# Broad-band X-ray/gamma-ray spectra of NGC 4151 and their theoretical consequences

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## The Spectra

• We present the broad-band spectra of NGC 4151 from a contemporaneous observation by OSSE, *ROSAT* and *Ginga* in May-July 1991 (Fig. 1), and from a simultaneous observation by OSSE and *ASCA* in May 1993 (Fig. 2). We find the high-energy data are well described by either an exponentially cut-off power law or by a thermal Comptonization model (Titarchuk & Mastichiadis 1994). The X-ray energy spectral index is $\sim 0.65$ and 0.45, and the plasma temperature is $\sim 65$ and 45 keV for the 1991 and 1993 observations, respectively. The OSSE data are based on a new improved response matrix. The results in the revised OSSE spectrum from July 1991 being substantially harder than that published earlier (Maisack et al. 1993; Zdziarski, Lightman & Maciołek-Niedźwiecki 1993), in particular $kT \approx 65$ keV now compared to the previously determined value of about 40 keV. Consequently, the high-energy cutoff of the thermal model is at higher energies, and there is no longer a need for a nonthermal tail above the thermal cutoff.

We also analyze other observations of NGC 4151 by OSSE. We find that all the observed spectra and fluxes are very similar, and can be described by thermal Comptonization at $kT \simeq 50$ keV.

• Those findings imply that the broad-band spectrum of NGC 4151 differs strongly from the average spectrum of radio-quiet Seyfert 1 objects. The X-ray spectrum is much harder, $\alpha \sim 0.5$ compared to $\alpha \simeq 0.9$-1 for average Seyfert 1s. The cutoff energy is much lower, $kT \sim 50$ keV compared to $\sim 500$ keV in typical Seyfert 1s. If the spectrum is interpreted in terms of thermal Comptonization, $\tau \sim 2$ compared to $\tau \sim 0.1$ in typical Seyfert 1's (Zdziarski et al. 1994, 1995).

## Geometry and Reprocessing

• The hardness of the X-ray spectra of NGC 4151 implies that the plasma is photon-starved, i.e., the power in the UV photons irradiating the hot plasma is a few per cent of the power emitted by the hot plasma in X-rays and $\gamma$-rays. This rules out the homogeneous corona model (Haardt & Maraschi 1993), in which the corona fully covers a cold disk, which reemits $\sim 50\%$ of the X-rays and $\gamma$-rays in the form of the UV radiation back to the corona. Therefore, the observed power in X-rays and $\gamma$-rays in that model equals that in the UV irradiating the corona, which is not compatible with the hardness of the X-ray spectra of NGC 4151. In NGC 4151, only a small fraction of the observed UV emission can irradiate the hot plasma. This is compatible either with a patchy corona or with a single hot cloud away from the disk.

• Finally, we study implications of the observed constancy of the $\gamma$-ray spectrum of NGC 4151 for the origin of the UV emission. The UV emission has been observed to strongly correlate with the 2–10 keV X-ray emission observed by *EXOSAT* (Perola et al. 1986). We have used the original *EXOSAT* data and fitted them with the thermal Comptonization spectrum at $kT$ = 50 keV = constant (using ionized absorption and including a soft X-ray excess), which spectrum is simply a power law in the 2–10 keV range (see open circles in Fig. 3). We then computed the power in the X-ray and $\gamma$-ray emission that would result from absorption (and subseqent reemission in the UV range) of such spectra by a cold medium (see filled circles in Fig. 3). We see in Figure 3 that the integrated absorbed power correlates with the UV flux as well as the 2–10 keV flux. Thus, the assumption of $kT$ = 50 keV = constant (as observed by OSSE) is compatible with the reprocessing model.

On the other hand, if the *EXOSAT* spectra extended to $\sim$ 4 MeV (as in the reprocessing model of Perola & Piro 1994), the linear correlation between the absorbed power and the UV flux disappears, as shown in Figure 4. We have checked the overall energy balance and found that the observed UV fluxes can be produced by reprocessing of emission of a patchy corona if the disk viewing angle is 65 degree (Evans et al. 1993), and $R_{\rm G} \simeq 10^{13}$ cm. This model also reproduces the observed UV spectral index of $\alpha \simeq -0.15$ (Perola et al. 1986).

## References


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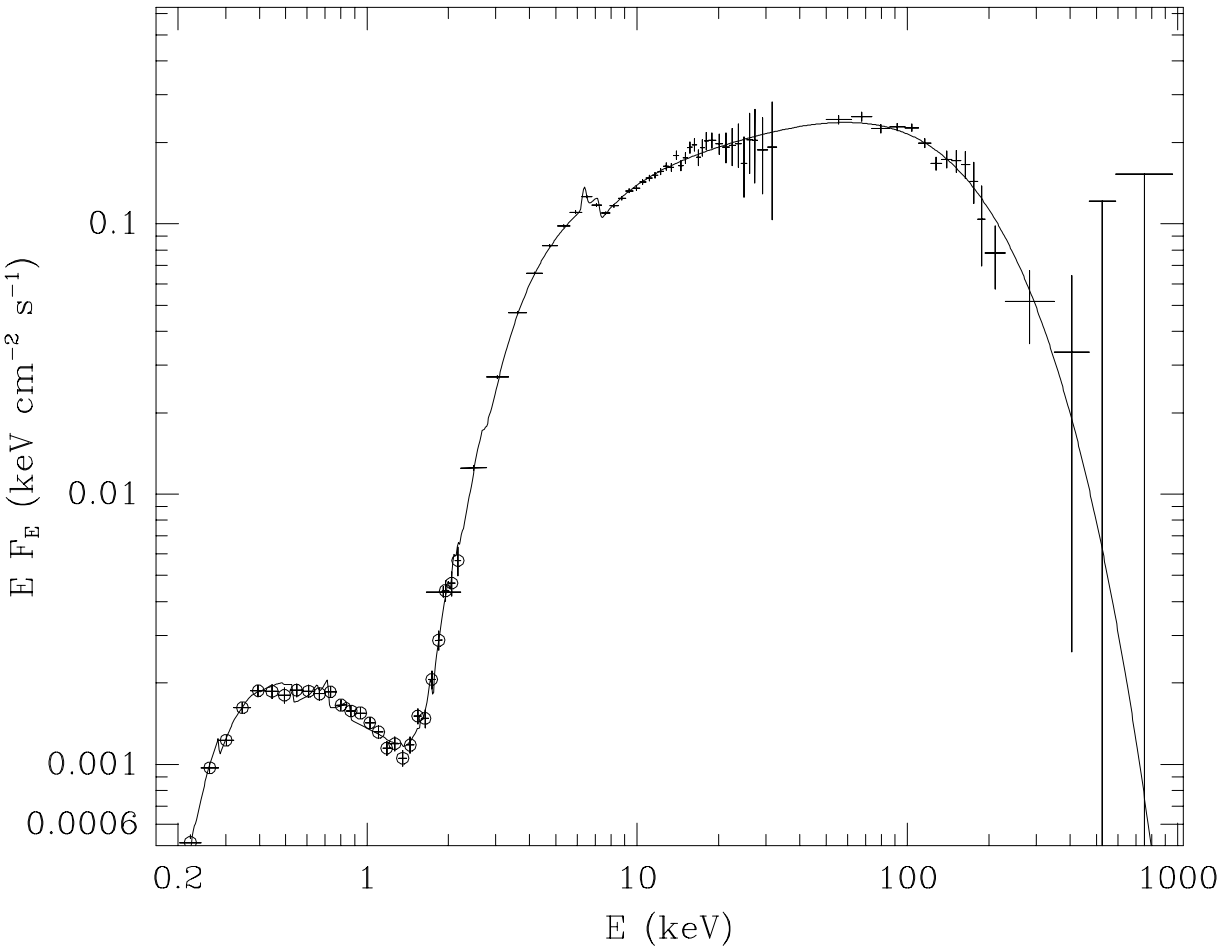


FIG. 1.—The spectrum observed by OSSE, 1991 June 29–July (using the currently improved response matrix), and by *Ginga* (Yaqoob et al. 1993) and *ROSAT* (marked by circles, Warwick, Done & Smith 1995), 1991 May 31–June 1. The solid curve represents a thermal Comptonization model with $kT = 65$ keV and $\alpha = 0.65$ absorbed by an ionized medium, and with addition of a soft excess.

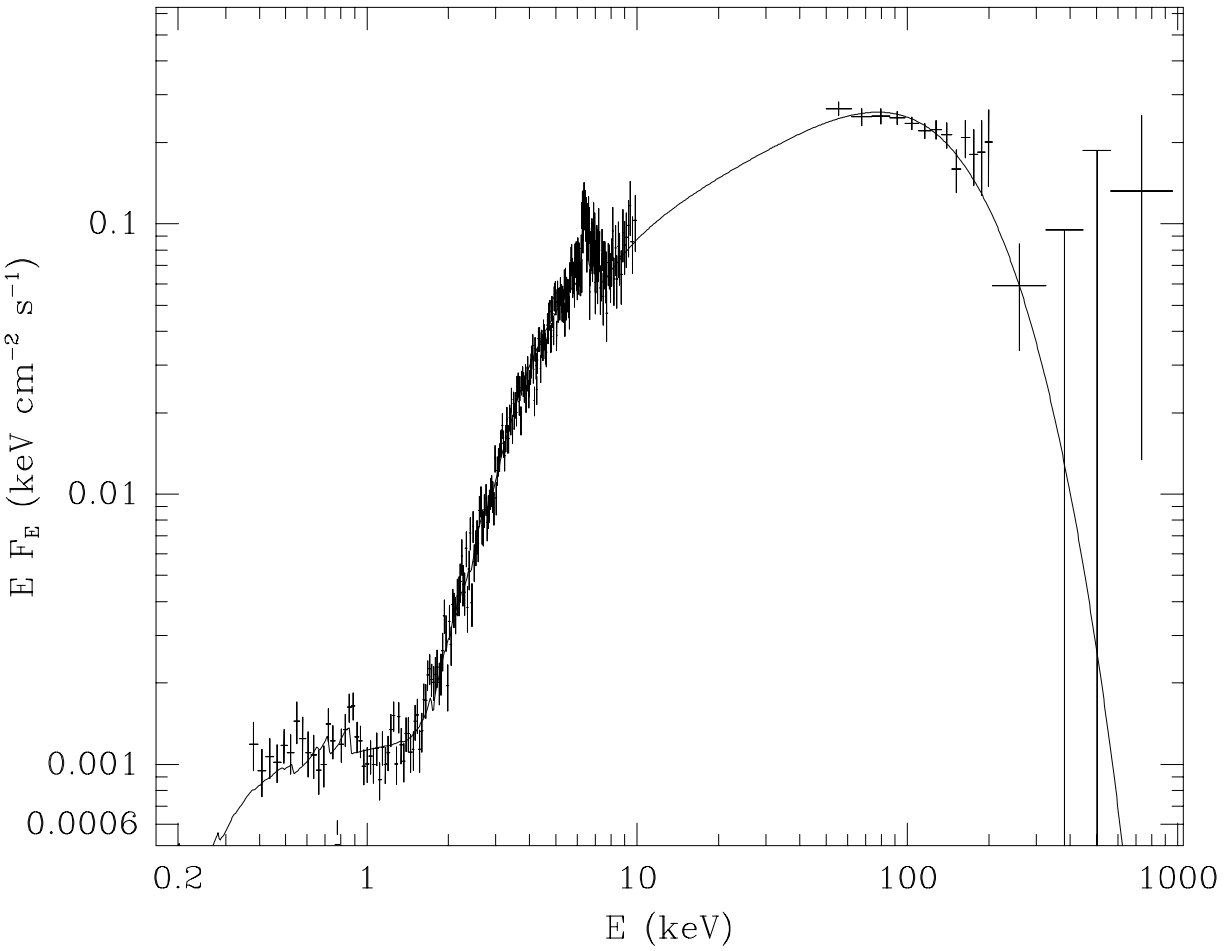


FIG. 2.—The spectrum observed by OSSE, 1993 May 24–31, and by *ASCA*, 1993 May 25. The solid curve represents a thermal Comptonization model with $kT = 47$ keV and $\alpha = 0.44$ absorbed by an ionized medium, and with addition of a soft excess.

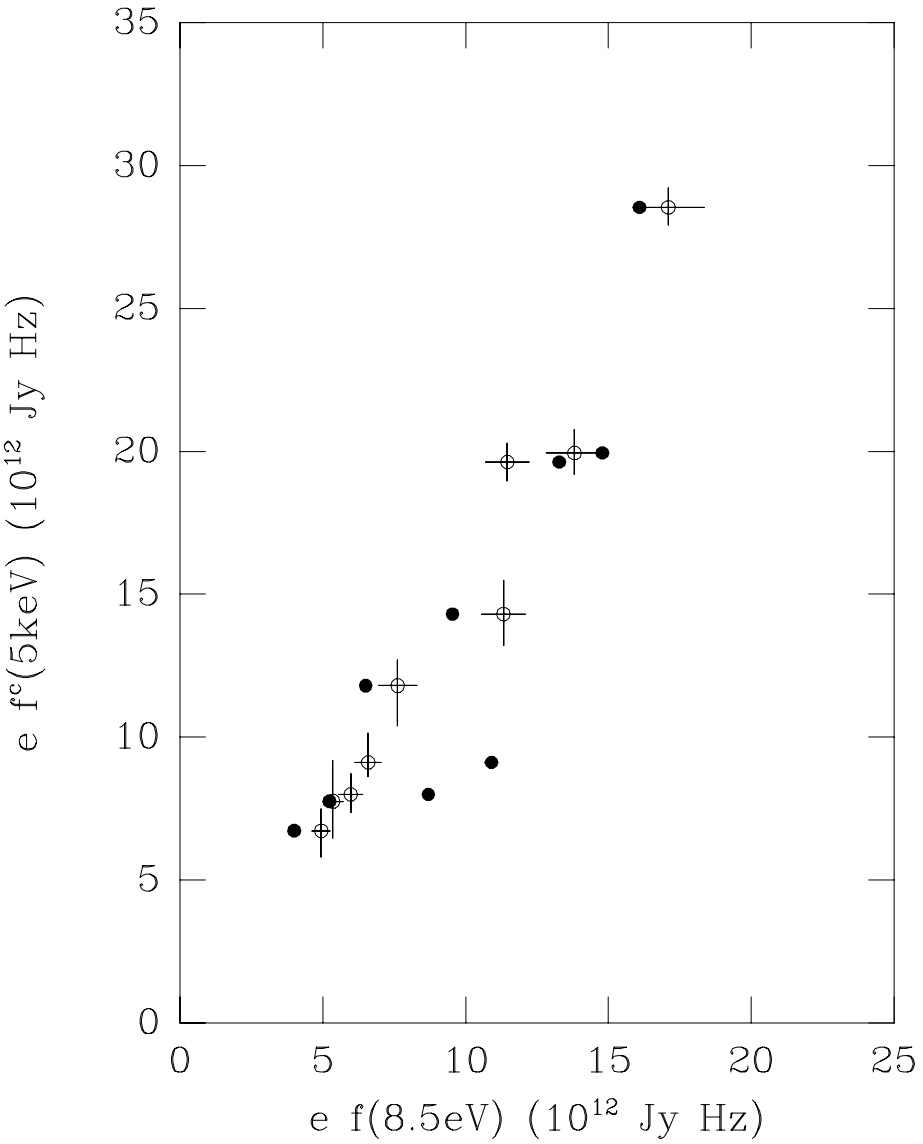


FIG. 3.—The correlation between the UV and X-rays/$\gamma$-rays. Both axes show $\nu F_\nu$ in the same units. The open circles and error bars give the power law normalization at 5 keV obtained from the *EXOSAT* data using a model analogous to that used in Figures 1 and 2. Note that $\nu F_\nu$ at 5 keV is almost identical to that at 8.5 eV. The filled circles show the total power in X-rays and $\gamma$-rays with $kT = 50$ keV absorbed by a cold disk, and divided by 8. Thus, the power absorbed by the disk is 8 times the power emitted near 8.5 eV. We find it is sufficient for the reprocessing model described in the text.

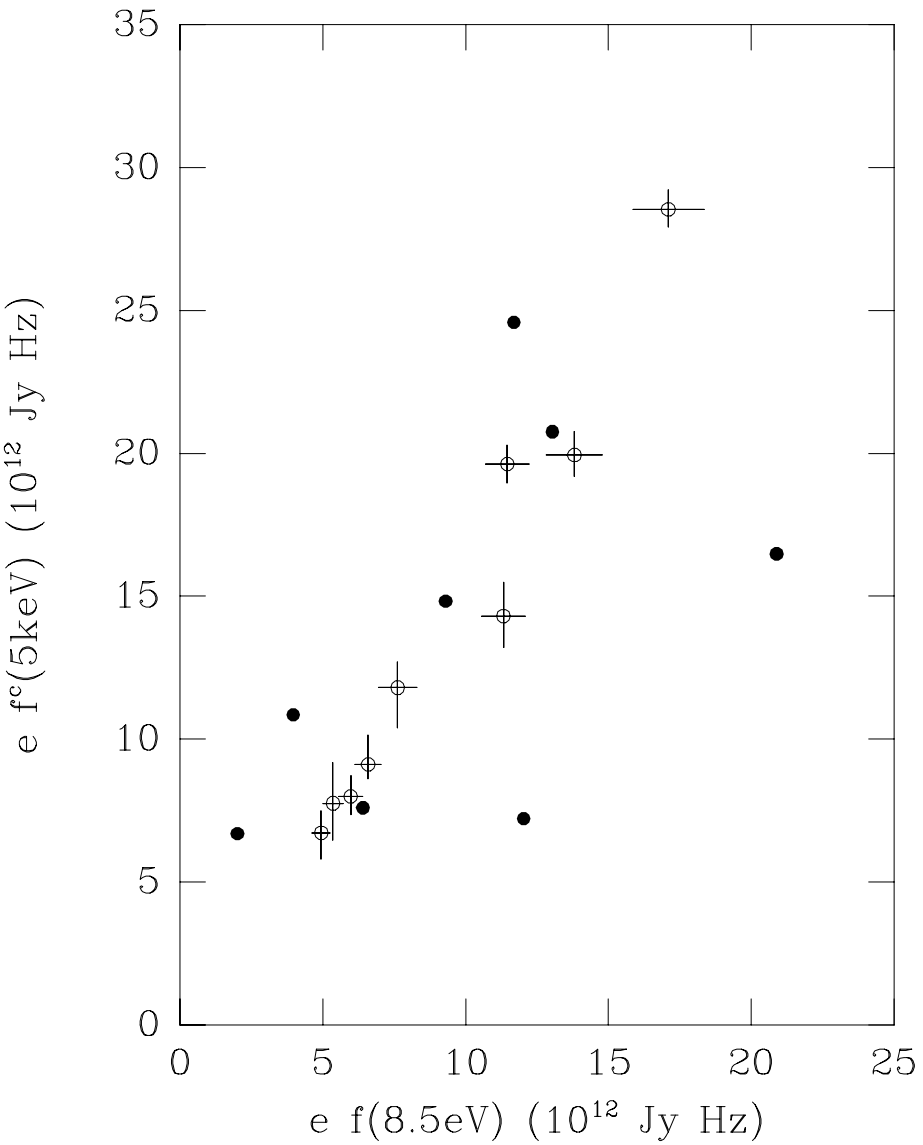


FIG. 4.—Same as in Figure 3 except that the X-ray emission has been assumed to extend to 4 MeV, as in the model of Perola & Piro (1994). The filled circles show the reprocessed power divided by a factor of 25 (to achieve the best possible correlation with the UV). We see that the correlation of the UV with the absorbed power is almost lost now, in contrast to the case in Figure 3. Thus, the assumption of the X-ray spectrum extending to 4 MeV is not compatible with the observed UV-X-ray correlation.