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ASTRONOMY AND ASTROPHYSICS

ROSAT **HRI discovery of luminous extended X-ray emission in NGC 6240**

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Abstract. We report the detection of luminous extended X-ray emission in NGC 6240 on the basis of ROSAT HRI observations of this ultraluminous IR galaxy. The spatial structure and temporal behavior of the X-ray source were analyzed. We find that $\gtrsim 70\%$ of the soft X-ray emission is extended beyond a radius of $5''$. Strong emission can be traced out to a radius of $20''$ and weaker emission extends out to $\sim 50''$. With a luminosity of at least $L_{\rm x} \simeq 10^{42}$ erg/s this makes NGC 6240 one of the most luminous X-ray emitters in *extended* emission known. Evidence for a nuclear compact variable component is indicated by a drop of 32% in the HRI count rate as compared to the PSPC data taken one year earlier. No short-timescale variability is detected. The HRI data, which represent the first high-resolution study of the X-ray emission from NGC 6240, complement previous spectral fits to ROSAT PSPC data that suggested a two-component model consisting of thermal emission from shocked gas immersed in a starburst wind plus a powerlaw source attributed to scattered light from an obscured AGN.

We discuss several models to account for the extended and compact emission. Although pushed to its limits the starburst outflow model is tenable for the essential part of the *extended* emission. For the AGN-type component we propose a model consisting of a near-nuclear 'warm scatterer' that explains the apparent fading of the X-ray flux within a year as well as the strong FeKα complex seen in an ASCA spectrum.

Key words: galaxies: active – galaxies: interactions – galaxies: starburst – galaxies: individual: NGC 6240 – X-rays: galaxies

1. Introduction

With a far-infrared luminosity of $\sim 10^{12} L_{\odot}$ (Wright et al. 1984) and a redshift of $z = 0.024$, NGC 6240 is one of the nearest members of the class of ultraluminous infrared galaxies (hereafter ULIRG). The basic, as yet unsolved, enigma of these objects is the nature of the primary power source that has to be situated inside the central few arcseconds (Wynn-Williams & Becklin 1993). An amount of $\sim 10^{10} M_{\odot}$ of cold molecular gas (e.g. Solomon et al. 1997), a record 2.121μm-line luminosity from shocked 'warm' H_2 (e.g. van der Werf et al. 1993), earthbound IR spectra (e.g. Joseph & Wright 1985, Rieke et al. 1985, Schmitt et al. 1996), MAMA (Smith et al. 1992) and HST (Barbieri et al. 1993) observations, and recent ISO-SWS spectra (Lutz et al. 1996) all point towards the presence of hidden prodigious star formation after onset of a galactic collision, which could be responsible for the FIR power. Heckman et al. (1987, 1990) found indications for superwind and supershell activity, a well-known result of strong starbursts.

However, the smallness of the recombination line flux (de Poy et al. 1986), the detection of a high-excitation component in HST images (Barbieri et al. 1995, Rafanelli et al. 1997) and general arguments valid for ULIRGs as a class (e.g. Sanders et al. 1988) suggest that a dust-shrouded AGN contributes significantly to the heating of the dust that emits the FIR radiation.

The unambiguous detection and investigation of an AGN in NGC 6240 and other interacting ULIRGs would be of prime importance for our understanding of the formation and evolution of AGN in general. It has been proposed that starbursts are the germ cell for the formation of AGN (Weedman 1983, Barnes & Hernquist 1991, Mihos & Hernquist 1996) and interaction may provide the triggers and fuel for both kinds of activity (see Sanders & Mirabel 1996 for a recent review). A large fraction of ULIRGs indeed turned out to be interacting systems (e.g. Andreasian & Alloin 1994, Clements et al. 1996).

As outlined above, there are indications for a starburst in NGC 6240, but what would be the best evidence for a hidden AGN? The far-infrared emission is reprocessed black-body like radiation containing no direct clue on the nature of the primary source. Near-IR and mid-IR line spectra provided signatures for a red giant population and a younger burst. A few high-excitation features in IR spectra and in optical HST narrow-band images could be due to an AGN but not necessarily. The optical emission-line spectrum (Fosbury & Wall 1979, Zasov & Karachentsev 1979, Fried & Schulz 1983, Morris & Ward 1988, Keel 1990, Heckman et al. 1987, Veilleux et al. 1995, Schmitt et al. 1996) is dominated by LINER-like line ratios over the central ~ 10 kpc. Its large extent and little variation in excitation tracers

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is more easily attributed to shock-heating rather than to a central photoionizing AGN continuum.

X-rays are an important tool for studying both, an AGN as well as starburst components. In the ROSAT band, AGN tend to be dominated by strong powerlaw (hereafter PL) emission while starbursts can usually be represented by thermal spectra. In a recent analysis of ROSAT PSPC spectra from NGC 6240, Schulz et al. (1998; hereafter paper I) found good fits by either a single thermal Raymond-Smith (hereafter RS) spectrum with $L_{0.1-2.4\mathrm{keV}} = 3.8\,10^{43}$ erg/s (for a distance of 144 Mpc) or a hybrid model consisting of 80% PL plus 20% thermal RS (dubbed 0.8PL+0.2RS below) contributions and a total luminosity of $5.2\,10^{42}$ erg/s. Since the spectral shape with PSPC resolution is not sufficiently distinctive the luminosity information was taken as an additional constraint. Due to the unprecedented high luminosity of the single RS model and additional severe difficulties to explain it in terms of scalable superbubble models, the hybrid model was favored. This is also supported by the ASCA detection of a strong FeKα line in the X-ray spectrum of NGC 6240 (Mitsuda 1995; the same data indicate further emission lines around 1–2 keV). The powerlaw was attributed to the electron scattered X-ray flux from a hidden AGN so that an AGN-plus-starburst scenario was proposed for the ultimate power source of NGC 6240 (paper I).

The deep HRI observations which are discussed below represent the first high spatial resolution study of the X-ray emission from NGC 6240. They allow to trace the emission from a thermal starburst source that is expected to be appreciably spatially extended while an AGN-induced powerlaw source should be much more compact unless there is extensive large-scale scattering. Further, they provide information on the long- and short-term X-ray variability of the source.

Luminosities given below are calculated assuming a distance $d = 144$ Mpc of NGC 6240. This yields a scale perpendicular to the line of sight in which $1''$ corresponds to 700 pc in the galaxy.

2. Observations and data reduction

The data analyzed here were taken with the HRI (Pfeffermann et al. 1987, Zombeck et al. 1990) on board of the X-ray satellite ROSAT (Trümper 1983, Trümper et al. 1991) and were retrieved from the archive. The HRI detector obtains images in the soft X-ray band (0.1–2.4 keV) at a spatial resolution of about $5''$.

Deep HRI X-ray images of NGC 6240 were taken on Feb. 24 - March 4, 1994, Aug. 23 - Sept. 15, 1994 and Aug. 23 - 25, 1995 with effective exposure times of 5.7, 28.3, and 15.7 ksec, respectively.

A source-detection procedure was carried out with the EXSAS X-ray analysis software package (Zimmermann et al. 1994). In total, 10 X-ray sources ($> 3\sigma$) were detected in the field of view. The background was determined in a source-free ring around the target source. The source photons were selected from a circular region large enough to ensure that all source photons were included, given the extent of the source (see Sect. 4). NGC 6240 is the brightest source in all pointings and we find a background-subtracted mean HRI count rate of 0.0177 cts/s.

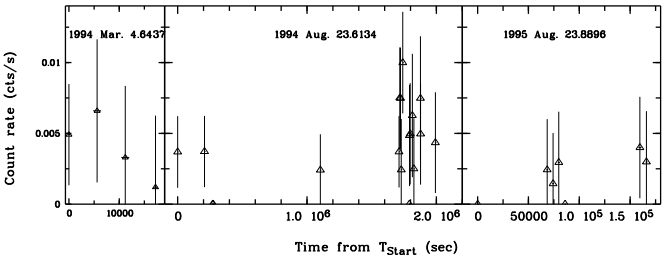

Fig. 1. HRI X-ray lightcurve for the central $5''$ of NGC 6240. The time is measured in seconds from the start (given in the top of each panel) of the individual observations. The binsize in time was chosen as $\geq$ 400s.

3. Temporal analysis

At first, we have checked for variability in the source flux on longer terms, i.e. between the individual HRI pointings and the earlier PSPC observations. For the individual HRI observations, we find mean source count rates of 0.0175 ± 0.0018, 0.0179 ± 0.0008 and 0.0174 ± 0.0010 cts/s, which is consistent with constant source flux between the respective epochs.

During the ROSAT all-sky survey in 1990, NGC 6240 was detected with a PSPC count rate of 0.086 ± 0.016 cts/s (Voges et al. 1996). Converting the count rate from the pointed PSPC observations of 0.064 ± 0.005 cts/s (see paper I; the PSPC observations were performed in Sept. 1992 and Feb. 1993) into an HRI count rate[1] (under the assumption of constant spectral shape between the observations) yields a value of $CR = 0.025 \pm 0.002$ cts/s, higher than in the HRI data. This indicates a fading by 32% within one year from the pointed PSPC to the HRI observation. We checked the sensitivity of the counts conversion to the spectral shape by comparing it for several different models that provided an acceptable PSPC spectral fit (like a weakly absorbed black body or a strongly absorbed single powerlaw to test extremes) and found no significant effect. Then, the conversion of the counts was performed for the favored 0.8PL+0.2RS hybrid model from paper I and, afterwards, this procedure was repeated after having halved the PL contribution which led to a $\sim$30% reduction of the converted counts closely mimicking the observed drop in count rate.

Consequently, a fading of the PL component by nearly a factor of two is consistent with the smaller HRI count rates measured one year after the last PSPC data had been taken.

Secondly, we have searched for short time-scale variability within each HRI observation. The X-ray lightcurve, binned to time intervals of 400 s or more, is shown in Fig. 1. Within the errors, the lightcurve is consistent with constant source emission.

[1] the PSPC–HRI count rate conversion was performed within EXSAS by folding the model spectrum with the detector response matrix and taking into account the effective area, as well as using the conversion program PIMMS; both yield the same results.

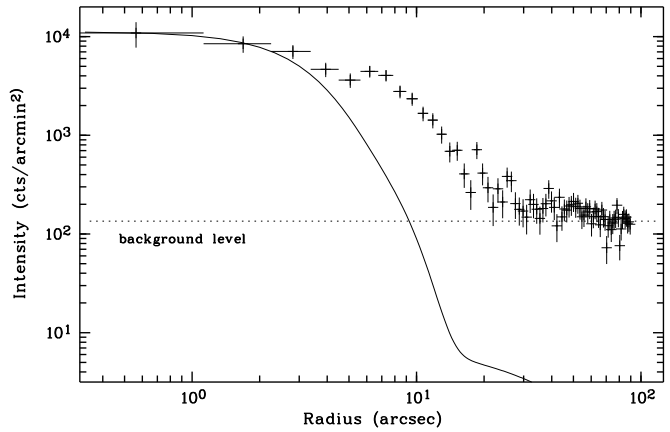

Fig. 2. Radial profile of the source emission (crosses) as compared to the theoretical PSF for an on-axis point source (solid line). Note the logarithmic scale. Extended emission is clearly detected.

4. Spatial analysis

The X-ray emission from NGC 6240 is found to be significantly extended in all three pointed HRI observations. For a more detailed analysis of the spatial structure we have used the HRI image with the longest exposure time of 28 ksec. Numbers given below refer to this observation if not stated otherwise. The apparent source extent (not corrected for the point spread function) is of the order of at least 25″ with evidence for weak emission extending outwards to ≈ 50″. Given residual errors in the aspect solution that occasionally produce an apparent source extent in HRI-observed sources (David et al. 1992, Briel et al. 1994) which was found to be of the order 1″ in FWHM (Morse 1994), we note that NGC 6240 extends well beyond 6″ and is the only source in the image for which we find significantly extended emission. The other (weaker) sources are consistent with a PSF-widened point source. E.g., we find a likelihood for source extent (for its definition see Zimmermann et al. 1994) of l_e = 362 for the on-axis target source whereas this value is l_e = 0 for the second-brightest source in the field and l_e = 2.1 for the source with the second-highest l_e. Finally, we also note that indications for source extent already showed up in the PSPC observation (paper I, Schulz & Komossa 1997). No point sources embedded in the extended emission were found.

The radial profile of the X-ray emission from NGC 6240 is shown in Fig. 2 together with the instrumental PSF. Only 31% of the source photons are found inside a radius of 5″(i.e. are unresolved by the HRI) whereas 90% would be expected for a point source. This provides an upper limit on the contribution to the X-ray emission from a central point source.

To further analyze the structure of the X-ray image we have performed a maximum likelihood (ML; Cruddace et al. 1988) analysis (Greiner et al. 1991). In this approach, a smoothed background image is first produced. Then, the point spread function of a source with a width appropriate for the corresponding off-axis angle is fitted to the background-subtracted source photons using a spatial grid of spacing 2.″5. The likelihood for the existence of a source is calculated for each grid point. The advantage of this method is the strong suppression of features which are smaller than the PSF while structures wider than the PSF are contrast enhanced (due to the steep likelihood variation as a function of counts) as compared to a simple count rate image.

The ML image is shown in Fig. 3. The X-ray contours for this ML image are superimposed on an optical image of NGC 6240 in Fig. 4. Due to the boresight error of the X-ray telescope there is a systematic uncertainty in source position of order 10″ (Briel et al. 1994). This causes a displacement of the X-ray emission maximum relative to the optical maximum. Within this 10″ error, the X-ray positions are consistent with the position of the optical maximum. The shift was corrected for in Fig. 4.

5. Discussion

5.1. Time variability

The search for variability in the data sets is of particular importance, since its detection would either imply a direct view of an active source or scattering on a small spatial scale. Constant source flux would be consistent with the superwind interpretation or a 'hidden' AGN the radiation of which is scattered on a more extended scale.

We do not find significant variability on short timescales but, as outlined in Sect. 3, there are indications for a 30% variation between the PSPC observations finished in Feb. 1993 and the HRI observations commencing in Feb. 1994. In any simple model, this limits the size of an appreciable part of the source plus possible scattering mirror to less than one light year. In paper I, in which no variability among the PSPC observations was found, we estimated the effect of scatterers of sizes ranging from about 600 to 30 000 lys. If the variation is real such large-scale scatterers cannot play the dominant role. Therefore, below (Sect. 5.4) we investigate in more detail the alternative possibility of a compact scatterer.

5.2. Source extent and structure

The exciting new discovery of the HRI observations is that the soft X-ray source in NGC 6240 is appreciably extended. For a point source, 90% of the photons are expected within the central radius of 5″ (the resolution limit), whereas we find only 30%. At face value, this limits the contribution of a central core source to 33%.

This percentage estimate only applies to the count rate, though, not to the flux contribution of a compact component. For instance, in our finally discussed hybrid model of paper I the (presumably compact) powerlaw component contributes 80% of the total *flux*, but only 60% in *count rate*. Major reasons for the lower percentage in count rates are the different spectral shapes and the relatively stronger effect of the absorption by cold gas on the powerlaw than on the thermal Raymond-Smith spectrum. When attributing the above discussed drop of the total count rate by 32% to the powerlaw component the flux had to decrease to 41% which would lead to a 34% contribution of the HRI counts inside 5″. Since 30% are observed the 0.8PL+0.2RS

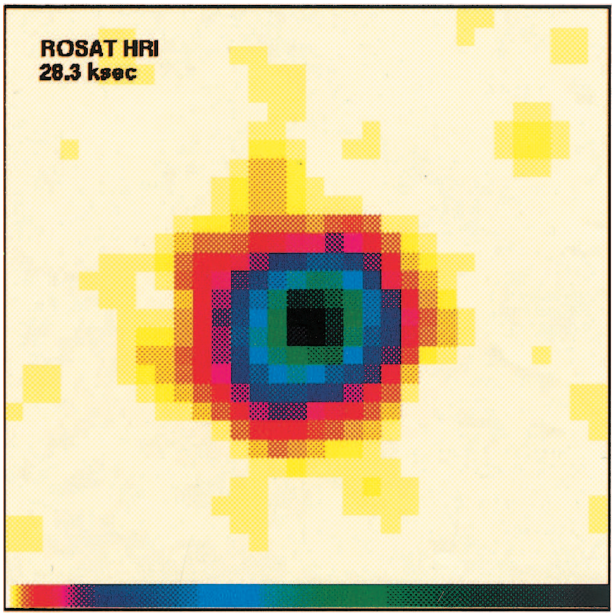

Fig. 3. Maximum likelihood image of the X-ray emission of NGC 6240 produced as described in the text. 1 pixel corresponds to a scale of 2.″5.

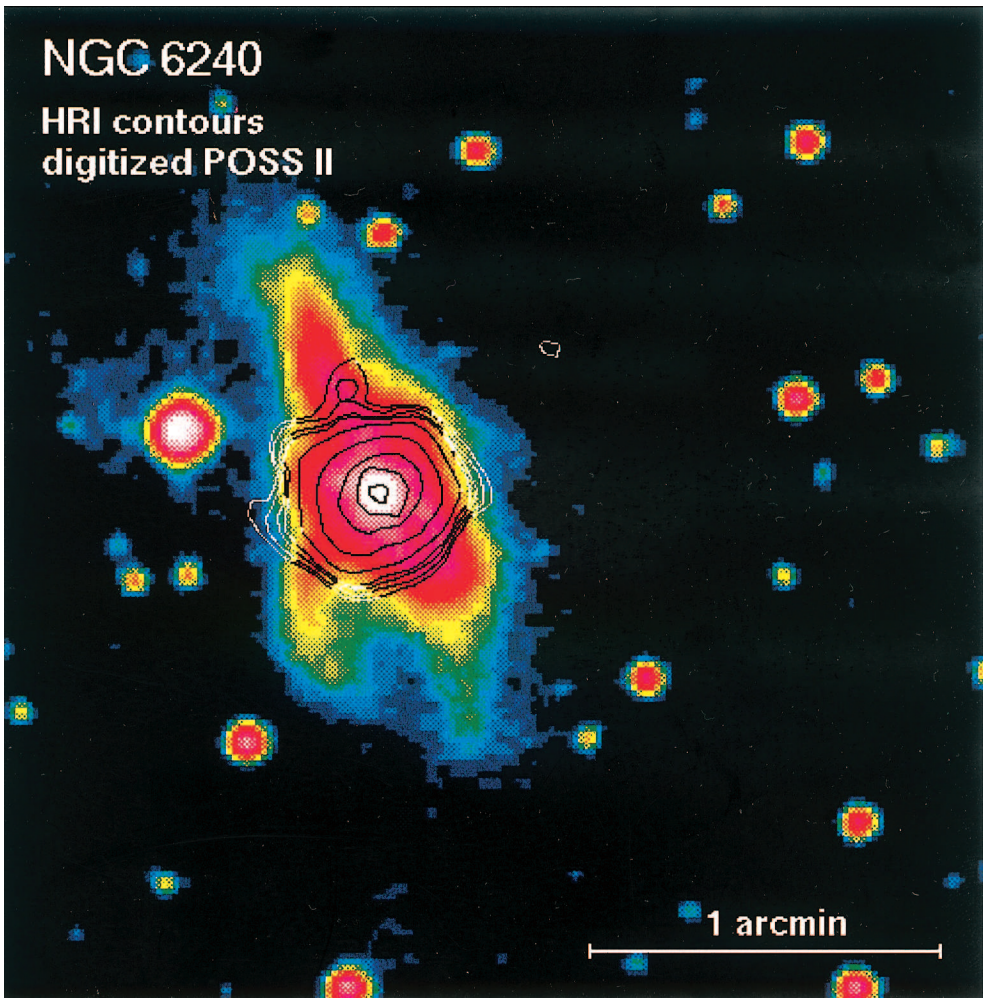

Fig. 4. Overlay of the ML-deconvolved X-ray contours on the optical image of NGC 6240 from the digitized Palomar sky survey (POSS) II. The contours are shown for likelihood values of l = 5.8, 8.0 (3σ), 12.5, 16.6, 33.2, 83, 207, 348, and 498.

model fitted to the earlier-epoch PSPC data is consistent within the errors with the new HRI data.

The X-ray emission can be traced out to a distance of at least 20″. Scenarios for the origin of this emission are discussed in

the next section. On a weak emission level, several 'fingers' are apparent that extend outwards and could be related to the tidal interaction.

5.3. Interpretation of the extended structure

The basic challenge for any model of the extended component is the huge luminosity required, at least 10^{42} erg/s in the soft X-ray band. This limit derives from PSPC spectral fits performed in paper I. None gave $L_{\rm x}$ below $2\,10^{42}$ erg/s. In order to determine the minimal luminosity consistent with the data we carried out further spectral fits. E.g., we fixed the cold column to the Galactic value and ran a two-component RS fit leading to a total luminosity of $3\,10^{42}$ erg/s. Even when taking into account the 32% lower count rate in the HRI observation, we consider $1\,10^{42}$ erg/s as a well established lower limit of the luminosity.

Since NGC 6240 is a merger, presumably the intermediate product of the collision of two gas rich disk galaxies, one might ask whether the shock converted kinetic energy of the interstellar media of both galaxies could have heated the X-ray nebula. Converting $Mv^2/2 = 10^{58}$ erg (with $M = 10^{10} M_\odot$ and $v = 300$ km/s) completely into the X-ray luminosity would suffice for 10^{7-8} years. This number fits because it is about the dynamical time scale of the collision. However, this energy could not sustain the total luminosity of the galaxy of $10^{12} L_\odot$ within the time it is generated (only for 10^5 years). Hence, the power source cannot be drawn from the collision.

In paper I we already noted that electron scattering of a nuclear component, e.g. from an obscured AGN, did not appear feasible on a 10 kpc scale. Scattering on small scales will be discussed in the next section. With large-scale inverse Compton scattering an extended PL component could be produced in principle but the relevant parameters (magnetic fields and diffusion lengths) estimated from the measured radio sources did not provide positive support for such a scenario (Colbert et al. 1994).

When relating the X-ray nebula to the nuclear energy source the most obvious candidate is the hidden starburst discussed in the introduction. A starburst evolves by first forming a cavity in the ISM of the host galaxy created by the accumulating winds of the early-type stars. Subsequently the hot gas develops a kpc-sized expanding superbubble that is fed by supernova explosions generated after the first few million years. The bubble is filled with shock-heated thin gas surrounded by a cold shock-compressed 'supershell' formed from swept-up ISM. The shell will be stable as long as the bubble expands decelerating. Evaporation will take place at the interface of the cold shell and hot cavity leading to a radial temperature and density distribution described analytically by Mac Low & McCray (1988; for numerical hydrodynamical simulations with specific initial conditions see e.g. Tomisaka & Bregman 1993, Suchkov et al. 1994). The theory is parameterized by the mechanical input power (given by the supernova rate), the initial ISM density and the expansion time. The corresponding equations given in paper I showed that from a minimum of shocked Hα emission or from the derived supernova rate one obtains a mechanical input power of $L_{\rm mech} = 3\,10^{43}$ erg/s which, within $3\,10^7$ yrs, can drive a single shell to an extent $R \sim 10$ kpc within a medium of 0.1 cm^{-3} particle density.

While the bubble size was guessed from uncertain Hα imaging in paper I it is now possible to derive the X-ray size from the HRI data. Figs. 2,4 show that $R = 20''$ corresponding to 14 kpc encloses the X-ray emission on the 3σ level. It is easy to increase the originally assumed 10 kpc - extent by 25% via increasing $L_{\rm mech}$ by a factor of 3 (still compatible with NGC 6240) or by 50% via doubling the time scale without getting into conflict with other observed parameters.

There is still some faint emission beyond 14 kpc below the 3σ-level. Only speculations about its origin are possible with present data. In vein of the supershell scenario, it could be old halo emission from previous bursts.

With a soft X-ray luminosity of at least $L_{\rm x} \simeq 10^{42}$ erg/s the *extended* emission in NGC 6240 is one of the most luminous extended X-ray emitters known. For comparison, starburst galaxies typically show $L_{\rm x} \simeq 10^{39}$ erg/s with a range between 10^{38} - 10^{41} erg/s (e.g. Fabbiano 1989, Vogler 1997); the total soft X-ray emission of the ultraluminous IR galaxy Arp 220 is of order $4\,10^{40}$ to $2\,10^{41}$ erg/s (depending on the value of cold absorption; Heckman et al. 1996) and the extended emission in the Seyfert 2 galaxy NGC 4388 is about $3\,10^{40}$ erg/s (Matt et al. 1994). It is interesting to note that despite early reports for a class of very X-ray luminous, but apparently inactive, galaxies, optical follow-up observations revealed AGN tracers in all objects examined (Moran et al. 1994, 1996, Wisotzki & Bade 1997) which led to the suggestion that X-ray emission above 10^{42} erg/s should always be attributed to an AGN. The extended emission in NGC 6240 slightly exceeds this limit.

Could the *whole* X-ray emission of NGC 6240 be due to shocked supershells? We already noted in paper I that lowering the PL contribution too much tends to strongly increase the luminosity demand for the extended component. For instance, a pure Raymond-Smith fit was considered improbable because in this case the thermal X-ray nebula would have to emit outstandingly powerful $10^{10} L_\odot$ in the ROSAT band which cannot be accommodated with any scalable superbubble model.

5.4. Contribution from a very compact component: AGN reflection mirror

Referring to the ROSAT PSPC and ASCA evidence for the contribution of a powerlaw component to the X-ray spectrum that represents scattered light from a 'hidden' AGN, some estimates for scattering in the ambient ionized gas on scales larger than a few hundred lyrs were presented in paper I. Such extended scatterers would, however, be unable to allow for a notable flux variation within such a short timescale like a year. This could only be achieved by a directly seen AGN or a sufficiently small scatterer very close to the continuum source to ensure a high covering factor or a collection of scatterers at larger distances from the continuum source but arranged in a way that light travel times to the observer are in close agreement. The last solution appears contrived.

Lacking any straightforward evidence for a significant optical nonstellar continuum an unextinguished direct view of the nonthermal continuum source appears precluded. An ASCA spectrum reveals an FeKα line complex with an equivalent width of $\sim$ 2 keV which indicates the presence of an AGN (Mitsuda 1995). Such a line is not generally observed in starbursters (e.g. Ptak et al. 1997). However, in Seyfert 1 galaxies FeKα is usually believed to arise via Compton reflection from an accretion disk yielding an equivalent width of only a few hundred eV with respect to the original continuum and could only reach a few keV with respect to the reflected continuum. If one looks face-on towards the accretion disk the original nonthermal continuum should be visible as well. Consequently, we have to locate the scatterer elsewhere.

The requirements for a compact scatterer are a size $R \lesssim$ 1 ly (from the temporal variability) and that for an efficient effect (to lower geometrical demands) the electron scattering optical depth $Rn_e\sigma_e$ ($\sigma_e = 6.65\,10^{-25}$ cm^2) should not be too much below unity. These conditions lead to $n_e \gtrsim 1.5\,10^6$ cm^{-3}. This component may be identified with a molecular torus and/or warm gas in the vicinity of the nucleus (so-called 'warm absorber'; e.g. Pan et al. 1990, Otani et al. 1996, Komossa & Fink 1997). This material will appear as a 'warm scatterer' under appropriate geometrical conditions.

We have tested this possibility by computing a simple model for such a highly ionized scatterer and emitter using the photoionization code *Cloudy* (Ferland 1993). The input continuum is our standard AGN continuum (e.g. Komossa & Schulz 1997) with an X-ray powerlaw of photon index $\Gamma = -1.9$ (defined as in $\Phi_{\rm photon} \propto E^{\Gamma}$). Solar abundances (Grevesse & Anders 1989) were assumed. With a column density of the reflector of $N_{\rm w} \simeq 23.0$ and an ionization parameter of $\log U \simeq 1.0$[2] we find strong intrinsic emission in FeKα due to recombination processes with a contribution from several ionization stages. We predict an equivalent width of $\sim$6 keV relative to the reflected continuum. The diffuse continuum at these photon energies from the warm gas is negligible compared to the reflected continuum. Hence, it is possible to fit the ROSAT spectrum with such a warm reflector and produce FeKα with an equivalent width of several keV. We also predict the presence of a (weak) Fe edge in the reflected spectrum and further line emission around 1–2 keV. For a more detailed study, in which also the abundance of the material could be varied, high spectral resolution X-ray observations (e.g. with AXAF) are needed.

[2] these values were found for an explicit single-component fit of the model of a 'warm reflector' to the ROSAT PSPC spectrum (Komossa 1997) neglecting the contribution of the extended component; we only intend to show trends here

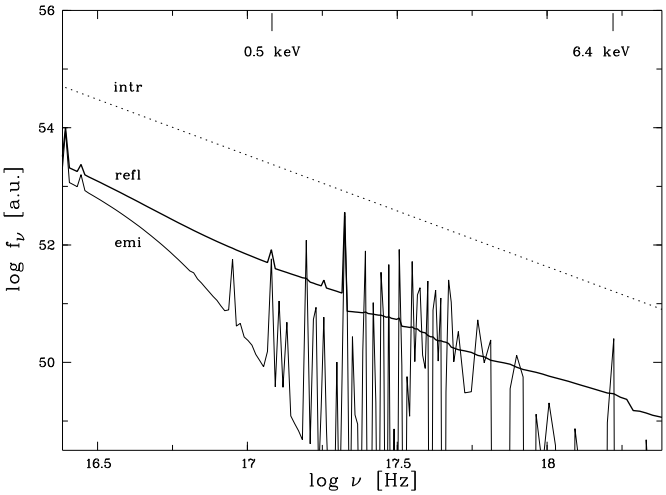

Fig. 5. Spectral components of the warm reflector. The incident continuum is shown as dotted line. The thin solid line corresponds to the emitted spectrum and the thick solid line to the reflected spectrum. The abscissa brackets the energy range 0.1 – 10 keV.

5.5. What powers the FIR emission of NGC 6240 ?

Given the strong evidence for both, a super-starburst as well as an AGN in NGC 6240, we may ask which component provides the ultimate power source for the FIR emission of this ULIRG[3].

From the mechanical power used above, models given in Leitherer & Heckman (1995) predict $L_{\rm bol}$(Starburst) to be all or a major fraction of the $10^{12}L_\odot$ which NGC 6240 emits. Several $10^{10}M_\odot$ of dense molecular gas are available in the central kpc of NGC 6240 to fuel the super-starburst. However, although the consistency is gratifying the theory applied is much too idealized and too boldly upscaled to be watertight.

In fact, the AGN component may provide enough power as well: Given an X-ray luminosity in scattered emission of a few 10^{42} erg/s one obtains an *intrinsic* luminosity of order 10^{44-45} erg/s, depending on the covering factor of the scattering material. This is, again, an appreciable fraction of the FIR luminosity.

So it seems that in case of NGC 6240, both components contribute in comparable strength.

6. Summary and conclusions

We detected luminous extended X-ray emission in NGC 6240 in ROSAT HRI data. At the given spatial resolution the source looks nearly spherical and contains its most significant emission within a radius of 20″ (or 14 kpc for a distance d=144 Mpc) where the total 0.1–2.4 keV X-ray luminosity amounts to at least $\sim 10^{42}$ erg s^{-1}. At the epochs of the observations at most 40% of this luminosity arises within the innermost region of 5″ radius.

[3] Lutz et al. (1996) addressed this question on the basis of ISO data, and conclude that the strengths of low-ionization emission lines can be consistently explained by *starburst* models.

The extended emission can be consistently described by crude supershell models thereby explaining it as the result of a super-starburst with a total luminosity close to $10^{12} L_{\odot}$.

The presence of an additional compact AGN component is in X-rays indicated by (i) a decrease in the count rate between Feb. 1993 (last PSPC observation) and Feb. 1994 (first HRI observation) by 32%, (ii) a probable powerlaw component necessary to fit PSPC spectra and (iii) a strong FeKα complex detected in ASCA spectra. We propose a model in which near-nuclear warm gas ionized by the AGN powerlaw continuum emits FeKα which is seen superposed on the reflected continuum.

Both components, the starburst as well as the AGN provide enough power to explain the luminous FIR emission in NGC 6240 and it seems that both contribute with comparable strength.

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References

Andreasian N., Alloin D., 1994, A&AS 107, 23
Barbieri C., Rafanelli P., Schulz H. et al., 1993, A&A 273, 1
Barbieri C., Rafanelli P., Schulz H., Komossa S., Baruffolo, A., 1995, in *17th Texas Symp. on Relativistic Astrophys. and Cosmology*, W. Voges, G. Wiedenmann, G.E. Morfill, J. Trümper (eds), MPE Report 261
Barnes J.E., Hernquist L.E., 1991, ApJ 370, L65
Briel U., Aschenbach B., Hasinger G. et al., 1994, *ROSAT user's handbook*
Clements D.L., Sutherland W.J., McMahon R.G., Saunders W., 1996, MNRAS 279, 477
Colbert E.J.M., Wilson A.S., Bland-Hawthorn J., 1994, ApJ 436, 8
Cruddace R.G., Hasinger G.R., Schmitt J.H.M.M., 1988, in *Astronomy from large databases*, F. Murtagh and A. Heck (eds), 177
David L.P., Harnden F.R., Kearns K.E., Zombeck M.V., 1992, Techn. Rep. (US ROSAT Science Data Center)
de Poy D.L., Becklin E.E., Wynn-Williams C.G., 1986, ApJ 307, 116
Fabbiano G., 1989, ARA&A 27, 87
Ferland G.J., 1993, University of Kentucky, Physics Department, Internal Report
Fosbury R.A.E., Wall J.V., 1979, MNRAS 189, 79
Fried J., Schulz H., 1983, A&A 118, 166
Greiner J., Boër M., Motch C., Kahabka, P., Voges, W., 1991, Proc. 22nd ICRC Dublin, vol. 1, 53
Grevesse N., Anders E., 1989, in *Cosmic Abundances of Matter*, AIP 183, C.J. Waddington (Ed.), New York: American Institute of Physics, 1
Heckman T,M., Armus L., Miley G.K., 1987, AJ 93, 276
Heckman T.M., Armus L., Miley G.K., 1990, ApJS 74,833
Heckman D.M., Dahlem M., Eales S.A., Fabbiano G., Weaver K., 1996, ApJ 457, 616
Joseph R.D., Wright, G.S., 1985, MNRAS 209, 111
Keel W.C., 1990, AJ 100, 356
Komossa S., PhD Thesis, LMU Munich
Komossa S., Fink H., 1997, A&A 322, 719
Komossa S., Schulz H., 1997, A&A 323, 31
Leitherer C., Heckman T.M., 1995, ApJS 96, 9
Lutz D., Genzel R., Sternberg A. et al., 1996, A&A 315, L137
Mac Low M-M., McCray R., 1988, ApJ 324,776
Matt G., Piro L., Antonelli A., Fink H., Meurs E.J.A., Perola G.C., 1994, A&A 292, L13
Mihos J.D., Hernquist L.E., 1996, ApJ 464, 641
Mitsuda K., 1995, Ann.N.Y.Acad.Sc. 759, Proc. *17th Texas Symp. on Relativistic Astrophys. and Cosmology*, eds. H. Böhringer, G.E. Morfill, J.E. Trümper (New York: The New York Acad. of Sc.), 213
Moran E.C., Halpern J.P., Helfand D.J., 1994, ApJ 433, L65
Moran E.C., Halpern J.P., Helfand D.J., 1996, ApJS 106, 341
Morris S.L., Ward M.J., 1988, MNRAS 230, 639
Morse J., 1994, PASP 106, 675
Otani C., Kii T., Reynolds C. S., et al., 1996, PASJ 48, 211
Pan H.C., Stewart G.C., Pounds K.A., 1990, MNRAS 242, 177
Pfeffermann E., Briel U.G., Hippmann H. et al., 1987, Proceedings of the International Society for Optical Engineering, 733, 519
Ptak A., Selemitsos P., Yaqoob T., Mushotzky R.F., Tsuru T., 1997, AJ 113, 1286
Rafanelli P., Schulz H., Barbieri C. et al., 1997, A&A 327, 901
Rieke G.H., Cutrie R.M., Black J.H. et al., 1985, ApJ 290, 116
Sanders D.B., Mirabel I.F., 1996, ARA&A 34, 749
Sanders D.B., Soifer B.T., Elias J.H. et al., 1988, ApJ 325, 74
Schmitt H.R., Bica E., Pastoriza M.G., 1996, MNRAS 278, 965
Schulz H., Komossa S., 1997, AG Abs. Ser. 13, 245
Schulz H., Komossa S., Berghöfer T.W., Boer B., 1998, A&A 330, 823 – paper I
Smith A.M., Hill R.S., Vrba F.J., Timothy J.G., 1992, ApJ 391, L81
Solomon P.M., Downes D., Radford S.J.E., Barrett J.W. 1997, ApJ 478, 144
Suchkov A.A., Balsara D.S., Heckman T.M., Leitherer C., 1994, ApJ 430, 511
Tomisaka K., Bregman J.N., 1993, PASJ 45, 513
Trümper J., 1983, Adv. Space Res. 2, 241
Trümper J., Hasinger G., Aschenbach B. et al., 1991, Nat 349, 579
van der Werf P.P., Genzel R., Krabbe A. et al., 1993, ApJ, 405, 522
Veilleux S., Kim D.-C., Sanders D.B., Mazzarella M., Soifer B.T., 1995, ApJS 98, 171
Voges W., Aschenbach B., Boller T. et al., 1996, ROSAT *all-sky survey bright source catalogue*
Vogler A., 1997, PhD Thesis, TU Munich
Weedman D.W., 1983, ApJ 266, 479
Wisotzki L., Bade N., 1997, A&A 320, 395
Wright G.S., Joseph R.D., Meikle W.P.S., 1984, Nat 309, 430
Wynn-Williams C.G., Becklin, E.E., 1993, ApJ 412, 535
Zasov A.V., Karachentsev I.D., 1979, Pis'ma Astron. Zh. 5, 237
Zimmermann H.U., Becker W., Belloni T., et al., 1994, MPE Report 257
Zombeck M.V., Conroy M., Harnden F.R. et al., 1990, Proceedings of the International Society for Optical Engineering, 1344, 267