Two Protogalaxy Candidates in One Night

Peter Eisenhardt, JPL/Caltech, and Mark Dickinson, UC Berkeley

On 20 March 1992 our ongoing program of infrared imaging of high redshift galaxies with the KPNO 4m turned up evidence for the flat spectrum considered characteristic of protogalaxies in two radio galaxies: B2 0902+34 at z=3.395 (hereafter 0902), and 3C 256 at z=1.819.

In spite of a lookback time of 77 to 89% (qo=0 - 0.5) of the age of the universe, Lilly provided evidence that the dominant stellar population in 0902 was surprisingly old, over 1 Gyr. This age estimate was based on the values K=18.8 and I-K=4.5 in the central 3.5 x 3.5". At Lilly's suggestion, we reobserved 0902 at K, and in initial reductions of our data found only an upper limit (K > 19.5). After extensive experimentation with reduction techniques and correction for low-level systematic effects, we succeeded in extracting a four sigma detection at K=19.9 in a 4" diameter circular aperture (see Figure 1). The morphology and location of this detection were more reminiscent of the Ly alpha image (Dickinson et al. 1992) than of CCD continuum images, and in March 1992 we obtained a narrow band image which included redshifted [OIII] 4959,5007 Angstrom line emission at 2.20um. This [OIII] image gave a strong detection which demonstrates that most of the central K flux, already reduced by a magnitude, is due to line emission. Our formal line corrected values in a 4" aperture are K=21.5 and R-K=1.9 (vs. a flat spectrum value R-K=1.7). Hence 0902 has been transformed from relaxed maturity into unsettled youth.

The morphology in each of the four images shown in Figure 1 is somewhat different, although there is a general east-west orientation. Since the radio morphology is generally north-south (van Breugel and McCarthy 1990), 0902, unlike most high redshift radio galaxies, does not have aligned radio and UV/optical emission. The difference between the K and [OIII] morphologies suggests that some K continuum flux distinct from the [OIII] emission is present. In fact our data may indicate the presence of an extended (>10" diameter) halo of K emission which would be consistent with the brighter K values found by Lilly in larger apertures using a single element photometer. However, the halo is not seen in [OIII] emission and could be a systematic error in the K data. If the halo is real our line corrected values become K=20 and R-K=3.4, but modelled ages are still much younger than those based on I-K=4.5.

In comparison, 3C 256 is a much more straightforward case for a protogalaxy. Despite its extreme faintness (K=19.1, 5000 times fainter than the sky) our K image (Figure 2) shows that the (rest frame 0.8um) light is highly elongated and aligned with the radio lobes, similar to the CCD R light (rest 0.23 um). The low ratio of K/R light (R-K=2.4), lack of a central red core, and dynamically young morphology all imply that 3C 256 is forming its first major generation of stars:, i.e. it is a protogalaxy. The excellent radio alignment suggests that radio jets triggered this formation.

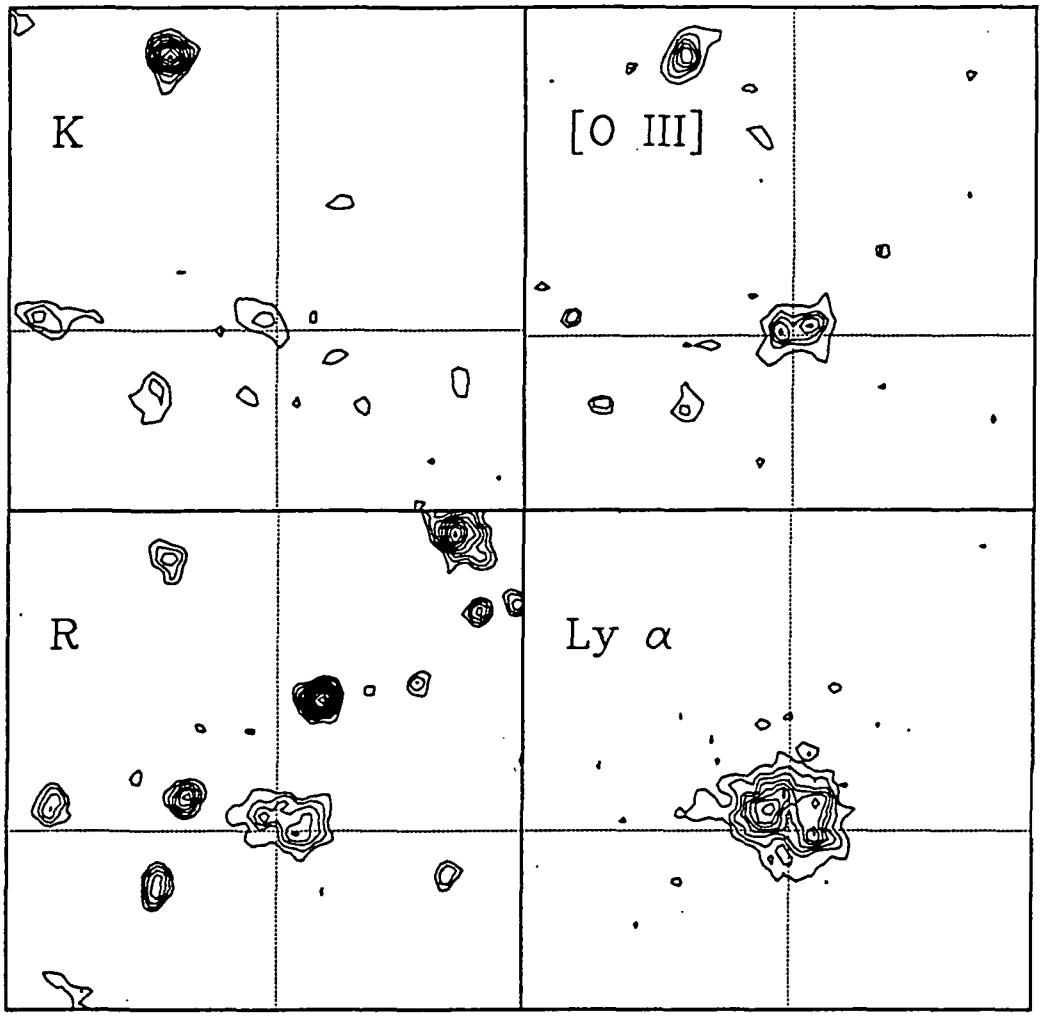

Figure 1: Montage of IR and optical imaging data for 0902+34. The upper panels show the K and narrow band 2.21um images. The latter includes flux from both the K band continuum and the redshifted [OIII] 4959,5007 Angstrom emission lines; no attempt has been made to subtract the continuum from the line image. The deep CCD R and Ly alpha images are taken from Dickinson et al. (1992). The field of view is 25 arcseconds on a side for each panel, and the 0902 radio core position (9h02m24.796s, 34o19'56.58") is marked by the intersection of the dotted lines. North is up and East is to the left.

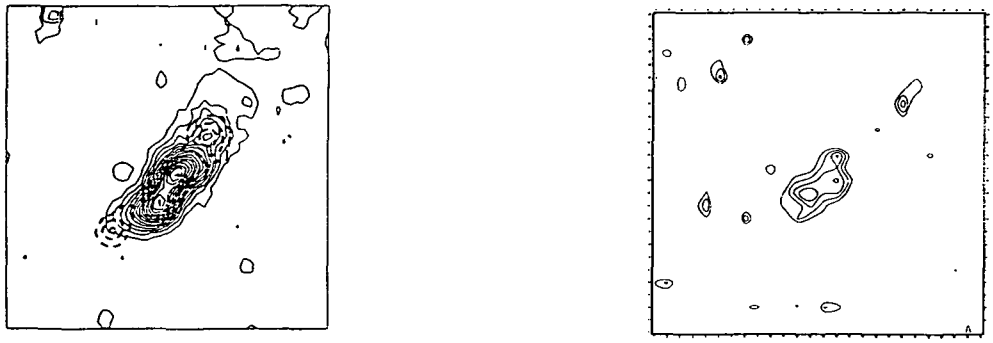

Figure 2: 3C 256 in R (left panel), with the radio data superimposed (from van Breugel and McCarthy 1990), and in K (right). The panels are 10" wide, north is up, east is to the left.