Chin. J. Astron. Astrophys. Vol. 6 (2006), No. 4, 430–434
(*http://www.chjaa.org*)

Chinese Journal of
Astronomy and
Astrophysics

Re-Identification of the 'Enigmatic' X-ray Source 1RXS J114003.0+124112 *

Jiang-Hua Wu[1], Tigran Movsessian[2], Yang Chen[3], Xiang-Tao He[3], Xu Zhou[1] and Jun Ma[1]

[1] National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100012; *jhwu@bao.ac.cn*
[2] Byurakan Astrophysical Observatory, Aragatsotn Prov. 378433, Armenia
[3] Department of Astronomy, Beijing Normal University, Beijing 100875

Received 2005 November 28; accepted 2006 February 17

Abstract The *ROSAT* X-ray source 1RXS J114003.0+124112 was identified as a starburst galaxy at redshift 0.177 by He et al. The authors also noted that the source is almost two orders of magnitude brighter in X-ray than the X-ray-brightest starburst galaxy and it seems to be in a merging system, making this source an enigmatic system demanding further observations. Here we report a re-identification of 1RXS J114003.0+124112 using observations on the 2.6 m telescope at Byurakan Astrophysical Observatory, Armenia and the SDSS data. The results indicate that the starburst activity is associated with the brighter object of the system, while the fainter object is a typical Seyfert 1 galaxy at a different redshift (0.282). Therefore, the two objects are not in a merging system, and the Seyfert 1 galaxy naturally accounts for the high X-ray flux. Three more objects reside in the vicinity, but they are all too faint to be responsible for the high X-ray flux.

Key words: galaxies: active — galaxies: Seyfert — galaxies: starburst — X-rays: individual (1RXS J114003.0+124112)

1 INTRODUCTION

In the first paper of the Multi-Wavelength Quasar Survey (MWQS, He et al. 2001), the *ROSAT* source 1RXS J114003.0+124112 was identified as a starburst galaxy at redshift 0.177 based on its optical spectrum. At the same time, the authors also noticed its peculiarities as a starburst galaxy: Its X-ray luminosity is almost two orders of magnitude higher than those of the X-ray-brightest starbursts. When assuming a power-law with a photon index of $\Gamma = 2.2$ and adopting a Galactic neutral hydrogen column density of $3.15 \times 10^{20}\,\mathrm{cm}^{-2}$ (computed by using Colden: the Galactic Neutral Hydrogen Density Calculator, *http://cxc.harvard.edu/toolkit/colden.jsp*), its X-ray flux is $0.67 \times 10^{-12}\,\mathrm{erg\,s^{-1}\,cm^{-2}}$, and the luminosity is $9.78 \times 10^{43}\,\mathrm{erg\,s^{-1}}$ when adopting $H_0 = 50\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ and $q_0 = 0.5$. The X-ray luminosity is typical of Seyfert 1 galaxies. In addition, the source shows on the Digitized Sky Survey (DSS) images two closely separated nuclei, a brighter and bluer one and a fainter and redder one. They are surrounded and connected by some fuzzy structures, implying a merging system. From these results three questions emanate immediately: (1) On which nucleus was the spectrum taken? Although it is likely to be the brighter one, it needs to be confirmed. (2) How can we understand the high X-ray luminosity from this system? It is

* Supported by the National Natural Science Foundation of China.

unlikely that a starburst galaxy is able to emit such a high X-ray luminosity. (3) What is the role of merging in this system? Is it related to the high X-ray luminosity?

In order to answer these questions, we re-observed this source with the 2.6 m telescope at Byurakan Astrophysical Observatory, Byurakan, Armenia. Soon afterwards, we found that the spectrum of the fainter object has also been obtained by the Sloan Digital Sky Survey (SDSS) and has been released on the website. Here we present the results of these new observations on this enigmatic X-ray source.

2 THE IMAGES

2.1 The DSS Images

Figure 1 presents the DSS blue (left) and red (right) images of the system centered on the *ROSAT* X-ray position which is marked by a cross. The system is labelled by a circle on the blue image. There is a bright nucleus (Object A) near the center of circle. A much fainter nucleus (Object B) resides to its close northwest. On the red image, however, they have comparable brightness, implying that Object B is relatively redder than Object A. The separation between the two nuclei is very small, and they are apparently surrounded and connected by some fuzzy structures, suggesting a merging system. The starburst spectrum in He et al. (2001) would have been focused on Object A, and may have included some light from Object B as well. There are two more even fainter objects located to the east and south of Objects A and B on the blue image, but they can hardly be seen on the red image. Obviously they are too faint to be responsible for the high X-ray luminosity.

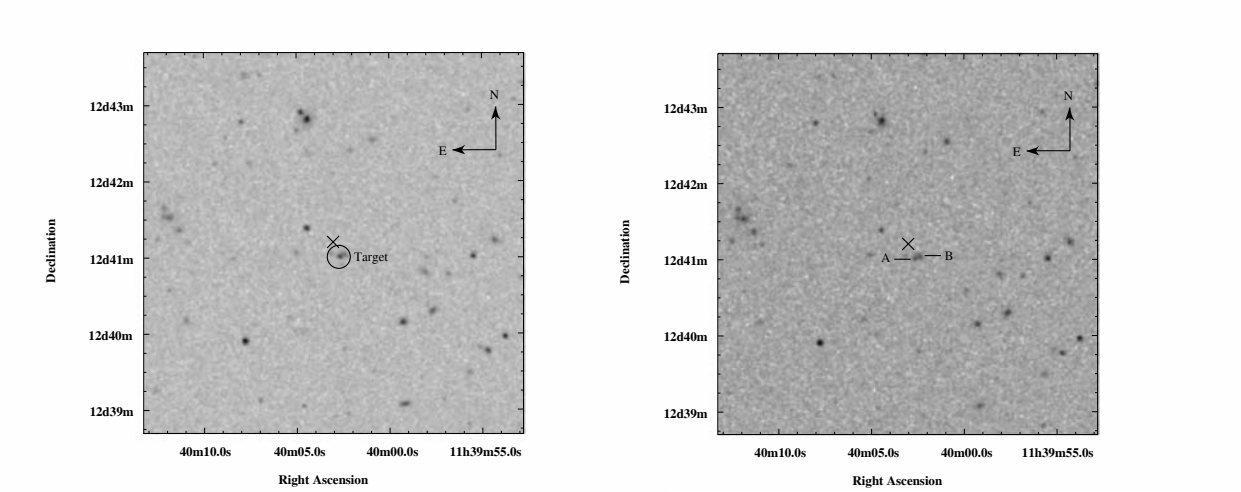

Fig. 1 DSS blue (left) and red (right) images centered on the X-ray position, size $5' \times 5'$. The target is labelled by a circle for the spectroscopic observations, while the X-ray position is labeled by a cross. Two nuclei are connected and surrounded by some fuzzy structures. To the east and south of these are two further fainter objects.

2.2 The SDSS Images

The system is well resolved on the SDSS images. Figure 2 displays the SDSS r' (left) and i' (right) band images (respective image $5' \times 5'$ and $1' \times 1'$). They are both centered on Object A, and a cross marks the X-ray position. No clear physical connections can be seen between Objects A and B. The projected separation between them is $\sim 4\farcs4$, as measured from the SDSS images. Three more and much fainter objects, C, D, and E, are also visible, of these, Objects C and D show up also on the DSS blue image (see Fig. 1, left). Object E is not visible on the DSS images. It is much brighter in the i' and z' bands than in the other three

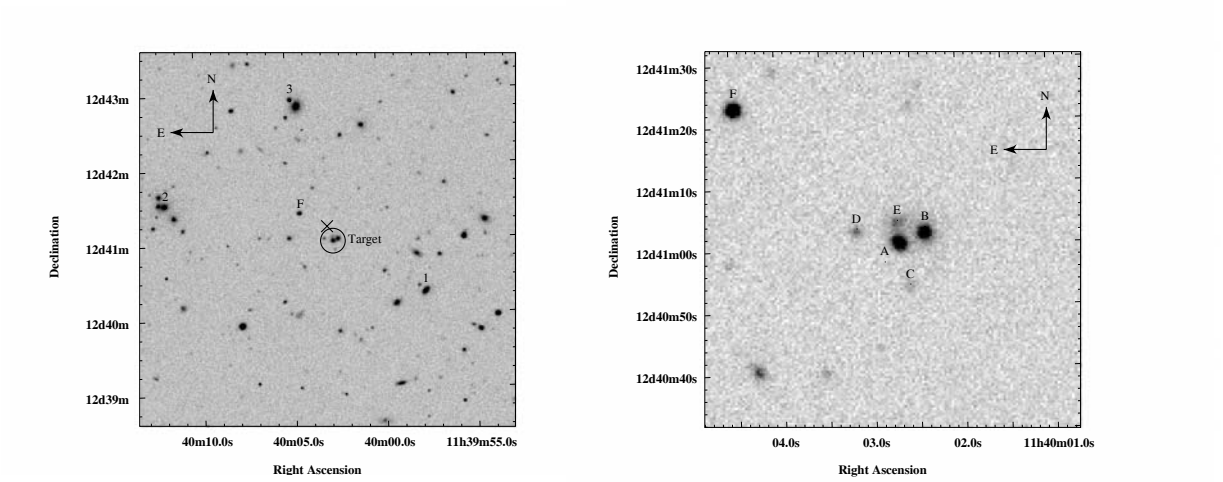

Fig. 2 SDSS images in the r' (left) and i' (right) bands centered on Object A, image size respectively $5' \times 5'$ and $1' \times 1'$. The circle labels the target of the spectroscopic observations, while the cross marks the X-ray position. Objects 1 and 2 are two galaxies both at redshift 0.274, and Object 3 is a quasar at $z = 2.482$, according to their SDSS spectra.

SDSS bands (see Table 1). Like Objects C and D, it is also too faint to be responsible for the high X-ray luminosity.

To the northeast of the X-ray position there is a bright object, Object F. Although it is bright and shows a blue color on the SDSS images, object F is not isolated as an AGN candidate by the target selection algorithm of the SDSS program (Richards et al. 2002). So it is not likely to be an AGN and will not be responsible for the high X-ray luminosity.

Table 1 Properties of All Five Objects

Obj	R.A. (J2000.0)	DEC (J2000.0)	u' (mag)	g' (mag)	r' (mag)	i' (mag)	z' (mag)	z	Type
A	11:40:02.69	12:41:00.67	19.40	19.04	18.66	18.69	18.83	0.177 ± 0.006	SB
B	11:40:02.41	12:41:02.10	19.20	19.27	18.71	18.48	17.85	0.282 ± 0.001	S1
C	11:40:02.58	12:40:53.28	21.82	21.55	21.18	21.12	21.38		
D	11:40:03.15	12:41:02.51	21.52	22.64	21.04	20.63	20.47		
E	11:40:02.70	12:41:03.84	24.89	24.34	24.78	20.45	19.51		

3 THE SPECTROSCOPIC OBSERVATIONS AND DATA REDUCTION

Observations were carried out on 2005 June 12 with the 2.6 m telescope at Byurakan Astrophysical Observatory, using a SCORPIO (Afanasiev & Moiseev 2005) spectral camera attached at the prime focus of the telescope. The multi-mode camera was used in long-slit mode, and during our observations the slit length was $7'$ and width was $2''$. The slit was fixed in the E-W direction and passed the two objects simultaneously. The instrument was equipped with a $600\,\mathrm{g\,mm^{-1}}$ grism, providing spectral range $3900 - 7200$ Å with a 6 Å resolution. A detector Loral 2063×2058 pixel CCD matrix was used, which provides a $14' \times 14'$ field in imagery mode and 3300 Å spectral range in long slit mode.

Data reduction was done by using IRAF with the standard procedures, including bias and flat field corrections, 1-D spectra extraction, and wavelength calibration. The spectra of the two objects are displayed in Figure 3.

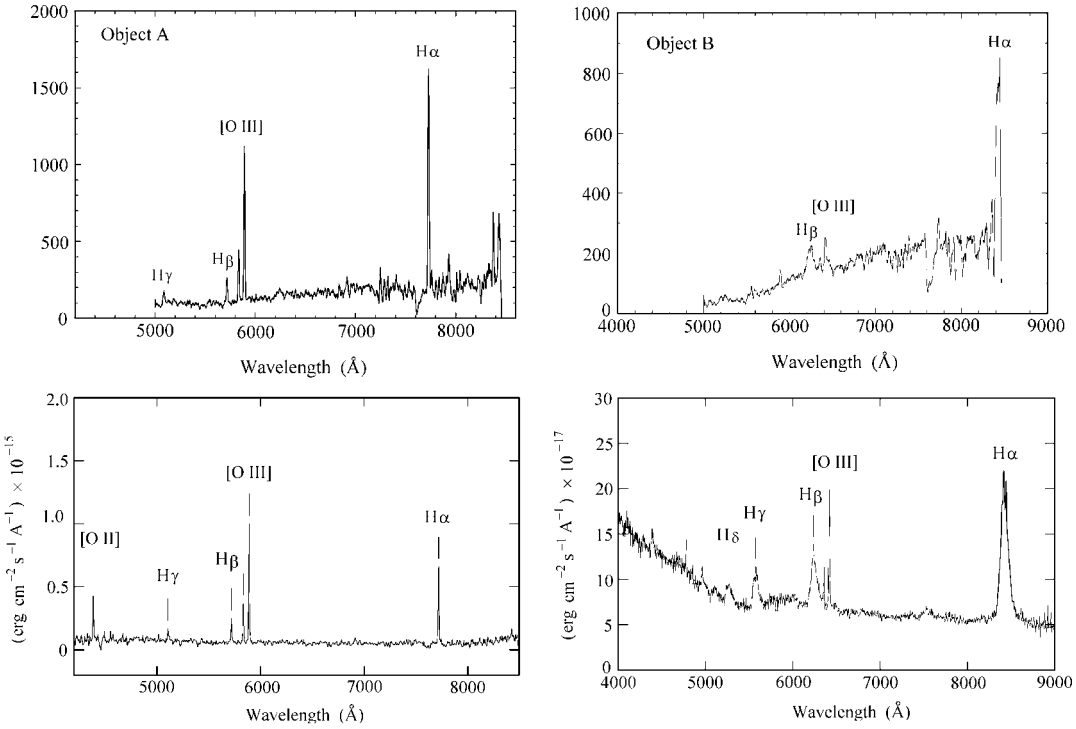

Fig. 3 Spectra of Objects A and B. The upper two spectra are taken on the 2.6 m telescope at Byurakan Astrophysical Observatory (flux in arbitrary scale). The broad trough at 7600 Å is night sky absorption. For comparison, the lower-left and lower-right panels show, respectively, the spectrum of Object A taken with the 2.1 m telescope at KPNO and the SDSS spectrum of Object B. The common emission lines are labelled. Object A has a typical starburst spectrum, while Object B has a typical Type 1 AGN spectrum. Their respective redshifts are 0.177 and 0.282.

4 THE SPECTRA

The spectra taken with the 2.6 m telescope at Byurakan Astrophysical Observatory are shown in Figure 3 (upper panels). The results confirm that Object A is a starburst galaxy at redshift 0.177 ± 0.006. Also presented (lower-left) is the spectrum taken with the 2.1 m telescope at the Kitt Peak National Observatory (KPNO), USA, on 1999 September 25. It shows a perfect power-law continuum and some quite narrow emission lines. Moreover, the spectrum displays some extreme properties for a starburst galaxy: (1) It shows a nearly unreddened Balmer decrement; (2) It has currently undetected [N II] emission, placing it at an extreme position for starburst or H II galaxies in the diagnostic diagrams of Veilleux & Osterbrock (1987). So it might be interesting to make further observations on this starburst galaxy.

Object B is a Seyfert 1 galaxy at redshift 0.282 (from the spectroscopic observation on the 2.6 m telescope, see the upper-right panel of Figure 3). At the same time, it should have been isolated as an AGN candidate for spectroscopic observation by the SDSS target selection algorithm (Richards et al. 2002), so its spectrum was also obtained by SDSS on March 19, 2004. The lower-right panel of Figure 3 displays the SDSS spectrum. The two spectra of Object B show some differences in the continuum: slightly different slopes and the night sky absorption at 7600 Å not being subtracted satisfactorily in the upper one. These should be attributed to the different observing facilities and different data reduction methods. However, emissions in both spectra are at exactly the same wavelengths, and both spectra indicate that Object B is a typical Type 1 AGN, with a blue color, broad and strong permitted emission lines and Fe II lines, and narrow forbidden lines, that give a redshift of 0.282 ± 0.001. Since Object A has a different redshift of 0.177,

the two objects A and B cannot be a merging system. Moreover, the 'enigmatic' high X-ray luminosity is naturally explained, and it should be dominated by the emission from Object B, the Seyfert 1 galaxy, rather than from Object A, the starburst galaxy.

The X-ray luminosity at the new redshift is re-calculated as $2.59 \times 10^{44}\,\mathrm{erg\,s^{-1}}$. The properties of all five objects are summarised in Table 1. In the table the first column is the Object ID, the second and the third columns are the positions of the objects. The following five columns are the magnitudes corresponding to the five SDSS bands. The 9th and 10th columns are the redshift and type of the object (SB for starburst, S1 for Seyfert 1 galaxy), respectively.

5 CONCLUSIONS AND DISCUSSION

The 'enigmatic' X-ray source, 1RXS J114003.0+124112, is re-identified with the observations on the 2.6 m telescope of the Byurakan Astrophysical Observatory, Armenia, and with the SDSS data. The starburst activity is proved to be associated with the brighter object of the system, while the fainter object is identified as a typical Seyfert 1 galaxy at redshift 0.282. Therefore, the two objects do not form a merging system, and the Seyfert 1 galaxy naturally accounts for the high X-ray flux. Three more objects reside in the vicinity, but they are too faint to be responsible for the high X-ray flux.

We once suspected that this source was a so-called starburst/Seyfert composite galaxy, a peculiar subclass of AGNs that was discovered by cross-correlation of the *ROSAT* All-Sky Survey with the *IRAS* Point Source Catalog (Moran et al. 1996). This class of objects shows optical spectral characteristics of starbursts based on the quite narrow emission lines and the diagnostic diagrams (Veilleux & Osterbrock 1987), while their X-ray luminosities are in range of $10^{42} - 10^{43}\,\mathrm{erg\,s^{-1}}$, which is typical of Seyfert galaxies, and is one or two orders of magnitude higher than those of the brightest starburst galaxies (Georgantopoulos 2000; Pappa et al. 2002; Georgantopoulos, Zezas & Ward 2003; Georgantopoulos et al. 2004). The new spectroscopic observations have ruled out this suspicion.

There may be a cluster of galaxies towards the direction of this system. On the SDSS r' band image (Fig. 2, left), there are two galaxies, labelled Objects 1 and 2, both at redshift 0.274 and very close to the redshift of Object B. Object 2 itself may belong to a subgroup of galaxies. Moreover, there is a clear overdensity of extended objects scattered inside and just outside of this image. Most of them have similar colors, implying similar distances. A photometric redshift estimate of these objects may help to confirm the existence of the cluster.

Acknowledgements The authors thank the anonymous referee for insightful comments. The Digitized Sky Surveys were produced at the Space Telescope Science Institute under U.S. Government grant NAG W-2166. Images of these surveys are based on photographic data obtained using the Oschin Schmidt Telescope on Palomar Mountain and the UK Schmidt Telescope. This work has made use of images and spectra from the Sloan Digital Sky Survey (SDSS, *http://www.sdss.org*), and has been supported by the National Natural Science Foundation of China (NSFC) under Nos. 10473012, 10573020 and 10303003.

References

Afanasiev V. L., Moiseev A. V., 2005, Astronomy Letters, 31, 193
Georgantopoulos I., 2000, MNRAS, 315, 77
Georgantopoulos I., Zezas A., Ward M. J., 2003, ApJ, 584, 129
Georgantopoulos I., Papadakis I., Zezas A. et al., 2004, ApJ, 614, 634
He X., Wu J., Yuan Q. et al., 2001, AJ, 121, 1863
Moran E. C., Halpern J. P., Helfand D. J., 1996, ApJS, 106, 341
Pappa A., Georgantopoulos I., Ward M. et al., 2002, MNRAS, 336, 714
Richards G. T., Fan X., Newberg H. J. et al., 2002, AJ, 123, 2945
Veilleux S., Osterbrock D. E., 1987, ApJS, 63, 295