ASCA OBSERVATIONS OF X-RAY EMISSION FROM ULTRA-LUMINOUS INFRARED GALAXIES

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1. Introduction

Since the discovery of ultra-luminous infrared galaxies (hereafter ULIRGs), the origin of their huge luminosities has been a controversial issue (see, e.g., Sanders & Mirabel 1996).

The peculiar morphologies of ULIRGs indicate that they are interacting/merging systems. Optical and near-infrared spectroscopic observations show that a starburst is present in almost all ULIRGs. These lines of evidence suggest that ULIRGs are starbursts, whose activity was induced by an interaction between galaxies.

On the other hand, optical spectroscopic observations also show that a significant fraction of galaxies with “warm” infrared colors (i.e., high $f_{25}/f_{60}$ ratios) are classified as Seyferts. Spectropolarimetry and near-infrared spectroscopy also show that many “warm” galaxies harbor hidden AGNs.

On the basis of these results, Sanders et al. (1988) proposed an evolutionary scenario from ULIRGs to optical quasars. They identified “cold” (small $f_{25}/f_{60}$ ratio) ULIRGs as those at an initial, dust-enshrouded stage which are energetically dominated by starbursts, and “warm” ULIRGs as
those at a transition stage to optical quasars, in which AGNs contribute significantly to their luminosities.

2. Hard X-ray observations by ASCA

In order to reveal the nature of ULIRGs, it is essential to establish which mechanism is the dominant source of luminosity at each stage. However it is very difficult to evaluate the relative contributions of the two activities in ULIRGs based only on optical and near-infrared spectroscopic observations, since these observations can be severely affected by heavy extinction present in ULIRGs.

We have two frequency windows which can penetrate the large column density of ULIRGs and reveal their natures: one is the mid- and far-infrared region (Genzel et al. 1998, Lutz et al. in these proceedings) and the other is the hard X-ray region. Here we present preliminary results of our on-going project to observe hard X-ray emission from ULIRGs using the Japanese X-ray satellite ASCA. Iwasawa (1998) also discuss hard X-ray emission from some of our sample galaxies. Hard X-ray observations are indispensable tools to reveal the origin of the luminosities in ULIRGs for the following reasons:

1. Hard X-ray emission can penetrate heavy extinction with $N_H$ as large as $10^{24}$ cm$^{-2}$.
2. Starburst and AGN show completely different spectra in hard X-rays, and each component has a different canonical value of $L_X/L_{bol}$: it is $\sim 0.1$ for Seyfert 1 type objects and is $\sim 10^{-4}$ for starburst galaxies (Kii et al. 1997). These characteristics enable us to make quantitative estimates of the relative contributions from AGN and starburst activity.

3. Results

3.1. STARBURSTS IN ULIRGS

Figure 1 shows three representative X-ray spectra of ULIRGs. The top panel shows the spectrum of Arp 220. The spectrum is very soft, can be fitted by thermal plasma models, and is similar to those of typical starburst galaxies. The $L_X/L_{bol}$ ratio is $3 \times 10^{-5}$, which is even lower than the average value for typical starbursts ($\sim 10^{-4}$).

No emission is detected above 3 keV, which would be mostly due to an AGN if present. The upper limit of the AGN contribution to the total luminosity is less than 0.1 %, even if we assume that the AGN is heavily obscured by a gas column with $N_H = 10^{23}$ cm$^{-2}$.