BeppoSAX detection of the Fe K line in the starburst galaxy NGC253

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Preliminary results obtained from BeppoSAX observation of the starburst galaxy NGC253 are presented. X-ray emission from the object is clearly extended but most of the emission is concentrated on the optical nucleus. Preliminary analysis of the LECS and MECS data obtained using the central 4’ region indicates that the continuum is well fitted by two thermal components at 0.9 keV and 7 keV. Fe K line at 6.7 keV is detected for the first time in this galaxy; the line has an equivalent width of $\sim 300$ eV. The line energy and the shape of the 2–10 keV continuum strongly support thermal origin of the hard X-ray emission of NGC253. From the measurement of the Fe K line the abundances can be unambiguously constrained to $\sim 0.25$ the solar value. Other lines clearly detected are Si, S and Fe X\textsubscript{III}/Ne, in agreement with ASCA results.

1. Introduction

Starburst galaxies are spirals (sometimes barred) in which gas is converted to stars at rates that could not be sustained over typical galaxy lifetimes. Such a phase is thought to represent a significant, if relatively brief, stage in galactic evolution lasting about $10^8$ years (Rieke et al. 1980).

Starbursts tend to be characterized by copious far-infrared (FIR) radiation from warm interstellar dust heated by massive young stars (Soifer et al. 1986), as well as by enhanced radio and X-ray emission. X-ray emission in starbursts has been attributed to individual point sources, within the central $10^3$ pc for nuclear starbursts, such as low-mass X-ray binaries and young supernovae, and to hot plasma heated by supernova explosions or strong stellar winds from young massive stars. Indeed, such hot plasmas have been termed “superwinds” ( Heckman et al. 1990), arising when the supernova rate (e.g. $\sim 0.1$ yr\textsuperscript{-1} for NGC253, Antonucci & Ulvestad 1988) and the mass of the gas involved ($\sim 10^8 M_\odot$) are high enough to create a shock-heated gas cavity within the galaxy. Such cavity could expand, break and then make the hot gas come out as superwind. Superwind emission has been suggested as an explanation for the plume of X-ray, discovered by Einstein, in the northern side of NGC253 ( Fabbiano 1988).

We present here BeppoSAX observations of a starburst galaxy, NGC253, that, for the first time, reveal the Fe K line at 6.7 keV. The detection of this line is fundamental because it constrains the origin of the X-ray emission, and provides a diagnostic for plasma temperatures higher than a few keV, and for elemental abundances. Studies of starburst galaxies are interesting as they help in the understanding of the physical processes behind the high stellar formation rate in the nucleus and in the search for a possible link between normal galaxies and AGN.
2. NGC253

NGC253 (see table 1 for data) is a nearby edge-on late-typed barred spiral ($i = 78.5^\circ$, Pence 1981) and represents one of the archetypical starburst galaxies. It is one of the brightest infrared sources in the extragalactic sky, with a 100$\mu$m luminosity of $3.04 \times 10^{10}$ L$_\odot$ (Rice et al. 1988), and has been studied extensively at high energies (Fabbiano & Trinchieri 1984; Ohashi et al. 1990; Ptak et al. 1997), showing a high degree of spectral and spatial complexity at X-ray wavelengths.

### Table 1: Relevant data of NGC253

| Dec    | RA     | D$^a$ | d$^b$ | M$_V$ |
|--------|--------|-------|-------|-------|
| -25h17m18s | 00h47m33s | ~3Mpc | 10' | 8.04 |

Note: $^a$ see Tully 1988  
$^b$ MECS observation

3. The BeppoSAX observation

NGC253 was observed from November 29 to December 2, 1996 (see table 2). In the central 4 arcmin region, we obtained a LECS count rate of $3.93 \times 10^{-2}$ cts s$^{-1}$ and a MECS count rate of $9.23 \times 10^{-2}$ cts s$^{-1}$. Data are characterized, in the 0.1-10 keV band, by S/N>3. The flux observed

### Table 2: Exposure time

| Instrument | En.range | Obs.time |
|------------|----------|----------|
| LECS       | 0.1-4    | 54689    |
| MECS       | 1.3-10   | 113403   |

by BeppoSAX in the 0.1-2.4 keV energy range, is $2.36 \times 10^{-12}$ erg s$^{-1}$ cm$^{-2}$, which is roughly a factor of two lower than the observed ROSAT flux in the same energy range (Moran et al. 1996); this lack of agreement may be attributable to their larger beam, a different background subtraction technique, or both. The observed 2-10 keV flux is $4.9 \times 10^{-12}$ erg s$^{-1}$ cm$^{-2}$, consistent with ASCA results (Ptak et al. 1997) and corresponding to a luminosity of $1.4 \times 10^{40}$ erg s$^{-1}$.

3.1. Spatial and timing analysis

The source is clearly extended in the BeppoSAX image in both the 0.1-2 keV and 2-10 keV band. Analysis of the resolved emission is postponed to future works; here we present only the analysis of the unresolved nuclear emission. In the following $N_{H_{gal}}=1.28 \times 10^{20}$ cm$^{-2}$ (Dickey & Lockman 1990) is taken.

No short or long term variability is detected from the present data in either energy band: this is consistent with a thermal origin of the 2-10 keV emission, as discussed below.

### Table 3: Bremsstrahlung + lines model

| KT$^{brem.}$ | Element | Energy | EW |
|--------------|---------|--------|----|
| keV          | keV     | eV     |
| 7.40$^{+0.18}_{-0.71}$ | Fe$^{XVIII}/Ne$ | 0.95$^{+0.04}_{-0.05}$ | 101$^{+49}_{-38}$ |
|               | Si$^{XIV}$ | 1.91$^{+0.04}_{-0.05}$ | 70$^{+23}_{-29}$ |
|               | S$^{XV}$  | 2.42$^{+0.05}_{-0.06}$ | 74$^{+34}_{-28}$ |
|               | Fe$^{XXV}$ | 6.69$^{+0.07}_{-0.07}$ | 310$^{+119}_{-78}$ |

Note: The value of the $A_{LECS}/A_{MECS}$ constant used for this simultaneous fit is 0.64$^{+0.04}_{-0.03}$

3.2. Spectral analysis

At first, we used a bremsstrahlung model plus emission lines to parameterize the line energies and intensities detected with BeppoSAX. The spectra in both bands were fit simultaneously with the relative normalizations free to vary. The emission lines are evident in Fig.1 and the fitted
The BeppoSAX 2-10 keV continuum clearly requires a thermal model: a hard power law alone (as allowed by ASCA data, Ptak et al. 1997) seems to be ruled out ($\Delta\chi^2=49$) by the present data.

We find that the spectra are well fitted by a double Raymond-Smith model (see Table 4 and Fig.2). The results found using alternative thermal models (e.g. Meka and Mekal models in XSPEC) confirm both the temperature and abundances found with the Raymond-Smith model. The LECS data show a residual excess below 1 keV, requiring a soft component with $K_T<1$ keV, as was also found by Ptak et al. (1997) with ASCA.

The Fe K line (consistent with emission from Fe$^{XXV}$) at 6.7 keV has been unambiguously detected for the first time in NGC253. It is relatively narrow, with an equivalent width of 310 eV, a value roughly consistent with the upper limits placed by previous studies (Ohashi et al. 1990; Ptak et al. 1997); we note that a similar emission line was also detected in M82 by ASCA (Ptak et al. 1997). Other lines clearly detected are Si, S and Fe$^{XVIII}$/Ne (see Table 3), in agreement with ASCA results. The best fit temperature obtained using a double Raymond-Smith model is ~6.5 keV, higher than expected but consistent with supernovae temperatures. The reliable detection of the Fe K line in NGC253 allows us to determine the metallicity of the line-emitting gas, and we find, for the hard component, a value of 0.25 solar, again consistent with the sub-solar values, based on upper limits, predicted by Ohashi.

### Table 4: Double Raymond-Smith model

| $K_T^{soft}$ keV | $A_{soft}$ | $K_T^{hard}$ keV | $A_{hard}$ |
|------------------|------------|------------------|------------|
| 0.90$^{+0.19}_{-0.23}$ | 1          | 6.52$^{+0.56}_{-0.50}$ | 0.25$^{+0.08}_{-0.07}$ |

Note: The value of the $A_{LECS}/A_{MECS}$ constant used for this simultaneous fit is $0.64^{+0.04}_{-0.03}$
et al. (1990) and Ptak et al. (1997). However, the quality of the LECS data is too poor to give a reliable estimate of the metallicity of the soft component.

4. Conclusions

The detection of the iron line at 6.7 keV in this starburst galaxy is particularly interesting: other galaxies, namely LINERs and/or low luminosity active galaxies tend to show Fe K line energies higher than AGN (Iyomoto et al. 1997) raising the question of the nature and origin of the line detected in these galaxies in the light of our results. The high temperature thermal plasma and the presence of the bump around 1 keV in the spectra of NGC253, are at present puzzling and require further investigation.

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