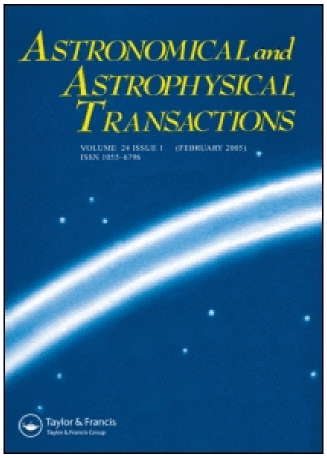

Astronomical & Astrophysical Transactions
The Journal of the Eurasian Astronomical Society
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453505

SPECTROGRAPH FOR FAINT OBJECTS: THE DEVICE AND THE MAIN RESULTS OF OBSERVATIONS

E. K. Denissyuk [a]
[a] Fessenkov Astrophysical Institute, 480020 Almaty, Kazakhstan.

To cite this Article: Denissyuk, E. K. (2003) 'SPECTROGRAPH FOR FAINT OBJECTS: THE DEVICE AND THE MAIN RESULTS OF OBSERVATIONS', Astronomical & Astrophysical Transactions, 22:2, 175 - 180
To link to this article: DOI: 10.1080/1055679031000084795
URL: http://dx.doi.org/10.1080/1055679031000084795

Astronomical and Astrophysical Transactions,
2003, Vol. 22(2), pp. 175–180

SPECTROGRAPH FOR FAINT OBJECTS: THE DEVICE AND THE MAIN RESULTS OF OBSERVATIONS

E. K. DENISSYUK[†]

Fessenkov Astrophysical Institute, 480020 Almaty, Kazakhstan

(Received May 29, 2002)

The original slit spectrograph intended for observations of faint objects is described. The main results obtained with this device are briefly discussed.

Keywords: Instruments; Emission line objects; Spectral observations; Galaxies

1 INTRODUCTION

In 1968 a new slit spectrograph was constructed in the workshop of the Astrophysical Institute. The original optical scheme of the spectrograph was developed by the present author, and its realization was executed by the engineers M. I. Musorin, I. M. Glushkov, A. A. Nokonenko and F. T. Lutz. The spectrograph was intended for research on the spectra of faint astronomical objects. The optical system is classic with glass optical elements and a diffraction grating. The spectrograph may be utilized with telescopes which have a D/F ratio of no more than $1/10$. It is attached to the 11.2 m Cassegrain focus of the AZT-8 telescope where the diameter of the main mirror is 700 mm ($D/F = 1/16$). In spite of the small size of the telescope a huge number of astronomical objects have been studied using this equipment, and results have been published in more than 100 scientific papers.

2 DESCRIPTION OF THE SPECTROGRAPH

A schematic diagram of the principle of the spectrograph is presented in Figure 1. It has a massive steel frame 3, to which all components are fixed. The spectrograph is attached to the telescope through the positional bearing 2. A flat mirror 9 allowed us to decrease the size of the device in spite of the long focus of the collimator (1400 mm). There is a set of filters 10 installed between the telescope and the spectrograph.

The main optical components such as the collimator lens 5, the camera lens 7 and a diffraction grating 6 are shown in Figure 1. They are enclosed in a massive casing 8 and thus are

---

[†]Correspondence: E. K. Denissyuk, Fessenkov Astrophysical Institute, 480020 Almaty, Kazakhstan.
E-mail: denis@afi.south-capital.kz

ISSN 1055-6796 print; ISSN 1476-3540 online
DOI: 10.1080/1055679031000084795

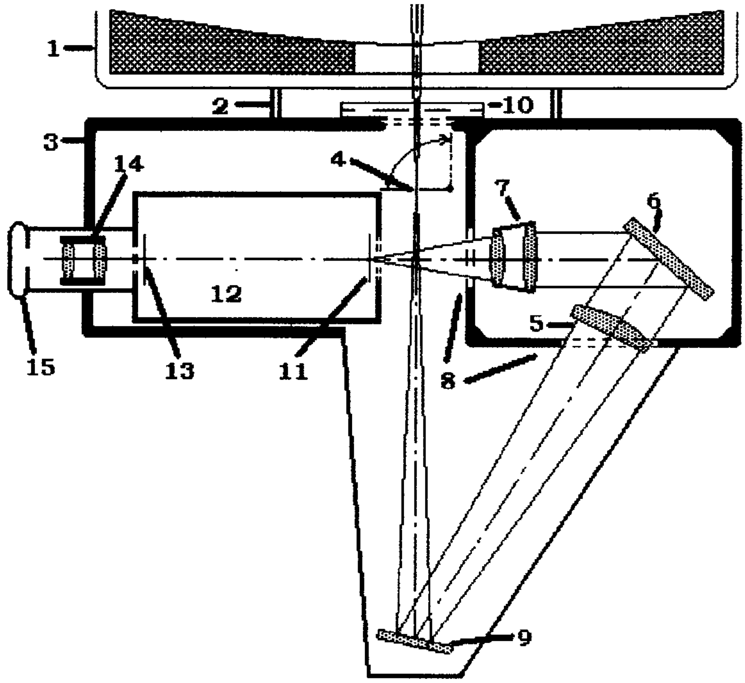

FIGURE 1 A schematic diagram of the principle of the spectrograph: 1, telescope; 2, positional bearing; 3, casing of the spectrograph; 4, exit slit; 5, collimator lens; 6, grating; 7, camera; 8, box of optical elements; 9, flat mirror; 10, set of filters; 11, photocathode of the image tube; 12, image tube; 13, screen of the image tube; 14, Aurora lens; 15, photographic cassette.

protected from any extraneous light. The levers for regulating all optical elements are placed on the external panel of the spectrograph casing. The angle of the rotating grating may be changed with a precision of 2 arcmin, using a scale. The mechanism of focusing of the camera lens and its control scale provide a precision of 0.01 mm. The construction of the spectrograph gives us an opportunity to change the camera lens and the grating during observations.

Usually it takes no more than 5 min to replace all optical elements. A three-stage image tube UM-92 is used as a flux receiver at the exit of spectrograph. It has a semitranslucent multialkaline cathode and is installed in the focal plane of spectrograph's camera. The image tube is installed in such a way that it may be inclined in order to compensate for chromatic aberration in the camera lens. The inclination fixture and a scale of angles are situated near the exit screen of the image tube. An additional lens of Aurora type is positioned after the image tube. It transfers an image from the exit screen of the image tube onto a photographic film. The usual camera (without a lens) is used as a cassette. A small optical system is placed between the camera and the Aurora lens. It consists of an eyepiece and a flat mirror, installed at an angle of 45°. This optical system may be placed inside and outside a beam of light. In the 'inside' position it allows us to see the exit screen of the image tube and simultaneously plays the role of a shutter for the film. This regime is used for positioning the telescope on an object and for focusing the optical elements of the spectrograph. When the eyepiece is in the 'outside' position, the image from the exit screen of the image tube is projected and is recorded on the film.

Now let us describe in detail those elements of the spectrograph which are not traditional in such an apparatus.

2.1 The entrance slit mode

A standard slit is established inside a round box with a rectangular aperture for the light flux from the telescope. There are two prisms on the inside of the top cover of this box. They send light from a special lamp, having a Ne–He–Ar spectrum, on to the edges of the slit. Both prisms may be moved to any symmetrical distance from the slit's centre with the help of a special mechanism. The length of a slit is 360″; the width may be varied in the range 0″.0–9″.0. The slit may also be removed, and then a needle of thickness 0.4 mm is situated in its place. This needle is placed in such a manner that its sharp end shows the position of the middle of the slit of the spectrograph. It is used to position the telescope exactly, in particular for faint objects.

2.2 The device used to position the telescope exactly and to obtain direct images of the sky

The device is placed near the point where the optical axes of the telescope and the camera lens intersect. A schematic diagram of the principle is shown in Figure 2. It consists of a lens 16, a flat mirror 17 and a metal rod, which is connected to a lens. The device may be placed on the optical axis of the telescope by moving along guiding rails, which are located perpendicular to the plane of Figure 1. It can also move along the optical axis of the telescope in order to obtain a good focus and to change the scale of the image. A focal plane image may be projected on to the image tube with two different scales, 1 : 1.5 and 1.5 : 1, because the optical path from the local plane of the telescope to the receiver's plane is more than 4*F*, where *F* is the focal length of the lens. The image tube has a high brightness amplification factor; thus even rather faint objects up to a magnitude of 18 may be visible on its exit screen. The image of the needle is also distinct against the background of the night sky; so an observer may place any studied object at the end of the needle (in other words, in the middle of the slit). In this way the procedure used to position the telescope exactly on an object becomes quite fast and easy.

The same device allows us to record the image of a sky region with a studied object and environmental stars. An exposure time of 10–30 s is sufficient to record images of stars up to magnitude 20 and the background of the sky. If necessary, a photometric wedge may be

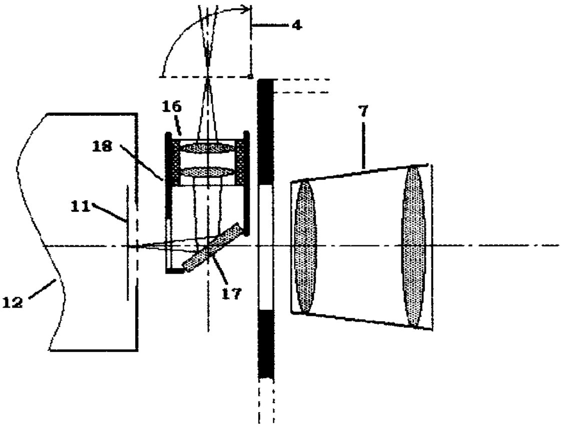

FIGURE 2 The device used to position the telescope exactly and to obtain direct images of the sky: 4, entrance slit in the "removed" position; 7, 11, 12, as in Figure 1; 16, additional lens; 17, flat mirror; 18, casing of the additional lens.

installed in the plane of the slit of the spectrograph. It is illuminated by light from the sky and its image recorded at the exit of the image tube may be used for photometric calibration.

3 CHARACTERISTICS OF THE SPECTROGRAPH

The set of lenses for the camera ($F = 250$, 180 and 150 mm) and the collimator ($F = 1.0$ and 1.4 m) and five gratings are available for utilization in the spectrograph. So we may obtain spectrograms in the wavelength range 3700–8600 Å with a dispersion 10–200 Å mm^{-1}. The spectral resolution depends on the quality of optical elements but in our case it is mainly influenced by the properties of the image tube. In the 30 years that the spectrograph was used, six different UM-92 image tubes were used. Each of these was investigated comprehensively; different regimes of the magnetic focusing system were examined carefully, and various scales of image transfer were tested in order to reach the highest image quality and lowest noise level. As a result the spectral resolution of the spectrograms was 0.5–10 Å depending on the dispersion.

Special astronomical films were used to record the spectrograms. The types A600, A600N, A600H and Kodak 103oaJ were chosen, because the wavelength of their maximal sensitivity corresponds to the colour of the exit screen of the image tube, that is $\lambda \approx 5500$ Å.

Spectrograms and images of the photometric wedge were scanned with the aid of an automatic microdensitometer; a package of software programs developed by the present author was used. Using image tube creates some specific effects, such as an S-like distortion of the image and a dependence of the sensitivity on the distance from the centre of the screen. All these effects as well as the absorption by the atmosphere are taken into account during data processing. In total the intensities of moderate, strong and faint emission lines are measured with precisions of 10, 15 and 50% respectively.

In 1999 modernization of the spectrograph was begun. In particular, a charge-coupled device (CCD) matrix was installed to receive the light flux. In this connection, significant mechanical alteration of the device was required which allowed us to continue to use the image tube to find and to centre an object exactly on the slit of the spectrograph. It is known that the image tube reacts to a change in the image projected on it almost instantaneously, while the processes of digitization and downloading of the CCD are rather slow. Thus the procedure for searching and centring the research object is more effective and rapid with the help of the image tube. The modified device combines the advantages of the original design of the spectrograph with modern techniques. It is expected that our device will work effectively for many years.

4 A BRIEF REVIEW OF THE RESULTS OBTAINED WITH THE AID OF THE SPECTROGRAPH

(i) The first research study performed with the aid of the spectrograph was on the spectra of galaxies from the first lists of Markarian galaxies. Spectral observations of such objects were first carried out in the USA, using the largest telescopes: rather interesting results were obtained. Almost simultaneously an analogous study was started by M. A. Arakelyan, E. A. Dibai and V. F. Esipov from The State Sternberg Institute (Moscow, Russia). The 1.25 m telescope of the Crimean Observatory was utilized. We decided to take part in this work and to begin observation of Markarian galaxies with our device. In spite of the smaller telescope diameter (70 cm), the results obtained appeared to be quite similar and, in some cases, even much better. For example, emission lines were found and measured in spectra of the objects Mr26, 37, 41 and so on (Denissyuk, 1971, 1974), which were classified by other workers from Russia and the USA, as galaxies without any emission. This study was carried out up to 1988. Altogether up to that time the spectra of 1500 objects of this type were obtained owing to the efforts of all participants of the programme. The contribution of the Fessenkov Astrophysical Institute was 28%. This work has been described in detail by Denissyuk (2000a).

(ii) One of the most important results of spectral research on Markarian galaxies was the detection among them of the large group of so-called ‘Seyfert galaxies’. These are objects of special interest because in some sense they are similar to quasars, the most powerful sources of radiation in the Universe. As they are rather rare objects, quasars are not found in the vicinities of our Galaxy. It is considered that some processes which take place in Seyfert galaxies are quite analogous to those in quasars, but with lower power. Therefore more than 2000 papers have been devoted to the study of Seyfert galaxies and quasars only within the last decade and the results are indeed excellent. For example, during the study of Markarian galaxies, 208 new Seyfert galaxies were discovered in addition to ten that were known earlier. By the way, 49 Seyfert galaxies were detected at the Fessenkov Astrophysical Institute.

(iii) Research on Seyfert galaxies showed that their central regions are of a small size and demonstrate high variability over rather short intervals of time, down to several days or even shorter. Thus it became clear that it is necessary to watch galaxies of this type constantly, and regular observations with a high resolution are needed in order to study their structure. Monitoring of some Seyfert galaxies is being carried out in a regular way with the participation of many observatories all over the world. These objects are also within the scientific programme of orbital telescopes as well. The Astrophysical Institute plays an active part in such programmes.

(iv) Spectral observations with a high spatial and spectral resolution were carried out to determine the rotation curves of some galaxies (Denissyuk and Pavlova, 1973). It must be emphasized that earlier such a study could be performed on only large instruments. Together with the State Sternberg Institute, the spectra of some ring-like and interacting galaxies were obtained (Denissyuk and Dostal, 1976).

(v) In accordance with the aim suggested by C. Casini (Institute of Astronomy, Milan) and J. Heidemann (Medon Observatory), successful searches for the emission lines in the spectra of galaxies that were physical pairs with Markarian galaxies, were carried out (Casini *et al.*, 1982).

(vi) In due course the very first spectrograms of about 50 Seyfert galaxies were obtained at the Astrophysical Institute, observations are still continuing, and spectral data that are the most extended in time for most of these objects have been accumulated at the Astrophysical Institute. Observations of galaxies were carried out by the present author and within the last few years by R. Valiullin. Measurements of spectrograms were made by V. Gaisina.

(vii) Some moving emission features near Hα were detected in the spectrum of one of the brightest Seyfert galaxies NGC 4151 (Denissyuk, 1996). It was concluded that such features may be formed in some emission clouds, which rotate in the gravitation field of the central body. Calculation of the possible orbits of such emission objects showed that the central body’s mass equals approximately $108 M_{\odot}$ (Demchenko and Denissyuk, 2001). This result is in agreement with estimations obtained in other ways.

(viii) The spectrograph was used successfully to observe various emission objects in our Galaxy. For example, in 1970–1984 a large amount of observational data were obtained for numerous compact H II regions by Ju. I. Glushkov. A spectral study of planetary nebular and symbiotic stars was performed by L. N. Kondratyeva. Observations of some current events (comets and asteroids) and exotic objects (novae and supernova outbursts) are also carried out from time to time.

(ix) In the last few years, research on the object SS433 was undertaken in the framework of international monitoring. This programme assumed simultaneous observations in X-ray and optical ranges, including participation of orbital telescope experiments. Astronomers at the Astrophysical Institute, R. R. Valiullin, L. N. Kondratyeva and the present author, took part in this programme at the invitation of the Goddard Space Flight Center, National Aeronautics and Space Administration.

Scientific results obtained with the aid of the spectrograph for various galactic and intergalactic objects have been published in more than 100 papers presented at symposia and conferences. Four dissertations were prepared on the basis of these data.

References

Casini, C., Denissyuk, E. K., and Heidmann, J. (1982) *Mon. Not. R. Astron. Soc.* **195**, 325.
Demchenko, B., Denissyuk, E. (2001) *Astrofizika* **44**, 667.
Denissyuk, E. K. (1971) *Astron. Tsirk.* No. 615, 4.
Denissyuk, E. K. (1974) *Astron. Tsirk.* No. 809, 2.
Denissyuk, E. K. (1996) *Astron. Astrophys. Trans.* **10**, 279.
Denissyuk, E. K. (2000a) *Astron. Astrophys. Trans.* **20**, 337.
Denissyuk, E. K. (2000b) *Izvestiya of National Academy of Sciences of Republic of Kazakhstan* **4**, 7.
Denissyuk, E. K., and Dostal, V. A. (1976) *Astron. Tsirk.* No. 931, 7.
Denissyuk, E. K., and Pavlova, N. N. (1973) *Astron. Tsirk.* No. 797, 1.