

CLAUDS

CFHT Large-Area U-band Deep Survey

300hr of Deep U band imaging in
the Hyper Suprime Cam Deep Layer

S. Arnouts

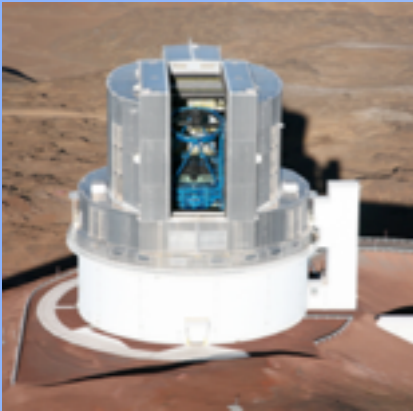
on behalf of the CLAUDS team

based on PI programs

	co-PIs
<u>China</u>	Jiasheng HUANG (Sebastien FOUCAUD)
<u>Canada</u>	Marcin SAWICKI
<u>France</u>	Stéphane ARNOUITS

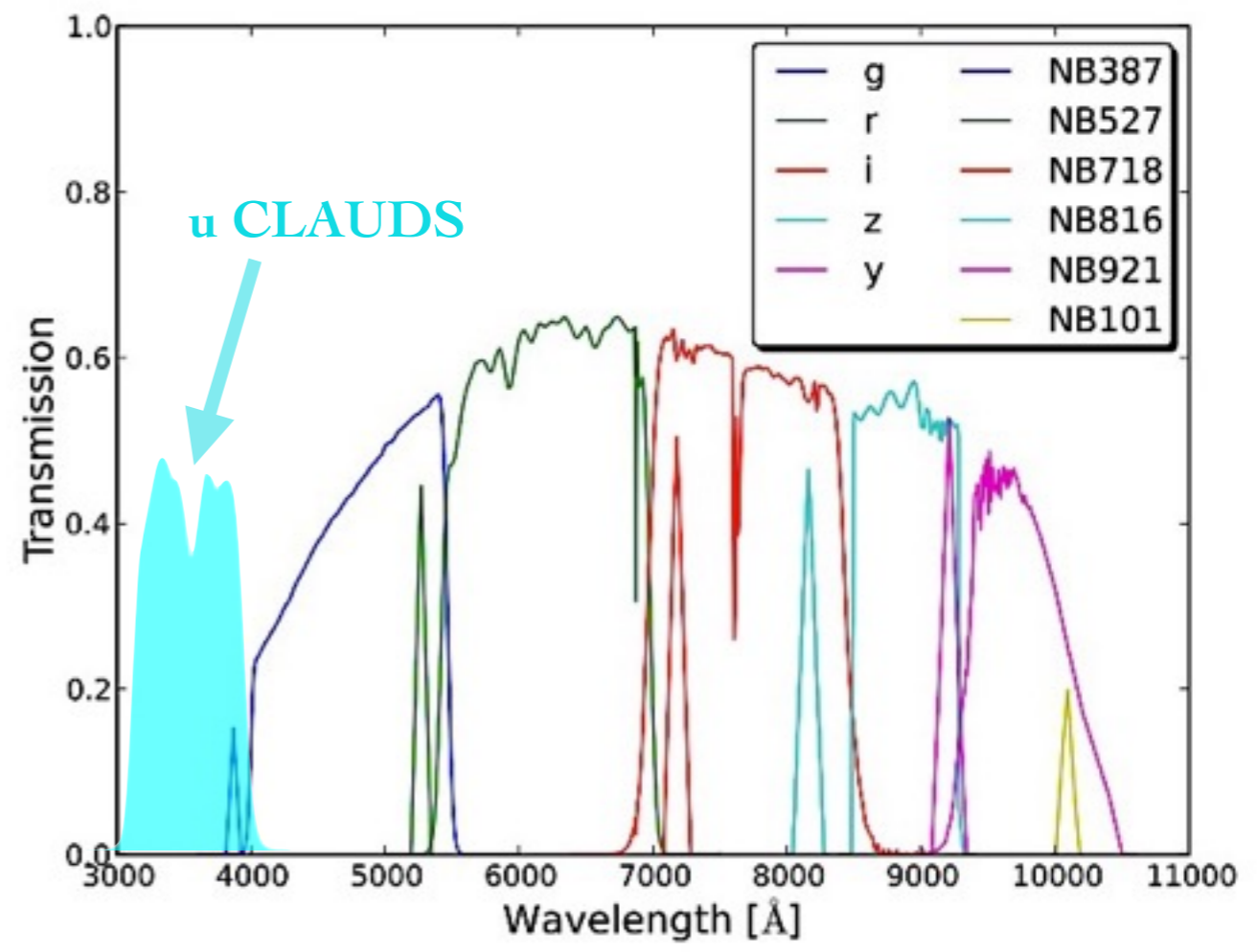
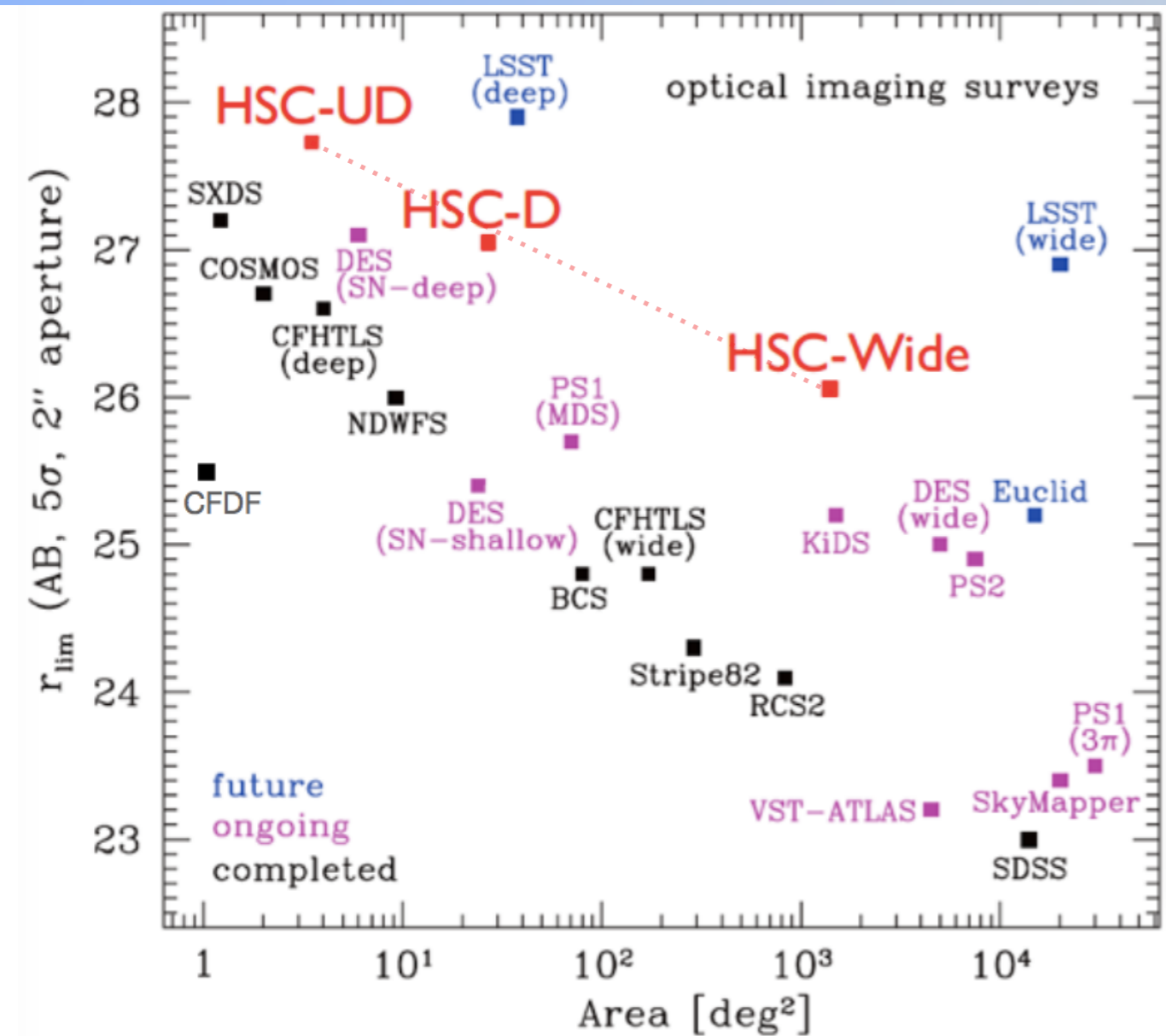
	co-Is
<u>Shanghai</u>	Jing Y., Yang X., Li C.
<u>Japan</u>	Yamada T., Bundy K., Iwata I., Matsuda Y., Nagao T., Ouchi M., Shimasaku K., Silverman J., Tanaka M.
<u>Canada</u>	Balogh M., Chapman S., Gwyn S., Willott C., Yee H.
<u>France</u>	Ilbert O., Le Fèvre O., de La Torre S., Tresse L., Moutard T, Coupon J.

The HSC Survey & CLAUDS

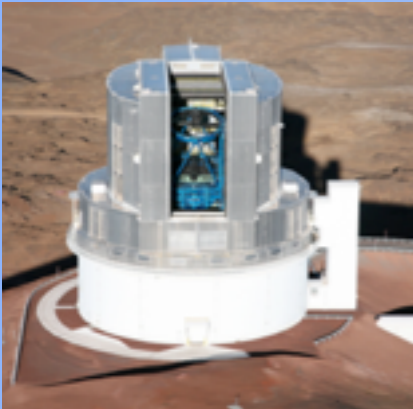


HSC : 3 Surveys

HSC Filters : *grizY* + NBs

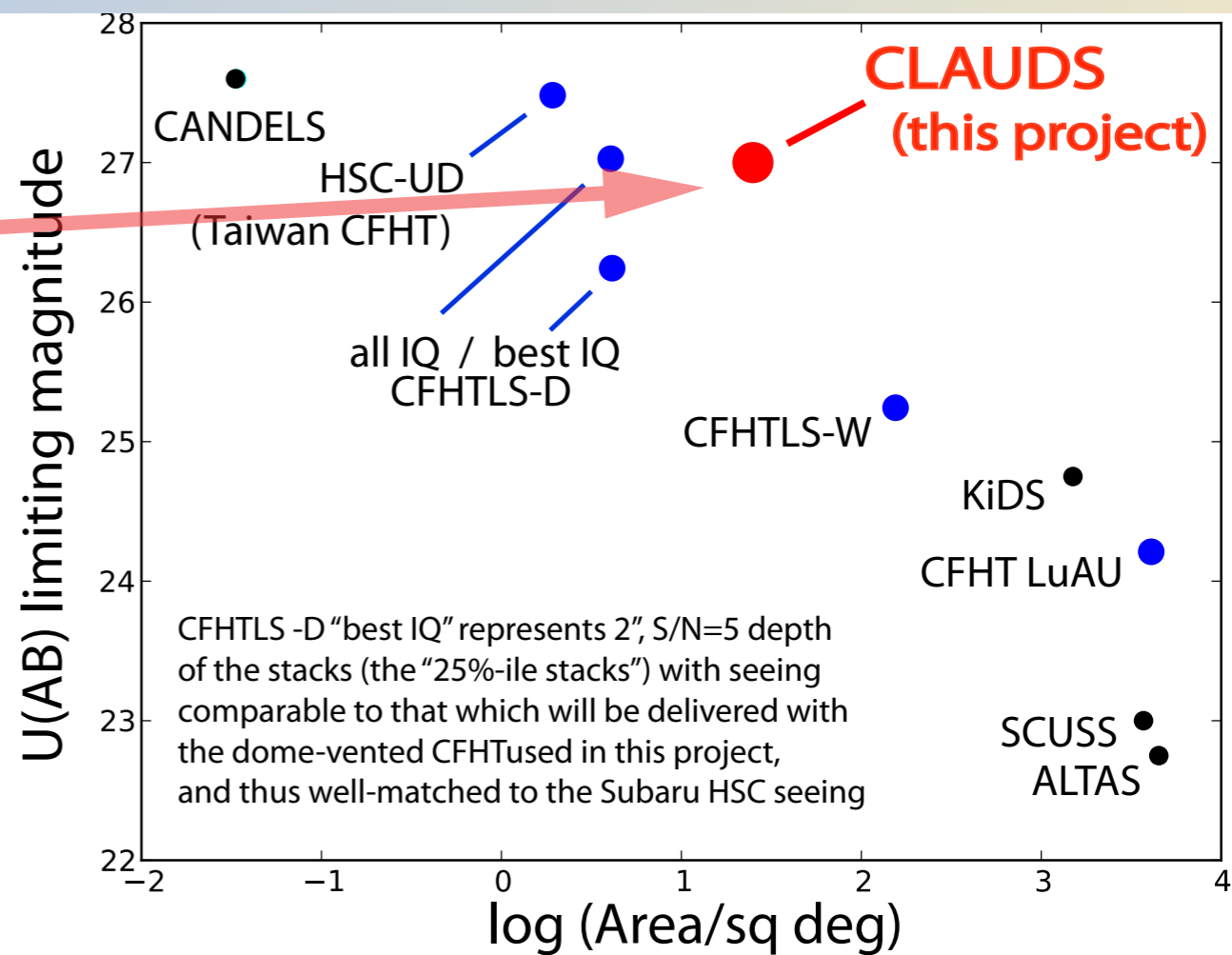
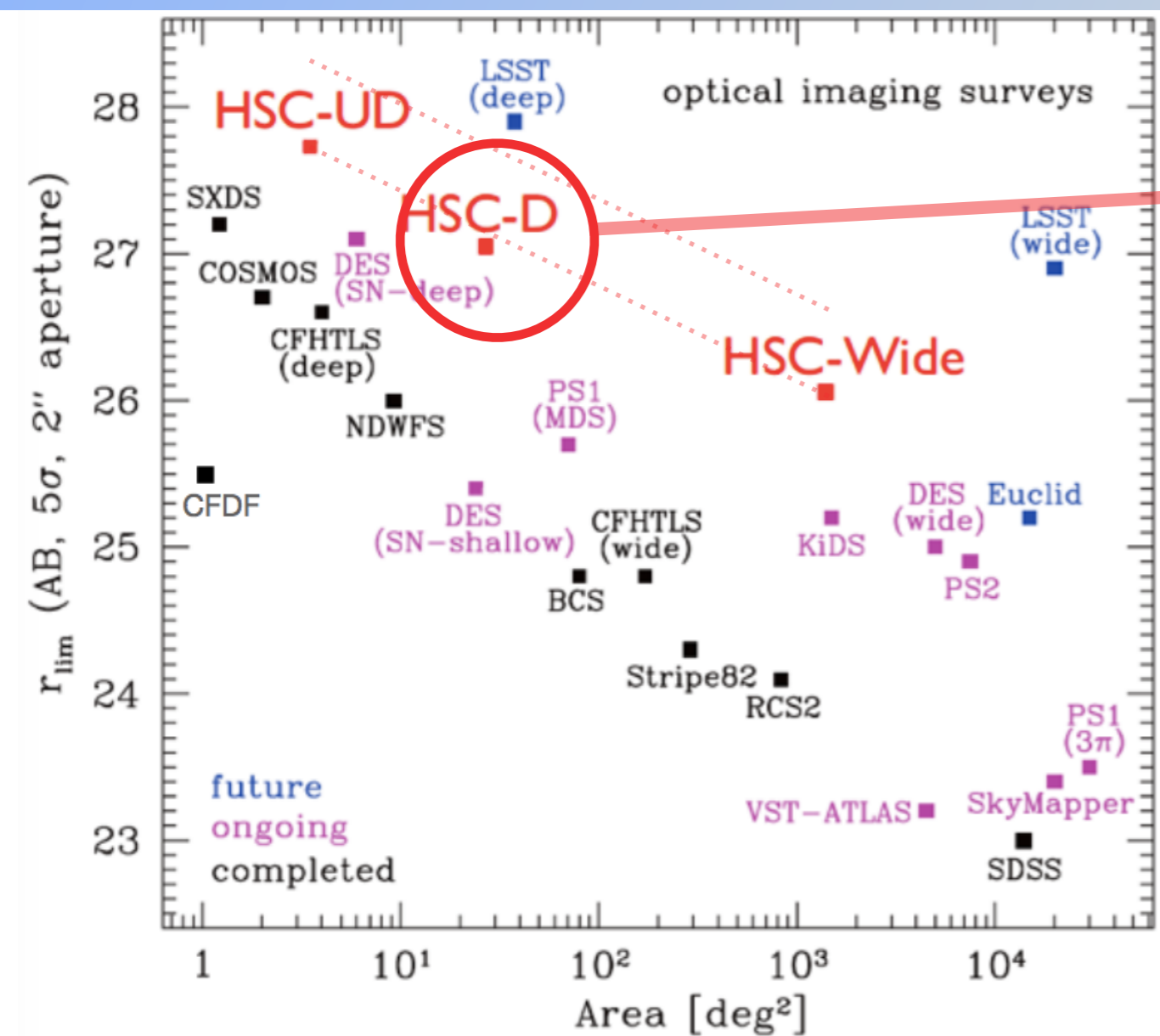


The HSC Survey & CLAUDS



HSC : 3 Surveys

CLAUDS u band for HSC-D



U ~ 27mag (5 σ , 2") over Area ~ 20 deg²
 Image Quality < 1 arcsec

HSC Deep Fields

* Located in Extragalactic regions with multi-wavelength & spec-z informations

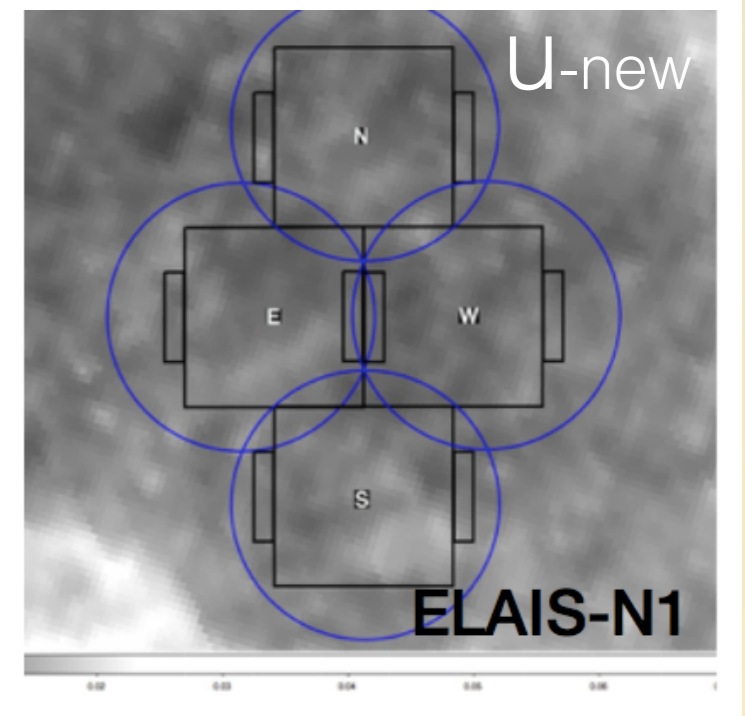
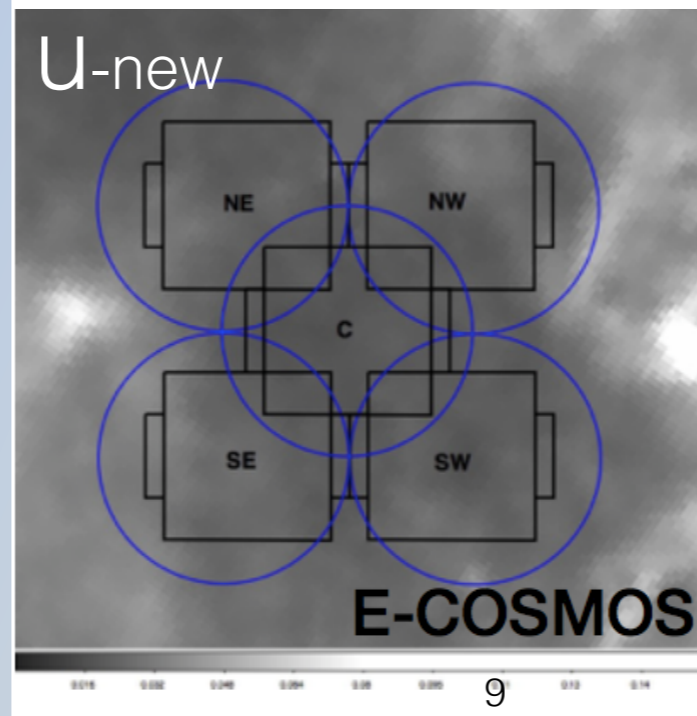
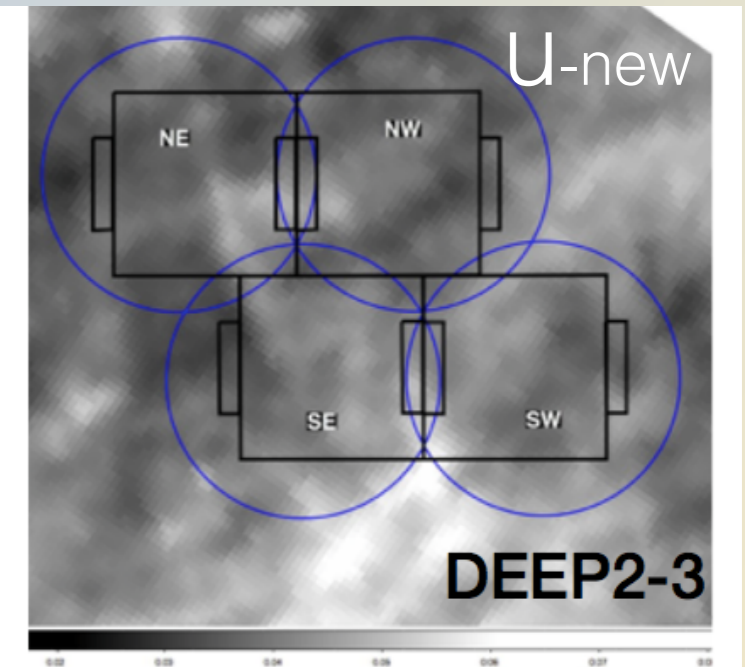
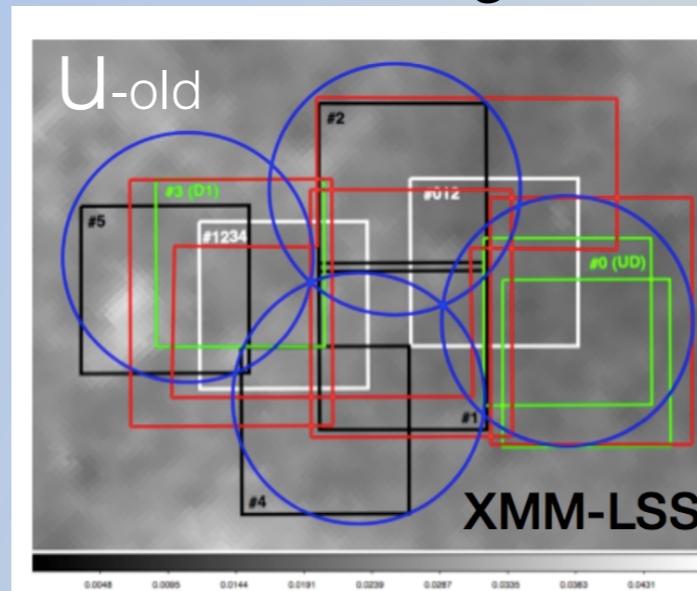
- * HSC pointings
- * MegaCam pointings
- u archives
- u CLAUDS

CFHT observations

- $T_{\text{exp}} \sim 16\text{hr}$ with u-old
- $T_{\text{exp}} \sim 15\text{hr}$ with u-new

Total: ~300hr program

- * Dark Time + IQ < 1"
- * 4 sem. (14B - 16A)
- * based on PI prog
(C/F/S)



combination of area & depth will be unmatched until LSST Deep !!

CLAUDS enables new HSC science

In addition to the spectacular HSC Deep data, the U band will provide :

- direct measurements of **rest-UV for SFRs** at low redshift $z < 1.5$ (improved SED fitting and dust estimates)
- a unique sample of **star-forming galaxies** at $2 < z < 3$ based on color techniques [BM/BX/ U-dropouts] will probe below M_{UV}^* of the UV Luminosity Function
- a significant improvement of the **HSC photo-zs** (fraction of catastrophic failures , scatter and critical at $z < 0.5$)
- a clean selection of **LAEs and Ly α blobs** (with NB387) at $z \sim 2.2$
- **PFS** (Prime Focus Spectrograph) **target selection** may converge toward a photo-z selection : **CLAUDS + HSC critical** [PFS : SDSS-like survey with a million galaxies $z > 0.7$ and up to $z \sim 2-3$]

CLAUDS enables new HSC science

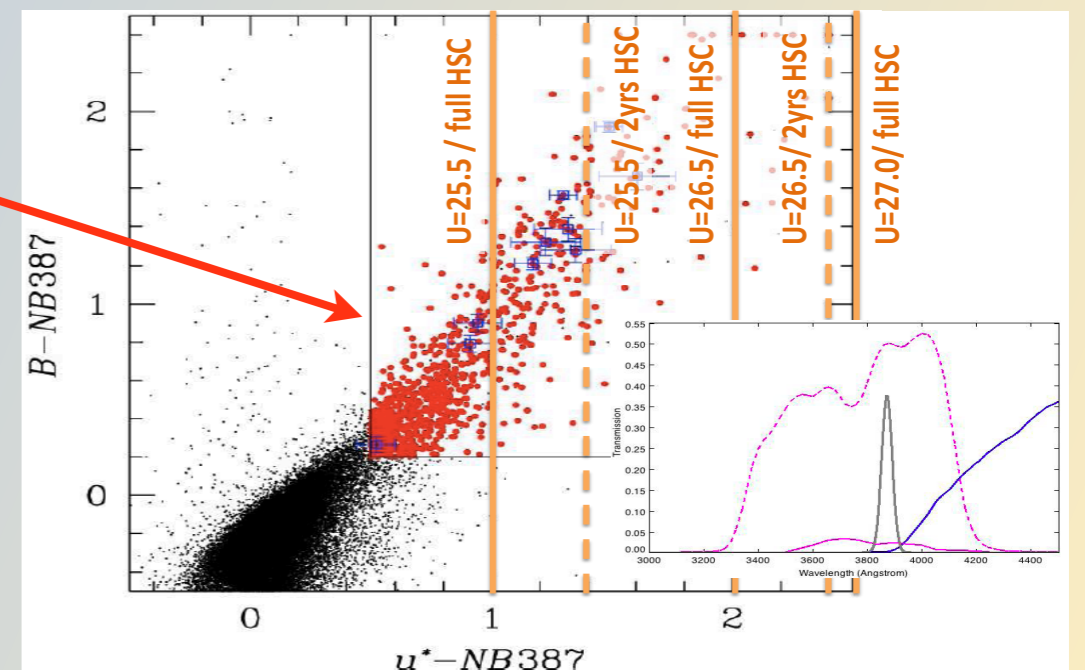
The samples assembled with CLAUDS + HSC Deep will be unique

Table 3: Expected number of objects

$\langle z \rangle$	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

* Lensing shape measurement is limited by low shear S/N for sources at $z > 1$

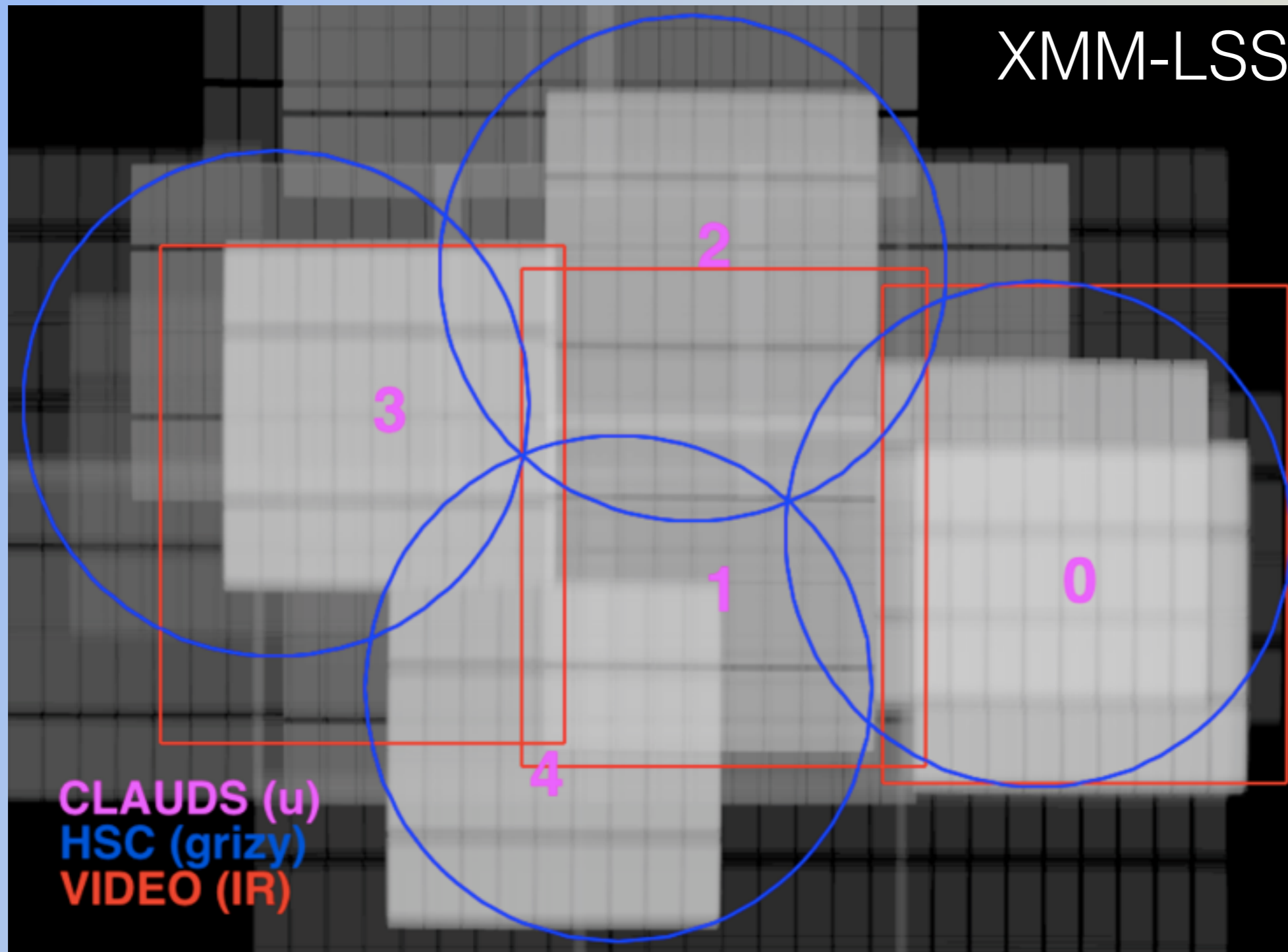
⇒ CLAUDS+HSC-Deep perfect for lensing magnification bias studies with LBG sample



CLAUDS : Data reduction

CLAUDS data are quickly reduced by Stephen Gwyn

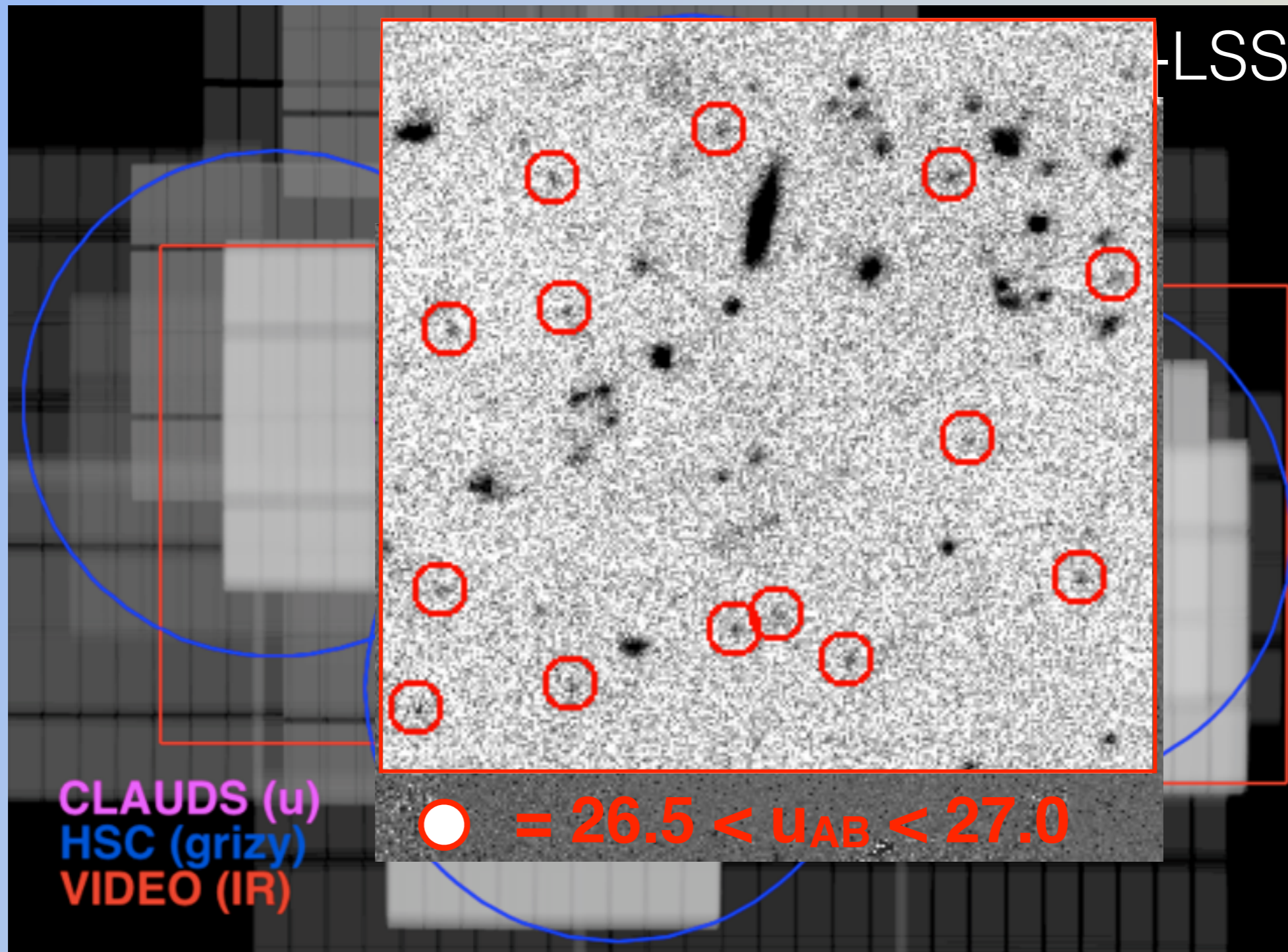
* photometrically & astrometrically calibrated stacked images at CADC



CLAUDS : Data reduction

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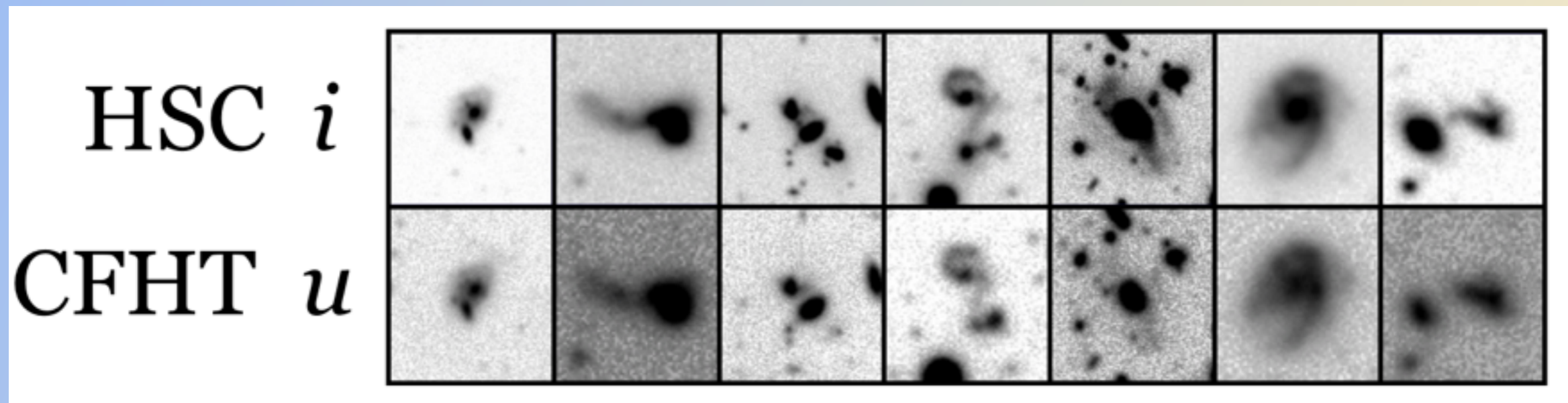
* photometrically & astrometrically calibrated stacked images at CADC



CLAUDS : Data merging effort underway

- HSC Deep survey is on going
 - * Agreement to use HSD-UD at the deep depth
The first two Deep fields are now available to the team for processing
- Big effort in CLAUDS team to develop data-merging with HSC:
 - * trick HSC pipeline to process CFHT stacks and to produce combined catalogs CLAUDS+HSC-D (Jean Coupon)
 - * backup plan also in parallel: using SExtractor in dual mode (Anneya Golob)

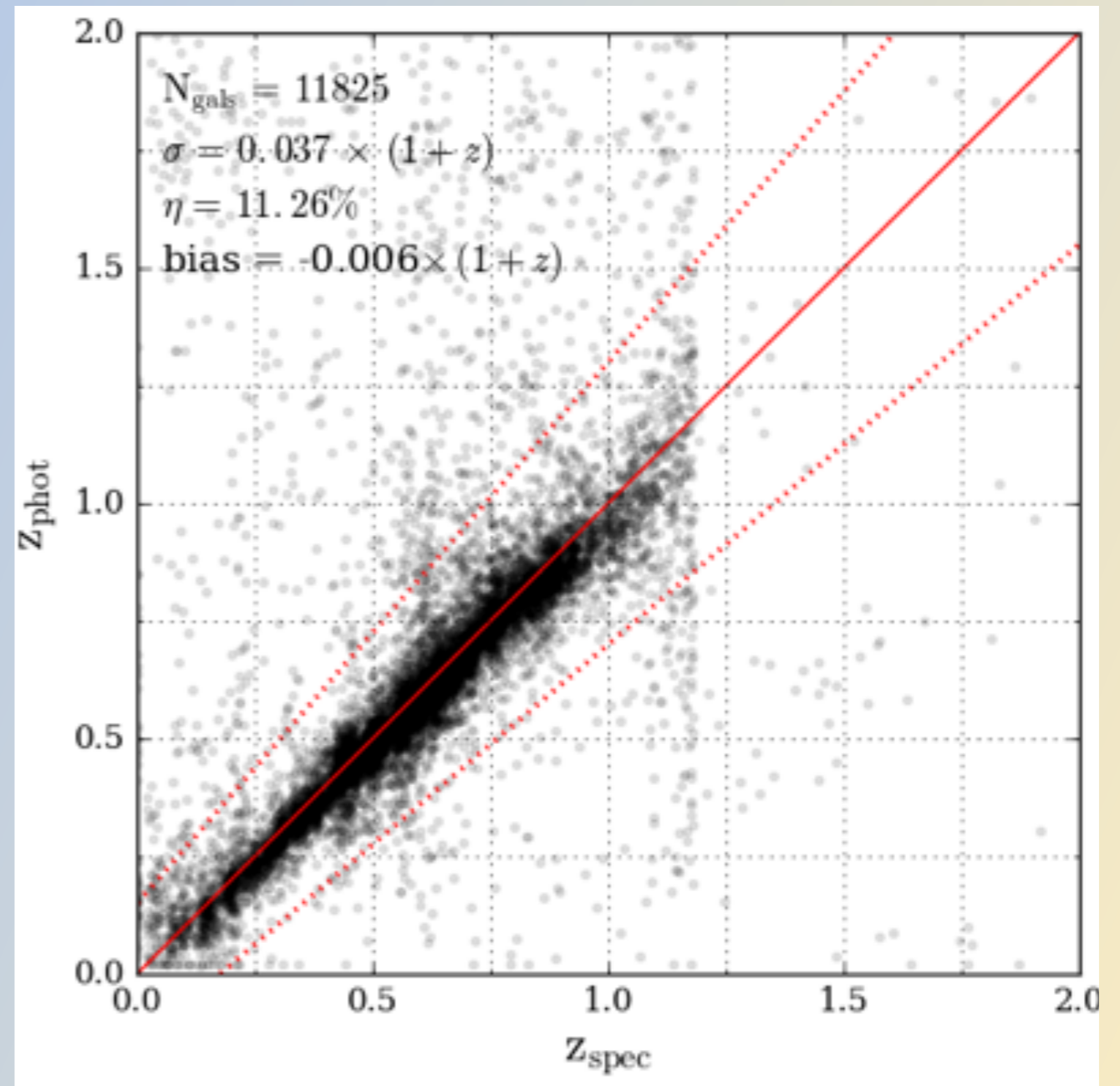
Illustration of u and i band at the Deep depth (Tidal features)



CLAUDS : Data merging effort underway

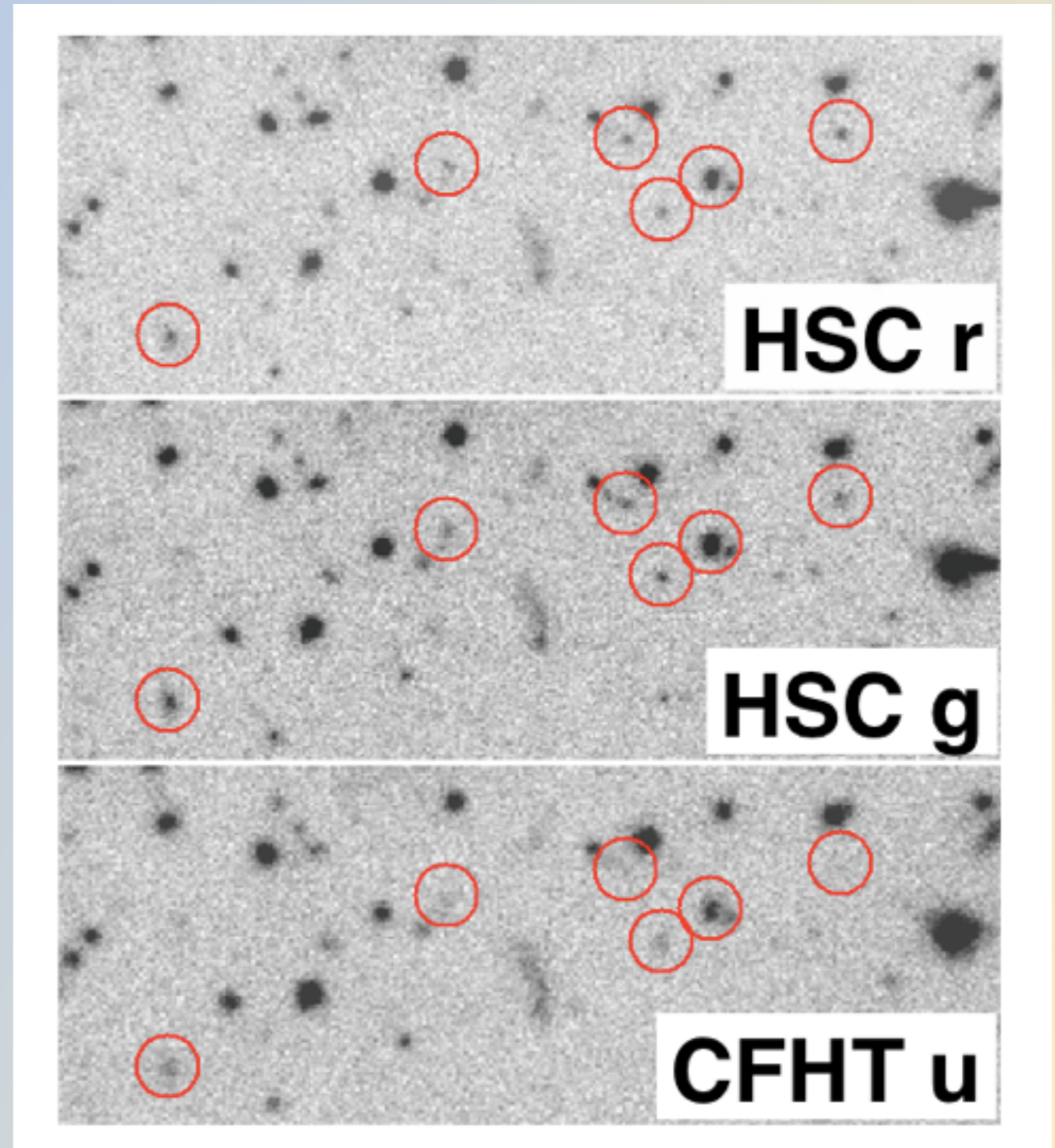
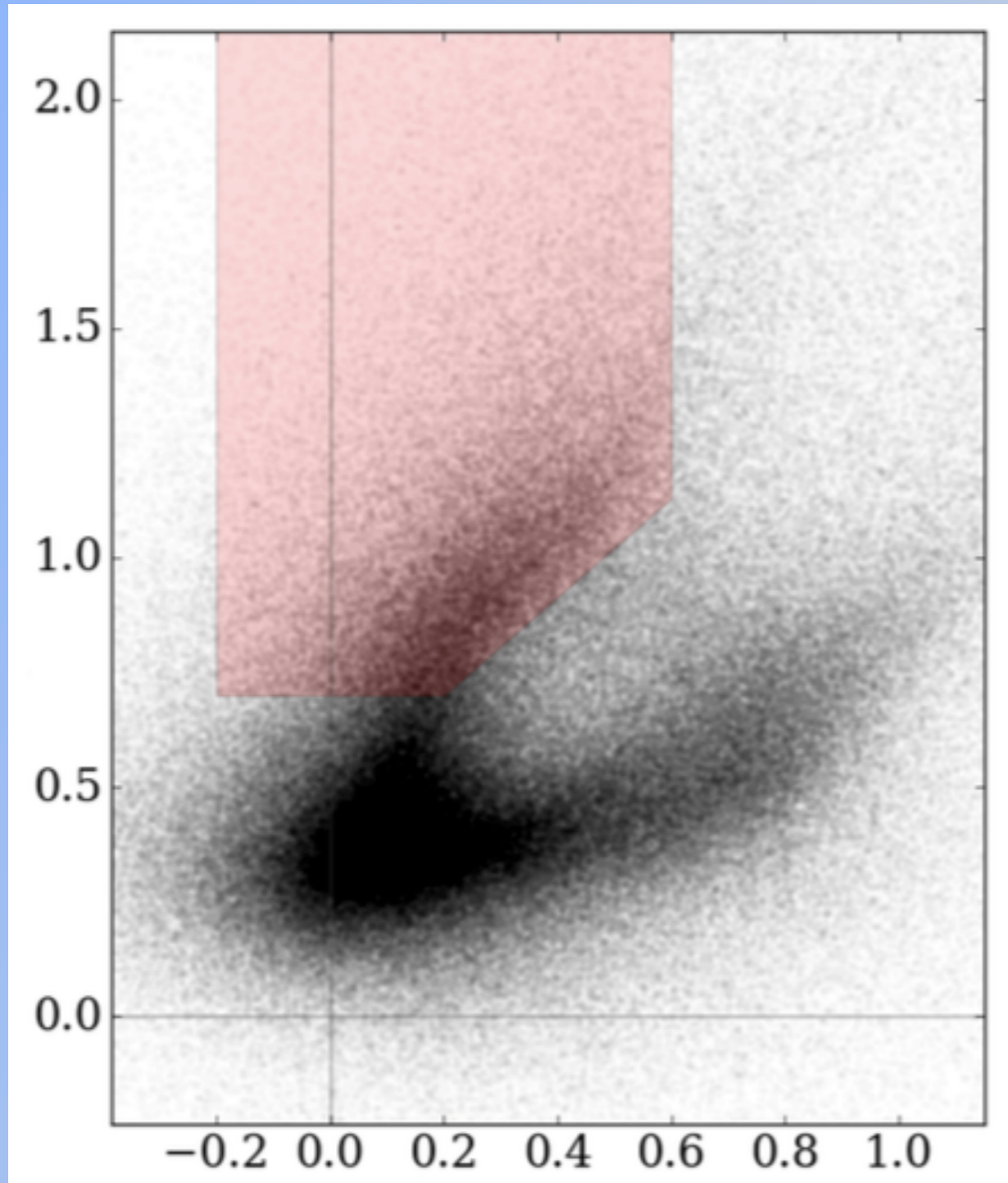
Preliminary CLAUDS+HSC photo-z's

- * good agreement at this early stage in our photo-z creation process.
- * tie relation at $z < 0.5$ thanks to u-band



CLAUDS : Data merging effort underway

LBGs galaxy selection at $2 < z < 3.5$ with CLAUDS+HSC catalog in XMM-LSS



CLAUDS status

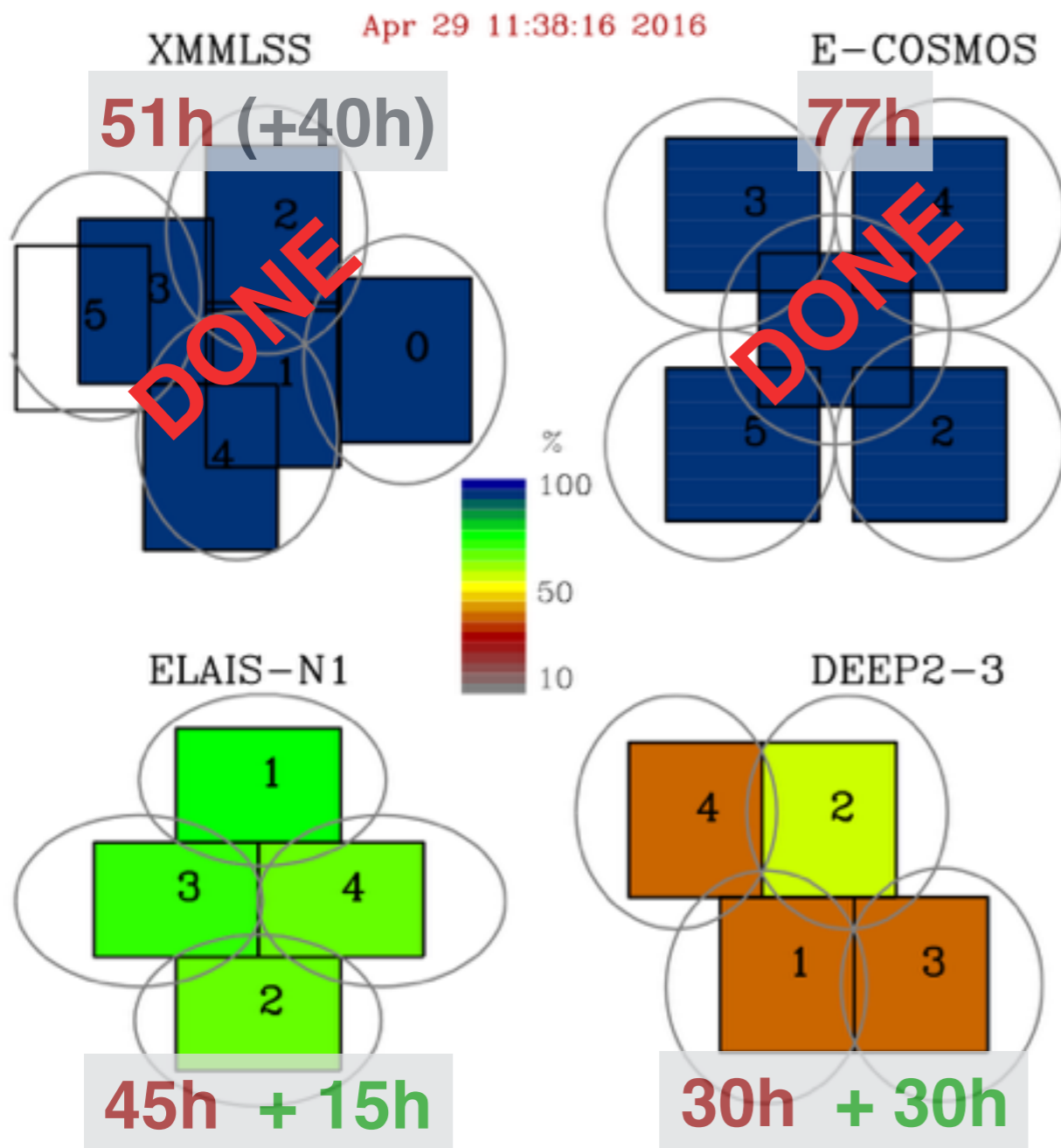
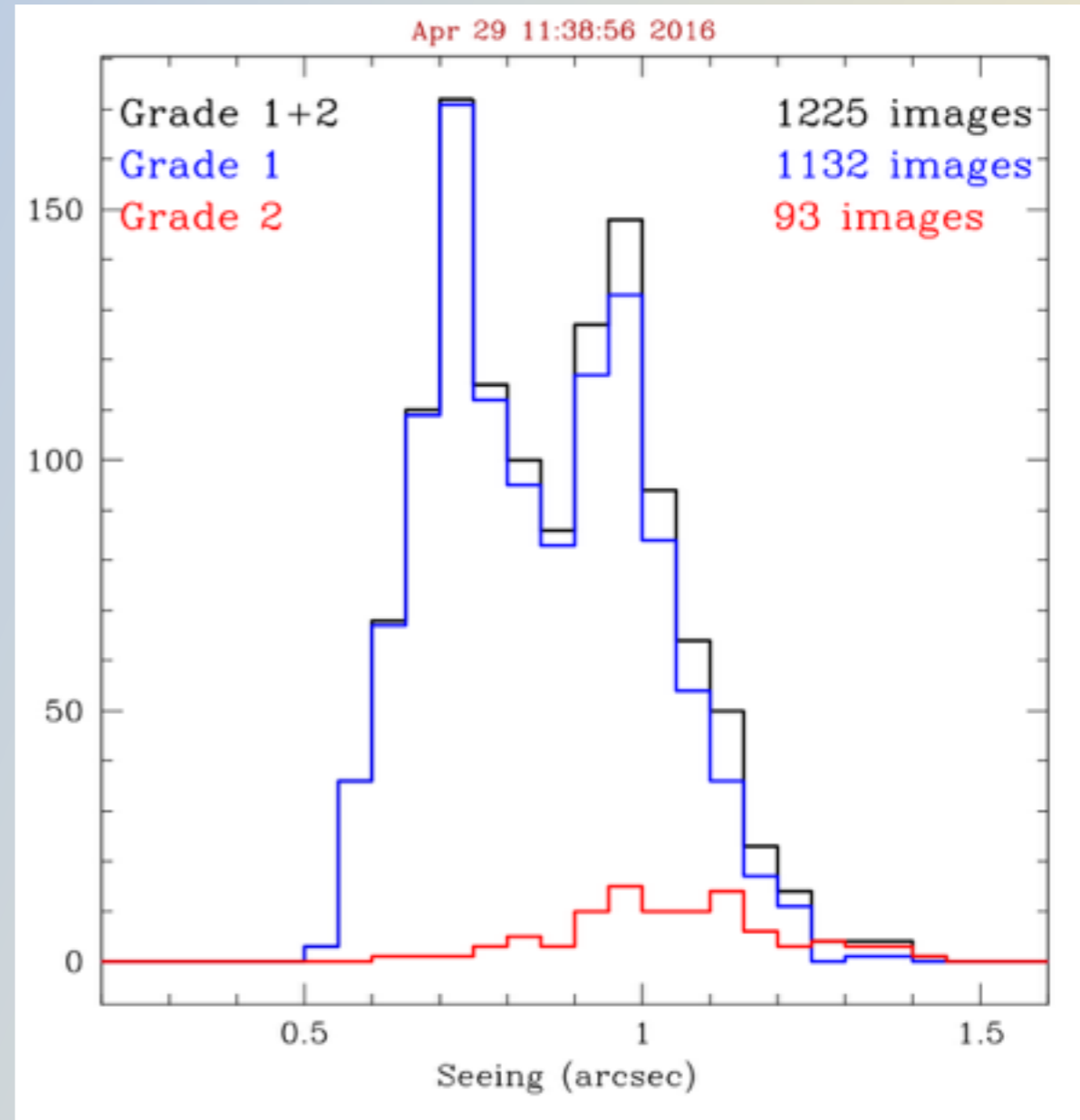


Image Quality



- Already 205 h of integration time
- ELAISN1 : 15h before completion
- DEEP2-3 : 30h before completion

Great Seeing in u band !

52% with $IQ < 0.85''$

14% with $IQ > 1.05''$

CLAUDS after 2 years

Time allocation per semester and Agency

The completeness includes all validated exposures (grade 1+2)

Semester Agencies[C/S/F]	Ranking	Allocated	Observed	Completeness
14BC34	A1	30hr	30hr	100%
14BS01	B1	20hr	13.5hr	67%
14BF16	B1	30hr	0hr	0%
14B Total		80hr	43.5hr	54%
15AC28	A1/B	32hr	29hr	91%
15AS03	B1	24hr	24hr	100%
15AF15 + 15AF98	B1+C2	14hr + 18hr	13.5hr	41%
15A Total		88hr	66.5hr	75%
15BC19	A1	32hr	24.9hr	78%
15BS02 + 15BS99	A1+B1	19hr + 3hr	21hr	96%
15BF11 + 15BF99	A1+B1	18.2hr+13.4hr	15.6hr	49%
15B Total		86hr	61.5hr	72%
16AC26 + 16AC99	A1 + B1	25hr + 6hr	22.7	
16AS02	B2	20hr	5.1	
16AF19 + 16AF96	A1+B5	15hr+16hr	20.1	
16A Total		82hr	48.0hr	58%

14B BAD!

15A OK!

15B OK!

16A OK?

58% ⇒ 75% ?

- Hope for the 15h in ELAIS field to be observed before end of 16A !
- We need 30h to finish DEEP2-3 field (16B Proposal Submitted)

CLAUDS summary

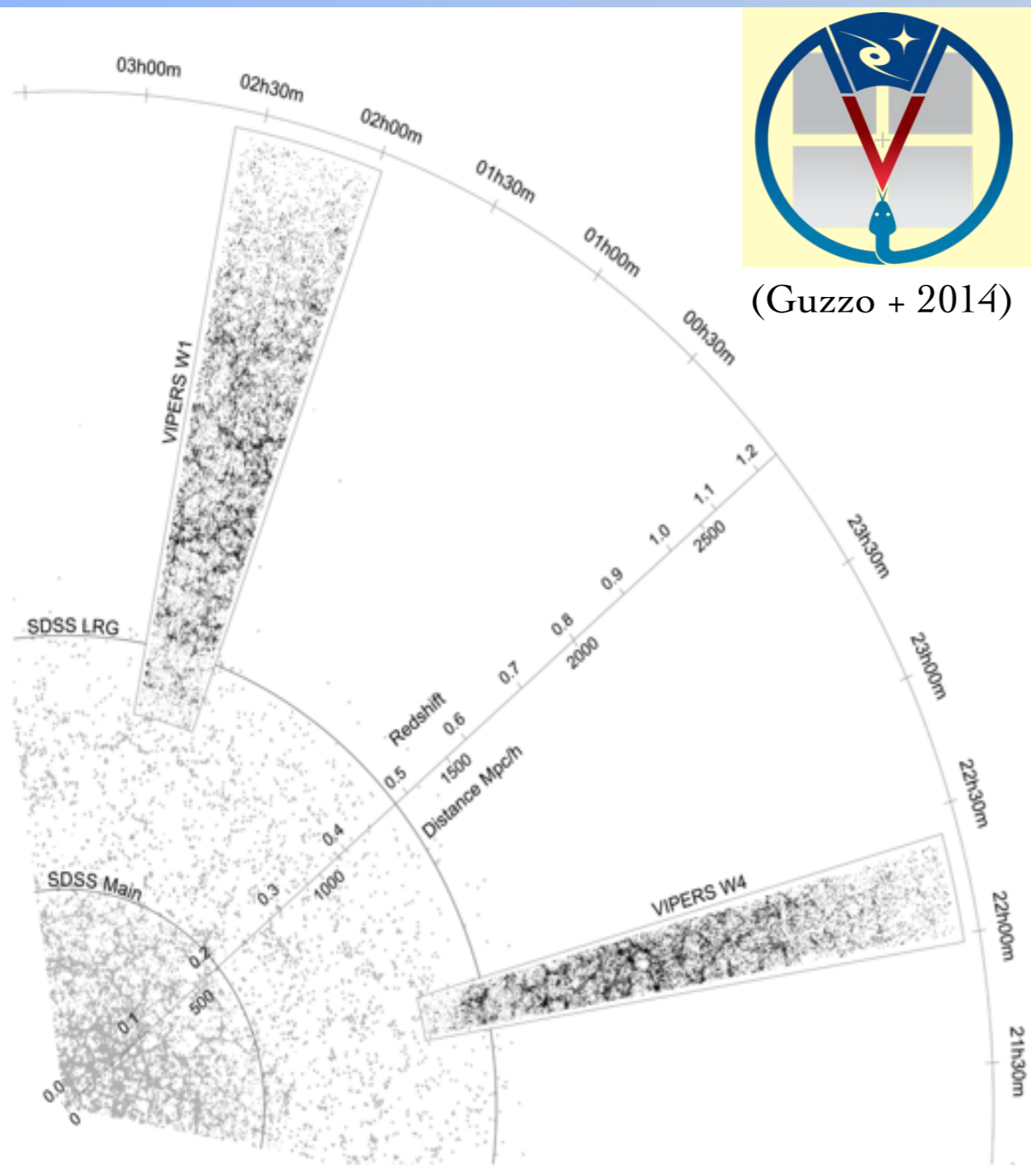
- CLAUDS is $u=27$ AB (5σ , $2''$) over ~ 20 sq. deg. in HSC-Deep Layer
exploits the unique UV capability of CFHT
- Data acquisition is well underway but will be not done end of 16A
due to bad weather in 14B, we need an extension in 16B semester
- HSC-Deep stacks in HSC-UD fields are combined with CLAUDS
first results will come soon after ...

- CLAUDS data will be available at CADC on regular basis
- CLAUDS+HSC data will follow the standard HSC release (first one in 2017)

on behalf of CLAUDS team : **MAHALO to the QSO team !**

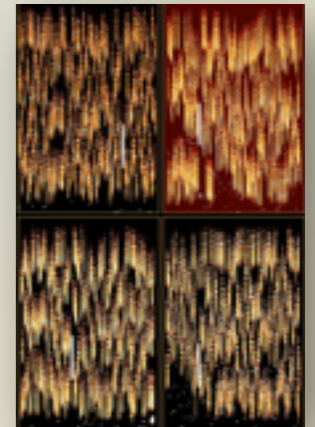
The Influence of Cosmic Web on galaxy Evolution

- **SDSS** Spectroscopic Survey (5000 deg^2): $z < 0.15$ (Aragon Calvo +2010, Tempel+2013, ...)
- **GAMA** Spectroscopic Survey (150 deg^2): $z < 0.3$ (Eardley +2015, Alpaslan+2014, 15, ...)
- **VIPERS** Spectroscopic Survey (24 deg^2): $0.5 < z < 1.2$



VIPERS : VIMOS spectroscopic survey

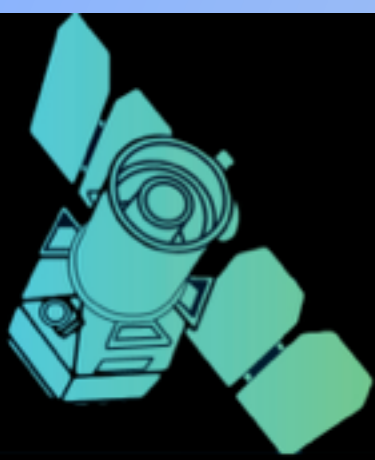
- * Flux limited : $i < 22.5$
- * color selected : $0.5 < z < 1.2$
- * sampling : 35% (one pass)
- * 100,000 redshifts in 2 fields



state of art galaxy survey to map the
Cosmic Web at high redshift

- Cosmic Web contains 80% of gas in IGM

Understand galaxy evolution within
this anisotropic network is a major challenge



GALEX

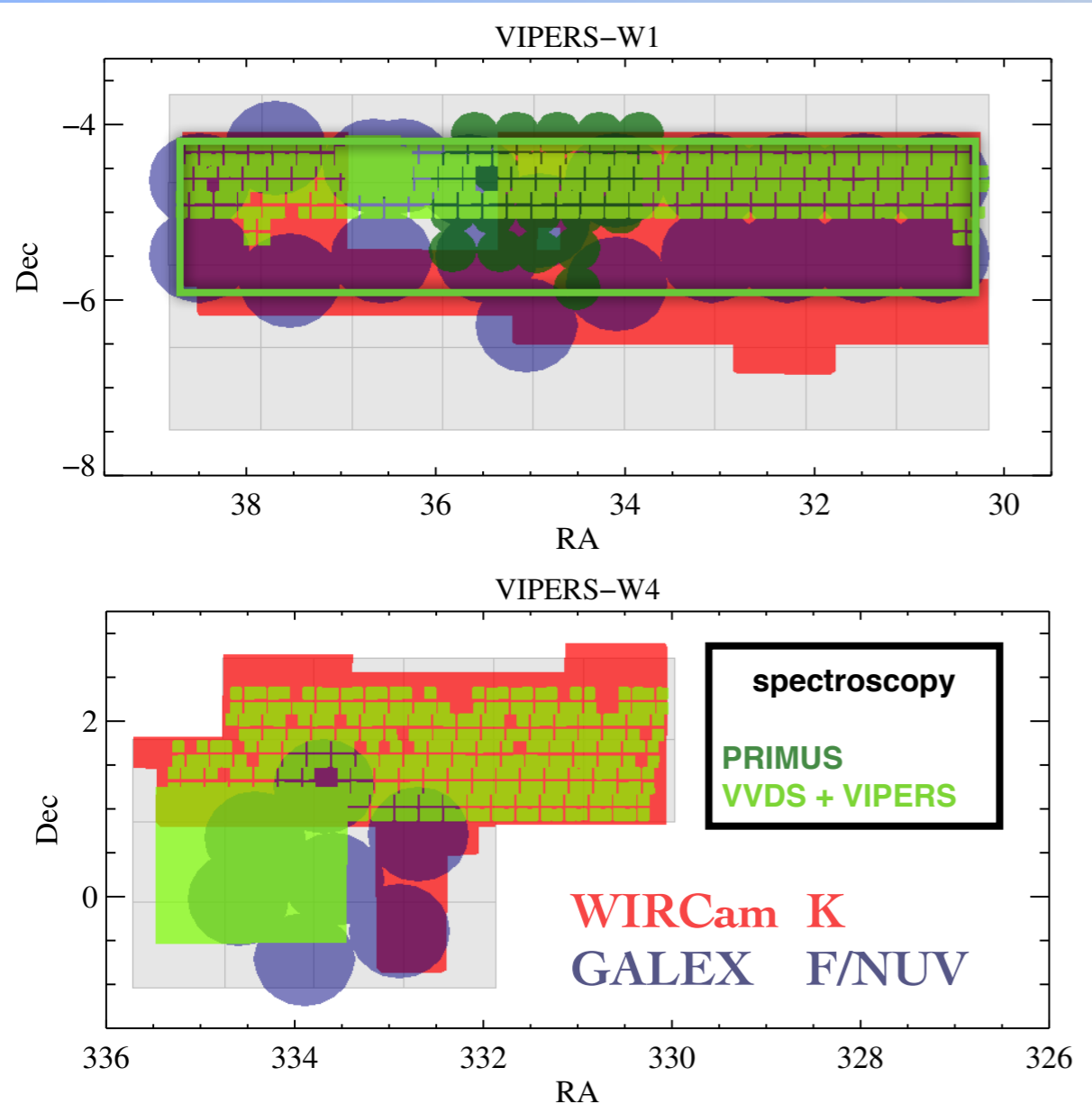


Multi- λ Survey

WIRCam



design by Fabio Guzzo



Multi wavelength campaign in UV with GALEX & WIRCam at CFHT since **2010** to assess galaxy properties in VIPERS regions
more details in Moutard, SA, Ilbert et al. 2016a

GALEX UV (FUV & NUV)
 * 100h Discret. Time + 200h public release
 * integration/pixel: between 20 to 30,000 sec

WIRCam Ks imaging @ CFHT
 * 120h Arnouts (F), Van Waerbeke (C), Morrison(UH)
 * integration/pixel: 1050sec

The photometric catalogues, photometric redshifts and the images are released :
<http://cesam.lam.fr/vipers-mls/>

... see the Poster for other science cases with photo-z ...

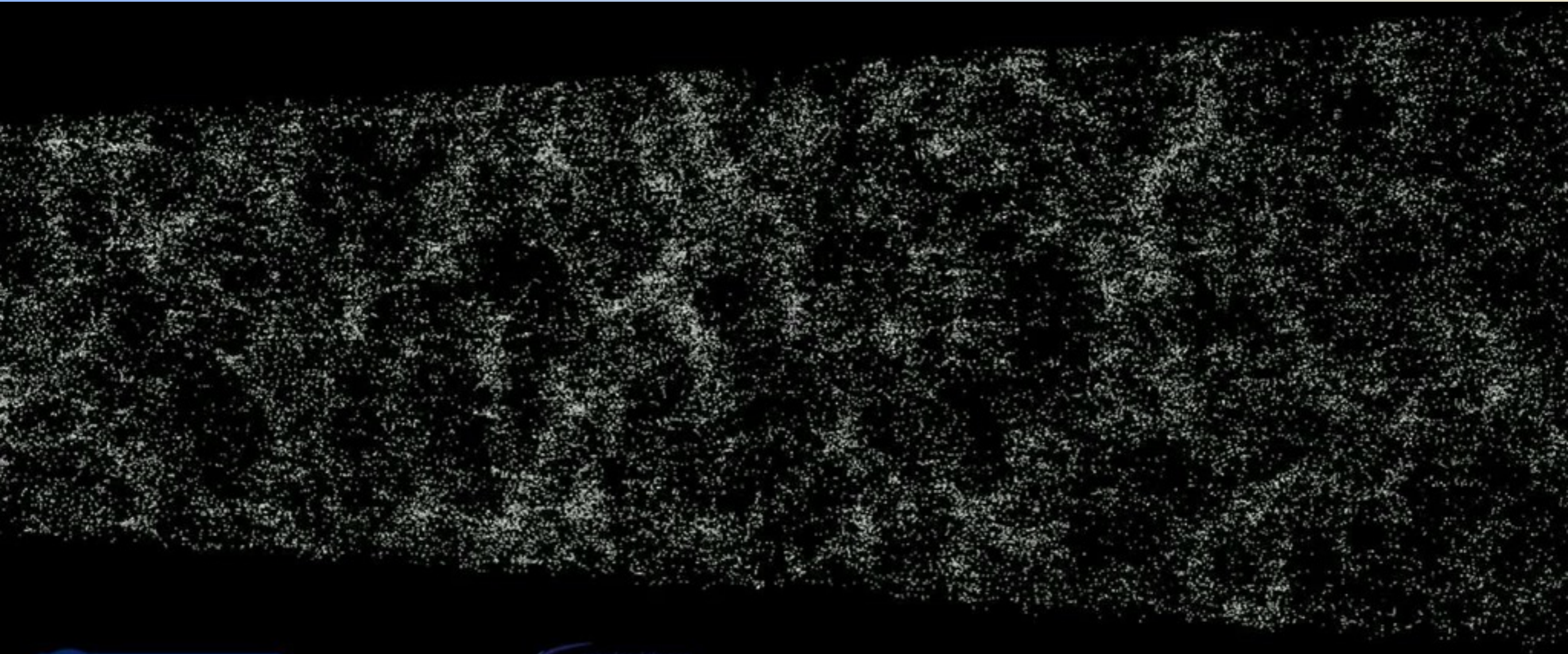
The Influence of Cosmic Web on galaxy Evolution



galaxies in the

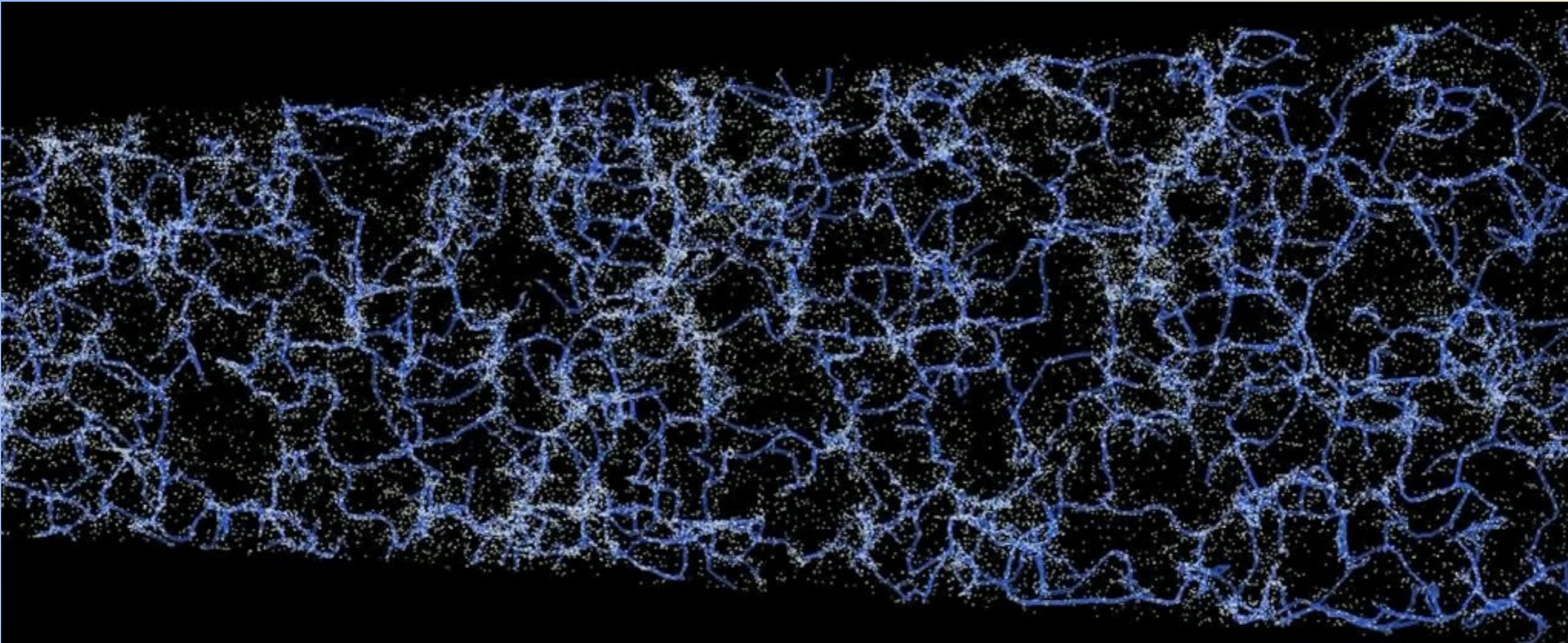


Malavasi, SA et al., in prep



**First opportunity to measure the cosmic web at high redshift
and to investigate its role on galaxy evolution.**

Malavasi, SA et al., in prep

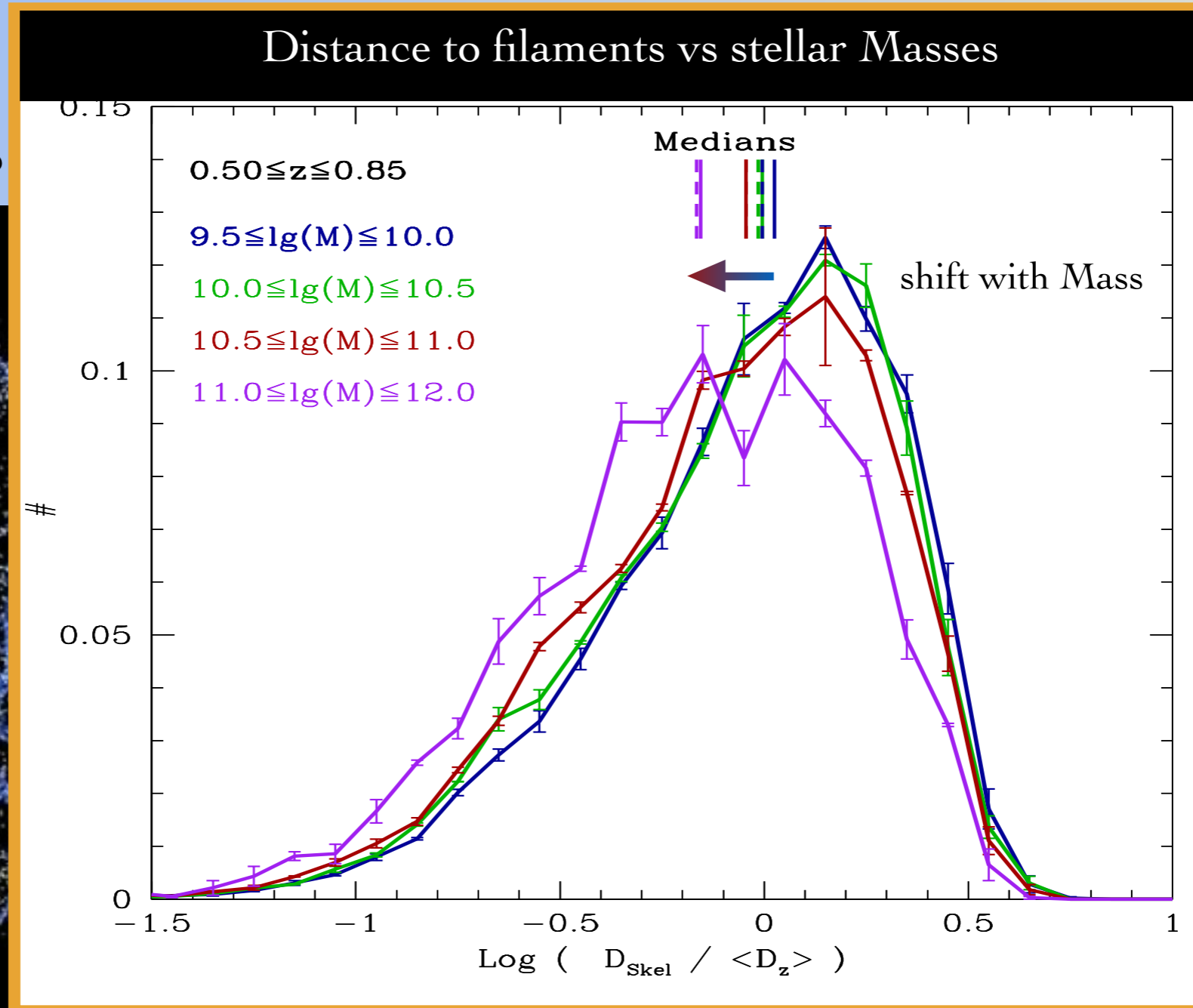


3D ridge Extractor : code Disperse (Sousbie+,09)

extracting the filamentary structures of the CW
connecting maxima and saddle points of density field
following the density ridge



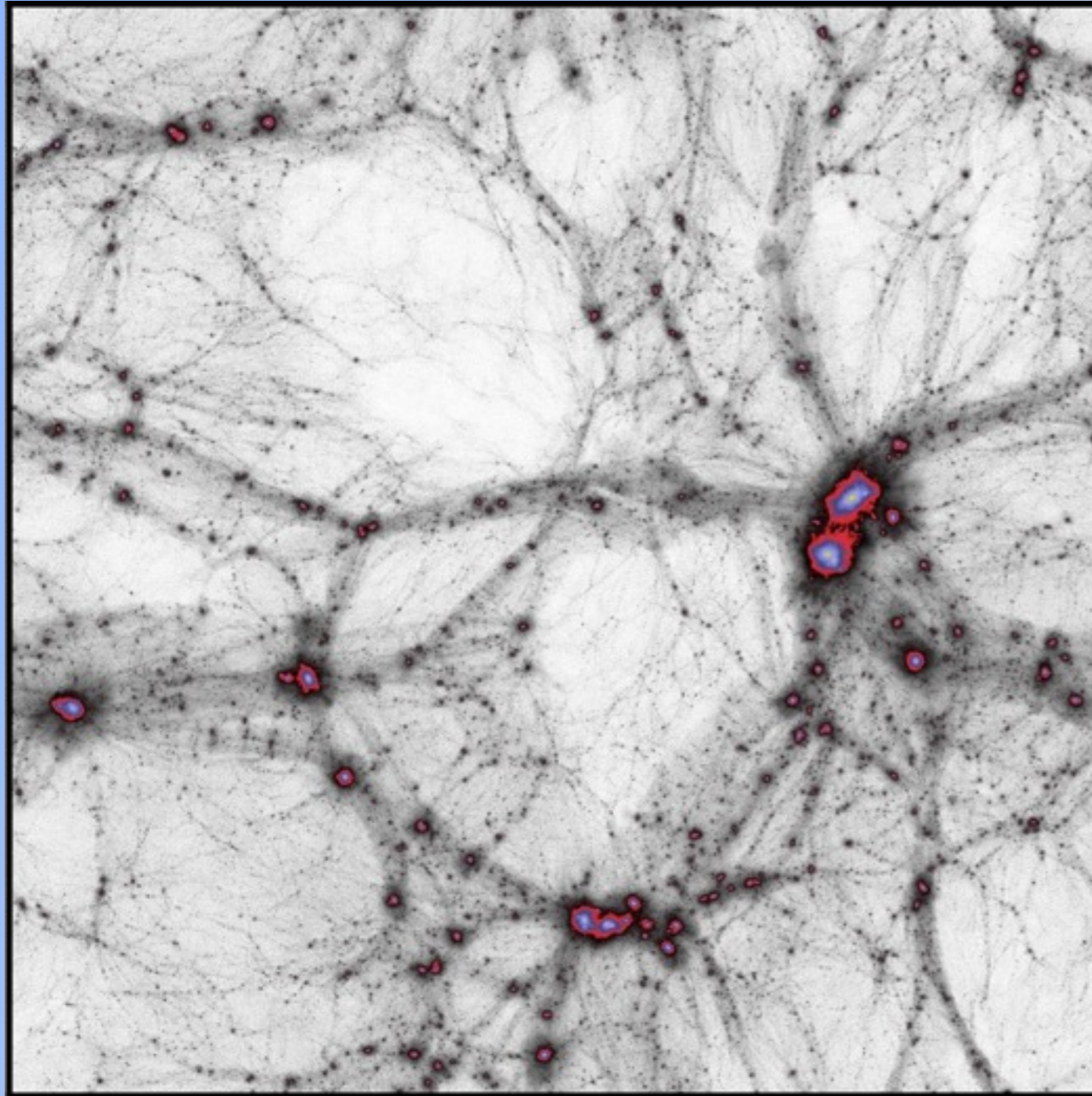
Malavasi, SA et al., in prep



The distribution of distances to filaments (weighed by $1/\rho$) reveals that

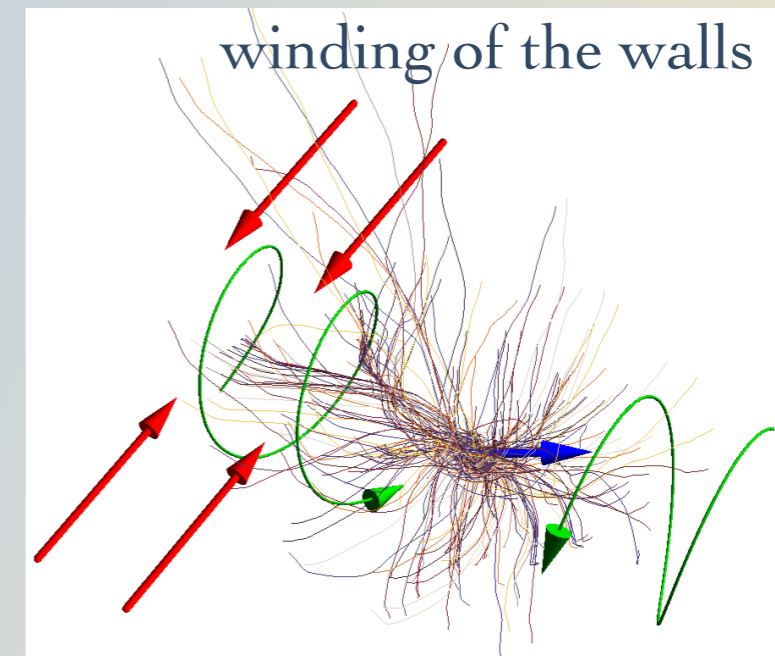
Most massive galaxies lie preferentially in the core of the filaments, where they end up their stellar mass assembly (via merging)

in line with some theoretical predictions (Codis+15)



- Cosmic Web emerges from the gravitational instabilities :

On large scales, matter departs from voids, flows through the walls, winds up in filaments and accretes into nodes

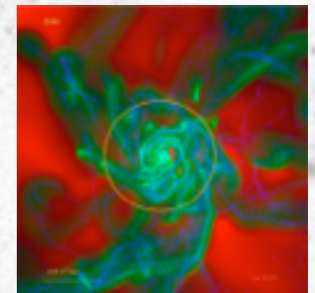


- Simulations successfully reproduce the observed Large Scale Structure

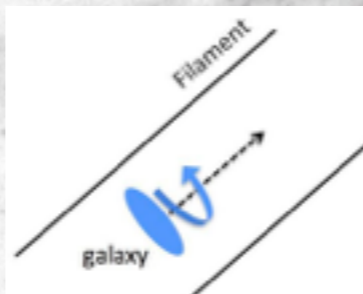
The Influence of Cosmic Web on galaxy Evolution

Evidences (theory/simulation) of the influence of CW on galaxies :

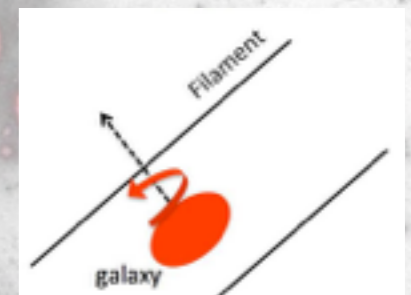
- **Cold streams** penetrate haloes and feed high- z galaxies in fresh gas (*Katz+03*)
- **DM halos inherit some level of coherence from LSS** with the advection of angular momentum



— **Spirals / Low Mass :**
spin aligned with filaments



— **Ellipticals / high Mass:**
mergers along the filaments,
spin ends up perpendicular



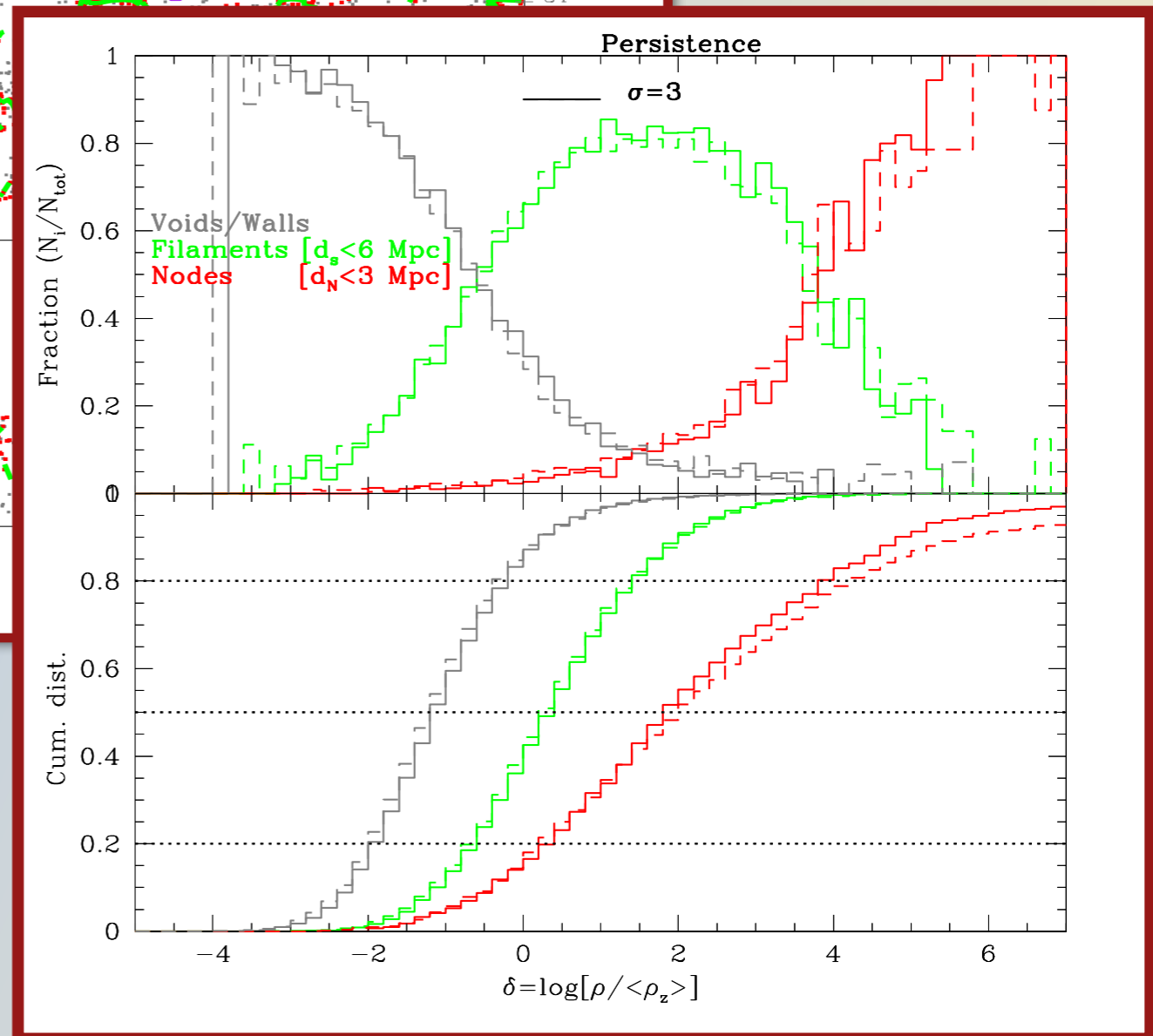
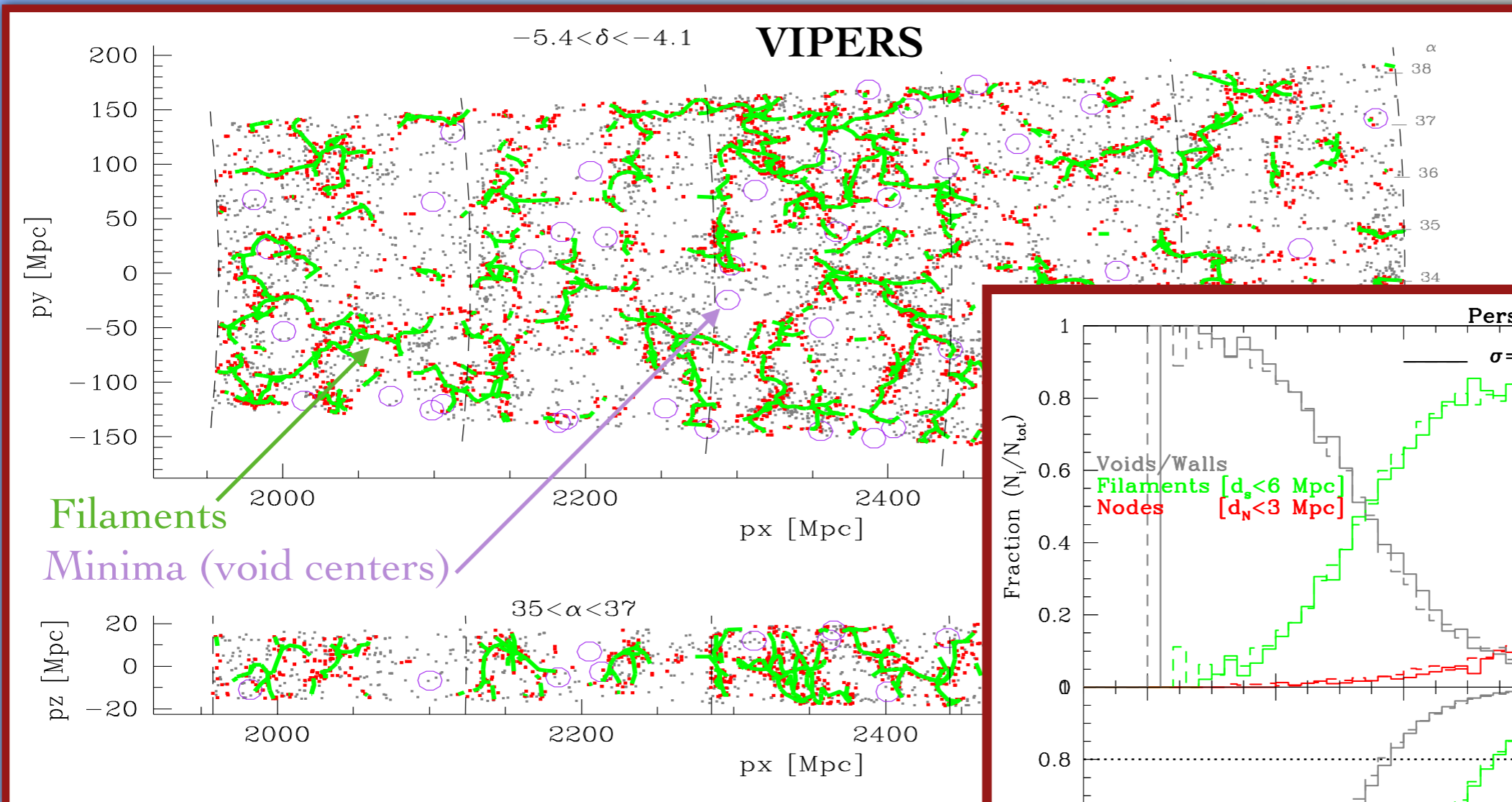
observationally confirmed in SDSS !! (*Tempel+ 13*)

- **CW contains 80% of gas in IGM**

Understand galaxy evolution within this anisotropic network is a major challenge

The Influence of Cosmic Web on galaxy Evolution

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

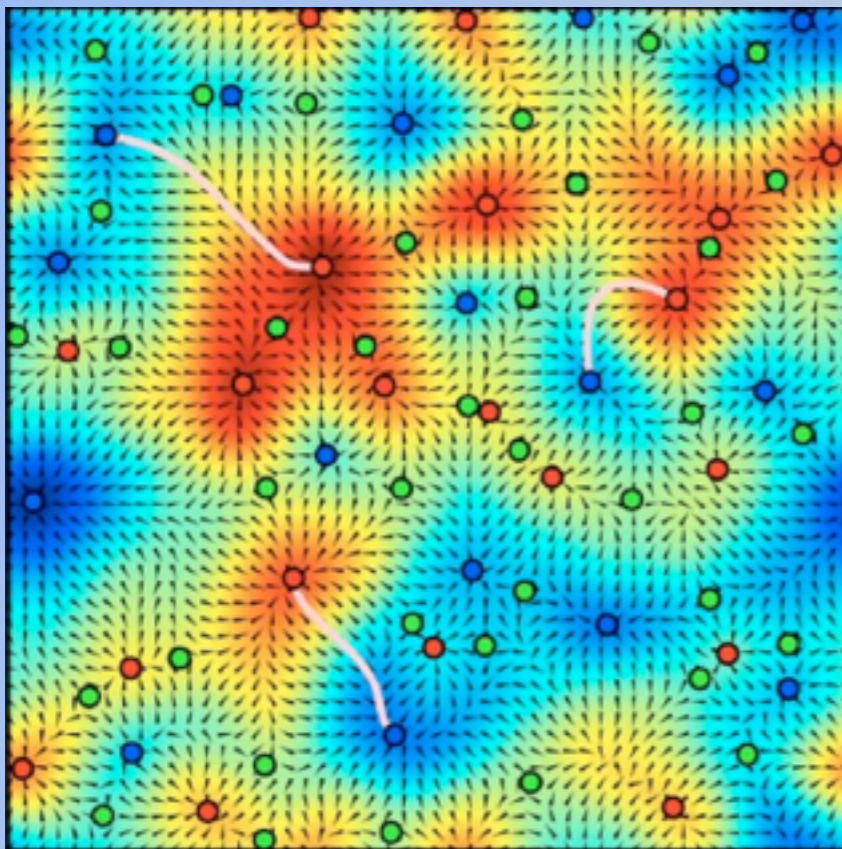
3D ridge Extractor :

extracting the filamentary structures of the CW
 connecting maxima of density field (anisotropic estimators)

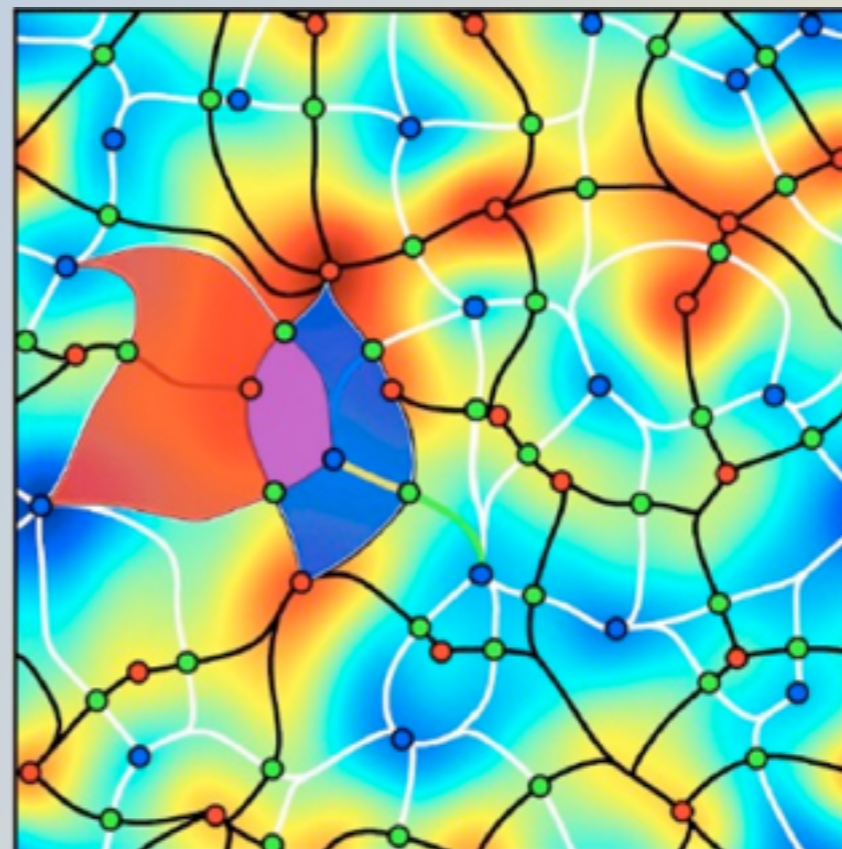
code **Disperse** (Sousbie+2013)



DisPerSE stands for "Discrete Persistent Structures Extractor" and it is an open source software for the identification of persistent topological features such as peaks, voids, walls and in particular filamentary structures within noisy sampled distributions in 2D, 3D. In DisPerSE, structure identification is achieved through the computation of the discrete Morse-Smale complex it can deal directly with noisy datasets via the concept of persistence (a measure of the robustness of topological features).



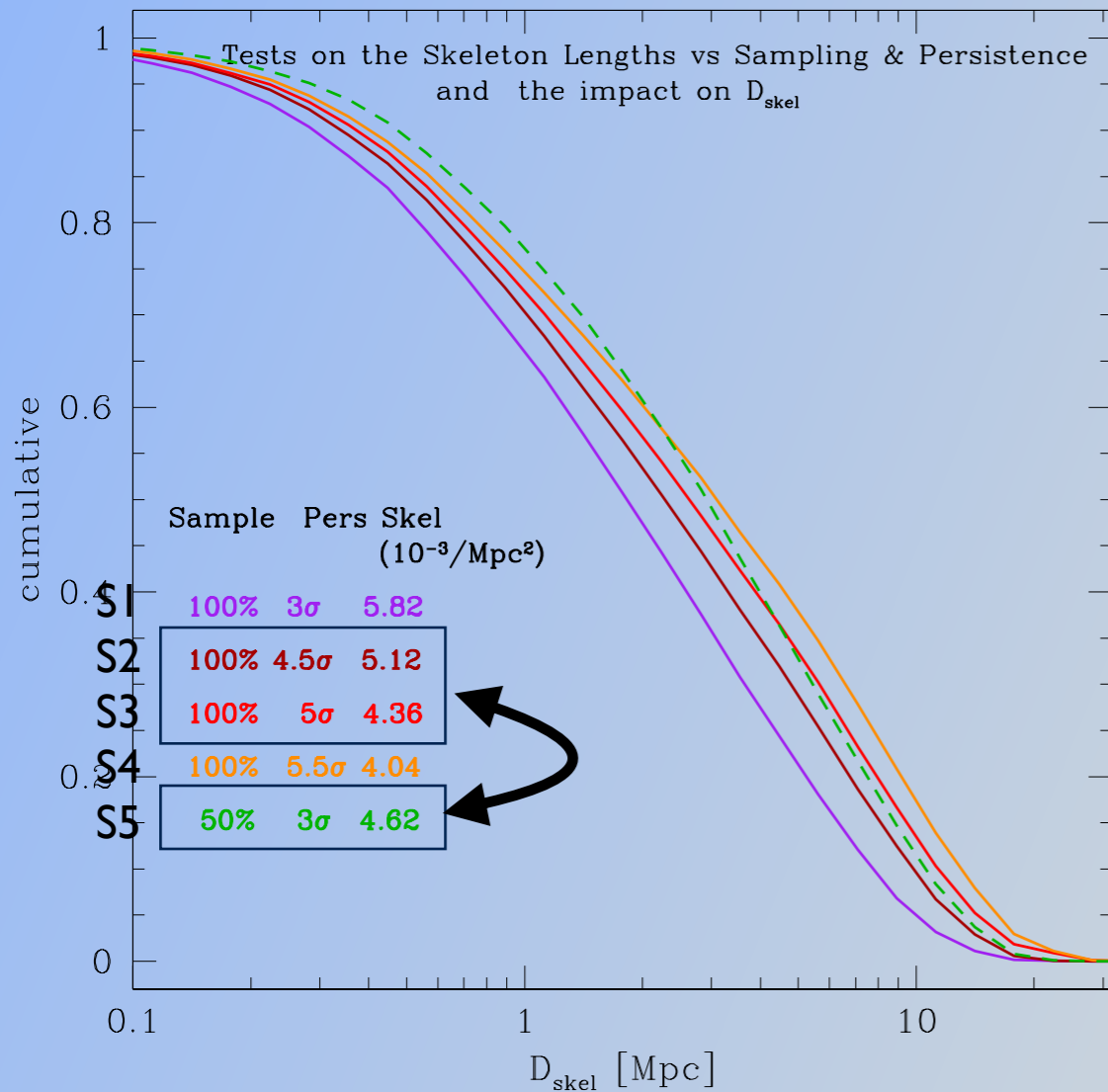
Density field with critical points :
 Max : red saddle: green , Min: blue



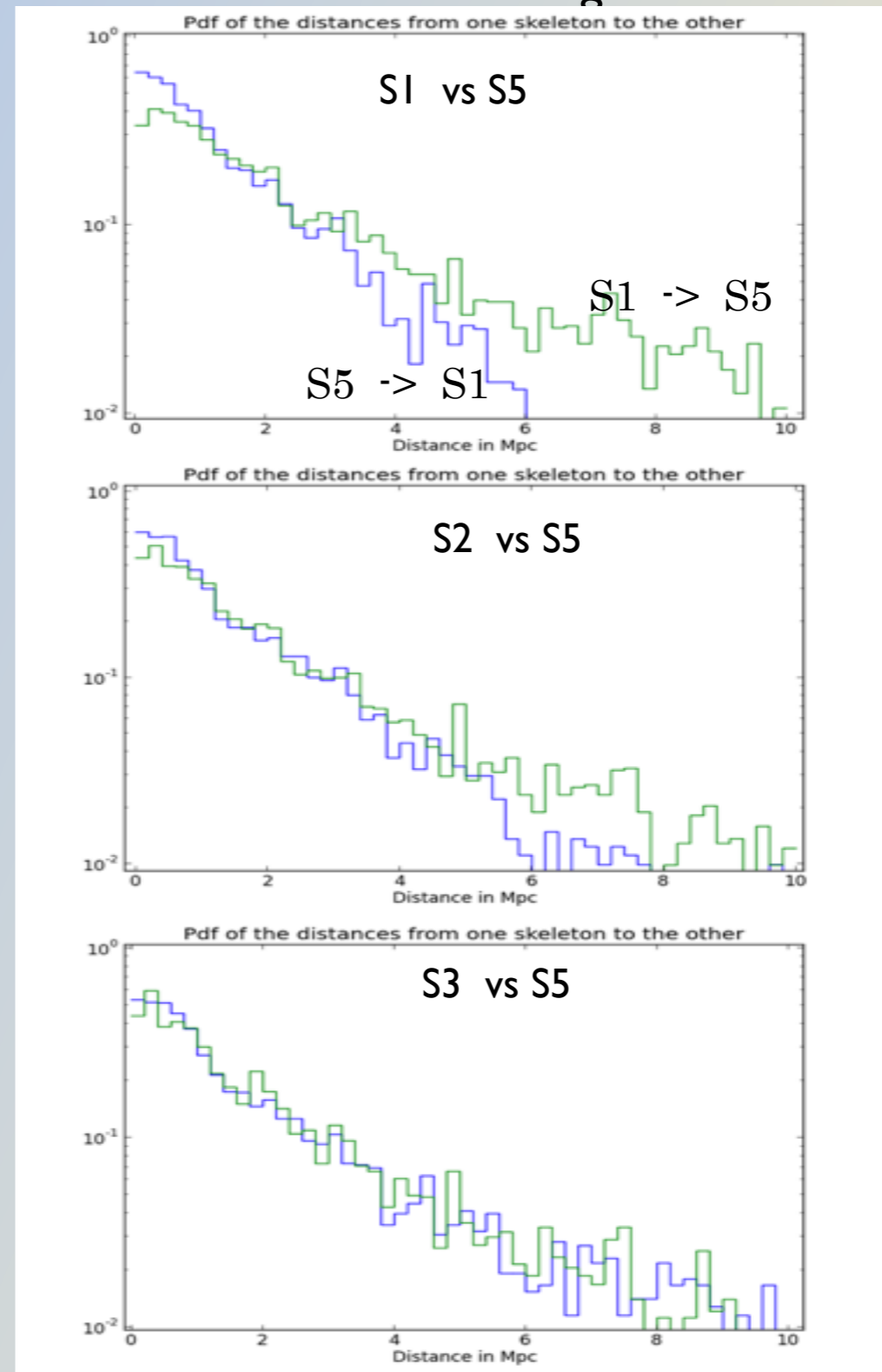
Upper skeleton: critical lines connecting maxima
 Lower skeleton: critical lines connecting minima

How do we compare observed skeletons with simulations ?

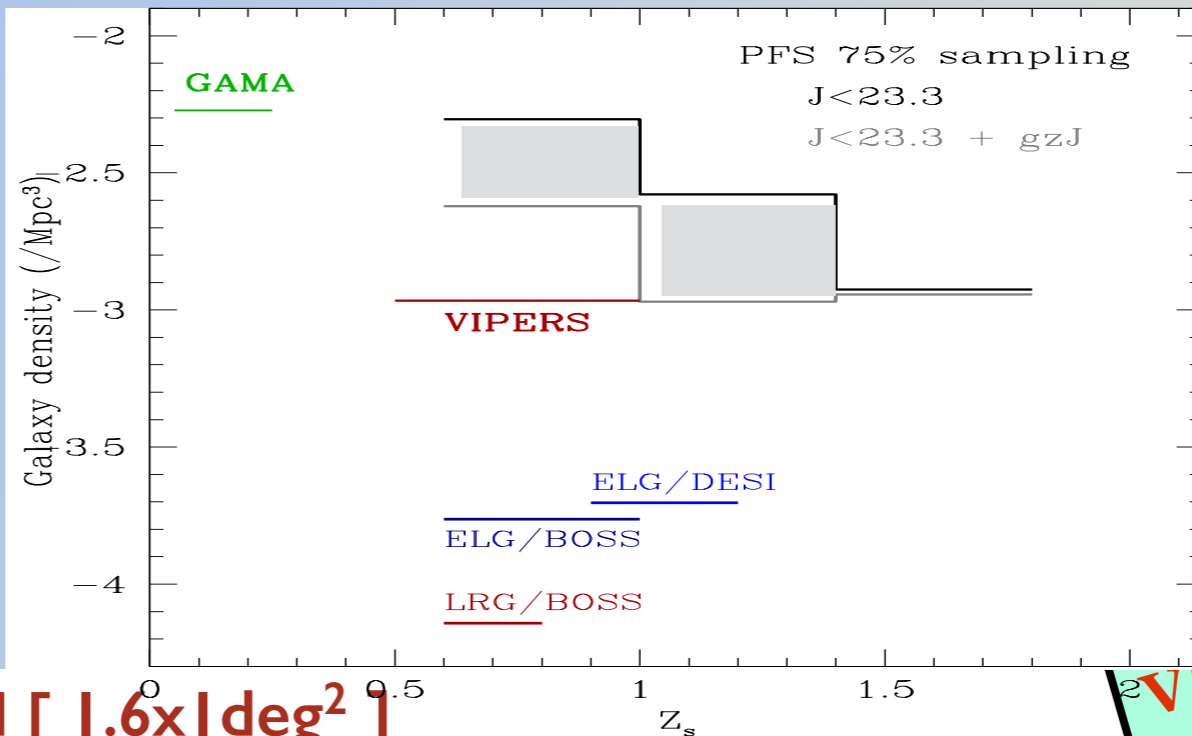
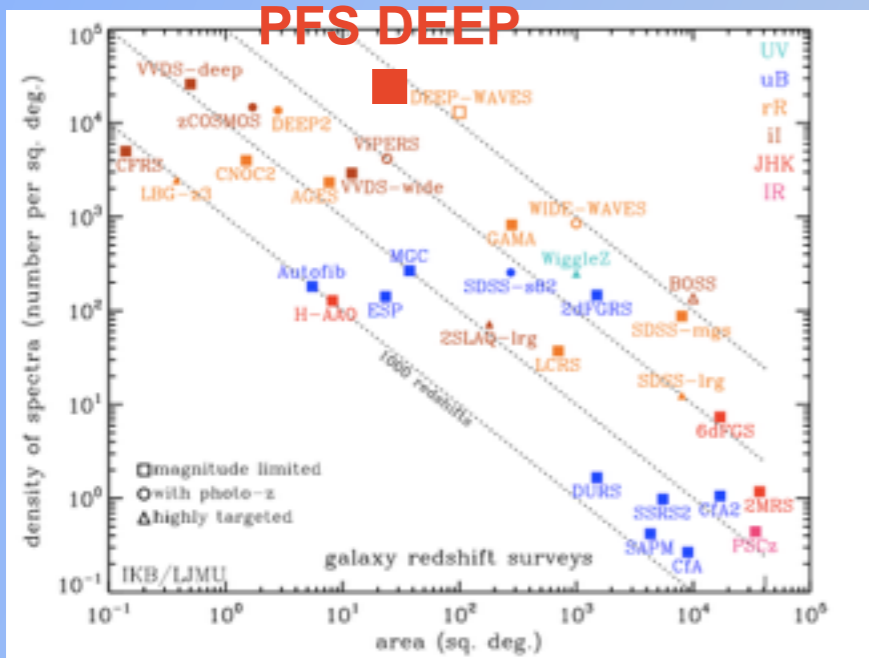
length of skeletons (Mpc / Mpc³)



Distribution of distances of segments in 2 skeletons

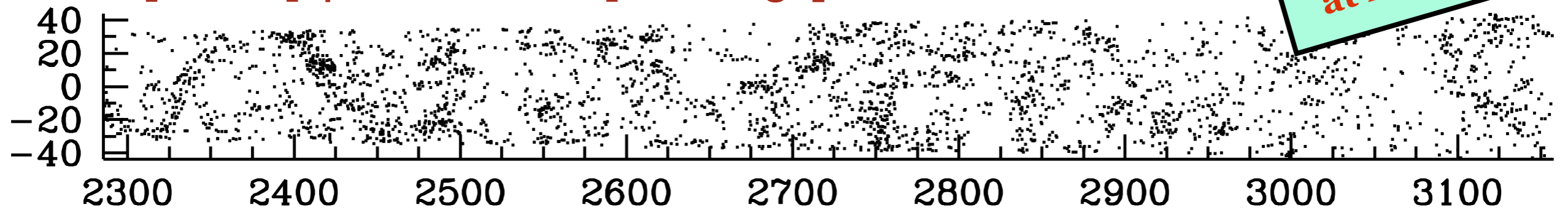


HSC-PFS SuMIRe surveys



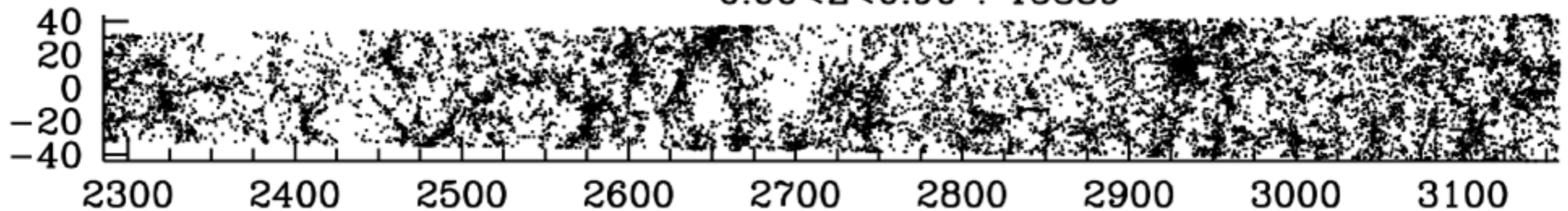
VIPERS best LSS at high z so far

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 LSS structures

HSC-PFS SuMIRe surveys

