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Studies of Gas in Cooling Flow Clusters

Principal Investigator: Dr. Esther M. Hu

Co-Investigator: Dr. Lennox L. Cowie

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Institution: Institute for Astronomy,
University of Hawaii
2680 Woodlawn Drive
Honolulu, Hawaii 96822

This report describes studies of cooling flows in rich clusters of galaxies, found to be sources of strong, extended X-ray emission seen by the *EINSTEIN* satellite. Two complementary lines of investigation were pursued: (1) studies of the dust content of the cluster gas using multi-wavelength data from archival records of the *IUE* and *IRAS* satellites in combination with previously obtained optical and (2) coronal line spectroscopic studies of the bright emission systems.

We have completed *IUE* observations and archival studies of 10 rich clusters of galaxies which show optical emission from gas cooling at the core. By applying a reddening analysis to line ratios of fluxed Lyα (UV) and Hα (optical) data on the emission systems, we have shown that there is a significant systematic excess above galactic extinction along the lines-of-sight towards these clusters. Mean cluster extinctions of $< E_{B-V} > \sim 0.19$ have been found, and the observed infrared emission of ~ 0.5 Jy at 100 μ as analyzed from *IRAS* observations is consistent with this extinction estimate. The amount of dust in the cluster atmospheres suggests that there has been significant evolution of the intracluster medium through gas injection from the member galaxies – a result consistent with the X-ray spectrometer abundance measurements. Further, we estimate that future missions such as *ISO* and *SIRTF* should have sufficient sensitivity to both resolve and map large samples of clusters at cosmologically significant distances. This work is now in press, and will appear in the *Astrophysical Journal.*

We have also studied the large mass inflows inferred in the cooling flow clusters from the *EINSTEIN* X-ray data by comparing these data with measurements of optical coronal lines. As probes of gas at temperatures intermediate to the X-ray ($\sim 10^8$ K) and the optical ($\sim 10^4$ K) emission, the coronal lines provide a means of studying details of the cooling process. Moreover, because these lines are accessible at optical wavelengths, detections of these features provide detailed spatial resolution (which is not available in the X-ray data) on the sites of mass deposition and well as a separate determination of the cooling rates. We have detected iron coronal lines ([Fe XIV] and [Fe X]) in both the nucleus and filament

systems using long-slit spectroscopy of one of the cooling flow clusters. This unambiguously shows that substantial cooling is occuring in these systems, and also indicates high mass inflow rates for the region sampled along the slit – on the order of $\sim$ 10% or more of the value obtained from the X-ray imaging data, thus confirming the high mass flow estimates for the cooling flow systems. This work is currently being written up for submission to the *Astrophysical Journal.*

References

Hu, E. M. 1991, "Lyman α Emission from Cooling Flows and Measures of the Dust Content of Rich Clusters of Galaxies" *Ap. J., in press.*

Hu, E. M. and Egami, E. 1991, "Coronal Line Detections in the A2597 Cooling Flow System" *in preparation.*