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BATC SURVEY : AUTOMATED PHOTOMETRY AND STRATEGY FOR OBJECT CLASSIFICATION, REDSHIFT, AND VARIABILITY

YONG-IK BYUN
Institute of Astronomy, National Central University, Chung-Li, Taiwan
and
Beijing Astronomical Observatory, Chinese Academy of Sciences, China

ABSTRACT

Beijing-Arizona-Taipei-Connecticut (BATC) survey is a long term project to map the spectral energy distribution of various objects using 15 intermediate band filters and aims to cover about 450 sq degrees of northern sky. The SED information, combined with image structure information, is used to classify objects into several stellar and galaxy categories as well as QSO candidates. In this paper, we present a preliminary setup of robust data reduction procedure recently developed at NCU and also briefly discuss general classification scheme, redshift estimate, and automatic detection of variable objects.

Key Words : methods: data analysis; stars, galaxies, quasars : photometry

I. INTRODUCTION

The observational goal of the BATC survey is to obtain accurate spectral energy distribution (SED) of all objects down to V=20 mag in ~450 square degree field of the northern hemisphere. A set of 15 intermediate-band filters of 200~300Å bandwidth is used to obtain SED from 3200Å to 1 μ covering the entire visible range. The survey is being carried out by the 0.6/0.9m f/3 Schmidt telescope of the Beijing Astronomical Observatory located at a dark site 150 km northeast of Beijing. With a Ford Aerospace 2048 × 2048 CCD, the plate scale is 1.67″ per pixel and the CCD covers a sky area of 0.9 square degree. This telescope has been modernized to include computer interface for telescope drive, dome and filters, permitting essentially automated finding and exposures of program fields. Full details of system description can be found in Chen et al (1996). Early results from the present survey are presented in Fan et al (1996), Shang et al (1996), and also in Chen (1996, this conference); these studies have proven the high quality of our large field photometry.

We are now gathering a large amount of observational data for a total of 500 program fields, from which we expect to have SED information for more than 2 million objects. With 5 to 10 exposures per each of 15 filters, each target field has about 100 images making the total number of frames $\approx$ 50,000. There are variety of information we plan to extract from this large set of images, but the primary task is to determine magnitude and color of every stellar objects efficiently and accurately.

In the present paper, we describe a pipelined procedure for fully automated photometry, which is being developed at the Institute of Astronomy, NCU, to handle the vast inflow of BATC data archive. This procedure does not require close human supervision, yet produces magnitude information of desired accuracy. With reliable magnitude information, we can pursue several scientific goals intended by the survey. We briefly discuss how we use our spectrophotometric data to classify field objects and identify active galaxies and QSO's, to derive approximate redshifts of galaxies, and to identify variable objects in the program fields.

II. AUTOMATED PHOTOMETRY

We employ DAOPHOT II (Stetson 1995) as a basis of our photometry. The advantage of DAOPHOT is that the point spread function (PSF) is constructed using both the observed PSF of bright stars and analytic approximation of stellar core. The use of analytic approximation reduces interpolation errors associated with critically sampled or undersampled PSF and the adopted stellar wings are more realistic as they come from bright stars in the same field.

DAOPHOT generally requires close human attendance for several critical steps, however we use it in such a way that all the photometry can be done automatically. Most of our program fields are not very crowded; this greatly helps the automation of DAOPHOT photometry. Iterative procedures are placed wherever needed to mimic human judgment. The user supplies the list of images, then the program returns aperture-calibrated instrumental magnitudes and image parameters for each of the input images. The program provides a concise report of performance and a list of encountered problems for each image. It also provides a diagnostic diagram which shows distribution of several photometric parameters as a function of magnitudes. A small diagnostic image is also constructed to show the original and residual images of two dozen bright stars. The user can evaluate the quality of photometry at a glance.

Instrumental magnitudes of input frames are subsequently combined to form a single SED database for the given BATC field. Objects are identified and matched in multiple frames via coordinate transformation. Magnitude transformation then follows to bring non-photometric data to photometric data, and to calibrate the magnitudes to the standard system of AB95 (Fukugita et al. 1996). For a typical target field, the observational random error is smaller than 0.02 mag for V$\lesssim$18.0 mag objects, increasing to 0.10 mag for V$\approx$20.0 mag objects.

III. OBJECT CLASSIFICATION, REDSHIFT, AND VARIABILITY

BATC survey produces a library of SED for all objects in the program field. The SED library is used to classify objects into several different groups; this is done in multiple stages. First, the SED library goes through a detection routine for strong emission features. Objects of this class include QSO and active galaxies as well as compact galactic emission nebulae. The exact nature of the source is being studied by followup spectroscopic observations. The SED library of remaining objects is processed by a χ^2 minimization routine for further classification. This routine uses several sets of template spectra such as Gunn & Stryker (1983)'s spectrophotometric atlas of galactic stars and Kurucz (1995) model atmospheres. We attempted to separate stars and galaxies of different Hubble type, using the templates of Kinney et al (1996), but the similarity between stellar and galaxy SED often results in ambiguous classification. The SED based star-galaxy separation is now being aided by FOCAS (Javis & Tyson 1981), which classifies objects by their image structure, i.e. departure from PSF.

For galaxies and QSOs, we can also derive their redshifts from the SED information. Similar technique has been proposed and used for broad band photometry (Koo 1985, Connolly et al. 1995) and also for narrow band photometry (Cabanac and Borra 1996). For QSOs with strong Lyman α emission, it is straightforward to estimate the redshift from the location of detected emission feature in BATC SED. For galaxies, we are using cross-correlation technique with a set of template spectra.

The multiple exposures taken for each program fields have time intervals ranging from minutes to years. Therefore we can identify various variable objects and construct light curves. The classical blinking method is highly inefficient and the detection gets very dubious when there is significant difference in seeing conditions. We use a new technique adopted from the recent work of Welch & Stetson (1993) and Stetson (1996). For each object, two independent photometric errors are derived, from the estimates of PSF fitting error and from the observed scatter among multiple exposures. The ratio of these errors turns out to be highly efficient not only for the identification of variable objects, but also to avoid false detection of emission line objects and peculiar SED objects.

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