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The QSO Q 0103−260 (z = 3.365) in the FORS Deep Field

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Abstract

Broad-band and narrow-band images as well as spectroscopy in the FORS Deep Field is presented. While the broad-band images where mainly used to determine photometric redshifts for $\sim$ 6300 galaxies, the narrow-band images were used to search for Lyα-galaxies at the redshift of the QSO Q 0103−260 (z = 3.365). We detected 3 nearby companion galaxies within a few arcsec of Q 0103−260 in our narrow-band images. At least two, most likely all three could be spectroscopically confirmed to be at similar redshifts as the QSO. The distributions of photometric redshifts shows a clear overdensity of galaxies in the redshift range z = 3.3-3.5. Again, 9 more galaxies could be spectroscopically be confirmed to be at similar redshifts as the QSO. Q 0103−260 is located in a large-scale structure at z $\sim$ 3.3-3.5 or even in a protocluster of galaxies as has recently been found for a high-z radio galaxy.

1.1 The FORS Deep Field project

The FORS Deep Field (FDF) project is a multi-colour, multi-object spectroscopic investigation of a $\sim 7' \times 7'$ region near the south galactic pole based mostly on observations carried out with the FORS instruments attached to the VLT telescopes. It includes the QSO Q 0103-260 (z = 3.365).

Broad-band images in UBgRIJKs have been obtained with FORS1@VLT1 and SofI@NTT. From the images a B+I selected photometric catalog containing 8753 objects was created (Heidt et al. 2002). The common area surveyed in all filters is 39.8 sq. arcmin. Seeing on the co-added images was always below 1" in the optical bands (from 0.53" in I up to 0.97" in U) and 1.2" in the NIR-bands. The formal 50% completeness limits for point sources, are 25.64, 27.69, 26.86, 26.68, 26.37, 22.85 and 20.73 in U, B, g, R, I, J and Ks (Vega-system), respectively.

Photometric redshifts could be derived for $\sim$ 6300 objects in the FDF according to the method described by Bender et al. (2001). Their distribution is displayed in Fig. 1.1 (left). Note the clear overdensity of FDF-objects in the range $z = 3.3 - 3.5$. Spectra of $\sim$ 400 galaxy candidates up to z = 5 (mostly z > 1) were collected using the MOS/MXU facilities with FORS1/2 at the VLT telescopes.. Using the grism 150I and a slit width of 1" the spectral range from $3000 - 10000$ Å with a resolution of 5 Å was covered. The aim was to reach a S/N of at least 10 per resolution element to study the continuum and absorption/emission features of the galaxies. Typical

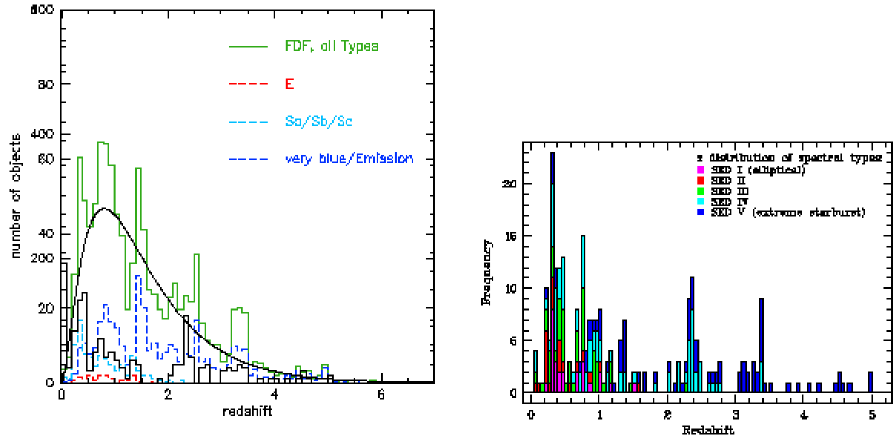

Fig. 1.1. Left) Photometric redshifts for ~ 6300 galaxies in the FDF. Right) Spectroscopic redshifts and types for about 250 galaxies in the FDF. Note the overdensity of objects between z = 3.3 and 3.5 in both diagrams.

integration times ranged from 2h up to 10h depending on the brightness of the objects (mostly between $m_I = 22-25$). For about 250 galaxies secure redshifts/galaxy types could be derived. Their distribution with redshift is displayed in Fig. 1.1 (right).

1.2 The QSO Q 0103−260 and its environment

While broad-band imaging of the FDF was mainly carried out for determining photometric redshifts (target selection for spectroscopic follow-up) and morphological studies, narrow-band imaging was conducted at the VLT specifically to search for Lyα-galaxies at the QSOs redshift. This technique has recently successfully been used to detect a protocluster at z = 4.1 associated with a luminous radio galaxy (Venemans et al. 2002).

In Fig. 1.2 the environment of the QSO in the narrow-band image centered at the redshifted Lyα of the QSO (530_25) is compared to the image taken in a "Veto" narrow-band filter (485_37) and the broad-band I image. On the broad-band I image the photometric redshifts of individual galaxies are displayed.

Several interesting features can bee seen in Fig. 1.2. On the 530_25 filter image two objects a few arcsec southeast and southwest of the QSO are detected, which are not visible on the 485_37 filter image, but faintly present on the broad-band I image. Moreover, one of the two objects has a photometric redshift (z = 3.08), close to the QSOs redshift. Additionally, an object with a similar photometric redshift (z = 3.06) was found, which is a few arcsec to the northwest of the QSO. Given an error of ≤ 10% for photometric redshifts of such faint objects (mainly due to the errors of the photometry) the QSO might well be surrounded by a group of at least 3 galaxies, two of which having relatively strong Lyα-emission. Alternatively, the three galaxies (or at least some of them) might be along the line of sight to the QSO, thus being responsible for absorption-line systems in the spectrum of the QSO.

In order to prove the physical association of the three companion galaxies to the

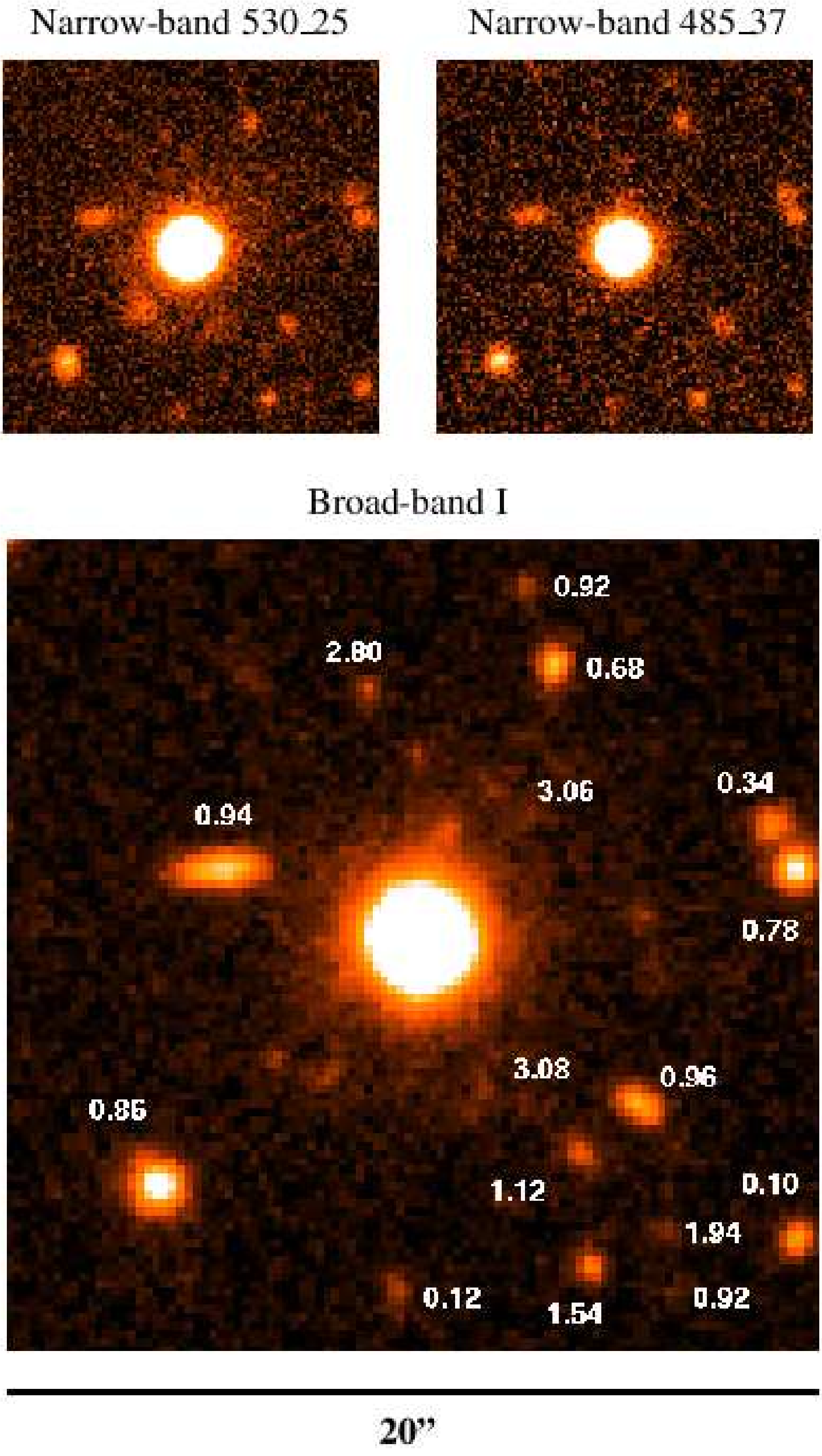

Fig. 1.2. Environment of the QSO Q 0103−260 (z = 3.365). The QSO is in the center of the images.

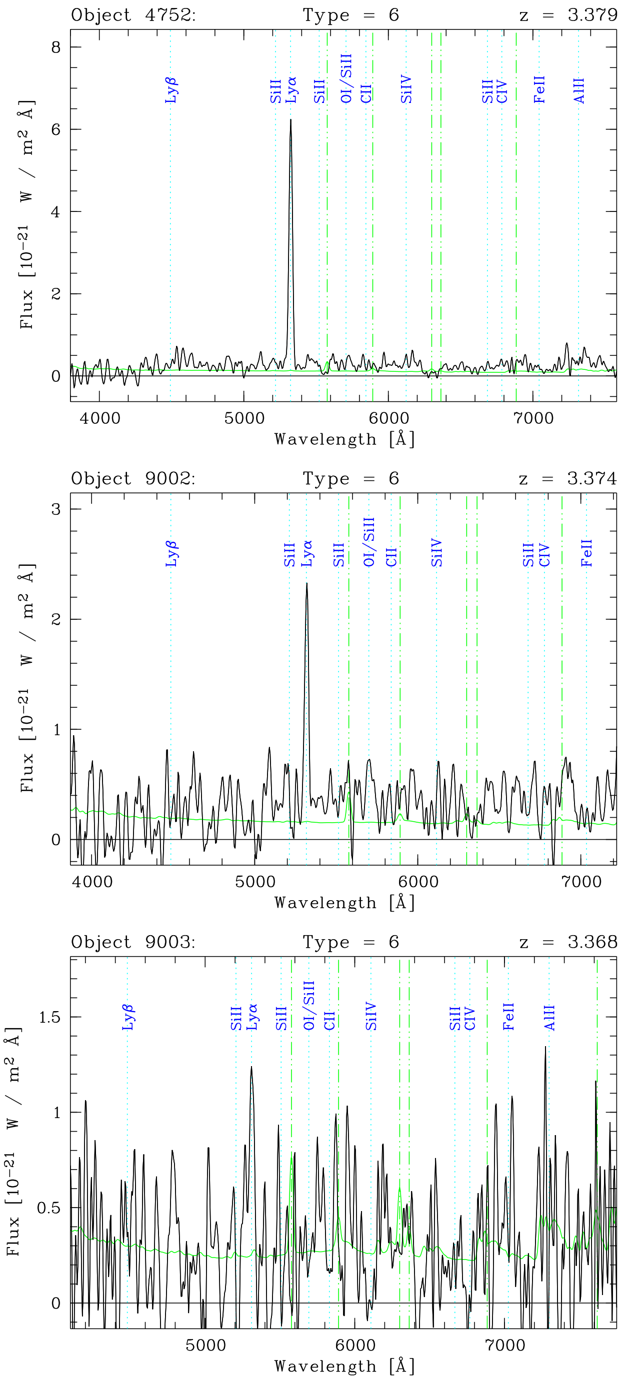

Fig. 1.3. Top) Spectrum of the companion galaxy south-east of Q 0103−260. Exposure time was 8h. Middle) Spectrum of the companion galaxy south-west of Q 0103−260. Exposure time was 8h. Bottom) Spectrum of the companion galaxy north-west of Q 0103−260. Exposure time was 4h.

Table 1.1. *Properties of the spectroscopically verified objects at z = 3.3 - 3.4.*

α	δ	I-mag	z	α	δ	I-mag	z
1:5:52.4	-25:48:33	23.60	3.401	1:6:04.4	-25:48:34	24.32	3.302
1:5:56.3	-25:47:37	23.78	3.313	1:6:04.6	-25:46:54	25.20	3.379[4]
1:5:59.7	-25:47:44	23.99	3.387	1:6:07.3	-25:46:59	23.63	3.376
1:6:02.0	-25:47:54	24.00	3.390	1:6:07.5	-25:47:00	23.12	3.382
1:6:04.2	-25:46:48	24.80	3.368[1]	1:6:08.2	-25:45:34	24.15	3.399
1:6:04.3	-25:46:55	25.20	3.374[2]	1:6:09.4	-25:48:07	22.56	3.396
1:6:04.4	-25:46:51	18.57	3.365[3]				

[1]Companion north-west, [2]Companion south-west, [3]Q 0103−260 , [4]Companion south-east.

QSO, spectra of them have been obtained in the course of the spectroscopical follow-up of the FDF. They are displayed in Fig. 1.3. As can be seen, the two companion galaxies south-east and south-west of the QSO could be confirmed as Lyα-emitters at a very similar redshift as the QSO itself. The spectrum of the third companion to the north-west has a similar redshift as well, but due to the low S/N, this is uncertain at present. We recently were able to collect more spectra of this galaxy lasting 4h, which will be able to clarify this issue. Nevertheless, we found strong indications that the QSO is part of a small group/cluster of galaxies, which may evolve towards a massive bulge-dominated system as we see them today.

In order to verify the overdensity of galaxies in the FDF in the redshift range z = 3.2-3.5 seen in the distribution of photometric redshifts (Fig. 1.1), we started a program to spectroscopically verify these sources. So far, we were able to confirm 9 more sources between z = 3.3 and 3.4 within 3' of the QSO, in particular 7 between z = 3.36 and 3.4 (typical errors for the redshifts are < 0.005). Most are extreme starbursting galaxies. Their properties are summarized in Tab. 1.1.

We have now first indication that the QSO might be either also part of a (proto)cluster at z $\sim$ 3.365 as seen for the strong radio source TN J1338−1942 at z = 4.1 (Venemans et al. 2002) or at least be part of large-scale structure at this redshift range. In the literature QSO Q 0103−260 has not been cited as a radio emitter. However, our recent radio-imaging of the FDF with the VLA showed that Q Q 0103−260 shows low-level radio emission ($\sim$ 1 mJy at 5 GHz). This support the recent finding that radio-emitter can be found in regions of high galaxy density in the young universe.

References

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