Large-Scale Magnetic Topologies of M-dwarfs

Julien Morin
jmorin[at]ast.obs-mip.fr

J.-F. Donati, P. Petit, B. Dintrans (LATT – CNRS)
X. Delfosse, T. Forveille (LAOG – CNRS)
M. M. Jardine (Univ. St Andrews)

CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE
ASTRO LATT PHYSIQUE
Université de Toulouse

Introduction

Stars with masses lower than about 0.35 $M_\odot$ are fully-convective [1] and thus do not possess a tachocline. However, they manage to produce magnetic fields and are very active [2,3,4]. Though significant progress were made since first non-solar dynamo mechanisms were proposed [5,6,7], theoretical and numerical modelling require observational constraints.

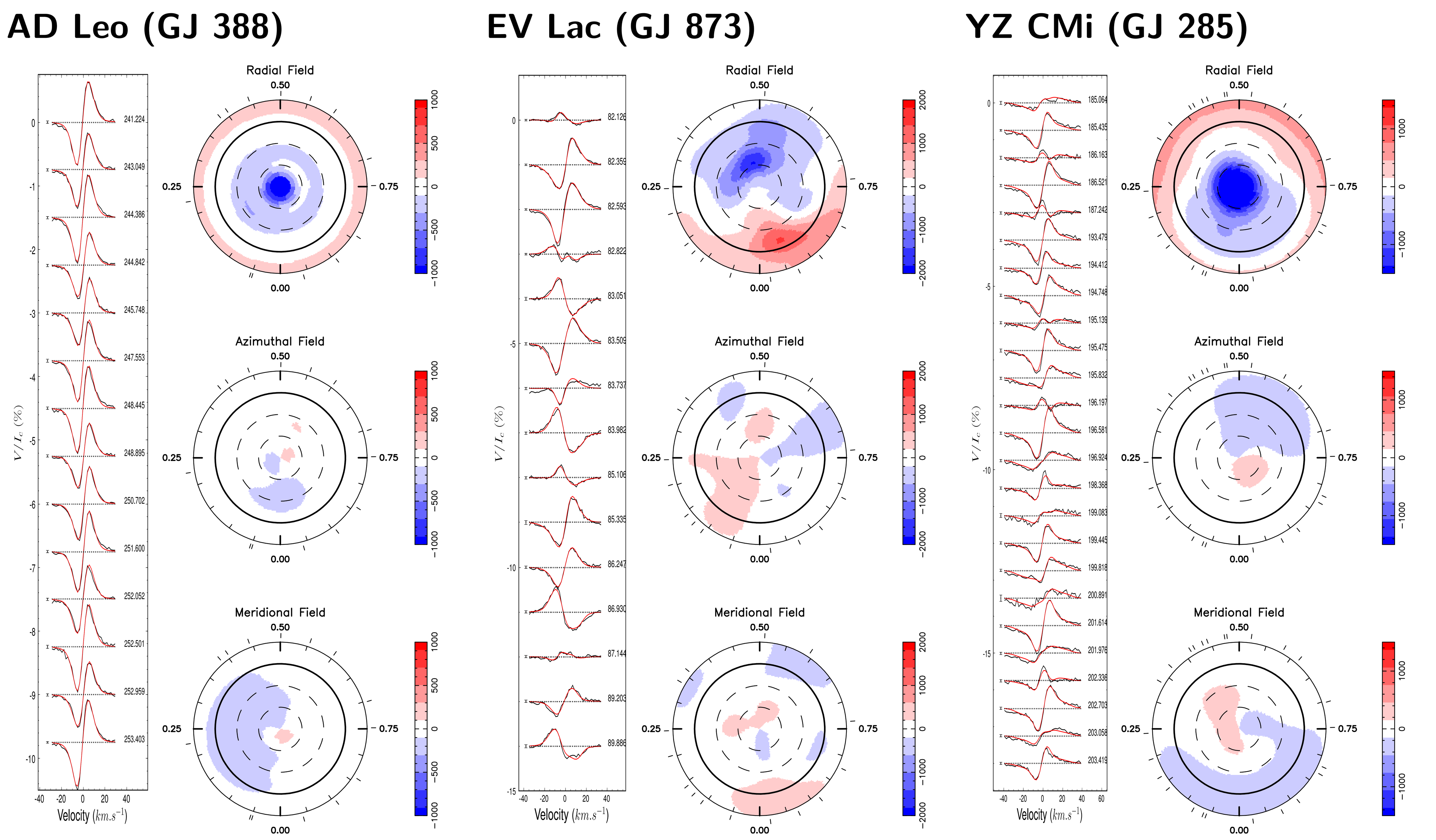
We present here the first results of a spectropolarimetric analysis of a small sample of active M dwarfs with spectral types ranging from M0 to M8, which are either fully convective or possess a very small radiative core. We aim at exploring the properties of the large-scale magnetic topologies of fully-convective stars, and their evolution with main stellar parameters (mass, rotation rate).

Techniques

- ✰ Spectropolarimetry with ESPaDOnS and NARVAL
  - ➥ Circular polarisation ⇒ Longitudinal magnetic field
- ✰ Least Squares Deconvolution
  - ➥ Extraction of the polarimetric information from most lines
- ✰ Tomographic imaging
  - ➥ Reconstruction of the large-scale magnetic field
- ✰ Spherical Harmonics
  - ➥ Physically meaningful field
  - ➥ Decomposition into poloidal and toroidal components

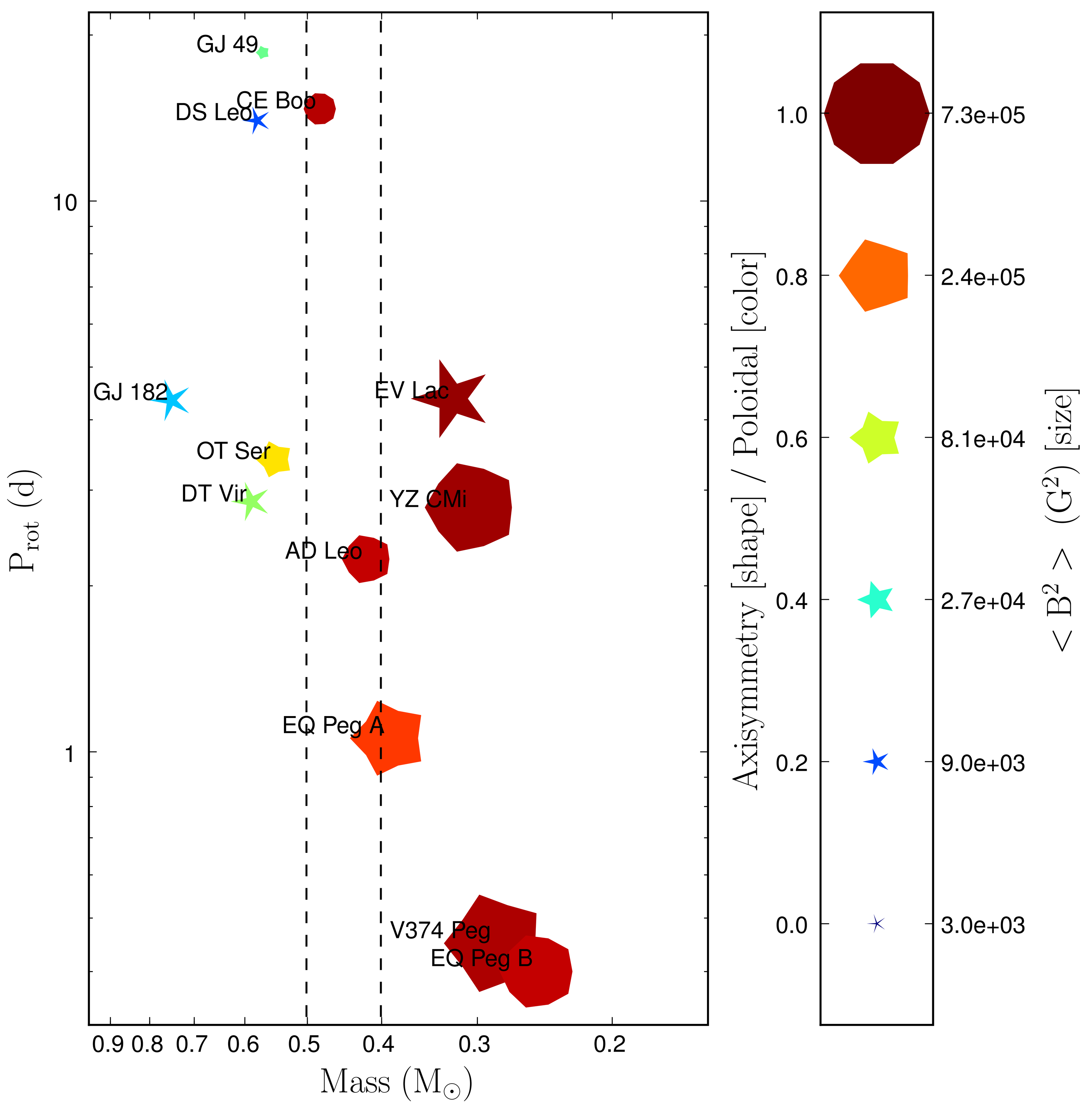
Examples of reconstructed magnetic fields

AD Leo (GJ 388) — EV Lac (GJ 873) — YZ CMi (GJ 285)



Magnetic Topologies

- ✰ Results for stars with ST earlier than M5
- ✰ Rotation periods and differential rotation inferred from tomographic imaging analysis
- ✰ Masses computed from empirical calibrations based on NIR photometry [8]



$M_\star > 0.5 M_\odot$	$M_\star < 0.5 M_\odot$
Significant **toroidal** component	Mainly **poloidal** field
Non-axisymmetric poloidal component	Strongly **axisymmetric** poloidal component
Complex large-scale topology	Nearly **dipolar** large-scale field
Short-lived structures	**Long-lived** structures (> 1 yr)
Significant **differential rotation** ($d\Omega \gtrsim d\Omega_\odot$)	**Very weak differential rotation** ($d\Omega \simeq \frac{d\Omega_\odot}{10}$)

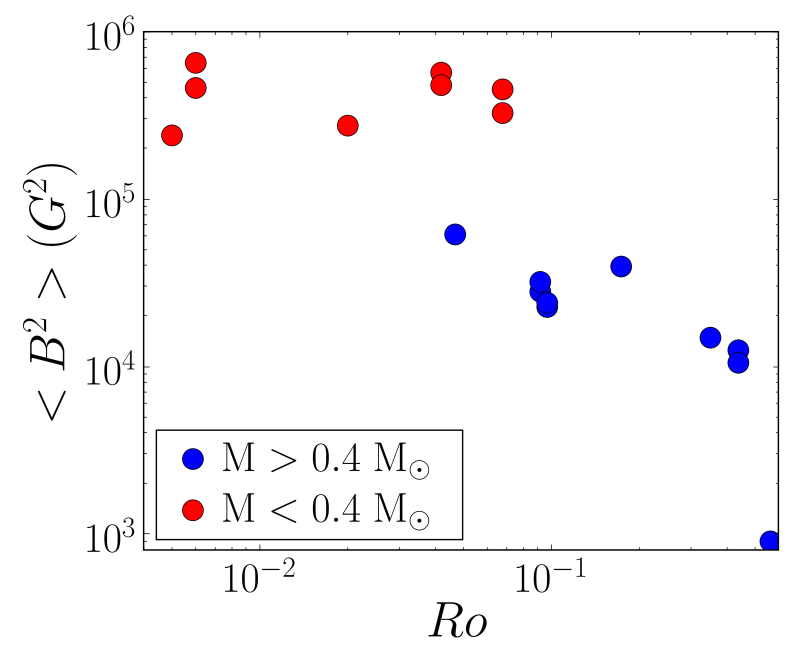
- ➥ Sharp threshold at a mass greater than the theoretical limit to full-convection
- ➥ Due to a fast change in the radiative core radius for $M_\star < 0.5 M_\odot$ [9] ?

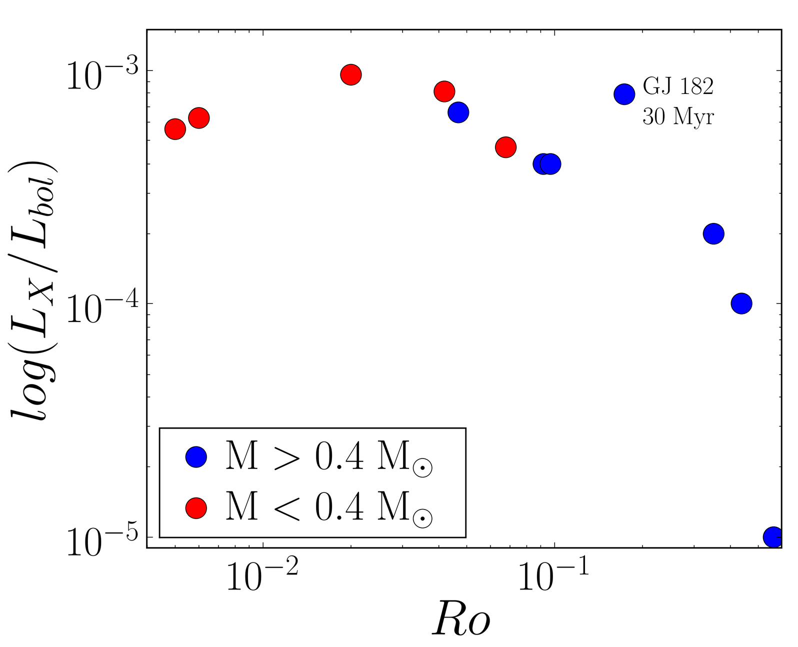
Evidence for a different dynamo regime

Estimating the Rossby number

- ✰ *Ro* allows to compare activity and magnetic fields in stars of different masses
- ✰ P_{rot} is rescaled by an empirical convective turnover time → $Ro = \frac{P_{rot}}{\tau_c}$ [10]

Large-scale Magnetic Energy vs X-ray Luminiosity





- ✰ Discontinuity in $< B^2 >$ vs *Ro* around 0.4 $M_\odot$
- ✰ No such discontinuity in $\log \frac{L_X}{L_{bol}}$ vs *Ro*
  - ➥ **Generation of large-scale magnetic fields is more efficient below 0.4** $M_\odot$
  - ➥ X-ray emission depends on the overall magnetic energy
  - ➥ For a given *Ro*, more energy lies in large-scales at constant overall magnetic energy below 0.4 $M_\odot$

> $M_\star < 0.4 M_\odot$
> New dynamo regime due to full-convection ?

- ✰ $0.4 M_\odot < M_\star < 0.5 M_\odot$
  - ➥ Intermediate region
  - ➥ Large-scale topology similar to cooler stars
  - ➥ Same large-scale magnetic energy as hotter stars (for a given *Ro*)

Bibliography

Donati J.-F., et al., 2006, Sci, 311, 633
Morin J., et al., 2008, MNRAS, 384, 77
Morin J., et al., 2008, submitted to MNRAS
Donati J.-F., et al., 2008, submitted to MNRAS

[1] Chabrier G., Baraffe I., 1997, A&A, 327, 1039
[2] Johns-Krull C. M., Valenti J. A., 1996, ApJ, 459, L95
[3] Reiners A., Basri G., 2007, ApJ, 656, 1121
[4] Delfosse X., Forveille T., Perrier C., Mayor M., 1998, A&A, 331, 581
[5] Durney B. R., De Young D. S., Roxburgh I. W., 1993, SoPh, 145, 207
[6] Dobler W., Stix M., Brandenburg A., 2006, ApJ, 638, 336
[7] Browning M. K., 2008, ApJ, 676, 1262
[8] Delfosse X., Forveille T., Ségransan D., Beuzit J.-L., Udry S., Perrier C., Mayor M., 2000, A&A, 364, 217
[9] Siess L., Dufour E., Forestini M., 2000, A&A, 358, 593
[10] Kiraga M., Stepien K., 2007, AcA, 57, 149