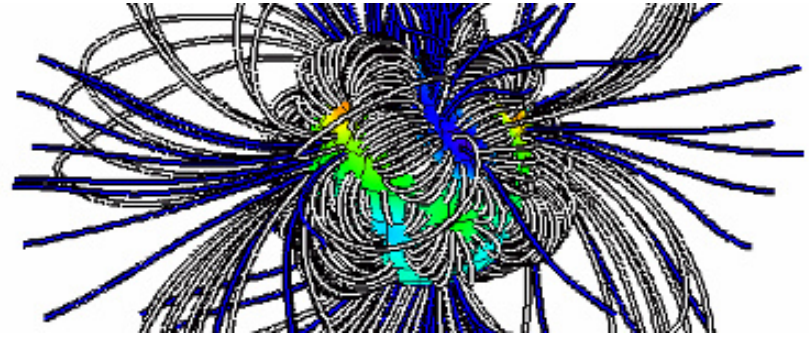
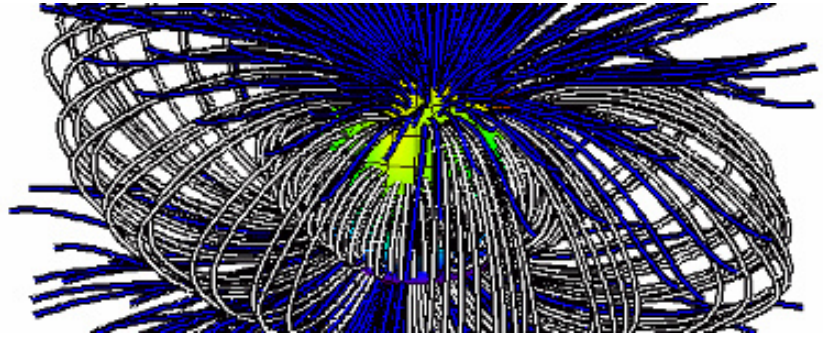



Magnetic fields of M dwarfs in the SPIRou context

Julien Morin

Laboratoire Univers et Particules de Montpellier

1st SPIRou science meeting – Paris, France
23rd September 2014

SPiRou

LUPM LABORATOIRE MONTPELLIER UNIVERS & PARTICULES

UNIVERSITÉ MONTPELLIER 2 SCIENCES ET TECHNIQUES

Outline

Outline

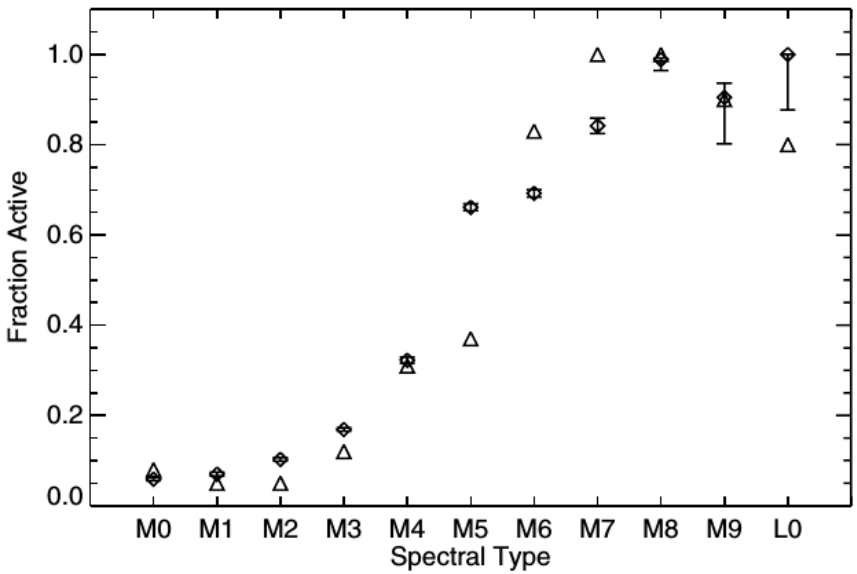
Why do we care about magnetic fields? (1/2)

- Magnetic activity is ubiquitous
- Magnetic fields and planets
  - Detection

➔ talks by X. Bonfils, X. Dumusque, É. Hébrard

  - Characterization: space weather

➔ talks by A. Vidotto, R. Farès, A. Strugarek



West et al. (2008)

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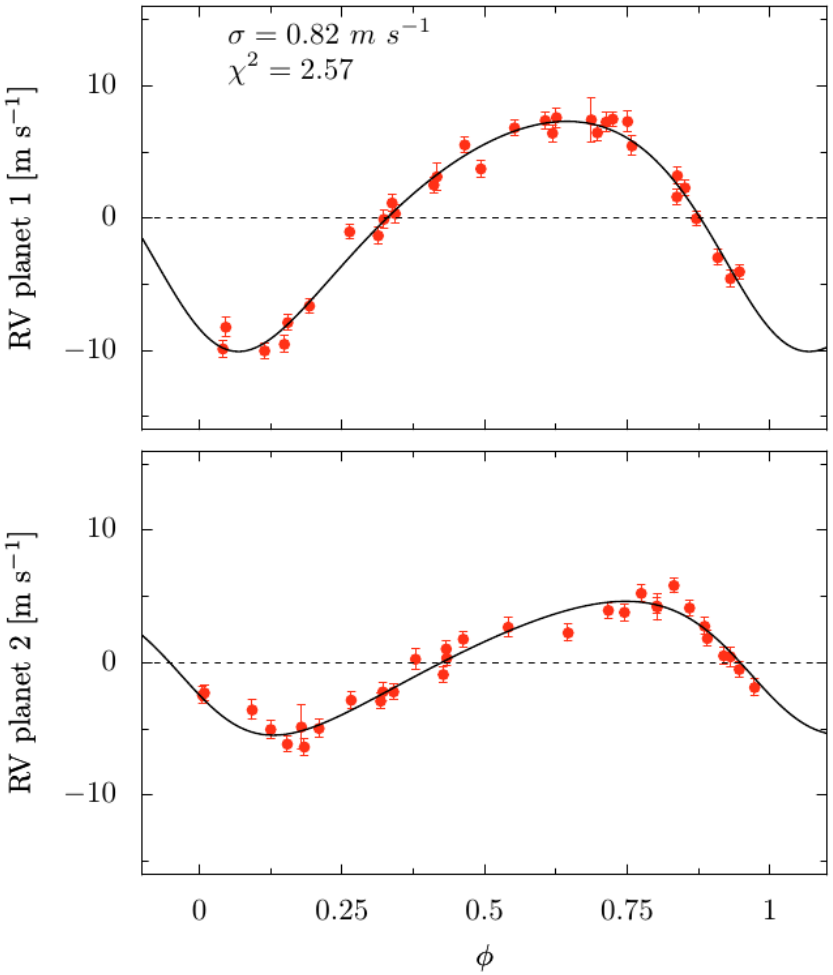

GJ 674 *Bonfils et al. (2007)*

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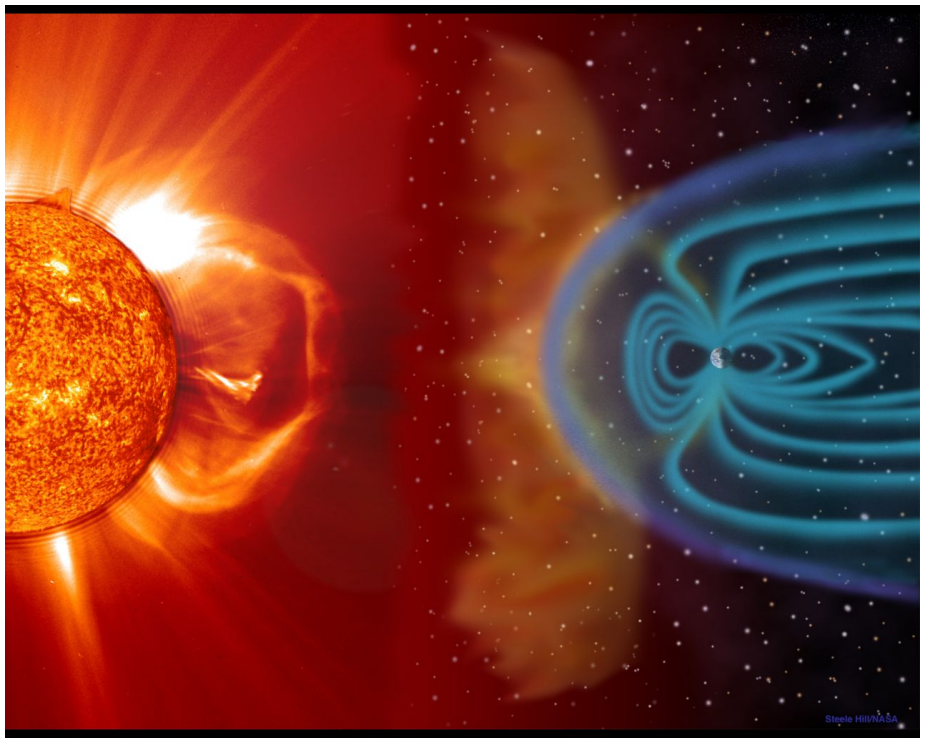


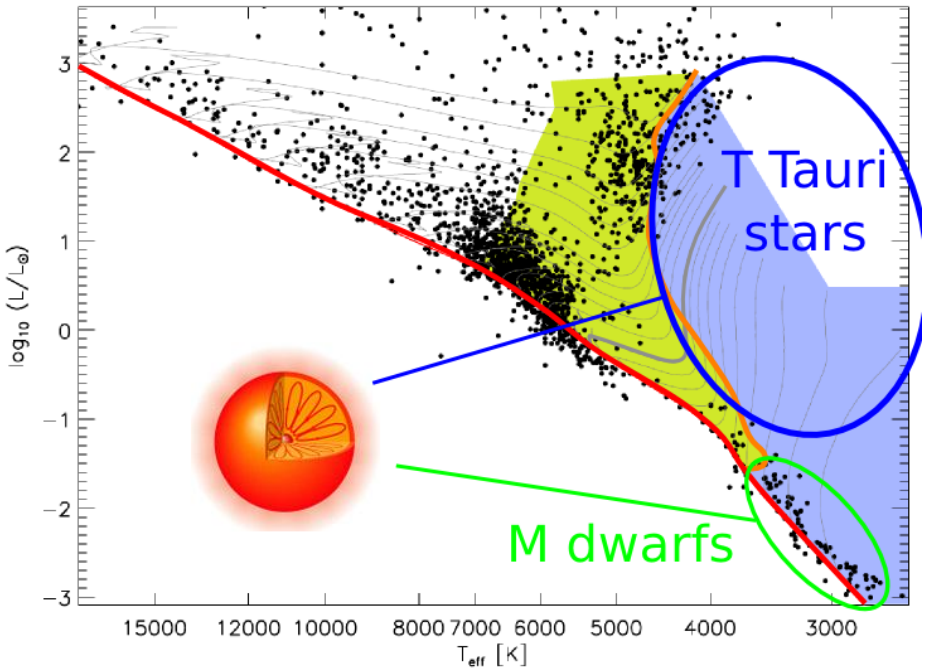
Credit: NASA / ESA

Why do we care about magnetic fields? (2/2)

- Advances in stellar physics
  - Dynamo processes

➔ talks by L. Jouve, S. Brun

  - Rotational evolution
    - *Irwin et al. (2011), Reiners & Mohanty (2013)*
  - Activity
    - *Berger et al. (2008), Hallinan et al. (2008)*



PMS and MS fully-convective stars in the HRD
Adapted from Reiners (2008)
Evolutionary tracks from Siess et al. (2002)

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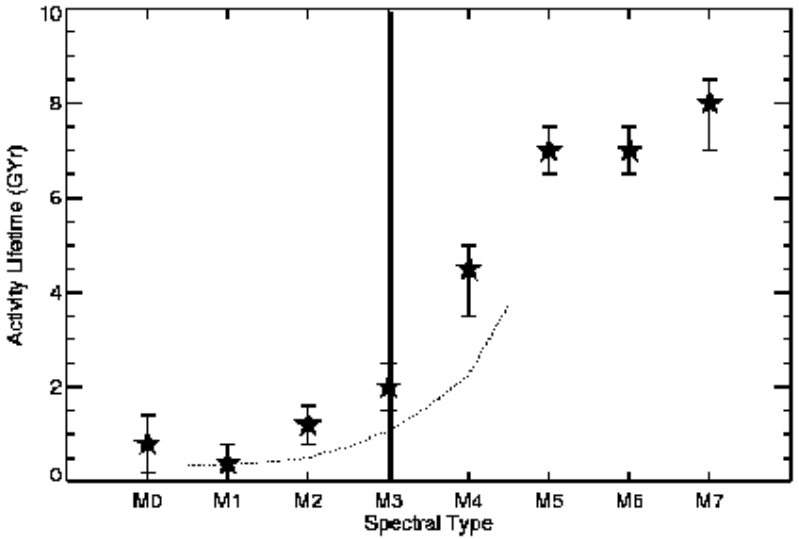

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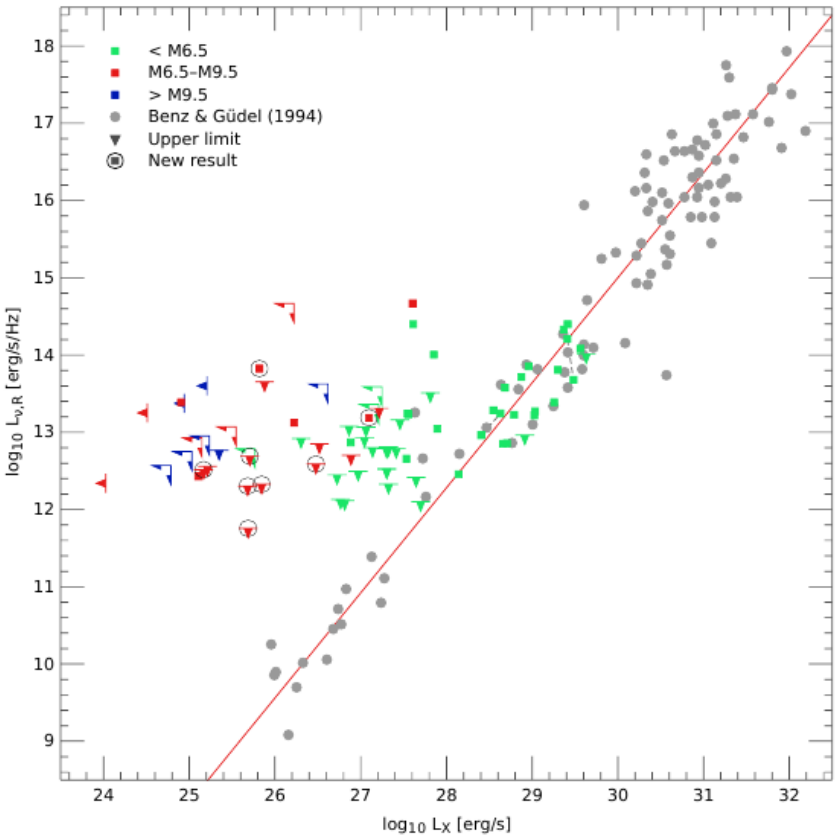
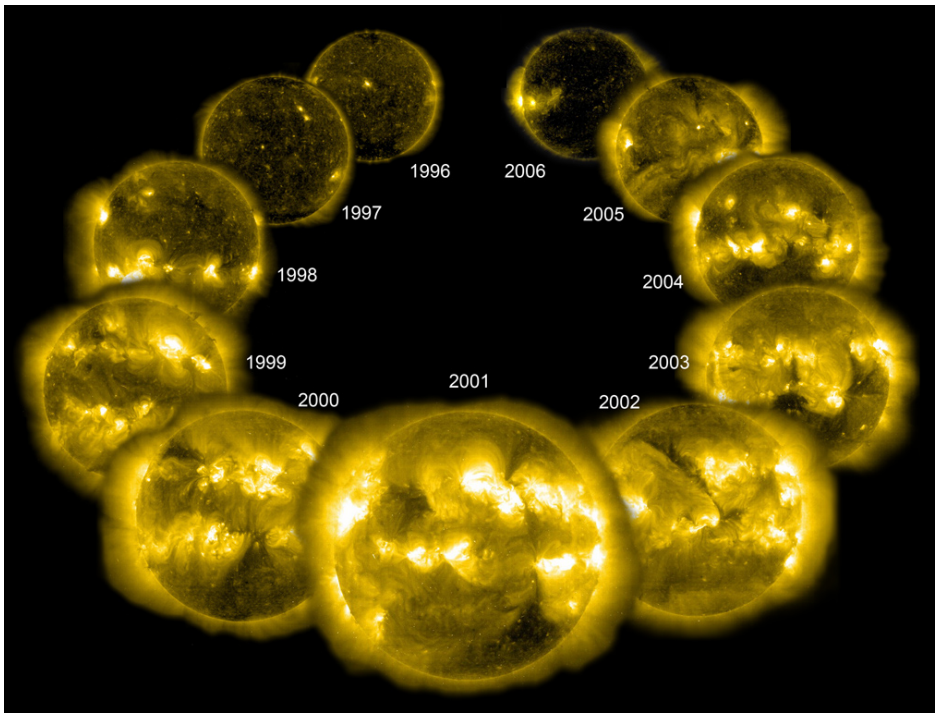


Williams, Cook & Berger (2013)

Outline

Indirect measurements: stellar activity

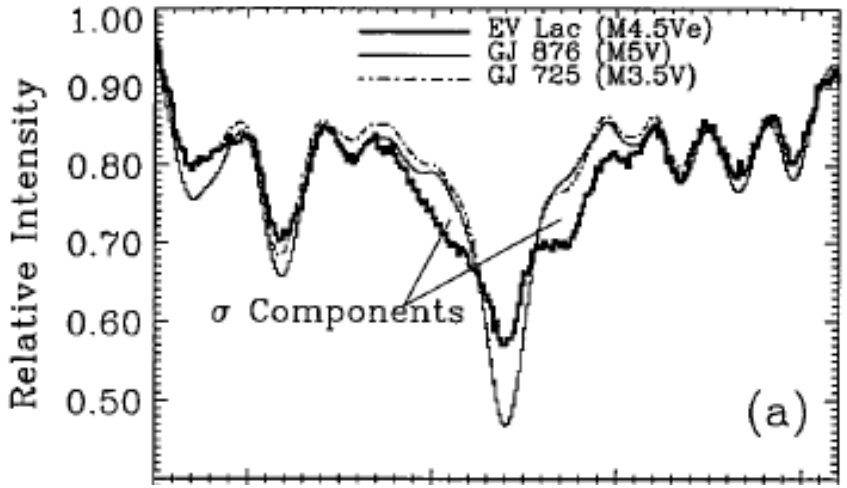
- Interaction $\vec{B} \leftrightarrow$ atmosphere
  - Spots, plages
    - Vis. photometry/spectroscopy
  - Chromosphere, TR, corona
    - Radio ➔ X-rays
- Usual proxies for stellar $\vec{B}$
  - CaII H&K, Hα emission
  - Coronal X-ray emission



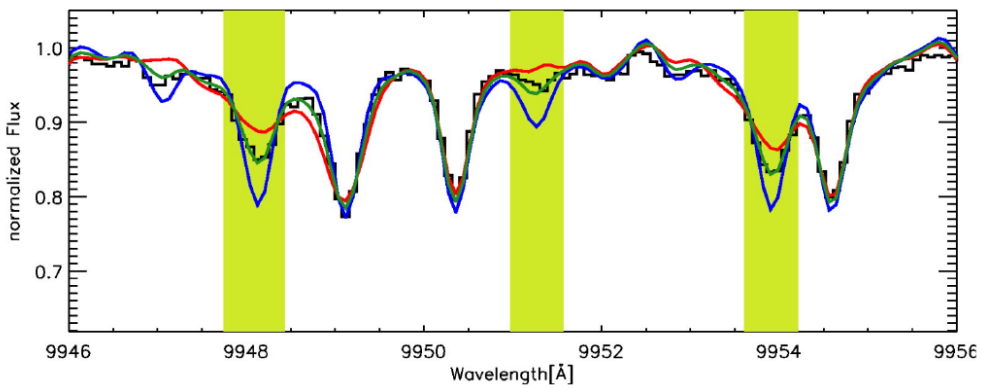
SOHO, EUV

Direct measurements of $\vec{B}$: unpolarised light

- Direct $\vec{B}_{photosph}$ measurements
  - ➥ Zeeman effect
- Measure "magnetic flux": $\left\langle \|\vec{B}\| \right\rangle$
  - Atomic lines
  - Molecular lines
- Weakly sensitive to $\vec{B}$ orientation
  - Almost no information
  - Equally sensitive to any geometry
- Low to moderate $v \sin i$



Johns-Krull & Valenti (1996)



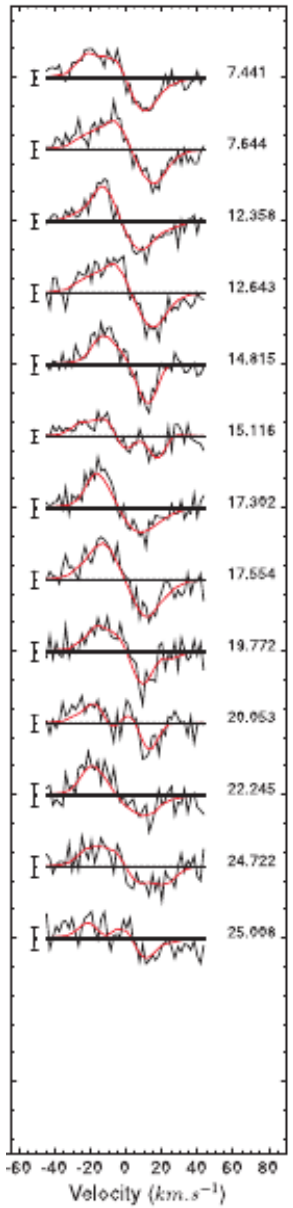
GJ 729, FeH Wing-Ford band
Reiners & Basri (2006)

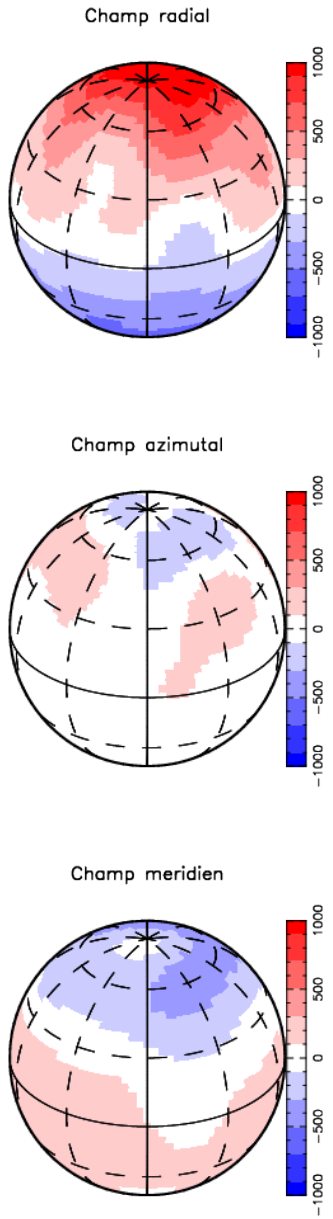
Direct measurements of $\vec{B}$: spectropolarimetry

- Sensitive to vector properties
- Partial cancellation
  - Blind to small-scale field
- Differential measurement / weakly affected by modelling error
- Requires high S/N ($\sim 10^4$)

➥ Multi-line techniques (LSD)
Donati et al. (1997)

- Interpretation/modelling
  - Zeeman-Doppler Imaging
    Semel (1989)
    Donati & Brown (1997)

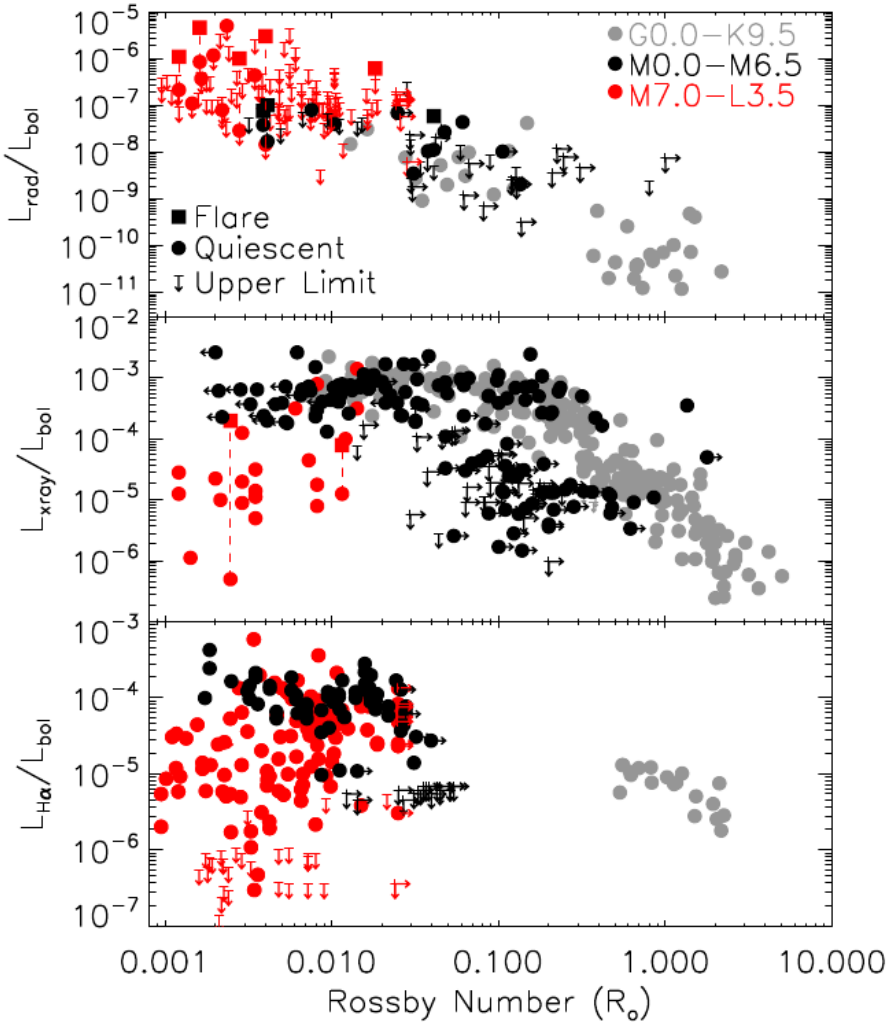




Outline

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
    - No L_{rad}/L_{bol} saturation
- Activity cycles
  - Evidence for long-term variability
  - Hints of cycles



McLean et al. (2011)

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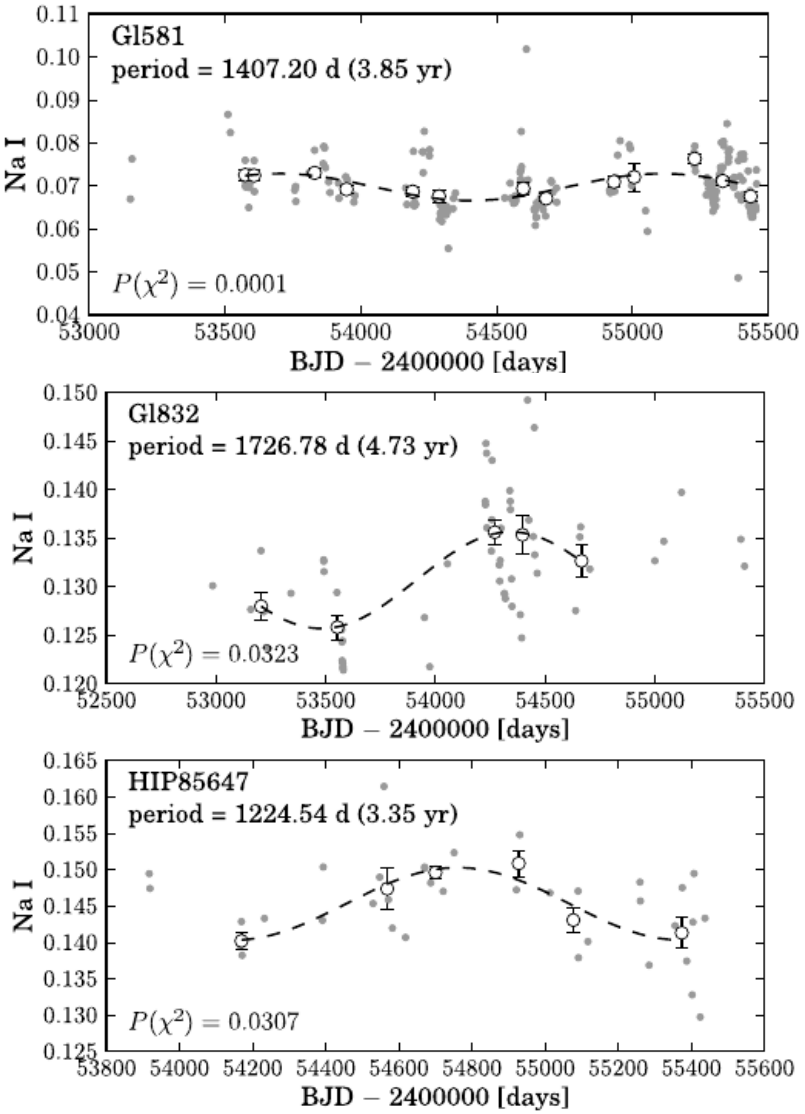

Gomes da Silva et al. (2012)

Magnetic fields of M dwarfs in unpolarised light

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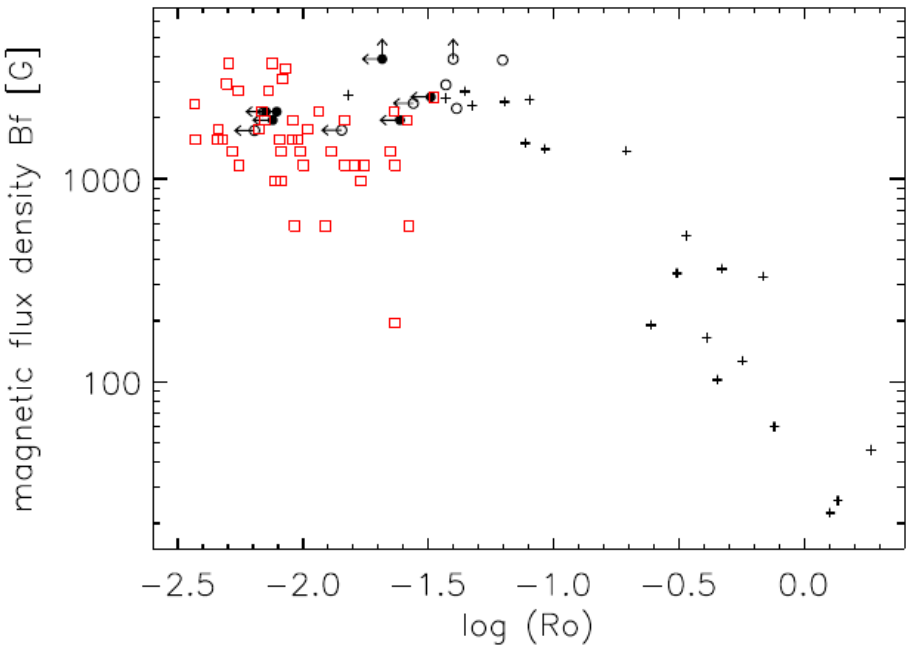
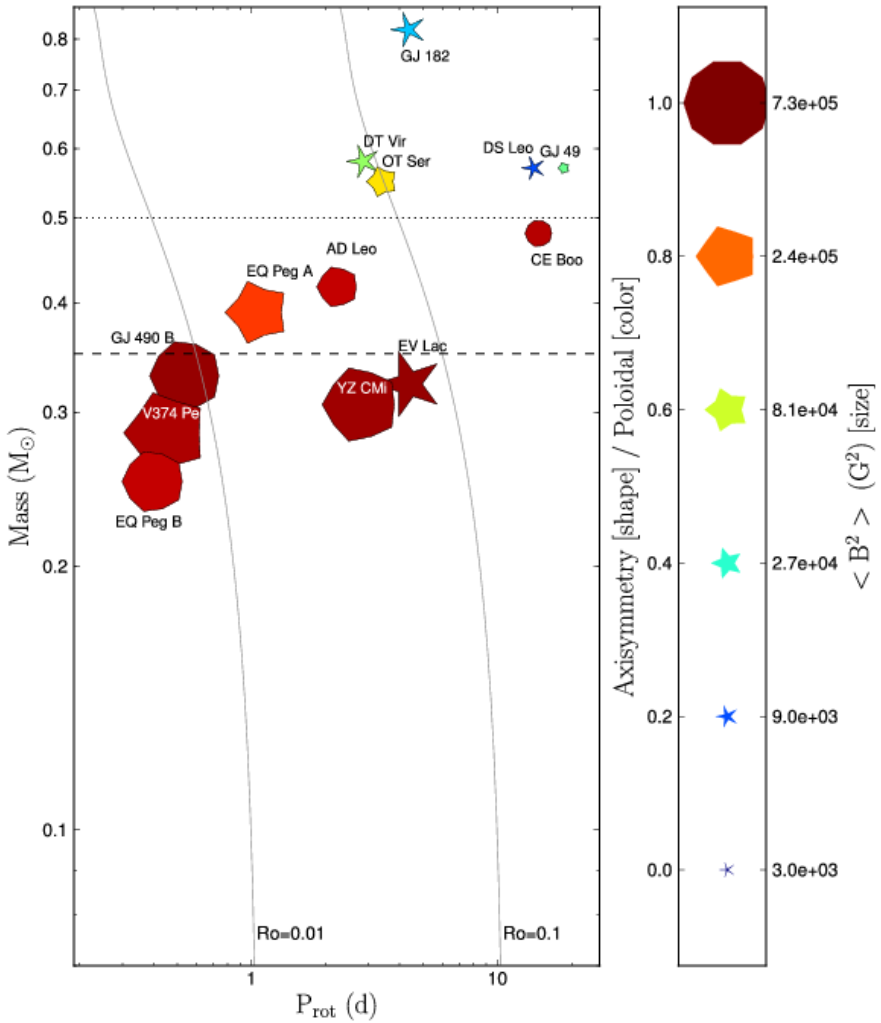


Reiners (2012)

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)
  Phan-Bao et al. (2009)

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

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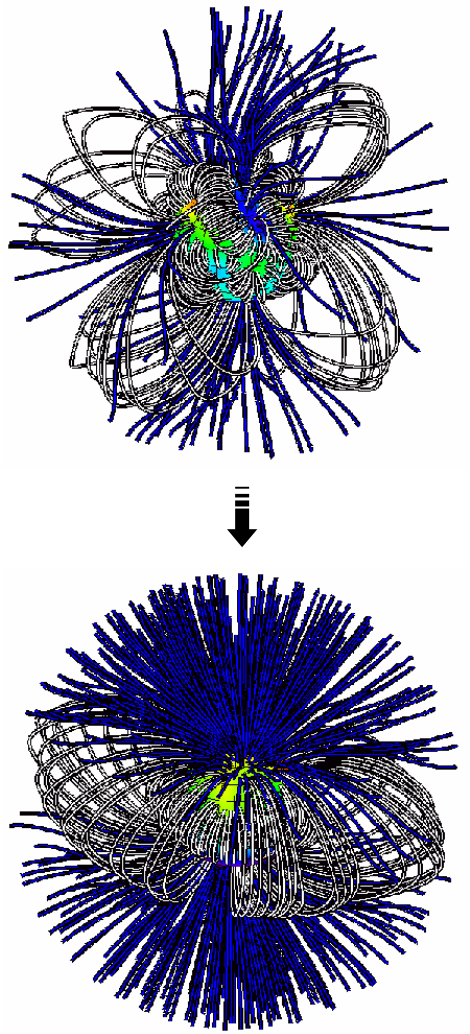

Coronal extrapolations by M. Jardine from surface magnetic fields reconstructed by

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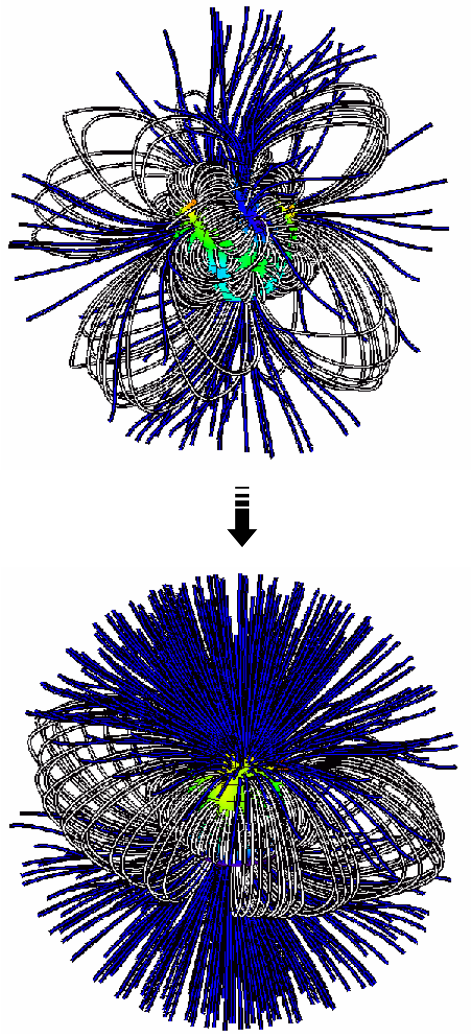

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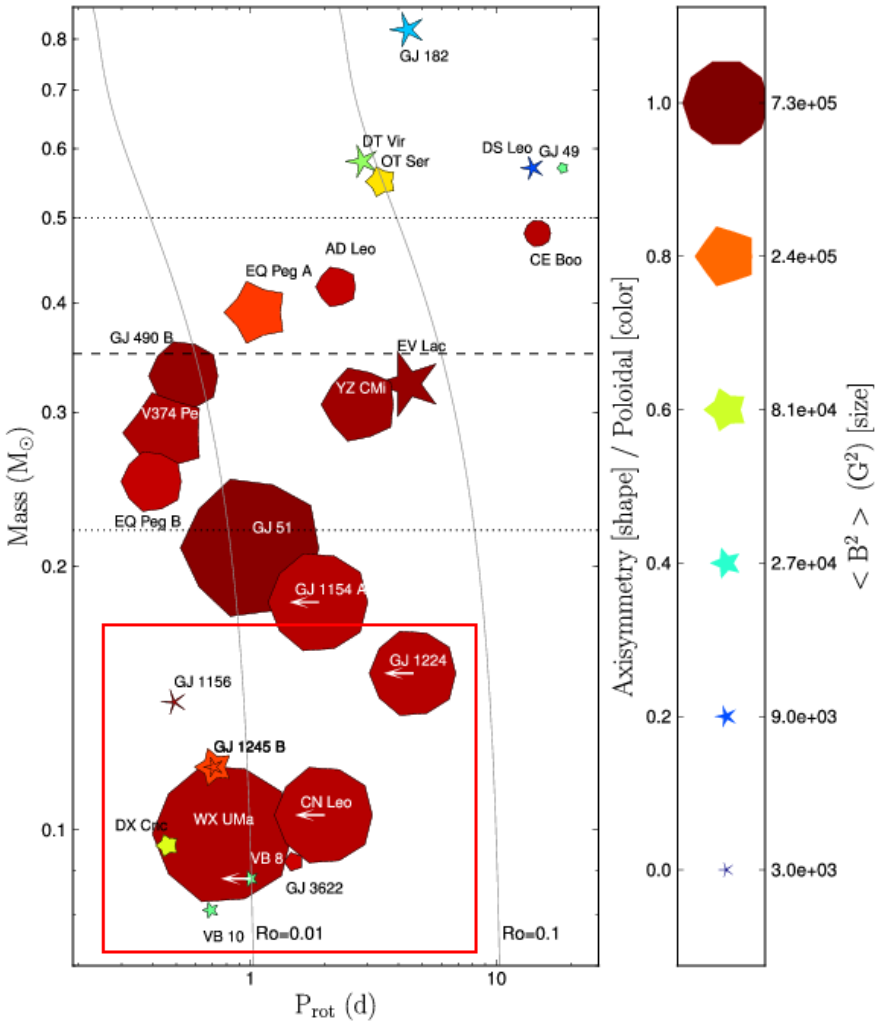
Spectropolarimetric survey: very low mass stars



VLM rapidly rotating stars

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

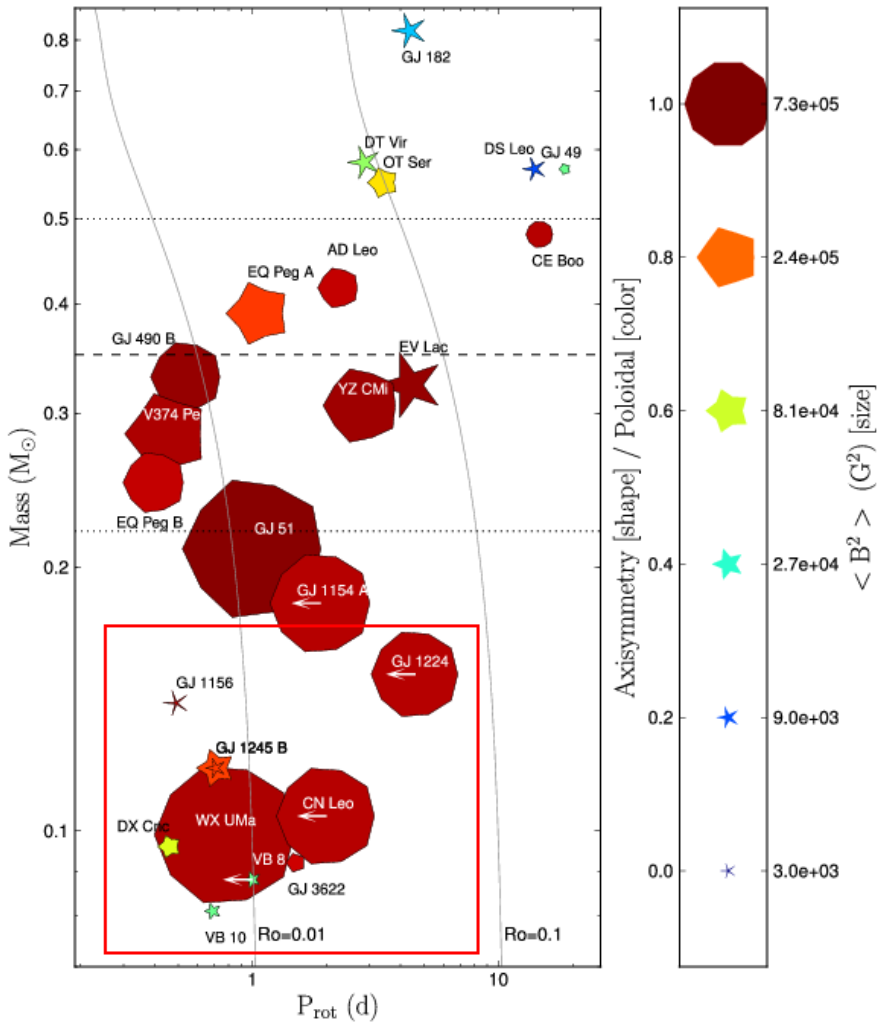
Explanation

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

Ongoing studies

- Further explore bistability
- M dwarf binaries

Spectropolarimetric survey: very low mass stars



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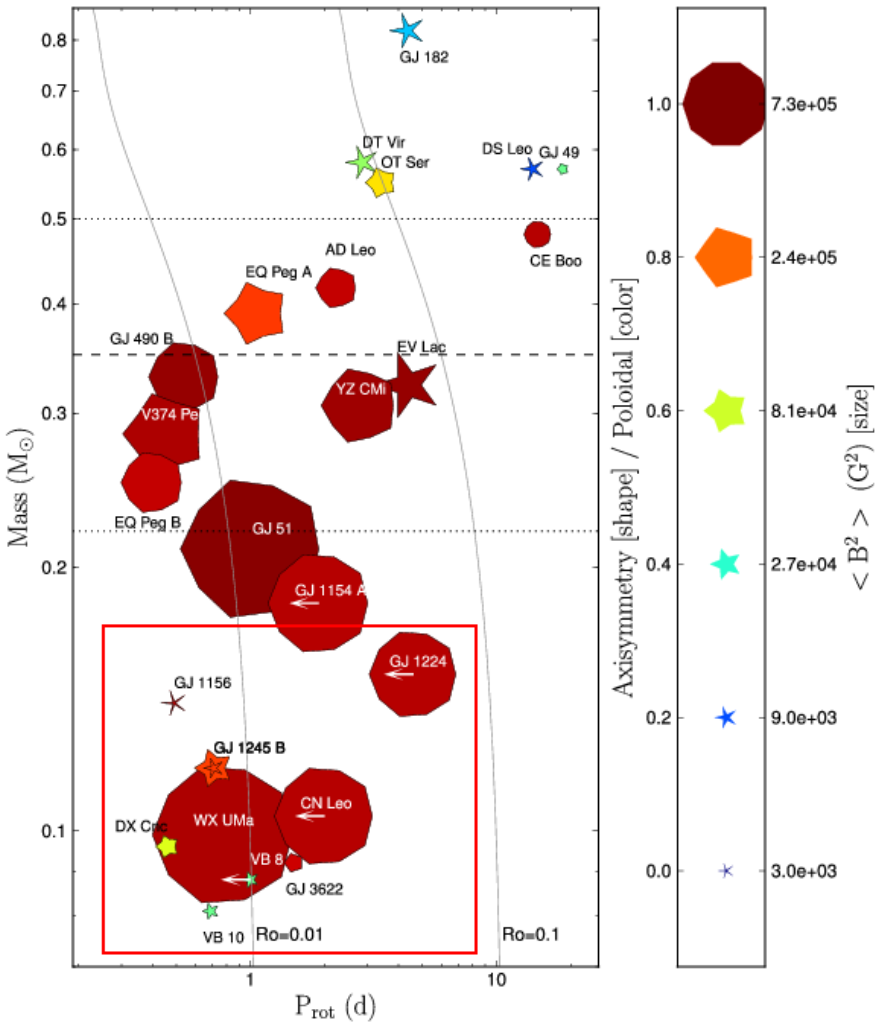

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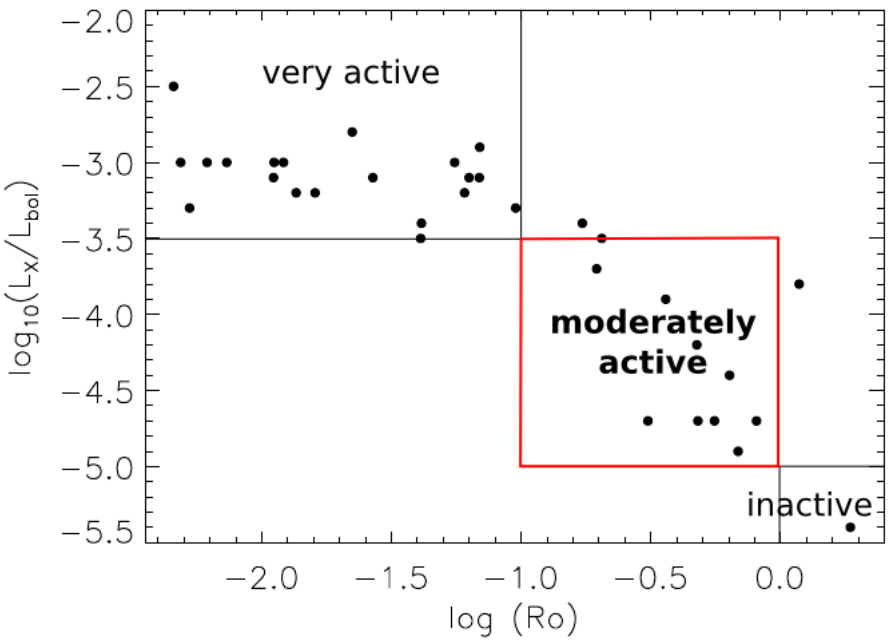
Outline

Activity level classes

- Input catalog ESPaDOnS observations

➔ L. Malo's talk

- Very active stars
  - Not suitable for planet searches
- Inactive stars
  - Magnetism characterization not possible/needed
- Moderately active stars
  - Planet serach
  - Coupled with activity/magnetism study



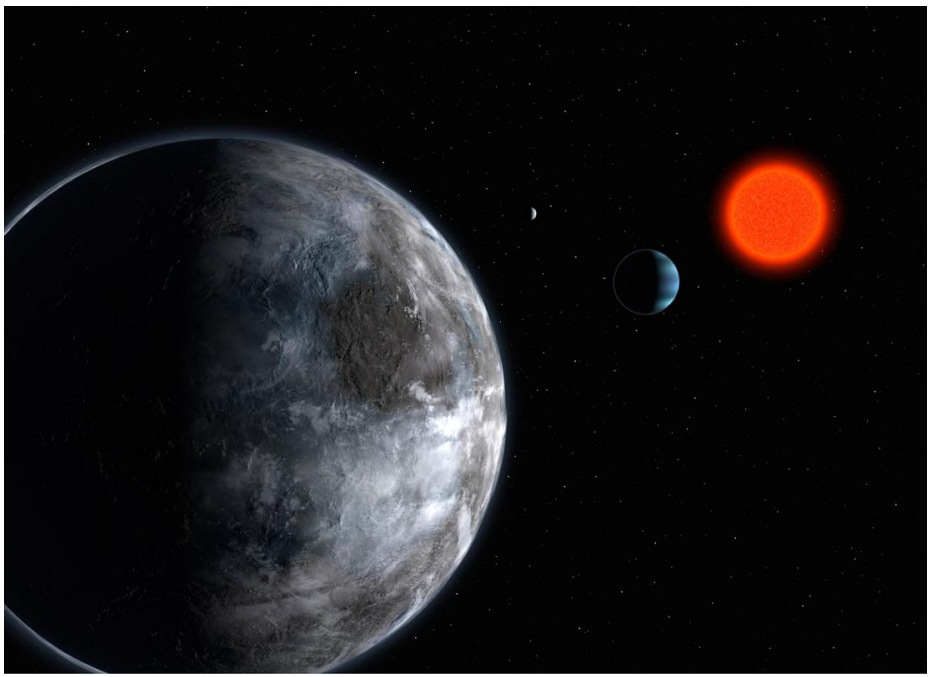
Adapted from Reiners et al. (2009)

M dwarfs' magnetism studies within SLS

- Moderately active stars
- charact. of $\vec{B}$/activity required
  - Planet detection
  - Planet characterization
- Studies of M dwarf magnetism

➔ Come for free!

  - Extend spectropolarimetric survey to intermediate activity
  - Rotation-activity-magnetic field relations at intermediate rotation
  - Magnetic cycles on M dwarfs?

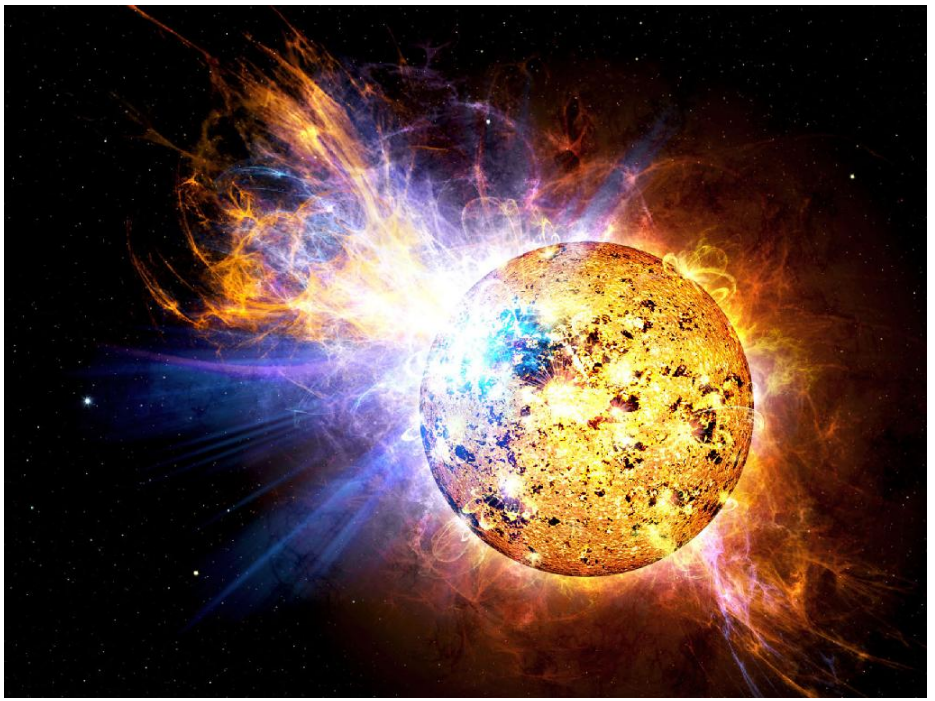


M dwarfs' magnetism studies outside SLS

- Very active stars
- Late SpT (Ultracool dwarfs)
- Complement SLS

➔ volume-limited sample

- Improve statistics on M0-M6
  - Bistability?
  - Connection w/ TTS?
- M7-M9
  - relation w/ other obs?



Outline

Summary

- Magnetic fields
  - Crucial for stellar physics and for planetary systems
- Spectropolarimetry
  - ESPaDOnS legacy
  - SPIRou : ideal for M dwarfs magnetism
- SLS
  - Huge potential for stellar science
  - Extend to very active / late SpT

➔ Build unique magnetic survey