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Active nucleus in a post-starburst galaxy: KUG 1259+280

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ABSTRACT

We report the discovery of an active nucleus in a post-starburst galaxy, KUG 1259+280, based on its X-ray and optical characteristics. The X-ray source in KUG 1259+280 was detected during a search for ultrasoft sources in the *ROSAT* pointings. High-resolution X-ray imaging observations with *ROSAT* HRI show that X-ray emission from KUG 1259+280 is unresolved. X-ray emission from KUG 1259+280 is highly variable; an episode in which X-ray intensity changed by a factor ~2.5 within ~1300 s has been detected. *ROSAT* PSPC spectra of this galaxy are found to be well represented by a steep power law of photon index $\Gamma_X \sim 4.25$, and a change in the absorbing column within ~1 d is indicated. The rest frame intrinsic X-ray luminosity of KUG 1259+280 is found to be $\sim 3.6\text{–}4.7 \times 10^{42}\,\mathrm{erg\,s^{-1}}$, similar to that of low-luminosity Seyfert galaxies. The mass of the central massive object within KUG 1259+280 is estimated to be in the range $10^5\text{–}10^7\,\mathrm{M_\odot}$. The optical spectrum of the nuclear region of the galaxy is complex and shows Balmer absorption and collisionally excited lines of [O III] and [N II]. The presence of forbidden emission lines and the absence of Balmer emission lines in the spectrum of KUG 1259+280 could be the result of photoionization by a diluted power-law continuum modified by enhanced stellar absorption owing to a post-starburst event. Estimated Balmer line strengths free of stellar absorptions and forbidden line strengths indicate the nucleus of KUG 1259+280 to be low-ionization nuclear emission region (LINER) like in nature. However, the low-ionization forbidden line [O I] $\lambda 6300$ usually present in LINER spectra is not detected in the spectrum of KUG 1259+280. X-ray characteristics – variability, point-like appearance, luminosity and steepness of spectrum – indicate that the nucleus in KUG 1259+280 is active and perhaps like that of narrow-line Seyfert type 1 galaxies.

Key words: galaxies: active – galaxies: individual: KUG 1259+280 – galaxies: individual: RX J1301.9+2746 – galaxies: nuclei – X-rays: galaxies.

1 INTRODUCTION

Recent optical (Ho, Filippenko & Sargent 1997a,b) and X-ray surveys (Grupe et al. 1998) are finding that nuclei of many nearby galaxies are active. Such activities manifest themselves through continuum and emission-line properties. Characterizing these properties helps us to measure the luminosity functions and evolution of different subtypes, and understanding the relationship between different types of activities, for example, between nuclear starbursts and active galactic nuclei (AGNs), and thus assist in creating unified models for active galaxies. Weedman (1983) has argued that starburst events in the nuclei of galaxies would evolve rapidly into compact configurations as dynamically distinct entities. Perhaps the compact configuration further collapses to form a single massive black hole generally favoured as the central engine for AGNs (Miller 1985). On the other hand, Goncalves, Veron-Cetty & Veron (1999) suggest that perhaps it is nuclear activity which triggers circumnuclear star formation. However, evidence for either case is fragmented at present. In this connection, it is very important to study AGNs in starburst and post-starburst galaxies. In this paper, we report new X-ray and optical observations of a post-starburst galaxy KUG 1259+280.

The galaxy, known as KUG 1259+280 (Takase & Miyauchi-Isobe 1985), is a post-starburst galaxy which appears to be in a small group of four galaxies within an arcminute, and is a member of the Coma cluster, where it is known variously as D-61 (Dressler 1980) or GMP 1681 (Godwin, Metcalfe & Peach 1983). KUG 1259+280 is the brightest among these four galaxies (Takase & Miyauchi-Isobe 1985) with $B = 15.88$ mag and has a heliocentric radial velocity of $7102 \pm 50\,\mathrm{km\,s^{-1}}$ (Caldwell & Rose 1997).

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From ground-based imaging, KUG 1259+280 has been classified as an SO galaxy. However, the high resolution images of KUG 1259+280 taken with the *Hubble Space Telescope* have revealed this galaxy to be an edge-on disc galaxy with a very bright unresolved nucleus (Caldwell, Rose & Dendy 1999, hereafter CRD). Two radial dust lanes in KUG 1259+280, to the east of the centre and about 1 arcsec away, have also been reported by CRD. An unusual bulge, which is boxy or peanut-shaped and, additionally, has an X morphology, has been found by CRD. They also report that the central (0.16 arcsec or 74 pc for $H_0 = 75\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$) luminosity of KUG 1259+280 is $M_B = -16.3$ (CRD), which is higher than any of the star clusters found in the merging galaxies studied by Whitmore et al. (1997) or by Carlson et al. (1998) and is also higher than the luminosity of nuclear star clusters found in normal early-type galaxies studied by Lauer et al. (1995). The nucleus is about 0.2 mag bluer than that of the surrounding bulge (CRD). In their spectroscopic study of galaxies in the Coma cluster, CRD have found that KUG 1259+280 is a very strong post-starburst galaxy with post-starburst age of ~0.5 Gyr which is shorter than the typical value of 1 Gyr for similar galaxies in Coma, thus indicating that the starburst in this galaxy had happened more recently as compared to other such galaxies in Coma. Based on the ratio of flux of [N II] $\lambda\lambda$6548, 6583 and Hα, CRD have concluded that the emission line spectrum of KUG 1259+280 to be arising as the result of low-ionization nuclear emission region (LINER) like nuclear activity.

The galaxy, KUG 1259+280, was first detected as a serendipitous *EXOSAT* X-ray source, EXO 125938+2803.1, in the region of the Coma cluster by Branduardi-Raymont et al. (1985). The galaxy was also identified as an X-ray source in the *EXOSAT* high Galactic latitude survey by Giommi et al. (1991). X-ray emission from KUG 1259+280 was again detected during the *ROSAT* pointings and was reported by Singh et al. (1995) to be an ultrasoft X-ray source – WGA J1301.9+2746 (RX J1301.9+2746) (White, Giommi & Angelini 1994). Based on this association, Singh et al. (1985) obtained soft X-ray luminosity (L_X) of $\sim 3\times10^{42}\,\mathrm{erg\,s^{-1}}$ for KUG 1259+280 which is similar to that of a low-luminosity AGN. The basic parameters of KUG 1259+280 are summarized in Table 1.

In this paper, we present a detailed analysis of X-ray data on the ultrasoft X-ray source – WGAJ 1301.9+2746 (RX J1301.9+2746), taken from the *ROSAT* archives. The data taken on five different days of observations during 1991 to 1995 have not been presented before. We confirm the identification of the X-ray source with KUG 1259+280 based on high resolution X-ray imaging data. We present X-ray light curves and spectra of KUG 1259+280 taken on three occasions. We also present our new optical spectroscopic observations of the galaxy, and discuss its peculiar nature.

Throughout the paper, luminosities are calculated assuming a Hubble constant of $H_0 = 75\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ and a deceleration parameter of $q_0 = 0$.

2 OBSERVATIONS

2.1 *ROSAT* X-ray observations

The region of the sky containing this source was observed three times with the *ROSAT* (Trümper 1983) Position Sensitive Proportional Counter (PSPC) and twice with the High Resolution Imager (HRI) (Pfeffermann et al. 1987). The PSPC observations were carried out during 1991 June 16–19. The Coma cluster was the target source in the PSPC observations, whereas KUG 1259+280 itself was targeted in the HRI observations of 1995 June 5. The galaxy was again in the field of view of the HRI observations during 1994 June 25, when NGC 4921 and NGC 4923 were targeted. The details of *ROSAT* observations are given in Table 2. The off-set of KUG 1259+280 from the field centre is also listed in Table 2. ROSAT X-ray data corresponding to the above observations were obtained from the public archives maintained at the High Energy Astrophysics Science Archive Research Center (HEASARC) in USA, and analysed by us. An X-ray source centred on the position of KUG 1259+280 was detected in all the observations. It is offset from the centre of the field of view of the PSPC by ~0.5°, however, it was not obstructed by the PSPC window support structure in the observations identified by the sequence numbers RP800006N00 (1991 June 16) and RP800013N00 (1991 June 18). In the 1991 June 17

Table 1. Basic parameters of KUG 1259+280.

Other names[a]:	CGCG 1259.6 + 2803, CG 0959, FOCA 0357, PGC 044947, RX J1301.9 + 2746, RX J1301.9 + 2747, Coma-D 61, GMP 1681.
Morphological type:	SO
Position[b]:	$\alpha(J2000) = 13^h02^m00\overset{s}{.}1$; $\delta(J2000) = +27°46'57''$
Redshift[c]:	$z = 0.02369 \pm 0.00017$
Magnitude[c]:	$B = 15.88$
Colour[c]:	$B - R = 1.63$

[a] NASA Extragalactic Database (NED).
[b] Doi et al. (1995).
[c] Caldwell & Rose (1997).

Table 2. Details of ROSAT observations of KUG 1259+280.

Serial No.	Sequence No.	Instrument	Off-set arcmin	Start Time Y, M, D, UT	End Time Y, M, D, UT	Exposure Time (s)
1.	RH900633N00	HRI	0.16	1995 06 05 22:36:48	1995 06 06 19:53:43	5616
2.	RH701579N00	HRI	9.8	1994 06 25 12:24:51	1994 07 07 04:29:39	17765
3.	RP800006N00	PSPC	29.8	1991 06 16 22:46:34	1991 06 17 22:44:23	21545
4.	RP800005N00	PSPC	31.8	1991 06 17 22:44:52	1991 06 18 22:43:06	21140
5.	RP800013N00	PSPC	28.6	1991 06 18 22:43:30	1991 06 19 22:41:59	21428

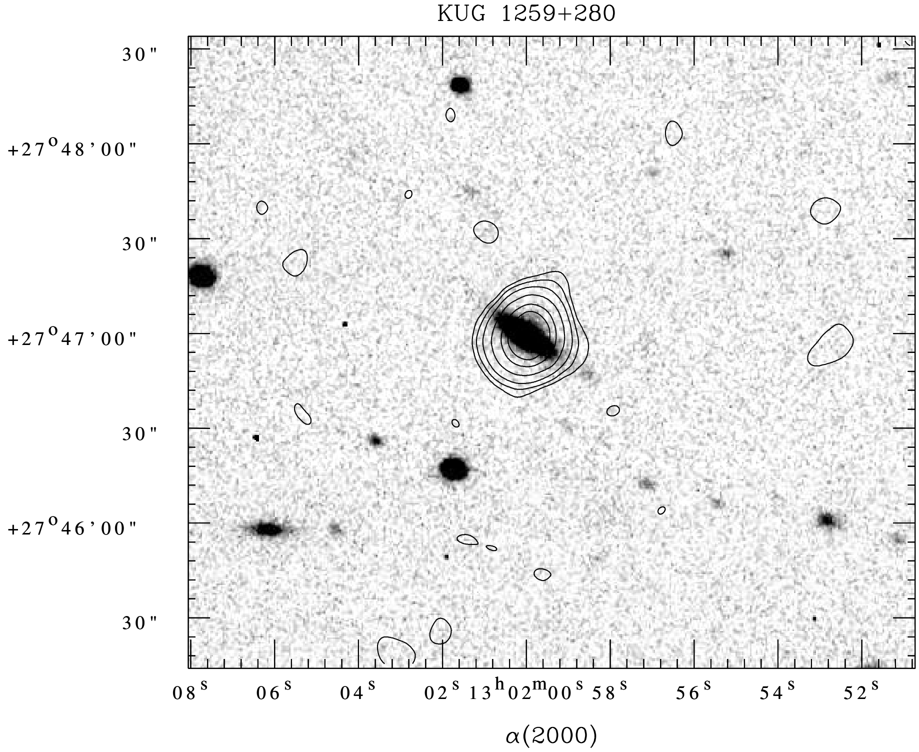

Figure 1. Contours of *ROSAT* HRI image of KUG 1259+280 overlaid on the *V*-band optical image observed with the 2.3-m Vainu Bappu Telescope, Kavalur, India. The contours are shown at 4, 6, 10, 20, 40, 60 and 80 per cent of the peak intensity (0.3153 count pixel^{-1}). Background level is 0.0056 ± 0.0004 count pixel^{-1}. The X-ray contours have been generated from the HRI image after smoothing by a Gaussian of $\sigma = 5$ arcsec. The HRI image was created from the data observed on 1994 June 25 (exposure time = 17 765 s).

observation (RP80005N00), the source is somewhat closer to the PSPC window structure, however, it does not appear to be obstructed in any significant way by the window structure even though the point spread function of the PSPC and the telescope system is very broad at this position.

2.2 Optical observations

An optical *V*-band image of KUG 1259+280 was obtained at the Vainu Bappu Telescope (VBT), Kavalur, India on the night of 1996 March 13. The observation was carried out using a 1024 × 1024 charge-coupled device (CCD) chip placed at the prime focus of the 2.3-m reflector. The pixel size of 24 μm pixel^{-1} of the CCD gives a scale of 0.61 arcsec and a total field of view 10.4 × 10.4 arcmin^2.

Spectroscopic observations of KUG 1259+280 were carried out under photometric conditions on the night of 2000 February 2 at the Cassegrain focus of the 2.12-m telescope of the Guillermo Haro Observatory (GHO), Cananea, Mexico. The Boller and Chivens Spectrograph with the TEX 1024 × 1024 CCD and a 150 line mm^{-1} grating was used. The slit position angle was 48° which passes roughly along the major axis. The slit width was 2 arcsec. The airmass of the observations was close to 1.0. The instrumental resolution (FWHM – full width at half-maximum) was ~10 Å. Three spectra of the central region of KUG 1259+280 were acquired in order to increase the signal-to-noise ratio and to reduce unwanted cosmic ray hits. The exposure times were 1800 s for each of the three exposures. To correct for the bias level and non-uniform response of the pixels in the CCD, bias frames and dome flat frames were also acquired on the same night. For the purpose of wavelength calibration, comparison (He-AR) spectra were obtained. The spectrophotometric standard star HR 4963 was observed (two exposures) on the same night to flux calibrate the object spectra.

Spectroscopic observations (two exposures of 2400 s each) of KUG 1259+280 were also carried out on the night of 1999 February 26 at the Cassegrain focus of the VBT using the opto-mechanical research (OMR) spectrograph (Prabhu, Anupama & Surendirath 1998) with a slit of width 2.8 arcsec, a 600 line mm^{-1} grating and a 1024 × 1024 CCD camera. The instrumental resolution (FWHM) was ~7 Å, and the slit position angle was 0°. The sky conditions were close to photometric. However, the spectra obtained were of poor signal-to-noise ratio owing to poor reflectivity of the primary. Because of the wider wavelength range covered and better signal-to-noise ratio obtained at the GHO, we present only the results obtained from the GHO.

3 ANALYSIS & RESULTS

3.1 Image analysis

The analysis of X-ray images has been carried out using the PROS[1] software package. X-ray images were extracted from all the observations listed in Table 2. The high-resolution (central full width half maximum of ~4 arcsec) images, obtained with HRI, were smoothed by convolving with a Gaussian of $\sigma = 5$ arcsec. The PSPC images were smoothed with a Gaussian of $\sigma = 10$ arcsec. X-ray contours of smoothed HRI and PSPC images

[1] The PROS software package provided by the *ROSAT* Science Data Center at Smithsonian Astrophysical Observatory.

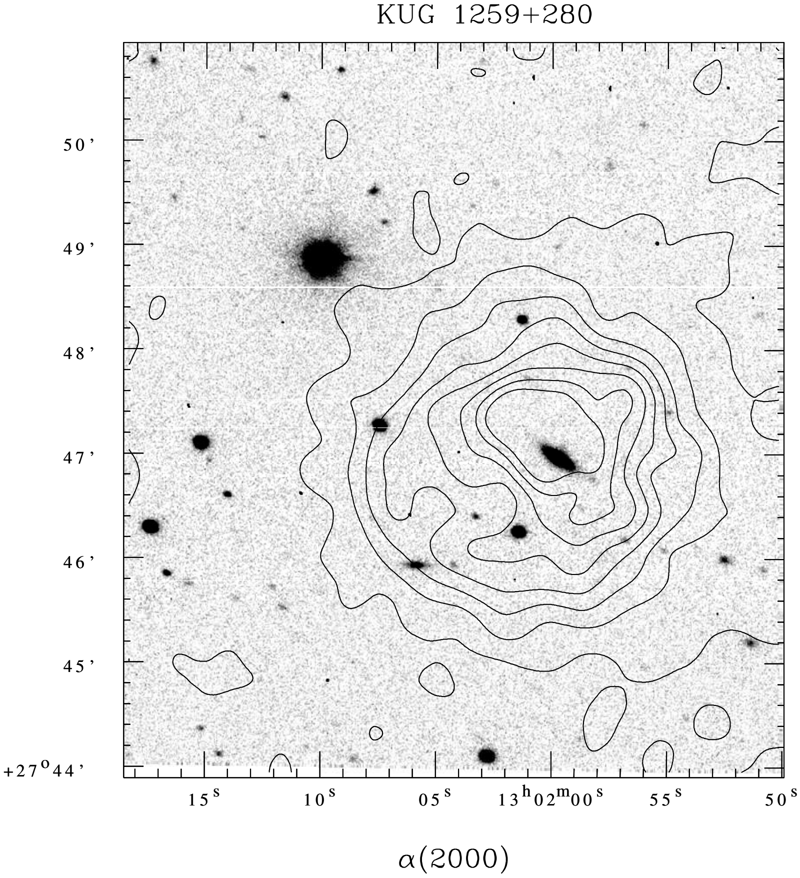

Figure 2. Contours of *ROSAT* PSPC image of KUG 1259+280 overlaid on the *V*-band optical image observed with the 2.3-m Vainu Bappu Telescope, Kavalur, India. The X-ray contours are shown at levels 10, 20, 30, 40, 50, 60, 70 and 80 per cent of the peak intensity (0.0471 count pixel^{-1}). The background level is 0.0035 ± 0.0001 count pixel^{-1}. X-ray contours were derived from the X-ray image after smoothing by a Gaussian of $\sigma = 10$ arcsec. The X-ray image was generated from the data observed on 1991 June 18.

Table 3. Position and count rates of KUG 1259+280 derived from *ROSAT* observations.

Date of observation	Instrument	Position α(2000)	Position δ(2000)	Source Count Rate 10^{-2} count s^{-1}
1995 June 06	HRI	13^h 01^m 59.9^s	+27° 47′ 00.8″	2.4 ± 0.24
1994 June 25	HRI	13^h 02^m 00.2^s	+27°46′ 59.7″	2.3 ± 0.13
1991 June 16	PSPC	13^h 02^m 00.0^s	+27° 47′ 03.9″	17.7 ± 0.43
1991 June 17	PSPC	13^h 02^m 00.8^s	+27° 47′ 04.0″	17.3 ± 0.44
1991 June 18	PSPC	13^h 02^m 00.5^s	+27° 46′ 59.7″	16.6 ± 0.40
1990 July 11 (RASS[a])	PSPC	13^h 01^m 58.9^s	+27° 47′ 08.5″	12.43 ± 1.95

[a] *IRAS* All Sky Survey (Voges et al. 1999).

have been overlaid on the optical *V*-band image and are shown in Figs 1 and 2, respectively. It is clear from Fig. 1 that the X-rays are centred on the galaxy, KUG 1259+280. No other X-ray source, within the angular spread comparable to the point spread function of *ROSAT* PSPC, was seen in either of the two HRI observations. Therefore, X-ray emission from KUG 1259+280 is not contaminated by emission from any other source.

We have estimated the count rate of KUG 1259+280 from the PSPC observations. Owing to the large off-axis angle (~30 arcmin) of KUG 1259+280 from the field centre in each of the PSPC observations, it is necessary to correct the PSPC images for exposure and vignetting. For this reason, we have created an exposure map for each of the PSPC observations using an appropriate devignetted detector map obtained from HEASARC. Exposure corrections to the PSPC images were carried out using the XIMAGE software. Source count rates were estimated from square boxes centred at the source position and after subtracting the background estimated from square annuli centred at the source position but outside the source region. The source box size was optimally selected to maximize the signal-to-noise ratio. The count rates thus estimated are corrected for exposure and vignetting and are given in Table 3. The X-ray intensity of KUG 1259+280 remained almost steady during the three pointed PSPC observations. X-rays from KUG 1259+280 were also detected in 1990 during the *ROSAT* All Sky Survey (RASS) (Voges et al. 1999). The X-ray intensity of KUG 1259+280 obtained from the *ROSAT* All Sky Survey Bright Source Catalogue (Voges et al. 1999) is given in Table 3, and is about 25 per cent less than that during the pointed mode observations in 1991.

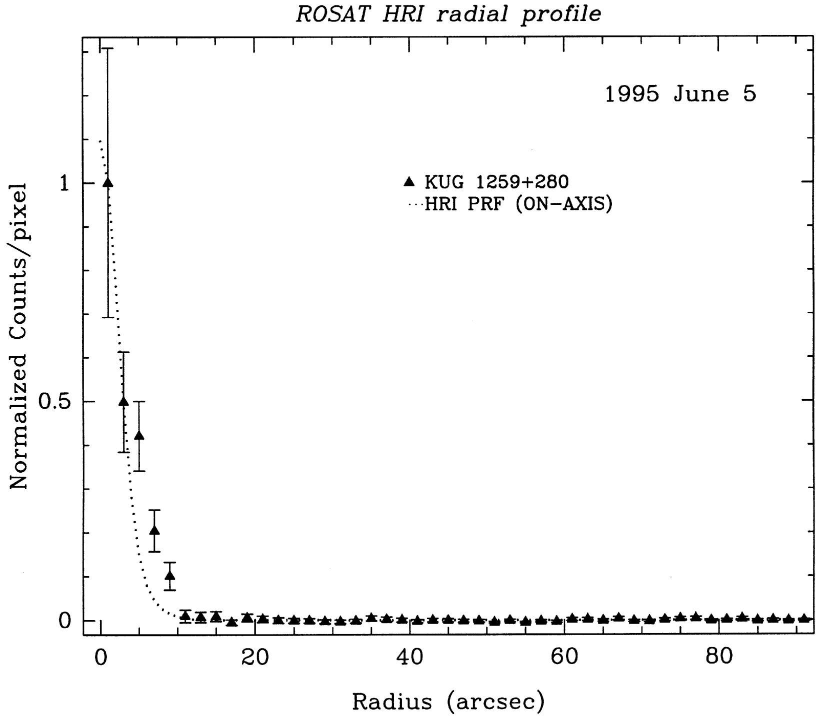

Figure 3. Radial HRI intensity distribution of KUG 1259+280 compared with the theoretical PRF of the *ROSAT* HRI. The radial profile of KUG 1259+280 has been derived from the data obtained on 1995 June 5, with minimum off-set (0.′16) from the centre of the field.

The source counts from the HRI images, extracted from the data observed on 1994 June 25 and 1995 June 5, were estimated from circles of radii 30 and 25 arcsec, respectively, after subtracting the background counts estimated from annular regions centred at the peak positions with inner and outer radii of 60 and 120 arcsec. The optimal extraction radii were chosen from radial profiles for the KUG 1259+280 to include the maximum signal and minimum background noise. The background estimates were checked by changing the width of the annuli and no significant change in total counts was noticed. The HRI count rates are given in Table 3. The count rates in the two HRI observations are unchanged.

In order to find the spatial extent of KUG 1259+280 in X-rays, we have generated a radial intensity profile of the X-ray source in KUG 1259+280 from raw *ROSAT* HRI images extracted from the 1995 June 5 data, and compared it with the point response function of the telescope and detector. We used this HRI observation because the source is centred on the axis, even though the exposure time is smaller than in the other HRI observation. This was done because the HRI point response function broadens at off-axis positions. The radial profile of KUG 1259+280 was generated by averaging azimuthally in radial bins of 2 arcsec from the raw HRI images. Background intensity was estimated from an annular region of width 60 arcsec centred at the galaxy, 2.5 arcmin away from the galaxy centre. The radial profile thus generated was normalized by the intensity at a radius of 1 arcsec and is shown in Fig. 3. The point response function (PRF) of the *ROSAT* telescope and HRI was generated using the analytic form of the on-axis point response function (David et al. 1993). As can be seen in Fig. 3, KUG 1259+280 has not been spatially resolved by *ROSAT* HRI. It should be noted that the slight excess over the theoretical PRF around radii of 5 to 10 arcsec does not imply that the galaxy is spatially extended. The work of Lehmann et al. (1998) has proved that the more realistic re-calibrated HRI PRF differs slightly but significantly from the theoretical HRI PRF in the range 10–30 arcsec. Thus we conclude that there is no evidence for extended X-ray emission from KUG 1259+280 based on the *ROSAT* HRI observations.

3.2 X-ray timing

In order to investigate the time variability of the soft X-ray emission from KUG 1259+280, we have extracted light curves from the three *ROSAT* PSPC observations. The light curves were extracted using the XSELECT package with time bins of 400 s and in the full energy band of *ROSAT* PSPC containing all the X-ray photons. For each PSPC observation, source + background light curve was extracted from a circle of radii 3.25 arcmin centred on the peak position, while the background light curve was extracted from three nearby circular regions away from the Coma cluster with their centres about 6.5 arcmin away from the source. The large radius for the source extraction circle was necessitated because of the broadening of the point spread function (psf) at large off-axis angle from the centre of the field of view of the telescope. The background subtractions were carried out after appropriately scaling the background light curves to have the same area as the source extraction area. The light curves of KUG 1259+280 thus generated are shown in Figs 4(a)–(c) for the PSPC observations carried out on 1991 June 16, 17 and 18 respectively. As can be seen in the Figs 4(a) and (b), X-ray emission from KUG 1259+280 is steady during the observations on 1991 June 16 and 17. However, the galaxy shows a remarkable X-ray variability on 1991 June 18 when an event with peak X-ray intensity of 2.5 times the average value, which subsequently declined to the average value within about 1300 s, was recorded. It should be noted that the variability amplitude and the time-scale could be larger than seen, since the observation does not cover the full time span of the variable event as a result of Earth occultation. After the decline,

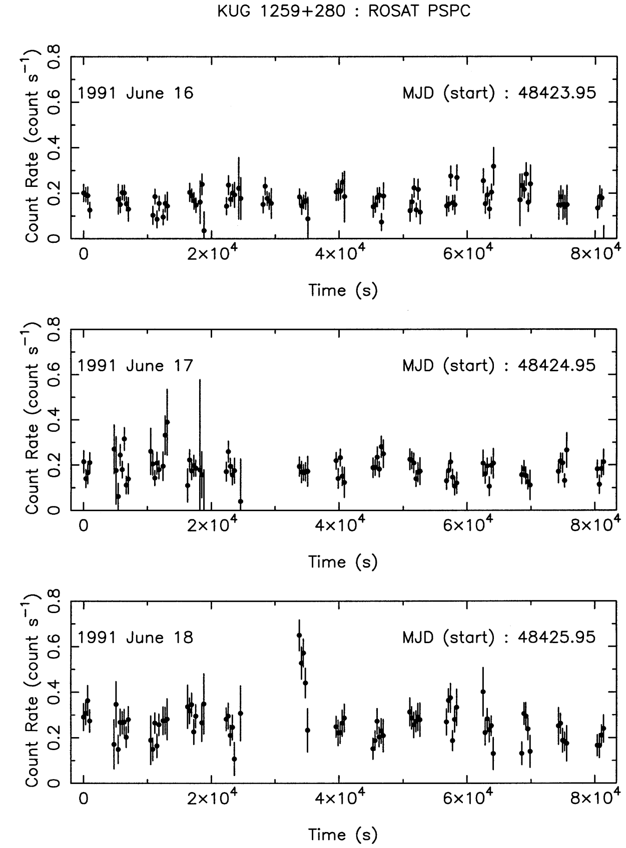

Figure 4. *ROSAT* PSPC light curves of KUG 1259+280 observed on (a) 1991 June 16, (b) 1991 June 17 and (c) 1991 June 18. The time bin size is 400 s. Short term variability is seen on 1991 June 18.

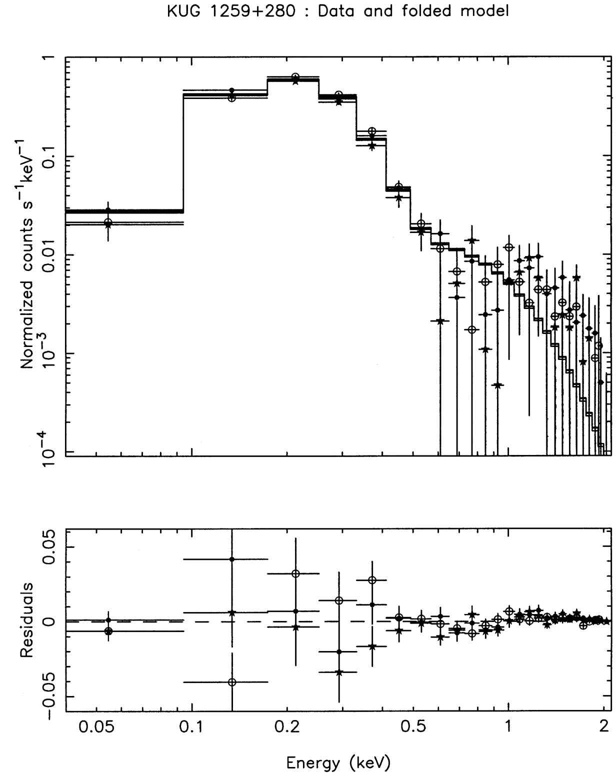

Figure 5. Spectral data and joint model fit to the *ROSAT* PSPC X-ray spectra of KUG 1259+280. The PSPC spectrum for 1991 June 16 observation is shown as solid circles. The spectrum marked with asterisks is for 1991 June 17 observation. The third spectrum marked with open circles is for 1991 June 18 observation. The jointly fitted power-law model absorbed by Galactic $N_{\rm H}$ and intrinsic $N_{\rm H}$ local to KUG 1259+280 is shown with a solid line.

the X-ray intensity from KUG 1259+280 remains almost steady. To investigate any change in the hardness ratio during the flare or outburst, we generated two light curves of KUG 1259+280 in the energy bands 0.1–0.3 and 0.3–1.5 keV. From these light curves, we calculated the hardness ratio as a function of time and found no changes in the hardness ratio during the outburst or flare. Since most of the X-ray photons are concentrated below 0.5 keV, we confirmed the above result by calculating hardness ratios using light curves extracted in the energy bands 0.1–0.35, 0.35–1.5, 0.1–0.4 and 0.4–1.5 keV.

In order to find any possible presence of long-term variation of soft X-ray emission from KUG 1259+280, we have searched the literature for observations of the galaxy with other X-ray observatories. The galaxy was not observed with the *Einstein* observatory (Branduardi-Raymont et al. 1985). The *EXOSAT* low energy (LE) count rate of KUG 1259+280 observed on 1985 June 17 is 7.5×10^{-3} count s^{-1} (Giommi et al. 1991). The *EXOSAT* count rate of KUG 1259+280 corresponds to an observed flux of $\sim4\times10^{-13}$ erg cm^{-2} s^{-1} in the energy band 0.05–2.0 keV using the spectral parameters measured with the *ROSAT* PSPC ($N_{\rm H} = 1.4\times10^{20}$ cm^{-2}, $\Gamma_{\rm X} = 4.25$) (see Section 3.3). Using W3PIMMS, this flux is found to be equivalent to the *ROSAT* PSPC count rate of ~0.12, which is similar to that obtained from the RASS in 1990 but smaller by ~25 per cent than during the pointed observation in 1991. We have also converted the *ROSAT* HRI count rates of KUG 1259+280 to the PSPC count rates using the best-fitting spectral parameters, for the purpose of comparison. The equivalent PSPC count rates are $(15.2\pm1.5)\times10^{-2}$ count s^{-1} and $(15.1\pm0.8)\times10^{-2}$ count s^{-1}, for the HRI observations carried out on 1995 June 6 and 1994 June 25, respectively. Thus X-ray emission from KUG 1259+280 is almost steady during the pointed PSPC and HRI observations. In summary, X-ray intensity of KUG 1259+280 was the same in 1990 observations as in the 1985 observations, and then increased by ~25 per cent in 1991.

3.3 X-ray spectra

Photon-energy spectra were accumulated from the PSPC events, separately for the three observations shown in Table 2, and using the same source and background regions as stated above. The *ROSAT* PSPC pulse height data obtained for 256 pulse height channels were re-grouped by adding counts in eight consecutive channels to improve the statistics. The X-ray spectra from the three observations thus obtained are shown together in the upper panel of Fig. 5. Bad channels have been ignored.

We used the XSPEC (Version 10.0) spectral analysis package to fit the data with spectral models. This requires a knowledge of the response of the telescope and the detector. Using the source spectral files and information about the source off-axis angle contained within them, we generated an auxiliary response file of the effective area of the telescope, by using the program *pcarf* in the FTOOLS (version 4.2) software package. This program uses the available off-axis calibration of the telescope, and the amount of scattering of X-ray photons and their dependence on energy are taken into account. An appropriate response matrix, provided by

Table 4. Best-fitting model spectral parameters for KUG 1259+280.

Date of observation	Model[a]	N_H $10^{20}\,cm^{-2}$	Excess N_H $10^{20}\,cm^{-2}$	Γ_X or kT (keV)	Norm[b]	f_X[c]	χ^2_ν/ν[d]
1991 June 16	phabs(zpl)	$1.1^{+0.25}_{-0.25}$	–	$4.0^{+0.3}_{-0.4}$	$4.1^{+2.0}_{-1.2}$	6.25	0.997/29
	phabs(zpl)	0.95	–	$3.8^{+0.14}_{-0.24}$	$4.5^{+2.0}_{-0.9}$	6.29	0.999/30
1991 June 17	phabs(zpl)	$1.15^{+0.37}_{-0.21}$	–	$4.1^{+0.75}_{-0.3}$	$3.3^{+1.4}_{-1.9}$	5.68	0.960/29
	phabs(zpl)	0.95	–	$4.0^{+0.2}_{-0.3}$	$3.2^{+2.0}_{-1.8}$	5.56	1.011/30
1991 June 18	phabs(zpl)	$1.9^{+0.45}_{-0.25}$	–	$4.5^{+0.6}_{-0.3}$	$3.5^{+1.1}_{-1.6}$	6.5	0.985/22
	phabs(zpl)	0.95	–	3.7	5.2	–	2.427/23
	phabs(zphabs)zpl	0.95	$1.0^{+0.5}_{-0.3}$	$4.57^{+0.56}_{-0.32}$	$3.4^{+1.2}_{-1.5}$	6.47	0.979/22
1991 June 16,17,18	phabs(zpl)	$1.4^{+0.2}_{-0.2}$	–	$4.25^{+0.25}_{-0.22}$	$3.6^{+0.9}_{-0.9}$	6.1	1.119/86
	phabs(zphabs)zpl	0.95	$0.5^{+0.2}_{-0.2}$	$4.25^{+0.25}_{-0.22}$	$3.6^{+0.9}_{-0.9}$	6.1	1.119/86
	phabs(zbbody)	0.95	–	$0.055^{+0.005}_{-0.006}$	$1.9^{+0.1}_{-0.05}$	5.75	1.737/89

[a] (z)phabs is the (redshifted)photoelectric absorption model using Balucinska–Church & McCammon (1992) cross-sections. zpl is redshifted simple power-law model. zbbody is the redshifted blackbody model. $z = 0.02369$ has been used.
[b] Power-law normalization in units of 10^{-5} photons $cm^{-2}\,s^{-1}\,keV^{-1}$ at 1 keV or blackbody normalization in units of $10^{34}\,erg\,s^{-1}$ $(10\,kpc)^{-2}$.
[c] Observed flux in units of $10^{-13}\,erg\,cm^{-2}\,s^{-1}$ in the energy band of 0.1–2.0 keV.
[d] Minimum reduced χ^2 for ν degrees of freedom.

the *ROSAT* Guest Observer Facility (GOF) at HEASARC, was used to define the energy response of the PSPC. The *ROSAT* PSPC spectra, shown in Fig. 5, were used for fitting spectral models. The spectra from the three observations were first fitted separately with a redshifted power-law model with photon index, Γ_X, and absorption owing to an intervening medium with absorption cross-sections as given by Balucinska–Church & McCammon (1992) and using the method of χ^2 minimization. The results of this fitting and the best-fitting spectral model parameters are shown in Table 4. This simple model is a good fit to the data of 3 d, as evidenced by the minimum reduced χ^2 values (χ^2_ν). The spectra corresponding to the first and the second observations are consistent with each other in the sense that both the best-fitting photon indices and the column densities of the absorbing material are similar within the errors. The absorber column densities are similar (within errors) to the 21-cm value ($N_H = 9.5 \times 10^{19}\,cm^{-2}$) measured from radio observations in this direction (Dickey & Lockman 1990), indicating that all the X-ray absorption is the result of matter in our own Galaxy. Therefore, we have also fitted the power-law models to these spectra after fixing the neutral hydrogen column density to the Galactic value. The best-fitting spectral parameters, in this case, are also given in Table 4. The best-fitting minimum χ^2_ν and the power-law index do not change significantly from those obtained while varying the N_H, as can be seen in Table 4. The photon indices thus obtained are, however, better constrained and are $3.80^{+0.14}_{-0.24}$ and $4.0^{+0.2}_{-0.3}$ for the spectra observed on 1991 June 16 and 1991 June 17, respectively. The errors quoted, here and below, were calculated at the 90 per cent confidence level based on $\chi^2_{min} + 2.71$. Based on the best-fitting model parameters, the observed X-ray flux from the source is estimated to be $6.3 \times 10^{-13}\,erg\,cm^{-2}\,s^{-1}$ for the observation on 1991 June 16 and $5.6 \times 10^{-13}\,erg\,cm^{-2}\,s^{-1}$ for the observation on 1991 June 17. We have also estimated the intrinsic flux of KUG 1259+290 by setting N_H to zero. The intrinsic flux of KUG 1259+280 in the energy band 0.1–2.0 keV is $2.4 \times 10^{-12}\,erg\,cm^{-2}\,s^{-1}$ on 1991 June 16 and $2.3 \times 10^{-12}\,erg\,cm^{-2}\,s^{-1}$ on 1991 June 17.

Power-law model fits to the spectral data obtained on 1991 June 18, however, show significant excess absorption over and above the Galactic value (see Table 4) when N_H is kept variable. The best-fitting value of N_H is about twice that of the Galactic value, thus suggesting an excess absorption local to the X-ray source in KUG 1259+280. The best-fitting photon index is slightly steeper than those obtained previously (see Table 4). In order to verify the presence of excess absorption, we fixed the neutral hydrogen column density to the Galactic value and fitted the absorbed power-law model. Although the photon index becomes flatter, the fit is not acceptable ($\chi^2_\nu = 2.427$ for 23 degrees of freedom) thus implying the need for an excess absorption. To estimate this excess absorption, we introduced an additional component for absorption local to KUG 1259+280 in our model, which makes the fit acceptable ($\chi^2_\nu = 0.979$ for 22 degrees of freedom) and the best-fitting value of excess (local to the source) N_H is $1.0^{+0.5}_{-0.3} \times 10^{20}\,cm^{-2}$. The best-fitting photon index in this case is $4.6^{+0.6}_{-0.3}$. The best-fitting power law is steeper on June 18 than on June 16 and 17 (see Table 4). The absorbed X-ray flux of KUG 1259+280 in the energy band 0.1–2.0 keV is $6.5 \times 10^{-13}\,erg\,cm^{-2}\,s^{-1}$ on 1991 June 18, and the corresponding intrinsic X-ray flux is calculated to be $7.3 \times 10^{-12}\,erg\,cm^{-2}\,s^{-1}$, based on the best-fitting parameters.

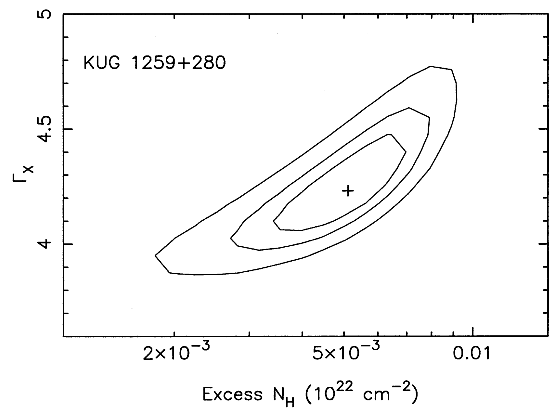

Figure 6. Allowed ranges of power-law photon index and 'excess' N_H (at the redshift of the source) for 68, 90 and 98 per cent confidence based on counting statistics derived from the joint fit of the three PSPC spectra. The '+' marks the best-fitting value.

In order to further investigate whether the differences in photon

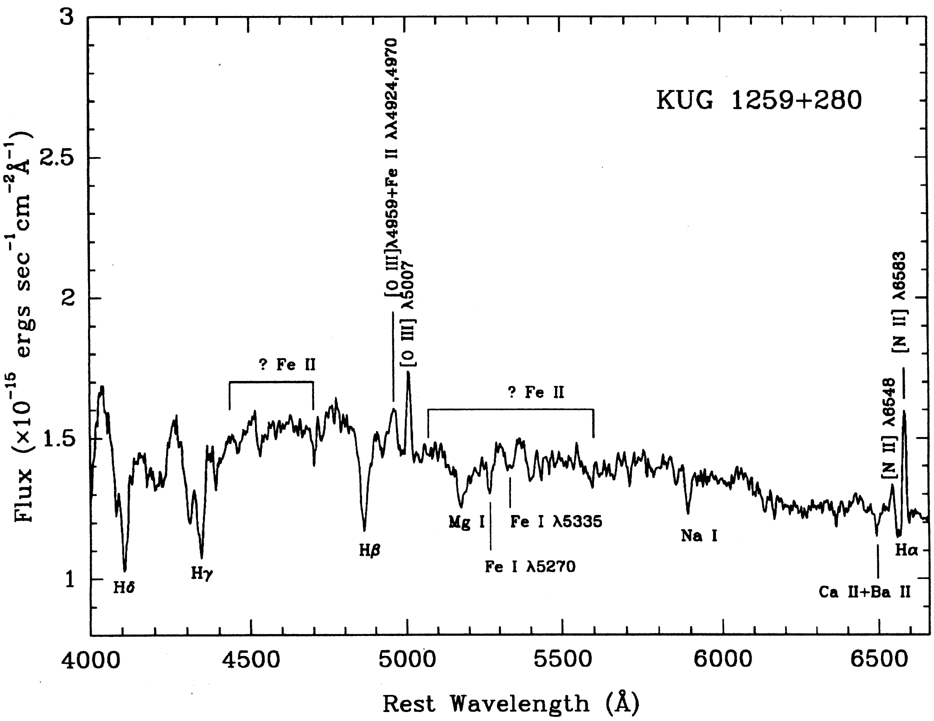

Figure 7. Doppler corrected and dereddened optical spectrum of KUG 1259+280. Balmer absorption line Hβ, Hγ and forbidden emission lines, e.g. [N II] λ6583, [O III] λλ4959, 5007 are seen clearly in the spectrum.

indices and N_H obtained for the three data sets are indeed real, we have fitted the absorbed and redshifted power-law model simultaneously to all three data sets. In this joint fit, the photon indices for the three observations were tied together and varied to obtain the best fit. Similarly, the N_H and normalizations were also tied together and varied. The best-fitting value of minimum χ^2_ν is 1.119 for 86 degrees of freedom, which corresponds to a probability of 0.21. The best-fitting value for the common photon index is $4.25^{+0.25}_{-0.22}$ and $N_H = 1.4^{+0.2}_{-0.2} \times 10^{20}\,\mathrm{cm^{-2}}$ (see Table 4). These results indicate that the shape of the spectrum of KUG 1259+280 has probably not changed over the three observations. However, the N_H column obtained is in excess of the Galactic value suggesting local absorption in all three observations. To find the excess N_H, we have carried out a joint fit after introducing additional absorption local to KUG 1259+280 apart from the fixed Galactic absorption. The excess N_H was found to be $5^{+2}_{-2} \times 10^{19}\,\mathrm{cm^{-2}}$. All other parameters do not change from that obtained in the previous joint fit. The fitted model is shown in Fig. 5, and the confidence contours of *excess* N_H and photon index are shown in Fig. 6. A photon index (Γ_X) between 3.8–4.8 and an excess absorption between $(0.2\text{–}1.0) \times 10^{20}\,\mathrm{cm^{-2}}$ are indicated for all three observations. The observed X-ray flux of KUG 1259+280 in the energy band 0.1–2.0 keV is $6.1 \times 10^{-13}\,\mathrm{erg\,cm^{-2}\,s^{-1}}$, and the corresponding rest frame intrinsic X-ray luminosity is $4.7 \times 10^{42}\,\mathrm{erg\,s^{-1}}$.

We have also fitted an absorbed blackbody model to all three data sets jointly. The absorbing column was fixed to the Galactic value for all three data sets. The common blackbody temperature was varied to obtain the best fit. Although the fit is not acceptable ($\chi^2_\nu = 1.737$ for 89 degrees of freedom), the temperature ($kT = 0.055\,\mathrm{keV}$) thus inferred reflects the ultra soft nature of KUG 1259+280.

3.4 Optical spectroscopy

Optical spectra were reduced and analysed using the IRAF[2] software package. Corrections for bias level and response variation of pixels were carried out using the standard procedures for each of the three spectra. Three different spectra of KUG 1259+280 were then combined to increase the signal-to-noise ratio. The one-dimensional spectrum of KUG 1259+280 was then optimally extracted from the two-dimensional spectrum using an aperture of size 4.2 arcsec by using the method of Horne (1986). The one-dimensional object spectrum was wavelength calibrated using an appropriate arc spectrum (He-AR). The wavelength calibration was accurate to ~2 Å in all the spectra. Correction for atmospheric extinction was based on the extinction curve of the Kitt Peak National Observatory. However, the correction is not critical as the standard star was observed almost at similar airmass as that of the object. Flux calibration was performed using standard IRAF procedures and using the observed spectrophotometric standard star HR 4963. The flux calibrated spectrum of KUG 1259+280 was corrected for Galactic extinction by adopting the extinction law in Cardelli, Clayton & Mathis (1989). Colour excess $E(B-V)$, owing to Galactic reddening along the line of sight of the galaxy KUG 1259+280 was calculated from the neutral hydrogen column density N_H using the relation

$$N_H = 5.8 \times 10^{21} \times E(B-V)\,\mathrm{cm^{-2}} \qquad (1)$$

(Bohlin, Savage & Drake 1978). The dereddened spectrum was

[2] IRAF is distributed by the National Optical Astronomy Observatories, which is operated by the Association of Universities, Inc. (AURA) under a cooperative agreement with the National Science Foundation. IRAF version 2.11.3 was used.

Table 5. Optical spectral line parameters of KUG 1259+280.

Spectral line	Line flux 10^{-15} erg cm^{-2} s^{-1}	Equivalent width Å
Emission lines[a]		
[O III]λ4959	3.6 ± 0.46	2.5 ± 0.32
[O III]λ5007	4.4 ± 0.3	3.0 ± 0.28
[N II]λ6548	1.6 ± 0.32	1.3 ± 0.26
[N II]λ6583	4.7 ± 0.24	3.9 ± 0.19
Absorption lines		
Hγ	8.4 ± 0.44	5.8 ± 0.31
Hβ	9.8 ± 0.40	6.5 ± 0.26
Mg I λ5176	3.1 ± 0.39	2.3 ± 0.28
Na I λ5890	2.2 ± 0.33	1.5 ± 0.24

[a]None of the emission lines have been spectroscopically resolved. [O III] λ4959 is blended with Fe II λλ5924, 4970. The instrumental resolution (FWHM) is about 600 km s^{-1}.

then corrected for Doppler shift ($z = 0.023\,69$). The final reduced spectrum of KUG 1259+280 is shown in Fig. 7. The signal-to-noise ratio of the spectrum is ~52 measured at 4500–6600 Å. The spectrum of KUG 1259+280 shows forbidden emission lines [N II] λ6548, [N II] λ6583, [O III] λ4959, [O III] λ5007. The Balmer lines Hβ, Hγ and Hδ are seen in the absorption. No Hα emission is observed in the spectrum. The absorption lines of Mg I (λ5176), Fe (λλ5270, 5335), Na I D (λ5890) and Ca II+Ba II blend (λ6497) are also present in the spectrum of KUG 1259+280.

We have fitted Gaussian profiles to the emission lines [N II] λ6583, [N II] λ6548, [O III] λ4959 and [O III] λ5007 using the profile fitting feature in the 'splot' task within IRAF. The spectral line parameters obtained from the fit are shown in Table 5. The error quoted for each parameter is the absolute deviation containing 68.3 per cent of the parameter and were estimated by 100 Monte Carlo simulations assuming constant Gaussian noise. The FWHM for the [O III] λ4959 line is about twice that for the FWHM for the [O III] λ5007 line and both have similar flux. This feature is not an artefact and is confirmed by the spectrum of the same object taken with the VBT, India but with a poorer signal-to-noise ratio (~30 at 5000 Å), albeit slightly higher resolution (~7 Å). This is not expected and can be attributed to the fact that the forbidden line [O III] λ4959 is blended with the Fe II lines at 4924 and 4970 Å. The FWHM of the forbidden lines [N II] λ6583, [N II] λ6548 and [O III] λ5007 are similar to the instrumental resolution deduced from the night sky emission lines. Thus the forbidden lines have not been resolved and have FWHMs ≤ 600 km s^{-1}. The VBT spectrum shows FWHM ≃ 300 km s^{-1} after removing the effect of instrumental resolution. There is some indication for the presence of Fe II blends between 4435–4700 Å in the blue, and between 5070–5600 Å. However, the blends seem to be modified by the galaxy absorption features, e.g. by the presence of the Fe λ5335 absorption line usually seen in a normal galaxy spectrum (Goudfrooij 1998). To confirm the possible presence of Fe II blends a higher resolution and a higher signal-to-noise spectrum is required. Subtraction of a template galaxy spectrum representing the stellar population of KUG 1250+280 from the observed spectrum will help in confirming the presence of Fe II blends. However, this requires data with a better signal-to-noise ratio and a higher resolution than the data presented here.

4 DISCUSSION

Recent optical spectroscopic surveys have been finding a large fraction (~43 per cent) of active galactic nuclei among nearby galaxies (Ho et al. 1997a). Nearly 10 per cent of all nearby galaxies surveyed by Ho et al. (1997a) are found to have Seyfert type nuclei, the rest being LINERS (low ionization nuclear emission region galaxies) or composite LINER/H II nucleus systems. While the optical emission lines are sensitive to many physical parameters, e.g. the shape and strength of the ionizing continuum arising from nucleus, temperature, density, composition and velocities of line emitting clouds surrounding the nucleus and dust in the ambient medium, X-rays probe the innermost regions of AGNs. Therefore, X-ray emission properties are more fundamental for inferring the nature of galactic nuclei. X-ray emission from KUG 1259+280 is found to be unresolved with the *ROSAT* HRI observations with a resolution of ~4 arcsec. This suggests that the X-ray emission from KUG 1259+280 is perhaps mostly of nuclear origin. The nuclear nature of X-ray emission is further strengthened by the observation of strong and rapid variability detected in the X-ray observations which also points to a very active nucleus – an AGN inside KUG 1259+280. This is consistent with the point-like appearance of the central region of KUG 1259+280 in the optical band in the *HST* observations with 0.1 arcsec resolution (CRD). In the following, we discuss the observed variability, X-ray and optical spectral characteristics, and broad-band multi-wavelength spectra and their implications on models of AGN.

4.1 X-ray characteristics and variability

The rest frame intrinsic X-ray luminosity of KUG 1259+280 is in the range of $3.6\text{–}4.7 \times 10^{42}$ erg s^{-1}. This is about a factor of 10 higher than the X-ray luminosity of LINERs studied by Komossa, Böhringer & Huchra (1990) using *ROSAT*. All the LINERs in the sample of Komossa et al. (1990) have $L_X \leq 10^{41}$ erg s^{-1} in the energy band 0.1–2.4 keV. On the other hand, Seyfert 1 galaxies studied by Rush et al. (1996) span over 4 orders of magnitude in soft X-ray luminosity, from below 10^{42} to above 10^{46} erg s^{-1} in the same energy band. Thus X-ray luminosity of KUG 1259+280 is similar to that of a low luminosity Seyfert 1 galaxy.

X-ray emission from KUG 1259+280 is highly variable. On 1991 June 18 X-ray emission from KUG 1259+280 varied by a factor of ~2.5 within ~1300 s (Fig. 4). This variability could be the result of an outburst or a flare event in the nucleus of KUG 1259+280. This kind of time variability is seen in several AGNs, e.g. the low luminosity Seyfert 1 galaxies such as NGC 4051, and narrow line Seyfert 1 galaxies such as IRAS 13224−3809 vary over periods of ~0.1–1 h (Pounds 1979; Lawrence et al. 1985; Boller et al. 1993; Singh 1999). On the other hand, rapid variability on time-scales of less than a day is generally absent in the case of LINERs (Ptak et al. 1998; Pellegrini et al. 2000). X-ray emission from KUG 1259+280 is also found to vary by ~25 per cent within a year between RASS and PSPC pointed observations. The large amplitude variation of the nuclear X-ray source over a short time-scale is possible only if the nucleus is very compact. Simple light travel time arguments imply that the nuclear X-ray source in KUG 1259+280 is very compact (size ≤ 1.2×10^{-5} pc). Assuming that the soft X-ray excess emission originates from a few Schwarzschild radii ($3R_S$ or more) away from the central massive object, the mass of the central compact object is expected to be $\leq 4.4 \times 10^7\,M_\odot$. A lower limit of the mass of the central object can be obtained from the Eddington luminosity. Since KUG 1259+280 is an ultrasoft X-ray source, it will be reasonable to assume that the bulk of the luminosity for the nuclear source in KUG 1259+280 is in the soft X-ray band. Assuming that the Eddington luminosity is about a factor of 5 larger than the soft X-ray luminosity in the energy band of 0.1–2.0 keV, the mass of the central object is inferred to be at least $2.0 \times 10^5\,M_\odot$. Thus the mass of the central compact object is in the range of $M \simeq 10^5$–$10^7\,M_\odot$. The X-ray luminosity of $\sim 4 \times 10^{42}\,\mathrm{erg\,s^{-1}}$, small amplitude long term variation, and large amplitude (by a factor of ~2.5) short term variation all indicate that the galaxy harbours an active nucleus. The X-ray spectra of KUG 1259+280 obtained from three *ROSAT* PSPC observations are very steep (Table 4). A joint fit has revealed that all three PSPC spectra are well represented by a single power law of $\Gamma_X \sim 4.25$, with an *excess* of $N_H = 5 \times 10^{19}\,\mathrm{cm^{-2}}$ over the Galactic value. This suggests the presence of an excess absorption above the Galactic value during all three observations. Such an absorber is seen convincingly in the observation on 1991 June 18. It is possible that a change in the absorbing column density local to KUG 1259+280 could have occurred within ~1 d as indicated by the individual power-law fits to the PSPC spectra, indicating the presence of moving clouds close to the central nuclear source. The physical state (warm or cold) of the absorbing medium is unclear from the present data. However, in the spectrum of 1991 June 18, there is an indication of an absorption edge at about 0.8 keV (see residuals in Fig. 5), which is very close to O VII and O VIII edges at 0.74 and 0.87 keV commonly seen in *ASCA* and *ROSAT* spectra of AGNs (Reynolds 1997). However, because of the poor signal-to-noise ratio of the data and owing to the poor energy resolution of the *ROSAT* PSPC, it is not possible to fit an absorption edge. Higher signal-to-noise data with better energy resolution will be required to confirm the presence of an absorption edge. The short time-scale of ~1 d for the change in local N_H also implies that the nuclear X-ray source is very compact, similar to those found in AGNs.

4.2 Optical characteristics

The optical spectrum of the nuclear region of KUG 1259+280 is not typical of either the spectra of normal galaxies or AGNs. In the optical spectrum of KUG 1259+280, Balmer emission lines are absent, instead, Hβ, Hγ and Hδ absorption lines are seen. Hα absorption appears to be almost balanced by emission as was also pointed out by CRD. Caldwell & Rose (1997) have shown that KUG 1259+280 is a very strong post-starburst galaxy in the Coma cluster, based on the presence of enhanced Balmer absorption lines, Hδ, Hγ, etc. and the weaker Ca II K line compared to those in normal galaxies. CRD have pointed out that the weak emission line spectrum of KUG 1259+280 is because of nuclear activity and not the result of residual star formation. From the equivalent widths of higher order Balmer absorption lines in the spectrum of KUG 1259+280, CRD have estimated the underlying Hα absorption to be ~5 Å and found the ratio of [N II] $\lambda\lambda$6548,6583 to Hα emission to be slightly greater than 1, which is a typical value for LINER emission line spectra. It is, however, well known that LINER, Seyfert galaxy and H II region spectra cannot be unambiguously distinguished from one another on the basis of any single intensity ratio from any pair of lines. The various types of objects with superficially similar emission line spectra can be distinguished by using a diagnostic diagram based on pairs of emission line intensity ratios (Baldwin, Phillips & Terlevich 1981). In the case of KUG 1259+280, weak Balmer emission lines arising from the centre are dominated by the enhanced absorption lines arising from young stellar populations. Assuming Case-B recombination (e.g. Osterbrock 1989), we estimate the Hβ emission flux to be $\sim 2.1 \times 10^{-15}\,\mathrm{erg\,cm^{-2}\,s^{-1}}$ from the equivalent width of Hα emission line estimated by CRD. Hence the ratio of [O III] λ5007 to Hβ emission is about 2 for KUG 1259+280. Ho et al. (1997b) have defined LINER nuclei to be those with [O III]$\lambda 5007/H\beta \leq 3.0$, and [N II]$\lambda 6583/H\alpha \geq 0.6$. Based on this definition, the estimated pair of line intensity ratios, [O III]$\lambda 5007/H\beta \sim 2$ and [N II]$\lambda 6583/H\alpha \sim 0.8$, suggest that the nucleus of KUG 1259+280 is, most likely, of LINER type. This confirms the conclusion by CRD. However, it should be noted that LINERs show the presence of the strong [O I] λ6300 forbidden line in their spectra, but this line is not detected in the spectrum of KUG 1259+280. Also, in the spectrum of KUG 1259+280, the forbidden line [O III] λ4959 is blended with Fe II $\lambda\lambda$4924, 4970. The Fe II lines are seen in the spectra of Seyfert galaxies and not in the spectra of LINERs. These raise questions regarding the LINER nature of KUG 1259+280. The lack of Balmer emission lines in the spectrum of KUG 1259+280 can be attributed to the post-starburst phenomena. To investigate quantitatively the origin of optical emission and absorption lines, a higher signal to noise and a higher resolution optical spectrum, as well as a UV spectrum, is required.

4.3 Comparison with steep spectrum X-ray AGNs

It is well known that the steep spectrum AGNs generally show optical spectra similar to those of optically identified NLS1 galaxies (Boller, Brandt & Fink 1996). In view of the steep X-ray spectrum of KUG 1259+280, if we assume that the intrinsic nuclear optical spectrum is similar to those of NLS1 galaxies modified by enhanced stellar absorption, then one would expect that the optical spectrum parameters, which are not affected significantly by the stellar absorption, should be similar to those of NLS1 galaxies. The interesting parameters are the ratio of X-ray to [O III] luminosity, f_x/[O III], and slope (α_{opt}) of the optical spectrum ($f_\nu \propto \nu^{-\alpha}$). Grupe et al. (1998) and Grupe et al. (1999) have studied soft X-ray and optical properties of 76 steep X-ray spectrum AGNs in detail. Based on their measurements, we have calculated f_x/[O III] for 71 AGNs and found that the ratio, f_x/[O III], spans a large range (6–3157) with a median value of 399.2. (We have excluded the two objects RXJ 0136−35 and a Seyfert 2 galaxy, IC 3599, with f_x/[O III] > 15 000 from our analysis. There are only eight objects with f_x/[O III] > 2000, and only two with f_x/[O III] > 3200.) For KUG 1259+280, f_x/[O III] = 156. Thus the ratio, f_x/[O III], for KUG 1259+280 is not different from those of steep spectrum X-ray AGNs. Since the optical continuum emission of the nucleus of KUG 1259+280 is contaminated by the stellar emission, as can be seen by the presence of strong absorption lines, we have not compared the slope of the observed optical spectrum to those of NLS1s from Grupe et al. (1998). The [O III] λ5007 luminosity of KUG 1259+280 is $4.8 \times 10^{39}\,\mathrm{erg\,s^{-1}}$, which is about a factor of about 90 smaller than the mean [O III] λ5007 luminosity of the three NLS1s (MS 2340−15, RX J0439−45 and RX J2144−39) of Grupe et al., having similar soft X-ray slopes as for the KUG 1259+280. This could be the result of a dilution of X-ray emission in KUG 1259+280, as the soft X-ray luminosity of KUG 1259+280 is smaller by a factor of ~750 than the average soft X-ray luminosity of the three AGNs in the sample of Grupe et al. (1998). The difference in the ratio of

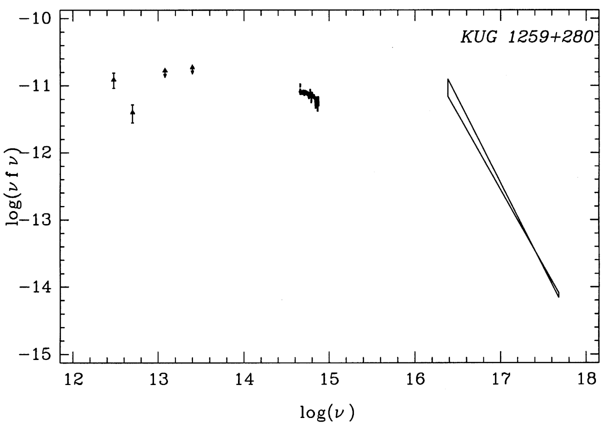

Figure 8. Spectral energy distribution of KUG 1259+280. Arrows indicate 3σ upper limits.

[O III] λ5007 to soft X-ray luminosity between KUG 1259+280 and the three AGNs with similar soft X-rays slopes could be either the result of the contribution of [O III] luminosity by H II regions owing to hot stars or the result of differences in the physical parameters of the line emitting clouds, or differences in the shape of the primary radiation in the UV–EUV region. Based on the above comparison, it is likely that KUG 1259+280 is a low luminosity version of NLS1 galaxies, where owing to the diluted power-law continuum, the optical emission lines are weak. Furthermore, the weak permitted lines are heavily modified by the enhanced stellar absorption in the post-starburst region.

4.4 Spectral energy distribution of KUG 1259+280

In Fig. 8, we have plotted far-infrared, optical and soft X-ray flux of KUG 1259+280 obtained from various observations. No far-infrared measurements have been reported from KUG 1259+280 in the *IRAS Point Source Catalogue* (Joint *IRAS* Working Group 1985). The *IRAS* satellite had, however, scanned the sky containing KUG 1259+280 during the surveys. We have obtained the *IRAS* flux after co-adding the available scan data. The *IRAS* data were processed using the facilities of IPAC[3]. The measured *IRAS* flux densities are 0.07 ± 0.025, 0.10 ± 0.047, 0.08 ± 0.024 and 0.41 ± 0.105 Jy at 12, 25, 60 and 100 μm, respectively. No radio emission is detected within 15 arcsec of KUG 1259+280 in the NRAO/VLA and FIRST sky surveys. The spectral energy distribution of KUG 1259+280 is contaminated by stellar emission in the optical region, otherwise it is similar in shape with those of narrow line Seyfert 1 galaxies reported by Grupe et al. (1999) and indicates a probable shift in the position of the big blue bump, although not covered in any observation, towards higher energies.

4.5 AGN–post-starburst connection

As noted earlier, KUG 1259+280 is a nuclear post-starburst galaxy with a post-starburst age of ~0.5 Gyr (CRD). To build a central massive object of mass $10^6\,M_\odot$ within KUG 1259+280 after the starburst event, the required average mass accretion rate would be only about $0.002\,M_\odot\,yr^{-1}$. On the other hand, the Eddington accretion rate for efficiency factor $\eta \simeq 0.1$, and $M = 10^6\,M_\odot$ is $\dot{M}_E \simeq 0.022\,M_\odot\,yr^{-1}$. Therefore, the required mass accretion rate to build a central massive object of mass $\sim 10^6\,M_\odot$ within KUG 1259+280 is about a factor of 10 less than the Eddington accretion rate. Thus it cannot be ruled out that the birth of the AGN in KUG 1259+280 took place after or during the starburst event. In such a scenario, the mass accretion rate onto the young AGN can be expected to be high as the fuel available would be enormous. It should be noted that some authors (e.g. Brandt & Boller 1998) have argued that a high mass accretion rate onto a low-mass (10^6–10^7) black hole can result in AGNs with a steep soft X-ray spectrum.

[3] The IPAC was founded by NASA as part of the *IRAS* extended mission program under contract to JPL.

5 CONCLUSIONS

(i) X-ray emission from KUG 1259+280 is found to be unresolved by *ROSAT* HRI observations suggesting a point-like nuclear X-ray source in it.

(ii) X-ray luminosity of KUG 1259+280 is estimated to be ~ 3.6–4.7×10^{42} erg s^{-1} which is similar to that of low luminosity Seyfert nuclei.

(iii) Variability by a factor of ~2.5 within ~1300 s is detected in X-ray emission from KUG 1259+280. The short time-scale of variability strongly suggests an AGN in the galaxy.

(iv) The mass of the central massive object in KUG 1259+280 has been estimated to be in the range 10^5–$10^7\,M_\odot$.

(v) X-ray spectrum of KUG 1259+280 is found to be very steep ($\Gamma_X \sim 4.25$) in the *ROSAT* band 0.1–2.4 keV. Individual power-law model fits to three PSPC spectra indicate a change in intrinsic absorbing column within about a day, while a joint fit of three PSPC spectra indicates excess absorption (total $N_H = 1.4 \times 10^{20}\,cm^{-2}$) over the Galactic value ($N_H = 9.5 \times 10^{19}\,cm^{-2}$).

(vi) The observed optical spectrum of the nuclear region of KUG 1259+280 is markedly different from that of any class of AGNs. The observed spectrum could be understood if the narrow-line region/broad-line region emission line spectrum has been substantially modified by enhanced stellar absorption lines. Estimated absorption-free Balmer line strengths and observed forbidden line strengths point towards the LINER nature of KUG 1259+280. However, the nature of the X-ray emission points towards the NLS1 nature of this galaxy. The presence of Fe II lines supports this picture.

(vii) It is quite possible that the central supermassive object in KUG 1259+280 was formed after or during the starburst event ~0.5 Gyr ago.

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Archive Research Center (HEASARC) of NASA's Goddard Space Flight Center have been used. We thank Booth Hartley for providing *IRAS* co-added data.

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