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ASERA: A spectrum eye recognition assistant for quasar spectra

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ABSTRACT

Spectral type recognition is an important and fundamental step of large sky survey projects in the data reduction for further scientific research, like parameter measurement and statistic work. It tends out to be a huge job to manually inspect the low quality spectra produced from the massive spectroscopic survey, where the automatic pipeline may not provide confident type classification results. In order to improve the efficiency and effectiveness of spectral classification, we develop a semi-automated toolkit named ASERA, A Spectrum Eye Recognition Assistant. The main purpose of ASERA is to help the user in quasar spectral recognition and redshift measurement. Furthermore it can also be used to recognize various types of spectra of stars, galaxies and AGNs (Active Galactic Nucleus). It is an interactive software allowing the user to visualize observed spectra, superimpose template spectra from the Sloan Digital Sky Survey (SDSS), and interactively access related spectral line information. It is an efficient and user-friendly toolkit for the accurate classification of spectra observed by LAMOST (the Large Sky Area Multi-object Fiber Spectroscopic Telescope). The toolkit is available in two modes: a Java standalone application and a Java applet. ASERA has a few functions, such as wavelength and flux scale setting, zoom in and out, redshift estimation, spectral line identification, which helps user to improve the spectral classification accuracy especially for low quality spectra and reduce the labor of eyeball check. The function and performance of this tool is displayed through the recognition of several quasar spectra and a late type stellar spectrum from the LAMOST Pilot survey. Its future expansion capabilities are discussed.

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1. Introduction

The Large Sky Area Multi-object Fiber Spectroscopic Telescope (LAMOST) is a special reflecting Schmidt telescope specialized for conducting spectroscopic surveys with a wide field of view and a large aperture (Wang et al., 1996). One of the key scientific goals of LAMOST is the extragalactic spectroscopic survey of the large scale structure of the Universe and the physics of galaxies and quasars (Wu, 2011). The pilot survey (Cui et al., 2012) performed from October 2011 to June 2012 and the regular survey started in September 2012. There have been already millions of targets observed, including thousands of quasar candidates. Then to recognize quasars via spectra becomes essential for critical candidate confirmation and follow-up scientific work.

Spectra with high signal-to-noise ratio (SNR) are easily classified and the physical parameters can be determined with high accuracy using the LAMOST data processing pipeline (Luo et al., 2012). However there are still a large number of spectra with low SNR and probably some defects (e.g., skylight residual, splice

connecting red part and blue part). Before the automatic pipeline is upgraded to be intelligent enough, eyeball check is in great need and enough astronomical knowledge is necessary. In the SDSS quasar survey, visual inspection has been widely used to ensure the reliability of spectral identifications (Pâris et al., 2012). However in a large sky spectra survey, the quantity of spectra is very large. In order to reduce human efforts, we developed a spectrum eye recognition toolkit which provides a flexible platform to help identifying quasar spectra and estimating their redshifts at the same time. We call this toolkit ASERA. Both fits-formatted and image-formatted spectral files are supported. The input source can be placed in a local storage device, or distributed on the internet, described by a URL name. Since the software is developed using the Java programming language, it can be either started as a desktop application or accessed via a web browser, after deploying it as a Java applet. ASERA is initially dedicated to experienced spectrum analysts. It can also be used by teachers, undergraduate students and amateur astronomers.

In the following sections, we first describe the detailed design and realization of the toolkit. Then several examples and figures are presented to explain how to use this toolkit on the spectra from LAMOST. In the end we discuss the system error on the estimated redshift z and the following upgrade plans to extend the functionality of ASERA.

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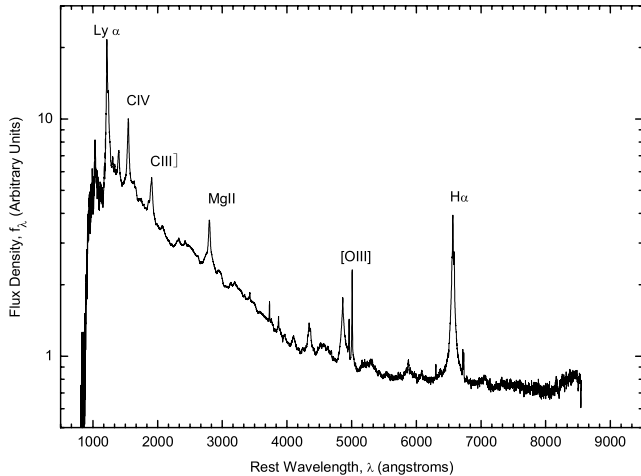


Fig. 1. The median composite quasar spectrum template from SDSS (Vanden Berk et al., 2001).

Table 1

Eight most distinct emission lines of the composite quasar (Table 2 of Vanden Berk et al., 2001).

ID	λ_{obs} (Å)
Ly α	1216.25 ± 0.37
C IV	1546.15 ± 0.14
C III]	1905.97 ± 0.12
Mg II	2800.26 ± 0.10
H β	4862.66^a
O III	4960.36 ± 0.22
O III	5008.22 ± 0.17
H α	6564.93 ± 0.22

^a The wavelength of H β is from Table 4 of Vanden Berk et al. (2001).

2. ASERA development status

The basic design idea of this toolkit is to overlay the quasar spectral template on the observed spectrum. With the help of the spectral identification experience, researchers try to superimpose these two spectra by choosing the appropriate redshift and flux scale ratio. The first important step is to choose a quasar template.

2.1. The quasar spectrum template

Due to the similar wavelength coverage and spectral resolution of LAMOST and SDSS, a median composite quasar spectrum generated by a sample of over 2200 quasars from SDSS is applied as the standard quasar template (Vanden Berk et al., 2001). The spectrum, as shown in Fig. 1, has over 80 identified emission lines within the band of wavelength from about 900 to 9000 angstroms. Eight most distinct emission lines are listed in Table 1.

In this toolkit, the composite quasar spectrum can be transformed to various shapes by adjusting the redshift and the flux scale via the mouse. By comparing the observed spectrum with the transformed composite spectrum, researchers can easily figure out the best fit and provide the apt redshift value if the observed target is a quasar.

2.2. Redshift calculation

Since the spectrum point is described by wavelength and flux density, a simple linear transformation is imported to get the pixel coordinate, and inversely to get the spectrum point from the pixel

coordinate. We construct a linear pixel transformation function from the observed target spectrum first and then apply it to the template.

In our toolkit, a default pixel transformation function is applied for the LAMOST spectrum products. To use this toolkit for image spectra from other spectral surveys, the user can choose the starting and end points in the pixel frame by a simple mouse click, and tag them with the correct wavelength value. Then the new transformation can be established on these two points.

The first step for plotting the template spectrum is to define the redshift z . We will choose one of the emission lines in Table 1 as the *reference line* and place it on the observed target spectrum. The redshift z of a wavelength which is shifted from λ_0 (from Table 1) to λ (calculated using the pixel transformation function inversely) is defined as

$$z = \frac{\lambda - \lambda_0}{\lambda_0}. \quad (1)$$

On the contrary, given the redshift value z , the wavelength λ_0 of a composite quasar spectrum can be shifted to λ defined by

$$\lambda = \lambda_0 \times (z + 1). \quad (2)$$

Then the whole template spectrum can be plotted at the specified redshift and flux scale. The user can find the most possible spectral type of the target and its corresponding redshift by changing and adjusting the template spectrum interactively.

2.3. Supported spectral formats and locations

The current version of this toolkit supports both image-formatted and fits-formatted spectral files produced by LAMOST. File types are identified by their suffixes.

Files ending with “PNG”, “JPG”, “JPEG”, “WBMP”, “GIF” and “BMP” are treated as images. The image file is plotted directly on a plane as the background and then the template spectrum as the foreground. The pixel transformation mentioned in Section 2.2 is used to calculate wavelength of any pixel point.

Files ending with “FITS” or “FIT” are treated as LAMOST fits products. The java fits library “nom.tam.fits” is imported to provide I/O for the FITS image and binary tables. Then the spectrum is obtained by referring to the fits header definition of the LAMOST spectra. In the latest version, “fits” files from SDSS are also supported.

The data file can be placed in a local storage device or on the internet. The Uniform Resource Locator (URL) is used to describe both the exact location and accessing protocol. The standard edition of Java Develop Kit supports several protocol types, such as “file”, “http”, “ftp” and “gopher”. The “file”, “ftp” and “http” protocol types have been tested for the current version. Here are some examples of the URL external format string used in Windows platform:

```
ftp://user:pwd@data.lamost.org/pdr/fits/20111024/F5902/spec-55859-F5902_sp16-249.fits
http://data.lamost.org/pdr/fits/20111024/F5902/spec-55859-F5902_sp16-249.fits
file://F:\B55878\spec-55878-B87808_sp02-002.fits
```

2.4. Installation

The local installation of the toolkit takes merely no time since the latest version is provided as a single JAR file. Java Virtual Machine (JVM) is required to run the toolkit. Once the JVM is installed, the toolkit can easily be launched on all the dominating operation systems such as Windows, Linux and Mac-OS.

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