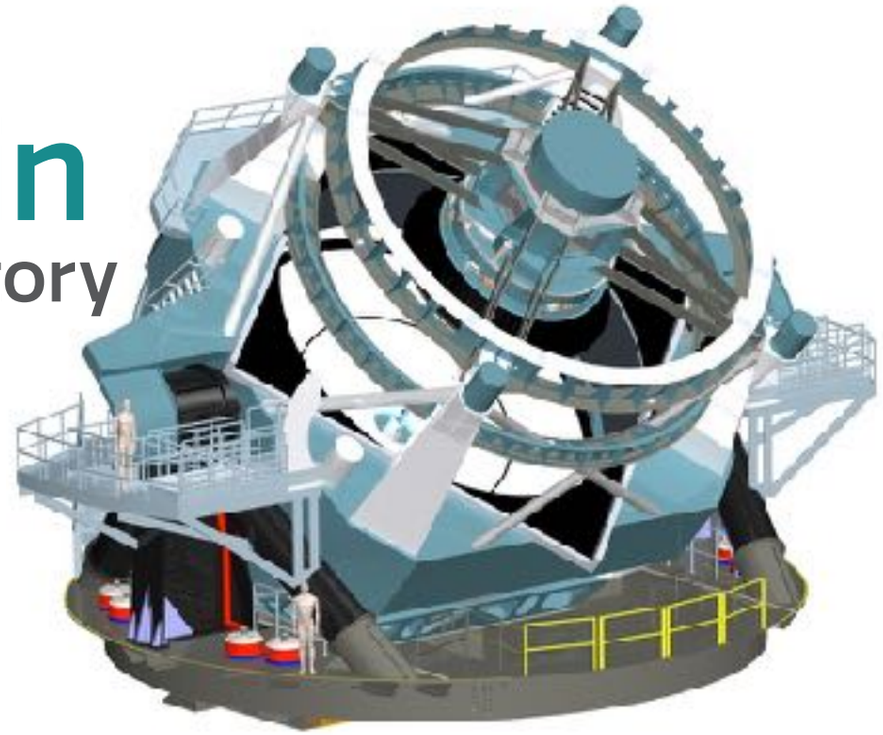
Present and Future Dark Energy Probes (II)

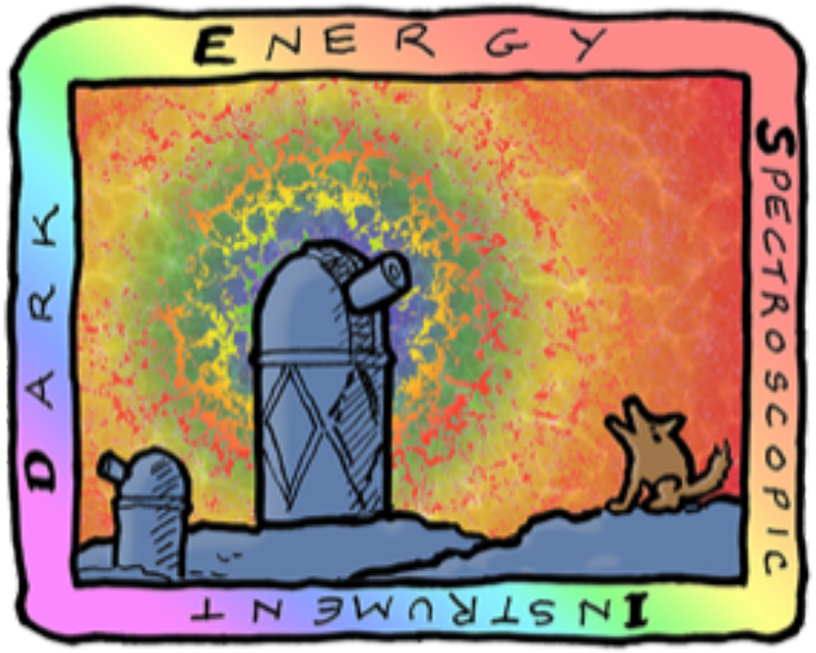
Aaron Roodman
SLAC National Accelerator Laboratory
August 20-21, 2020
SLAC Summer Institute

Next Generation of Galaxy Surveys

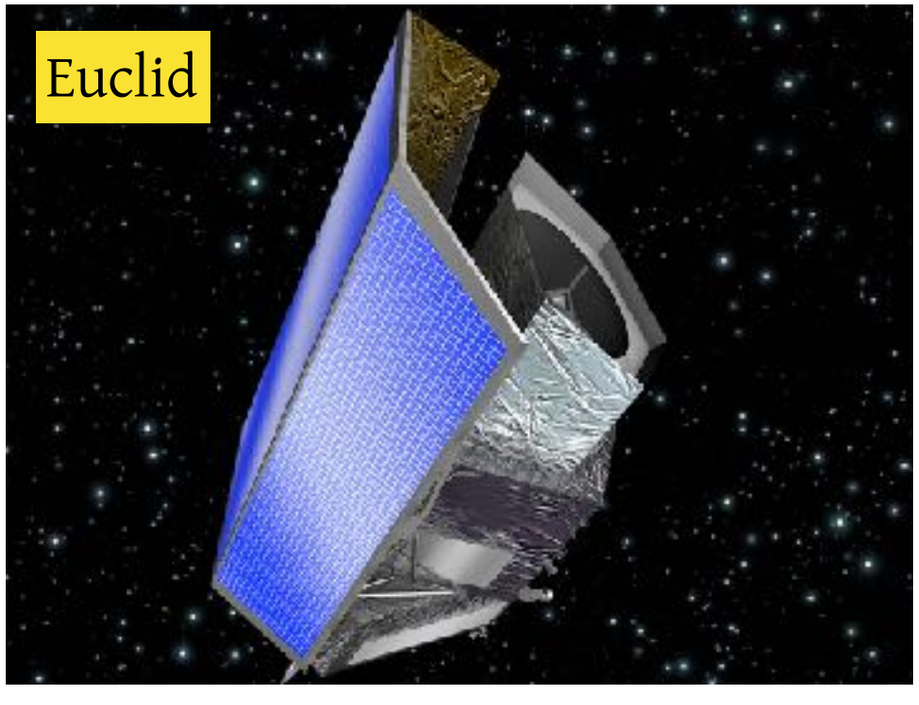
Ground

Rubin
Observatory





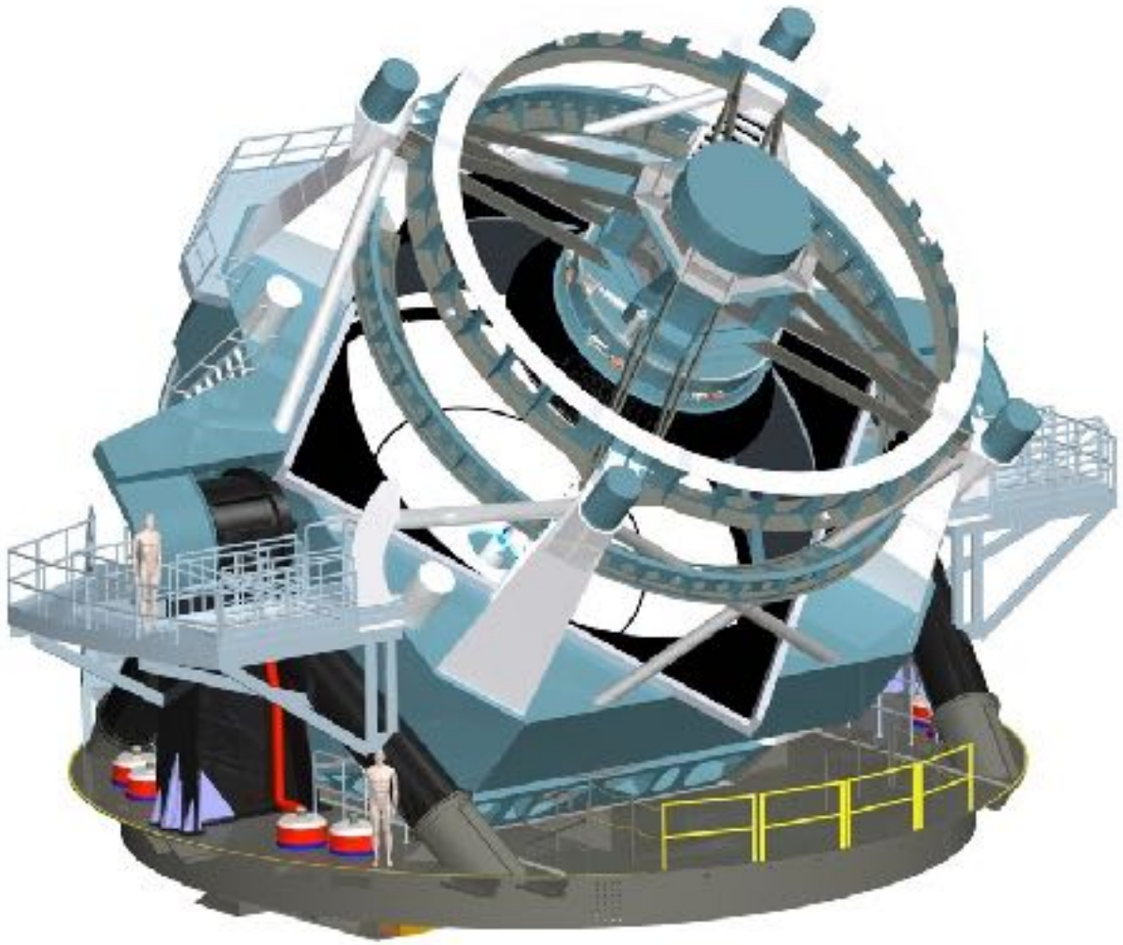
Space

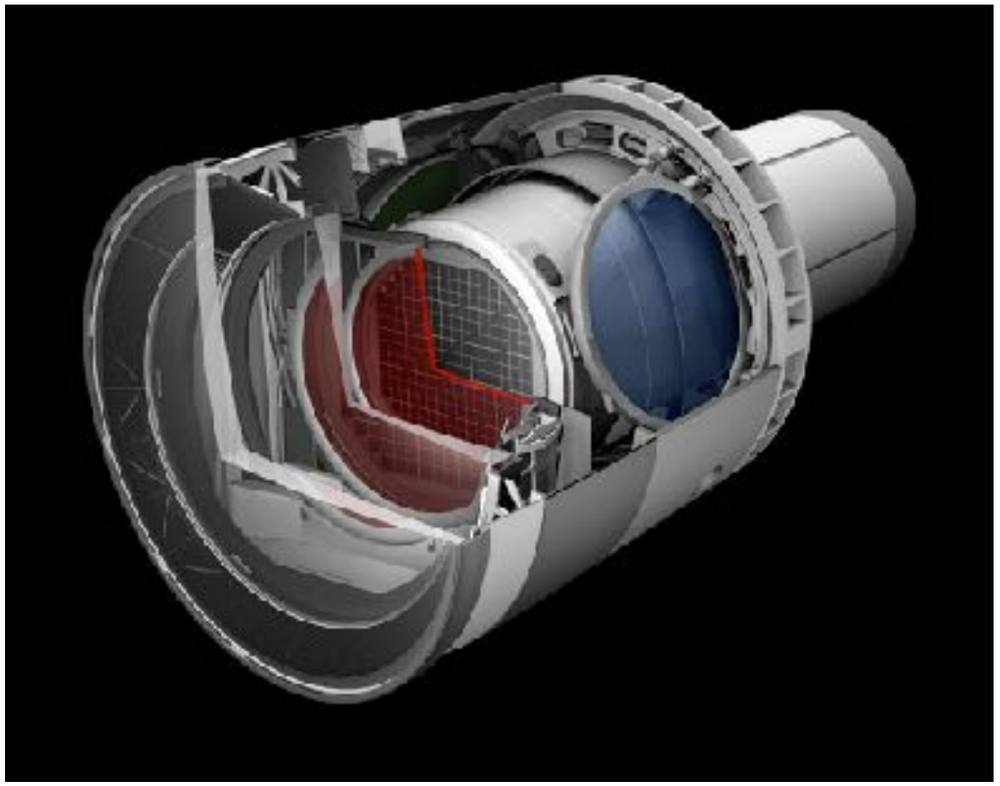


Nancy Roman Space Telescope

Vera C. Rubin Observatory

LSST: Legacy Survey of Space & Time

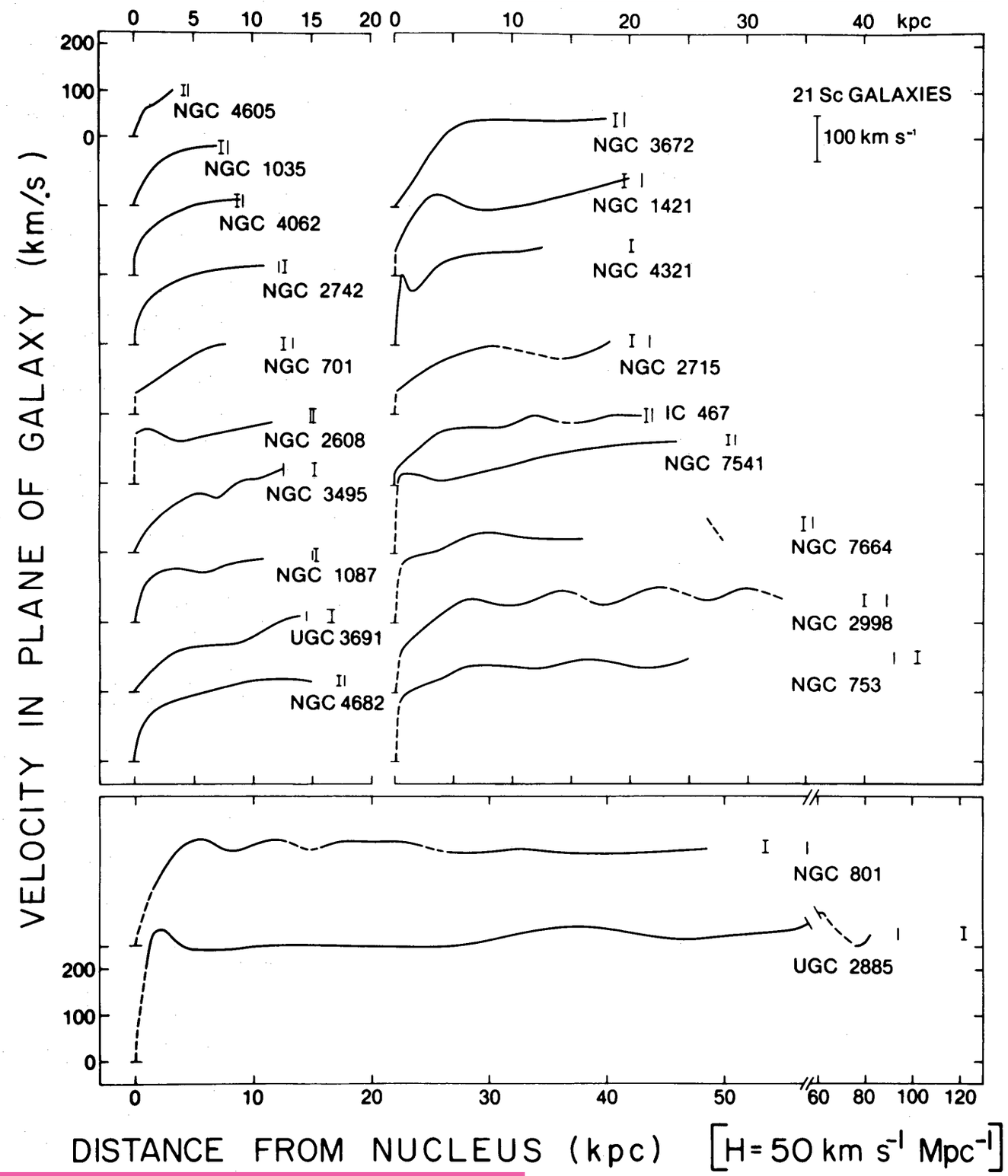




a Color Movie of the Sky:
an Optical/NIR survey of the entire Southern Sky to a depth of 27th Magnitude, imaged 825 times in 6 bands over 10 years
Wide, Deep, Fast

Vera C. Rubin

Rubin etal (1980)



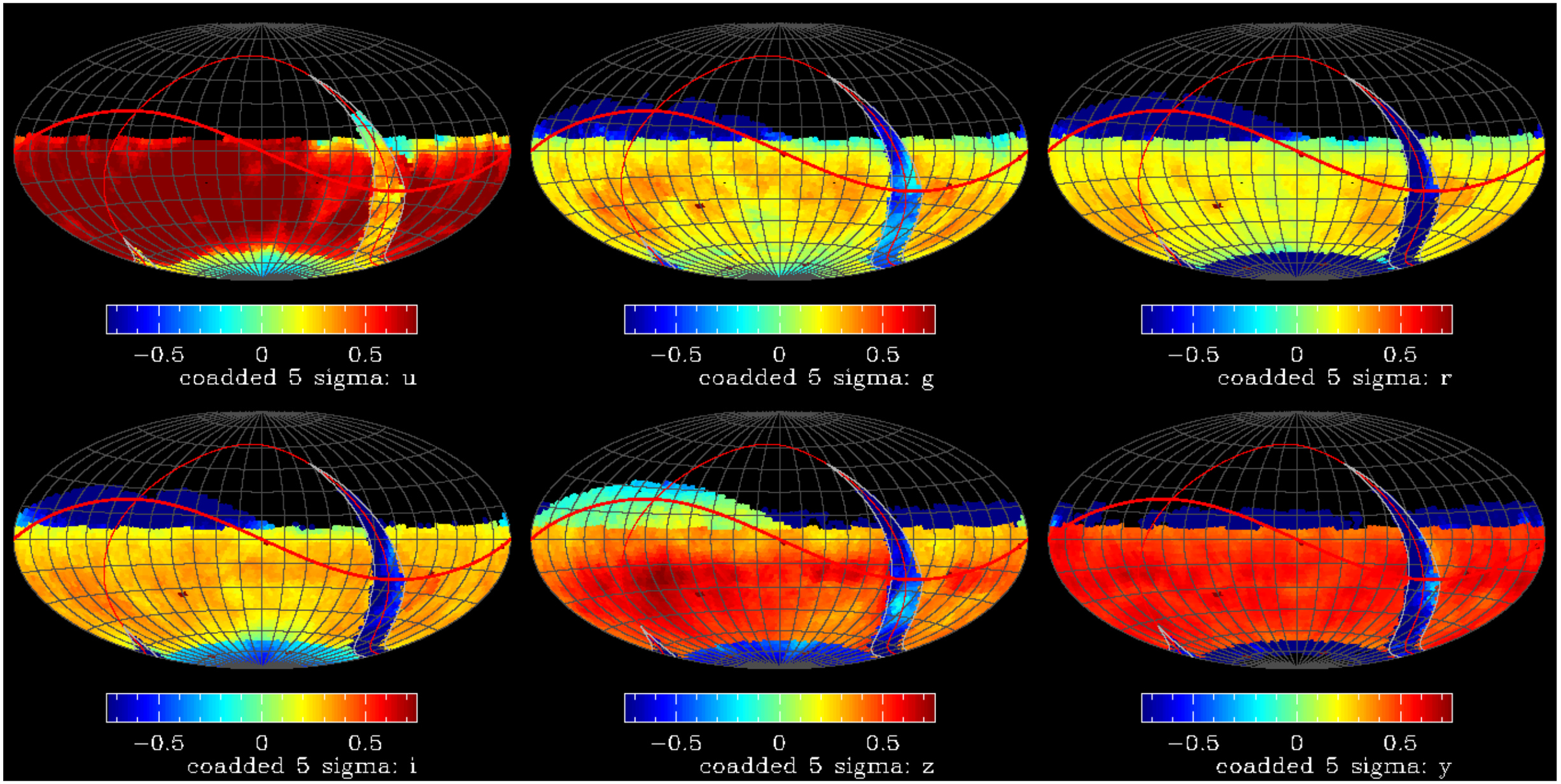
compelling evidence for Dark Matter

Rubin Observatory & LSST Design Optimization

Galaxy Surveys should maximum the product of
Etendue=AΩ
and Observing Time

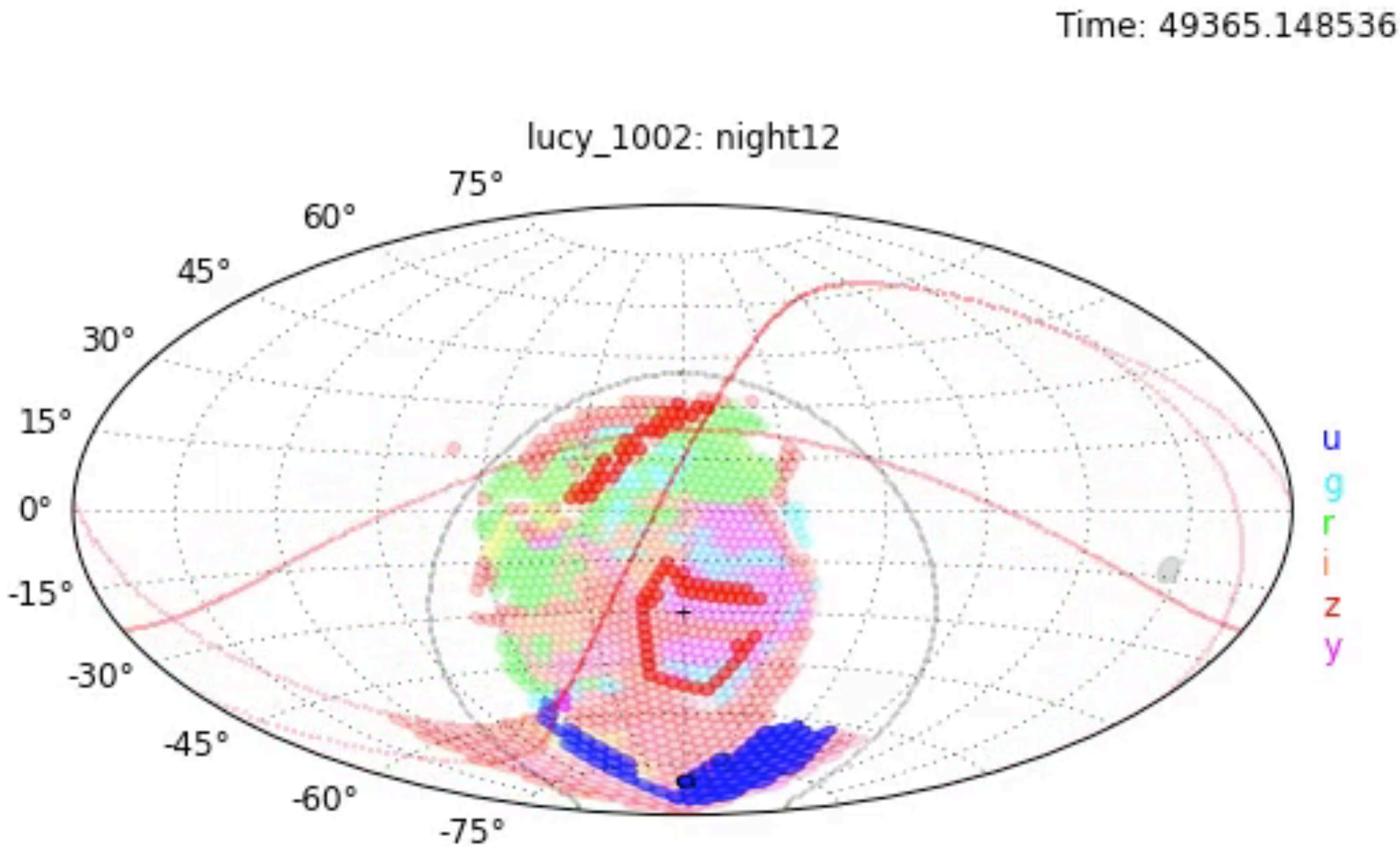
- Rubin Observatory: AΩ = 340 [m^2 deg^2]
  - vs. Blanco & Dark Energy Camera ~ 40
- Rubin Observatory: Dedicated Telescope & only 1 instrument
  - vs. Subaru & HyperSuprimeCam, shared facility
- Maximize Image Quality and Optical Throughput
  - Cerro Pachon
  - Three Mirror Design
  - Deep Depletion CCDs

LSST: Wide, Fast, Deep



will image the Entire Southern Sky in 6 Bands

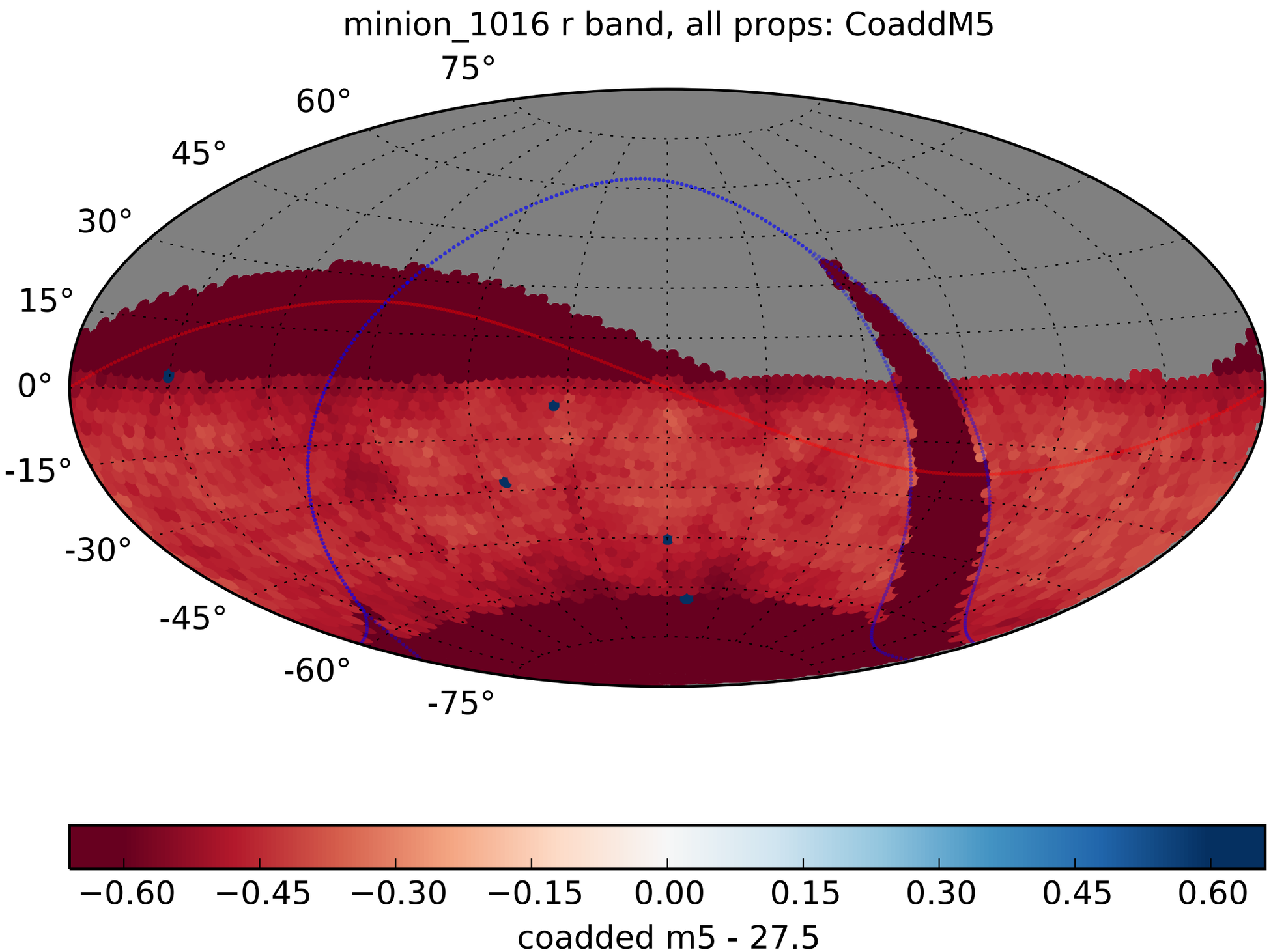
LSST: Wide, Fast, Deep



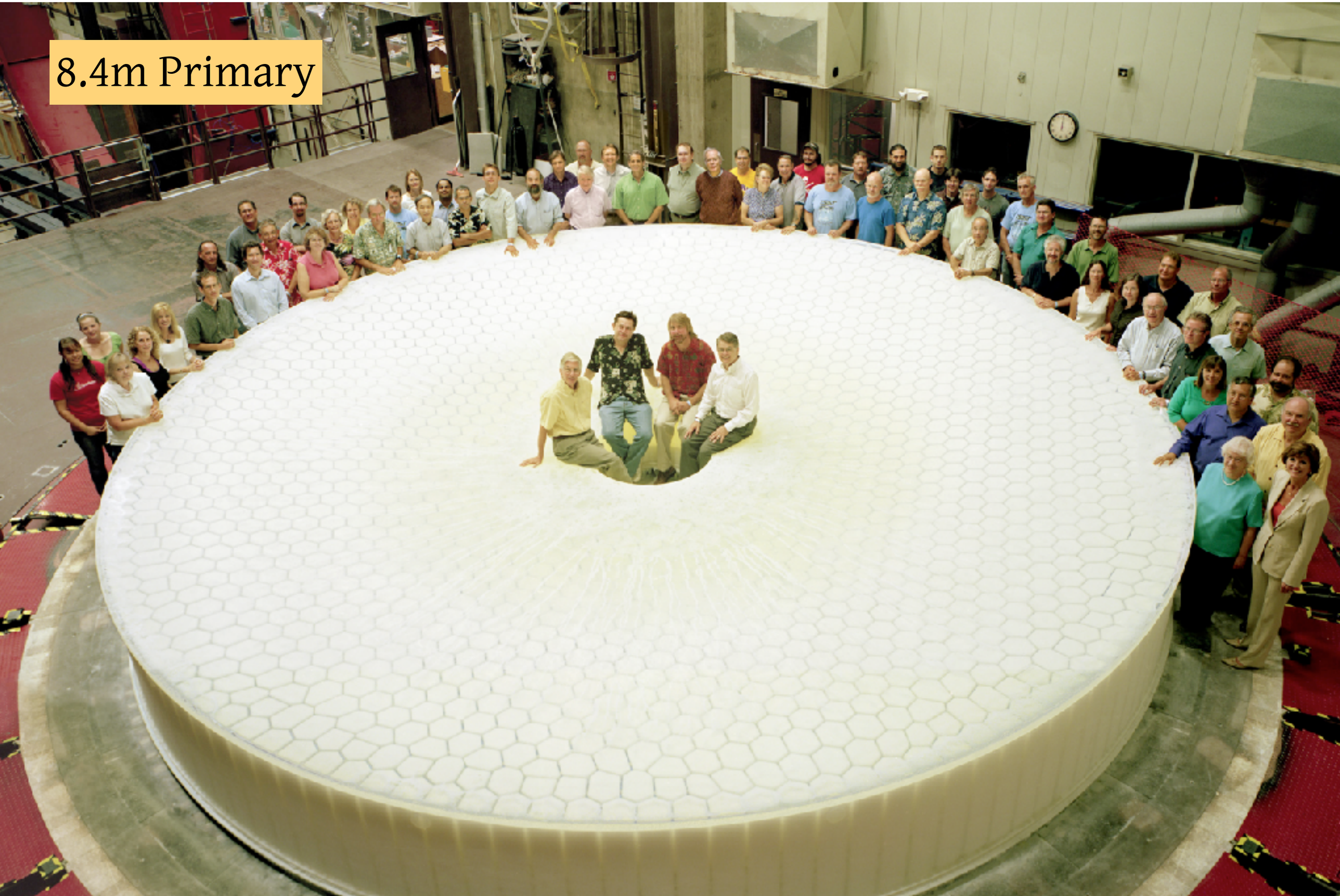
L. Jones

LSST: Wide, Fast, Deep

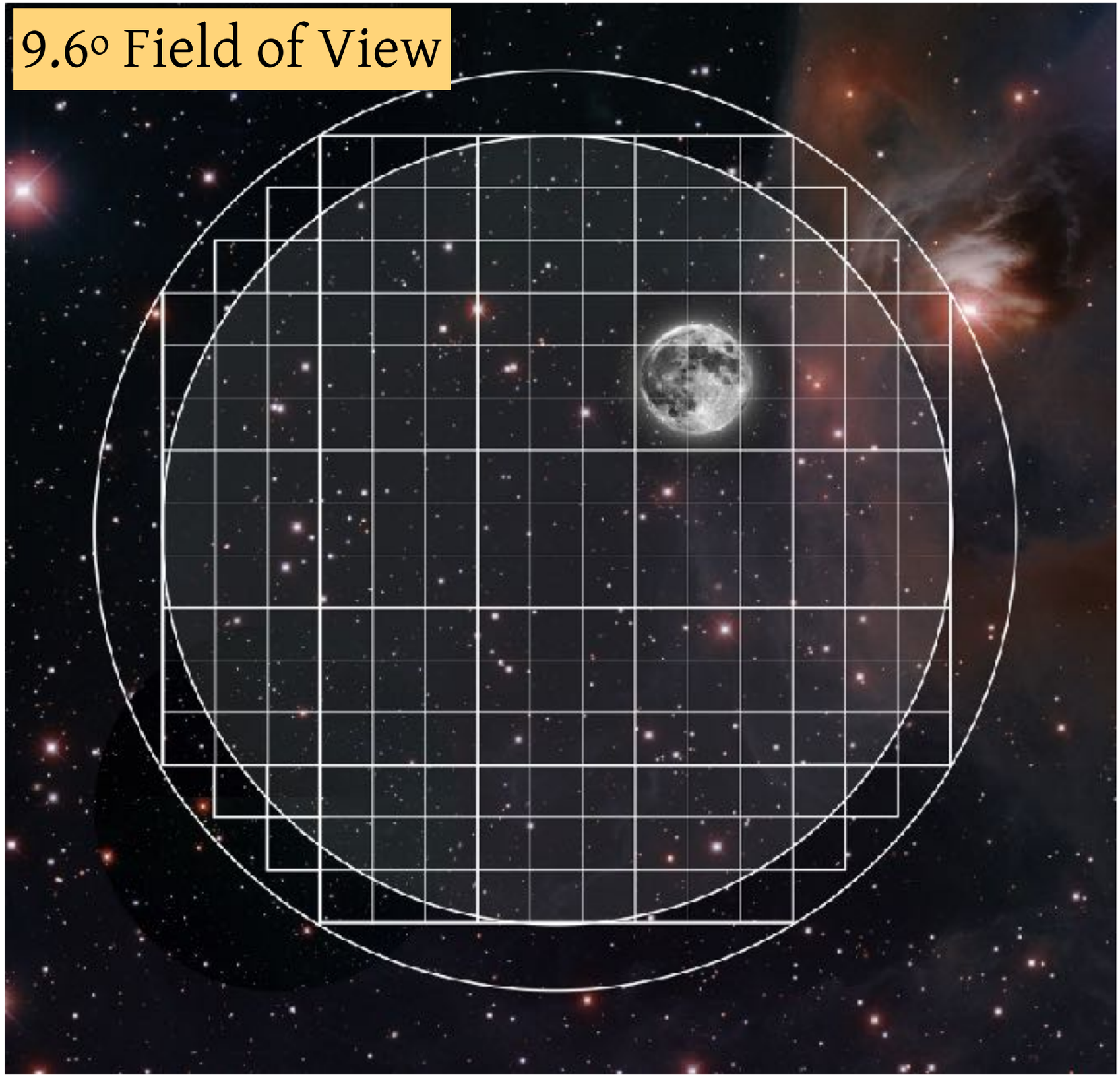
LSST: Wide, Fast, Deep



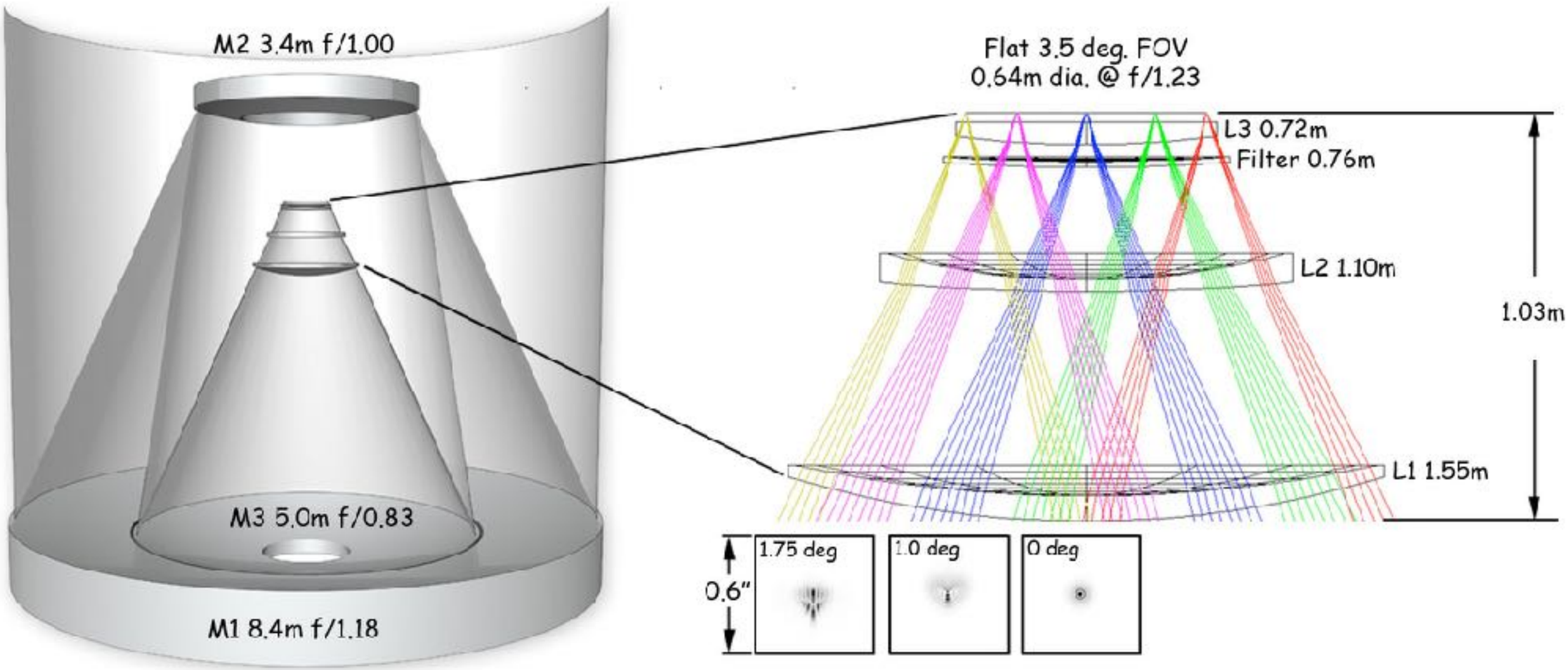
Telescope: Large Aperture



Optical System & Focal Plane: Field of View

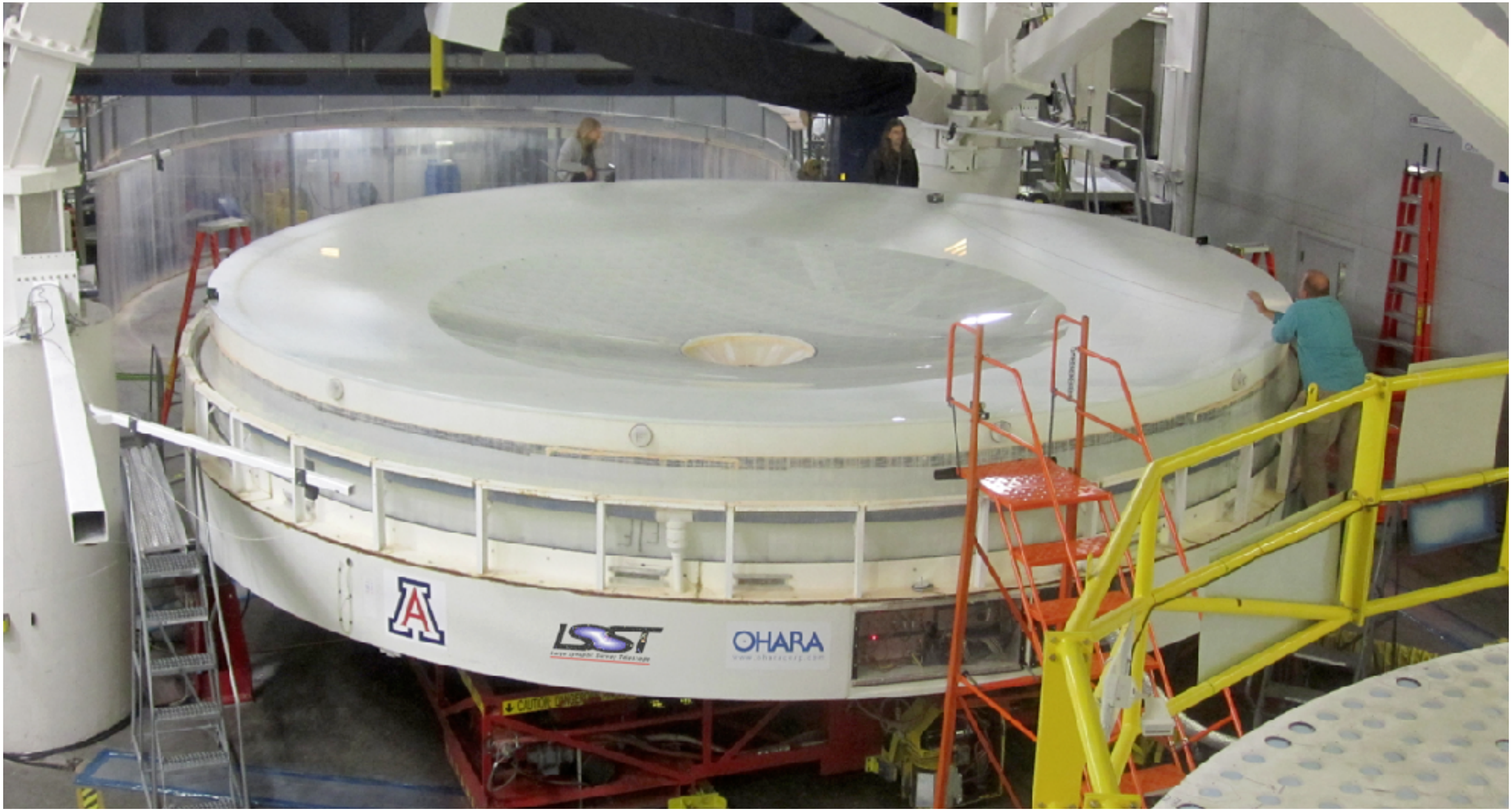


Optical System: Fast system with F=1.23

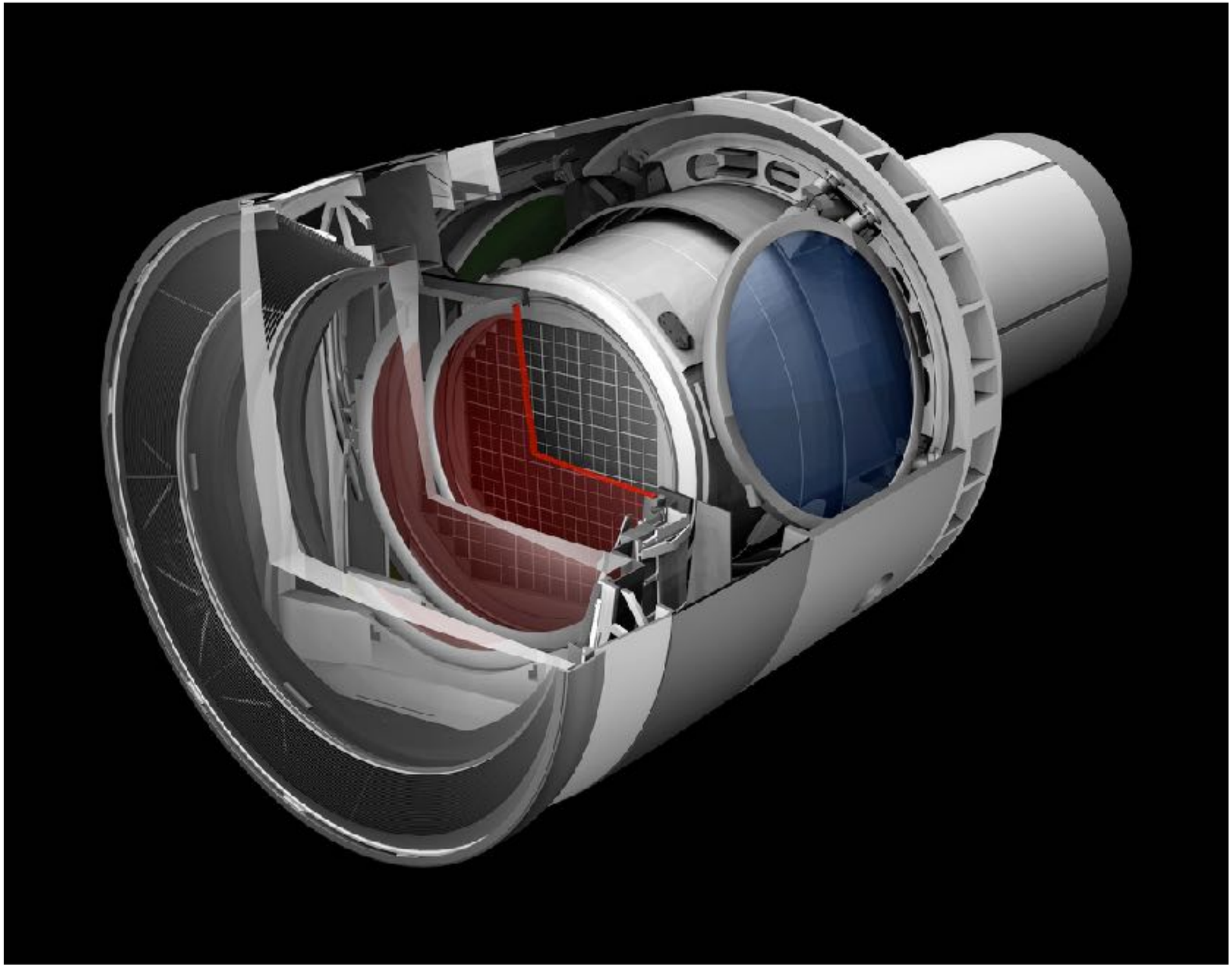


- Three Mirror Paul-Baker
- Fast Optical Design with F# 1.23
  - combined primary-tertiary mirror
  - small optical aberrations over 9.6° FOV
  - squat structure for rapid slewing: ~5sec for 3.5° slew

Combined Primary-Tertiary Mirror



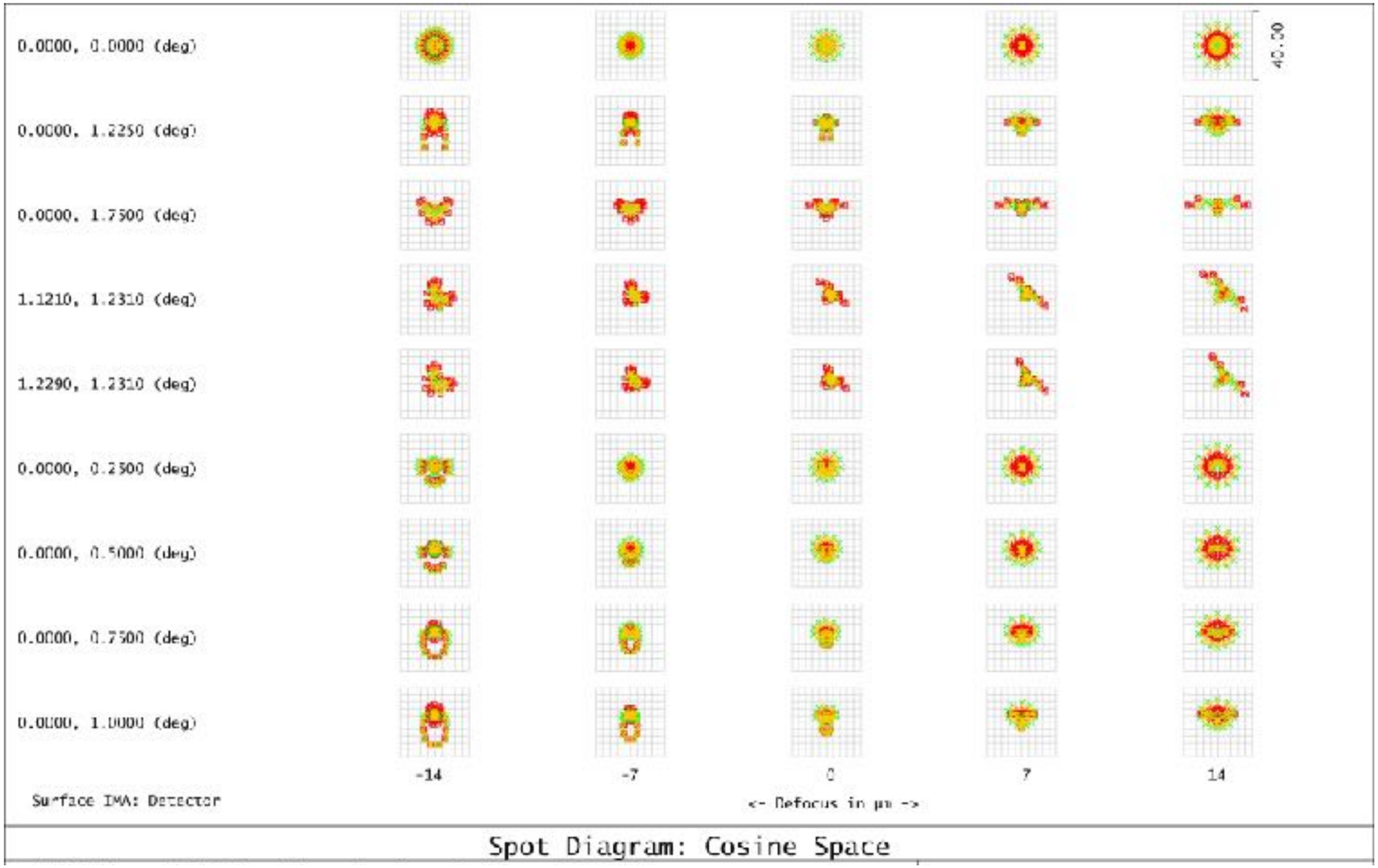
LSST Camera



LSST Camera Design Rationale

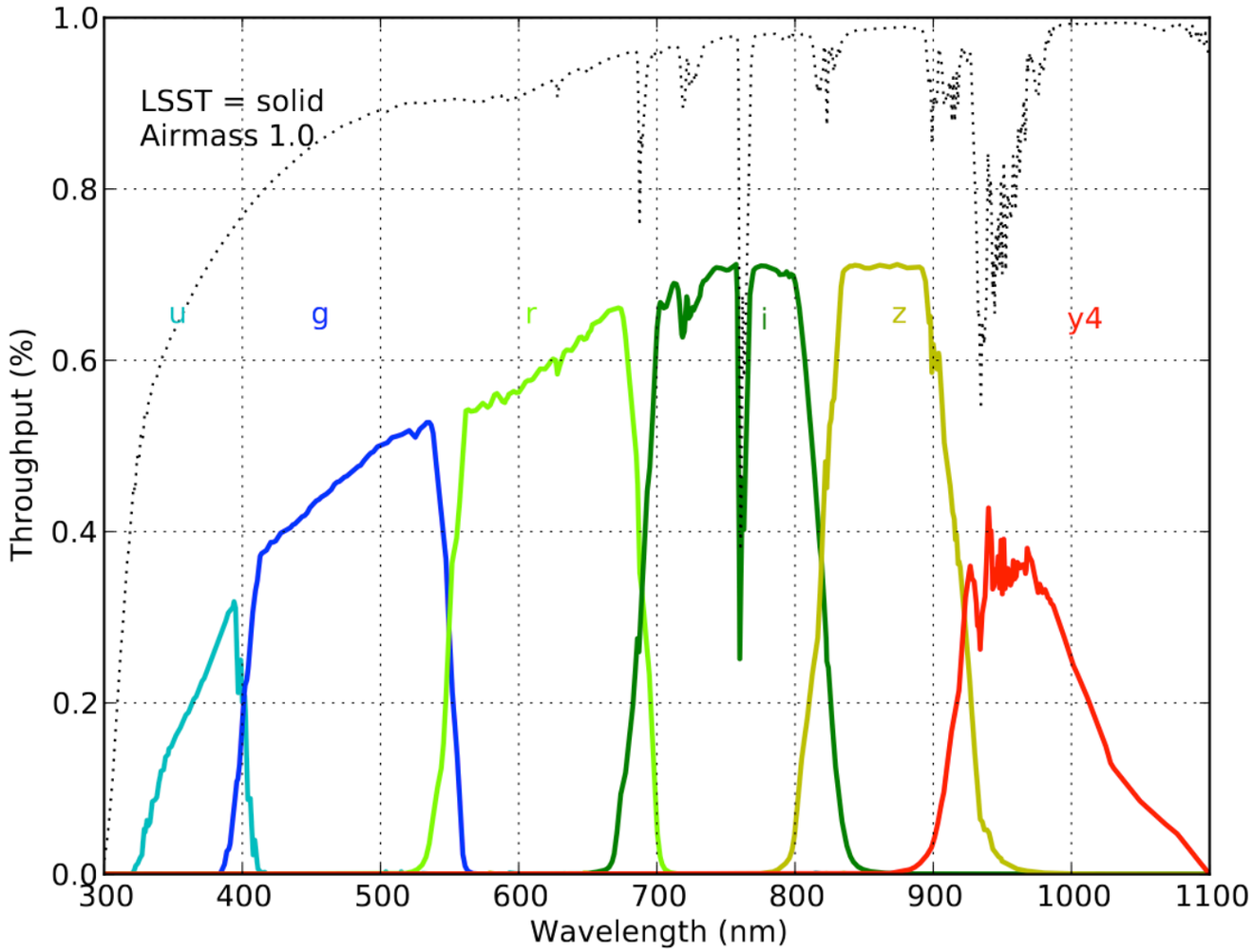
- Focal Plane 64cm Diameter with 3.5° Field of View
  - Nominal PSF of 0.7”
    - 0.2”/10μm pixel
    - 3.2 Giga-Pixels: 189 4k x 4k CCDs
- Image Entire Available Sky in 3-4 nights
  - Pairs of Short Exposures: two 15sec exposures in a *visit*
    - 2sec readout to minimize deadtime
    - 16 channel CCDs
    - 3 metric tons: light-weight for fast slewing
  - 189×16 Channels total
    - electronics in the Cryostat
- Fast Optics F# 1.23
  - Shallow Depth of Focus
    - very flat focal plane

Contributions to Image Quality



- Point Spread Function from Camera < 0.3”
  - largest contribution is diffusion in CCD ≲ 0.2”
  - focal plane needs to be flat to within ±11 µm

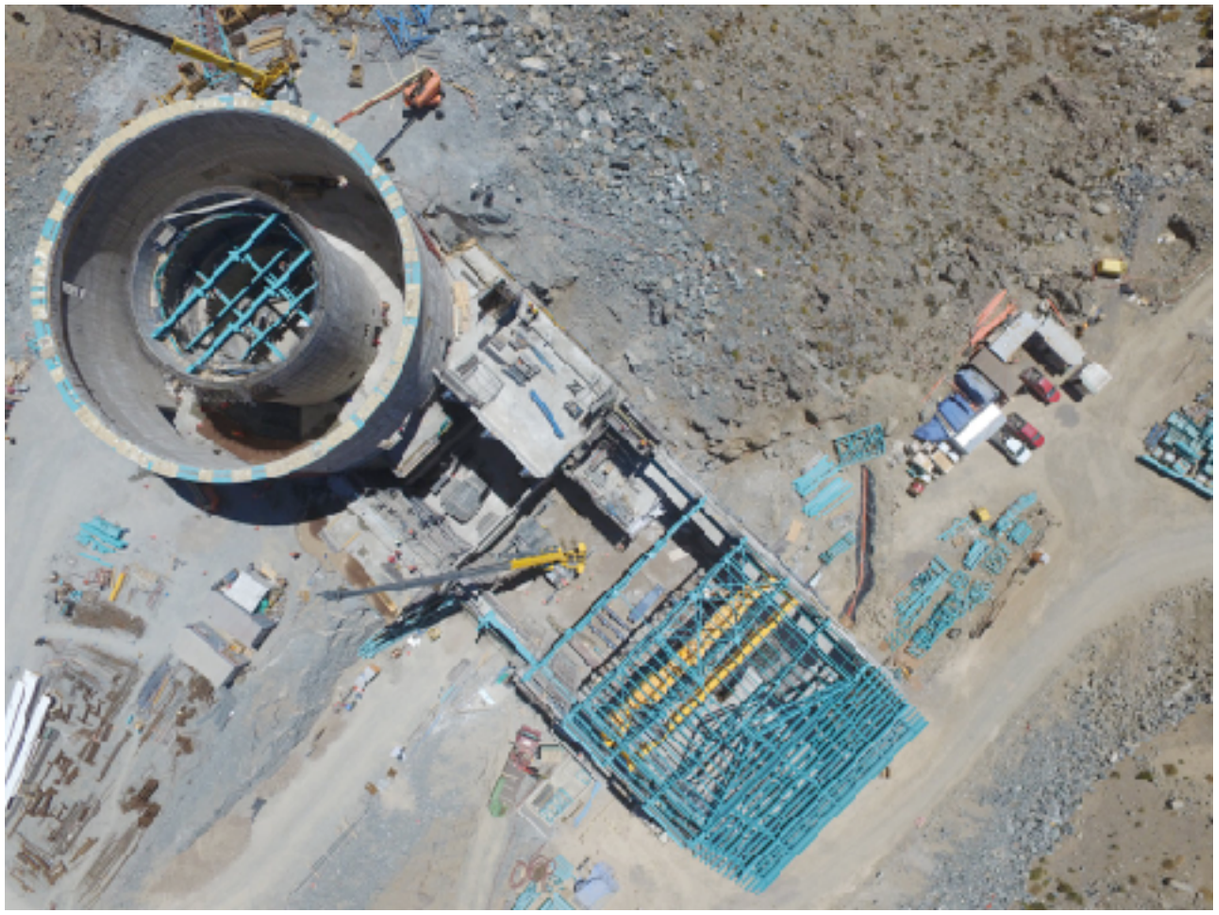
LSST Camera Throughput



	5 sigma point source detection per visit
u	23.5
g	24.8
r	24.4
i	23.9
z	23.3
y	22.1

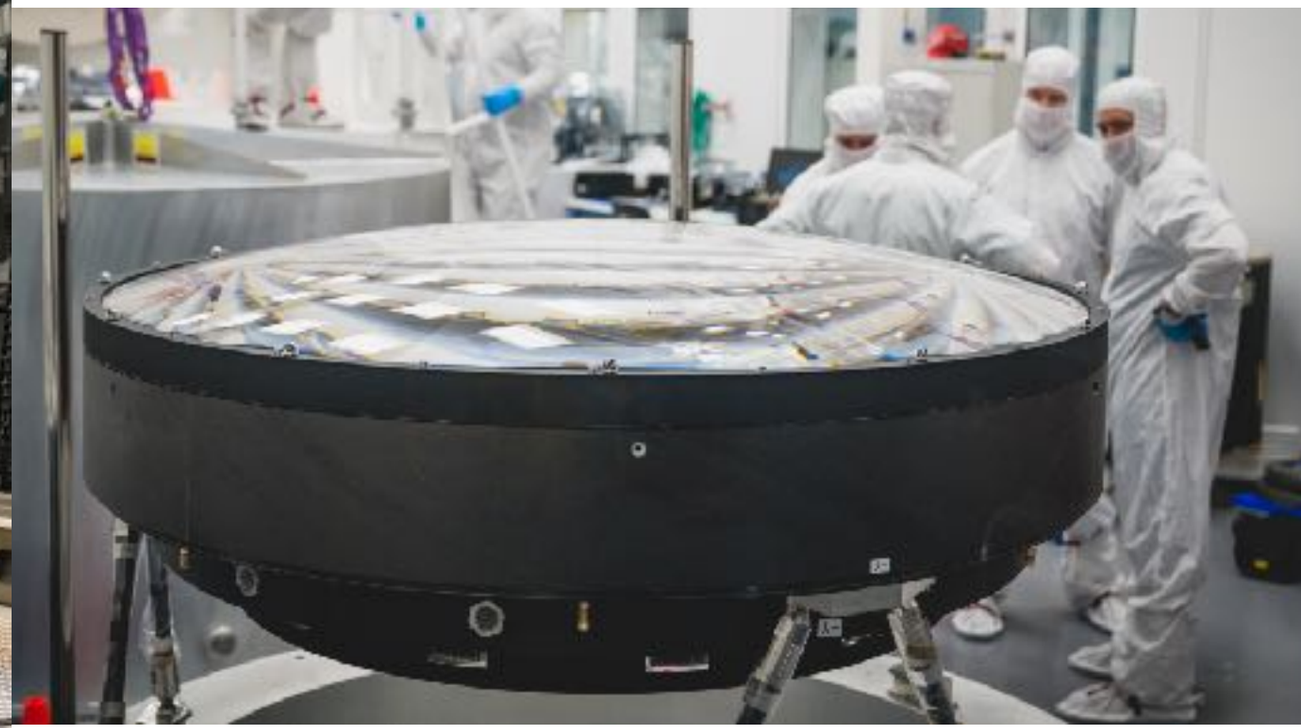
- Optical throughput close to maximum possible given
  - CCD Quantum Efficiency from 100μm thick Si
  - AR coatings on 3 Refractive elements
  - Interference Filter band-passes

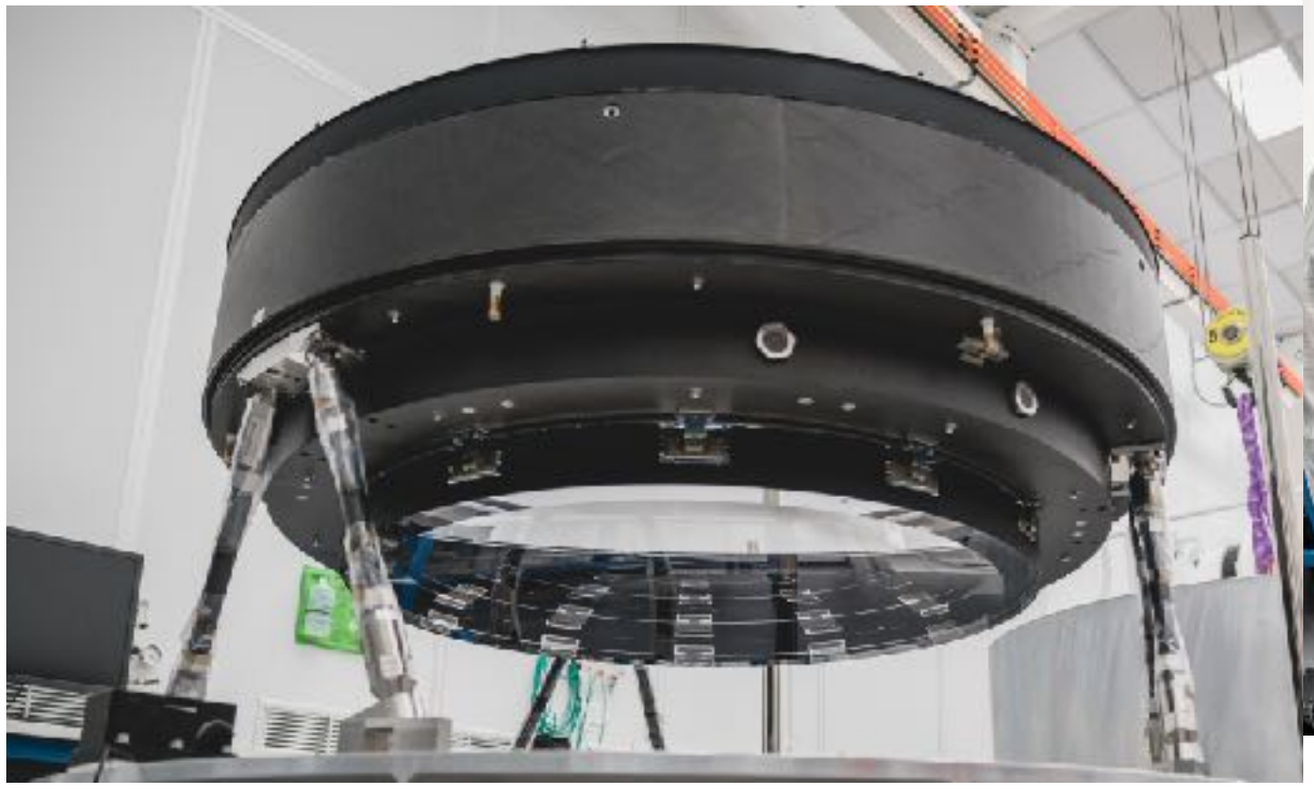
Rubin Observatory Construction



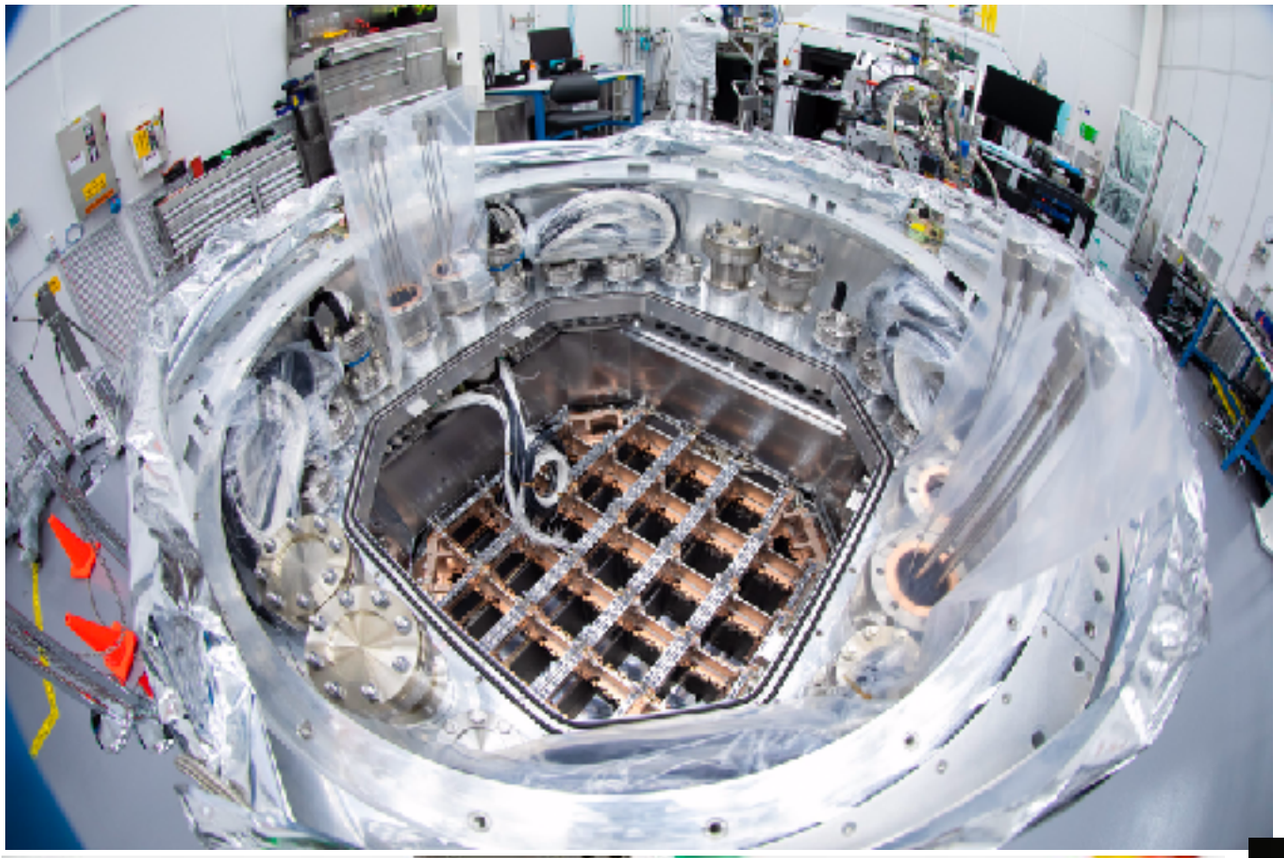
Rubin Observatory Telescope Mount

Rubin Observatory Optics





LSST Camera Focal Plane



LSST Camera Charged Coupled Devices

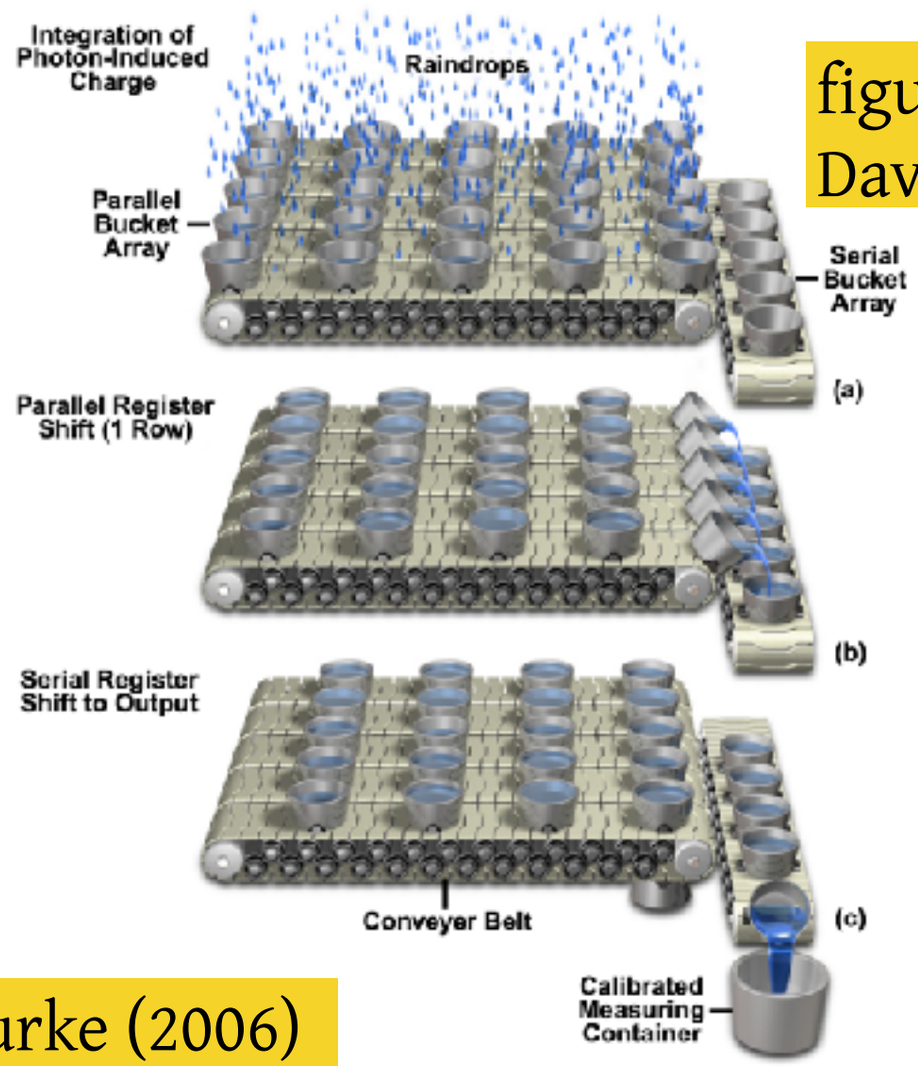
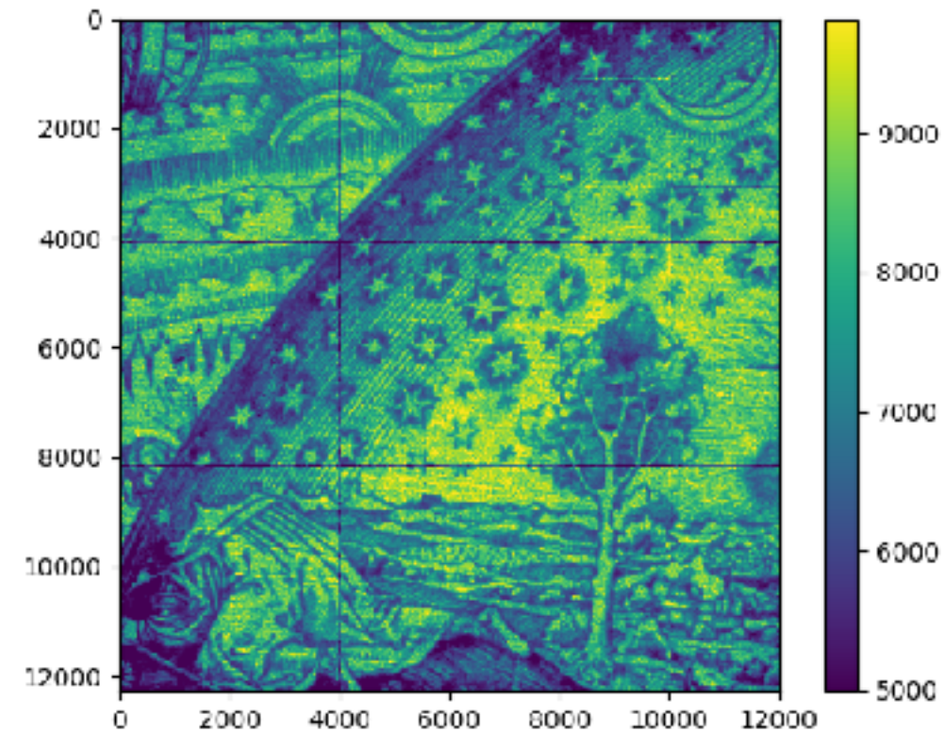
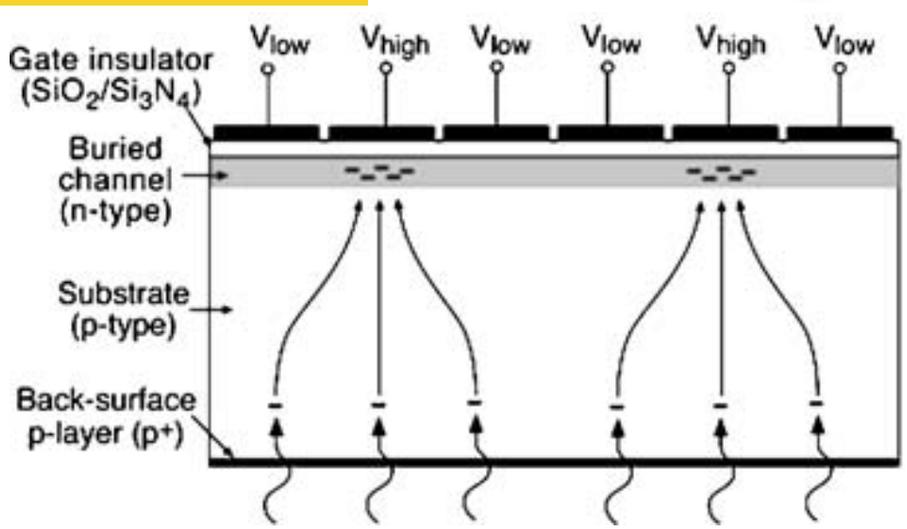
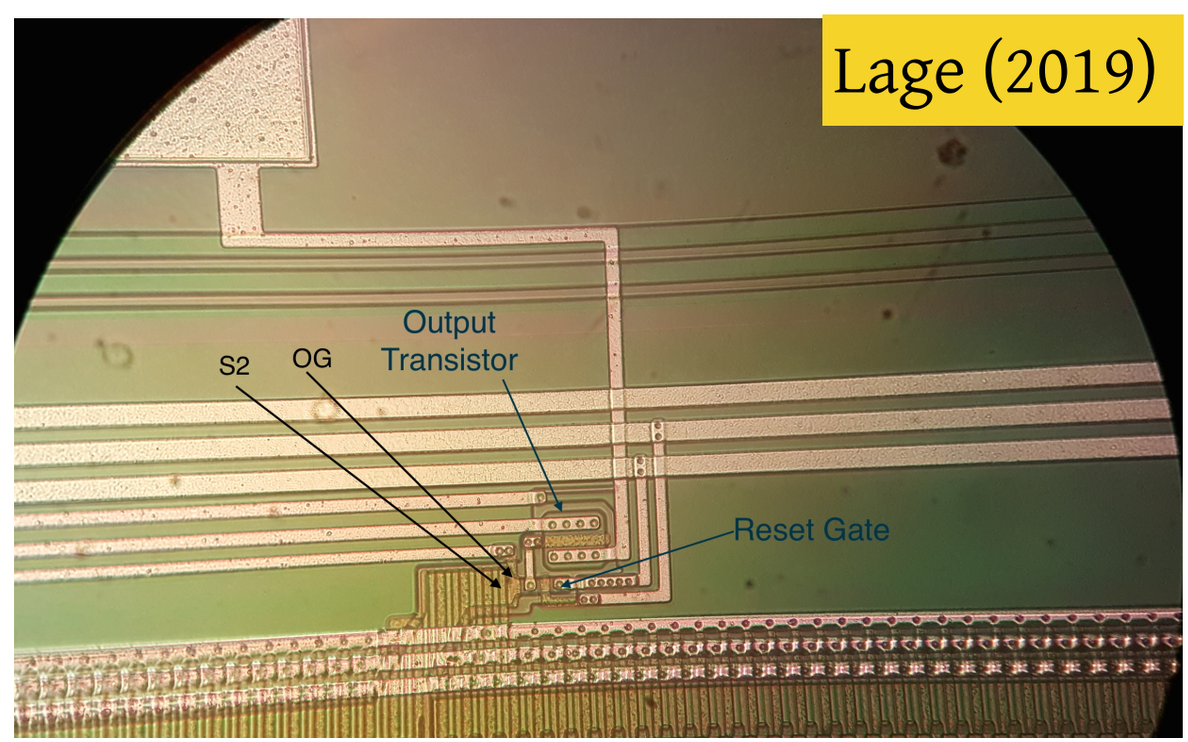


figure from Davidson



Burke (2006)





Lage (2019)

A Question:

Respond at **PollEv.com/aaronroodman286**

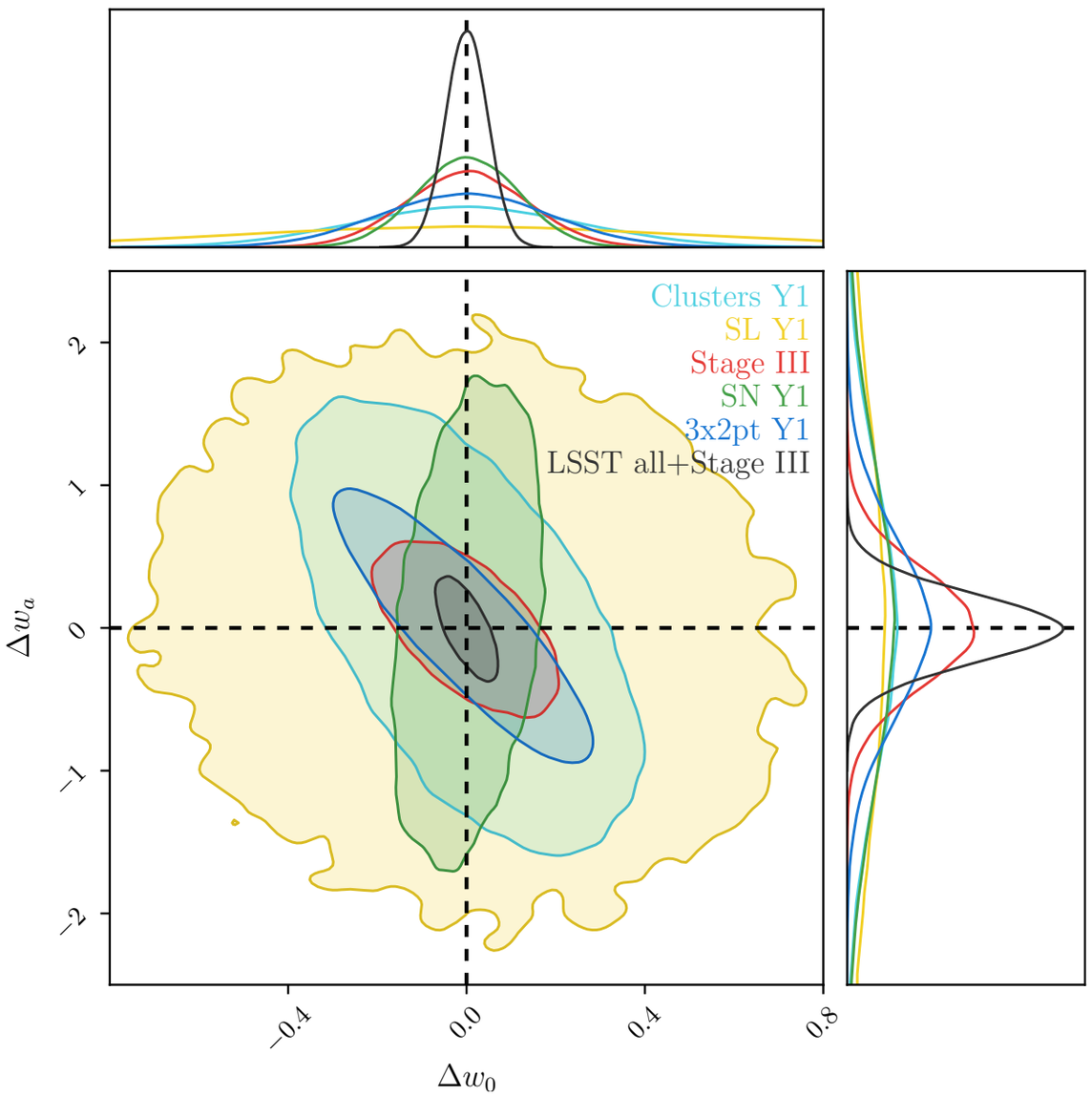
Text **AARONROODMAN286** to **22333** once to join, then **A, B, C, D, or E**

What has been the biggest challenge in building the LSST Camera?

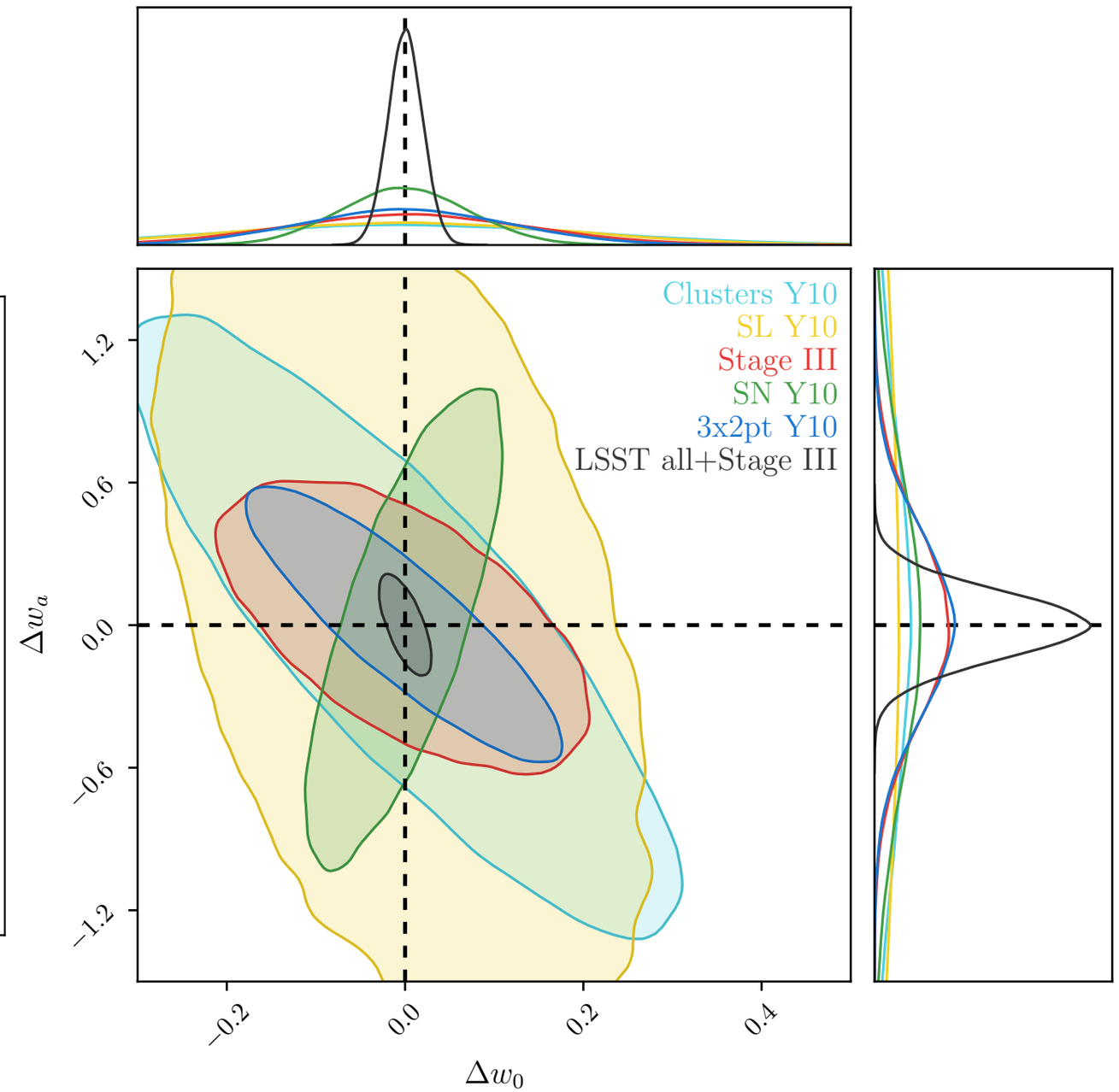
CCDs	**A**
Lenses	**B**
Limited Space Constraints	**C**
Fasteners (ie. Screws & Bolts)	**D**
All of the Above	**E**

LSST Predicted Cosmology Constraints

Dark Energy Science Collaboration
Science Requirements Document



Year 1



Year 10

Dark Energy Spectroscopic Instrument

Five target classes

35 million redshifts

(SDSS x20)

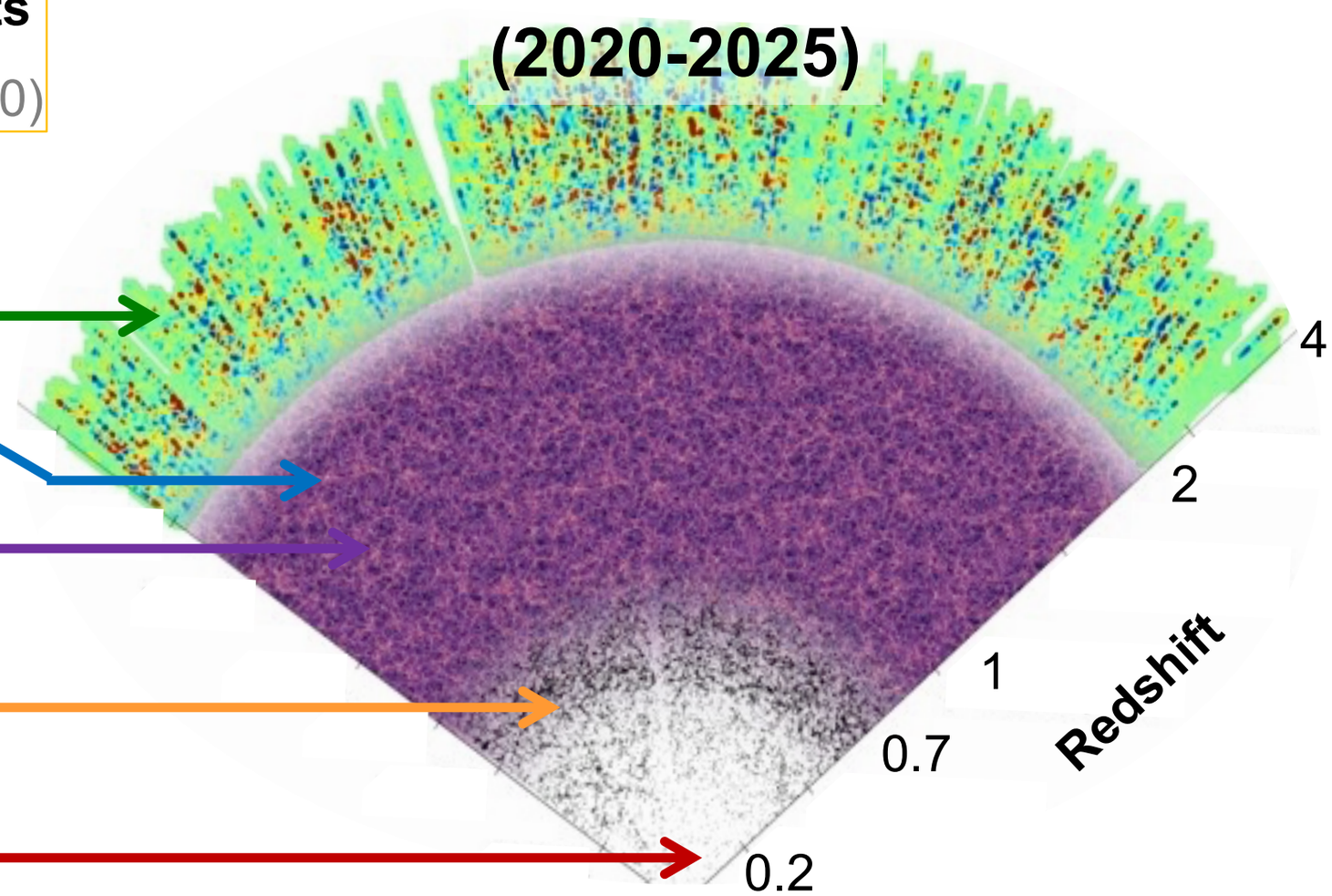
DESI
(2020-2025)

2.4 million QSOs
Lya z > 2.1
Tracers 1.0 < z < 2.1

17 million ELGs
0.6 < z < 1.6

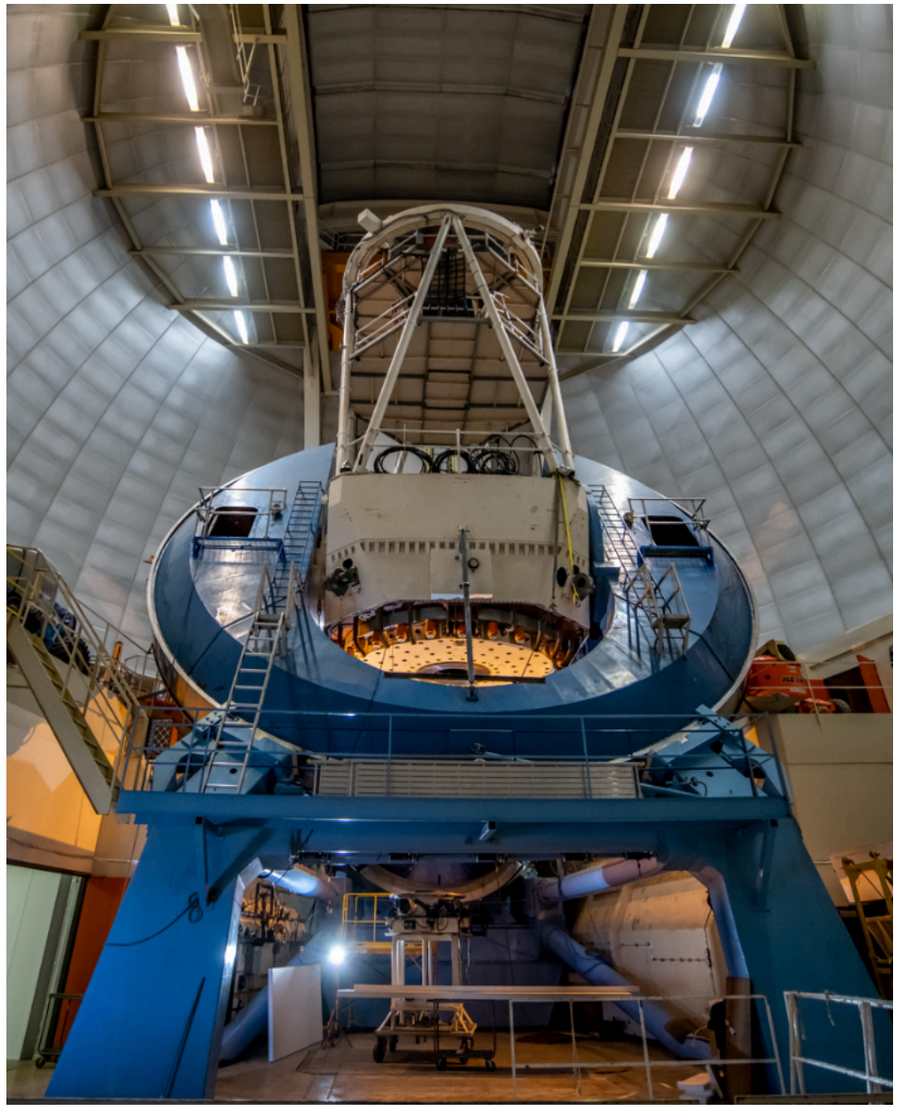
6 million LRGs
0.4 < z < 1.0

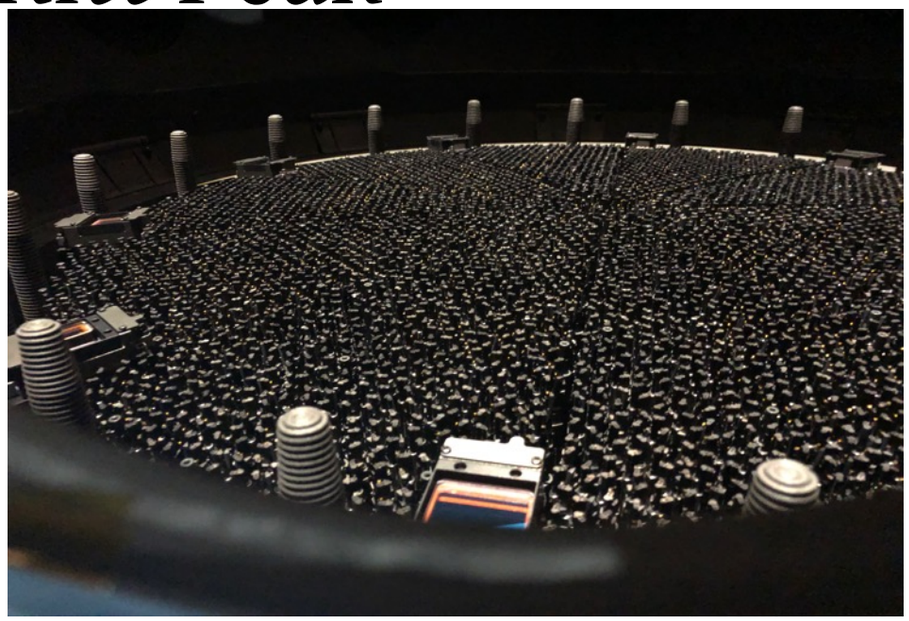
10 million
Brightest galaxies
0.0 < z < 0.4

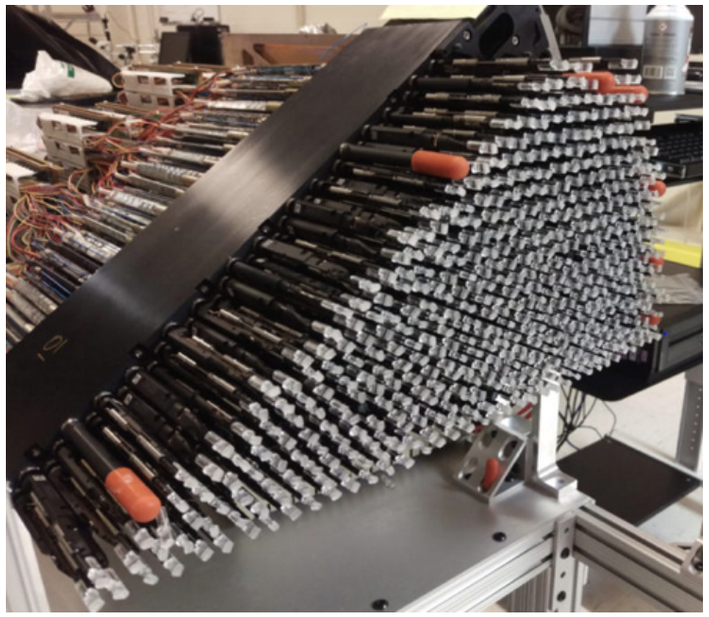


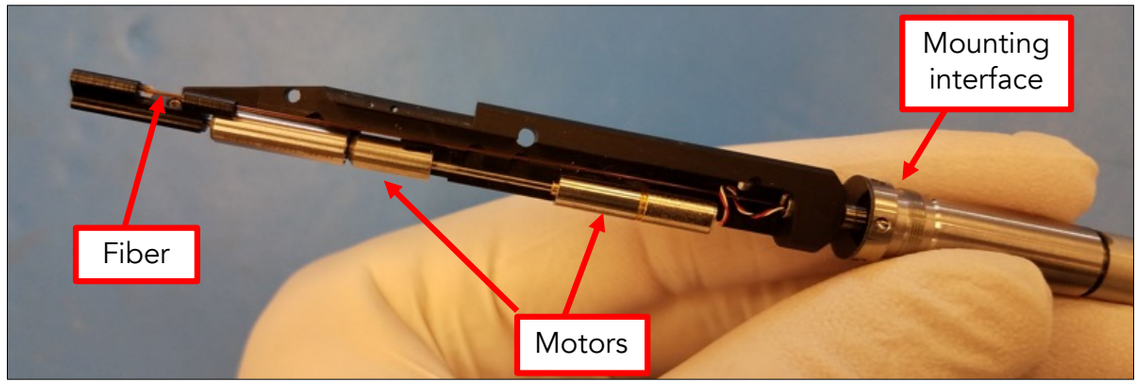
Palanque-Delabrouille for DESI Collab.

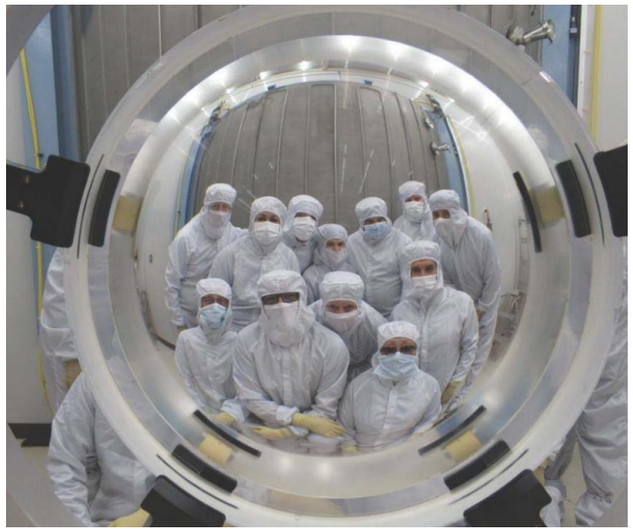
DESI Instrument at Kitt Peak

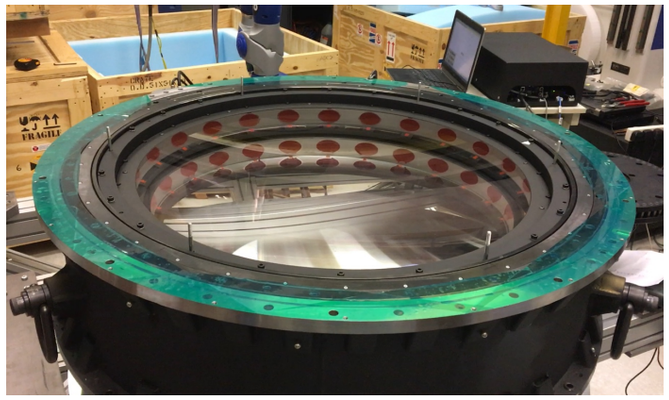


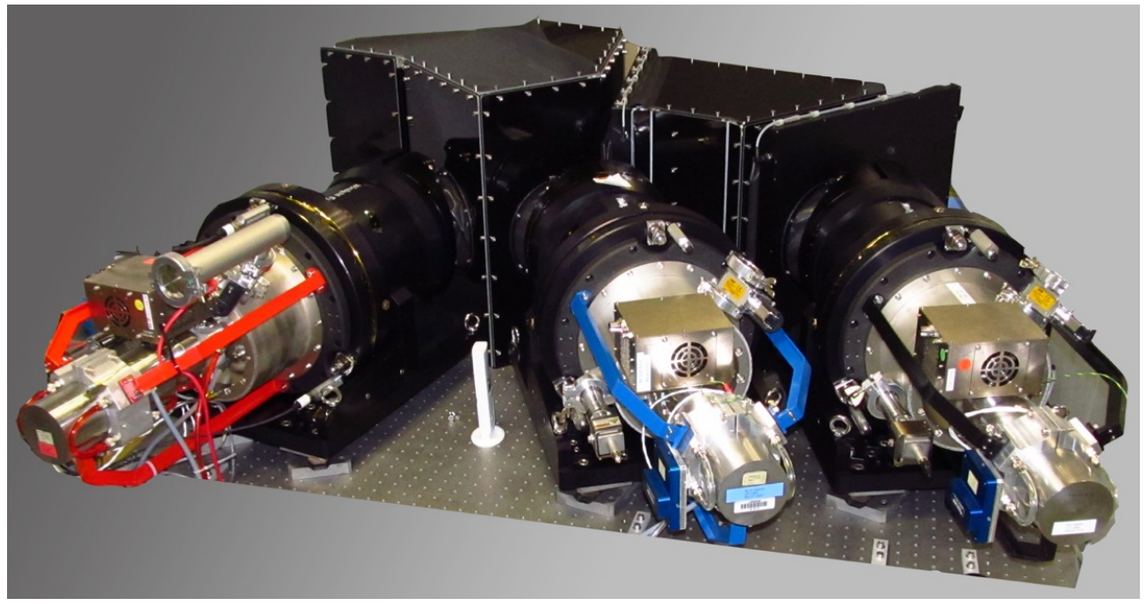




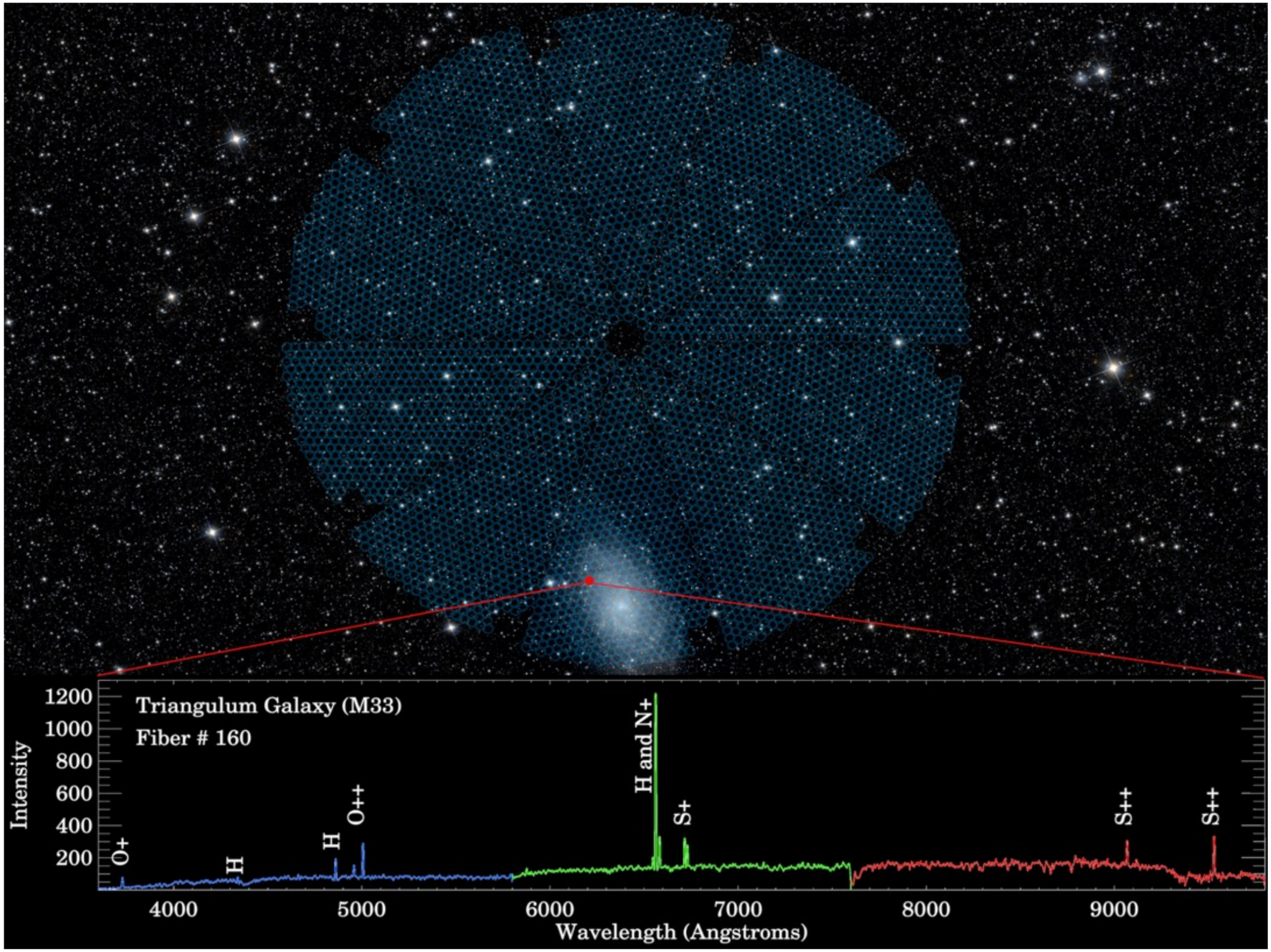




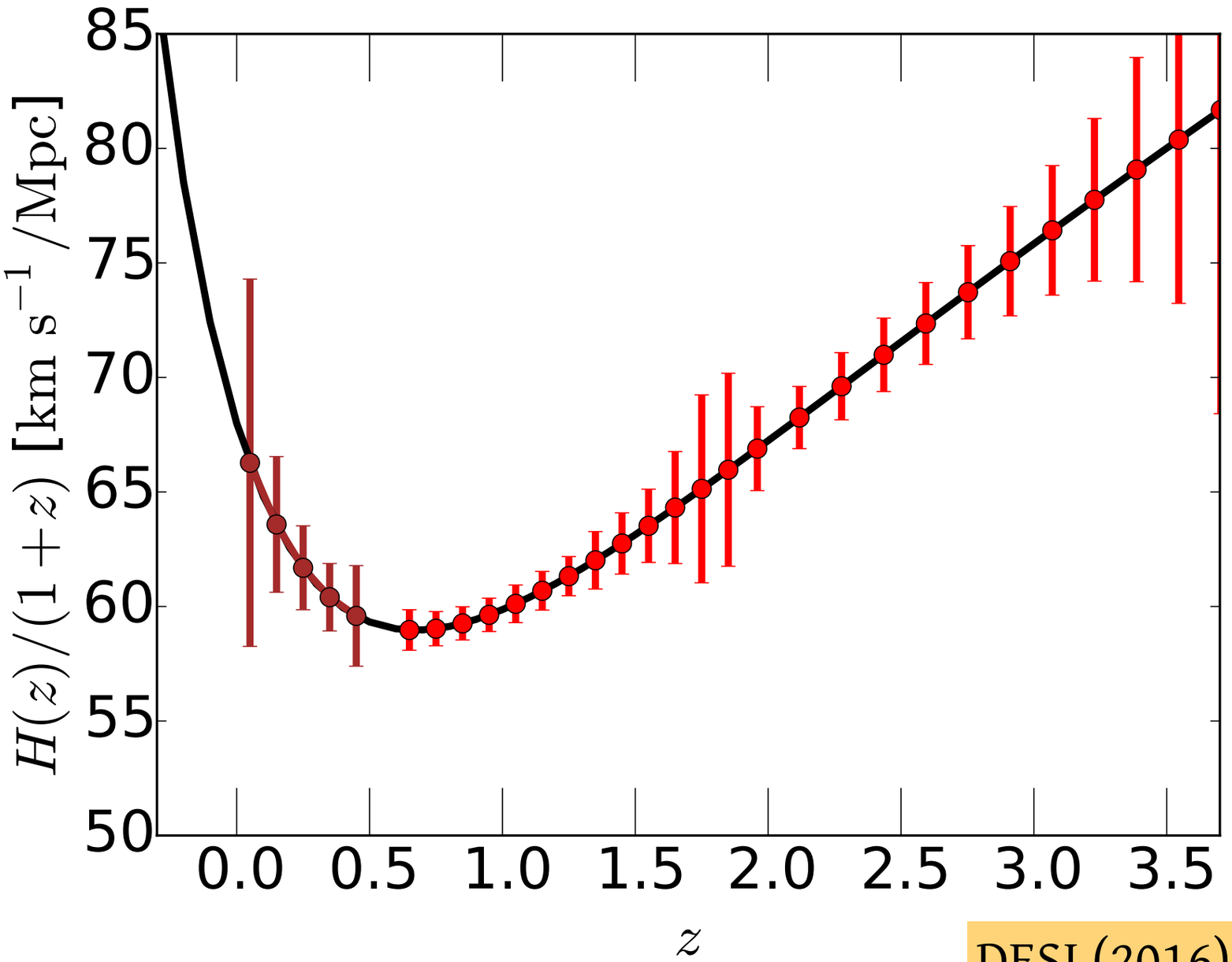




DESI First Light Spectra



DESI Hubble Diagram



DESI (2016)

Vera Rubin Observatory Schedule

- LSST Camera scheduled for shipment to Chile in 2021
- First light with a Commissioning Camera (9 CCDs) 2021
- Camera Installed on the Telescope 2021-2
- Start of 10 year LSST survey in 2022-3