Status Report: The Oxford Deep WFC Imaging Survey

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Review of Scientific Objectives and Strategy

Our four primary survey objectives are:

1. To investigate in detail the evolution of the angular clustering of galaxies at faint magnitudes as a function of colour.

2. To search for QSOs in the redshift range $5 < z < 6.5$ at a depth which samples the QSO luminosity function at least as deep as L_*.

3. To generate a catalogue of ~ 1000 rich clusters of galaxies to $z \sim 1$, which will provide a tracer of large-scale structure over this redshift range that is independent of the complex physics of galaxy formation.

4. To investigate the clustering properties of the population of $U-$ and $B-$ band Lyman-break dropout galaxies at redshifts $\gtrsim 3$ and compare these with our findings from the $z < 1$ cluster survey.

These goals are best addressed by a survey which covers large contiguous areas of sky such that the zero points of individual CCD frames can be adjusted to determine a self-consistent solution over a large region.

Observations to Date

The INT observations to date cover four dark weeks in August 1998, February & December 1999, and May 2000. The observations are restricted to three fields which met our criterion of low Galactic extinction. The final choice of field centres was determined to give optimum observability for the scheduled dates of the first two runs so as to allow for follow-up observations to be carried out at any time of year. This necessarily precluded observations of the other fields listed in our proposal for which data at some other wavelengths were already available, but does not affect out primary science goals. (The $E(B-V)$ values below are based on ref [5]):

$\alpha(2000)$	$\delta(2000)$	l	b	$E(B-V)$	Coverage (WFC fields)
00 17 30	+34 30 00	115	−27	0.054	11 ($BVRiZ$)
09 09 45	+40 50 00	181	+42	0.017	14 ($BVRiZ$)
16 39 30	+45 24 00	70	+41	0.014	5 ($BVRiZ$) 1(U)

After careful consideration of the filter characteristics we decided to use the SDSS i' filter in favour of RGO I due to the lack of a red cut-off in the latter. R has been used instead of r' as the latter was not available for our first run. Exposure times have been fixed at 3×900s (B), 3×1000s (V), 3×1200s (R), 3×1100s (i), 600s (Z) and 6×1200s (U). Observing conditions have been either clear (i.e. photometric or very light, sparse cloud), or clouded out,

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and seeing conditions have been in the range 0.9″–1.3″, with the exception of one night of poor ($> 2''$) seeing in February 1999. Coverage of the 0^h field in December 1999 was restricted to i-band catchup observations of existing fields due to a combination of bad weather and M31 microlensing observations (carried out as a PATT-scheduled override at the start of each night). Multiple exposures in the same band have been offset by 5″ to provide sampling of each object by more than one pixel. In each region we have observed fields in a diagonal grid pattern with the camera rotated by 180° for alternate strips of fields to give complete sky coverage and appropriate overlaps between adjacent fields.

These data represent a total of ~ 11 deg^2, or just over one third of our original goal of 9 deg^2 per field. Of the 28 nights we have been allocated to date we have lost at least 14 full nights due to combinations of weather and instrument problems. We therefore estimate that to complete a survey of these three regions in $BVRi'Z$ will require a further three weeks of clear observing. To complete two regions each of 5 deg^2 in U will require a further 4 dark nights override in good seeing conditions. Allowing for some weather lossage, a reasonable timescale for the completion of the survey is therefore 4 further weeks of observations. Our 9^h field is closest to completion, and so we would prefer to schedule this future to consolidate observations of the 0^h and 16^h fields.

Data Reduction

Photometrically matched catalogues of image detections (using the method of ref [1]) are available for most of the data from the first two runs, and procedures are in place to extend these catalogues to the remaining data. Final combined images with photometric and astrometric calibration information are being archived on CDROM. We find detection limits consistent with the numbers in our original proposal. Image detection and photometry is being performed using the Sextractor package. The astrometric solutions are adequate for multi-object spectroscopic follow up with 8m telescopes. A common-user interface for wider access to the survey catalogues is under construction.

Follow-up Observations and Analyses

In October 1998 we began a follow-up study of our survey K-band using the ONIS 1024×512InSb camera on the MDM 1.3m telescope. The initial aim of this study was to extend the cluster catalogue beyond $z \sim 1$. To date we have obtained roughly 2 deg^2 of K-band data to a limiting magnitude of $K \sim 19.0$. We have detected large numbers of objects (~ 100 deg^{-2}) with $R - K \gtrsim 6$ which can be classified as EROs[2] (Figure 2). Spectroscopic follow-up observations of a sample of these objects are in progress with NIRSPEC on the Keck-II telescope and with OHS on Subaru. A proposal has been submitted to Gemini for the current round to obtain 10μm observations of our spectroscopic sample to tie down the SEDs of these objects. We plan to make our K-band data a full component of the public survey database.

VLA A & D-array observations at 1.4Ghz are now available which cover all three of our WFC survey regions. We aim to complement these with B/C-array data to reach a confusion-free survey (5-σ limits at 100μJy) over the full survey region. The expected surface density of sources in this region is ~ 1000 deg^{-2}.

The combination of radio and IR data with our survey targets two populations which are presently very poorly differentiated, and whose properties and cosmic evolutions are poorly known. The first of these (dominant at the faintest flux levels) are star-forming spiral galaxies. The second (dominant at the brighter levels) are weak AGNs in elliptical galaxies. Our comprehensive multi-colour optical/near-IR dataset will be essential in decoupling these populations since dust-reddening in the spirals means that crude (one or two colour) separations are unreliable. We expect to separate the populations and to obtain (using mainly photometric methods) their redshift distributions. This will allow the first determination of their relative cosmic evolutions at these epochs, and provide the strongest constraints yet on the collapse redshift of the elliptical population. We will search for correlations between the radio population and the galaxies, clusters and special objects like the EROs in our survey.

The optical data are of comparable depth to the recent surveys[5] for Lyman-break galaxies at $z \sim 3$ and 4. We expect to detect the same populations as found by those authors. It is known that the galaxies are strongly clustered[6], and the large contiguous coverage of our survey (much larger than the 0.3 deg^2 of ref [5]) will enable us to make a definitive measurement of the correlation length for comparison with large-scale numerical simulations.

The 9-hr field was centred on new deep images at 74 MHz and 330 MHz observed with the VLA in A-array, aimed at finding the highest redshift radio galaxies which are characterized by very steep spectra. Observations at 74 MHz select $z = 5$ objects at 440 MHz rest frequency. Previous low-frequency surveys (151 MHz) sample distant objects very nearly in the GHz regime which are depleted by synchrotron and inverse-Compton losses. This is part of an on-going Oxford project to quantify both the co-moving space density and birth-function of powerful classical double radio-sources. We have since obtained B-array data at these frequencies for our 9-hr and 0-hr fields. With these data we are sensitive to structures up to 0.6 degrees in extent. Cross-matching our 74 MHz catalogue with our multi-colour optical/near-IR data is ideal for identifying the bulk of the radio sources, thus making spectroscopic follow-up more efficient.

Resources:

We currently have a substantial share of the processing power of five fast alpha workstations and a number of high performance PCs, with $\sim$ 100Gb of disk space currently dedicated to this project. Web space is available for the final catalogues to be made easily available.

GD is acting as overall coordinator for this project. JB, KB, GD and JK are working together on the data reduction, image detection/classification, catalogue creation and astrometry. EO, GD, LAM and GW are undertaking the K-band survey and associated ERO follow-up. SR, KB and JW are responsible for the radio observations and reductions. GD and JB are working on the large-scale clustering, and JK is coordinating the high-redshift QSO search. LM and WB are working on the use of these data to investigate the properties of the shear signal due to weak gravitational lensing. HT, GD, EO and WS are investigating optimal detection filters for galaxy clusters from the WFC and K-band data (Figure 2).

References:

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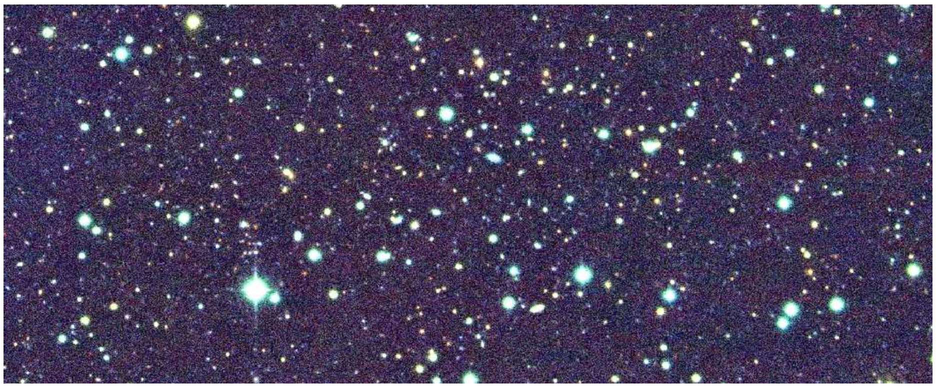

Figure 1: A sub-area of roughly 60 arcmin^2 taken from a pseudo-colour (BVR) image made up of one of the OWFC frames. The faintest objects visible in this image have $B \sim 27$. The bluest galaxies clearly exhibit a stronger clustering signal than complete B-band magnitude-limited sub-samples.

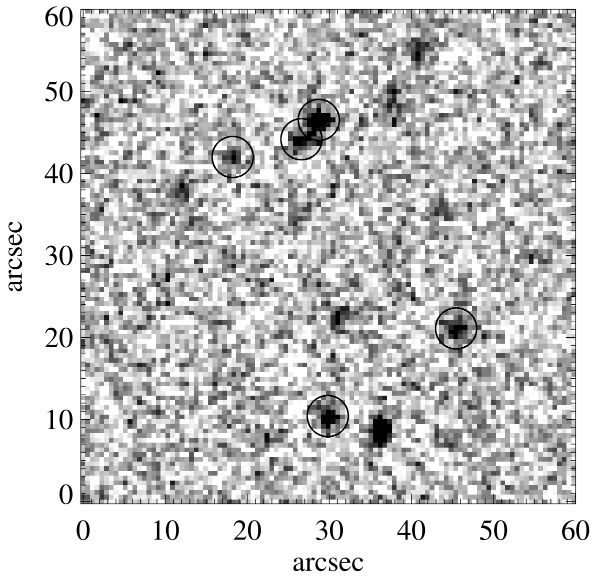

Figure 2: An example of a likely high-redshift cluster as seen in our K-band survey data. The five objects circled are all identified as EROs with $R - K > 6$. Gemini NIRSPEC observations of this cluster are scheduled in May 2000.