THE 6DF GALAXY SURVEY

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The 6dF Galaxy Survey (6dFGS) will measure 160000 redshifts and up to 15000 peculiar velocities over the whole southern sky with |b| > 10°. The survey sample is primarily selected from the 2MASS near-infrared sky survey, supplemented by a wide variety of other additional target samples. The goals of the survey are to map the positions and velocities of galaxies in the nearby universe, providing new constraints on cosmological models, and a better understanding of the local populations of normal galaxies, radio galaxies, AGN and QSOs. The survey uses 75% of the time on the UKST. Observations have so far been obtained for 25% of the survey fields and completion is expected early in 2005. The data is non-proprietorial, and will be released in annual tranches. See page 13.

Survey Description

The 6dF Galaxy Survey is a spectroscopic survey of bright galaxies and quasars covering the 17,000 deg^2 of the southern sky with |b|>10°.

The primary targets for the z-survey are 113765 K_s-selected galaxies from the 2MASS Extended Source Catalog, version 3 (XSC). Since the survey is attempting a 'census' of the local Universe, we want to avoid any bias against lower-surface-brightness galaxies, and ideally we would like to use total magnitudes. The 2MASS data does not have the depth or resolution to derive robust total magnitudes for galaxies to low latitudes, but has very robust isophotal magnitudes to an isophote of $\mu_K=20^m/\mathrm{arcsec}^2$. We found that at high latitudes, we were able to make a surface-brightness correction to these standard isophotal magnitudes, which gave an excellent approximation to the total magnitude (Figure 1); also this 'corrected' isophotal magnitude was extremely robust to stellar contamination. Our final selection was then galaxies with $K_{cor}<12.75^m$, corresponding approximately to $K_{20}<13^m$ for typical K-selected galaxies. Roughly half the sample is early type. All galaxies are observed, even where the redshift is already known, to give a complete spectroscopic sample at reasonable resolution (R ~ 1000) and S/N (S/N ~ 10/pixel).

Merged with the primary sample are 16 other smaller extragalactic samples – most of these could not be undertaken on any other telescope, being too large for long-slit work, but too sparse for multiplexing in their own right. These samples heavily overlap, increasing the efficiency of the telescope – the combined grand sum of all the samples amounts to 500,000 sources, but only 160,000 spectra are needed.

Table 1 gives a breakdown of the samples. 'PID' is the program ID number, 'pri' is the priority, with higher numbers meaning higher priority and consequent higher completeness; 'new' means not already included in a higher listed sample; 'unique' means unique to that survey; 'spectra' is the expected number of new spectra needed, to complete each sample to adequate completeness.

The Peculiar Velocity Survey

The goal of the *v*-survey is to measure peculiar velocities for an all-southern-sky sample of galaxies. Peculiar velocities will be measured for early-type galaxies via the $D_n – \sigma$ relation, using 2MASS photometry to give diameters (D_n) and 6dF spectroscopy to give velocity dispersions (σ). The *v*-survey sample consists of all early-type galaxies from the primary *z*-survey sample that are sufficiently bright to yield precise velocity dispersions. Because we cover the sky twice, suitable candidate galaxies (selected on the basis of either 2MASS morphology or first-pass 6dF spectroscopy) can be observed a second time in order to extend the *v*-survey sample to fainter limits. Based on the high fraction of early-type galaxies in the *K*-selected sample and the S/N obtained in our first-pass spectroscopy, we expect to measure distances and peculiar velocities for 10 – 15000 galaxies out to distances of at least 15000 km s^{-1}.

Tiling

Figure 2 shows the surface density of survey targets over the sky, together with the adaptive tiling used to efficiently cover the survey region with 1360 6dF fields. The survey area is 17000 deg^2, so 1360 5.8°–diameter 6dF fields give a mean of 124 sources per tile (well-matched to the number of 6dF fibres) and cover the sky twice over. This adaptive tiling gives an overall sampling rate for the input source catalogue of 94%, with excellent uniformity despite the large fluctuations

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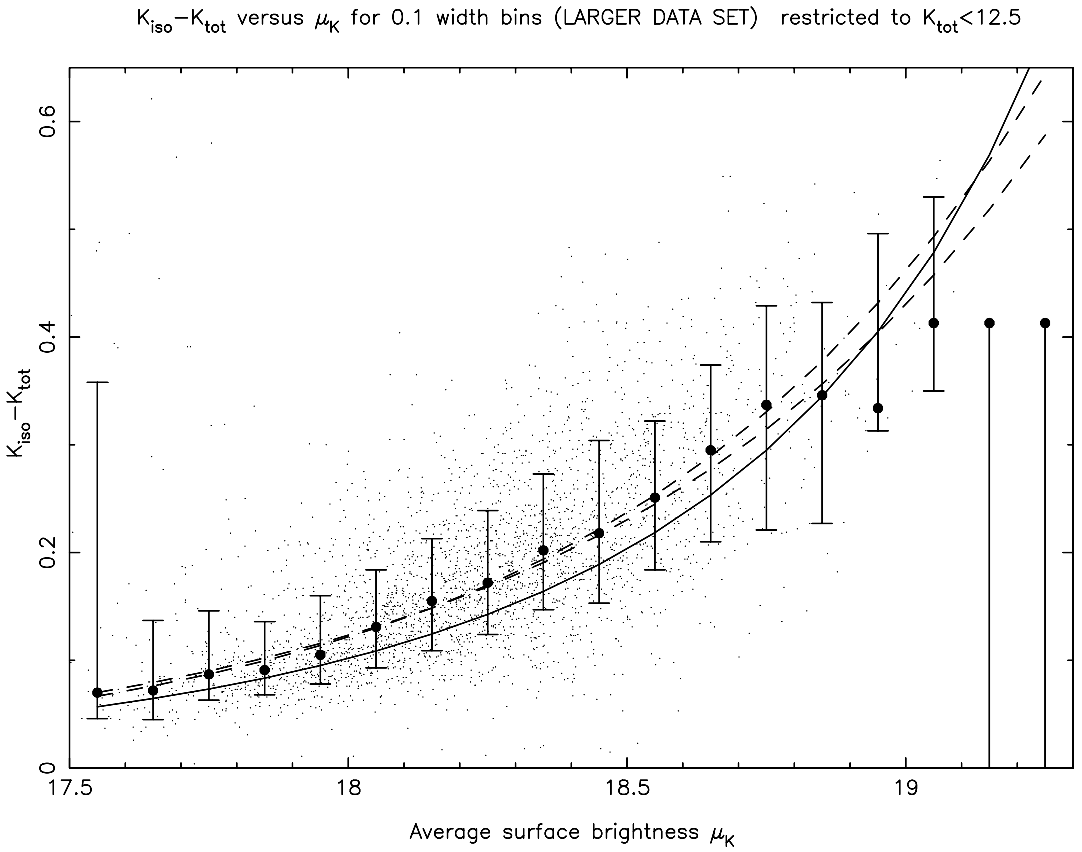

Figure 1. Correlation between isophotal-total magnitude deficit and surface brightness, vs a simple exponential disc model (solid curve) and the finally adopted correction (upper dashed curve).

Table 1: Samples included in 6dFGS

Program name (contact)	PID	pri	raw	new	unique	spectra
2MASS K ≤ 12.75 (Jarrett/IPAC)	1	8	113765	113644	15280	108063
Supercosmos r_F≤ 15.6 (Read/ROE)	7	6	64144	9228	1057	8305
Supercosmos r_F≤ 16.75 (Read/ROE)	8	6	66911	9752	8692	8776
IRAS FSC (Saunders/AAO)	126	6	22769	10712	9742	9641
ROSAT RASS (Croom/AAO)	113	6	3406	2915	2556	2623
2MASS H ≤ 13.0 (Jarrett/IPAC)	3	6	90217	3271	1702	2944
2MASS J ≤ 13.75 (Jarrett/IPAC)	4	6	93701	2003	1748	1802
HIPASS 4σ (Drinkwater/Brisbane)	119	6	1151	821	809	739
Durham/UKST (Hoyle/Drexel)	78	6	1145	466	459	419
Shapley S/cluster (Proust/Meudon)	19	6	1328	939	931	845
Horologium S/cluster (Rose/UNC)	109	6	1325	724	722	688
DENIS I<14.85 (Mamon/IAP)	5	5	22907	4560	3077	3876
DENIS J<13.85 (Mamon/IAP)	6	5	22631	2080	2057	1768
2MASS red AGN (Nelson/IPAC	116	4	2260	2132	2091	1706
HES quasars (Wisotzki/Potsdam)	129	4	3846	3539	3462	2831
NVSS quasars/rg's (Gregg/UCDavis)	130	4	4460	4334	3051	3467
SUMSS quasars/rg's (Mauch/USyd)	125	2	13171	4488	4488	2693
Totals			**529137**	**175608**	**61924**	**161187**

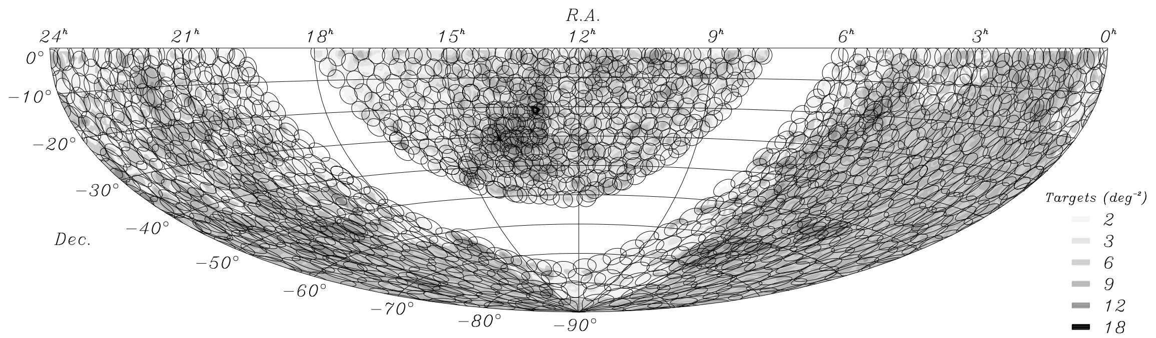

Figure 2. The greyscale shows the density of 6dFGS targets on the sky; the arrangement of the survey fields produced by the adaptive tiling algorithm is overlaid.

in density of these bright sources on a 6° scale. The twice-over sky coverage and the adaptive tiling are necessary, in any case, to reduce the number of close pairs lost from the sample because of the minimum fibre separation constraint.

Science Goals

The main scientific goals of the *z*-survey are:

- To measure the luminosity function of NIR-selected galaxies, and so also the mass function of collapsed structures, and to determine the variations with local environment and spectral type.
- To quantify the small- and large-scale clustering of galaxies in the NIR, where the relationship between mass and light is simplest, and so constrain the scale-dependence of the biasing of the galaxies with respect to the mass.
- To measure the power spectrum of galaxy clustering over even larger scales and with greater uniformity than achieved by the 2dF galaxy survey.
- To study the evolution of the luminosity function and clustering properties for a large sample of X-ray-selected QSOs and AGN.
- To construct a large, all-sky, volume-limited sample of early-type galaxies as the basis for the peculiar velocity survey.

The major advantage of this survey over previous redshift surveys is the NIR sample selection. A galaxy's NIR luminosity is dominated by the light from the old stellar population, which means that the luminosity is integrated over the galaxy's star-formation history and is thus the most direct measure of the stellar mass. Compared to surveys selected in the optical or far infrared, NIR selection avoids over-weighting those galaxies with high current star-formation rates (SFRs).

The extra parameter provided by the *v*-survey is the galaxy's internal velocity dispersion, which is a dynamical measure of the galaxy's mass that can be compared to the measure obtained from the NIR luminosity. As well as masses, measurements of the internal velocities also provide distances (*D*) to a precision of at least 20% from the Fundamental Plane or $D_n - \sigma$ relations for early-type galaxies. The *v*-survey will reveal the precise nature of the mass concentrations

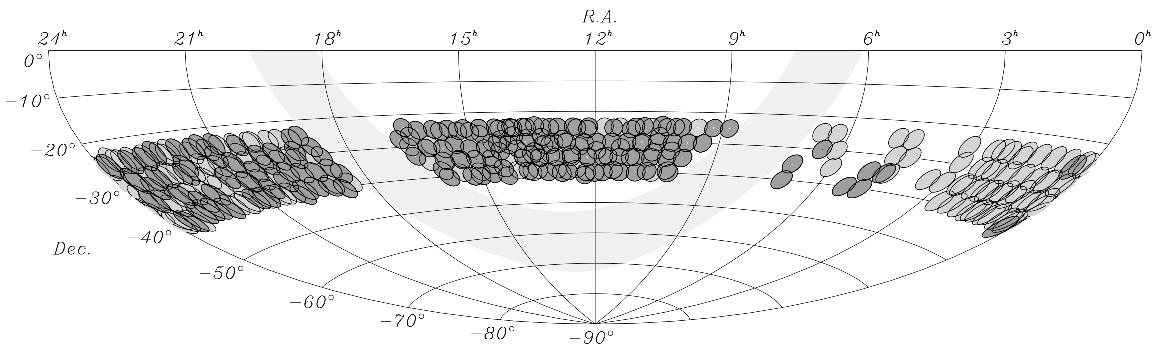

Figure 3. The observed (light grey) and redshifted (dark grey) fields obtained to date.

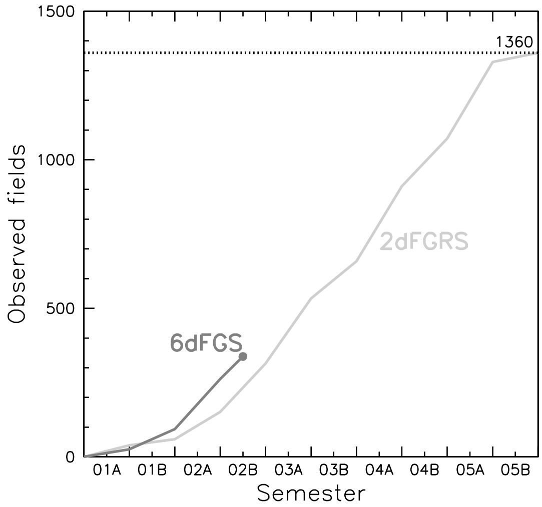

Figure 4. The progress of the 6dFGS, and a comparison with the 2dFGRS.

that are the proximate cause of the motion of the Local Group with respect to the CMB. The volume probed is large enough to provide, for the first time, a fair sample of the velocity field in the universe on all scales of interest, giving a very direct constraint on cosmological models for the large-scale mass distribution.

Survey Observations

Each field is observed with both V and R gratings, covering 4000 Å to 5600 Å at 5 Å FWHM (the 'V' spectrum) and 5500 Å to 8500 Å at 9 Å FWHM (the 'R' spectrum); these are spliced to reconstruct a full 4000 Å to 8500 Å spectrum from these two observations. Integrations are approximately 1 hr for the V spectrum and 0.5 hr for the R spectrum (these times are increased in poor observing conditions). This gives spectra with typical S/N greater than 10 pixel^{-1}, yielding >90% redshift completeness. For bright early-type galaxies (approximately 10% of the sample) we get sufficient S/N (>20 pixel^{-1}) to measure velocity dispersions down to 120km s^{-1} with 10% precision.

This observing strategy typically allows 4 survey fields to be observed on a clear night. With 75% of the UKST time and an average clear fraction of 60%, we should be able to observe 32 fields per lunation or 416 fields per year.

Survey Status

To date we have observed 367 6dFGS fields. At present the survey is concentrating on the $\delta = -30^o$ declination strip (actually $-42^o < \delta < -23^o$); the equatorial strip ($23^o < \delta < 0^o$) will be done next, and then finally the polar cap ($\delta < -42^o$). We have so far observed 323 fields in the current strip (excluding repeats), leaving 92 to go (i.e. the strip is 78% complete). Overall the survey is approximately 25% complete. Figure 3 shows the observed and redshifted fields to date.

The progress of the survey is summarized in Figure 4, which shows the cumulative number of survey fields observed and the target of 1360 fields. For comparison, the rate of accumulation for the 2dFGRS is shown over the same timescale. Assuming conservatively that the current rate is simply maintained, the survey seems to be heading for a completion date in early 2005. An alternative estimate for the completion date is based on the requirement that the survey still needs to observe about 1100 fields (including an approximate 10% allowance for repeat observations of fields of sub-standard quality). Then, at 4 fields per clear night and 60% clear fraction (allowing for both weather and technical problems), we require 460 nights to complete the survey. With an allocation of 75% of each lunation we get 176 nights per year, so the estimated time to completion is 2.6 years from now – i.e. about March 2005.

To date, redshifts have been measured for 180 of the 209 fields taken in the period January 2002 to July 2002 inclusive (the remaining 29 fields either have only one of the V and R spectra, or have other problems requiring re-observation or re-reduction). In the 180 fields redshifted so far, we have measured 13947 galaxy redshifts from 17026 objects. The mean redshift completeness (# galaxy redshifts/# objects observed) is 82% (although this includes the ~10% of fields taken in poor conditions which have such low completeness that they need to be re-observed); and also the inevitable contamination of the quasar samples by stars. This rate varies significantly from field to field, due both to variations in observing conditions and to variations in the contamination of the source catalogue by non-galaxy sources, especially at low Galactic latitudes. The redshift completeness for *galaxies* (# galaxy redshifts/# galaxies observed, i.e. excluding contaminating sources) is around 90%.

The power of the 6dFGS for mapping the large-scale structure of the local universe is well-illustrated by the figure which can be seen at: http://www.mso.anu.edu.au/6dFGS/Pics/Slices/6dFzslice.gif, which shows the slice through the local large-scale structure obtained by projecting the observed strip in the R.A. – redshift plane.

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