MAGNETIC FIELDS IN BINARY SYSTEMS

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LIÈGE université

With help of E. Alecian & C. Neiner (BinaMIcS),
M. Shultz & G. Wade

And T. Morel (BOB)

Magnetic fields in binary systems

↓

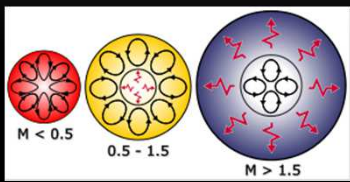
Magnetic fields in OBA+OBA binary systems

↓

Magnetic fields
in close OBA binary systems

MAGNETISM & THE UPPER HRD

- Spectral types ABO
  - No convective envelope



- *Magnetism* in intermediate- and high-mass stars :
  - Rare: about 7% for OB *(BOB - Fossati et al. 2015, MiMeS - Grunhut et al. 2017)*
    ~2% for Ap (depending on M_* - *Power et al. 2007*)
  - Strong, stable & large-scale (dipolar!?) B
    /!\ ∃ weak B (e.g. ζ Ori or β UMa, *Blazère et al. 2015, 2016*
    β & ε CMa, *Fossati et al. 2015*)

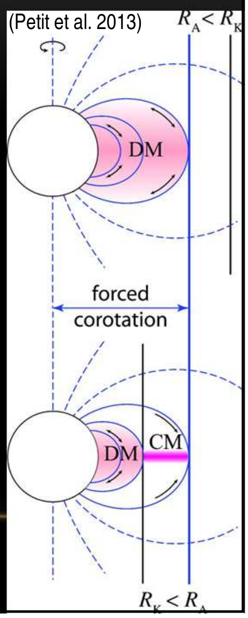
See also P. Petit & G. Wade's talks

MAGNETISM & THE UPPER HRD

- *Massive* star = spectral types BO
  - Wind !
- *Magnetism* in massive stars :
  - Magnetically confined winds ⇒ X-rays
    - *Dynamical* magnetosphere
    - *Centrifugal* magnetosphere

See also G. Wade's talk

(Petit et al. 2013)



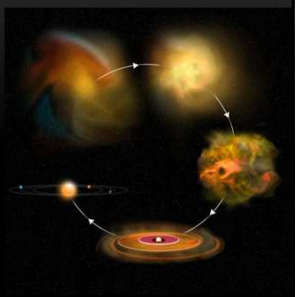
MAGNETISM & CLOSE BINARIES

- *Advantages*
  - Parameters can be determined with precision
    + same age, composition,…
  - Exquisite test of theoretical models
  - Additional phenomena: interactions (tidal, wind-wind,…)
- *Inconvenients*
  - Two (or more) stars, hence twice more problems
  - Good coverage of orbital & rotational periods needed
  - Additional phenomena complicate diagnostics

ORIGIN OF THE FIELD?

- Fossil ! (« same » as HAeBe, *Alecian et al. 2013, Hubrig et al. 2013*)
  - Primordial (from cloud)
  - Early dynamo @ PMS
  - Mergers *(Ferrario et al. 2009, Schneider et al. 2016)*
    - Only a fraction (8%?, *de Mink et al. 2014*)
    - @ PMS or MS
      (but then more mag * in MS?)
    - Rejuvenation, ejecta, rapid rotation, abondance anomalies

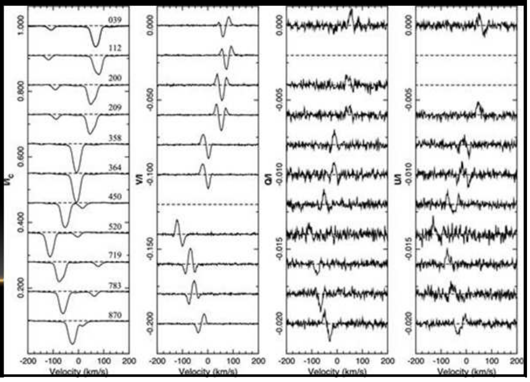
    (observationally: maybe, one case sometimes, sometimes)



See also many talks

ORIGIN OF THE FIELD?

- Mergers *(Ferrario et al. 2009, Schneider et al. 2016)*
  - If merging occurred, no more companion… there should be *no* close magnetic massive binaries !
- Observations?



HD98088, Porb=5.9d
(Folsom et al. 2013)

ORIGIN OF THE FIELD?

- Observations?
  - First detection in 1958 : HD98088 *(Babcock 1958)*
  - Ap stars: overall fraction of binaries somewhat > in normal A*, almost complete lack of binaries with P<3d *(Carrier et al. 2002)*
  - Surveys: 2% incidence rate for hot binaries *(BinaMIcS - Alecian et al. 2015, Schöller et al. 2017, Grunhut et al. 2017)*, only one of the two hot components is magnetic in all but one case

CLOSE MAGNETIC BINARIES

2% = Only a dozen currently known !

Questions:

- Are they coeval ?
- ∃ tidal interactions?
  - Synchronization & alignment for orbital/rotational motions, orbit circularization
- Anything else (geometry,…) ?

CLOSE MAGNETIC BINARIES

Name	Sp types	P_orb (<30d)	e	Recent reference for B
Plaskett's star	O8III+O7.5III	14.4d	0	Grunhut et al. 2013, in prep
BD-19 5044L	Bp+Am	17.6d	0.474	Landstreet et al. 2017
HD1976	B5IVp+?+?	25-28d	0.1-0.2	Neiner et al. 2014
HD36485	B3p+A	30.0d	0.32	Leone et al. 2010
HD37017	B2V+?	18.7d	0.47	Borra&Landstr.1979, Shultz 2016
HD149277	B2IV/V+?	11.5d	0.24	Bagnulo et al. 2015, Shultz 2016
HD156324A	B2V+?+?	1.6d	<0.03	Alecian et al. 2014, Shultz 2016
NU Ori	B0.5V+?+?	14.3d	<0.07	Petit et al. 2008, Shultz 2016
ε Lupi	B2V+B3V	4.6d	0.27	Shultz et al. 2015, Shultz 2016
HD161701	B9+Ap	12.5d	0.004	Hubrig et al. 2014
HD5550	Ap+Am	6.8d	0.006	Alecian et al. 2016
HD98088	Ap+Am	5.9d	0.18	Folsom et al. 2013

CLOSE MAGNETIC BINARIES

There are also:

- HD35502 *(Sikora et al. 2016)*
- HD164492C *(Gonzalez et al. 2017, Wade et al. 2017)*

Triple systems with a close A+A binary + a magnetic Bp *

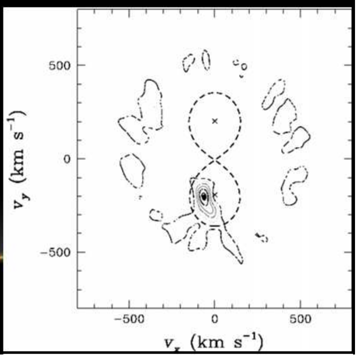
Note:

- 2 other Ap+Am systems proposed but dismissed *(Colsom et al. 2013)*
- HD34736 first thought to have P_orb ~0.3d
  now P_orb~83d and high e *(Semenko et al. 2014, in prep)*

PLASKETT'S STAR

- Two late O-stars with P_orb=14.4d *(Bagnuolo et al. 1992, Linder et al. 2008)*
  - Secondary = fast rotator
  - Mismatch dynamical/spectroscopic masses
  - Abondances anomalies (He enrichment, N_sec <, N_prim >, C_prim <)

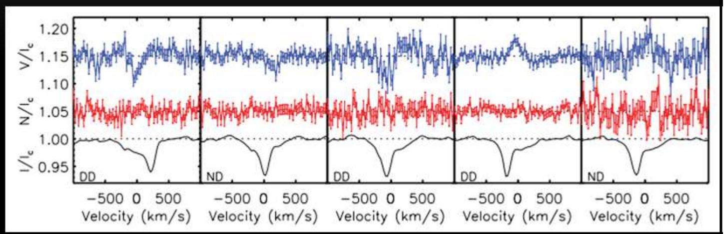
  ⇒ Post-mass transfer binary
- Doppler map of Hα, HeII4686 : flattened wind region @ equator



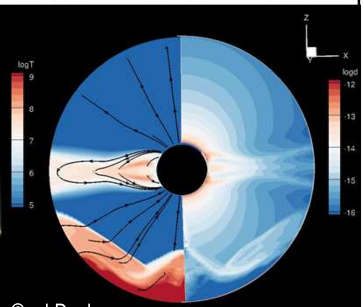
(Linder et al. 2008)

PLASKETT'S STAR

(Grunhut et al. 2013)



- Magnetic detection…
  in secondary *(Grunhut et al. 2013)*
  - Flattened wind = MCW
  - Complex interactions: MCW + CWs !



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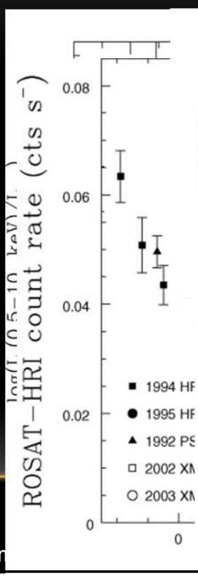
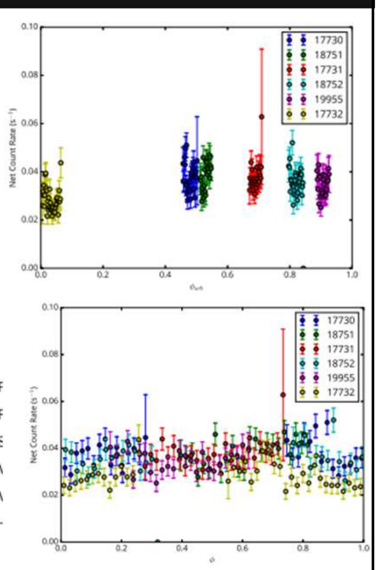
PLASKETT'S STAR: X-RAYS

- Brighter than other magnetic massive stars *(Nazé et al. 2014)*
- Variable source: which link with Porb/rot ?
  - XMM/ROSAT *(Linder et al. 2006)*
  - Chandra *(Leutenegger et al. in prep)*

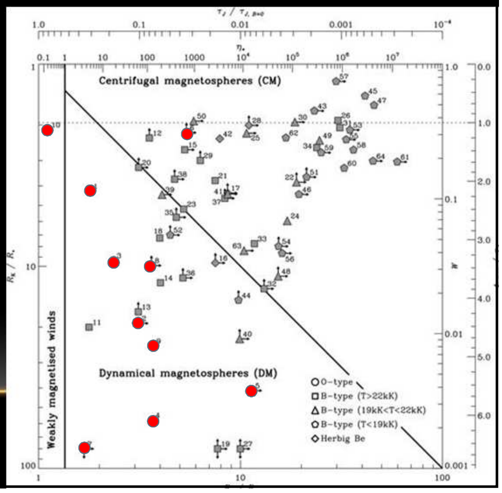




(Lin(Nazé et al. 2014)uten

PLASKETT'S STAR : ORIGIN OF THE FIELD?

- The only O star with a centrifugal magnetosphere !
- Not merging product, but RLOF phase: is shear sufficient to trigger B?
- Testable !



(Petit et al. 2013)

PLASKETT'S STAR : ORIGIN OF THE FIELD?

- Observational test: what occur to « twins »? *(Nazé et al. 2017)*
  - Twins??? short-P, massive binaries with current/past interactions
  - 15 cases studied with FORS2, ESPaDOnS, Narval
  - No magnetic detection
    - Overall limit for the whole sample : Bd < 200G
    - Incidence rate (adding Plaskett's star) compatible with surveys 1/16 systems, 1/19 indiv. stars with stringent constraints (1/9 with the most stringent ones, Bd<1kG), 1/8 mass gainers

$\Rightarrow$ Binary interactions play a negligible role

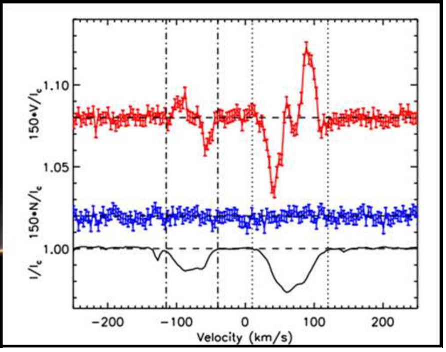
In parallel, no detection of B in blue stragglers (Grunhut et al. in prep)

ε LUPI

- Two early B stars with P_orb=4.6d, e=0.27, both likely β Cep *(Uytterhoeven et al. 2005)*
- First magnetic detections *(Hubrig et al. 2009, Shultz et al. 2012)*
- Clear signature in *both* components *(Shultz et al. 2015)*

ONLY CASE OF DOUBLY MAGNETIC MASSIVE BINARY

/!\ merging not applicable



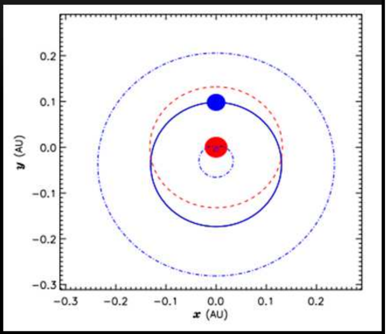
(Shultz et al. 2015)

ε LUPI

- Separation ~ Alfven radii

⇒ Overlap of magnetospheres
⇒ Magnetospheric interactions!

the search for signature is on…



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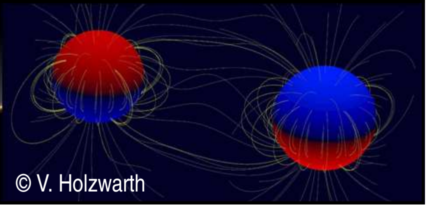

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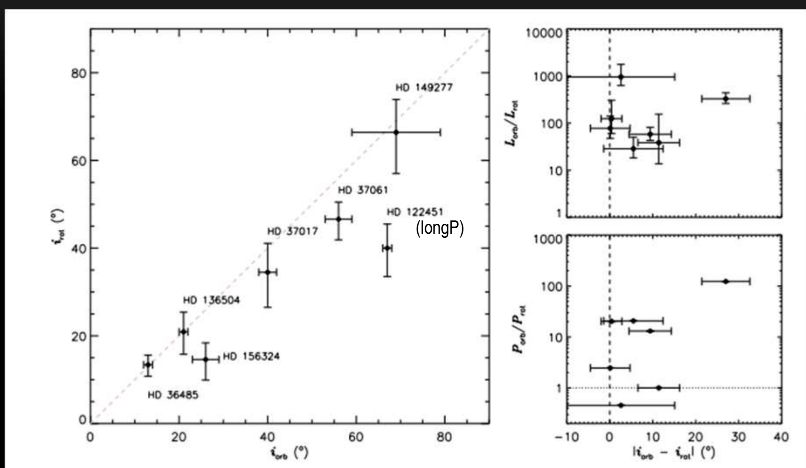
Plaskett's star	No		>>	~2.0	Post-interaction
BD-19 5044L	No but…	Yes	26	1.4	Ang velocity_orb=rot @ periast.
HD1976					Pulsations
HD36485	No	Yes	<52	7-12	
HD37017	No	Yes	63	6.5	
HD149277	No	Yes	72	9.8	
HD156324A	Yes	~Yes	69	12.3	
NU Ori	No	~Yes	56	1.8	
ε Lupi	No	Possibly	36 5	0.8 0.5	
HD161701	Probably		>>		
HD5550	Yes		-24	0.065	Very low B
HD98088	Yes	Yes	75	3.85	Coeval

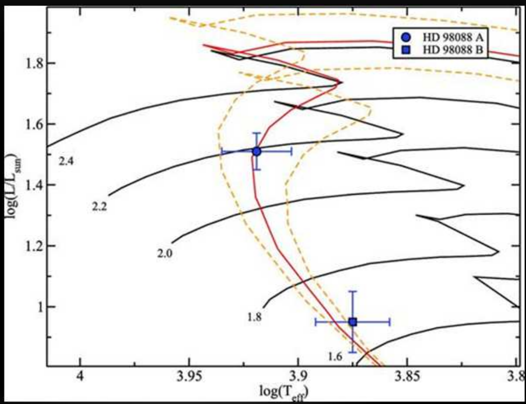
(Shultz 2016)



Alignement is common, circularization & synchronization much less

HD98088

(Folsom et al. 2013)



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Note the generally large obliquity !

CONCLUSIONS

- Massive magnetic stars exists in short-P binaries
- But they are few in number
  (and generally only one star is magnetic)
- Obliquity is generally high
- Many things remain to be done:
  - More statistics, more models (& comparisons)
  - Interactions @ high-E