Magnetic field topologies of M dwarfs

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Stellar Magnetic Fields

A key ingredient

- At every step in a star's life
- Engine of activity phenomena

Dynamo

- MHD generated field
- Convection + differential rotation
- Tachocline : Crucial role

Low-mass stars

- $M_\star < 0.35 \ M_\odot \Rightarrow$ Fully-convective

$\longrightarrow$ No solar-type dynamo
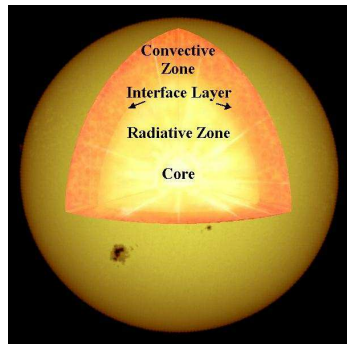
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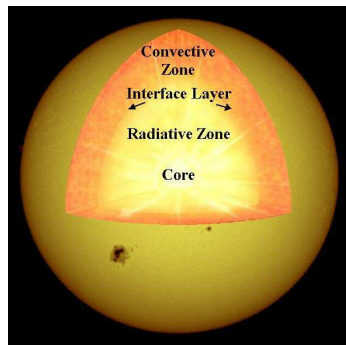- Engine of activity phenomena

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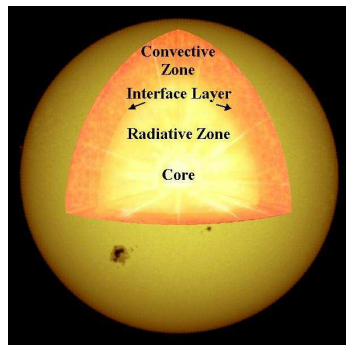# Stellar Magnetic Fields

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- Very active : Radio, Hα, X-ray
- Rapidly rotating late M
- Direct detection of magnetic fields

$\longrightarrow$ Type of dynamo ?
$\longrightarrow$ Magnetic field properties ?

Theroretical and Numerical approaches

- Cyclonic convection + turbulence
- Small-scale dynamo
- Mean field modelling
- 3D MHD DNS

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Delfosse et al 1998

West et al 2007

Johns-Krull & Valenti 1996

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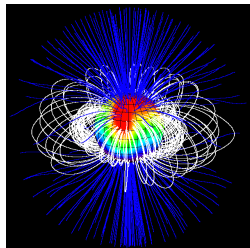- Direct detection of magnetic fields

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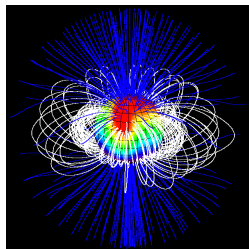- Rapidly rotating late M
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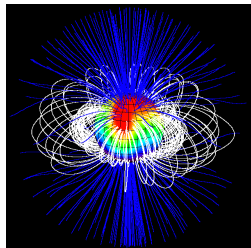- Rapidly rotating late M
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Durney et al 1993

Dorch & Ludwig 2002

Küker & Rüdiger 1999

Dobler et al 2006, Browning 2008

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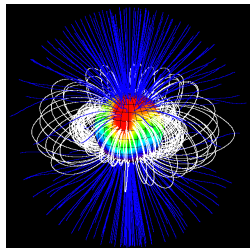- Direct detection of magnetic fields

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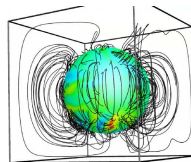$\longrightarrow$ Magnetic field properties ?

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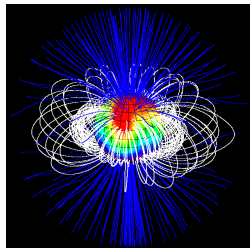- Rapidly rotating late M
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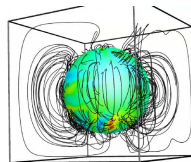$\longrightarrow$ Magnetic field properties ?

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Spectropolarimetric analysis of a sample

Aims

- Providing observational constraints

    - Large-scale magnetic field : topology / intensity / time-variability

- Dependency on stellar parameters

    - Mass / rotation rate

- On both sides of the full-convection threshold

Approach

- Exploration of a small sample $\sim$ 20 active $\star$ M0 $\rightarrow$ M8

- NIR photometry $\Rightarrow$ masses *Delfosse et al 2000*

- Tomographic imaging

    - Large-scale magnetic topologies

        - Spherical harmonics $\Rightarrow$ poloidal-toroidal decomposition

    - Rotation periods / differential rotation

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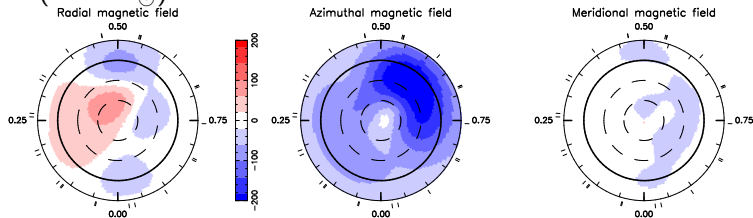- On both sides of the full-convection threshold

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Magnetic field reconstruction
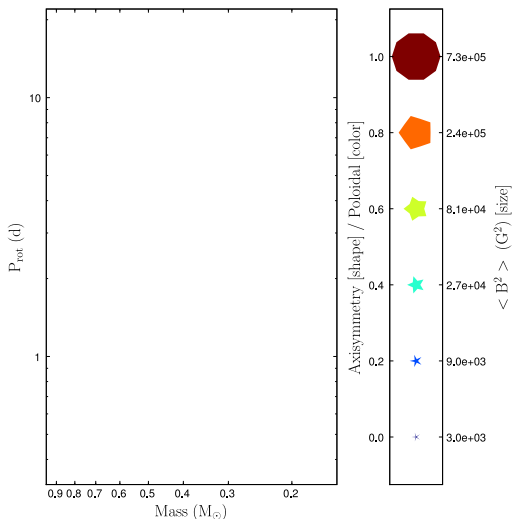
V374 Peg (0.28 M$_\odot$)
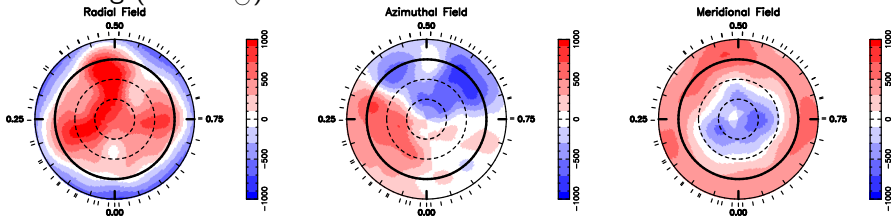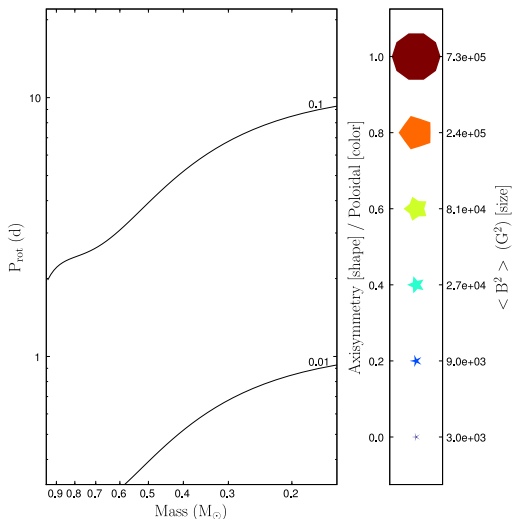

DS Leo (0.58 M$_\odot$)

⇨ More stars on poster I8

Mass / Rotation period plane

A synthetic view

- Magnetic field properties
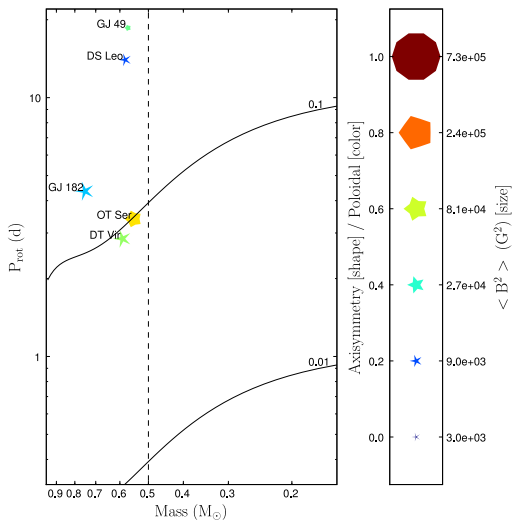- Main stellar parameters

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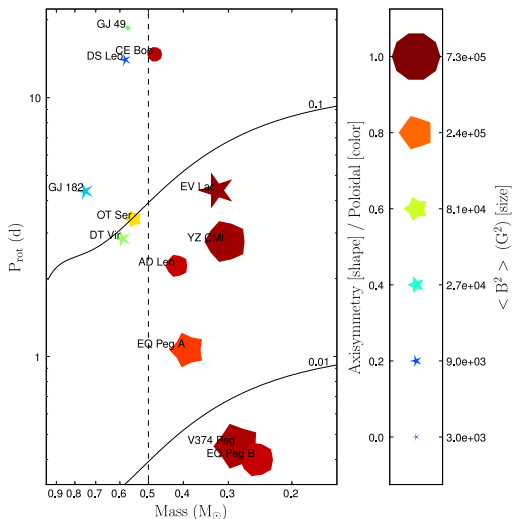- Main stellar parameters

$M_\star > 0.5\ M_\odot$

Properties

- Toroidal
- Non-axisymmetric

Differential rotation

- $d\Omega \gtrsim d\Omega_\odot$
- Short-lived structures
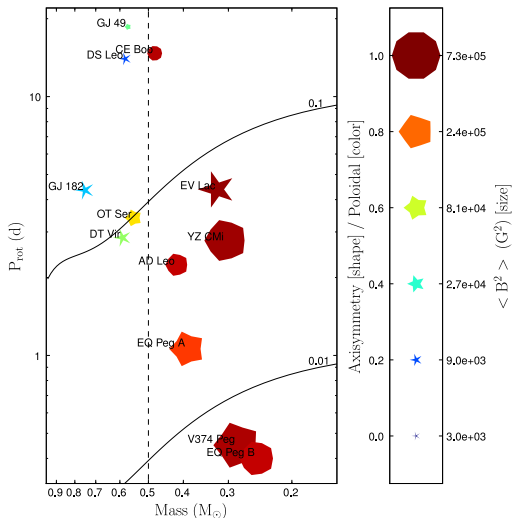
$M_\star < 0.5\ M_\odot$

Properties

- Poloidal
- Axisymmetric
- Stronger

Differential rotation

- $d\Omega \simeq \frac{d\Omega_\odot}{10}$
- Long-lived structures

First Results

Regions

- 2 regions
- Very different properties
- No dependance on rotation rate ?

Work in progress

- Completing the survey
  - Saturated partly-convective ★
  - Non-saturated fully-convective ★
  - Cooler stars

Evidence for a different dynamo regime

Rossby number

- $P_{\rm rot} \ \rightarrow \ Ro = \frac{P_{\rm rot}}{\tau_c}$
- Compare activity in stars of different masses

Rossby number

- Discontinuity
- Generation of large-scale field more efficient below $0.4 {\rm M}_\odot$
- $\longrightarrow$ Different spatial scales
  Same magnetic energy

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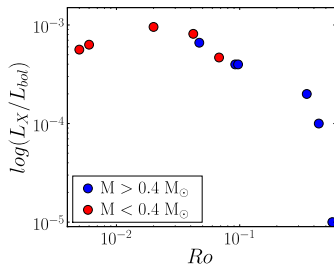
Noyes et al 1984

Kiraga & Stepien 2007

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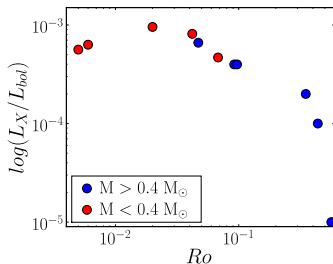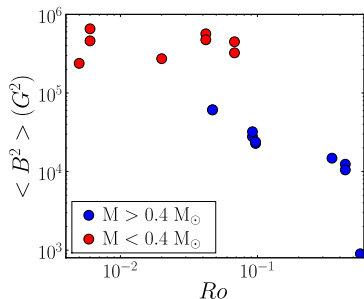- Compare activity in stars of different masses

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Conclusions

Study

- Spectropolarimetric survey
- A few active stars
- $0.1 < M_\star < 0.8\ M_\odot$
- $0.4 < P_{\rm rot} < 20\ d$
- Tomographic imaging

Perspectives

- Complete the survey
- Explore cooler stars
- Implications
  - Rotational braking
  - Coronal emission

First results

- Large-scale topologies of early and mid-M dwarfs
- Transition at $\sim 0.5 M_\odot$
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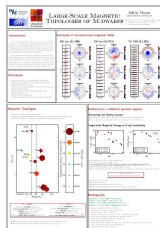 - Rotational braking
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Poster I8