Recent results from VEGA
Perspective of a 6T visible combiner

Denis Mourard

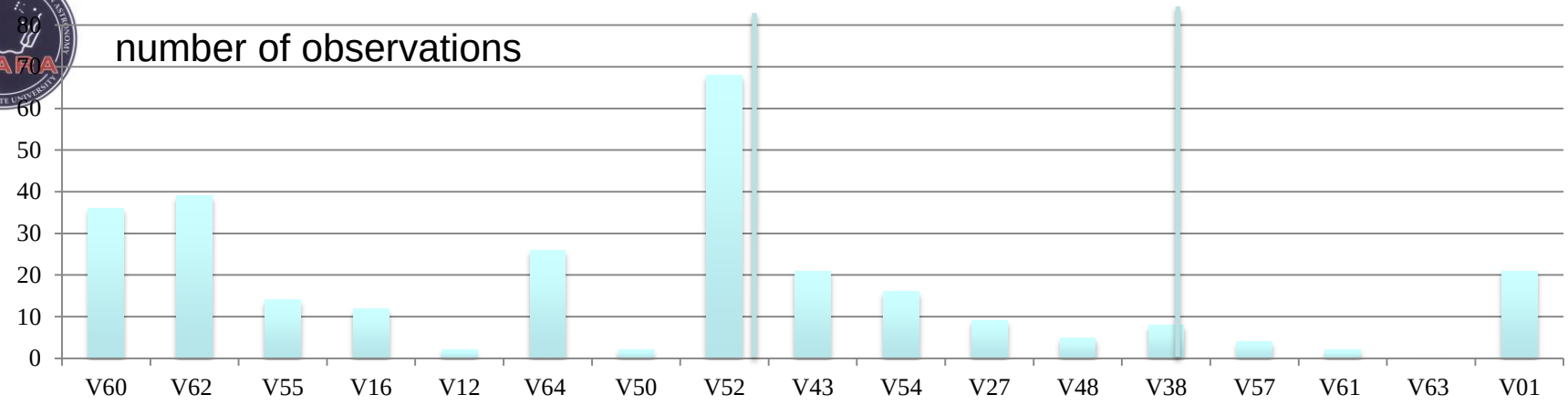
O. Creevey, N.Nardetto, K. Perraut

And the VEGA group

2014 Statistics

- 17 proposals (13 from Nice, 3 from Grenoble, 1 from Paris)
- 6 runs (4 remote, 1 on site, 1 on site vega+friend)
- 48 nights: 13 bad conditions, 10 poor condition and 25 with good conditions.
- 286 measurements: ~8 per good night

	PI	Title	nights allocated by CHARA
V60	NardettoA	Improving the calibration of the surface brightness – color relation for late type stars	4,60
V62 (new)	Meilland	Critical rotation and mass-loss: new insights from the study of edge-on Be stars.	3,30
V55	Valls-Gabaud	The distance to the Pleiades using the double-lined detached eclipsing binary HD23642	2,20
V16	PerrautA	Fundamental parameters of the magnetic rapidly oscillating Ap stars	2,50
V12	PerrautB	Accrétion/Ejection in intermediate mass young stars	2,00
V64 (new)	SteeB	Global Fast Rotation and Surface Differential Rotation of Bn stars	1,60
V50	CreeveyA	The radius of the metal-poor post T-O star: HD140283	0,90
V52	NardettoB	Breaking the frontier to the cosmic distance scale using Cepheids.	6,80
V43	CreeveyB	Determining masses of asteroseismic targets	1,80
V54	Jamialahmadi	The late youth of fast rotating stars: connecting the environment and the photosphere of 51Oph and HD141569	2,30
V27	Mourard	Post eclipse high spectral and spatial resolution follow-up of ε Aurigae	0,60
V48	PerrautC	Observing the accretion disk and wind in the symbiotic star SS Leporis.	0,80
V38	Challouf	Calibration of the surface-brightness relation of BA early type stars: Toward a very accurate distance determination of LMC eclipsing binaries	0,50
V57	Chesneau	Time monitoring of the angular diameter of two yellow hypergiants: long-term follow-up and short-term activity (eruptions)	0,50
V61 (new)	Bigot	Fundamental parameters and chromospheric extents of active magnetic Red Giants	5,70
V63 (new)	SteeA	Investigation of the magnetic effects on the disk around the classical Be star ω Ori	1,60
V01	Ligi	Characterization of exoplanet host stars	2,20



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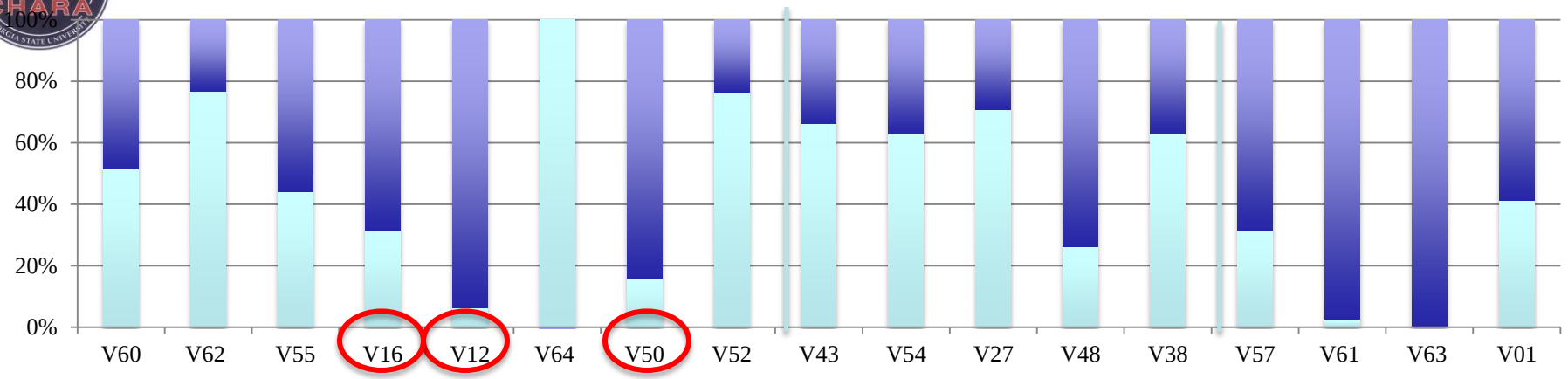
A

B

C



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A

B

C

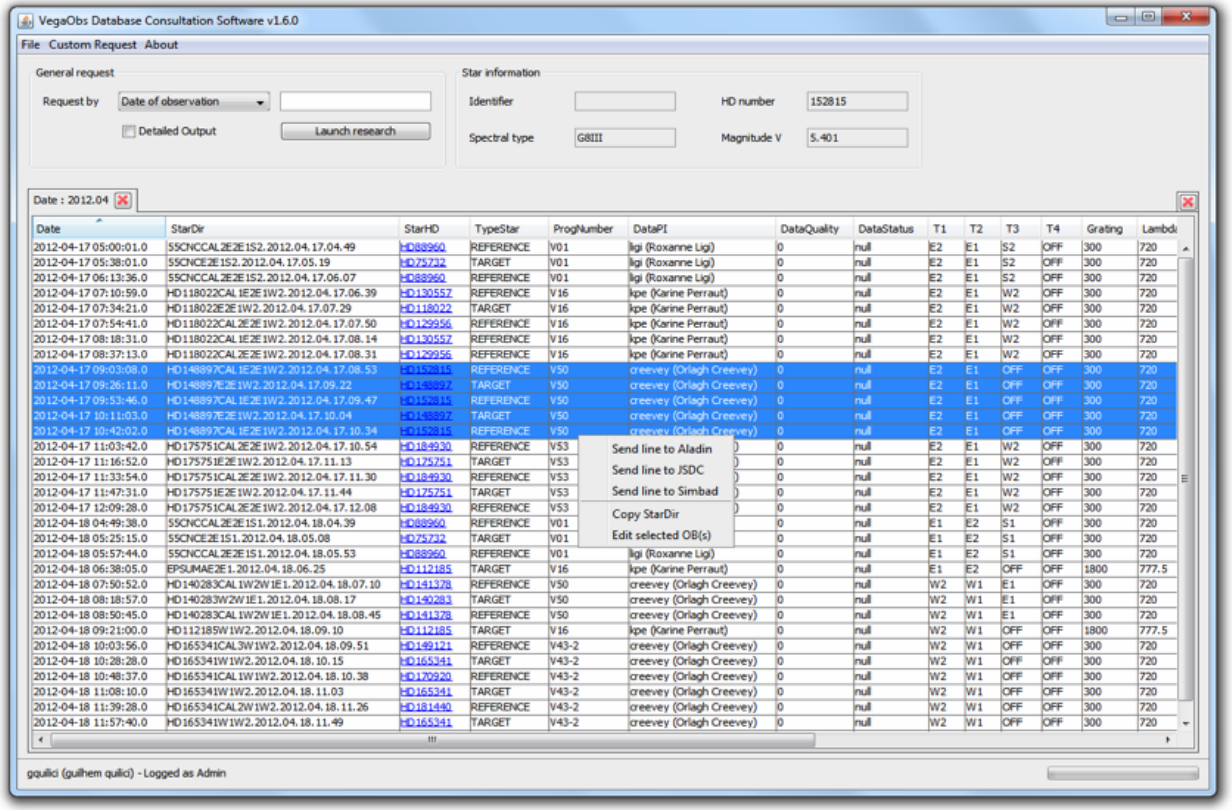
Papers in preparation

Draft in good shape for submission

- 51 Oph, Jamialahmadi et al., in revision
- 78 Vir, Perraut et al.
- p-factor and δ Cep, Nardetto et al.
- ksi Tauri, Nemravova et al.
- HR7349, Bigot et al.

VegaObs Database Consultation Software

Current version : 1.7.1



Project links

- Project homepage
- Publications

Documentation

- User manual [ENG]
- User manual [FR]

- Implemented functions

- Web service API documentation
- Web service description file

- The maintenance manual of the project is available from the SVN VegaObs repository.

Downloads

- Current version (1.7.1)
- Version 1.7.0
- Version 1.6.0 (no longer available)
- Version 1.5.0 (no longer available)
- Version 1.4.0 (no longer available)
- Version 1.3.0 (no longer available)
- Version 1.2.0 (no longer available)

http://vegaobs-ws.oca.eu/

2015-S1 programs

PI	Prog	#nuits	04	05	06	07	08
BERIO	FRIEND	4				20	
CREEVEY	metal poor stars	3	16				
		2,5			14		
		0,5				4	
HUBERT	giants + PAVO	2					8
LIGI	exoplanet host stars	4	8				12
MEILLAND	Be survey	4			20		
MILLOUR	Imaging kappa Dra	6	48				
MOURARD	4T & binaries	7				48	
NARDETTO	Cepheids	7					36
PERRAUT	roAp	3,5			24		
		3					18
PERRAUT	eps Uma	5	12		8		
NOAO	YSO	2				10	
		54n	**84h**		**66h**	**82h**	**74h**

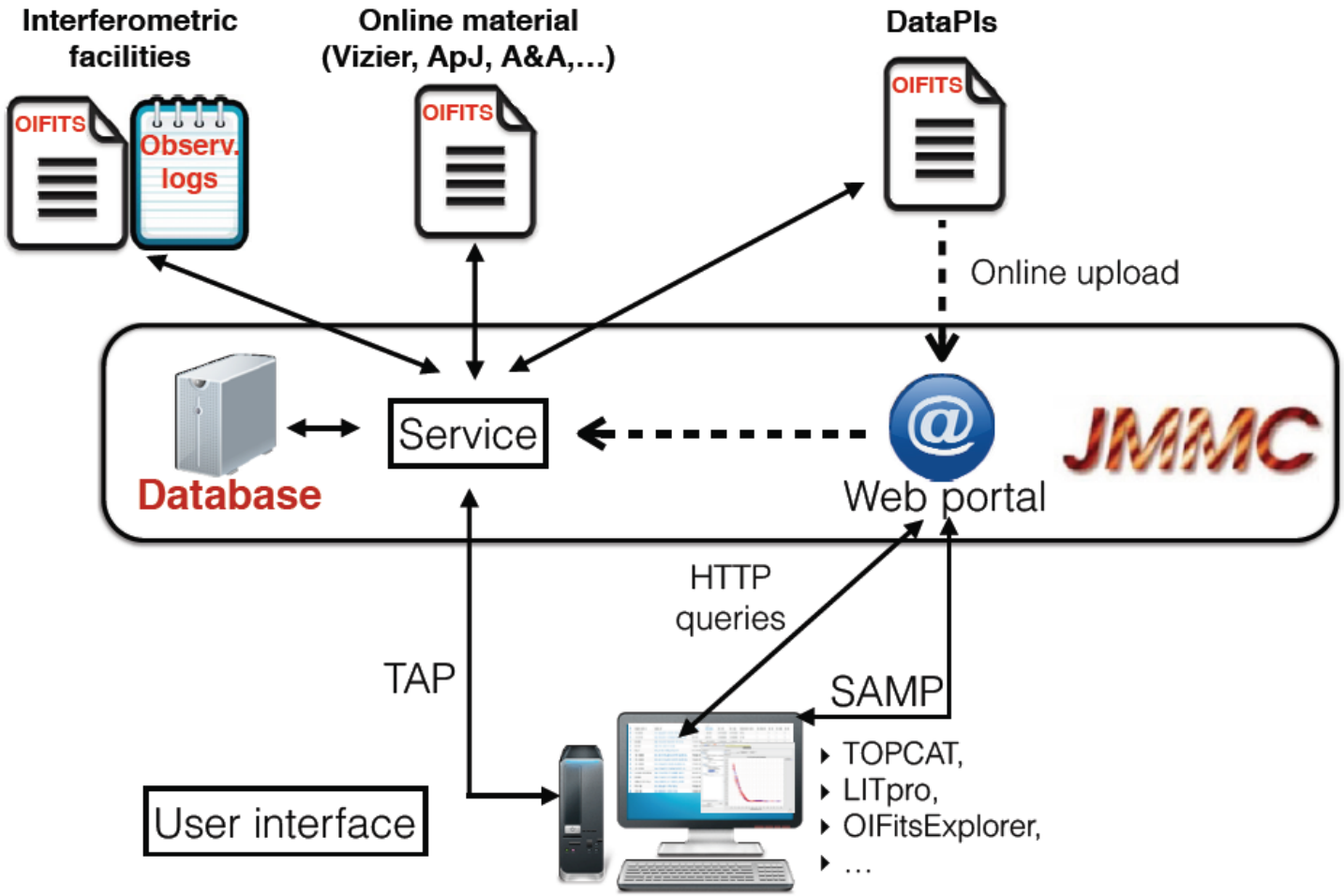
April: 8 nights 7-14
May-June: 8 nights: 29/05-5/06
July: 10 nights: 5-14
August: 8 nights: 24-31

Recent technical activities

- Improvement of the real-time processing thanks to the parallelization of the code
- Improvement of the quick-look processing at the end of the night during the archiving (//)
- Better implementation of the link between the VEGA database and the JMMC OIDB for L0 data

JMMC OIDB

Architecture



Recent and current technical activities

- Improvement of the real-time processing thanks to the parallelization of the code
- Improvement of the quick-look processing at the end of the night during the archiving (//)
- Better implementation of the link between the VEGA database and the JMMC OIDB for L0 data

- Development of a new alignment sensor
- Science detector @ 200Hz
- Routine 4T operation

VEGA 2014/2015 Science highlights

"**Separated fringe packet observations with the CHARA Array. II. w Andromeda, HD 178911 and x Cephe**i", C. Farrington, T. ten Brummelaar, D. Banerjee et al., AJ 148, 3 (2014)

"**Improving the surface-brightness color relation for early-type stars using optical interferometry**", M. Challouf, N. Nardetto, D. Mourard et al., A&A (2014)

"**A resolved, au-scale gas disk around the B[e] star HD 50138**", L.E. Ellerbroek, M. Benisty, S.Kraus et al., A&A (2014)

"**Benchmark stars for Gaia .Fundamental properties of the Population II star HD140283 from interferometric, spectroscopic and photometric data**", O. Creevey, F.Thévenin, P. Bério et al., AA 575, A26 (2015)

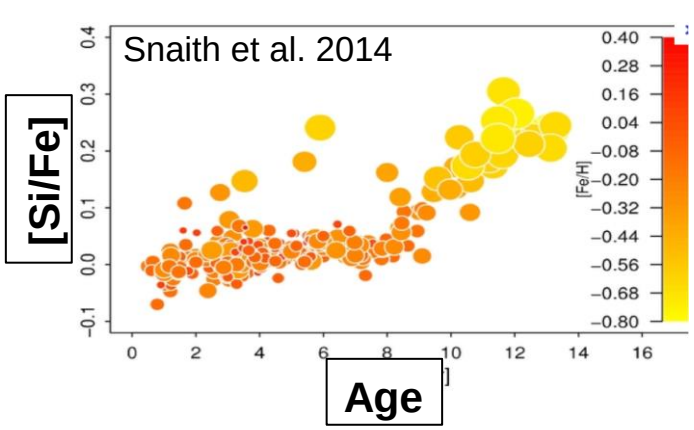
"**Spectral and spatial imaging of the Be+sdO binary phi Per**", D. Mourard, J. Monnier, A.Meilland et al., AA in press (2015)

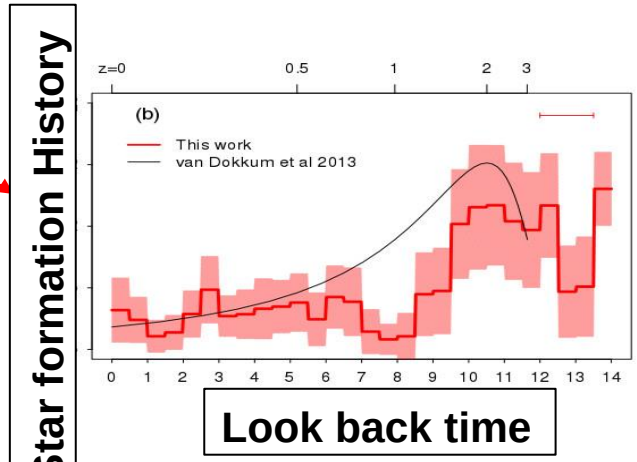
Interferometry of metal-poor benchmark stars

Creevey, Thevenin, Boyajian, Heiter, von Braun, Mourard, Berio, Chiavassa, Bigot, Nardetto,

Pop II (metal-poor halo) stars

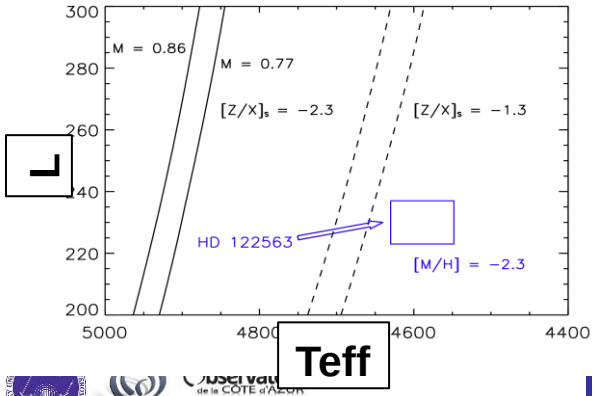
Oldest stars in Galaxy: - ages and initial composition for formation scenarios
- chemical evolution





Poorest in metals

- Teff scale poorly calibrated
- Model atmospheres need complex treatment
- Treatment of physics in models



Gaia Context

CU 3 →
CU 5 →
CU 6 →

Data:
- G band photometry, astrometry
- BP/RP spectro/photometry
- RV spectrometer

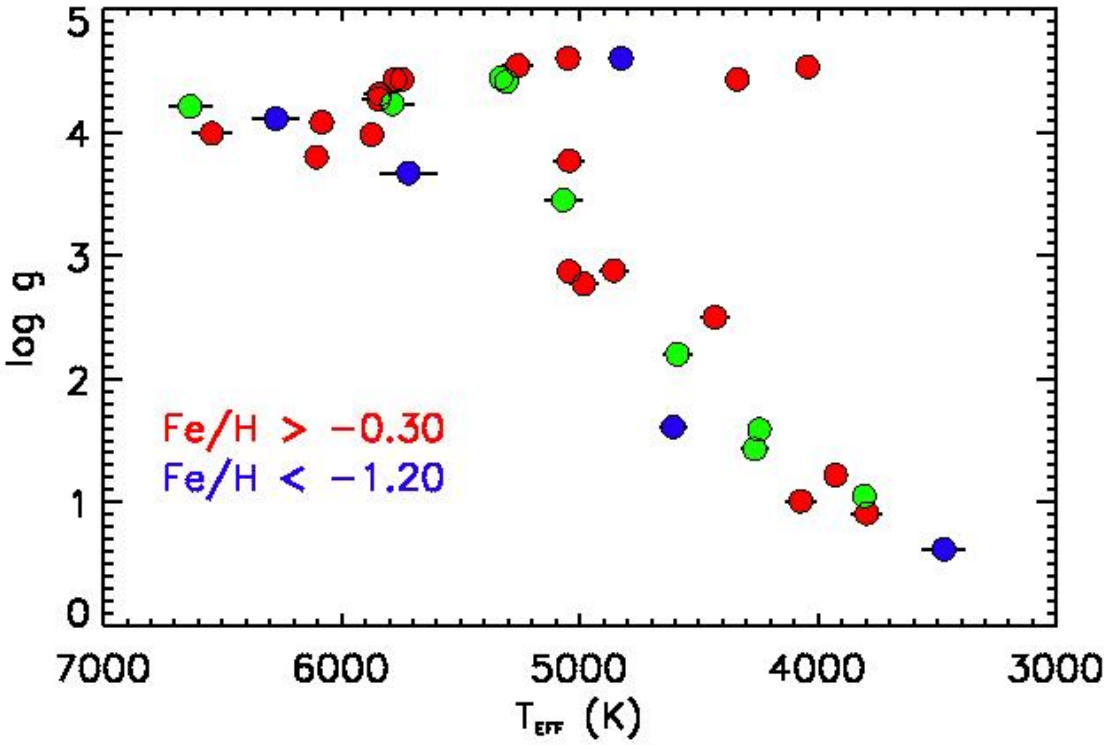
Principle objective:

5D-6D mapping of Galaxy
3: parallax, coordinates,
- 2: proper motions,
- [1: radial velocities]

CU8
Astrophysical Parameters

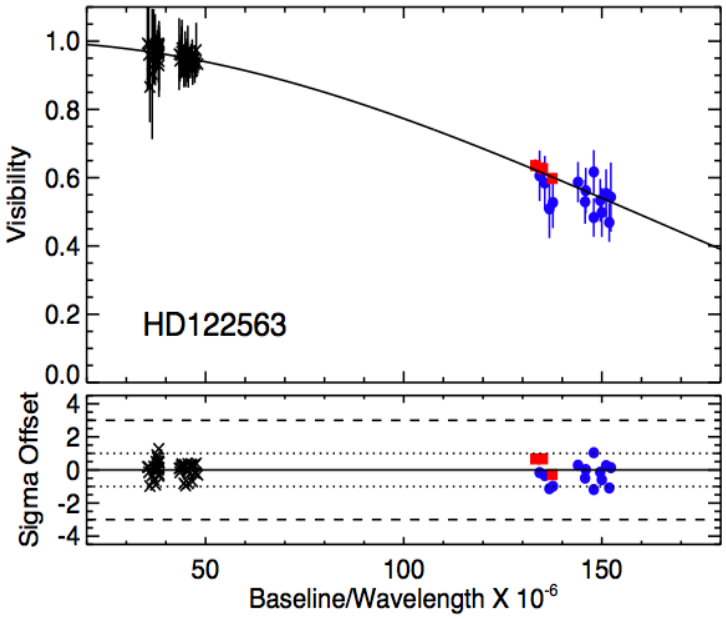
GSP_Phot (T_{eff}, g, [Fe/H], A_0)
GSP_Spec (T_{eff}, g, Fe/H, α)
FLAME (M, Age)

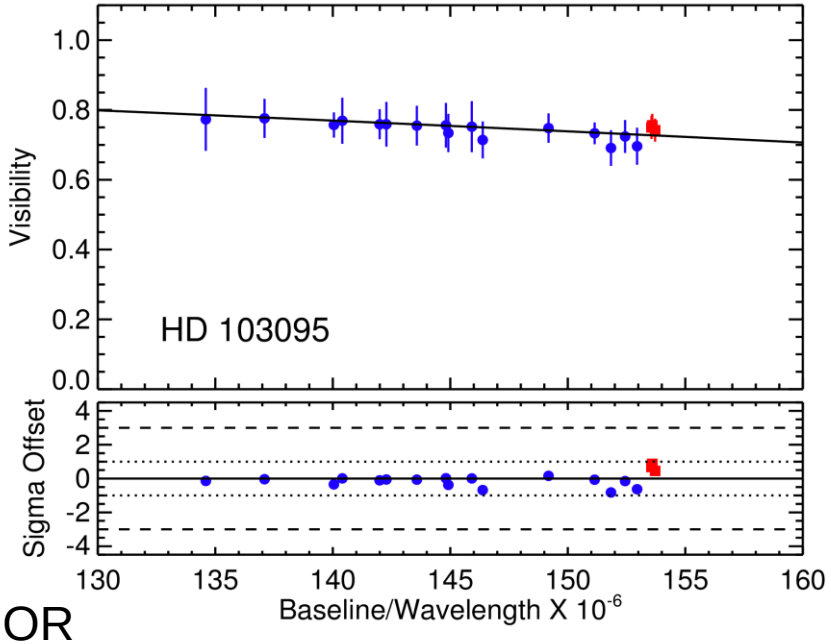
Benchmark Stars



Data from Heiter et al. 2014

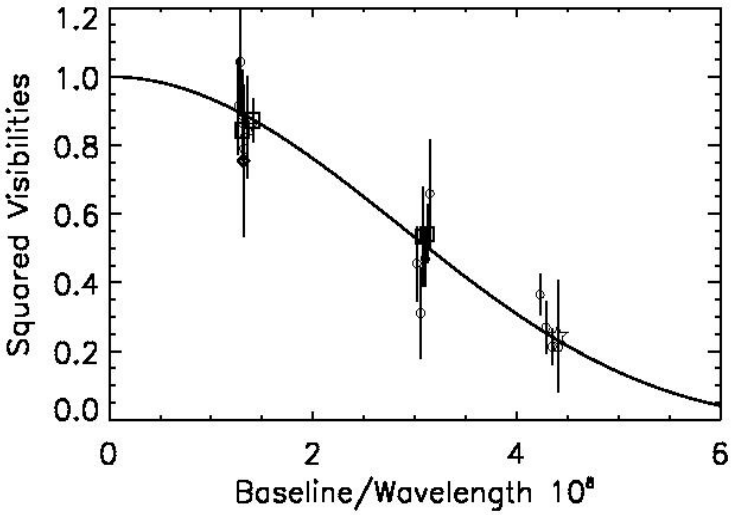
Visibility Fits





Creevey et al. 2012: Classic/PTI/FLUOR

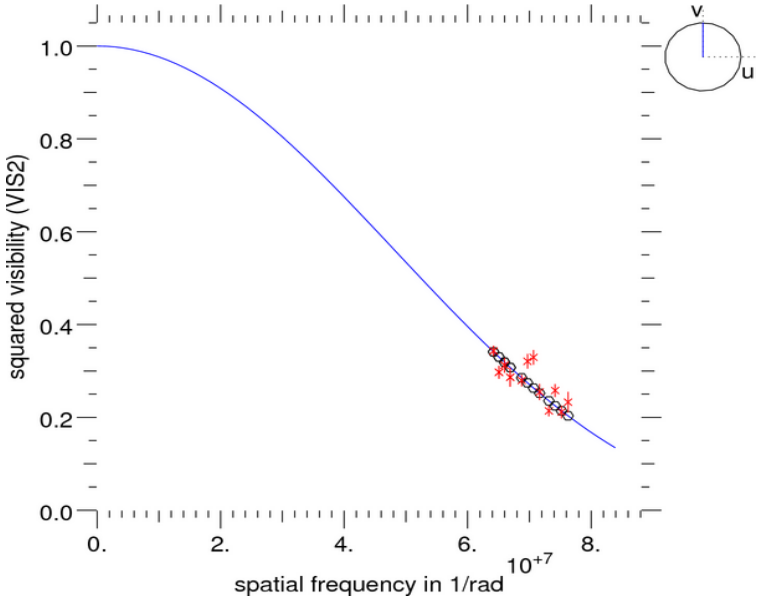
Visibility Fits



HD140283@VEGA

Creevey et al. 2015

HD220009@VEGA

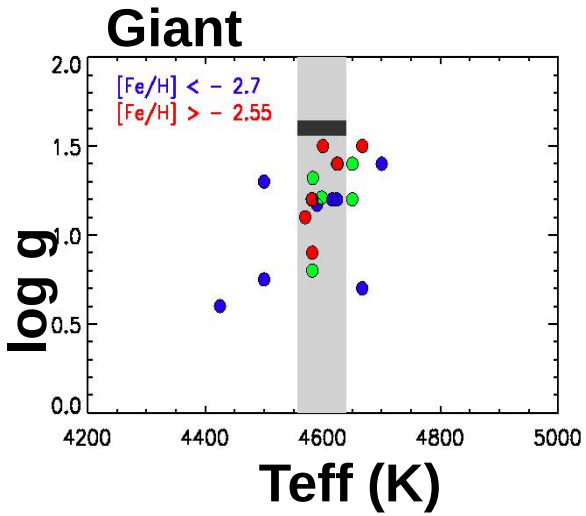


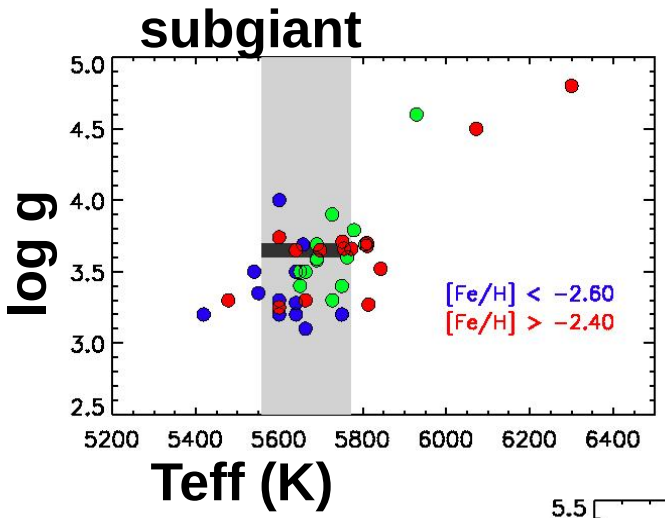
Direct determination of parameters

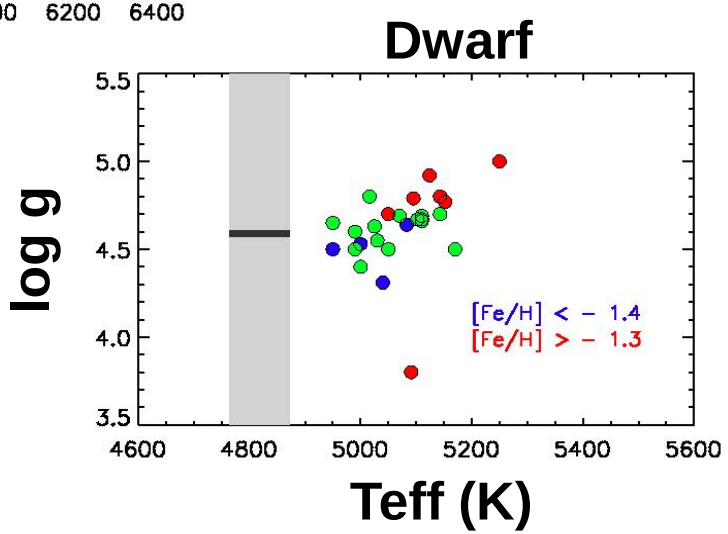
	HD 122563	HD 140283	Gmb 1830
[Fe/H]/Class	–2.5/III	–2.5/IV	–1.3/V
θ (mas)	0.948 ± 0.012	0.353 ± 0.013	0.679 ± 0.007
R ($R_\odot$)	24.1 ± 1.1	2.21 ± 0.08	0.665 ± 0.014
$T_{\rm eff}$ (K)	4598 ± 41	5665 ± 106 *	4818 ± 54
$\log g$	1.60 ± 0.04	3.65 ± 0.05	4.59 ± 0.02

- Parallax from Hipparcos & Bond et al. (2013)
- Bolometric flux analysis in papers
- Loose assumption on mass
- * Based on non-zero reddening fit
- Constraints for metallicity analysis -> calibration of GSP_phot, _spec

Comparison of effective temperatures







Data from PASTEL (Soubiran et al. 2010)
Solution for HD140283 is “reddened one‘
Av=0-> Teff = 5545 K
note Teff_(Halpha) = 5624 K (consistent!)
Gmb1830 to be reobserved with VEGA and PAVO this semester (PIs Ireland/Creevey)

Modelled stellar properties

	HD 122563	HD 140283	Gmb 1830
[Fe/H]/Class	−2.5/III	−2.5/IV	−1.3/V
M ($M_\odot$)	0.855 ± 0.025	0.800 ± 0.020	0.635 ± 0.025
Age (Gyr)	12.6 ± 1.0	12.2 ± 0.7	12.3 ± 1.6
α	1.31 ± 0.08	1.00 ± 0.15	0.68 ± 0.10

- Masses to 3%, ages to 10% (FLAME, GSP_phot (g))
- Mixing-length parameter (alpha) NOT solar
- Correlation initial helium – mass – age (seismology)

Fundamental parameters of stars

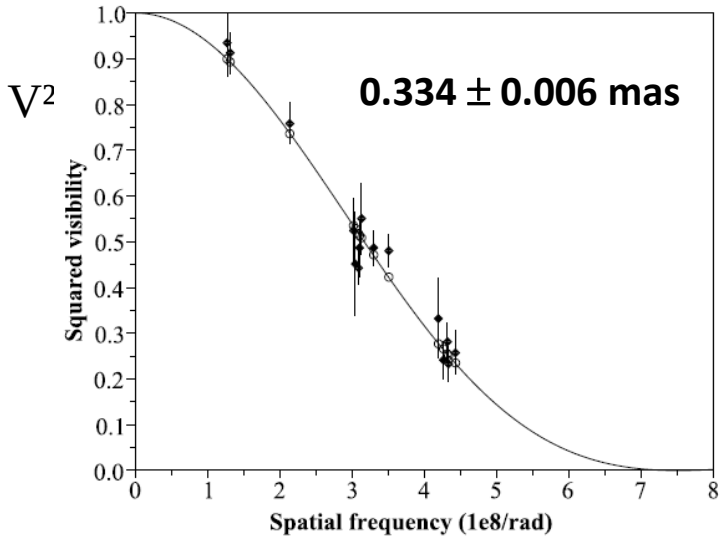
(ro) Ap stars

Aims:

- determine unbiased effective temperatures of these peculiar stars
- estimate mass and age,
- test non-adiabatic pulsation models

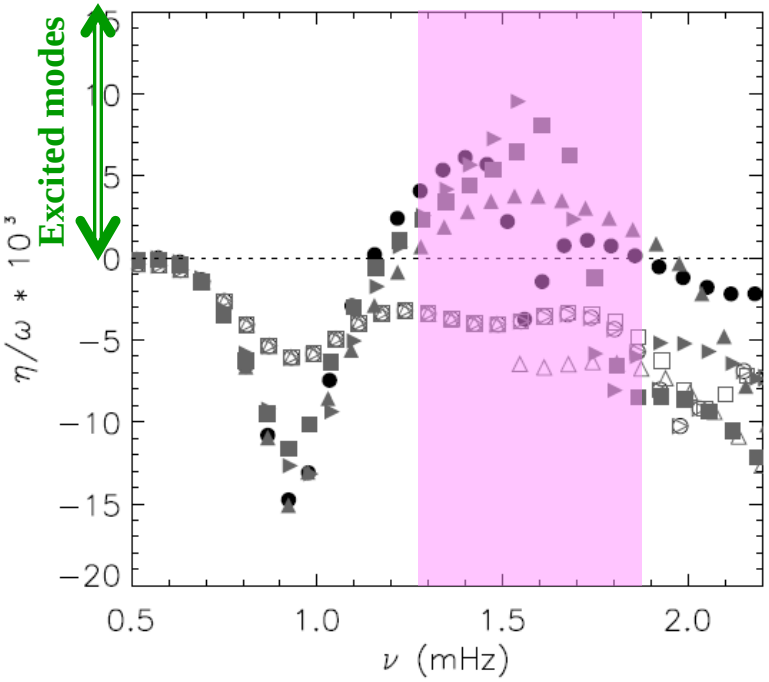
Sample:

A few ro Ap stars (Perraut+, 2011, 2013, 2015)



78Vir

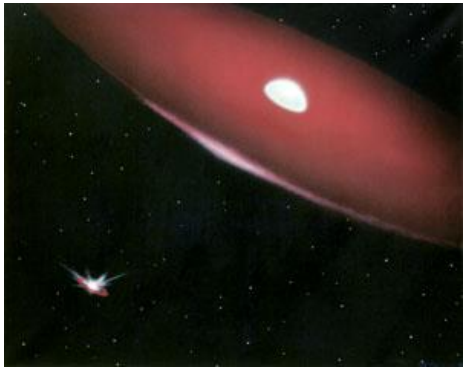
Perraut+ (2015, in prep)



Could 78 Vir be a rapidly oscillating Ap star?

See SONG data

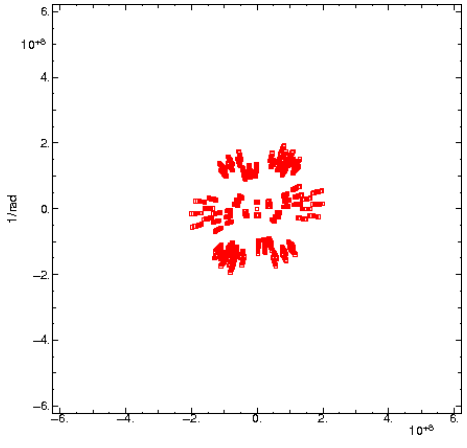
Spectral imaging VEGA+MIRC

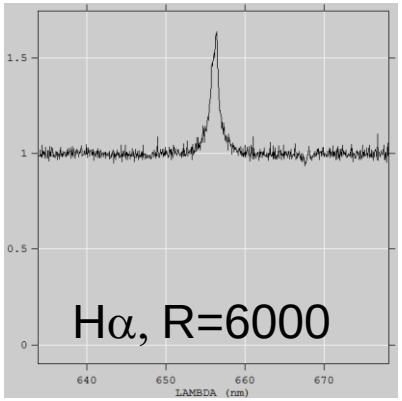


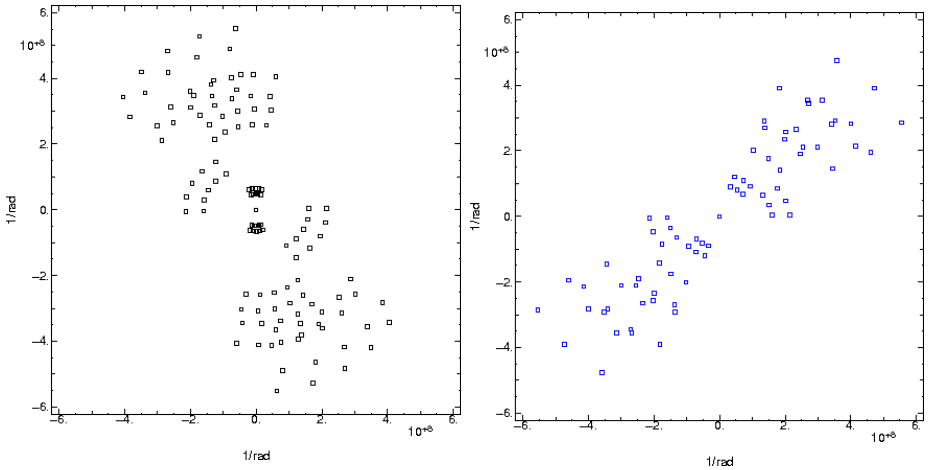
2011 October 18th and 19th on CHARA

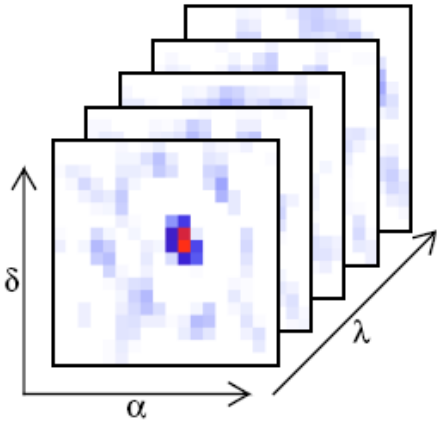
φ Persei (Be + subdwarf-HST)

MIRC 6T @ 1.6µm, VEGA 4T @ 656-487nm

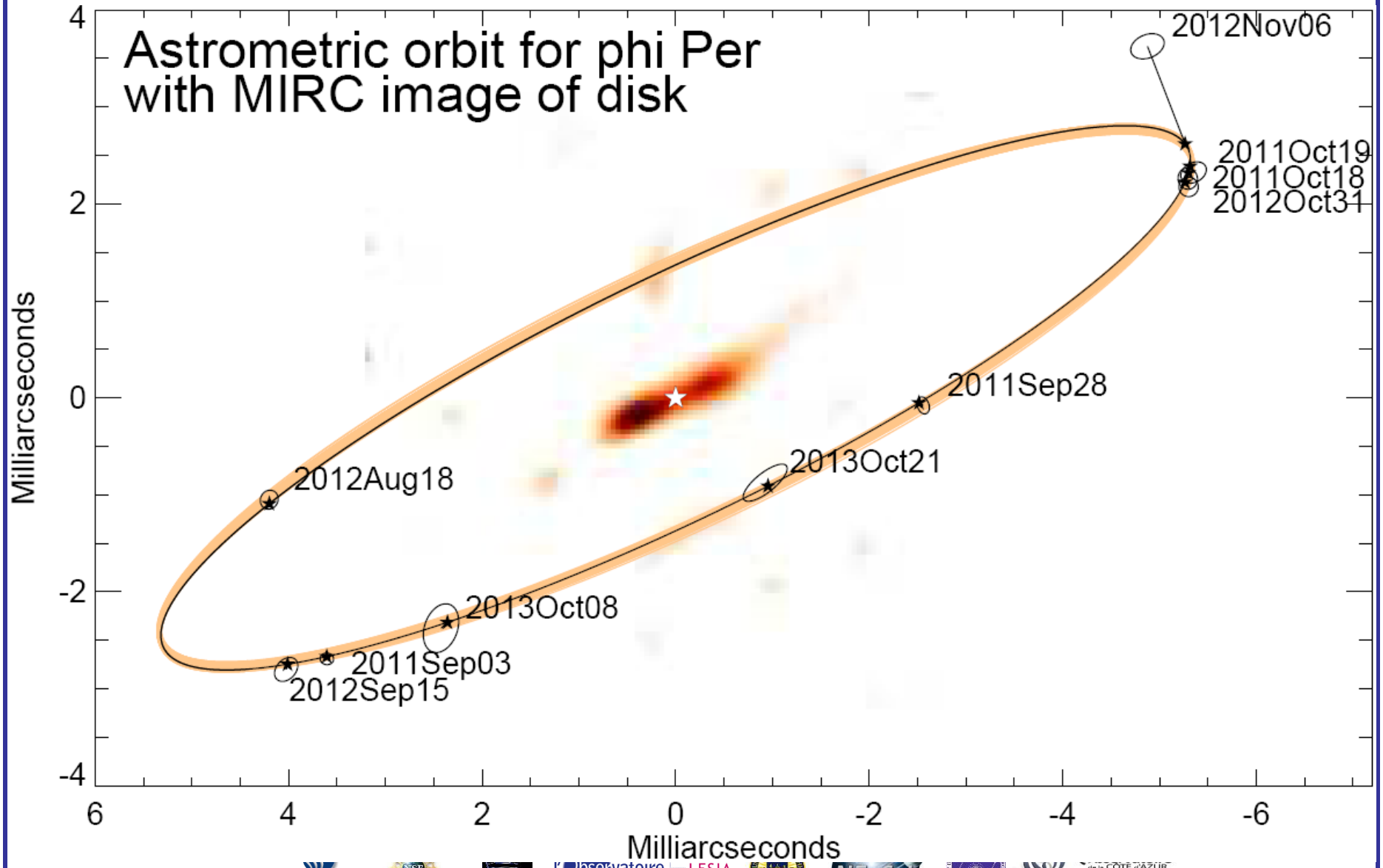


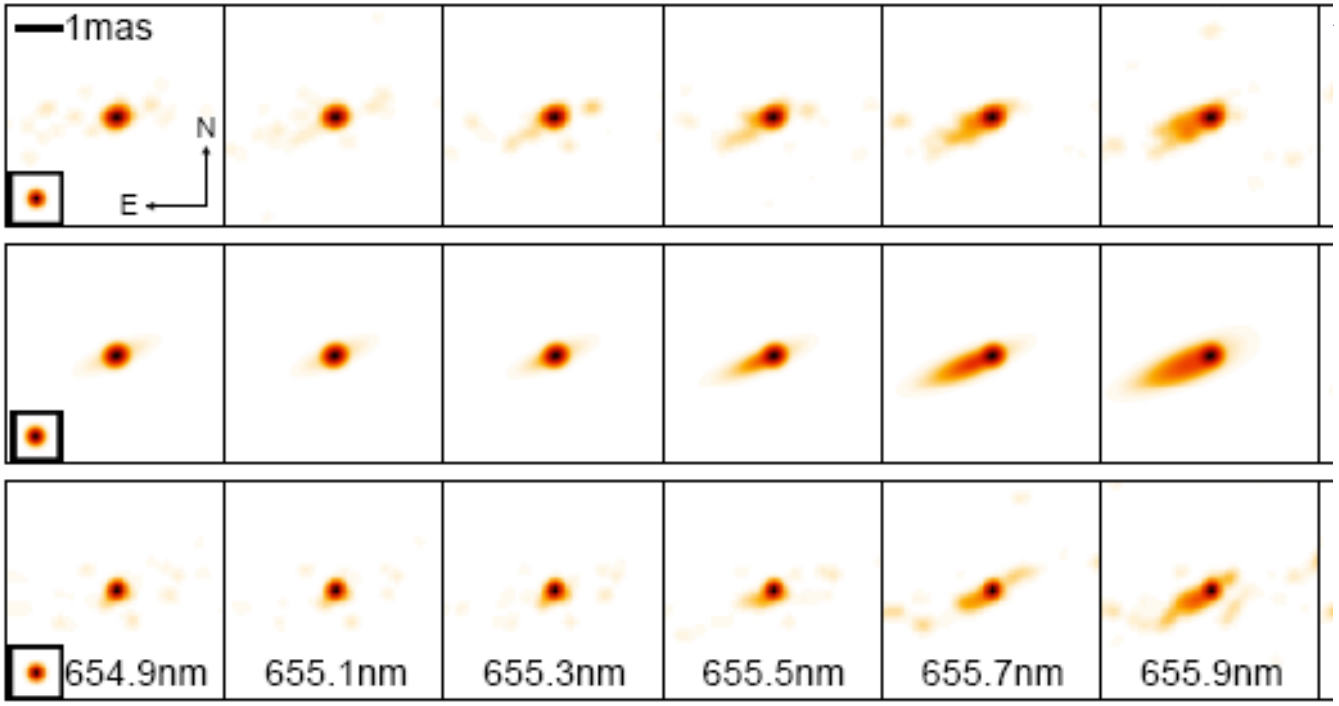






H-band disk +orbit of the companion (RV+astrometry)

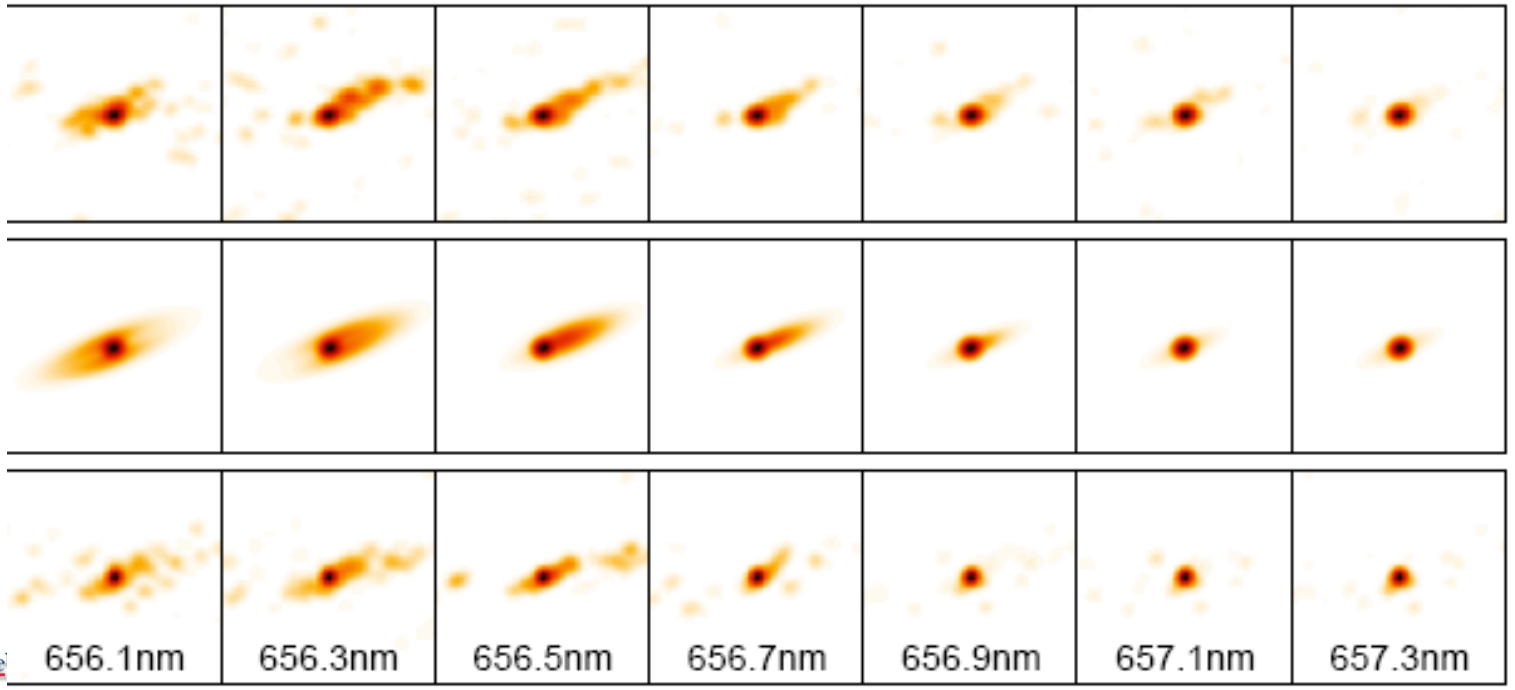




VEGA imaging in the Hα line

Model fitting in the Hα line

Reconstruction from model



GeorgiaState

Main conclusions

- New ephemeris and physical parameters
- Revision of the distance (close to α Per cluster in fact)
- Consequences for the evolution of the Be star itself (large mass only recently reached)
- Improved characterization and understanding of the Be disk

Parameter	Value
$T_{RV\ min}$ (RJD)	56110.03±0.08
P (d)	126.6982 (fixed)
a (mas)	5.89±0.02
e	0 (fixed)
i (°)	77.6±0.3
ω(°)	0 (fixed)
Ω(°)	-64.3±0.3
γ (km s^{-1})	-2.2±0.5
K_a (km s^{-1})	10.2±1.0
K_b (km s^{-1})	81.5±0.7
M_{a+b} ($M_\odot$)	10.8±0.5
M_a ($M_\odot$)	9.6±0.3
M_b ($M_\odot$)	1.2±0.2
$d(pc)$	186±3

Some reflexions about the future

- Short term activities: VEGA-4T
  - VEGA+MIRC but mH<4.5
  - VEGA+CLIMB123 mK<6.5 and VEGA34 on short baseline ➔ VEGA-4T up to mK=6.5

- Future of visible interferometry?
  - Current limitations of VEGA
  - Arrival of AO on CHARA
  - No short/mid-term perspective on VLTI (Gravity, Matisse → 2025?)
  - But Gaia, Kepler/K2, PLATO, CHEOPS… many space missions for exoplanets and host stars, for asteroseismology!

We need a visible 6T beam combiner

- Excellent opportunity for **fundamental parameter** of stars survey or **'legacy' program**. Already started yes but could be extended thanks to visible wavelengths, sensitivity and 'fast' observations with 6T.
- Also excellent case for **imaging and spectral imaging**
- Convergence of various efforts
  - PAVO, VEGA: visible and spectro-interferometry
  - MIRC: imaging and 6T operations
  - FLUOR: high precision
  - AO@CHARA
- Science preparation and technology developments

Science preparation

- Different ongoing efforts
  - VLTI roadmap
  - Planet Formation Imager
  - Visible perspective
- Visible Interferometry Working Group
  - *Pre-main sequence stars*
  - *Main sequence stars, Fundamental parameters, asteroseismology*
  - *Pulsating stars*
  - *Evolved stars*
  - *Massive Stars*
  - *AGNs*
  - *Imaging, technics*
  - *Interacting binaries*

Technology development

- FRIEND prototype: fibers for spatial filtering, new technology detector.
- Fiber injection after AO stage
- Possibilities of visible Integrated Optics (IPAG)
- Improved detectors (larger format, mosaicing?)

- Which spectral resolutions, bands? (minimum number of observing modes)
- How to better preserve and analyze polarized visibilities?
- Sensitivity, accuracy?
- A sensitive infrared coherence tracker is fundamental

- Fully CHARA's software compliant
- Webservice for data reduction pipeline / automatic pipeline
- AO information?

To conclude

- Global collaboration for a 6T visible combiner AU+US+EU
- If yes, decision on a plan but with ‘external’ constraints
  - AO@CHARA and visible performance
  - FRIEND performance without and with AO
  - Science preparation
  - Conceptual definition
  - Resources
- Improved IR instrument in //, for itself and as coherence tracker