Ten years of VLTI:  from first fringes to core science

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# Zoomingin  on circumstellar matter around B stars with the  AMBER high resolution mode


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# Syllabus

1) Why HR spectro-photometry, data modeling

3) Selected projects

– ζ Tau: detection of disk density waves

-- 48 Lib: a huge disk activity recovered

-- δ Sco 2011 periastron passage

ӿ HR 5907 the first interferometric detection of the magnetosphere of a He-rich star – see Rivinius et al., this workshop

4) Limitations of present AMBER HR observations

5) Conclusions

Coordinated spectroscopic, photometric (optical, IR), polarimetric and radio (sub-mm/mm) observations were executed for ζ Tau, δ Sco and 28 CMa. Only interferometric results are reported here.

# General framework

Why high-resolution spectro-interferometry?

Each bin across the spectral line represents a projection in the given RV range. Emission lines of Be stars provide dynamical profile of the circumstellar disk.

Why Be stars?

- Broad lines due to the fast rotation. Pole-on stars – 15 spectral bins over Br $\gamma$, equator-on seen Be stars – 25 -30 bins.
- Solution of the general astrophysical problems: disk viscosity (proto-planetary disks, AGN disks), star-to-disk angular momentum transfer
- Unresolved point (star) present in the system

# Modeling of HR data:

No simple models in LITpro (see JMMC page), physical models necessary

HDUST - viscous decretion disk model: Carciofi & Bjorkman (2006, ApJ 639, 1081, Carciofi 2011, IAU Symp 172, 325) + ongoing modifications

- 3-D, NLTE code solving coupled problems of radiative transfer, radiative and statistical equilibrium for arbitrary gas density and velocity distribution.
- NLTE Monte-Carlo simulations solve the temperature and density disk profiles. The only input are stellar parameters, disk inclination, stellar mass-loss and kinematic viscosity of the gas.

# Direct detection of disk density waves in ζ Tau

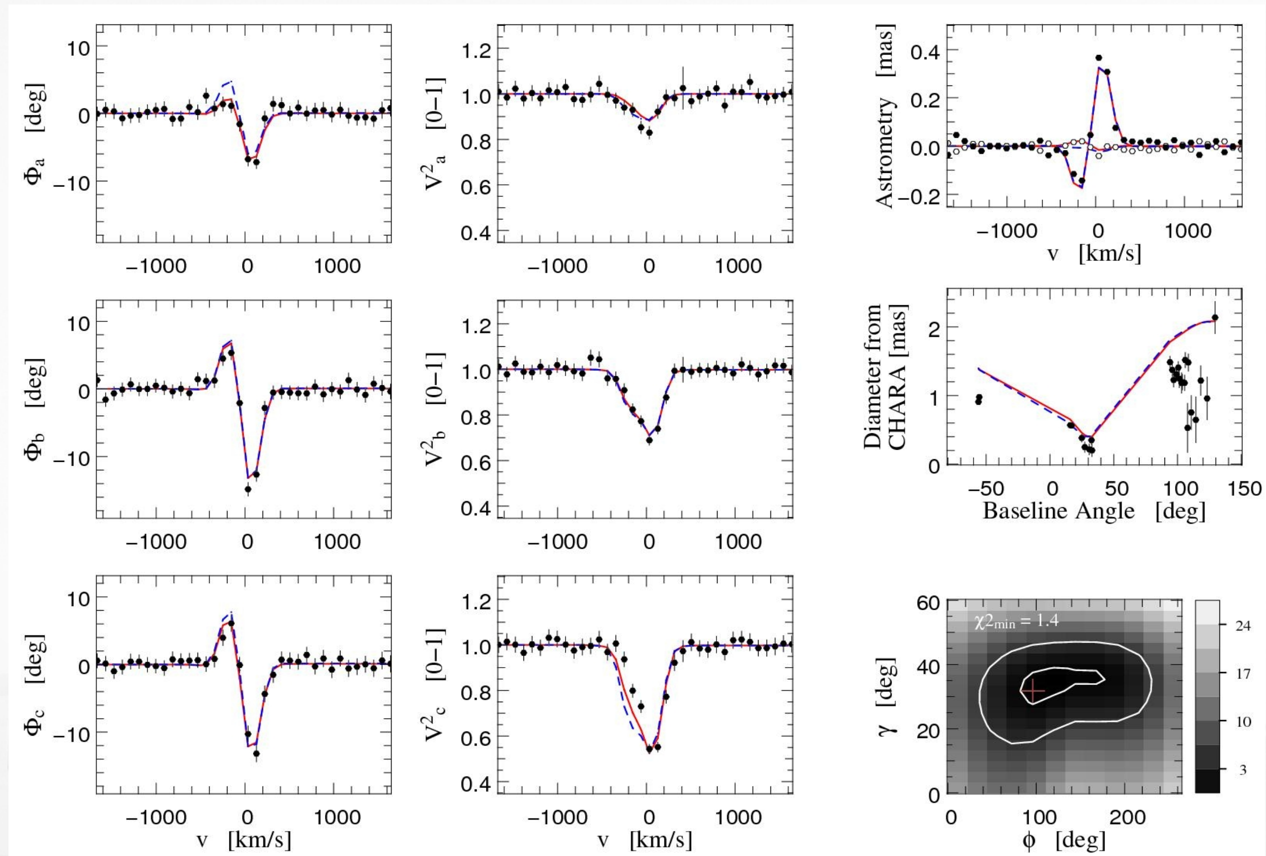
ζ Tau (HD 37202, B2IV) AMBER MR, Dec 2006, Br γ
Štefl et al. 2009 (A&A 504, 929), Carciofi et al. 2009 (A&A 504, 915)

- AMBER data analyzed and modeled together with extended spectroscopic and polarimetric datasets

- disk position angle and rotation vector derived

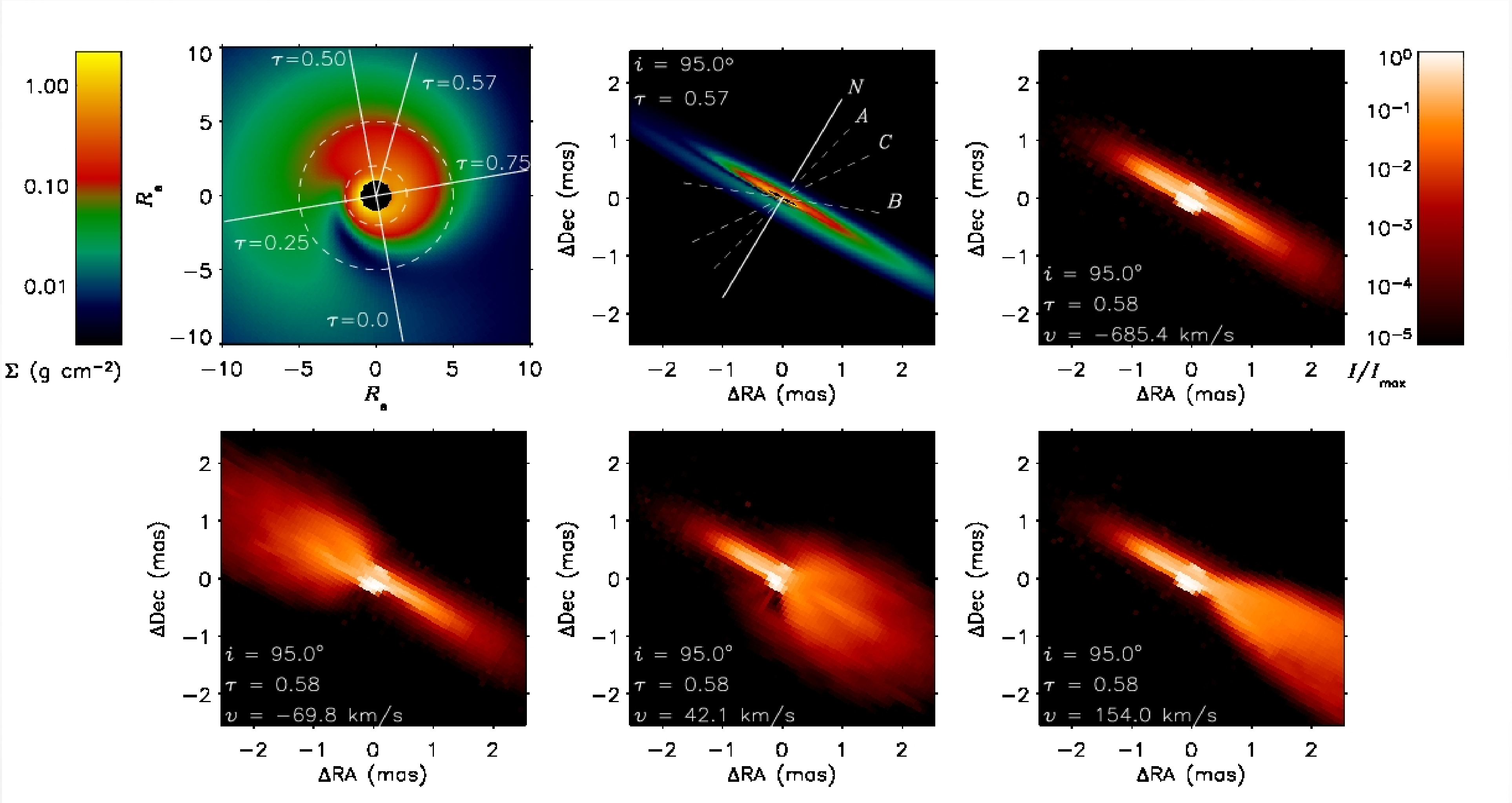
- consistent fit of AMBER data and spectroscopic variations over 12 years

- quantitative test of the density wave model




HDUST fits of differential visibilities and phases of ζ Tau (Carciofi et al. 2009)

# ζ Tau- cont.




Modeling of the ζ Tau density wave (from Carciofi et al. 2009) at the time of AMBER observations. Top: seen pole-on, in the disk plane and as an synthetized image at 2.16 µm. Bottom: synthetic images at RV= -70, +42 and +154 km/s.

# ζ Tau conclusion:

The density wave directly detected.

The performed modelling provides strong theoretical evidence that the viscous disk model is the mechanism responsible for disk formation

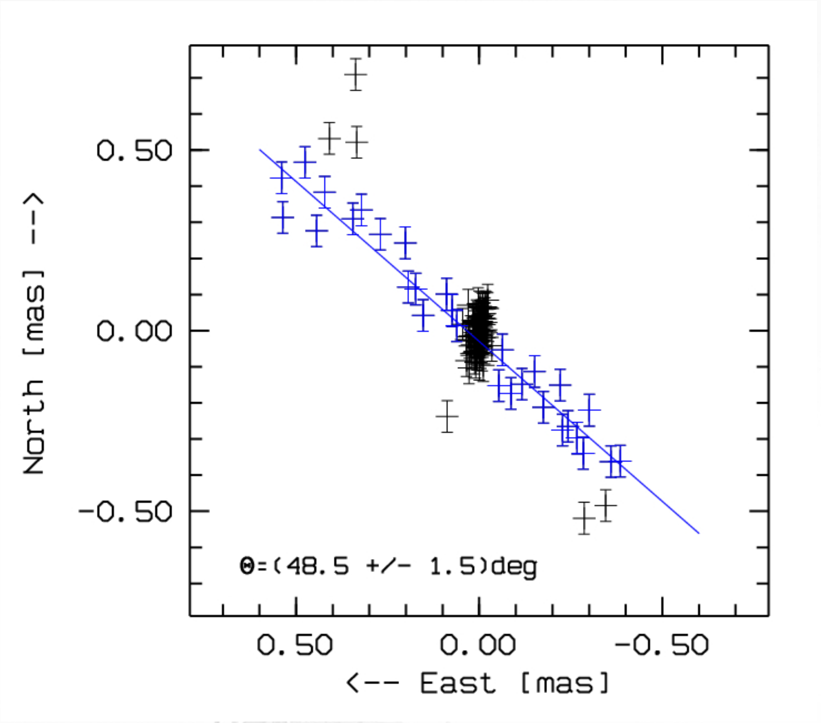
# 48 Lib – huge disk reaching the photosphere

48 Lib (HD 142983, B3Ve)

AMBER: HR, Br γ, 2009; Pionier, H, 2011; Štefl et al. 2011, A&A submitted

- disk position angle ~50°, consistently from the Br γ photocenter, LITpro elliptical disk fit to Pionier data and polarimetry
- H continuum disk diameter ~1.7 mas (15 stellar radii), Br γ region diameter > 100 stellar radii
- relatively low disk flattening (~1.7)

-spectroscopy: a smooth transition between the photosphere and the disk – suitable for a study of momentum transfer to the disk




Relative photocenter shift for Br γ. NE points correspond to the blue line Line wing and approaching part of the disk. SW point to the red wing and receding side (Štefl et al. 2011)

# 48 Lib conclusion:

Determination of basic disk parameters as a starting point for a study of the disk dynamics at different distances from the star – mysterious mechanism of momentum transfer.

# δ Sco 2011 periastron passage

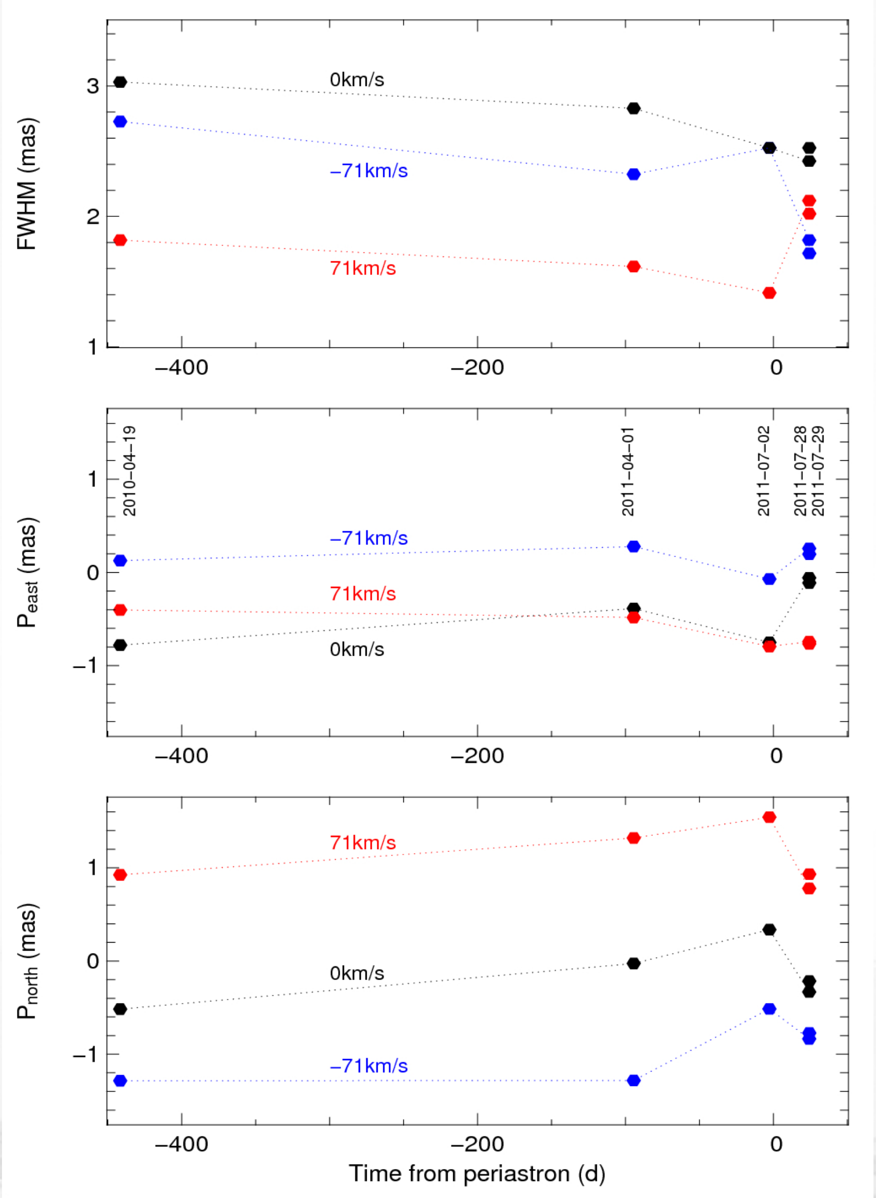
- δ Sco (HD143271, B0Ve), 10.8 year binary, secondary at a very eccentric orbit, periastron passage on July 4, 2011
- AMBER HR, 2008-2011, Br γ; Pionier, H, 2011
  LeBouquin et al. A&A, in preparation

Preliminary results:

- Periastron appeared 2 days earlier than predicted
- Orbital plane and equatorial plane of the disk are parallel
- The direction of the secondary orbital motion and disk rotation vectors are opposite - strong impact on modeling
- Variations of the disk FWHM and orientation detected and quantified using a simple model fitting.

# δ Sco - cont.

## δ Sco -Br γ region: diameters and astrometric position changes




- The largest variations appear during the first month after the periastron in the orbital plane, N-S direction, that is along the major orbit axis.

Only D0-H0-G1 data shown, Gaussian FWHM fit.

- By combining Pionier continuum model with AMBER differential data, the image reconstruction of the Br γ emitting region was performed

# δ Sco conclusion:

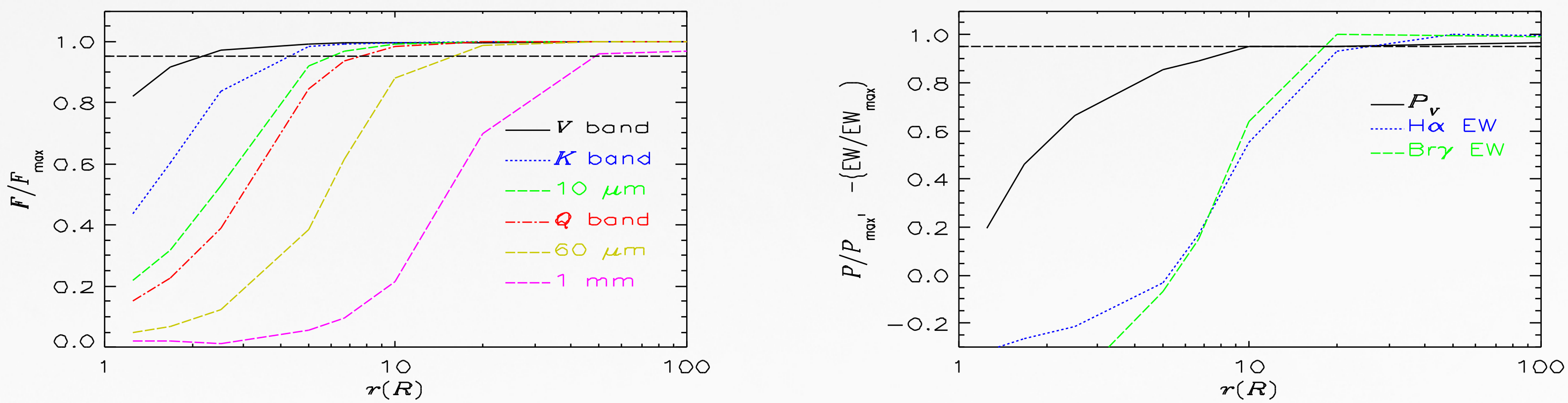
AMBER HR and Pionier data provide information on disk distortion due to the close pass-by of the secondary star. Exact modeling of all data in progress.

# Present limitations of the HR AMBER data

- Wavelength calibration: fixed, yorick procedure fitting telluric lines included in the amdlib3 calibration script
- Unreliable absolute calibration: FINITO effects, jitter scatter (Kraus et al. 2011) → only differential data used
- Most observations done in Br γ, although 13 HR configurations are offered at present.

  28 CMa (Štefl et al. 2009, Rev. Mexicana Astron. Astrof., 38, 89 ; Štefl et al., in preparation): Early phase of the outburst monitored but Br γ line showed no changes, not formed in the inner disk.

# AMBER limitations - cont.




From Carciofi (2011, IAU Symp. 272)

- Emission lines in the disk are formed at different stelocentric radii. Can we already do such a multi-line dynamical disk tomography or spectro-imaging at VLTI?
  -- Br γ, He I 2.06 μ + high Pfund lines available in the HR mode
  -- no HR setting in H  or J bands (Paschen lines)
  -- imaging not possible only for differential HR visibility and phases - complementary Pionier data can help

# Conclusions

- AMBER spectro-interferometry provides a unique view of the dynamics of circumstellar disk of Be star
- The more advanced physical analysis of Be star disk can be done by
  - using available HR settings covering Pfund lines
  - offering HR settings in the H band
  - inclusion of He I lines in disk models