SDSS-IV and eBOSS Science

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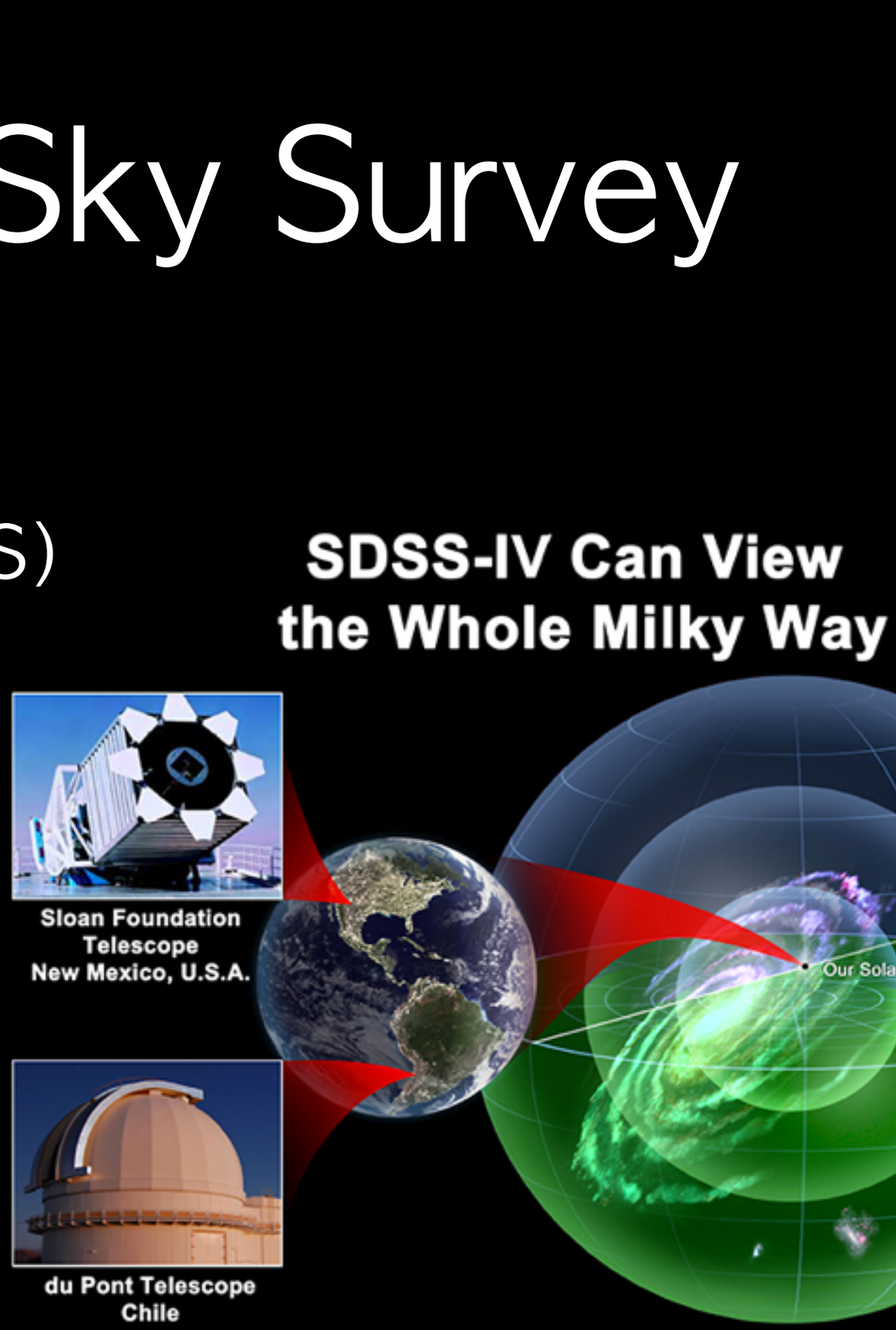
3rd Korea-Japan Workshop on Dark Energy

April 4, 2016 at KASI

Sloan Digital Sky Survey

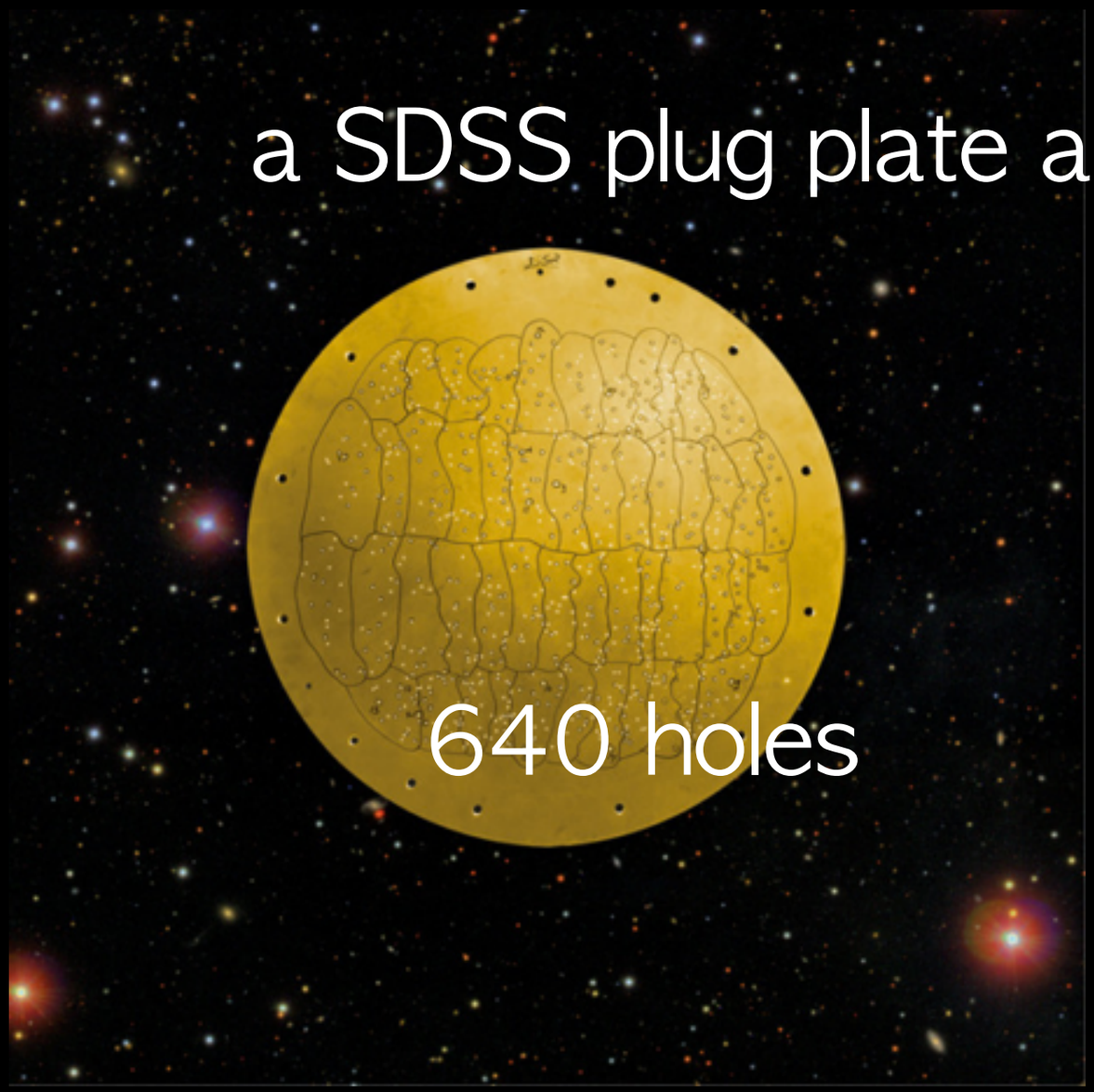
- 2.5m telescopes at
  Apache Point Observatory (US)
  and
  Las Campanas Observatory
  (Chile, included for SDSS-IV)



SDSS

- SDSS facility's key advantage is its wide-field spectrographs that observe many objects simultaneously.

SDSS



SDSS

- SDSS-I/II
  2000-2008
  Legacy, Supernova, SEGUE-1

- SDSS-III
  2008-2014
  APOGEE, BOSS, MARVELS, SEGUE-2

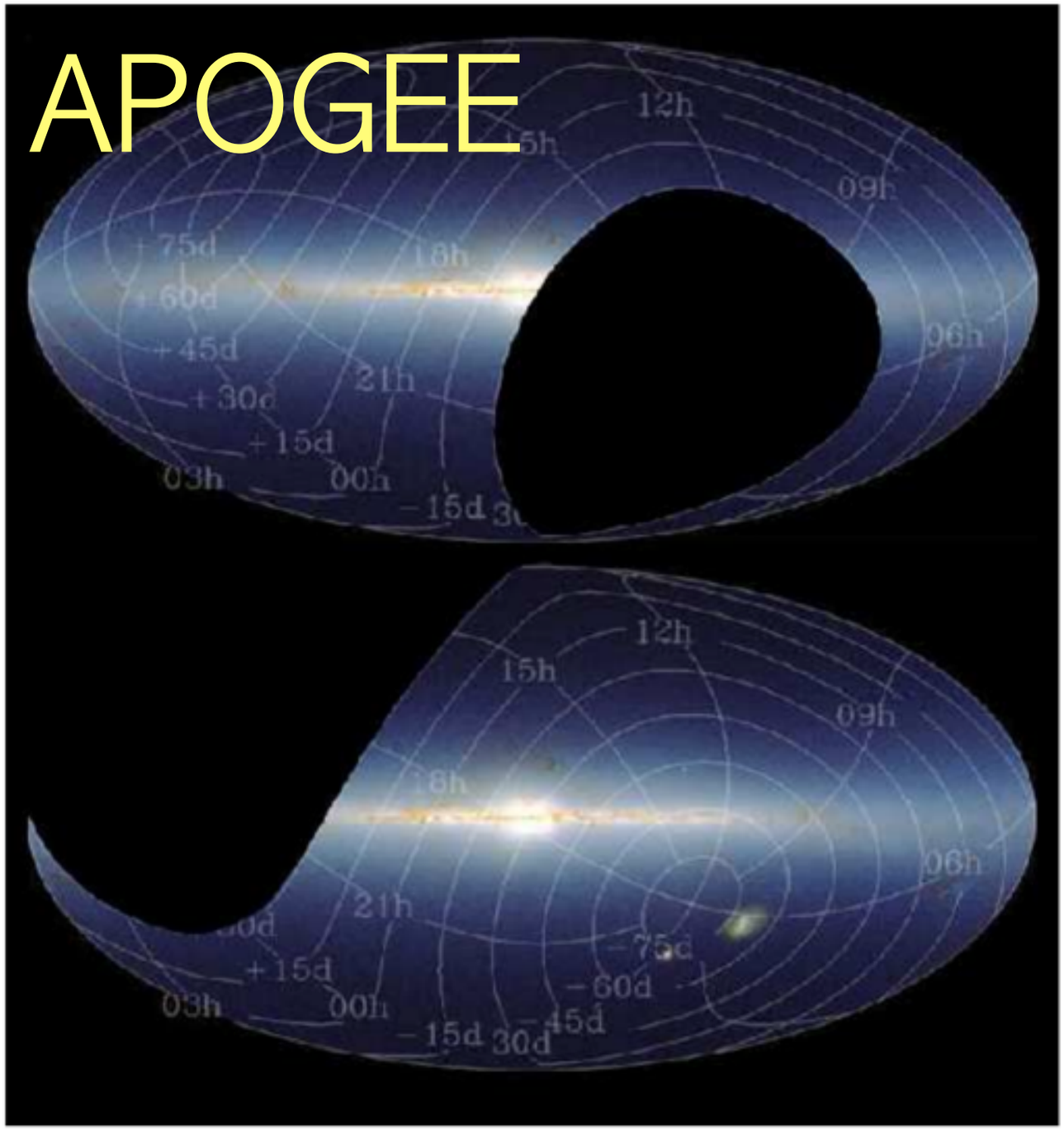
- SDSS-IV
  2014-2020
  APOGEE-2, eBOSS, MaNGA

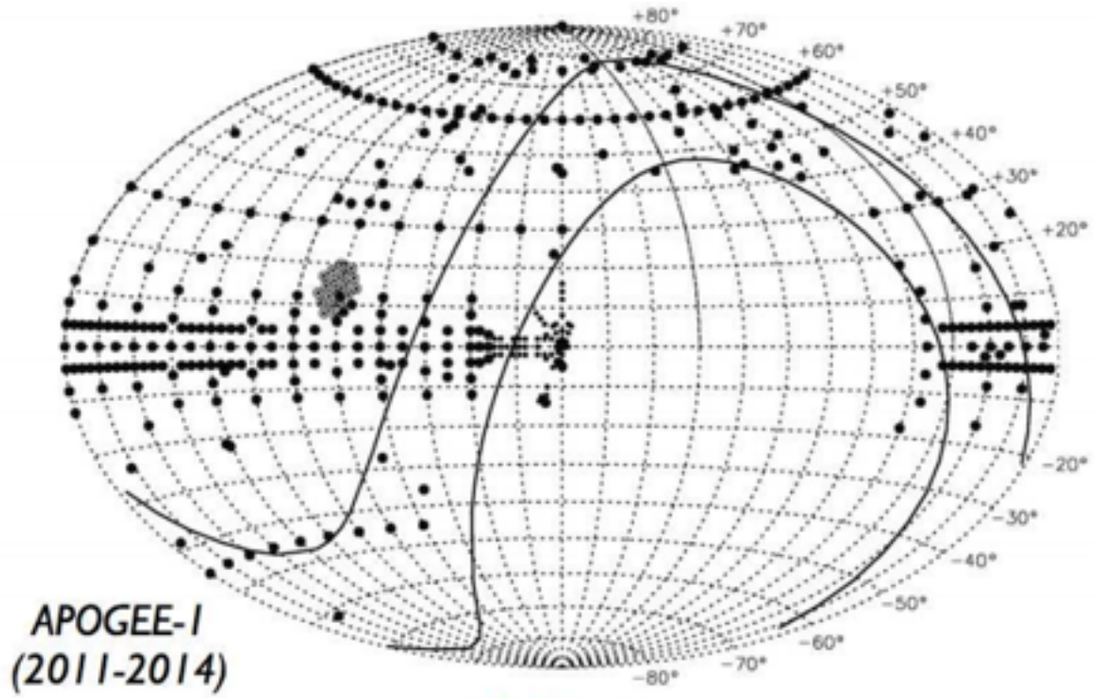
SDSS

- Three SDSS projects (I-III) created an extraordinary legacy of mapping structure across a vast range of scales, from asteroids in our own Solar System to quasars over 10 million light-years away.

- SDSS-IV will expand this legacy by studying the detailed assembly history of the Milky Way (APOGEE-2) and thousands of other nearby galaxies (MaNGA), and extending precision measurements of expansion to the cosmic epochs when dark energy first became important (eBOSS).

APOGEE





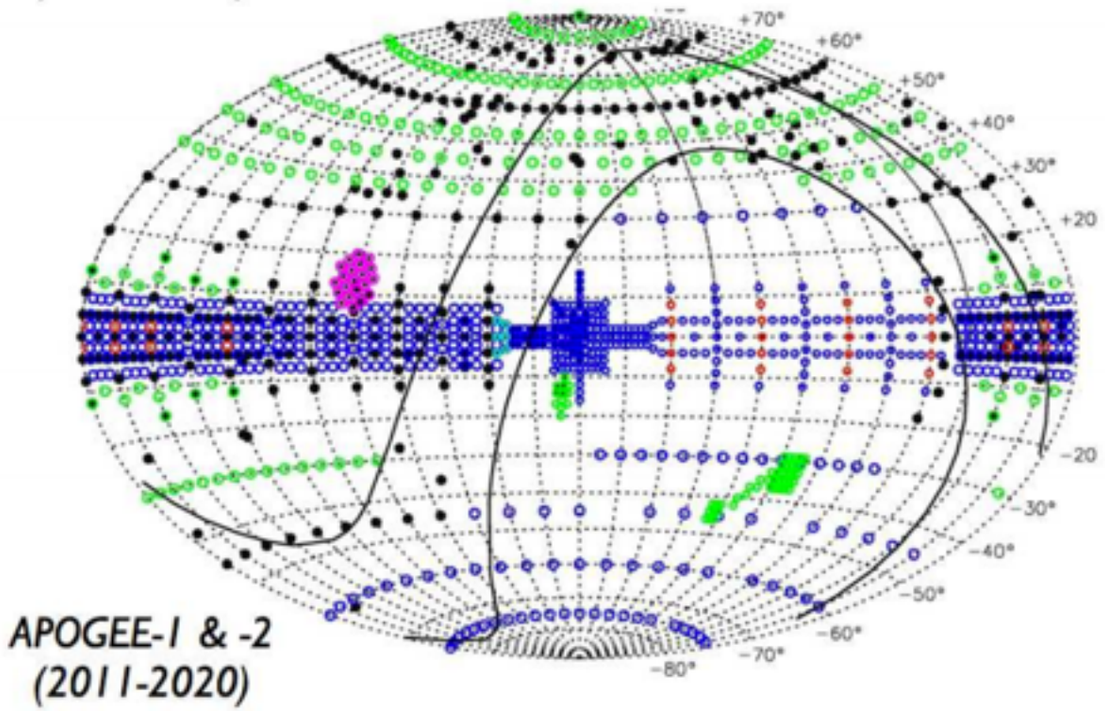
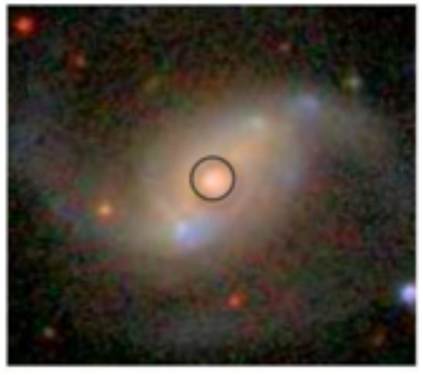


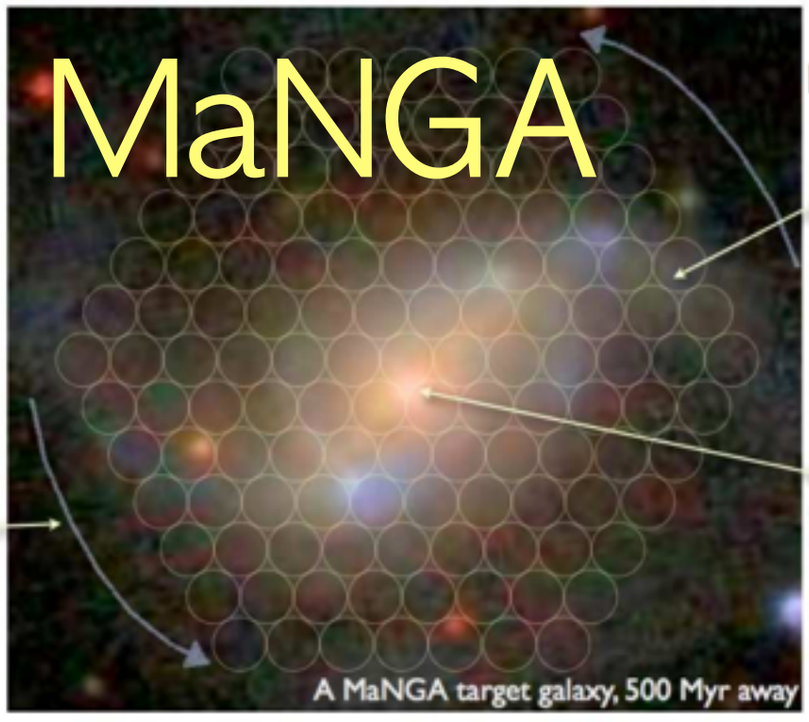
Fig. 4.— *Left:* Panoramic views of the accessible sky at the Sloan Foundation (*top*) and the du Pont (*bottom*) Telescopes. The 2MASS data in these images prominently show the Milky Way structure and the Magellanic Clouds. *Right:* The APOGEE targeting plan for SDSS-III (*top*) and the next phase of SDSS (*bottom*).

http://trac.sdss.org/wiki/SDSS-IV-Project>>SDSS-IV project description



SDSS-I only used a central light-collecting fiber

Birth:
Rotational motion records early formation within a dark matter halo



Life:
New stars forming from fresh gas

Death:
Is "quenching" of star-formation in galaxies due to central black hole feedback?

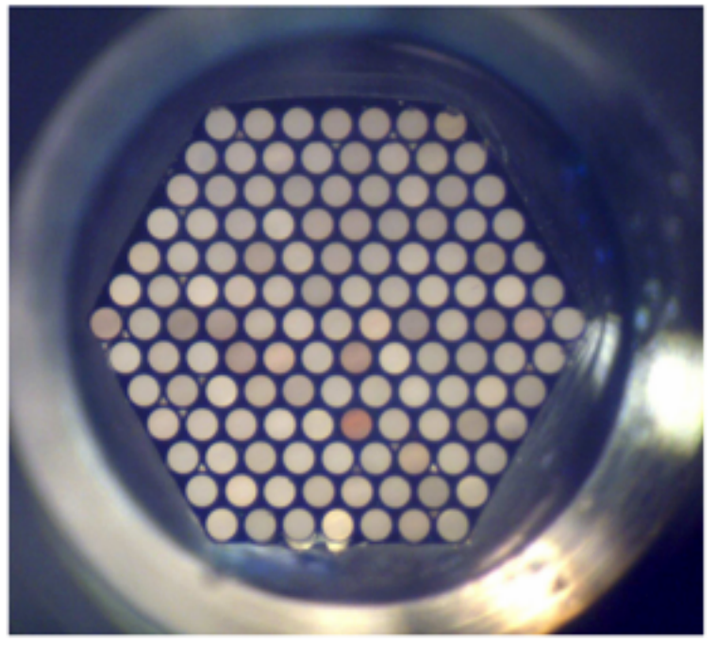
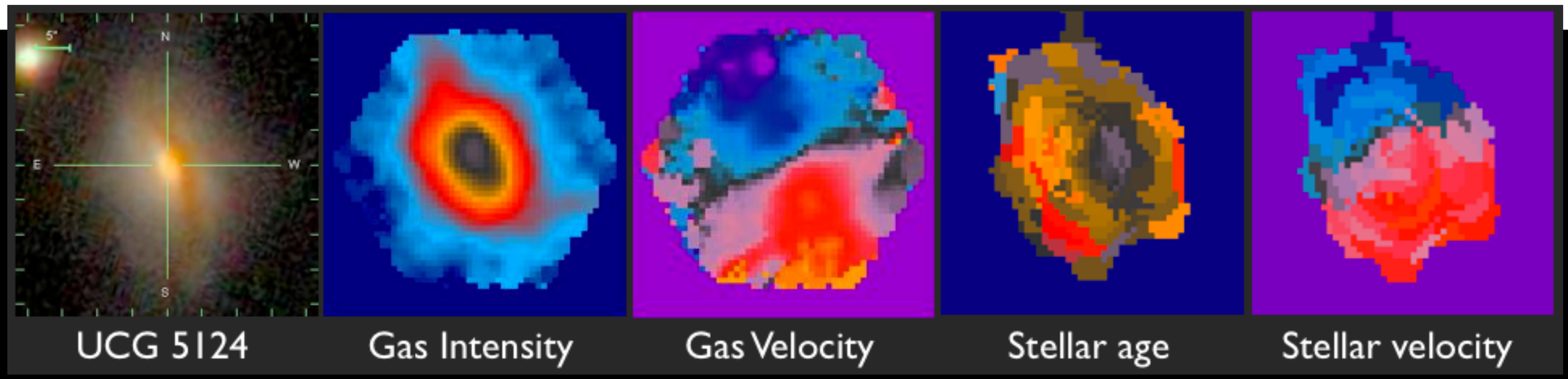


Fig. 5.— A schematic description of MaNGA's ability to probe fundamental questions in our understanding of galaxy formation and evolution. *Left:* Coverage of a standard single-fiber observation of a nearby galaxy. *Middle:* MaNGA resolved spectroscopic coverage of the same galaxy. The grid of circles represents the 127 fibers in MaNGA's largest fiber bundles. *Right:* Example of the actual hex-packed fiber bundles recently built and tested on-sky by the MaNGA team.



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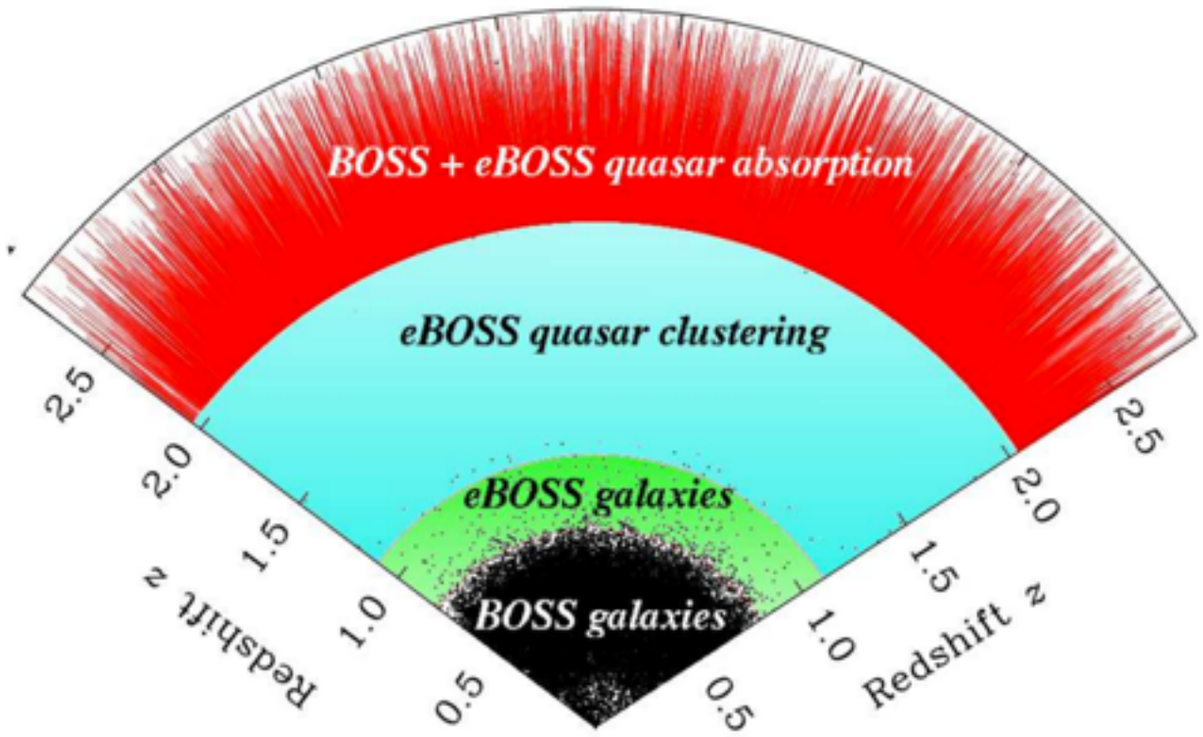
eBOSS



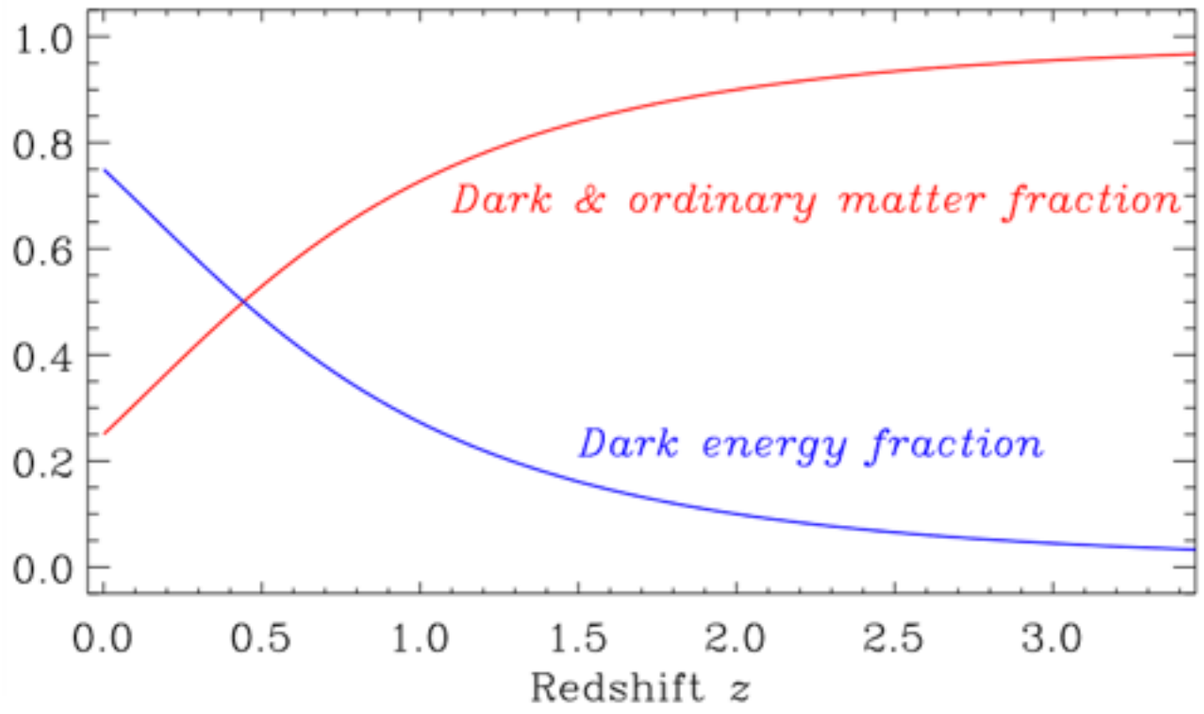


Fig. 7.— *Left:* eBOSS redshift coverage. eBOSS will be the first large-scale structure survey in the critical range $0.7 < z < 2$. *Right:* Fraction of energy density due to dark and ordinary matter (red line) and dark energy (blue line), showing onset of dark energy at $z \sim 2$.

http://trac.sdss.org/wiki/SDSS-IV-Project>>SDSS-IV project description

extended

eBOSS

BOSS

Baryonic Oscillation Spectroscopic Survey

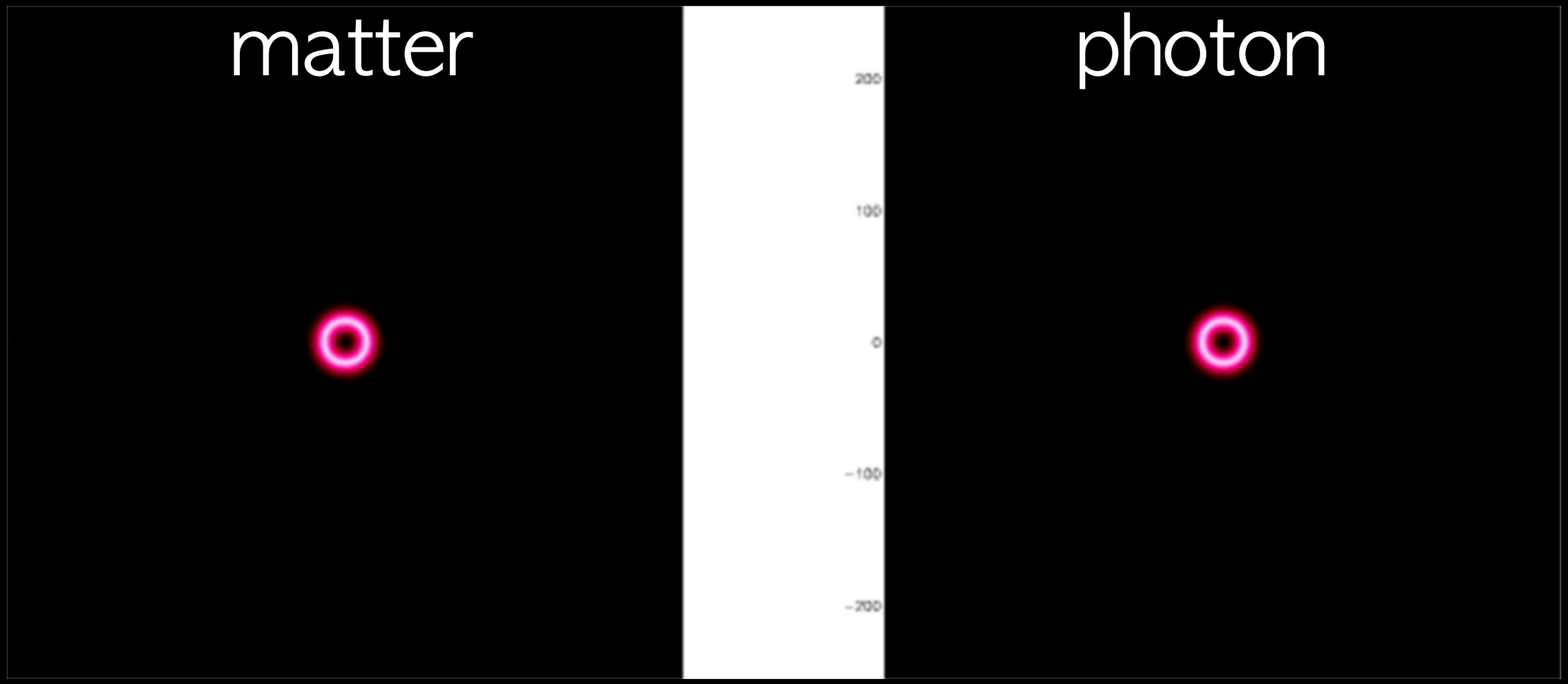
Baryonic Acoustic Oscillation

matter

photon

http://w.astro.berkeley.edu/~mwhite/bao/

Baryonic Acoustic Oscillation



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Baryonic Acoustic Oscillation

matter

photon

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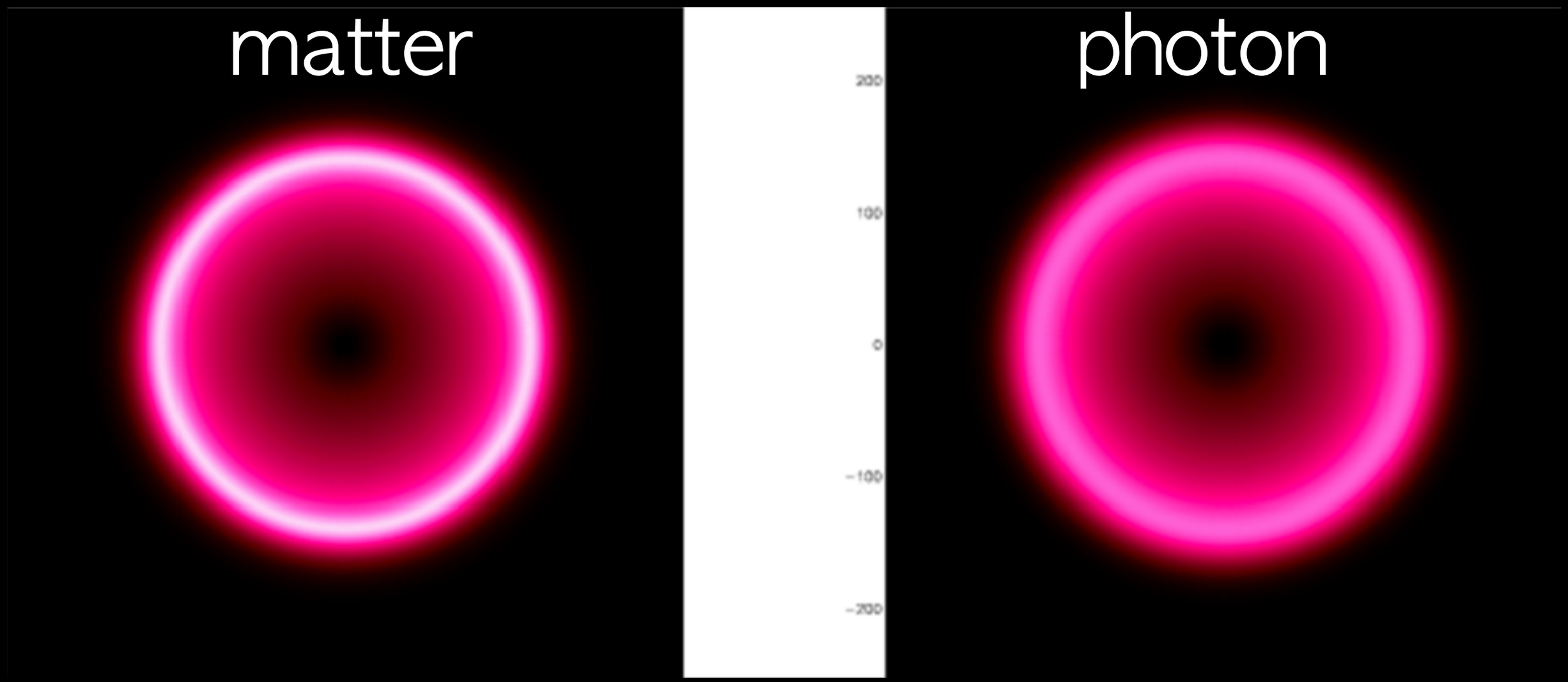
Baryonic Acoustic Oscillation

matter



photon

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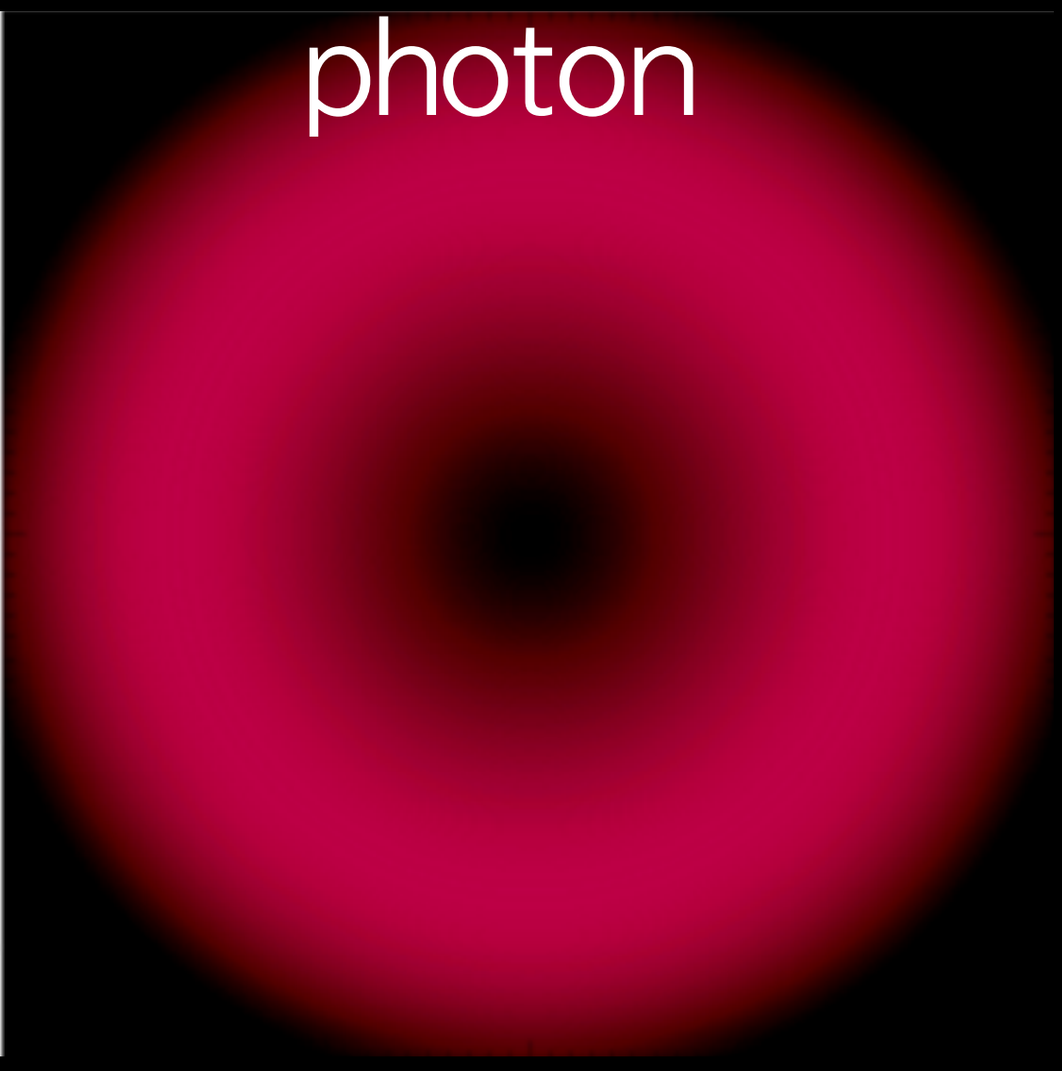

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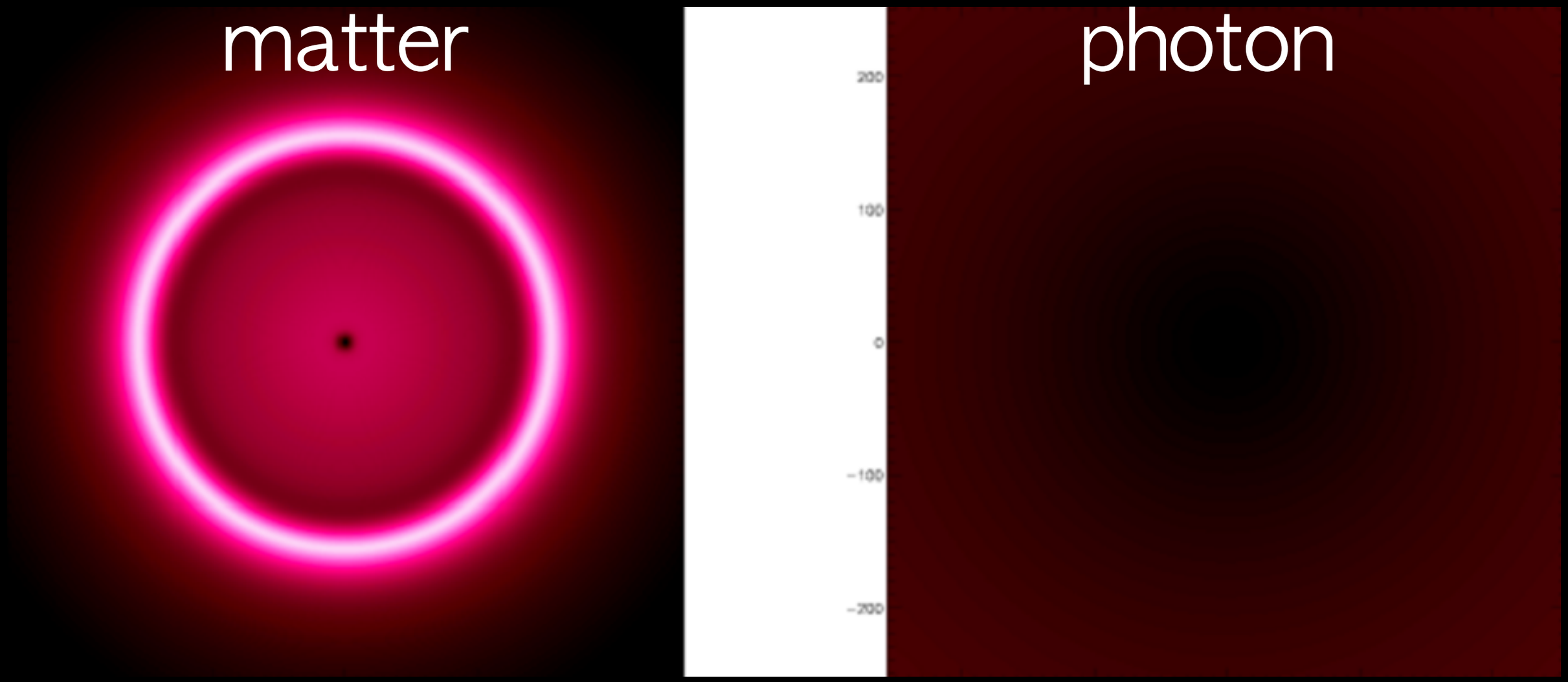
Baryonic Acoustic Oscillation



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Baryonic Acoustic Oscillation

matter

photon

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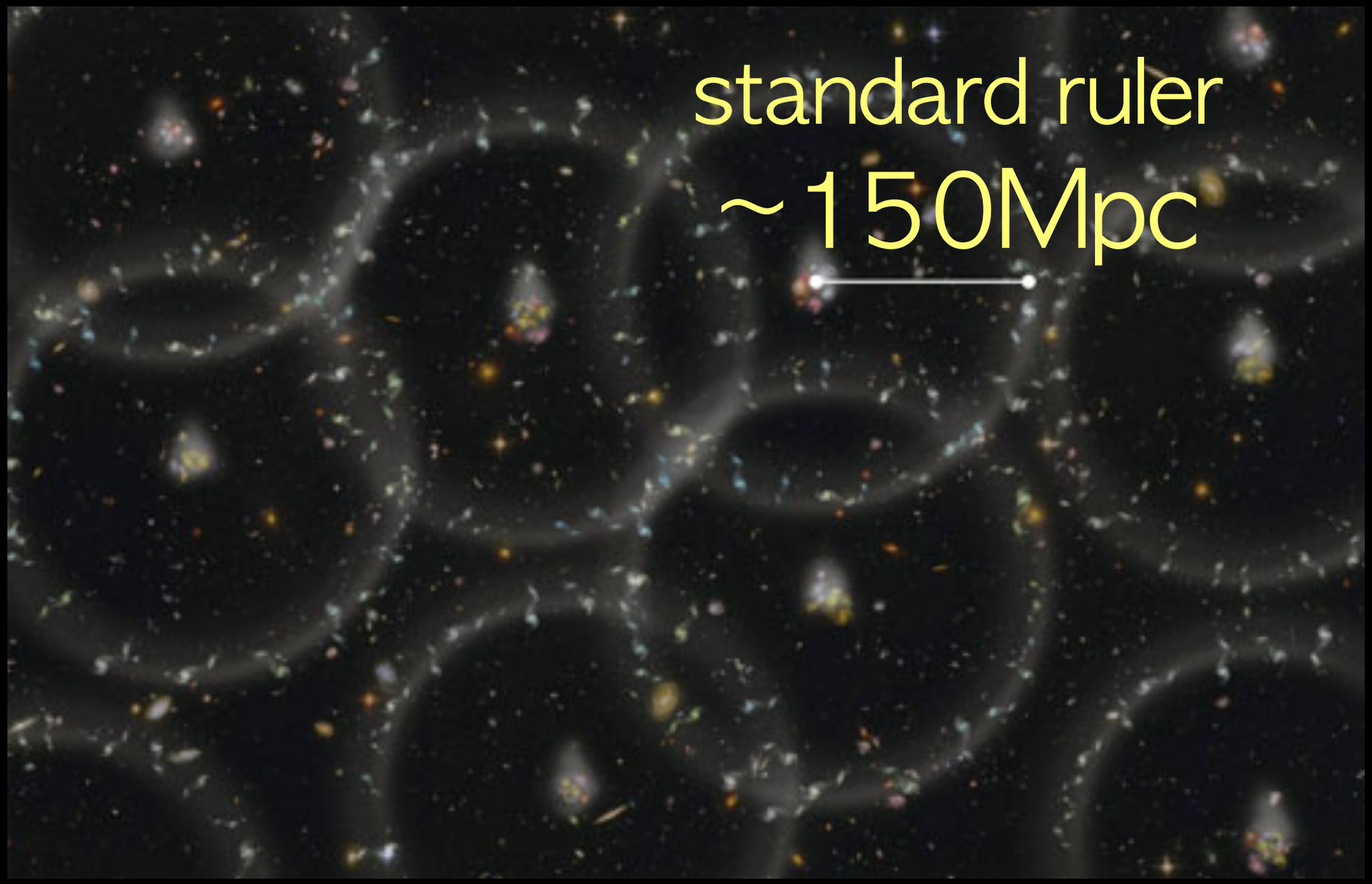
BAO



http://www.astro.ucla.edu/~wright/BAO-cosmology.html

BAO

- Tracers
  - SDSS Luminous Red Galaxies (LRGs)
  - BOSS galaxies (extension of SDSS LRG)
  - BOSS Lya quasars
    (suggested as a new tracer in SDSS-III BOSS)

BOSS in a nutshell

- 10 000 sqdeg (1/4 of entire sky)
- 343 160 low-z galaxies (LOWZ, z_{median}=0.32)
- 862 735 mid-z galaxies (CMASS, z_{median}=0.57)
- 181 605 quasars at 2.1<z<3.5

BOSS/eBOSS

- Spectrograph, compared to SDSS-I/II
  - more objects
    (640 -〉 1000 holes per plate)
  - improved spectrographs
    (smaller fibers 3”-〉2”,
    new improved detectors,
    higher throughput,
    and a wider wavelength range)

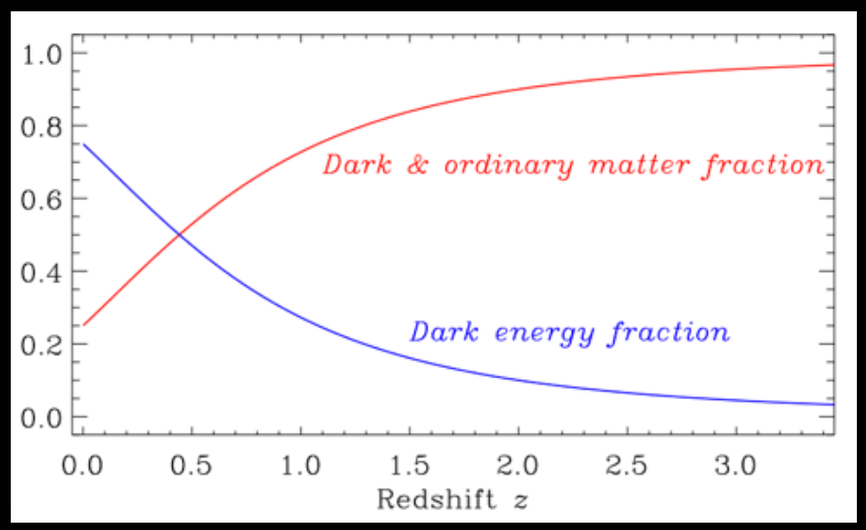
eBOSS

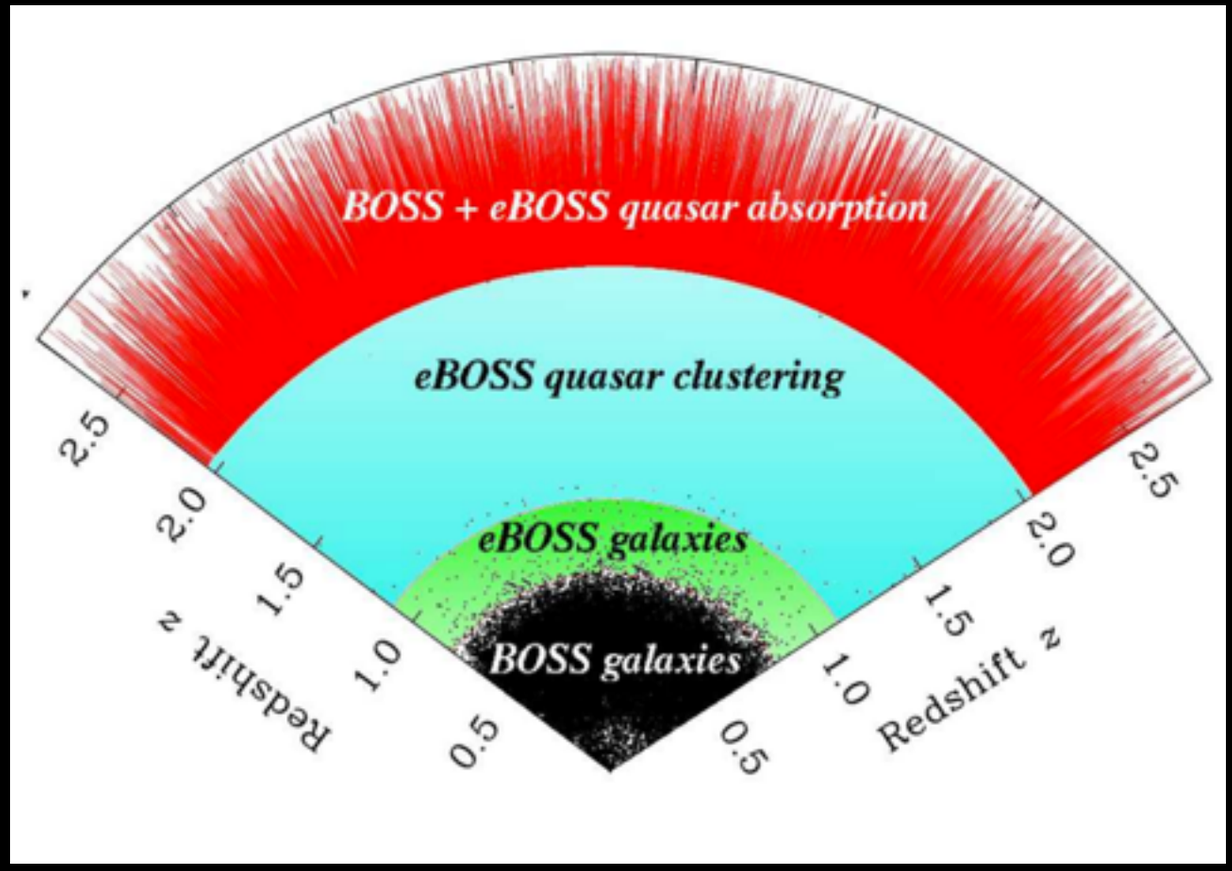
- Compared to BOSS
- additional imaging resources
  of infrared imaging data from WISE
  (previously entirely based on SDSS photometry)

eBOSS

- Compared to BOSS
  - higher redshift

first measurement
across the critical epoch,
the predicted “onset time”
for dark energy





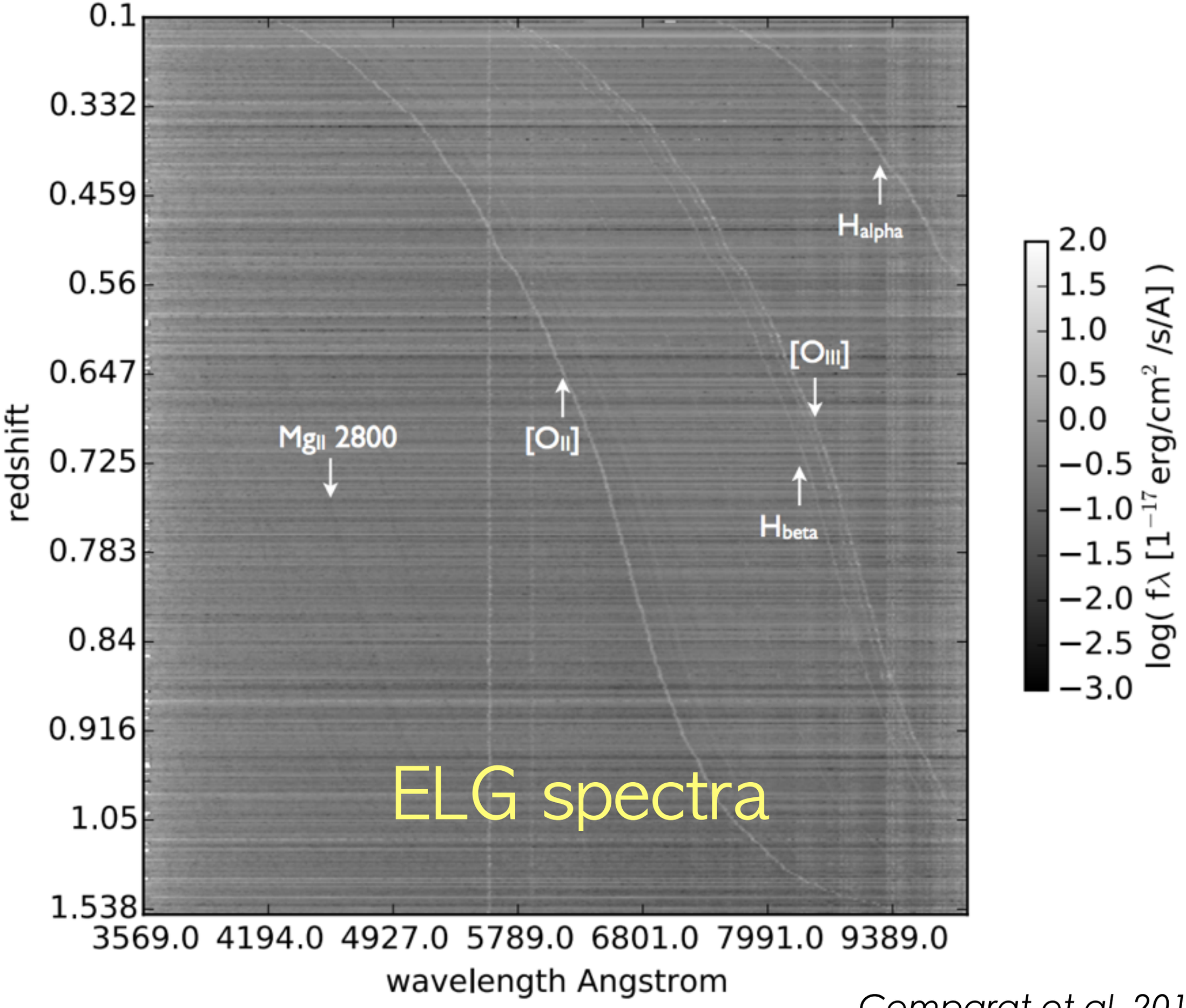
eBOSS

- Compared to BOSS
  - new tracer — star-forming galaxies /Emission Line Galaxies (ELGs)

ELG

- Emission lines
  in blue galaxies with significant star formation
  facilitate spectroscopic confirmation
  at high redshifts with an optical spectrograph.

- Because ELGs are numerous
  and have emission line fluxes correlated with
  the observed u or g-band magnitudes,
  they can be selected at a much higher density
  than LRG sample.



Comparat et al. 2015

eBOSS

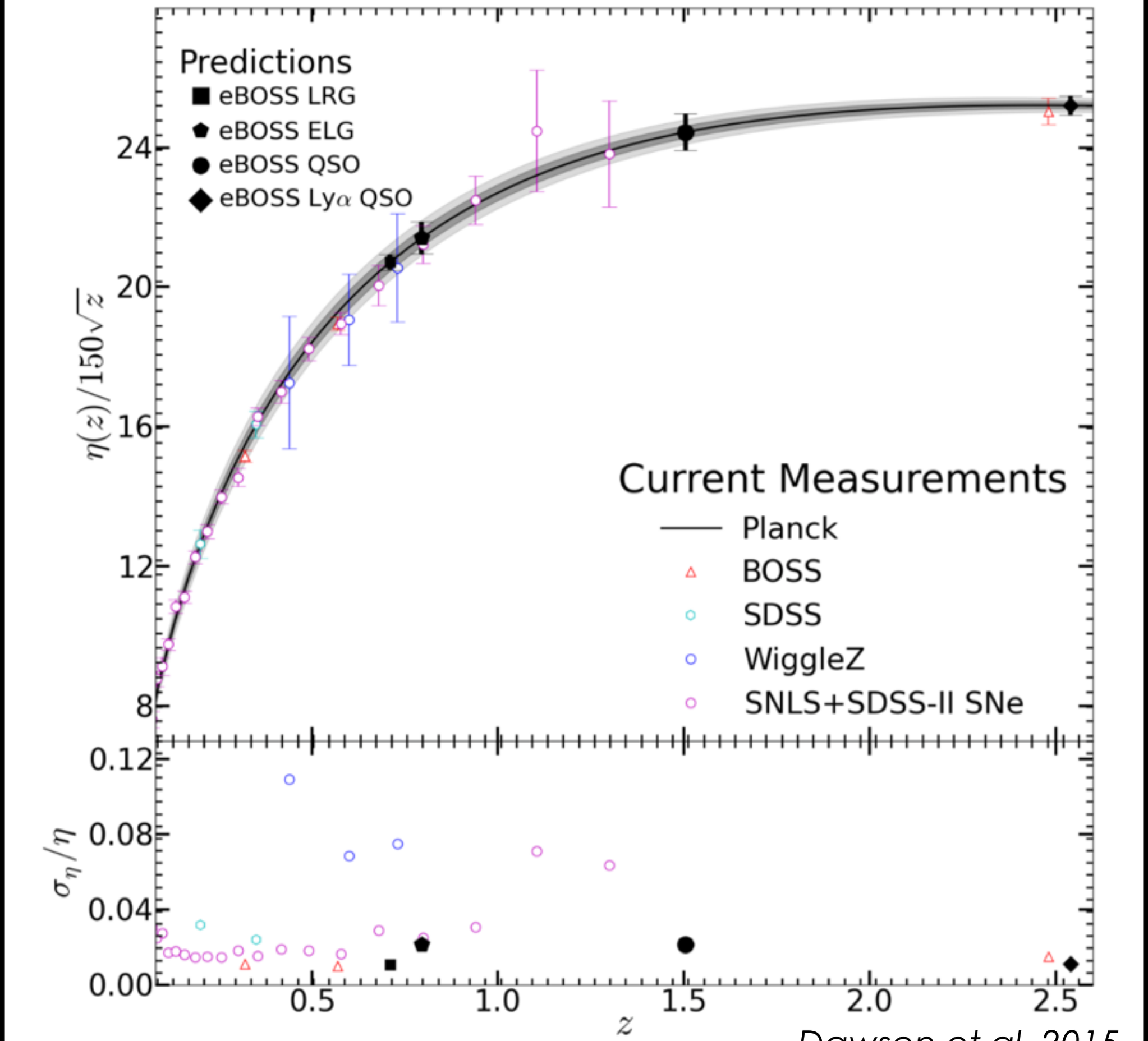
- 1.4 million targets in 4 different classes (target #)
  - elliptical galaxies (LRGs, 375 000 at 0.6<z<0.8)
  - star-forming galaxies
    (260 000 at 0.6<z<1, over a 1500 sqdeg)
  - mid-z quasars (700 000 at 1<z<2.2)
  - high-z quasars (40 000 at 2.2<z<3.5)

eBOSS

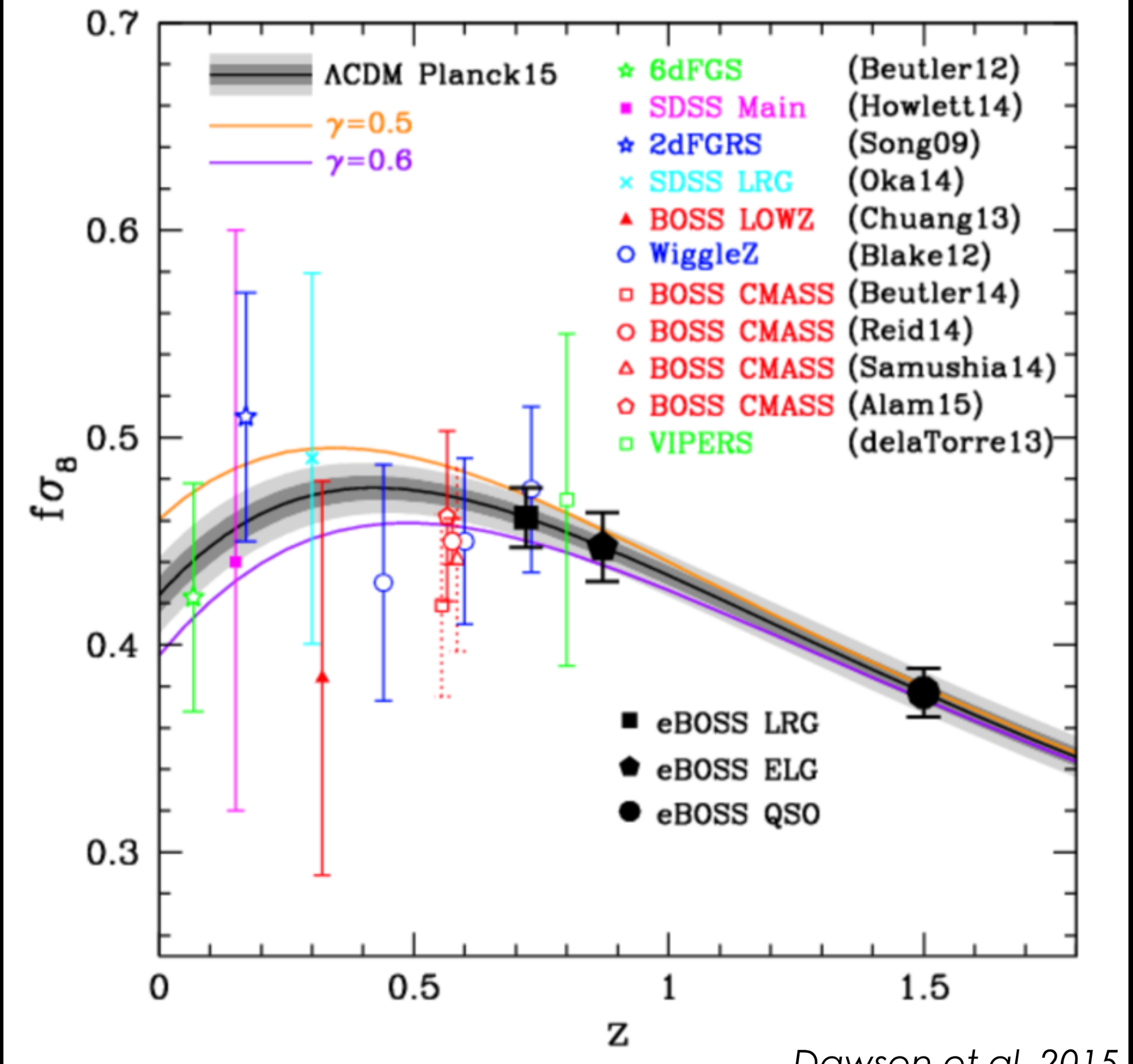
- Geometrical constraint (BAO)
- Growth of structure
  - Redshift Space Distortion (RSD) – how galaxies are moving in response to gravity

Cristiano Sabiu's talk on Friday

Seokcheon Lee's talk on Wednesday



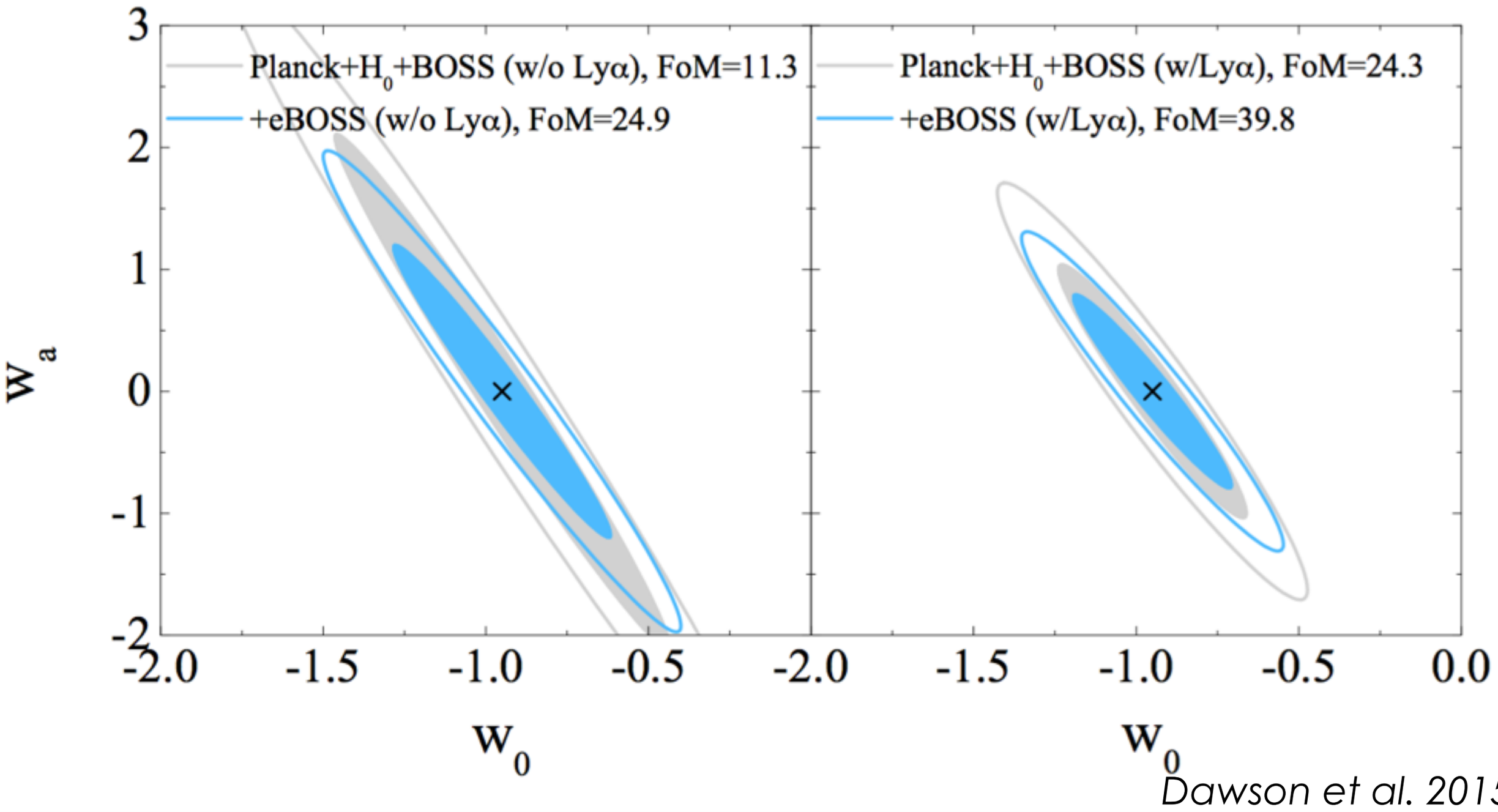
Dawson et al. 2015



Dawson et al. 2015

eBOSS forecast

- BOSS constrains the distance to a precision of
  - 2.1% at z=0.32 (LOWZ)
  - 1.7% at z=0.57 (CMASS)
  - 2.1% 2.1<z<3.5 (Lya)
- eBOSS aims at 1%, 2%, and 2% BAO distance measurements on the LRG, quasar, and ELG samples.



Dawson et al. 2015

eBOSS

- Sub-programs
  - TDSS (Time Domain Spectroscopic Survey)
  - SPIDERS
    (SPectroscopic IDentification of Rosita Sources)

Other than BAO

- Alcock-Paczynski test
  — Xiao-Dong Li's talk on Friday

- Large-scale structures
  — Ho Seong Hwang's talk on Friday

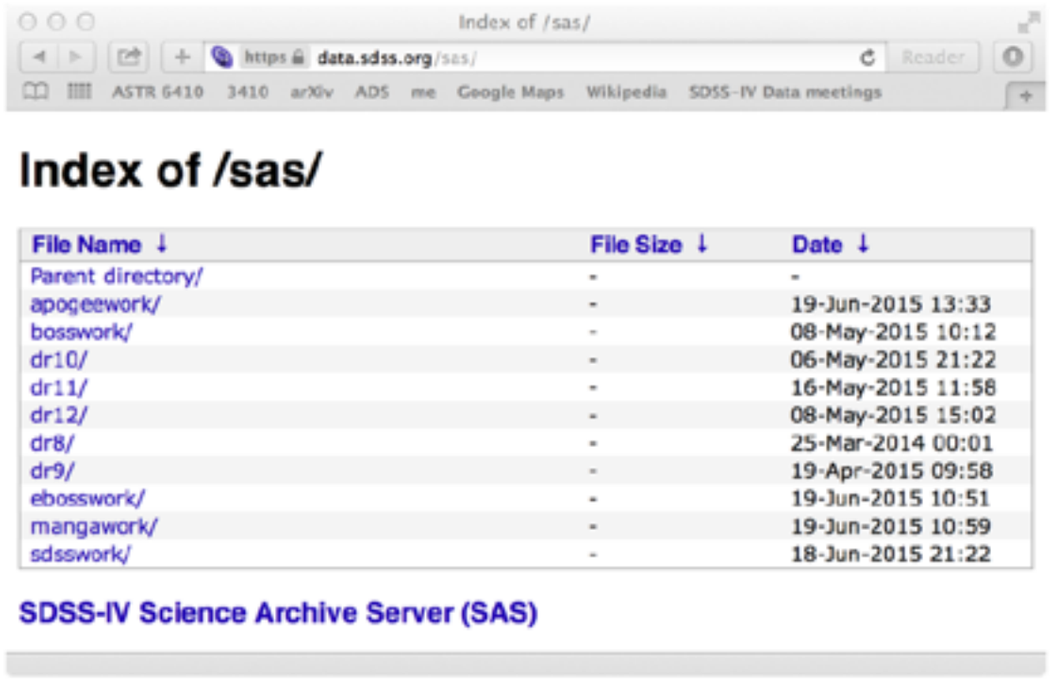
- Galaxy evolution and environment
  — cf. Benjamin L'Huillier talk

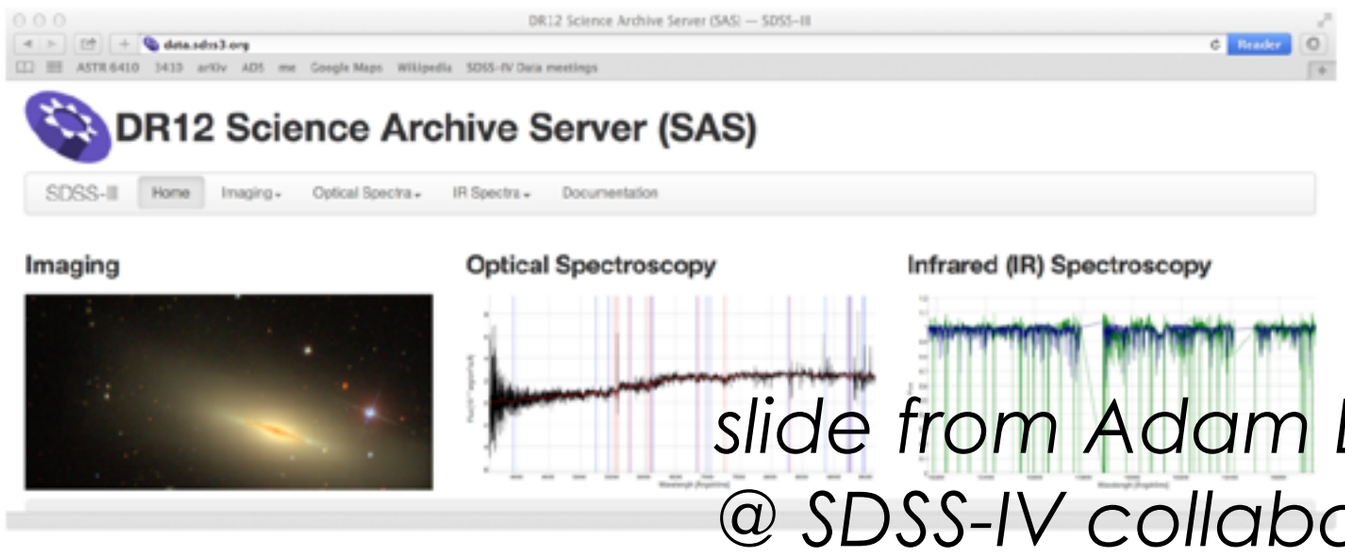
Public Data Release

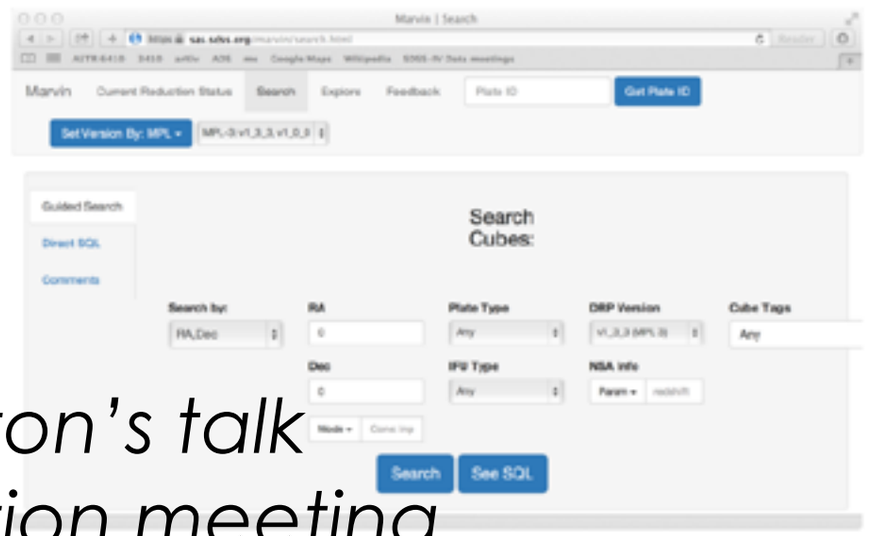
- DR13 (the first data release of SDSS-IV) will be in July 2016.
- Few hundred Terabytes of data
- New datacubes from MaNGA
  + new photometry and SEQUELS spectra from eBOSS/TDSS/SPIDERS
  + new reductions of all APOGEE data from SDSS-III
  + legacy data

Interfaces for data release

- HTTP, rsync, and Globus interface to SAS/SAM flat files
- Catalog Archive Server / SkyServer
  - (see http://skyserver.org/doc/CASoverview.pdf)
- Webapp front-end (III-to-IV development) & “Marvin”







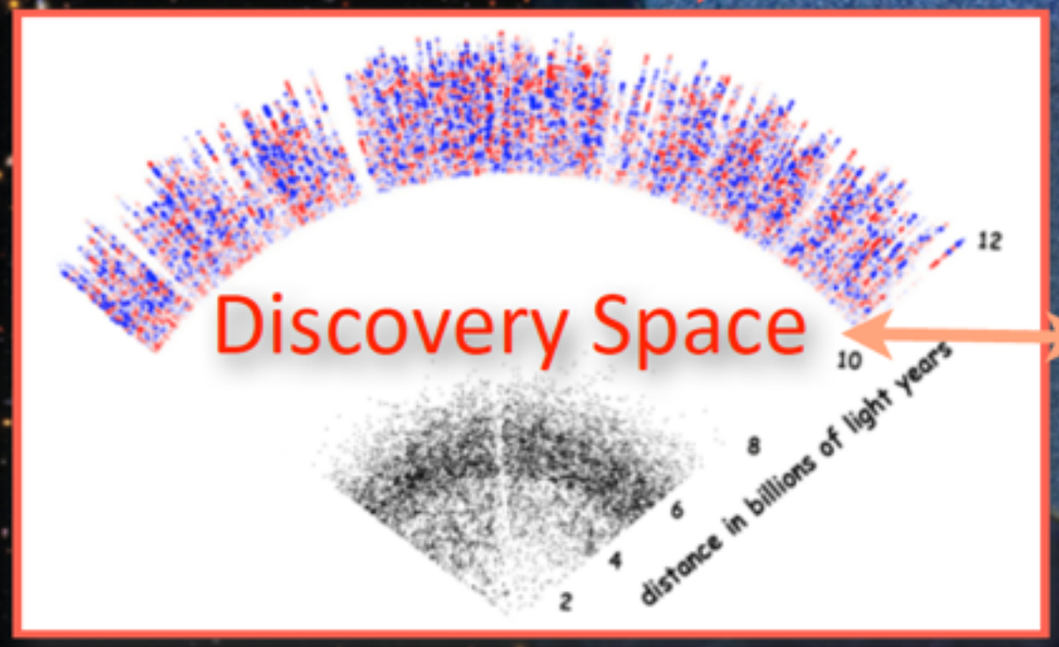
slide from Adam Bolton’s talk @ SDSS-IV collaboration meeting

Goals of eBOSS ?

Understanding our Cosmological world model:

- *Are we leaving in a Lambda-CDM Universe?*
- *What is Dark Energy?*
- *Do we understand Gravitation on Large Scales? link with DM?*
- *Neutrino Masses?*
- *Non-Gaussianities and inflationary models?*

slide from Jean-Paul Kneib's talk @ SDSS-IV collaboration meeting



eBOSS

eBOSS

- While photometric selection for BOSS galaxy sample was based entirely on imaging from SDSS

(cf. UKIRT Infrared Deep Sky Survey/UKIDSS and the Galaxy Evolution Explorer/GALEX were used for Lya forest quasar selection),

additional imaging resources for eBOSS are considered — highly-uniform, infrared imaging data from WISE satellite (3.4 and 4.6 micro-m)

eBOSS

- ELG target selection still under investigation
  - SDSS griz + South Galactic Cap U-band Sky Survey (SCUSS) U-band — available over the entire SGC area
  - deeper grz imaging from the Dark Energy Camera (DECam) — deeper imaging data allows more precise identification of strong emission-line galaxies

eBOSS

- Over six years, eBOSS will provide the first percent-level distance measurements with BAO and RSD in the redshift range $0.6 < z < 2$, where cosmic expansion transitioned from deceleration to acceleration.

- Using LRG, quasar, ELG, and Lya absorption as tracers of the underlying density field, eBOSS will probe the largest volume to date of any cosmological redshift survey.

eBOSS

- In total, the final eBOSS spectroscopy will consist of: LRG targets (0.6<z<1.0) at a density of 50/sqdeg and desired purity exceeding 80%, ELG targets at a somewhat higher redshift over 300 dedicated plates with a desired purity exceeding 74%, “clustering” quasar targets (QSO_CORE) to directly trace large-scale structure (0.9<z<2.2) at a density of 90/sqdeg and desired purity exceeding 50%, re-observations of faint BOSS Lya quasar (z>2.1) at a density of 8/sqdeg, and new Lya quasar candidates identified by variability at an average density of 18/sqdeg.