Investigating the magnetic fields of young solar-twin stars

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The study

Why: Magnetic fields play a key role in stellar evolution

- ✧Affects the star – slows down rotation => Sun used to rotate more rapidly => stronger magnetic activity (Vidotto et al. 2014, Marsden et al. 2014)
- ✧Affects surrounding objects, planets

Goal: Learn more about the young solar magnetic field

How: Focus on young solar analogues, all from "Sun in Time" sample (Güdel 2007)

- ✧ Ages of 100-600 Myr, all with a mass and temperature similar to the Sun
- ✧ Use spectropolarimetric Stokes IV data
- ✧ Derive maps of surface magnetic field using the same ZDI code for all observations
- ✧ Evaluate possible collective trends and individual results

Observational data

- Six stars observed for 16 epochs in total
- Archival data from Polarbase (Petit et al. 2014)
  - NARVAL: Resolution ~65000
  - Five stars: EK Dra: 2007.1, 2012.1
    HN Peg: 2007.6, 2008.6, 2009.5, 2010.5, 2011.5
    π^1 Uma: 2007.1
    χ^1 Ori: 2007.1, 2008.1, 2010.8, 2011.9
    κ^1 Cet: 2012.8
- Observation program “Active Suns” (Hackman et al. 2015)
  - HARPSpol: Resolution ~110 000
  - Three stars: HN Peg: 2013.7
    BE Cet: 2013.7
    κ^1 Cet: 2013.7

The sample

✧ All stars are selected from the ”Sun in Time” sample

Star	T_{eff} (K)	Mass ($M_\odot$)	P_{rot} (d)	Age (Myr)	Membership
EK Dra	5845	1.044	2.6	100	Pleiades
HN Peg	5974	1.103	4.6	230	Hercules-Lyra
π^1 Uma	5873	1.00	4.9	270	Ursa Major
χ^1 Ori	5882	1.028	5.08	300	Ursa Major
BE Cet	5837	1.062	7.65	500	Hyades
κ^1 Cet	5742	1.034	9.2	600	-

Valenti & Fischer 2005, Takeda et al. 2007, Strassmeier & Rice 1997, Montes et al. 2001a,b, Boro Saikia et al. 2015, Eisenbeiss et al. 2013, King et al. 2003, Messina & Guinan 2003, Güdel 2007, Gonzalez et al. 2010

Polarisation profile analysis

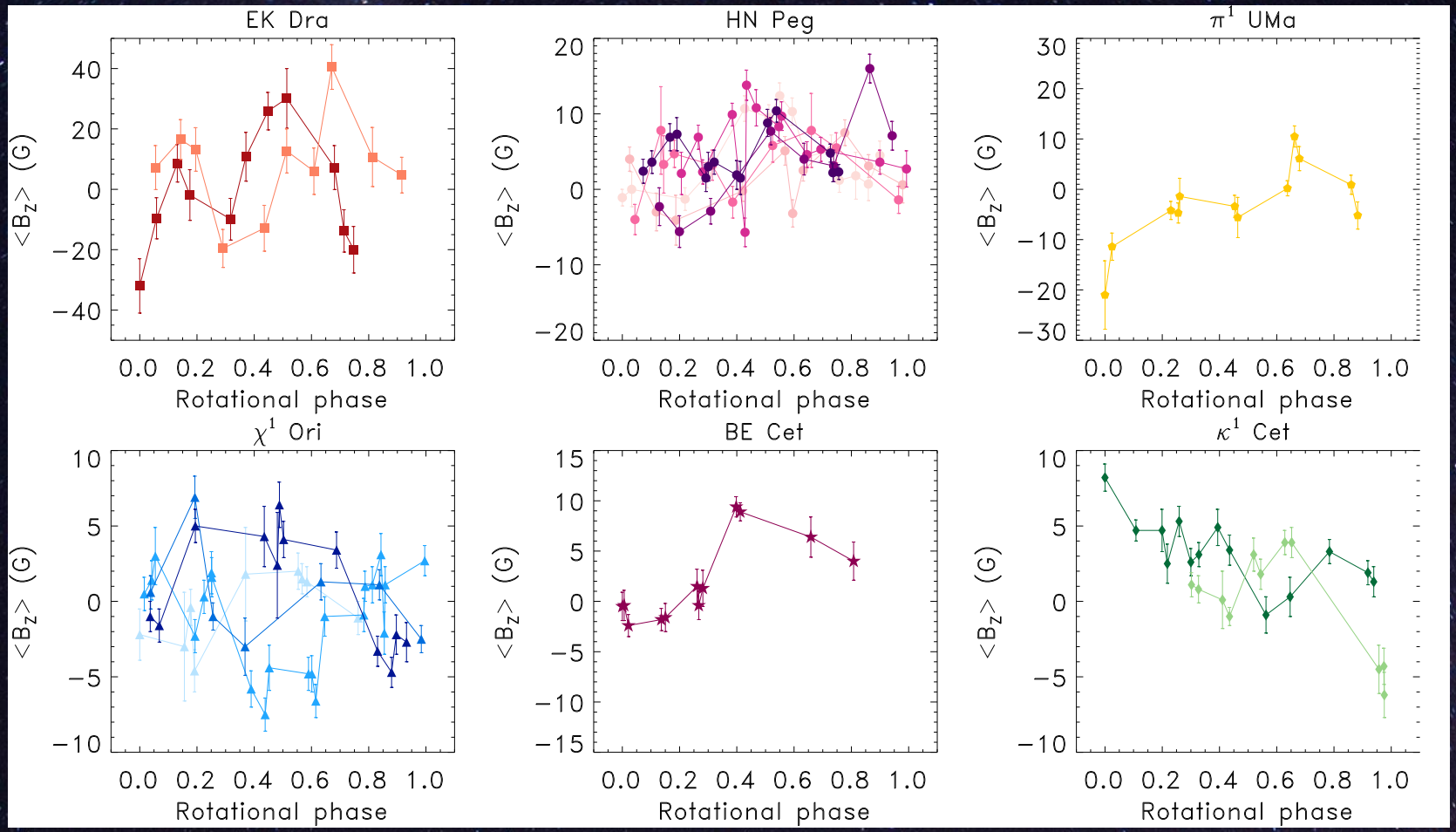
- No polarisation signatures in individual lines
  - Apply least-squares deconvolution to increase S/N
- ZDI using the single-line approximation of LSD profiles (weak field and no linear polarisation)
- Only one target, EK Dra, showed any distortion in Stokes I
  - Brightness mapping together with magnetic field mapping

Mean longitudinal magnetic field

40.5 G
32.0 G

16.0 G
7.5 G

-21.0 G



7.5 G
-3.0 G

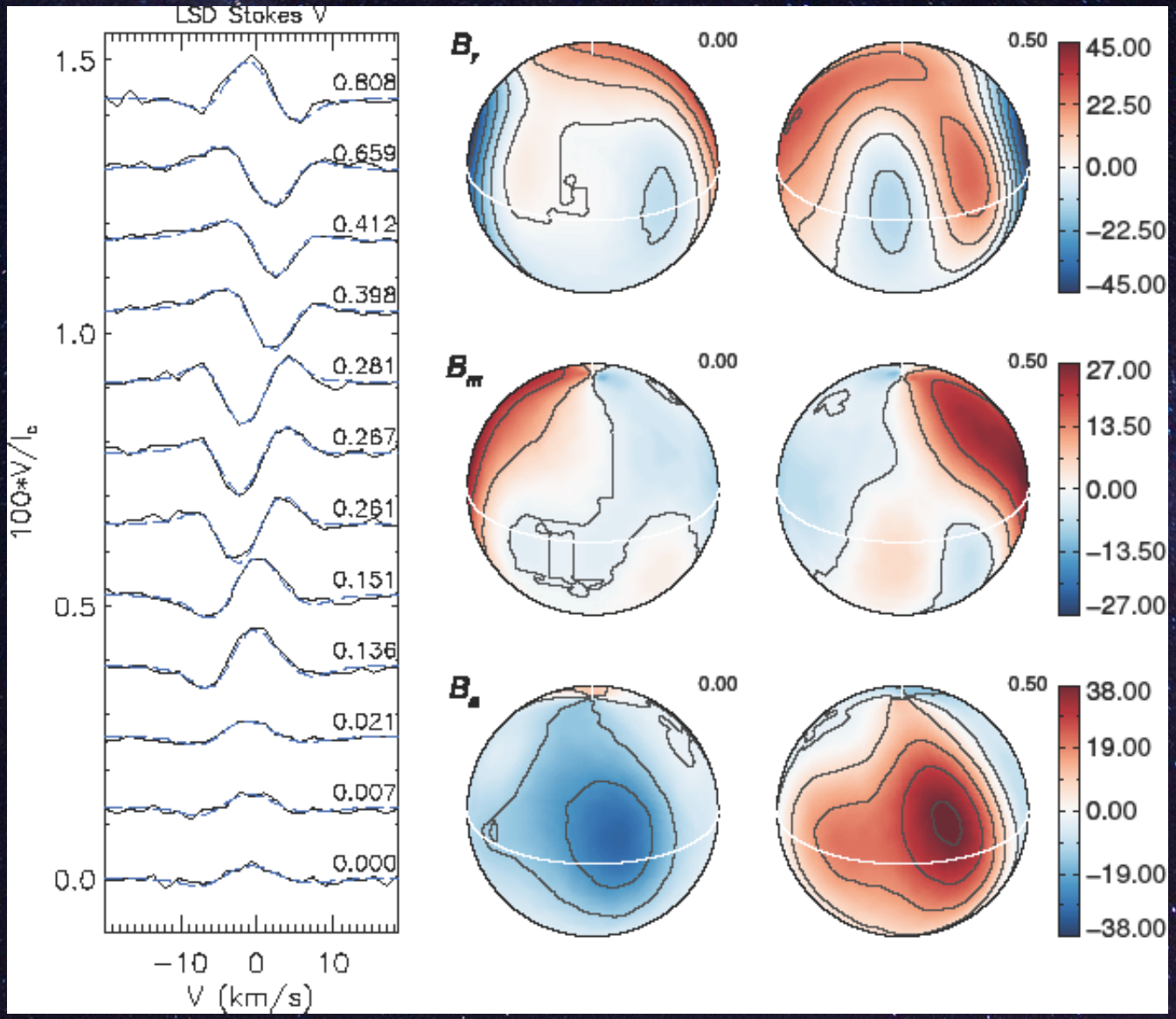
9.4 G

8.2 G
-6.4 G

- ✧ Complex magnetic fields
- ✧ Decreasing with age?

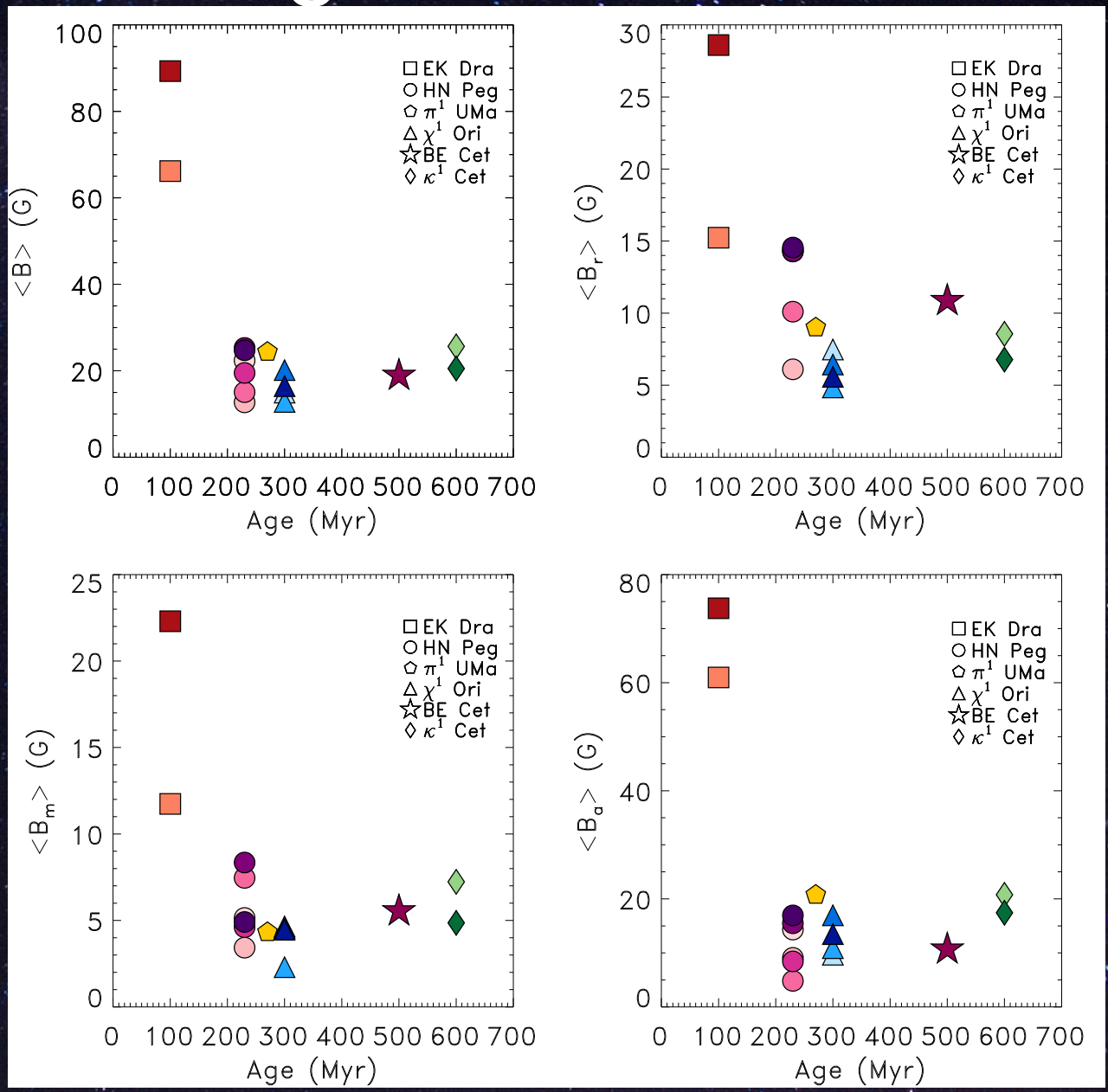
BE Cet

2013.7


LSD Stokes V
1.5
1.0
0.5
0.0
100*V/I_c
0.808
0.659
0.412
0.398
0.281
0.267
0.261
0.151
0.136
0.021
0.007
0.000
−10
0
10
V (km/s)
B_r
B_m
B_a
0.00
0.50
45.00
22.50
0.00
−22.50
−45.00
27.00
13.50
0.00
−13.50
−27.00
38.00
19.00
0.00
−19.00
−38.00

Mean magnetic field

- Significant decrease of <B> and $<B_a>$ from 100-200 Myr
- Similar variation between different epochs of the same star as between different stars
- $<B_m>$ is weakest in 15/16 epochs
- $<B_a>$ is strongest in 13/16 epochs

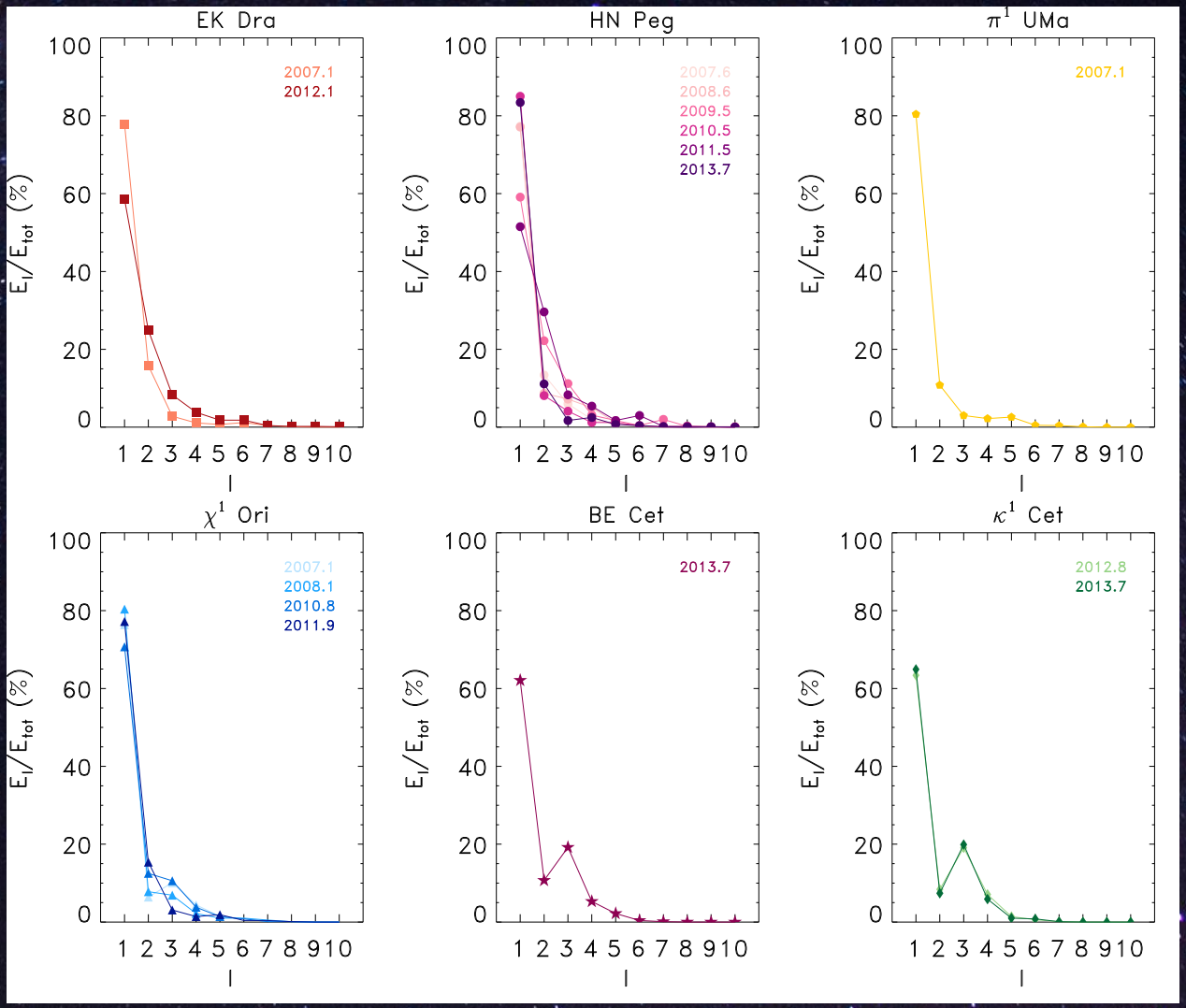


Possible trends and other results

- B_z decreasing with age
- <B> decrease from 100-200 Myr, but then ~ similar
- Decrease in B_z due to change in topology rather than field strength?
- $\langle B_a \rangle$ field is strongest in 13/16 epochs
  - Free of cross talk?
- $\langle B_m \rangle$ field is weakest in 15/16 epochs
  - Underestimated with Stokes V only

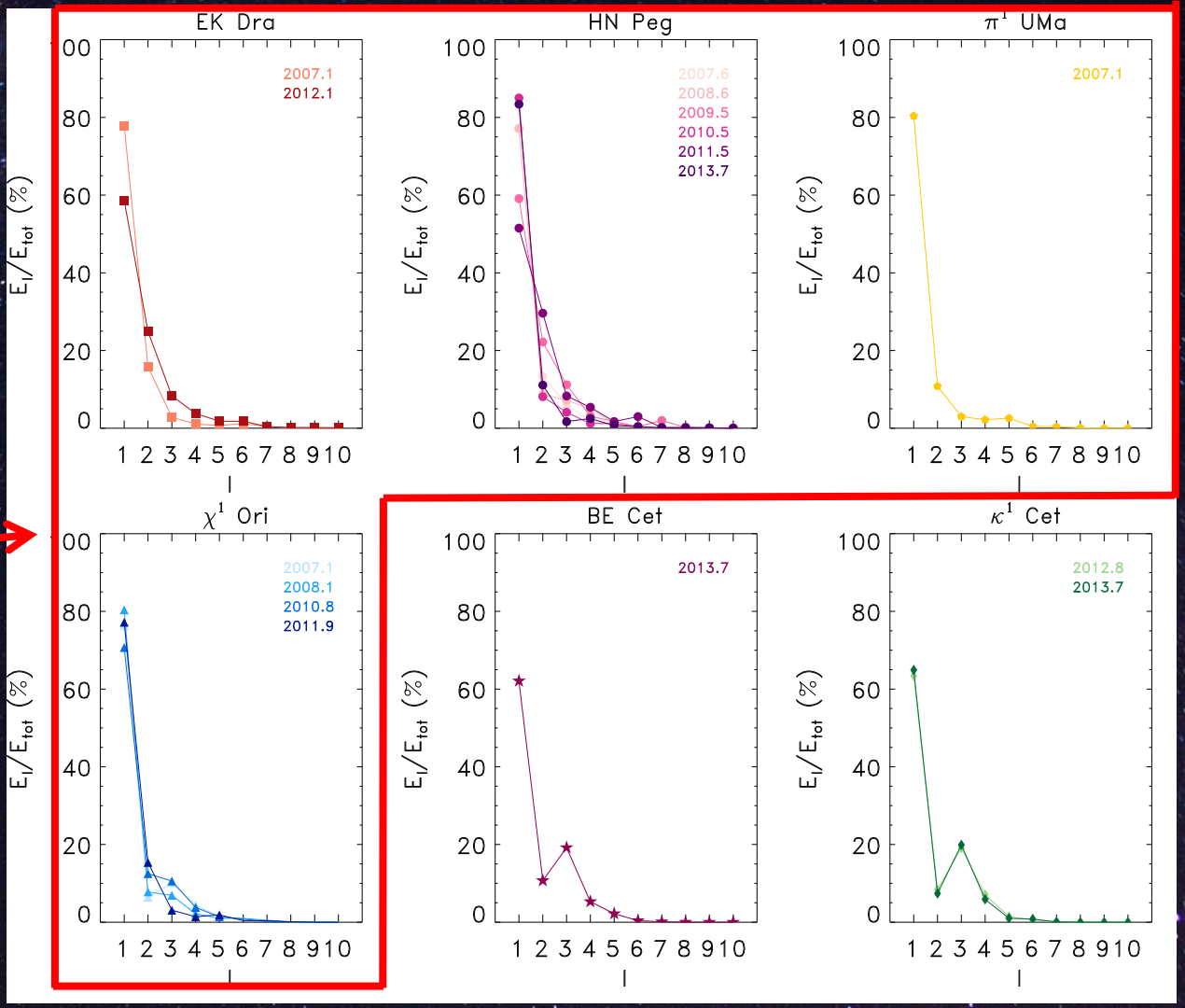
Global magnetic field topology

- 89-97% in l=1-3



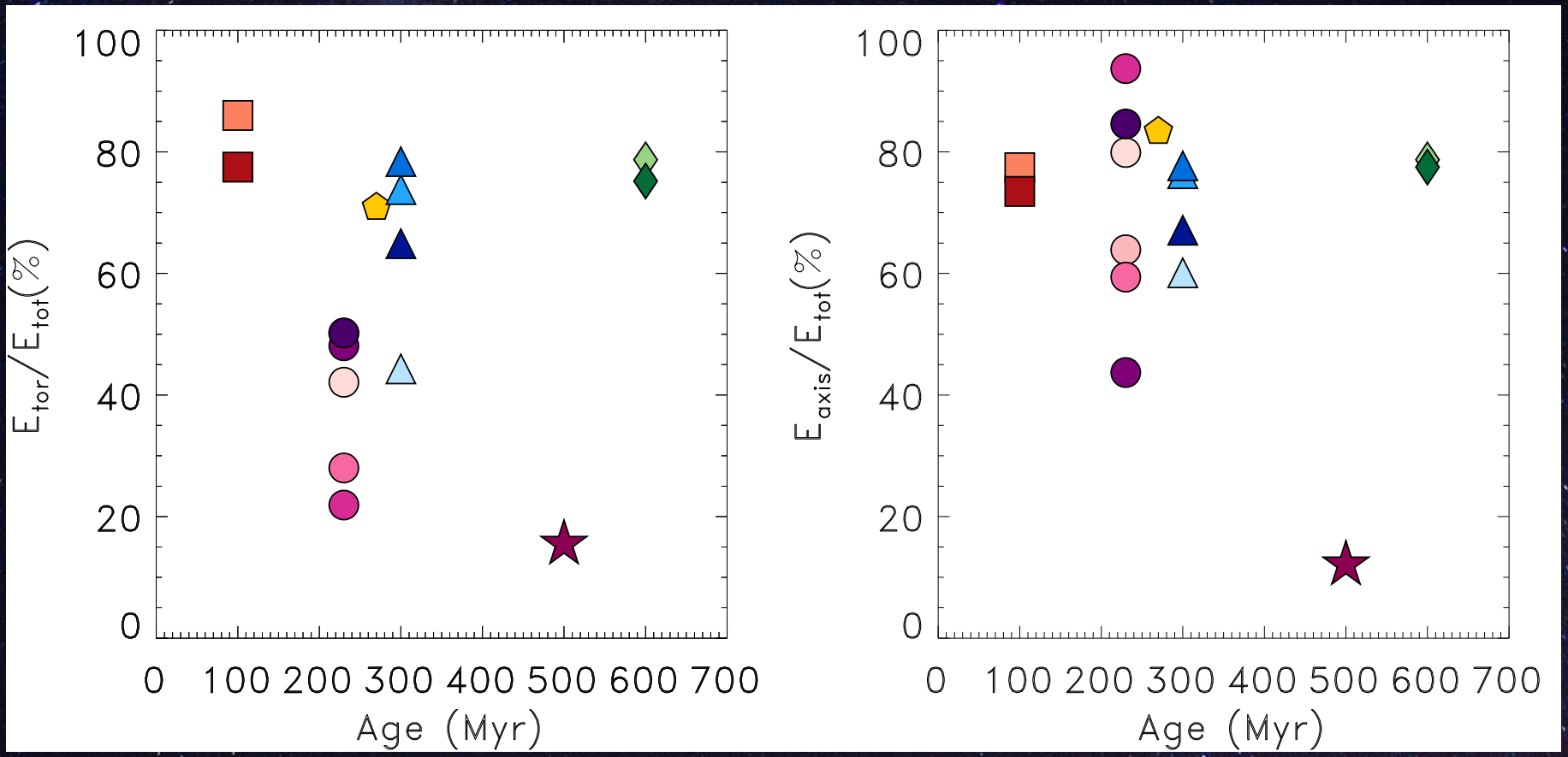
Global magnetic field topology

- 89-97% in l=1-3
- E_l decrease as l increase in 12/13 epochs



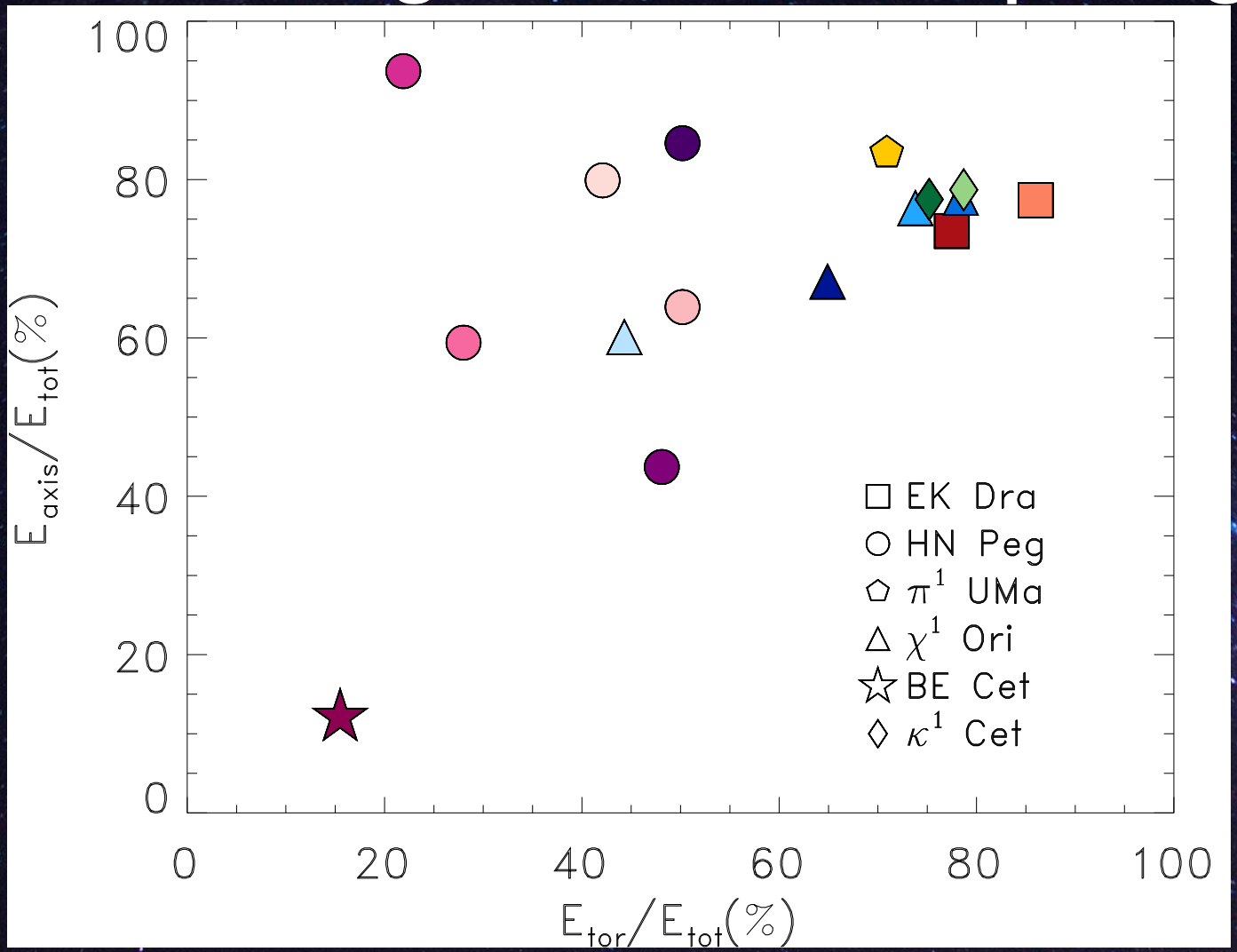
- $E_{l=3}=2\times E_{l=2}$

Global magnetic field topology



- Dominantly toroidal in 8/16 epochs +3 where $E_{tor} \approx E_{pol}$
- Dominantly axisymmetric in 14/16 epochs

Global magnetic field topology



- Follows the relation $E_{axis} \geq E_{tor}$ (See et al. 2015)
- No trend with age, youngest and oldest star have similar topology
- BE Cet lowest E_{axis} and E_{tor}

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- $\langle B_m \rangle$ field is weakest in 15/16 epochs
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- Two oldest stars have twice as large octupole compared to quadrupole component
- Magnetic field is dominantly toroidal for half the epochs (+ 3 close to 50%).
  - No trend with age

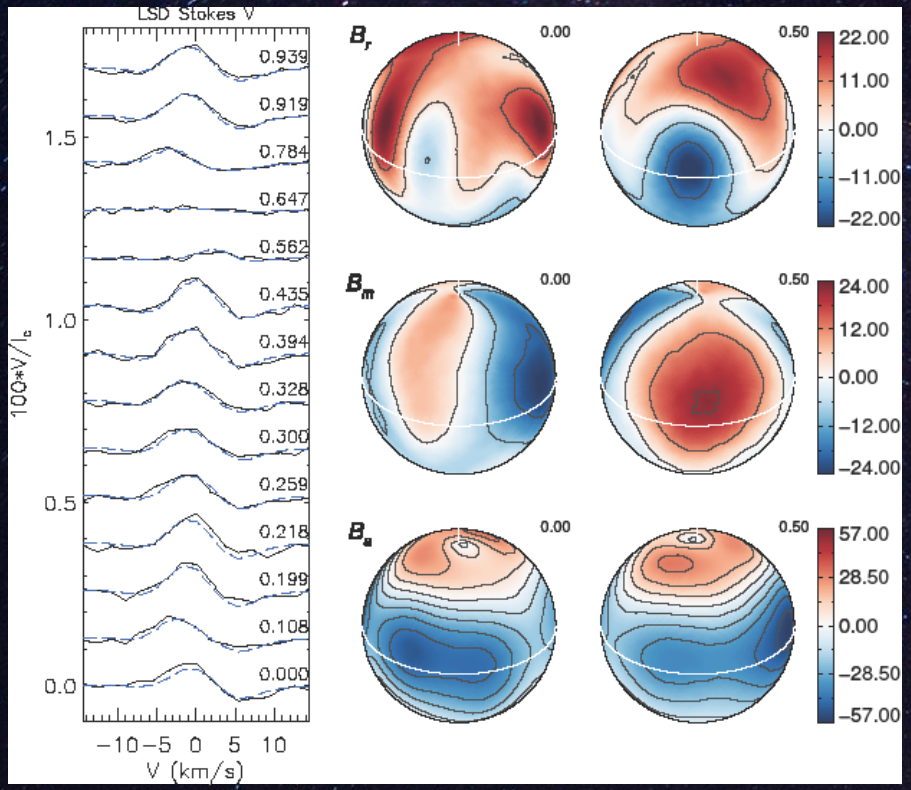
Magnetic cycles?

- EK Dra, HN Peg, χ^1 Ori and κ^1 Cet observed at multiple epochs

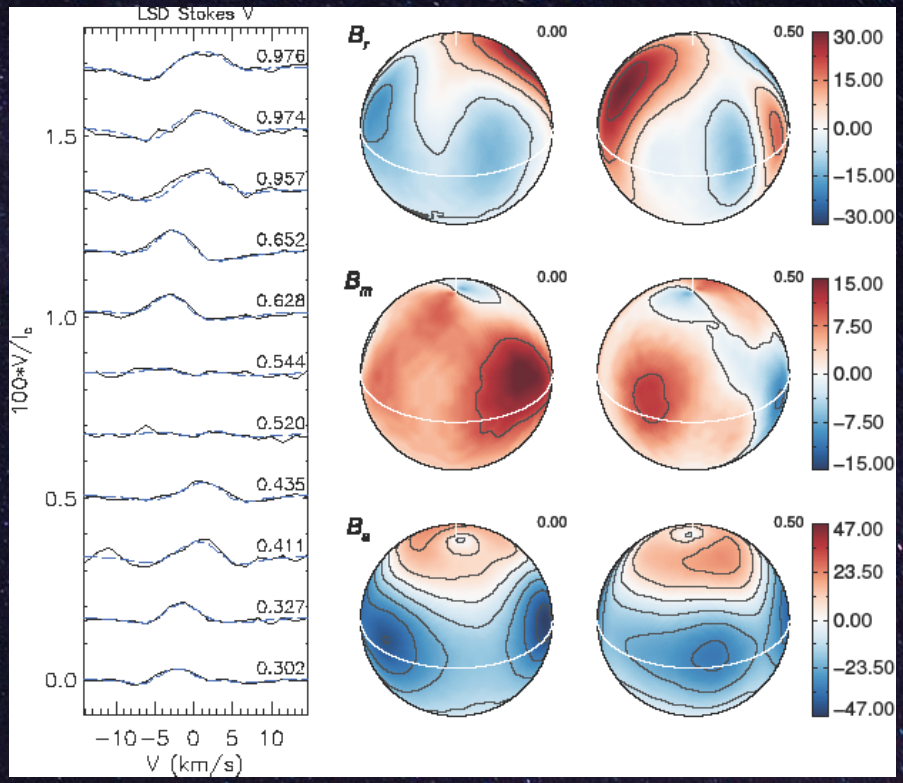
- EK Dra and HN Peg show the same radial polarity for all epochs

κ^1 Cet

2012.8



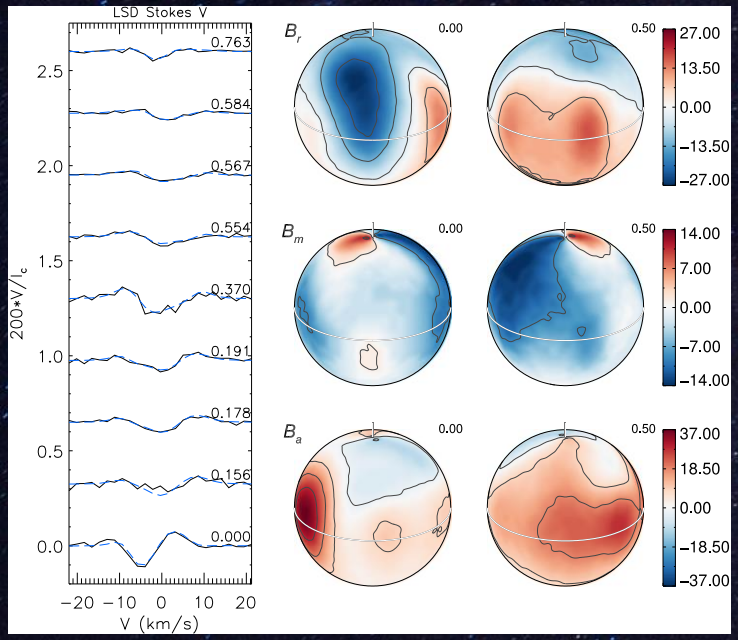
2013.7



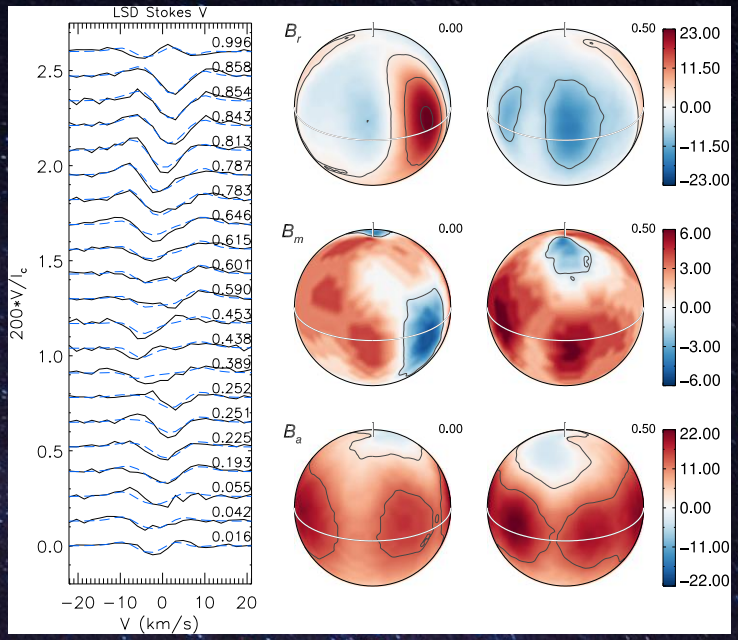
χ^1 Ori

- Radial field changes polarity twice
- Meridional field also changes
- Magnetic cycle of either 2 or 8 years

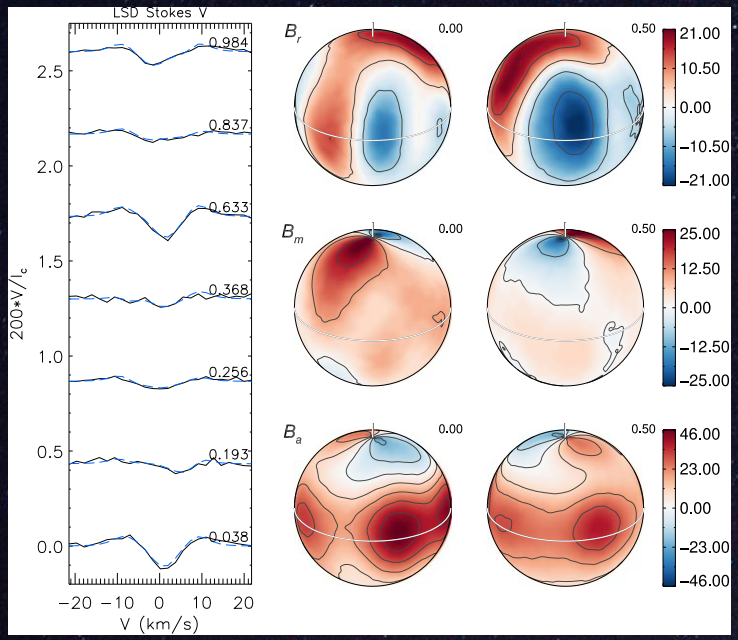
2007.1



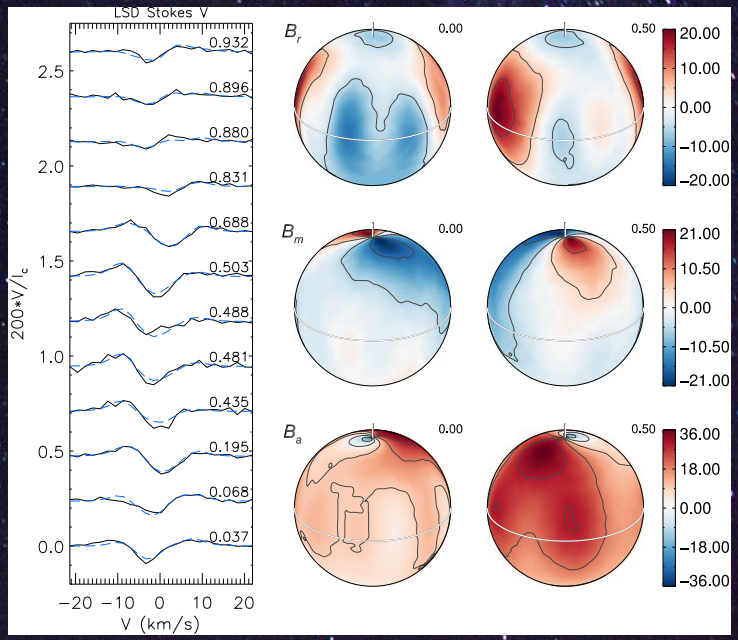
2008.1



2010.8



2011.9



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  - No trend with age
- Possible magnetic cycle for χ^1 Ori


Thank you!