

# Stellar surveys

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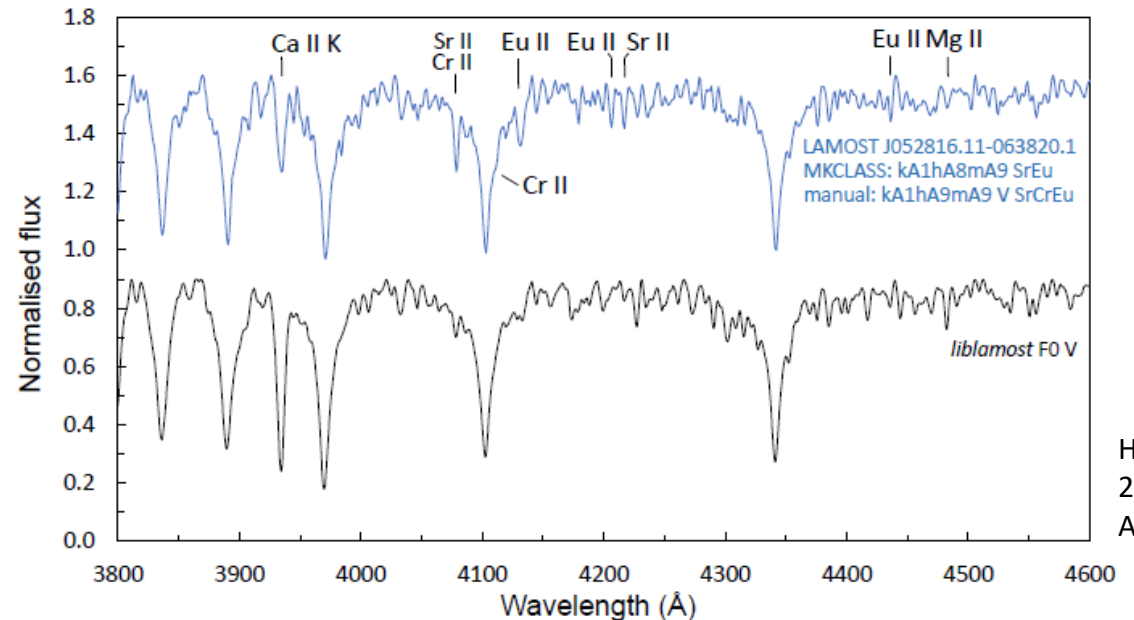
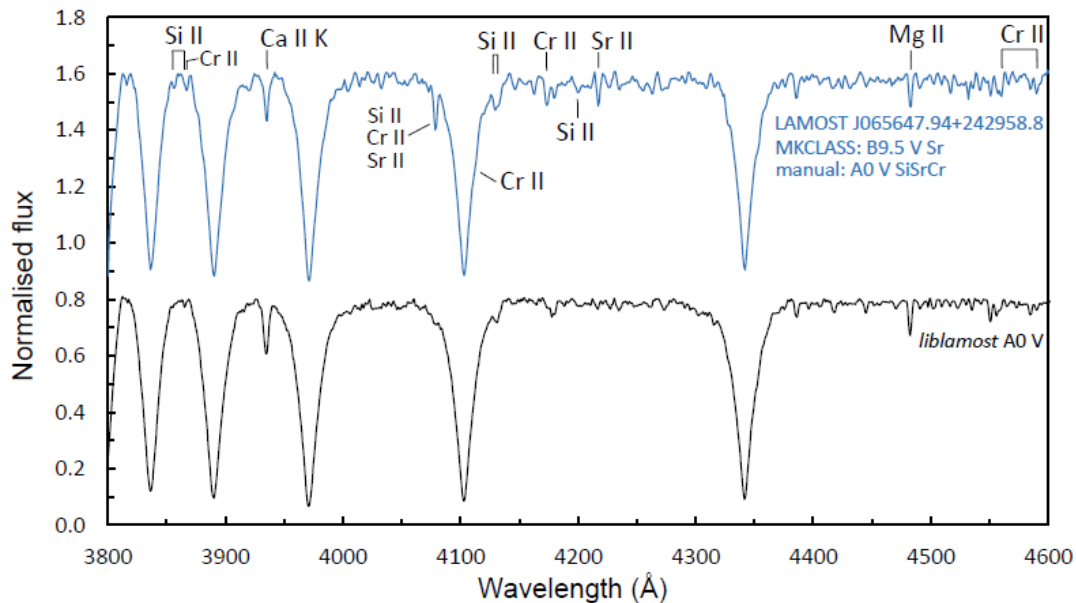


# Overview

- Spectroscopic search for new chemically peculiar (CP) stars
  - LAMOST survey
  - 5200 Å flux depression
  - MKCLASS
  - Adopted versions of MKCLASS to search for CP stars
  - Some results
- Photometric search for new  $\alpha^2$  Canum Venaticorum (ACV) variables
  - Ground-based photometric surveys
  - Light curves of ACV variables
  - Search for variables in photometric surveys
  - Automatic search for ACV variables

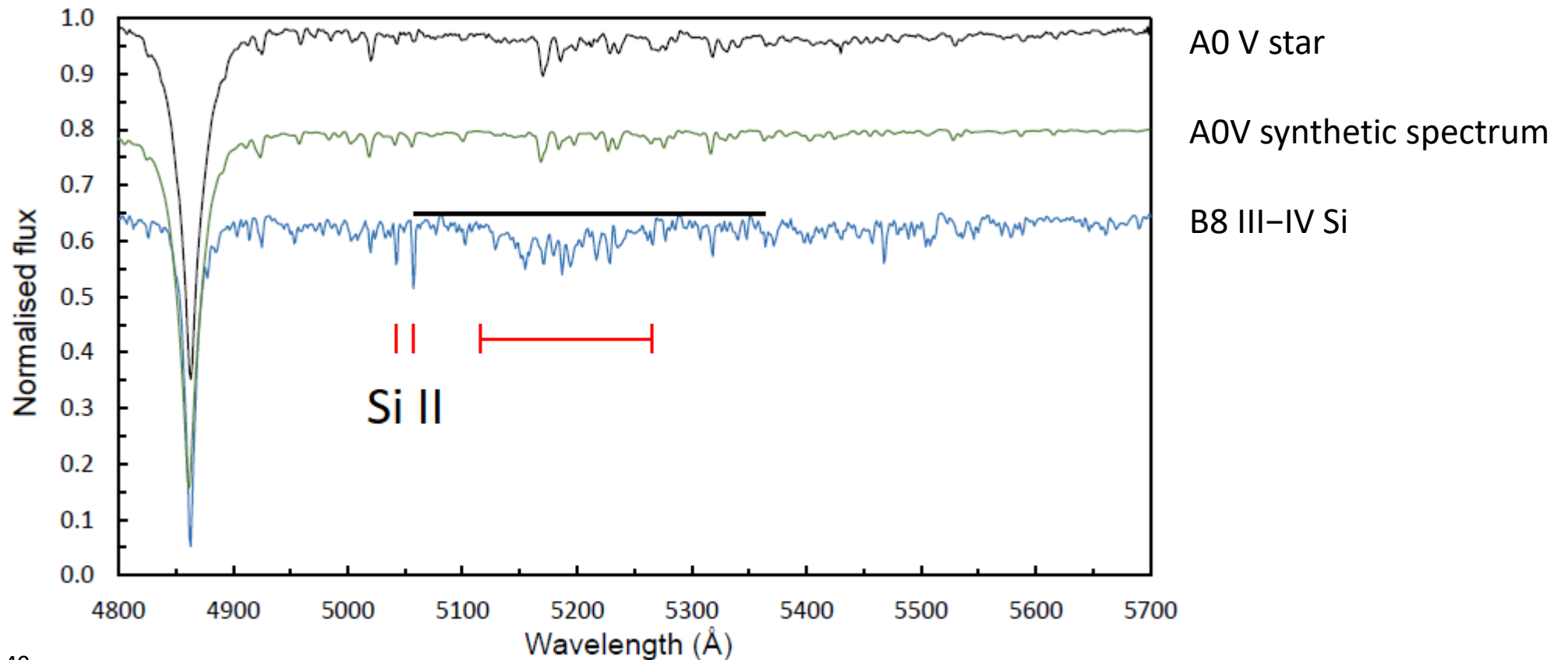
# LAMOST survey

- Xinglong Observatory in Beijing, China
- Effective aperture of 3.6 – 4.9m
- Field of view of  $5^\circ$
- $R \sim 1800$ , 3700 to 9000 Å,  $r$  up to 19 mag
- DR8: about 10 000 000 stars



# The 5200Å flux depression

- The 5200Å flux depression is well suited to find magnetic CP stars, as has been proven using  $\Delta a$  photometry (Paunzen et al., 2005, A&A, 441, 631)



# MKCLASS

- Gray et al., 2016, AJ, 151, 13: *LAMOST Observations in the Kepler Field: Spectral Classification with the MKCLASS Code*
- <http://www.appstate.edu/~grayro/mkclass/>
- Automatic command line tool for Linux and Windows
- Standard spectral libraries included but can also be added
- Normalization not necessary
- Code can be easily adapted

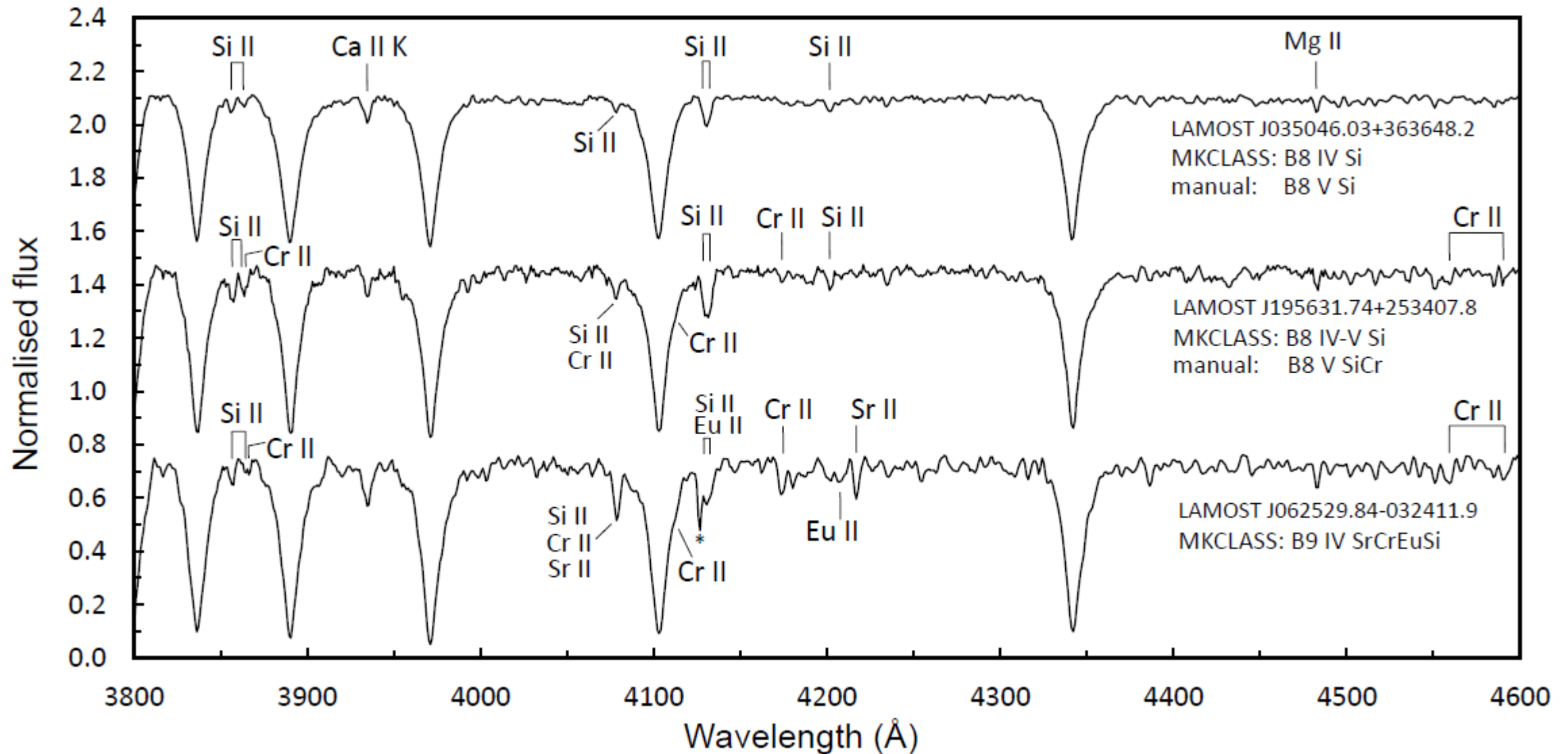
# Adapted version of MKCLASS

- MKCLASS was adapted and tested with known CP stars
- The new versions trace the following lines beside the standard ones like Ca K, Mg II or Fe:
  - Blends at 4077 (Si/Cr/Sr) and 4130 (Si/Eu) Å
  - Cr: 3866 and 4172 Å
  - Eu: 4205 Å
  - He: 4009, 4026, 4144, and 4387 Å
  - Hg: 3984 Å
  - Mn: 4136, 4206, and 4259 Å
  - Si: 3856, 4200, 5041, 5056, 6347, and 6371 Å
  - Sr: 4216 Å

# Adopted versions of MKCLASS - results

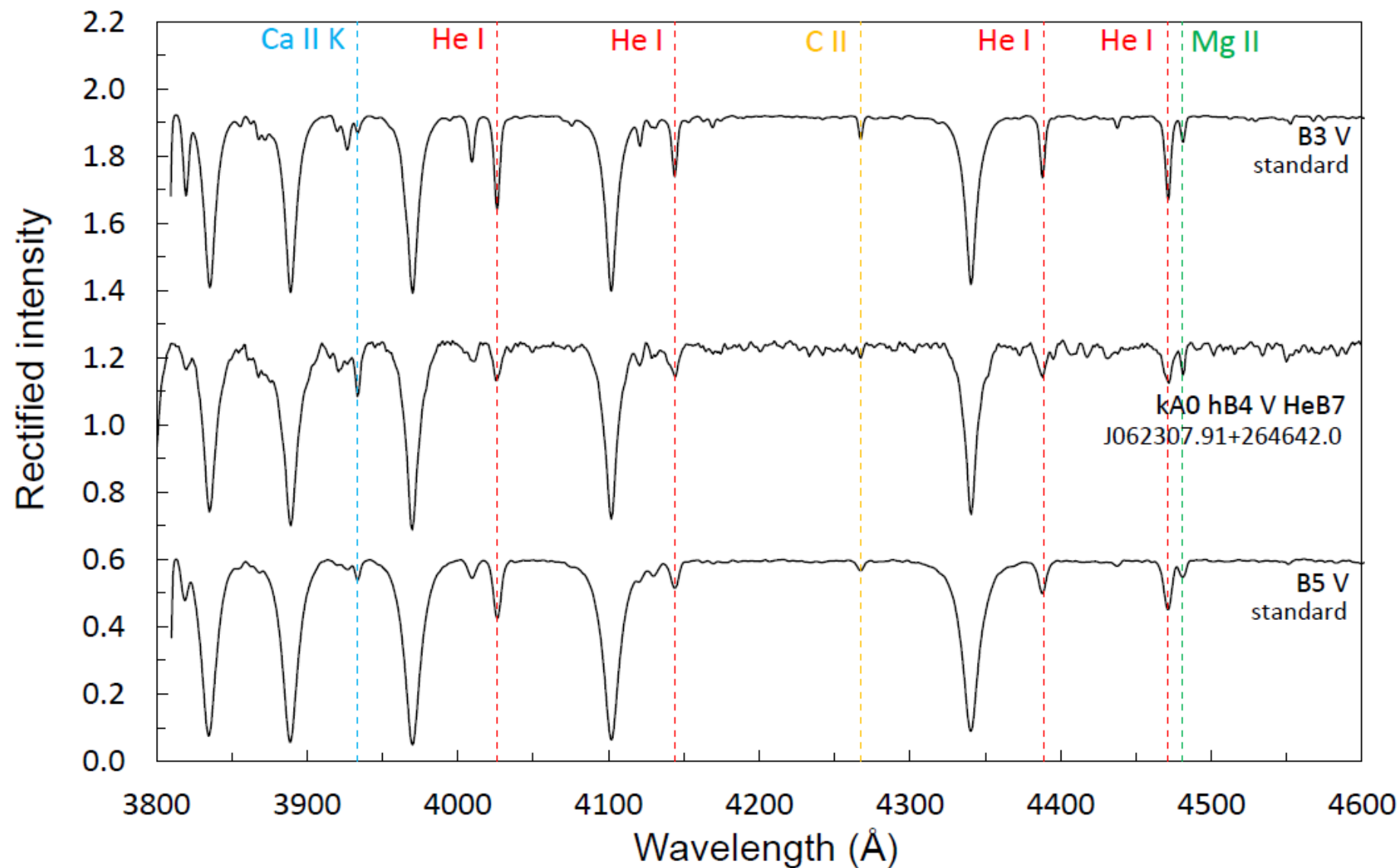
- Paunzen et al, 2021, A&A, 645, A34: *New mercury-manganese stars and candidates from LAMOST DR4*
- Hümmerich et al., 2020, A&A, 640, A40: *A plethora of new, magnetic chemically peculiar stars from LAMOST DR4*
- Search for magnetic CP (CP2/4) and HgMn (CP3) stars

# Adopted versions of MKCLASS - results

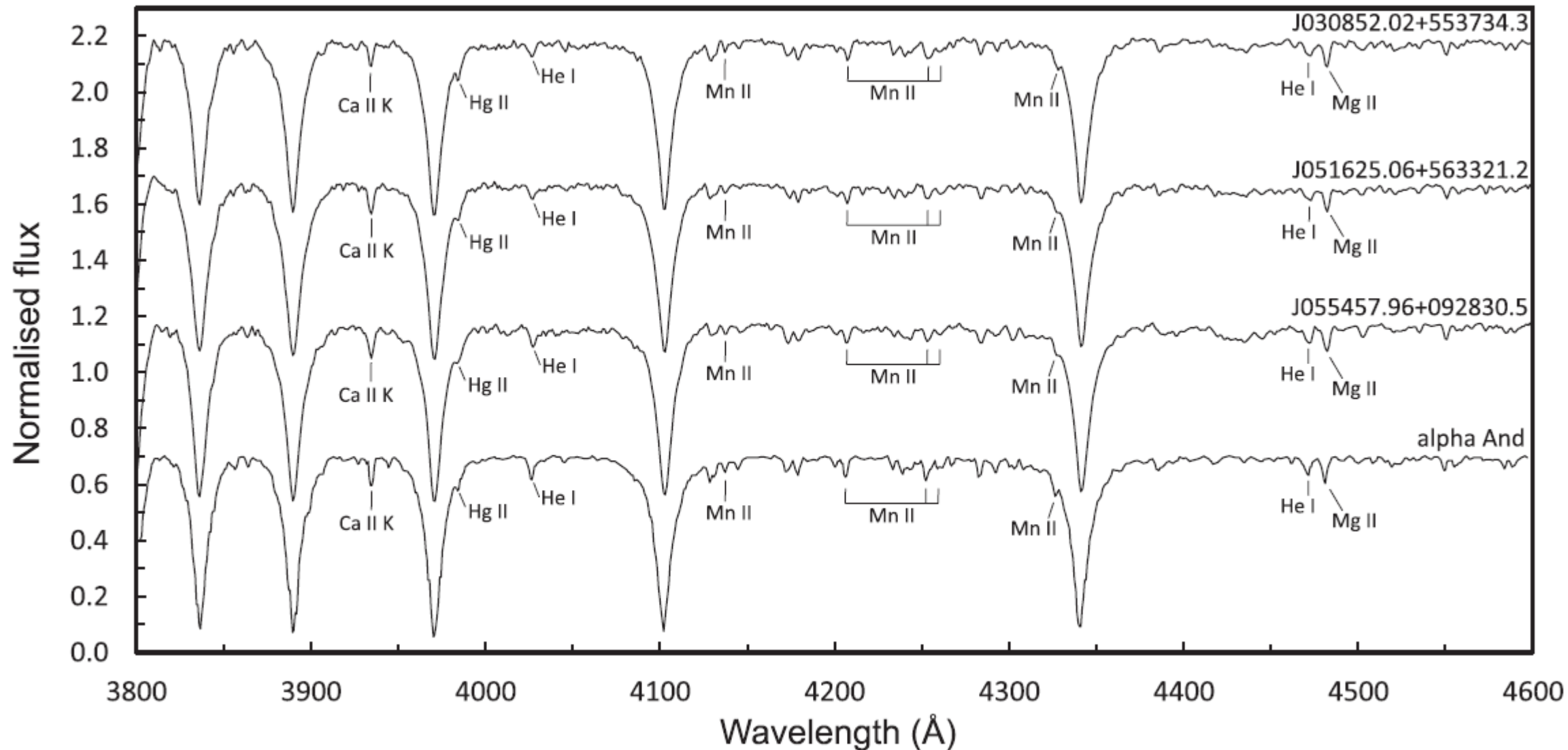




# Adopted versions of MKCLASS - results



# Adopted versions of MKCLASS - results



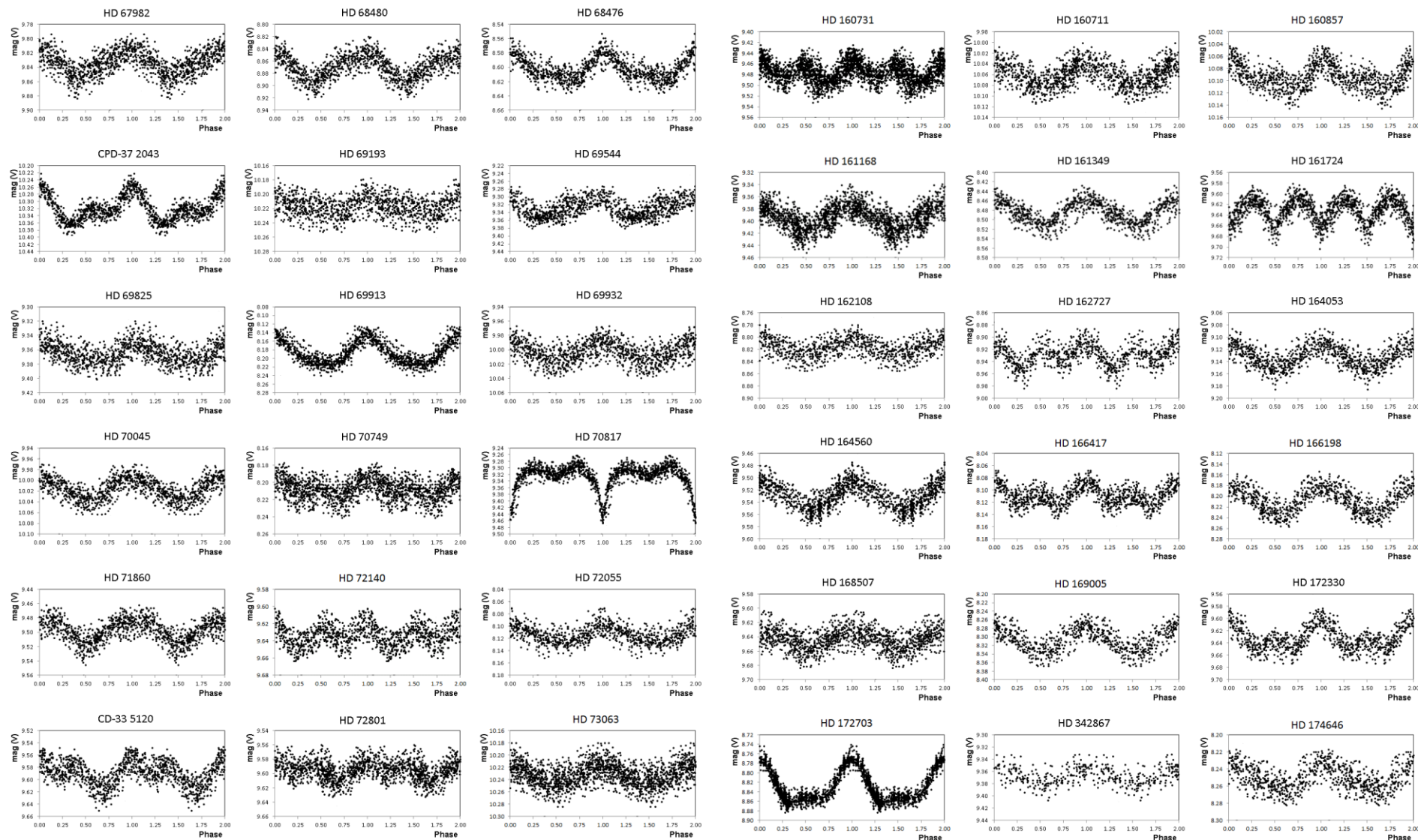
# BAF variables

- The following variables can be found in the region of the magnetic CP stars:
  - $\alpha^2$  Canum Venaticorum (ACV)
  - rapidly oscillation Ap stars
  - $\gamma$  Doradus
  - $\delta$  Scuti
  - $\beta$  Cepheids
  - Slowly Pulsating B-type stars
  - Binaries

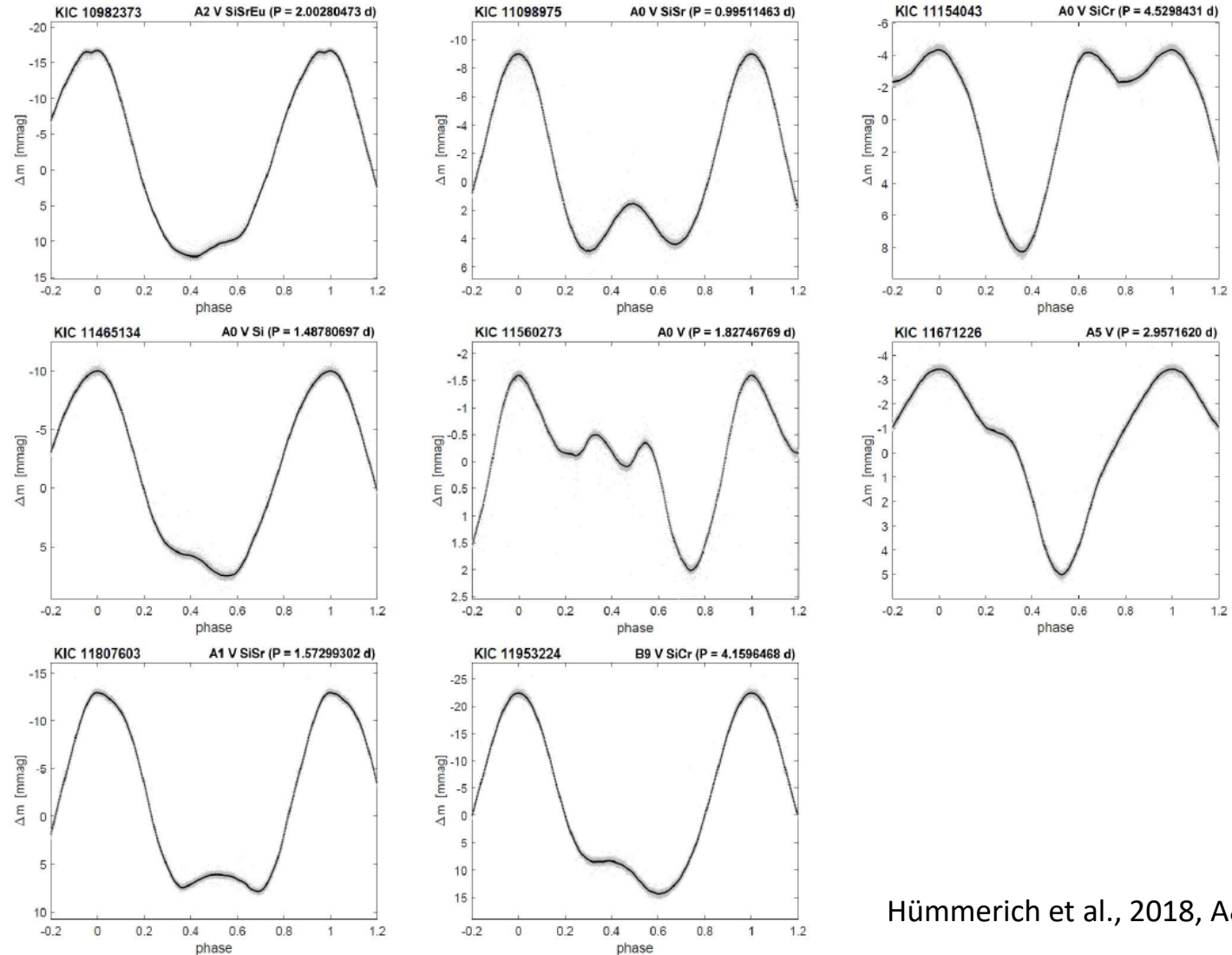
# Some useful ground based photometric surveys

- The All Sky Automated Survey (ASAS)
- All-Sky Automated Survey for Supernovae (ASAS-SN)
- Asteroid Terrestrial-impact Last Alert System (ATLAS)
- The Kilodegree Extremely Little Telescope (KELT)
- The Multi-site All-Sky CAmERA (MASCARA)
- Super-Wide Angle Search for Planets (SuperWASP)
- The Zwicky Transient Facility (ZTF)
- Widely different time coverages, time bases, integration times, and limiting magnitudes

# ACV variables – ASAS-3



# ACV variables – Kepler



# Search for variables in available data sets

- Several methods and algorithms are available.
- Van Roestel et al., 2021, AJ, 161, 267: *The ZTF Source Classification Project: I. Methods and Infrastructure*
- Bass & Borne, 2016, MNRAS, 459, 3721: *Supervised ensemble classification of Kepler variable stars*
- Kügler et al., 2015, MNRAS, 451, 3385: *Featureless classification of light curves*
- Blomme et al., 2010, ApJ, 713, L204: *Automated Classification of Variable Stars in the Asteroseismology Program of the Kepler Space Mission*
- *None of them includes the class of ACV variables.*



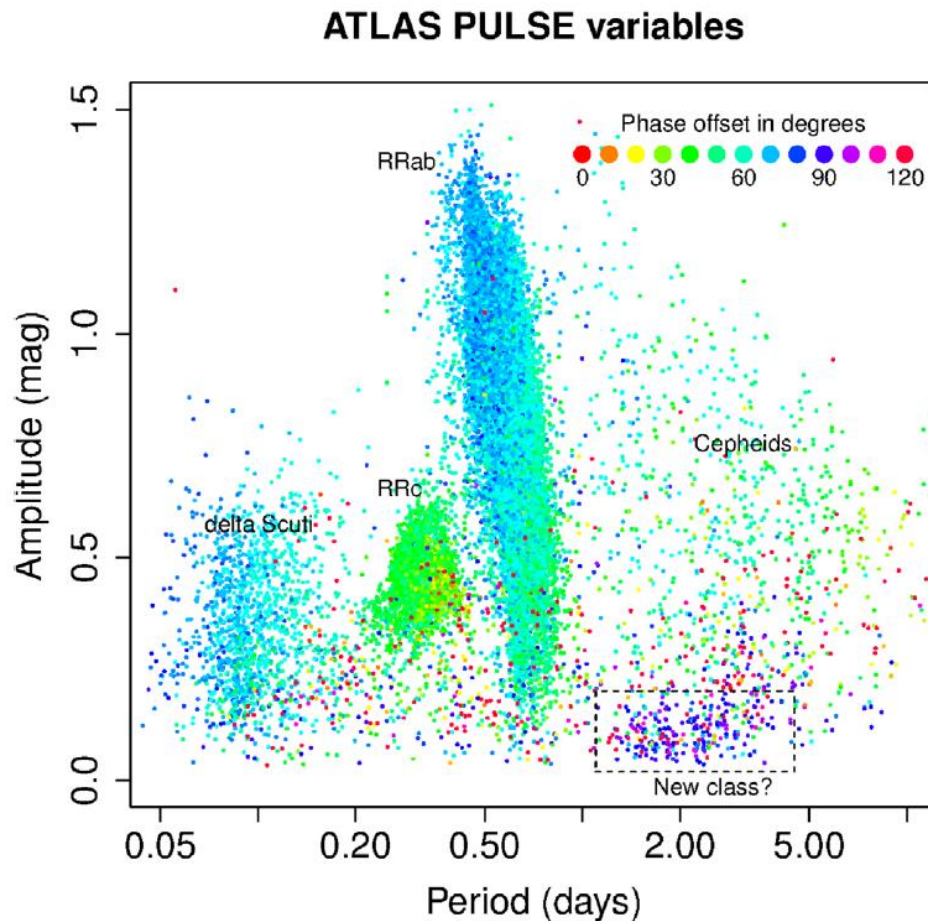
# The mystery of a new variable class

- Heinze et al., 2018, AJ, 156, 241: *A First Catalog of Variable Stars Measured by the Asteroid Terrestrial-impact Last Alert System (ATLAS)*

## 7. Interesting and Mysterious Subtypes

### 7.1. “Upside-down CBH” Variables

These objects correspond to the possible new class of variables labeled in Figure 23. We first noticed them long before constructing the figure, when we were screening light curves manually in order to construct the training set for machine learning. A distinctive light-curve shape, not matching any known type of variable, was seen repeatedly in the course of our screening. When we made Figure 23, we were able to confirm the connection between the unusual light curves and the unusual cluster of points. As implied by their location in that figure, these stars exhibit low-amplitude variations with periods ranging from about 1 to 5 days—and consistent with the clustering of their phase offsets near  $90^\circ$ , they have narrow, symmetrical maxima very similar to the minima of CBH eclipsing binaries. Figure 30 shows four of the most representative light curves. In the course of by-hand screening, we have identified a total of about 70 such objects, but there are probably many more in our catalog.

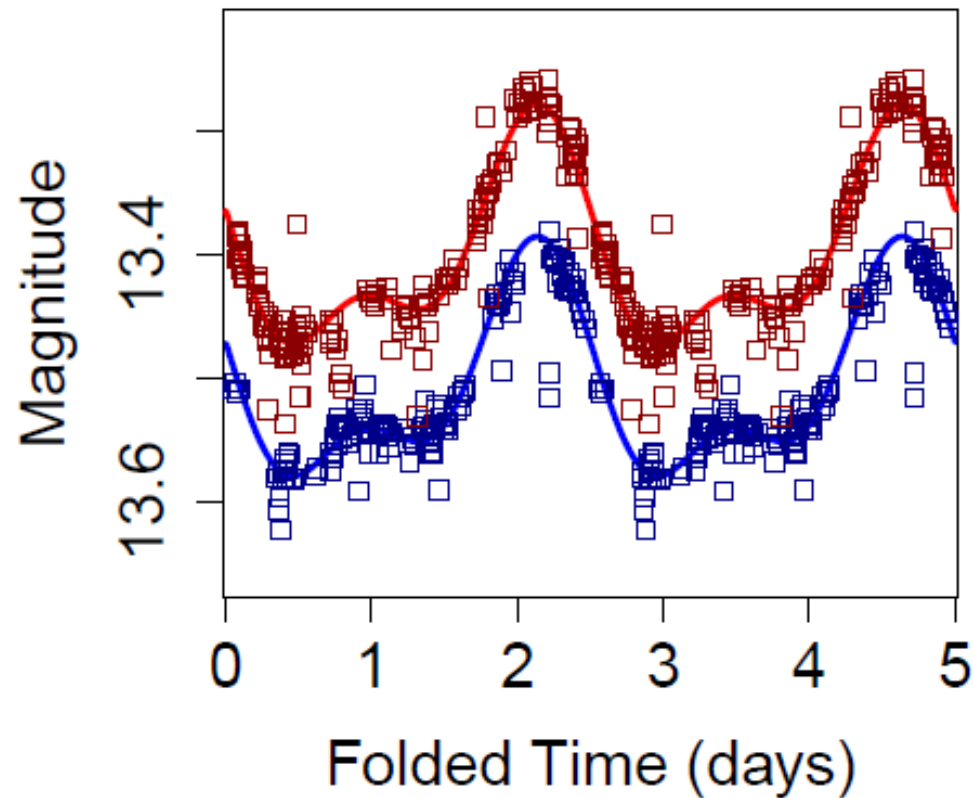




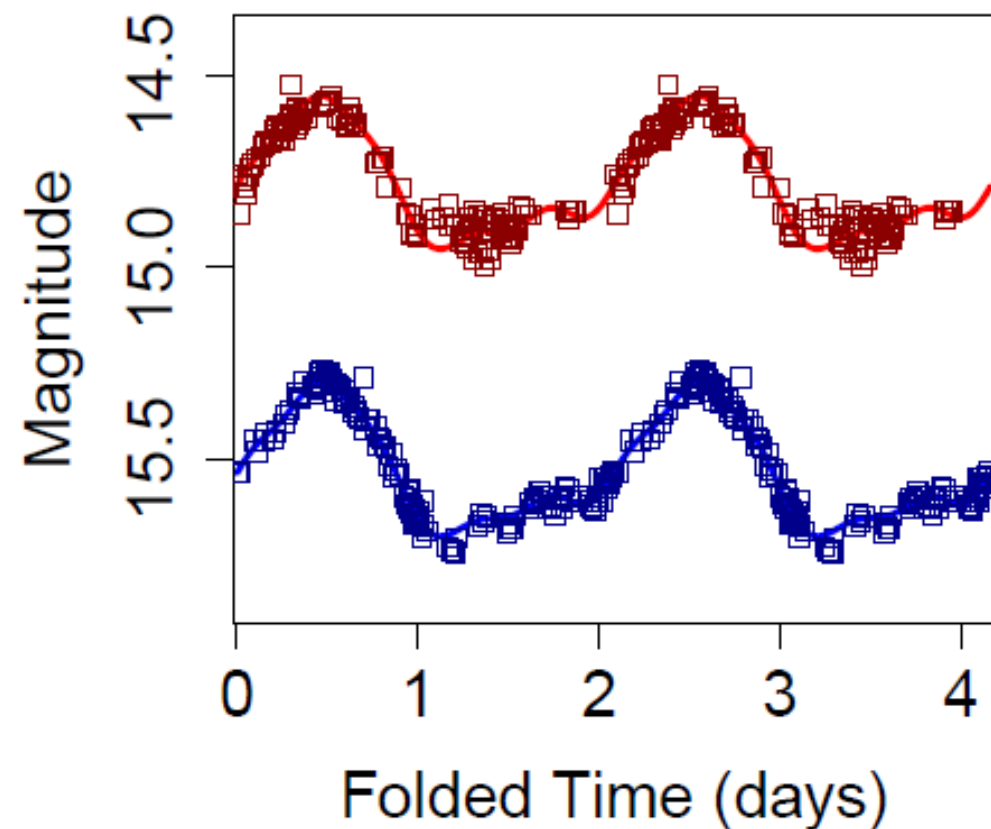
# The mystery of a new variable class

- These are classical ACV variables

**ATO J097.8891-02.7981**



**ATO J083.1858+21.5801**

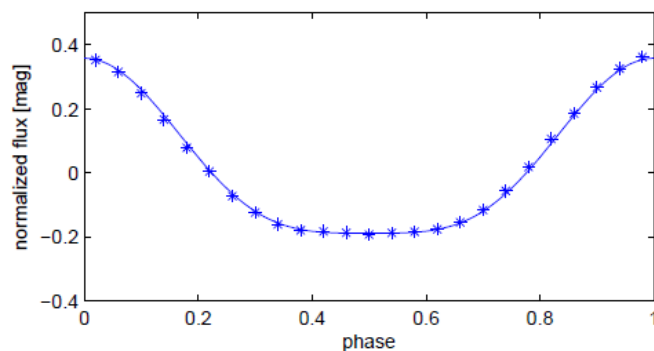


# Automatic search for ACV variables

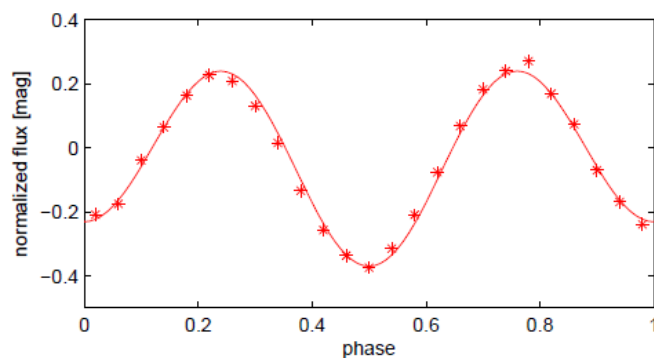
- What do we know?
  1. Strictly mono-periodic
  2. The period does not change over thousands of cycles.
  3. Light curve shape can be confused with ellipsoid variables.
- How to search?
  1. Take already known CP stars
  2. Search through all light curves of BAF stars selected, for example, on the basis of Gaia data
- Jagelka et al., 2019, A&A, 622, A199: *Global properties of the light curves of magnetic, chemically peculiar stars as a testbed for the existence of dipole-like symmetry in surface structures*
- Light-curve morphology divide into representative classes described using a principal component analysis (PCA)

# Automatic search for ACV variables

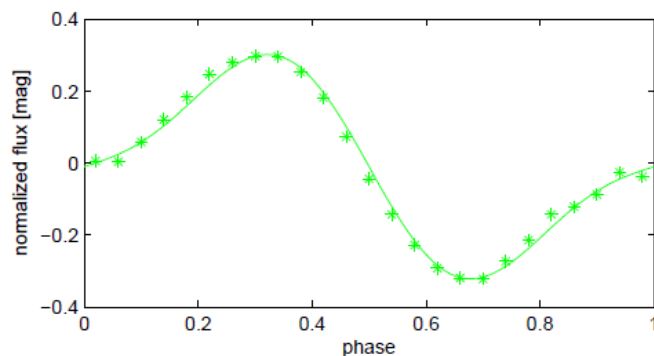
First three PCA components



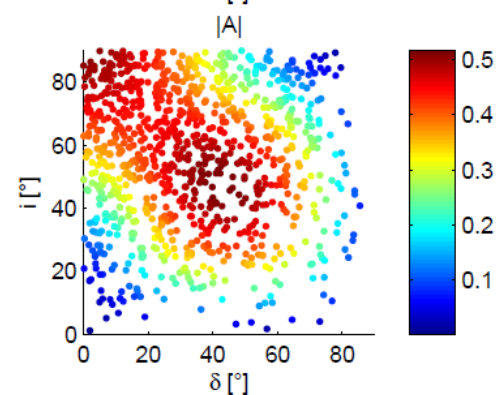
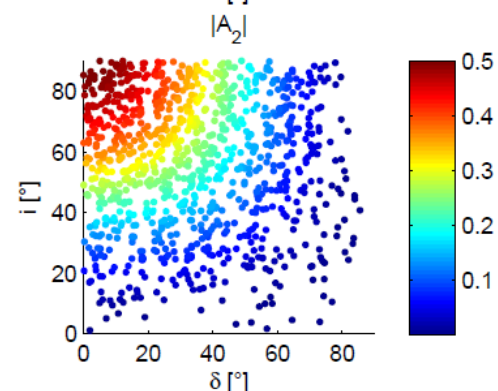
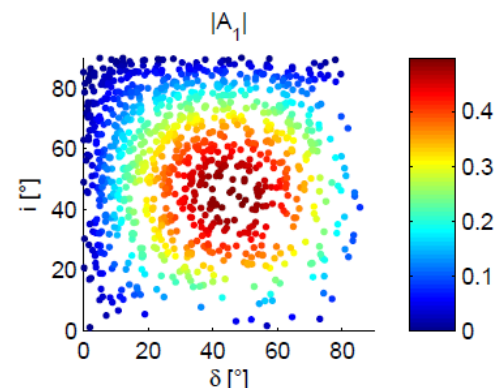
single-wave light curve



double-wave light curve



antisymmetric light curve



Dependence of the PCA components on the inclination of the rotation axis  $i$  and the declination of the spots  $\delta$ .