

Galaxy formation with Panchromatic Imaging Surveys

S. Arnouts (LAM)

**T. Moutard, J. Coupon (Gen.),
I. Davidson, O. Ilbert. S. de La Torre,
K. Kraljic, E. Le Floc'h (CEA)
J. Chevallard (Brasil)
L.v.Waerbeke (UBC), G. Morrison(CFHT)**

VIPERS L. Guzzo, M. Bolzonella, O. Cucciati & VIPERS team

SPINe C. Pichon, T. Sousbie, L. Tresse & SPINe team

GALEX B. Milliard, M. Treyer, D. Vibert, S. Conseil
M. Zamojski, D. Schiminovich

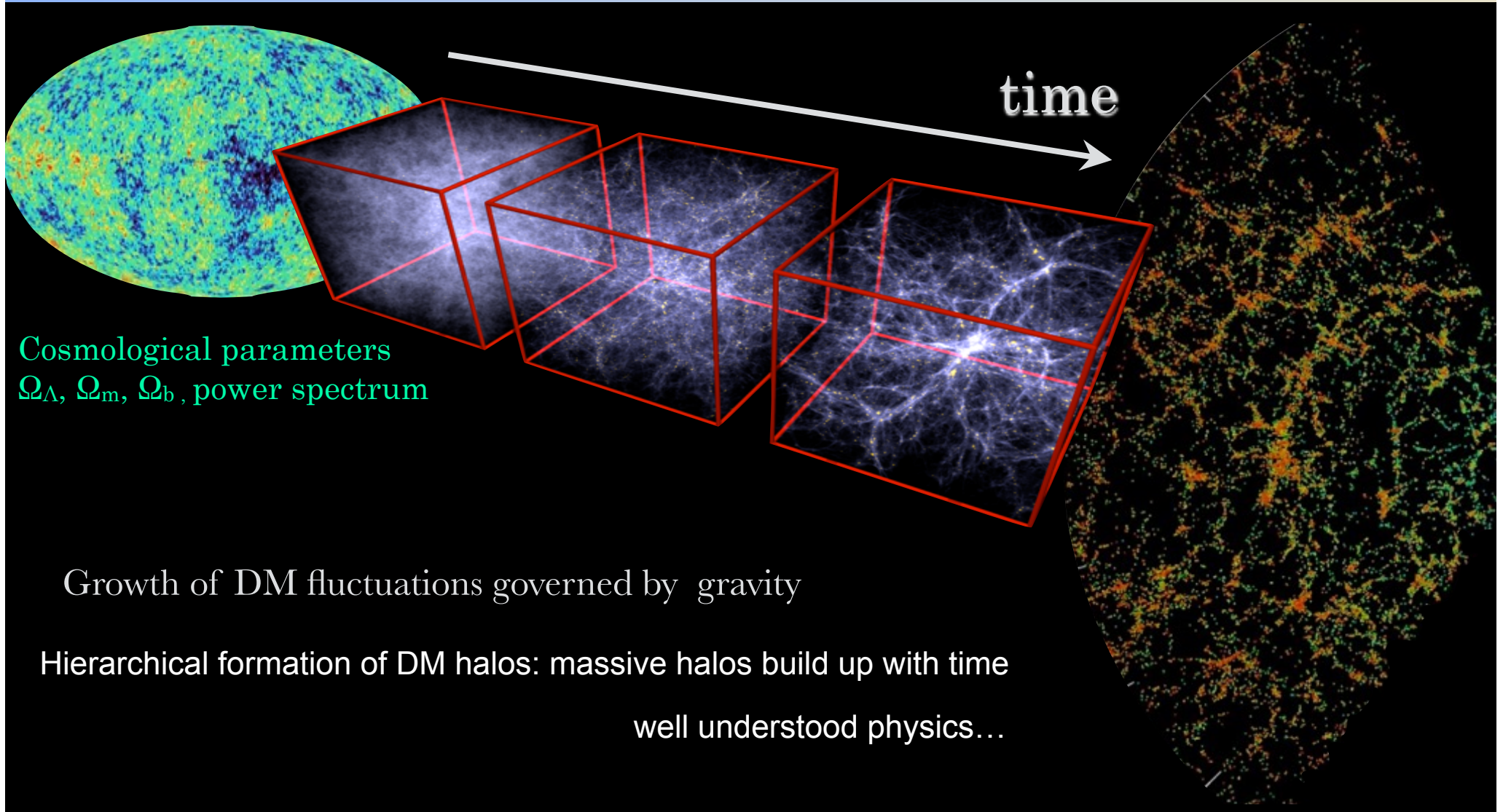


Theoretical Framework : Λ CDM

Dark side of the universe

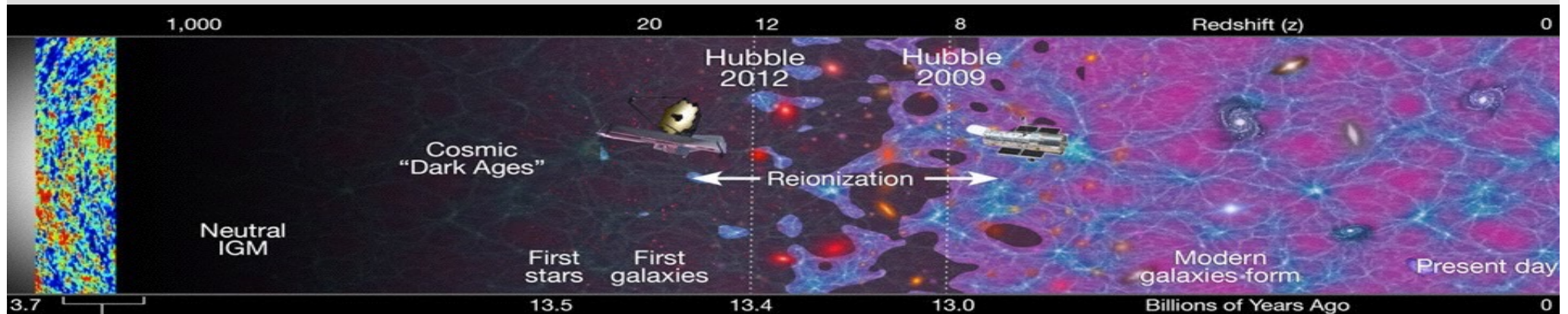
WMAP / PLANCK

Local LSS , SDSS



Theoretical Framework : Λ CDM

Bright side of the universe

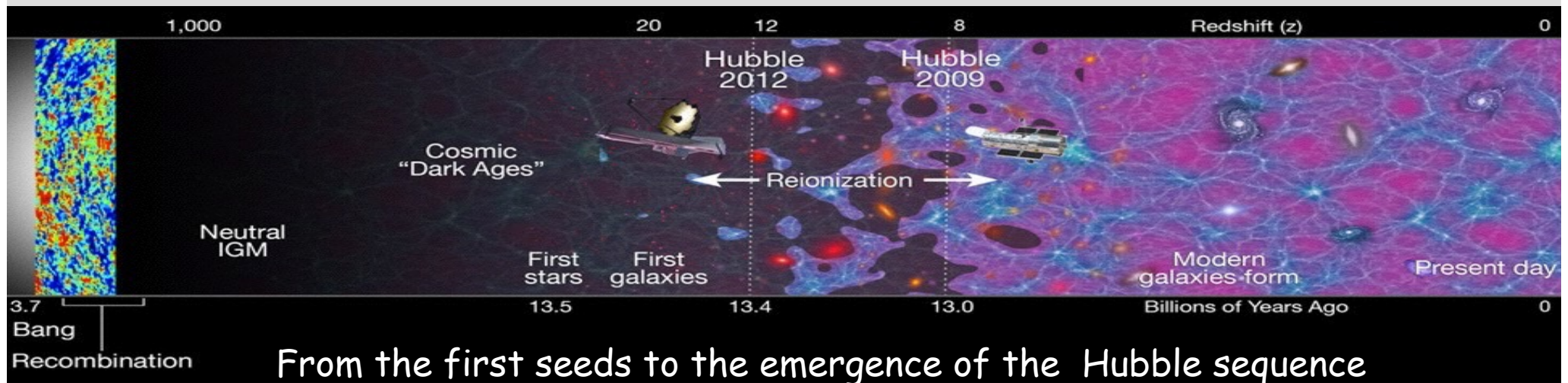


From the first seeds to the emergence of the Hubble sequence

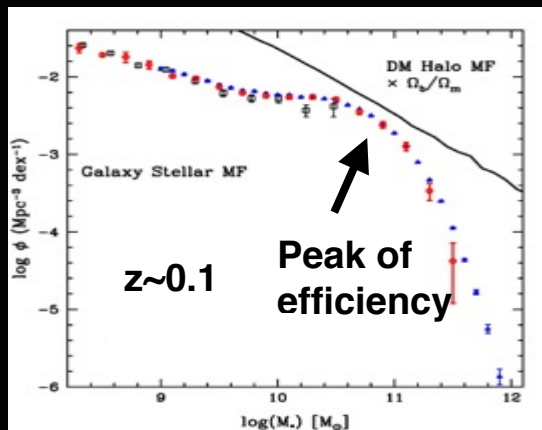
complex physic of baryons

Theoretical Framework : Λ CDM

Bright side of the universe

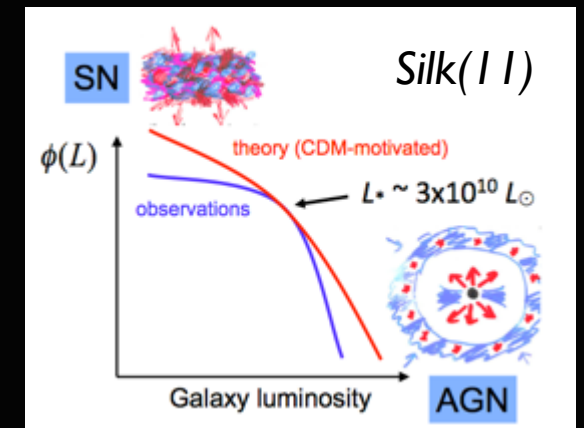


- Star Formation is inefficient : Only 10% of baryon in star today !
- Comparison Halo Mass Function and Stellar Mass Function



- * Peak of efficiency around $M_h \sim 10^{12} M_\odot$
- * drop on both sides of the MF

Galaxies are not a closed box
many mechanisms can be involved ...



Infall: simul.

Galaxies and their Environment

Galaxies : Complex interplay between

infall* - *SFR* - *feedback

(gal. Equilibrium : $dM_s = dM_{in} + SFR + dM_{out}$ Davé,12)

Feedback : M82



baryons :

~ 80 % in IGM

~ 10 % in CGM

~ 10 % in stars

Horizon-AGN simulation (Dubois+14)

1 Mpc

Infall: simul.

Galaxies and their Environment

Feedback : M82

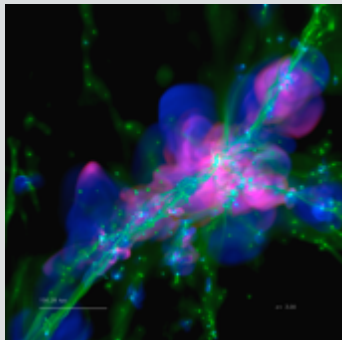
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infall* - *SFR* - *feedback

(gal. Equilibrium : $dM_s = dM_{in} + SFR + dM_{out}$ Davé,12)

- Gas accretion :

- * Merging vs smooth accretion (high velocity clouds)
- * IGM : Hot vs Cold mode (Cold stream @ high z)



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Galaxies and their Environment

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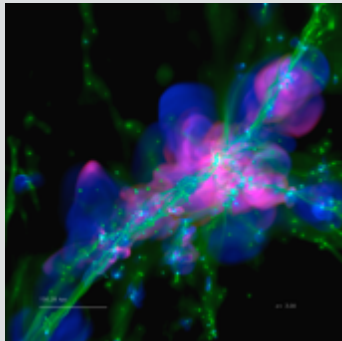
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Horizon-AGN simulation (Dubois+14)

1 Mpc

- Feedbacks :

- * AGN driven / SN / stellar wind
- * quench or keep gas @ high T



Infall: simul.

Galaxies and their Environment

Feedback : M82

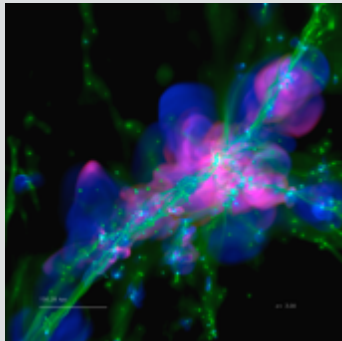
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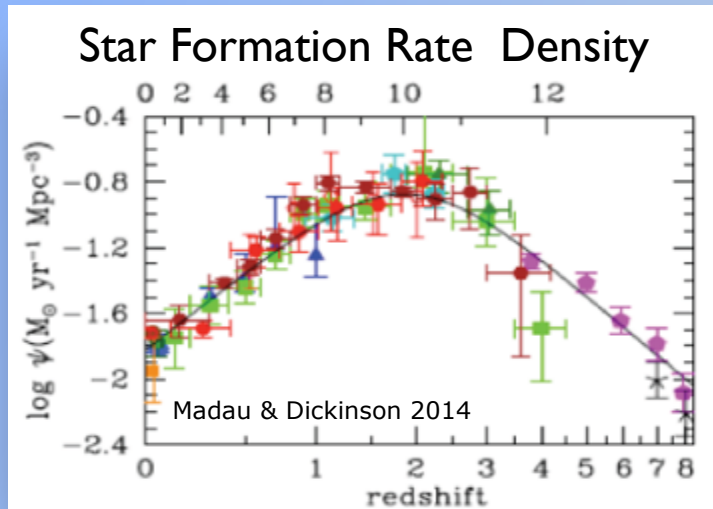
- * AGN driven / SN / stellar wind
- * quench or keep gas @ high T



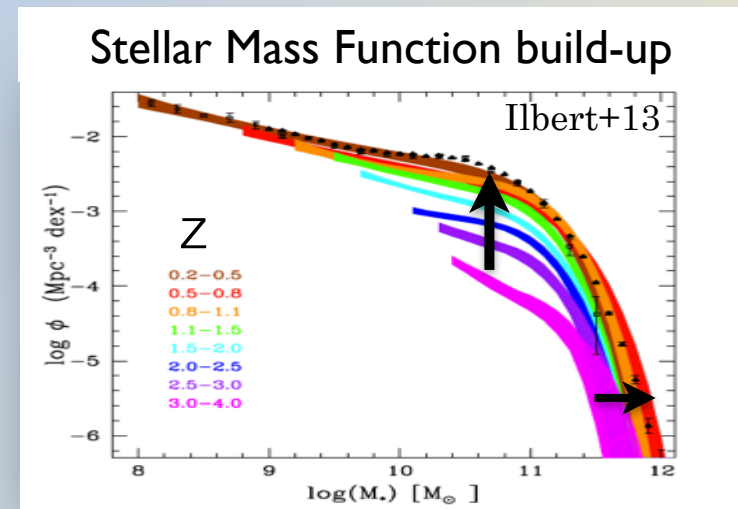
Mechanisms poorly known.
contributions may change with time

*Observations must provide phenomenological constraints
to disentangle these complex mechanisms*

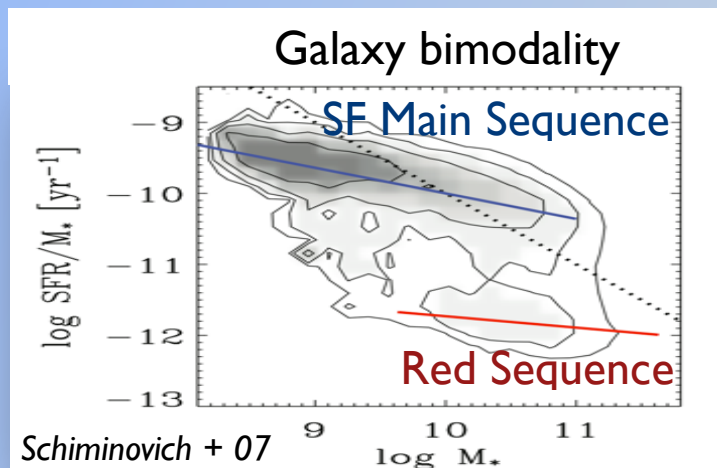
observations ...



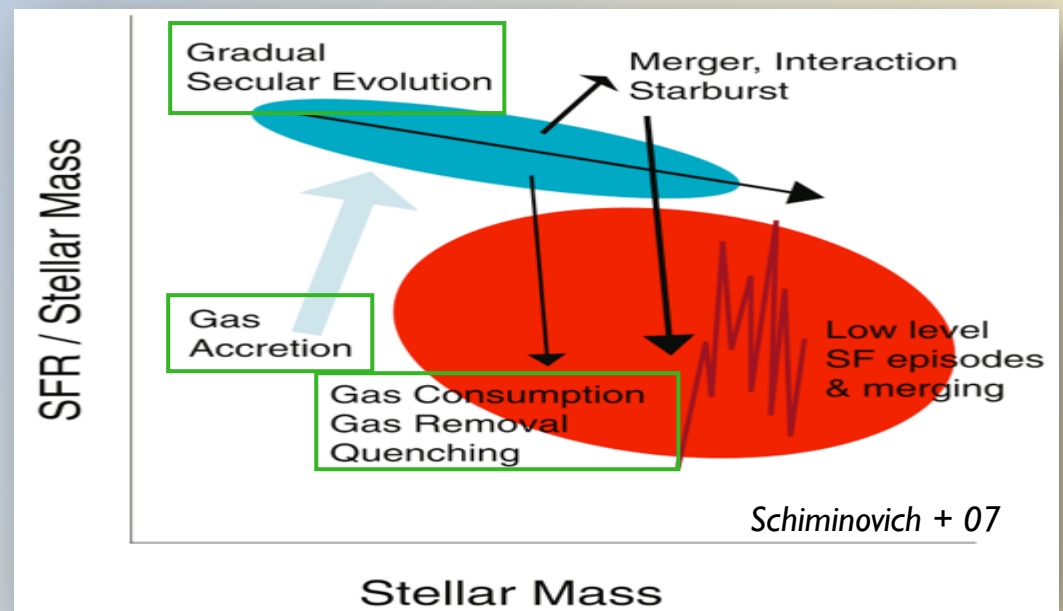
- * Decline of the SFRD since 10Gyrs



- * Early build up of massive end



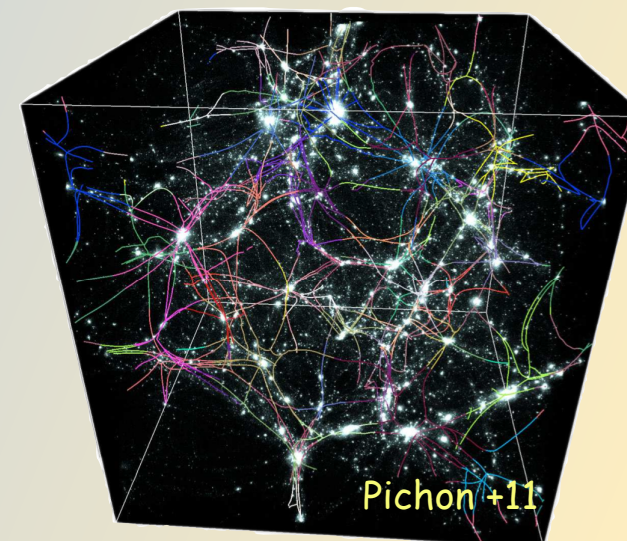
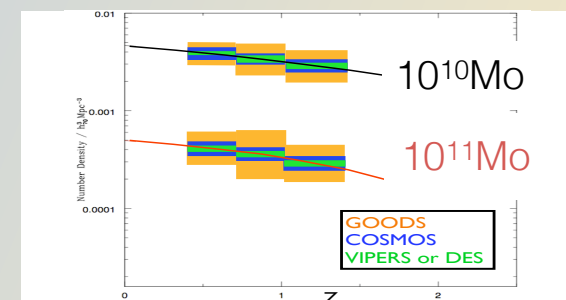
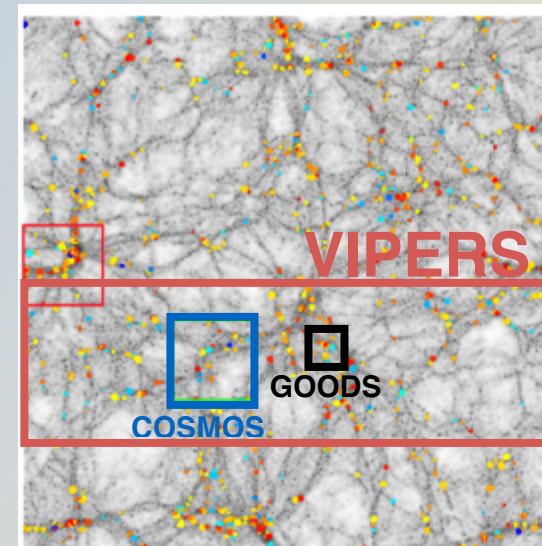
- * MS : SFR prop to Mass
- * quenching -> Red Seq.



Outline

Large Scale multi-wavelength Surveys

- adding up on the VIPERS Spectroscopic survey
why do we need of multi-wavelength data
 - Is there a mass assembly downsizing ?
constrain the evolution Massive end of the MF, Quenching ,...
 - Star Formation efficiency (SHMR) **at high redshift**
exploring SMHR from typical $M_h \sim 10^{12} M_\odot$ to clusters $M_h \sim 10^{15} M_\odot$
 - Influence of Cosmic Web on Galaxy evolution
anisotropic environment ... very preliminary analysis ...
-
- HSC - PFS SuMIRe survey
a unique dataset until the advent of LSST



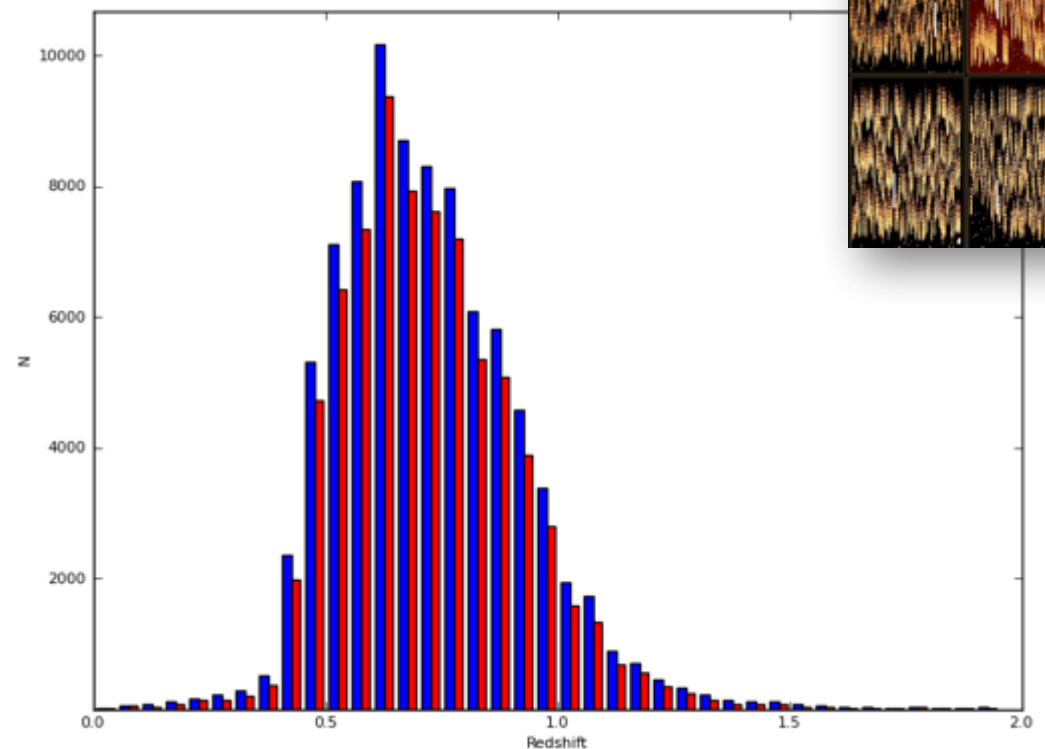
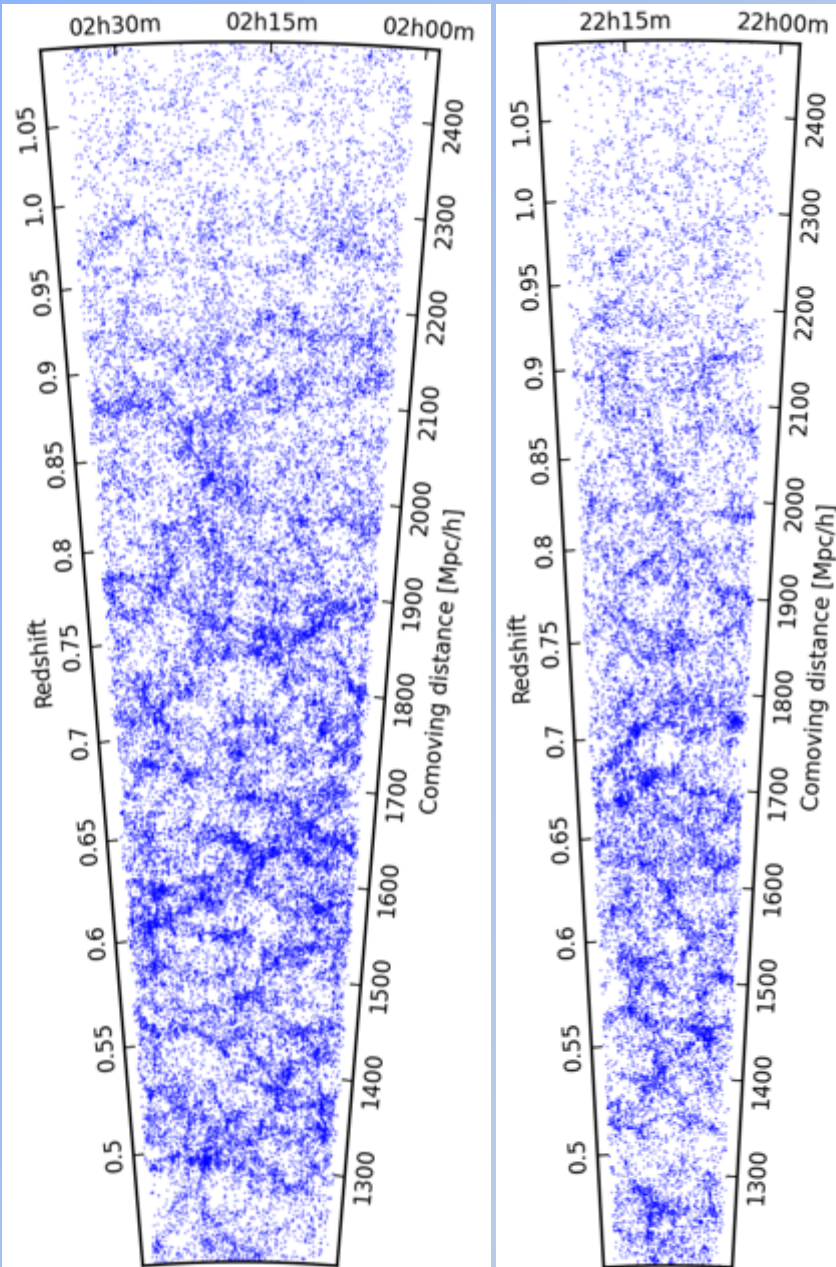
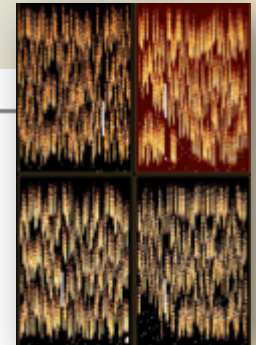
-Ia- VIPERS spectroscopic survey

<http://vipers.inaf.it>

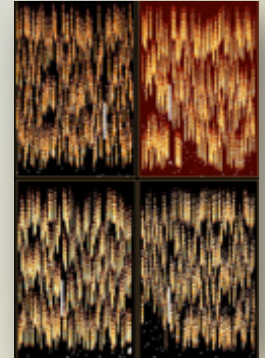
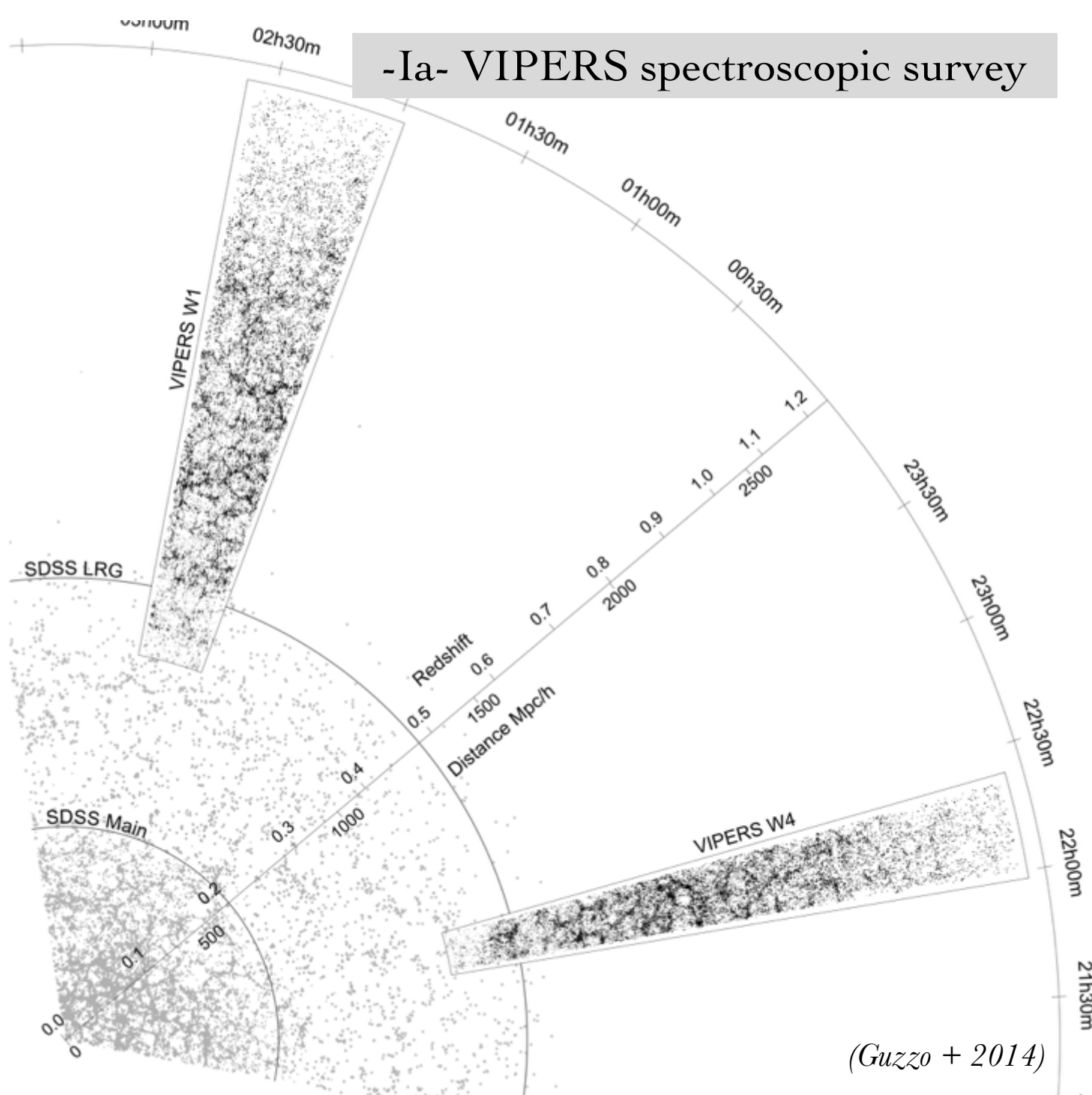


VIPERS (Guzzo + 2014)

- ESO-VLT Large Program 182.A-0886
- 24 deg² in the CFHTLS Fields W1, W4 equivalent volume as local 2dFGRS survey
- Flux limited : $i < 22.5$
- Color selected, 40% sampling (one pass)
- 100,000 redshifts $0.5 < z < 1.2$



-Ia- VIPERS spectroscopic survey



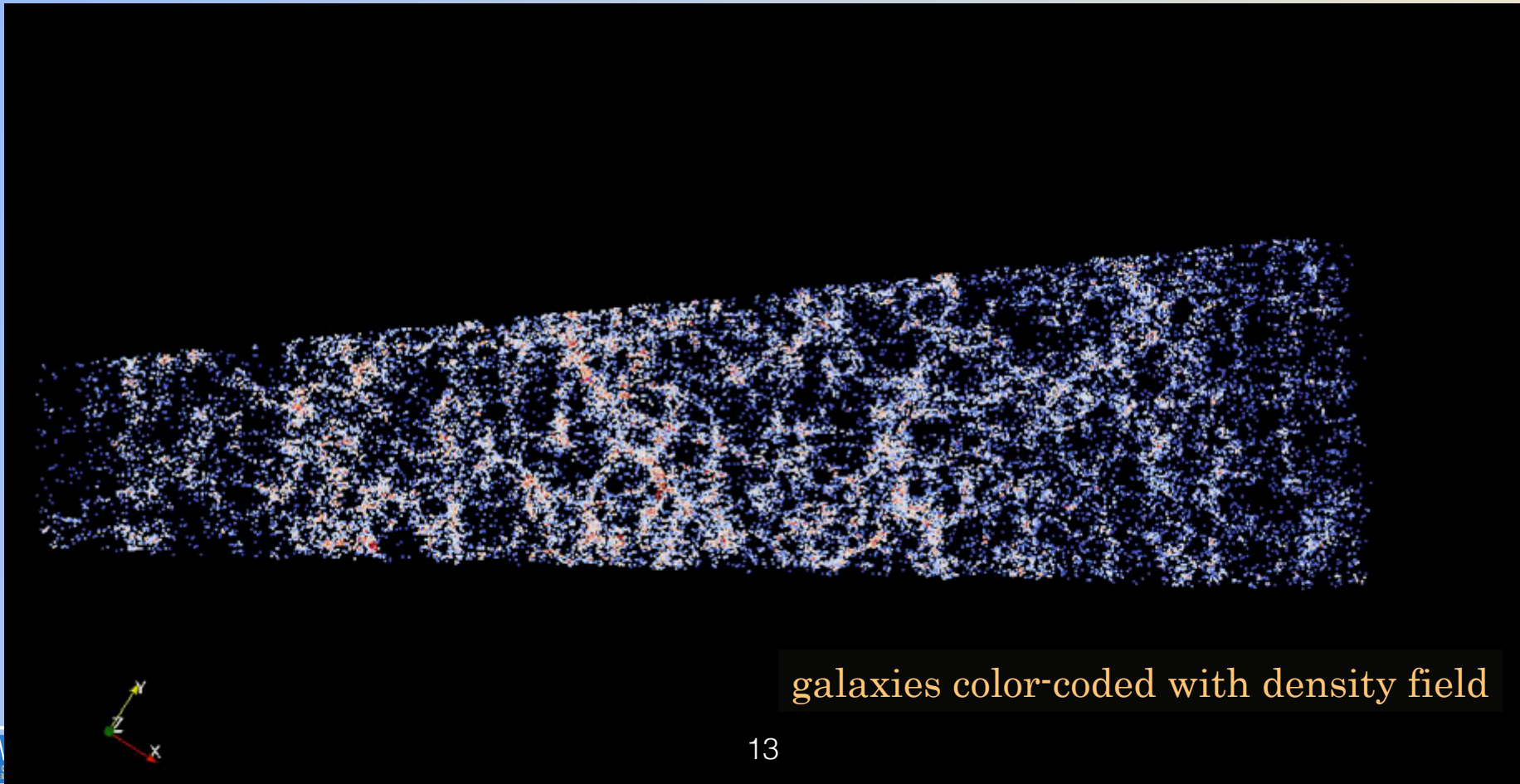


Uniqueness of VIPERS

- spectroscopic coverage $>100,000$ Z
Largest Volume probed at high- z
- High Imaging optical quality (ugriz)

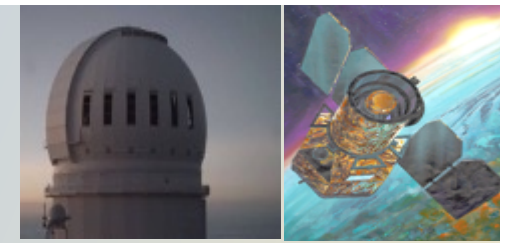
Multi-wavelength follow-up :

- stellar masses, SFR for VIPERS sources
 - > Galaxy evolution and Large Scale Structure
- robust photo- z s to extend science $0 < z < 2$



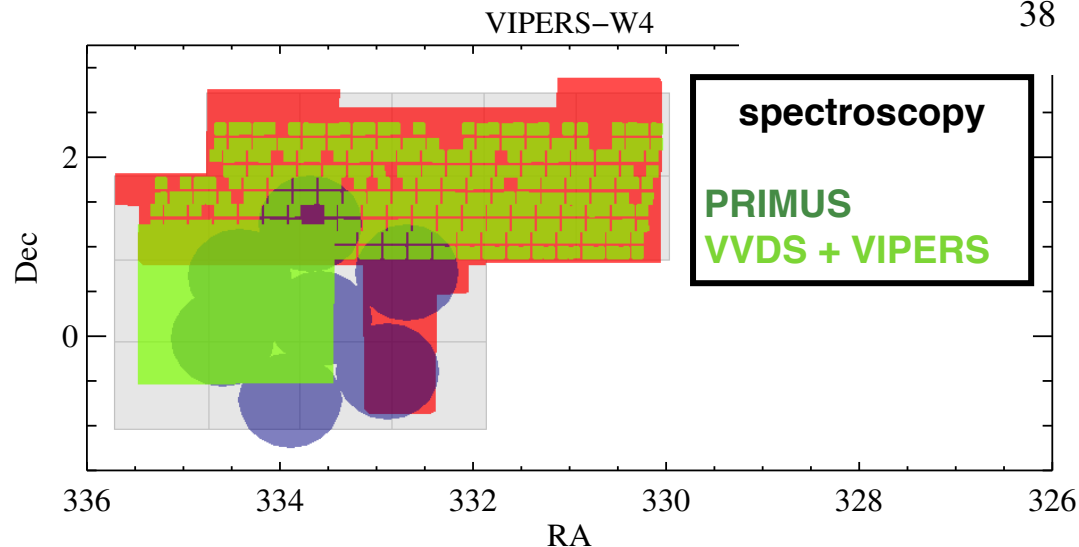
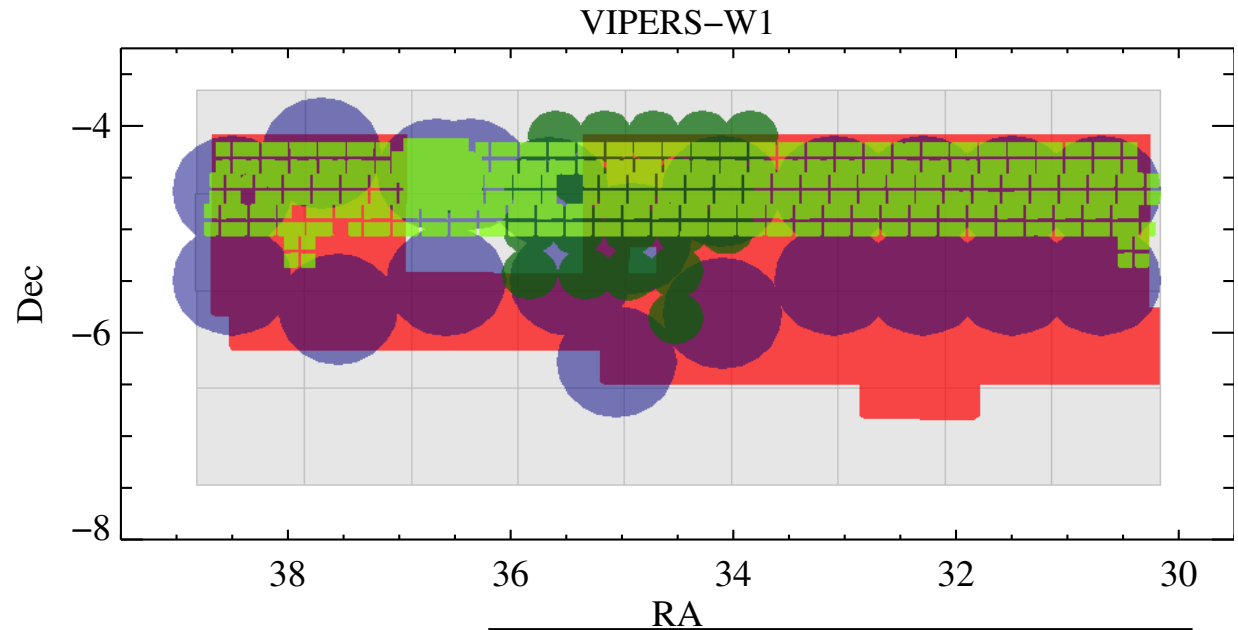
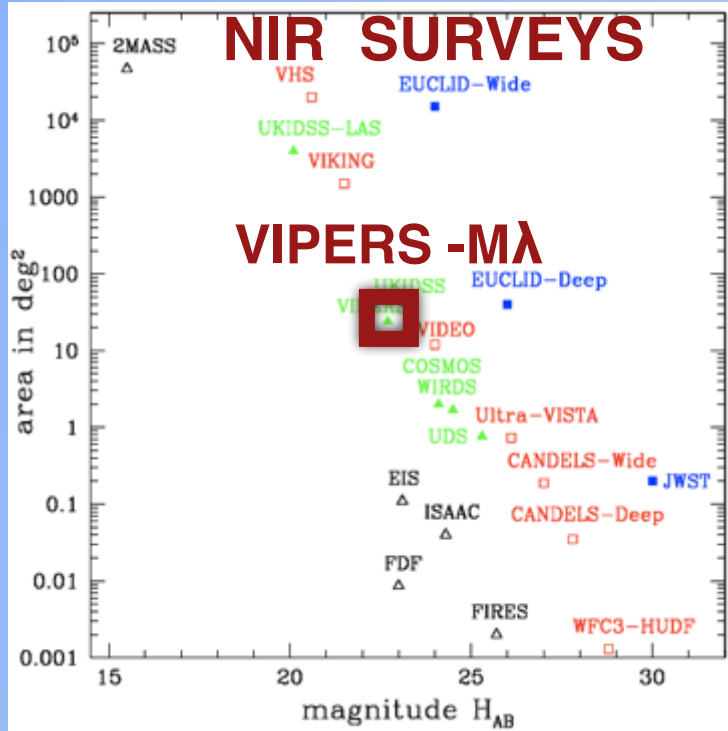
galaxies color-coded with density field

-Ib-VIPERS - CFHTLS multi λ Follow-up



Coupon, SA, L_vW+15

Multi-wavelength follow-up :
 UV (F/NUV) with GALEX satellite
 NIR (K_s) with WIRCam at CFHT



spectroscopy

PRIMUS
 VVDS + VIPERS

photometry

CFHTLS (ugriz)

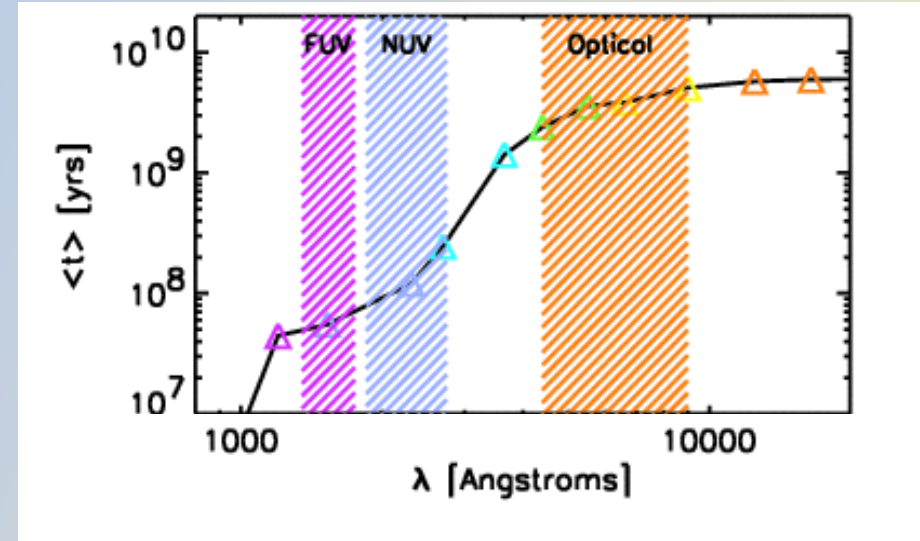
WIRCam ~ 120h at CFHT (PI: SA, L_vW)
 integration/pixel: 1050sec
 Total area ~ 27 deg²

NUV/FUV ~ GALEX : 100h D-Time
 +200h pub. release
 integration/pixel: 30,000sec
 Total area ~ 22 deg²

The UV continuum - SFR

Martin et al (2005)

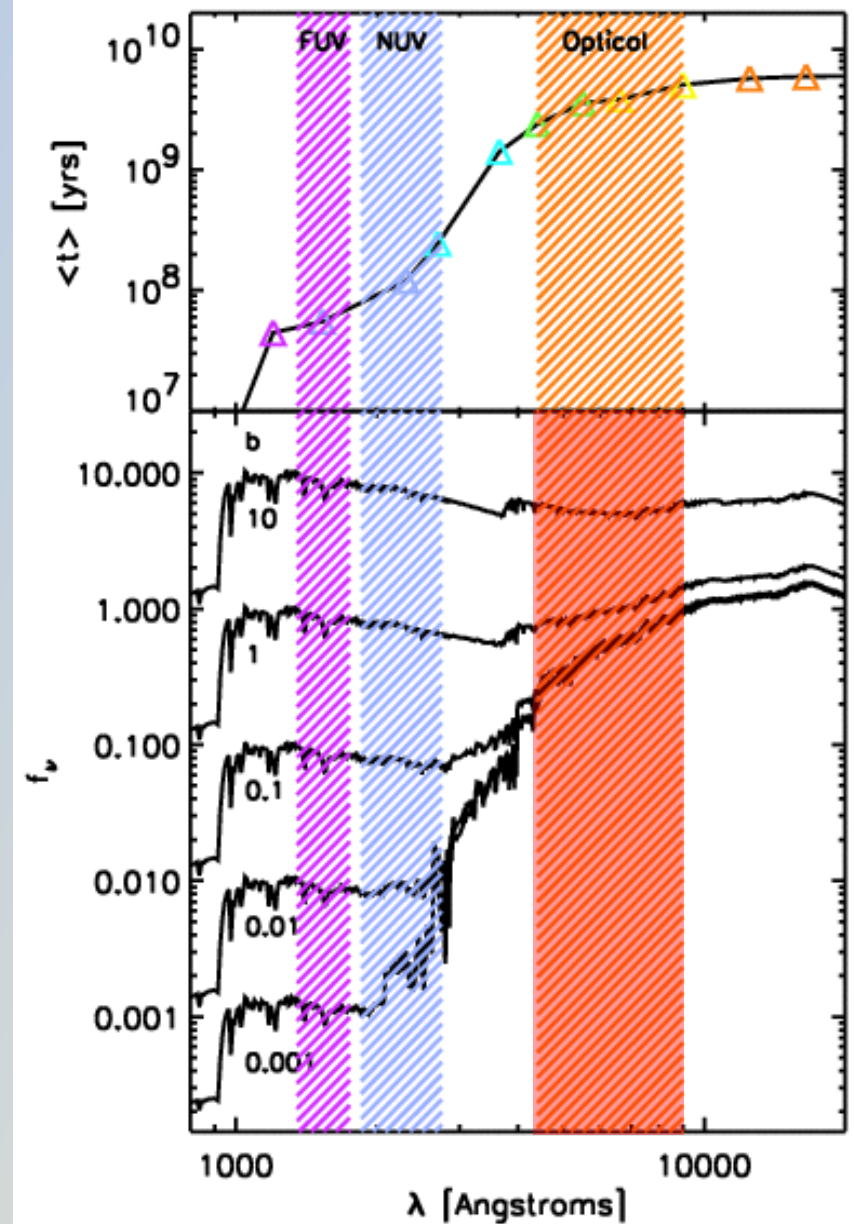
- FUV , NUV dominated by : B, A, F stars
- Light weighed Age : $\langle t \rangle = 10^8$ yr



The UV continuum - SFR

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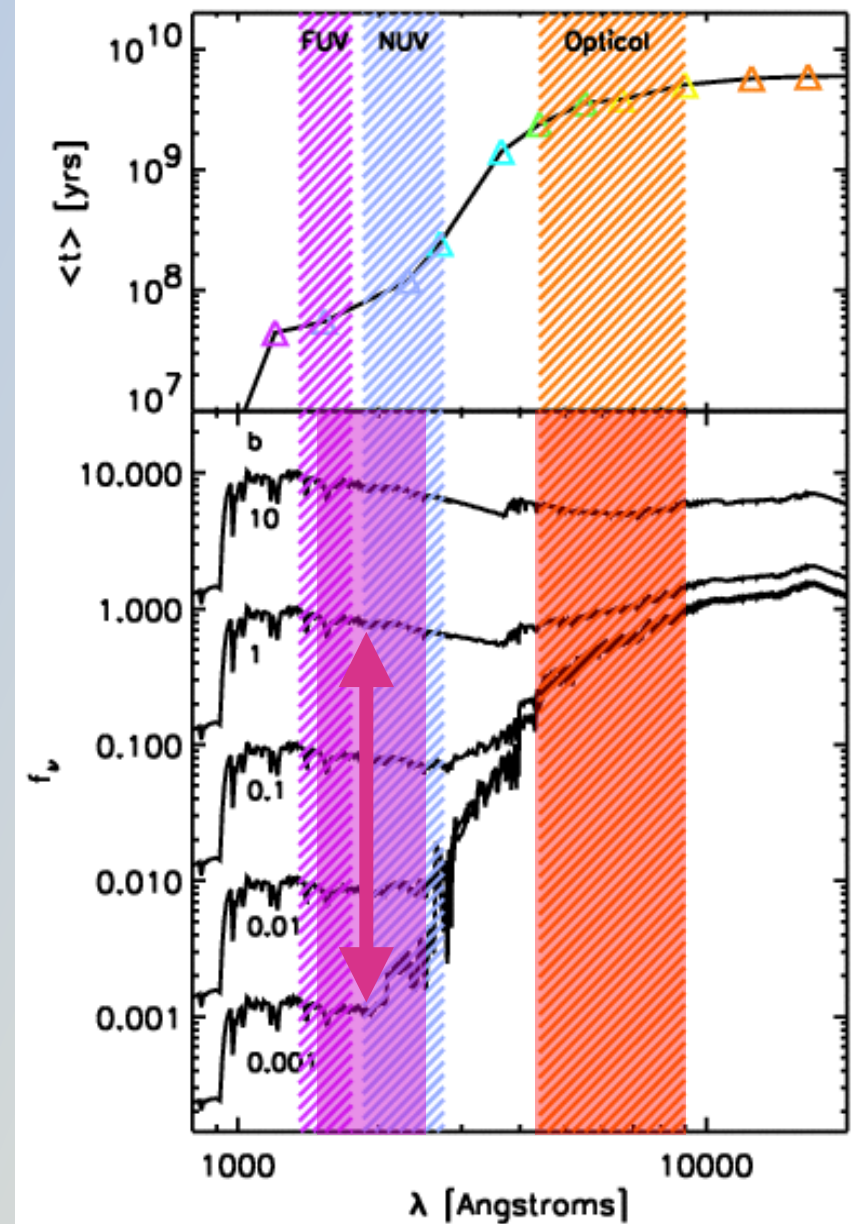
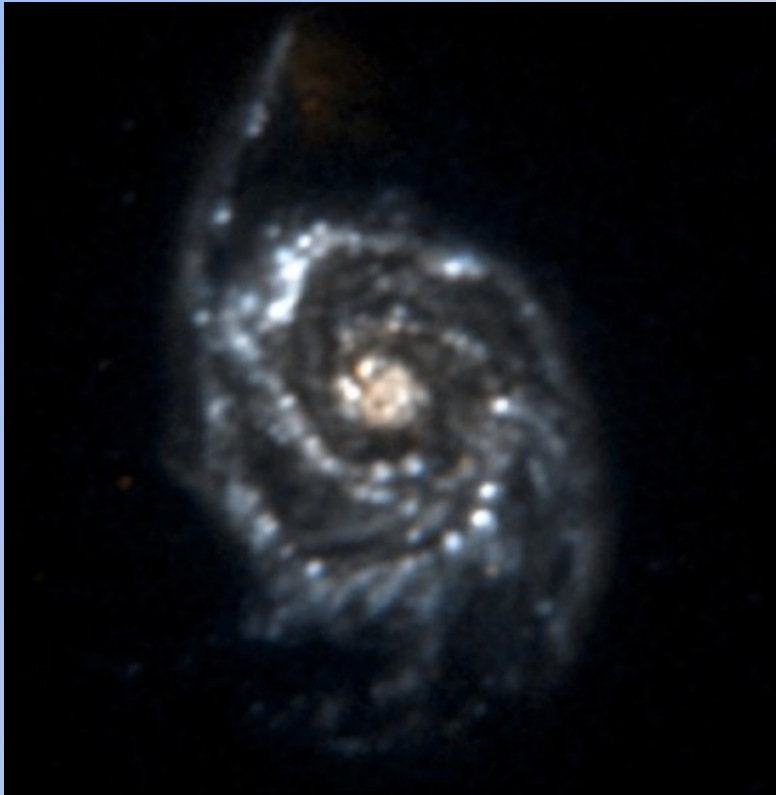
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- Large range of SFR for same optical



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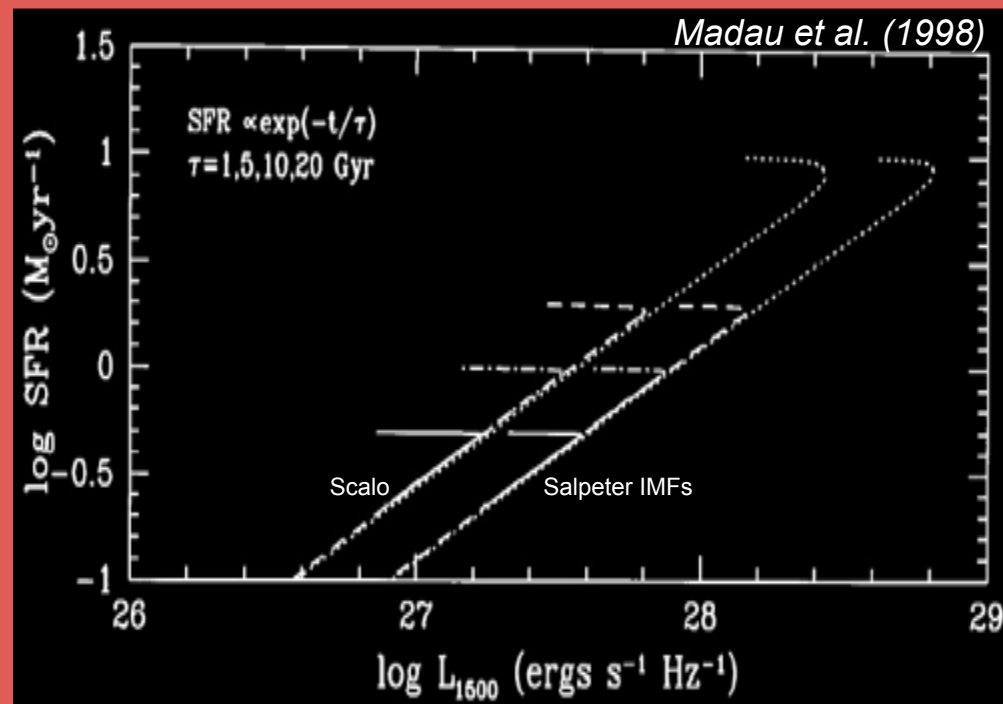
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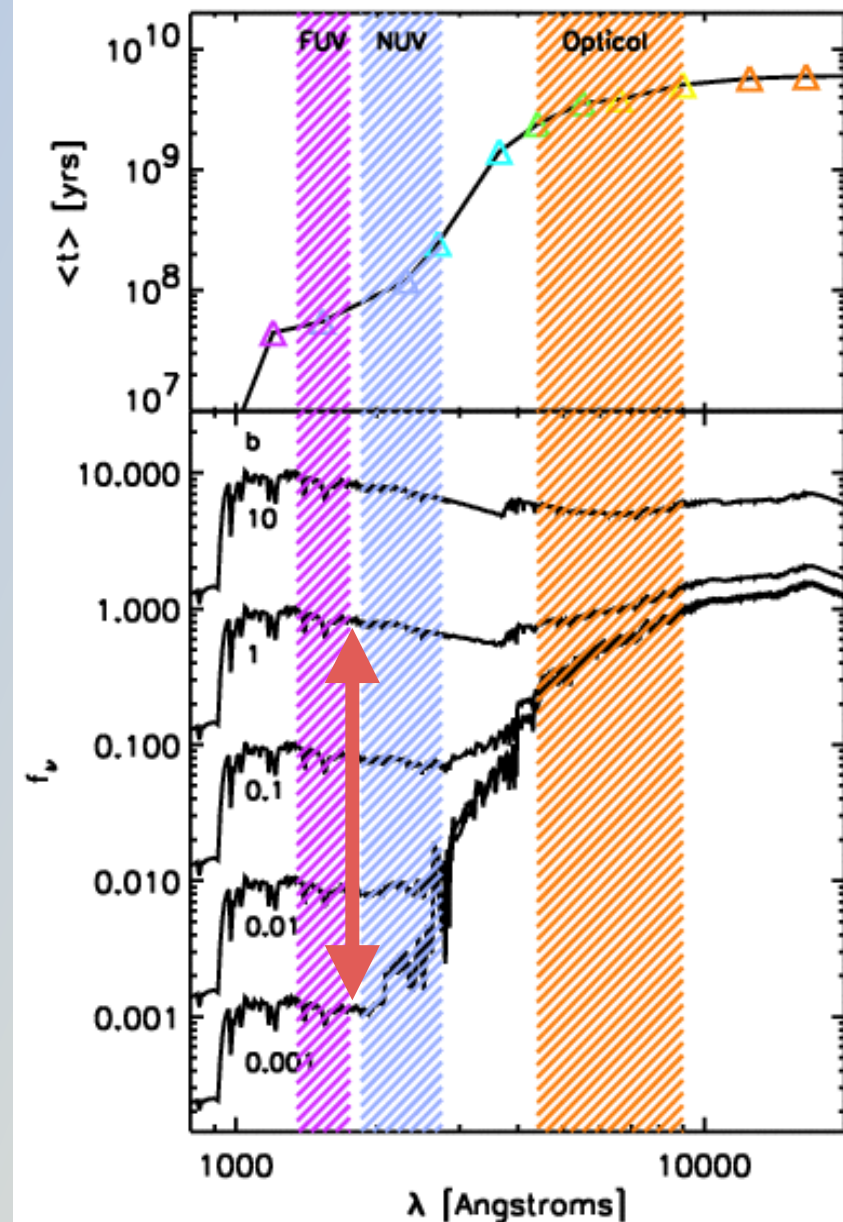


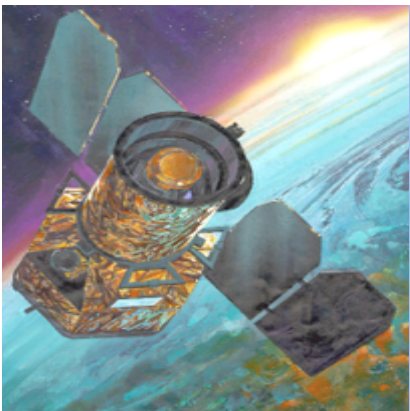
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UV Luminosity direct tracer of SFR



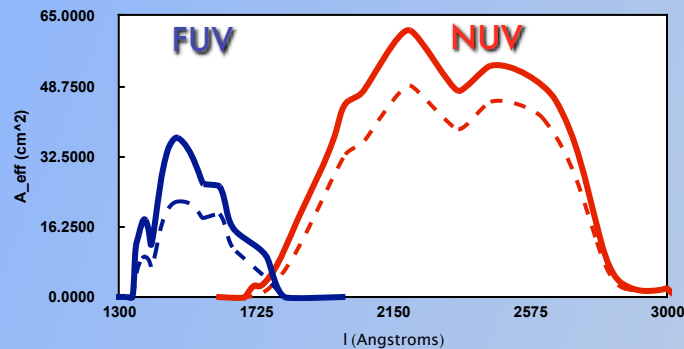
- Unique tracer visible at all redshifts
- But affected by the presence of dust





GALEX Deep Imaging Survey

GALEX: UV Imager + Low Res. Spectrograph (Martin+, 05)



*** 2 channels:**

FUV (1500A) NUV (2300A)

*** Field of View : 1.5°**

PSF $\sim 5\text{arcsec}$ ($1.5''/\text{pix}$)

*** Survey Modes :**

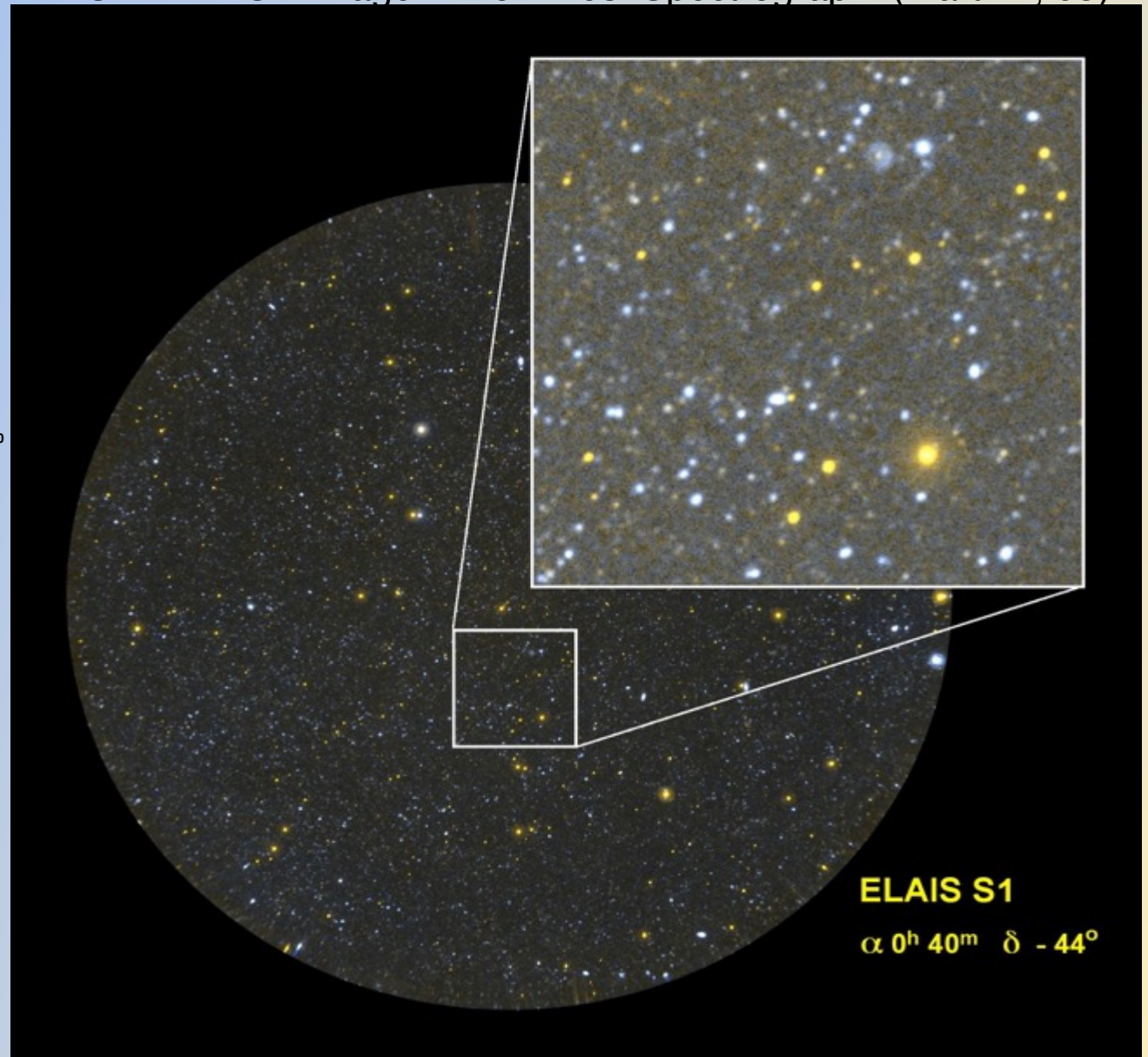
I- All-Sky Survey ($\sim 100\text{s}$)

II- MIS ($\sim 1.5\text{ks}$)

III- DIS ($>30\text{ks}$)

Confusion limit
(30 beam-per-source)

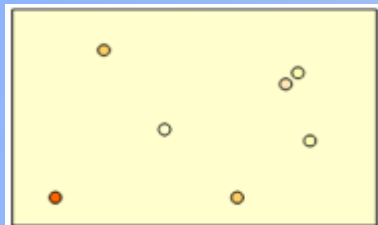
FUV ~ 25.3 , NUV ~ 24



GALEX : EM photometry

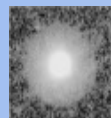
D. Vibert, S. Conseil, S. Arnouts, B. Milliard, A. Lebaria, M. Guillaume (LAM), M. Zamojski (Geneve), D. Schiminovich (Col.)

Dirac or stamps PRIORS



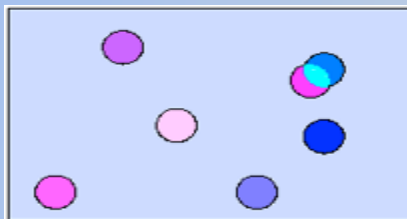
$O_{k,i}$: k at pixel i

GALEX PSF



f_{i-j}

GALEX Reconstruction image



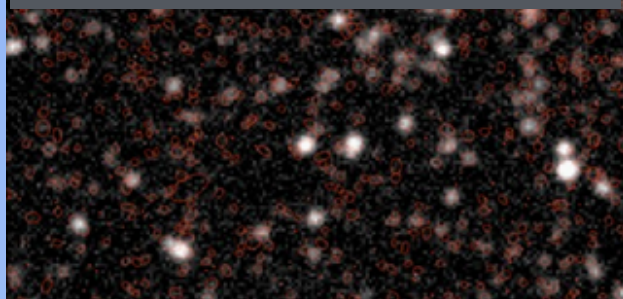
$$h_{k,i} = \sum_j o_{k,j} f_{i-j}$$

over one tile: x_i observed count. μ_i expected counts @pixel i

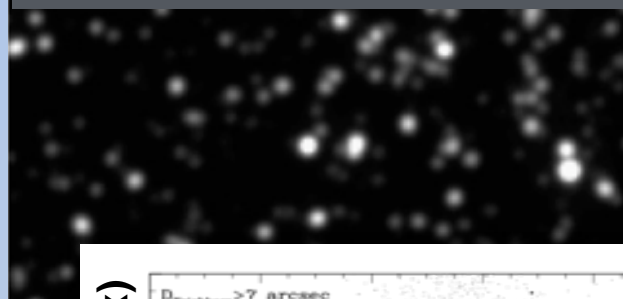
$$\forall i \in \{1, \dots, M\} \begin{cases} \mu_i = \sum_{k=1}^K \alpha_k h_{k,i} + b \\ P = \{X_i = x_i\} = \exp(-\mu_i) \frac{\mu_i^{x_i}}{x_i!} \end{cases} \quad \begin{array}{l} P(x_i) \text{ probability to} \\ \text{observe count } x_i \end{array}$$

Maximization of the likelihood $L(\mathbf{x}, \boldsymbol{\mu}) = \prod_{i=1}^M \exp(-\mu_i) \frac{\mu_i^{x_i}}{x_i!}$
solves with the iterative Expectation - Maximisation algorithm

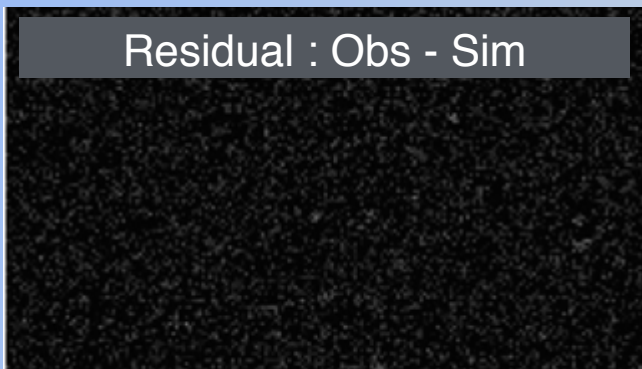
GALEX image + U priors



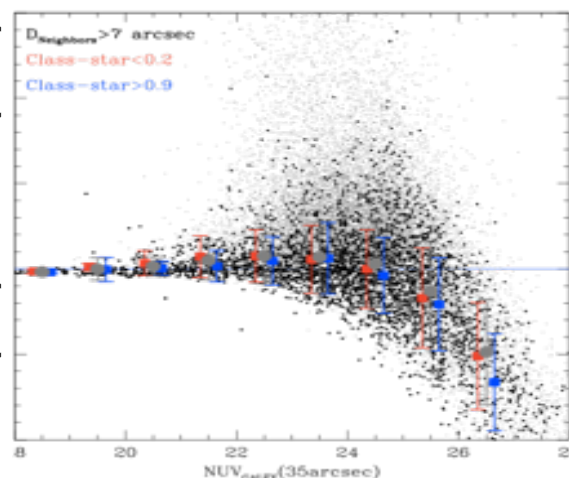
GALEX Simulated with EM



Residual : Obs - Sim

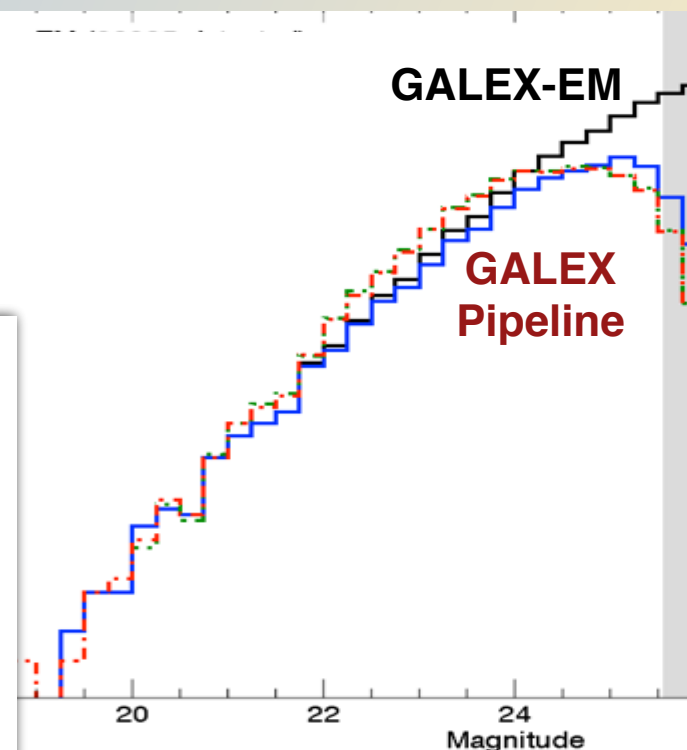


NUV(EM) - NUV(SEX)



GALEX-EM

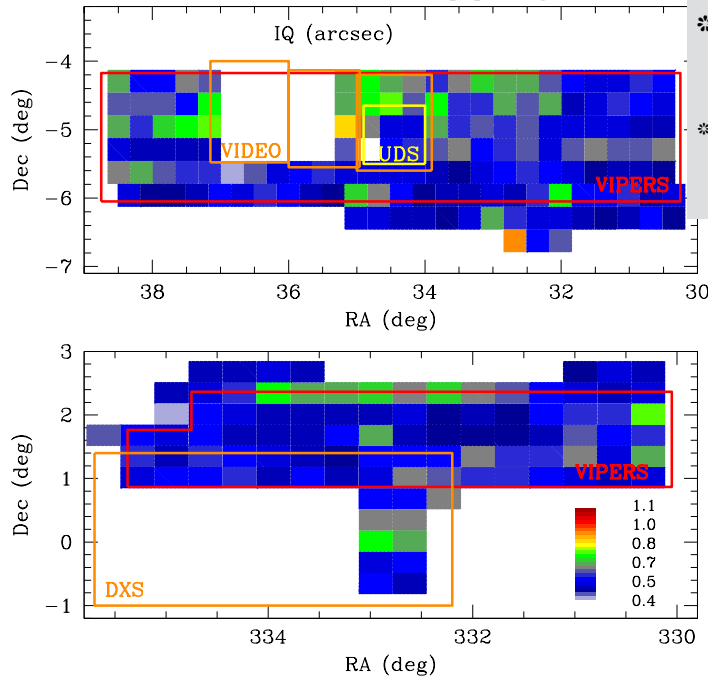
GALEX Pipeline



-Ib- WIRCam Ks photometry

Moutard, SA, Coupon + 15b

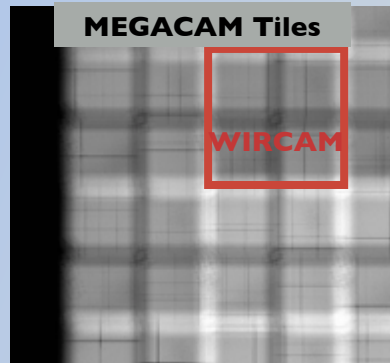
WIRCAM mapping



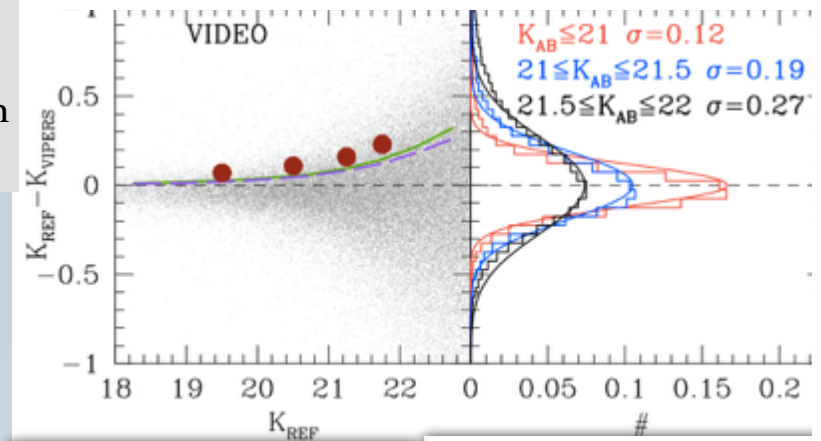
data reduction: TERAPIX (IAP)

* WIRCam tiles warp on MegaCam Tiles

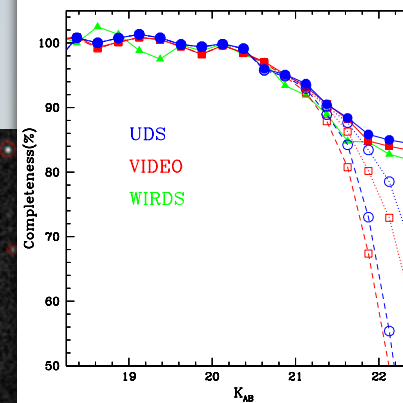
* Sources extraction based on grip Chi-square image



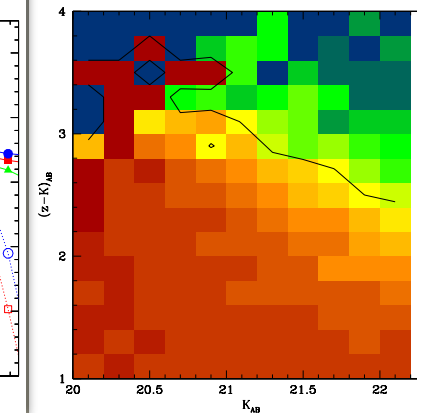
Comparison with Deep Surveys



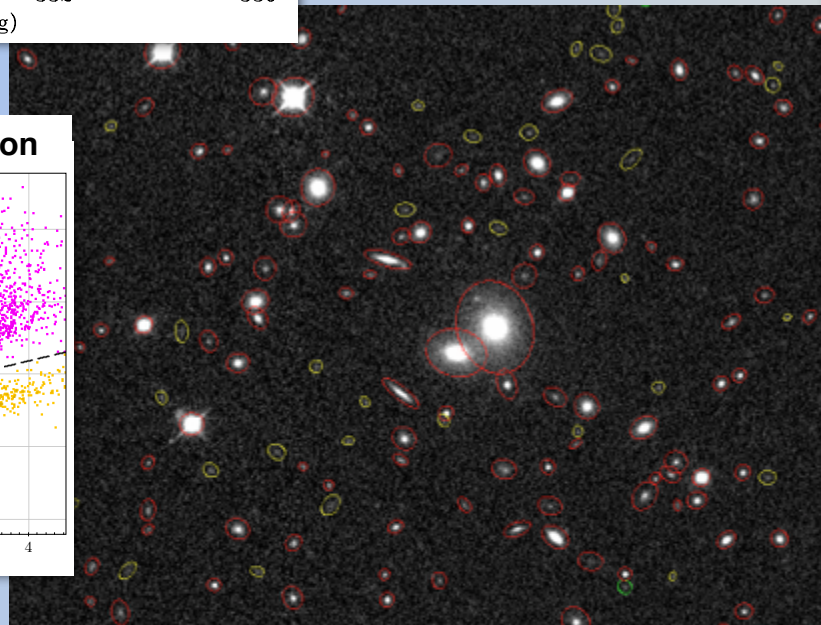
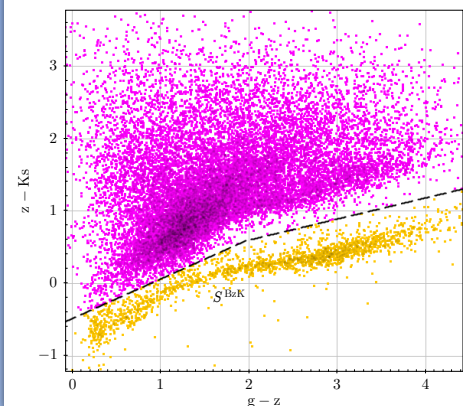
Completeness vs mag



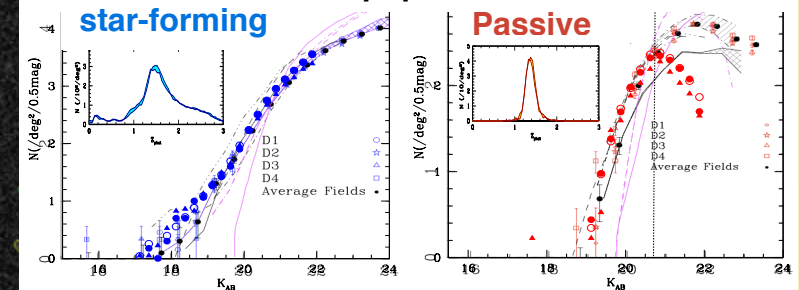
Completeness vs mag, Color



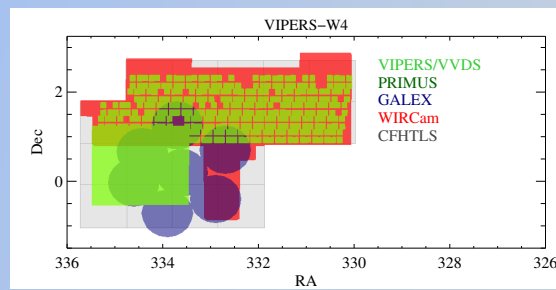
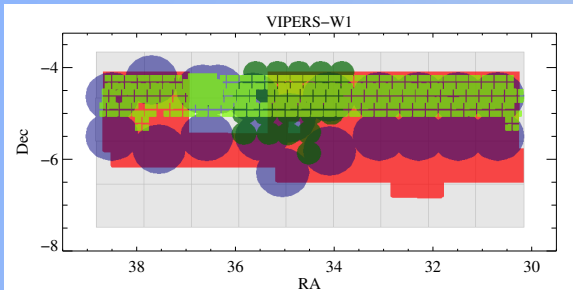
Star - galaxy separation



BzK population



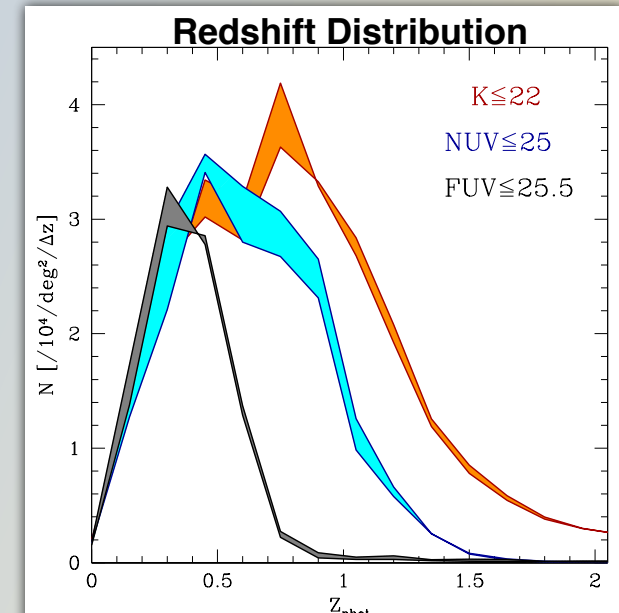
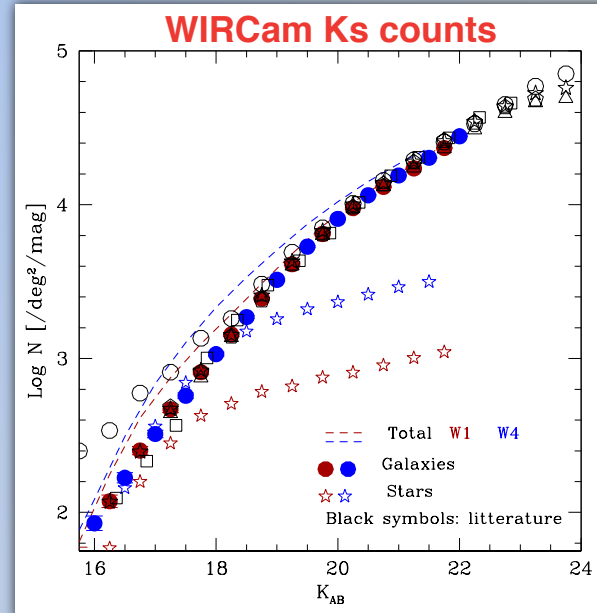
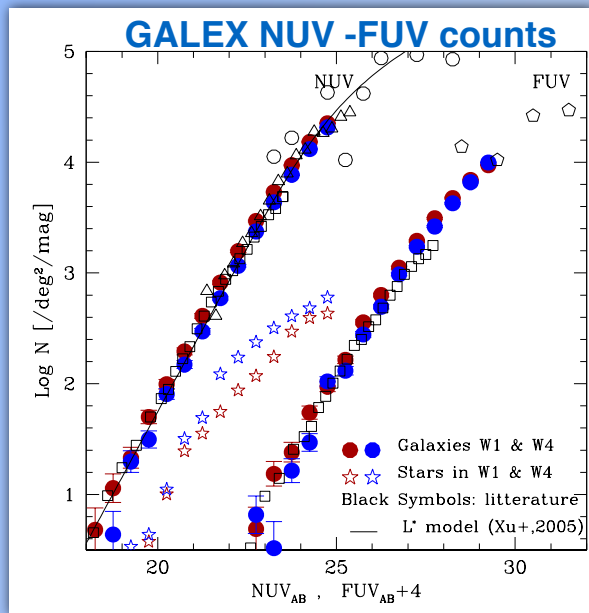
-Ib- VIPERS - CFHTLS multi-wavelength Follow-up



Moutard, SA, Coupon + 15b

The photometric catalogues, photometric redshifts and the images will be released in december 2015

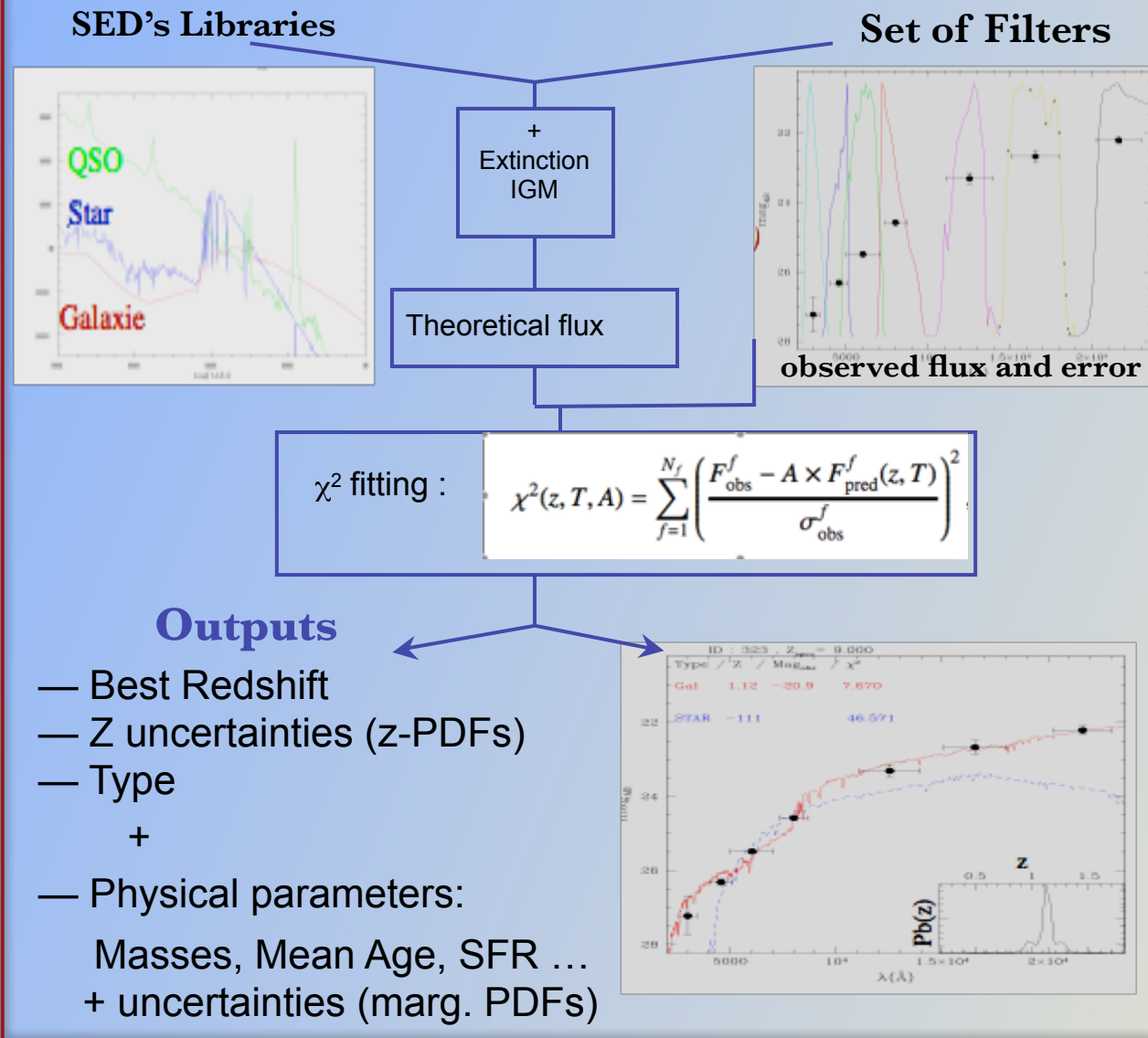
<http://cesam.lam.fr/cfhtls-vipers>



A large HIGH QUALITY multi-Lambda dataset over a unique area/volume $\sim 25 \text{ deg}^2$ & $0 < z < 1.5$

Scientific Drivers: Understand Star Formation Processes / Stellar Mass Assembly up to $z=1.5$

SED fitting technique



pro

- * work at any redshift
- * independent of training dataset
- * redshift uncertainties
- * classifier: Star/Galaxy/QSO
- * access to physical parameters
- * you know what you are doing !

con

- * representativity of SEDs ?
- * require a good knowledge of dust attenuation
- * time consuming compared to machine learning, NN ...

-Ic- VIPERS - CFHTLS photometric redshifts

with Le Phare code <http://cesam.lam.fr/lephare>

LePhare Download Install Syntax Examples Acknowledgement

SA+1999 ; Ilbert,SA,McCracken+2006

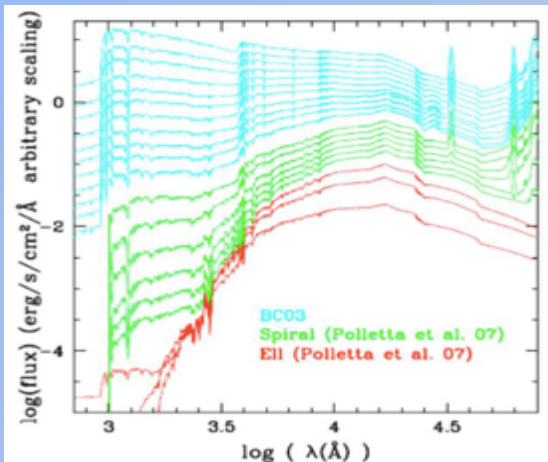
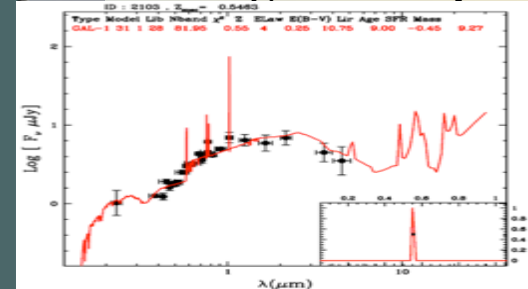
SED fitting technique

Le PHARE

Photometric Analysis for Redshift Estimate

Arnouts S. & Ilbert O.

Latest Version Feb. 2011



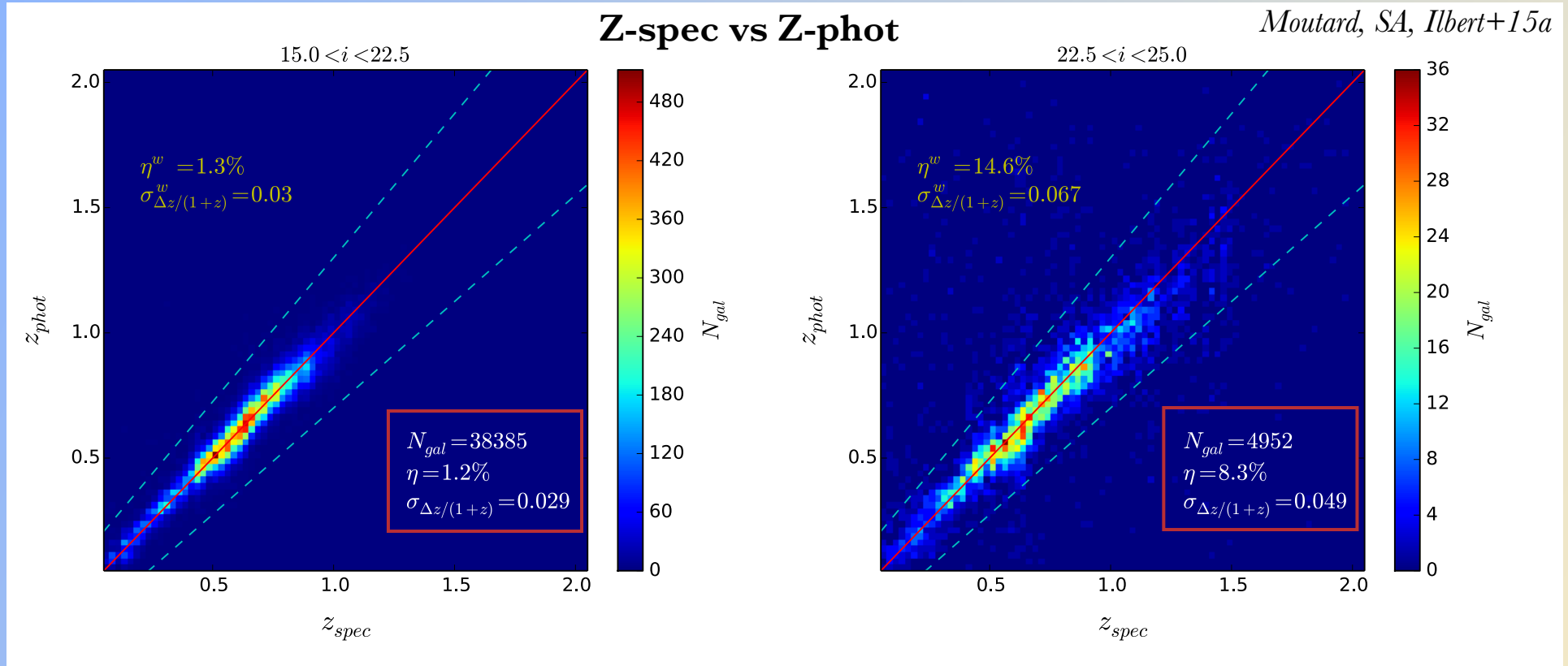
Photometric Redshifts (Ilbert +09)

- empirical SEDs [Poletta+, 07] + BC03 blue templates
- ZP calibration using spectroscopic redshifts
- Emission Lines + 3 extinction laws

Physical Parameters (Arnouts+13)

- wavelength range : FUV to 2.2 μm [stellar light]
- BC03 library
- 3 extinction laws : SB, SMC, intermediate curves
- Mass, SFR, Age (68% err. marginalized over each para.)

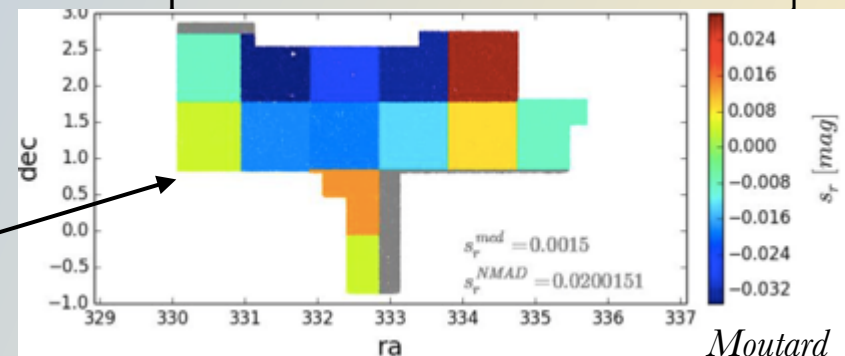
-Ic- VIPERS - CFHTLS photometric redshifts



Large spectroscopic sample available in this region (~50,000) to optimize

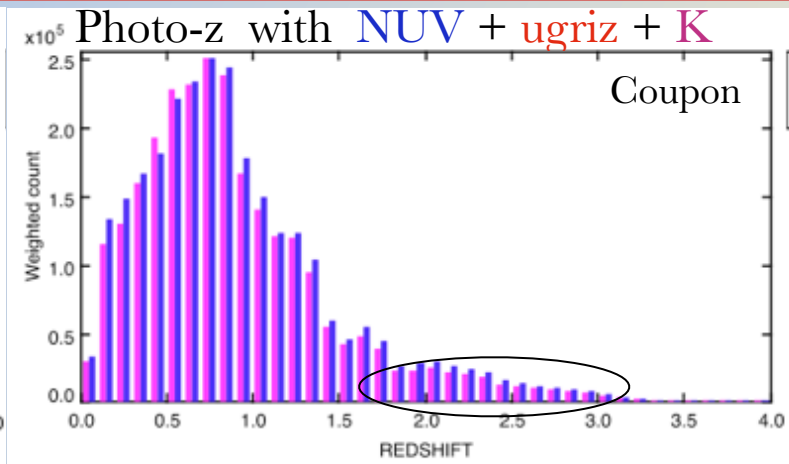
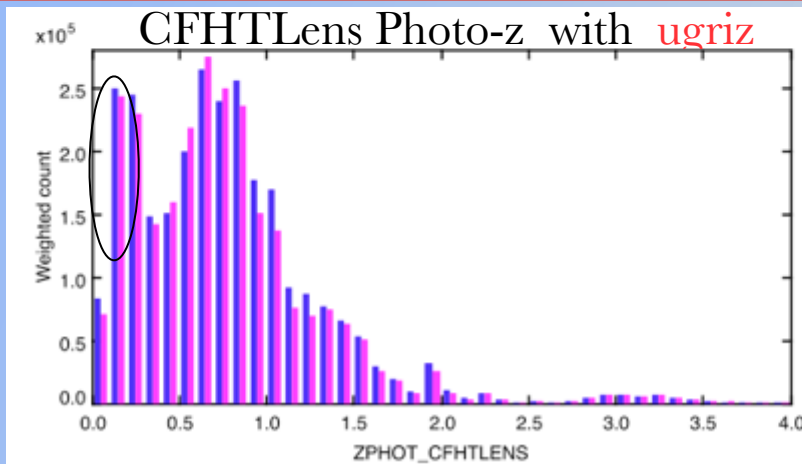
- the SED libraries & extinction laws [here : COSMOS empirical SEDs + 3 extinction laws]
- choice of magnitudes for the best colors
- zero-point adjustments tile-by-tile

ex. across the CFHTLS tiles in r band

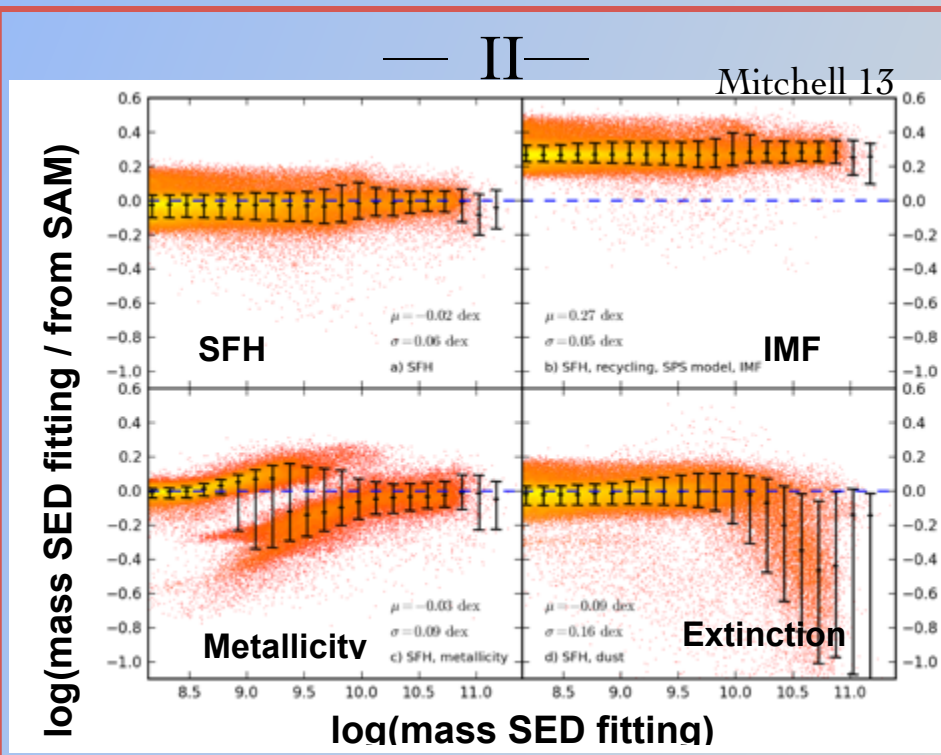


-Ic- Impact of wavelength coverage & attenuation laws

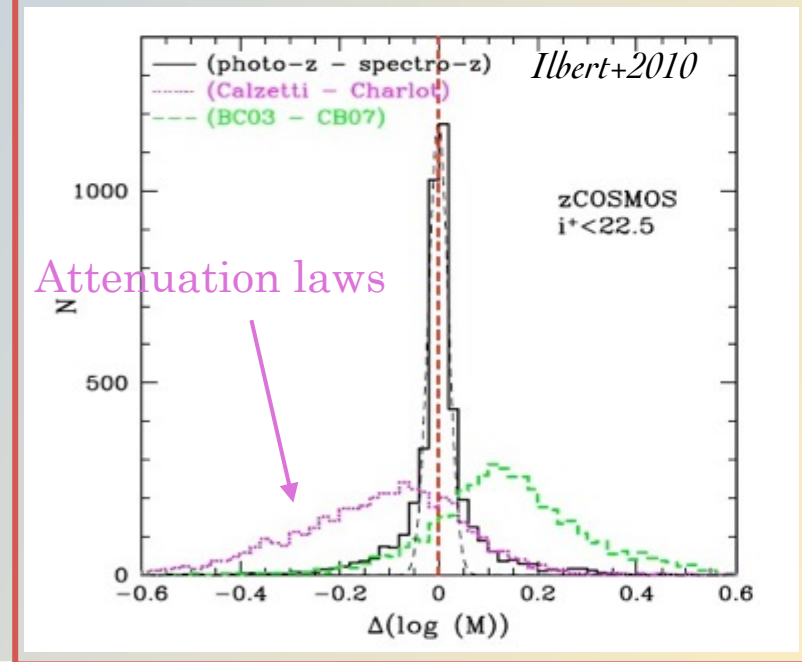
- I -



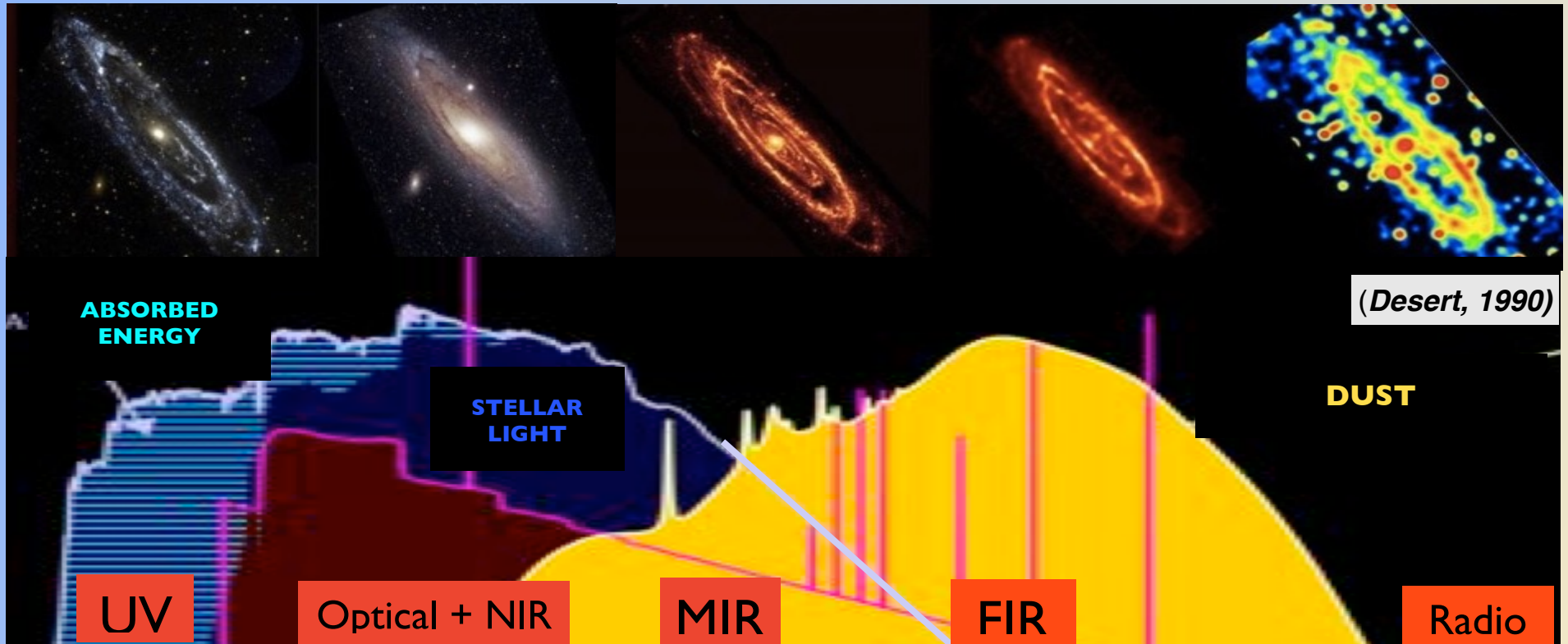
— II —



— III —

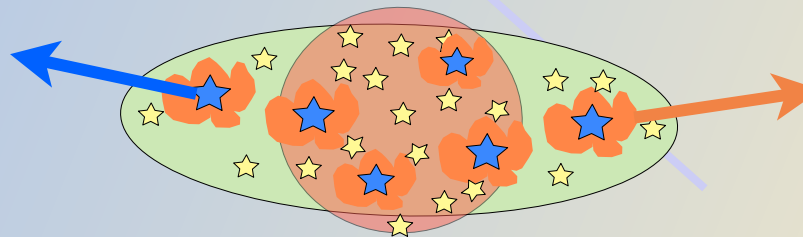


Multi-wavelength components



UV attenuation :

- Extinction curve (dust composition)
- star/dust distribution
- galaxy geometry + inclination



FIR emission:

Dust grain
Temperature,
size
composition

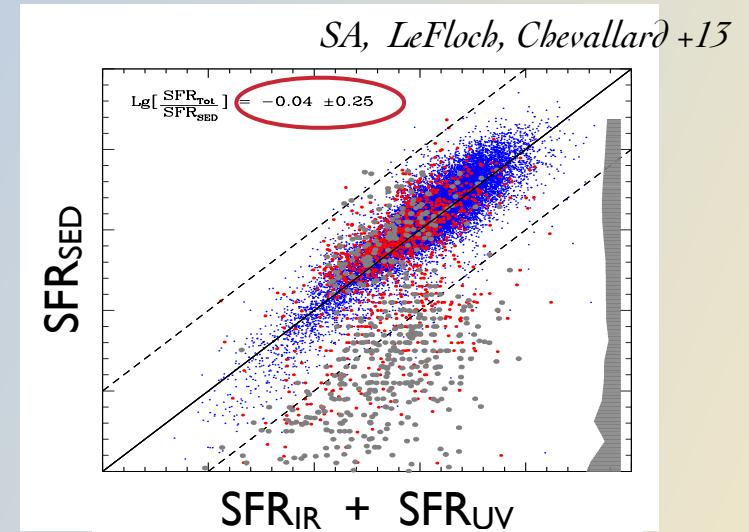
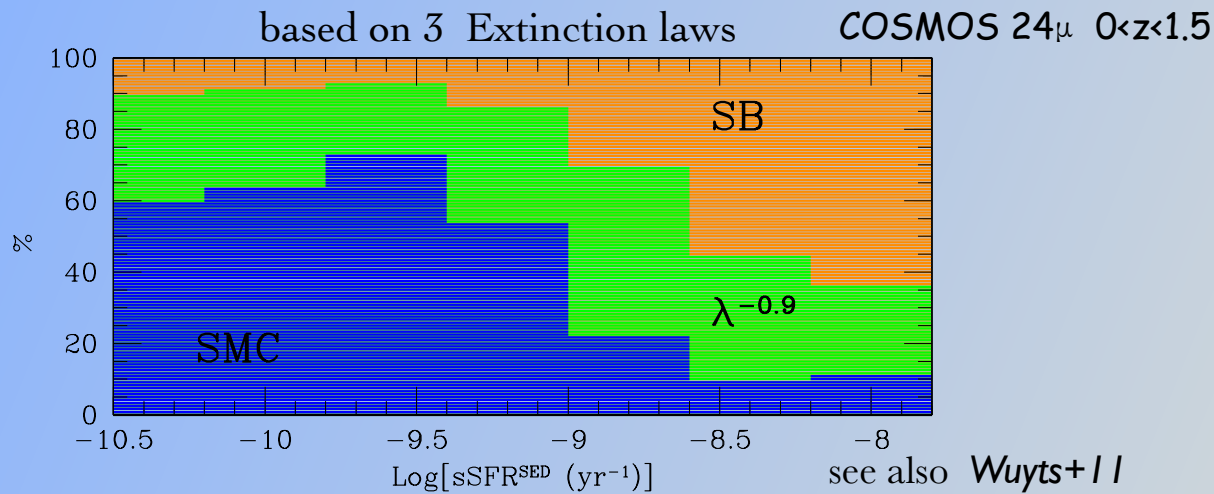
The absorbed energy in UV is re-radiated by heated dust grain in Far-Infrared

Energy Budget $\text{SFR} = \text{SFR}(\text{UV unextinguished}) + \text{SFR}(\text{Far-IR})$

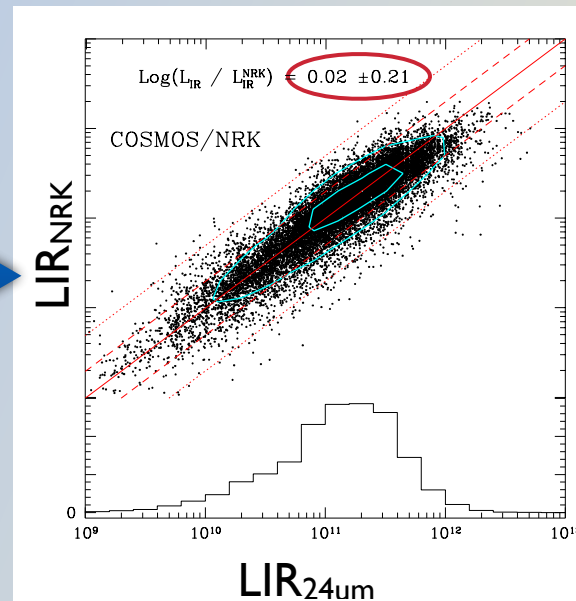
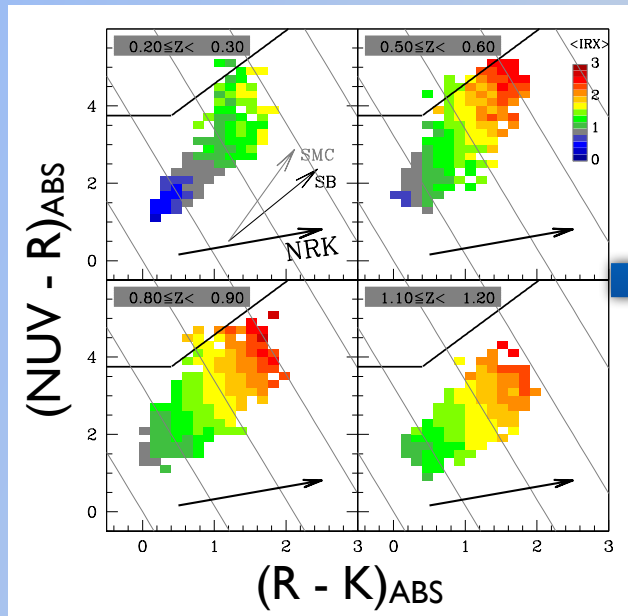
➔ When only UV available : good modeling of the UV attenuation is required !

Multi-wavelength SFR estimates

→ Need to adopt several attenuation laws to derive a robust SFR measurement



→ direct estimate of IRX in (NUV-r)₀ vs (r-K)₀ diagram [independent of attenuation law]



SFR derived with one single optical parameter NRK !!

Interesting for future optical/NIR survey

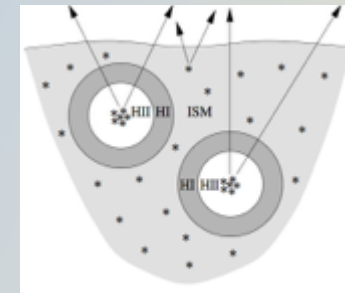
Multi-wavelength SFR estimates

→ Can we understand the shape & location of the IRX ?

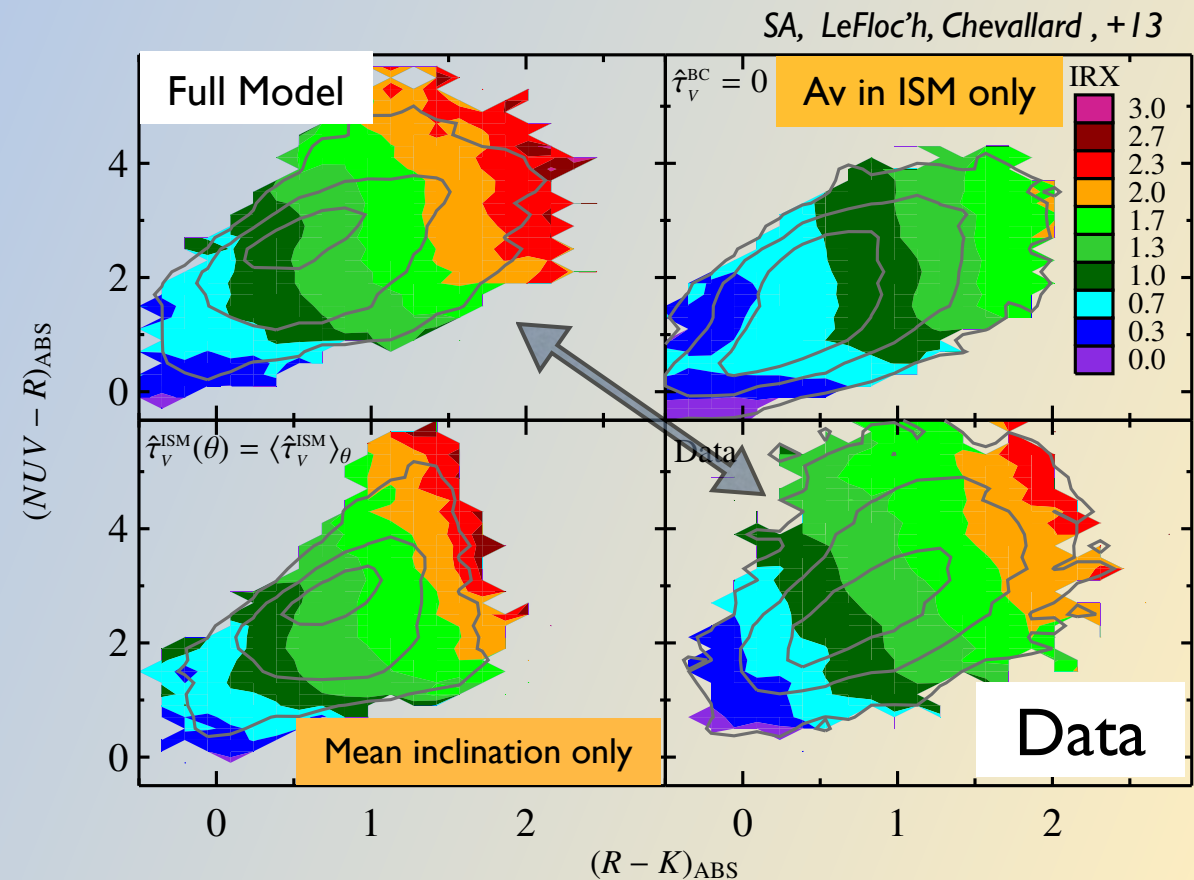
by J. Chevallard

model's ingredients :

- 1- Stochastic SFH from SAM (*Pacifici, 12*)
- 2- Attenuation : balance between the ambient ISM and the Birth Clouds (*Charlot & Fall, 00*)
- 3- Inclination effects (*Chevallard+, 2013*)



→ Good modeling if all ingredients included !



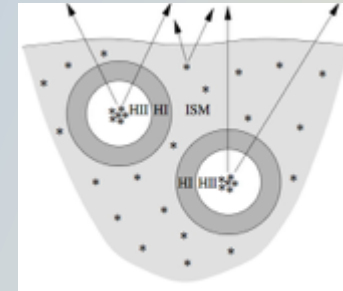
Multi-wavelength SFR estimates

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by J. Chevallard

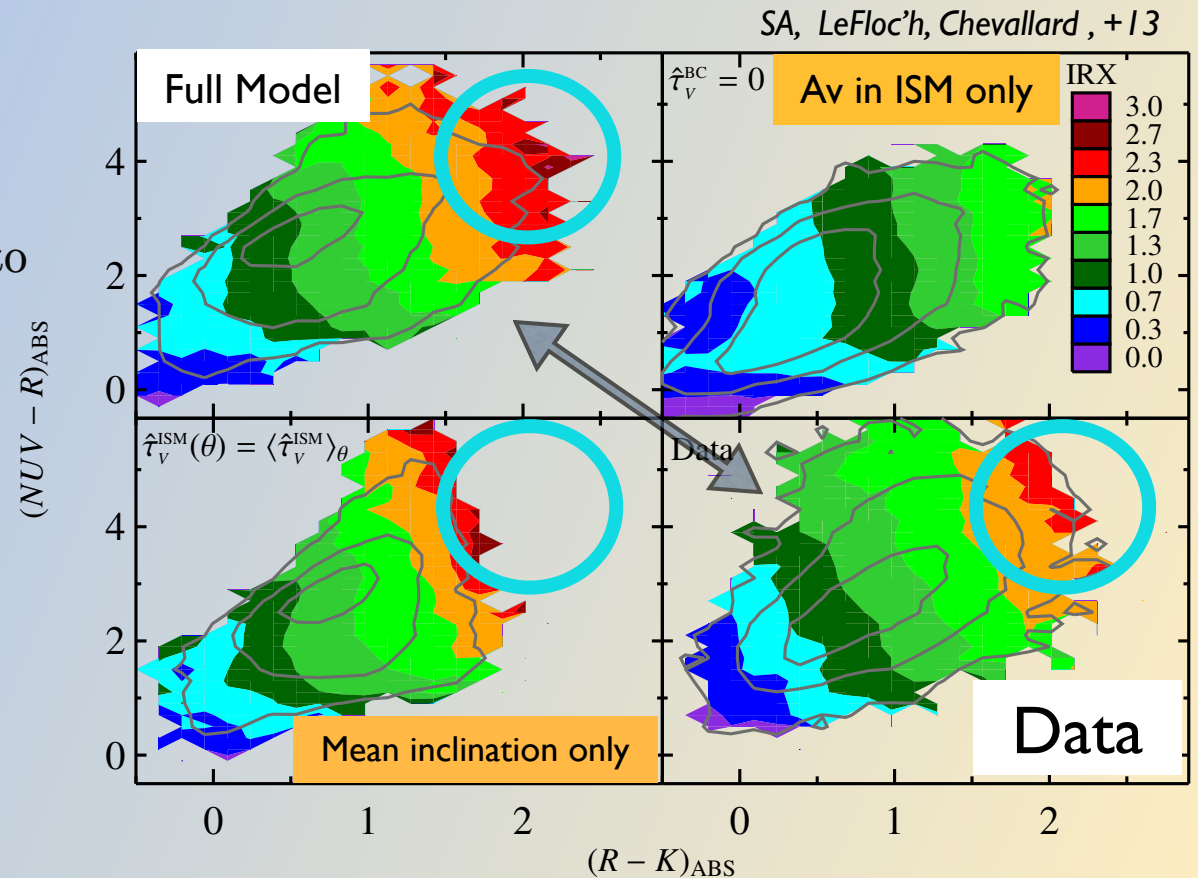
model's ingredients :

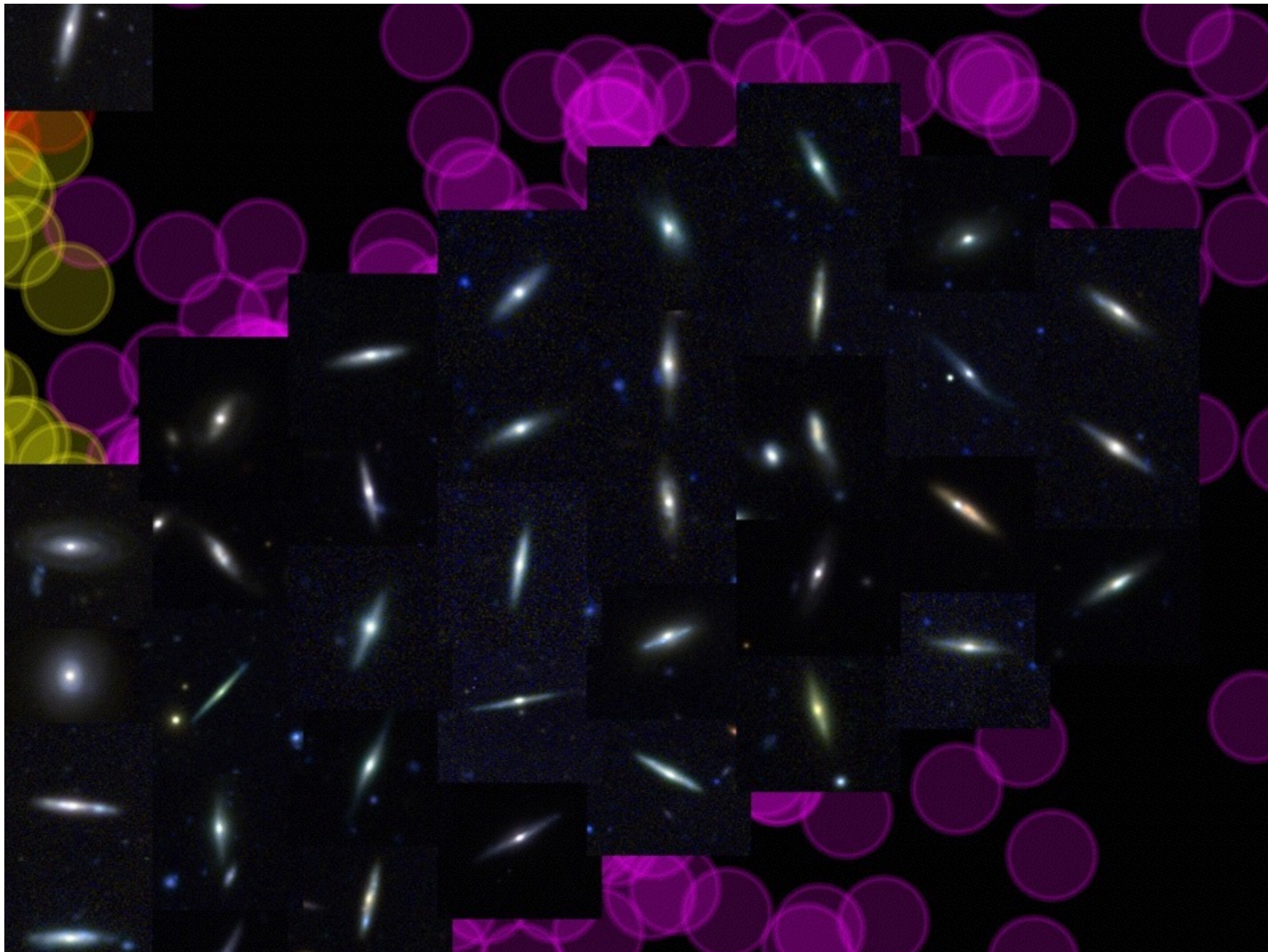
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→ Good modeling if all ingredients included !

Disk inclination important to explain large IRX !





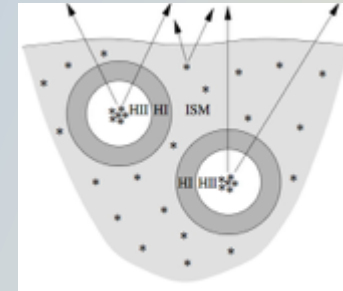
Multi-wavelength SFR estimates

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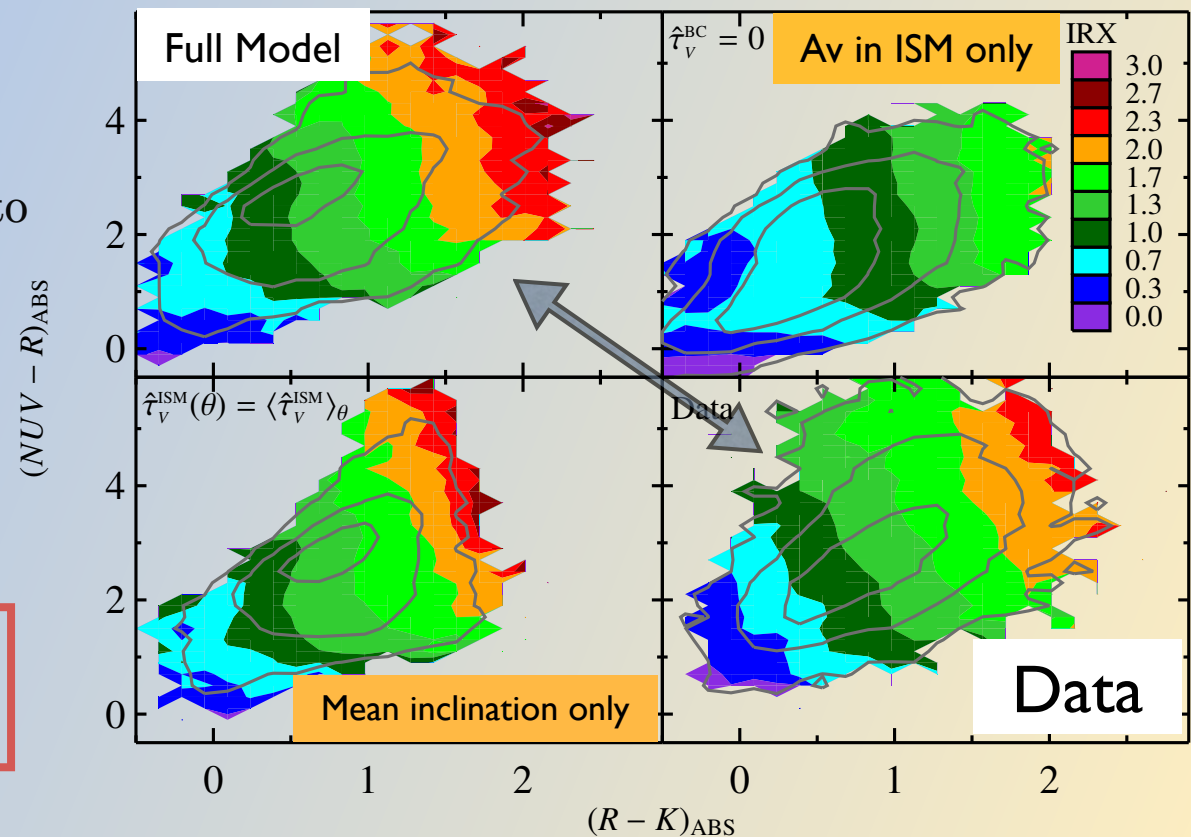
→ Good modeling if all ingredients included !

Disk inclination important to explain large IRX !

Need a new modeling of attenuation law to better account for this effect

Important for SFR from SED
BUT also for Photo-z !!

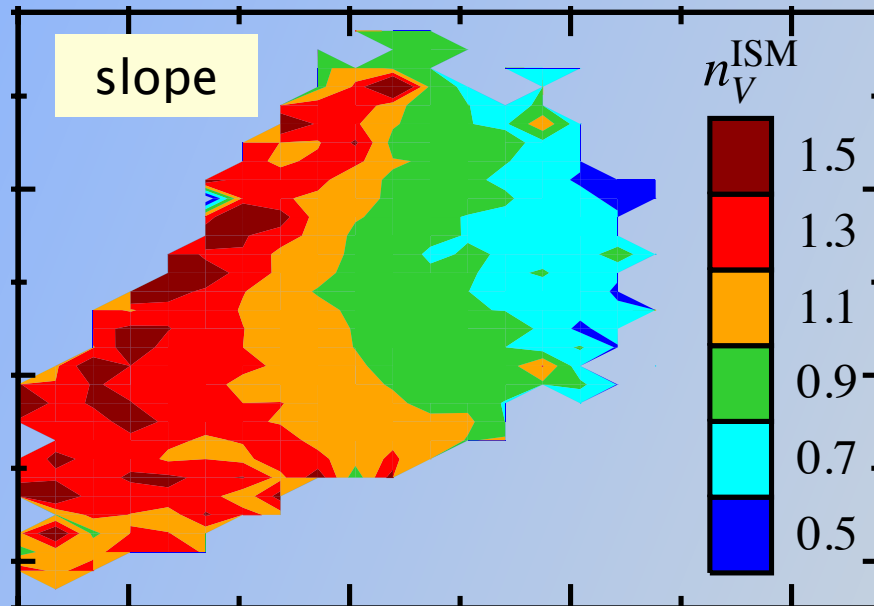
SA, LeFloc'h, Chevallard, +13



Multi-wavelength SFR estimates

→ A new treatment of attenuation laws ?

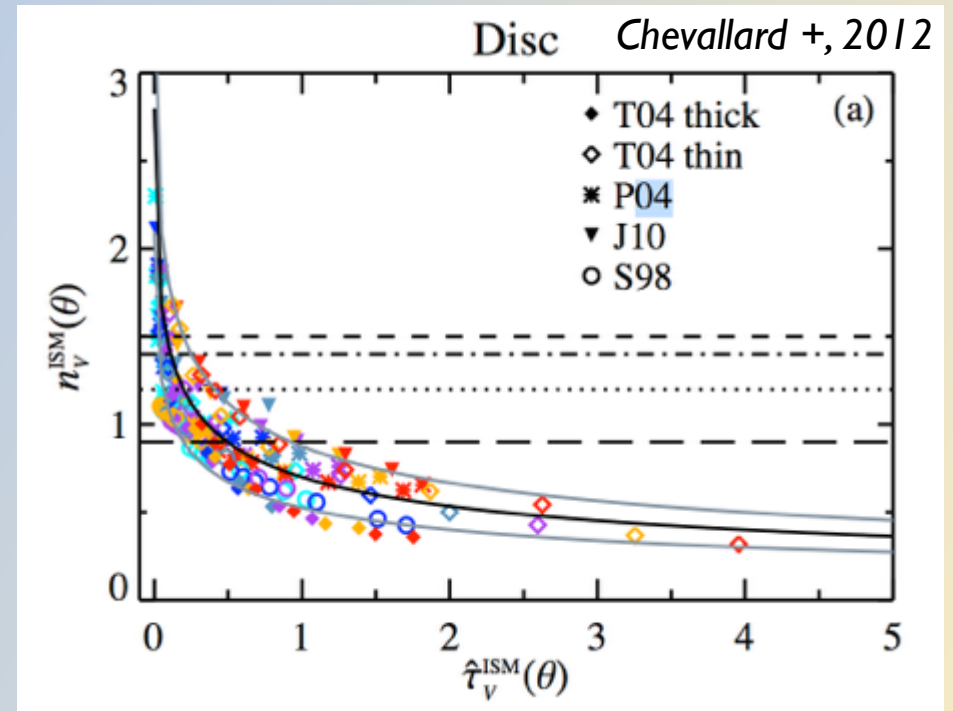
Model prediction for the slope of the attenuation law near 5500Å



Large range of slope for the attenuation curves

- * steeper/shallower slopes than LMC and SB laws
- * how many attenuation laws do we need ?? :-(
- ... BUT ...

full set of Radiative Transfer models



Chevallard +, 2012 ran full set of RT models.

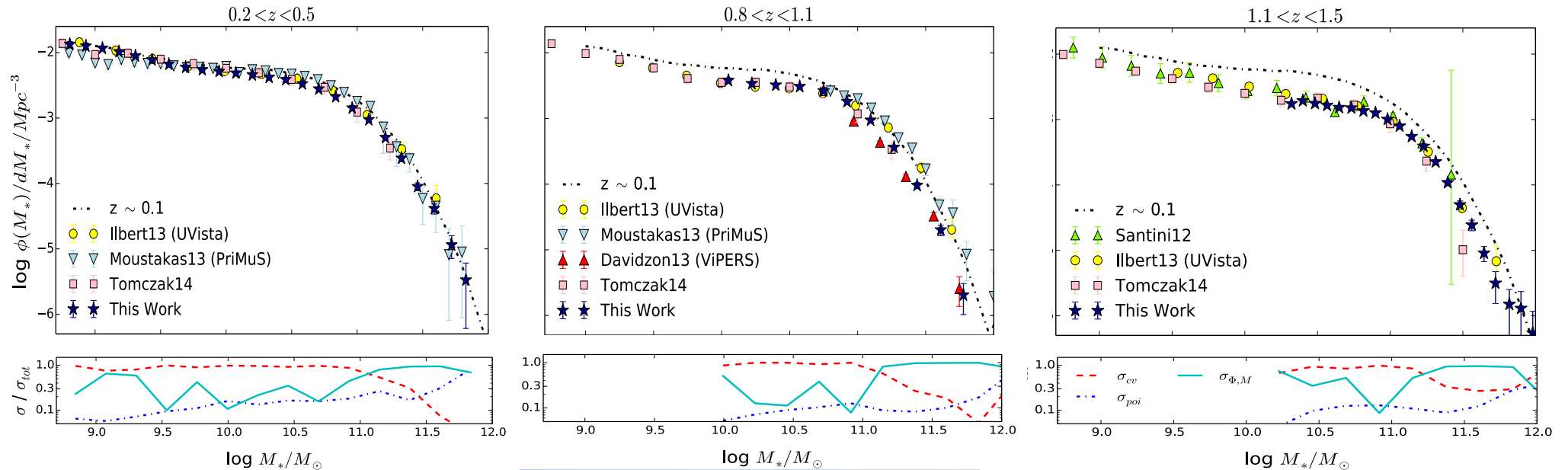
- They all predict a quasi-universal relation between slope of the attenuation curves and V-band attenuation optical depth at all galaxy inclinations

In principle, this should simplify the treatment of dust for SED fitting !

-Id- VIPERS Stellar Mass Function

Moutard, SA, Ilbert +13

VIPERS photo-z K~22 GSMFs



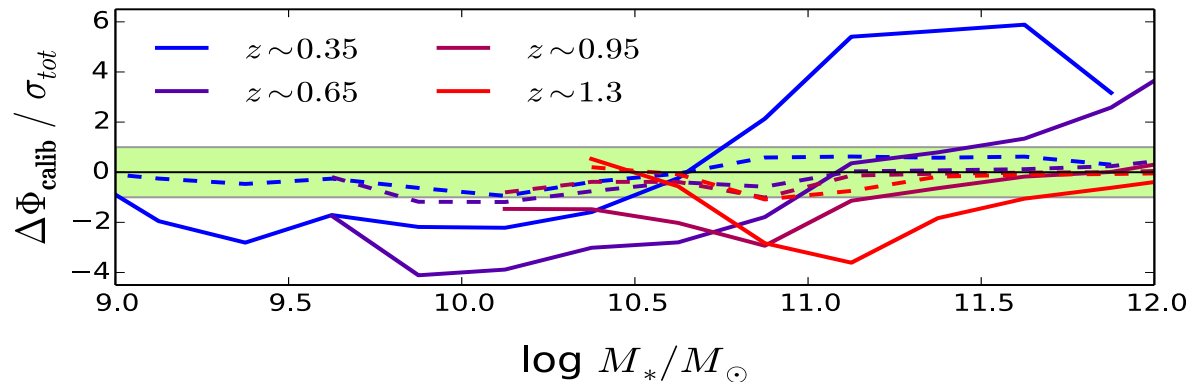
- * Gradual decline of the global GSMF with redshift
- * Good agreement with deeper surveys.
- * Excellent constraints down to 10^{-5} Mpc^{-3}
 - Massive End dominated by stellar mass uncertainties

-Id- VIPERS Stellar Mass Function

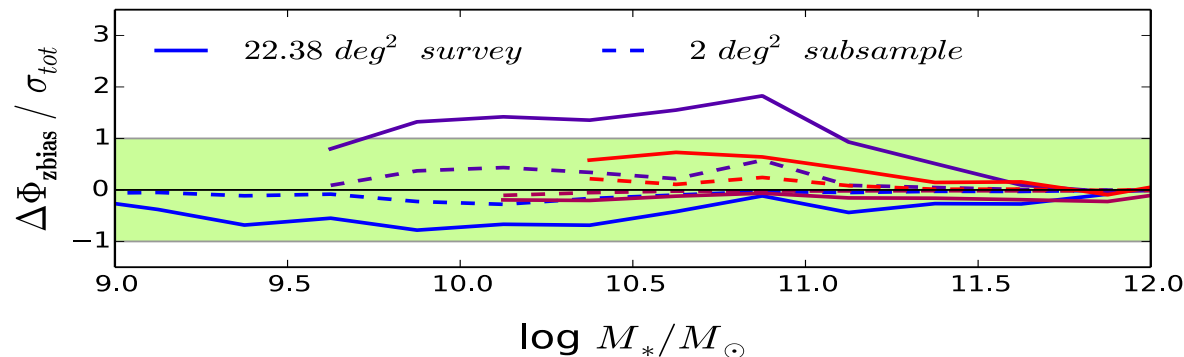
Importance of systematics in the GSMFs

- ➔ Photometric calibration variations (i.e. differences between CFHTLS- T06 and T07)
difference between the GSMFs compared to σ_{tot} in 2 deg² and 22 deg²

Moutard, SA, Ilbert +13



- ➔ z-bias corrections

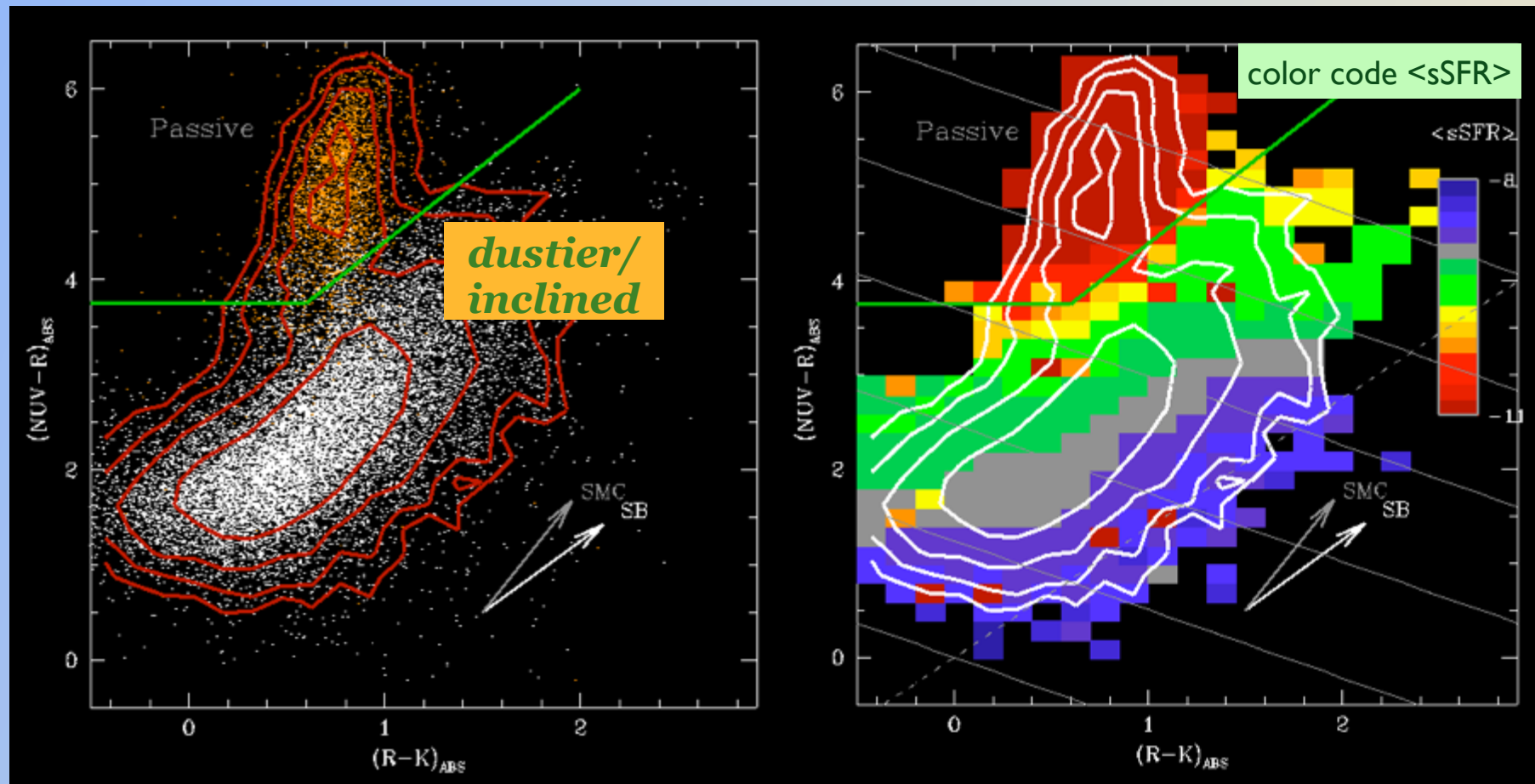


In 2 deg² field the impact of systematics is lower than σ_{tot}
but it is significantly larger (2 to 4 times) for a 22 deg² field !

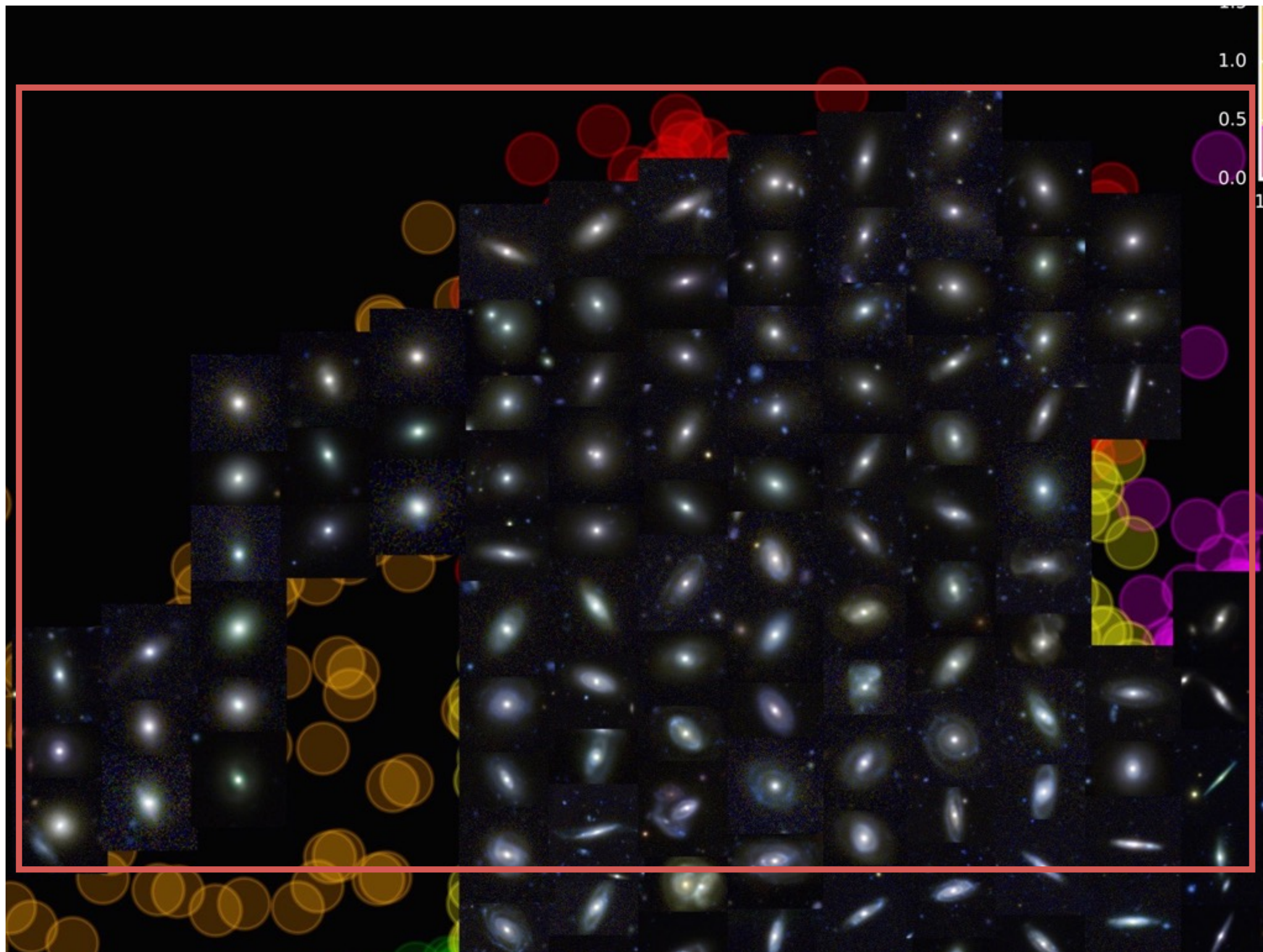
-Id- VIPERS Stellar Mass Function

Separation of Quiescent vs Star-forming galaxies

NUVrK diagram as alternative to UVJ diagram from Williams 2010)



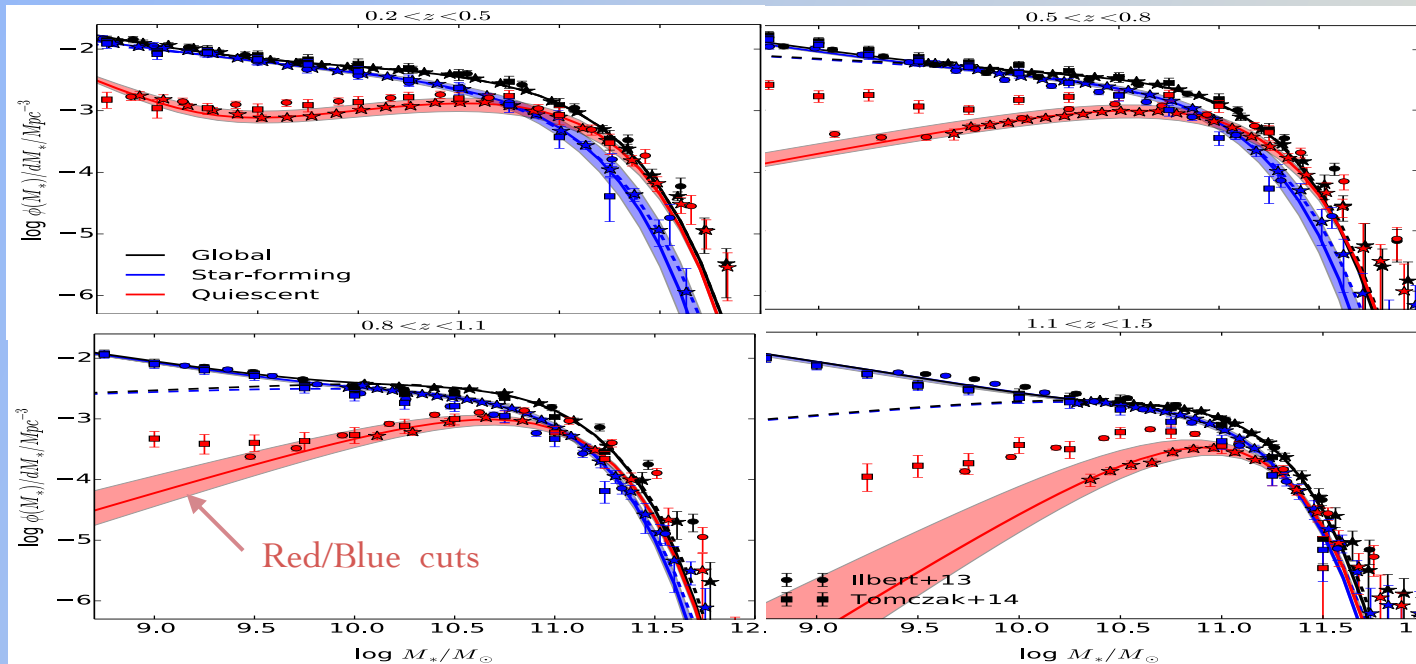
- Clear spread of star-forming galaxies from un-obscured to heavily dusty or inclined (Pattel+12)
- morphological classification



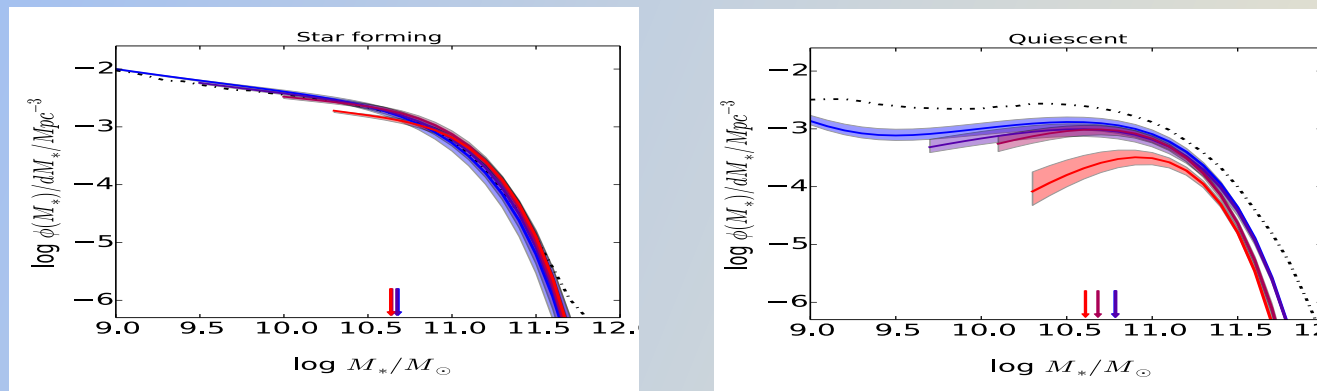
-Id- VIPERS photo-z Stellar Mass Function

Moutard, SA, Ilbert +13

→ Evolution of the GSMF by type : Star-Forming vs Quiescent



- Quiescent MF progressively exceed SF MF at massive end
- Low-mass quiescent galaxies at low z

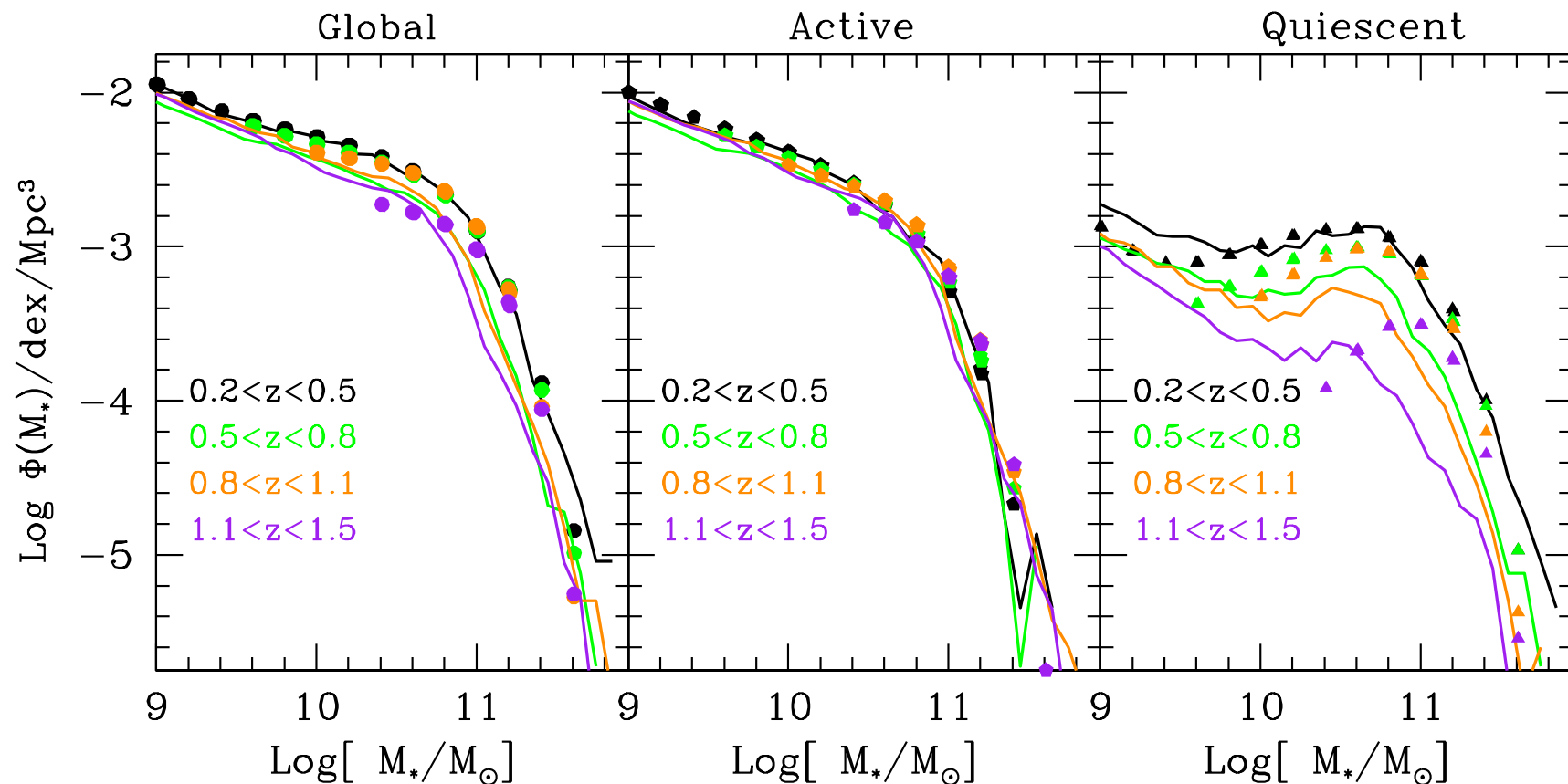


→ No evolution of the SF up to $z=1.5$ and quiescent up to $z=1$

-Id- VIPERS photo-z Stellar Mass Function

Moutard, SA, Ilbert +13

→ Comparison with SAM (Guo+11, Henriques+13)

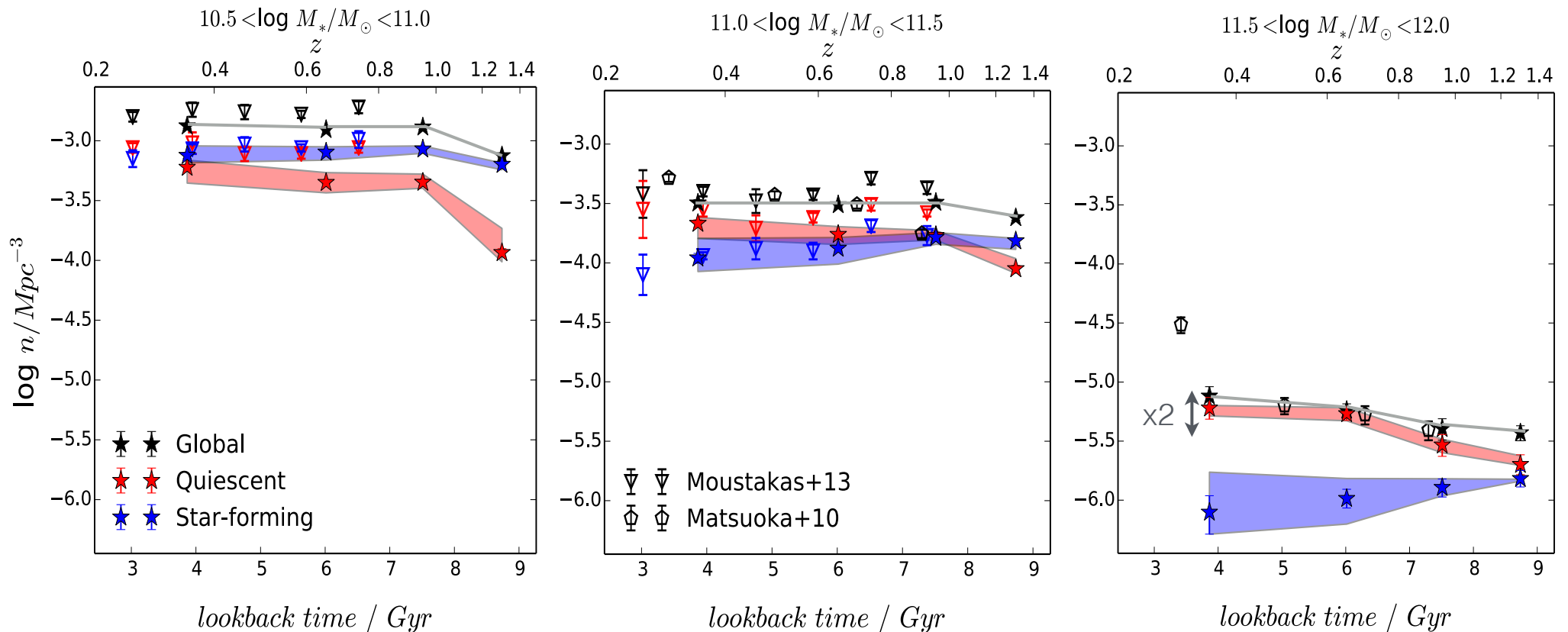


- Good agreement with the MF of the star-forming
- Strong evolution of MF for Quiescents at all masses Not Observed !
- Steep slope of the MF of Quiescent. Less well constrained here

-Id- VIPERS photo-z Stellar Mass Function

Moutard, SA, Ilbert +13

→ density of massive galaxies



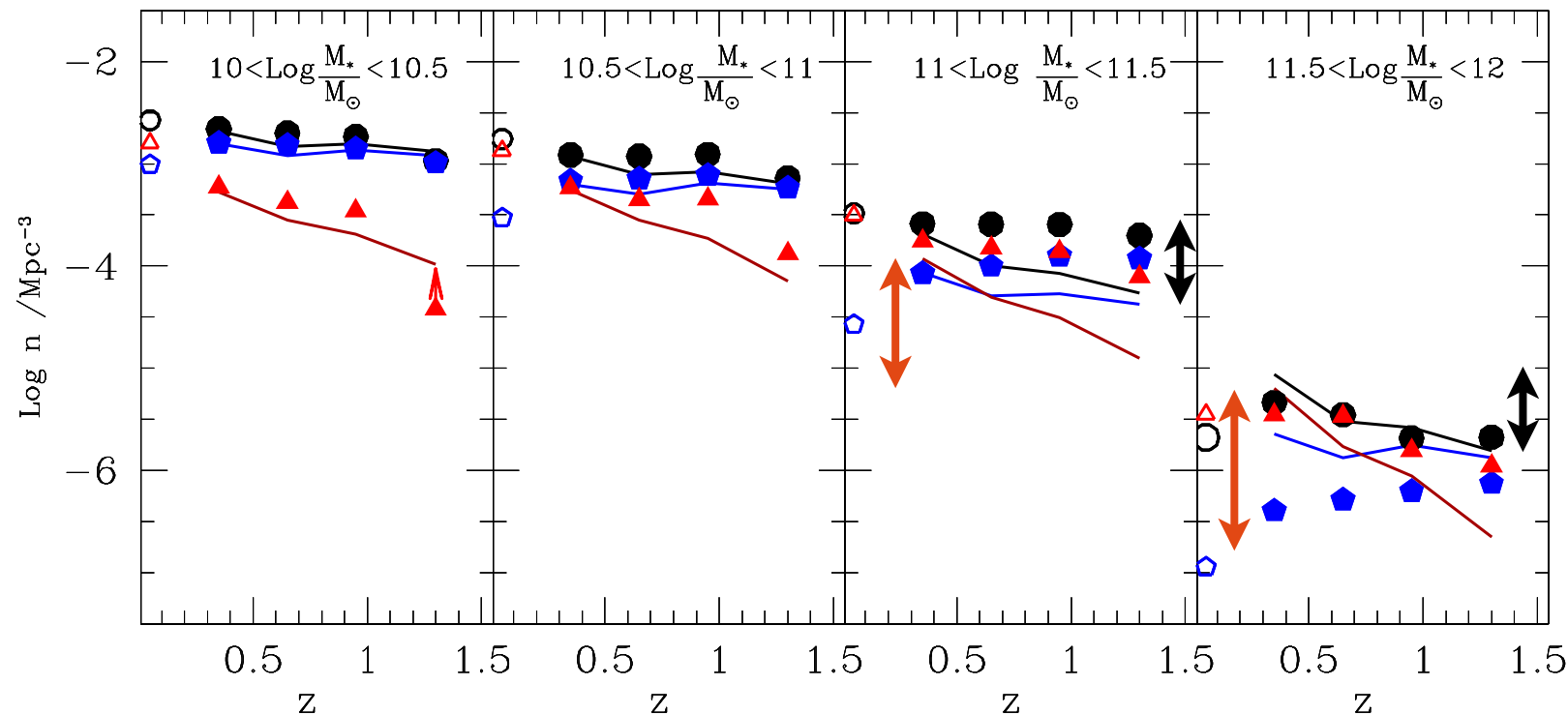
→ First significant measurements :
half of the most massive galaxies are already in place at $z \sim 1.5$
a dominance of Quiescent in the very Massive already at $z \sim 1.5$

Star-Forming density is constant or even decreases with time at high mass.
Quiescent density gradually increase with time and at higher masses

-Id- VIPERS photo-z Stellar Mass Function

→ Comparison with SAM (Guo+11, Henriques+13)

Moutard, SA, Ilbert +13



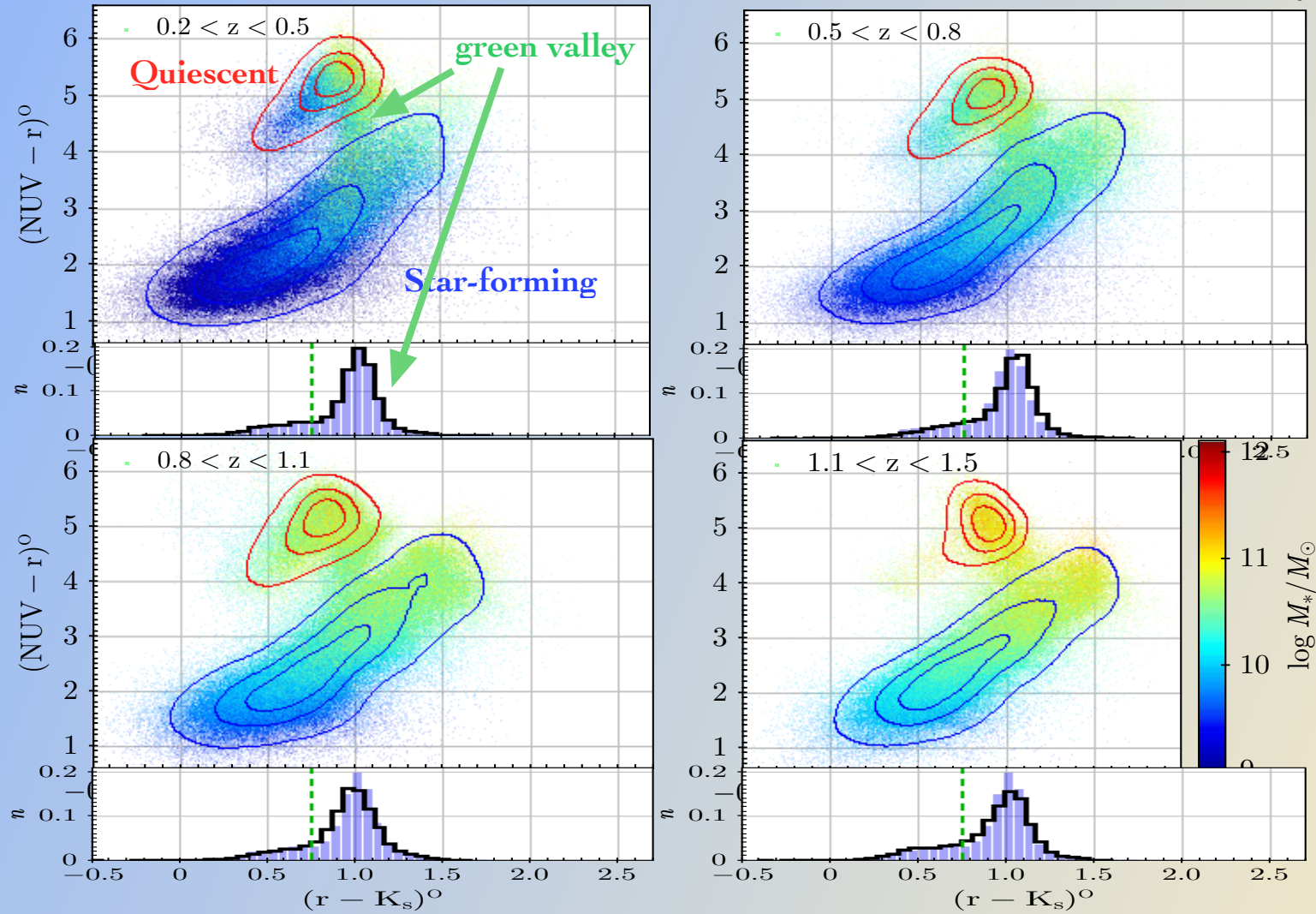
→ SAM predicts a strong density evolution of the massive ones
i.e. a late mass assembly

- Fast build up of the massive Quiescents : in place at z~1
- No constancy or decline of the SF density at high masse

-Ie- Quenching Channels

→ What is the main channel for star-forming to turn quiescent ?

Moutard, SA, Ilbert +13

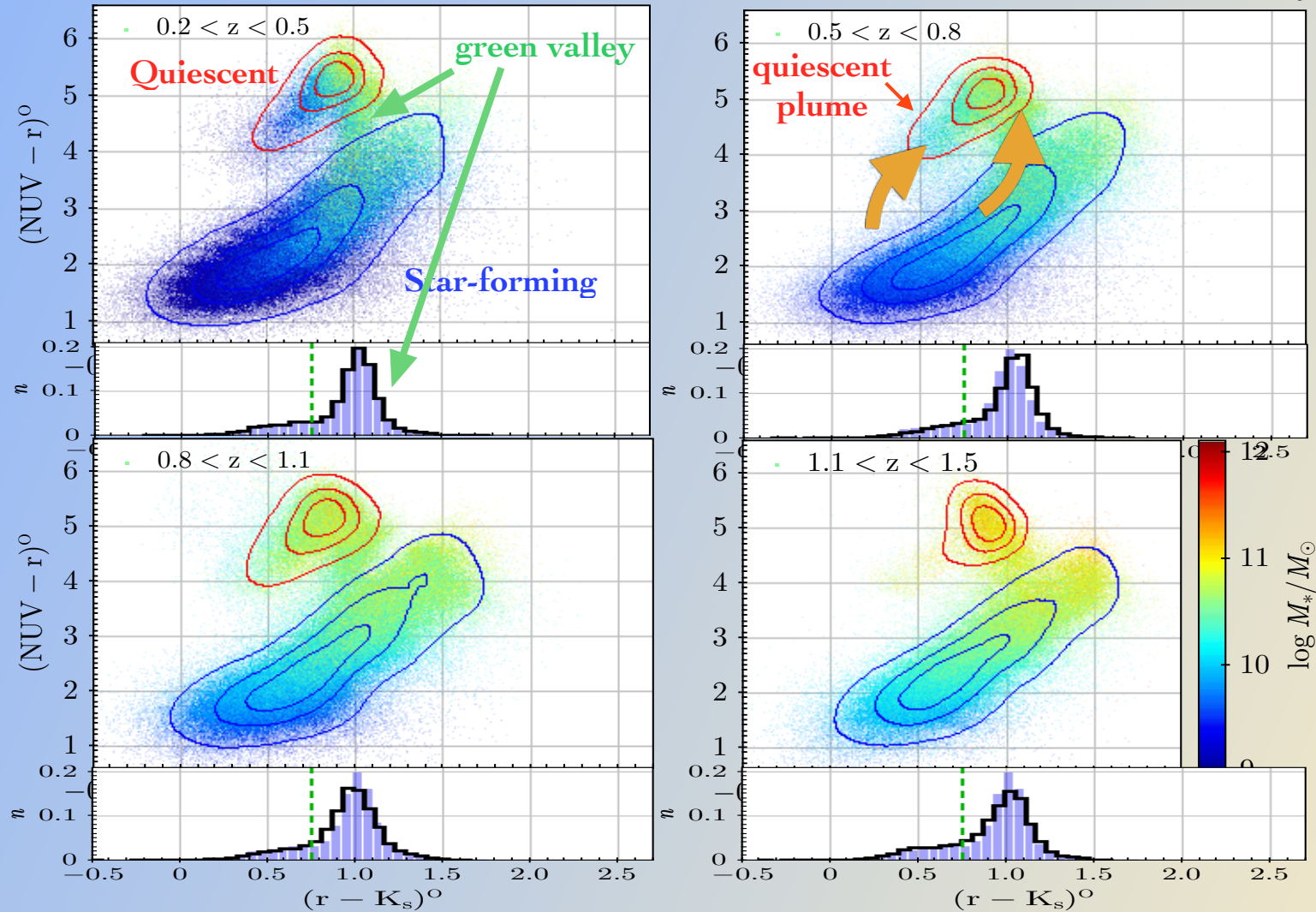


→ TWO channels ?

-Ie- Quenching Channels

→ What is the main channel for star-forming to turn quiescent ?

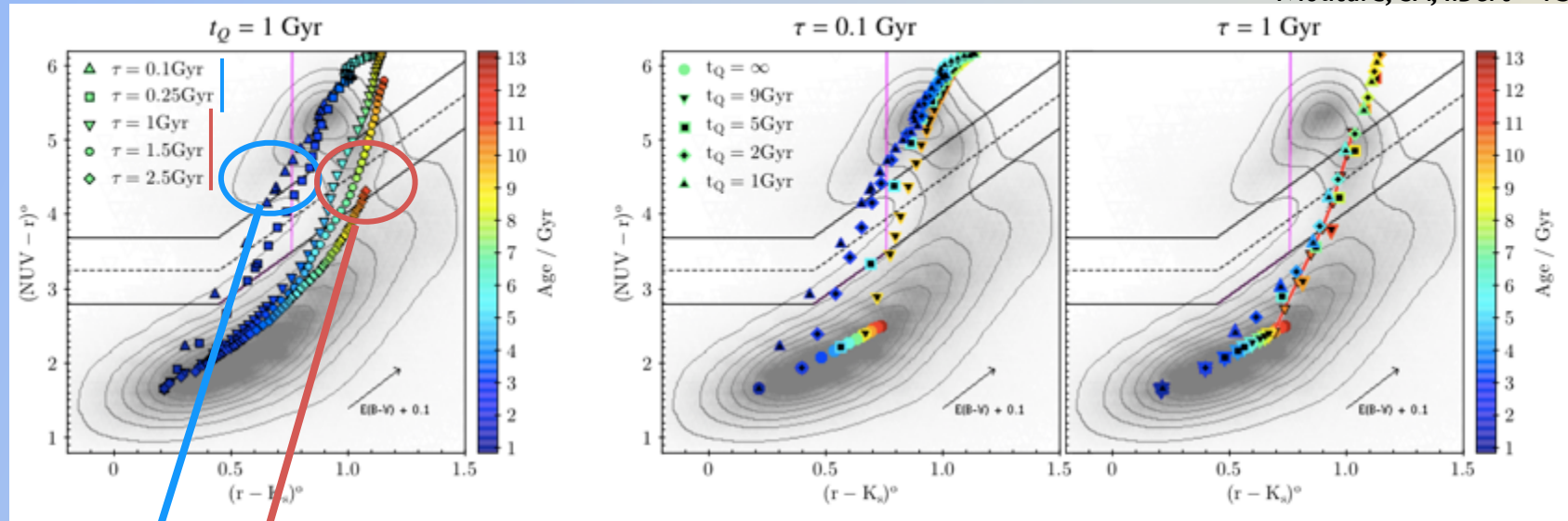
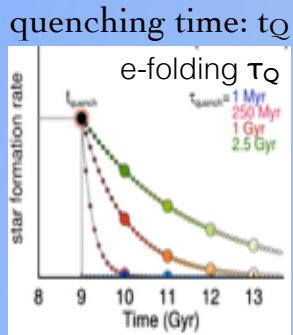
Moutard, SA, Ilbert +13



→ TWO channels ?

-Ie- Quenching Timescale

Moutard, SA, Ilbert +13

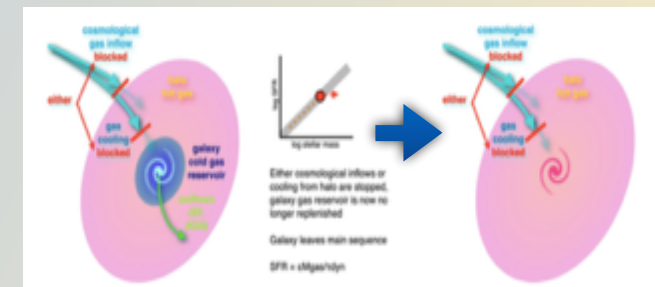


→ M^* quenching channel : $1 \text{ Gyr} < \tau_Q < 2.5 \text{ Gyr}$
equivalent to timescale ~ 3 to 4 Gyr .

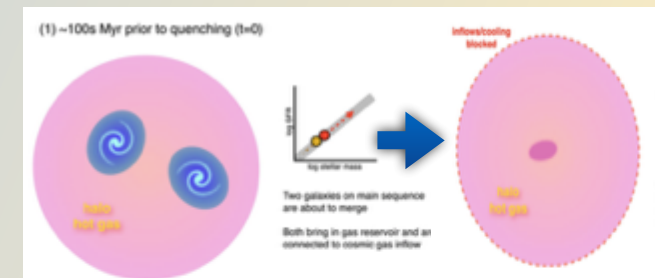
- Physical mechanism must be a slow process.
consistent with strangulation (Peng+15)

→ Low mass channel: $0.25 \text{ Gyr} < \tau_Q$

- dramatic events : major merger + morph. transformation
- scarcity in Green valley : Most likely satellite galaxies (Schawinski+14)



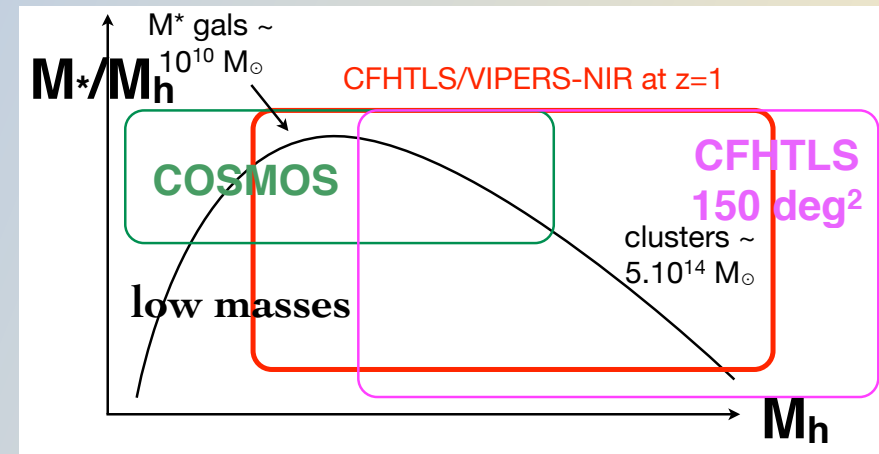
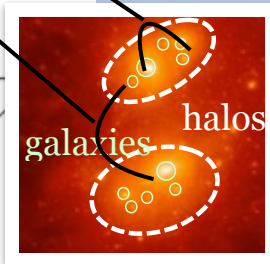
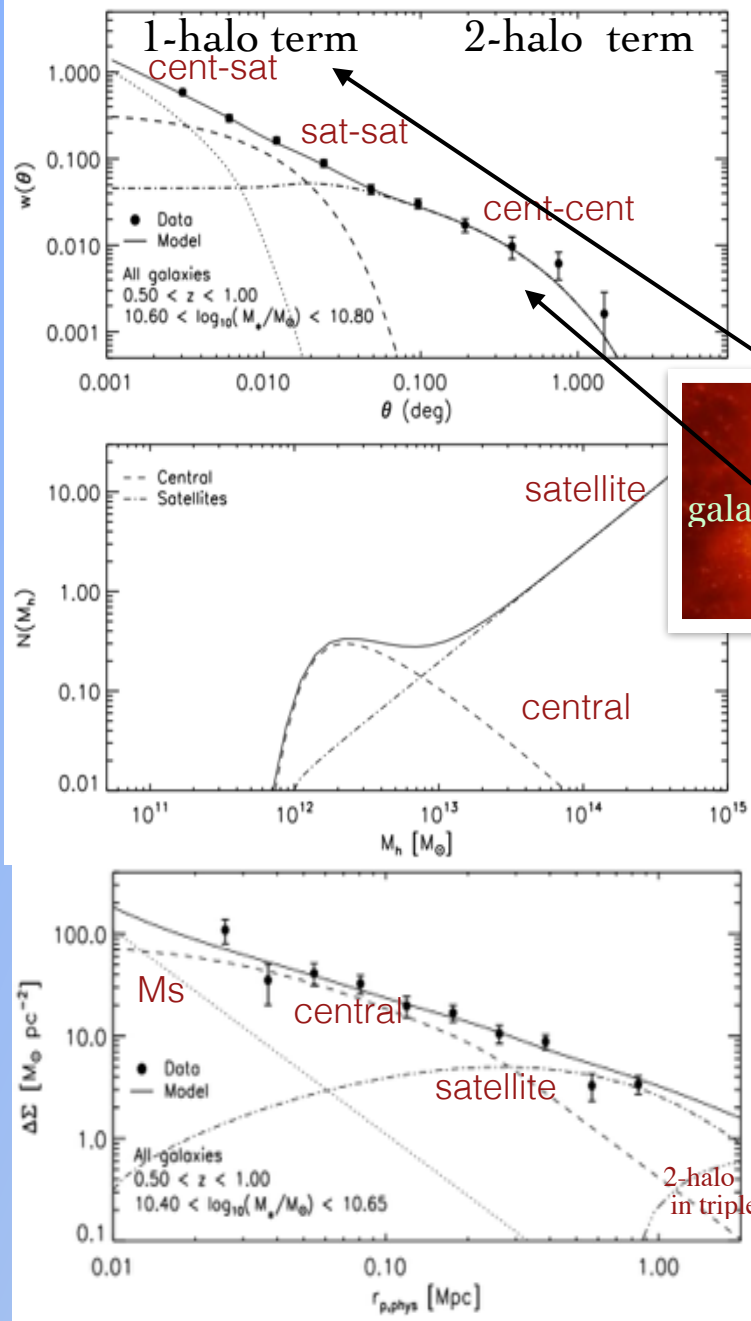
Schawinski +14



-II- Stellar to Halo Mass relationship (SHMR)

by Jean Coupon

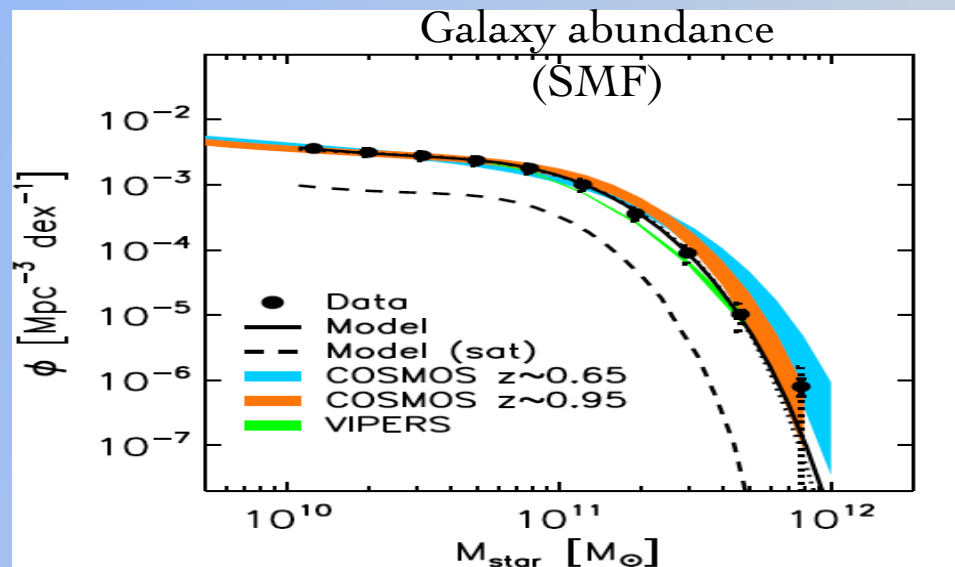
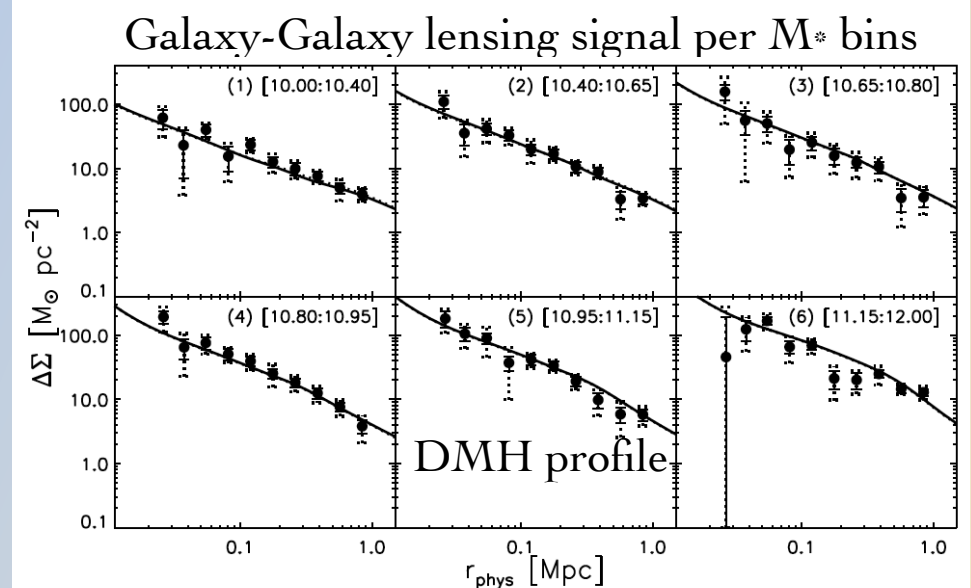
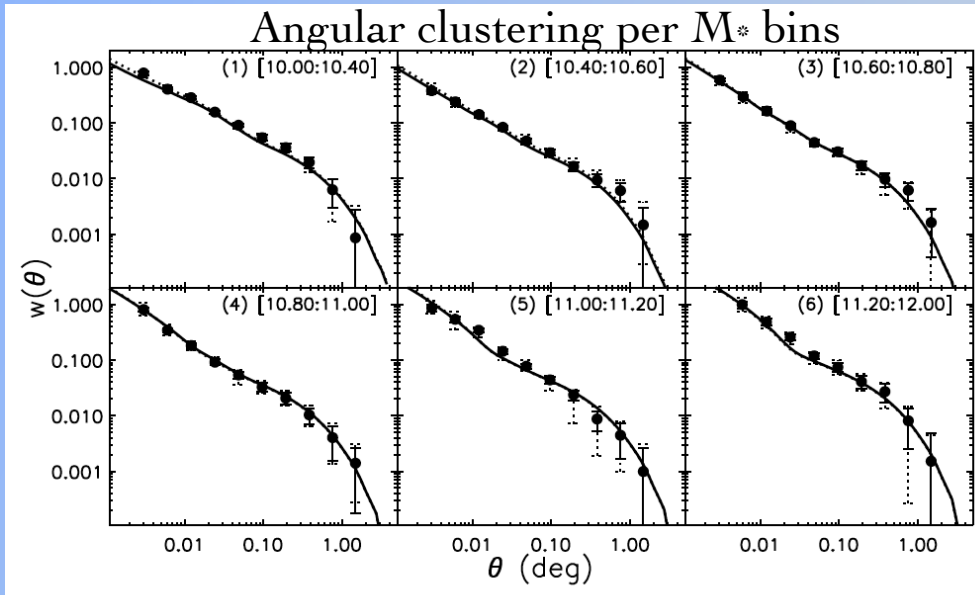
- SF efficiency vary strongly with halo mass
 - connect Galaxy to Halo (one-to-one only central)
 - interpretation within Halo Occupation Distribution model [separating central and satellite galaxies] by combining :
 - * Halo-MF : $N(M_h)$
 - * Halo bias clustering amplitude
 - * Halo density profile



- SMHR with CFHTLS/VIPERS-NIR
Depth and volume 0.1 Gpc^3 in $0.5 < z < 1$ allows us to explore down to the peak of efficiency and up to cluster scales

-II- Stellar to Halo Mass relationship (SHMR)

Coupon, SA, LvW +15



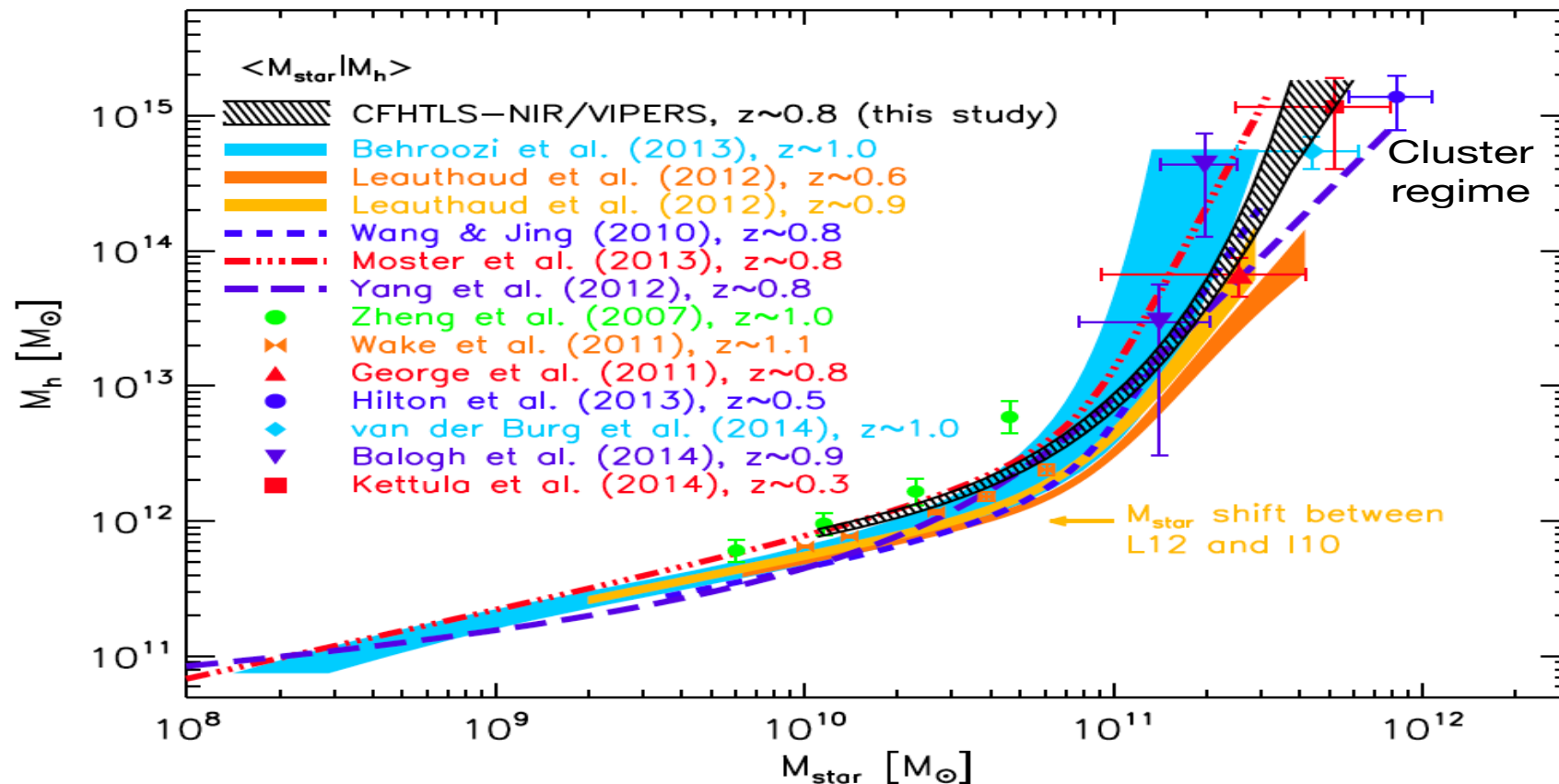
Combined these distinct measurements

- 10 parameters of the HOD model solves with a MCMC sampling technique

-II- Stellar to Halo Mass relationship (SHMR)

Evolution of the SHMR for central galaxies

Coupon, SA, LvW +15

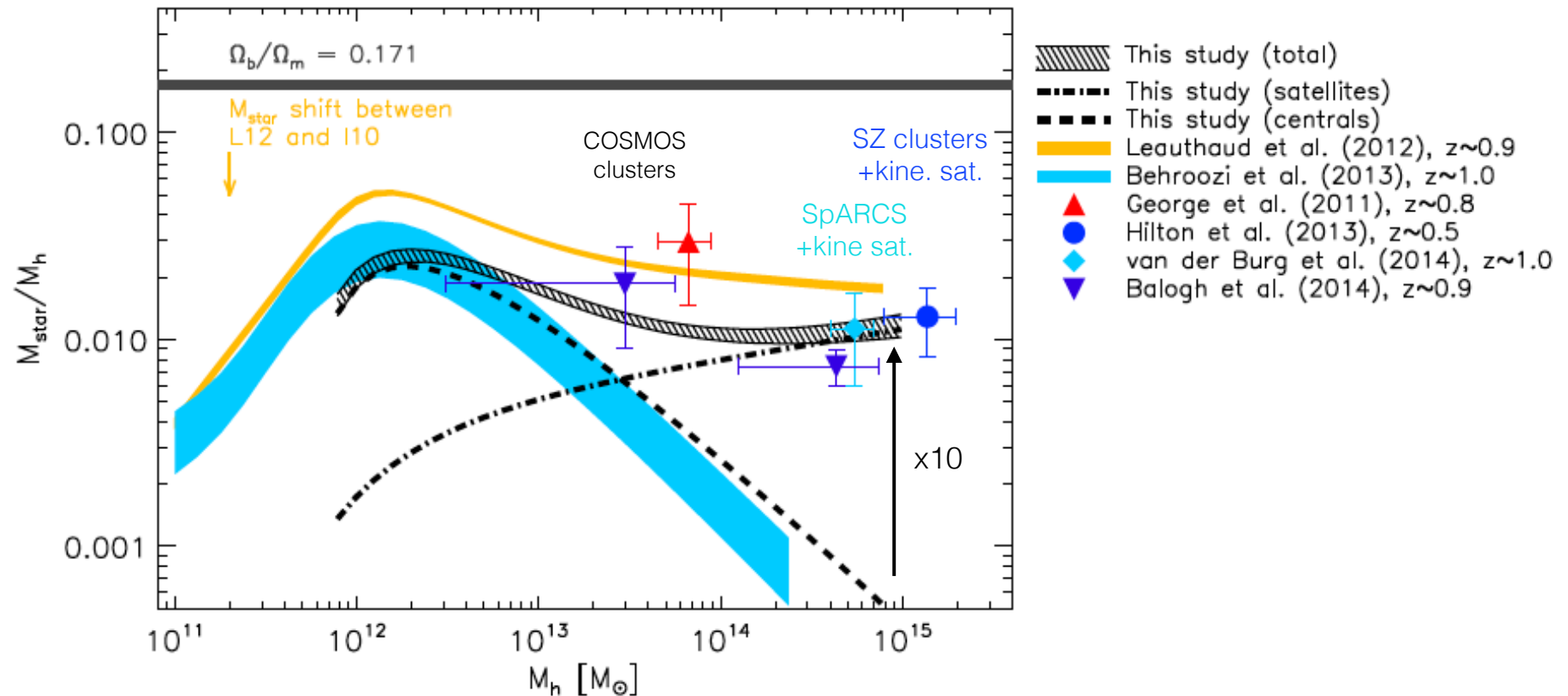


- Best constraints over 3dex of M_h
- Overall good agreement with literature consistent with cluster analysis
- systematic shift with Leauthaud+2012 : stellar mass issue !

-II- Stellar to Halo Mass relationship (SHMR)

Evolution of the SHMR for central + satellite galaxies

Coupon, SA, LvW +15



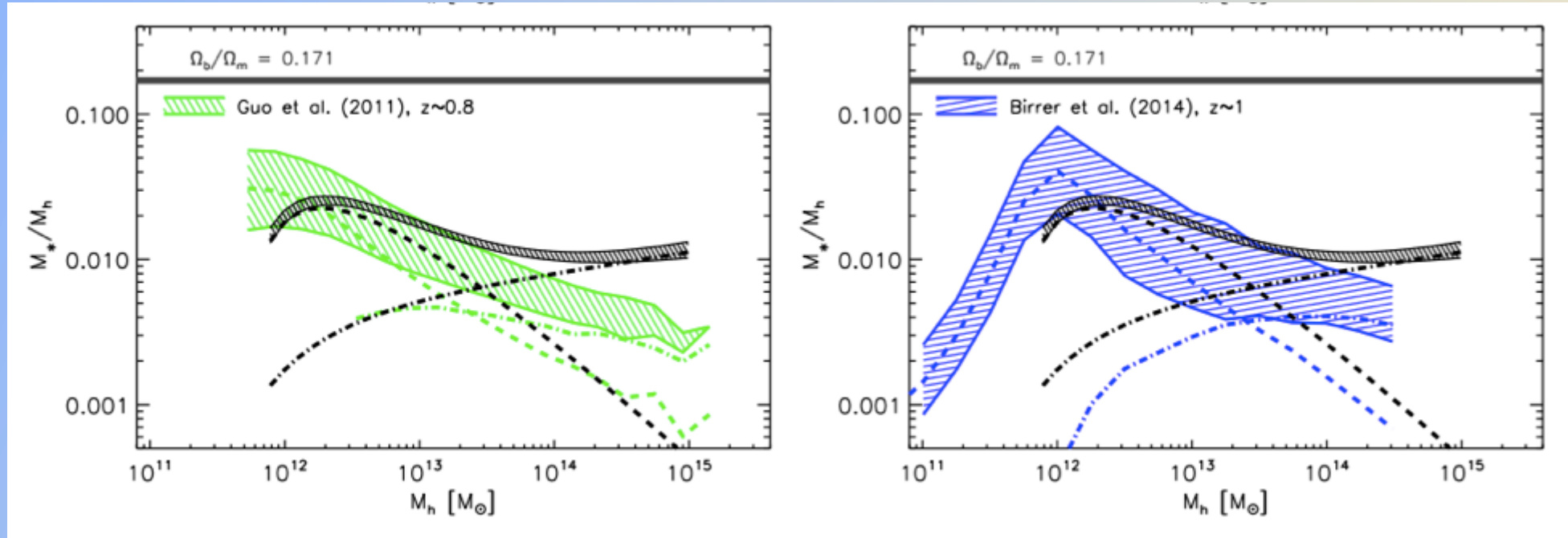
- total SHMR dominated by satellites ($M_s > 10^{10} M_\odot$), boost by $\times 10$ in cluster regime
- excellent agreement with cluster analysis at $z \sim 0.5 - 1$
- small variation ($< \times 2$) of SF Efficiency on 3dex of halo Mass
- Total baryon : stellar mass + ICL + not detected ...

-II- Stellar to Halo Mass relationship (SHMR)

Comparison with SAM (Semi-Analytical Models)

Coupon, SA, LvW +15

... follow DM history with merger trees + recipes for baryons ...

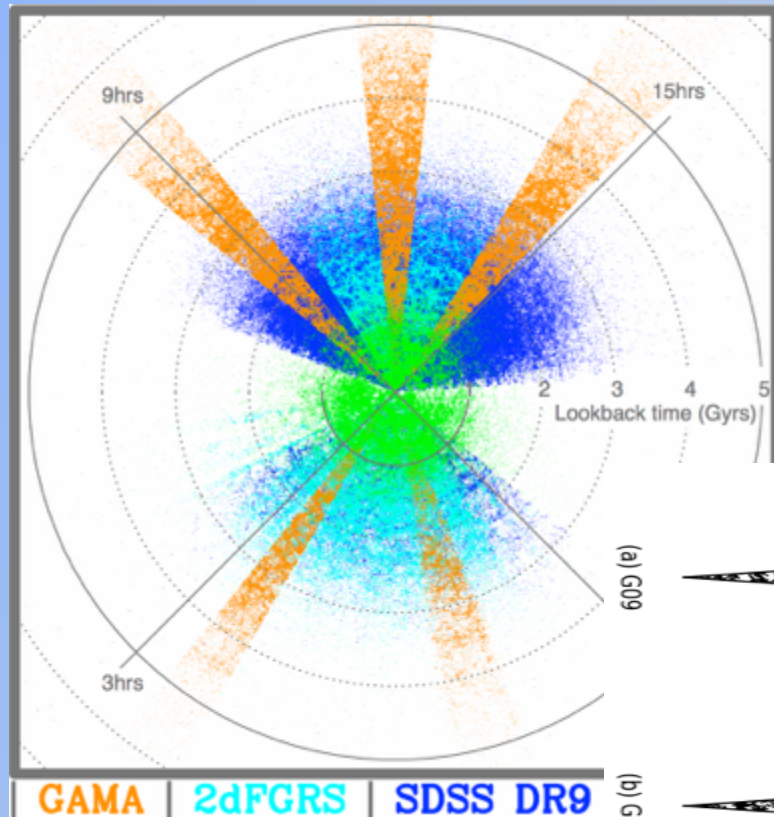


- Similar trend for the central SHMR
 - bulk of SF occurs in low mass halos $M_h \sim 10^{12} M_\odot$
- SAM under-estimate the stellar mass in massive satellites ($M > 10^{10} M_\odot$)
 - too strong quenching recipes in large halos

-II- Group environment in GAMA survey

K. Kraljic, M. Treyer, S. de La Torre
I. Davidzon, D. Vibert, B. Milliard

- The GAMA fields Driver + 15

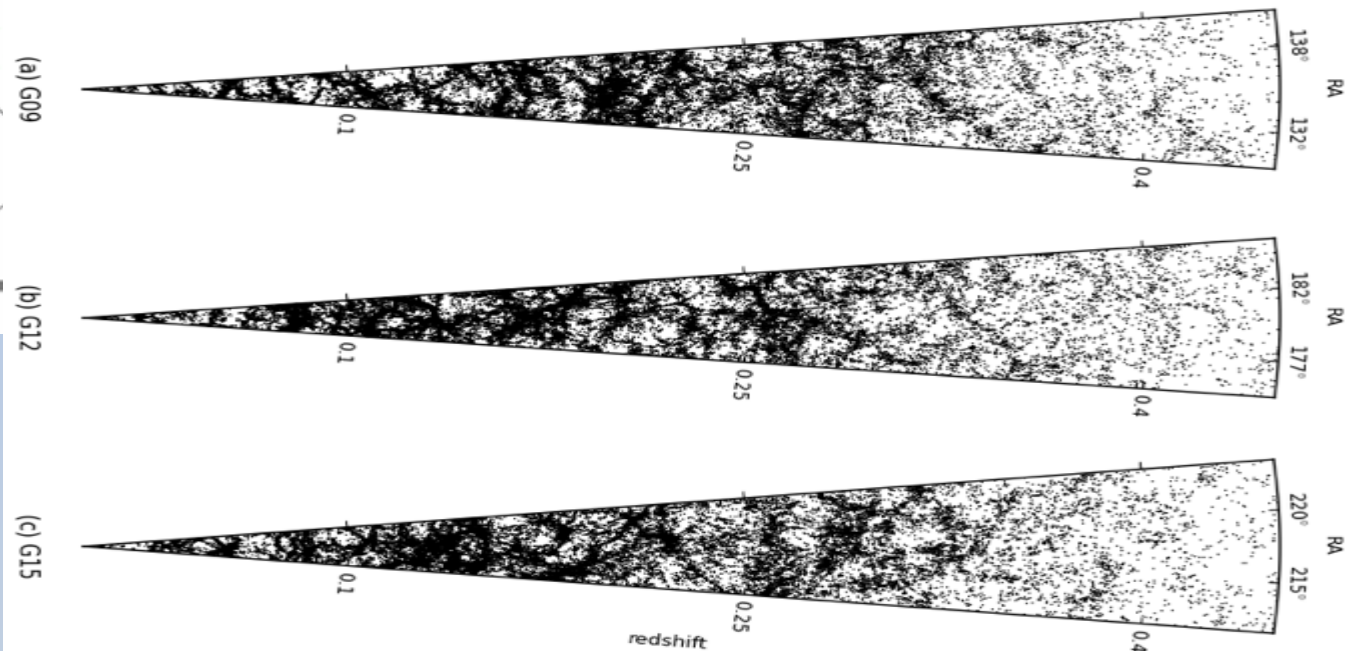


over $3 \times 48 \text{ deg}^2 \sim 150 \text{ deg}^2$

* spectroscopy to $r \sim 19.8 / 19.4$

* 15 times the SDSS density

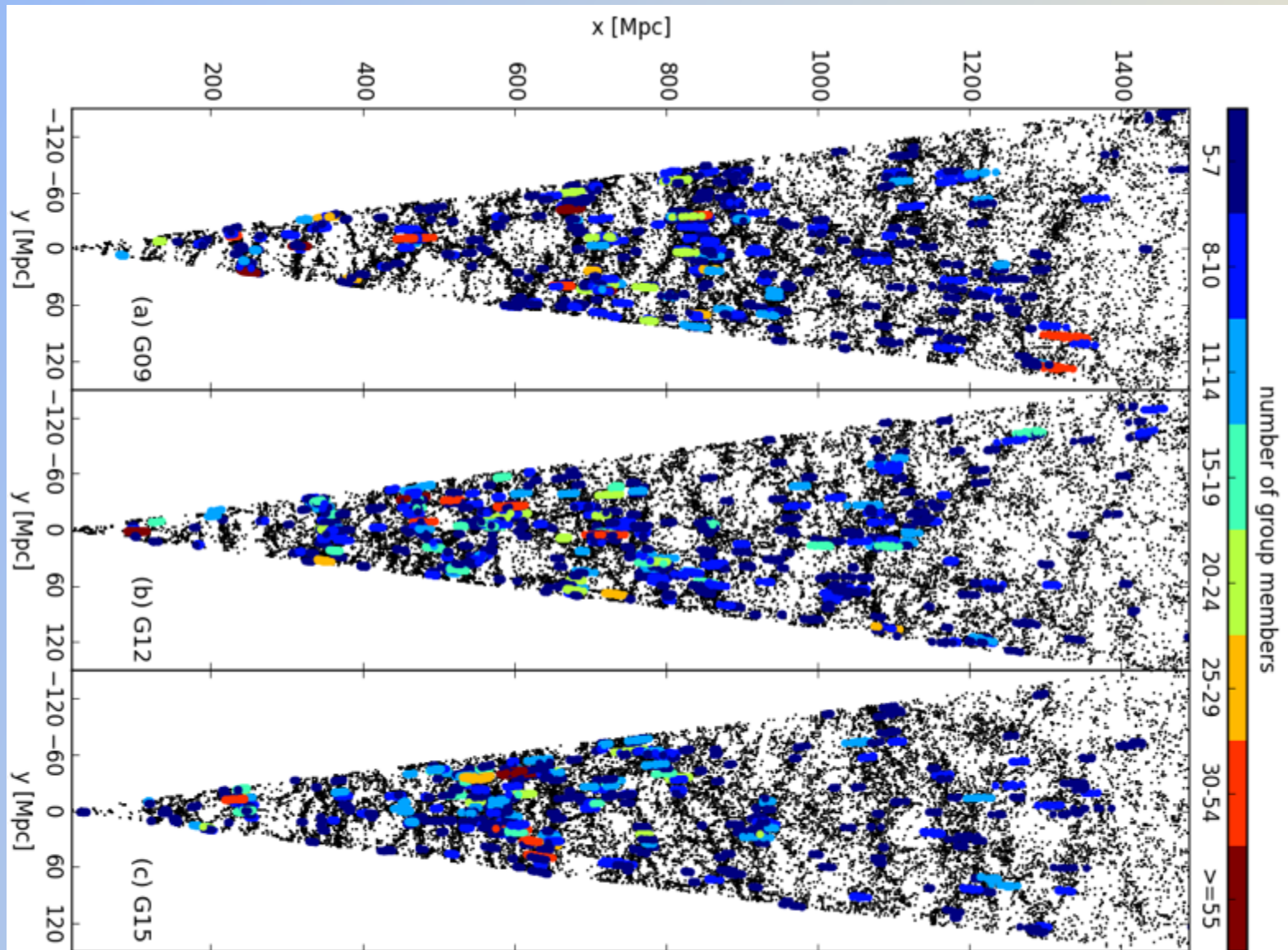
* multi- λ dataset



-II- Group environment in GAMA survey

- Detection of groups with anisotropic f.o.f

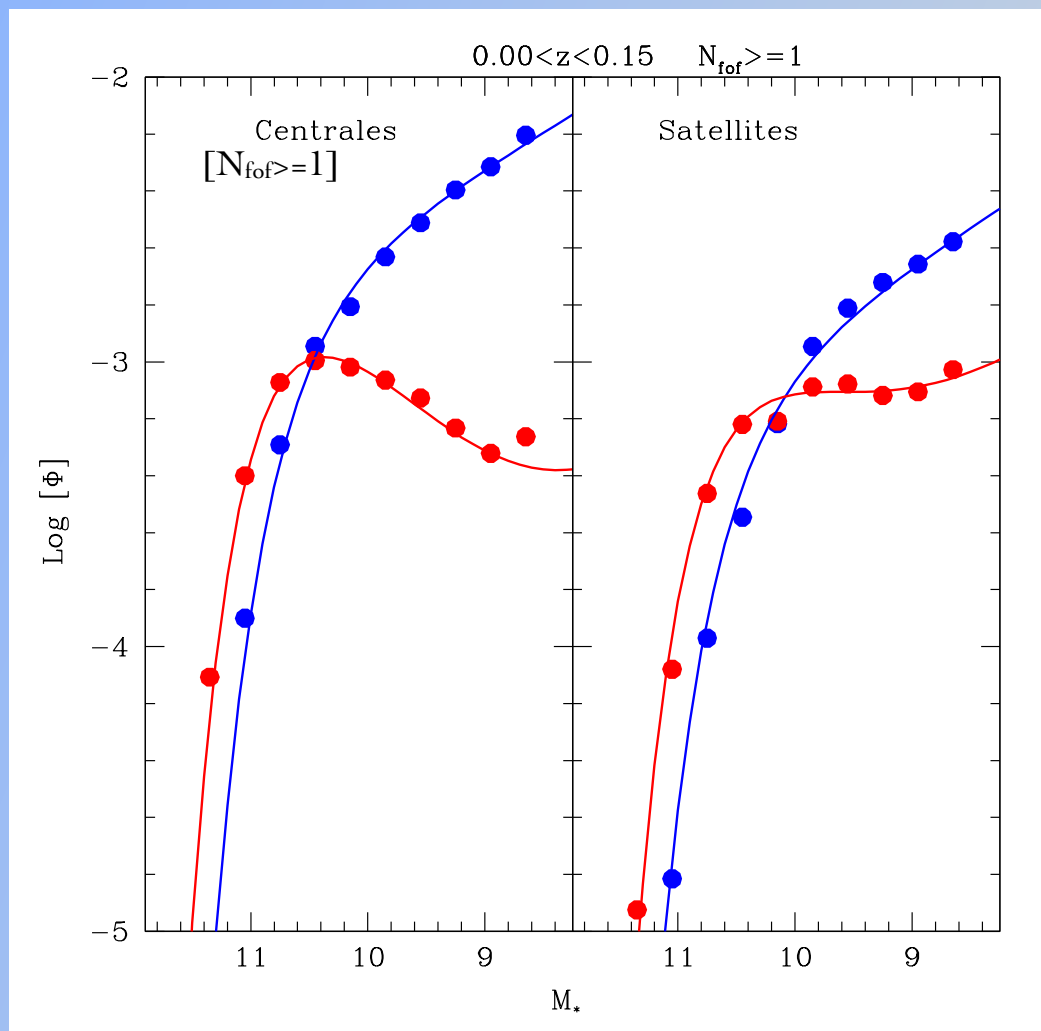
Kraljic (in prep.)



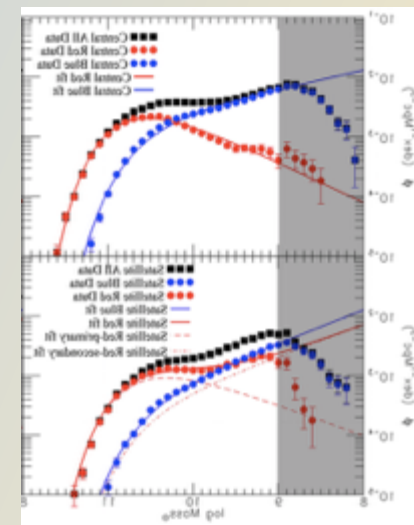
-II- Group environment in GAMA survey

Kraljic (in prep.)

GAMA : Mass function in Groups



- change in the slope of Quiescent MFs consistent with SDSS but less pronounced (Peng+ 2010)

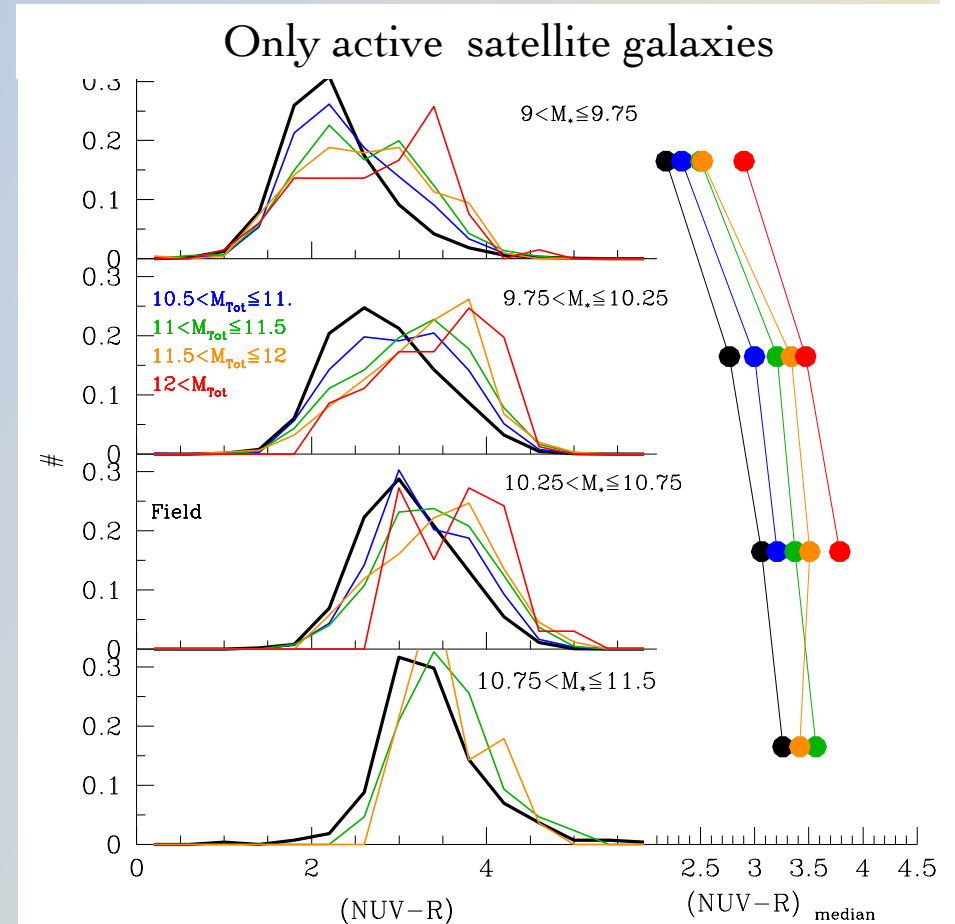
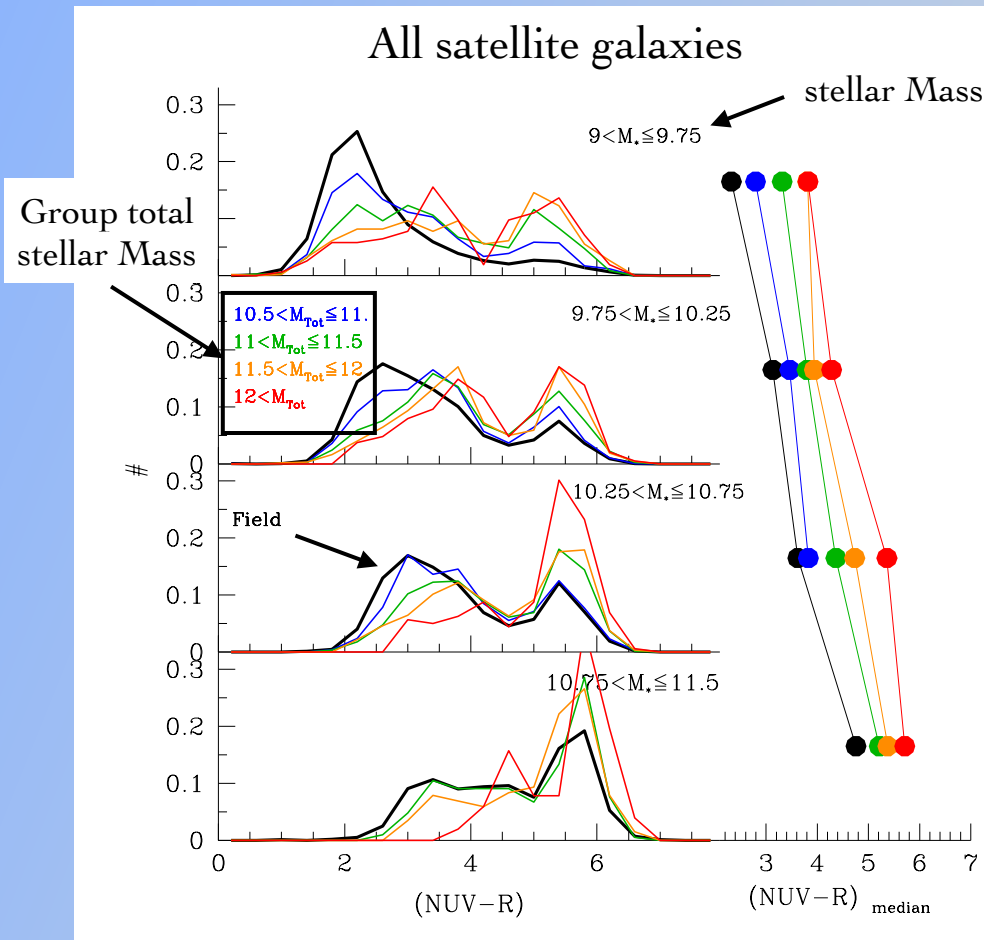


- Environmental Quenching at Low Mass. Quenched galaxies are preferentially in group environments
 - agrees with the recipes in SAM but needs tuning ...

-II- Group environment in GAMA survey

Kraljic (in prep.)

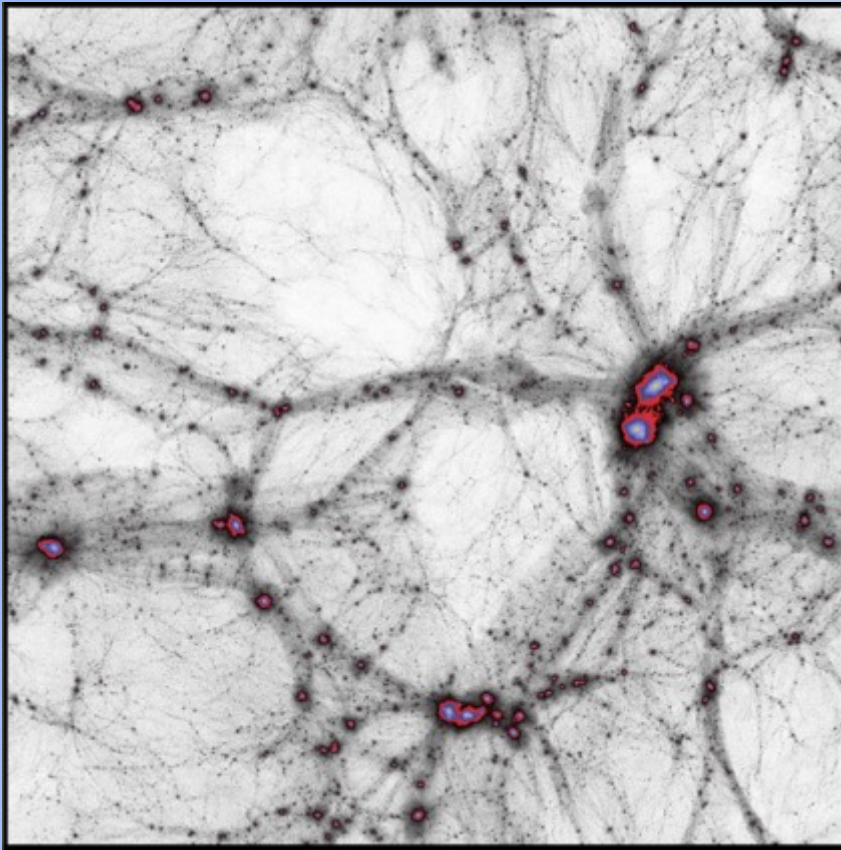
GAMA : Evolution of the satellite galaxies per stellar mass in different group sizes



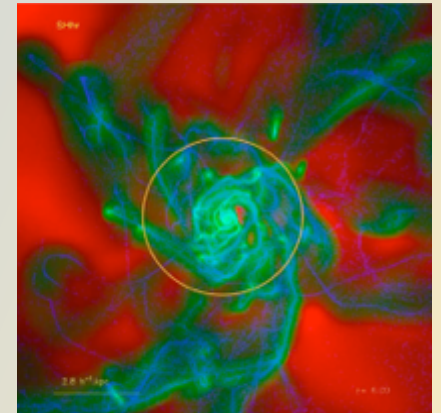
General evolution with M_* : given by Field galaxies

- change of blue vs red fraction with group mass in all M_* bins
- Satellite Galaxies of a given M_* are redder in larger groups
environmental effects in act

-III- Influence of Cosmic web on galaxies



- Cosmic web made of voids/walls/filaments/nodes coming from the growth of primordial fluctuations in a nearly Gaussian initial density field
- Galaxies are formed within these large-scale flows



What is the influence of such an anisotropic environment on galaxy formation/evolution/properties ?

Everything is still under construction !



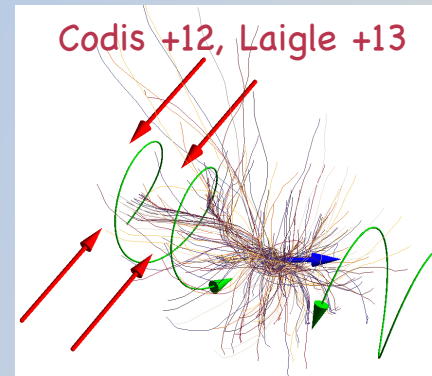
C. Pichon (IAP)
S. Arnouts (LAM)

Connecting the LSS and galaxy dynamic

* Theoretical prediction :

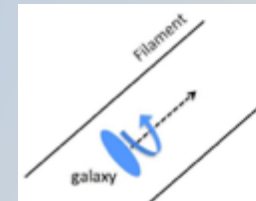
On large scales, matter departs from voids, flows along the walls (red arrows) and winds up in filaments along ribbons (green arrows), forming low-mass haloes.

—> advection of angular momentum in DM halos



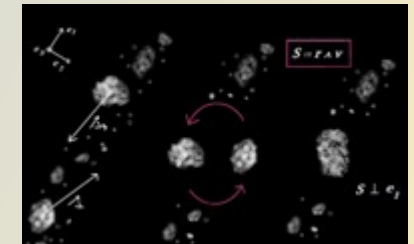
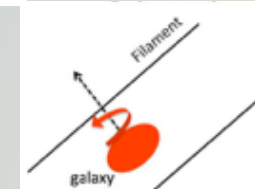
* Observational evidences in SDSS by Tempel+13

Spirals: Alignment of gal. spins with the filament orientation

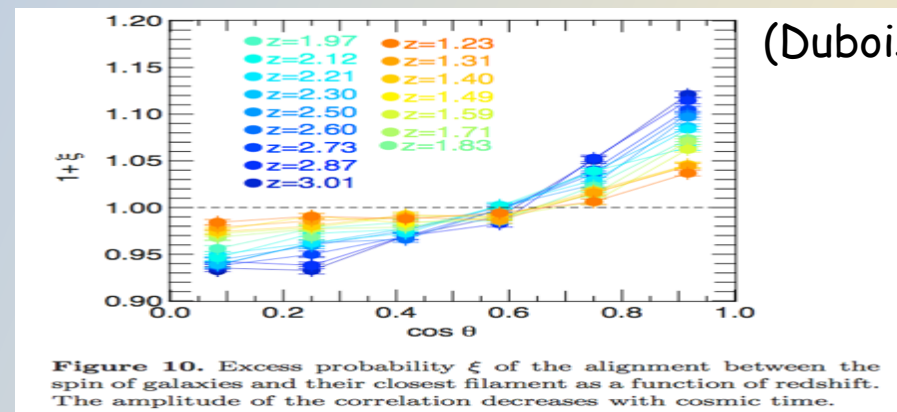


Ellipticals: spin axes perpendicular to the filament orientation

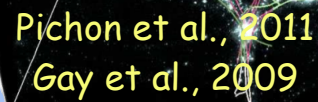
—> mergers along the filaments



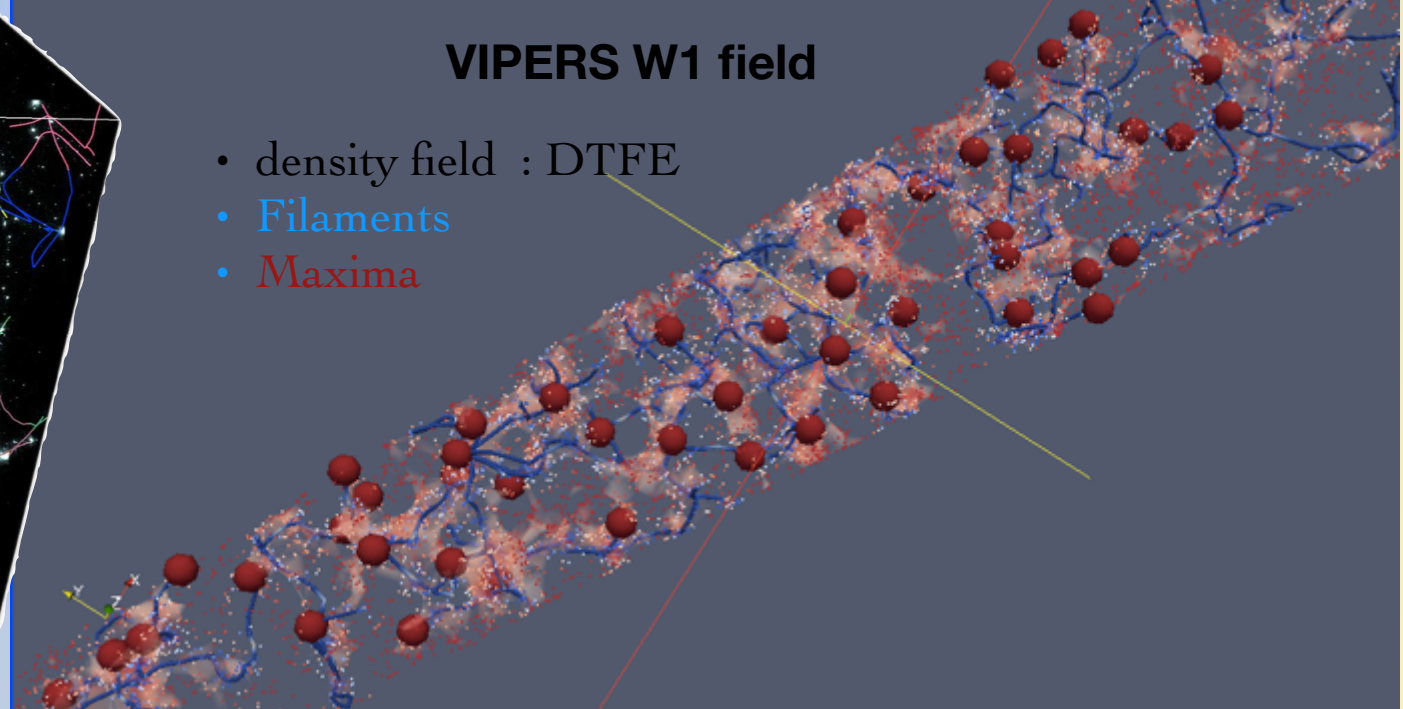
* Effect should be stronger at higher redshift



-

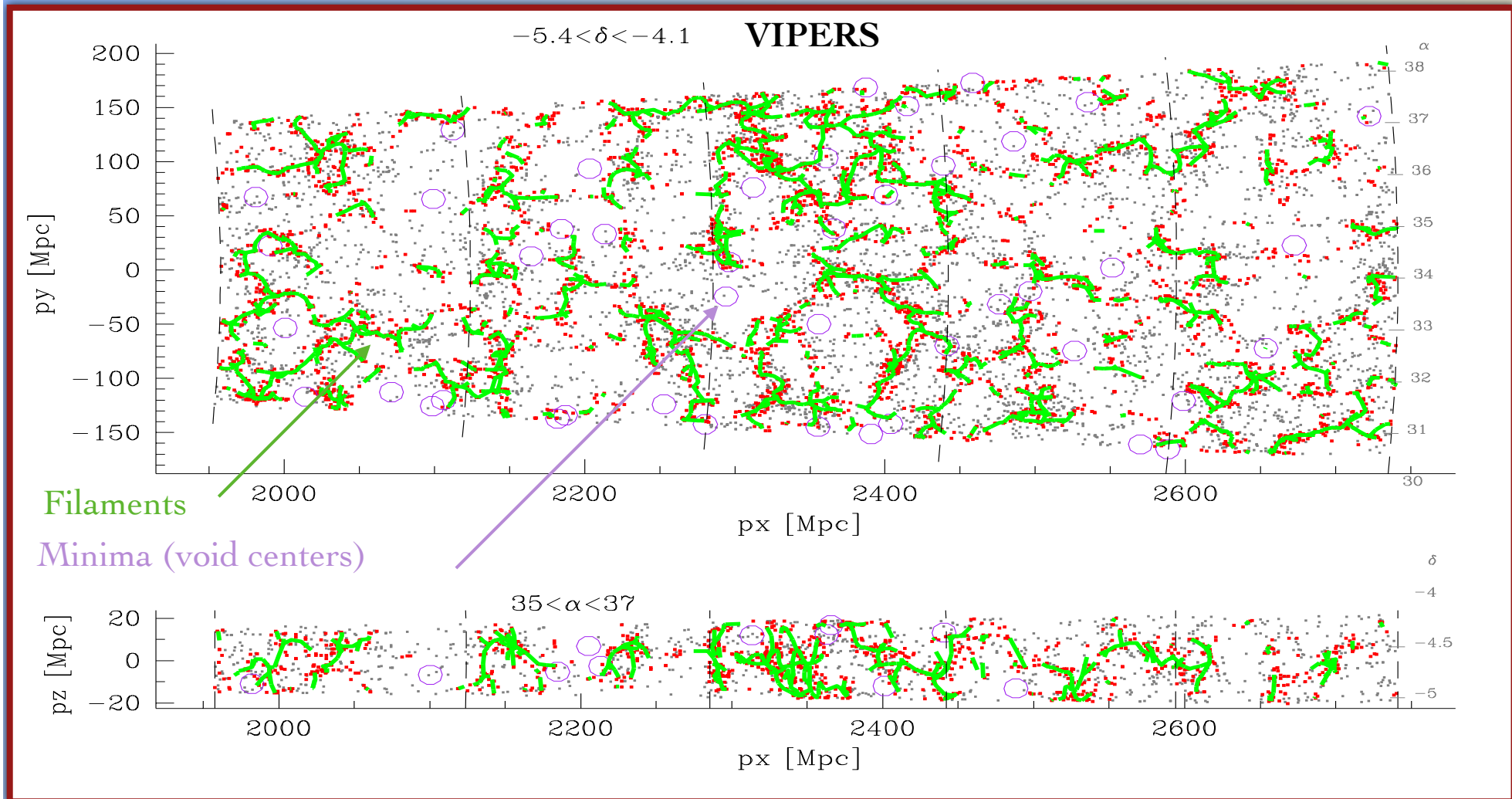


- density field : DTFE
- Filaments
- Maxima



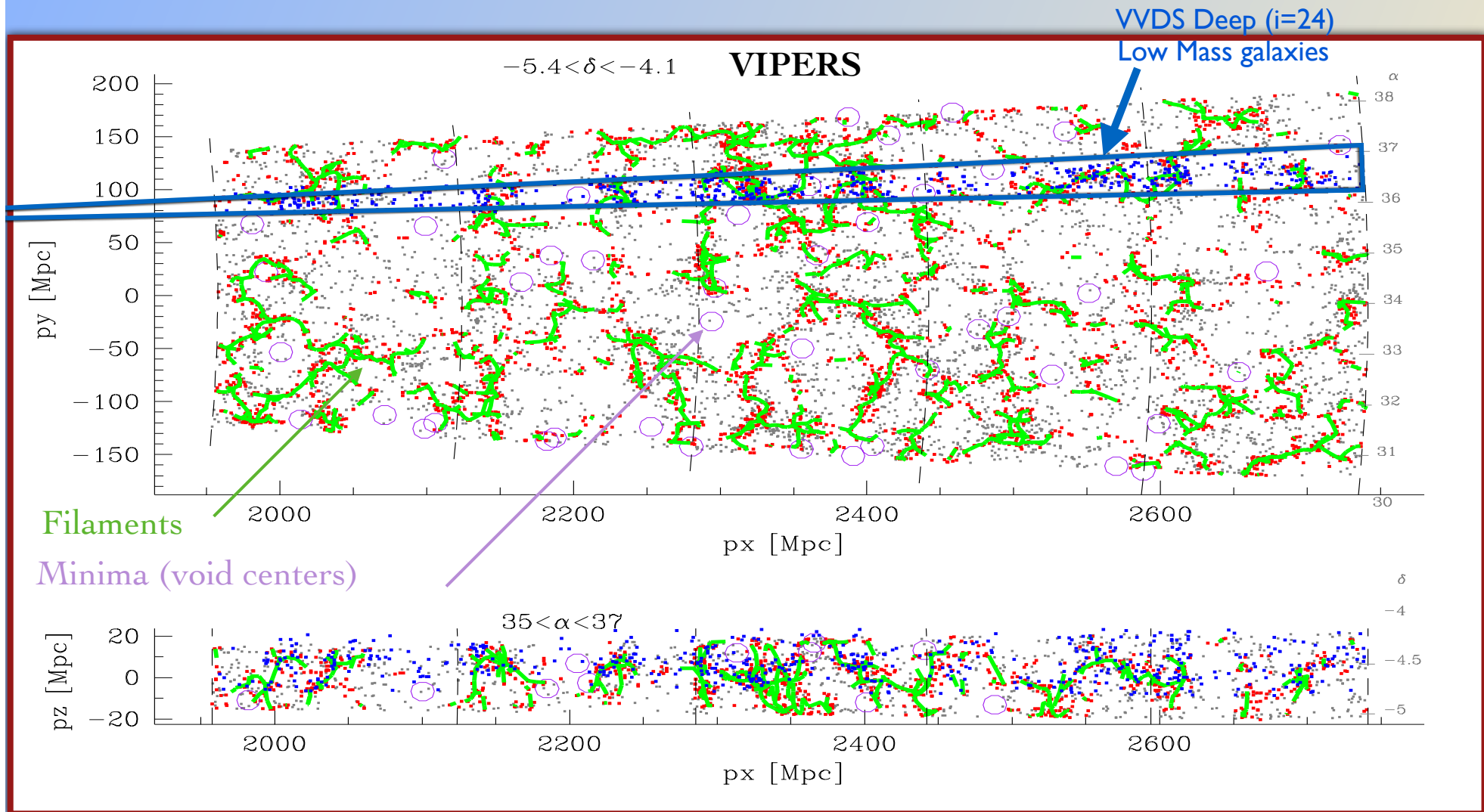
-III- Influence of Cosmic web on galaxies

Attach to each galaxy a CW property (Nodes/filaments/voids-walls)



-III- Influence of Cosmic web on galaxies

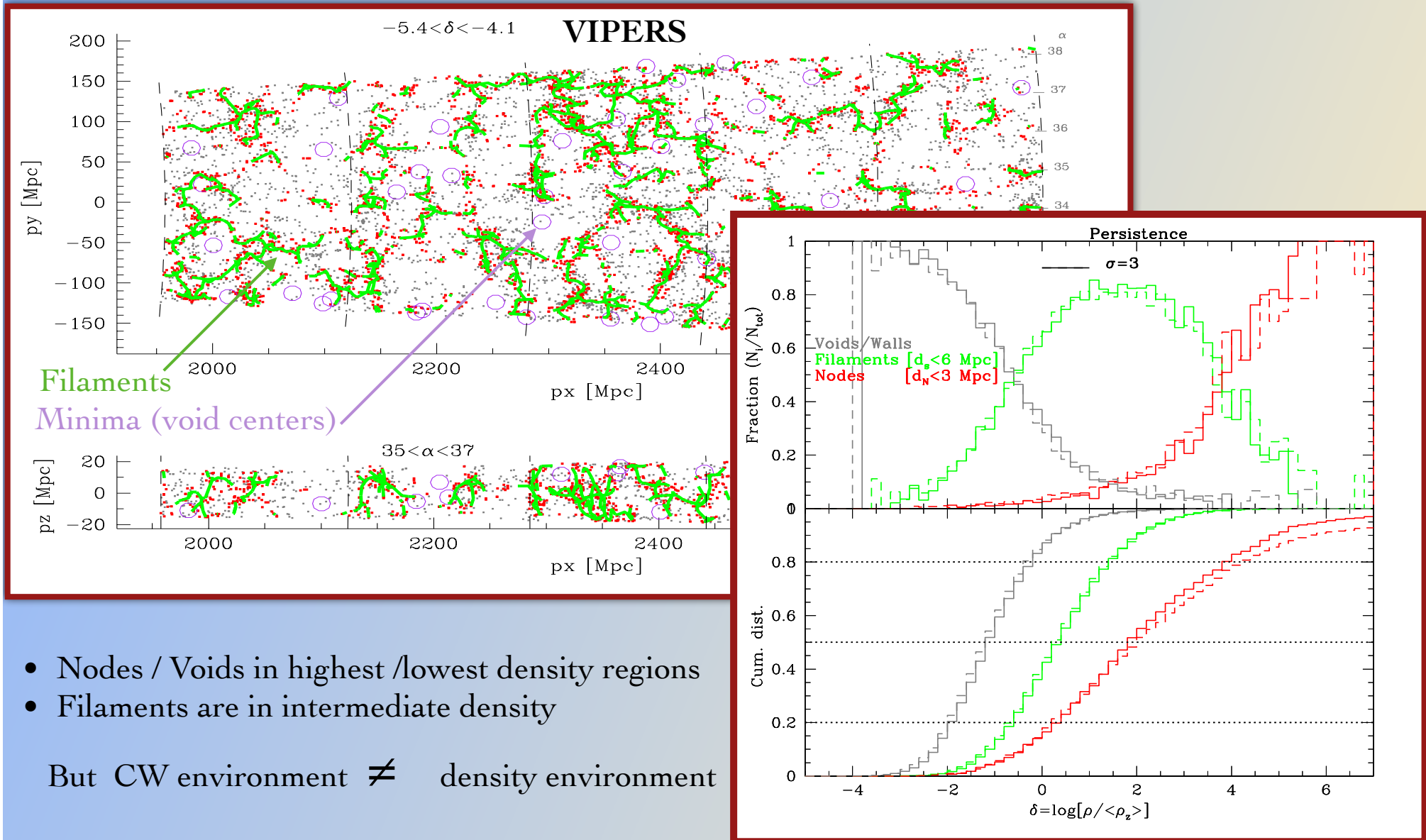
Attach to each galaxy a CW property (Nodes/filaments/voids-walls)



- Pencil beam : inadequate for environmental analysis

-III- Influence of Cosmic web on galaxies

Attach to each galaxy a CW property (Nodes/filaments/voids-walls)

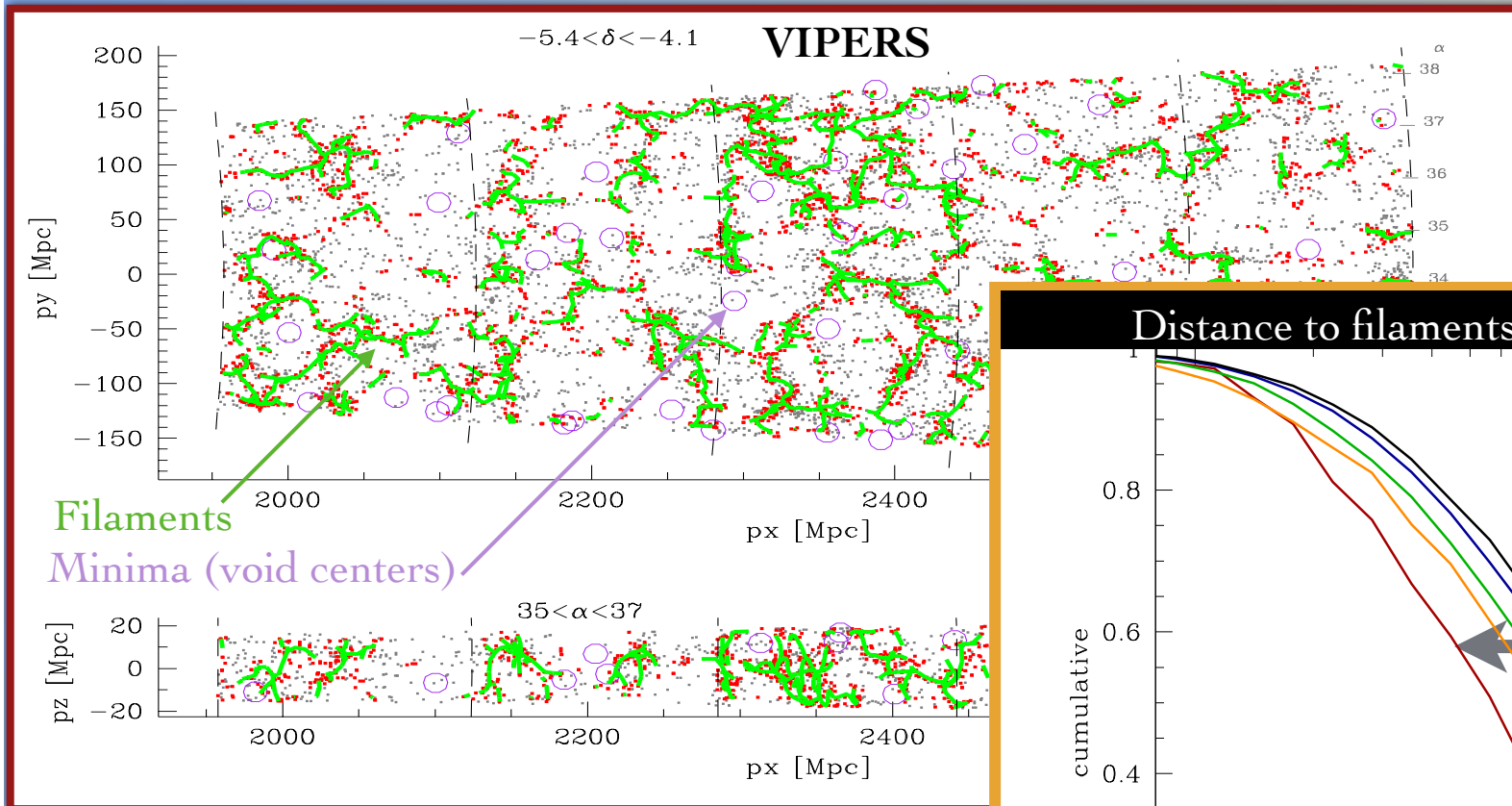


- Nodes / Voids in highest /lowest density regions
- Filaments are in intermediate density

But CW environment $\neq$ density environment

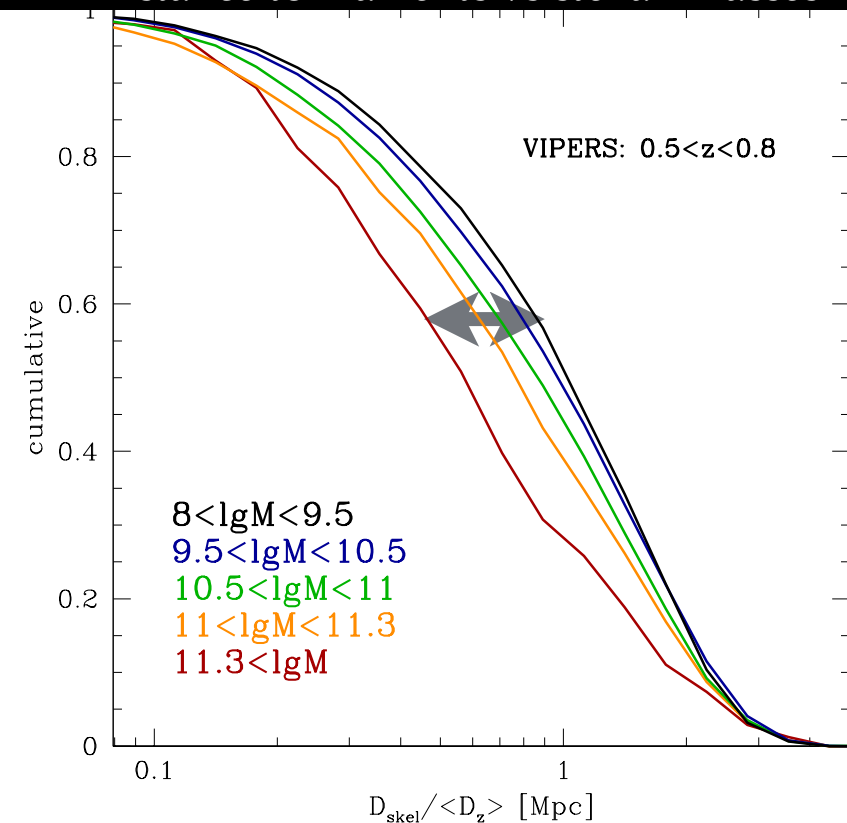
-III- Influence of Cosmic web on galaxies

Attach to each galaxy a CW property (Nodes/filaments/voids-walls)



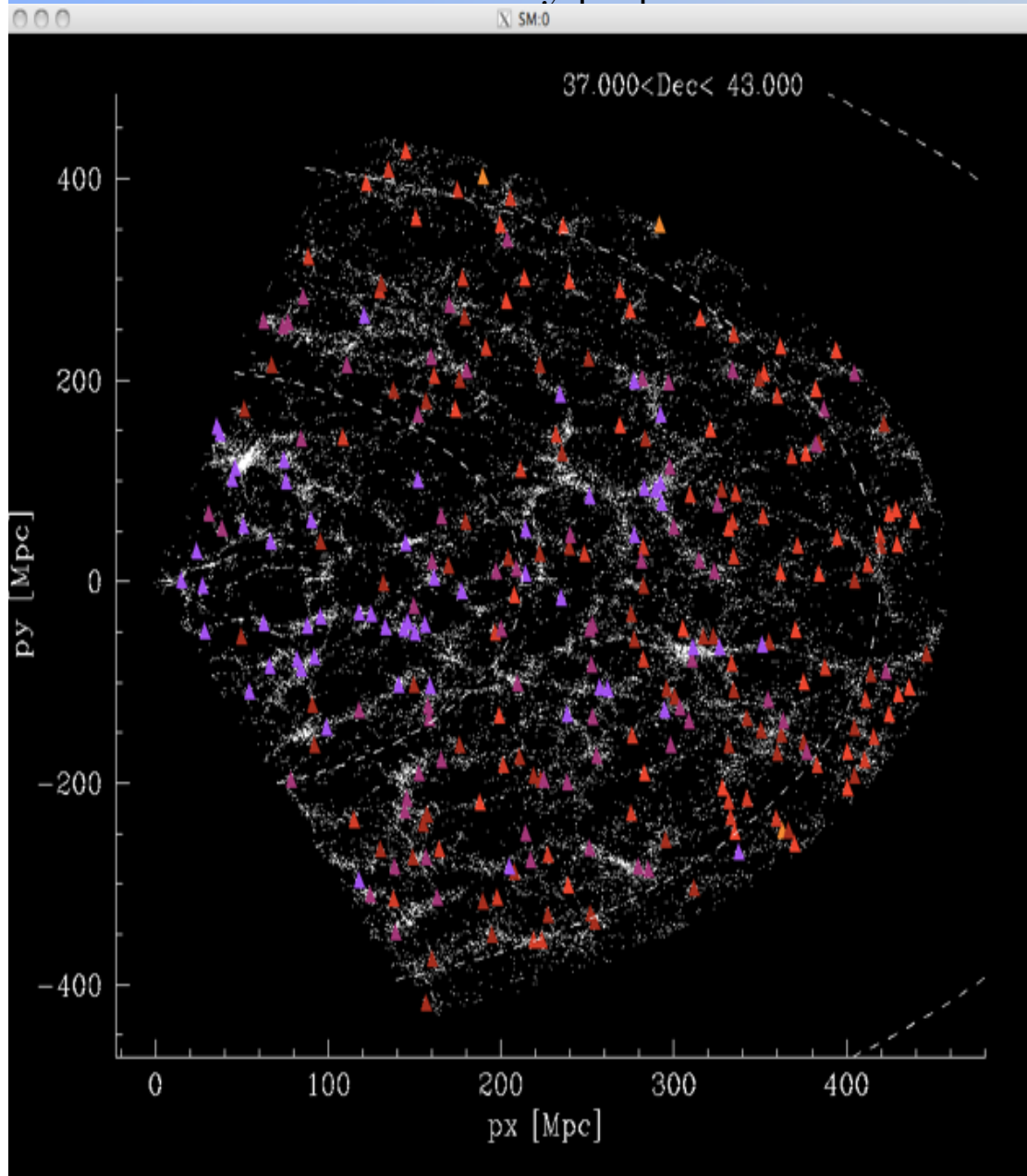
- More massive galaxies closer to filaments !

Distance to filaments vs stellar Masses



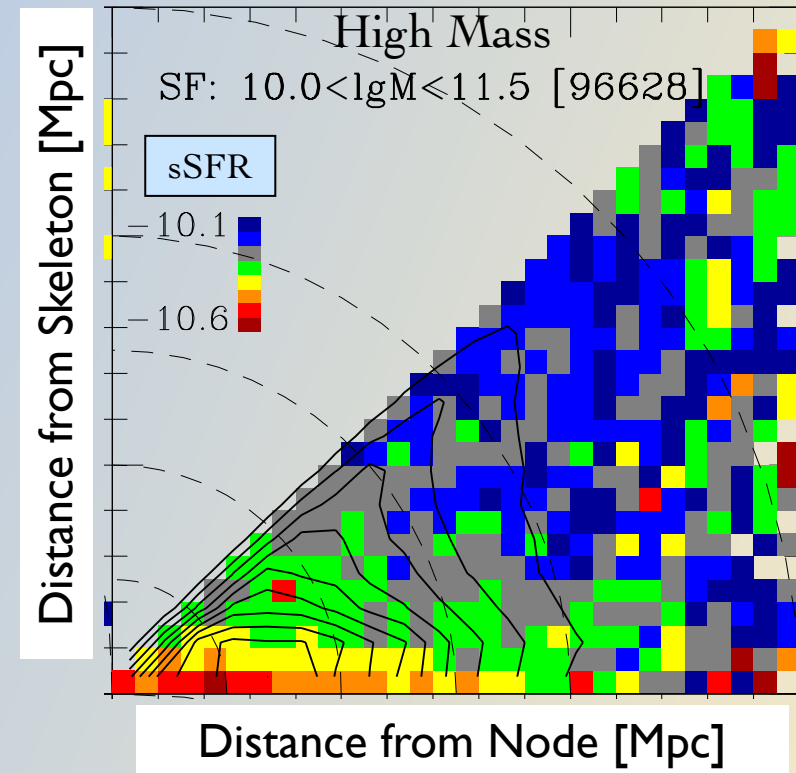
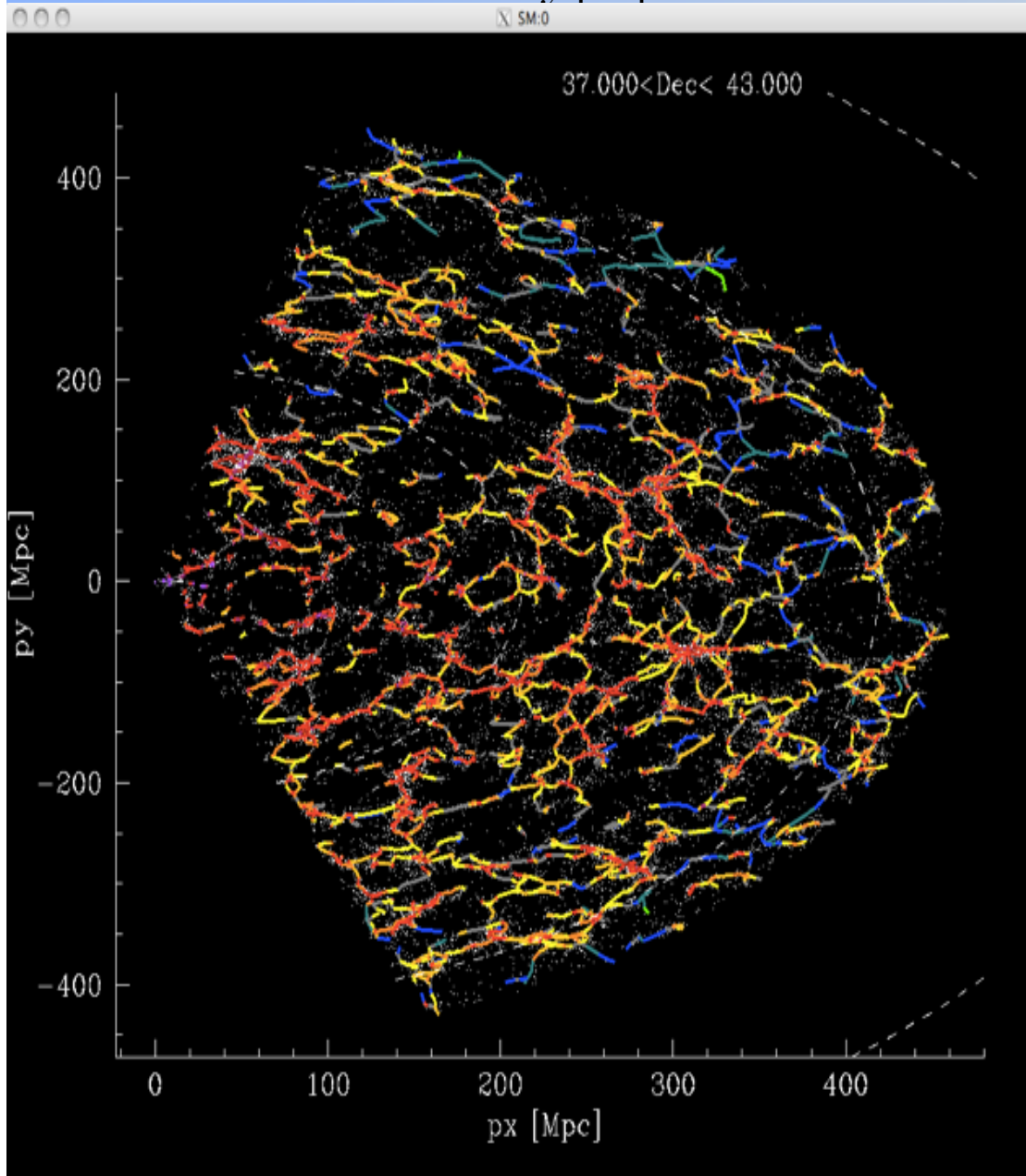
-III- Influence of Cosmic web on galaxies

SDSS : Galaxy properties as a function of distance of the Cosmic Web



-III- Influence of Cosmic web on galaxies

SDSS : Galaxy properties as a function of distance of the Cosmic Web



- rapid change of $\langle \text{sSFR} \rangle$ with distance to Skeleton
- slower change within the filament toward near the node

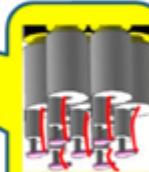
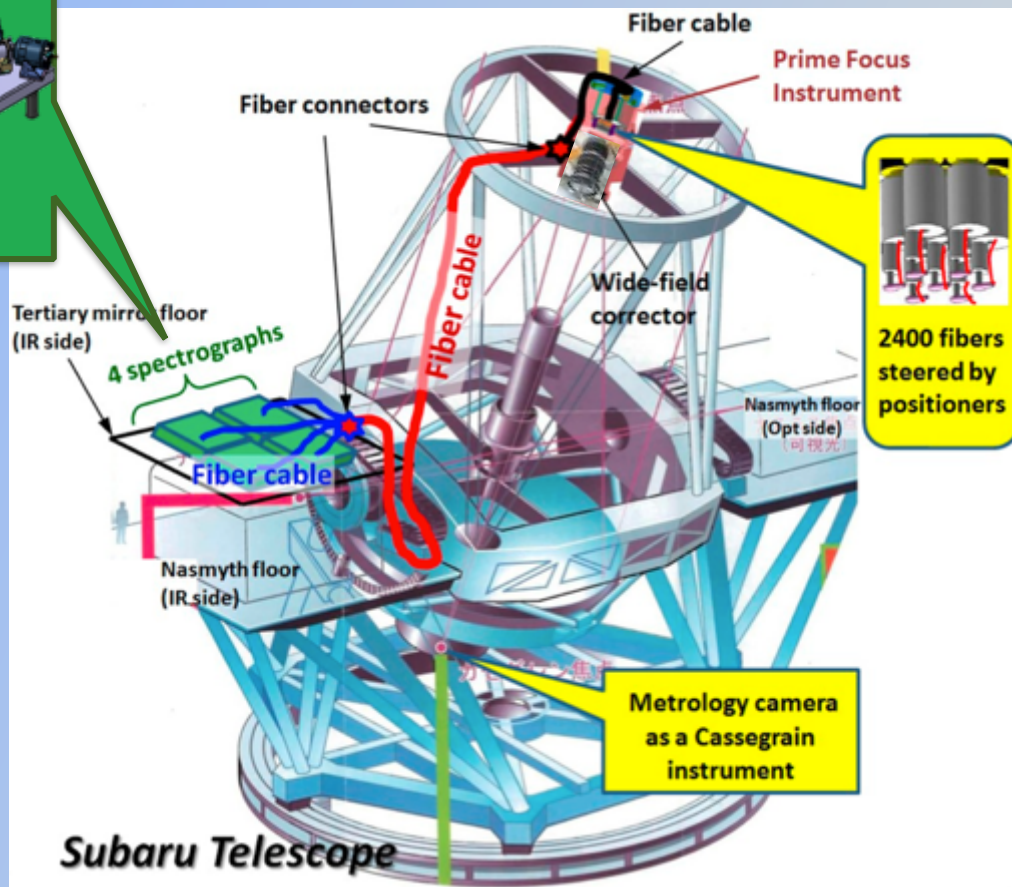
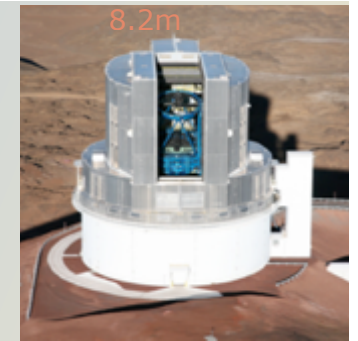
Part of the evolution happens before galaxies “reach” the center of the filaments

PFS SuMIRe surveys

Prime Focus Spectrograph for Subaru Measurement of Images and Redshifts

SuMIRe Science Driver: The Origin and Fate of the Universe

Elucidate the Nature of Dark Matter and Dark Energy



2400 fibers
steered by
positioners

Precision MOS Spectroscopy
with

Prime Focus Spectrograph (PFS)
P.I. H. Murayama (Kavli, IPMU)
~ \$50M

IPMU, NOAJ, Princeton, LAM, JHU,
Caltech/JPL, LNA, ASIAA, MPA

PFS Specifications

Approved by Preliminary Design Review (March, 2013)

Number of fibers	2400		
Field of view	1.3 deg (hexagonal-diameter of circumscribed circle)		
Fiber diameter	1.13" diameter at center	1.03" at the edge	
	Blue	Red	NIR
Wavelength range [nm]	380-650	630-970 (706-890)	940-1260
Central resolving power	~2350	~2900 (~5000)	~4200
Detector type	CCD	CCD	HgCdTe

- Share WFC with HSC
- 4 spectrographs for 600 fibers each
- $\lambda = 0.38 - 1.26 \mu\text{m}$ with 3 arms
- Fiber density: 2200/sq. degs ($\Rightarrow$ ~140 for BOSS; ~570 for DESI)
- The medium resolution mode ($R \sim 5000$) for the red arm is our baseline design



Feb 2018 : engineering first light

HSC SuMIRe surveys

SuMIRe Hyper SuprimCam imaging project

Wide-Field grizy Photometric Survey
FOV 1.77 deg^2 (1.5 deg^2 in diameter)

1. HSC-Wide 1400 deg^2 ($i_{AB}=26, 5\sigma$)

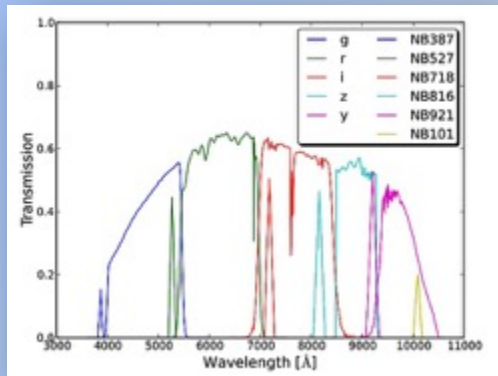
- Cosmology science driver
- Weak lensing, strong lensing, galaxy clusters
- galaxy clustering + other science

2. HSC-Deep 28 deg^2 ($i_{AB}\sim 27, +NB$)

HSC-UltraDeep 3.5 deg^2 ($i\sim 28, +NB$)

- Galaxy and AGN evolution up to $z\sim 7$
- High-z galaxies, QSO, reionization

300 nights started in Feb. 2014 until 2019

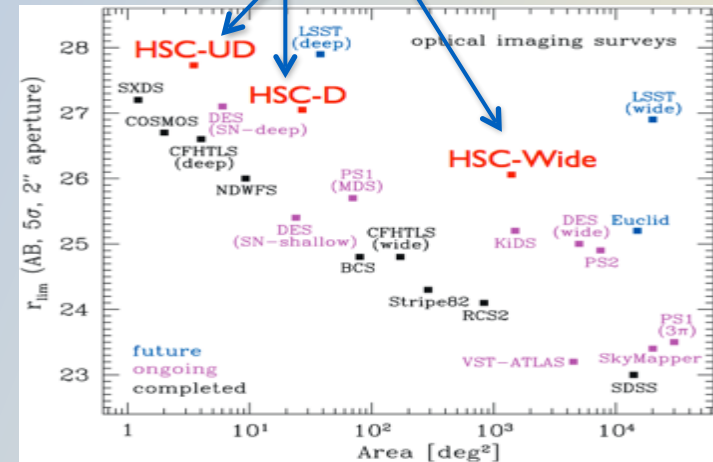


Unique dataset until LSST Deep

PFS extragalactic surveys

PFS-Galaxy 100n
 25 deg^2

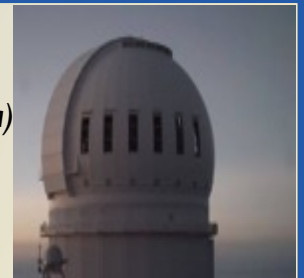
PFS-Cosmology 100n
 1400 deg^2



U band follow-up of HSC-D

Sawicki (Canada) + Arnouts (France) + Huang (China)

CLAUDS ($\sim 300\text{h}$) : $U\sim 27$ in 25 sq. deg

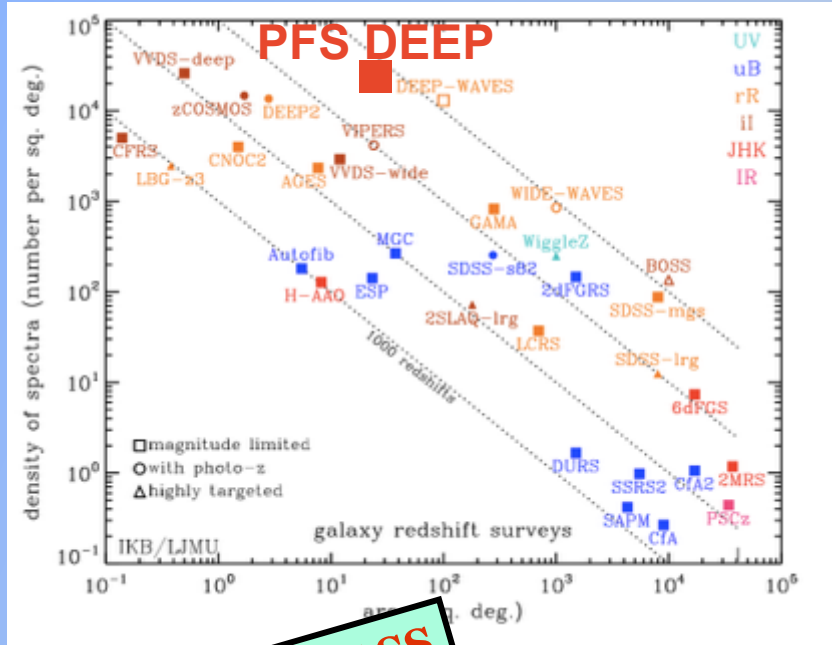


- LBG galaxies
- photo-zs
- SFRD

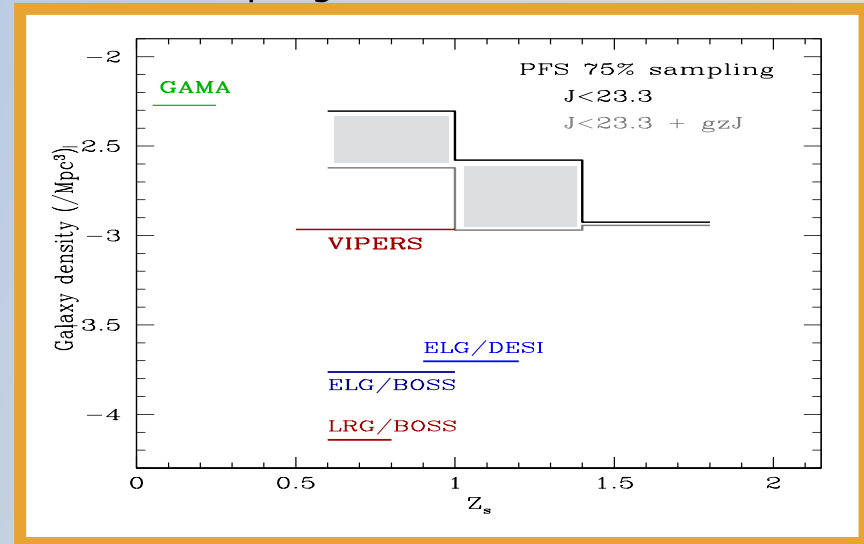
Table 3: Expected number of objects

$< z >$	sample	Vol(Gpc^3)	$M_*(M_\odot)$	N of galaxies
0.1	photo-z	0.001	$10^{8.7}$	7.2k
0.3	photo-z	0.008	$10^{9.3}$	38.3k
0.5	photo-z	0.019	$10^{9.8}$	71.8k
0.7	photo-z	0.029	$10^{10.1}$	94.4k
0.9	photo-z	0.040	$10^{10.2}$	137.3k
2.3	BM/BX	0.341	—	2.5M
3.0	U-dropout	0.340	—	0.9M
3.0	QSOs	0.340	—	1000
2.2	LAE / LAB	0.017	—	9k / 700

HSC-PFS SuMIRe surveys

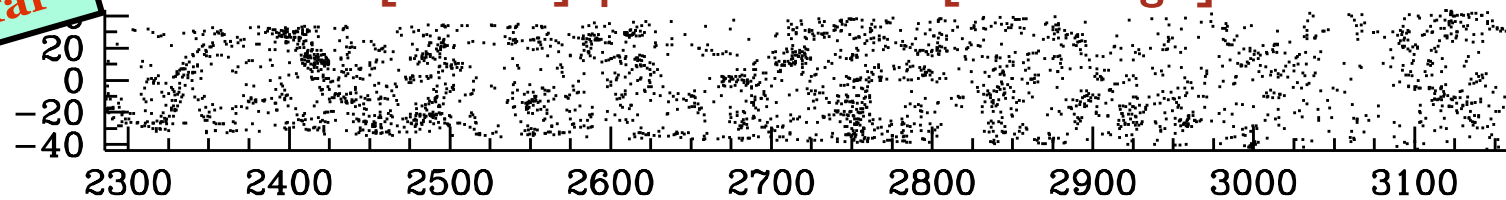


1. SDSS-like survey : Million galaxies up to $z \sim 2$
2. Dense sampling of faint sources



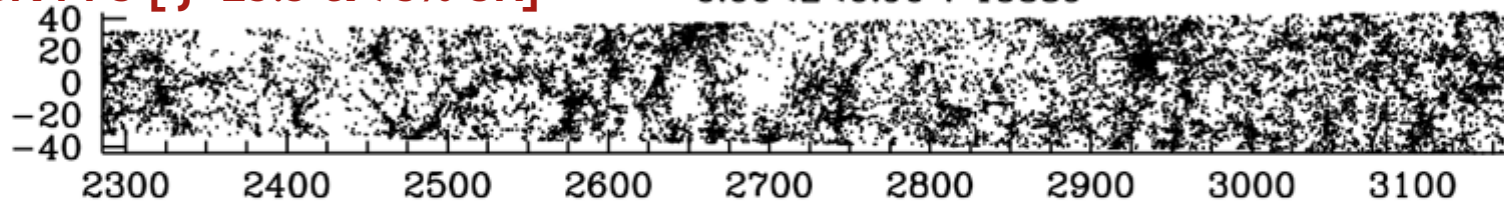
VIPERS best LSS at high z so far

VIPERS [$I < 22.5$] part of W1 field [$1.6 \times 1 \text{ deg}^2$]



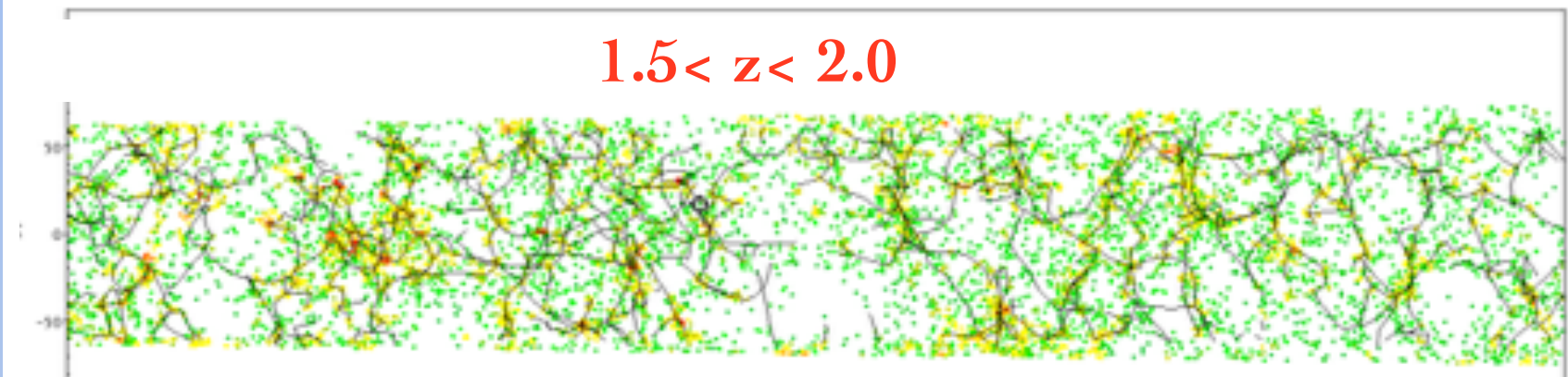
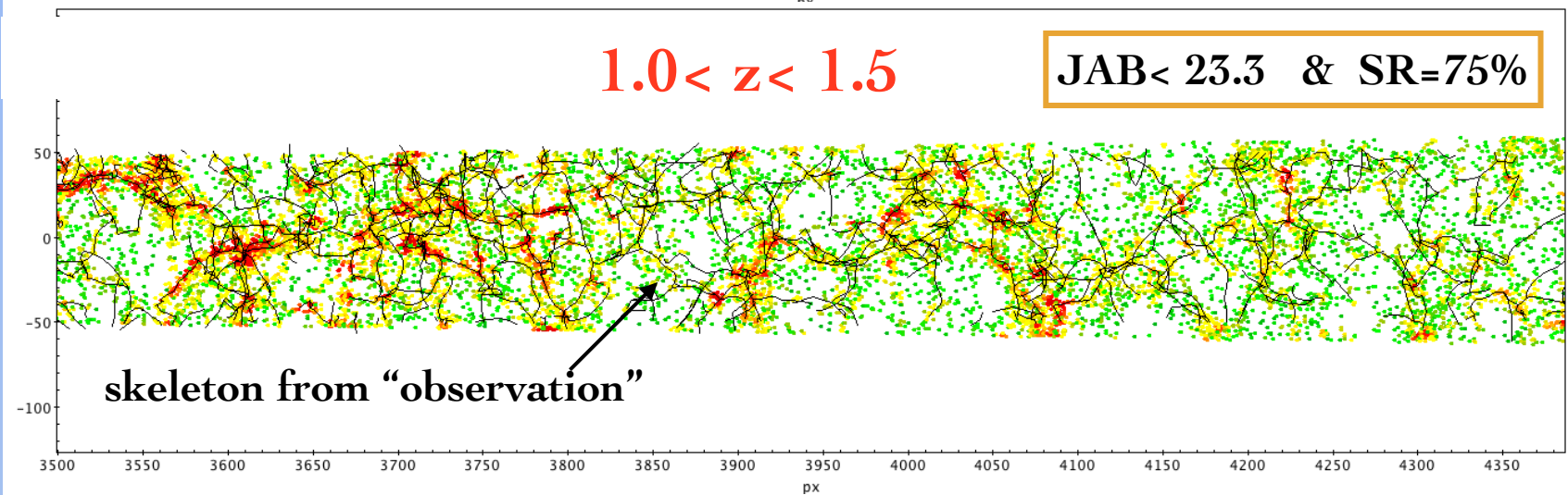
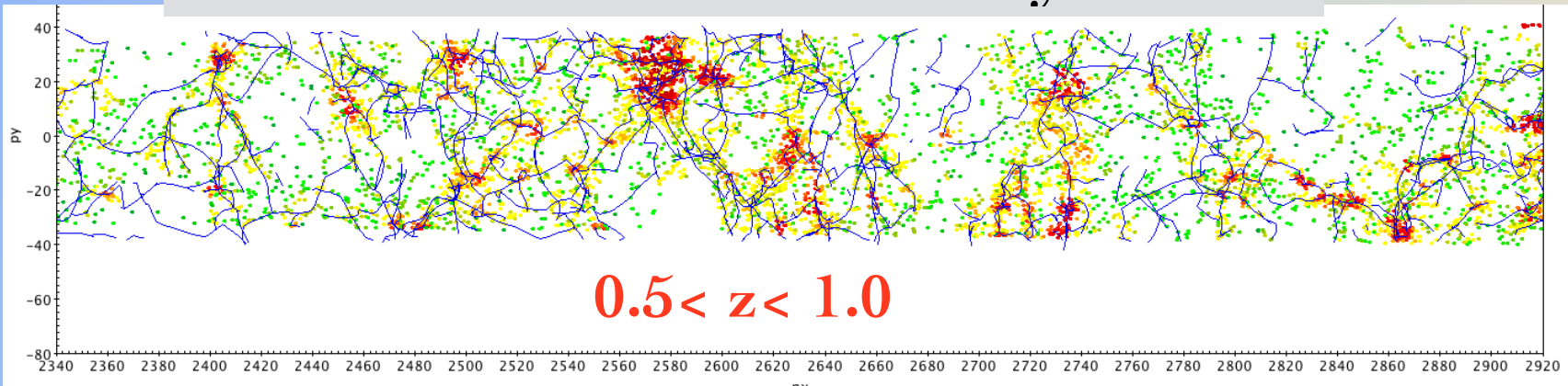
MOCK PFS [$J < 23.3$ & 75% SR]

$0.60 < Z < 0.90$: 15389

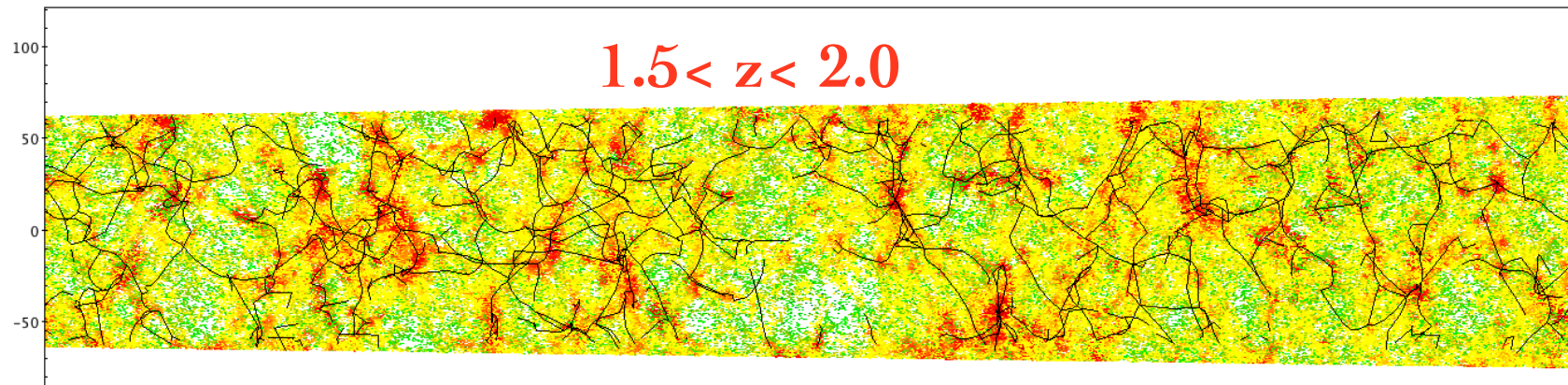
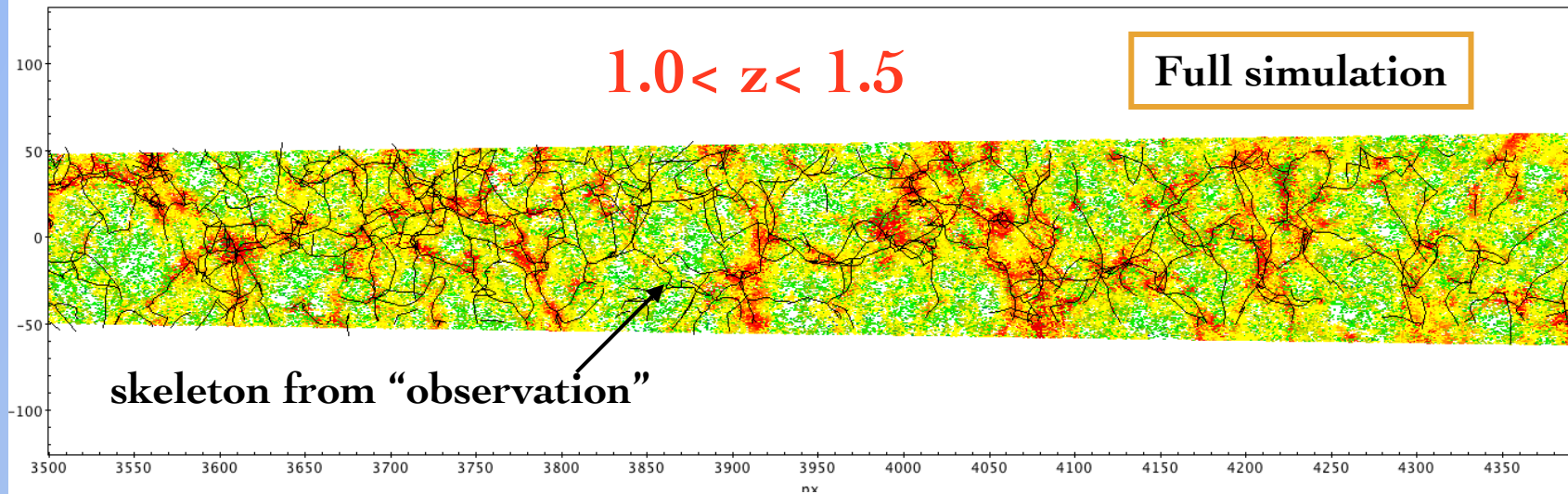
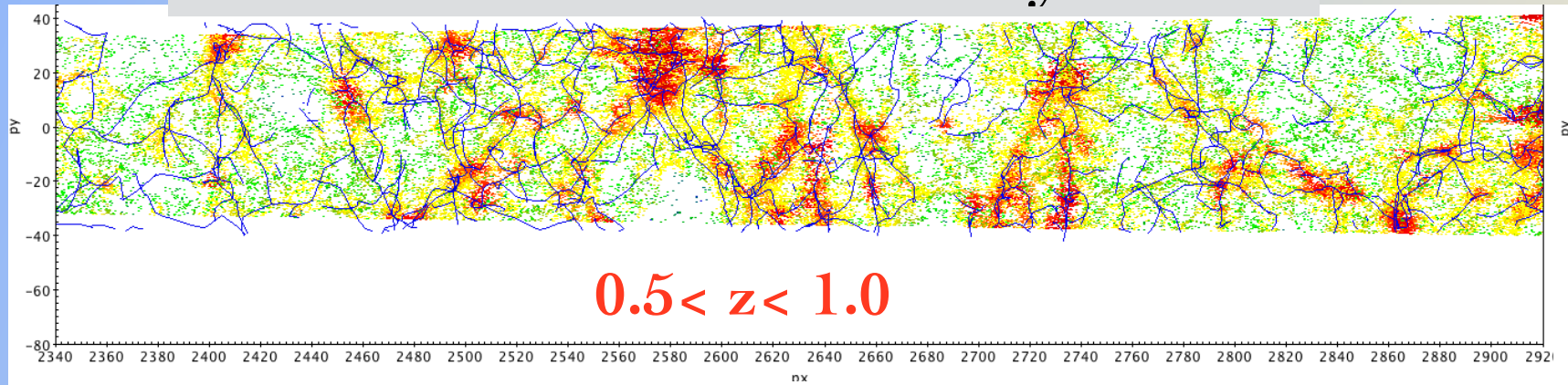


PFS will improve the contrast of the structures

HSC-PFS SuMIRe surveys



HSC-PFS SuMIRe surveys



-III- Improving Photo-z with the Cosmic web

Once the CW is reconstructed from spectroscopic survey, this information can be used to reduce the PDFs of galaxies with photo-z

(Aragon-Calvo+ 15)

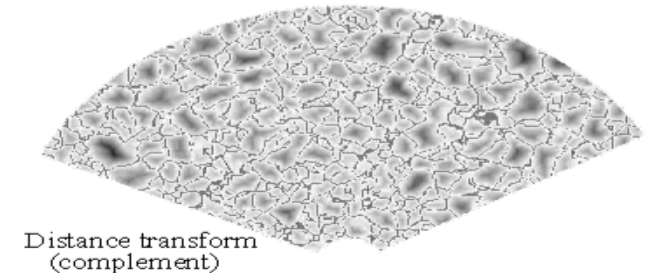
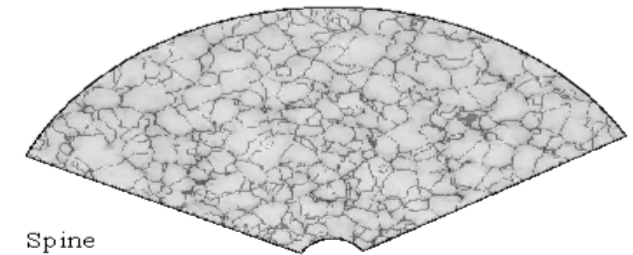
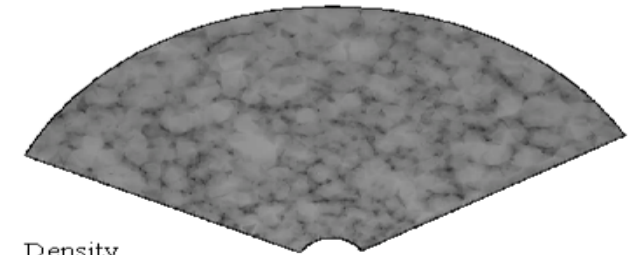
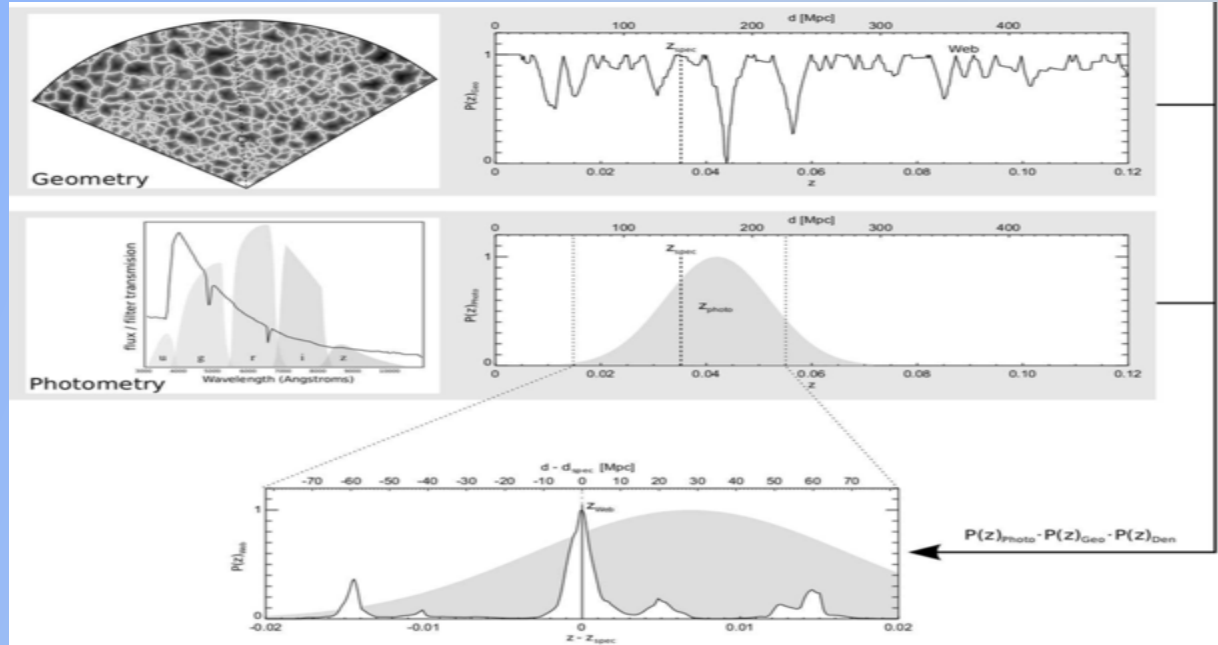
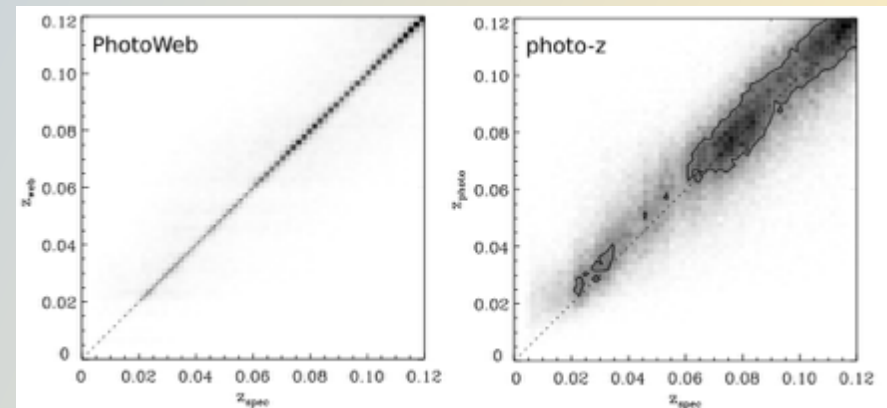


Photo-z improvements (Aragon-Calvo+ 2015)

$$P(z)_{\text{web}} = P(z)_{\text{photo}} \cdot P(z)_{\text{den}} \cdot P(z)_{\text{geo}}. \quad (1)$$

Where $P(z)_{\text{den}}$ is the density field sampled along the LoS and $P(z)_{\text{geo}}$ is a function that follows the geometry of the cosmic web in a similar way to the density field but giving equal weight to all cosmic structures. The normalization

Many applications within VIPERS and HSC deep !



Conclusion

Intermediate Scale Multi-wavelength Survey (VIPERS-ML)

between deep pencil beams and future Large photometric surveys

- * provide unique constraints on galaxy statistics
 - confirm early mass assembly of Massive galaxies
 - first measurement of the SHMR for satellite galaxies
 - existence of two quenching channels with different timescale
- * systematics in larger surveys will be the limiting factor !
- * Major role of photo-z's to exploit coming surveys
 - urgent to progress here; to improve dust recipes
to consolidate physical properties & photo-z accuracy

Large spectroscopic surveys :

a new insight for galaxy evolution via Cosmic Web analysis

* HSC + u band (CLAUDS) + PFS

A unique window on the LSS & environment at high redshift

This dataset will be unique until the advent of LSST !!



MAHALO