The SAO RAS Zeiss-1000 Optical Telescope

V. V. Komarov, V. N. Komarova, E. V. Emelyanov, N. V. Borisov, S. V. Drabek, V. S. Shergin, O. I. Spiridonova, A. S. Moskvitin, and T. A. Fatkhulin

Special Astrophysical Observatory, Russian Academy of Sciences, Nizhny Arkhyz, Russia
komarov@sao.ru

Abstract. We present the chronology of 30-year observations at the 1m Zeiss-1000 telescope of SAO RAS. The main equipment and observational techniques of this period are described. New modern possibilities of astrophysical research are demonstrated, which are realized thanks to the complex modernization of the telescope and the introduction of new photopolarimetric comlex.

Keywords: techniques: photometric; techniques: imaging spectroscopy

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1 Introduction

Zeiss-1000 is a family of 1m telescopes of the serial production, built at the "Carl Zeiss, Yena" in Germany. The main advantage of a Ritchie–Chretien-coude optical system is a maximum possible versatility at a moderate cost of instrument manufacturing. The Zeiss-1000 telescope belongs to the middle class telescopes and has two foci:

- Cassegrain—with a focal length of 13.3 m and
- coude—at 36.5 m from the telescope.

Our telescope is the 10th out of 11 manufactured. The Zeiss-1000 was ordered for SAO RAS as an auxiliary instrument for Big Telescope Azimuthal in 1982 and brought to the place of operation in 1986. The first light at 1m telescope was received in October, 1989. The very first photodetectors to store images of stars were photographic plates. The telescope was operated by a control computer, which worked with a "Vilati" control device made in Hungary. The control system was designed to apply photographic observational methods

with semi-automatic positioning of the telescope and subsequent manual correction and constant tracking of the object by the eyepiece guiding directly at the equipment used at the moment. For this, manual correction panels were provided directly near the Cassegrain focus and in the room of the slotted part of the coude one.

2 First Decade of Observations

The first years, more exactly, the first decade of observations at the telescope are the 90s. It is the most difficult period. The telescope is equipped according to a residual basis. Nevertheless, observations are carried out applying different devices, namely:

- CCD photometer,
- CCD photometer with the off-axis TV guide,
- Coude–echelle spectrometer CEGS,
- 2-chanel polarimeter,
- Specle interferometer,
- 4-chanel electrophotometer.

Since 1993, the telescope is provided with some stationary equipment and, in general, the creation of observational methods is being completed. From this moment on, the telescope normal operation starts, with quarterly and then six months planning of observations. The main observation programs during the first ten years of the telescope exploitation are:

- photometry of bright quasars,
- photometry of nearby Seyfert galaxies,
- photometry of X-ray binary system,
- magnetic survey of main sequence stars,
- compilation of spectral atlases of bright Ae/Be Herbig stars,
- studying variability of magnetic peculiar stars,
- spectral monitoring of AGNs and binary system,
- spectral monitoring of bright supernovae at al.

The main devices used in observations at the telescope Zeiss-1000 this period are:

CCD Photometer The photometer was developed and manufactured in SAO RAS and put into operation in 1994. It was built using the standard set of astronomical image recording system based on a CCD of 530×580 pixels. The device incorporates: a set of 8 filters, automatic remote filters control, a fast shutter allows short-time exposures, up to milliseconds.

Coude-Echelle Spectrometer The main apparatus for spectroscopic observations at the Coude focus of Zeiss-1000 is a Coude-Echelle/Grating Spectrometer (CEGS) for solving problems in the field of astrospectroscopy with high and ultra-high resolution (Musaev 1996). The detector is a CCD of 520×580 pixels.

Fast Spectrograph The spectrograph UAGS (Universal Astronomical Grating Spectrograph) is designed for spectral investigation of extended objects with a moderate (2–8Å) spectral resolution. UAGS with fast Schmidt camera and CCD 530×580 elements and slit TV guide are located at the Cassegrain focus.

Along with the scientific equipment for the Zeiss-1000, specialized TV guides are being created — for slit guiding in observations with CEGS and UAGS, and later, for the telescope guide. At first, receivers with image intensifier tubes were used. Nowadays highly sensitive CCDs are used as photodetectors.

3 Second Decade of Observations

The rapid development of information technologies begins in the late 90s. The Department of Informatics of the SAO RAS (headed by V. V. Vitkovsky) is creating a unified information network of the SAO. Zeiss-1000, which previously worked completely autonomously is included in the unified network. The prerequisites for remote observation appear. In the same years, the unified digital television complex of the BTA and Zeiss-1000 was created to visualize remote monitoring of weather conditions. On the Zeiss-1000 roof television systems are installed for observing the night sky, which allows one to assess the astroclimatic situation near the telescopes in real-time mode.

In the 2000s, the main observational instruments are:

- new CCD-photometer,
- Coude-echelle spectrometer CEGS,
- Universal Astronomical Grating Spectrograph UAGS.

New CCD-photometer was designed for direct imaging of astronomical objects without a filter, in white light (3600–10000Å), and in the bands of the Johnson–Cousins system U, B, V, R_c, I_c as well. The CCD EEV 42-40 detector (2048×2048 px, $13.5 \times 13.5 \mu$m) with a maximum quantum efficiency of 82% (at a wavelength of 4500Å) is used.

Coude-echelle spectrometer CEGS continues to be the main instrument for observations in the coude focus. The spectrometer is equipped with a circular polarization analyzer and replaceable diffraction echelle gratings providing operation in several observation modes: of high, medium, moderate and low resolution. A limiting magnitude for an hour exposure in good weather conditions

is about 7 magnitude (Bychkov 2008). Up to 2015, the only one CCD detector, EEV 4240, was used with all the equipment, that caused definite service problems. Currently the Apogee Aspen CG16M CCD camera, 4k×4k px, air-cooled down to −35°C, is used in the coude focus (Komarov 2018).

Universal Astronomical Grating Spectrograph UAGS solves a wide range of astrophysical problems—from the study of faint extragalactic objects (up to 16 magnitude) to the study of bright stars (6 – 8 magnitude). Spectra are recorded using the CCD EEV 42-40 detector (2048 × 2048 px, 13.5 × 13.5μm) mounted on the Schmidt–Cassegrain camera ($F = 150$ mm).

4 Third Decade of Observations

Complex automation of the telescope began in 2007. By 2013 the automated control system creation with simultaneous upgrade of the main telescope units has raised Zeiss-1000 to a new standard of observations (Vlasyuk et al. 2014). Replacement of control systems of telescope axes drives, main axis sensors, implementation of calculation and tracking algorithms has yielded a pointing accuracy increase and a significant tracking quality improvement, including the possibility of program tracking of fast-moving celestial bodies. In 2015, the telescope optical system was adjusted (Drabek et al. 2017). This made it possible to improve its quality and bring the level of its matching to the image quality close to the diffraction limit. Presently it ensures an image quality of about $0.5''$ at 80% of energy level. This significantly expands the observational capabilities of the telescope. But, of course, new equipment is needed for new tasks.

Since 2018 Zeiss-1000 has been conducting observations with a new photometer-polarimeter. The Multi-Mode Photometer-Polarimeter (MMPP) (Emelyanov & Fakhullin 2019) has been recently designed to be installed in the Cassegrain focus with an Eagle-V liquid-cooled camera (down to −100°C). It is equipped both with highly effective broadband interferential filters of the Johnson–Cousins system and mediumband filters centered on the wavelengths of basic emission lines of the objects under investigation. In the polarimetric mode there is a possibility of linear and circular polarization studies. MMPP is a modern instrument for solution of a wide range of photometric and polarimetric tasks (Uklein et al. 2019). New observational programs have appeared: search for isolated magnetic white dwarfs, photometry of close binary systems and exoplanet transits. Polarimetric observations began to be carried out regularly. For the last 2 years, the telescope carries out observations with new "guest" instruments: Mapper of Narrow Galaxy Lines (MaNGaL)—a new tunable-filter photometer (Perepelitsyn et al. 2018), and Stokes Polarimeter (StoP). They are used to study ionized gas in galaxies and formation of broad lines in AGNs.

5 Conclusion

Astrophysical research has been carried out on the 1m optical telescope Zeiss-1000 of the SAO RAS practically non-stop for 30 years. Through the efforts of the SAO staff, the telescope is being modernized, the observation methods are improved and new devices are developed. Since 2015 the telescope has been almost completely automated. The adjustment (Drabek et al. 2017) of the optical system and the new software made it possible to observe with high accuracy. In 2020 automation of the telescope focusing was finished, it became the final stage of complex automation of all control systems. Owing to the work done observations in any mode by all the methods can be carried out remotely, without interruption. At present Zeiss-1000 is a modern multimode complex capable of performing a variety of scientific programs: from photometry in wide and narrow wavelength ranges to spectropolarimetric studies with medium and high spectral resolution. The new equipment installed expands observational capabilities and tasks, adding polarimetric research, studies of exoplanets, etc.

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