The 6dF Galaxy Survey
A low-redshift benchmark for bulge-dominated galaxies

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The 6dF Galaxy Survey

• A redshift and peculiar velocity survey of galaxies in the local universe
• Observations obtained over 5 years (2001-2006) using the UK Schmidt Telescope and the 6dF spectrograph
• Covers the southern sky with |b|>10°
• Primary galaxy sample from 2MASS with $K_{tot}$<12.75 (88% complete)
• Also $H<13.0$, $J<13.75$ (2MASS) and $r<15.6$, $b<16.75$ (SuperCosmos)
• 11 other samples (radio, X-ray, IRAS)
• Peculiar velocity survey measures FP distances for 15,000 bright early-types
• Database: 137k spectra & 124k galaxy redshifts plus photometry and images
Comparison with other redshift surveys

Sky coverage

- **6dFGS**: 17,000°
  - K<12.7, H<13.0, J<13.8
  - r<15.6, b<16.75
- **2MRS**: 4π, K<11.25
- **2dFGRS**: 2,000°
  - b<19.5
- **SDSS-DR5**: 5740°
  - r<17.8

Number & volume

- **SDSS**
- **2dFGRS**
- **6dFGS**
- **CfA+SSRS**
- **LCRS**
- **PSCZ**
- **ORS**
- **SAPMa**
- **QDOT**

Fibre aperture

- **6dFGS**: 6.6 kpc
- **SDSS**: 5.5 kpc
- **2dFGRS**: 3.7 kpc
The 6dFGS is primarily a LSS z+v-survey, but it provides a huge 2MASS-selected sample, including \(~15,000\) early-type galaxies with good-quality spectra from which dynamics and stellar populations can be inferred. So it is a mine of information on the properties of bulge-dominated galaxies as a function of environment at low redshifts, and a benchmark against which to compare more detailed or higher-redshift studies.
NIR luminosity functions

- The 6dFGS K-band LF extends 1.5–2 mags further at both bright and faint ends (range is a factor of $10^4$ in L)
- The 6dFGS K, H, J, r & b-band LFs agree with most other recent LF measurements, up to small differences in magnitude systems
- Previous samples are smaller, have less range in L and larger normalisation uncertainties

9500 sq deg

6dFGS

83028 galaxies

2MASS + 2dF

2MASS + ZCAT

2MASS + SDSS

NIR luminosity functions

- The 6dFGS K-band LF extends 1.5-2 mags further at both bright and faint ends (range is a factor of $10^4$ in $L$).
- The 6dFGS $K$, $H$, $J$, $r$ and $b$-band LFs agree with most other recent LF measurements, up to small differences in magnitude systems.
- Previous samples are smaller and have lesser range in $L$ and larger normalisations uncertainties.
- Some low-surface-brightness galaxies are missed at faint magnitudes, however.

### 6dFGS

- 83028 galaxies
- 9500 sq deg

Luminosity density in optical and NIR

- Luminosity densities in optical and NIR estimated from 6dFGS are consistent with, but more precise than, those from 2dFGRS/SDSS.
- K-band luminosity density lies at lower end of range.
- From optical through NIR, the variation of luminosity density with wavelength is consistent with an old stellar population.
- The 6dFGS data provides (up to uncertainties in the models) the most precise measurement of the low-z stellar mass density:
  \[ \rho_* = (5.0 \pm 0.1) \times 10^8 \, h \, M_\odot \, \text{Mpc}^{-3} \]
  \[ \Omega_* h = (1.80 \pm 0.04) \times 10^{-3} \]
6dFGS velocity dispersions

- Velocity dispersions measured for about 20,000 galaxies selected as having $cz<16500$ km/s and Tonry & Davis (1979) cross-correlation parameter $R>8$

- Comparisons with other high-quality samples show good agreement & imply the 6dFGS errors go as $\delta\sigma = 355/(1+R)$, with a mean 6dFGS $\sigma$ error of 10.9%
Stellar and dynamical masses

- Relation between velocity dispersion and stellar mass is consistent with $M_* \propto \sigma^2$

- Naively, this implies that star-formation efficiency in bright galaxies is broadly independent of their dynamical masses $M_*/M_{\text{dyn}} \approx \text{const}$

- The scatter in the relation translates to a scatter in star-formation efficiency of about 40%
**Ages & metallicities**

- Lick indices measured for 7000 DR2 galaxies at high S/N; fit range of indices to SSP models (Korn et al. 2005) to derive ages, metallicities and [$\alpha$/Fe]
  - $<z> = 0.035$
  - $<M_K> = -24.5$ ($= M^*$)
  - $<B-K> = 3.8$

- The joint distribution of ages and metallicities shows that...
  - The youngest galaxies have higher minimum metallicities
  - The least metal-rich galaxies have older minimum ages
  - The age-metallicity trend is consistent with projection of age-$[Z/H]$-$\sigma$ relation

Proctor et al., 2007, in prep.
Correlations of age, [Fe/H], [α/Fe] and σ

- The well-known correlation of increasing metallicity with increasing velocity dispersion is seen for both the passive galaxies and the low-emission galaxies.
- The high-emission sample shows a much broader range in metallicity and no obvious correlation between metallicity and velocity dispersion.
- For passive galaxies, there is a weak correlation between [α/Fe] and σ; a stronger correlation is between [α/Fe] and age (older ages ↔ higher [α/Fe]).
- The weak correlation of age with σ seems to be driven by a down-sizing tendency - for passive galaxies, the age of the youngest objects increases with σ.
Intrinsic scatter in the stellar populations

- The marginal distributions of $[Z/H]$ and $[\alpha/Fe]$ are approximately Gaussian, while the age distribution is approximately exponential.
- Fit the intrinsic scatter in the stellar population parameters using Monte Carlo simulations including observational errors.
- The intrinsic e-folding of the age distribution is $\sim 900$ Myr.
- The intrinsic Gaussian scatter in $[Z/H]$ is $\sim 0.3$ dex and in $[\alpha/Fe]$ is $\sim 0.07$ dex.
- The scatter is $[Z/H]$ is mainly due to the $[Z/H]-\sigma$ relation, but scatter in $[\alpha/Fe]$ is not.
M/L correlations with M and L

- To eliminate age effects take only old galaxies (>10Gyr)
- Find an increasing trend in M/L vs M
- This trend is steeper in bluer passbands
- Trend of M/L vs L is weaker than the trend with M
- Are these trends due to stellar population effects?
**M/M_\odot** correlation with M and L

- For old (>10Gyr) galaxy sample, apply Bruzual & Charlot (2003) SSP models to adjust observed M/L vs M slopes (thick lines) for metallicity trend (dashed lines)

- The luminosity at each mass is adjusted to the corresponding luminosity at a common [Z/H] (equivalent to computing M/M_\odot)

- Slope of M/L (or M/M_\odot) with M or L is now identical in all wavebands - i.e a consistent relation for old galaxies allowing for mass-metallicity correlation

- K band does not change as it is insensitive to [Z/H] (so use K band to avoid corrections)
Summary

• The 6dFGS provides a sample of ~15,000 low-redshift, bulge-dominated galaxies for studying stellar populations & their correlations with mass & environment
• Both a benchmark & a suitable sample for selecting subsets for detailed follow-up
• Correlations between stellar population parameters and mass for 7000 galaxies...
  - Strong $[\text{Fe/H}] - \sigma$ relation for old galaxies (more massive $\Leftrightarrow$ more metal-rich), but no such correlation for younger galaxies
  - Strong correlation between $[\alpha/\text{Fe}]$ and age (older ages $\Leftrightarrow$ more $\alpha$-enhanced), but only a weak correlation of $[\alpha/\text{Fe}]$ with $\sigma$
  - Weak correlation of age with $\sigma$, but this is mainly due to a down-sizing tendency, in that the age of the youngest objects increases with $\sigma$
  - For old galaxies, variations in $M/L$ vs $M$ with $\lambda$ are a consequence of the mass-metallicity relation
  - Allowing for this gives a common $M/L$ vs $M$ ($M/M_*$) relation at all $\lambda$
• Next step is to study these relations as functions of local density & environment
6dFGS Final Data Release

- **Final Data Release**
  - Available August 2007
  - Complete 6dFGS dataset
    May 2001 - Jan 2006
    - 137,000 spectra
    - 124,000 unique z’s
    - Photometry/images

- **6dFGS online database**
  - Searchable via SQL query commands or WWW form
  - Each source has its own multi-extension FITS file, (spectra, image stamps)
  - Target catalogues are fully searchable online

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