Recent progress in CP star research

Ernst Paunzen

Ústav teoretické fyziky a astrofyziky
Masarykova Univerzita
Brno

CP subgroups

Classical name	Prestons's group	Discovery criteria	Spectral types	Magnetic Field
Am – Fm	CP1	weak Ca II and/or Sc II; enhanced metals	A0 – F4	N
Bp – Ap	CP2	enhanced Sr, Cr, Eu, and/or Si	B6 – F4	Y
HgMn	CP3	enhanced Hg II and/or Mn II	B6 – A0	N
He – weak	CP4	weak He I compared with colours	B2 – B8	Y
He – strong		enhanced He I compared with colours	B0 – B2	Y

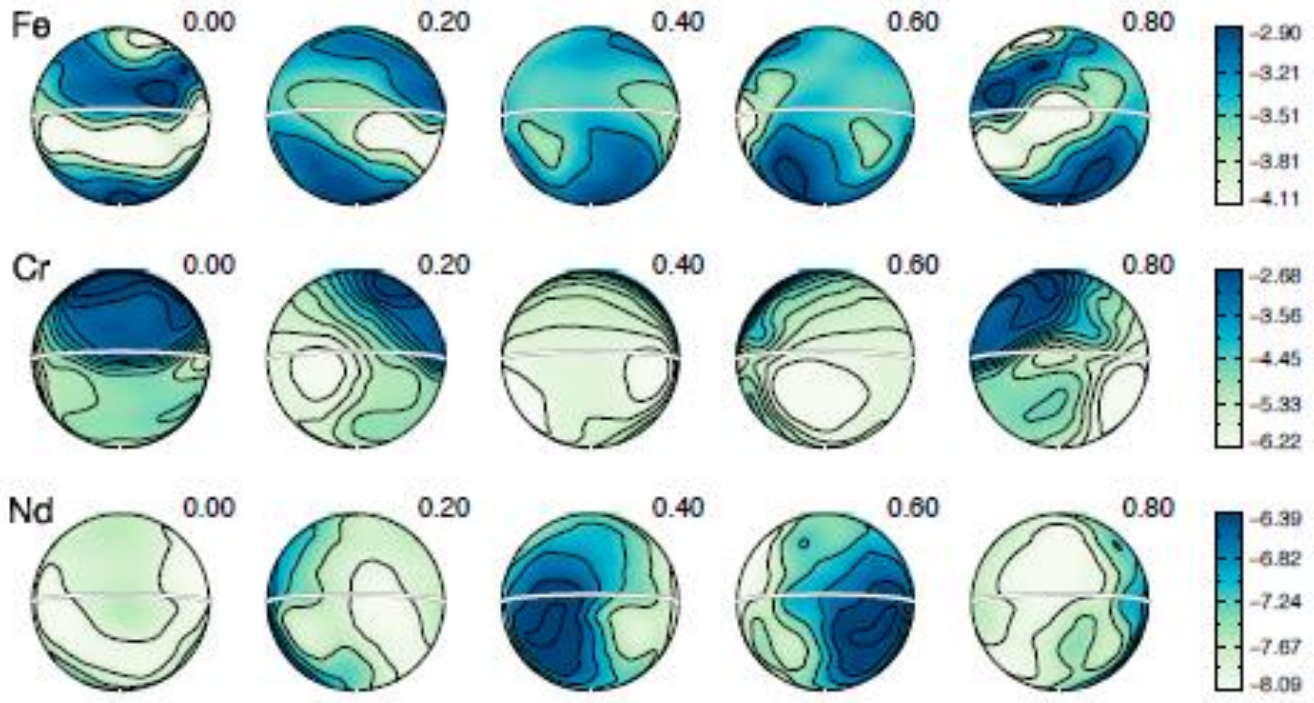
Preston (1974, ARA&A, 12, 257), Pedersen & Thomsen (1977, A&AS, 30, 11)

Hydrogen burning stars (LK V)

Slow rotation (< 60 km s^{-1})

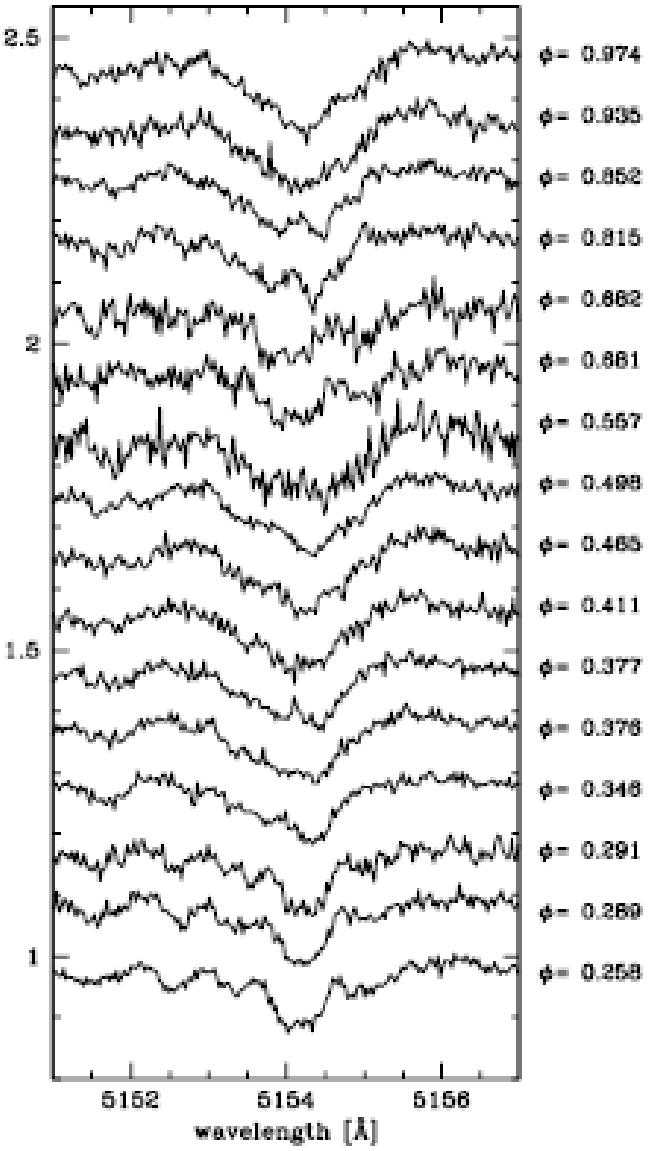
ACV Variables – surface spots

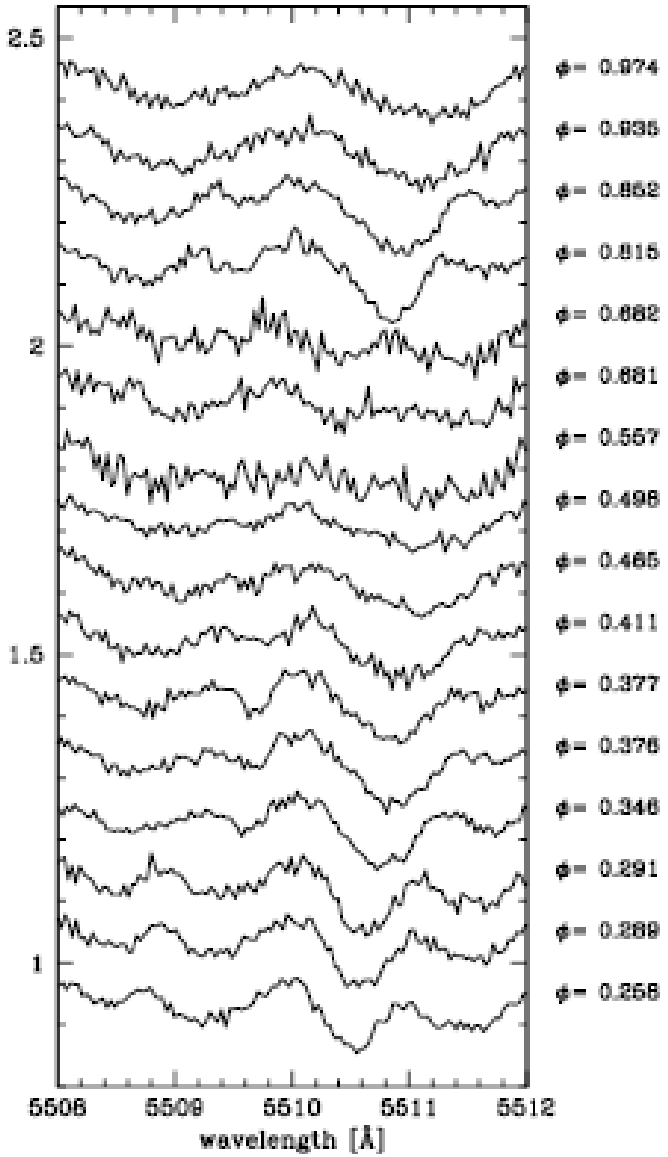
- α^2 Canum Venaticorum (ACV) variables
- Direct measurement of rotation
- Due to stellar spots on surface



Rusomarov et al. (2016, A&A, 588, A138)

Zeeman – Doppler - Maps





Zeeman – Doppler - Maps

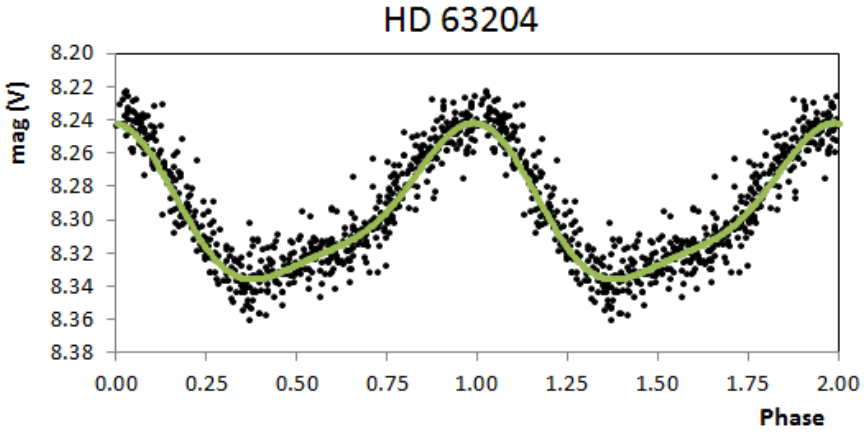
- Stift (2016, A&A, accepted; arXiv:1604.06960)
- Stift & Alecian (2016, MNRAS, 457, 47)
- Zeeman – Doppler – Mapping: calculation of surface maps from line profile variations over rotation cycle
- Free parameters

1. Inclination
2. Stellar parameters
3. Magnetic field characteristics (neglected)

ACV Variables – what can we learn?

- Rotation among the Main Sequence
- Differential rotation
- Magnetic braking
- Distribution among the ZAMS and TAMS
- Correlations with other astrophysical parameters
- Statistical sound sample needed
- Renson & Catalano (2001, A&A, 378, 113): 362 stars
- Since then, no systematic searches

New ACV variables

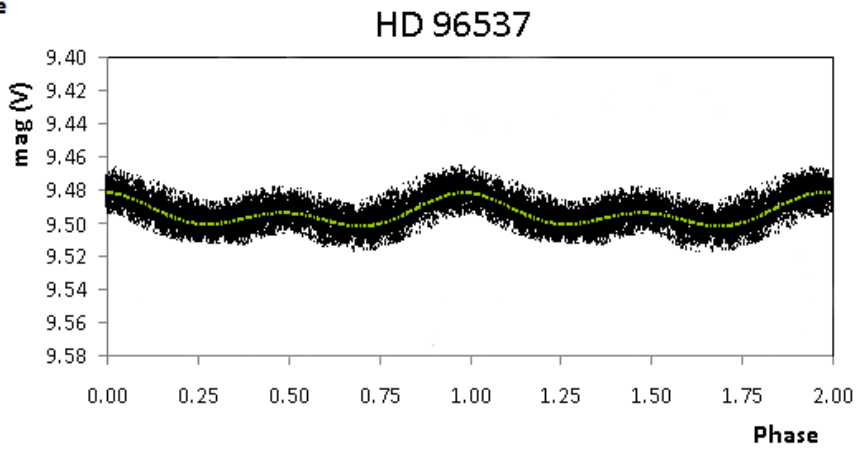


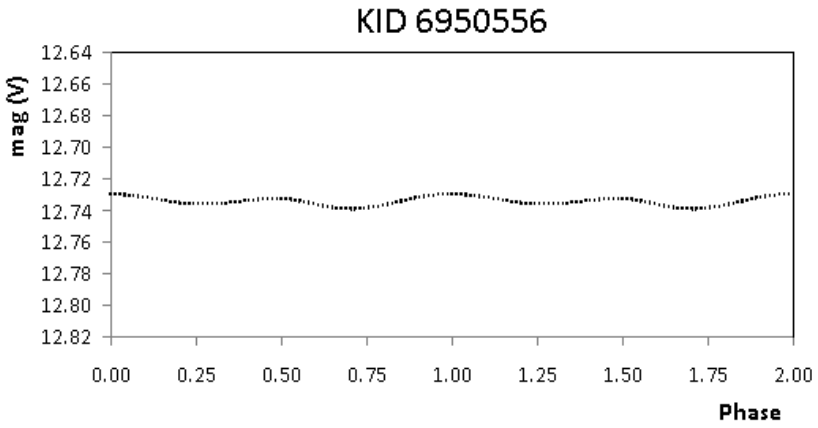
ASAS: 580 new

- Bernhard et al. (2015, A&A, 581, A138)
- Hümmerich et al. (2016, AJ, accepted)

SuperWASP: 74 new

- Bernhard et al. (2015, AN, 336, 981)

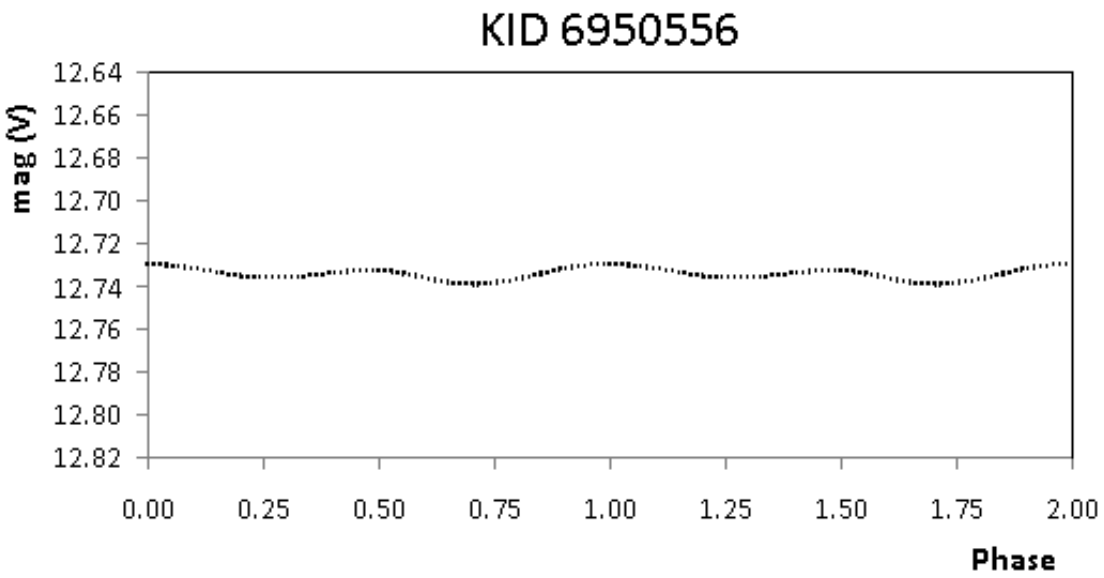


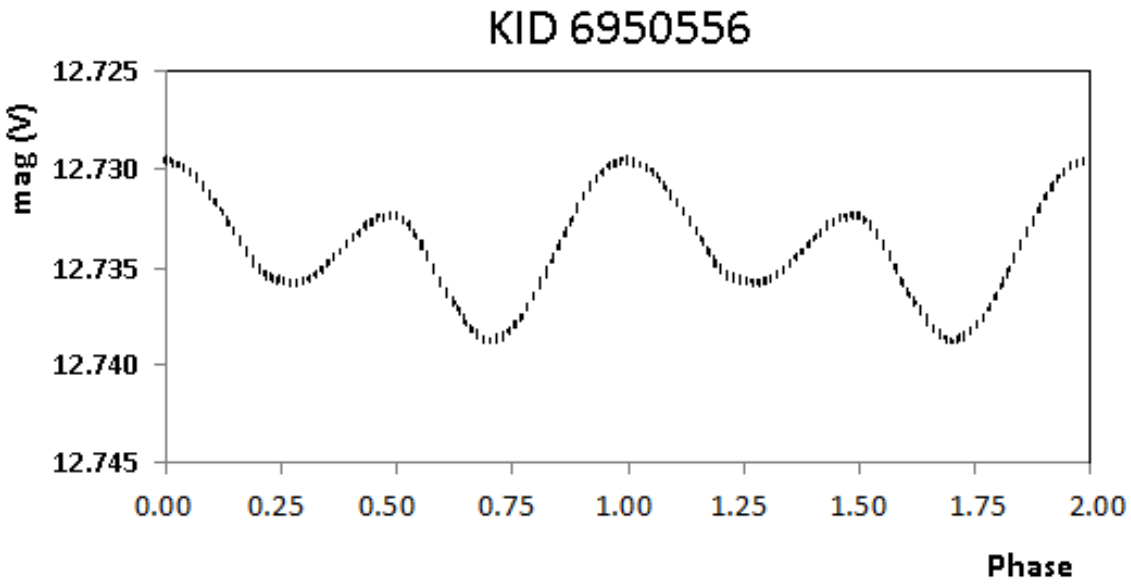


Kepler: 52 new

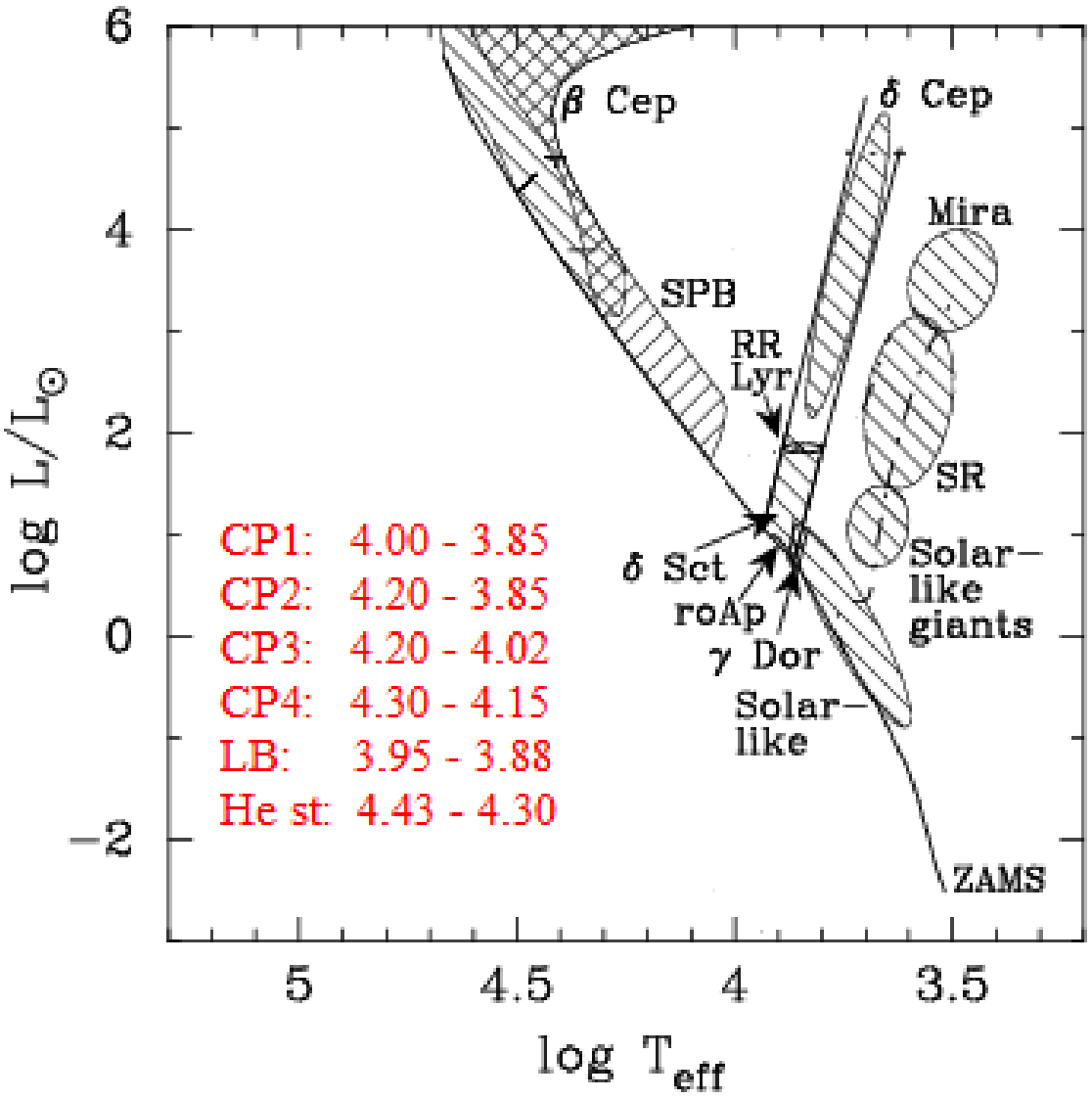
- unpublished

New ACV variables





Pulsating CP stars?

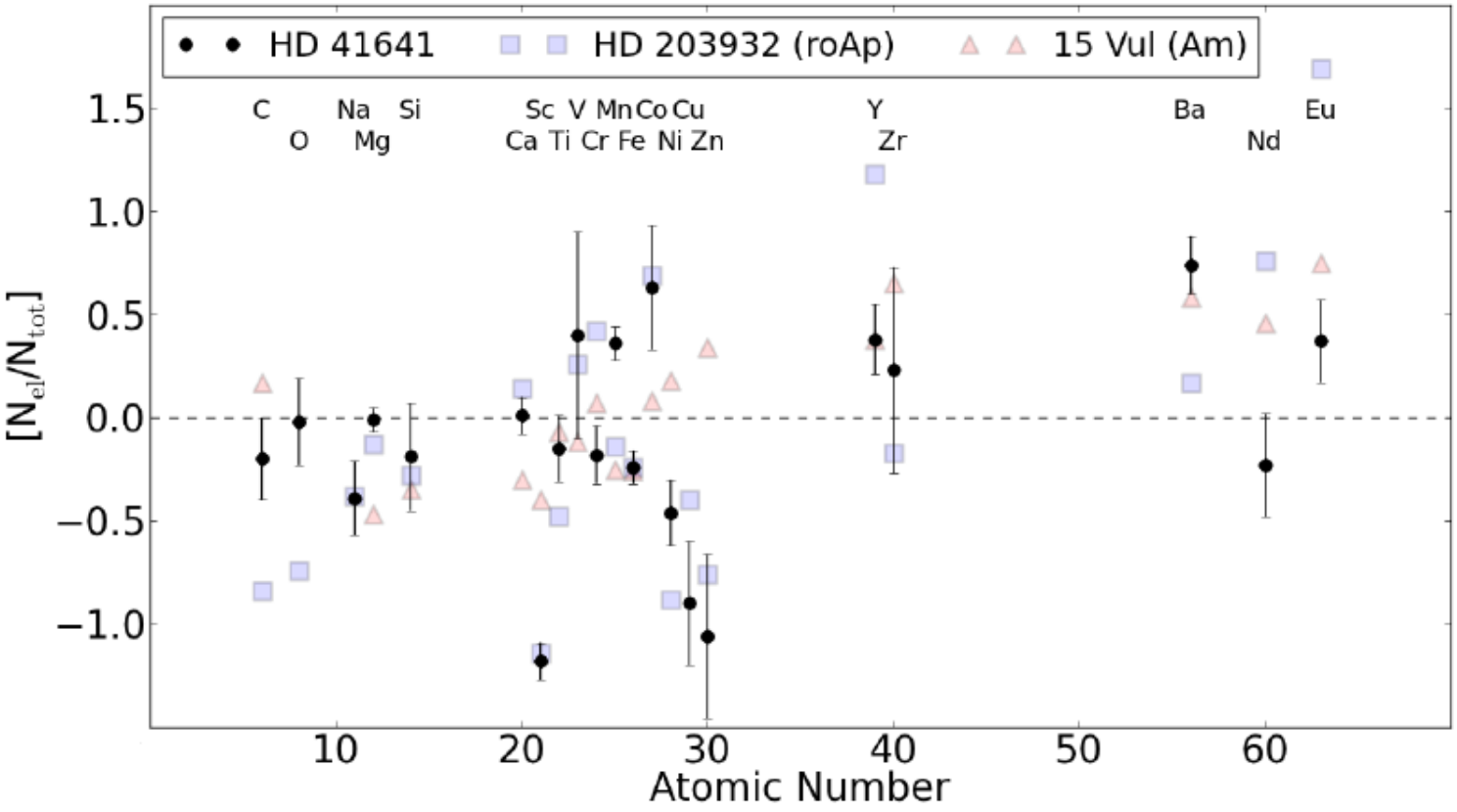


Pulsating CP stars?

- Rapidly oscillating Ap (roAp) stars
  - only 50 known although large surveys (Joshi et al., 2016, A&A, 590, A116)
  - Periods below 25 minutes, small amplitudes (< 10 mmag)
- CP1 (Am) stars
  - Know to show δ Sct and γ Dor pulsations (Smalley et al., 2011, A&A, 535, A3)
  - Only low percentage
- No other pulsating CP stars known
- δ Scuti stars with magnetic fields?

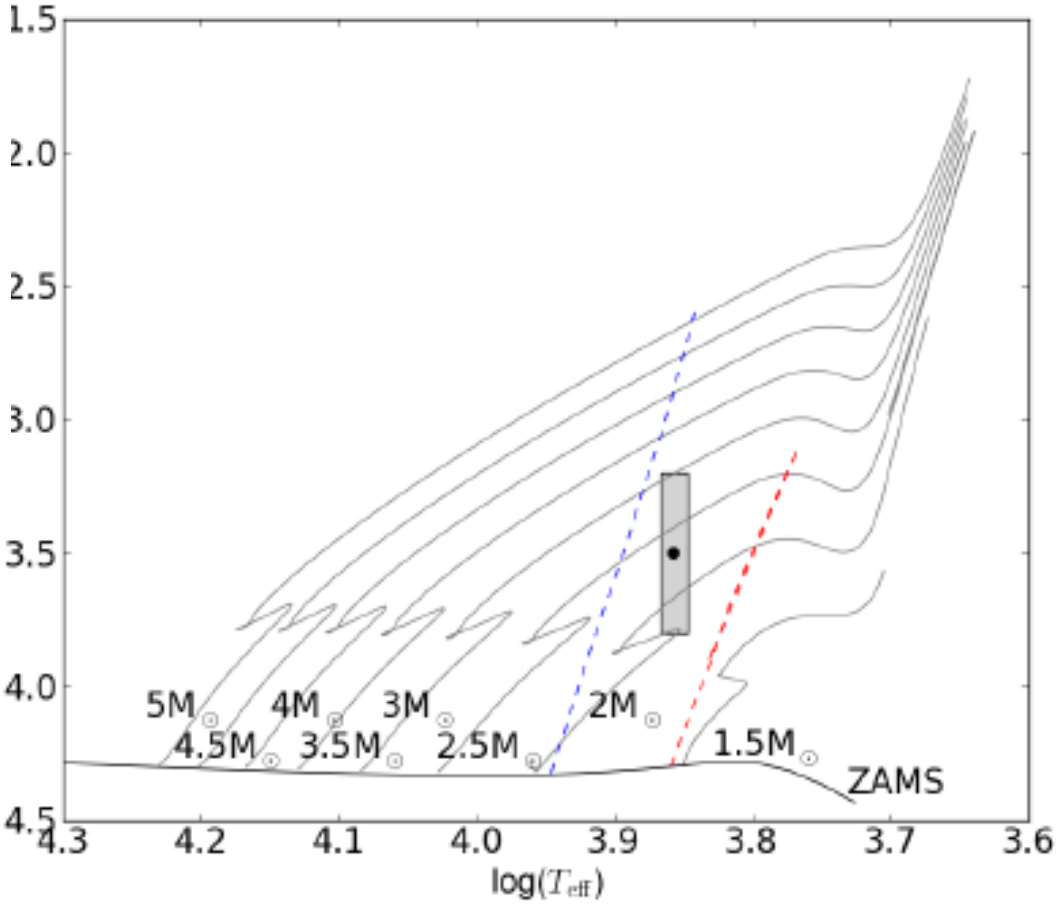
Pulsating CP stars?

Escorza et al. (2016, A&A, 588, A71): "HD 41641: A classical δ Sct-type pulsator with chemical signatures of an Ap star"



Pulsating CP stars?

RV	29.3 ± 0.3 km s^{-1}
$T_{\rm eff}$	7200 ± 80 K
$\log g$	3.5 ± 0.3 dex
$v \sin i$	30 ± 2 km s^{-1}
$[M/H]$	-0.19 ± 0.08 dex
ξ	1.1 ± 0.3 km s^{-1}
M_*	$2.3^{+0.7}_{-0.5}\ M_\odot$
R_*	$4.5^{+2.7}_{-1.7}\ R_\odot$



Evolved star?

Pulsating CP stars?

- Neiner & Lampens (2015, MNRAS, 454, L86): "First discovery of a magnetic field in a main-sequence δ Scuti star: the Kepler star HD 188774"

Table 1. Spectropolarimetric measurements of HD 188774. The dates, heliocentric Julian dates corresponding to the middle epoch of the measurements, and exposure times are given. The computed longitudinal field B_l and N values, with their respective error bars σ and significance level z are also shown, as well as the field detection probability in per cent and in terms of type of detection.

Date	Mid-HJD −2450000	T_{exp} (s)	$B_l \pm \sigma_B$ (G)	z_B	$N \pm \sigma_N$ (G)	z_N	Prob. (per cent)	Detect.
2014 Sep 7	2456907.951	4×840	23.2 ± 17.1	1.4	6.9 ± 17.1	0.4	99.999	Definite
2015 Jul 23	2457227.027	10×4×129	75.8 ± 13.0	5.8	7.6 ± 12.9	0.6	100	Definite

Pulsating CP stars?

Table 1. Fundamental parameters and the 1-σ formal errors as derived from the mean spectrum.

[M/H]	$T_{\rm eff}$ (K)	$\log g$	$v \sin i$ (km s^{-1})	ξ (km s^{-1})	SpT
		this work			
–0.30 (0.05)	7600 (30)	3.39 (0.12)	52.0 (1.5)	3.16 (0.20)	A7.5 IV-III
		KIC			
–0.54 (0.50)	7451 (200)	3.54 (0.50)	–	–	A8 IV-III
		Catanzaro et al. (2011)			
–	7400 (150)	3.7 (0.3)	–	–	–

RV	29.3 ± 0.3 km s^{-1}
$T_{\rm eff}$	7200 ± 80 K
$\log g$	3.5 ± 0.3 dex
$v \sin i$	30 ± 2 km s^{-1}
$[M/H]$	-0.19 ± 0.08 dex
ξ	1.1 ± 0.3 km s^{-1}
M_*	$2.3^{+0.7}_{-0.5}\ M_\odot$
R_*	$4.5^{+2.7}_{-1.7}\ R_\odot$

HD 188774 (Lampens et al., 2013, A&A, 549, A104) HD 41641

Not hydrogen burning

Pulsating CP stars?

- Hubrig & Schöller (2016, IBVS, 6174): "Confirmation of the magnetic nature of the δ Scuti star HD 21190"
- Result: Bz = −254 ± 59G
- "The confirmation of the presence of a magnetic field in HD 21190 shows that δ Scuti pulsations can indeed exist in stars with a magnetic field."
- General properties from the literature
  - F2 III SrEuSi
  - 7000K, 3.5 dex

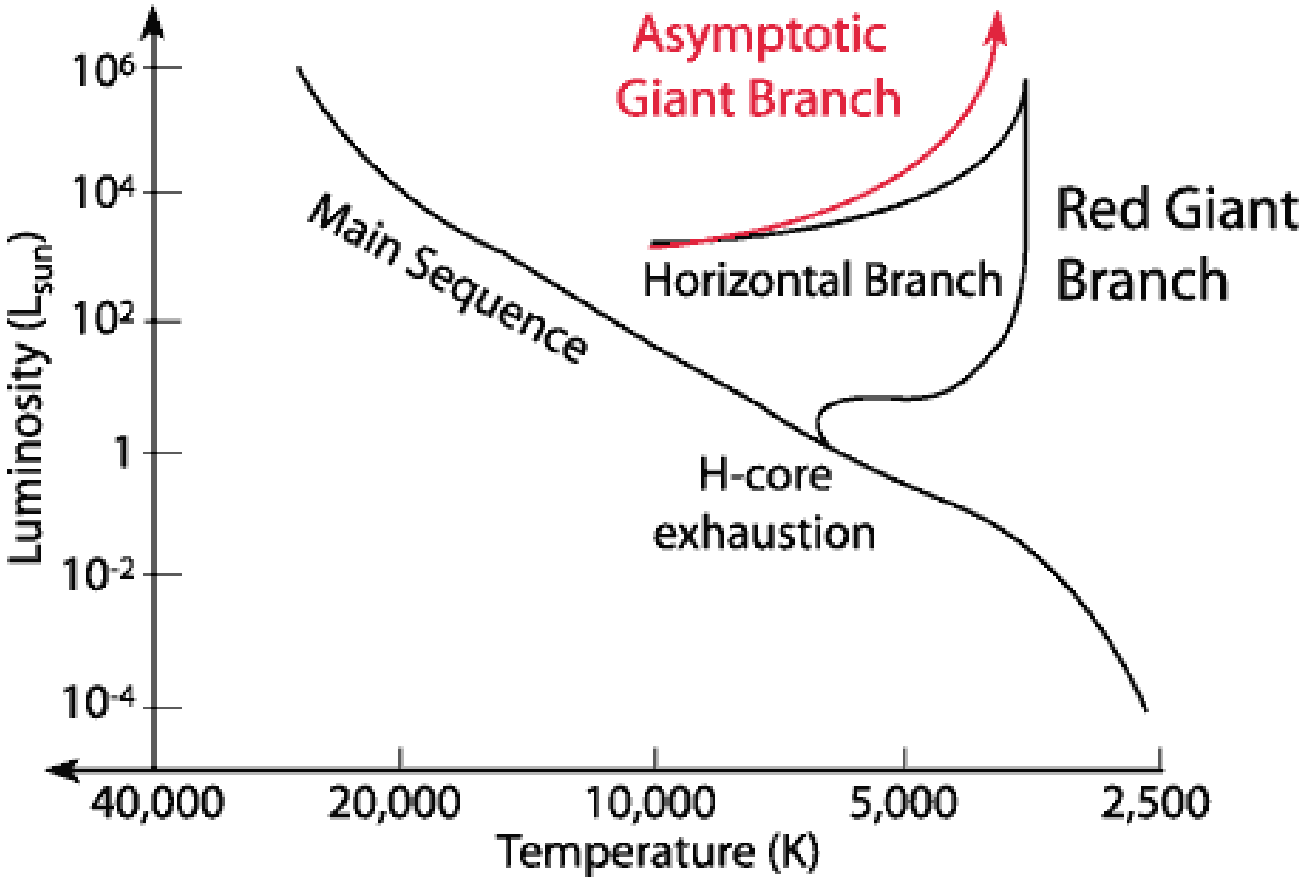
Pulsating CP stars?

- Summary:

1. HD 21190, HD 41641, and HD 188774 seem to be no classical CP2 stars
2. Still no classical pulsating CP2/4 star known so far

- During our survey we found twelve good candidates
- Spectroscopy as confirmation done here

Blue Horizontal Branch (BHB)



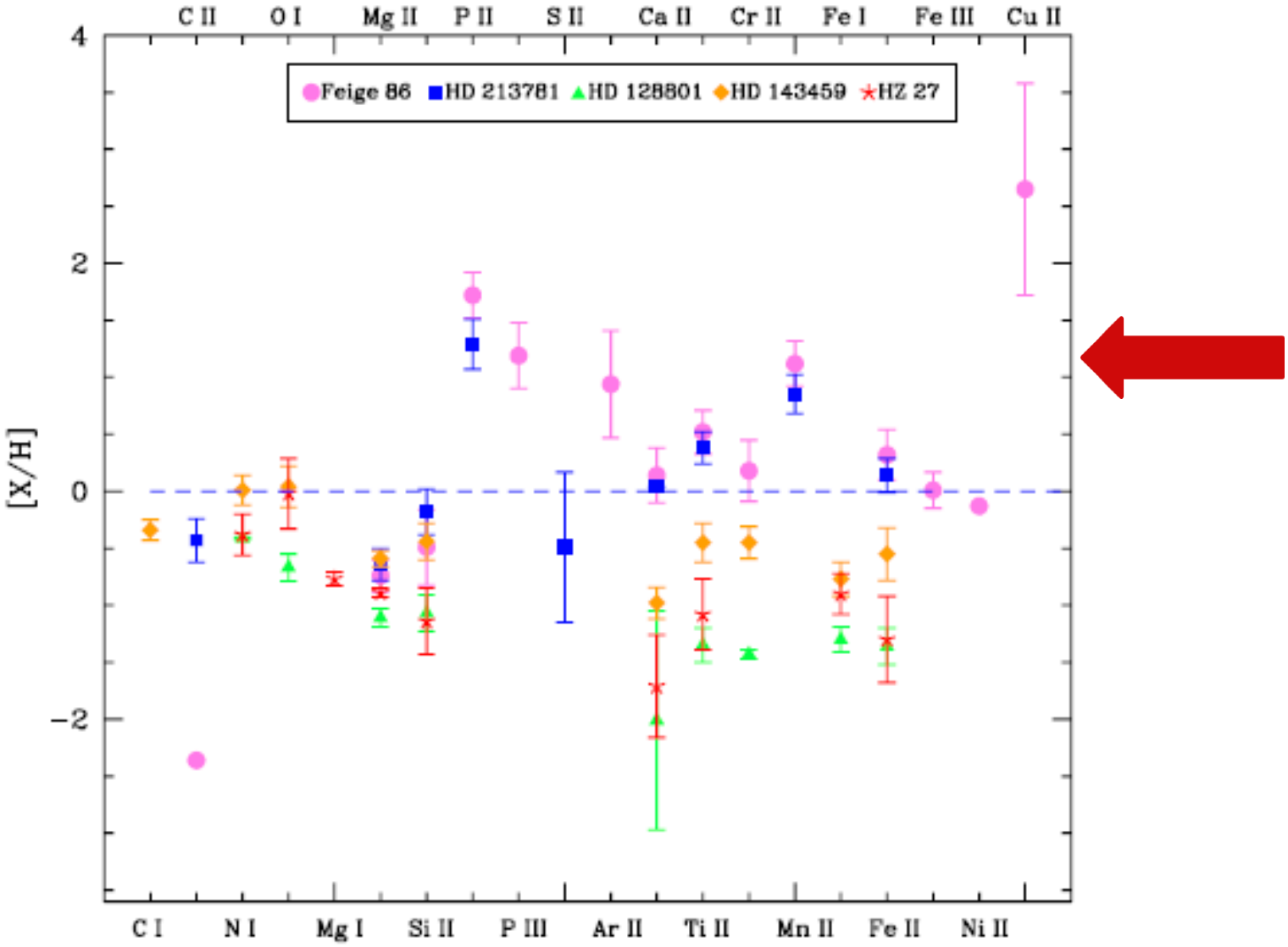
Am – Fm (CP1): 10 000 – 7 000K

Bp – Ap (CP2): 16 000 – 7 000K

Blue Horizontal Branch

- Overview: Moehler et al. (2014, A&A, 565, A100)
- Same Teff range as classical CPs
- Slow rotation (< 50 km s^{-1})
- Diffusion in atmospheres
- Stratification
- No strong magnetic fields
- Abundance peculiarites
- Spots and variability?

Blue Horizontal Branch



Kafando et al., 2016, MNRAS, 459, 871

BHB – What needs to be done?

- Galactic Field and Globular Clusters

1. Compile catalogue of stars (Santucci et al., 2015, ApJ, 801, 116)
2. Try the estimate stellar parameters
3. Search for photometric time series in archives
4. Search for ACV like variability
5. Get additional spectroscopy