Spectropolarimetric studies of M dwarfs

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U. Christensen, X. Delfosse, J.-F. Donati, T. Forveille, T. Gastine, G. Hallinan, L. Hebb, G. Hussain, M. Jardine, P. Lang, P. Petit, A. Reiners, D. Shulyak, A. Vidotto, S. Wende, and the Bcool collaboration

2nd Bcool meeting
Göttingen 15–19 October 2012

Institut für Astrophysik Göttingen

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Outline

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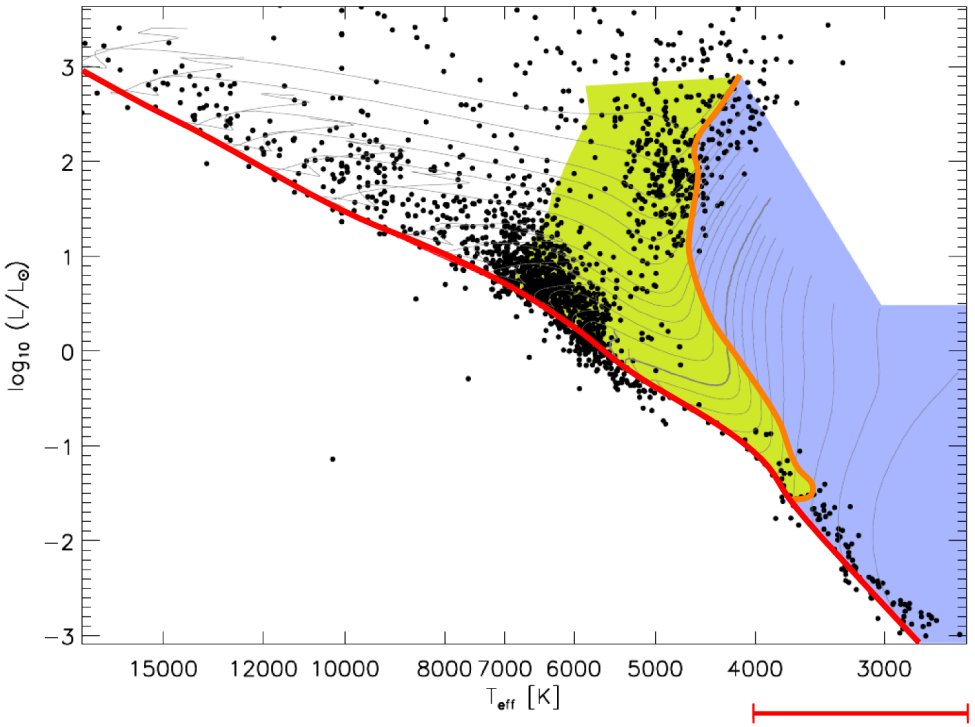
Fully-convective vs solar dynamo



Adapted from Reiners (2007)

M dwarfs

Solar-type dynamo

- $\alpha\Omega$: cyclonic convection + $d\Omega$
- Crucial role of the tachocline ?

M dwarf dynamo

- Importance of aspect ratio ?
- Differential rotation ? α^2 ?

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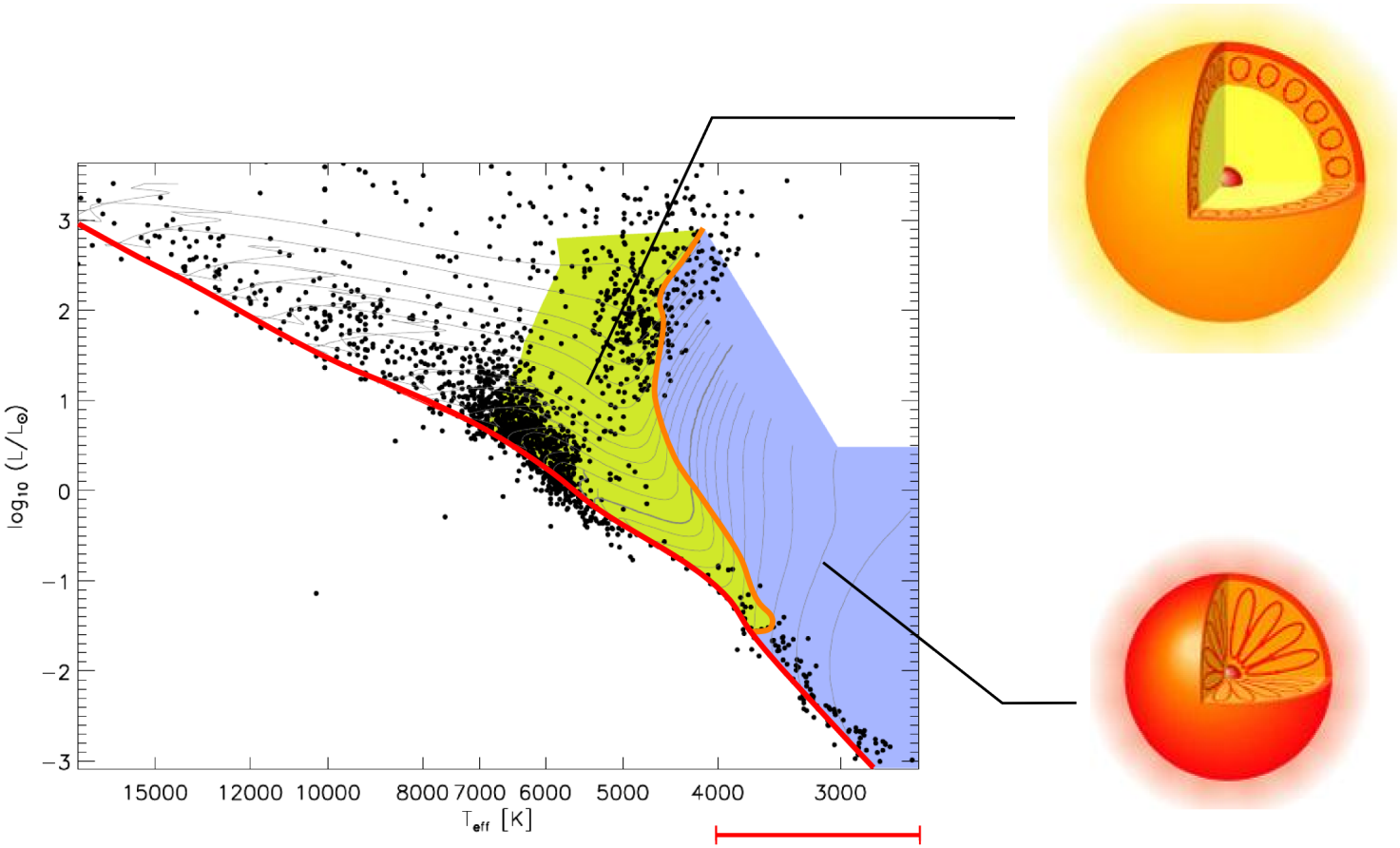

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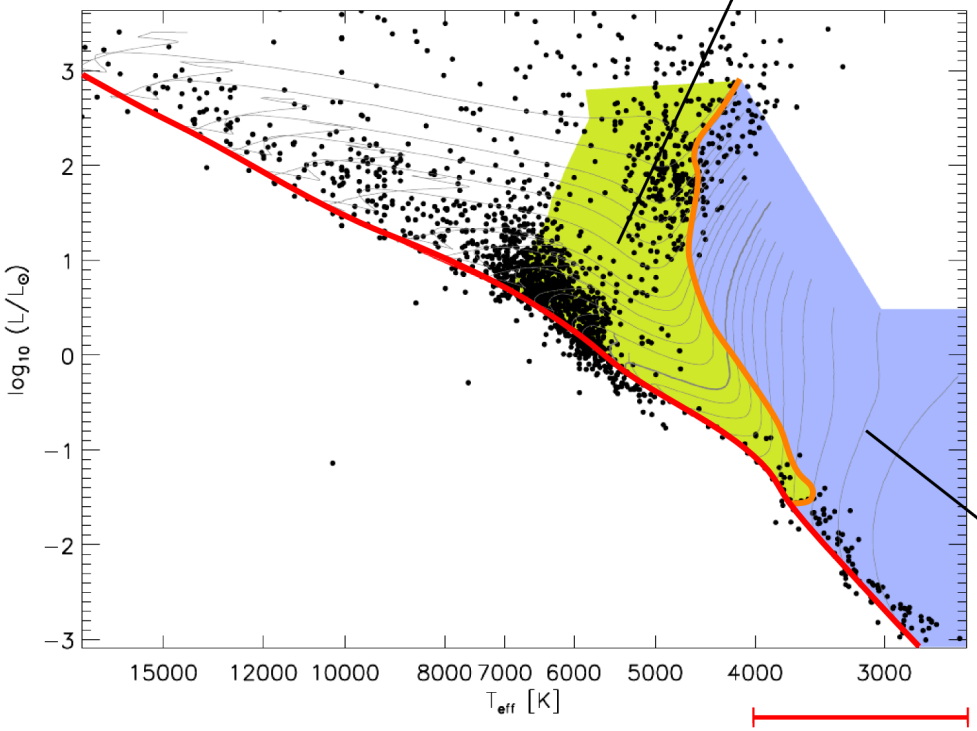

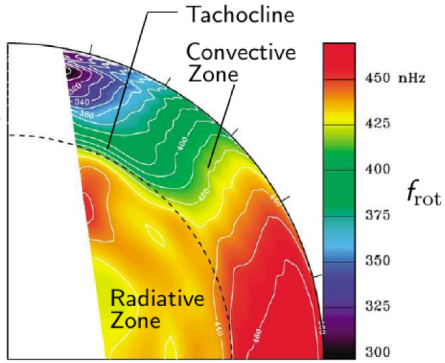

Schou et al. (1998)

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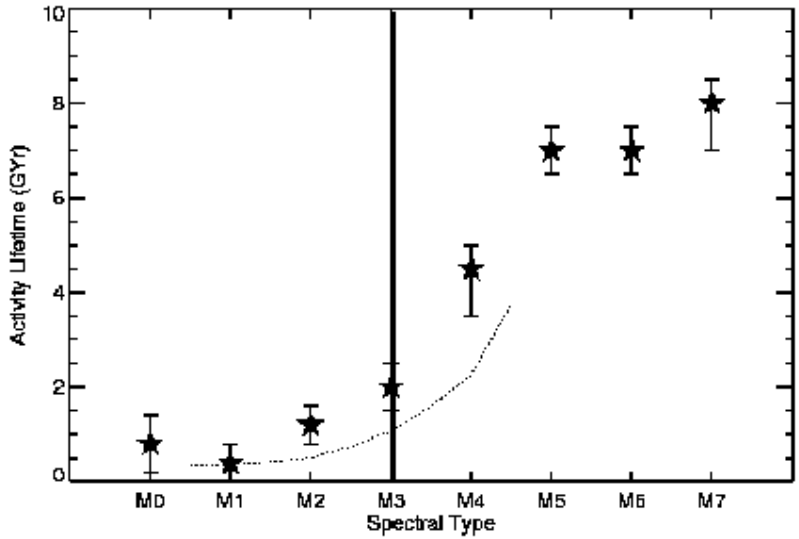
What magnetic fields may help us to understand ?

- Rotation
  - Winds on MS
  - Why mid-late M dwarfs brake less ?
  - *Reiners & Mohanty (2012)*
  - *Lang et al. (2012a,b)*
- Activity
  - FC dynamo ➔ activity ?
  - Radio – X-ray correlation down to ∼M7
  - Radio emission of VLMS and BDs
- Planets
  - SPI
  - Habitability
  - Prevents detection ?



West et al. (2008)

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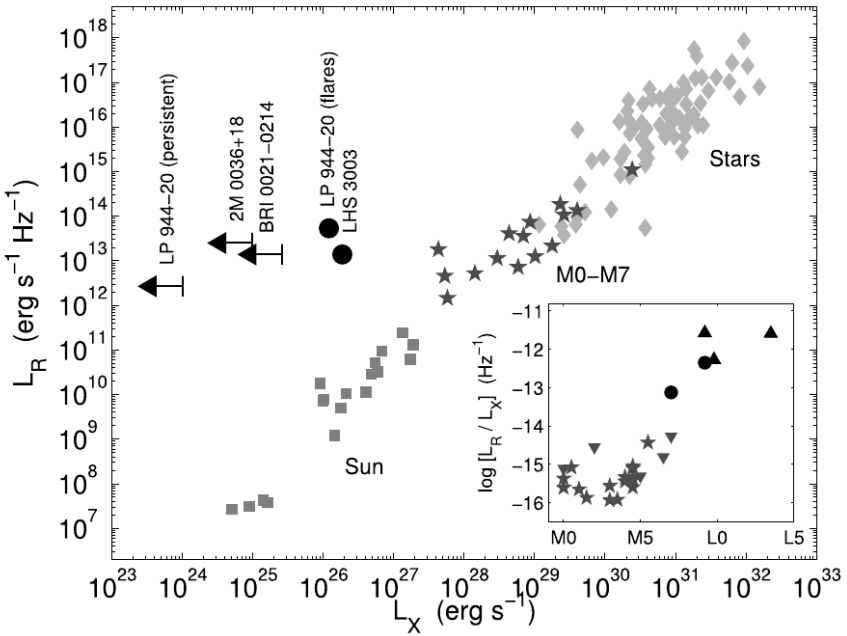


Berger (2006)

Outline

The survey

- Multi-line + New generation instruments ESPaDOnS and NARVAL

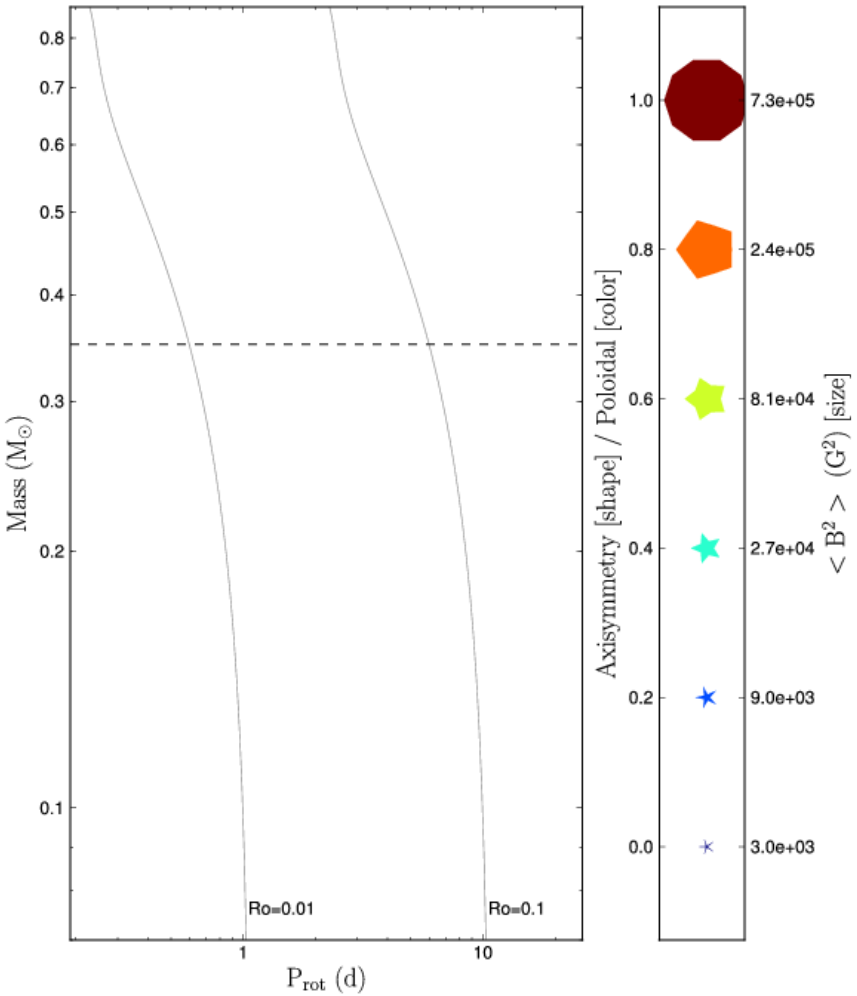
➥ Study of a sample of M dwarfs

- Explore dynamo response to
  - Mass
    - Depth of convective zone
  - Rotation period

- Measurements
  - Stokes V time-series
  - **B**: pol., tor., axi.
  - Differential rotation
  - Long-term evolution

- M dwarfs
  - 23 stars
  - $0.08 < M_\star < 0.75\ \mathrm{M}_\odot$
  - $0.33 < P_{\mathrm{rot}} < 18.6\ \mathrm{d}$
  - Active

Results: the mass-period diagram



- Spectropolarimetry
  - Fully-convective stars
    - Stronger large-scale **B**
    - Stronger dipolar component
  - Very low mass stars
    - Similar stellar parameters
    - Two distinct magnetisms
    - ➥ strong/weak dipole

    Morin, Donati et al. (2008–2010)
- Unpolarized spectroscopy
  - No difference fully-/partly-conv.
  - No bimodal distrib. in spectropol. sample
  - ➥ Only large-scale **B** affected

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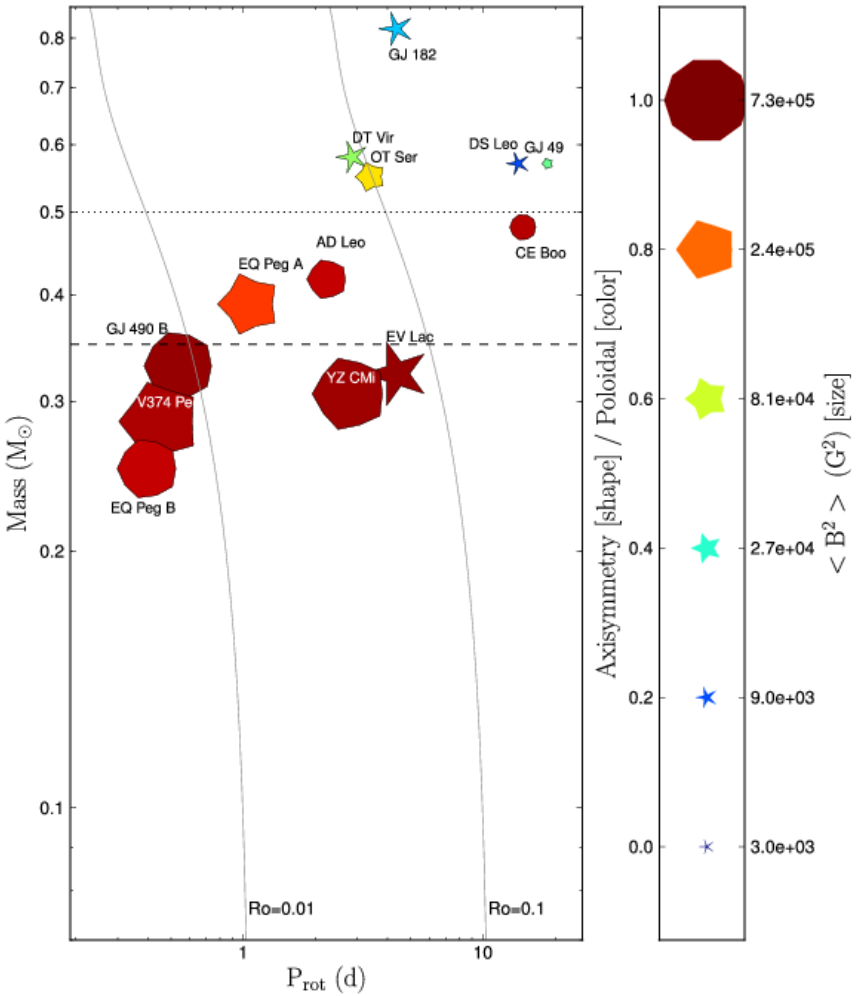

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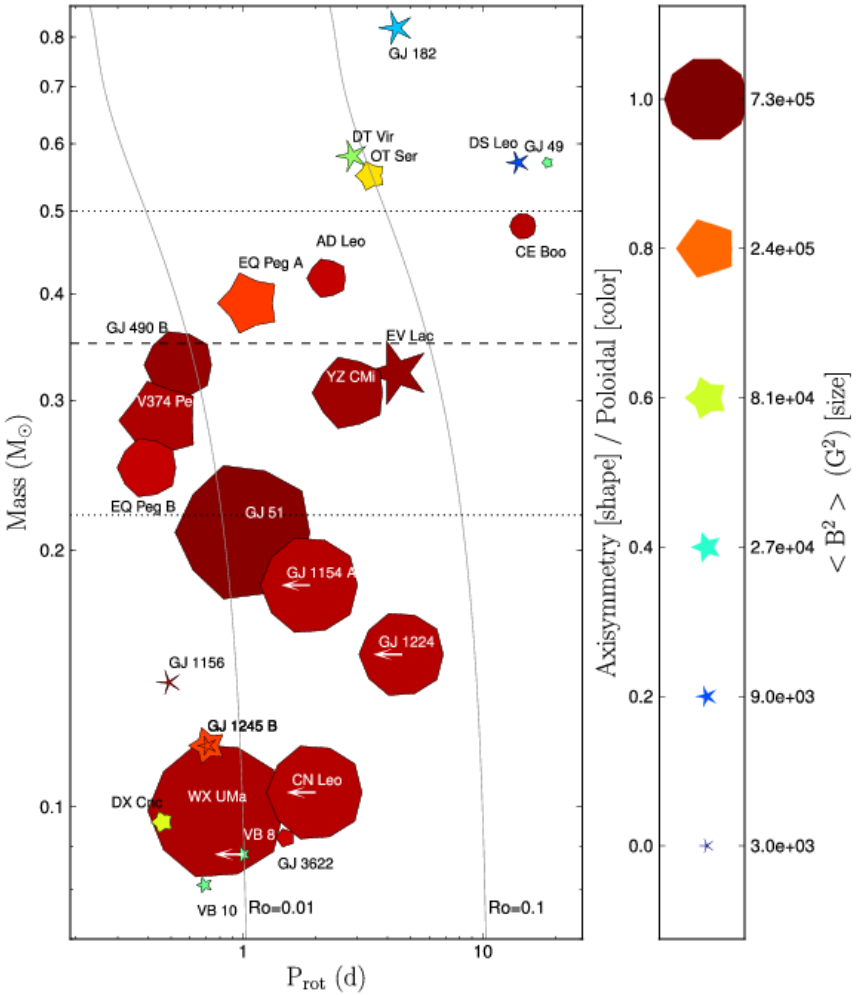

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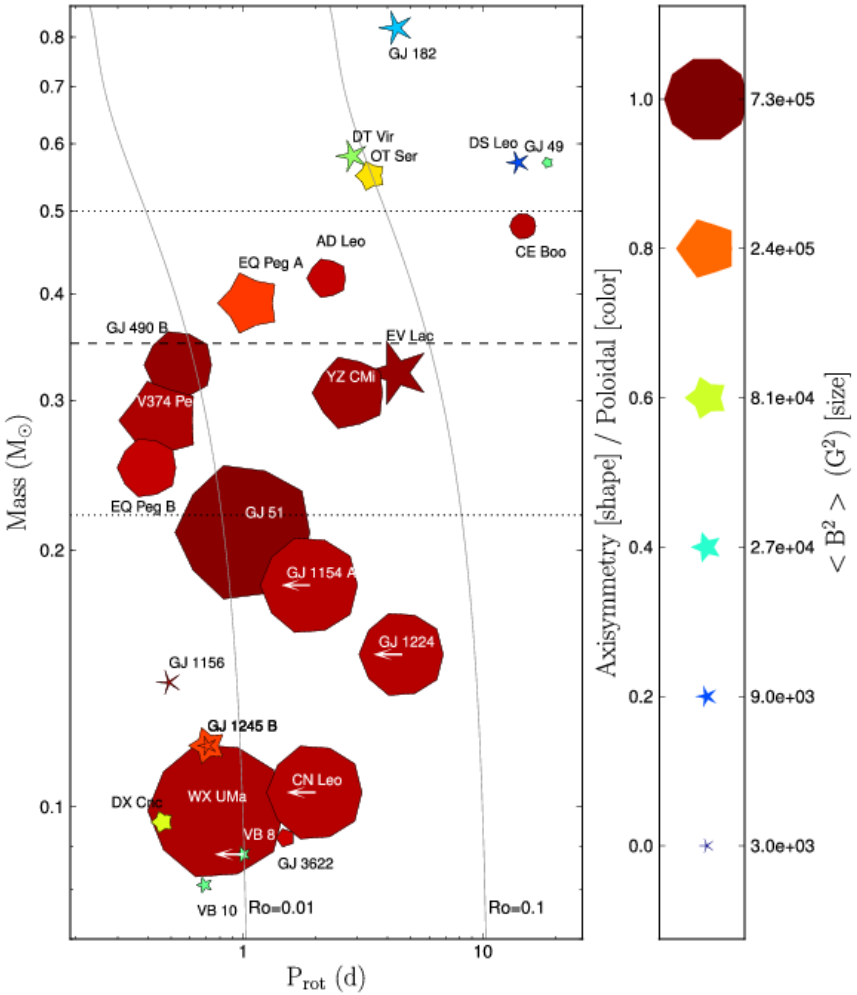

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Dynamo bistability among VLMS

- Weak- and strong- field dynamos
  - 2 branches: $\neq$ force balances
  - *Morin, Dormy, Schrinner & Donati (2011)*
- Effect of inertia in DNS
  - Transition to dipole at low Ro_ℓ
    Christensen & Aubert (2006)
  - $\exists$ dipolar and multipolar branches at low Ro_ℓ
    Schrinner et al., Gastine et al. (2012)

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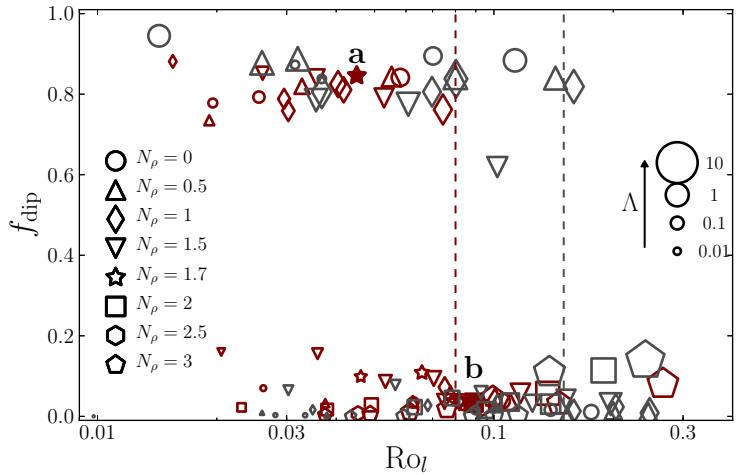
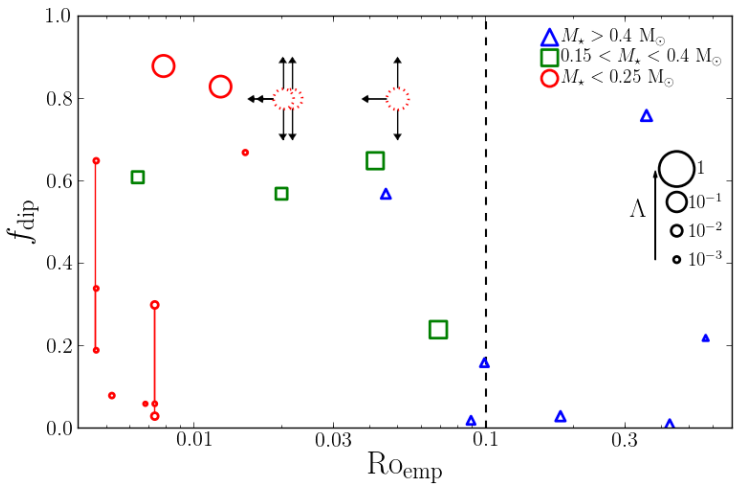


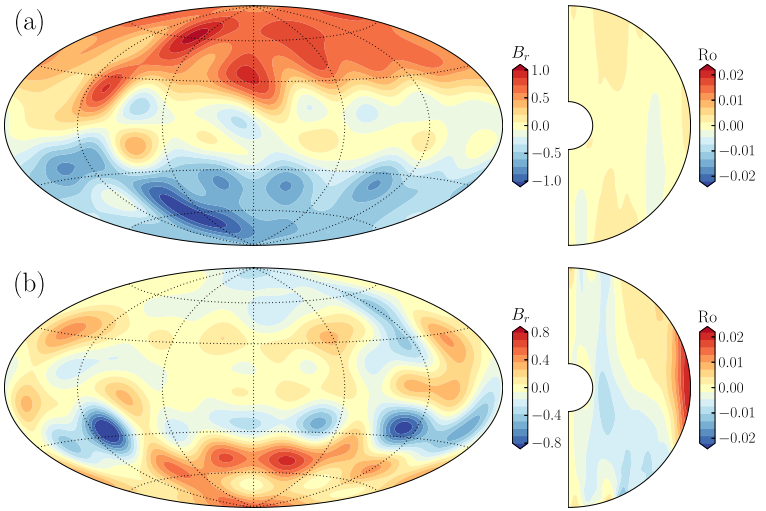
Gastine et al.(2012)



Gastine, Morin et al.(submitted)

Dynamo bistability among VLMS: further observations

- Differential rotation
  - Dipolar field ↔ ∼ solid-body
  - Multipolar field ↔ strong DR
- Extent of the bistable domain
  - Multipolar fields expected over wide range of $M_\star$, $P_{\rm rot}$
  - Effect of age?



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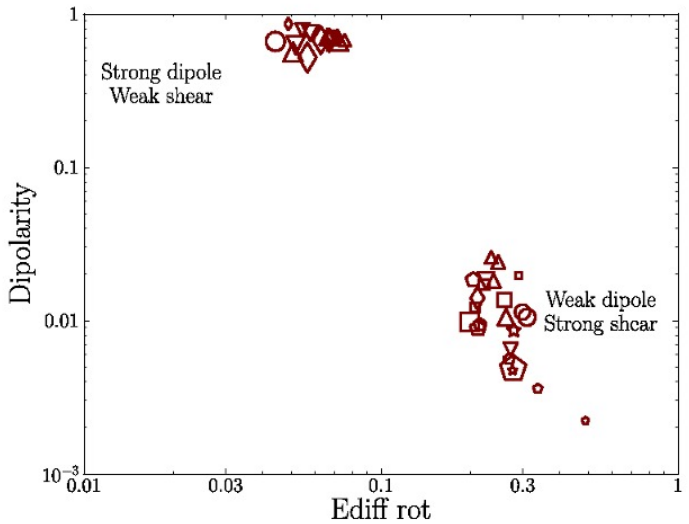

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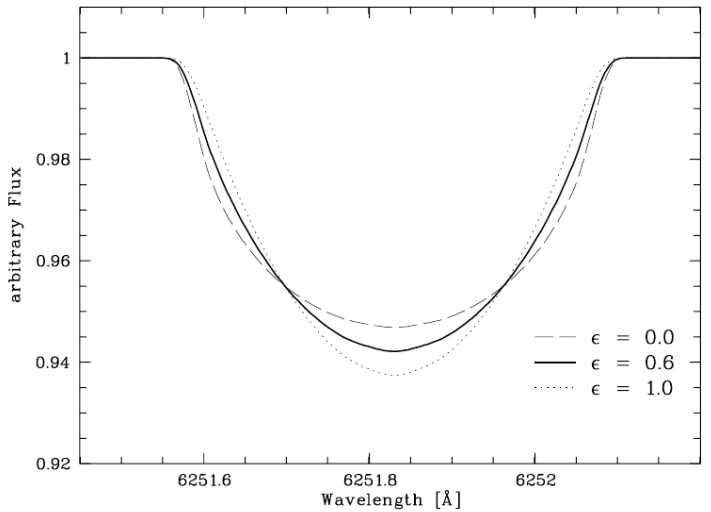

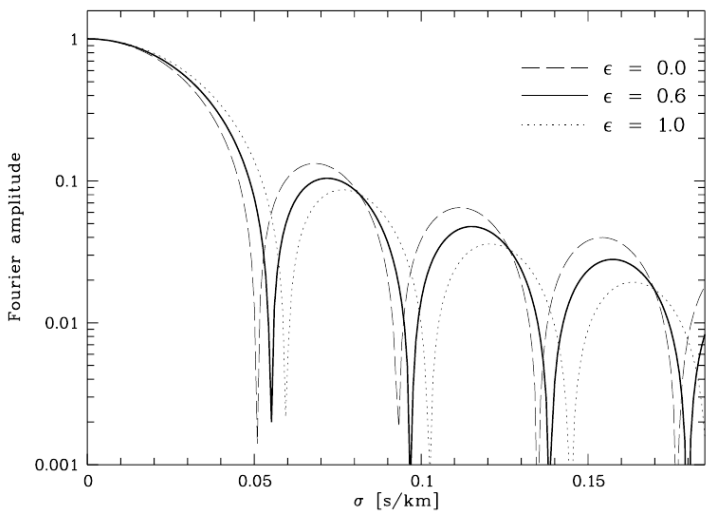

Reiners & Schmitt (2002)

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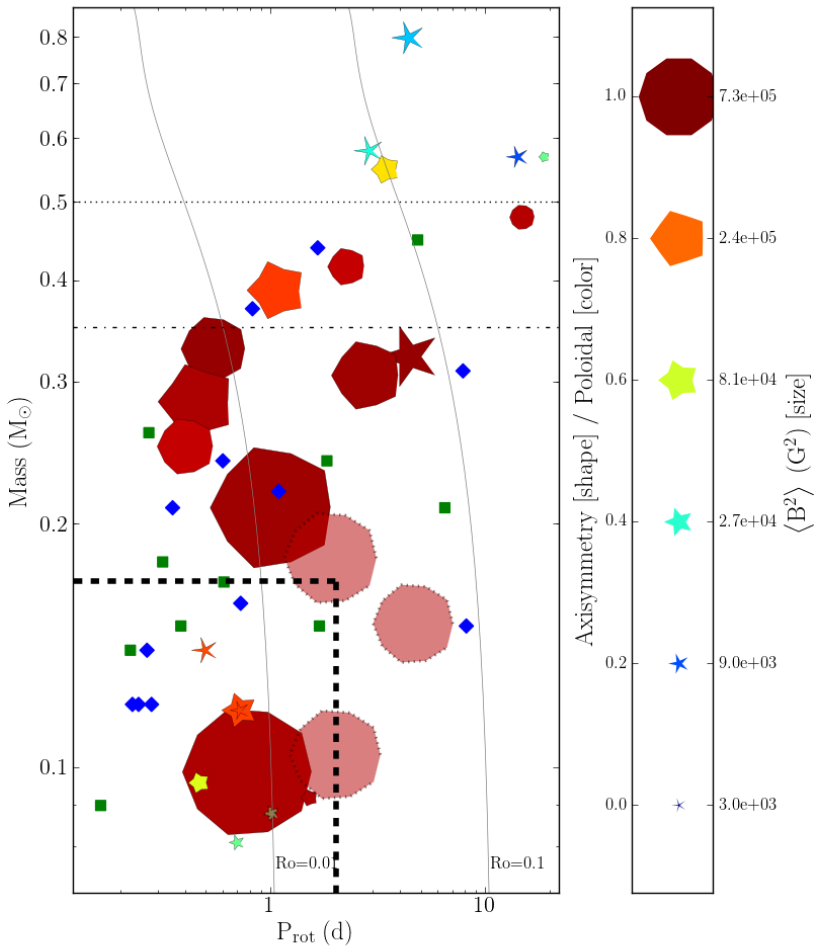
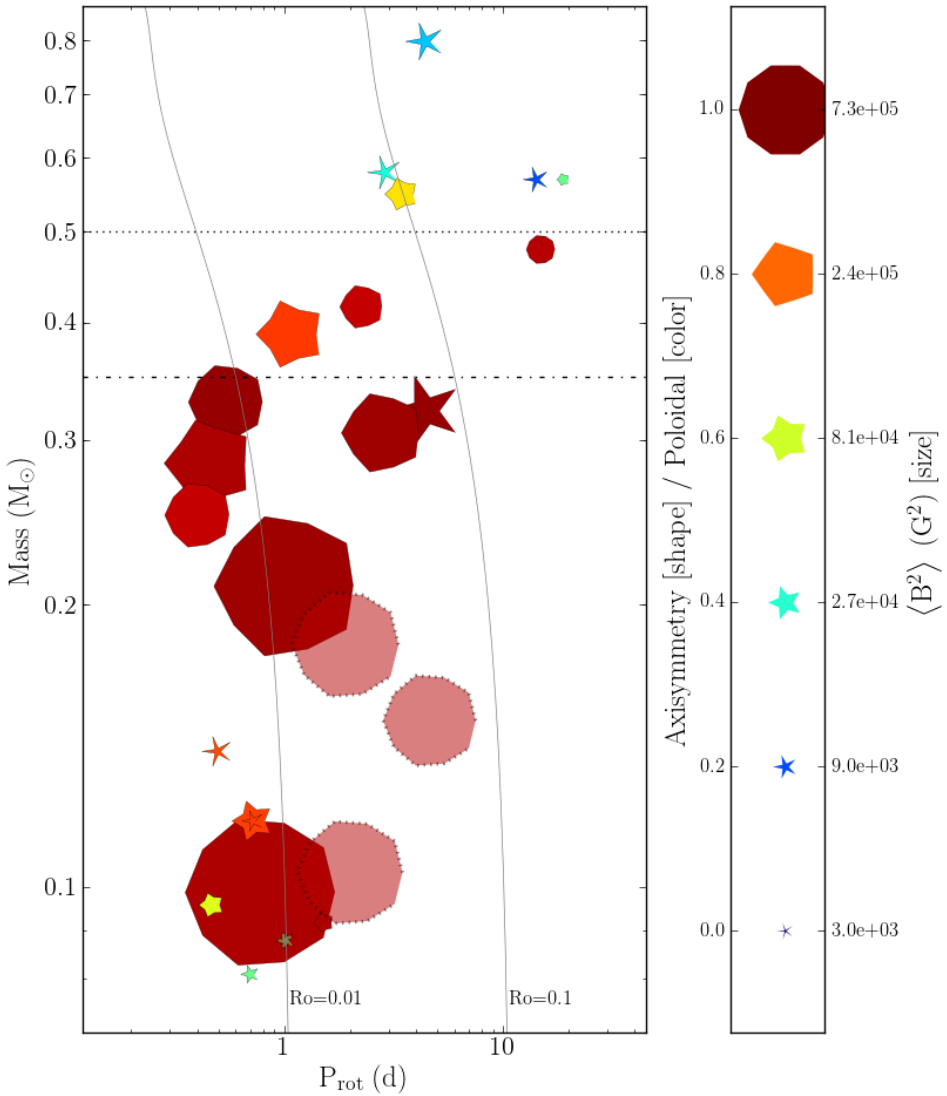


Sample proposed for CFHT 13AB

What is missing in the present data ?

- Disentangling Mass–$P_{\rm rot}$
  - Extend to weakly-active stars
- Very low mass regime
- Long-tem evolution ➔ cycles ?
- Relation w/ other mesurements
  - Total magnetic field *Bf*
  - Activity indices
- Effect of binarity ?



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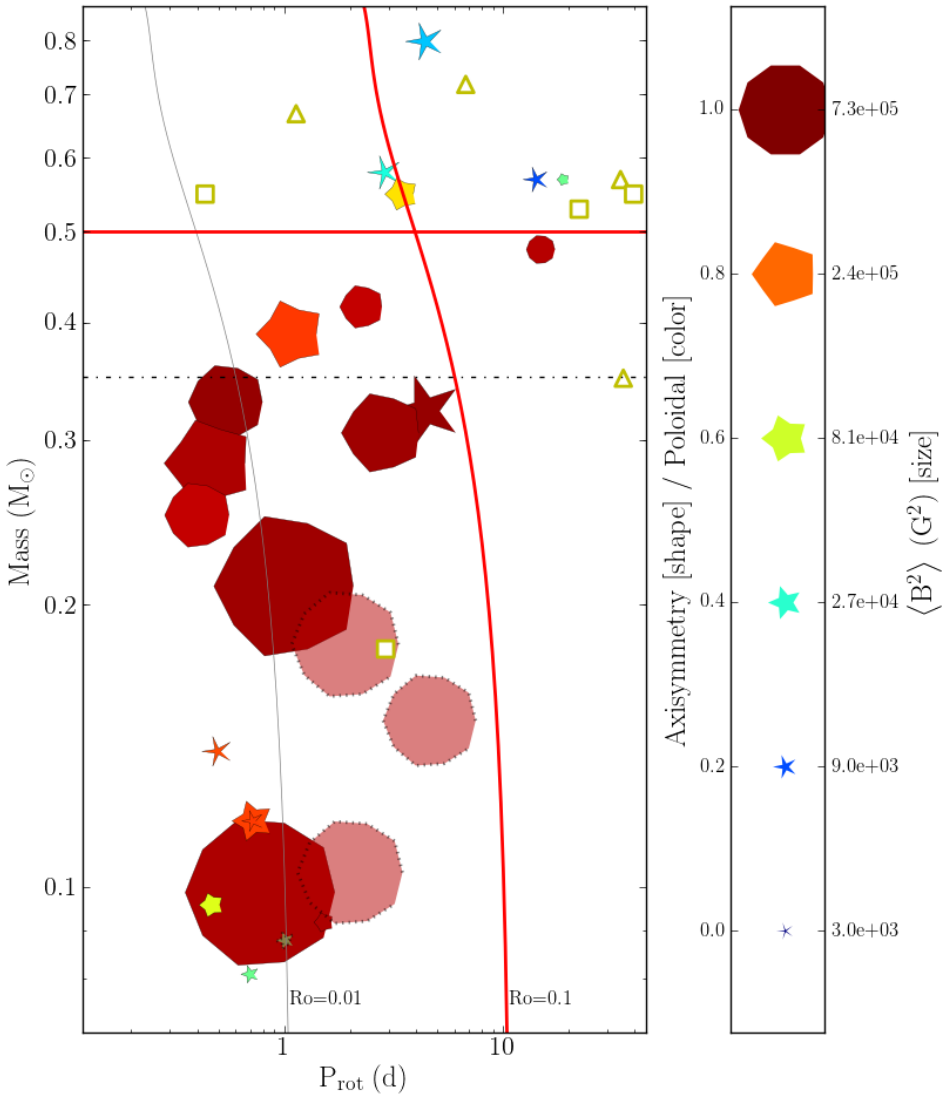
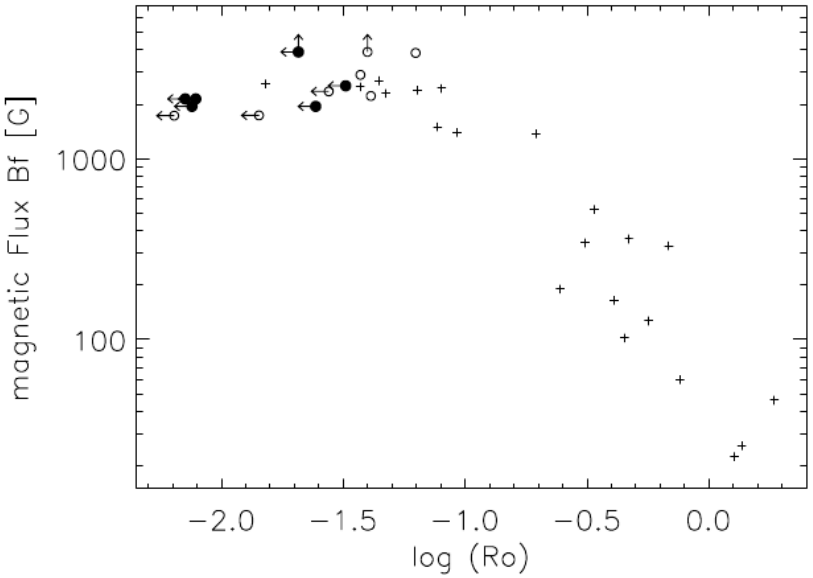
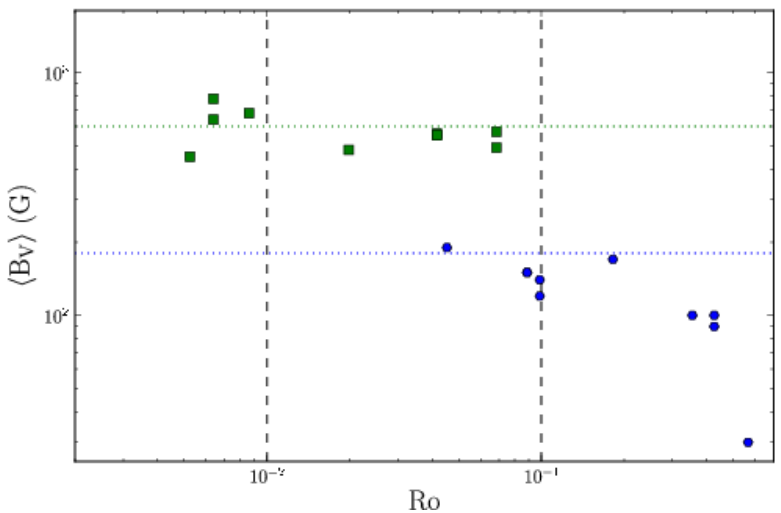


Bf measurements from unpolarised spectroscopy

- Spectroscopy + spectropolarimetry
  - Ratio of large-scale to total field
    - Increase at FC boundary
- Low number of objects
- Non-simultaenous measurements
  - Rotational modulation ?
  - Long-term variations ?
- Very low mass domain



Reiners, Basri & Browning (2009)



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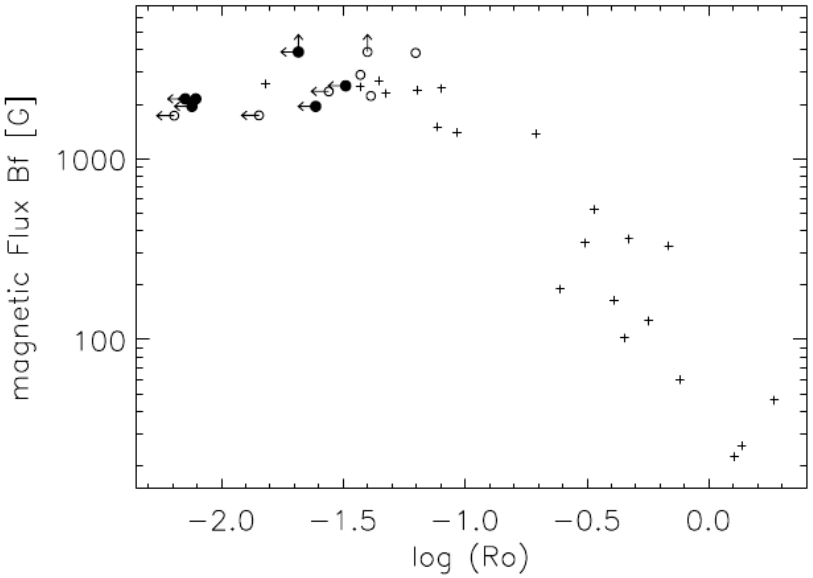

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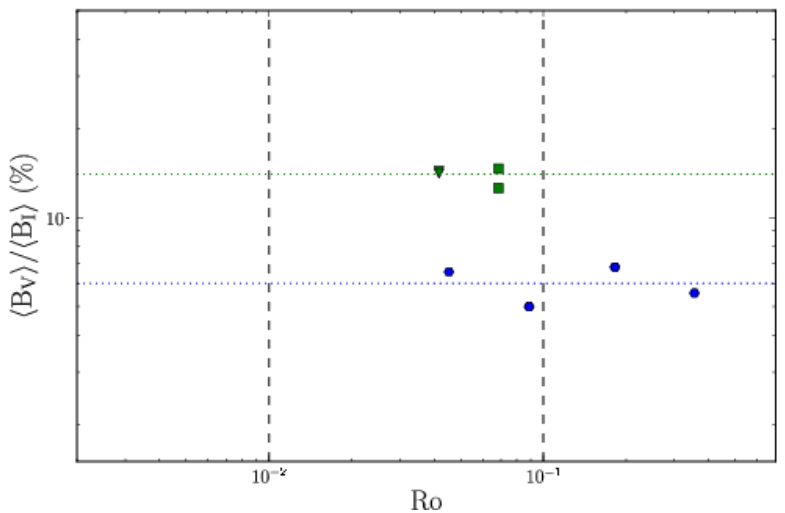

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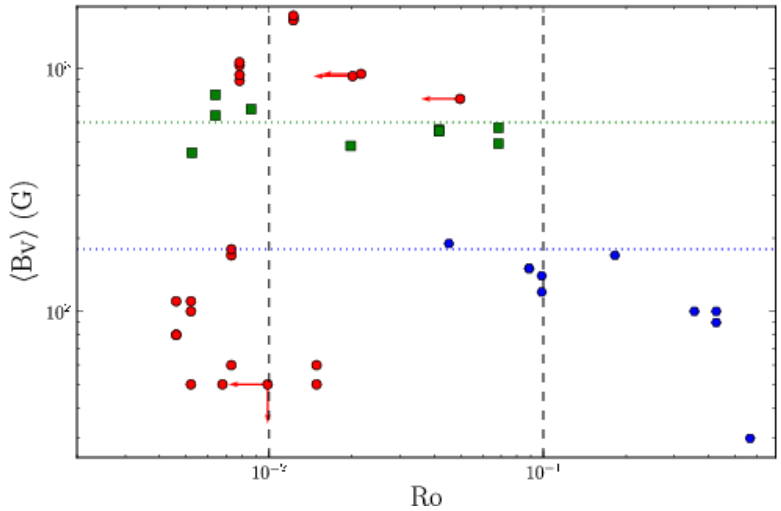
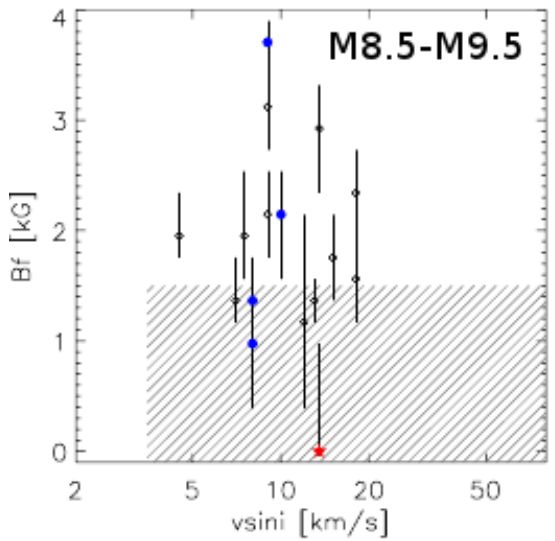
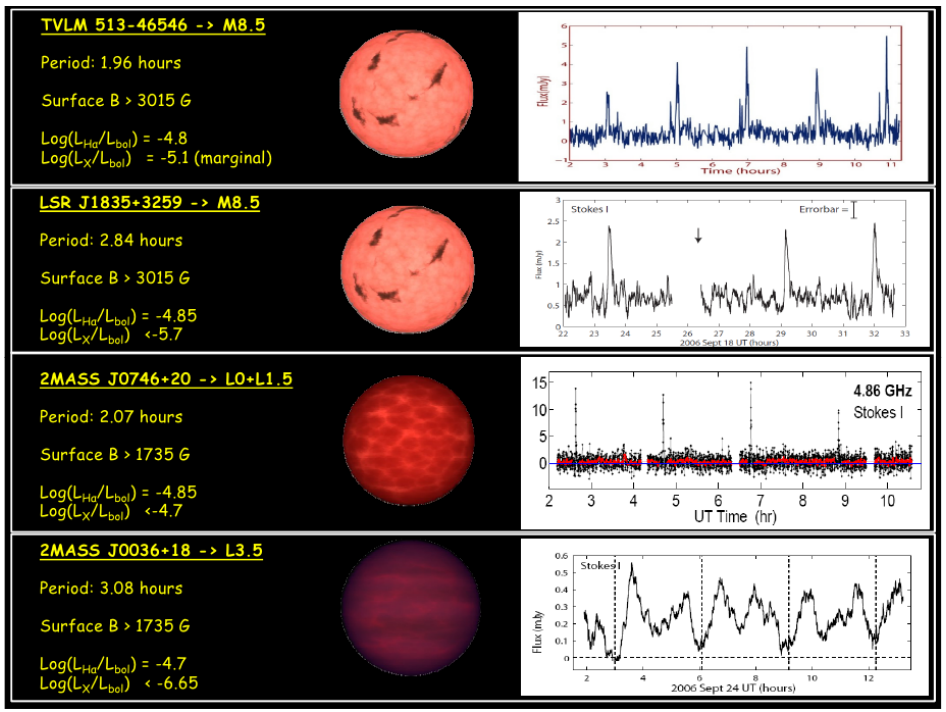




Reiners & Basri (2010)

Radio observations brown and red dwarfs

- Polarized periodic radio emission
  - ➥ ECMI emission
  - ➥ Similar giant planets, AKR
- Observed on M/L dwarf
  - ➥ How related to surface field?
- Systematic radio obs of ZDI targets
  - G. Hallinan et al.
- *McLean et al. (2012)* predict 8 kG dipole on a M7.5 dwarf
  - Included in the CFHT 13AB sample



Credit: G. Hallinan

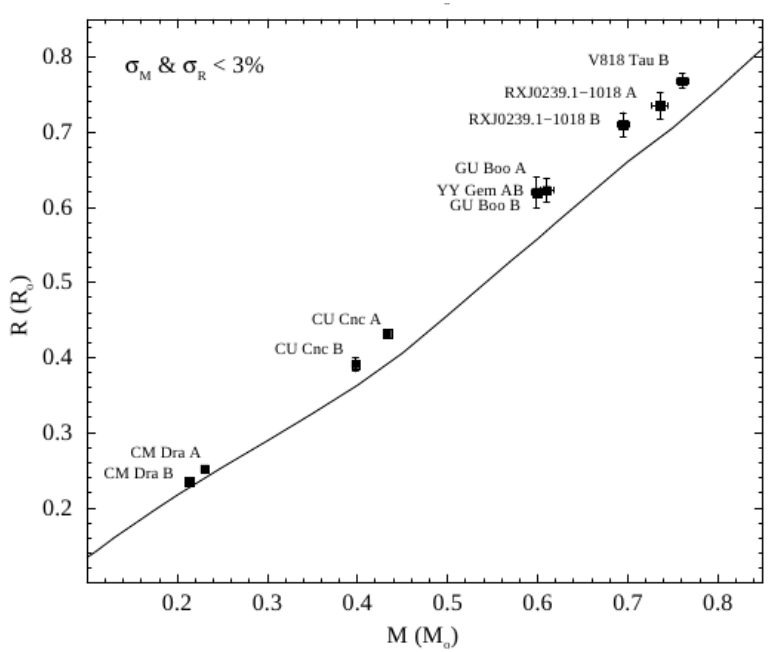
Effect of binarity on magnetism

- Close eclipsing binaries
  - Strong tidal interaction

➥ Effect on dynamo ?

➥ Related to SPI

- Stellar models: Mass-Radius relationship
  - Large discrepancy for EBs
  - Accurate for inactive objects



Ribas (2006)

Results and prospects on M dwarfs magnetism

- 1st spectropol. survey of M dwarfs
  - Topology change $\sim$ FCL
  - Bistability among VLMS
- Investigate bistability
- Disentangle Mass–$P_{\rm rot}$
- Long-term evolution
- Multi-technique approach
- Close binaries
- Link w/ **B** of TTS *Gregory et al. (2012)*
- Detection of extrasolar planets
- ...