HOT GASEOUS HALO IN THE ELLIPTICAL AND SPIRAL GALAXIES

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1. Introduction

The Einstein observations revealed that starburst and luminous elliptical galaxies had X-ray halo. These galaxies have quite different stellar population. Starburst galaxies contain young massive stars, while elliptical galaxies generally contain an old-metal rich population dominated by K and M giants. Therefore a question is why these two type of galaxies commonly have hot gas, in spite of quite different stellar populations. In order to address this question, we observed these galaxies with ASCA. In this paper, I would like to present observational results, then compare the physical parameters of the hot gas in these galaxies.

2. Hot Gaseous Halo in Spiral Galaxies

2.1. STARBURST GALAXIES

Starburst galaxies are one type of spiral galaxies with violent star formation of a rate > 1 Mo yr^{-1}. M82 is a well-known nearby starburst galaxy. Figure 1a shows an X-ray image of M82, superposed on the optical image. The diffuse X-rays are extending toward the minor axis of the galaxy with the extension of $\sim$ 6 kpc.

We analyzed the ASCA SIS spectrum within a 6 arcmin radius (Figure 1b). The X-ray spectrum was well described by a model consisting of a two-temperature plasma with kT$\sim$ 0.31 keV and kT$\sim$0.95 keV and a power law spectrum. The lower temperature plasma was more extended than the higher temperature plasma (Tsuru et al. 1997), consistent with the temperature gradient found by the ROSAT PSPC (Strickland et al. 1997). We further obtained that the metal abundance in the hot gas is less than 1 solar, in particular, iron abundance is found to be extremely small.

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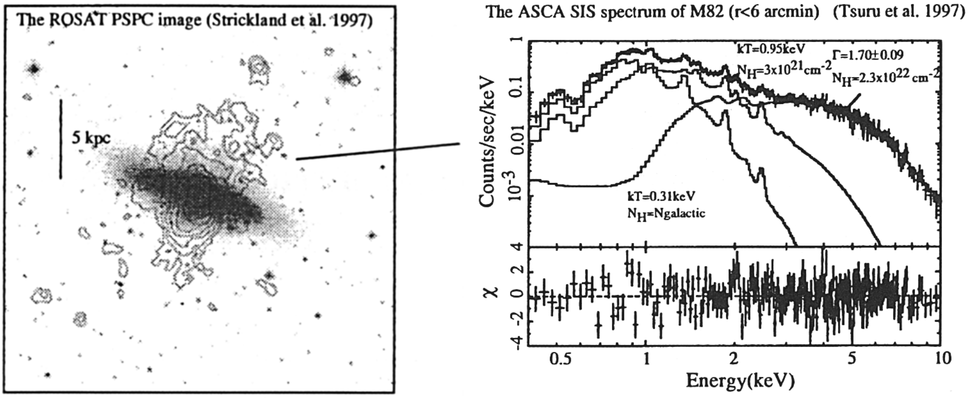

Figure 1. (a) the ROSAT PSPC image and (b) the ASCA SIS spectrum for M82.

TABLE 1. Summary of the hot gas in M82

size of halo	6 kpc
temperature	(0.3-1)$\times 10^7$ K
abundance	$<$ 1 solar, (Fe/H) $<$ 0.1 solar
total gas mass	10^7 Mo
total energy	10^{56} erg
cooling time	1 Gyr
outflow	yes (dM/dt$\sim$0.7Mo yr^{-1}, v_w=(1-3)$\times 10^3$ km s^{-1})
morphology	extending to the minor axis

The Soft band X-ray luminosity has been found to be well correlate to the far infrared luminosity (e.g. David et al. 1992) and the Bracket γ luminosity (e.g. Ward 1988). Therefore the origin of hot gas would be the starburst activity. Type II SNe frequently occurs in starburst galaxies with the SN rate of 0.1 ($L_{fir}/10^{44}$ erg s^{-1}) yr^{-1}, and total energy of 10^{51} erg. Then the energy input rate by the SN is estimated to be 10^{43} erg s^{-1}, far exceed the observed luminosity of 10^{40} erg s^{-1}. Therefore the soft X-ray can be explained by hot gas heated by type II SNe.

2.2. LINERS AND NORMAL SPIRAL GALAXIES

LINERs are another types of spiral galaxies. ASCA observed several LINERs, and found thin thermal X-rays with kT$\sim$0.5 keV (Terashima et al. 1997). The metal abundance was sub-solar. For NGC 1097 and NGC 5194, iron abundance was extremely small. These parameters are similar to those for starburst galaxies, hence most of LINERs would have similar hot gas

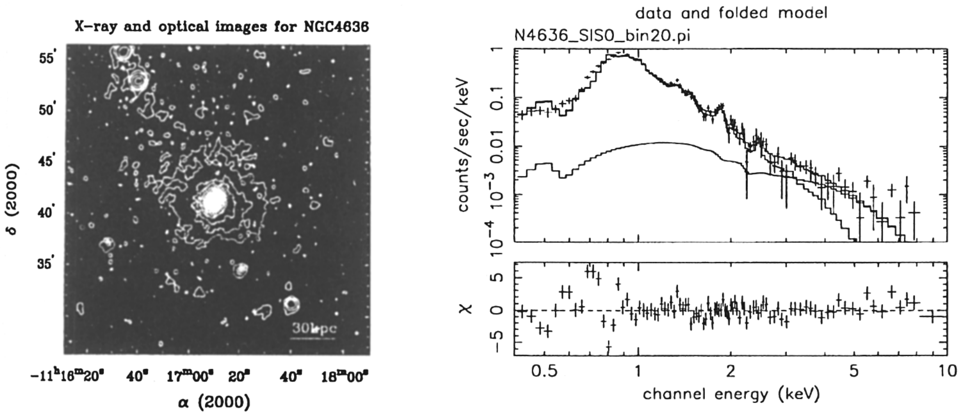

Figure 2. (a) the ROSAT PSPC image and (b) the ASCA SIS spectrum for NGC4636.

with starburst galaxies.

How about normal spiral galaxies? Fabbiano & Trinchieri (1985) pointed out that the X-rays from normal galaxies are described by the superposition of discrete sources. In fact, ROSAT HRI observed M31, and found that most of the X-rays are resolved into point sources (e.g. Primini et al. 1993). Normal galaxy, which have less activity in the nuclear region, would be gas-poor system.

3. Hot Gaseous Halo in Elliptical galaxies

The other famous halo object is an early type galaxy. Figure 2a is the X-ray contour of NGC 4636 overlayed on the optical image. An extended emission with r$\sim$50 kpc surrounding the galaxy is clearly seen. The radial profile of the Einstein results was well fitted with a single β model of β=0.45. Using this model, the total mass of X-ray gas was estimated to be 7×10^9Mo. Recently ASCA performed deep observations on NGC 4636, and found that the radial profile was described with a two-β model (Makishima et al. 1997).

We found that the ASCA SIS spectrum is well fitted by a two-component model; a thin thermal emission (kT$\sim$0.76 keV) and a hard component (kT >4 keV) (Awaki et al. 1994). The abundance ratio of the thin thermal component was obtained to be similar to the solar, but smaller than 1 solar.

I note that there are luminous elliptical galaxies with less halo. NGC 4365 has the same optical luminosity as that of NGC4636. The spectrum of NGC 4365 is characterized by a thermal model with kT> 4 keV (Matsumoto et al. 1997).

In early type galaxies, there are many evolved star. Using the mass loss

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TABLE 2. Summary of the hot gas in NGC 4636

size of halo	40 kpc
temperature	1×10^7 K
abundance	0.3 solar
total gas mass	10^{10} Mo
total energy	10^{59} erg
cooling time	1 Gyr
wind	no (static halo,binding mass 10^{12} Mo)
morphology	spherical

rate of 0.015 $[L_B/(10^9Lo)]$ Mo yr^{-1} (Faber & Gallagher 1976), the accumulated mass from evolved stars is estimated to be 10^{10} $[L_B/(7\times10^{10}Lo)]$ [t/10Gyr] Mo. This is comparable to the mass of the hot gas. Therefore, evolved stars can supply all the mass of the hot gas. Unlike to starburst galaxies, type Ia SN frequently occurs in early type galaxies. The energy input rate by the SN is estimated to be 4×10^{41} $(r_{SNIa}/0.22)(E_{SNIa}/6\times10^{50}erg)$ $(L_B/10^{11}$ Lo) erg s^{-1}. This is nearly equal to the luminosity of the hot gas. Accordingly, the origin of the hot gas would be late type stars; red super giants and/or type Ia SN.

4. Summary

Although spiral and elliptical galaxies have hot gas, the physical parameters (e.g. iron abundance, wind, etc) are different with each other. The difference is attributable due to the stellar population in the galaxy. The stellar population depends on evolutional stage of a galaxy. Therefore, the hot gas in starburst galaxies and in elliptical galaxies would be produced in an early stage (<1Gyr) and a late stage after star formation, respectively.

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