Meeting on Fundamental Cosmology

Institute of Cosmos Sciences, Barcelona

June 15th - 17th, 2016

The Dark Energy Spectroscopic Instrument

E. Sánchez (CIEMAT)

BCN-MAD DESI RPG

ICE IEEC IFAE Institut de Física d'Altes Energies

Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

ift Instituto de Física Teórica UAM/CSIC

On behalf of the DESI Collaboration

GOBIERNO DE ESPAÑA MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

EXCELENCIA MARÍA DE MAEZTU

Outline

- Dark Energy and the DESI Project
- The DESI Science Goals
- The Survey
- The Instrument
- Spain Contributions
- Status
- Conclusions

DESI Science Goals

Is cosmic expansion accelerating because of a breakdown of General Relativity (GR) on cosmological scales or because of a new energy component that exerts repulsive gravity within GR?

If the latter, is it consistent with a cosmological constant or does it evolve in time?

Any answers to this will point to new physics!

Measure the expansion rate of the Universe

- ***The distance-redshift relation $D_A(z)$***
- ***Directly measure $H(z)$***

Measure the rate at which structures grow in the Universe

- ***Growth function and its derivatives***

DESI will do both in one survey

DESI Science Goals

Use BAO to measure the distance scale of the universe over nearly the whole northern sky and nearly the entire age of the universe (out to z~3.5, 12 billion years ago)

Test modifications of gravity by measuring the growth rate of structures with RSD

Measure the mass of the neutrino through the suppression of small-scale clustering (~20 meV precision on the measurement of the sum of neutrino masses)

Test inflation by measuring non-Gaussianity and spectral shape of inflationary perturbations

DESI Survey Data Set

These measurements can be achieved by means of 5 populations that should give the easiest redshifts over a broad redshift range:

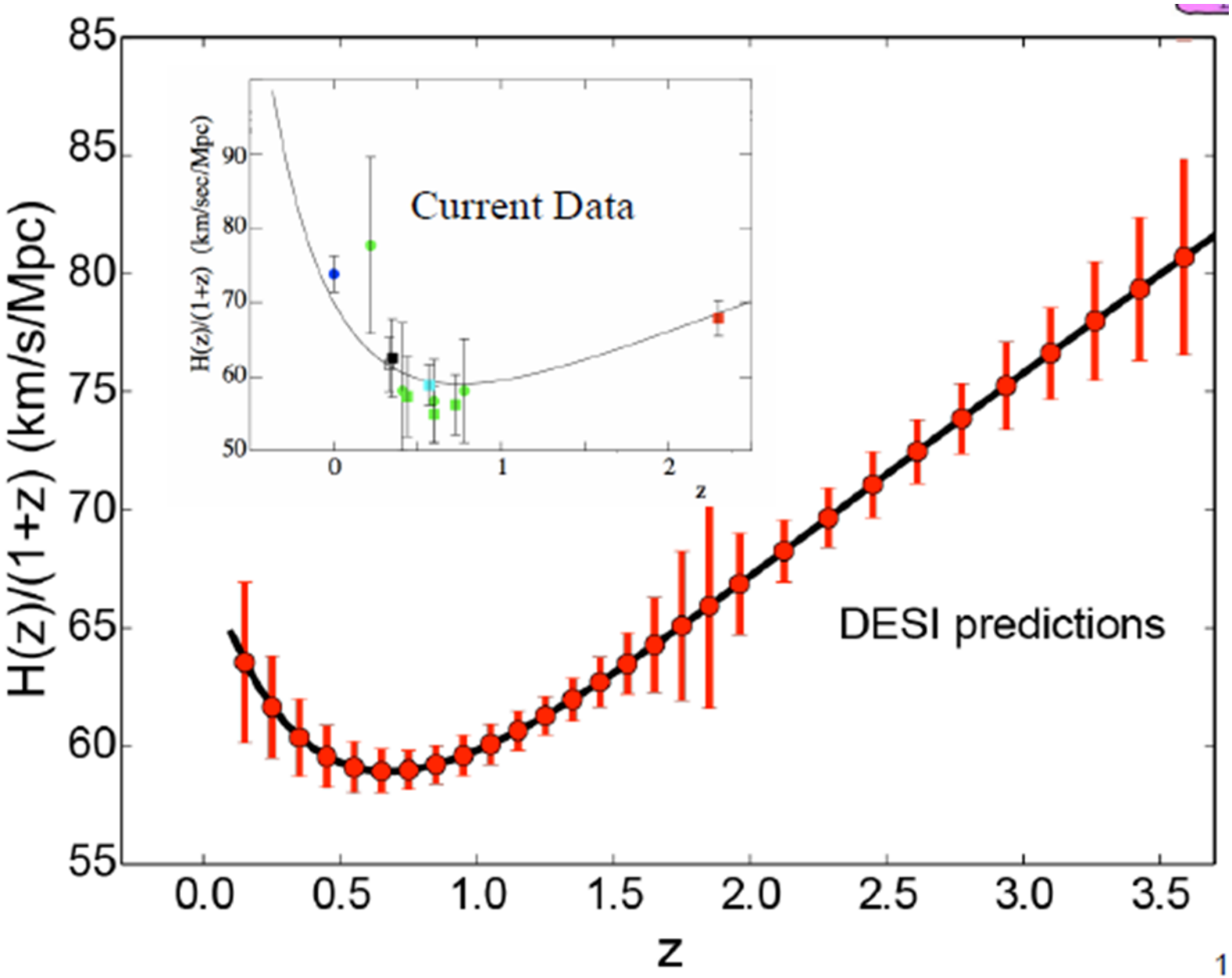
- Bright Galaxies (BG) ($0<z<0.4$)
- Luminous Red Galaxies (LRG) ($0.4<z<1$)
- Emission Line Galaxies (ELG) ($0.6<z<1.6$)
- Tracer Quasars (QSO) ($1<z<2.1$)
- High Redshift Quasars (Ly-α forest) ($z>2.1$)

Successful z object density/sq-deg

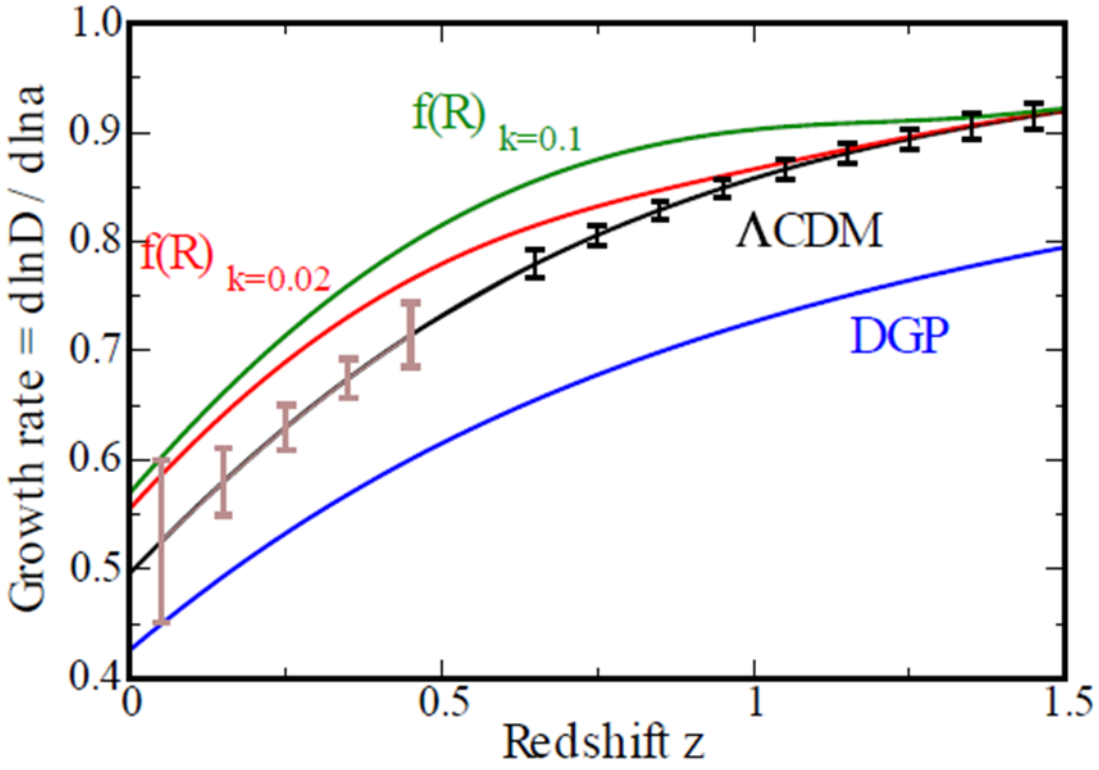
- BGs > 700
- LRGs>300
- ELGs>1280
- QSOs>120
- Ly-α>50

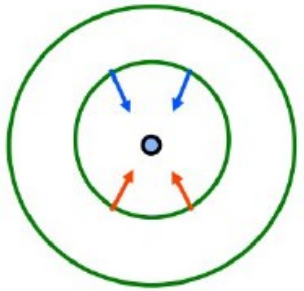
Number of redshifts ~34 M

DESI Survey Data Set

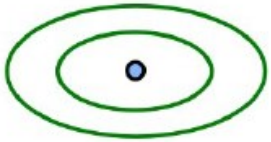


DESI Survey Data Set

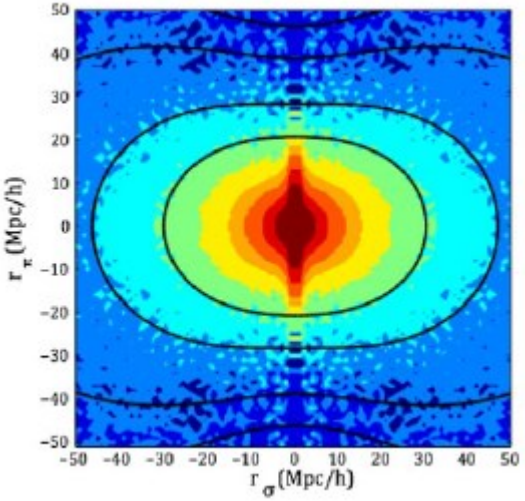




"real" space



"redshift" space

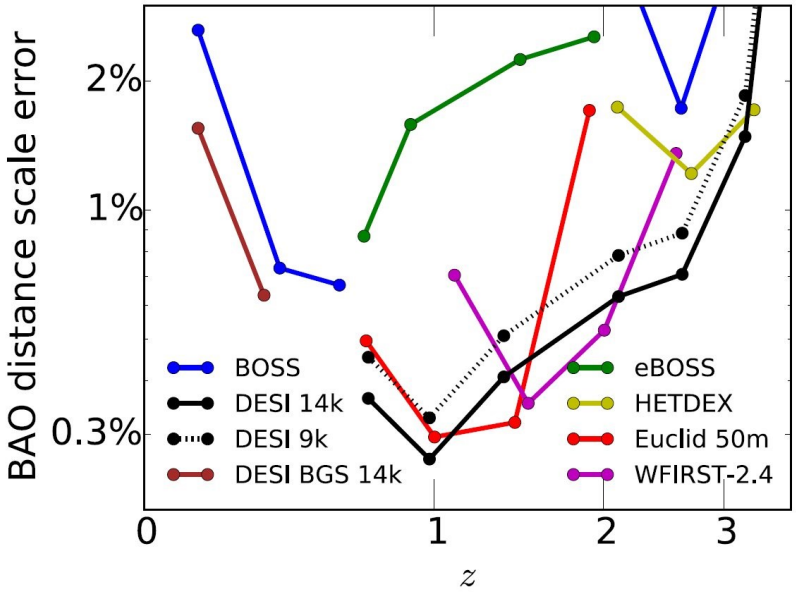


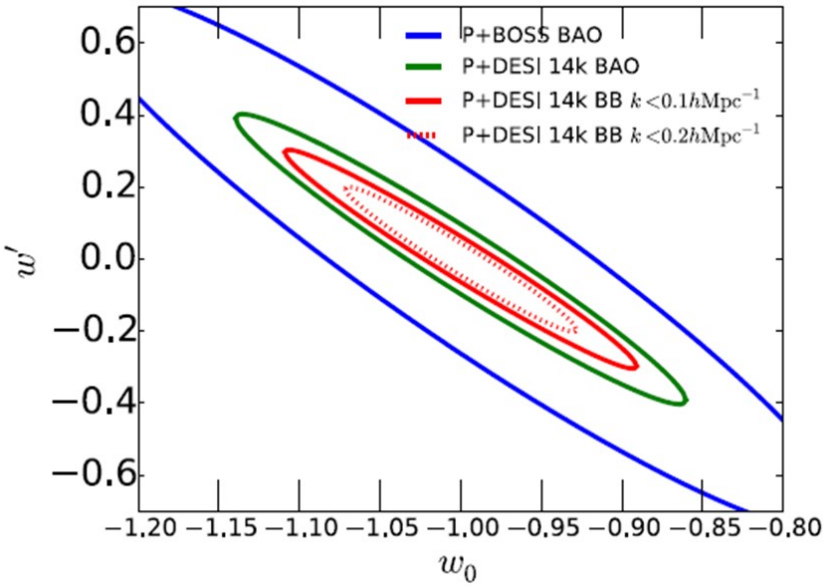
RSD observed in BOSS

RSD constrain the growth rate → Test of GR

DESI will measure the growth rate with precision <1% over 0.5<z<1.4

DESI Survey Data Set





Will measure distance scale to better than 0.3% statistical errors.

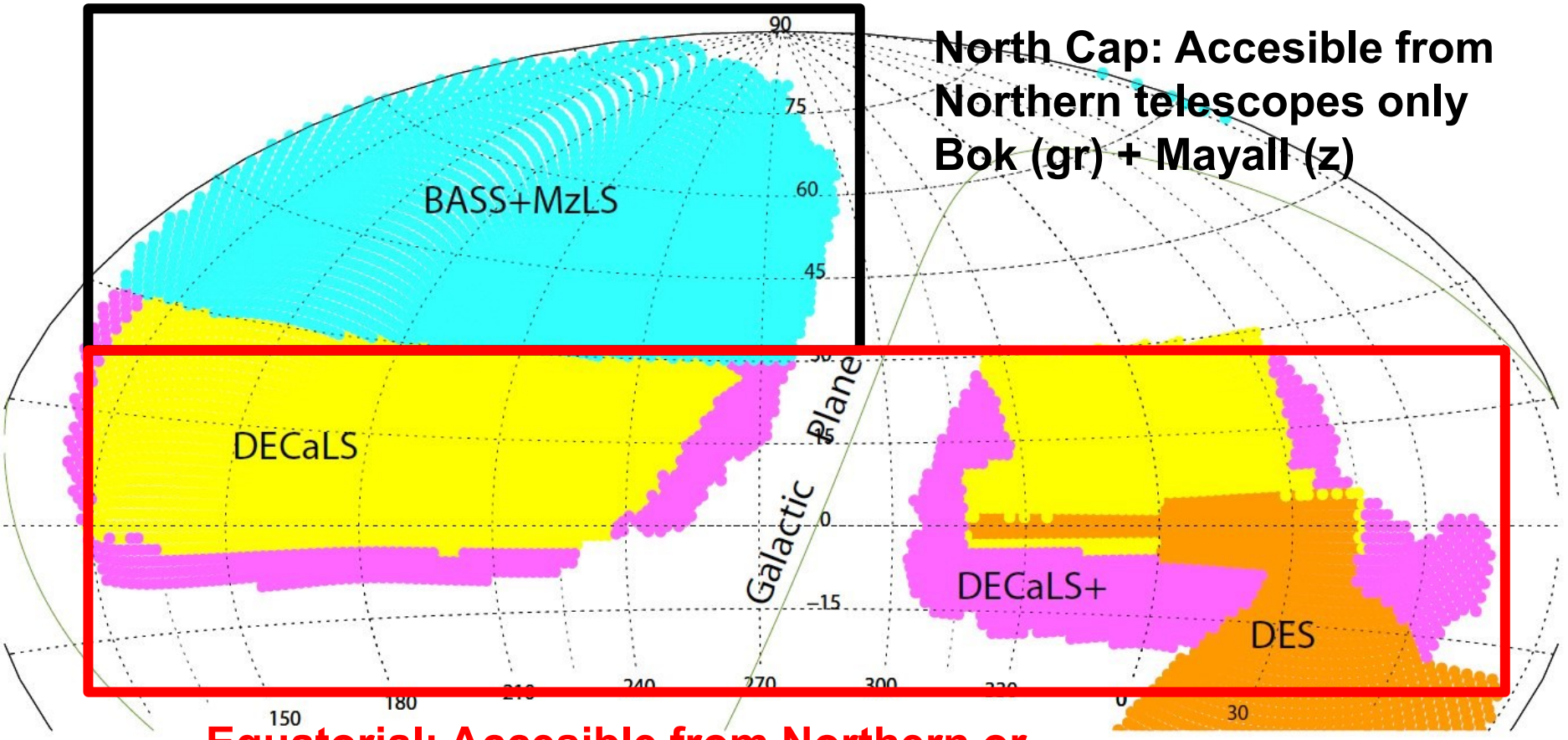
Figure of Merit (FoM) surpasses definition of a Stage-IV Dark Energy Experiment with margin

Surveys	FoM
BOSS BAO	37
DESI 14k galaxy BAO	133
DESI 14k galaxy and Ly-α forest BAO	169
DESI 14k BAO + gal. broadband to $k < 0.1\ h\ \mathrm{Mpc}^{-1}$	332
DESI 14k BAO + gal. broadband to $k < 0.2\ h\ \mathrm{Mpc}^{-1}$	704

DESI Survey Data Set

14000 sq-deg footprint

DESI targeting requires new imaging over this area



North Cap: Accesible from Northern telescopes only Bok (gr) + Mayall (z)

Equatorial: Accesible from Northern or Southern telescopes

DESI

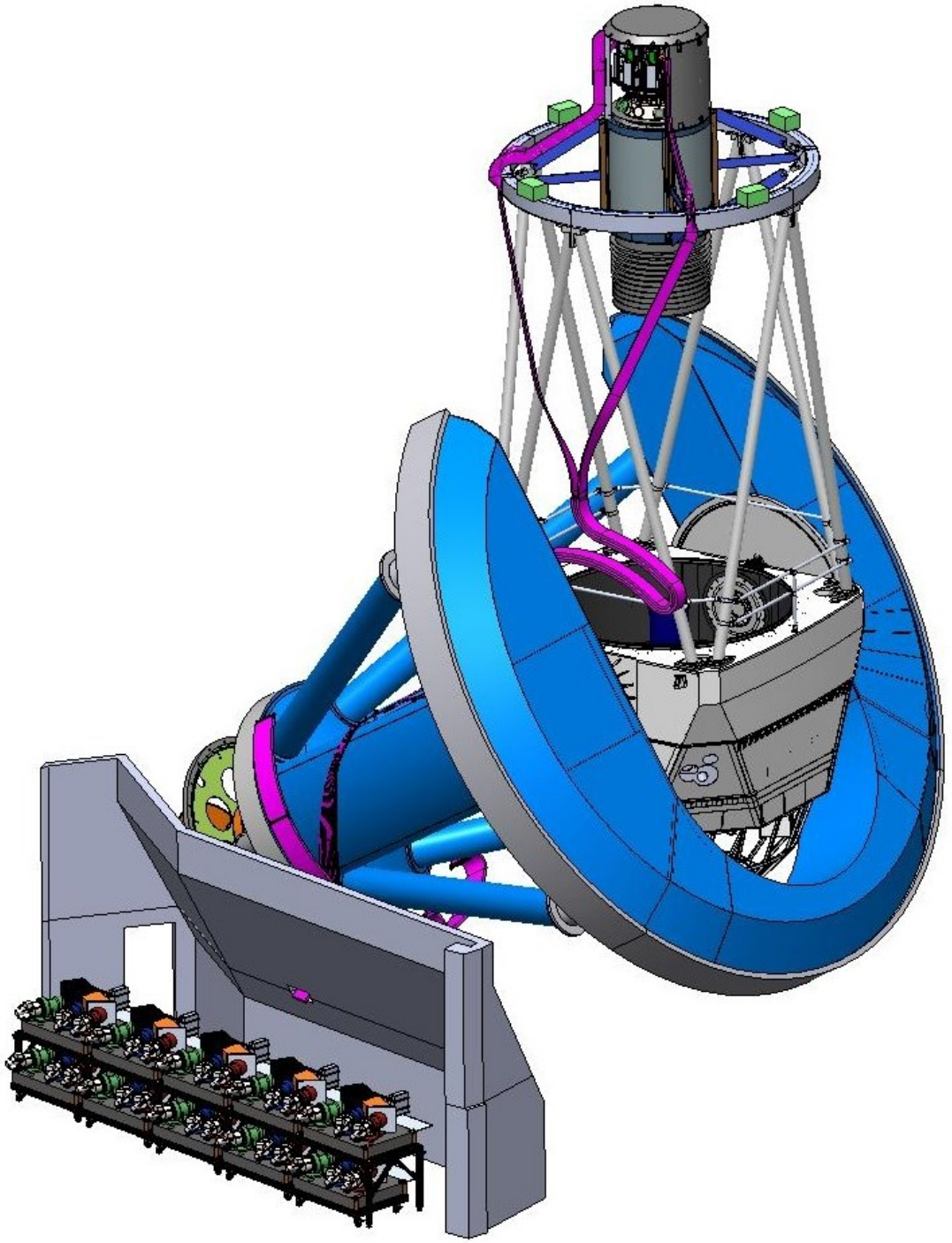
To achieve these measurements, we need:

4m telescope: Mayall @ Kitt Peak

8 sq-deg field of view optics

5000 fibers in robotic actuators

10 spectrographs x 3 bands (blue, red and NIR; 360-1020 nm)



DESI Instrument

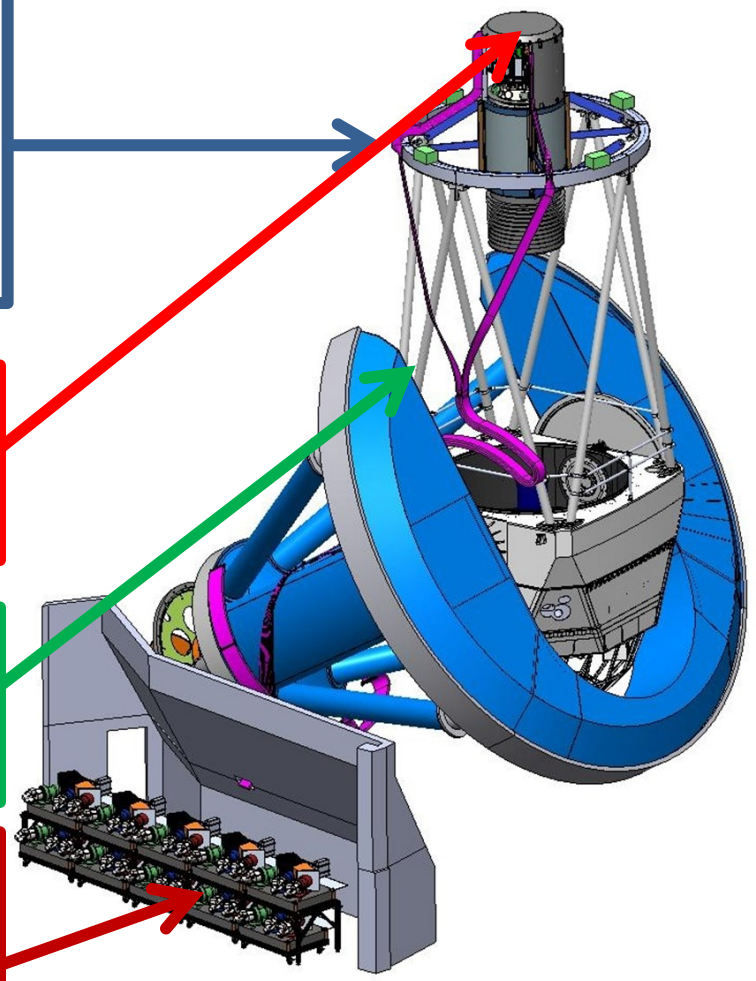
The DESI project will build:

A new corrector for the telescope (creating a 8 deg2 FOV)
A new top ring and cage, barrel and hexapod assembly

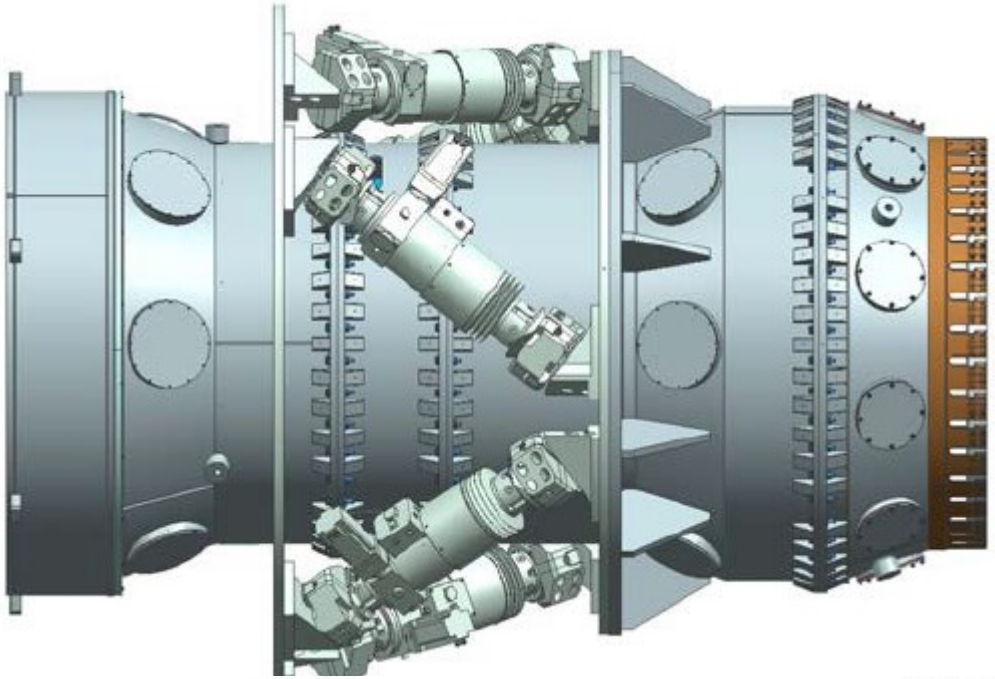
A focal plane with 5000 fiber positioner robots in 10 petals

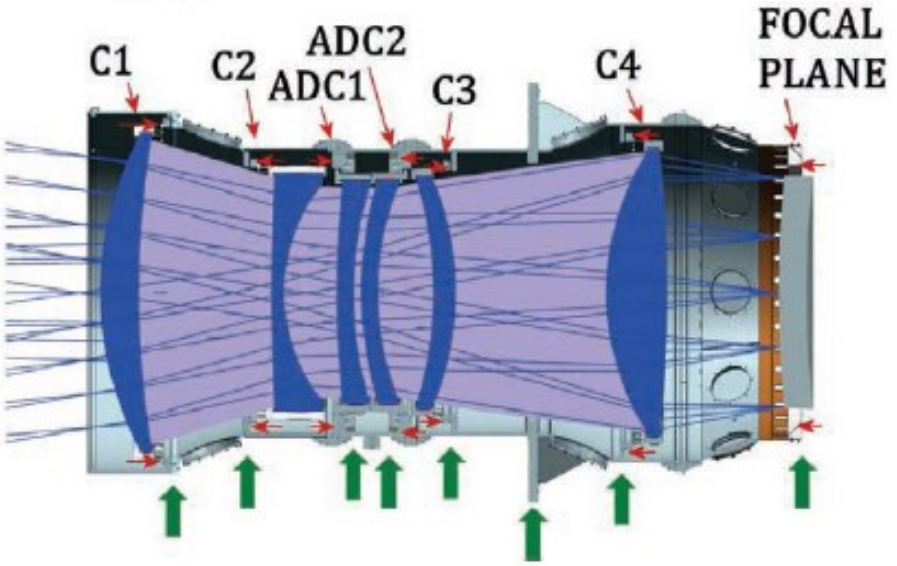
A fiber optic system to transport the light to spectrographs

Ten 3-arm spectrographs based upon the BOSS design
Instrument controls and data processing



DESI Instrument: New Corrector

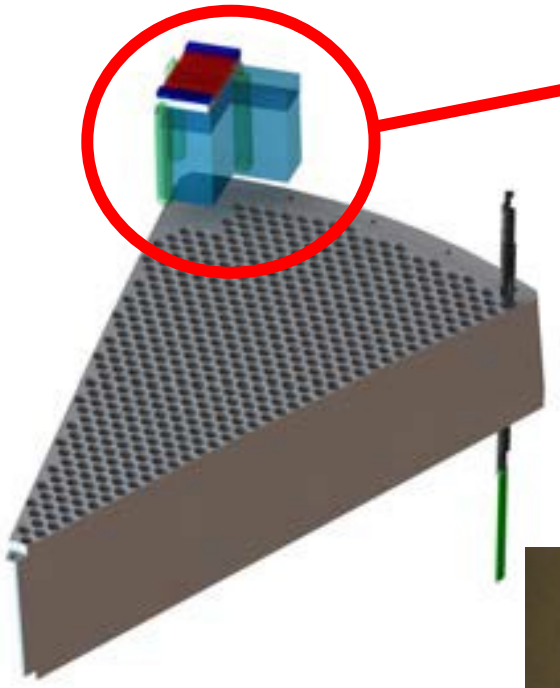




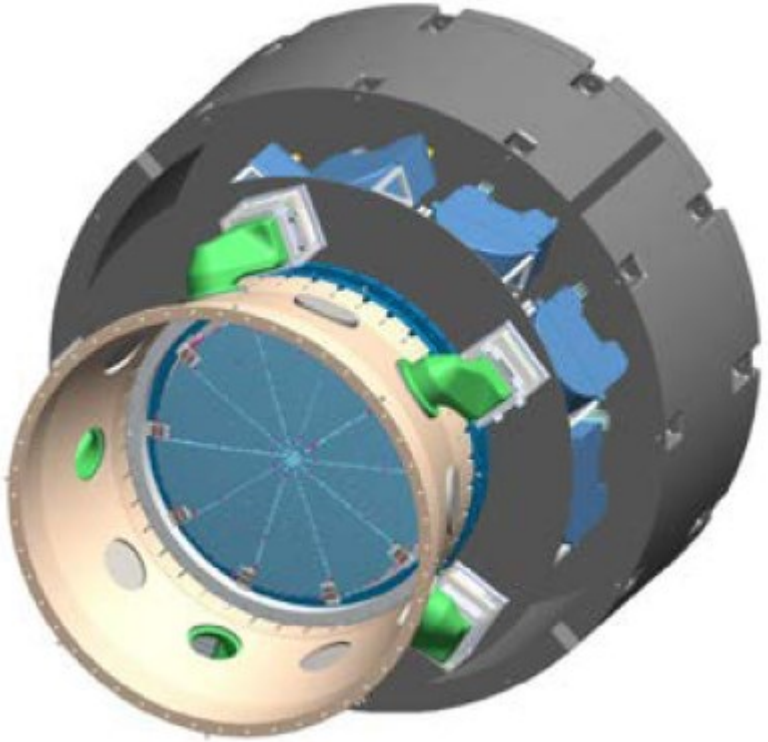
C4 Lens, ~1m diameter!!!

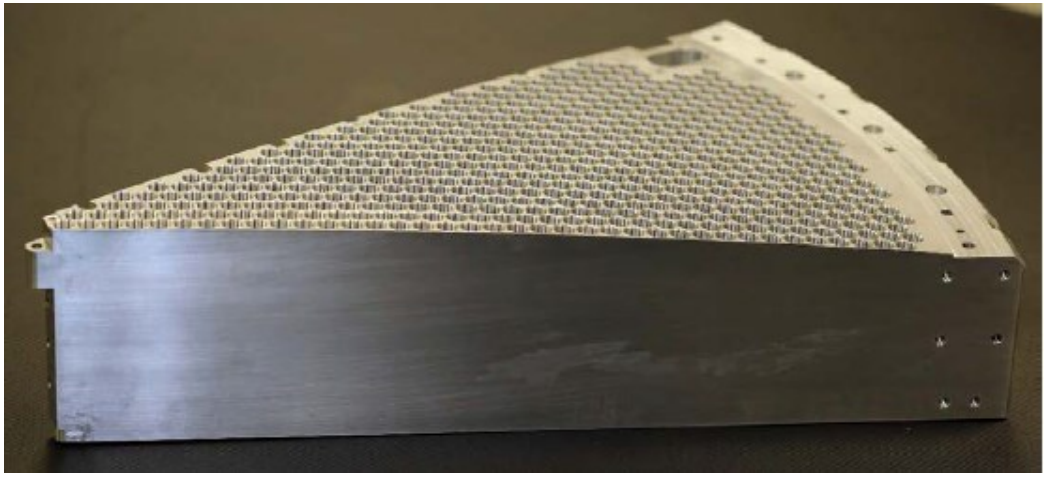
DESI Instrument: Focal Plane

10 Petals. Each one contains 500 optical fiber positioners and one GFA camera

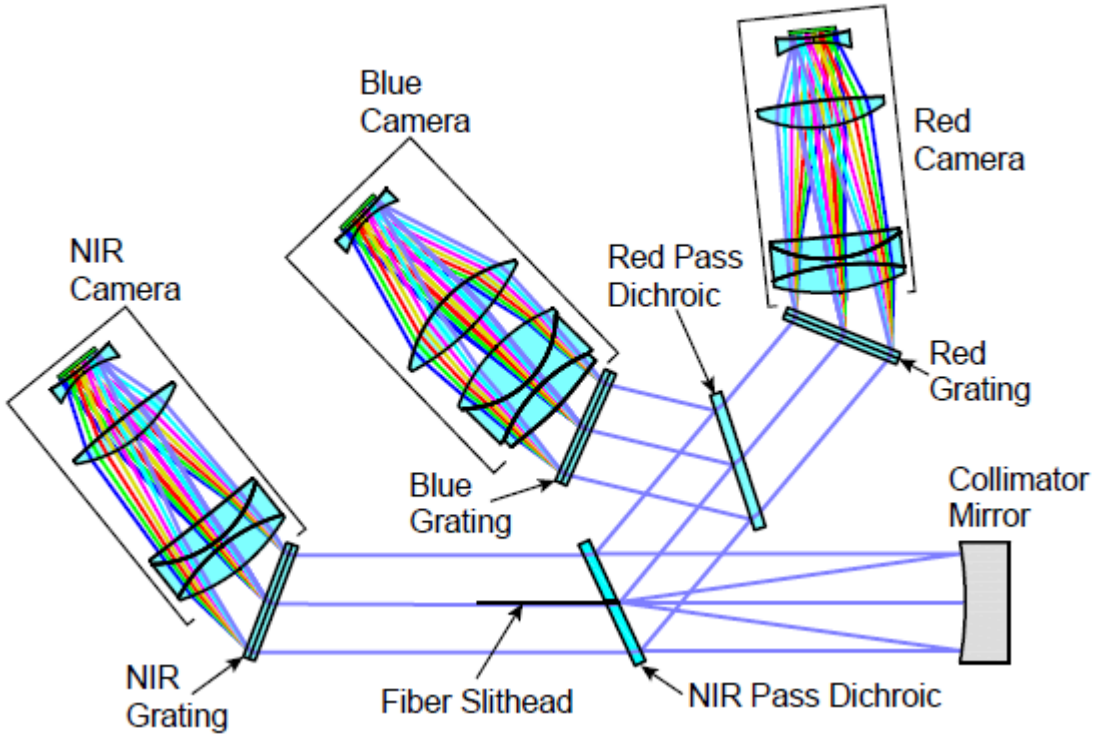


Responsibility of BCN-MAD





DESI Instrument



Schematic of a spectrograh. DESI will have 10 spectrographs with 3 bands each (Blue, Red, NIR)

Some of the spectrograph cameras

DESI: Spanish Contribution

2 spanish RPGs + some individuals

Barcelona-Madrid Regional Participation Group Institutions

ICE, IEEC/CSIC, IFAE, CIEMAT, IFT/UAM

Instrumentation

Guide Focus and Alignment Units

Guiding software

Science

Working Group participation

Leading image validation task force

Management

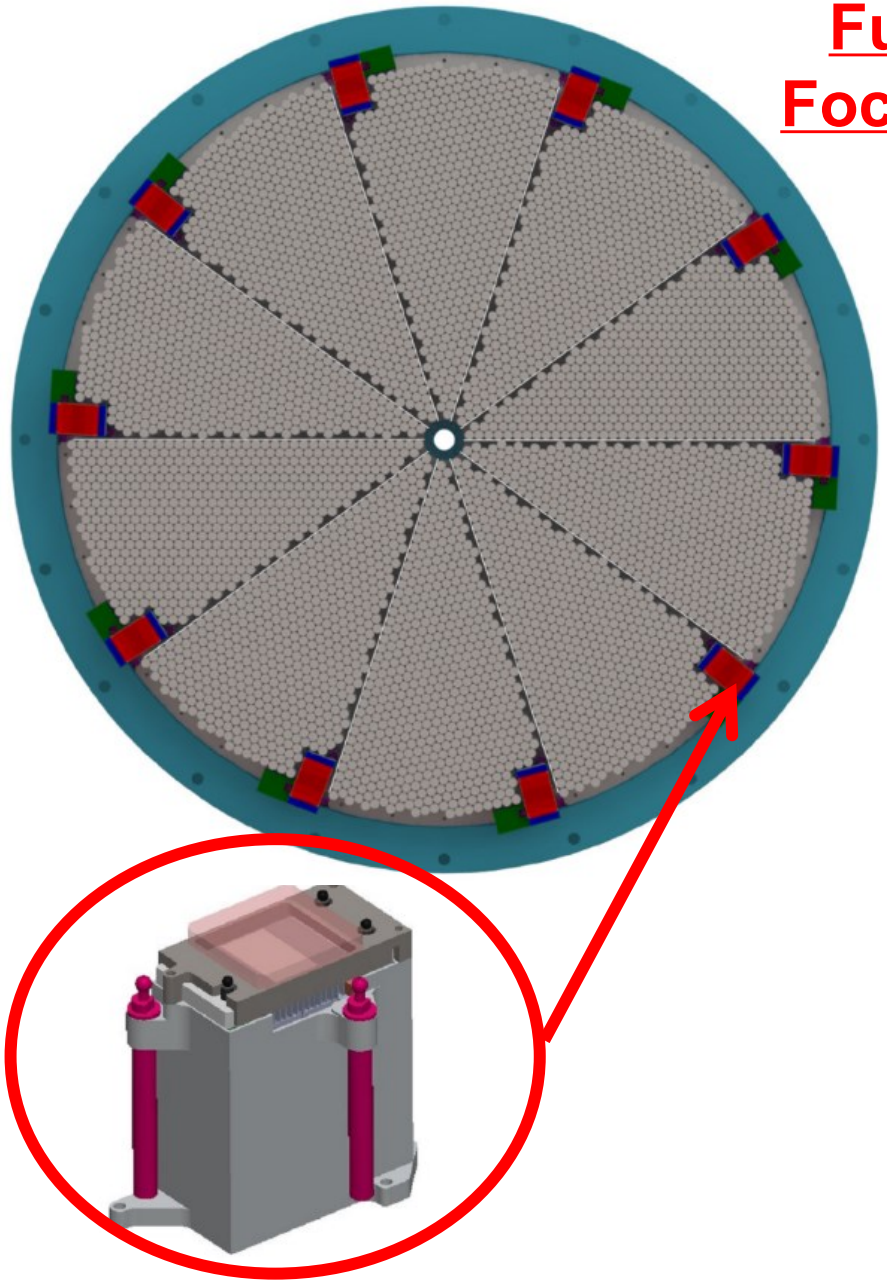
Part of Institutional Board

Member of several committees

GMT Regional Participation Group Institutions

CEI/UAM+CSIC, IAA, IAC

DESI Instrument: Spanish Contribution



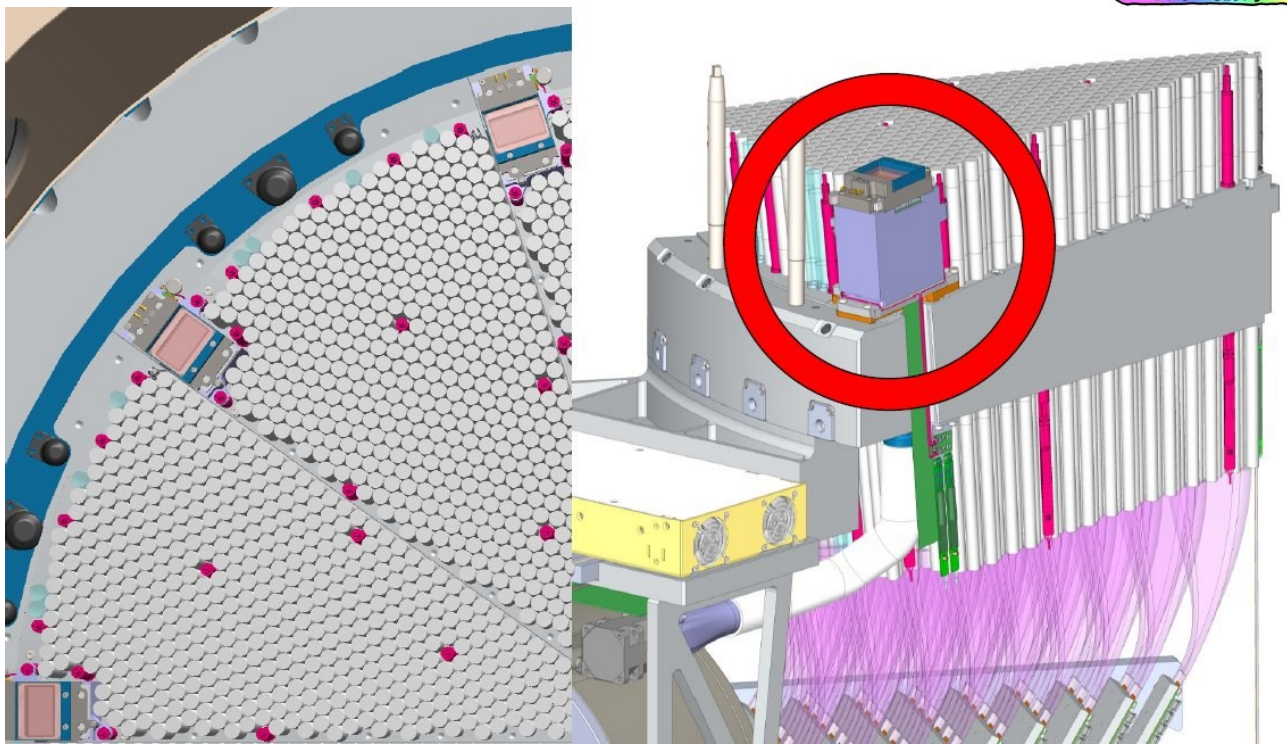
Full construction of the Guiding, Focus and Alignment (GFA) System

- Focal Plane composed of 10 petals
- Each petal contains a GFA camera (There are 10 cameras)
- GFA of two types:
  - 6 for guiding and field acquisition
  - 4 for focus and alignment
  - Identical except for optical filter
- The only imaging systems in DESI
- GFA cameras use stars to provide the guide signal and measure focus and alignment

DESI Instrument: Spanish Contribution

The GFA cameras have to operate at ambient temperature to minimize local heating near the focal surface

The GFA camera footprint has to be such as to minimize the number of science fibers displaced



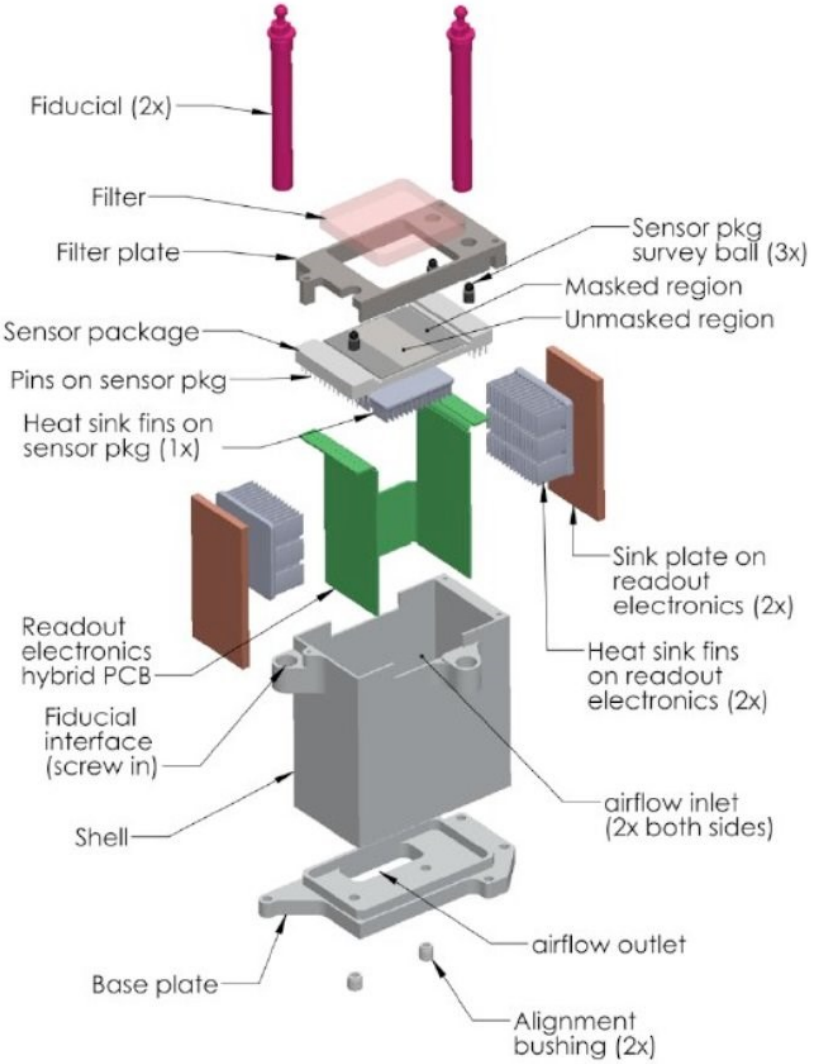
GFA system requiremets:

- Provide imaging data during commissioning of the instrument
- Determine the current telescope pointing within 20 seconds after telescope slew
- Determine focal plane scale, rotation and astrometric solution
- Monitor the intensity and PSF of stars during observations to provide feedback on observing conditions
- Provide guide signals to the telescope at 1Hz to a precision of <30 mas
- Determine the wavefront error in focus, decenter, tip and tilt, and provide corrective information to the hexapod system

DESI Instrument: Spanish Contribution

Each 10 GFA camera contains a single CCD sensor, mounted and operated as a standalone instrument

Each camera contains all CCD readout electronics and all controls, and requires only DC power and a Gigabit Ethernet connection



DESI Instrument: Spanish Contribution

GFA System Status:

Design has been finalized and is ready for fabrication

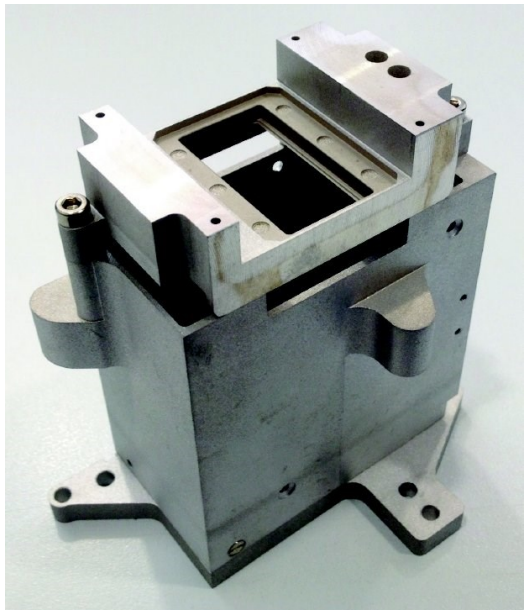
Mechanics: Prototype built and tested

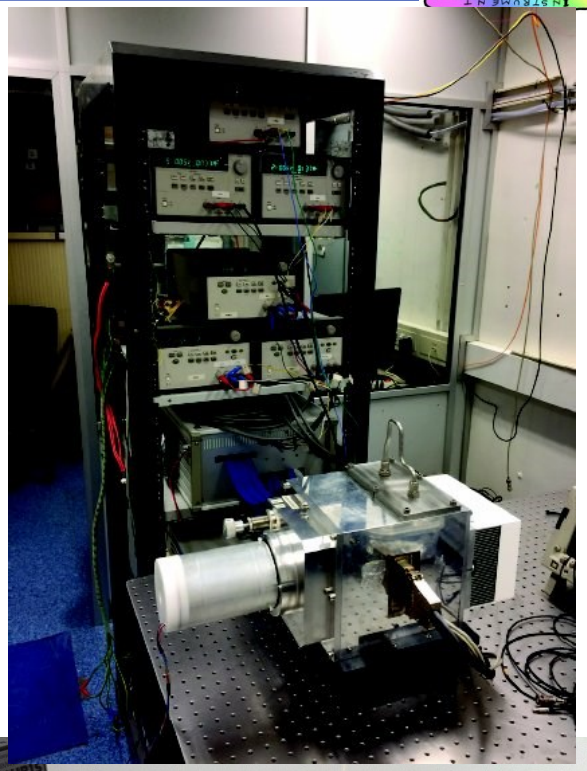
Electronics Schematics defined, Layout finished

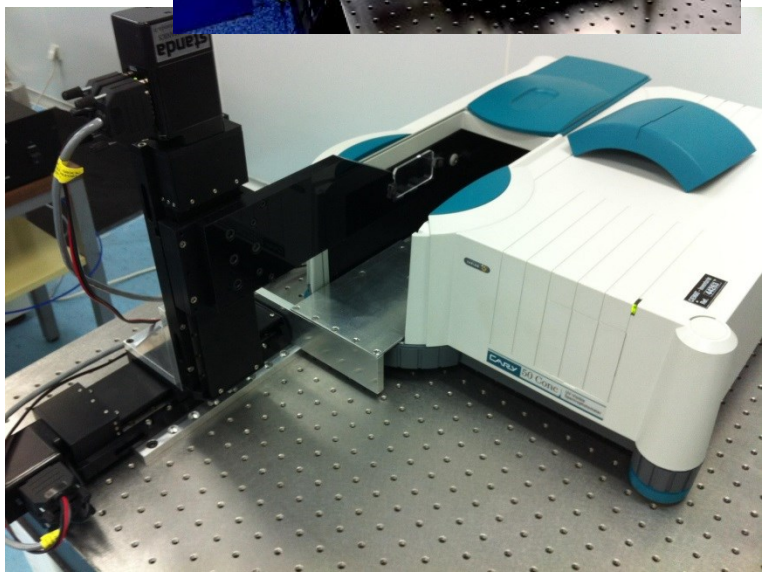
Software: Designed and being written

CCDs have been selected, in process of purchasing Characterization and test setups for CCDs (BCN) and filters (MAD) are ready

The plan is to have the GFA completed by the end of 2017







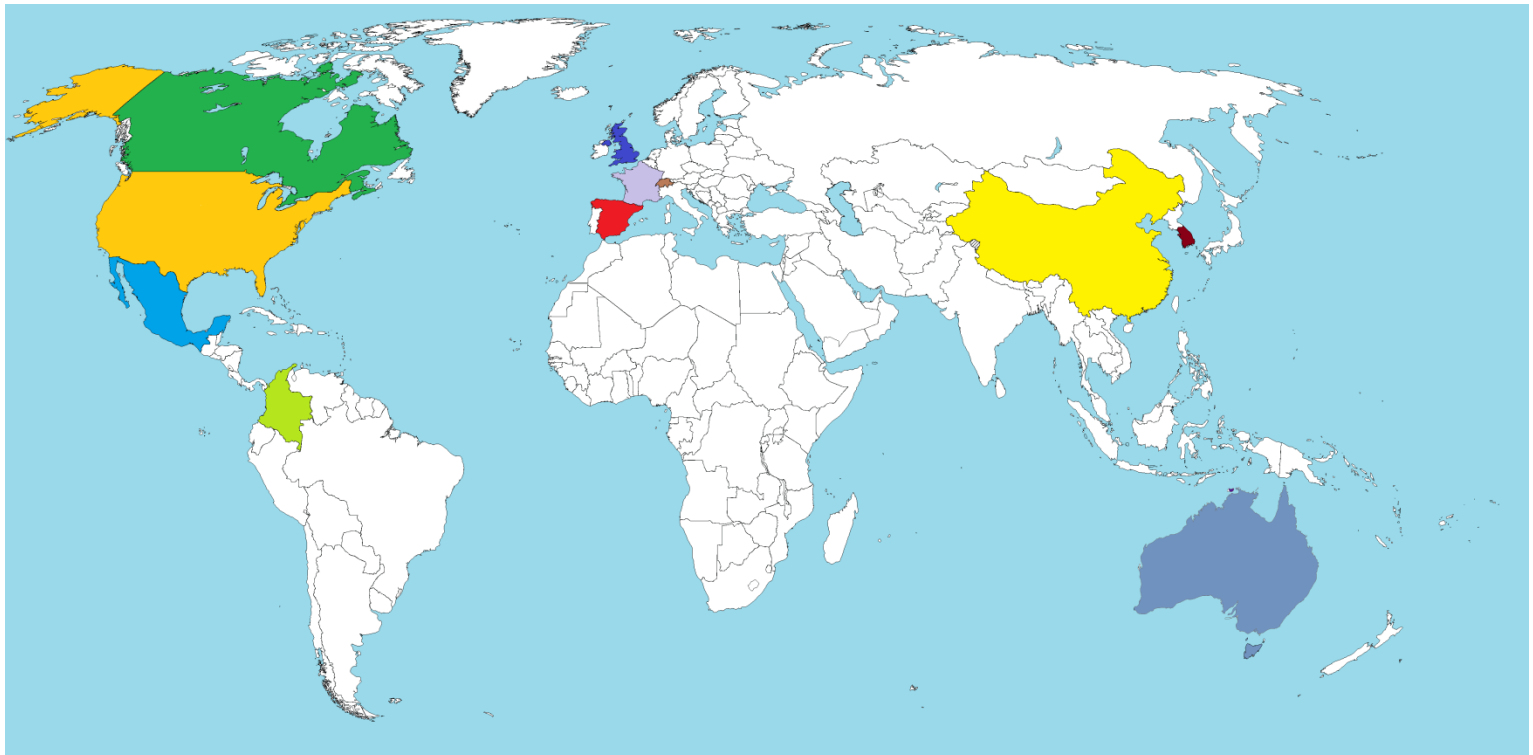
The Collaboration

The DESI Collaboration has ~200 Participants from ~40 institutions

Project Director: **M. Levi (LBNL)**

Spokespersons: **D. Eisenstein (Harvard), R. Weschler (SLAC)**

USA (ANL, Arizona, BNL, BU, CMU, Cornell, FNAL, Harvard, Irvine, **LBNL**, LLNL, Michigan, NOAO, OSU, Ohio, Pennsylvania, Pittsburgh, Siena, SLAC, SMU, UCB, UCSC, Utah, Yale), Australia (Queensland, Swinburne), **Canada** (Toronto) , **China** (NAOC RPG) , **Colombia** (Andes) , **France** (CEA, CPPM, LAM, LPNHE, OHP) , **Korea** (KASI,KIAS) , **Mexico** , **Spain** (BCN-MAD RPG, GMT RPG) , **Switzerland** (EPFL, ETHZ) , **UK** (Durham, Portsmouth, UCL, RPG)



Conclusions

- Dark energy is one of the most important puzzles of fundamental physics. Baryon Acoustic Oscillations and Redshift Space Distortions are key probes of Dark Energy, complementary to other probes with low systematics

- DESI is a massive spectroscopic survey, which will use those probes with impressive forecast. DESI will be the final measurement of BAO up to z<2.

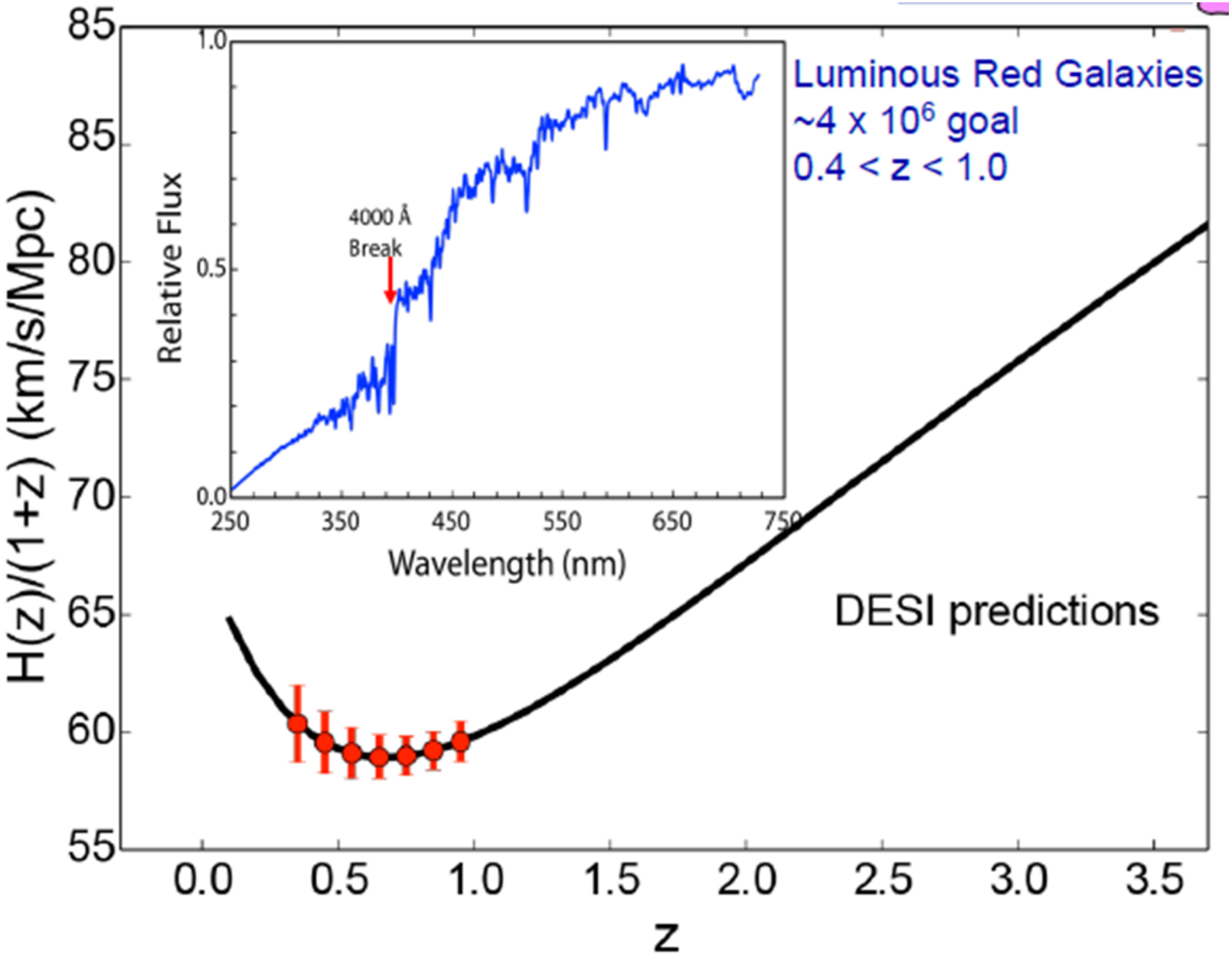
- The project is funded and construction has started.

- On track for on-sky commissioning <4 years from now in 2019 and start of the survey in second-half of 2019!

- BCN-MAD RPG is actively involved in the collaboration

Backup Slides

DESI Survey Data Set



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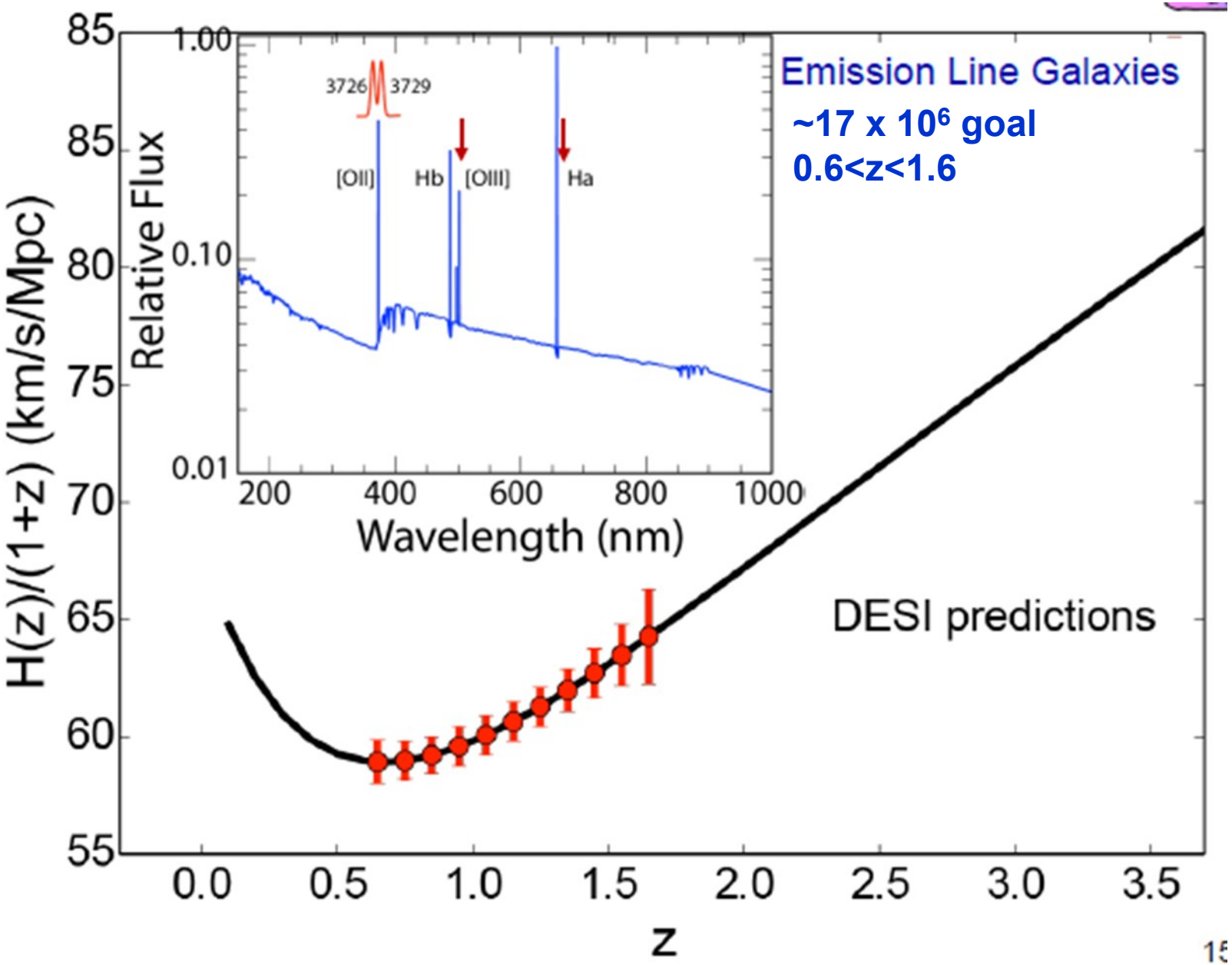

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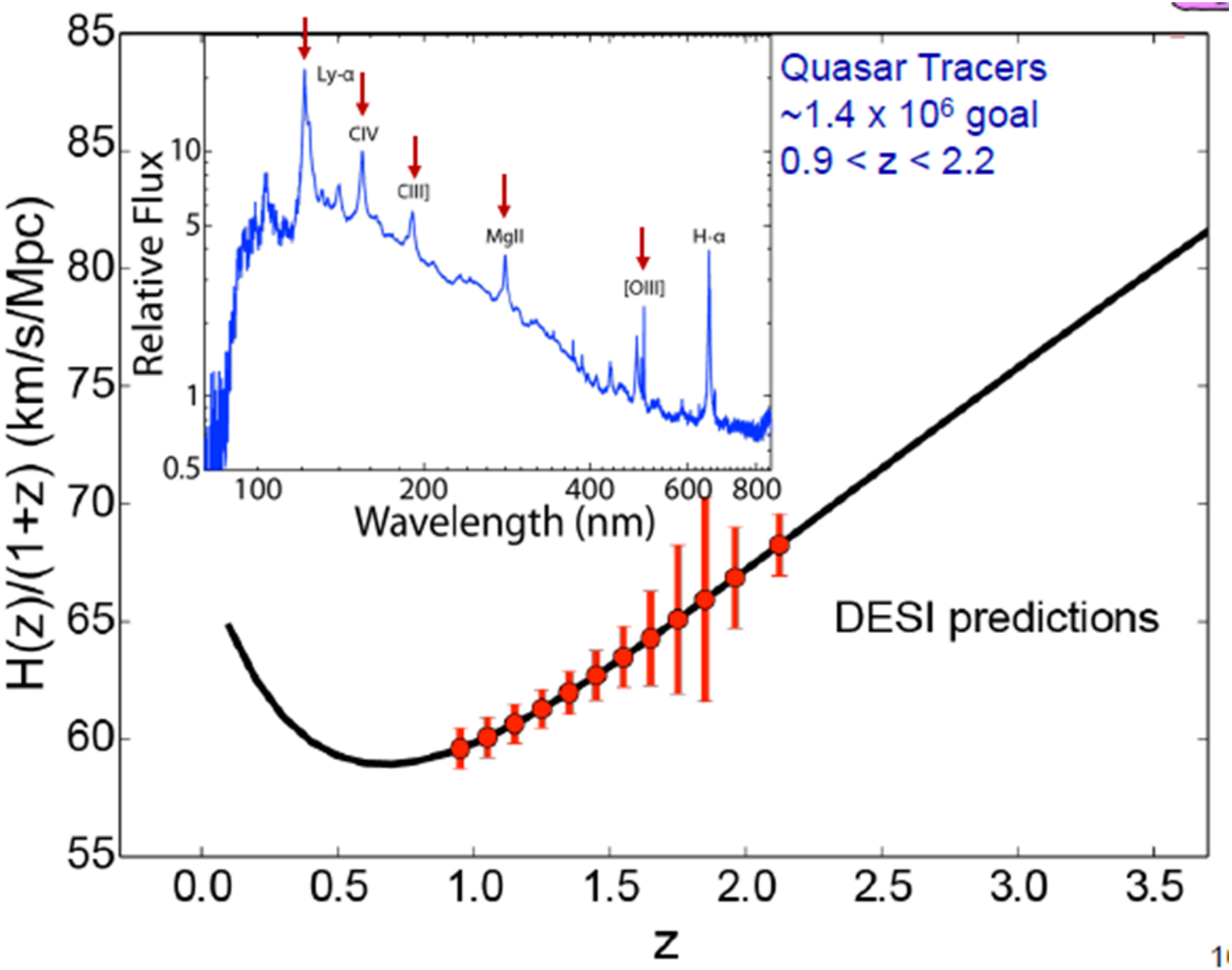

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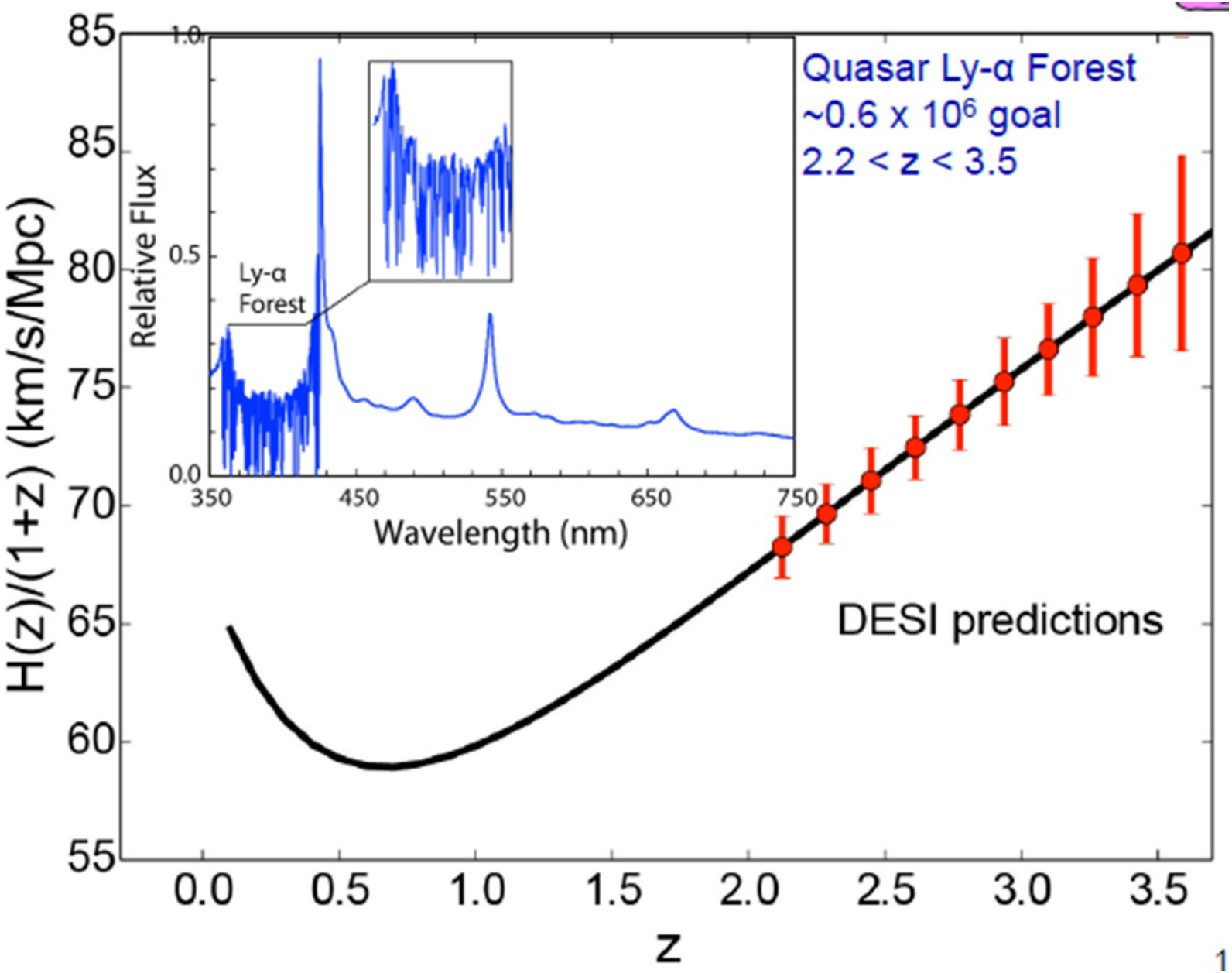

DESI Funding

- Office of High Energy Physics of the U.S. Department of Energy,
- U.S. National Science Foundation,
- Science and Technologies Facilities Council of the United Kingdom,
- Gordon and Betty Moore Foundation,
- Heising-Simons Foundation,
- National Council of Science and Technology of Mexico,
- DESI Member Institutions (Spanish from Plan Nacional)