Contrib. Astron. Obs. Skalnaté Pleso **53/4**, 144 – 152, (2023)
https://doi.org/10.31577/caosp.2023.53.4.144

Comparison of Gaia BP/RP spectra with LDS (Low Dispersion Spectroscopy) photographic sky surveys

R. Hudec[1,2,3]

[1] *Czech Technical University in Prague, Faculty of Electrical Engineering (E-mail: hudecren@fel.cvut.cz)*

[2] *Astronomical Institute of the Czech Academy of Sciences 251 65 Ondřejov, The Czech Republic*

[3] *Engelhardt Observatory, Kazan Federal Universitry, Kazan, Republic of Tatarstan*

Received: July 13, 2023; Accepted: October 2, 2023

Abstract. Blue (BP) and Red (RP) Photometer low-resolution spectral data is one of the exciting new products in the third data release of ESA satellite Gaia (Gaia DR3)[1]. The Gaia "photometric mode" RP/BP generates ultra-low-dispersion prism spectra of celestial sources. The LDS (Low-Dispersion Spectroscopy) astrophysics was evolved and performed at numerous observatories (many in US) between ca 1909 and 1980. Mostly LDS with Schmidt telescopes was performed (plates with objective prism). These data were used in the past for various projects e.g. QSO, emission line and Halpha surveys, star classifications, etc. but little used after 1980. My estimate is that there are more than 100 million LDS star spectra in these databases. I will discuss their astrophysical scientific potential in recent astrophysics. I will show that these data can be used e.g. for the redshift estimation and study of High z Universe)

Key words: Gaia – spectroscopy – low dispersive spectroscopy

1. Introduction

Blue (BP) and Red (RP) Photometer low-resolution spectral data (Low dispersion spectra, LDS) is one of the exciting new products in Gaia Data Release 3 (Gaia DR3)[2] Montegriffo et al. (2023); De Angeli et al. (2023); Zhang et al. (2023); Witten et al. (2022); Carrasco et al. (2021) (Figs. 1, 2, 3)[3]. LDS data are also available in numerous historical photographic sky surveys (access after digitization). My estimate is that there are more than 100 million LDS star spectra are in these databases.

[1] `https://gaia.aip.de/cms/services/spectra-access/`

[2] `https://gaia.aip.de/cms/services/spectra-access/`

[3] `https://www.gaia.ac.uk/sites/default/files/media/images/bpi_spec.jpeg`, `https://www.cosmos.esa.int/web/gaia/iow_20201222`

These archival data have the potential to add historical epochs to recent LDS provided by Gaia RP/BP Hudec & Hudec (2011) Hudec et al. (2012). (Large) spectral variations with time (so far little exploited) can be studied this way effectively. Also, recent astrophysical tasks, e.g. searches for high z objects and optical counterparts of GRBs, represent an important application of these data Hudec & Šimon (2012) Hudec & Hudec (2013) Hudec (2018a) Hudec (2018b).

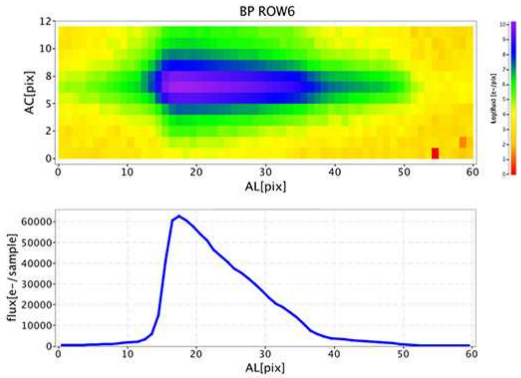

Figure 1. Examples of Gaia BP/RP LDS `https://www.gaia.ac.uk/sites/default-/files/media/images/bp_spec.jpeg`.

2. Astrophysics with LDS in the past

The LDS (Low-Dispersion Spectroscopy) astrophysics was evolved and performed at numerous observatories (many in the US) between ∼1909 and ∼1980 (Figs. 4, 5). Mostly was LDS performed with Schmidt telescopes (photographic plates with an objective prism in front of the telescope). This approach was used for various projects e.g. QSO, emission line and Halpha surveys, star classifications, etc., but was little used after ∼1980. Today knowledge in the astronomical community is very limited.

The most important LDS Plate Surveys/Databases for providing historical epochs for Gaia BP, RP are as follows:

1. German La Paz Bolivia Expedition, 1926–1929: Southern Sky Coverage D
2. Hamburg Quasar Spectral Survey D

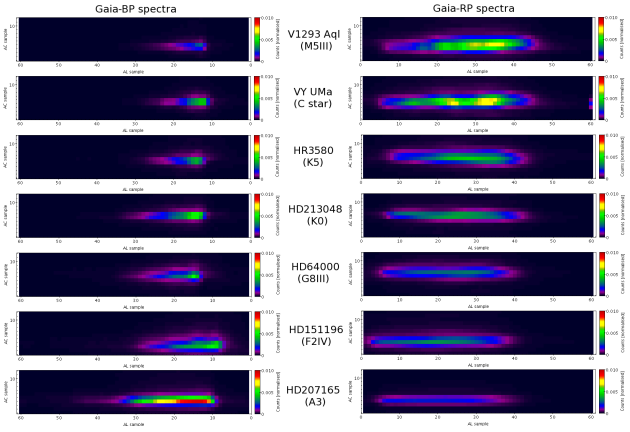

Figure 2. Examples of Gaia BP/RP LDS `https://www.gaia.ac.uk/sites/default-/files/media/images/bp_spec.jpeg`.

3. Byurakan Spectral Survey D

4. Northern Halpha MtWilson-Michigan Sky Survey PD

5. Southern Halpha MtWilson-Michigan Sky Survey PD (Figs. 6, 7, 8). (here D = Digitised, PD=Partly Digitised)

The Digitized First Byurakan Survey (DFBS) is the digitized version of the First Byurakan Survey (FBS). It is the largest photographic LDS spectroscopic database in the world, providing low-dispersion spectra for 20,000,000 objects on 1139 FBS fields = 17,056 deg2 with online access. Sky coverage: DEC $\geq$-15 deg, all RA (except the Milky Way). The survey is based on prisma spectral plates taken by by 1 m aperture Schmidt telescope. The limiting magnitude amounts to 17.5 in V, The spectral range is 340–690 nm, spectral resolution 5 nm, and dispersion: 180 nm/mm near H-gamma

The Hamburg survey is a wide-angle objective prism survey searching for quasars with B brighter than 17.5 on the northern sky. The survey plates have been taken with the former Hamburg Schmidt telescope, which is located at Calar Alto/Spain since 1980. For the survey, the 1.7-degree prism was used providing unwidened objective prism spectra with a dispersion of 139 nm/mm at Hgamma. Under conditions of good seeing the FWHM of the images is 30 m (plate resolution) giving a spectral resolution of 4.5 nm at Hgamma on the objective-prism plates. The survey has online access.

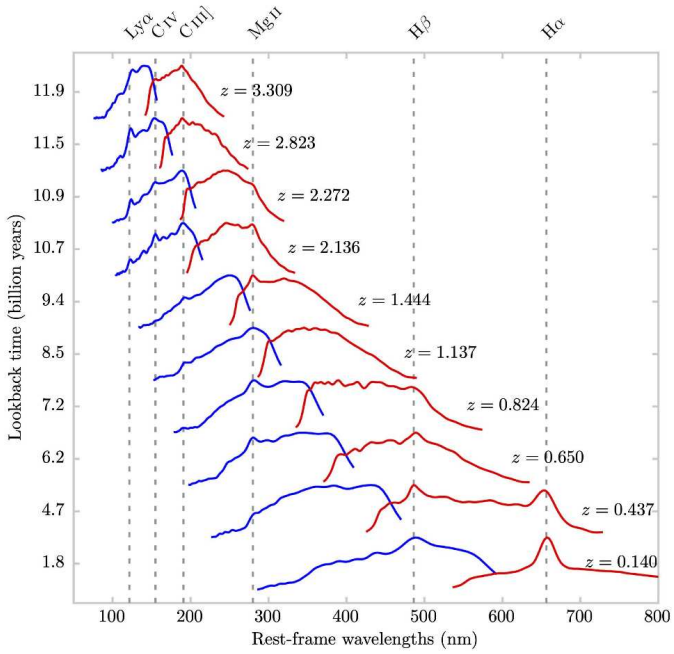

Figure 3. Gaia low-resolution BP and RP spectra (blue and red, respectively) of ten known quasars selected with apparent G magnitudes between 17 and 18. The QSO spectra are plotted in their rest-frame `https://www.cosmos.esa.int/web/gaia/iow_20201222`.

3. Astrophysics with Ultra LDS provided by Gaia RP/BP

The Gaia BP/RP LDS is able to provide (i) Continuum profiles, including high z objects (ii) Searches for objects with strong emission lines (iii) Searches for strong variable emission lines and (iv) Prominent spectral variability.

There is also the possibility of spectroscopic Gaia alerts and Follow-up by ground-based RTs with LDS. As already mentioned, the plate sky surveys can add long-term coverage and historical epochs to these analyses Hudec & Hudec (2013) Hudec (2019).

The Gaia BP/RP provides a unique chance to provide early or simultaneous LDS for GRBs (so far LDS mostly late), chance to recognize/classify OAs and OTs of GRBs using LDS and/or color information, chance to detect/study orphan OAs of GRBs, Study possible spectral time changes/evolution, and Chance of redshift estimation up to z∼7 and study of high z Universe (Figs. 9, 10).

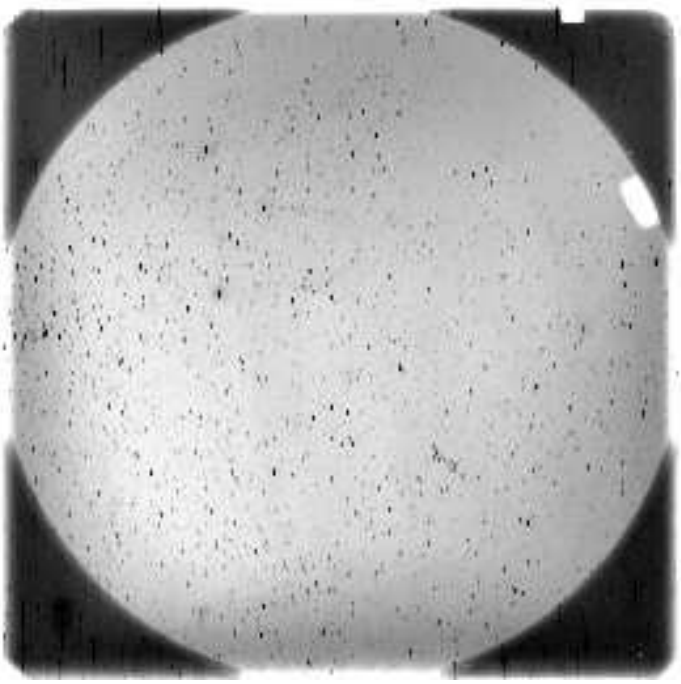

Figure 4. Example of digitized LDS photographic plate, PARI USA. Scan of a plate from the PARI Case Western Reserve Univ. collection. This plate (#10246) was taken on November 17, 1974 (dec= +23.5, RA= 4h50m) and is part of the Tau Cloud Survey. The exposure is 72min, Emulsion 103aE, Filter = OG2, 1.8 deg prisma.

4. Conclusion

With Gaia BP/RP, LDS spectral data are available for huge number of celestial sources, both galactic as well as extragalactic. Adding historical epochs to these data obtained from digitized LDS photographic surveys will allow large spectral variations over long time intervals (up to 100 years) to be studied. Both types pf LDS can be also used for searches for highly redshifted objects up to z $\sim$ 7.

Acknowledgements.

The research leading to these results has received funding from the European Unions Horizon 2020 Programme under the AHEAD2020 project (grant agreement n. 871158). Also, support by the project RVO:67985815 is acknowledged.

References

Carrasco, J. M., Weiler, M., Jordi, C., et al., Internal calibration of Gaia BP/RP

Figure 5. Early photographic LDS plate, Lick Observatory, USA, 1909.

low-resolution spectra. 2021, *Astronomy and Astrophysics*, **652**, A86, DOI: 10.1051/0004-6361/202141249

De Angeli, F., Weiler, M., Montegriffo, P., et al., Gaia Data Release 3. Processing and validation of BP/RP low-resolution spectral data. 2023, *Astronomy and Astrophysics*, **674**, A2, DOI: 10.1051/0004-6361/202243680

Hudec, R., Astrophysics with digitized astronomical plate archives. 2018a, *Astronomische Nachrichten*, **339**, 408, DOI: 10.1002/asna.201813515

Hudec, R., Low-dispersion spectroscopy with cubesats and photographic plates. 2018b, *Astronomische Nachrichten*, **339**, 416, DOI: 10.1002/asna.201813517

Hudec, R., Astronomical photographic data archives: Recent status. 2019, *Astronomische Nachrichten*, **340**, 690, DOI: 10.1002/asna.201913676

Hudec, R. & Hudec, L., Tests of simulated Gaia BP/RP spectra with LDS (Low Dispersion Spectroscopy) photographic sky surveys. 2011, in Journal of Physics Conference Series, Vol. **328**, *Journal of Physics Conference Series*, 012018

Hudec, R. & Hudec, L., Finding Hidden Treasures: Investigations in US Astronomical Plate Archives. 2013, *Acta Polytechnica*, **53**, 23

Hudec, R. & Šimon, V., ESA Gaia, ultra-low dispersion spectroscopy and GRBs. 2012, *Memorie della Societa Astronomica Italiana Supplementi*, **21**, 186

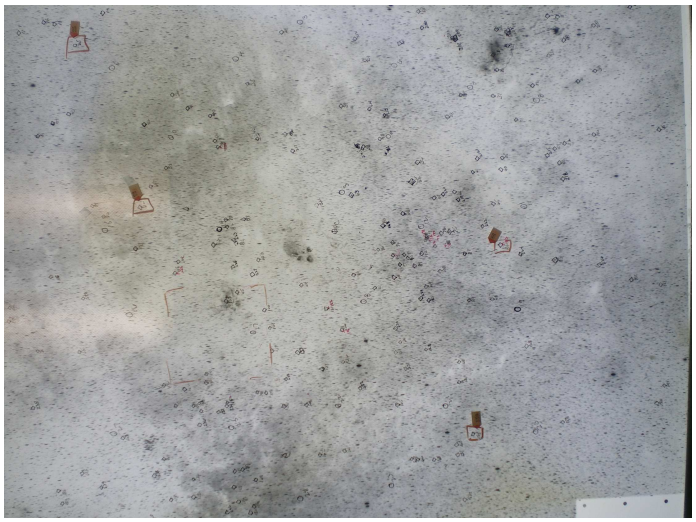

Figure 6. Southern Ha Mt Wilson Michigan Survey Plate extensively analyzed by K. Henize. 20 000 spectra were investigated by eye on every plate. 290 high-quality plates 15 x 15 inches were taken in 1950-1952 in South Africa by a dedicated telescope by Karl Henize (for his Dissertation). Taken by telescope D25 cm, 45 nm/mm at Halpha.

Figure 7. Example of prominent emission spectral features found by K. Henize in objective spectrum sky survey (Rate 1: 10 000), Michigan-Mt Wilson Southern Halpha Survey. There are hints that at least some of these strong emissions are variable. Taken by telescope D25 cm, 45 nm/mm at Halpha.

Figure 8. Example of prominent emission spectral features found by K. Henize in objective spectrum sky survey (Rate 1: 10 000), Michigan-Mt Wilson Southern Halpha Survey. There are hints that at least some of these strong emissions are variable. Taken by telescope D25 cm, 45 nm/mm at Halpha.

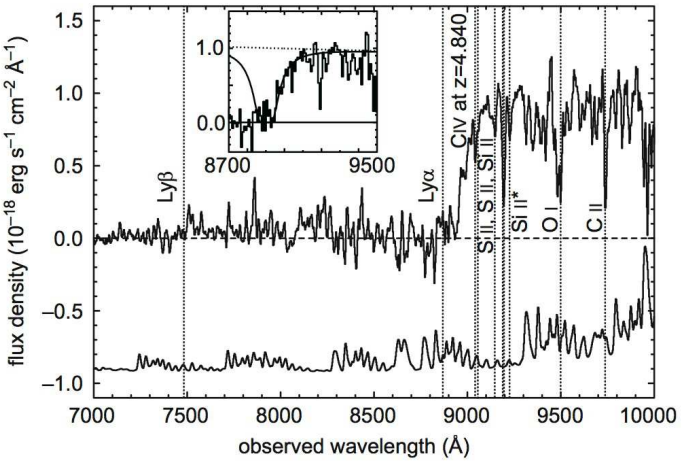

Figure 9. GRB 050904 at z=6.29. The target is visible only in very red. Kawai et al. (2005)

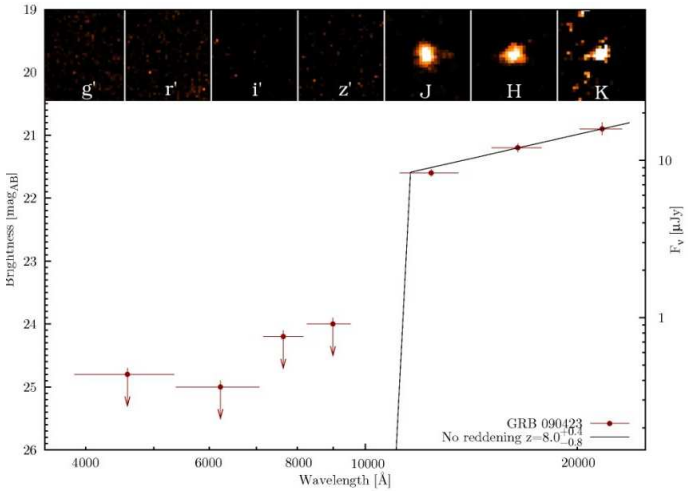

Figure 10. GRB 090423 at redshift 8, GROND observation (`https://www.mpe.mpg.de/ jcg/GROND/grb090423.html`) Confirmation that even very low resolution spectrum can provide valuable results for GRBs science. Analogous results can be expected from Gaia BP/RP but the limit will be 1 micron (due to RP energy range) hence redshifts up to 7 are feasible.

Hudec, R., Šimon, V., Hudec, L., & Hudcová, V., ESA Gaia & the multifrequency behavior of high-energy sources with ultra-low dispersion spectroscopy. 2012, *Mem. Societa Astronomica Italiana*, **83**, 342

Kawai, N., Kosugi, G., Aoki, K., et al., Afterglow spectrum of a gamma-ray burst with the highest known redshift z=6.295. 2005, *arXiv e-prints*, astro, DOI: 10.48550/arXiv.astro-ph/0512052

Montegriffo, P., De Angeli, F., Andrae, R., et al., Gaia Data Release 3. External calibration of BP/RP low-resolution spectroscopic data. 2023, *Astronomy and Astrophysics*, **674**, A3, DOI: 10.1051/0004-6361/202243880

Witten, C. E. C., Aguado, D. S., Sanders, J. L., et al., Information content of BP/RP spectra in Gaia DR3. 2022, *Monthly Notices of the RAS*, **516**, 3254, DOI: 10.1093/mnras/stac2273

Zhang, X., Green, G. M., & Rix, H.-W., Parameters of 220 million stars from Gaia BP/RP spectra. 2023, *arXiv e-prints*, arXiv:2303.03420, DOI: 10.48550/arXiv.2303.03420