

Exploring the magnetic fields of M dwarfs with spectropolarimetry at CFHT

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IPAG – CNRS / Université de Grenoble

University of St Andrews

Caltech

ESO Garching

Vanderbilt University

MAG – ENS Paris / IPGP

IfA Göttingen

MPS

ASIAA

CFHT Users' Meeting 2013 – Campbell River – 7th May 2013

Outline

- 1 Magnetic fields of cool stars
- 2 The first spectropolarimetric survey of M dwarfs
- 3 What's coming next?
- 4 Summary

Magnetism of fully convective stars

Dynamo action in FC stars

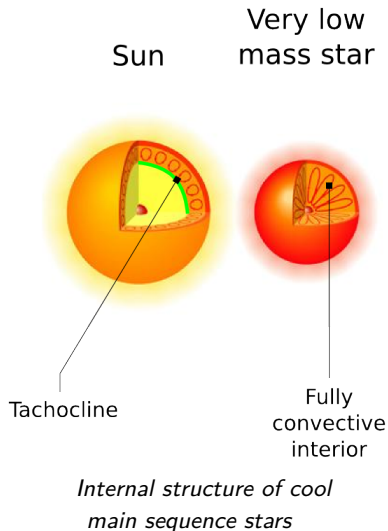
- Solar dynamo
 - Tachocline: crucial role?
- Fully convective stars
 - Tachocline → solar-dynamo
- observable effects?

Main sequence FC stars

- Activity
- B from Zeeman broadening
- No change at the fully-convective boundary

Young FC stars

- Some TTS are fully convective
 - Same dynamo processes?
 - MaPP, MaTYSSSE LPs



Magnetism of fully convective stars

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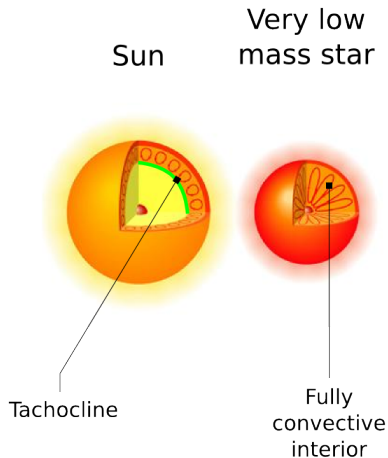
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Internal structure of cool main sequence stars

Magnetism of fully convective stars

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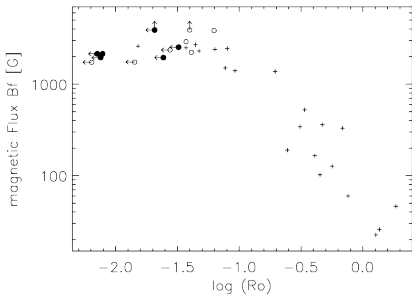
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Rotation-total magnetic field relation
Reiners, Basri & Browning et al. (2009)

Magnetism of fully convective stars

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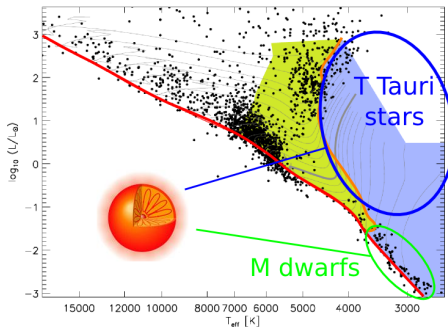
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*PMS and MS fully-convective stars
in the HRD*

*Adapted from [Reiners \(2008\)](#)
Evolutionary tracks from
[Siess et al. \(2002\)](#)*

Why and how using spectropolarimetry?

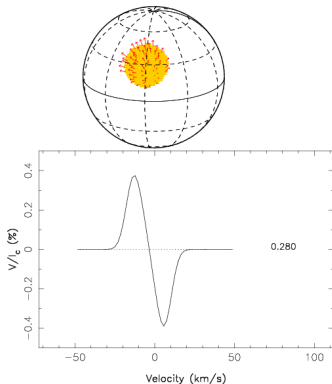
Spectroscopy vs spectropolarimetry

- Zeeman effect
- Unpolarized light
 - Total “magnetic flux”
 - **B**-geometry
- Spectropolarimetry
 - Large-scale field only
 - Vector properties + resolution

Detecting polarization

- Cool active stars
 - Circular polarization
 - $\sim 0.1\% \times I_c \rightarrow S/N \sim 1000s$
- Efficient instruments
- Multi-line techniques
- ESPaDO nS: M dwarfs within reach!
- Survey of M dwarfs

Vector magnetic field



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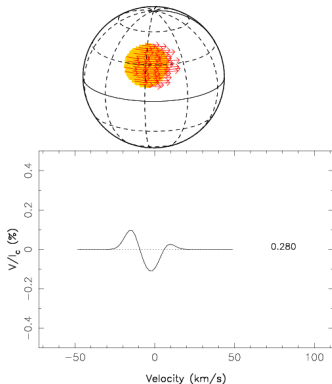
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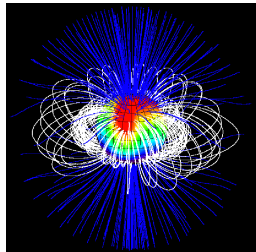
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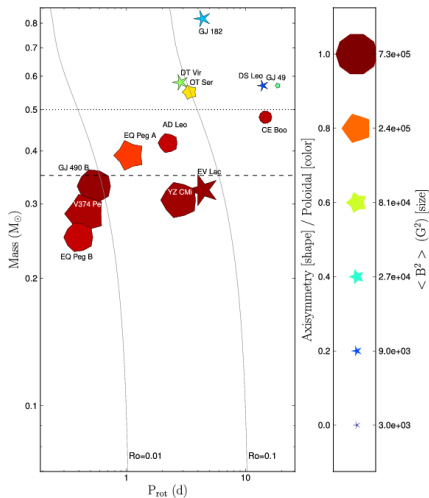
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*1st spectropolarimetric observations
of the magnetic field of
a fully convective star*

Donati et al. (2006), Morin et al. (2008a)

Spectropolarimetric survey: fully convective stars

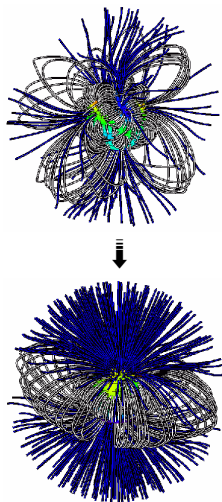


Fully convective boundary

- Sharp transition $\sim 0.5 M_{\odot}$
- Magnetic topology
- Differential rotation
- Partial agreement with DNS
Browning (2008)
- *Morin et al. (2008a,b)*
Donati et al. (2008)
Phan-Bao et al. (2009)

- Similar transition among TTS
MaPP Large Program
Gregory et al. (2012)

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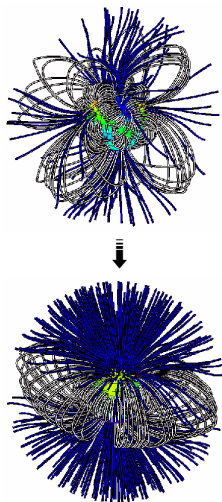
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Coronal extrapolations by M. Jardine from surface magnetic fields reconstructed by *Donati et al. (2008)*, *Morin et al. (2008a)*

Spectropolarimetric survey: fully convective stars

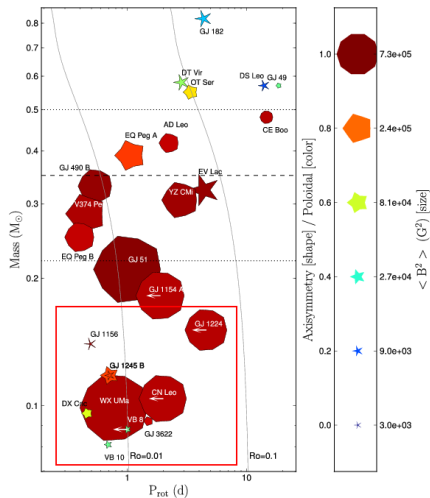


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Spectropolarimetric survey: very low mass stars



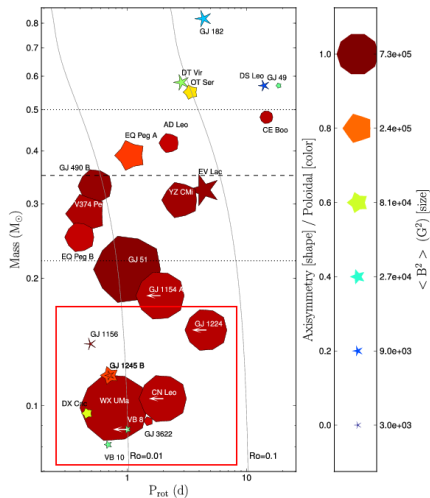
VLM rapidly rotating stars

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

Explanation

- Variability / cycles?
- No switch in 3 yr
- Effect of age?
- Dynamo bistability?

Spectropolarimetric survey: very low mass stars



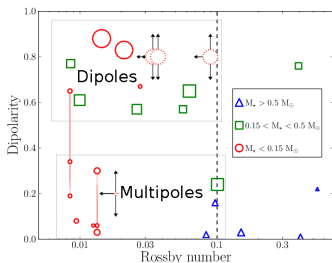
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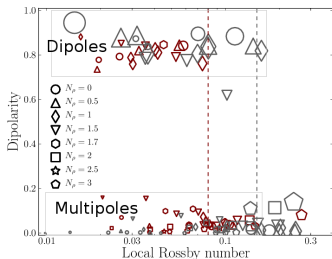
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Dynamo bistability for very low mass stars?



(a) Spectropolarimetric observations



(b) Numerical simulations

Gastine, Morin et al. (2013)

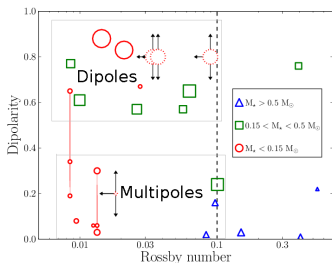
Dynamo bistability?

- Observations 2 \neq types magnetism
- Dependence on initial conditions
 - Two types of fields generated
- *Morin, Dormy et al. (2011)*

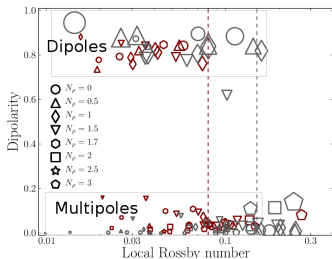
Parallel with numerical simulations

- *Gastine, Morin et al. (2013)*
- Predictions for M dwarfs
 - Extent bistable domain
 - Differential rotation

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Horizon 2016: more science with ESPaDOs

Very low mass stars

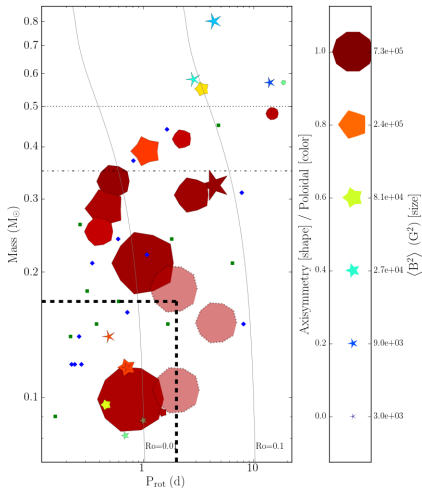
- Disentangle between hypothesis
- Snapshot survey 2013AB
 - Bistability? → Test predictions
 - Effect of age? → Improve statistics
- Monitoring (to be proposed...)
 - Variability
 - Polarity reversal
 - Switch dipolar ↔ multipolar

Binary systems

- BinaMlcS Large Program

→ Impact binary interactions → B?

→ How do close active stars interact?



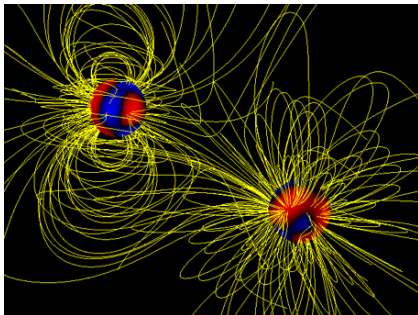
*Observations ongoing for semester 13A
and proposed for 13B*

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*Coronal extrapolation for a binary system
Credit: S. Gregory, BinaMIcS collaboration*

Next generation spectropolarimeter: SPIRou

SPIRou: a unique instrument

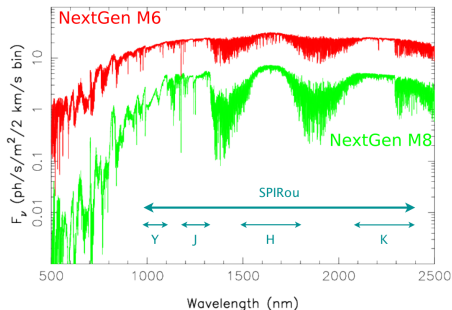
- YJHK-bands in single exposure
- Resolution/Throughput/Polarimetry

Major advances to come

- Systematic study of M dwarfs
 - Volume-limited sample
 - Down to low-activity regime
 - Extended to brown dwarfs domain

Stellar magnetism / exoplanets synergy

- Similar monitoring needs
 - Comes for free!
- Science synergy
 - Filtering activity jitter
 - Effects of B_* → habitability?



SPIRou wavelength coverage vs SED of M dwarfs

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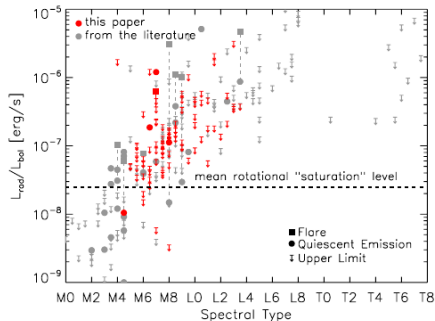
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McLean et al. (2012)

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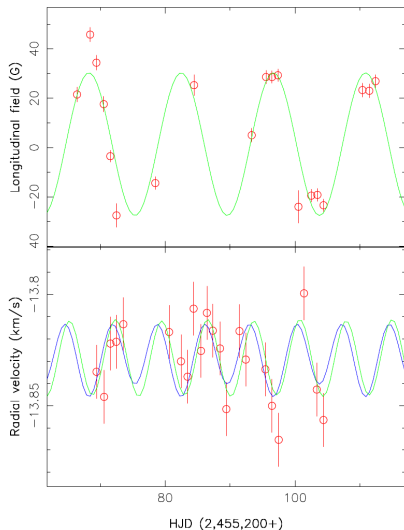
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*RV jitter compared w/ longitudinal field
SPIRou science case*

Summary

Magnetism of M dwarfs

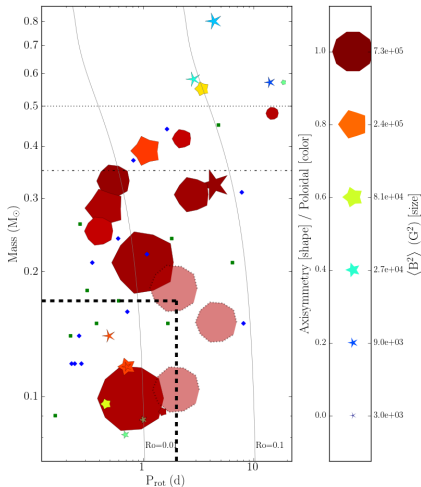
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 - Non-solar dynamo
 - Fast rotation

The major role of ESPaDOnS

- Achievements
 - Fully-convective transition
 - Dynamo bistability?
- Ongoing projects
 - Confirm theoretical predictions
 - Close binary systems

SPIRou

- Ideal for M dwarfs magnetism
 - Next big step forward
 - Synergy w/ planet search



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