PROCEEDINGS OF SCIENCE

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

René Hudec*

[1] *Astronomical Institute of the Academy of Sciences of the Czech Republic*
Fricova 298 - CZ 251 65 Ondrejov, Czech Republic
[2] *Czech Technical University in Prague, Faculty of Electrical Engineering,*
Technicka 2, CZ 160 00 Prague, Czech Republic
[3] *Engelhardt Astronomical Observatory, Kazan Federal University, Kazan, Republic of Tatarstan*

E-mail: rene.hudec@gmail.com

I will briefly present and discuss the potential of LDS (low dispersivve spectroscopy) with digitized photographic plates taken mostly by Schmidt telescopes. Extended databases of these records are available at numerous observatories, mainly in the USA, with total estimated number exceeding 100 000. They represent valuable source of astrophysical information, especially for automated searches for objects with peculiar spectra as well as for (prominent) spectral changes including highly reshifted injects such as distant GRBs.

Blue (BP) and Red (RP) Photometer low-resolution spectral data is one of the exciting new products in ESA satellite Gaia Data Release 3 (Gaia DR3) .† 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 the 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.

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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)[1], [1][2][3],[4], [5], (Figs. 1,2, 3) [2],[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.

These archival data have the potential to add historical epochs to recent LDS provided by Gaia RP/BP [6] [7]. (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 [8] [9] [10] [11].

2. LDS - historical background

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
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 ≥-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

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

[2] https://www.gaia.ac.uk/sites/default/files/media/images/bp$_{s}pec.jpeg$

[3] https://www.cosmos.esa.int/web/gaia/iow$_2$0201222

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 µm (plate resolution) giving a spectral resolution of 4.5 nm at Hgamma on the objective-prism plates. The survey has online access.

3. Gaia RP/BP and ultra LDS

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 [9] [12].

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$\sim$7 and study of high z Universe (Figs. 9, 10).

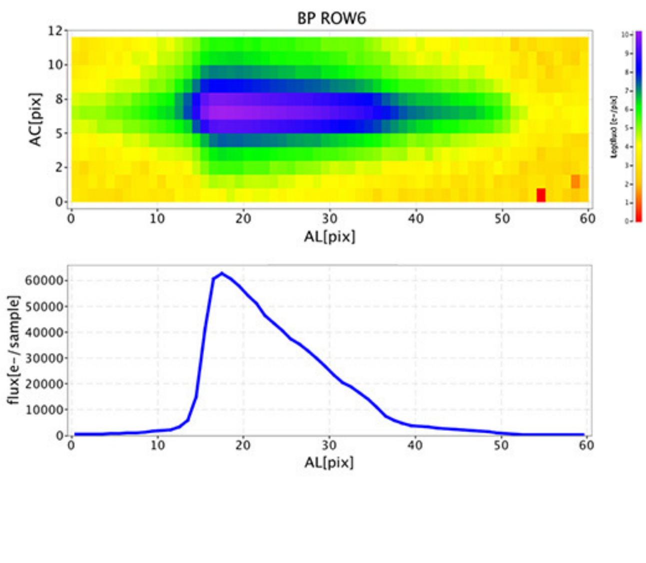

Figure 1: Examples of Gaia BP/RP LDS[a=] https://www.gaia.ac.uk/sites/default/files/media/images/bp$_s$*pec.jpeg*.

4. LDS with photographic plates

The LDS (Low-Dispersion Spectroscopy) astrophysics in optical light was evolved and per-

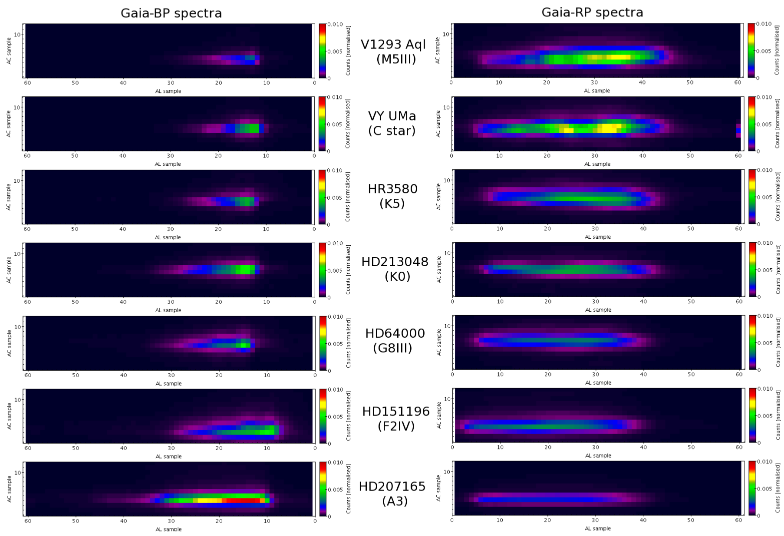

Figure 2: Examples of Gaia BP/RP LDS[b=]
https://www.gaia.ac.uk/sites/default/files/media/images/bp$_{s}pec.jpeg$.

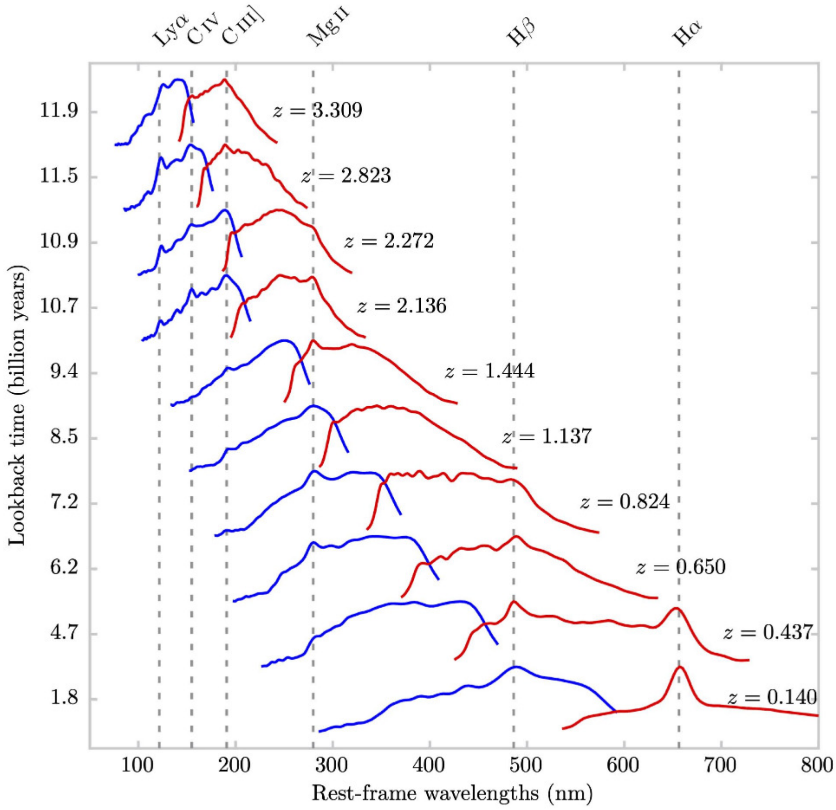

Figure 3: Gaia low-resolution BP and RP spectra (blue and red, respectively) of ten known quasars selected with apparent G magnitudes between 17 and 18. The QSO spectra are plotted in their rest-frames https://www.cosmos.esa.int/web/gaia/iow$_2$0201222.

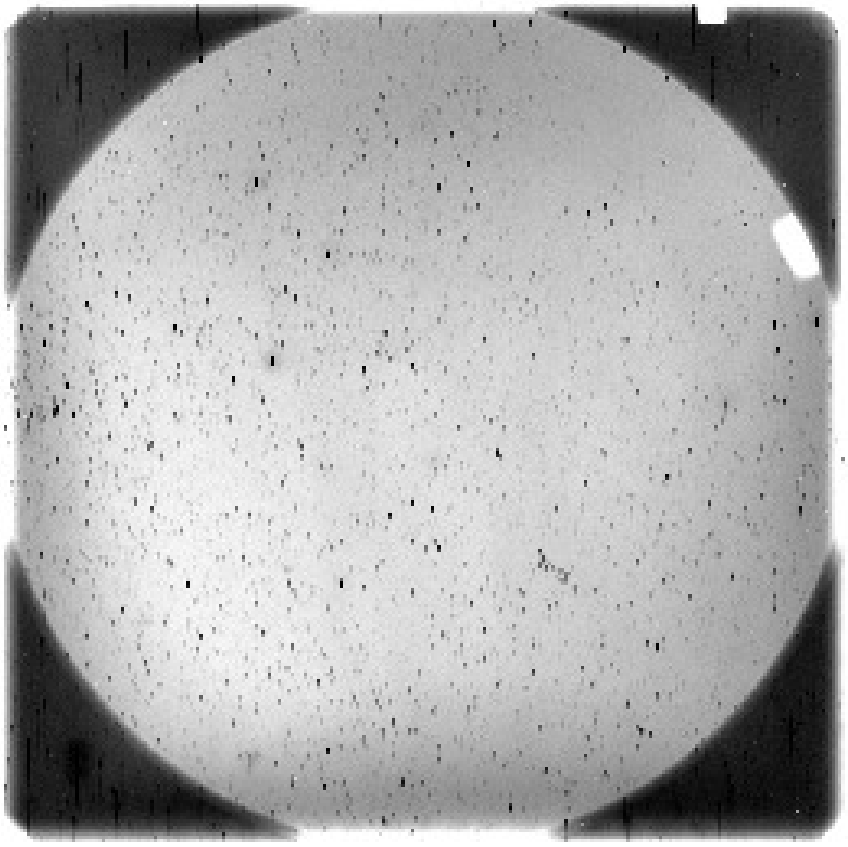

Figure 4: Example of digitized LDS photographic plate, PARI USA. Scan of a plate from the PARI Case Western Reserve Univ. collection. This plate (10246) was taken on November 17, 1974 (dec= +23.5, RA= 4h50m) and is part of the Tau Cloud Survey. The exposure is 72min, Emulsion 103aE, Filter = OG2, 1.8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

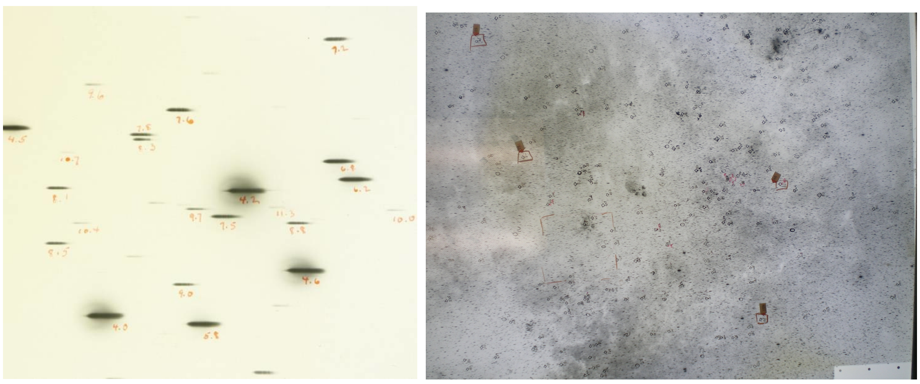

Figure 5: Left Early photographic LDS plate, Lick Observatory, USA, 1909. Right Southern Ha Mt Wilson Michigan Survey Plate extensively analyzed by K. Henize. 20 000 spectra were investigated by eye on every plate. 290 high-quality plates 15 x 15 inches were taken in 1950-1952 in South Africa by a dedicated telescope by Karl Henize (for his Dissertation). Taken by telescope D25 cm, 45 nm/mm at Halpha

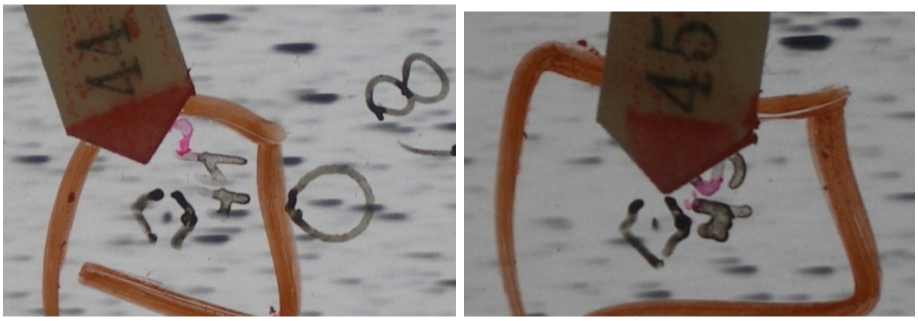

Figure 6: Examples of prominent emission spectral features found by K. Henize in objective spectrum sky survey (Rate 1: 10 000), Michigan-Mt Wilson Southern Halpha Survey. There are hints that at least some of these strong emissions are variable. Taken by telescope D25 cm, 45 nm/mm at Halpha.

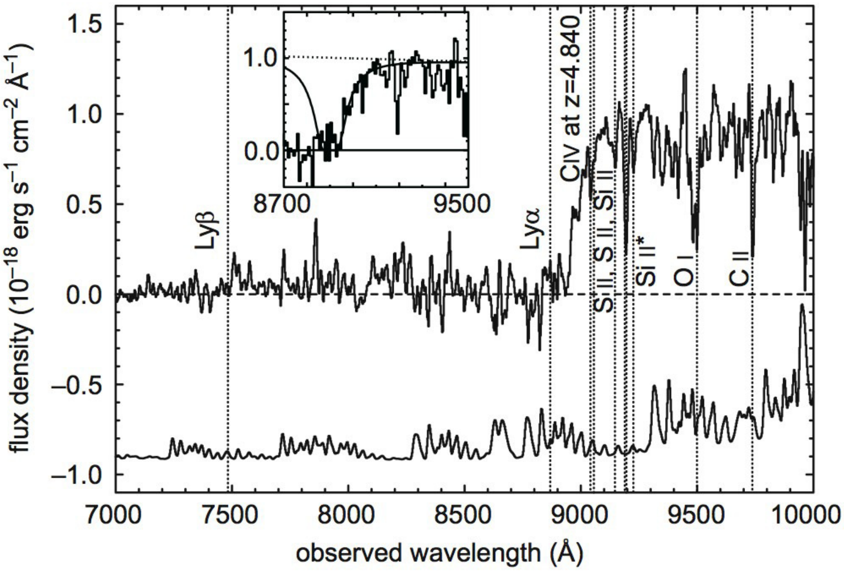

Figure 7: GRB 050904 at z=6.29. The target is visible only in very red. [13]

formed at numerous observatories (many in the US) between ca 1909 and 1980. The LDS surveys were provided mostly with Schmidt telescopes (plates with objective prism) and were used for various projects e.g. QSO, emission line and H–alpha surveys, star classifications, etc. This technique was however little used after 1980, and the consequence is that today knowledge among astronomers is very limited.

Below we list a few examples of LDS astronomical photographic plate archives, but there are many others. (1) Schmidt Sonneberg plates (typical mean value): the dispersion for the 7 deg prisma 10 nm/mm at H–gamma, and 23 nm/mm at H–gamma for the 3 deg prisma. The scan resolution is 0.02 mm/px, thus about 0.2 and 0.5 nm/px, respectively, (2) Bolivia Expedition plates: 9 nm/mm, with calibration spectrum, (3) Hamburg QSO Survey: 1.7 deg prisma, 139 nm/mm at

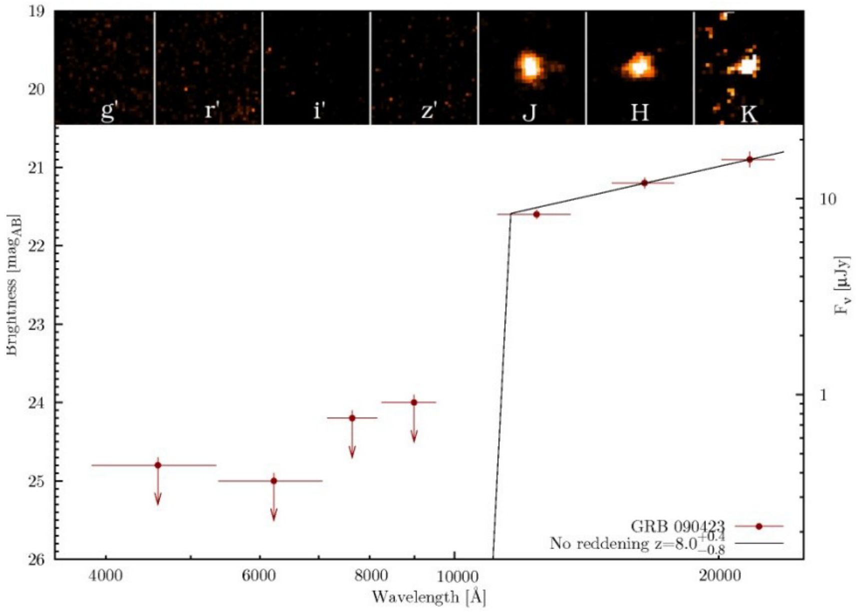

Figure 8: GRB 090423 at redshift 8, GROND observation, confirmation that even very low resolution spectra can provide valuable results for GRBs science. Analogous results can be expected from Gaia BP/RP but the limit will be 1 micron (due to RP energy range) hence redshifts up to 7 are feasible.d= https://www.mpe.mpg.de/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

H-gamma, spectral resolution of 4.5 nm at H, (4) Byurakan Survey: 1.5 deg prisma, 180 nm/mm at H-gamma, resolution 5 nm at H-gamma. (5) Michigan–Mount Wilson Southern H-alpha Survey. From 1949 – 1951, Karl Henize conducted a full southern survey at the Lamont–Hussey Observatory in Bloemfontein, South Africa. The purpose of the survey was to photograph the entire southern sky south of −25 degrees. A 10 inch refractor with a red–corrected Cooke triplet lens and a 52 inch focal length yielded a 16 x 16 degree field of view on 15 × 15 inch^2 glass plates coated with 103aE emulsion sensitive from 480 – 680 nm. A 15–degree objective prism gave a dispersion of 45 nm/mm at H–alpha with a plate scale of 159–arcsecs/mm.

5. LDS projects in space

5.1 Gemini UV experiments

The Henize Gemini UV experiments used lens of aperture 22 mm, f = 73 mm, f/3.3, field of view (FOV) 30 degrees, for the spectral range 230 - 500 nm. Some experiments (Gemini X, XI and XII) used grating 18.4 nm/mm at 200 nm, with 600 lines/mm. Other experiments (Gemini XI, XII) used a prism 140 nm/mm at 250 nm. These experiments were operated during EVA (outside spacecraft).

5.2 Skylab UV experiment

Upgraded and larger version of Gemini UV experiments with f/3 Ritchey–Chretien telescope with aperture 15 cm and FOV of 4x5 deg was used onboard Skylab orbital station. The used prism

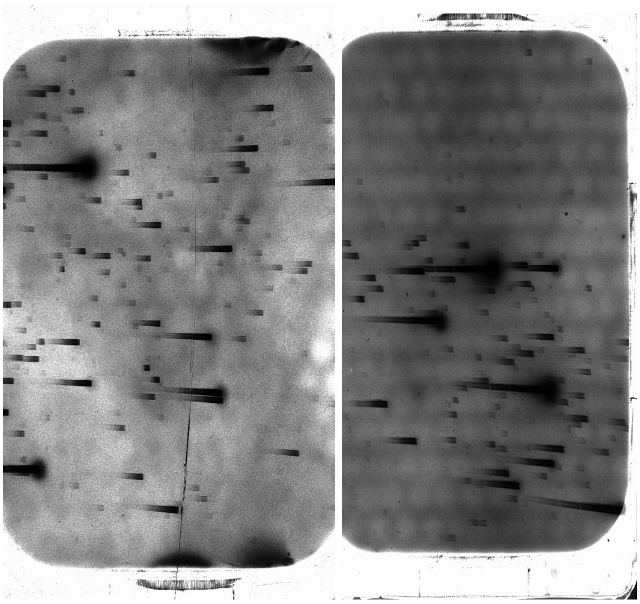

Figure 9: The example of digitized UV low dispersive spectral photographic photographic image taken with objective prism (Skylab UV experiment). New image scan 2016.

had dispersion 6.4, 36.5 and 128.1 nm at 140, 200, and 280 nm. The spectral resolution was 0.2, 1.2, and 4.1 nm, respectively. The recording medium was film.

The limiting magnitude for stars was 9 mag. For the considered cubesat UV mission, similar aperture can provide limiting magnitude of 12, due to use of CMOS detector instead of photographic emulsion.

5.3 Apollo UV spectrographic experiment

The small Far Ultraviolet Camera/Spectrograph was carried on Apollo 16. It used a 3-inch telescope to obtain images and spectra at wavelengths between 50 and 160 nm.

This experiment constituted the first planetary-based astronomy observatory and consisted of a tripod-mounted, 3-in electronographic Schmidt camera with a cesium iodide cathode and film cartridge. Spectroscopic data were provided in the 30-135 nm range (3 nm resolution), and imagery data were provided in two passbands (105 to 126 nm and 120 to 155 nm). Difference techniques allowed Lyman-alpha (121.6 nm) radiation to be identified. The astronauts deployed the camera in the shadow of the Apollo lunar module and then pointed it toward objects of interest. Specific planned targets were the geocorona, the earth's atmosphere, the solar wind, various nebulae, the Milky Way, galactic clusters and other galactic objects, intergalactic hydrogen, solar bow cloud, the lunar atmosphere, and lunar volcanic gases (if any). At the end of the mission, the film was removed from the camera and returned to earth. A back-up version of this experiment was later flown on the final Skylab flight and was used to study ultraviolet emission from Comet Kohoutek and other objects.

It should be noted that, before Apollo and Skylab flights, small UV experiments were flown several times on sounding rockets.

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6. Astrophysics with LDS

The low dispersive spectra, both in UV as well as in optical, will be useful for study of stars with very strong spectral emissions including spectral changes with time, as well as for searches for objects with strange spectral profile e.g. highly redshifted objects e.g. GRB afterglows. We also note that fraction of ESA Gaia data are also delivered as very low dispersive spectra (BP and RP photometers) hence long–term spectral evolutions can be investigated.

7. Conclusions

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 LDS types can also be used to search for highly redshifted objects up to a redshift of about 7.

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