# The 6dF Galaxy Survey

## A low-redshift benchmark for bulge-dominated galaxies


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( also Will Saunders, Mike Read, Duncan Forbes, Warrick Couch & the 6dFGS team )



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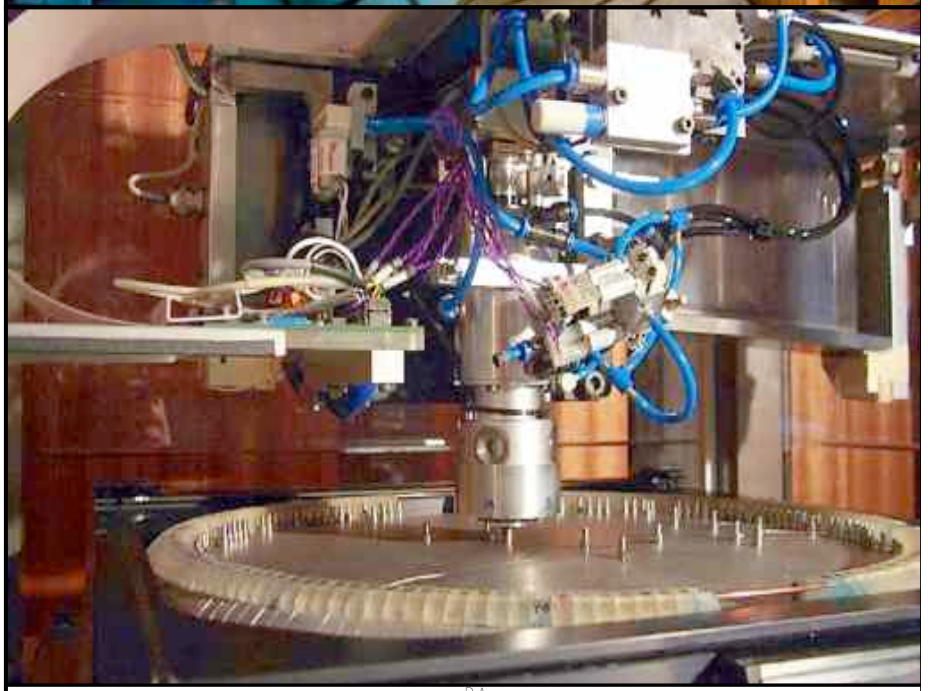
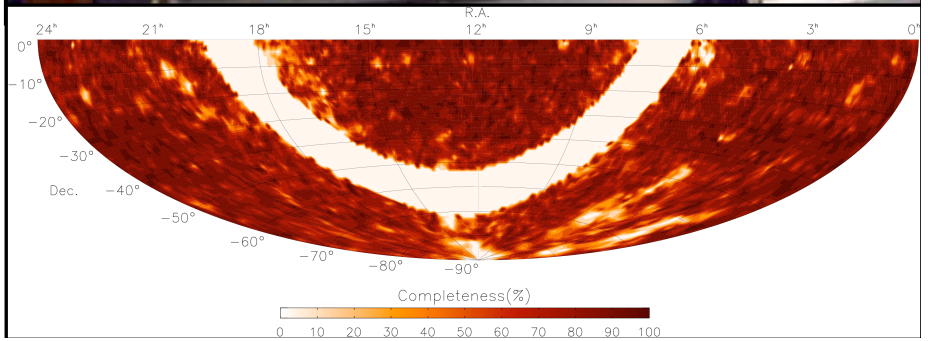
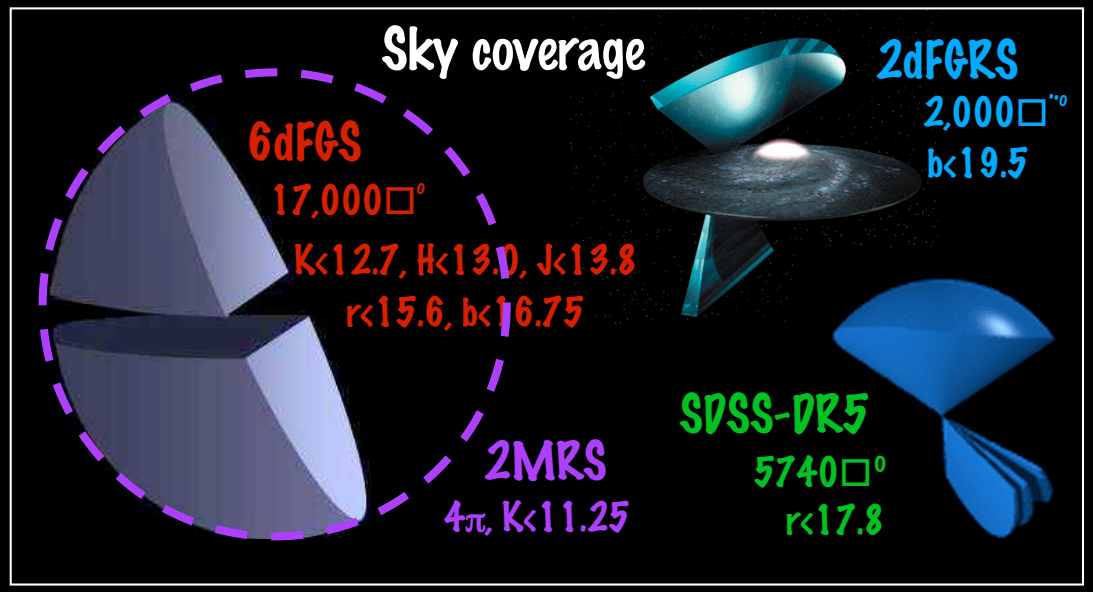
# The 6dF Galaxy Survey

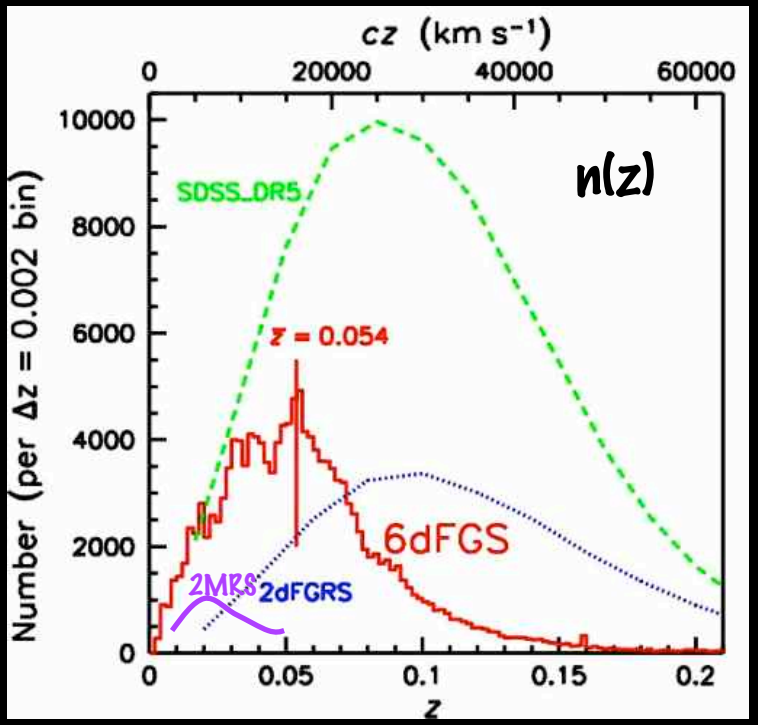
- A redshift and peculiar velocity survey of galaxies in the local universe
- Observations obtained over 5 years (2001-2006) using the UK Schmidt Telescope and the 6dF spectrograph
- Covers the southern sky with $|b|>10^{o}$
- Primary galaxy sample from 2MASS with $K_{tot}<12.75$ (88% complete)
- Also 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
- Data releases: Dec 2002, Mar 2004, May 2005; final release Aug 2007

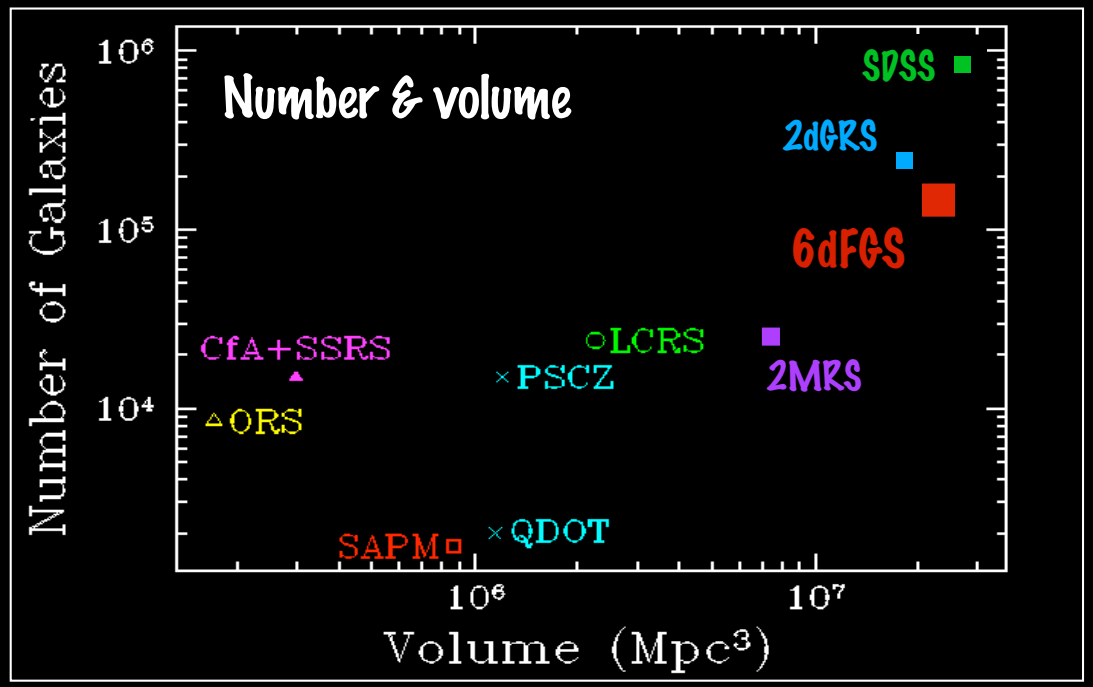


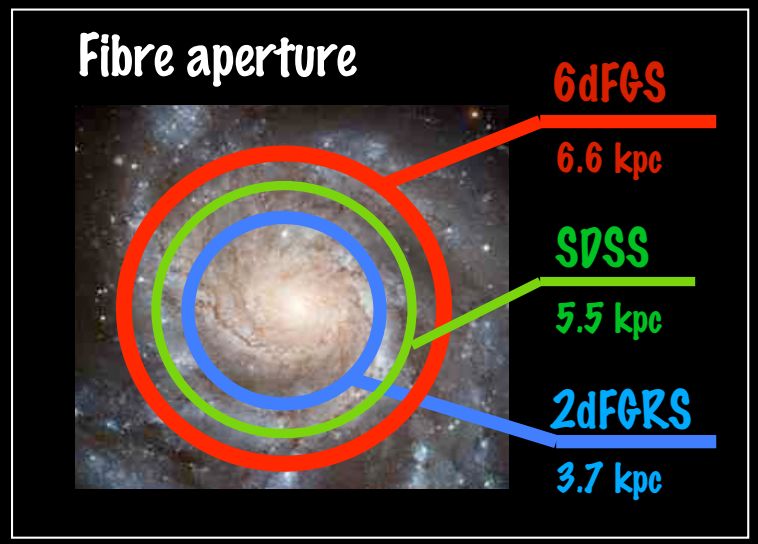


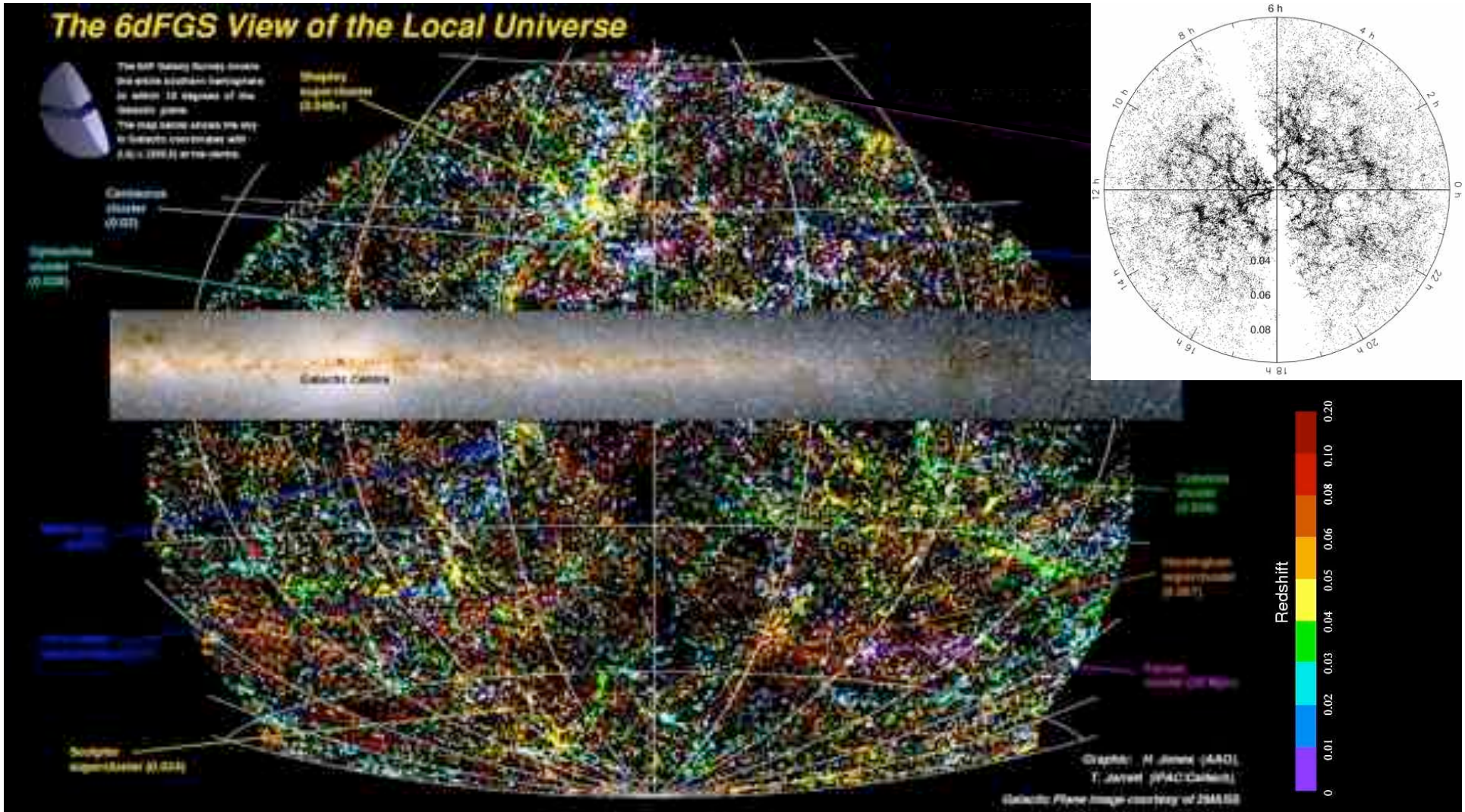
# Comparison with other redshift surveys



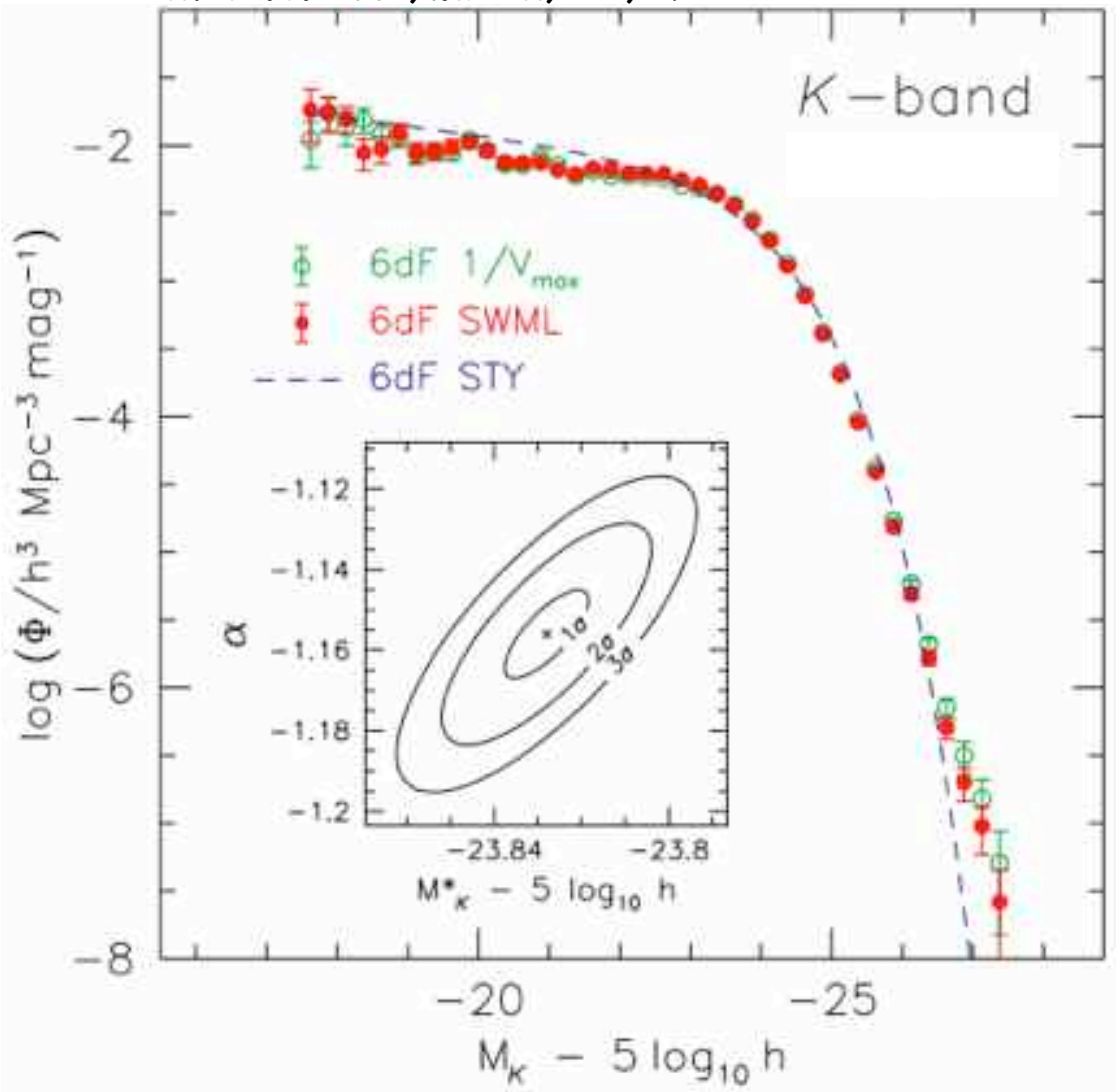



The 6dFGS is primarily a LSS z+v-survey, but it provides a huge 2MASS-selected sample, including ~15,000 early-type galaxies with good-quality spectra from which dynamics and stellar populations can be inferred. So it is a mine of information on the properties of bulge-dominated galaxies as a function 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

Jones et al. 2006, MNRAS, 369, 25

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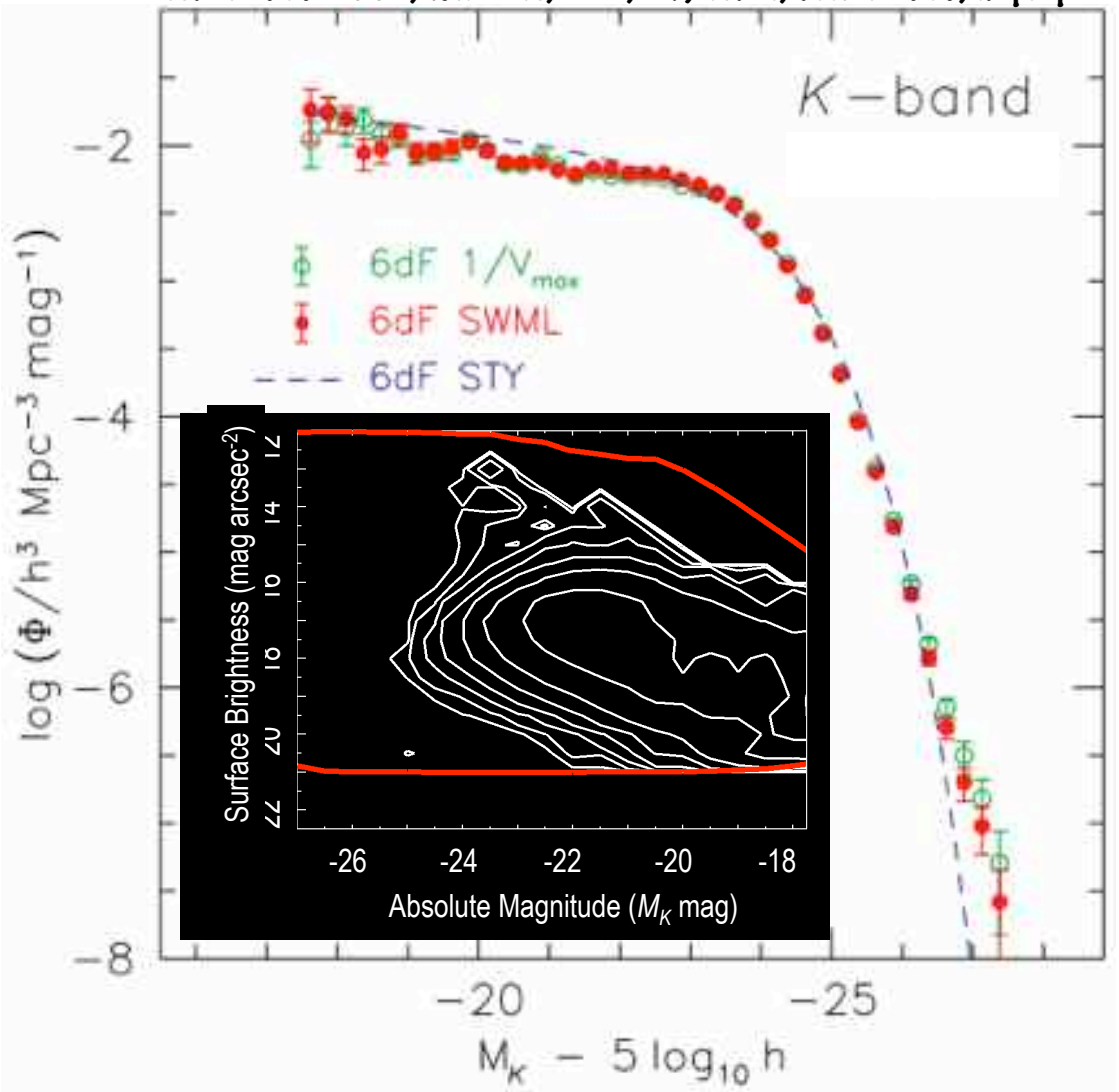
- Previous samples are smaller and have lesser range in L and larger normalisations uncertainties
- Some low-surface-brightness galaxies are missed at faint magnitudes, however.

Jones et al. 2006, MNRAS, 369, 25; Jones, Driver et al., in prep.

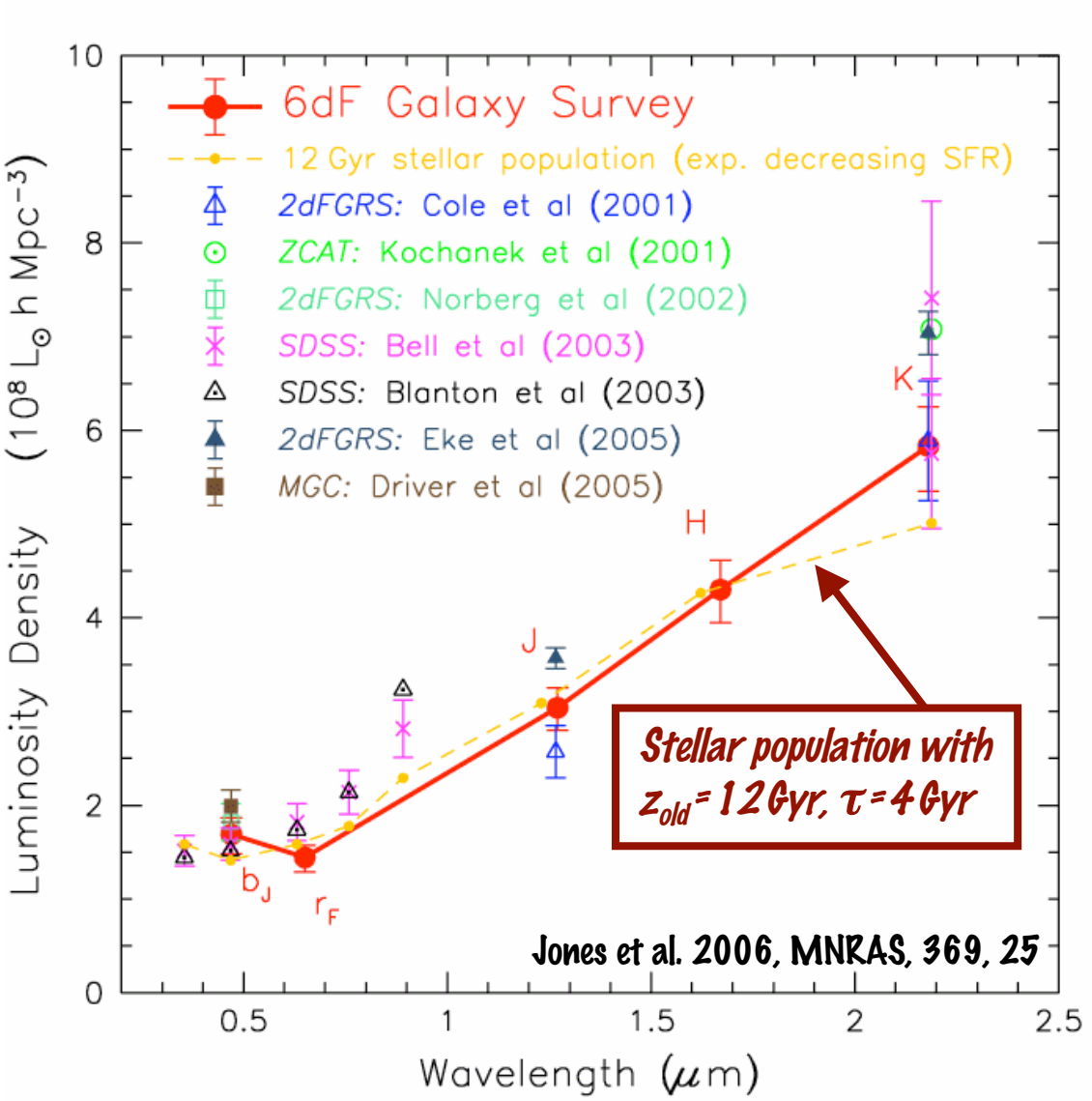



# Luminosity density in optical and NIR

- 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:

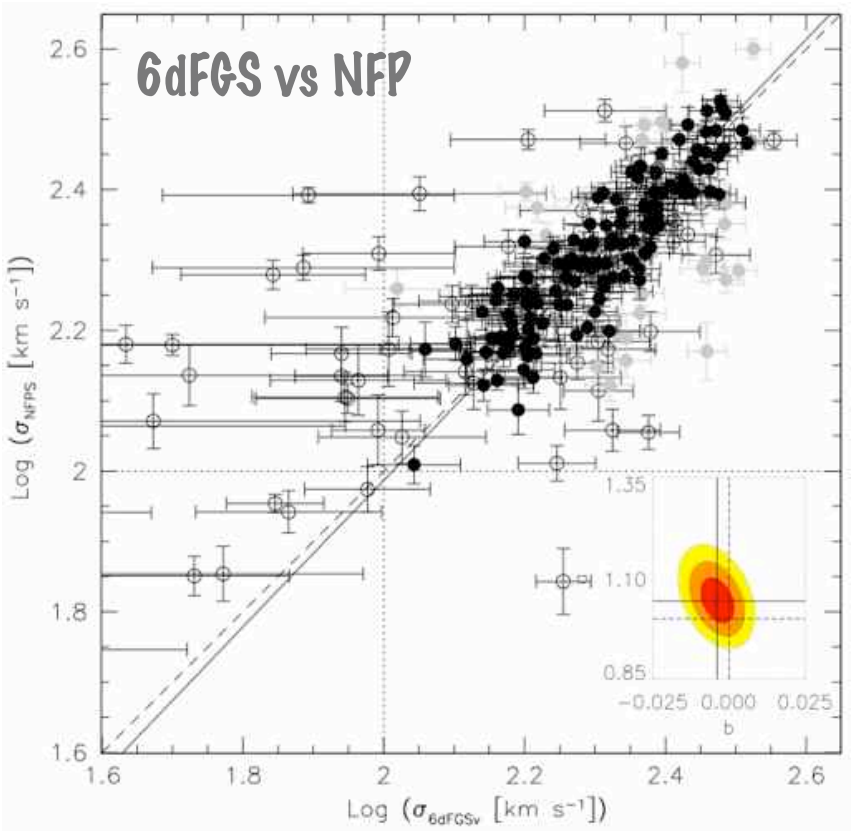
$\rho_\star = (5.0 \pm 0.1) \times 10^8\ h\ M_\odot\ Mpc^{-3}$

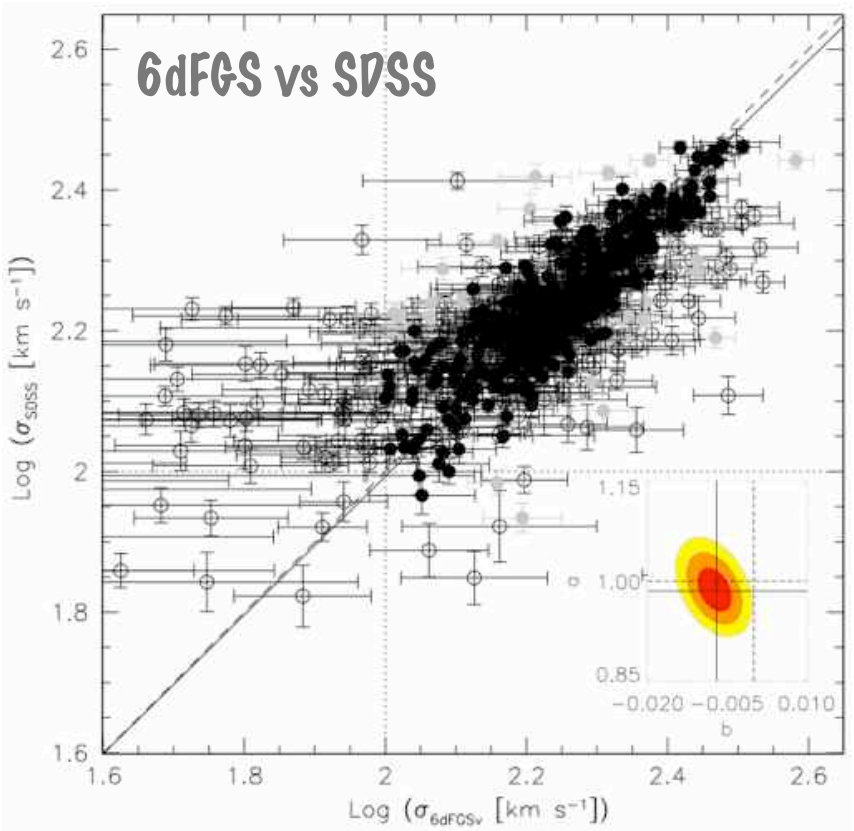
$\Omega_\star h = (1.80 \pm 0.04) \times 10^{-3}$



# 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 $\delta\sigma \approx 355/(1+R)$, with a mean 6dFGS $\sigma$ error of 10.9%

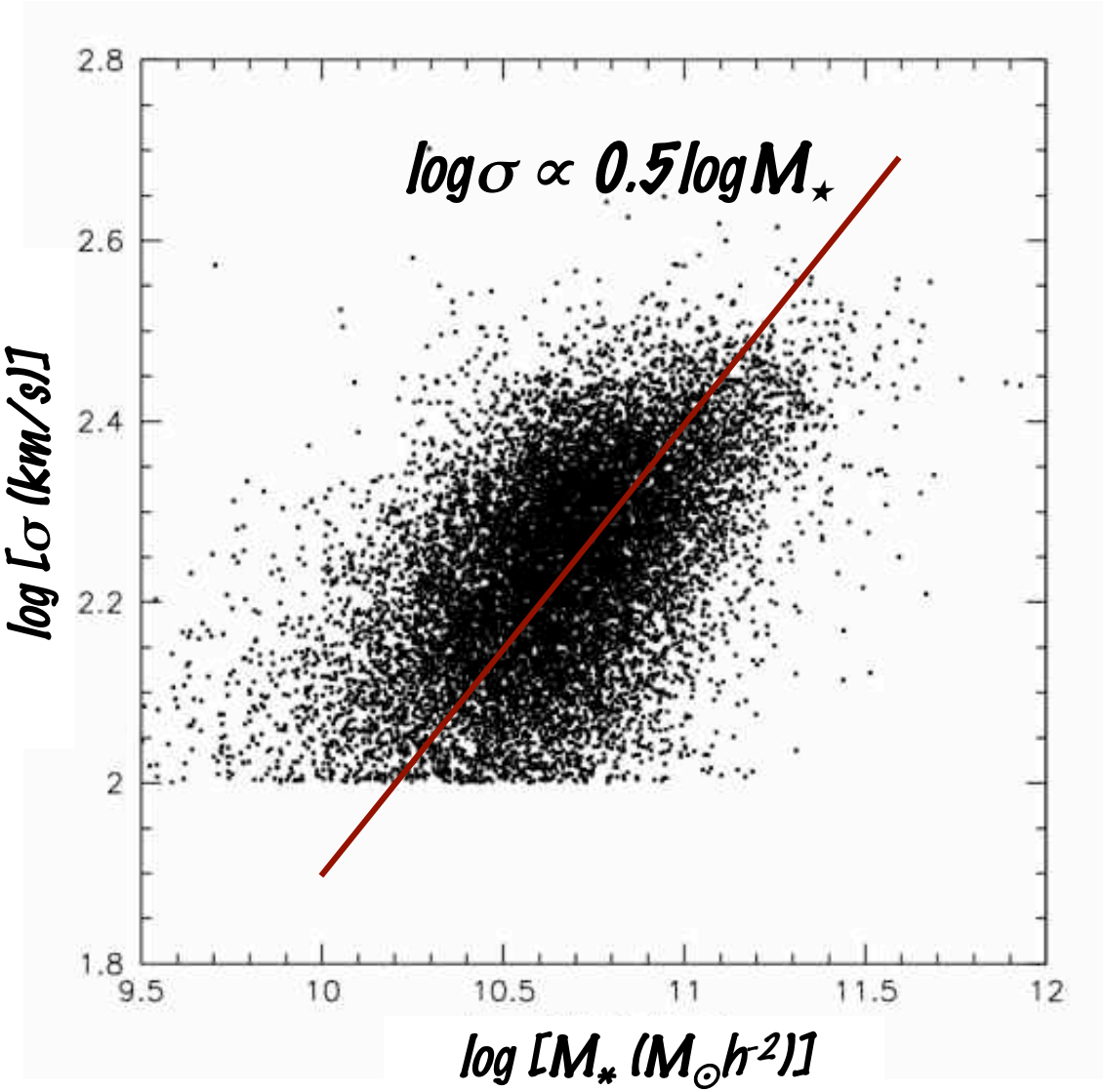



Campbell et al., in prep.

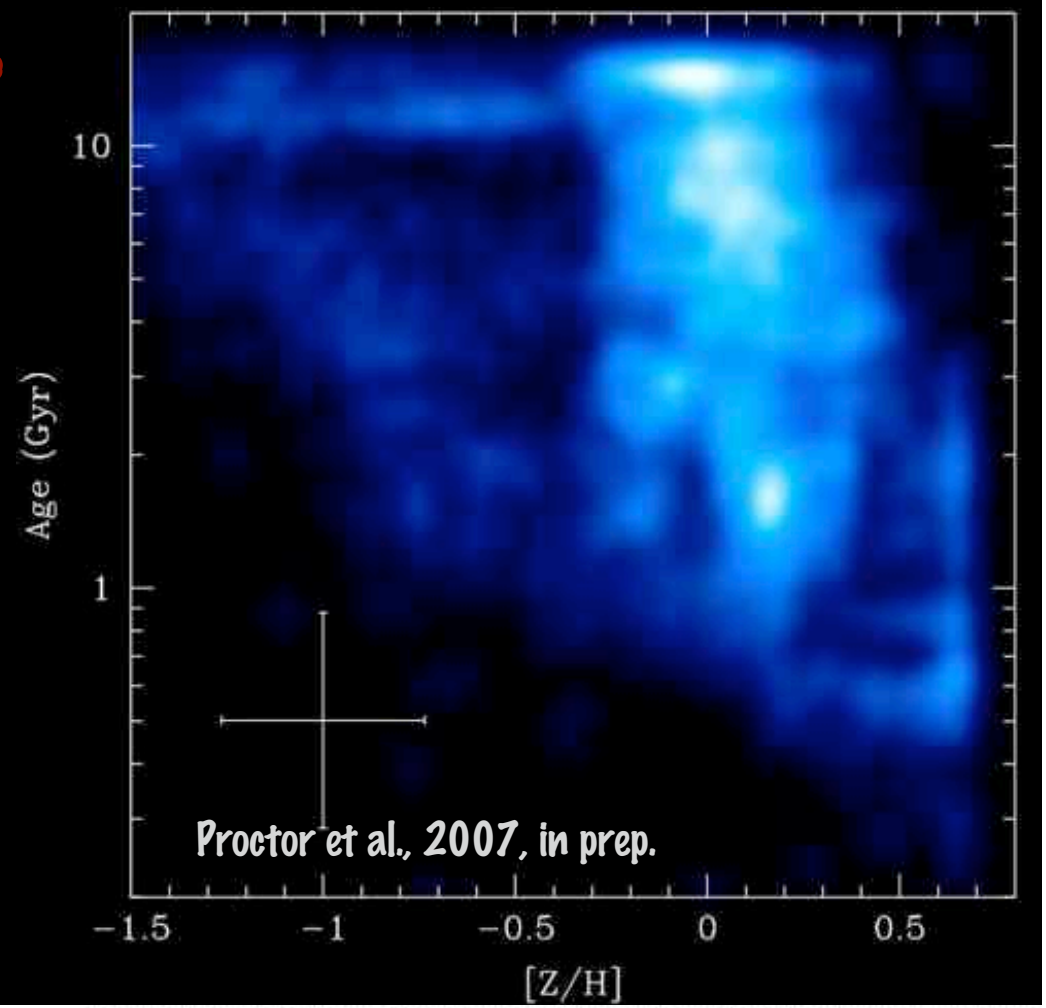
# Stellar and dynamical masses

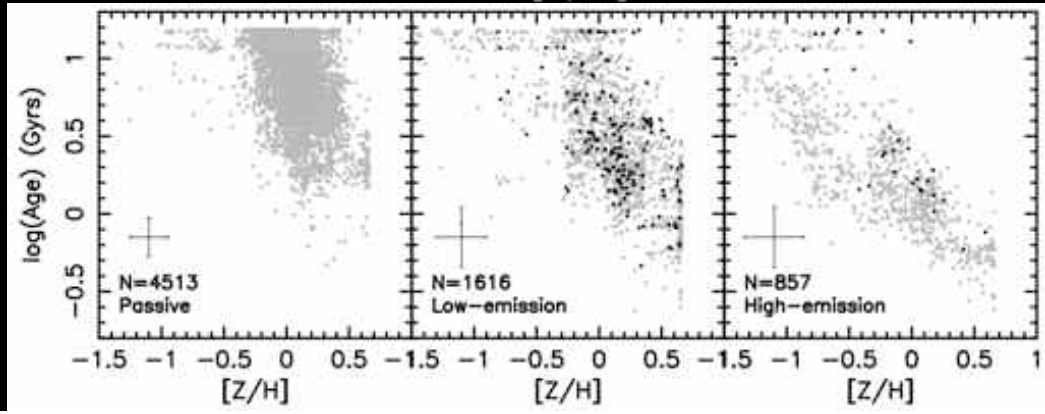
- Relation between velocity dispersion and stellar mass is consistent with
  $M_\star \propto \sigma^2$
- Naively, this implies that star-formation efficiency in bright galaxies is broadly independent of their dynamical masses
  $M_\star / M_{dyn} \approx const$
  (cf. Gallazzi+ 2006, MNRAS, 370, 1106)
- The scatter in the relation translates to a scatter in star-formation efficiency of about 40%



# Ages & metallicities

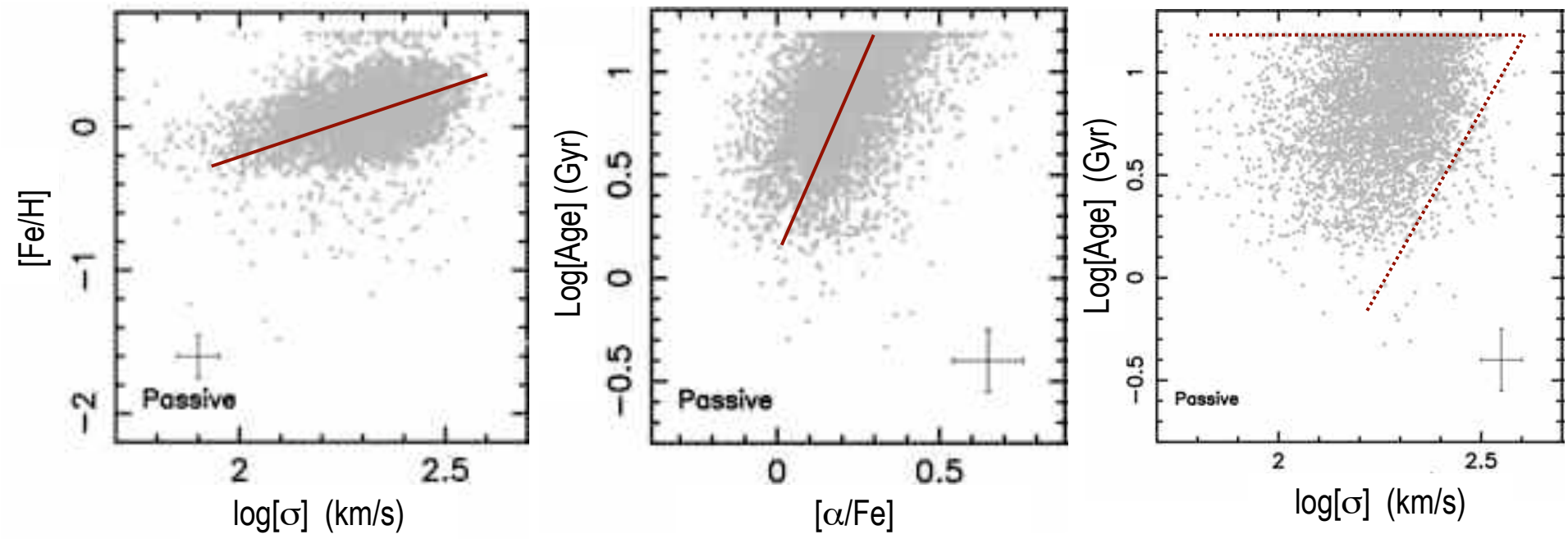
- Lick indices measured for 7000 DR2 galaxies at high S/N; fit range of indices to SSP models (Korn et al. 2005) to derive ages, metallicities and [$\alpha$/Fe]
  - $\langle Z \rangle = 0.035$
  - $\langle M_K \rangle = -24.5$ ($\approx M^*$)
  - $\langle B-K \rangle = 3.8$
- The joint distribution of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



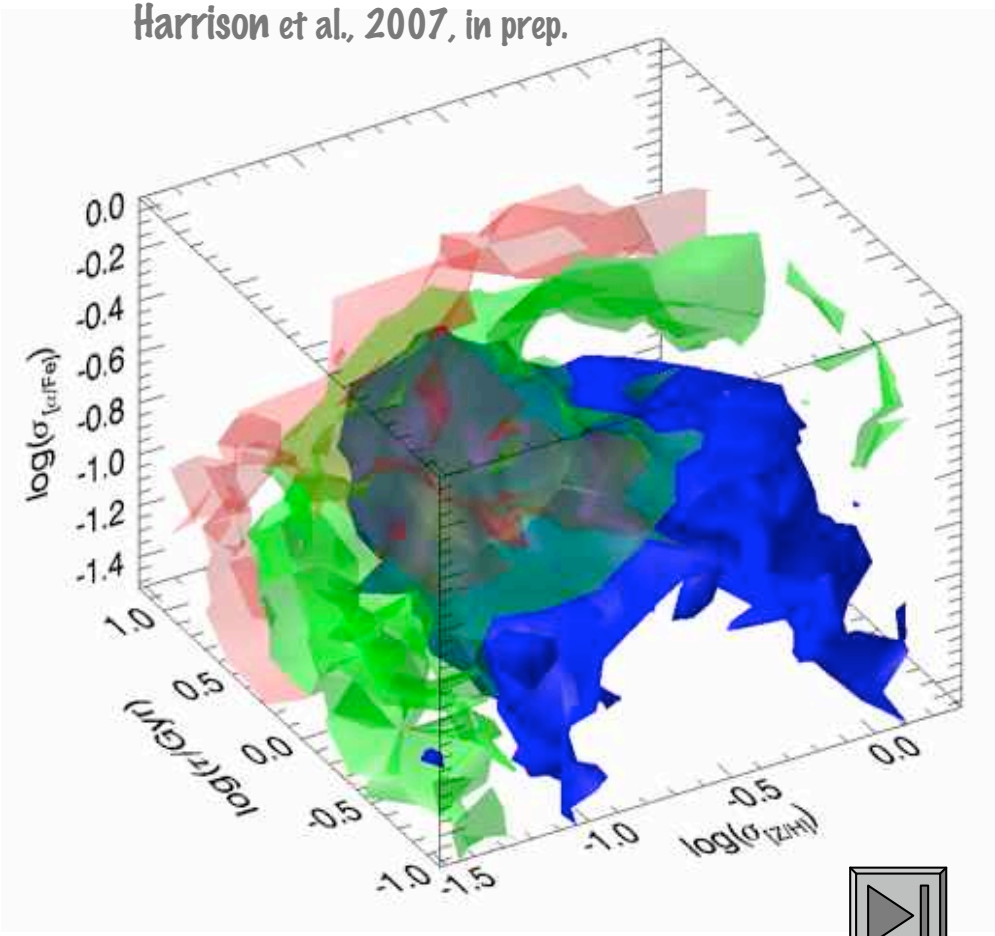
# Correlations of age, [Fe/H], [α/Fe] and σ

- 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



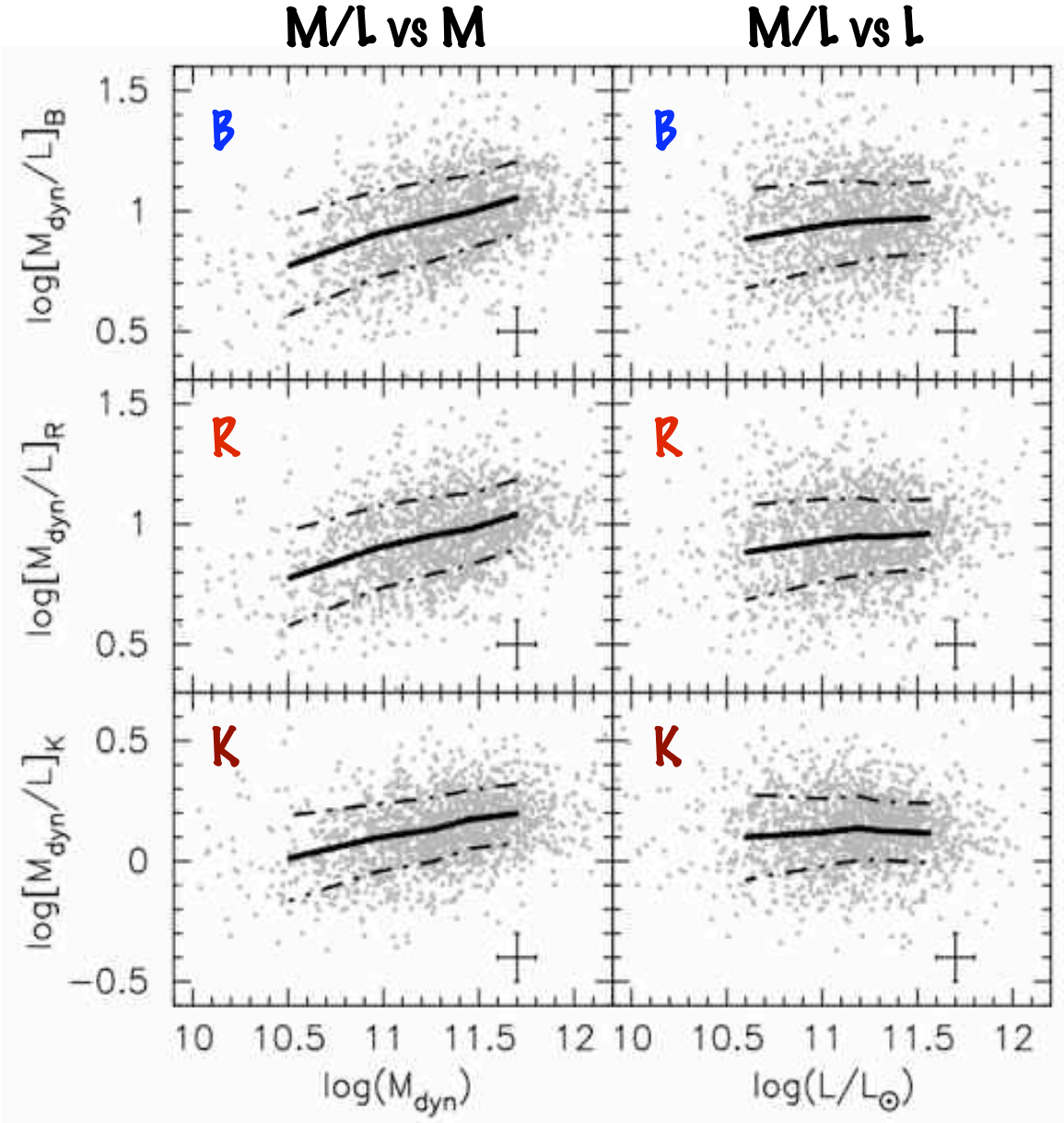
# Intrinsic scatter in the stellar populations

- 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 ~900 Myr
- The intrinsic Gaussian scatter in [Z/H] is ~0.3 dex and in [$\alpha$/Fe] is ~0.07 dex
- The scatter is [Z/H] is mainly due to the [Z/H]-$\sigma$ relation, but scatter in [$\alpha$/Fe] is not



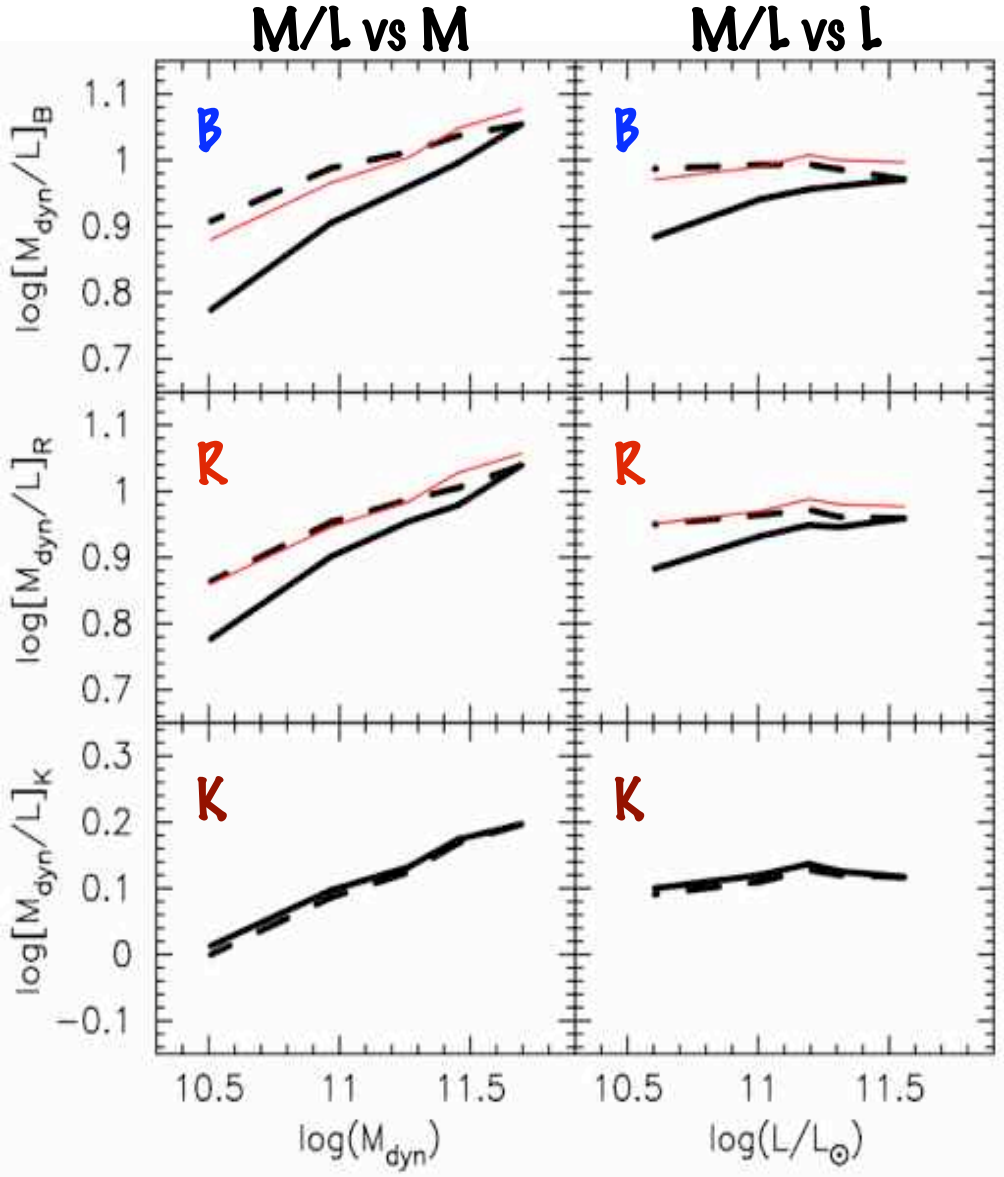
# M/L correlations with M and L

- 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?



# $M/M_\star$ 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 $M/M_\star$)
- Slope of M/L (or $M/M_\star$) 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

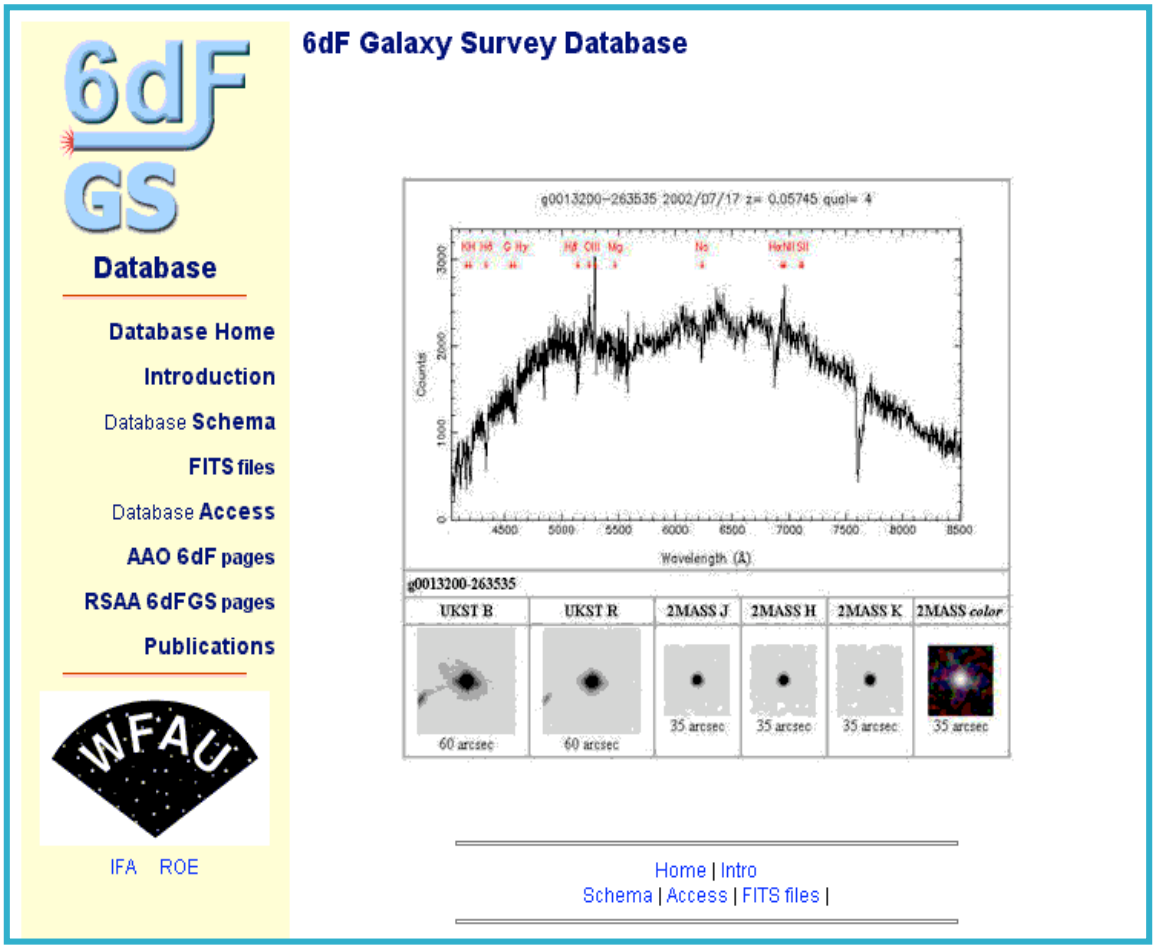
- The 6dFGS provides a sample of ~15,000 low-redshift, bulge-dominated galaxies for studying stellar populations & their correlations with mass & environment
- Both a benchmark & a suitable sample for selecting subsets for detailed follow-up

- Correlations between stellar population parameters and mass for 7000 galaxies...
  - Strong [Fe/H]-$\sigma$ relation for old galaxies (more massive $\Leftrightarrow$ more metal-rich), but no such correlation for younger galaxies
  - Strong correlation between [$\alpha$/Fe] and age (older ages $\Leftrightarrow$ more $\alpha$-enhanced), but only a weak correlation of [$\alpha$/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 ($M/M_\star$) 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/