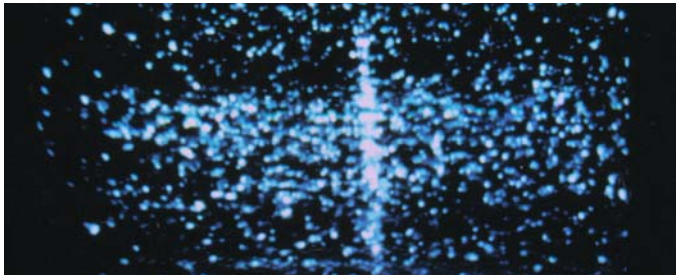


Image plane, 2D analysis, photon noise limitation
Bério et al., 1999, 2001

$$\left\langle \left|\tilde{I}\right|^2 \right\rangle \Rightarrow \left\langle V^2\left(\frac{B}{\lambda}\right)\right\rangle_{\left[\frac{B-D}{\lambda};\frac{B+D}{\lambda}\right]} + V^2(f) \text{ with } f \in \left[\frac{B-D}{\lambda};\frac{B+D}{\lambda}\right]$$

$$\left\langle \tilde{I}_1.\tilde{I}_2^* \right\rangle \Rightarrow \left|V_1 V_2\right| + \left(\arg(V_1) - \arg(V_2)\right)$$

- SNR increases $\sqrt{N_{Speckle}}\sqrt{N_{frame}}$
- Differential Interferometry approach
  - Increased limiting magnitude and SNR

$$SNR(DI) = \sqrt{SNR_{Ch1}.SNR_{Ch2}}$$

- But external fringe tracking is clearly a must!

Observing Modes 2T

(3T and 4T modes are still in qualification)

- Differential Visibility ($Ve^{i\phi}$ mode)
  - Medium Resolution
    - Hβ in blue channel, Hα in red channel
    - …
  - High Resolution
    - Spectral Line on one detector, continuum on the second one
  - Low Resolution (not really adapted)

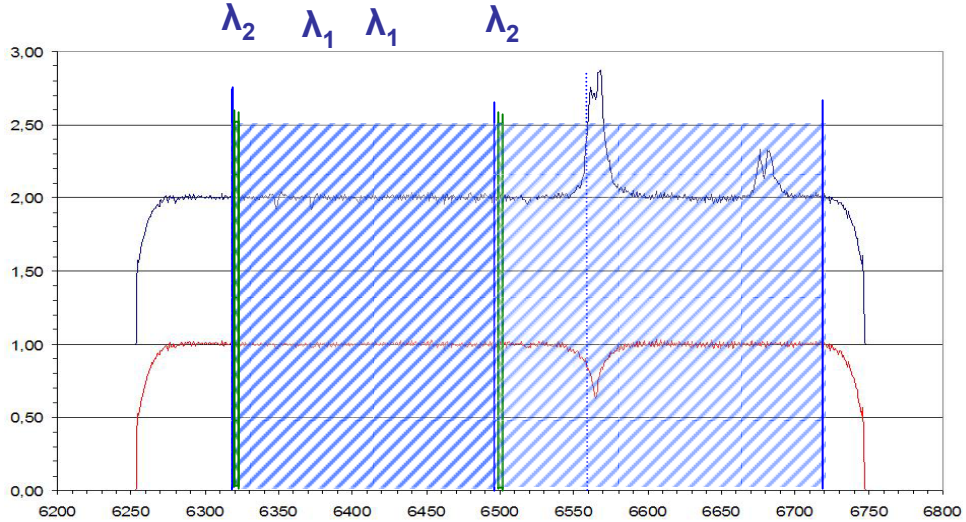
- V^2 measurements (V^2 mode)
  - Low Resolution: best choice is λ=620nm
  - Medium Resolution: λ_{red}=690, 720 or 740nm
  - High Resolution: only bright object

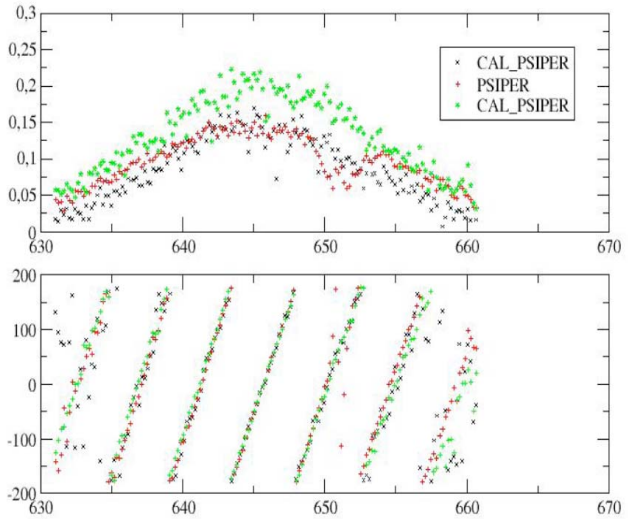
- SPIN mode
  - Small slit, red channel only.

Control System Issues

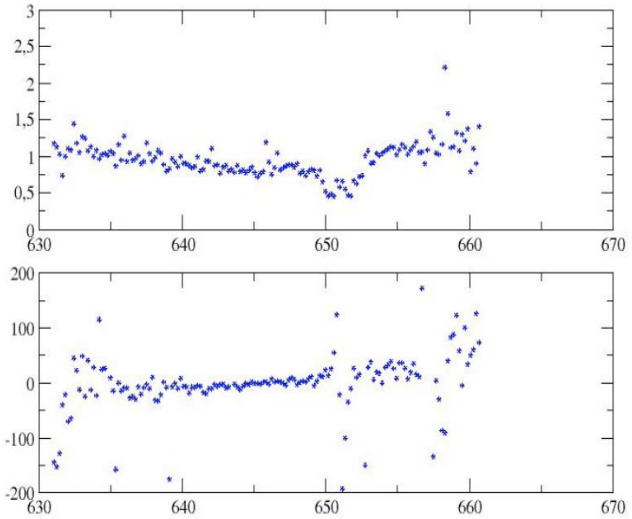
- VEGA_PLAN + SCHEDULING (OB + night schedule)
  - Needs for more than one baseline!
  - Needs for automatic scheduling
- CONTROL (local and remote) (OB player)
  - Group Delay Tracking for 4T
- ARCHIVE
  - Data base in development
- PROCESSING (local and remote)
  - See later

VEGA-DRS: $Ve^{i\phi}$ issues

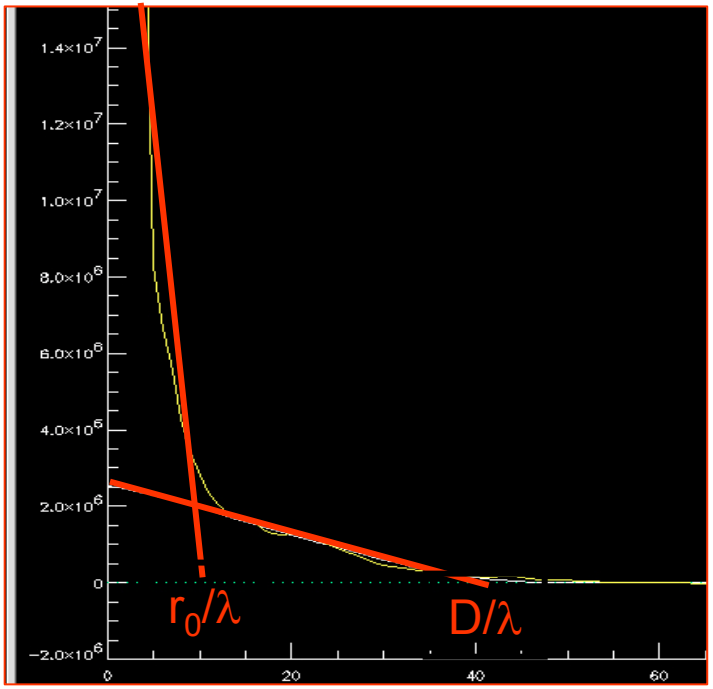




$\sigma_\phi \approx 1°$



VEGA-DRS: V² issues



D/r0 not large enough for our analysis

Speckle function not good enough (pupils)

Use of the low frequency estimator

Consequences on the calibration strategy

Other issues:

- Photon filtering (detector issues)
- Photon centroiding
- Adaptation to new data
- A lot of bug corrections …

Study of the instrumental visibility

Observations in August 08 on S1S2/W1W2/S2W2 of five calibrators

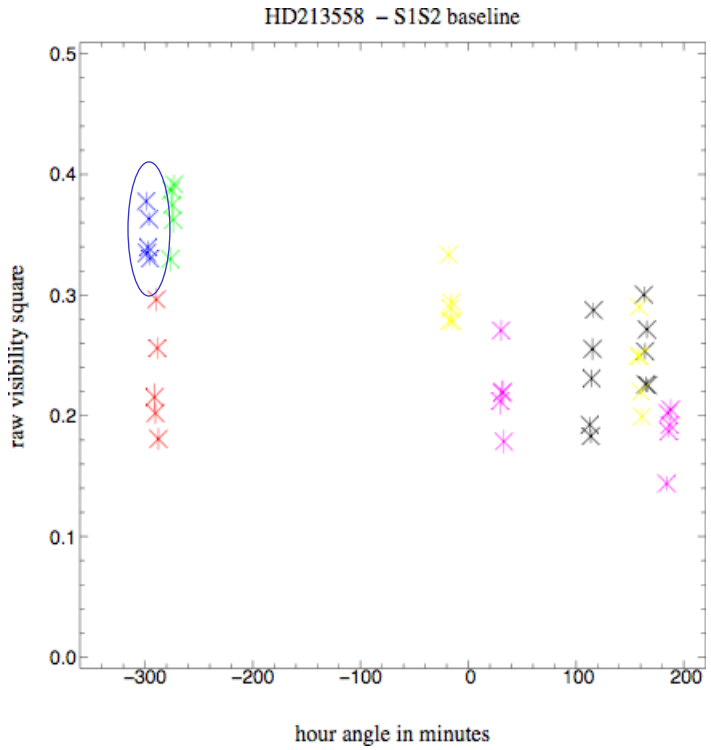
- Rapid changes between stars, all along the night
- Repetition on different nights

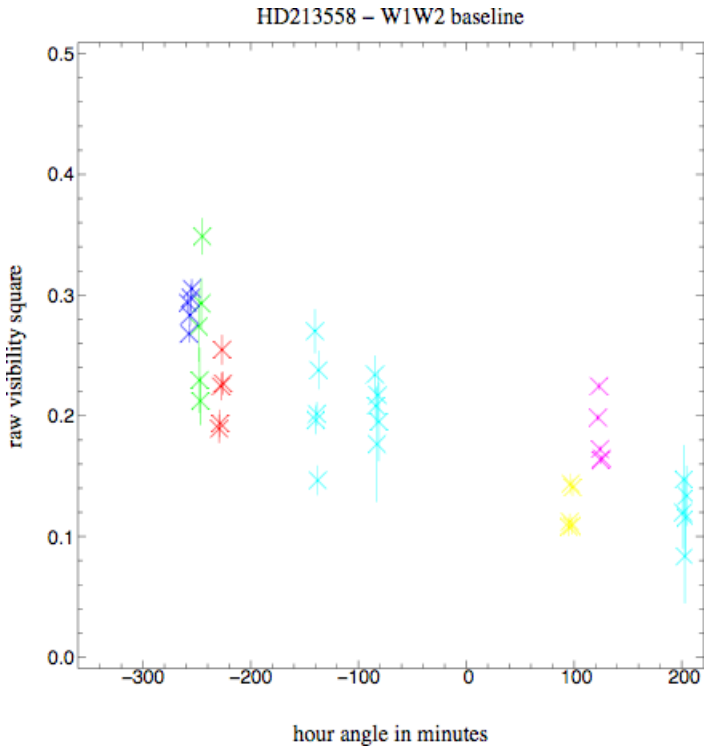
Study of the instrumental polarization

- Observations in August 08 on S1S2 of three calibrators
  - Observations in linearly polarized light sandwiched by observations in natural light
  - Observations during 4 or 5 hours after the transit
  - Calibrators of various declinations
  - 56 recorded files processed in autocorrelation

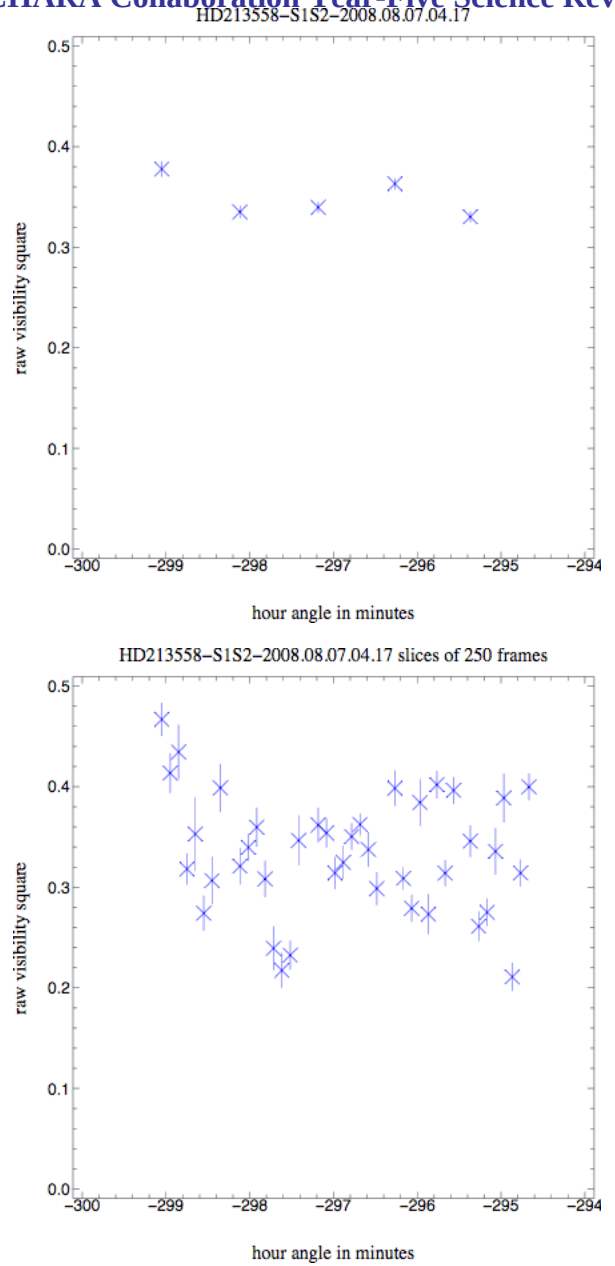
HD	δ	V	Spectral Type
166014	28°45'45.0''	3.8	B9.5V
184006	51°43'47.2''	3.8	A5V
195725	62°59'38.7''	4.2	A7III

V^2 study

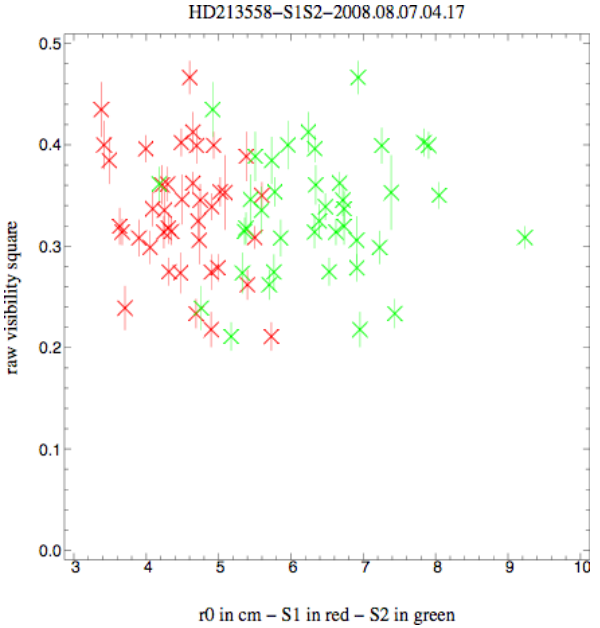

HD213558 – S1S2 baseline
raw visibility square
0.5
0.4
0.3
0.2
0.1
0.0
−300
−200
−100
0
100
200
hour angle in minutes


HD213558 – W1W2 baseline
raw visibility square
0.5
0.4
0.3
0.2
0.1
0.0
−300
−200
−100
0
100
200
hour angle in minutes

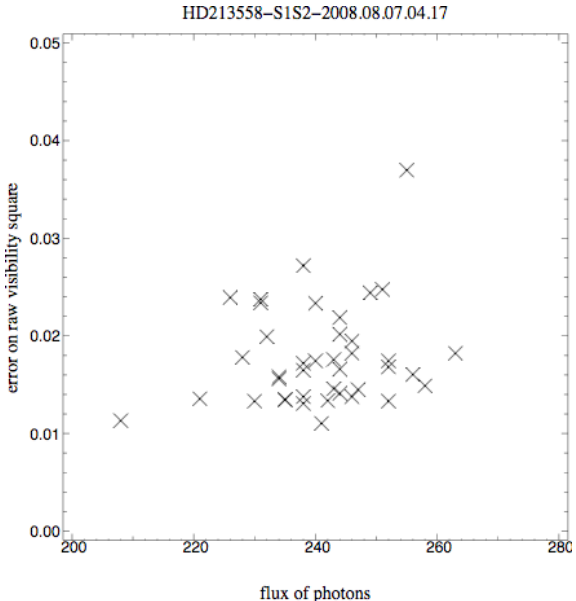
$V^2(t)$



$V^2(r_0)$

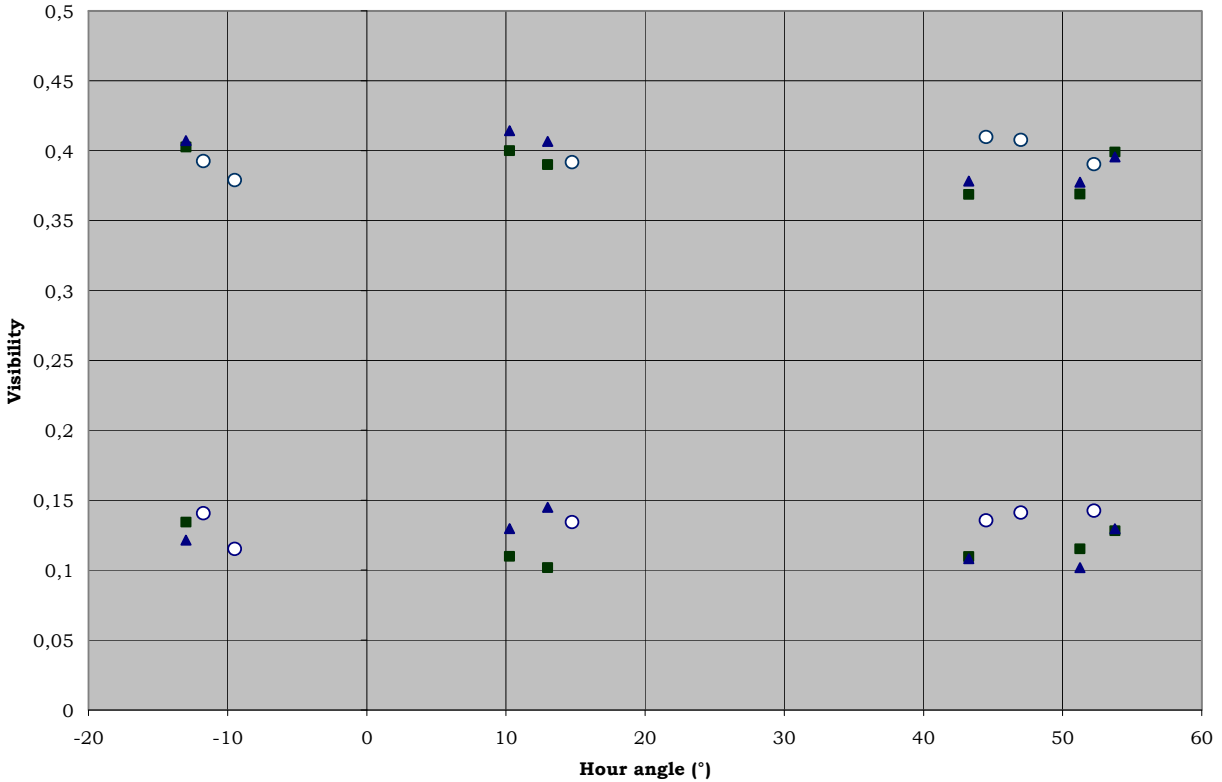


$\sigma_{V^2}(h\nu)$



V² vs. hour angle (on S1S2)

HD 195725 (δ = 62°59'39")



(λ = 650 nm)

(λ = 635 nm)

No significant visibility effect vs. angle hour whatever λ

Average V^2 vs. polarization

HD166014 (28°)	V_NAT	V_High	V_Low
λ = 640 nm	0.36 ± 0.02	0.34 ± 0.02	0.36 ± 0.03
λ = 650 nm	0.34 ± 0.03	0.36 ± 0.02	0.38 ± 0.04

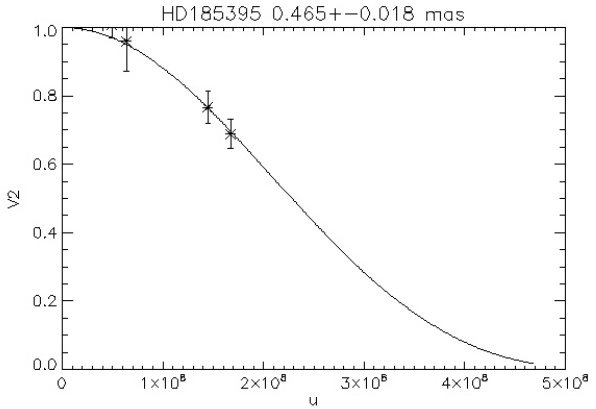
HD184006 (51°)	V_NAT	V_High	V_Low
λ = 640 nm	0.40 ± 0.04	0.34 ± 0.03	0.38 ± 0.02
λ = 650 nm	0.38 ± 0.03	0.38 ± 0.03	0.44 ± 0.01

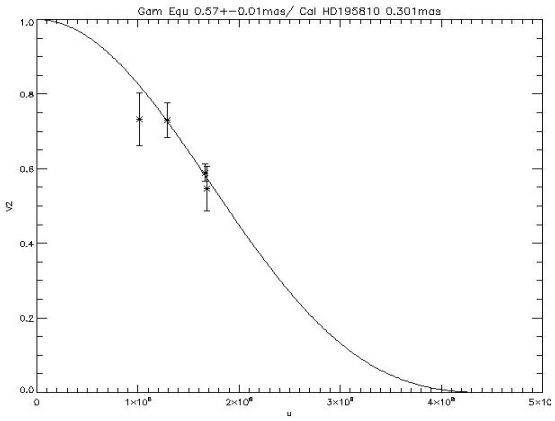
HD195725 (63°)	V_NAT	V_High	V_Low
λ = 640 nm	0.26 ± 0.01	0.24 ± 0.01	0.24 ± 0.02
λ = 650 nm	0.28 ± 0.01	0.28 ± 0.02	0.28 ± 0.02

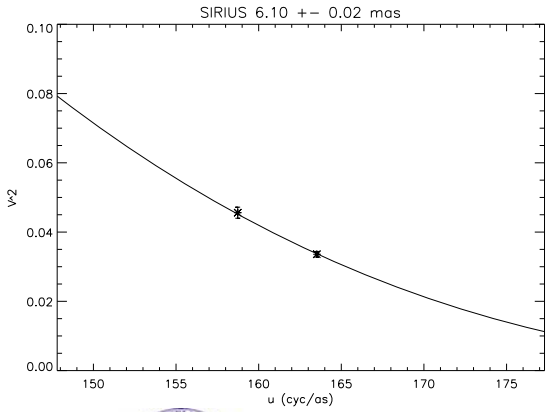
V² conclusion

- Processing is almost qualified
  - More analysis of the V² qualification program
  - OIFITS production validated for model fitting
- Main instrumental bias
  - Noise detector
  - Group delay
  - Differential photometry (measurement?)
  - Pupils (lateral and longitudinal) (to be done)
  - Difference of air path (to be done)
- Absolute calibration
  - Various examples (13 Cyg, gam Equ, Sirius, …)
  - 2 to 5% accuracy (to be improved by temporal analysis)

Spectral Resolution	Typical Magnitude	Best performances
30000	3.5	4.2 (δ Cep)
6000	5.5	5.8 (?)
1500	6.5	7.4 (MWC361)

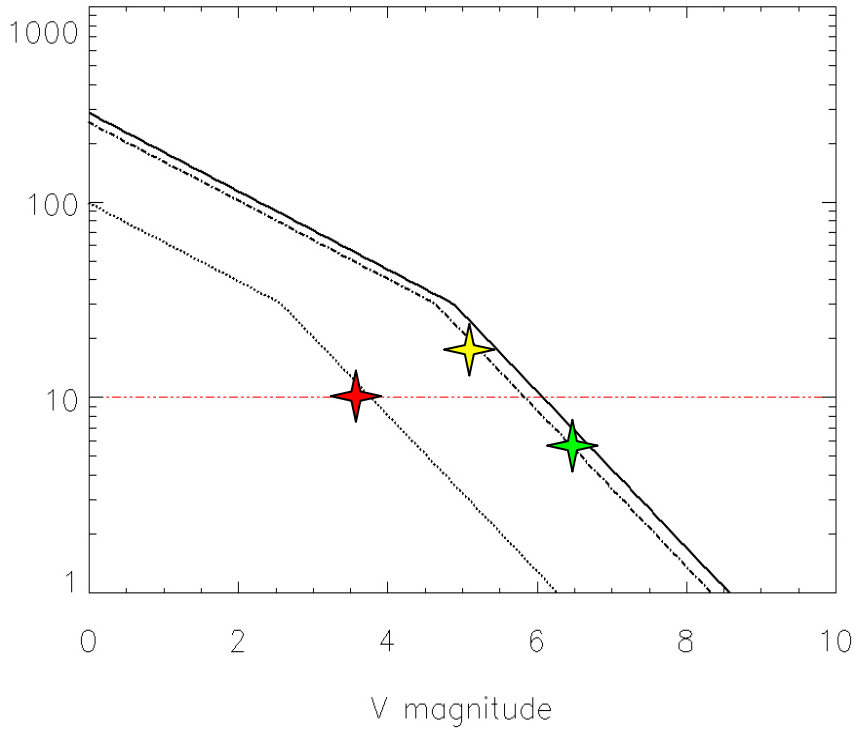




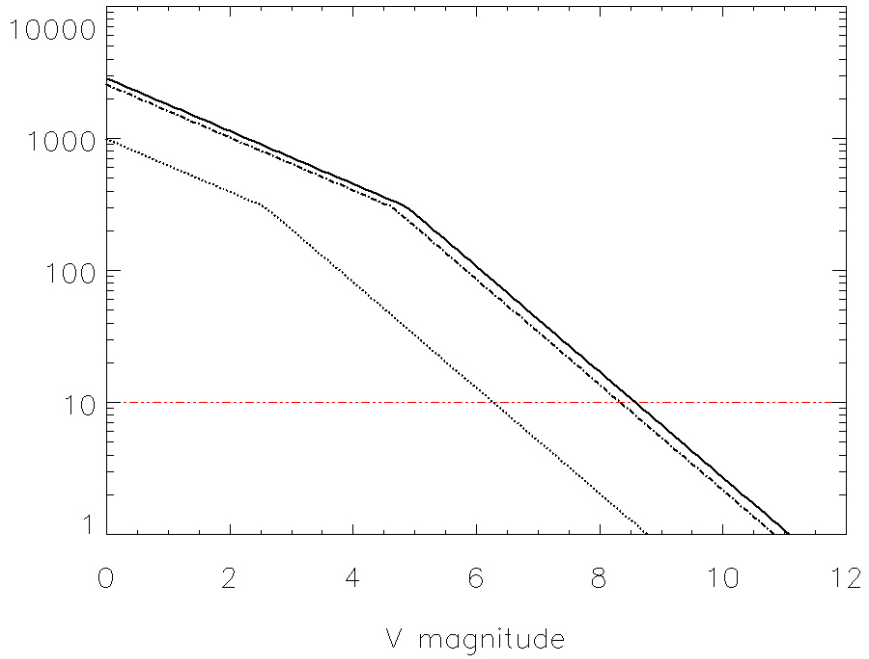


Validation of the SNR estimations with the 2008 measurements

10s observation with VEGA tracking



1000s observation with external tracking



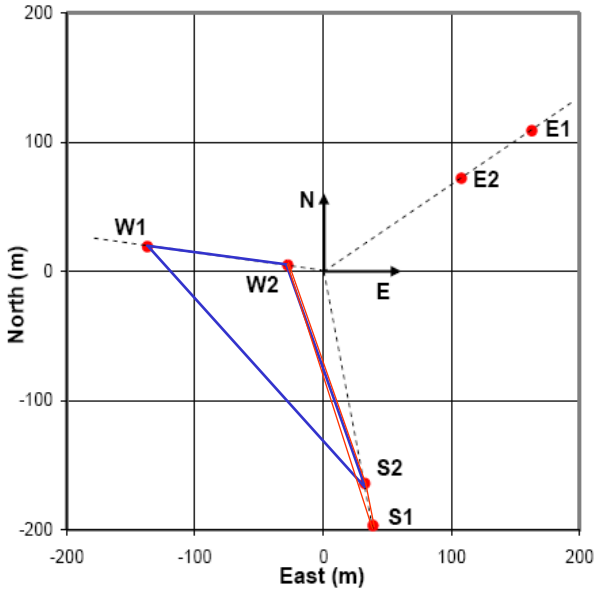
r_0 = 8cm

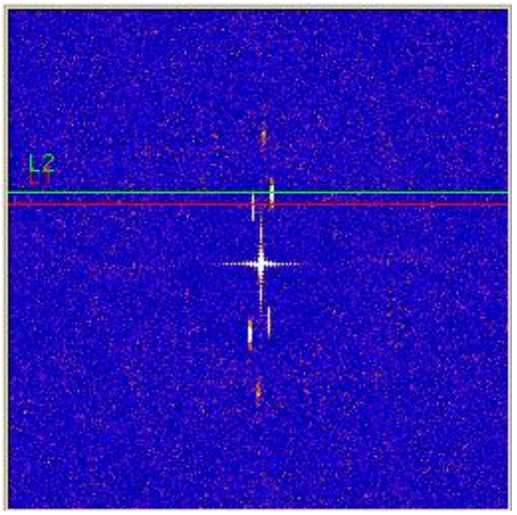
$\Delta\lambda$ = 5nm (HR) ✦ 40nm (MR) ✦ 50nm (LR) ✦

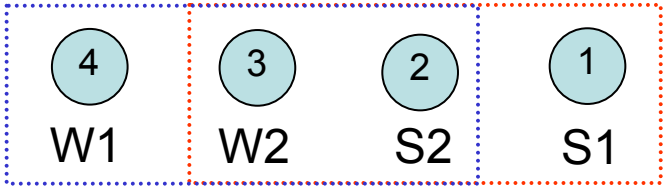
V^2instr ≈ 0.4

Transmission: 0.1%

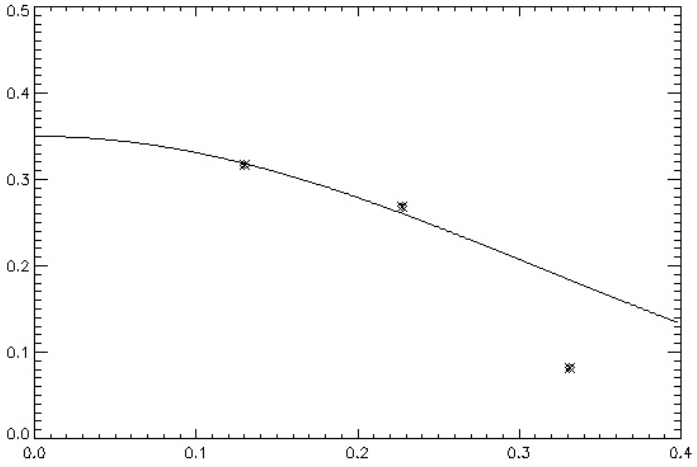
3T operation. HD3360, oct. '08





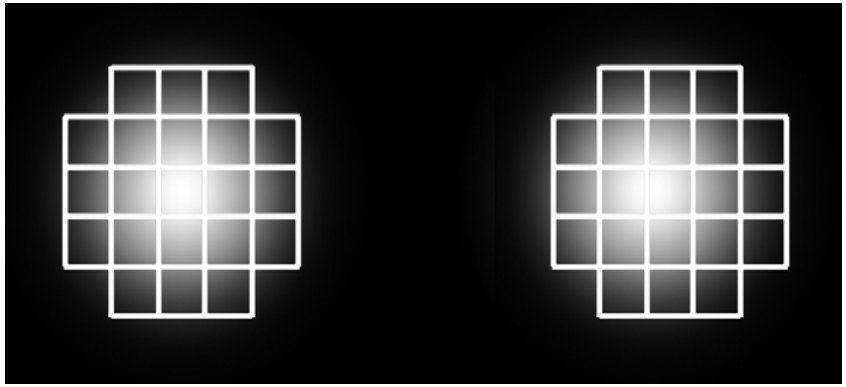


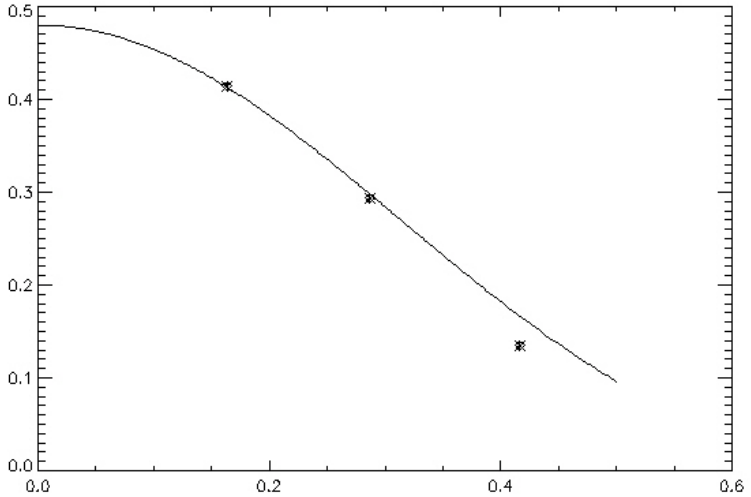
1-3 and 2-4 → Sampling pb



¼ pixel for photon centroiding

- Photon events localization
  - Photon events localization and 21 surrounding pixels recorded
  - Centroiding in post processing
- Needed in real time for coherence tracking





KO

0%

20%

50%

80%

	Jun 08 (4n/13)	Aug 08 (12n/13)	Oct 08 (6n/9)	Nov 08 (3n/9)
Qualification				
P Cygni				
β Lyr				
ups Sgr				
δSco				
Fast rotators				
g Equ (ro Ap)				
δ Cep (HR)				
βCep				
Deneb				
MWC 361				
chi Oph				
Theta1 Ori C				
Rigel				
48 and				
AB Aur				
Be				
Sirius				
13 Cyg				
3T				

Limiting magnitude in low spectral resolution

- MWC361 observations in July 08 on S1S2 and W1W2
- AB Aur observations in October 08 on S1S2 and W1W2

- Spectral decorrelation implies to track fringes over a reduced spectral window (i.e. quasi blind mode)
- Fringe drift is faster with the low resolution and very nearby calibrators are mandatory in order to minimize this effect that prevents us for long integration.

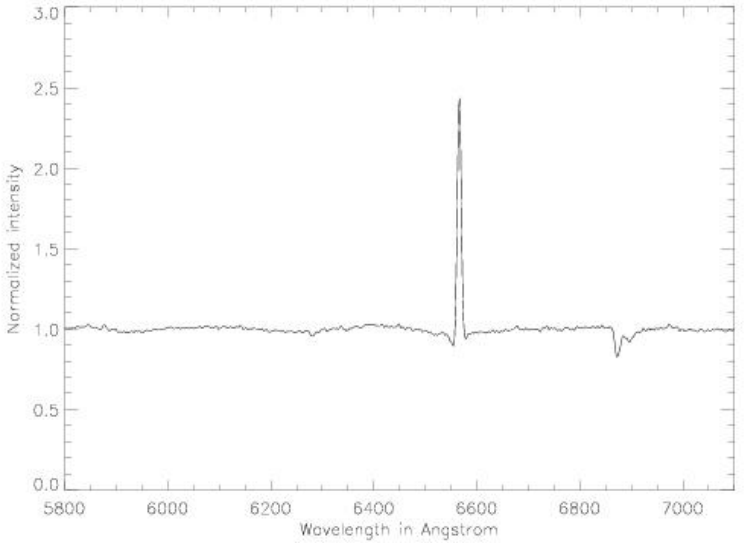
AB Aur

- AB Aur is a **prototype of Herbig Ae/Be stars** and, as such, it has been fully observed in spectroscopy, in infrared interferometry (PTI, IOTA, …)
  - Spectral type : A0
  - Magnitudes : V = 7 / K = 4.4
  - Distance : 144 pc
  - Luminosity : 144 $L_{\odot}$
  - Large infrared excess
  - No jets, no CO flow
  - Variability of the Hα emission at

a scale of a few hours

⇨ **Stellar activity, link wind and disc, …**

CHARA/VEGA spectrum (October 8th)

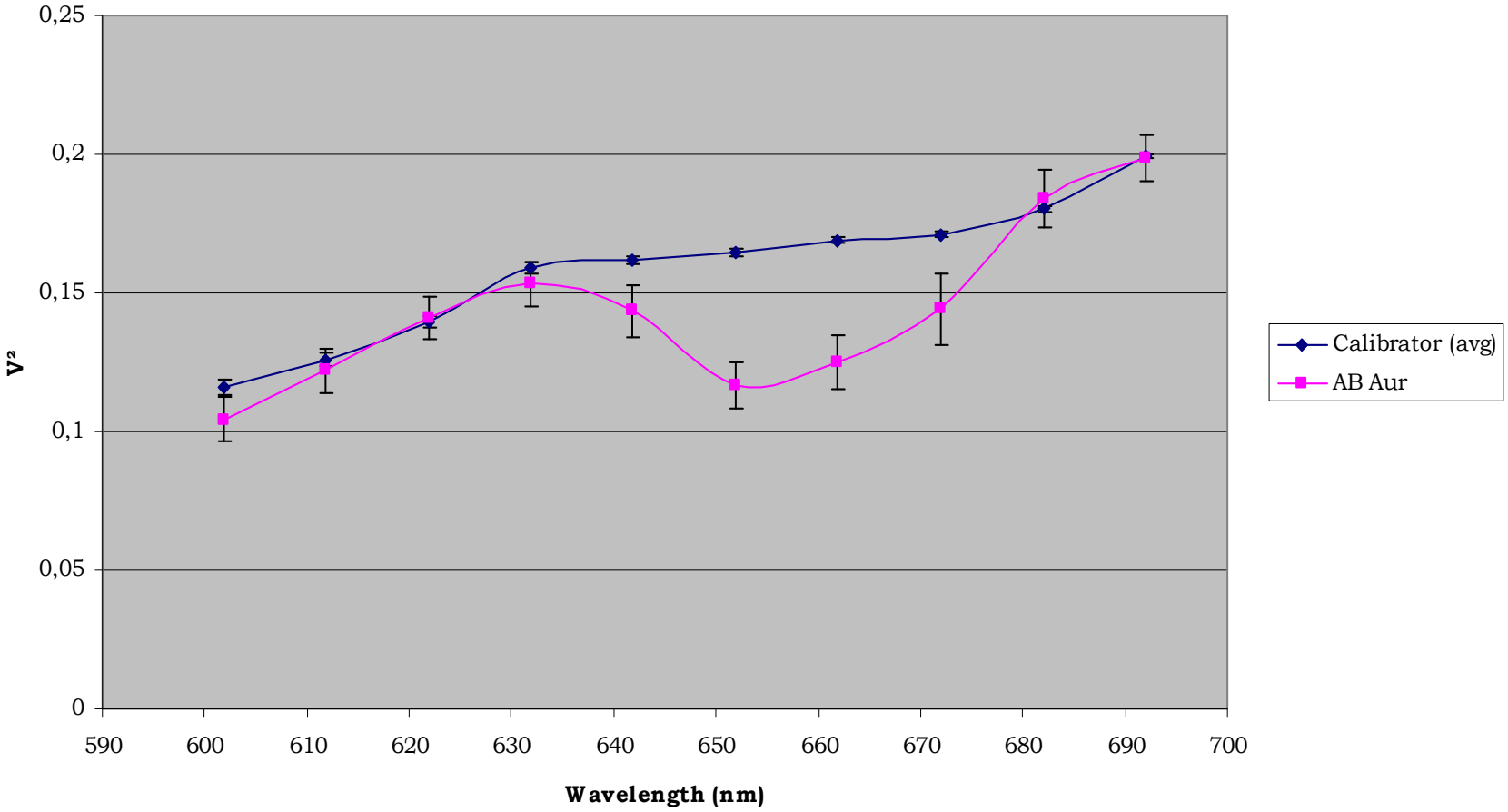


AB Aur observations

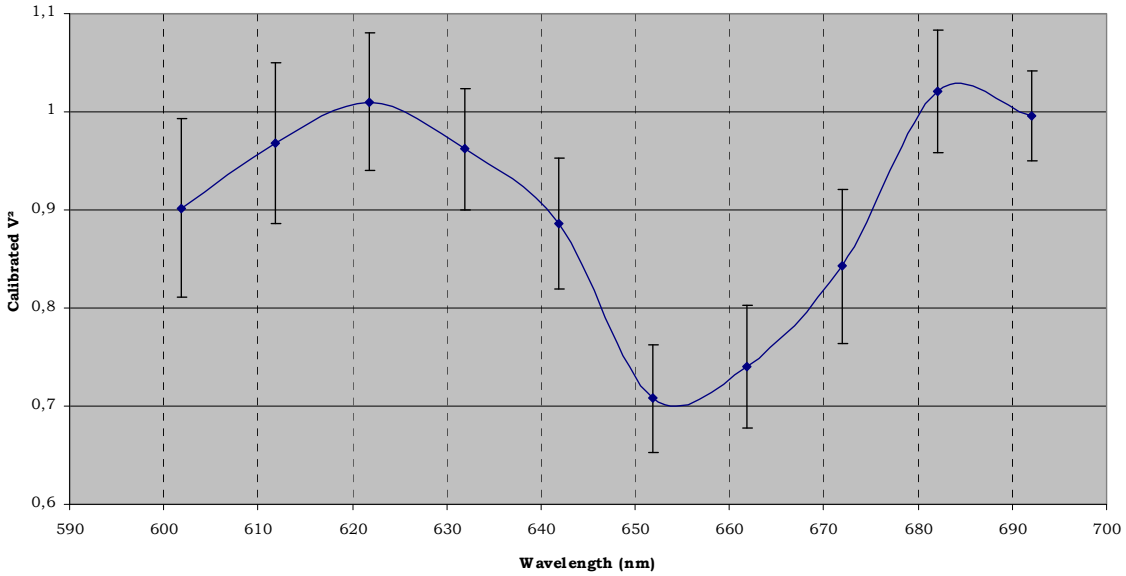
- **Baseline S1S2:** 2 recordings on the calibrator HD29646 and 2 on AB Aur on October 8th with good seeing (r_0 > 10 cm)
- **Baseline W1W2:** 2 recordings on the calibrator HD29646 and 2 on AB Aur on October 9th with lower seeing

- Processing by **spectral densities** with a bandwidth of 20 nm (SNR issue)
  - **W1W2**: even if the fringe peak is visible, its position is not significantly detected and data cannot be processed
  - **S1S2:**
    - Clear detection of the fringes in all data files
    - Correction for the residual optical path difference and for the bias due to the red detector noise.
    - Analysis V^2 vs. λ to detect effects across the Hα emission line.

V² vs. λ (on S1S2)



Calibrated V² vs. λ (on S1S2)



AB Aur is clearly resolved in the Hα line on S1S2 baseline.

Due to the large spectral window of the autocorrelation (and the induced convolution effect), interpretation in terms of angular size in Hα has to be carefully performed.

Need for a realistic model of AB Aur

R_{in} radius where dust sublimation occurs
R_t magnetic truncation radius
R_c corotation radius

R_{in} is strongly model-dependent and especially depends on the scattered light model :
- Benisty & Pinte: R_{in} ~ 3.2 mas
- Tannirkulam et al. (2008): R_{in} ~ 1.6 mas

MWC 361

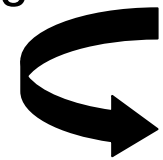
. Close-binary system seen by spectroscopy and interferometry with IOTA (H band, Monnier et al. 2006) ($\rho \approx 15$mas, $\Delta M \approx$ 1-1.5)

. Young early Be star (Herbig B[e]) with a resolved disk (3 mas) and a lower mass late-type Be companion (not common such young star in a multiple system)

. Excellent tool for disk evolution models

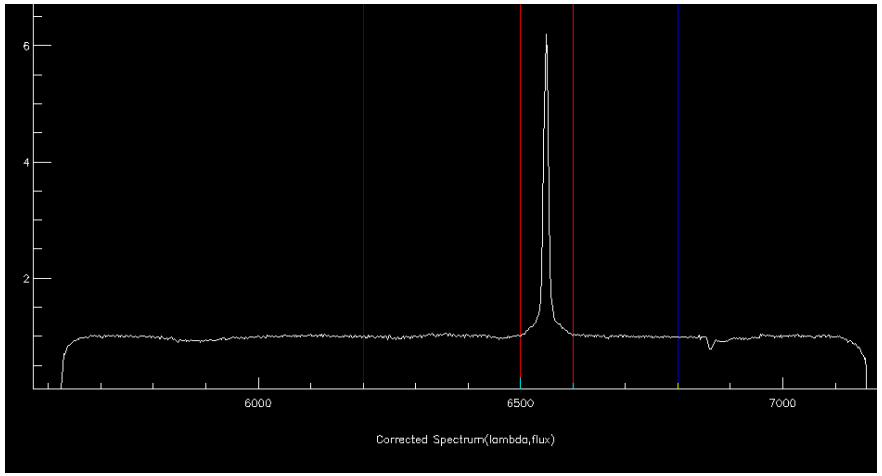
A challenge for CHARA/VEGA: M_V = 7.4

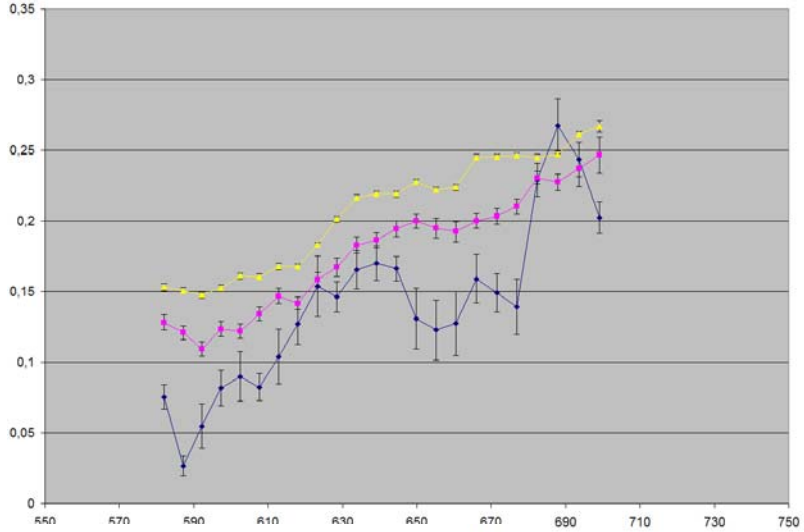
Fringes obtained using the shortest baseline S1S2 (~ 34 m)

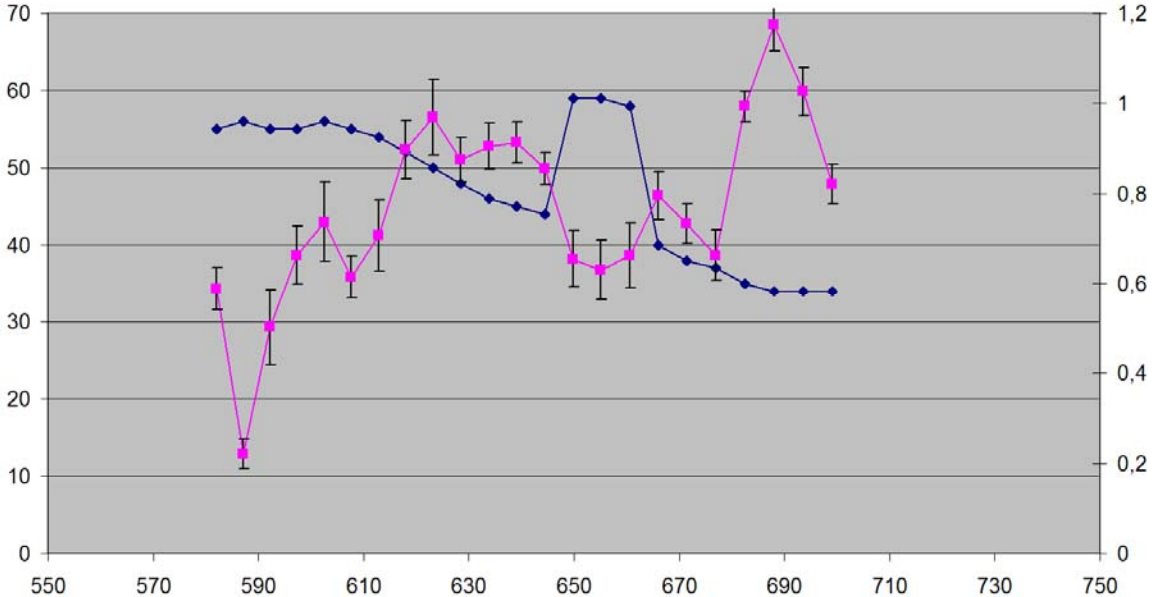


Study of the disk characteristics in the visible from the analysis of Hα region is in progress

MWC 361 (preliminary analysis)







Feedback on VEGA

- Routine operation for the alignment and observations.
- Remote operation is validated.
- Lot of work for the night scheduling.

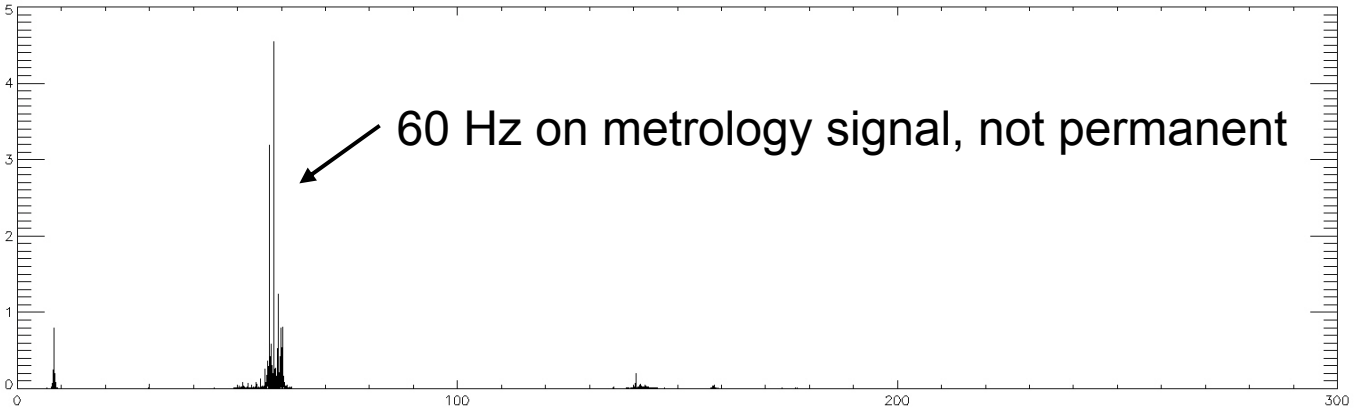
- Huge effort on the data processing. Things are almost stabilized now but important developments are in progress.

- Some difficulties for the spectral calibration in HR mode
- Cooling of red detector + cosmetic of red detector.
- $V^2(ALGOLR) < V^2(ALGOLB)$

- Important problems with calibrators: at least 5 bad calibrators found. Accurate and exact estimations of diameter?

Feedback on CHARA

- W1W2 with W1 as ref. gives much higher V^2 than W2 as ref.



- Clock issues and fringe drift ?
- Variation of offset on same base+pop ?

- Great improvement on pupil and image quality.

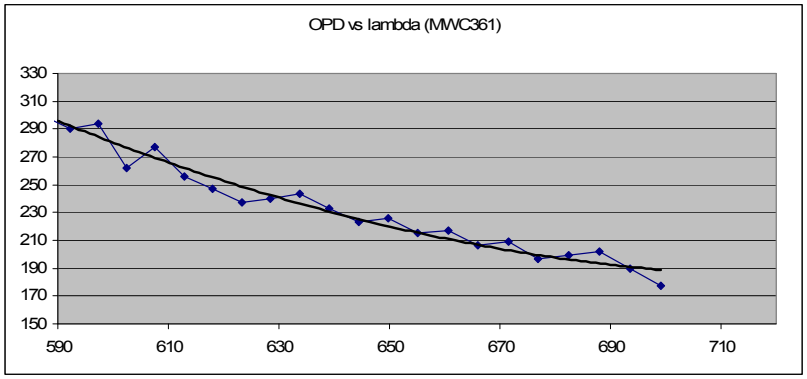
- Most important: CHARA is working really very well!

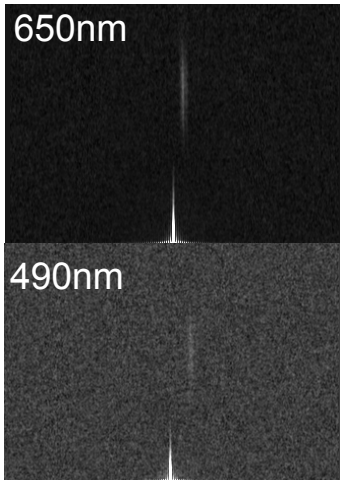
Future Plans

- New data processing release
- 3T with calibrators and ¼ pix. Validation and science use
- 4T group delay tracking validation (fringes validation for the 1-4 baseline)

- Installation of the new VIS/TT beam splitters (85%→VEGA, 15%→TT)
- New spectral lamp?

- Use of the CHARA LDC
  - How?
  - Fully qualified?





- VIS + IR simultaneously (VEGA+FLUOR in june)

- Improved acquisition (cal-target-cal more rapidly)

Future plans (Science)

- Conclude the current good programs
- Complete the open programs

- 3T routine operation in 2009 (improved DRS needed)
- 4T validation (check interest)

- VIS+IR (+LDC): really important issue for science purpose
- External fringe tracking for low V^2 or low mV?

- Development of more photosphere science (fundamental characteristics of stars) in parallel to the spectrally resolved approach: benefit from the highest angular resolution.

Thanks to CHARA team:

Hal, Theo, Judit, Laszlo, Nils, Chris, PJ, Gail and Larry

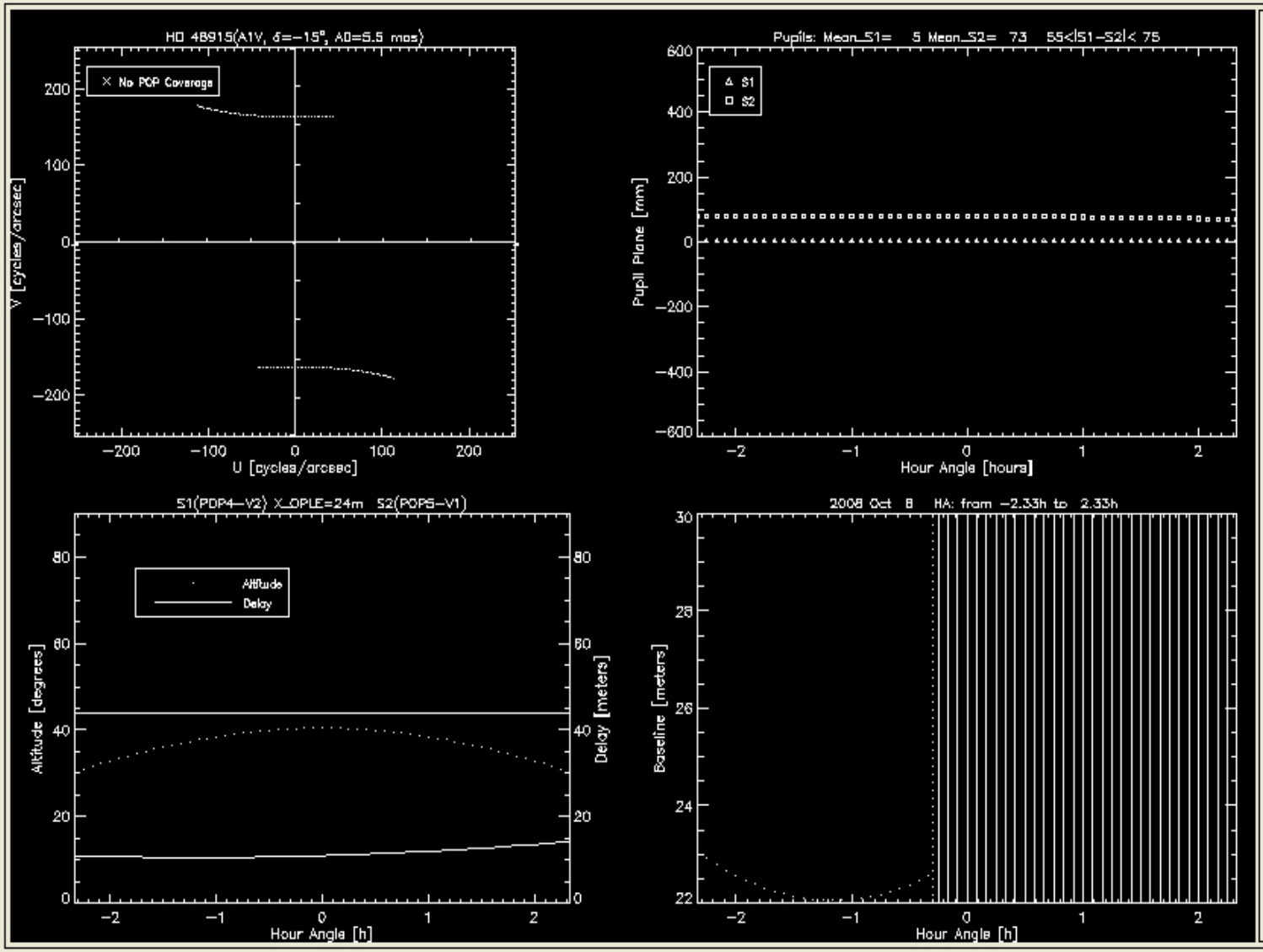
Thanks to VEGA team:

Alain, Alain, Aurélie, Daniel, Isabelle, Jean-Michel, Karine, Michel, Olivier, Omar, Philippe, Philippe

Welcome to Jean-Baptiste (postdoc for VEGA >09/09)

We are looking for PhD students….

VEGA PLAN Version 06-Oct-2008



HD Nb	UD	Spec.Typ.
48915	5.51000	A1V

RA	6:45:8.9	mV	-1.47
DE	-16:42:58.0	mK	-1.39
TT	UT:13h30m	Dia	5.51

Plot: (U,V) Plane

2008 | Oct | 8

Tel_1	Tel_1 POP	Tel_1 Beam
S1	POP2	V1
S2	POP3	V2
E1	POP4	V3

X OPLE Tel_1 Ref: 24

Tel_2	Tel_2 POP	Tel_2 Beam
S1	POP3	V1
S2	POP4	V2
E1	POP5	V3

Make PS file

Load an observation

QUIT

Slit	Grating	Camera	Lambda	SPIN	Red Filter	Blue Filter	Record	# Blocks	# Frames	Tracking
W070H4	1800	RB	656	OFF	1	1	RB	10	3000	R

634. Blue 638. | 653. Red 659. | #Phot-R 2788 | #Phot-B 2013 | TARGET | Obs. Name: sirius | Record Config

sirius S1S2 1800 656.200 POL-OFF
siriusC1 S1S2 1800 656.200 POL-OFF
siriusC2 S1S2 1800 656.200 POL-OFF

CONTROL

File Edit View Help

Star / time info | Chara Active Config | Vega Active Config

Date	Julian day	Universal Time	
3/15/2009	2454905.8	7:29:19	
Obs Type		Hour Angle 00:00:00.0	
Alpha (right ascensi	Delta (declination)	UD mV	Transit Time 00:00:00.0

Select StarList File

DirName: ---------- FileName: ---------- NbBlock: 20 Send

Scheduler

- (•) test and init
- ( ) Generate Script
- ( ) setup Vega
- ( ) wait Chara ready
- ( ) verify pupil & image
- ( ) Vega camera HV
- ( ) flux optimization
- ( ) fringe tracking
- ( ) record data on Vega
- ( ) record LP on Vega
- ( ) next observation ?
- ( ) archive data
- ( ) shutdown

Run | Next Step | Abort

Restart | Skip Line | Reload

Log

Chara Status: ----- Pwd Chiller RedHv BlueHv OptLab

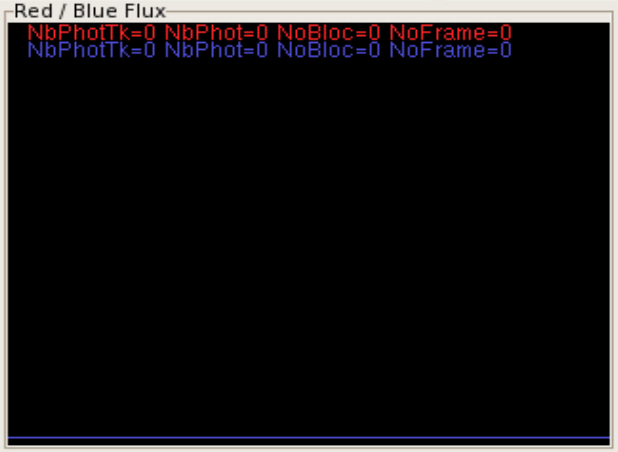
ICS Status: -----

Technical Detector Status & Actions: ----- TechCamOf MaxImg 0 + - MaxPup 0 + -

Red Det Status: ----- Hv1Of Hv2Of

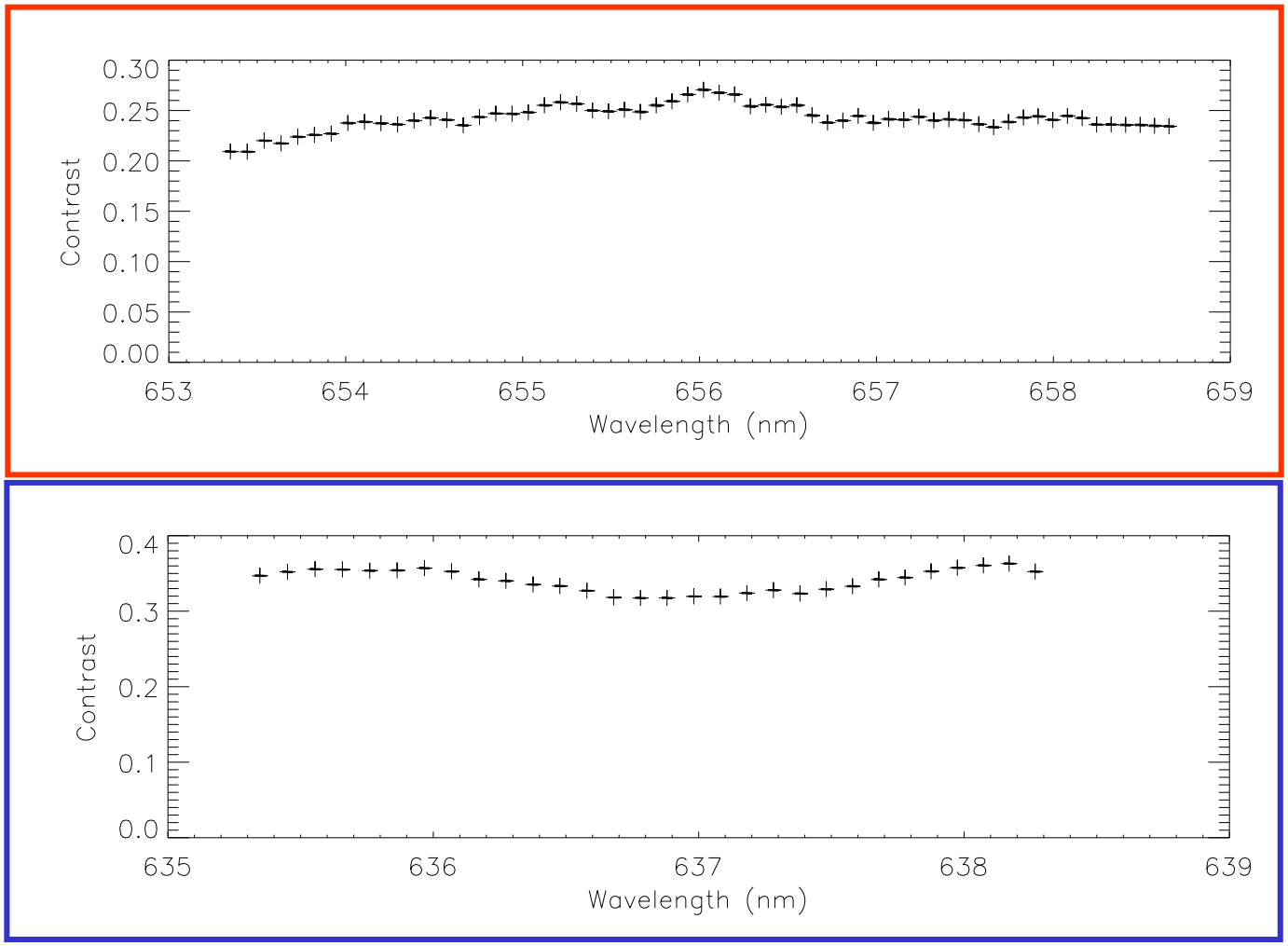
Blue Det Status: ----- Hv1Of Hv2Of

Red / Blue Flux

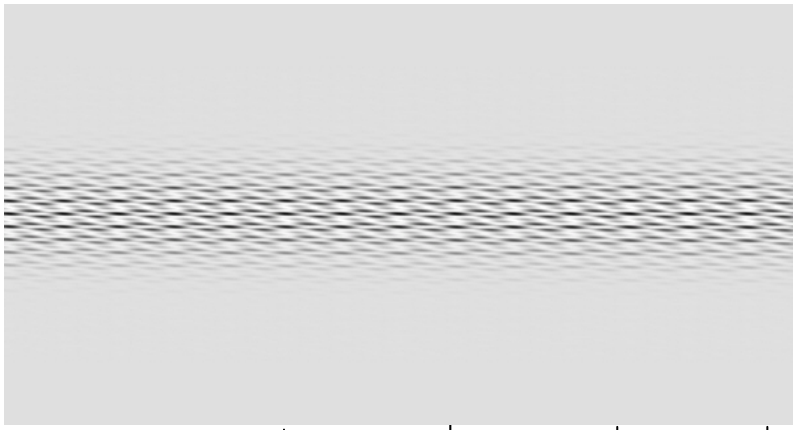


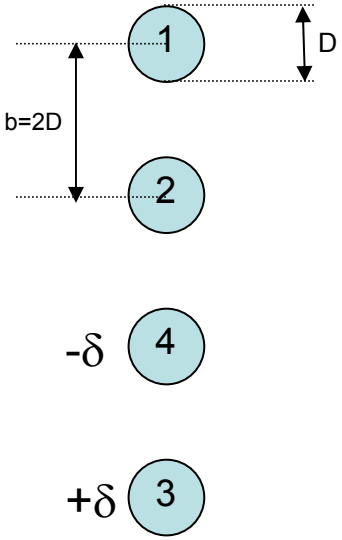
Tracking Status: ----- Raz Tracking

V² ALGOLR vs V² ALGOLB

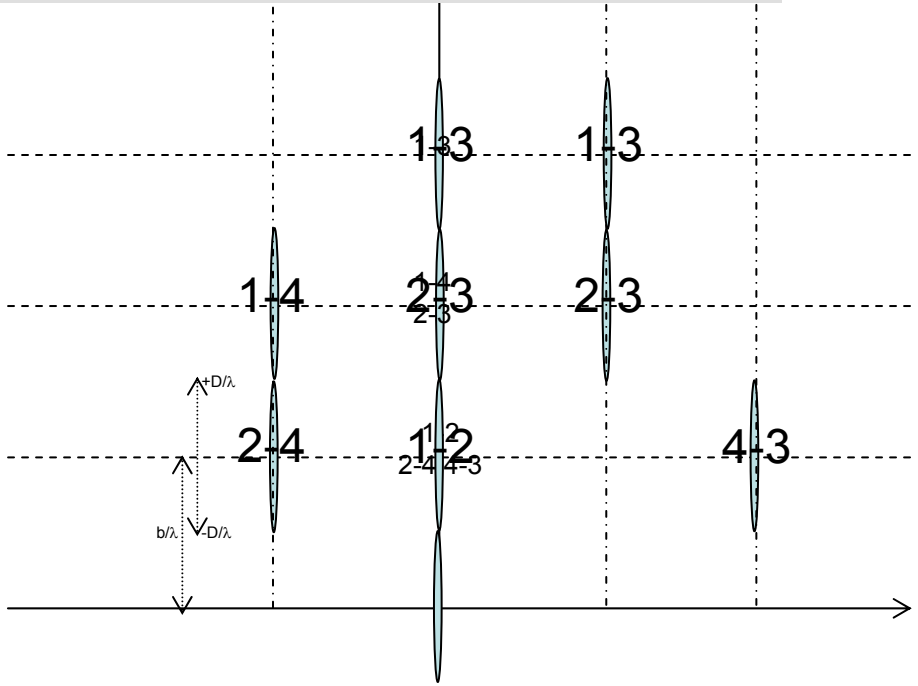


VEGA, a 4 beams dispersed fringes combiner





Pupil plane



Modulation Transfer Function