The dichotomy between strong and ultra-weak magnetic fields among intermediate-mass stars

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with

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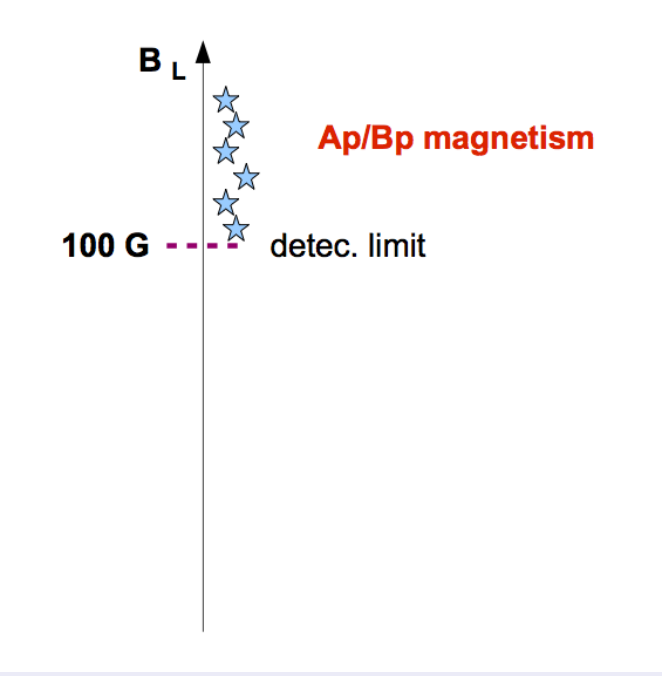
PNPS, Besançon, 2014

Intermediate-mass star magnetism

Summary of the recent observational progress

Before



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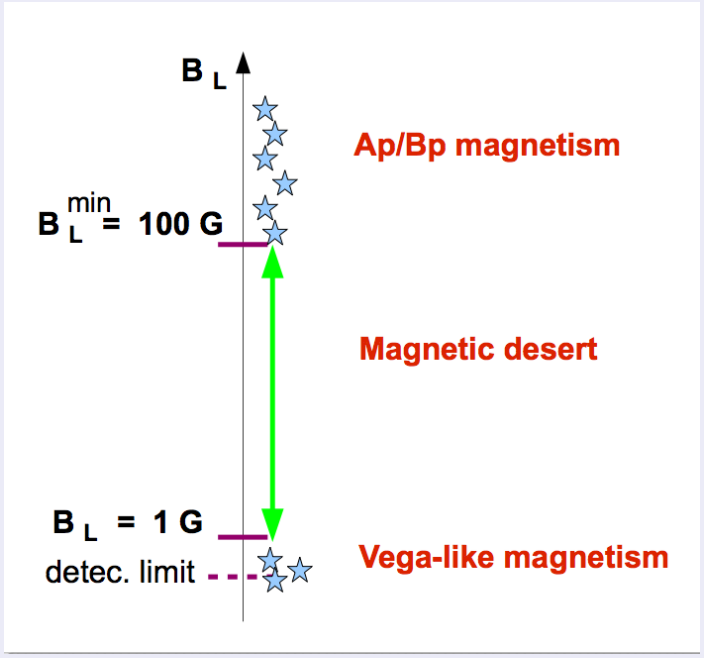
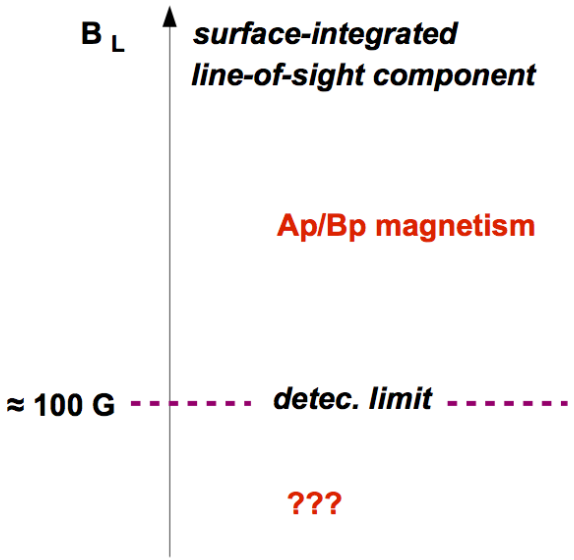


- two magnetisms separated by a magnetic desert
- Vega-like : constraint on the magnetic fields of typical intermediate-mass stars ?

Intermediate-mass star magnetism ... some years ago

Observations

- all detected magnetic stars have Ap type aboundance anomalies
- approximatively inclined dipole, with B_d from the detection limit $\sim$ 300 G up to 30 kG
- stable over time



Interpretation

- Ap type peculiar abundances require strong enough fields (Michaud 1970)
- the fossil field hypothesis

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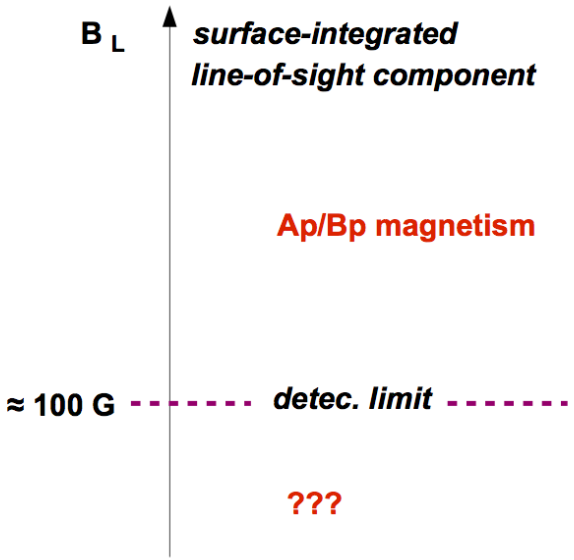

Open questions

- are all Ap/Bp stars magnetic ?
- a low tail of the magnetic strength distribution among non Ap/Bp stars ?

All Ap/Bp stars are magnetic
(Auriere et al. 2007)

A survey of 28 suspected weakly magnetic Ap/Bp stars

- all stars were detected (Musicos/Narval)
- fitted dipolar fields higher than $\sim$ 300 G

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What about a low field continuation of Ap/Bp magnetism among non-Ap/Bp stars ? ?

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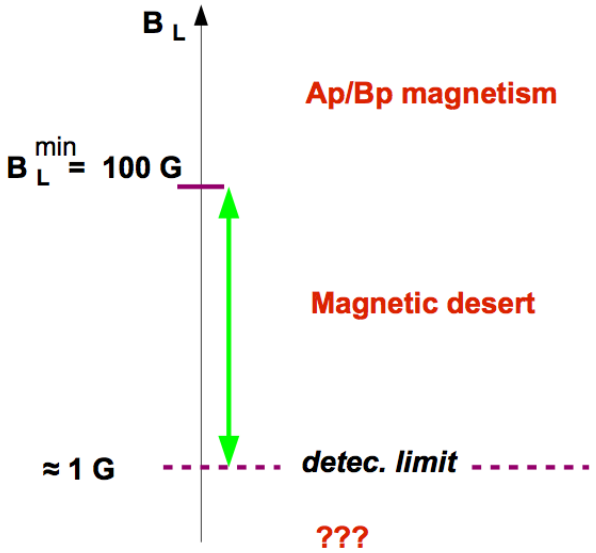
No magnetic fields detection among non-Ap/Bp intermediate-mass stars, down to a few Gauss (in B_L)

Spectropolarimetric surveys of sharp line late-B and A stars

- $\sim$ 50 stars (Am, HgMn, normal A/B stars) with Musicos@TBL, $\sim$ 50 G upper limit (Shorlin et al. 2002)
- 15 stars (11 Am, 4 HgMn) with Narval@TBL and Espadons@CFHT, $\sim 1-10$ G upper limit, (Auriere et al. 2010)
- 47 HgMn stars with HARPSpol@ESO, $\sim 3-30$ G upper limit, (Makaganiuk et al. 2011)



Consequences of the magnetic desert

- a true magnetic dichotomy
- B_d^{min} contains informations about the origin of Ap/Bp magnetism
- $B_d^{min} = 300G$ higher but not necessarily equal to the field that prevents chemical mixing in Ap/Bp stars

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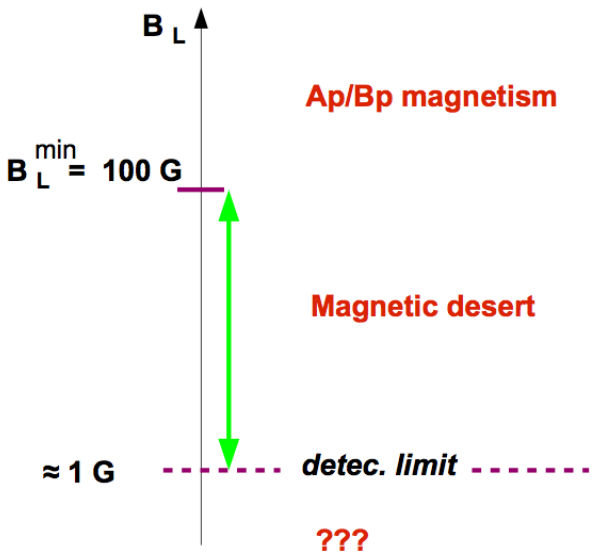

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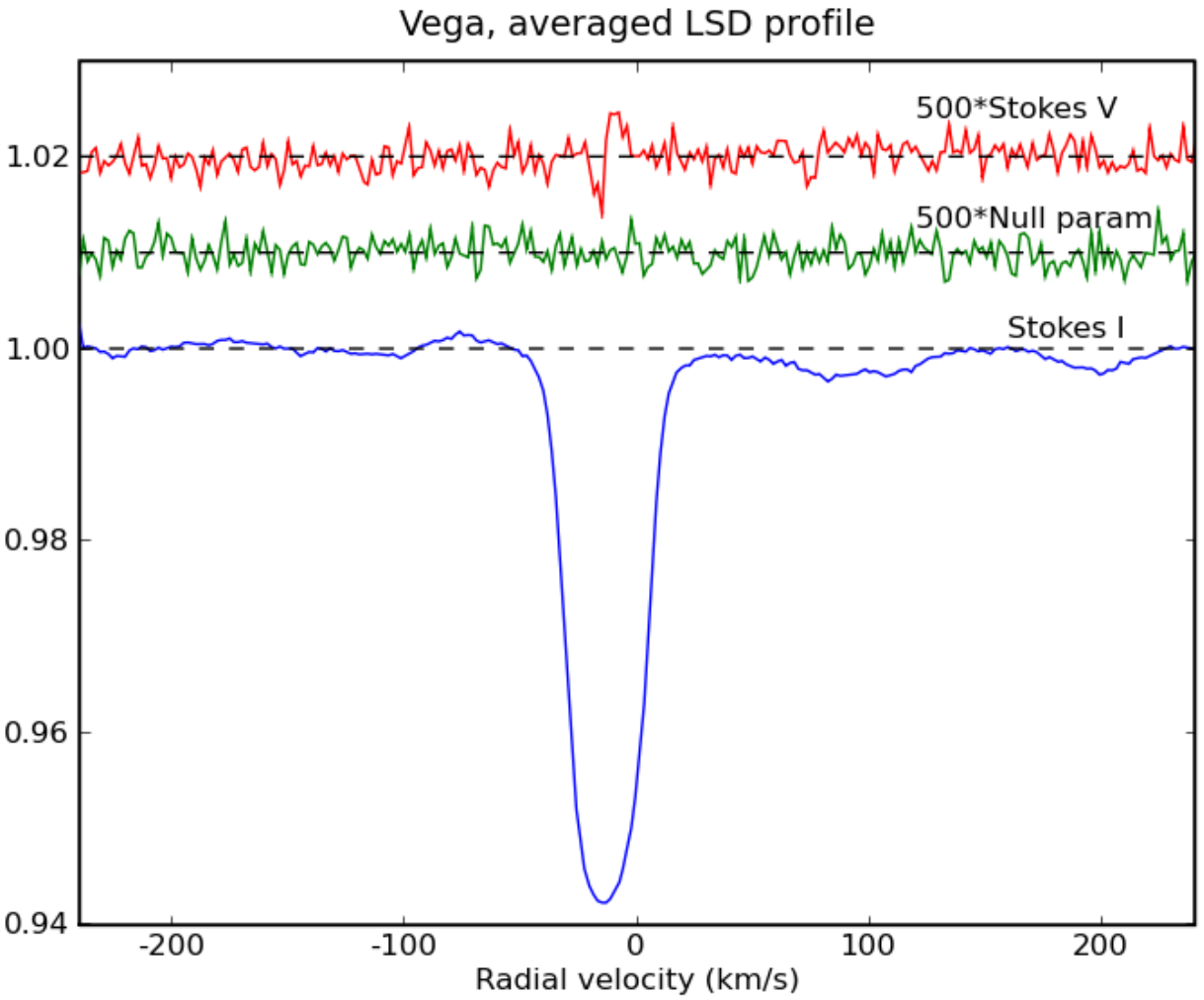
Vega : a sub-Gauss magnetic field on a normal A0 star
(Lignières et al. 2009, Petit et al. 2010, Alina et al. 2011)

- Stokes V detection from a 4-nights Narval run dedicated to pulsations search



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- $\sigma = 2 \times 10^{-6}$ I
- B_L = - 0.6 $\pm$ 0.3 G

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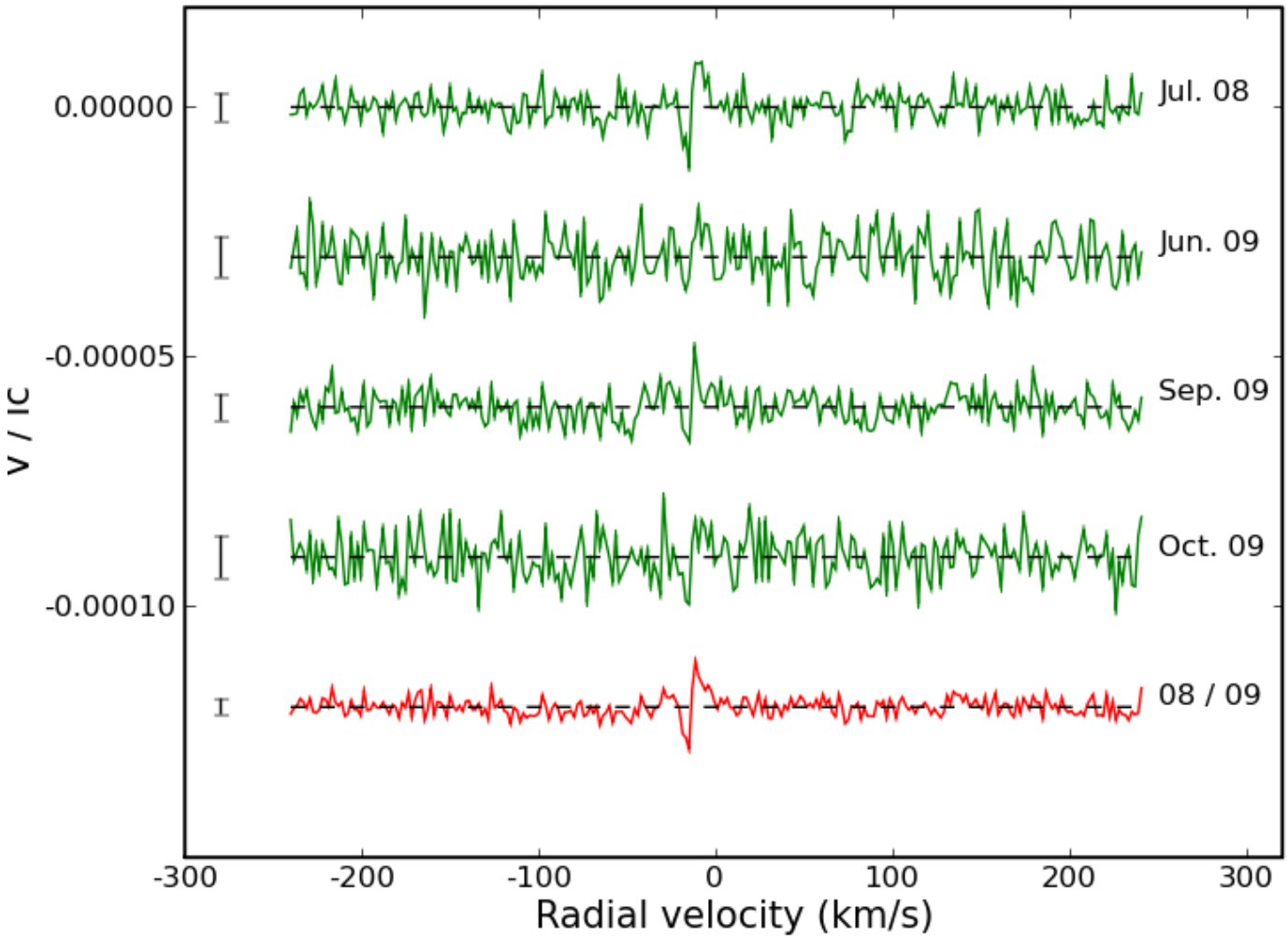

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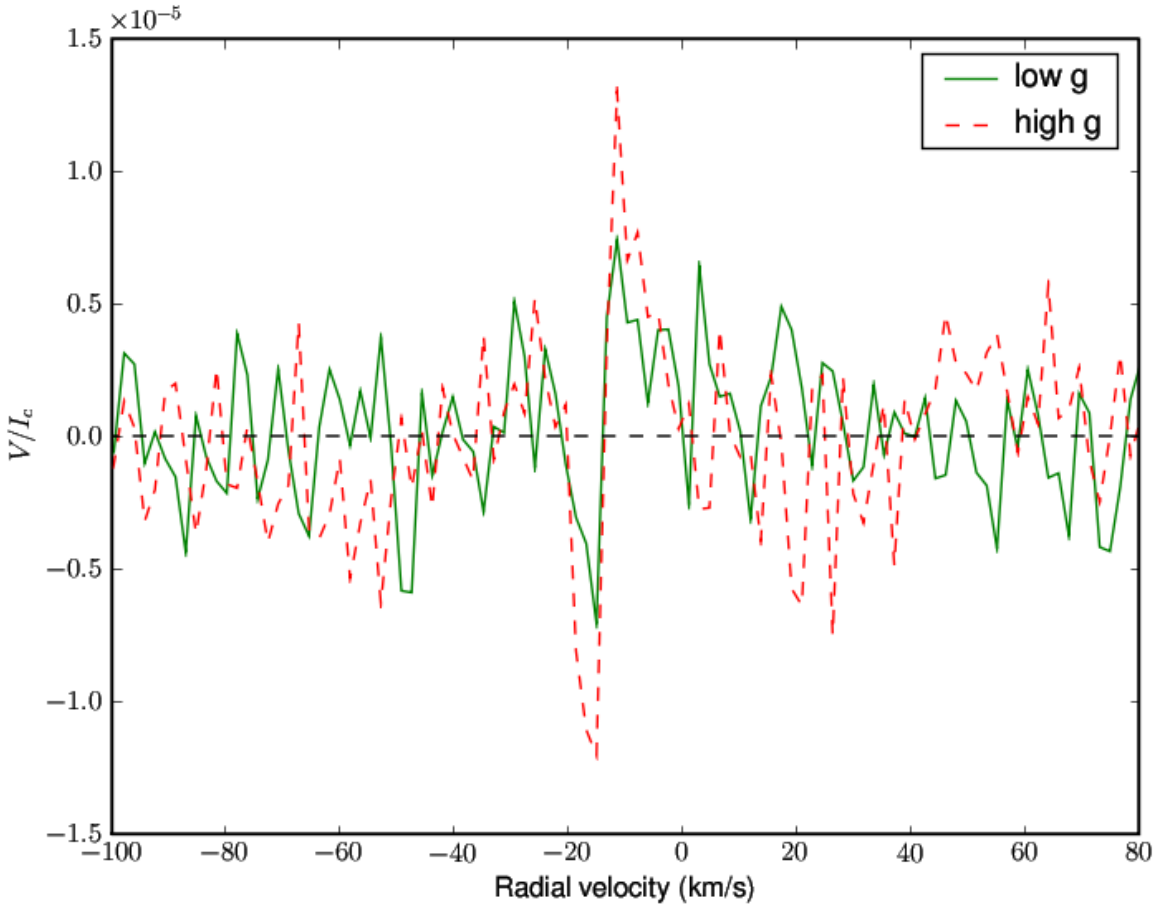

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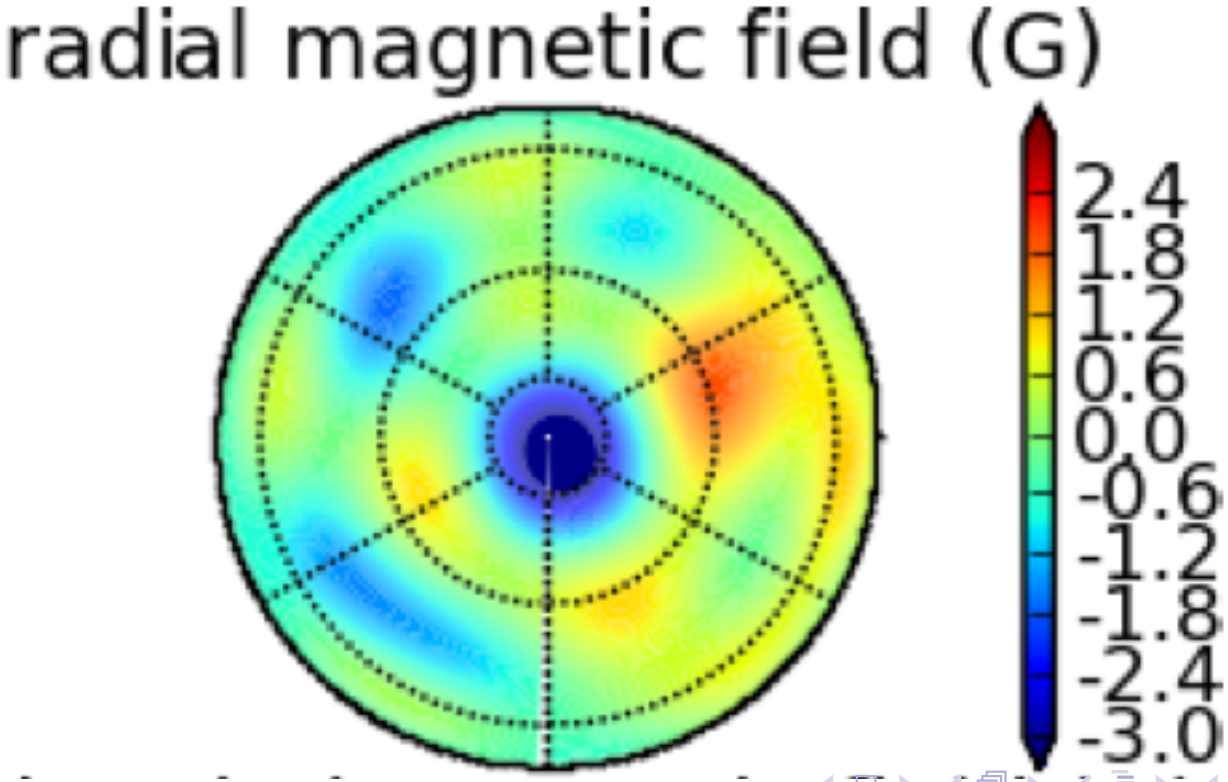

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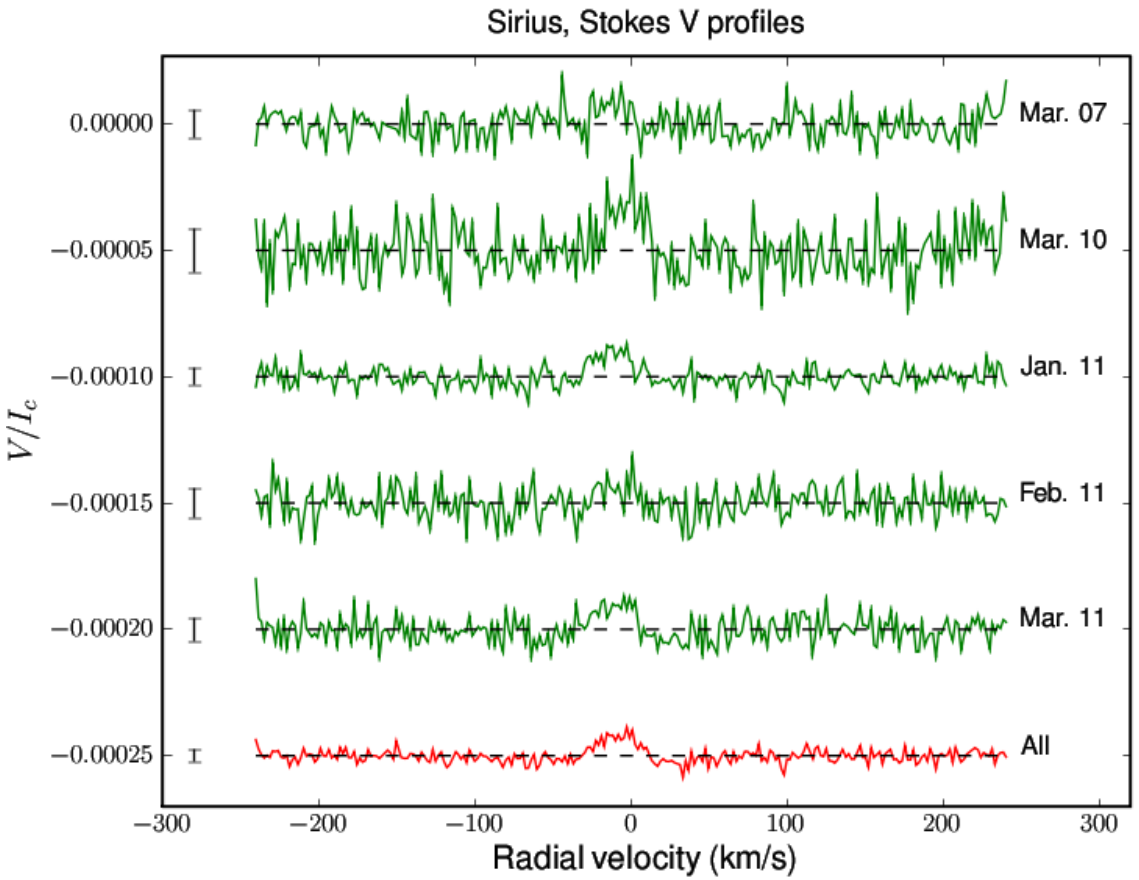
- no detectable time variability over three years

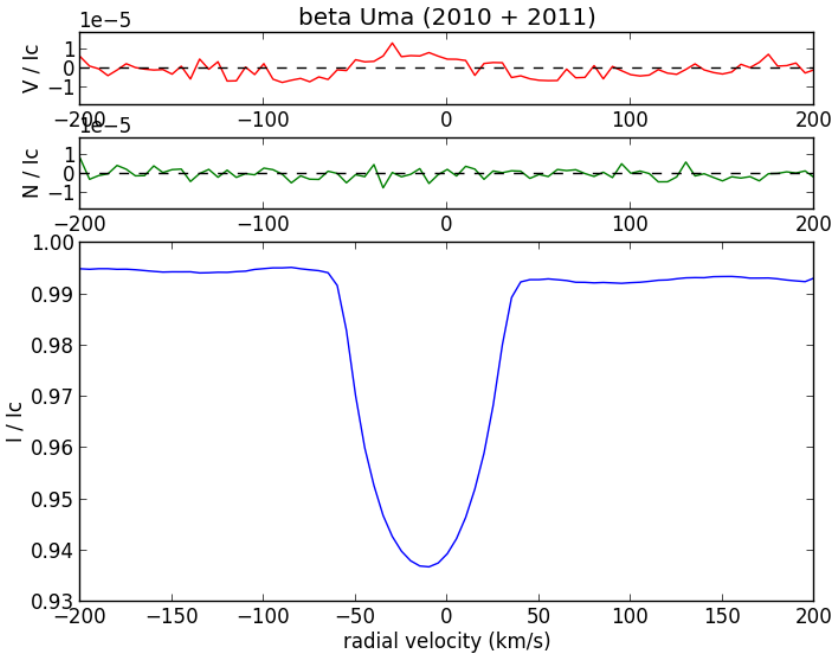
Weak Stokes V signal on Sirius and two others Am stars

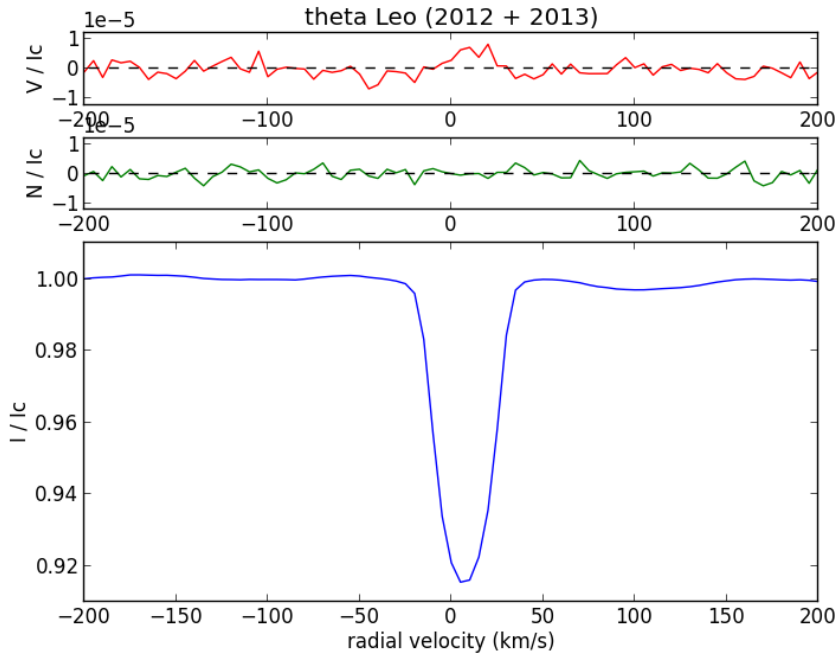


- Detection with Narval and Espadons (Petit et al. 2011) recently with HARPSpol (Kochukhov, 2013)
- $V_{max} = 2 \times 10^{-5}$ I
- $\sigma = 2 \times 10^{-6}$ I
- $B_L = 0.2 \pm 0.3$ G
- Asymmetric V profile

Weak Stokes V signal on Sirius and two others Am stars

- Strong evidence for a magnetic field on Sirius
- Similar Stokes V profiles on two others bright Am stars : θ Leo and β Uma (Blazere, Petit et al. in preparation)





Intermediate-mass star magnetism

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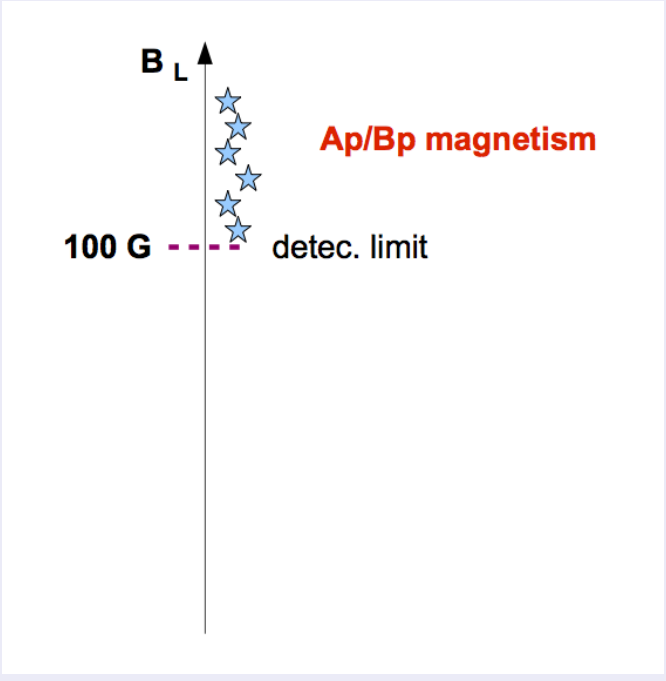

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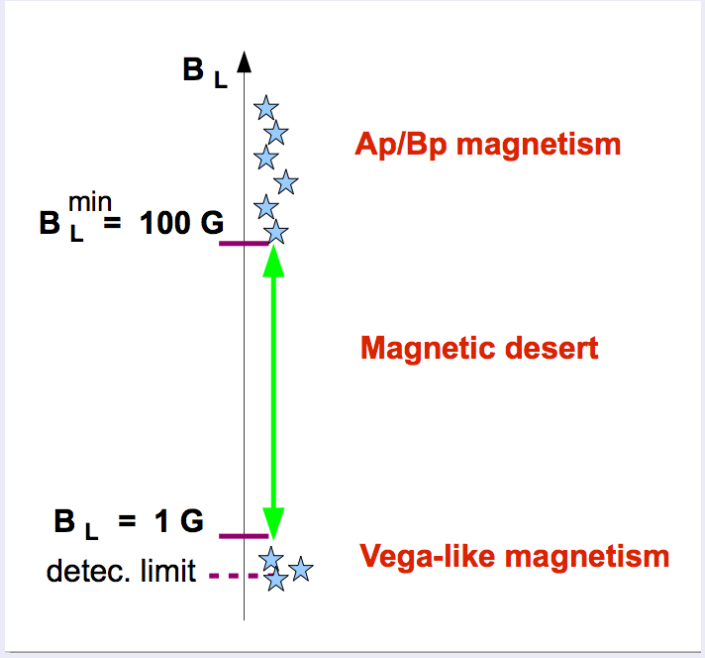

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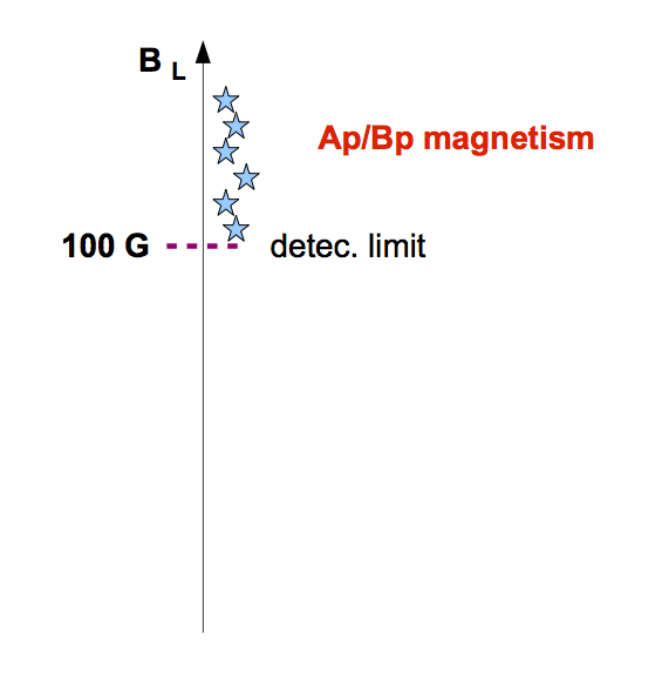

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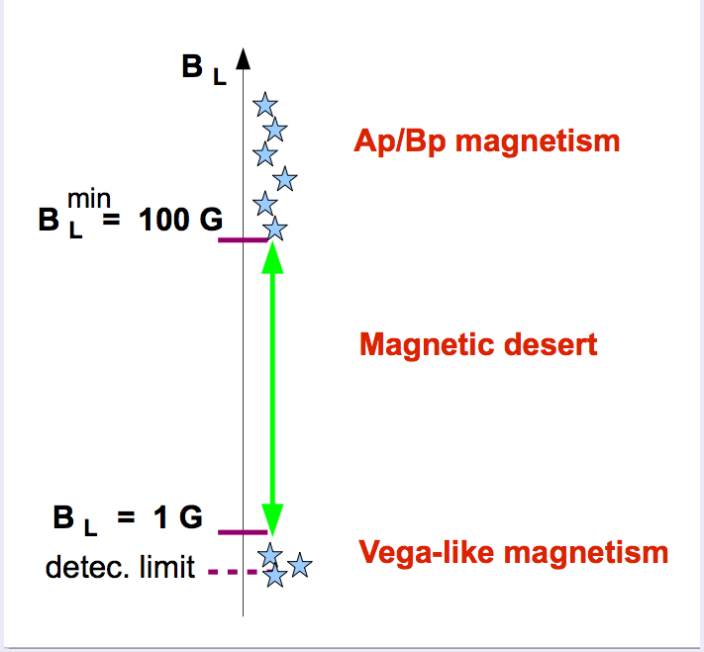


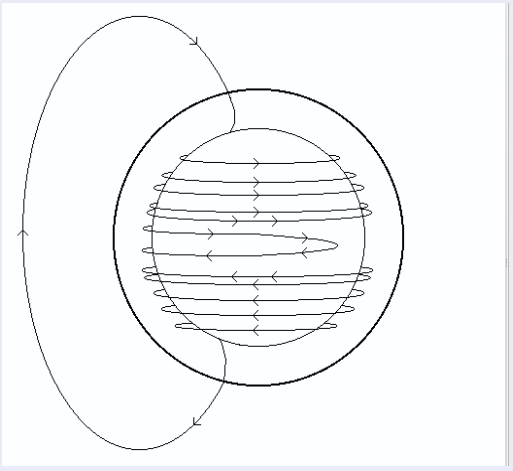
Two magnetisms separated by a magnetic desert

- either the same origin and a bifurcation
- or two different origins (Braithwaite & Cantiello 2012, Tutukov & Fedorova 2010)

A scenario for the Ap magnetic lower bound and the magnetic desert

$\vec{B}$ stability in a differentially rotating star (e.g. Spruit 1999)

- Strong B suppress differential rotation and reaches stable configurations
- Weak poloïdal field B_p $\Rightarrow$ stong azimuthal field B_ϕ $\Rightarrow$ Tayler instability



Order of magnitude of the critical field (Auriere et al. 2007)

magnetic forces react just on time to avoid $B_\phi > B_{pol}$
$\Rightarrow$ stable if $B_{pol} > B_c = (4\pi\rho)^{1/2} r\Omega$

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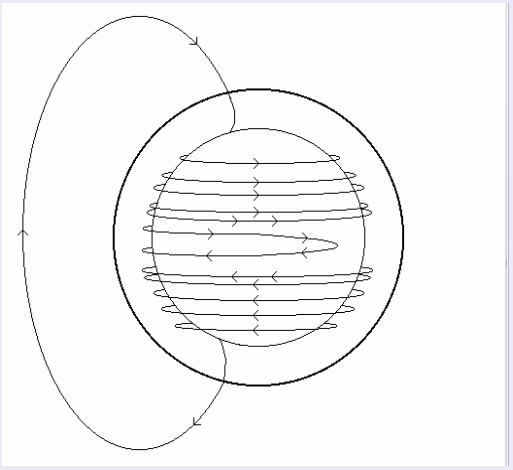

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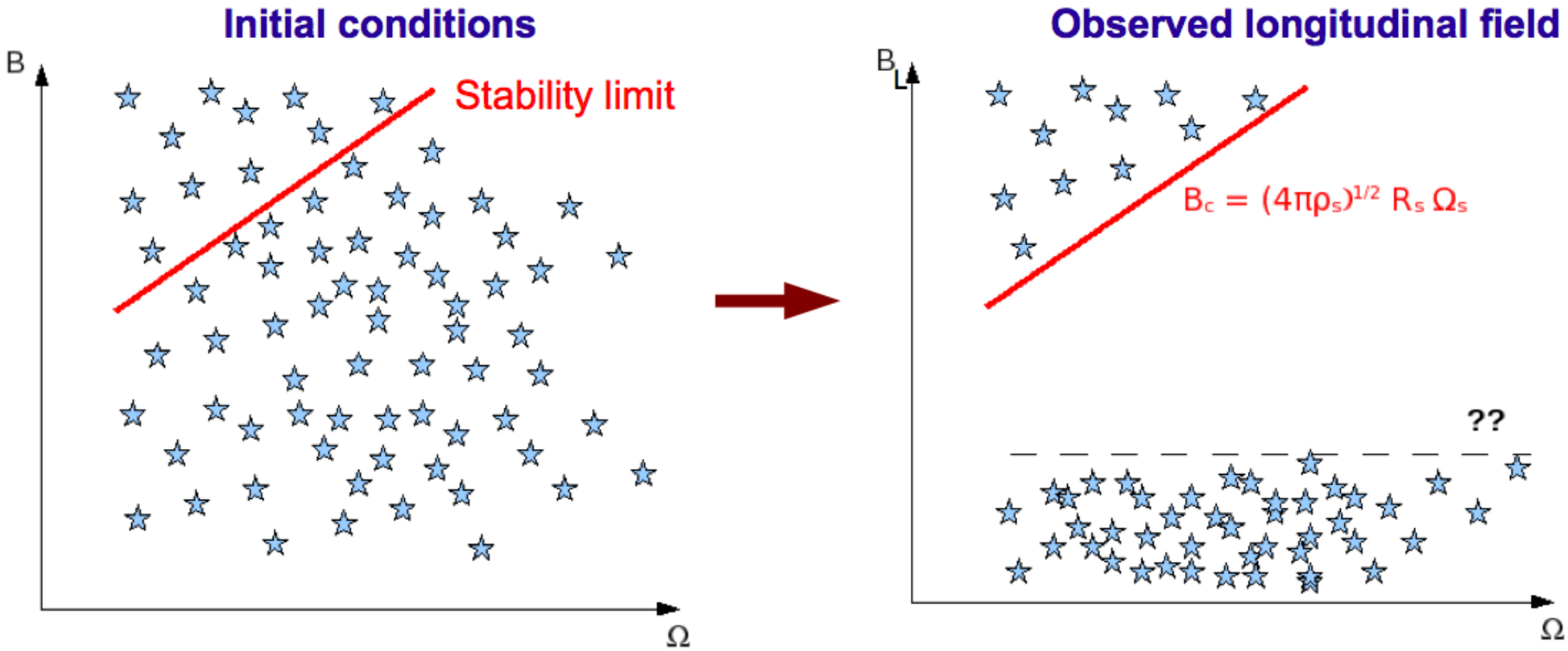
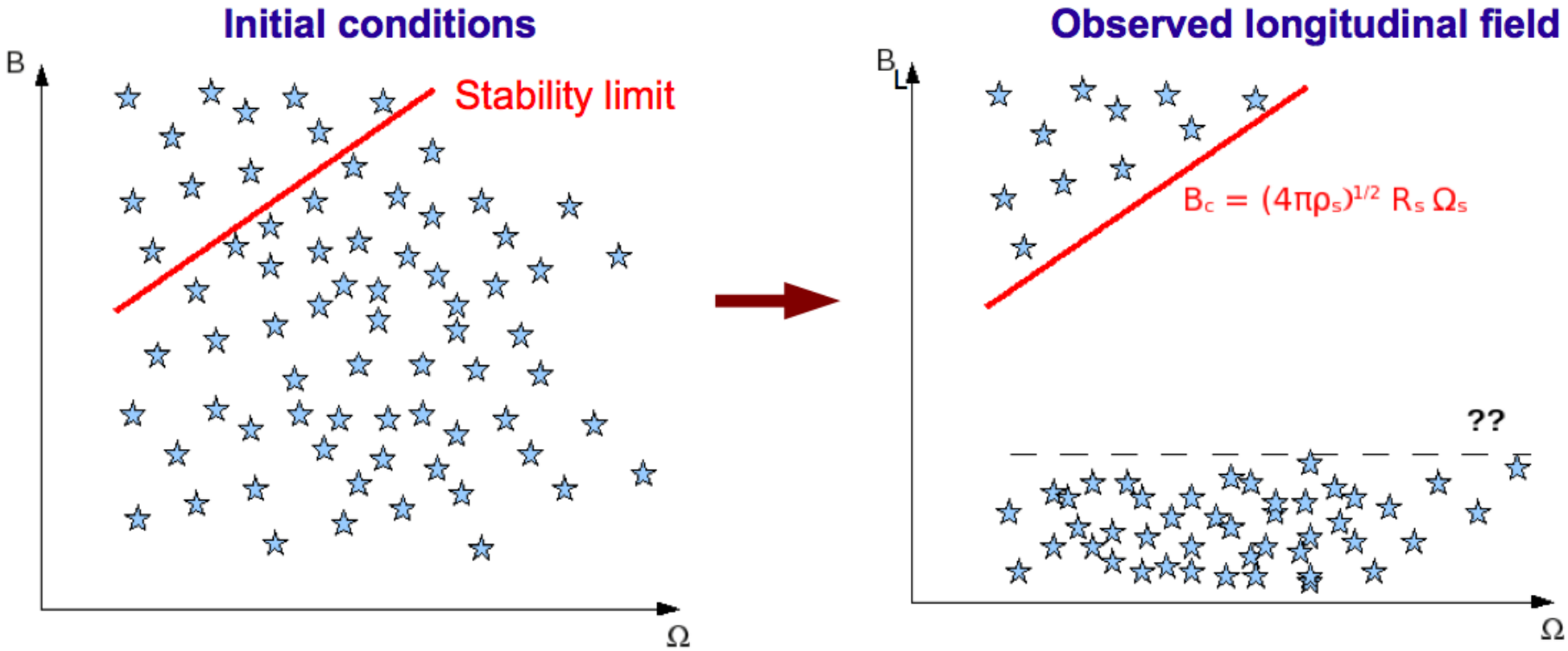


A B_L magnetic desert opens due to the polarity cancellation effect at the surface of stars with destabilized fields

- a good point : $B_c = (4\pi\rho)^{1/2} r\Omega$ at the surface of a typical Ap star (2 $M_\odot$, 2 $R_\odot$, $T_{\rm eff} = 10^4$ K, $P_{\rm rot} = 5$ d) is close to the observed value 300 G
- a prediction : B_c increases with Ω

A scenario for the Ap magnetic lower bound and the magnetic desert



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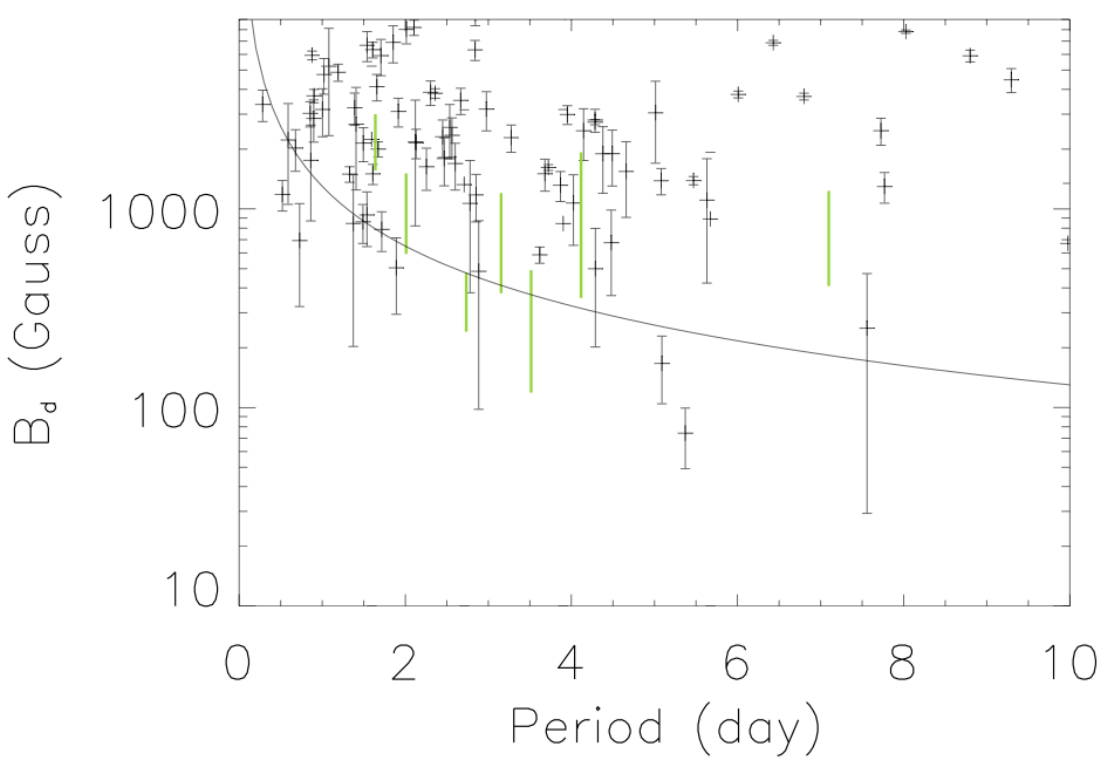
The Ω dependance of the lower bound of Ap/Bp magnetic fields

B_d and Ω from published data



— B_d lower limit from $B_d > 3.3\ B_L^{max}$

— B_d from inclined dipole models

Conclusions

- a new observational view :
  two magnetisms separated by a magnetic desert in B_l
- Vega-like magnetism hard but important to study
  a 10 targets Large Programme (!) on Narval
- triggers new ideas and modelling efforts (see next talk)
- extention to massive and pre-main-sequence stars ?

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