Starspots: active longitudes and flip-flops

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At ESO Garching since 01.09.2007
Collaboration

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Why to study starspots?

- They give information on stellar magnetic fields
- Even the solar magnetic behaviour is not completely understood
- Solar activity effects the Earth’s climate
Starspots, photometry

Long-term V band photometry of FK Com (Korhonen et al. 2001)

Phased light-curves for 1990-1993 and results from the light-curve inversions

Korhonen et al. 2002
Starspots in detail?

- Stars are point sources, no possibility for spatially resolved observations
- For detailed observations of stellar surface indirect means are needed
In Doppler imaging the distortions appearing in the observed line profile due to the presence of spots and moving due to the stellar rotation

Ill-posed inversion problem

Many methods for solving:
- Maximum Entropy Method (e.g., Vogt et al 1987),
- Tikhonov Regularization (e.g., Piskunov et al 1990),
- Occamian Approach (Berdyugina 1998),
- Principal Components Analysis (Savanov & Strassmeier 2005)
Requirements for Doppler imaging

● Models
  ● Accurate line profile modelling

● Instrumentation
  ● High spectral resolution
  ● High signal-to-noise ratio

● Object
  ● Good phase coverage (convenient rotation period)
  ● Rapid rotation
  ● Not too long exposure time (bright)
  ● Something to map!
Spots on FK Com 1994-2003

Korhonen et al. 2007, in press
The flip-flop phenomenon

- Discovered in FK Com in the early 1990’s (Jetsu et al. 1993)
- Activity concentrates on two permanent active longitudes, and flips between the two every few years

Jetsu et al. 1993
Flip-flops and active longitudes in RS CVn binaries

Berdyugina & Tuominen 1998
Flip-flops in detail

Korhonen et al 2001
Stars with flip-flops

Up to now 13 stars with flip-flops are known:

<table>
<thead>
<tr>
<th>Description</th>
<th>Flip-flop period</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Sun</td>
<td>3.7 years</td>
</tr>
<tr>
<td>3 young solar analogues</td>
<td>4.0-5.5 years</td>
</tr>
<tr>
<td>2 FK Com type single giants</td>
<td>4.0-6.4 years</td>
</tr>
<tr>
<td>8 RS CVn binaries</td>
<td>4.0-17.5 years</td>
</tr>
</tbody>
</table>

Modelling flip-flops I

- Axisymmetric dynamos do not show preferred longitudes, but oscillate (solar 11 year cycle)
- Non-axisymmetric dynamos show active longitude structure, but no oscillations

For explaining the flip-flop phenomenon both properties are needed

Models:
Moss 2004, 2005; Fluri & Berdyugina 2004; Elstner & Korhonen 2005
Modelling flip-flops II

Thin convection zone model Rin = 0.8R₀

Solar-like rotation law

Weak differential rotation, about 10% of the solar

Axisymmetric component acting in the equatorial region

Non-axisymmetric close to the poles

Elstner & Korhonen 2005
Korhonen & Elstner 2005
Light-curves from the dynamo models

The dynamo calculations were converted into synthetic photometric observations to study the patterns caused by the flip-flop phenomenon.

Korhonen & Elstner 2005, similar results also by Fluri & Berdyugina 2004
Finding new flip-flop stars

- Interesting targets for further study from old photometry
  - Stars with long-term photometry showing the same patterns as in the models
  - Stars with at least 10 years of photometric data
- Investigated 11 stars (Korhonen et al. 2008)
Comparison to the models

Models imply that the flip-flops occur during the minimum amplitude.

Based on the observations the minimum photometric amplitude can imply:

- Flip-flops
- Phase shifts
- Nothing

Korhonen et al., in preparation
What else did we find?

Korhonen et al., in preparation
Flip-flop 'survey' results

- Active longitudes: (from our 11 targets)
  - 7 stars showed two active longitudes with a separation of 0.5 in phase
  - 4 showed signs of two permanent active longitudes which were 0.3-0.4 in phase apart

- Flip-flops:
  - 3 stars did not show clear flip-flops
  - 2 showed flip-flops, but no periodicity, or not enough data to measure the period
  - For 6 stars we could estimate a flip-flop period
For improving the modeling of the flip-flop phenomenon

- Create statistically significant sample of stars showing the flip-flop phenomenon
- Study which stellar parameters the flip-flops depend on
- Investigate the spot polarity during a full flip-flop cycle
- Adding meridional flow to the dynamo calculations