Activity and Doppler Imaging

of the late-type giant star

= OU Andromedae =

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БЕЛОГРАДЧИК -- May 2018

Outline

- Doppler Imaging: Rationale and limitations

- Active regions on OU And:
  Large-scale stability and small-scale fragility

- Summary

Context

Doppler Imaging of the Hertzsprung gap star OU Andromedae

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(Borisova+ 2018, BAstJ in prep.)

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Astronomy & Astrophysics

The different origins of magnetic fields and activity in the Hertzsprung gap stars, OU Andromedae and 31 Comae★

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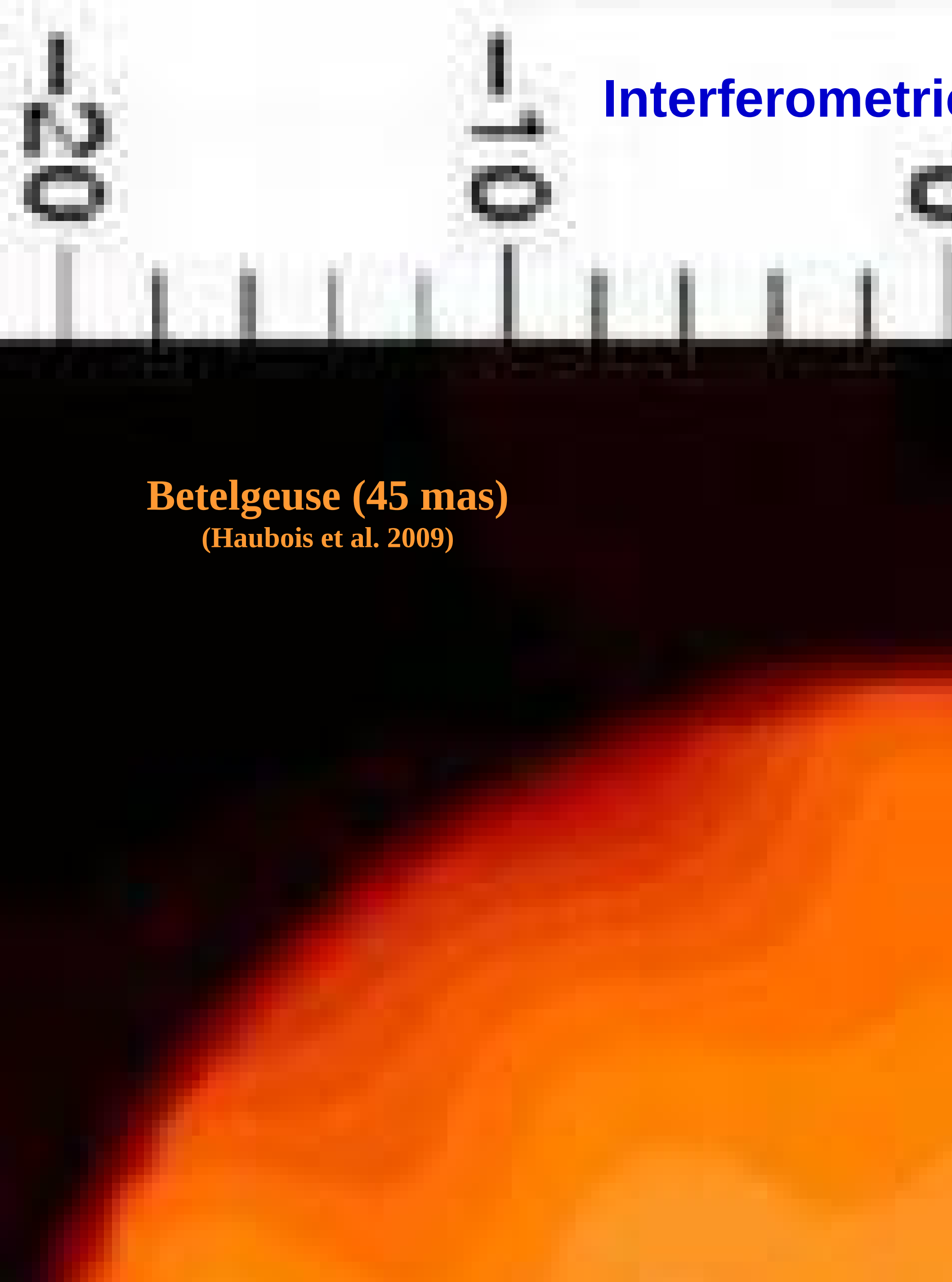
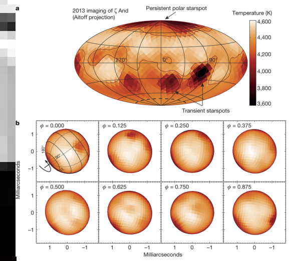
(Borisova+ 2016, A&A 591)

= DI basics =

Interferometric imaging



Betelgeuse (45 mas)
(Haubois et al. 2009)



zeta And (2.5 mas)
(Roettenbacher+, Nature 2016)
(cf. also 2017 ApJ 849)

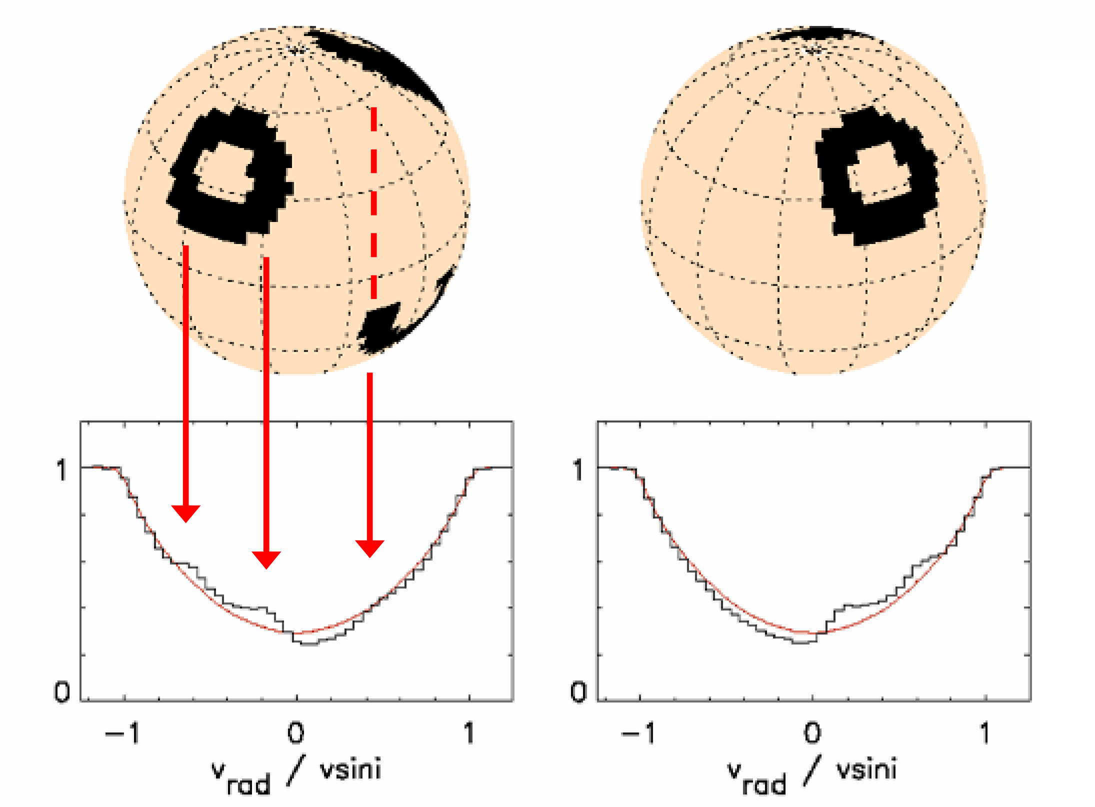
CHARA (0.5 mas)

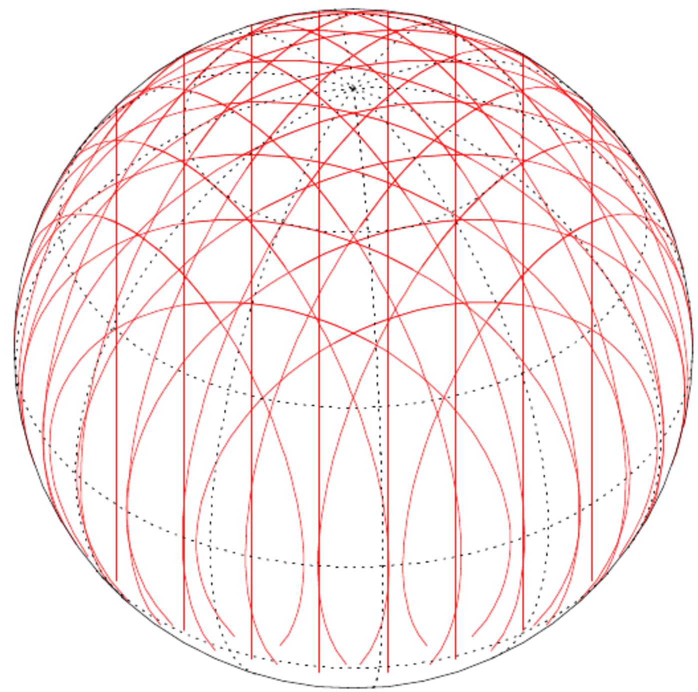
VLTI (3 mas)

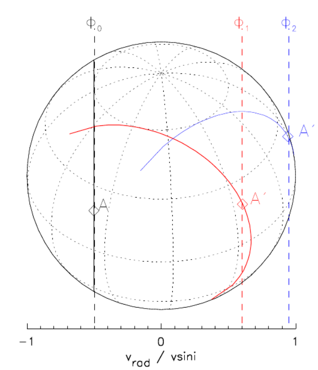
SPHERE
(7 mas)

Sun at 10pc (1 mas)

Doppler Imaging (DI) – basics





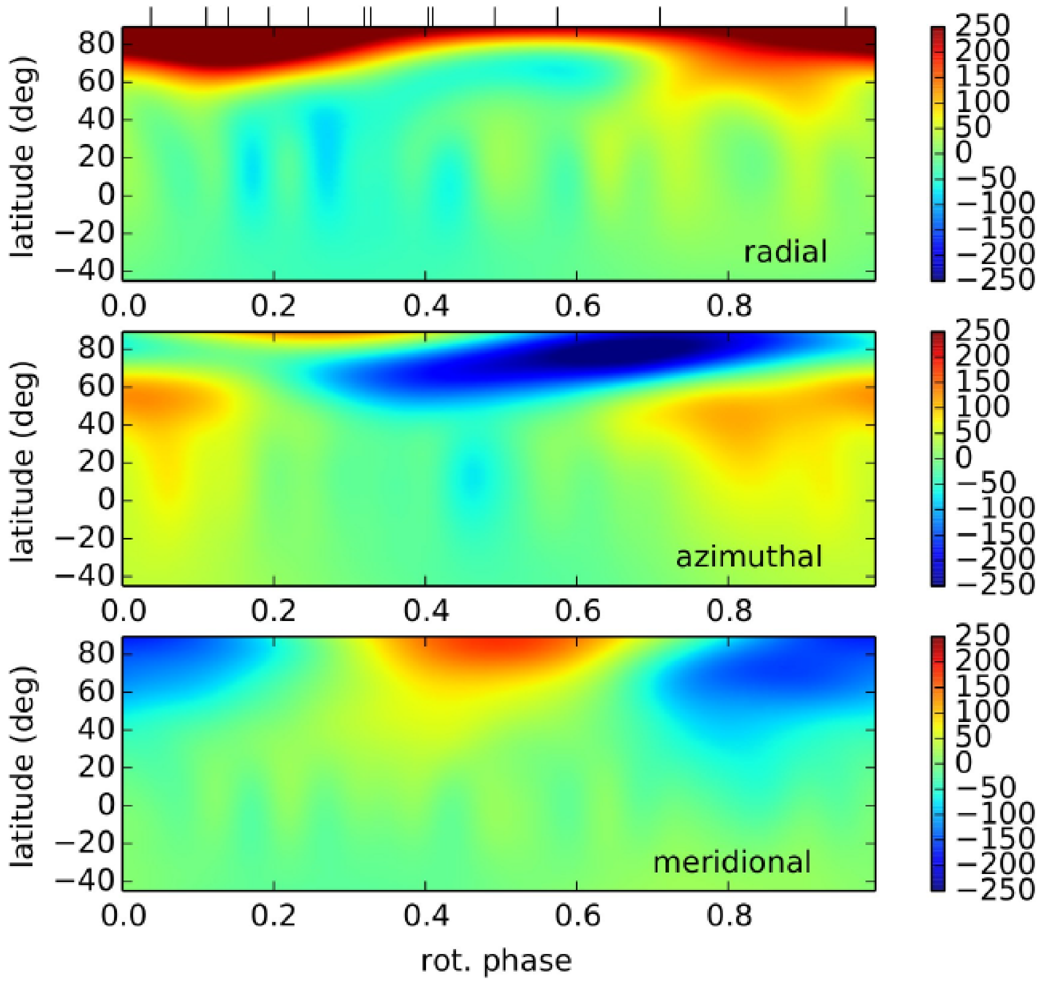


Deutsch 1958, Falk & Wehlau 1974, Goncharski et al. 1982
Vogt & Penrod 1983, <u>Rice</u>, Wehlau & Khoklova 1989
<u>Donati</u>, Semel & Praderie 1989; Piskunov & Kochukhov 1992
Kürster, Schmitt & Cutispoto 1994; Rice & Strassmeier 2003
Wolter & Schmitt 2005

= Active regions on OU And =

OU Andromedae in Zeeman DI (2013)

2013

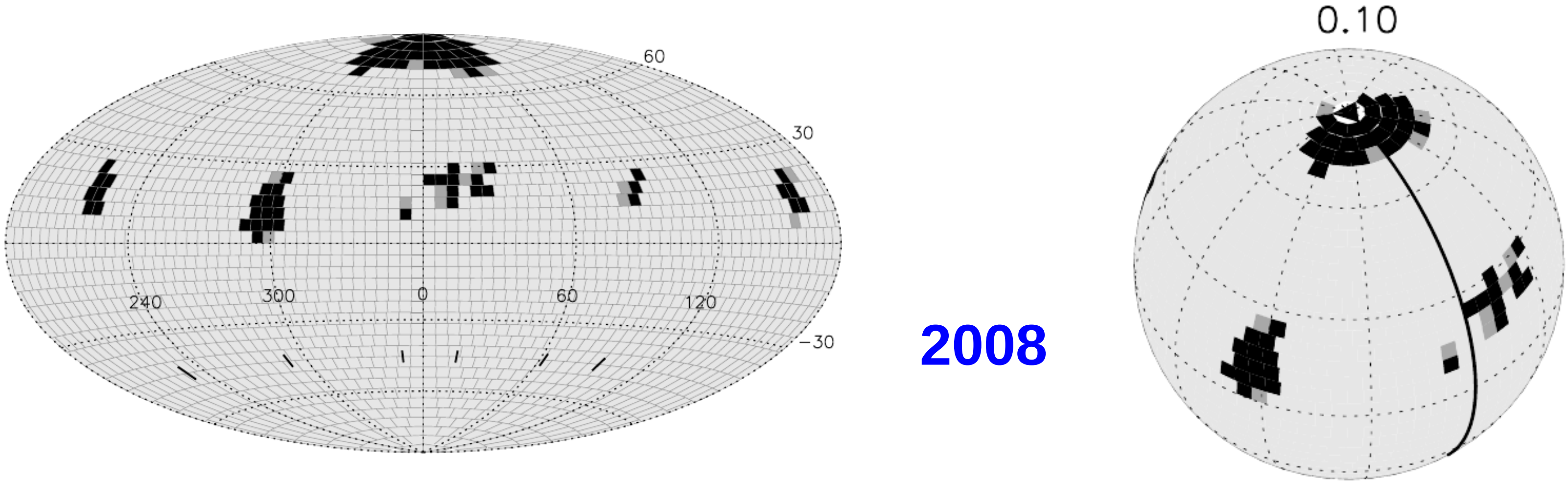


(Borisova+ 2016, A&A 591)

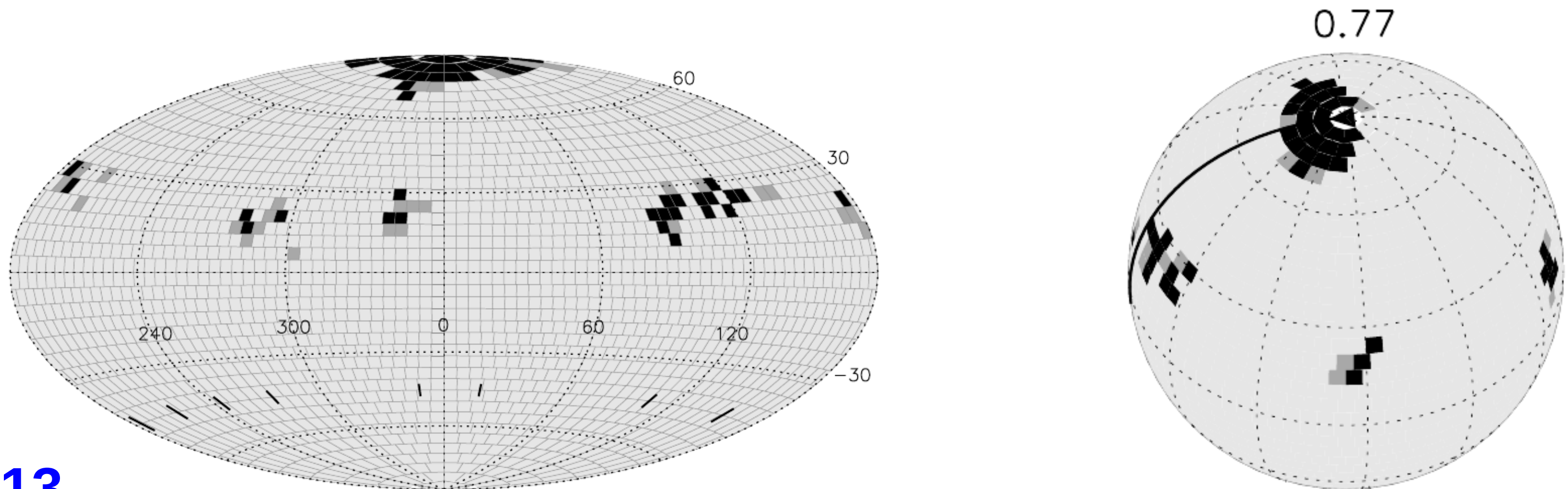
Parameter	Value	
V, mag	5.86	H
Distance, pc	$129.7^{-5.5}_{+6.0}$	
Sp Type	G1 III	
$T_{\rm eff}$, K	5360	B
L_x, 10^{27} erg/s	8203	
Radius, $R_\odot$	9.46	
Mass, $M_\odot$	2.85	
Luminosity, $L_\odot$	71.2	
$logg$	2.8	
[Fe/H]	-0.07	
$vsini$, km s^{-1}	21.5 ±2.1	
$P_{\rm rot}$, days	24.2 ±	
Inclination, deg	45	
Radial velocity, km s^{-1}	-2.47	

(Borisova+ 2018, BAstJ in prep.)

'Conventional' DI 2008 + 2013



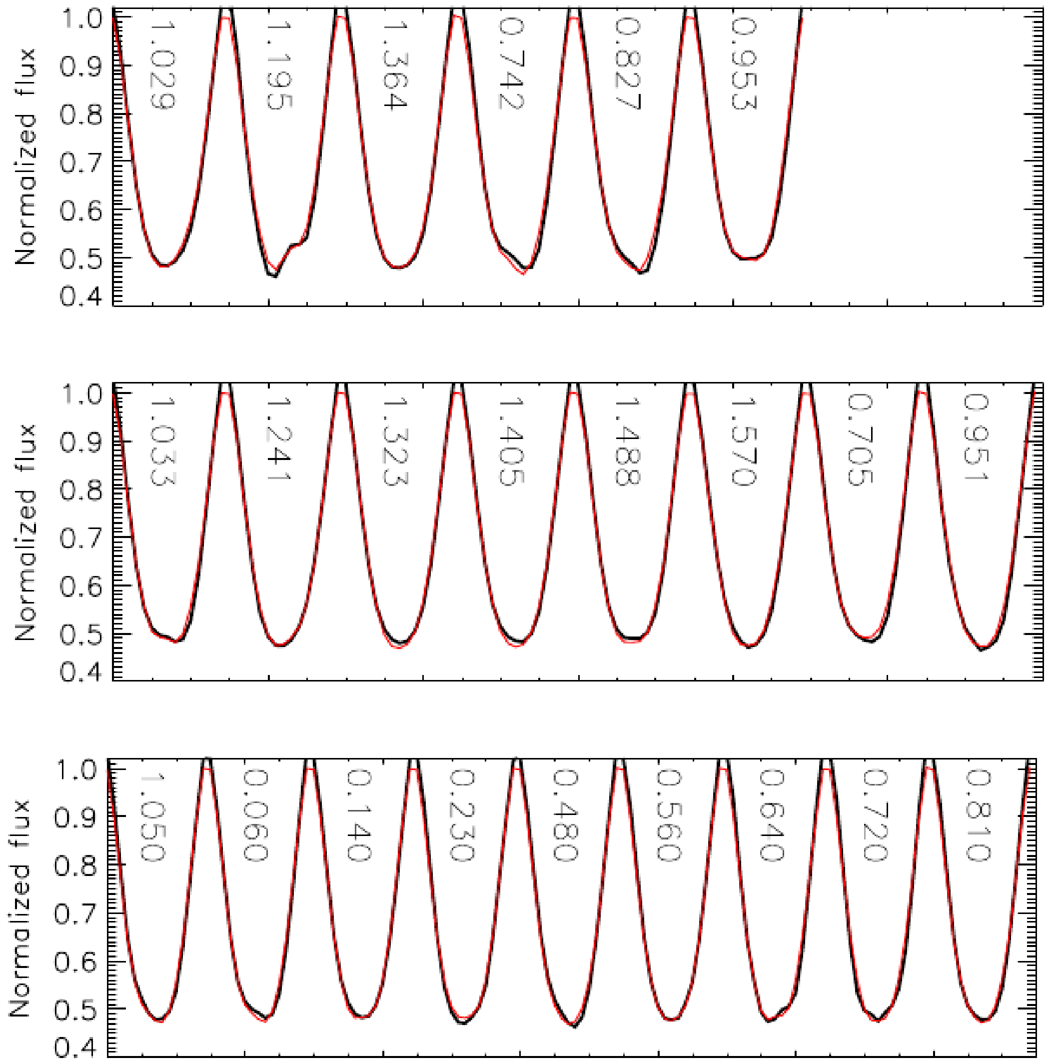
2008



2013
(September)

(Borisova+ 2018, BAstJ in prep.)

DI photospheric line profiles 2008 to 2015

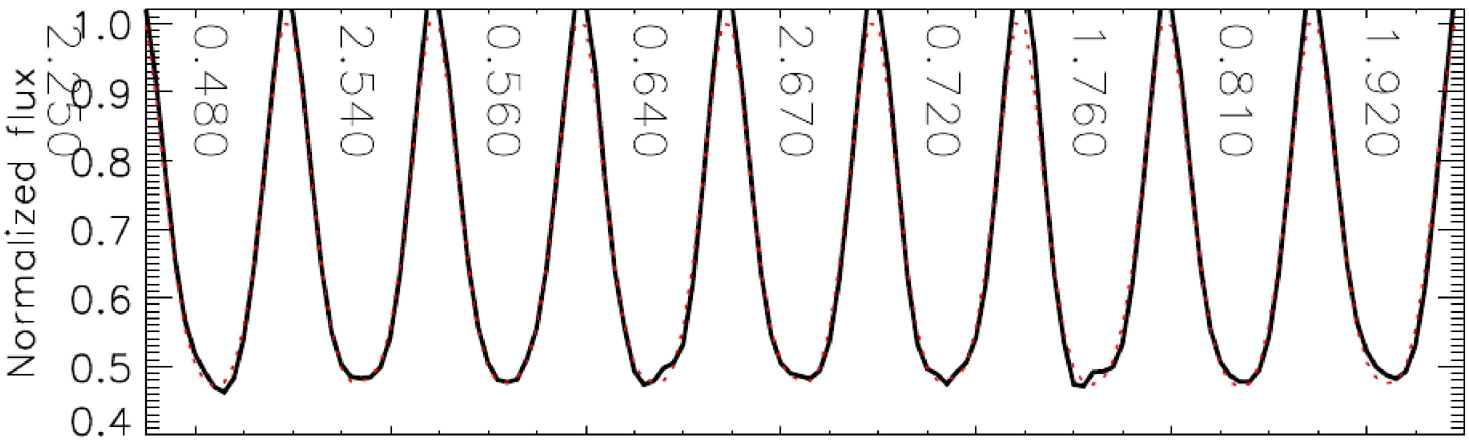


2008

2013
(September)

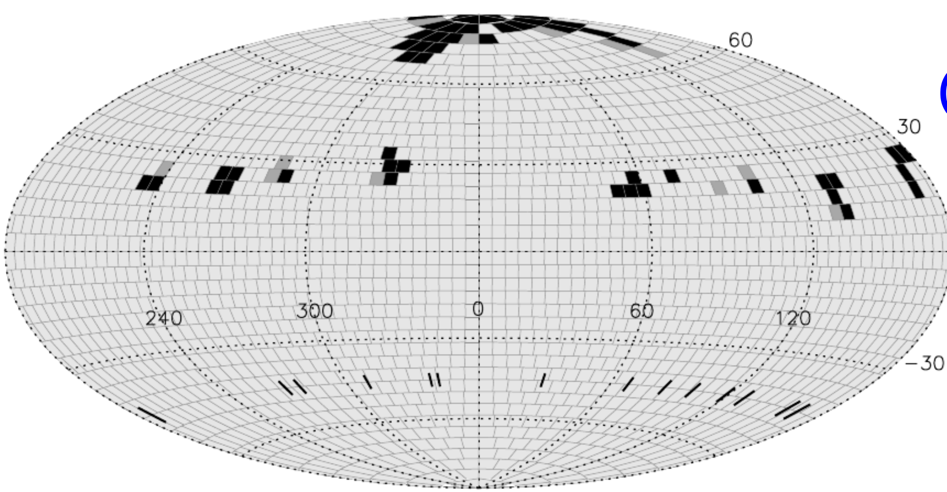
2015
(June-July)

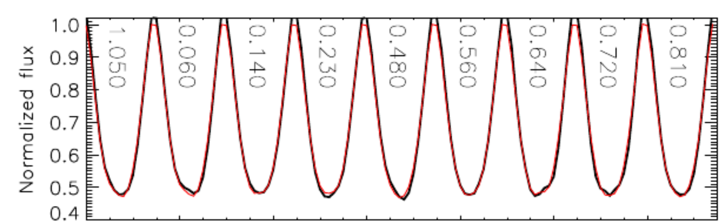
The 'truncated' DI of 2015



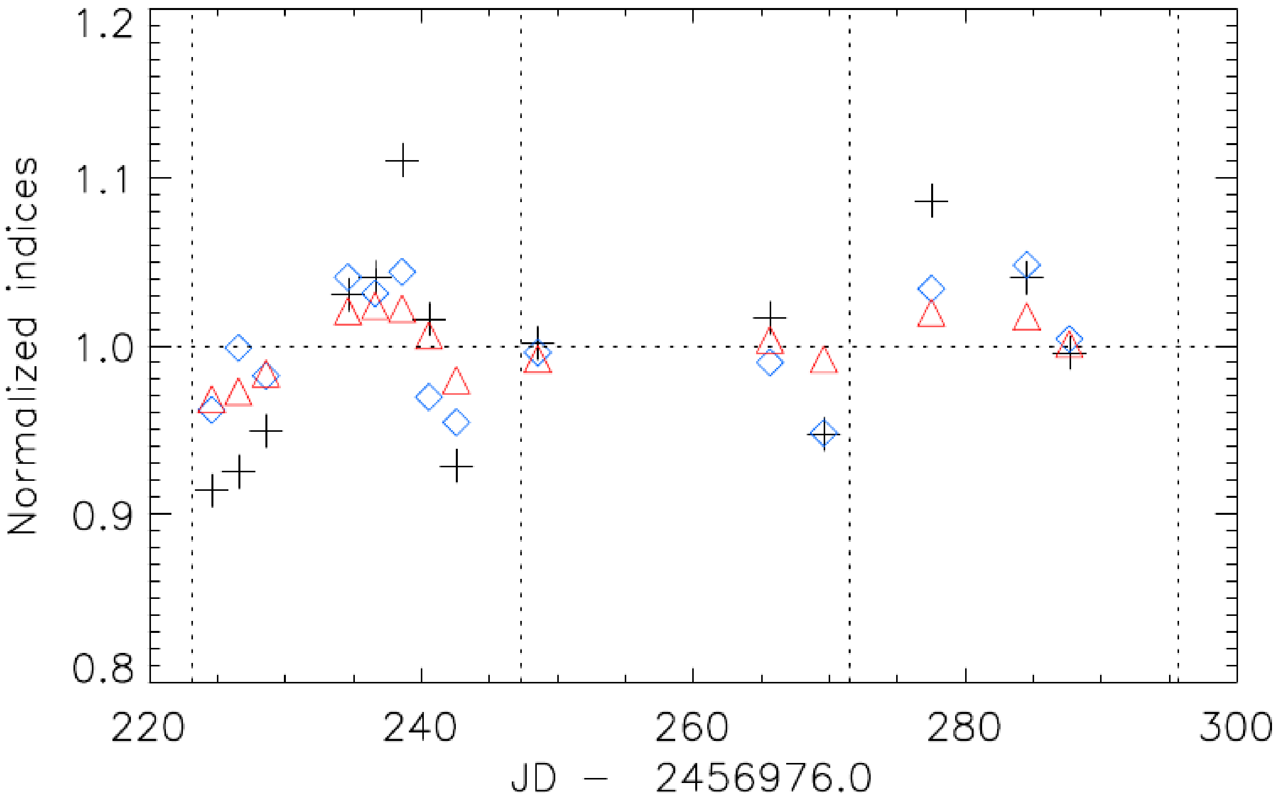
2015
(July-August)

2015
(June-July)

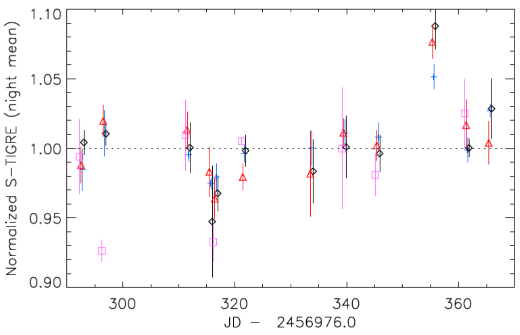




Chromospheric emission I

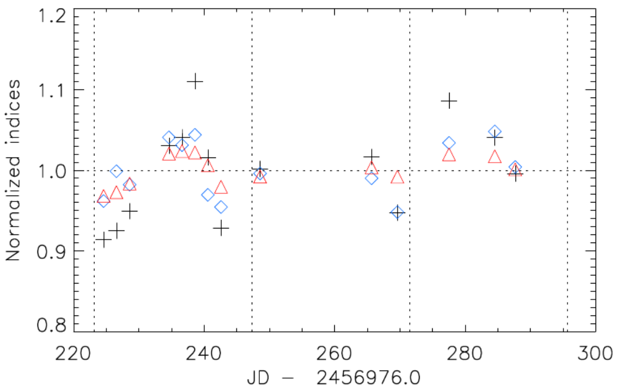


2015 NARVAL
(June-August)

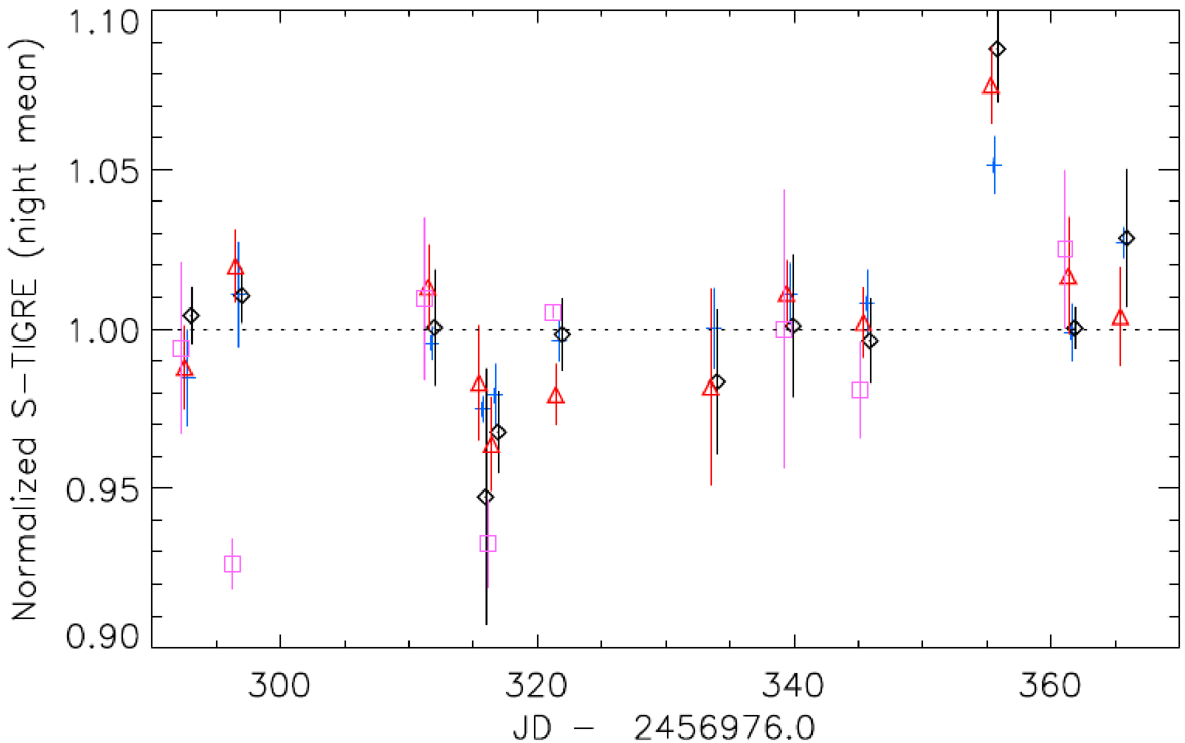


2015 TIGRE
(September-Nov.)

Chromospheric emission II



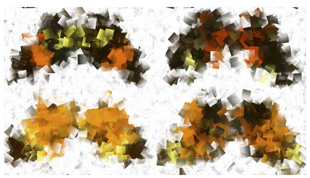
2015 NARVAL
(June-August)



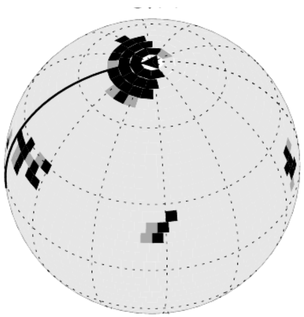
2015 TIGRE
(September-Nov.)

Summary

(wikimedia)



- DI uses rotational modulation in stellar spectra to overcome the diffraction limit
- DIs are ill-posed back-projections



- OU And hosts a long-lived polar spot
- Rotational modulation of activity signatures is weak on OU And

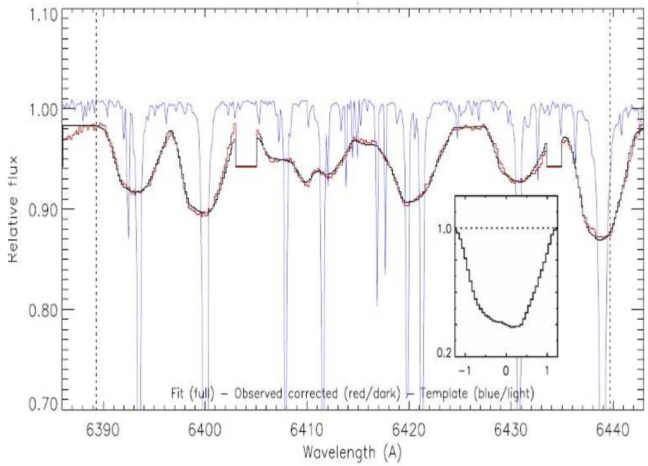
- Active regions evolve on OU And on rotational time scales

→ **Borisova+ 2018, BAstJ in prep.**

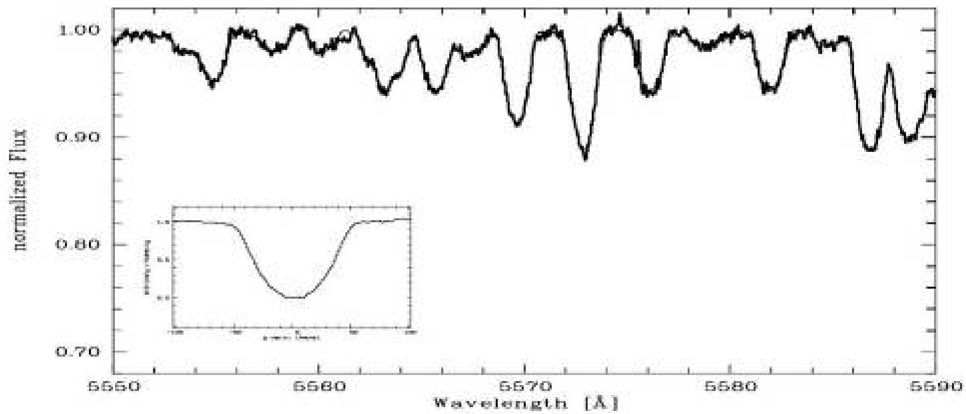
APPENDIX

Line profile deconvolution – LSD, pLSD, sLSD, iLSD, ...

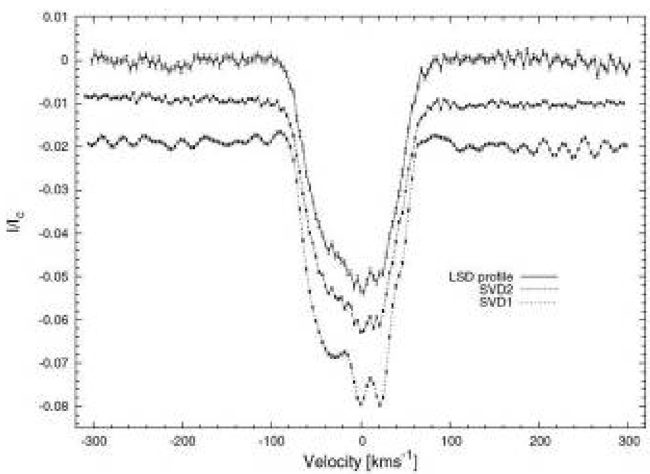
„Least-squares-deconvolution“



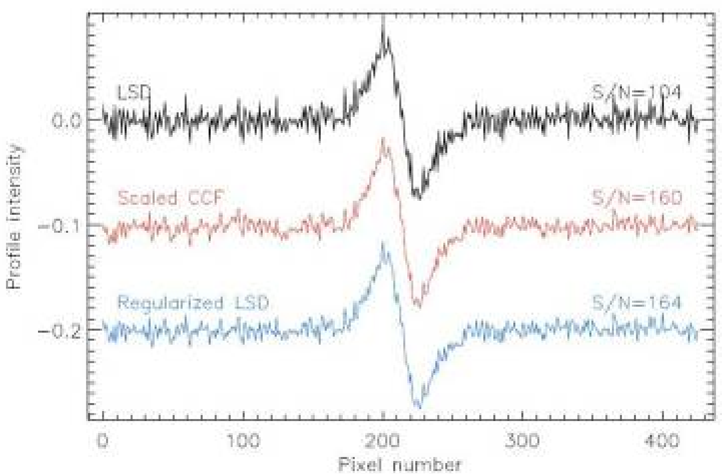
sLSD (Wolter & Schmitt 2005, A&A 435)



pLSD (Reiners & Schmitt 2003, A&A 412)

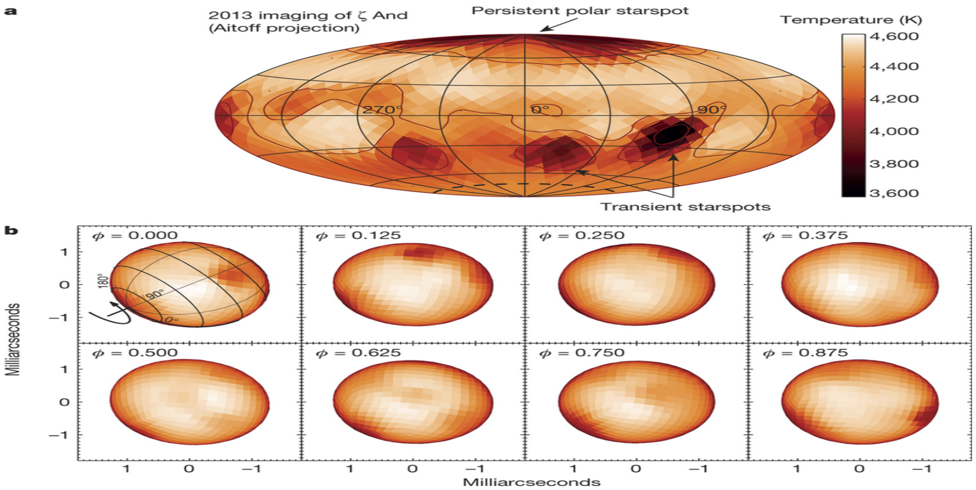


LSD (Barnes 2004, MNRAS 348;
Donati et. al 1997, MNRAS 291;
Rucinski et al . 1992, AJ 104)



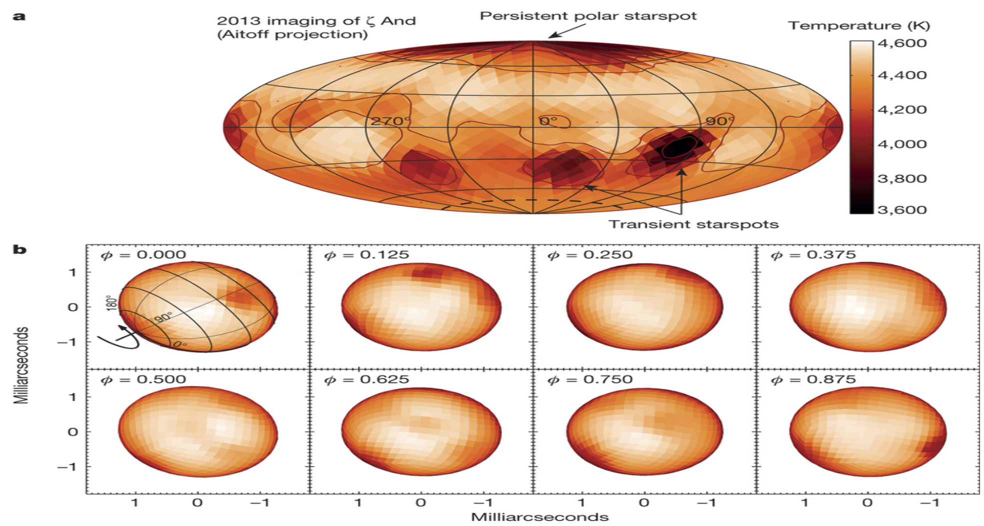
iLSD (Khochukhov et al. 2010, A&A 524)

DI vs. interferometric imaging



zeta And (K1III+KV, 57 pc)

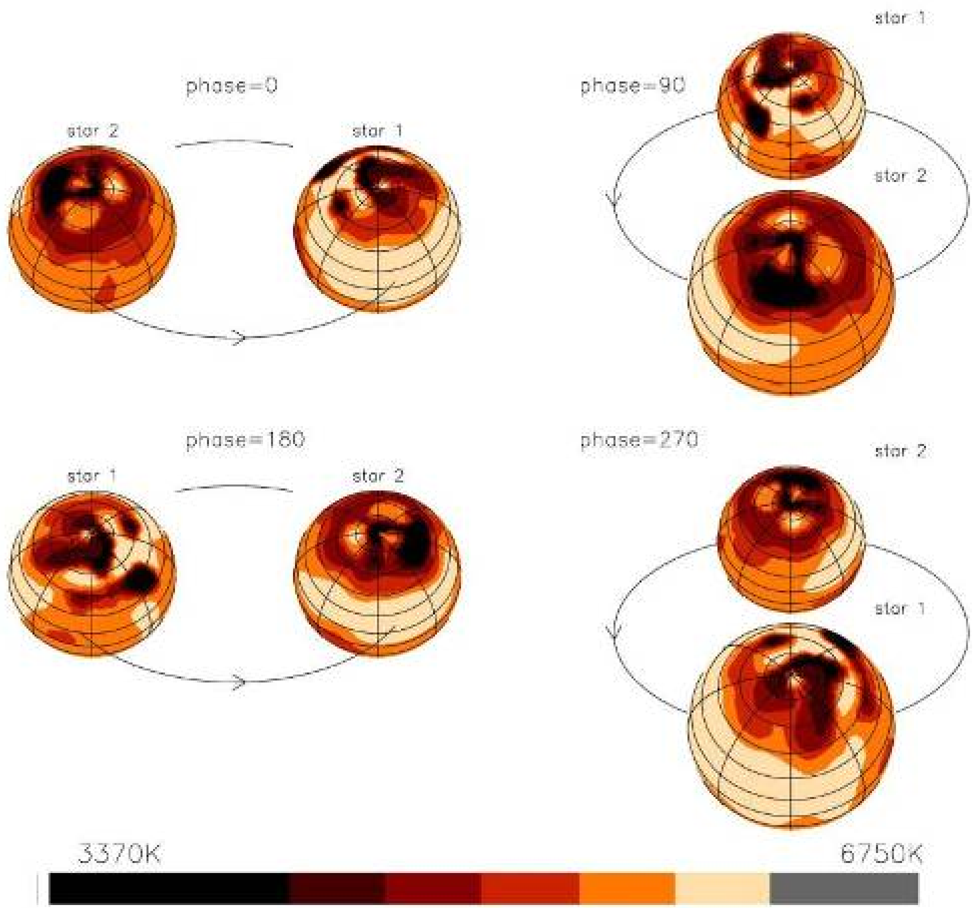
(Roettenbacher+, Nature 2016)



see also
sigma Gem

(Roettenbacher+, 2016 ApJ 849)

State-of-the-art temperature DI



σ² CrB
(Rice & Strassmeier 2003, A&A 399)

T_{eff}

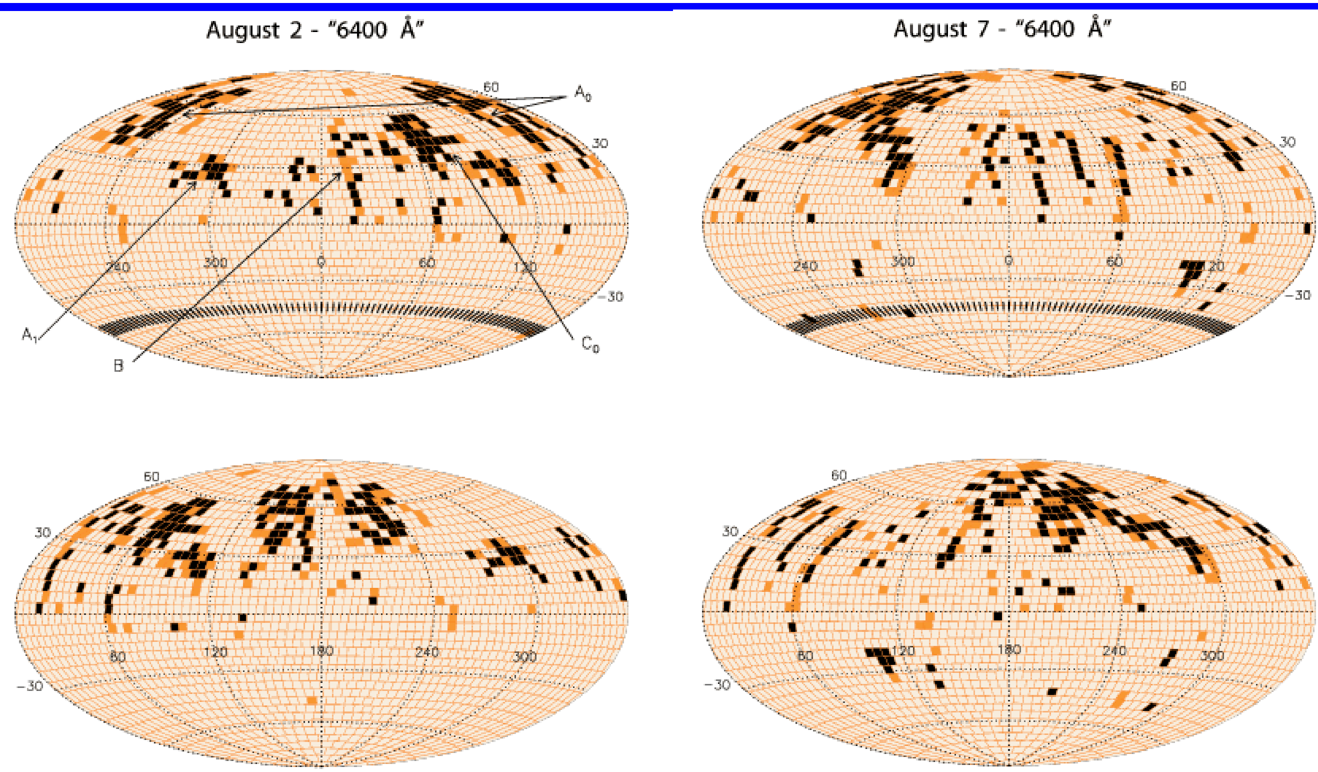
3200 K M4V	V 374 Peg (Morin et al. 2008)
6150 K F8V/G0V	AE Phe A/B (Maceroni at al. 1994)

vsini

9 km/s	BP Tau (Donati et al. 2008)
238 km/s	VXR45A (Marsden at al. 2004)

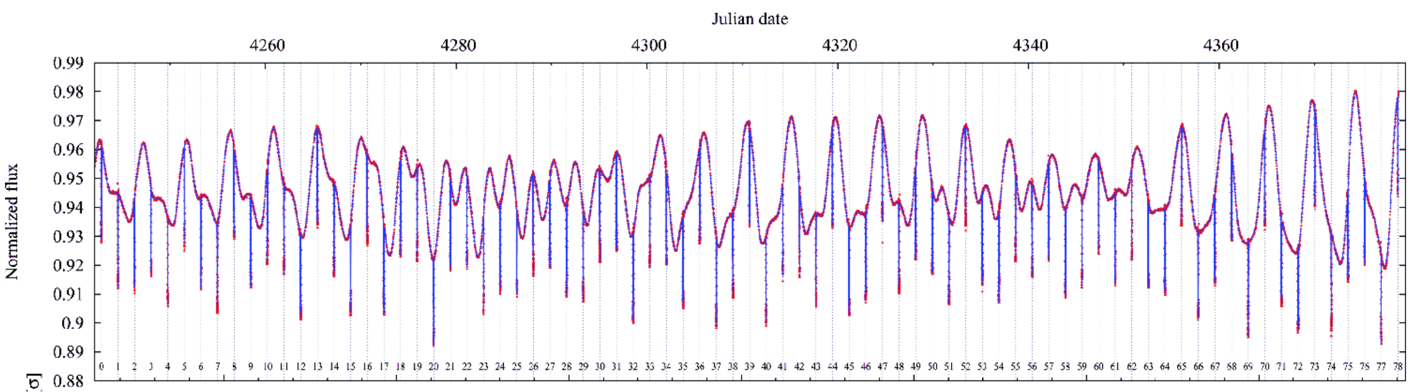
(Strassmeier 2009, A&ARv 17)

DI: Evolution of starspots



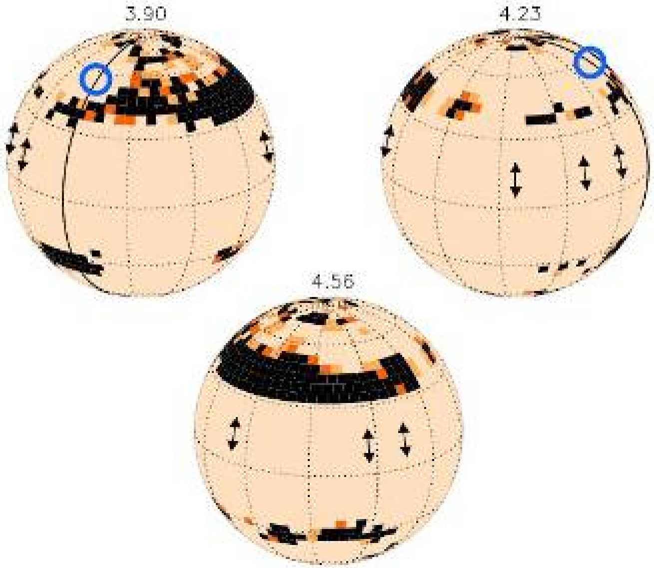
BO Mic **(Speedy Mic)**
(Wolter & Schmitt 2005)

cf. also
OU And
(Borisova+ 2018 subm.)

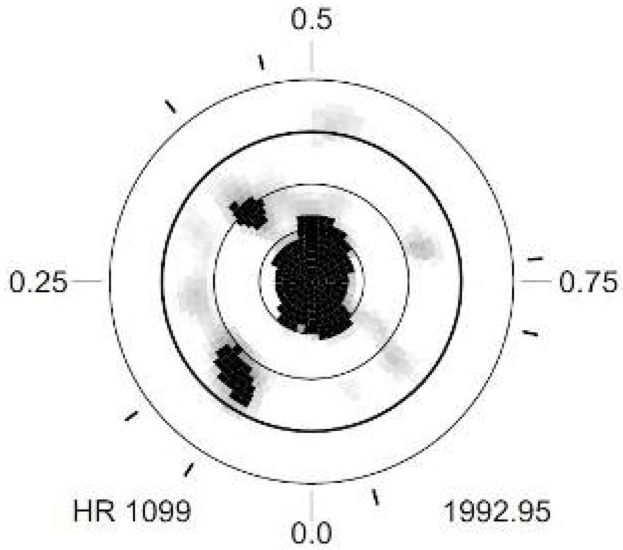


CoRoT 2
(Huber+ 2010)

Polar spots



BO Mic (Wolter et al. 2008, A&A 520)



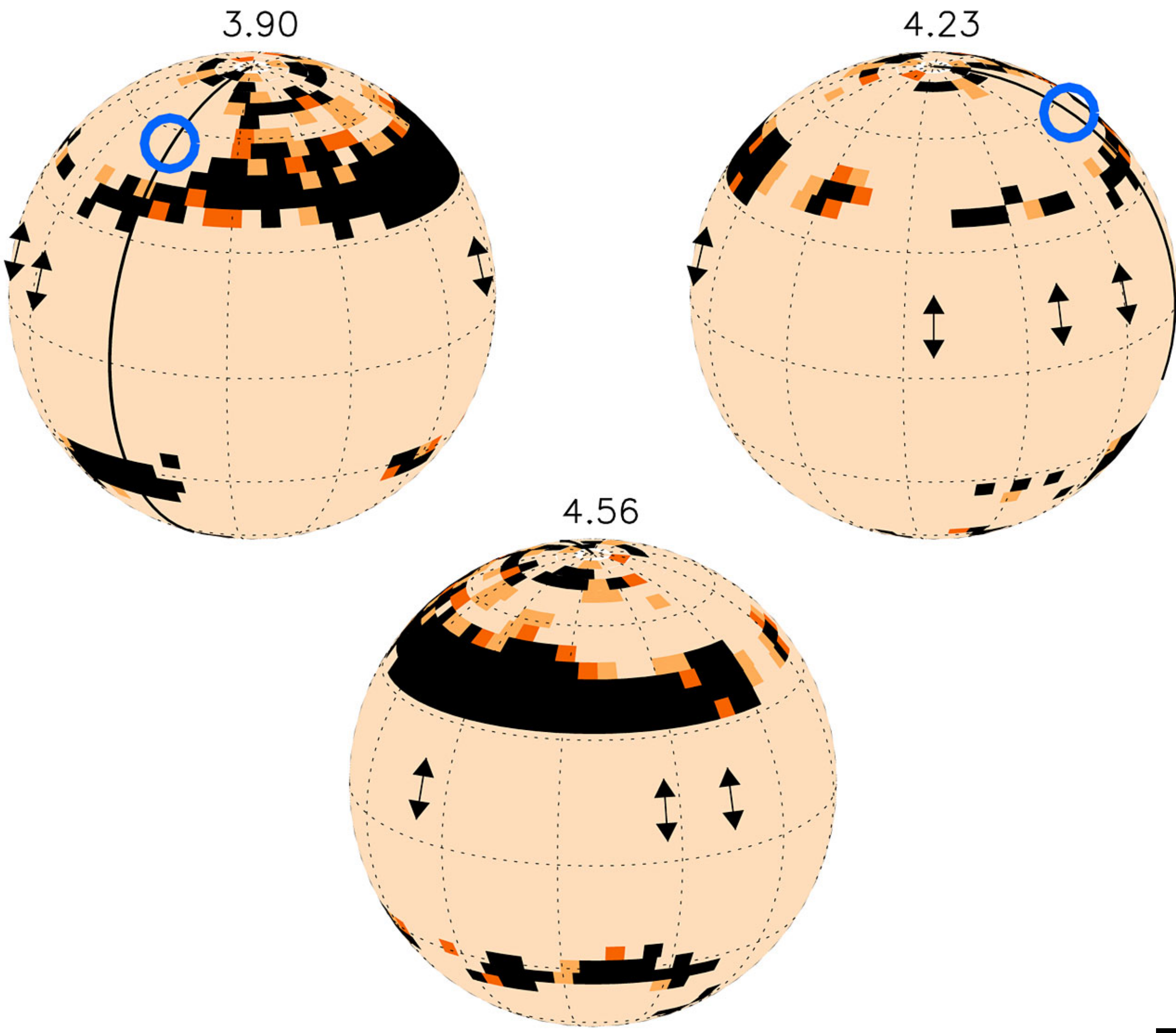
HR 1099 1981-92
(Vogt, Hatzes et al. 1999, ApJS 121)

Publications titled „Polar spot“ (ADS)

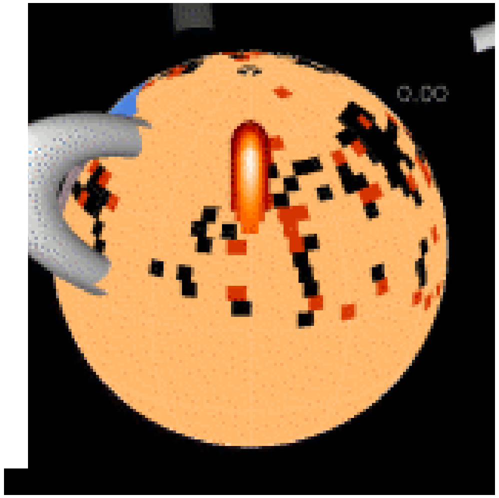
Why rapid rotators have polar spots (Schüssler & Solanki 1992, A&A 264)

“.. a spot which essentially straddles the pole” BY Dra, HR 1099 (Vogt 1981, Vogt & Penrod 1983)

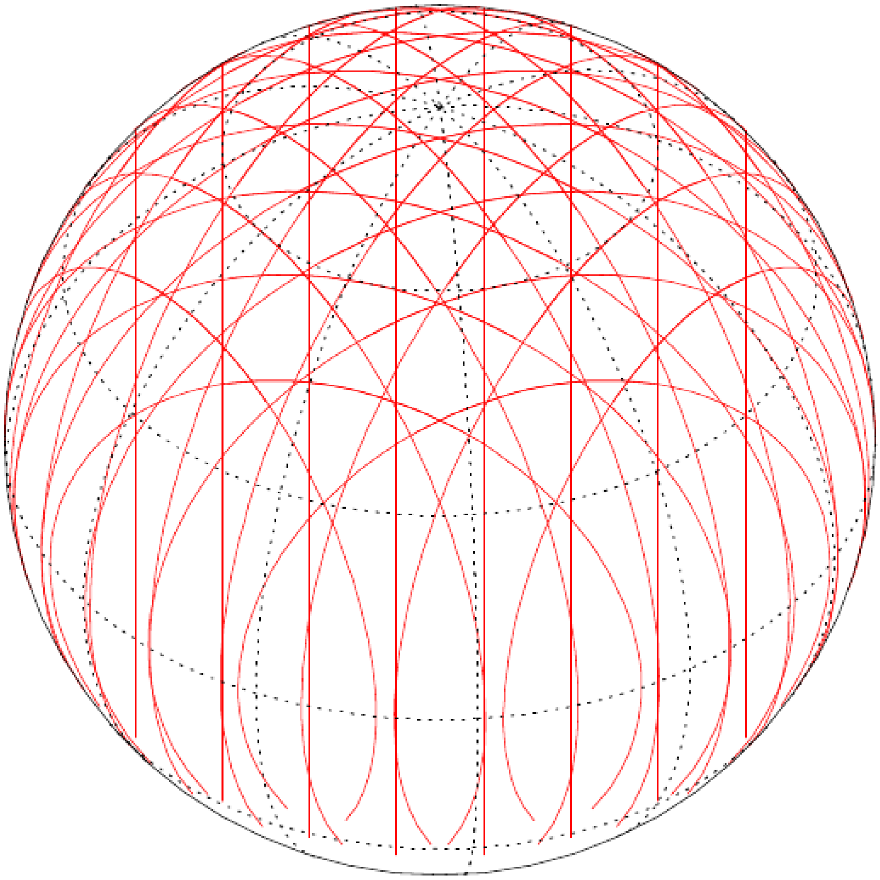
DI including the upper atmosphere

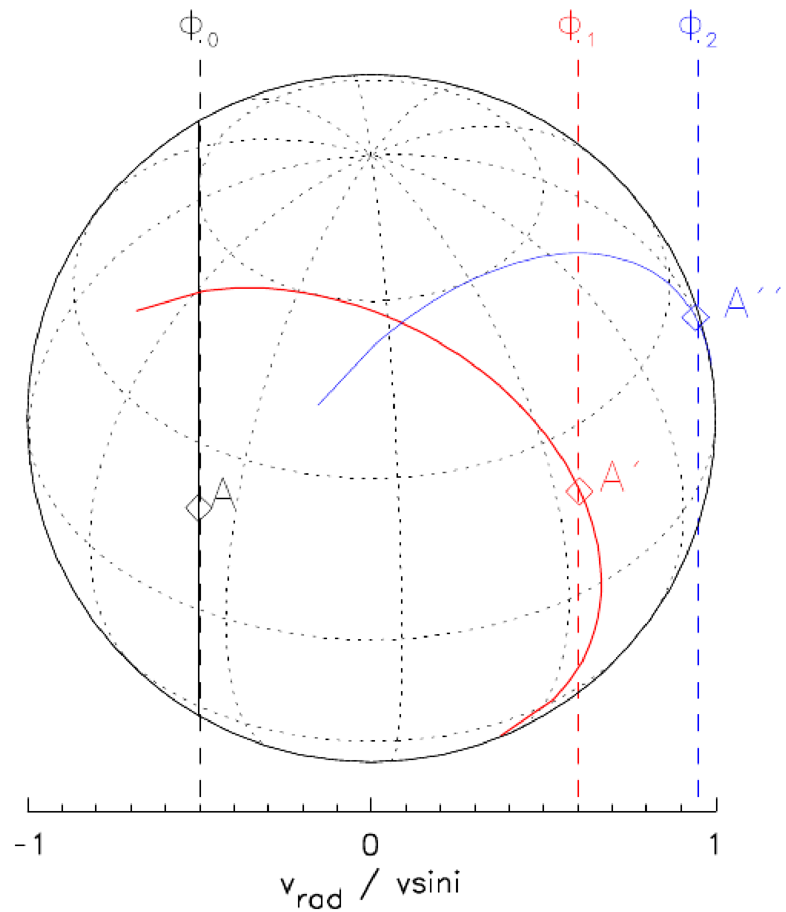


BO Mic (Speedy Mic)
(Wolter+ 2008)



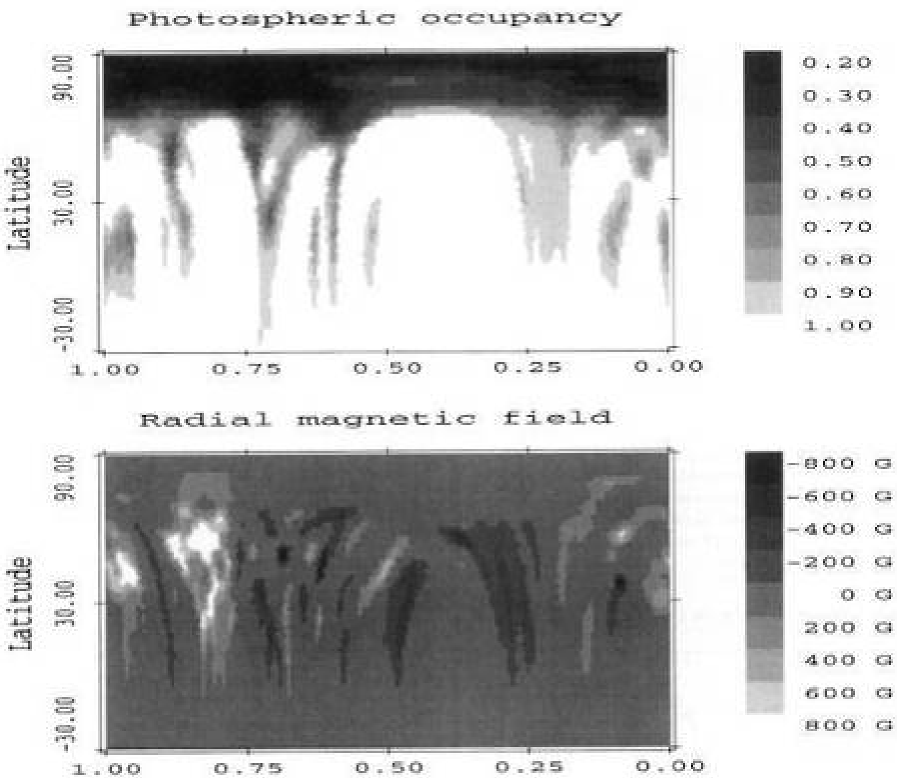
The DI resolution grid

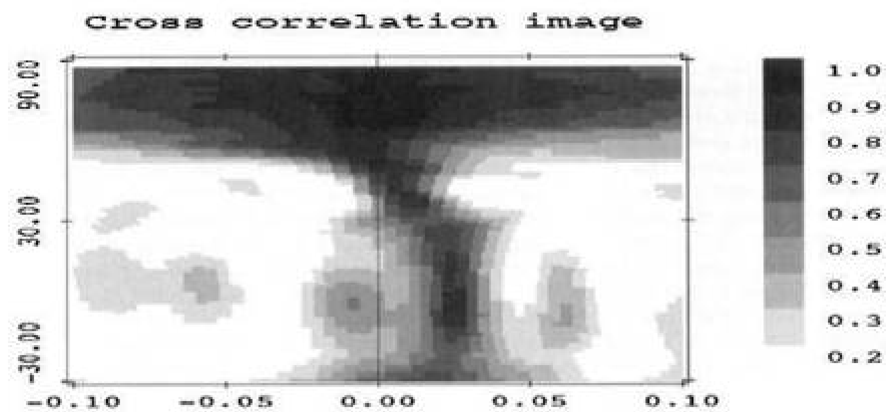




(Wolter & Schmitt 2005, A&A 435)

DI: Differential rotation

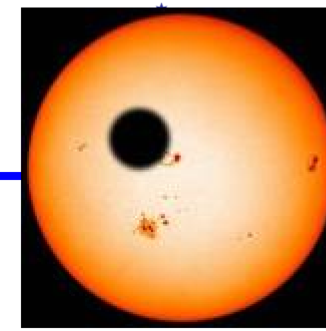


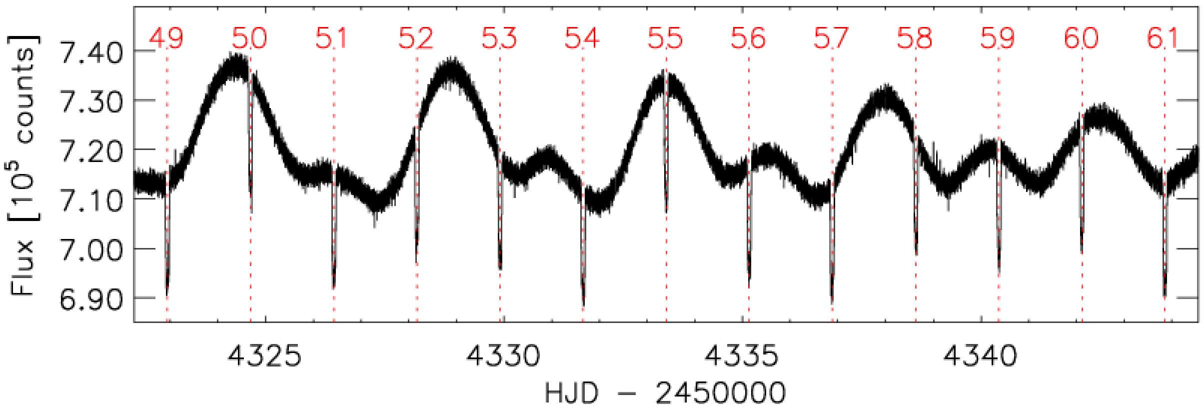


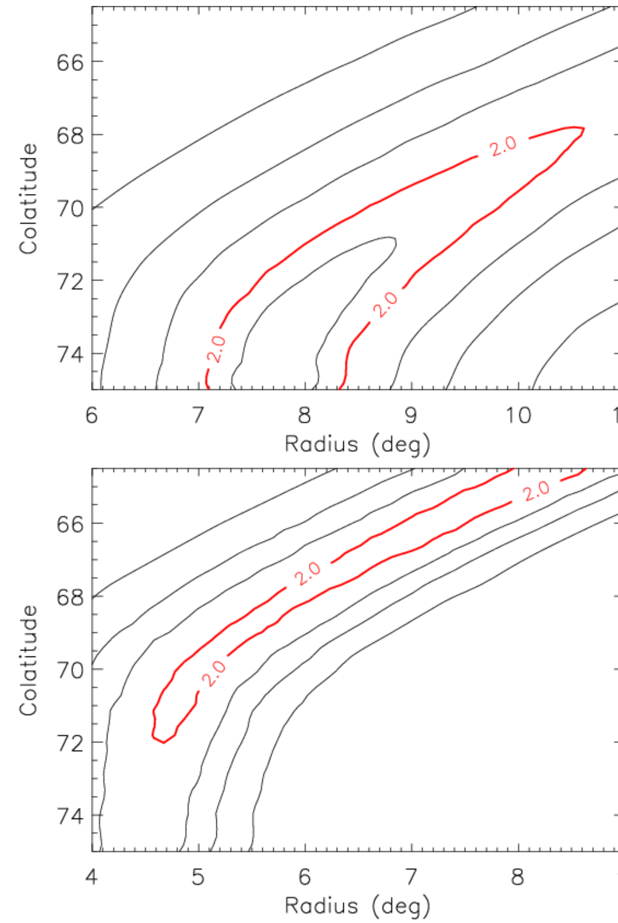
AB Dor

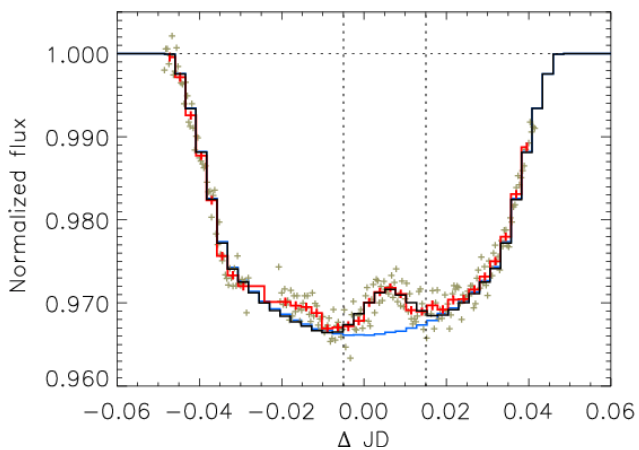
(Donati & Collier Cameron 1997)

„Prepare for the unexpected“:
Exoplanet transit mapping





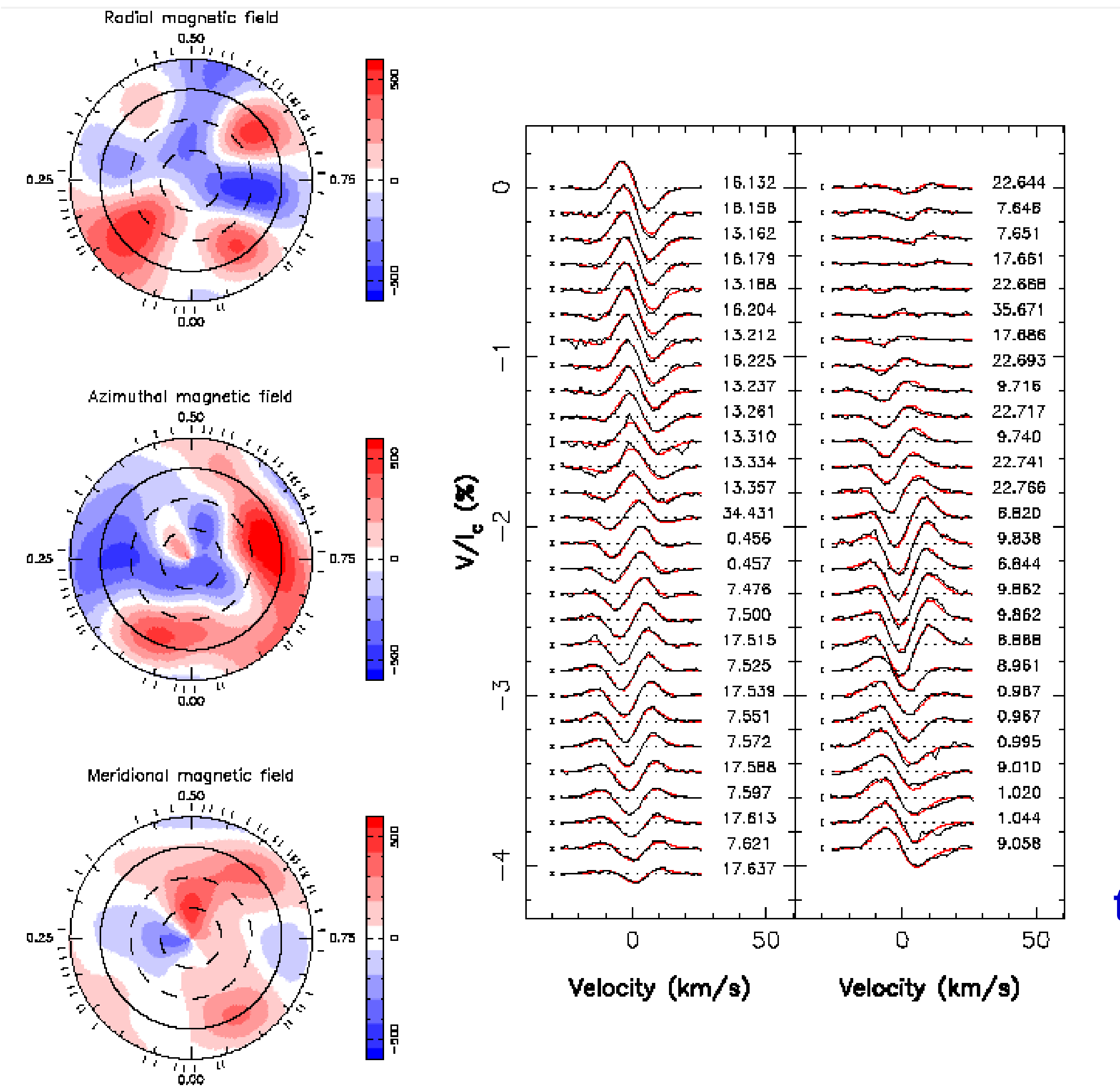


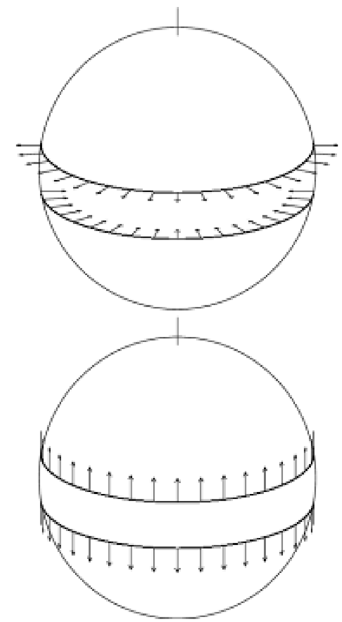


CoRoT-2
(Wolter, Schmitt+ 2008)

Empty

Magnetic DI at a glance





V = I

(Piskunov & Kochukhov 2002)

tau Sco (B0.2 V, V= 2.8 mag) ZDI

(Donati & Landstreet 2009, AR&A 47)