10.1515/astro-2017-0105

Baltic Astronomy, vol. 25, 23–30, 2016

ON THE ASTRON UV SPACE MISSION DATA

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Received: 2016 January 14; accepted: 2016 March 4

Abstract. The Soviet UV space mission Astron, launched in 1983, had been operational for eight years as the largest ultraviolet space telescope during its lifetime. Astron provided a lot of observational material for various types of astrophysical objects, but unfortunately these data were not widely available and, as a result, unduly forgotten. Here we present some results of our comparison of the Astron data to the modern UV stellar data, such as the NGSL spectral library, discuss the precision and accuracy achieved with Astron, and make some conclusions on potential application areas of these data.

Key words: space missions: Astron – ultraviolet: stars – astronomical databases

1. INTRODUCTION

Compiling empirical atlases of stellar spectra has become more active during recent decades, with both the number of data sets and the number of included stars growing. Unfortunately, this is not the case for the ultraviolet (UV) range, not accessible from the ground. On the other hand, the UV spectral range is of principal interest for astronomy since the energy distribution of hot stars, responsible for the chemical enrichment of the Galaxy, peaks at the UV wavelengths. Also, interstellar extinction affects the continuous energy distributions of astronomical objects, and its effects are particularly strong for observations at ultraviolet wavelengths. That is why the results from each UV space-borne observatory are of prime importance for construction/expansion of stellar spectral libraries towards high-temperature range.

Astron was a Soviet astrophysical space mission launched in 1983, and it had been operational for about eight years as the largest ultraviolet space telescope during its lifetime. Probably due to the difficult political and economic situation in the country in the 1990s, the data from the mission were not widely distributed. The Astron data are not included in the MAST archive, they are also not reflected in the VizieR. There are only 32 records in the NASA Astrophysics Data System, where the Astron mission is mentioned, and even among these publications, a part are devoted to the general description of the mission, and the rest of them deal only with a few objects from the list of targets observed by Astron (e.g., SN1987A and Comet Halley, the remarkable astronomical events during the operation of Astron). The only source of the Astron UV data is a separate issue (Boyarchuk 1994) published in 1000 copies in Russian language and, unfortunately, this book has been virtually inaccessible to the worldwide astronomical community.

We think that the Astron data do not deserve to be forgotten, and thus we decided to provide access to these data in the framework of the Russian Virtual Observatory project (see Malkov et al. 2016).

In this paper we compare the Astron low-resolution stellar spectra to the NGSL data, discuss the precision and accuracy achieved with Astron, and make conclusions on potential application areas of the Astron data. The spectral data for 90 stars have been submitted to the CDS (Strasbourg) and are available via VizieR. The submission of the data for other objects is also planned for the nearest future.

2. SOME FACTS ABOUT THE ASTRON MISSION

Astron was launched on 23 March 1983 by the Proton launcher and had been operational for eight years.

Its high-apogee orbit (with apogee at ∼200 000 km and perigee at ∼ 2 000 km, inclination 51.5°) permitted to exclude from the measurements the influence of the radiation belts.

Astron's payload consisted of the ultraviolet telescope Spica and a set of X-ray spectrometers. The Spica telescope was based on the classical Ritchey–Chrétien scheme, with the primary mirror of 0.8 m in diameter and a focal length of 7.86 m. The UV spectra were registered by the Rowland spectrograph in two channels. The first channel worked in the 2400–3500 Å range with $\Delta\lambda \approx 30$ Å and the second one, in the 1524–2600 Å range with $\Delta\lambda \approx 0.4$ Å and $\Delta\lambda \approx 30$ Å (originally there were three channels, but the third one appeared to be non-functional).

Spectral observations were obtained for more than a hundred stars of various types, dozens of galaxies and nebulae, as well as for several comets. Several sets of observations were devoted to Her X-1 and to X-ray sources in Orion, Taurus, and Leo. The Astron instruments observed also such phenomena as the supernova SN 1987A in the Large Magellanic Cloud (4–12 March 1987). The observations of Comet Halley (December 1985) allowed the Soviet scientists to develop a model of the comet's coma surrounding. The observations of symbiotic stars were also performed using Astron. Some important results were achieved in the study of non-stationary phenomena (flare stars). A more detailed description of the mission can be found in Boyarchuk et al. (2014).

The successful experience of the Astron mission is now used in the preparation of the WSO-UV ultraviolet space mission (Gomez de Castro et al. 2009; Boyarchuk et al. 2013; Shustov et al. 2014).

3. UV STELLAR DATA. ASTRON VERSUS NGSL

Among the most significant results from Astron, there are studies of stars in the UV spectral range (1500–3500 Å) at low resolution. The spectral energy distributions for 90 stars were obtained from 142 observations and published as tables with a wavelength step of 20 Å. The two spectral channels registered spectral ranges of 2400–3500 Å and 1524–2600 Å, respectively. In most of the cases, the spectrum of each star was obtained once; two, three or four observations were conducted more rarely.

Table 1. Stars common to both the Astron and NGSL atlases.

Name	HD	V	$B-V$	$U-B$	Sp. type	SIMBAD type
ε Eri	22049	3.73	+0.88	+0.59	K2 V	BY Dra variable
53 Tau	27295	5.35	–0.08	–0.25	B9 IV	α^2 CVn variable
α Cam	30614	4.29	+0.03	–0.88	O9.5 Iae	Emission-line star
AE Aur	34078	5.96	+0.22	–0.70	O9.5 Ve:	Orion variable
ζ Gem	52973	3.79	+0.79	+0.41	F7–G3 Ib	Classical Cepheid
UW CMa	57060	4.98	–0.15	–1.01	O7e+O7	β Lyr eclipsing binary
τ CMa	57061	4.40	–0.15	–0.99	O9 Ib	β Lyr eclipsing binary
κ Cnc	78316	5.24	–0.11	–0.43	B8 IIIp	α^2 CVn variable
η Leo	87737	3.52	–0.03	–0.21	A0 Ib	Star
ρ Leo	91316	3.85	–0.14	–0.96	B1 Ib	Pulsating variable
θ Leo	97633	3.34	–0.01	+0.06	A2 V	Variable star
β CrB	137909	3.68	+0.28	+0.11	F0p	α^2 CVn variable
τ Her	147394	3.89	–0.15	–0.56	B5 IV	Double or multiple star
γ Cyg	194093	2.20	+0.68	+0.53	F8 Ib	Variable star

Almost all stars selected for the Astron scientific program are variable. The available data are calibrated in absolute energy units by comparing the spectrum of 139 Tau (which served as a standard source) to the data obtained by the IUE mission (Boggess et al. 1978). For technical reasons (significant degradation of one of the channels in the course of the mission), unfortunately, the estimated inaccuracy of the Astron absolute fluxes can reach 15%. However, the relative SEDs are similar to those available in other spectral atlases. For data comparison, we used in this work the STIS Next Generation Spectral Library (NGSL) (Heap & Lindler 2007). Fourteen stars are found in both the Astron and NGSL atlases (accuracy of the NGSL atlas was discussed in Kilpio et al. 2012). These stars are listed in Table 1. Star types according to SIMBAD are also given.

Examples of data comparison for these stars are shown in Figs. 1 and 2 (the Astron data are represented by black color; the NGSL data are shaded grey); brief descriptions are given below for each of the stars. The variability type given here is taken from the General Catalogue of Variable Stars (GCVS) (Samus et al. 2007–2013), therefore, in some cases, it differs from that presented in Table 1.

HD 22049 = ε Eri. A BY Dra-type K2 V variable with the amplitude $\Delta V = 0.05$ mag. Planets have been discovered near this star. Normalizing of the Astron SED is probably inadequate (the magnitude difference between those of Astron and NGSL, 0.2 in $\log F$, corresponds to about 0.5 mag); however, the main spectral features are represented similarly in both SEDs. The spectrum was registered in the first Astron channel only (2400–3500 Å).

HD 27295 = 53 Tau = V1024 Tau. This low-amplitude ($\Delta U = 0.03$ mag), B9 IV rotating variable star shows a satisfactory agreement between the Astron and NGSL spectra.

HD 30614 = α Cam. An absorbed O9.5 Iae supergiant located at $b = +14°$. The interstellar extinction bump is clearly seen. It is also a variable star (NSV 16180) with the amplitude $\Delta H = 0.04$ mag. A rather good agreement is observed between the Astron and NGSL data (the difference is about 0.075 mag). The difference can probably be explained by the star's variability. The slopes of the spectra are almost identical in the whole spectral range.

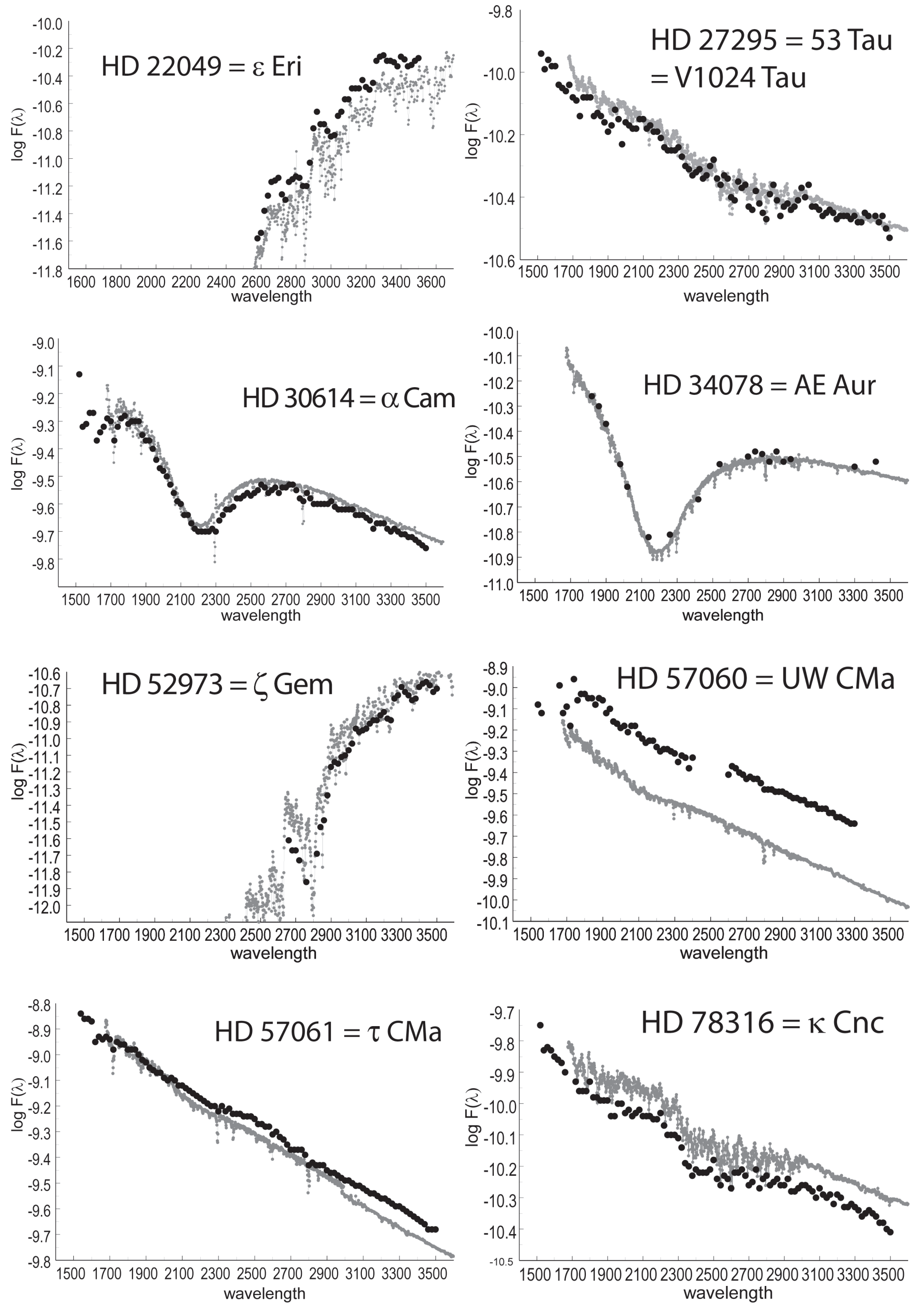

Fig. 1. Comparison between the NGSL and Astron data. Grey color: NGSL; black solid circles: Astron. (Continued in Fig. 2.)

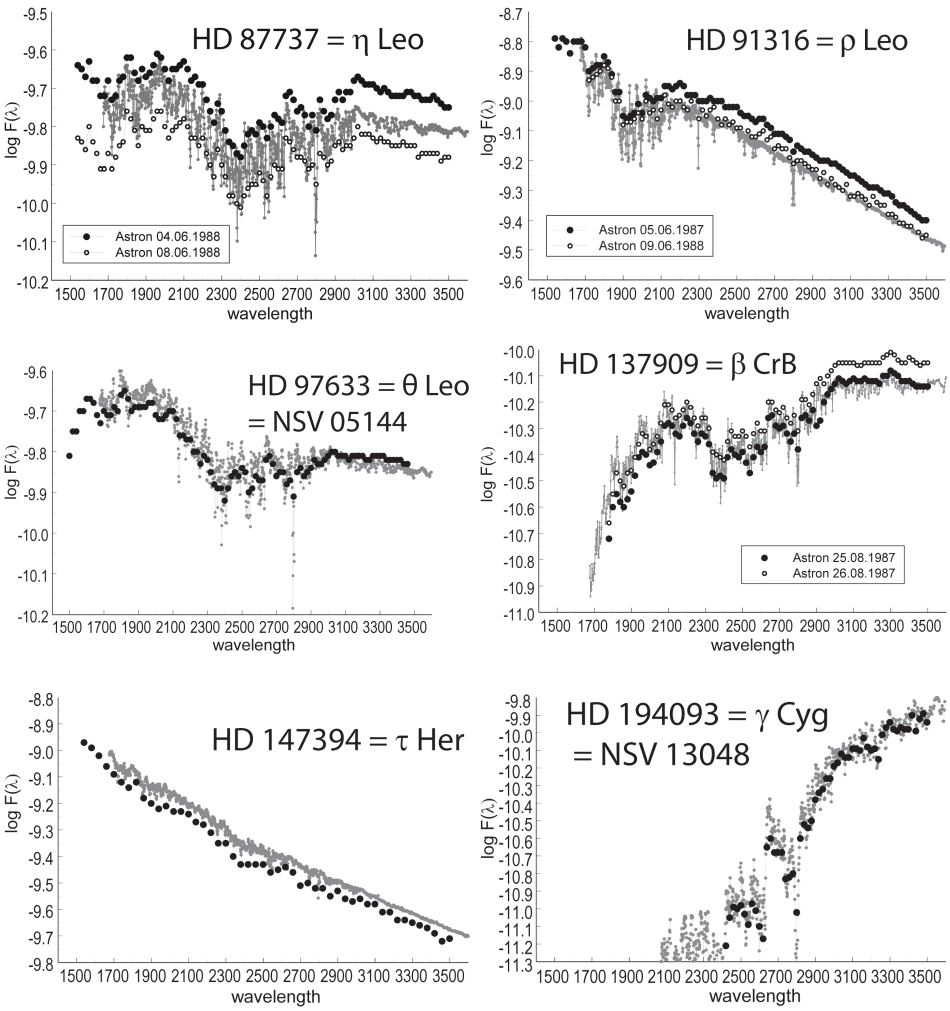

Fig. 2. Comparison between the NGSL and Astron data. Grey color: NGSL; black solid or open circles: Astron. (Continued from Fig. 1.)

HD 34078 = AE Aur. An eruptive variable (O9.5 Ve) with the amplitude $\Delta V = 0.3$ mag. It is also known as a "runaway star" from Ori OB1. No systematic difference between the Astron and NGSL data is observed; however, the Astron counts are given with a rather large wavelength step.

HD 52973 = ζ Gem. An F7–G3 Ib Cepheid with the amplitude $\Delta V = 0.6$ mag. The agreement between the Astron and NGSL data is satisfactory. Unfortunately, only one exposure of the Cepheid was made by Astron, on its descending branch, at the phase about 0.35. It is probably advisable to compare the Astron data with individual STIS observations stored in the HST archive. The SED difference (about 0.1 in $\log F$, corresponding to the magnitude difference 0.25

mag) can be easily explained by the star's variability. The spectrum was registered in the first Astron channel only (2400–3500 Å).

HD 57060 = UW CMa. An eclipsing O7 Ia+OB variable with the amplitude $\Delta V = 0.6$ mag. The slopes of the SEDs are almost identical, and the differences of the levels (0.2 in $\log F$, 0.5 mag in Δm) can be easily explained by the variability of the eclipsing binary.

HD 57061 = τ CMa. An eclipsing supergiant (O9 Ib) low-amplitude ($\Delta V = 0.05$ mag) variable star. The slopes of the SEDs are slightly different and, with such a small amplitude, it is difficult to explain the difference by temperature changes. An interpretation of the difference in slopes is complicated in this case; probably it is explainable by a systematic error.

HD 78316 = κ Cnc. This is an α^2 CVn-type B9 IIIp variable and a spectroscopic binary, with the amplitude $\Delta V = 0.05$ mag. Note that the Astron flux resides about 0.18 mag (or 0.07 in $\log F$) lower than that of NGSL for this star, and it is unlikely that the difference can be explained by the star's variability (cf. HD 22049). We note also that κ Cnc is a well-known (prototype) HgMn star (cf., for instance, a recent study in Maza et al. 2014).

HD 87737 = η Leo. Two SEDs were obtained by Astron for this variable star (NSV 04738). Their difference (by about 0.37 mag, or 0.15 in $\log F$) cannot be explained by the variability of the star, whose amplitude does not exceed 0.15 mag in V.

HD 91316 = ρ Leo. Two exposures with a time span of about one year were obtained by Astron for this pulsating B1 Ib variable with the amplitude $\Delta V = 0.07$ mag. These two SEDs agree with each other and with the NGSL SED for wavelengths shorter than 2000 Å. For longer wavelengths, however, one of the Astron spectra does not match the others by about 0.1 mag. The difference in the SED behavior for shorter and longer wavelengths does not permit us to explain this mismatch by the star's variability.

HD 97633 = θ Leo = NSV 05144. The Astron spectrum was obtained in the background diaphragm; it agrees with the NGSL one satisfactorily.

HD 137909 = β CrB. This F0p low-amplitude ($\Delta V = 0.07$ mag) rotating variable was observed during nine sessions. The SEDs from Astron exposures obtained on 1985/07/13, 1987/07/27, 1987/08/01, 1987/08/04, and 1987/08/25 coincide with the NGSL data for the 2300–3500 Å spectral range and reside lower than the NGSL SED in the 1600–2300 Å range. An example of such an Astron SED is plotted as black circles. On the contrary, all other Astron results (obtained on 1984/03/22, 1987/07/24, 1987/07/28, and 1987/08/26) coincide with the NGSL data in the 1600–2300 Å spectral range, and the Astron SEDs lie above the NGSL data in the 2300–3500 Å spectral range. An example of such an Astron SED is plotted as open circles. Thus, these two groups of SEDs (having virtually the same slope) are shifted relative to each other by about 0.07 in $\log F$ (or about 0.18 mag) and have a steeper slope than that of the NGSL SED. Note that the displayed spectra were obtained within two consecutive days, thus the equipment properties should be identical. Note, also, that some discrepancies for β CrB can be explained by its magnetic activity (see, for instance, Dimitrijević et al. 2005).

HD 147394 = τ Her. The slopes of the Astron and NGSL SEDs are practically identical, but the Astron SED resides about 0.15 mag lower than that of NGSL. This shift exceeds significantly the variability amplitude ($\Delta V = 0.03$ mag) of this long-period pulsating star, therefore an incorrect calibration should be responsible for the discrepancy.

HD 194093 = γ Cyg = NSV 13048. The spectrum of this F8 Ib star of unknown variability type with the amplitude $\Delta V = 0.09$ mag was registered in the first Astron channel only (2400–3500 Å) and is in satisfactory agreement with the NGSL data.

4. CONCLUSIONS

Comparison of the Astron and NGSL data allows us to make the following conclusions. The slopes and main details of the SEDs from Astron and NGSL coincide, and the flux discrepancies present can be explained by both the Astron's inaccuracy of absolute fluxes and by the variability of the observed stars. We note that some of the flux discrepancies can be caused by degradation of the charge-transfer efficiency (CTE) of the STIS CCD, reported, e.g., in Dixon (2011). Generally speaking, the CTE degradation differs for stars of different spectral type and brightness.

It should also be noted that the standard deviation of tabulated values of the Astron SEDs, according to the estimate from Boyarchuk (1994), is rather small, about 0.1% in the logarithm of flux [erg/(s cm^{2}Å)]. The Astron data confirm the NGSL fluxes and expand them to the far-UV domain (down to 1500 Å). Thus, the data obtained by the Astron satellite can make a substantial contribution to understanding the nature of variable-stars spectral energy distribution in the ultraviolet range. Constant-brightness stars were not observed by Astron. The Astron low-resolution UV stellar spectra of 90 stars obtained in 142 observations have been submitted to CDS (Strasbourg) and are available via VizieR.

ACKNOWLEDGMENTS. We are grateful to A. Boyarchuk and I. Savanov for their helpful comments and suggestions. We also thank E. Kanev, M. Scherbina, and V. Spirina for their assistance in digitizing the data. This work was partially supported by the program “Support to Leading Scientific Schools” of the Presidium of the Russian Academy of Sciences. This research has made use of the GCVS database, operated at the Sternberg Astronomical Institute, Moscow and the Vizier database (CDS, Strasbourg).

REFERENCES

Boggess A., Carr F. A., Evans D. C. et al. 1978, Nature, 275, 372

Boyarchuk A. (ed.) 1994, *Astrophysical Research with the Space Station Astron* (Astrofizicheskoe issledovanie na kosmicheckoi stantcii ”Astron”), Nauka, Moscow

Boyarchuk A., Shustov B., Moisheev A., Sachkov M. 2013, Solar System Research, 47, 499

Boyarchuk A., Savanov I., Kanev E. et al. 2014, Ap&SS, 354, 247

Dimitrijević M. S., Ryabchikova T. A., Popović L. Č. et al. 2005, Mem. Soc. Astron. Ital. Suppl., 7, 126

Dixon W. 2011, Instrument Science Report STIS 2011-02 (v2)

Gomez de Castro A. I., Pagano I., Sachkov M. et al. 2009, in *New Quests in Stellar Astrophysics. II. Ultraviolet Properties of Evolved Stellar Populations* (Proc. of the conference held on 2007 April 16–20 at Puerto Vallarta, Mexico) eds. M. Chavez et al., Springer, p. 319

Heap S. R., Lindler D. J. 2007, ASPC, 374, 409

Kilpio E., Malkov O., Mironov A. 2012, in *International Workshop on Stellar Libraries* (Proc. of the conference held on 2011 December 5–9 at University of Delhi, India), eds. P. Prugniel & H. P. Singh, Astron. Soc. of India Conf. Series, 6, 31

Malkov O., Dluzhnevskaya O., Bakanas E. et al. 2016, Baltic Astronomy, 25, 107

Maza N. L., Nieva M.-F., Przybilla N. 2014, A&A, 572A, 112

Samus N. N., Durlevich O. V., Kazarovets E. V. et al. 2007–2013, *General Catalogue of Variable Stars* (Samus+ 2007–2013); VizieR online data catalog: B/gcvs

Shustov B., Gomez de Castro A. I., Sachkov M. et al. 2014, Ap&SS, 354, 155