



# Observing a magnetosphere with interferometry

**Thomas Rivinius**

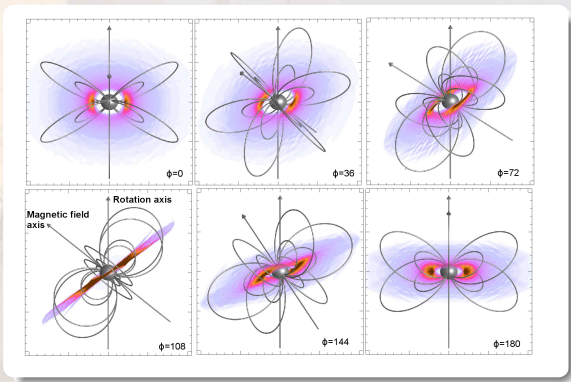
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**European Southern Observatory, Chile**

October, 2011

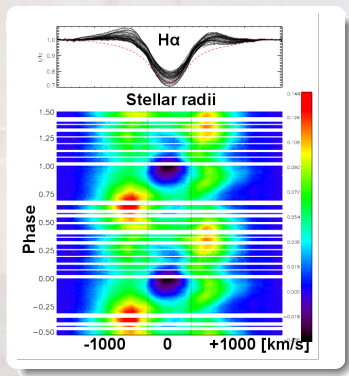
R. Townsend, A. Carciofi, J. Grunhut, G. Wade, S. Štefl, D. Baade, D.M. Faes

# The magnetosphere of HR 5907 ( $V \approx H \approx K = 5.5$ )



- Rapidly rotating B2V star with tens of kG dipolarish field
  - At intersection of mag and rot equators clouds accumulate
  - Clouds are **magnetically bound** in forced corotation,  $P=0.51$  d.
- Pictures above span half a rotation cycle

# The spectroscopic signature



- Across emission lines, one side approaches, one side recedes.
- Because of **bound** corotation, projected velocity maps to radius
  - Two cycles are shown for clarity

## Some guesswork on observables

### Phase offset vs. continuum

$$\Delta\phi \propto \alpha \frac{B}{\lambda}$$

Photocenter displacement of line emission vs. unresolved point source?

- Emitting plasma at  $3-4 R_*$  (because at  $3-4 v \sin i$ )
- Can estimate density, since we have Balmer decrements
  - $\text{Br}\gamma$  emissivity, about 10% of continuum.

## Some guesswork on observables

### Phase offset vs. continuum

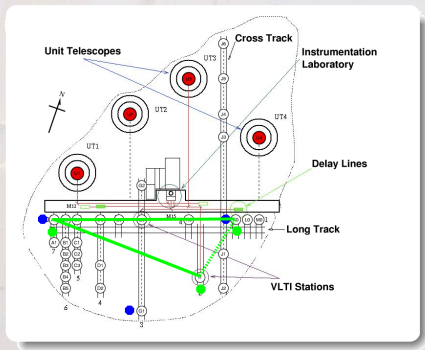
$$\Delta\phi \propto \alpha \frac{B}{\lambda}$$

Photocenter displacement of line emission vs. unresolved point source?

- Emitting plasma at 3-4  $R_*$  (because at 3-4  $v \sin i$ )
- Can estimate density, since we have Balmer decrements
  - $\text{Br}\gamma$  emissivity, about 10% of continuum.
  - $4/2 \times 0.1 \rightarrow 20\%$  of photospheric diameter
- At Hipparcos distance, **photospheric diameter 0.15 mas**
  - Displacement: 30  $\mu\text{as}$
- In K-band and at 100 m BL this should be about **4 degree in phase.**

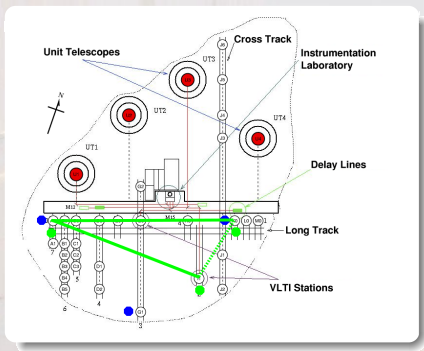
**Feasible with AMBER**

# Observing strategy



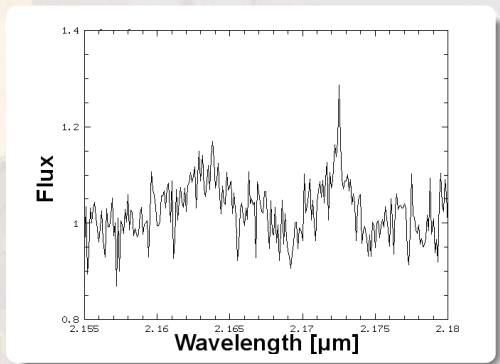
- Two “opposite” appearances of magnetosphere ( $n.5$  cycles)
- Observe at identical projected baseline (same LST)
- $P_{\text{rot}}$  implies observations two weeks apart, observed April 2011

# The first secret principle of interferometry



- It never works the way you plan:  $\phi = 0.47$
- First run 100% weather loss (domes closed)
- Second run 50% weather loss (seeing), inadequate triplet  
 → but there are advantages!

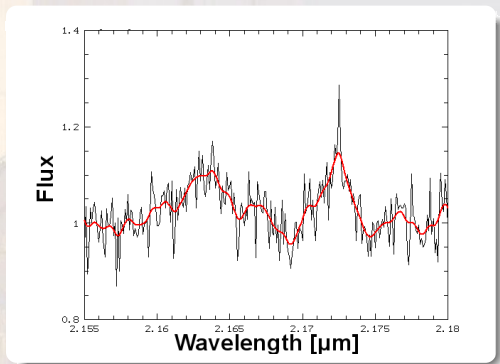
## The observed data



- Noisy!

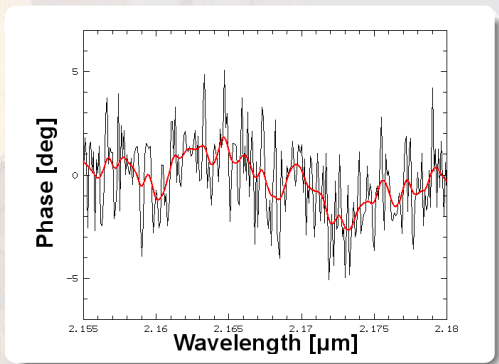


## The observed data



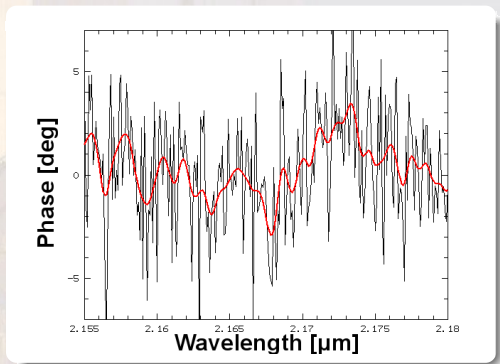
- Noisy! Filter for clarity
- on the flux,

## The observed data



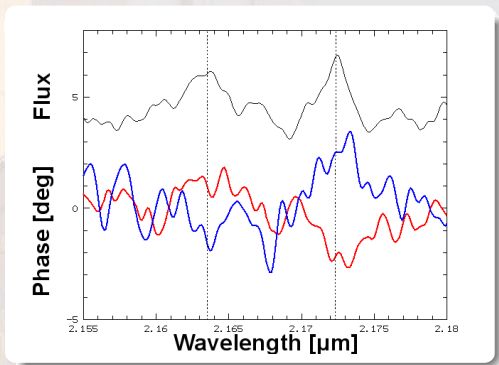
- Noisy! Filter for clarity
- on the flux, and phase on **BL 1**

## The observed data



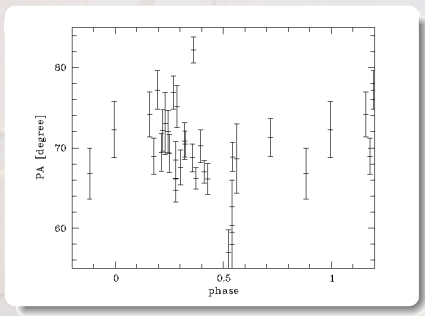
- Noisy! Filter for clarity
- on the flux, and phase on **BL 1** and **BL 2**

## The observed data



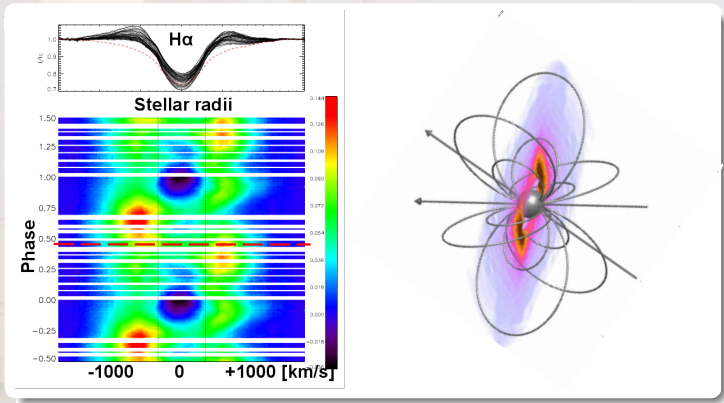
- Noisy! Filter for clarity
- on the flux, and phase on **BL 1** and **BL 2**
- Data pretty much at the limit, but everything right in place!
  - Due to baseline limitations, very weak constraint on target

## Polarimetry comes to help



- Continuum polarimetry measures orientation of clouds
  - and its phase modulation
- Polarization angle essentially E–W ( $75^\circ$ ), meaning CS material is N–S ( $-15^\circ$ )
  - Array is aligned at  $+19.55^\circ$  → Small angle!

## Polarimetry comes to help



- Combining both datatypes, model can be constrained
- Red lobe extends to about  $5$  to  $6R_{\star}$ , but blue one only to  $3$  to  $4R_{\star}$  at time of observation.

## Summary

- Observationally extremely **challenging**, but **feasible**.
  - First interferometric detection of **magnetically bound** material
- Data so far **hardly enough** to constrain model
    - Already clear: Have to give up symmetry. Model has been developed to that point.
  - Strategy change: Apply for more data in service mode with UTs
  - Complementary polarimetry allows interpretation of data to some extent
- Target varies rapidly, but with precisely known ephemeris. Would require load of time, but how about an “interferometric movie”?

# Ceterum censeo

## Circumstellar Dynamics at High Resolution

Foz do Iguaçu, Brazil  
Feb 27 to Mar 2, 2012

### Sessions:

Circumstellar Disks & Outflows: Theory  
Circumstellar Disks & Outflows: Observations  
Be Stars as Laboratories for Disk Physics  
Dynamics of Circumstellar Material and Tidal Interactions in Binaries  
Massive Star Formation out of a Dynamic Environment  
Magnetospheres of Hot Stars

### SOC:

D. Baade, ESO  
J. E. Bjorkman, USA  
A. C. Carciofi, Brazil (co-chair)  
A. Damiani, Brazil  
W. Dent, ALMA  
A. Domiciano de Souza, France  
T. Rivinius, ESO (co-chair)  
S. Stefl, ESO  
J. Vink, UK  
G. Wade, Canada

### LOC:

C. Barbog  
M. Borges Fernandes  
A. C. Carciofi (chair)  
D. M. Faus  
M. E. Gomez  
X. Heubols  
C. Martayan  
T. Rivinius  
M. Teodoro

Web: <http://www.eso.org/sci/meetings/2012/csdyn/>  
Email: [csdyninfo@eso.org](mailto:csdyninfo@eso.org)

Photos: Alex Cordell, Yuri Izrael



### Invited Speakers:

E. Alecian, France  
J. Bjorkman, USA  
W. Dent, ALMA  
W. J. de Wit, ESO  
J.H. Groh, Germany  
C. E. Johns, Canada  
M. Krumholz, USA  
A. M. Magalhães, Brazil  
F. Millour, France  
A. Miroshnicenko, USA  
A. Okazaki, Japan  
S. Owocki, USA  
R. Oudmaijer, UK  
R. Townsend, USA  
A. ud-Doula, USA