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An X-ray Red-shift Test For Clusters of Galaxies Up to $z \geqslant 1$

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Abstract

Correlated measurements of red-shifted iron line emission and apparent surface brightness are suggested for unambiguously defining intrinsic X-ray characteristics for clusters of galaxies up to $z \gtrsim 1$. If some of the weak unidentified high galactic latitude X-ray sources are clusters at $z \sim 1$-3, then such correlated measurements should be feasible within the complement of instruments aboard the HEAO-B orbiting X-ray telescope observatory. In addition, those clusters at $z < 1$ would require spectral data from broader bandwidth experiments, such as the all-sky survey to be provided by the proportional counters aboard the first mission of the High Energy Astronomy Observatory (HEAO-A).

I. INTRODUCTION

As pointed out by Schwartz (1975), the X-ray signature of a cluster of galaxies (i.e., a spatially extended source) will be detectable with the HEAO-B X-ray telescope out to red-shifts $z \sim 1$ for sources of linear dimension greater than 200 kpc. In this note, it is suggested that the measurements of red-shifted X-ray line emission and apparent surface brightness could be combined to determine the intrinsic surface brightness for clusters up to $z \geqslant 1$ which may not be detectable in the visible band. The impetus for this suggestion comes from the recent Ariel 5 observation of iron K line emission from the Perseus Cluster (Mitchell et al., 1976).

II. TEST

According to general relativity (cf., Sandage, 1961) the apparent surface brightness (B') of an extended source may be expressed in terms of an intrinsic surface brightness (B) and the red-shift parameter (z) as follows

$$B' = B\,(1+z)^{-4} \tag{1}$$

for <u>all</u> values of the deceleration parameter (q_o), including that for the steady state model. Hence, if we assume that the dominant X-ray line observed for clusters at $z \geqslant 1$ is indeed emission from highly ionized iron (i.e., Fe XXV and/or Fe XXVI) then we may use the resulting value of z to correct the apparent surface brightness (via equation (1)) for a direct comparison with the intrinsic surface brightness measured for more nearby clusters (cf., Kellogg, 1974), with the aim of identifying regularity in the evolution of B with respect to z. Conversely, such regularity of inferred intrinsic surface brightness among several such sources (from $z \geqslant 0$ to $z \geqslant 1$) could be used to verify that the determination of z under the assumption that the line emission arises from iron is in fact valid.

III. DISCUSSION

Although 23 clusters of galaxies have been identified among known X-ray sources (Kellogg, 1974; Murray and Ulmer, 1976) there are about 40 high galactic latitude sources that remain unidentified (Markert et al., 1976). Bahcall et al. (1975) and Bahcall and Bahcall (1975) have ruled out several classes of visible objects (including Abell clusters) as candidates for all but a few of those sources. However, if we adapt the notion of the X-ray galaxy conjecture (Giacconi et al., 1971) to that of X-ray galactic clusters (i.e., clusters radiating mainly in X-rays) we might achieve a more readily verifiable sort of identification. In particular, Longair (1975) has suggested that some of the weak UHURU high galactic latitude sources may be clusters at $z \sim 1$ for which the plasma density may be ten times greater than in the Coma cluster (e.g., for a hot plasma that includes almost <u>all</u> of the virial mass rather than a tenth or less) and where the luminosity is thereby a hundred times greater. Since the cooling time in such a case would be $\sim 10^9$ years, Longair further suggests that a modest increase of sensitivity would permit the possibility of detecting such clusters out to $z \sim 3$, where the time-scale of the universe itself becomes $\sim 10^9$ years and where some of the clusters of galaxies forming at these epochs should be very intense X-ray sources. Such a conjecture is compatible with the results of an analysis of background fluctuations by Schwartz, Murray and Gursky (1976) where they conclude that the high-latitude X-ray sources are likely to contain a new class of objects, at cosmological distances.

IV. AN EXPERIMENT

K_α emissions by Fe XXV and/or Fe XXVI are red-shifted down in energy by a factor $(1+z)^{-1}$ to ~ 1.7 keV for $z \sim 3$ and ~ 3.4 keV for $z \sim 1$. This defines an X-ray band well suited to the HEAO-B X-ray telescope observatory. If we assume that some of the weakest unidentified high galactic latitude UHURU sources are clusters of galaxies at $z \sim 1$-3, then the solid state spectrometer aboard this observatory (Holt, 1976) will be sufficiently sensitive to detect such red-shifted lines of equivalent continuum width $\gtrsim 50$ eV, comparable to that already measured for the unshifted iron line from the Perseus Cluster (Mitchell et al., 1976). In general, the appropriate experiment involves defining the angular size of weak high galactic latitude sources that are extended but might otherwise be unidentified (e.g. no optical counterpart) by means of imaging instruments such as those aboard the HEAO-B observatory and then examining them further for apparent luminosity and spectral structure with a high resolution non-dispersive spectrometer such as the HEAO-B Si(Li) counter. Those extended sources without red-shifted iron line structure at or below 3.4 keV would include objects at $z < 1$ for which one would have to obtain spectral data from broader bandwidth experiments, such as the sensitive all-sky survey provided by the large proportional counter arrays aboard HEAO-A (cf., Peterson, 1975) and/or experiments especially designed for a limited number of well defined targets in shuttle-borne exposures.

Those unidentified high latitude sources exhibiting any spectral evidence of a line component (especially if the energy seems anomalous) in the data obtained from proportional counter experiments on current orbiting X-ray observatories (e.g., Ariel 5, SAS-3 and OSO-8) would be candidates for possible distant clusters to be included in the pointing programs of both the A and B HEAO missions. The monitor proportional counter co-alligned with the HEAO-B telescope itself would then serve as the follow-on standard for the measurements at the focal plane described in this paper.

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