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YSTAR : Yonsei Survey Telescopes for Astronomical Research

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Abstract. The YSTAR program is a general sky survey looking for variability. The main equipments are three 0.5-m telescopes. These telescopes have fast F/2 optics covering nearly 3.5 square degree field onto a 2K CCD. They also have very fast slew capability, which exceeds 10 degrees per second. These two factors make them most suitable for rapid target acquisition and wide-field surveys of various kinds. Our primary objective is to identify and monitor variable stars down to 18th R-magnitude, and our observing mode allows the same data set to be also useful in identifying asteroids. Our first telescope has just begun regular automated operation, and the second telescope will be installed in South Africa within this year to provide coverage of the southern sky.

1. Introduction

We have been preparing an observational program to catalog and monitor variable events in both northern and southern hemispheres. The program is starting with three 0.5-m wide field robotic telescopes and, contingent on funding, we intend to increase the number of our survey telescopes and place them around the globe. The observational and computational facilities involved in this project are named as YSTAR (Yonsei Survey Telescopes for Astronomical Research). This will be the major observational campaign of Yonsei University Observatory (YUO) in the coming years.

Sky surveys have been made in various wavelengths in the past, both from the ground and from the orbit. Variability of different kinds have also been investigated from such survey data. However, as expressed by several contributions in this conference, there is still a very large area left for further explorations. In fact, the vast majority of variable phenomena has never been properly investigated. Instead of going into the details here, we would like to encourage the readers to read Paczynski (2000) and references therein, which are in our opinion the best starting places for the subject.

Variability monitoring requires time-series observations, which give the opportunity to look for both photometric variability and positional variability. The former involves identification and light curve study of variable stars and galaxies, as well as transient events such as Gamma Ray Bursts (GRB), planet transits,

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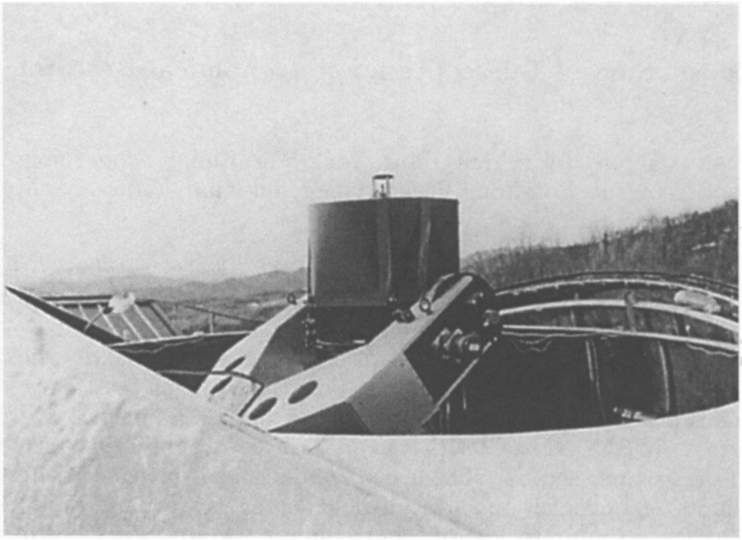

Figure 1. YSTAR No.1 telescope installed in the Chun-an site

and microlensing events. The latter usually involves the detection and tracking of asteroids and comets.

The advanced digital detector technology, computer controlled robotic operation, and high speed computing capability for photometric analysis are now making it possible to carry out an all sky survey with unprecedented photometric accuracy. Such attempts have recently been made with small aperture instruments, no larger than 10-cm in diameter, nevertheless still producing thousands of new variable star discoveries (see Pojmanski 2000, Akerlof et al. 2000a) and the first optical detection of a GRB during the actual burst (Akerlof et al. 2000b).

YSTAR project shares the same goal as these studies, i.e. monitoring of all sky for variability, but aims to reach somewhat fainter photometric depth with larger aperture. Our telescopes will fill the gap between existing small aperture surveys and future big aperture surveys, which will cover the much fainter and more distant universe.

2. Telescopes

Our 0.5-m telescopes, manufactured by Torus Technology in Iowa, are identical to those designed by the TAOS project team (Taiwan American Occultation Survey, see King 2001) except in minor details. The optical configuration of this hybrid Cassegrain uses an F/1.5 parabola primary, a large spherical secondary, and a field corrector consisting of 5 lenses. The FOV onto a 2K CCD of 14-micron pixel is nearly 3.5 square degrees. The CCD is attached to a 10 position filter wheel. The filter wheel contains B, V, R, I broad band filters and three

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interference filters of H-alpha, [SII], and continuum. We intend to carry out most of our routine observations in R-band, occasionally using other broad bandpass for standard star calibrations.

The telescope drive system, based on friction drive with DC servo motor, has a capability of very fast slew speed over 10 degrees per second. This feature makes the telescope ideal for observations which require immediate pointing. GRB followup observations are good examples. It also contributes to reduce the down-time for our scheduled survey observations; the telescope can usually point and stabilize at the next target position during the few seconds it takes to read out the CCD.

The telescope control system is connected to a GPS, a weather station, and an enclosure control. We are presently developing a cloud monitoring device as an added safety measure. The control computer is connected via internal Ethernet network to a group of on-site computers for near real-time data processing and mass storage.

3. Observing Strategy

With the present FOV of YSTAR telescopes, the entire sky can be covered by 14916 Target Fields (TF) with slight overlap between them. This is still too large a number for efficient observation management. Therefore we grouped them into 452 Target Clusters (TC) according to their positions, each TC containing 33 TFs. The scheduling and survey progress monitoring are automated based on the TC list and their mean coordinates.

Each observation of a TC involves three consecutive coverages of all TFs in the given TC. With a typical exposure time of 30 seconds for each frame, the total time required to finish a TC is somewhat more than 1 hour, and this can be adjusted by changing the exposure time or by grouping two TCs into one as needed. Three exposures with nearly equal time intervals become useful data to search for moving objects, while providing opportunity to detect brightness variabilities of relatively small time scales.

The data processing pipeline is divided into an on-site operation and an off-site operation. On-site operation includes basic image preprocessing such as bias, dark, and flats. The astrometric plate solution and estimate of image quality are made almost immediately after each exposure. The on-site operation includes data pipelines for photometric and astrometric analysis. This consists of two independent phases; the first being based on Sextractor (Bertin & Arnouts 1996) for near real time data reduction and the second procedure based on DAOPHOT (Stetson 1987). The Sextractor provides quick and robust source detection and photometric data, which are very useful to identify candidates for moving objects and also for objects with significant brightness changes. Alerts are generated based on the Sextractor outputs, and transmitted to the YSTAR home institute via Internet together with small postage images extracted from the data frames for visual verification. The DAOPHOT routines run during daytime only, as it requires more extensive computing time, in order to derive more accurate photometric information especially for crowded fields. The resulting photometry files as well as the original images are archived at the telescope site. We use a tape library using SONY AIT tapes as a local data storage device. The tapes

Figure 2. Opening of Yonsei University Survey Observatory on November 24, 2000.

are regularly forwarded to the home institute for the main data archive of RAID arrays, and then sent back to the site to be used again.

The off-site data pipeline includes the construction of light curves for individual sources, image difference photometry for very crowded fields in low galactic latitudes, and general database management tools. It is our plan to release the data to the general astronomy community once proper calibration has been done.

4. Project Status

The first YSTAR telescope was temporarily installed near the YUO site in Chunan, Korea, on March 2000 and used as a testbed for various experiments. These included telescope setup procedures, automated observations, and CCD integration and enclosure operations. The site was however without any infra structure except for a single power line, making the experiments harder to perform.

In November 2000, the YUO Survey Observatory was formally opened. Modest living quarter was also built together with the observatory building which houses three piers. Internet connection based on a dedicated 256 Kbps optical fiber line was also established, enabling us to monitor and control the facility remotely from the campus in Seoul. The first telescope was moved to the new observatory and is presently being used to generate commissioning data. Data pipelines and automatic survey routines are being tested and constantly improved using the facility.

Not everything went as planned. The fast nature of our optics made it very difficult to collimate the telescope. The unreliable pointing and tracking of the telescope also caused much delay. The list of problems grew very long as we strove to make progress with the program. However, in order to resolve these issues, we have been working closely with the telescope manufacturers and also with astronomers experienced in similar fast optics and automated operation. Most problems have already been solved at the time of writing.

One of the major progresses in the year 2000 is that YSTAR is no longer just a university project. Korea Astronomy Observatory (KAO) and YUO have decided to work together for the common goal of efficient sky surveying. While KAO's main interest lies in detecting near-earth objects and comets, the observational strategy and software development are almost identical to ours. By sharing experiences and existing facilities of each party, we believe that we can maximize the chance of success in general sky monitoring.

5. 2001 and Beyond

Good sky condition is crucial for the efficiency of a survey project. Since ours is not a target oriented short term observation but a general long term survey of entire sky, the number of clear nights directly dictates the sky coverage and coverage frequency of our observational campaign. Unfortunately the climate of Korea is not suitable for our purpose and, from the start of this project, we have been planning to locate our survey telescopes elsewhere.

With the kind invitation of South African Astronomical Observatory (SAAO) we are now preparing to set up YSTAR No. 2 telescope in Sutherland within this year. Large number of clear nights as well as its dark sky condition make our facility much more competitive in all sky monitoring. The access to the southern sky is also a very important factor, as nearly all photometric and astrometric monitoring programs are being run in the northern hemisphere. After successful commissioning at SAAO, we will expand the facility to other places around the globe.

KAO and YUO are now working together to secure more survey telescopes of somewhat larger aperture. Five or more telescopes will be constructed and placed around the world making a network of survey telescopes working 24 hours a day. International cooperation is essential in this effort, and we welcome anyone who is interested in working with us.

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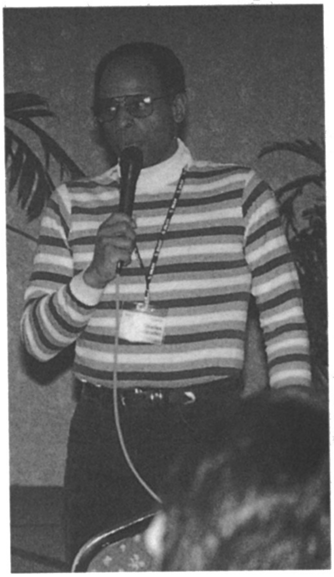
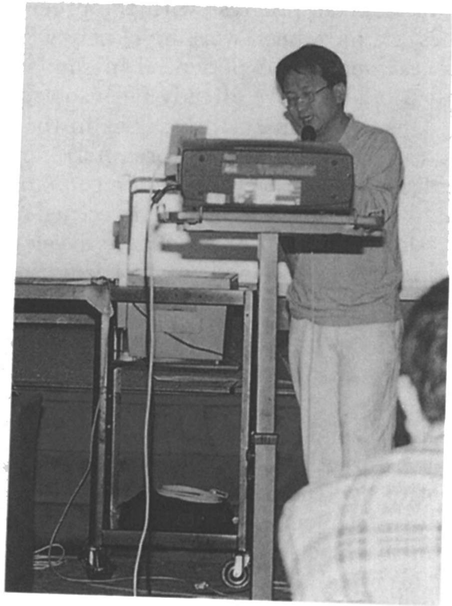

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