Properties of galaxy groups and clusters in the fields of lensed quasars

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Abstract

Gravitationally lensed quasars can be used as a cosmological tool, however modeling of these systems requires mapping the gravitational potential along the line of sight to the quasar, including the lensing galaxy and its environment. Keeton et al. (2000) predict that at least 25% of lensing galaxies are part of a group or cluster and the growing observational evidence seems to confirm this. Finding and studying these lensing groups and clusters enhances the science that can be accomplished with lensing and provides a method for finding groups and clusters at cosmologically interesting redshifts ($0.1 < z < 0.7$). We have identified all observations of gravitationally lensed quasars available in the Chandra archive to search for diffuse X-ray emission from groups or clusters along the line of sight. We present a uniformly analyzed catalog of X-ray luminosities and temperatures for those fields with significant diffuse emission. These measurements are compared with optical data, where available, and with scaling relations.

Key words: galaxies: clusters — X-rays: galaxies: clusters

1. Introduction

Gravitational lenses that produce multiple images of background quasars can be an invaluable tool for measuring cosmological parameters, to better study the magnified distant quasars, and to explore the structure of the lensing galaxies. Modeling of these systems requires mapping the gravitational potential along the line of sight to the quasar, including the lensing galaxy and its environment. Keeton et al. (2000) predict that at least 25% of lensing galaxies are associated with a group or cluster, in agreement with growing observational evidence. Finding and studying these lensing groups and clusters enhances the science that can be accomplished with gravitational lensing and provides a method for finding groups and clusters at cosmologically interesting redshifts ($0.1 < z < 0.7$). We are searching for X-ray emission from galaxy groups and clusters in the fields of multiply-imaged quasars using Chandra s resolving power to separate the faint diffuse emission from the brighter quasar images. We present a uniformly analyzed catalog of cluster and group properties for fields with significant diffuse emission, and upper limits in the remaining fields. These measurements are compared with optical data, where available, and with cluster/group scaling relations.

2. Data Analysis

Our sample includes all ACIS observations of gravitationally lensed quasars available in the Chandra public archive from launch through early 2009. Forty-seven lenses were observed in 119 separate observations. The data were reduced following the standard CIAO 4.1.1 threads. After merging, exposure times range from 4 ksec to over a Msec. Disentangling the weaker extended emission from the bright quasar images is difficult. To maximize the diffuse signal and minimize the background, the eventlists were filtered to include energies between 0.5 and 2 keV. To remove the spatial distribution of the quasar emission, a model was constructed for the lens, with positions fixed to those measured in the optical and radio, and fit to the X-ray data. This lens model was then subtracted from the original image. Remaining point sources were excised. The images were smoothed with a 30 pixel FWHM Gaussian and normalized for exposure variations and instrumental features.

3. Diffuse Source Detection

A four arcminute region in the quasar-subtracted smoothed images was examined to search for diffuse emission. Regions higher than 5-σ above the background level are considered detections. Fifteen targets have detectable diffuse emission, including all seven previously known X-ray sources. One of the fifteen, RXJ1131-1231, has two diffuse detections.

For each of the detections a radial surface brightness plot was used to determine the radius at which the extended emission drops below 1-σ above the background. Counts within this extraction region were fit to a mekal

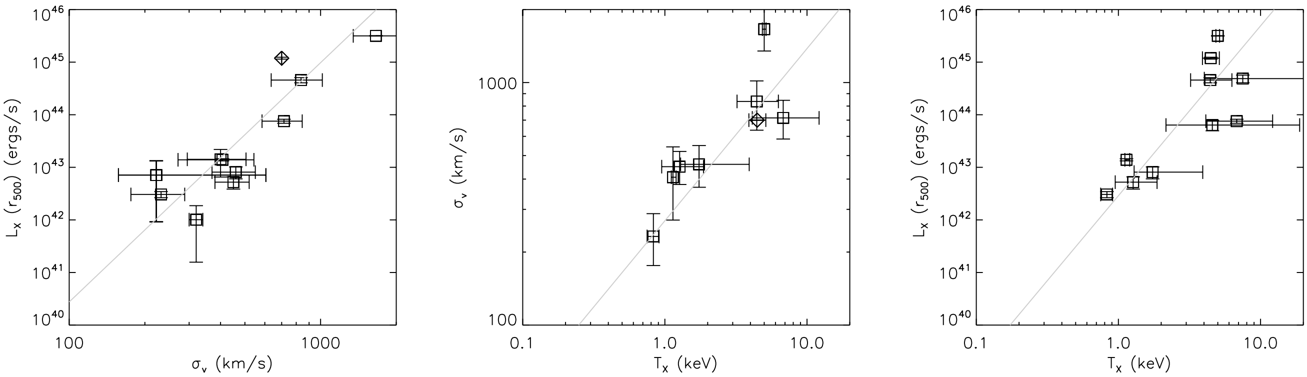

Fig. 1. Comparison of group/cluster properties to the scaling relations of Osmond & Ponman (2004). Velocity dispersions are from the literature; temperatures and luminosities are from this work. The diamon indicates a system with a σ_v estimate from lens modeling.

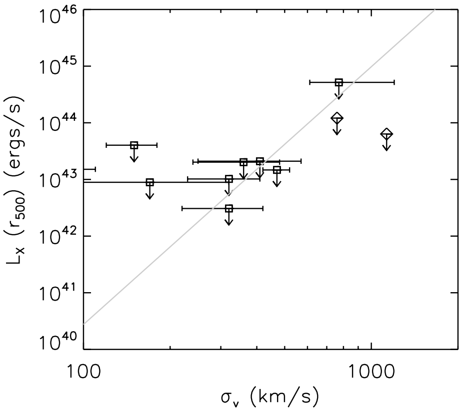

Fig. 2. Comparison of luminosity upper limits to the L_X - σ_v scaling relation of Osmond & Ponman (2004). The diamonds indicate systems with a σ_v estimate from a weak shear analysis.

plasma model with Galactic N_H and $0.3Z_\odot$. The emission was assumed to be at the redshift of any known galaxy group or cluster, or at the redshift of the lensing galaxy. For fields with no significant diffuse emission, we calculate 3-σ upper limits on luminosity.

4. Discussion

We have detected diffuse X-ray emission towards fifteen of our forty-seven gravitational lens targets. They span a wide range of temperature and luminosity and indicate the variety of possible lens environments. In many cases the group or cluster is nearby and/or massive enough that the effects must be included in lens modeling. Six of these X-ray detections are new and have not been previously reported in the literature. Three of these are in fields with an optically studied group or cluster. The remaining three detections, HE0435-1223, SDSS0924+0219 and Q1208+1011, are in poorly studied fields.

The properties of the detected groups and clusters are compared to the scaling relations of Osmond & Ponman (2004) in Figure 1. Although the sample size is small, there is no indication of any significant deviations from the scaling relations beyond the usual scatter, even though the Osmond & Ponman sample is at lower redshift (z < 0.03) than this sample (0.08 < z < 0.8).

Thirty-one of the lens systems do not show any significant diffuse X-ray emission in these observations. For the cases with an X-ray undetected, optically known group, these upper limits are also compared to the L_X - σ_v scaling relation in Figure 2. The undetected groups do not appear to be anomalous, rather just under-exposed.

Our "hit" rate of 15 detections out of 47 lensing fields or ∼32% is consistent with previous studies of lensing environments. Including the X-ray undetected but optically known objects increases this fraction of lens environments containing groups or clusters to over 50%. We cannot rule out a much higher fraction of groups and clusters since many of the fields with non-detections have low statistics and do not place strong constraints on the X-ray luminosity. Our sample may be biased toward high density environments due to the fact that these lenses, on average, have larger image separations than the full gravitational lens catalog. These larger separations are indicative of higher lensing mass.

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References

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