CASE

Low Redshift survey @ Calar Alto

LoRCA

Presented by Johan Comparat (CSIC/UAM IFT) on behalf of the LoRCA team.

CASE phase 1

Low Redshift survey at Calar Alto

Mapping completely the low redshift Universe (2018-2021)

Comparat et al. 2015. MNRAS (arXiv 1510.00147)

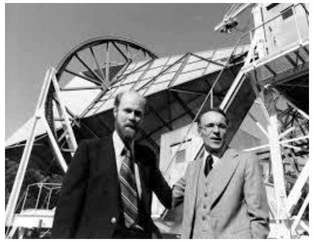
Mapping the Universe, some history

- Where instrumentation, astronomy and theoretical physics meet
- Long tradition in astronomy proven efficient to acquire knowledge on the Universe we live in.
- During the Renaissance, the solar system was charted and the heliocentric system was uncovered using naked eye observations (by N. Copernic and T. Brahe).
- In the 19th and 20th century, cepheid variable stars (by H. Leavitt) and stellar classification (by A. Cannon) were observed and our Milky way was starting to take shape.
- In the 1930's the first extra-galactic objects were confirmed using spectrographs (by E. Hubble, G. Lemaitre) and were interpreted in the context of relativity (Einstein).
- The discovery of the cosmic microwave background finally launched cosmology as a field of science in itself (Penzias & Wilson 1965).
- In the current paradigm of modern cosmology, observers try to produce the largest and most accurate maps of the observable universe at all wavelengths to understand the dynamics of the Universe and how galaxies populate it.

Kepler / Brahe

Leavitt / Cannon

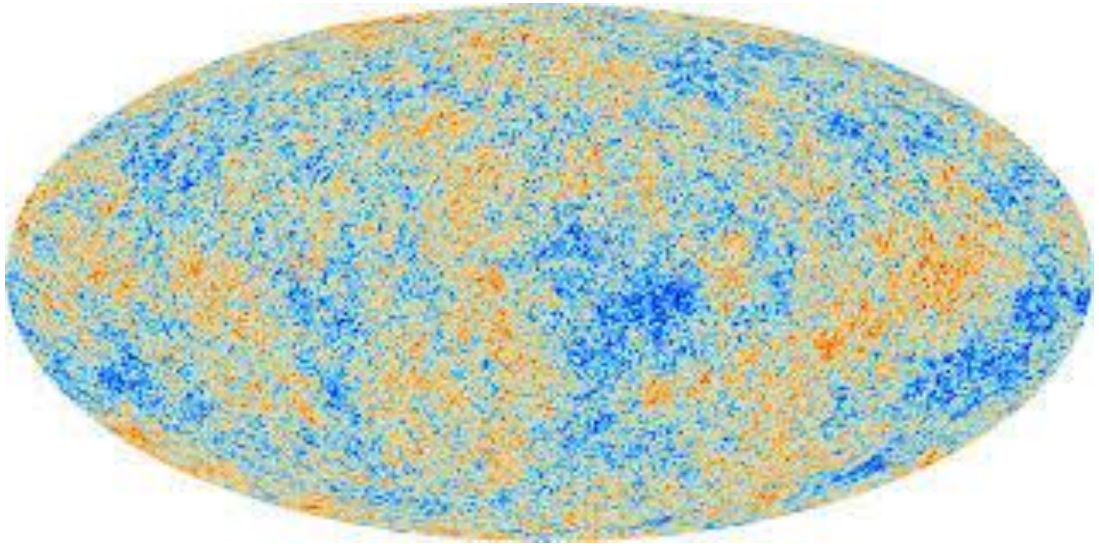
Lemaitre / Einstein / Hubble



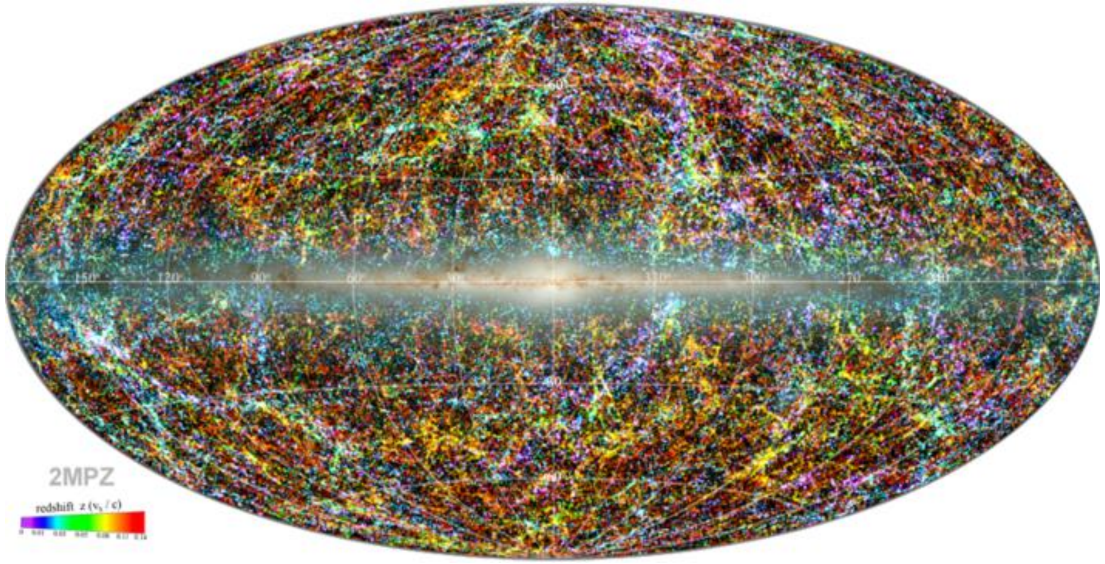
Penzias / Wilson

A few maps

- At redshift 1,100 with the cosmic microwave background (COBE, WMAP, PLANCK)
- And at redshift 0.1 in the local universe, we have a photometric map: 2MASS, WISE
- We are not done with the local Universe :
  - LoRCA +TAIPAN will add a factor of 10 in redshift precision and a factor of 3 in volume.
  - A high accuracy full sky map of the local Universe is on its way



z=1100, t=3.6e5 yr Planck collaboration 2015



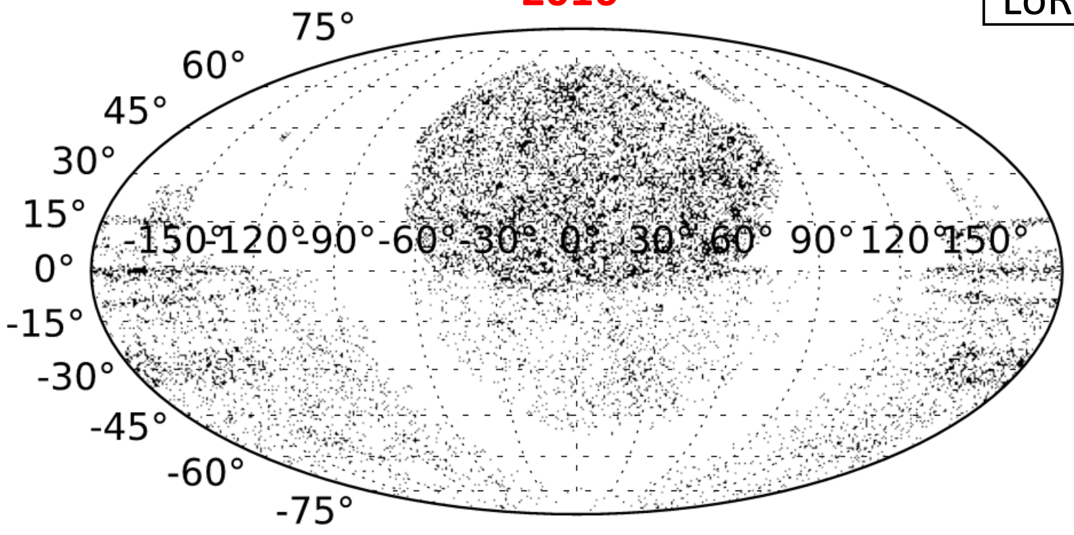
z=0.1, t=1.2e10 yr 2MASS, Bilicki et al. 2015

LoRCA in a nutshell

- Exhaust information in the local volume:
  - >10 times more precise spectroscopic observations of K<14 galaxies
  - At z=0.1 a 4% BAO measurement (1% after reconstruction)
  - Peculiar velocities: Pvv, Pgv, Pgg in the local volume. RSD constraint on growth of structures
  - Stellar mass function and strong lensing
- Very complementary to other cosmology surveys: eBOSS, 4MOST, DESI.
- It has different systematics and degeneracy compared to Cepheids and SN standard candle measurements
- Project well received by the community
- Kick-off meeting goal :
  - Narrow focus on the CASE instrumentation
  - Write up of a technical paper on the instrument specifications
  - https://workshops.ift.uam-csic.es/lorca
- Facility upgrade has started :
  - 19 fiber robot prototypes
  - Concept of the focal plane
- Collaborators are most welcome to help with :
  - Construction,
  - Operations,
  - Science

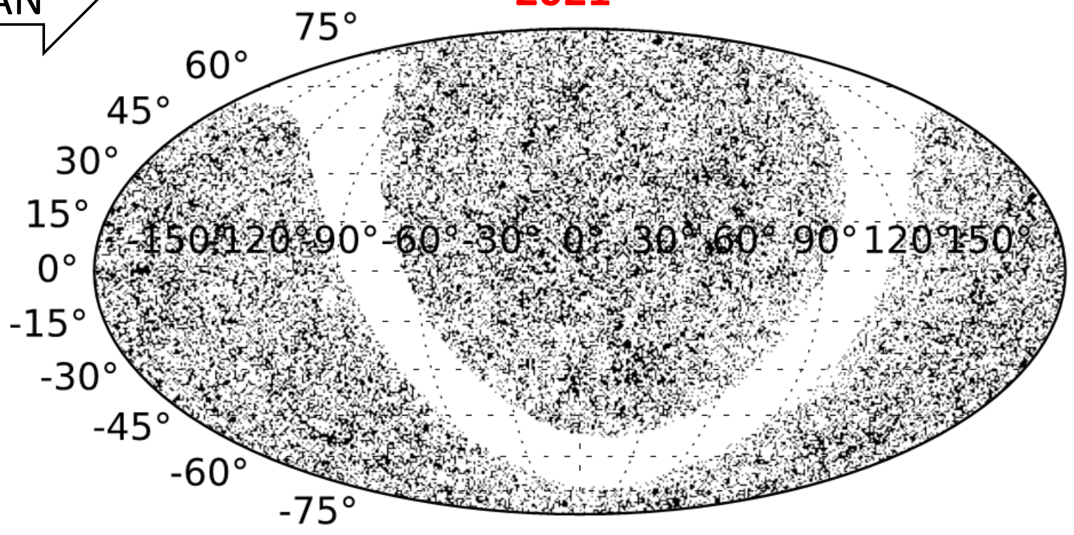
Expected mapping: all galaxies with K<14

2016



LoRCA + TAIPAN →

2021



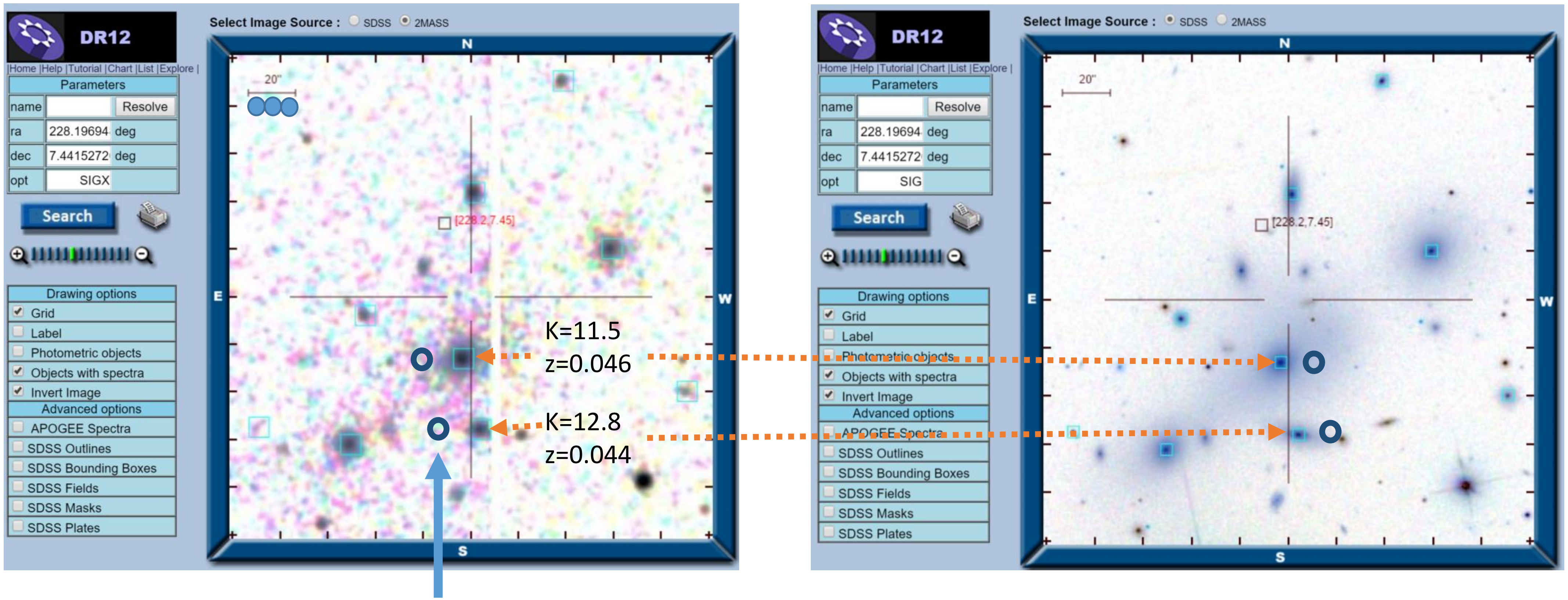
Target selection coordinated with TAIPAN (with J. Lucey)

* 2MASS XSC and PSC, WISE.
* SDSS
* J-plus
* Legacy survey

Photometry and targets

2MASS

SDSS



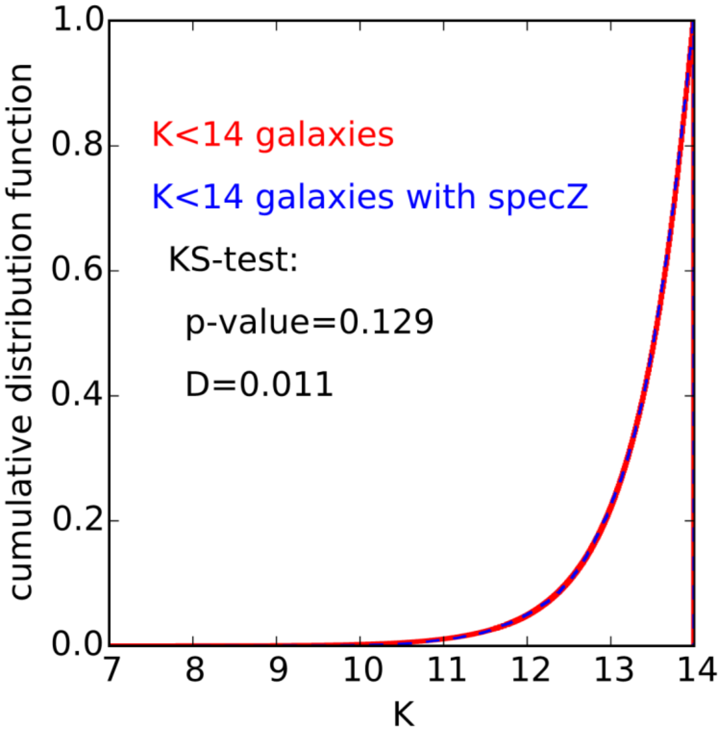
6.7 arc second fiber projection on the sky

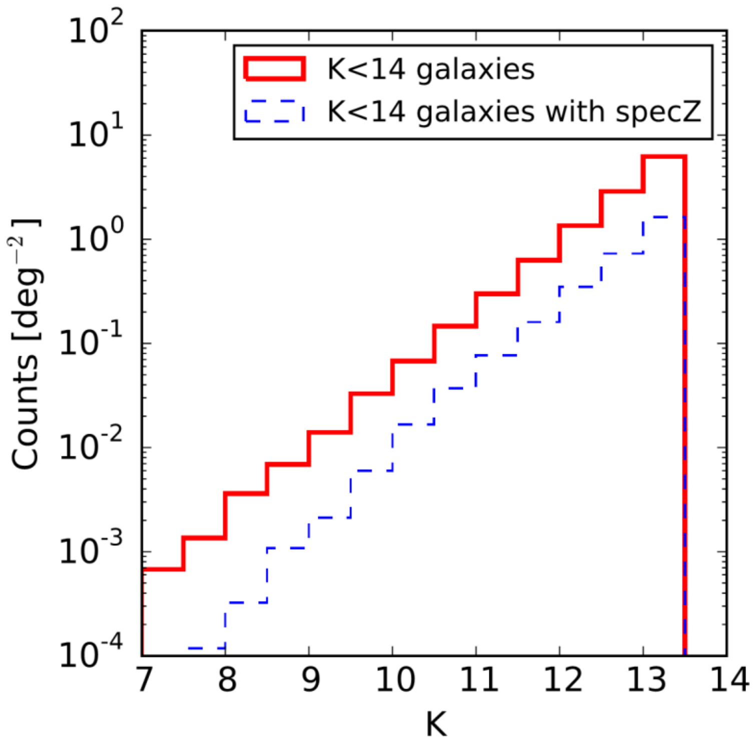
WHY K band ? K-band correlates best with stellar mass at low z

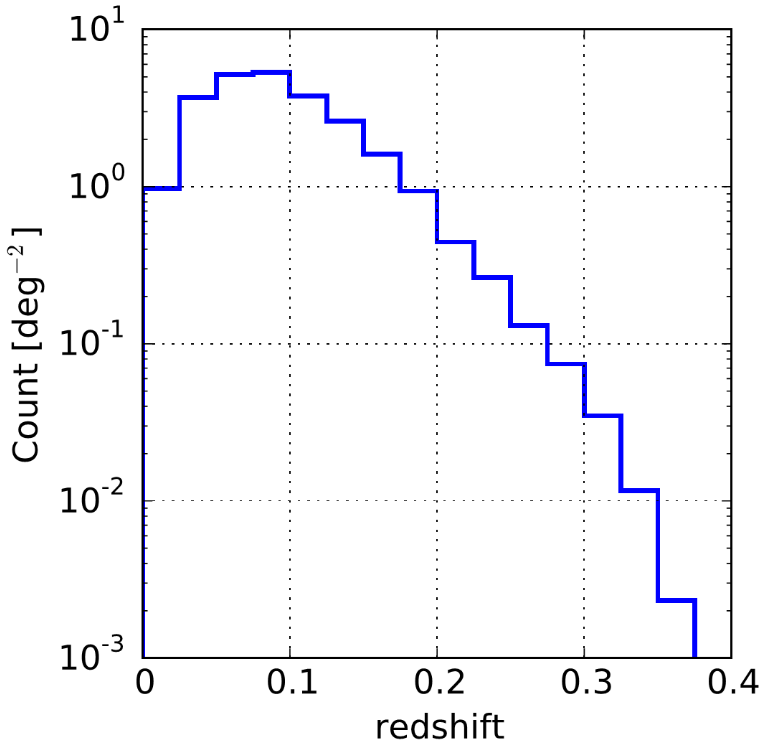
K<14 is the magnitude limit of 2MASS (can be improved / refined using WISE)

How many targets ? 853,458 XSC objects on 34,089 sq. deg. ($|g_{lat}|$>10, 82.6% full sky)

V(z<0.2)=0.64 $(\mathrm{Gpc}/h)^3$ V(z<0.07)=0.03 Density(0.07<z<0.2)=6.5 x $10^{-3}(\mathrm{Mpc}/h)^{-3}$







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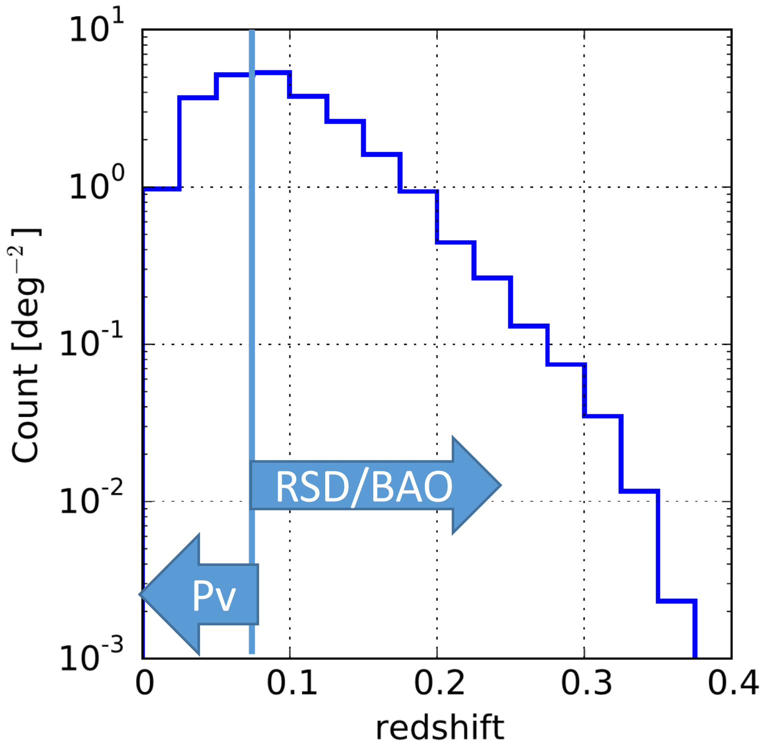
With about 20 targets per deg2 (half for peculiar velocities and half for RSD/BAO) :

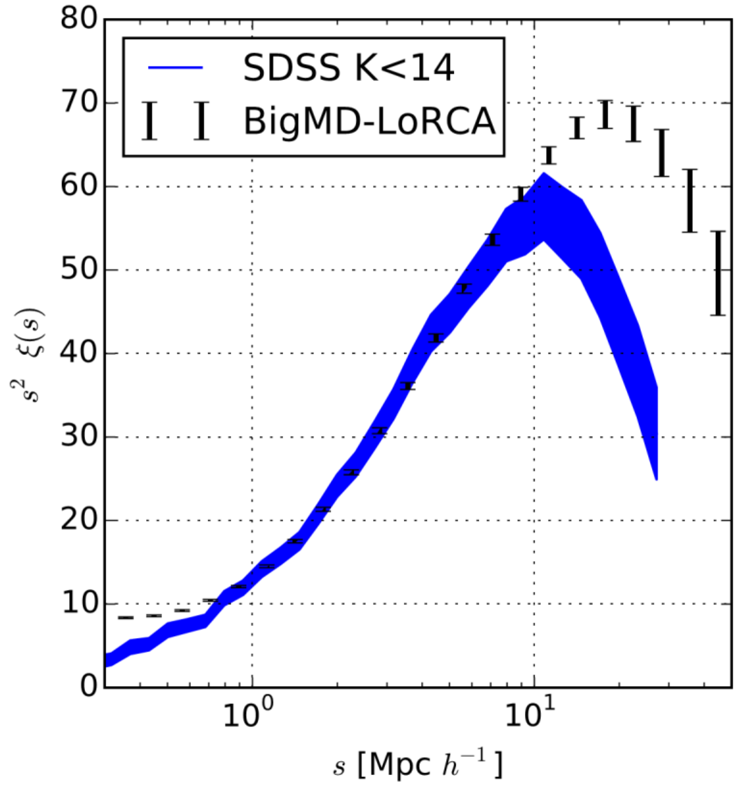
1,000 targets per field of view (50 deg2) : average visit per field with the Schmidt : 2.
=> Fiber collisions will be negligible.
=> Dynamical exposure time tuning with robotic fibers to increase fiber hour use efficiency by sub sampling bright galaxies

With 350 fiber per field for the science (50 stars, 50 sky), we need about 600 pointings to cover the desired 200, 000 targets + 100 pointings to overlap with SDSS : total 700 pointings.



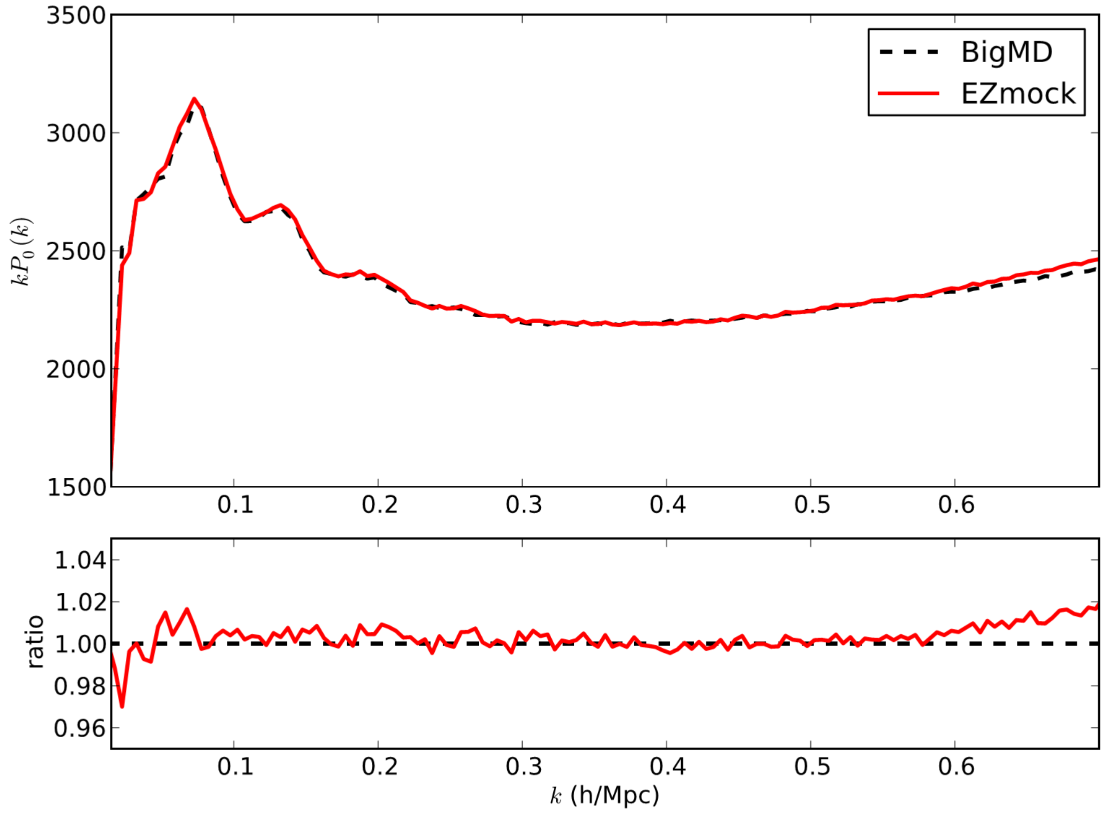
Clustering analysis

- Current data
  - On SDSS footprint, was observed a fair sample => clustering with 55,000 K<14 galaxies
  - 0.07 < z < 0.2
  - Bias = 1.5
- Simulation
  - MultiDark N body simulation (cosmosim.org).
  - L=2.5 Gpc/h, 3840 cube particles
  - Light-cone construction, 20 snapshots
  - Halo Abundance Matching
  - 8 independent LoRCA light cones



EZ mocks

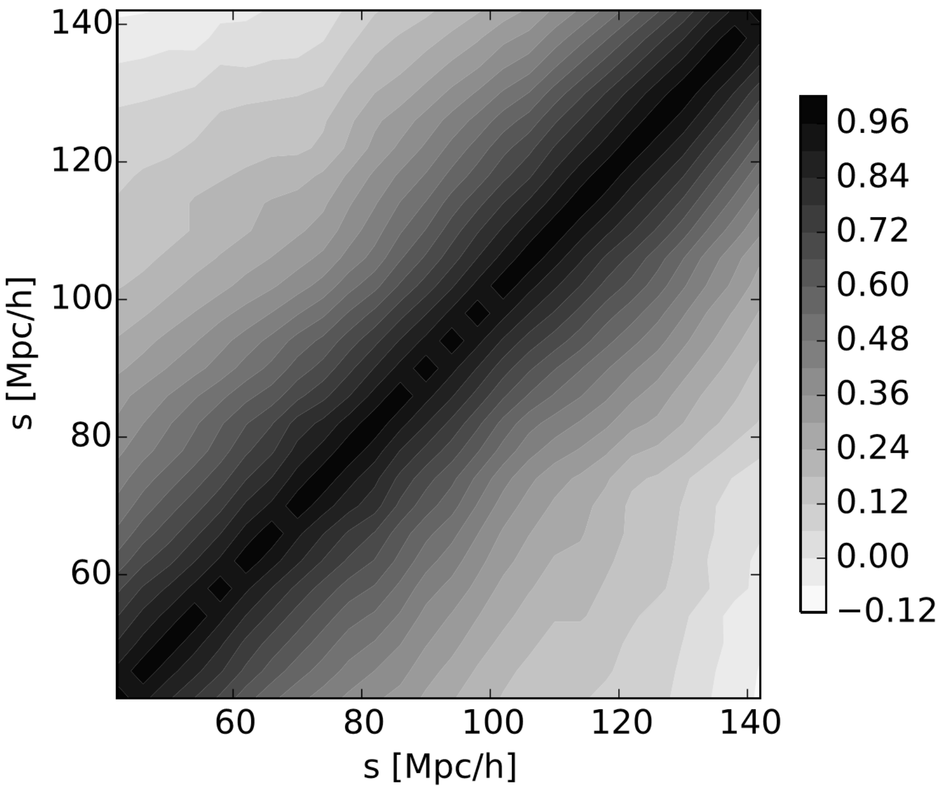
- Generates mocks with accurate clustering properties
- Based on Zel'dovich approximation + stochastic scale-dependent, non-local and non linear bias contributions
- 1pt, 2-pt function within 1% of N body simulation for r > 10Mpc/h
- Computing time = log normal mocks

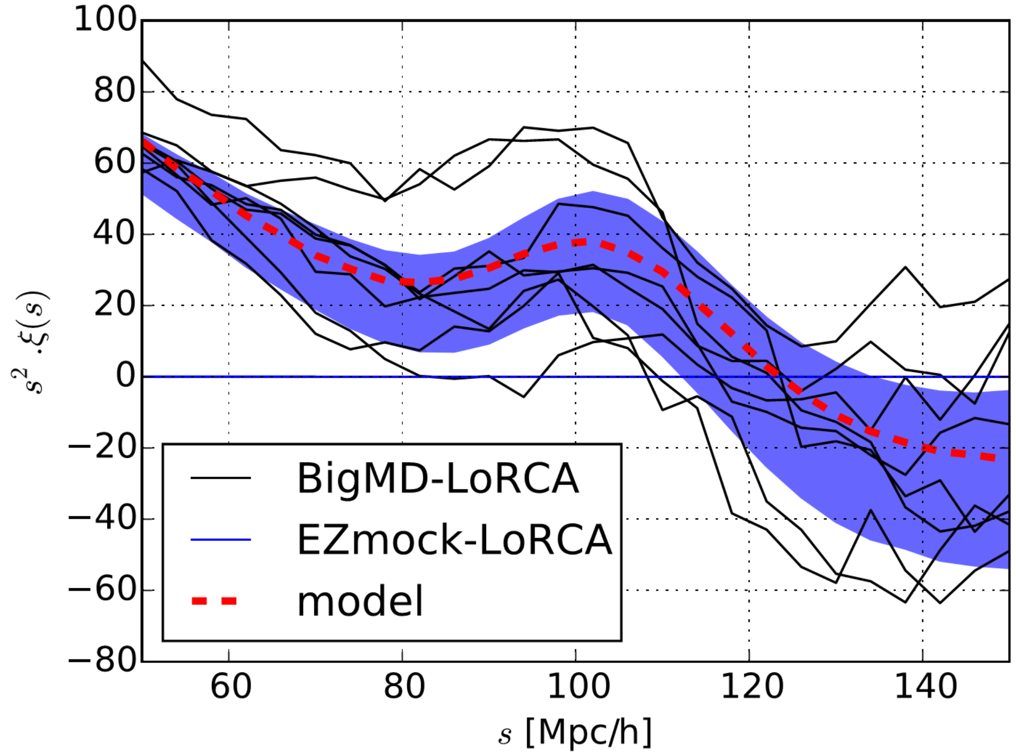


Chuang et al. 2014

BAO prediction

We generated 1,024 EZmocks light cones to compute the 2-pt function covariance matrix





Model to fit the BAO

- Model the 2-pt function including:
  - peculiar velocities
  - Nonlinear structure formation

$$P_{dw}(k) = P_{lin}(k) e^{\left(-\frac{k^2}{2k_\star^2}\right)} + P_{nw}(k) \left[1 - e^{\left(-\frac{k^2}{2k_\star^2}\right)}\right]$$

- Fit α

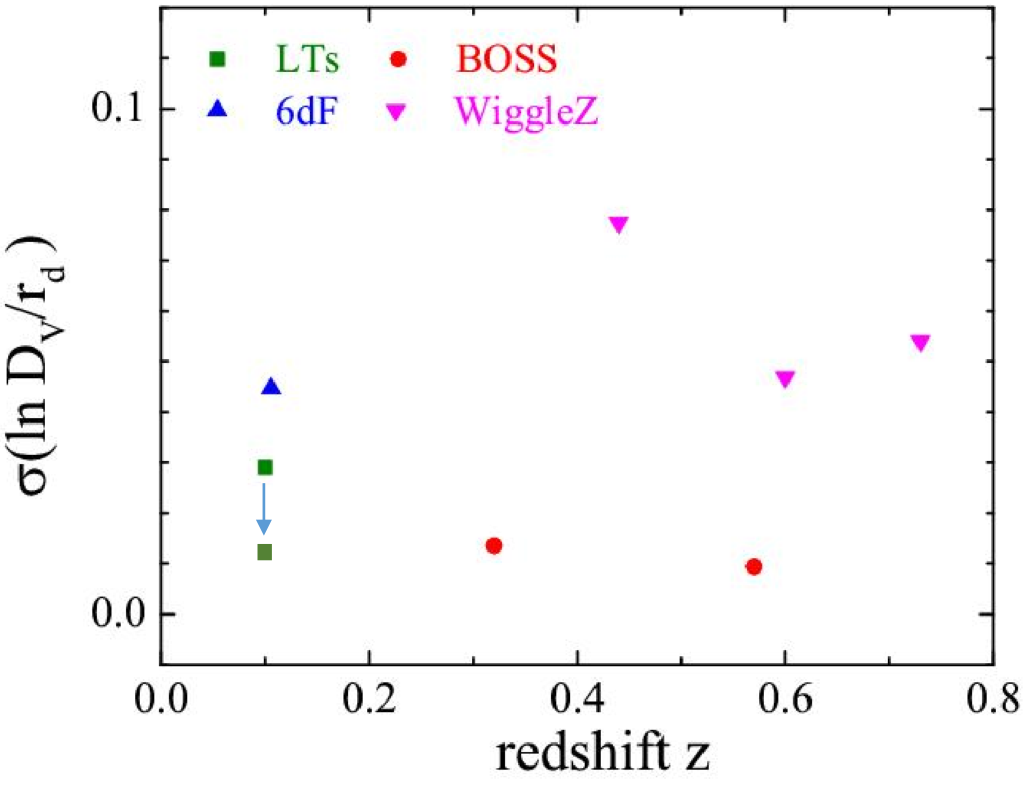
$$\xi_{th}(s) = \xi_{dw}(\alpha s)$$

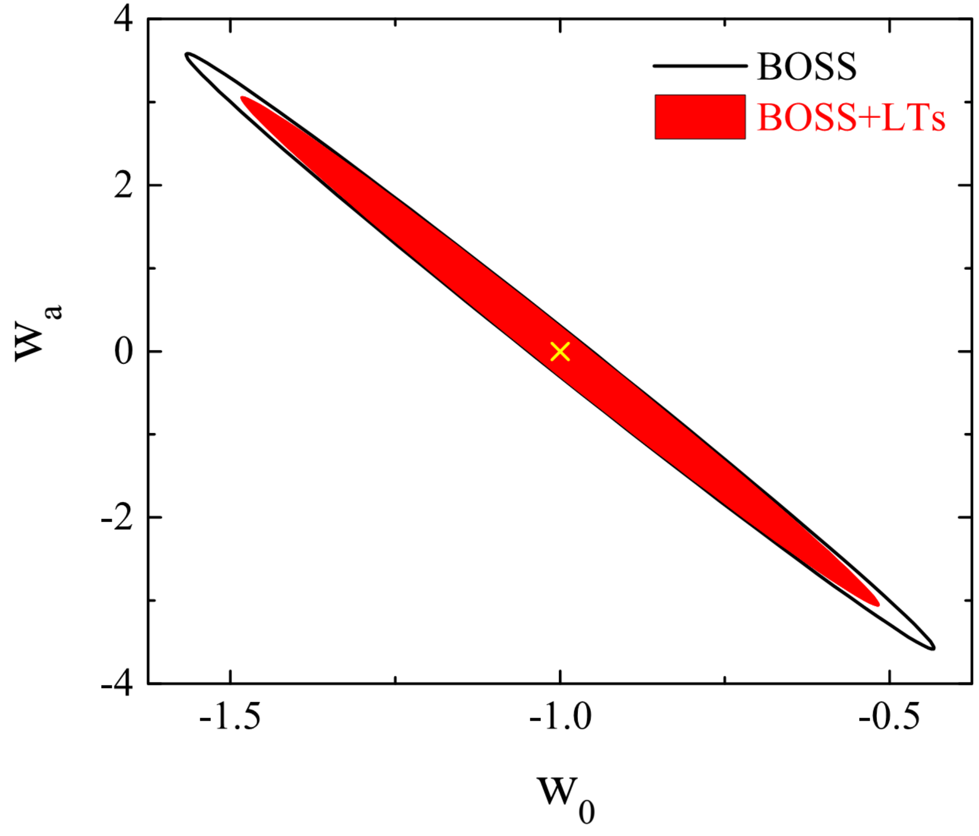
$$\chi^2_{\rm mock} \equiv \sum_{i,j=1}^{N_{\rm bins}} \left[\xi_{\rm th}(s_i) - \xi_{\rm mock}(s_i)\right] C_{ij}^{-1} \left[\xi_{\rm th}(s_j) - \xi_{\rm mock}(s_j)\right]$$

Full sky	α	σ_α	χ^2/d.o.f
Mock 1	1.001	0.051	0.60
Mock 2	1.013	0.035	0.90
Mock 3	0.939	0.029	1.06
Mock 4	0.979	0.043	0.93
Mock 5	0.966	0.022	1.13
Mock 6	1.059	0.063	0.80
Mock 7	0.936	0.027	1.49
Mock 8	0.986	0.032	1.01
Average	0.985	0.038 ± 0.016	0.99
Linear CF	1.001	0.012	

Predicted measurement

LTs = LoRCA + TAIPAN



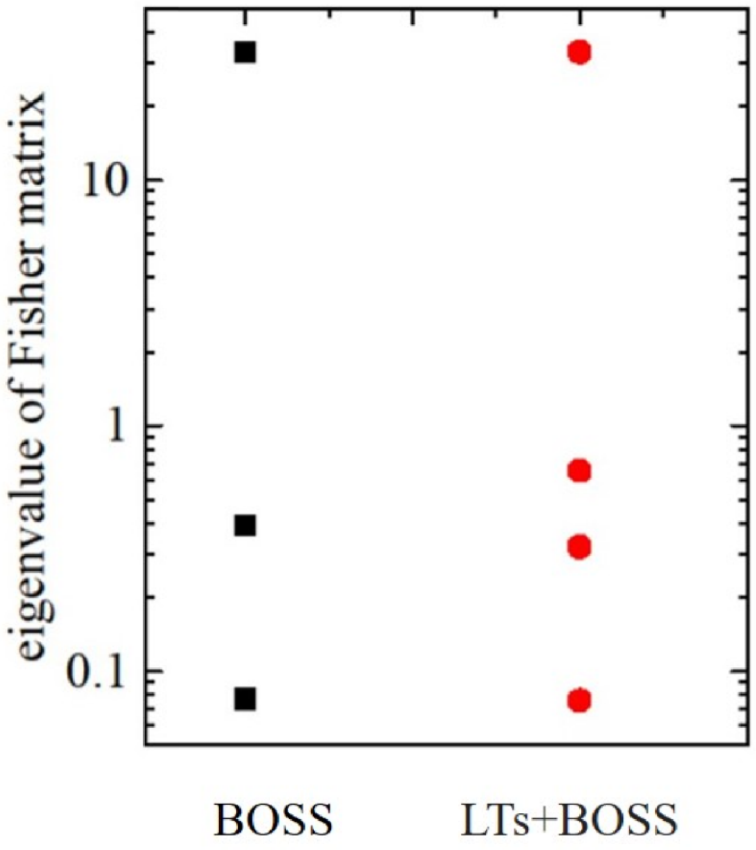


Dynamical Dark Energy

- w=-0.98(0.06) (Aubourg et al. 2014) allowing redshift variation gives a hint of DDE.

$$w(z) + 1 = \sum_i c_i e_i(z)$$

- It increases the sensitivity to low redshift mode variations
- FoM improves by 17%



Zhao et al. 2012

Adding observational systematics

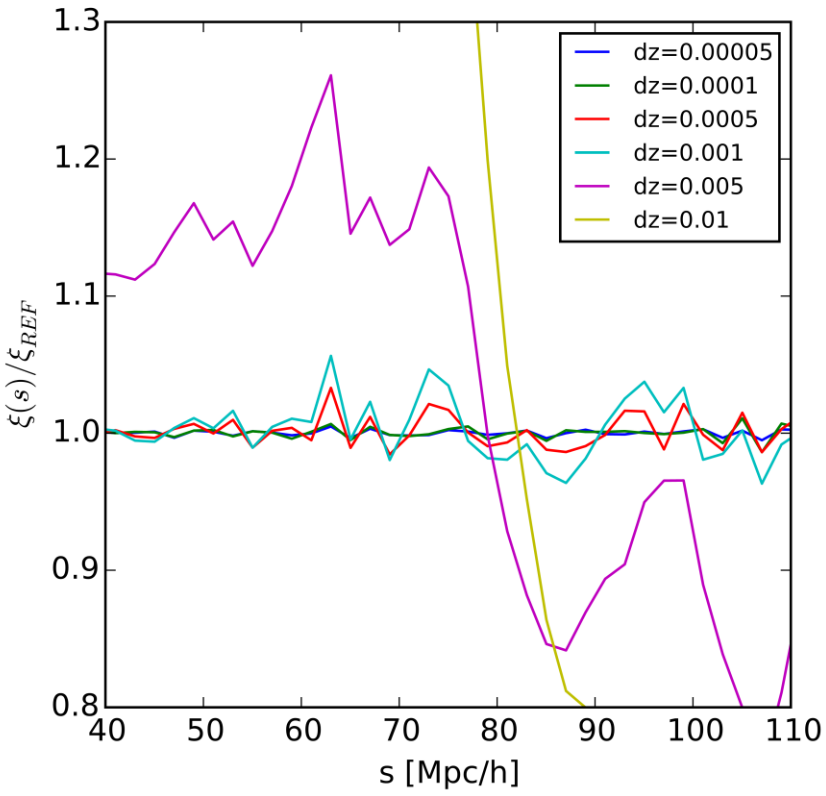
- 2-pt fct full shape fitting.
- Impact is small

$$\xi(\mathrm{r, with\ systematics}) = \mathrm{a}_0 + \frac{\mathrm{a}_1}{\mathrm{r}} + \frac{\mathrm{a}_2}{\mathrm{r}^2} + \xi(\mathrm{r, no\ systematics})$$

	α(no systematics)	$\chi^2/d.o.f.$	α(with systematics priors)	$\chi^2/d.o.f.$	α (with double priors)	$\chi^2/d.o.f.$
mock 1	1.001 ± 0.051	0.60	0.997 ± 0.062	0.683	1.002 ± 0.075	0.685
mock 2	1.013 ± 0.035	0.90	1.011 ± 0.039	1.025	1.011 ± 0.042	1.017
mock 3	0.939 ± 0.029	1.06	0.932 ± 0.038	0.956	0.937 ± 0.050	0.819
mock 4	0.979 ± 0.043	0.93	0.967 ± 0.041	1.014	0.967 ± 0.053	1.017
mock 5	0.966 ± 0.022	1.13	0.956 ± 0.022	0.980	0.953 ± 0.027	0.986
mock 6	1.059 ± 0.063	0.80	1.055 ± 0.063	0.747	1.049 ± 0.063	0.693
mock 7	0.936 ± 0.027	1.49	0.946 ± 0.026	1.537	0.944 ± 0.027	1.537
mock 8	0.986 ± 0.032	1.01	0.989 ± 0.044	1.108	0.993 ± 0.057	1.112
Average	0.985 ± 0.038	0.99	0.982 ± 0.041	1.01	0.982 ± 0.049	0.98

Redshift precision

- Simulate Gaussian redshift errors and check deviations in the 2PCF:
  - dz=0.0001 => dev<1%
  - dz=0.001 => dev<4%
  - Resolution need>1000
- Catastrophic errors
  - Ncata<1% => dev<1%
- 2MASS photoz catalog precision is dz=0.015



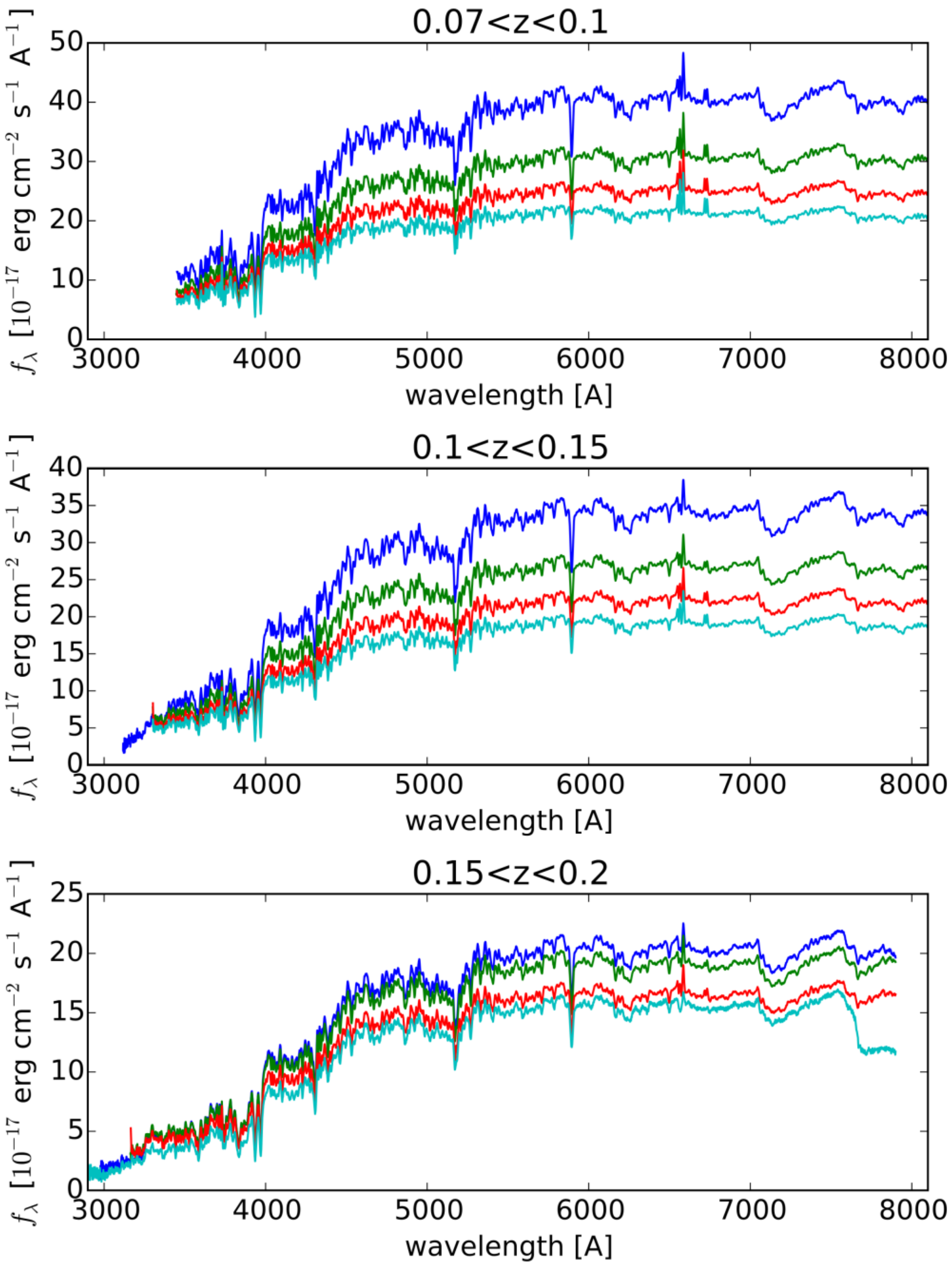
Instrumental set-up needed by L RCA

- Measuring 200,000 redshifts with dz<0.001 requires
  - Wavelength coverage: 3,600 A – 9,500 A
  - Resolution > 1,100 (aim 3,500)
  - T exposure = 3h
- Fiber of 100 micron is 6 arc second on the sky: order of the half light radius of the targeted galaxies
- Instrument
  - 80cm Schmidt reflector
  - Field of view 30x30 cm = 6.8ºx6.8º = 47 sq. deg
  - 450 robotic fiber positioners fixed on a curved focal plate
  - Fibers: 10 meters
  - One 2-arm spectrograph
- Dedicated facility
  - Remotely controlled

Website

- http://lorca-survey.ft.uam.es/

- Online data
  - BigMD mocks
  - EZ mocks
  - Galaxy spectra stacked as a function of redshift and magnitude



Peculiar velocities, stellar mass function

- Mapping the cosmic flows in the local volume (Courtois et al. 2013)
- Use the Fundamental Plane to estimate distance (Campbell et al. 2014)
- Constraint on the growth rate of structure improved by a factor of 2-5 (galaxy density alone).
- Expect 40 K<14 galaxies to be strong lenses on the full sky (SLACS extrapolated, Bolton et al. 2012)
- Galaxy – velocity and velocity – velocity power spectra leads to cosmological parameters (Johnson et al. 2014)
- Fiber size will allow accurate estimate of the stellar masses and reach the most accurate local mass function possible !

CASE/LoRCA timeline

- 2016:
  - Participate in the design of the instrument: state the requirements (now !)
  - Studies (volunteers welcome !):
    - the RSD measurements at $z=0.1$ (…)
    - peculiar velocities at $z<0.07$ (…)
    - Stellar mass function (…)
- 2017: optimize the survey (volunteers welcome !)
  - Target selection: create a database with the relevant imaging (Lucey, Comparat …)
  - End-to-end simulation from target selection to redshift fitting (…)
  - Survey strategy + exposure time calculator (…)
- 2018: start observations
- 2019, 2020, 2021: data releases + results

L o R C A

¿ Questions ?

Thank you for your attention

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