Starspots: active longitudes and flip-flops

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At ESO Garching since 01.09.2007

Collaboration

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- Katalin Oláh & Zsolt Kővári, Konkoly Observatory, Hungary
- Sergio Messina, INAF Catania Observatory, Italy
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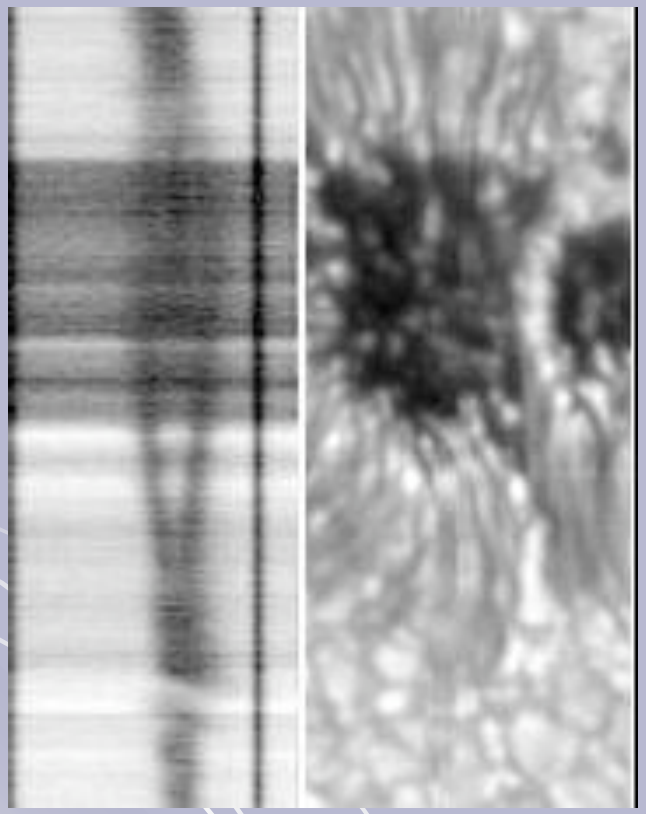
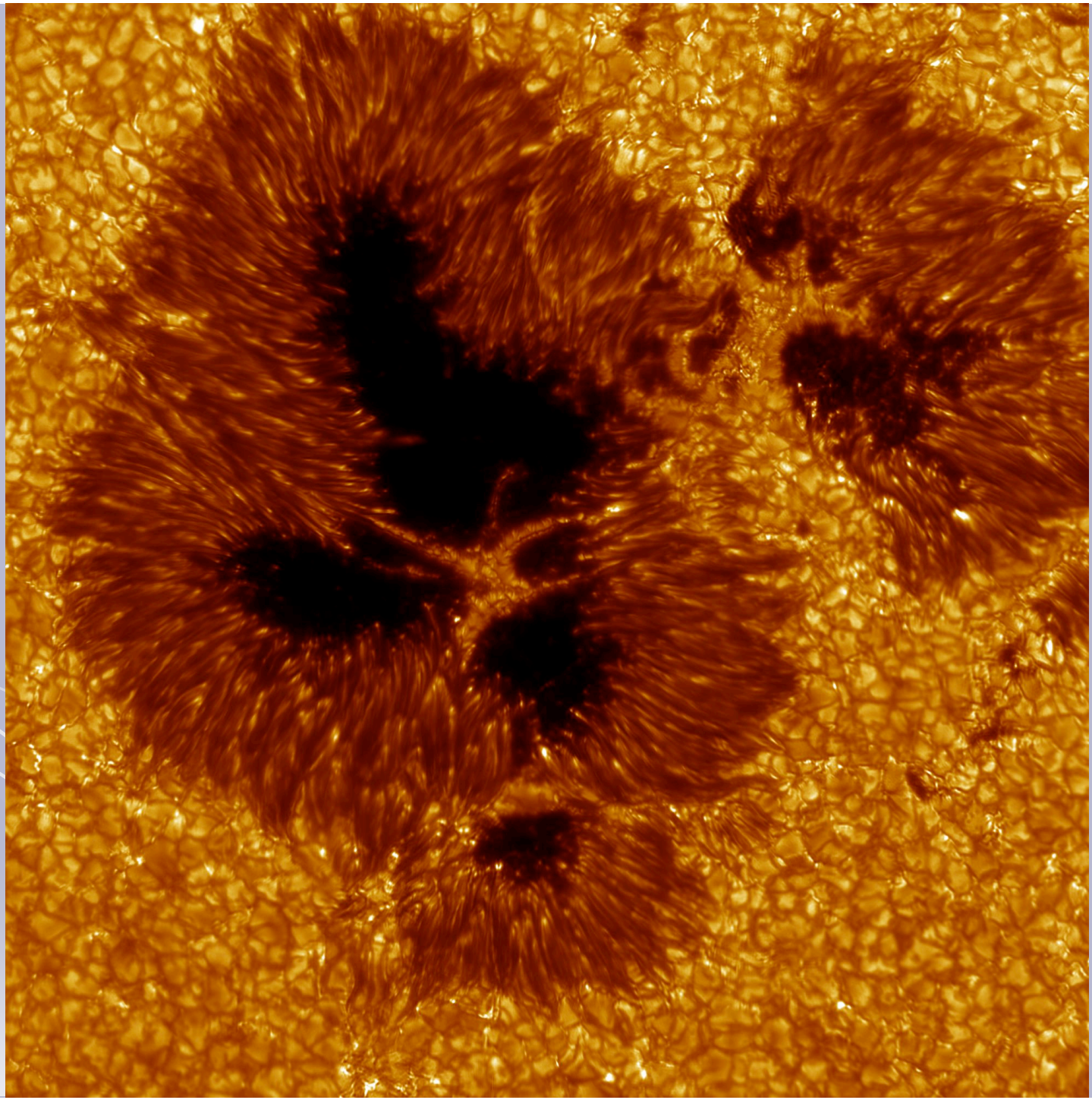
Why to study starspots?

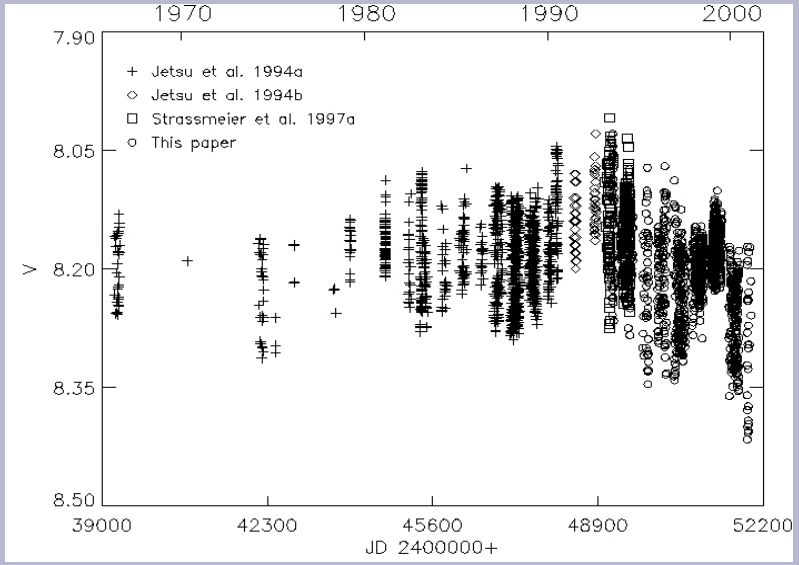


- They give information on stellar magnetic fields
- Even the solar magnetic behaviour is not completely understood
- Solar activity effects the Earth’s climate



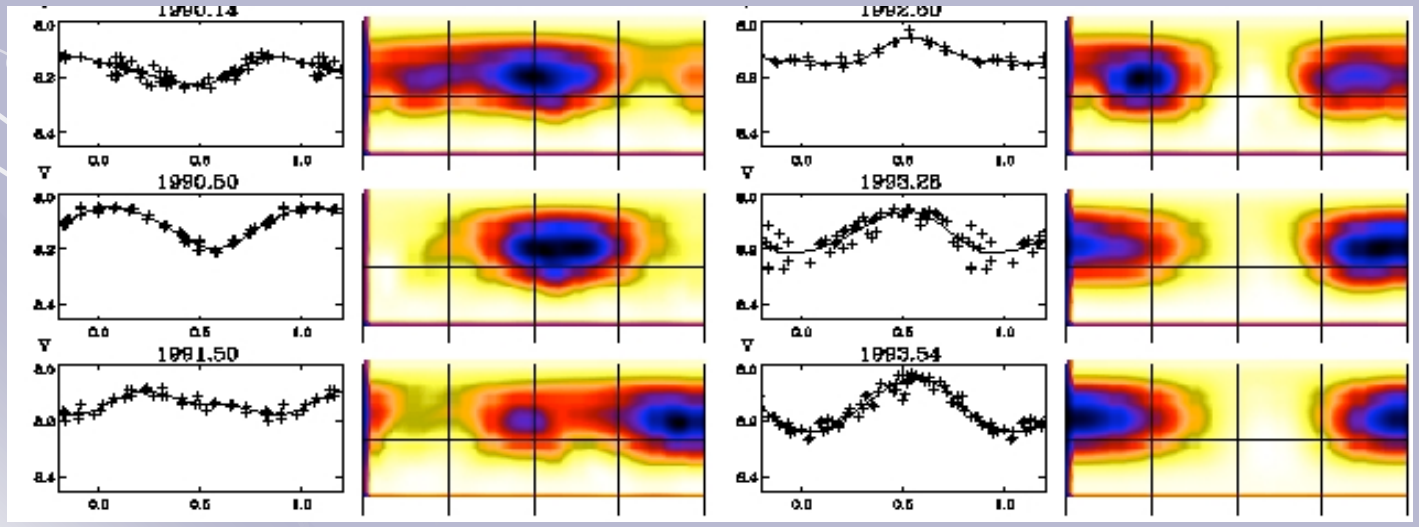
SST

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?

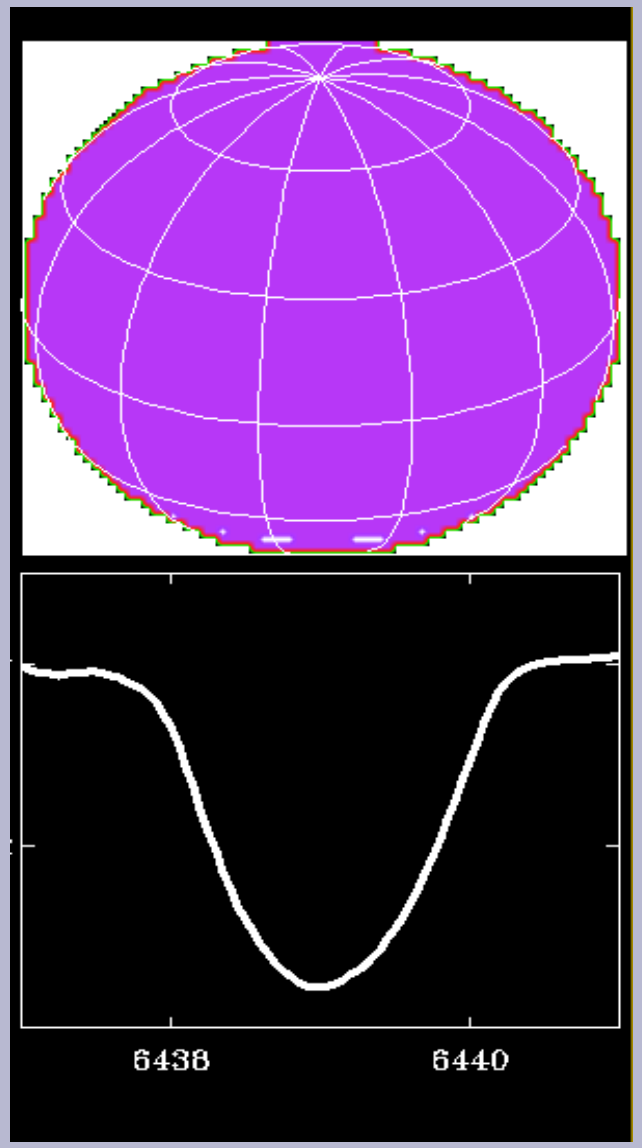
- Stars are point sources, no possibility for spatially resolved observations
- For detailed observations of stellar surface indirect means are needed

Doppler imaging

Doppler imaging

From Berdyugina

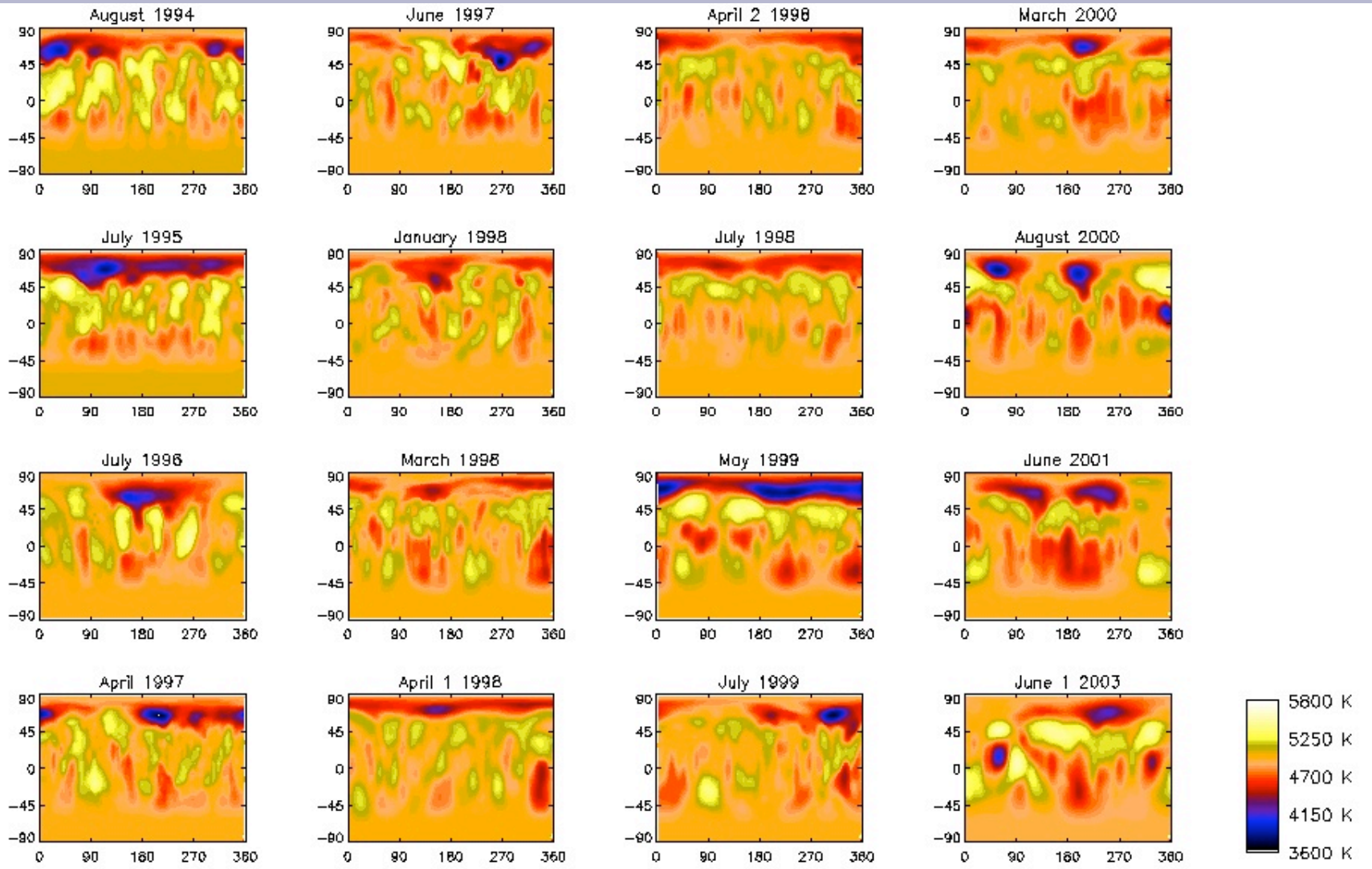
- In Doppler imaging the distortions appearing in the observed line profile due to the presence of spots and moving due to the stellar rotation
- Ill-posed inversion problem
- Many methods for solving: Maximum Entropy Method (e.g., Vogt et al 1987), Tikhonov Regularization (e.g., Piskunov et al 1990), 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!

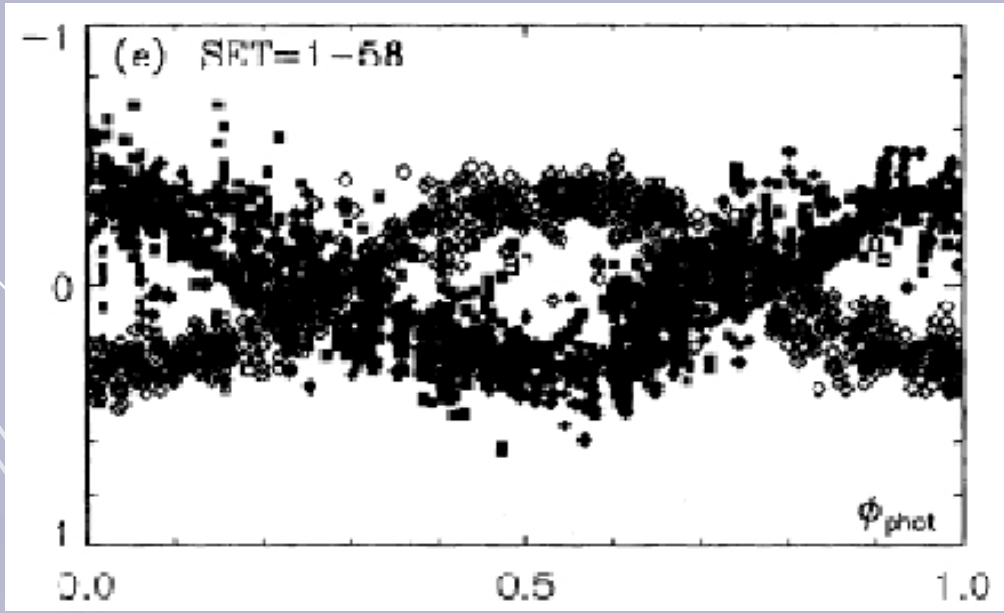
Spots on FK Com 1994-2003



Korhonen et al. 2007, in press

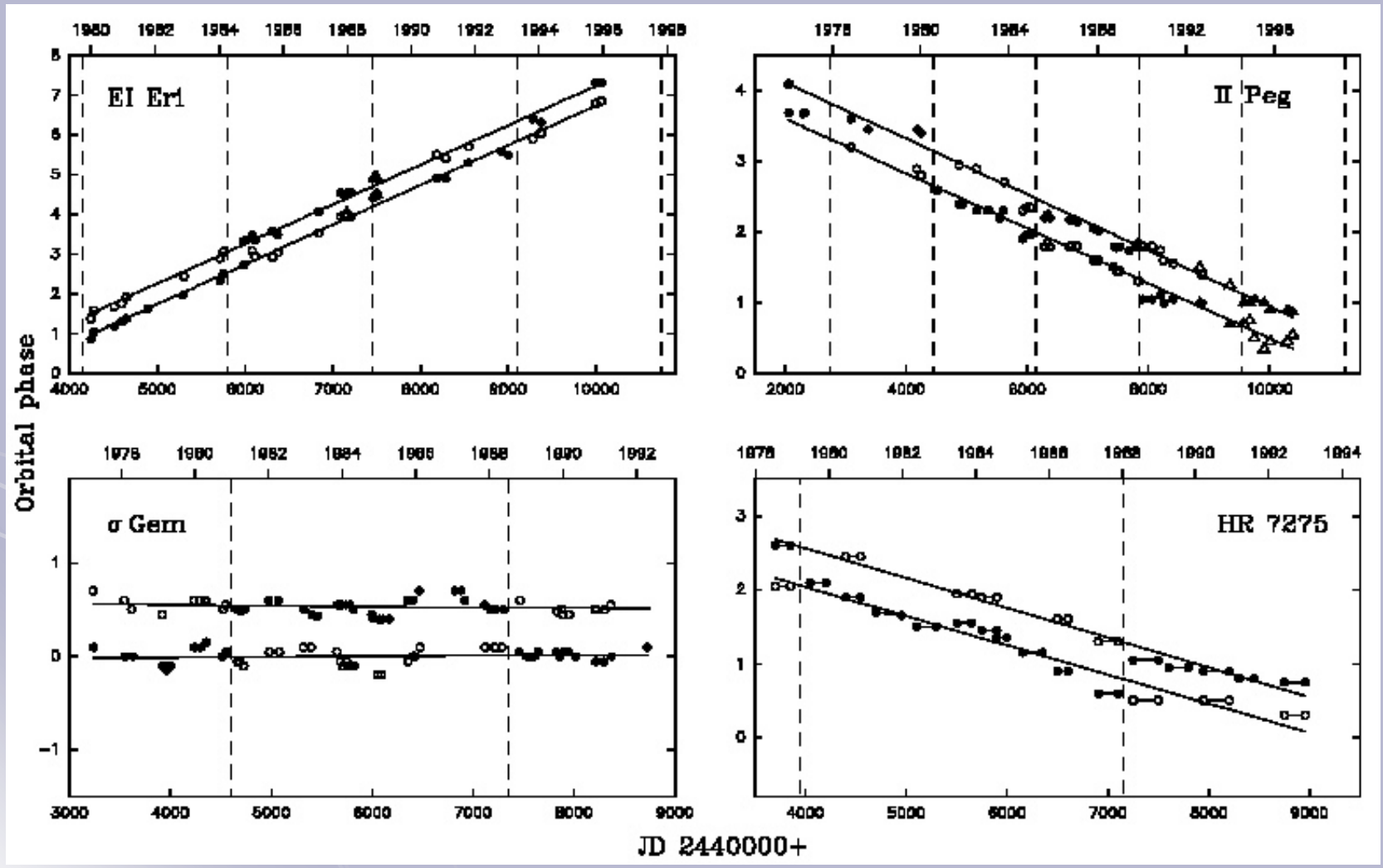
The flip-flop phenomenon

- 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



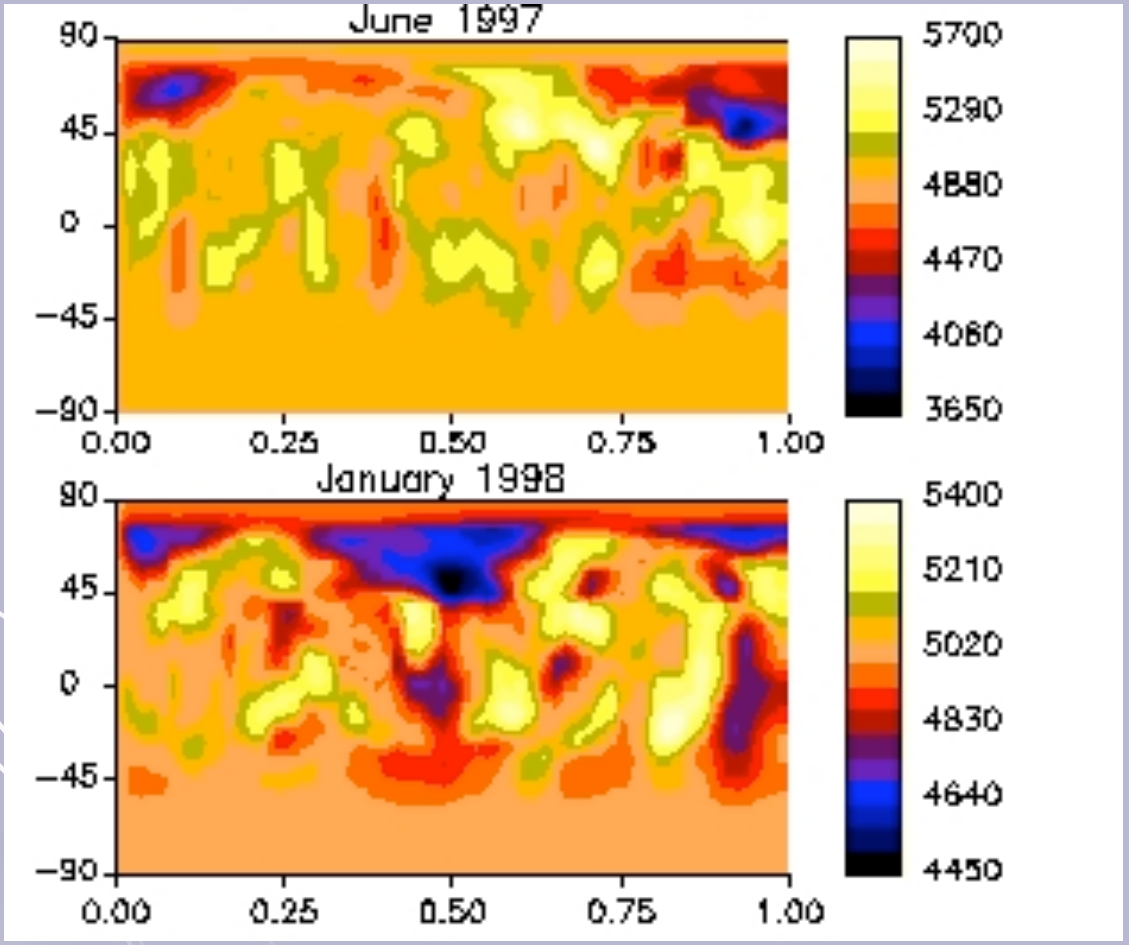
Jetsu et al. 1993

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:

	flip-flop period	
The Sun	3.7	years
3 young solar analogues	4.0-5.5	years
2 FK Com type single giants	4.0-6.4	years
8 RS CVn binaries	4.0-17.5	years

Berdyugina & Tuominen 1998; Korhonen et al. 2002, Berdyugina & Usoskin 2003; Hackman 2004; Järvinen et al. 2005a, 2005b; Fekel & Henry 2005; Berdyugina & Henry 2007

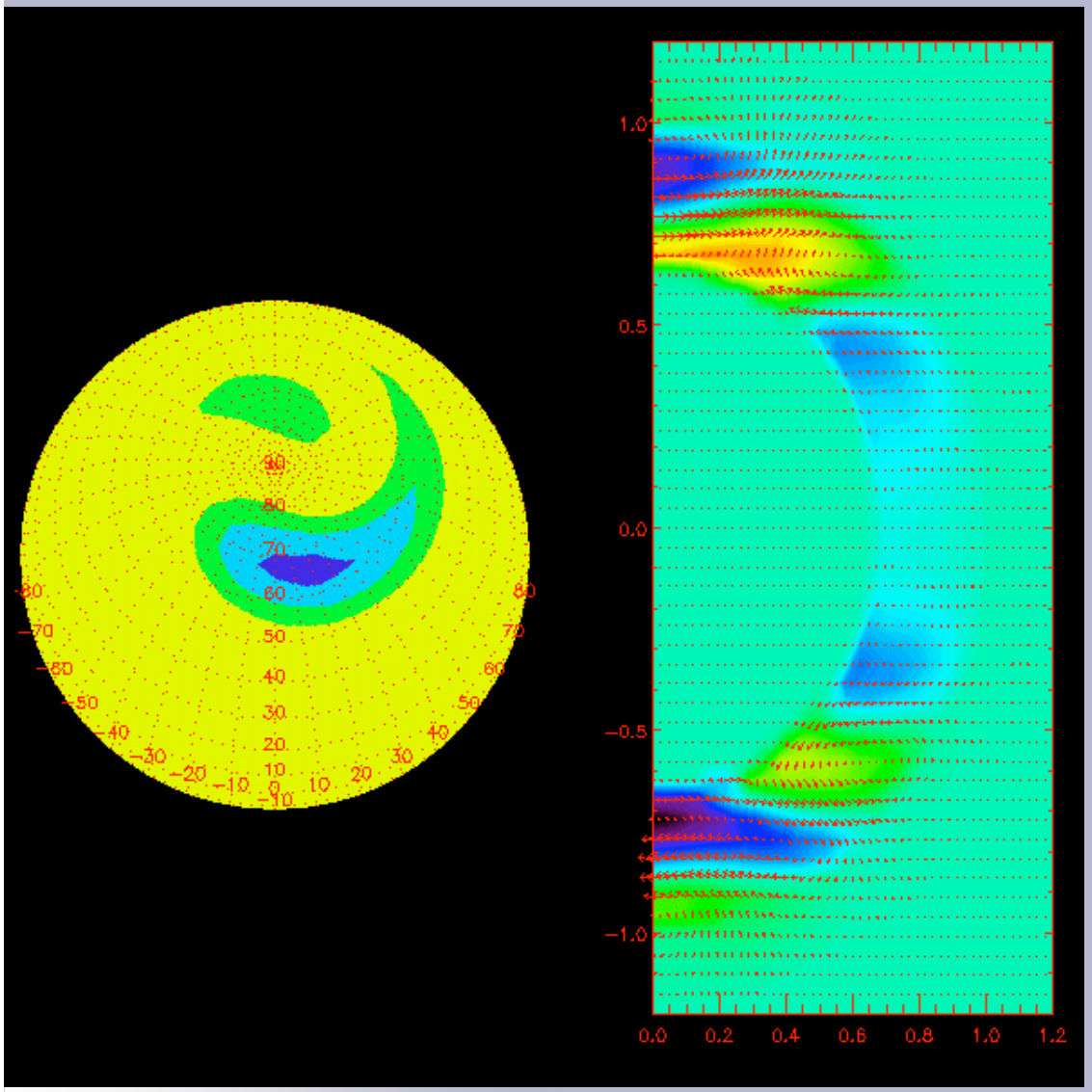
Modelling flip-flops I

- 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 = 0.8R⊙

Solar-like rotation law

Weak differential rotation, about 10% of the solar

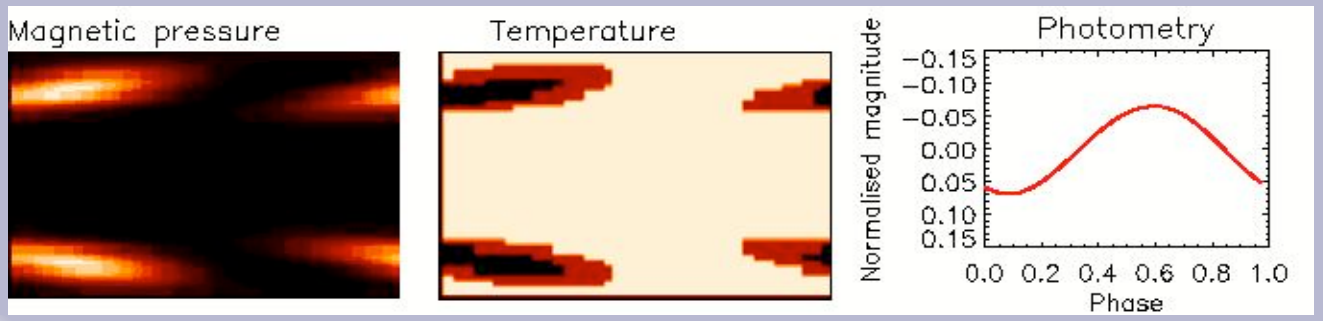
Axisymmetric component acting in the equatorial region

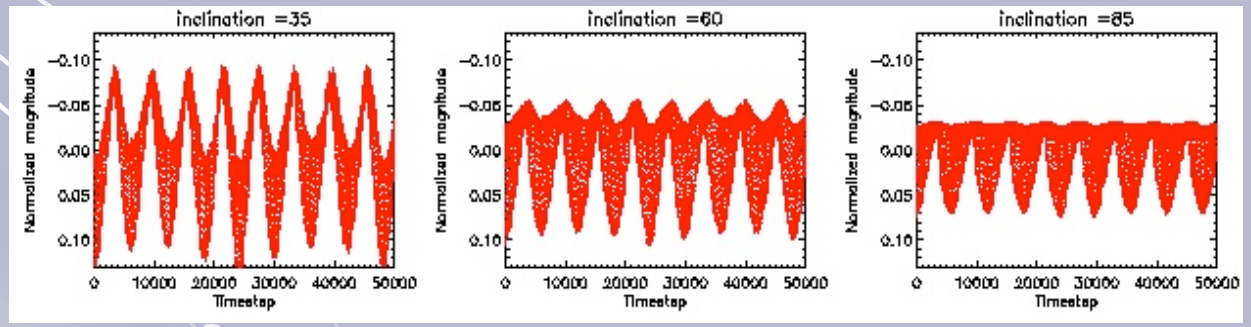
Non-axisymmetric close to the poles

Elstner & Korhonen 2005
Korhonen & Elstner 2005

Light-curves from the dynamo models

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





Korhonen & Elstner 2005, similar results also by Fluri & Berdyugina 2004

Finding new flip-flop stars

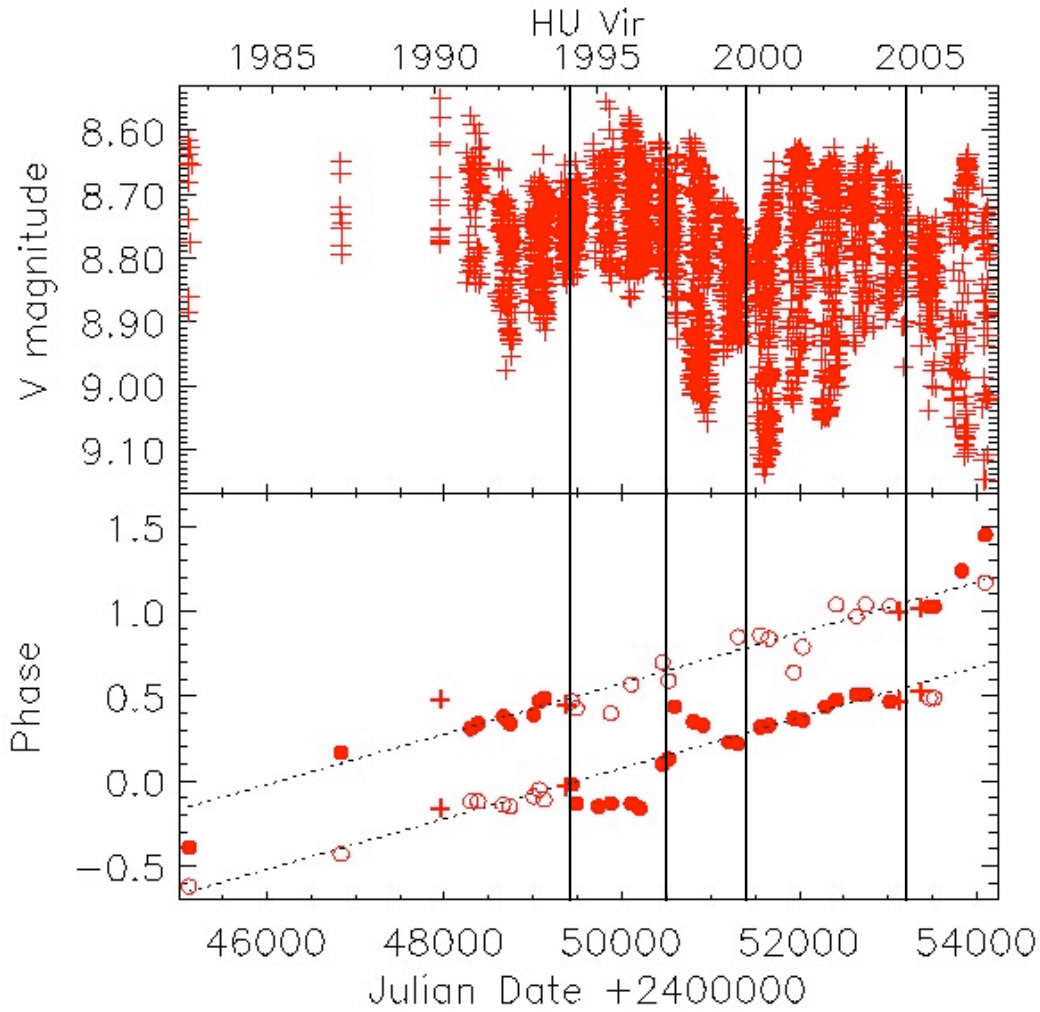
- Interesting targets for further study from old photometry
  - Stars with long-term photometry showing the same patterns as in the models
  - Stars with at least 10 years of photometric data
- Investigated 11 stars (Korhonen et al. 2008)

Comparison to the models

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

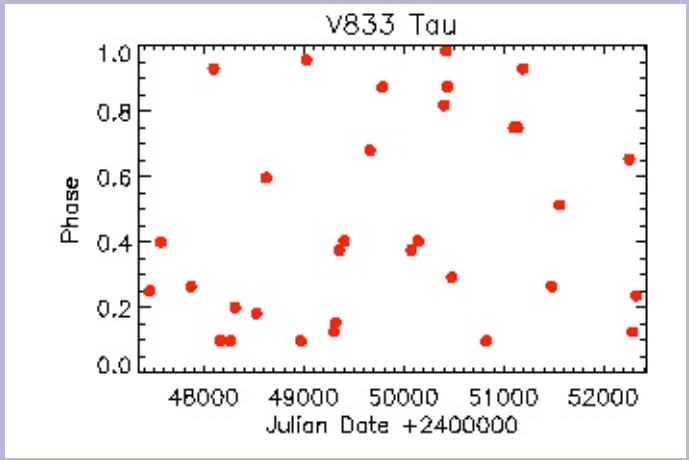
Based on the observations the minimum photometric amplitude can imply:

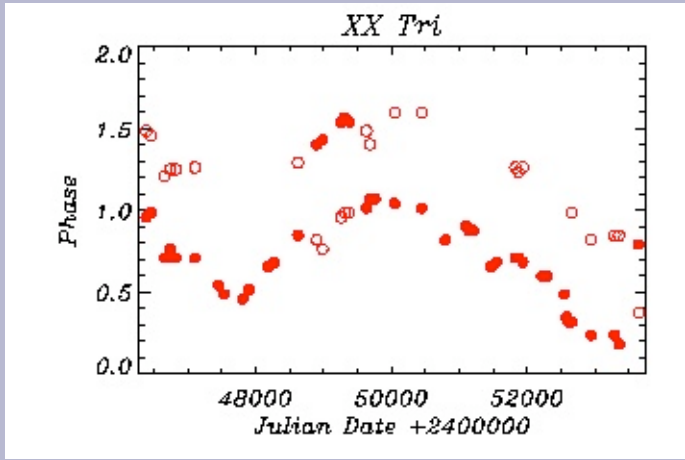
- Flip-flops
- Phase shifts
- Nothing

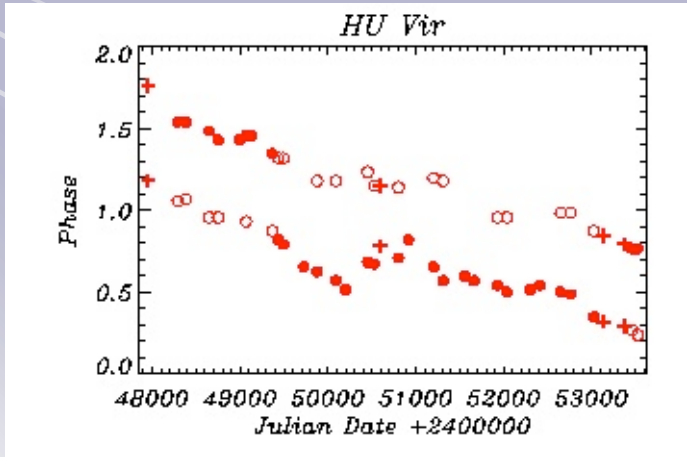


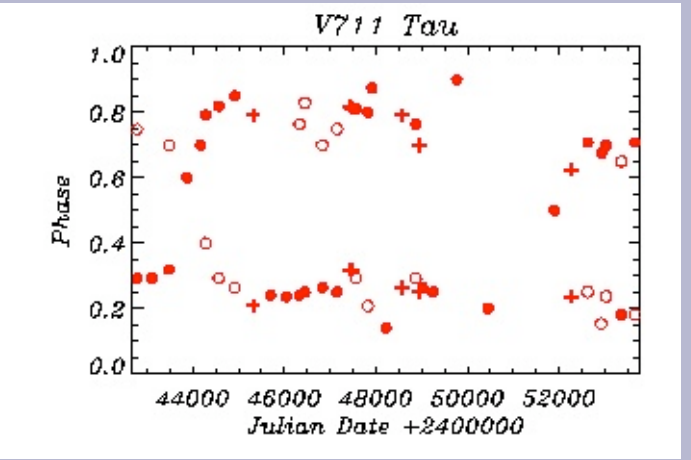
Korhonen et al., in preparation

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