NASA-CR-201823

X-RAY SPECTROSCOPY OF COOLING FLOWS

NASA Grant NAG5-2607

Final Report

For the Period 1 June 1994 through 30 November 1995

Principal Investigator
Dr. Andrea Prestwich

July 1996

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, NASA, Goddard Space Flight Center, Greenbelt, MD 20771.

Introduction

Cooling flows in clusters of galaxies occur when the cooling time of the gas is shorter than the age of the cluster; material cools and falls to the center of the cluster potential. Evidence for short X-ray cooling times comes from imaging studies of clusters (e.g. Forman and Jones 1982; Fabian 1994) and X-ray spectroscopy of a few bright clusters. Because the mass accretion rate can be high (a few 100 $M_\odot$ year^{-1}) the mass of material accumulated over the lifetime of a cluster can be as $10^{12} M_\odot$. However, there is little evidence for this material at other wavelengths, and the final fate of the accretion material is unknown. X-ray spectra obtained with the Einstein SSS show evidence for absorption; if confirmed this result would imply that the accretion material is in the form of cool dense clouds. However ice on the SSS make these data difficult to interpret.

We obtained ASCA spectra of the cooling flow cluster Abell 85. Our primary goals were to

- Search for multi-temperature components that may be indicative of cool gas
- Search for temperature gradients across the cluster
- Look for excess absorption in the cooling region

Figure 1 - Spectrum of the Cooling Region

We fit a two-temperature(Raymond thermal plasma) model to the inner 210 Kpc of the SIS0 spectrum of Abell 85 (the exposure time was 35,000s) The models are summarized in Table 1 below. The second model, with N_H in excess of galactic, is a better fit. There are residuals at 1-2keV which may be due to uncertainties in the atomic data.

Model	χ^2/DOF	Reduced χ^2
<u>Two temperature</u> kT=6.7 (fixed) kT=2.1 (fit) $N_H = 3 \times 10^{20}$ (fixed, galactic)	347/229	1.54
<u>Two temperature</u> kT=6.7 (fixed) kT=1.8 (fit) $N_H = 8 \times 10^{20}$ (fit)	276/229	1.23

We also evaluated the N_H as a function of radius. The central bin encompassing the cooling region shows clear evidence for excess absorption, indicative of cool gas. There is a slight rise in absorption in the outer bin, probably an artifact of mirror scattering.

Summary of Results

- Spectra extracted outside of the cooling flow region are fit by a single temperature plus galactic absorption.
- The central bin requires a two temperature fit, showing the presence of cool gas.
- The central bin shows clear evidence for excess absorption.
  - The excess absorption $N_H \sim 5 \times 10^{20}$, less than that reported by Fabian et al., 1994 for other clusters. Because of uncertainties in the early ASCA response matrices, the absorption reported by Fabian et al., may be overestimated.
  - The gas mass implied by this N_H is $\sim 2 \times 10^{11} M_{\odot}$. This is approximately a factor of 10 below that expected if the current cooling rate (230 $M_{\odot}$ year^{-1}) has been constant over the age of the cluster (10^{10} years).