WFPDB DEVELOPMENT: RESTORING CHARACTERISTIC CURVE FROM DIGITIZED IMAGES OF SCANNED PHOTOGRAPHIC PLATES

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Abstract. In progress is a process of cataloguing and digitization of direct observation astro-plates archives stored in the National Astronomical Observatory Rozhen, Bulgaria. This is a part of a project aimed to develop the Wide-Field Plate Database from direct astronomical observations archives of all astronomical institutions over the world being in possession of such observations. One natural step for the future appropriate processing of digitized images is their transfer into relative intensities as well the photographic emulsion is nonlinear detector of light. For this reason we offer an algorithm to restore emulsion characteristic curve. The algorithm is based on a method offered by de Vaucouleurs 1984. Our contribution is to develop the algorithm using IRAF routines only.

1. SAVING ASTRONOMICAL PHOTOGRAPHS

Today astronomical photography is rarely applied, but for the sake of this a huge amount of photographic plates and films with valuable and still only partially utilized information for the astronomical objects and phenomena have been accumulated in the archives of the astronomical observatories. The *preservation* and *utilization* of this treasure is of great importance for contemporary astronomy. In 1991 the IAU adopted a resolution, in which, underlining the importance of the astronomical archives, recommends to the astronomical institutions to exert efforts and allocate funds for their *preservation* and *cataloguing* (IAU Information Bulletin 1992, No. 67, p. 41). By initiative of the Working Group on Wide-Field Imaging at Commission 9 of IAU, the creation of a Wide-Field Plate Database (WFPDB) started in the Institute of Astronomy at the Bulgarian Academy of Sciences with the support of the National Science Fund (NSF) (research projects F-311/93 and F-650/96).

2. DEVELOPMENT OF THE PROCESS

WFPDB is generated by merging data from a number of observation catalogues, available in astronomical observatories around the world. In 1997 an on-line access was provided to WFPDB through the system VizieR of the Strasbourg Data Center (CDS) at address http://vizier.u-strasbg.fr/cats/VI.htx (catalogue number VI/90). Since years WFPDB is constantly among the first 100 most used astronomical catalogues from a total number of 3 000 catalogues disseminated by CDS and is regularly enlarged with new data. In 2001 a new enlarged version of WFPDB was installed at the Institute of Astronomy in Sofia http://www.skyarchive.com. The development of WFPDB is connected with the digitization of the astronomical plates and films. It was started with the micro densitometers devices like PDS and Joyce Loebl. Recently it is accomplished by help of appropriate scanners, and partially by digital cameras. Digital images of the photographic plates are obtained in two modes: low resolution preview image in JPG format (usually ≤600 dpi) and high resolution FITS format image (≥1200 dpi). An on-line access to the former – the so called "preview" – is provided for the WFPDB users. The process of digitization of the photographic plates has been started by scanning direct photographic plates found in the archive of the National Astronomical Observatory Rozhen taken in the RC focus of the 2-m telescope (scale 12.86 arcsec per mm).

3. DIGITIZATION PROCESS

At the moment more than 500 astro-plates with dimension 30x30 cm has been scanned with Epson Expression 10000XL Graphic Arts Scanner. This way astronomical information of more than 300 GB has been accumulated at the moment. The scanning procedure is performed in the conditions as follows:
- resolution 1600 dpi which corresponds to 16 microns pixel size
- output is 16 bit gray-scale image in FITS
- scanner speed 5.3 msec per line
- auto-focus mode on the every plate
- as a preview option, to take control on the quality of the astro-plate every plate is scanned additionally with a less resolution - 800 dpi, 24 bit color JPG image.

The scanning duration for 30x30 cm plate in FITS format mode is 18 minutes, but JPG format takes 8 minutes. For comparison reason we like to point out that scanning of the same plate with Joyce Loebl microdensitometer takes 50 hours.

Digitization of the astro-plates preserves the information stamped on for future analyze and gives the opportunity old astronomical observations to be processed and analyzed in digital manner. A serious disadvantage of the photographic emulsion is its nonlinearity. In order to overcome this problem one have to build-up the emulsion characteristic curve – the relation between photographic density and the relative intensity. The professional astronomy practice requires on every

astronomical plate a photometric wedge to be stamped additionally (see Fig. 1).
Figure 2 demonstrates the characteristic curve of the emulsion recovered on the
base of this wedge image. There are some exceptions of recommended
astronomical practice - most often when the object of scientific interest is a
globular cluster such wedge is missing as well as the calibration of the
instrumental stellar images uses photometric stellar standard established for most
clusters. In this cases the recovering of the emulsion characteristic curve is tricky
in some sense.

Figure 1. The wedge available at NAO Rozhen.
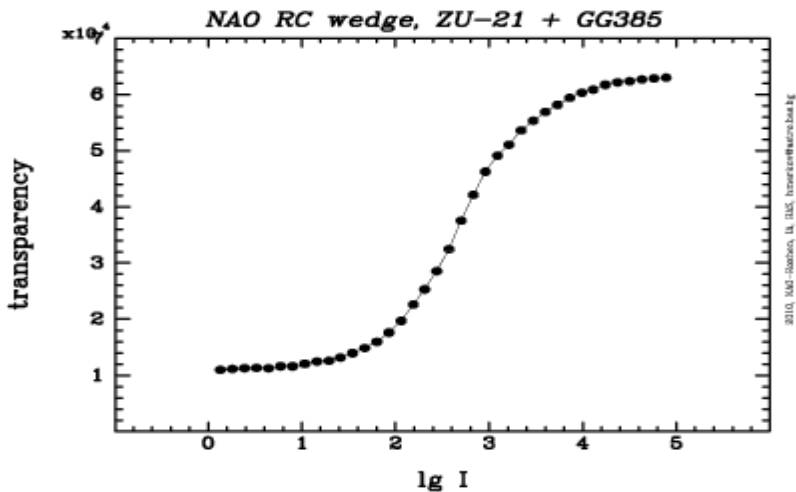
Figure 2. Characteristic curve of the emulsion gained via the wedge.

4. THE ALGORITHM

Our main goal was to develop an algorithm recovering the emulsion
characteristic curve only by means of appropriate tasks available in IRAF
packages. Here we demonstrate the principles of the algorithm we developed and
would like to emphasize that no additional software or routines were used. Our
presentation is not a review of the available methods to recover characteristic
curves but will demonstrate one of them – a method offered by de Vaucouleurs in
1984 The method is based on azimuthally integrated stellar profiles extracted

from a digital image. Important feature of the method is the stellar magnitudes of the stars which profiles will be exploited to be known very well. It gets clear that to apply the method of de Vaucouleurs one needs to identify in the field of the plate of interest some stars with known magnitudes as shown on figure 3 .
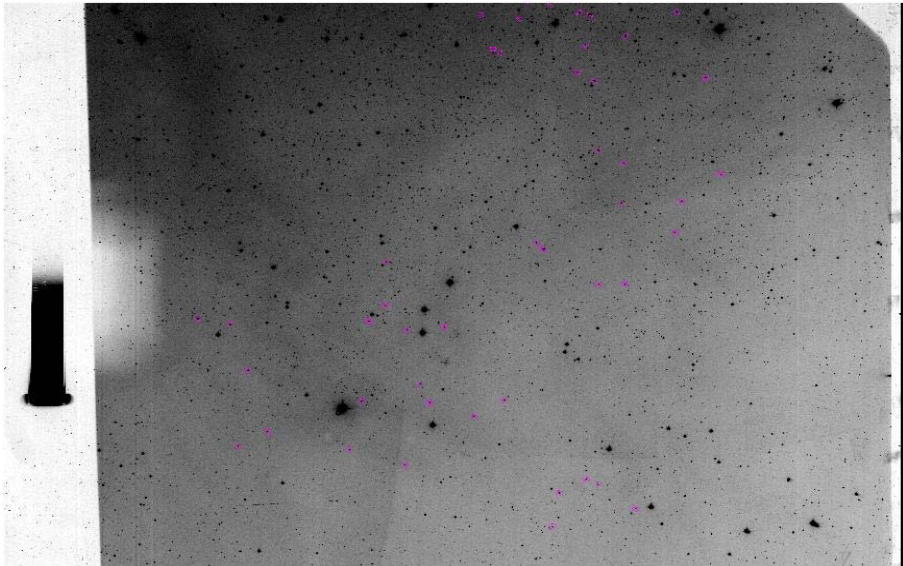

Figure 3. Image of scanned photographic plate with stamped wedge. Stars with known magnitudes are marked.
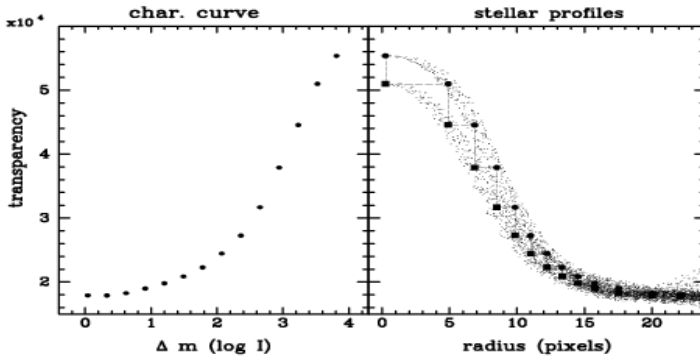

Figure 4. Graphical illustration of de Vaucouleurs method.

The method is demonstrated on figure 4. The right panel of Fig. 3 shows two stellar profiles. The abscissa presents the distance from the image center but the ordinate photographic density. It is easy to be realized that points corresponding to one and the same density on the two stellar profiles is cased by known light intensities – the magnitude difference between the two stars. "Jumping" between

the two profiles we can mark those densities on one and the same profile caused by one and the same light intensity. This way we can construct a new graph on which abscissa are marked points with a constant step corresponding to brightness difference of the two stars, but on the ordinate their corresponding density values taken from the right panel (see left panel, Fig. 3).

As well as stellar magnitude scale is arbitrary and magnitude difference corresponds to the logarithm of relative intensities such figure actually presents the characteristic curve of the photographic emulsion. Important requirement for the two stellar profiles to be used in a couple is to merge in the same background. The background density over the plate could changes as result of non uniform sky illumination as well as result from the non-equal chemical fog caused by improper treatment of the plate during the development process. Any way profiles with non equal background are useless.
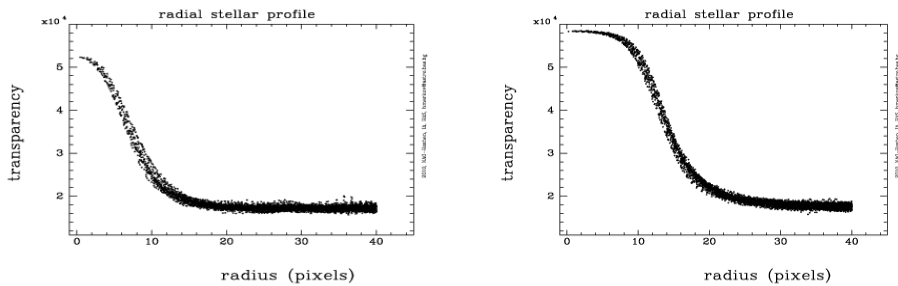

Figure 5. Azimuthally integrated stellar profiles of two stars.
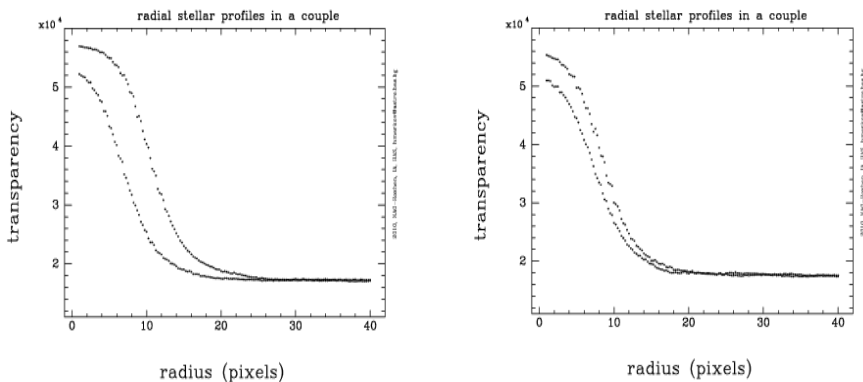

Figure 6. Stellar profiles with appropriate difference in brightness.

Concerning the above demonstrated method every two couples of stellar profiles contains information for the characteristic curve of the emulsion. It is evident that the more close profiles (in transparency) will produce more points on the characteristic curve.

Key moment to apply the above outlined method to achieve an appropriate characteristic curve is the accuracy of stellar magnitudes or at last their exact difference. On figure 7 is demonstrated the importance of adopted magnitude difference on the shape of the curve. On both panels of this figure with a curved line is shown characteristic curve obtained from direct scan of the wedge shown on fig.4(left) and with black dots is marked the characteristic curve of the same emulsion obtained by using couple of stars with known magnitudes (as referred from GSC). Left panel demonstrates the characteristic curve based on magnitude difference of 0.29 mag. Discrepancy of the two curves is obvious. The right panel demonstrates a new version of characteristic curve adopting magnitude difference 0.21 mag. More about conditions required for appropriate application of de Vaucouleurs method are discussed in Markov (1994).
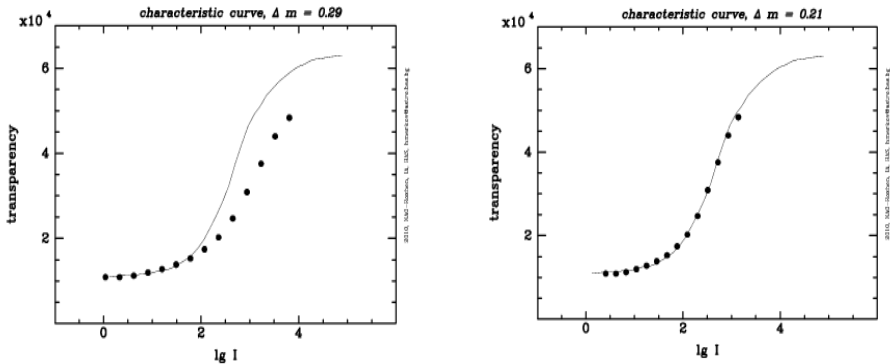

Figure 7. The importance of the magnitude difference on the shape of characteristic curve - left panel $\Delta m = 0.29$ *mag*; right panel $\Delta m = 0.21$ *mag*

5. ANOTHER APPROACH

One particular case of the outlined method to recover the characteristic curve of the emulsion uses rich sample of stars with known magnitudes. This approach relies on the fact that the top pixels of the stellar image (or the max values in the profile) are well proportional to the brightness of the star. So if we have rich sample of stars with known magnitudes (photometric standard) which cover the whole dynamic range in transparency (density) we can successfully build-up the characteristic curve of the emulsion. The most appropriate fields filling such requirements are the regions of globular clusters. where we can find many stars with well established brightness (Stetson, 2001, Catalog of CCD standards). Figure 8 shows CCD standard in the region of globular cluster M3 used to build-up the characteristic curve demonstrated on figure 9.
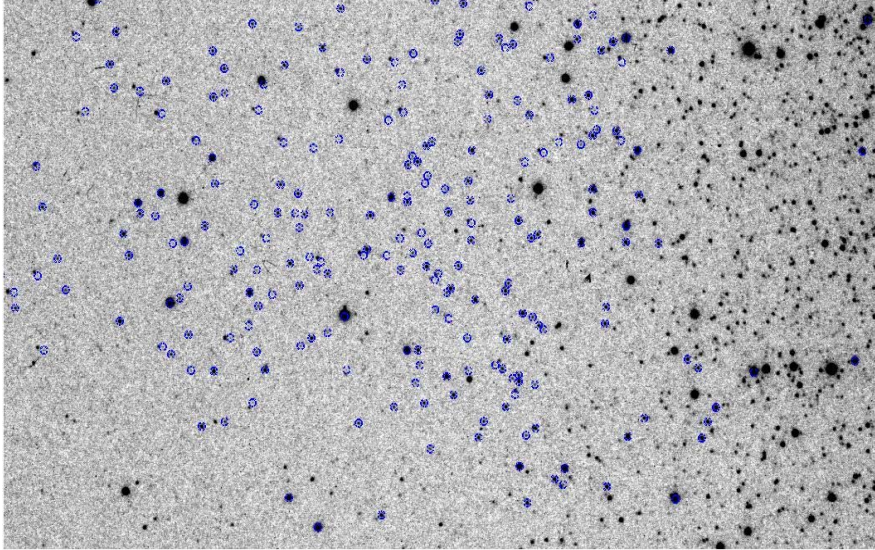
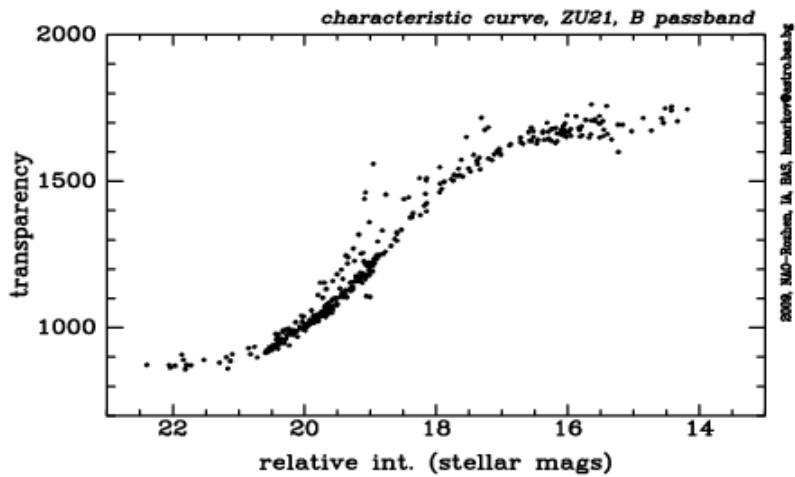**Figure 8.** Stetson's CCD standard in the region of globular cluster M3.

Figure 9. Characteristic curve based on Stetson's CCD standard in the field of M3.

6. BASIC IRAF PACKAGES AND ROUTINES

The main goal of this article is to demonstrate the ability to build-up the characteristic curve of an astro-plate using IRAF routines only. None additional software routines were used. The outlined algorithm uses a method offered by de Vaucouleurs (1984) and is based on azimuthally integrated profiles of stellar images with known difference in the brightness. Here are the IRAF packages and routines used to cover the entire process.

● **DAOPHOT** (*DAOFIND, PHOT*) - to find stellar images and to define their instrumental magnitudes;

● **APPHOT** (*RADPROF*) - this was used for the purpose of azimuthal integrated stellar profile establishment;

● **MATH** (*CURFIT*), **STSDAS** (*NFIT1D*) - for appropriate smooth fitting of the characteristic curve and establishing its analytic form;

● **IMAGES** (*DISPLAY, IMEXAM*) - supplementary routines for interactive analyzing of the digital images;

● **TABLES** – data files management and processing.

Acknowledgments

References

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Markov, H.: 1994, *A&A*, **291**, 1027-1032.
Stetson, P.: 2000, *PASP*, **112**, 925.