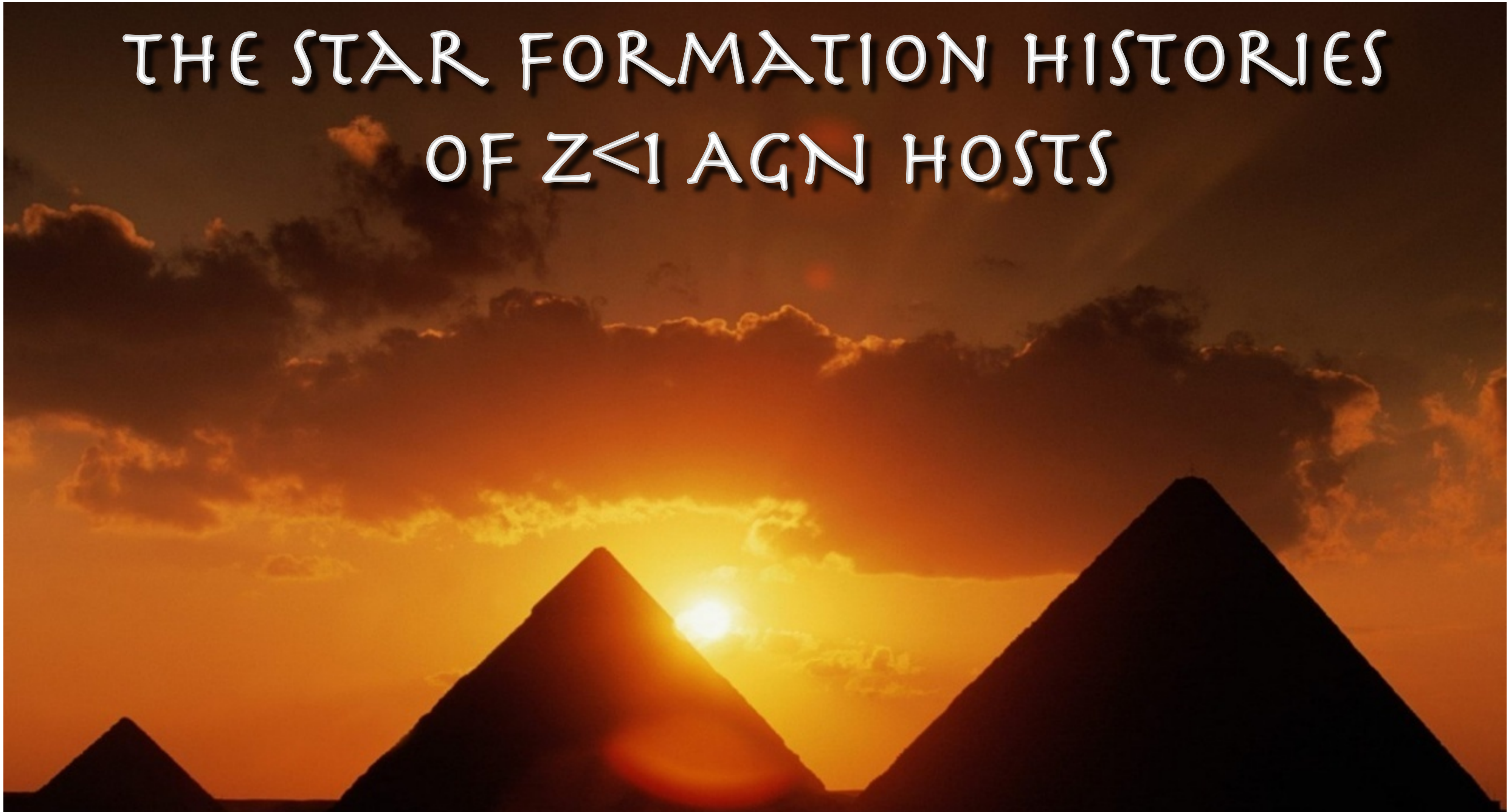
The Star Formation Histories of z<1 AGN Hosts



II SHARDS Team Meeting
Universidad Complutense de Madrid
May 13-14, 2015

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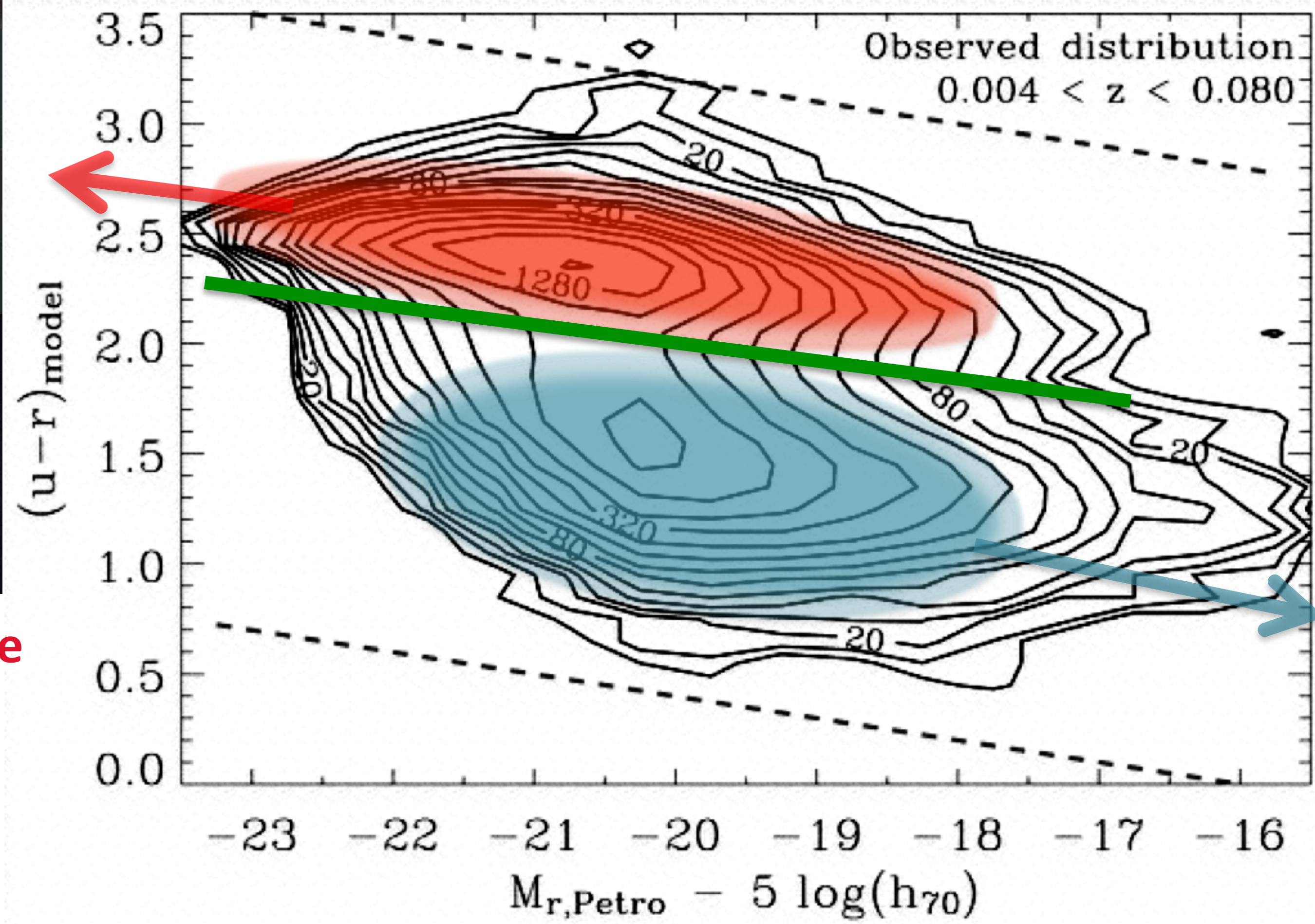
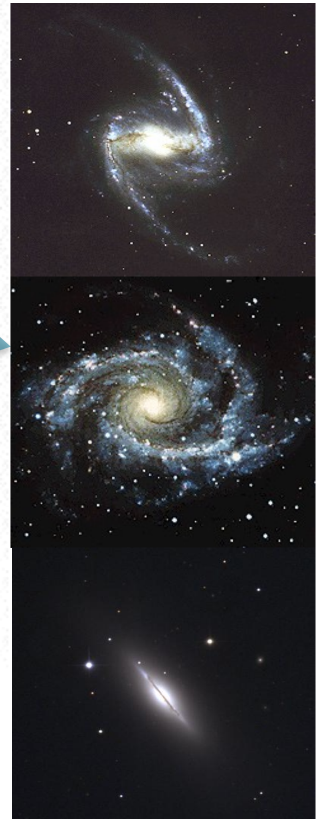
SHARDS
Consolider - Ingenio
GTC

IFCA
Instituto de Física de Cantabria

Bimodal Galaxy Distribution





Red sequence

Red colors

Early type

Old stars

Gas-poor

Passive evolution

Blue cloud

Blue colors

Late type

Young stars

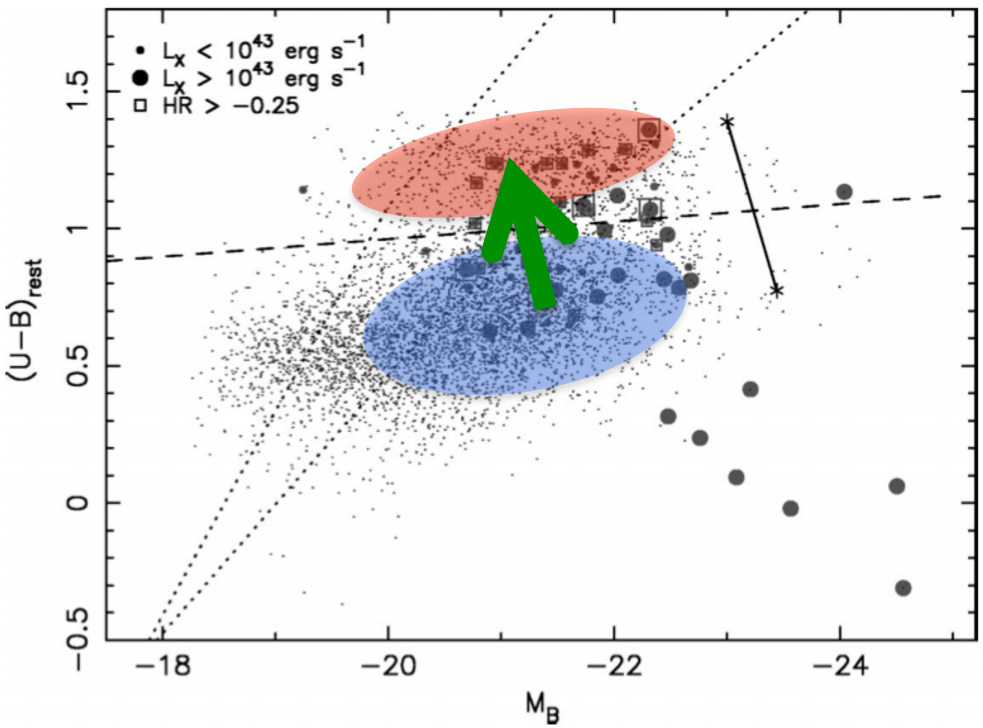
Gas-rich

Actively starforming

Baldry et al. 2004

AGN prefer the green valley

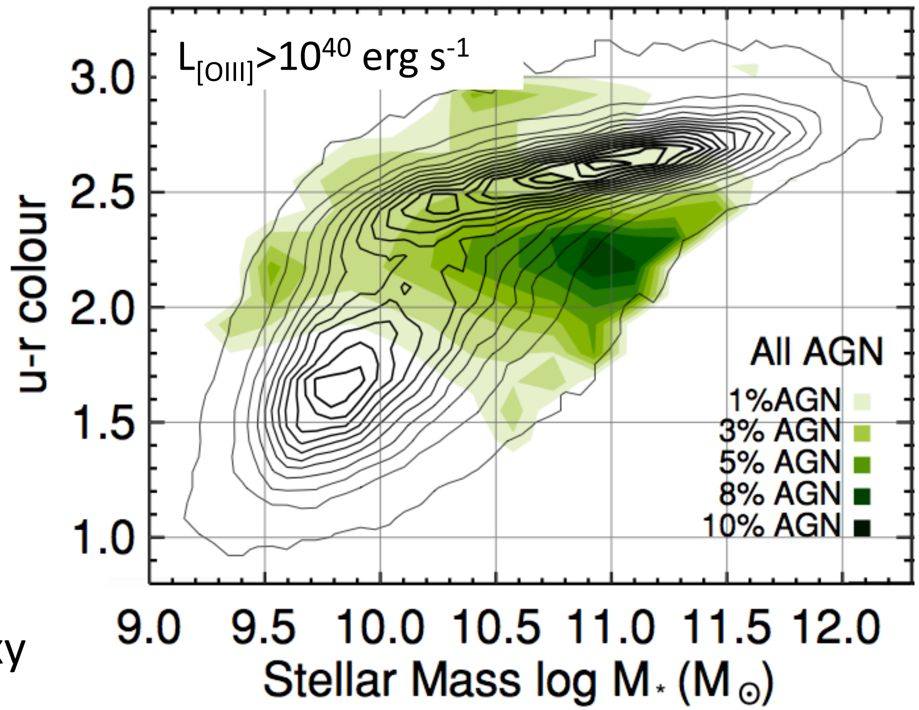
Nandra et al. (2007)



Moderate luminosity AGN often found at or close to the green valley

Transition population? ➔ Quenching

Schawinski et al. (2010)



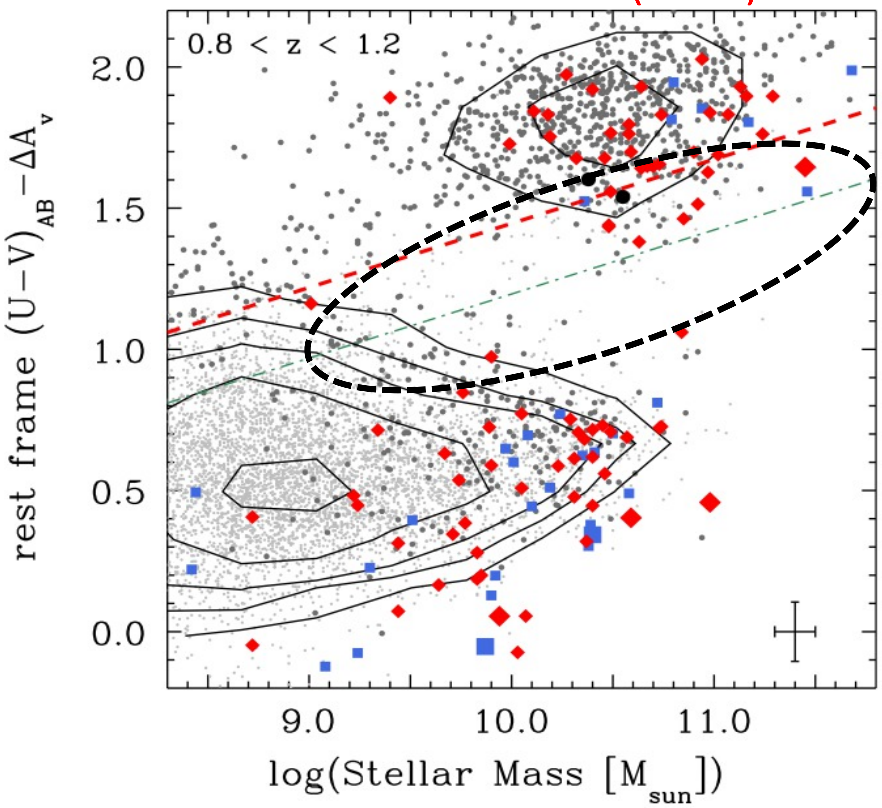
Preference of the green valley most evident in low luminosity local AGN

green valley → 1) quenched galaxy
green valley → 2) dusty star-forming galaxy

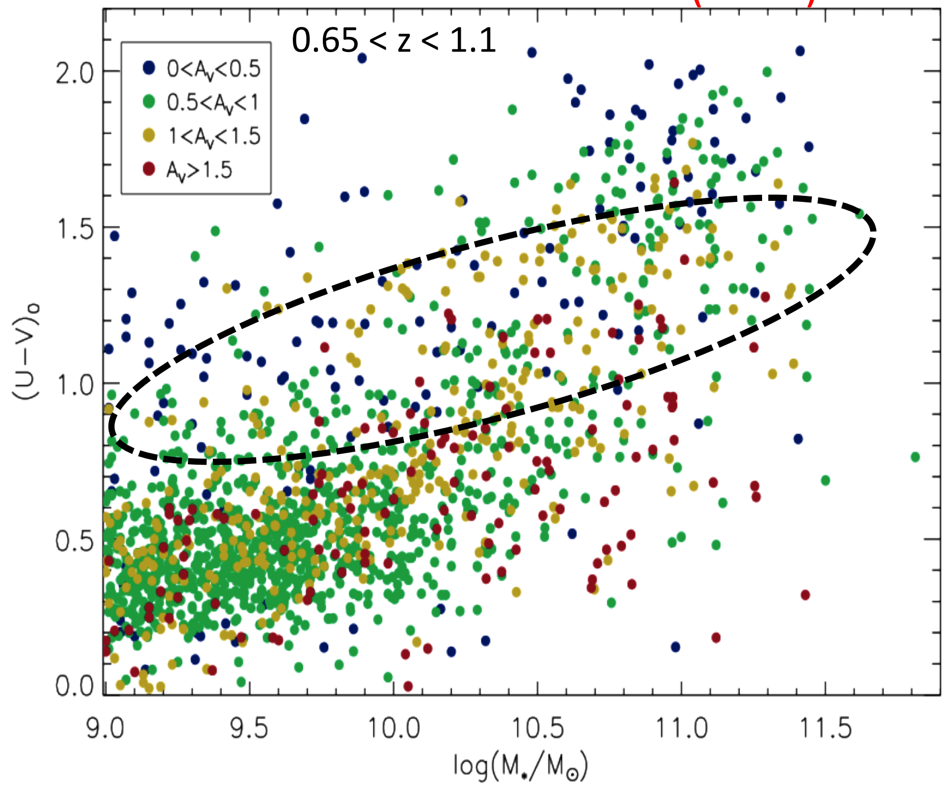
Extinction correction is tricky

- Extinction correction in broadband photometry relies on SED-fitting
- Strong degeneracy between stellar age, metallicity, extinction
- Results are model-dependent (SPS, SFH, τ(λ),...)

Cardamone et al. (2010)



Hernán-Caballero et al. (2013)



The D(4000) index

Measures the strength of the 4000 Å break

Two definitions:

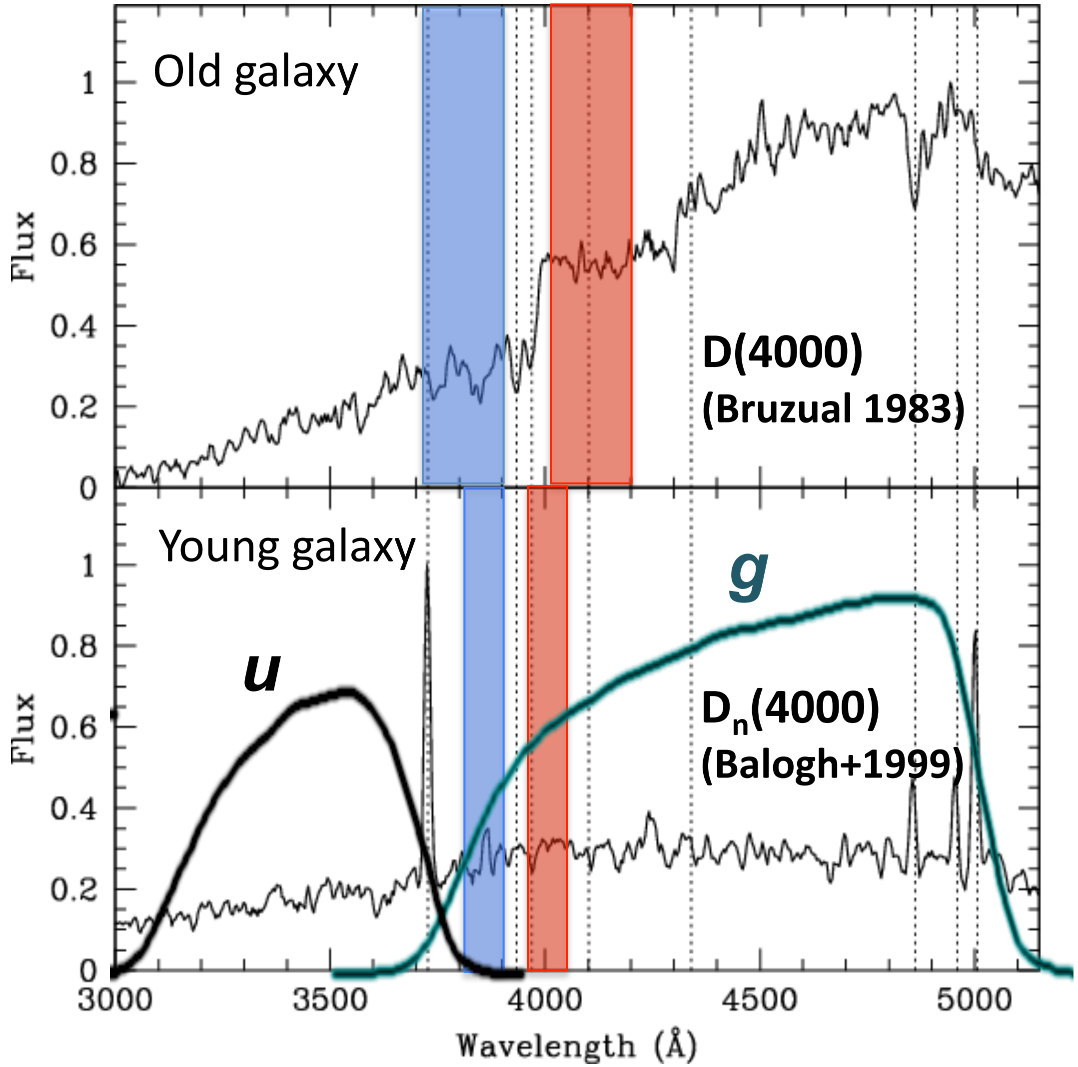
- Bruzual (1983): 20nm bands
- Balogh+ (1999): 10nm bands

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….

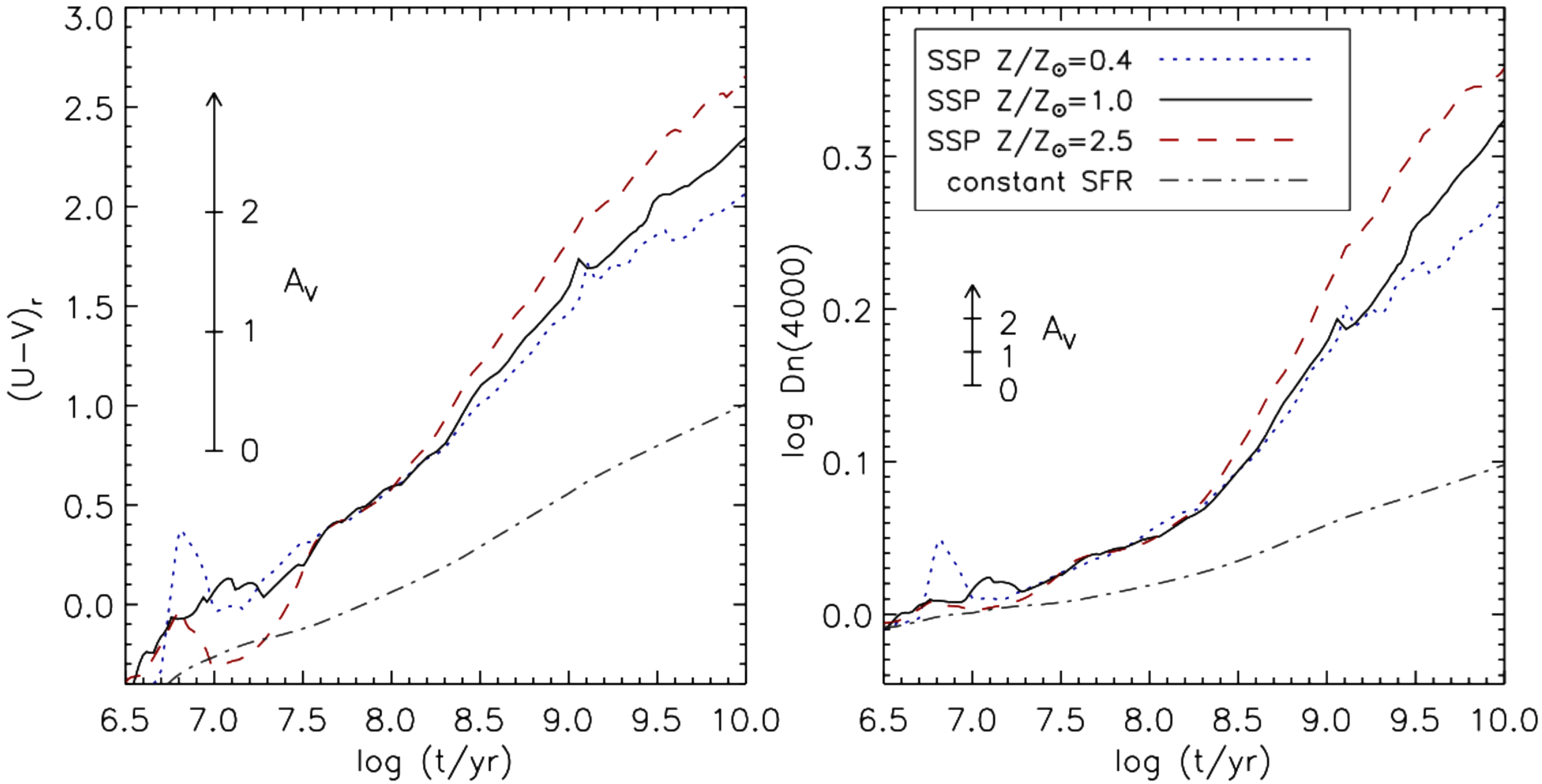
…but much less sensitive to the continuum slope



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

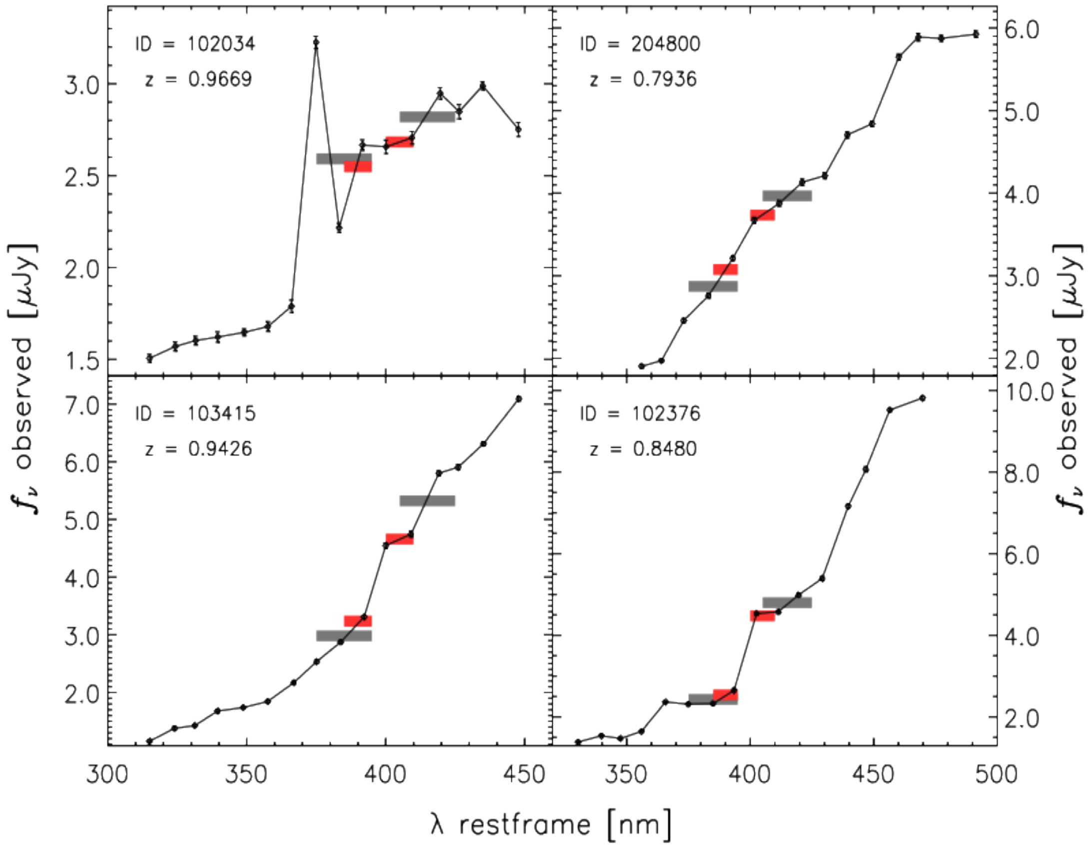
Hernán-Caballero et al. (2013)



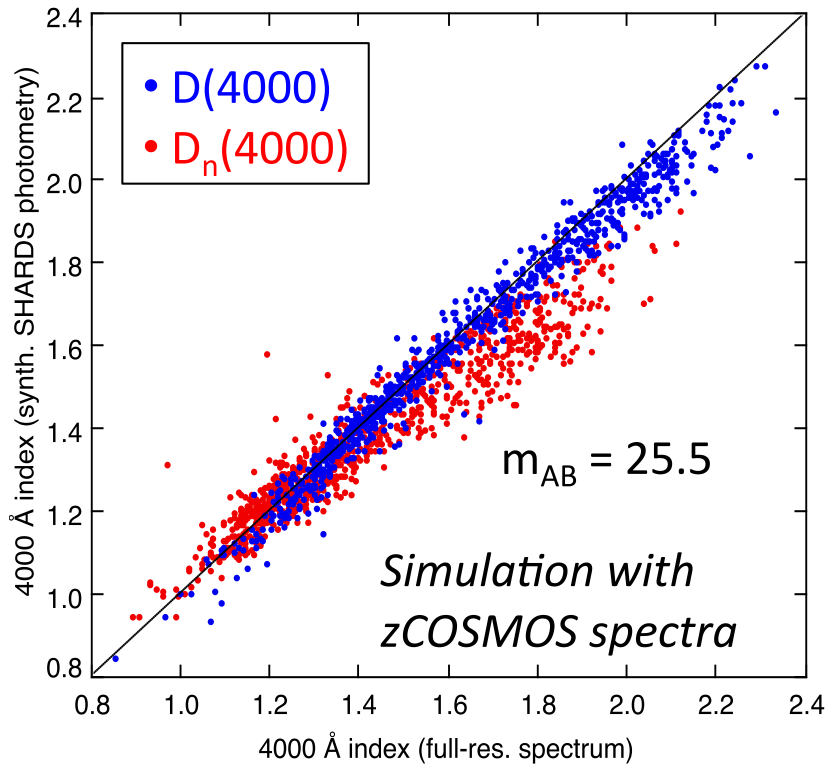
The impact of spectral resolution

SHARDS photospectra have λ/Δλ~50
Correction of interpolation bias required
Simulations show reliable estimates of $D_n(4000)$ possible (~ 10% error at m_{AB}=25.5)

Examples of D(4000) measurements with SHARDS



Hernán-Caballero et al. (2013)



X-ray selected AGN sample

SHARDS covers 141 arcmin in the central region of the 2 Ms Chandra Deep Field North

Optical (Subaru R) and near-IR (IRAC 3.6μm) counterparts with LR method (Ciliegi+03)

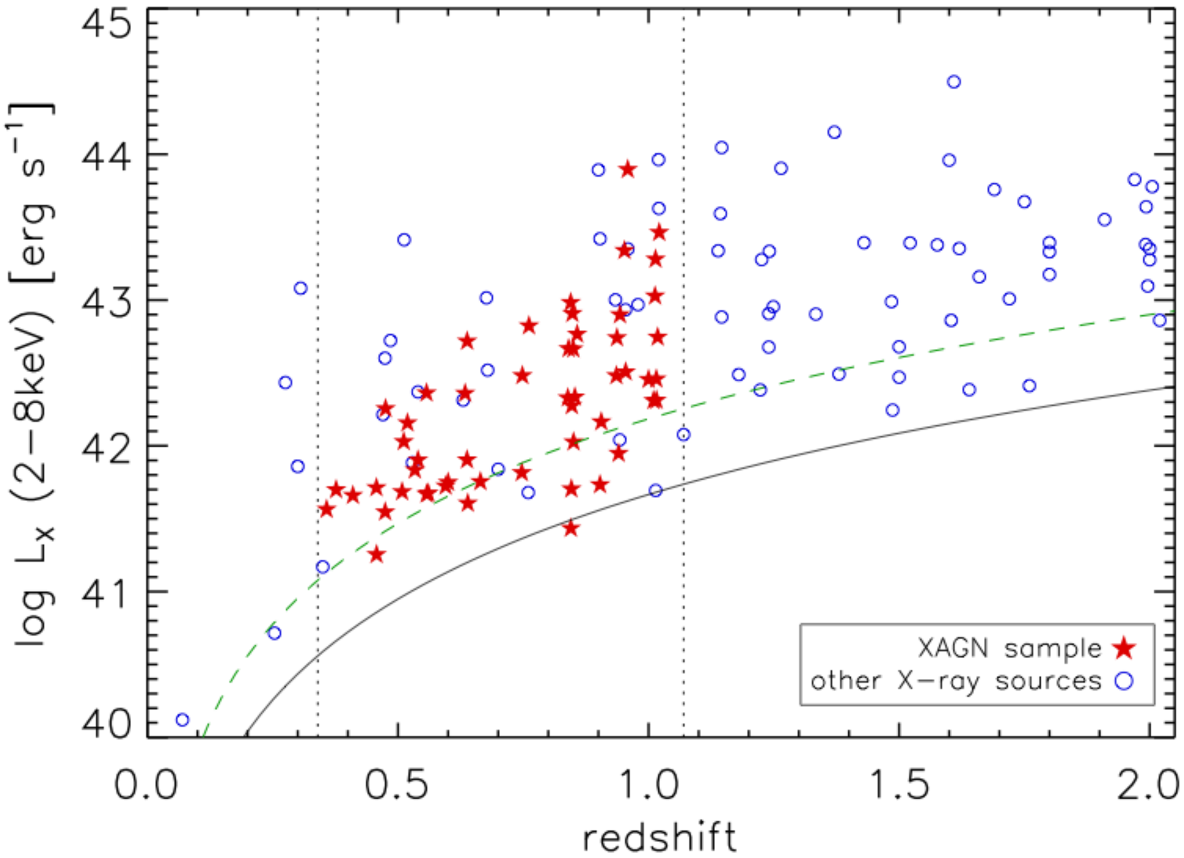
HST/ACS images used to identify and remove optically bright AGN

Selection criteria:

- detection in hard X-ray (2-10 keV) band
- $0.35 < z < 1.07$
- no obvious point source in ACS images
- no IRAC power-law

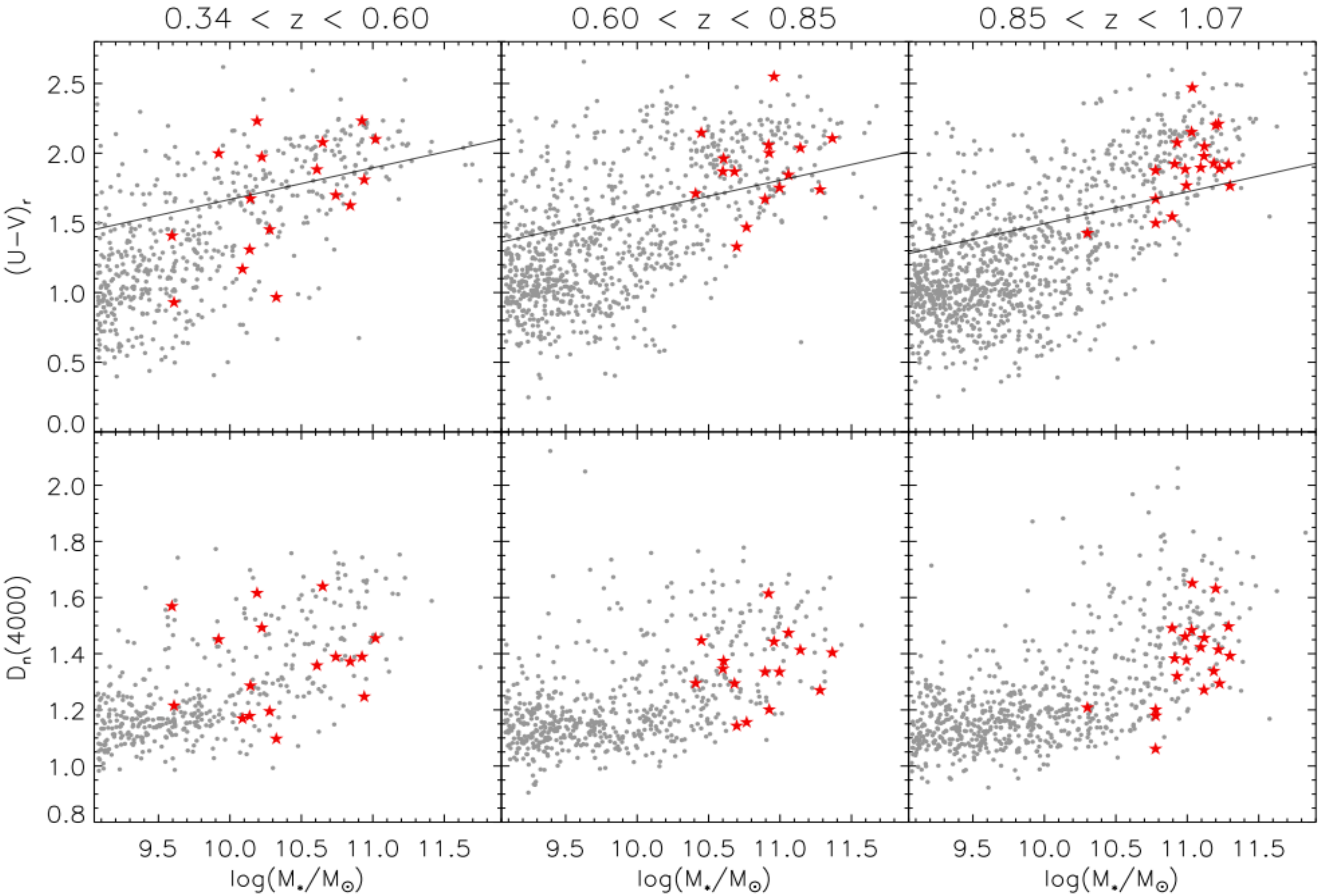
53 sources selected

(51 zspec, 2 zphot)



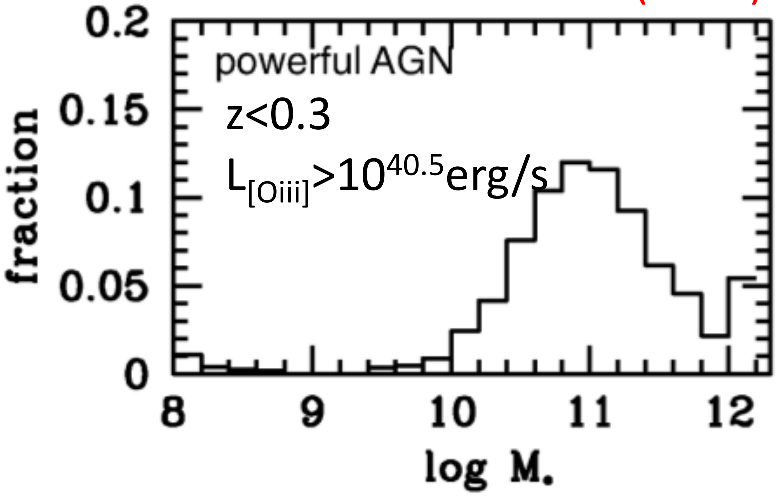
Mass dependency of U-V and Dn(4000)

Hernán-Caballero et al. (2014)



AGN found in the most massive galaxies

Kauffmann et al. (2003)

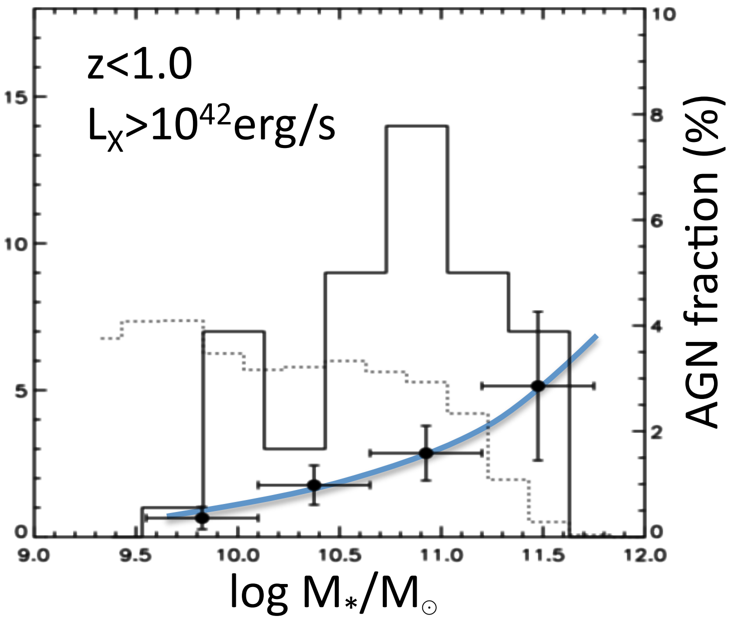


AGN fraction increases **steeply** with stellar mass irrespective of selection method (X-ray, [OIII], radio)

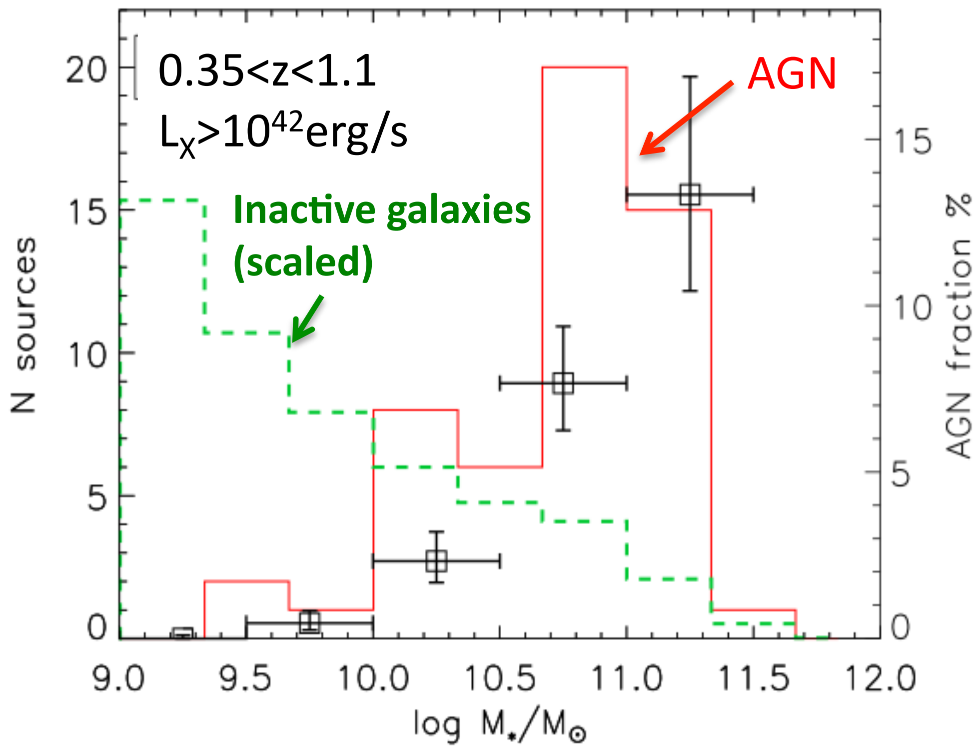
AGN luminosity depends on M_{BH}, ε

Massive galaxies host massive BH (M-σ relation)

Silverman et al. (2009)



Hernán-Caballero et al. (2014)



Selecting random comparison samples

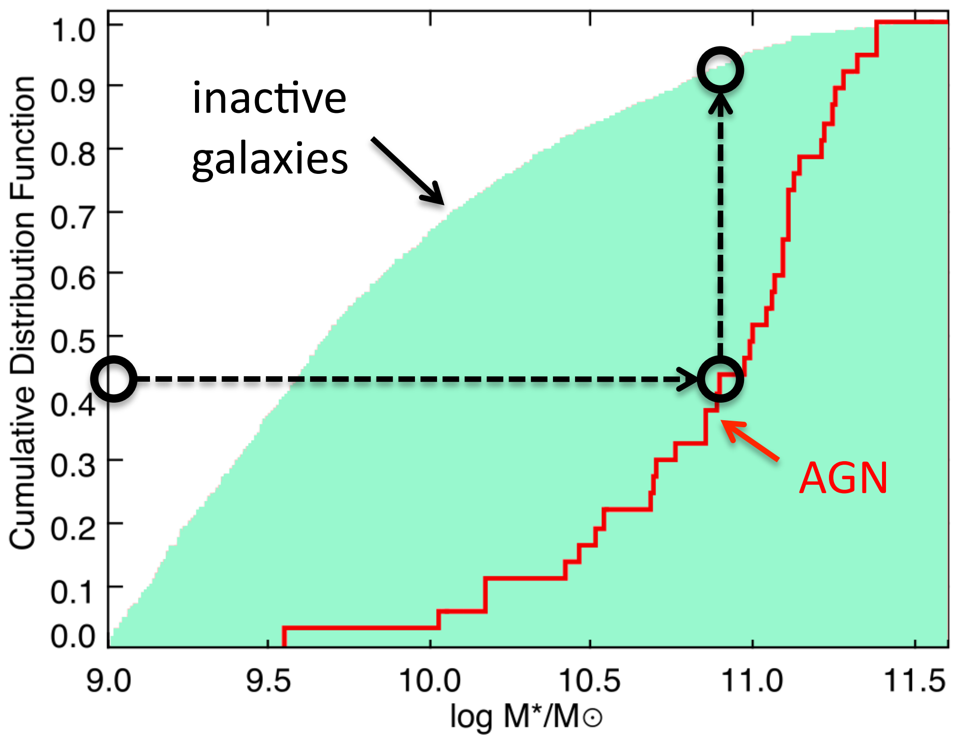
- M_* dependency of AGN detection rates
- Correlation colour - M_*
- redshift evolution of galaxy colours, AGN rates

Comparison samples of inactive galaxies **must** reproduce the M_* and z **distributions** of the AGN

Bootstrapping method:

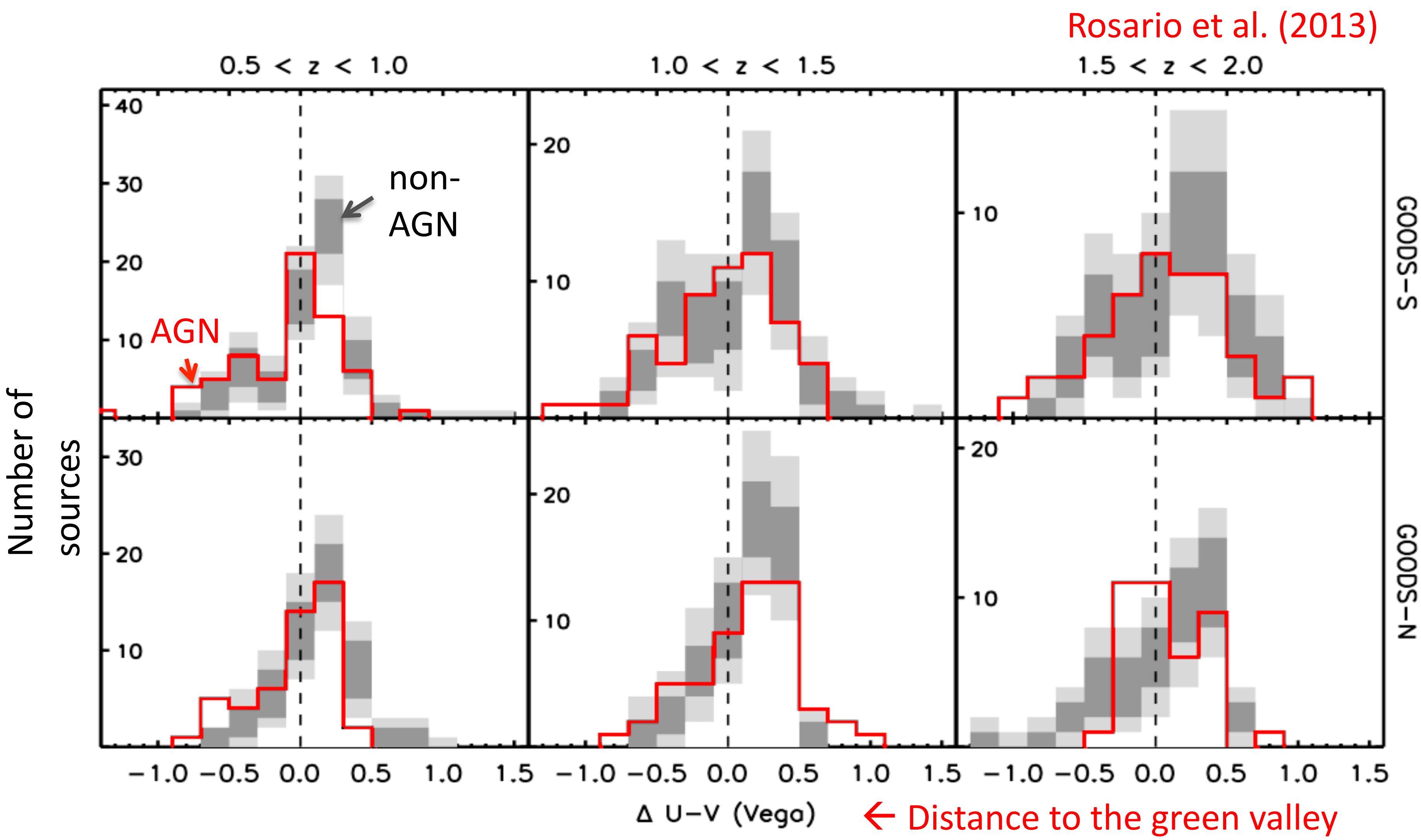
For each AGN, select a random inactive galaxy within ±0.2 dex in M_* and ±0.1 in z

Obtain **1000** random samples



Restframe colours of AGN host at z>0.5

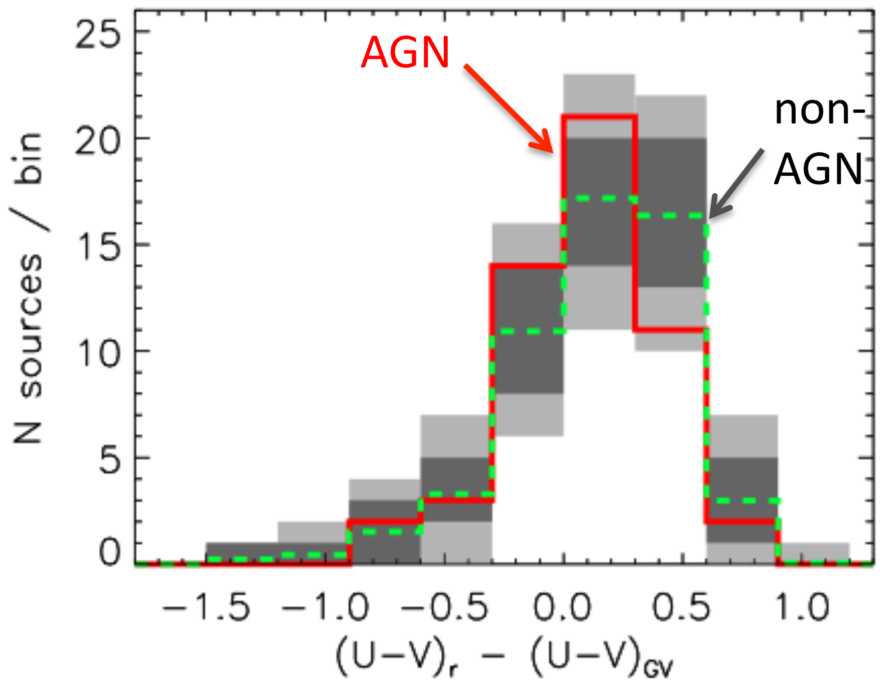
*No significant differences in host colours compared to **same-mass** inactive galaxies*

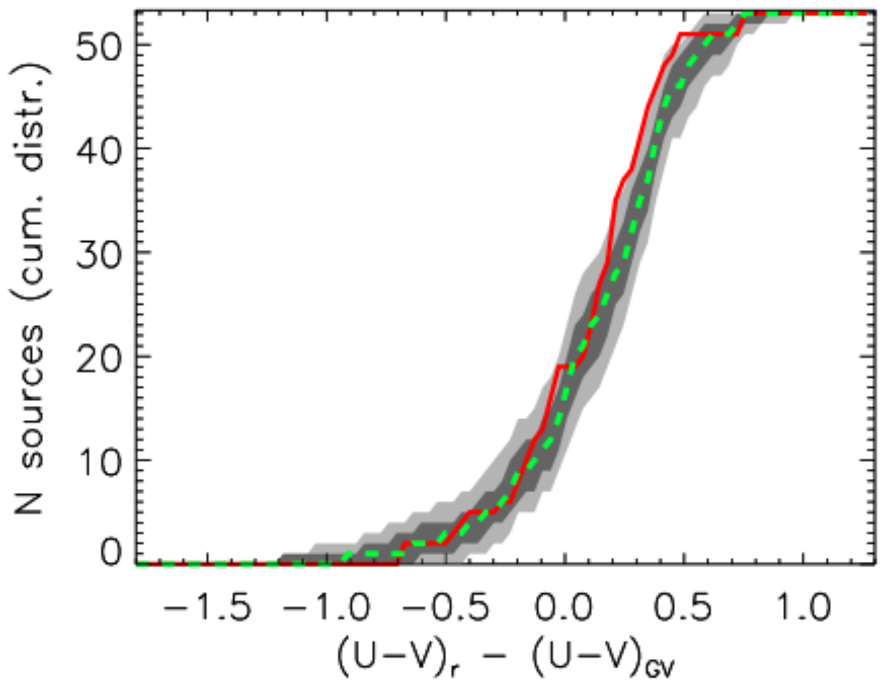


Distance to the GV in the SHARDS AGN

- Histogram of **AGN** host colours peaks close to the **green valley**
- Same-mass **inactive** galaxies peak in the **red sequence**
- K-S test can't rule out **same population** at α=0.05 significance level

Hernán-Caballero et al. (2014)

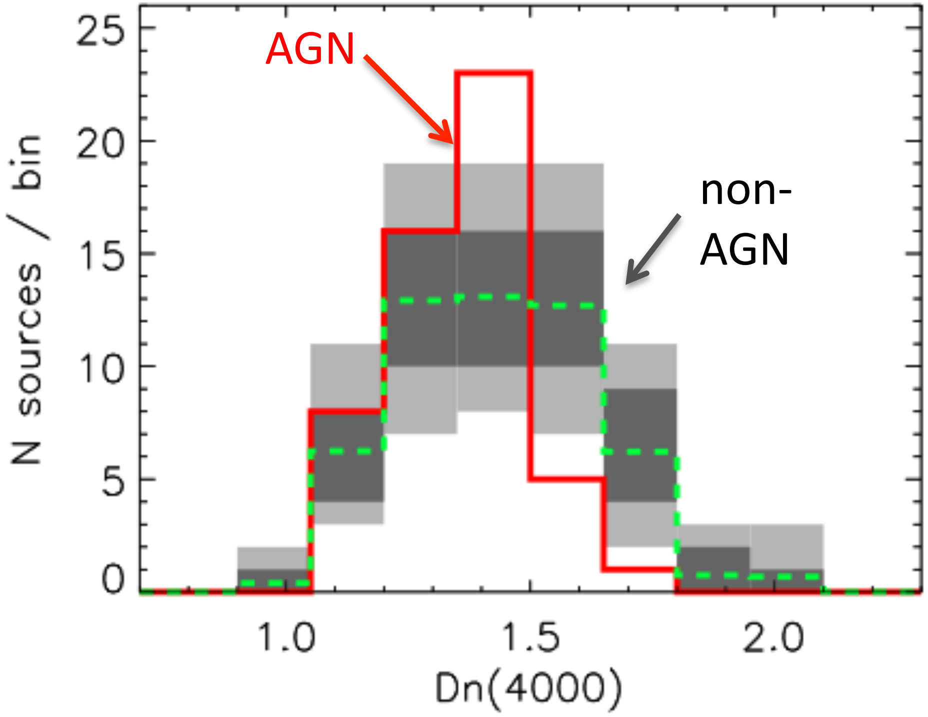


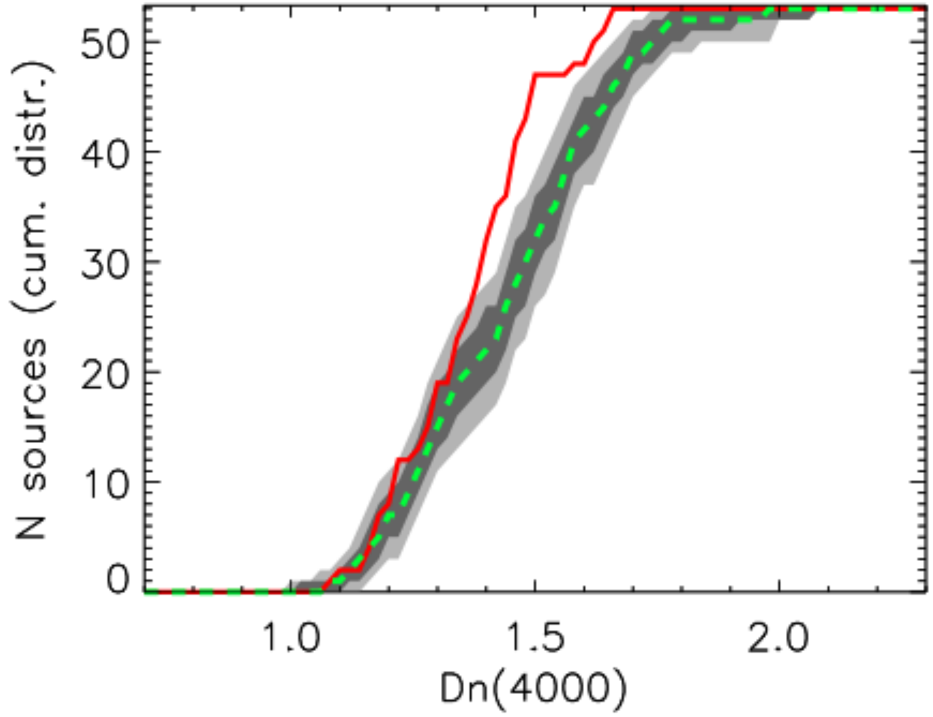


Distribution of D_n(4000) index

- 3σ excess in AGN counts at Dn(4000)~1.4 (t_{ssp}~500 Myr)
- K-S test confirms different populations (P-value < 0.05 in 75% of samples)
- Strong deficit of AGN at Dn(4000)>1.5
- Indicates AGN less likely to be found in quiescent galaxies

Hernán-Caballero et al. (2014)

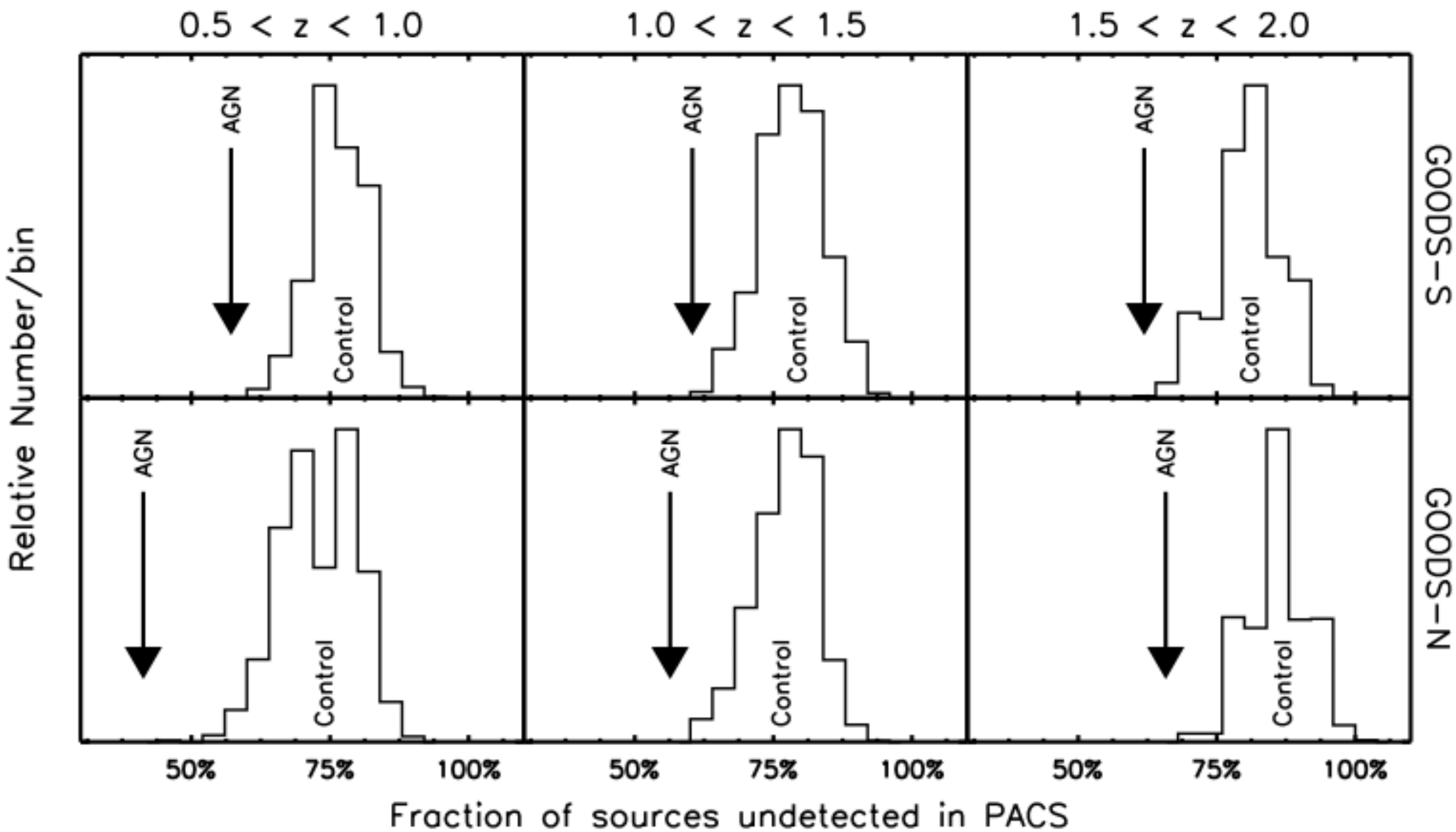




AGN avoid quiescent galaxies

AGNs are preferentially found in star-forming host galaxies, or, in other words, AGNs are less likely to be found in weakly star-forming or quenched galaxies

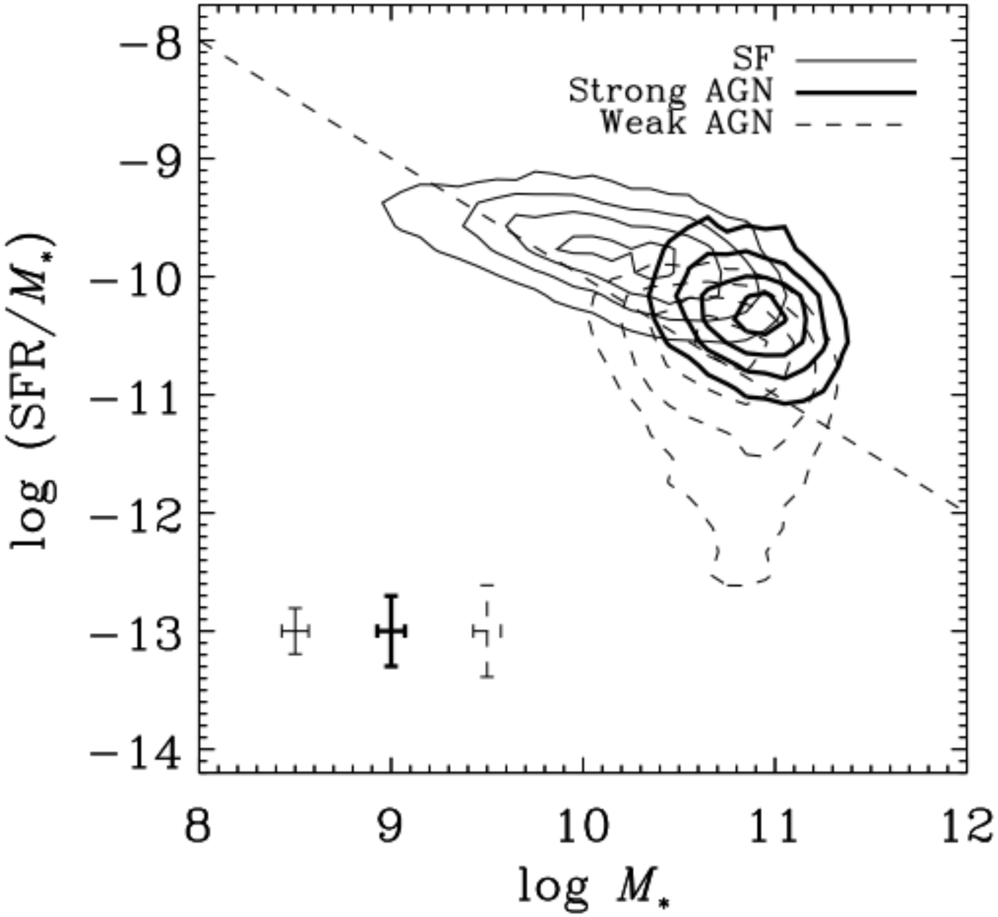
Rosario et al. (2013)



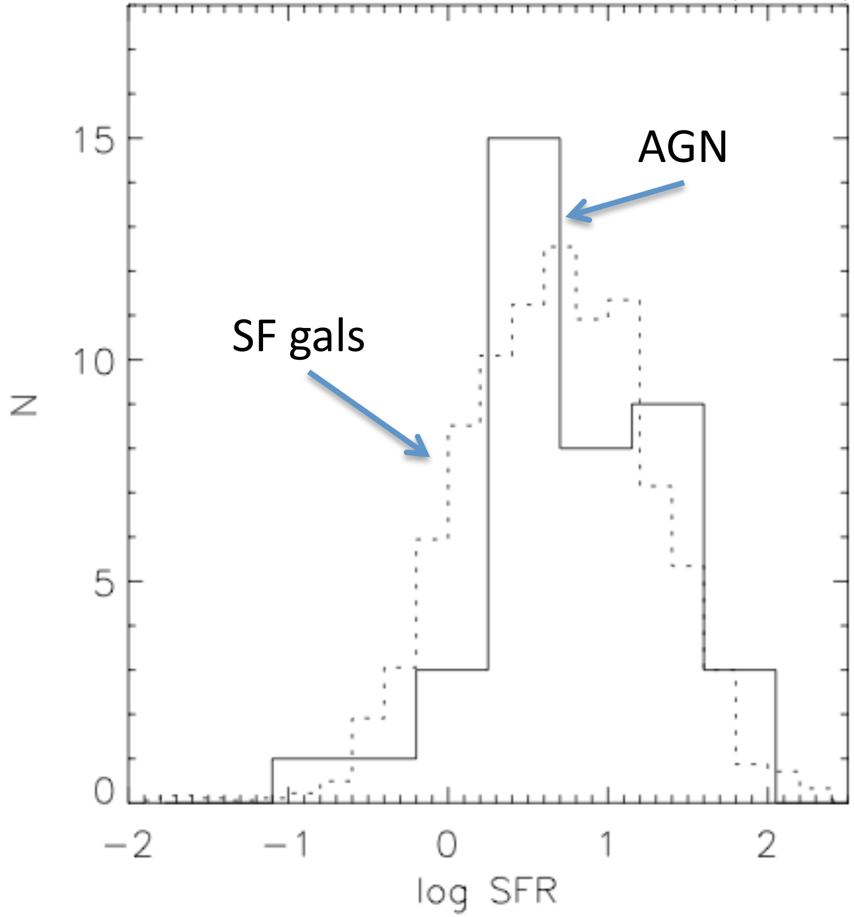
[OII] Star formation rates of AGN hosts

- specific SFR of moderate luminosity AGN comparable to starforming galaxies
- AGN have higher average SFR compared to average of same mass galaxies

z~0.1 Salim et al. (2007)

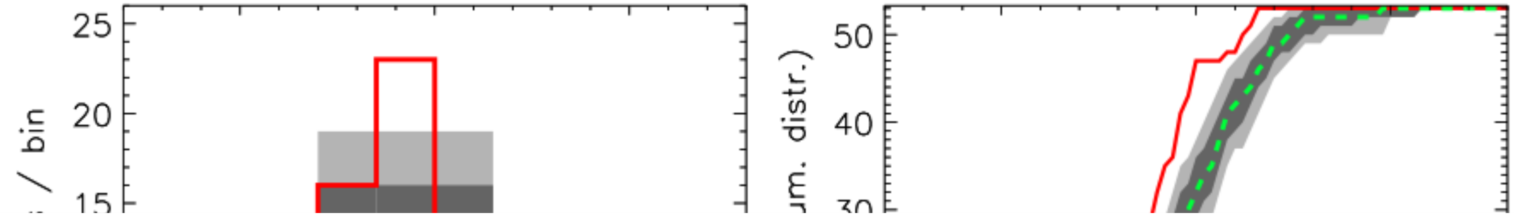


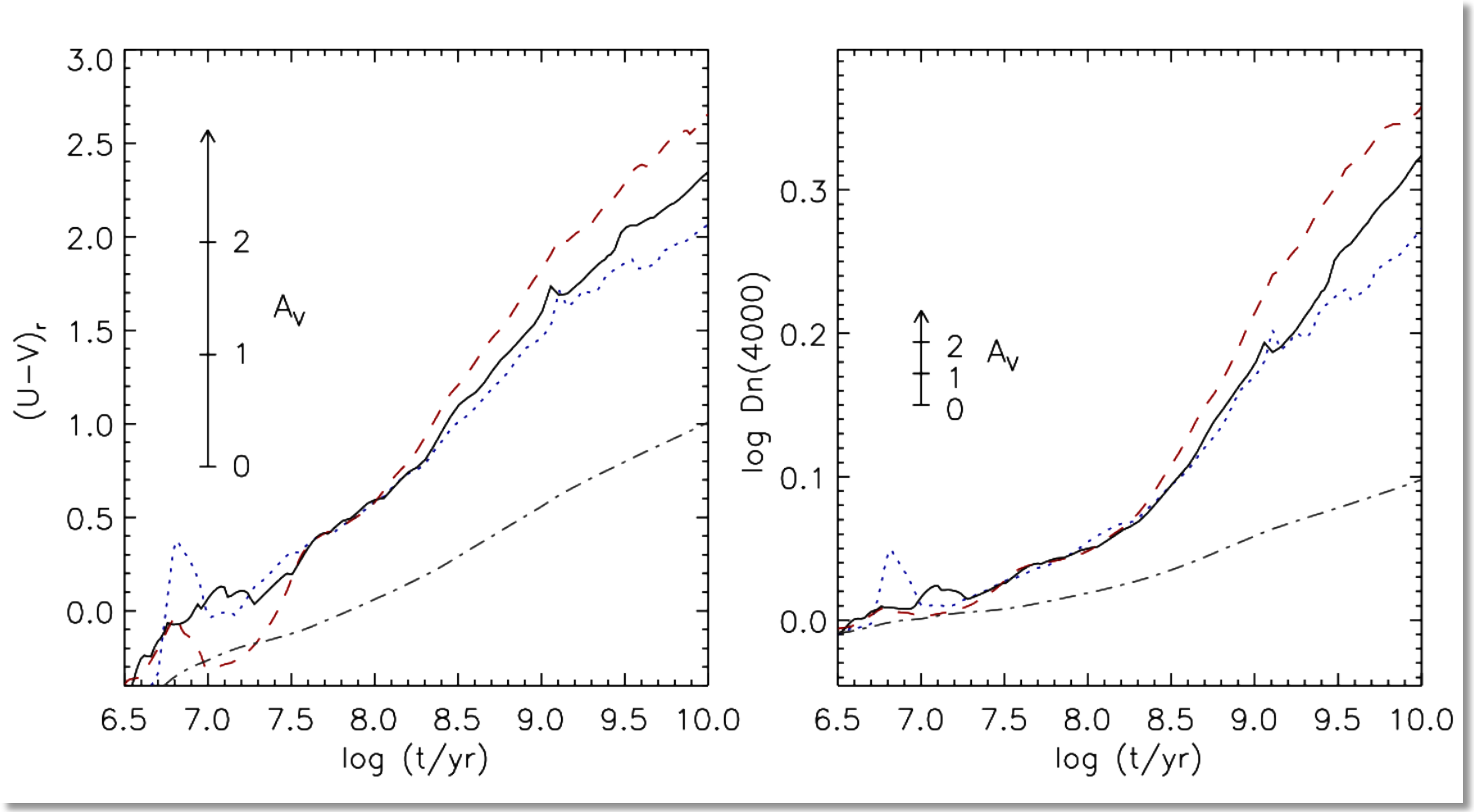
0.1<z<1.0 Silverman et al. (2009)



U-V and D_n(4000) distributions

Hernán-Caballero et al. (2014)





AGN prefer 'dusty' starforming galaxies

UVJ diagram offers independent evidence for higher extinction in AGN hosts

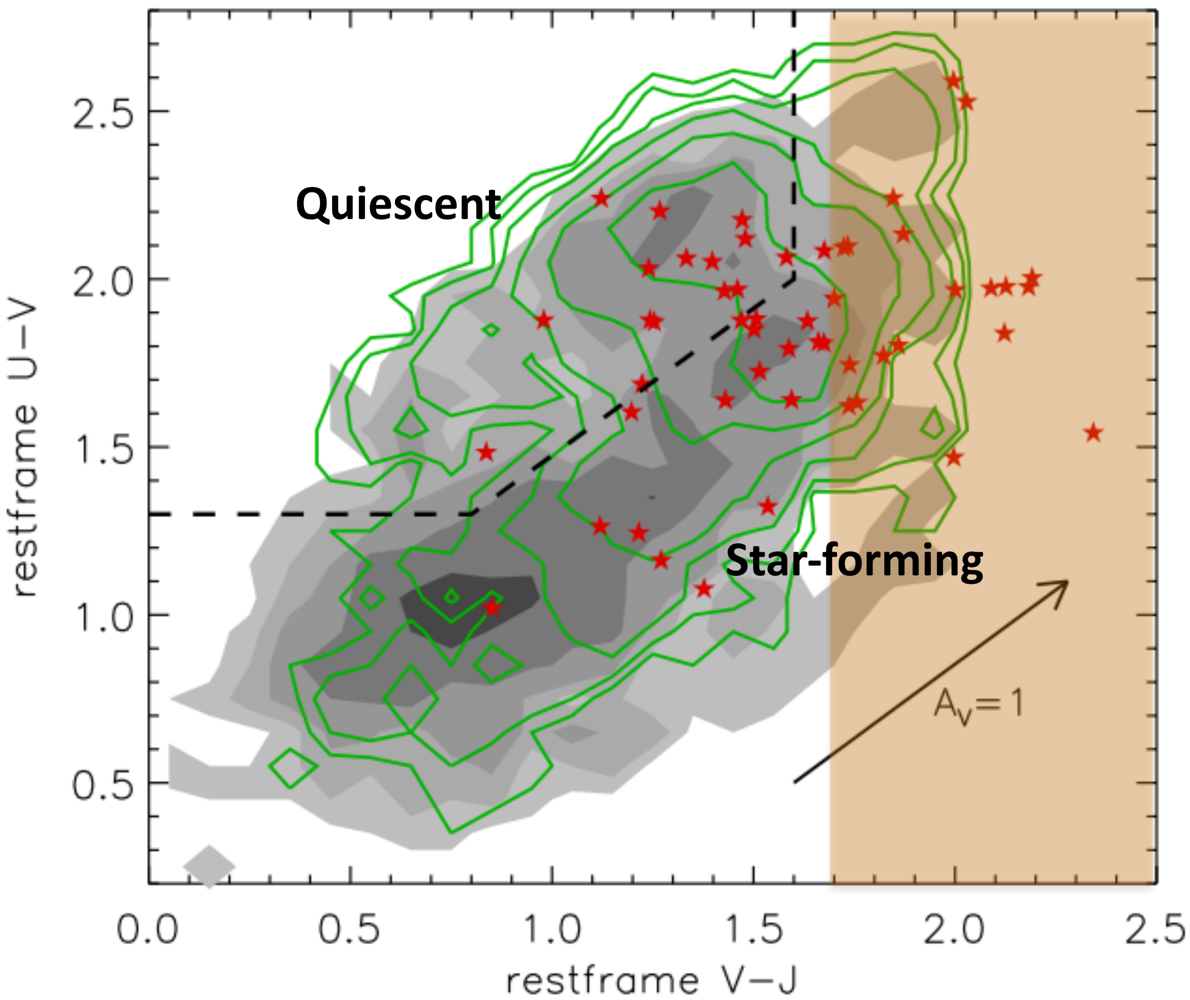
Quiescent wedge contains:
21% of all AGN hosts
44% of inactive control galaxies

***V-J* > 1.7 (AB mag):**
32% of all AGN hosts
17% of inactive control galaxies

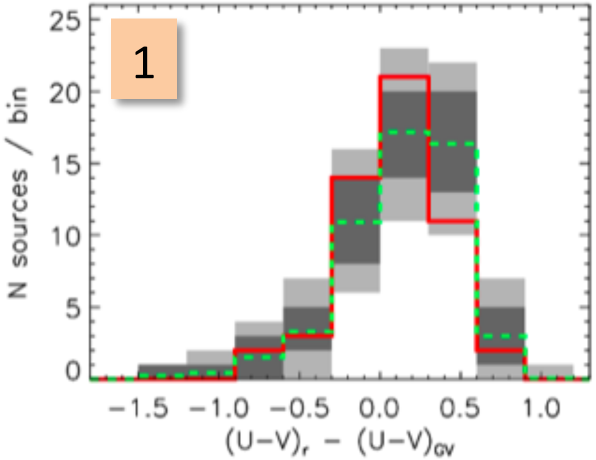
Prob. of detecting an X-ray AGN is:

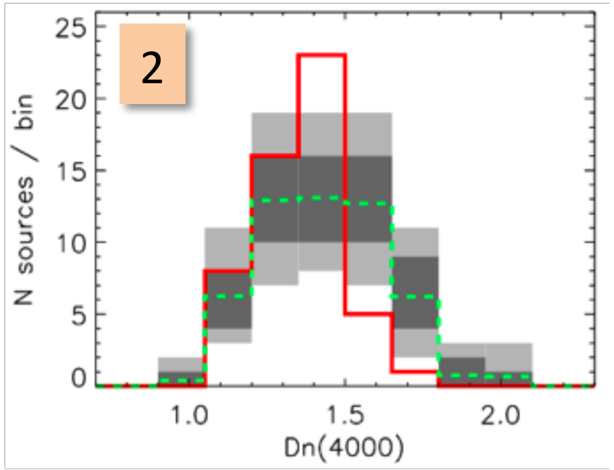
- Highest in dusty star-forming
- Lowest in passively evolving

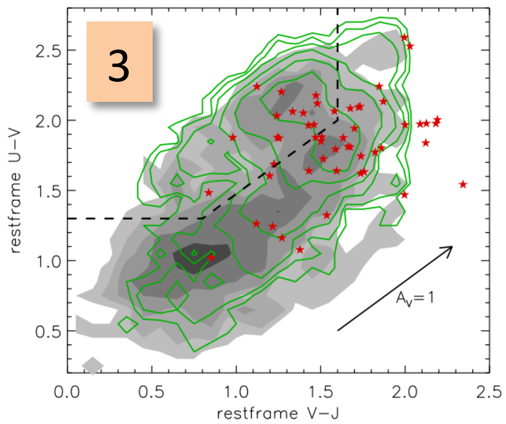
Hernán-Caballero et al. (2014)



Summary to this point







1) X-ray selected AGN concentrate in Green Valley (just like control samples)

2) D_n4000 indicates AGN hosts are younger, lack of AGN in quiescent galaxies

3) Conflicting 1+2 compatible if AGN hosts are younger ***and*** dustier

Extinction corrected U-V *should* reflect younger stellar ages of AGN hosts

SED fitting → degeneracy between age, metallicity, and extinction

Degeneracy broken for extinction with new D_n4000 vs U-V method

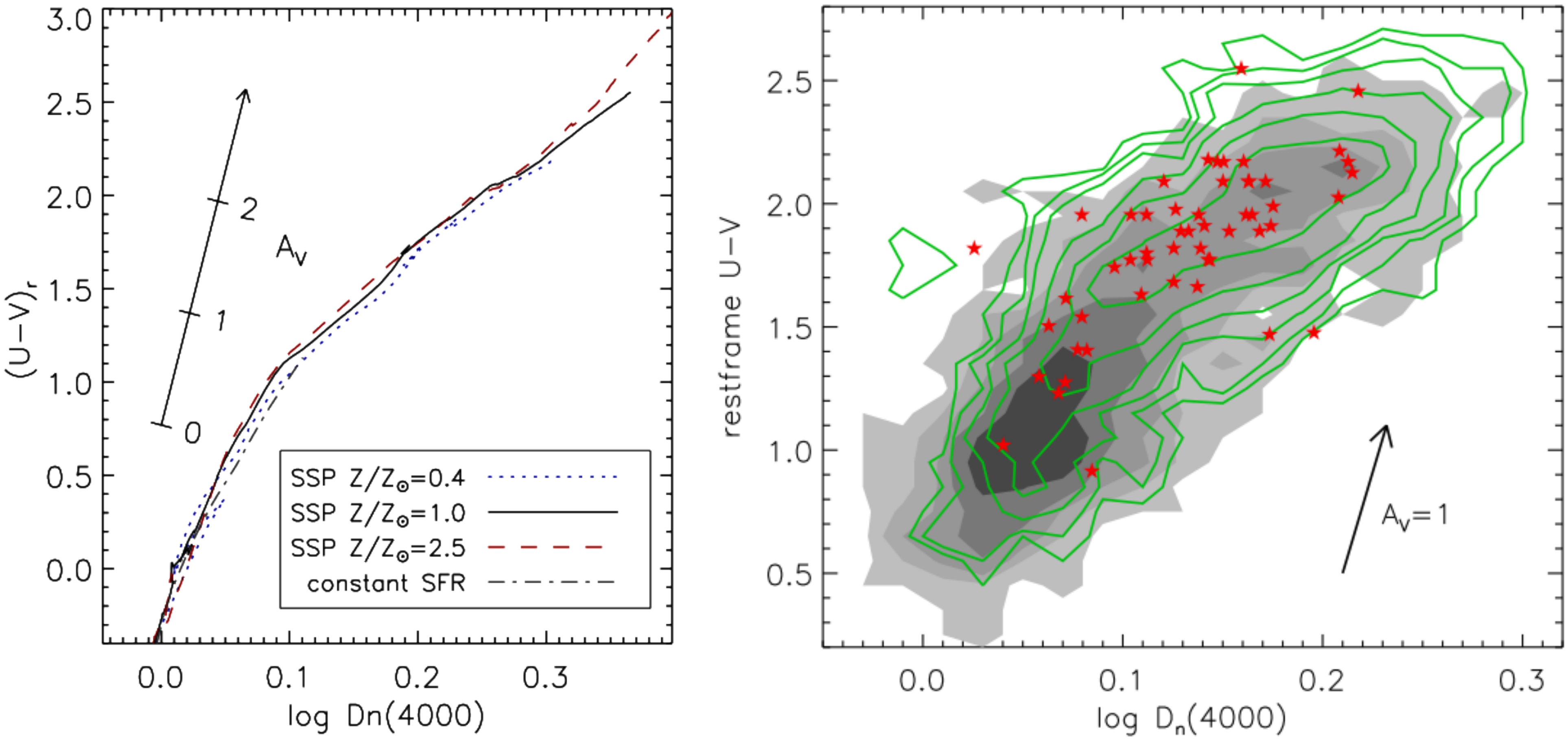
U-V vs D_n(4000) diagram

Both U-V and D_n(4000) measure the 4000 Å break

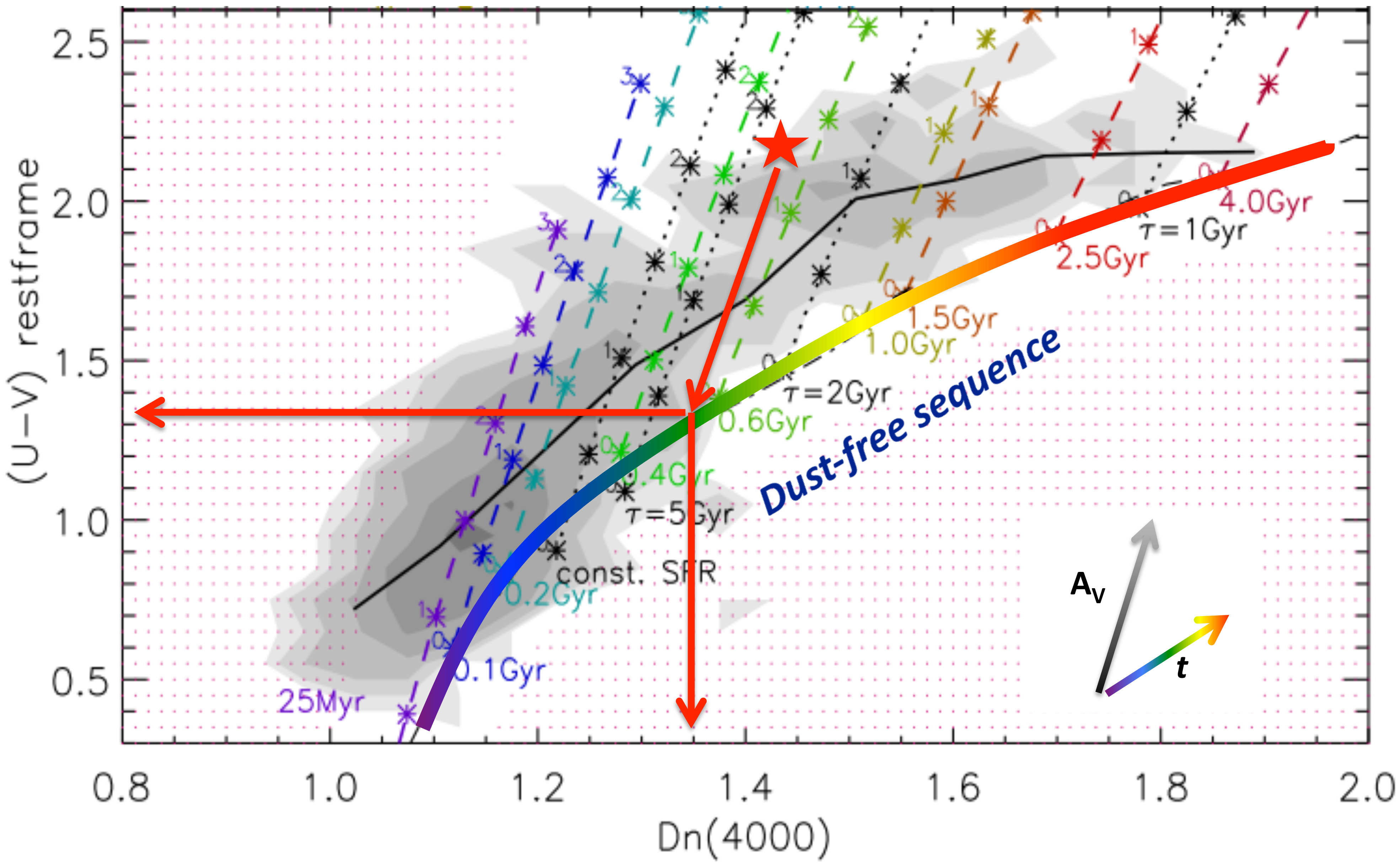
Tight correlation in extinction-free stellar population models

Loose correlation in real data due to extinction, uncertainties

Hernán-Caballero et al. (2014)



Breaking the age-extinction degeneracy

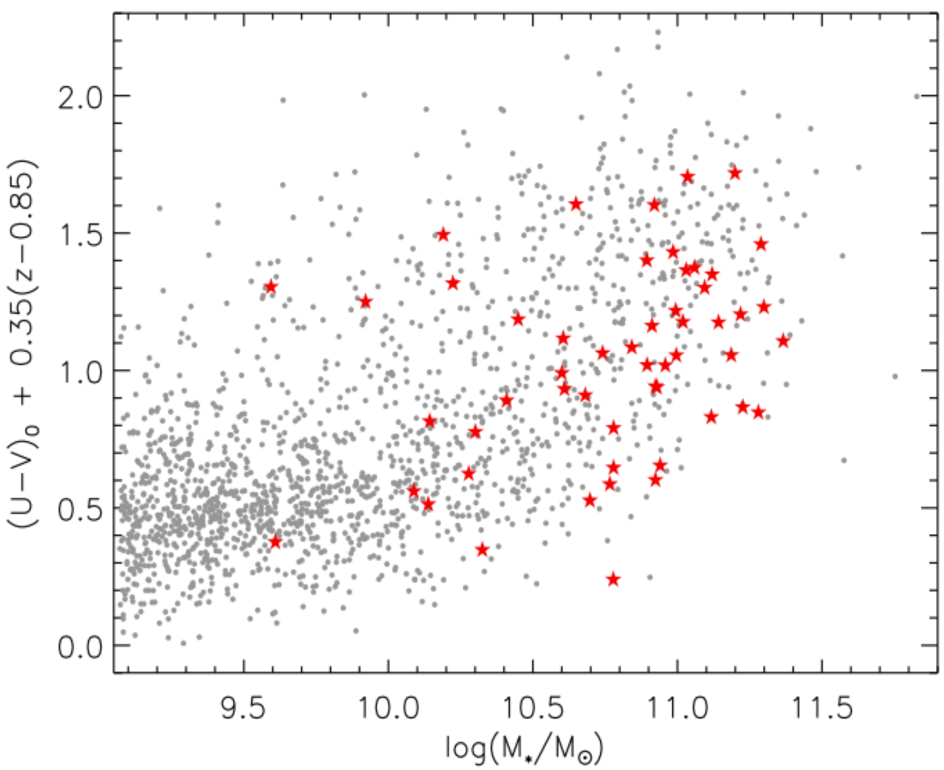


Extinction-corrected *U-V*

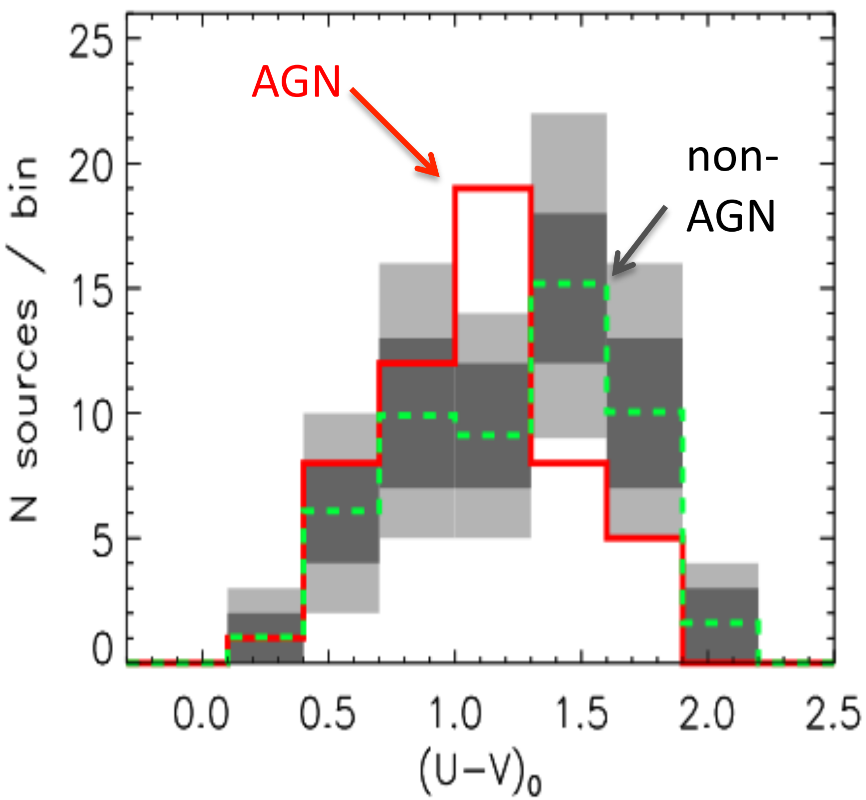
Very few AGN with extinction-corrected *U-V* in the red sequence

Slightly bimodal distribution of $(U\text{-}V)_0$ in the control samples

Clear peak in colour distribution at intermediate values for AGN



Hernán-Caballero et al. (2014)



Converting $D_n(4000)$ to time units

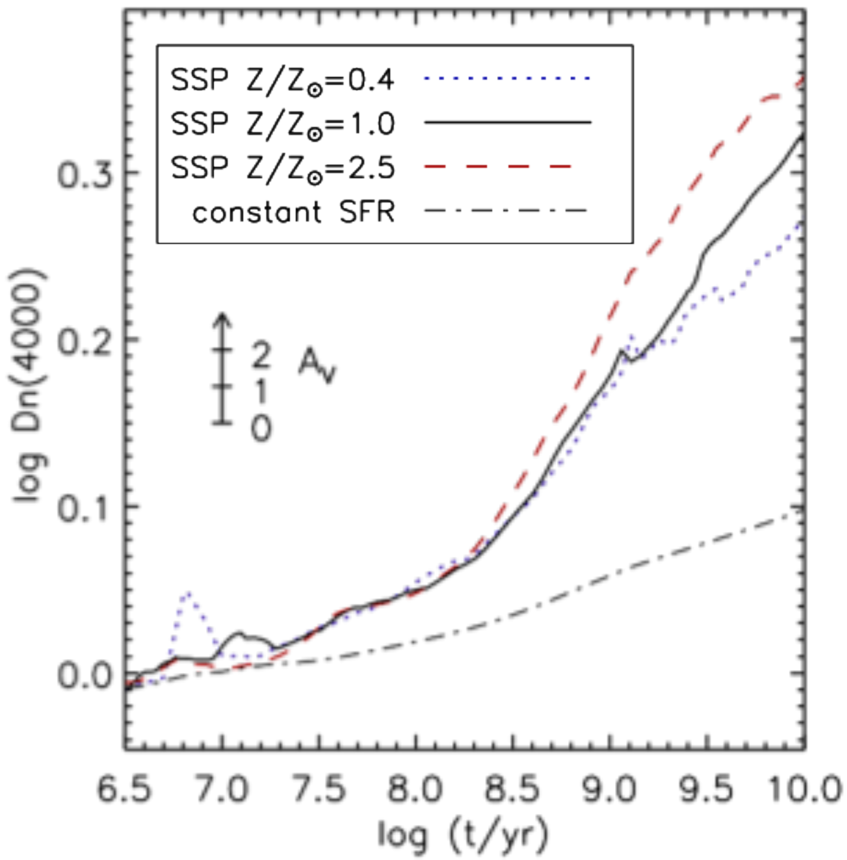
Fixed Z, SFH → functional relation between extinction corrected $D_n(4000)$ and age

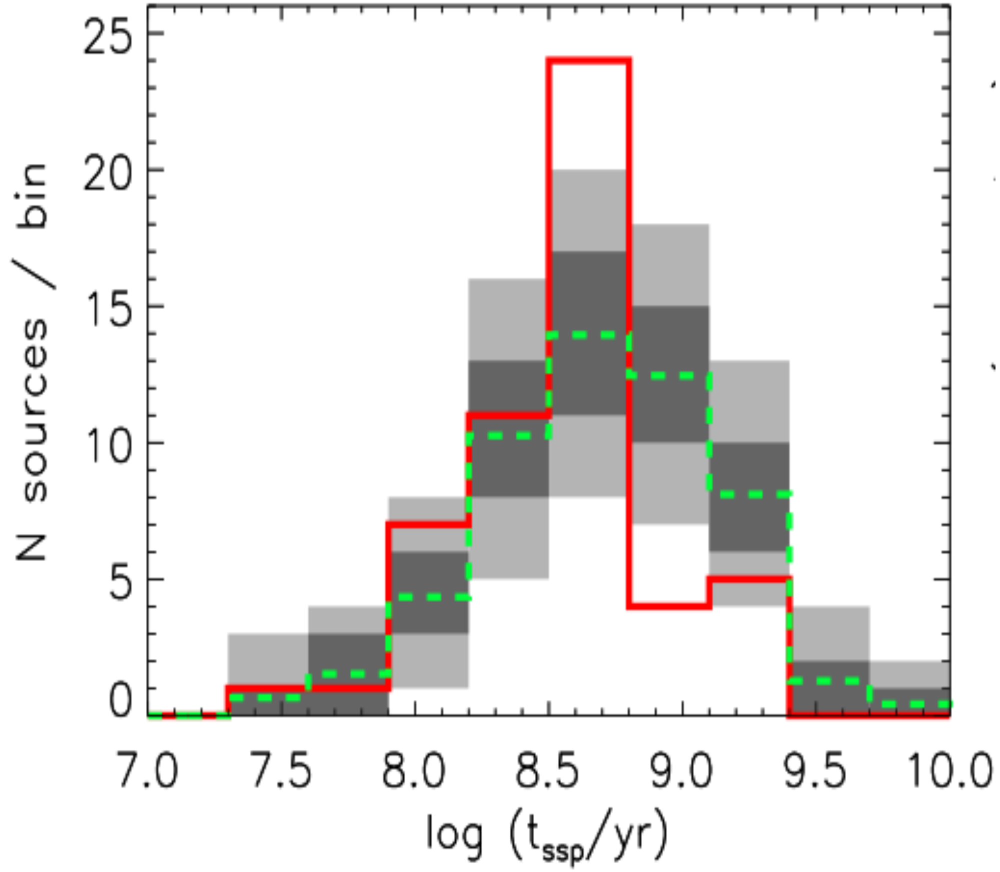
t_{ssp} = age of $Z=Z_\odot$ single stellar population model with equal $D_n(4000)$

>3σ excess of AGN hosts at t_{ssp}~500 Myr

Deficit of AGN hosts at t_{ssp}> 1 Gyr

Hernán-Caballero et al. (2014)





$L_X - t_{ssp}$ relation?

No $L_X - t_{ssp}$ **correlation** found

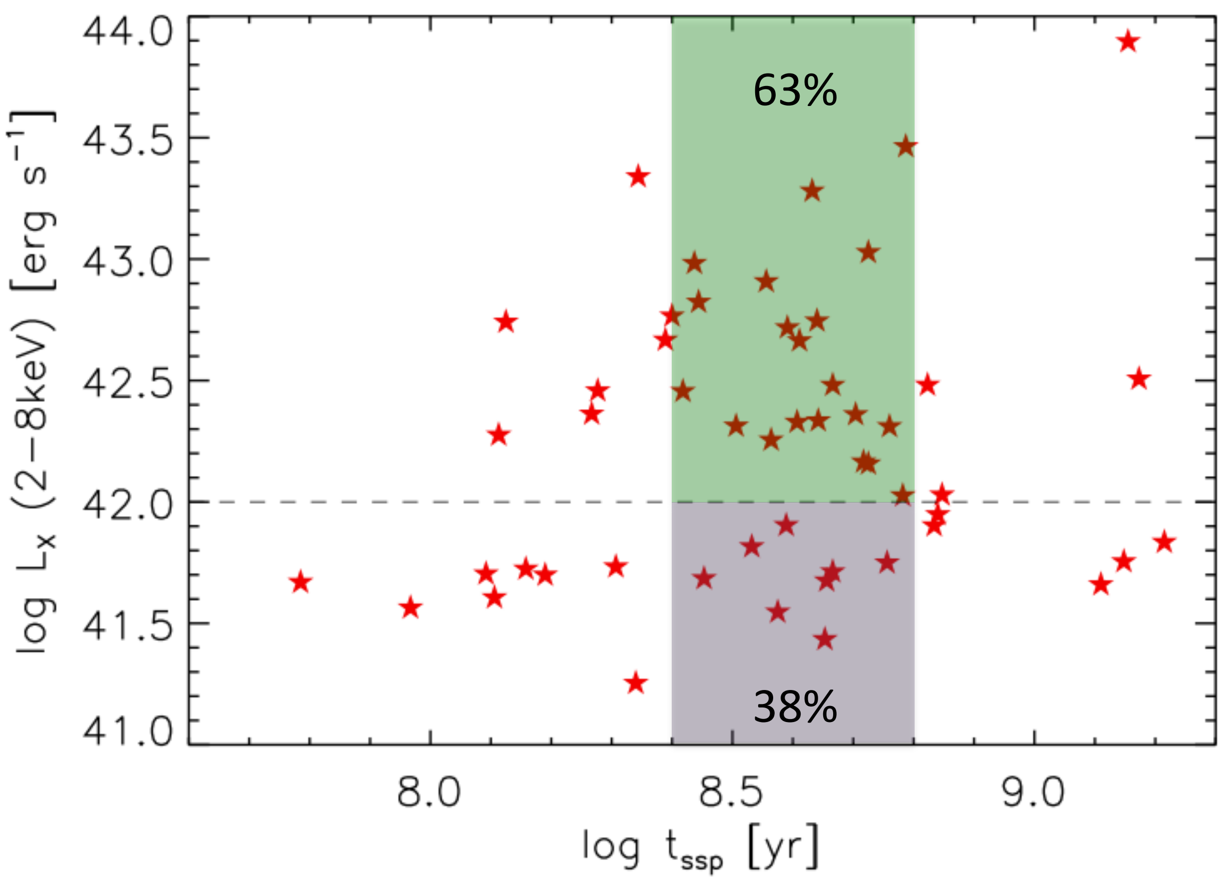
Stronger clustering at t_{ssp}~500 Myr for $L_X > 10^{42}$ erg/s AGN?

(*difference significant at 90% confidence level only)*

$L_X - t_{ssp}$ relation consistent with delayed onset of AGN activity after starburst phase

Larger sample required!

Hernán-Caballero et al. (2014)

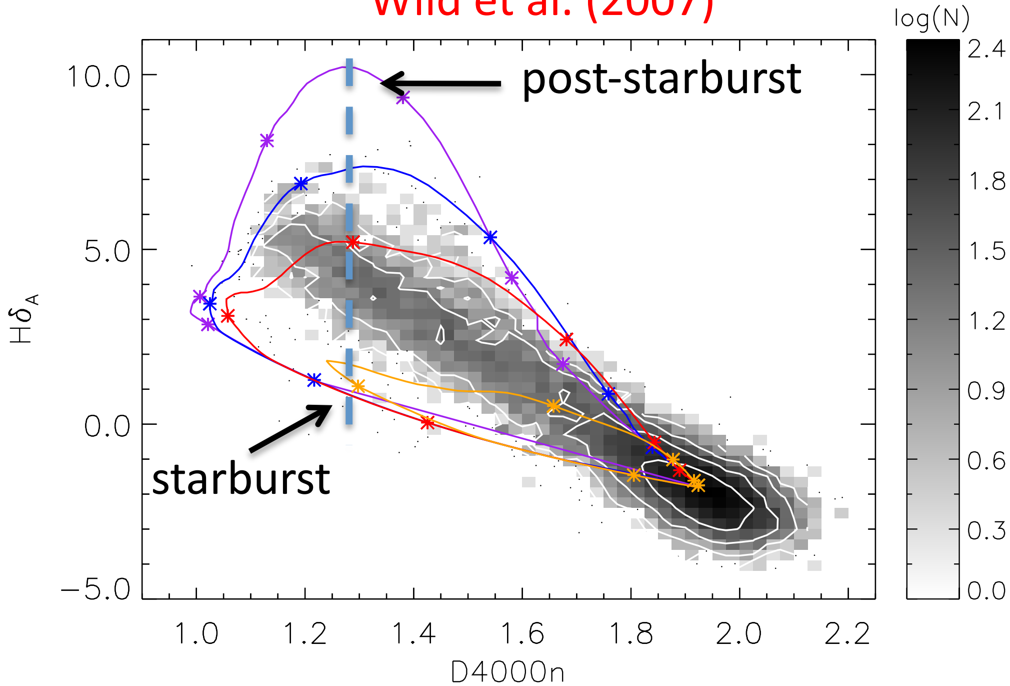


What next?

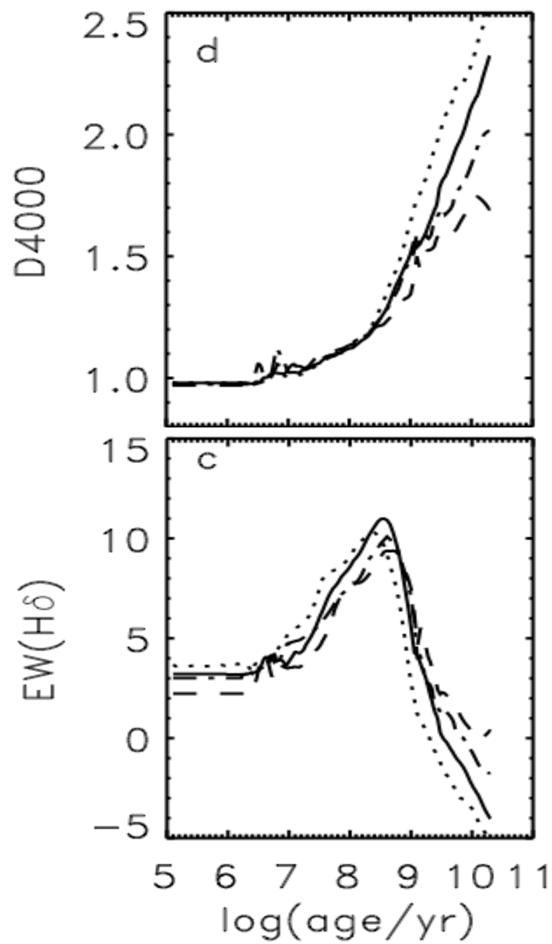
The recent star formation history of z~1 AGN hosts

- Multiple SFH compatible with a given t_{ssp} value
- Additional stellar age indicators needed ($H\delta_A$)
- $H\delta_A$ distinguishes SB, post-SB, and MS galaxies

Wild et al. (2007)

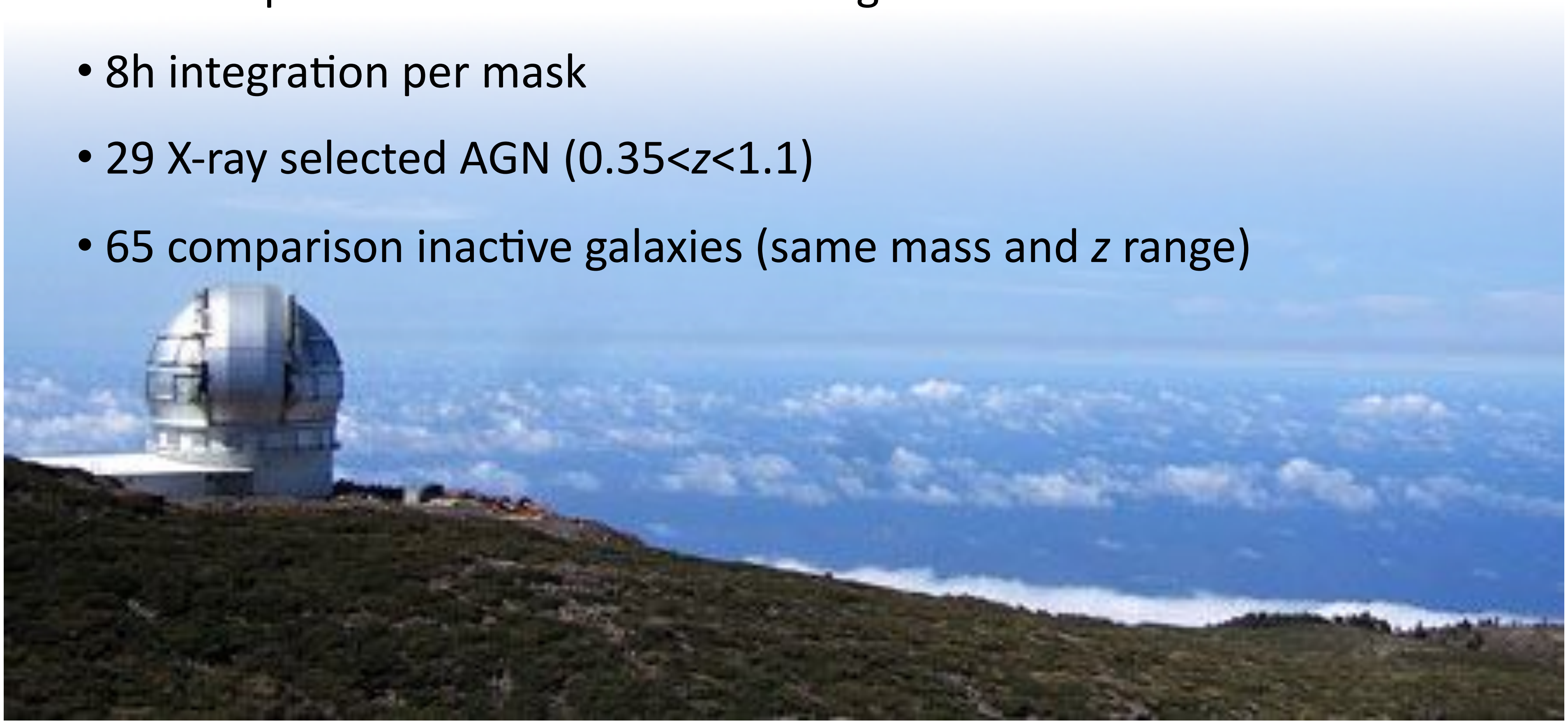


Marcillac et al. (2006)



2015A GTC MOS observations

- Allocated 3 nights for GTC/OSIRIS multi-object spectroscopy
- R~500 spectra in the 5000-9000Å range
- 8h integration per mask
- 29 X-ray selected AGN (0.35<*z*<1.1)
- 65 comparison inactive galaxies (same mass and *z* range)



Summary

- U-V is **NOT different** in X-ray selected [$10^{42} < L_X < 10^{44}$ erg/s, 2-8keV] AGN hosts compared to **same mass** inactive galaxies (0.35<z<1.1)
- **UVJ** diagram and D_n(4000) distribution imply **deficit** of **quiescent/old** galaxies among AGN hosts
- **Younger** stellar ages with higher **extinction** explain the observed trends
- We find **overabundance** of AGN in **intermediate age (t_{ssp}~500 Myr)** galaxies at 0.35<z<1.1, similar to local Universe
- $L_X - t_{ssp}$ relation consistent with delayed onset of AGN activity
- We will explore in greater detail the recent SFH with MOS observations

Further reading:

Higher prevalence of X-ray selected AGN in intermediate age galaxies up to z~1
Hernán-Caballero et al. (2014), MNRAS, 443, 3538