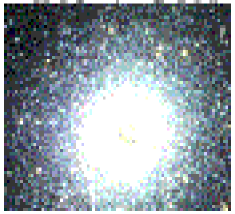
Mapping the Universe
About SDSS
Q&A
Image Gallery
Tour the Project
Contact Us
Credits
News
Archive
Documents
Survey Status
Data Products
SDSS@Work
Management
Collaboration
Survey Ops
Publications
Other Links

Sloan Digital Sky Survey

Image of the Week



Participating Institutions

The Advisory Council is the body which represents the Participating Institutions and advises the ARC Board of Governors on matters relating to the SDSS. The Participating Institutions are the six ARC institutions and seven non-ARC institutions participating in the SDSS.

- University of Chicago
- Fermi National Accelerator Laboratory
- Institute for Advanced Study
- Japan Participation Group
- Johns Hopkins University
- Los Alamos National Laboratory
- Max-Planck-Institute for Astronomy/Heidelberg
- Max-Planck-Institute for Astrophysics/Garching
- New Mexico State University
- University of Pittsburgh
- Princeton University
- United States Naval Observatory
- University of Washington

The Sloan Advantage

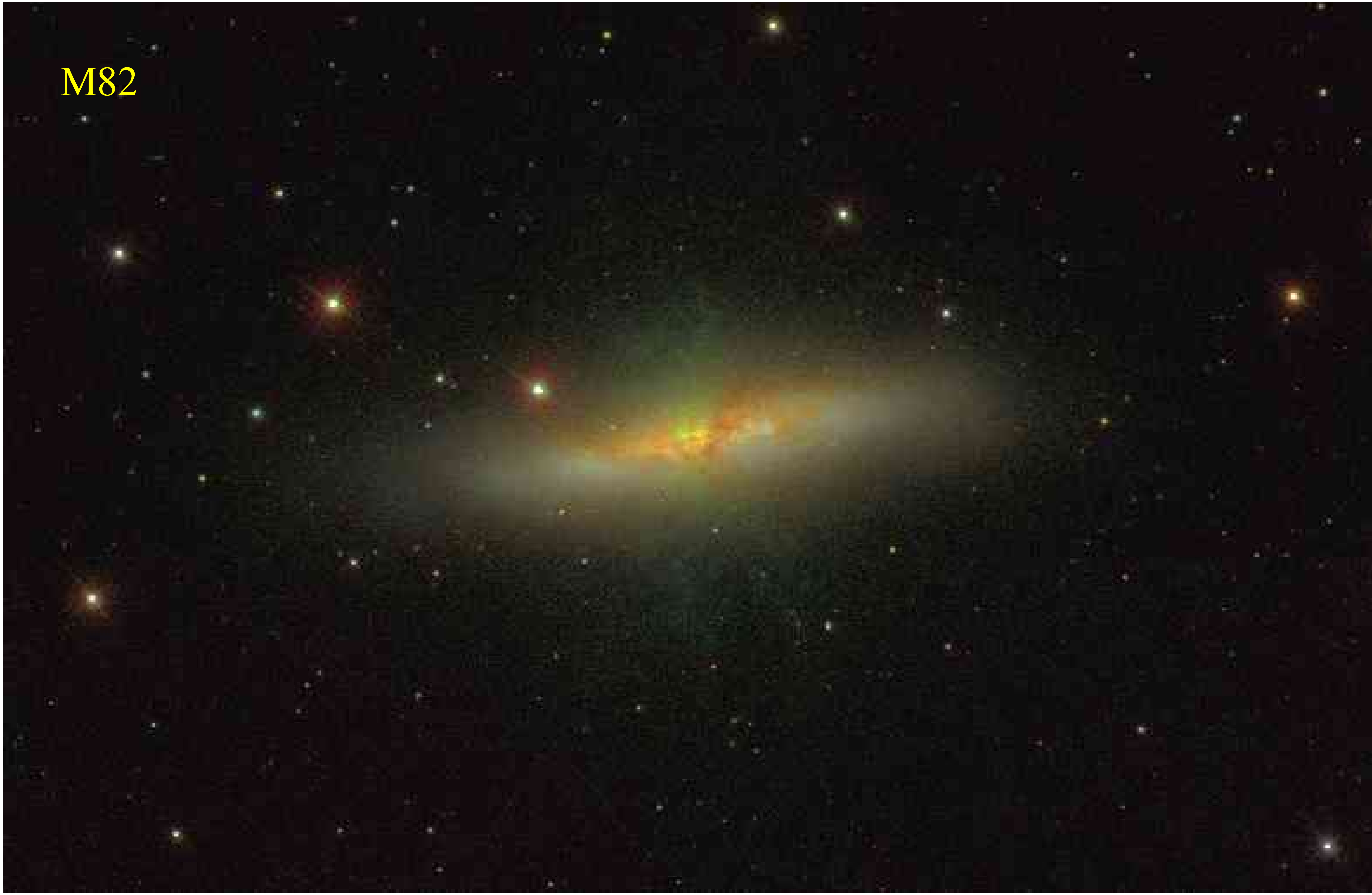
- Accurately calibrated, homogeneous and uniform photometry in five bands u, g, r, i and z across a large fraction of the high latitude sky (> 7000 square degrees)

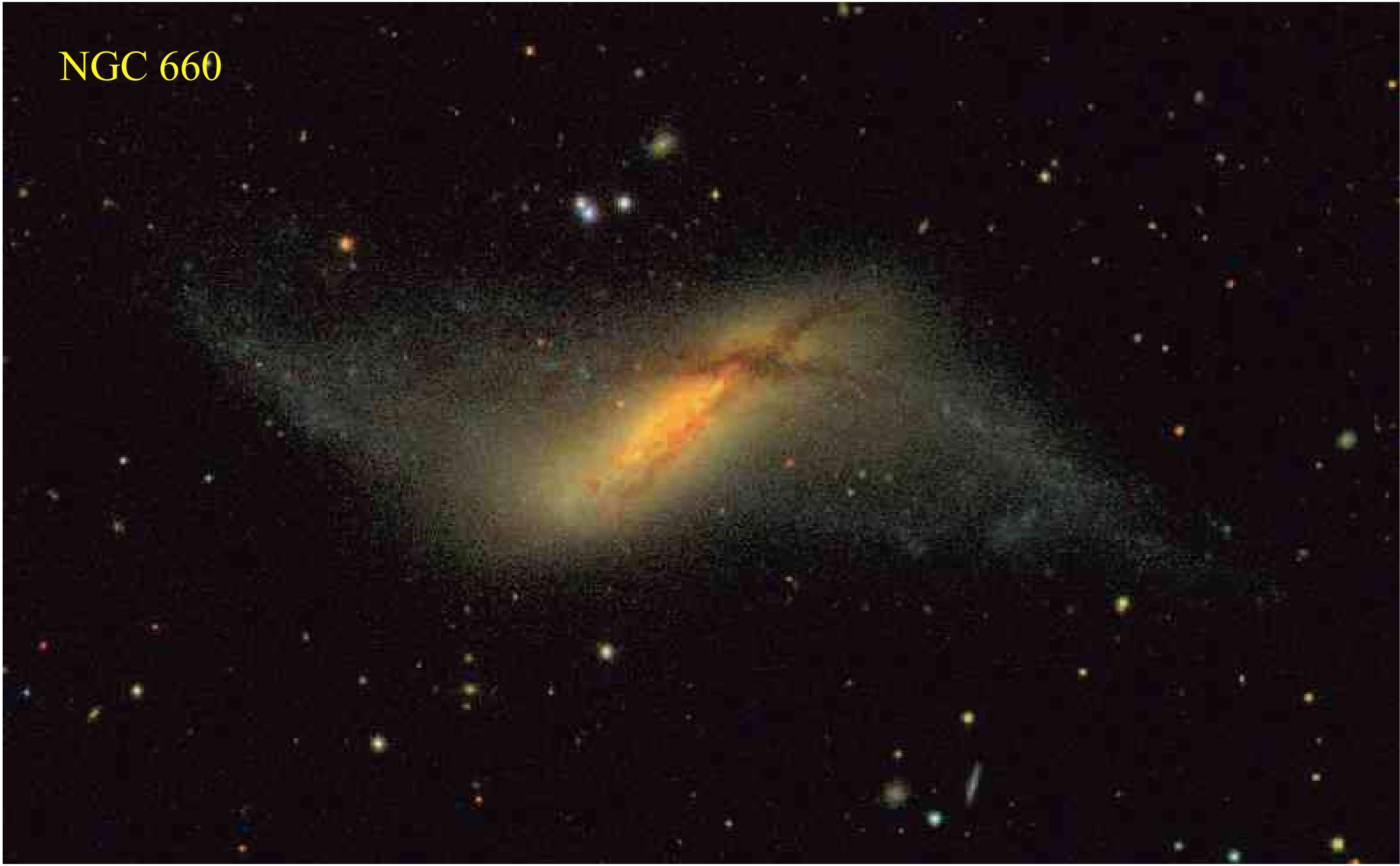
- Accurately calibrated spectroscopy from 3700 to 9200 Å at a resolution of 2000 for homogeneously selected samples of galaxies (>700,000) and quasars (>70,000)

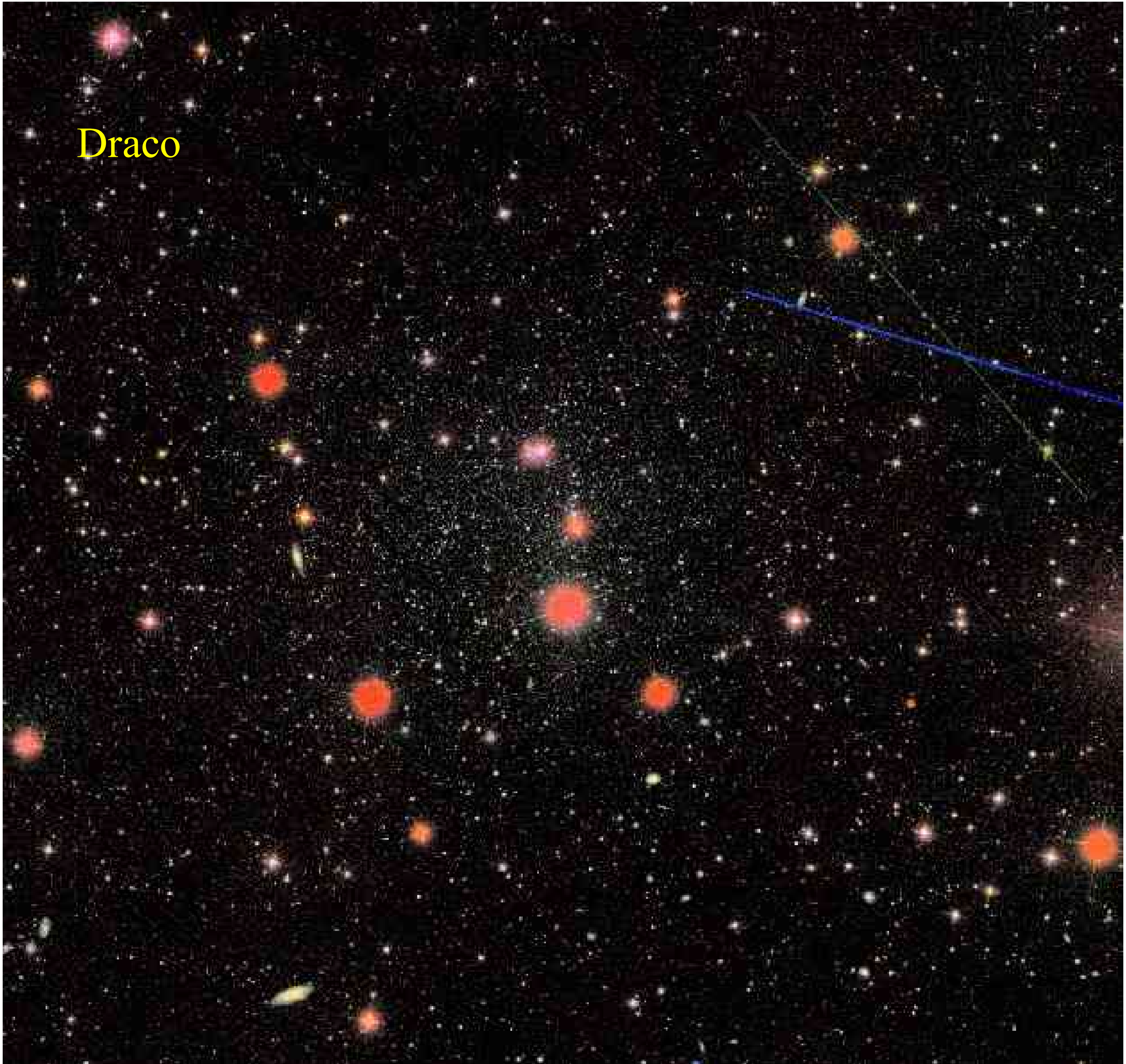
- Fully reduced and calibrated data are publically available.

M51


M101


M82


NGC 660


Draco


Core of the Perseus cluster

MPA/JHU Sloan galaxy population programme

MPA Jarle Brinchmann, Stephane Charlot, Anna Galazzi, Guinevere Kauffmann, Simon White

JHU Tim Heckman, Eric Peng, Mark Seibert, Christy Tremonti

GOAL: Use the large, complete and homogeneous samples available from SDSS to characterise the joint distribution of low redshift galaxies($z < 0.15$) over stellar mass, size, concentration, star formation history, metallicity and nuclear activity, as well as the dependence of this distribution on environment

New methodology is required to analyze the data:

Traditional observational quantities are difficult to interpret within the framework of a physical model of galaxy formation

- Galaxy luminosities and colours are sensitive to a combination of star formation history, metallicity and dust attenuation.

- Hubble type is a subjective classification that is done 'by eye'. It combines elements of galaxy structure (B/T,...) and star-formation history. This confuses the interpretation of morphology/luminosity/environment relations

- Simple measures from galaxy spectra (equivalent widths of [OII] or Hα) or PCA classification are not easy to translate into physically meaningful quantities such as star formation rate, metallicity, black hole accretion rate....

Stellar absorption line spectra constrain

1) The stellar mass-to-light ratio

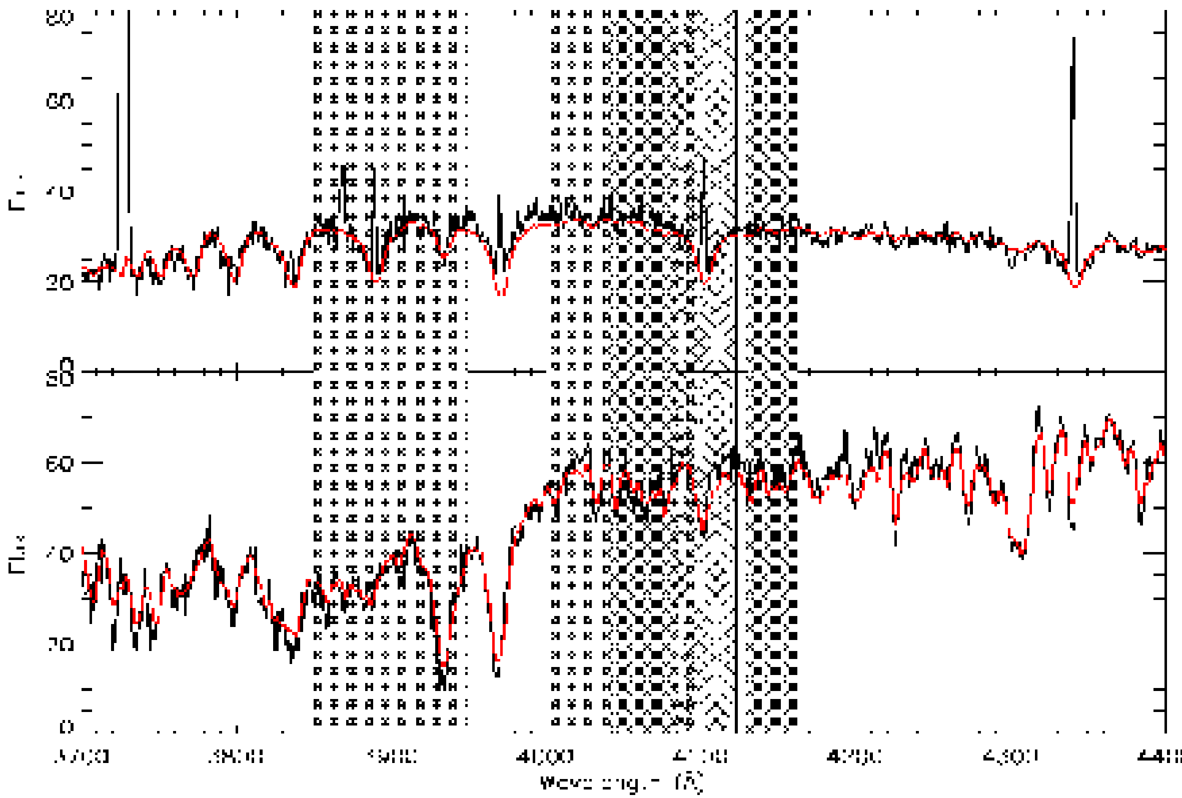
2) The star formation history over scales from 10 Myr to 2 Gyr

3) The metallicity of the stars (including element ratios)

4) Stellar velocity dispersions

Spectra + SDSS photometry yield estimates of:

Stellar mass, dust attenuation, metallicity, burst likelihood, velocity dispersion



Fits to stellar component using new high resolution models (Bruzual & Charlot 2003)

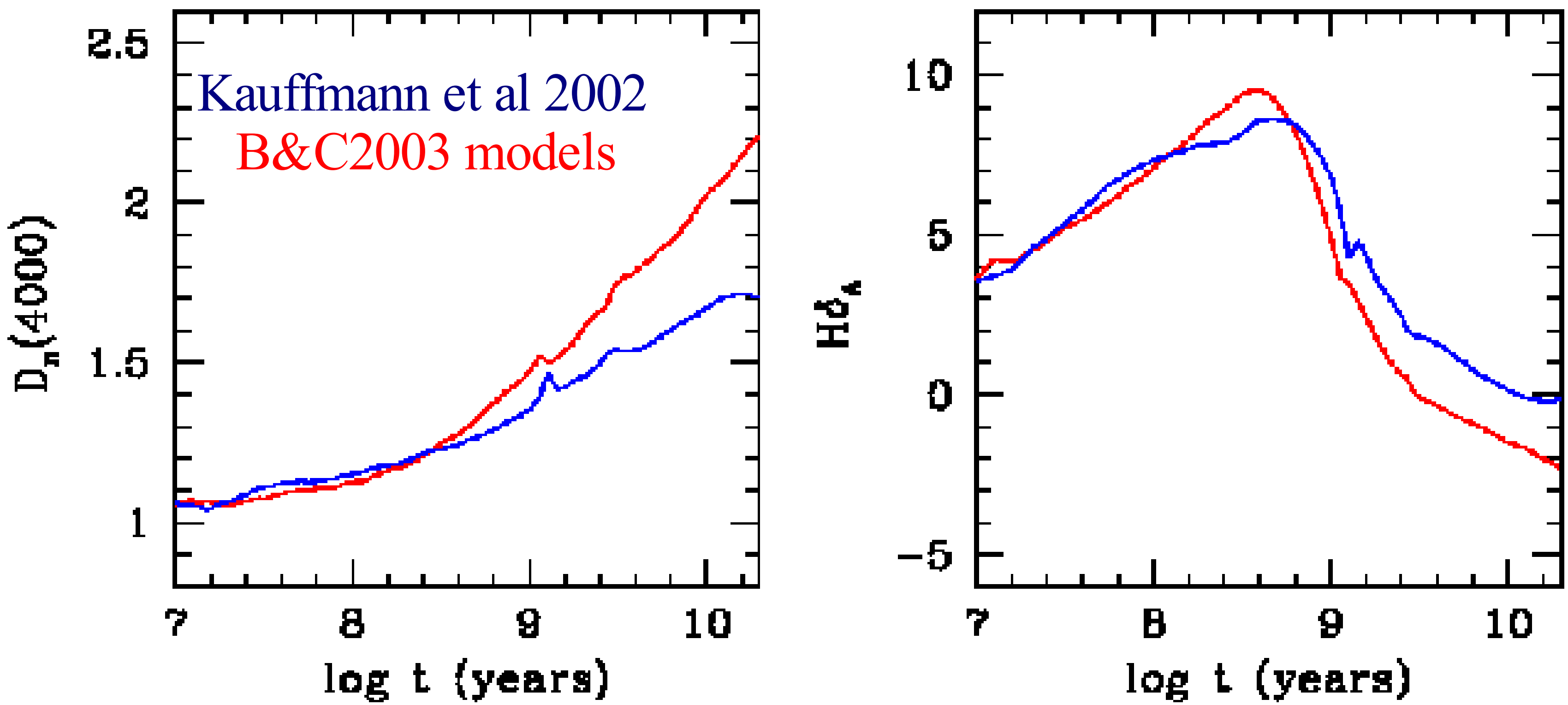
From spectra to stellar masses, dust (and ages)

- The strengths of the 4000 A break and the Balmer lines are (differently) sensitive to age
- They are insensitive to dust
- They are weakly sensitive to metallicity

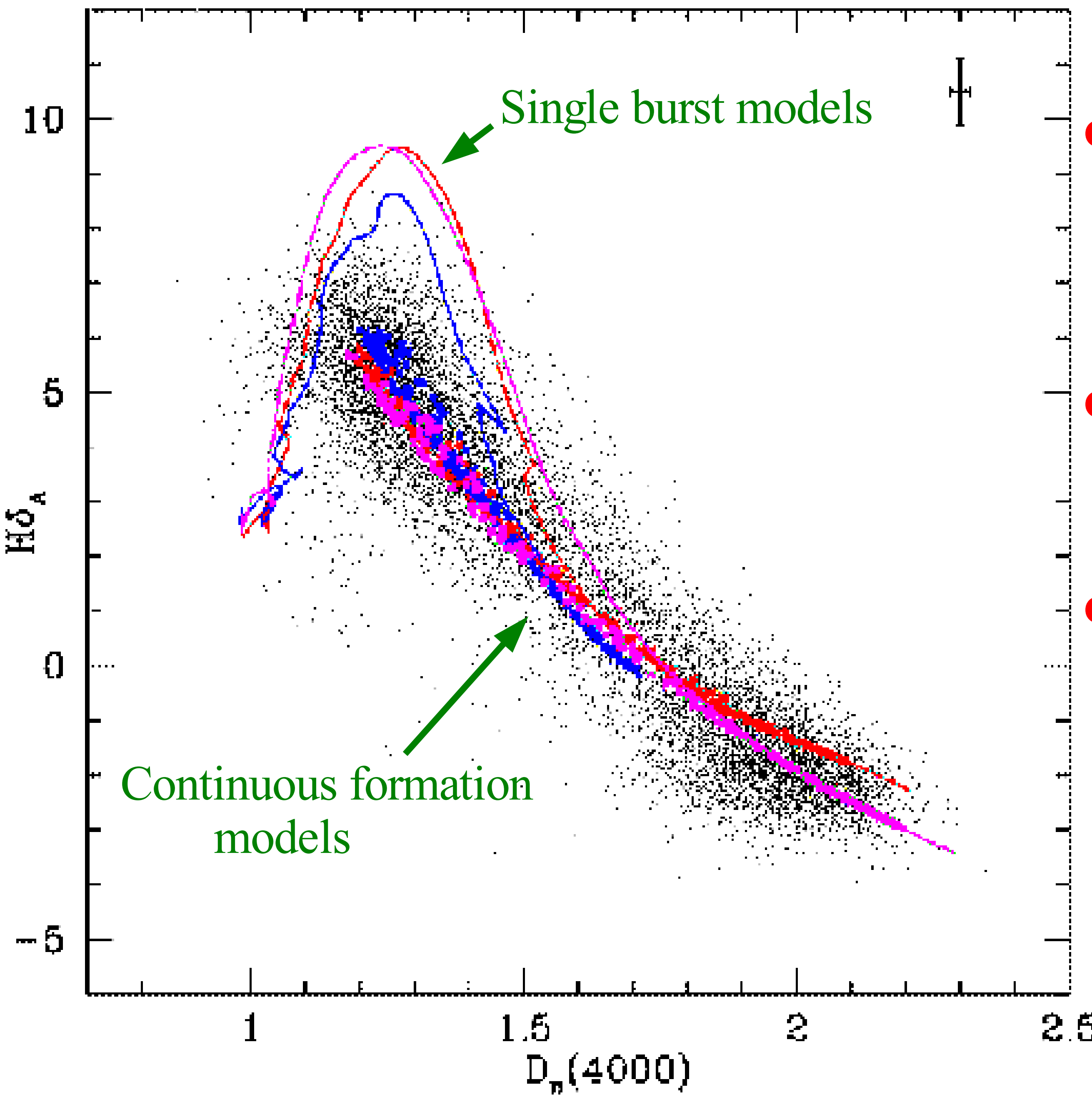
D4000 + Hδ → stellar intrinsic colours, M/L, (age, Z degen.)

intrinsic + observed colours → dust content, extinction

extinction + M_z + $(M/L)_*$ → stellar mass of galaxy

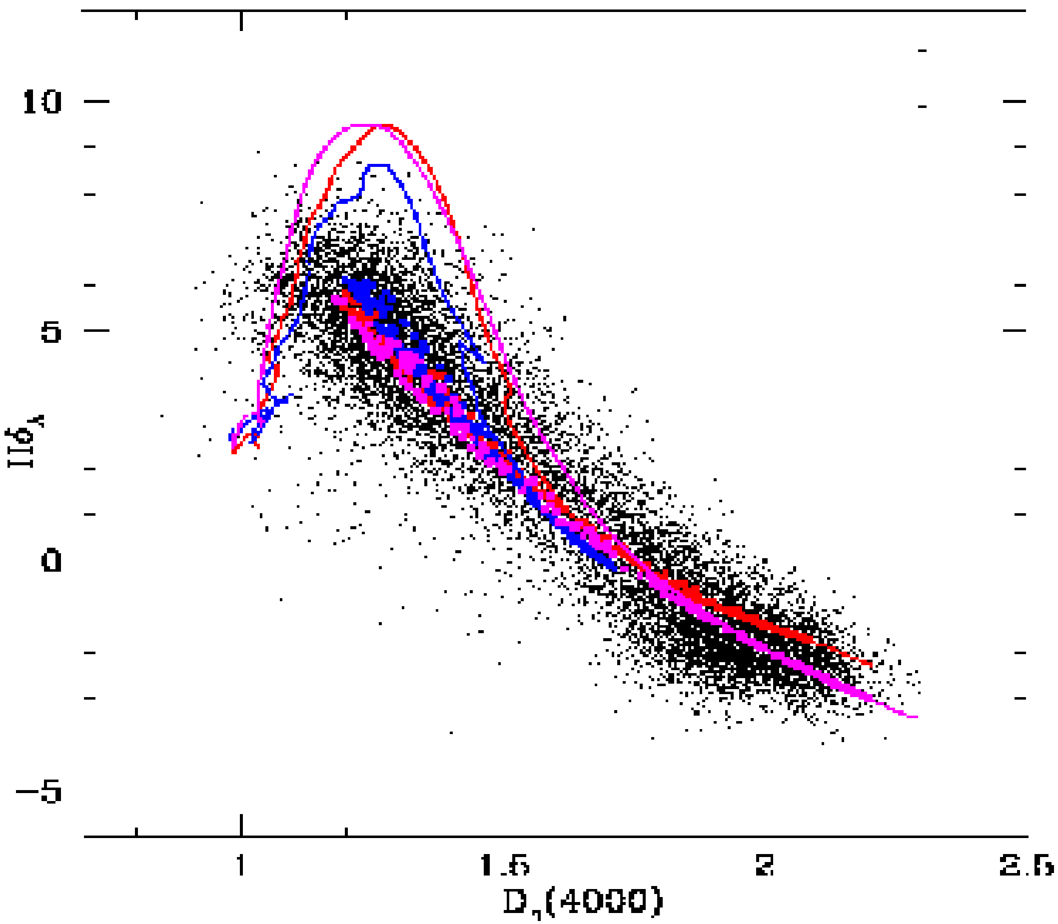


Comparison of SDSS indices with models

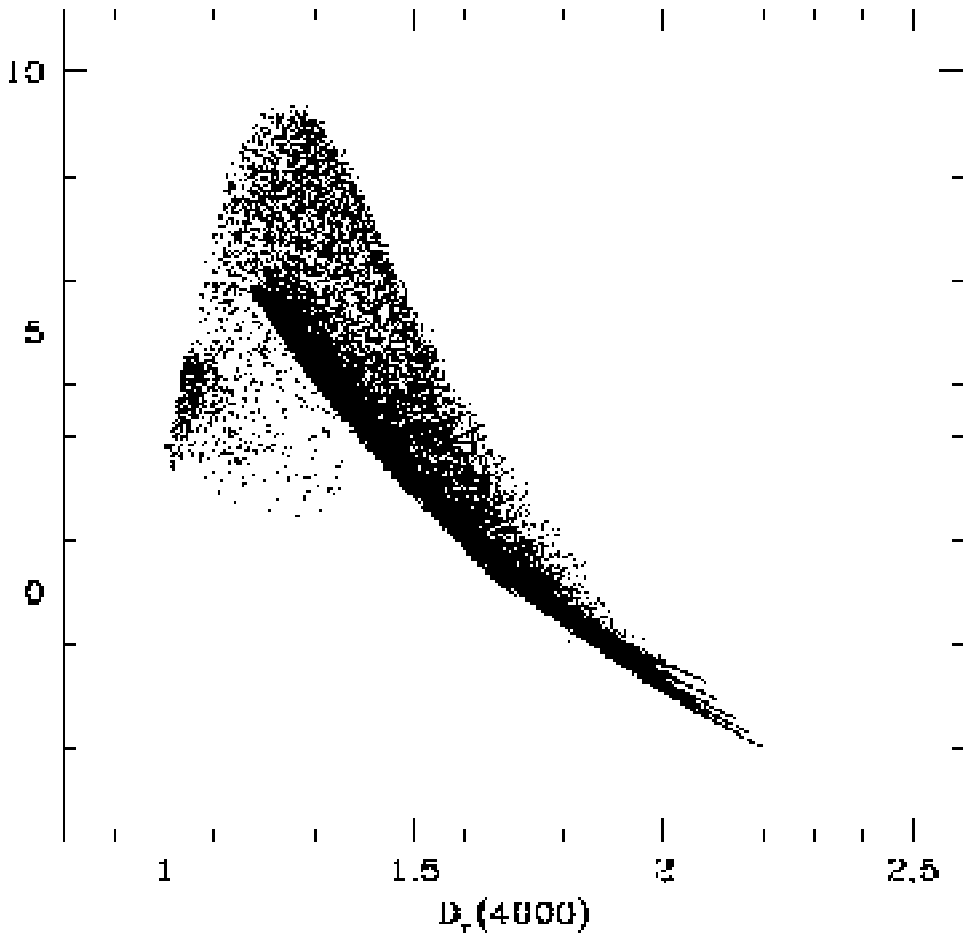


- Index values from about 20,000 'random' SDSS galaxies of high S/N
- Models from Bruzual & Charlot 2003
- Model metallicities are 0.2, 1.0 and 2.5 $Z_\odot$

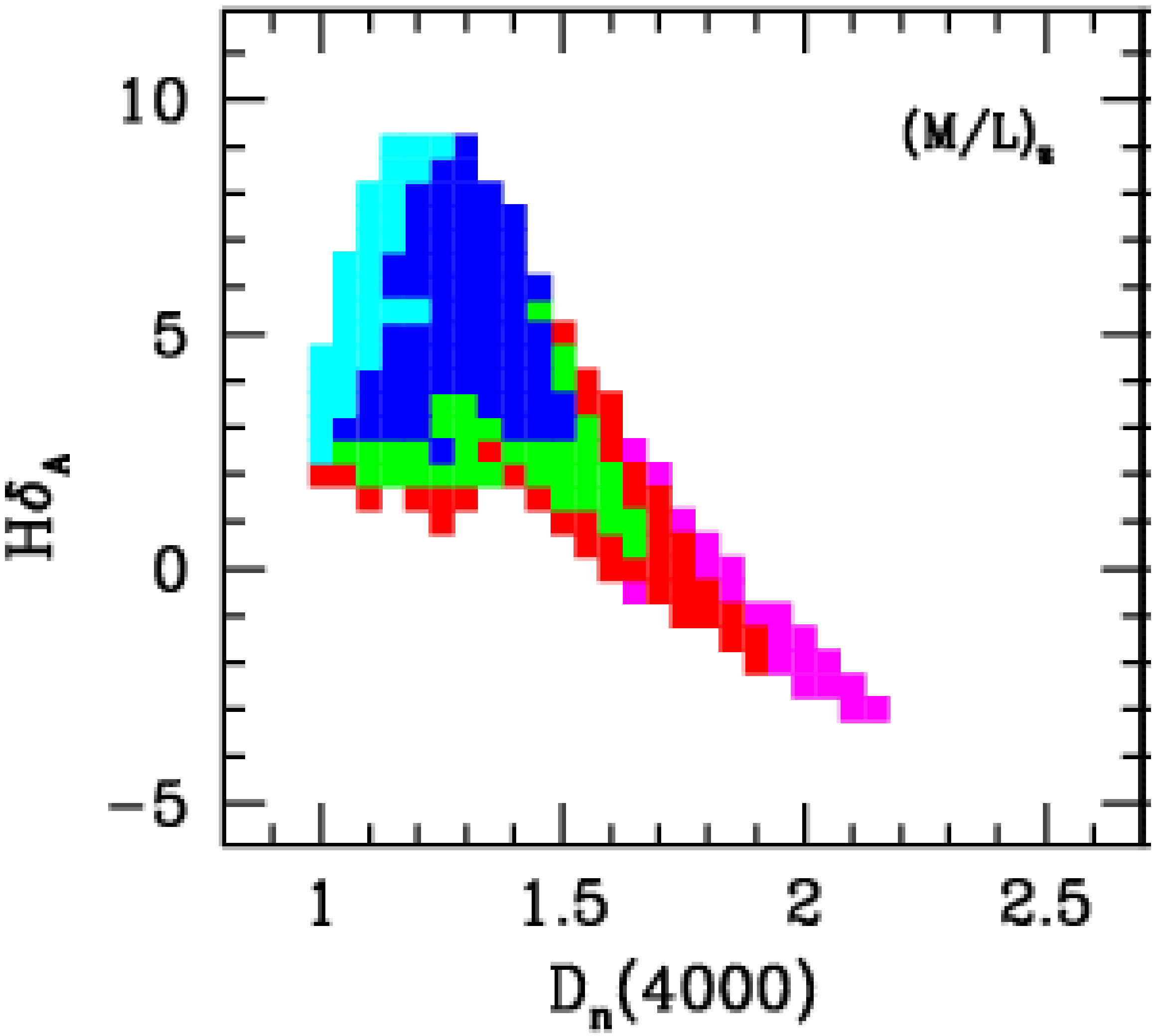
A starburst diagnostic diagram



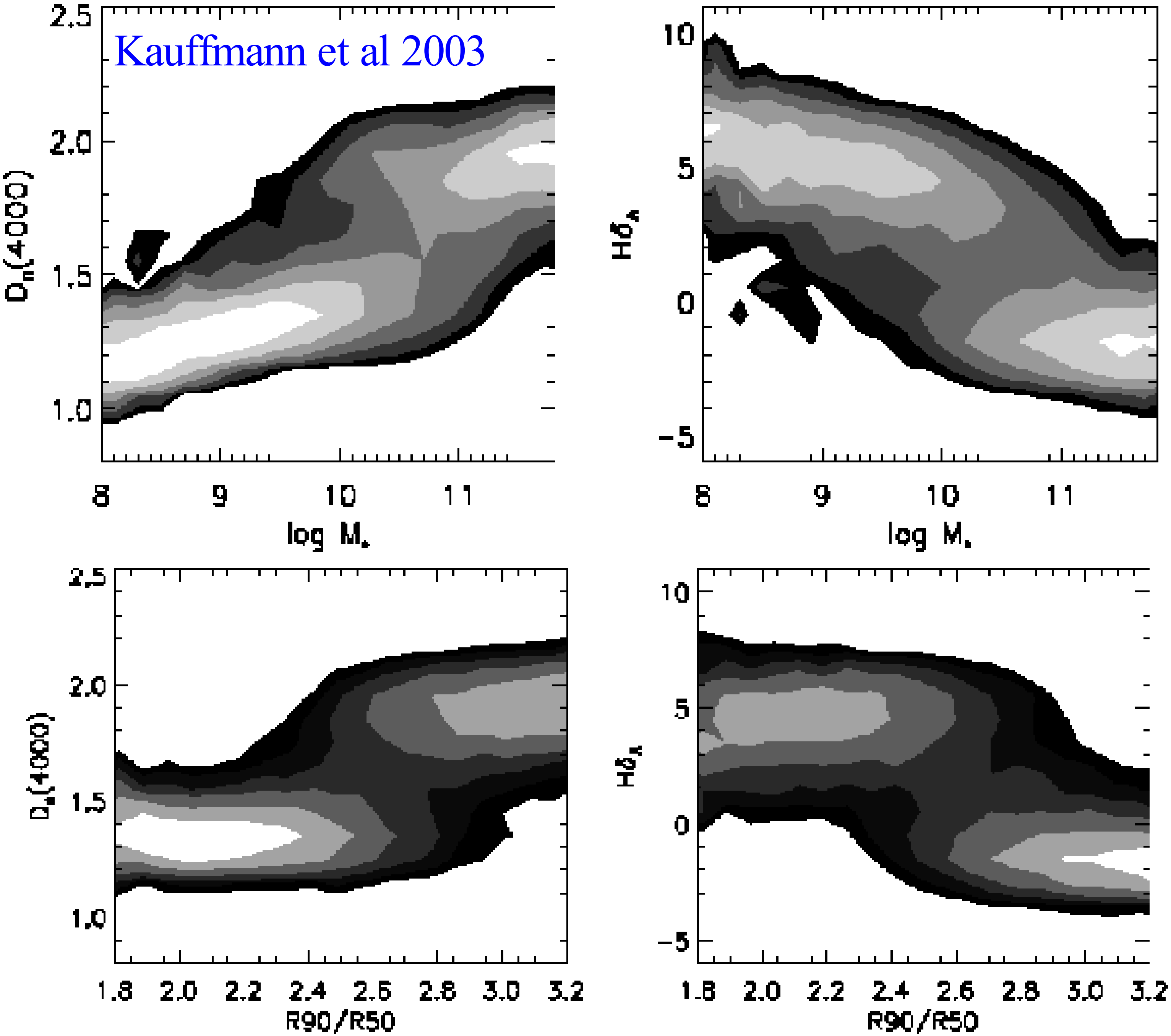
A library of model SFHs



Estimating Mass-to-Light Ratios



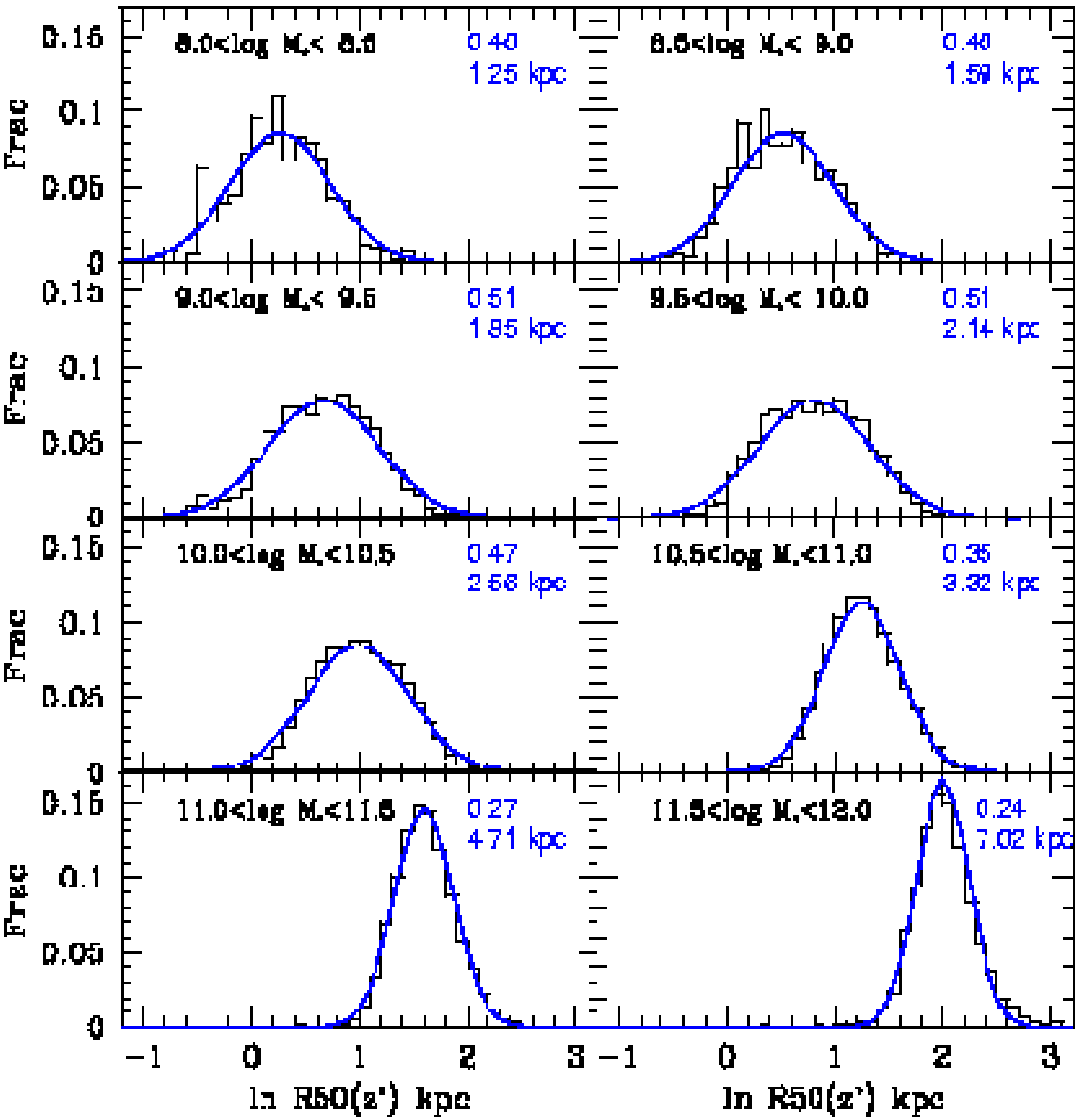
Stellar mass dependance of age and structure

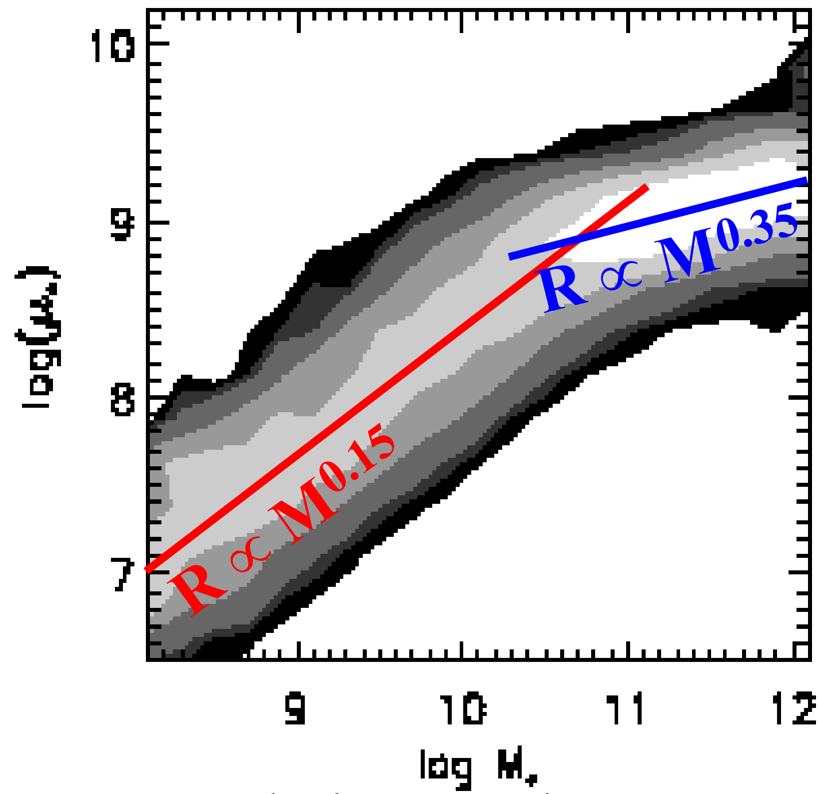


- Data for 120,000 SDSS galaxies in a magnitude-limited sample
- Two disjoint populations split at $M_* \sim 3\ 10^{10} M_\odot$
- Massive galaxies have old stars and 'bulge-like' concentration
- Low mass gals have young stars and 'disk-like' concentration

Galaxy sizes as a function of *stellar* mass

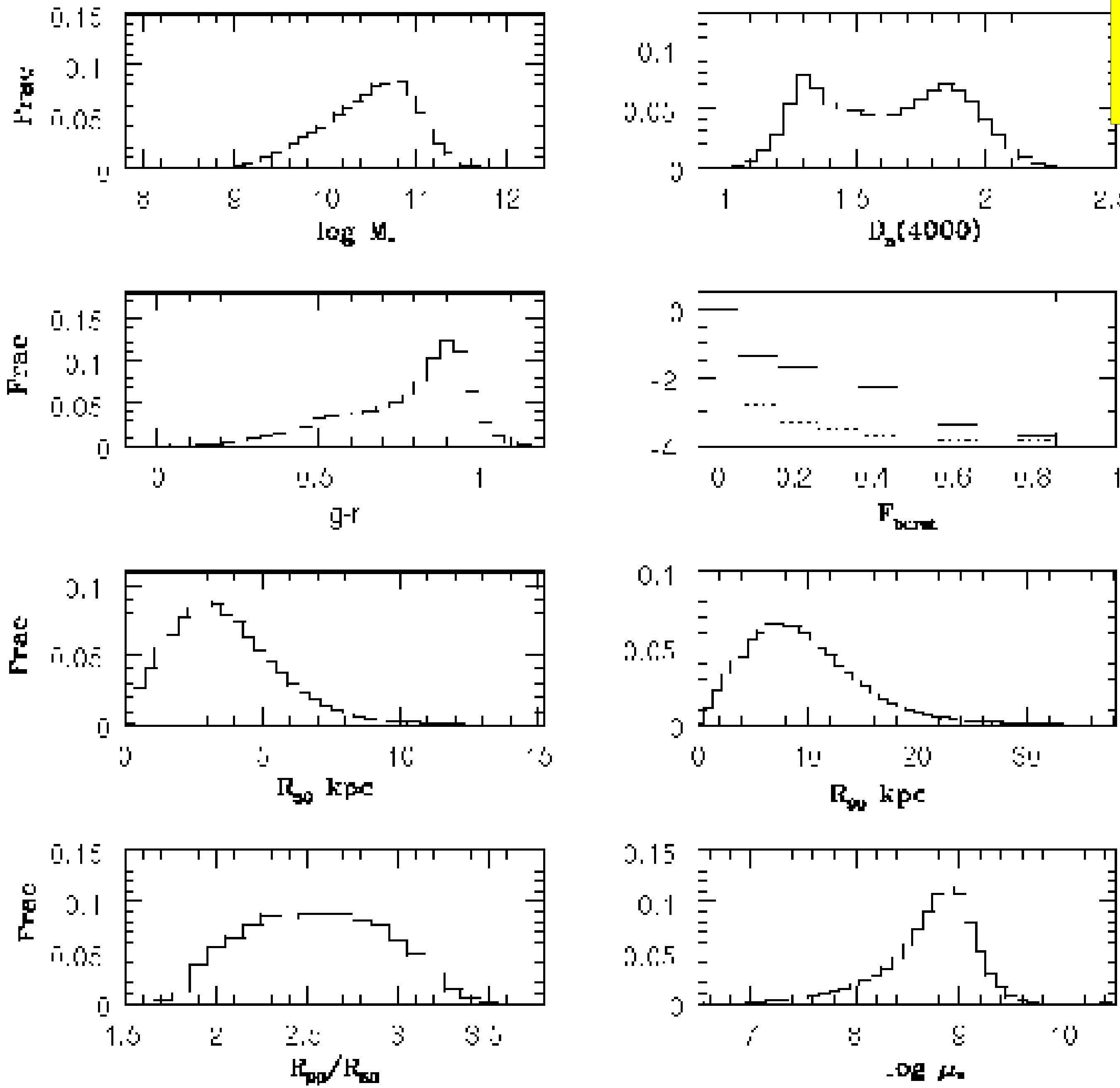
Kauffmann et al 2003





- Measured sizes and star masses for a magnitude-limited sample of 120,000 SDSS galaxies
- 3 $10^{10} M_\odot$ again!
- Log-normal distributions $\sigma(\ln R) \sim 0.5$ at small mass

Kauffmann et al 2003

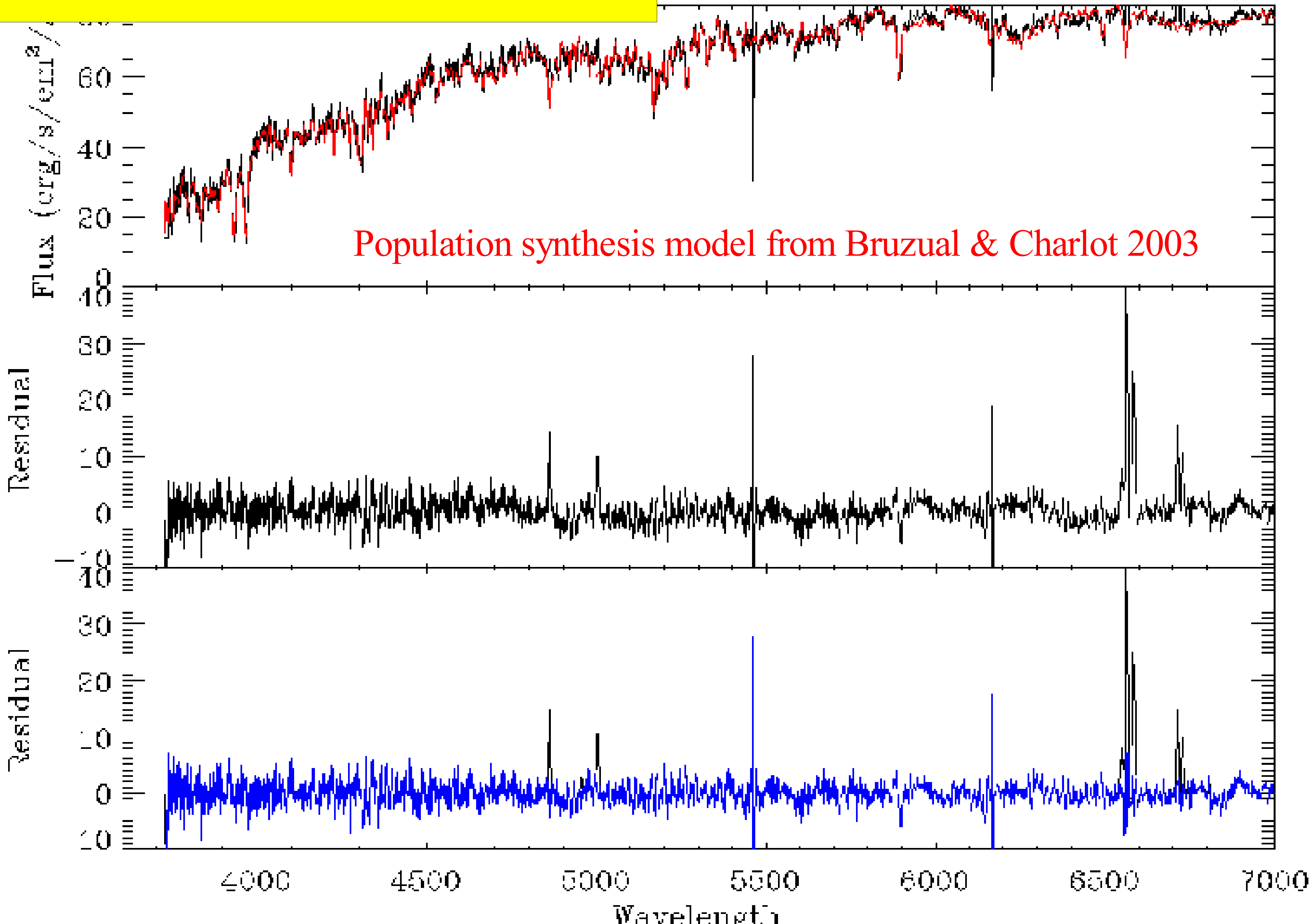


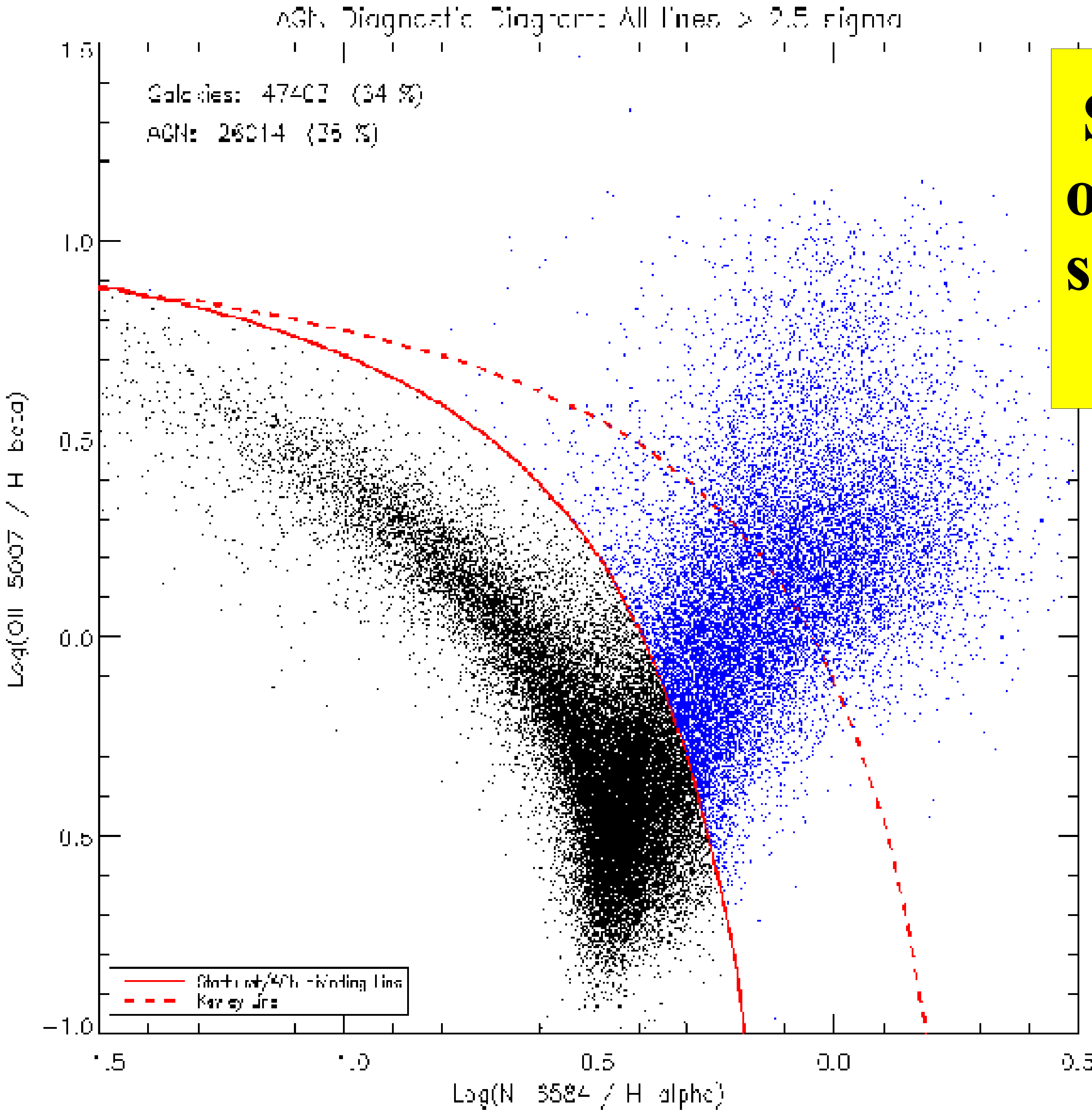
Cosmic star mass distributions

- Half the stars in the Universe are in galaxies with $M_* < 3\ 10^{10} M_\odot$
- Most stars in galaxies within a factor of 3 of this mass
- Half the stars are in 'old' galaxies and half are in 'young' galaxies
- Only 10^{-3} of all stars are in galaxies that have definitely had a burst in the last 2 Gyr

Emission lines in SDSS

Tremonti & Brinchman





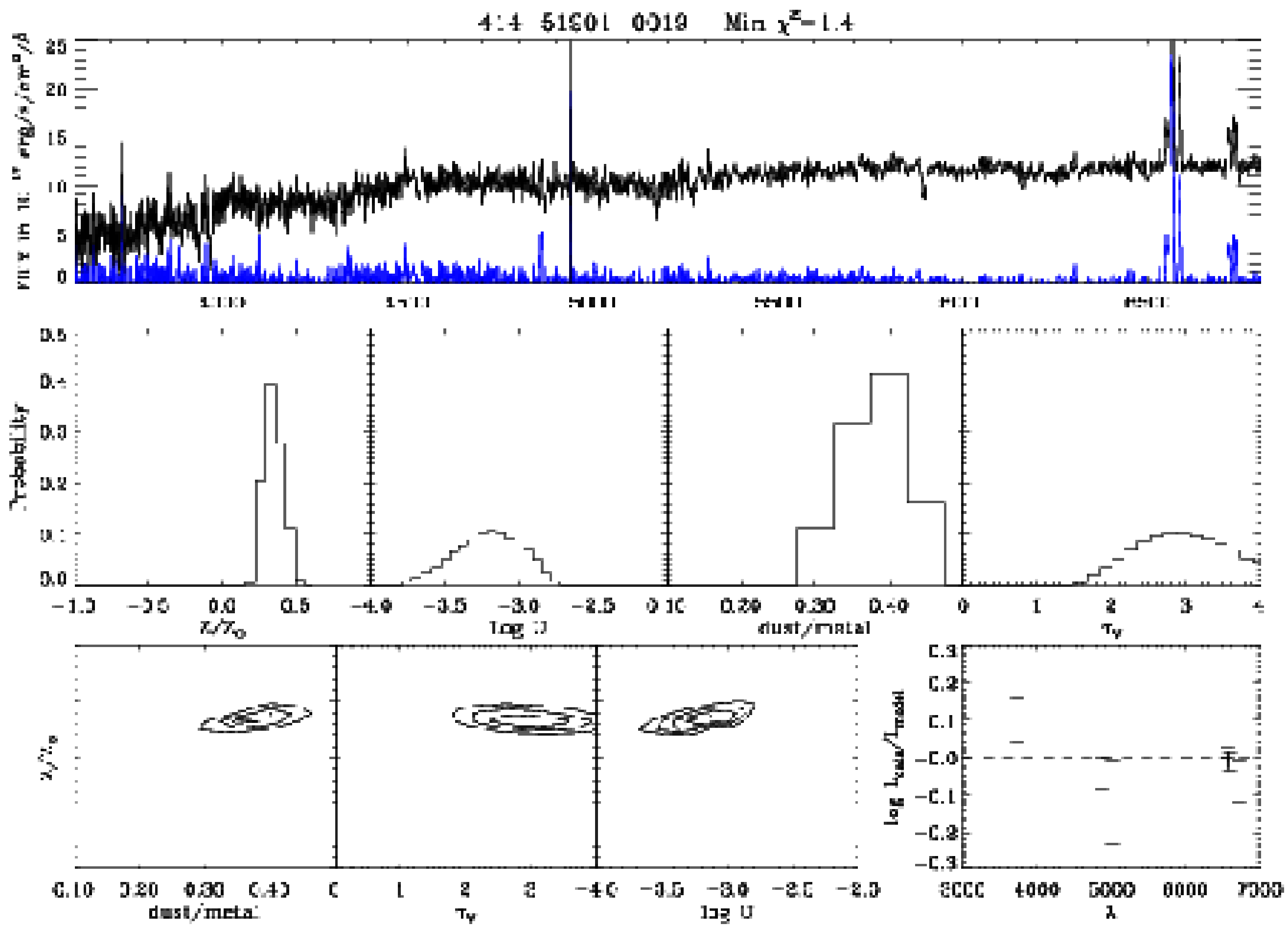
Separation of AGN and star-forming galaxies

- 2/3 of galaxies with emission detected can be classified in the BPT plot
- About half of these are AGN and half are star- forming

Emission-line fluxes plus photo-ionization models yield:

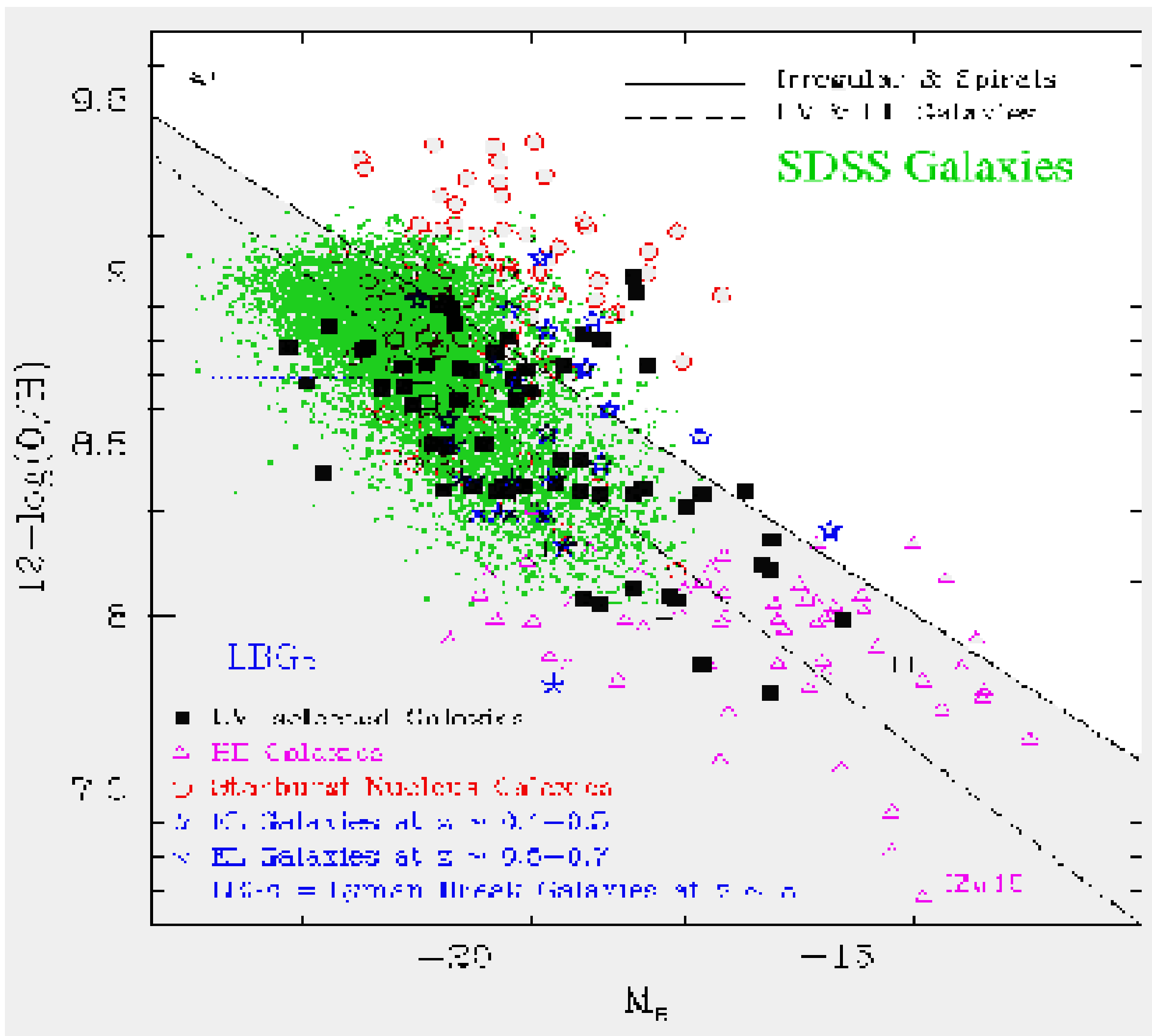
- Gas-phase metallicities
- Dust in HII regions
- Ionization parameter
- Star Formation rates

Charlot & Longhetti 2000

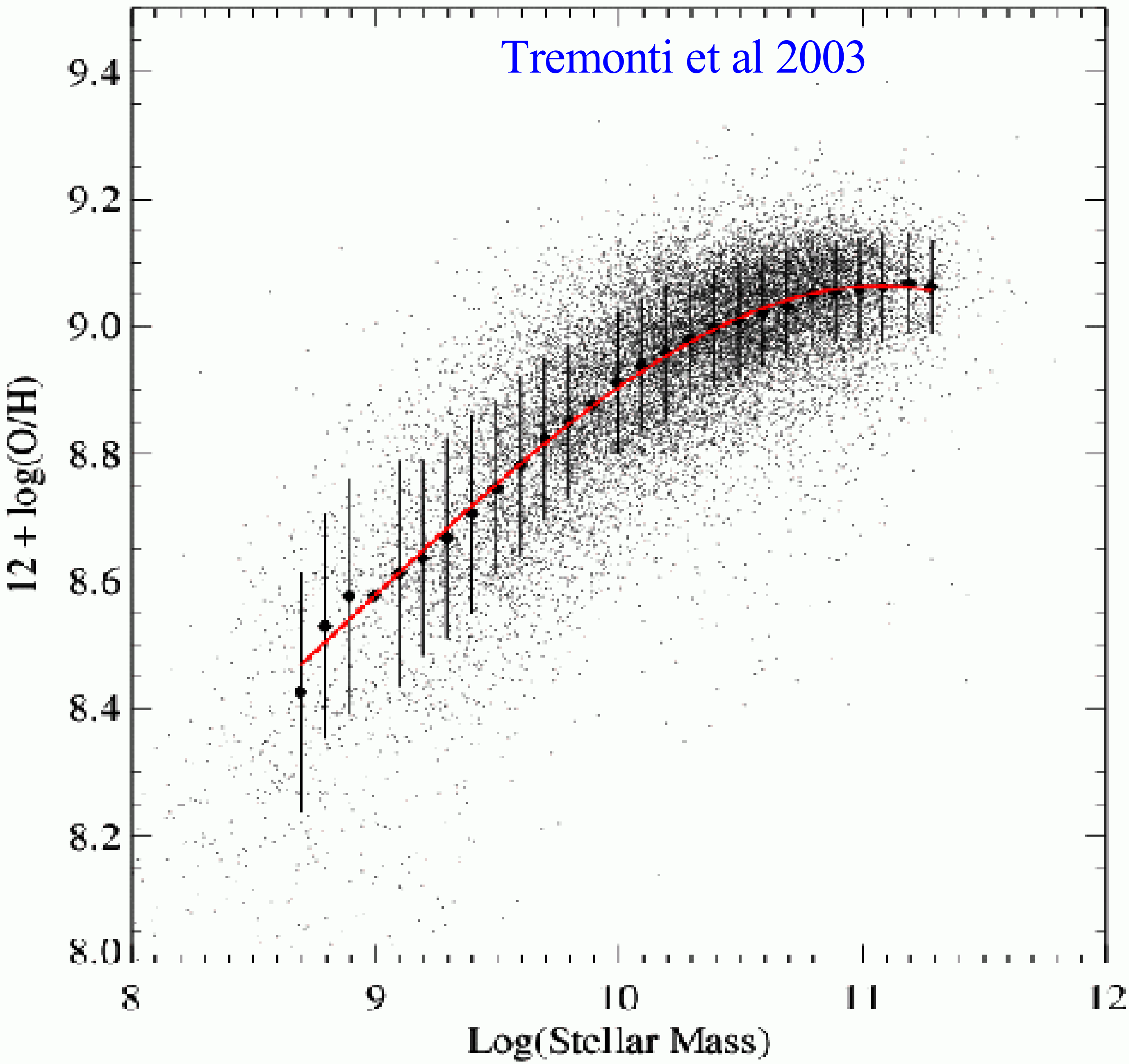


Tremonti et al 2003

The Relation Between Metallicity and Luminosity



Gas phase metallicity vs stellar mass



- Below $10^{10}M_{\odot}$

  $$Z_{gas} \propto M_*^{0.5}$$

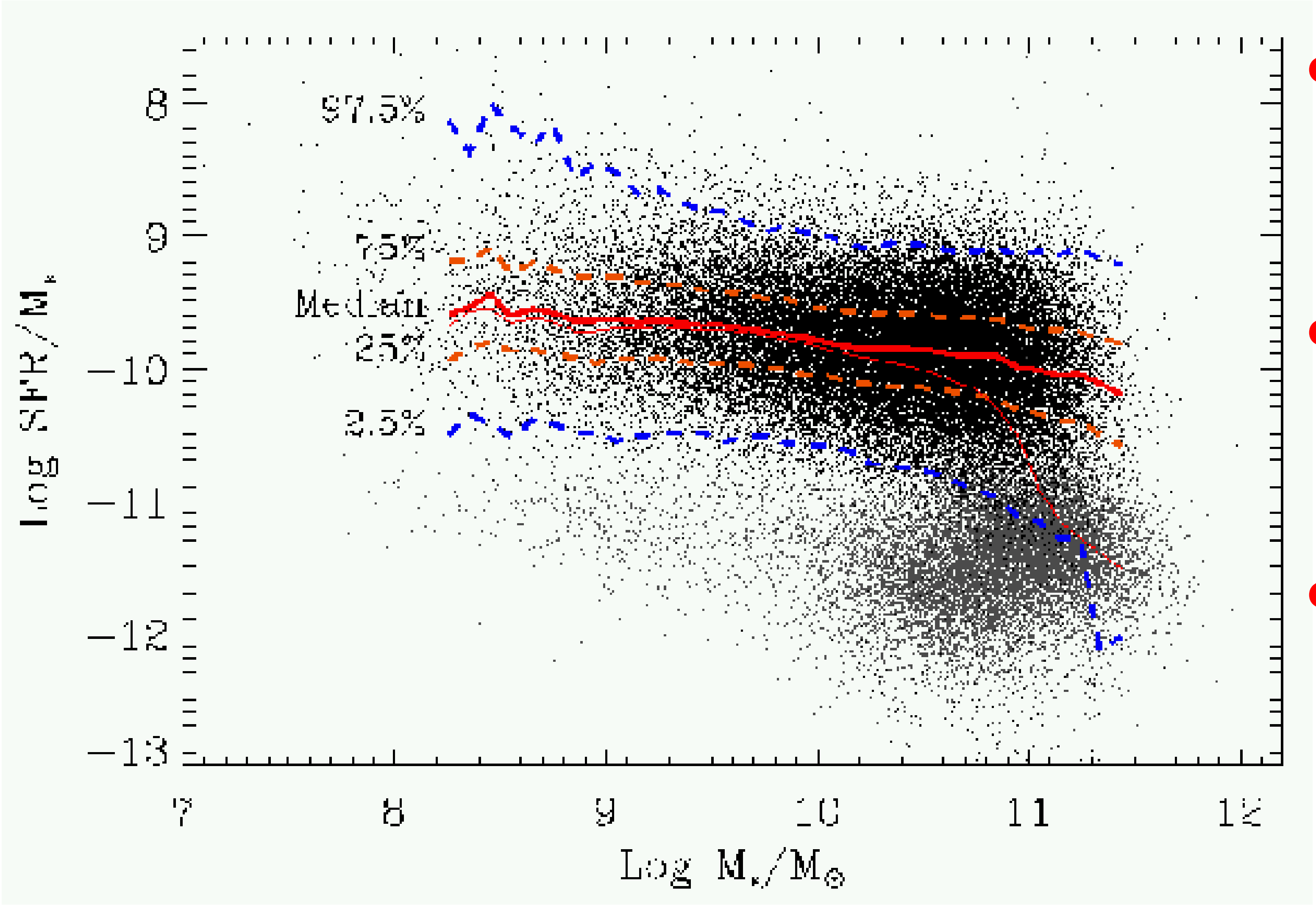
- At high mass, gas metallicity depends little on stellar mass

- In low mass systems metallicity and size depend on mass as expected if star formation efficiency

  $$\epsilon_* \propto M_{halo}^{0.4}$$

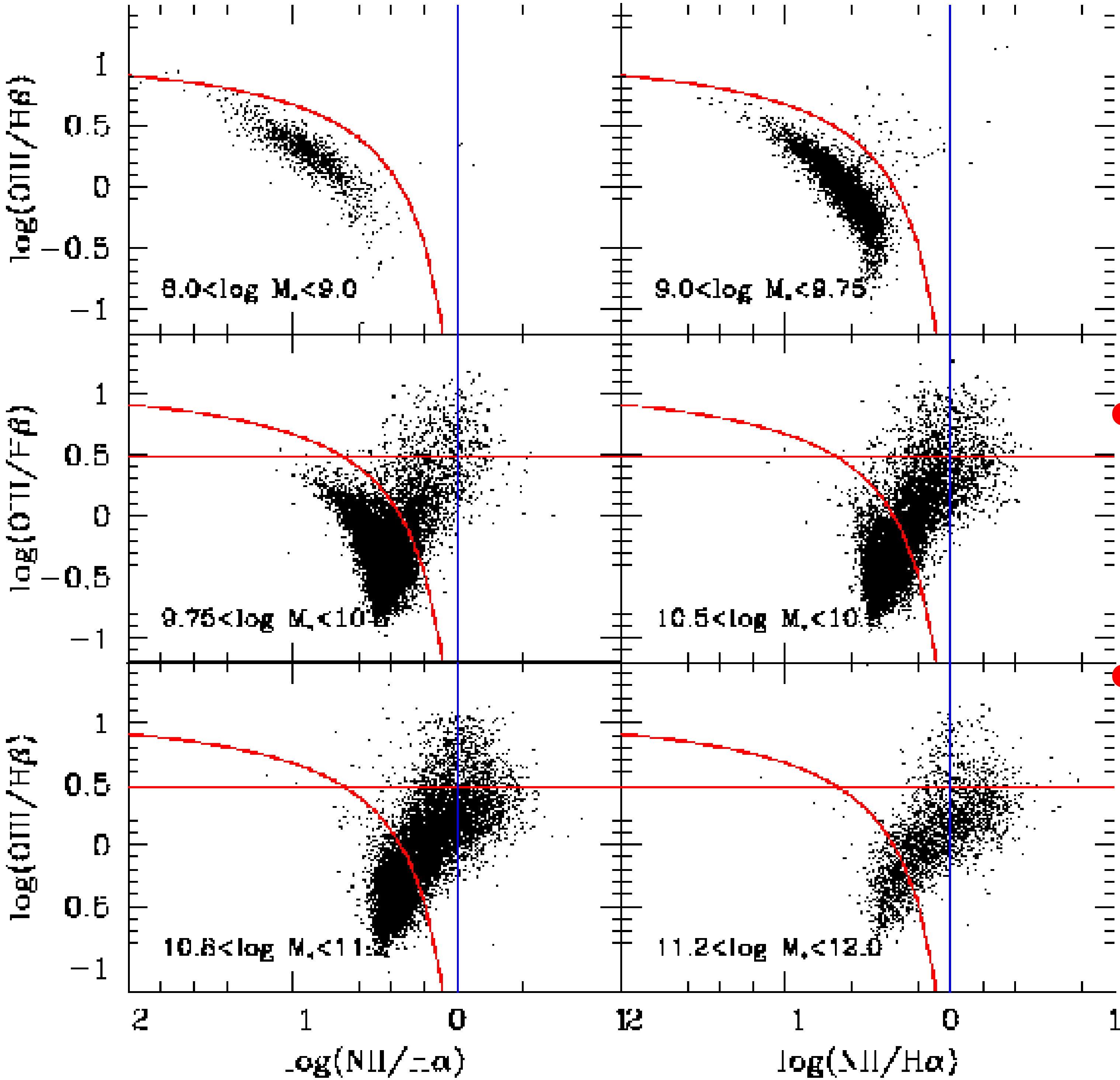
Specific star formation rate vs stellar mass

Brinchmann et al 2003



- Roughly half of all SDSS galaxies have detected SFR
- Non-detected galaxies are almost all massive
- Specific SFR depends little on stellar mass for the star-formers

Kauffmann et al 2003



Emission properties as a function of stellar mass

- Low mass emission galaxies are almost all star-formers
- High mass emission galaxies are almost all AGN

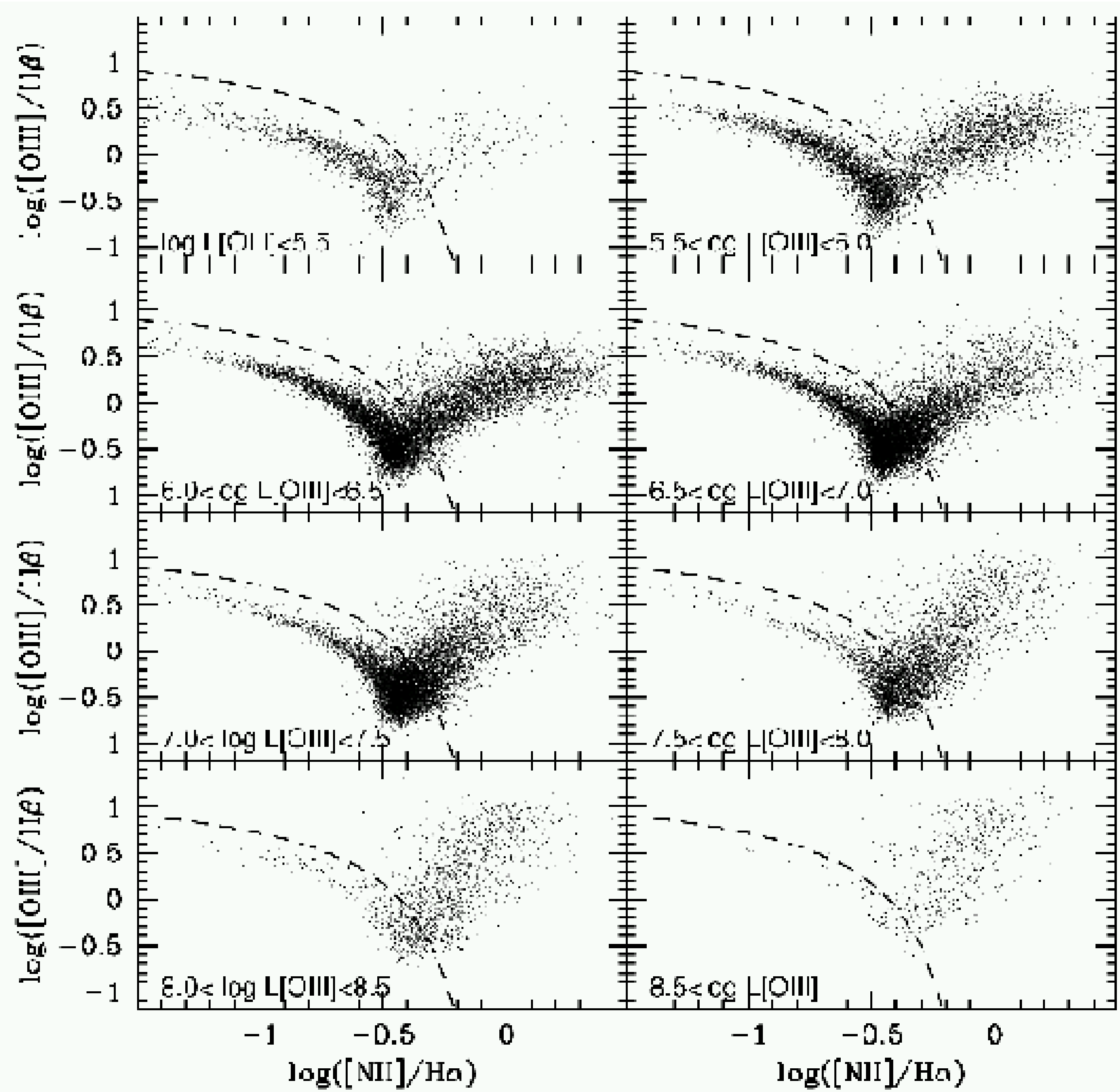
A characteristic stellar mass for galaxies

At least five independent properties of galaxies change their behaviour abruptly at the same stellar mass: $M_* \sim 3 \times 10^{10} M_\odot$

- **Size:** $R \propto M_*^{0.15}$, $\sigma \sim 0.5$ → $R \propto M_*^{0.35}$, $\sigma < 0.5$
- **Metallicity:** $Z_{gas} \propto M_*^{0.5}$ → $Z_{gas} \sim$ constant
- **Concentration:** disk-like → bulge-like
- **Stellar age:** young, bursty → old, continuous
- **Gas emission:** SF dominated → AGN dominated

--This transition must be a consequence of star-formation and interstellar medium physics, not of CDM dynamics --

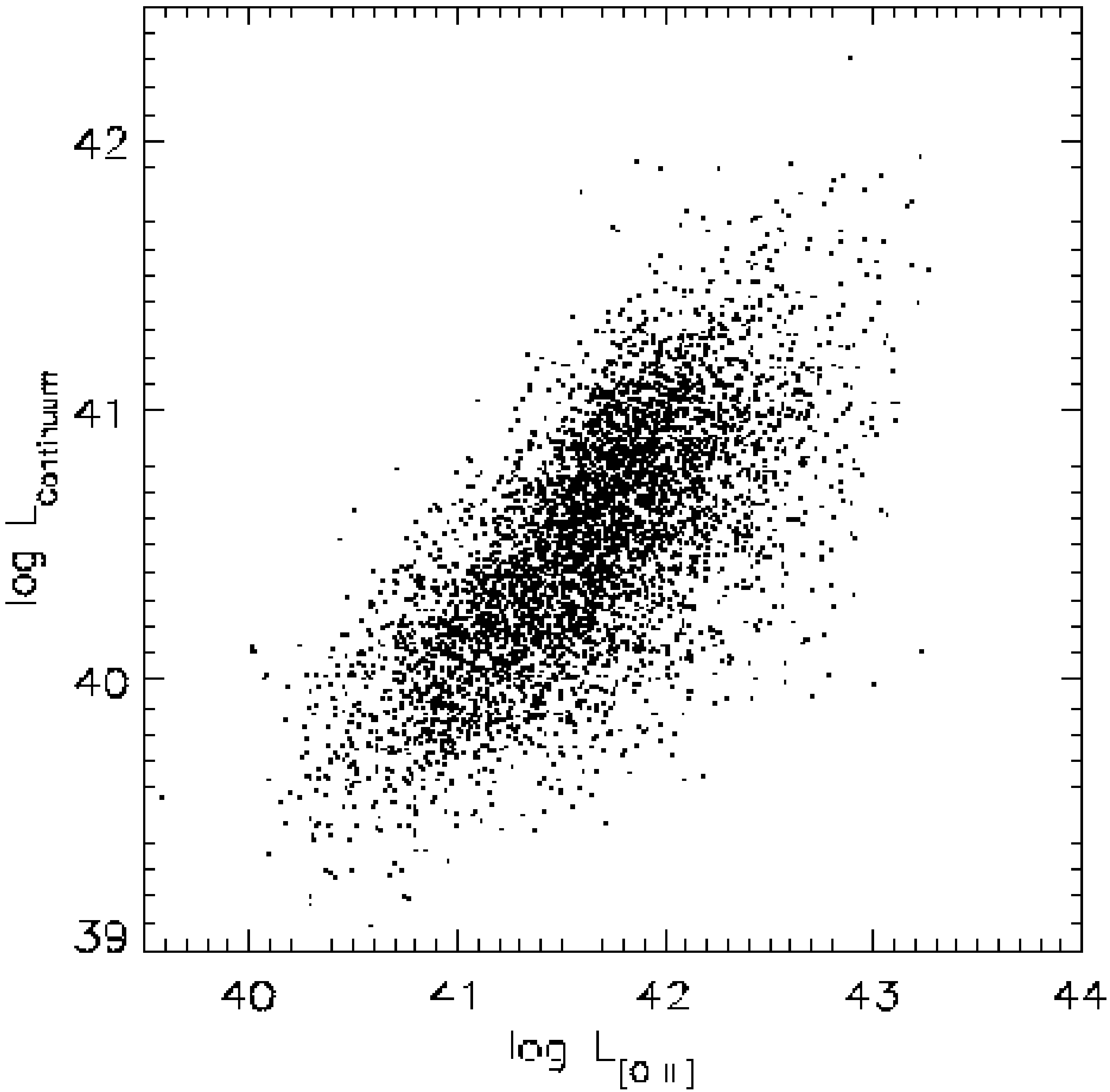
Emission properties versus L([OIII])



Kauffmann et al 2003

- Low L([OIII]) comes from dwarf galaxies, from weakly star-forming massive gals and from Liners
- Strong L([OIII]) comes from strongly star-forming massive galaxies and from Seyfert2's
- Strongest L([OIII]) comes from powerful Seyfert2's (type 2 quasars?)

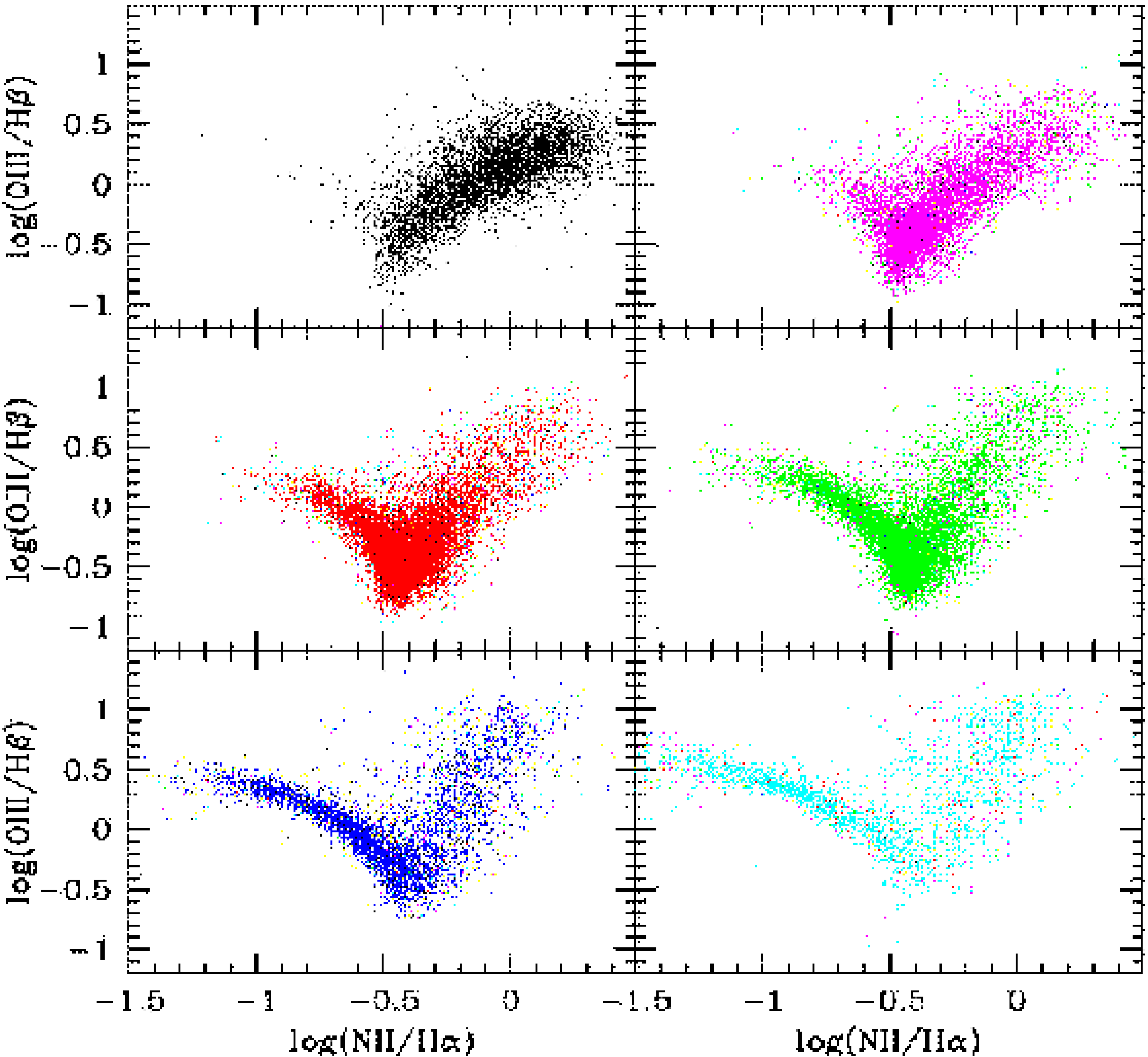
The Correlation between [OIII] and Continuum Luminosity for Type I AGN



The luminosity in the [OIII] line is quite well correlated with continuum luminosity in unobscured or type 1 AGN. This in turn is thought to be well correlated with the AGN fuelling rate

Since L([OIII]) is not affected by the torus of obscuration it can be used to get the accretion rate in type 2 AGN

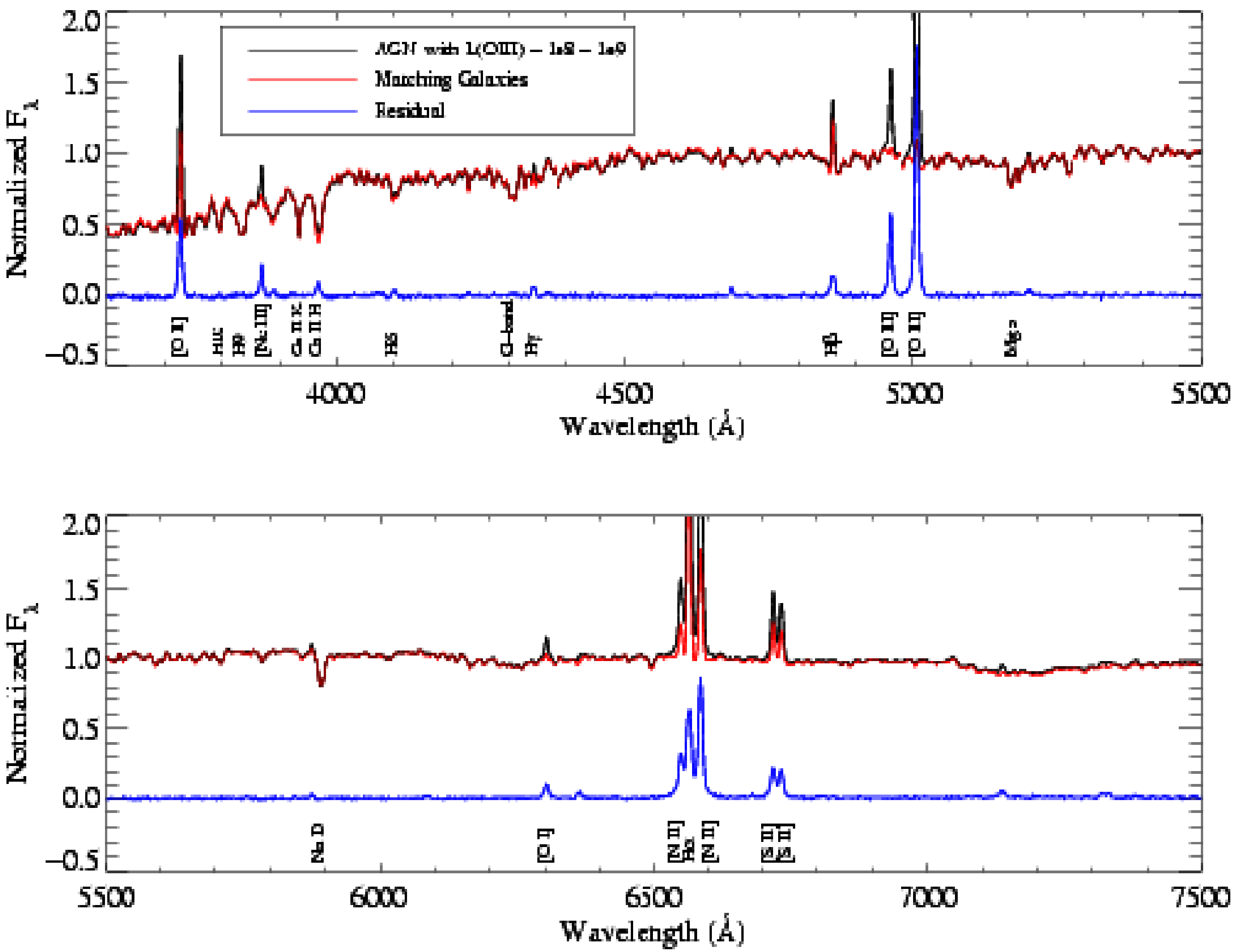
Emission properties versus L([OIII])/M_*



Kauffmann et al 2003

- Low L([OIII])/M_* comes from Liners
- Intermediate L([OIII]) /M_* comes from star-forming massive galaxies and Liners
- Strong L([OIII])/M_* comes from Seyfert 2's and star-bursting low Z dwarfs

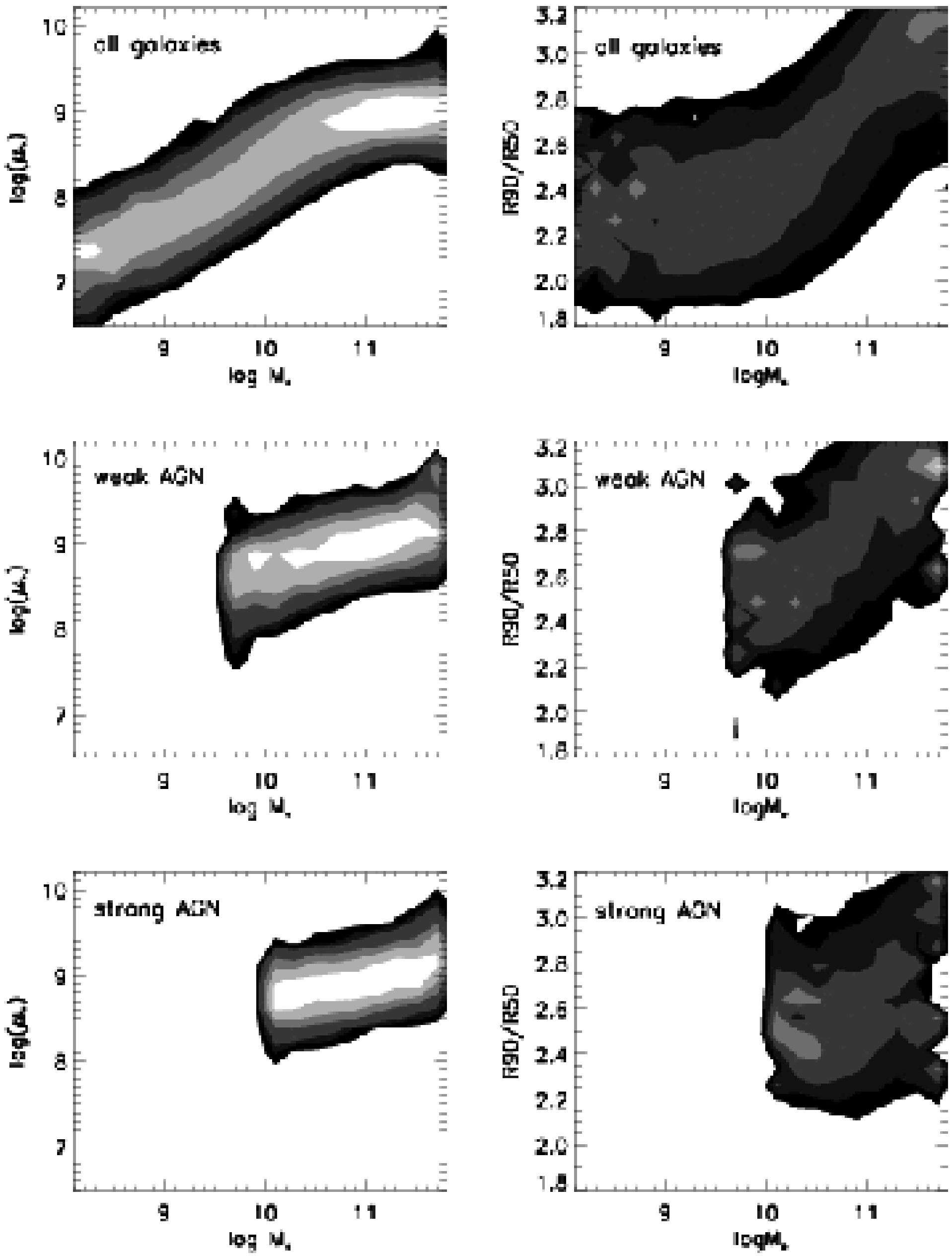
Can our Spectral Indicators be used for AGN?



Each high L([OIII]) active galaxy is matched to a galaxy with similar z, M_*, D4000 and size but with no detected [OIII] emission

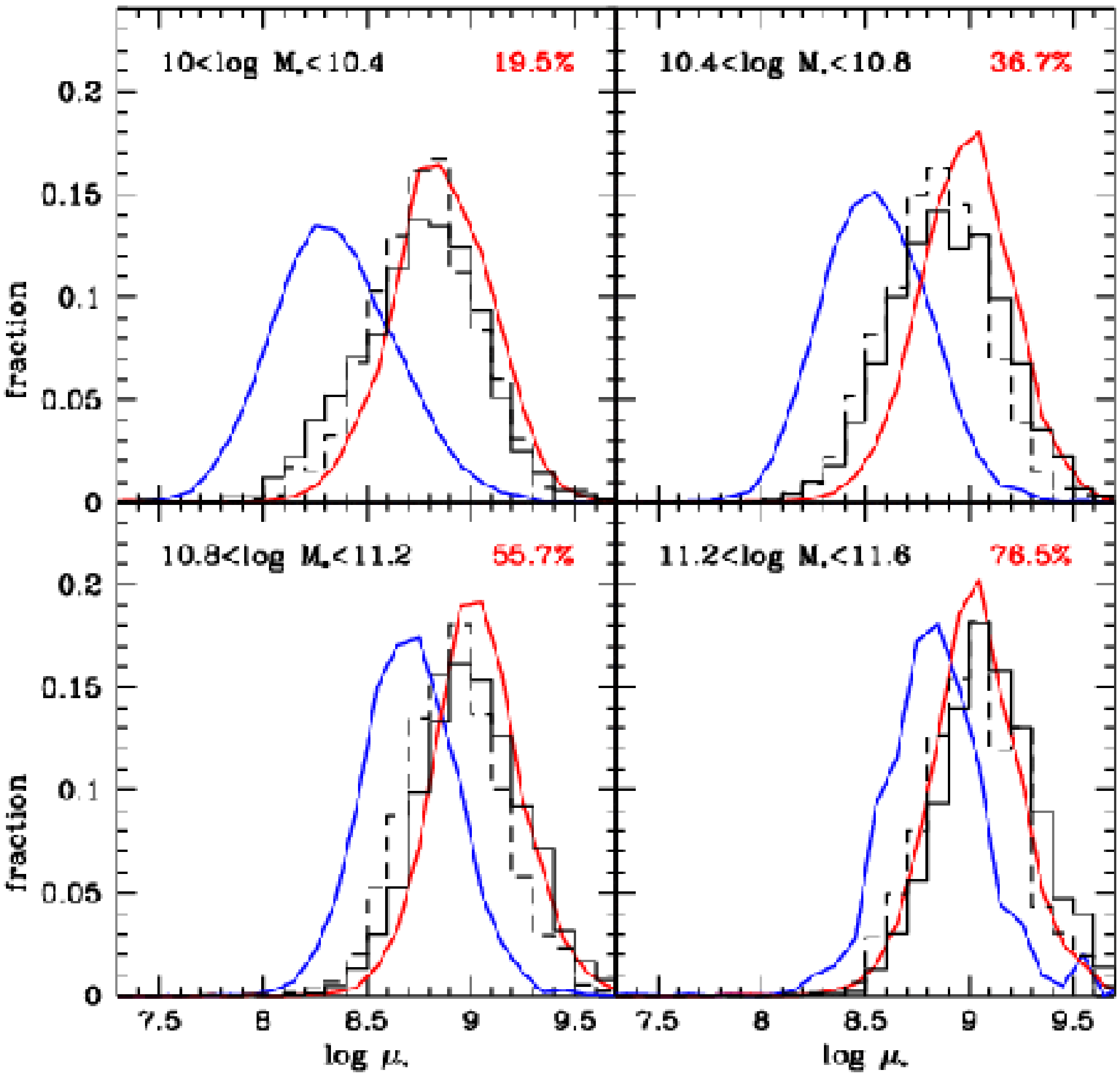
The stacked AGN spectrum is then compared to the stacked reference sample

The Structural Properties of AGN Host Galaxies



AGN hosts have similar sizes and concentrations to inactive galaxies of the same mass

Sizes of AGN Hosts compared to Early- and Late-type Galaxies

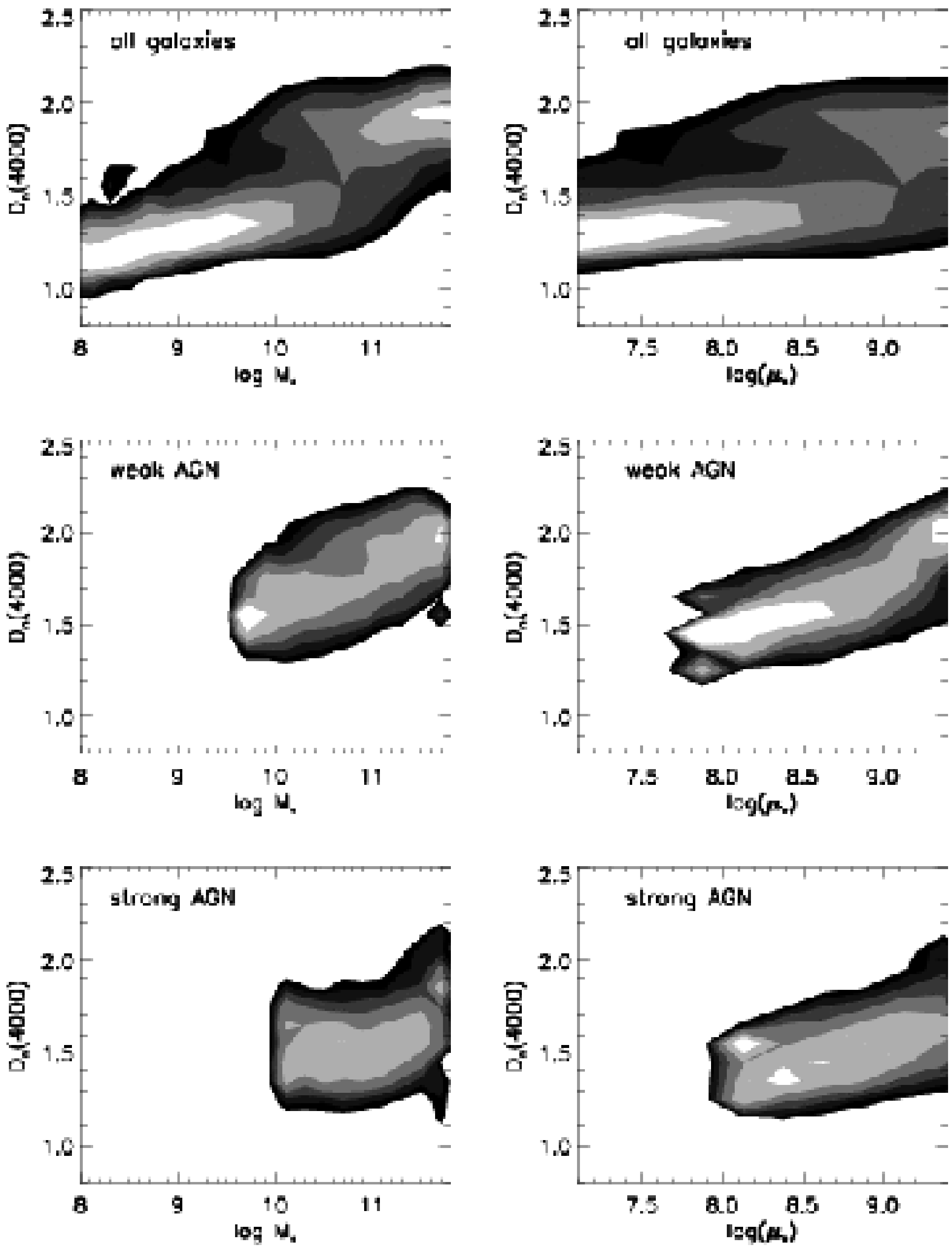


Galaxies are separated into early and late types according to their measured concentrations (at R90/R50 = 2.6)

Red/blue histograms are early/late types for the full sample in each mass interval

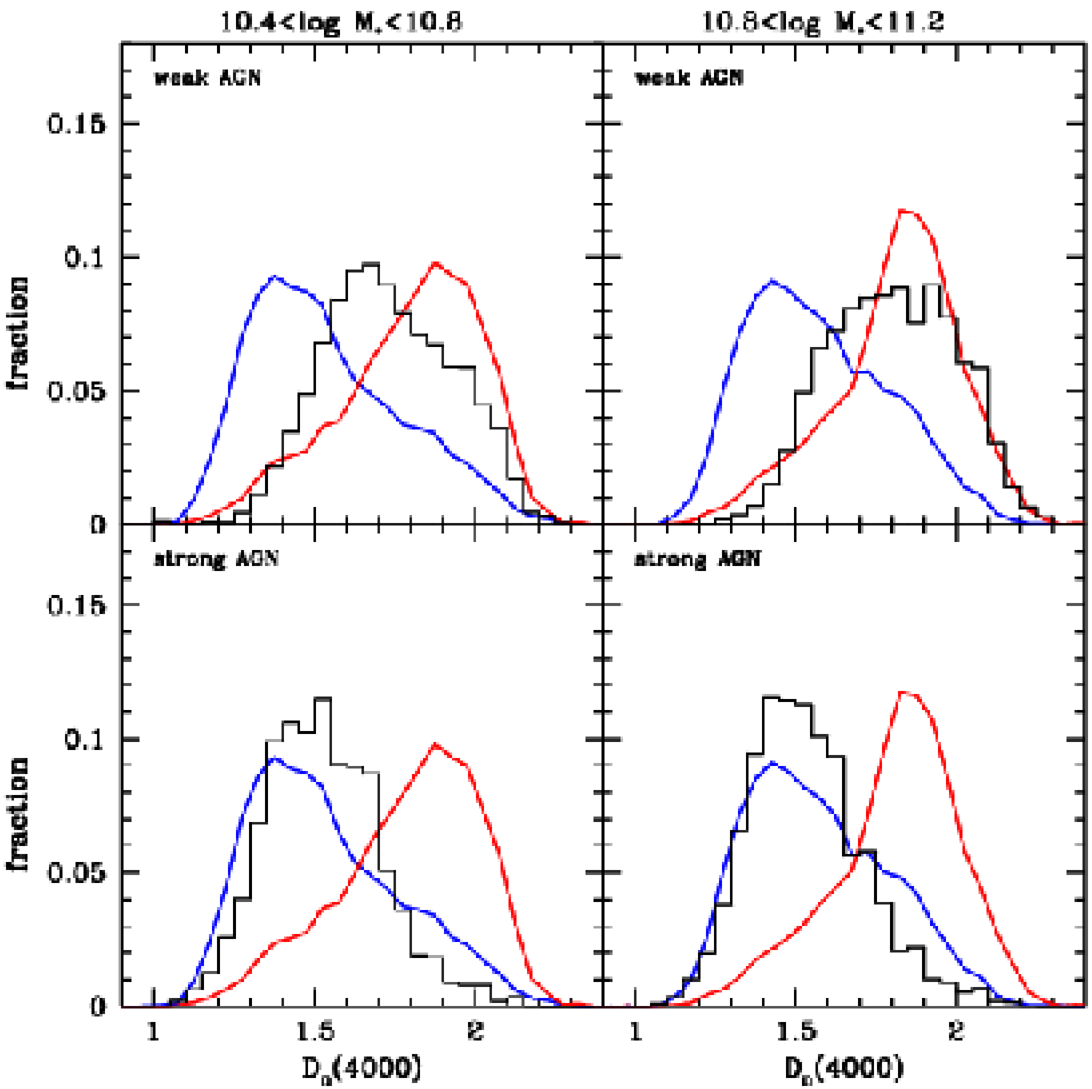
Full/dashed histograms are for strong/weak AGN
Both look like the early types

The Stellar Populations of AGN Host Galaxies



While the stellar populations of weak AGN hosts are quite similar to those of similar mass inactive galaxies, the stellar populations of the hosts of strong AGN are *younger*

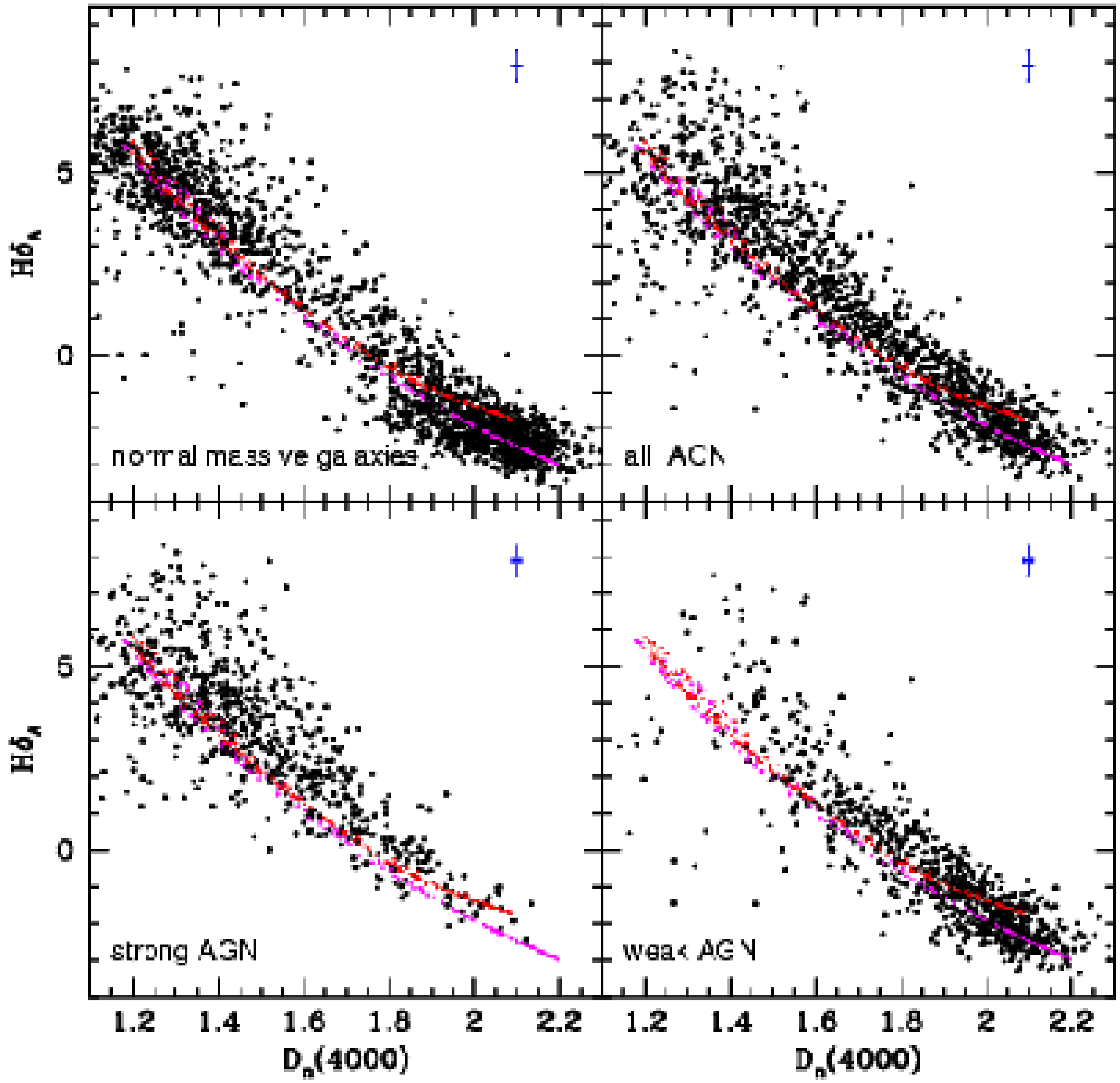
Mean Stellar Ages of AGN compared to Late- and Early-type Galaxies



Distributions of D(4000) for early/late types as defined by concentration are shown as red/blue histograms for each mass bin, while the histograms are for the AGN

Weak AGN have stellar ages similar to the early types while the strong AGN have stellar ages similar to the late types

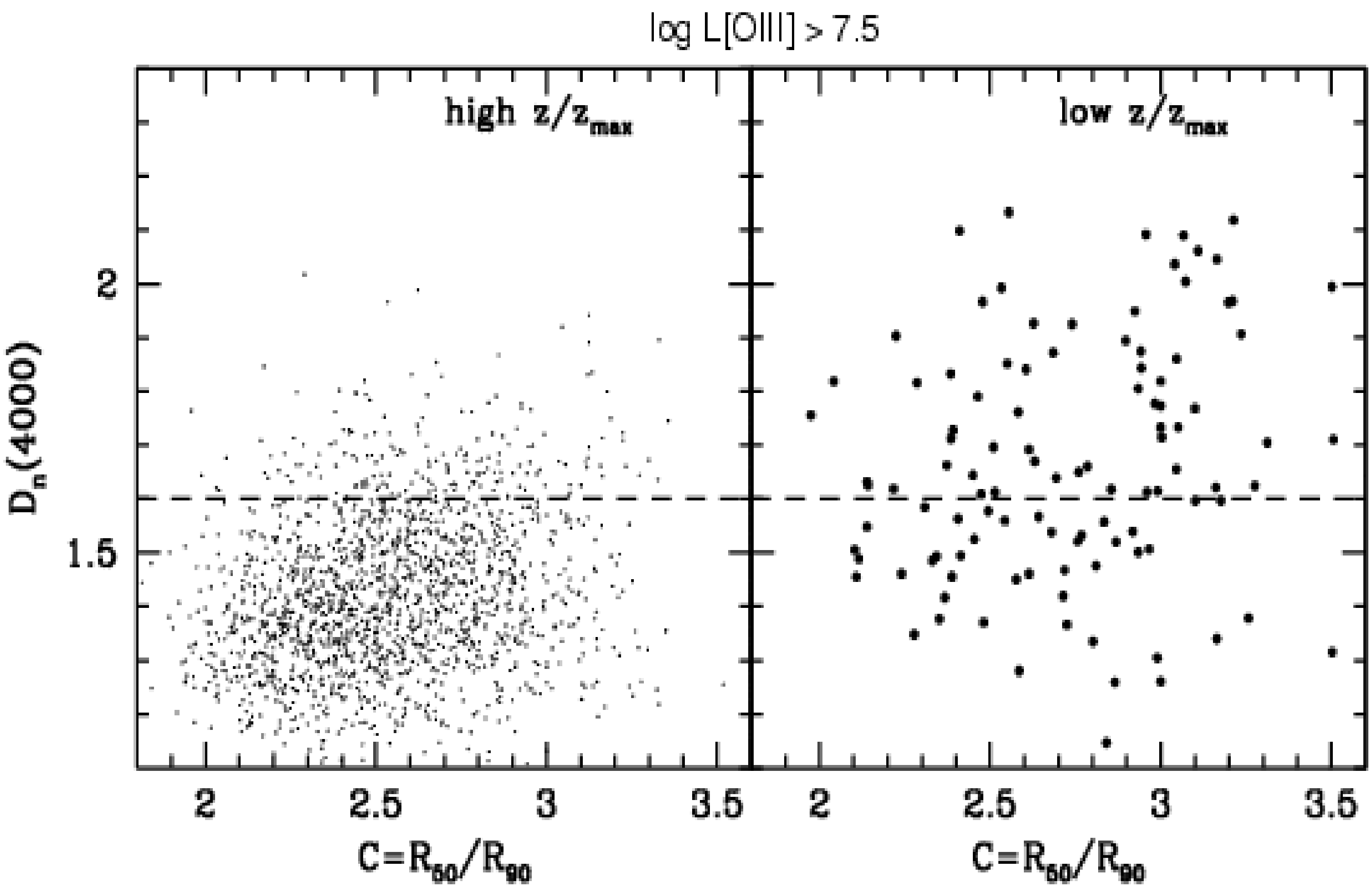
Many powerful AGN have experienced recent starbursts



Weak AGN mostly have old stellar populations

Strong AGN have young stellar populations, often with Balmer line strengths indicating a recent burst

Young stellar populations do not occur preferentially near the nucleus....



AGN CONCLUSIONS

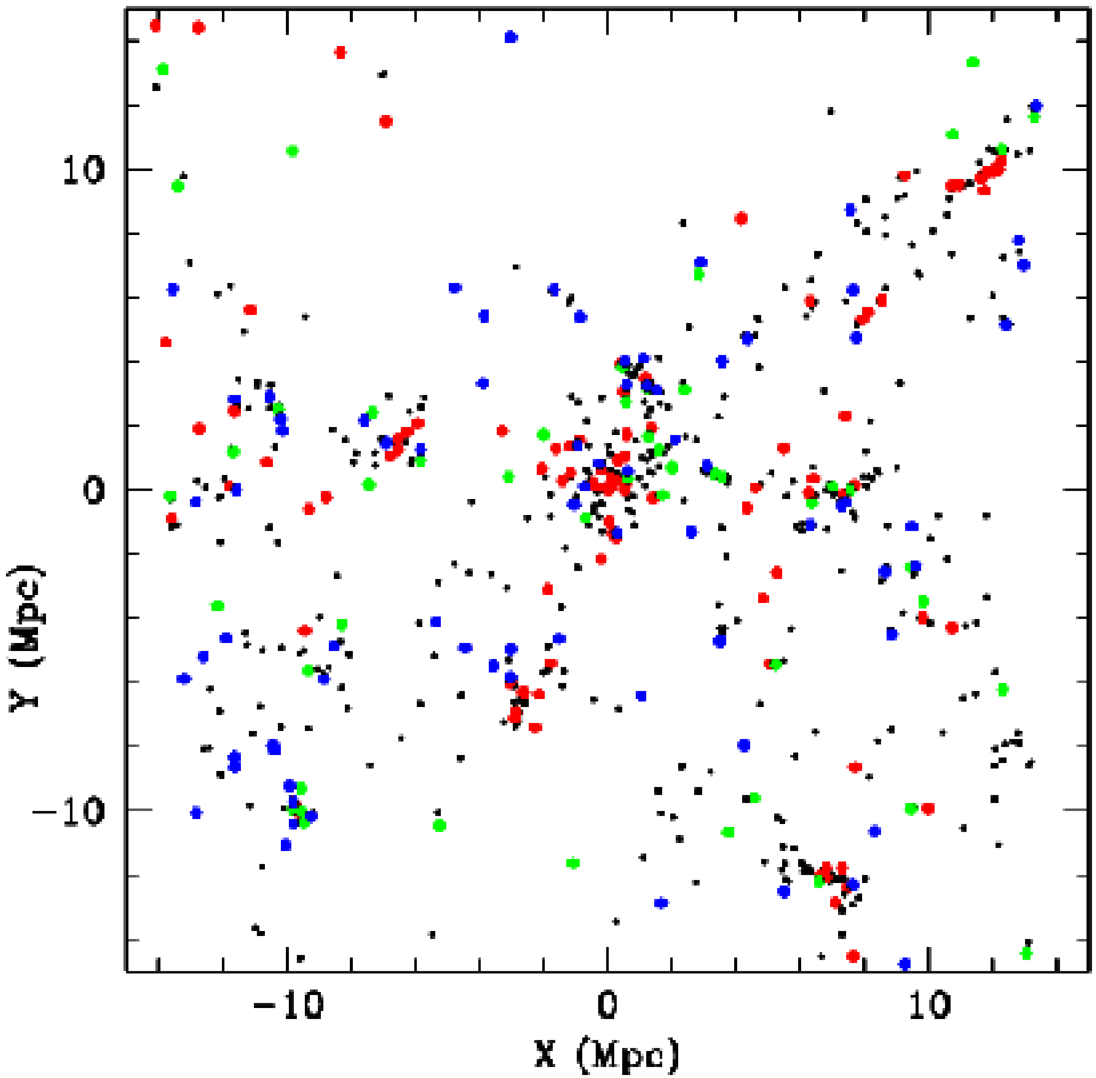
1) AGN reside almost exlusively in galaxies with masses greater than 10^{10} $M_\odot$.
2) AGN reside in galaxies with structural properties similar to those of early-type galaxies.

3) Low-luminosity AGN have stellar populations similar to normal early-types.

4) High-luminosity AGN have much younger stellar populations. A significant fraction have undergone recent starbursts.

Growth of bulges and black holes closely linked even at low redshifts.

Environment dependence of stellar populations



Kauffmann et al 2004

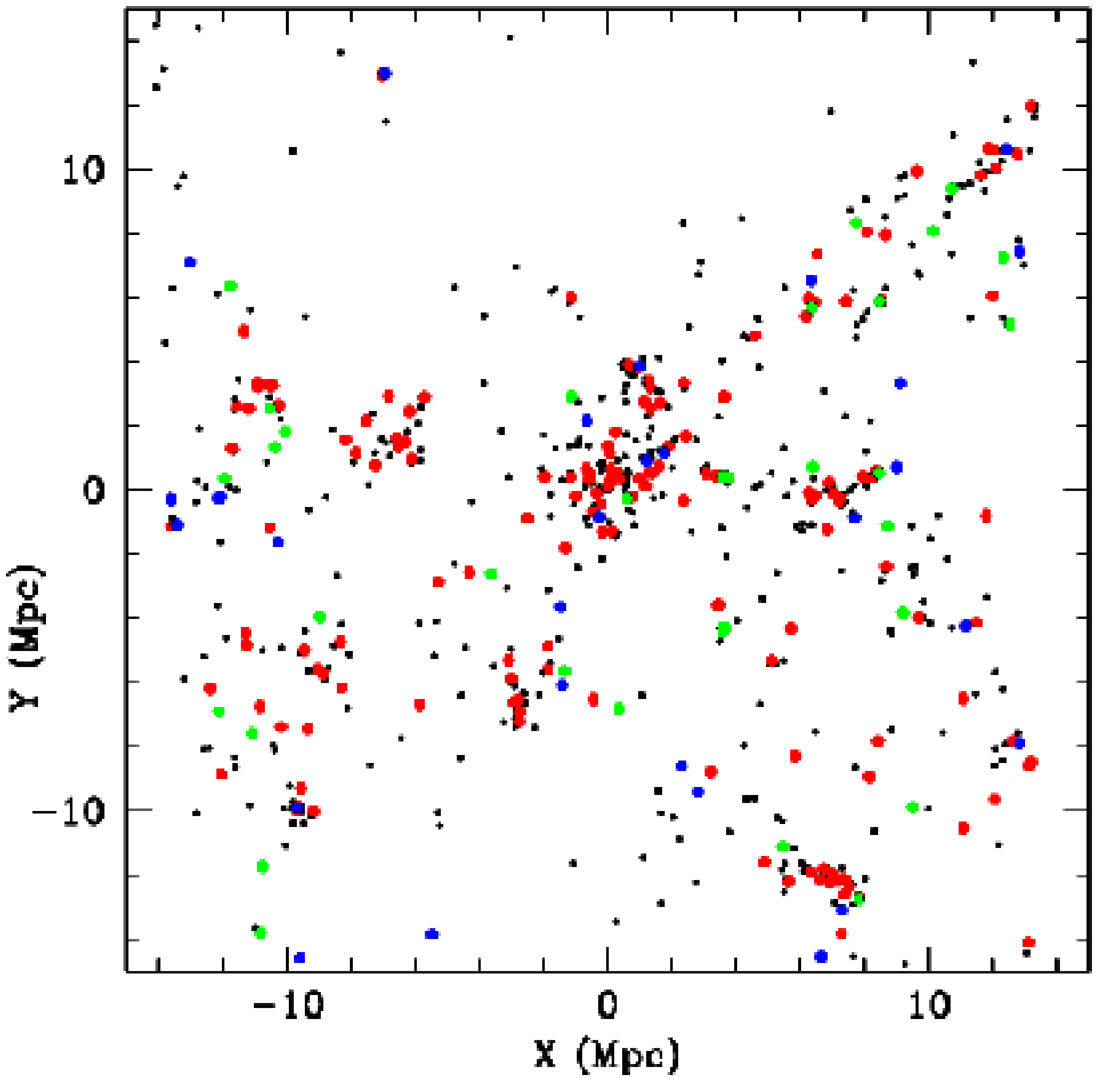
SDSS spectroscopic sample
$z = 0.05$
Depth of slice ± 500 km/s

Galaxies with $M_* < 3 \times 10^{10}$

Colour code indicates the value of $D_n(4000)$

Oldest galaxies are in the densest regions

Environment dependence of stellar populations



Kauffmann et al 2004

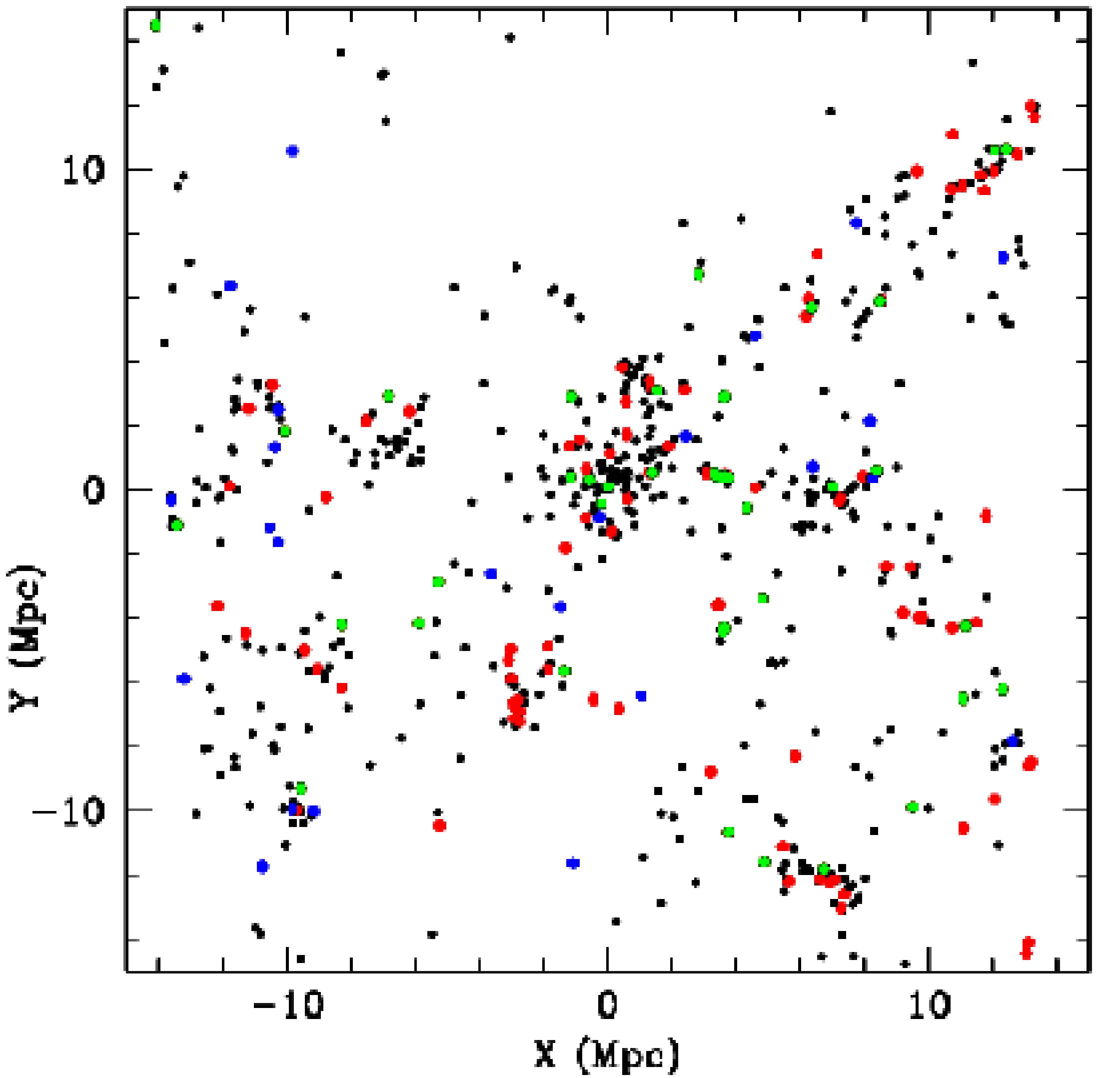
SDSS spectroscopic sample
$z = 0.05$
Depth of slice ± 500 km/s

Galaxies with $M_* > 3 \times 10^{10}$

Colour code indicates the value of $D_n(4000)$

High mass galaxies are older and are in denser regions

Environment dependence of stellar populations



Kauffmann et al 2004

SDSS spectroscopic sample

z = 0.05

Depth of slice ± 500 km/s

Galaxies with type 2 AGN

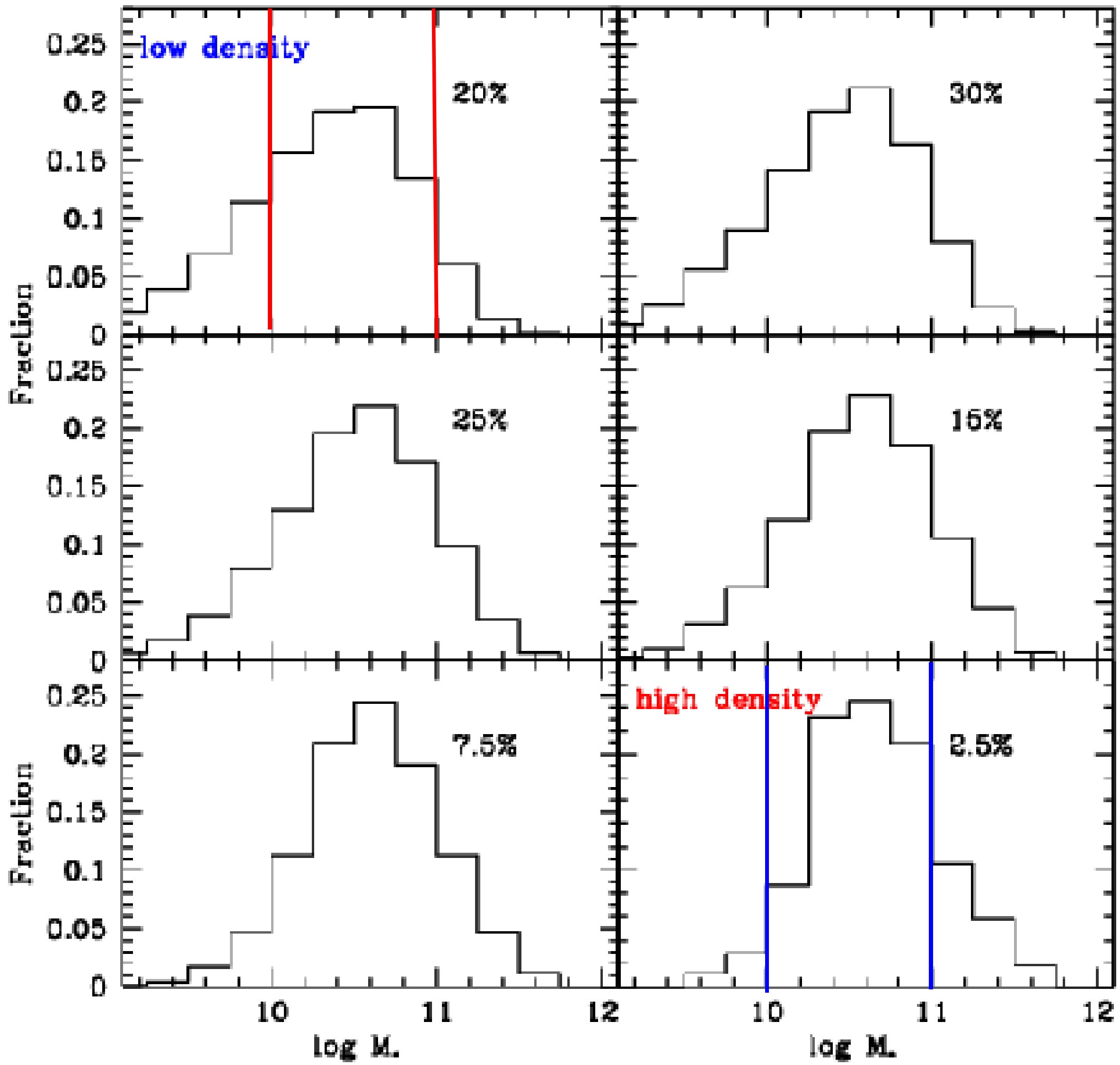
Colour code indicates AGN luminosity (in [OIII])

Many *high mass* galaxies are AGN

Brighter AGN have younger stars and are less clustered

The Dependence of Galaxy Mass on Local Density

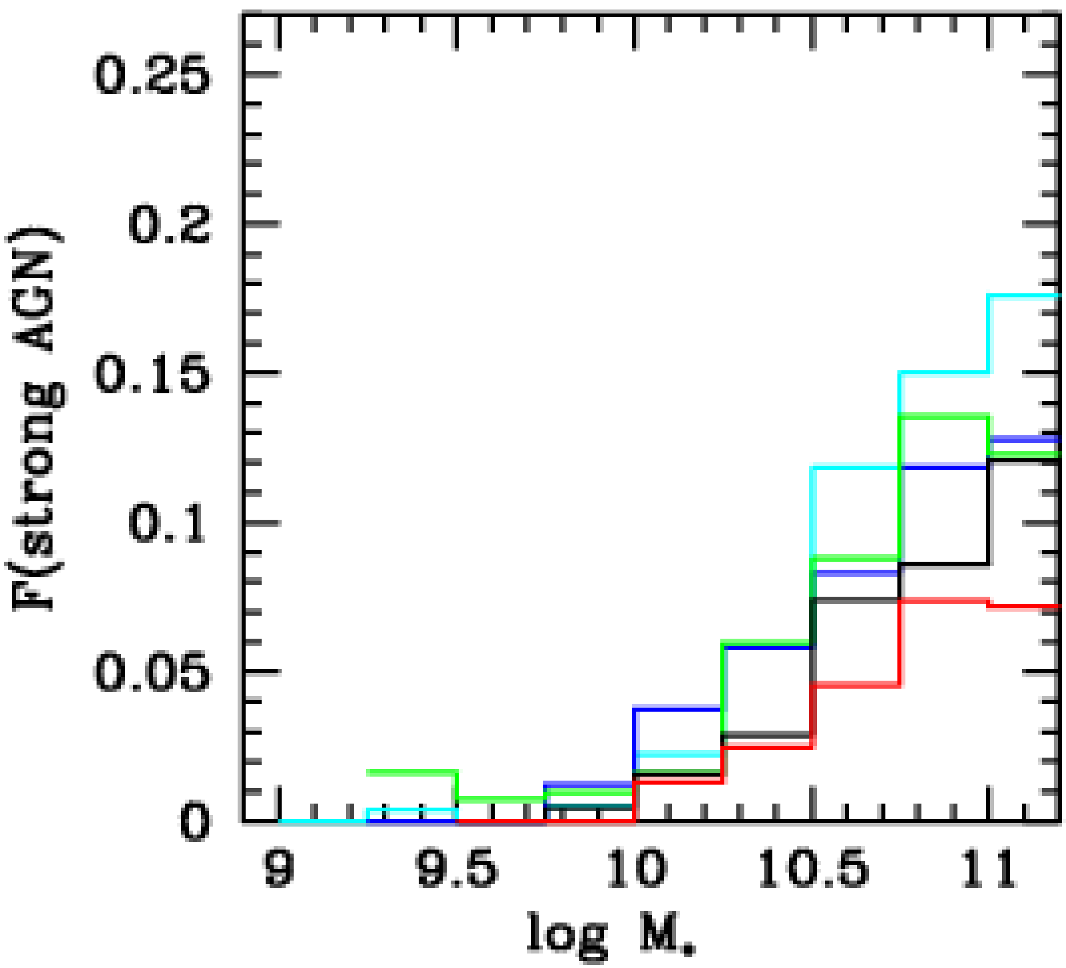
Kauffmann et al 2004



The stellar mass distribution of galaxies shifts to higher masses in higher density regions

The density around each object is defined here and below by counting galaxies down to a fixed absolute luminosity in a cylinder of radius 2 Mpc and depth ± 500 km/s

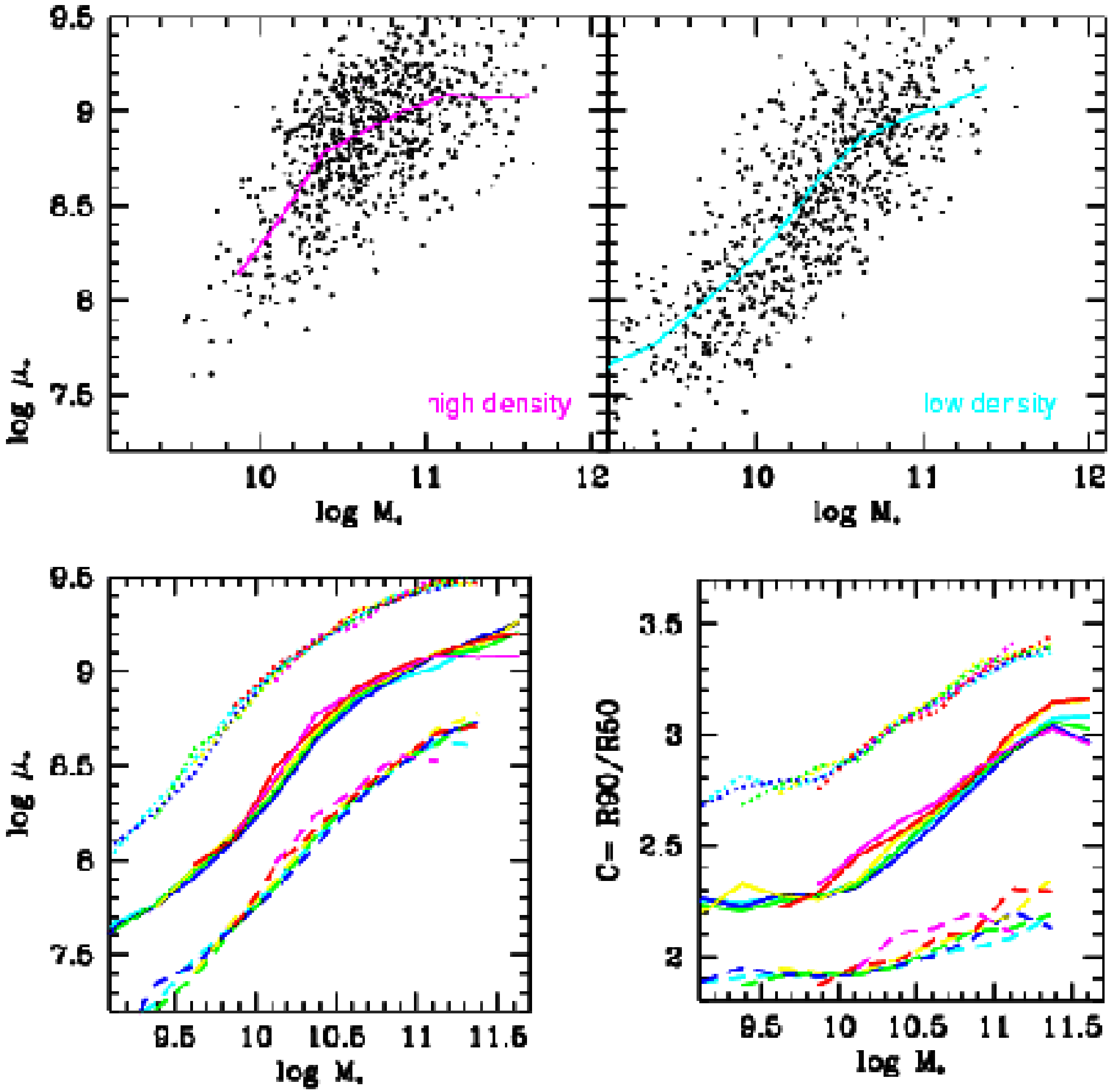
Fraction of AGN as a function of mass and environment



The fraction of strong AGN (log L([OIII]) > 7) is greater in massive galaxies and in low density regions

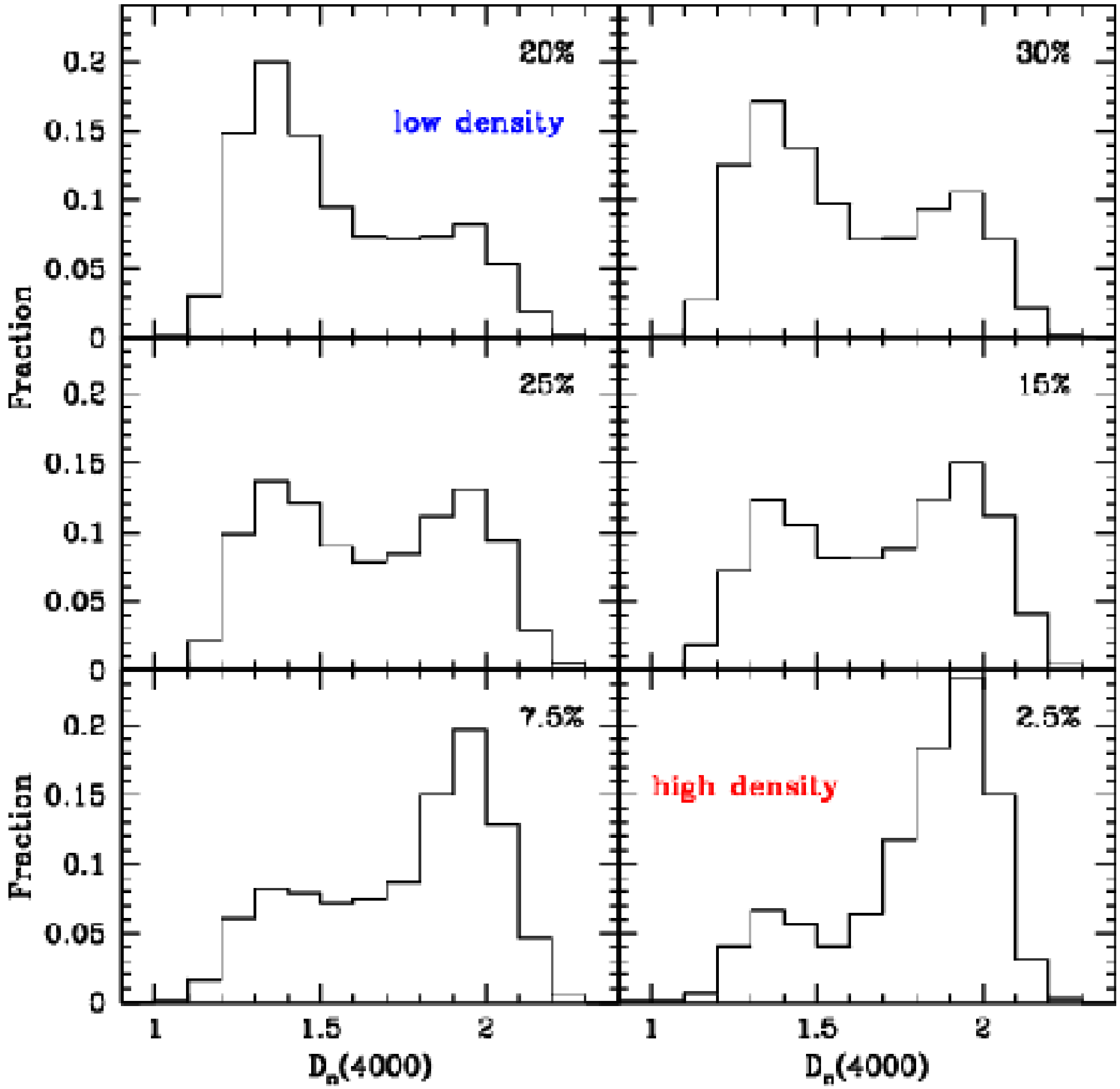
However, the relation between galaxy structure and mass does NOT depend on density! There is NO structure density relation at fixed stellar mass!

Kauffmann et al 2004



The Dependence of Stellar Age on Local Density

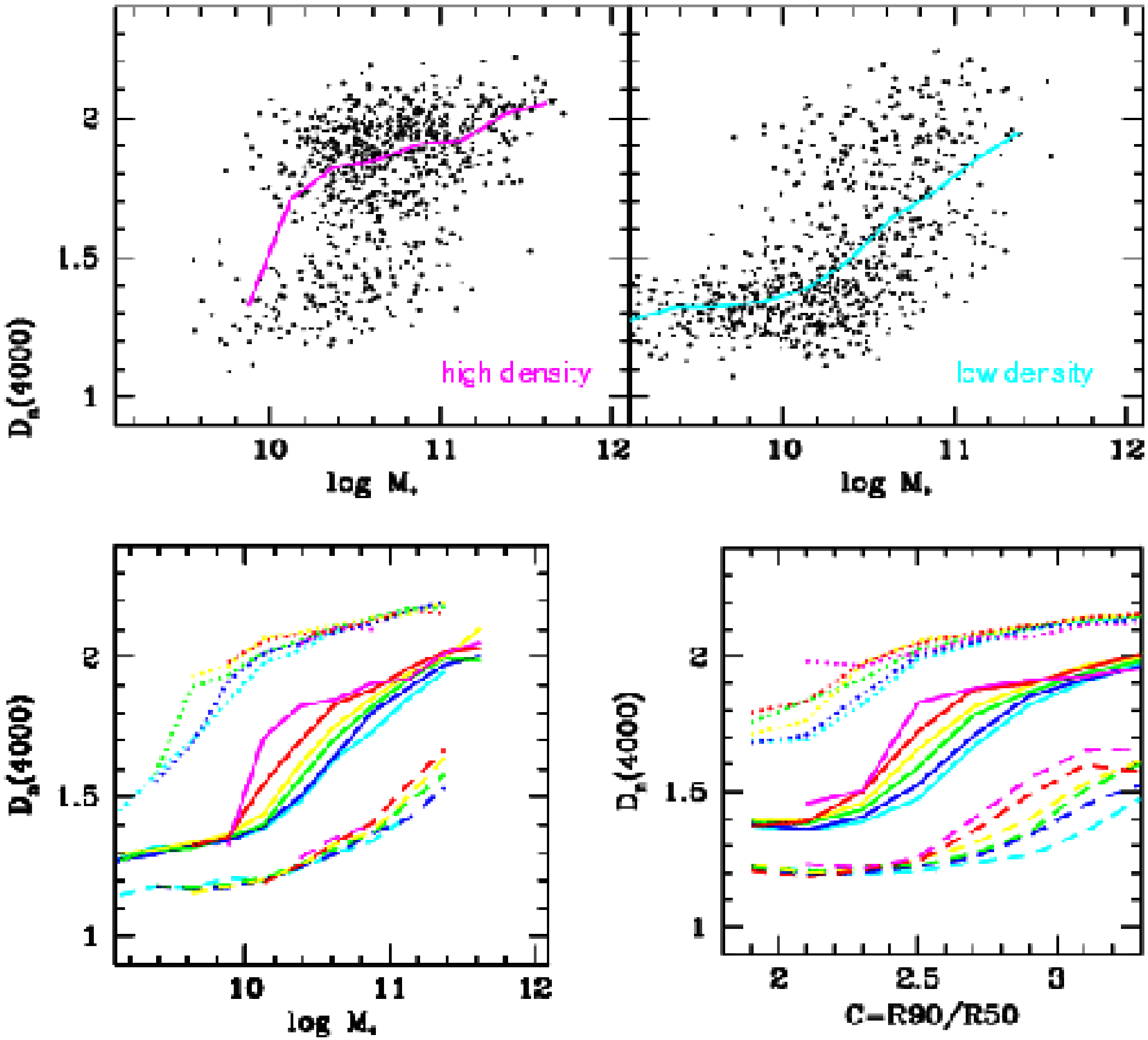
Kauffmann et al 2004



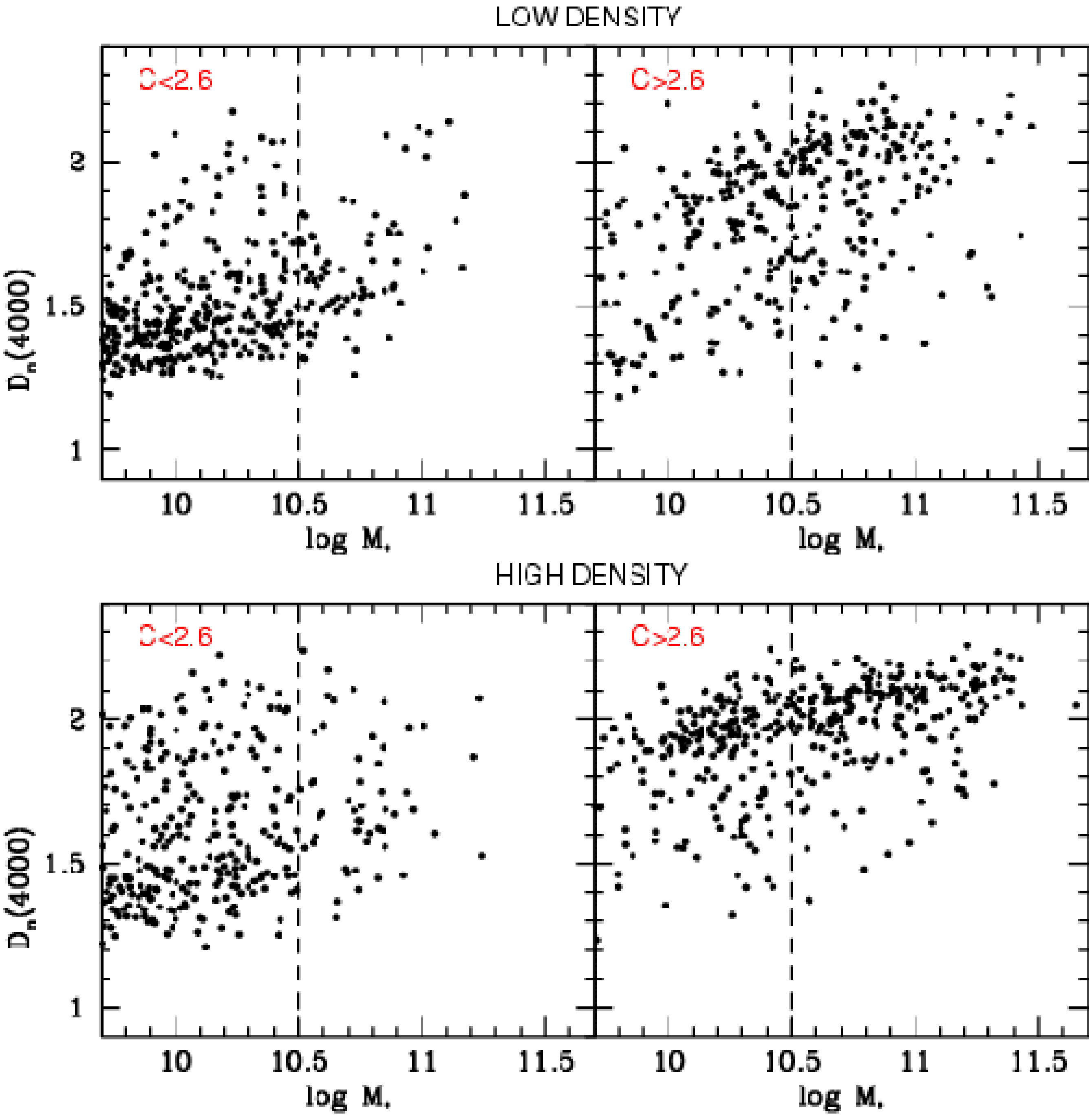
Stellar populations shift from predominantly young in low density regions to predominantly old in high density regions

The relation between age and galaxy mass/structural parameters exhibits a strong dependence on density.

Kauffmann et al 2004



SUMMARY



- Low density regions have lower mass and lower concentration galaxies but brighter AGN
- Concentration doesn't depend on density at fixed mass
- The blue/red ratio shifts with density for both early- and late-type concentrations
- Structure has no density dependence but SFH does