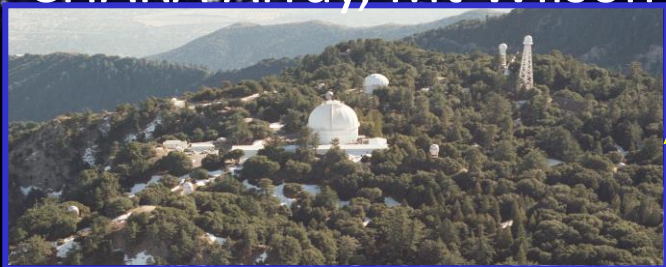


VEGA/CHARA High spatial and spectral resolution (0.3mas et R=6000/30000)

Remote, Nice



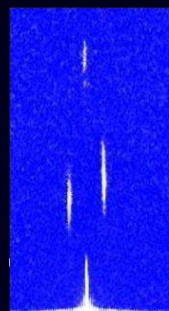
CHARA Array, Mt Wilson



09-2007: Integration
07-2008: First light
10-2009: 3T Mode
10-2010: 4T Mode

Since 2011 :

3T VEGA + IR in // (CLIMB, MIRC)
~20 programs, 60 nights per year

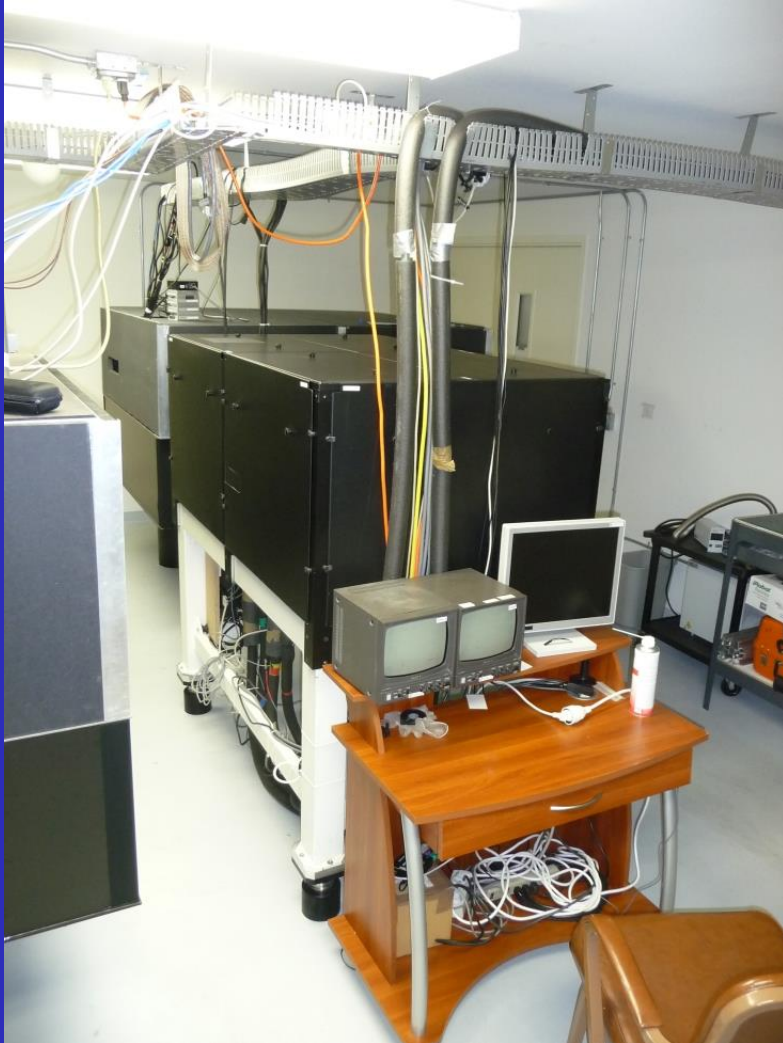


Mode 3T

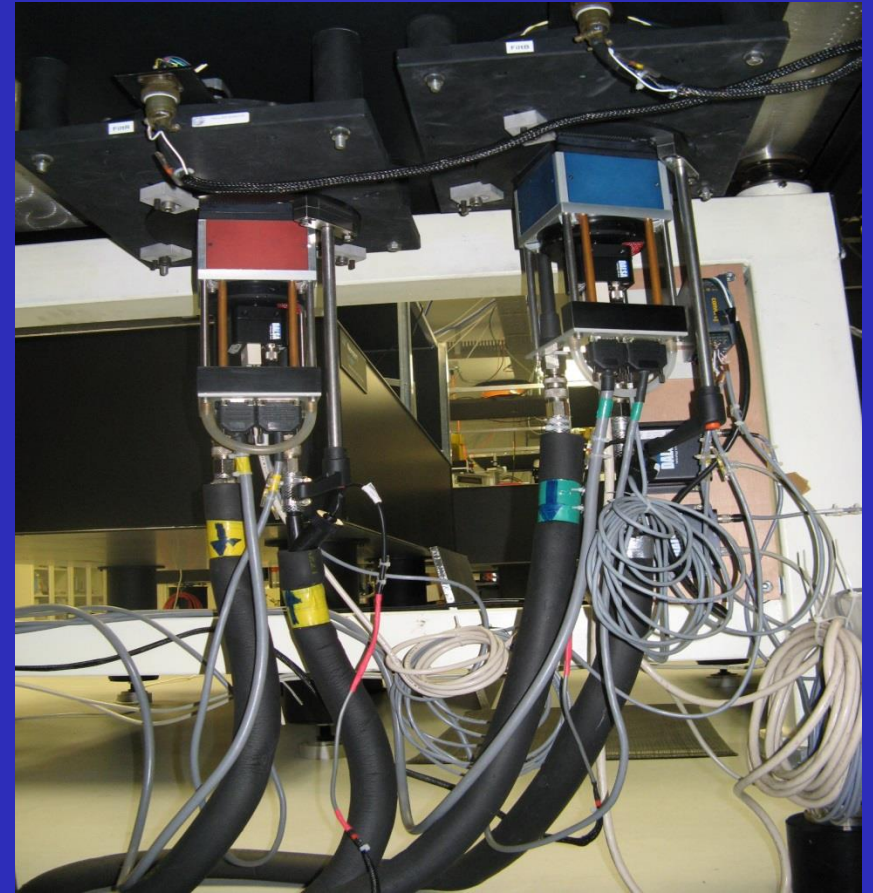
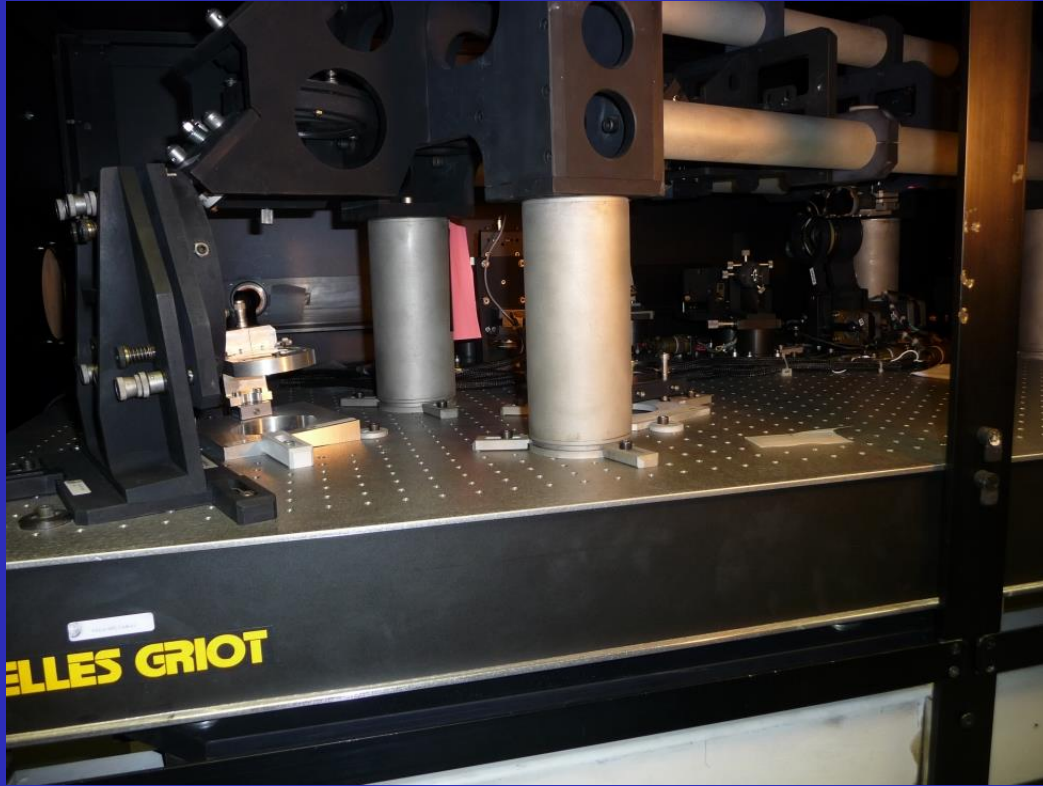


Mode 4T

VEGA in images



VEGA in images



Main characteristics of VEGA/CHARA

Mourard et al. A&A 2009, 508 (for 2T) & Mourard et al. 2011, 531 (for 3T/4T)

Spectrograph Characteristics

Grating	R	$\Delta\lambda$ (Blue)	$\Delta\lambda$ (Red)	$\lambda_R - \lambda_B$
R1: 1800 gr/mm	30 000	5 nm	8 nm	25 nm
R2: 300 gr/mm	5000	30 nm	45 nm	170 nm
R3: 100 gr/mm	1700	100 nm	150 nm	not possible

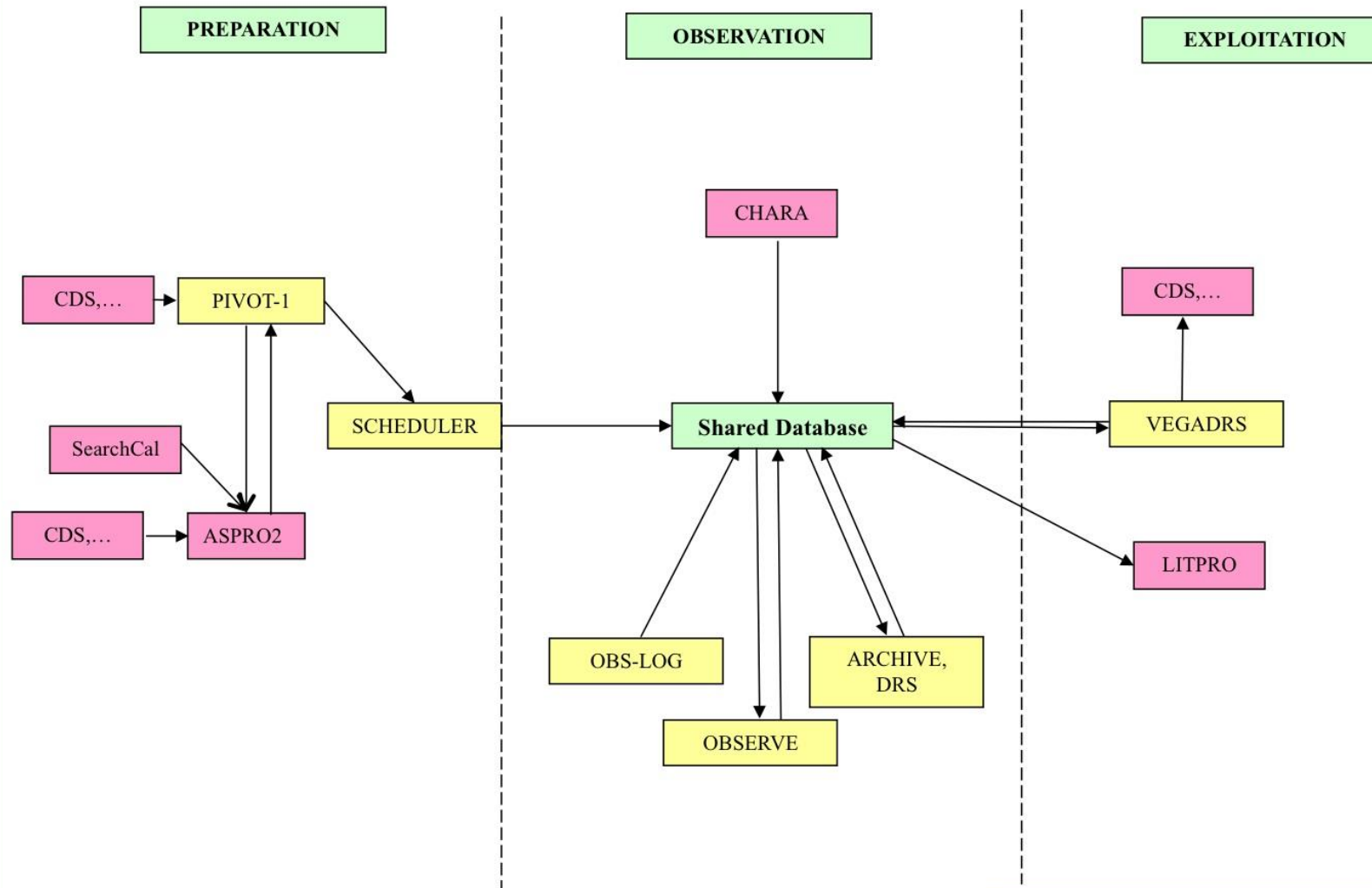
Limiting magnitude

R0=8cm

R0=15cm

Resolution	R	Typical lim. magnitude	Best perf.
Low	1700	6.8	7.5
Medium	6000	6.5	8.0
High	30 000	4.2	5.5

Interferometric toolbox



PIVOT :
Prototype of Interferometric VO Tool

PIVOT: proposals and runs management

web service, interoperability

PIVOT v1.5.4.4

Exit Plugins

P1.1 : Proposal | P1.2 : Semester Planning | **P2.1 : Starlist Settings** | P2.2 : Strategy Settings | P3.1 : Run Management | P3.2 : Night Management

Type	Name	HD	CHARA	VEGA	Record	Instru IR
TARGET	HD 165341W2W1	HD 165341	W2POP5V2-W1POP1V1	W070H4 300 720.0 R.	40 1000	*
REFERENCE	HD 165341Cal1W2W1	HD 170920	W2POP5V2-W1POP1V1	W070H4 300 720.0 R.	20 1000	*
REFERENCE	HD 165341Cal2W2W1	HD 181440	W2POP5V2-W1POP1V1	W070H4 300 720.0 R.	20 1000	*
REFERENCE	HD 165341Cal3W2W1	HD 149121	W2POP5V2-W1POP1V1	W070H4 300 720.0 R.	20 1000	*

SPEC	R2720					
####						

Period : 3-(S1/2012)

Choose active proposal : 372/Characterisation of asteroseismic targets/165341

Buttons: Edit Starlist, Associate to this starlist, Remove from this starlist, Delete current starlist, Import file, Export file, From DB, Sent proposal to Aspro2

STL_P372

372/Characterisation of asteroseismic targets/165341

Mourard Denis -- logged as PI_vega

comments

PIVOT: defining observing's strategy

PIVOT v1.5.4.4

Exit Plugins

P1.1 : Proposal | P1.2 : Semester Planning | P2.1 : Starlist Settings | **P2.2 : Strategy Settings** | P3.1 : Run Management | P3.2 : Night Management

Periode : 3-(S1/2012) Configuration Summary : W1W2-R2720+CLIMB

Proposal : 372/Characterisation of asteroseismic targets/165341 Template : W2POP5V2-W1POP1V1

Starlist : STL_P372 Comment : 3x CTC from HA=-3h to transit CLIMB 3T recording Orlagh

Name	type	duration	V2	Hour Angle
HD165341W2...	TARGET	26	18:05:27.28	-3.66 : 2.71
HD165341Cal...	REFERENCE	18	18:31:56.99	-3.46 : 2.73
HD165341Cal...	REFERENCE	18	19:20:35.69	-3.47 : 2.73
HD165341Cal...	REFERENCE	18	16:32:35.69	-3.81 : 2.71
W2720	SPEC	11		
	####			

Name	Type	Start	Duration
HD165341Cal3...	REFERENCE	14h2m	18
HD165341W2W1	TARGET	14h25m	26
HD165341Cal3...	REFERENCE	14h53m	18
HD165341W2W1	TARGET	15h20m	26
HD165341Cal1...	REFERENCE	15h50m	18
HD165341W2W1	TARGET	16h20m	26
HD165341Cal2...	REFERENCE	17h5m	18

Add Remove Up Down

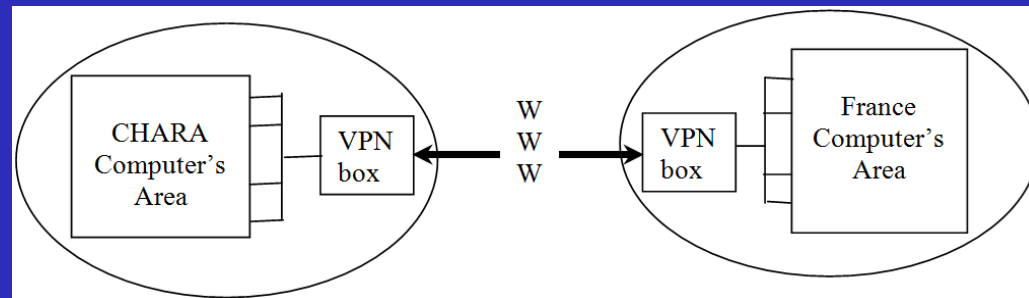
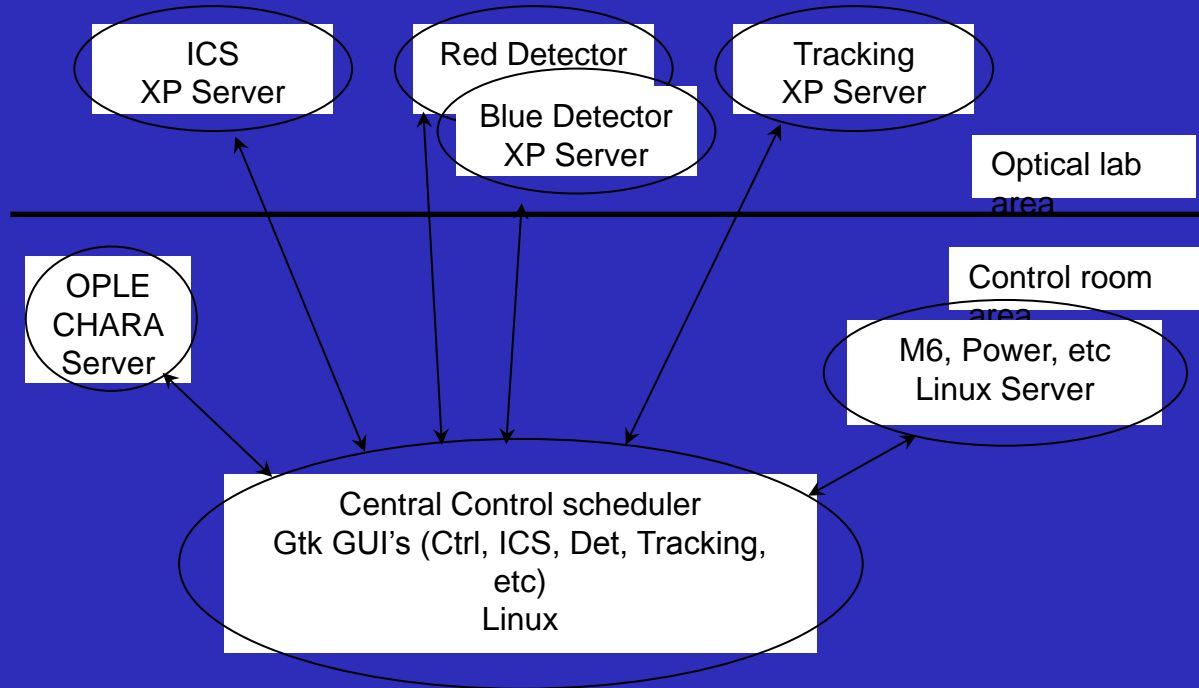
HA -8 -6 -4 -2 0 +2 +4 +6 +8

LST 10h 12h 14h 16h 18h 20h 22h 0h 2h

Export (.jpg) use ASPRO Save strategy << < > >>

Mourard Denis -- logged as PI_vega comments

VEGA Control system



VEGA Control System

CONTROL

File Edit View Help

Star / time info

Chara Active Config

Vega Active Config

Date 9/12/2013	Julian day 2456548.0	Universal Time 13:10:46	Sideral Time 04:45:20
Obs Type REFERENCE	Hour Angle 01:14:43	Alpha 03:30:37.06	Delta -05:04:30.5
NbBlocs 20	NbFrames 1000	UD mv 99.00 4.73	Transit Time (UT) 11:56:14

Current Observation

StarList File

Tracker

DirName

FileName

NbBlock

NbFrame

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

Conf Server Functions

-
-
-
-

Log

```
Time Track=-ret=0
Time CamB=-ret=0
Time CamR=-ret=0
Time TechCam=-ret=0
```

Chara Status

 Pwd
 Chiller
 RedHv
 BlueHv
 OptLab-ICS Status

Technical Detector Status & Actions

Red Det Status

Blue Det Status

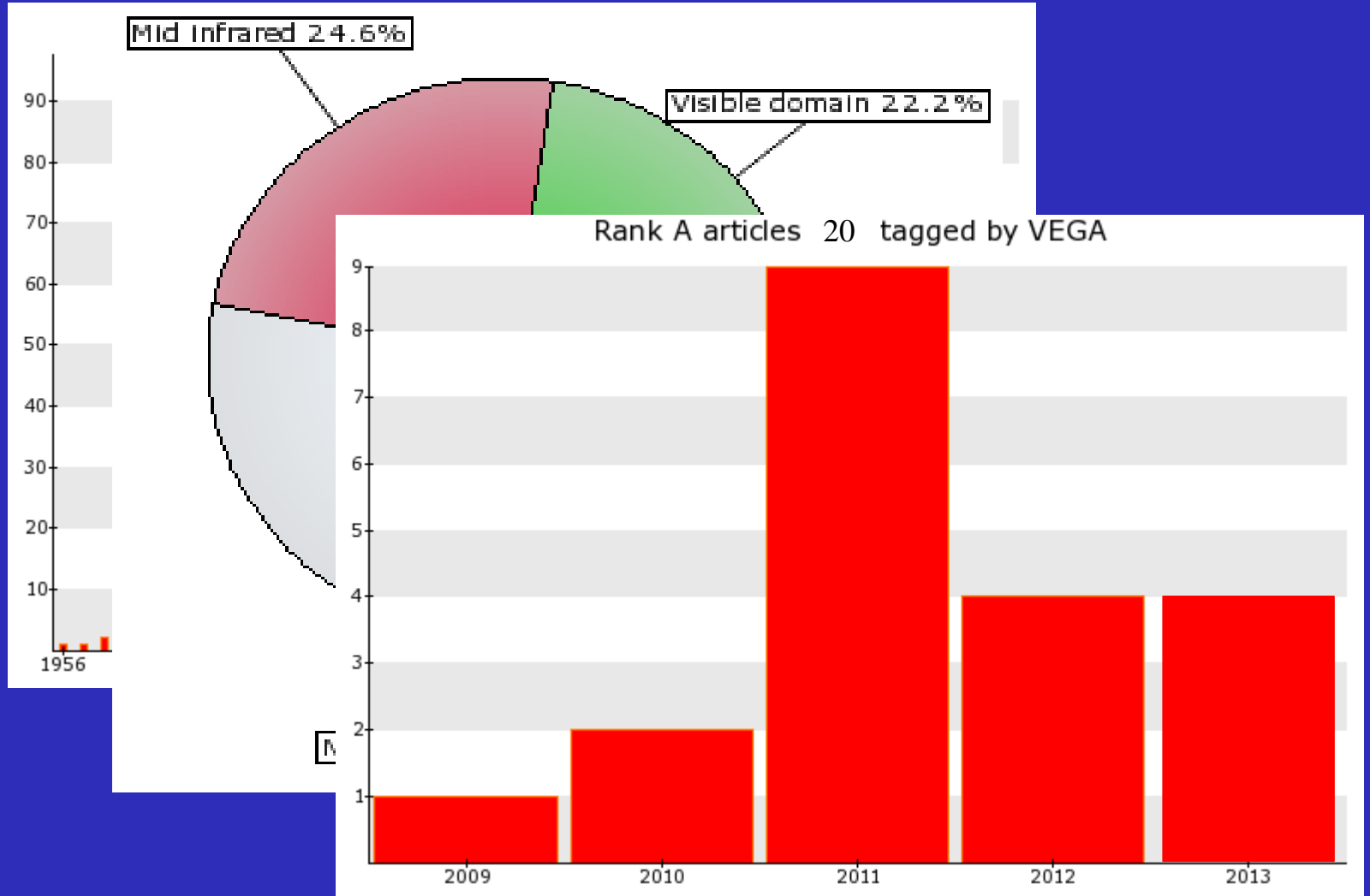
Red / Blue Flux

```
NbPhotTK=0 NbPhot=0 NoBloc=0 NoFrame=0
NbPhotTK=0 NbPhot=0 NoBloc=0 NoFrame=0
```

Vega Tracking Status

External Tracking Status

Some statistics



Main VEGA/CHARA programs

<http://www-n.oca.eu/vega/en/publications/index.htm>

- **Circumstellar environments: high spectral resolution**

- A/B Supergiants (wind): Chesneau et al, A&A 521 (2010)
- β Cep (disk): Nardetto et al. , A&A 525 (2011)
- Be stars
 - Wind studies: Delaa et al. A&A 529 (2011), Stee et al. A&A (2012)
 - Interactive massive stars: Bonneau et al., A&A 432 (2011), Meilland et al. A&A 532 (2011)
- The chromosphere of K giants: Berio et al. A&A (2011)
- Eps Aur : Mourard et al., A&A 2012
- Young Stellar objects (MWC361, AB Aur, ...): Perraut et al., Benisty et al.,
- Rotation of stars and interaction with environment

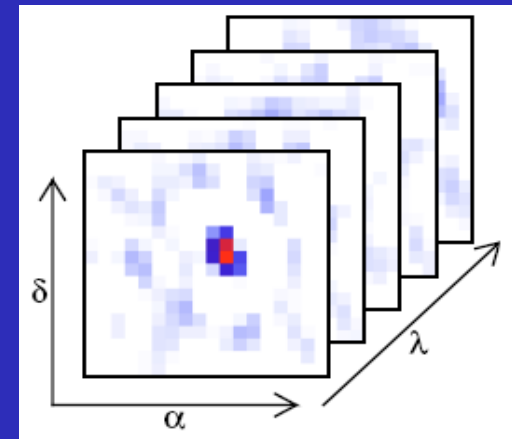
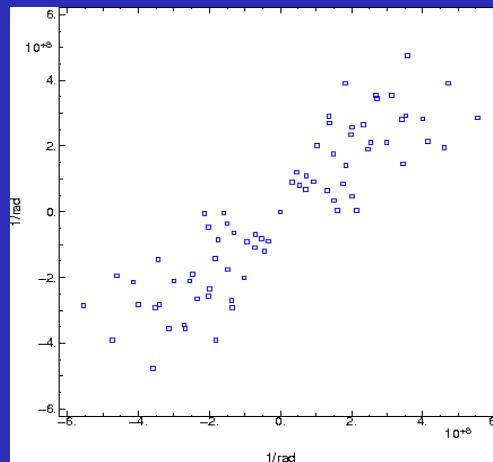
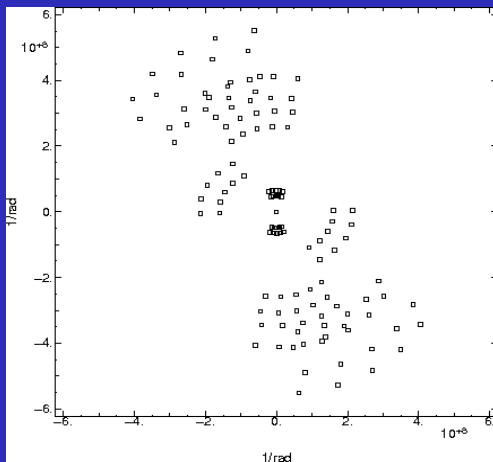
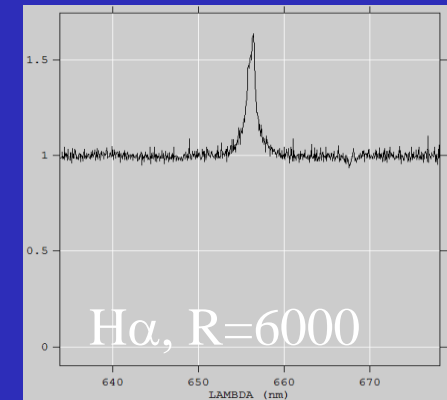
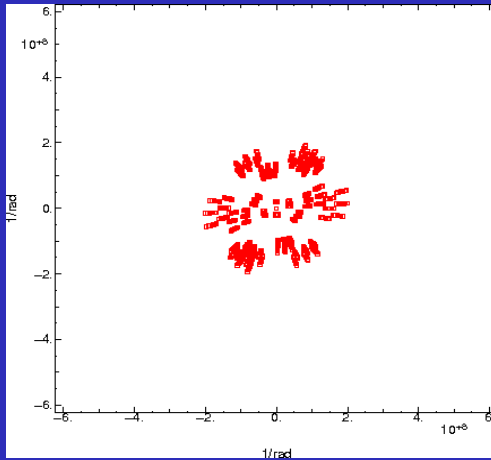
- **Fundamental parameters: Visible + 300m baseline + IR coherencing**

- roAp stars: Perraut et al., A&A 526 (2011)
- CoRoT Targets: HD49933: Bigot et al., A&A (2011)
- Exoplanet host stars: Ligi et al., A&A (2012)
- Surface brightness relationships

- **Spectral imaging**

Spectral imaging VEGA+MIRC

2012 October 18th and 19th on CHARA ϕ Persei (Be + subdwarf-HST)
MIRC 6T @ 1.6 μ m, VEGA 4T @ 656-487nm



Summary of 'known' facts on phi Per (1)

Be star for sure!

- Slettebak 1966, Abt 2002
 - $V_{\text{ini}} = 450 - 410 \text{ km/s}$, 85% of the equatorial breakup velocity
 - The highest projected velocity among B stars
- Distance
 - Hipparcos 2007: $\pi = 4.54 \pm 0.2 \text{ mas}$, ie $d = 220 \text{ pc} \pm 10 \text{ pc}$
 - Megier 2009 (indicator CaII), $d = 195 \pm 32 \text{ pc}$
- Compagnon
 - Gies 1998 HST: subdwarf $T_{\text{eff}} = 53000 \text{ K}$, $\log g = 4.2$, flux ratio 0.165/0.154 @ 137.4/164.7nm
- Polarization
 - Clarke 1998: polar & binary but no detection of variations
 - Ghosh 1999: Spectral dependence on polarisation
 - $P_B = 1.57\%$ $P_V = 1.36\%$ $P_R = 1.19\%$ $P_I = 0.98\%$
 - $PA = 27^\circ \pm 2^\circ$
 - → electron-scattering disks with attenuative hydrogen opacities, combined with dilution due to the visible central star

Summary of 'known' facts on phi Per (2)

Spectroscopic and photometric studies

- Bozic-Harmanec 1995:
 - Linear ephemeris and true orbital elements + masses
 - Period for the spectroscopic binary: 127d
 - B0.5e for the primary, sdO6 for the secondary
 - Secular variations in the RV curves + orbital light variations
- Stefl 2000:
 - Study of the He lines: outer regions of the circumstellar (primary) disk and excited by the O-type secondary
 - Emission line assymetry due to the global density pattern in the inner regions
- Hummel 2001:
 - Axisymmetric disk $R=10R_p$. Keplerian rotation in question
 - Complex structure of emission lines due to external illumination

Summary of 'known' facts on phi Per (3)

Previous interferometric studies

- Quirrenbach MarkIII 1997
 - Equator-on. Disk MajorAxis=2.67mas, $r=0.46$, PA disk $62\pm 5^\circ$
 - Bande large sur Halpha
- Tycner NPOI 2006
 - Gaussian model: 2.89mas, $r=0.27$, $\text{phi}=-61.5^\circ$
 - Inclination $>75^\circ$, half-opening angle $<8^\circ$
 - Bande large sur Halpha
- Gies, CHARA K' 2007
 - 2.30mas, $r=0\pm 0.2$, $\text{phi}=-44$

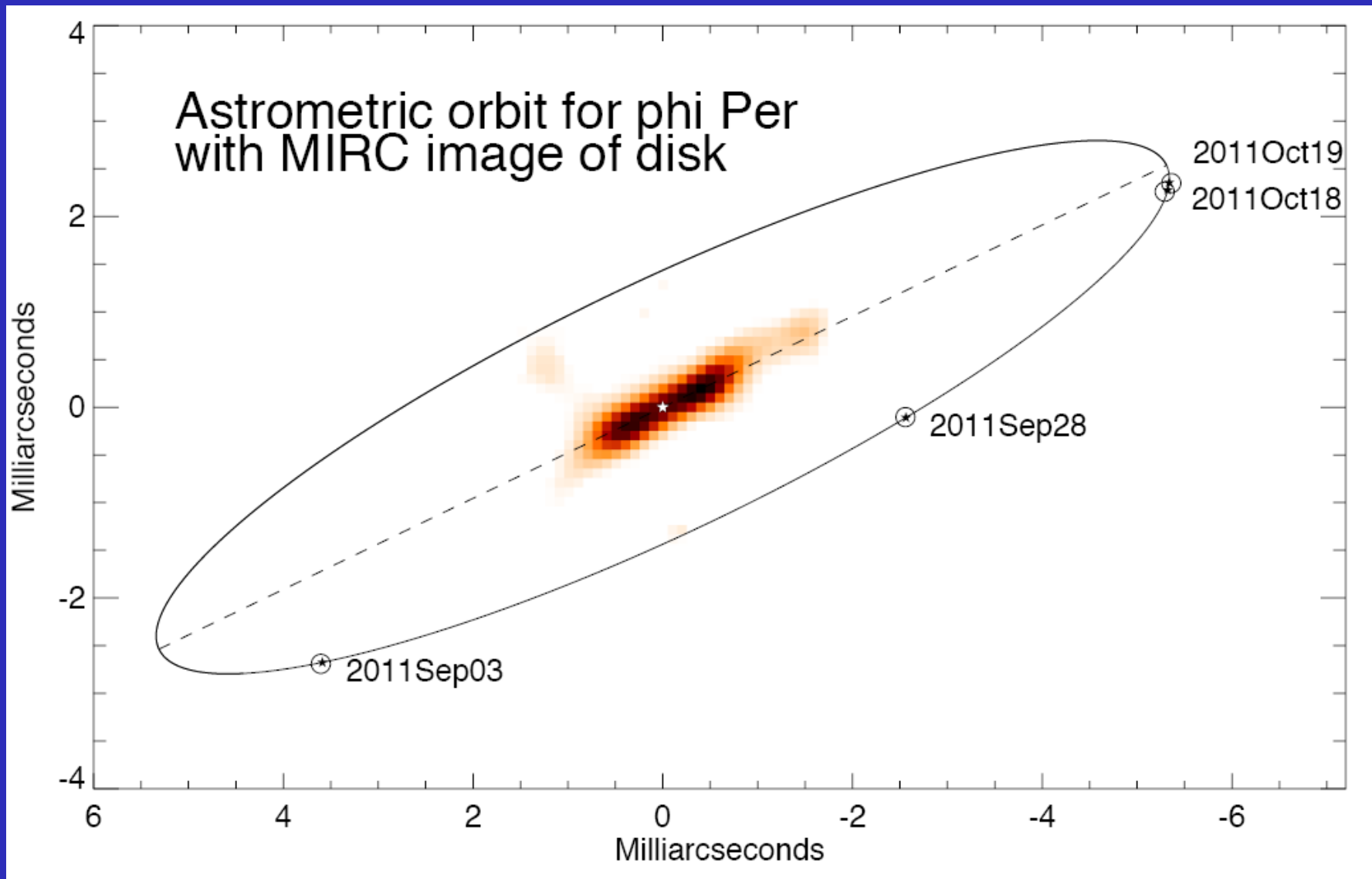
Starting points

- Be star, very elongated disk, see equator-on
- $V \sin i = 450 \text{ km/s}$
- Spectroscopic binary with 127d period
- Companion UV \rightarrow 5% of flux in V, 8% in H band

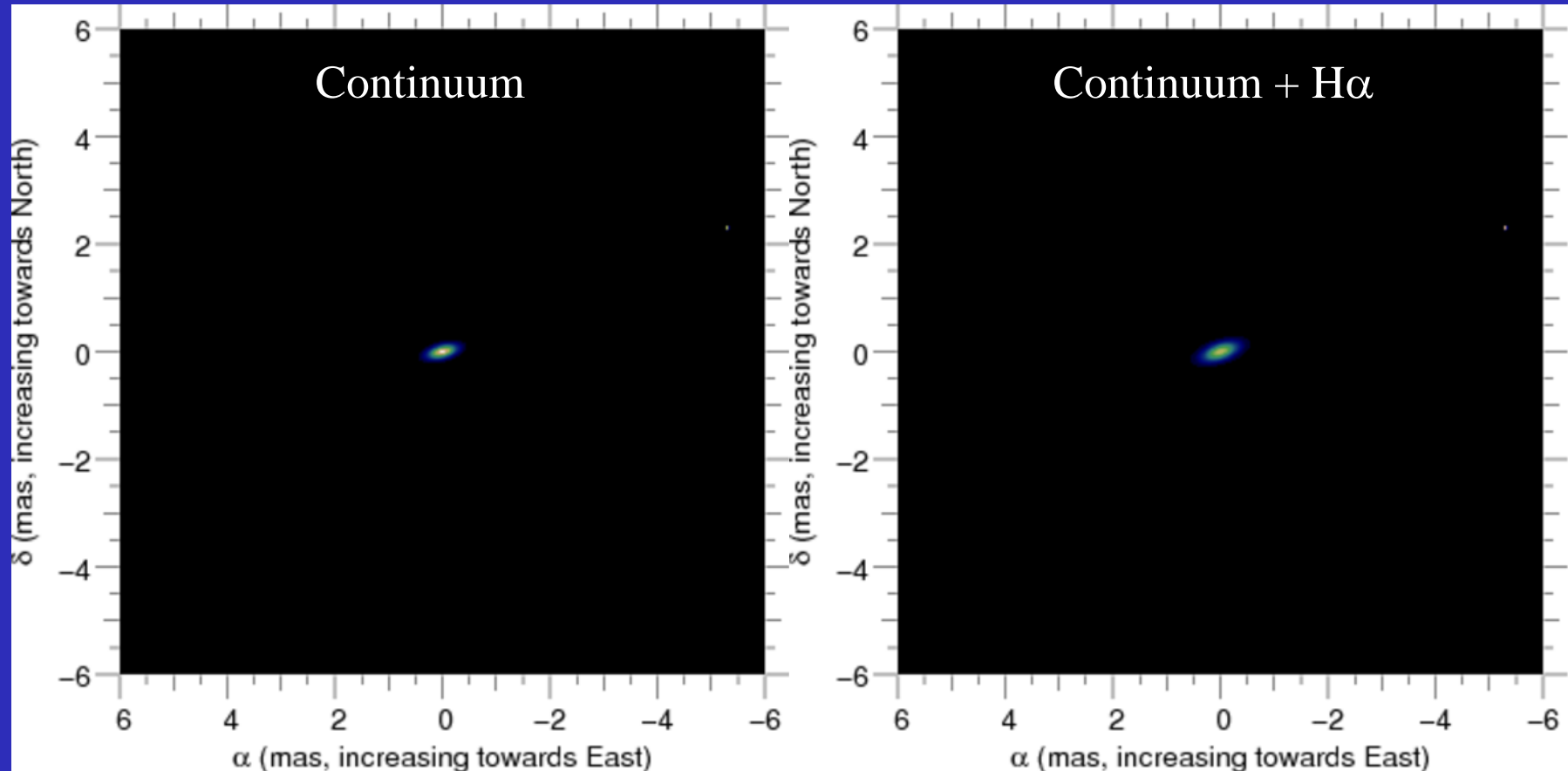
- Maximum uv coverage
- H band and V band continuum observation
- H α spectrally resolved interferometry
- 2 dates for companion identification

- Goals
 - Detection and Spectral type of the companion (never seen in optical)
 - Disk geometry + kinematics. Spectral study, influence of secondary
 - Stellar disk geometry

MIRC 6TH band (done by J. Monnier, X. Che)



Model fitting, V^2 VEGA only (done with JMMC/LitPro software)

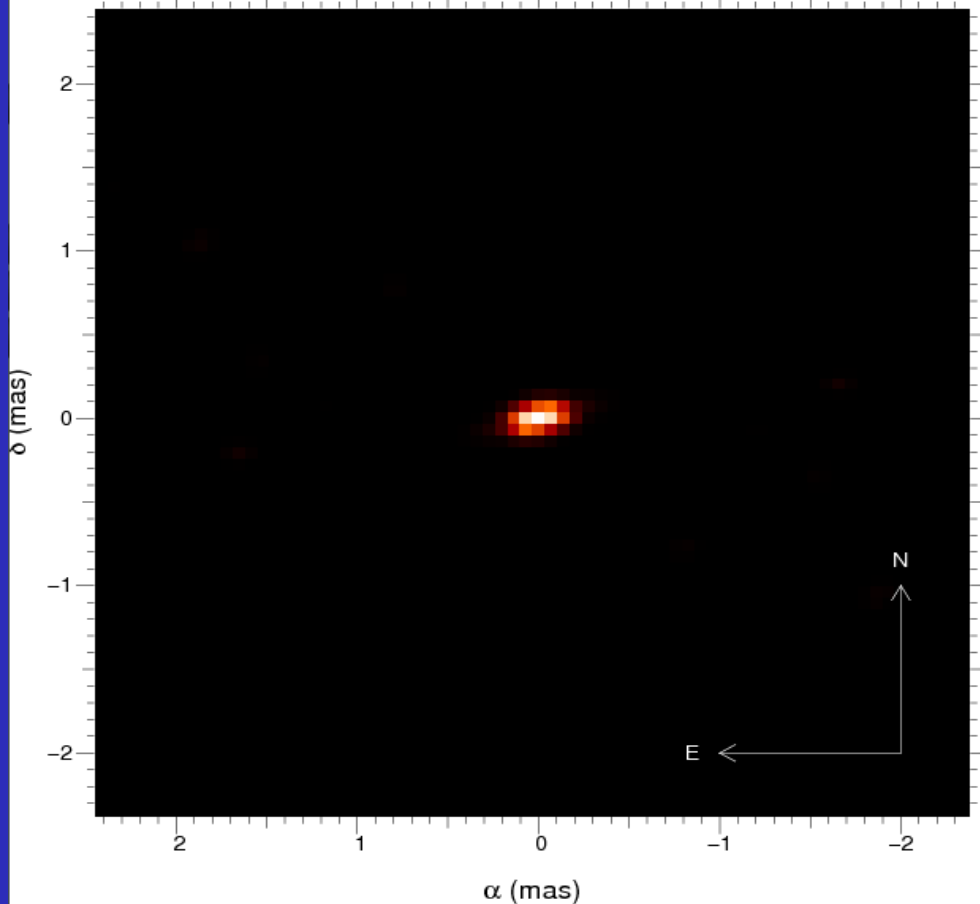


Very low contribution of the disk in the continuum
Stellar disk elongated by a factor more than 2
 $\sim 10^\circ$ tilt between the continuum and continuum+H α region

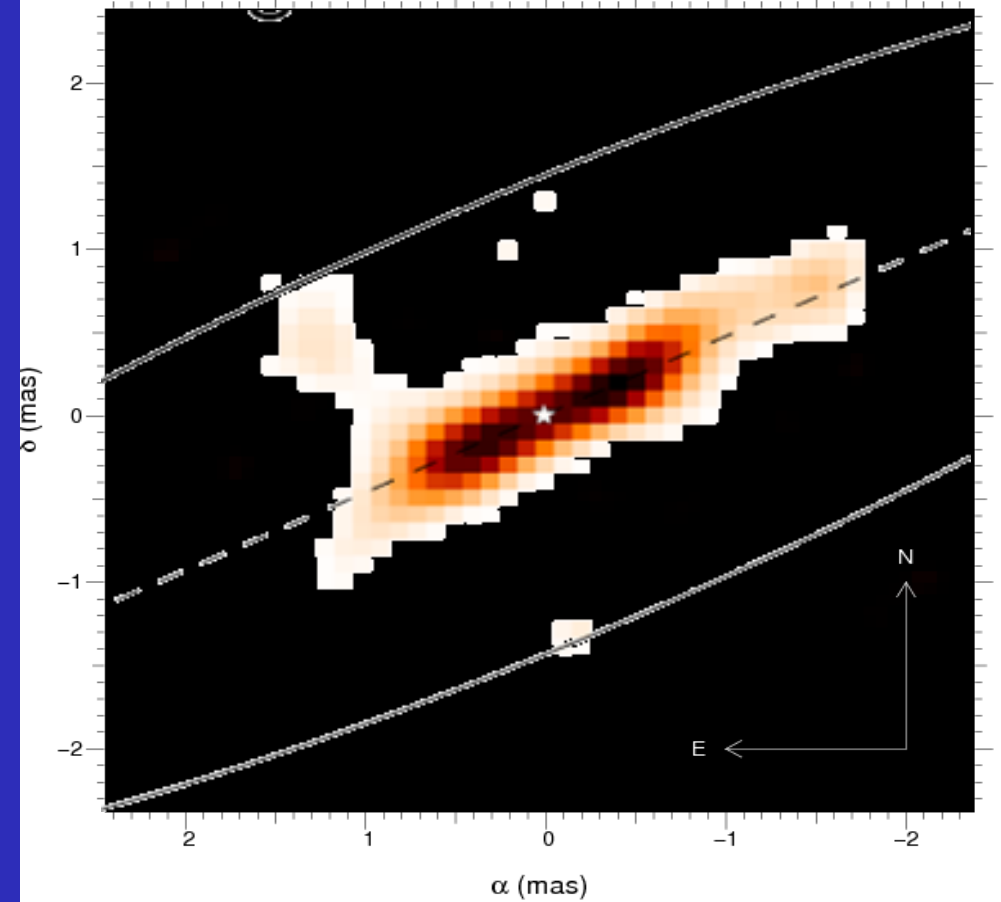
Image reconstruction VEGA V² only

(done by F. Millour, OCA)

Red detector (continuum)



Red detector (H α)



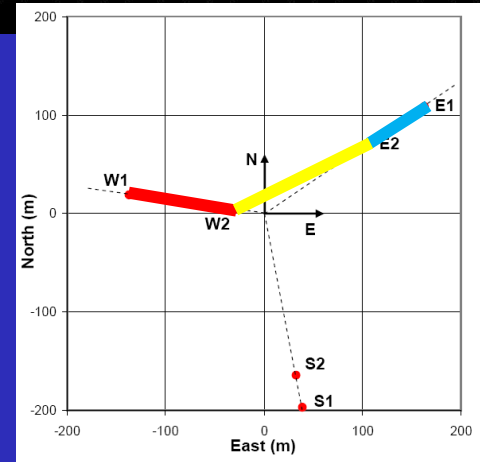
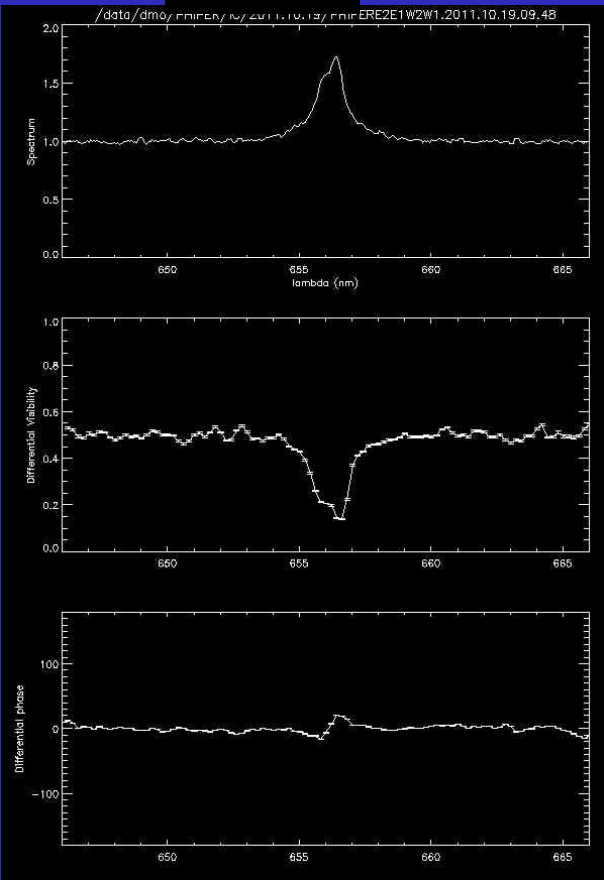
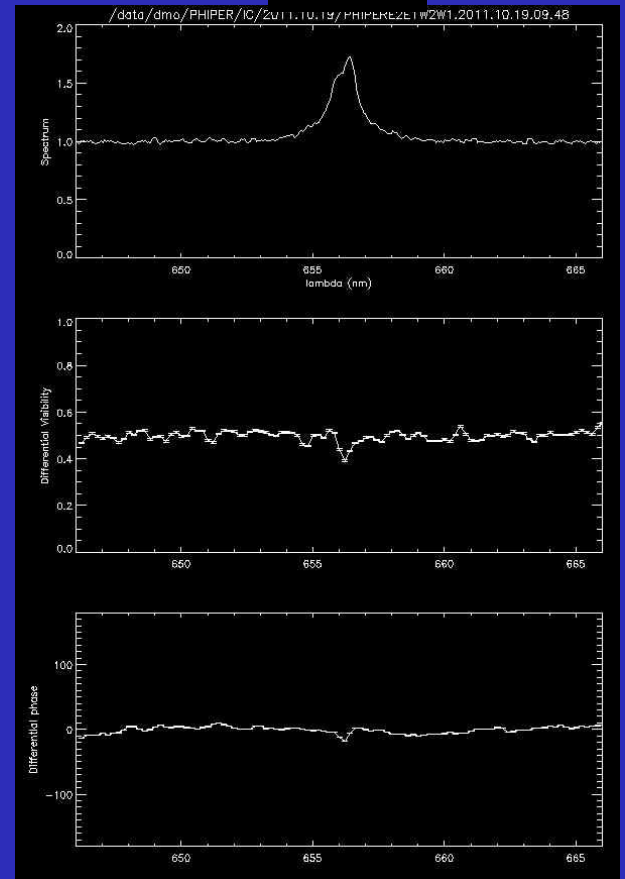
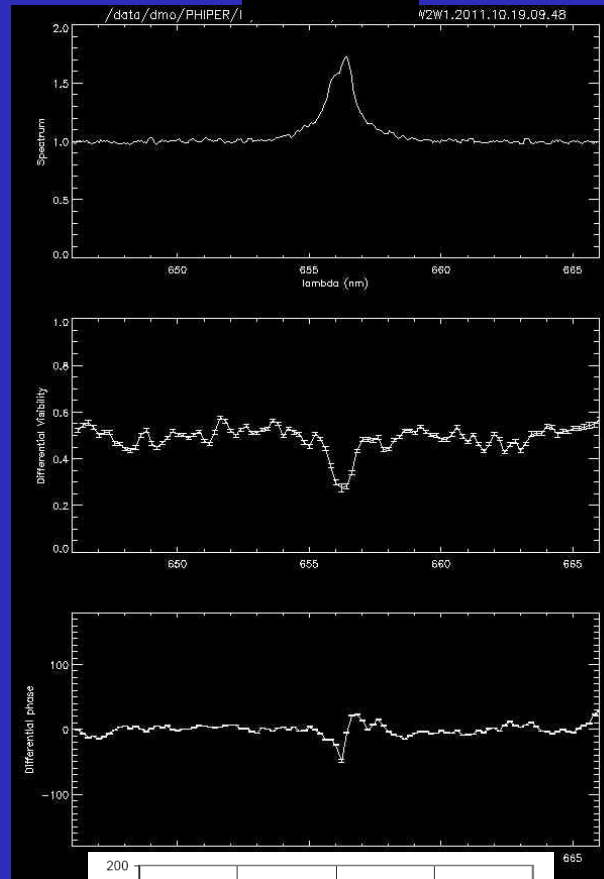
First image VEGA/CHARA in the visible
Disk orientation ok with MIRC
Quantitative analysis in progress: central star, disk

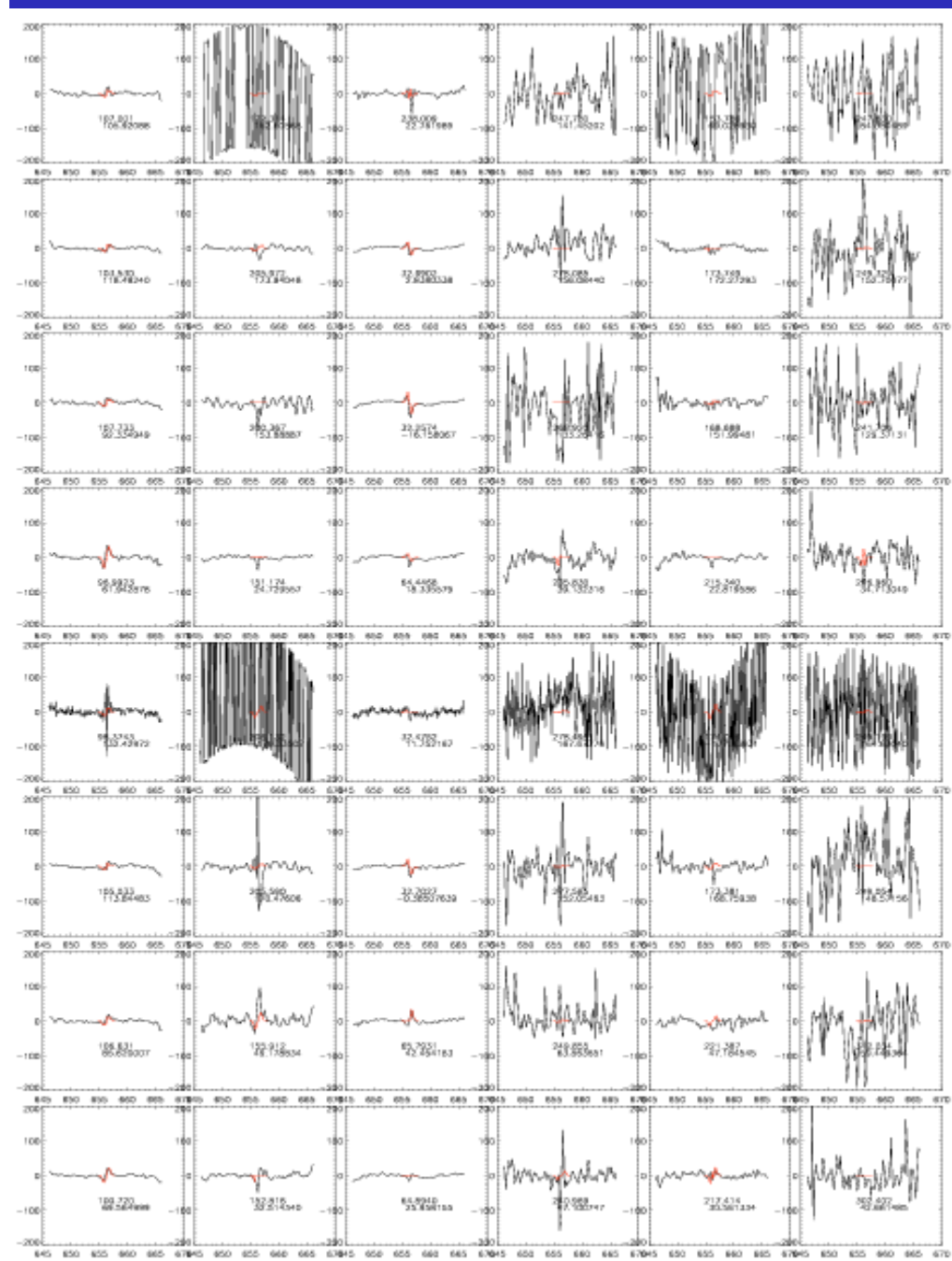
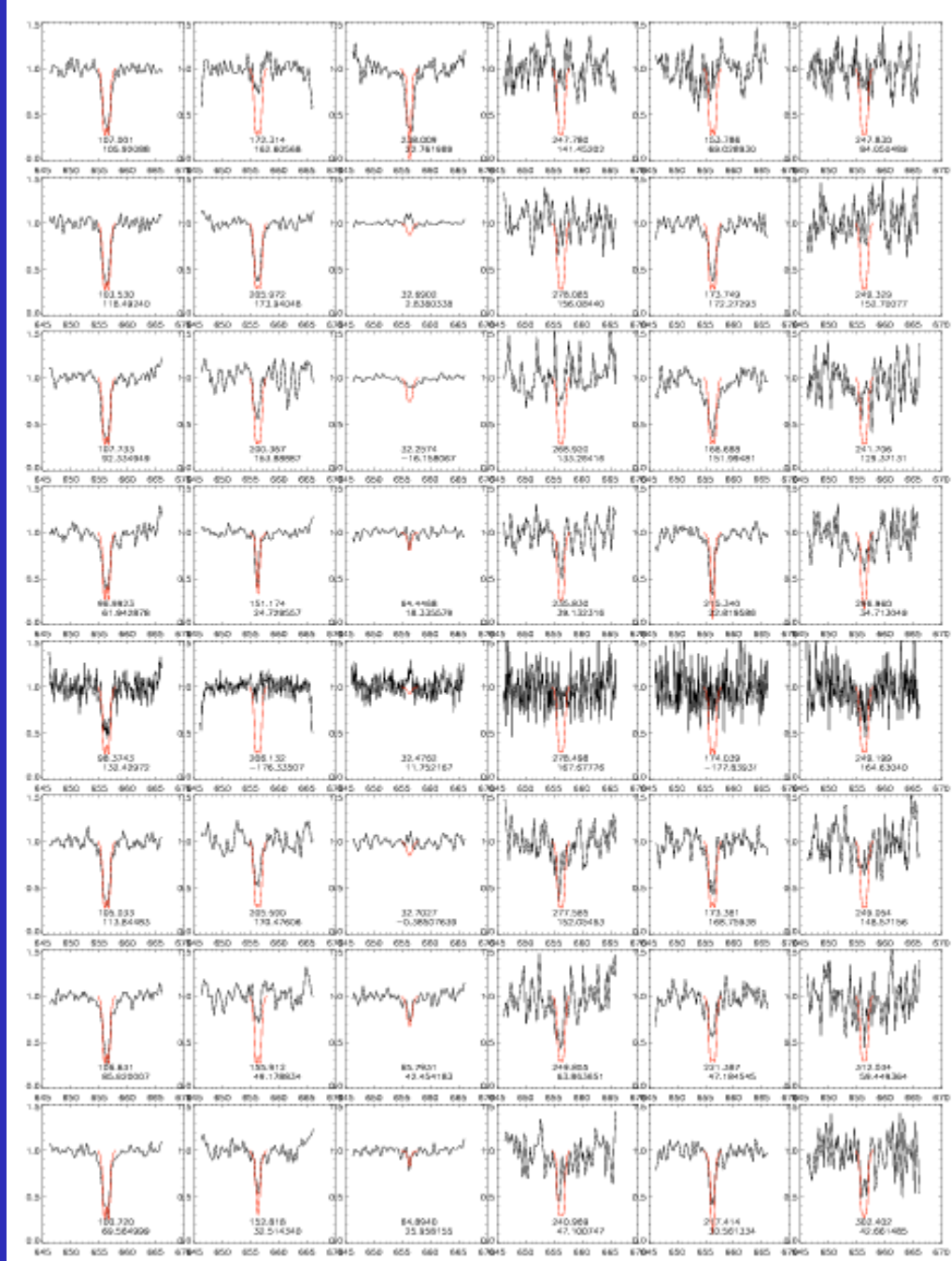
W2E2

Exemples of V_DIFF

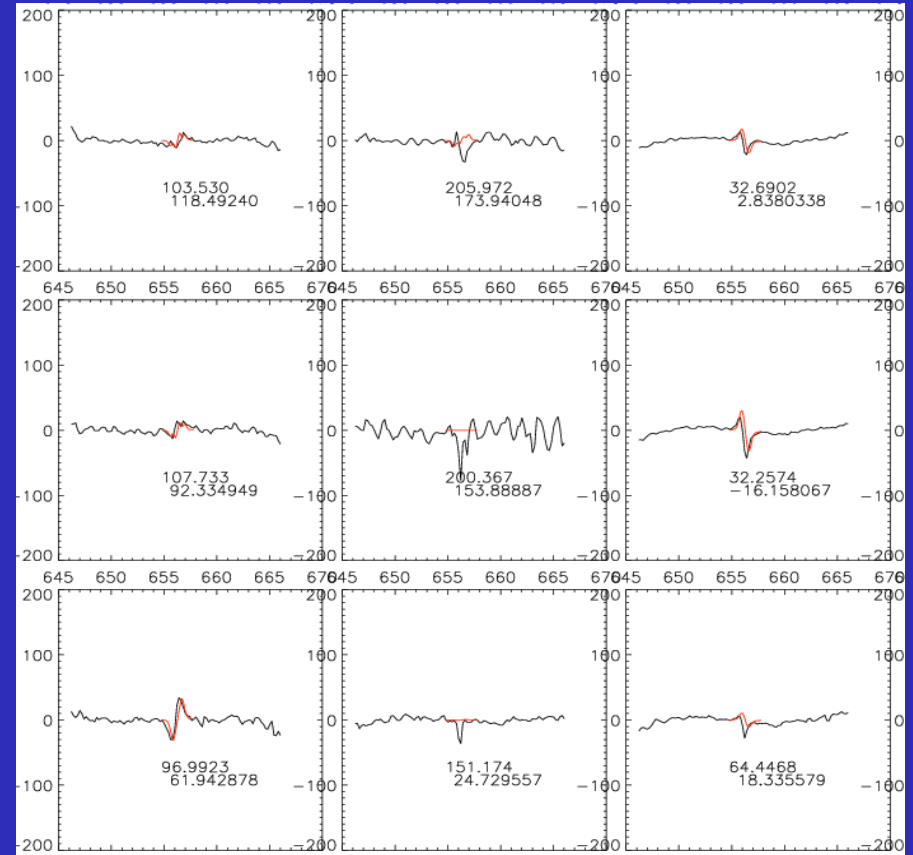
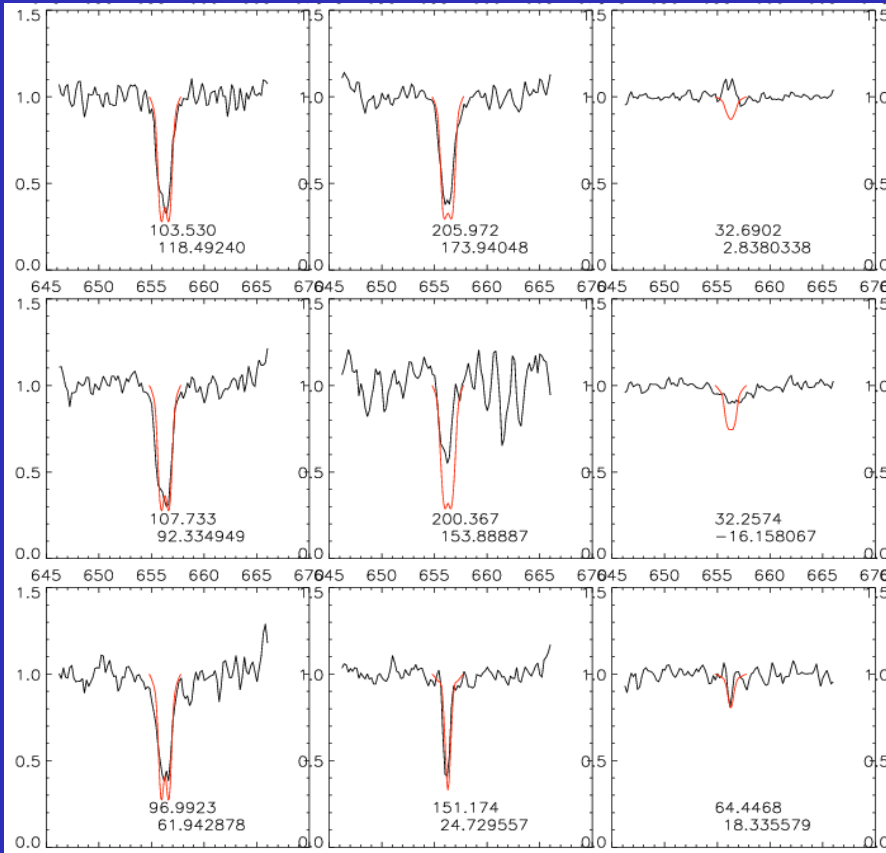
E2E1

W1W2





Rotating disk modeling H α line profile + VIS(λ) + PHI(λ) (done by A. Meilland, OCA)



FWHM disk = 4 stellar diameters, PA=-65°.
Vrot~500kms⁻¹ keplerian rotation

Why an instrument of second generation ?

- Installation of OA system in the next 2 or 3 years
- Saturation problems with photon counting detectors (high flux or small D/r0)
- Low visibilities measurements are difficult
 - Increase the limiting magnitude
 - Increase the measurements precision
- Combine 6 telescopes simultaneously

Low noise analog detectors

Single-mode spatial filters

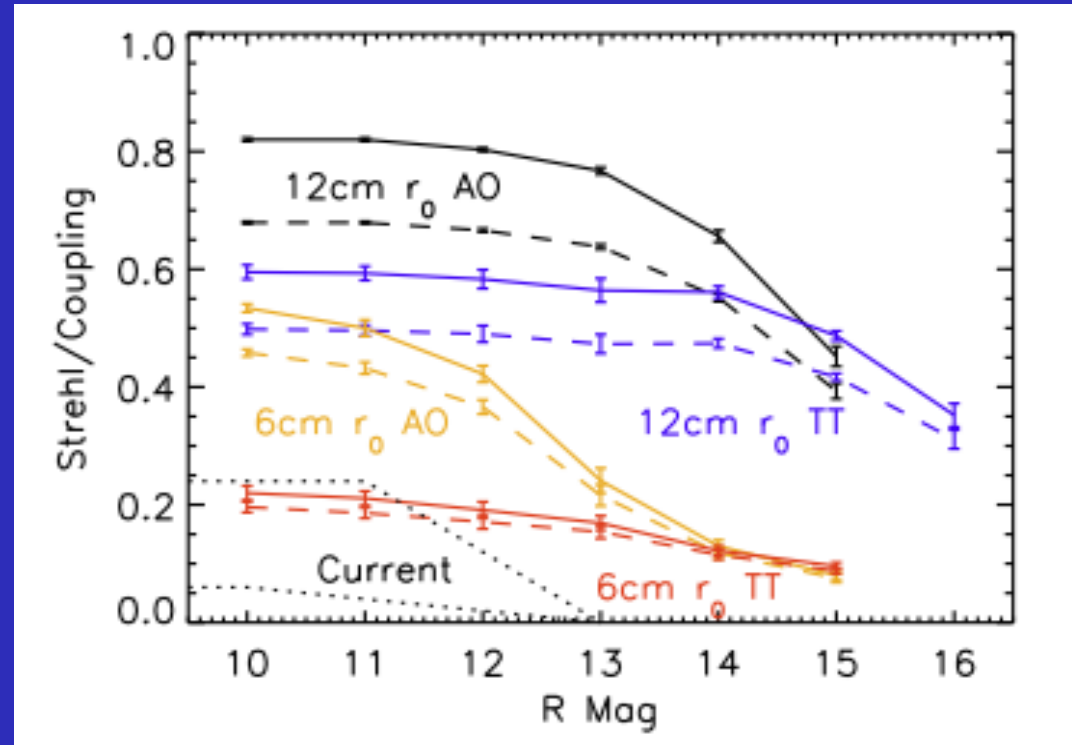
OA characteristics

- OA installed in the telescopes
- Shack-Hartmann sensors
- Modal correction
- 30 sub-pupils / 19 actuators

Scheduling

- PDR 60 days after funding agreement
- Systems should be ready for scientific observations 2 years after PDR

Performances attendues en bande H

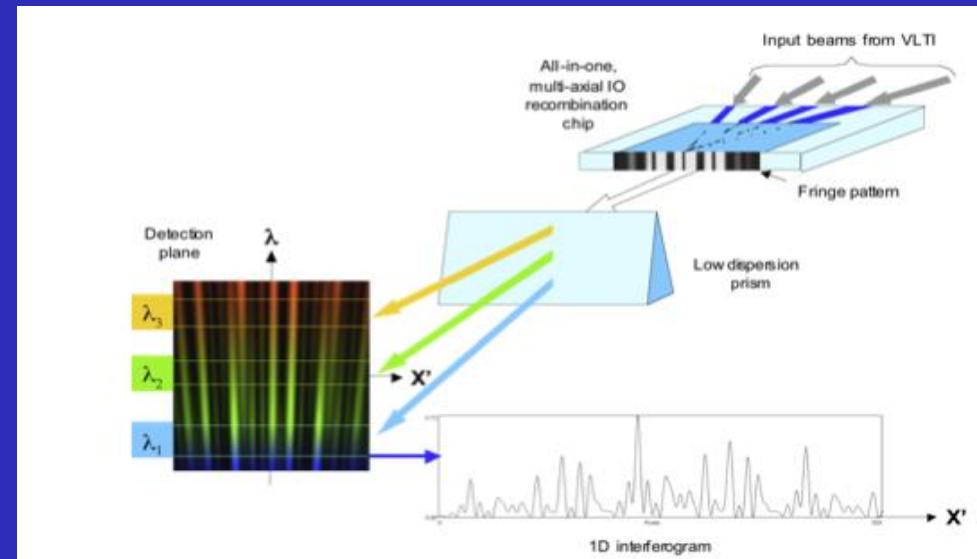


Expected performances in the visible (700nm)

- Strehl $\approx 30\%$ for $r_0=12\text{cm}$
 => coupling $\approx 25\%$
- Strehl $\approx 6\%$ for $r_0=6\text{cm}$
 => coupling $\approx 5\%$

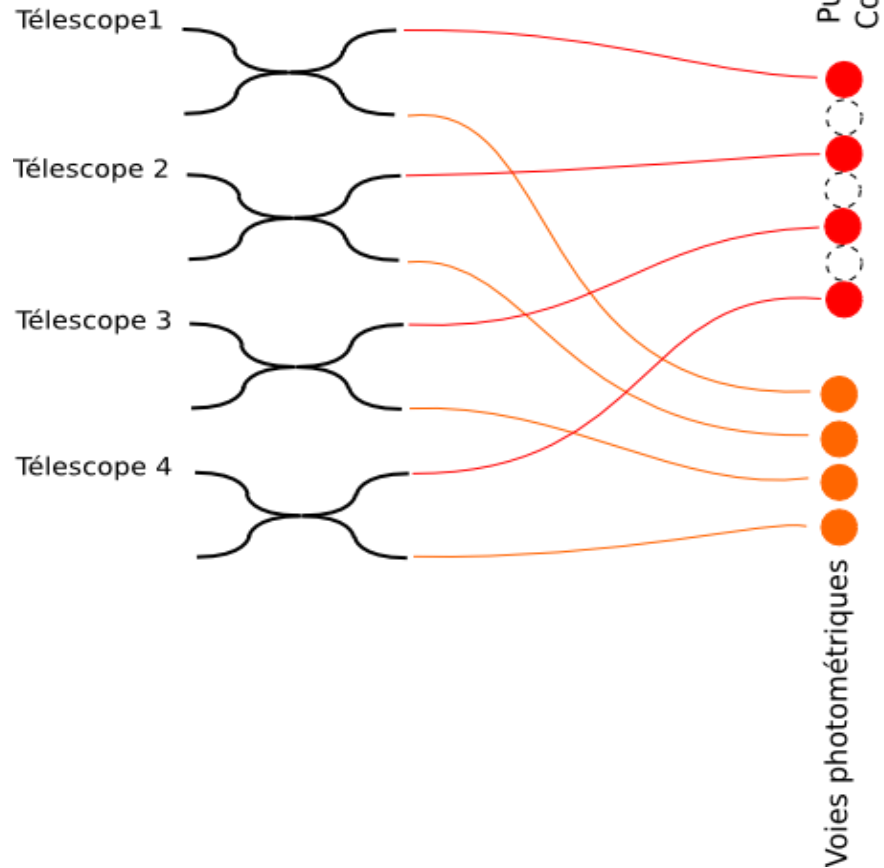
3 possible solutions :

- **with single mode optical fibers**
easy transportation
good transmission over $\Delta\lambda < 100\text{nm}$
- **with integrated optics**
Compact system (multi-axial combiner)
active modules (OPD modulation, ...)
transmission loss (2-3dB)
- **with pinholes**
not studied



Filtrage spatial par fibres optiques monomodes

Séparation des voies photométriques au travers d'une jonction en X



SPECTROGRAPHE

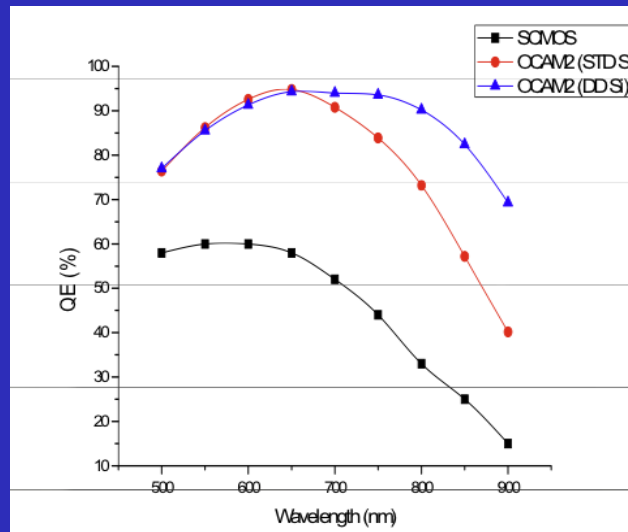
DéTECTEUR
Franges dispersées
et photométries



OCAM2:

Low noise camera developed by IPAG-LAM

- 1500 frames per second maximum
- quantum efficiency > 90% between 600nm and 800nm
- RON $\sim 0.13 e^-$
- 240x240 pixels

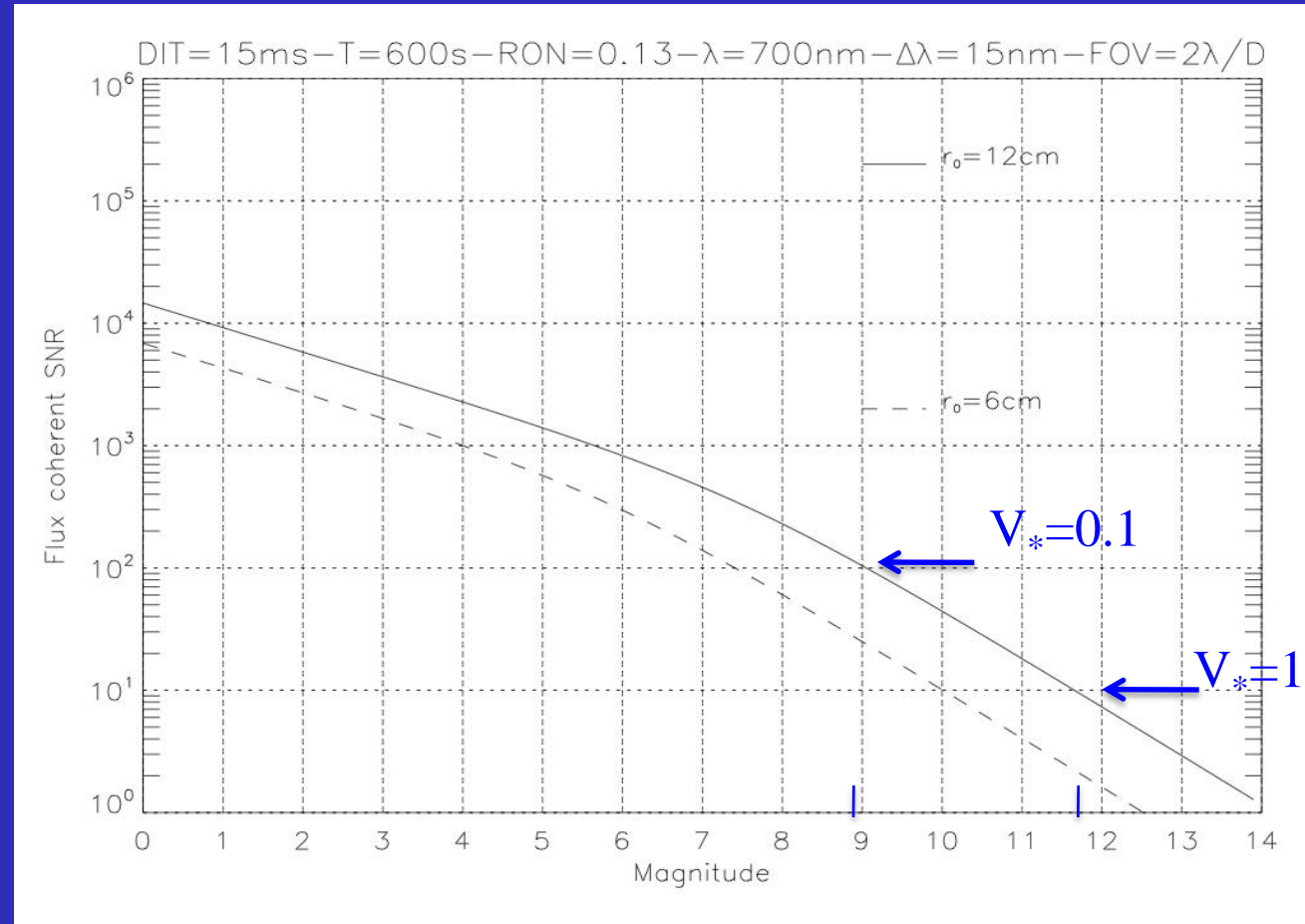


SNR expression

$$SNR_V = \frac{\sqrt{MNV_{inst}V_*}}{\sqrt{n_{tel}N + n_{pix}RON^2}}$$

Parameters:

- Quantum efficiency: 90%
- CHARA Transmission : 3%
- Spectro Transmission : 46%
 - OA Transmission : 80%
 - Polar Transmission : 50%
 - RON : 0.13
 - 4 pixels per fringe
 - FOV: $2\lambda/D$
 - $\Delta\lambda$: 15nm @ 700nm
 - n_{pix} : 48x214
 - DIT: 15ms
- M: 40000 (10 minutes)
 - V_{inst} : 0.7
 - RatioPhot: 20%



=> Gain of 4 magnitudes wrt current VEGA



Test de la caméra OCAM au foyer de l'instrument CHARA/VEGA

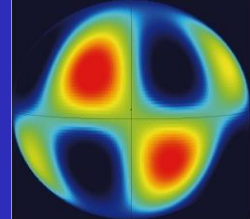
- 4 demi nuits d'observation en Novembre 2012 (2 nuits exploitables)
- Installation et observation réalisées par S.Lagarde, P.Feautrier et P.Balard
- 10 étoiles observées :
 - Magnitude de $m_V=0$ à $m_V=5.5$
 - Mode 2T (S1S2) et 3T (E1E2W2)
 - Moyenne résolution spectrale ($R=5000$) autour de $H\alpha$ et à 800nm
 - Temps de pose testés : 1ms – 2ms - 5ms – 10ms – 20ms - 40ms

→ Franges détectées sur toutes les étoiles dans toutes les configurations

Towards a VLTI visible instrument

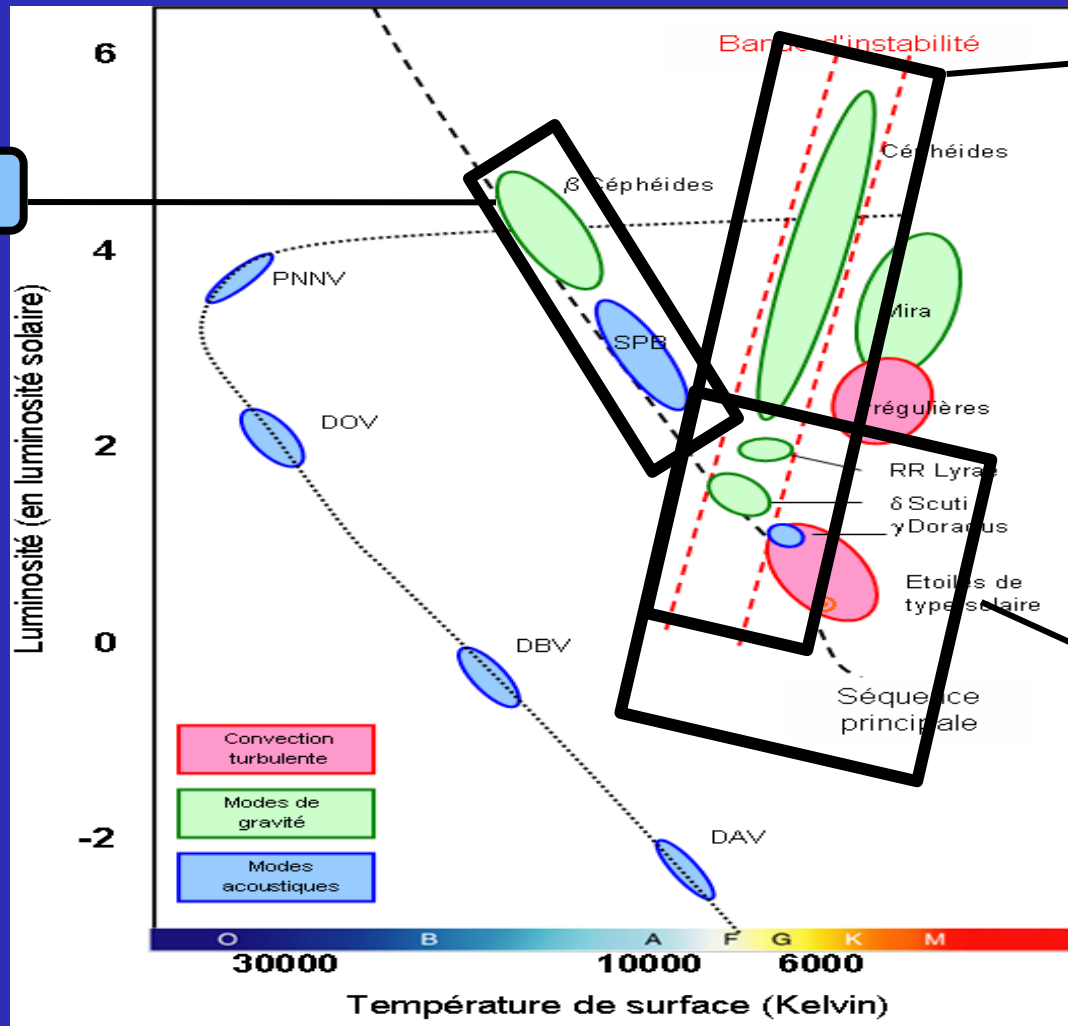
- Progresses of VLTI + VEGA/CHARA bring unique opportunities for key astrophysical questions.
- Imaging at very high angular and spectral resolution for asteroseismic sources, exoplanet's host stars and general stellar physics.
- Main features:
 - 4T/6T beam combiner + spectrograph
 - IR group delay tracking
 - VISA infrastructure: *well-optimized for imaging in the visible.*
 - # of ATs, AO on ATs: *denser than CHARA (more short baselines)*
 - longest baselines, fast reconfiguration.

Perspective : pulsating star / asteroseismology



- 1- distances IBW : Cepheids + HADS
- 2- asteroseismology : Solar types/ γ Dor/ δ -Scuti/RR Lyrae/ α Cen/ β -Cepheids
- 3- environment : β -Cepheids, ...

3- $\langle \theta \rangle$ & CSEs



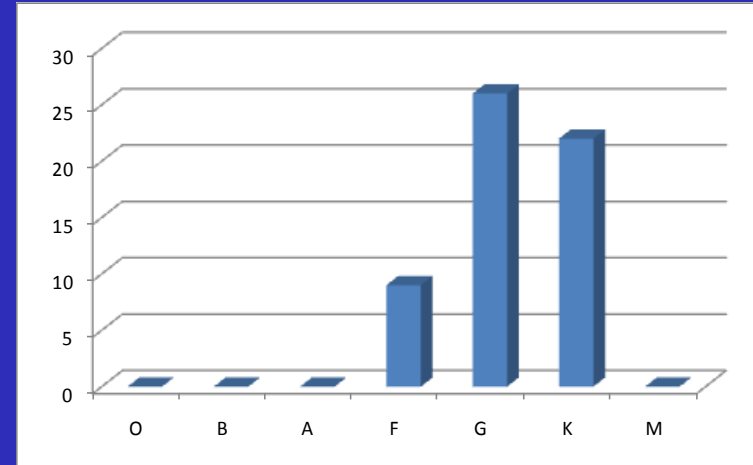
1- $\Delta \theta (\varphi)$

2- $\langle \theta \rangle$

Exoplanet's host stars

- Angular diameter @ 1% of relative uncertainty
- Direct limb darkening characterization

• Example of VEGA/CHARA possibilities



- **Science Goals**
 - Better determination of planet's parameters
 - Removal of stellar noise due to activity (spots, pulsation) for RV systems
 - Direct removal of limb darkening bias for transit systems
- Importance of the definition of a large program: study in progress at VEGA consortium level.



**You can propose VEGA programs...
Please join and be part of the future!**

