SDSS J120011-020452: Unusual I Zw 1 object or a nearby BAL Seyfert?

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Abstract. Emission line diagnostics in active galactic nuclei (AGN) provide vital clues about the physical conditions of gas accountable for the emission emanating from the central region. We typically identify a region of narrow-line formation that normally includes oxygen, nitrogen, sulfur, and other forbidden lines. In some objects (Type 1 Seyferts) we in addition detect broad Balmer lines, helium lines and, in some instances, emission features attributed to Fe II. During a search for AGN in the Sloan Digital Sky Survey (SDSS), we discovered a spectrum of SDSS J120011-020452, a z$\sim$0.091 Seyfert galaxy that displays some unusual features. The narrow forbidden lines are all but absent (with only [O II] very barely visible), the Fe II spectrum is prominent and Na I absorption is clearly detected. In these respects, the object resembles the usually much more distant "broad absorption line" quasars (BAL) with strong Fe II lines (e.g., IRAS 07598+6508). The emission lines are in addition comparatively narrow, which makes this object an interesting hybrid between the BAL Seyferts and the class of AGN referred to as "narrow line Seyfert 1" galaxies (NLS1) with weak forbidden lines (e.g., I Zw 1 objects). We perform spectral line fitting on the SDSS data and compare line ratios in an attempt to shed light on the nature of the nuclear region of this interesting object. We discuss the limitations of the available data, and conclude that a better signal to noise (S/N) spectrum would allow us to determine the relative strengths of any other forbidden lines in the spectrum, get better profiles of the absorption features and better define the Fe II spectrum. We use this to motivate for follow-up observations using the the South African Large Telescope (SALT) Robert Stobie Spectrograph (RRS) in the upcoming round of proposals.

1. Introduction

Type 1 Seyfert galaxies have broad H I, He I, and He II emission lines with full-width at half-maximum (FWHM) of the order 1-5 $\times 10^3$ km/sec and typically oxygen, nitrogen and sulfur forbidden lines with FWHM of about 5 $\times 10^2$ km/sec. The spectra of Seyfert galaxies are virtually always characterized by prominent [O III] $\lambda\lambda$4959, 5007 lines. Many Seyfert 1 galaxies also show broadened permitted (and sometimes even forbidden) Fe II emission lines which overlap in two broad 'bands' near λ4570 and λ5250 [1]. The Narrow Line Seyfert 1 (NLS1) galaxies are a sub-class of Seyferts in which broad H I and He emission lines are relatively narrow (FWHM < 2000 km/sec). These objects also have strong Fe II emission, but their [O III] emission tends to be weak compared to other Seyferts ([2], [3], [4], [5], [6]). Broad absorption line (BAL) quasars are yet another, normally luminous, class of objects with spectra that may be broadly classified as Seyfert 1. Characteristic features of the BAL systems are the absorption features of Mg II

λ2798, He I λ3889 and Na I $\lambda\lambda$5889, 5895 lines. Markarian 231 and IRAS 07598+6508 are two well-known examples of comparatively nearby BAL systems ([6], [7], [8]).

During a search for AGN in the Sloan Digital Sky Survey (SDSS) archive [9], we noticed the spectrum of SDSS J120011-020452, which displays some unusual features. In the spectrum the forbidden lines are narrow and weak. Only [O II] $\lambda\lambda$3726, 3729 evident, but the feature at the approximate position of [O III] λ5007 is in fact one of the Fe II lines. The Fe II spectrum is clearly prominent, and furthermore the Balmer and Fe II line widths are small (as found in NLS1). In that respect the spectrum matches that of the well known I Zw 1 [6], which is also the prototype of a sub-class of NLS1 with strong iron features named after it. However, unlike in typical I Zw 1 objects, Na I absorption is clearly detected in SDSS J120011-020452. These uncommon characteristics suggests that the subject of this study is a rare hybrid whose spectrum encompasses attributes present in I Zw 1 type objects on the one hand and BAL AGN on the other. In this report we provide a preliminary analysis of the SDSS data on the basis of which we will justify the need to obtain higher quality spectra of this object using the SALT.

2. Data Analysis

We examined a multi-wavelength image of SDSS J120011-020452 displayed on the SDSS website (Fig. 1) as well as the spectrum (Fig. 2) of the source, also from the SDSS archive [9]. The estimated redshift (z $\sim$ 0.0911) puts the source at $\sim$412 Mpc away (based on the SDSS-adopted parameters). This implies a host galaxy disk size of $\sim$10 kpc. The u, g, r, i, and z magnitudes of the source are given as $19.63 \pm 0.03, 18.20 \pm 0.01$, $17.42 \pm 0.01, 16.80 \pm 0.01$,and 16.52 ± 0.01, respectively [9]. The parameters fitted to the emission or absorption lines and the continuum are provided by the SDSS data reduction pipeline and we use these estimates. The lines are fitted with Gaussian profiles.

The continuum-subtracted spectrum shows moderately broad Balmer lines (Fig. 3). The peaks flux densities of Hα, Hβ, Hγ, Hδ lines are 436, 92, 23, and 9 $\times 10^{-17}$ erg cm^{-2} s^{-1} Å^{-1}, respectively, and the FWHM of these lines are 1189, 1436, 1198, and 640 km/sec. A significantly lower FWHM of Hδ line (factor of 2) compared to other Balmer lines can be attributed to poor S/N. The Hϵ line is barely visible. The Balmer line ratio Hα/Hβ $\sim$ 4.7 suggests presence of reddening in the emission line region. This is supported by the presence of the absorption. The He I λ5875, λ6678, λ7065 lines are present in the spectrum albeit weakly. For these lines we find He I/H$\beta \sim 0.11 - 0.16$. With the exception of the previously mentioned [O II] λ3727,λ3729 line, [S II] λ6716, λ6731 also shows up weakly, but all other spectral features can be attributed to Fe II. Despite the poor S/N, we tried to estimate the forbidden line peak flux densities and widths. We find these to be 10-20 $\times 10^{-17}$ erg cm^{-2} s^{-1} Å^{-1} and FWHM $\sim$ 200-300 km/sec.

An interesting property of this spectrum is the absorption of the Na I λ5889, λ5895 doublets. The equivalent width of this absorption feature is $\sim$ 3 Å, strength Na I D/H$\beta \sim 0.12$, and the FWHM corresponds to an outflow velocity $\sim$385 km/sec. The prevalence of both narrow and broad Fe II emission lines from ultra-violet to near-infrared is a characteristic of type I Seyfert galaxies. The spectrum of SDSS J120011-020452 clearly shows signatures of Fe II λ4570 and λ5250 multiplet. The peak ratio between these lines and Hβ is $\sim$ 0.12. In Fig. 4 we identify several Fe II emission lines present in the λ4570 multiplet using the narrow and broad Fe II emission template provided by [4].

3. Discussions

In contrast to the previously discovered and earlier mentioned BAL AGN, SDSS J120011-020452 has narrower and thus more sharply defined emission features. Its spectrum therefore presents the opportunity to identify and fit blended lines with an accuracy otherwise not possible in the more nearby BAL AGN.

To gain insight about the properties of the central emitting regions, and especially to determine the nature of the narrow-line forming gas clouds, we need high quality spectra with better S/N. In order to achieve this we are planning to make a follow-up observation of this object using the SALT RRS. A better S/N spectrum could 1) determine the relative strengths of any other forbidden lines in the spectrum (in the SDSS spectrum we only see extremely weak [O II] and [S II], 2) get better profiles of the absorption features (which are visible even in the SDSS spectrum), 3) enable us to better define the FeII spectrum, and 4) apply improved fits to the data to be consistent with the emission line diagnostics studies in the literature. The planned further study is likely to offer a unique insight into the nature of BAL AGN weak narrow-line regions and the formation of the absorption bands.

Acknowledgments
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4. References

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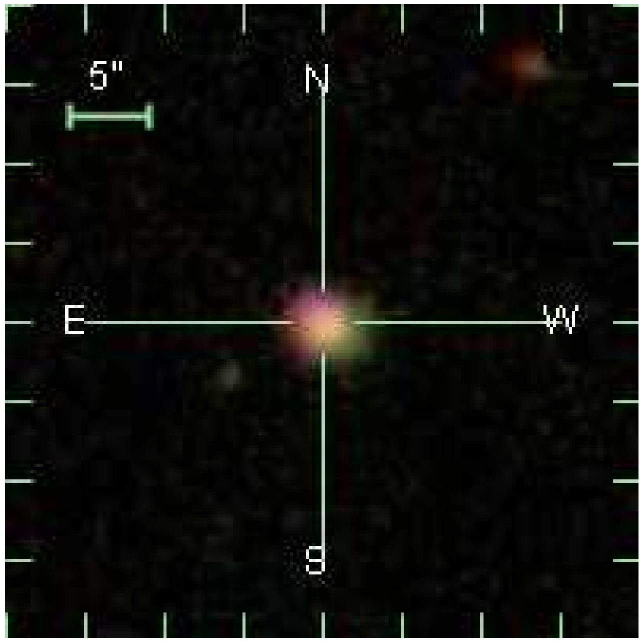

Figure 1. The SDSS multi-wavelength image of the source SDSS J120011-020452. The field-of-view is $\approx 40^{"} \times 40^{"}$.

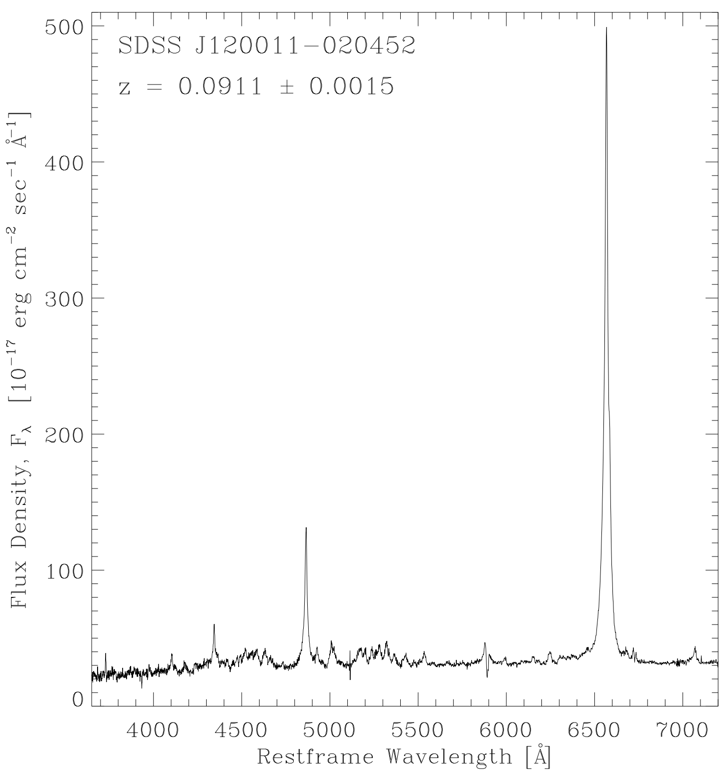

Figure 2. The rest-frame optical spectrum of the source containing both continuum and line fluxes.

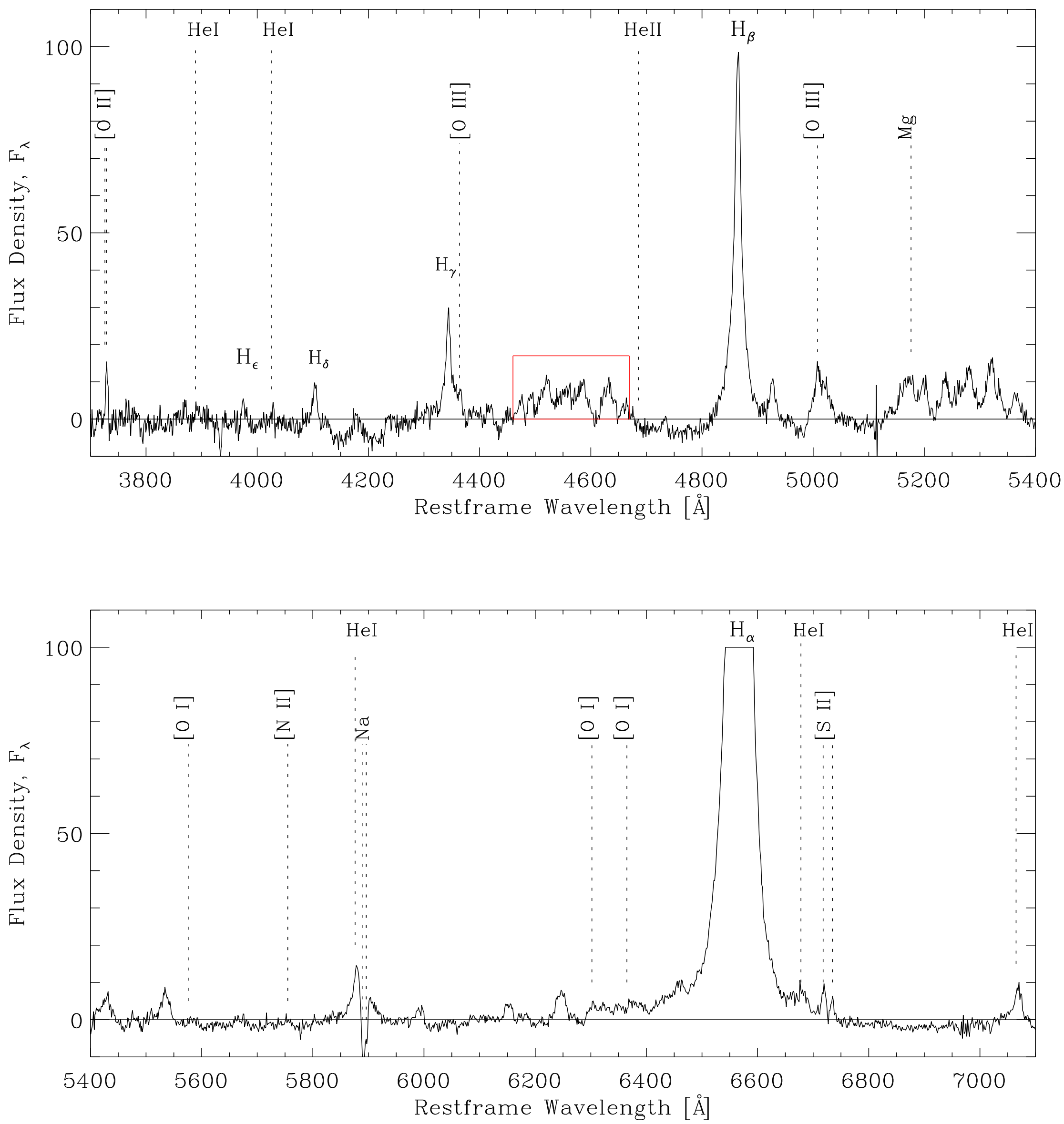

Figure 3. The emission and absorption lines in the continuum subtracted rest-frame spectrum of the source. The box highlights part of the spectrum containing both permitted and forbidden lines of Fe II $\lambda4570$ multiplet. The flux density is in unit of 10^{-17} erg cm^{-2} s^{-1} Å^{-1}.

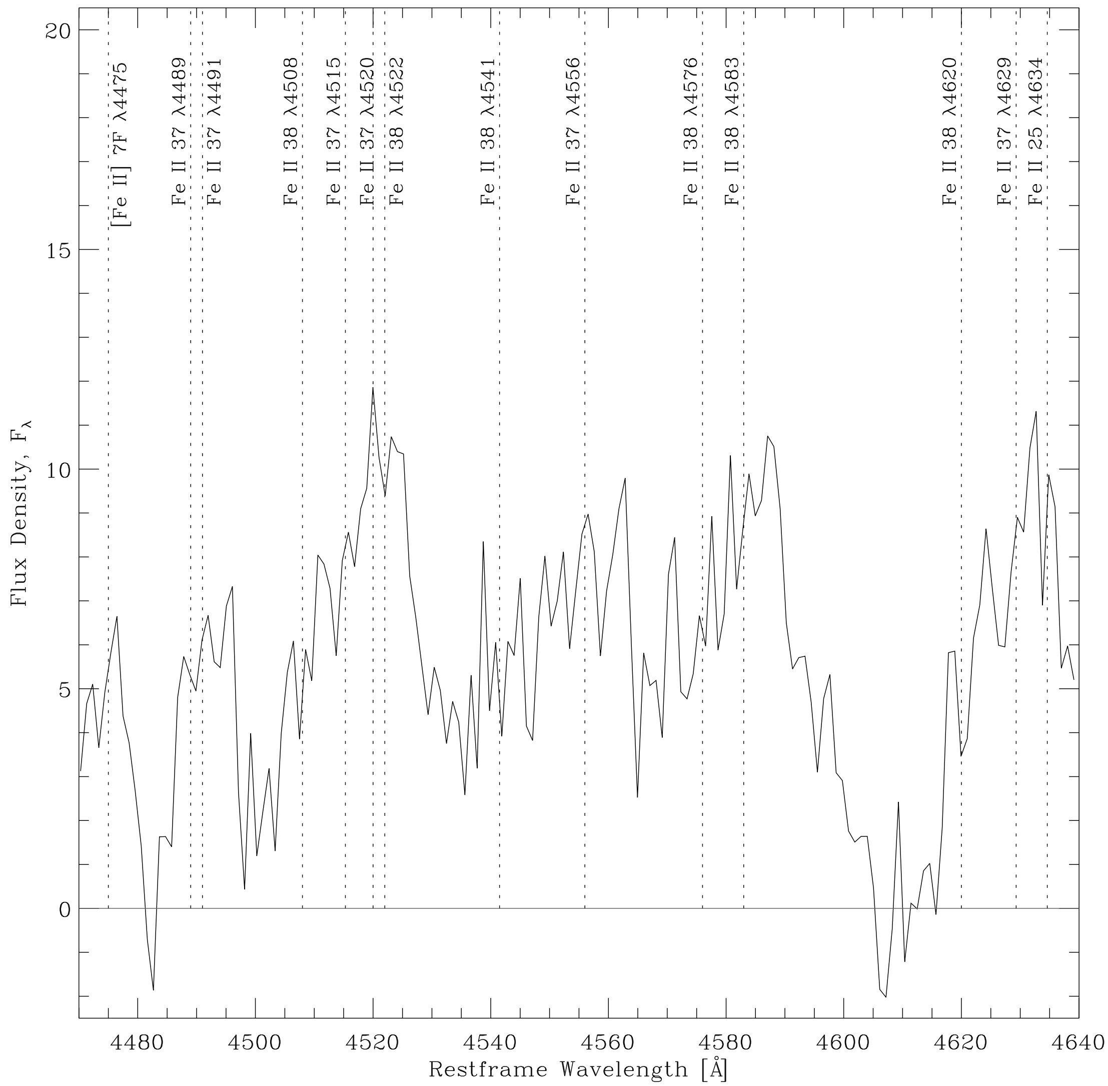

Figure 4. The region within the box in Fig. 3 is enlarged and several Fe II emission lines are identified using the template provided by [4]. The flux density is in unit of 10^{-17} erg cm^{-2} s^{-1} Å^{-1}.