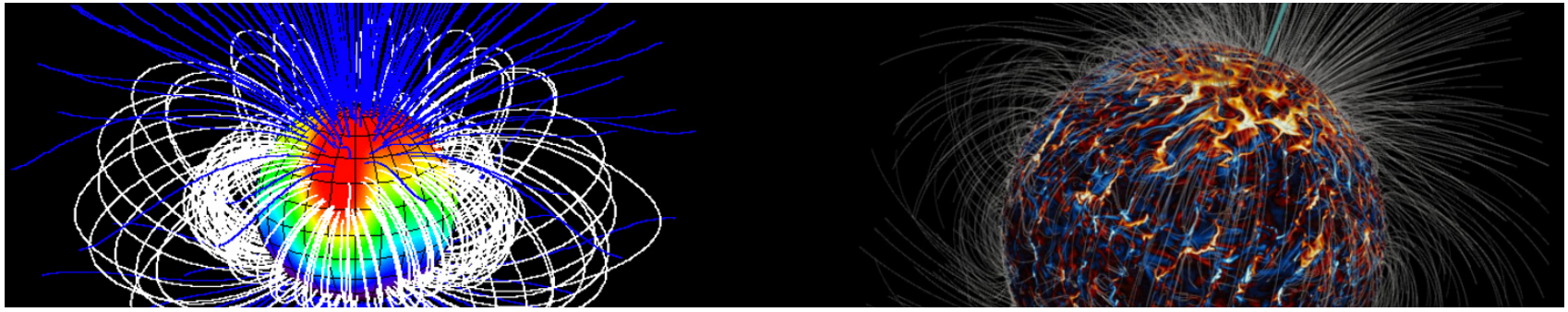

EXPLAINING THE COEXISTENCE OF LARGE-SCALE AND SMALL-SCALE MAGNETIC FIELDS IN FULLY CONVECTIVE STARS

Rakesh K. Yadav[1,2], Ulrich R. Christensen[2], Julien Morin[3], Thomas Gastine[2], Ansgar Reiners[4], Katja Poppenhaeger[1], and Scott J. Wolk[1]

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[2] Max-Planck-Institut für Sonnensystemforschung, Justus-von-Liebig-Weg 3, D-37077 Göttingen, Germany
[3] LUPM, Université de Montpellier, CNRS, Place Eugène Bataillon, F-34095, France
[4] Institut für Astrophysik, Universität Göttingen, Friedrich Hund Platz 1, D-37077 Göttingen, Germany

Julien Morin

Laboratoire Univers et Particules de Montpellier

5th Bcool meeting

16th February 2016

Outline

1 Magnetic fields of fully-convective stars

2 A brief overview of M dwarfs' magnetism

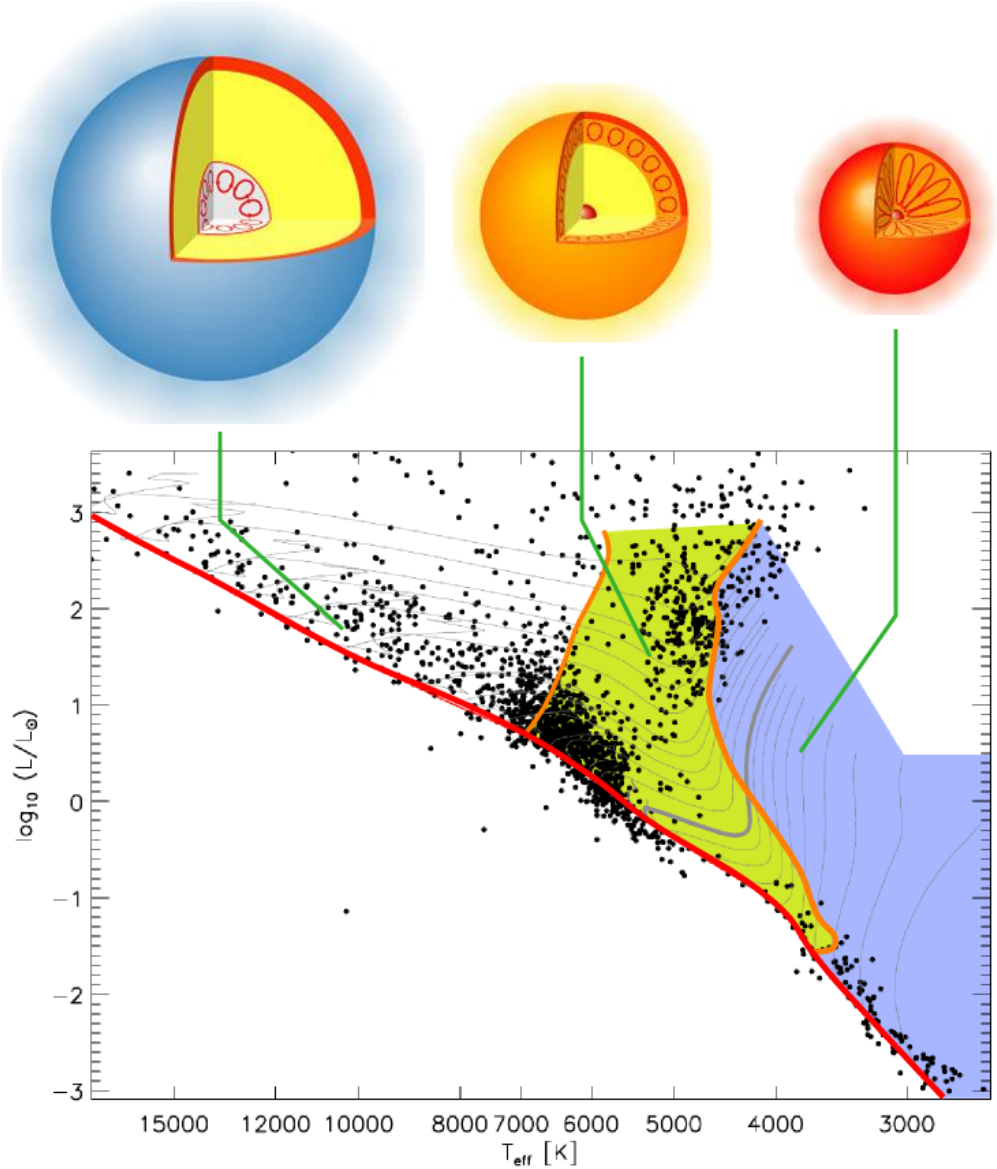
3 Numerical simulations of dynamo action in FC stars

4 Summary

Outline

1. Magnetic fields of fully-convective stars
   - The origin of stellar magnetic fields
   - What magnetic fields may help us to understand ?
2. A brief overview of M dwarfs' magnetism
3. Numerical simulations of dynamo action in FC stars
4. Summary

The origin of stellar magnetic fields



Adapted from Reiners (2008)
star sketches credit J. Bennett et al.

High-mass star:
Simple steady field

➥ Fossil field ?

Partly convective star:
Complex **B**
temporal evolutions

➥ Solar-type dynamo

Fully convective star:
No tachocline

➥ Non-solar dynamo

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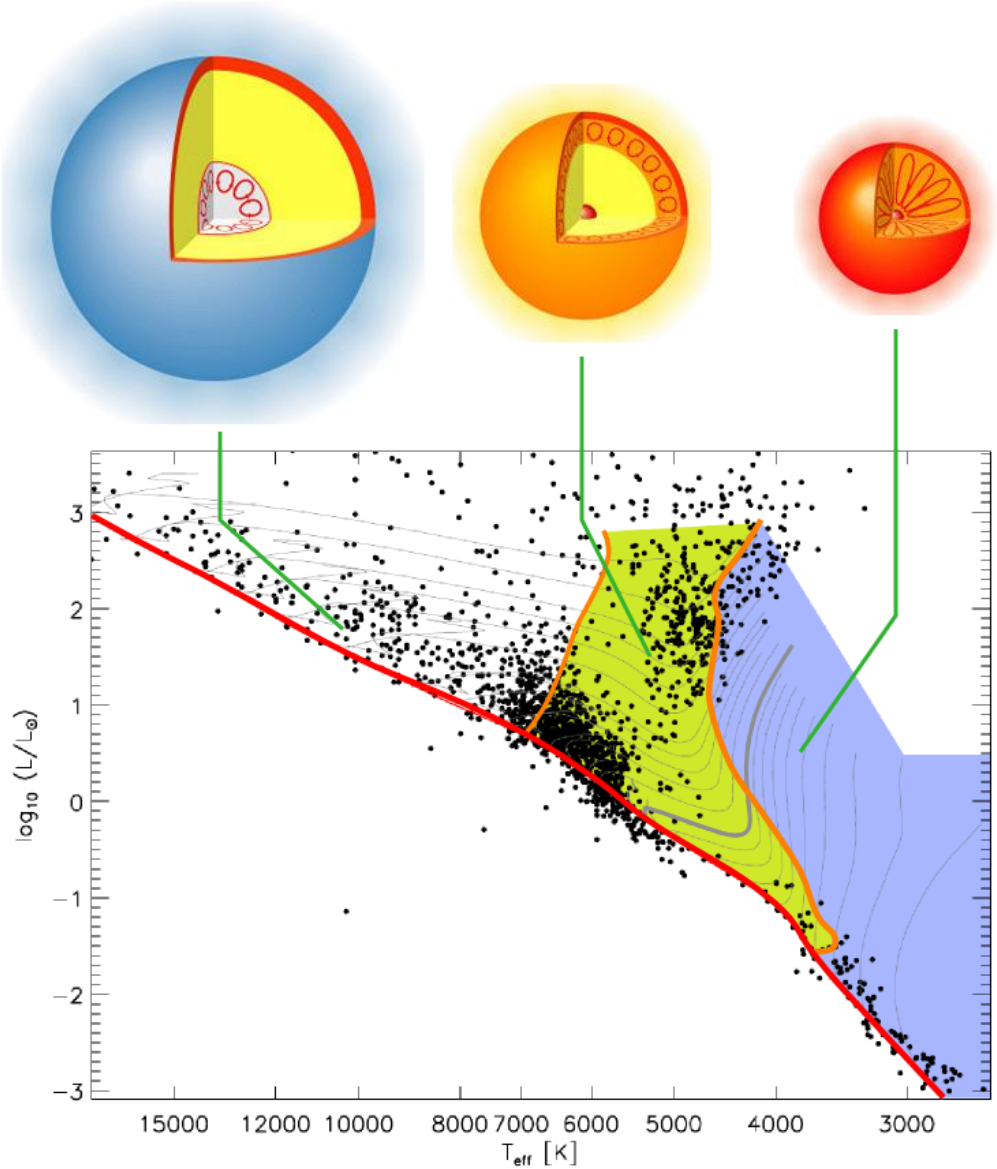

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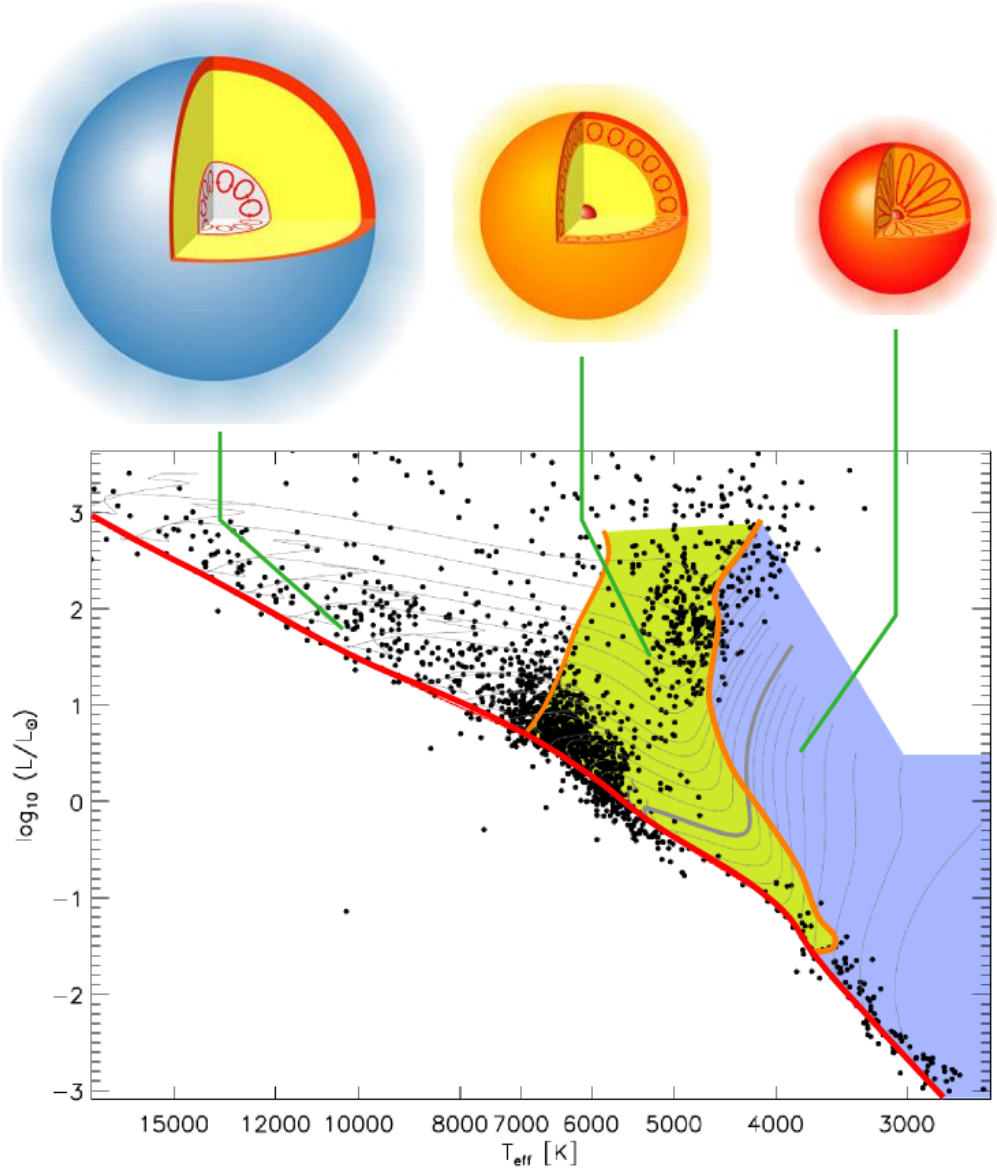

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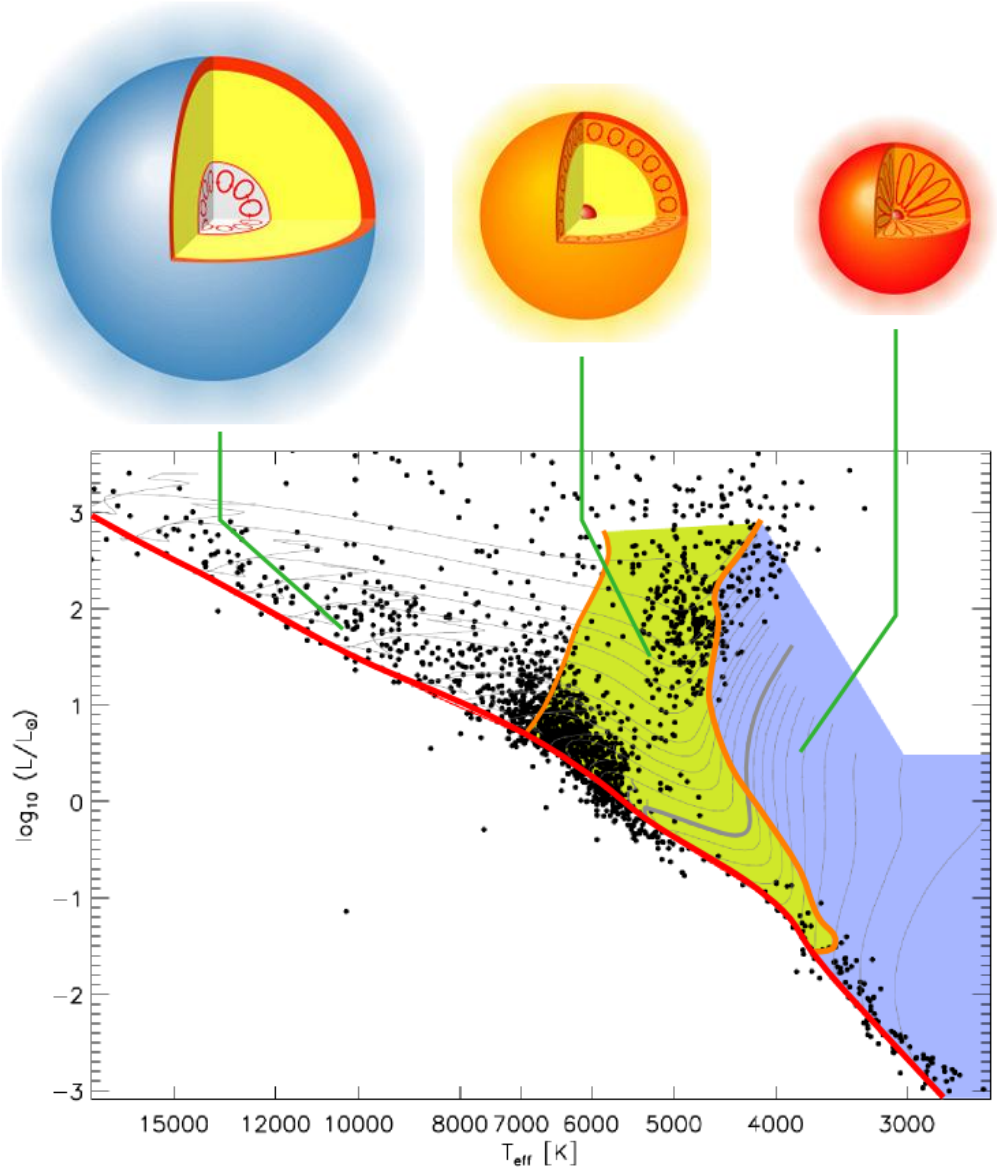

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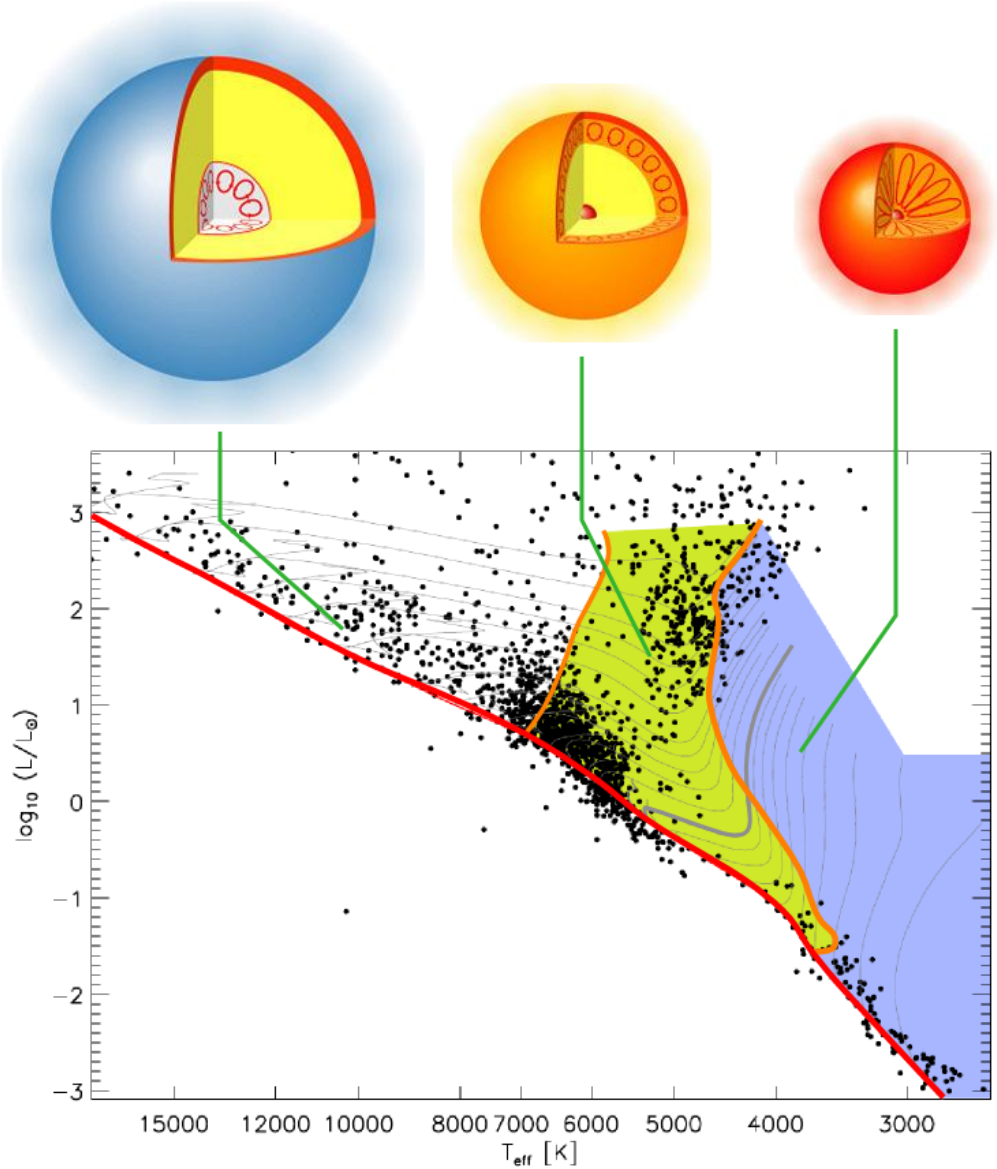

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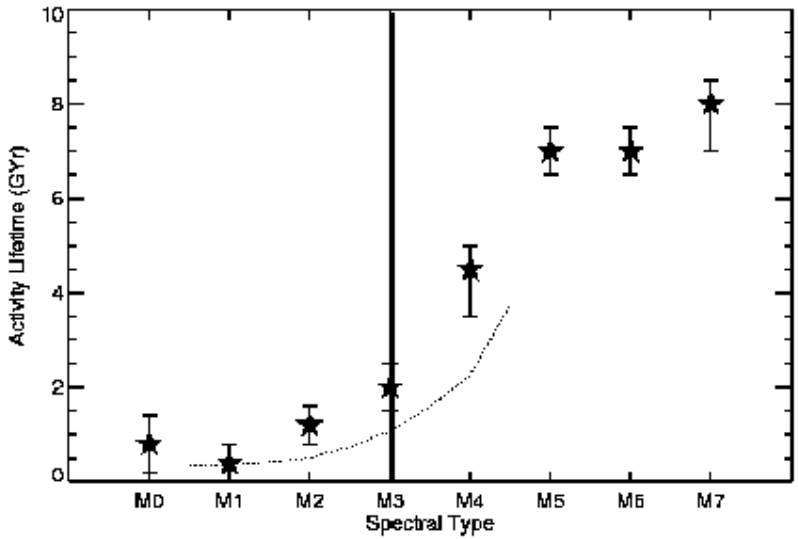
Relation
$\star$ parameters
$\leftrightarrow$ **B** properties?

What magnetic fields may help us to understand ?

- Rotation
  - Winds on MS
  - Why mid-late M dwarfs brake less?
  - *Reiners & Mohanty (2012)*?
  - *Vidotto et al. (2013); Lang et al. (2014)*
- Activity
  - FC dynamo ➔ activity ?
  - Radio – X-ray correlation
  - Radio emission of VLMS and BDs
- Planets
  - SPI
  - Habitability
  - Prevents detection ?



West et al. (2008)

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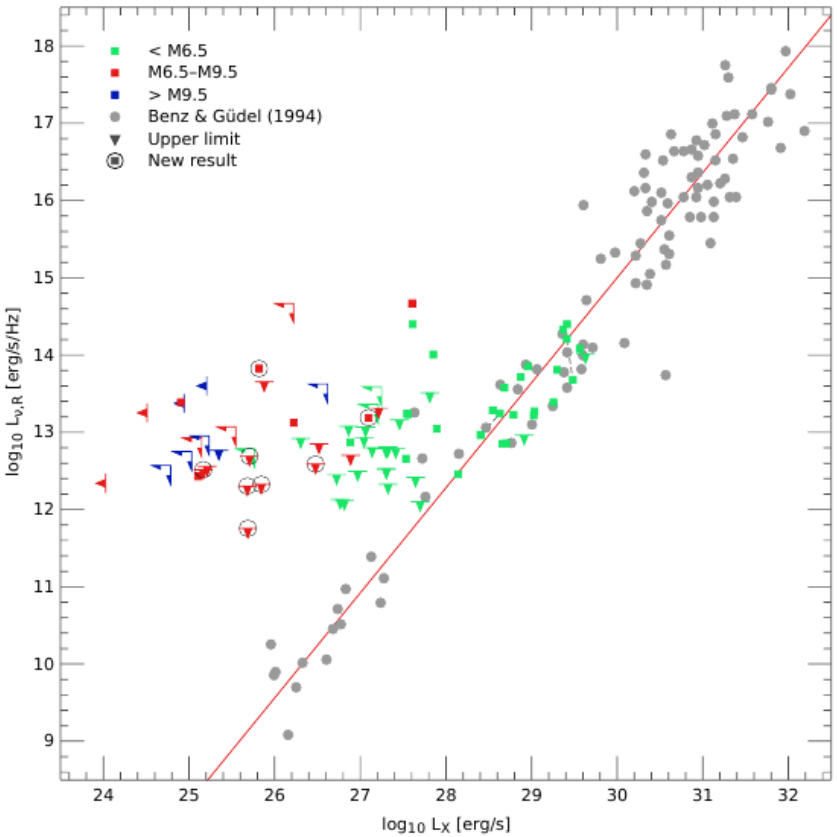

Williams, Cook & Berger (2013)

Berger et al. (2006) +
Hallinan et al. (2008) +

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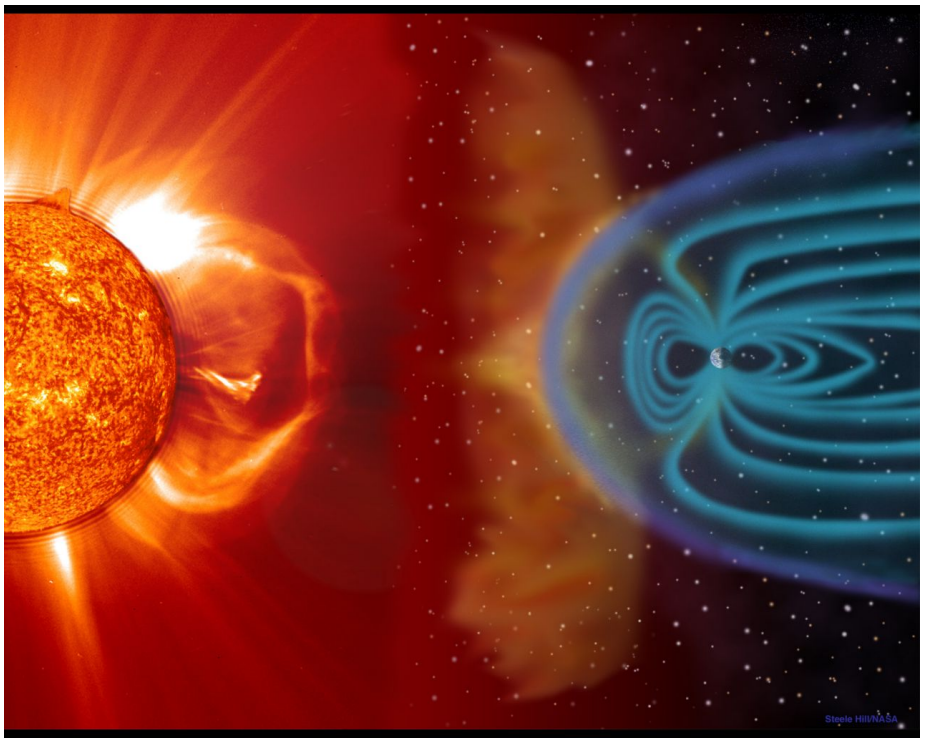

Credit: NASA / ESA

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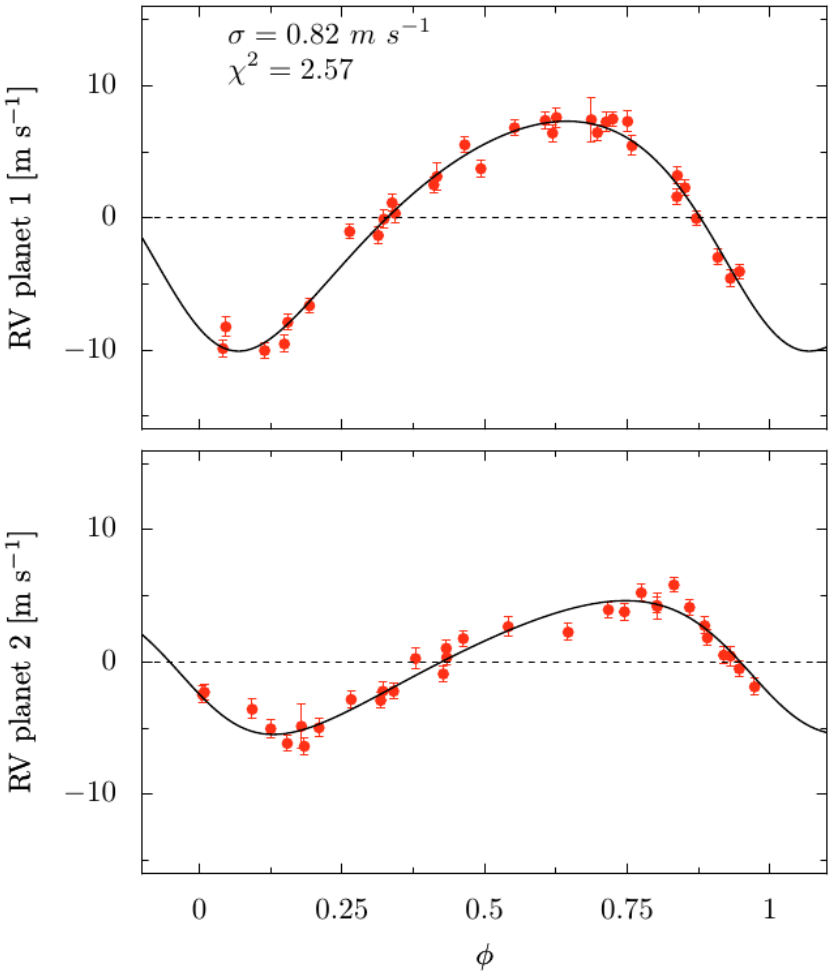


GJ 674 *Bonfils et al. (2007)*

Outline

1 Magnetic fields of fully-convective stars

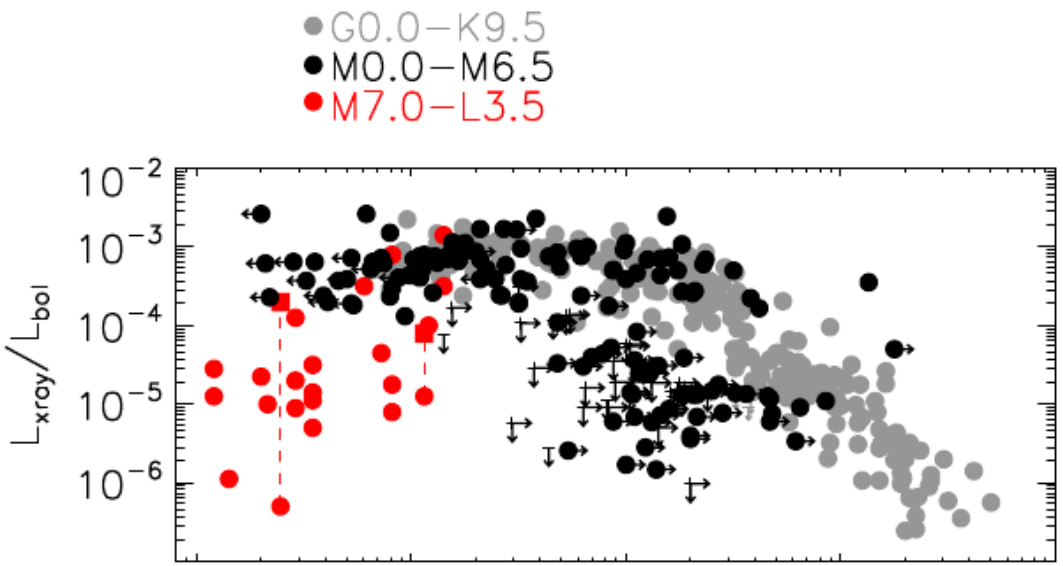
2 A brief overview of M dwarfs' magnetism
- Activity of M dwarfs
- Magnetic fields of M dwarfs in unpolarised light
- The first spectropolarimetric survey

3 Numerical simulations of dynamo action in FC stars

4 Summary

Activity of M dwarfs

- Rotation–activity relation
  - Early-mid M dwarfs: similar G-K
    - High Ro: anti-correlated
    - Low Ro: plateau
    - No break at FCL
  - Late M dwarfs
    - $\exists$ low activity at low Ro
- Activity cycles
  - Evidence for long-term variability
  - Hints of cycles



McLean et al. (2011)

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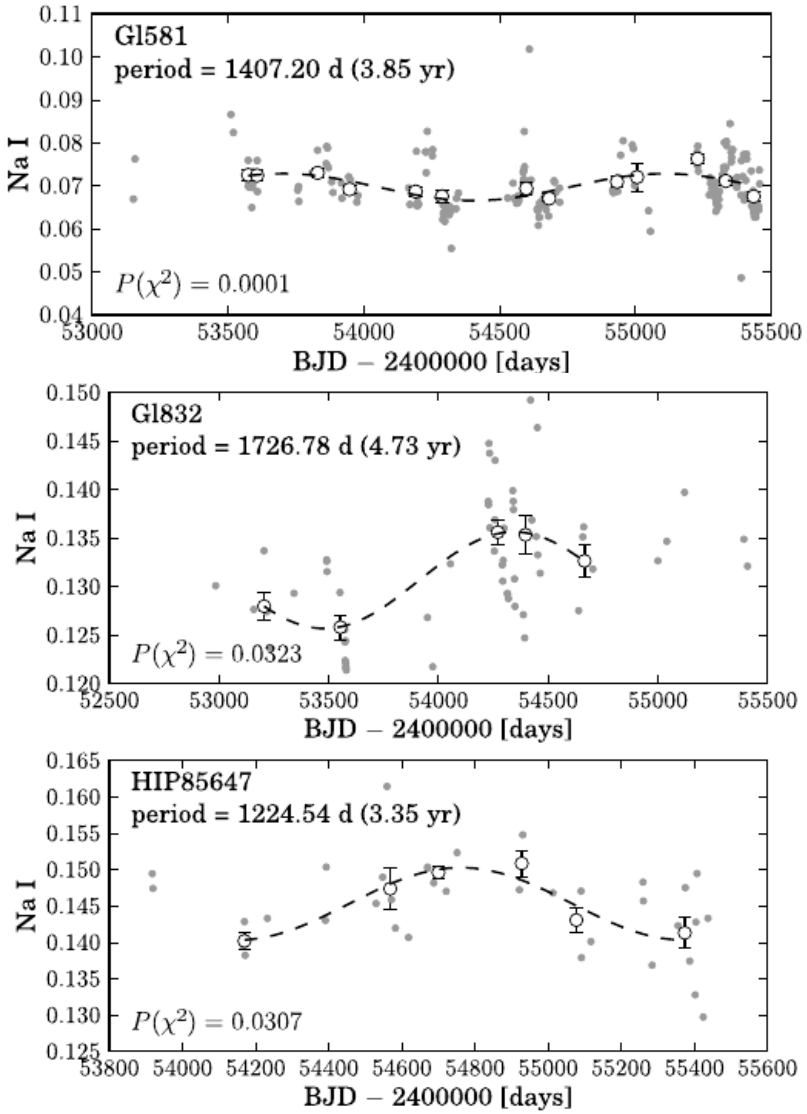

Gomes da Silva et al. (2012)

Magnetic fields of M dwarfs in unpolarised light

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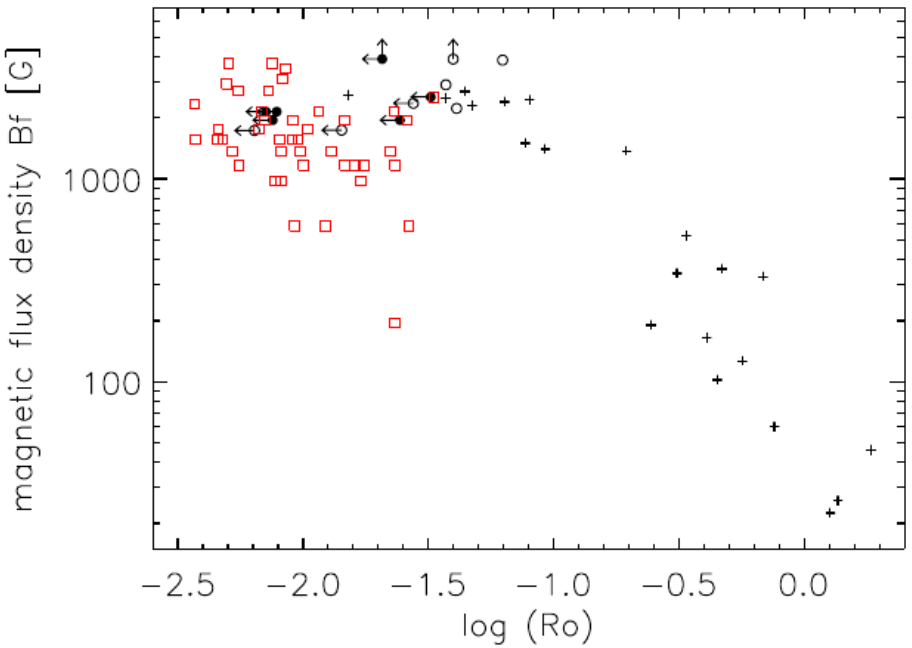
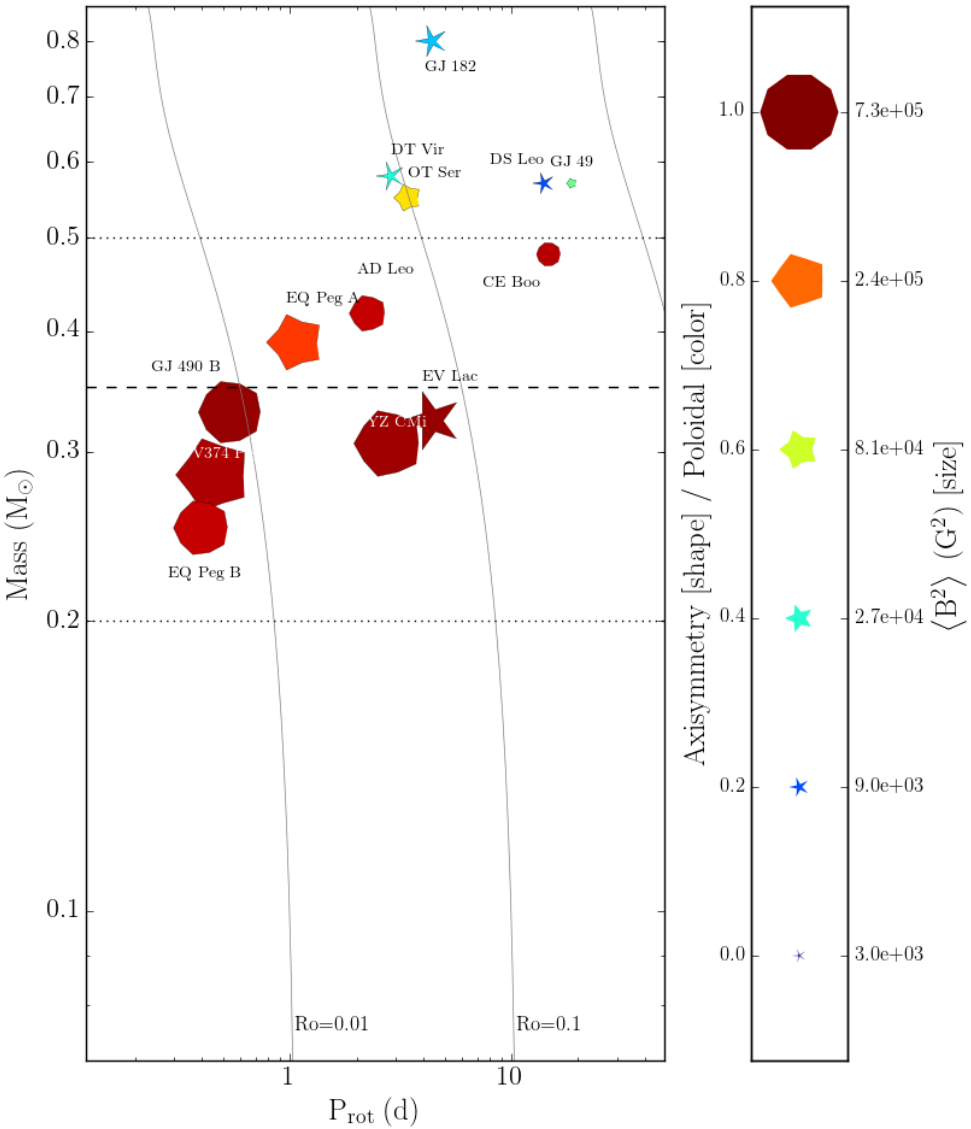


Reiners (2012)

Spectropolarimetric survey: fully convective stars



Fully convective boundary

- Sharp transition $\sim 0.5\ \mathrm{M}_\odot$
  - Magnetic topology
  - Differential rotation
- Partial agreement with DNS
  Browning (2008)
- *Morin et al. (2008a,b)*
  Donati et al. (2008)
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- Similar transition among TTS
  - MaPP Large Program
  - *Gregory et al. (2012)*

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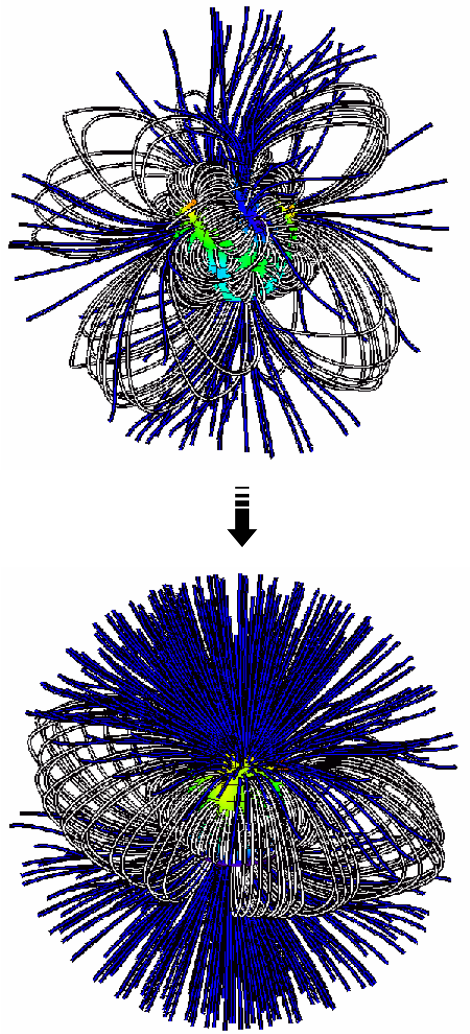

Coronal extrapolations by M. Jardine from surface magnetic fields reconstructed by

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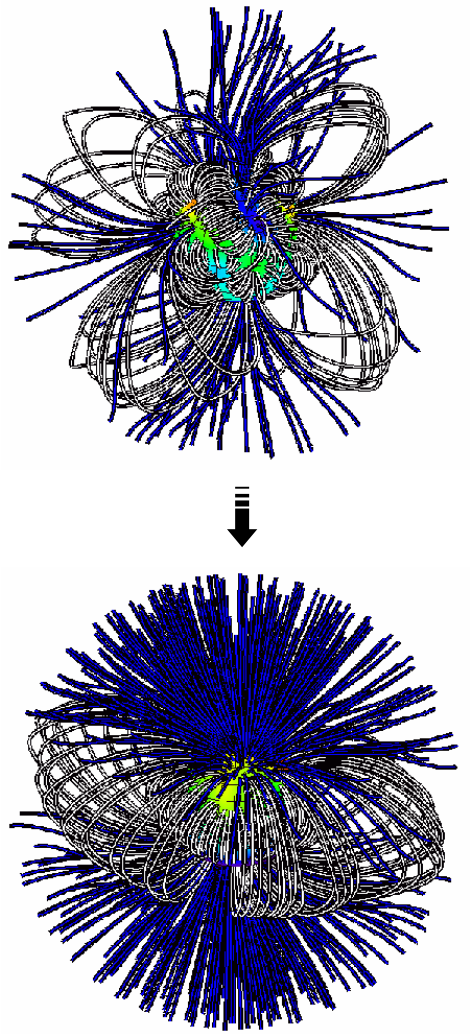

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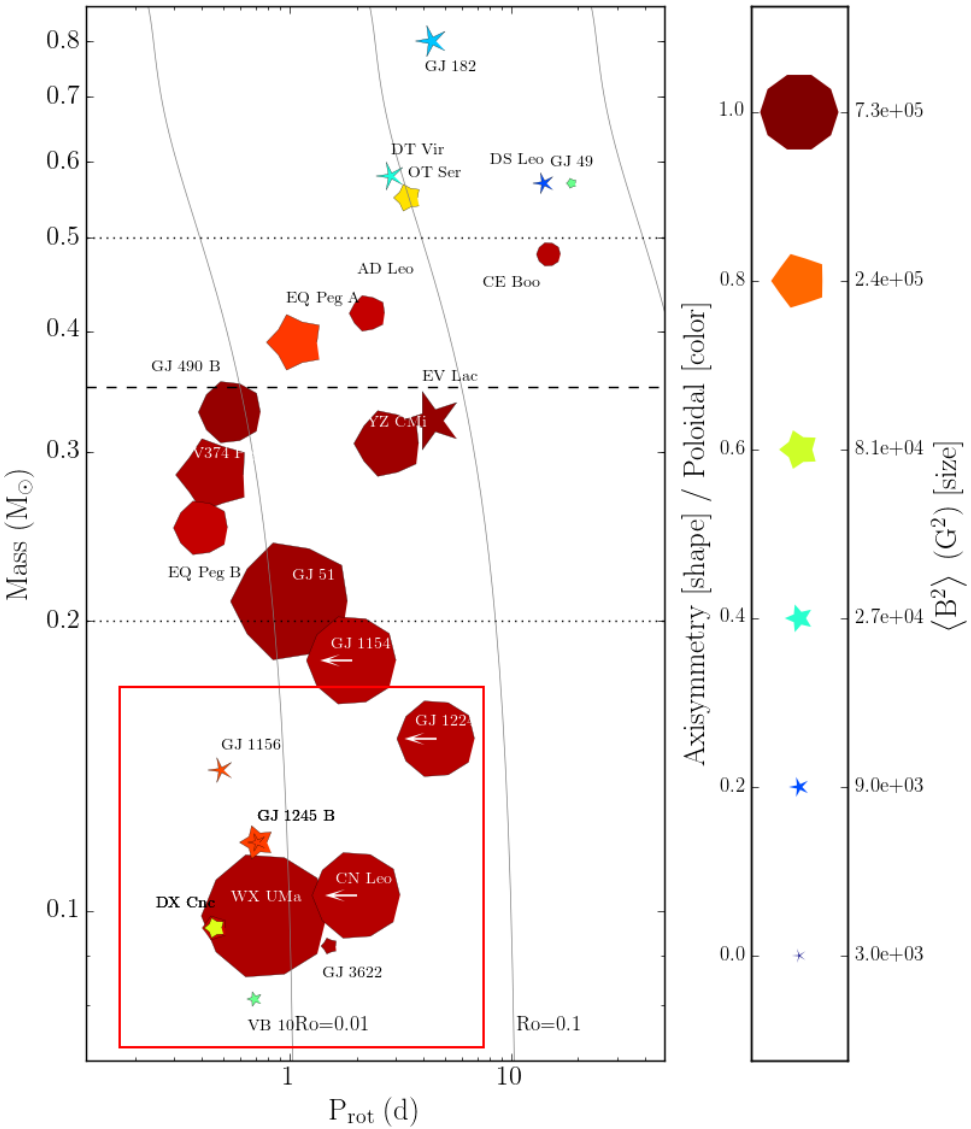
Spectropolarimetric survey: very low mass stars



VLM rapidly rotating stars

- 2 groups of stars $\lesssim 0.2\ \mathrm{M}_\odot$
  - Similar stellar params
  - Radically $\neq$ magnetisms
- *Morin et al. (2010)*

Explanation

- Variability / cycles?
  - No switch in 3 yr
- Effect of age?
- Dynamo bistability?
  Morin et al. (2011)
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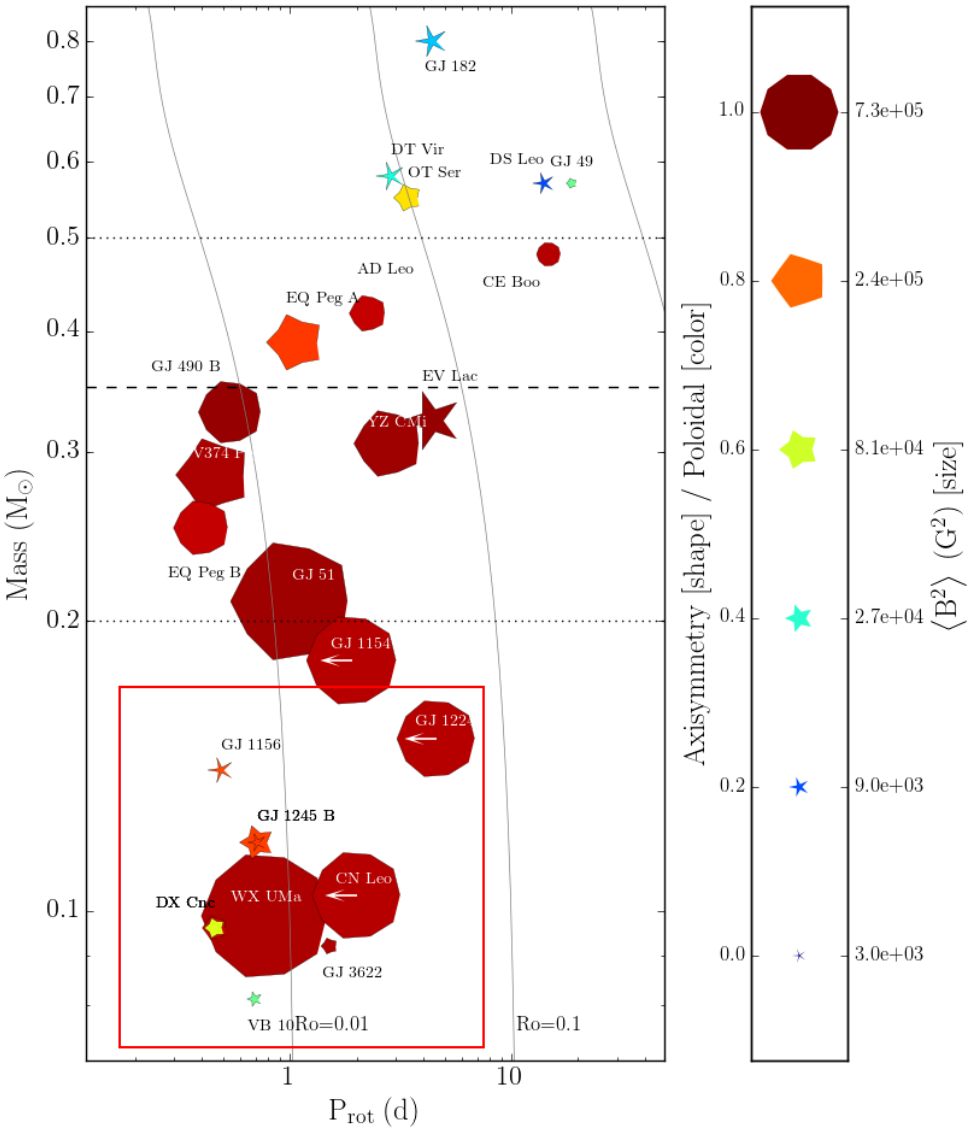
Spectropolarimetric survey: very low mass stars



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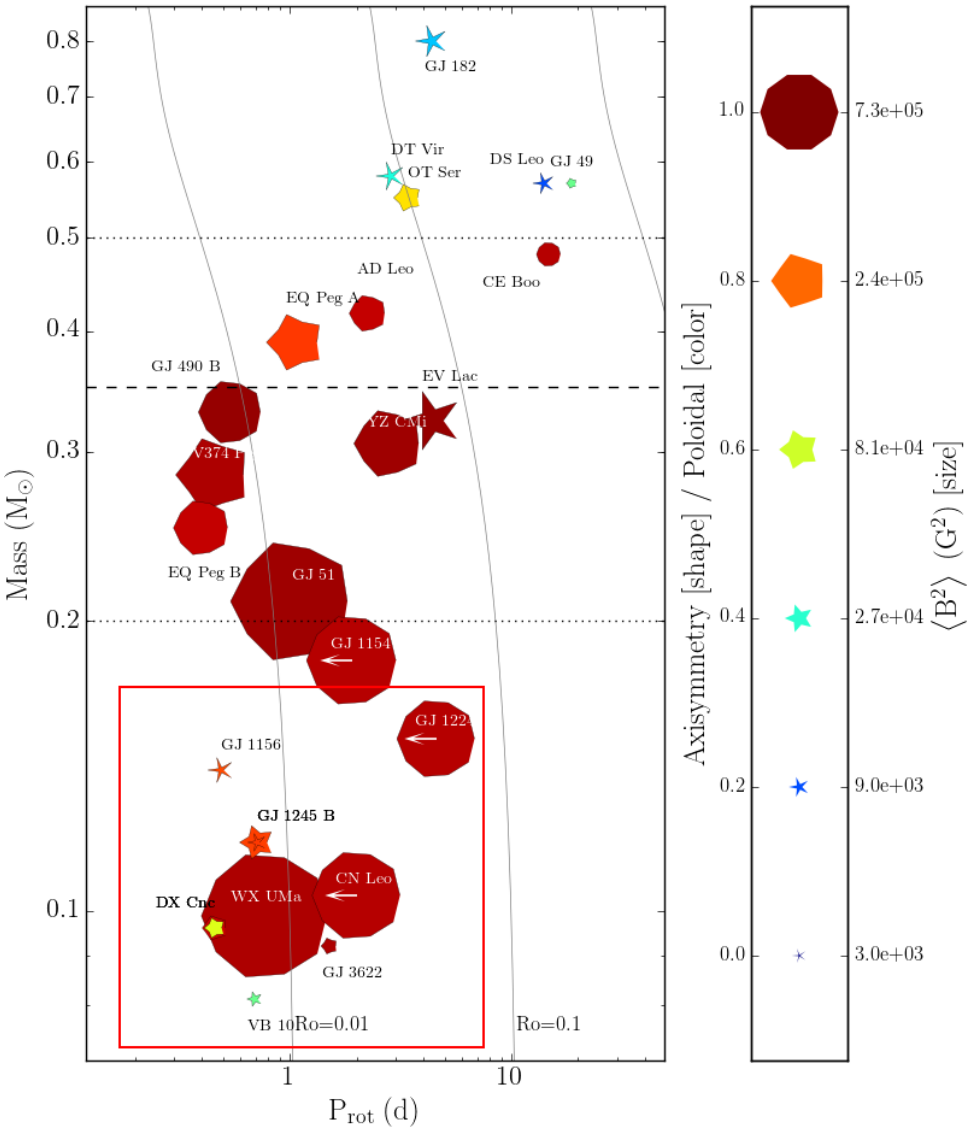

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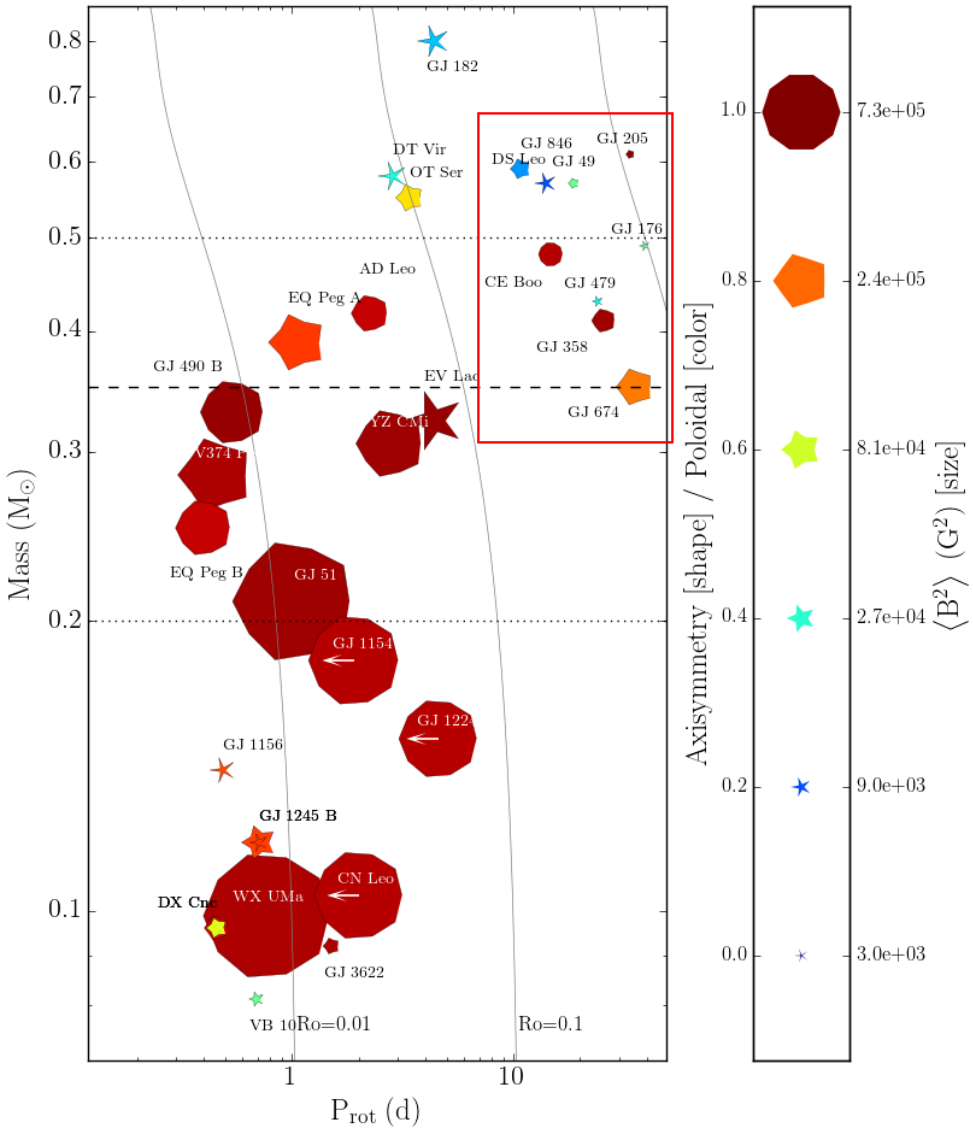
Spectropolarimetric survey: latest developments



Moderately active M dwarfs

- dipole-dominated Ro>1
  - similar to Sun-like
- Dipole-dominated 0.1<Ro<1
  - similar to more active FC
- Multipolar+toroidal 0.1<Ro<1
  - bistability?
- *É. Hébrard et al. in prep.*

Reconciling Stokes I and V?

- $\langle B_V \rangle = 2 - 30\% \langle B_I \rangle$
  - Apparent jump FC/PC
  - Large spread for VLMS
  - *Morin et al. (2008b,2010), Reiner & Basri (2009)*

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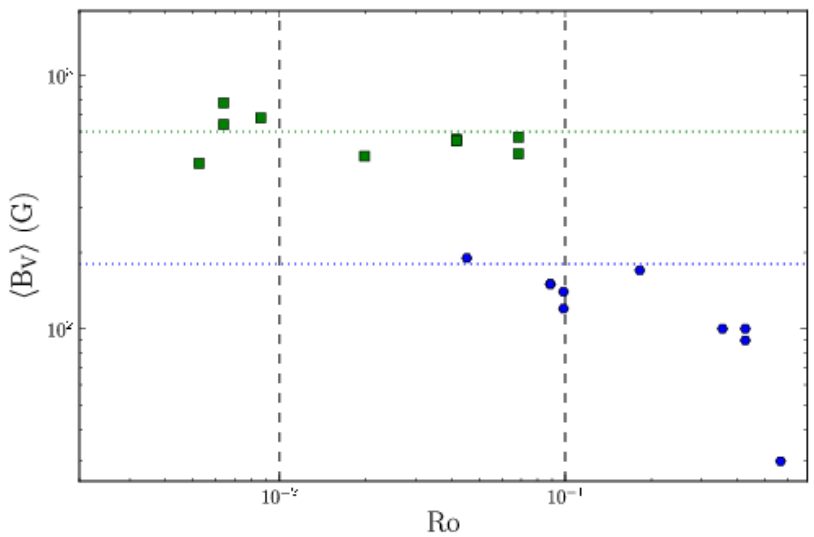

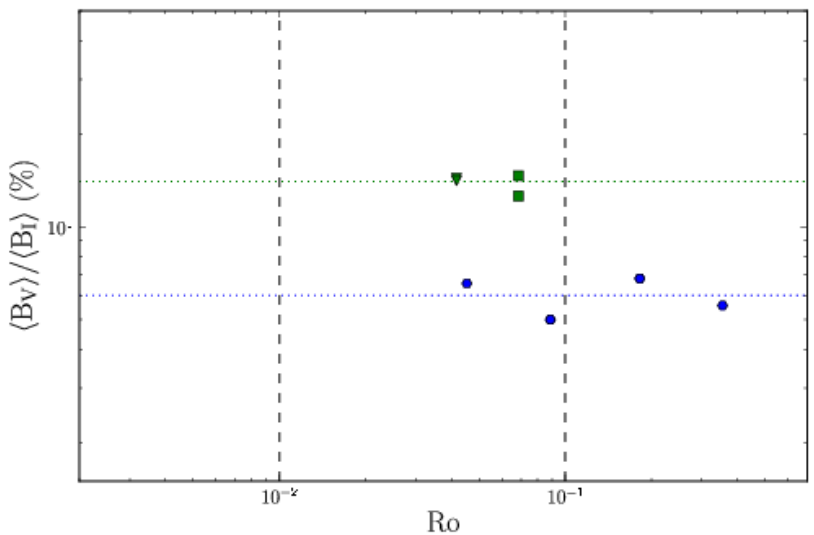

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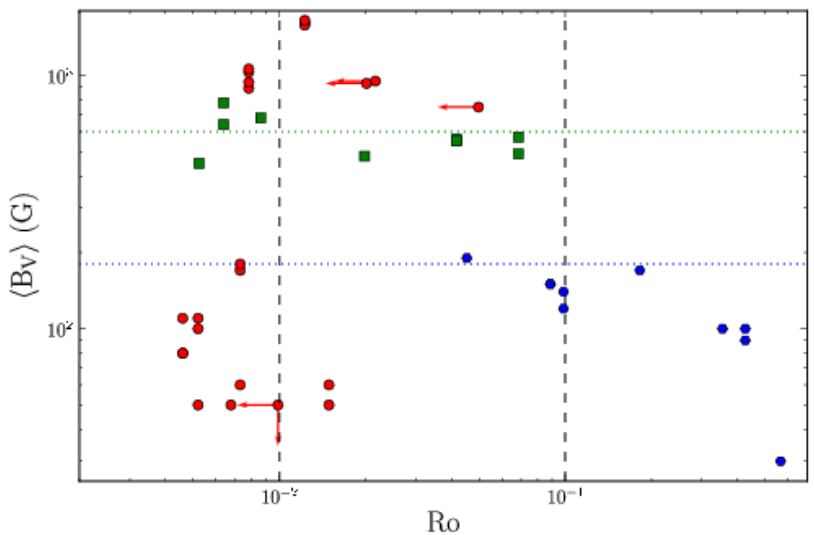

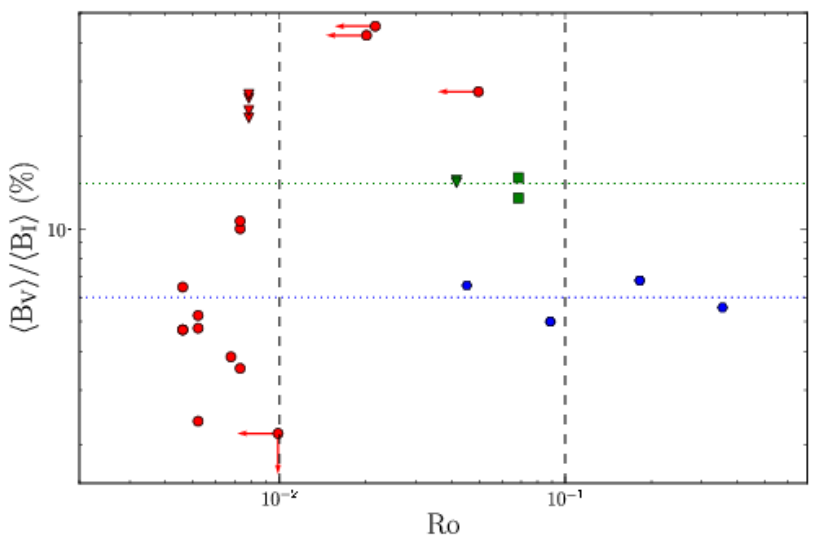

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2 A brief overview of M dwarfs' magnetism

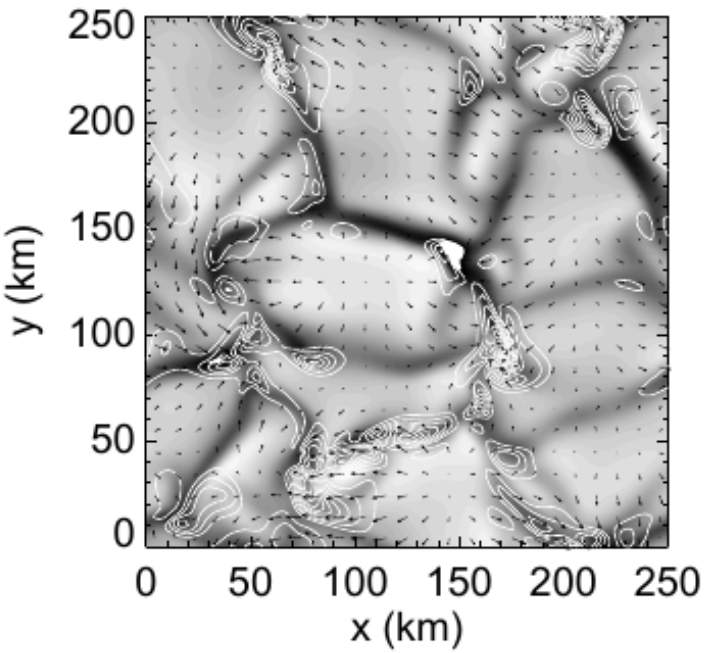
3 Numerical simulations of dynamo action in FC stars
- Earlier studies
- Explaining the coexistence of large- and small-scale fields

4 Summary

Earlier studies

- Small-scale field generation
  - *Durney et al. (1993), Dorch & Ludwig (2002)*
- Mean Field models
  - α^2 model, no DR
  - *Küker & Rüdiger (1999), Chabrier & Küker (2006)*
- Global DNS
  - Partly-consistent with observations
  - *Dobler et al. (2006), Browning (2008), Schrinner et al. (2012), Gastine et al. (2012)*
  - Bistability idea
  - *Gastine et al. (2013)*

→ Small- vs large-scale **B** discrepancy



Dorch & Ludwig (2002)

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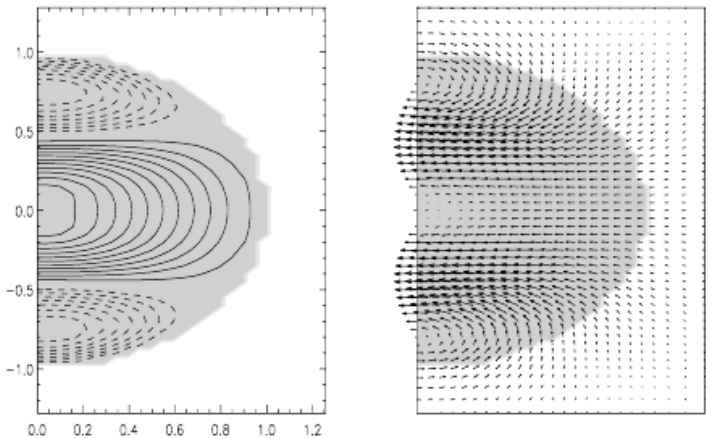

Chabrier & Küker (2006)

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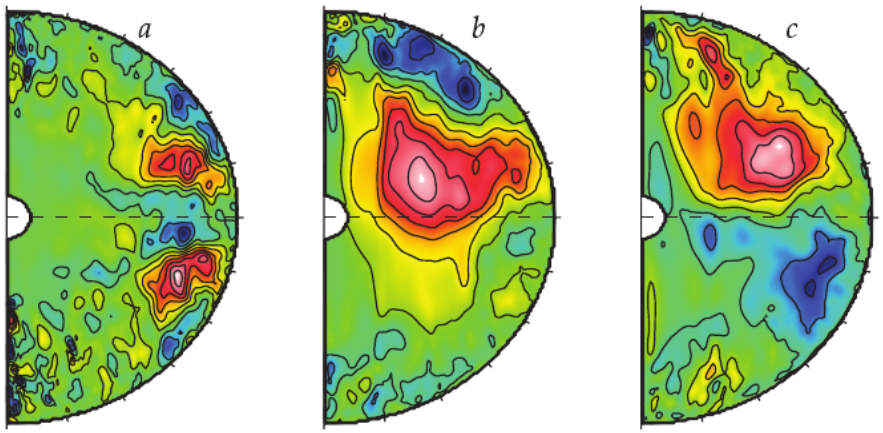

Browning (2008)

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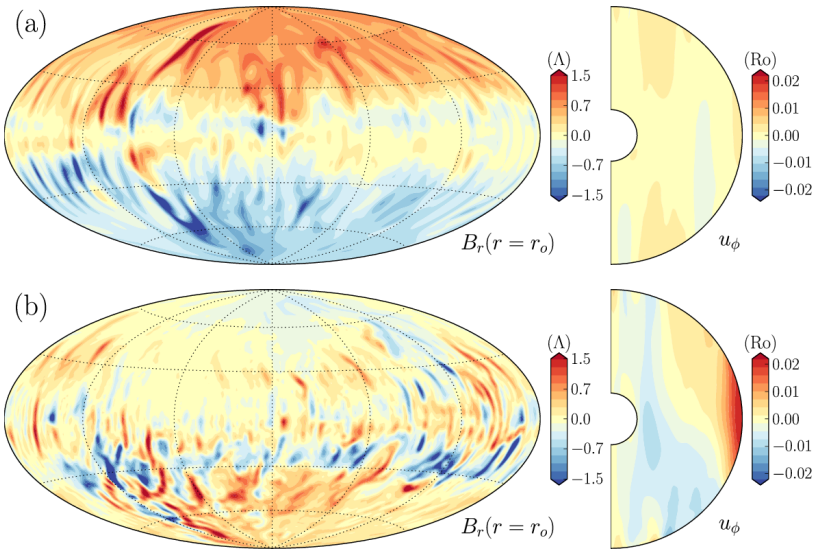
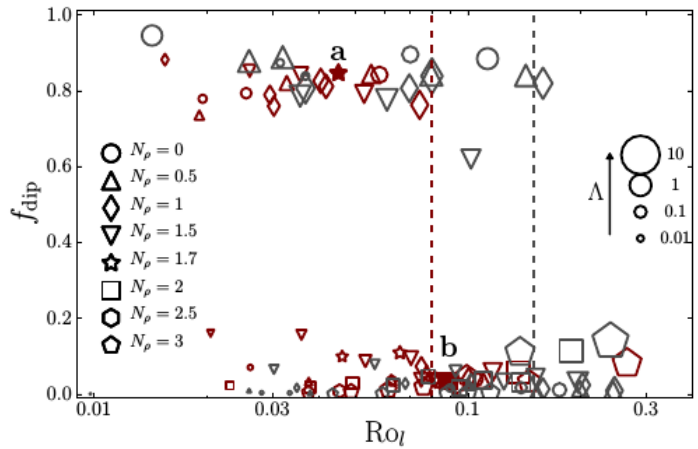
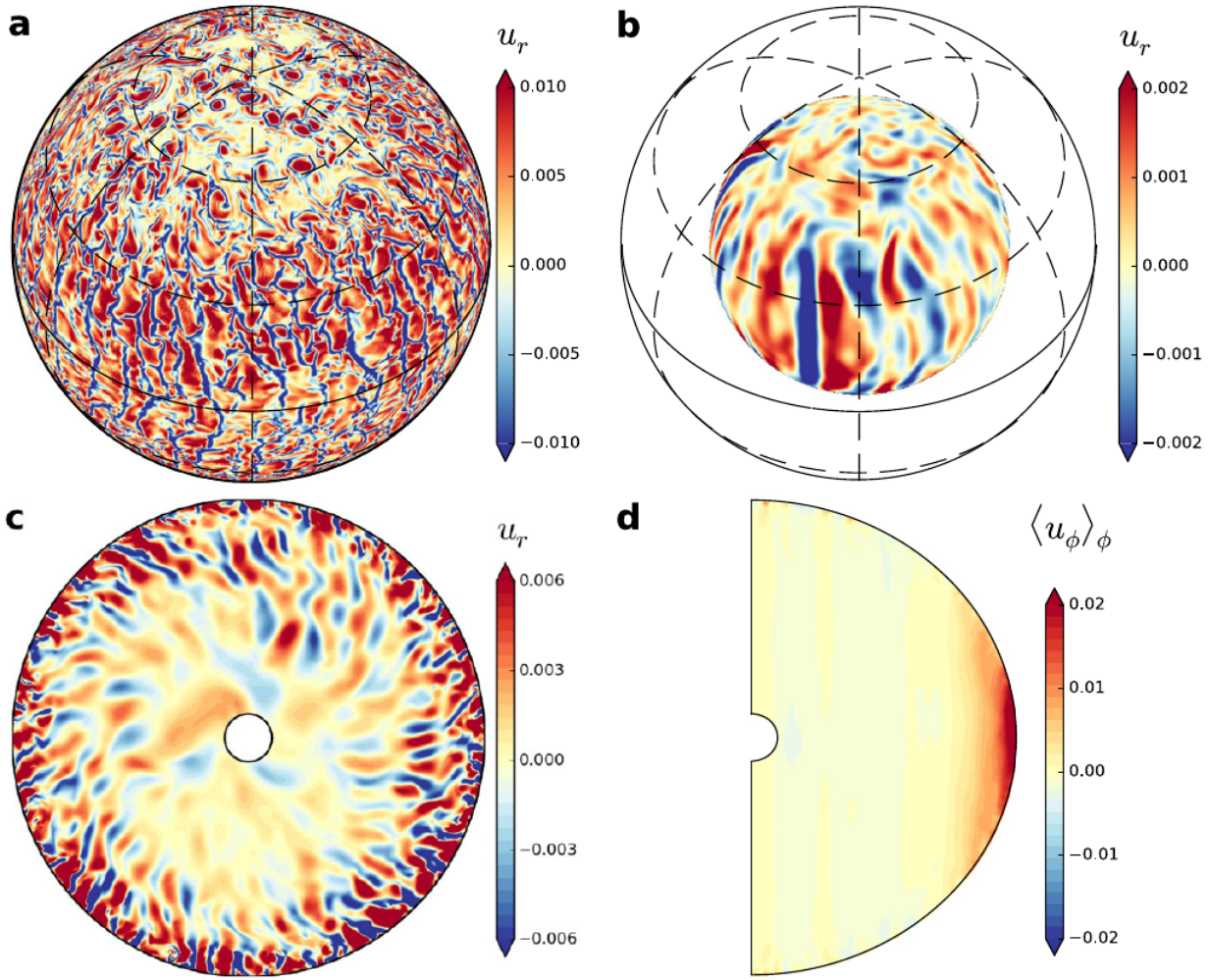




Gastine et al. (2013)

Coexistence of large- and small-scale fields



➔ GPL-licensed MagIC code: `https://github.com/magic-sph/magic`

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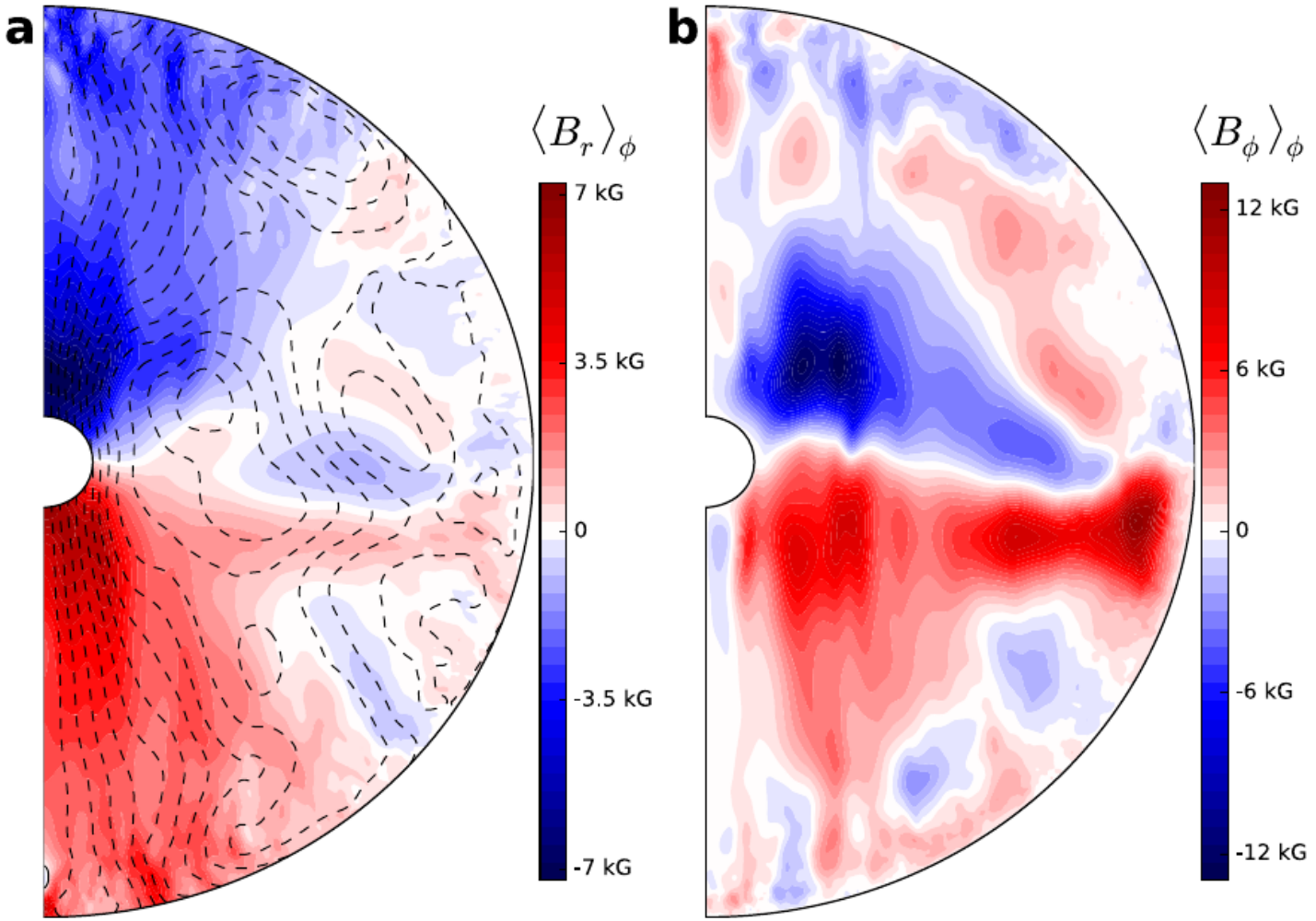
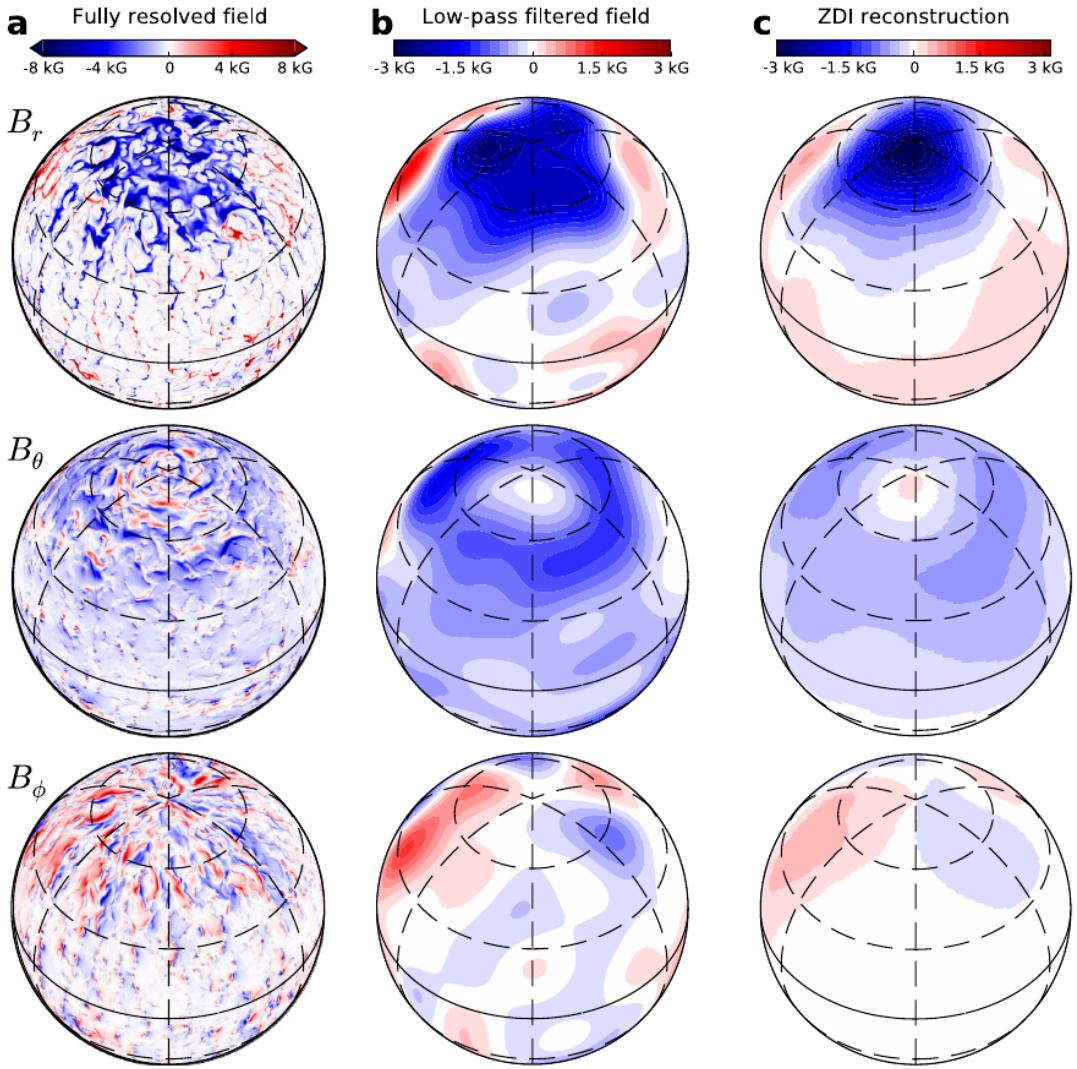


Coexistence of large- and small-scale fields



Outline

1 Magnetic fields of fully-convective stars

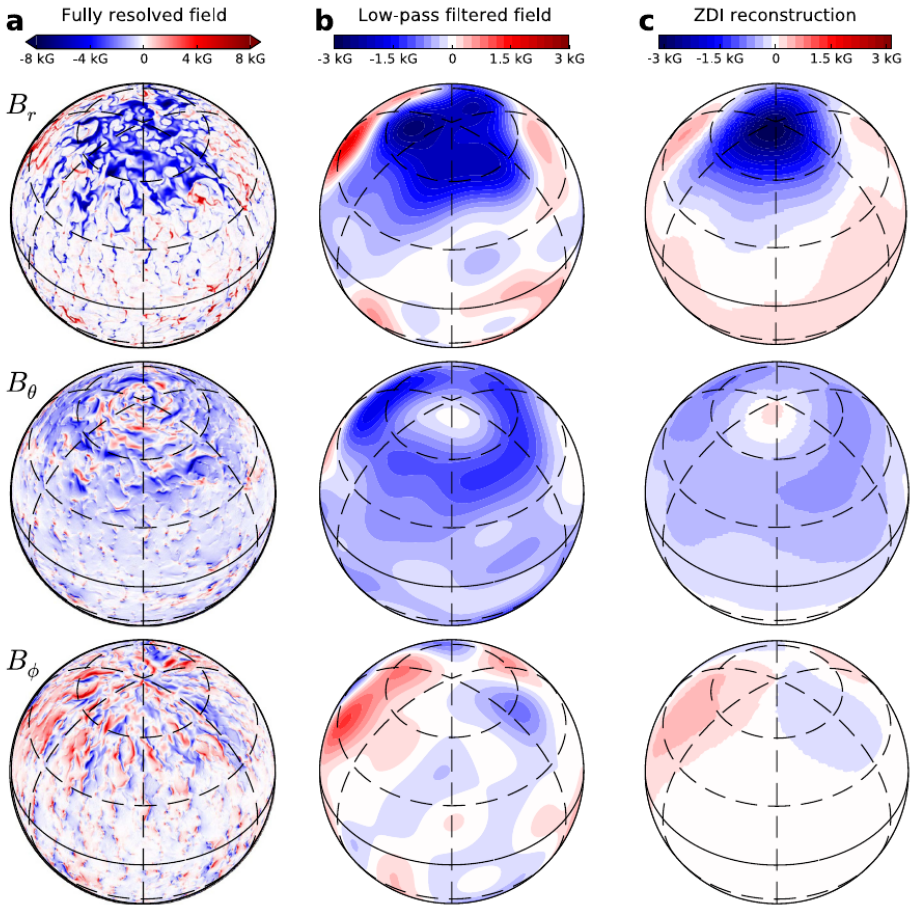
2 A brief overview of M dwarfs' magnetism

3 Numerical simulations of dynamo action in FC stars

4 Summary

Summary

- Magnetic fields
  - Crucial for stellar physics and for planetary systems
- Spectropolarimetry
  - Important developments
  - Base for further modelling
- New numerical simulations
  - reconcile Stokes I/V meas
- Future instruments
  - CFHT/SPIRou
  - TBL/NeoNARVAL+SPIP
  - CRIRES+
  - UVMag



Yadav et al. (2015)