

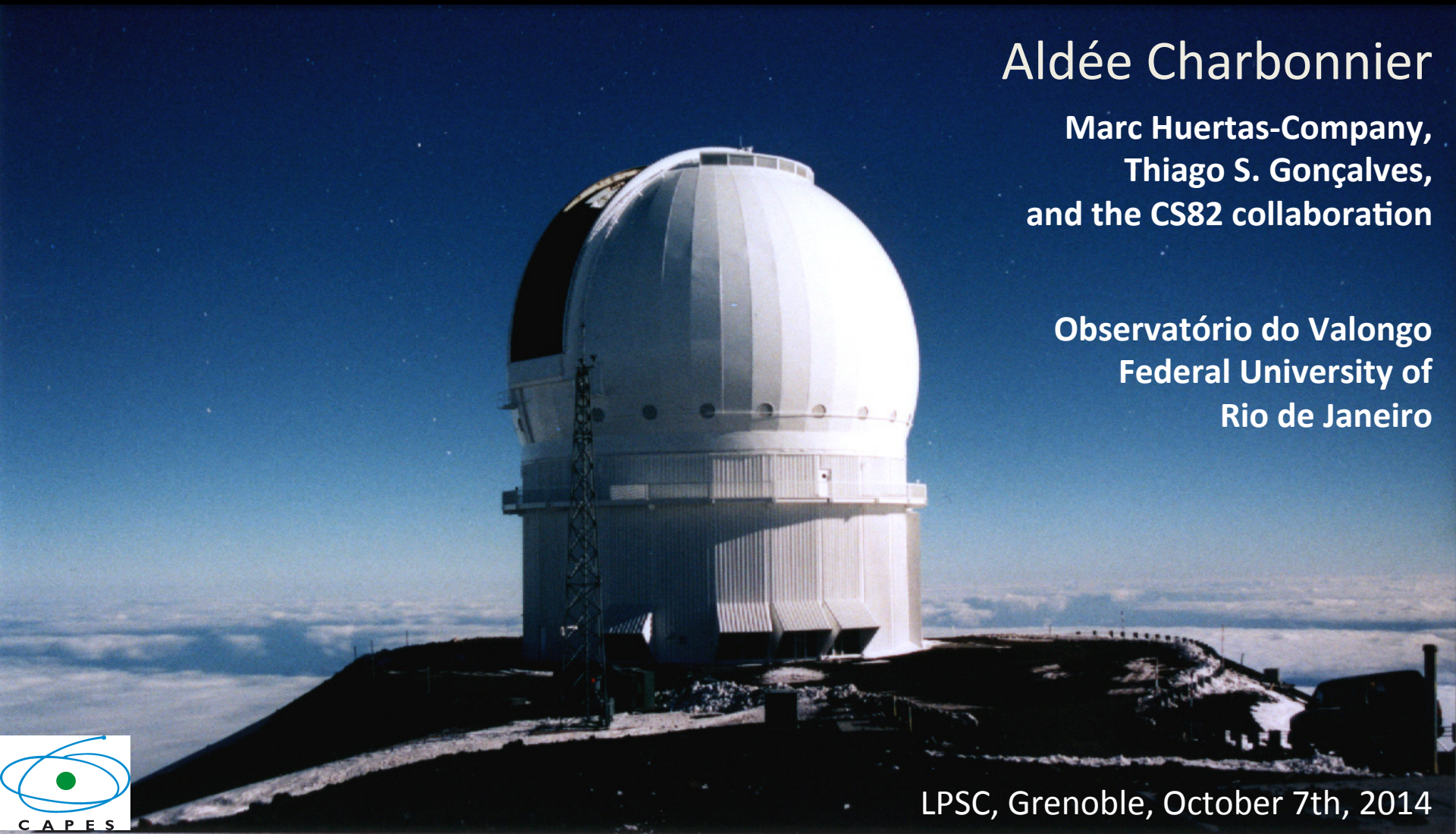
Compact massive galaxies in the Stripe-82 region



Aldée Charbonnier

Marc Huertas-Company,
Thiago S. Gonçalves,
and the CS82 collaboration

Observatório do Valongo
Federal University of
Rio de Janeiro

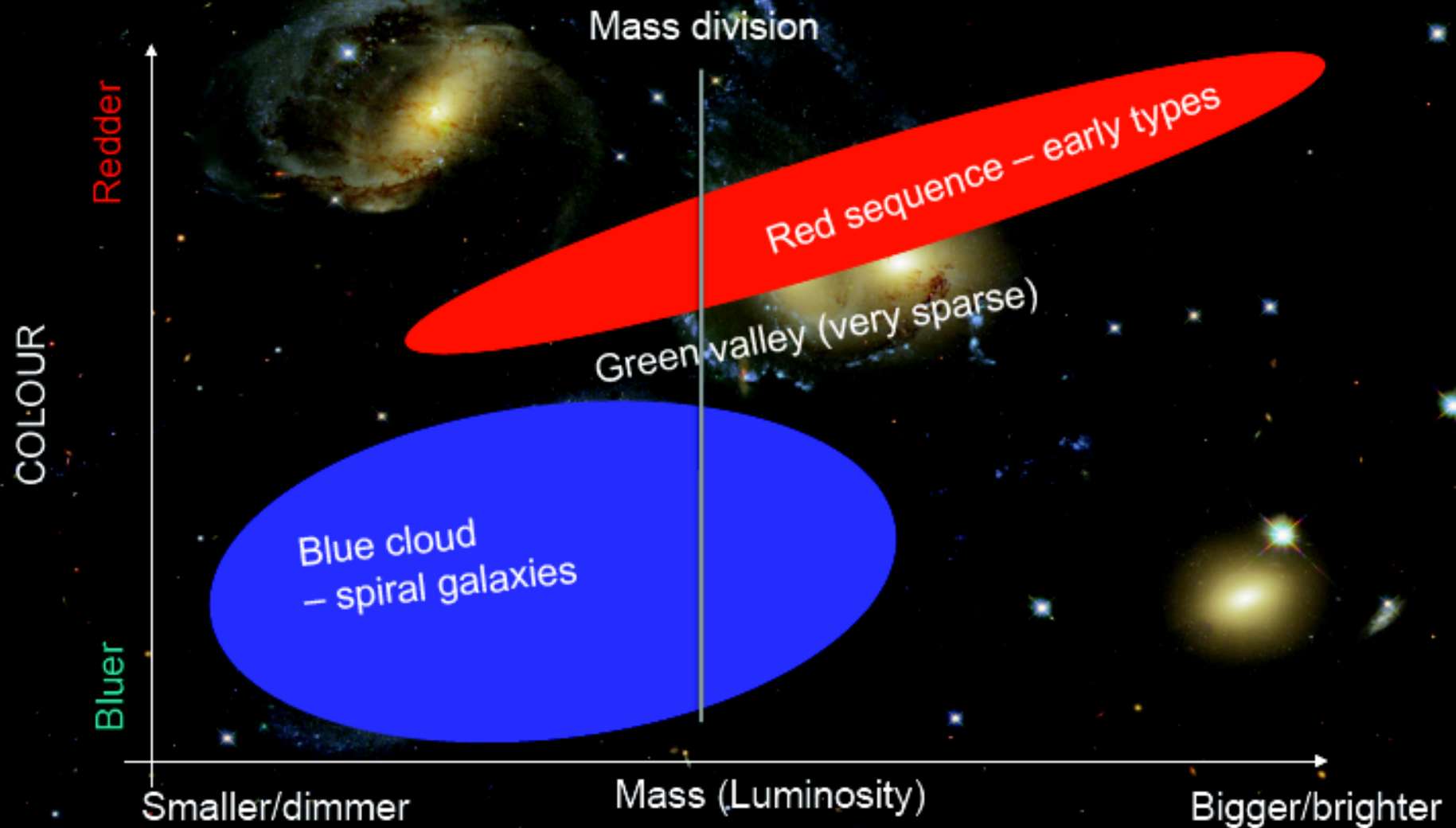


LPSC, Grenoble, October 7th, 2014

Outline

- Compact massive quiescent galaxies:
why do we care?
- CFHT Stripe-82 survey
- Looking for them

Why Look – galaxies aren't all the same...



Morphology of galaxies

Early type

$n_{\text{Sersic}} > 2.5$
(**de Vaucouleurs** profile)
Elliptical or lenticular,
bulge
Preferentially round

« **red sequence** »
Slowly evolving galaxies
Passive early galaxy
Older and redder

Late type

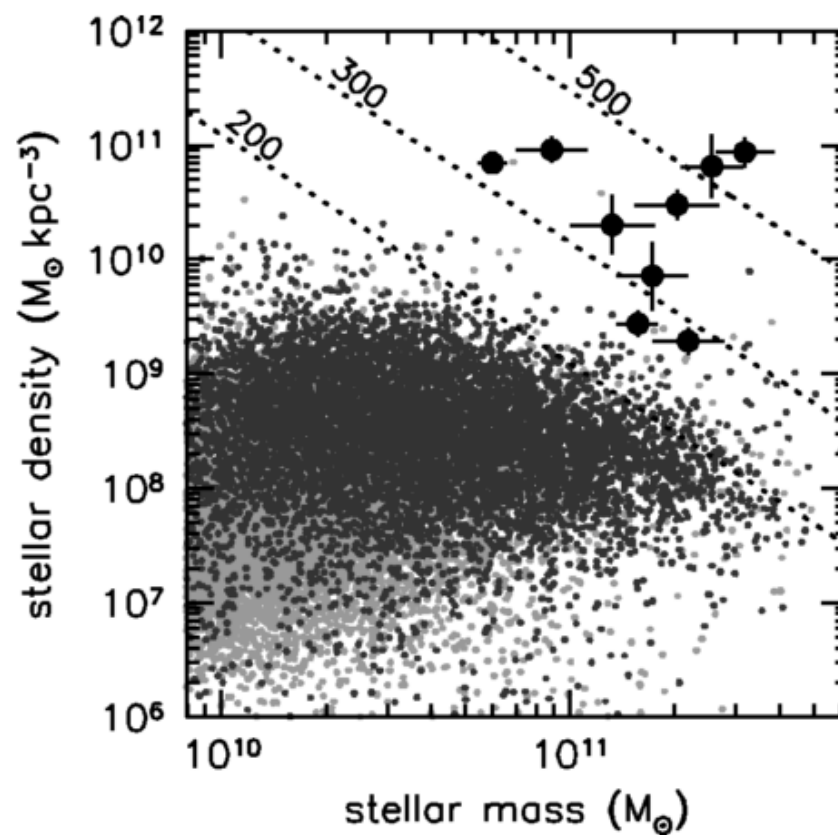
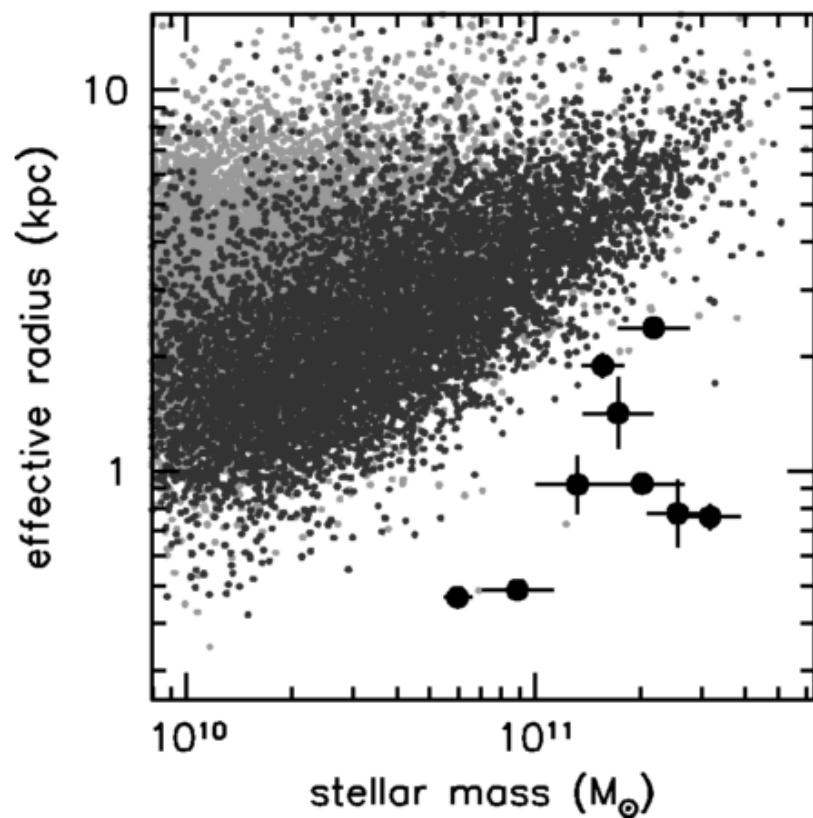
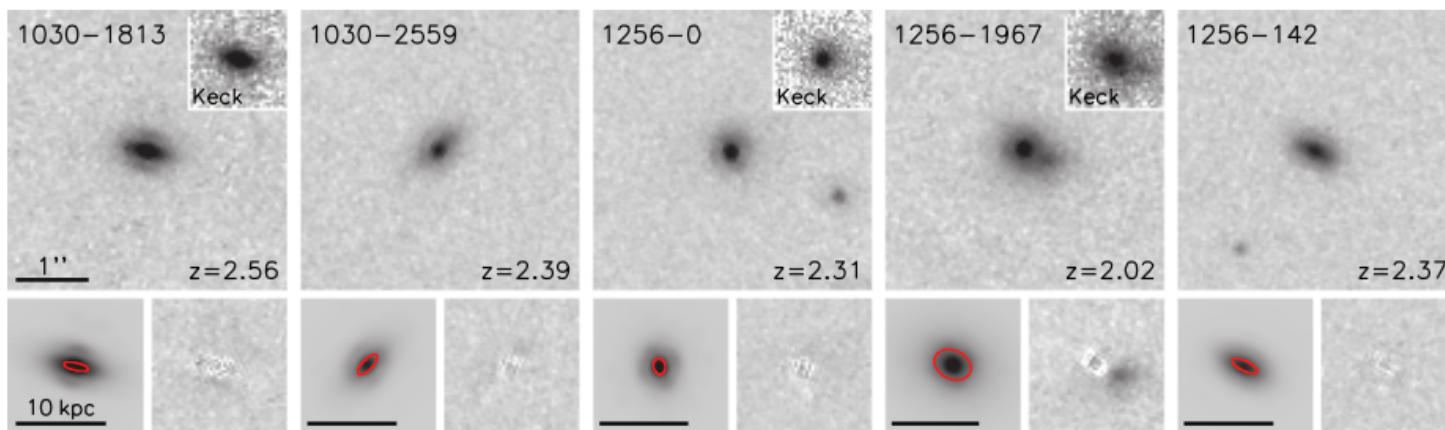
$n_{\text{Sersic}} < 2.5$
(**exponential** profile)
Spiral disk
With disk/bar

« **blue cloud** »
Actively star-forming
galaxies

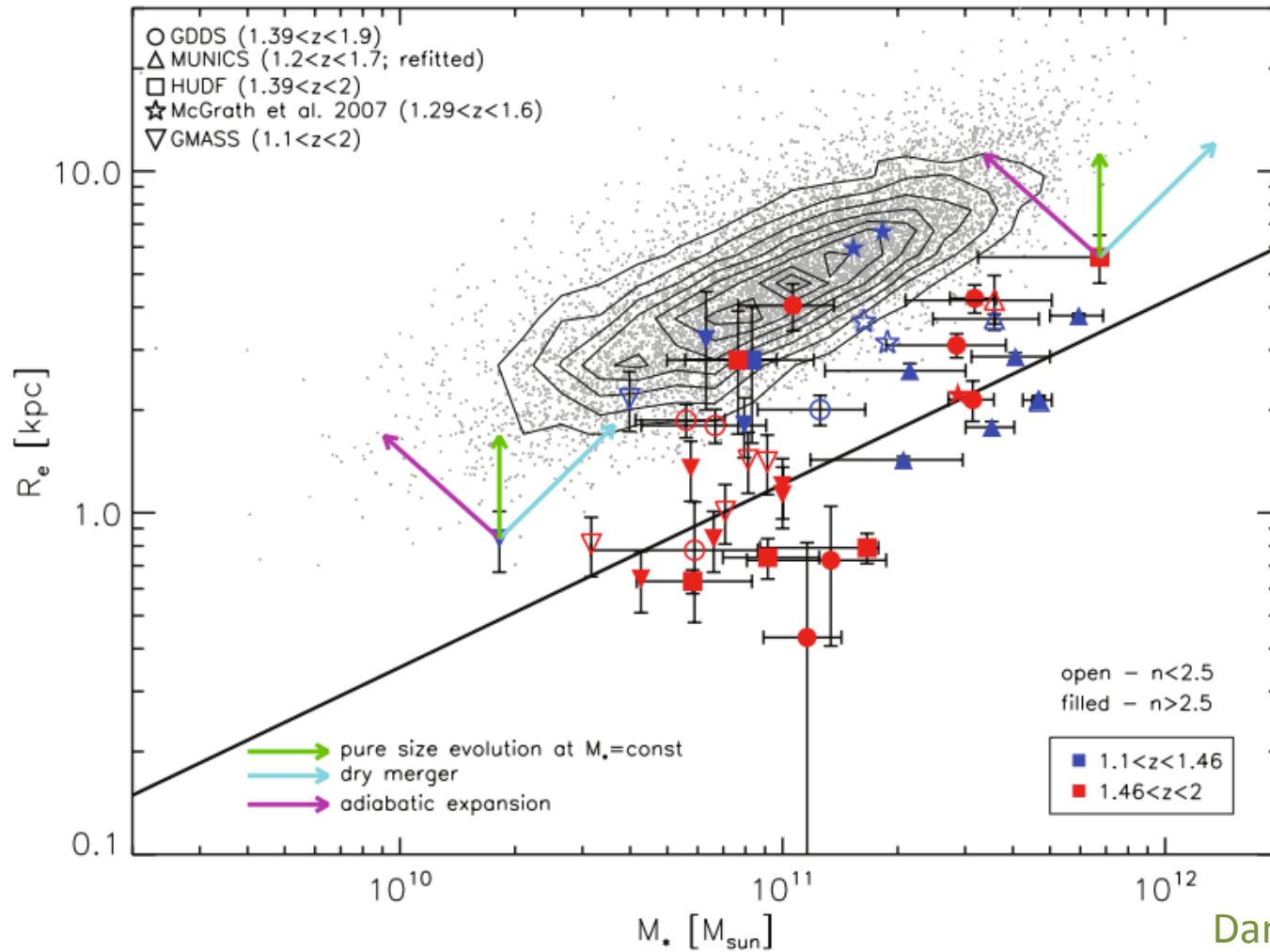


Massive-compact-quiescent: first observations

- 2005: Daddi +** Hubble Ultra Deep Field ($1.4 < z < 2.5$)
7 quiescent massive galaxies: quite compact
- 2006: Kriek +** K-bright galaxies survey (Gemini Near-IR Spectrograph)
~45% have evolved stellar populations or no ongoing star formation
- 2007: Toft +** HST/NICMOS+ACS & Spitzer/IRAC+MIPS ($2 < z < 3.5$)
quiescent galaxies are more compact than star forming ones
(...)
- 2008: Van Dokkum +** HST/NIC2 data of 9 quiescent galaxies ($2 < z < 2.7$)
 $r_{\text{eff}} < 1 \text{ kpc}$, $M_{\star} > 10^{11} M_{\odot}$
- 2009: Damjanov +** “red nuggets”
($1.2 < z < 2$) HST/NICMOS observation of 19 high mass passively evolving galaxies identified by GDDS



Mechanisms of size evolution?

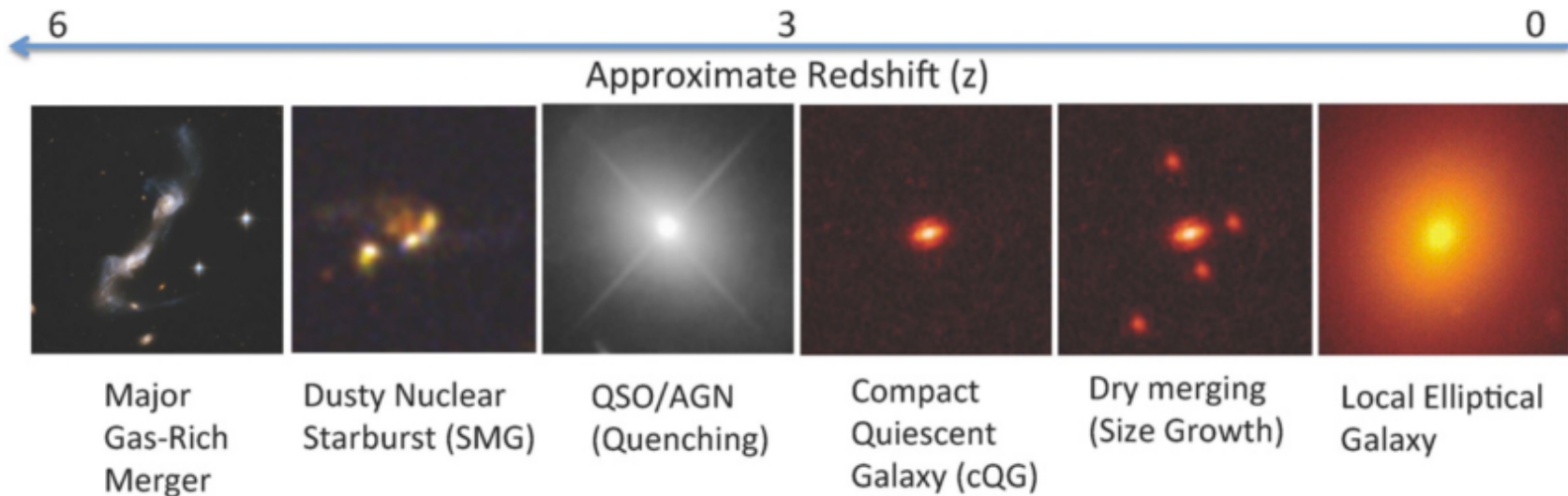


Damjanov + 2009

- pure size evolution at $M_* = \text{const}$
- dry merger
- adiabatic expansion

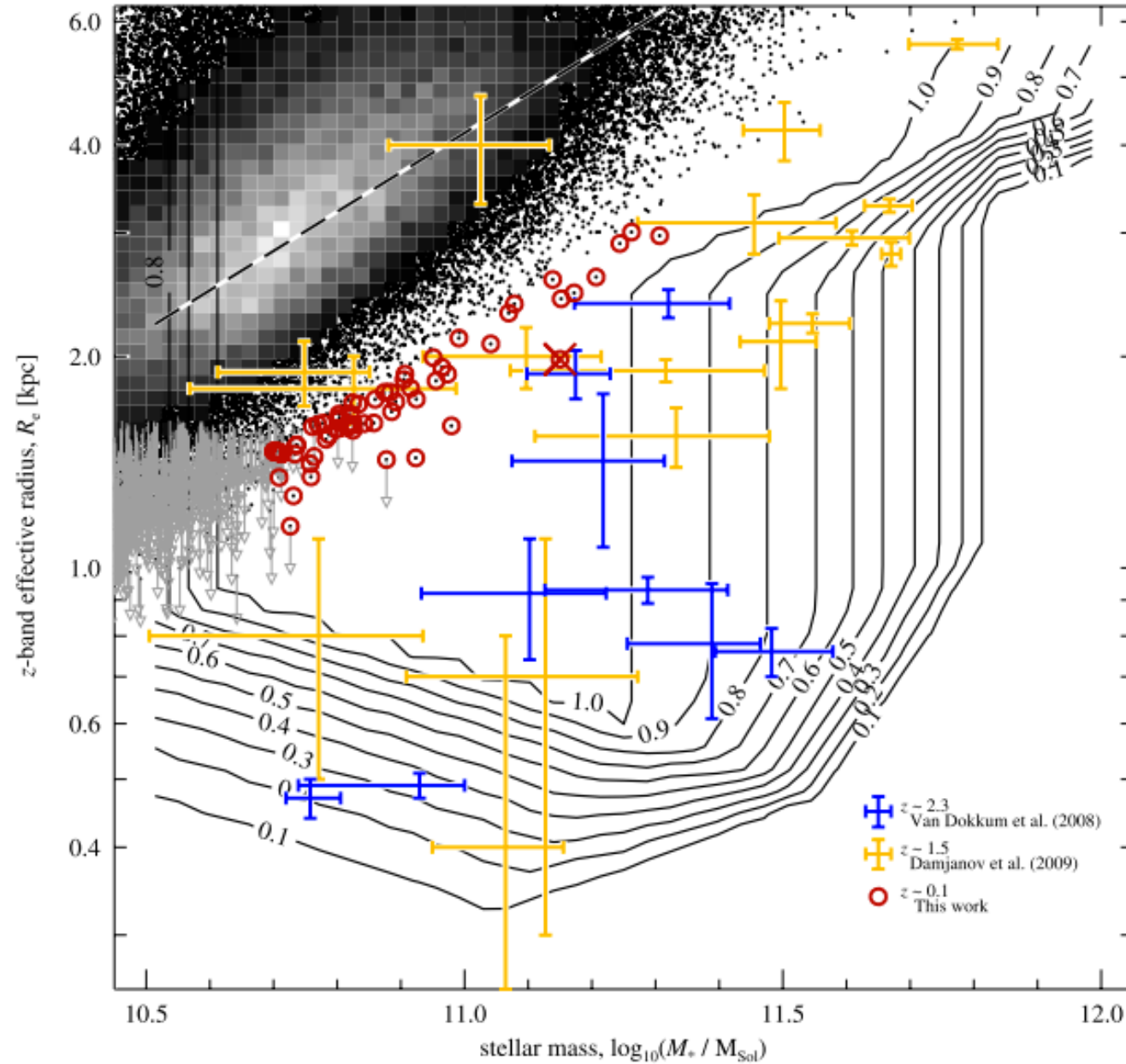
A possible scenario

Toft + 2014



Towards lower redshifts

- 2010: Valentinuzzi +** Wide field Nearby Galaxy cluster Survey ($0.04 < z < 0.07$)
Isaac-Newton, MPG/ESO telescopes, + spectroscopy
high density of superdense candidates
- 2010: Taylor +** SDSS spectroscopic sample ($0.066 < z < 0.12$)
63 candidates, but different from high-redshift ones
- 2013: Quillis & Trujillo** Millennium N-body simulation from $z \sim 2$ to $z \sim 0$
10% to 30% of increase of the mass
fraction of massive relics: 0.1% to 1%
- 2013: Damjanov +** SDSS spectro=GALAXY, image=STAR ($0.3 < z < 0.5$)
+ HST/ACS data: 9 identified, similar to high-redshift
- 2014: Stockton +** SDSS + UKIRT, follow-up: Keck spectroscopy and AO ($z \sim 0.5$)
2/5 candidates for relics, prolate morphology
- 2014: Trujillo +** NGC 1277, HST/ACS, Long slit spectro @Herschell ($z = 0.0169$)
Massive, compact, old stellar population: closest candidate

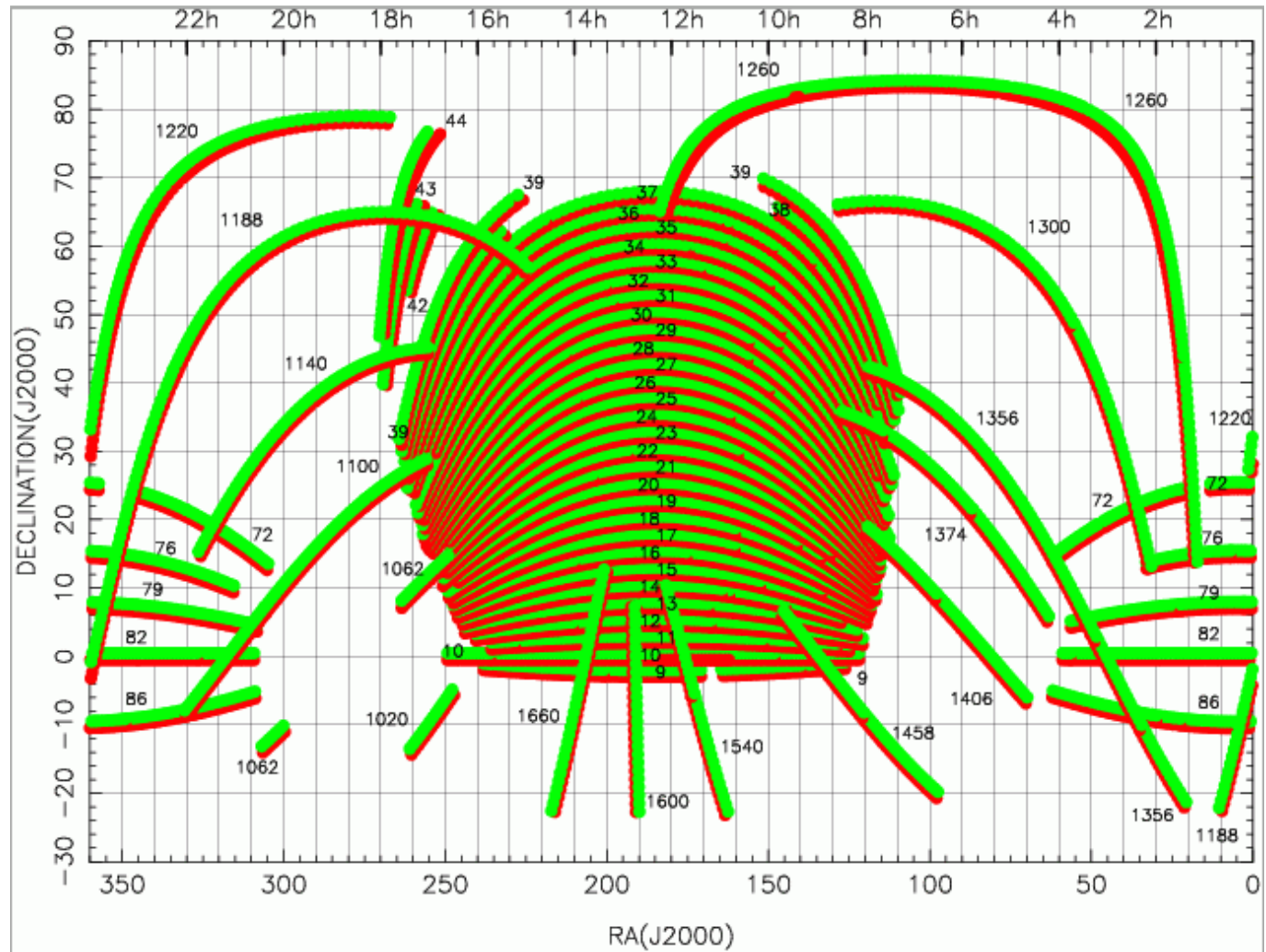


CFHT-Stripe 82 survey

Why “Stripe-82”?

<http://dame.dsf.unina.it/catalogues.php>

**SDSS uses
Earth's
rotation**

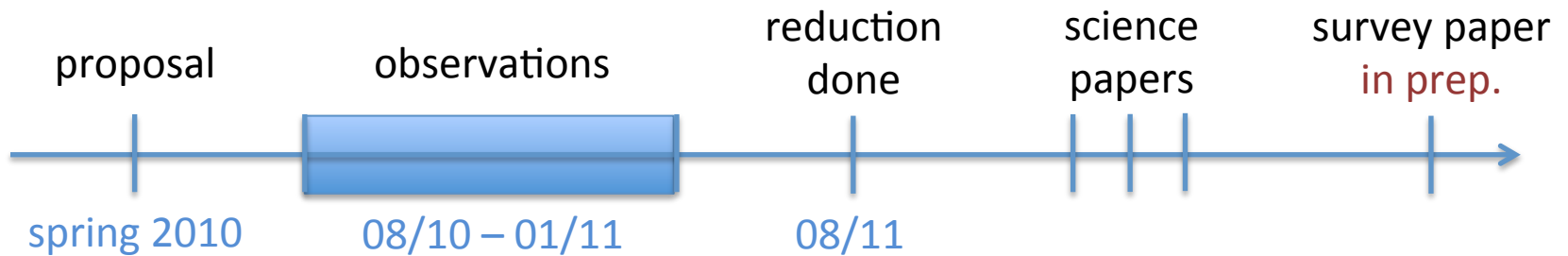


Stripe-82 Multi-WL coverage

- Optical/UV Imaging:
 - SDSS Co-adds (Jiang, Annis, Huff & LSST)
 - CFHTLS
 - CFHT i-band (CS82, Leauthaud)
 - DES, HSC
 - Pan-STARRS, PTF, Skymapper
 - GALEX
- Near-IR:
 - UKIDSS
 - VHS
 - NEWFIRM (Jiang)
 - 2MASS
- Mid-IR:
 - SHELA (Mehrtens)
 - SpIES (Ross), IRAC high-z quasars
 - WISE (Stern)
 - VICS82 (Makler)
- Far-IR:
 - HELMS (Viero)
 - HerS (Viero)
- Radio/mm:
 - VLA-L, A-array (Hodge et al. 2011)
 - VLA-L, C-array (Jarvis)
 - VLA-S (Hallinan)
 - ACT, ACTPol (Marriage)
 - Planck
 - CCAT
- X-ray:
 - Chandra (LaMassa)
 - XMM (LaMassa)
 - Swift (UVOT also)
 - NuSTAR (Civano)
- Spectra:
 - SDSS-I/II,III,IV
 - HETDEX (Gronwall)
 - Wigglez (DR1)
 - VVDS
 - PRIMUS (Coil)
 - DEEP2
 - AUS/2SLAQ
 - DESI
 - SuMIRe/PFS

CS82 survey in a nutshell

- France-Canada-Brazil
- **CFHT, MegaCam**
- 173 pointings
- 'Stripe 82'
- **lensing** survey
- i-band
- seeing $\sim 0.6''$



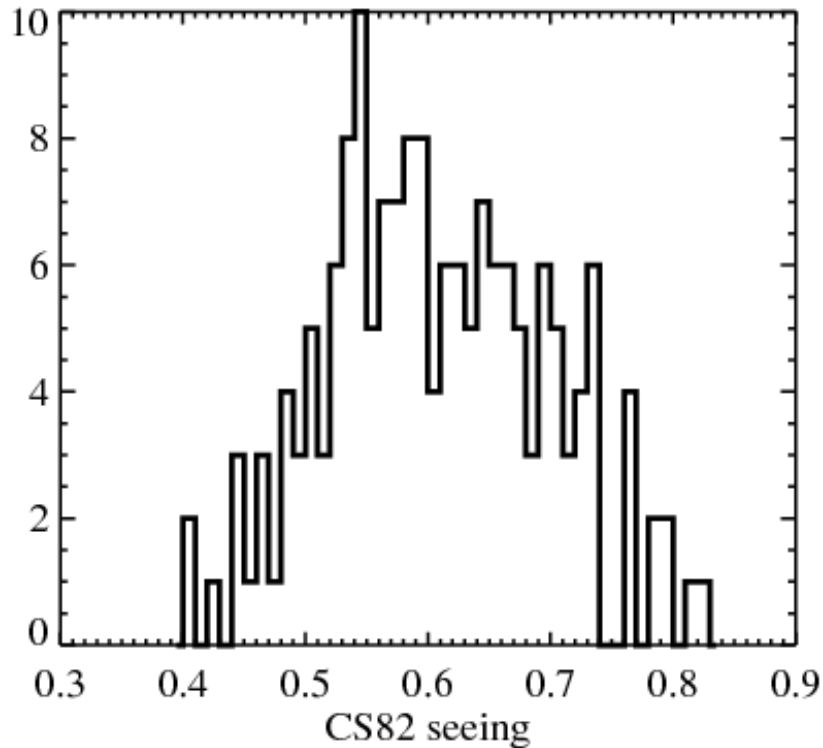
CFHT – Stripe-82

Erben et al. in prep (2014)

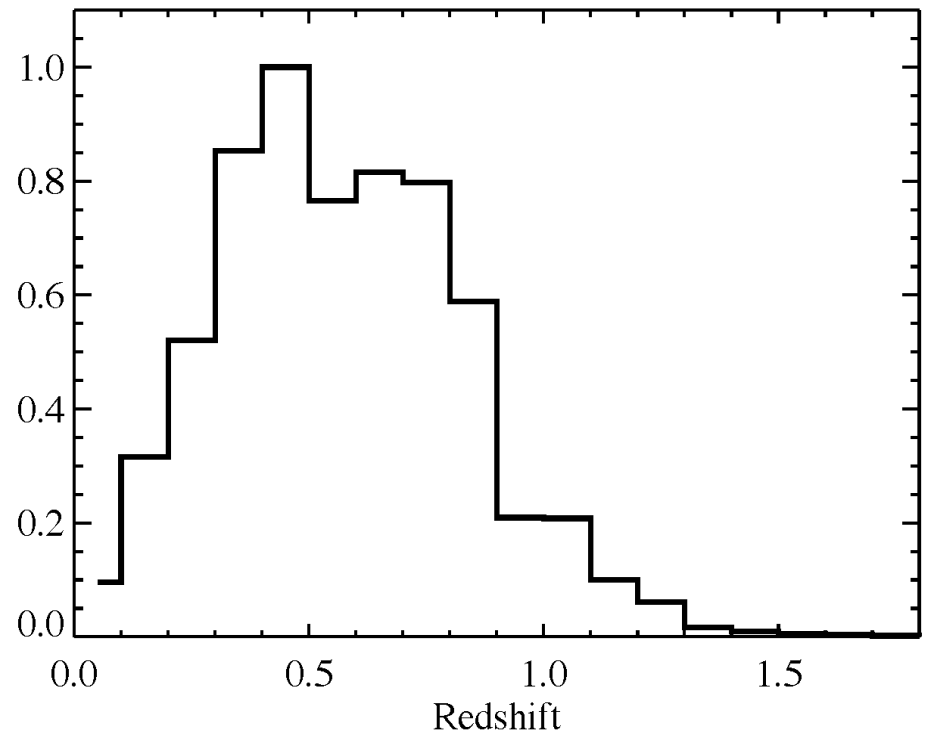


Properties of CS82 images

Mean seeing 0.6"



Redshift distribution



Magnitude limit:
- ~23.5 for galaxies

General procedure

**1- SExtractor
(detection)**

image



catalog

2- PSFEx

catalog



Point Spread
Function

**3- SExtractor
(model fitting)**

image
+ PSF file



morphology
catalog

SExtractor: <http://www.astromatic.net/software/sextractor>

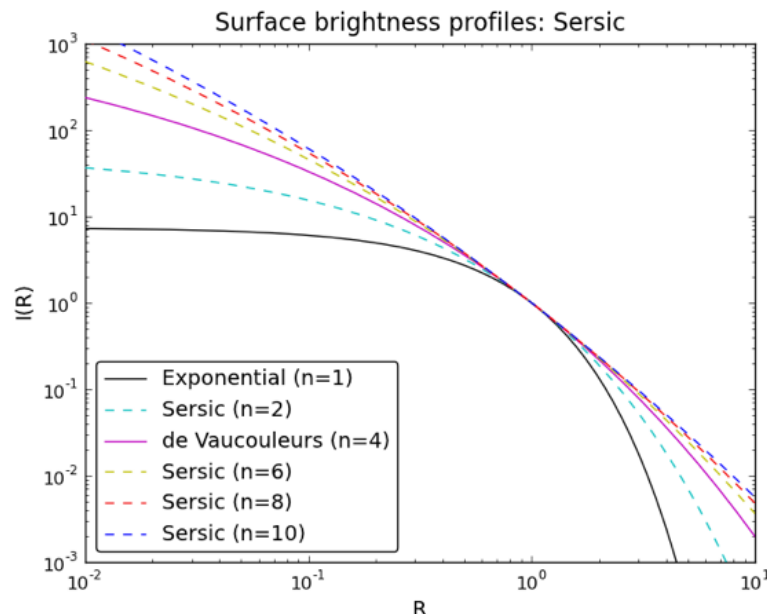
PSFEx: <http://www.astromatic.net/software/psfex>

Morphology catalogues

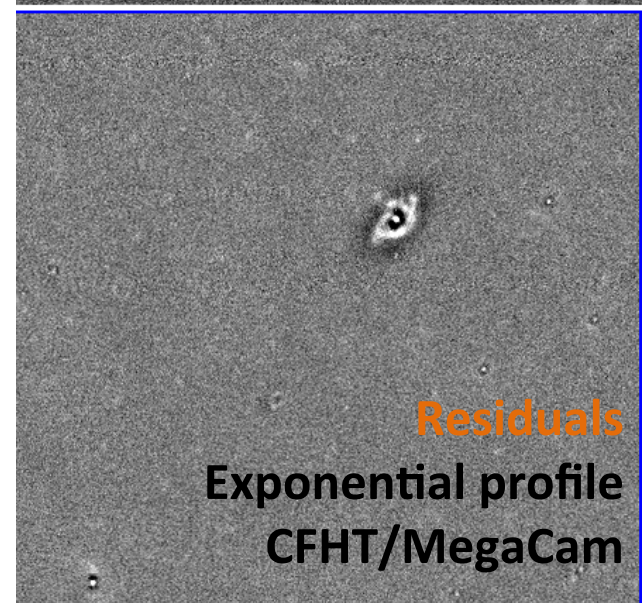
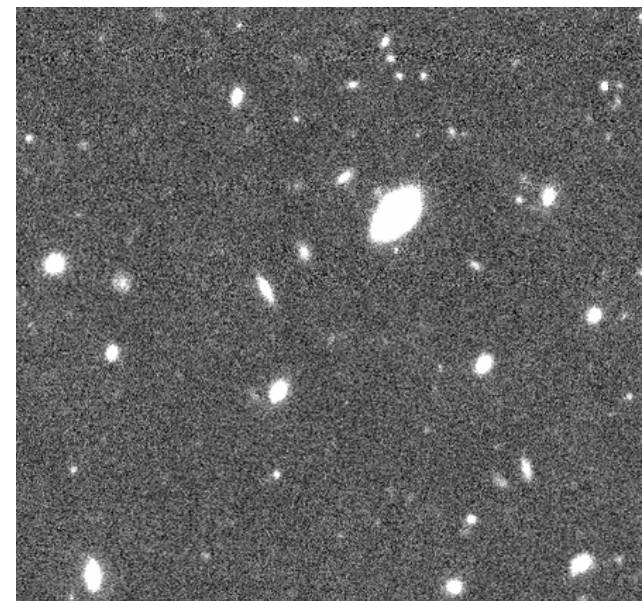
~**16,700,000** objects (150,000/tile)

4 profiles: de Vaucouleurs, exponential, Sersic, deV +exp

CPU time: 12h/profile/tile



Moraes, Charbonnier + 2014 (in prep.)



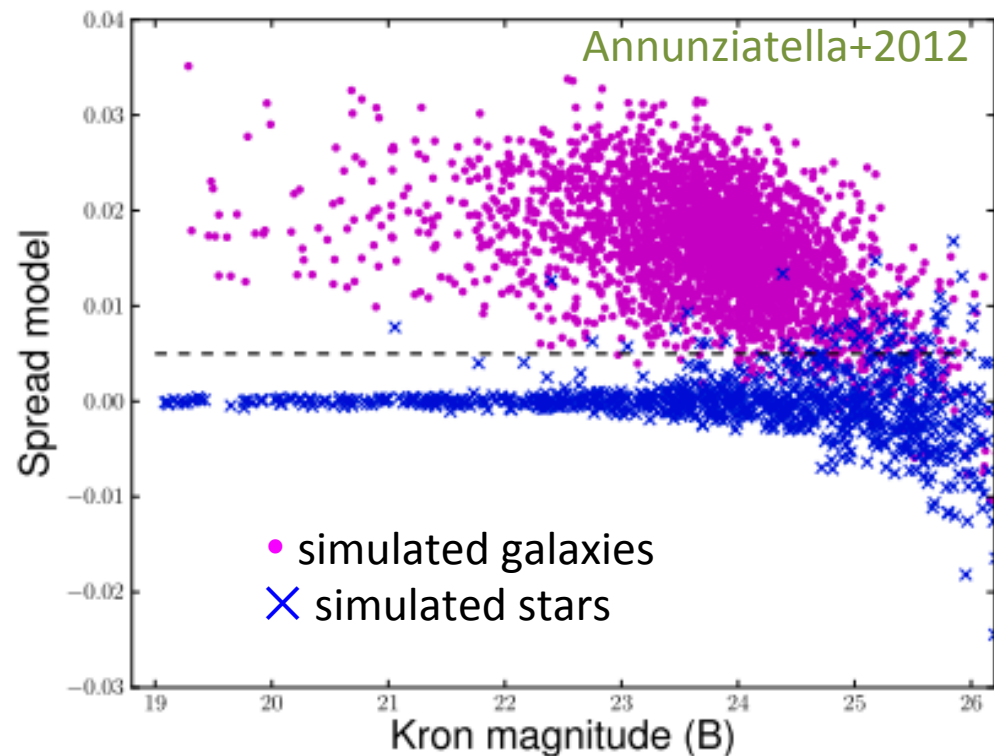
SPREAD_MODEL parameter

- Star/galaxy discriminator from SExtractor
- Diagnostic for a good PSF reconstruction

$$\text{spread_model} = \frac{\phi^T \mathbf{x}}{\phi^T \phi} - \frac{\mathbf{G}^T \mathbf{x}}{\mathbf{G}^T \phi}$$

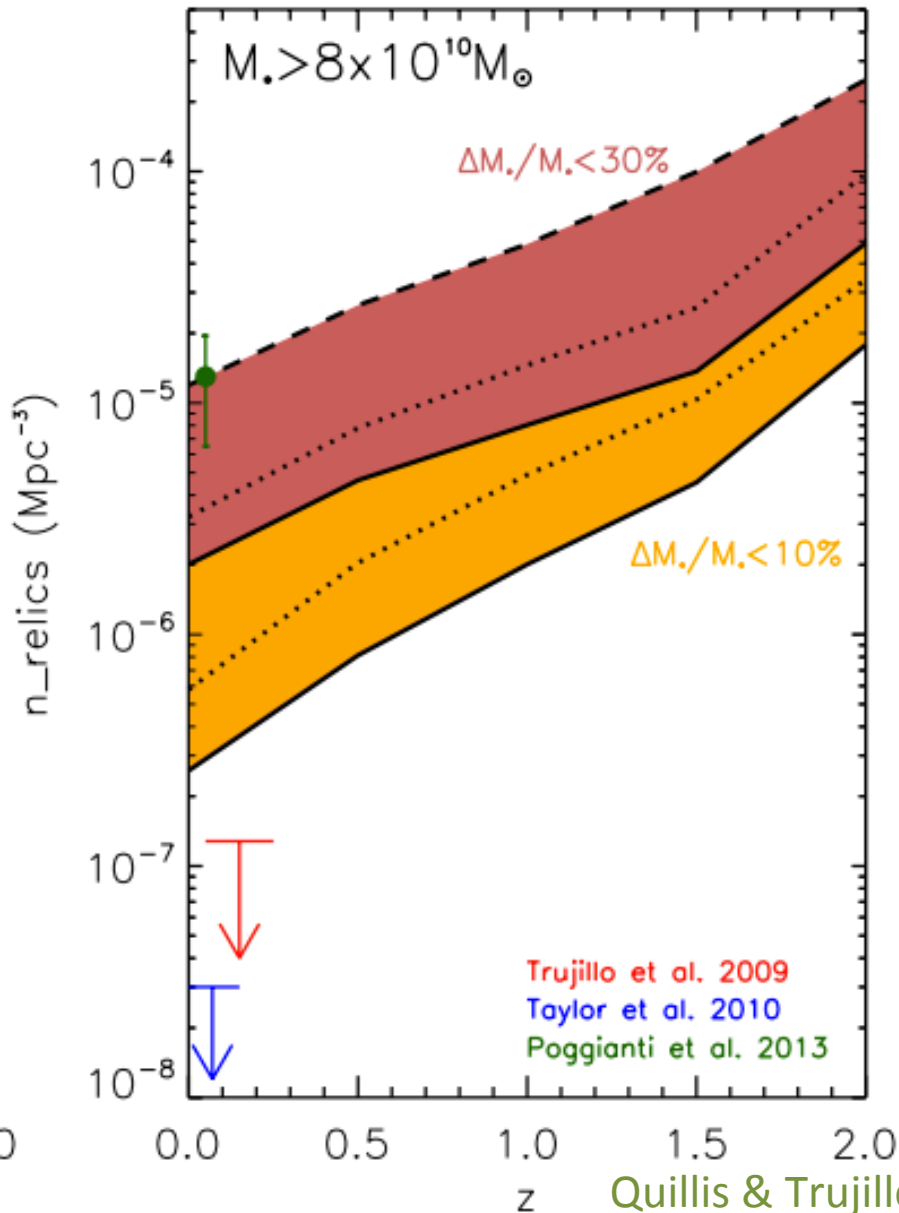
ϕ : PSF model

$\mathbf{G}$: slightly more extended model



Looking for massive compact quiescent galaxies

Expectations?



Estimated density of high redshift relics:

Hyp - all objects are detected
- WMAP7 cosmology

Comoving volume between $0.2 < z < 0.6$:
 $V_{0.6} - V_{0.2} \sim 43.5 \text{ Gpc}^3$

Solid angle of Stripe-82 ($A_{\text{eff}} \sim 124 \text{ deg}^2$):
 $\Omega_{\text{stripe 82}} \sim 0.038 \text{ sr}$

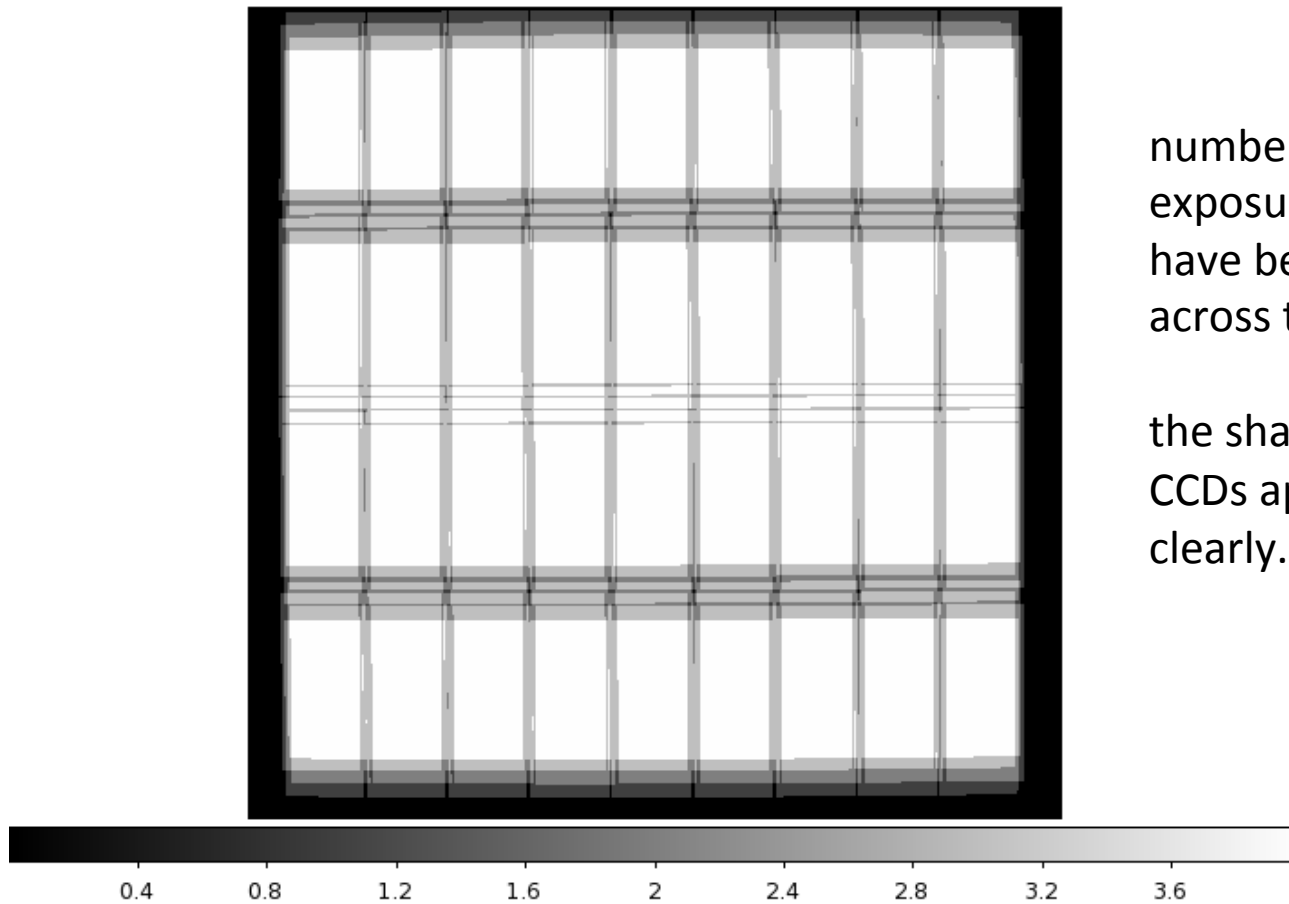
For $\langle n_{\text{relics}} \rangle \sim 10^{-5} \text{ Mpc}^{-3}$

$n_{\text{expected}} \sim \mathbf{1300}$

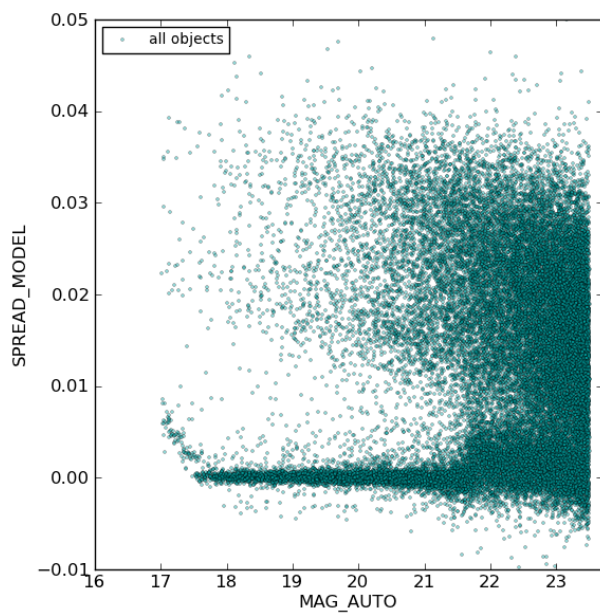
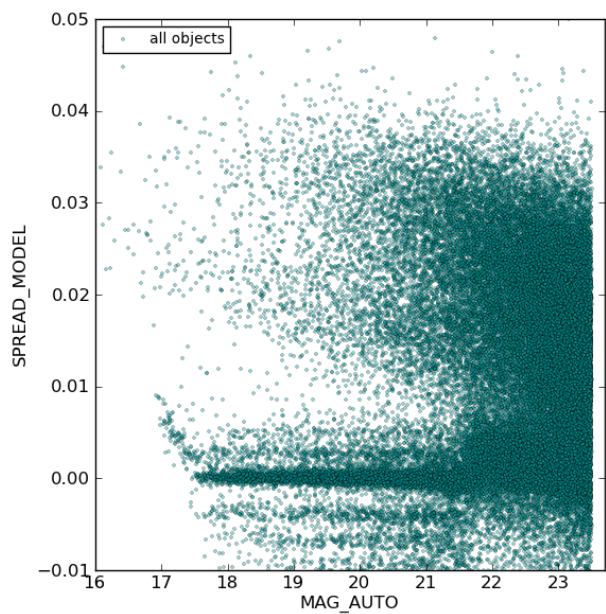
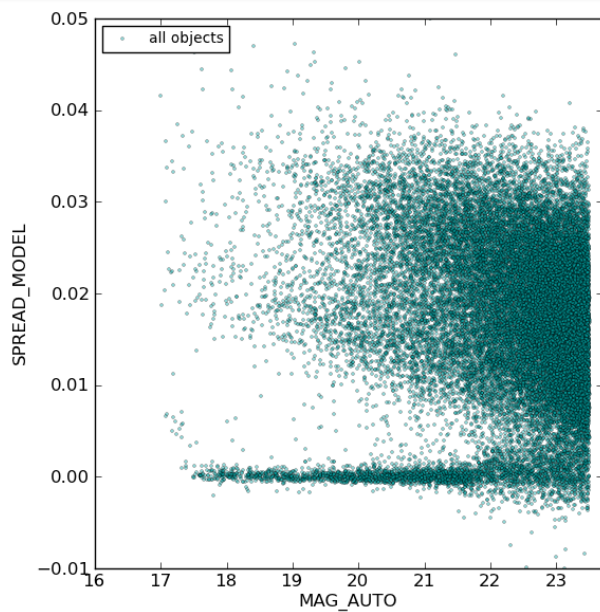
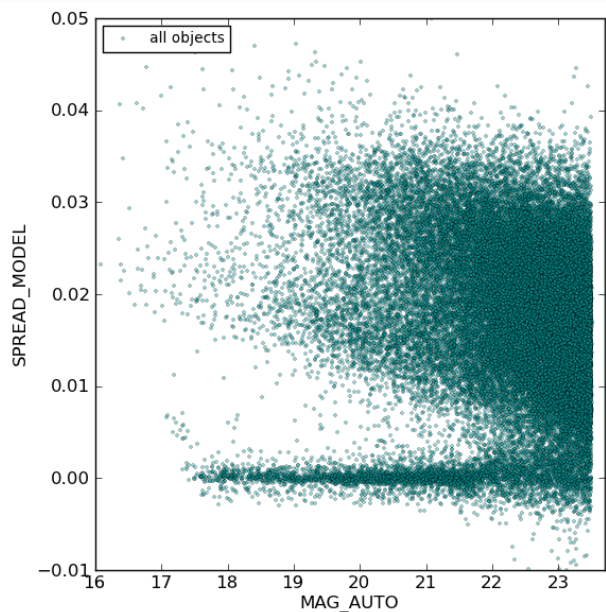
For $\langle n_{\text{relics}} \rangle \sim 5 \cdot 10^{-7} \text{ Mpc}^{-3}$

$n_{\text{expected}} \sim \mathbf{65}$

Working with coadds: avoiding PSF discontinuities

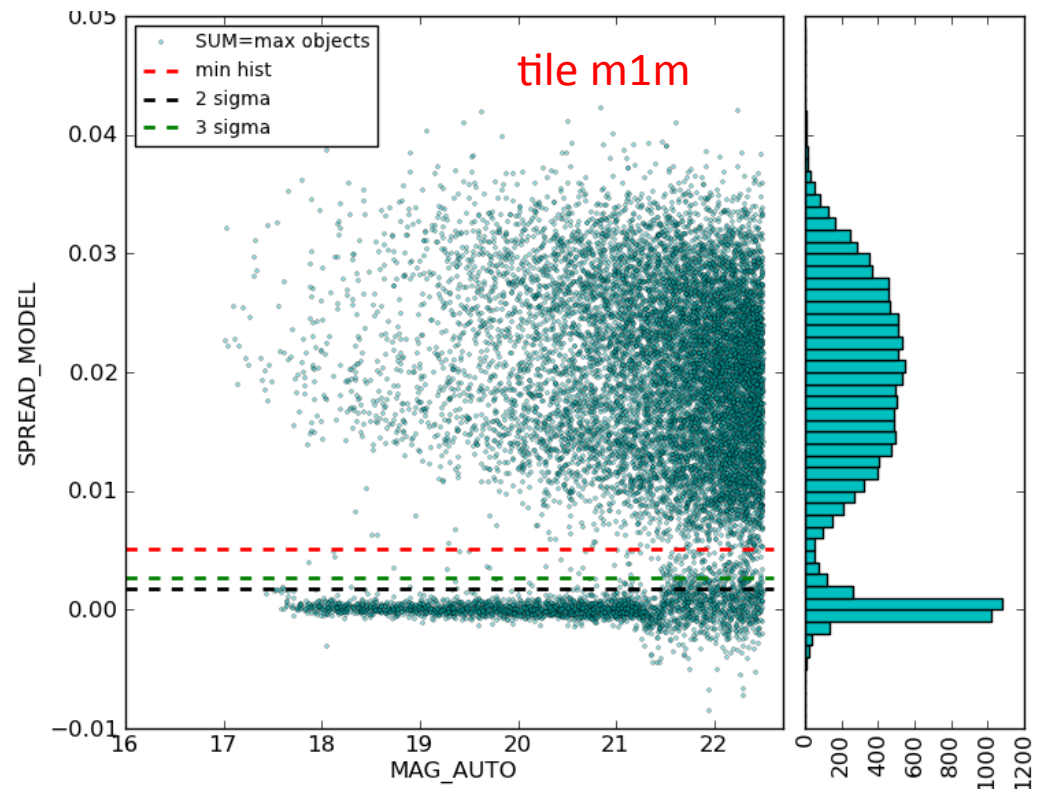


Examples: p28m and m33m tiles



Star/Galaxy separation -I-

- fit by a gaussian of the star branch
- objects with $\text{SPREAD_MODEL} > \mu + 2\sigma$ are potentially galaxies (black dashed line on the graph)



possible contamination by stars, corrected later by a color selection

Stellar masses and redshifts

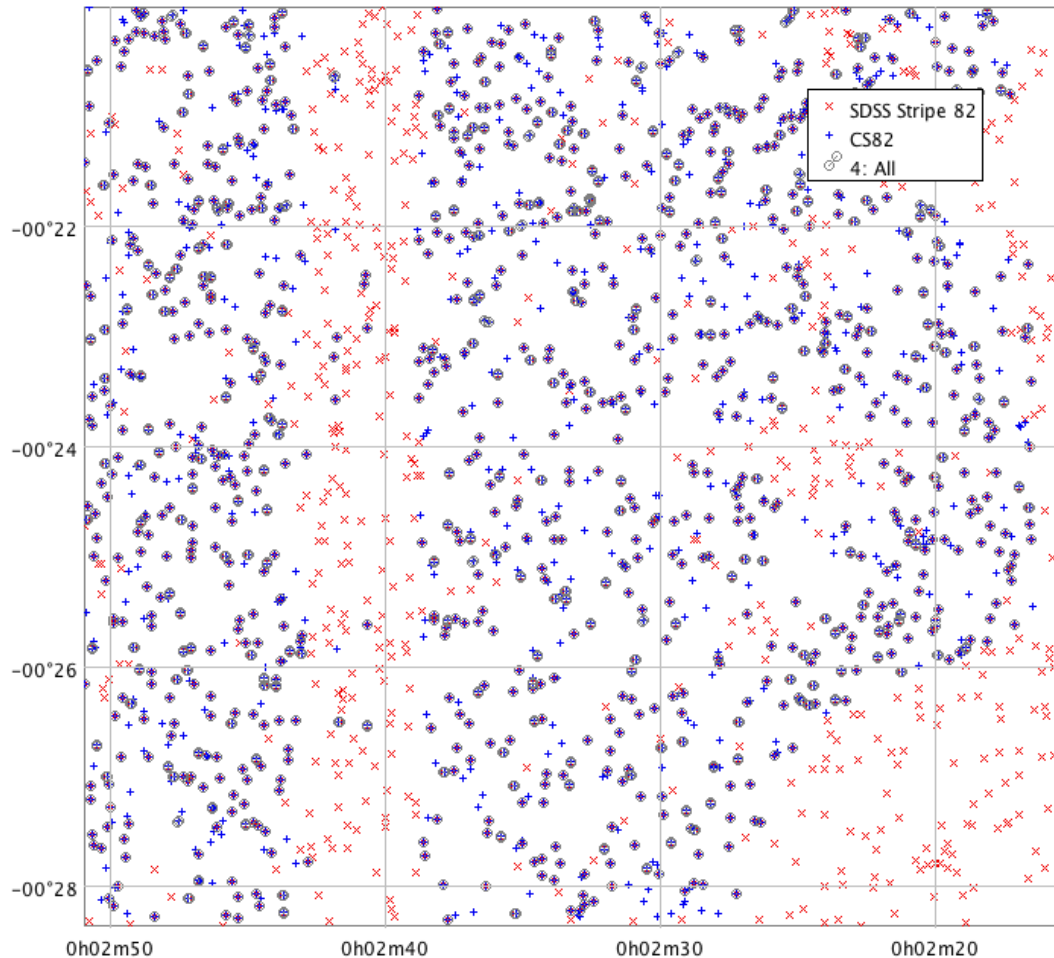
Redshift: SDSS photometric (Reis+2012) + spectroscopy

Stellar masses: Kevin Bundy's code, SYNMASS Bundy+2012

- | | |
|-----------------------|------------|
| • full SDSS-Stripe 82 | 15,342,585 |
| • masked CS82 | 9,647,535 |

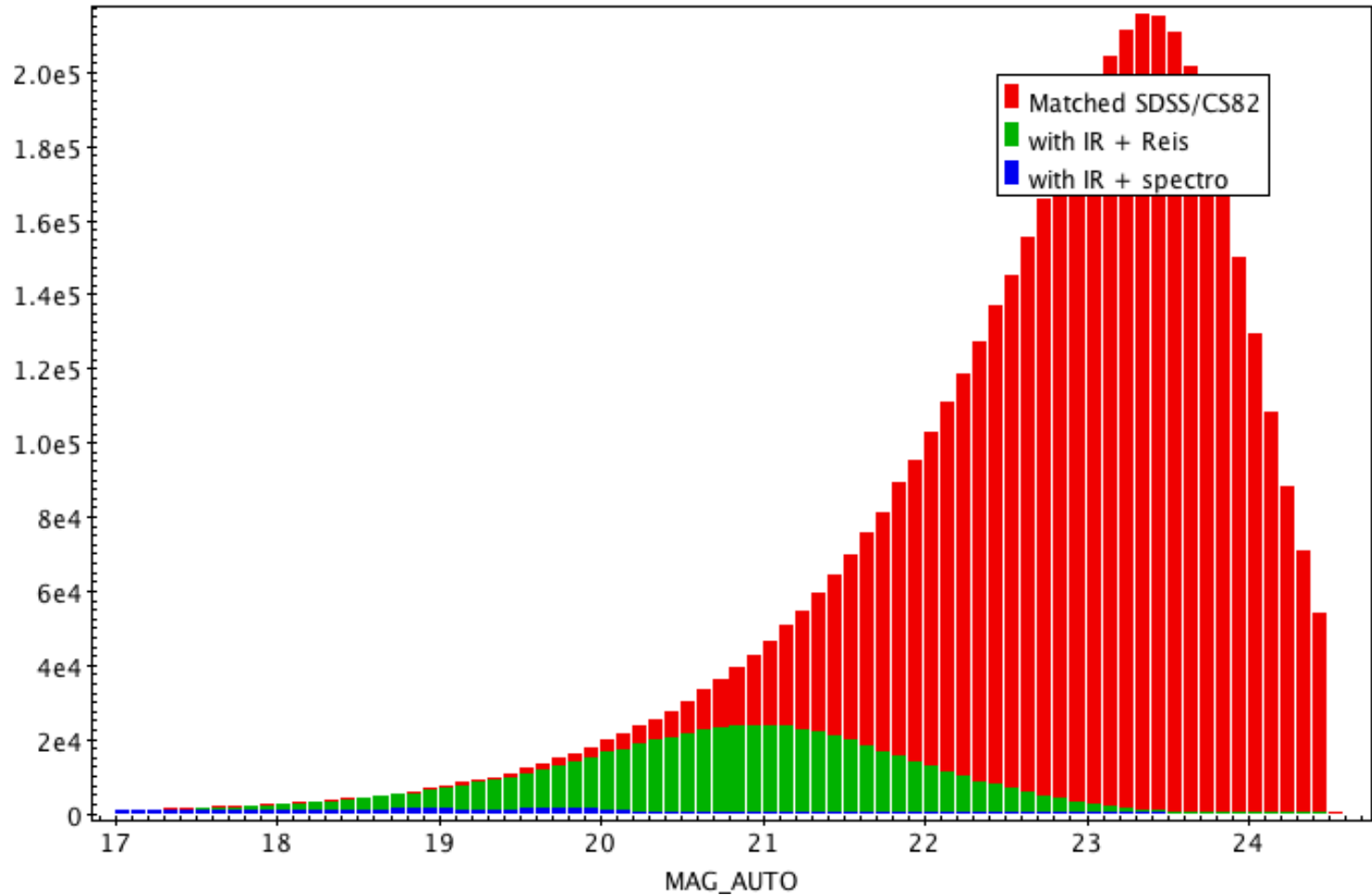
- | | |
|---------------------------------|-----------|
| • matching | 5,928,169 |
| • stars | 930,379 |
| • galaxies | 4,997,790 |
| • near-IR photometry + redshift | 643,441 |

Matching SDSS/CS82



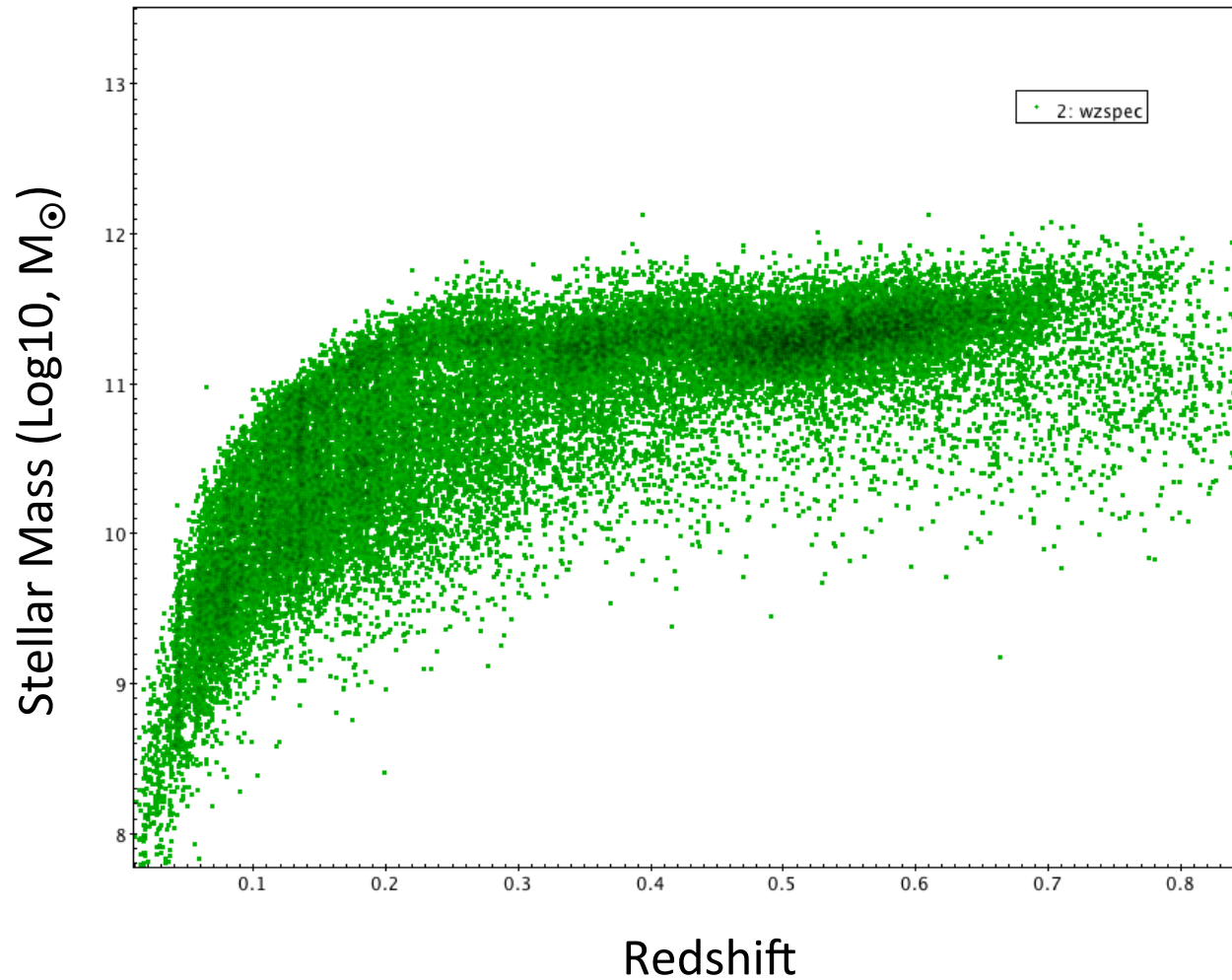
- CS82 masked regions appear clearly
- almost 1-to-1 matching

Near-IR data: lower completeness



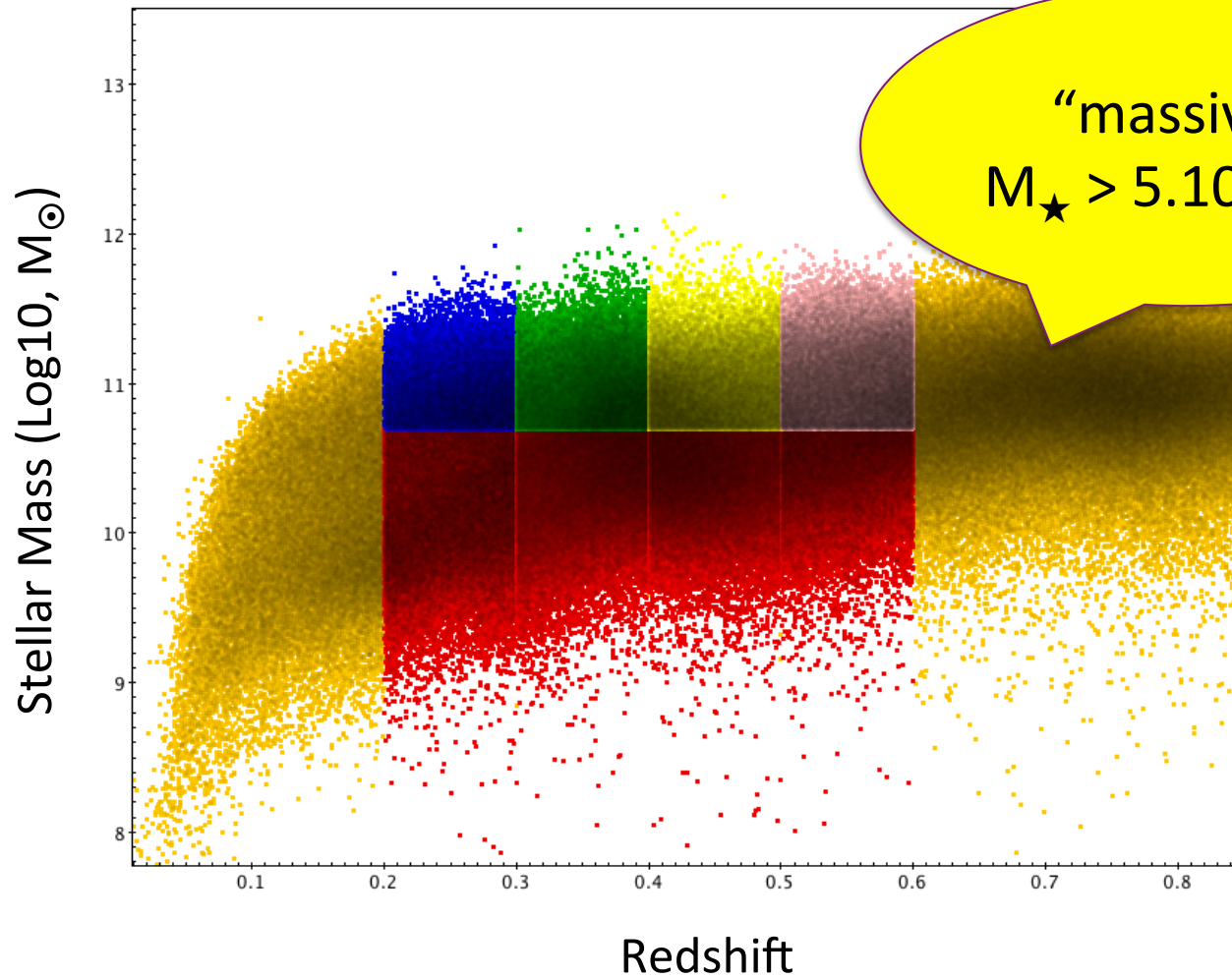
Spectroscopic data

33,295 galaxies



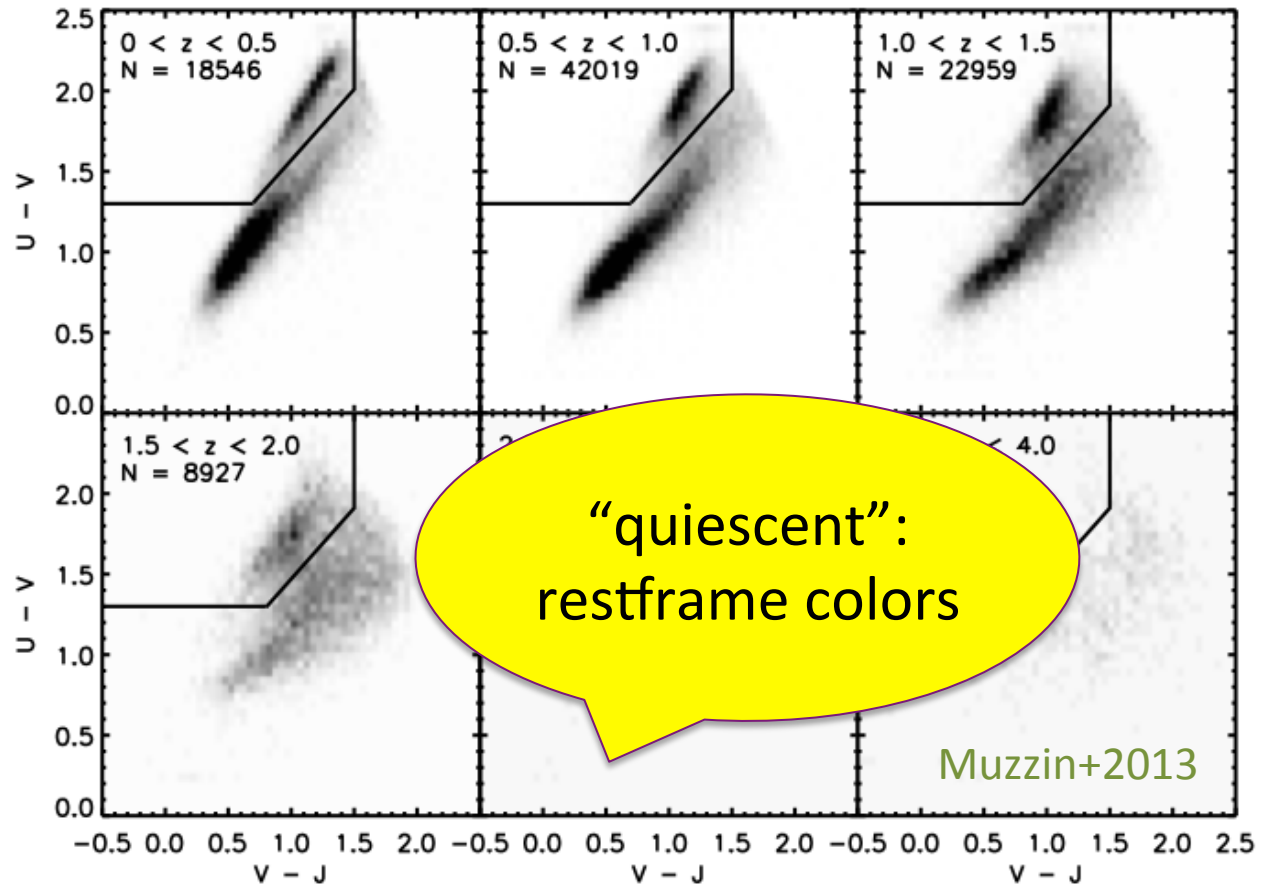
Photometric data

610,146 galaxies



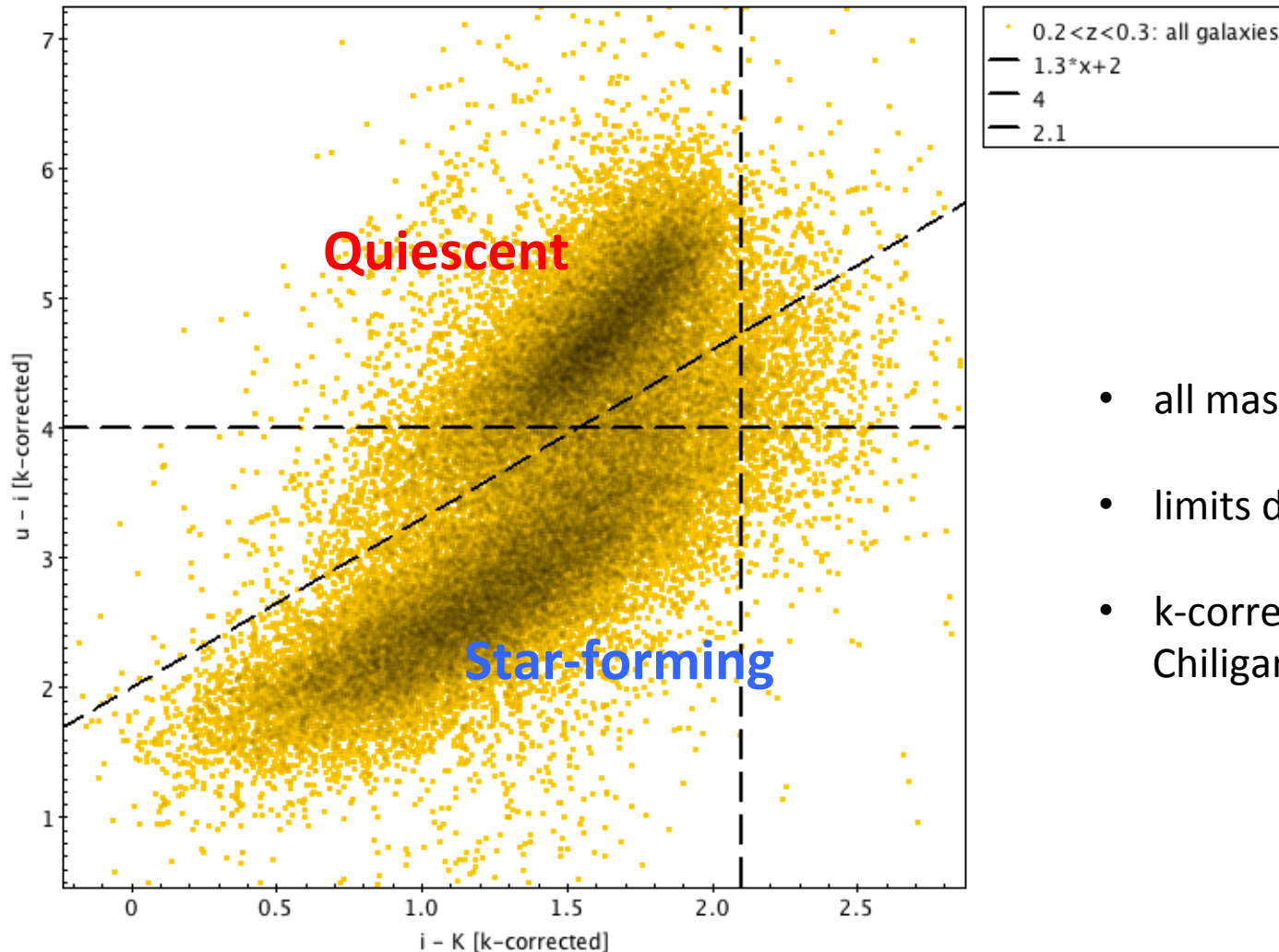
Quiescent/Star Forming selection

- restframe colors
- (U-V) vs. (V-J)
- COSMOS field



$0.2 < z < 0.3$

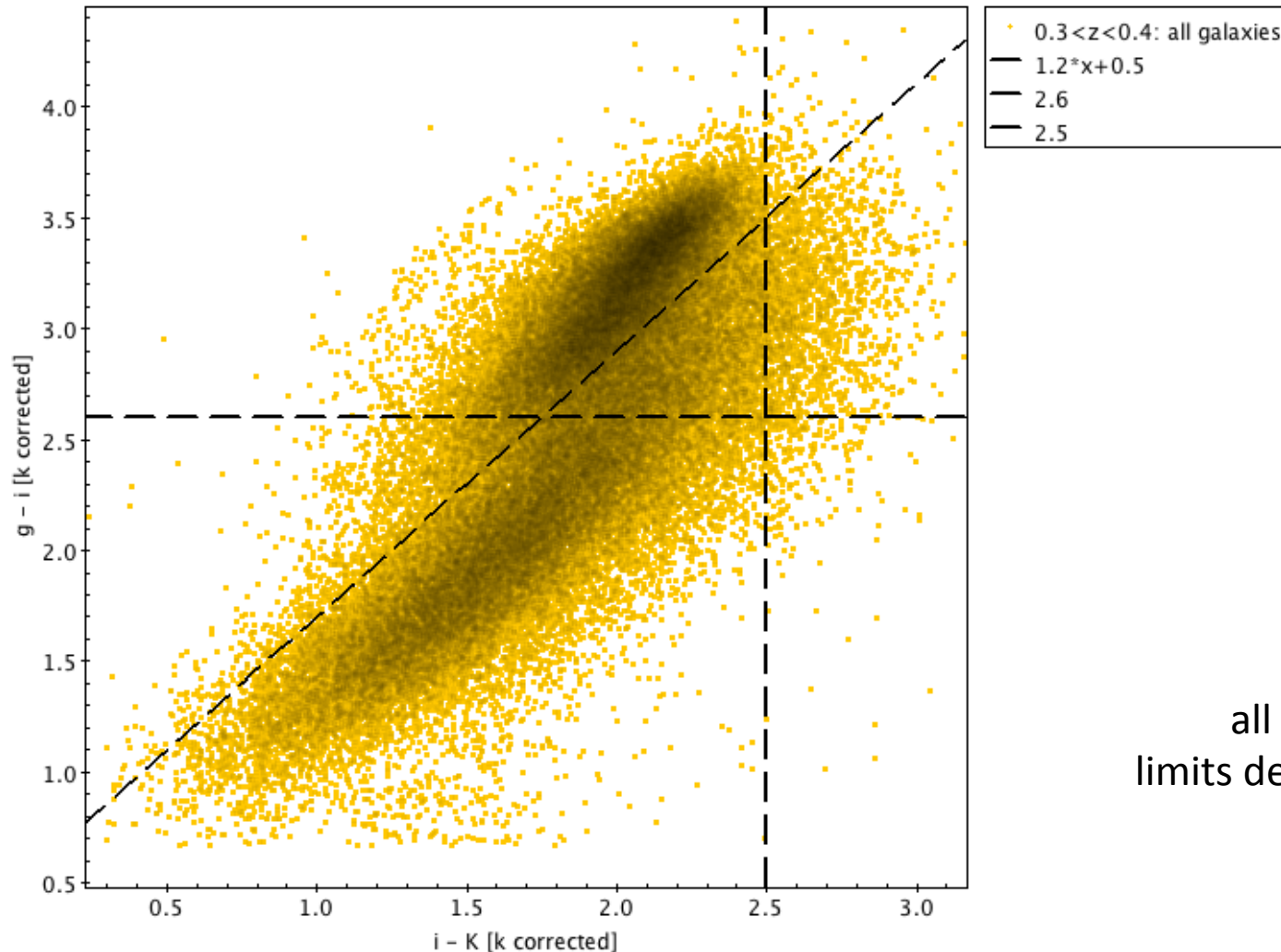
(u-i) vs. (i-K) with k-correction



- all masses
- limits defined by eye
- k-correction using Chiligarian+2010

$0.3 < z < 0.4$

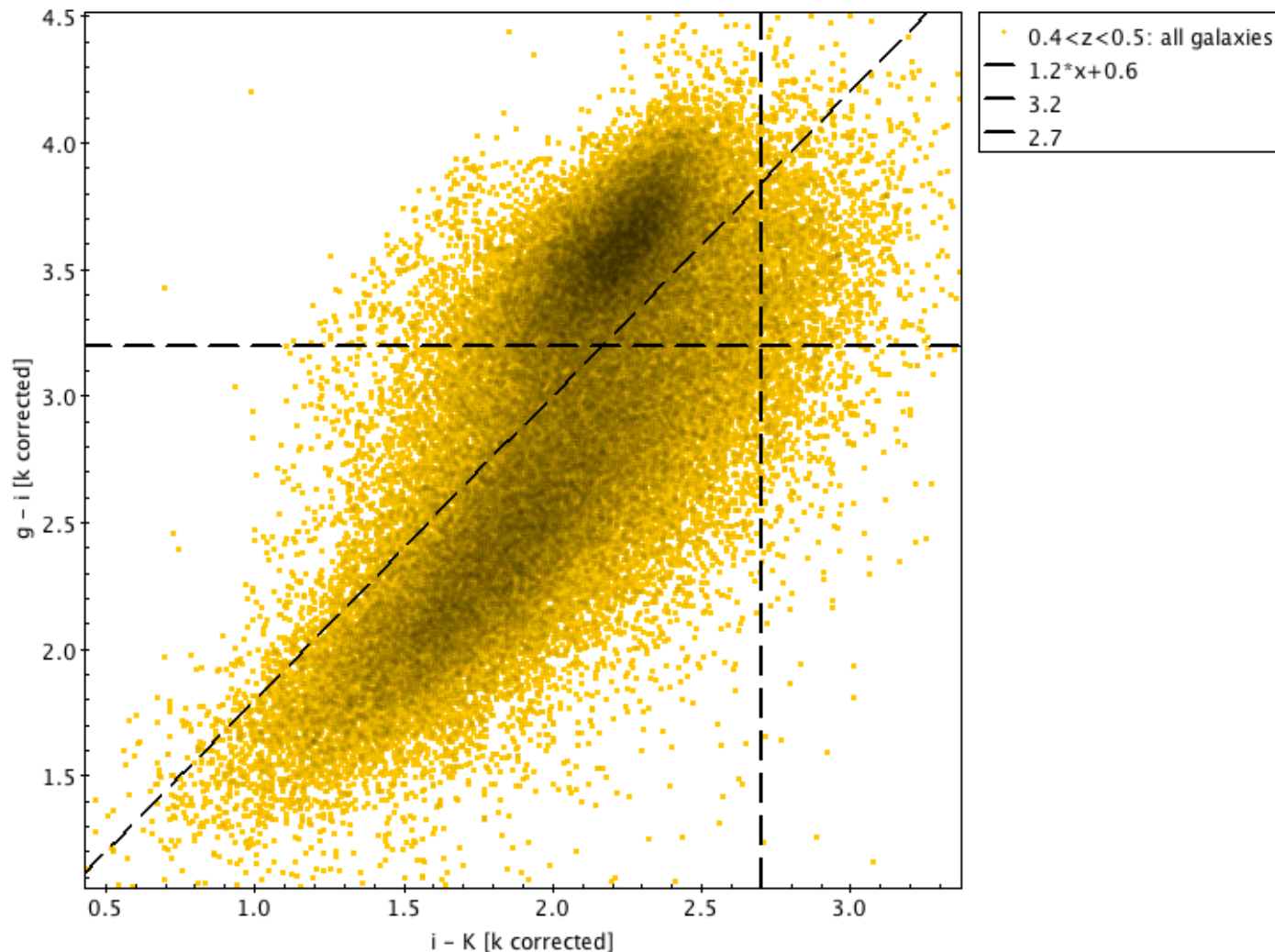
(g-i) vs. (i-K) with k-correction



all masses
limits defined by eye

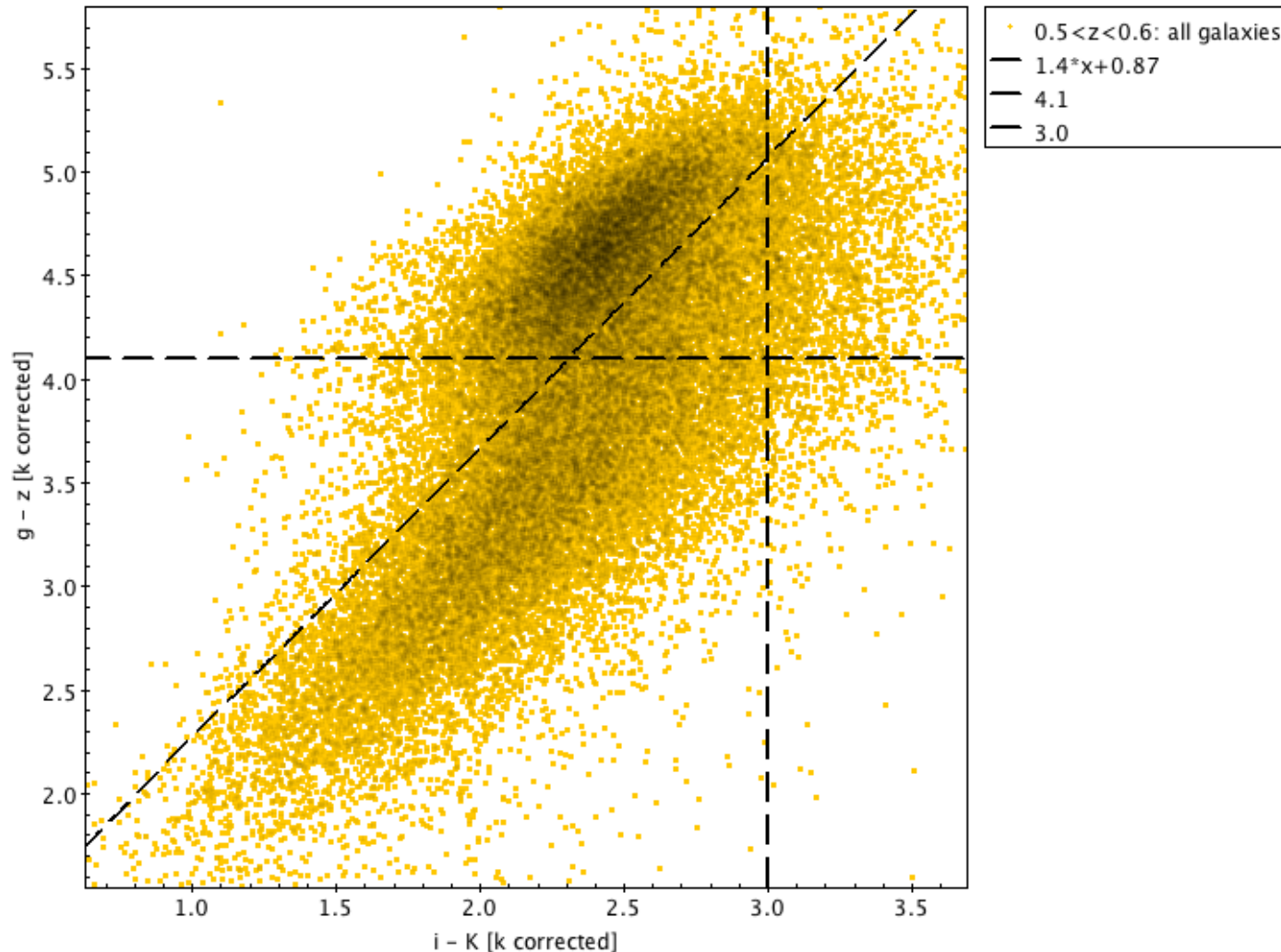
$0.4 < z < 0.5$

$(g-i)$ vs. $(i-K)$ with k-correction

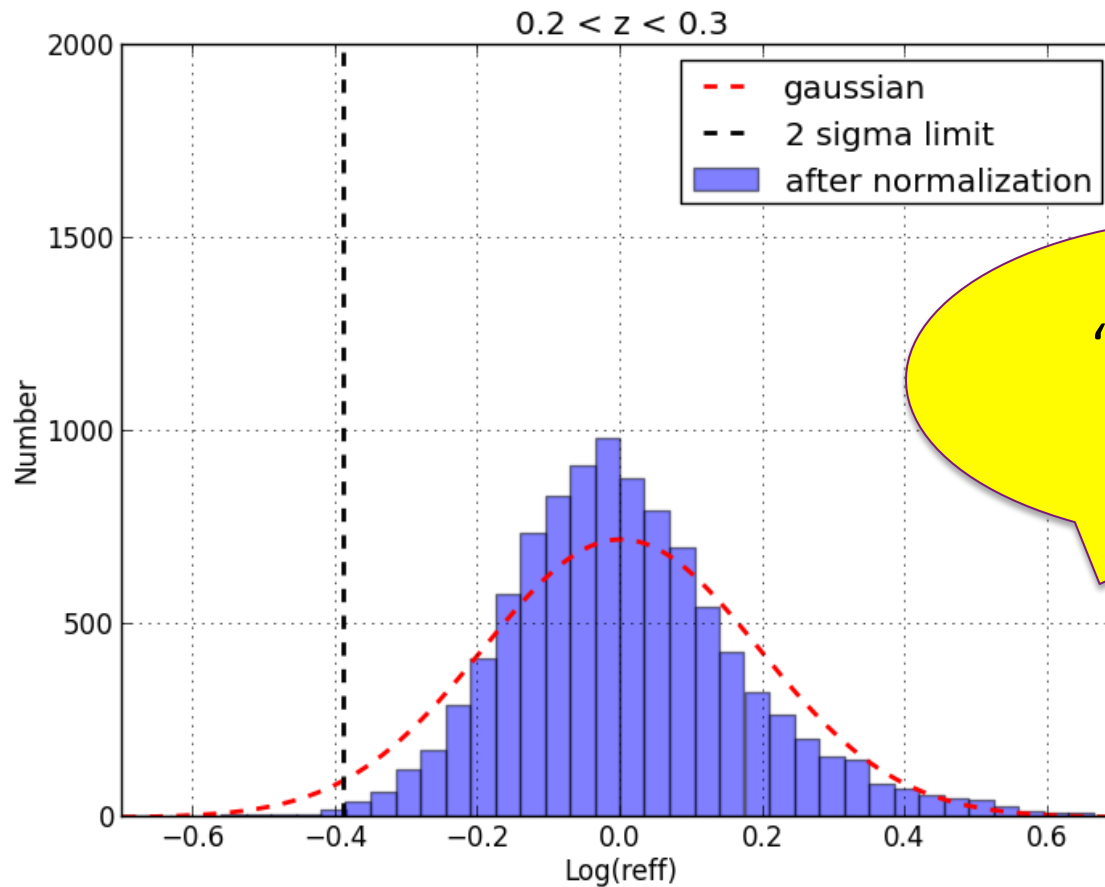


$0.5 < z < 0.6$

$(g-z)$ vs. $(i-K)$ with k-correction

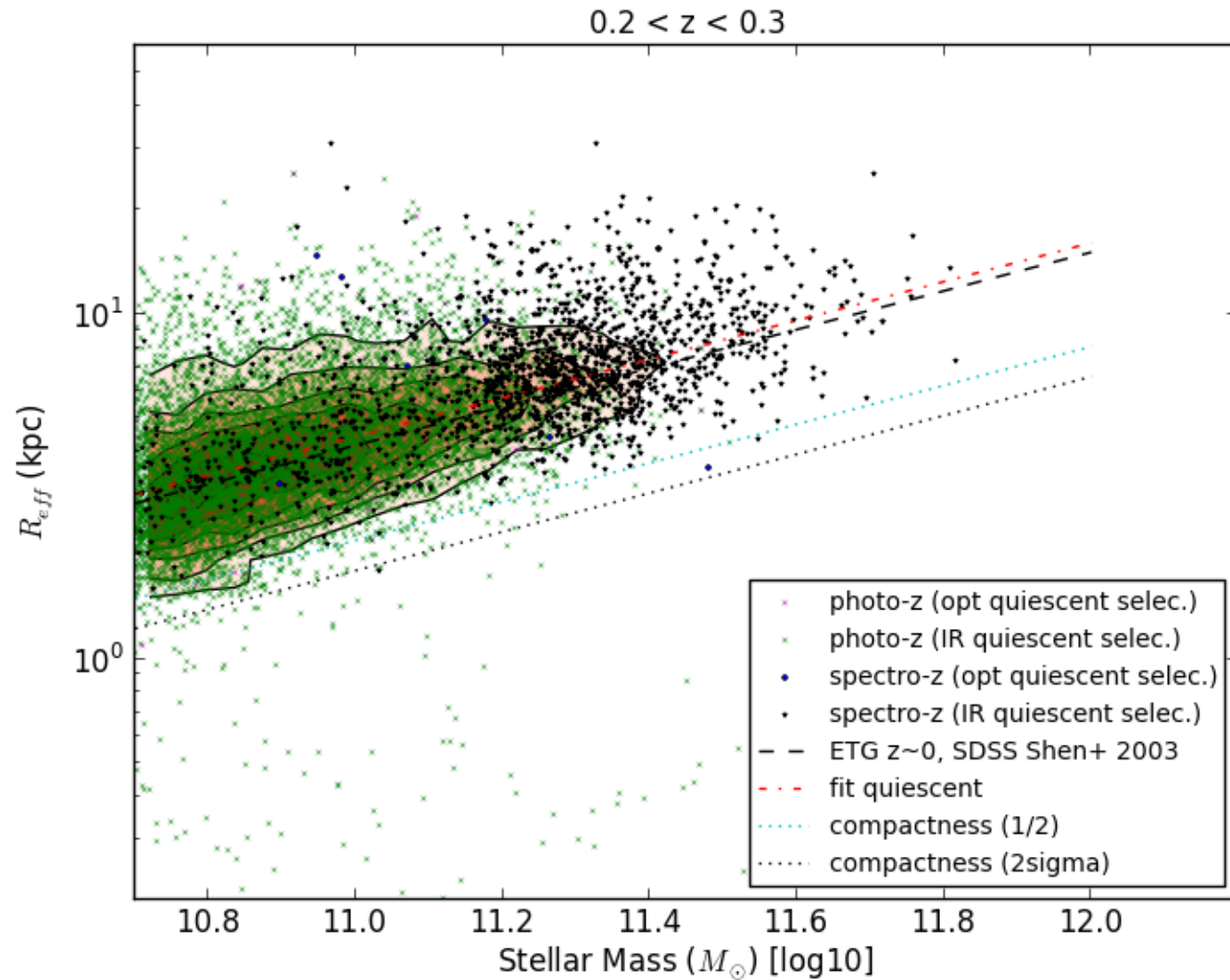


Selection of compact galaxies

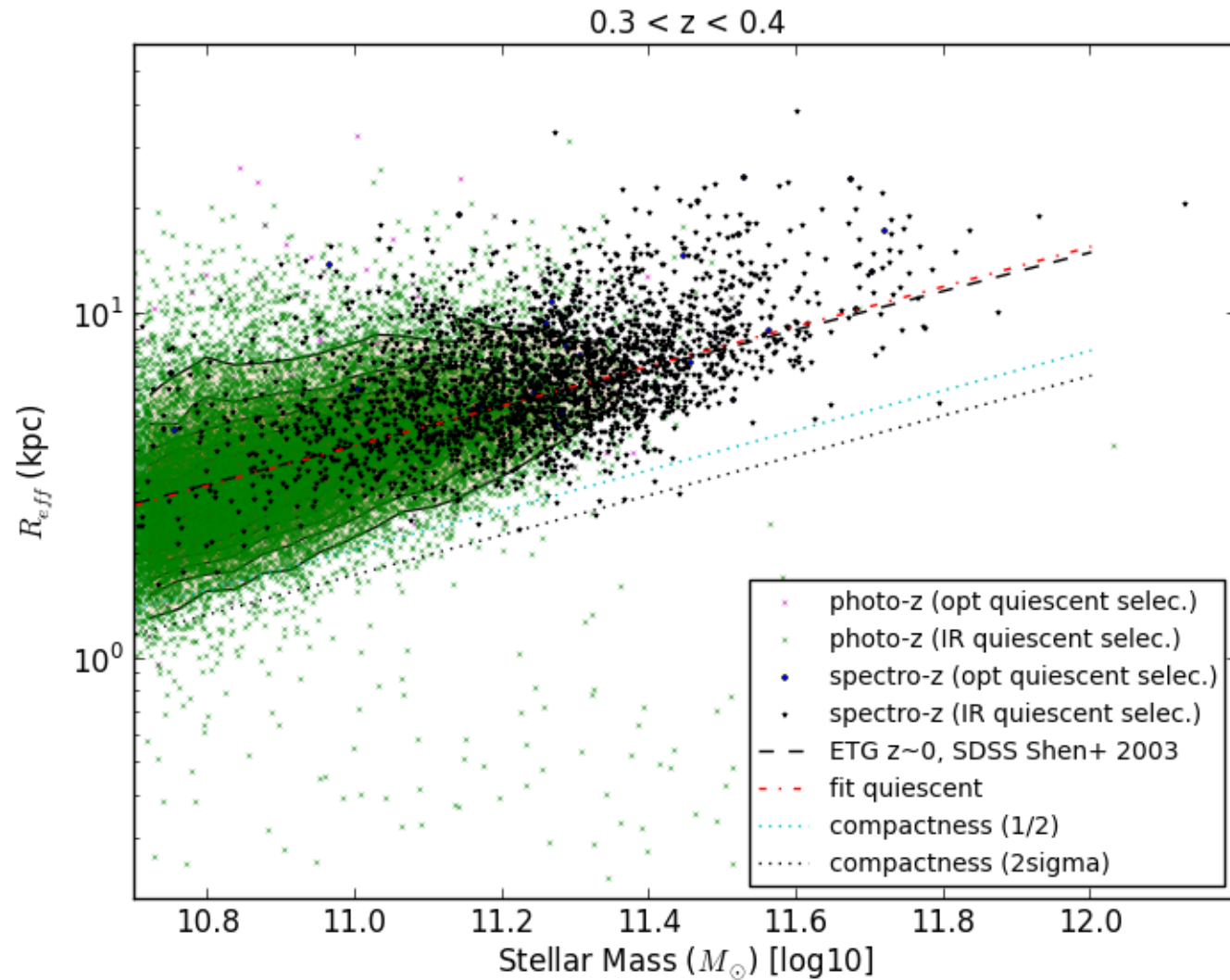


“compact”:
 $r_{\text{eff}} < \mu - 2\sigma$

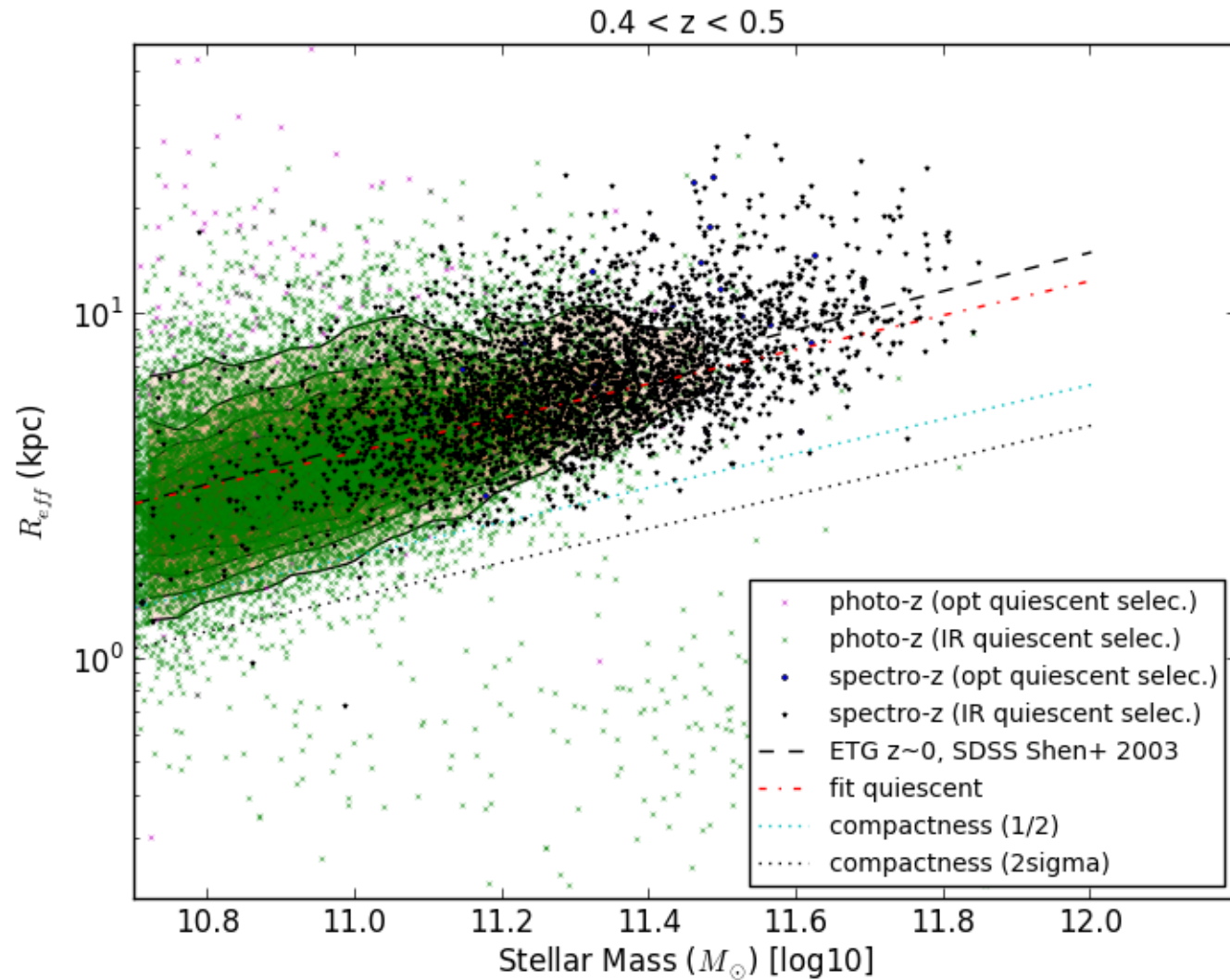
$$0.2 < z < 0.3$$



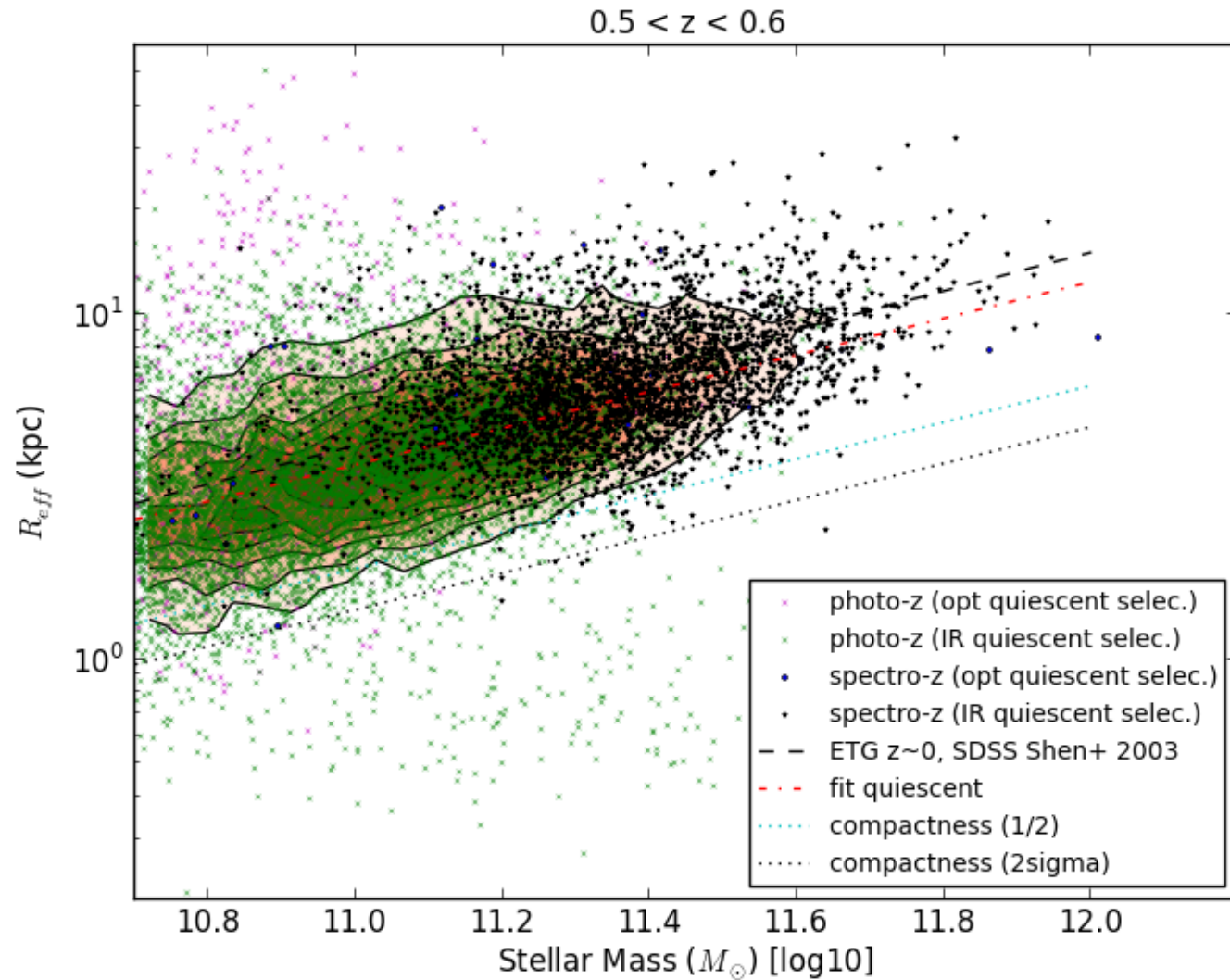
$$0.3 < z < 0.4$$



$$0.4 < z < 0.5$$

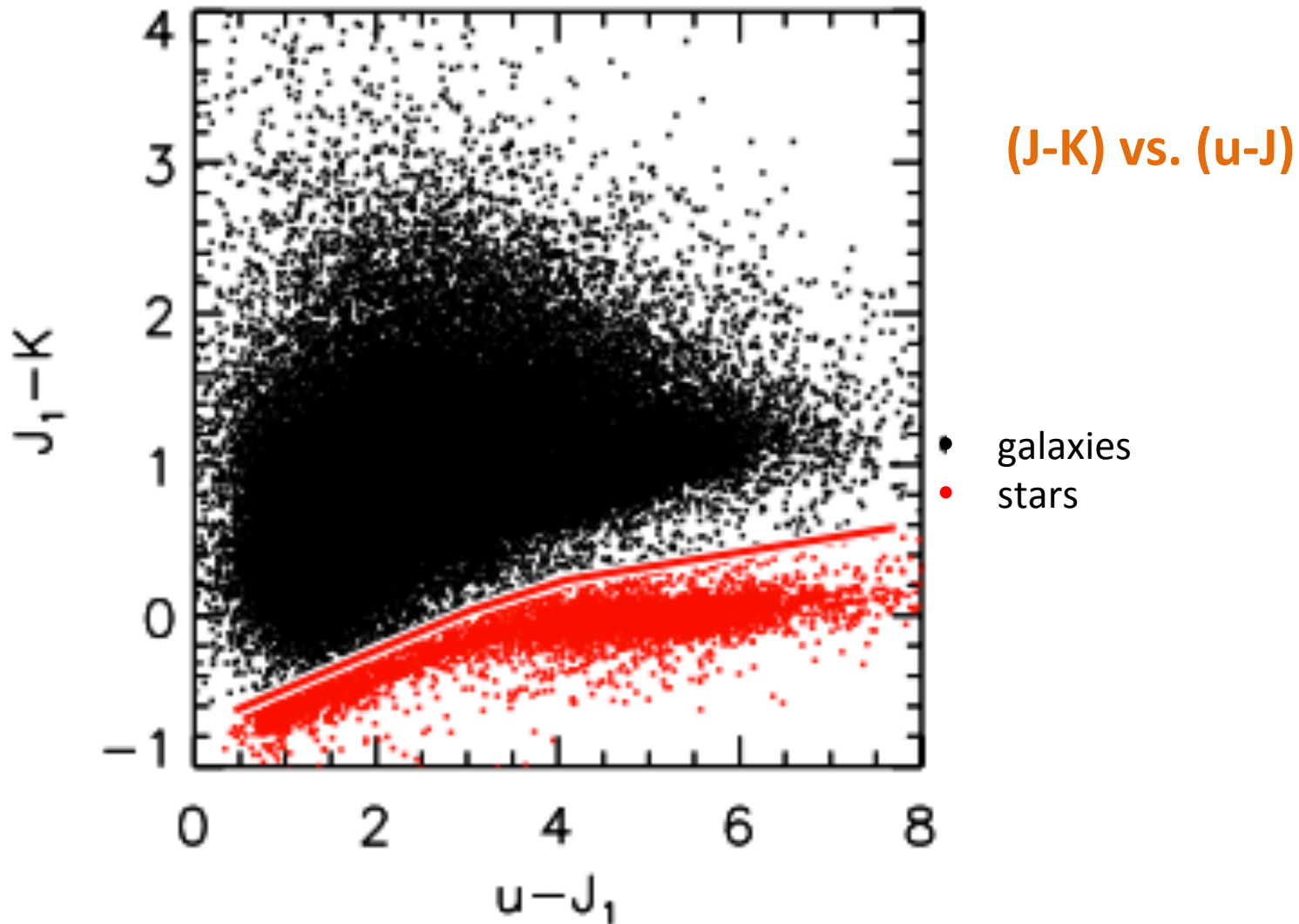


$$0.5 < z < 0.6$$

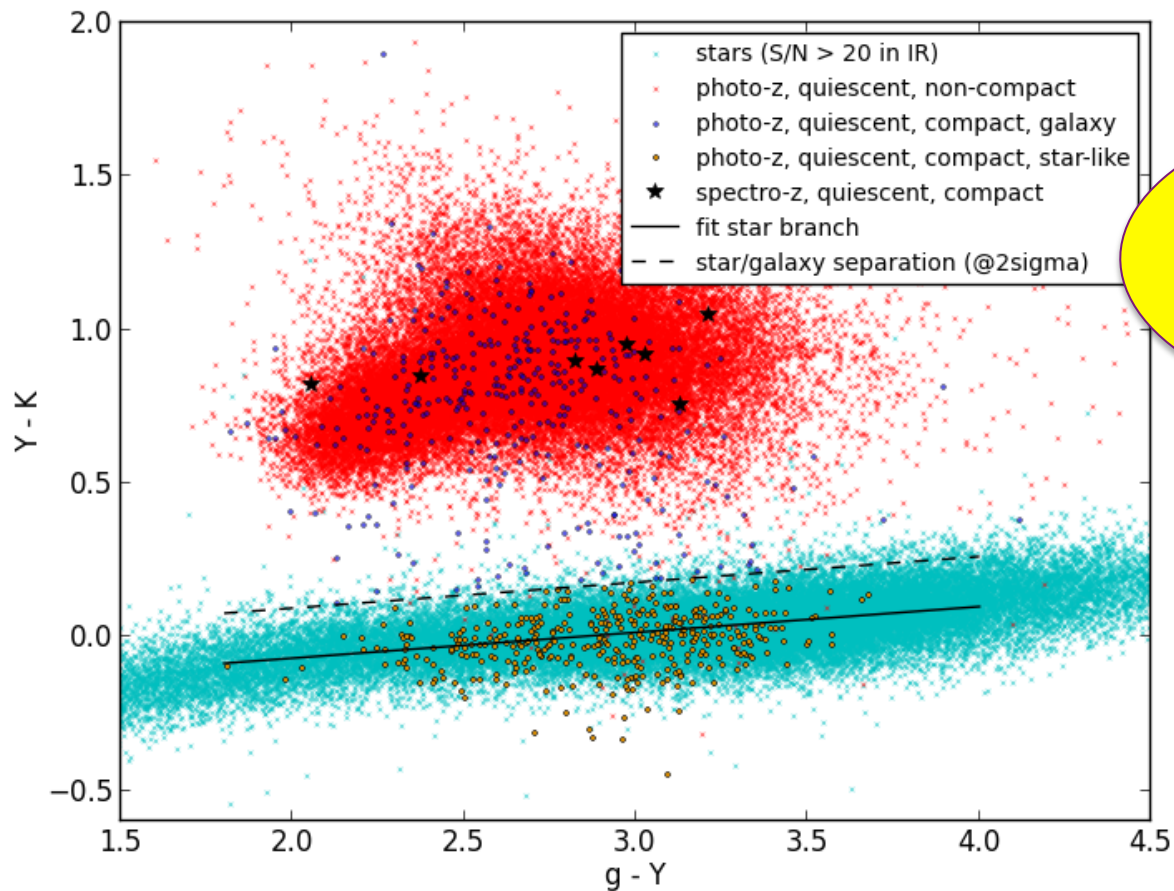


Star/Galaxy separation -II-

Whitaker+2011

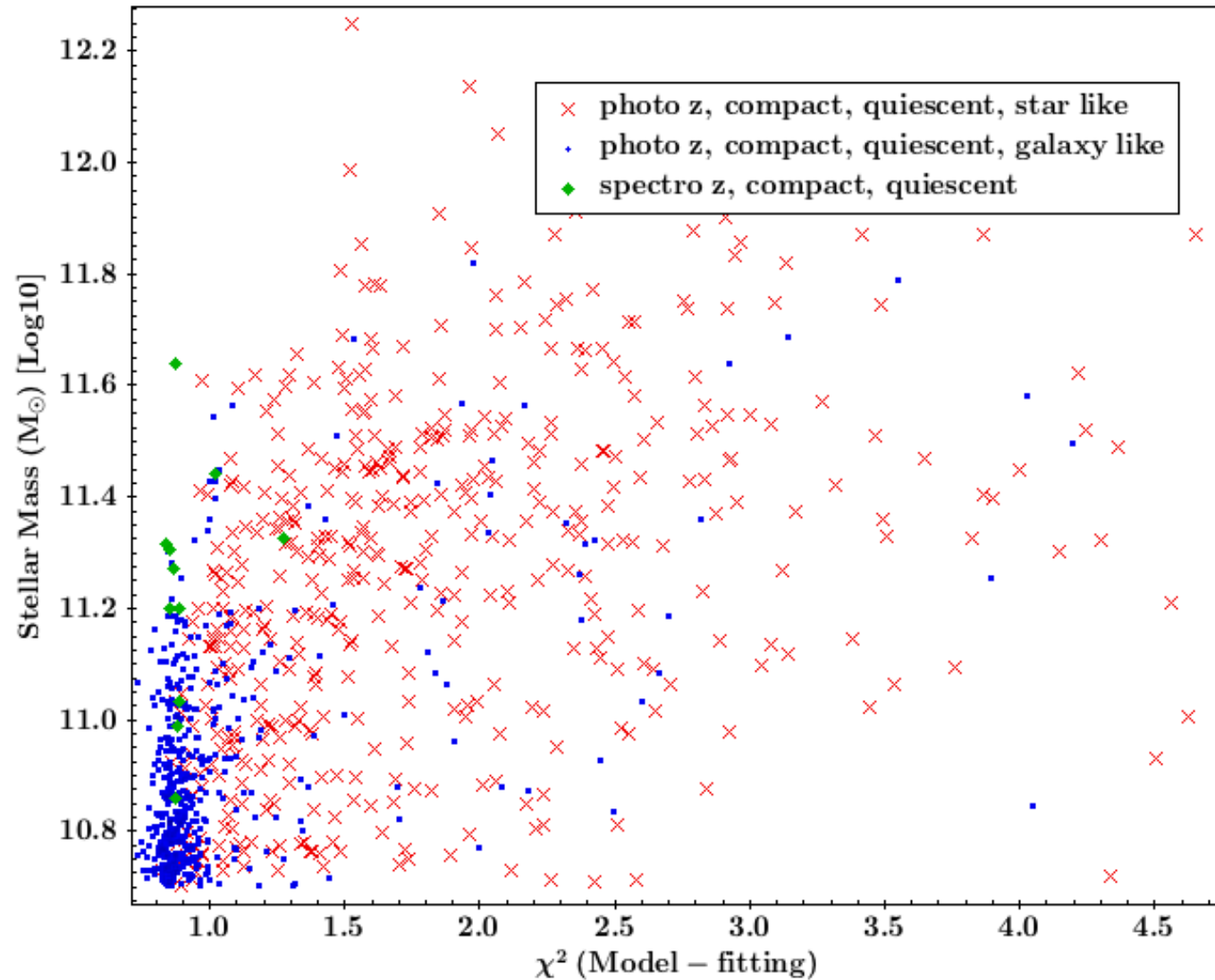


Star/Galaxy separation -II- (Y-K) vs. (g-Y)

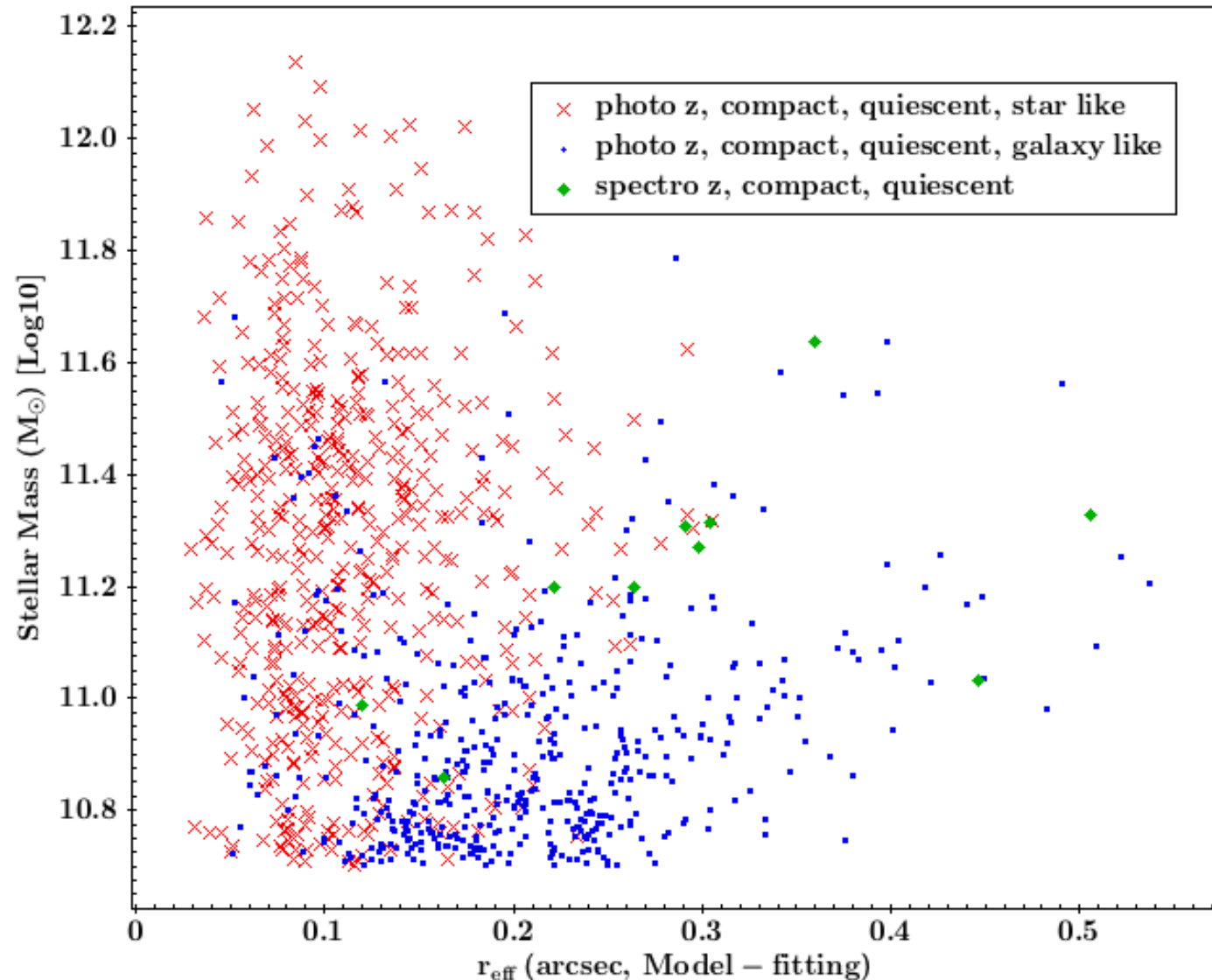


“galaxy”:
(color) > $\mu + 2\sigma$

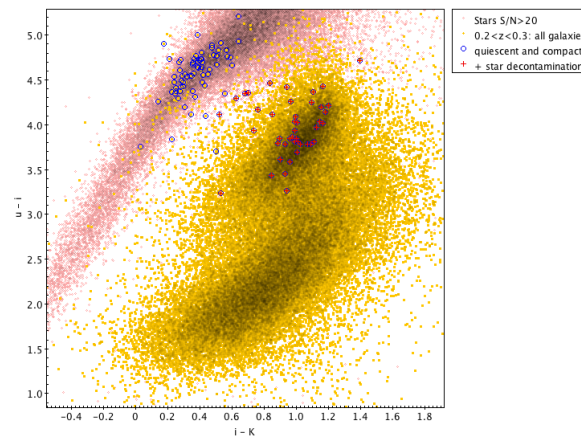
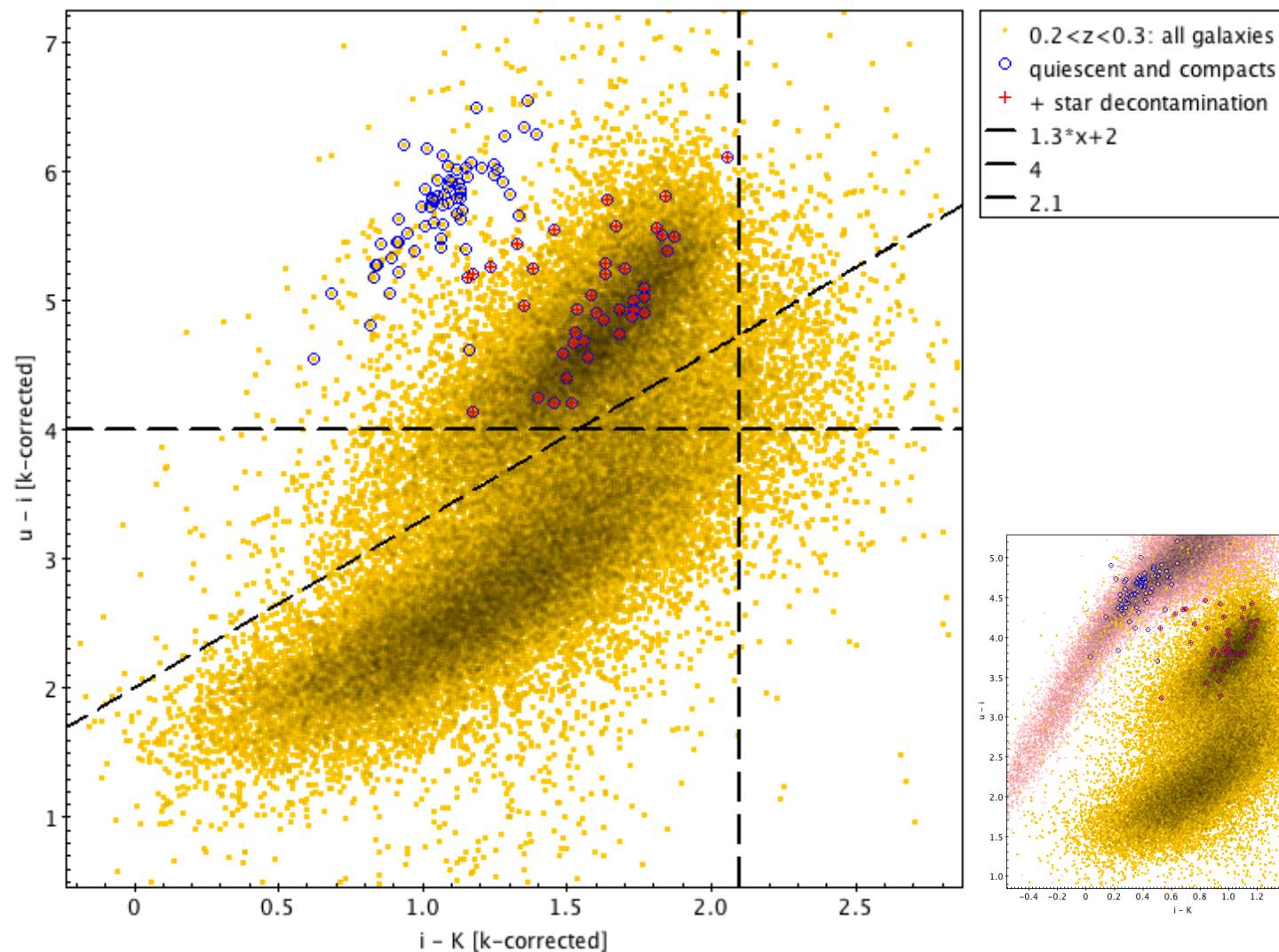
Stellar Mass vs. χ^2 (model)



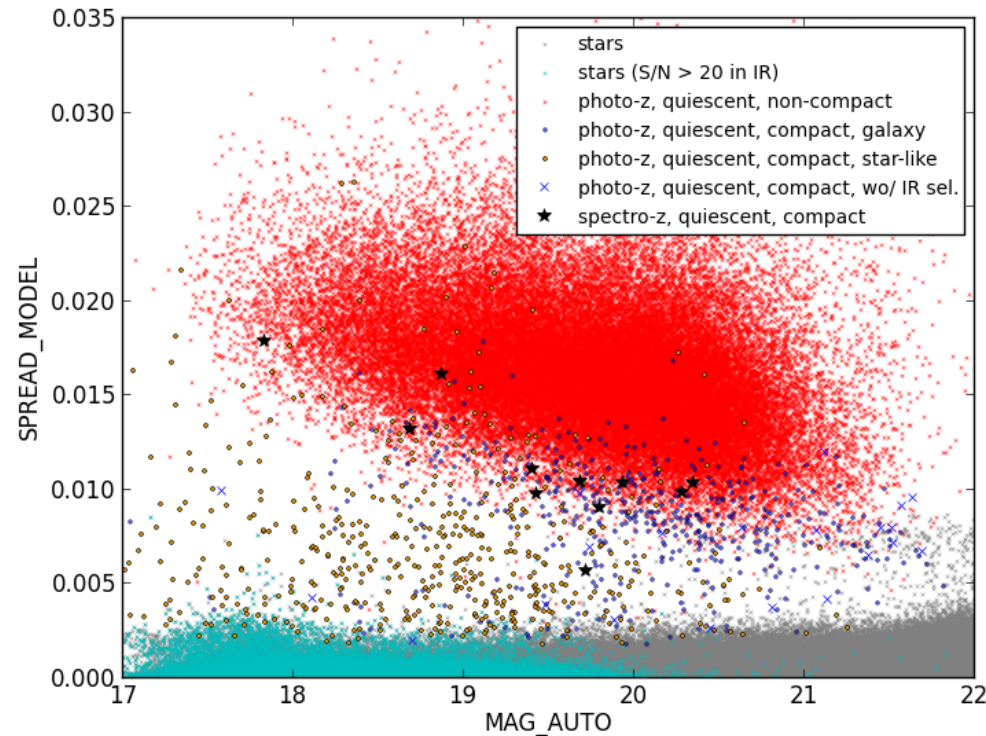
Stellar Mass vs. Effective radius



Further check

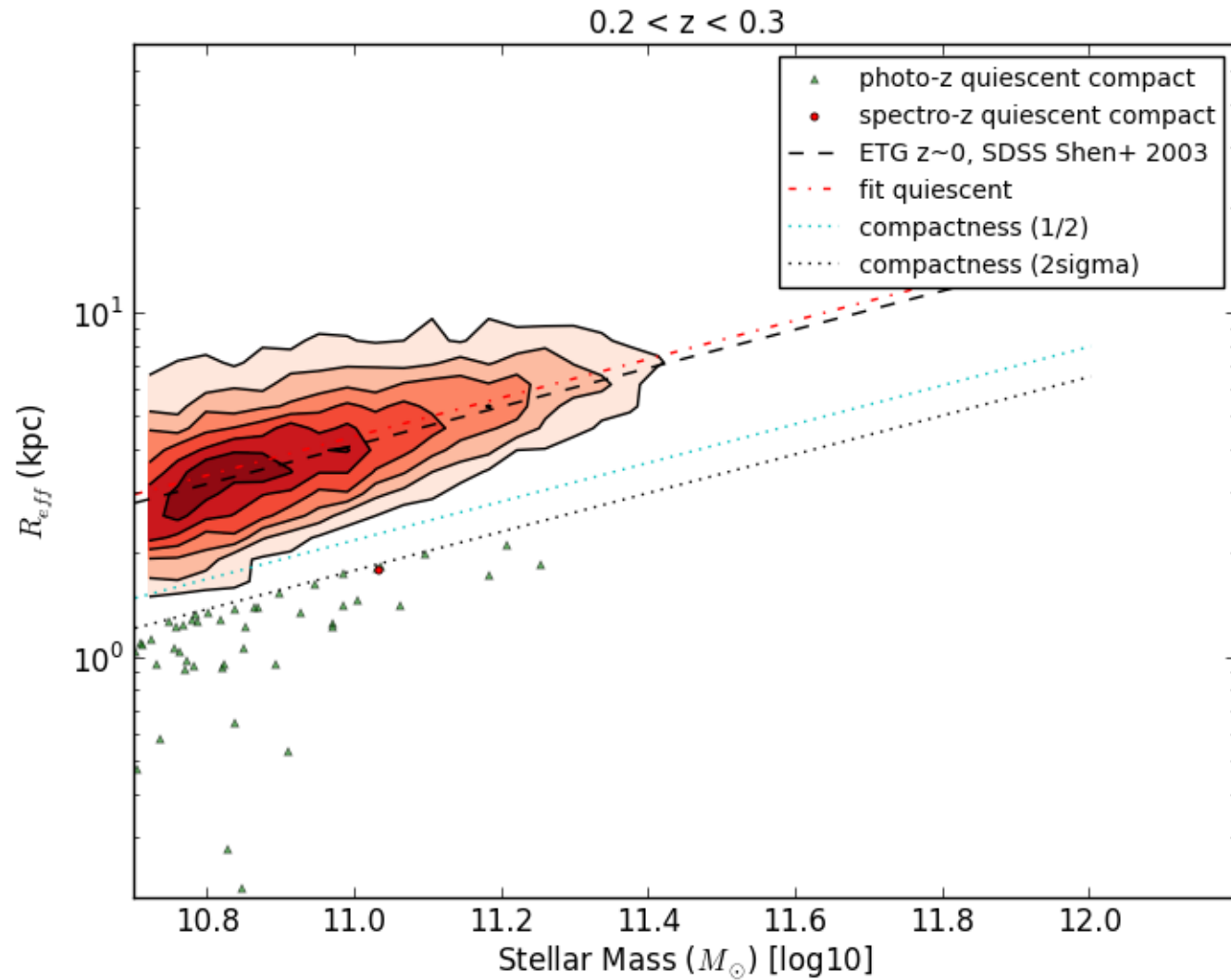


Compact quiescent massive galaxies

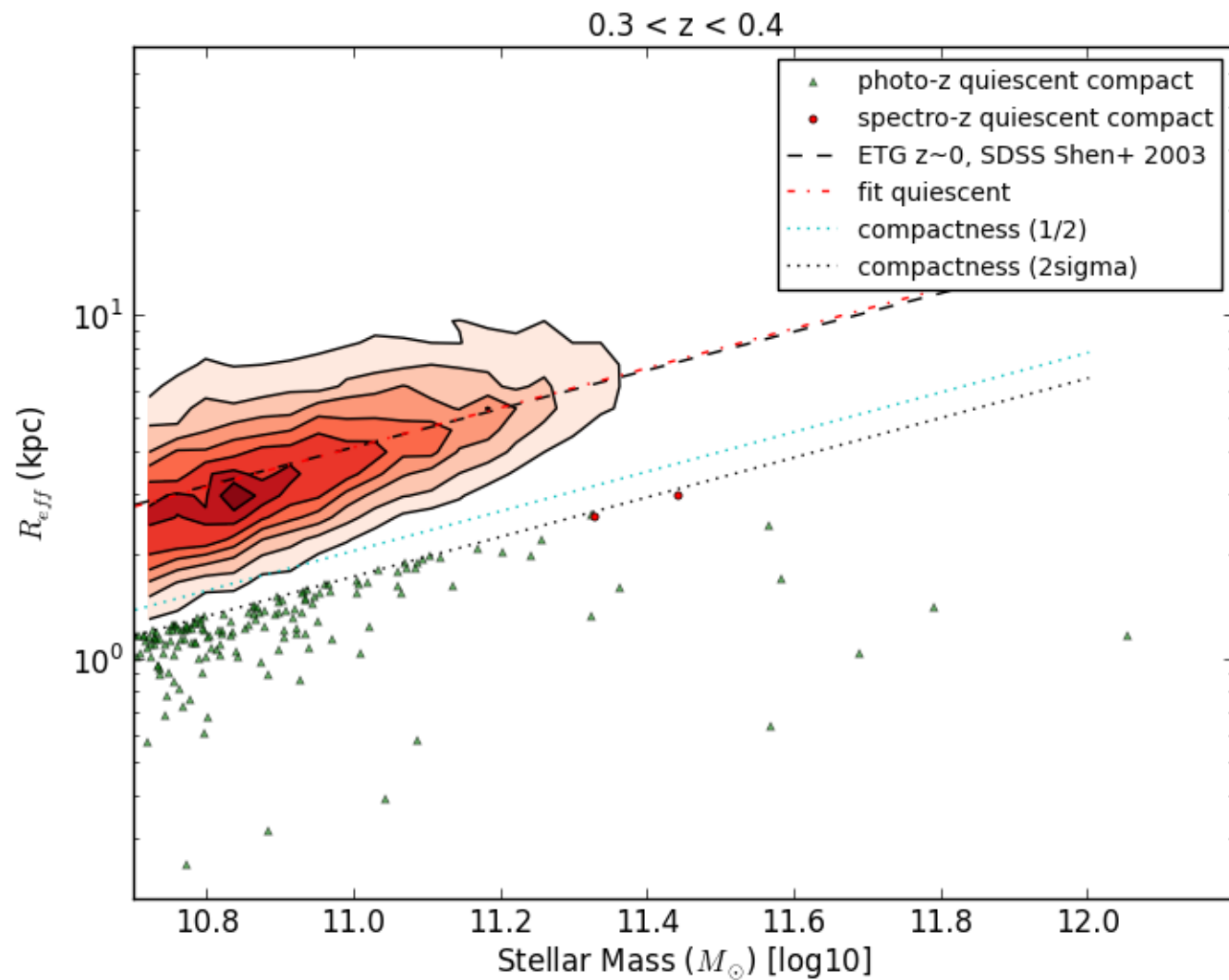


	Spectro-z Sample	Photo-z Sample
Quiescent	6422	51243
Quiescent compact	11	966
Quiescent compact galaxy-like	11	477

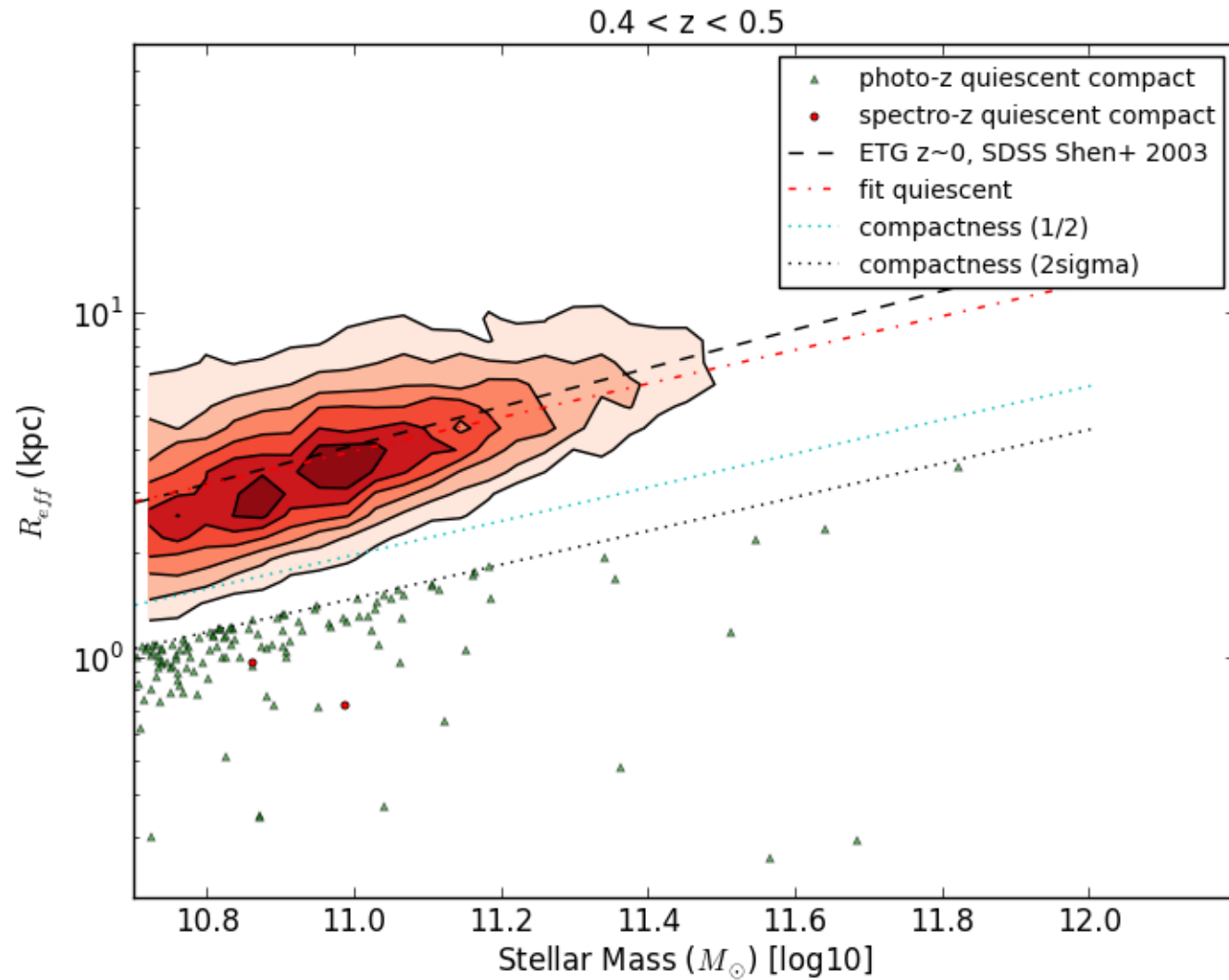
$$0.2 < z < 0.3$$



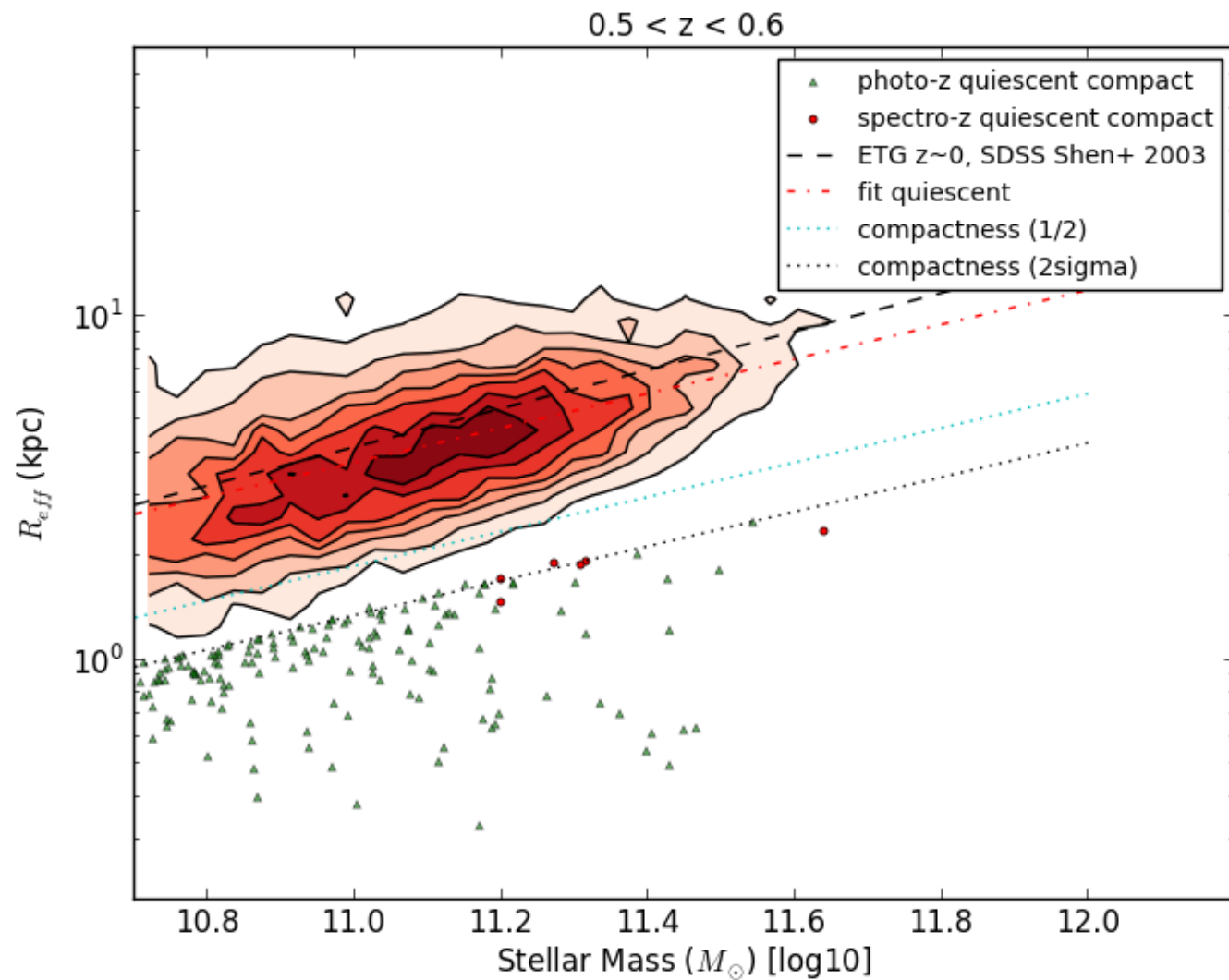
$$0.3 < z < 0.4$$



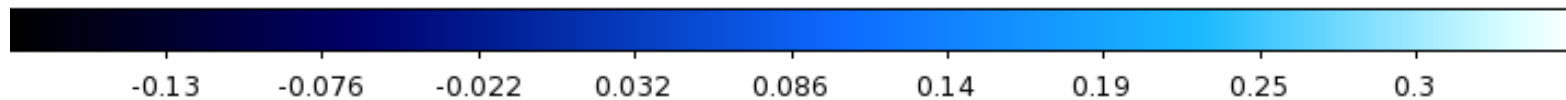
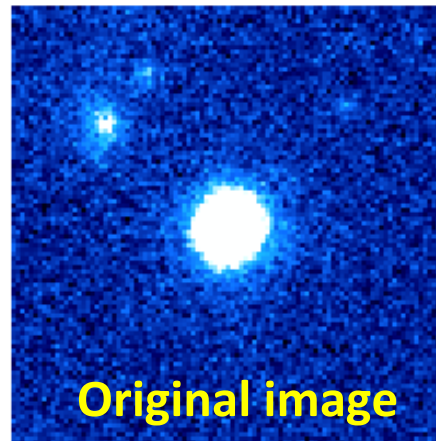
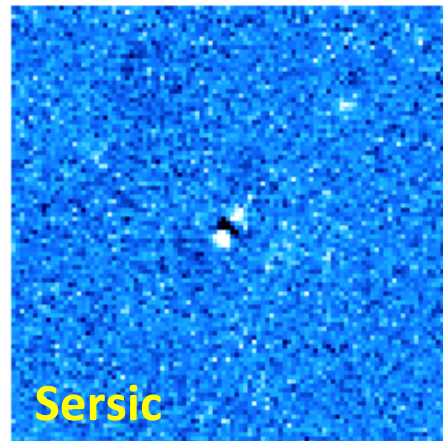
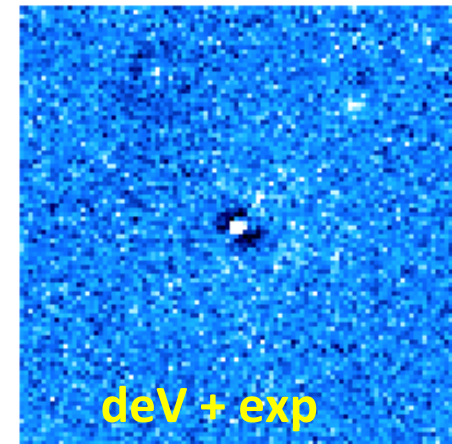
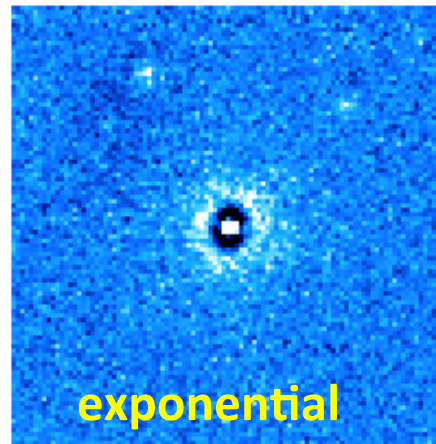
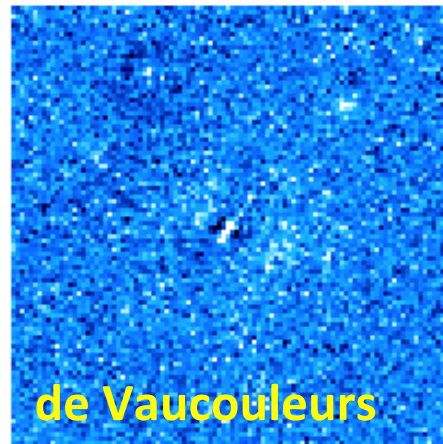
$$0.4 < z < 0.5$$



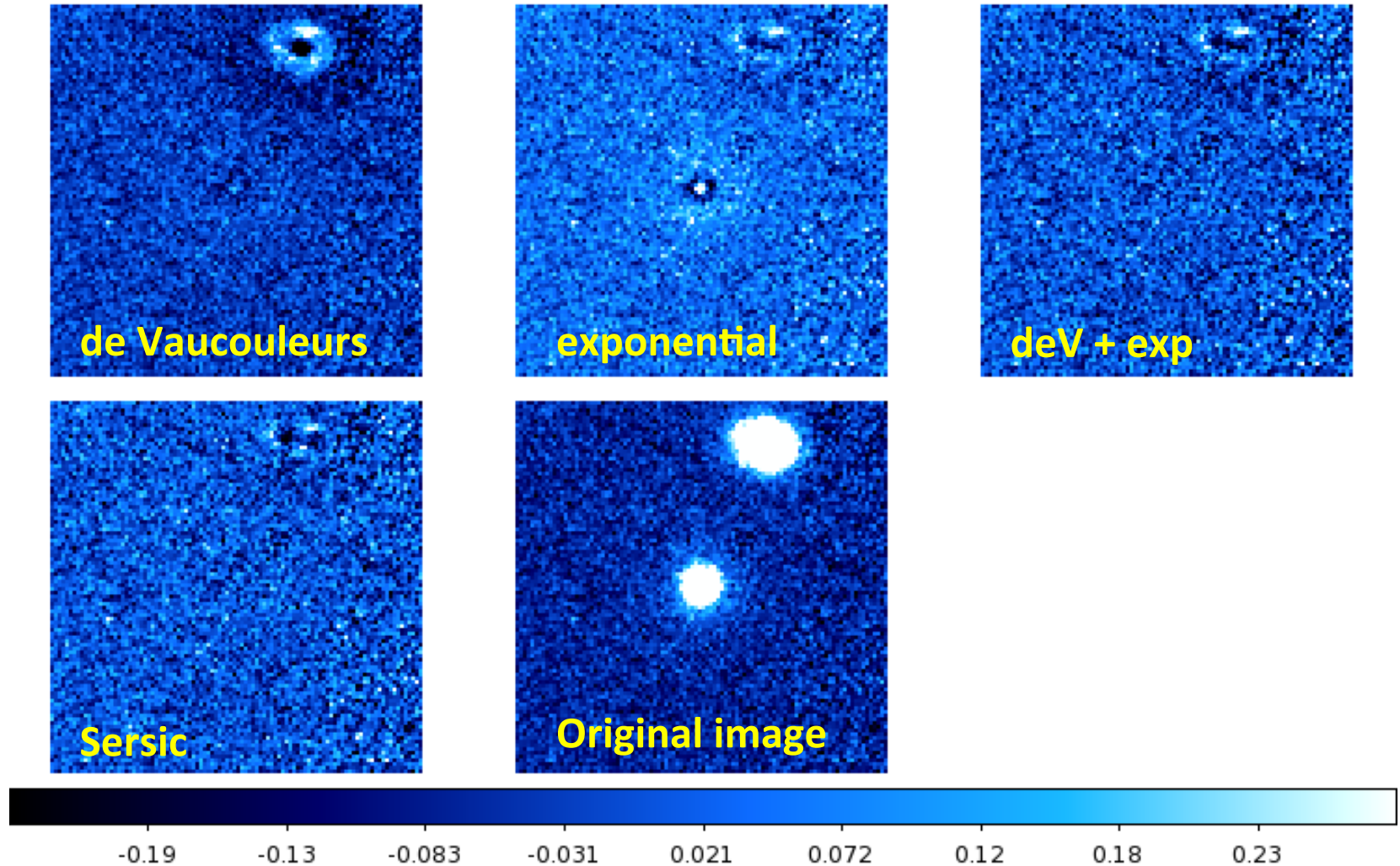
$$0.5 < z < 0.6$$



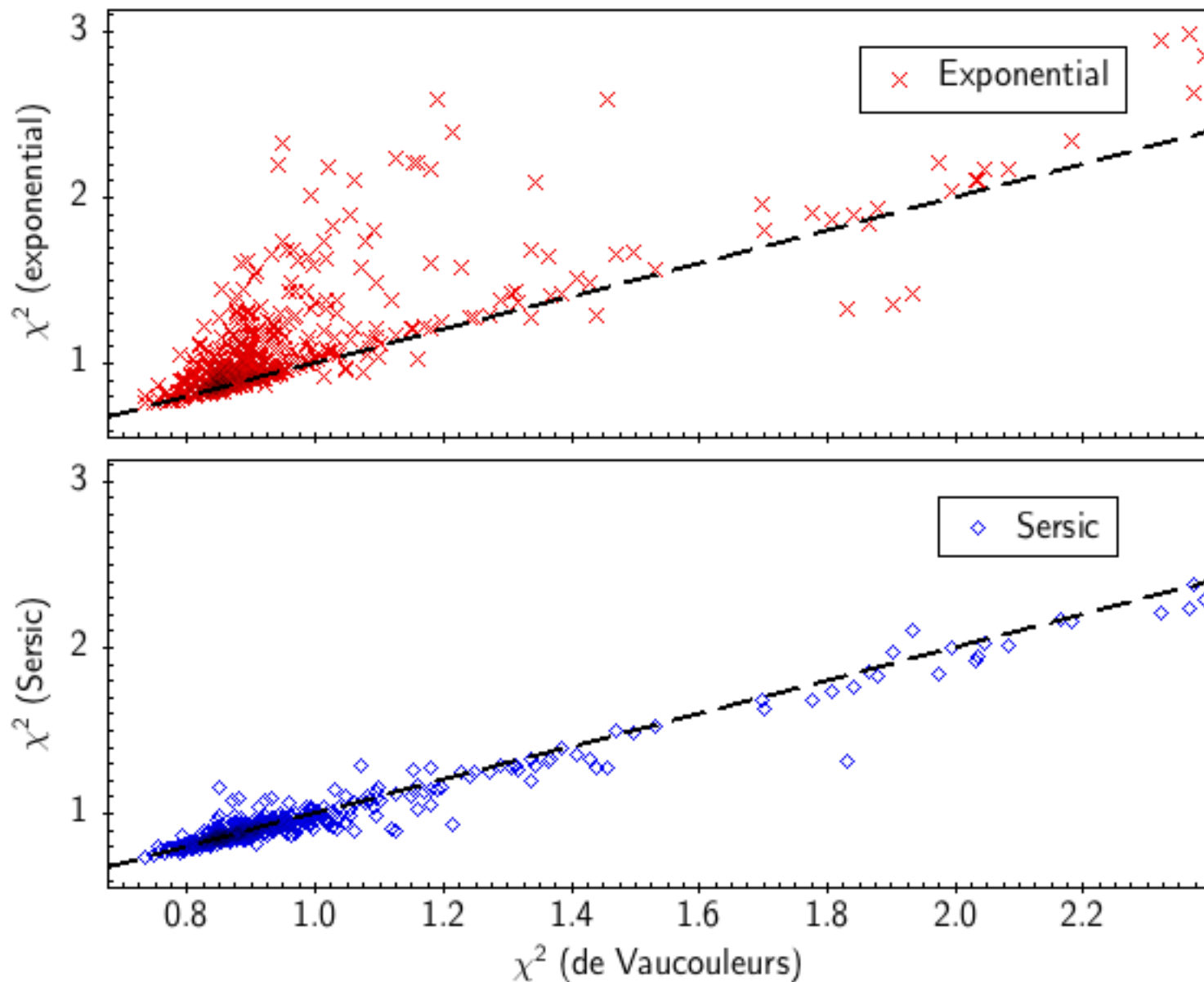
Residuals of the morphology



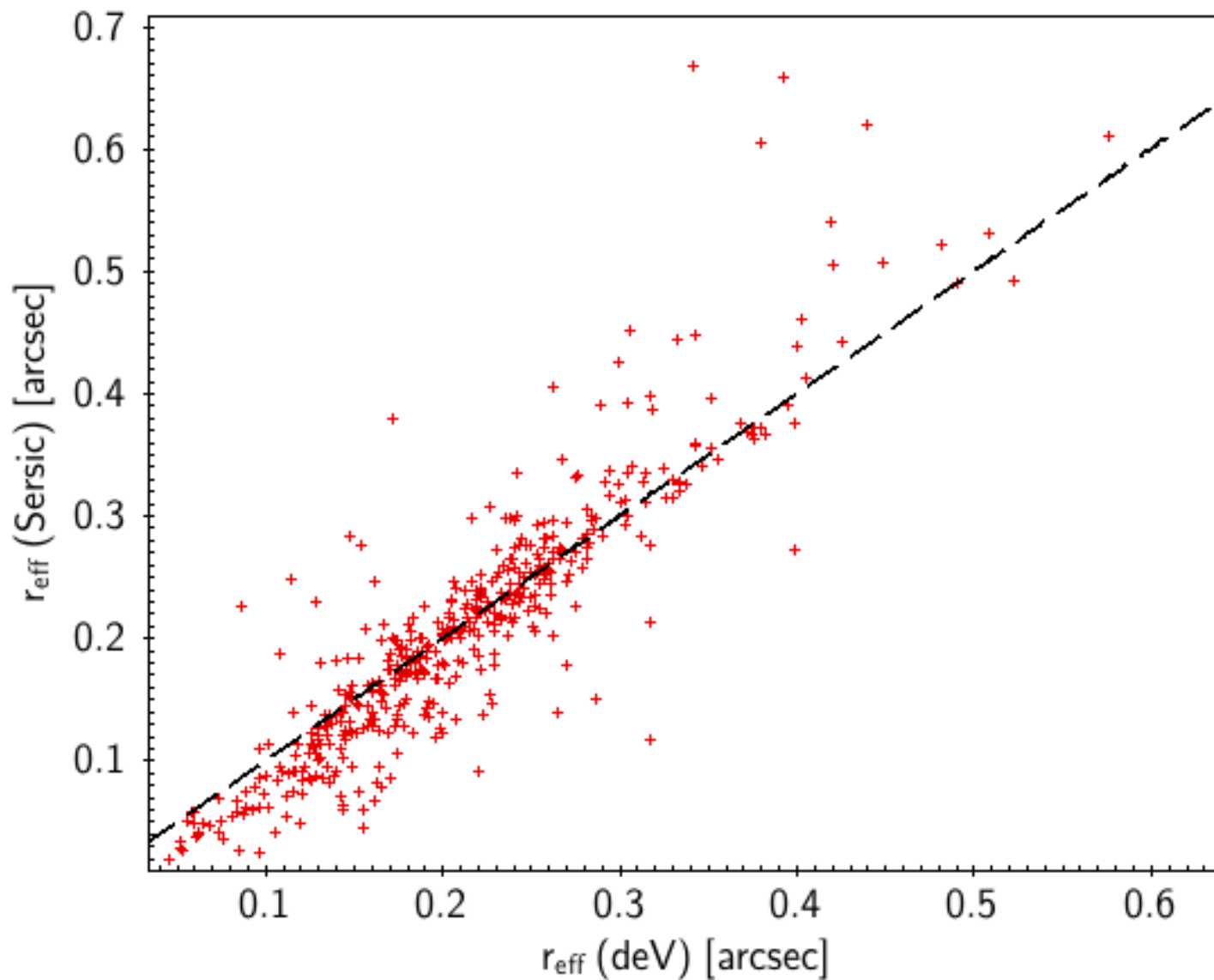
Residuals of the morphology



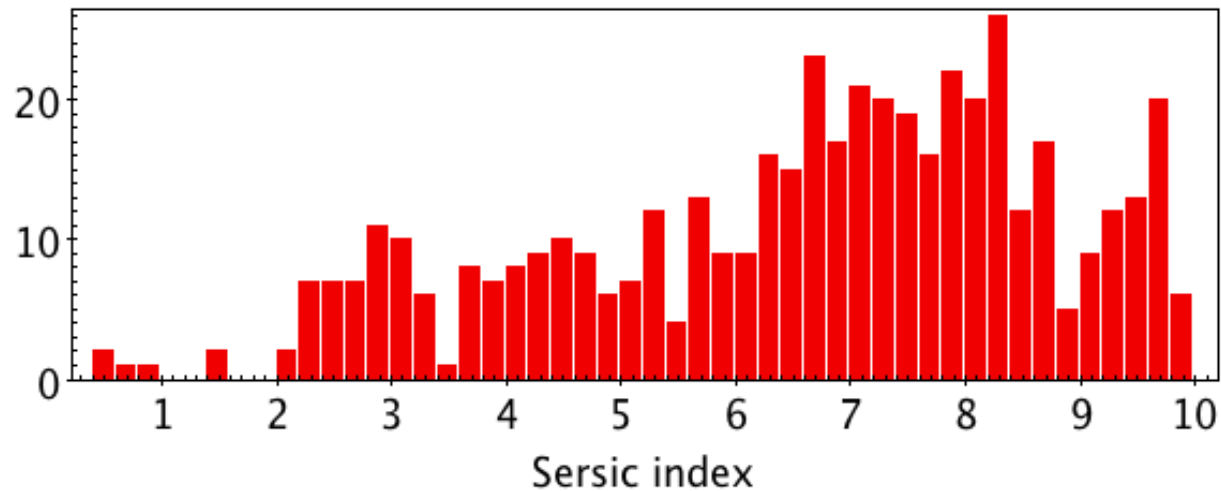
Exp/deV comparison



Sersic/deV Effective radii

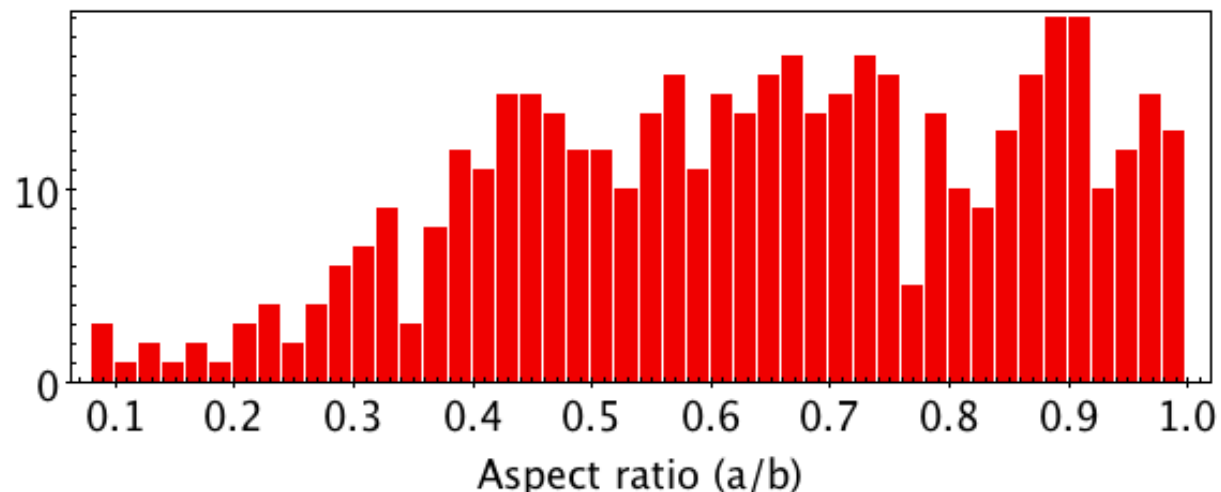


Morphology of C.M.Q. galaxies



Exponential profile is not preferred (χ^2 , residuals)

Sersic/de Vaucouleurs equivalent



Sersic index > 2.5
early-type morphology

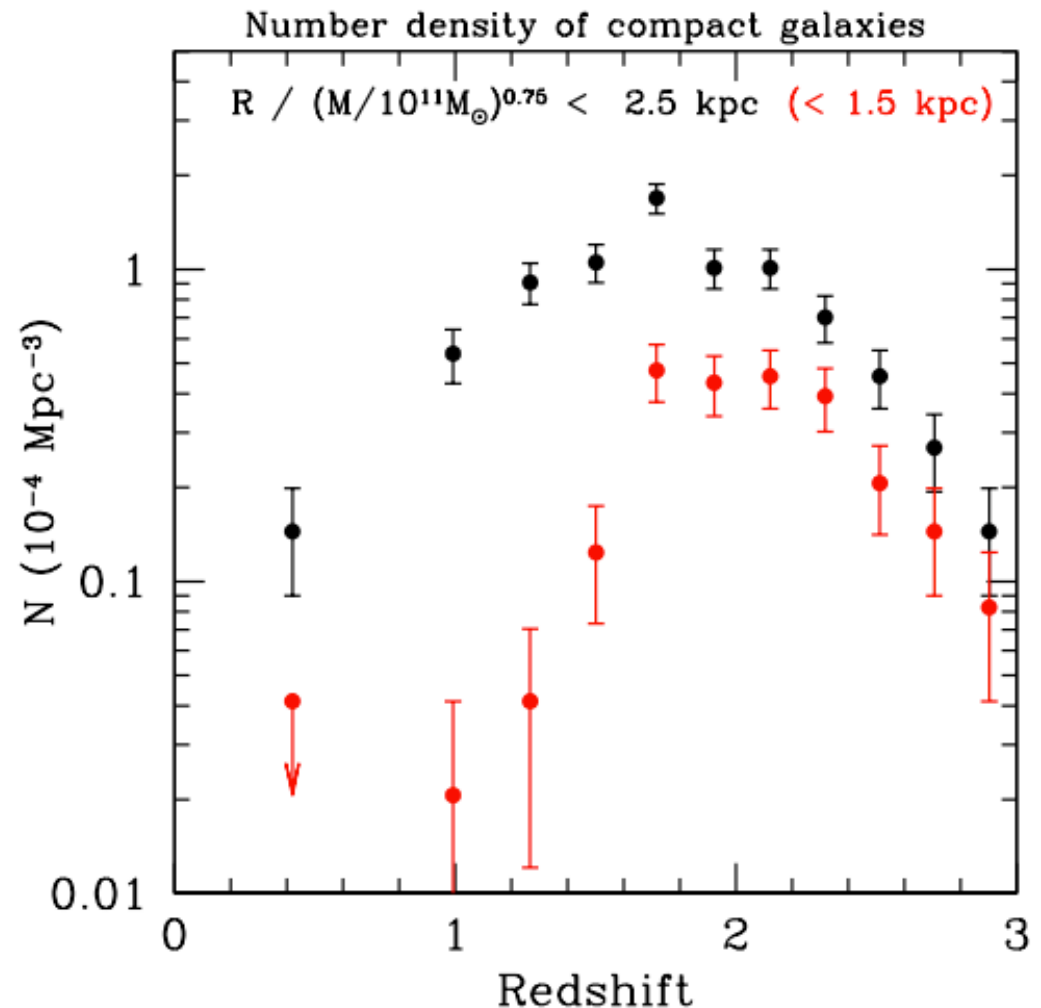
Objects mainly roundish

Density evolution with redshift

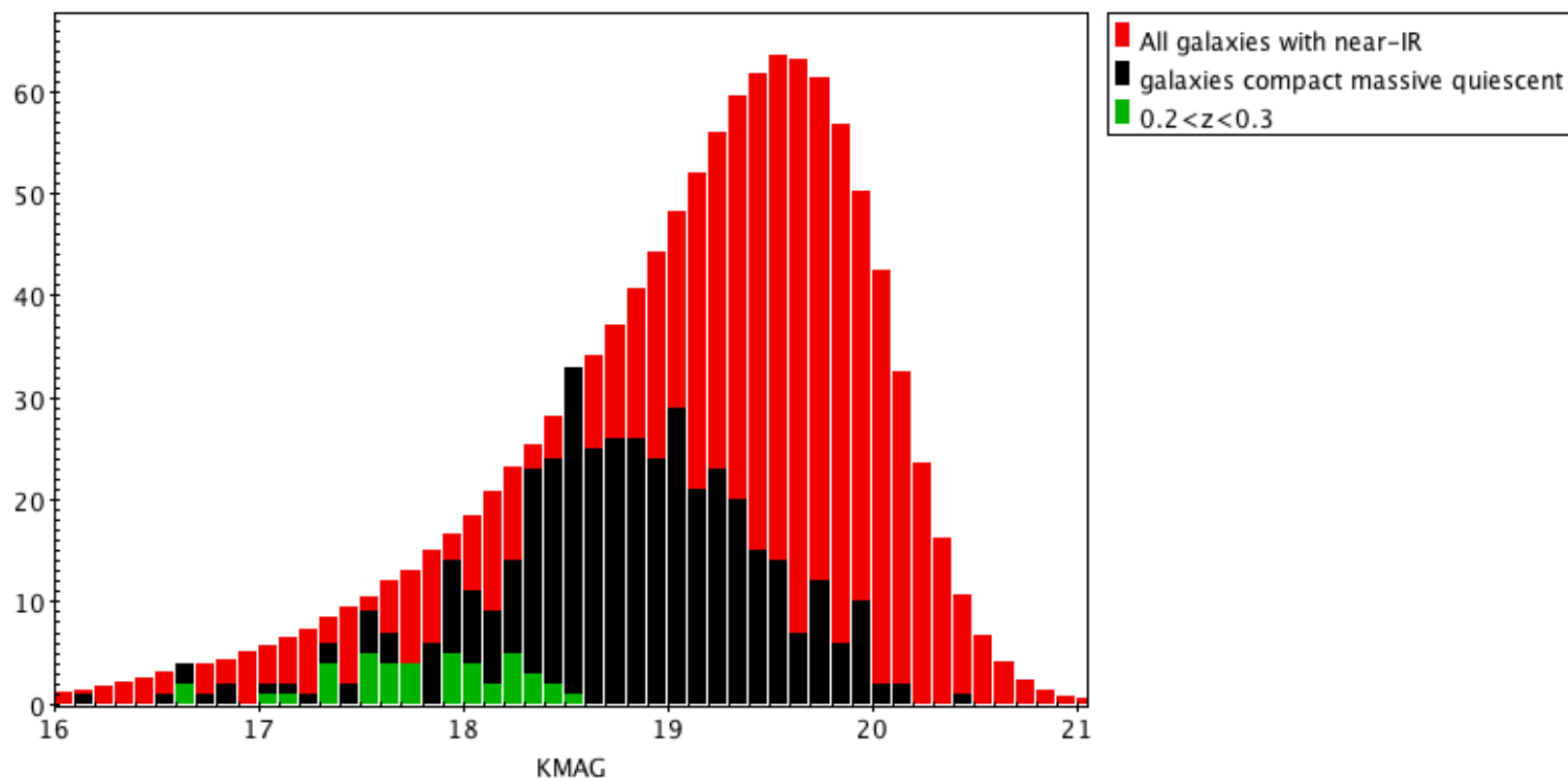
van der Wel+2014

Redshift	10^{-4} Mpc^{-3}
0.2 – 0.3	0.032
0.3 – 0.4	0.061
0.4 – 0.5	0.032
0.5 – 0.6	0.028

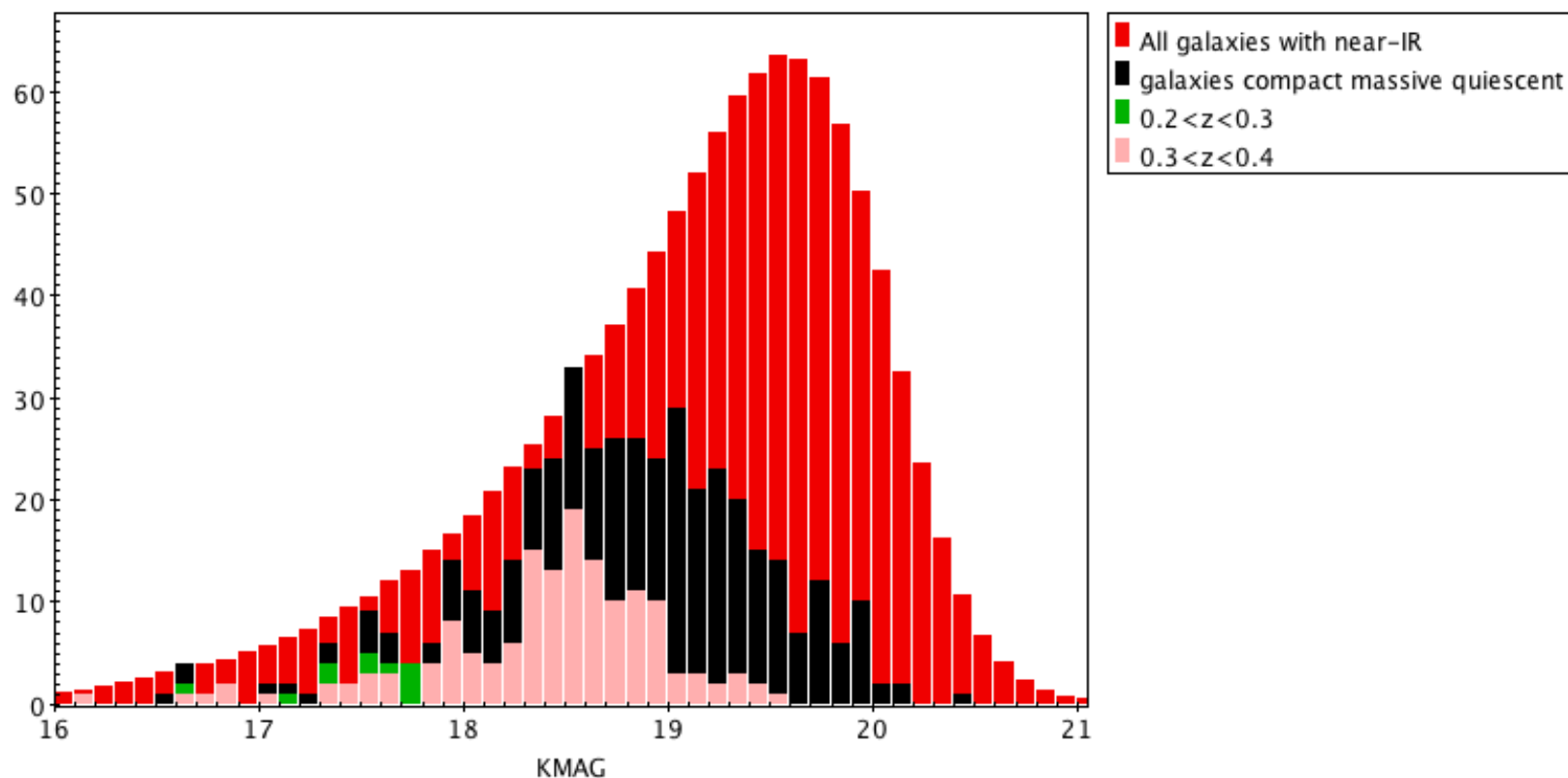
- good order of magnitude
- complete sample?



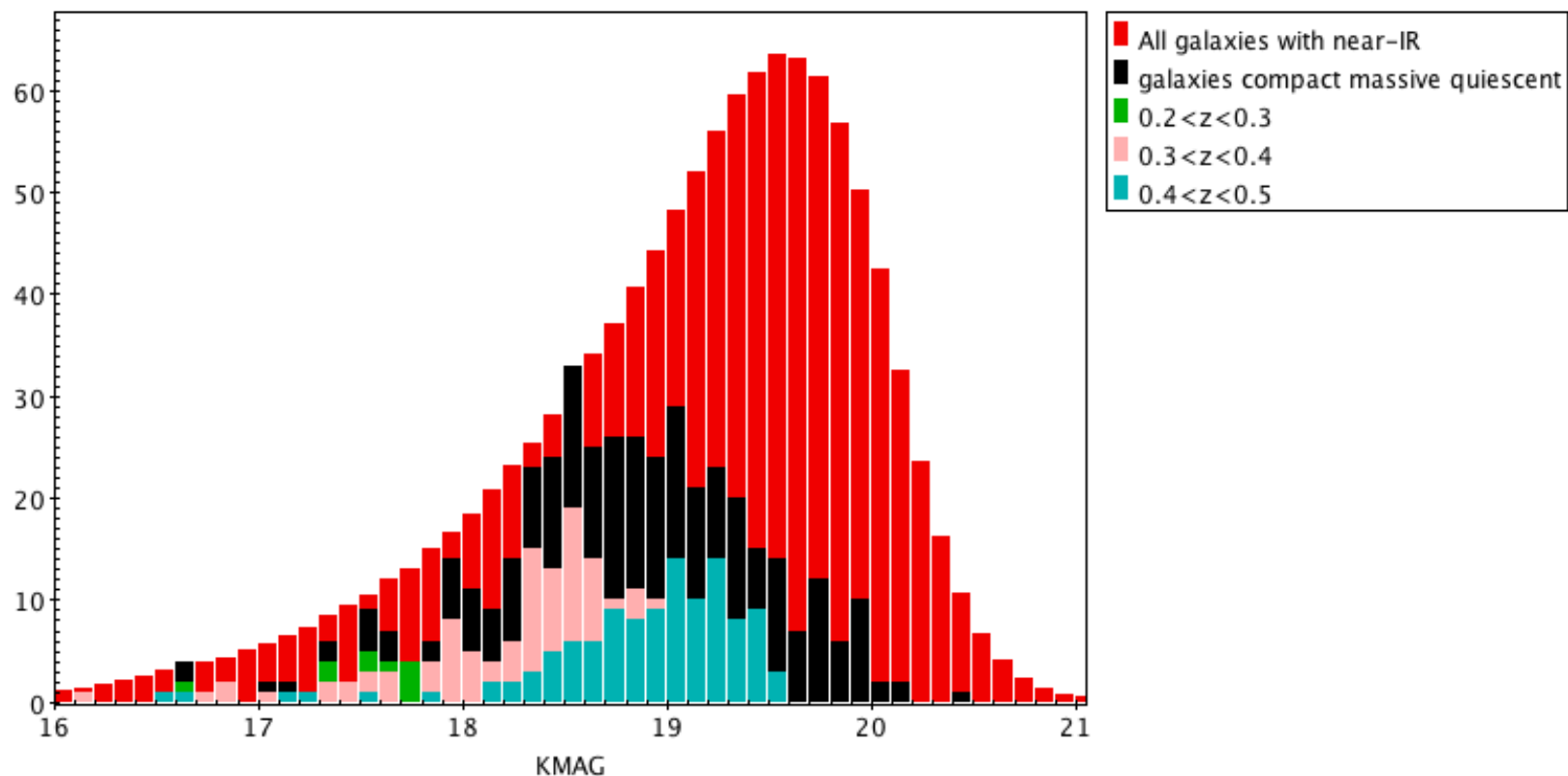
Completeness of the sample



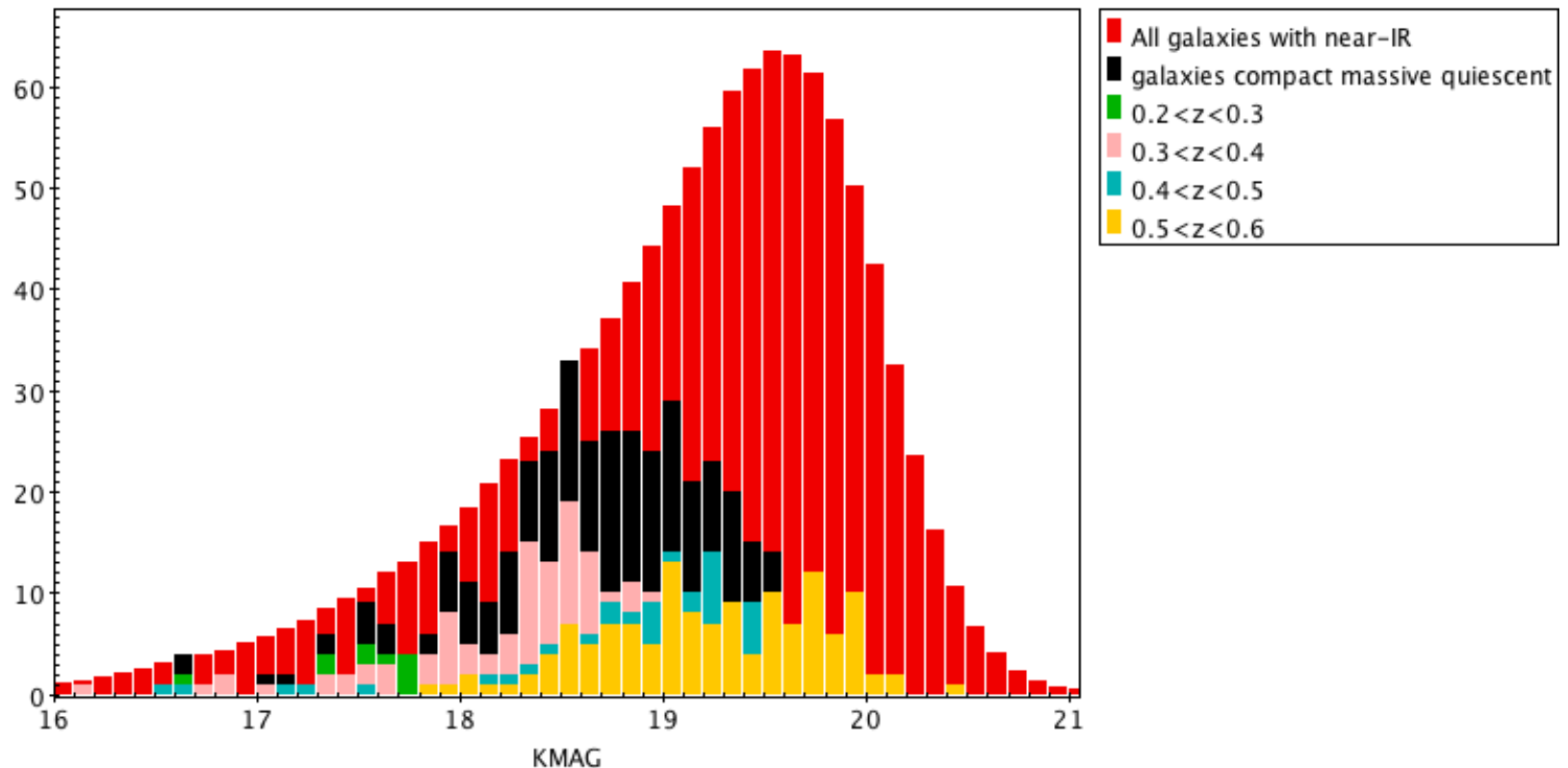
Completeness of the sample



Completeness of the sample



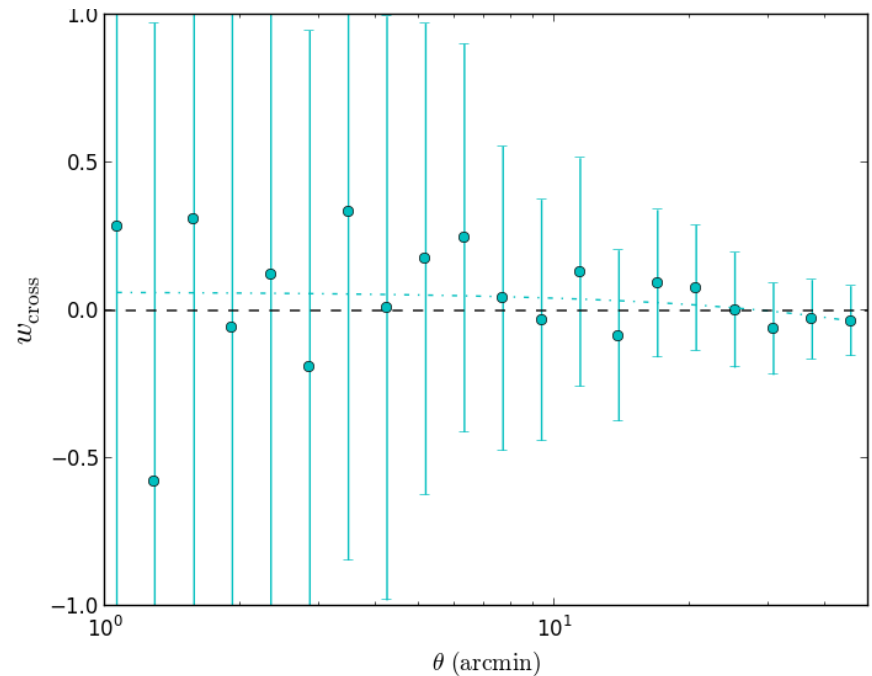
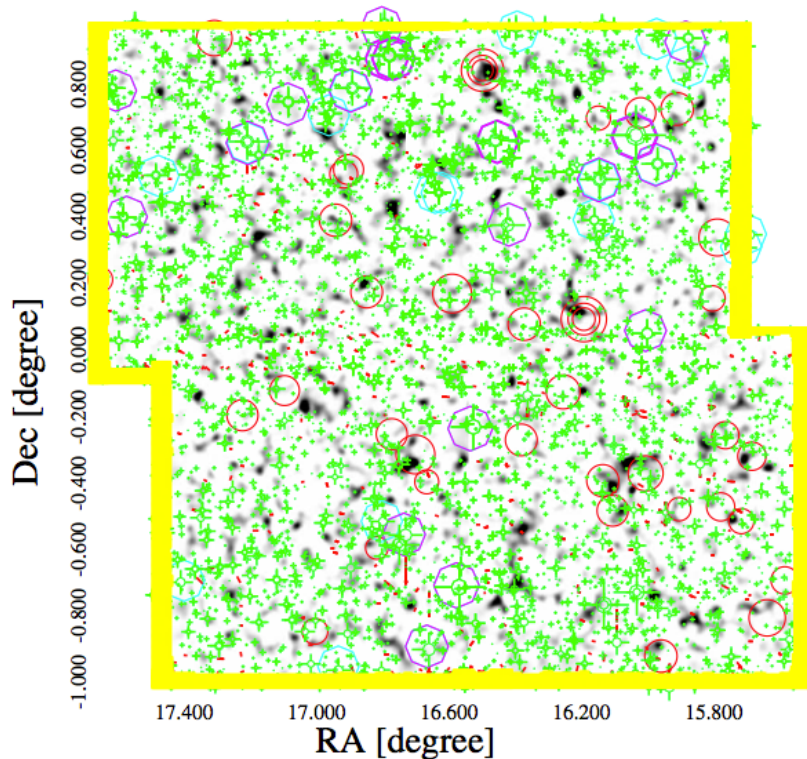
Completeness of the sample



upper limit at higher redshifts, to be continued!

Weak lensing mass map

Shan + 2014



- Convergence field ($z_m=0.75$)
- Dark matter distribution
- Noisy



currently no angular
correlation with DM..!

Perspectives

CFHT/Stripe-82 survey: exceptional image quality

$0.2 < z < 0.6$

~500 candidates in the Stripe-82 region

Early type morphology

- **Environment analyses**
- **Density evolution estimation**
- **Some details (k-correction, criteria)**

