

## Archives of CrAO spectral observations. Catalogues of objects and images

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### ABSTRACT

The work described in this article is a continuation of the previously initiated research on archival spectral observations carried out in Crimea. It covers a time interval of about 90 years and contains information about spectroscopy using various facilities: from the wide-angle astrographs with an objective prism to the main CrAO telescope – ZTSh. A brief history of telescopes and their equipment is presented. The article is illustrated with possibilities of a network access to the catalogues of observations taken with various instruments in the interactive Aladin Sky Atlas with the redirection to original spectrograms. To this aim, the linear coordinates of scanned negatives were converted into a scale that corresponds to the wavelengths. The possibilities of taking into account the spectral sensitivity of the recorded images by the absolute energy distribution are shown. A feature of this work is the connection of digitized original observations and results of their independent processing with data published for objects in the *Izvestiya Krymskoi Astrofizicheskoi Observatorii*.

**Key words:** archives of observations, databases, spectra, catalogues

## 1 Introduction

An extensive archive of spectral observations has been compiled for over the century history of astronomical observations at the Crimean Astrophysical Observatory (CrAO). It includes both photoplates and photofilms obtained with astrographs with an objective prism and with telescopes with various spectrographs and photoelectric, television and CCD-records (Polosukhina et al., 1998; Gorbunov, Shlyapnikov, 2013; Pakuliak et al., 2014).

For most part of archives there was made a description and prepared lists of observations and catalogues of objects in the digital format. Some of them are posted on the CrAO server and available in the local regime. The current work provides some recommendations on using spectral archives of the observatory.

## 2 Short description of archives

### 2.1 Spectroscopy with an objective prism

A collection of spectral observations carried out with an objective prism involves three parts what is caused by instruments with which these negatives were acquired. Table 1 lists basic characteristics of astrographs and dispersion for digitized spectrograms.

Table 1.

| Spectrograph name | Objective diameter (mm) | Focal length (mm) | Dispersion in the $H_{\alpha}$ line ( $\text{\AA}/\text{pix}$ ) |
|-------------------|-------------------------|-------------------|---|
| Unar              | 117                     | 600               | 1.5   |
| Dogmar            | 167                     | 750               | 1.4   |
| 400 mm            | 400                     | 1600              | 1.5   |

SOPCA archive<sup>1</sup> includes about 1000 spectral plates derived with astrographs with objectives Unar, Dogmar and 400 mm in the period between 1929 and 1965. Most part of the collection involve negatives of observations carried out based on the Plan of Academician G.A. Shajn<sup>2</sup> organized for studying the Galaxy structure in 1950–1965 (Pronik, 2005). This project resulted in 13 catalogues containing about 35 thousand stars with identified photometric

<sup>1</sup> Abbreviations used in the Crimean Astronomical Virtual Observatory (CrAVO): “Spectroscopy with an objective prism. Collection of astronegatives” (CrAVO SOPCA) (in Russ.), or English version “Spectroscopy with Objective Prism” (CrAVO SwOP).

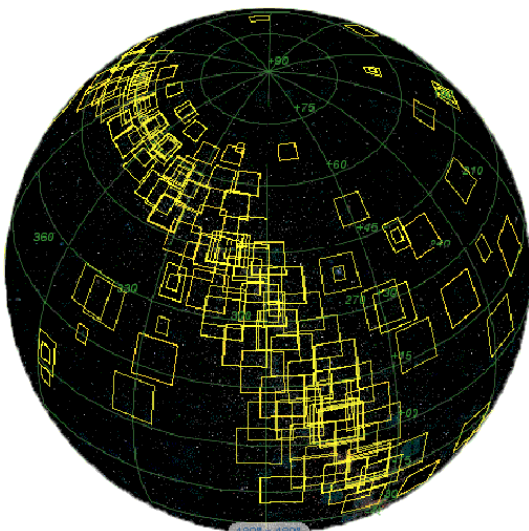
<sup>2</sup> Shajn’s Plan on the CrAO server: <http://www.crao.ru/~aas/PROJECTS/SPPOSS/SPPOSS.html>.



**Fig. 1.** Double 400 mm astrograph at CrAO

and spectral characteristics (Gorbunov, Shlyapnikov, 2017a; Gorbunov, Shlyapnikov, 2017b).

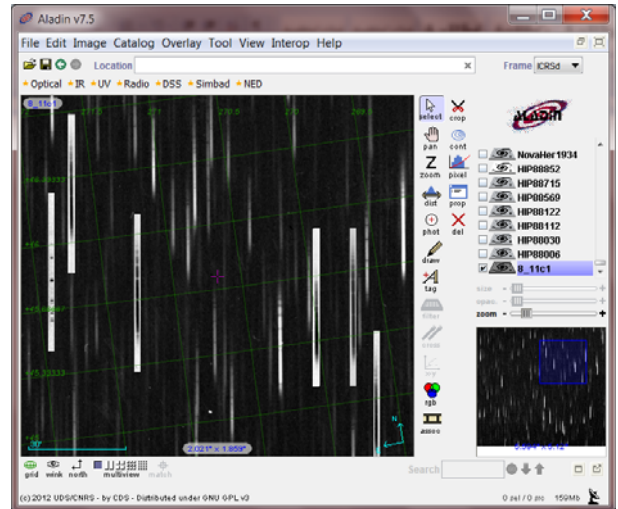
Fig. 1 shows the double 400 mm astrograph at CrAO used during the implementation of the Plan of Academician G.A. Shajn. An objective prism was mounted on the front part of one of the telescopes. This results in stellar spectral images in the astrograph focal plane (see Fig. 3). The second telescope was applied to record direct images. A combination of emulsions makes it possible to perform photometry in three bands.



**Fig. 2.** Collection SOPCA on the celestial sphere

Fig. 2 shows the celestial sphere coverage by photographic plates from the collection SOPCA. The negatives were mainly taken along the Milky Way.

Fig. 3 presents a fragment of the negative from the archive SOPCA taken with an objective prism and down-



**Fig. 3.** A fragment of the negative from the archive SOPCA

loaded into the interactive Aladin Sky Atlas (Bonnarel et al., 2000). Marked spectra are described in Section 3.2.

## 2.2 Spectroscopy with slit spectrographs. Short description

### 2.2.1 40-inch reflector designed by Goward Grabb

40-inch (1000 mm) telescope (Fig. 4) for the then existing Simeiz Branch of the Main Pulkovo Observatory was or-



**Fig. 4.** Meter telescope of the Simeiz Observatory

dered in 1912 in Goward Grabb. The World War I followed by events in the Russian Empire hampered the delivery of the telescope to Crimea for 13 years. The mounting of the telescope was started in October 1925 and the first image was

taken on May 28, 1926. The telescope has the Newton focus – 5200 mm and the Cassegrain focus – 18600 mm. Later, the 40-inch reflector was equipped with a large one-prisma spectrograph with the thermostat and two cameras having various focal lengths, a spectrograph for the Newton focus and a cassette for direct images (Shain, 1926; Kryuchkov et al., 2009).

Observations of binary stars and the determination of stellar line-of-sight velocities (Shain, 1929; Shajn, Albitzky, 1932) became the basic research program at the Simeiz 1000 mm reflector.

The telescope was transported to Germany during the World War II; after the war it was found, but appeared to be invalid for reconstruction.

### 2.2.2 48-inch (1220 mm) reflector designed by Carl Zeiss (Zeiss-50<sup>3</sup>)

The 48-inch (1220 mm) telescope<sup>3</sup> (Fig. 5) was designed by the Germany firm *Carl Zeiss* for the Berlin-Babelsberg Observatory in 1909. Due to the World War I followed by the world crisis the telescope didn't start its regular observations till 1924. The 48-inch telescope remained the largest telescope in Europe throughout 20 years (between 1924 and 1944). After the World War II the telescope was transported to the Crimean Astrophysical Observatory instead of the destroyed meter telescope of the Simeiz Observatory.



Fig. 5. 48'' reflector at CrAO

The telescope has the Cassegrain – Nasmyth system with an equivalent focus length of 24000 mm. It was equipped with three spectrographs: large ‘glass’, quartz, and diffraction ASP-11. The latter was also operated in combination with the image tube FKT-1A.

The paper by I.M. Kopylov (1954) provides a detailed information on investigations with the 48'' telescope, and the history of the telescope is described by K.N. Grankin (2013).

<sup>3</sup> The 1220-mm reflector at CrAO is often called Fifty rounding its 48 inches to 50.

Astronomical investigations with the telescope carried out at the Crimean Astrophysical Observatory are presented in papers by A.A. Boyarchuk (2013) and T.M. Rachkovskaya (2013).

The second part of Volume 109 of the *Izvestiya Krymskoi Astrofizicheskoi Observatorii* includes proceedings of the international conference “Telescope Zeiss-50”: first hundred years serving for astronomy”, which was held in the observatory in 2012.

### 2.2.3 2600 mm Shajn telescope (ZTSh)

Designed at the Leningrad Optical and Mechanical Association (LOMO) and named after academician G.A. Shajn, the largest optical telescope at CrAO ZTSh was put into operation in 1961 (Fig. 6). The instrument has four optical schemes



Fig. 6. ZTSh telescope

in which the following equipment was mounted. In the prime focus (9965 mm) – slitless spectrographs: SP-79, SP-80, and SP-110. In the Cassegrain system (42500 mm) – a diffraction CCD spectrometer. In the Nasmyth system (40750 mm) – spectrographs SP-72, SPEM with an image tube, and CCD. In the Coude focus (104250 mm) – spectrographs ASP-14, a diffraction CCD spectrometer, a stellar spectrograph with echelle (Ioannisianni et al., 1976; Gershberg, 1995).

The ZTSh spectral archive over the period between 1964 and 2000 includes information about 378 objects observed by photographic way (approximately 3000 records for direct images and for the registration with an image tube) and about 845 objects whose spectra were derived with CCD detectors (about 50000 images). In Fig. 9 photographic observations are denoted by yellow markers and CCD ones – by red circles.

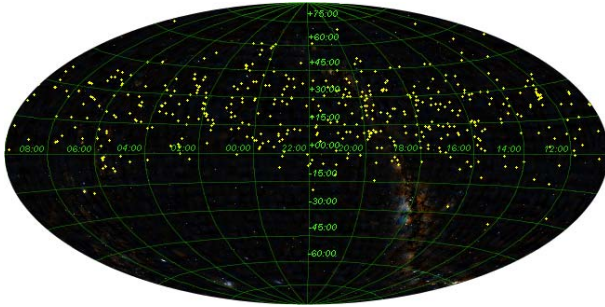
### 2.2.4 Archives of observations and databases

Spectral photographic archives of observations taken with three described above telescopes are maintained in the ‘glass’

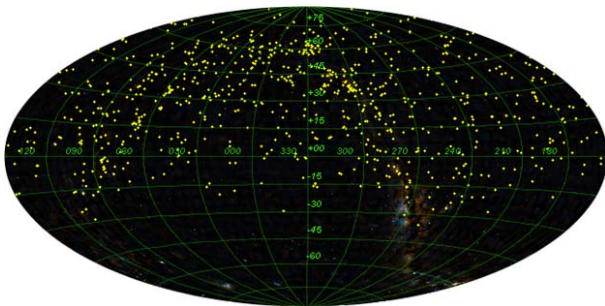


library at CrAO. Journals of observations and publications of data processing results form the basis for these databases.

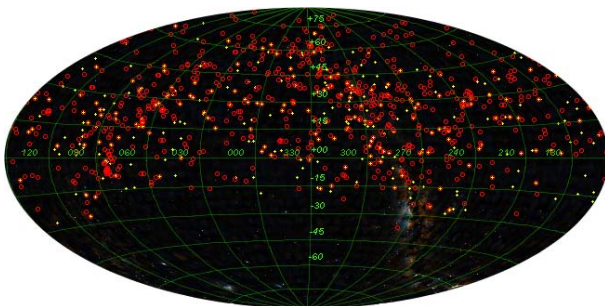
The spectroscopy database at the Simeiz 1 m telescope contains more than 3000 records. Based on it the ajs-file was created (Aladin Java Script) for 491 objects, which provides access to the information on stars with the program Aladin (Fig. 7).



**Fig. 7.** Distribution of objects on the celestial sphere observed with the 1000 mm telescope



**Fig. 8.** Distribution of objects on the celestial sphere observed with the 48'' telescope



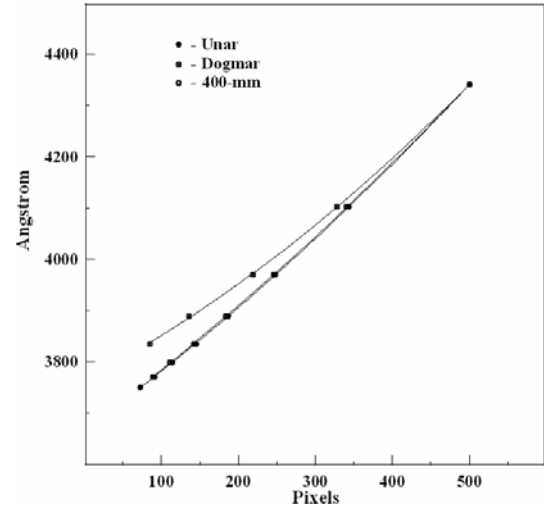
**Fig. 9.** Distribution of objects on the celestial sphere with ZTSh (explanation in the text)

The paper “The sky of Fifty: a catalogue and bibliography of objects observed with Zeiss 50”. Updated version” (Shlyapnikov, 2013) and its addition (Dolgov, Shlyapnikov, 2013) were published in 2013. The database of spectral observations includes 5570 records. To access Aladin, the ajs-file was created containing 808 objects (Fig. 8).

The database of spectral photographic observations with ZTSh includes 1223 records about objects. Information is available in the interactive Aladin Sky Atlas (Fig. 9).

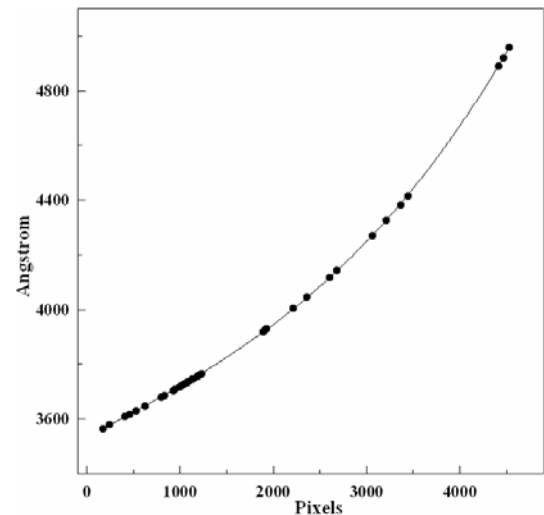
### 3 Calibrations and examples of digital versions of spectra

#### 3.1 Dispersion curves and spectral sensitivity



**Fig. 10.**

Wavelength calibrations of digital versions of observations carried out with an objective prism are performed based on the most characteristic spectral lines.



**Fig. 11.**

For the slit prism spectrograms – based on the comparison spectrum. Examples of such dispersion curves are shown in Fig. 10 and Fig. 11.

A comparison of normalized data of the spectrophotometric standard (black line) with data extracted for the object from the digitized negative (red line) is shown in Fig. 12. Fig. 13 shows spectral sensitivity of the image (based on data from Fig. 12) for further reduction of spectra extracted from negatives derived with an objective prism.

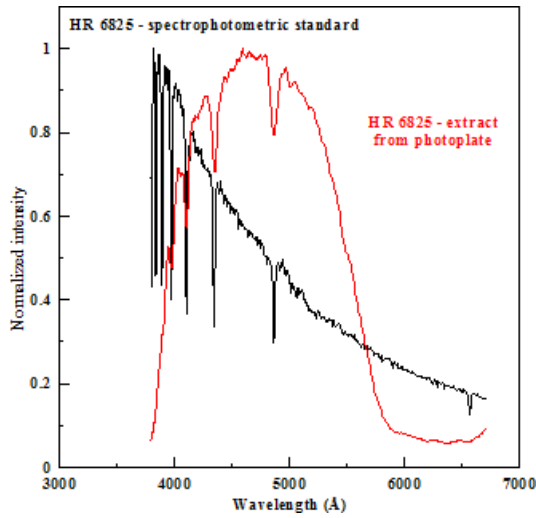


Fig. 12.

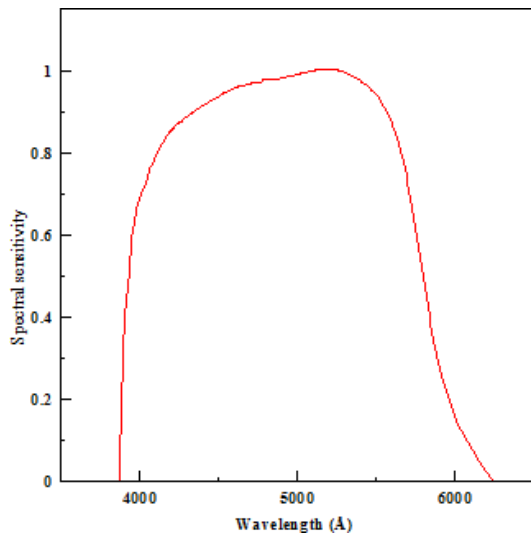


Fig. 13.

### 3.2 Scale reduction of the low-dispersion spectrum image in angstroms

In what follows, in Fig. 14, we present an example of conversion of the pixel scale into angstroms for the spectrum from the archive SOPCA. Fig. 14a shows the extracted with the program Aladin the HIP 88569 star spectrum from the negative derived with an objective prism (in the upper part).

The star has spectral type A0 and magnitude  $8^m.34$  in the V band. The abbreviation CrAOB008-11 corresponds to the fact that the original negative has number 11 in box 8 of the CrAO archive of spectral observations. A photometric section of the spectrum image is presented in the lower part of the figure.

Fig. 14b shows the calibration curve for the scale reduction of pixels into angstroms constructed based on the gravity center of HIP 88569 basic spectral lines at the level of half intensity depending on the corresponding wavelength. The approximation function represents a second-degree polynomial with coefficients found by the least-square method on

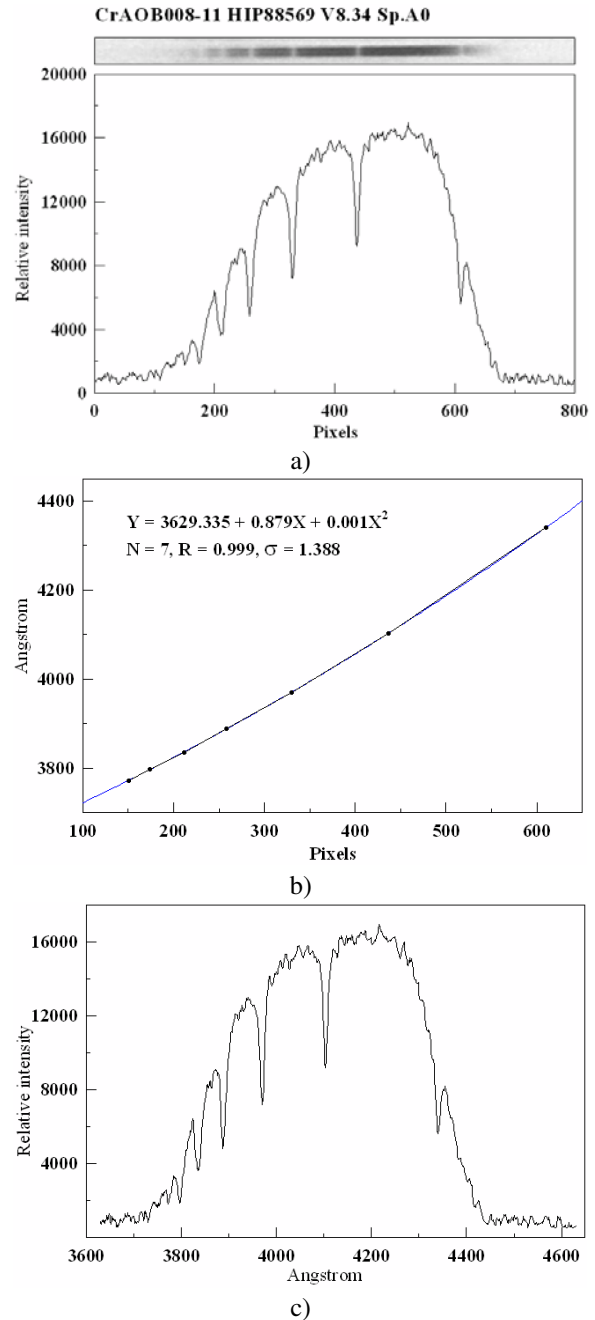


Fig. 14.

seven values of pixel – wavelength. The data correlation coefficient is close to a unit value at an error in determining the wavelength of  $\sim 1 \text{ \AA}$ .

Fig. 14c presents the final result of converting the pixel scale in the low-dispersion spectrum image into the wavelength scale expressed in angstroms.

### 3.3 Conversion of the pixel scale into angstroms for high-dispersion spectra

The conversion of the pixel scale into angstroms was performed based on the comparison spectrum (empty iron cathode with argon filling) imprinted above and under the AG Peg spectrogram (Fig. 15a).

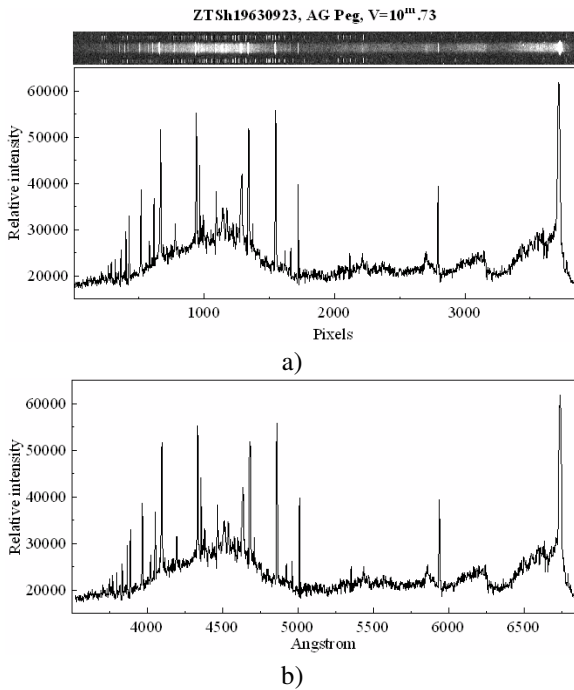


Fig. 15.

To construct a dispersion curve (an example is in Fig. 11), the gravity center positions of individual spectral line profiles of the upper and lower photometric section of the comparison spectrum are averaged to eliminate a possible image shift. The result of converting the pixel scale into angstroms is shown in Fig. 5b.

#### 4 Interactive access and processing digital versions of spectra

##### 4.1 Representation of information in the HTML format

Fig. 16 shows a fragment of the HTML page that provides access to the digital version of spectrograms from the archive of academician A.A. Boyarchuk. Here one may see the date of

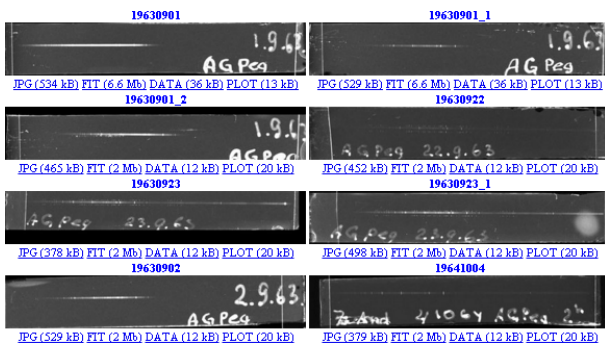


Fig. 16.

negative acquisition and its number according to the journal of observations, images of the negatives' reduced copies, hyperlinks (denoted by the blue color in Fig. 16) to the scanned

photoplate in the JPG and FIT formats, the transfer to the photometric section data and to its picture.

#### 4.2 Identification of spectral lines

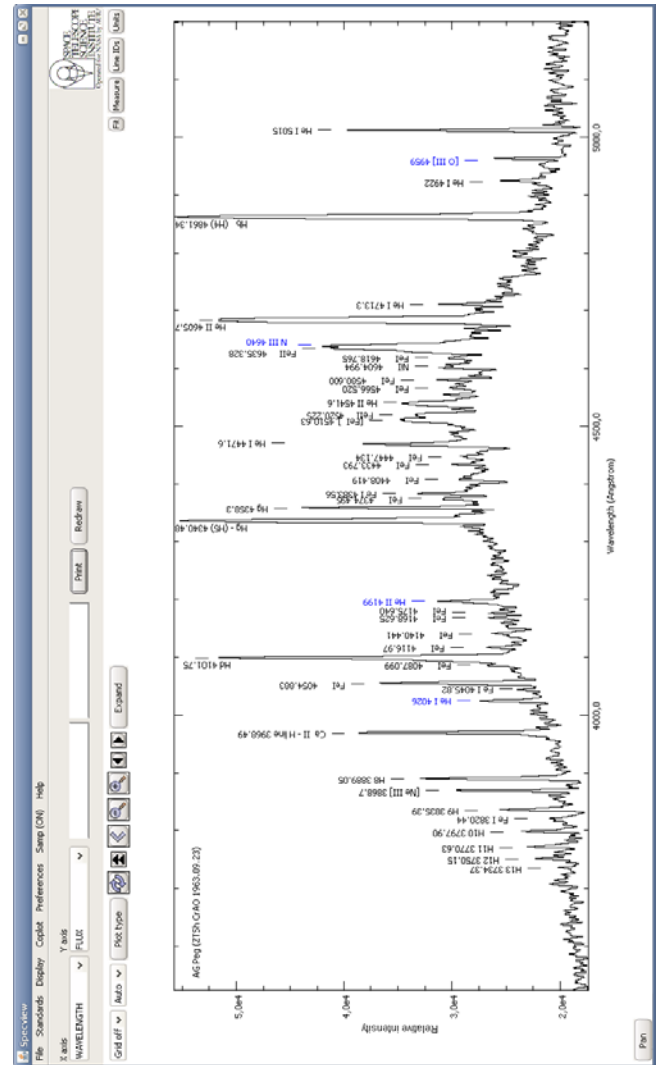


Fig. 17.

To identify spectral lines in the scanned spectrum of AG Peg, its photometric section was prepared in the format supported by the program *Specview* developed by the Space Telescope Science Institute (Busko, 2000). The program is the application of the International Virtual Observatory and provides interactive access to the information hosted via the internet, and to the CrAO spectral archives as well.

From the set of spectral lines maintained in the database *Specview* we extracted the best seen ones. Fig. 17 shows the program interface and points out elements with corresponding wavelengths. Nebular lines are indicated by the blue color. Note that the independent identification of spectral lines from the digitized spectrum of AG Peg is in good agreement with information published for this star in Vol. 35 of the *Izvestiya*

*Krymskoi Astrofizicheskoi Observatorii*. The paper “Spectroscopic observations of symbiotic stars Z And, AG Peg and AG Dra in 1963” by (Boyarchuk, Gershberg, 1966) provides information on relative intensities of 50 spectral lines for AG Peg. Fig. 17 indicates 42 the best seen spectral lines in one of the digitized archive negatives.

More examples of the digitized versions of photographic spectral archives are described by us in the paper “Examples of Digital Versions of the CRAO Spectral Photographic Archives” (Gorbunov, Shlyapnikov, 2013).

## 5 Conclusions

When implementing the work described in the article, we continued the catalogization of CrAO spectral observations. The procedure of scanning negatives with the scanner Epson Perfection V370 Photo was worked out, as well as their calibration, writing HTML, VOTable and AJS files for the online access to the archive information. On the portal of the Crimean Astrophysical Observatory there was created a special page devoted to the digital spectral archives of CrAO. To gain access, use the link: [http://www.crao.ru/~aas/Spectral\\_Digital\\_Archives/CrAVO\\_SDA.html](http://www.crao.ru/~aas/Spectral_Digital_Archives/CrAVO_SDA.html)

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