The contribution of Narrow-Line Seyfert 1 galaxies to the soft X-ray background

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Abstract

The ROSAT Ultradeep HRI survey in the Lockman Hole contains a complete sample of 91 X-ray sources with fluxes in the 0.5-2 keV band larger than $1.2 \cdot 10^{-15}$ erg cm^{-2} s^{-1}, where over 75 % of the sources are quasars or Seyfert galaxies. During the course of our optical identification work, we have obtained optical spectra of 67 narrow emission line galaxies (NELG), which are physically not associated with the X{ray sources. We have derived the equivalent width (EW) and the full width at half maximum (FWHM) for the most prominent emission lines of 41 quasars and Seyfert galaxies taken from the ROSAT Deep Survey (RDS), which has a flux limit of $5.5 \cdot 10^{-15}$ erg cm^{-2} s^{-1} in the 0.5-2.0 keV band. Furthermore we have obtained the EW and FWHM values of the field NELGs. Here we present the spectroscopic discrimination between RDS Seyfert galaxies and field galaxies (NELG). The analysis of the emission lines has revealed that a single object out of 69 spectroscopically identified AGN fits the optical criteria of Narrow-Line Seyfert 1 galaxies (NLS1). This may indicate that NLS1 contribute only marginally to the soft X-ray background, but we can not exclude a possible larger contribution.

Key words: galaxies: active; quasars: general; quasars: absorption lines; X-rays: galaxies

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1 The ROSAT Deep Surveys in the Lockman Hole

The most sensitive ROSAT surveys consist of a 207 ksec ROSAT PSPC exposure, a 205 ksec HRI raster scan and a total 1112 ksec HRI expsoure of a 0.3 deg^2 area in the Lockman Hole region. The HRI images are the basis for the Ultradeep HRI Survey (Hasinger at al. 1999). At a flux limit of 10^{-15} erg s^{-1} in the 0.5–2.0 keV energy band, the HRI survey has resolved about 70–80% of the soft X-ray background into discrete sources. The ROSAT Deep Survey (RDS), based on the PSPC image, includes a statistically complete sample of 50 X-ray sources with fluxes in the 0.5–2.0 keV band greater than $5.5 \cdot 10^{-15}$ erg s^{-1} (Hasinger et al. 1998). The spectroscopic identification of the RDS using the Keck and Palomar telescopes have shown that about 75% of the sources are quasars and Seyfert galaxies (Schmidt et al. 1998, Lehmann et al. 2000).

Both surveys contain 91 X-ray sources, where the faintest sources reach a flux of $1.2 \cdot 10^{-15}$ erg s^{-1} in the 0.5–2.0 keV band. Recent optical/infrared work has led to an identification of 88 of the 91 X-ray sources, confirming a high fraction of AGNs (72 objects). This is the largest fraction of AGNs found in any previous X-ray survey (Boyle et al. 1995, Georgantopolous et al. 1996, Bower et a. 1996 and McHardy et al. 1998). Among our AGNs is the most distant X-ray selected quasar at a redshift of 4.45 (Schneider et al. 1998). Groups and clusters of galaxies (10%) form the second most abundant class of objects. One X-ray source has been classified as a narrow emission line galaxy (NELG), whereas some deep ROSAT PSPC surveys found a significantly larger fraction of NELGs (Boyle et al. 1995, McHardy et al. 1998). We see no evidence that NELGs or other classes of objects dominate the soft X-ray counts at faint fluxes.

2 Optical spectral properties of RDS quasars and Seyfert galaxies

In the following we discuss the emission line properties of the 41 spectroscopically confirmed RDS quasars and Seyfert galaxies. 33 X-ray sources have been identified with quasars and Seyfert 1 galaxies in the redshift range between 0.08 and 2.83. Their optical spectra show broad emission lines (FWHM > 1500 km s^{-1}) of Ly 1216, C IV 1548, C III] 1908 and Mg II 2798 at medium and large redshifts, or of Balmer lines (H 6563, H 4861) at lower redshifts. Most of them can be classified as type I AGN, whereas the large Balmer decrement of two Seyfert galaxies having broad H or H emission lines indicates type II AGN (see object 59A in Fig. 1).

The optical spectra of six RDS AGNs show only narrow emission lines with FWHM < 1500 km s^{-1} indicating a type II AGN. When their redshifts are

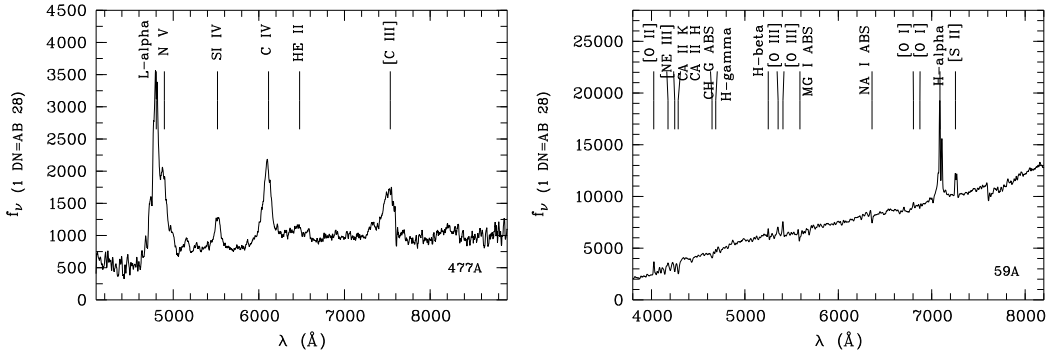

Fig. 1. Keck LRIS spectra of the quasar 477A ($z = 2.949$) and of the Seyfert 1.5 galaxy 59A ($z = 0.080$), which shows only a broad H emission line (FWHM 8300 km s^{-1}.)

above 0.5, the spectra do not allow a classification using the diagnostic diagrams of Osterbrock (1981). But the existence of high excitation [Ne V] 3426 (see 26A in Fig. 2) or strong [Ne III] 3868 narrow emission lines, together with an X-ray luminosity above 10^{43} erg s^{-1} in the 0.5–2.0 keV band, reveal an AGN (Schmidt et al. 1998). Two further sources have been classified as type II AGNs, because of their high X-ray luminosity ($\log L_X > 43$). One of them is a radio galaxy at $z = 0.708$ showing only typical galaxy absorption lines. Several RDS AGNs (type I and II) below $z = 1$ show a significant continuum emission originating in the host galaxy (Fig. 1/Fig. 2). The RDS sample contains in total 35 type I and 6 type II AGNs. The large $R - K'$ colour of two spectroscopically unidentified sources indicates either obscured AGNs or high-redshift clusters of galaxies (Lehmann et al. 2000).

3 Spectroscopic discrimination of Seyfert galaxies and field NELGs

In the course of the spectrocopic identification of our X-ray sources we have taken optical spectra of 83 field galaxies. 67 of them are narrow emission line galaxies (NELGs) with no physical connection to the X-ray sources. There is no soft X{ray emission (0.5–2.0 keV band) detected above a limiting flux of 10^{-15} erg cm^{-2} s^{-1} associated with these sources. The optical spectra of the field NELG (cf. 14C in Fig. 2) show only narrow emission lines, but no strong [Ne III] 3868 or high ionization [Ne V] 3426 emission lines. The possible misidentification of faint X-ray sources with NELGs is discussed by Schmidt et al. (1998) and Lehmann et al. (2000).

To study the emission line properties we have derived the FWHM and the rest frame EW for the most prominent emission lines of the RDS quasars/Seyfert galaxies and of the field NELGs. The mean FWHM/EW values for the broad emission lines of RDS quasars/Seyfert 1 galaxies are consistent with those values found for other X-ray selected AGN samples at lower mean redshift, eg.,

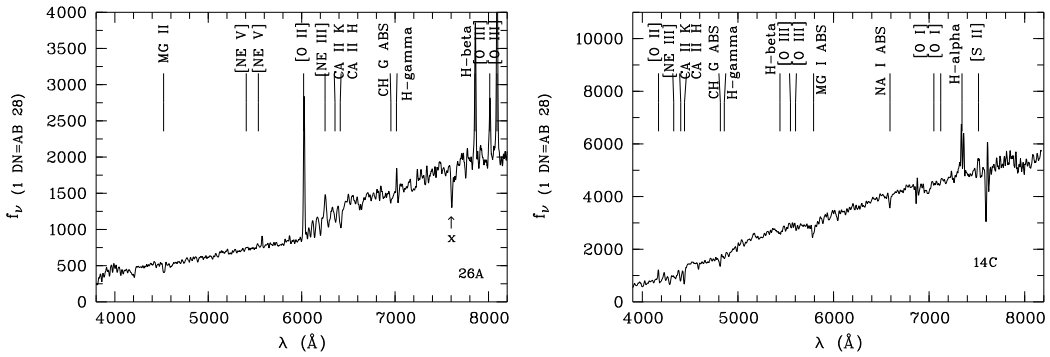

Fig. 2. Keck LRIS spectra of the narrow emission line AGN 26A ($z = 0.616$) from the RDS sample and the narrow emission line field galaxy (NELG) 14C at $z = 0.119$. The spectra of 26A and the NELG show a prominent galaxy continuum above the Ca H+K 3934/3968 break. The high-ionization [Ne V] 3426 emission line in the spectrum of 26A confirms the AGN nature of this object.

the RIXOS-sample (Puchnarewicz et al. 1997) and the CRSS-sample (Boyle et al. 1997), and the mean values derived from several emisssion line and UV/optical selected AGN samples (Schmidt et al. 1986).

lines	RDS AGN EW/FWHM				Field NELG EW/FWHM			
	mean	σ	error	n	mean	σ	error	n
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
[Ne V] λ3426	4/680	4/250	1/90	9/8	-	-	-	-
[O II] λ3727	12/440	11/200	3/60	17/11	30/290	28/120	4/30	61/18
[Ne III] λ3868	5/820	4/400	2/180	8/5	4/770	2/100	1/60	8/3
[O III] λ4959	6/380	5/270	2/120	8/5	8/600	8/320	2/130	21/6
[O III] λ5007	20/310	28/80	9/30	9/5	26/290	30/100	6/40	29/7

Tab. 1. Rest frame EW [Å] and FWHM [km s^{-1}] values of the forbidden narrow emission lines of the RDS AGN in comparison with those of the field NELGs. High ionization [Ne V] 3426 emission lines have been detected only in AGN.

The mean RDS EW values of the forbidden narrow emission lines, found for Seyfert galaxies at redshifts below 1, are slightly smaller than those from the AGN comparison samples (Lehmann et al. 2000). The RDS EW of [Ne III] 3868 and the [O III] 4959/5007 lines seem to be in better agreement with those from field NELGs (Tab. 1) than with those from other AGN samples. The optical spectra of most RDS AGNs, which contain forbidden narrow emission lines, show several typical galaxy absorption lines, eg., Ca H+K 3934/3968, CH G 4301 (see 26A in Fig. 2). A strong continuum contribution produced by the host galaxy could account for these less stronger forbidden lines in our RDS AGNs.

4 Contribution of NLS1 to the soft X-ray background

Although the majority of our faint X-ray sources have been spectroscopically identified with quasars and Seyfert galaxies, only one out of 69 AGNs matches the optical criteria of narrow line Seyfert 1 galaxies taken from Osterbrock & Pogge (1985) and more precisely defined by Goodrich (1989). These somewhat subjective criteria are as follows. 1) NLS1 have slightly broader Balmer lines (< 2000 km s^{-1}) in comparison to the forbidden lines such as [O II] 3727 or [O III] 4959/5007. 2) The flux ratio [O III] 5007 to H 4861 is < 3, a level which allows to discriminate between NLS1 and Seyfert 2 galaxies (Shuder & Osterbrock 1981). 3) Emission lines of Fe II or of high ionization [Fe VII] 6087 and [Fe X] 6375 are often present.

The spectrum of the NLS1 37A (Fig. 3) shows prominent Fe II bumps at 4500–4600 A and at 5250–5350 A (in the rest frame). The FWHM of the broad component of the H 4861 emission line is slightly above the limit for NLS1 (2070 20 km s^{-1}). The flux ratio [O III] 5007/H 4861 is clearly below 3. The NLS1 37A at $z = 0.462$ belongs to the highest-redshift objects of this class. The bright soft X–ray selected sample of Grupe et al. (1999) contains for example only 4 objects (12%) above $z = 0.3$.

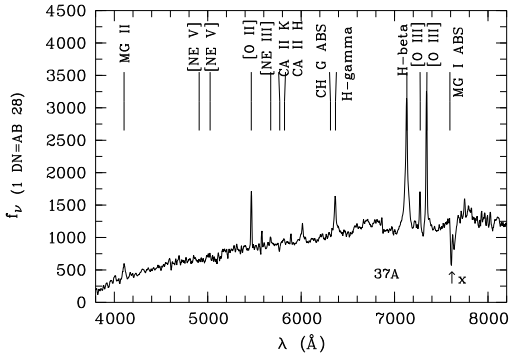

Fig. 3. Keck LRIS spectrum of the NLS1 galaxy 37A ($z = 0.467$). The symbol "x" marks a region of an atmospheric absorption band (7600 A).

The fraction of NLS1 in X-ray selected AGN samples (see for an overview Grupe in these proceedings) has to be considered with caution. NLS1 at redshifts above 0.65 could be missed due to the limited wavelength coverage of the optical spectra (< 8200 A). The H /[O III] region is covered in 13 of 69 spectroscopically identified AGNs from the ROSAT Deep Surveys. Most of our AGNs show only broad UV emission lines, eg., C III] 1908 or Mg II 2798, at high redshifts. Recently, Rodriguez-Pascual et al. (1997) have detected broad components of strong UV emission lines (eg., L 1216 and C IV 1548) in several NLS1. If this is a common property we can not exclude a significantly larger fraction of NLS1 in high-redshift AGN samples.

But even the fraction of NLS1 in some low-redshift AGN samples, eg. 7% of

the ROSAT Bright Survey (Schwope et al. 2000) or 22% of the RIXOS AGN sample (Puchnarewicz et al. 1997), could result from a different classification scheme of NLS1 objects (upper limit for $FWHM_H$ < 1500 or 2000 km s^{-1}). Without well-controlled samples at low and high redshifts it is not possible to obtain reliable statements about the cosmological evolution of NLS1.

The fraction of NLS1 found in the ROSAT Deep Surveys (1%) may indicate a marginal contribution of NLS1 to the soft X-ray background. Nevertheless we have to consider this as a lower limit so far.

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