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THE PROGRESS OF BATC PROJECT

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ABSTRACT

The large field multi-color CCD sky survey program based on the 60/90 Schmidt telescope of NAOC has been processed in cooperation among many observatories and universities of Asian countries. The observation and scientific results are reviewed.

Key words : observation: survey — observation: photometry

I. INTRODUCTION

The Beijing-Arizona-Taiwan-Connecticut (BATC) large field multi-color sky survey has been carried out for more than 10 years. BATC is a long term informal cooperation program where many astronomers have been involved. They present many institutes and universities of China mainland and China Taiwan, Korea, Japan and United Stats (see the author list of published BATC papers).

The initial observational goal of the BATC Survey is to do spectrophotometry from 3300 Å to 1 μ of all objects found within hundreds pre-selected areas of about 1 deg^2 in the northern sky, to an effective magnitude limit of V = 21, using the 0.6 m Schmidt telescopes of the National Astronomical Observatories of China (NAOC) with specially designed intermediate and narrow band interference filters. One third of the preselected areas are centered on quasars of known properties, another third of the areas are centered on bright, nearby spiral galaxies, and the rest are randomly selected including areas centered on calibration objects (star clusters; spectrophotometric standard fields, etc.). The main scientific goals of our survey are to discover high-z quasars, to study the stellar population of nearby galaxies and to study the Galaxy structure by star counting.

Various kinds of observations and studies were performed during last years, depending on the character of the photometric system, interests of the astronomers and the weather conditions. Those include the QSO survey, nearby galaxy clusters and galaxies, the stellar cluster in the Galaxy and near by extra-galaxies, supernovae, HH objects, comets and minor planets. Until now, more than 80 papers based on the BATC data have been published or accepted for publication.

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II. OBSERVATION

The BATC photometric system includes the 60/90 cm f/3 Schmidt Telescope of National Astronomical Observatories (NAOC), located at the Xinglong station, altitude 900 m, about 150 km north-east from Beijing, China. A full description of the NAOC Schmidt, CCD and the data-acquisition system, and a definition of the BATC filter system is presented elsewhere (Fan et al. 1996; Zhou et al. 2001). A Ford 2048×2048 CCD camera was attached to the prime focus. The field of the image covers 0.95 deg^2 of sky with 1.7″/pixel. The BATC 15 intermediate-band filters cover the whole optical wavelength range from 3000 Å to 1 μ. (Zhou et al., 2003). The filters have a band width of 200-300 Å, and block bright sky lines. The narrow band filters isolate well-known emission line features such as Hα and O[III].

Almost all nights were thought to be photometric by the observers. The standard stars were observed between air-masses 1 and 2 for each programmed filter band. Normally 4 to 6 filters were selected to make flux calibration during each photometric night. The extinction coefficient and the magnitude of the zero point obtained from standard stars were used for making the flux calibration on BATC field images (Zhou et al. 2001). Because the number of good photometric nights is not enough to calibrate all the BATC field in 15 colors, we have also developed a method of relative flux calibration and have been successfully used in many field (Zhou et al. 1999).

The observation process can be remotely monitored from BATC web site and the observation can be controlled from anywhere via the internet with the BATC remote interface.

III. GALAXY CLUSTERS

Multi-color observations of a galaxy cluster provide important constraints on the formation of large-scale structures and cosmology. The investigation of the luminosity function and the spectral features of the member galaxies in a rich cluster can be used for understanding not only the structures and dynamics of the cluster, but also the formation and evolution of galaxies in a dense environment.

Spectral observations in the optical band are the most straightforward and powerful approach for the membership determination. However, reliable spectroscopy for the faint galaxies in a cluster is still a difficult task even for large telescopes. With the development of our photometric redshift technique (Xia et al. 2002), the redshifts of faint galaxies can be fairly well determined based on their spectral energy distributions (SEDs). The method of photometric redshift have been successfully applied in the analysis of a galaxy cluster Abell 566 (Zhou et al. 2003).

We have also added the SDSS 5 color photometric data to BATC data. The composed SEDs are used for analyzing many nearby galaxy cluster such as Abell 2255, Abell 168, Abell 339 and Abell 401. The structure, luminosity function and the history of the cluster evolution are studied (Yuan et al. 2003). For Abell 168, our investigation implies that it is likely to be a head-on merging system at the early stage of the process and that the collision plausibly occurs along the direction perpendicular to our line of sight (Yang et al. 2004a,b).

Now, we are observing a sample of galaxy clusters which show interaction and merging effects.

IV. NEARBY GALAXIES

For individual nearby galaxies, deep photometries were done on edge-on galaxies. Two BATC filters, centered at 666nm and 802nm, are used to make deep observation. The flux level where the errors of observation reach 1 mag arcsec^{-2} are 29.0 and 27.4 in the combined images of the two bands. In the images, we have found that NGC 5907 has a luminous ring around it, which is most plausibly caused by the tidal disruption of a dwarf spheroidal galaxy by the much more massive spiral (Shang et al. 1998). We show that, for values fainter than 27 R mag arcsec^{-2}, the surface brightness around NGC5907 is strongly asymmetric. This asymmetry rules out a halo as the cause of the faint surface brightness we see. We found this asymmetry is likely to be an artifact resulting from a combination of ring light and we conclude that NGC 5907 does not have a faint extended halo (Zheng et al. 1999). The existence of very faint surface brightness features around edge-on spiral galaxies is further investigated with BATC observation of the well-know galaxy NGC 4565. We find the axis ratio of the halo to be 0.44 and its core radius to be 14.4 *kpc*. We also agree with others that the bulge of NGC 4565 is fitted well by an exponential luminosity distribution with a scale height similar to that found for the thin disk (Wu et al. 2002). From a similar work on the elliptical galaxy M87, the cD envelope can be clearly seen around this giant elliptical galaxy (Liu et al.,2005, submitted).

The BATC multi-color photometry is able to provide accurate SEDs for local areas of the whole galaxy. As the first work of our series on galactic structure, Kong et al.(2000) presented the observation and data reduction of M81, and gave the distributions of age, metallicity and reddening with the SSPs of GISSEL96 (GSSPs). Then, we continue our study on the structure and the evolution of M81 with PEGASE on the basis of Kong et al.(2000). Unlike GSSPs, PEGASE affords an evolutionary spectral synthesis and can give the evolutionary history of the galaxy. By comparing in detail the fitting results using different forms of SFR in PEGASE, we find the exponential form of star formation (ESF) is appropriate to describe the evolution of M81 (Li et al. 2004a). A similar work has been done for M33, too (Li et al. 2004b). Now, we are trying to study interactive galaxies, such as M51 and M52, with the stellar population analysis.

The field star photometry in BATC data base is very useful for studying the structure and formation of the main components of the Galaxy. Du et al.(2003) provided information on the density distribution of the main components of the Galaxy that can be used to impose constraints on the parameters of models of the Galactic structure. By using F and G dwarfs from the BATC survey data only, we obtained the metal abundance information. The main-sequence lifetime of F- and G-type stars is longer than the age of the Galaxy, and hence the chemical abundance distribution function of such stars provides an integrated record of the chemical enrichment history. Based on synthetic flux spectra calculated from theoretical atmospheric models, the calibration of temperature and metallicity for the dwarfs was performed. The metallicity gradient was found to be -0.37 dex kpc^{-1} for $Z < 4$ kpc and -0.06 kpc^{-1} between 5 and 15 kpc. These results can be explained in terms of different contributions in density distribution to Galactic model "thin disk", and "thick disk" and "halo" components (Du et al. 2004).

In the field of M81 and M82, recently, we found a wide stellar distribution similar to the HI observation and the simulation of the tidal effect.

V. STELLAR CLUSTERS

Since a single star cluster is a luminous packet comprising stellar populations with a single age and chemical abundance, it can be used to study the ongoing and past star formation of the host galaxies. The globular clusters can give clues about the earliest epochs of their host galaxies, and young clusters can provide insight into the chemical evolution and star formation history of the parent galaxies. The studies of the star cluster populations can be used for get the relationship between cluster formation and the physical morphology of the host galaxies.

For the study of stellar clusters in the Galaxy, we have developed a new method of age and metallicity determination by full SEDs of BATC data (Wu et al., 2005), replacing our previous work based on HR diagram (Fan et al. 1996). This method is now used for the study of many open stellar clusters.

For the known stellar clusters and HII regions in nearby extra-galaxies, our result shows that the formation of globular cluster in M33 is different from our Galaxy (Ma et al. 2001, 2002a,b,c,d, 2004a,b), but M31 has apparently been formed globular at roughly almost 10 Gyr ago (Jiang et al. 2003). That means the local environment plays a very important role in the formation and evolution of the galaxies.

VI. SUPERNOVAE

From the beginning of BATC program, we have monitored supernovae with BATC photometric system (Zhou et al. 1993; Wu et al. 1995). The observations were performed in a set of intermediate-band of BATC filters that have the advantage of tracing the strength variations of some spectral features. By using 10 years data of SN1993J, we found that SN1993J faded very slowly at late times, declining only by 0.05 ± 0.02 mag per 100 days in most of the filters from 2 to nearly 10 yr after discovery. Our data suggest that the circumstellar interaction provides most of the energy that powers the late-time optical emission of SN1993J. This is manifest in several flux peaks seen in the rough spectral energy distributions constructed from the multicolor light curves. The flux peaks near 6600 Å, 5800 Å, and 4900 Å may correspond to the emission lines of Hα, NaID+HeIλ5876, and [O III] $\lambda\lambda$4959, 5007, respectively. The evolution of these emission lines suggests a power-law SN density model (Wang et al. 2004; Zhang et al. 2004). Until now, we have collected the light curves of about 30 supernovae that including 2004DJ. It is located in spiral galaxy NGC2403, which was one field of BATC multicolor sky survey during last 9 years. The SED from 14 intermediate-band allows us to know that the SN progenitor should have a main-sequence star with 12 $M_\odot$ and in a cluster of 18.6 Myr (Wang et al. 2005, Submitted to Science).

VII. THE OTHER RESEARCH WORKS

The other research works include doing observation and study of variable stars in open clusters (Zhang et al., 2002, 2003, 2004) and in field stars (Li et al. 2004), discovering HH objects in big nebular of our Galaxy (Wu et al. 2002; Sun et al. 2003), discovering QSO and monitoring AGN (Peng et al. 2003; Wu et al. 2004; Zhang et al. 2004; Wu et al. 2005), the photometric and discovering observation of asteroids (Yang et al. 2003a,b; Zhu et al. 2002; Gao et al. 2002), multi-color monitoring comets, astrometry (Yu et al. 2004) and site quality monitoring (Liu et al. 2003).

VIII. THE SYSTEM IMPROVEMENT

We have improved the instrument, developing method of data reduction (Zhou et al. 2003, 2005; Yang, 2002) and making our observational system more and more automatic. We can monitor the observation in real time from BATC internet web page (http://batc. bao. ac. cn/cgi-bin/obslist/obsstatus. cgi) and make remote control observation.

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