Observing Stellar Spot Activity

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Outline

- Active late-type stars
- Optical observational methods
- Some results

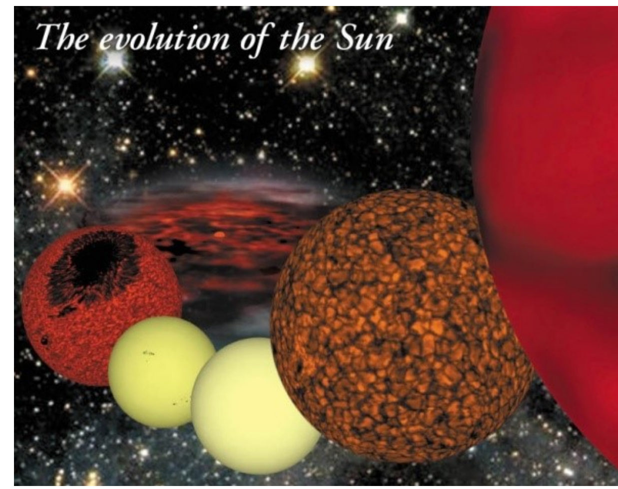
1. Active late-type stars

- Stars with spectral class F2 or later
- Activity increases with decreasing Rossby number (Noyes et al. 1984)
- => rapid rotation and/or deep convective zone: Higher level of activity
- Some classes of very active stars:
  - Young solar analogues and BY Draconis variables (single and binary stars)
  - RS CVn stars
  - FK Comae stars (single)

$$R_o = \frac{P_{\rm rot}}{\tau_{\rm conv}}$$

1.1 Why observe starspots?

- Active stars are analogues to the young Sun
- By studying starspots:
  - Stellar magnetic cycles
  - Differential rotation
  - Comparison with dynamo models
- -> Better models for solar activity



The evolution of solar magnetic activity (Schrijver)

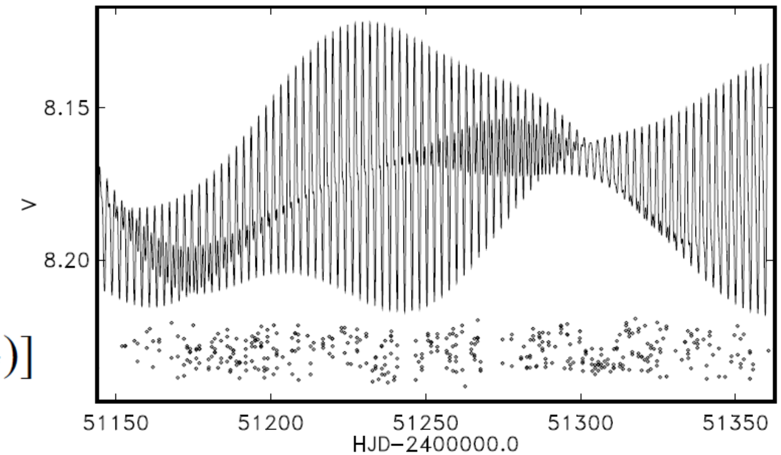
2. Observing starspots

Obbservations	Facilities	Method
Photometry	APT:s, optical satellites	Time-series analysis, light-curve inversion, direct modelling
HR spectrometry	SOFIN & FIES @NOT, UVES@VLT	Doppler imaging
Spectropolarimetry	SOFIN@NOT, HARPSpol@ESO3.2, ESPaDOnS@CFHT	Zeeman-Doppler imaging

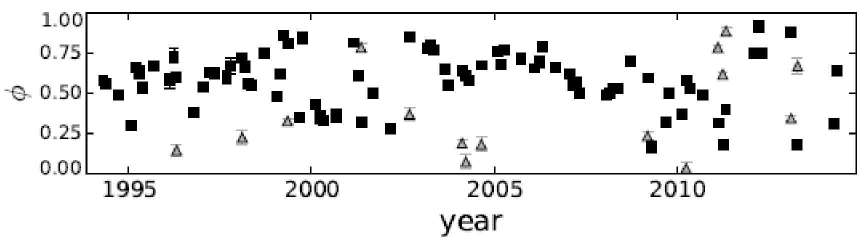
2.1 Time-series analysis of photometry

- Carrier fit (Pelt et al.)
- Continuous period search (Lehtinen et al.)

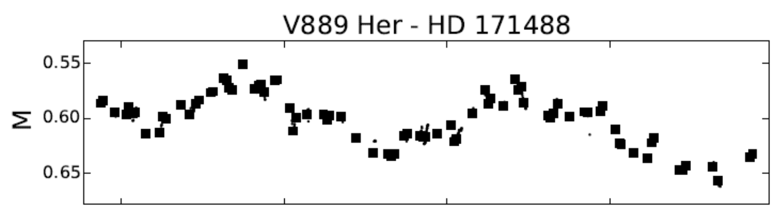
$$\hat{y}(t_i) = M + \sum_{k=1}^{K} [B_k \cos(k2\pi f t_i) + C_k \sin(k2\pi f t_i)]$$



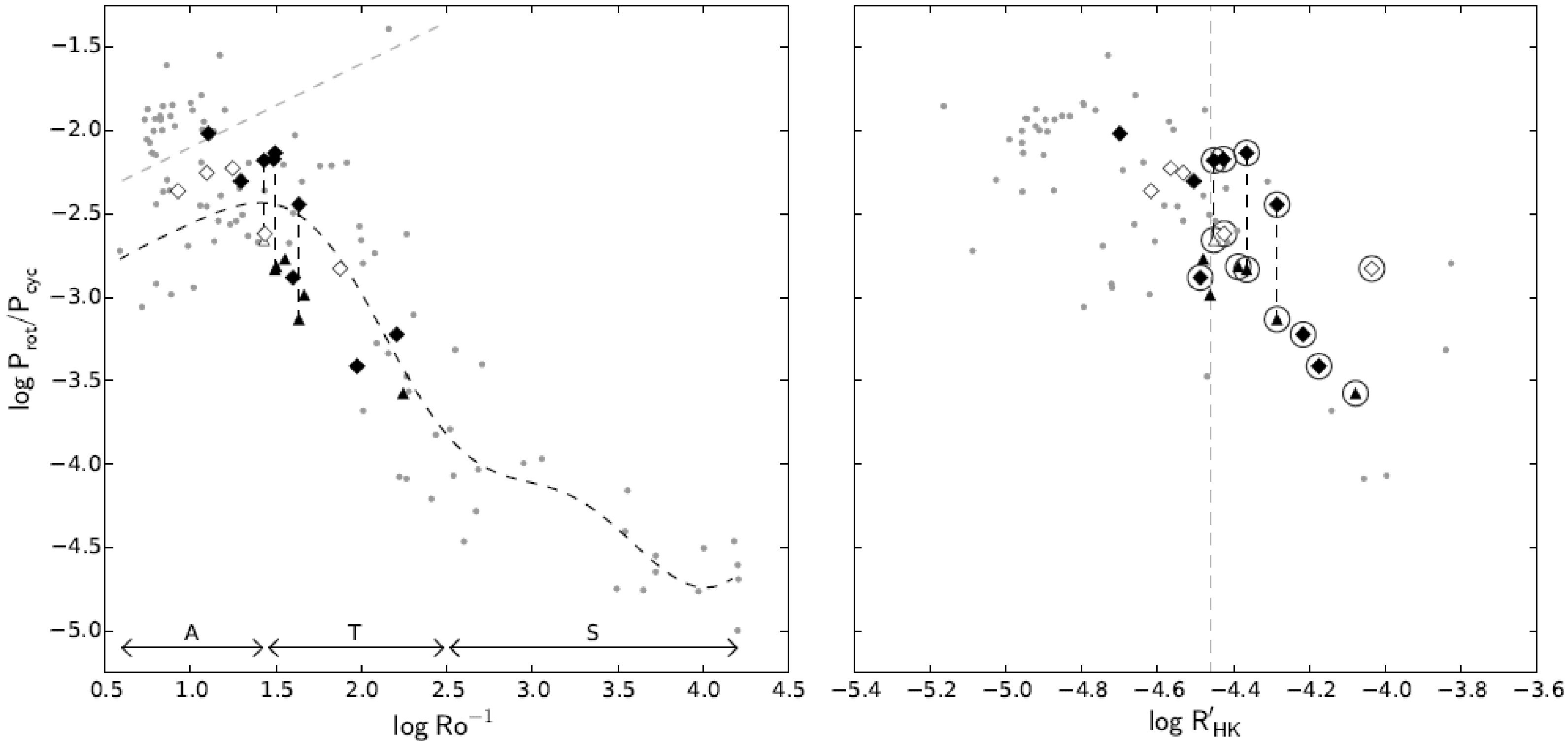
CF light curve fit for FK Com (Hackman et al. 2013)



Photometric minima and mean V-magnitude of V889 Her (Lehtinen et al. 2015).



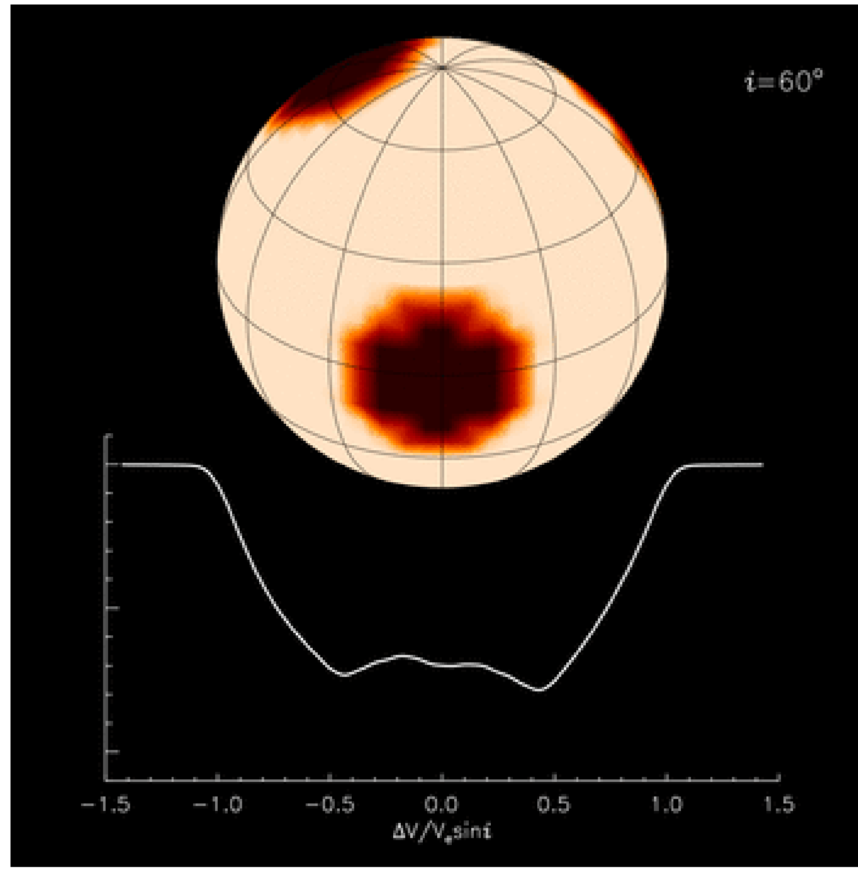
2.2 Time-series analysis results



Different branches of activity indicate different types of dynamos (Lehtinen et al. 2015)

2.3 Doppler imaging

- Star rotates => “bumps” moving across the absorption lines



Animation by O. Kochukhov.

2.4 Mathematical formulation of Doppler imaging

- Inverse problem: Search for the surface distribution X (e.g. temperature) that minimizes

$$D(X) = \sum_{\phi_{\text{sp}},\lambda} \omega_{\phi_{\text{sp}},\lambda} \frac{\left(r_{\phi_{\text{sp}}}(\lambda) - r_{\phi_{\text{sp}}}^{\text{obs}}(\lambda)\right)^2}{N_{\phi_{\text{sp}}} N_\lambda},$$

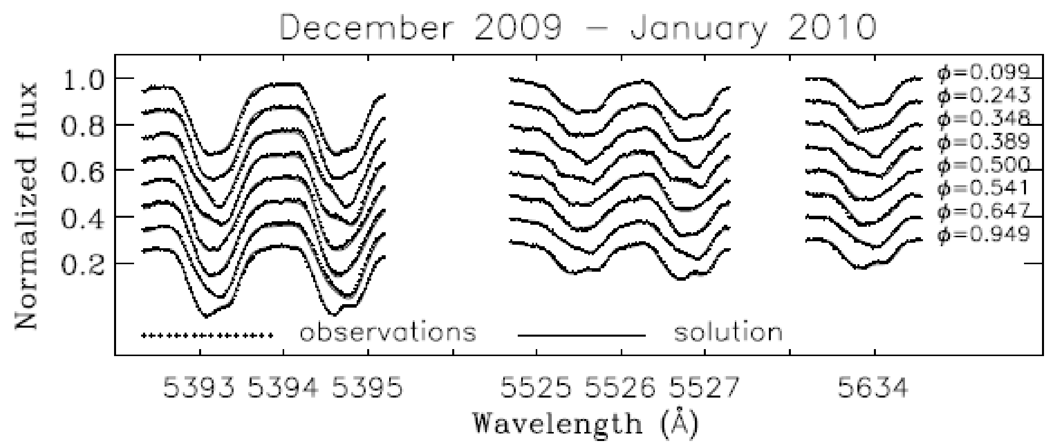
  where $r_{\phi_{\text{sp}}}$ can be calculated solving radiative transfer in numerical stellar atmospheres
- Ill-posed problem => regularisation needed:

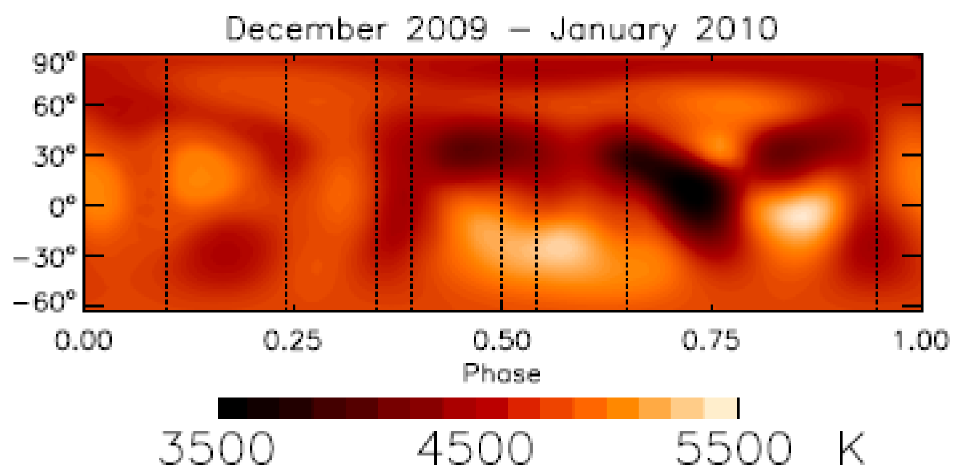
$$\Phi(X) = D(X) + \Lambda R(X)$$

2.5 Application example: II Peg

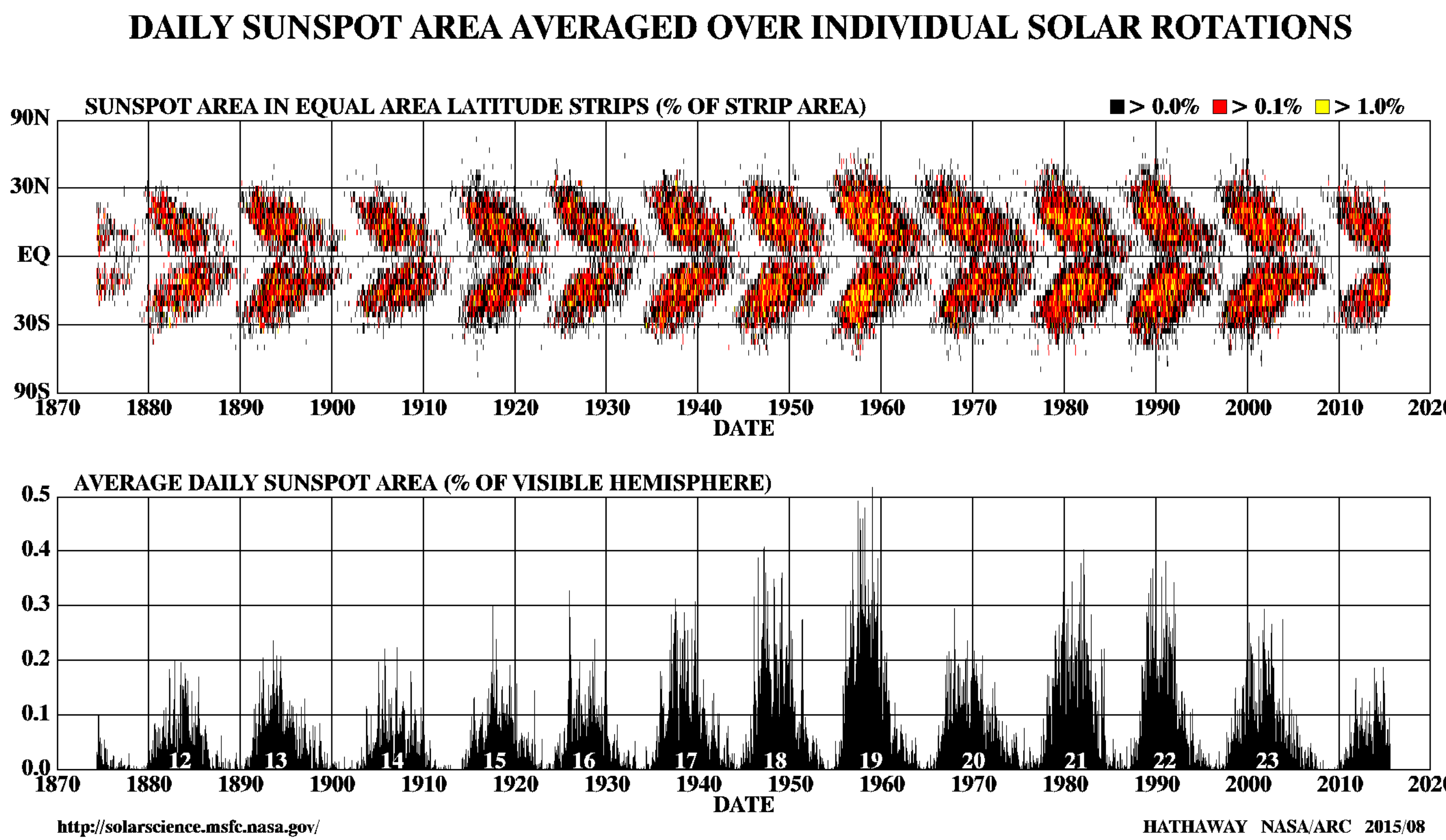
- RS CVn –type star
- Spectral class K2 IV
- Rotation period: 6.72 d
- Inclination: ~60°
- $v\sin i \approx 23$ km/s
- Observations: SOFIN / Nordic Optical Telescope

Hackman et al., 2012, A&A 538, A126



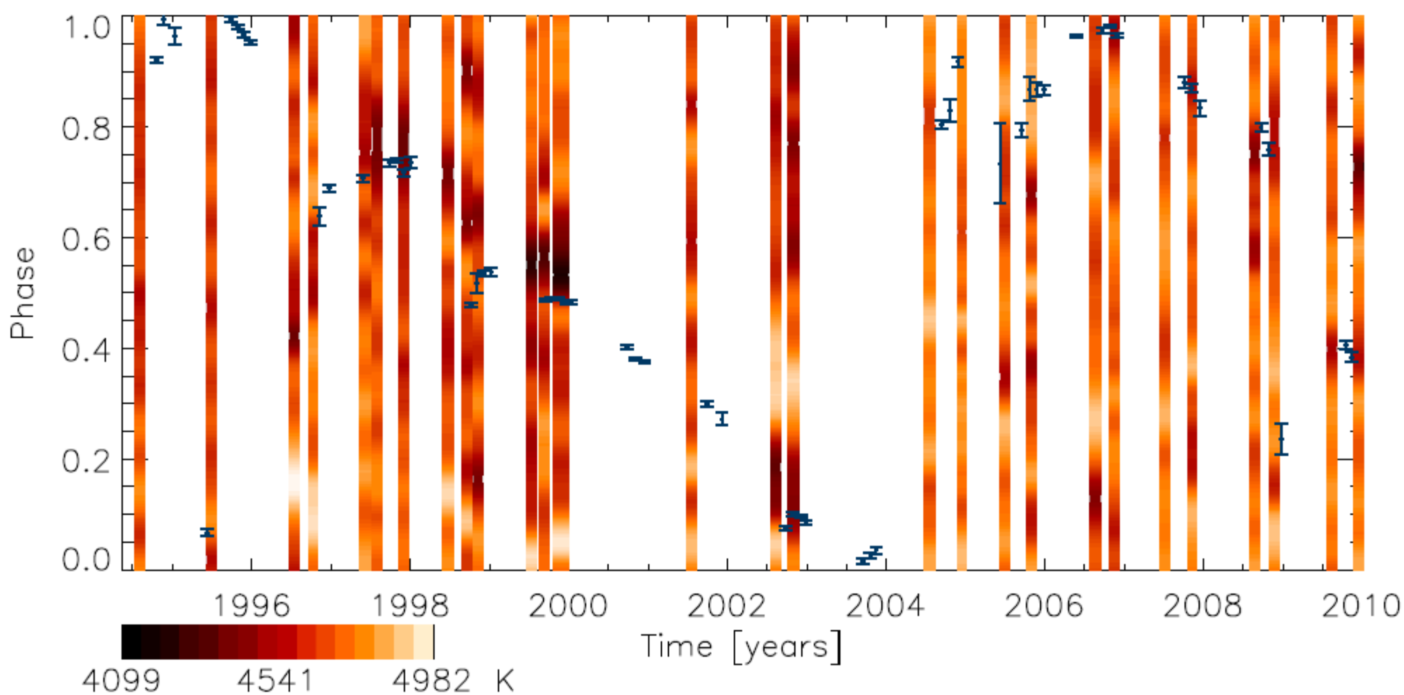


2.6 Solar butterfly diagram



Thomas Hackman, ReSoLVE meeting 29/10/ 2015

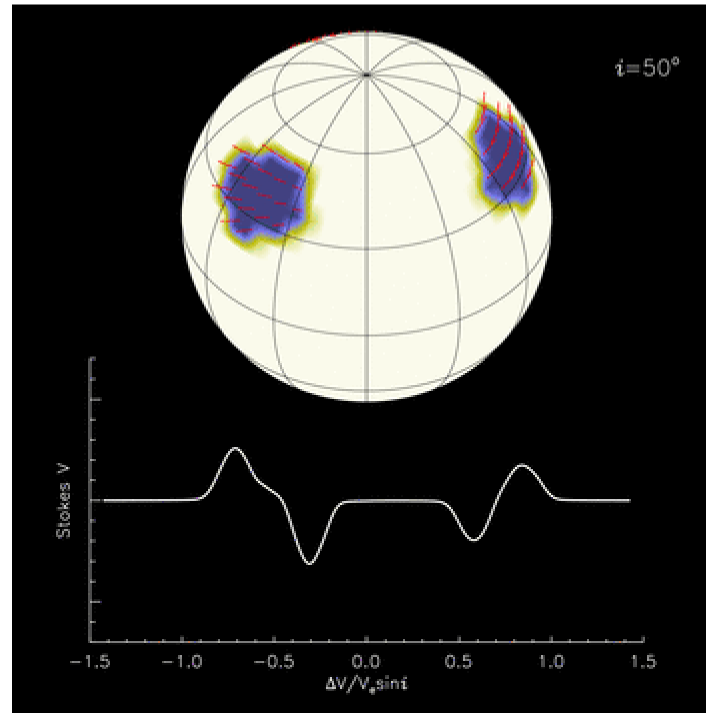
2.7 II Peg: Azimuthal dynamo wave?



Temperature averaged over latitude and phases for photometric minimum in the orbital rotation frame P=6.^{d}724333 (Hackman et al. 2011).

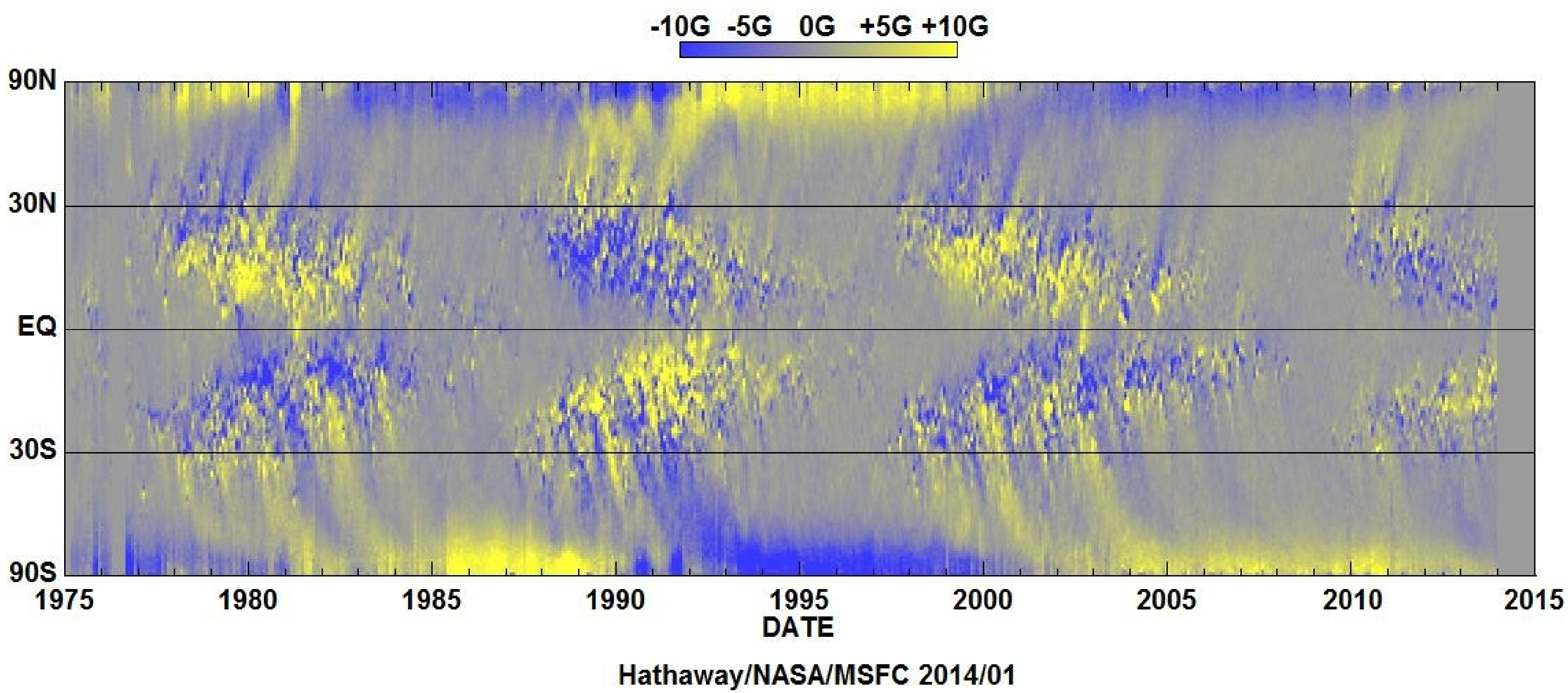
2.8 Zeeman-Doppler imaging

- Spectropolarimetric observations:
  - Stokes I (intensity)
  - Stokes V (circular pol.)
  - Stokes Q & U (linear pol.)
- Solution: Surface magnetic vector

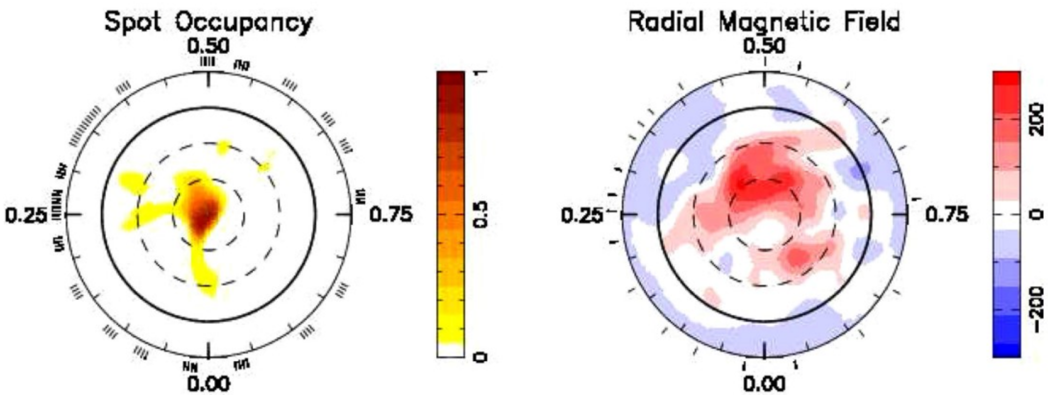


Surface magnetic field changes Stokes V (O. Kuchokhov)

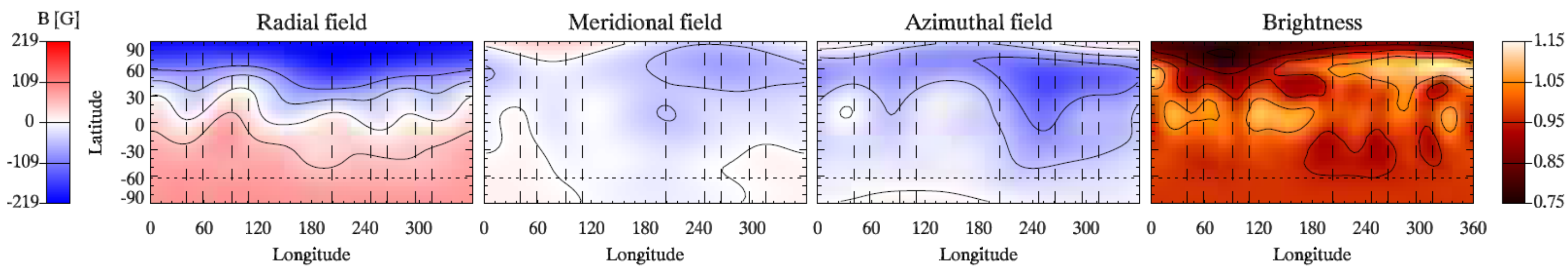
2.9 Solar magnetic butterfly diagram



2.10 ZDI:s of HD29615



Nov-Dec 2009
(Waite et al. 2015)



September 2013 (Hackman et al. 2015)

3. (Near) future prospects: Observing programmes

- ”Active Suns” with HARPSPol@ESO3.6:
  - 7 young solar analogues
- ”Topology and evolution of surface magnetic fields in active late-type stars” with FIES@NOT:
  - ~ 20 stars
- Continuous observations with APTs etc. …

Questions?