RevMexAA (Serie de Conferencias), **17**, 85–86 (2003)

AGN AND STARBURST COMPONENTS OF THE ULIRG NGC 6240: THE *CHANDRA* HIGH-RESOLUTION VIEW

Stefanie Komossa[1]

RESUMEN

Se cree que muchas galaxias masivas distantes y polvosas son los equivalentes de los ULIRGs a altos corrimientos al rojo. Los ULIRGs locales son laboratorios ideales para el estudio de la física de la formación de galaxias (muchos ULIRGs son galaxias fusionadas), de los procesos de enriquecimiento del medio intergaláctico, de la física de los supervientos impulsados por los brotes estelares en los centros, y para buscar AGNs ocultos. Se piensa que el ULIRG NGC 6240 es una fusión en proceso de formar una galaxia elíptica. Su cercanía (es una de las más cercanas de la clase ULIRG) hace que sea apropiada para estudiar este tipo de objetos. En este trabajo analizamos las propiedades en rayos X de NGC 6240 y presentamos los primeros resultados de nuestras observaciones profundas con el *Chandra* ACIS-S, que permiten estudios espaciales y espectrales simultáneos de las componentes que emiten rayos X en NGC 6240. Se detectan ambos núcleos, así como una emisión extendida cuya rica estructura cambia en función de la energía.

ABSTRACT

Many distant massive and dusty galaxies are believed to be ULIRG equivalents at high redshift. *Local* Ultraluminous Infrared galaxies (ULIRGs) are ideal laboratories to study the physics of galaxy formation (many ULIRGs are mergers), the processes of IGM enrichment, the physics of superwinds driven by the nuclear starbursts, and to search for the presence of hidden AGN. The ULIRG NGC 6240 is believed to be a merger in the process of forming an elliptical galaxy. Its proximity - the galaxy is one of the nearest members of the class of ULIRGs - makes it well suited to study the physics of this class of objects. In this contribution, we provide a discussion of the X-ray properties of NGC 6240, and present first results from our deep *Chandra* ACIS-S observation which allows for the first time a simultaneous spatial and spectral study of the X-ray emitting components of NGC 6240. Both nuclei as well as extended emission, changing its rich structure in dependence of energy, are detected.

Key Words: **GALAXIES — X-RAYS — INDIVIDUAL OBJECTS: NGC 6240**

1. INTRODUCTION

Ultraluminous infrared galaxies (ULIRGs) are characterized by their huge luminosity output in the infrared, predominantly powered by super-starbursts and/or hidden AGN (e.g., Genzel et al. 1998, Sanders 1999). Many distant *SCUBA* sources, massive and dusty galaxies, are believed to be ULIRG equivalents at high redshift. *Local* ULIRGs are therefore ideal laboratories to study the physics of galaxy formation (many ULIRGs are mergers), the processes of IGM enrichment, the physics of superwinds driven by the nuclear starbursts, and to search for the presence of hidden AGN.

NGC 6240 is one of the nearest members of the class of ULIRGs, and is considered a key representative of its class. The galaxy is a merger in the process of forming an elliptical galaxy.

In X-rays, NGC 6240 was detected by *ROSAT* as one of the most luminous X-ray emitters in extended emission among galaxies (Komossa et al. 1998). It was suggested to harbor a hidden AGN, seen in scattered emission in X-rays (e.g., Mitsuda 1995; Schulz et al. 1998; Komossa et al. 1998; Iwasawa & Comastri 1998), confirmed by the detection of hard X-ray emission extending up to 20-100 keV (Ikebe et al. 2000; Vignati et al. 1999).

It remained basically open, which of the two nuclei of NGC 6240 is the active one (or whether even both of them are); *HST* observations (Rafanelli et al. 1997) suggested that the southern nucleus harbors an AGN or a heavily obscured LINER.

The questions regarding the onset of starburst and AGN activity and their evolution in mergers are of fundamental importance for our understanding of AGN/black hole formation and evolution in general. Given the complex nature of the X-ray emission of NGC 6240 with contributions from many components suggested from previous X-ray observations, spatially resolved spectroscopy is crucial to disentangle all contributing components, to determine their nature, and to derive their physical properties. Here, we report first results from the first spatially re-

[1]MPE Garching, Germany

Galaxy Evolution: Theory and Observations (Cozumel, Quintana Roo, México, 8-12 April 2002)
Editors: Vladimir Avila-Reese, Claudio Firmani, Carlos S. Frenk & Christine Allen

solved X-ray spectroscopy of NGC 6240, carried out with the ACIS-S instrument onboard the *Chandra* X-ray observatory (full results will be published by Komossa et al. 2002).

2. RESULTS

The *Chandra* observation of NGC 6240 was carried out in 2001 with an effective exposure time of 37 ksec. Standard data reduction and analysis procedures were applied.

2.1. *X-ray morphology*

The *Chandra* image of NGC 6240 reveals a wealth of structure, changing in dependence of energy. A large part of the X-ray emission of NGC 6240 is extended, confirming previous results from *ROSAT* (Komossa et al. 1998, Schulz et al. 1998) and a short *Chandra* HRC-I observation (Lira et al. 2002). The previous observations did not provide any energy information, though.

Several X-ray 'loops' and knots are visible which correlate well with the Hα emission of NGC 6240. These features are most prominent between 1 and 2.5 keV. Above 1.5 keV, X-ray emission from the direction of the northern nucleus of NGC 6240 starts to emerge. The hard X-ray image is dominated by emission from two compact sources, spatially coincident within the errors with the IR positions of the two nuclei of NGC 6240. The southern nucleus is more prominent than the northern nucleus.

2.2. *X-ray spectroscopy*

The widely extended X-ray emission of NGC 6240 is generally well described by a MEKAL model with $kT = 0.81 \pm 0.05$ keV and absorption with column density $N_{\rm H} = (3.1{\pm}0.4)\,10^{21}$ cm^{-2}.

The spectra of both nuclei of NGC 6240 are very hard in X-rays and show strong, neutral iron Kα lines. The southern nucleus is brighter in the iron line than the northern nucleus.

3. DISCUSSION

Using *Chandra* ACIS-S we found that *both* nuclei of NGC 6240 are emitters of luminous hard X-ray emission, on which a strong neutral iron Kα line is superposed. These properties identify both nuclei of NGC 6240 as active. In particular, a strong, neutral Fe Kα line is not produced in a starburst-superwind, but originates from fluorescence in cold material illuminated by a hard continuum spectrum. For the first time, we can disentangle the contribution to the hard X-ray luminosity from the southern and northern nucleus. The observed (0.1-10) keV, absorption-corrected, fluxes correspond to *observed* X-ray luminosities of the southern and northern nucleus, $L_{\rm x,S} = 1.9\,10^{42}$ erg/s, $L_{\rm x,N} = 0.7\,10^{42}$ erg/s, respectively. The *intrinsic* luminosities are significantly larger, because it has been repeatedly argued that the emission we are seeing in X-rays below 10 keV is scattered emission. The strength of the neutral Fe Kα line in both nuclei suggests a scattering geometry for *both* AGN.

The presence of supermassive binary black holes, as now discovered in NGC 6240, is of importance for our understanding of the formation and evolution of AGN and the formation of elliptical galaxies via mergers.

Ultimately, the binary AGN of NGC 6240 will coalesce to form one nucleus. The final merging of the supermassive black holes is expected to produce a strong gravitational wave signal. In fact, such events are expected to generate the clearest signals detectable with the gravitational wave detector LISA which will be placed in earth-orbit in the near future.

REFERENCES

Genzel, R., Lutz, D., Sturm, E., et al. 1998, ApJ, 498, 579
Ikebe, Y., Leighly, K., Tanaka, Y., et al. 2000, MNRAS, 316, 433
Iwasawa, K., Comastri, A. 1998, MNRAS, 297, 121
Komossa, S., Schulz, H., Greiner, J. 1998, A&A, 334, 110
Komossa, S., Burwitz, V., Hasinger, G., et al. 2002, ApJL, subm.
Lira, P., Ward, M., Zezas, A., Murray, S. S. 2002, MNRAS, in press
Mitsuda, K. 1995, Ann.N.Y.Acad.Sc., 759, (New York: The New York Acad. of Sc.), 213
Rafanelli, P., Schulz, H., Barbieri C., Komossa, S., Mebold, U., Baruffulo, A., Radovich, M. 1997, A&A, 327, 901
Sanders, D. B. 1999, Ap&SS, 266, 331
Schulz, H., Komossa, S., Berghöfer T., Boer, B. 1998, A&A, 330, 823
Vignati, P., Molendi, S., Matt, G., et al. 1999, A&A, 349, L57

Stefanie Komossa: Max-Planck-Institut fuer extraterrestrische Physik, Giessenbachstr. 1, D-85748 Garching, Germany, skomossa@mpe.mpg.de.

Galaxy Evolution: Theory and Observations (Cozumel, Quintana Roo, México, 8-12 April 2002)
Editors: Vladimir Avila-Reese, Claudio Firmani, Carlos S. Frenk & Christine Allen