VEGA status report and recent results

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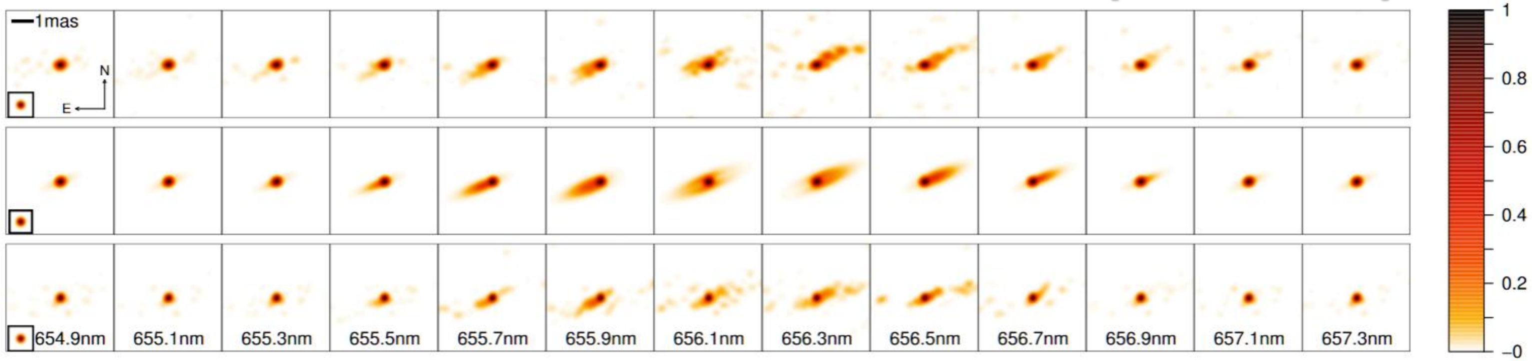
and Mickael BONNEFOY, Isa Brandão, Margarida CUNHA, Pietr HARMANEC, Roxanne LIGI, Anna Romanovskaya, Tanya Ryabchikova, Denis SHULYAK

VEGA in a nutshell

- 3T – 4T visible combiner used with CLIMB for coherencing (+ self-coherencing in 4T)
- Spectrograph over [480 nm ; 850 nm] with 2 cameras and $\mathcal{R}$~ (1700), 5000, 30000

Kinematics and environments

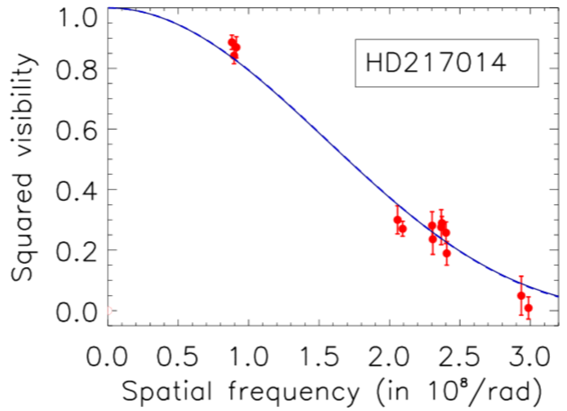
[Mourard+2015]



Mass-loss, winds, Be and supergiant environments, spectro-imaging

[see Elisson and Robert's talks tomorrow]

Accurate angular diameters

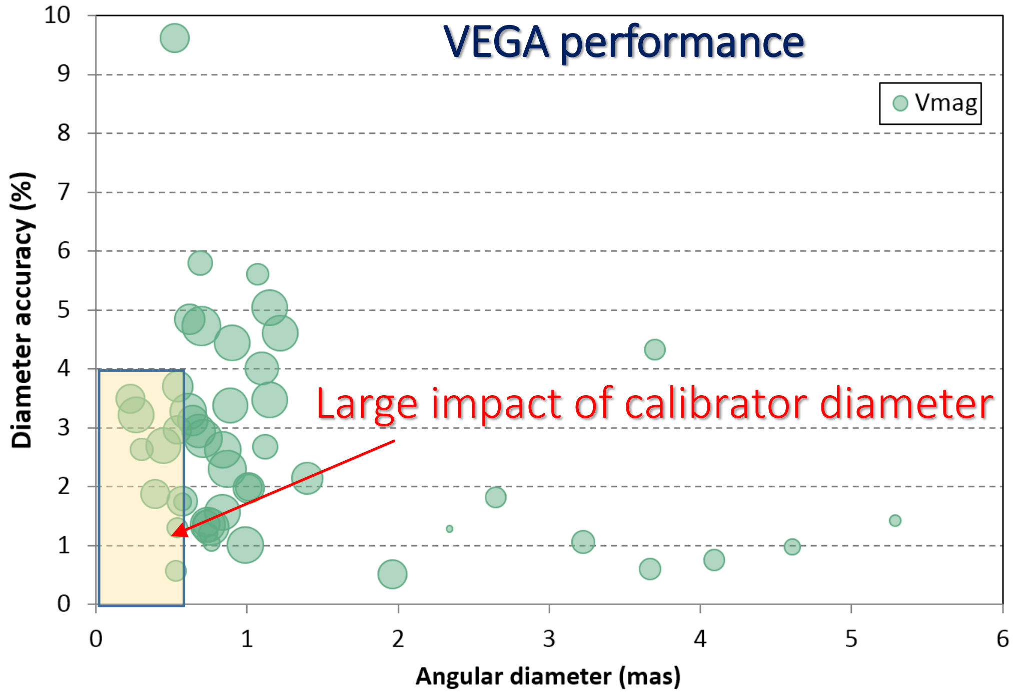


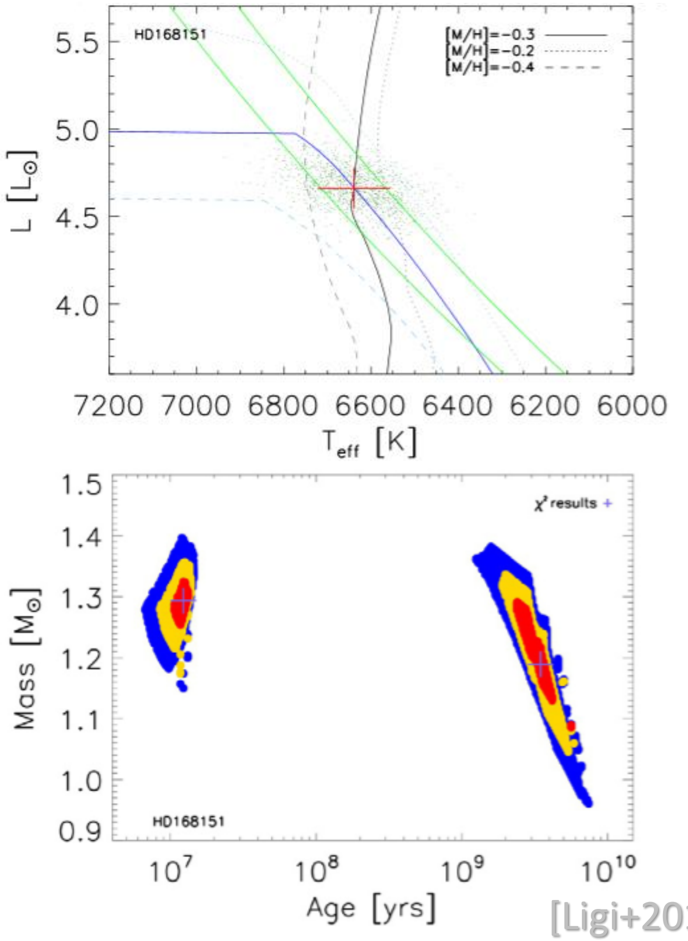
[Ligi+2016]

Towards accurate fundamental parameters

Science cases

- Fundamental parameters of exoplanet host stars, benchmark stars, peculiar stars, …
- Surface-brightness relations (early-type stars, small diameters)
- Hierarchic system properties
- Cepheid environments (δ Cep: Nardetto+2016, η Aql: in prep.)

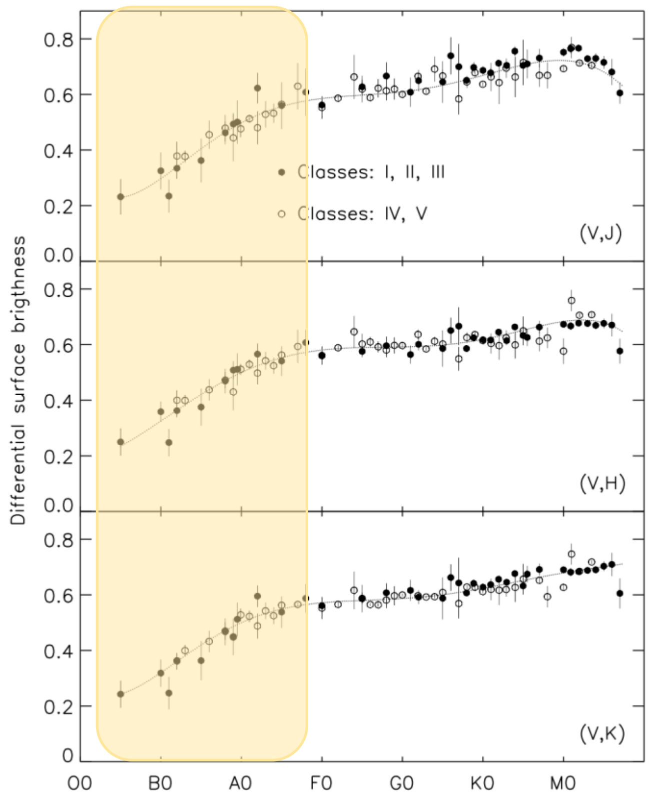




[Ligi+2016]

Towards fundamental parameters – The calibrator issue

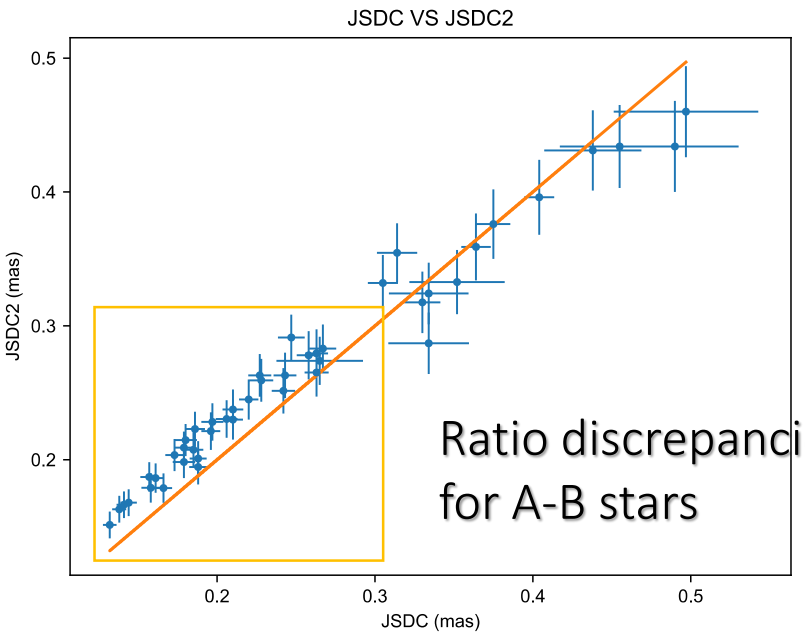
- Need for accurate and precise angular diameters of the calibrators
- JSDC2 catalog: diameter determination through pseudo-magnitudes and spectral types



[Chelli+2016]

But:

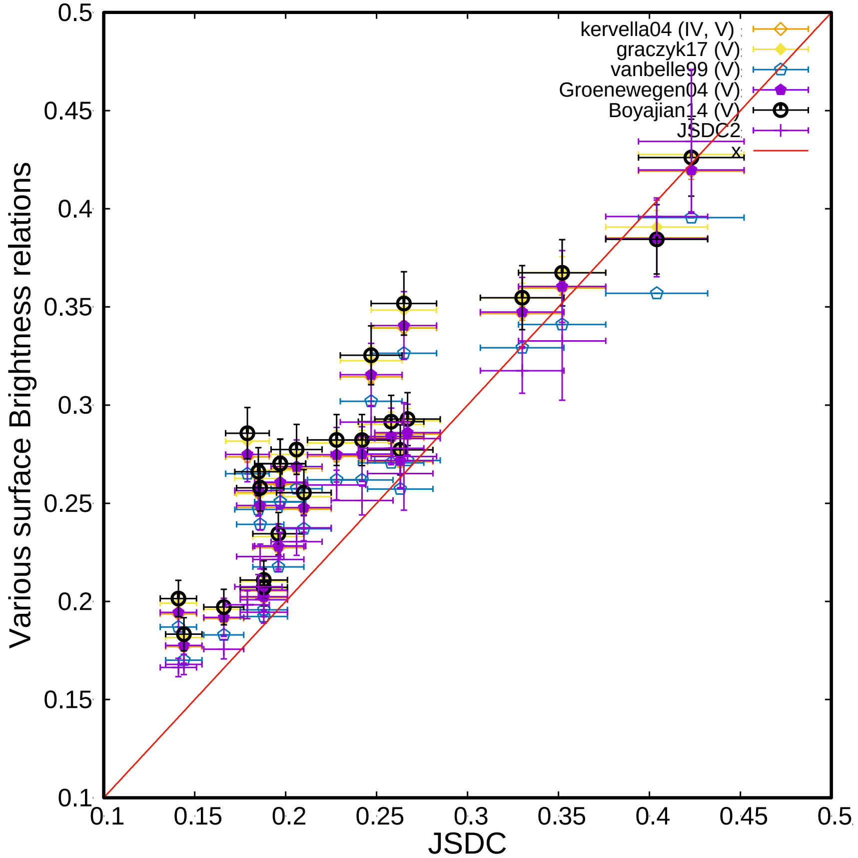
- lack of statistics for early-type stars (fast rotators, …)
- discrepancies between JSDC1 and JSDC2 catalogs for A-B spectral types

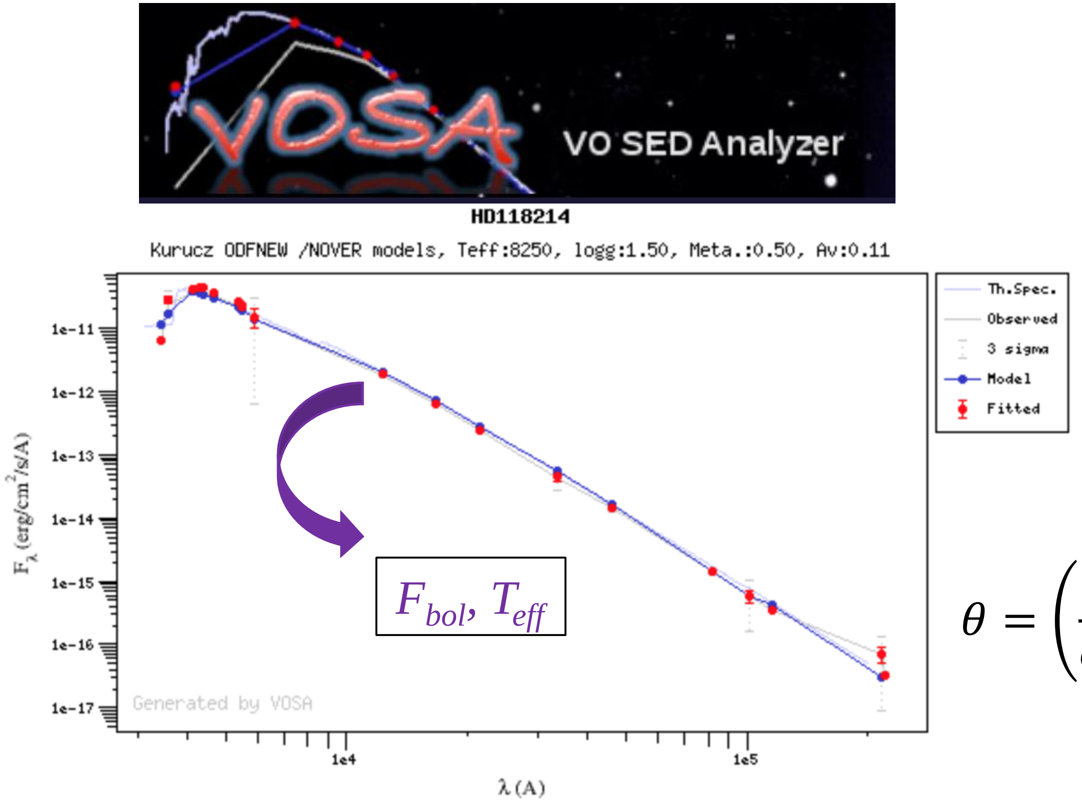


Ratio discrepancies as large as 15-20% for A-B stars

Towards fundamental parameters – The calibrator issue

During a 2-day workshop, we tried to bring back together all the diameter determinations: JSDCs, Surface-Brightness relations, SED fit (through the VOSA tool), …

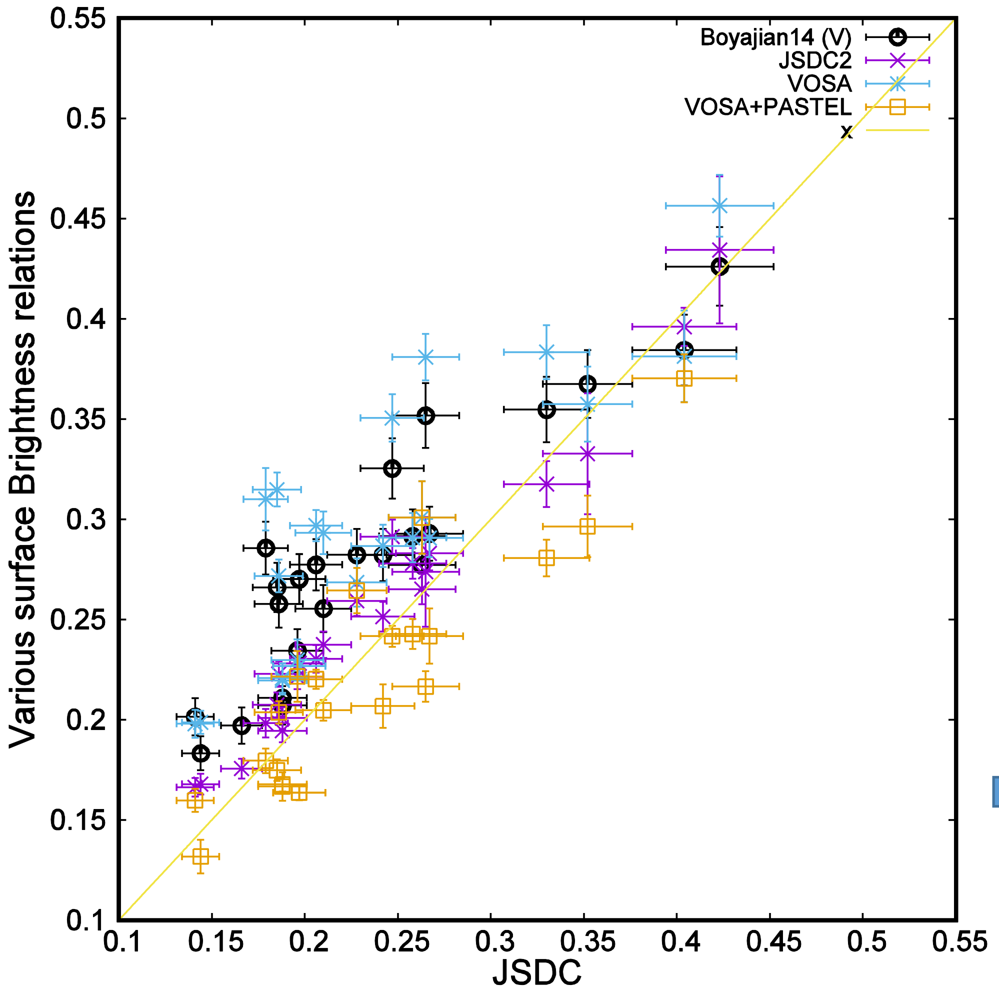




$$\theta = \left(\frac{4F_{bol}}{\sigma T_{eff}{}^{4}}\right)^{1/2}$$

Towards fundamental parameters – The calibrator issue

Not so easy to bring back together all the angular diameter determinations



… and radii from GAIA DR2 to come!

Several tricky steps in VOSA:

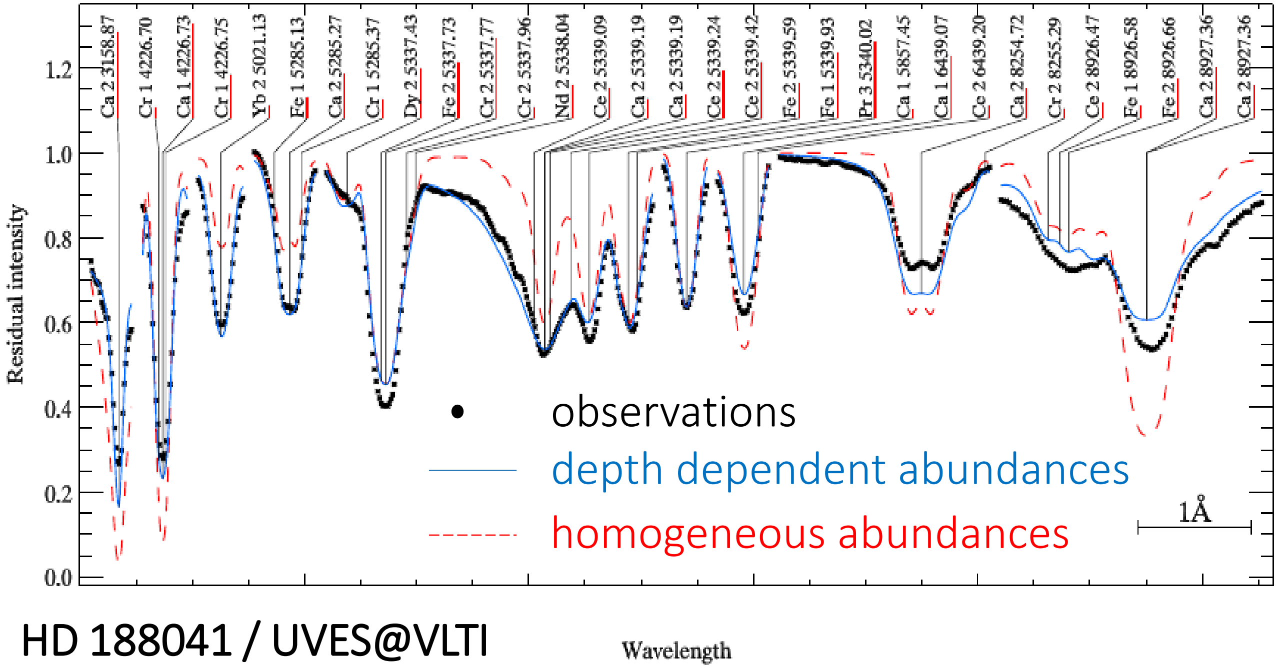
- Selection of photometry data sets
- Extinction
- Models
- Effective temperature range (check with the PASTEL catalog but depends on … spectral type!)

JSDC2 + SBR + « clean » VOSA method sound to be in good agreement whatever the spectral type

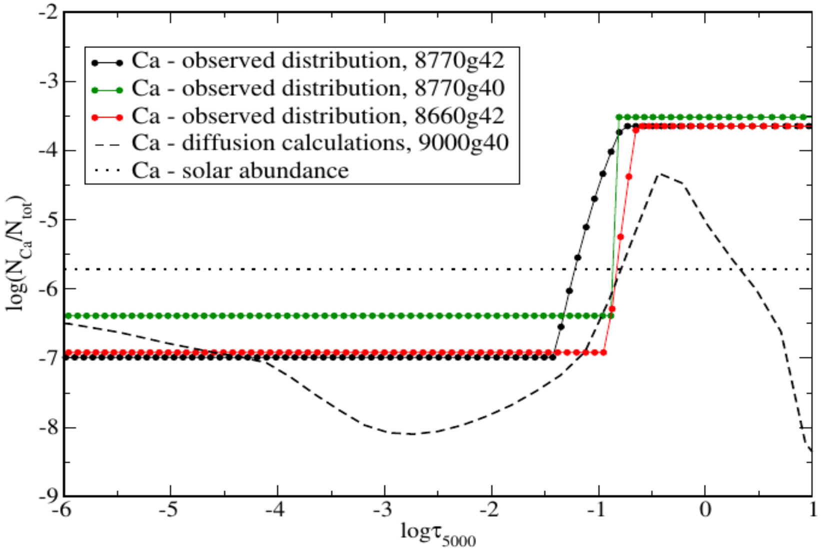
The Ap star program

Scientific objectives:

- Derive accurate fundamental parameters as independently as possible
- Compare to theoretical models (atmosphere, Bolometric Correction, excitation mechanism(s) of oscillations)
- Derive trends, i.e. for effective temperatures, with magnetic field strength … for these peculiar stars



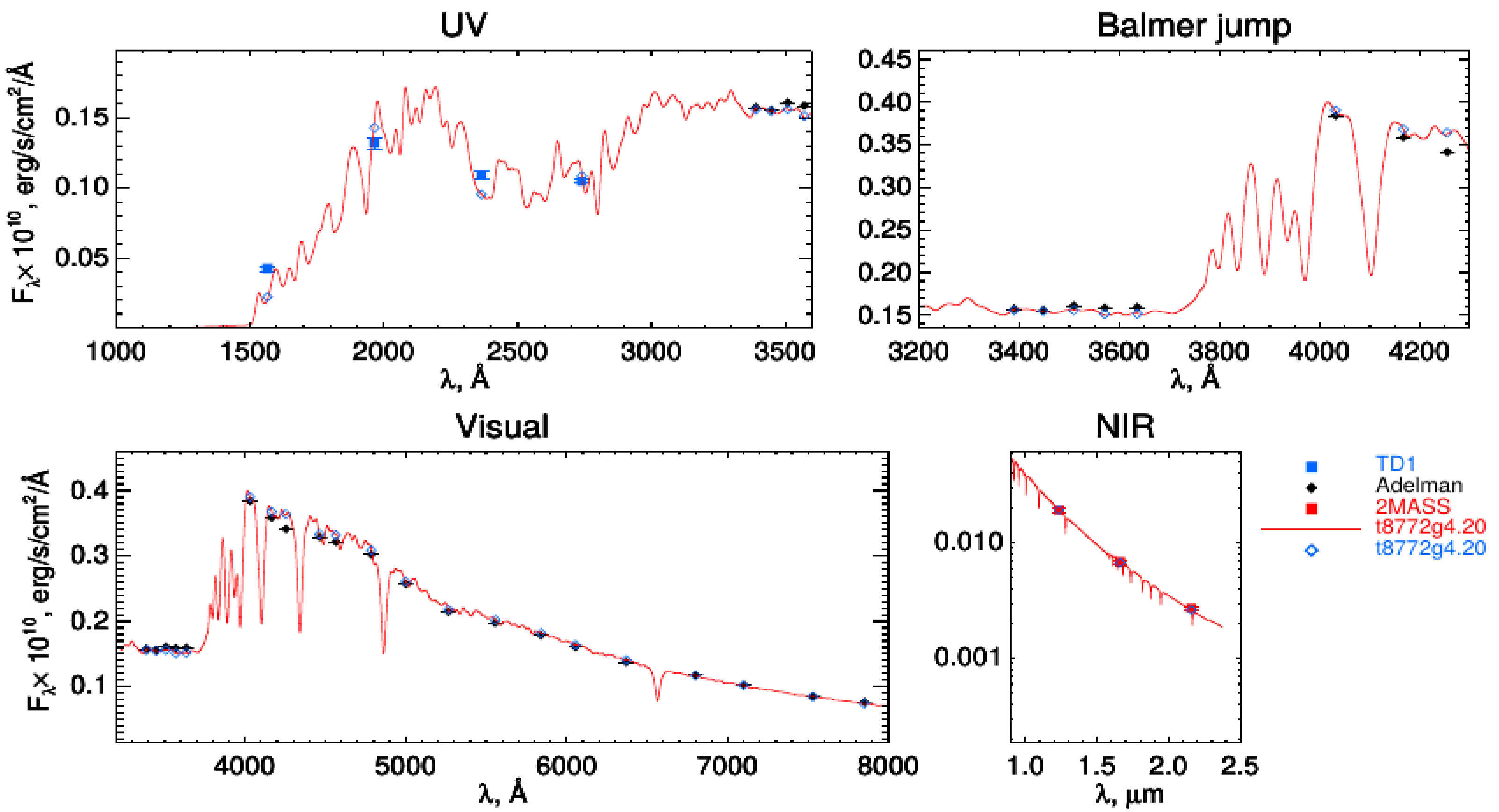
HD 188041 / UVES@VLTI

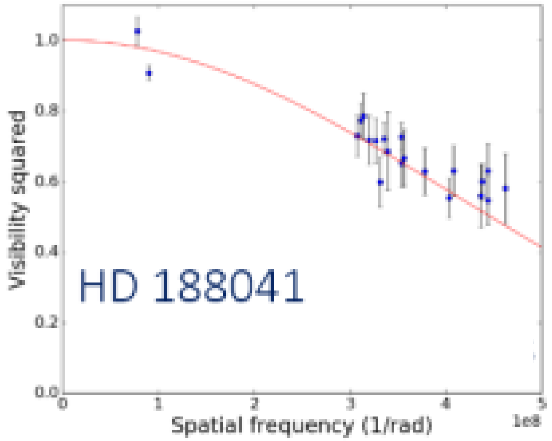


Main difficulty: θ < 1 mas (visible OLBI)

HRS ➡ abundances ➡ predicted SEDs ➡ predicted radii

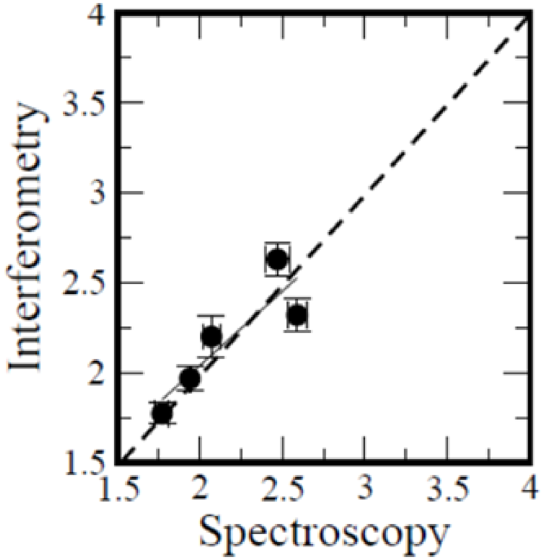
The Ap star program





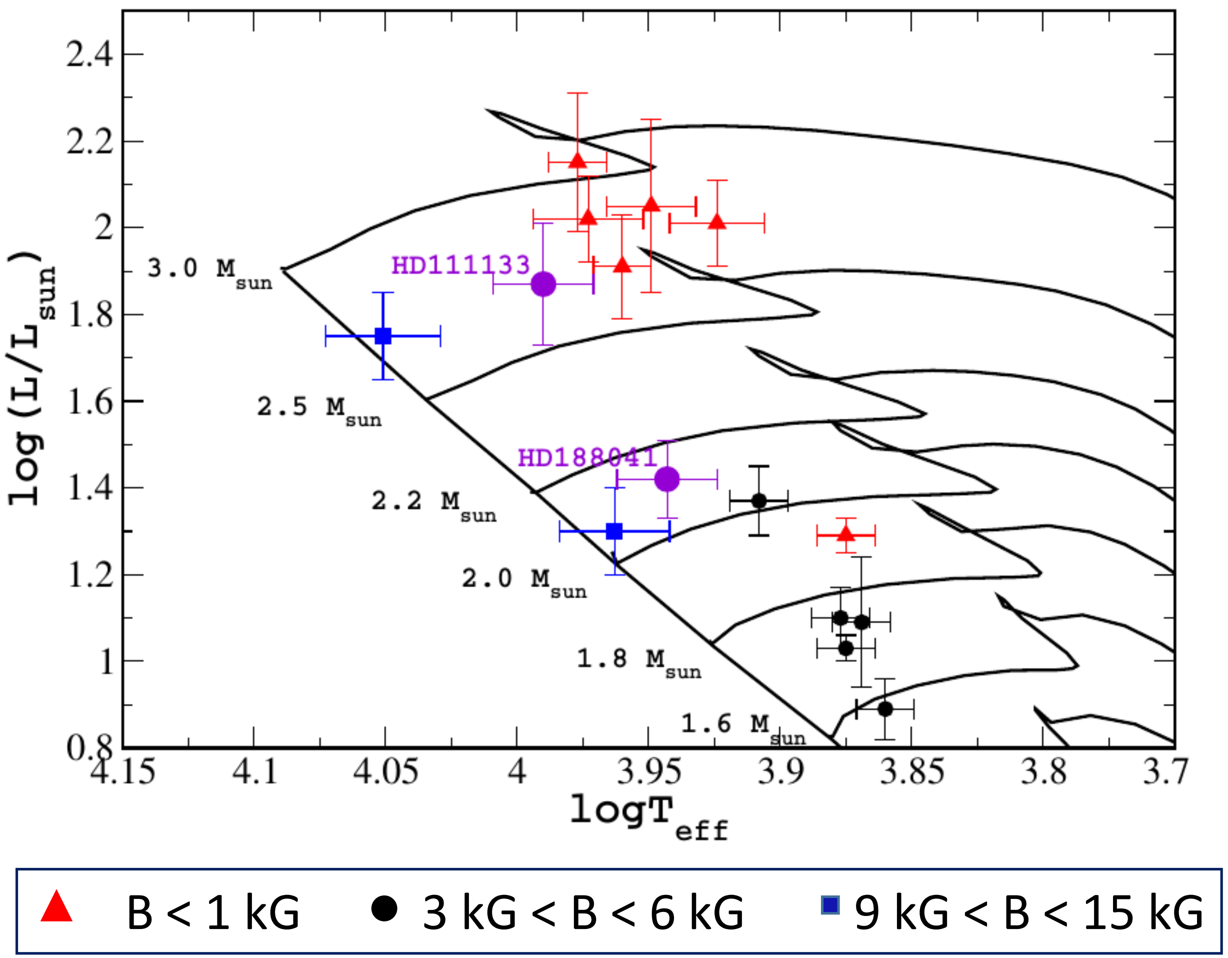
$R_{interf} \sim 2.2\ R_\odot$

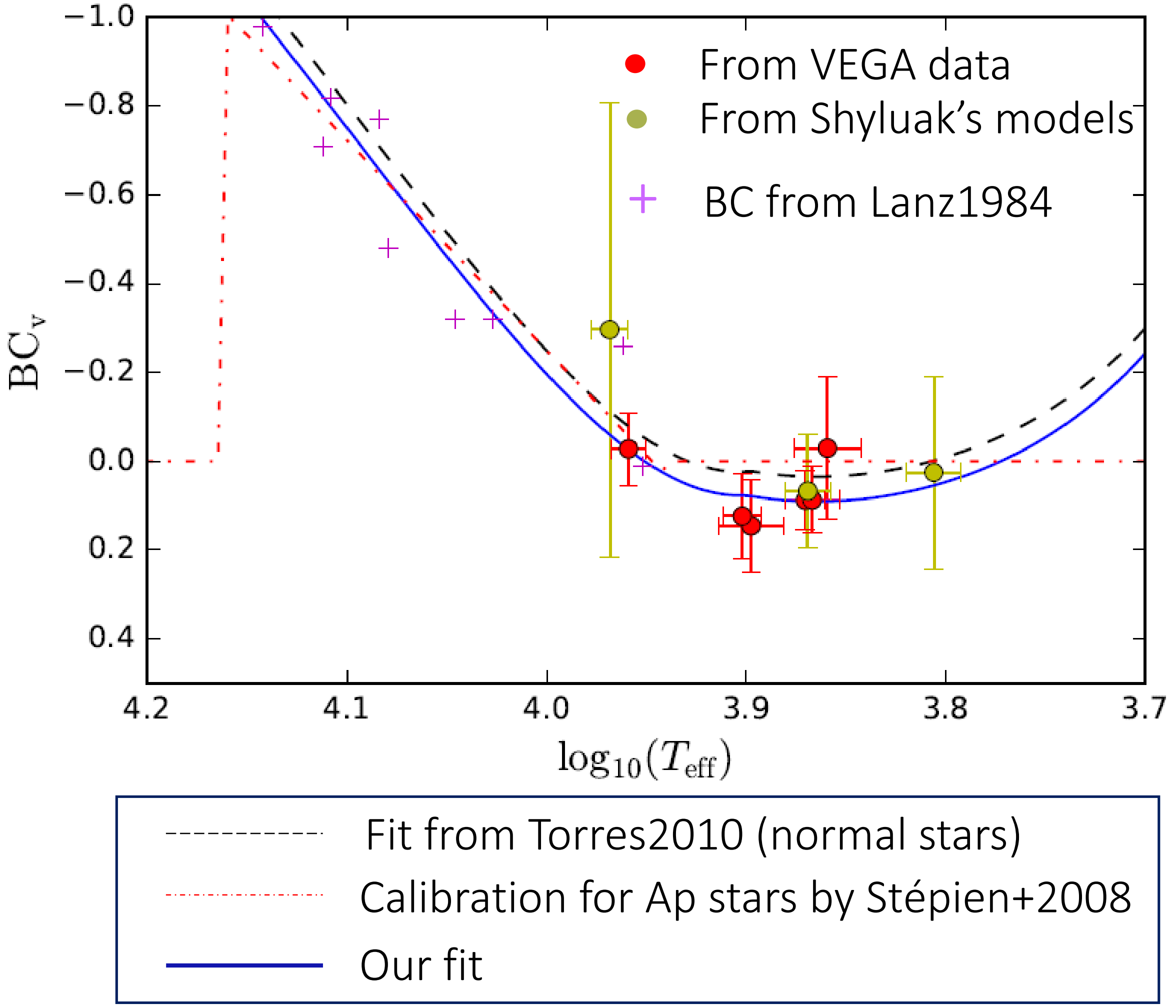
SED shape for Ap stars often different from that for normal stars



➡ $R_{mod} = 2.24 \pm 0.12\ R_\odot$

The Ap star program: towards general trends





The GJ504 system

[Bonnefoy, Perraut et al., submitted]

The faintest companion found with an AO instrument

43.5 au / 2.5'' from a G-type star

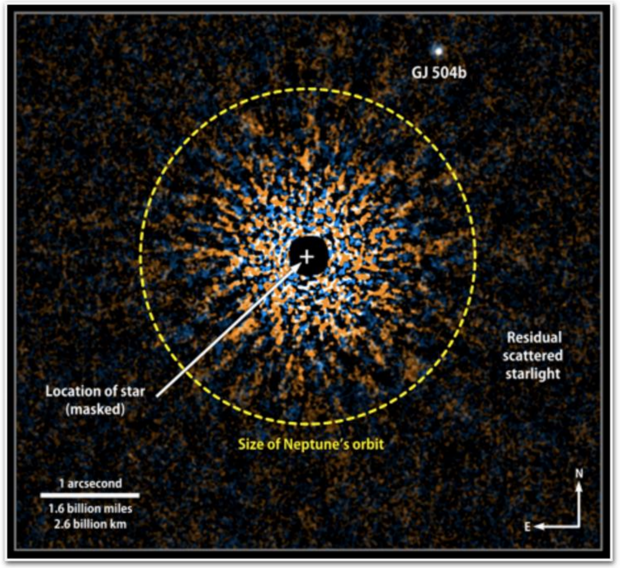
[Fe/H] = 0.22 ± 0.04

d = 17.56 ± 0.08 pc

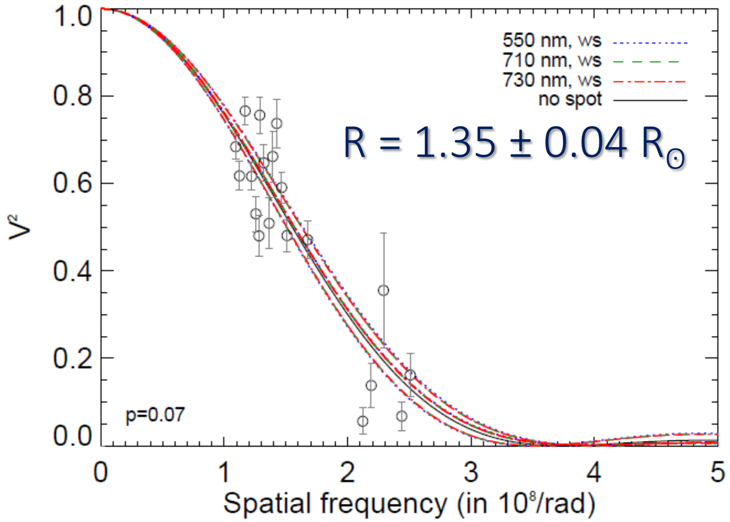
Debated age : 100 Myr …. 5 Gyr

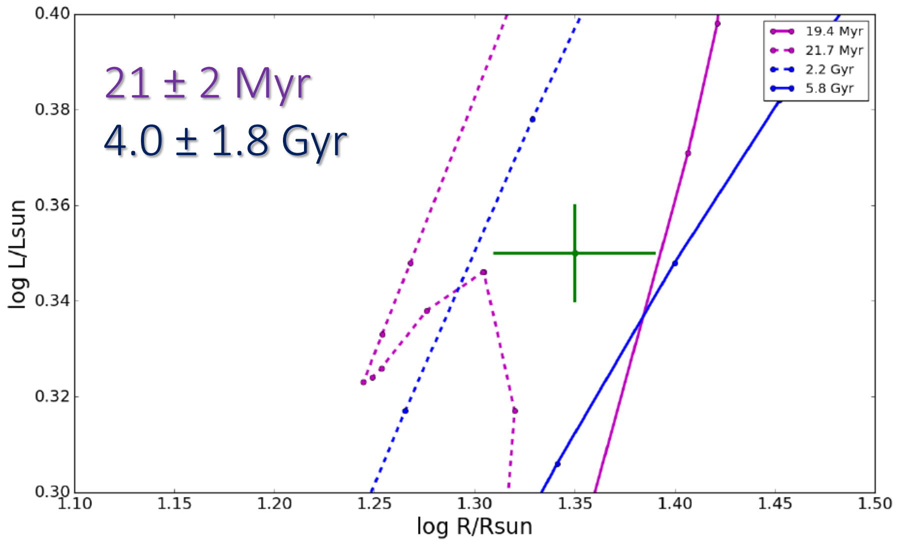
What interferometry brings:

- Angular diameter of the host star
- Accurate position in the HR diagram
- Age of the system



Part of the SHINE SPHERE survey





GJ504b

- Teff = 550 ± 50 K, log g = 3.5-4.0
- $M = 1.3^{+0.6}_{-0.3}\ M_{Jup}$ / $23^{+10}_{-9} M_{Jup}$ (young/old ages)

→ Constraints on formation, atmosphere composition, ….

[see Roxanne's talk]

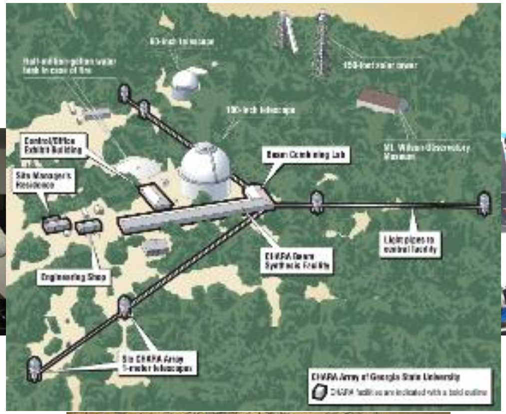
β Lyr: the 2013 campaign

- Well-known object with direct imaging with MIRC-4T [Zhao+2010]
- Nice laboratory for studying the mass-transfer mechanisms (role of the hot spot) [Lomax2012]

Joint effort combining photometry, spectroscopy, interferometry observations, and a new modelling strategy:

- Paper I [Mourard, Harmanec et al., submitted] with photometry and interferometry in the continuum
- Paper II [in progress] with spectro-interferometry in Hydrogen and Helium lines + spectroscopy

CHARA



VEGA

MIRC

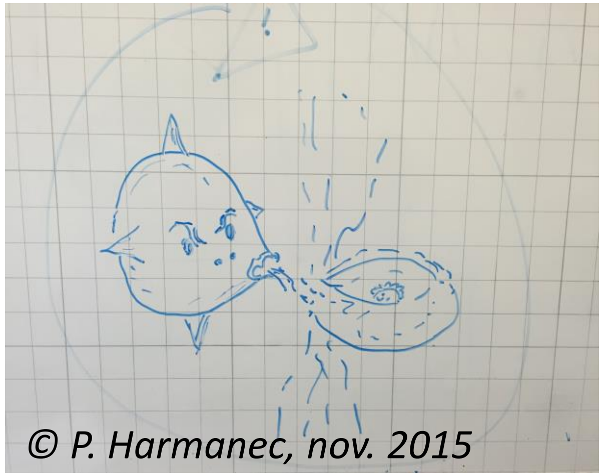
NPOI

Hvar Obs

IUE, Voyager data

β Lyr: the opaque disk modelling

From general idea…



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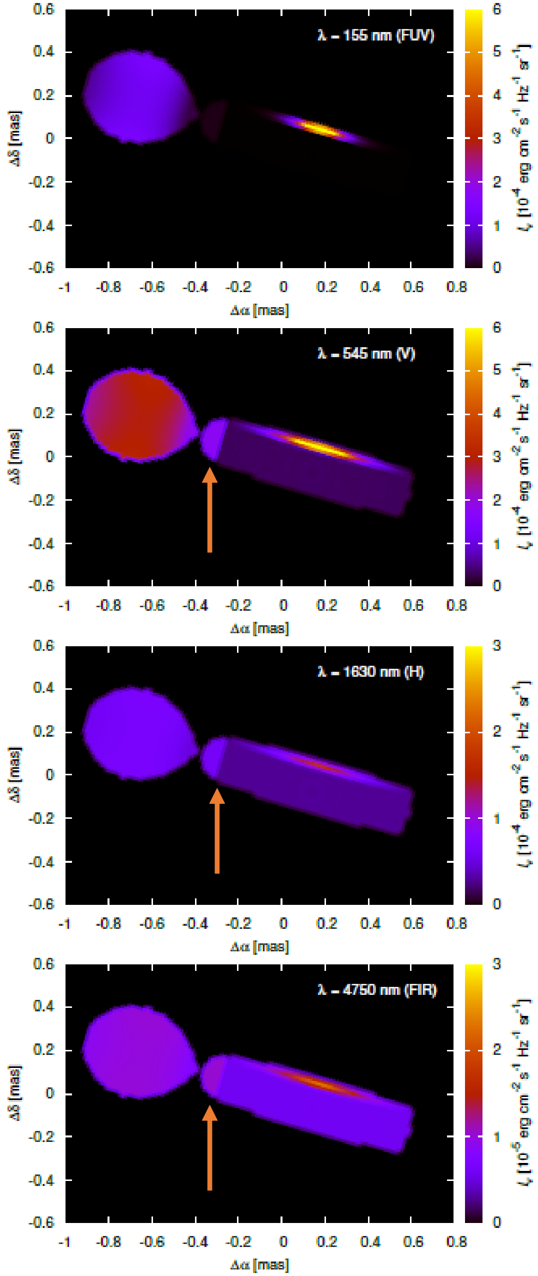
… to a global and detailed modelling

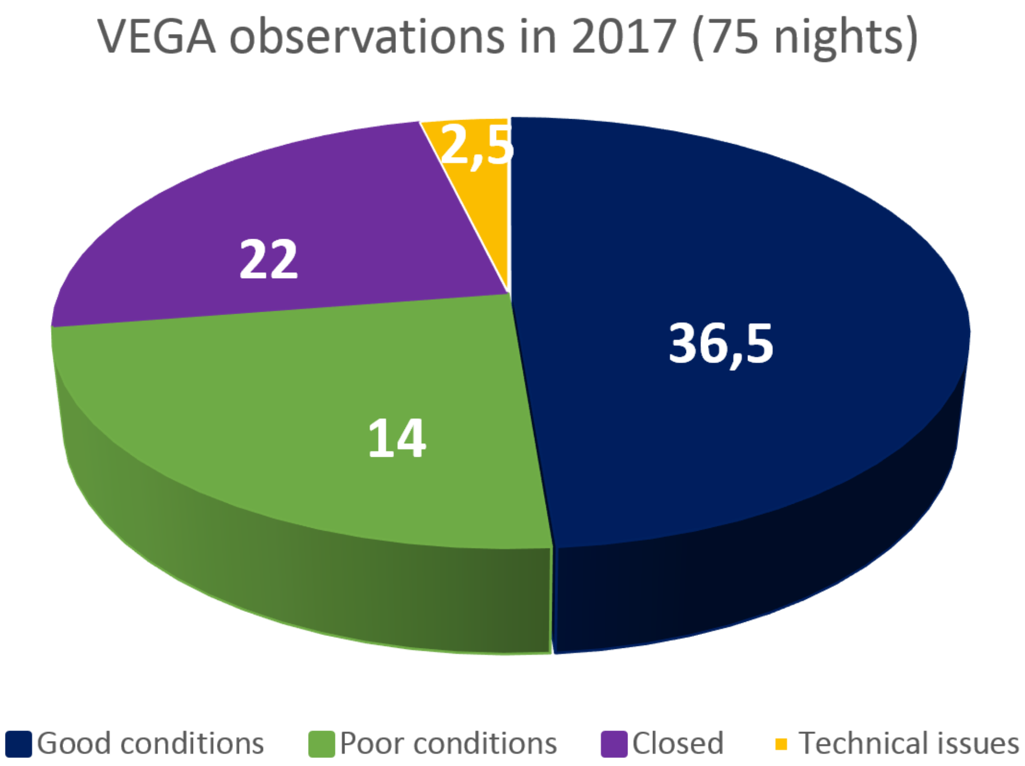
- Adaptation of the SHELLSPEC code (Budaj 2004): global model fitting approach including light curves (from UV to FIR), V^2, CP, T3, (and, differential interferometric observables and line profiles soon).
- LTE radiative transfer code
- Models based on 'opaque' objects (donor, disk, and 'hidden' star) and including a hot spot (heated region of the disk by incoming flux)

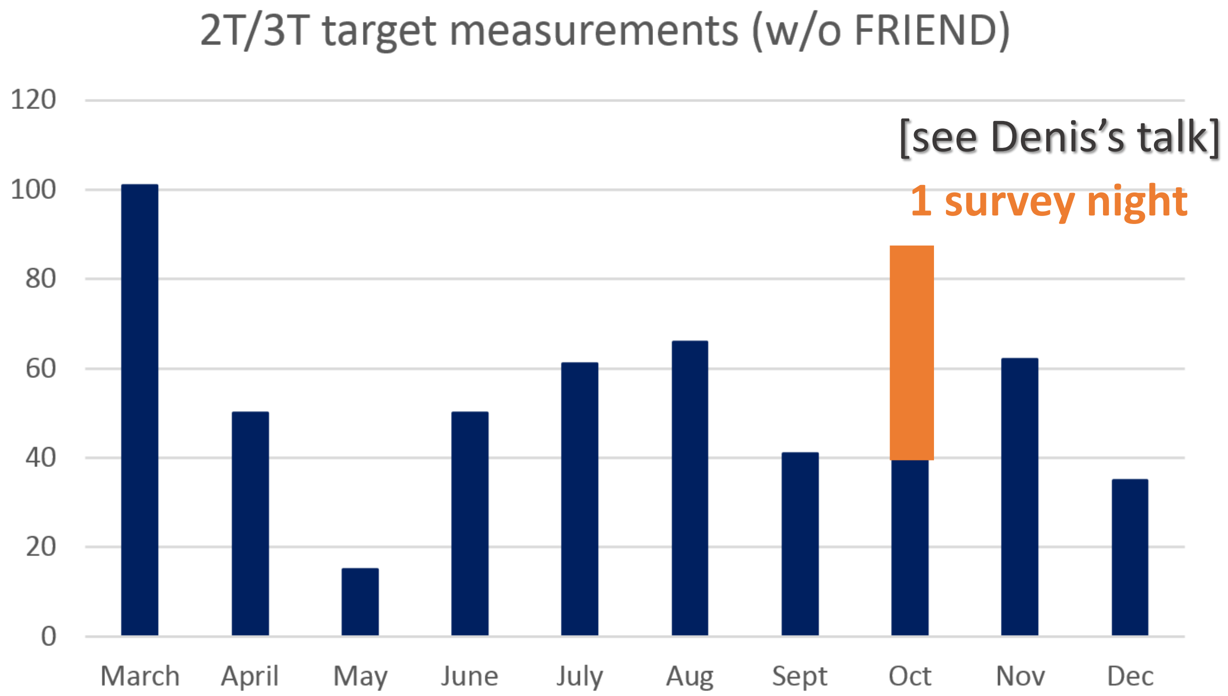


- Accretion disk not in a vertical hydrostatic equilibrium (in agreement with the ongoing mass transfer)
- Hot spot detected in the continuum
- $i = 93.5 \pm 1.0°$; $\Omega = 253.7 \pm 1.0°$; $d = 319.7 \pm 2.7$ pc

[Mourard+, submitted]

2017 statistics



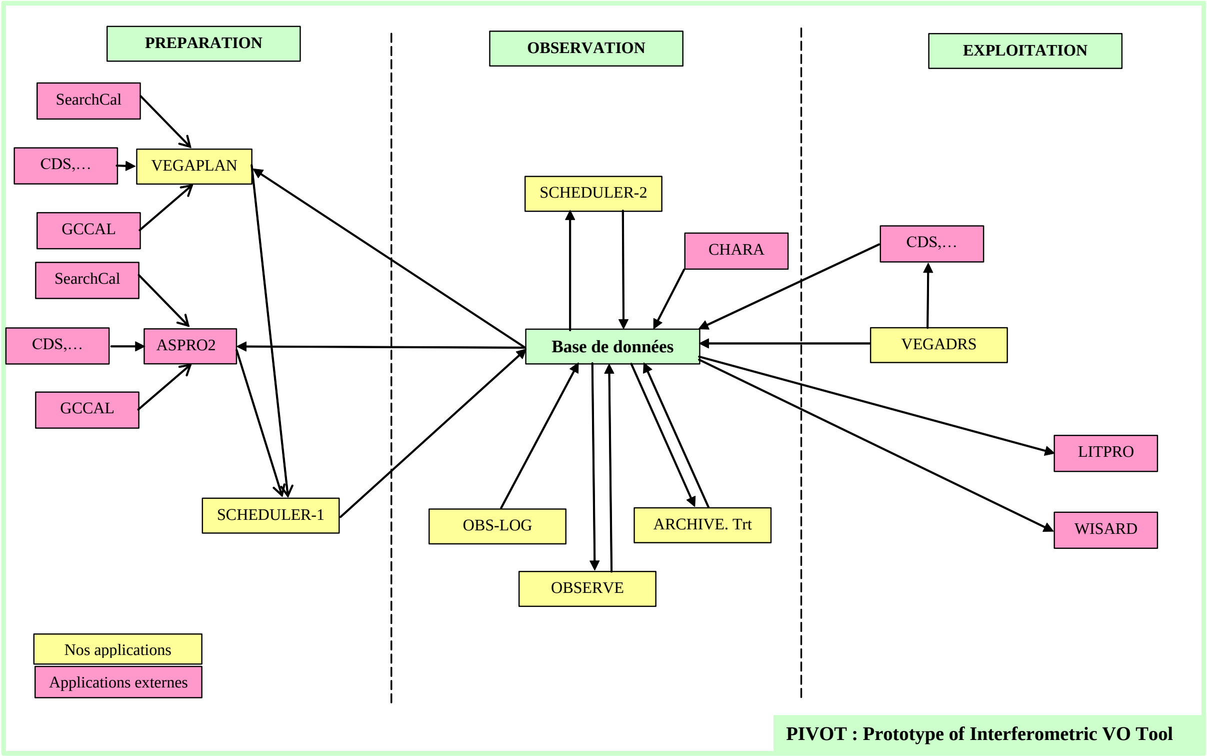


+ FRIEND observations in March, May, June, and October [see Marc-Antoine's talk]

VEGA observing software – MSIP & SPICA framework

J.M. Clausse, D. Mourard, F. Morand

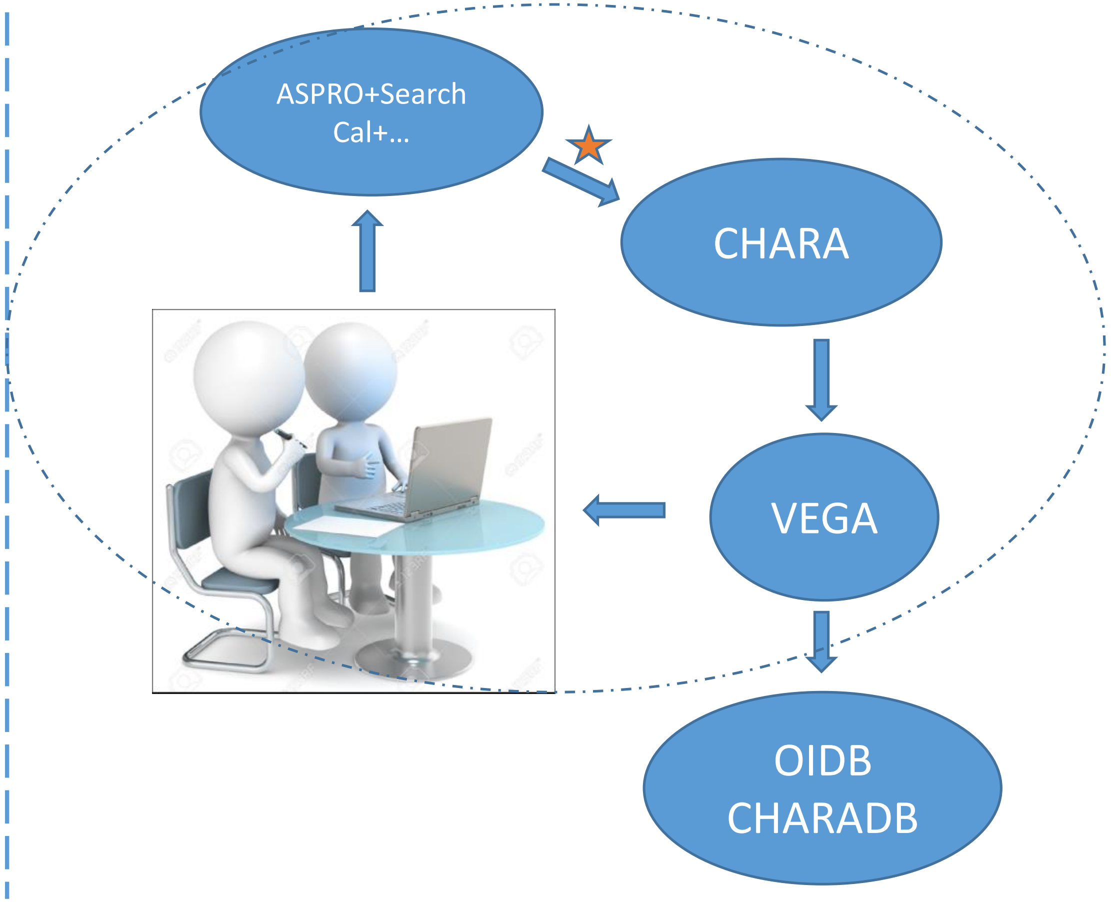
The old way: heavy preparation scheme + Database management



Fully operational and validated on the sky

Automatic data reduction pipeline (to be done)

The new way: simplified preparation and operation + more CHARA compliant



★ *'manual' transmission but automated way considered*

Conclusion and perspectives

- Several long-term on-going programs to go towards statistical studies (Be, Ap stars, exoplanet host stars, benchmark, metal-poor stars, …)
- NOAO programs
- Multi-instrument programs
- Niches for visible (spectro-)interferometry with CHARA, i.e.
  - search for envelop around Cepheids as observed around δ Cep. Similar findings around η Aql [Nardetto+, in prep]
  - accurate angular diameters of exoplanet host stars

- 2017: a very fruitful year for FRIEND, tests for SPICA also.

Many thanks to the whole CHARA group!

GJ504

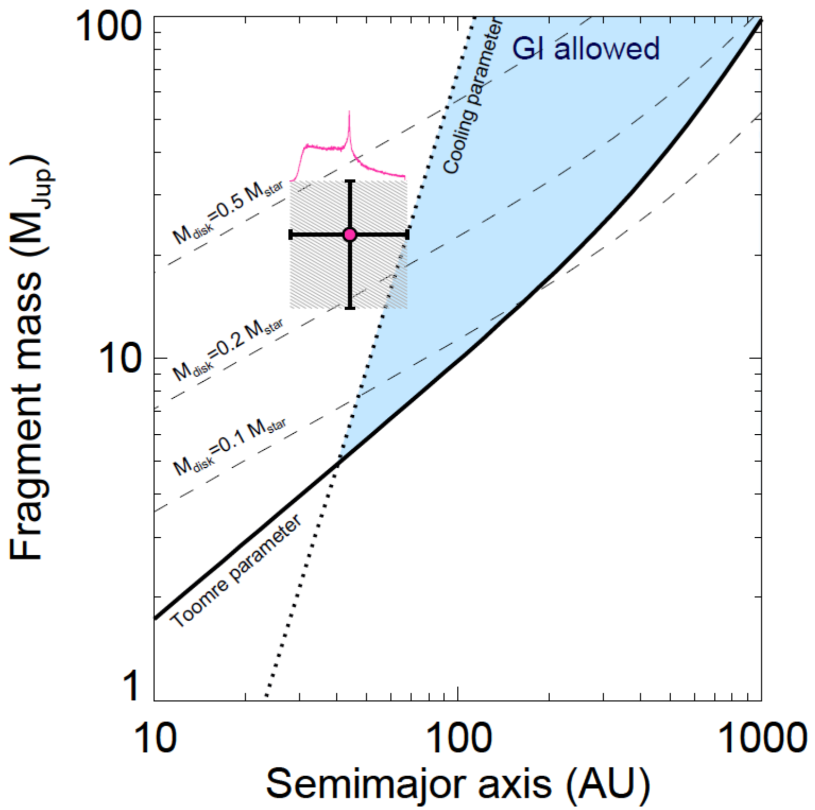


Fig. 21. Gravitational instability model adapted to the case of GJ 504. Fragments are allowed to form if they respect the Toomre and cooling criteria. GJ 504b properties are reported. The pink curve corresponds to the posterior distribution of the companion semi-major axis found with our MCMC orbit fitting package (Section 7.1). The dashed lines correspond to the disk mass distribution for different hypothesis on the initial disk mass.

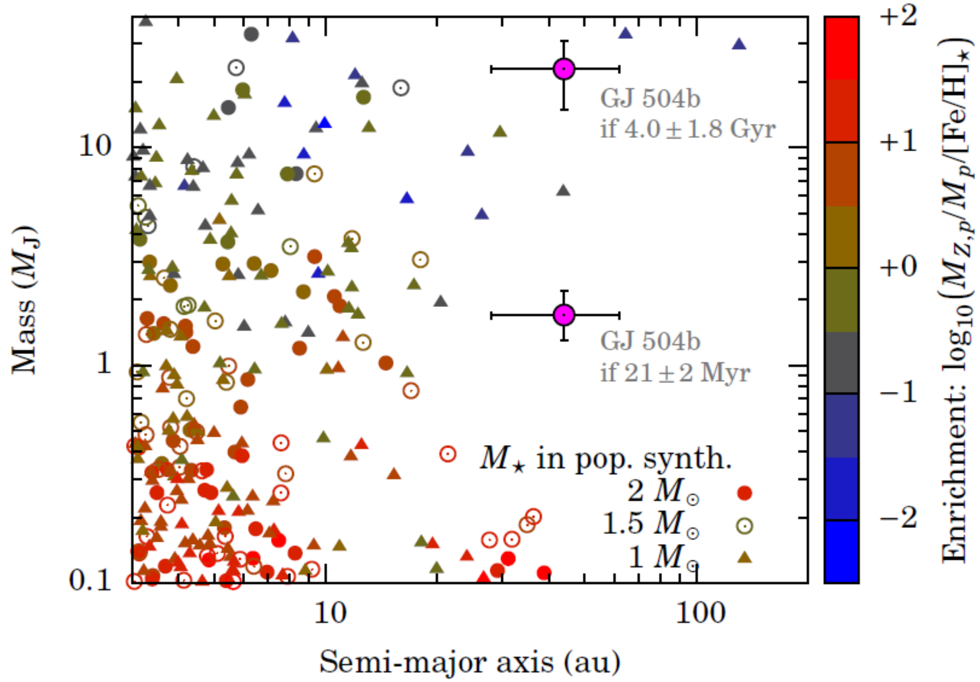


Fig. 22. Population synthesis at 20 Myr for core-accretion models including Type I and II migration and dynamical scattering between multiple planet embryos in the disk. We considered the case of a 1, 1.5, and 2 $M_\odot$ central stars. The colour shows the enrichment relative to the star.

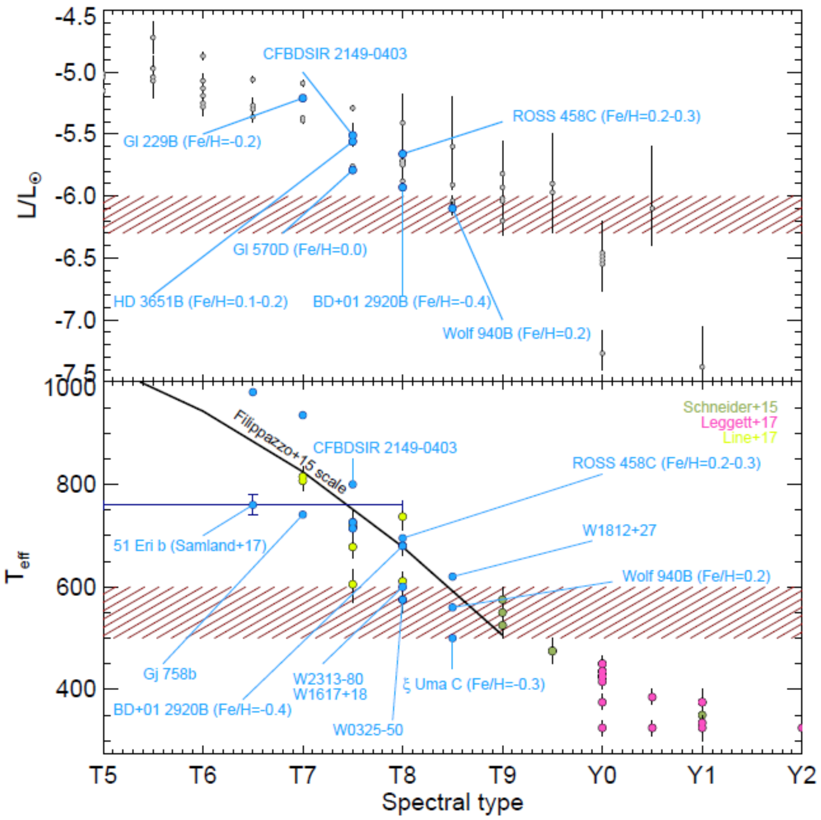


Fig. 12. Comparison of the final T_{eff} and bolometric luminosity of GJ 504b (dashed zone) to those of late-T and early-Y dwarfs. The bolometric luminosity values are taken from Dupuy & Kraus (2013) and Delorme et al. (2017a). The temperatures and luminosity of benchmark companions are taken from Tab. B. We added the T_{eff} determined by Leggett et al. (2017), Line et al. (2017), and Schneider et al. (2015) using atmospheric models and report the T_{eff}/spectral type conversion scale of Filippazzo et al. (2015).

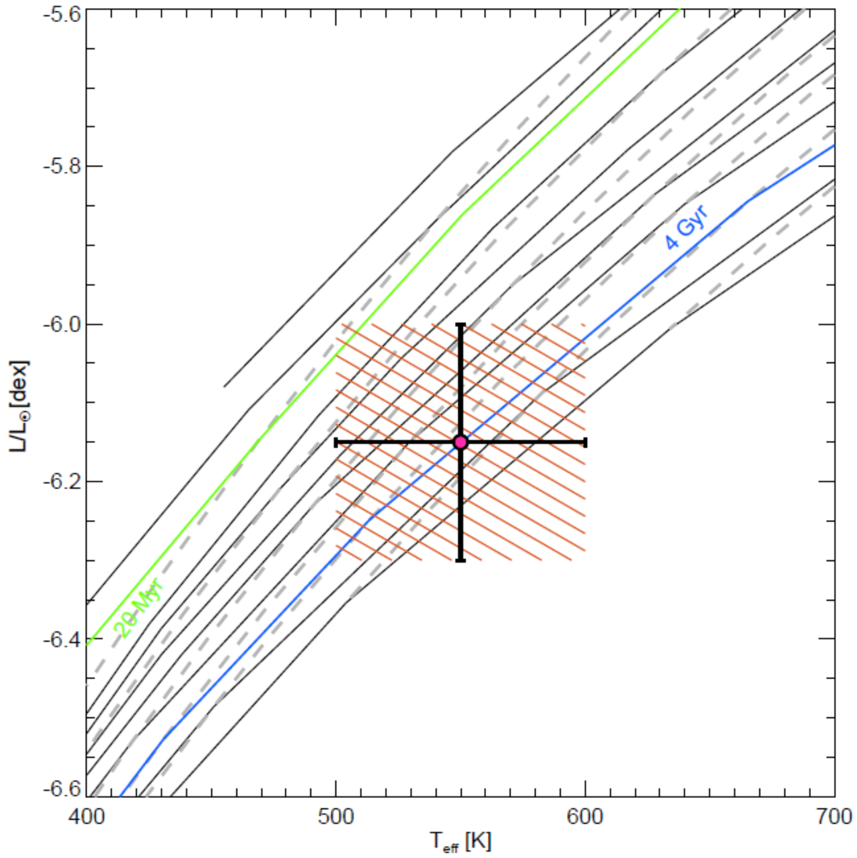


Fig. 13. Luminosity and T_{eff} of GJ 504b compared to the COND03 ("hot-start") evolutionary tracks. The solid lines correspond to the 5, 10, 20, 100, 300, 600 Myr and 1, 2, 4, 6, and 10 Gyr isochrones (from top to bottom). The dashed lines correspond to the model predictions for masses of 1, 5, 10, 15, 20, 30, and 40 M_{Jup} (from top to bottom).

β Lyrae

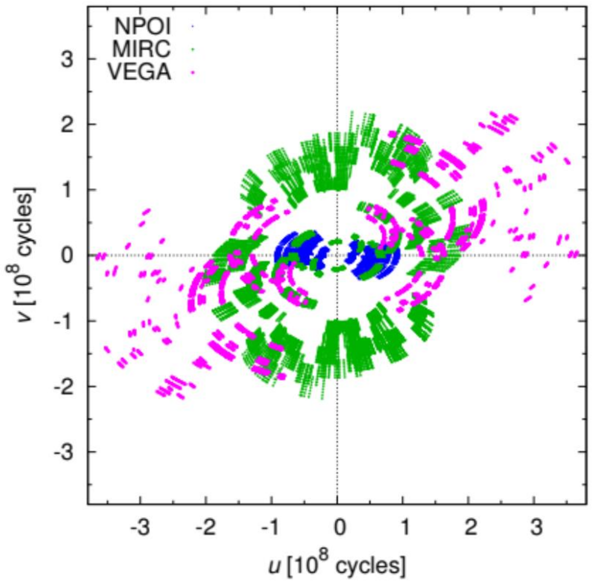


Fig. A.1. (u, v) coverage of all interferometric observations. Colours correspond to three different instruments: NPOI (blue), CHARA/MIRC (green), CHARA/VEGA (magenta).

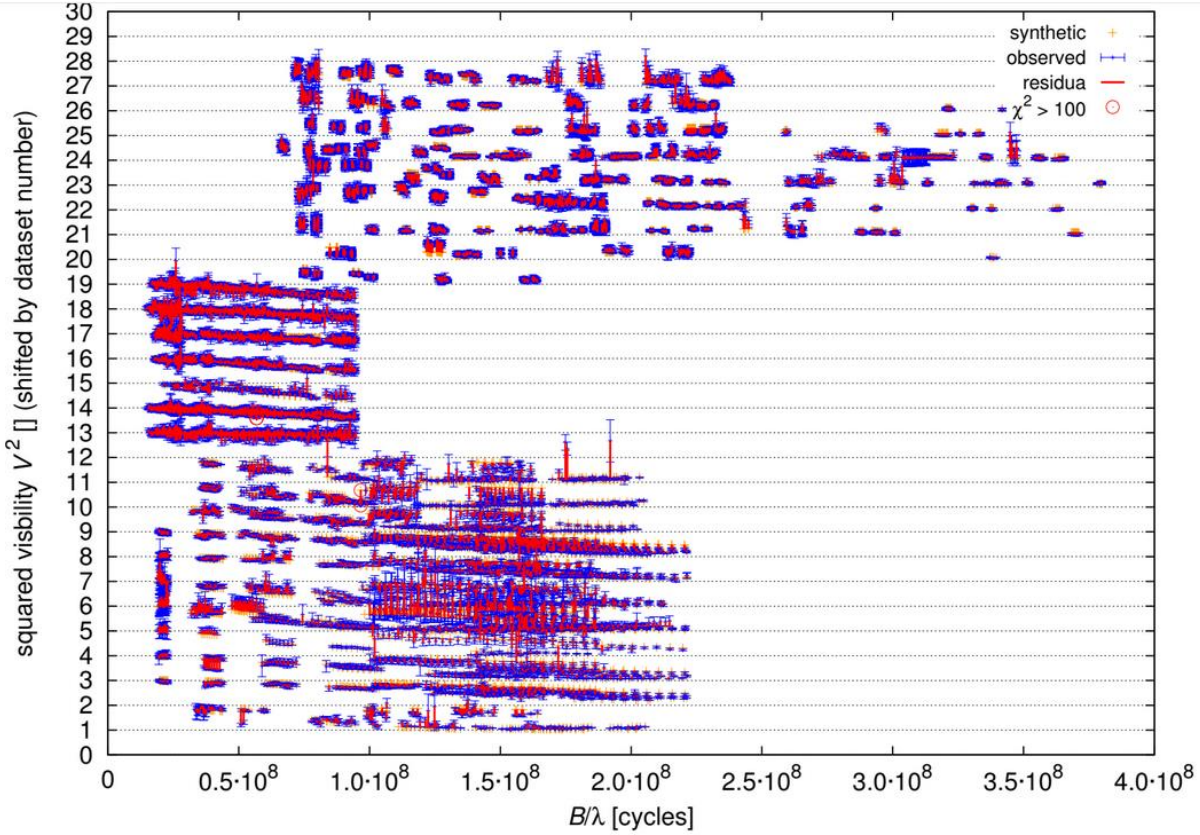
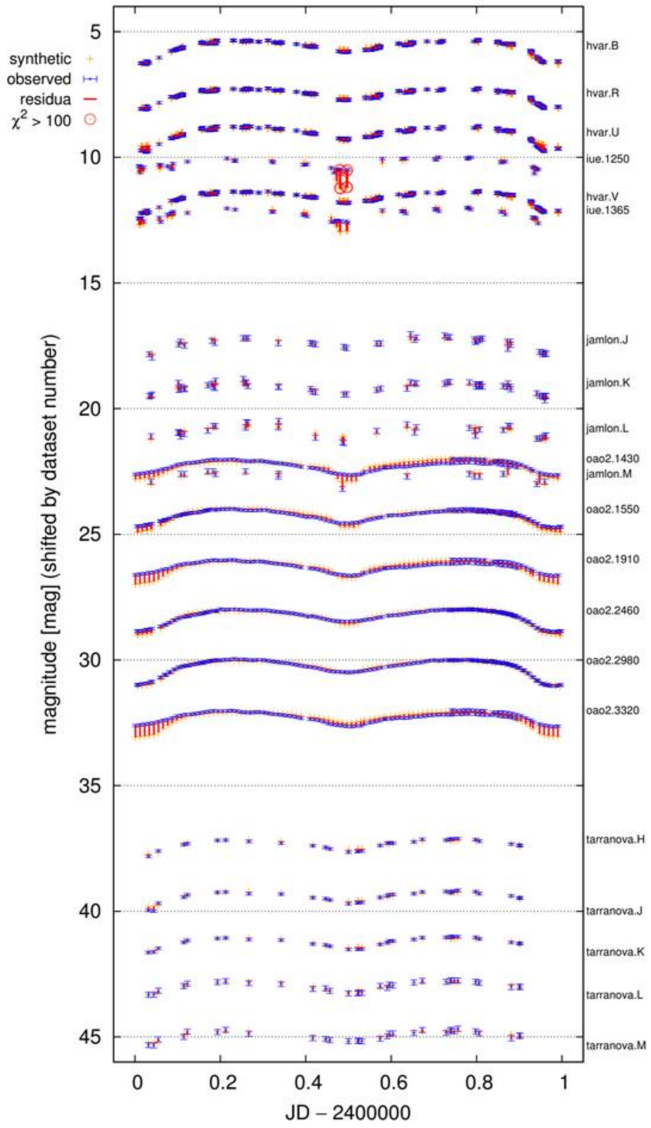


Fig. 8. A similar comparison as in Figure 7, but for squared visibilities $|V|^2$, with a contribution $\chi^2_{V2} = 54\,137$. The $|V|^2$ values are plotted against projected baseline B/λ (in cycles), and shifted vertically according to the dataset number. The are CHARA/MIRC data at the bottom, NPOI in the middle, and CHARA/VEGA at the top. Synthetic data are denoted by yellow crosses, observed data by blue error bars, and residua by red lines. Few outliers with large uncertainties, which do not contribute much to χ^2 anyway, were purposely removed from the plot to prevent clutter. Even though there are some systematic differences for individual segments of data, overall trends seem to be correctly matched.

β Lyrae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