# Chapter 2

# Observations

## 2.1 The Hamburg/ESO Survey

The quasar HE 0940–1050 was discovered as part of the wide-angle Hamburg/ESO survey (HES), which began in 1990 with the objective of obtaining a large homogeneous sample of bright QSOs in the southern hemisphere (Reimers et al. 1996). The objective-prism photographs taken with the ESO 1-meter Schmidt telescope were digitized and examined according to a variety of selection criteria that included the ultraviolet excess, continuum slope and presence of strong emission lines typical of QSO spectra (Wisotzki et al. 1996). For the QSO candidates thus selected, follow-up slit spectroscopy was carried out on the 1.52 m, 2.2 m and 3.6 m ESO telescopes.

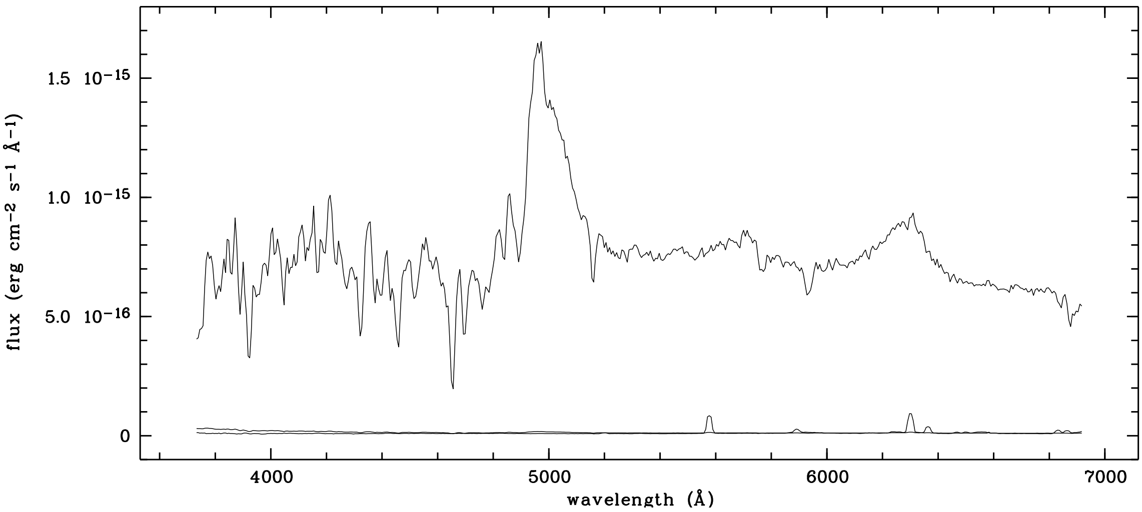


**Figure 2.1:** *Spectrum of HE 0940–1050 obtained from two 30-minute exposures taken with the ESO 1.52-meter telescope (courtesy of L. Wisotzki).*

The follow-up spectrum of HE 0940–1050 in Figure 2.1 was taken at the 1.52-meter telescope on March 21, 1993. The instrumental magnitude of $B = 17.2$ obtained via CCD photometry with the EFOSC1 spectrograph has an error smaller than $\Delta B = \pm 0.1$. Because the centroid of the Lyman $\alpha$ emission line can be distorted by the Lyman $\alpha$ forest, the QSO redshift of $z_{em} = 3.054$ was determined by taking the peak wavelength of the C IV emission line (Reimers et al. 1996).

| **HE 0940–1050** | | | |
|---|---|---|---|
| Coordinates: | $\alpha(1950)$ | = | $9^{h}\ 40^{m}\ 27.2^{s}$ |
| | $\delta(1950)$ | = | $-10^{\circ}\ 50'\ 41''$ |
| | $\alpha(2000)$ | = | $9^{h}\ 42^{m}\ 53.5^{s}$ |
| | $\delta(2000)$ | = | $-11^{\circ}\ 04'\ 26''$ |
| Magnitude: | $B$ | = | $17.2 \pm 0.1$ |
| Redshift: | $z_{em}$ | = | 3.054 |

**Table 2.1:** *Quasar HE 0940–1050*

## 2.2 Data Collection

The raw CCD images analyzed in this work were obtained by Susanne Köhler on February 3–5, 1994 at the 3.6 m telescope of the European Southern Observatory (ESO) at La Silla, Chile with the Cassegrain Echelle Spectrograph (CASPEC).

Echelle spectrographs use diffraction gratings with greatly increased blaze angles that allow them to observe higher diffraction orders and so achieve higher resolutions. But the resulting image consists of many short spectral orders superimposed on each other. They must be separated out by a second spectroscope, called a cross disperser, whose dispersion direction is perpendicular to that of the first (Kitchin 1995 has a clear explanation of the optics involved). Thus the final image on the CCD is a two-dimensional array of different segments of the spectrum.

In the case of the CASPEC observations, light passed through a slit 500 $\mu$m long and 280 $\mu$m wide (which corresponds to $2''$). Then it went through a collimator, an echelle grating with 31.6 lines mm$^{-1}$, and a cross disperser with 300 lines mm$^{-1}$ and a maximum efficiency at 4224 Å (Pasquini 1993). Finally, the light was focused on the CCD by the Short Camera (which is no longer in use; Randich and Pasquini, 1996). The CCD (ESO #32) is a thinned, multi-phase-pinned Tektronix CCD with $512 \times 512$ pixels and a pixel size of 27$\mu$m $\times$27$\mu$m. No on-chip binning was done.

Table 2.2 lists all of the calibration and object exposures, for which the seeing was between $1.3''$ and $1.5''$. In column 2, BIAS AV5 means that the image stored on tape was the simple average of 5 bias frames. Flat-fields are labelled FLAT, and exposures of the thorium-argon lamp used for the wavelength calibration are labelled WLC. The STD exposure of $\mu$ Columbæ, an HST standard of spectral type O9V suitable for flux calibration, was used for the response correction in section 4.9. Where available, the universal time at the start of the exposure, the exposure time in seconds, and the telescope coordinates are listed in the last 4 columns of the table.

| Frame name | Identifier | Date | U.T. | Sec | R.A. | Decl. |
|---|---|---|---|---|---|---|
| casp0004 | BIAS AV5 | 00100 | 00:00:00 | 1 | $0^h00^m00^s$ | $00°00'00''$ |
| casp0005 | BIAS AV5 | 00100 | 00:00:00 | 1 | $0^h00^m00^s$ | $00°00'00''$ |
| casp0006 | BIAS AV5 | 00100 | 00:00:00 | 1 | $0^h00^m00^s$ | $00°00'00''$ |
| casp0007 | BIAS AV5 | 00100 | 00:00:00 | 0 | $0^h00^m00^s$ | $00°00'00''$ |
| casp0021 | FLAT | Feb 3 | 03:32:14 | 35 | $9^h42^m38^s$ | $-11°02'46''$ |
| casp0022 | WLC | Feb 3 | 03:34:56 | 2 | $9^h42^m38^s$ | $-11°02'46''$ |
| casp0023 | **HE0940** 90m | Feb 3 | 03:36:46 | 5400 | $9^h42^m38^s$ | $-11°02'46''$ |
| casp0024 | WLC | Feb 3 | 05:09:07 | 2 | $9^h42^m38^s$ | $-11°02'42''$ |
| casp0025 | FLAT | Feb 3 | 05:11:14 | 35 | $9^h42^m38^s$ | $-11°02'43''$ |
| casp0029 | FLAT | Feb 3 | 05:48:13 | 35 | $9^h42^m38^s$ | $-11°02'58''$ |
| casp0030 | WLC | Feb 3 | 05:51:04 | 2 | $9^h42^m38^s$ | $-11°02'59''$ |
| casp0031 | **HE0940** 2h50m | Feb 3 | 05:53:10 | 10200 | $9^h42^m38^s$ | $-11°02'58''$ |
| casp0032 | WLC | Feb 3 | 08:45:10 | 2 | $9^h42^m38^s$ | $-11°03'00''$ |
| casp0033 | FLAT | Feb 3 | 08:47:10 | 35 | $9^h42^m38^s$ | $-11°03'01''$ |
| casp0034 | DARK a.m. | Feb 3 | 08:55:38 | 3600 | $13^h05^m37^s$ | $-29°25'40''$ |
| casp0035 | BIAS | Feb 3 | 16:45:25 | 1 | $20^h56^m40^s$ | $-29°25'40''$ |
| casp0036 | BIAS | Feb 3 | 16:47:11 | 1 | $20^h58^m27^s$ | $-29°25'40''$ |
| casp0037 | BIAS | Feb 3 | 16:48:20 | 1 | $20^h59^m36^s$ | $-29°25'40''$ |
| casp0038 | BIAS | Feb 3 | 16:49:27 | 1 | $21^h00^m44^s$ | $-29°25'40''$ |
| casp0039 | BIAS | Feb 3 | 16:50:37 | 1 | $21^h01^m53^s$ | $-29°25'40''$ |
| casp0067 | DARK a.m. | Feb 4 | 09:17:21 | 3600 | $13^h31^m22^s$ | $-29°25'37''$ |
| casp0069 | BIAS AV5 | 00100 | 00:00:00 | 1 | $00^h00^m00^s$ | $00°00'00''$ |
| casp0070 | DARK p.m. | Feb 4 | 20:23:17 | 3600 | $0^h39^m07^s$ | $-29°25'36''$ |
| casp0076 | WLC | Feb 5 | 03:18:30 | 2 | $5^h45^m48^s$ | $-32°18'40''$ |
| casp0077 | FLAT | Feb 5 | 03:20:27 | 35 | $5^h45^m48^s$ | $-32°18'41''$ |
| casp0078 | **STD** | Feb 5 | 03:22:52 | 20 | $5^h45^m48^s$ | $-32°18'41''$ |
| casp0087 | FLAT | Feb 5 | 06:48:44 | 35 | $9^h42^m37^s$ | $-11°02'51''$ |
| casp0088 | WLC | Feb 5 | 06:51:15 | 2 | $9^h42^m37^s$ | $-11°02'51''$ |
| casp0089 | **HE0940** 2h30m | Feb 5 | 06:53:35 | 9000 | $9^h42^m37^s$ | $-11°02'52''$ |
| casp0090 | WLC | Feb 5 | 09:25:27 | 2 | $9^h42^m38^s$ | $-11°02'53''$ |
| casp0091 | FLAT | Feb 5 | 09:27:24 | 35 | $9^h42^m38^s$ | $-11°02'53''$ |

**Table 2.2:** *List of CCD exposures Feb. 3–5, 1994.*