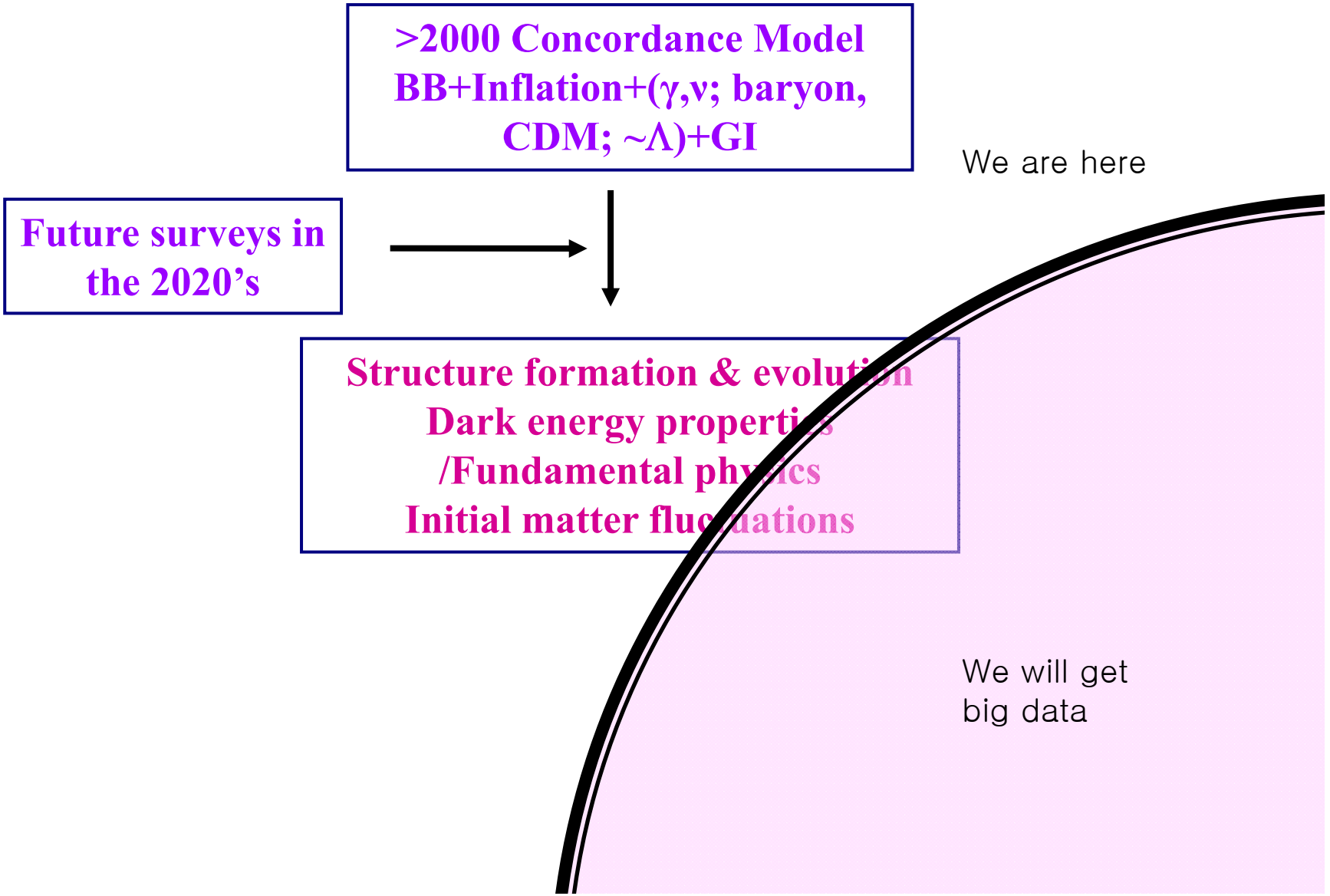
Future Survey Astronomy in Korea

Future Sky Survey and Big Data

Apr. 25-29, KASI

Changbom Park (Korea Institute for Advanced Study)


>2000 Concordance Model
BB+Inflation+(γ,ν; baryon, CDM; ~Λ)+GI
We are here
Future surveys in the 2020's
Structure formation & evolution
Dark energy properties
/Fundamental physics
Initial matter fluctuations
We will get big data

Some major on-going/future surveys or facilities that Korea is involved

Optical/IR: GMT, MMT, Gemini, KMTnet
optical surveys: SDSS4, DESI, KMTnet, LSST
Space ... IR: (SPHEREx, WFIRST?)

Radio/mm/sub-mm: KVN, ALMA, JCMT

Preparation of the GMT era being made by KASI through the Korean astronomical community

GMT Science and Instrumentation Working Group

➔ GMT White Paper 2015

Other activities

(Time on large telescopes;
GMT summer school)

Key GMT science goals:

- Star and planet formation
- Stellar populations and chemical evolution
- The nature of dark matter and dark energy
- The evolution of galaxies and intergalactic matter
- Black hole growth
- The first stars and galaxies

vs

Science goals of LSST

- Taking an Inventory of the Solar System
- Mapping the Milky Way
- Exploring the Transient Optical Sky
- Probing Dark Energy and Dark Matter.

Some survey sciences of the Korean community

Survey proposals in the GMT White Paper
Research topics using major survey data
.....

Deep and dense galaxy redshift survey : JH Kim et al., GMT WP

220K galaxies with Ks=22 ~ 23 & 24 within 4.5 sd

→ Spectroscopic survey using 100 days of GMT GMACS (500 masks assumed)

→ Distribution of galaxies upto z=2 and in z=3~5.

→ 1. Dense 3D map to examine LS environment with a large dynamic range

2. Evolution of high-z galaxies in the general LS environment,
from voids to superclusters and clusters of galaxies.
Development of galaxy morphology at z=0.5 ~ 2

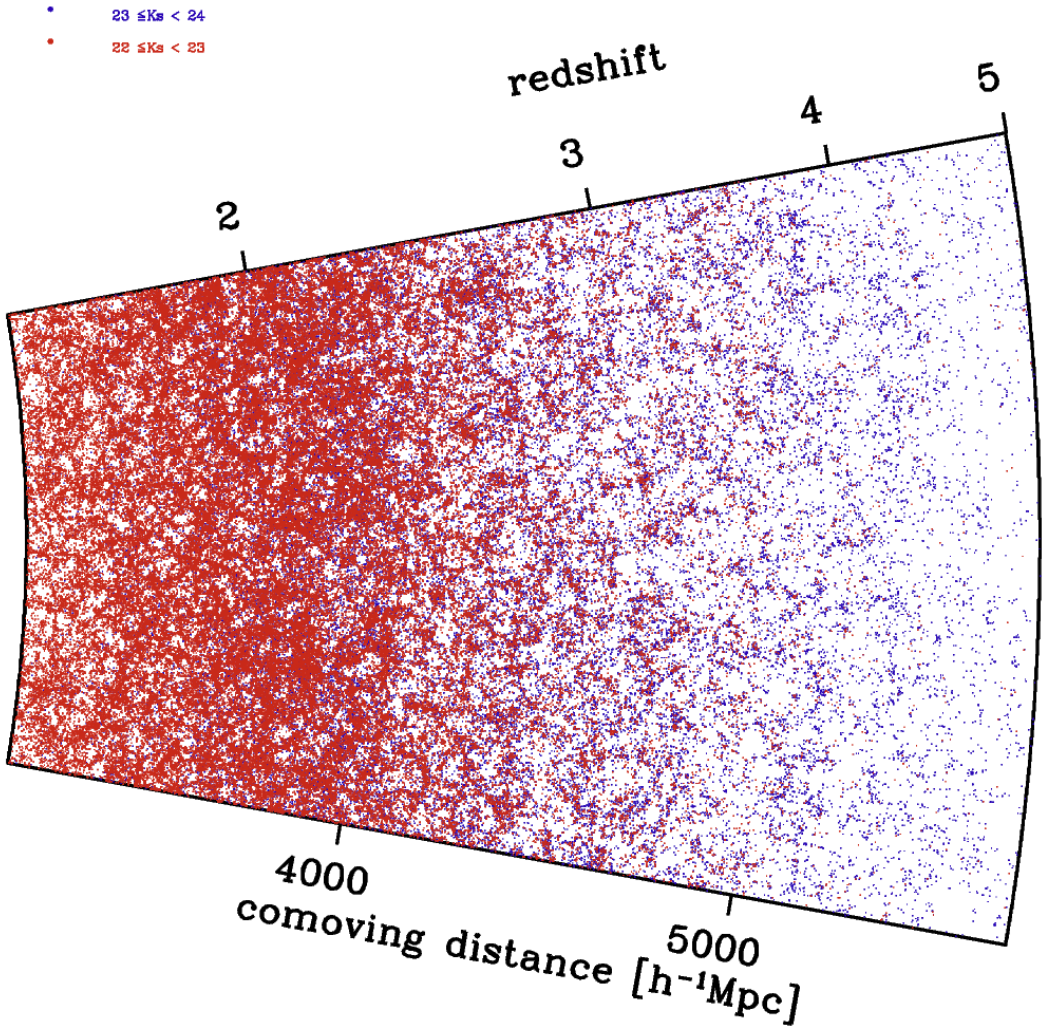
3. Identification of satellite galaxies over a large range of redshift.

Existing deep & dense surveys

	<z>	R	Area(sd)	Ref.
zCOSMOS-Deep	2.1	200	1	Lilly+2007
VVDS-Deep	0.92	230	0.74	Le Fevre+2013
VIPERS	1	210	24	Guzzo+2013

(Need for ~wide DD samples with intermediate resolution and with no color constraints)

$\Delta\theta = 20'$ & $\Delta\phi = 20^{o}$



Distribution of mock galaxies in the Horizon Run simulation (JH Kim+2011) within a 20d-wide & 20'-thick wedge. It was proposed to observe galaxies in 4sd area between Ks=22-23, and 1.4sd area between Ks=23-24.

Sciences with the DDN data

: GMT can provide this!

1. Dense 3D map to examine large-scale structures with a large dynamic range
   → Development of cosmic web
   → Constraints on cosmological models

1-1. Linear-regime sciences if the survey is also wide (DDW) : LSST will provide this!
   → Initial conditions, cosmological parameters

2. LLSs from voids to superclusters and clusters of galaxies
   → Evolution of high-z galaxies in the general LS environment
   Development of galaxy morphology at z=0.5 ~ 2

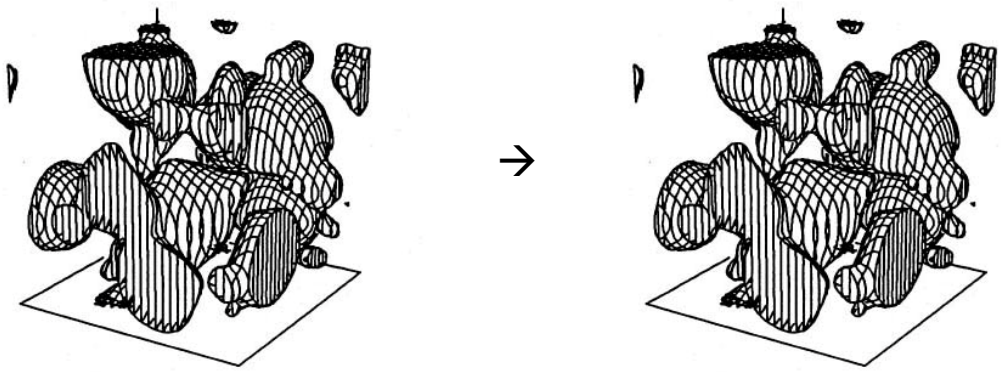
3. Regions around low-z galaxies
   → Satellite galaxies over large ranges of luminosity & redshift.

…….

DD Survey Science example:
Gaussianity of the initial matter fluctuations, a linear regime science

On large scales the topology of LSS is still in its primordial state &
the Gaussianity of the initial matter fluctuations can be tested.

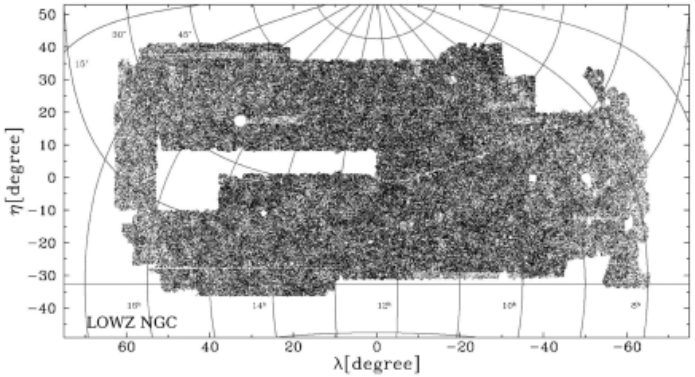
At high redshifts the non-linear scale is on smaller scales
→ one can inspect the statistical properties of the primordial density fluctuations with a higher precision.
(if the bias in the distribution of high-z galaxies can be estimated)
(Ex. σ_8 = 0.8, 0.51, & 0.27 at z=0, 1, & 3 in WMAP 7yr ΛCDM)

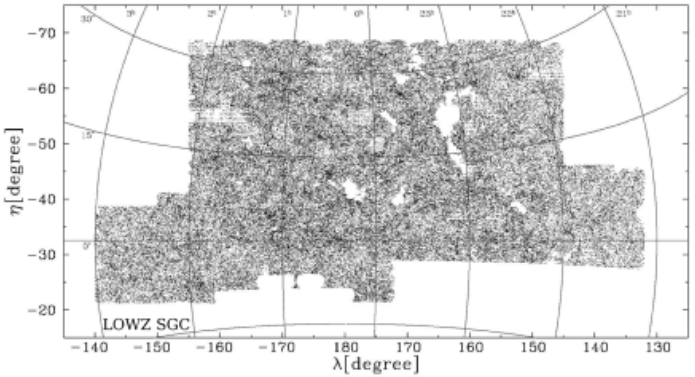


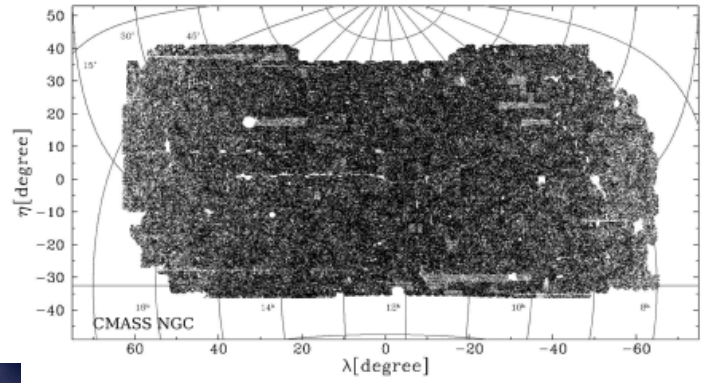
DD Survey Science example: Cosmological parameter estimation

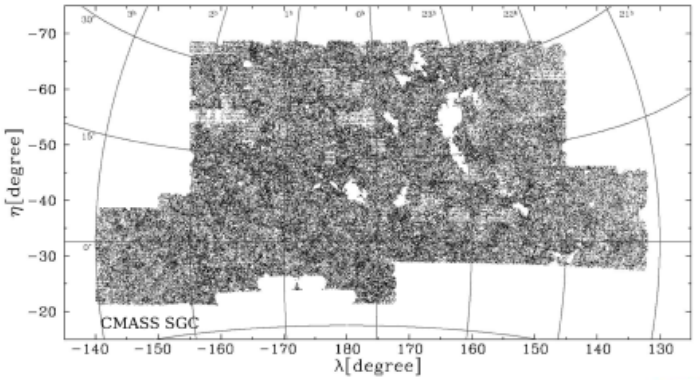
SDSS-III BOSS DR12 sample (X.-D. Li, C. Park, C.G. Sabiu, et al. 2016)

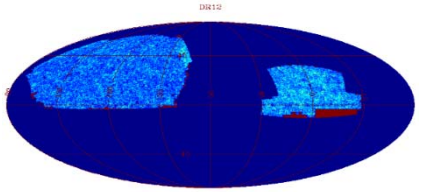
LOWZ 8,337 deg ^{2} . CMASS 9,376 deg ^{2} (~1/4 sky). ~1.13 M gals at $0.15 \leq z \leq 0.7$





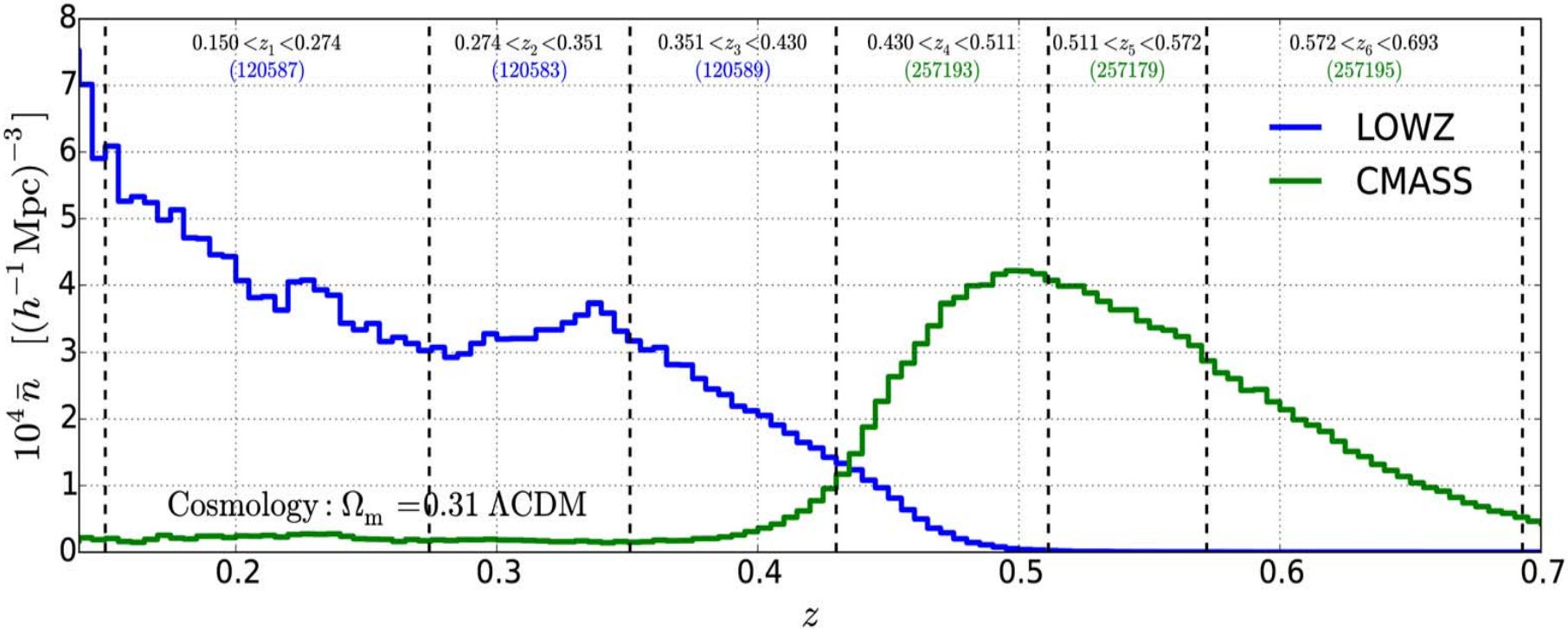






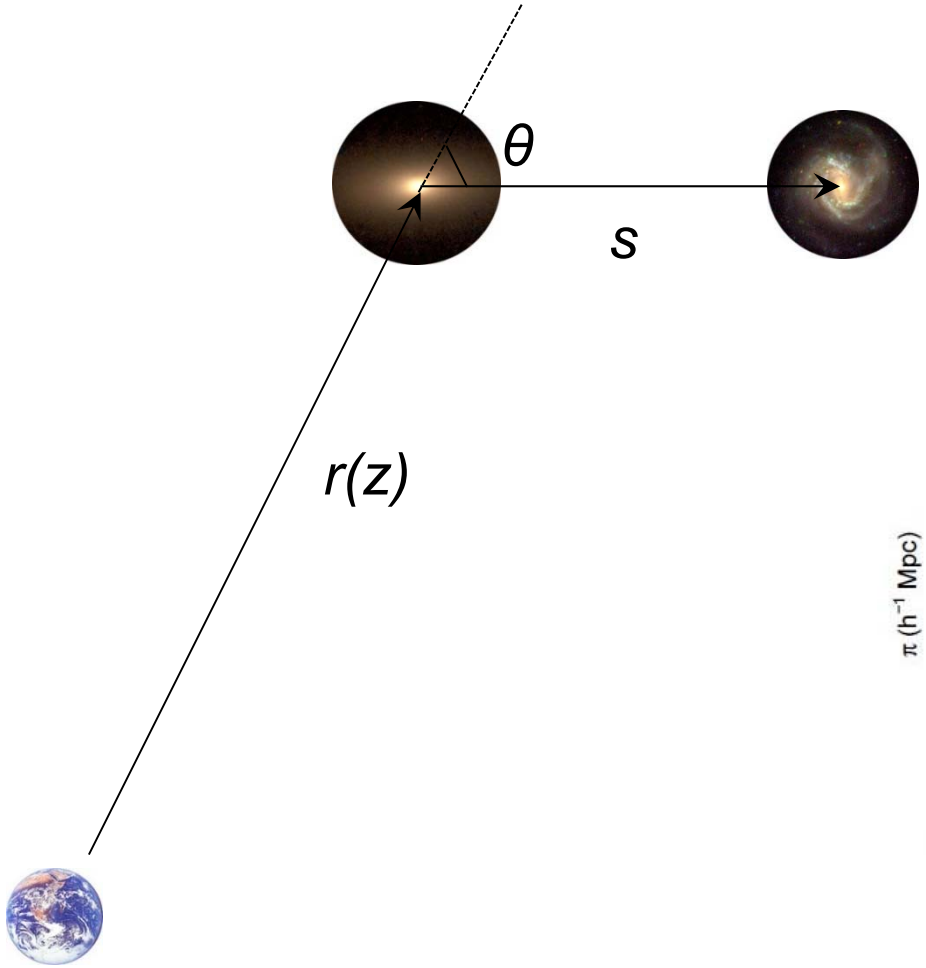
BOSS is an intermediate depth, sparse survey.

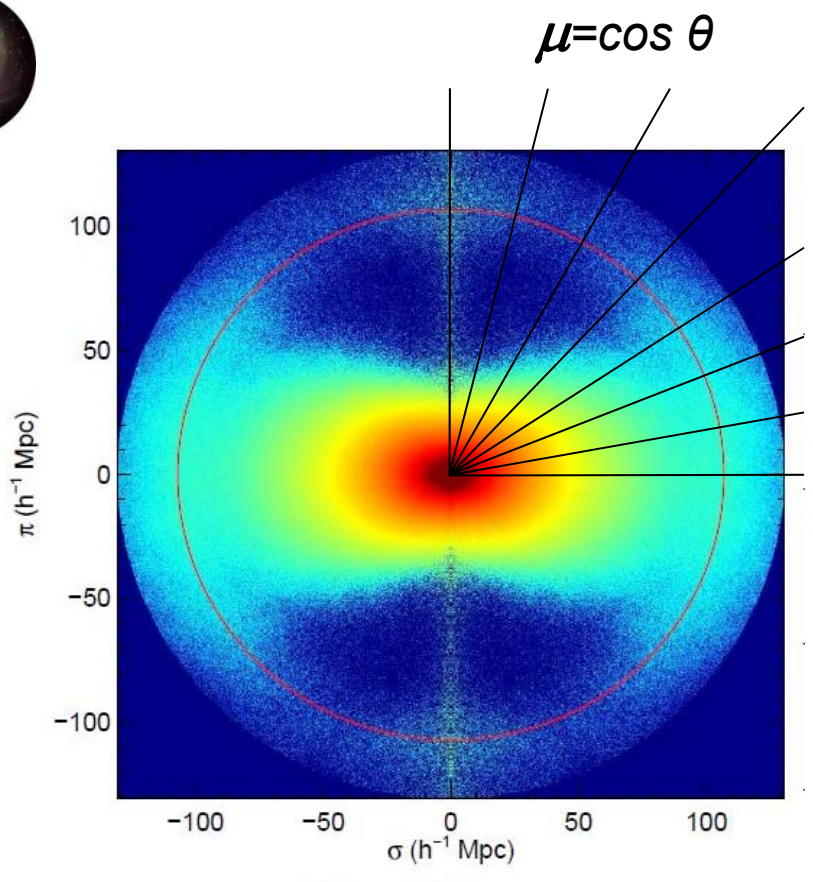
But currently the best …



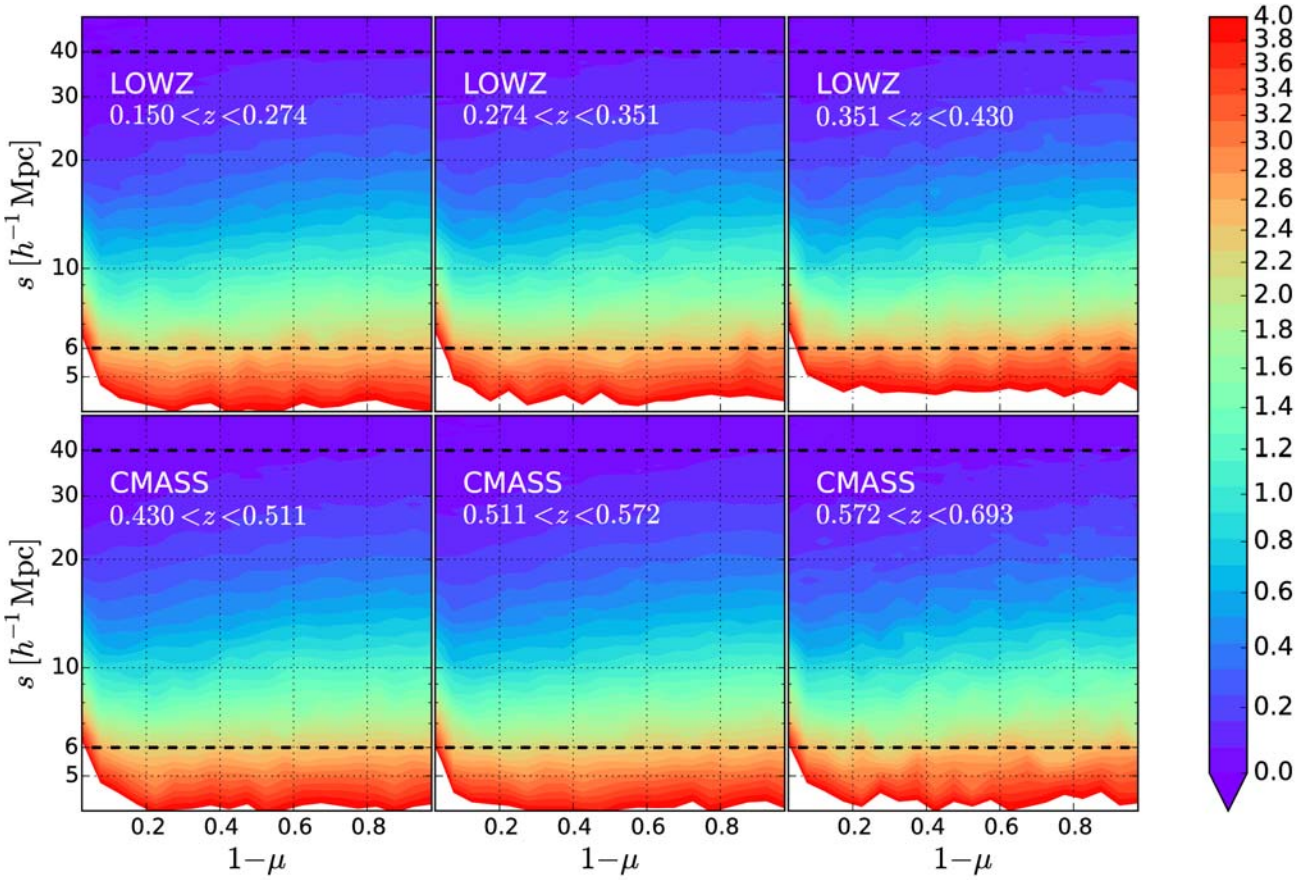
AP effects measured in 6 redshift bins.

2pCF as a measure of clustering anisotropy $\xi(s, \mu)$





2pCF in 6 redshift bins



$$\xi_{\Delta s}(\mu) \equiv \int_{s_{\min}}^{s_{\max}} \xi(s,\mu)\, ds$$

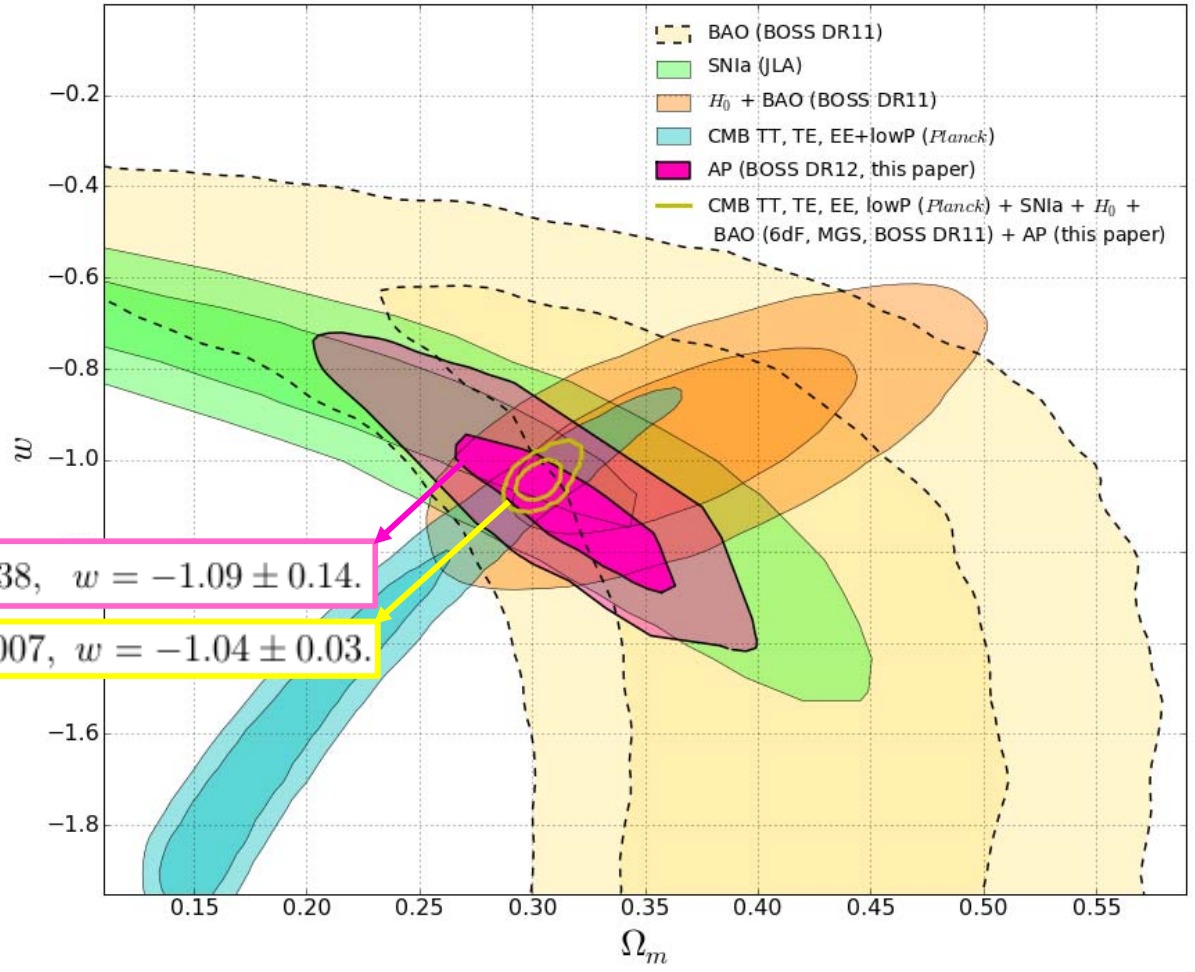
s = 5 – 40 Mpc/h

$\Omega_m = 0.31$ ΛCDM

adopted in these particular plots

FOG at $1-\mu \rightarrow 0$ and Kaiser effect at $1-\mu > 0.1$
Similar to each other: Small redshift evolution of RSD

Cosmological constraints (X. Li et al. 2016)



$\Omega_m = 0.314 \pm 0.038, \quad w = -1.09 \pm 0.14.$

$\Omega_m = 0.304 \pm 0.007, \quad w = -1.04 \pm 0.03.$

Unlike BAO, dense sample can give much stronger constraints by the AP test, which uses only the isotropy of space and physics!

References

Planck temperature and polarization anisotropies: Ade et al. (2015)

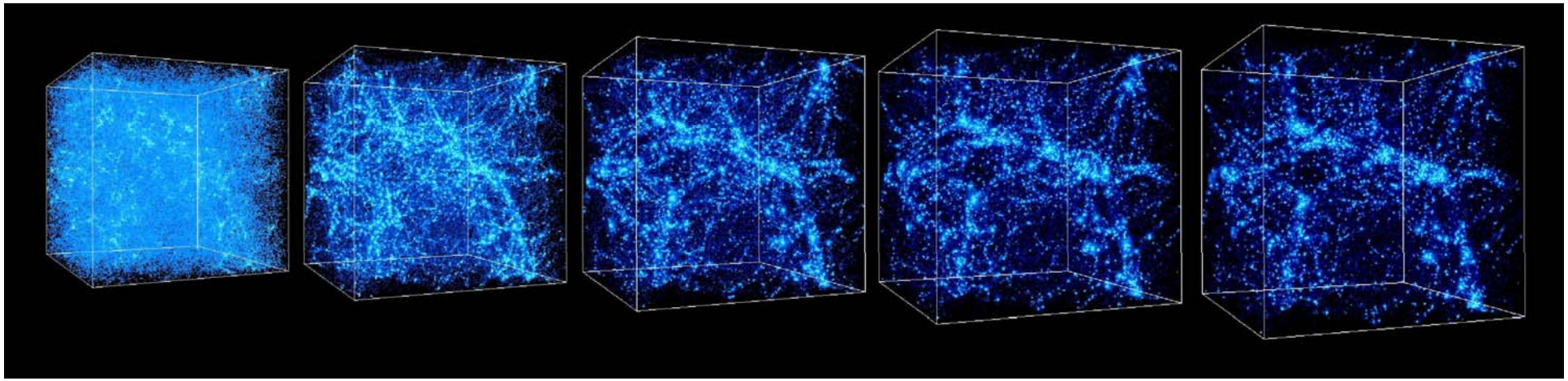
JLA SNIa : Betoule et al. (2014)

BAO from BOSS DR11: Anderson et al. (2013)

BOSS DR11 BOSS combined with HST measurement (H0=70.6+-3.3)
: Riess et al. (2011), Efstathiou et al. (2014)

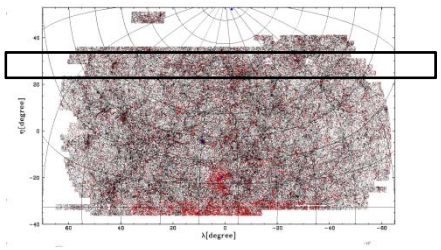
DD Survey Science example:
Development of the cosmic web

Classification of LSS on the past light cone surface
→ Formation of LSS (void, wall, filament, cluster)
→ Constraints on cosmology, gravitational instability theory, & galaxy/quasar/Ly-a clouds biasing

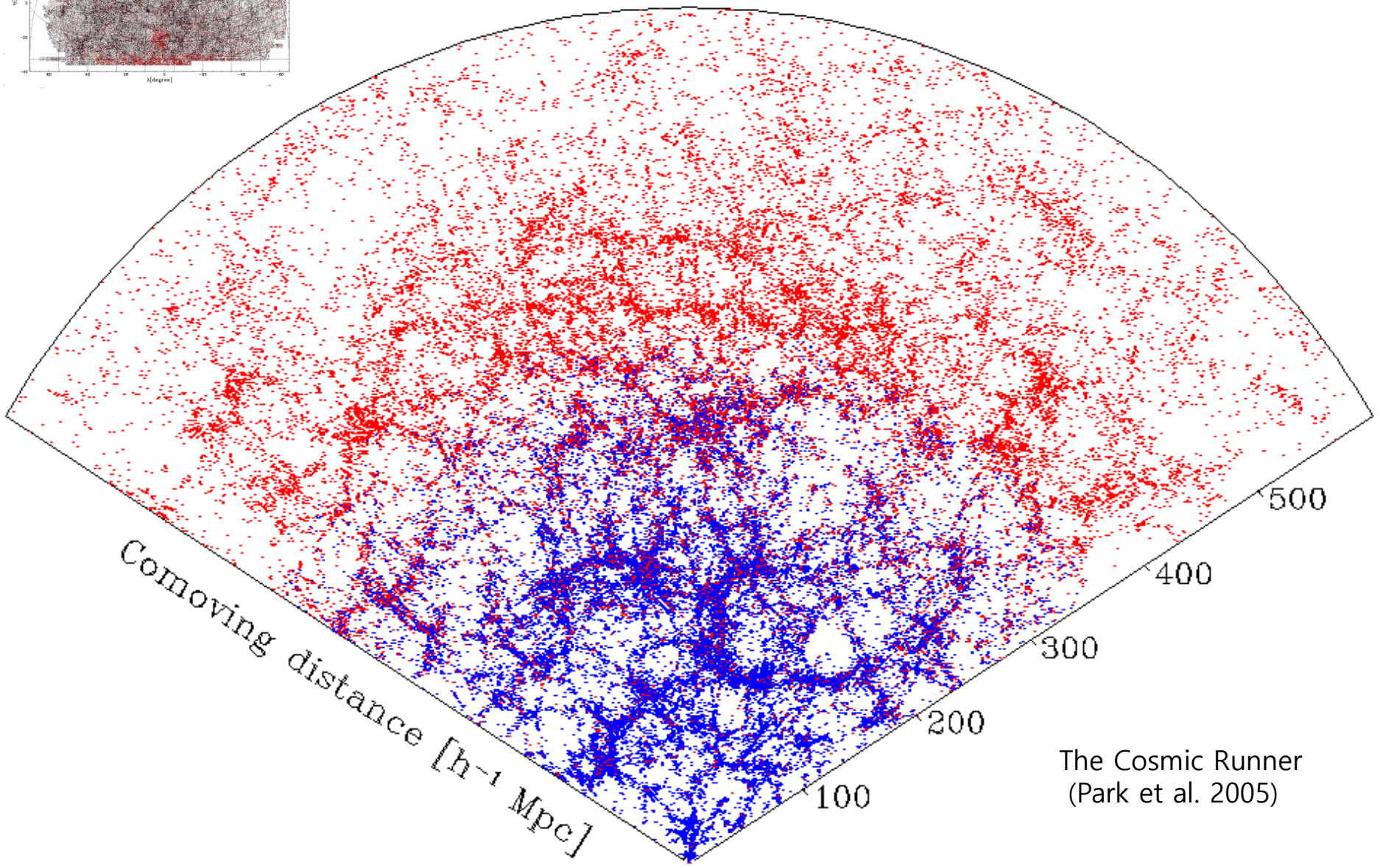


Formation of filaments, voids and clusters over a long time interval
Dependence on the type of LSS tracers

(courtesy: A. Kravtsov).



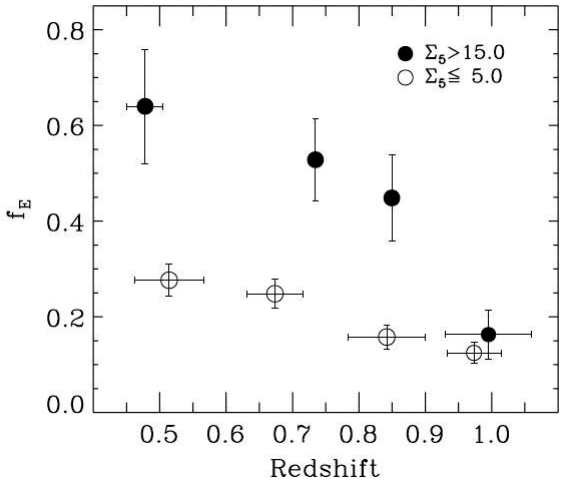
$22.0<\eta<32.0,\ -57.0<\lambda<60.0$



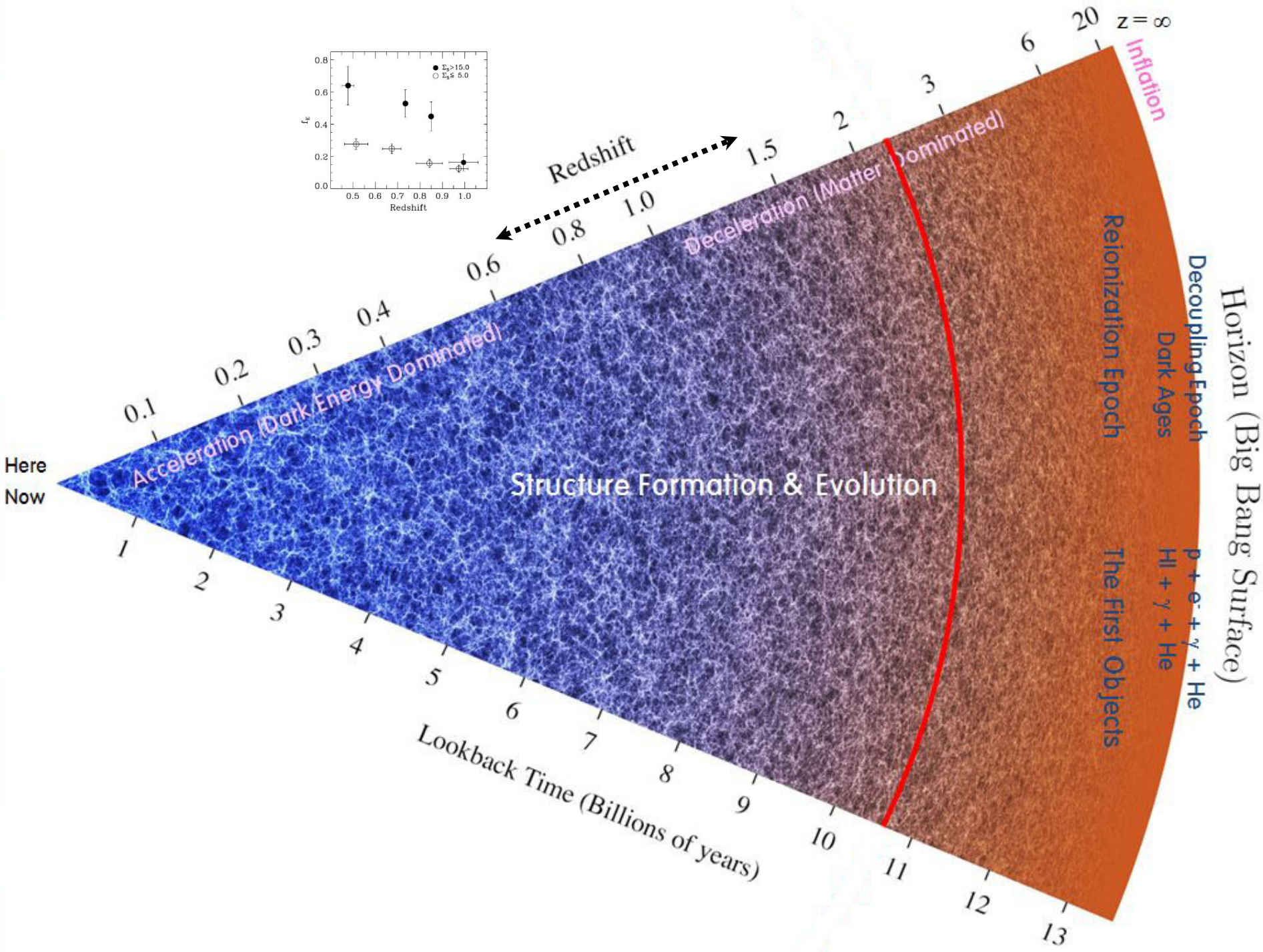
The Cosmic Runner
(Park et al. 2005)

DD Survey Science example:
Evolution of the galaxy-environment connection

Evolution of galaxy properties (L, SFR, M*, MBH, color, morphology, bulge-disk, interaction rate/type etc.)
in different environments (local density, shape, LSS types, local potential)
: The epoch with z=0.8 ~ 3 is relatively unexplored. Only statistically heterogeneous, sparse & rare objects are observed.

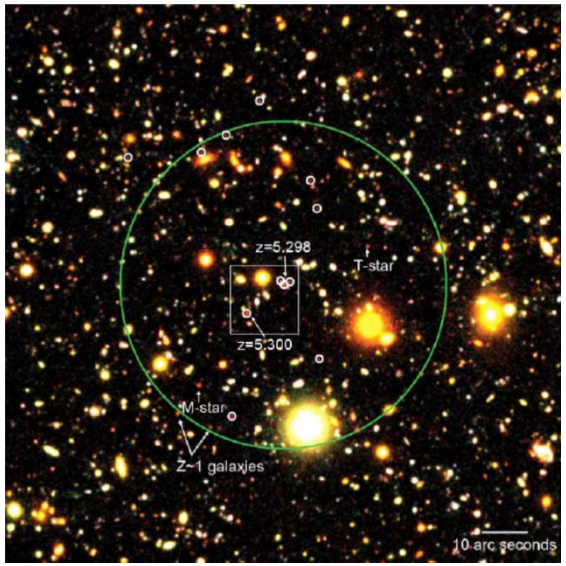


Development of
the morphology-density relation
between z=~1 and ~0.5
(Hwang & Park 2009)


Here
Now
Acceleration (Dark Energy Dominated)
Deceleration (Matter Dominated)
Structure Formation & Evolution
Redshift
0.1
0.2
0.3
0.4
0.6
0.8
1.0
1.5
2
3
6
20
z = ∞
1
2
3
4
5
6
7
8
9
10
11
12
13
Lookback Time (Billions of years)
Inflation
Decoupling Epoch
Dark Ages
Reionization Epoch
The First Objects
p + e⁻ + γ + He
HI + γ + He
Horizon (Big Bang Surface)
Redshift
Redshift

Proto-clusters of galaxies survey : JC Lee et al., GMT WP

Photometric redshifts from multi-band photometric data over a large area of the sky
→ Proto-clusters of galaxies candidates at z >~ 3
I.e. target regions are selected instead of a blind field survey!
(→ Spectroscopic confirmation by GMT GMACS. FoV of GMT ~4'x8' matches the size of clusters.)
→ 1. Constraints on cosmology from abundance/mass function of galaxy clusters
2. Effects of environment in star formation activity and evolution of galaxies



A galaxy cluster candidate at z~5.3.
Circles are member candidate galaxies and the green circle has 2 Mpc radius.

Galaxy cluster survey : SY Yi+, HS Hwang+, H.Jeong+, GMT WP

~20 known clusters at z=1~2 (Hwang+); clusters at z=0.2~1 (Yi+); clusters at z~0.05(Jeong+)

→ Spectroscopic survey with GMT GMACS (FoV r=7Mpc/h at z=1.5)

→ Large # of member galaxies per cluster

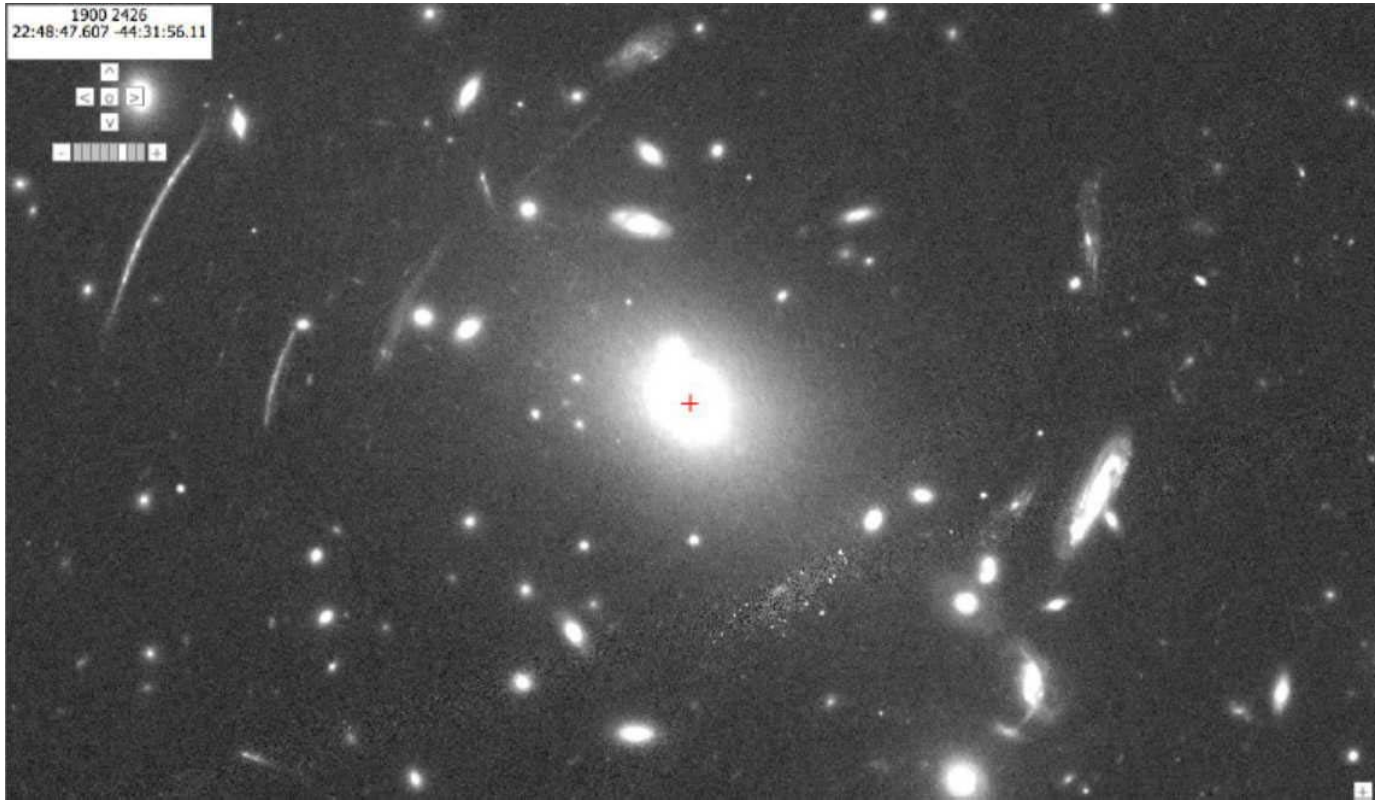
→ 1. mass distribution within cluster

2. Galaxy properties as functions of r and z (down to faint magnitude & late morph. types)
   morphology, chemical composition, kinematic properties, … & environment

3. Black hole evolution through high-z background galaxies

Existing high-z galaxy cluster surveys

	z	# clusters	#galaxies /cluster	Instrument/R	Ref.
EdisCS	0.5~1.0	10	~20	VLT FORS2/1000	White+05
ISCS	1.0~1.5	16	~20	KECK LRIS/R/~900 HST WFC3/~130	Eisenhardt+08; Brodwin+13
GCLASS	0.8~1.3	10	~45	Gemini-N&S GMOS/~440	Muzzin+12
MaDCoWS	0.7~1.3	19	~10	KECK DEIMOS/~2000 Gemini-N GMOS/~1900	Stanford+14



Central part of RXJ2248.7-4431, a CLASH cluster at z=0.348
: spectroscopic observation of the background high-z galaxies & AGNs (Yi et al.)

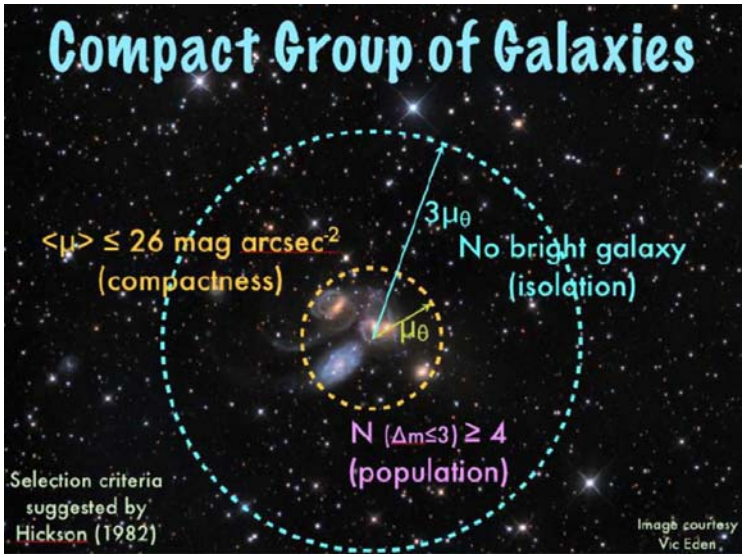
Distant compact galaxy group survey : JB Son et al., GMT WP

Compact galaxy group candidates from photometric data

→ Spectroscopic survey with GMT GMACS (FoV r=3.3Mpc/h at z=0.5)

→ >50 compact galaxy groups

→ 1. Galaxy evolution.
Galaxy groups are where the g-g interactions are active.
2. Population of compact GG



Selection criteria of CGG
(Hickson 1982)

Massive early-type galaxies at high redshifts : JW Ko et al., GMT WP

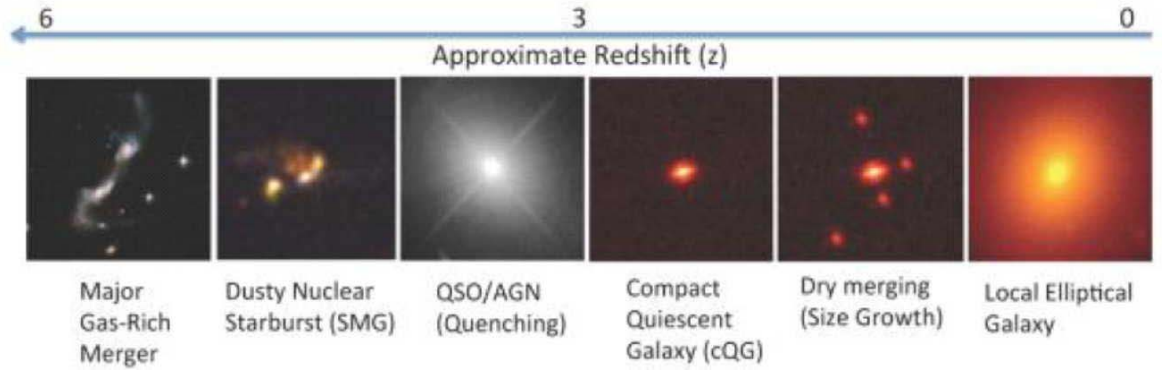
Massive early-type galaxy targets at z=1~2 from HST images

→ Spectroscopic data of >>100 high-z early-type galaxies from GMT GMACS observations

→ 1. Star formation history in massive early-type galaxies upto z~2. burst/passive/quasi-steady

2. Understanding of evolution of massive galaxies. stellar mass

3. Large-scale structures traced by massive ETGs



Formation of massive early-type galaxies (a scenario of Toft et al. 2014)

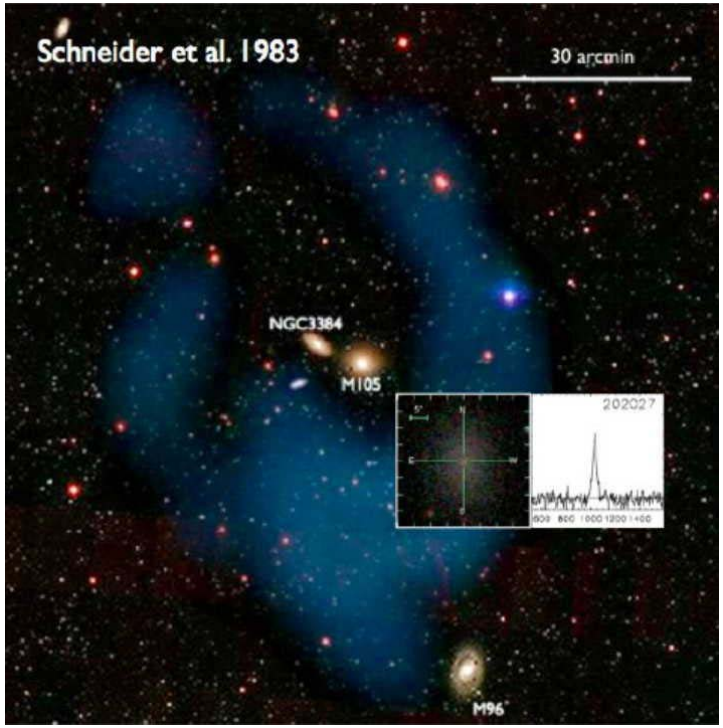
Dwarf galaxy survey : A. Chung et al., GMT WP

Nearby dwarf galaxy candidates with detected HI

→ Optical (and radio) spectroscopic data of dwarf galaxies from GMT GMACS observations

→ 1. properties of dwarf galaxies

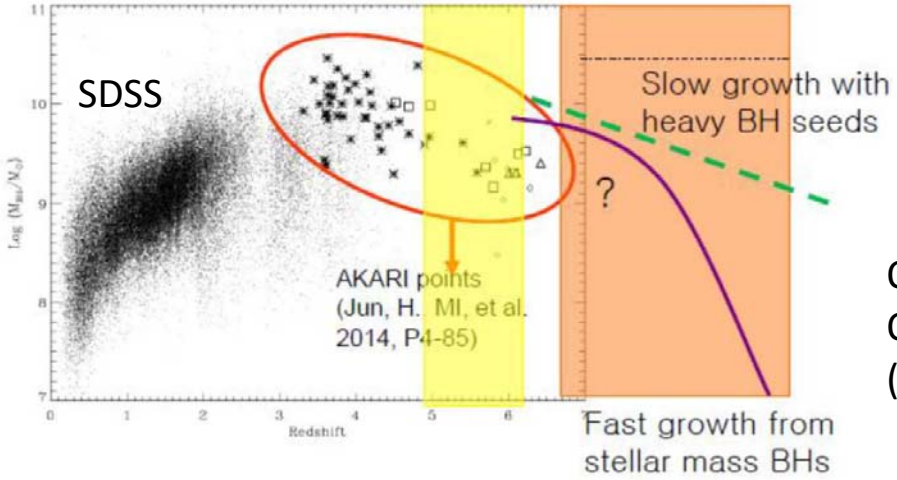
2. star-gas connection in galaxies



HI gas ring (blue) associated with a galaxy group. Many dwarfs are found in the cloud. (Chung+2015)

High-redshift quasar surveys : MS Im+, GMT WP

>300 high-z (4<z<7) quasar candidates from the future WF imaging surveys
→ Spectroscopic survey with GMT GMACS (1h exposure of m_z=24 quasar at z=6)
→ Large # of high-z quasar sample (>100)
→ 1. Growth of SMBH. Properties of seed BHs
2. Impact of high-z quasars on reionization



Quasar BH mass.
Only a few BHs at z>4
(Im+)

Survey of CGM of high-redshift galaxies : HJ Sim+, GMT WP

Spectroscopic sample of high-z quasars & multi-λ imaging data around them

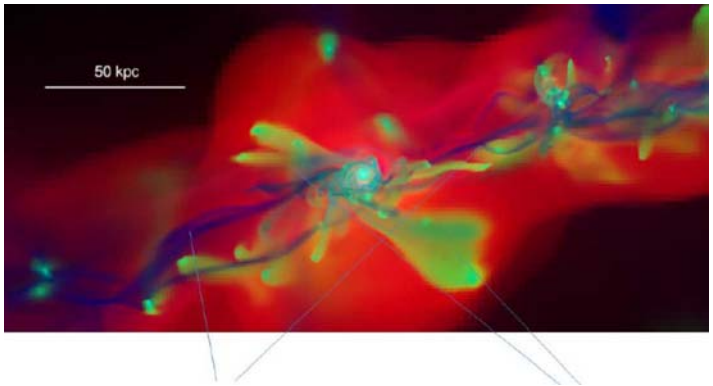
→ Background (3<z<6) quasar + foreground (z>2) galaxy pairs

→ GMT GCLEF observation of bright quasar (R<21) + galaxy pairs
GMT GMACS observation of high-z (z>6) quasar + galaxy or g-g pairs

→ Information on CGM with wide ranges of host luminosity, impact factor & z

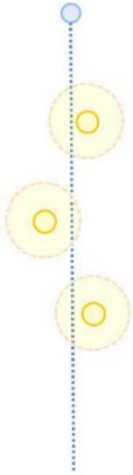
→ Dependence of characteristics of CGM on the host galaxy properties as function of z

CGM around a simulated galaxy at z~3 (Agertz+2009)

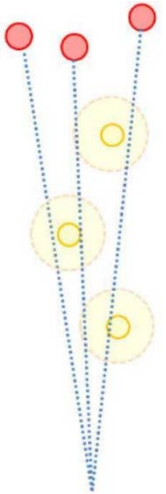


Accretion of low T, high density gas stimulating SF

Ejection of metal-rich gas to IGM



A quasar in the background (Sim+)



More LoS's if bg galaxies or AGN are used (Sim+)

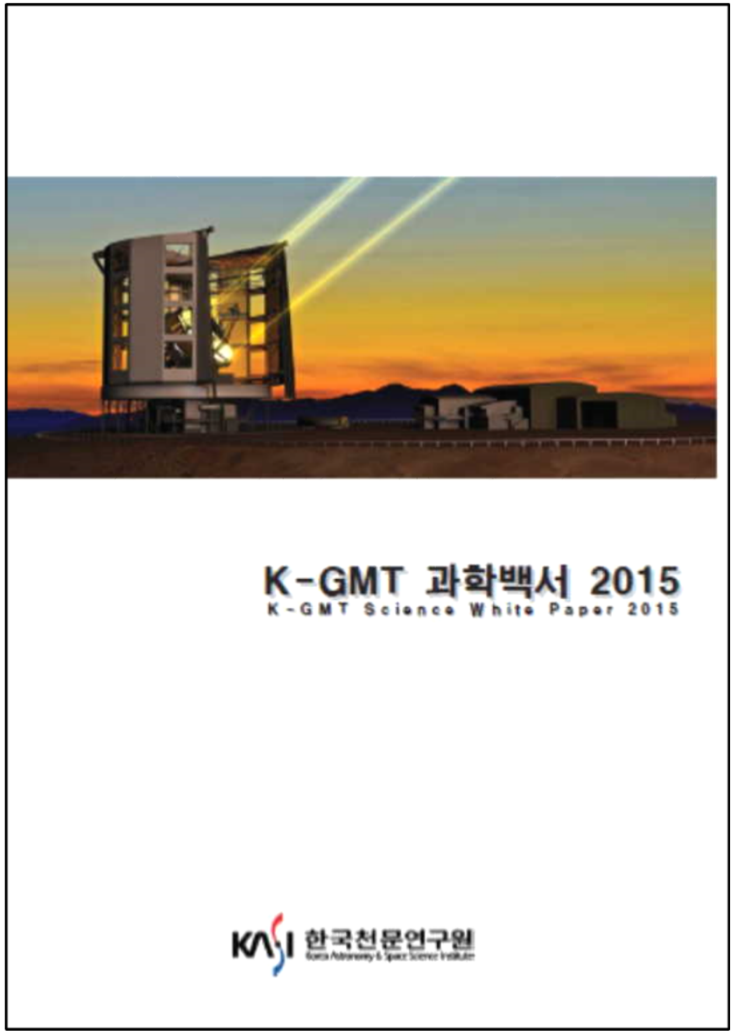
Existing CGM surveys

	Background quasar z	Foreground galaxies z	comments	Ref.
Quasar Probing Quasars	1.8<z<4.0		27 absorption objects	Prochaska+2013: Hennawi+2013
Keck Baryonic Structure Survey		1.6<z<3.4	Impact parameter 0<b<100kpc	Steidel+2014; Trainor & Steidel2012; Rudie+2012; Rakic+2012
COS-Halos	~0.5	0.15<z<0.35	Wide mass range	Tumlinson+2013

GMT White Paper 2015

36 proposals for surveys with GMT

1. Cosmology and Galaxy Clustering * 5
2. Galaxy Formation * 10
3. High-redshift universe * 7
4. Stellar Population and Formation of the Galaxy * 7
5. Exo-solar planets * 4
6. Star Formation and Evolution * 3



Survey Science Group of Korea

Since Apr. 1, 2011, regular meetings and annual workshop
to share ideas of new surveys and
to combine the efforts to initiate & carry out big surveys in all wavelength bands.

Optical/IR: GMT, MMT, Gemini
optical/NIR surveys: SDSS4, DESI, LSST
Radio/mm/sub-mm: ALMA, JCMT, KVN.
Space IR: SPHEREx, WFIRST …… have been reported/discussed.

Large telescope user group formed: KASI+KIAS+SNU+Yonsei

Continuation of the tradition is important!

[1st SSG workshop. Feb., 2012]

[5th SSG workshop. Feb., 2016]

Summary

Characteristics of the scientific interests of Korean astronomical community

Big focus on cosmology, structure (galaxy/quasar/cluster/LSS) formation
- gravitational lensing, SN, CMB sciences less popular

Relatively less focused in Galactic astronomy, planets, & time-domain sciences

Compact objects are not much studied too (except AGNs).

Preparation for the GMT and LSST era

Strengthen our expertise in cosmology and extra-galactic astronomy

Enlarge the size of the stellar and planetary astronomy communities

Need community-wide and continuous effort to share information, exchange ideas, & combine efforts for carrying out the future surveys.

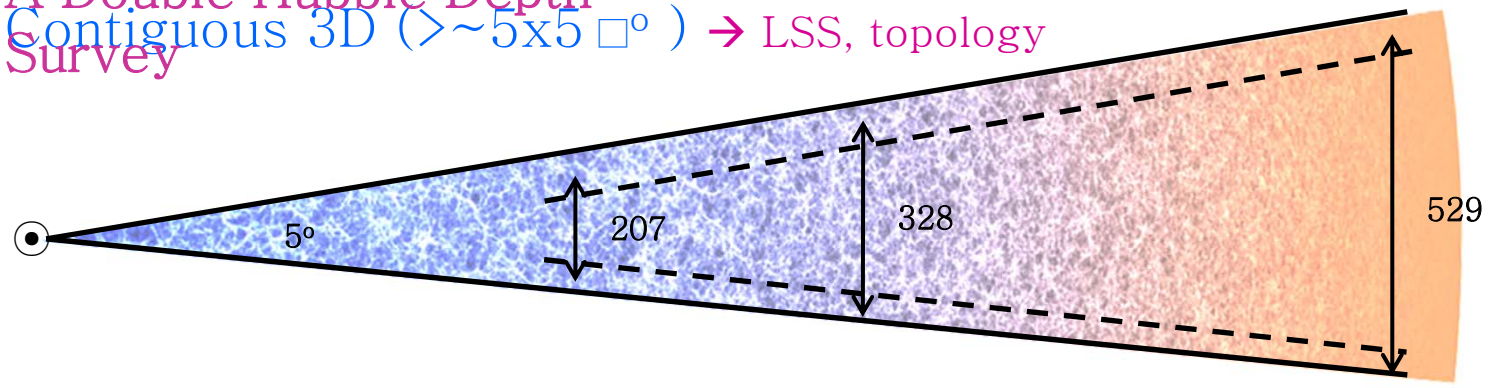
A Proposal for a survey of the coupled evolution of LSS and galaxies

Deep (z_{eff}>~5) → evolution sciences

Dense (full flux limited survey) → full spectrum of objects, high-order statistics

Wide (>5° or >200h^{-1}Mpc at z=1) → high statistical significance, low variance

A Double Hubble Depth Contiguous 3D (>~5x5 □°) → LSS, topology Survey



r=2370h^{-1}Mpc (z=1)

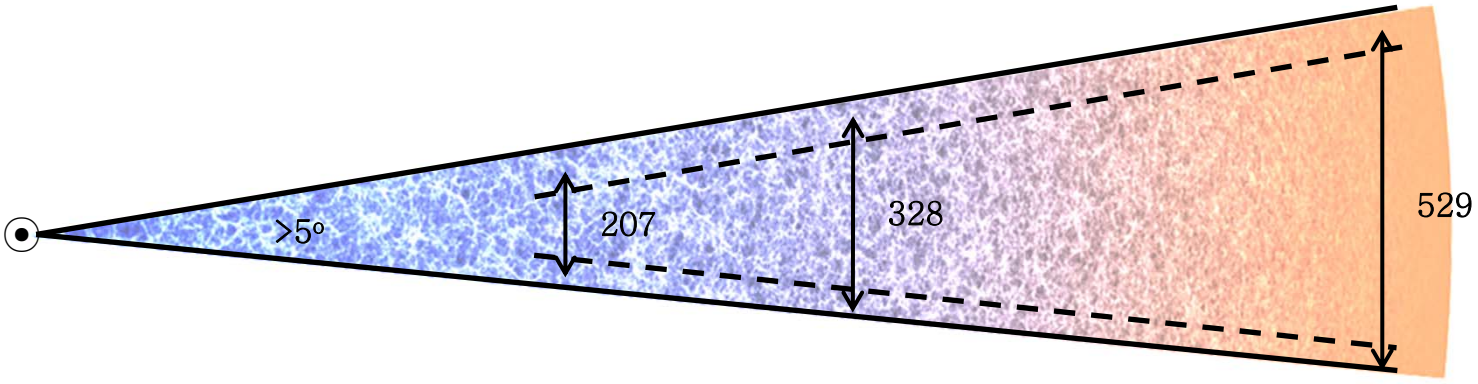
3759 (z=2)

6057 (z=6)

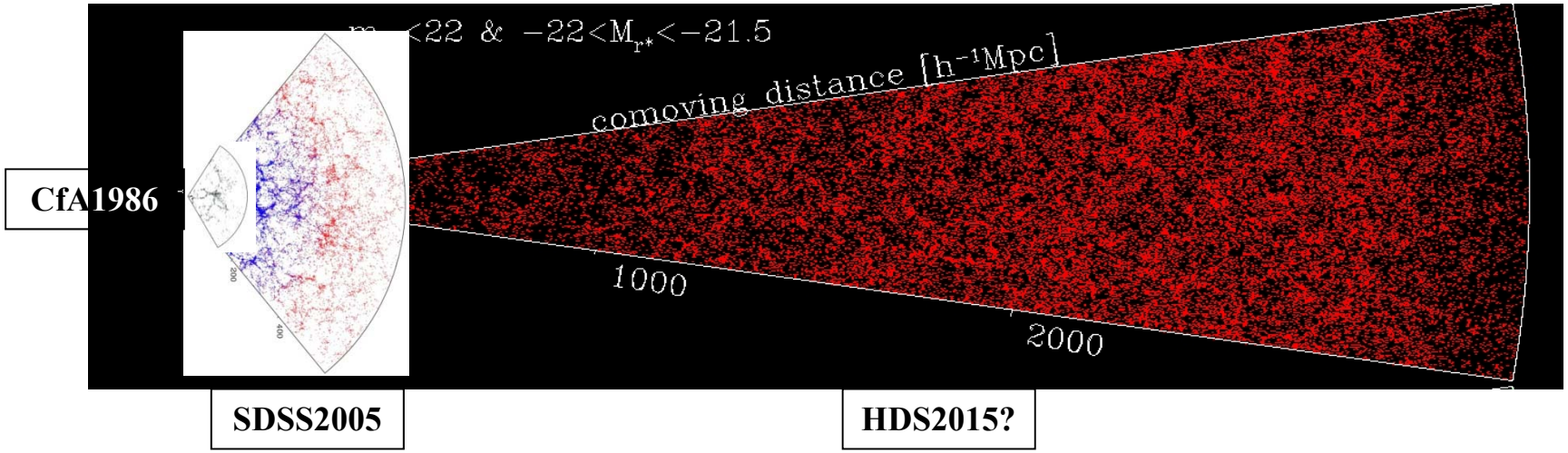
Summary

A Double Hubble (EdeS) Depth Survey
: A deep dense 3d surveys of galaxy distribution

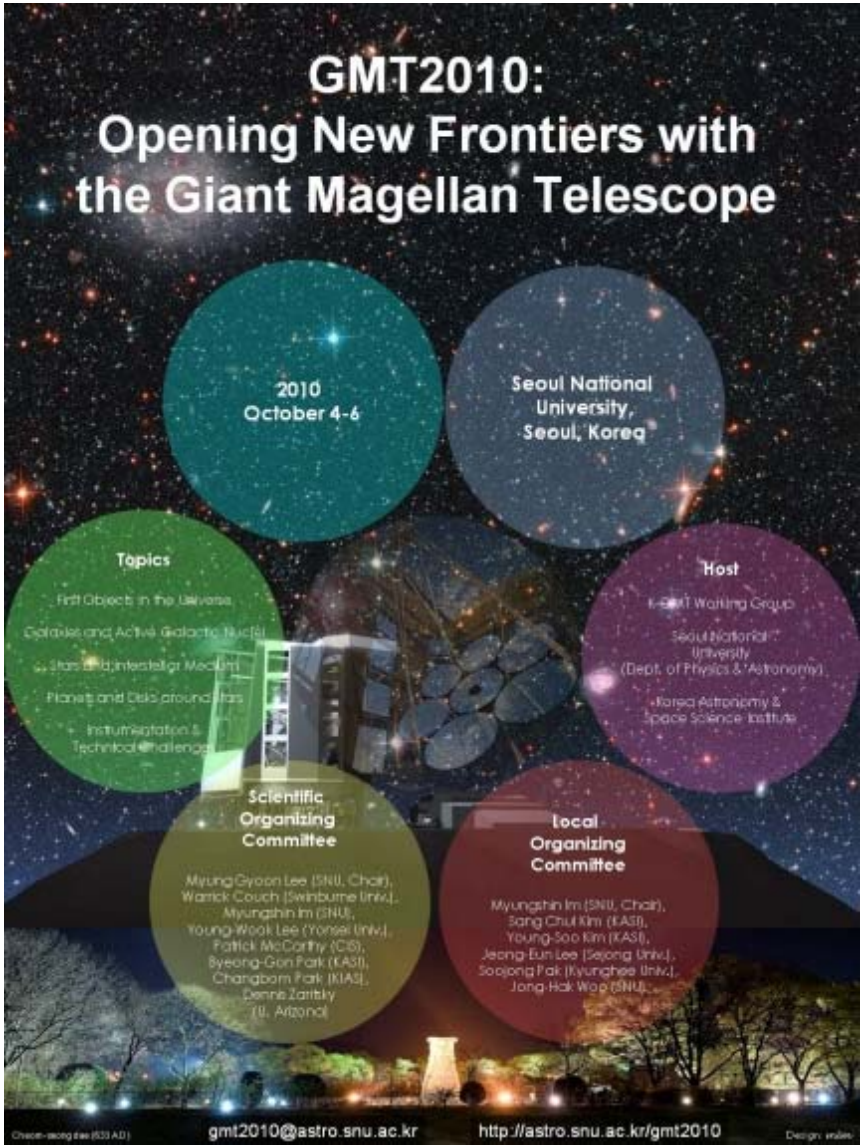
➔ Past-light cone sciences & Study of primordial fluctuations

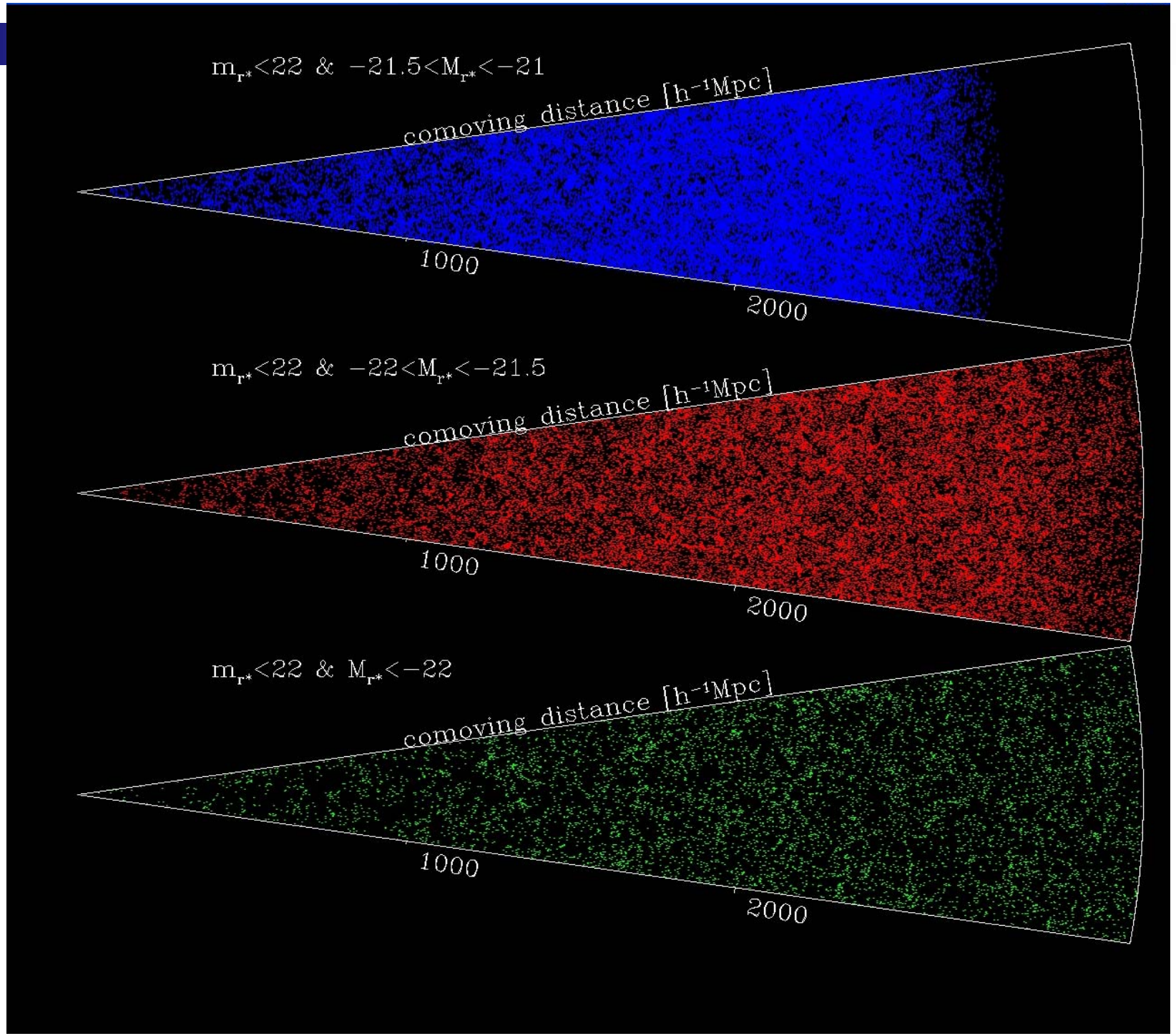


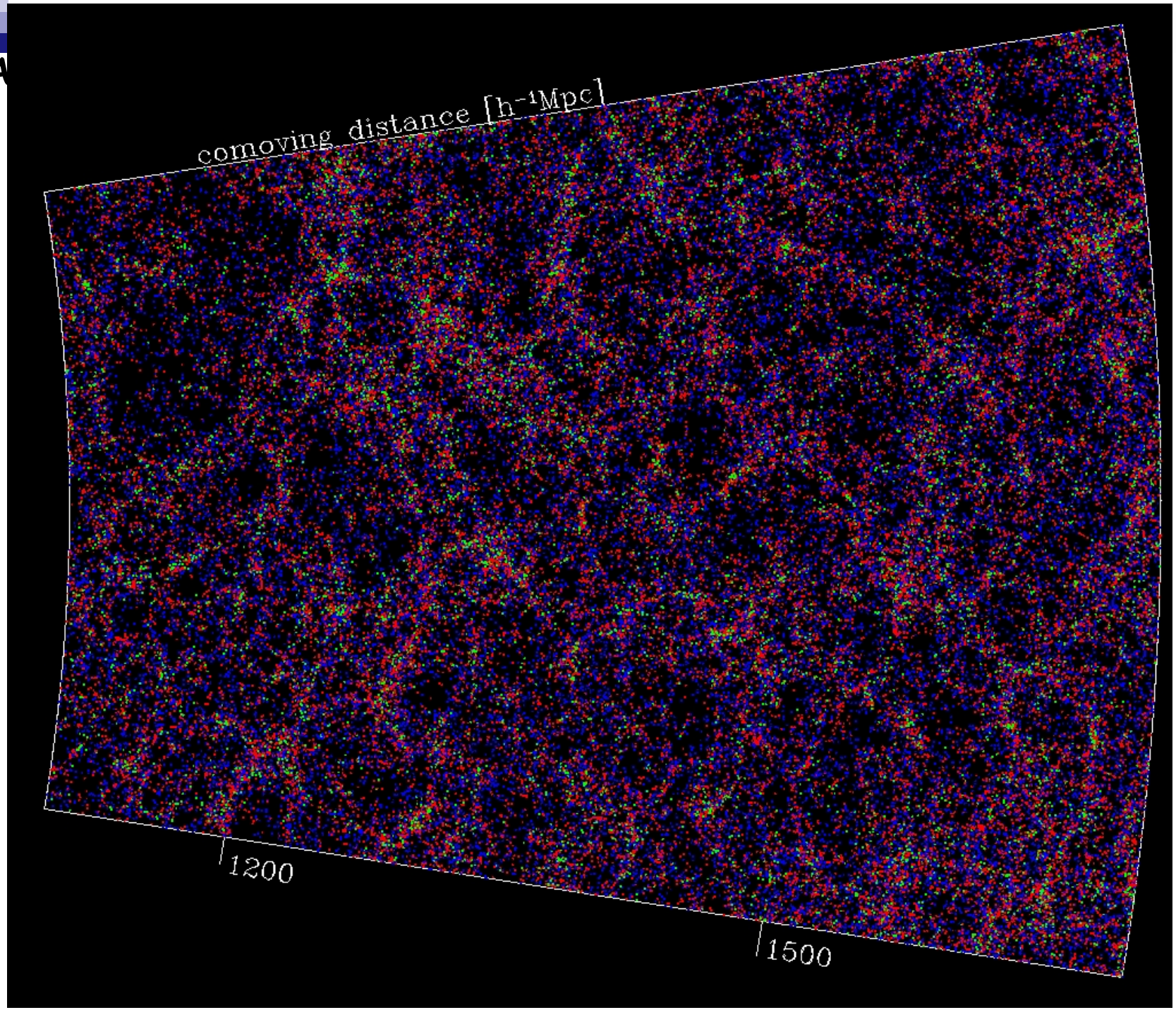
The Hubble Depth Survey



Expansion of human exploration of our Universe


GMT2010:
Opening New Frontiers with
the Giant Magellan Telescope
2010
October 4-6
Seoul National
University,
Seoul, Korea
Topics
First Objects in the Universe
Galaxies and Active Galactic Nuclei
Stars and Interstellar Medium
Planets and Disks around Stars
Instrumentation &
Technical Challenges
Host
K-GMT Working Group
Seoul National
University
(Dept. of Physics & Astronomy)
Korea Astronomy &
Space Science Institute
Scientific
Organizing
Committee
Myung Gyoon Lee (SNU, Chair),
Warrick Couch (Swinburne Univ.),
Myungshin Im (SNU),
Young-Wook Lee (Yonsei Univ.),
Patrick McCarthy (CIS),
Byeong-Gon Park (KASI),
Changbom Park (KIAS),
Dennis Zaritsky
(U. Arizona)
Local
Organizing
Committee
Myungshin Im (SNU, Chair),
Sang Chul Kim (KASI),
Young-Soo Kim (KASI),
Jeong-Eun Lee (Sejong Univ.),
Soojong Pak (Kyunghee Univ.),
Jong-Hak Woo (SNU),
gmt2010@astro.snu.ac.kr
http://astro.snu.ac.kr/gmt2010


$m_{r*}<22$ & $-21.5<M_{r*}<-21$
comoving distance [h^{-1}Mpc]
1000
2000
$m_{r*}<22$ & $-22<M_{r*}<-21.5$
comoving distance [h^{-1}Mpc]
1000
2000
$m_{r*}<22$ & $M_{r*}<-22$
comoving distance [h^{-1}Mpc]
1000
2000


comoving distance [h⁻¹Mpc]
1200
1500