Deep I-band Imaging of $z=5.99$ Quasar

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Abstract. Deep I-band imaging was carried out to search for the optical counterpart of the X-ray jet candidate near SDSS 1306+0356, reported by Schwartz (2022, astro-ph/0202190). The data suggest that the extended X-ray source may be a jet, related to a galaxy rather than to the quasar itself.

Key words. quasars: general – Galaxies: jets – Galaxies: high redshift

1. Introduction

Synchrotron jets are observed in many quasars and nearby radio galaxies. They have been detected in a broad range of wavelengths, from radio to hard X-ray (e.g. Scarpa et al. 1999). The highest redshift quasars are among the earliest objects in the Universe. Any evolution of quasar properties would be the most obvious if they are used as baseline in comparison with the nearby population. The X-ray emission produced close to the central black hole is related intimately to the processes in the central engine and therefore offers the possibility to probe directly the processes occurring in the quasar nuclei.

Recently, Brandt et al. (2002) carried out a Chandra survey of the quasars with highest known redshifts up to date, spanning the range from $z=5.8$ to 6.3. All three objects targeted by this program were detected and in case of SDSS 130608.26+035626.3 (SDSS 1306+0356 hereafter; $z=5.99$, Fan et al. 2001), a serendipitous source was found 23.3 arcsec to the North-East of the quasar (Schwartz 2002). The source was extended over $5 \times 2$ arcsec box, aligned with the quasar. Schwartz suggested that it can be a jet, associated with the quasar.

The goal of this project is to find an optical counterpart of the X-ray source, and to explore its nature.

2. Observations and Data Reduction

Deep Bessel I-band imaging was carried out at the VLT with FORS1. A series of four 787 sec images was obtained on Mar 18, 2002. The standard data reduction was applied, and the four images were combined. The seeing measured on multiple unresolved sources is 0.56 arcsec. The outer parts of the images were affected by reflection from a bright nearby star but the quasar itself was not contaminated. Gray scale reproduction of the final image is shown in Figure 1.

3. Results

Two candidates for an optical counterpart were discovered near the location of the X-ray source. The first one is at...
RA=13:06:09.34 Dec=+03:56:42.1 (J2000), 22.7 arcsec to the North-East from the quasar. It is extended in NW-SE direction (Figure 2). The source spans at least 1.5 arcsec along the major axis, corresponding to a projected diameter of at least 9 kpc at the redshift of the quasar. A flat universe with $H_0 = 65$ km s$^{-1}$ Mpc$^{-1}$ and $\Omega_0 = 0.3$ was assumed, same as in Schwartz (2002). The radial profiles of the quasar and the source are plotted in Figure 3. A bright star is shown for comparison. Clearly, the source is well resolved, while the quasar is not. The total apparent I-band magnitudes of the source is $23.01 \pm 0.11$ mag.

The second candidate is located at RA=13:06:09.19 Dec=+03:56:39.3 (J2000). It is unresolved and has I-band brightness of $24.81 \pm 0.20$ mag. It was discarded from further considerations because its position differs from the location of the X-ray source by more than 4 arcsec, which exceeds the accuracy of our coordinates ($\sim 0.5$ arcsec, as estimated from the quasar coordinates). The apparent I-band magnitudes of the quasar was measured as well: $20.65 \pm 0.05$ mag.

The transverse elongation of the optical source with respect to the elongation of the X-ray source casts a strong doubt on the interpretation offered by Schwartz (2002). The data indicates a foreground galaxy, rather than UV/optical emission from a jet associated with SDSS 1306+0356.

However, Schwartz (2002) demonstrated that the extended X-ray source is statistically significant. It is comprised of 7 counts, which exceeds by far the expected background flux of 0.13 counts. He estimated that the probability of observing 7 photons in a 10 arcsec$^2$ box is $10^{-10}$.

What are the chances of observing a galaxy with the given magnitude in such a close proximity ($\sim 0.6$ arcsec) from the X-ray source? An integration of the I-band number counts provided by Yasuda et al. (2001) suggests that $3.8 \times 10^5$ galaxies brighter that I$\sim 23$ mag can be found per square degree. Therefore, the probability of random coincidence of the X-ray source and a galaxy is $\sim 0.01$.

In the light of the new data, the most likely explanation is that the X-ray source is a jet, associated with the galaxy, rather than the quasar. Multiband observations are needed to determine the redshift of the galaxy and the jet. The bright nearby star (SAO119762, K0, V=8.32 mag) affects the sky background preventing meaningful galaxy number counts in the vicinity of the quasar.

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References