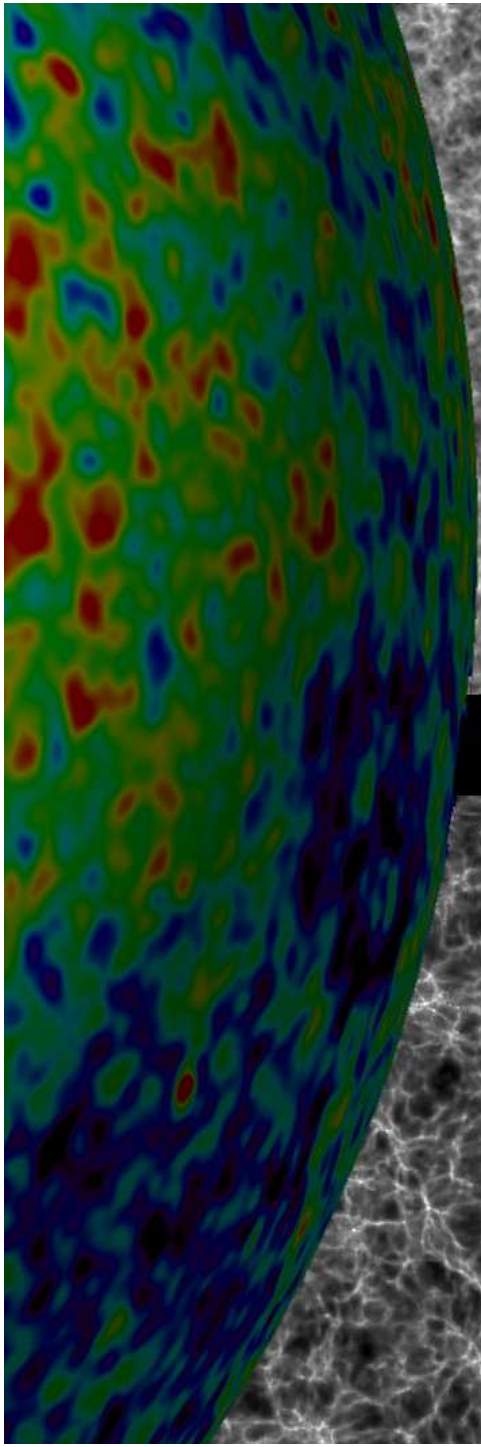

Large Scale Structures of the Universe & cosmological scenarios

The importance of IR data

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Observatoire de la Côte d'Azur, Nice (France)

Outline:

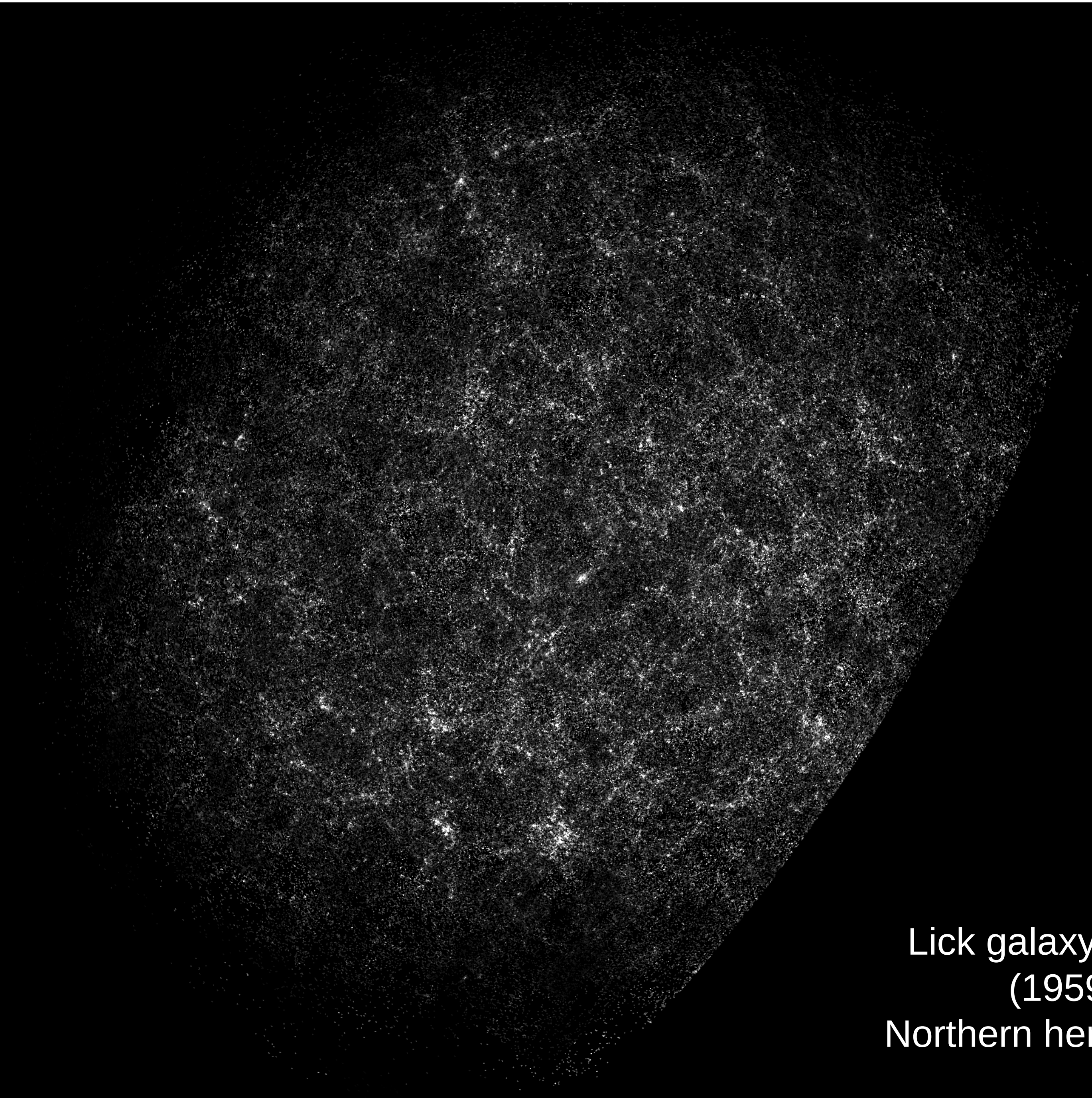
Some basics about Large Scale Structures

Pb of the acceleration of the expansion of the Universe

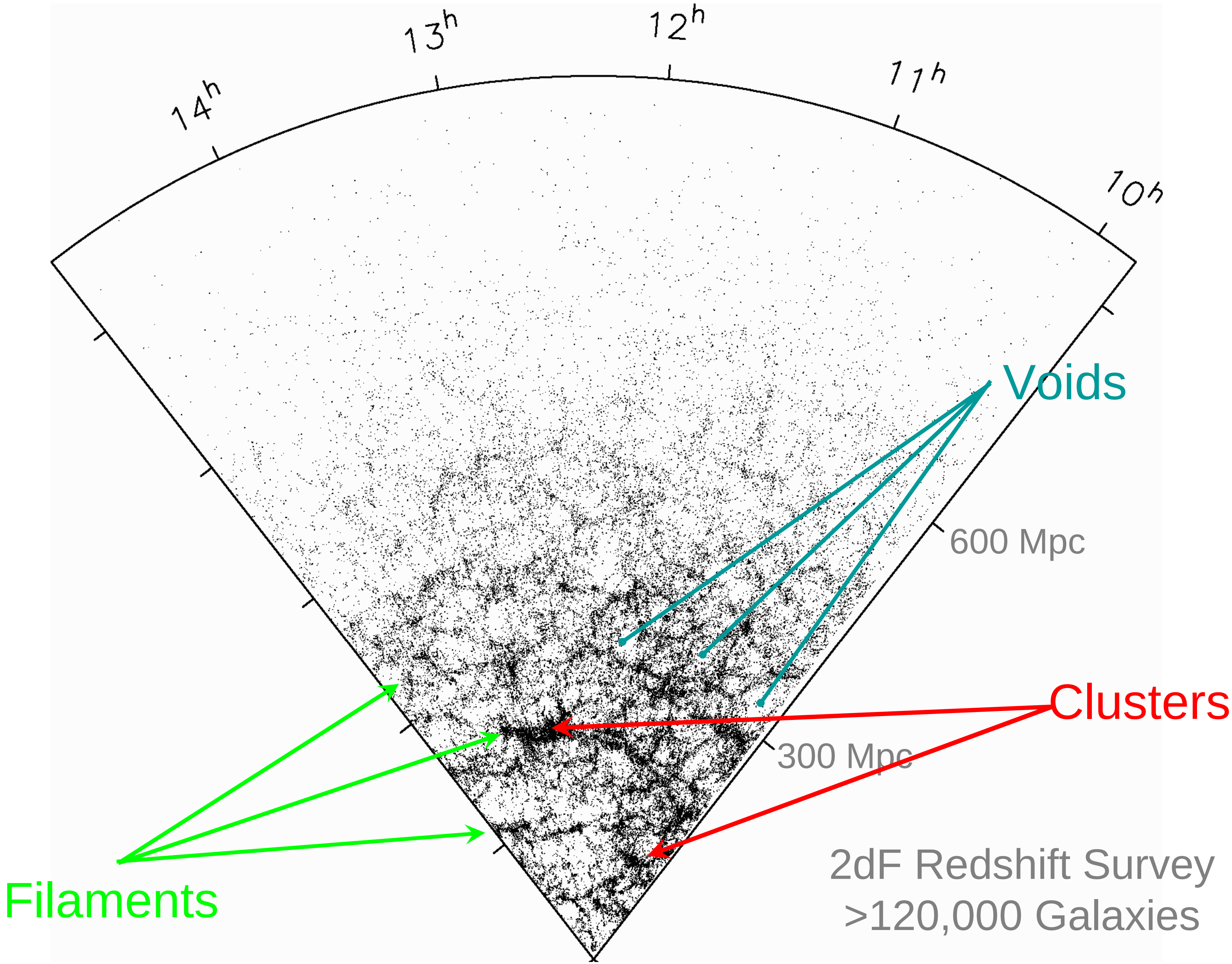
Experiments based on Galaxy clusters

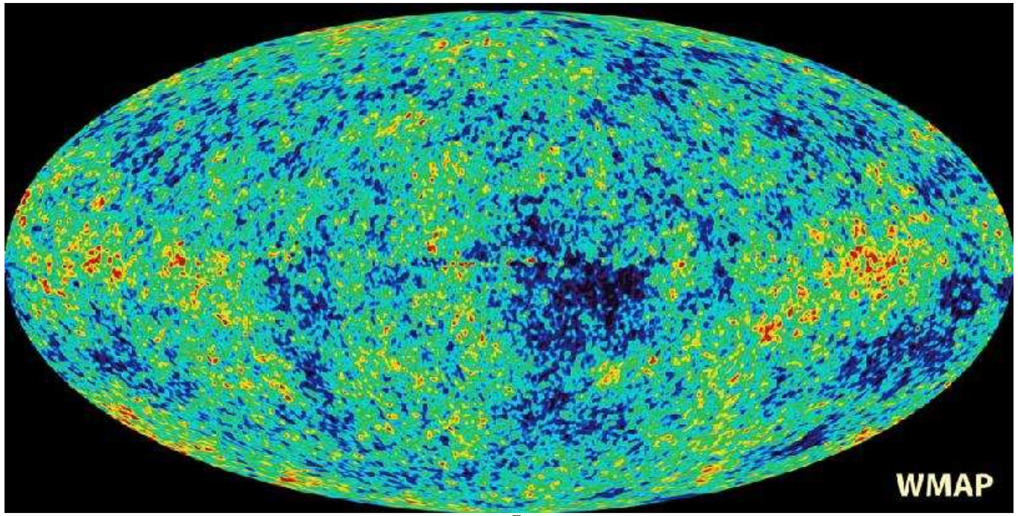
IR data – the key ingredient !

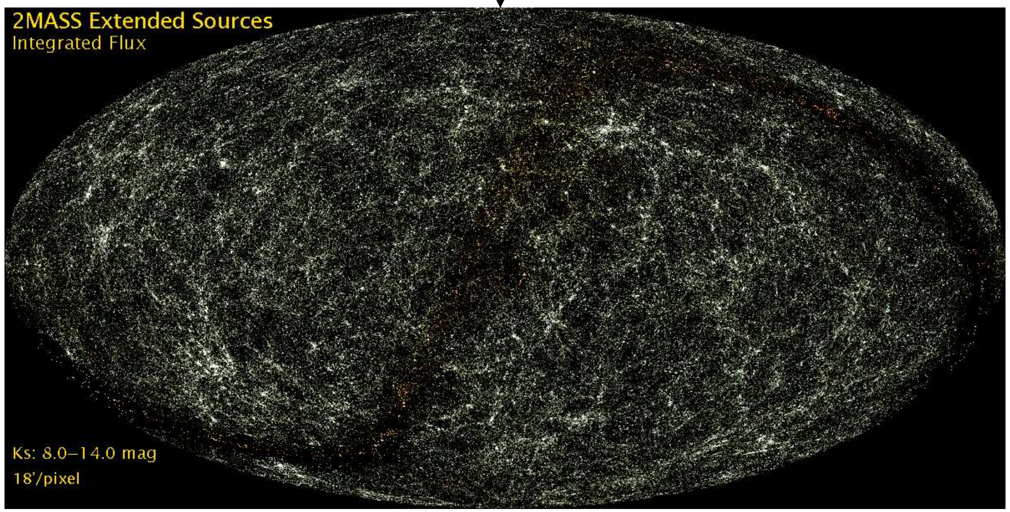
Some rough requirements for this science case



Lick galaxy counts
(1959)
Northern hemisphere


14h
13h
12h
11h
10h
Voids
600 Mpc
Clusters
300 Mpc
Filaments
2dF Redshift Survey
>120,000 Galaxies

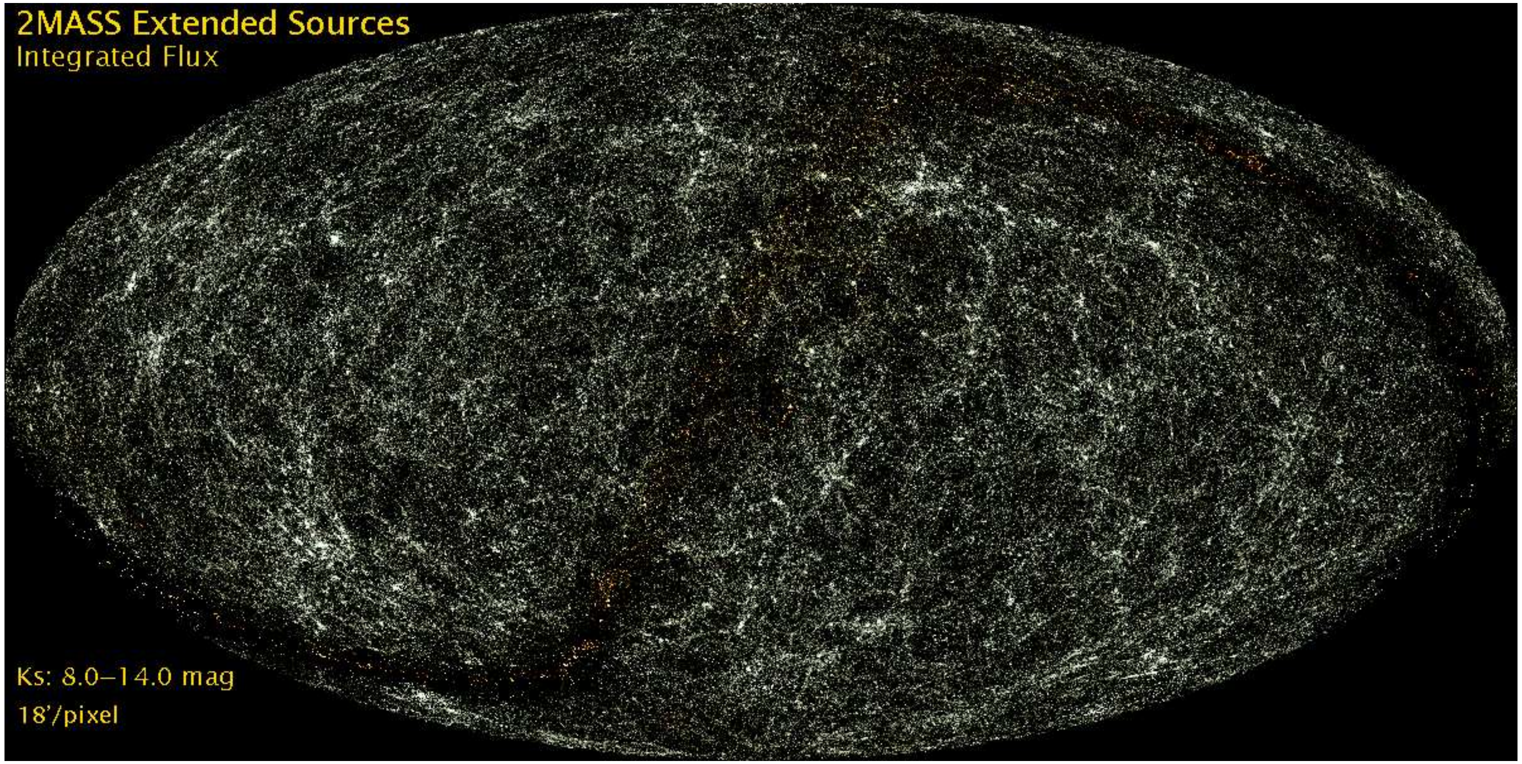




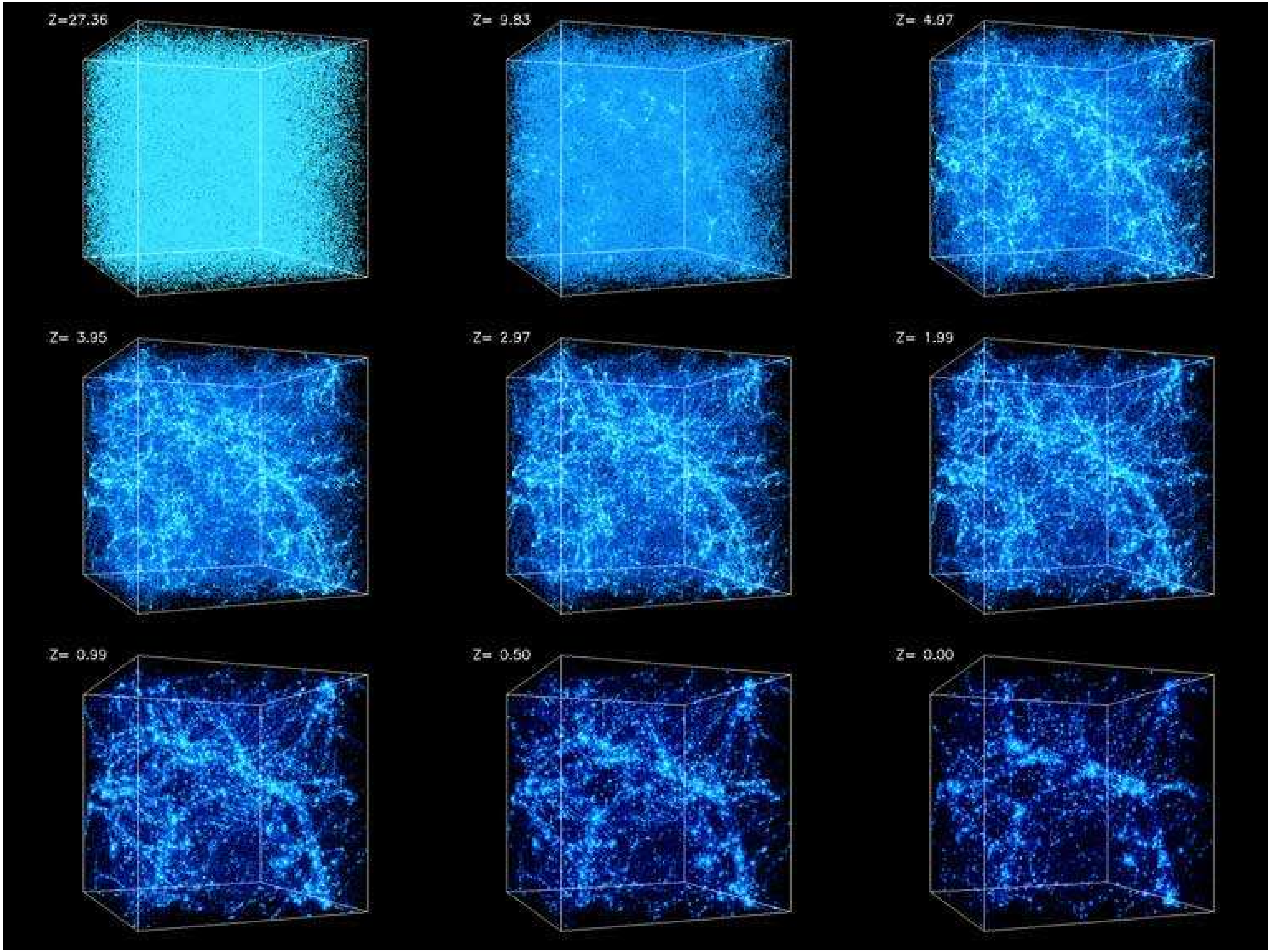
⇒Gravitational instability + expansion

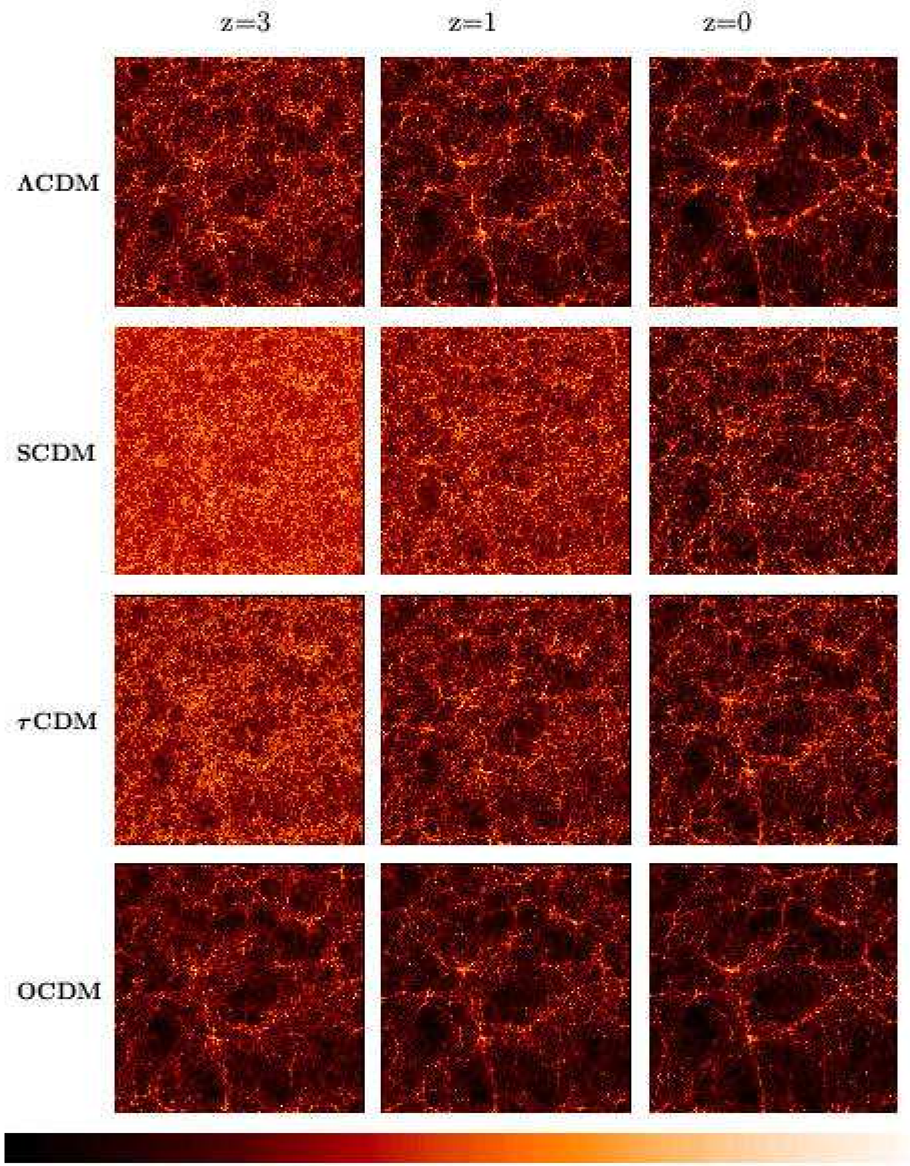
⇒Dominated by Dark Matter (growth rate)

The cosmic network



- 4 types of large scale structures:
  - Sheets – beginning of the collapse.
  - Filaments – more advanced state but still out of equilibrium
  - Halos – final state: collapse stops
  - Voids – regions empty of matter
- Diffrerent regions of the Universe are in different states of evolution depending upon the initial density at the location being considered.

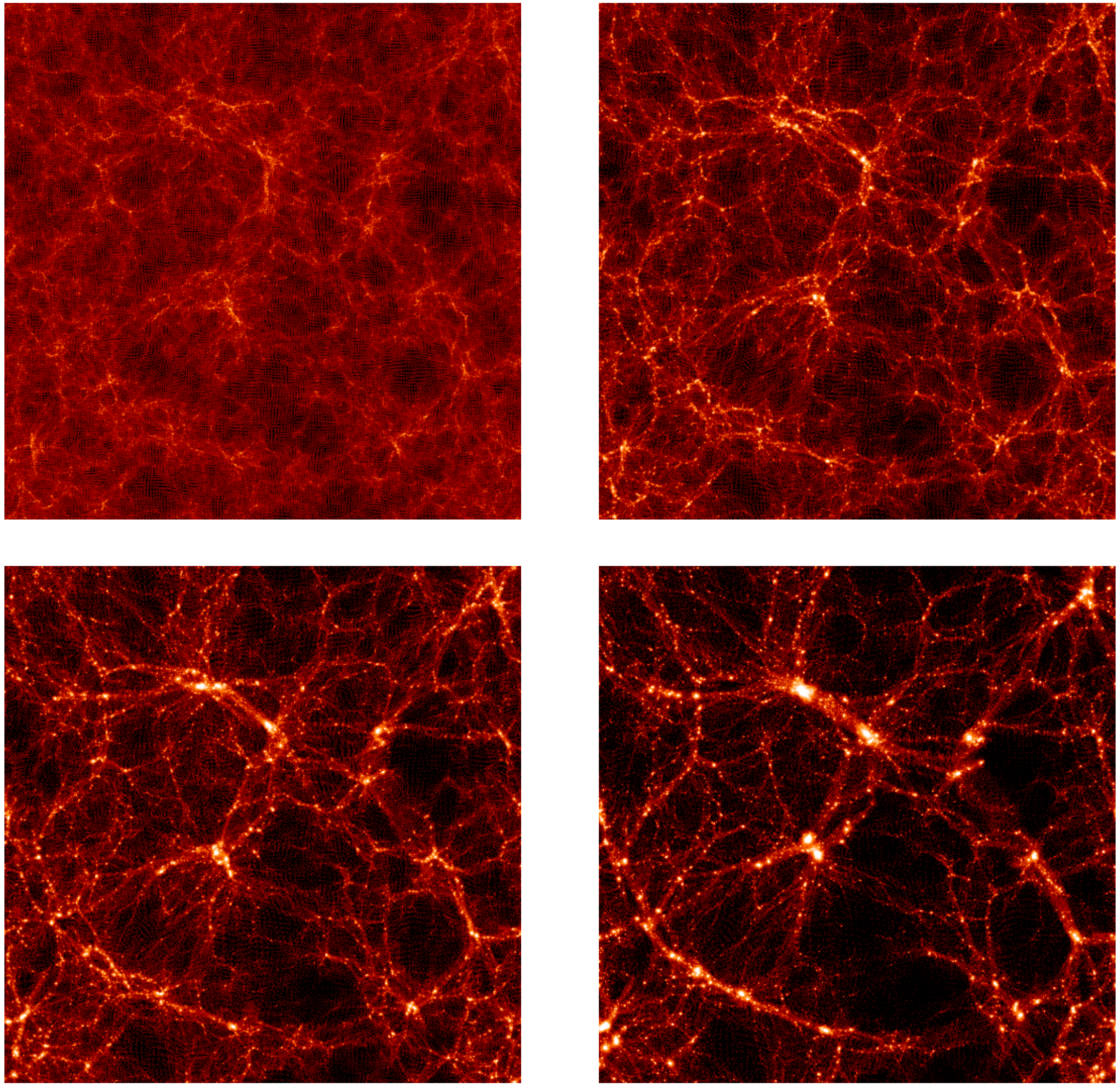

Z=27.36
Z= 9.83
Z= 4.97
Z= 3.95
Z= 2.97
Z= 1.99
Z= 0.99
Z= 0.50
Z= 0.00



The VIRGO Collaboration 1996

DM simulation **box = 100 Mp/h** **ΛCDM** ***(R. Teyssier - CEA Saclay)***

z = 5 **z = 2**

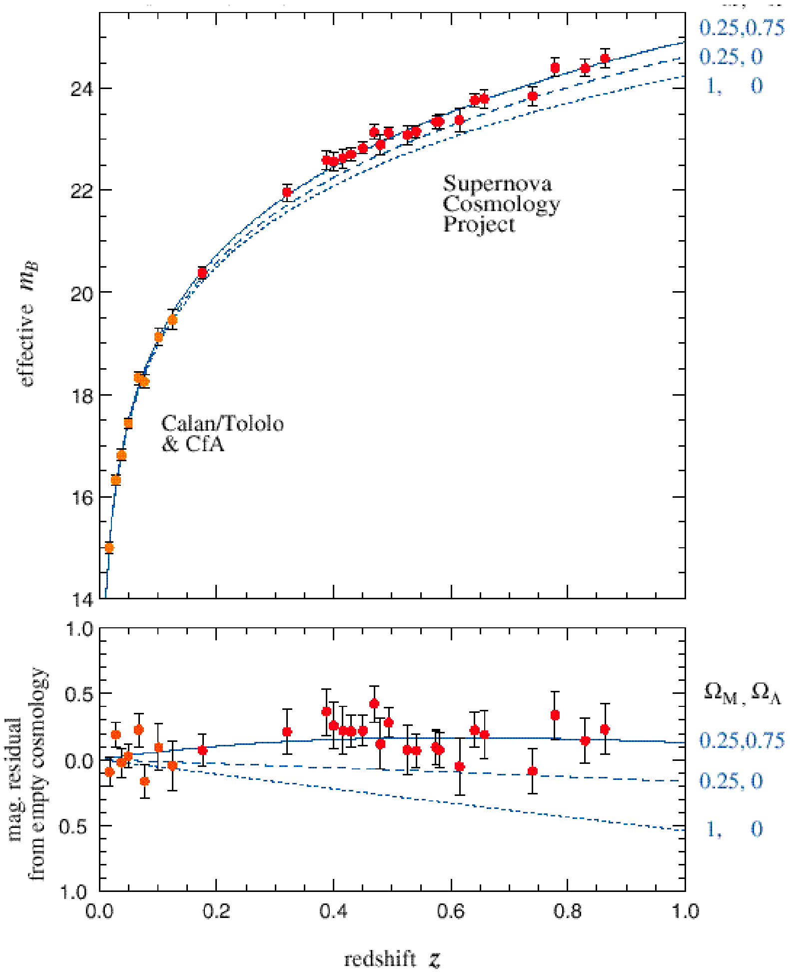


z = 1 **z = 0**

The growth of structures is traced by galaxy clusters

Low mass clusters appear at z~2-3

The cosmic acceleration



SN1a's used as standard candles

$$D_L = f(z)$$

$\Rightarrow$ Cosmic acceleration (Perlmutter et al. 1998)

$\Rightarrow$ Very visible at $z \sim 1$

Interpret the cosmic acceleration

In the framework of a homogeneous and isotrope Universe, one of the 2 Friedman equations leads to:

$$\frac{1}{a}\frac{d^2a}{dt^2} = -\frac{4\pi G}{3}\sum_i(\rho_i + 3p_i)$$

How to accelerate the expansion of the Universe?

1. « Dark Energy »

   $p_i = w_i\rho_i$ if $w_i < -1/3$ acceleration

   $$G_{\mu\upsilon} - \Lambda g_{\mu\upsilon} = \frac{8\pi G}{c^4}T_{\mu\upsilon} \qquad p_{vac} = -\rho_{vac} = \Lambda / 8\pi G$$

2. Modification of GR at large scales

3. Cosmological principle?

⇒Measure the growth rate of structures

Several experiments from large galaxy surveys

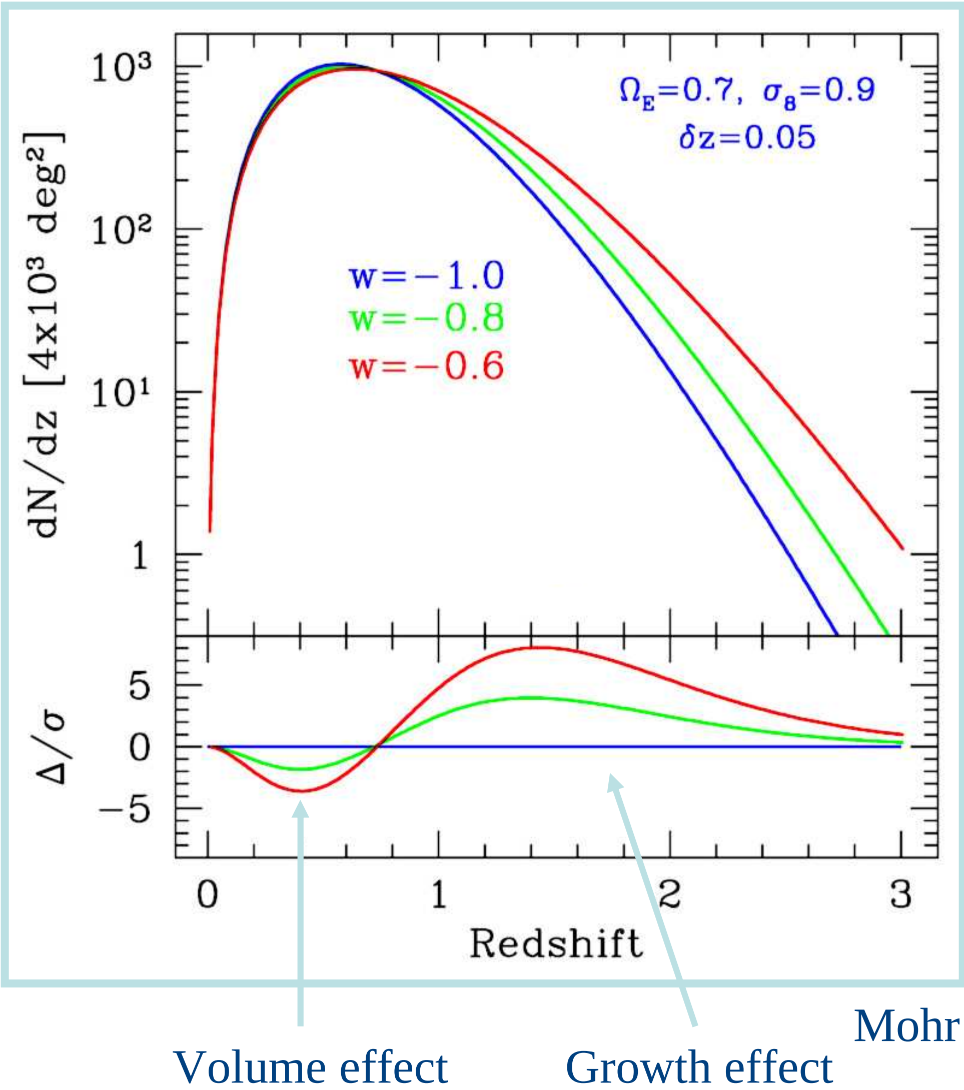
⇒Quantify clustering properties of galaxies as a function of z

⇒Estimate the abundance of galaxy clusters N(M,z)

Evolution of cluster number counts and DE

Increasing *w* with fixed Ω_{DE} :

- decreases the volume
- decreases the growth rate of perturbations



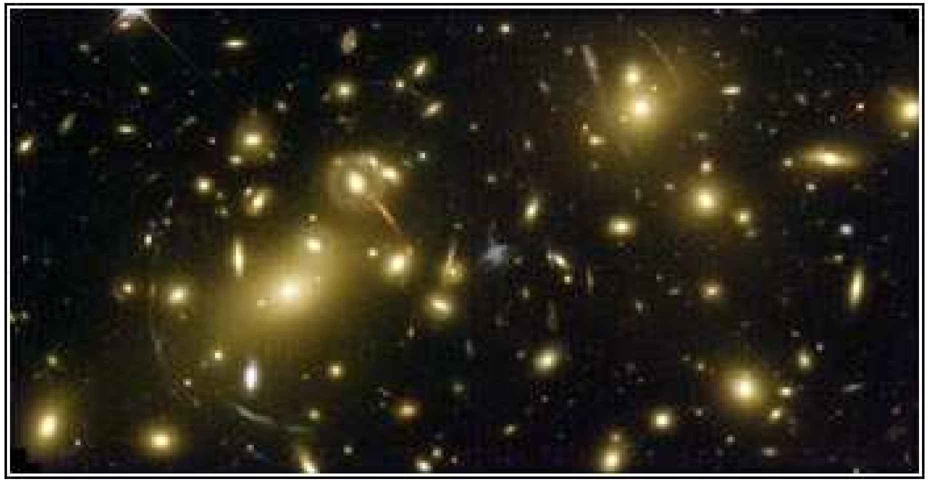
Mohr 05

⇒We need clusters at z > 1

Galaxy cluster mass content

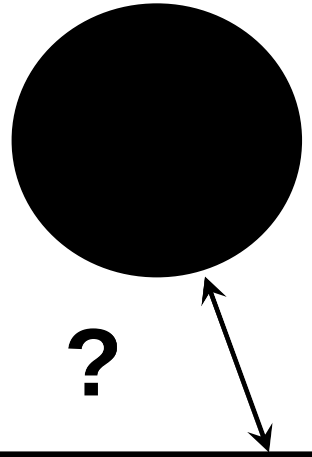
Most massive bound systems

in the universe: 10^{13} to 10^{15} $M_\odot$



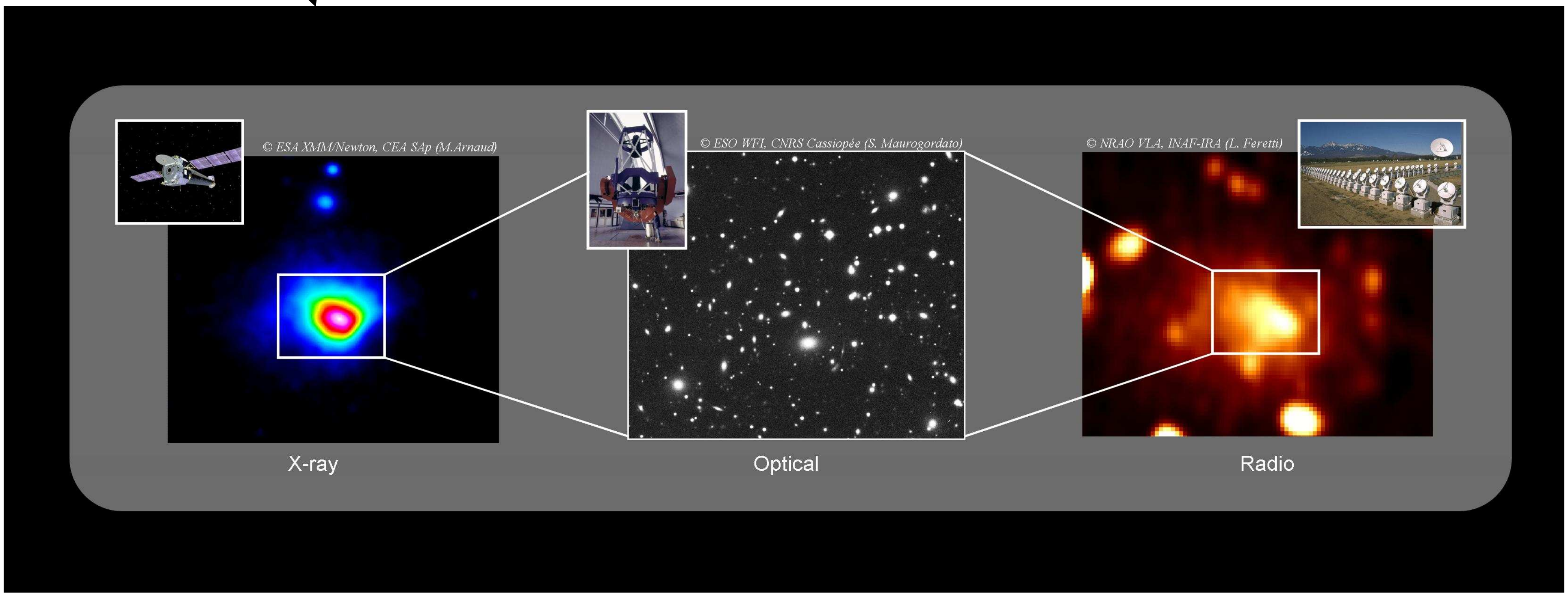
- 3% : **galaxies** optical-IR
- 16% : **hot and diffused gas** X
- ~0% : **relativistic particles + magnetic fields** radio
- >80% : **dark matter** optical - lensing

From halos to clusters



For clusters to be used as cosmological tools, one needs to understand in detail the astrophysical processes which determine their observational characteristics, i.e.

- the properties of the cluster galaxy population &
- those of the diffuse intra–cluster medium (ICM).



Requirements for building up a cluster sample

- Information we would like to get
  - position on the sky
  - redshift (photometric)
  - mass

- Information we can access

  X-ray (position_x; Lx - Tx)
  SZ (position_sz; SZ decrement)
  Optical – NIR (position_opt, z_est; Richness - Total luminosity)

- Find Clusters with an understandable selection function

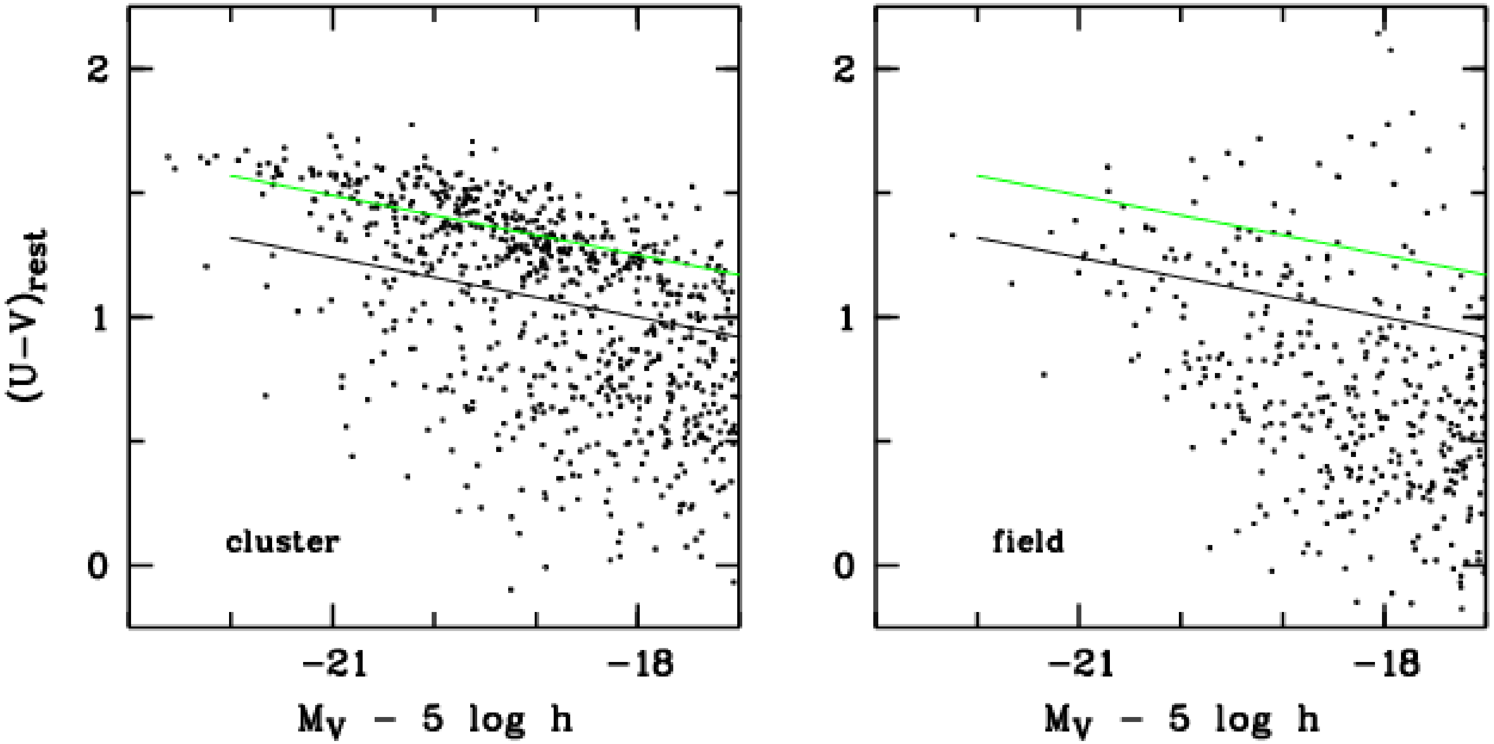
- Calibrate the masses of the clusters
  using WL / velocity dispersion
  with full control on systematics and scatter

Detection of galaxy clusters

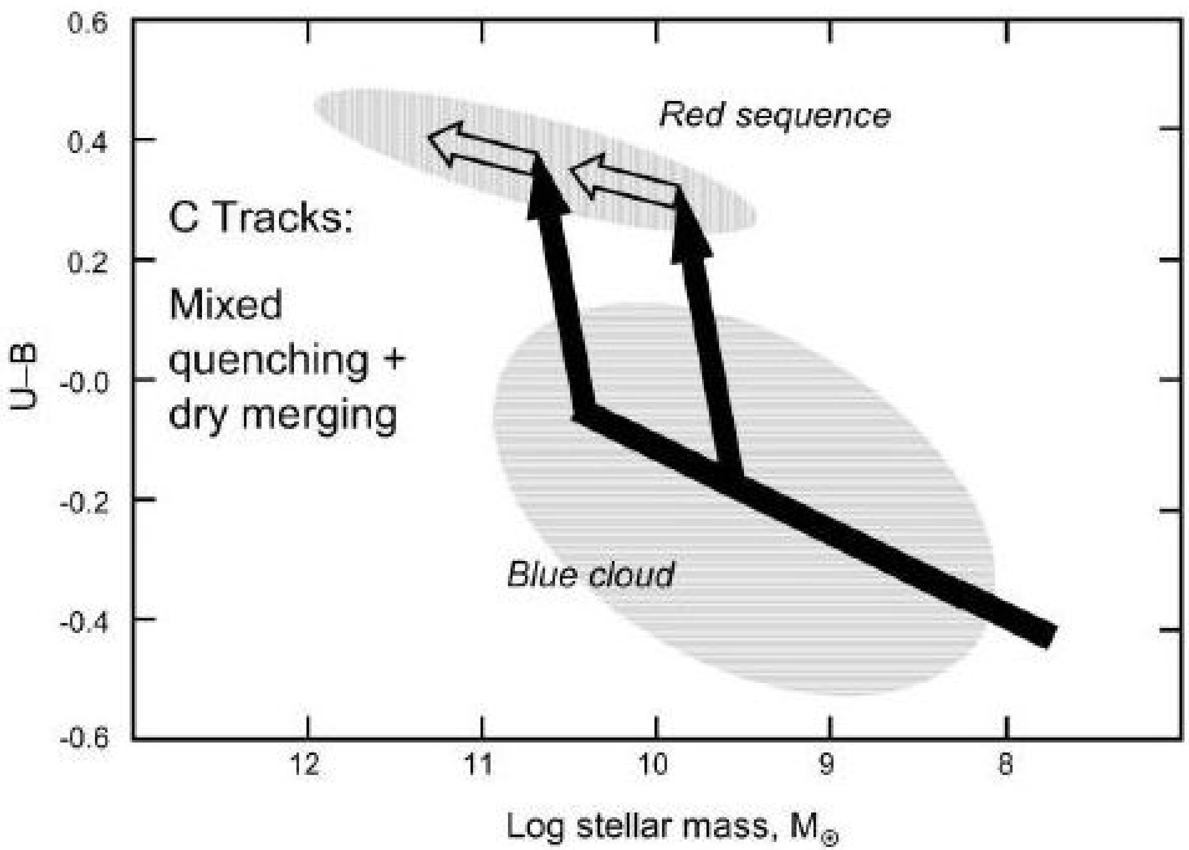
Origin	Mean	Pro's	Con's
gas	X	Limited projection effects	time consuming contamination
gas	SZ	Limited projection effects	Resolution contamination
DM	lensing	access to mass	projections
galaxies	Opt	Area Gives redshift	projection effects
	+NIR		
	+IR		

Galaxy populations in clusters:

1. The « Red Sequence »



The building up of the red sequence



Brightest end appears first

Build up of the red-sequence is delayed in low density environments

Slope due to age and metallicity

From Faber et al. 2007

⇒ Collaboration in progress with Korhan Yelkenci on the galaxy morphology density relation

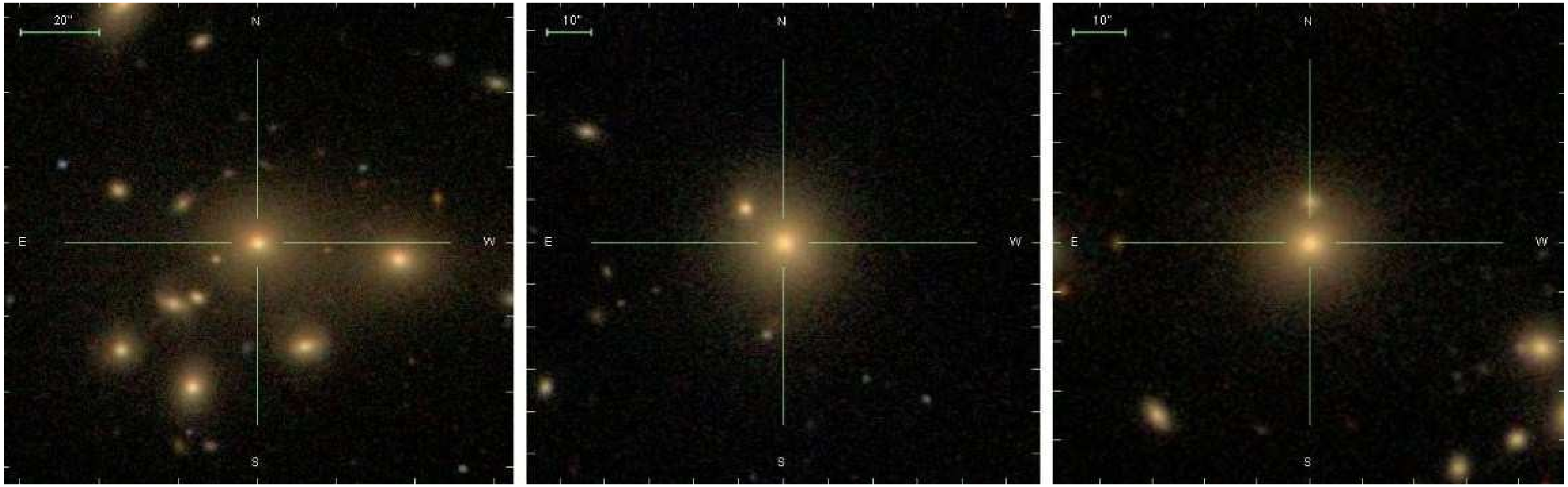
Galaxy populations in clusters

2. Brightest Cluster Galaxies (BCG's)

BCGs in rich clusters usually take the form of giant elliptical galaxies, so large that they are only found at the centers of galaxy clusters.

⇒ Collaboration in progress with Sinan Alis based on CFHT Legacy Survey

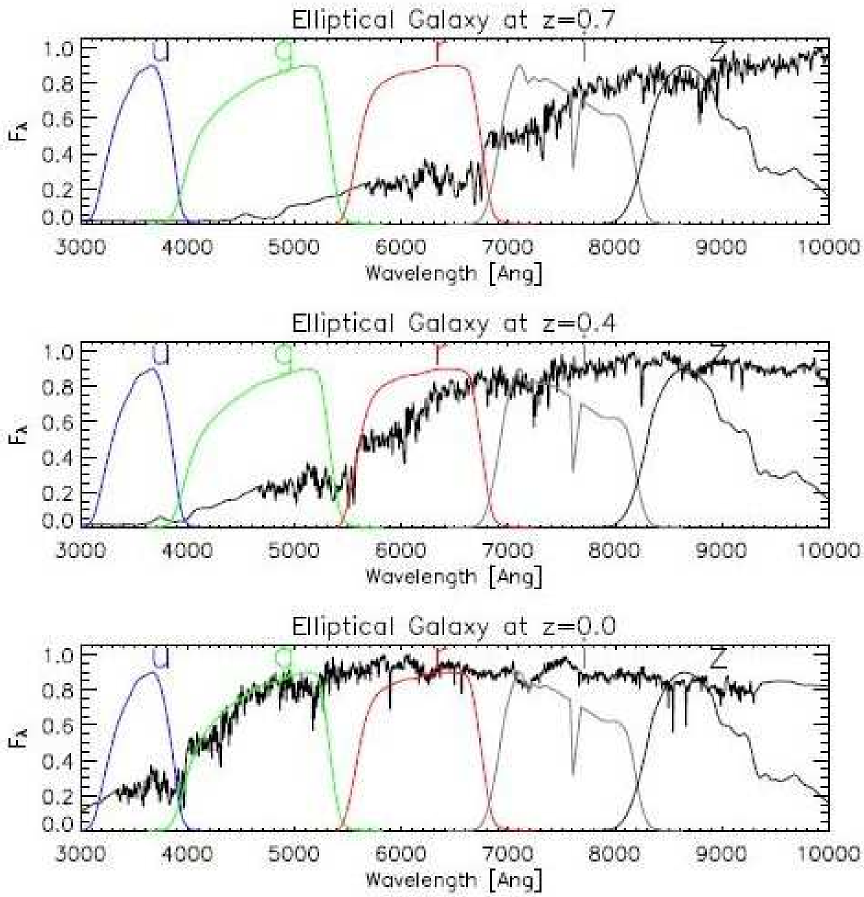
⇒ Several spectroscopic follow ups of low redshift BCG's @ TUG

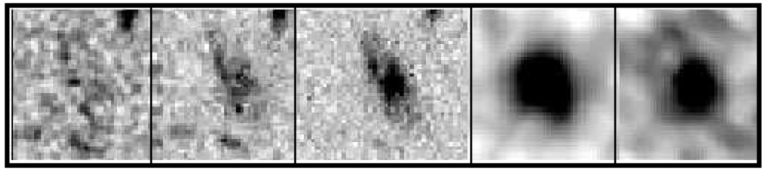


$\Rightarrow$We need to detect early type galaxies

- the reddests -

Elliptical galaxies at z > 1





⇒We need NIR to detect them

⇒K ~ 21

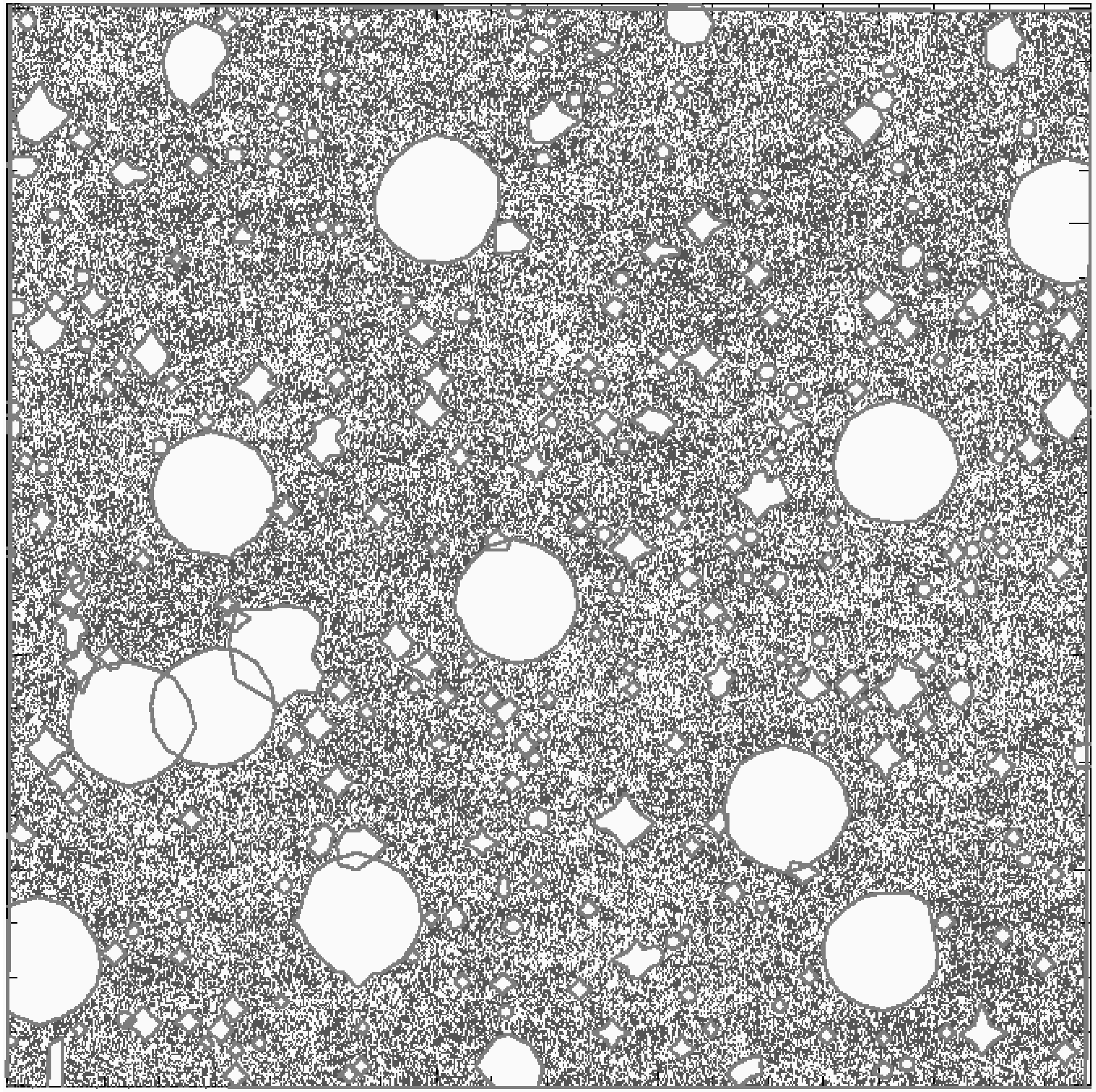
Detecting clusters from optical-NIR data

Since ~12 years   automated filtering methods

improve the detection of overdensities by making assumptions about the signal to be detected:

- morphology
- radial profile
- luminosity function
- galaxy populations (red sequence)
- BCG properties

Detecting clusters in optical surveys



1 deg²

i < 25

150.000 galaxies

Z = 0.9

5’

From CFHT Legacy Survey

Detection of galaxy clusters

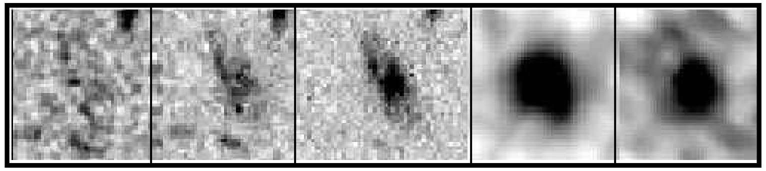
Origin	Mean	Redshift	Pro's	Con's
gas	X		Limited projection effects	time consuming contamination
gas	SZ	any	Limited projection effects	Resolution contamination
DM	lensing	not high	access to mass	projections
galaxies	Opt	z < 1.	Area Gives redshift	projection effects
	+NIR	z < 1.6		
	+IR	z < 2.2		

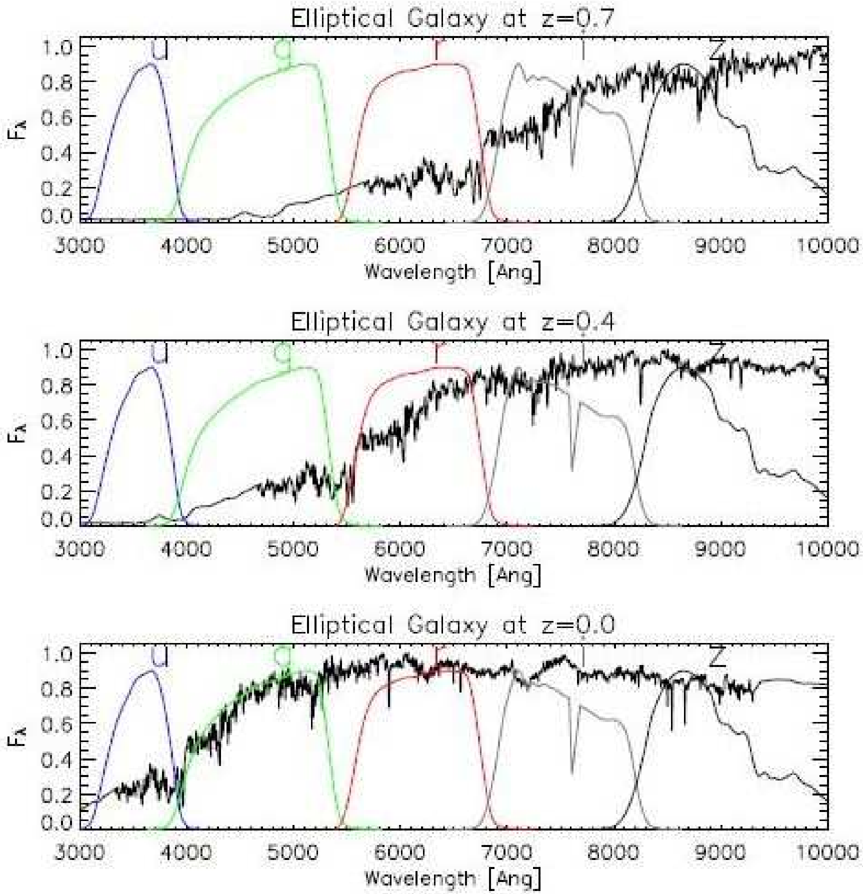
N (mass, z)

Not only we need to detect but also estimate:

- The redshift (z)
- The mass

Spectroscopy or … photometric redshifts





The concept:

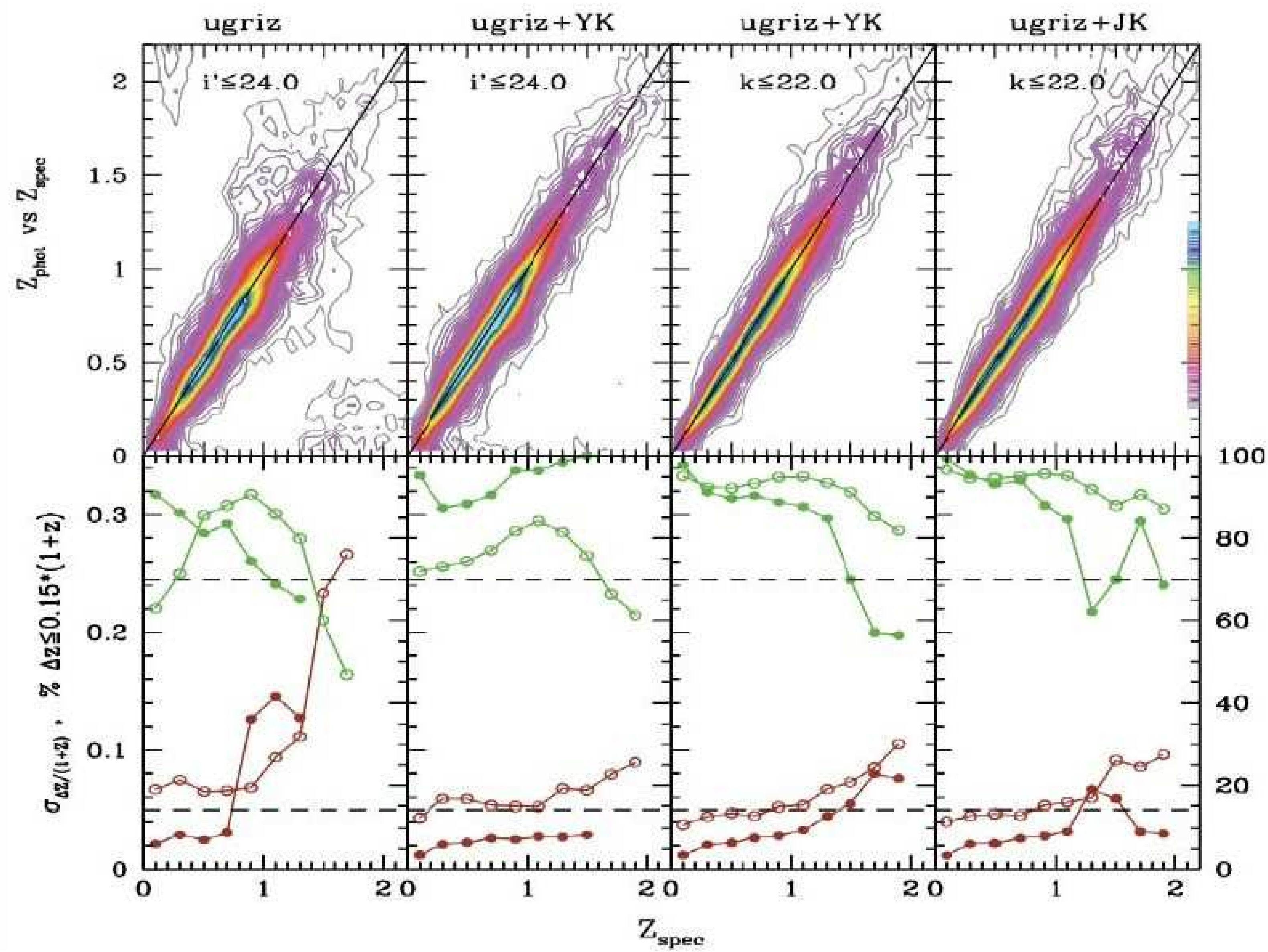
Compare measured colors to those that would be produced by a variety of spectra at different redshifts.

- SED (type, redshift)

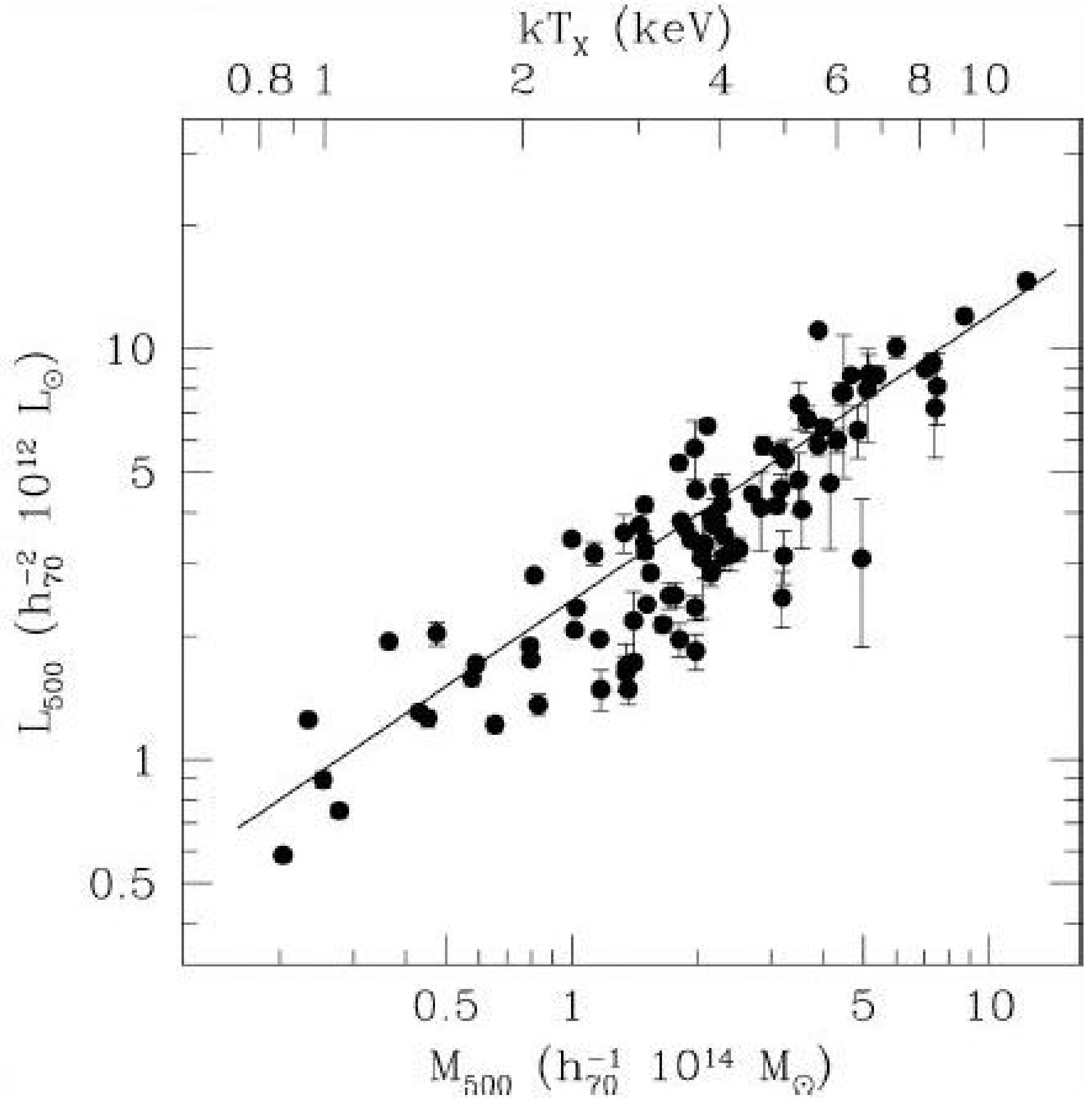
- Compute colours in your set of filters

- Minimize

Improving photometric redshifts with NIR data



Estimating the mass of clusters using K-band total luminosity



From Lin et al. (2004)

Some numbers about current cluster catalogs

Low-z	**Mid-z**	**High-z**	**« Desert »**	**Lyman-break proto clusters**
z < 0.5	0.5 < z < 0.8	0.8 < z < 1.5	1.5 < z < 2.2	2.2 < z
> 10.000	1000’s	10’s	1’s	10’s

- optical (/NIR) surveys available and to come

SDSS	7500 deg^2	low z	
CFHT Legacy Survey	170 deg^2	z~1	
UKIDSS (DXS)	35 deg^2	z~1.5	
DES	5000 deg^2	z~1	(2011)
LSST	20000 deg^2	z~1	(2012)
EUCLID	20000 deg^2	- space	(2017)

But for reaching the z> 1 domain one needs additional NIR

Requirements for constraining DE using galaxy clusters:

- Reach the redshift domain z>1
- At least 2 NIR bands including K
- K>21 (=> 4m class)
- Wide field of view preferable (survey)
- Importance of having several optical pass-bands in addition to NIR => Collaborations with same class of telescopes (optical / spectro)

Note: similar requirements for at least several other extragalactic studies (e.g. galaxy evolution, cluster physics)