Large Galaxy Surveys for Cosmology

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Outline

- Introduction
- Landscape of Large Galaxy surveys
- Current Status
- Near Future
- Conclusions

Cosmology and Dark Energy from Galaxy Surveys

What is causing the acceleration of the expansión of the universe?

- Cosmological Constant
- New field
- Modifications to General Relativity

Dark Energy can be studied in two main cosmological observables:

- **History of the expansion rate of the universe:**
  - SN1a, BAO, weak lensing, cluster counting…
- **History of the rate of growth structure of the universe:**
  - RSD, weak lensing, LSS, cluster counting…

For all other probes than SN1a, LARGE GALAXY SURVEYS ARE NEEDED

- Spectroscopic: 3D (redshift), médium depth, low density, selection effects
- Imaging: “2.5D” (photo-z), deeper, higher density, no selection effects

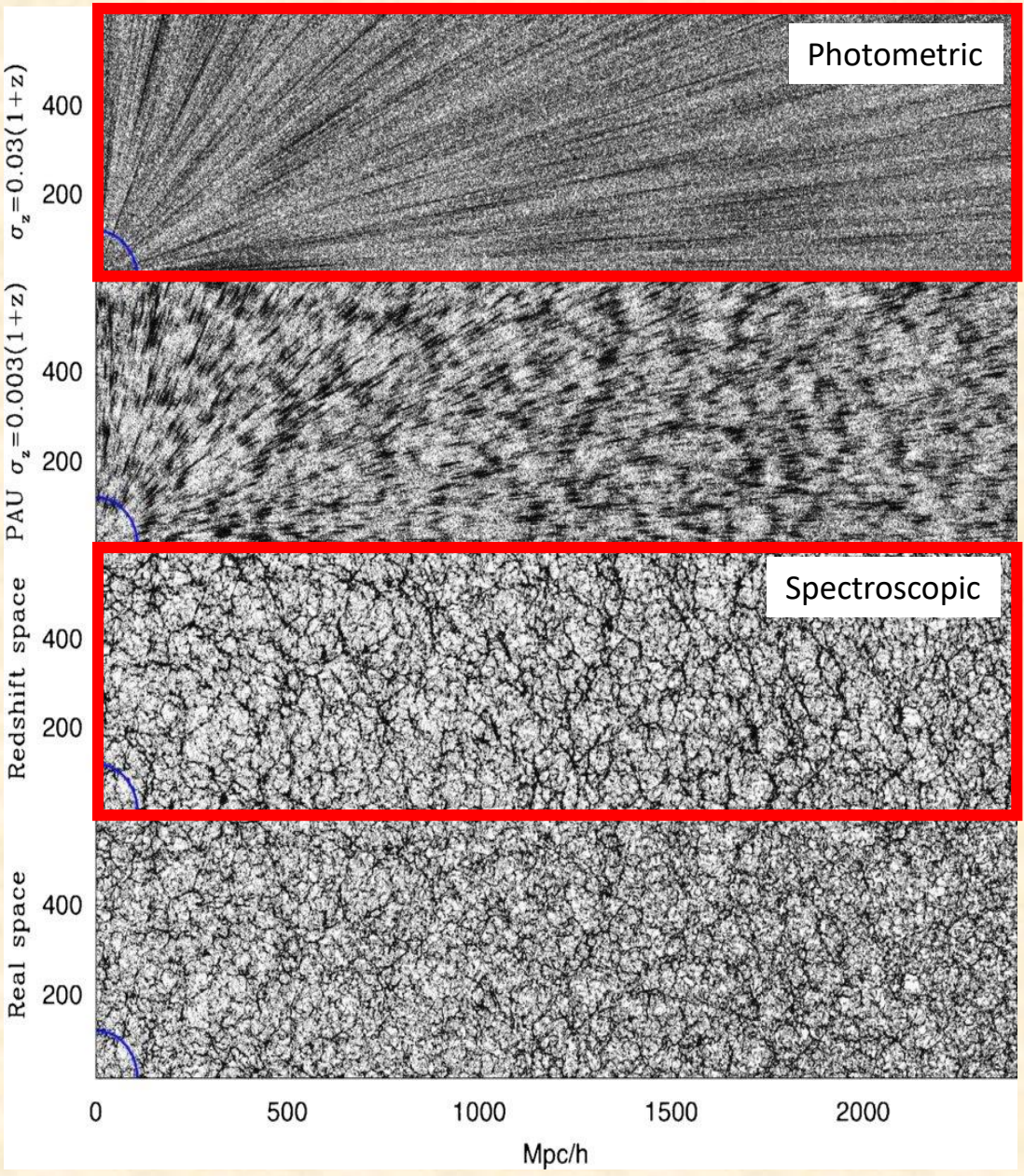
What is a Galaxy Survey

A map of a section of the sky (as large as possible), that locates all its contents. To do this we need big telescopes (to see faint objects), and some method to measure distances.

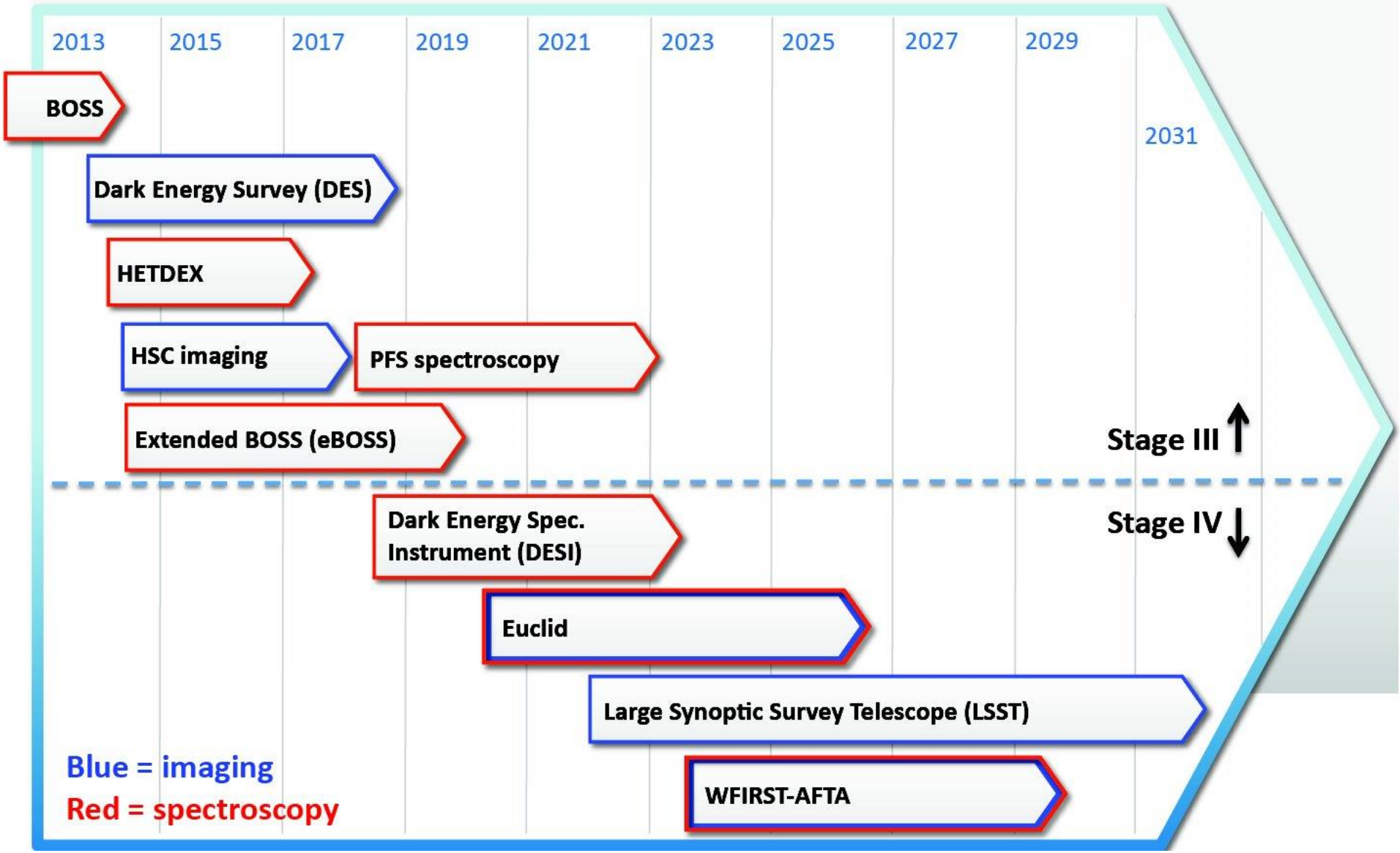
The clustering signal is 3D. However, while angular positions are in general easy to measure, the radial distance is difficult. Two ways to do it:

1) Spectrum of previously selected galaxies
2) Estimate from broadband colours with templates or training samples

Large advance in the last years and bright future, mainly due to technological developments that made possible larger and deeper surveys



Timeline of cosmological surveys



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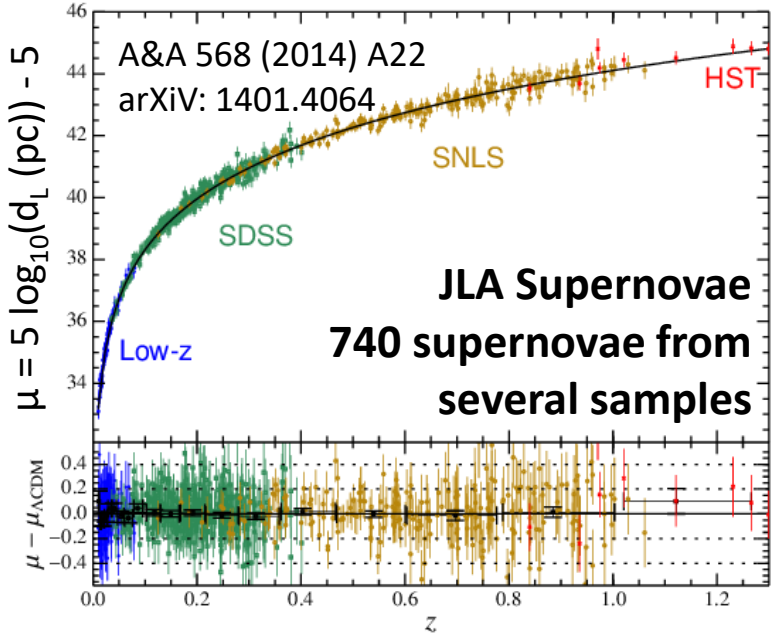
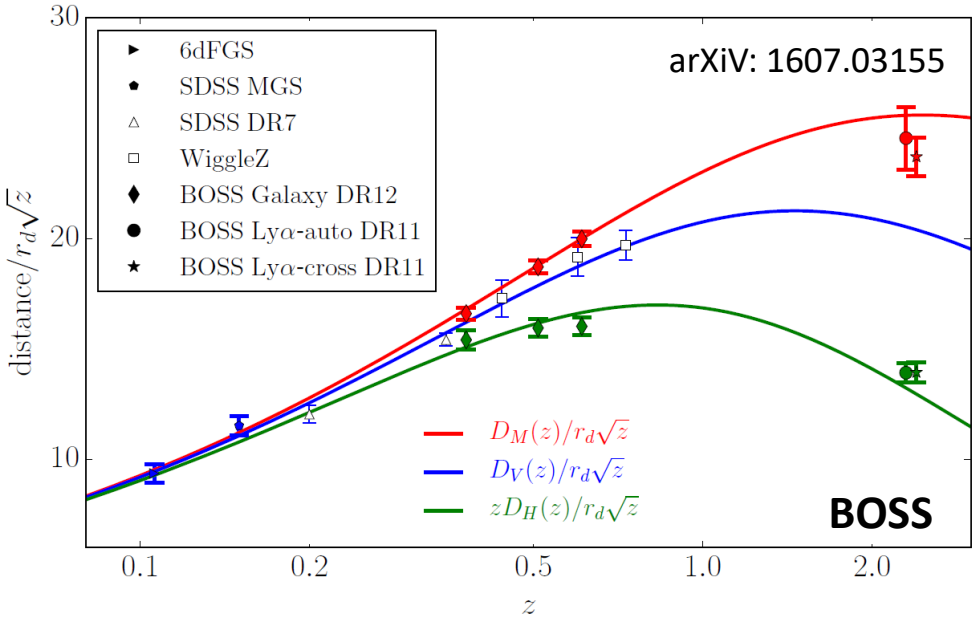
Galaxy surveys

Project	Dates	Area/deg2	Data	Redshift	Methods
BOSS	2008-2014	10000	Opt-S	0.3-0.7 (gal) 2-3.5 (Lyα Forest)	BAO/RSD
DES	2013-2018	5000	Opt-I	0.2-1.5	WL/CL/BAO/SN
eBOSS	2014-2020	7500	Opt-S	0.6-2.0 (gal/QSO) 2-3.5 (Lyα Forest)	BAO/RSD
SuMIRE	2014-2024	1500	Opt-I Opt-NIR-S	0.2-1.5 0.8-2.4 (gals)	WL/CL/ BAO/RSD
HETDEX	2014-2019	300	Opt-S	1.9-3.5 (gals)	BAO/RSD
DESI	2019-2024	14000	Opt-S	0-2 (gals) 2-3.5 (QSO/Lyα Forest)	BAO/RSD
LSST	2020-2030	20000	Opt-I	0.2-2	WL/CL/BAO/SN
Euclid	2020-2026	15000	Opt-I NIR-S	0.2-2 0.7-2.2 (gals)	WL/CL/BAO/RSD
WFIRST	2024-2030	2200	NIR-I NIR-S	1.0-3.0 (gals)	WL/CL/SN/BAO/RSD

From PDG 2016

Current Status



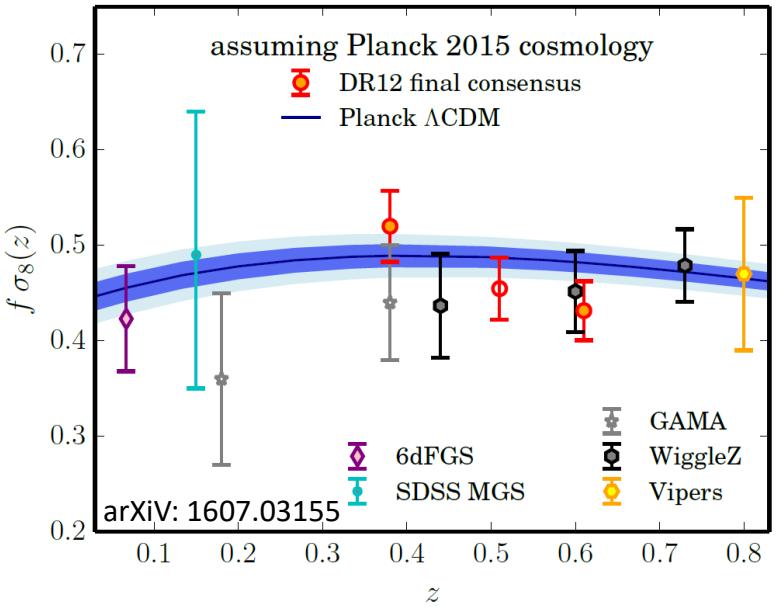


Wider and deeper Galaxy surveys are needed to improve the current cosmological constraints, both for distances and for the growth of structure

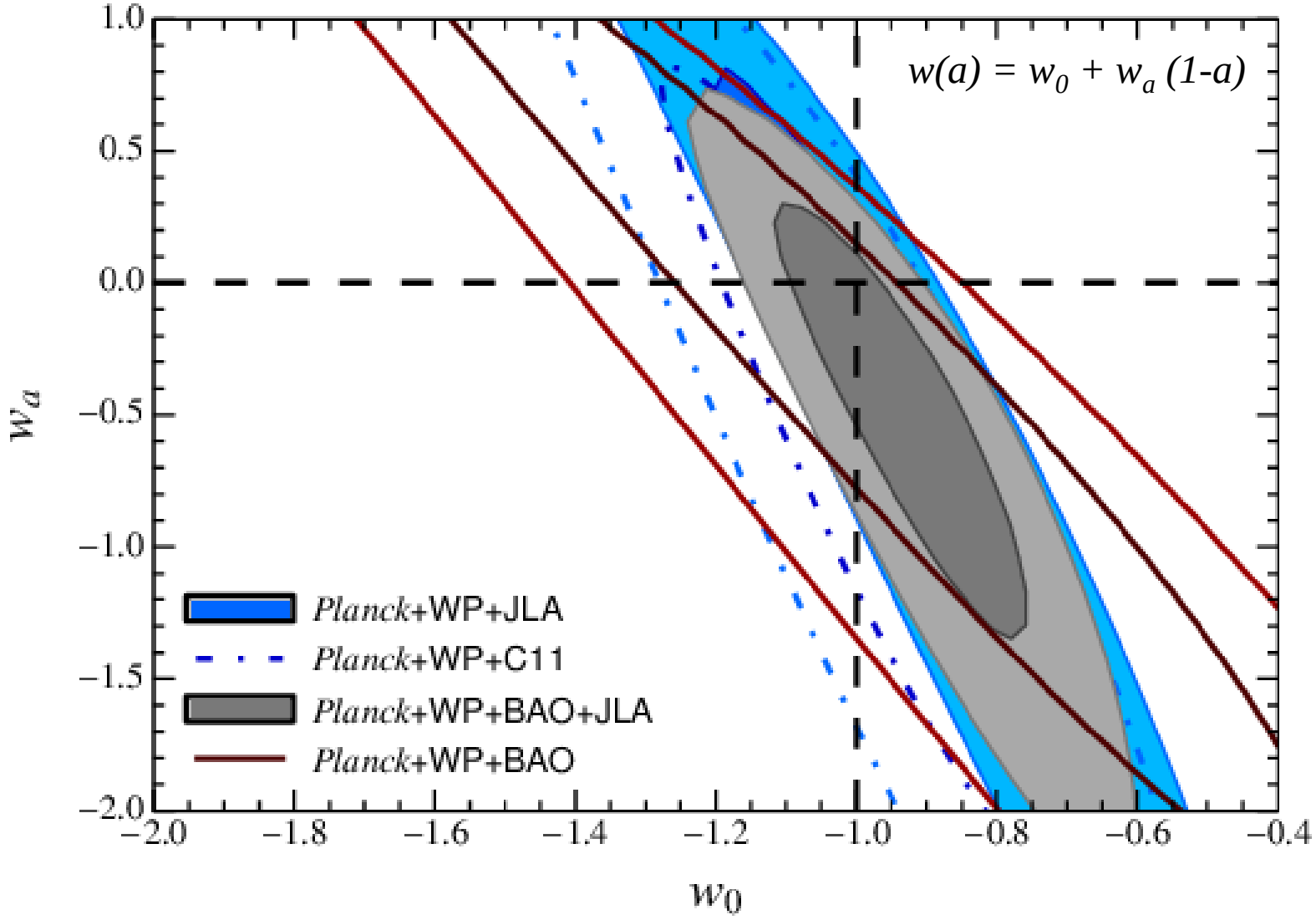
σ_8: amplitude of power spectrum of matter density fluctuations (on scales of 8 Mpc/h)

f: d lnD(a)/da

and D(a) is the linear growth function of fluctuations



Current Status: Cosmological Parameters



Current data are compatible with dark energy being the cosmological constant, but the evolution with time is not very well constrained yet → Next Surveys

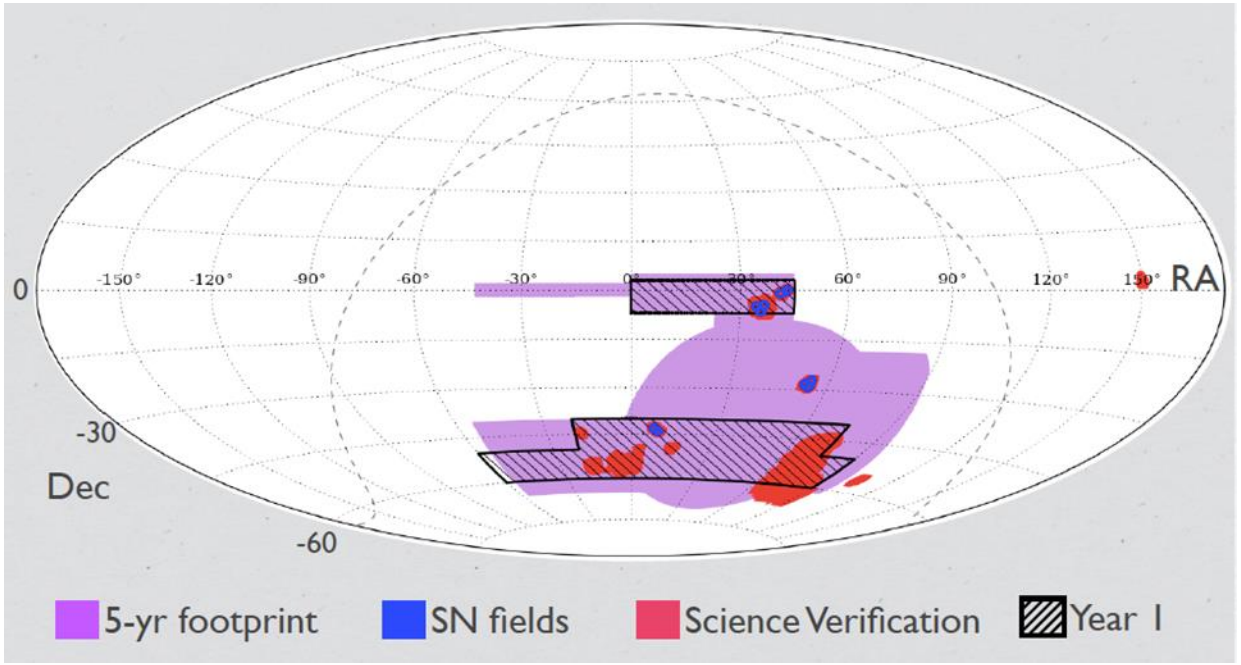
DES (Dark Energy Survey)

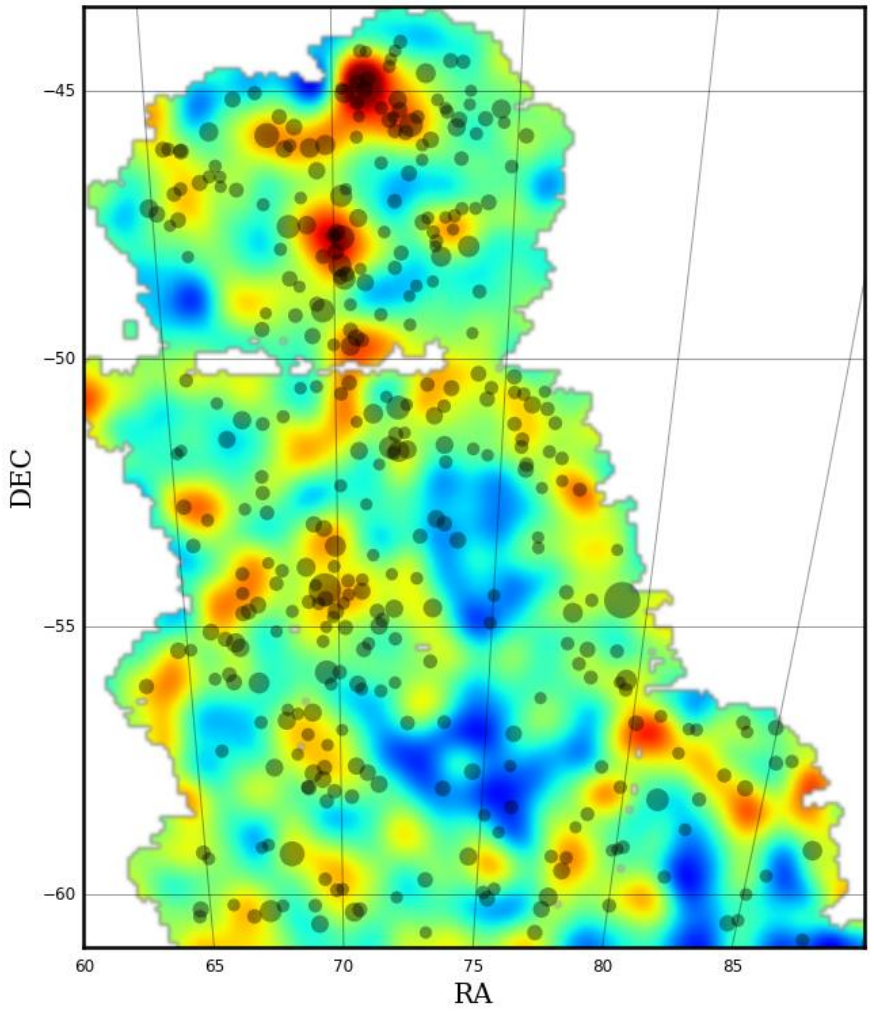
New optical-NIR camera (DECam) at the Blanco telescope (4m) in Chile since 2012.

Taking data (80% completed)

4 techniques to study dark energy: Supernovae 1a, BAO, weak lensing and galaxy clusters

Will improve 1 order of magnitude the current measurements on dark energy





Projected Mass Map

Based on measurements of shapes of background galaxies

Chang et al., PRL 115 (2015) 05301
Vikram et al., PRD 92 (2015) 022006

Blue: under-dense regions
Red: over-dense regions
Circles: visible foreground galaxy clusters

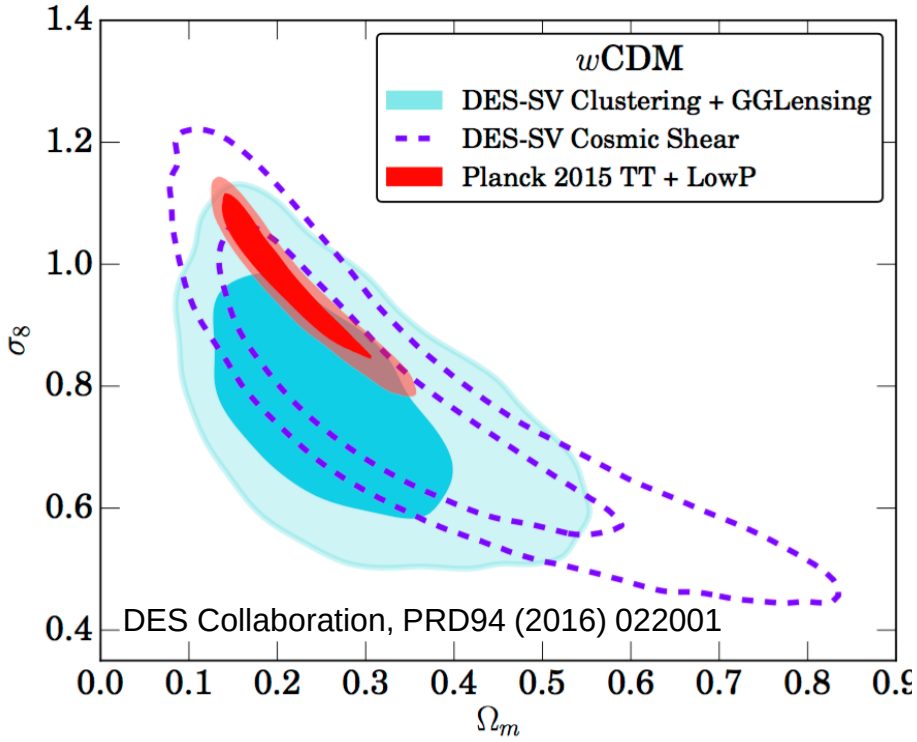
Largest contiguous lensing mass map ever, yet only 3% of final DES area

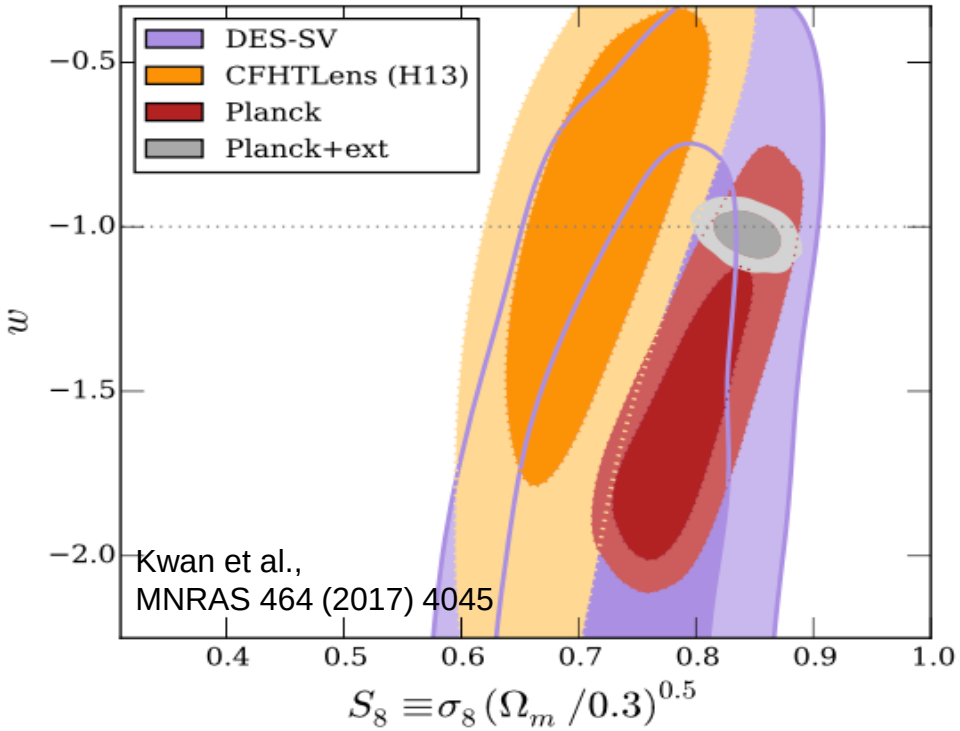
DES (Dark Energy Survey)

Multiprobe approach

DES should be able to clarify if there is a discrepancy WL-Planck within 1-2 years

These results are from SV data (3% of the survey). Will improve by 1 order of magnitude

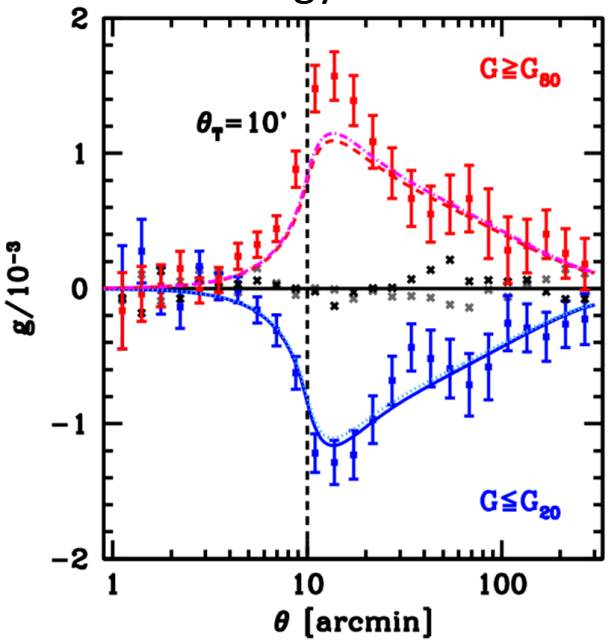




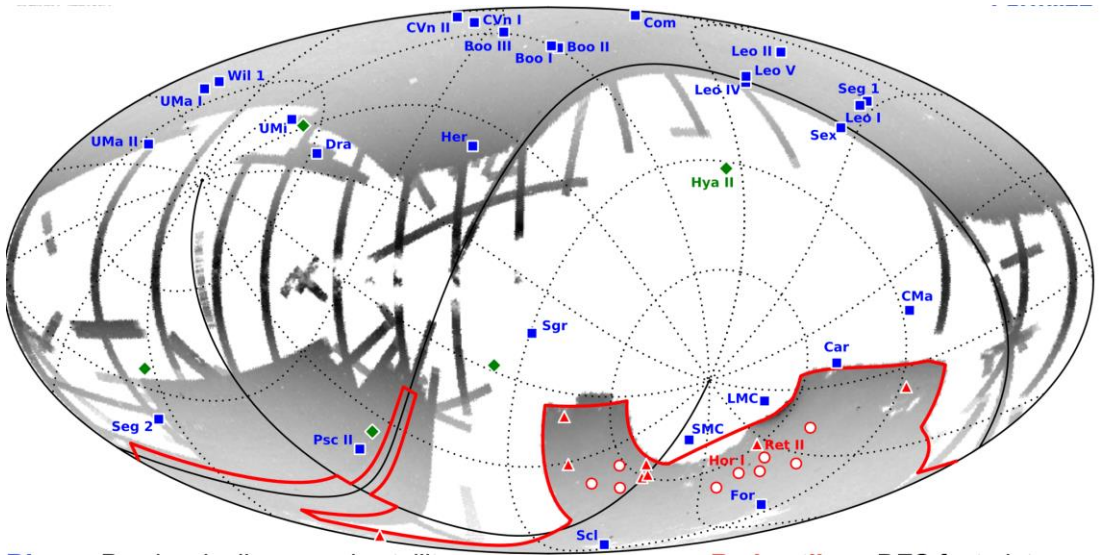
DES (Dark Energy Survey)

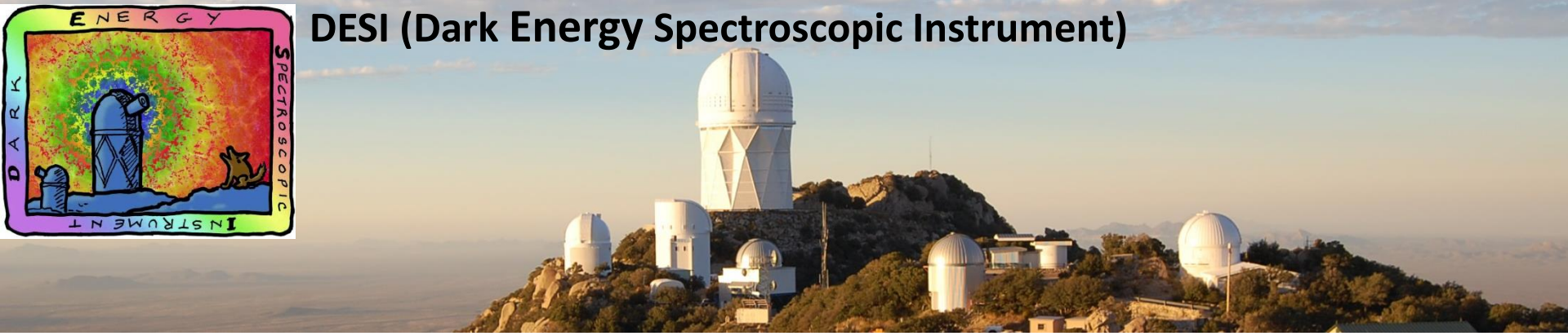
Science Verification data provided a wealth of exciting science, with 3% of the survey Cosmological results using combined probes (lensing, clustering, CMB lensing).
Year 1 data covering 1600 deg2 are being analyzed now. Expect results by summer
Years 2-4 data are in the can. Y1-Y3 dataset covers 5000 deg2 to iAB ~ 23.2 mag: unique data set, extremely powerful for cosmology. Results by 2018-2019

Cosmology with voids



New dwarf satellites of the Milky Way: Dark Matter





DESI (Dark Energy Spectroscopic Instrument)

DESI is building:

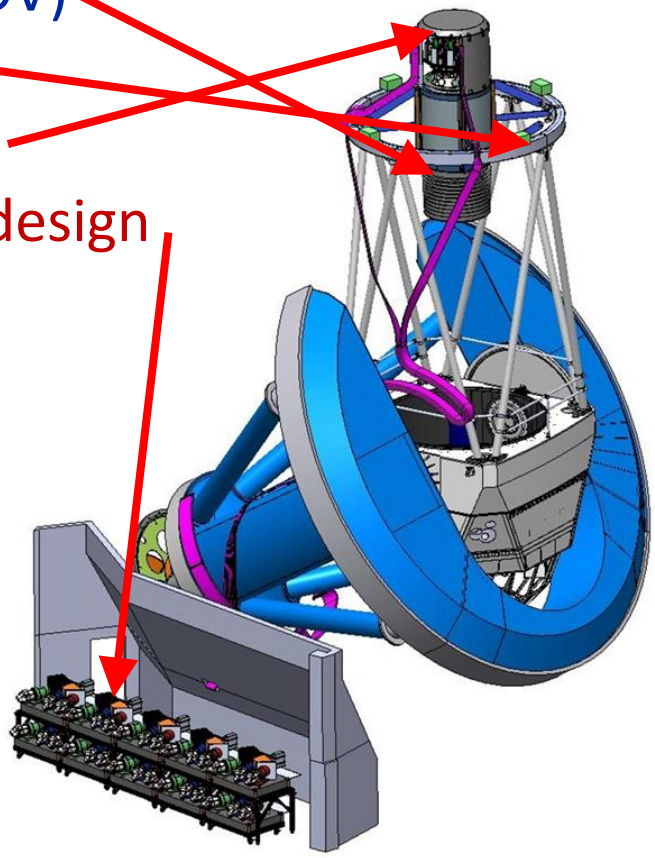
New corrector for Mayall at Kitt Peak (8 deg2 FOV)

A new top ring and cage, barrel and hexápod

A focal plane with 5000 fiber positioner robots

10 3-arm spectrographs, based upon the BOSS design

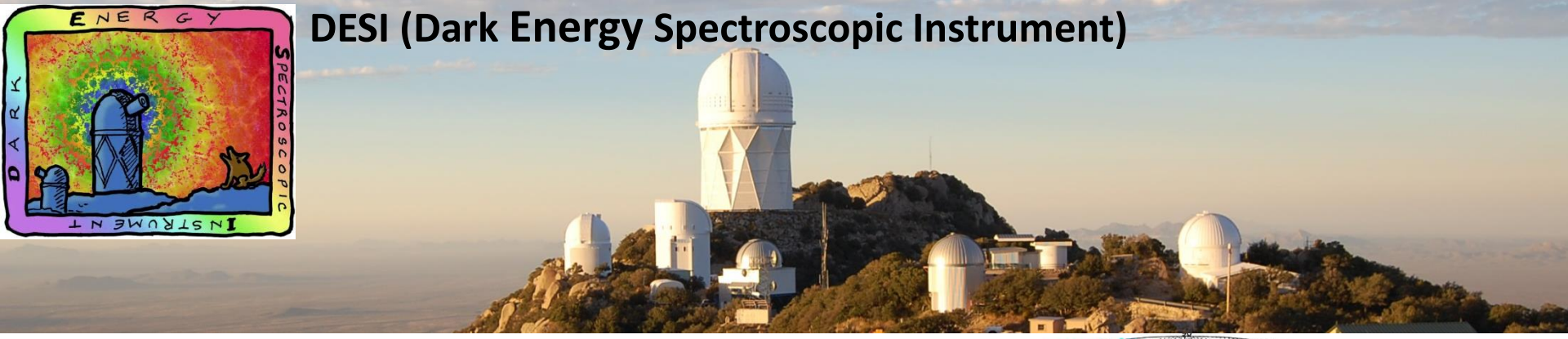
Instrument controls and data processing



The project is funded and construction has started

On track for starting of the survey in second-half of 2019

DESI (Dark Energy Spectroscopic Instrument)



14000 sq-deg footprint

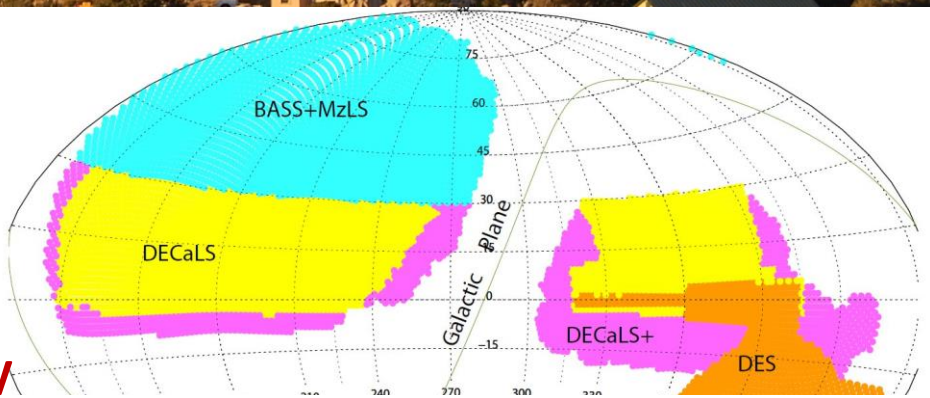
New imaging over this área for targetting

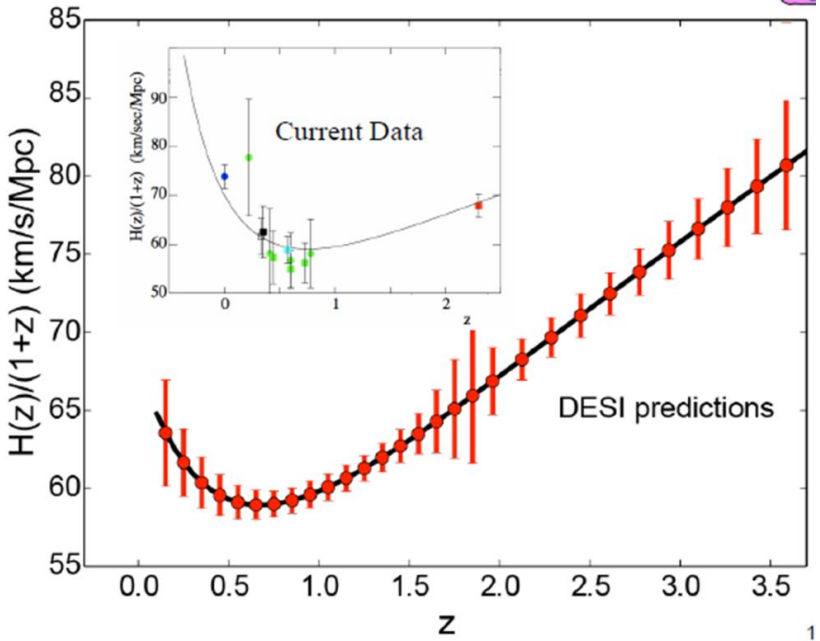
Scientific Goals

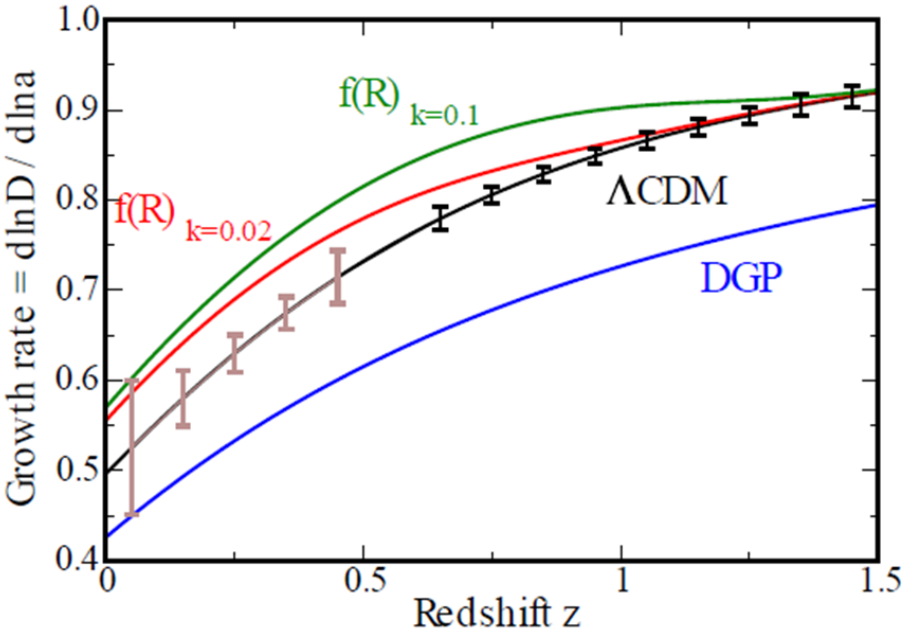
Distances using BAO better than 0.3%

Growth factor better than 1% → Test of GR

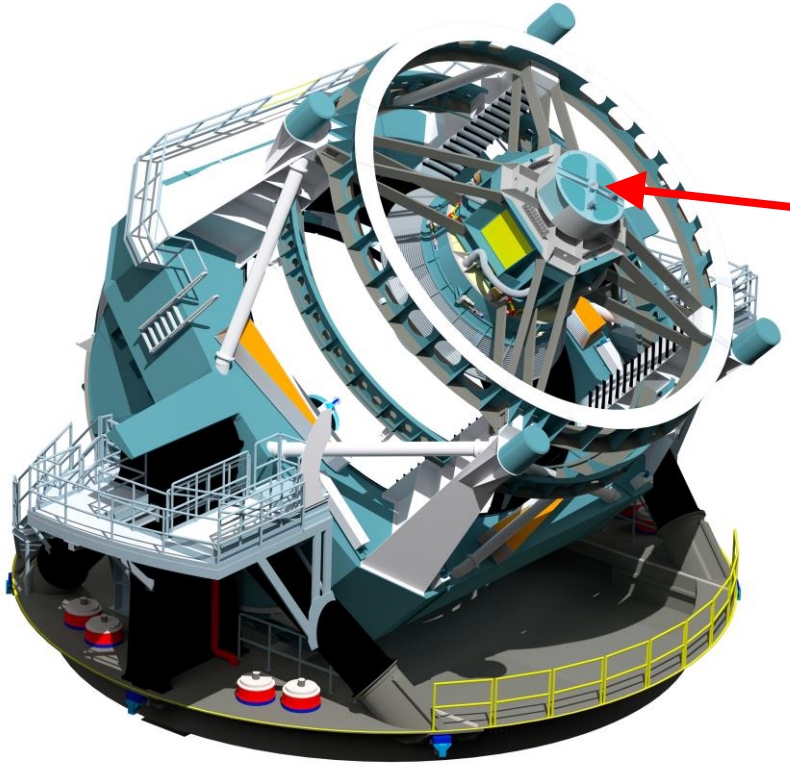
Sum of neutrino masses better than 20 meV

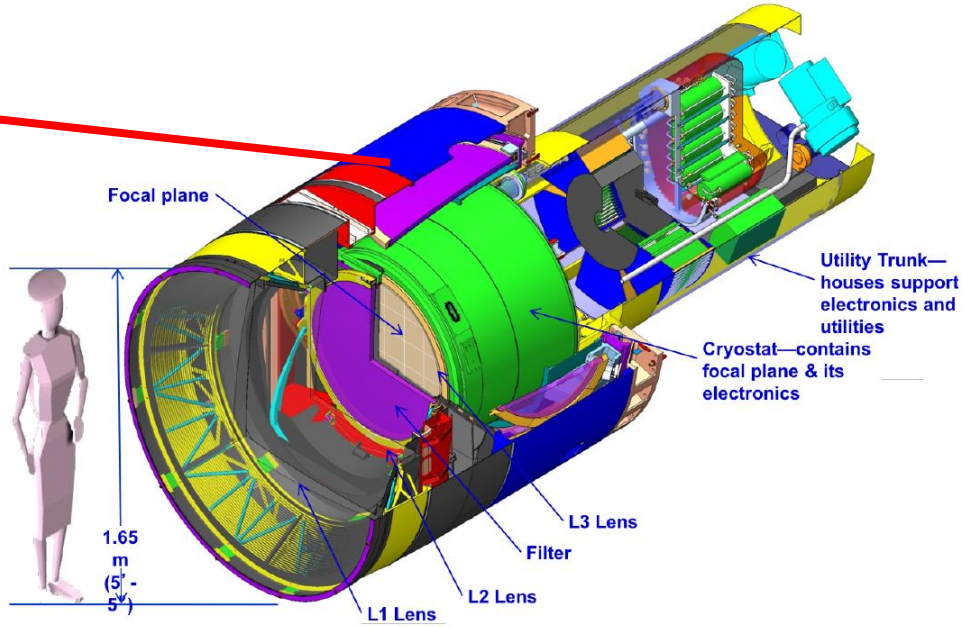






- New telescope of 8.4 m at Cerro Pachón (Chile) in construction
- New camera of 9.6 sq-deg field of view (49 times the area of the Moon in a single exposure) in construction

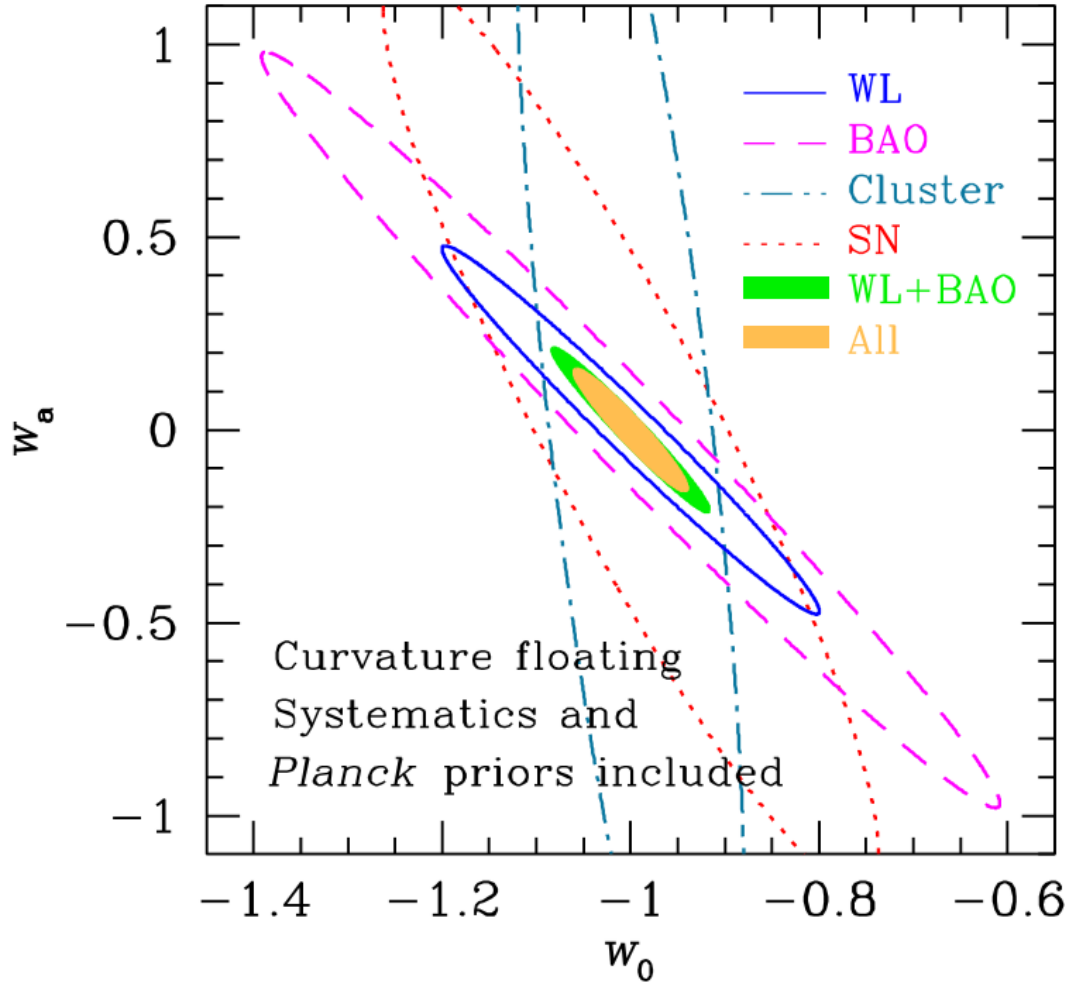




Huge Survey

- 825 visits per pointing
- **10 million alerts per night**
- 40 billion objects
- 500 PB of images
- 10-year survey
- Commissioning starts in 2021
- **Weak lensing with 4 billion galaxies**

BAO
Weak Lensing
Clusters
Supernovae 1A
Faster, deeper and wider tan DES

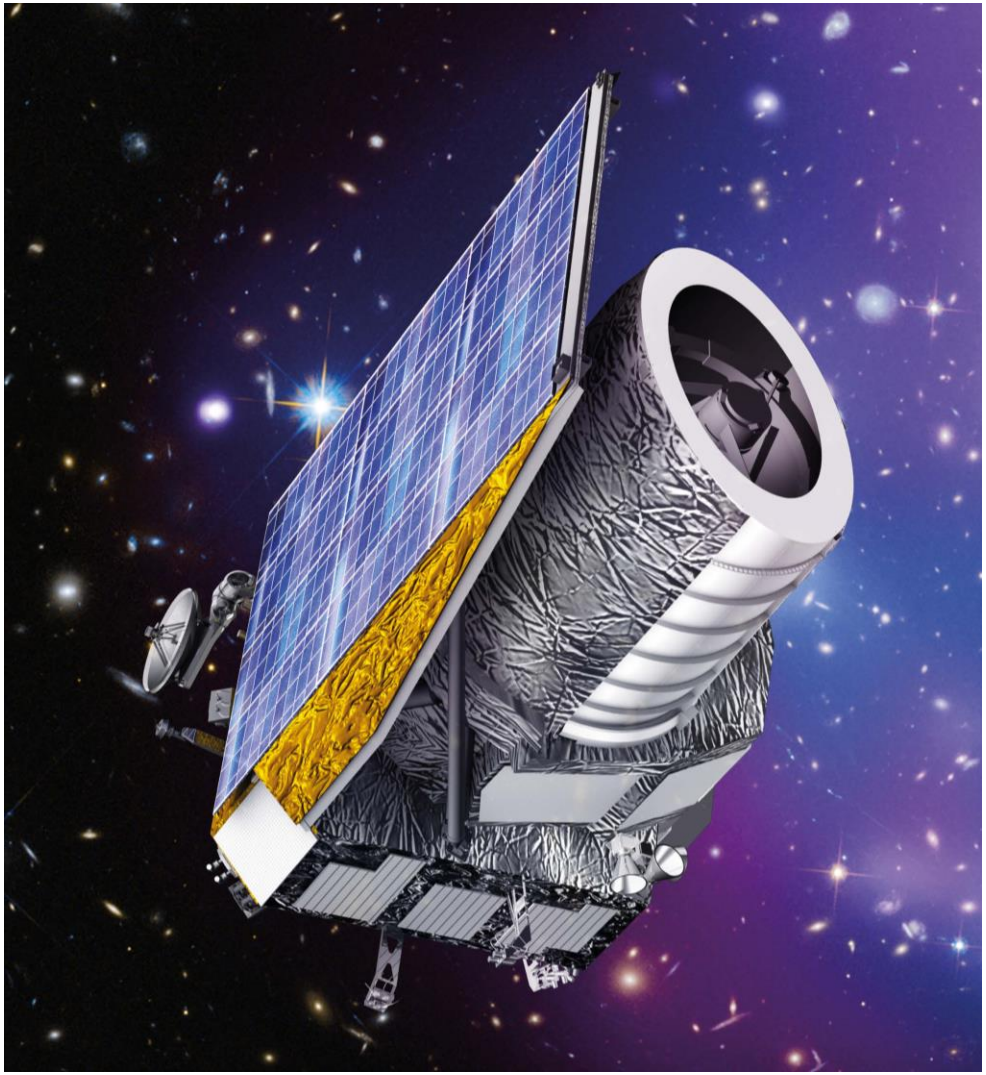


ESA medium-size astronomy and astrophysics space misión

Will be launched by a Soyuz rocket to the L2 Sun-Earth Lagrangian point

Will survey 15,000 sq. deg.
Weak lensing in optical with 1.5 billion galaxies
BAO + RSD with slit-less spectroscopy in infrared for 50 million galaxies
Photometry for photo-z in infrared (YJH), complemented with optical bands from the ground

To be launched in late 2020



Conclusions

All current data are consistent with ΛCDM (dark energy being the cosmological constant)

Imaging/Spectroscopy, Ground/Space are complementary and synergistic

- Imaging: Efficient, Deep; 2.5D many methods, allow weak lensing
- Spectroscopy: 3D info for BAO, RSD and cross-correlations
- Space: Exquisite stable PSF for lensing, Access to NIR
- Ground: Larger telescopes allow fast, wide Deep surveys

Combination of data from different surveys can be very powerful; also the combination with CMB

In the next 10 years, there is going to be a huge quantitative jump in the amount of available data, hopefully leading to a huge qualitative jump in our understanding of dark energy and cosmology