PROCESSING OF CCD IMAGES OF STAR FIELDS WITHOUT THE FRAME OF A FLAT FIELD BY USING NEW SOFTWARE IN PROGRAM SHELL OF MIDAS/ROMAFOT

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Results of CCD frames of star fields processing obtained by two ways, are analyzed. In the first case (a traditional method) the frame of flat field are used. In the second one the own large-scale flat field is obtained directly from the processable frames of image. That is we suggest to find the frame of a flat field individually for each frame of the image. Photometric researches of regular errors are carried out for a wide interval of exposures (up to 100 times) for the same celestial objects in zones of overplanning of displaced frames (up to half of the frames size). Comparison of an instrumental photometric scale with a scale of photometric standards shows the absence of photometric field errors and brightness errors. Software procedure of cyclic processing of any quantity of CCD frames of star fields is realized in program shell of MIDAS/ROMAFOT.

INTRODUCTION

CCD frame $S(i,j)$ with the image of a star field, contains the information on separate celestial objects and background. Such frame refers to as the "crude" one. For obtaining of the undistorted photometric scale of star magnitudes for all field's objects on the frame it is necessary to have auxiliary flat field $F(i,j)$ of the frame. Normalized flat field $<F(i,j)>$ of CCD frame allows excluding a photometric error from the "crude" CCD frame $S(i,j)$ with the image of a star field. The photometric error of a star's field is caused by instrumental optics and non-uniformity of sensitivity of a working field of a CCD matrix. Transformed CCD frame, free from a photometric field's error, we shall name as a pure CCD frame of star field $I(i,j)$. It is necessary to have the CCD frames with the exposures for dark current $D(i,j)_S$ and $D(i,j)_F$, respectively. Mainly the frames of dark current $D(i,j)_S$ and $D(i,j)_F$ have different exposures. So, it is possible to write down for the pure frame $I(i,j)$:

$$I(i,j) = \{S(i,j) - D(i,j)_S\} / < \{F(i,j) - D(i,j)_F\} >, \quad (1)$$

where matrixes elements (pixels) have current number i and j, and normalized frame $<\{F(i,j) - D(i,j)_F\}>$ is obtained after division of the frames difference $\{F(i,j) - D(i,j)_F\}$ by average value of this difference [1]. In practice (as a rule) the frame of flat field $F(i,j)$ is to be obtained by short exposures of the early morning or twilight sky, *i.e.*, the frame of flat field $F(i,j)$ and the "crude" frame of star field $S(i,j)$ are obtained separately and under different conditions. There are two sub signals from celestial objects in frame $S(i,j)$ as the registered signal: actually required value $I(i,j)$ and background from the night sky, *i.e.*, weakened analogue of the $F(i,j)$. Therefore, if all registered objects will be removed (any way) from the "crude" CCD frame of a star field, it will be obtained the own flat fields $F(i,j)$ (for the frame). Thus, the "crude" CCD frame image of a star field and the frame flat field $S(i,j)$ were obtained under identical physical conditions. Moreover, $D(i,j)_S$ and $D(i,j)_F$ are identical, *i.e.*, $D(i,j)_S = D(i,j)_F$. Means, for reception of the pure CCD frame of star field $I(i,j)$ from "crude" CCD frame $S(i,j)$ it is enough to have only one auxiliary frame of dark current $D(i,j)_S$. Exposure time for frame $S(i,j)$ and $D(i,j)_S$ is identical.

Procedure of reception of pure frame $I(i,j)$ according to equation (1) we shall name "traditional way" (or "the first type"), and similar procedure without using of separately obtained frame of a flat field we shall name "the second way". In operational shell LINUX/MIDAS/ROMAFOT software (as MIDAS procedures) is created for a cyclic processing of finite quantity of CCD frames in FITS-format.

For software debugging we used the observational data obtained with the Zeiss-600 telescope of the Andrushivka Astronomical Observatory [2]. The images were obtained with S1C-017 CCD camera. This matrix size is 1024×1024 pixels, scale is equal to 1 pixel = 0.47 of arc seconds.

PROCESSING OF CCD FRAMES OF STAR FIELDS IMAGES IN MIDAS/ROMAFOT. THE COMPARATIVE ANALYSIS OF TWO WAYS OF CCD FRAMES PROCESSING

Two different programs on processing of CCD frames of star fields images are created to determine the rectangular coordinates *X, Y* and photometric sizes of objects. Using the first one the CCD frames are processed by standard way with subtraction of noise from the frame with a flat field and the frame of star fields with the subsequent normalization of the CCD frames of star fields by the CCD frames with a flat field. Procedure of standard processing is described in MIDAS Users Guide, Volume B [1] in detail.

For a standard way the normalizing frame with a flat field is situated in regular intervals lit up to observations or after them, *i.e.*, it turns out separately. But we have showed that it is possible to obtain the frame of a flat field directly from each working frame by removal of objects from the frame. The iterative method of removal of objects and obtaining of the own flat fields from the working frame has been realized as MIDAS-procedure.

We shall consider Fig. 1. On the left there are photometric cuts along X coordinate of the frame with a flat field obtained at different exposures (hot pixels are removed by the frame operation of smoothing with a window of some pixels smoothing). On the right of Fig. 1 one can see the photometric cuts after subtraction the frame with a noise from the frame with a flat field. For a quantitative estimation of distinction between the frames we have used factor of curvature k, which is equal to the ratio of the maximal value of readout to it average value for all frame. The frames of a flat field are obtained during several days at different brightness and three top and two bottom frames are distinguished by their exposures. We have obtained that the change of k factor on 0.01 causes the change of a field photometric error on 0.01−0.02 star magnitude. This effect is demonstrated in upper row in Fig. 6. Two "untilled" CCD frames obtained with different exposures (10 and 840 s) were compared, but the dark current from these frames was not subtracted. The factor k changing is the consequence of linear trend of the magnitude differences from the centre to edge of the frame. The results of CCD frames with star field processing after dark current subtraction are presented in the second row of Fig. 6.

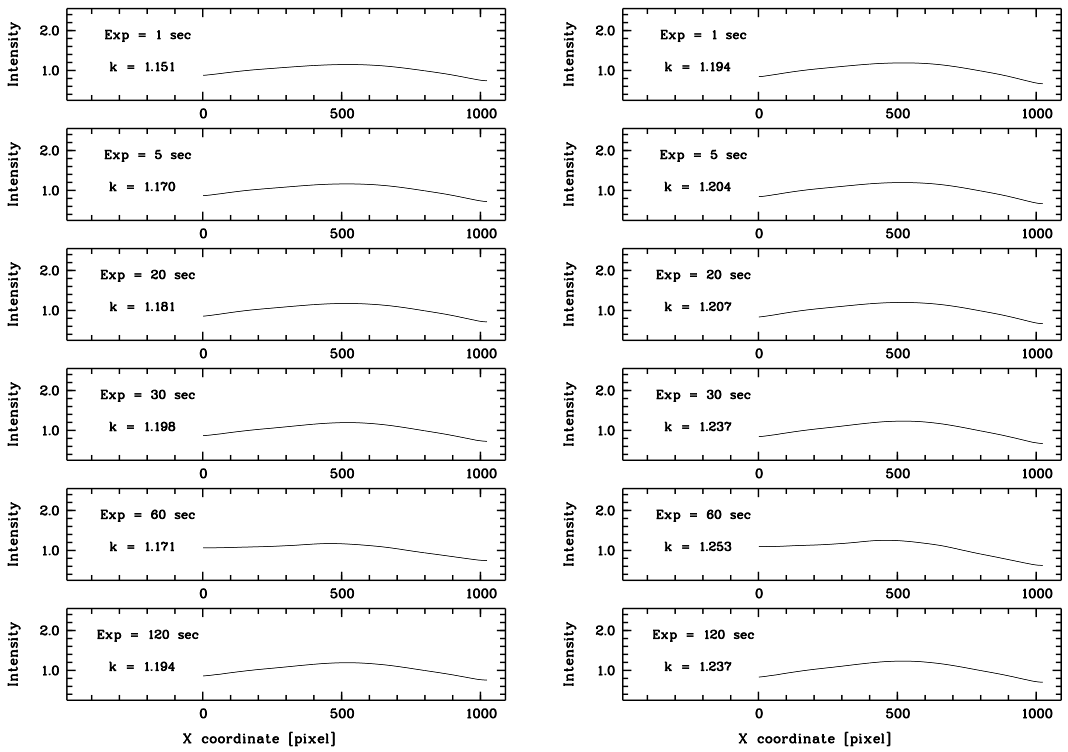

Figure 1. Photometric curves for CCD frames with a flat field at different exposures. On the left the curves are for "crude" CCD frames with a flat field; on the right ones are after subtraction of frames with dark current at the same exposure

The similar cuts are shown in Fig. 2, but here flat fields are derived from the frame of star fields images after removal of all objects. We mark distinction of k factor values for the right parts of both figures.

We shall consider the procedure of the second programs type of the CCD frames processing by the example of photometric cuts of two frame of the second and third type (frame 1 and frame 2, with exposure of 10 and 840 s, respectively). The photometric cuts for the "crude" frame are shown above in Fig. 3; the marked over exposure objects are shown in the second line. The intermediate stage of images restoration is in the third line, and the final kind of images is below. The photometric cuts after removal of hot pixels are shown above in Fig. 4. The change of photometric cuts during removal of objects from the frame is shown in the second, third, and fourth lines. In the bottom line the photometric cuts for the frame are given after removal of objects, *i.e.*, it is required flat fields which we have derived from the image. After dividing of the "crude" frame of star field on normalized frame of a flat field the photometric cuts will look like shown above in Fig. 5. After removal of hot pixels in the increased kind the photometric cuts are shown in the middle line. After photometric correction of over exposure the photometric cuts (in the second line of Fig. 1) are shown in the bottom line of Fig. 5. The influence of the photometrical correction on the object's photometry for over exposure frames is shown in the third (without correction) and fourth (with correction) rows of Fig. 6. The influence of the photometrical correction on the determination of coordinates accuracy of over exposure objects is shown in the fifth and sixth rows of Fig. 6.

We shall consider the comparison of photometric accuracy of two types of over exposure CCD frames. The observations are performed with a 60 s exposure; the average background from the sky is several units. It is an extreme case of applicability of the second type of processing in sense of exception of a field photometric mirror. Two sites of the sky after processing in MIDAS/ROMAFOT are shown in Fig. 7. The frame is made with overlapping; crosses designate the photo-electric standards in the Vilnius system. Photometric results in ROMAFOT processing both by standard method and our method (with a flat field obtained from the image frame) are shown in Fig. 8 on the left and on the right, respectively. In the top line the star magnitudes differences are shown for two frames depend on distance from the frame center; in the second line the values of photometric differences are given versus star magnitudes. The differences of star magnitudes in a zone of overlapping of two frames are shown in the third and fourth lines. Comparison with photometric standards is

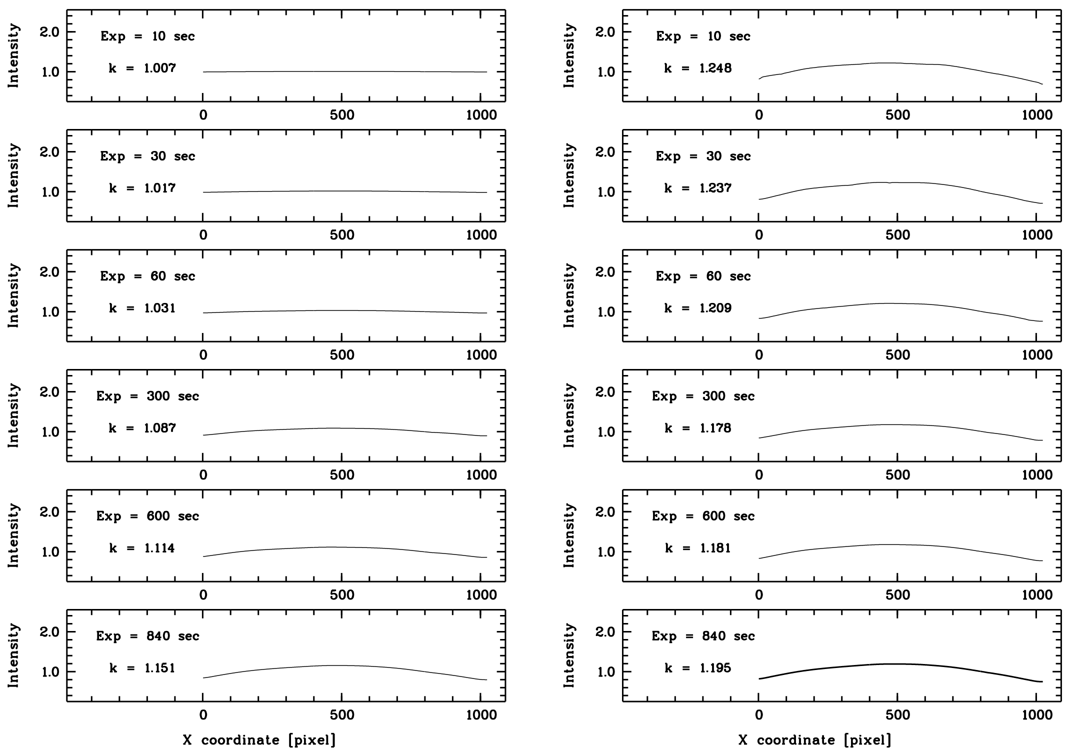

Figure 2. Photometric curves for CCD frames with star's fields at different exposures. The photometric curves of CCD frames after objects removal from them are on the left. Ones after subtraction of the dark current from the frame at the same exposure are on the right

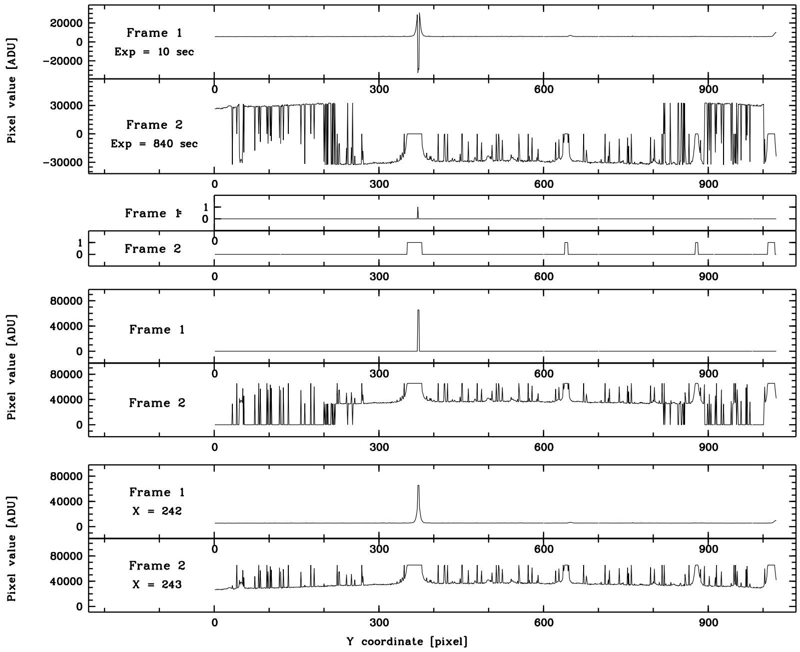

Figure 3. Photometric curves for two CCD frames with an exposure of 10 and 840 s. The first frame contains one over exposure object; the second frame contains extensive over exposure site. In the second line of the figure over exposure objects are marked with "one". In the third line the intermediate stage on reduction of the frame is shown to a normal kind. In the bottom line the final result of restoration of over exposure separate objects and extensive over exposure sites of the frame is shown

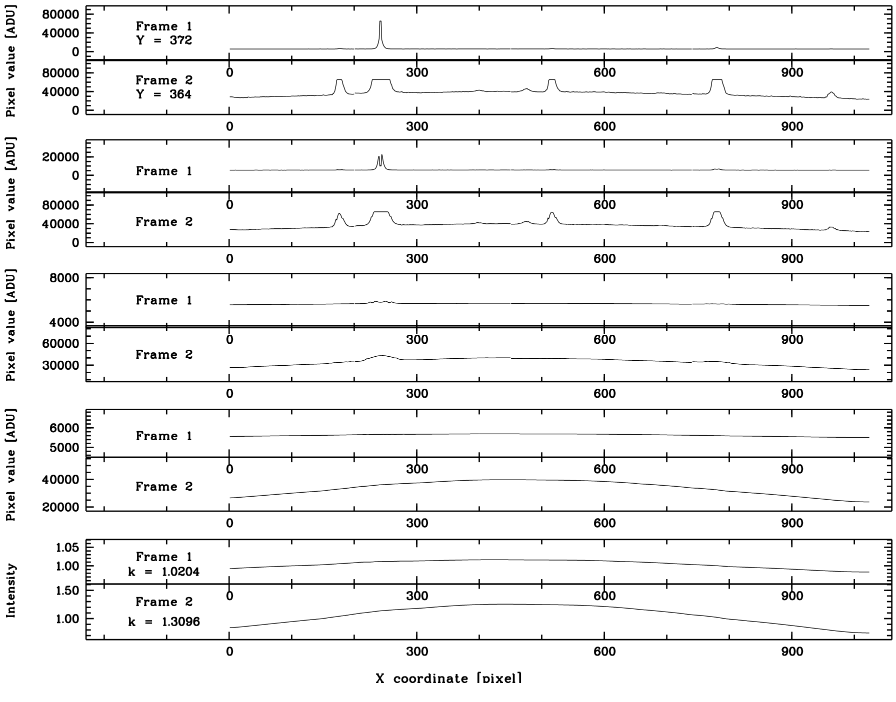

Figure 4. Continuation of Fig. 3. It is shown a process of objects removing from the frame and finding of the own flat field for two frames

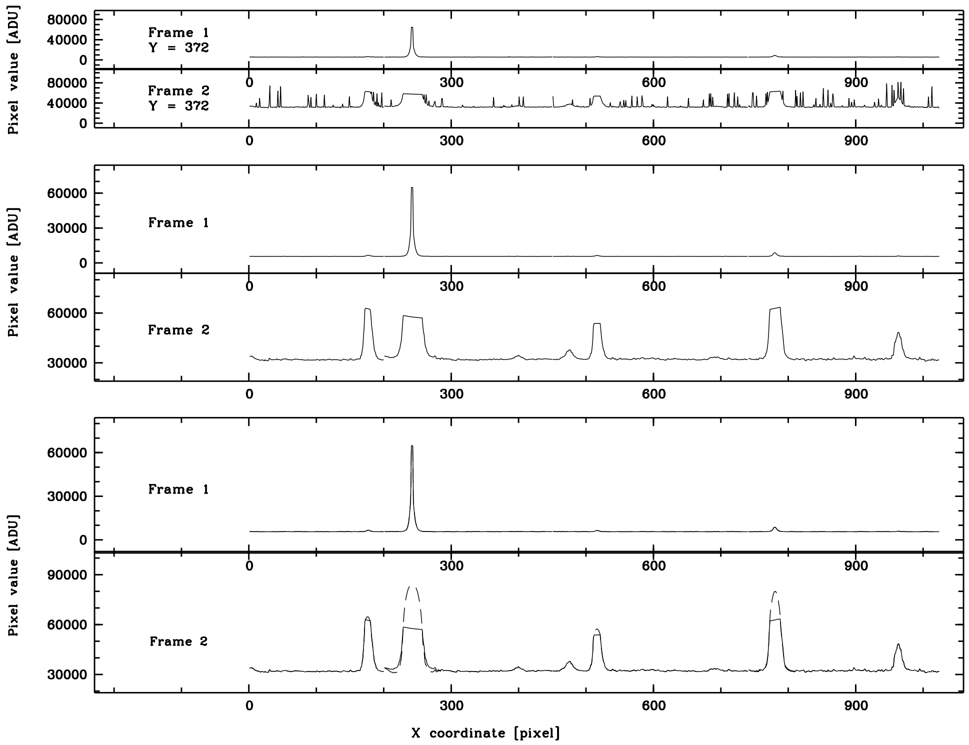

Figure 5. Continuation of Fig. 4. In the top line the correction of a flat field (own flat fields are used) for "crude" CCD frame is executed. In the second line the results are shown after removing of "hot" pixels. In the bottom line the photometric curves are shown after photometric correction for bright over exposure objects

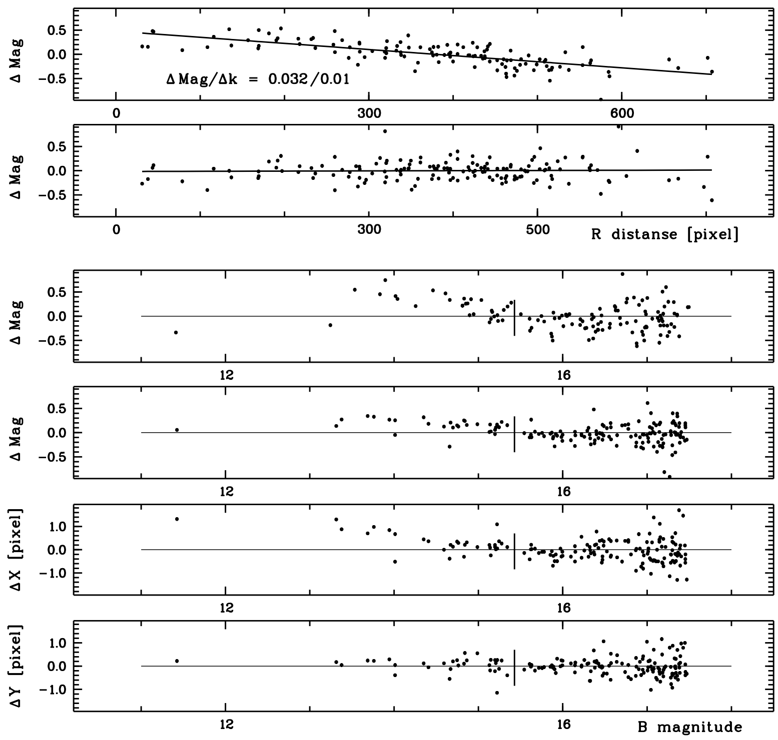

Figure 6. Errors of determination of star magnitude and objects coordinates obtained from two frames comparison

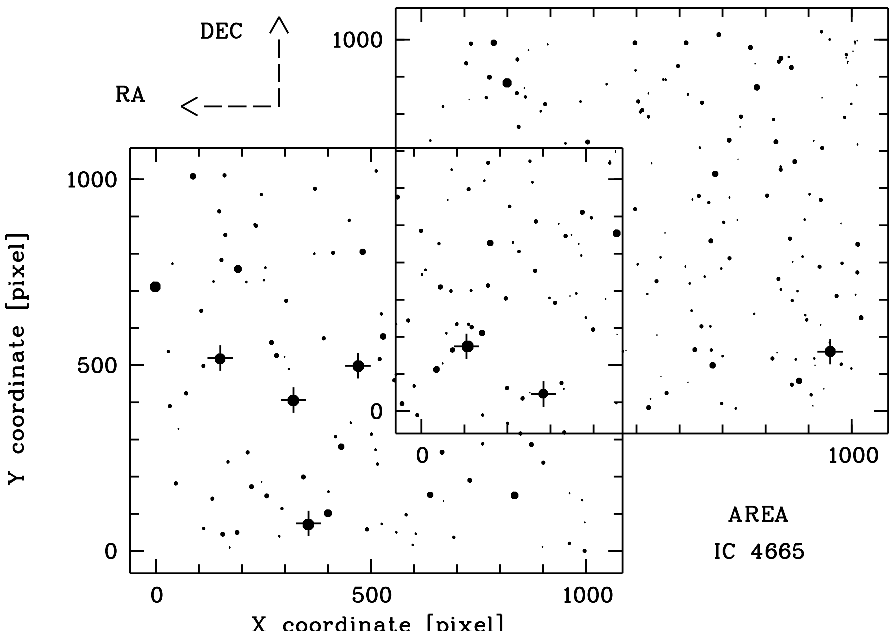

Figure 7. Resulting maps of IC 4665 sky field after processing of two CCD frames in MIDAS/ROMAFOT. Crosses are photo-electric standards of the Vilnius system

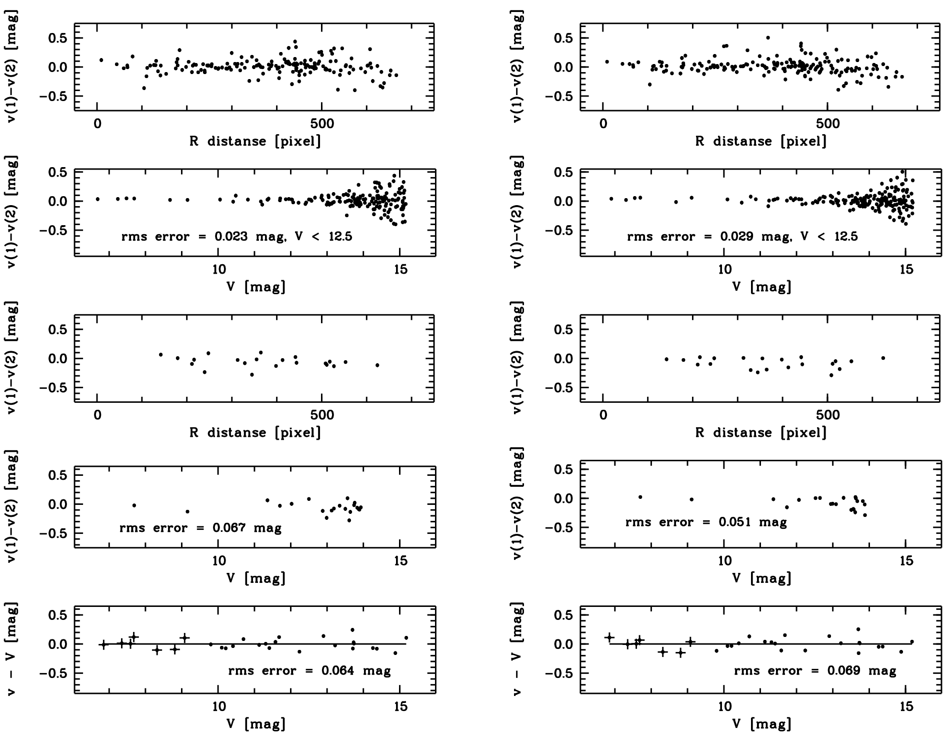

Figure 8. Results of photometric processing in ROMAFOT are shown: the standard method applied for the account of a flat field is on the left; the frame of a flat field obtained from the image frame is on the right. In the top line the differences of star magnitudes depending on distance up to the frame center are successive shown for two frames; in the second line the photometric differences depending on star magnitude are shown. In the third and fourth lines dependence on star magnitudes differences in a zone of overlapping of two frames is shown. In the bottom line a comparison of our obtained results with photometric standards is shown

shown in the bottom line. Our analysis of the observational data shows that it is possible to process the CCD frames of star fields without specially obtained frame of a flat field. It is possible to derive the frame with own flat field from the frame of a star field image by removal of objects from the frame. Photometric and astrometric accuracy of both methods is practically identical. But time of observations decreases more than twice!

CONCLUSION

The method of the CCD frames processing without using of specially obtained frames for flat field is offered, realized, and is successfully put into practice. The method is approved in software MIDAS/ROMAFOT. It is shown that the method does not have photometric field's error. Programs (such as MIDAS procedures) of cyclic processing of final quantity of CCD frames in FITS-format are created.

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[1] MIDAS Users Guide, European Southern Observatory – Image Processing Group 1994, Garching, ESO, 1994.–Vol. **A**, **B**, **C**.

[2] *Ivashchenko Yu. M., Andruk V. M.* Andrushivka Astronomical Observatory in 2001 // Extension and connection of Reference frames using group based CCD technique: Intern. Astron. Conf.–Mykolaiv: Atoll, 2001.–P. 224–230.