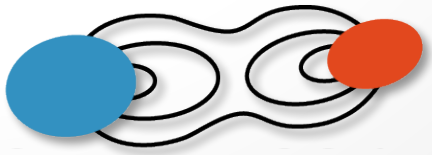
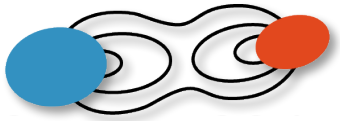
Magnetic fields in Massive close binaries

E. Alecian (U. Grenoble – IPAG)

C. Neiner (Obs. Paris), **G. Wade** (RMC, Canada),
J. Morin (U. Montpellier), **S. Mathis** (CEA/Saclay),
M. Shultz (Uppsala U., RMC), **E. Semenko** (SAO, Russia)),
S. Gregory (U. Saint Andrews), **A. ud-Doula** (Penn State U.),
J. Grunhut (U. Toronto), **Y. Nazé** (U. Liège)

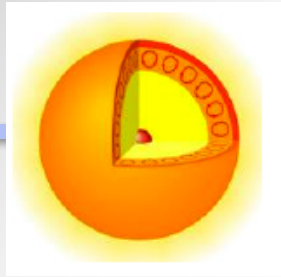
+ The **BinaMIcS** collaboration





Stellar magnetic fields

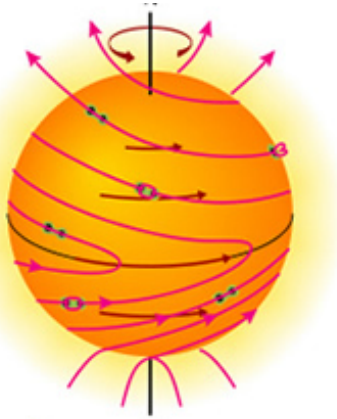
...



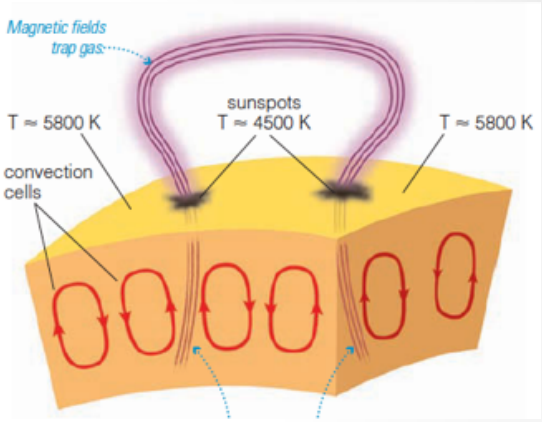
In solar-type stars

$\alpha - \Omega$ (solar-type) dynamo

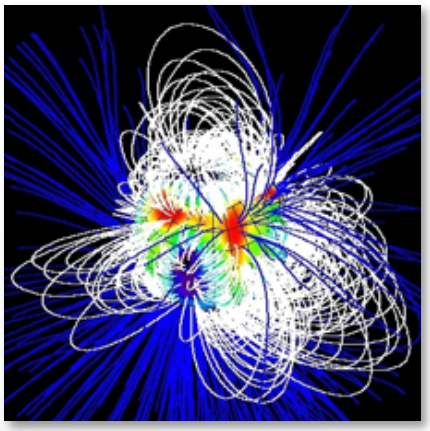
Differential rotation



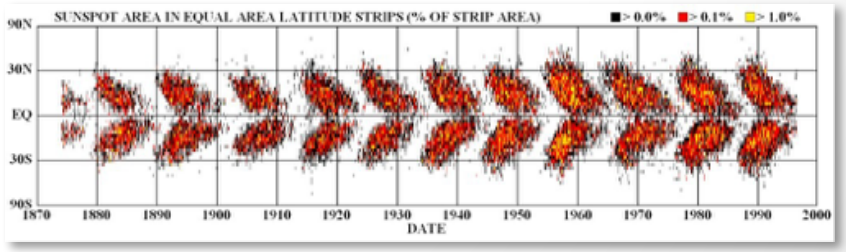
Convection



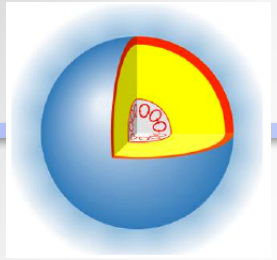
Complex magnetic fields



with sometimes cycles



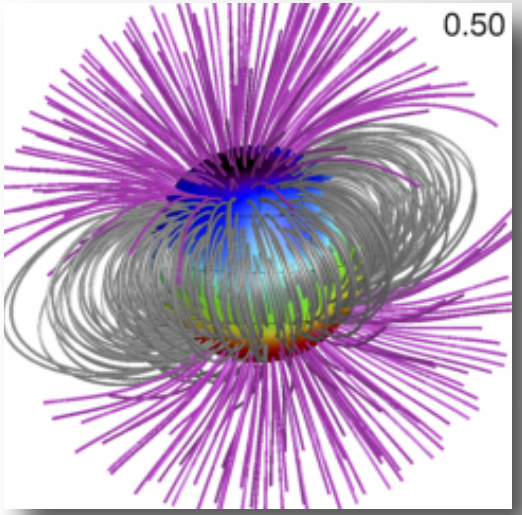
Varying on short timescales (days, weeks)



In higher-mass stars

- Low-order fields
- Strong (~kG)
- Stable (decades)

$\Rightarrow$ **Fossil fields**



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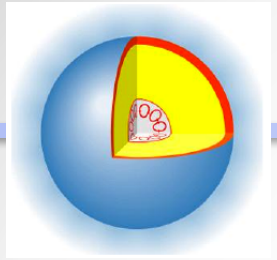
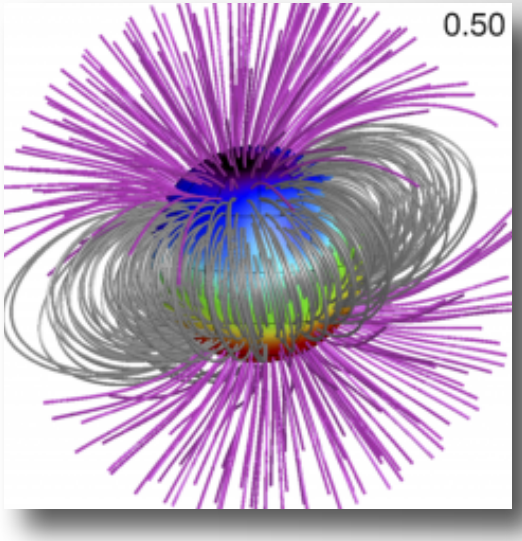


In higher-mass stars

- Low-order fields
- Strong (~kG)
- Stable (decades)

$\Rightarrow$ **Only in 5-10%**

$\Rightarrow$ **Fossil fields**



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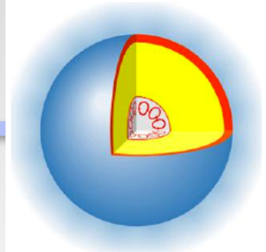
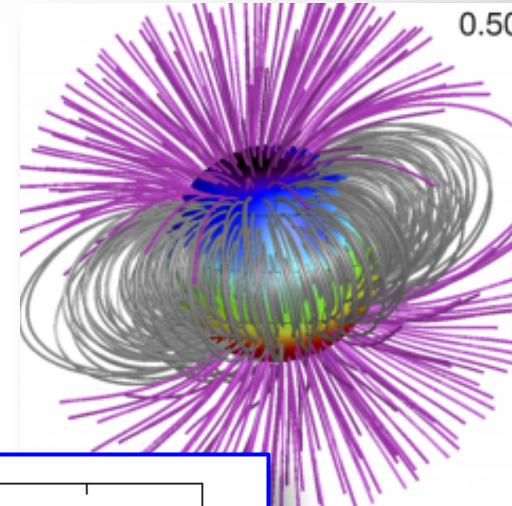


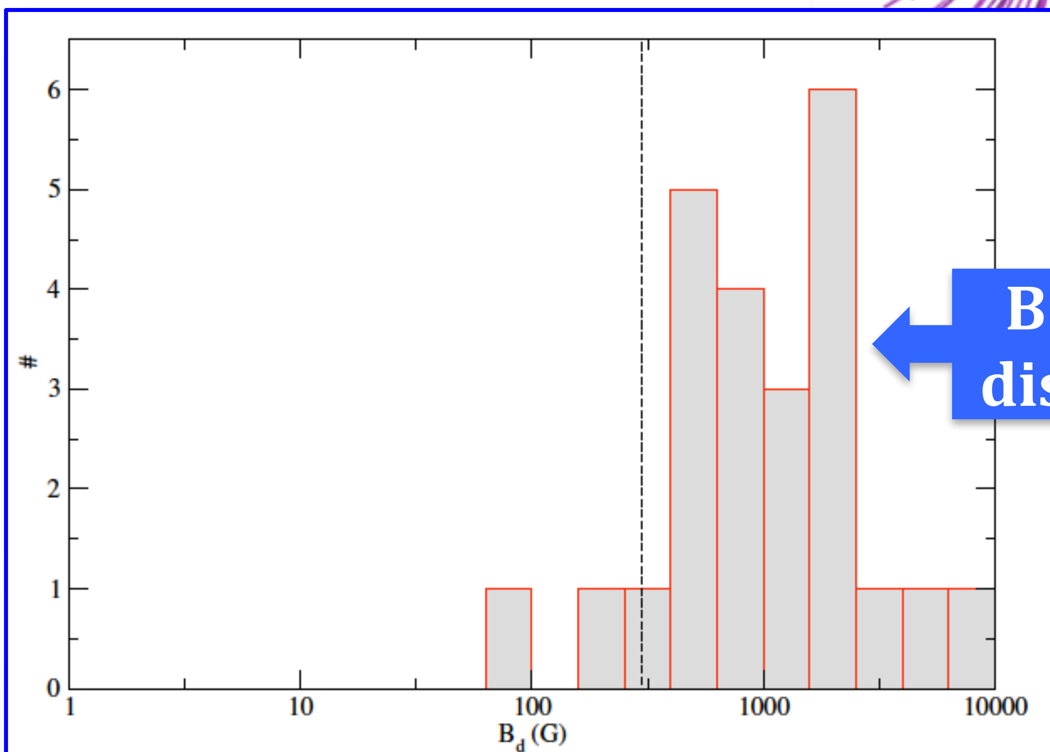
In higher-mass stars

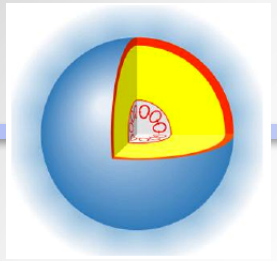
Strong fossil fields



lvester

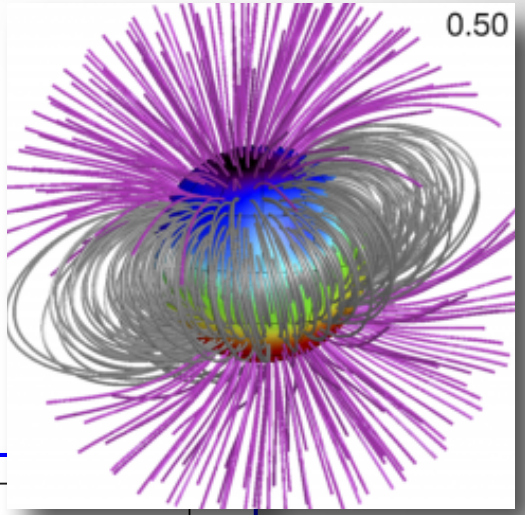
B strength distribution





In higher-mass stars

Strong fossil fields



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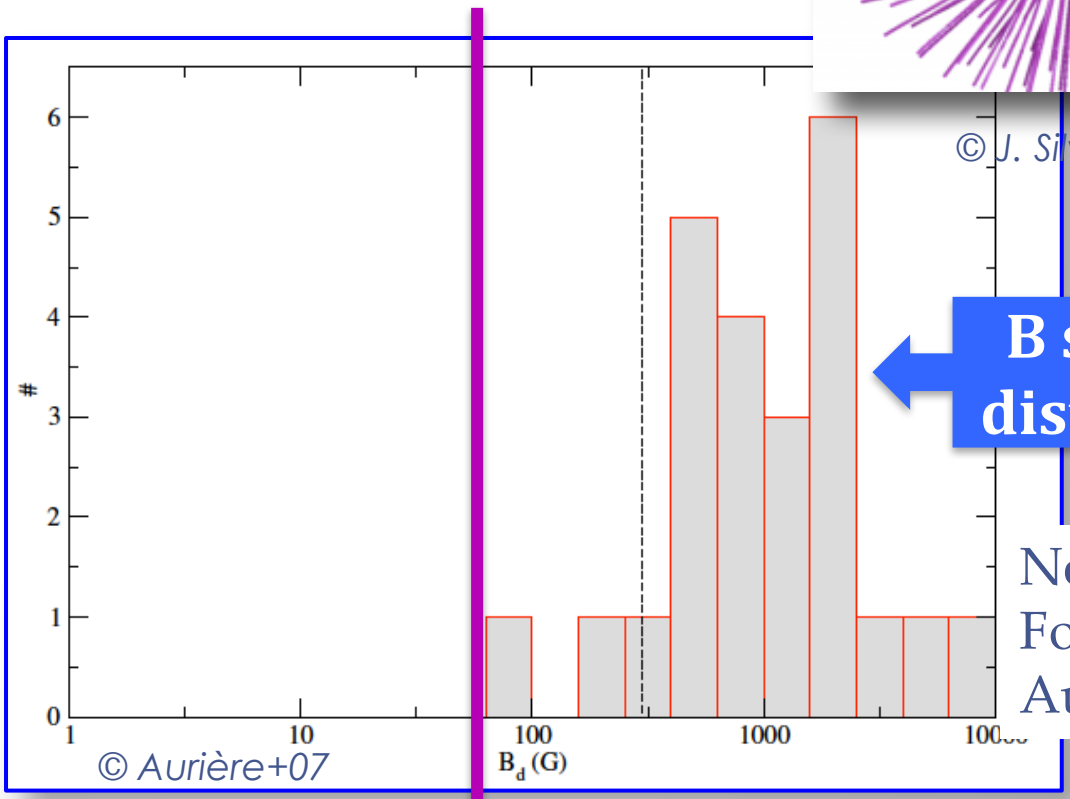
~60 G



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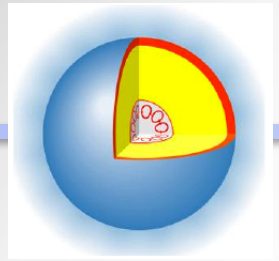
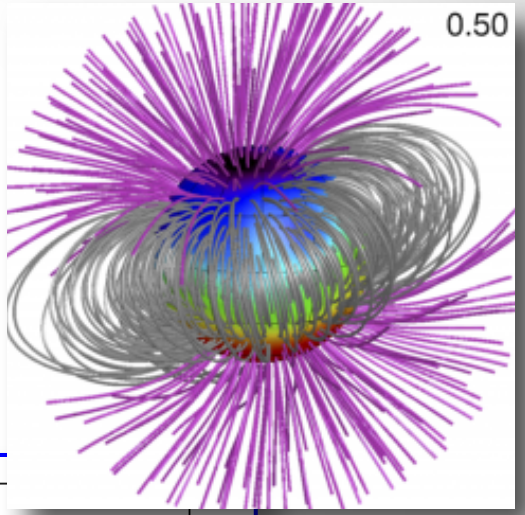
B strength distribution

Neiner+ in pr.
Fossati+15
Aurière+07

In higher-mass stars



Strong fossil fields



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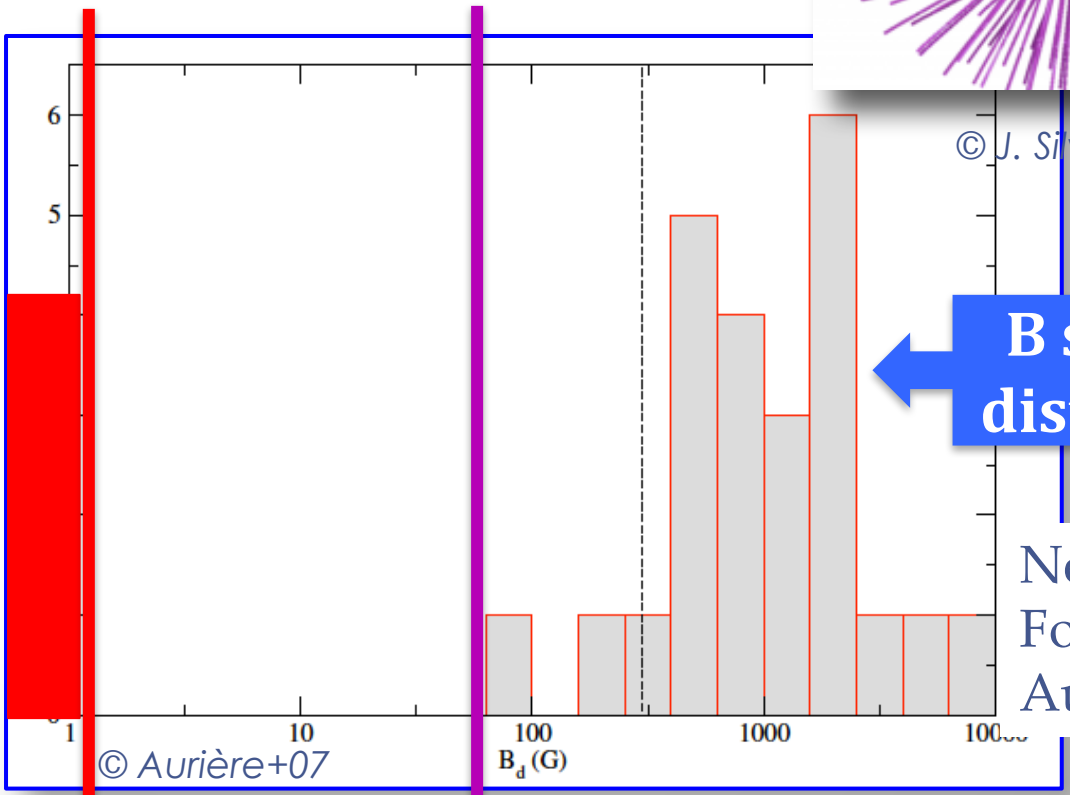
~1 G **~60 G**



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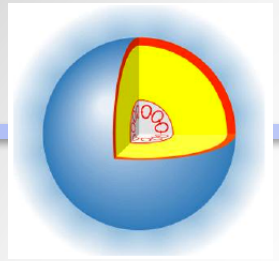
B strength distribution

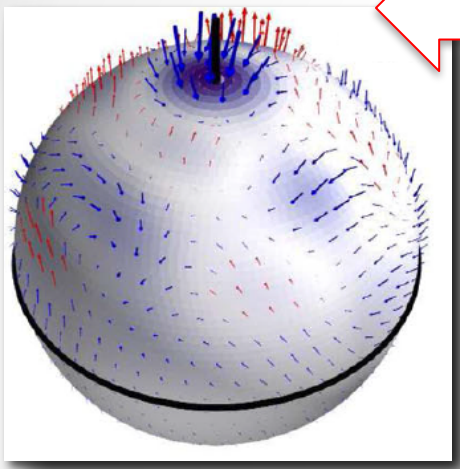
Neiner+ in pr.
Fossati+15
Aurière+07

In higher-mass stars



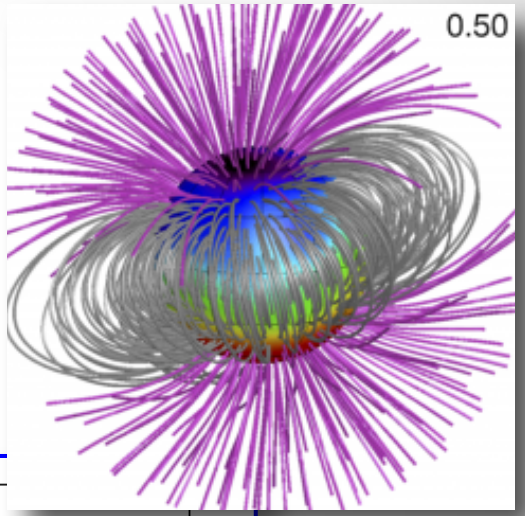
Weak fossil fields

~1 G



Strong fossil fields

~60 G



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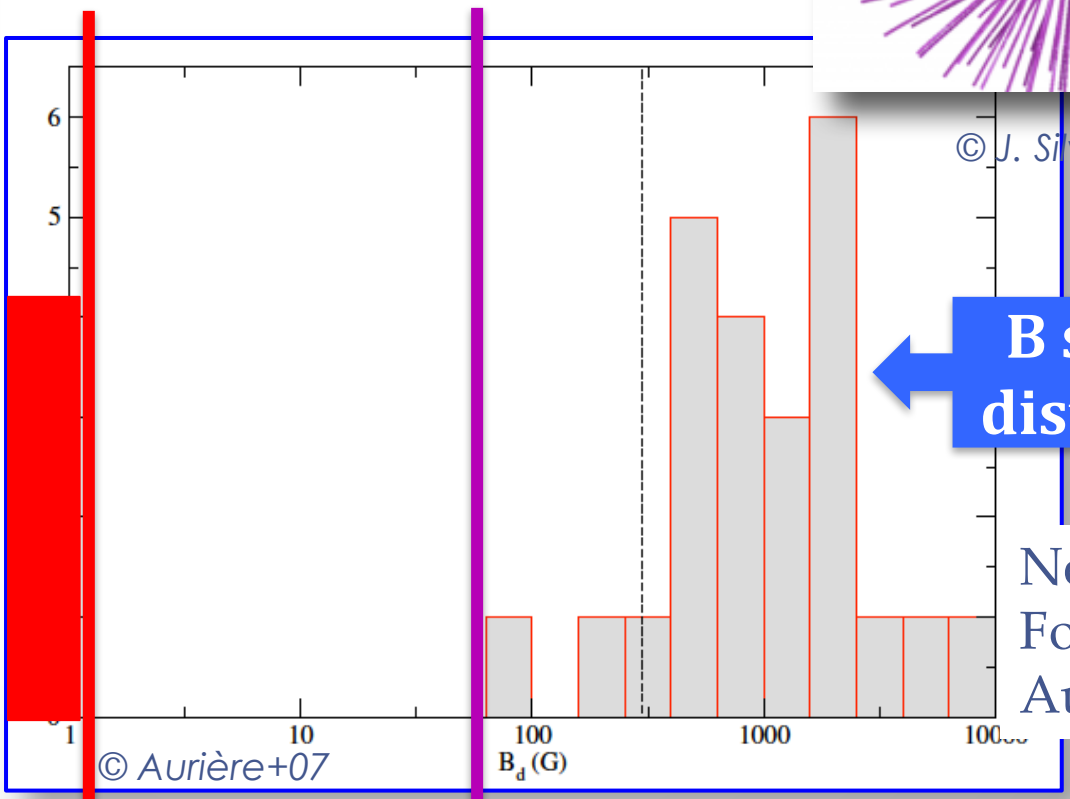

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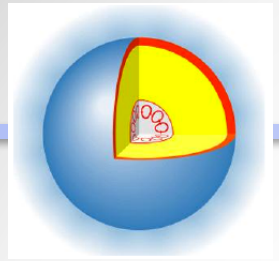
B strength distribution

Blazère+16
Petit+11
Lignières+09

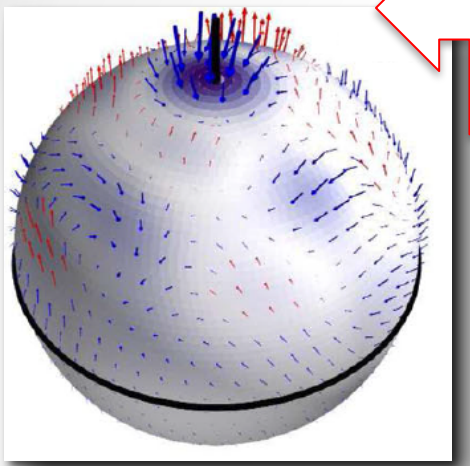
Neiner+ in pr.
Fossati+15
Aurière+07

In higher-mass stars



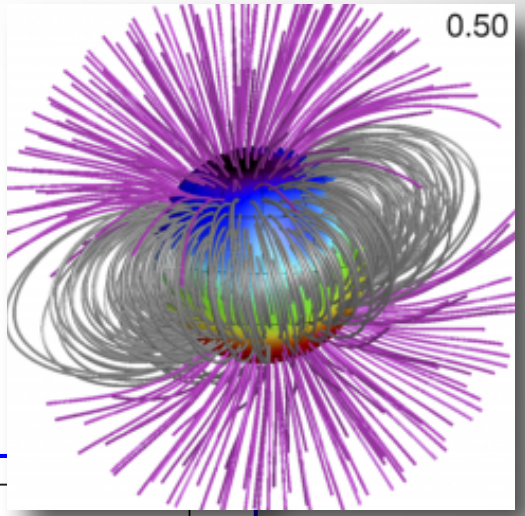
Weak fossil fields

~1 G



Strong fossil fields

~60 G



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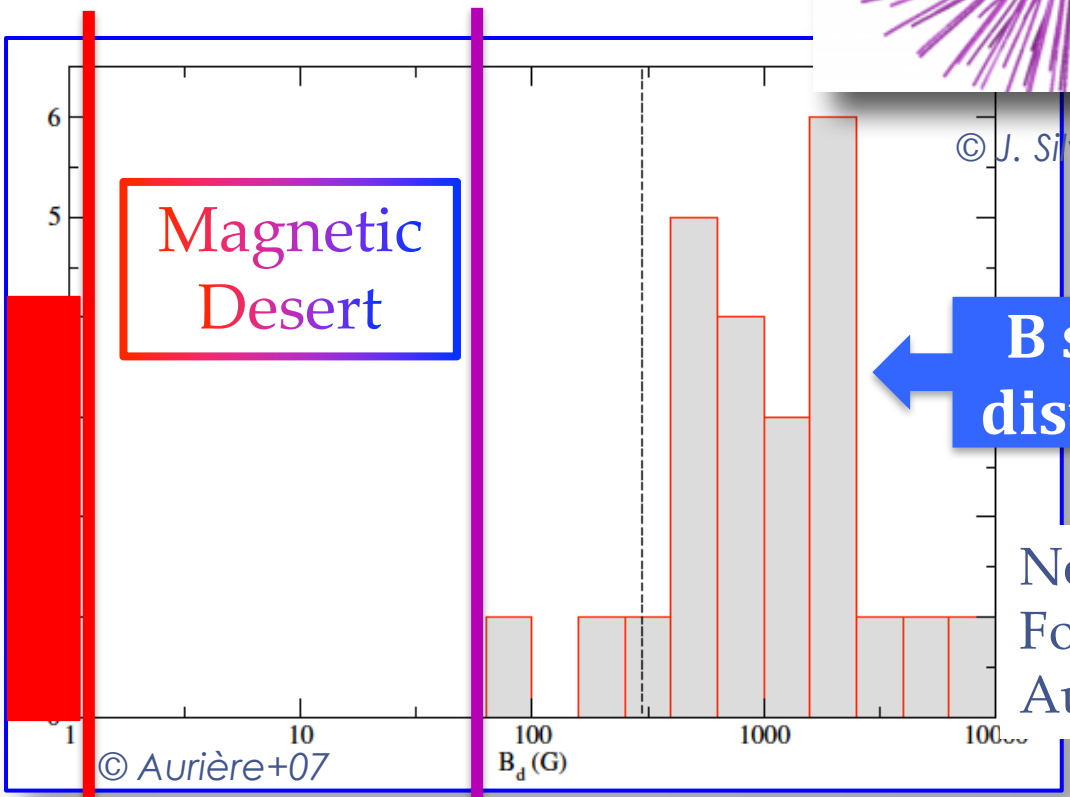
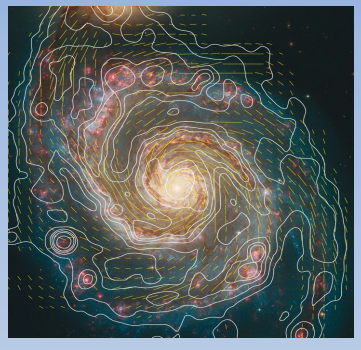


Blazère+16
Petit+11
Lignières+09

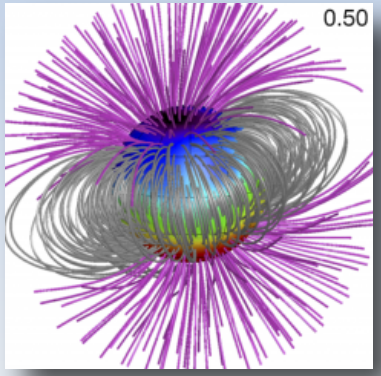
Neiner+ in pr.
Fossati+15
Aurière+07

Origin of fossil fields

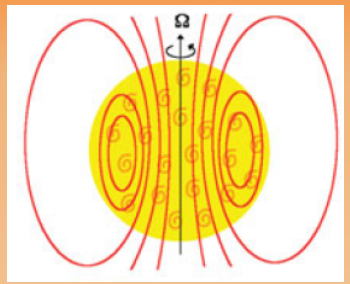
Fossilised Galactic field

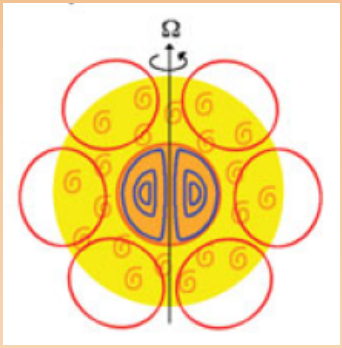


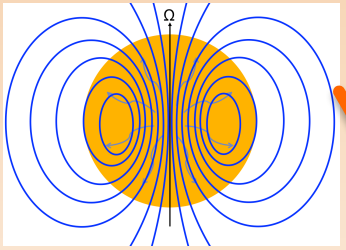
B flux conservation



PMS relaxation



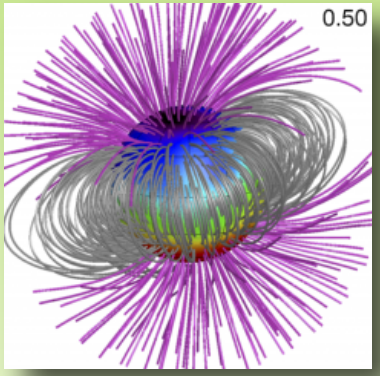


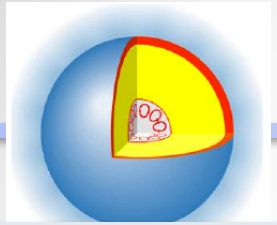


Dyn. B relaxes inside rad. zones

Mergers

Strong shear + MRI

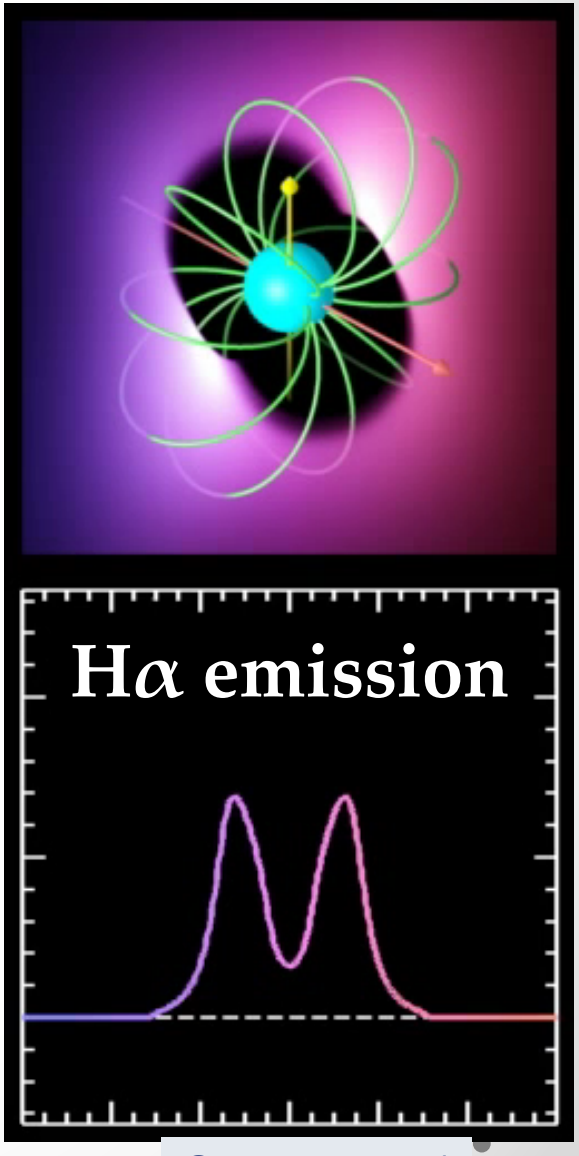


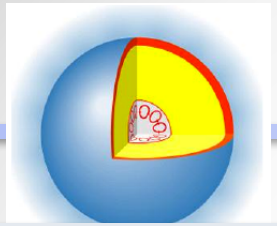


Rigidly Rotating Magnetosphere

Townsend+07 ; Oksala+15

- In the most massive stars
- Radiative winds material trapped into the magnetosphere





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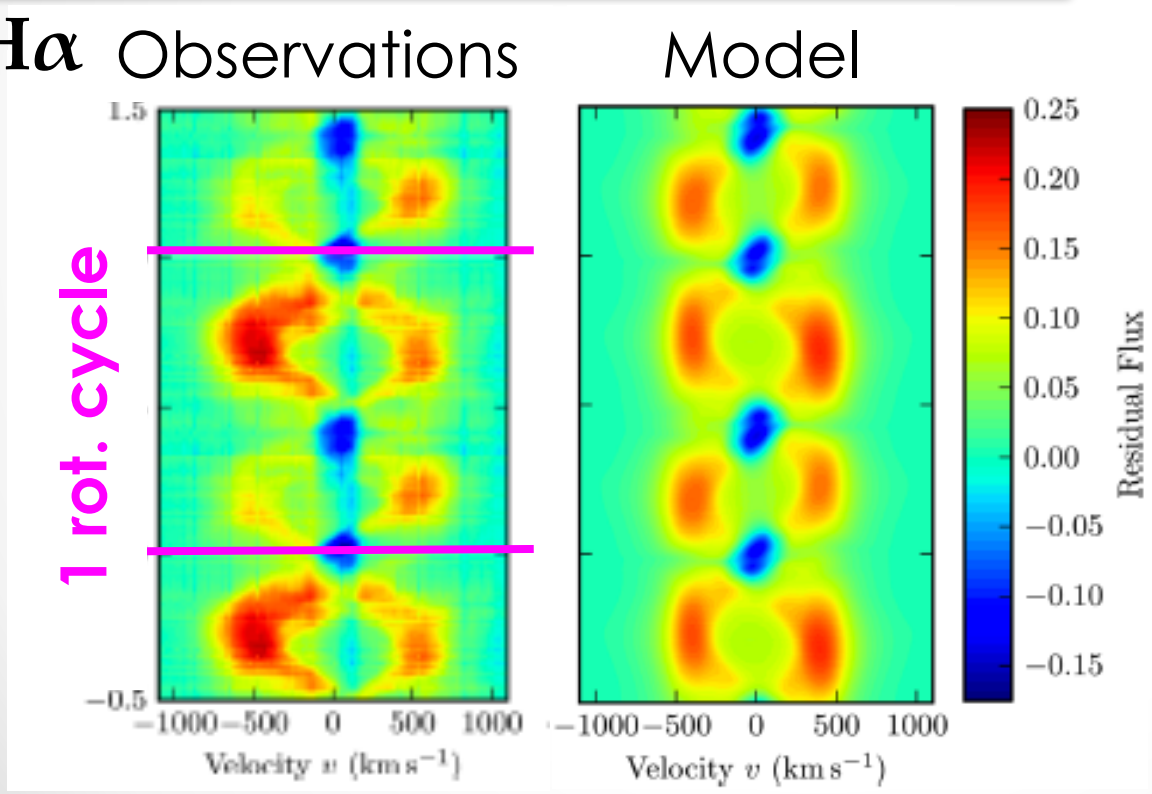
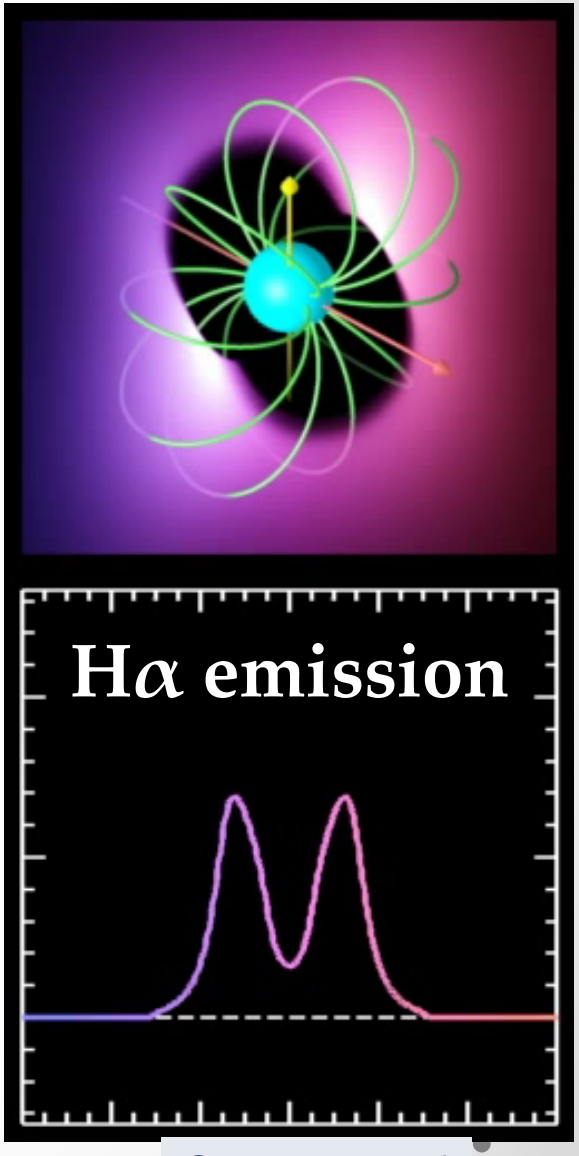


Oksala+15



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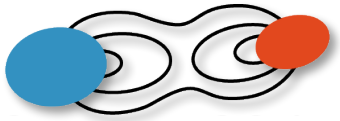

What happens if you add a close companion ?

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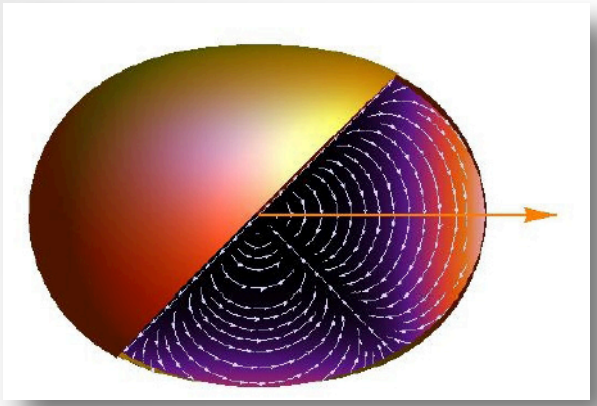
The BinaMIcS project

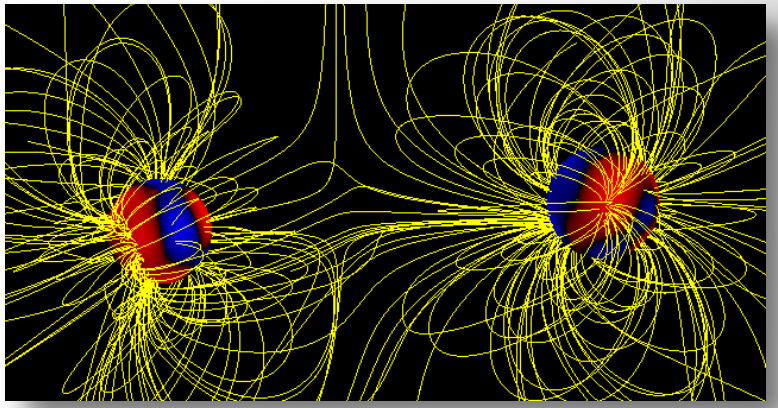
Binarity and Magnetic Interaction in various classes of stars

Tidal flows ⇔ Magnetic fields



© Remus et al. 2012

Magnetospheric interaction



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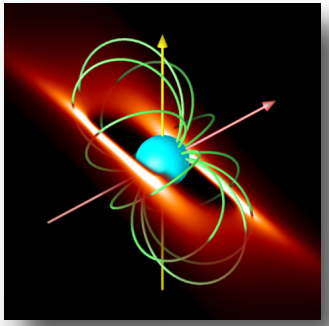
BinaMICS

CSE and AM evol.



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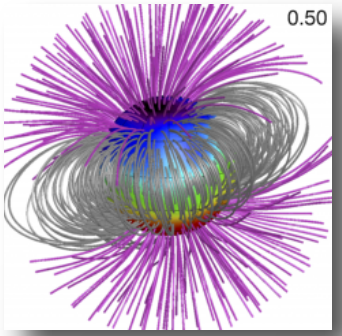
Origin of fossil fields



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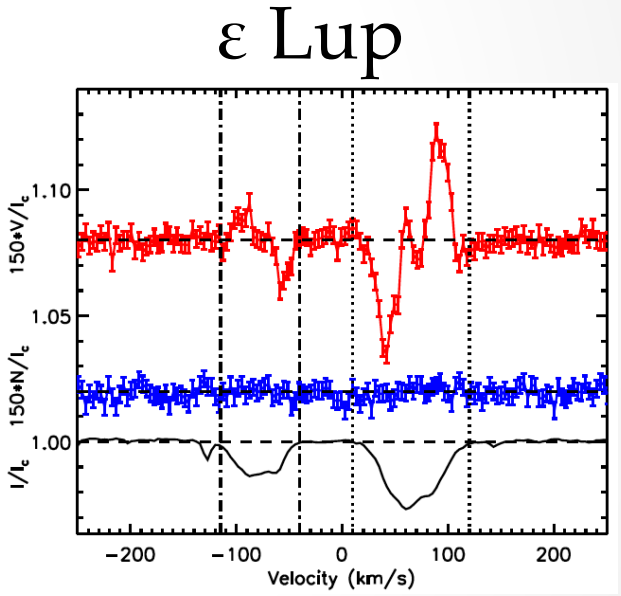
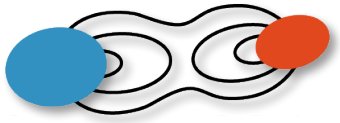
Observations

- >800 h **ESPaDOnS/CFHT, Narval/TBL**
  PIs: E. Alecian, C. Neiner, G. Wade
- ~170 short-P binary (Porb < 20d), V < 8 mag, SpT > F5
  => statistical sample
- 10 magnetic systems with Porb < 100 d, V < 10 mag
  => monitoring sample



Shultz+15

- Libre-Esprit reduction
  => optimal extraction of spectra
- Least-Square-Deconvolution
  => increases the SNR



Selected Results

• • •

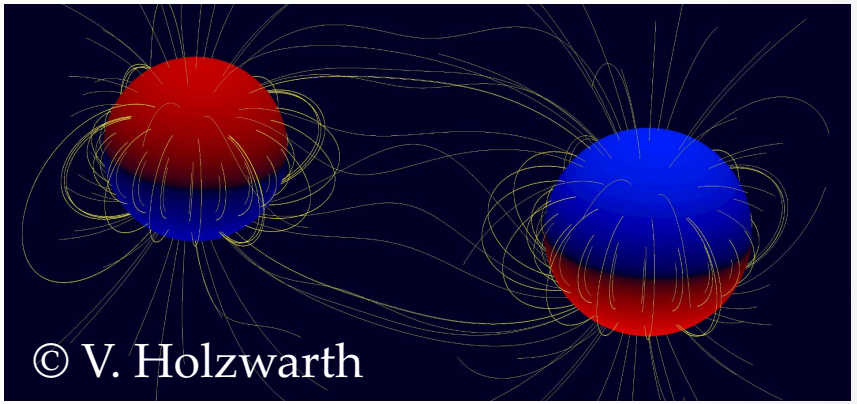
Origin of Fossil Fields

- B detected in <2% of the sample (vs 5-10% in isol. stars)
  => IC of formation are retained ?
- B detected in only one of the two components
  => IC of formation are not dominating

Alecian+ in prep.

- B detected in the two components of εLup
  => merger impossible

Shultz+15



- Post-interacting binaries have also less than 10% magnetic stars
  => binary interaction is not playing an important role

Nazé+17
Grunhut+17

Magnetic vs orbital properties

ID	Porb	M2/M1	e	Teff	Prot (d)	β (°)	Bd (kG)	
Plaskett	14.4	<0.1	0.00	34000	1.22	90	2.00	
NU Ori	14.3	0.33	0.00	31000	1.09	60	1.80	
HD 37017	18.7	0.49	0.47	23000	0.90	70	8.30	Massive
HD 149277	11.5	0.91	0.24	22000	25.4	75	9.90	
HD 156324 A	1.6	0.39	0.00	22000	1.58	71	14.0	
ε Lup Aa	4.6	0.84	0.27	22000	2.24	38	0.80	
ε Lup Ab	4.6	0.84	0.27	20000	2.48	15	0.33	
BD-19 5044 L	17.6	0.68	0.47	13000	5.04	26	1.40	
HD 5550	6.8	0.65	0.00	11400	6.84	24	0.065	I-M
HD 98088	5.9	0.73	0.18	8300	5.90	75	3.80	
	Orbit				**Star**			

Grunhut+ in prep. ; Shultz+. in prep. ; Shultz+ sub. ; Shultz+2015 ; Landstreet+2017 ; Alecian+2016 ; Folsom+2012

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ID	Porb	M2/M1	e	Teff	Prot (d)	β (°)	Bd (kG)	
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NU Ori	14.3	0.33	0.00	31000	1.09	60	**1.80**	
HD 37017	18.7	0.49	0.47	23000	0.90	70	**8.30**	
HD 149277	11.5	0.91	0.24	22000	25.4	75	**9.90**	
HD 156324 A	1.6	0.39	0.00	22000	1.58	71	**14.0**	
ε Lup Aa	4.6	0.84	0.27	22000	2.24	38	**0.80**	
ε Lup Ab	4.6	0.84	0.27	20000	2.48	15	**0.33**	
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HD 5550	6.8	0.65	0.00	11400	6.84	24	0.065	
HD 98088	5.9	0.73	0.18	8300	5.90	75	3.80	

Orbit **Star**

Grunhut+ in prep. ; Shultz+. in prep. ; Shultz+ sub. ; Shultz+2015 ; Landstreet+2017 ; Alecian+2016 ; Folsom+2012

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Plaskett	14.4	<0.1	0.00	34000	1.22	**90**	2.00	Massive
NU Ori	14.3	0.33	0.00	31000	1.09	**60**	1.80	
HD 37017	18.7	0.49	0.47	23000	0.90	**70**	8.30	
HD 149277	11.5	0.91	0.24	22000	25.4	**75**	9.90	
HD 156324 A	1.6	0.39	0.00	22000	1.58	**71**	14.0	
ε Lup Aa	4.6	0.84	0.27	22000	2.24	**38**	0.80	
ε Lup Ab	4.6	0.84	0.27	20000	2.48	**15**	0.33	
BD-19 5044 L	17.6	0.68	0.47	13000	5.04	26	1.40	I-M
HD 5550	6.8	0.65	0.00	11400	6.84	24	0.065	
HD 98088	5.9	0.73	0.18	8300	5.90	75	3.80	

Orbit **Star**

Magnetic axis highly inclined,

Magnetic vs orbital properties

ID	Porb	M2/M1	e	Teff	Prot (d)	β (°)	Bd (kG)	
Plaskett	14.4	<0.1	0.00	34000	1.22	**90**	2.00	Massive
NU Ori	14.3	0.33	0.00	31000	1.09	**60**	1.80	
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HD 98088	5.9	0.73	0.18	8300	5.90	75	3.80	

Orbit **Star**

Magnetic axis highly inclined,

- except for the only system with 2 magnetic stars, or

Magnetic vs orbital properties

ID	Porb	M2/M1	e	Teff	Prot (d)	β (°)	Bd (kG)	
Plaskett	14.4	<0.1	0.00	34000	1.22	**90**	2.00	Massive
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HD 98088	5.9	0.73	0.18	8300	5.90	75	3.80	

Orbit **Star**

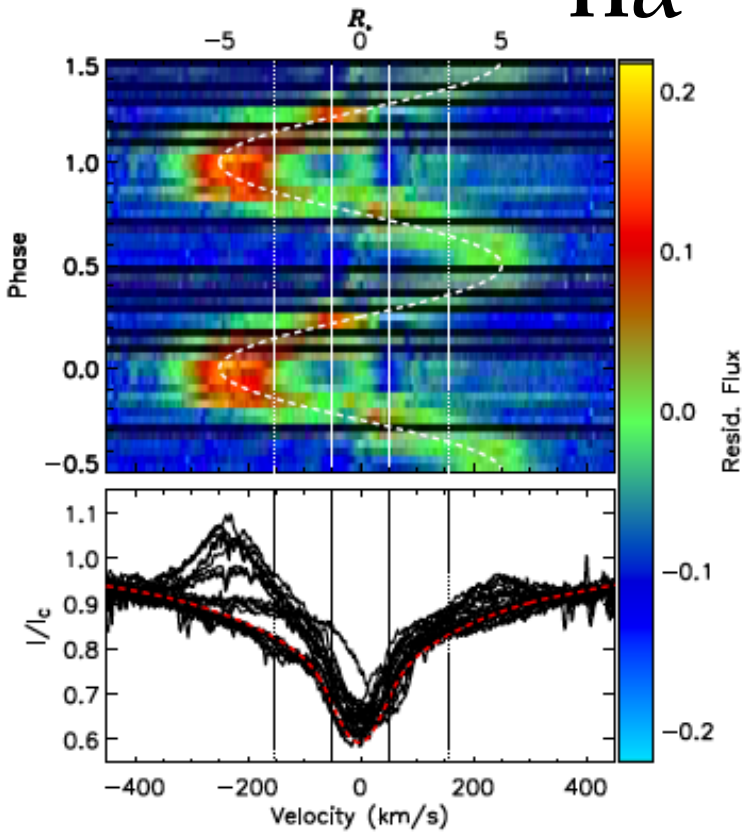
Magnetic axis highly inclined,

- except for the only system with 2 magnetic stars, or
- except for the only stars with faint magnetic fields

Magnetospheres

The short period SB2
HD 156324

Hα

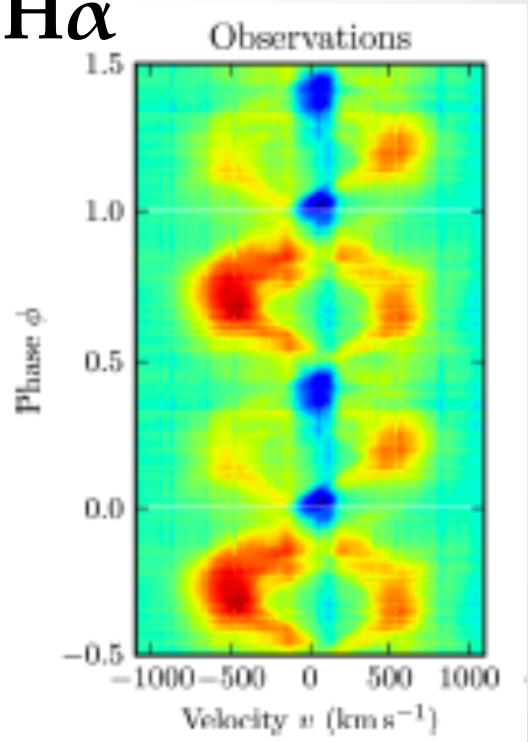


Shultz+ in prep.

Reminder :

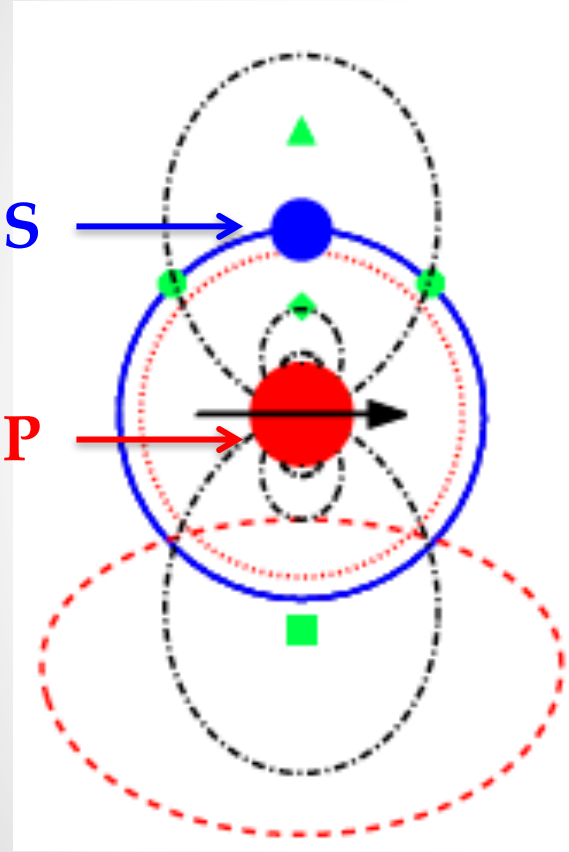
The single star
σ Ori E

Hα



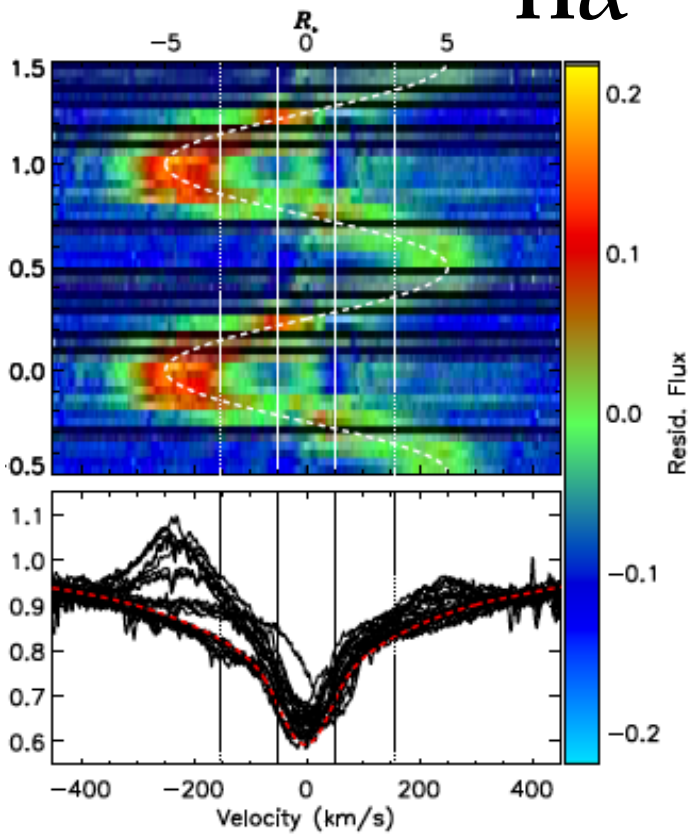
Magnetospheres

The short period SB2
HD 156324



Hα emission

Hα

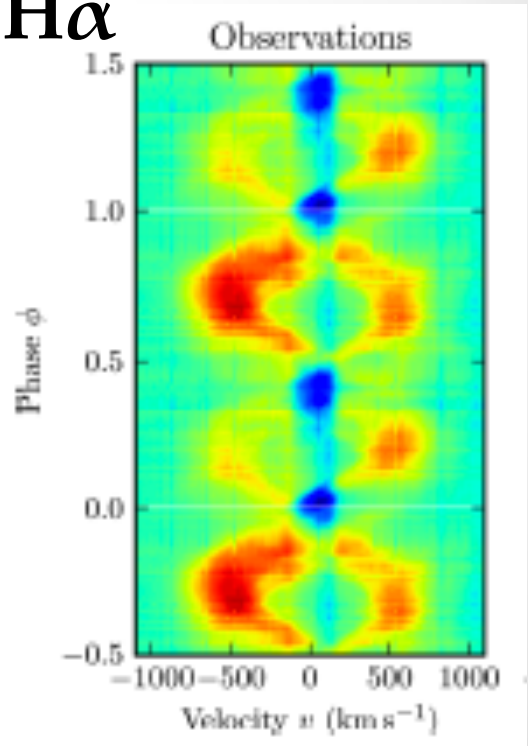


Shultz+ in prep.

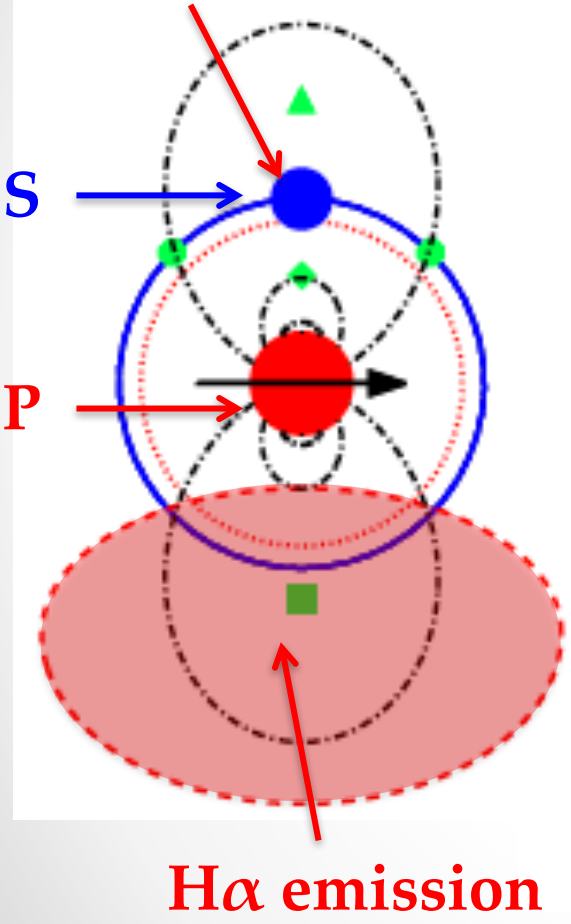
Reminder :

The single star
σ Ori E

Hα

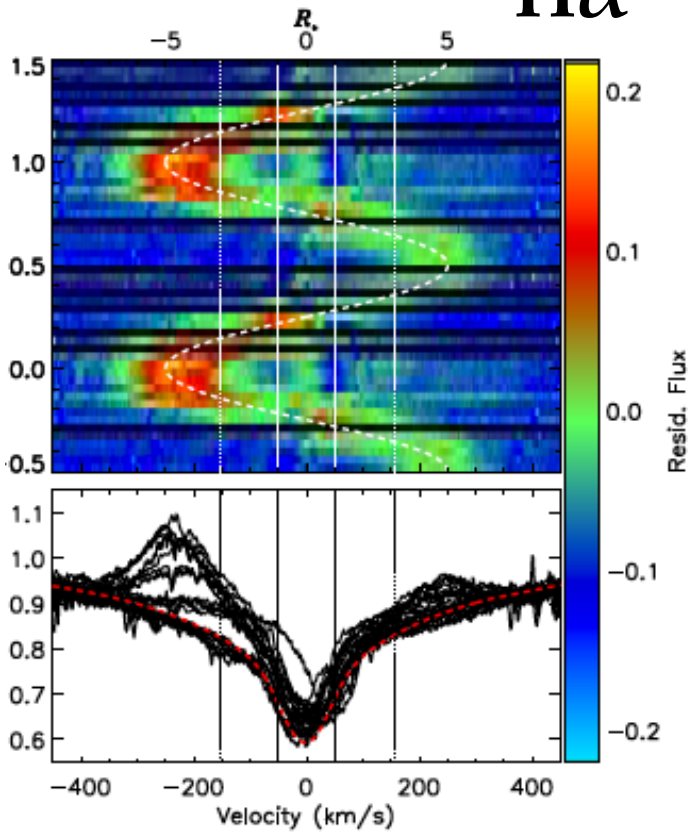


Magnetospheres



The short period SB2
HD 156324

Hα

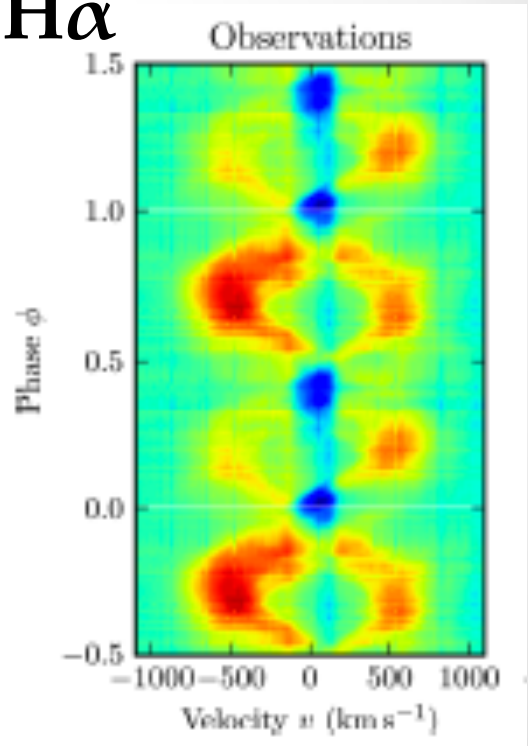


Shultz+ in prep.

Reminder :

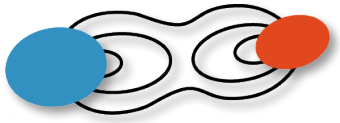
The single star
σ Ori E

Hα



Conclusions

- Magnetic properties:
  - Fossil fields in less than 2%
  - B filed in only one of the two components
  - B strength distribution similar to isolated stars
  - Preferentially large obliquity in the massive stars
- In Ap/Bp stars:
  - Confirm the findings of Carrier+02
  - However, very low statistics
- Additional work required to understand the impact on the CSE and AM loss



Thank you !

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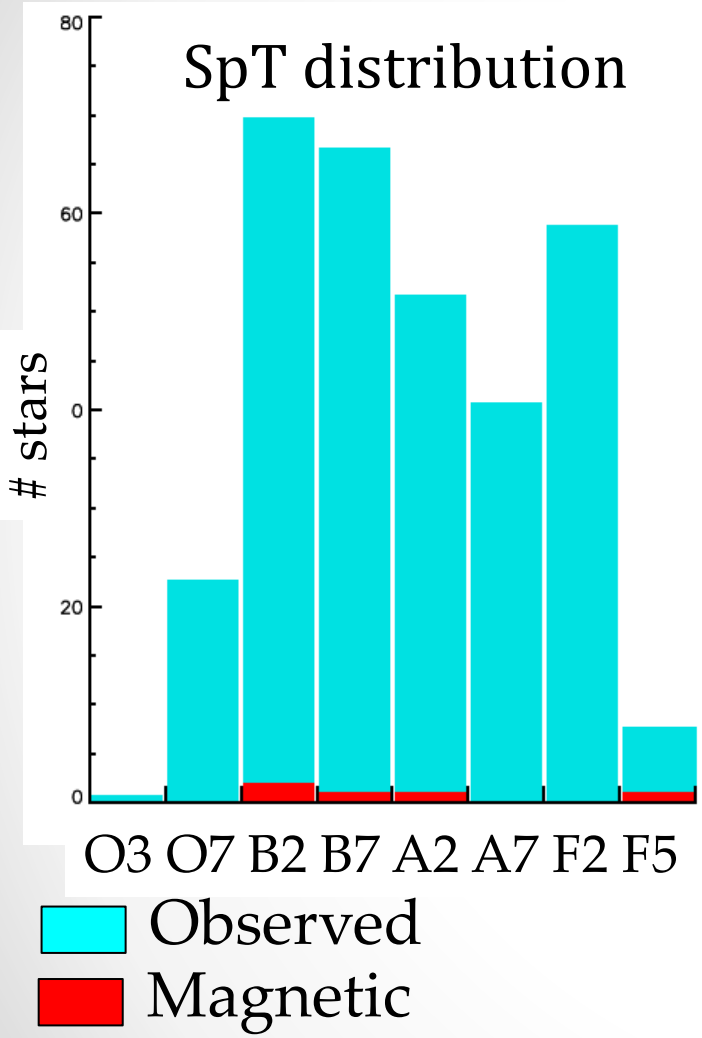
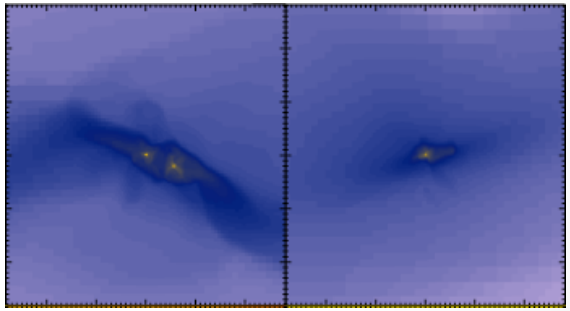
Origin of fossil fields (1)



Alecian et al. in prep.

~170 SB2 systems observed
2 mag. detections
⇒5 in total among ~340 stars
⇒< 2% mag. ★ in SB2
(5-10% mag. isolated stars)

Fragmentation simulations
B low => easier to form binaries



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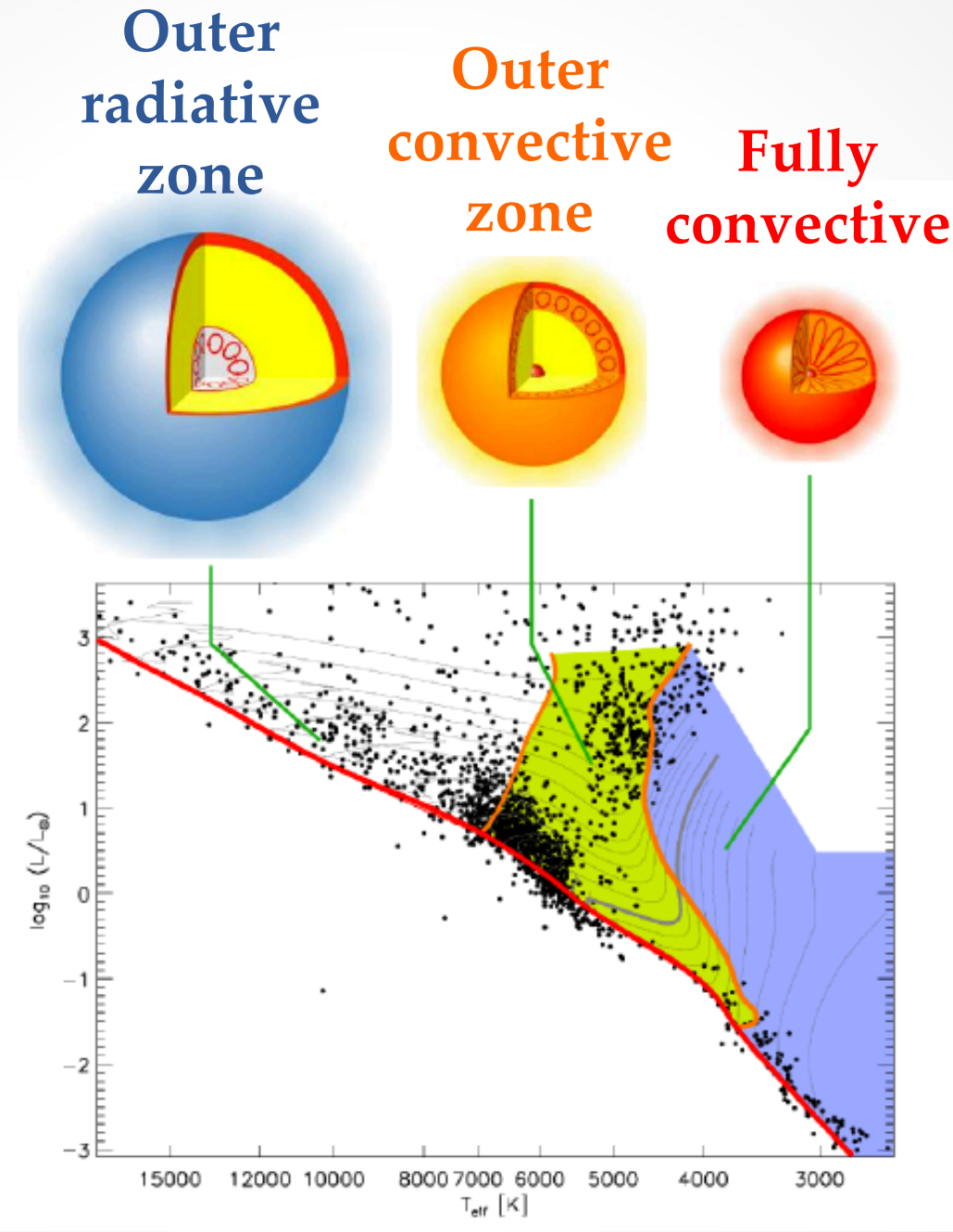
Memory of IC of fragmentation may have been retained



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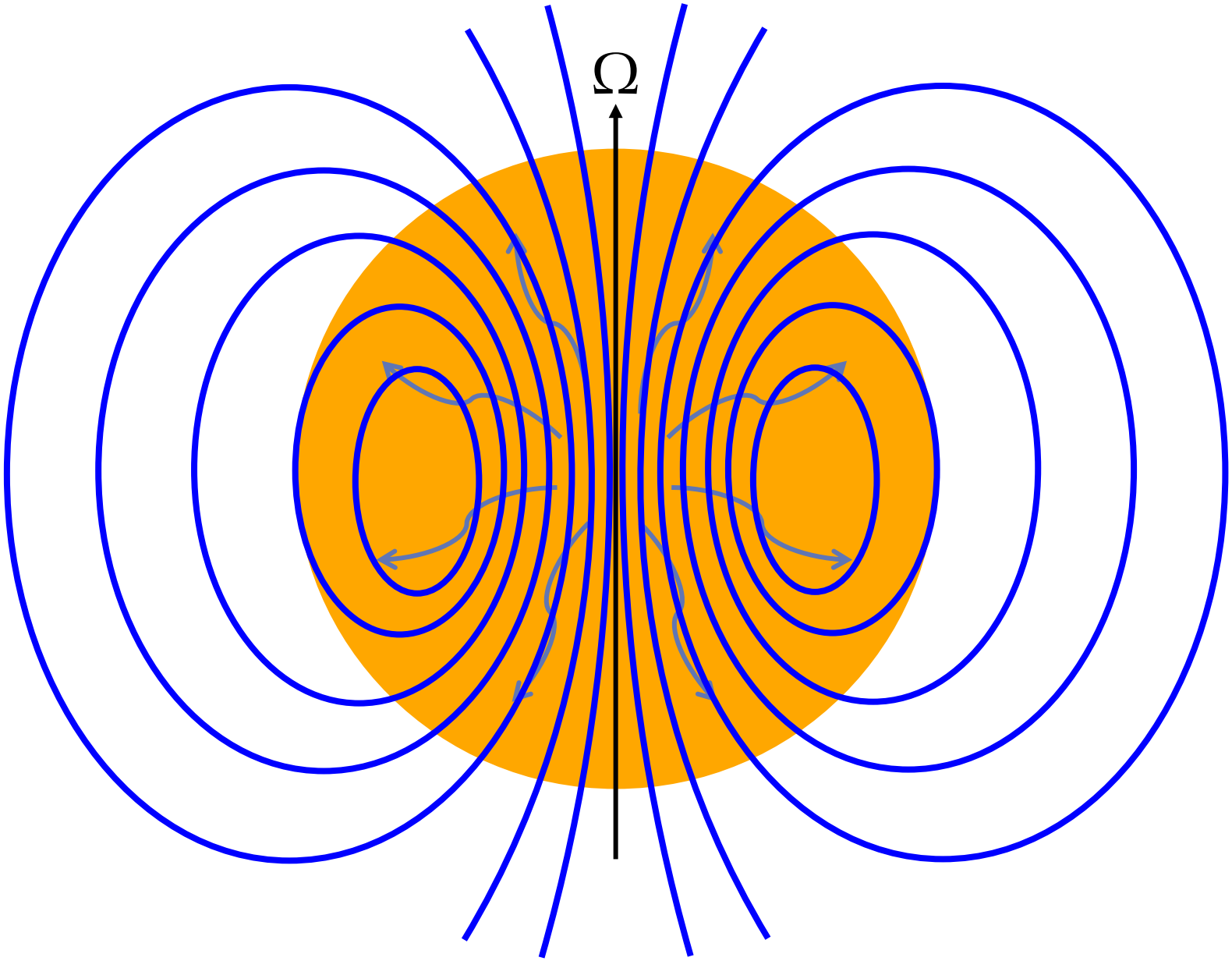
Ω