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The Detection of Large Amounts of Cool, X-ray Absorbing Gas in Distant Clusters of Galaxies What Does This Mean?

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SUMMARY

We present an X-ray spectral study of 12 distant ($z = 0.17 - 0.54$) rich clusters of galaxies observed with the *Einstein* Observatory Imaging Proportional Counter. These X-ray spectral data show evidence for substantial excess absorptions beyond those expected in the Galaxy, indicating the presence of large amounts of X-ray absorbing cool gas in these distant clusters. The mean value of the excess absorptions corresponds to an absorbing gas column density $\gtrsim 10^{21}$ cm^{-2}. We calculate the X-ray luminosities of the clusters with observed fluxes only in the 0.8-3.5 keV band where the fluxes are less effected by the absorptions, and use the temperature-to-luminosity correlation (known only for nearby clusters) to estimate the temperatures of the hot intracluster medium (ICM) in the distant clusters. These temperature estimates, together with the spectral fits, provide further constraints on the column densities in the individual clusters. For the cluster CL 0016+16 (Fig. 1), the lower limit on the column density is found to be $\sim 8 \times 10^{20}$ cm^{-2} at the $\sim 99\%$ confidence limit. We also show that the ratio of the temperature obtained from the spectral fit to the temperature expected from the correlation tends to decrease with increasing look-back time, indicating possible temperature evolution of the hot ICM in the recent past. The inclusion of this evolutionary effect further increases the absorptions required in fitting the spectra. There are some important implications of these findings:

- ▷ The absorptions, together with temperature evolution, may explain why there are more high-luminosity clusters now than there were in the past.
- ▷ There might be a link between the excess absorption and the redness of some distant clusters. An apparent anti-correlation between the absorption and the percentage of blue cluster galaxies may be caused by dust extinction, likely associated with the cool gas.

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▷ The free-free emission from the X-ray absorbing gas, if existing in the $\sim 10^4$ K warm phase, could cause some serious confusion in the measurements of the Sunyaev-Zel'dovich effect of the hot ICM. Rim-brightened radio continuum emission features may be produced in the case that the gas is distributed primarily in shell-like regions surrounding the X-ray emitting central regions of the clusters. This could cause an overestimate of the S-Z effect in these clusters and an underestimate of H_o obtained by such studies.

A conceivable origin of the cool gas is the ram-pressure stripping of the gas from individual galaxies when they were falling into the clusters. This may connect the production of the cool gas to the high percentage of "post-starburst" galaxies seen in distant clusters.

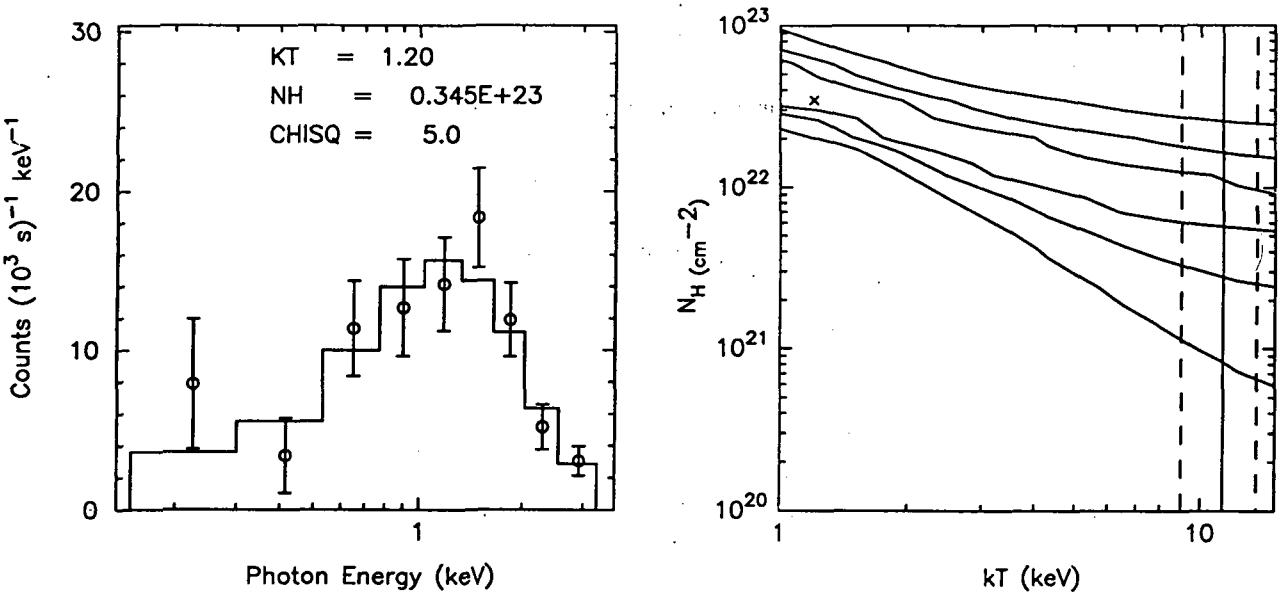

Fig. 1 The X-ray spectrum of the cluster CL0016+16 (z=0.54) and a model fit. The left side panel shows the best fit to the spectrum with a Raymond & Smith optically-thin thermal plasma model. The right side panel shows the 68%, 90%, and 99% confidence contours for T and N_H. The cluster temperature (solid line) and its uncertainties (dashed lines) are marked which are estimated from the cluster's luminosity using the $T - L_x$ correlation observed for nearby clusters.