Abstract:
We give a summary of more than 25 years of research within the three filter, intermediate-band, \( \Delta a \) photometric systems. It investigates the flux depression at 5200Å found for magnetic chemically peculiar (CP) objects. Starting with photoelectric measurements it has steadily developed introducing new and more efficient filters as well as the modern CCD technique. Up to now, more than twenty papers were devoted to search for new CP-stars in our Milky Way up to distances of 5000 pc and even in the Large Magellanic Cloud. In the latter, the first extragalactic CP stars were detected. In addition, we have presented theoretical isochrones and synthetic colors from the newest available stellar atmospheres. The theoretical predictions agree very well with observations allowing not only to determine the reddening and age of open clusters from our photometry but also to investigate the flux depression at 5200Å in more detail. As an outlook, we present a new approach to search for chemically peculiar horizontal branch stars in globular clusters and to detect stellar variability of various objects observed during our photometric observations.

The tool of \( \Delta a \)-photometry

Photometry offers an easy possibility for investigation of larger samples of CP stars, especially through the discovery of characteristic broad absorption features, the most suitable of them located around 5200Å. Nearly three decades ago, Maitzen (1976) introduced the narrow-band, three filter, \( \Delta a \) photometric system, slightly changed within the last years, in order to investigate the flux depression at 5200Å. It samples the depth of this flux depression by comparing the flux at the center (5205Å - \( \Delta a \)) with the adjacent regions (5075Å -\( \Delta a \) and 5590Å - \( \Delta a \)) using band-widths of 221Å (\( \Delta a \)), 107Å (\( \Delta g \)) and 120Å (\( \Delta r \)). The respective index was introduced as:

\[
\text{\( \Delta a \)} = a - (a_2 + a_3)
\]

Since this quantity is slightly dependent on temperature (increasing towards lower temperatures), the intrinsic peculiarity index had to be defined as \( \Delta a = (a-g) - (g-r) \) (the difference between the individual \( a \)- and \( g \)-values) and the \( a \)-values of non-peculiar stars of the same colour - the "normality line" was determined. (e.g. Vogt et al., 1998, A&A, 330, 455) It virtually all peculiar stars with metallic fluids (CP2 stars) have positive \( \Delta a \)-values up to 0.075 mag whereas Be/Ae and Bootes stars exhibit significant negative ones (Maitzen & Pavlović 1998b). The index \( (g-r) \) shows an excellent correlation with \( \text{\( \Delta a \)} \) and can be used as an index for the relative activity. Any \( \text{\( \Delta a \)} \)-photometry diagram (in-color-magnitude-diagram) for a cluster can then easily sorts out non-members. Assuming that all stars exhibit the same interstellar reddening, peculiar objects deviate from the normality line more than \( 3 \sigma \). (see Figure 1).

Open cluster survey

The survey for CP stars in open clusters using photometric \( \Delta a \)-photometry (one star at one time) is the most accurate and sensitive method for detecting CP stars. To date, more than twenty papers were devoted to CP stars in open clusters. The observations span very different time intervals (0.02 to 60 days) yielding different possibilities for detecting the whole set of variations. We want to emphasize that these observations are not optimized for the well known error which exists in the optical magnitude data. The cool CP and lambda Bootis stars were investigated in a series of 5 open clusters. The total set of variations consists of nearly 2600 stars, more than 20 CP candidates and 11 Bootes stars were found.

Our search for new variable stars in open clusters is a serendipitous result from already published CCD Delta a photometry. The observations span different time intervals (0.02 to 60 days) yielding different possibilities for detecting the whole set of variations. We want to emphasize that these observations are not optimized for the well known error which exists in the optical magnitude data. The cool CP and lambda Bootis stars were investigated in a series of 5 open clusters. The total set of variations consists of nearly 2600 stars, more than 20 CP candidates and 11 Bootes stars were found.

Evolutionary status of CP stars of the upper main sequence

For many decades the evolutionary status of the CP stars has been controversial. Oelker (1994, AN, 316, 167) concluded that the CP2 (magnetic CP stars) phenomenon appears at the late stages of the main-sequence evolution. Hubrig et al. (2000, A&A, 359, 352) found that the observation of CP2 stars in the globular clusters in the Hertzsprung-Russell diagram differs from that of the "normal" stars in the same temperature range at a high level of significance: magnetic stars are concentrated toward the center of the main-sequence band. The results of the Hipparcos mission on the other hand do not support the mentioned above findings. Gómez et al. (1999, A&A, 359, 133) presented the Hertzsprung-Russell-diagram of about 1000 CP2 stars in the solar neighbourhood using astrometric data from Hipparcos satellite, as well as photometric and radial velocity data. Most CP2 stars lie on the main sequence until about 0.96 of their main-sequence life-time. This clearly proves that the observable CP2 phenomenon occurs already well before a star has reached 30% of its life-time on the main sequence (Pilorrí et al. 2003).

Extragalactic CP stars

The first extragalactic classical chemically peculiar stars more than 100 years after the discovery of this group were detected (Maitzen et al. 2001). Using the tool of CCD \( \Delta a \)-photometry, eight definite positive detections in the globular-cluster NGC 6208 was established via photometric as well as spectroscopic data. We have investigated four young (age not more than 100 Myr) open clusters with known CP2 members. The peculiarity of these clusters was established via photometric as well as spectroscopic data. We have derived effective temperature and luminosities for these objects and calibrated ages as well as masses with the help of standard evolutionary models taking the overall metallicities of the individual clusters into account.

Theoretical Aspects

A synthetic photometric system was developed by Kupka et al. (2003) that can be used to explore the capability of model atmospheres with individual element abundances to predict photometric \( \Delta a \)-values. The observed dependency of the \( \Delta a \)-index as a function of various colour indices sensitive to the effective temperatures as well as its average scatter expected from surface gravity variations within the main-sequence stars is confirmed, also the behaviour of the normality line is well reproduced. Kupka et al. (2003) have also shown the metallicity dependence of the \( \Delta a \)-index. Thus, \( \Delta a \)-photometry is a viable tool to identify CP2 stars in samples with metallicities slightly different from the solar ones and it is well suited to draw statistically meaningful conclusions about their distribution.

Additionally, C Camelot et al. (2003) have investigated the capability of theoretical isochrones for the photometric \( \Delta a \)-system to derive age and distance parameters of CP-stars, reddening and distance moduli for open clusters. As a test, the published data of 23 open clusters were used to fit these isochrones with parameters from the literature. The model show an excellent agreement between the isochrone and the theoretical grid. The observational data have also been filled with knowledge of age, reddening and distance modulus, yielding an accuracy of 6 to 15% depending on the well known error sources of such a method.

A new Approach

The existence of peculiar stars at the Blue Horizontal Branch was already shown by Behr et al. (1999, ApJ, 517, L135). He used high resolution spectra to determine elemental abundances of individual objects to prove the peculiarity. Our approach is to search for simultaneously all members of a globular cluster. A preliminary result of our photometric survey by means of \( \Delta a \)-photometry is shown in Figure 5. Another capability of the \( \Delta a \) tool is to detect Novae. Only a small sample was investigated up to now, but the synthetic \( \Delta a \)-photometry by Maitzen et al. (1999, ApJ, 517, L135) showed a significant negative \( \Delta a \)-values up to 0.1 mag. Further observations on that topic are at present underway at the Friel-Observatory (Australia).