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MULTIBAND PHOTOMETRY OF SELECTED AREAS IN A STUDY OF GALACTIC STRUCTURE

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ABSTRACT. The BATC (Beijing-Arizona-Taipei-Connecticut) intermediate-band 15 filter photometry system has been tested by using the Michigan Curtis Schmidt telescope at CTIO taking one-degree fields around NGC 288, SA 92, 94, 95, Lp 543-32/33. BVRI and uvby, Hβ filter observations of these same fields were also made using the 0.9 m CTIO telescope. The main purpose of these observations is to compare the results from the standard filter color systems (UBVRI and ubvy, Hβ) to those we can construct from the BATC filter system. These fields were chosen based on available filter color data in those systems. The BATC data are being taken on a Schmidt telescope similar to that at CTIO, so that these observations can provide an independent source of calibration for the BATC data. This is a report on the status of this study.

Key Words: Techniques: photometric – stars: fundamental parameters – Galaxy: structure

1. INTRODUCTION

The observational goal of the BATC survey is to obtain accurate spectral energy distributions (SEDs) of all objects - stars, galaxies, AGNs - found in 500 selected 1-degree fields in the northern hemisphere. The scientific goals of this survey are many, spanning galactic structure, stellar populations, structure of galaxies, interstellar medium of galaxies, active galaxies and cosmology. The telescope used for this survey is the 0.6/0.9 m Schmidt telescope of the Beijing Astronomical Observatory, located at its Xing Long Station, 150 km NE of Beijing. We have designed a new intermediate band filter system to cover the wavelength range 3360 Å to 1 micron, avoiding bright night sky features in the near-IR, and emphasizing galactic and extragalactic studies in the blue and UV. The passbands for the filters are presented by Fan et al. (1996).

Two sets of filters have been made, one to be used on the BAO Schmidt telescope, the other to be used separately for related programs, including calibrations of the survey data. The Michigan Curtis Schmidt telescope at CTIO and the BAO Schmidt are approximately of the same aperture, f-ratio and focal plane CCD pixel size. A full description of the observatory site, BAO Schmidt, CCD and data-taking system are described in Chen et al. (1996). The first calibration and testing of this system was made using observations of the open cluster M 67 (Fan et al. 1996). The BATC survey is designed to be calibrated on an absolute flux scale using Oke and Gunn (1983) spectrophotometric standards as primary calibrators, and developing secondary calibrators from our own observations.

The present study uses the second BATC filter set to begin defining the relationship of our filter system to the more standard color systems in use today. By establishing these relationships both empirically and theoretically, the usefulness of the BATC survey data can be expanded to include accurate UBVRI and uvby, Hβ colors of stars and galaxies. In so doing, we can make use of the extensive literature that explores the physical properties of stars using these filter systems.

2. OBSERVATIONS AND ANALYSIS

Two CTIO telescopes were used for these observations. The BATC filters were used with the Michigan Curtis Schmidt telescope. The angular resolution of the 2048 x 2048 CCD on this telescope is about 2"/pixel, compared to a resolution of 1$''\!.$67/pixel for the BAO Schmidt CCD system. In both cases, the field of view is about 1 square degree. The large pixel size means typical good seeing at CTIO ($<$ 1$''\!.$5 during our run) will undersample the seeing disk in the CCD image. As such a problem also affects the BATC data, these observations give us a separate data set against which we can test our methodology of stellar photometry. We also used the 0.9 m telescope to observe the same fields with UBVRI and uvby, Hβ filters, so as to have complete data for the comparison.

With both good weather and excellent support from CTIO staff, we were able to observe all five fields in all 15 BATC filters over a three night period, 29 - 31 October 1995. Simultaneously, we also observed with the standard filter sets on the 0.9 m. The BATC filters were divided into three sets of five each, as detailed in Table 1. In each set we placed filters with a range of central wavelengths, so as to reasonably cover the spectrum each night. The typical observing time per image for each part of the spectrum is given in Table 1 using the CTIO Schmidt Telescope. Sky flats were obtained at the beginning and end of each night; bias and flatfield exposures were obtained in the usual manner during the day. Broad band and uvby, Hβ measures were obtained with the 0.9 m Telescope.

The majority of the images were reduced at the Institute of Astronomy (Chung-Li, Taiwan), using DAOPHOT II and ALLSTAR. About 50 stars were used to define the point spread function (PSF) in each image. The mean FWHM of the PSFs for this was 2". The data reduction was also carried out at the Center for Galactic Astronomy (WCSU) for many images. At the present

TABLE 1. Central wavelengths of filters in BATC sets observed in 1995

Night	#	CWL	#	CWL	#	CWL	#	CWL	#	CWL(A)
10/29/30	1	3360	4	4550	7	5795	10	7050	13	8480
10/30/31	2	3890	5	4925	8	6070	11	7490	14	9190
10/31/01	3	4210	6	5270	9	6660	12	8020	15	9745
Exp(s)		~1200		~900		~700		~500		~400

time, only the data in the NGC 288 field have been calibrated in all standard filter passbands. The overall photometric accuracy is about ±0.024 in magnitude and ±0.028 mag in color for UBVRI, and ±0.017 in mag and ±0.023 in color for uvby, Hβ and ±0.06 in mag and ±0.1 in color for BATC data We expect to obtain ±0.01 accuracy for the BATC filters eventually.

It is desirable to obtain more than one exposure with each BATC filter, for cosmic ray removal and related issues. In the case of the blue and the UV filters, multiple images are needed to go as faint as for the red filter. However, the Schmidt telescope had occasional guiding problems which limited how many exposures could be taken in this run. As a result, the limiting magnitude in each filter is not optimum, and the total number of stars detected in each field in each filter varies. This is shown in Fig. 1 for Sa 92.

In attempting to combine all filters, we find that the number of point sources (stars and AGNs) in coincidence among the 15 filters is a monotonically decreasing function of the number of filters used. This is shown in Fig. 2a for the NGC 288 field, and is consistent with what we found in the M 67 study (Fan et al. 1996). The total number of stars for any two filters merged together is about 4500 stars in the NGC 288 field, declining to about 400 stars to be found at the same position in all 15 filters.

The effect due to stars of different colors is particularly important, as is shown in Fig. 2b. Here we show the total number of stars in other BATC filters in common to one BATC filter (m7, centered at 5795 Å magnitude and equivalent to V mag) in the NGC 288 field, for instrumental magnitudes 12 to 22. Also shown are the number of stars detected in each filter, independent of being in common with another filter. As can be seen, the number of stars in common with the filter m7 image decreases both to the blue and the red. Interestingly, it is the difference, total number of stars/filter detected minus stars in common with m7 filter, that remains approximately constant, rather than the ratio. This is consistent with what we see in Fig. 2a.

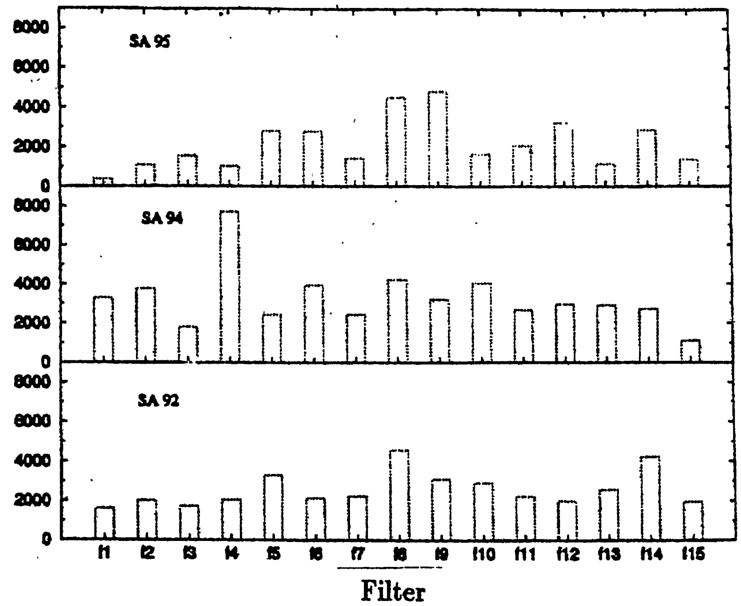


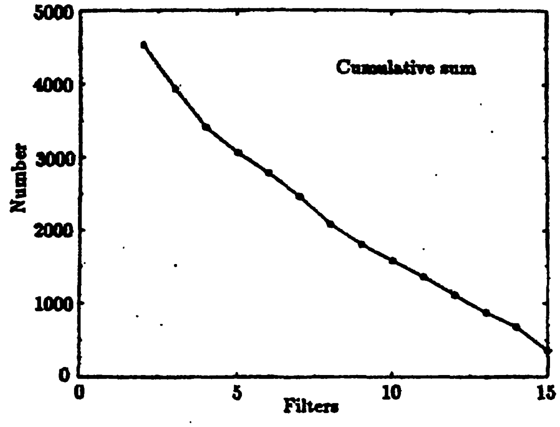
Fig. 1. Numbers of stars by BATC filter

Unfortunately, these trends are not surprising. Random noise sources, including cosmic rays and bad pixels, ensure a loss of stars for each image added. Stars with a range of color ensure differences in the detected stars near the mag- nitude cutoff for each filter. This is one reason we desire to obtain the same magnitude limit per filter. Multiple exposures per filter that are "dithered" can eliminate some of these problems, but not all.

Separately, Fig. 3 shows the distribution of stars detected as a function of instrumental magnitude per filter for the SA 92 field. As is evident, we detect mostly red objects among the brighter point sources, mostly objects that are either blue or of intermediate color at the faint end. As this kind of difference is also seen in the other fields observed, this indicates that our integration times for the near-infrared filters is too short by a wide margin (see Table 1). On future observing runs, integration times will be increased to be equal to the UV filters.

3. RESULTS AND SUMMARY

Fan et al. (1996) discuss a number of tests done with the BATC filters in the M 67 field, using the BAO Schmidt telescope and the first BATC filter set. For the present observations our ultimate goal is to calibrate the second BATC



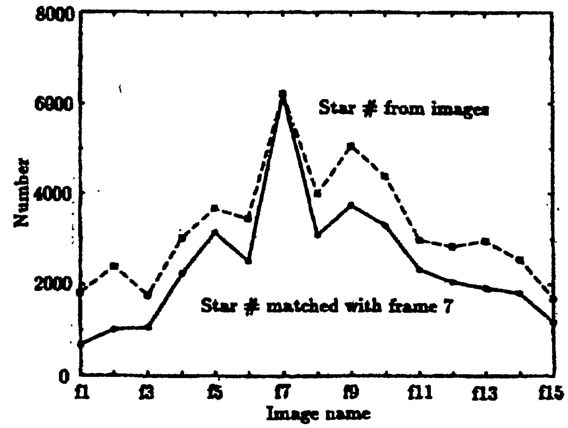


Fig 2a. NGC 288. Merge # by filter.

Fig. 2b. Number matched with m7.

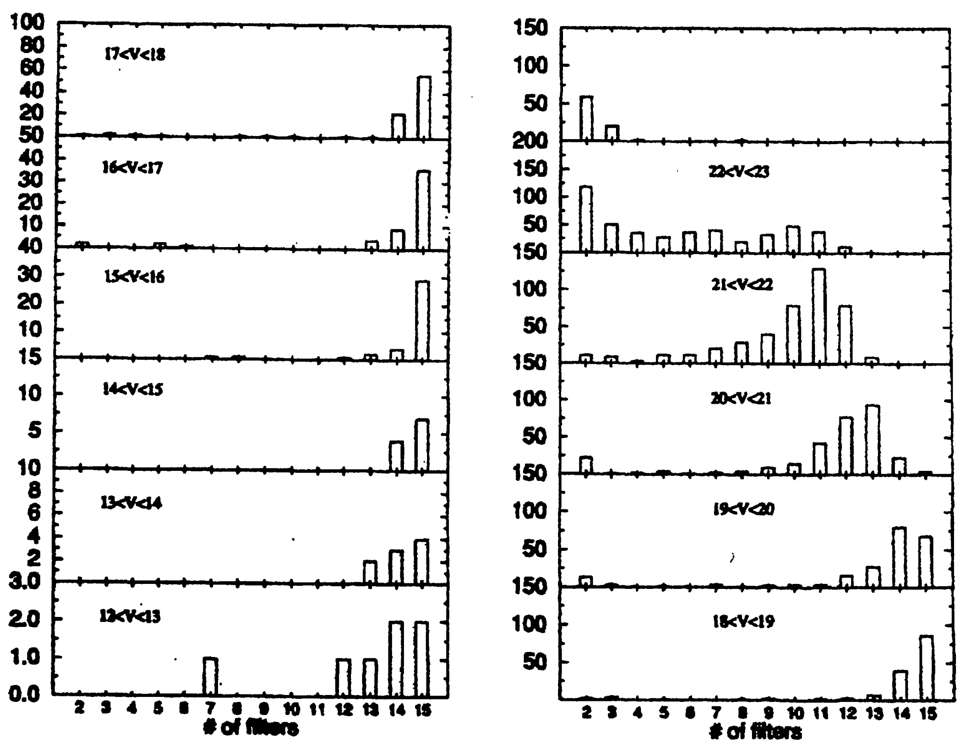


Fig. 3. SA 92 # distribution by magnitude and filter.

filter set to the first set as accurately as possible. This goal is yet to be met, but we can still examine the relative accuracy of our data using the preliminary calibrations to UBVRI and uvby, Hβ systems. BATC filter m7 (5795 Å) is that closest to the V passband, and filter m4 (4550 Å) is closest to the B passband. Similarly m7 is closest to Strömgren y, m5 (4925 Å) to b and m3 (4210 Å) to v.

Color-magnitude diagrams for the full one square degree field in terms of the V - (B-V) BATC equivalent, m7 versus (m4 - m7), for SA 92 and SA 95 show no unusual distributions. The scatter in these diagrams is as expected for an arbitrary galactic field, and color cutoffs at the red and blue end are evident (cf. Fan et al. 1996.). We note that in our instrumental magnitudes, the mean colors of stars in SA 92 are substantially bluer than in SA 95, and the magnitude cutoff is fainter. This difference is consistent with the difference in V mag extinction for these two fields, which is predicted to be 0.41 mag by using the Burstein and Heiles (1978) method. Such a large difference in extinction can also lead to systematically sampling different parts of the Galaxy in magnitude-limited data.

The color magnitude diagrams of the Strömgren system, y vs b-y for the field around NGC 288 (Chen 1996), have been compared with the BATC filter system, m7 vs m4 - m7, B-V for a one half square degree field. The major features of the color magnitude diagram of the field around a well-studied globular cluster have been reproduced (cf. Bergbushc 1993, Montgomery and Janes 1994). The scatter is larger using the BATC filters owing to the coarser current calibration of these data and problems relating to the undersampling of the seeing disk. Relative to the known scatter, the BATC data reproduces the uvby data fairly well. A CM-Diagram (m7 vs m4 - m7 is shown in Fig. 4.

This paper is but a brief introduction into the kind of analysis and science we intend to do with the BATC filter set, both in the survey itself with Set 1, and using Set 2 to pursue selected topics. We expect to report at a later date the scientific results that will come when the BATC filter data are fully calibrated.

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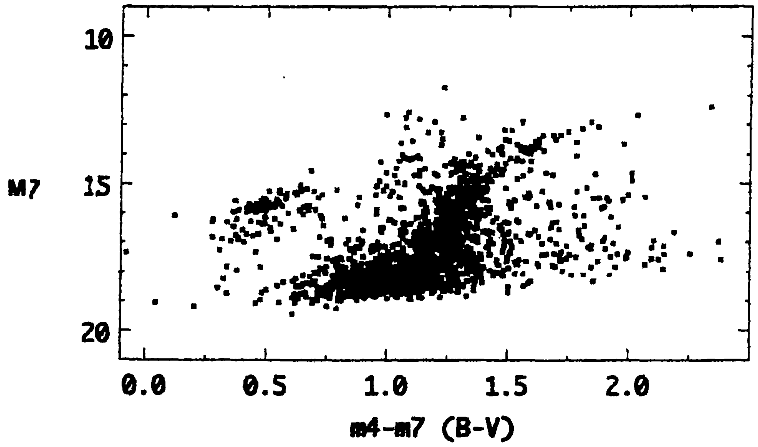

Fig. 4. m7(V) versus m4 - m7 (B-V) for NGC 288.

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