Stellar populations and SFH with **SHARDS**

Results from a mass-selected sample of 0.65<z<1.1 galaxies

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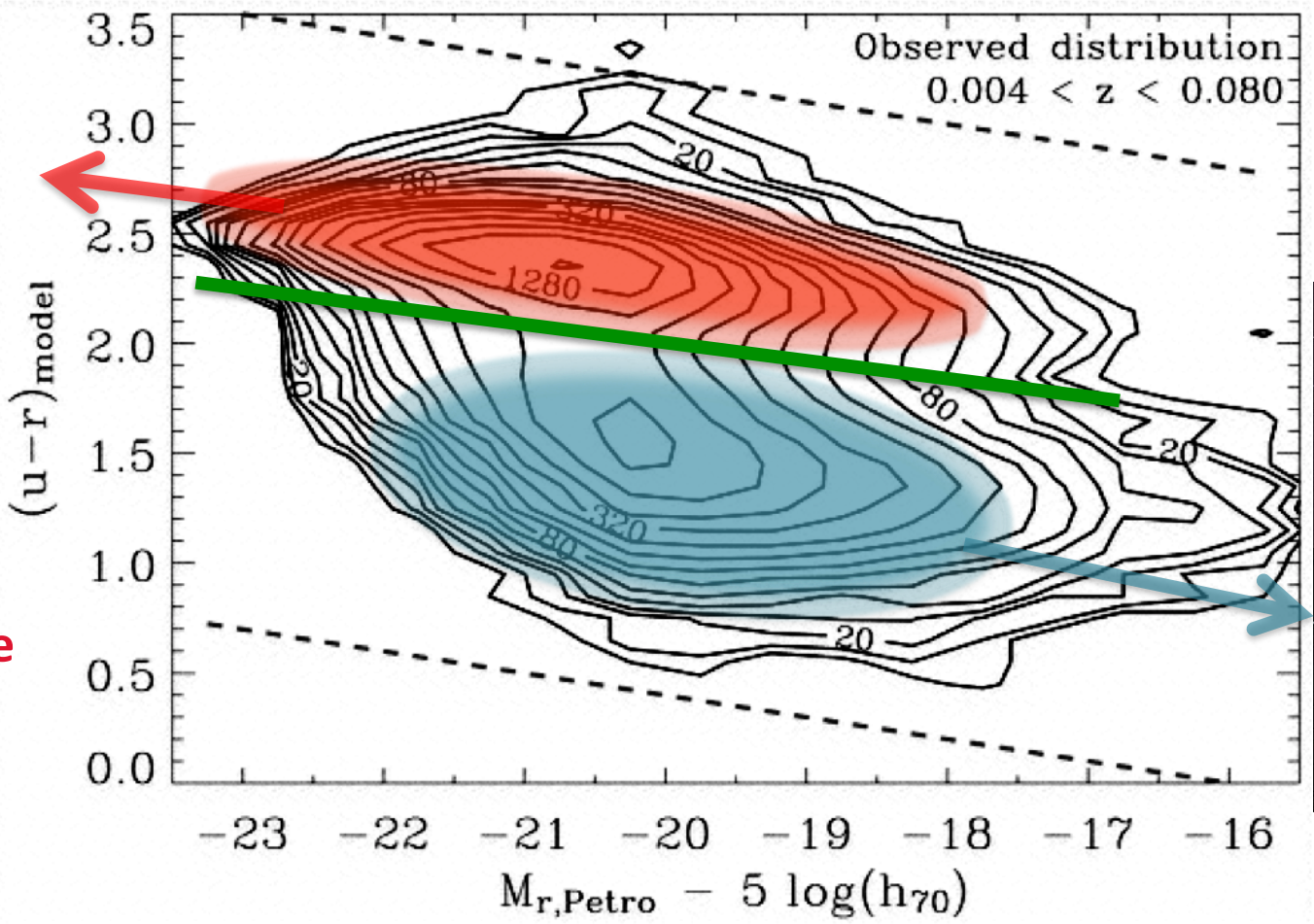
Bimodal Galaxy Distribution

Red sequence

- Red colors
- Early type
- Old stars
- Gas-poor
- Passive evolution



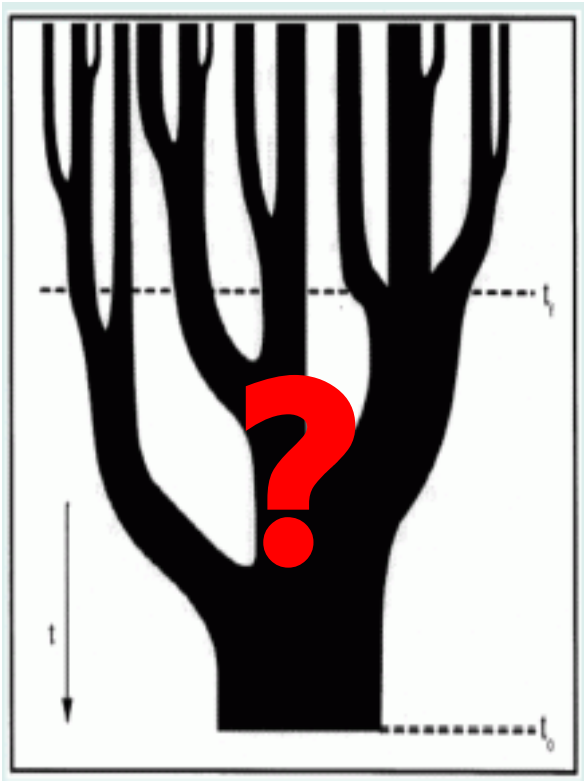
Blue cloud

- Blue colors
- Late type
- Young stars
- Gas-rich
- Actively starforming

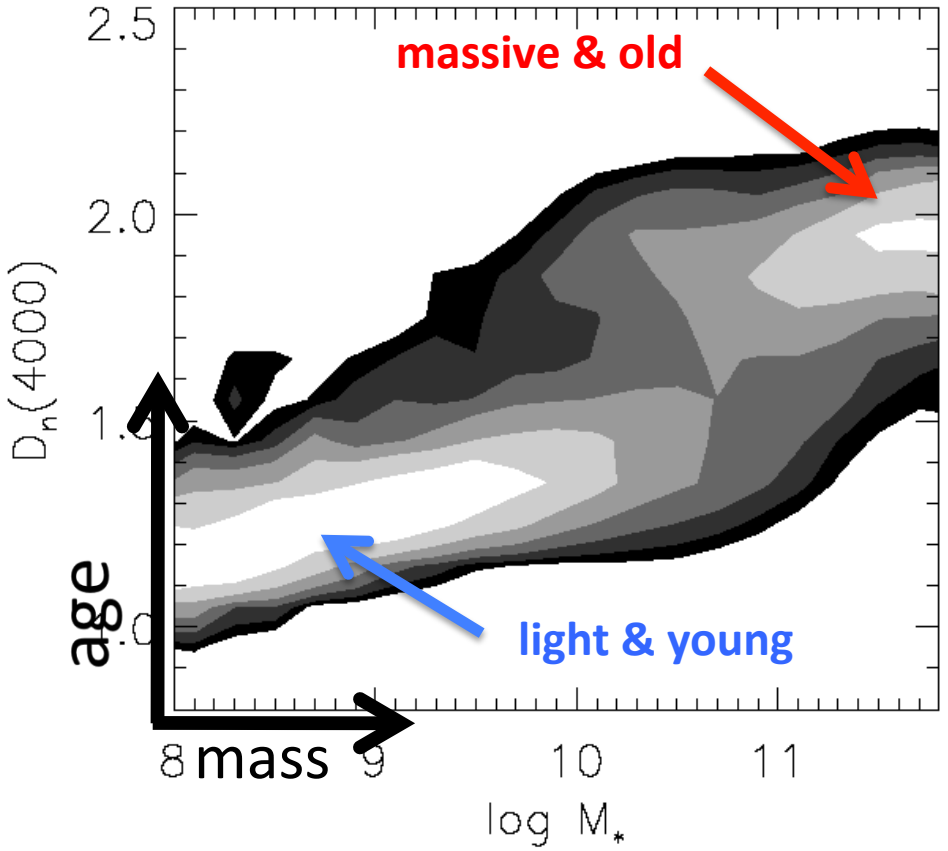
Baldry et al. 2004

The local mass-age relation

- Strong bimodality in mass-age relationship
- Conflicts with models of hierarchical galaxy formation ?
- Typical mass of red sequence galaxies increases with redshift
- Star formation moves to smaller galaxies at later epochs (downsizing)



Kauffmann et al. 2003



Outline

- How to meassure the 4000 break with SHARDS
  (and not die while trying)
- Breaking the age-extinction degeneracy

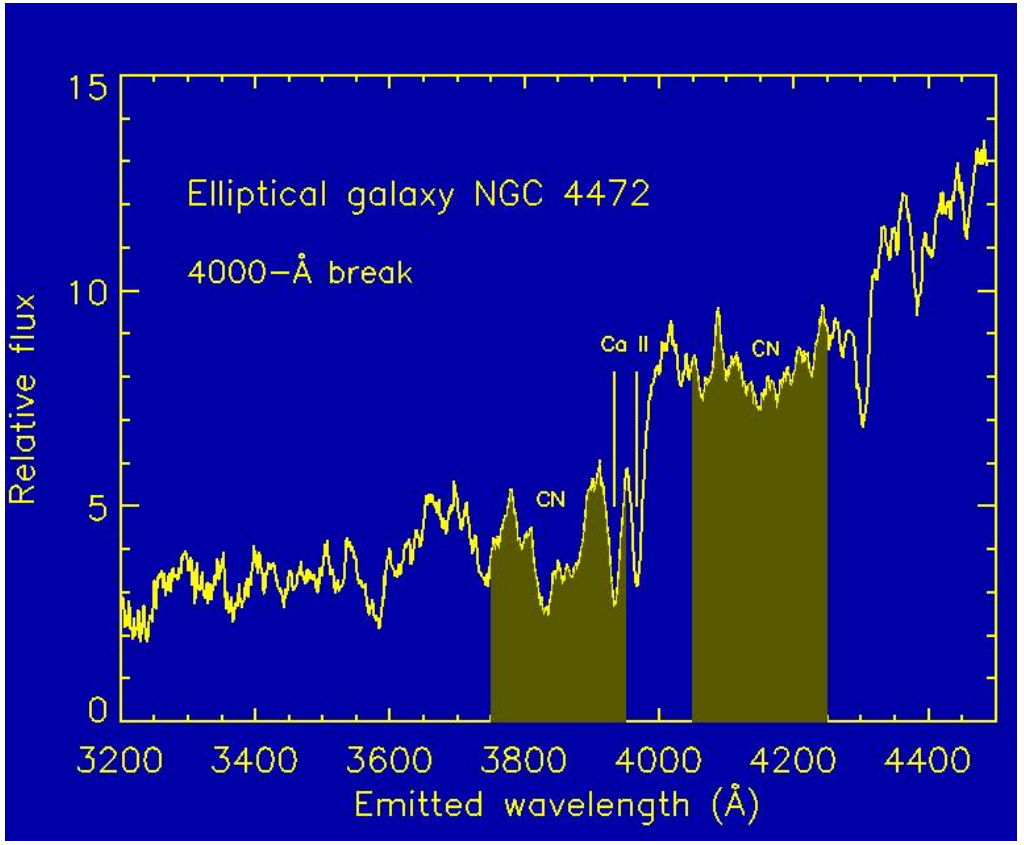
Science results:

- Mass-dependency of galaxy properties
- Smooth transition blue cloud → red sequence
- Fraction of galaxies with SF in decline at z~1

The 4000 Å spectral break: physics

- Strongest discontinuity in the optical spectrum for old galaxies (>1 Gyr)
- Accumulation of absorption features at ~4000 Å (CN band, Ca II H+K lines,…)
- Strong in cold stars
- Weak in hot stars

AGE INDICATOR FOR STELLAR POPULATIONS



The D(4000) index

Measures the strength of the 4000 Å break

Two definitions:

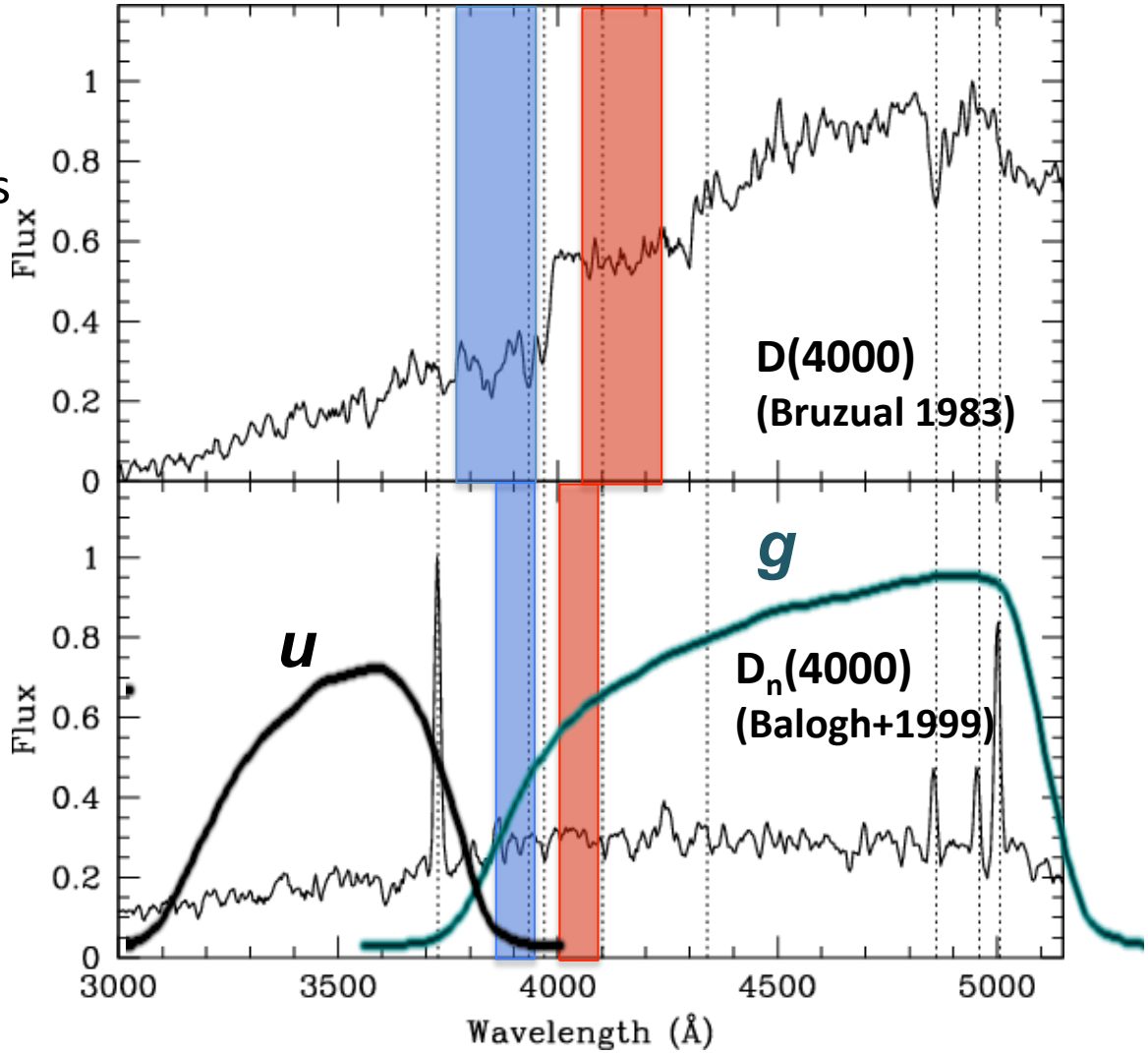
- Bruzual (1983): 20nm bands
- Balogh+ (1999): 10nm bands

Ratio of the average f_ν in the red and blue bands

$$D(4000) = \frac{\int_{red} f_\nu(\lambda) d\lambda}{\int_{blue} f_\nu(\lambda) d\lambda}$$

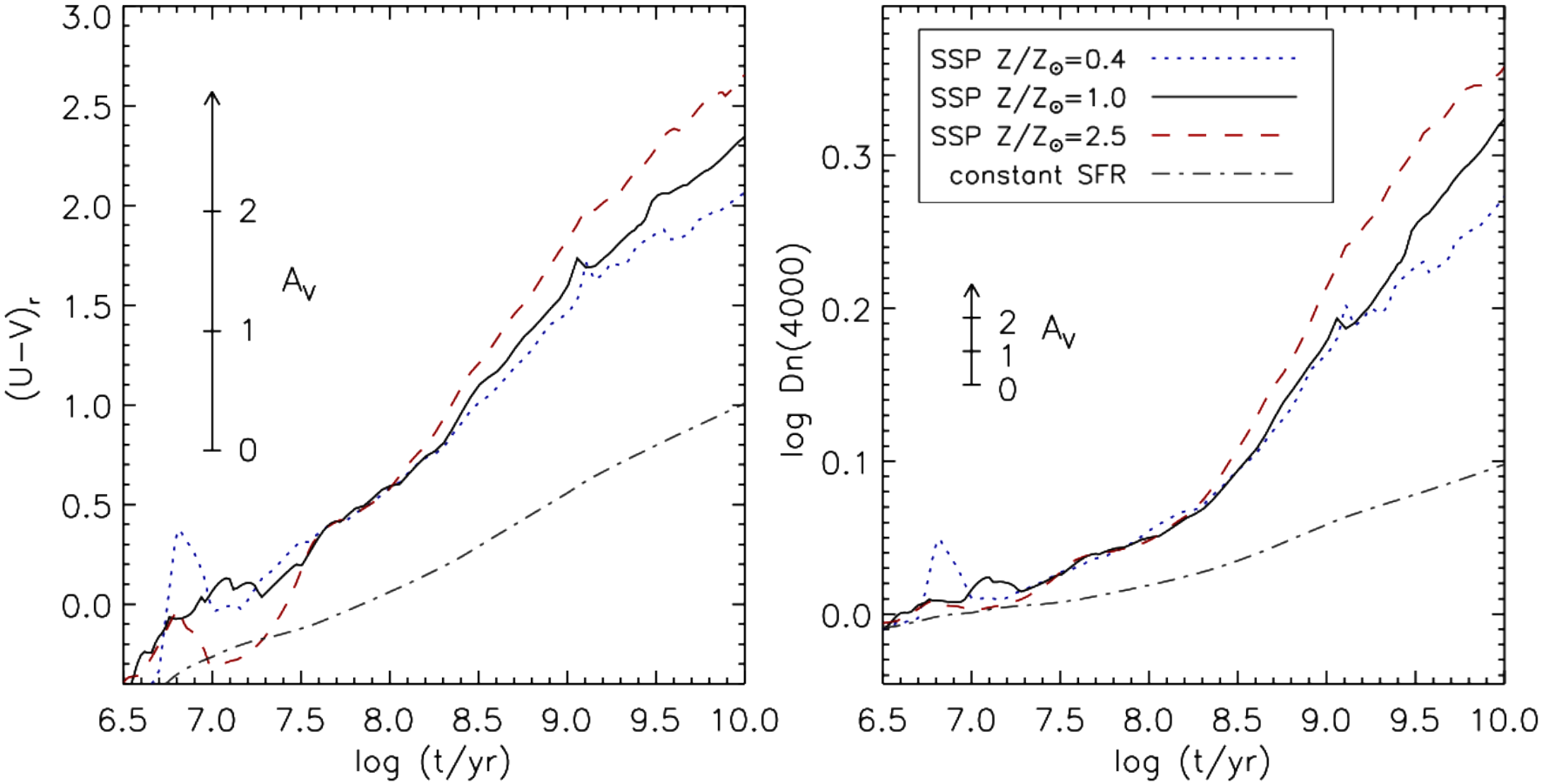
2.5 log D(4000) is a rest-frame color index like *u-g* or U-V….

…but much less sensitive to the continuum slope

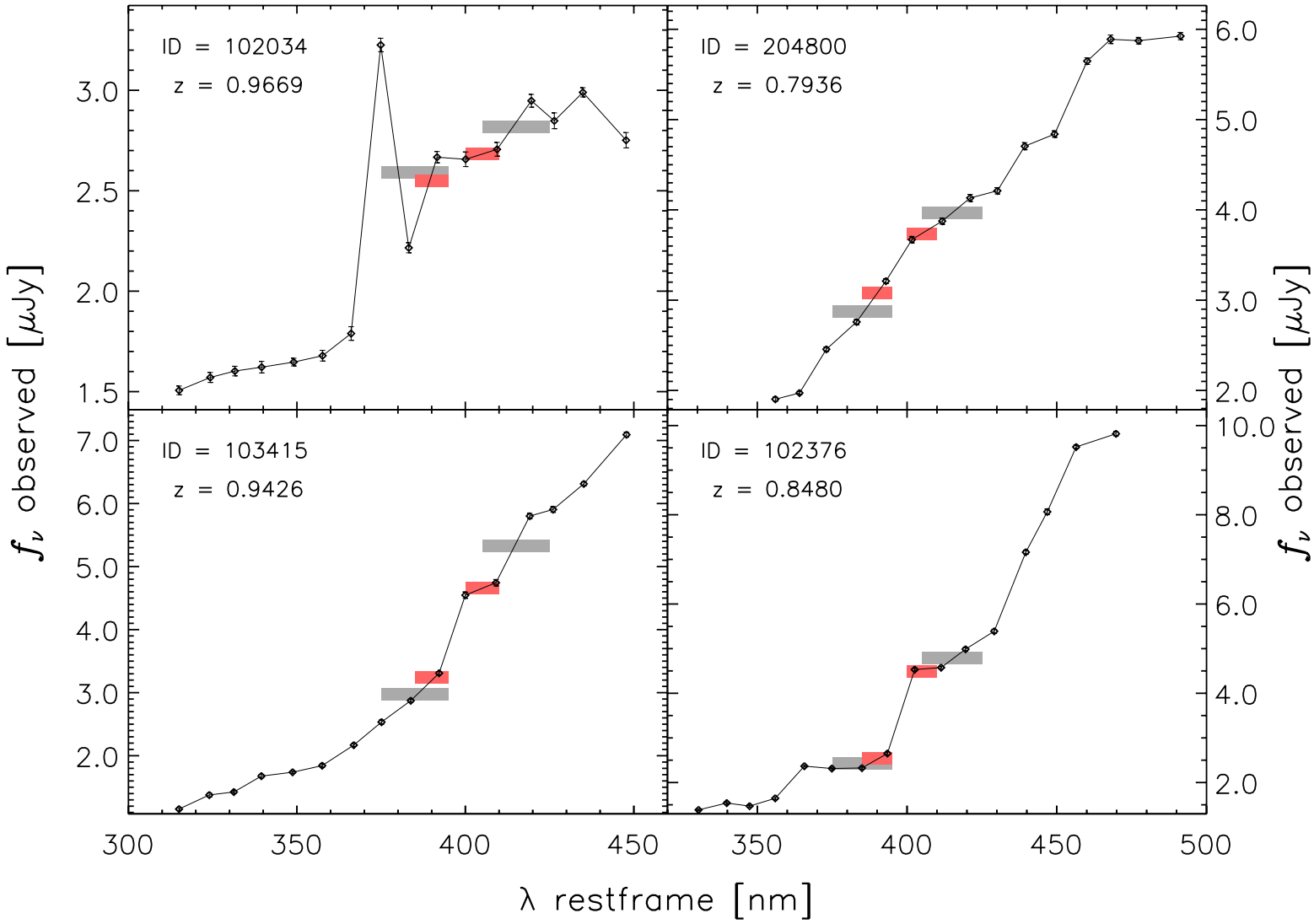


Trends with age, extinction, and metallicity

- Metallicity important only in old (>1Gyr) stellar populations
- Impact of extinction ~3x higher in U-V compared to log Dn(4000)
- Age: U-V linear with log t, Dn(4000) nearly flat for t<300 Myr



The 4000 Å break as seen by SHARDS



The impact of spectral resolution

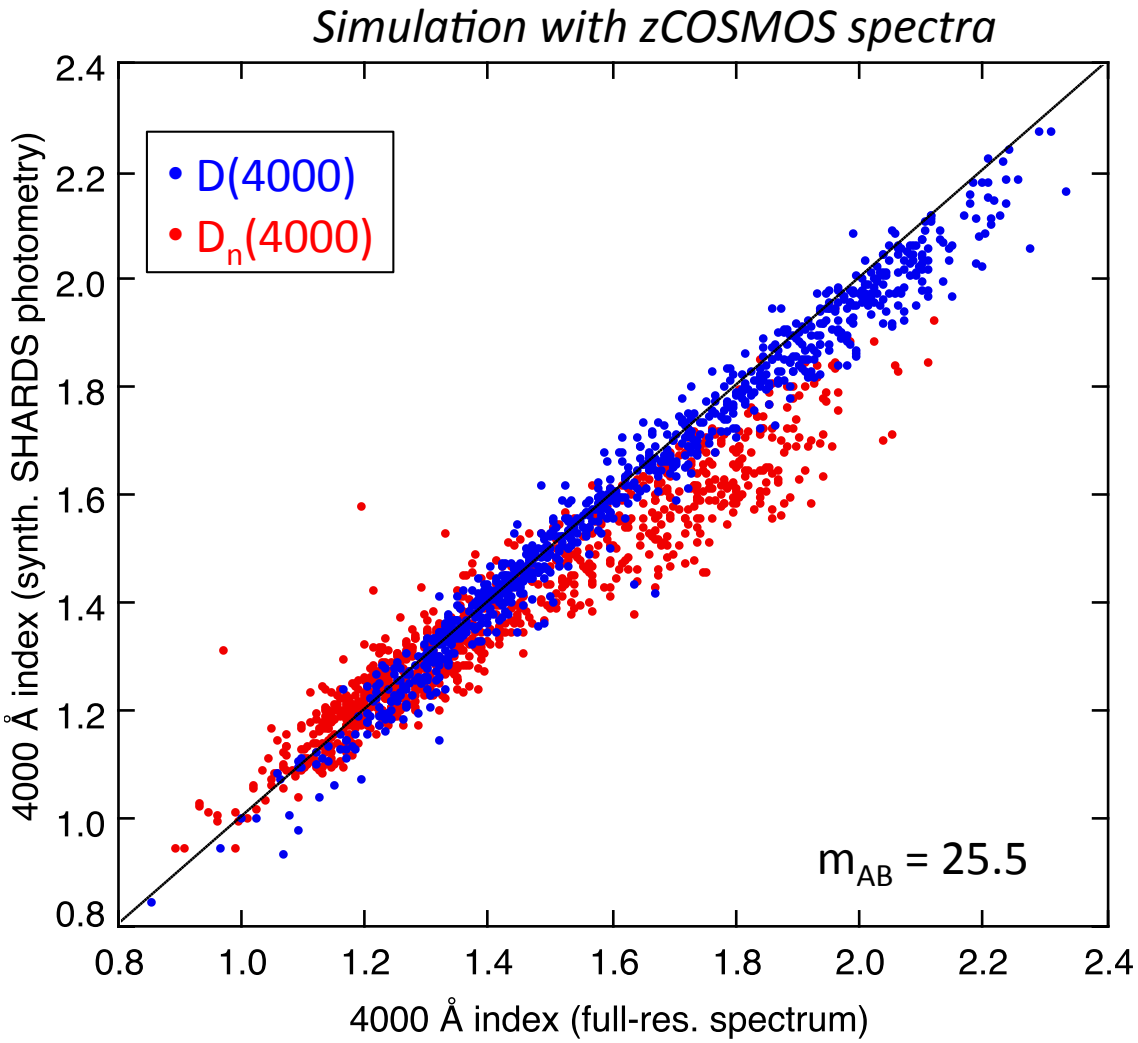
D(4000) measured on synthetic SHARDS photometry from 1377 zCOSMOS spectra

Sources of error for D(4000) measurements:

- Photometric errors
- Redshift uncertainty
- Interpolation error

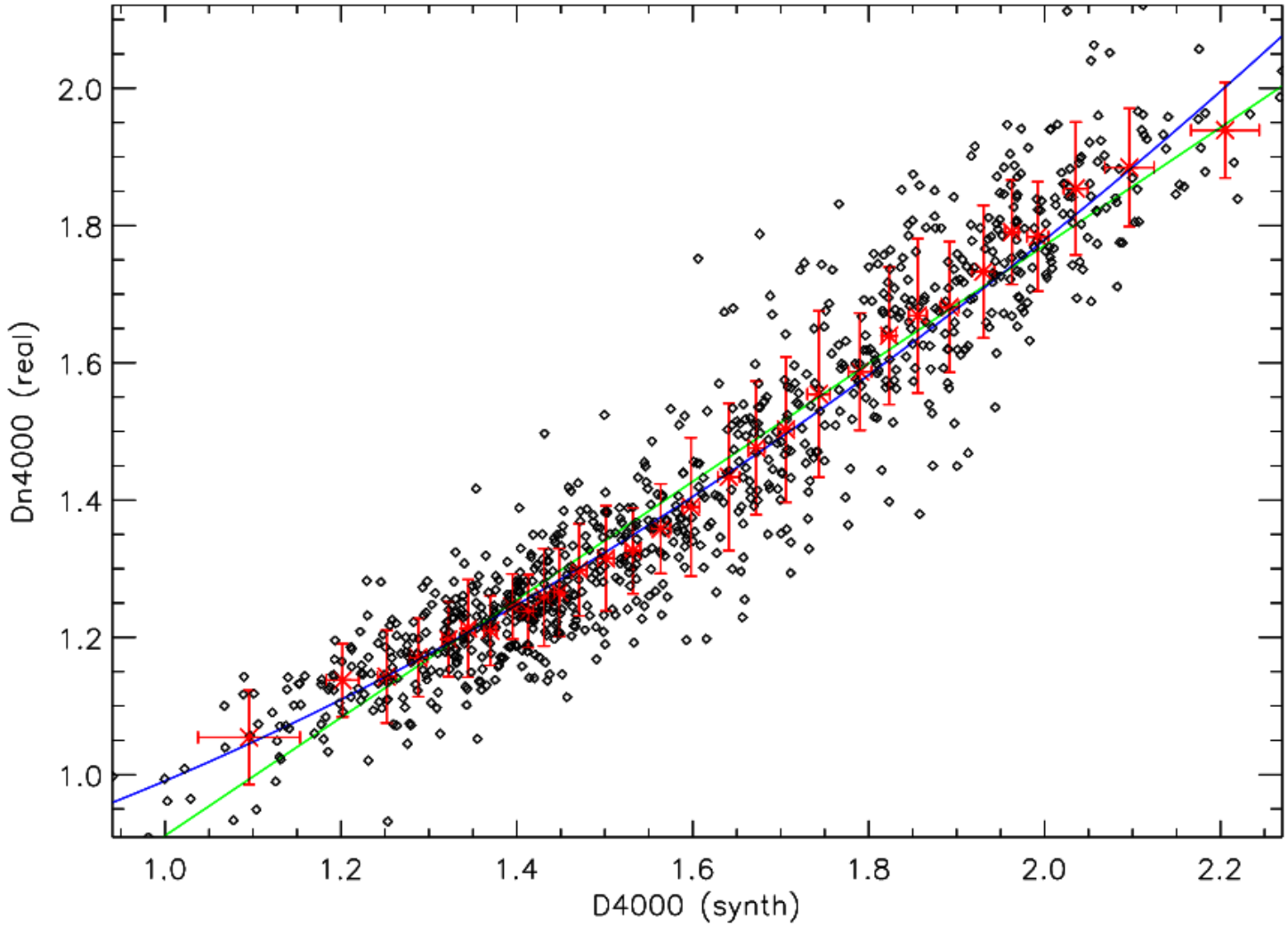
Interpolation error introduces bias: $D(4000)_{synth} < D(4000)_{full}$

Bias & dispersion is worse for $D_n(4000)$

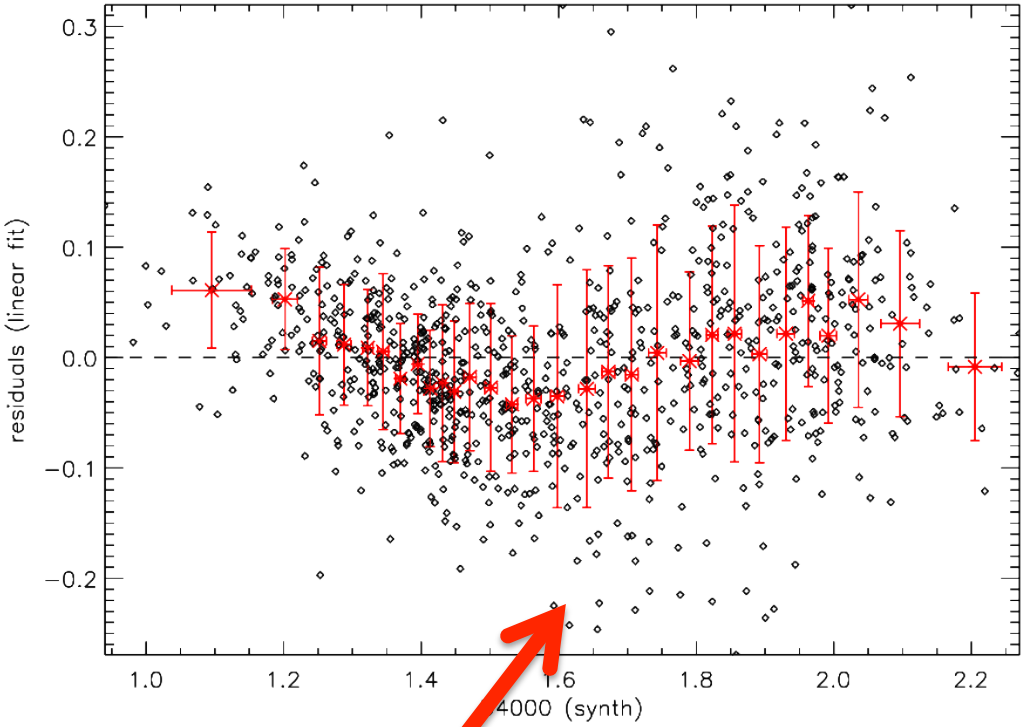


Calibration of $D_n(4000)$ measurements (I)

Polynomial fit converts raw D(4000) into corrected $D_n(4000)$



Calibration of $D_n(4000)$ measurements (II)

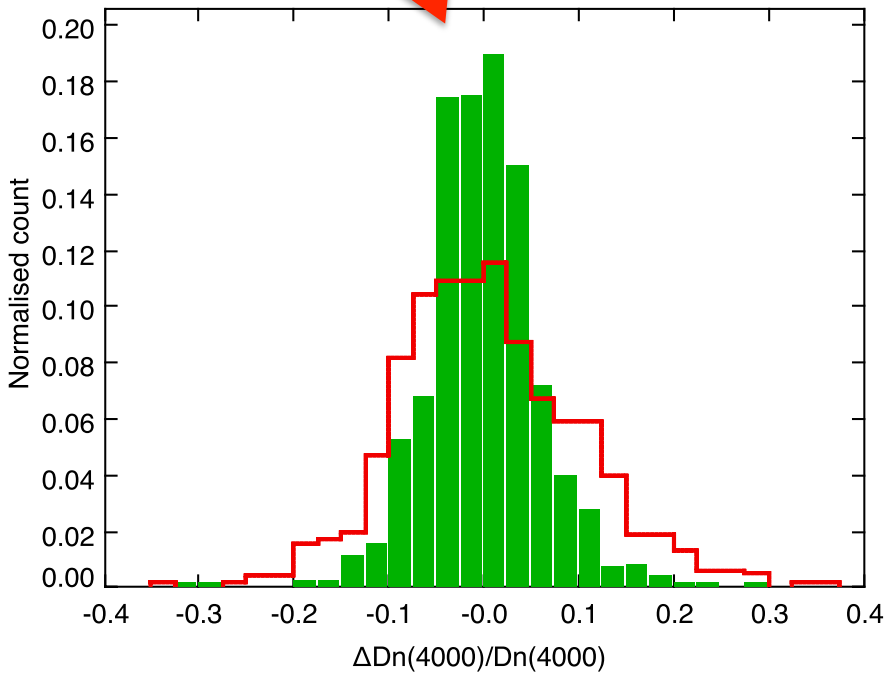


Systematics

<3%

Total uncertainty

5-10%



The mass-selected SHARDS sample

Sample selection:

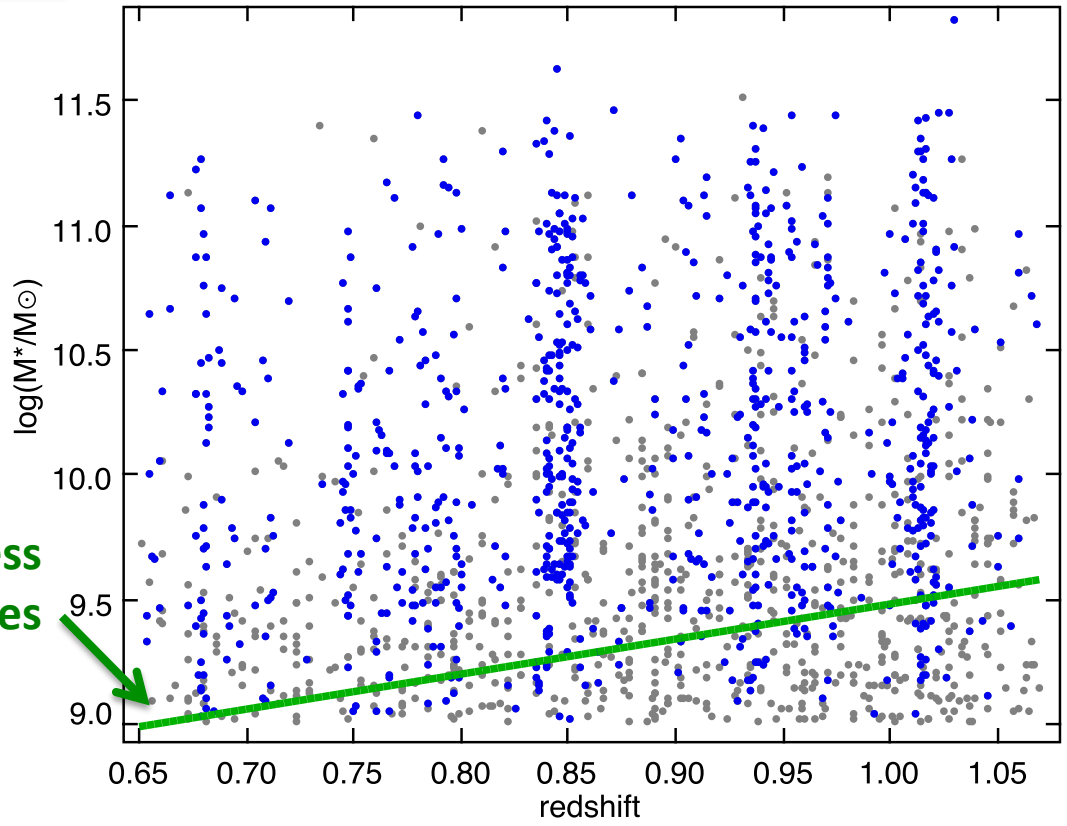
- ✓ Rainbow source (3.6μm detec.)
- ✓ SHARDS counterpart within 1″
- ✓ 0.65 < z < 1.07
- ✓ $M_* > 10^9\ M_\odot$

98% completeness down to $10^9\ M_\odot$

1644 sources selected:

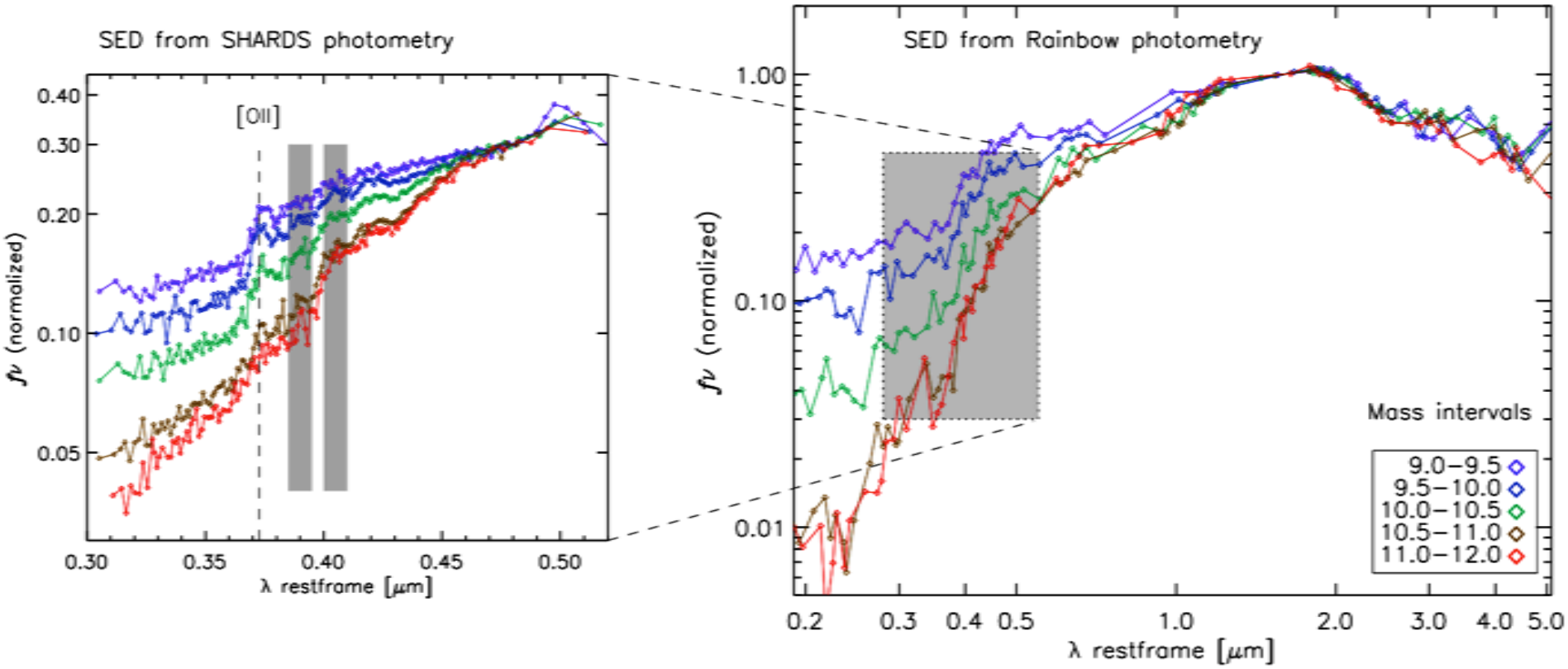
807 spectroscopic redshifts
562 SHARDS photo-z's (Ferreras+2013)
245 Rainbow photo-z's (PG08)

75% completeness for quiescent galaxies



Trends with stellar mass (I)

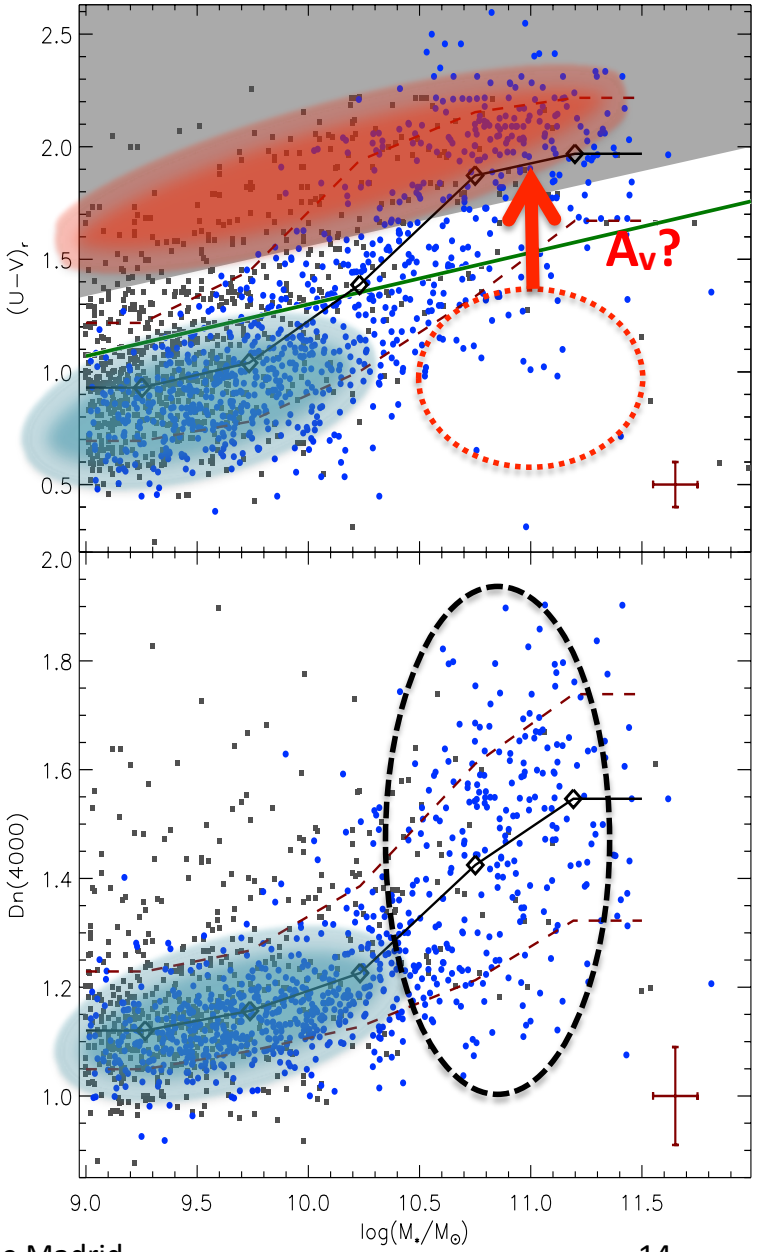
- Average SEDs in bins of mass: **increasingly red** UV-optical SED at **higher masses**
- Both **age** and **extinction** could be responsible for this trend
- SHARDS: 4000 Å break and [OII] line imply **age is dominant** factor



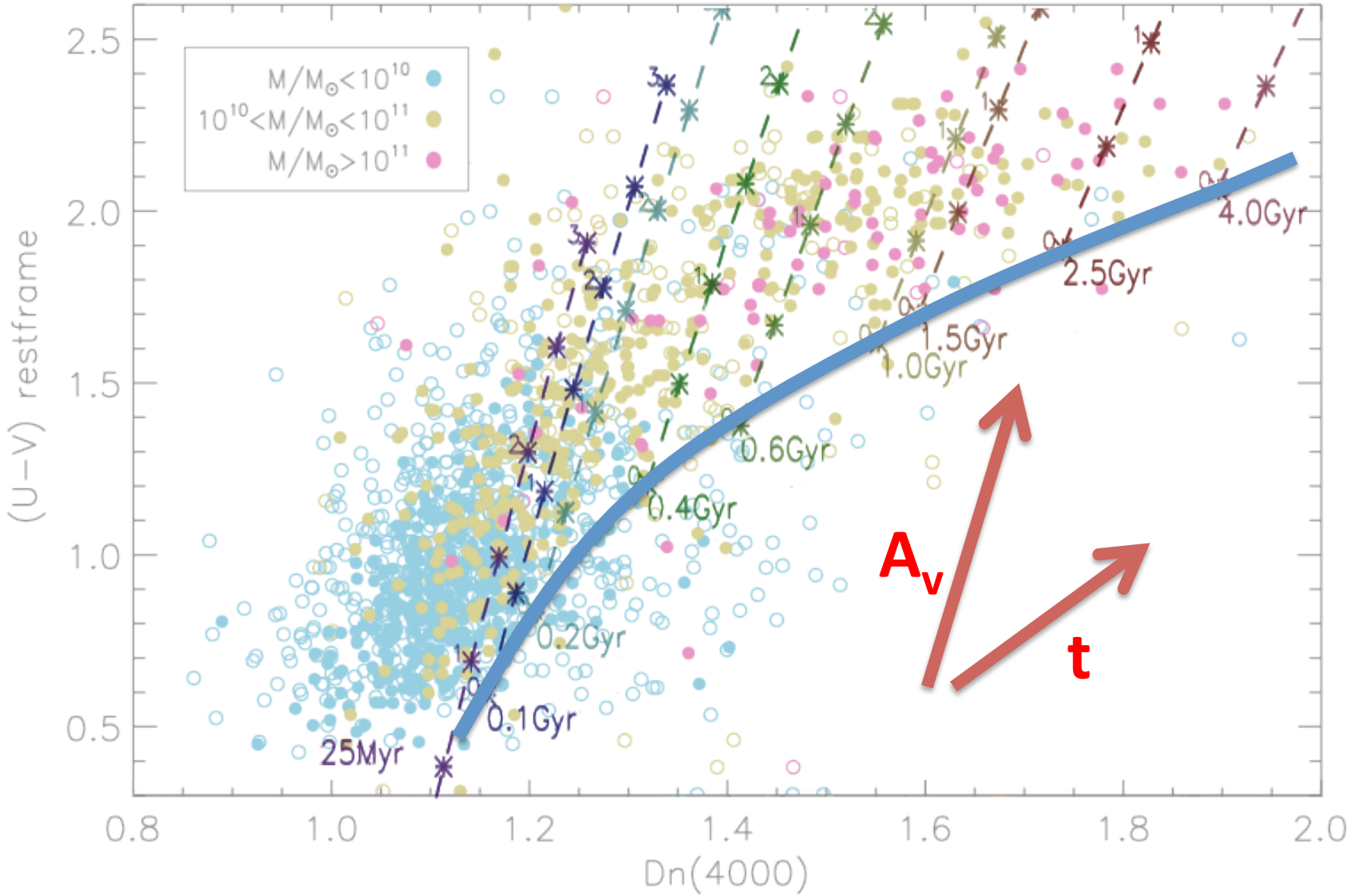
Trends with stellar mass (II)

- Both U-V and Dn(4000) increase with M_*
- Dn(4000) dispersion ↑ while for U-V ↓
  ¿caused by extinction?
- Green valley galaxies could be:
  a) transitioning to red sequence
  b) dusty star-forming galaxies

Extinction-corrected colors required!



The U-V vs $D_n(4000)$ diagram



Breaking the age-extinction degeneracy

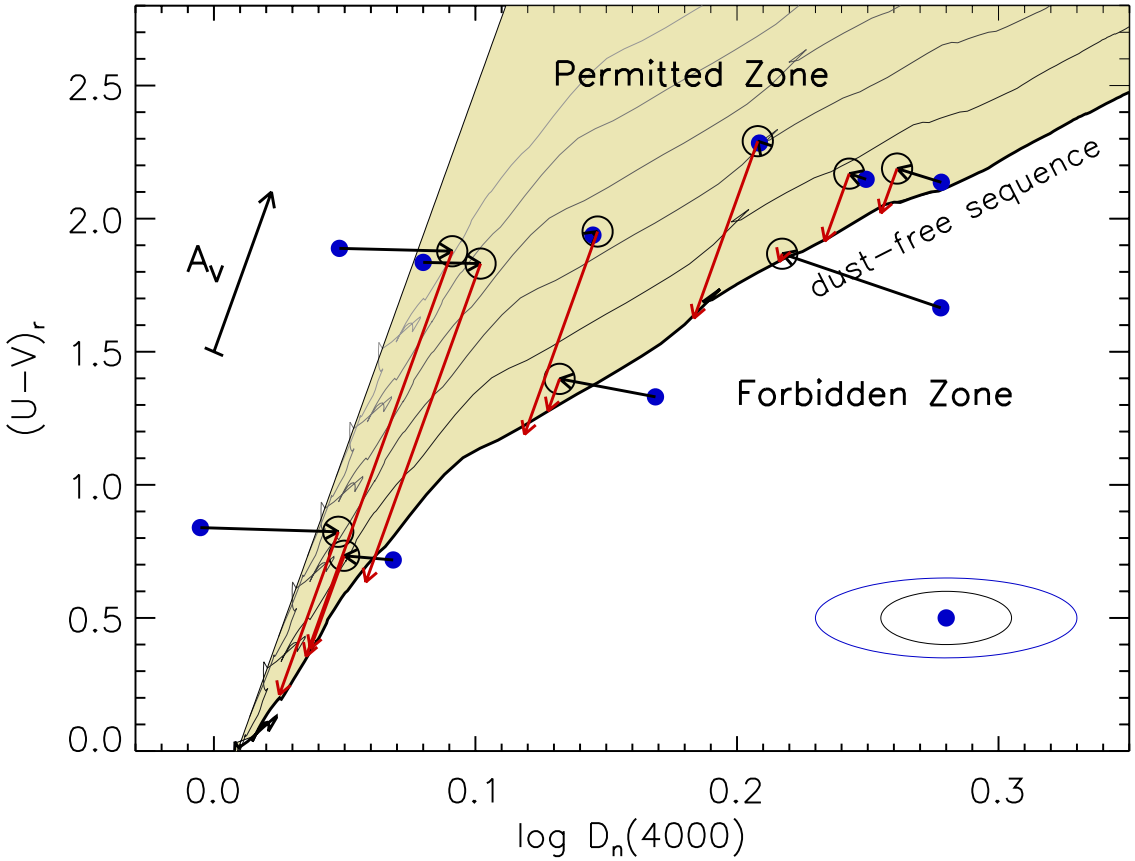
Method: Projection onto the Dust-Free Sequence

1) Obtain ML estimates for U-V and Dn(4000)
2) Translate // to A_V until intersection with DFS

Advantages over SED-fitting:

Less sensitive to selection of:
- Stellar libraries
- IMF
- Extinction law

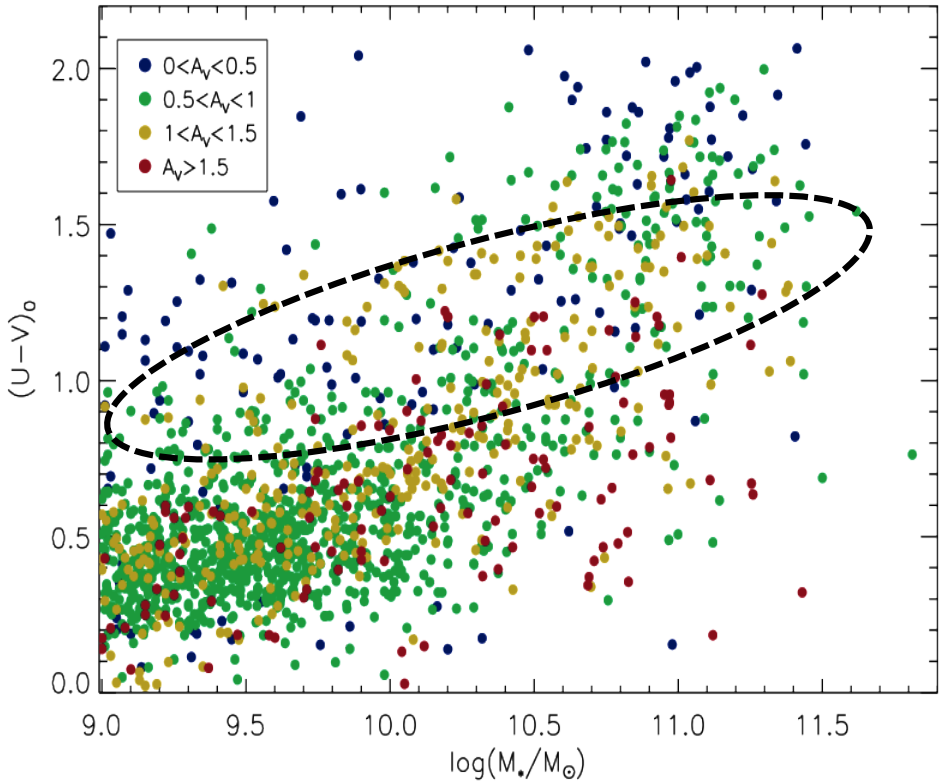
Requires just a 3000-5000 Å SED (or spectrum)



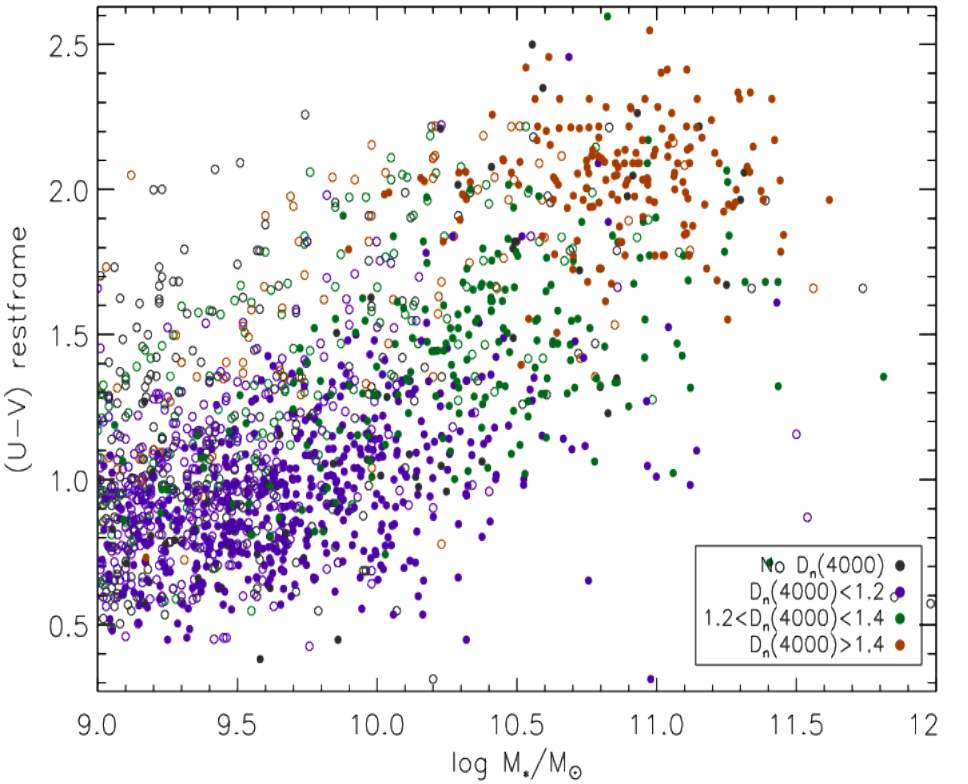
Extinction-corrected U-V color

- Trend with M_* unchanged
- Dispersion ↓ for $M_*<10^{10}M_\odot$, ↑ for $M_*>10^{10}M_\odot$
- Still many sources in the green valley

Dereddened U-V color



Observed U-V color

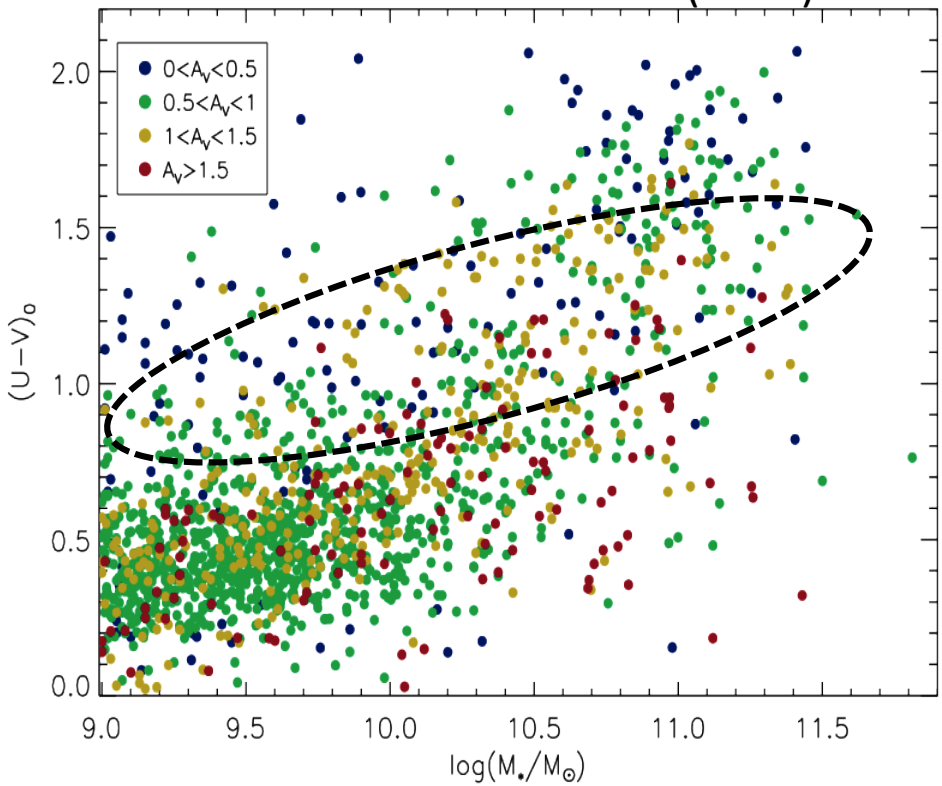



A *crowded* green valley

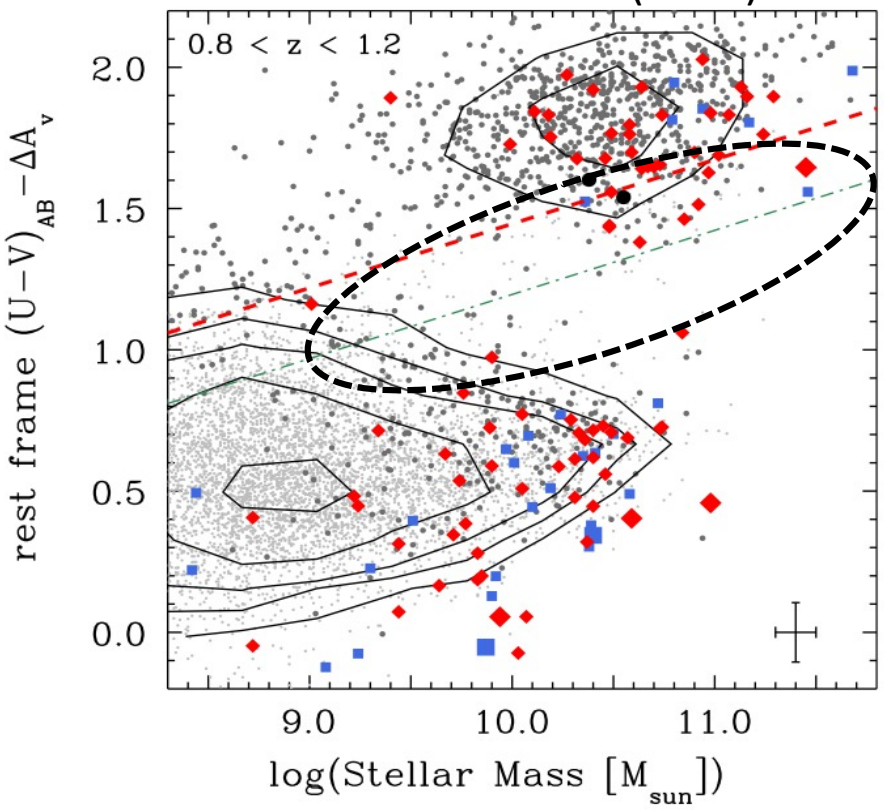
Extinction-corrected U-V color

- Large intrinsic green valley population (in stark contrast to Cardamone+2010)
- Different stellar templates & IMF does NOT explain discrepancy
- It's the method, stupid!

Hernán-Caballero et al. (2013)

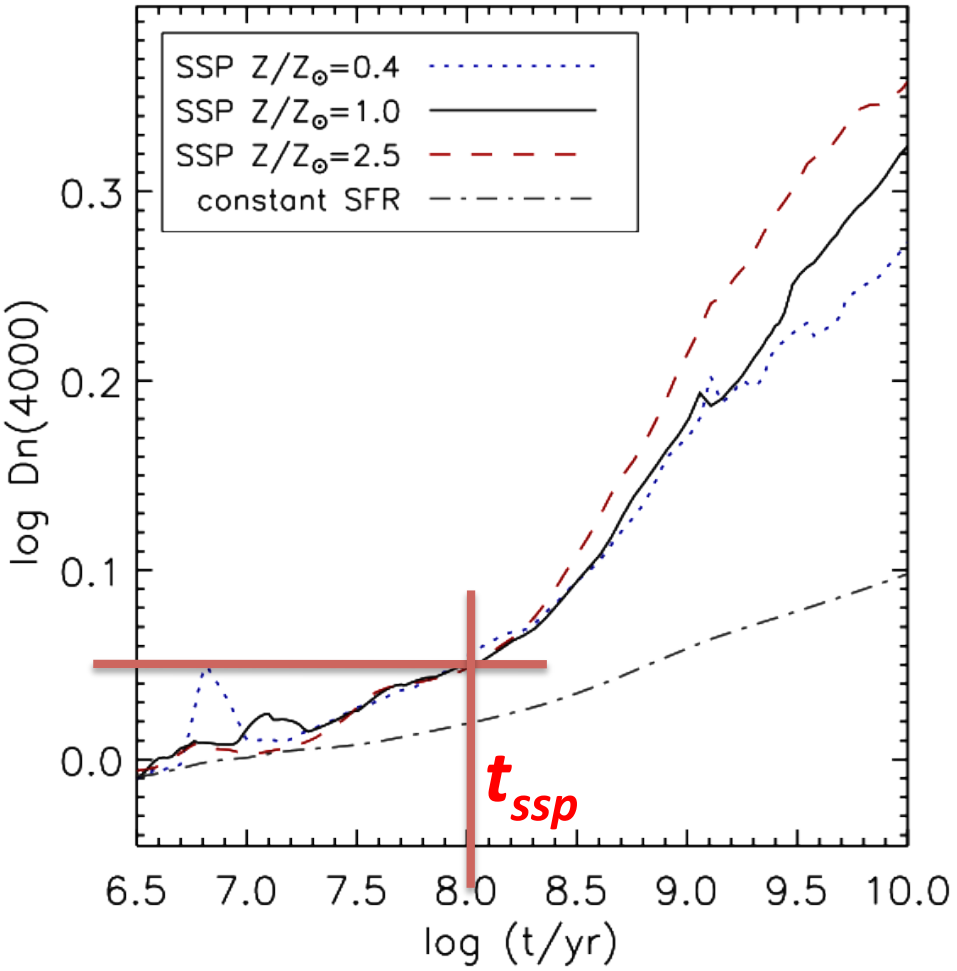


Cardamone et al. (2010)



Light-weighted stellar ages

Extinction-corrected Dn(4000) gives age of a SSP



- Weak sensitivity to Z for t< 1Gyr
- Galaxy: t_{ssp} is light-weighted AVG
- **t_{ssp} ≠ typical age of stars**
  (young stars dominate t_{ssp})

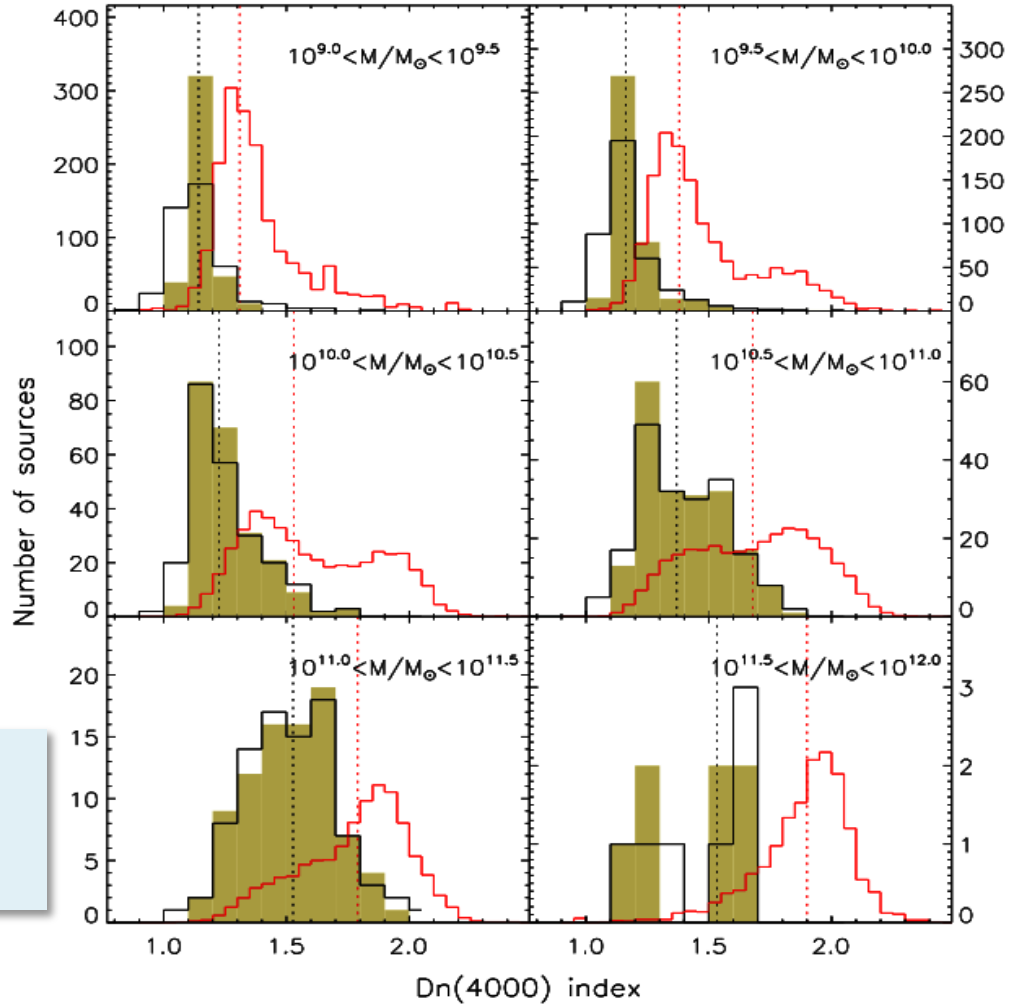
For star-forming galaxies, t_{ssp} correlates with the specific SFR (see Almudena's presentation)

Comparison to the local Universe

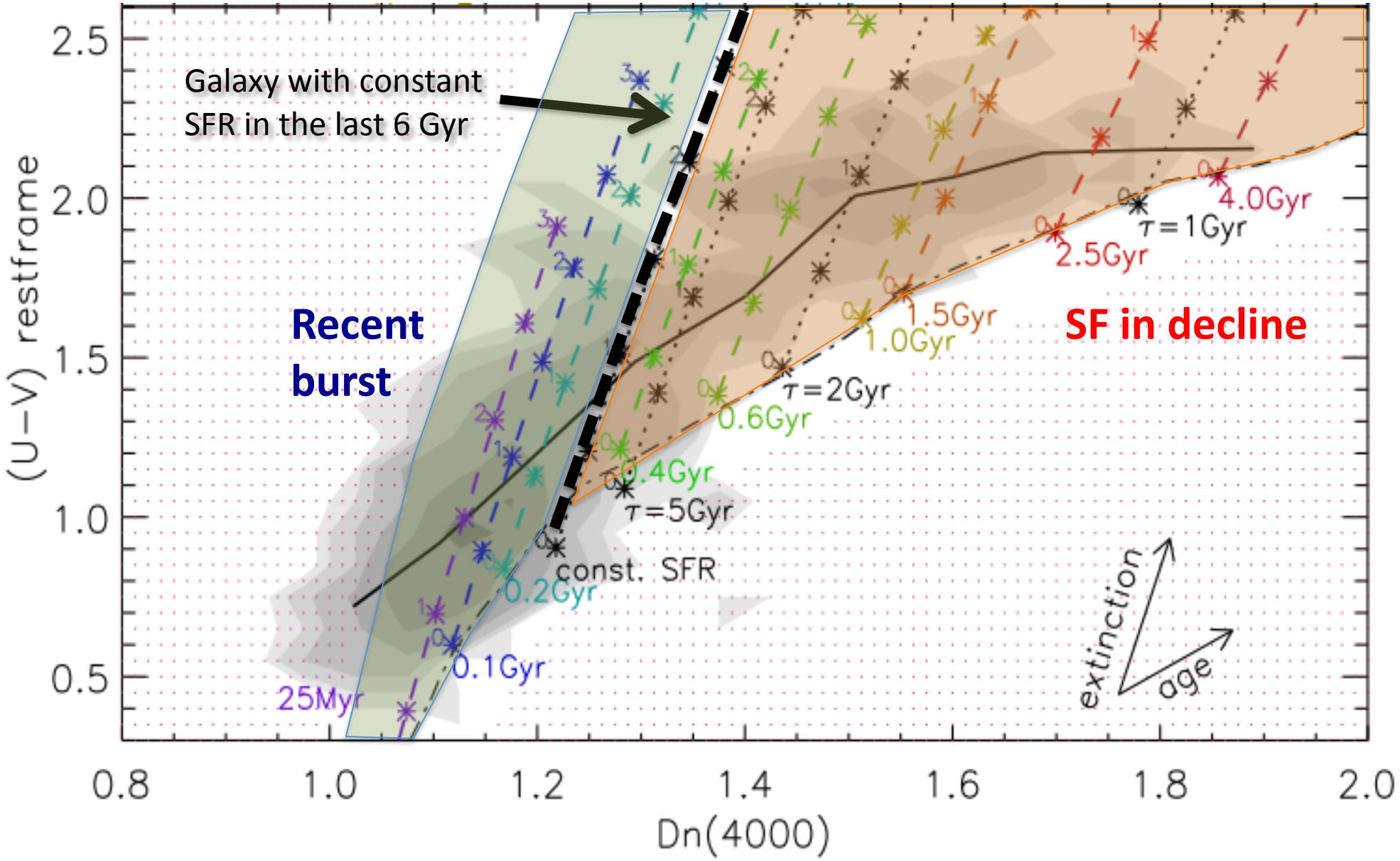
Low-z sample: SDSS DR1, 14.5<r<17.0 (<z> ~0.1) *Kauffmann et al.(2003)*
z~1 sample: SHARDS, $M_*>10^9 M_\odot$ (0.65<z<1.07) *Hernán-Caballero et al. (2013)*

z~1 sources show:

- Lower Dn(4000) in all mass bins
- Weaker or absent bimodality
- Young stellar populations in massive galaxies



Comparison to the local Universe



Comparison to the local Universe

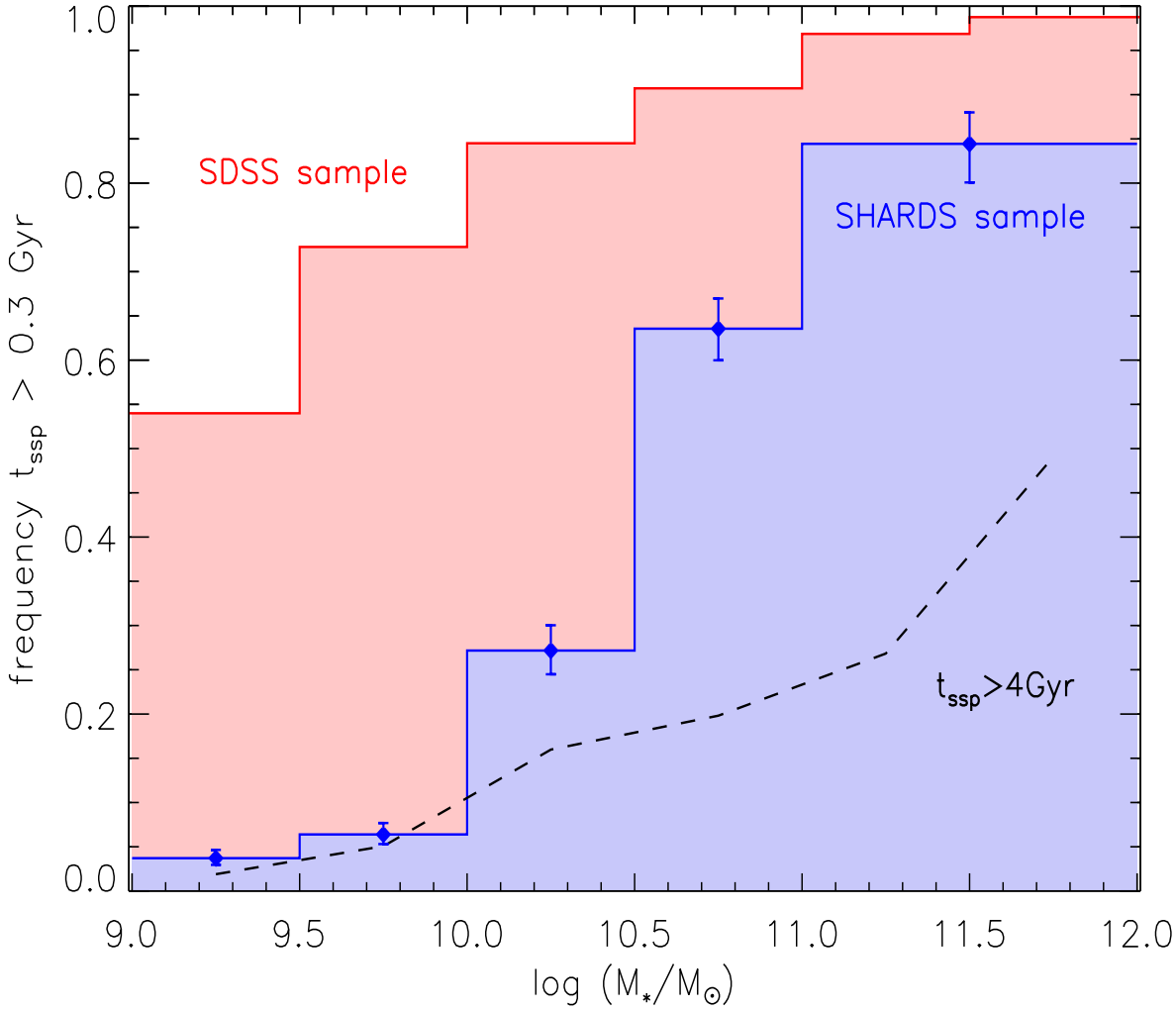
SDSS sample:

- SFR in decline for all M_* bins
- 70% declining at M_*~$10^{9.5}$
- ~100% declining at M_*>$10^{11.5}$

SHARDS sample:

- SFR **not** in decline at M_*<$10^{10.5}$
- 5% declining at M_*~$10^{9.5}$
- ~80-90% declining at M_*>$10^{11.5}$

Fraction of galaxies with declining or halted star formation (t_{ssp}>300Myr)



Summary

- SHARDS spectral resolution enough to meassure Dn(4000)
- We reach 10 times deeper compared to spectroscopy
- Color-mass relation dominated by stellar age
- U-V + Dn(4000) → A_v estimate independent of age, Z
- Extinction corrected U-V: crowded green valley
- z~1 galaxies have younger stellar populations at all M*
- Bimodality of Dn(4000) distribution not well developed at z~1
- Strong mass-dependency of declining SFR at z~1