The $L_x - \sigma$ Relation For Poor Groups of Galaxies

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Abstract.
We use a sample of 20 poor groups of galaxies to study the low $L_x$ tail of the $L_x - \sigma$ relationship. We have obtained redshifts for fainter members and deep X-ray imaging of these groups. We find that the $L_x - \sigma$ relationship derived for the rich clusters in the sample of Mushotzky & Scharf (1997) is consistent with the data for our 20 poor groups. However, it is not possible to reach strong conclusions about differences in the $L_x - \sigma$ relationship for groups and clusters in general at the present time because of significant differences between various cluster samples.

1. Introduction

Poor groups of galaxies, such as the Local Group are the most common environment for galaxies. ROSAT observations indicate that approximately half of all nearby groups of galaxies contain a diffuse, X-ray emitting ‘intragroup medium’ analogous to the intracluster medium in rich clusters (Mulchaey 2000). Recently it has been realized that the intragroup medium may hold important clues into the formation and evolution of groups (see for example, Davé et al, these proceedings). Numerical simulations indicate that in the absence of non-gravitational heating, the relationships between X-ray luminosity ($L_x$), X-ray temperature ($T$) and optical velocity dispersion ($\sigma$) are expected to be similar for groups and clusters. The true nature of the scaling relationships for groups and clusters has proved to be a very controversial topic. For example, different authors have reached vastly different conclusions about the relationship between the optical velocity dispersion $\sigma$ and the X-ray luminosity $L_x$. Previous work has found either a similar (Zabludoff & Mulchaey 1998) or a more shallow (Helsdon & Ponman 2000; Mahdavi et al. 2000) relation for groups than for clusters. Several explanations for a shallower group slope have been proposed including the possibility that individual galaxy halos contribute significantly to the X-ray luminosity of groups (Mahdavi et al. 2000).
Most studies of the $L_x - \sigma$ relationship for groups have been based on velocity dispersions determined from only 3 or 4 of the brightest group members. Simulations indicate that when small numbers of galaxies are used, the velocity dispersion does not trace the group mass (Davé et al., these proceedings). We have embarked on a study to measure velocities for more group members and therefore obtain accurate dispersions for a large number of groups.

2. The $L_x - \sigma$ Plot

Our sample contains 20 groups of galaxies observed with fiber spectrographs at the 2.5m telescope at Las Campanas Observatory and the 3.5m WIYN telescope (Zabludoff & Mulchaey 1998; Zimer et al. 2001). The X-ray properties of these groups have been derived from ROSAT PSPC data (Mulchaey et al. 2001). Fourteen of these groups are detected in the ROSAT images. From the fiber spectroscopy, we measure velocities for typically $\sim$ 15–50 group members. These numbers are high enough to derive reliable velocity dispersions (Davé et al., this proceedings). Figure 1 shows the resulting $L_x - \sigma$ relationship we derive (data points), with various other fits to the $L_x - \sigma$ relationship found in the literature.

A summary of the various published $L_x - \sigma$ relationships is also given in Table 1. The upper left panel in Figure 1 shows the best fit to our cluster and group data using a parametric bootstrap technique (Lubin & Bahcall 1993):

$$\log L_x = (4.39 \pm 0.27) \log \sigma + (31.29 \pm 0.80)$$

(1)

while for the cluster data alone (Mushotzky & Scharf 1997), we derive:

$$\log L_x = (3.67 \pm 0.51) \log \sigma + (33.46 \pm 1.54).$$

(2)

Within the errors, these fits are in agreement with each other and with the earlier results of Mulchaey & Zabludoff (1998) (see Table 1). Given the small number of groups in our sample, we have not attempted to fit the group data alone. However, a visual inspection of Figure 1 suggests the group + cluster fit adequately describes the groups. In the upper right panel we compare our data with fits in Xue & Wu (2000). Their group + cluster fit is consistent with our result within the errors. The lower left panel shows the best fit slopes for groups only from Mahdavi et al. (2000) and Helsdon & Ponman (2000). It is immediately obvious that the Mahdavi et al. (2000) fit is inconsistent with our data and cannot be correct for groups in general. The Helsdon & Ponman (2000) group fit is consistent with our group + cluster fit. However, Helsdon & Ponman (2000) claim to find a significant difference between the $L_x - \sigma$ relation for groups and the relation for clusters. Despite finding similar slopes for groups, we reach a different conclusion than Helsdon & Ponman (2000) because there are significant differences in the cluster samples used in each survey. Helsdon & Ponman (2000) use the White et al. (1997) cluster sample (see the lower right panel in Figure 1), which has a considerably steeper $L_x - \sigma$ relation than the Mushotzky & Scharf (1997) clusters sample we use (White et al. 1997: $L_x \propto \sigma^{6.38}$, Mushotzky & Scharf 1997: $L_x \propto \sigma^{3.67}$). The reason for the differences in these cluster samples is not apparent. It is clear, however, that these differences must be understood before any strong conclusions can be made regarding differences in the $L_x - \sigma$ relationship of groups and clusters.
Figure 1. Logarithm of velocity dispersion vs. logarithm of X-ray luminosity for the X-ray detected groups and clusters. The non-detected groups are plotted using the upper limits on $L_x$ (arrows).

Table 1. The $L_x - \sigma$ Relation fits

|                      | Helsdon & Ponman 2000 | Mahdavi et al. 2000 | Xue & Wu 2000 |
|----------------------|------------------------|---------------------|---------------|
| clusters only        | 6.38$\pm$0.46 (6)      | 3.90$\pm$0.10       | 5.30$\pm$0.21 |
| clusters + groups    | /                      | /                   | 4.75$\pm$0.18 (3) |
| Zabludoff & Mulchaey 1998 | /                | /                   | /             |
| clusters only        | /                      | /                   | 3.67$\pm$0.51 (7) |
| clusters + groups    | 4.29$\pm$0.37          | 4.39$\pm$0.27 (1)   | /             |
3. Conclusion

There is still considerable debate about the nature of the $L_x - \sigma$ relationship for groups and clusters. Some of the discrepancies in the literature may be due to poorly determined $\sigma$'s and/or $L_x$'s. In many studies, the $\sigma$'s are quite uncertain because they were derived from only the three or four brightest group members. The $L_x$ measurements may also be uncertain because of the low signal-to-noise of most ROSAT images and contamination from other sources.

From our fiber spectroscopy program we have found:

• low-mass groups have many members if the luminosity function is sampled down to sufficiently low luminosities.

• robust velocity dispersions for groups require at least $\sim 10$–$15$ velocity measurements.

• strong conclusions about differences in the $L_x - \sigma$ relationship for groups and clusters cannot be reached at the present time because of differences in the various cluster samples.

• the uncertainties in the various scaling relationships suggest that it may be somewhat premature at this time to draw strong conclusions about the need for additional heating mechanisms in groups.

References

Davé, R., Katz, N., & Weinberg, D., this proceedings.
Helsdon, S.F., & Ponman, T.J. 2000, MNRAS, 315, 356
Lubin, L.M., & Bahcall, N.A. 1993, ApJ 415, L17
Mahdavi, A., Boehringer, H., Geller, M.J., & Ramella, M. 2000, ApJ, 534, 114
Mulchaey, J.S. 2000, ARA&A, 38, 289
Mulchaey, J.S., Zabludoff, A.I., & Zimer, M.E. 2001, ApJL in Prep
Mulchaey, J.S., Davis, D.S., Mushotzky, R.F., & Burstein, D. 2001, in Prep.
Mushotzky, R.F., & Scharf, C.A. 1997, ApJ, 482, L13
White, D.A., Jones, C., & Forman, W. 1997, MNRAS, 292, 419
Xue, Y., & Wu, X. 2000, ApJ, 538, 65
Zabludoff, A.I., & Mulchaey, J.S. 1998, ApJ, 496, 39
Zimer, M.E., Mulchaey, J.S., & Zabludoff, A.I. 2001, ApJ, in Prep