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X-ray emission from the field of the hyperluminous *IRAS* galaxy IRAS F15307+3252

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ABSTRACT

We report on a 20-ks observation of the $z = 0.93$ hyperluminous galaxy IRAS F15307+3252 with the *ROSAT* HRI. No X-ray source is detected at the position of F15307+3252 at an upper limit of $\sim 4 \times 10^{43}$ erg s^{-1}. This is less than 2×10^{-4} of the bolometric luminosity of the object, and indicates either that the nucleus emits an unusually small fraction of its total power in X-rays, or that little of the nuclear X-ray flux is scattered into our line of sight by electrons. The lack of an X-ray detection around F15307+3252 also rules out it being at the centre of a cluster, such as is observed for IRAS P09104+4109. A weak, possibly extended, X-ray source is detected 13 arcsec south of the galaxy, spatially coincident with a clump of faint objects visible in a Keck K_s-band image of the field. This may be the core of a cluster near the line of sight to F15307+3252.

Key words: galaxies: individual: IRAS F15307+3252 – infrared: galaxies – X-rays: galaxies.

1 INTRODUCTION

Several galaxies found from the *IRAS* catalogues are among the most luminous objects in the Universe. They include P09104+4109 (Kleinmann et al. 1988), F10214+4724 (Rowan-Robinson et al. 1991) and F15307+3252 (Cutri et al. 1994). If the emission is isotropic, they all exceed $10^{13} L_\odot$ in bolometric luminosity, most of which is emitted in the mid- to far-infrared. The origin of the high luminosity is unclear, but it is probably due to either a massive burst of star formation or an embedded active nucleus (see e.g. Rowan-Robinson et al. 1993). In the case of F10214+4724 the luminosity appears to be greatly enhanced by gravitational lensing (e.g. Eisenhardt et al. 1996), so it is no longer considered to be such an extreme object, although it still appears to be a type 2 quasar (Goodrich et al. 1996). The situation with F15307+3252 is ambiguous. Liu, Graham & Wright (1996) have recently suggested that it too may be lensed, due to its complex morphology on arcsecond scales, although there is no other clear evidence for this possibility.

The high-ionization optical emission-line spectra and the discovery of a strong polarized component to the optical flux suggest that the hyperluminous galaxies host active nuclei. As is the case for Seyfert 2 galaxies, some of which are similar to hyperluminous *IRAS* galaxies in optical appearance, X-ray observations may be a useful discriminant between starburst and active galaxy, especially if they enable the detection of either an absorbed active nucleus or a scattered component. In the case of F10214+4724, Lawrence et al. (1993) made only a marginal X-ray detection. We have begun a programme to observe other hyperluminous galaxies in X-rays. A source coincident with P09104+4109 was detected with *ASCA* (Fabian et al. 1994) and resolved with the *ROSAT* HRI (Fabian & Crawford 1995). Most of the X-ray emission from that object comes from a surrounding cluster. Here we report on a *ROSAT* HRI observation of F15307+3252.

2 THE *ROSAT* HRI IMAGE OF F15307+3252

IRAS F15307+3252 was observed with the *ROSAT* (Trümper 1983) High Resolution Imager (HRI) (David et al. 1995) for 20 749 s during 1995 February 17–19. No source is detected at the position of F15307+3252 with a 3σ upper limit of 3×10^{-4} count s^{-1}. A weak source at $15^h\,32^m\,44^s$, 32° 42′ 33″, J2000 (with a count rate of 4×10^{-4} count s^{-1} and a probability of $0.0016 = 3.2\sigma$ of being a chance fluctuation in the background), lies about 13 arcsec south of F15307+3252 (Fig. 1). The upper limit at the position of F15307+3252 (determined as 3σ of the background predicted at that position) corresponds to a source flux in the 0.1–2.4 keV band of 8×10^{-15} erg cm^{-2} s^{-1} or a luminosity of 3.5×10^{43} erg s^{-1} at the redshift of 0.93, assuming a power-law continuum with a photon index of 2, the Galactic column density of 2.1×10^{20} cm^{-2}, $H_0 = 50$ km s^{-1} Mpc^{-1} and $q_0 = 0.5$.

A moderately bright source in the field, at $15^h\,31^m\,59\overset{s}{.}2$, +32° 48′ 25″.7 (J2000) with 4×10^{-3} count s^{-1}, falls within 3 arcsec of the centroid of a bright object on the Digitized Sky Survey (Fig. 2). We therefore conclude that the pointing of *ROSAT* was good to that

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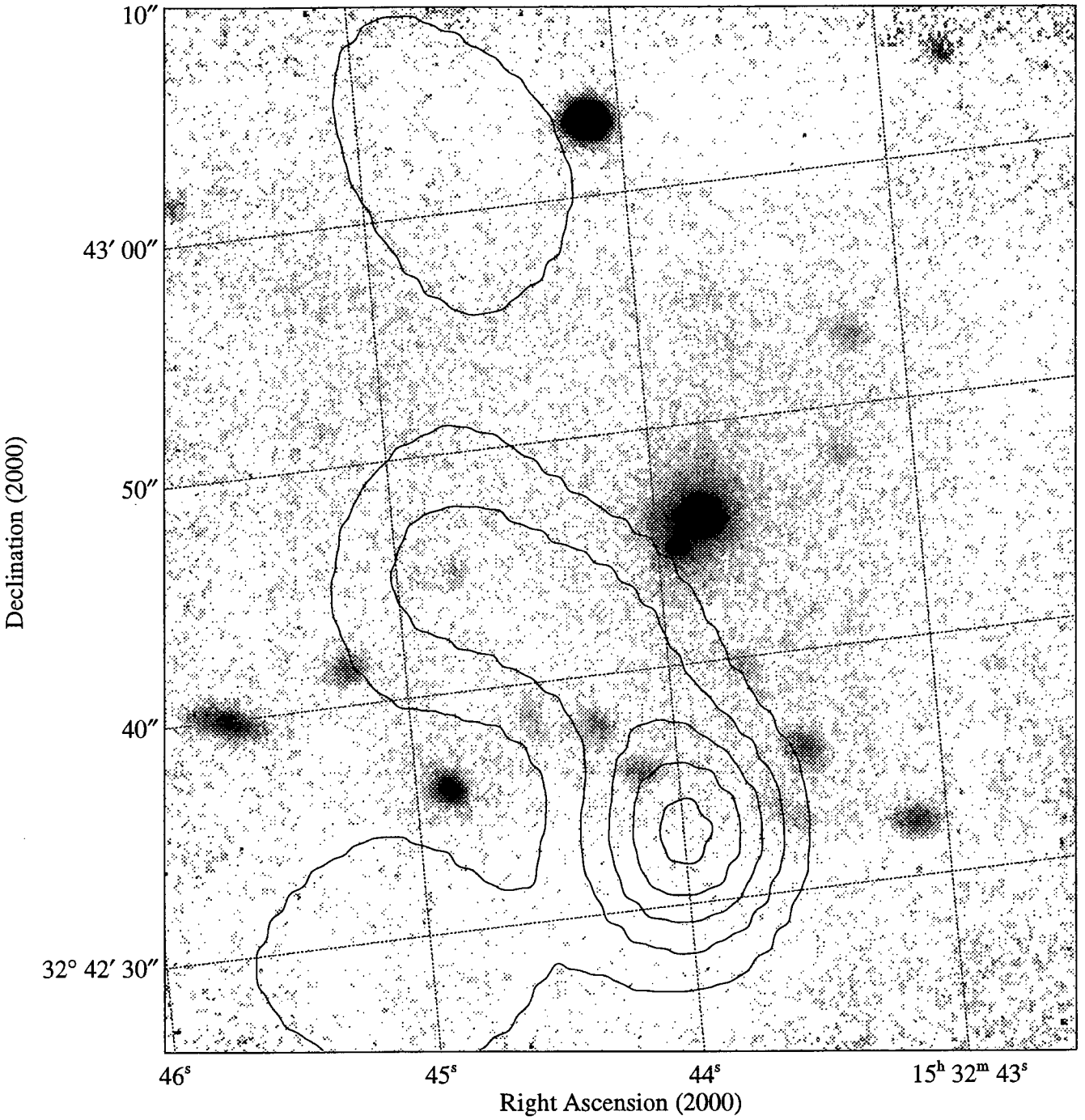

Figure 1. Contours of the adaptively smoothed *ROSAT* HRI image around F15307+3252 (bright object with double structure near the centre) overlaid on a K_s-band image from the Keck Telescope. The contours are linearly spaced from 66 to 100 per cent of the peak flux (see text for normalization).

accuracy. This object does not appear to be catalogued by either NED or SIMBAD.

The weak X-ray source near F15307+3252 lies close to a clump of faint objects seen in a K_s-band mosaic image. This image, which was obtained in moderate seeing (FWHM 1.0 arcsec) with the Near IR Camera at the Keck Telescope on 1995 April 9, is the average of 15 shifted and registered 60-s exposures. Although it is centred slightly south of the near-infrared image presented by Liu et al.. (1996), our image is otherwise consistent with their data. The X-ray image in Fig. 1 was originally binned on a scale of 2 arcsec, then adaptively smoothed for 9 counts per bin using the algorithm of Ebeling, White & Rangarajan (1996). The appearance of the X-ray source suggests that it might be extended, although it is too weak to quantify any extent. Given the proximity of the X-ray source to the faint K_s-band objects, it is plausible that the core of a poor cluster of galaxies lies about 13 arcsec south of F15307+3252. If this is the case then the X-ray luminosity of the cluster is at least 5×10^{43} erg s^{-1} if at the redshift of F15307+3252, and less, of course, at lower redshifts (the upward correction factor if the source is extended is probably 2–3).

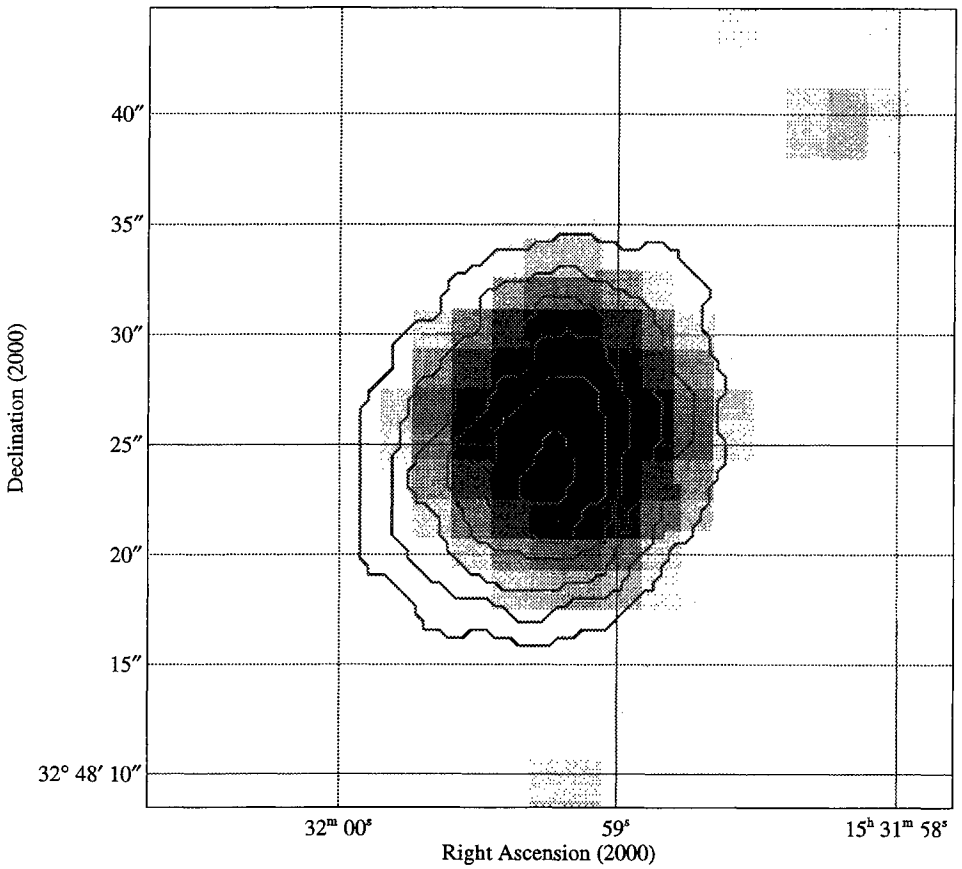

Figure 2. Contours of the brightest source in the *ROSAT* HRI image overlaid on the Digitized Sky Survey (copyright National Geographic Society).

3 DISCUSSION

Our *ROSAT* limit of $\sim 4 \times 10^{43}$ erg s^{-1} to the (0.1–2.0 keV) X-ray luminosity of F15307+3252 is about 4 times lower than the 2–10 keV limit from *ASCA* (Ogasaka et al. 1996). The bolometric luminosity of the object $\sim 1.6 \times 10^{47}$ erg s^{-1}, making it among the most luminous galaxies known (Cutri et al. 1994). The 0.1–2.4 keV luminosity is less than 2×10^{-4} of the bolometric luminosity. Superficially this is as expected if the object is a Type II quasar (i.e. a direct line of sight to the nucleus is blocked for us by a high, X-ray absorbing, column density of matter which is Thomson thick, $N_H > 10^{24}$ cm^{-2}).

F15307+3252 is polarized in the (observed) optical band at the level of 16 per cent and shows broad Mg II in the polarized continuum, indicating the presence of an active nucleus (Hines et al. 1995). The polarized component is accounted for by scattering. If the scattering medium consists of free electrons then we expect a significant scattered X-ray flux. Using the quasars common to the bolometric luminosity L_{Bol} list of Padovani & Rafenelli (1988) and the 0.3–3.5 keV X-ray luminosity L_X list of Wilkes & Elvis (1987), we find a mean ratio for L_X/L_{Bol} of 4.8 per cent, with a range from 2.4 to 7.3 per cent (3C 273 is close to the mean at 4.9 per cent). Adopting 5 per cent, our *ROSAT* limit implies that less than 0.4 per cent of the X-ray luminosity of the nucleus is scattered into our line of sight. This is considerably below the 10 per cent scattering fraction in the optical band inferred by Hines et al. (1995) from considerations of the equivalent widths of the narrow emission lines seen in F15307+3252 and the strength of the scattered nuclear continuum.

This mismatch leads us to conclude that either the nucleus emits less than about 0.2 per cent of its power in X-rays or the scattering mirror is composed of dust (which does not scatter X-rays through large angles), not electrons. We note that there must then be little ionized gas capable of scattering X-rays into our line of sight, which is surprising for such a powerful object. If the result is general, then it may be difficult to detect any Thomson-thick Type II quasars in the X-ray band.

Alternatively, the unusually weak X-ray flux can be explained if the active nucleus accounts for only about 5 per cent of the bolometric flux. This is doubtful, given the optical magnitude and polarized fraction of F15307+3252, and the scaling of the polarized optical spectrum carried out by Hines et al. (1995).

From deep counts of sources in high Galactic latitude fields (e.g. Barcons et al. 1995), we estimate that there are about 100 sources deg^{-2} at the level of the weak X-ray source to the south of F15307+3252. The probability that it lies by chance within 13 arcsec of F15307+3252 is then about 0.4 per cent, and even less that it lies so close to the cluster. It is therefore likely that the X-ray source is in some way related to both: perhaps it is the core of a cluster, of which F15307+3252 is a member, or it is a foreground cluster which has some gravitational lensing effect on F15307+3252. It is most unlikely from the richness inferred from its X-ray luminosity that the cluster potential is the sole lensing object; the morphology of F15307+3252 is not obviously similar to that of an object lensed by a cluster core (Liu et al. 1996).

We note that our strong limit on X-rays from immediately around F15307+3252 rules out it being at the *centre* of a cluster, as is the

case for P09104+4109. Also it argues against the host object being a cD galaxy – at the present epoch these are generally found in cluster cores. Where they occur in poor clusters there is still a moderate cluster X-ray luminosity (e.g. MKW3s).

4 CONCLUSIONS

Along our line of sight, the quasar nucleus of F15307+3252 emits in X-rays less than 0.02 per cent of the bolometric luminosity of F15307+3252 and, through scattering, about 10 per cent of its optical luminosity. This indicates that either the scattering medium is dust, not electrons, or the quasar is anomalously weak in X-rays.

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