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Discovery of a new NLQSO: RX J1334.2+3759

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Abstract. A new narrow-line QSO, RX J1334.2+3759, has been identified at a redshift of 0.3858. The QSO has intrinsic soft X-ray luminosity ~ 2.8 x 10^{44} erg s^{-1}. Soft X-ray emission from the QSO is highly variable. Rapid variability (change in intensity by a factor of ~ 4 within ~ 400 s) has also been found. The soft X-ray spectra of the QSO is well described by a power-law of photon index, Γx ~ 3.8. The optical spectrum of RX J1334.2+3759 is typical of narrow-line Seyfert 1 galaxies. The NLR of RX J1334.2+3759 appears to be significantly different from those of normal Seyfert 1 galaxies.

Key words : galaxies:active – galaxies:nuclei – X-rays:galaxies

1. Introduction

Narrow-line Seyfert 1 (NLS1) galaxies are characterized by their optical spectra having permitted lines that are narrower than those found in the normal Seyfert 1 galaxies, e.g., full width at half maximum (FWHM) of Hβ line is $\leq$ 2000 km s^{-1}, relatively weak forbidden lines, $\frac{[OIII]\lambda 5007}{H\beta} < 3$ (Osterbrock & Pogge 1985), and strong Fe II emission. NLS1 galaxies also have distinctive soft X-ray properties as well. They show steep soft X-ray spectrum with little or no absorption above the Galactic value (Grupe et al. 1998). A small fraction of NLS1 galaxies show significant excess absorption above the Galactic value (Leighly 1999). They often show rapid and large amplitude as well as long-term X-ray variability (Boller et al. 1993). In spite of the dominance of soft X-ray emission, soft X-ray luminosity of NLS1 galaxies are similar to those of normal Seyfert 1s.

We present soft X-ray and optical emission line properties of a new narrow-line Seyfert 1 class object – RX J1334.2+3759 (R = 19.5; z = 0.3858 M_R = –21.8 assuming H_0 = 75 km s^{-1} Mpc^{-1} and q_0 = 0), and investigate the origin of the NLR and BLR emission line ratios. The object has been classified as a QSO by McHardy et al. (1998), in view of its optical and X-ray properties (see below) we call this object as a narrow-line QSO (NLQSO). QSOs and

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NLQSOs are high luminosity versions of Seyfert 1s and NLS1s, respectively (Philips 1976, Brandt 1995; Forster & Halpern 1996). The distinction is mostly based on the boundary defined by the absolute magnitude, $M_B = -21.5 + 5log h_0$ (h_0 is the Hubble constant in units of 100 km s^{-1} Mpc^{-1}; Peter-son 1997; Schmidt & Green 1983), without a clear difference in their optical spectra or in their X-ray properties. As the luminosity of RX J1334.2+3759 is close to the dividing luminosity and a host galaxy is not seen in a deep R-band image, we use the term NLS1 and NLQSO interchangeably for RX J1334.2+3759.

2. Observations

The region of the sky containing the source RX J1334.2+3759 was observed twice with the *ROSAT* (Trümper 1983) Position Sensitive Proportional Counter (PSPC) during 1991-1993, and once with the High Resolution Imager (HRI) (Pleffermann et al. 1987) in 1997 June 19-July 16. The two PSPC observations with exposure times 71803 s and 37658 s, respectively, together comprise the second deepest *ROSAT* PSPC survey in a region of sky of extremely low obscuration (Galactic $N_H = 7.9 \times 10^{19}$ cm^{-2}). The HRI observation was also a deep survey with an exposure time of 201513 s.

An optical spectrum of RX J1334.2+3759 was obtained on the night of 1994 April 7 with the Multi Object Spectrograph (MOS) on the 3.6-m Canada France Hawaii Telescope (CFHT). A 300 l mm^{-1} grism in the first order with a Lorel3 CCD detector was used to cover a wavelength range of 4000 Å–9000 Å with ~ 15 Å resolution. The integration time was 2700 s. The spectrum was taken under photometric conditions, however, the absolute flux calibration is uncertain because the slitlets were not aligned at the parallactic angle. For details of the reduction of the spectrum see McHardy et al (1998).

A CCD image of RX J1334.2+3759 in the R-band was obtained from the University of Hawaii 2.2m telescope on the night of 1992 May 6.

3. Results and discussion

Analysis of the X-ray data has been carried out using HEASOFT package (for details, see Dewangan et al. 2001). Soft X-ray emission from RX J1334.2+3759 is highly variable. During the 1991 observations, RX J1334.2+3759 showed soft X-ray variability on times scales of ~ 20000 – 40000 s by a factor of ~ 2. Rapid variability events have also been detected from the QSO. The most extreme variable event has $\frac{\Delta L}{\Delta t} = (1.95 \pm 1.02) \times 10^{42}$ erg s^{-2} corresponding to a change in intensity by a factor of ~ 4 within $\lesssim$ 400 s.

The soft X-ray spectrum of RX J1334.2+3759 is very steep and is well represented by a power-law of photon index, $\Gamma x = 3.8^{+0.3}_{-0.3}$ with an excess absorption, $\Delta N_H \sim 3.3 \times 10^{20}$ cm^{-2}, local to the source and apart from the Galactic absorption, $N_H \sim 7.9 \times 10^{19}$ cm^{-2}. The amount of excess absorption found in the NLQSO is similar to that found for the proton-type object I Zw 1 of the NLS1 class (Leighly 1999). The soft X-ray spectrum of Rx J1334.2+3759 is steeper than those of normal Seyfert 1s [$< \Gamma x >$ (90% range) = 2.0 – 2.7], and similar to those of NLS1 galaxies [Γx (90% range) = 2.3 – 3.7] (Grupe et al. 1998). The steeper photon indices of NLS1 galaxies is usually interpreted as the excess soft X-ray emission. ASCA observations of

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NLS1 galaxies have confirmed the presence of excess soft X-ray emission below ~ 2 keV and the hard X-ray power-law (e.g., Leighly 1999). The excess soft X-ray emission of NLS1 galaxies is usually attributed to a higher accretion rate relative to the Eddington accretion rate ($\dot{m} = \frac{\dot{M}}{\dot{M}_{Edd}}$) than that for normal Seyfert 1 galaxies.

The optical spectrum of RX J1334.2+3759, shown in Figure 1, is typical of NLS1s and shows the presence of Balmer Hα, Hβ, and forbidden lines of [O III]λ5007, [Ne III]λ3869. Also present is the Fe II emission seen as two broad humps at 4450 Å–4700 Å and 5150 Å–5350 Å in the spectrum. The Fe II blends complicate the measurement of line strengths of Hβ, [O III]λ5007 etc. due to their contamination. In order to reliably estimate their strength and to measure the line fluxes, we have adopted the method of Borson & Green (1992) and used their Fe II template. Spectral line parameters were measured from the Fe II subtracted spectrum.

The FWHM velocity (~ 2850 km s^{-1}) of the broad components of Balmer lines in the spectrum of RX J1334.2+3759 is similar to that found in the other NLS1 galaxies but is significantly lower than in the Seyfert 1 galaxies. For example, Grupe et al. (1999) found mean values of the broad components of Hβ to be 2790 ± 160 km s^{-1} for a sample of NLS1s, and 4210 ± 360 km s^{-1} for a sample of Seyfert 1s. Similarly, the ratio of fluxes of narrow and broad components of Hα and Hβ, $\frac{H\alpha_n}{H\beta_b}$ = 1.8 ± 0.46, and $\frac{H\beta_n}{H\beta_b}$ = 1.26 ± 0.37, for RX J1334.2+3759 are similar to those found in other NLS1 galaxies (Rodriguez-Ardila et al. 2000). This implies

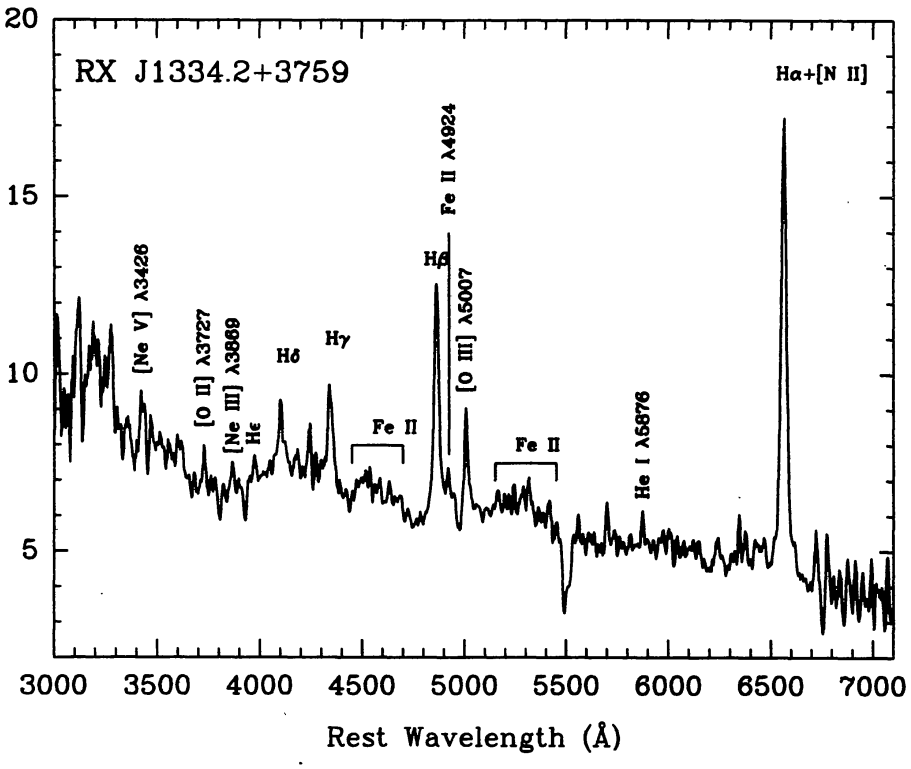

Figure 1. Optical spectrum of RX J1334.2+3759. Vertical scale is the relative flux. The spectrum has been smoothed by a box filter of width 12.5 Å. The absorption feature at 5500 Å is due to atmospheric absorption.

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that the relative contribution of the board components to the line flux is greatly reduced in RX J1334.2+3759 compared to that in Seyfert 1 galaxies for which the ratio of narrow to broad component is around 0.1.

The narrow components of the permitted lines and the forbidden lines such as [O III]λ5007, [N II]λ6583 etc. are thought to arise from the NLR of AGNs. For RX J1334.2+3759, the flux ratio of [O III]λ5007 line and the narrow component of Hβ, $\frac{[OIII]\lambda 5007}{H\beta_n}$, is 0.30 ± 0.06 which is much smaller than the ratio of ~ 10 found in Seyfert 2 galaxies, but is similar to that found in NLS1 galaxies.

RX J1334.2+3759 shows strong Fe II emission. The ratio of fluxes of Fe II and Hβ, $\frac{Fe\ II}{H\beta}$, ≃ 4.5 which is similar to that found in the order NLS1 galaxies (Grupe et al. 1999). Thus all the characteristics are consistent with of RX J1334.2+3759 being a NLQSO.

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