1) UNDERSTANDING THE PUZZLING X-RAY SPECTRUM OF THE SO GALAXY NGC 4382
2) NGC 43819: SPECTRAL ANALYSIS OF THE PROTOTYPICAL EARLY MERGER
3) ASCA OBSERVATIONS OF A DYNAMICALLY YOUNG ELLIPTICAL: NGC 4125

NASA Grant NAG5-2946

Final Report

For the Period 1 June 1995 through 31 December 2000

Principal Investigator
Dr. Giuseppina Fabbiano

March 2001

Prepared for:

National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

Smithsonian Institution
Astrophysical Observatory
Cambridge, Massachusetts 02138

The Smithsonian Astrophysical Observatory
is a member of the
Harvard-Smithsonian Center for Astrophysics

The NASA Technical Officer for this grant is Dr. Nicholas White, Code 668, Laboratory for High Energy Astrophysics, NASA/Goddard Space Flight Center, Greenbelt, Maryland 20771.

We have analyzed the ASCA observationsof NGC 4382, NGC 4038/9, NGC 4125 and produced papers for publication.

NGC 4382 is one of the E and S0 galaxies detected with the lowest X-ray to optical luminosity ratio. These galaxies have a peculiar X-ray (0.1-3 keV) spectrum, with a significant excess of counts in the lowest spectral channels (< 1 keV) relative to the spectral count distributions of X-ray brihter E and S0 galaxies. Analyzing the ROSAT PSPC observation of NGC 4382 it was unclear whether this soft excess was due to a real very soft component in a multi-component spectrum, or reflected an extremely low metal abundance in an isothermal hot gas. Our ASCA observations show that the low-abundance single-temperature model does not fit well to the X-ray spectrum, in agreement with our previous suggestions. A better explanation is a composite spectrum with a very soft component (0.3 keV) in addition to a harder (5 keV) component from X-ray binaries. In this model, the abundance cannot be constrained. More complex spectral models are also possible.

The ASCA observations of The Antennae (NGC4038/9) show that at least two spectral components are rquired to describe the emission: thermal emission from a plasma at 0.8 keV, and a component at higher energies. The hot gas contributes about half of the flux in the 0.5 to 6 keV band. If the column density to the higher energy componet is $> 2 \times 10^{21}$ cm^{-2}, then the fitted abundance in the hot gas component is less than 0.2 solar. This low abundance is not expected for the hot interstellar medium in NGC4038/9 in which supernovae and star formation (expected to enrich and heat the gas) are ongoing. We do not detect any spatial variations in the spectrum. We relate these findings to data obtained by other satellites (*Einstein*, ROSAT) for this interacting galaxy pair.

NGC4125's ASCA data was analyzed jointly with its Beppo-SAX observation. A hard component (kT */sim* 4-10 keV) is observed together with a thermal component with line emission.

Additional work included the analysis of the observation of M94 with Dr. Matsushita from Tokyo University, and the analysis of the archival ASCA observations of the source M81 X-9, together with archival Einstein, ROSAT and BeppoSAX data. This latter work is part of the Ph.D. thesis of Ms. Valentina LaParola, a graduate student at Palermo University in Italy, and has been accepted for publication in Ap.J. We find that the spectral/temporal behavior of this source is typical of black-hole binaries and suggest that the source is an intermediate mass (about 100 solar masses) black hole.

Published papers resulting from this work are:

1. ASCA Observations of 'The Antennae' (A. E. Sansom, T. Dotani, K. Okada, A. Yamashita, and G. Fabbiano) 1996, MNRAS, 281, 48.

2. X-Rays from the Interacting Galaxy Pair NGC4038/9 (A.E. Sansom, T. Dotani, and G. Fabbiano), in 'Roetgenstrahlung from the Universe', H.U. Zimmermann, J.E. Truemper, and H. Yorke, eds., MPE Report No. 263 (Garching: MPE), p.393.

3. ASCA Spectra of the X-ray Faint S0 Galaxy NGC 4382 (D.-W. Kim, G. Fabbiano, H. Matsumoto, I. Koyama, and G. Trinichier), *The Astrophysical Journal*, 468, 175.

4. Understanding the X-ray Propertiesof E and S0 Galaxies (G. Fabbiano), an invited talk was given at the meeting on 'X-ray Probing of Complex Gravitational Systems' at the Accademia dei Lincei in Roma, Italy (November 23, 1996).

5. Broad band properties of medium and low Lx/Lb early type galaxies (G. Trinchieri, S. Pellegrini, A. Wolter, G. Fabbiano, F. Fiore), Astronomy and Astrophysics, v.364, p.53-69 (2000)

6. The Ultra-luminous M81 X-9 source: 20 years variability and spectral states (V. La Parola, G. Peres, G. Fabbiano, D.-W. Kim, F. Bocchino) 2001, *The Astrophysical Journal*, in press.