Search for Balmer Absorption Lines in FeLoBAL Quasars

Kentaro Aoki

Subaru Telescope, NAOJ

Abstract

The SDSS has discovered unprecedented number of Iron Low Ionization Broad Absorption Line (FeLoBAL) quasars. Those newly-discovered FeLoBAL quasars show unique characteristics which were not recognized before. One of them is non-stellar Balmer absorption lines.

Our near-infrared spectroscopy discovered three FeLoBALs with Balmer absorption lines among 11 FeLoBALs.

Two z < 1 FeLoBALs were confirmed to have Balmer absorption lines. Balmer absorption lines have similar line widths and velocity shifts to Fe II and Mg II absorption lines.

All objects show relatively strong [O III] emission lines and rare He I absorption lines.

Large change in Fe II and Balmer absorption lines are seen between six years in one FeLoBAL quasar, SDSS J1632+4204 while Mg II and He I absorption lines remain same strength.

Introduction

Broad absorption line (BAL) quasars are quasars which show absorption troughs in UV resonance lines, with velocity widths of 2000 - 20000 km/s. The troughs are blue shifted and the largest blueshift reaches up to 0.2*c*.

BAL quasars are divided into three subtypes, depending on what kind of ions are seen as absorption. High-ionization BAL quasars (HiBALs) show absorption from C IV, N V, Si IV and Lyα. Low-ionization BAL quasars (LoBALs) show absorption from Mg II, Al III, and Al II, in addition to the above high-ionization absorption.

A fraction of LoBALs shows absorption from excited fine-structure levels of the ground term and excited terms of Fe II and Fe III. They are called iron LoBALs (FeLoBALs). FeLoBALs are rare and only seven FeLoBALs were known before the Sloan Digital Sky Survey (SDSS) started. However, the number of known FeLoBALs has been increasing (Hall et al. 2002, hereafter H02; Reichard et al. 2003; Trump et al. 2006) thanks to large sample of quasars in the SDSS.

Search for Balmer Absorption in FeLoBAL

We discovered Hα absorption in one z=2.32 FeLoBAL with near-infrared spectroscopy. (Aoki et al. 2006). Our discovery was the first Hα absorption in quasars. The FeLoBAL, SDSS J0839+3805, shows many low-ionization absorption lines such as Si II, Al II, Zn II, and Cr II. The spectrum is very similar to those of so-called many-narrow-trough BAL (mntBAL) quasars in H02.

We started Balmer line survey in mntBALs with near-infrared spectroscopy using Subaru and IRTF. We observed 11 mntBALs (three at 1.3 < z < 1.65 and eight at 2.1 < z < 2.8), and discovered Balmer absorption in three mntBALs (Fig. 1, 2). SDSS J1019+0225 was observed with IRTF/SpeX (*R* ~ 750), and the others, SDSS J0839+3805 and SDSS J1723+5553 with Subaru/CISCO (*R* ~ 400).

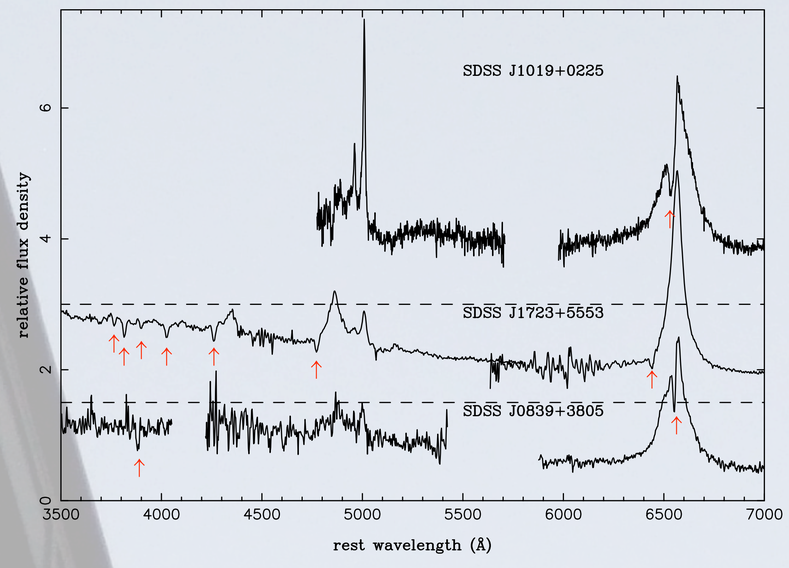

Fig. 1 Rest optical spectra of z > 1 mntBALs with Balmer absorption observed with near-infrared spectroscopy. For clarity, each spectrum is offseted by 1.5 each. All spectra are shifted to rest frame of Hα emission line. The Balmer and He I 3890 absorption lines are indicated by arrows.

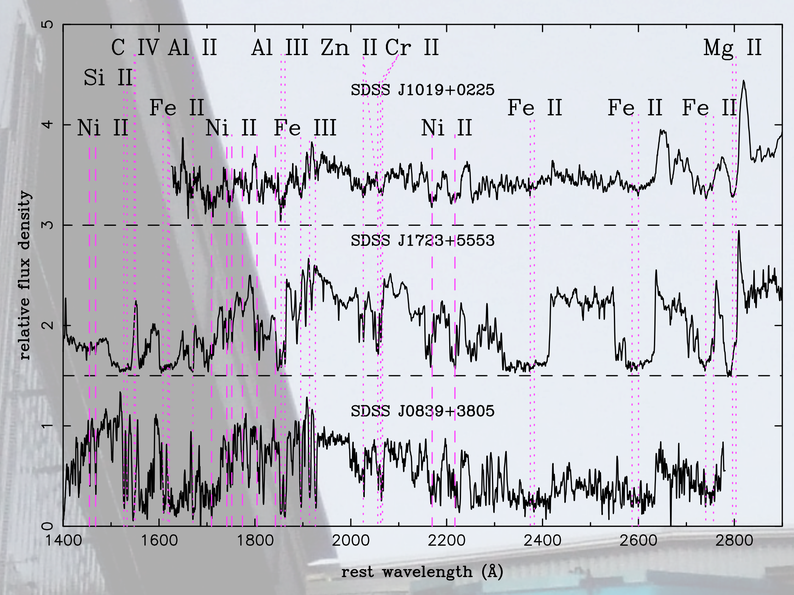

Fig.2 Rest UV spectra of z > 1 mntBALs with Balmer absorption in SDSS database. For clarity, each spectrum is offseted by 1.5 each. All spectra are shifted to rest frame of Al III or Mg II absorption line. Dashed lines indicate Ni II absorption lines, and dotted lines indicate absorption lines from other ions.

We also examined the SDSS spectra of z < 1 mntBALs, and discovered four mntBALs with Balmer absorption (Fig. 3). SDSS J1259+1213 has been already reported in Hall (2007). The other three mntBALs were observed with Subaru/FOCAS, and confirmed Balmer absorption in two of them (Fig. 4). The spectrum of SDSS J1632+4204 showed large change, and discussed later.

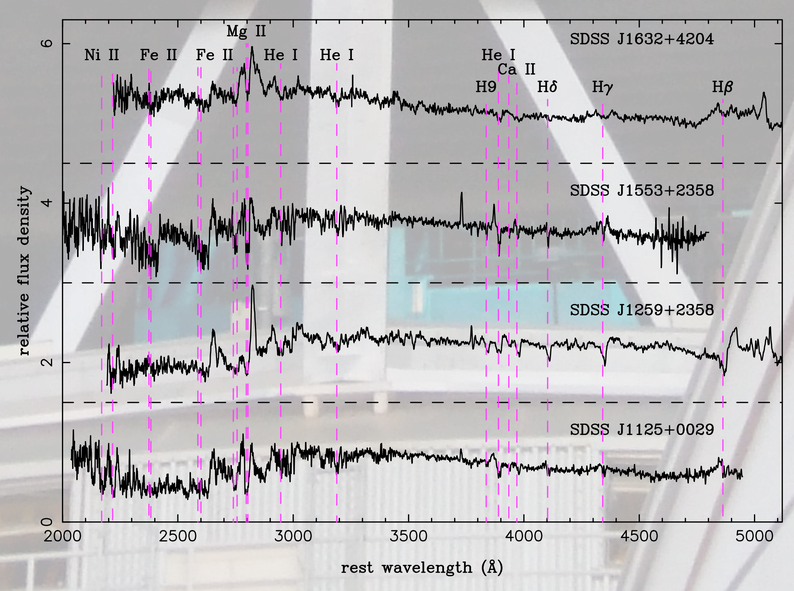

Fig. 3 Rest near-UV spectra of z < 1 mntBALs with Balmer absorption in SDSS database. All spectra are shifted to rest frame of Mg II absorption line.

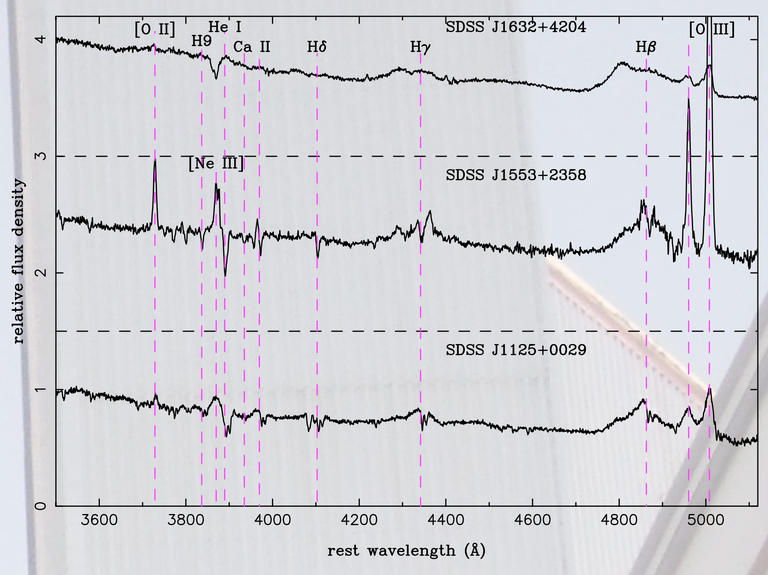

Fig. 4 Rest optical spectra of z < 1 mntBALs with Balmer absorption taken with Subaru/FOCAS. All spectra are shifted to rest frame of [O III] emission line.

Characteristics of FeLoBALs with Balmer Absorption

- All objects show He I absorption lines. It may suggest high column density (> 10^{21} cm^{-2}) and/or moderate ionization parameter (U~10^{-2}).
- All objects show relatively strong [O III] emission line. It suggests the covering factor of absorbing matter is not large and nuclear radiation reaches narrow-line region.
- All objects are **not** strong Fe II emitter. This fact make large contrast to the previous observations of LoBALs/FeLoBALs (Boroson & Meyers 1992; Yuan & Wills 2003).

Large variation of SDSS J1632+4204

We discovered that the spectrum of SDSS J1632+4204 shows dramatically change since April 2002. (Fig. 5) Our 2008 February spectrum shows weak Fe II absorption and almost no Balmer absorption. On the other hand Mg II and He I absorption remain constant. The continuum became brighter and bluer.

It is indicated that increase of ionization occurred due to increase of nuclear radiation. The response time of ionization condition to the radiation is anti-proportional to electron density. The upper limit of time scale of variation (3.4 yr in quasar's frame) gives us lower limit of electron density, ~10^4 cm^{-3}. The time scale also limits the size of the absorber, < 1pc.

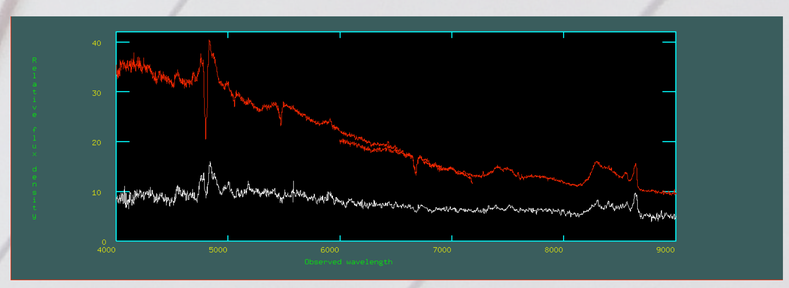

Fig. 5 Time variation of SDSS J1632+4204 between 2002 April (white) from the SDSS and 2008 February (red) taken with Subaru/FOCAS. The spectra were scaled by [O III] flux assuming constant its flux.

References

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