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RADIO SOURCE PROPERTIES AND THE ALIGNMENT EFFECT

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Abstract. Powerful radio galaxies often display regions of enhanced optical/UV emission, elongated and aligned with the radio jet axis. The expanding radio source strongly affects the surrounding IGM, and the properties of the aligned emission regions vary considerably with both radio source properties and cosmic epoch. The results of deep rest-frame UV and optical imaging of high redshift 6C radio galaxies are discussed, considering the influence of radio power on the strength of the observed alignment effect, the galaxy colors and the dominant emission mechanisms.

Key words: galaxies: active, jects – intergalactic medium

1. INTRODUCTION

Extensive regions of UV/optical continuum emission are often observed around high redshift radio galaxies, usually well aligned with the radio source axis. This alignment effect has been well studied in the 3CR sample, with some interesting results. At $z \sim 1$, the aligned structures are typically brighter, more extensive than at lower redshifts and more closely aligned with the radio emission. However, it is unclear whether the observed variation in the alignment effect with redshift is due to the increasing radio power within the sample or a true evolutionary trend with cosmic epoch.

We have carried out a program of multiwavelength imaging of a complete subsample of 11 6C radio sources (Inskip et al. 2003) with flux densities of $2.0\,\mathrm{Jy} < S_{151} < 3.93\,\mathrm{Jy}$, $08^{\mathrm{h}}20^{\mathrm{m}} < \alpha < 13^{\mathrm{h}}01^{\mathrm{m}}$, $34^{\circ} < \delta < 40^{\circ}$ and $0.85 < z < 1.5$. The 6C galaxies are ~6 times less powerful than the previously well studied 3CR sources at the same redshift (Best et al. 1997). HST WFPC2 observations of these 6C galaxies reveal extensive UV emission around many sources, with a variety of morphological structures similar to those observed for the $z \sim 1$ 3CR sources. However, whilst the smaller 3CR sources display a clear tendency to have more extensive, luminous and knotty aligned structures, this is not obvious for the 6C galaxies at the same redshifts. The aligned emission surrounding the 6C galaxies is usually less extensive, and rarely displays the extended strings of very bright knots of emission seen around the smaller 3CR sources.

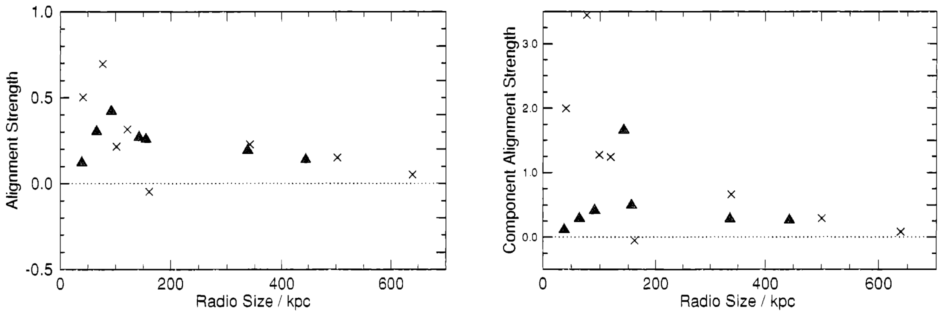

Fig. 1. Alignment strength (left) and component alignment strength (right) vs. radio size for the galaxies with $1.0 < z < 1.3$. 6C sources are represented by triangles and 3CR sources by crosses.

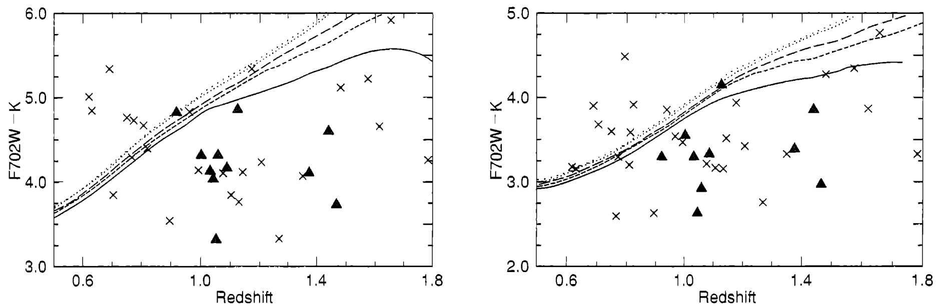

Fig. 2. Left panel. $4''$ diameter aperture HST–K colors for the 6C and 3CR sources. Right panel. Mean galaxy colors in equal redshift bins. Tracks represent passively evolving galaxies formed at $z = 2$ to $z = 20$.

2. THE ALIGNMENT EFFECT AND GALAXY COLORS

The power of a radio source is clearly linked to the observed properties of the alignment effect. We have quantified the alignment effect in terms of the physical extent of the aligned emission, the degree to which it is aligned with the axis of the radio source, and the *knottiness* of the aligned structures[1].

For the resulting parameters, both the alignment strength (a_s) and the component alignment strength (a_c) increase with redshift out to $z = 1.1$, reflecting the increasing importance of the alignment effect at higher redshifts. Figure 1 displays the variation in a_s and a_c with radio size ($D_{\rm rad}$) for the galaxies in both samples with $1 < z < 1.3$. We find that a_s varies similarly for both samples, decreasing with $D_{\rm rad}$. However, a_c is considerably stronger for the more powerful 3CR radio sources: the less powerful sources display fewer multiple components of bright discrete emission. Where multiple components are observed in the 6C data, they generally lie closer together.

Similar trends with $D_{\rm rad}$ and z are also seen for the galaxy colors (Figure 2). Bluer colors are observed for the higher redshift and the smaller radio sources, for which the alignment effect is of greater importance. However, the 6C/3CR colors are statistically indistinguishable; a surprising result given the strong radio power

[1] *Alignment strength* is defined as $a_s = \epsilon(1 - \Delta PA/45)$, where ϵ is the ellipticity of the aligned emission, and ΔPA is the difference in position angle between the radio and rest-frame UV emission. The *knottiness* of the aligned structures can be considered in terms of the *component alignment strength*, defined as $a_c = N_c a_s$, where N_c represents the number of discrete bright components of emission.

dependence of a_c. These results suggest that the emission mechanisms which produce the bulk of the excess UV emission scale with galaxy mass rather than radio power.

3. DISCUSSION

Given the very different distributions of luminous UV emission for the two samples, the most problematic result is the similarity in colors. We see much greater values of a_c for the 3CR data: the excess UV emission for the 6C sample must therefore lie closer to (or within) the host galaxy. Where multiple emission components are observed in the 6C data, they do generally lie closer to each other and the host galaxy, although this may not fully explain the unexpectedly blue colors of the 6C galaxies. Our analysis of the 6C data suggests that the proportion of point source contamination from the AGNs is similar for both samples, and that the 6C galaxies may on average simply have younger stellar populations.

Several different emission mechanisms have been proposed in order to explain the alignment effect, including scattering of AGN continuum emission (Cimatti et al. 1993), jet-induced star formation (Chambers et al. 1987) and nebular continuum emission (Dickson et al. 1995). Just as for previous studies, no single emission mechanism dominates. Given that strings of several bright emission components are generally not seen in the 6C data, and the strong radio power dependence of a_c, one might assume that the emission mechanisms which produce these particular features scale with radio power. However, our analysis of the 6C sources shows that line and nebular continuum emission (which do scale with radio power) only account for a small fraction of the luminous knotty emission, whilst a large percentage of the diffuse/filamentary emission can be explained by these processes.

The evolution of the aligned structures with D_{rad} for the 3CR sources is consistent with the evolution of a young stellar population formed as the radio source expands (Best et al. 1996), and is well matched to our finding that bright knotty features are best explained by either star formation or scattered emission. Although the alignment effect still becomes less as sources grow and age, the reduced frequency of luminous knotty features for the 6C data and the weaker radio size trends imply that the efficiency of these processes are greatly reduced in the case of for less powerful radio sources. Whilst star formation is likely to be an important process in producing the excess UV emission for both samples, it typically seems to occur closer to the host galaxies for less powerful radio sources.

REFERENCES

Best P. N., Longair M. S., Röttgering H. J. A. 1996, MNRAS, 280, L9

Best P. N., Longair M. S., Röttgering H. J. A. 1997, MNRAS, 292, 758

Chambers K. C., Miley G. K., van Breugel W. J. M. 1987, Nature, 329, 604

Cimatti A., di Serego Alighieri S., Fosbury R. A. E., Salvati M., Taylor D. 1993, MNRAS, 264, 421

Dickson R., Tadhunter C., Shaw M., Clark N., Morganti R. 1995, MNRAS, 273, L29

Inskip K. J., Best P. N., Longair M. S., Rawlings S., Röttgering H. J. A., Eales S. 2003, MNRAS, 345, 1365