Deep multicolour imaging of the field towards the quasar pair PC1643+463 A&B

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Abstract.
We present the first results of a deep imaging programme to identify the system responsible for the Cosmic Microwave Background decrement in the field towards the $z = 3.8$ quasar pair PC1643+4631 A&B. Using the prime focus camera at the William Herschel Telescope we have carried out deep multicolour optical imaging to search for candidate cluster galaxies at extremely high redshift. Using UGR colour selection we find the surface density of $z > 3$ Lyman-break galaxy candidates is at least as great as that found in the field of the $z = 3.1$ structure discovered by Steidel et al. (1998), and may be somewhat greater.

1. Introduction
The field towards the $z = 3.8$ quasar pair PC1643+4631 A&B contains a Cosmic Microwave Background (CMB) decrement, believed to be the Sunyaev-Zel’dovich (SZ) effect of a massive cluster or proto-cluster of galaxies (Jones et al. 1997; Saunders, these proceedings). Initial optical and infrared follow-up programme revealed no evidence for cluster galaxies to at least $z = 1$ (Saunders et al. 1997), and, using an X-ray upper limit obtained with a deep ROSAT observation, Kneissl et al. (1998) argue that an isothermal cluster similar those seen at low-redshift clusters would have to lie at $z > 2.8$. A second candidate high-redshift SZ cluster, towards a quasar pair at $z = 2.56$, also appears blank in deep optical and X-ray observations (Richards et al. 1997). We were thus prompted to initiate a search for cluster galaxies at $z >> 1$, and as a first step we have carried out a very deep multicolour optical imaging programme of the PC1643+4631 field.

2. Optical imaging
In 1996 April we observed the central $5' \times 5'$ region of the PC1643+4631 A&B field with the prime focus camera at the 4.2-m William Herschel Telescope. Images were obtained in $U,V,R$ and $I$; with a custom-made $G$ filter kindly lent to
us by R. McMahon; and with two custom-made narrow-band filters, one centered on Ly-α at the redshift of the quasars and one centered on the wavelength of the damped Ly-α absorption system at $z = 3.14$ towards quasar PC 1643+463 A. We reached one-sigma surface brightness limits (in AB mag arcsec$^{-2}$) of $U = 29.6$, $G, R = 29.1$, and between 27.4 and 28.6 in the other bands. Full details of the observations and data analysis will be published shortly (Haynes et al. in preparation) and an investigation of the properties of candidate galaxies in the redshift range $1 < z < 3$ is underway (Cotter et al. in preparation). In this contribution we focus on the candidate members of what is rapidly becoming a well-studied population: the Lyman-break galaxies at $z > 3$.

3. Lyman-break galaxies in the field

We have followed the principle adopted in the surveys of Steidel et al. (1995, 1996) to identify galaxies at $z > 3$ via the characteristic colours caused by the Lyman-limit break straddling the $U$ and $G$ bands. Although we use standard Johnson $U$ and $R$ filters rather than the custom filters of Steidel et al., we find that the locus of $z > 3$ galaxies is still well defined. As shown in Fig. 1, the colour criteria $U − G > 2$, $U − G > 4(G − R) + 0.5$ isolate model galaxies at $z > 3$ and avoid contamination from stars—the region of the colour-colour plane is equivalent to the “robust” criteria of Steidel et al.

In this region of colour-colour space we find 27 objects (excluding the two quasars) to $R_{AB} = 25.5$, which gives a surface density of $\approx 1.1 \pm 0.2$ arcmin$^{-2}$. This surface density is comparable to the 0.73 arcmin$^{-2}$ surface density of “robust” candidates in the field of the $z = 3.1$ structure discovered by Steidel et al. (1998); indeed, tantalizingly, it is greater at the two-sigma level.

Naturally, we urge caution in interpreting this result as representing a real structure at $z > 3$. Firstly, until the clustering properties of Lyman-break galaxies are known in detail, it will not be possible to evaluate the probability that an above-average surface density in a small field of view corresponds to a real large structure (we note that our images are several times smaller than those of Steidel et al. 1998). Of course, prior knowledge of an SZ-producing structure along the line of sight would increase this probability. Secondly, an excess of candidate objects at $z > 3$ does not necessarily imply a structure at this redshift. Lyman-break galaxies have very small characteristic sizes (see, e.g., Giavalisco et al. 1996), and so are essentially unresolved with the typical 0.8" seeing disk of our images. Thus, for a fixed surface brightness limit, one would expect to find an excess of these galaxies if the field contains an unseen lens at a lower redshift, as in the model proposed by Saunders et al. (1997).

The only way to determine if these candidates objects represent a real structure at $z > 3$ is to proceed with spectroscopy on 10-m class telescopes. To this end, we are currently planning Keck LRIS observations in collaboration with the Berkeley group. Whatever the cause of the excess of $z > 3$ Lyman-break candidates, it will provide a strong indication of the nature of the system causing the CMB decrement in the field.
Stars

$t = 2 \text{ Gyr}$

$t = 7 \text{ Gyr}$

$t = 1 \text{ Gyr}$

Const. S.F.R.

Figure 1.  $UGR$ colour-colour diagram for objects in the central 5' × 5' of the PC1643+463 field; compare with, e.g., Fig. 1 of Pettini et al. (1997). Objects with $R_{AB} < 25.5$ are shown as dots if detected with one-sigma significance or better in $U$ and as triangles if undetected to one sigma in $U$. The colours of stars taken from the atlas of Gunn & Stryker (1983) are shown as crosses. Evolutionary tracks calculated using the GISSEL96 model spectra of Bruzual and Charlot and model absorption by intergalactic neutral hydrogen (Madau 1995) are superimposed. Tracks have been calculated for galaxies forming at redshift $z = 5$ and having various star-formation histories—constant SFR and exponentially decreasing SFR with scale times of 1 Gyr, 2 Gyr and 7 Gyr. The model tracks run to $z = 0$ with points plotted at redshift intervals of 0.1. The dashed line shows the region of colour-colour space which isolates $z > 3$ model galaxies, equivalent to the “robust” selection criteria of Steidel et al.; we find 27 objects in this region.
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The investigation of the PC1643+4631 CMB decrement to date has been carried out by the authors of Jones at al. (1997) and Saunders et al. (1997).

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