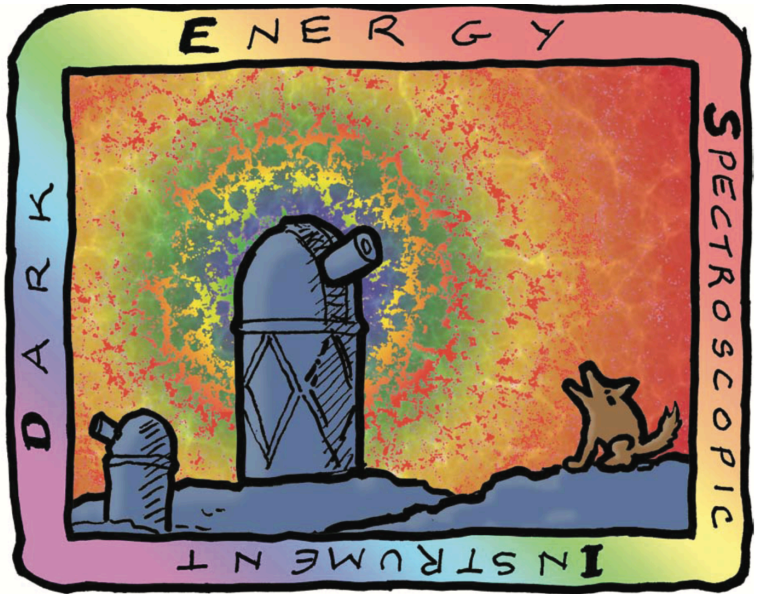
Dark Energy Spectroscopic Instrument(DESI)



Student: Jiacheng Meng
Advisor: Prof. Xiaofeng Wang
2018.11.2

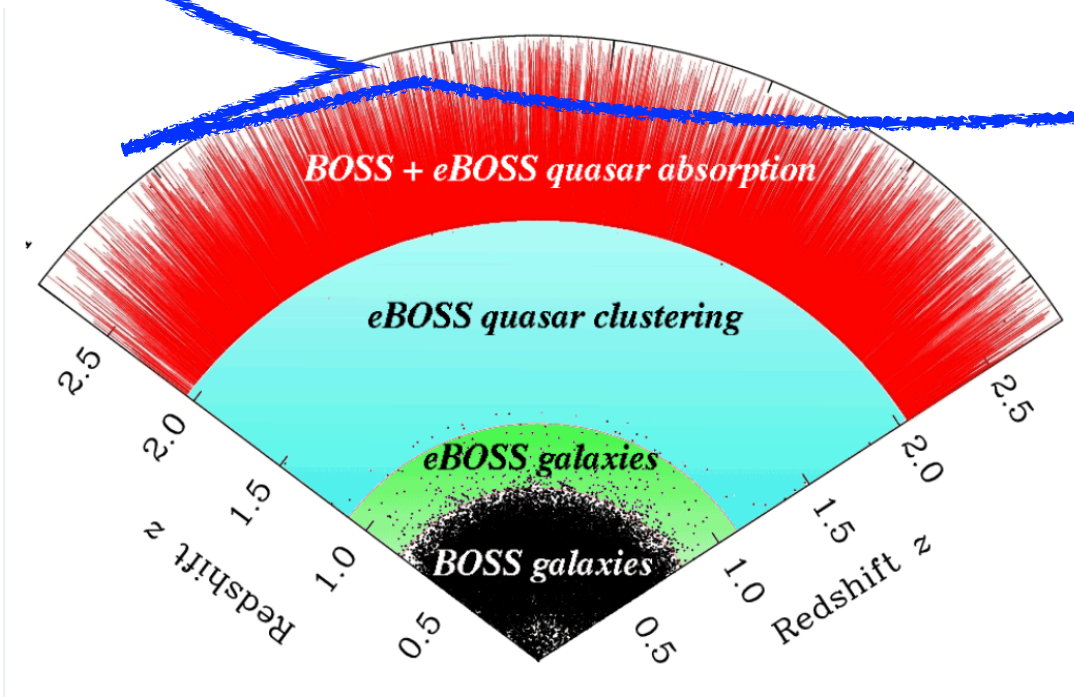
Content

1. The introduction of DESI
2. Survey design of DESI
3. Science goals of DESI
4. Complementarity with Other Surveys

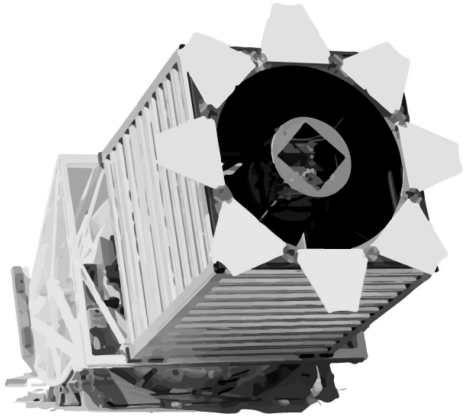
1. The Introduction of DESI

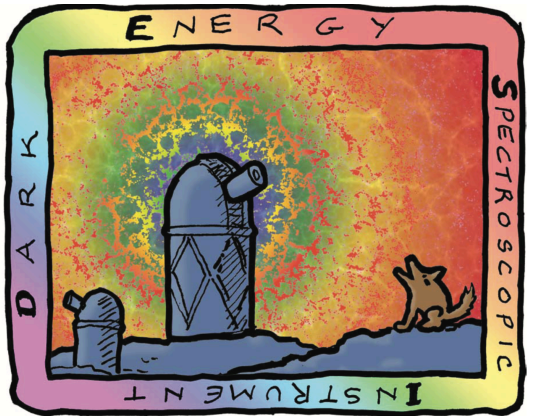
- DESI is a five-year galaxy redshift survey. It will start in 2019.
- Construct a 3D map of galaxies with 30 millions of galaxy's spectra.
- DESI is the successor to the successful BOSS survey.

Why do we need DESI survey?



Huge Success

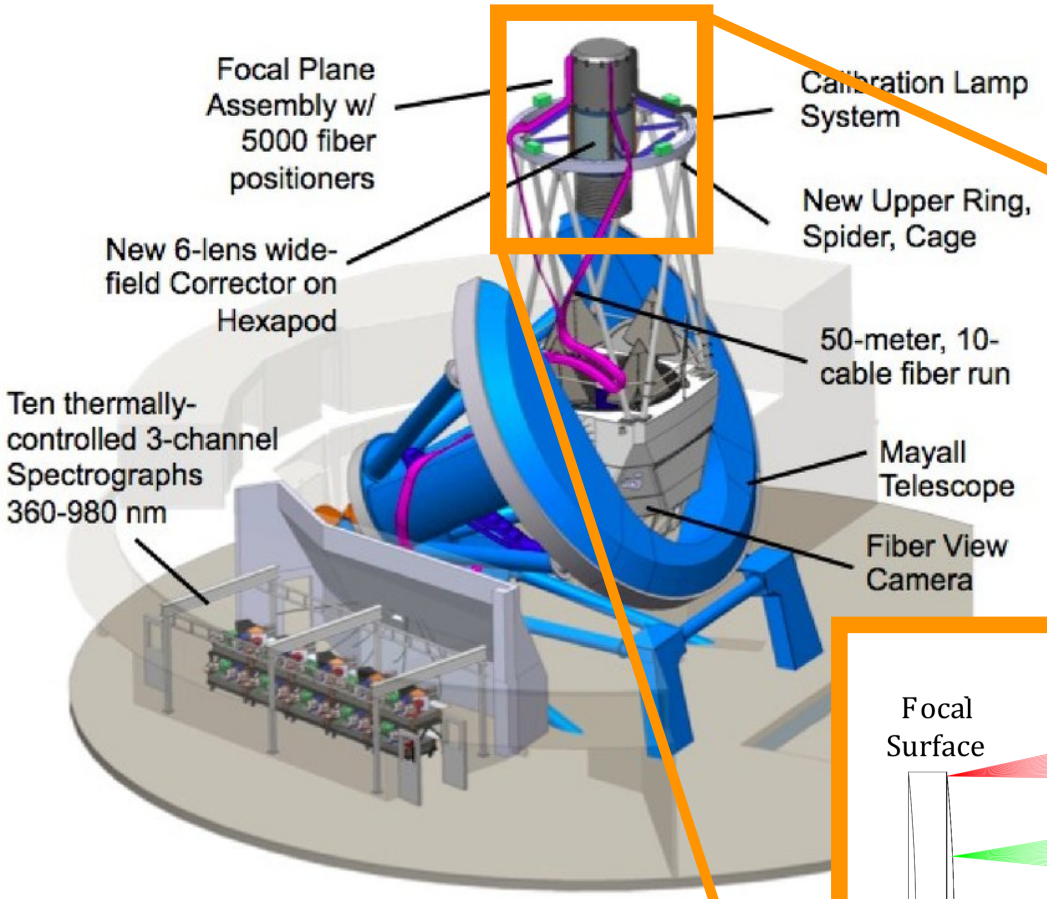


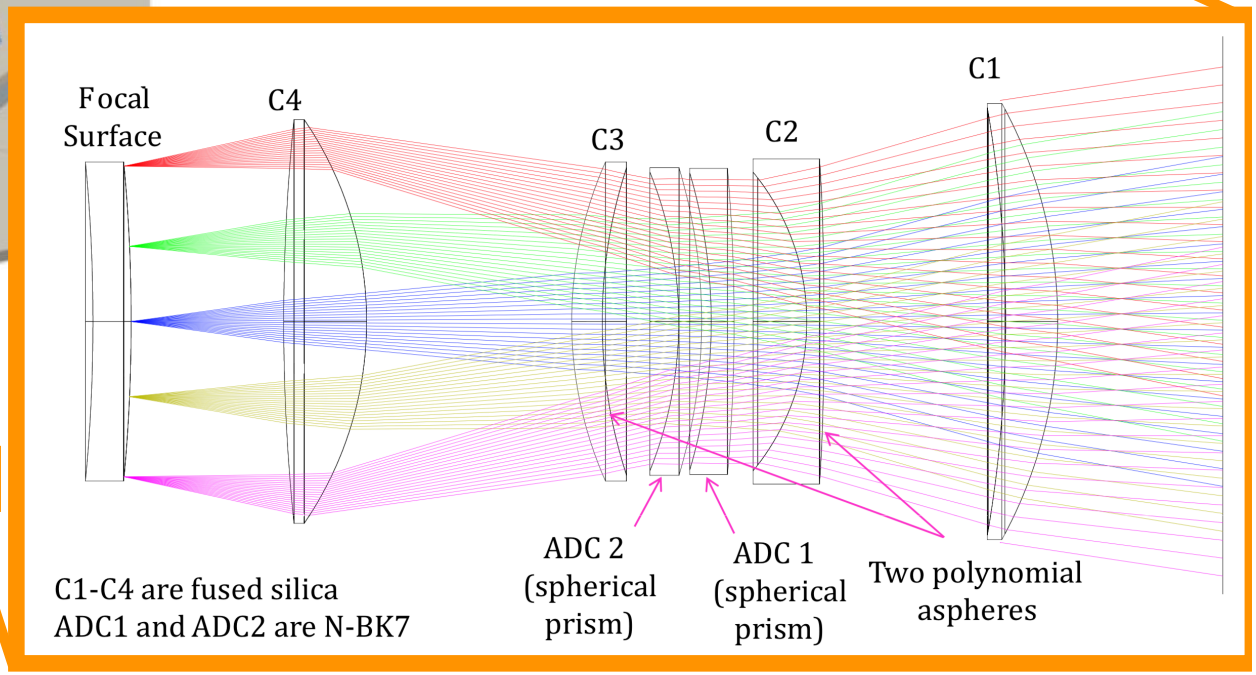


SDSS(BOSS, eBOSS)		DESI
2.5 m	**Diameter**	4 m
1000	**Number of fibers**	5000
2000	**Resolution**	2000~5500
360~1000nm	**Wavelength**	360~980nm
7 deg^2	**Field of view**	7.5 deg^2
BOSS: LRGs: 1.5M, 10,000 deg^2, z<0.7 QSOs: 0.16M, 2.2<z<3 **eBOSS:** LRGs: 0.3 M, 7,500 deg^2, 0.6<z<0.8 ElGs: 0.18M, 1,000 deg^2,0.6<z<1 QSOs: 0.57M, 7,500 deg^2, 0.9<z<3.5	**Targets number**	14,000 deg^2 LRGs: 4 M, 0.4<z<1 ElGs: 17 M, 0.6<z<1.6 QSOs: 2.4 M, z<3.5

Telescope

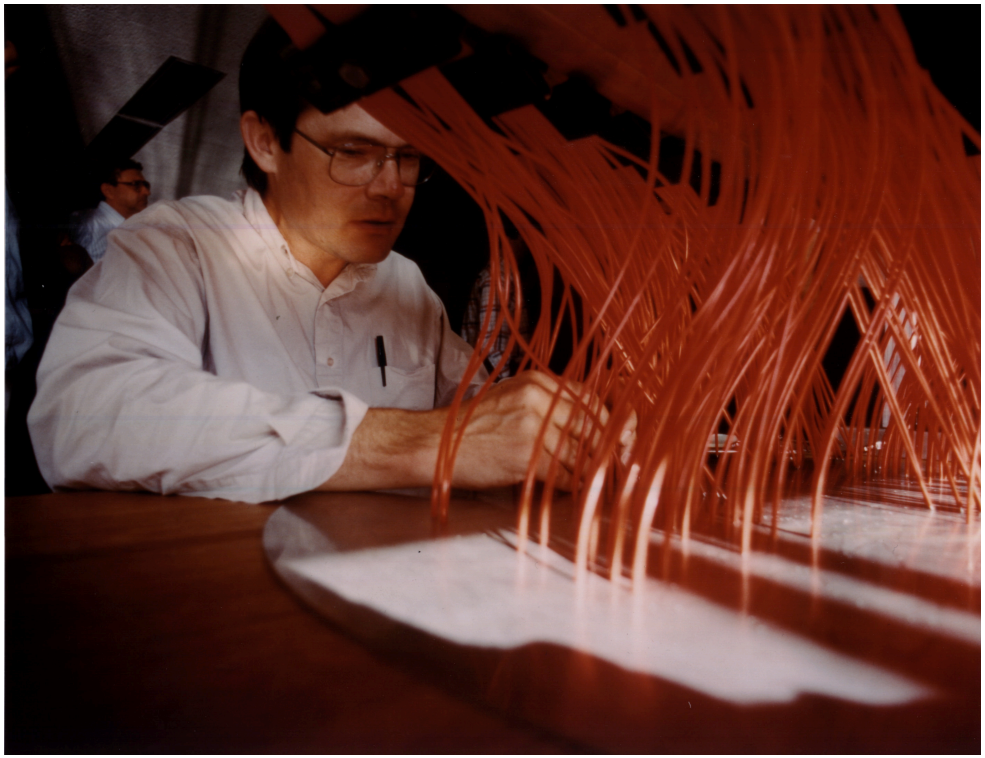
- Reflector telescope
- Prime focus
- Corrector is used to eliminate aberration to get larger FoV

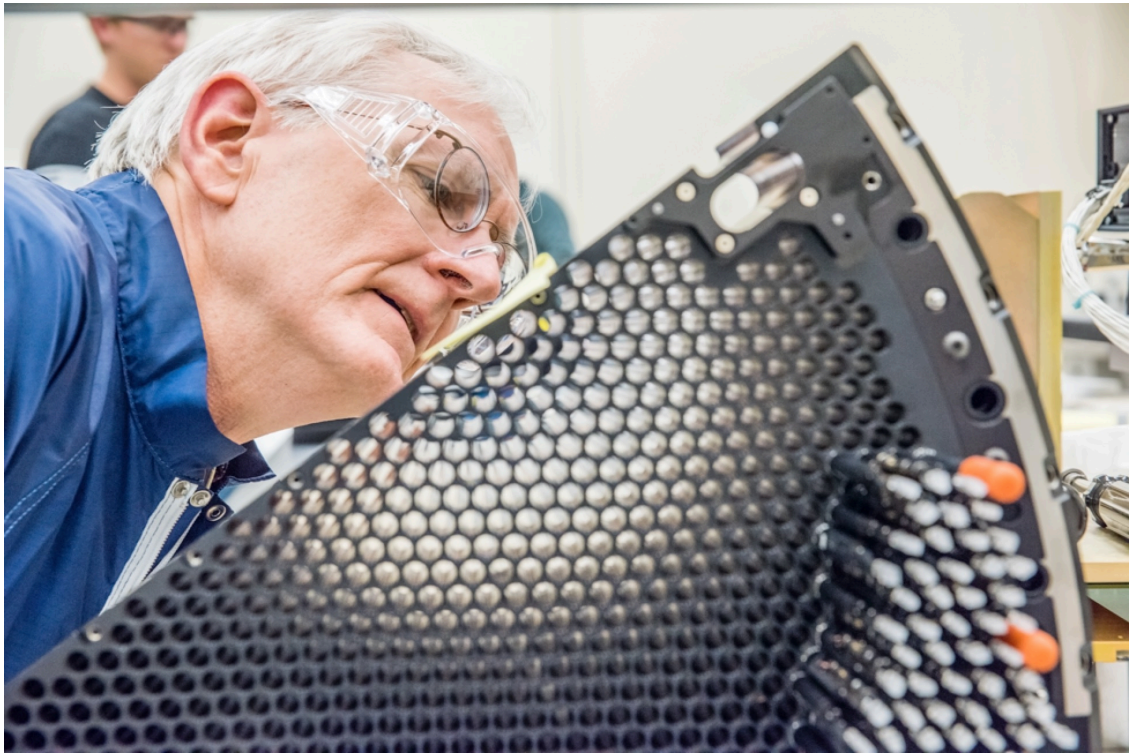




3-degree-diameter FoV

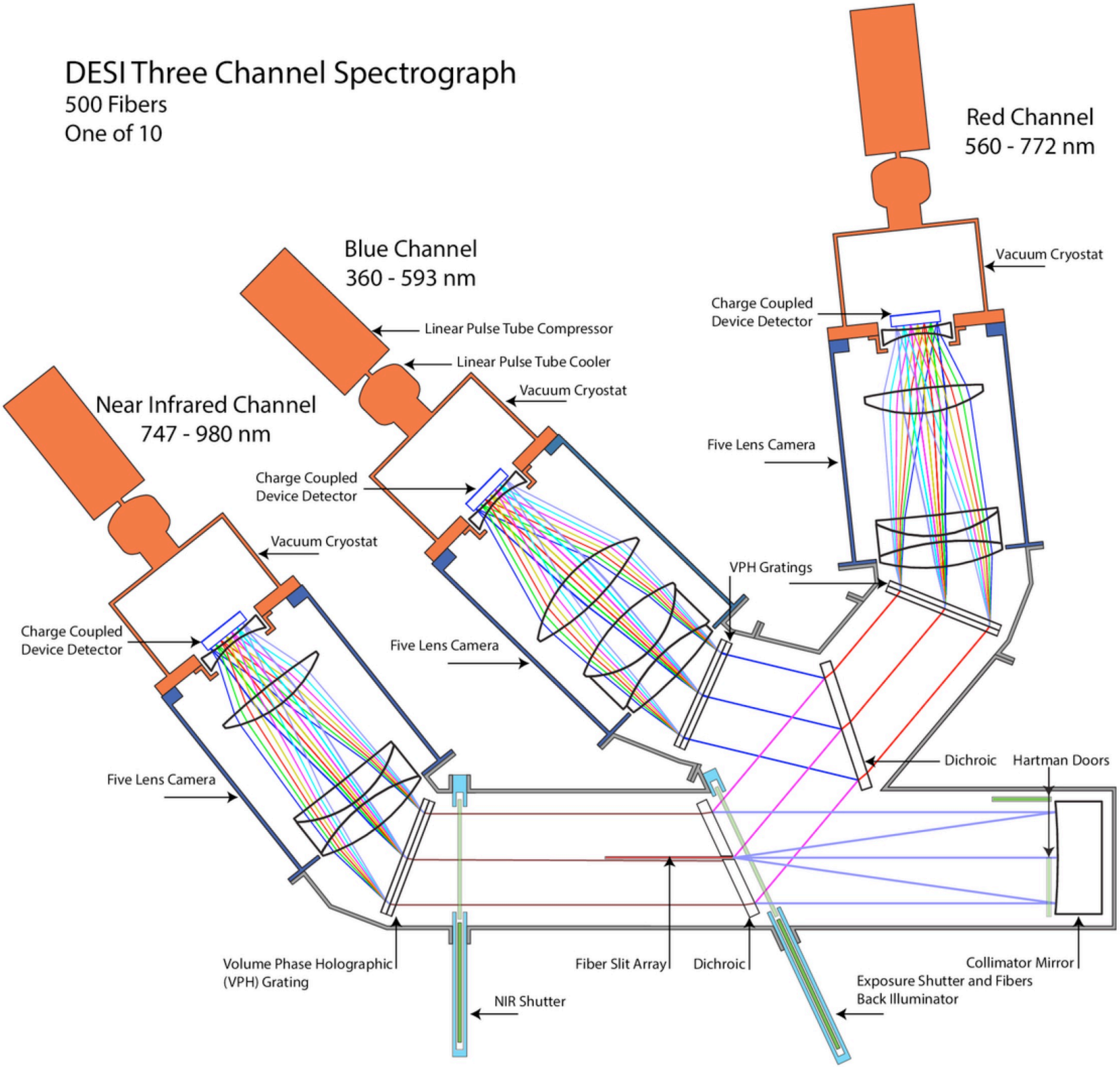
SDSS



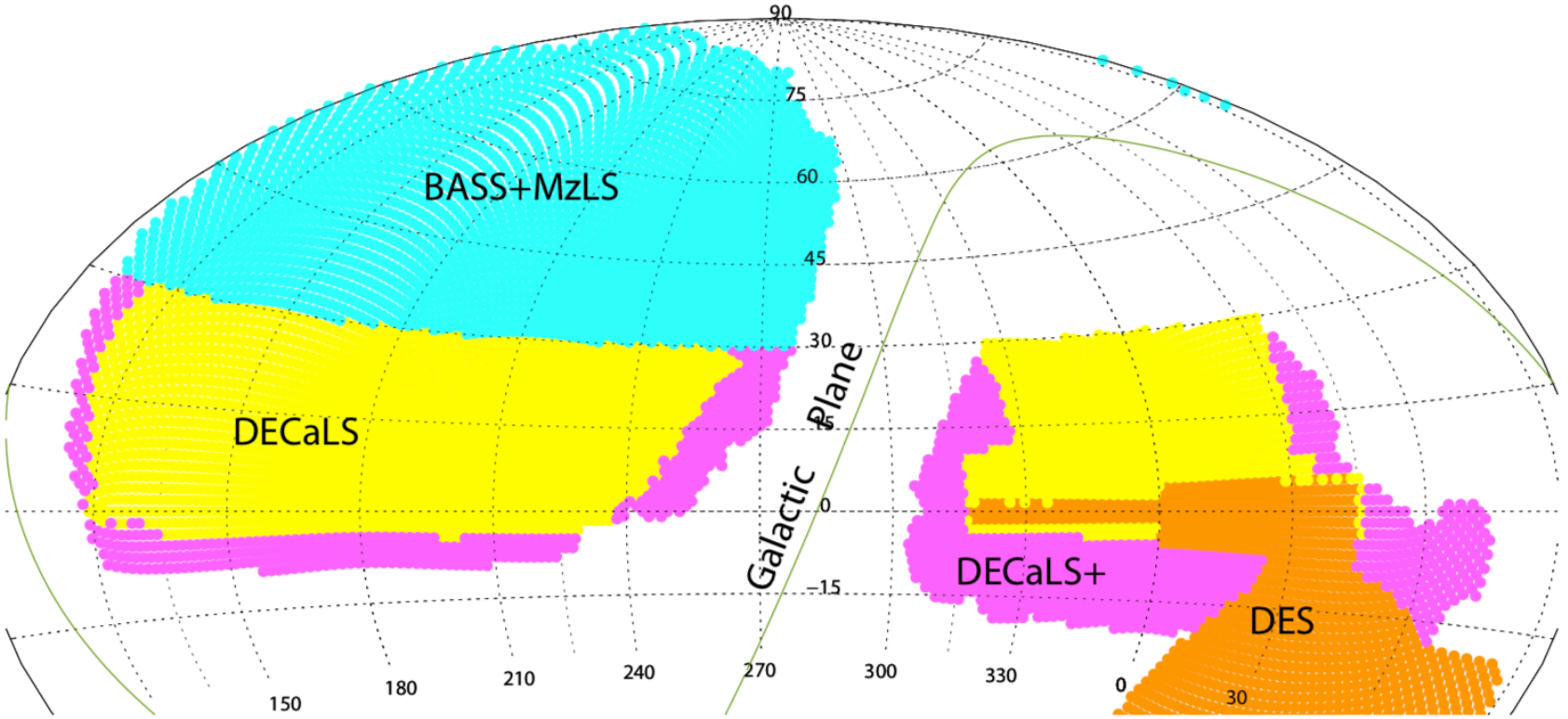


- 1000 fibers
- Fibers plugged into the halo by hand

- 5000 robotic positioners
- Reconfigured within 3 minutes
- All aotumatic!

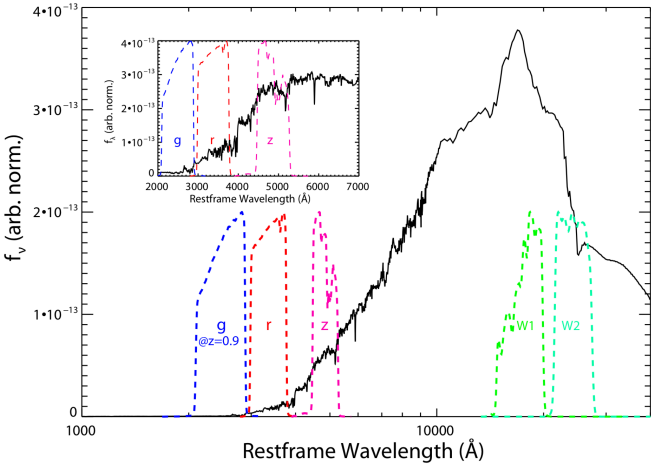

DESI Three Channel Spectrograph
500 Fibers
One of 10
Red Channel
560 - 772 nm
Blue Channel
360 - 593 nm
Near Infrared Channel
747 - 980 nm
Linear Pulse Tube Compressor
Linear Pulse Tube Cooler
Vacuum Cryostat
Charge Coupled
Device Detector
Five Lens Camera
VPH Gratings
Dichroic
Hartman Doors
Volume Phase Holographic
(VPH) Grating
NIR Shutter
Fiber Slit Array
Exposure Shutter and Fibers
Back Illuminator
Collimator Mirror

2. Survey design of DESI

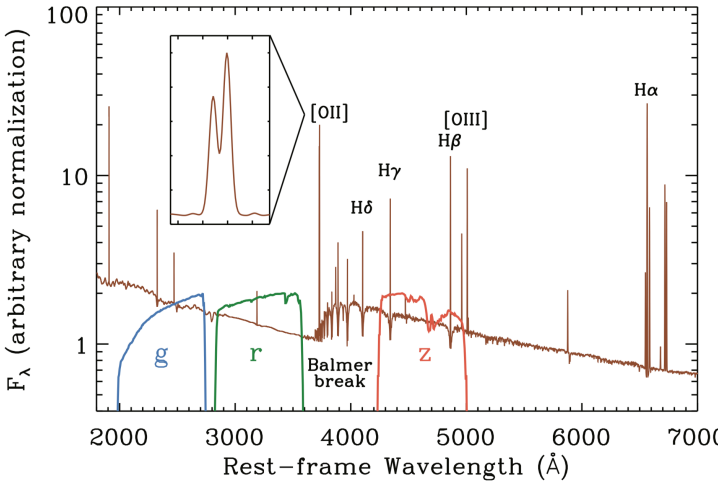


Survey	Bands	Location	Area/deg^2
BASS	g, r,	NGC+SGC (Dec ≤ +34 deg)	9k
DECaLs	g, r, z	NGC (Dec ≥ +34 deg)	5k
MzLS	z	NGC (Dec ≥ +34 deg)	5k
WISE-W1,W2	3.4, 4.6μm	All-sky	All-sky

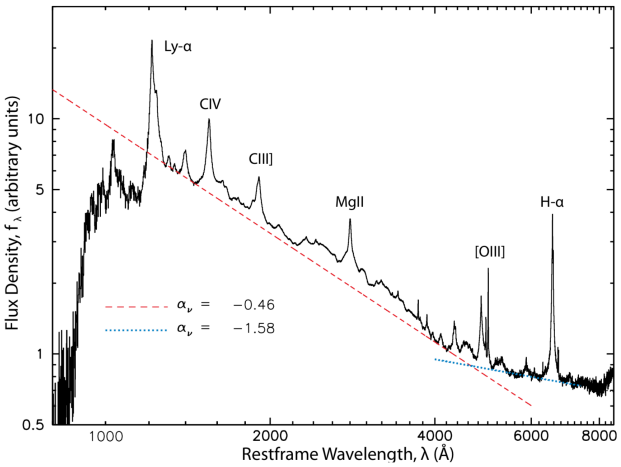
Galaxy Type	Redshift range	Bands used	Number
Luminous red galaxy (LRG)	0.4~1.0	r, z, W1	4 M
Emission line galaxy (EIG)	0.6~1.6	g, r, z	17.1 M
Quasi-stellar object (QSO) (tracers)	< 2.1	g, r, z, W1, W2	1.7 M
Quasi-stellar object (QSO) (Ly-α)	> 2.1	g, r, z, W1, W2	0.7 M
Bright galaxy sample (BGS)	0.05~0.4	r	9.8 M



LRG



EIG

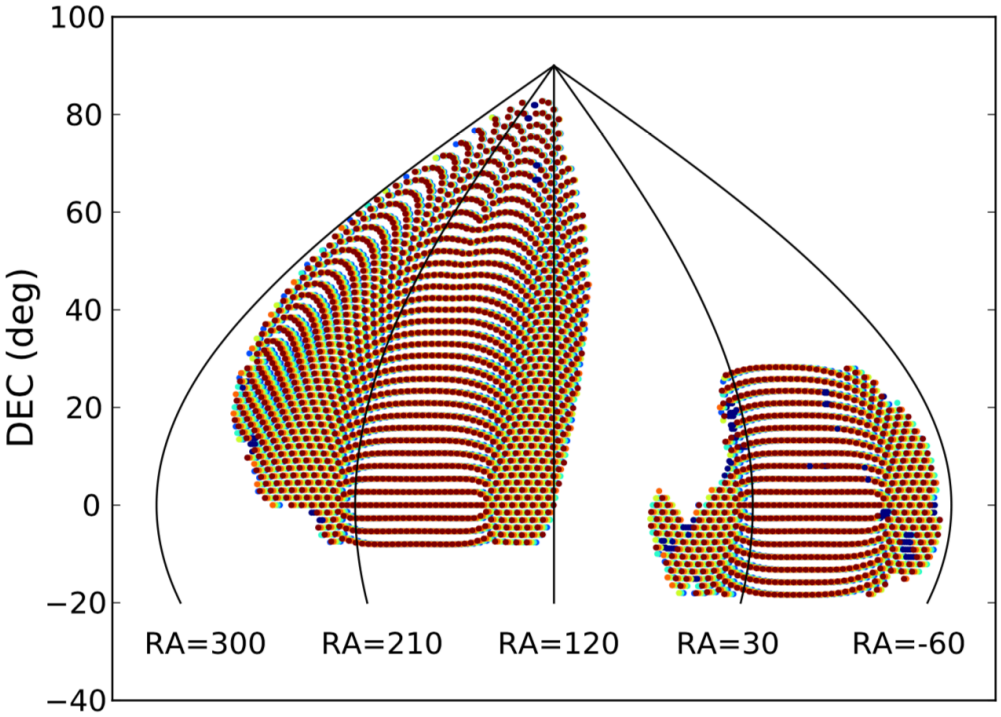


QSO

2000 tiles cover 14000 deg^2

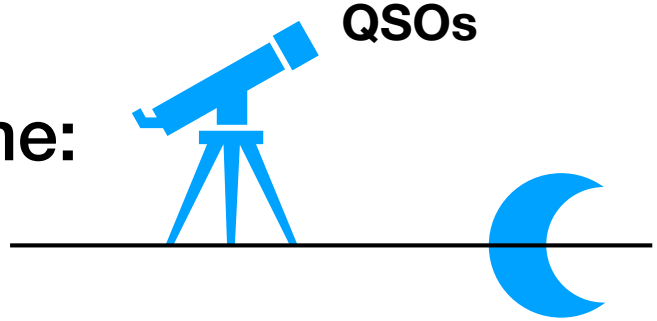
A layer

5 layers in total



Dark time:

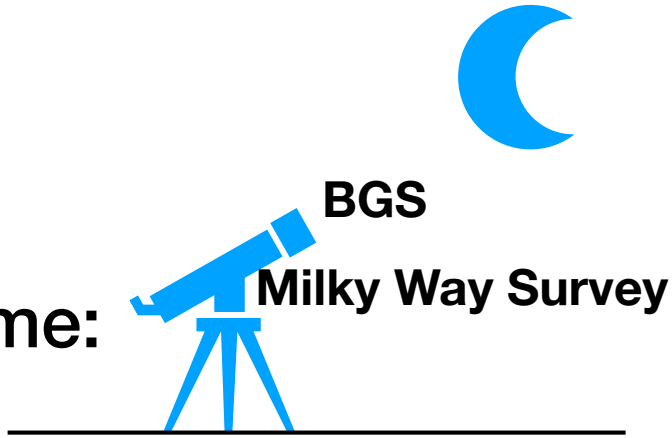
LRGs
EIGs
QSOs



Bright time:

BGS

Milky Way Survey



3. Science Goals of DESI

The nature of Dark Energy

Type Ia supernova

Accelerated expansion universe

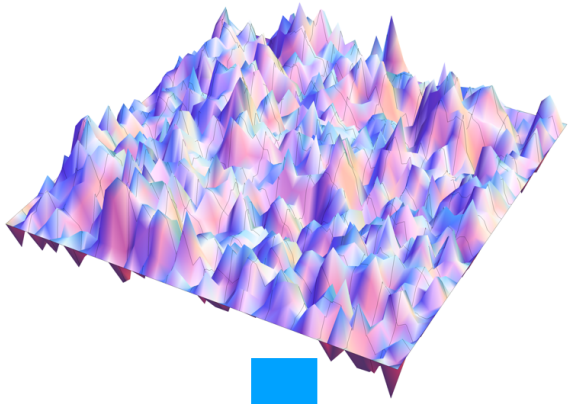
$$\rho = wp$$

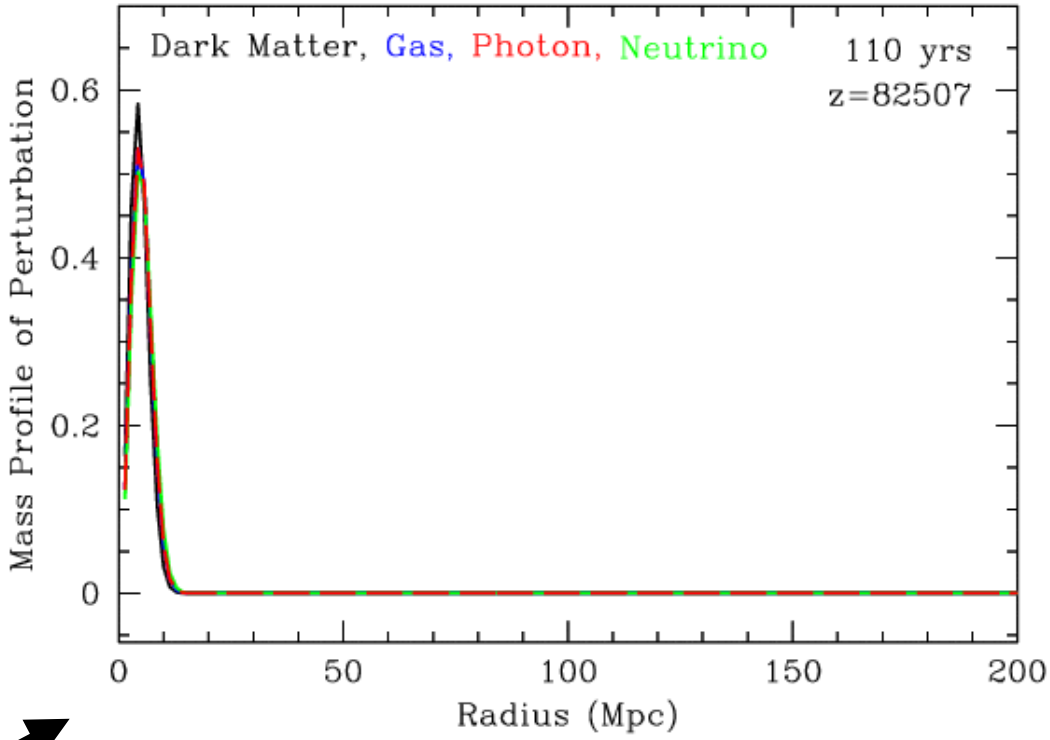
Explanation:

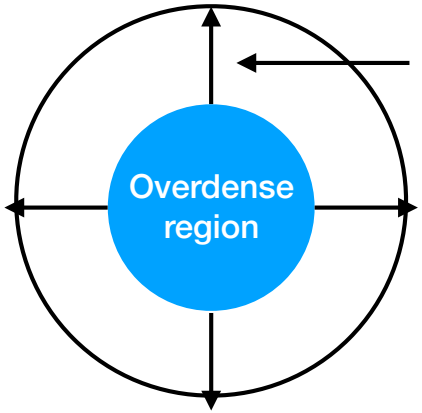
1. Cosmological constant → $w = -1$
2. Dynamical dark energy → $w(a) = w_0 + (1-a)w_a$
3. Failure of GR

Baryon Acoustic Oscillations(BAO)

Quantum fluctuations from inflation

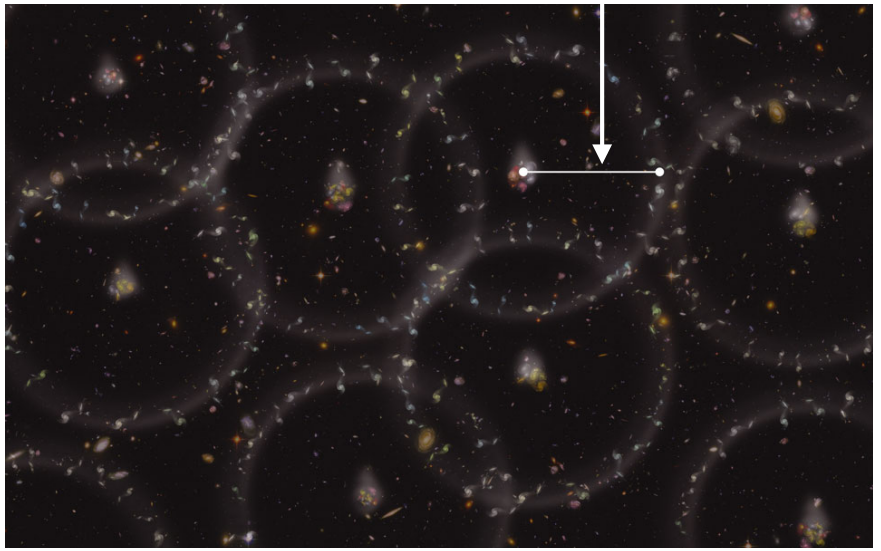




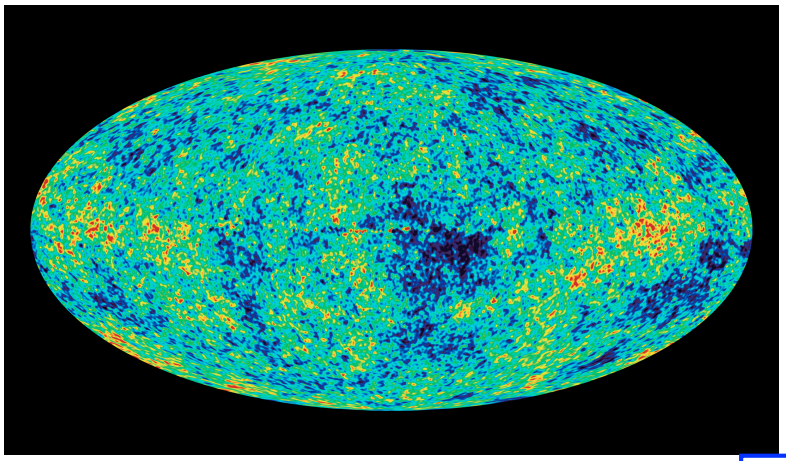


Sound wave

Sound horizon



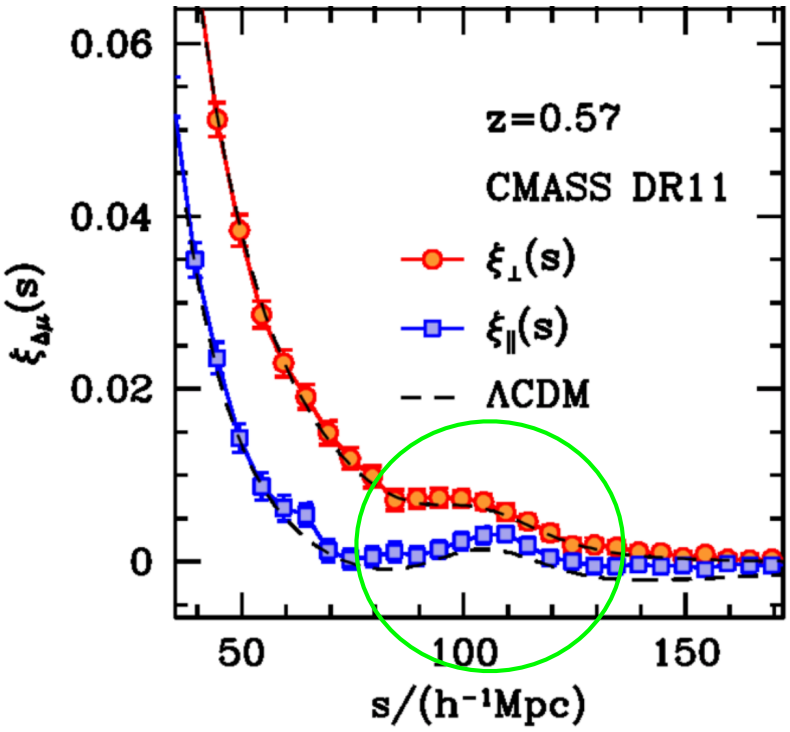
BAO: standard ruler



Sound horizon:150 Mpc,

precision 0.3%

Two-point correlation function

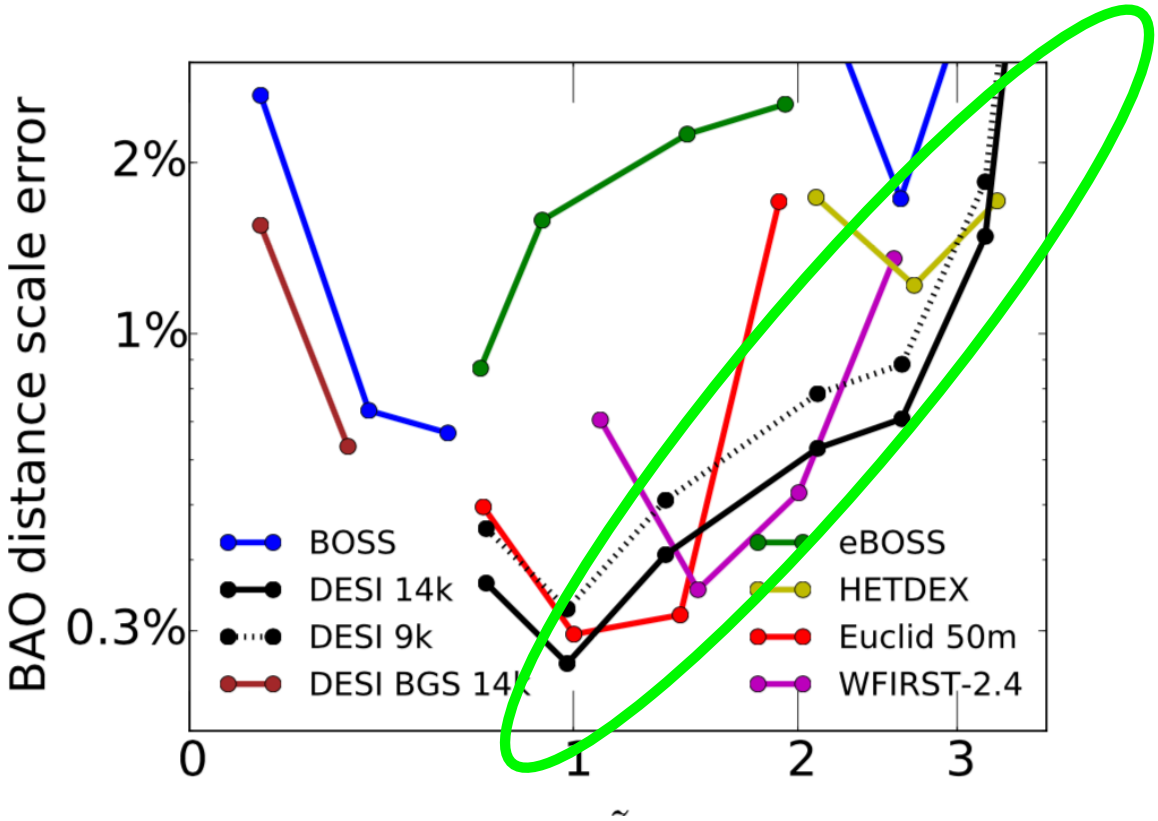


Viewed transversely $s = (1+z)D_A\theta = \theta\int_0^z \frac{cdz'}{H(z)'}$

Viewed along the line of sight $\frac{c\Delta z}{H(z)} \approx s$

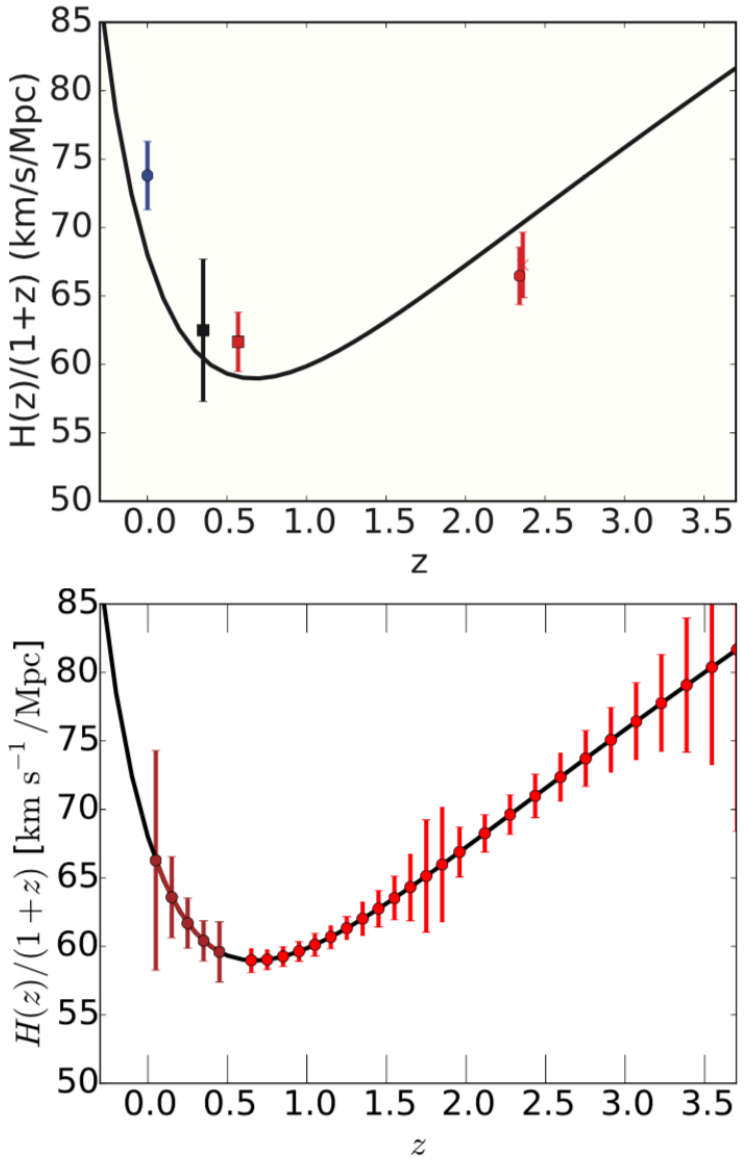
$H(z)$

Constrain cosmological parameter, distinguish different dark energy model.

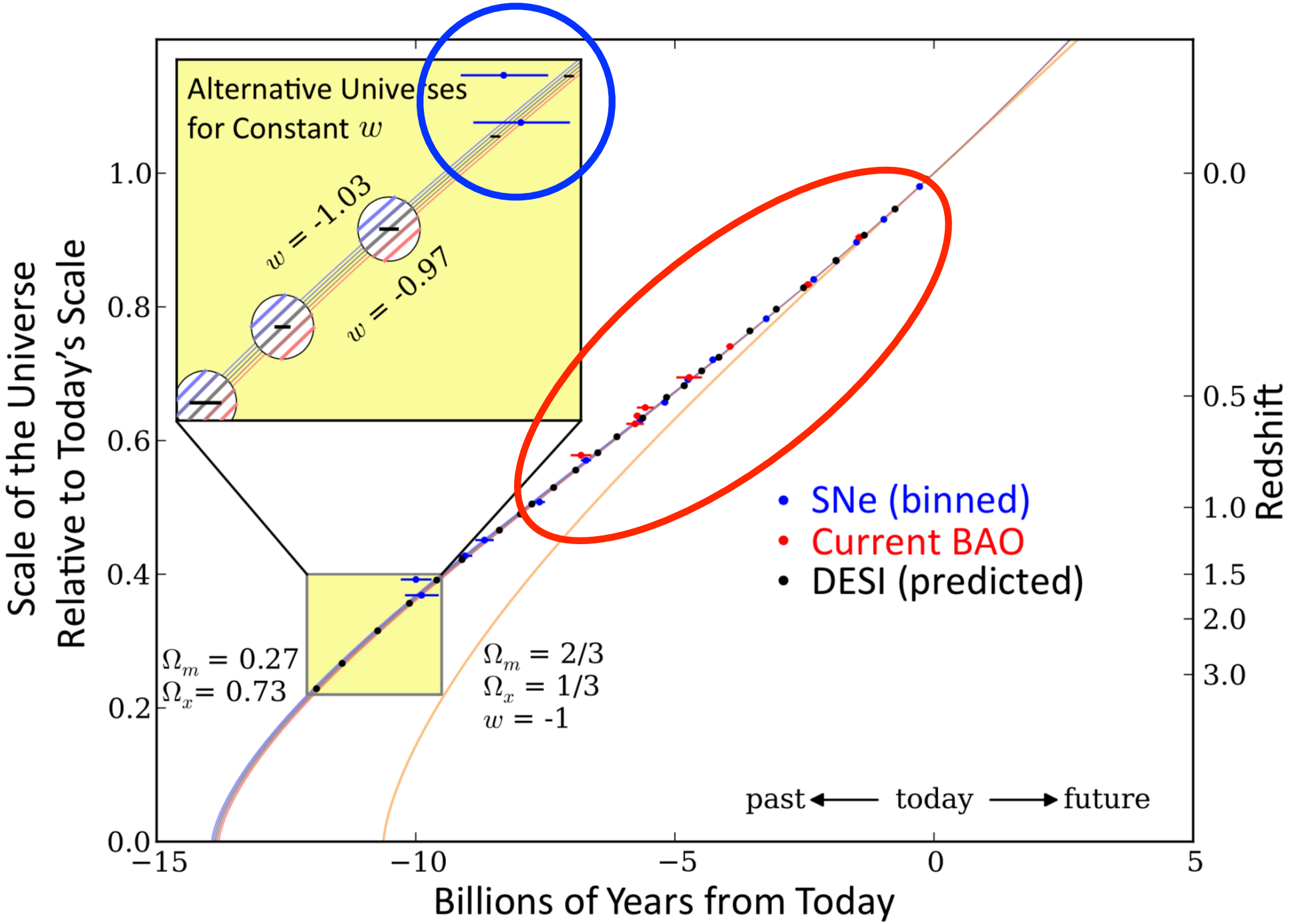


BAO distance scale error from different redshift survey

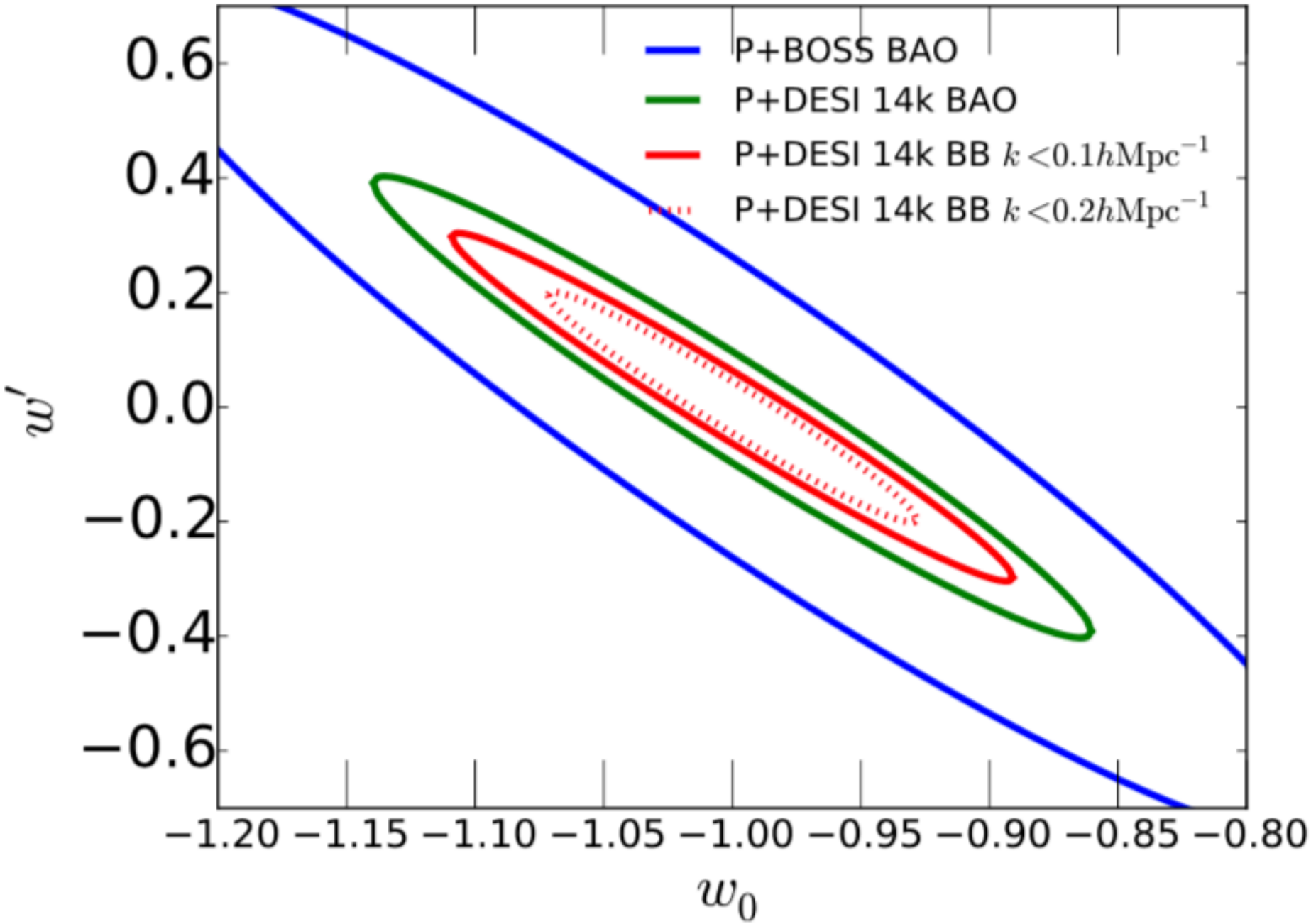
DESI have better BAO measurement



Expansion rate of the Universe as a function of redshift. Upper plot is the result from BOSS. The lower plot is the result predicted by DESI


Alternative Universes
for Constant w
w = -1.03
w = -0.97
SNe (binned)
Current BAO
DESI (predicted)
Ω_m = 0.27
Ω_x = 0.73
Ω_m = 2/3
Ω_x = 1/3
w = -1
past
today
future
Scale of the Universe
Relative to Today's Scale
Billions of Years from Today
Redshift
0.0
0.2
0.4
0.6
0.8
1.0
−15
−10
−5
0
5
0.0
0.5
1.0
1.5
2.0
3.0

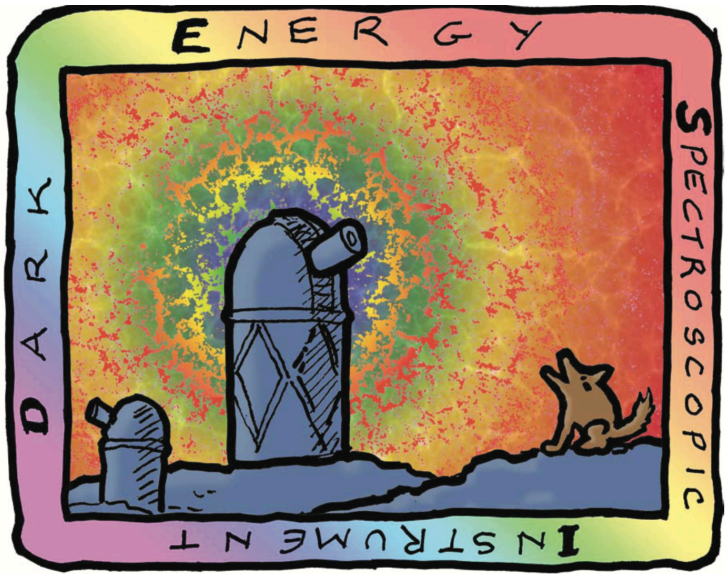
The w0 – wa plane showing projected limits (68%) from DESI and BOSS



4. Complementarity with Other Surveys

Image Survey

DARK ENERGY
SURVEY

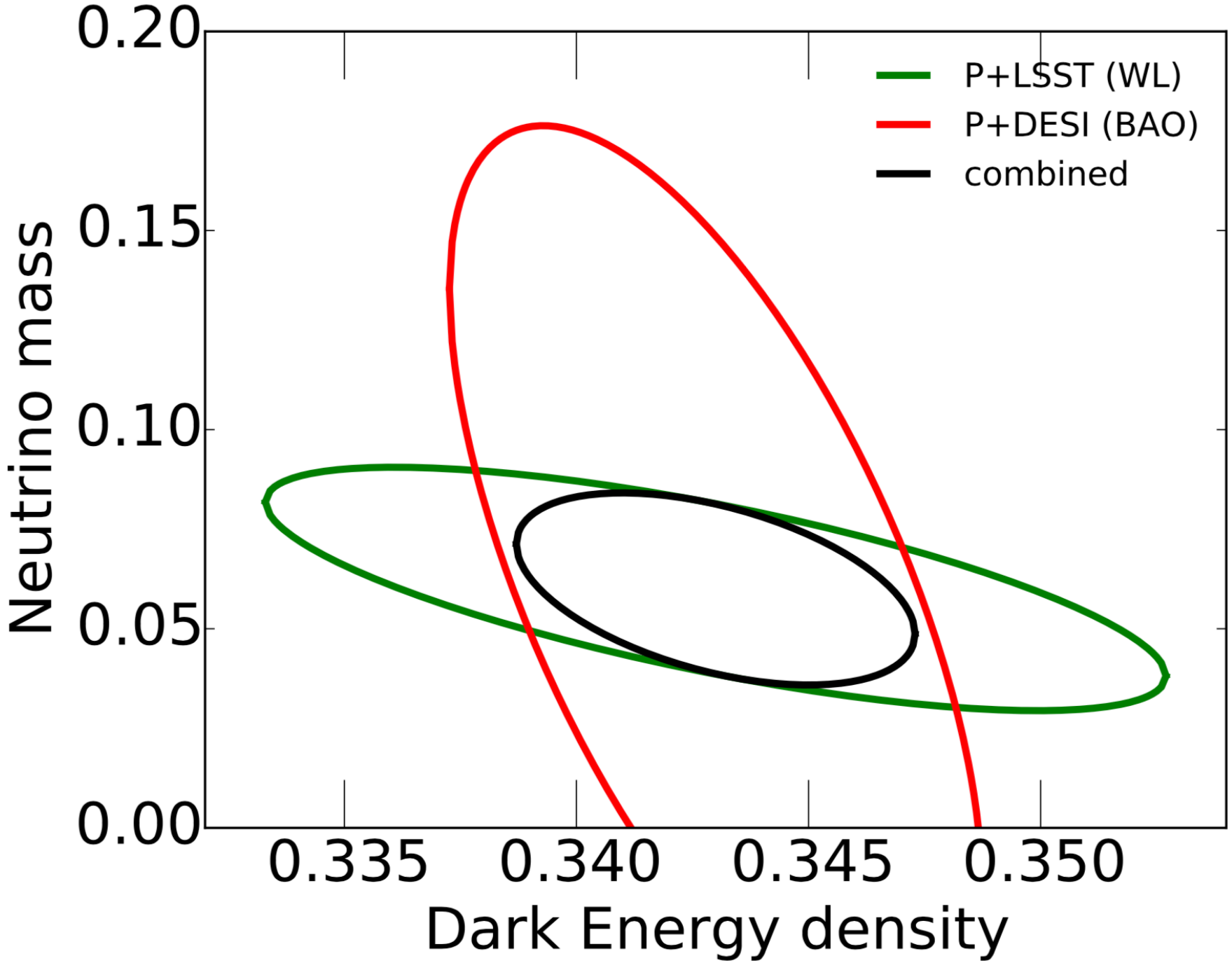


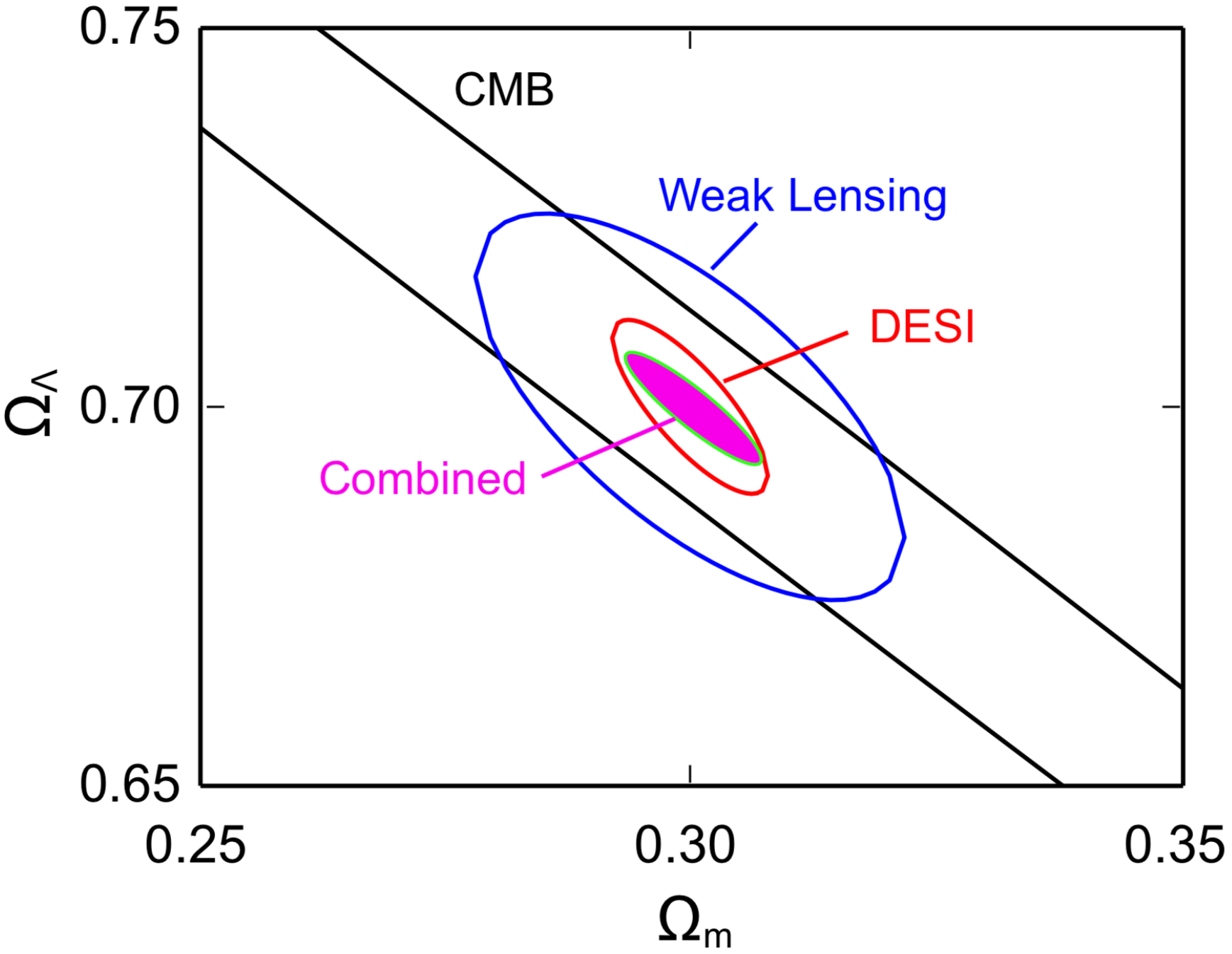
Photometric redshift test

Supernova cosmology

Large Synoptic Survey Telescope

Constrain cosmological parameter more precisely


0.20
0.15
0.10
0.05
0.00
Neutrino mass
0.335
0.340
0.345
0.350
Dark Energy density
P+LSST (WL)
P+DESI (BAO)
combined


0.75
0.70
0.65
Ω_Λ
CMB
Weak Lensing
DESI
Combined
0.25
0.30
0.35
Ω_m

Summary

- DESI will gain 30 million objects' spectra in five years and will play an important role in probing the dark energy
- The survey will make spectroscopic observations of BGS, LRGs, ELGs, QSOs more efficiently.
- BAO can be measured very precisely. Combining with image survey, cosmological parameter can be determined more precisely.

Reference

- The DESI Experiment Part I: Science,Targeting, and Survey Design(http://adsabs.harvard.edu/abs/2016arXiv161100036D)
- The DESI Experiment Part II: Instrument Design (http://adsabs.harvard.edu/abs/2016arXiv161100037D)
- Imprint of DESI fiber assignment on the anisotropic power spectrum of emission line galaxies(http://adsabs.harvard.edu/abs/2017JCAP...04..008P)
- Report of the Dark Energy Task Force(http://adsabs.harvard.edu/abs/2006astro.ph..9591A)
- The clustering of galaxies in the SDSS-III Baryon Oscillation Spectroscopic Survey: cosmological constraints from the full shape of the clustering wedges(http://adsabs.harvard.edu/abs/2013MNRAS.433.1202S)