Spectrophotometric analysis of the 5200Å region for peculiar and normal stars

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ABSTRACT

Context. Many chemically peculiar (CP) stars, especially the magnetic CP2 stars, show a flux depression at 5200Å. The Δα photometric system takes advantage of this characteristic to detect these objects in an efficient way. In addition, it is capable of finding metal-weak, emission-type, and shell-type objects of the upper main sequence.

Aims. To compare available observations and to detect new peculiar objects, we used a spectrophotometric catalogue consisting of 1159 stars. From this catalogue, we selected 1067 objects to synthesize three different a indices to find the most efficient one for further observations. In addition, we extended the analysis to stars cooler than F5.

Methods. We employed classical Δα photometry described by Maitzen, using simulated filter curves, the spectrophotometric Δα index by Adelman, and a modified index.

Results. Even though the accuracy of the spectrophotometry used for this investigation is significantly lower than the photometric Δα measurements, we are able to confirm peculiarity for most of the known CP2 stars above a certain limit of Δα. We investigated 631 stars hotter than spectral type F5 to find additional that are not yet identified peculiar objects. We find that for very low mass stars (M0), the a index is independent of the colour (effective temperature).

Conclusions. The Δα photometric system is very closely correlated with the effective temperature over a wide range of the main sequence. It is able to detect any kind of peculiarity connected to the 5200Å region. Especially for low-mass stars, this opens up a new possibility of detecting peculiar objects in an efficient way.

Key words. Stars: chemically peculiar – early-type – techniques: photometric

1. Introduction

Chemically peculiar (CP hereafter) stars of the upper main sequence differ in their abundances of heavy and rare-earth elements in their photosphere from normal-type objects of the same effective temperature and luminosity range. Preston (1974) divided this group into four subgroups according to their astrophysical characteristics. Since then several investigations about their local environment and stellar parameters were performed. Babcock (1943) discovered a global dipolar magnetic field in the star 78 Virginis, which was soon followed by the detection of several other similar stars. Therefore the correlation of stellar magnetic field strengths with astrophysical processes such as diffusion and meridional circulation can be very well studied in this stellar group (Glagolevskij 2013). Another important often studied aspect is the cause of the peculiar (surface) abundances. The observed phenomenon can be explained by either classical diffusion of chemical elements depending on the balance between gravitational pull and uplift by the radiation field through absorption in spectral lines (Stift & Alecian 2012) or selective accretion from the interstellar medium via the stellar magnetic field (Havnes & Conti 1971). While diffusion seems to be appropriate for both magnetic and non-magnetic stars to explain spectral peculiarity, it is not yet clear to which extent the interaction with the interstellar medium via accretion and transport of angular momentum may modify the effects of diffusion and break the stellar rotational velocities during the stars' main sequence life time.

Using spectrophotometry, Kodaira (1969) was the first to notice broad-band flux depressions at 4100, 5200 and 6300Å during his investigation of the magnetic CP (CP2) star HD 221568. Photometrically, the main depressions (4100 and 5200Å) of another CP2 star were later also found by Maitzen & Moffat (1972) when they investigated the spectrum-variable HD 125248. This resulted in the development of the Δα photometric system (Maitzen 1976), which makes use of the most efficient depression at 5200Å. The flux depression itself is a combined contribution of Si, Cr and Fe for strongly overabundant surface metallicities (Khan & Shulyak 2007). The upper main sequence is unique for CP stars. No detailed observational analysis of this region for cooler objects has been performed so far.

In this paper, we present a study that was conducted to detect CP stars on the basis of spectrophotometric data for which we employed three different methods that use the flux depression at 5200Å. In addition to the original method, the a' system developed by Adelman (1979) and a newly modified method were investigated. Furthermore, we investigated the capability of these systems of finding new, previously undetected, peculiar objects including metal-weak and emission-type objects of the upper main sequence. For the first time, the low-mass regime was searched for the behaviour of the a indices in correlation with the effective temperature and luminosity.
2. Data and reduction

Our source of spectrophotometric data is the stellar catalogue by Kharitonov et al. (1988). It contains data for 1159 bright stars of different spectral classes in the wavelength range from 3200 to 7600 Å, with a spectral resolution of 50 Å. Each star was observed at least three times, on different nights. The root mean square (rms hereafter) relative error of the measurements is between 2% and 4% per 50 Å bandpass. Stars with only two-digit measurements in the wavelength region around 5200 Å were not considered in the analysis because of the statistical inaccuracy of these measurements. We also excluded early-type supergiants because of their strong photometric and spectroscopic variability. The remaining data of 1067 stars were used to synthesized different peculiarity indices. The methods used to detect CP stars are designed to have magnitudes as input. Therefore the intensity and flux values given in the catalogue were converted into magnitudes.

We are aware that there are more extensive corresponding catalogues with higher resolutions available in the literature, for example the one by Burnashev (1985). We note that this author also used at that time unpublished data by Kharitonov et al. (1988), but interpolated the data to a resolution of 25 Å. However, the catalogue we used is the basis of a list of spectrophotometric standards published by Glushneva et al. (1992). Therefore the quality of the data is beyond any doubt. In addition, the spectral resolution is similar to that used for the Gaia mission (Jordi et al. 2010).

Spectrophotometric observations of classical CP stars were published before, for example by Maitzen & Muthsam (1980) and Adelman et al. (1989). However, all these analyses concentrated either on individual stars or on the comparison with results from synthetic spectra. To our knowledge, no systematic analysis of spectrophotometric observations with respect to synthesizing Δa was conducted before.

The goal of this paper is not only to detect CP stars, but also to compare our findings with already existing Δa photometry and spectrophotometry. For this purpose, we employed three different systems.

The Δa photometric system by Maitzen (1976): this system compares the flux in the centre of the depression (filter g2, \( \lambda_c = 5220 \) Å) with the adjacent spectral regions (filters g1, 5000 Å and y, 5500 Å) using a band-width of 130 Å, which represents the continuum of the star. With these measurements the index \( a \) can be calculated as

\[
 a = g_2 - \frac{g_1 + y}{2}. \tag{1}
\]

In principle, the positioning of the continuum filters \( g_1 \) and \( y \) relative to \( g_2 \) minimizes the influence of temperature on the peculiarity index. However, due to slight wavelength mismatches
of the filters, a second-order dependence on temperature is apparent in addition to a general increase of opacity around 5200Å with decreasing temperature. Therefore, one has to normalize \( a \) with the index \( a_0 \) of a non-peculiar star of the same temperature (normality line), to compare different peculiar stars with each other. The photometric peculiarity index is therefore

\[
\Delta a = a - a_0. \tag{2}
\]

To do so, the corresponding filter curves had to be simulated. For simplicity, the three filters were represented by Gaussian curves with a FWHM of 130Å and a transmission maximum of 100% each. The fact that these simulated filters, in contrast to the original definition of \( g_1, g_2 \) and \( y \), all have the same transmission curves, probably does not significantly affect \( \Delta a \), because its value is always the difference between a peculiar star and the corresponding normal star with the same colour index. To convolve the Gaussian curves with the measurements of the spectrophotometric catalogue, transmission values of 50Å (bins) of the simulated filters were optimised with respect to a low variance of values for normal stars and secondly the highest possible values for peculiar stars. For this purpose, all stars hotter than F5 were selected to calculate \( a \), \( a_0 \), all have the same transmission error by a factor of \( \sqrt{2} \). This new index is referred to as \( \Delta a' \mod \) and is defined as

\[
a' \mod = m_{5264} - [m_{4785} + 0.453(m_{5840} - m_{4785})]. \tag{4}
\]

The calculation of the indices \( a \) and the \( a' \mod \) was straightforward. They were obtained by simply applying the values of the corresponding measurements to the formula.

As next step, the indices had to be corrected with the \( a, a' \), and \( a' \mod \) obtained from non-peculiar stars of the same temperature. For this purpose, all stars hotter than F5 were selected to calculate \( a_0, a'_0 \), and \( a' \mod \).

According to [Maitzen] (1976), the indices are expected to be very well correlated with the colour index \((B - V)_0\). To deredden the programme stars, we made use of photometric data in the Johnson, Geneva, and Strömgren systems, compiled from the General Catalogue of Photometric Data (GCPD) [Mermilliod et al. 1997]. For the first two systems, the well-known calibrations based on the X/Y parameters [Cramér 1999] and Q-index [Gutiérrez-Moreno 1975], respectively, which are applicable for O/B type stars were applied. Objects with available Strömgren data were treated with the routines by [Napiwotzki et al. 1993], which allow dereddening of cooler-type stars. For about 60% of the targets we were able to determine reddening values, transformed to \( E(B - V) \) with the ratios summarised by [Netopil et al. 2008]. If several estimates

\[
\Delta a = a - a_0. \tag{2}
\]
for a particular object were available, a mean value was calculated. Since all objects are rather bright and therefore close-by, a strong reddening especially for cool-type stars is hardly expected. We therefore adopted non-reddening for these when no Strömgren photometry was available, which is justified by the obtained overall mean $E(B-V) = 0.02(6)$ mag.

To find the normality lines, we performed an iterative linear regression of $a$, $a'$ and $a'_{mod}$ versus $(B - V)_0$. In each iterative step, we discarded the outliers that lay more than $5\sigma$ from the normality line. After three iterations, the errors did not significantly decrease any more. In total, we defined the normality for a particular object were available, a mean value was calculated. We therefore adopted non-reddening for these when no strong reddening especially for cool-type stars is hardly obtained overall mean $\Delta a_{mod}$ for the peculiar step, we discarded the outliers that lay more than $5\sigma$ from the normality line of $(B - V)_0$. All stars above the threshold of $3\sigma$ are expected to be chemically peculiar, whereas those below are emission-type and/or metal-weak objects. The region of $(B - V)_0$ in which CP2 stars are expected (hotter than spectral type F5) contains 631 stars (Fig. 2).

At $(B - V)_0$ of about 1.5 mag, corresponding to a spectral type M0, the indices $a$, $a'$ and $a'_{mod}$ lose their correlation with $(B - V)_0$ although they are nearly linearly correlated at bluer colour indices. This may indicate a dependency of $a$, $a'$ and $a'_{mod}$ on the luminosity class of the stars (see Fig. 3).

3. Results

The findings of our investigation are summarized in Tables 1 and 2. The first table lists all well-known CP stars taken from the catalogue by Renson & Manfroid (2009). The second table includes apparently normal-type objects (according to spectral classification) hotter than spectral type F5 that have $\Delta a$ values both higher and lower than the $3\sigma$ thresholds. The tables contain the HD number, spectral type, the $\Delta a$ values of each applied method, and the CP class (Table 1 only) of the stars. For comparison with existing peculiarity measurements, they also include published $\Delta a$ values (Pauzen et al. 2005) and $\Delta a_{mod}$ values. The $\Delta (V1 - G)$ index is a measurement for peculiarity derived from the Geneva photometric system. Hauck (1974) was the first to propose an index as peculiarity parameter:

$$\Delta (V1 - G) = (V1 - G) - 0.289(B2 - G) + 0.302. \quad (5)$$

On average, normal stars have $\Delta (V1 - G)$ values of $-5$ mmag, therefore we added $+5$ mmag to the calculated values. The photometric data of the Geneva system were collected by using the GCPD.

3.1. Known peculiar objects

First of all, we analysed the 55 CP stars listed in Table 1 that are included in the catalogue by Renson & Manfroid (2009). Altogether, 19 stars were detected beyond the $3\sigma$ threshold by any of the systems. The modified system of Adelman yields 18 stars above $3\sigma$ for this sample. This is the highest ratio of spectrophotometric to otherwise identified peculiar stars of the three applied detection methods.

In Fig. 4 we present the observed $\Delta (V1 - G)$ versus the synthetic $\Delta a_{mod}$ values for our sample. The observed $\Delta a$ values were not used because there are too few available. There is a clear correlation of the observed and synthesized values. The five outliers (HD 111415, HD 115735, HD 189849, HD 201601, and HD 206088) are described below.

The CP1 (Am) stars have, with some rare exceptions, observed $\Delta a$ values well below $+10$ mmag and are normally inconspicuous in the $\Delta (V1 - G)$ index. However, we detected four stars, three above and one below, the $3\sigma$ threshold; these are.

- HD 29479: a moderate overabundance of Fe-peak elements and $[\text{Ba}/\text{H}] = +1.77$ dex compared with that of the Sun was reported by Iliev et al. (2006).
- HD 76756: $\alpha$ Cancri is one of the prototype Am stars, with no other conspicuous features.
- HD 173648: this is a hot Am star with overabundances of most Fe-peak elements, and considerable overabundances of Sr, Y, Zr, and Ba as well as some rare earths (Adelman et al. 1999).
- HD 189849: a weak magnetic field of about 250 G was detected on a $20\sigma$ level (Bychkov et al. 2009), so it might be misidentified.

It seems that some very peculiar CP1 stars are detectable via spectrophotometric observations and our peculiar indices.

The magnetic CP2 stars are mainly detectable via $\Delta a$ photometry, which is reflected in our results. Figure 5 shows the spectrophotometric data of standard star HD 102647 (A3 V) and HD 118022 (A2 Cr Eu Sr) for the whole spectral range (upper panel) and the region where the $\Delta a$ system is situated (lower panel). The UV excess (Sokolov 2006) and the 5200 Å depression, both typical for CP stars, are clearly visible for HD 118022.
The spectrophotometry of both objects might be severely influ-
ted by the unusual elemental peculiarity and the variability. The remaining objects have two characteristics in common:

1. Except for one object (HD 22951), all of them are very fast rotators (v sin i ≥ 150 km s⁻¹) which is atypical for CP stars.
2. Almost all objects are in binary systems, which might distort the spectrophotometry.

For the following objects we found additional interesting characteristics in the literature:

- **HD 24554**: Schröder & Schmitt (2007) found strong X-ray emission indicating an undetected binary nature of the object.
- **HD 28052**: this is the second-brightest X-ray source in the Hyades and a possibly quadruple system with at least one component of θ Scuti type (Simon & Ayres 2000).
- **HD 83808**: this spectroscopic binary system is listed as CP1 candidate in Renson & Manfroid (2009).
- **HD 107700**: Griffin & Griffin (2011) analysed this close-binary system and found a slight metal-weakness for both components.
- **HD 119765**: Renson & Manfroid (2009) listed it as questionable CP candidate without any designation to a specific subgroup.

For these samples, Δα′ is superior to the other two systems. For almost all of the newly discovered peculiar objects among the normal-type objects, photometric Δα and/or spectroscopic observations are needed to clarify their nature. We also identified nine cool-type objects (0.5 < (B − V) < 1.5 mag) that significantly deviate in the positive direction. Those stars are

- **HD 19373**: Canto Martins et al. (2011) analysed the chromospheric activity of the G0 V object.
- **HD 26965**: this is a young triple binary system including flare-type objects (Petterersen 1991).
- **HD 35369**: Prugniel et al. (2011) found an underabundance of [Fe/H] = −0.22 dex compared with the Sun.

3.2. Apparent normal-type objects

Table 2 lists the apparently non-CP stars detected via synthetic photometry. This sample can be divided into emission-type and metal-weak objects as well as inconspicuous stars.

![Graph](image-url)
Table 1. Synthetic ($\Delta a$, $\Delta a'$, and $\Delta a'$ mod) and observed ($\Delta a$ obs and $\Delta(V1 - G)$) peculiarity indices in mmags for well-established CP (flag “*”) stars taken from Renson & Manfroid (2009). The synthetic photometric values for detected objects are given in boldface italics.

| HD    | SpType | $\Delta a$ | $\Delta a'$ | $\Delta a'$ mod | $\Delta a$ obs | $\Delta(V1 - G)$ | CP group |
|-------|--------|------------|-------------|-----------------|----------------|------------------|----------|
| 6116  | A3−A9  | +8         | +20         | +16             | −7             | −8               | 1        |
| 20320 | A2−A9  | −6         | −13         | −14             | −3             | 0                | 1        |
| 27045 | A3−F3  | −3         | +1          | −4              | −1             | 1                | 1        |
| 27962 | A1−A4  | +13        | +26         | +31             | −2             | 1                | 1        |
| 28355 | A5−F1  | −1         | +2          | +2              | −3             | 1                | 1        |
| 29140 | A3−A7  | +12        | +25         | +23             | −6             | 1                | 1        |
| 29479 | A3−A9  | +6         | +37         | +28             | −2             | 1                | 1        |
| 40536 | A4−F1  | −3         | +18         | +16             | +7             | 1                | 1        |
| 41357 | A4−F2  | −4         | +6          | −1              | −1             | 1                | 1        |
| 76756 | A3−F1  | +17        | +34         | +39             | +2             | 1                | 1        |
| 116657| A1−A7  | −6         | +19         | +25             | +10            | −1               | 1        |
| 125337| A2−A7  | −11        | −8          | −9              | −7             | 1                | 1        |
| 141795| A2−A8  | −1         | −6          | +3              | −7             | 1                | 1        |
| 173648| A4−F1  | +3         | +40         | +34             | −2             | 1                | 1        |
| 173654| A2−A7  | +3         | +17         | +13             | −11            | 1                | 1        |
| 189849| A5−A9  | −17        | −40         | −40             | +2             | 1                | 1        |
| 197461| A7−F0 dD | −6     | −10         | −7              | +1             | 1                | 1        |
| 198743| A3−F3  | +8         | +5          | −9              | −1             | 1                | 1        |
| 207098| A5−F4 dD | −4     | +7          | +1              | +5             | 1                | 1        |
| 223461| A3−F0  | +3         | +7          | +8              | −1             | 1                | 1        |
| 10221 | A0 Si Sr Cr | +12   | +25        | +33             | −17            | 2                | 2        |
| 115023| A1 Si Cr Sr | +10   | +45        | +43             | +39            | +17              | 2        |
| 15089 | A4 Sr   | −1        | −4          | 0               | +4             | 2                | 2        |
| 19832 | B8 Si   | +14        | +43         | +40             | +10            | +17              | 2        |
| 26571 | B8 Si   | +2         | −25         | −20             | +14            | −10              | 2        |
| 32549 | B9 Si Cr | +10        | +50         | +52             | +25            | +17              | 2        |
| 32650 | B9 Si   | +8         | +12         | +12             | −11            | 2                | 2        |
| 34452 | B9 Si   | +36        | +65         | +78             | +54            | 2                | 2        |
| 40312 | A0 Si   | +7         | +30         | +25             | −17            | 2                | 2        |
| 68351 | A0 Si Cr| +24        | +58         | +53             | +24            | +24              | 2        |
| 90569 | A0 Sr Cr Si | +26   | +42        | +57             | +36            | +26              | 2        |
| 112185| A1 Cr Eu Mn | +18   | +35        | +34             | −6             | 2                | 2        |
| 112413| A0 Eu Si Cr | +13   | +19        | +22             | +40            | +26              | 2        |
| 118022| A2 Cr Eu Sr | +43   | +78        | +77             | +51            | +34              | 2        |
| 120198| A0 Eu Cr Sr | +1    | +40        | +39             | +38            | +31              | 2        |
| 137909| A9 Sr Eu Cr | +39   | +21        | +47             | +25            | +4               | 2        |
| 148112| A0 Cr Eu | −6        | +7          | +8              | +13            | 2                | 2        |
| 170000| A0 Si   | +7         | +6          | +6              | −2             | 2                | 2        |
| 183056| B9 Si   | +13        | +23         | +20             | +2             | 2                | 2        |
| 201601| A9 Sr Eu | −14        | −54         | −48             | +10            | +4               | 2        |
| 206088| A7−F3 Cr | +1        | −50         | −48             | +7             | +2               | 2        |

| 358   | B9 Mn Hg | 0      | −7       | −6       | −       | +5     | 3       |
| 23950 | B9 Mn Hg Si | +3   | −19      | −14      | −       | 0      | 3       |
| 33904 | B9 Hg Mn  | −1     | +3       | +3       | −       | −4     | 3       |
| 35497 | B8 Cr Mn  | +3     | +4       | +3       | −       | −7     | 3       |
| 77350 | B9 Sr Cr Hg | −4   | +10      | +9       | +1      | +5     | 3       |
| 78316 | B8 Mn Hg  | 0      | +18      | +20      | +12     | +6     | 3       |
| 106625| B8 Hg Mn  | +3     | −18      | −11      | −       | −9     | 3       |
| 129174| B9 Mn Hg  | −4     | +4       | +1       | −       | 0      | 3       |
| 143807| A0 Mn Hg  | −7     | +13      | +3       | −       | −6     | 3       |
| 145389| B9 Mn Hg  | +15    | +8       | +19      | −       | +4     | 3       |
| 220933| A0 Hg Mn  | −3     | −2       | +7       | −       | −5     | 3       |
| 11415 | B3 He wk. | +13    | −41      | −34      | −       | +28    | 4       |
| 23408 | B7 He wk. Mn | +13  | −9       | −9       | +5      | +3     | 4       |
| 115735| B9 He wk. | −11    | −42      | −49      | +2      | −2     | 4       |
Table 2. Synthetic (Δα, Δα′, and Δα’mod) and observed (Δαobs and Δ(V1 – G)) peculiarity indices in mmags for apparent non-CP stars detected via synthetic photometry. The synthetic photometric values for detected objects are given in boldface italics. The upper panel lists well-known emission-type and metal-weak objects.

| HD     | SpType  | Δα   | Δα′  | Δα’mod | Δαobs | Δ(V1 – G) |
|--------|---------|------|------|--------|-------|-----------|
| 5394   | B0.5IVE | +17  | −37  | −21    | +5    | +1        |
| 6811   | B7Ve    | −10  | −45  | −41    | −5    | +2        |
| 18552  | B8Ve    | +40  | +100 | +97    | −2    |           |
| 22192  | B5Ve    | −9   | −49  | −44    | −4    |           |
| 23016  | B8V(e)  | −16  | −38  | −30    | −6    |           |
| 32537  | F1VpMGII4481Åweak | −10 | −51  | −31    | −7    |           |
| 34078  | O9.5Vep, var. | +4  | −57  | −52    | −10   |           |
| 35439  | B1Vpe   | −11  | −34  | −49    | +5    | +3        |
| 67934  | A0VnpMGII4481Åweak | −1  | +40  | +13    | −4    |           |
| 74873  | kA0.5hA5mA0.5V 47Boo | −18 | −37  | −25    | −15   | −15       |
| 111604 | A5Vp 47Boo | −11 | −34  | −39    | −2    |           |
| 112014 | A0IllspMg,Siweak | −9  | −39  | −30    | −2    | +2        |
| 193237 | B1ep    | +6   | −97  | −14    | +25   | +17       |
| 209409 | B7Ive   | −18  | +53  | +24    | −4    |           |
| 210839 | O6If(n)p(e) | +6  | −69  | −55    | −19   |           |
| 217891 | B6IIIe  | +4   | +65  | +48    | −1    | +4        |
| 17769  | B7V     | +18  | +41  | +39    | −3    |           |
| 19374  | B1VβCep | +50  | +62  | +91    | −5    |           |
| 22951  | A1Vn    | +32  | +33  | +33    | −7    |           |
| 24554  | A1V     | +32  | −6   | −10    | −3    |           |
| 28052  | F0V     | +32  | +17  | +19    | −6    |           |
| 28149  | B5V     | +42  | +28  | −4     | +6    |           |
| 29248  | B2IIIβCep | +4  | +44  | +32    | −9    |           |
| 35671  | B5VSB   | +18  | +51  | +53    | −5    |           |
| 35770  | B9.5Vn  | +26  | +40  | +53    | −4    |           |
| 70011  | B9.5V   | −2   | +40  | +22    | −2    |           |
| 76582  | A7V     | +24  | +18  | +25    | −6    |           |
| 83808  | F8-G0III+A7m | +18 | +18  | +34    | −10   |           |
| 107700 | G7III+A3IV | +29 | +1   | +18    | −4    |           |
| 119765 | A0V     | −7   | −50  | −33    | +1    |           |
| 139891 | B6VB2   | +11  | +41  | +28    | −3    |           |
| 166182 | B2IV    | +6   | +38  | +27    | −3    |           |
| 178596 | F2IV-V  | −3   | −45  | −28    | −8    |           |
| 188260 | B9.5III | −15  | −47  | −38    | −5    |           |
| 188350 | A0III   | −13  | −49  | −42    | −8    |           |
| 212120 | B6Vell.var. | −45 | −15  | −41    | −2    |           |
| 222603 | A7V     | +7   | −69  | −36    | −5    | −4        |

- HD 49878: there are no detailed investigations for this K-type giant available in the literature.
- HD 68375: Takeda et al. (2008) investigated it in more detail, and found no peculiarities.
- HD 82635: this is a highly chromospherically active RS CVn type giant (Strassmeier et al. 1994).
- HD 155899: according to Antipova et al. (2004), this is a moderate Barium star classified as K3.5III Ba1.0. This group of chemically peculiar stars consists of G to K giants, whose spectra indicate an overabundance of s-process elements.
- HD 192577: it is a Cepheus type eclipsing binary of spectral type K4I (Foster 2008).
- HD 194093: Gray (2013) presented photometric and spectroscopic time series of this variable star. The variations are found on all time scales up to several hundred days.

We found that the α indices are linearly correlated with the effective temperature up to a spectral type of M0. For cooler-type objects, there is a strong indication of an additional luminosity effect that is superimposed on the temperature dependency. Up to now, no photometric α data of cool-type stars have been published. Our findings suggest that such observations will be very interesting for the study of low-mass peculiar objects.

4. Conclusions and outlook

We used the spectrophotometric data of the stellar catalogue by Kharitonov et al. (1988) to synthesize three different “a systems”. These data cover the complete spectral range from low- to high-mass objects. For the first time, we presented a indices for stars cooler than F-type. Excluding low-quality data and early-type supergiants, 1067 stars were used to synthesize different peculiarity indices. Our main results are

- Most of the known classical magnetic chemically peculiar stars were detected.
We presented a list of about 50 normal-type objects across the complete spectral range that were detected.

The most efficient $\alpha$ system is very similar to that previously employed by Maitzen (1980).

The normality line of the $\alpha$ system correlates with the effective temperature up to a spectral type of M0.

Our analysis showed that spectrophotometric data can be used for calculating synthetic $\alpha$ indices and for detecting peculiar objects across the complete spectral range up to M0. As next steps, we will observe cool-type objects to establish the corresponding correlations. In addition, we will use classification resolution spectra (for example from LAMOST) to search for chemically peculiar objects in a semi-automatic way.

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