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Binarity and Magnetic Interactions in various classes of Stars:
The BinaMIcS project

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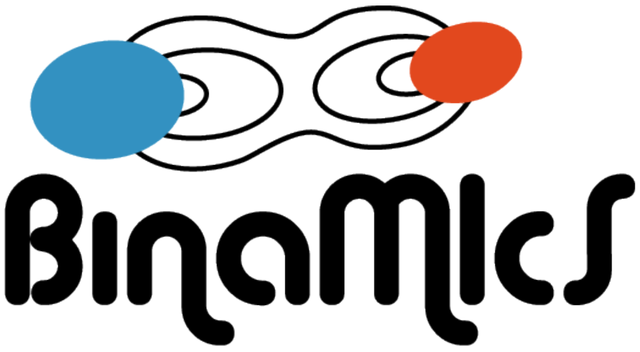
BinaMIcS

BinaMIcS

Binarity and Magnectic Interaction in various classes of stars

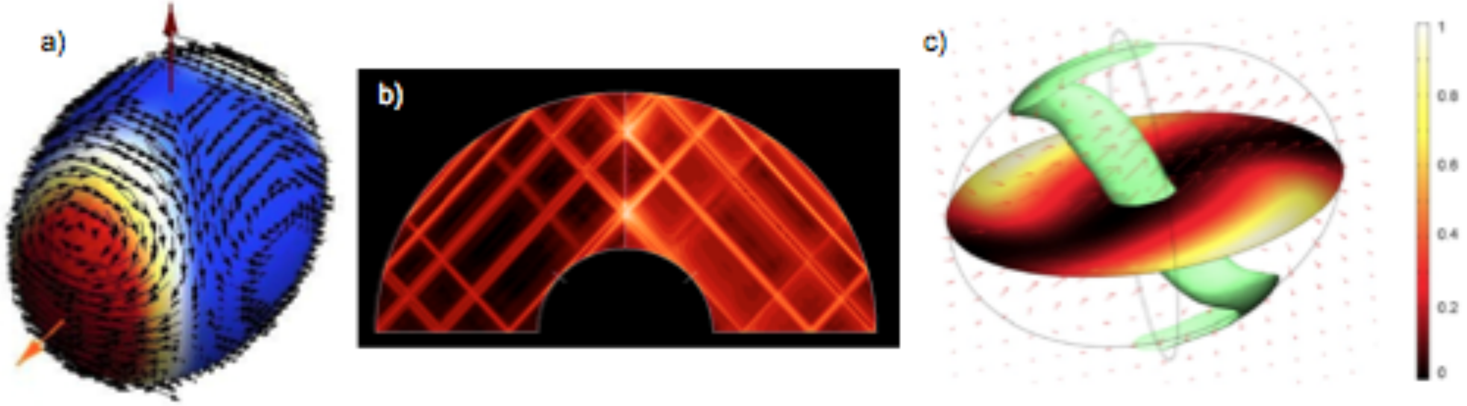
- Aim: use the binarity to bring constraints on the physical processes of a magnetic star

Problematics



How do tidally-induced internal flows impact fossil or dynamo fields ?

- An initially eccentric system with non-synchronised, non-aligned components => asymptotic state where, orbit is circular, components are synchronised and spins are aligned
  - due to transfert of the kinetic energy of tidal flows to heat
- During this process 3 type of velocity fields are generated:
  - equilibrium tide (3D large scale flow, Rémus et al. 2012)
  - dynamical tide (helical oscillation, Ogilvie & Lin 2007)
  - spin-over flow (instability of gravito-inertial waves, Cébron 2011)



How do magnetospheric Star-Star interactions modify stellar activity ?

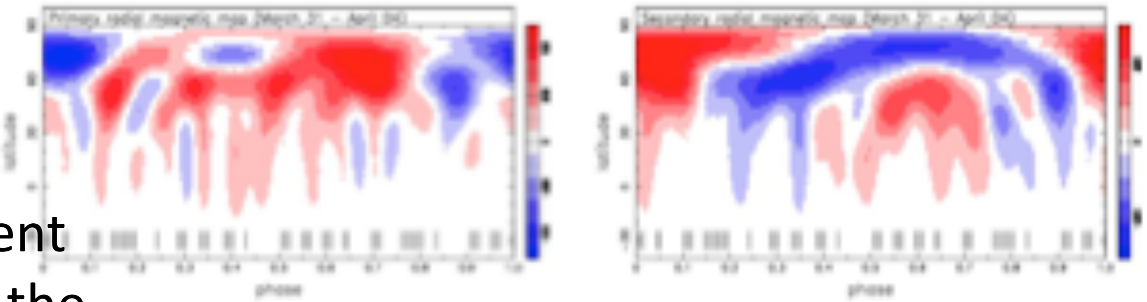
- Close component

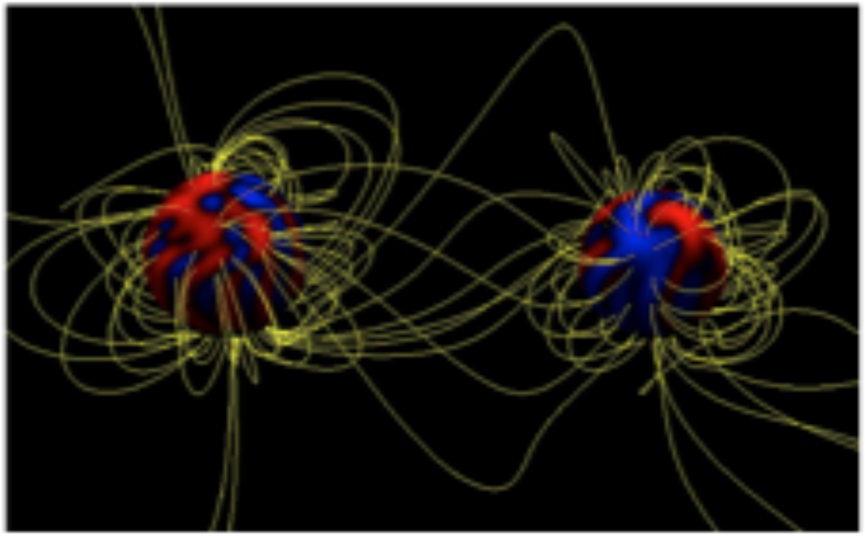
⇒ interacting magnetosphere

⇒ reconnection as one of the component pass through the magnetosphere of the secondary:

  - e.g. Star-Planet Interaction (Shkolnik 2008)
  - e.g. V774 Tau A: cyclical variability of flaring (Torres et al. 2012)

- 3D magnetospheric model :
  - Enhanced magnetic activity
  - Model the coronal emission
  - Location of open field lines

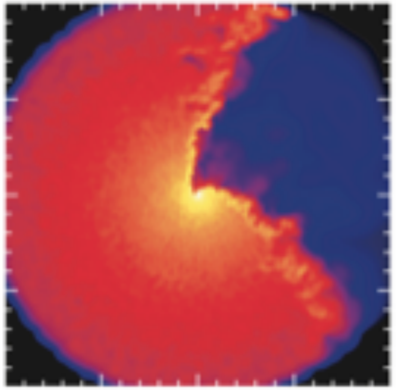




HD 155555 Dunstone et al. (2008)
Dunstone & Holwarth, priv. comm.

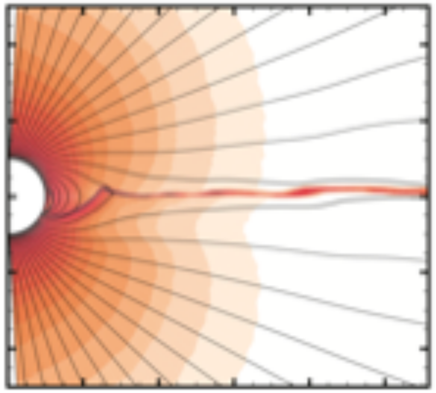
What is the magnetic impact on outflows and mass transfers ?

Colliding stellar wind
(Russell 2011)



- Winds are present in low and high mass stars
- These winds carry away angular momentum
- These winds can be at the origin of mass transfer
- Magnetic fields can play a role in the mass transfer
- e.g. W-UMa stars, RS CVn, Algol ...:
  magnetic cycles are proposed to be at the origin of the orbital period modulation (Applegate 1992)

⇒ Constraints on magnetic fields are crucial to better understand these phenomena



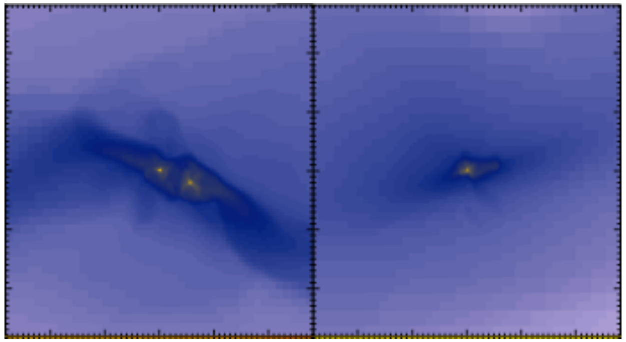
Magnetic wind
(ud-Doula & Owocki 2002)

What is the impact of magnetic fields during stellar formation, and vice-versa ?

- Magnetic fields in massive stars is of fossil origin
- But:
  - Magnetic fields observed only in < 10% of intermediate- and high-mass stars *(e.g. MiMeS project: e.g. Grunhut et al. 2012)*
  - Magnetic fields detected only in one component of SB2s

- Star formation modelling with magnetic field
  => reduce fragmentation => reduce binarity

Commerçon, Hennebelle et al.

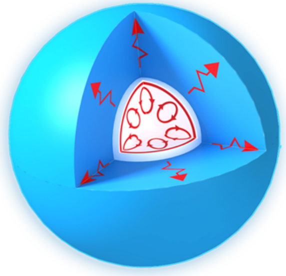


Commerçon et al. (2011)

Observing strategy and resources

BinaMIcS

Spectropolarimetric Observing Strategy: the hot components



- Close SB2 systems:
  - P < 20 d, V < 8 mag, 2 components with SpT > F5
- The hot-SC (Survey Component):
  - ~200 close systems selected in SB2 catalogues (Taylor 2003, Pourbaix et al. 2009, Sana et al.)
  - One or two observations per target
  - aim: statistical properties + new magnetic discoveries
- The hot-TC (Targeted Component):
  - 6 OBA SB2 containing supposedly a magnetic star
  - Monitoring
  - aim: confirmation then follow-up to model the magnetosphere and magnetic fields and to compare with single star magnetosphere and fields

Spectropolarimetric Observing Strategy:

the cool TC component

- 11 dwarfs, 4 RS CVn (+ 1-3 cool-PMS)
  - various eccentricities (from 0.00 to 0.34), masses (from 0.16 to 2.5 $M_{\odot}$), and orbital periods (from 1.88 to 18.78 d)
  - includes 2 eclipsing binaries
  - all show signs of activity

- Aims:
  - obtain magnetic maps of both components
  - study the variations over the orbit for the most eccentric systems
  - compare the magnetic properties with single stars
  - explore magnetic activity under the most extreme conditions (W UMa systems)

Observational resources

- An ESPaDOnS large program (PIs: E. Alecian, G. Wade):
  - 604 h allocated over 8 semesters (2013A-2016B)
- A Narval large program (PI: C. Neiner):
  - 150 h allocated over 4 semesters (2013A-2014B)

- Additional observing programs
  - Interfero. obs. PIONIER and PAVO (PI: J.-B. Le Bouquin)
  - CHANDRA X-rays observations (PI: C. Argiroffi)
  - Photometric observations (PI: A.-E. Essayed)
  - HARPSpol PI programs (Pis: T. Böhm, R. Fares)

Narval LP Observations

- 339 obs. of 109 targets until now
- 60 hot SC targets + 35 additional SC
- 4 hot TC targets:

  HD 5550, HD 1976, HD 25558, HD 160922
- 5 cool TC targets:

  BH CVn, Capella, sig CrB, OU Gem

  => See Julien’s presentation
- 4 cool SC targets:

  ER Vul, V1379 Aql, bet1 Cap, IM Peg, BC Psc

  => See Julien’s presentation

ESPaDOnS LP Observations

- 436 obs. of 172 targets until now
- 142 hot SC targets
- 11 hot TC targets:

  BD-19 5044L, HD 136504, HD 149277, HD 156324, HD 164492 C, HD 25558, HD 34736, HD 37017, Plaskett, HD 55719, HD 56495
- 7 cool TC targets:

  BY Dra, ER Vul, FK Aqr, GJ 735, V1878 Ori, V471 Tau

  => See Julien's, Alexis' and Gaitee's presentations
- 12 cool SC targets:

  AR Psc, BD+33 4462, BK Psc, EK Cep, GJ 268, **GJ 644**, BC Psc, **KZ And**, **SAO 90449**, **TY Pyx**, UZ Tau E, UZ Tau W

  ⇒See Julien's presentation

ESPaDOnS LP Observations

- 6 semesters completed over a total of 8
- Very good completeness

All	Allocated (h)	Validated (h)	Completeness (%)
2013A – 2015B	436	440	**101**
2016A	63	-	-
2016B	106	-	-

Cool	Allocated (h)	Validated (h)	Completeness (%)
2013 – 2015	135	135	-
2016A	34	-	-

Some results of the hot components

BinaMIcS

HD 5550 (Ap SrCrEu)

25 Narval obs.

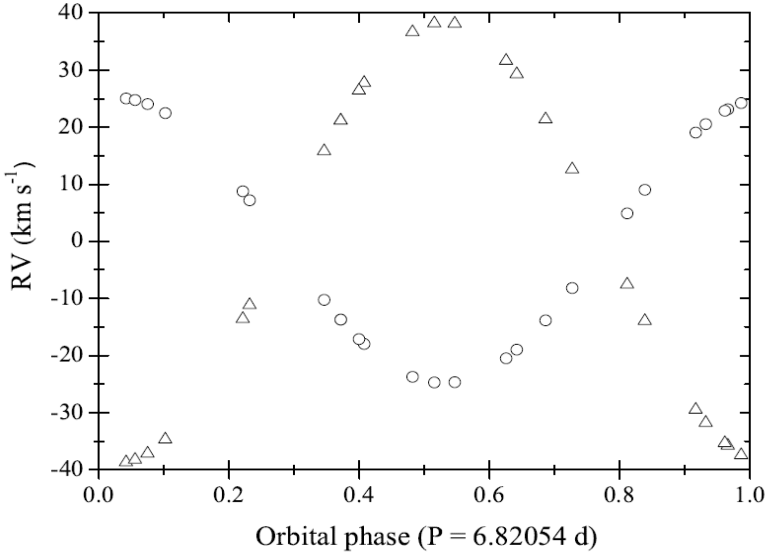
Porb = Prot = 6.8 d

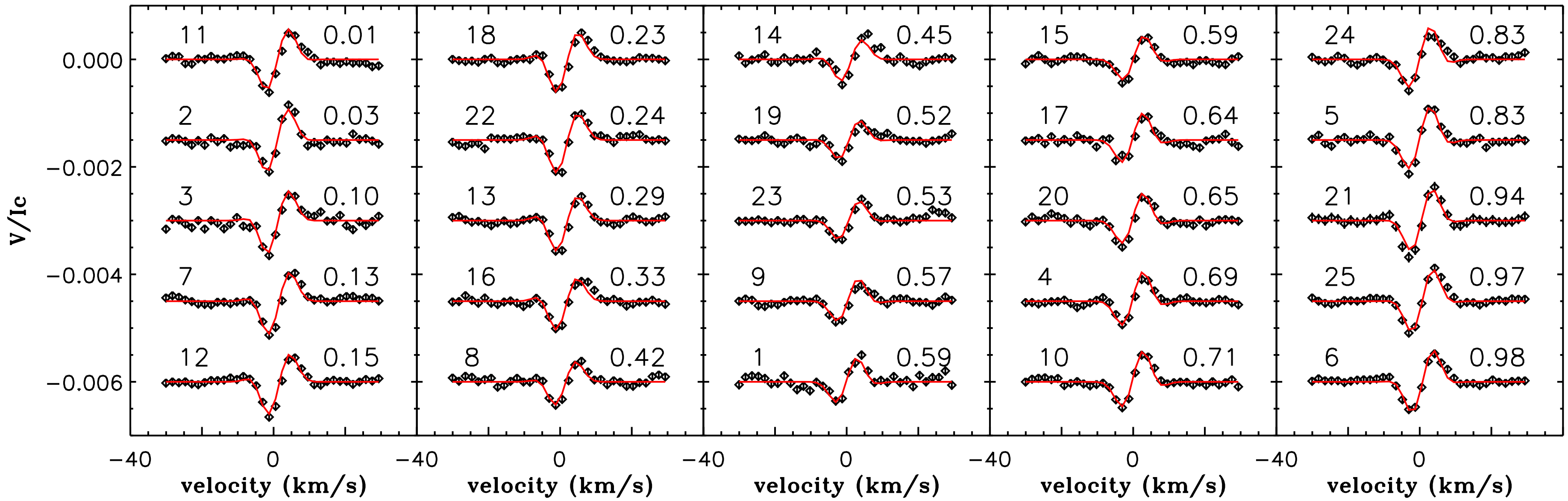
A: Ap (11400 K), Bd = 65 +- 20 G

=> The weakest magnetic Ap field

B: Am (7800 K), Bd < 40 G

Alecian et al. (2016, in press)





HD 55719 (A3 V)

Ap orbiting a more massive comp.

Porb = 46 d (Bonsack et al. 1976)

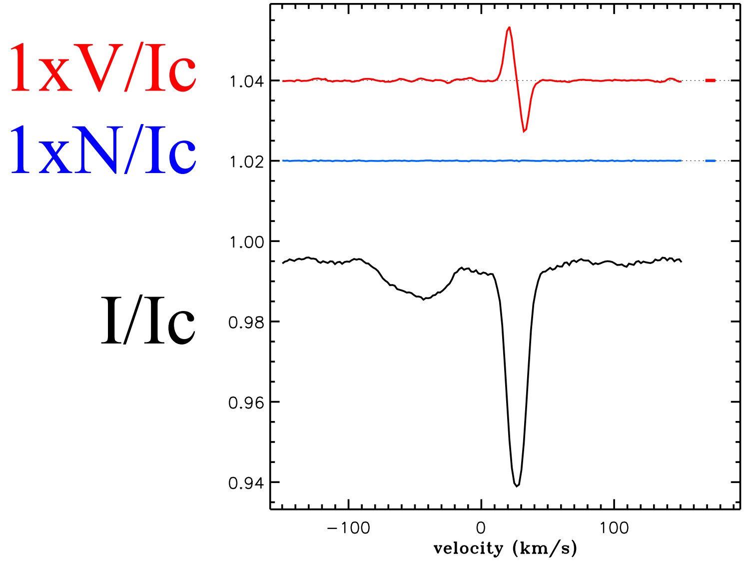
ecc = 0.11 (with our data)

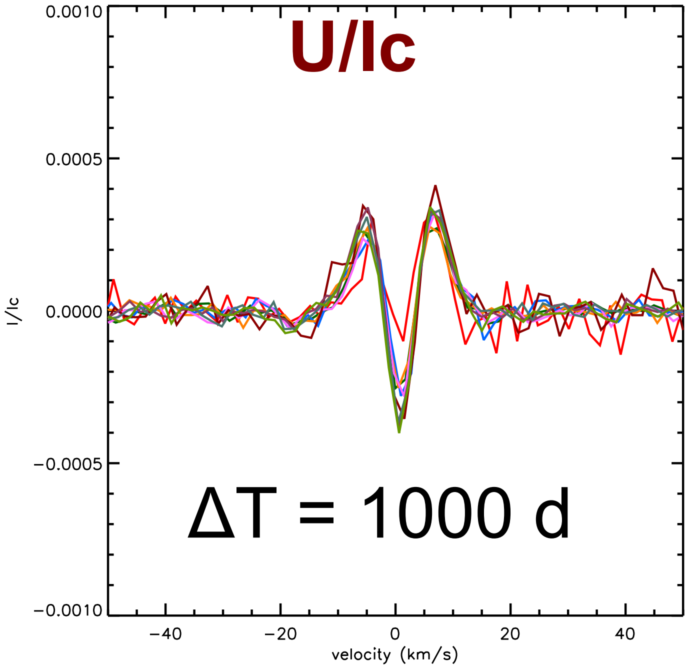
25 V observations => no var.

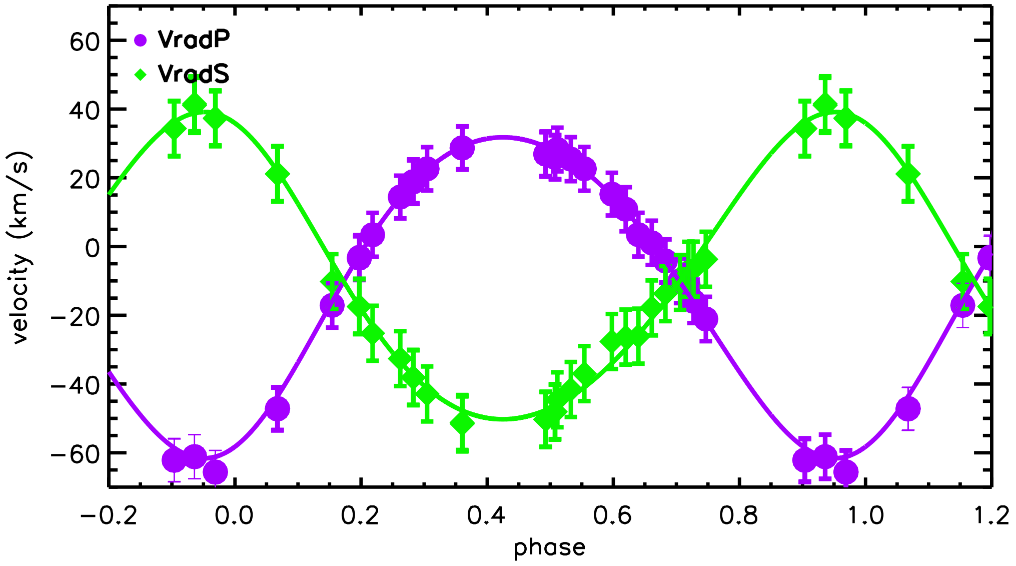
9 Q,U observations each

=> faint var. in U over 1000 d

=> Gregg Wade







HD 34736 (B9)

Romanyuk & Semenko (2015)

⇒ Short-period magnetic SB2

ESPaDOnS: 10 obs.

⇒ Confirmed SB2

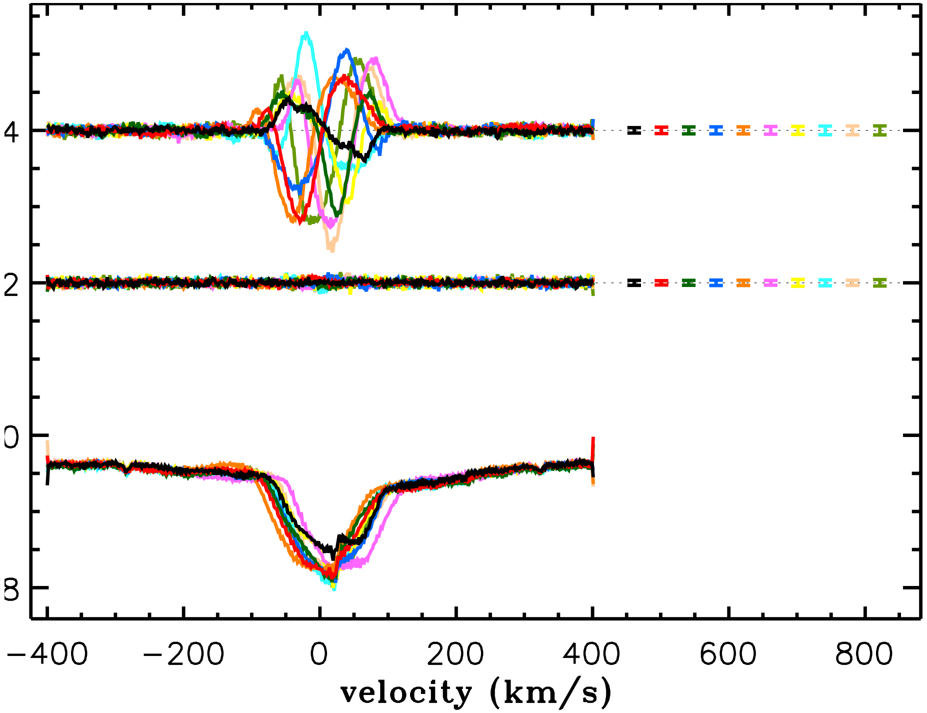
⇒ Bz var => Prot = 1.28 d

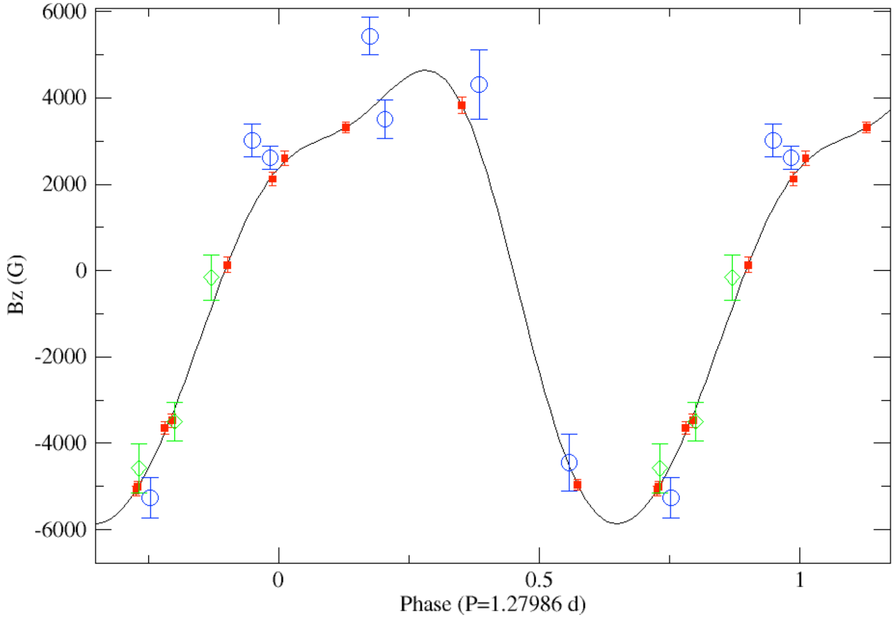
⇒ Departure from sin curve

⇒ Magnetic comp. not synchr.

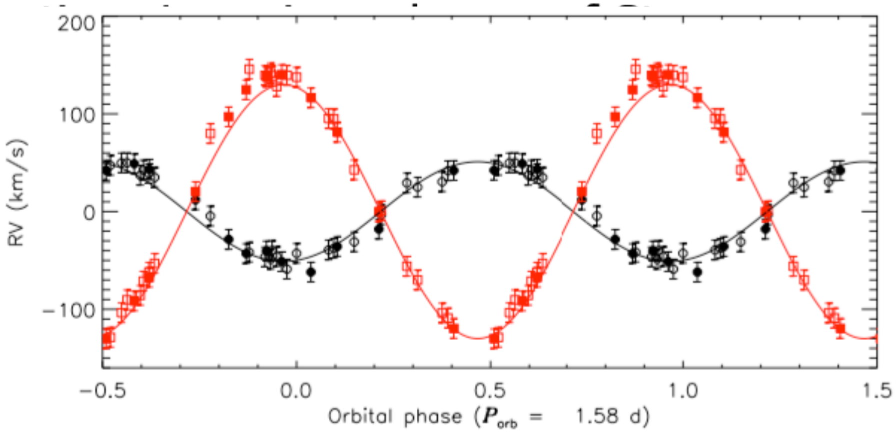
⇒ Observing campaing in January 2016 (spectropol. + phot.)

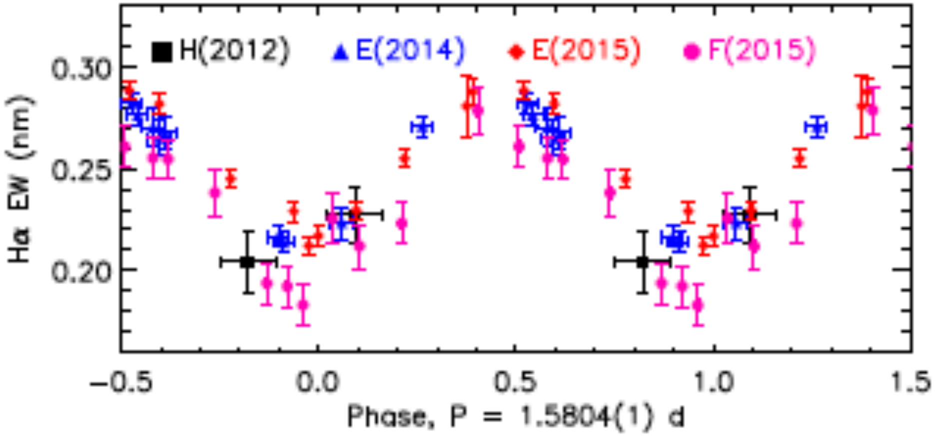
⇒ Eugene Semenko

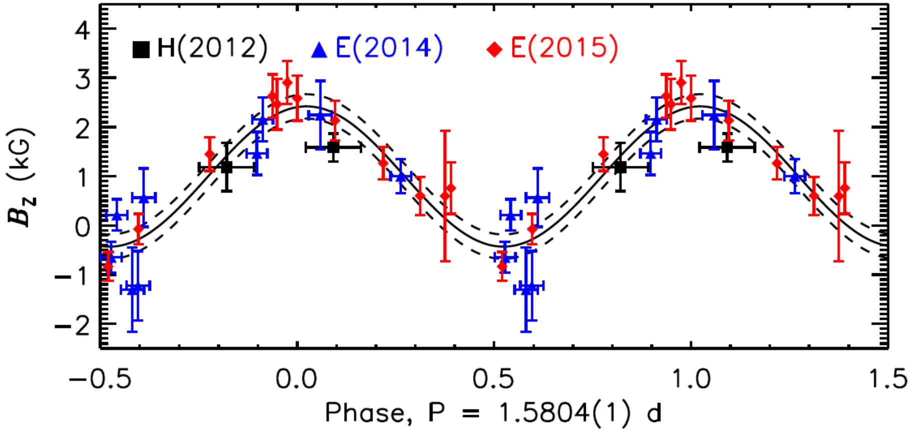




HD 156324 (B2 V)







MiMeS detection

⇒ SB3 system

⇒ P: He-strong magnetic,

S: Teff = 14000-17000 ?

T: He-weak Pga

ESPaDOnS, HARPSpol, FEROS data:

⇒ Porb = 1.58 d and Porb = 6.66 d

⇒ Bz var => Prot = 1.58 d

⇒ Halpha in emission: P = 1.58 d

Analysis of the magnetic field and magnetosphere in process

⇒ Matt Shultz

Alecian et al. (2014), Shultz et al. (in prep.)

HD 149277 (B2V + B2V)

MiMeS detection

⇒ Short-period SB2

BinaMIcS data:

11 observations

⇒ Porb = 11.5 d

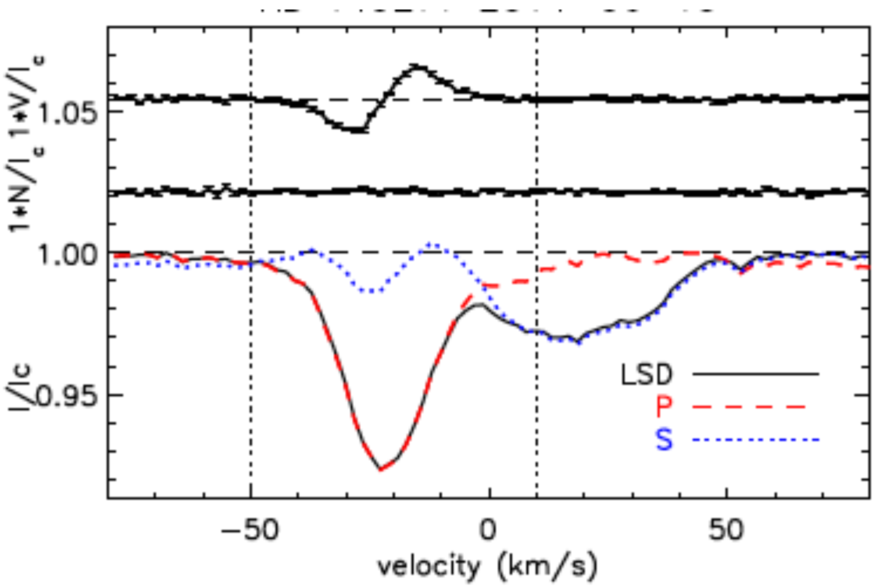
⇒ Prot = 25.4 d

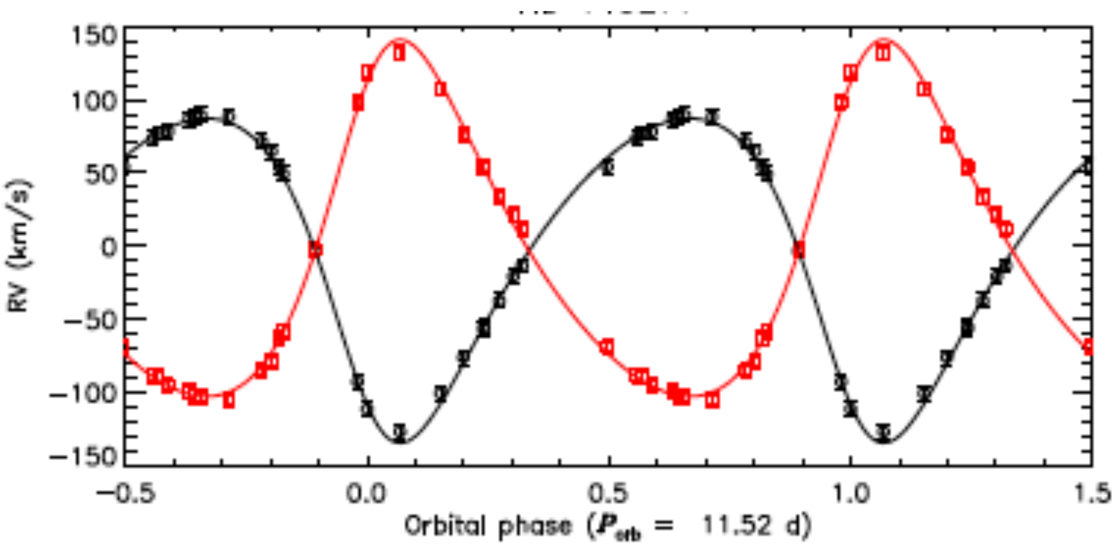
⇒ Good orb. phase sampling

⇒ Need additional data for

ϕ_{rot} = [0.0,0.5]

⇒ Matt Shultz





Petit et al. (2013), Shultz et al. (in prep.)

HD 164492 C (O6)

BOB detection

Maybe SB2

BinaMIcS data:

17observations

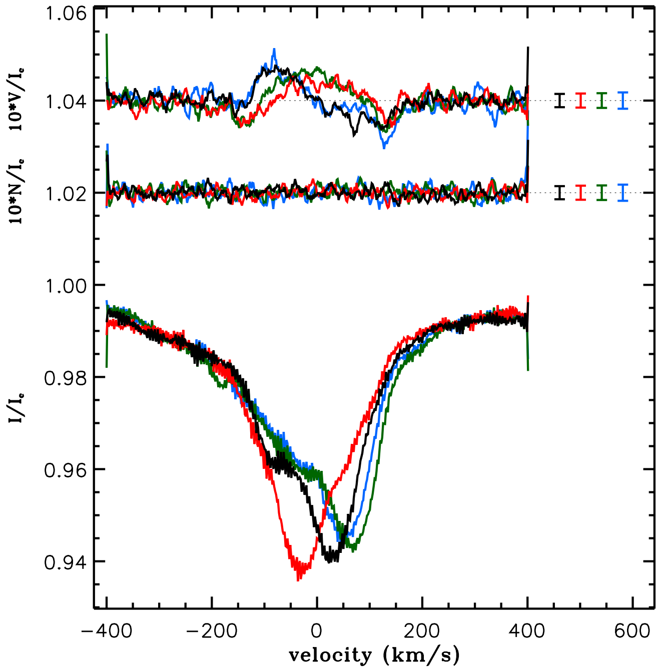
⇒ Confirm binarity and magnetism

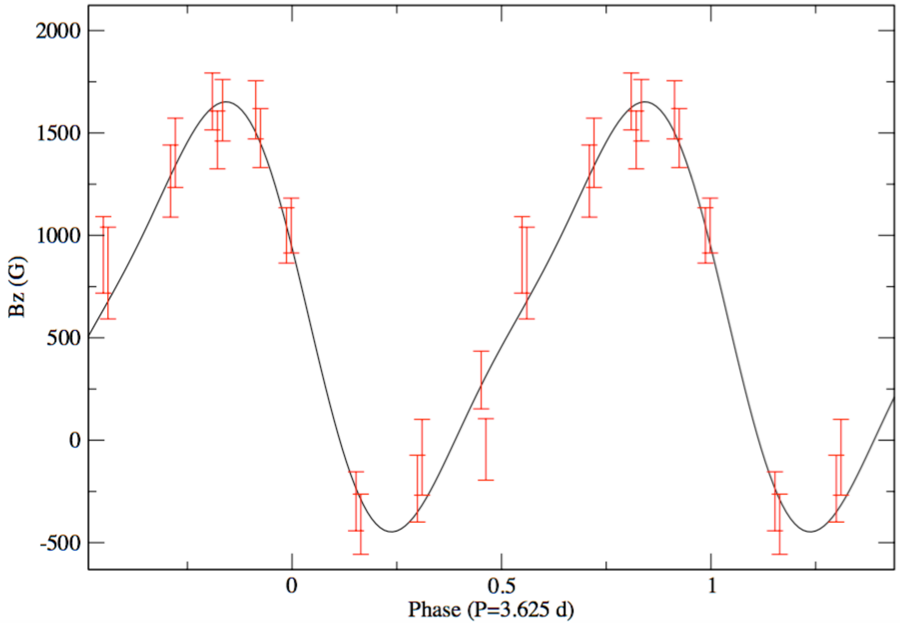
⇒ Prot = 3.625 d

⇒ Prob ~ 10 d

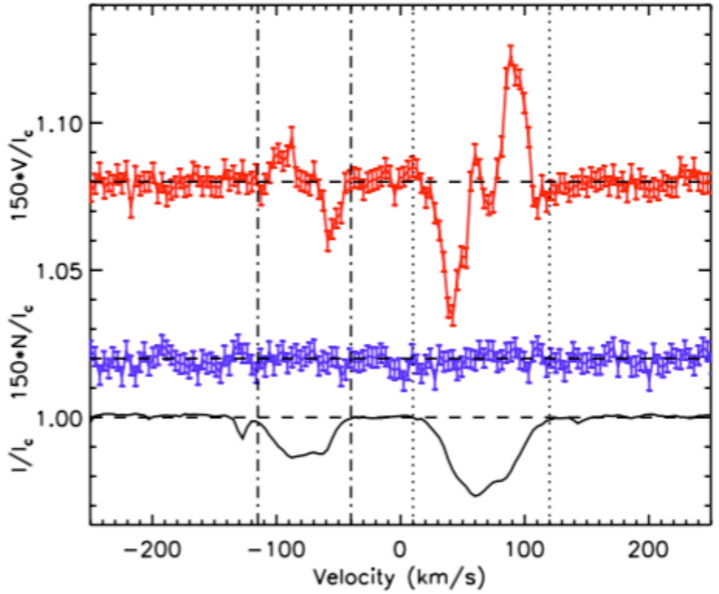
Additional work in progress

⇒ Gregg Wade





eps Lupi (B2 IV-V)



MiMeS detection

Maybe both components magnetic

BinaMIcS data:

9 Deep observations

⇒ Confirm binarity in 2 components

⇒ First and unique system

⇒ Weak var. in Bz

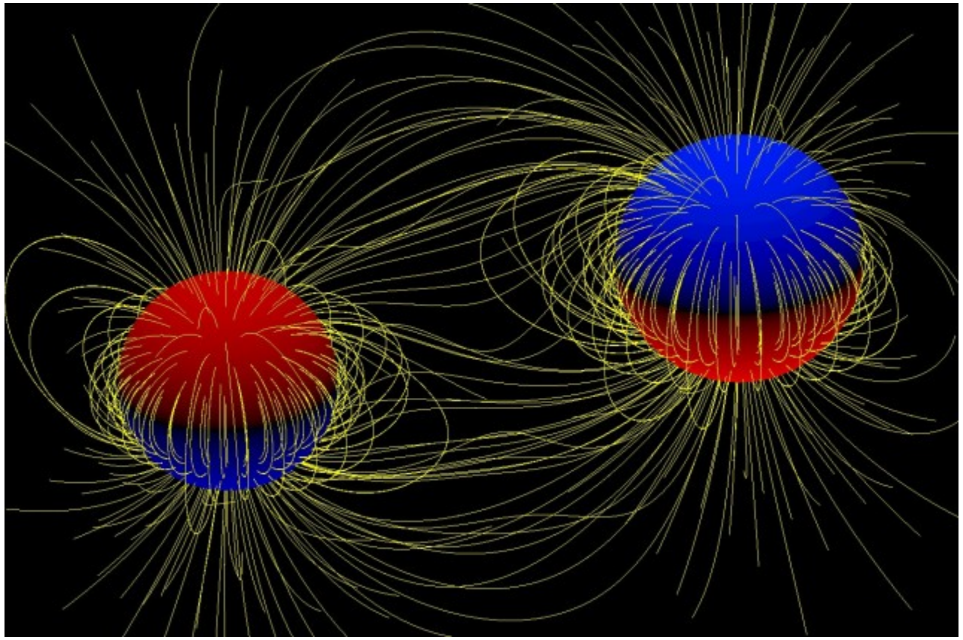
⇒ Prot unknown

⇒ $R_A > 5.8\ R_*$ and sep = $3 – 4\ R_*$

=> shared magnetospheres ?

⇒ Additional data

⇒ Matt Shultz



Shultz et al. (2015)

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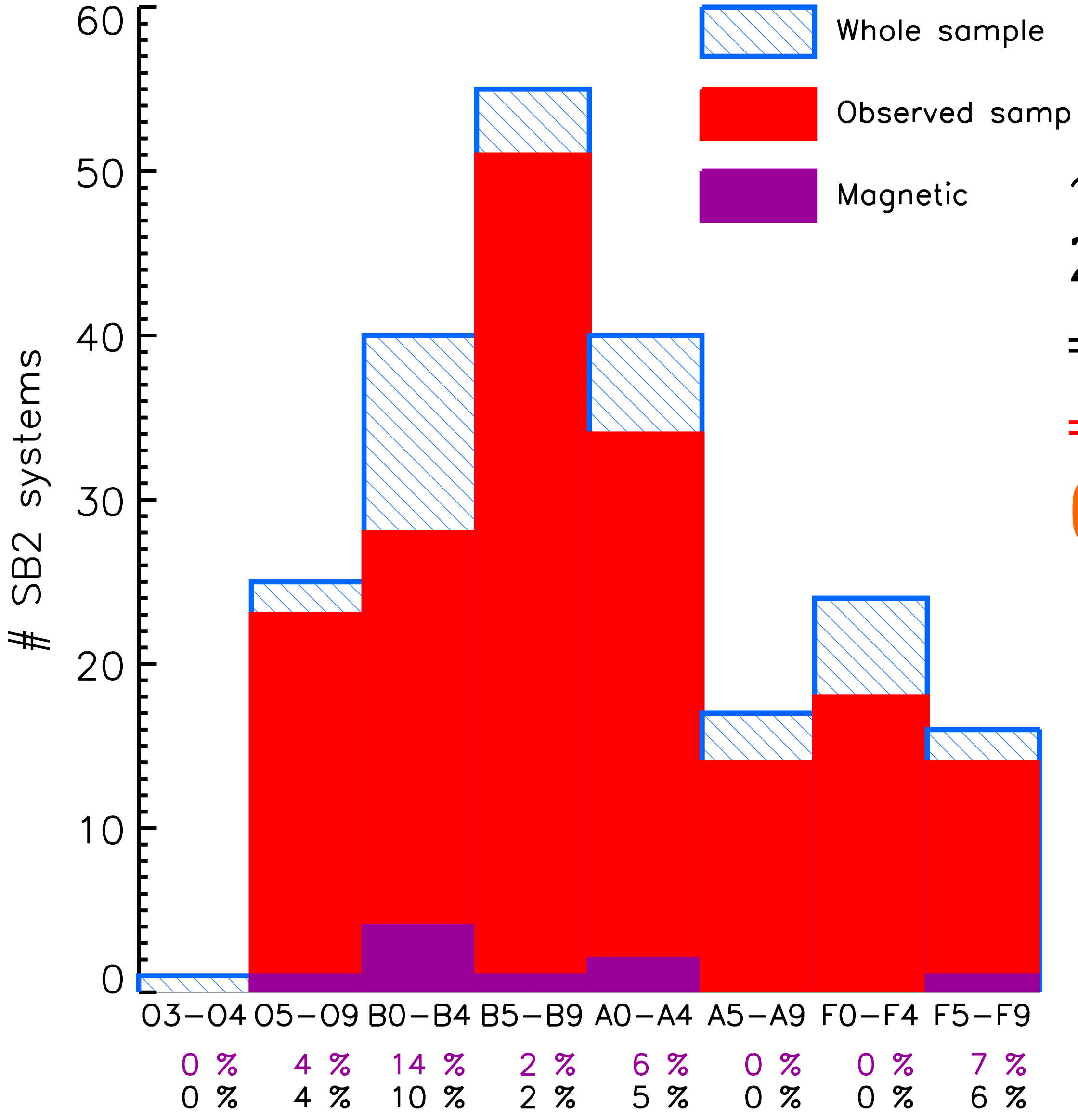
SC: Magnetic vs non-Magnetic



~200 SB2 systems observed

2 detections

⇒8 in total among ~400 stars

⇒< 2% mag. ★ in SB2

(5-10% mag. isolated stars)

← ‘systems’ statistics