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COMPTON X-RAY EMISSION FROM NGC 253

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ABSTRACT

A calculation is presented of X-ray emission from the disk and radio halo of the starburst galaxy NGC 253. Compton scattering of the radio emitting electrons off the far-infrared radiation field in the halo of this galaxy can account for the 50–200 keV emission recently detected by OSSE. This could possibly be the first detection of diffuse Compton emission from a galaxy which is not a bona fide active galactic nucleus.

Subject headings: galaxies: individual (NGC 253) — galaxies: starburst — gamma rays: theory — radiation mechanisms: nonthermal

1. INTRODUCTION

The prototypical starburst galaxy NGC 253 has been extensively studied in all regions of the electromagnetic spectrum, from radio to low-energy X-rays. Detection by the OSSE experiment, aboard the *Compton Gamma-Ray Observatory*, of high-energy X-ray (HEX) emission in the band 50–200 keV from this galaxy has recently been reported by Bhattacharya et al. (1994). The enhanced stellar formation and SN activities in starburst galaxies suggest a few likely mechanisms and environments of X-ray emission, and it is quite interesting to determine which of these can viably account for the observed emission from this galaxy.

Compton scattering of the moderately intense far-infrared (FIR) radiation field in this galaxy by cosmic-ray electrons is a natural process of HEX emission in the OSSE energy range. Bhattacharya et al. (1994) have estimated that this mechanism can only account for a small part (up to 20%) of the observed flux. (It would even seem that they over estimated the emission by taking a low value for the magnetic field, $B = 1\ \mu$G.) They have also estimated that free-free emission cannot provide more than 3% of the observed flux, and that a prohibitively large numbers of low mass X-ray binaries and supernova remnants would be required to account for this emission. Nor is continuum emission from obscured supernovae at peak brightness a viable origin, because OSSE would have detected the lines from ^{56}Ni radioactive decay chain (see also § 5).

These deductions are preliminary, pending more observations (which are planned) and quantitative analysis. In particular, a more appropriate calculation has to be made of the emission from Compton scattering of electrons (relativistic, unless noted otherwise) off the FIR radiation field. Bhattacharya et al. (1994) considered only emission from a 300 pc disk region in NGC 253. However, radio disks of spiral galaxies are usually thicker than the stellar disks. In the particular case of NGC 253 Klein et al. (1983) estimated the thickness of the radio disk to be 0.5–1 kpc. Moreover, recently Carrilli et al. (1992) reported a detection of a radio halo around this galaxy. The halo is extensive (16′ in diameter or ~ 19 kpc at a distance of 4.17 Mpc) and quite intense—it accounts for about 25% of the total emission at 330 MHz. Since it is very reasonable to expect the magnetic field in the halo to be weaker than in the disk, then it follows that the contribution of halo electrons to HEX emission may be significant.

The radio halo is direct evidence for escape of electrons from the disk. Together with diffusion, convection plays an important role in electron propagation, especially for lower energy electrons. Gas outflows perpendicular to the disk have been detected in optical line studies (McCarthy, Heckman, & van Breugel 1987), implying gas velocities of a (few) hundred km s^{-1}. These outflows carry magnetic fields and cosmic rays out of the galactic plane. A typical scale of the electron distribution in the vertical direction is $\sim V\tau$. where V is the convective velocity, and τ is the electron energy loss time; in NGC 253 this scale is a few kpc.

The centrally concentrated FIR radiation field is still substantial at a few kpc from the center. Compton scattering may continue to be an efficient process even at larger distances because of the ubiquitous cosmic microwave background (CMB) radiation. These considerations—the presence of electrons in the halo, and the strength of the radiation fields there—motivate the need for a proper calculation of the total HEX emission from the disk and the halo of NGC 253. Interest in this and related phenomena is not limited to the study of NGC 253, but rather to starburst galaxies in general (e.g., Rephaeli, Gruber, & Persic 1994). It is also interesting to note that if indeed the flux detected by OSSE is due to Compton scattering, then it would turn out to be the first detection of diffuse emission from a galactic halo.

A detailed calculation of the emission due to Compton scattering in the disk and halo of NGC 253 is presented in the next two sections. In the two subsequent sections our results are presented and discussed, followed by a brief summary.

2. RADIATION FIELDS

The FIR emission from dust is the dominant radiation field scattering electrons in NGC 253, a luminous *IRAS* galaxy. At a distance of 4.17 Mpc, its 42.5–122.5 μm luminosity is $3.04 \times 10^{10}\ L_{\odot}$ (Rice et al. 1988). According to these authors, emission in the

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IRAS bands is from two dust components: a cool component at $T_c \approx 36.8$ K, and a warm one at $T_w \approx 172.8$ K. The emission spectrum is blackbody (at each of these temperatures), and the dust absorption efficiency is assumed proportional to frequency (note that such a modification of the Planck spectrum is equivalent to attributing a finite optical depth to the FIR source; Dwek & Arendt 1992). Integration over these spectra yields a total FIR luminosity of $5.58 \times 10^{10}\ L_\odot$, with $4.07 \times 10^{10}\ L_\odot$ coming from the cool dust, and $1.51 \times 10^{10}\ L_\odot$—from the warm dust.

Almost all the FIR emission comes from the very compact nucleus of the galaxy. Harper & Low (1973) estimated the radius of the emission region to be 150 pc, whereas Telesco & Harper (1980) estimated it to be between 60 and 300 pc. Recent near-IR observations (Sams et al. 1994) are also consistent with a ~ 150 pc source. Krügel et al. (1990) resolved a 1300 μm source with FWHM of $16'' \times 11''$, which corresponds to a mean radius $R_s = 136.5$ pc. Although we are primarily interested in shorter wavelengths, we shall adopt this last value of the source radius, assuming that emissivity is constant within this radius and negligible outside. The former observations do not resolve the central source, but are consistent with the adopted value for its radius.

In what follows, we take the dust absorption efficiency to be proportional to ν^σ, with $\sigma = 1$ used in our numerical estimates (in accordance with the model of Rice et al. 1988). The photon density per unit energy (ϵ) interval is

$$n(\epsilon) = C \frac{\epsilon^{2+\sigma}}{\exp(\epsilon/kT) - 1} \tag{1}$$

For an isotropic radiation field the constant C can simply be determined by normalizing the energy density of the field, $\int_0^\infty d\epsilon \epsilon n(\epsilon)$, to $w = 4f/c = L/(\pi R_s^2 c)$. Here, however, the radiation field is not isotropic, so at a given distance r from the center of the emitting region the photon density is given by

$$n(\epsilon) = \frac{\Omega(R)L}{\pi R_s^2 c(kT)^{4+\sigma}\Gamma[4+\sigma]\zeta[4+\sigma]} \frac{\epsilon^{2+\sigma}}{[\exp(\epsilon/kT) - 1]}\,, \tag{2}$$

where $\Omega(R)$ is the radiation dilution factor,

$$\Omega(R) = \begin{cases} [1 - (1 - R_s^2/R^2)^{1/2}]/2 & \text{if } R \geq R_s\,; \\ \dfrac{1}{2} + \dfrac{R_s^2 - R^2}{4R_s R} \ln\left(\dfrac{R_s + R}{R_s - R}\right) & \text{if } R < R_s\,. \end{cases} \tag{3}$$

(Γ and ζ are the usual gamma and zeta functions.)

The FIR radiation field is now fully determined: it is the sum of two components having the form of equation (2) at temperatures T_c and T_w. We will also take into account the CMB radiation, although it is much weaker in the region where most of the electrons are present. The CMB is an undiluted blackbody, so its density (per unit energy) is

$$n_{\rm CMB}(\epsilon) = \frac{1}{\pi^2(\hbar c)^3} \frac{\epsilon^2}{\exp(\epsilon/kT) - 1}\,, \tag{4}$$

where T is the CMB temperature.

3. ELECTRON DISTRIBUTION

In a spiral galaxy acceleration of particles to relativistic energies occurs largely in the disk, out of which they eventually diffuse or are convected along in mass outflows. Lerche & Schlickeiser (1980, hereafter LS) generalized the simple diffusion model to include convection; the model successfully reproduces the spectral and spatial radio properties of the radio halos of the edge-on galaxies NGC 4631 and NGC 891. In this steady state, one-dimensional model relativistic electrons are injected into a thin galactic disk with a power-law spectrum with index p. Electron propagation in directions orthogonal to the disk is by convection and diffusion, and energy loss—by Compton and synchrotron processes. (That the mass outflow in NGC 253 is mostly in the perpendicular z direction, rather than spherically symmetric, is deduced from observations of optical lines; McCarthy et al. 1987.) The LS model is adopted here, with the additional assumption (whose consequences are discussed below) that the convection velocity, V, the diffusion coefficient, $D(E) = D_0 E^\mu$, and the radiative energy loss rate, $b_0 E^2$, do not depend on the spatial coordinates. As concluded by LS in their analysis of NGC 4631 and NGC 891, even with this assumption—which results in a significant mathematical simplification—the model gives a reasonably complete physical picture of electron escape from a spiral galaxy. (Note that some results of LS are erroneous. Most of these errors are irrelevant for our analysis, and correct expressions were used where needed.)

The source function for the electrons is (LS)

$$q_e(r, \varphi, z, E) = A(r, \varphi)\delta(z)E^{-p}\,, \tag{5}$$

in galactocentric cylindrical coordinates. The δ-function reflects the fact that the sources are located in a thin disk, and the spatial function $A(r, \varphi)$ is to be determined. In fact, we mainly need its integral over the area of the disk

$$A = \int_0^{2\pi} d\varphi \int_0^\infty dr r A(r, \varphi)\,. \tag{6}$$

The electron distribution in the disk can be well approximated by a "top hat" function—constant out to a certain radius, and negligible outside. We take this characteristic radius to be equal to the HWHM of the radio brightness temperature distribution in the disk, or $\simeq 1$ kpc (Klein et al. 1983).

At sufficiently high energies where radiative losses dominate, the energy loss rate is

$$-\frac{dE}{dt} = b_0 E^2 . \tag{7}$$

The radiative loss coefficient (averaged over the disk) is

$$b_0 = 0.04[B^2/(8\pi) + W_{\rm FIR} + W_{\rm CMB}] \text{ ergs}^{-1} \text{ s}^{-1} , \tag{8}$$

with energy densities expressed in units of ergs $\rm cm^{-3}$. B is assumed to be the mean "equipartition" field in the disk. We compute $B \approx 9\ \mu$G from the observed radio flux of Klein et al. (1983), taking the radio disk thickness to be 0.5 kpc, and assuming the nominal value of 100 for the proton-to-electron energy ratio. The FIR energy density can be calculated from the total FIR luminosity (Rice et al. 1988), taking dilution into account (see eq. [3] in § 2). Substitution into equation (8) yields $b_0 = 4.75 \times 10^{-13}$ $\rm ergs^{-1}\ s^{-1}$. Realistically, both B and $W_{\rm FIR}$ vary with z. We shall take this into account when we calculate the Compton flux, but *not* when we calculate the electron distribution. If anything, this underestimates the importance of halo electrons relative to those in the disk.

The relative roles of convection and diffusion in electron propagation can be assessed by comparing the respective distances travelled during an energy-loss time, $\tau(E) = (b_0 E)^{-1}$; these are $L_V \sim V\tau(E)$, and $L_D \sim 2[D(E)\tau(E)]^{1/2}$. It is easy to see that low-energy electrons travel mainly by convection, while the outward motion of high-energy electrons is dominated by diffusion; the characteristic energy separating these regions is

$$E_c = [(1-\mu)V^2/(4b_0 D_0)]^{1/(1+\mu)} . \tag{9}$$

The electron energy distribution exhibits a break at $E = E_c$, with a corresponding break in the radio spectrum (LS). The radio spectral index in the disk of NGC 253 (Klein et al. 1983) changes from 0.46 to 0.72 at about 400 MHz. If the break is interpreted as due to the change in propagation mode, then $E_c \approx 1.4$ GeV, $p \approx 1.92$ and $\mu \approx 0.01$ (see LS). (Note that at high frequencies the halo radio spectral index is ~ 1.0, in accord with the observations of Carilli et al. 1992.)

From the spectral index map of Carilli et al. (1992) we can estimate the vertical distance at which the spectral index steepens to its mean halo value of ~ 1.0. This distance, $L_c = V/(b_0 E_c)$ (LS), is roughly 2 kpc, so that $V \approx 66$ km $\rm s^{-1}$ (about equal to the value deduced by LS for NGC 891), in rough agreement with ~ 100 km $\rm s^{-1}$ from optical line observations (McCarthy et al. 1987). (Note that the electron convection velocity does not have to equal the gas velocity.) Equation (9) then leads to a value of the diffusion coefficient: $D(E) = 1.24 \times 10^{28} E^{0.01}\ \rm cm^2\ s^{-1}$.

Deduction of the electron energy spectrum is incomplete without the consideration of energy loss due to electronic excitations (Coulomb losses) in the gas, a process which is important at low energies. The Coulomb loss rate is (Gould 1972)

$$-\frac{dE}{dt} = b_1 = 4\pi e^4 (mc)^{-1} n_e \left[37.37 + \frac{1}{2} \ln \frac{E/(mc^2)}{n_e/(1\ \rm cm^{-3})} \right] , \tag{10}$$

where n_e is the electron density in the disk. We are interested in the value of b_1 in the disk plane. It is expected that the electron density in the interstellar medium of NGC 253 is significantly higher than that in the Galaxy. A reasonable nominal value is $n_e = 1$ $\rm cm^{-3}$, in accord with the value of interstellar density used by Bhattacharya et al. (1994). With this density, $b_1 \approx 9 \times 10^{-19}$ ergs $\rm s^{-1}$, and Coulomb losses dominate up to electron energy $E_e = (b_1/b_0)^{1/2} \approx 0.87$ GeV. The weak dependence of b_1 on E and n_e can be neglected in this range of energies.

As a further simplification, electrons with $E < E_e$ are assumed to lose energy only by electronic excitations, while those with $E > E_e$ lose energy only by the Compton and synchrotron processes. Thus, the total number of electrons with energy $E > E_e$ is

$$N_e(E) = \frac{AE^{-(p+\mu/2+1/2)}}{[(1-\mu)\pi D_0 b_0]^{1/2}} \int_0^1 ds s^{(p-1)/(1-\mu)-1}(1-s)^{-1/2} \times \int_0^\infty dz \exp\left\{ -\left(\frac{E_c}{E}\right)^{1+\mu} \frac{[1-s^{1/(1-\mu)} - (E/E_c)z/L_c]^2}{1-s} \right\} . \tag{11}$$

For $E < E_e$,

$$N_e(E) = \frac{AE^{-(p+\mu/2-1/2)}}{[(1-\mu)\pi D_0 b_0]^{1/2} E_e} \left(\frac{1-\mu}{1+\mu}\right)^{1/2} \int_0^1 ds s^{(p-1)/(1-\mu)-1/2}(1-s)^{-1/2}$$
$$\times \int_0^\infty dz \exp\left\{ -\left(\frac{1+\mu}{1-\mu}\right)\left(\frac{E_c}{E}\right)^{1+\mu} \frac{[(E/E_e)(s^{-1/(1+\mu)}-1) - z/L_c]^2}{1/s - 1} \right\} . \tag{12}$$

Similarly, emission from just the disk is calculated by simply changing the upper limits of the z-integrals to half the disk thickness.

The only parameter which is yet unknown, A, can be determined from the radio flux. We use the well determined disk flux at 10.7 GHz, equal to 1.556 Jy after subtraction of thermal emission (Klein et al. 1983). At this relatively high frequency, the high-energy limit of equation (11) can be taken

$$N_e(E) = \frac{Al_d}{[(1-\mu)D_0 b_0]^{1/2}} \frac{\Gamma[(p-1)/(1-\mu)]}{\Gamma[(p-1)/(1-\mu)+1/2]} E^{-(p+\mu/2+1/2)}$$
$$= KE^{-(p+\mu/2+1/2)} . \tag{13}$$

The corresponding equation for the radio flux density is

$$f_\nu = \frac{\alpha h \nu_B}{D^2(mc^2)^{p+\mu/2-1/2}} K a(p + \mu/2 + 1/2)\left(\frac{3\nu_B}{2\nu}\right)^{(p+\mu/2-1/2)/2} \tag{14}$$

(Dermer & Rephaeli 1988), where $\alpha = e^2/(\hbar c)$ is the fine-structure constant, $\nu_B = eB/(2\pi mc)$, and $a(p)$ is defined in Blumenthal & Gould (1970). Thus, the normalization parameter A can easily be derived from equations (13) and (14).

4. RESULTS

With the radiation field and electron distribution specified, the Compton flux from NGC 253 can than be calculated by integrating over these quantities, and over the volumes of the disk and halo. In order to compare directly with observations, we present the results of this calculation, together with the data of Bhattacharya et al. (1994) in Figure 1, where the dashed line represents the emission from the disk (taken to be 300 pc thick, to compare directly with Bhattacharya et al. 1994), and the solid line is the total emission from the disk and halo. Our main result is apparent in Figure 1: the total calculated emission from the disk and halo is at the level of the observed emission in the OSSE band. Most of the emission is from the halo, with the disk contributing only about one-third of the total emission.

More specifically, the calculated emission between 50 and 1000 keV can be fitted very well by a power law:

$$\phi_\epsilon = 4.17 \times \epsilon^{-1.69} \text{ photons cm}^{-2} \text{ s}^{-1} \text{ MeV}^{-1} , \tag{15}$$

where the photon energy ϵ is in keV. The emission from the 300 pc disk is well approximated by

$$\phi_\epsilon = 0.67 \times \epsilon^{-1.55} \text{ photons cm}^{-2} \text{ s}^{-1} \text{ MeV}^{-1} . \tag{16}$$

From equations (15) and (16) it can be readily estimated that at 100 keV the disk provides only about 30% of the total emission. This fraction depends only weakly on the photon energy (in the OSSE range): at 50 keV it equals ~28%, while at 200 keV it is ~34%. Thus, the Compton emission comes from a region that is a few times thicker than the disk. In fact, we find that 90% of the emission at 50 (100) keV comes from a region whose thickness is $\simeq 3$ ($\simeq 2.5$) kpc. The actual sizes of these regions are determined by the characteristic scale of the electron distribution (estimated as $L_c \simeq 2$ kpc), the increased dilution of the FIR radiation field at larger distances, and by the increased relative contribution of the (undiluted) CMB radiation field. Indeed, the contribution of CMB to the flux in the OSSE range is significant. This contribution decreases with energy: for the adopted values of the parameters it is ~50% at 50 keV, less than 40% at 100 keV, less than 30% at 200 keV, and less than 20% at 1 MeV. In addition to the larger number of

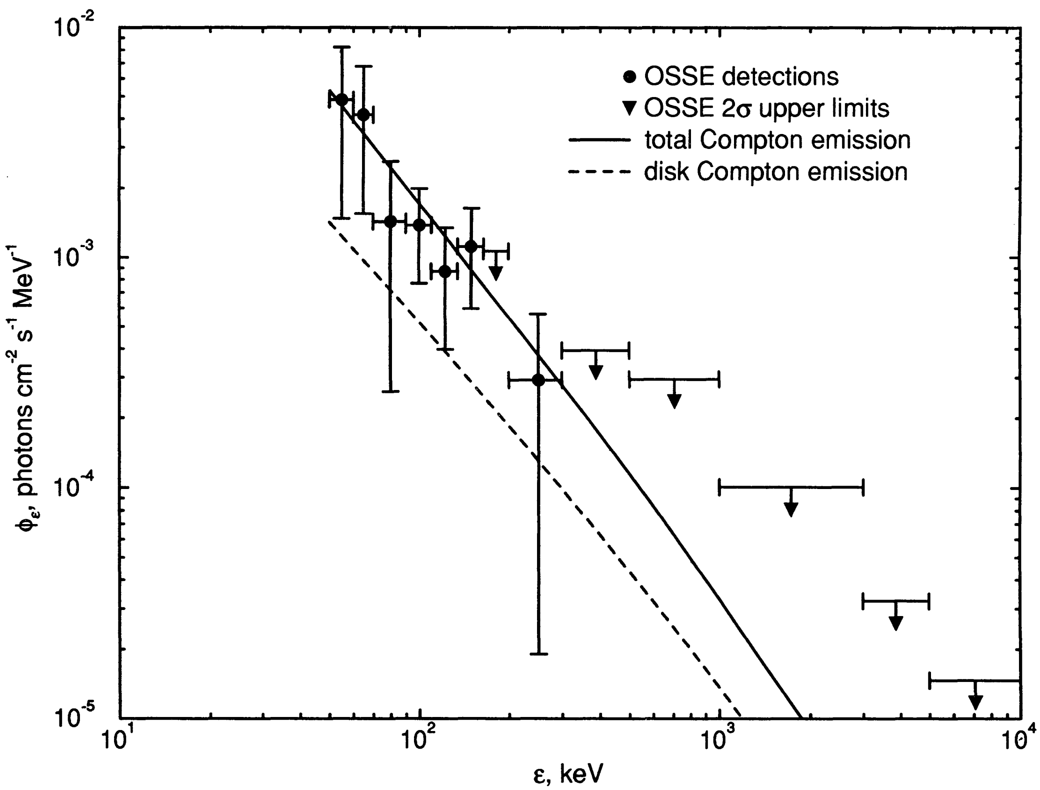

FIG. 1.—Compton X-ray emission from NGC 253. The filled circles are the OSSE data, the arrows are the OSSE 2 σ upper limits, the solid line is the calculated total Compton emission, and the dashed line is the calculated emission from the 300 pc disk.

lower energy CMB photons, the increasing contribution of this radiation field at lower X-ray energies simply stems from the fact that the lower the energy, the wider is the spatial distribution of the electrons, and the smaller is the contribution of the FIR field.

Measurements at energies lower and higher than the OSSE band are also of interest. Integrating the Compton emission over the *ROSAT* 0.1–2.4 keV range, we obtain a total flux of $\sim 1.1 \times 10^{-11}$ ergs cm^{-2} s^{-1}. Photoelectric absorption is significant in the *ROSAT* band, especially so in dust-rich starburst galaxies. With hydrogen column density of 10^{22} cm^{-2}, which may be typical in these galaxies (see, e.g., Rephaeli et al. 1991), we estimate the overall attenuation of the flux in this band to be ~ 6.7, which yields a flux of 1.64×10^{-12} ergs cm^{-2} s^{-1}. The flux measured by *ROSAT* is $\sim 6 \times 10^{-12}$ ergs cm^{-2} s^{-1} (Boller et al. 1992). Thus, given that the *ROSAT* field of view was smaller than the $8' \times 8'$ halo, we conclude that the Compton contribution to the low-energy X-rays is at most a few tenths of the total emission detected by *ROSAT*.

Whereas emission at low X-ray energies can be directly predicted in our treatment of the electron energy spectrum (because of the inclusion of energy losses by electronic excitations), the calculation of emission at the very high 100 MeV γ-ray range requires extrapolation of this spectrum to much higher energies than directly deduced from radio measurements. This extrapolation would be valid only if the population of very energetic electrons is constantly maintained by acceleration processes, so that a steady state is established. If it is assumed so, then extrapolation of our calculated flux would give a flux higher by about a factor of 5 than the current EGRET upper limit of 10^{-7} photons cm^{-2} s^{-1} on γ-ray emission above 100 MeV (Fichtel et al. 1994). If anything, this very rough comparison only serves to emphasize the inadequacy of extension of the electron spectrum to very high energies. (For a recent discussion of the related issue of "ageing" of electron spectra, see, e.g., Goldshmidt & Rephaeli 1994).

5. DISCUSSION

Our basic result, that emission comparable to the level detected by OSSE is likely to be due to Compton scattering of electrons in the disk and inner halo of NGC 253, needs further elucidation given the particular choice of the relevant parameters and simplifying assumptions made in the calculation.

An important parameter is the "equipartition" value of the mean magnetic field in the disk, taken to be 9 μG, a substantially uncertain value. While a higher field value is possible, in principle, this estimate is probably on the high side (Bhattacharya et al. 1994 assumed a value of 1 μG): The equipartition estimate is based on the nominal value of 100 for the proton-to-electron ratio. If this ratio is lower, so is the field. It should also be noted that a value of 9 μG is significantly higher than what is usually common in the disks of spiral galaxies. The lower the field, the higher is the predicted Compton emission (for a given level of radio emission).

Uncertainty is introduced by adopting the simplified LS model, mainly with respect to its steady state nature. A typical "starburst" phase, which is estimated to last 10^7–10^8 years, is comparable to the energy loss time of electrons of relevant energies [$\tau = 1/(b_0 E_c) \approx 3 \times 10^7$ yr], so the steady state assumption has to be justified. We also have assumed that both b_0 and $D(E)$ are spatially independent. In general, we can resort to the significant level of success of the LS model in reproducing the detailed radio properties of NGC 4631 and NGC 891. Moreover, the scaling of the predicted Compton emission to the observed level of radio emission provides a measure of validity of our final results, irrespective of possible modifications of the details. In any case, the available data of Bhattacharya et al. (1994) are not of sufficient quality to warrant a more detailed treatment than given here.

The simplified geometry and the introduction of the dilution factor also lead to uncertainties, implying either a lower or higher level of Compton emission. The assumed geometrical picture of vertical propagation of electrons out of the cylindrical disk is supported by observations. For instance, optical line observations indicate bipolar, rather than spherical gas outflows (McCarthy et al. 1987). The characterization of the FIR radiation field is based here directly on results from *IRAS* measurements, with a conservatively reasonable choice of the size of the FIR-emitting region.

So far we have considered only one likely mechanism for emission of high energy X-ray emission from NGC 253. Other relevant mechanisms have already been (qualitatively) considered by Bhattacharya et al. (1994), who concluded that neither free-free emission, nor compact X-ray sources nor a Type Ib Wolf-Rayet supernova at peak brightness, can account for the observed emission. The only other possibility, they argued, is continuum emission from a Type Ia supernova at peak brightness. A problematic aspect of this interpretation is the lack of detection of the associated 847 keV iron line. Note also that the upper limits on the SN rate derived by Bhattacharya et al. (1994) from the nondetection of the γ-ray lines are very high: 1.9 yr^{-1} for Type Ia supernovae and 6.3 yr^{-1} for Type Ib supernovae at 3 σ level, as compared with a value of 0.08 yr^{-1} (Van Buren & Greenhouse 1994). With this lower SN rate the probability the OSSE observed a Type Ia supernova at the peak of its brightness should be rather small.

Consider, finally, the possibility that the emission detected by OSSE is from a compact active nucleus in NGC 253, such that might be conjectured if it is presumed that starburst galaxies are a link between AGNs and normal galaxies (with successively less massive central blackholes as the unifying phenomenon). Such an interpretation is not obvious: the starburst activity which characterizes these galaxies is spread out over an extended central region, not confined to a compact nucleus. Nonetheless, if we model the NGC 253 emission by that from NGC 1275—one of the few AGNs with known high-energy X-ray emission—then we might expect a rough similarity when scaling their respective emissions in different spectral regions. However, the FIR emission of Seyferts is not much stronger than that of starburst galaxies; the 42.5–122.5 μm luminosity of NGC 1275 is about 4.6×10^{44} ergs s^{-1}, as compared to 1.2×10^{44} ergs s^{-1} of NGC 253 (Rice et al. 1988). This should be contrasted with the inferred 50–1000 keV luminosities which differ by more than four orders of magnitude: $\sim 6 \times 10^{45}$ ergs^{-1} for NGC 1275 (extrapolated from the results of Rothschild et al. 1981), as compared with $\sim 2.2 \times 10^{41}$ ergs s^{-1} for NGC 253 (our calculation). (Another consideration is the use of the radio emission from NGC 253 to predict its X-ray emission in the context of the synchrotron-self-Compton mechanism which is commonly invoked to relate radio and X-ray emission in AGNs. Scaling the main model parameters in NGC 1275 to NGC 253, we deduce a source size of 1.6 pc, from which comes about half of the total radio emission, and emitting also an X-ray flux which is more than 40 times higher than observed by OSSE. However, this scaling—which depends sensitively on model parameters—is substantially uncertain.) Thus, while the possibility of AGN-like emission mechanism is not ruled out, it certainly does not look very likely based on current observational data.

We conclude that the predicted Compton X-ray emission from the disk and inner halo of NGC 253 agrees well with the emission detected recently by the OSSE experiment. The fractional contribution of the disk to the total emission is $\sim 30\%$. The OSSE detection and its proposed interpretation make NGC 253 the first non-AGN from which Compton emission has been detected.

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REFERENCES

Bhattacharya, D., et al. 1994, ApJ, 437, 173
Blumenthal, G. R., & Gould, R. J. 1970, Rev. Mod. Phys., 42, 237
Boller, T., Meurs, E. J. A., Brinkman, W., Fink, H., Zimmermann, U., Adorf, H.-M. 1992, A&A, 261, 57
Carilli, C. L., Holdaway, M. A., Ho, P. T. P., & De Pree, C. G. 1992, ApJ, 399, L59
Dermer, C. D., & Rephaeli, Y. 1988, ApJ, 329, 687
Dwek, E., & Arendt, R. G. 1992, ARA&A, 30, 11
Fichtel, C. E., et al. 1994, ApJS, 94, 551
Goldshmidt, O., & Rephaeli, Y. 1994, ApJ, 431, 586
Gould, R. J. 1972, Physica, 60, 145
Harper, D. A., & Low, F. J. 1973, ApJ, 182, L89
Klein, U., Urbanik, M., Beck, R., & Wielebinski, R. 1983, A&A, 127, 177
Krügel, E., Chini, R., Klein, U., Lemke, R., Wielebinski, R., & Zylka, R. 1990, A&A, 240, 232
Lerche, I., & Schlickeiser, R. 1980, ApJ, 239, 1089 (LS); 1981, ApJ, 246, 360
McCarthy, P. J., Heckman, T., & van Breugel, W. 1987, AJ, 93, 264
Rephaeli, Y., Gruber, D., & Persic, M. 1994, A&A, in press
Rephaeli, Y., Gruber, D., Persic, M., & MacDonald, D. 1991, ApJ, 380, L59
Rice W., Lonsdale, C. J., Soifer, B. T., Neugebauer, G., Kopan, E. L., Lloyd, L. A., de Jong, T., & Habing, H. J. 1988, ApJS, 68, 91
Rothschild, R. E., Baity, W. A., Marscher, A. P., & Wheaton, W. A. 1981, ApJ, 243, L9
Sams, B. J., Genzel, R., Eckart, A., Tacconi-Carman, L., & Hoffman, R. 1994, ApJ, 430, L33
Telesco, C. M., & Harper, D. A. 1980, ApJ, 235, 392
Van Buren, D., & Greenhouse, M. A. 1994, ApJ, 431, 640