*Binary Stars as Critical Tools & Tests*
*in Contemporary Astrophysics*
*Proceedings IAU Symposium No. 240, 2006*
*W.I. Hartkopf, E.F. Guinan & P. Harmanec, eds.*

doi:10.1017/S1743921307006400

# Frontiers of Transient Phenomena in X-ray Binaries and Cataclysmic Variables Investigated by a High-Speed CCD Camera and an Automated Monitor Telescope

**D. Nogami[1] and S. Mineshige[2]**

[1]Hida Observatory, Kyoto University, Kamitakara, Takayama, Gifu 506-1314, Japan
email: nogami@kwasan.kyoto-u.ac.jp

[2]Yukawa Institute, Kyoto University, Sakyo-ku, Kyoto 606-8502, Japan
email: minesige@yukawa.kyoto-u.ac.jp

**Abstract.** We are developing two new systems of a high-speed CCD camera, and an automated monitor telescope. This camera using a frame transfer-type CCD that enables us to take images each 27.3 msec at the highest speed. We wish to investigate accretion and eruption phenomena around compact stars by optical light. The system we have developed for automated monitoring of X-ray binaries and cataclysmic variables consists of a 30-cm reflector, a CCD camera, and a computer. It is a cheap system, but can monitor more than 150 systems each night. It will reveal long-term light curves of programmed stars of those transient systems, and catch sudden outbursts/decays. We will be able to start follow-up observations to clarify the mechanism of these activities as early as possible. We here report the current status of these projects, the target physics, and the future development.

**Keywords.** instrumentation: miscellaneous, accretion, accretion disks, black hole physics, novae, cataclysmic variables

## 1. Introduction

Mass transfer between the components of interacting close binary stars is responsible for activity and evolution quite different from those of single stars. In those binaries which include a black hole, neutron star, or white dwarf as a component, we can observe a variety of dramatic phenomena related to mass accretion and jet activity. However, most of the mechanisms of such phenomena are still open problems. We aim to obtain new insights into those problems by developing an automated monitor telescope and a high-speed CCD camera.

## 2. Automated monitor telescope

This system consists of a publicly available instrument: a Meade LX200-30GPS telescope and an SBIG ST-7XMEi (NAGB) CCD camera. No filter is used. A commercial package 'Stellar Gear' (AstroArts) automatically controls the telescope and takes images of programmed stars. Then, a free siftware package 'PIXY-II' (MISAO project; `http://www.aerith.net/misao/index.html`) does real-time reduction of the images, registration to the database of individual stars, and detection of brightening/declining stars, and also sends alerts to VSNET (Kato *et al.* 2004). This system can detect stars of $16^{\rm th}$ magnitude in a 30-sec exposure under a clear sky. Two images will be taken to avoid fault detections by cosmic ray events. Since it takes about 3 minutes to observe 1

star, we can check 150–200 stars in one night. The initial cost of this system is about 10 thousand USD, including the telescope, CCD camera, and computer. We can also do surveys of SNe, novae, and comets using the same set of instruments.

## 3. High-speed CCD camera

The camera we have developed uses a chip of back-illuminated frame transfer CCD87 (e2v). This camera contains 512×512 pixels of 16×16 $\mu m^2$/pix, and it has a 14-bit A/D converter. The exposure time is varied between 27.1 msec and 10 sec (35.8 frame/sec at the highest speed). Images totalling some 600 GB in size are obtained during a 10-hour observing period at the highest speed.

This CCD camera was tested with a 60-cm telescope at the Hida Observatory, Kyoto University, and has been recently attached to a 1.5-m telescope at the Higashi-Hiroshima Astronomical Observatory, of Hiroshima University.

## 4. Science

A combination of long-term monitoring and real-time alerts by the automated monitor telescope and ToO observations of high time-resolution from the very beginning through the activity will certainly lead to increased knowledge of the nature and mechanism of these systems. Large-amplitude optical variabilities with short timescales have been recently discovered in X-ray binaries. Some of these have been performed simultaneously with X-ray observations, and correlations of optical/X-ray variabilities and some delay/precedence of optical behavior from the X-ray counterpart have been observed in, for example, V4641 Sgr (Uemura *et al.* 2004), KV UMa (Malzac *et al.* 2004), and SS 433 (Revnivtsev *et al.* 2004). We can probably make some constraints on the mechanism of these activity, which may be related to jet phenomena.

In cataclysmic variables, high-speed photometry has recently revealed variabilities with short timescales, including dwarf nova oscillations (DNOs), short-period DNOs, and QPOs. Warner & Woudt (2006) discovered a 1:2:3 frequency suite of DNOs in the dwarf nova VW Hyi in the optical, which mimics what has been observed in X-ray binaries at X-ray wavelengths. This may mean that the mechanism driving kHz QPOs in X-ray binaries does not require the effects of general relativity. Information on the nature of short-term variabilities in CVs is also desired.

The high-speed CCD camera system may be a useful instrument to investigate short-term variability of GRB afterglows, to detect extrasolar planets by eclipse, to study pulsations of neutron stars and white dwarfs, and so on. We welcome proposals of investigation using this camera system in any field of astronomy.

### Acknowledgements

This work is partly supported by a Grant-in-Aid from the Ministry of Education, Culture, Sports, Science, and Technology (No. 16340057, 17740105).

### References

Kato, T., *et al.* 2004, *PASJ* 56, S1
Malzac, J., *et al.* 2004, *MNRAS* 351, 253
Revnivtsev, M., *et al.* 2004, *A&A* 424, L5
Uemura, M., et al 2004, *PASJ* 56, S61
Warner, B. & Woudt, P.A. 2006, *MNRAS* 367, 1562