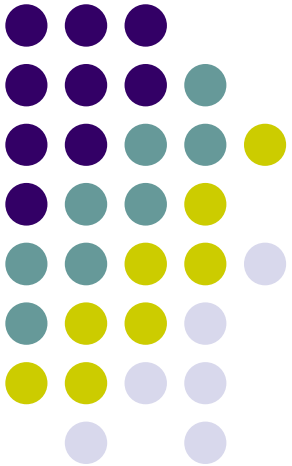
Open questions
in the mCP stars physics

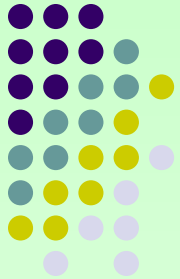


Zdeněk Mikulášek

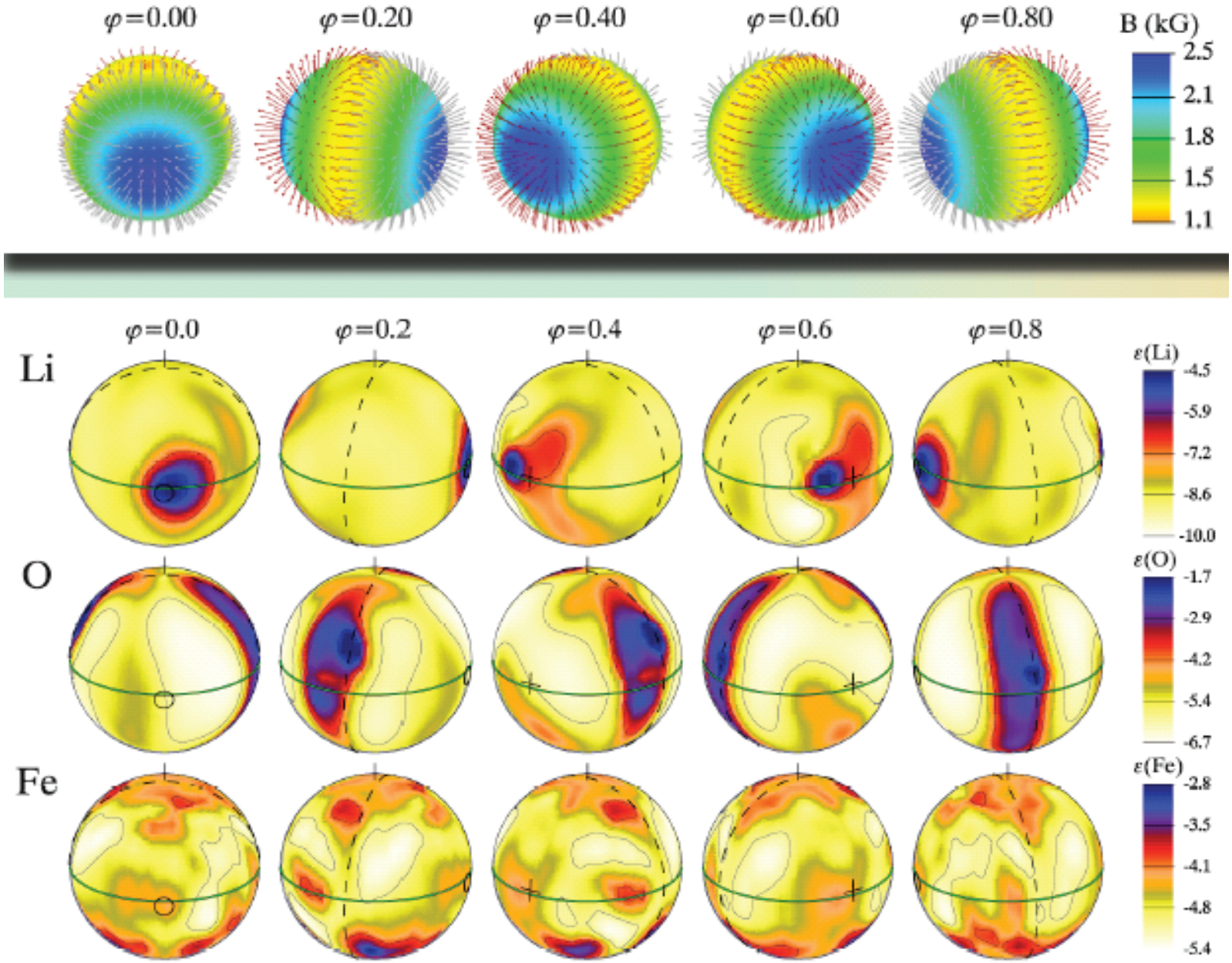
Jiří Krtička, Gabriel Szász

Universitäts-Sternwarte, 19 October 2009, Vienna, Austria

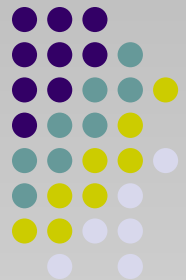
Chemically peculiar stars



- Atmospheres of 10% of hot Main Sequence stars display considerable deflections from standard (solar) chemical composition – overabundance or underabundance of particular elements amounted sometimes to several orders.
- ZOO of CP stars - non magnetic types: Am, Hg-Mg, magnetic stars: cool ones - SrCrEu, hotter Si, He weak, He strong.
- CP stars are relatively slow rotators (days to years), being hot they do not suffer from the convection. Many of them pose a strong global (fossil) magnetic field → their surface layers are very stable.
- Here can take place slow **radiative diffusion**: ions with large radiative cross sections are pushed ↑, others (He) are settling down. The type of chem. peculiarity depends mainly on T_{ef}.


φ=0.00
φ=0.20
φ=0.40
φ=0.60
φ=0.80
B (kG)
2.5
2.1
1.8
1.5
1.1
φ=0.0
φ=0.2
φ=0.4
φ=0.6
φ=0.8
Li
O
Fe
ε(Li)
-4.5
-5.9
-7.2
-8.6
-10.0
ε(O)
-1.7
-2.9
-4.2
-5.4
-6.7
ε(Fe)
-2.8
-3.5
-4.1
-4.8
-5.4

Why are photometric spots so sexy?



- Light changes are caused by the incidence of “photometric spots” on the surface a rotating chemically peculiar star.

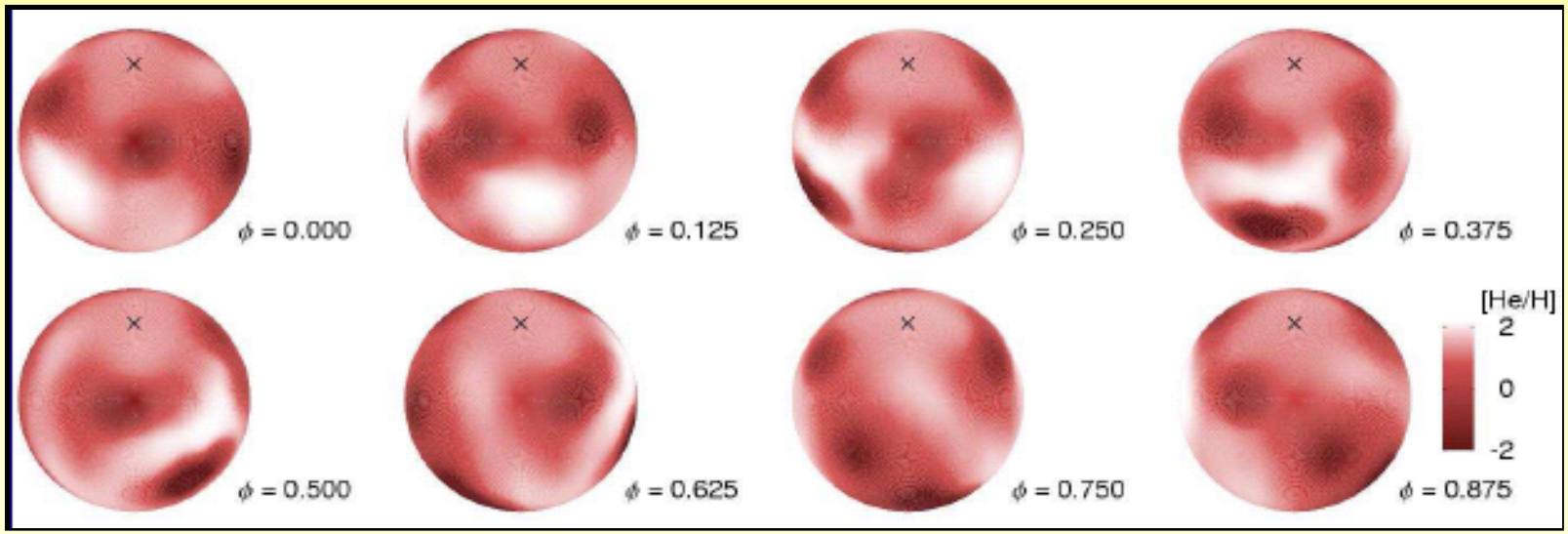
Quite different from spots on cool stars:

- They cover large areas, they are persistent. Their effective temperatures correspond to the effective temperature of stars.
- Monochromatic brightness contrast is due to different spectral energy distribution of the emergent flux in and outside of the PS. → **Photometric spots** are nor bright not dark, but color ones! **PS** are products of a specific **stellar make-up**.
- An artful make-up is indispensable for each star. Do you agree?

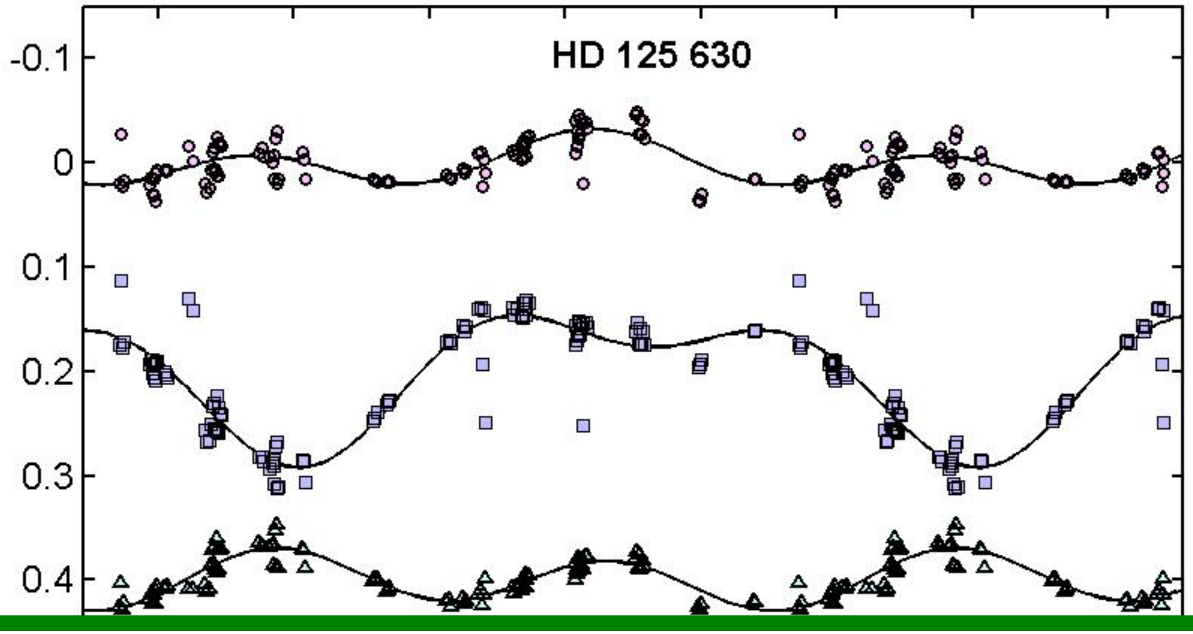
Why I love CP stars?

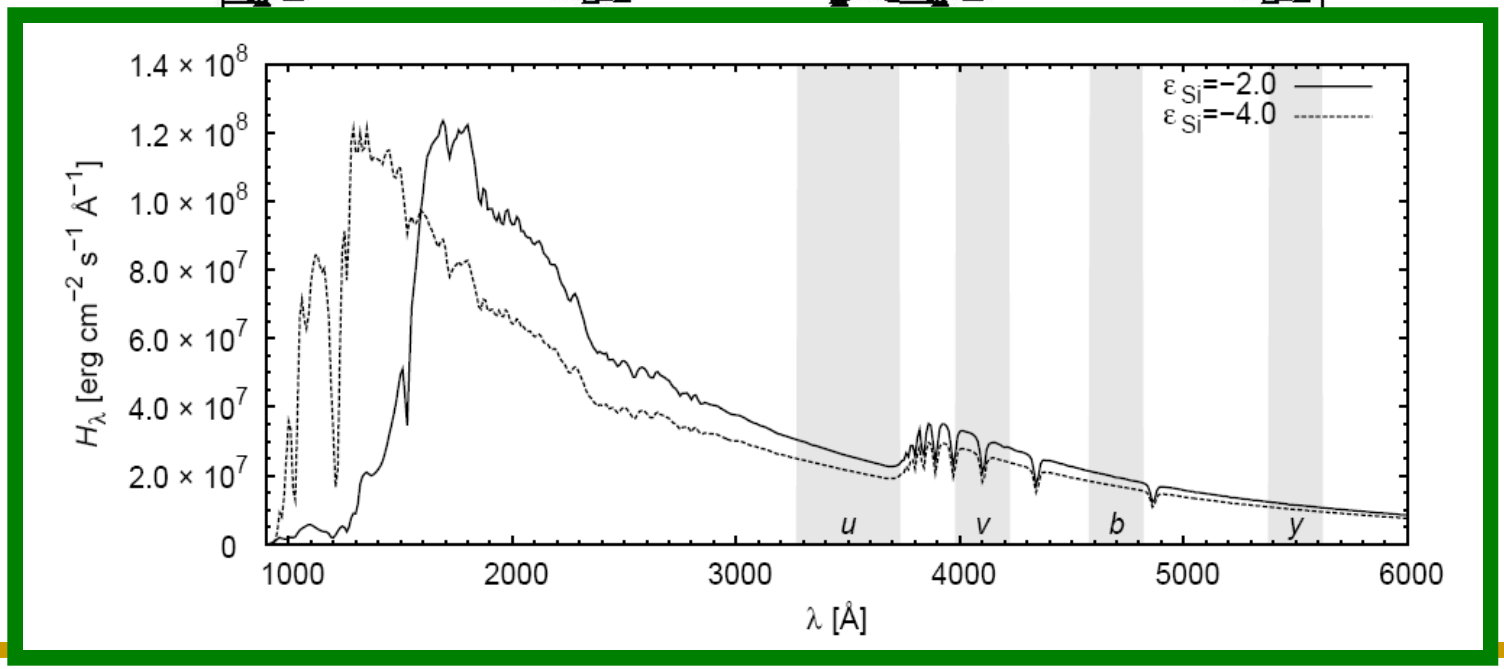
- They are attractive, fascinating and very disparate. There are no two CP stars with the same or similar **spectrum** – abundances of chemical elements differ. At the top the appearance of spectrum vary considerably as the star rotates. It is due to extra uneven distribution of chemical elements – differences: several orders. The positions of spots of individual elements generally do not coincide.
- There are no two CP stars with similar **light curves** in *uvby* colours – LCs can serve as faithful identification tool like thumb-mark → the distribution of photometric spots on the surface and their colour contrasts are very diverse. The range of magnitude of **global magnetic fields**, their geometry and complexity is enormous.
- **Nevertheless, there is only a weak (if any) correlation among these manifestations of stellar peculiarity. It enhances demands on the theory of the CP phenomenon.**

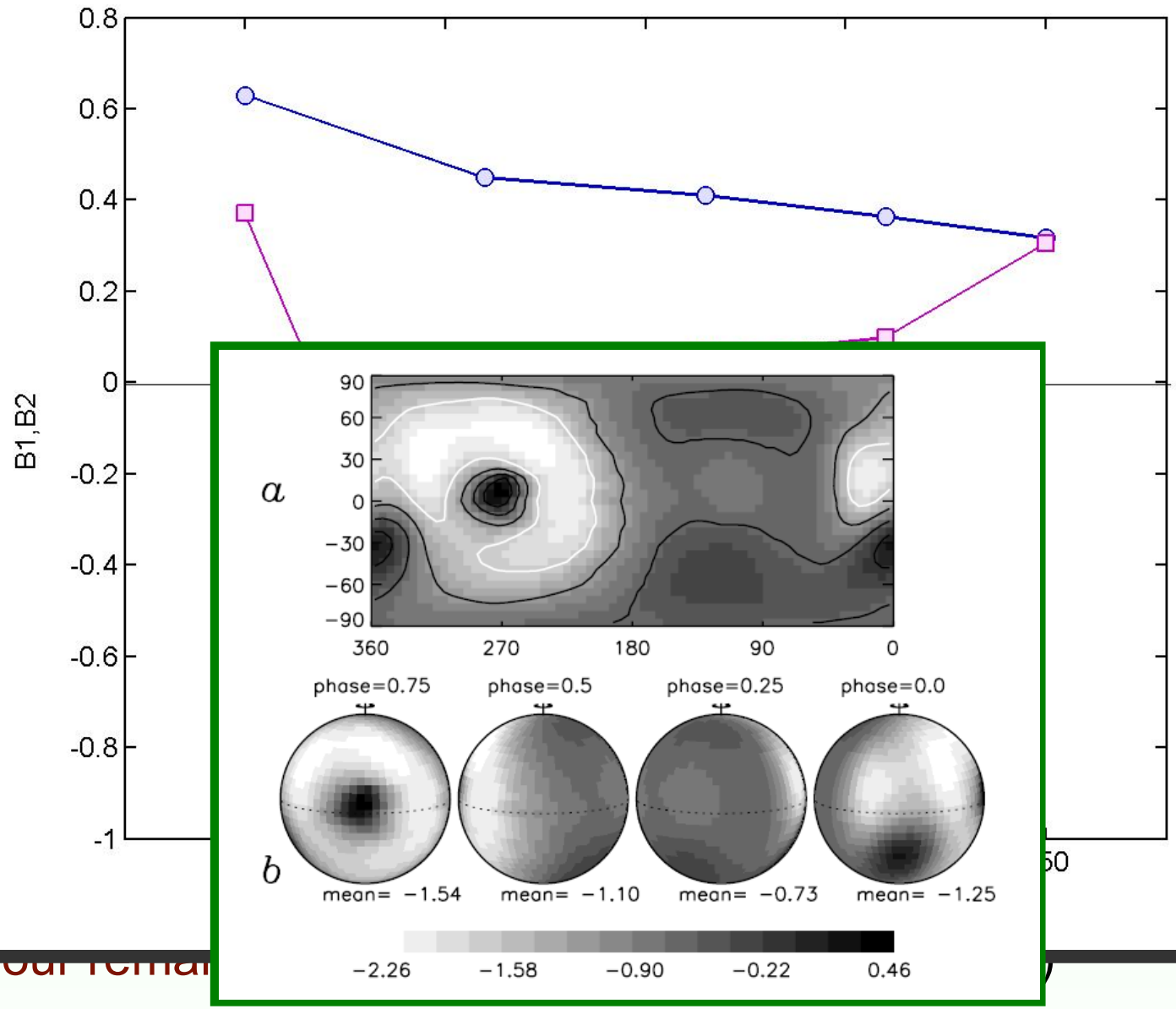
Spots on CP stars: How they form? What holds them together?



- The structure of abundance spots used to be often rather complex – could it provide **magnetic field**?
- Hardly – its complexity is smaller. I cannot imagine how **ONLY** the magnetic field could influence the diffusion process so it could create such complicated patterns.

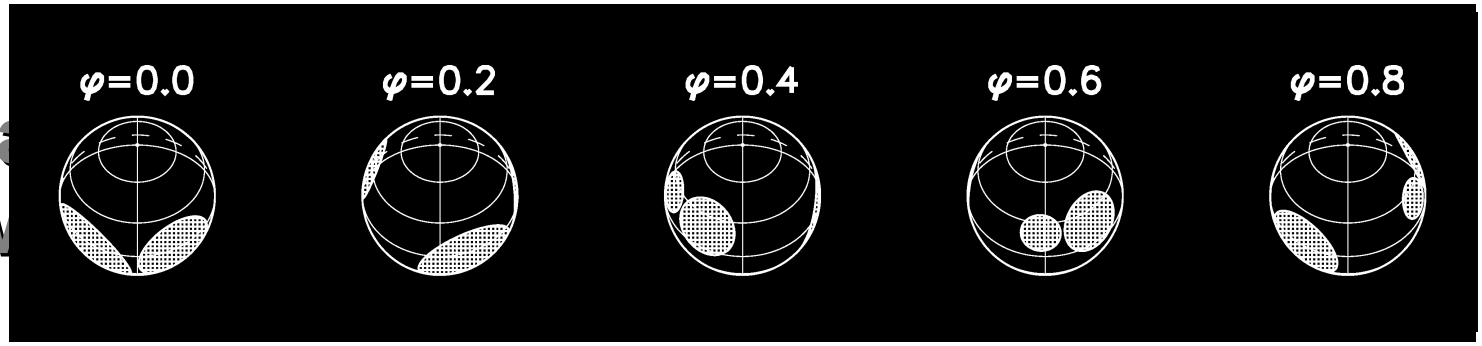

HD 125 630
-0.1
0
0.1
0.2
0.3
0.4

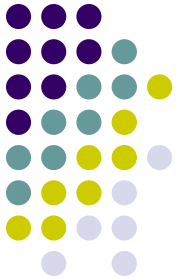

ε_{Si}=−2.0
ε_{Si}=−4.0
H_λ [erg cm^{-2} s^{-1} Å^{-1}]
1.4 × 10^8
1.2 × 10^8
1.0 × 10^8
8.0 × 10^7
6.0 × 10^7
4.0 × 10^7
2.0 × 10^7
0
u
v
b
y
1000
2000
3000
4000
5000
6000
λ [Å]


B1,B2
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
a
90
60
30
0
−30
−60
−90
360
270
180
90
0
b
phase=0.75
phase=0.5
phase=0.25
phase=0.0
mean= −1.54
mean= −1.10
mean= −0.73
mean= −1.25
−2.26
−1.58
−0.90
−0.22
0.46

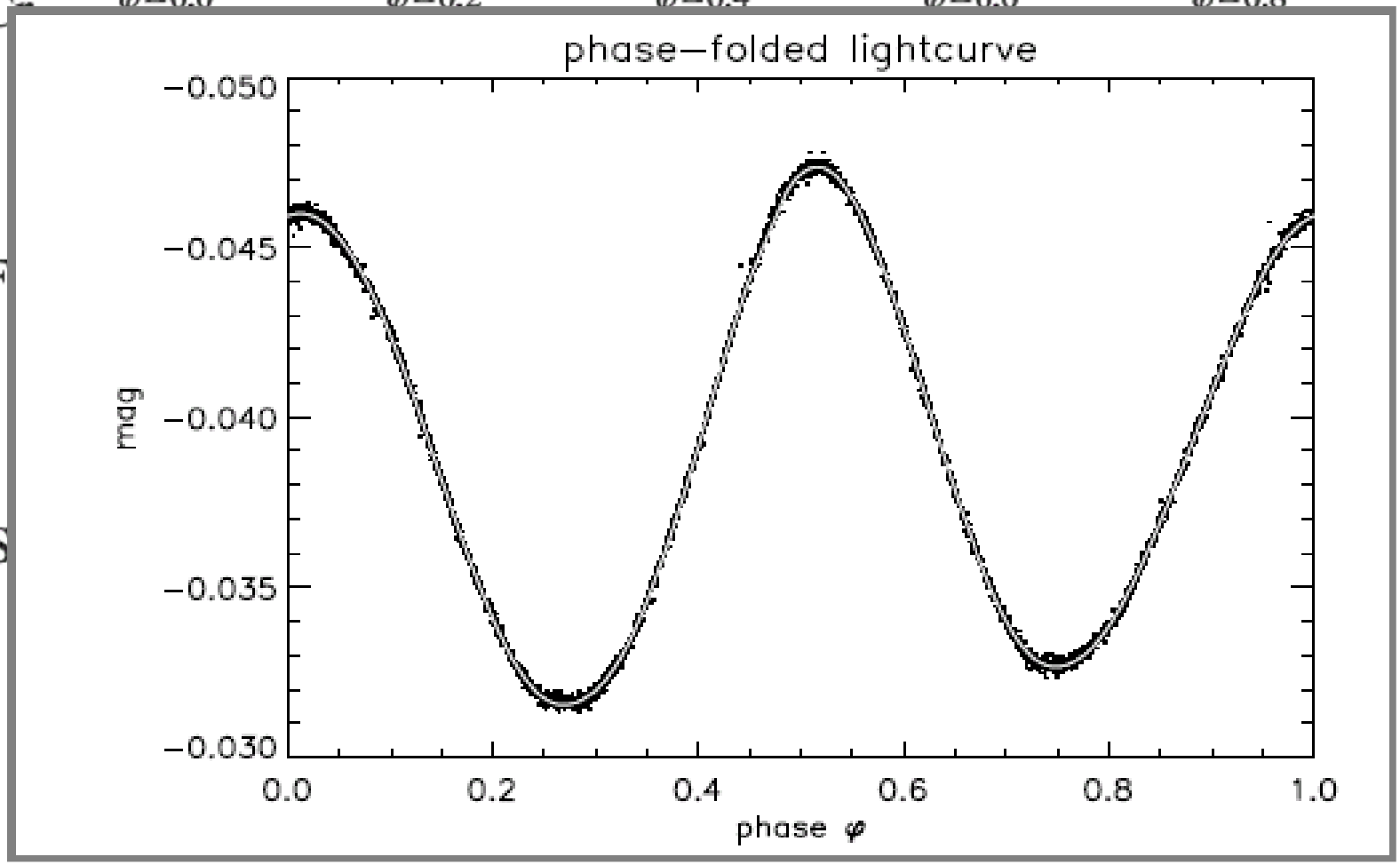
The controversial role of magnetic field

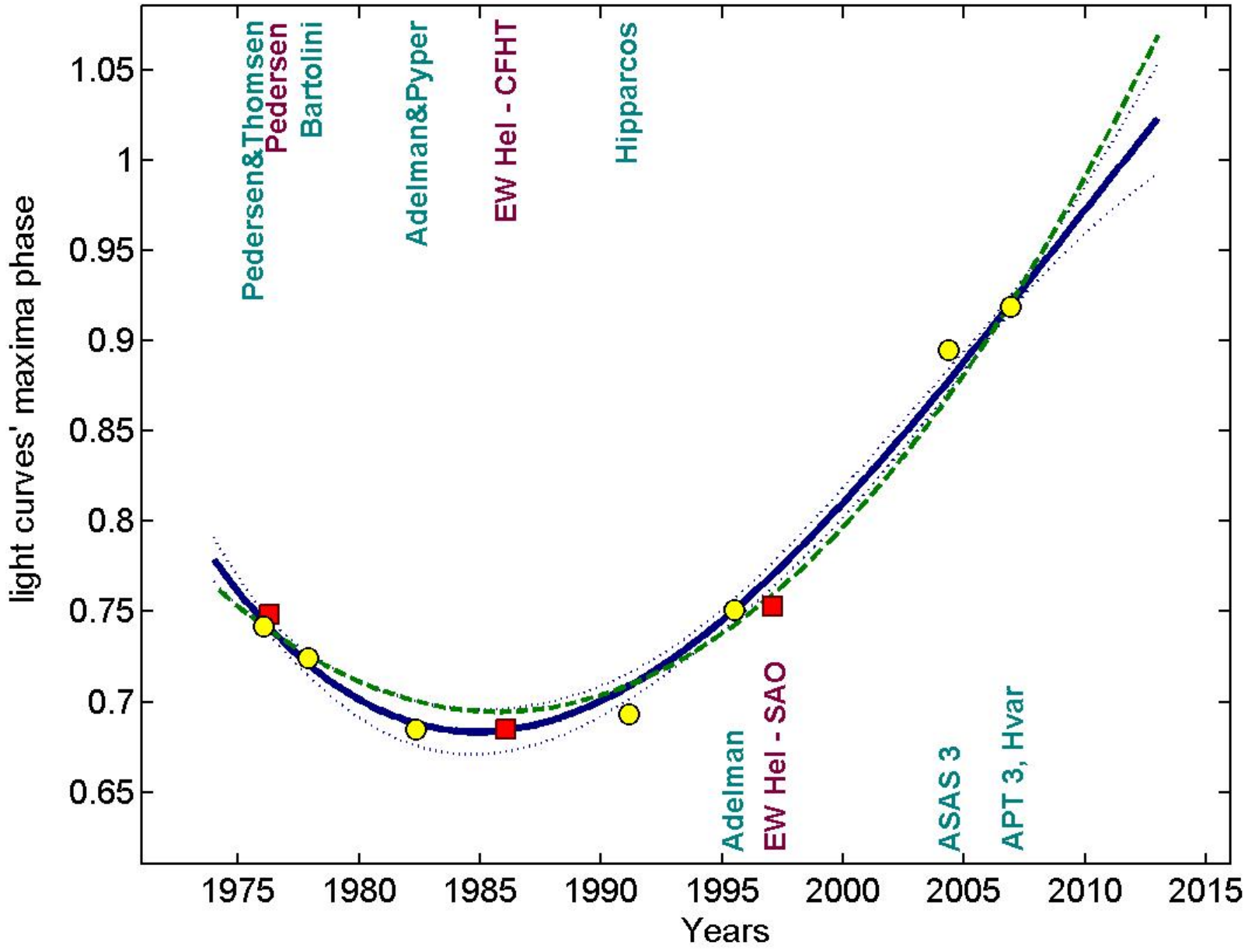
- Magnetic field affects the atmospheres of CP stars, but is its influence significant for their light variations?
- Can we estimate its contribution?
- The question has not been completely solved because the effect of magnetic field is very complex (contribution to pressure, intensification of lines due to Zeeman splitting etc.).
- Nevertheless, it seems that in the most cases the influence of magnetic field on LCs is negligible.


φ=0.0
φ=0.2
φ=0.4
φ=0.6
φ=0.8



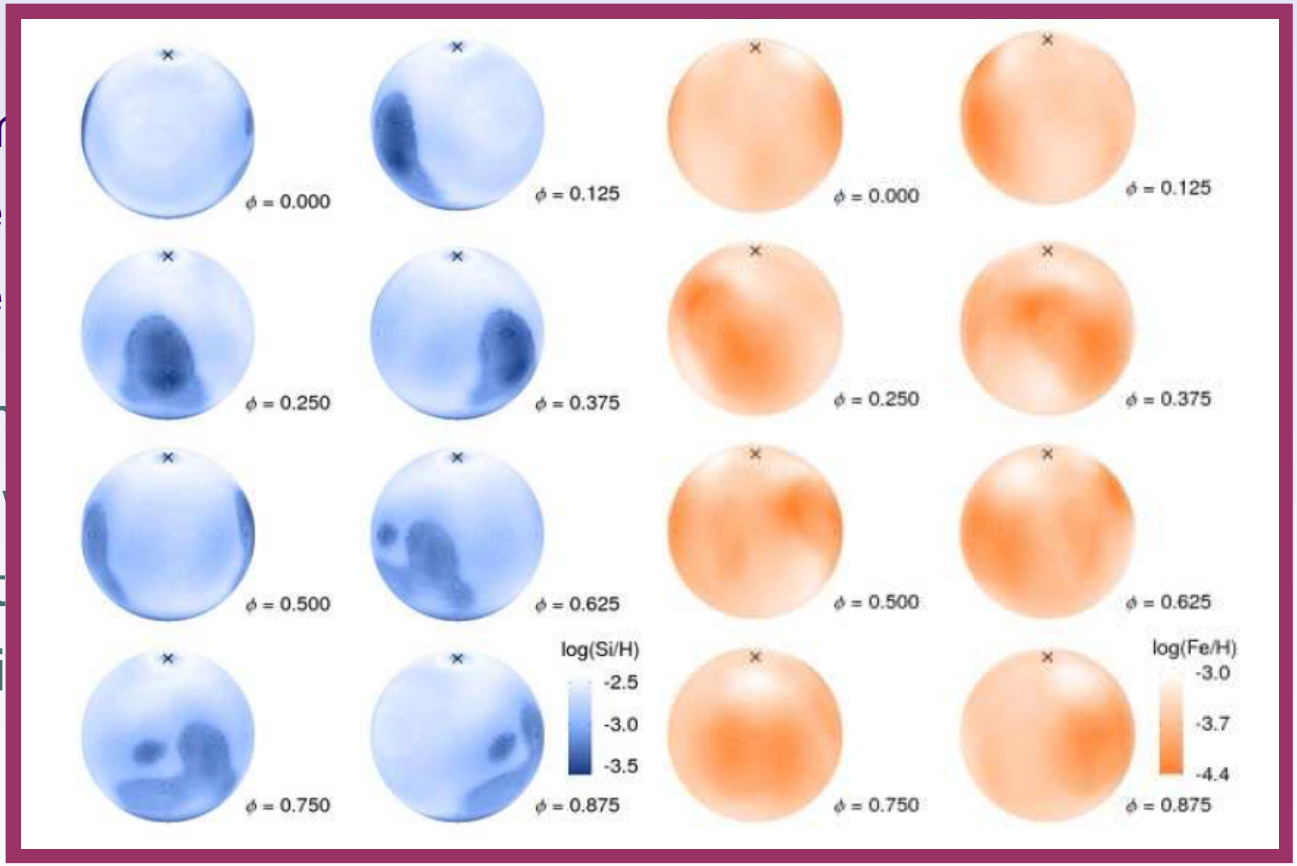
- C
- F
- S
-


phase−folded lightcurve
−0.050
−0.045
−0.040
−0.035
−0.030
mag
0.0
0.2
0.4
0.6
0.8
1.0
phase φ
e(Cr)
-3.0
-3.9
-4.9
-5.8
-6.8
e(Fe)
-1.9
-2.8
-3.6
-4.5
-5.3
e(Si)
-2.6
-3.2
-3.8
-4.4
-5.0


Pedersen&Thomsen
Pedersen
Bartolini
Adelman&Pyper
EW Hel - CFHT
Hipparcos
Adelman
EW Hel - SAO
ASAS 3
APT 3, Hvar
light curves' maxima phase
Years
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
1975
1980
1985
1990
1995
2000
2005
2010
2015

Are all “magnetic” CP stars really magnetic?

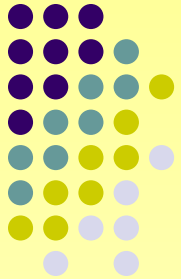
- The Si+He weak B9V **HD 177410** star is relatively well studied CP star – with overabundance of optically active Si and Fe.
- Photometric
  theoretical m
  magnetic fie
  magnetic fie
- More extrem
  LC (MOST)
  – we found t
  any magneti



Are spots on CP stars really as persistent and rigid as we assume?

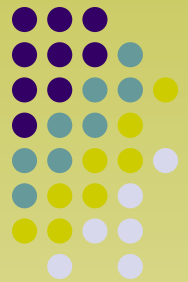
- All changes in the shape and contrast of photometric spots (connecting with spectroscopic ones) should manifest themselves by **secular variations of light curves**.
- We are collecting all available photometric observations of mCP stars – On-line photometric catalogue (mCPod) – now it comprises 140 thousands of individual measurements of 132 mCP stars.
- Some changes in light curves form were announced by various authors, but we have not found any well-documented case of light curves variations yet.

How is the CP phenomenon connected with the stellar rotation?



- CP stars are slow rotators among other MS stars – we know stars with extremely long rotational period of several hundreds days.
- Have they rotated so slowly from the very beginning of their MS carrier? Have they been braking during MS stage? What mechanism?
- What is the threshold of the rotational velocity for a CP star? The record breaking CP star is now helium strong southern star **HR 7355** with the rotational period of 0.521 days.

Some evolutionary oriented quests



- Does a star become a CP star immediately after its entering the MS? – we know very **young CP stars**.
- What is the origin of the **magnetic field** of CP stars? Most believe it is fossil field. But, why there are binary stars consisting of normal and CP star?
- Are they **progenitors** and **successors** of MS CP stars? Are **magnetic white dwarfs** such successors? ETC, ETC, etc...

Thanks for your attention.

I apologize I have not mentioned other open questions in the chemically peculiar stars physics, namely:

- APCA classification of CP light curves, atomic data for CP stars, CP stars in close binaries, CP star in open clusters, CP stars among blue strugglers, chromospheres of CP stars, convection in CP stars, depressions in SED, Doppler imaging, dynamo effect, education, extragalactic CPs, emission lines, invisible companions and their role, methods of period determination and improvement, microturbulence in CP stars, poloidal/torroidal magnetic field and its evolution, popularization, population II CP stars, precise light curves and their exploitation, spectropolarimetry, rapidly oscillating Ap stars, spots on non-magnetic CP stars, subsynchronously rotating CP components, UV spectra, vertical structure, youngest and oldest CP stars,
- individual CP stars: **HD 2453, 3980, 4778, 5497, 7676, 27309, 30849, 32633, 33331, 37017, 37776, 38823, 47152, 48331, 50773,51418, 55522, 62140, 63843, 65949, 66605, 71866, 81009, 83368, 86592, 96616, 98088, 105382, 110956B, 112185, 114365, 119213, 125248, 125615, 125630, 131120, 137909, 138769, 143418, 161321, 177410, 178892, 182180, 184905, 188401, 203006, 204411, 216533**, AR Aur and many, many others.