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LARGE-SCALE ERRORS IN CCD PHOTOMETRY OF M 67

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Abstract. The accuracy of new CCD photometry in the *Vilnius* system of the M 67 cluster is analyzed. The observational material is obtained during six observing runs in 1994–2001 with the 1 meter telescope of the USNO Flagstaff Station. The main task was to establish CCD standards of high accuracy and to eliminate large-scale errors from our CCD photometry. We compare our results with the published CCD photometric data in other photometric systems. The comparison reveals considerable systematic errors in some datasets.

Key words: clusters: individual: M 67 – methods: observational, data analysis

1. OBSERVATIONS

The observational material was obtained during six observing runs in 1994–2001 with a 2k×2k CCD camera on the 1 meter telescope of the USNO Flagstaff Station with an unvignetted field of 20′ diameter. Our main task was to establish CCD standards in the *Vilnius* photometric system of high accuracy. The long-lasting flatfielding problem on this telescope was solved by applying flat field correction determined by differential photometry of shifted star fields. For reduction to the standard system we used 50 photoelectric standards observed in 2000–2003 with the 1.5 meter telescope

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of the Steward Observatory (for details see the paper in the next BA issue). The final catalog contains 412 stars with magnitudes and color indices with an accuracy of $\sigma_V \leq 0.012$ mag down to $V=16$ mag.

2. RESULTS

Since the cluster M 67 is well studied in various photometric systems, it offers an opportunity to verify the new photometric techniques by comparing our results with the results of other authors. Here we present the main results of the comparison and disclose the systematic errors found in different datasets.

One of the best CCD photometric investigations of M 67 has been published by Fan et al. (1996, hereafter BATC). We calculated $V_{\rm BATC}$ magnitudes using their Eq. (4), and then compared these magnitudes with the $V_{\rm VIL}$ magnitudes of the *Vilnius* system (Figure 1). Left panels show that there are some systematic differences between $V_{\rm BATC}$ and $V_{\rm VIL}$ depending on $Y{-}V$, and the scatter increases for faint stars. However, in right panels, which exclude faint stars and are limited within narrow color range, we do not see any large-scale position-dependent differences between these two photometries which would exceed $\pm 1\%$.

Recently, BV CCD photometry of M 67 was obtained by Momany et al. (2001, hereafter ESO) with the 2.2 meter telescope at ESO. We find very large systematic differences between $V_{\rm ESO}$ and $V_{\rm VIL}$ datasets as it is shown on Figure 2 (left panels). The comparison of the $V_{\rm ESO}$ and the $V_{\rm BATC}$ (Figure 2 right panels) reveals even larger systematic errors which undoubtedly are related with systematic ESO flat field errors. The systematic errors as large as 10% are observed in the ESO photometry.

Figure 3 shows the comparison of V magnitudes from the Montgomery, Marshall and Janes (1993) dataset (hereafter MMJ) with our (left panels) and the BATC datasets (right panel). Along the RA axis there are several inclined strips of about 5–6% amplitude. Thus, MMJ photometry is also affected by considerable systematic errors which appear as a result of systematic flatfielding errors.

The accuracy of photometry can be estimated by looking at the scatter of stars in the CMD diagram of M 67 (Figure 4). It is evident that the Vilnius and the BATC magnitudes and color indices are of comparable accuracy, while the ESO and MMJ photometry are less accurate. This confirms that our method of flatfielding, which uses the shifted exposures of the standard stars, gives the best results.

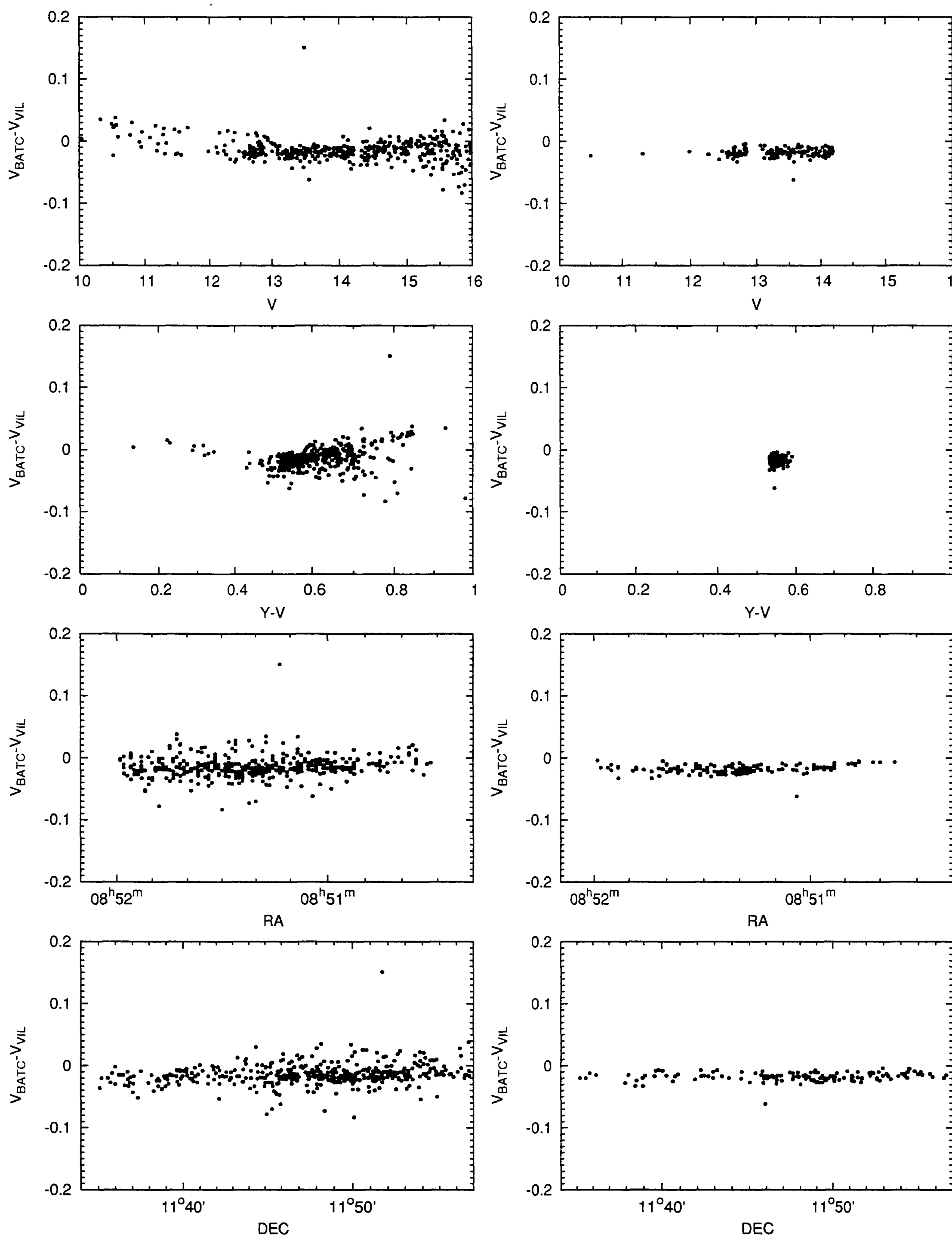

Fig. 1. Differences between the V_{BATC} and V_{VIL} magnitudes. Left panels show all 412 stars in common, and right panels are only for the stars brighter than 14.2 mag in V and within the narrow color interval: $0.53 < Y - V < 0.59$. Large-scale differences between these photometries are within $\pm 1\%$.

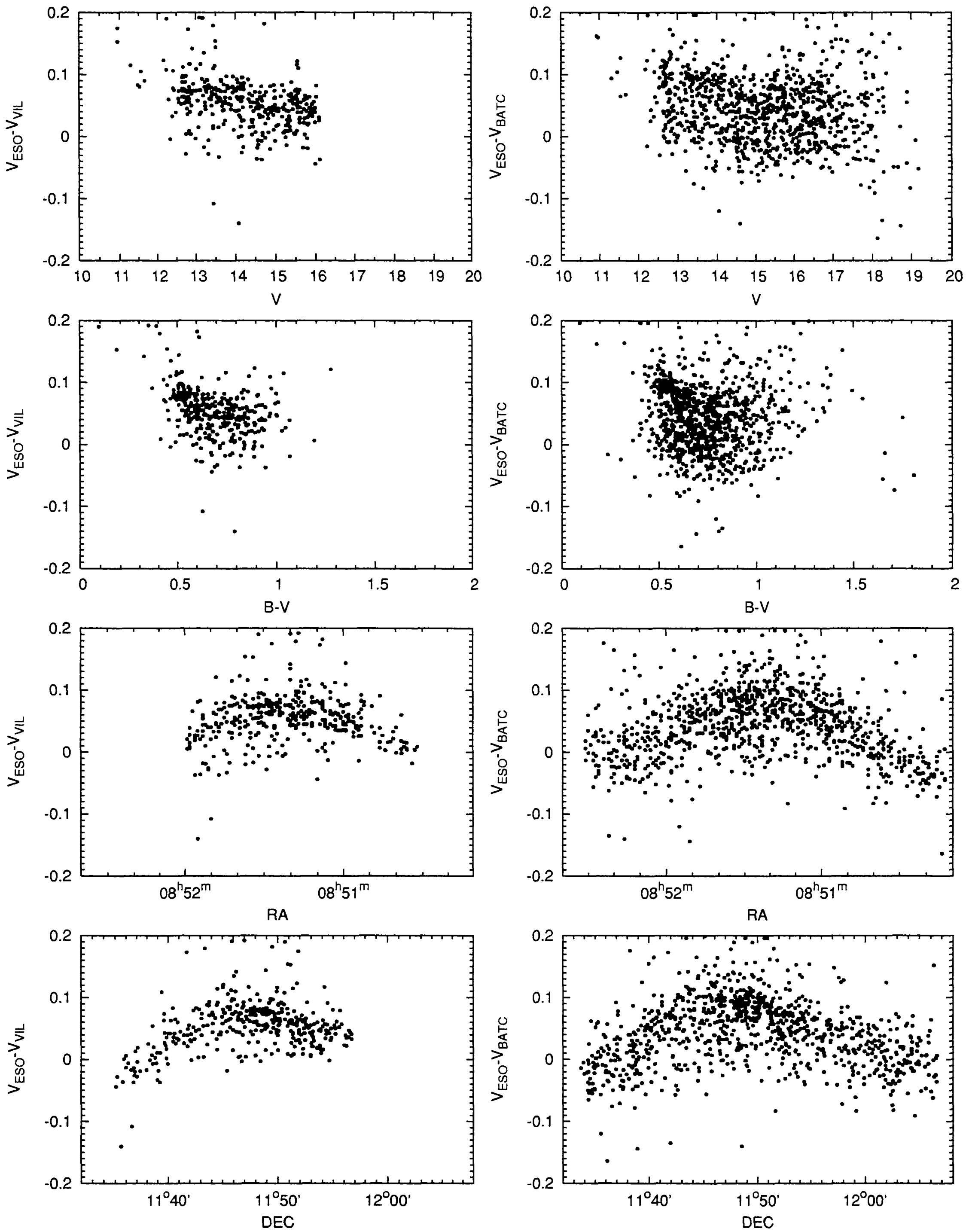

Fig. 2. Differences between $V_{\rm ESO}$ and $V_{\rm VIL}$ (left panels), and between $V_{\rm ESO}$ and $V_{\rm BATC}$ (right panels). Large-scale systematic errors up to 10% are seen in the ESO data.

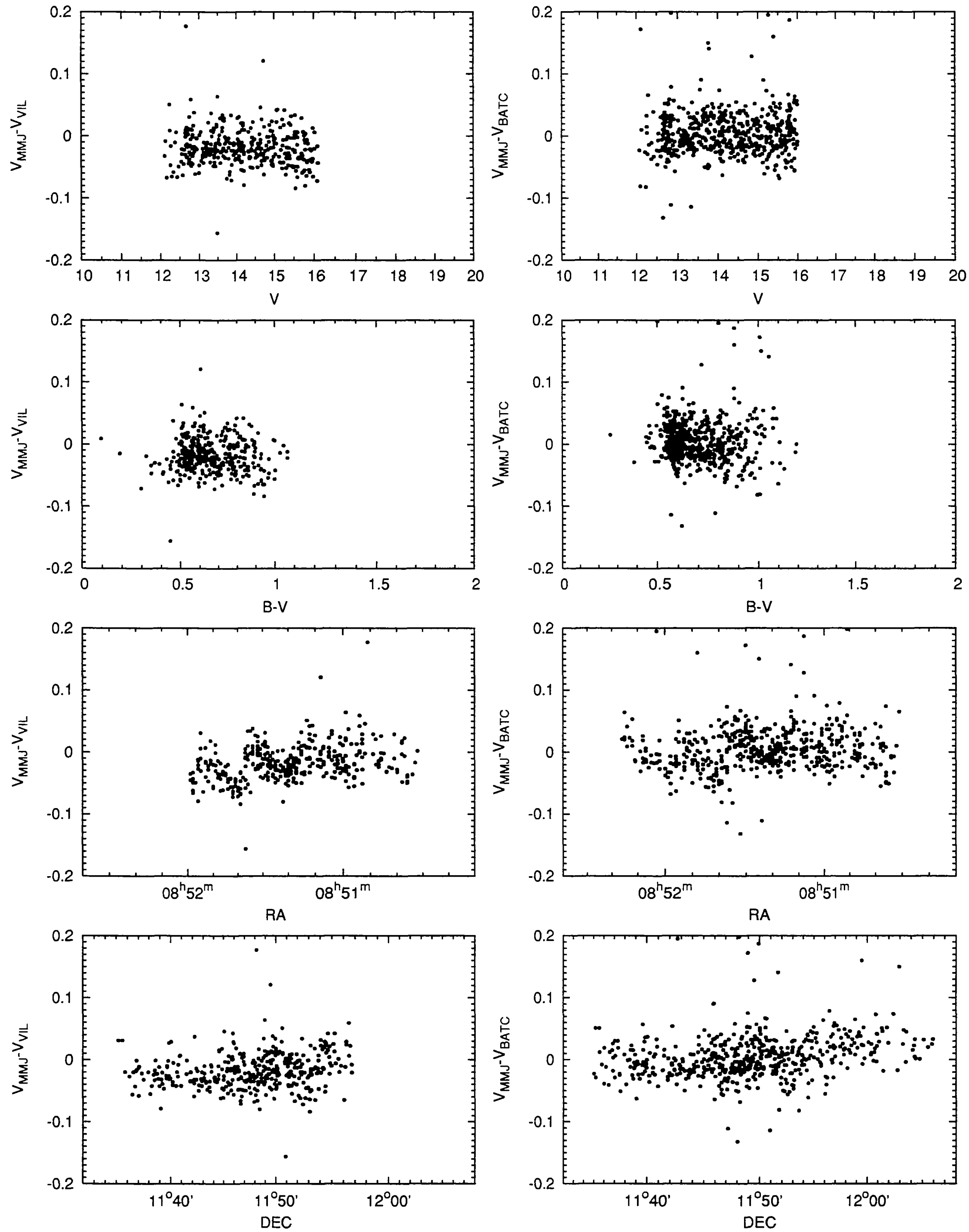

Fig. 3. Differences between $V_{\rm MMJ}$ and $V_{\rm VIL}$ (left panels), and $V_{\rm MMJ}$ and $V_{\rm BATC}$ magnitudes (right panels). This comparison reveals in MMJ photometry 5–6% large-scale systematic errors along RA.

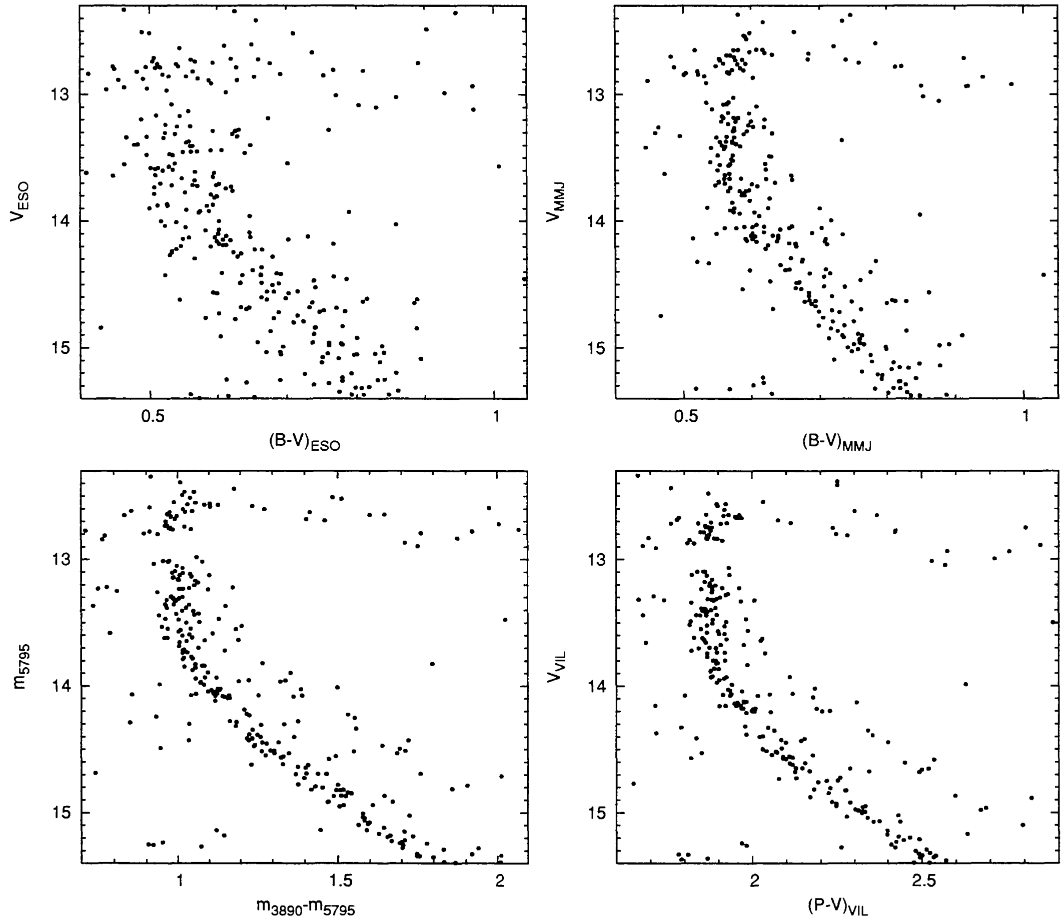

Fig. 4. The CMD diagram of M 67 near the MS turnoff for stars in common to Vilnius, BATC, ESO and MMJ datasets. The sharpness of gaps in the MS at $V \approx 13.0$ and 14.2 mag and the sequences of subgiants and binaries can be used as the indicators of photometric accuracy.

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