Investigation of QSO spectra having measured L_α from GALEX FUV

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Abstract

Active Galactic Nuclei, especially quasars, have not been thoroughly investigated in far UV range. There are few observations in this range, and most of this range is available for objects with high redshifts, whose UV range is shifted to the optical one. But on the other hand, there is GALAXY Evolution Explorer (GALEX) space UV telescope catalog, where 82,992,086 near-UV (NUV, 1750–2800 Å) and far-UV (FUV, 1350–1750 Å) flux measurements in UV bands are available. In order to find a connection between the fluxes of two of the most important emission lines, λ5007 ([OIII]) and λ1216 (L_α) in the spectra of quasars, we created a sample of quasars with measured L_α. For this, we took the Milliquas 2023 catalog, which contains 1,021,800 objects. From these objects, we selected those having redshifts lying between $0.15 < z < 0.40$, so that L_α spectral line is located in GALEX FUV window. As a result, we have 42,150 objects. These sources were identified with SDSS DR16 and GALEX DR6+DR7, and as a result we have 11,697 identifications which have data from both SDSS and GALEX. Using a pilot survey (for 177 objects), we found a preliminary connection between L_α and [OIII] lines.

Keywords: *Active Galactic Nuclei, Quasars, UV sources, redshifts, emission lines*

1. Introduction

For our investigation we used catalogues: **Milliquas 2023, GALEX DR6+DR7** and **SDSS DR16**. Milliquas (Million Quasars) (Flesch, 2023) quasar catalogue which presents all published quasars to 30 June 2023, including quasars from the first releases of the Dark Energy Spectroscopic Instrument (DESI) and the SDSS-DR18 Black Hole Mapper. Its totals are 907,144 type-I QSOs/AGN and 66,026 high-confidence (∼99% likelihood) radio/X-ray associated quasar candidates. Type-II and Bl Lac type objects are also included, bringing the total count to 1,021,800. Gaia-EDR3 astrometry is given for most objects.

The Galaxy Evolution Explorer (GALEX) (Bianchi et al., 2017) imaged the sky in two ultraviolet (UV) bands, far-UV (FUV, 1350–1750 ÅÅ, λeff ∼ 1528 Å), and near-UV (NUV, 1750–2800 Å,λeff ∼ 2310 Å), delivering the first comprehensive sky surveys at these wavelengths. The GALEX database contains FUV and NUV images, ∼500 million source measurements and over 100,000 low-resolution UV spectra. The UV surveys are a unique resource for statistical studies of hot stellar objects, $z \lesssim 2$ QSOs, star-forming galaxies, nebulae and the interstellar medium, and provide a roadmap for planning future UV instrumentation and follow-up observing programs. We present science-enhanced, "clean" catalogs of GALEX UV sources, with useful tags to facilitate scientific investigations.

The **Sloan Digital Sky Surveys (SDSS-16)** (Ahumada et al., 2020), the fourth and penultimate from the fourth phase (SDSS-IV). This is the first release of data from the Southern Hemisphere survey of the Apache Point Observatory Galactic Evolution Experiment 2 (APOGEE-2); new data from APOGEE-2 North are also included (see Tables 1 and 2).

Using Milliquas 2023 catalogue we selected 11,697 objects which have data from both SDSS and GALEX catalogues.

Figure 1 shows examples of spectra where it can be seen that the L_α and [OIII] 5007 lines in our sample are among the strongest lines, and we were able to separate them from the continuum.

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Table 1. SDSS DR16 imaging data statistics

SDSS DR16 imaging data statistics	
Total unique area covered	14,555 square degrees
Number of catalog objects	1,232,051,050
Number of unique detections	932,891,133

Table 2. SDSS DR16 optical spectroscopy data statistics

SDSS DR16 optical spectroscopy data statistics	
All programs combined	
Total spectra	5,789,200
Useful spectra	4,846,156
Galaxies	2,863,635
Quasars	960,678
Stars	1,021,843
Sky	475,531
Standards	108,603
Unknown	352,320

2. Investigated data

In order to find a connection between the fluxes of the λ5007 ([OIII]) and λ1216 (L_α) lines in the spectra of quasars, we created a sample of quasars with L_α line. For this way, we took the Milliquas 2023 catalog, which contains 1,021,800 objects. From those objects we selected objects having redshift between 0.15<z<0.40, so that L_α spectral line located in GALEX FUV window. As a result, we have 42,150 objects. These sources were identified with SDSS DR16 and GALEXY DR6+DR7; as a result we have 11,697 identifications which have data from both SDSS and GALEX (see Table 3).

Table 3. Number of QSOs in Milliquas 2023 with z between 0.15<z<0.40 and associated objects in SDSS and GALEX catalogues.

Catalog/Database	**Studied objects**	**Fraction of Milliquas 2023 objects**
Milliquas 2023 all	1,021,800	100.00
Milliquas 2023 z-selected	42,150	4.12
SDSS DR 16 associations	33,607	3.29
GALEX DR6+DR7 associations	**11,697**	**1.14**

We see that very small fraction of Milliquas 2023 objects can be studied for the connection between L_α and [OIII]. However, this may be a key for the rest of the QSOs to calculate (or at least estimate) L_α flux just having [OIII] flux. Thus, such approach may be very efficient for numerous QSOs.

3. Connection between L_α and [OIII] lines

For 177 objects we found initial connection between L_α and [OIII] lines.

In Figure 2 we created the plot for these sources. In the further work we will create connection between L_α and [OIII] lines for all 11697 objects. We obtained a preliminary linear relationship for the spectral lines of 177 objects (empirically described by the formula y= 0.624X -6.11). More sources are needed to verify the reliability of this result.

4. Color-color diagrams

Having information from SDSS catalogue for 11,697 investigated objects we build color-color diagrams. In Figure 3 we can distinguish 2 groups. At this moment we cannot say anything about these groups, because we need more information about optical classification of these sources.

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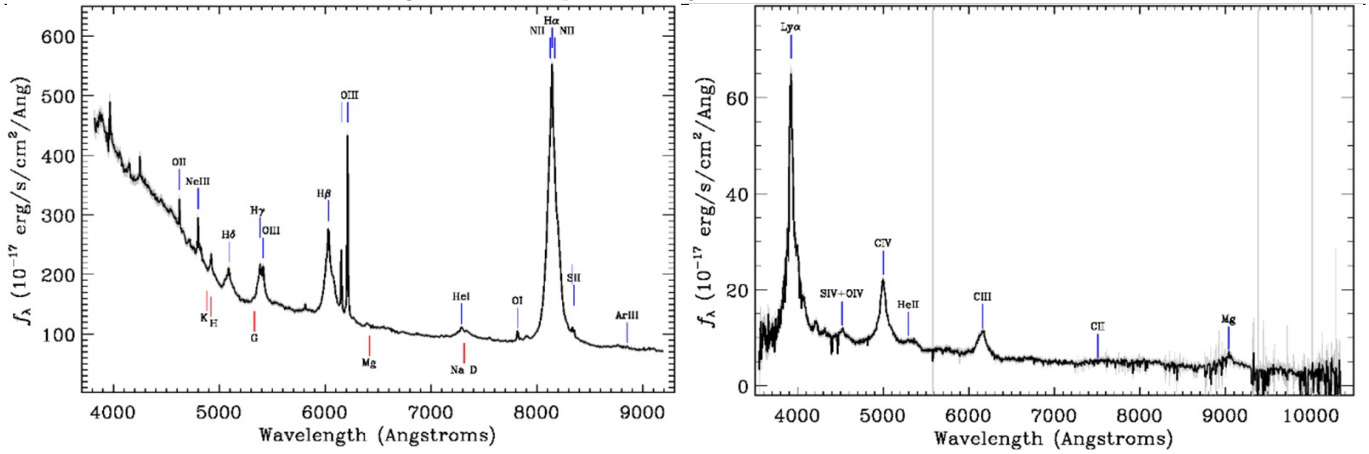

Figure 1. Examples of spectra of QSOs. Typically, L_α line is dozens of times stronger than the continuum, so that GALEX FUV flux may be presented as L_α for the respective redshifts.

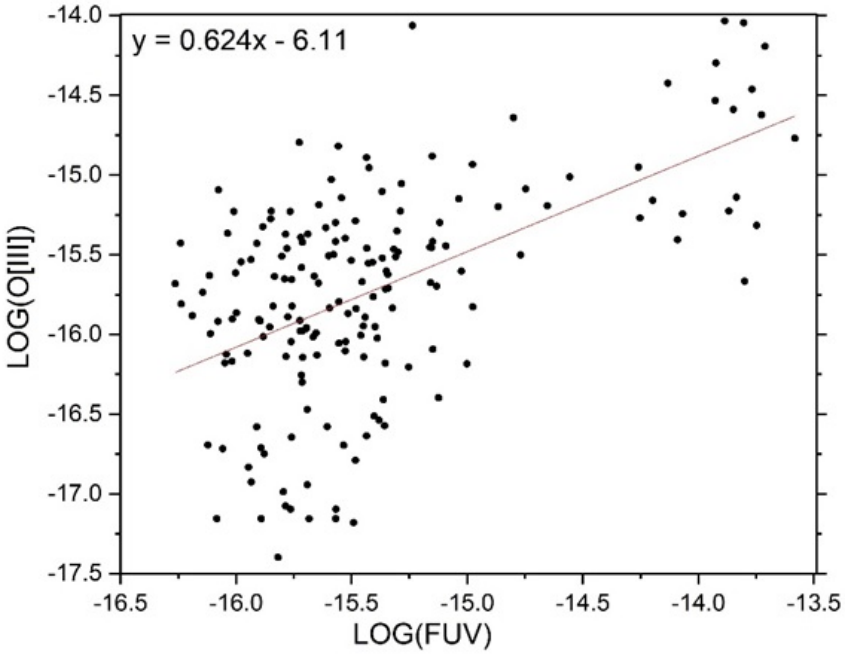

Figure 2. Connection between L_α (GALEX FUV flux) and [OIII] lines for 177 objects.

5. Summary

Active Galactic Nuclei, especially quasars, have not been thoroughly investigated in the far UV range. There are few observations in this range, and this range is mostly available for objects with a high redshift, having UV shifted to the optical range. But on the other hand, there is GALAXY Evolution Explorer (GALEX) space UV telescope catalog, where 82,992,086 near-UV ($NUV, 1750–2800\mathring{A}\mathring{A}$) and far-UV ($FUV, 1350–1750\mathring{A}\mathring{A}$) flux measurements are available. In order to find a connection between the fluxes of the λ5007 ([OIII]) and λ1216 (L_α) lines in the spectra of quasars, we created a sample of quasars with measured L_α. For this, we took the Milliquas 2023 catalog, which contains 1,021,800 objects. From these objects we selected objects having redshift between $0.15 < z < 0.40$, so that L_α spectral line is located in GALEX FUV window. We suppose that FUV flux may be considered as L-alpha flux as its width for QSOs is enough large (occupying almost the whole FUV range) and the continuum is typically 10 times weaker. As a result, we have 42,150 objects. These sources were identified with SDSS DR16 and GALEX DR6+DR7, and as a result we have 11,697 identifications which have data from both SDSS and GALEX. As a result (for 177 objects) we found preliminary connection between L_α and [OIII] lines.

In further work we plan to do a similar work using GALEX NUV, which will give us connection for more

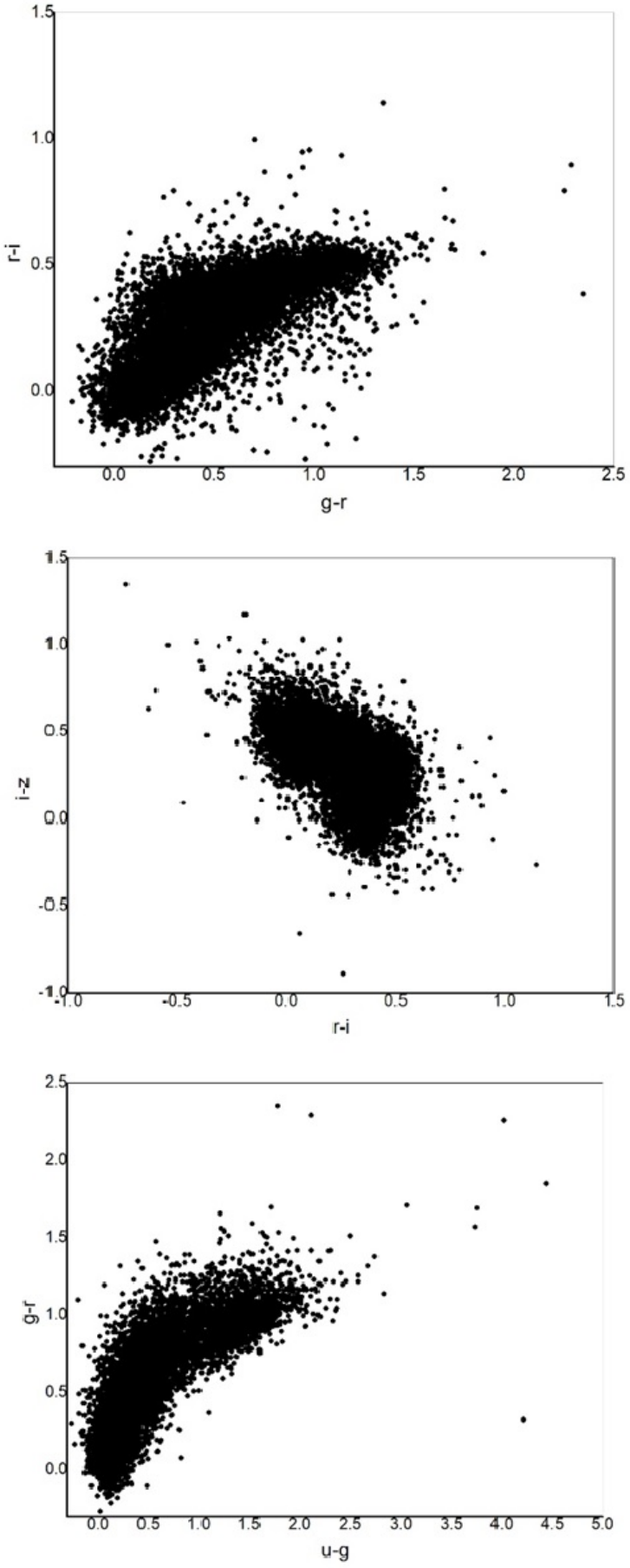

Figure 3. SDSS color-color diagrams for 11,697 investigated objects.

QSOs having z between 0.40 and 1.2 (we expect 60000 more QSOs), thus having L_α located in GALEX NUV. We will have L_α/[OIII] relation to make larger statistics and derive a better empiric formula. We

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plan also to investigate MgII line of quasars and try to find connection of our fine classification with UV range.

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