The 6dF Galaxy Survey: Initial results on large-scale structure and galaxy evolution

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The 6dF Galaxy Survey - an introduction

- The 6dFGS is a combined redshift and peculiar velocity survey of the local volume of the universe...
  - Near-infrared selected primary sample (from 2MASS)
  - Also redshift survey of other ‘interesting’ source samples
  - Peculiar velocities from Fundamental Plane distances

- The survey uses the 6dF spectrograph on the AAO’s UK Schmidt Telescope...
  - 5.7° diameter FoV (25.5 deg²)
  - up to 150 objects simultaneously
The 6dF Galaxy Survey - an introduction

• Survey strategy...
  – Cover the whole southern sky with $|b| > 10^\circ$
  – Primary sample selected from 2MASS to $K_{tot} < 12.65$
  – Secondary samples: $H < 13.0$, $J < 13.75$, $r < 15.6$, $b < 16.75$
  – 11 additional samples: radio, X-ray, IRAS…
  – Peculiar velocity sample: 15,000 brightest early-type galaxies

• Observations now complete: May 2001 to Jan 2006
  – 137k spectra, 120k galaxy redshifts over 80% of southern sky
6dFGS view of the Local Universe:

6dFGS data have established new redshifts for over 430 southern Abell clusters. (Andernach, et al.)

Galactic plane image courtesy of 2MASS
Example 6dFGS structure seen in a 1000 km/s-wide slice in supergalactic coordinate space.

Adjacent galaxies are enclosed in surfaces to highlight structure and texture (Labyrinth software: Hultquist/Perumal)

Over 500 voids with diameters ranging from 1500 to 6000 km/s have been identified.
6dFGS compared to other wide redshift surveys

- 6dFGS: 17,000 deg², K<12.65, H<12.95, J<13.75, r<15.6, b<16.75
- 2MRS: 5,740 deg², K<11.25, r<17.77
- 2dFGRS: 2,000 deg², b<19.45
- SDSS-DR5: 5,740 deg²
6dFGS compared to other wide redshift surveys

**Sample Size & Volume**
- 6dFGS: 17,000°
  - K<12.65, H<12.95, J<13.75, r<15.6, b<16.75
- SDSS-DR5: 5,740°
  - r<17.77
- 2MRS: K<11.25

**Aperture Size**
- 6dFGS: 6.6 kpc
- SDSS: 5.5 kpc
- 2dFGRS: 3.7 kpc
Near-infrared Luminosity Functions

- The 6dFGS K-band LF extends 1.5-2 mags further at both bright and faint ends (covers a factor of $10^4$ in $L$)
- Agrees with other recent LF measurements up to small differences between magnitude systems
- Previous, smaller samples have larger uncertainties in their normalisations

Final NIR and optical luminosity functions

- Revised LFs for FINAL sample in all bands (30% more galaxies)
- Small recalibrations of the photometry (most significant in $K_{\text{b}}$ $J$ $r_{\text{F}}$)
- Otherwise consistent with published LFs
Luminosity density in optical and NIR

- The luminosity densities in optical and NIR estimated from 6dFGS are broadly consistent with the 2dFGRS and SDSS results.

- K-band luminosity density lies at lower end of range.

- From optical through NIR, the variation of luminosity density with wavelength is consistent with models for an old stellar population.

Stellar population with $z_{\text{old}} = 12$ Gyr, $\tau = 4$ Gyr.
Stellar Mass Function

- NIR luminosities are good proxies for the total stellar masses in galaxies, so we can estimate the stellar mass function from the K-band luminosity function...

- NIR light is dominated by the older and cooler stars comprising the bulk of the stellar mass

- NIR mass-to-light ratios are well constrained, and k-corrections & extinctions are smaller in NIR

Model uncertainties dominate the errors
**Stellar Mass Function**

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**Model uncertainties dominate the errors**

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**Mann Function Comparison**

**Different Initial Mass Functions**
The present-day stellar mass density

- The 6dFGS data provides (up to systematic errors in the models) the most precise measurement of the stellar mass density today

\[ \Omega_\ast h = (1.80 \pm 0.04) \times 10^{-3} \]

\[ \rho_\ast = (5.00 \pm 0.11) \times 10^8 \, h \, M_\odot \, \text{Mpc}^{-3} \]
Stellar and Dynamical Masses

- The relation between velocity dispersion and stellar mass is consistent with $M_* \propto \sigma^2$
- This implies that star-formation efficiency in galaxies is roughly independent of their dynamical masses - i.e. $M/M_{\text{dyn}} \sim \text{const}$ (cf. Gallazzi et al. 2006)
- The scatter in the relation translates to a scatter in star-formation efficiency of about 40%
Galaxy colours and stellar populations

- NIR and optical samples have different mixes of galaxy types
- Age and metallicity are substantially degenerate w.r.t. colours
Galaxy ages and metallicities

- For 7000 DR1 galaxies we can measure Lick indices and emission lines at high S/N and get ages & metallicities

- The distribution of ages & metallicities shows...
  - Most galaxies have $-0.2 < [Z/H] < 0.3$
  - The youngest galaxies have higher minimum metallicities
  - The least metal-rich galaxies have older minimum ages

(Proctor et al, in prep)
Metallicity and Mass-to-Light Ratios

- Old galaxies show a clear mass-metallicity relation. Young galaxies do not.


- While the effects of age have been eliminated (by our deliberate selection), metallicity has not.

(Proctor et al, in prep)
**Metallicity and Mass-to-Light Ratios**

- Old galaxies show a clear mass-metallicity relation. Young galaxies do not.

- When metallicity is accounted for, all three bands show remarkable agreement in the $(M_{\text{dyn}}/L)$ relations.

- From the $(M/L) - M^{0.15}$ relation found, one would expect $(M/L) \sim L^{0.18}$. In fact, $(M/L) \sim L^0$.

- Therefore simple $(M/L)$ variations with $M$ or $L$ cannot be used to explain the ‘tilt’ of the Fund Plane.

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(Proctor et al, in prep)
6dFGS science from the redshift survey

• Luminosity and mass functions (Jones et al 2006; Jones et al in prep)
• The influence of local density and velocity distributions (Erdogdu et al 2006a,b; Inoue & Silk 2006)
• Galaxy groups and their properties (Brough et al 2006a,b; Forbes et al 2006, Firth et al 2006, Kilborn et al 2006)
• Studies of special interest samples such as radio sources (Sadler et al 2006, Mauduit & Mamon 2007, Mauch & Sadler 2007), infra-red luminous galaxies (Hwang et al 2007) among many others.

6dFGS Peculiar Velocity Survey

• To map in detail the density and peculiar velocity fields over half the local volume to ~15,000 km/s.
• To provide additional constraints on cosmological models, and better measurements of fundamental parameters, from statistics of these fields.
• To study the ages, metallicities and star-formation histories of early-type galaxies over a wide range of masses and environments.
6dFGS Database

- 6dFGS online database
  - Searchable using either SQL query commands or a WWW form
  - Each source has its own multi-extension FITS file, of spectra & postage stamps
  - The different target catalogues are also fully searchable online

- Current - Data Release 2
  - Released April 2005
  - Data Jan 2002-Oct 2004
  - 89211 spectra
  - 83014 unique redshifts
  - 936 fields

- Final Data Release
  - Expected Sept 2007
  - Complete dataset from May 2001 to Jan 2006
  - 137k spectra
  - 120k unique redshifts
  - 1464 fields

http://www-wfau.roe.ac.uk/6dFGS/

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