CLUSTER EVOLUTION IN THE WIDE ANGLE ROSAT POINTED SURVEY (WARPS)

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A new catalogue of low luminosity ($L_x \leq 10^{44}$ erg s$^{-1}$) X-ray galaxy clusters covering a redshift range of $z \sim 0.1$ to $z \sim 0.7$ has been produced from the WARPS project. We present the number counts of this low luminosity population at high redshifts ($z > 0.3$). The results are consistent with an unevolving population which does not exhibit the evolution seen in the higher luminosity cluster population. These observations can be qualitatively described by self-similarly evolving dark matter and preheated IGM models of X-ray cluster gas, with a power law index for the spectrum of matter density fluctuations $n \geq -1$.

1 Galaxy cluster evolution

The dynamical timescales of clusters of galaxies are of the order $t_0$, the Hubble time. Clusters are therefore still young systems. Measurements of the evolution of the X-ray luminosity function (XLF) of the most luminous ($L_x \geq 10^{44}$) clusters in the Einstein Medium Sensitivity Survey (EMSS) show evidence for some negative evolution at redshifts $z \gtrsim 0.3$. Although these results allow some constraints to be put on cosmological and structure formation models they sample only the high end of the cluster XLF. The WARPS was designed to extend this measurement to the faint end of the XLF, at $z > 0.3$ (c.f. other similar projects), and to further test cosmological models.

2 The WARPS cluster sample

Serendipitous X-ray sources were detected in ROSAT PSPC archived fields in the 0.5-2 keV band using the Voronoi Tessellation and Percolation (VTP) method. From the 16.6deg$^2$ currently surveyed ($\sim 90$ fields) a sub-sample of sources with detected flux $> 3.5 \times 10^{-14}$ erg s$^{-1}$ cm$^{-2}$ (total flux $> 5.5 \times 10^{-14}$ erg s$^{-1}$ cm$^{-2}$) was extracted, extents and corrected fluxes were determined and complete optical followup was performed. Redshifts were obtained for most of the 34 cluster candidates which confirmed them as groups and clusters of galaxies with $10^{42} < L_x \leq 10^{44}$ erg s$^{-1}$ (0.5-2 keV) and $0.1 \lesssim z \lesssim 0.7$. 

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Since the detection efficiencies, exposure maps and flux corrections are well understood the statistical weight of each cluster can be accurately calculated.

3 Testing for evolution

In Figure 1 the differential number counts of WARPS clusters (corrected to a uniform sky coverage) with $z > 0.3$ are presented. For comparison, at $z > 0.3$ the RIXOS survey found a surface density of $0.33 \pm 0.15$ clusters deg$^{-2}$ (to a similar, slightly lower flux limit). The WARPS finds $0.84 \pm 0.22$ clusters deg$^{-2}$, a factor of 2.5 times higher. This discrepancy is almost certainly due to different detection efficiencies and data modeling.

We have compared our results with models constructed from the low redshift cluster XLF of the ROSAT BCS. The model predictions plotted in Figure 1 are the expected number counts obtained by integrating the $z = 0$ BCS XLF to high redshift and low luminosity with $q_0 = 0.5$ under varying assumptions about the cluster evolution.

Our conclusion is that the WARPS results show no significant evolution in the low luminosity cluster population at $z > 0.3$ (mean sample redshift $\simeq 0.4$). The amount of negative evolution allowed by the EMSS result is not seen. Interestingly, this is in qualitative agreement with the model described by Kaiser, where self-similar dark matter evolution combined with an initially hot IGM can reproduce the basic cluster observations. The low luminosity data here would suggest that Kaiser’s model could succeed if the power law index of the spectrum of matter density fluctuations is $n \geq -1$. Recent X-ray observations of element abundances in cluster gas also suggest a preheated IGM.

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Figure 1: Cluster differential number counts at high redshift. Points indicate WARPS cluster counts, dotted lines indicate possible spread in these counts due to remaining gaps in spectroscopic followup. The uppermost curve is the model prediction with no evolution ($q_0 = 0.5$), the middle curve is the prediction of negative evolution modeled as number density evolution, $\propto (1 + z)^{-2}$, and the lowest curve is the prediction from the minimum amount of evolution seen in the EMSS (approximated as number density evolution, $\propto (1 + z)^{-3}$).

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