Maunakea Spectroscopic Explorer

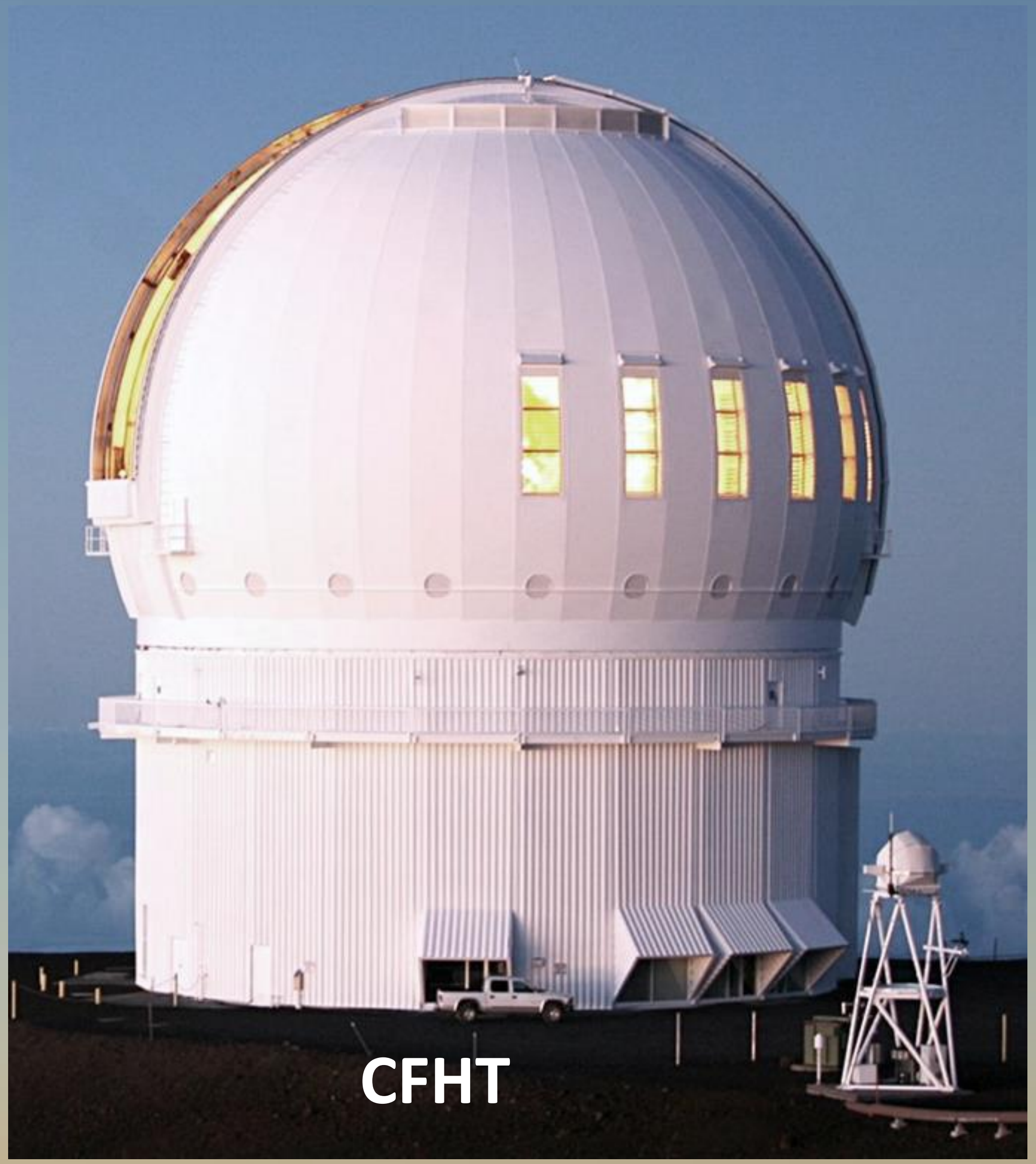
The Future of Massively Multiplexed Spectroscopy: The Maunakea Spectroscopic Explorer

Jen Marshall
MSE Project Scientist
Texas A&M University

The Maunakea Spectroscopic Explorer

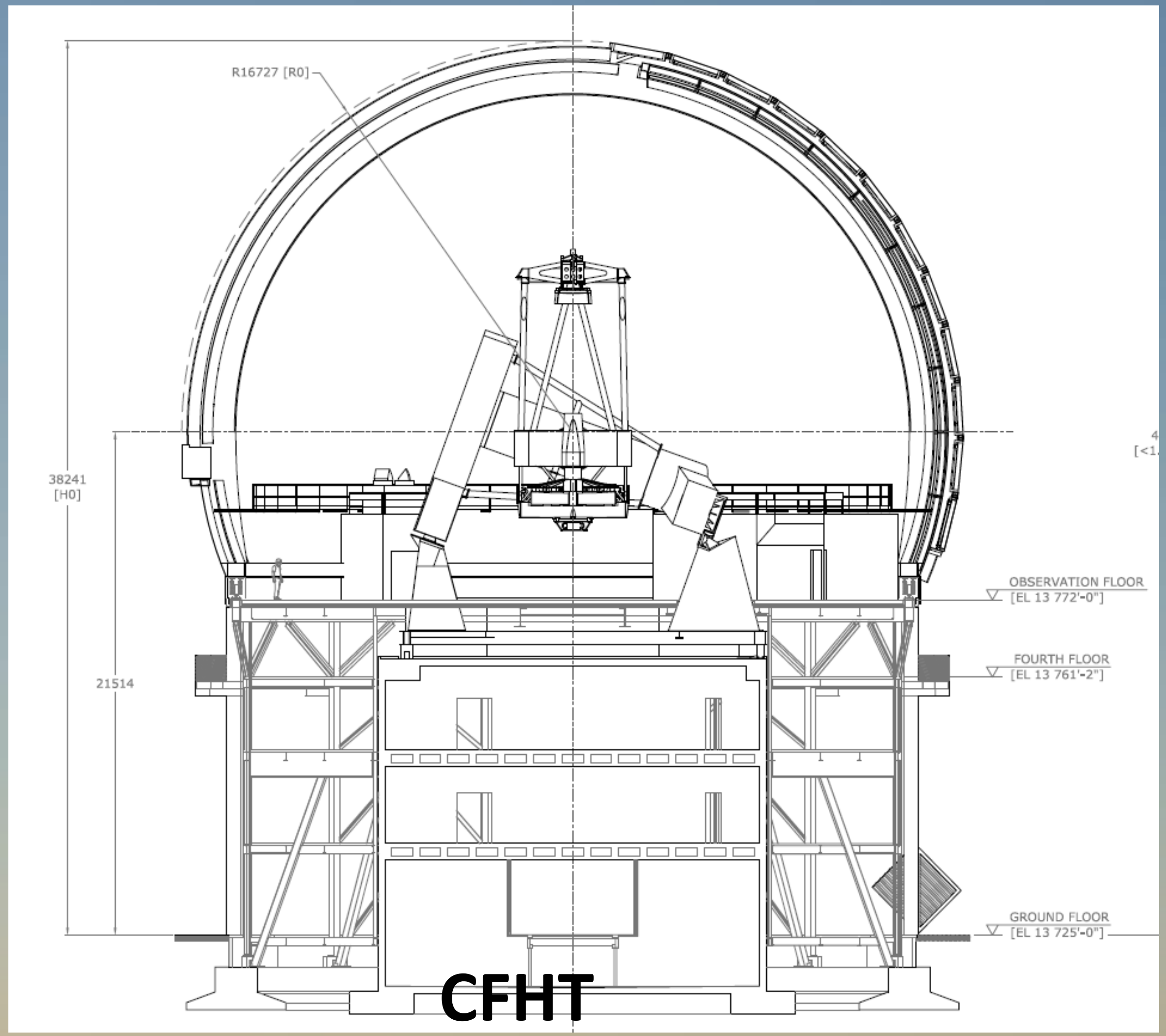
https://www.youtube.com/watch?v=c16MYxBgMu4

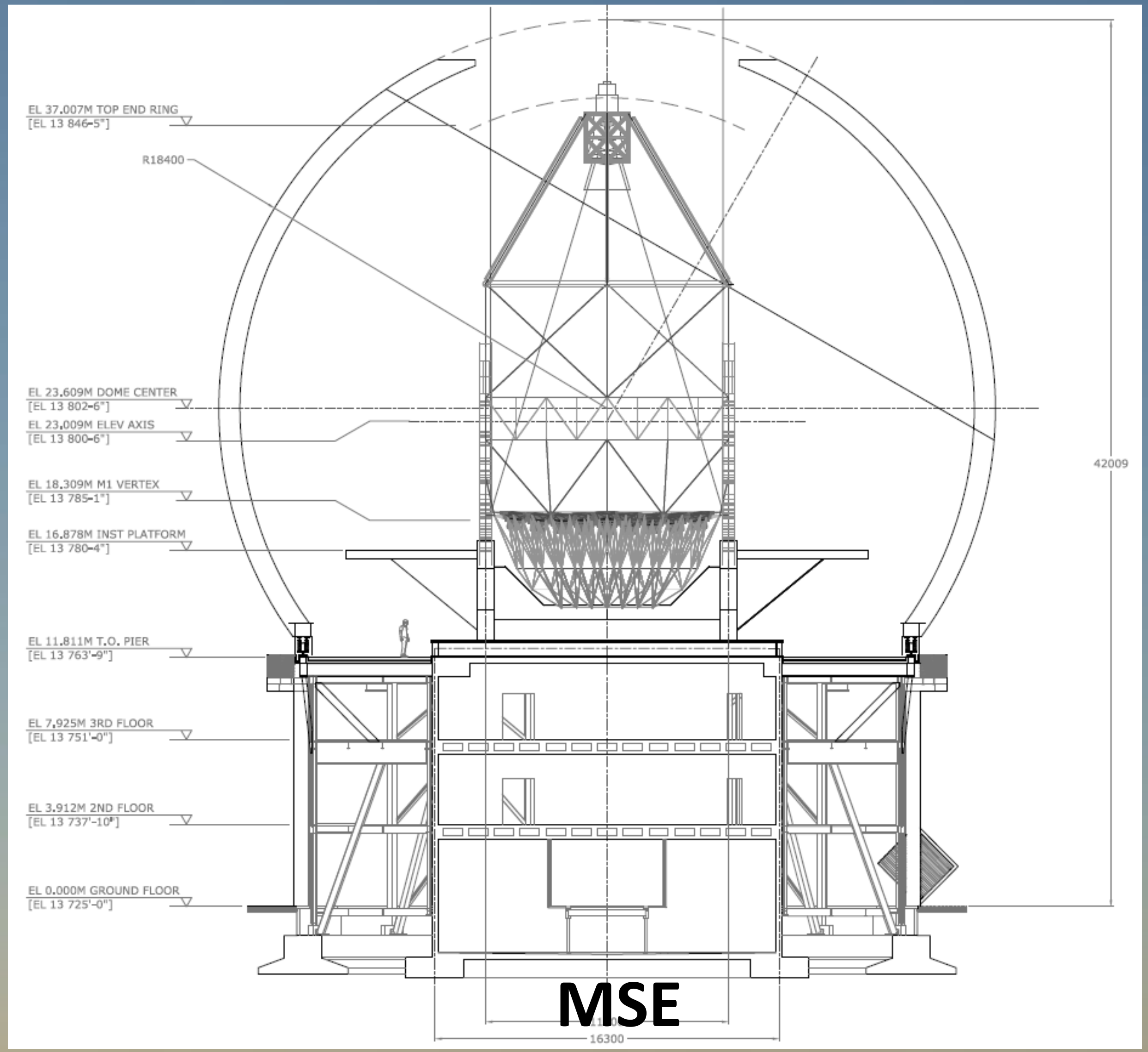
Facility transformation



- CFHT has a 40 year history of scientific and outreach leadership on Maunakea
- Out of environmental and cultural respect, a strong desire to preserve the external appearance of CFHT after MSE completion
  - MSE will reuse the CFHT summit building without additional ground disturbances
  - Limiting size increase of the new facility building and enclosure to 10%

Facility transformation





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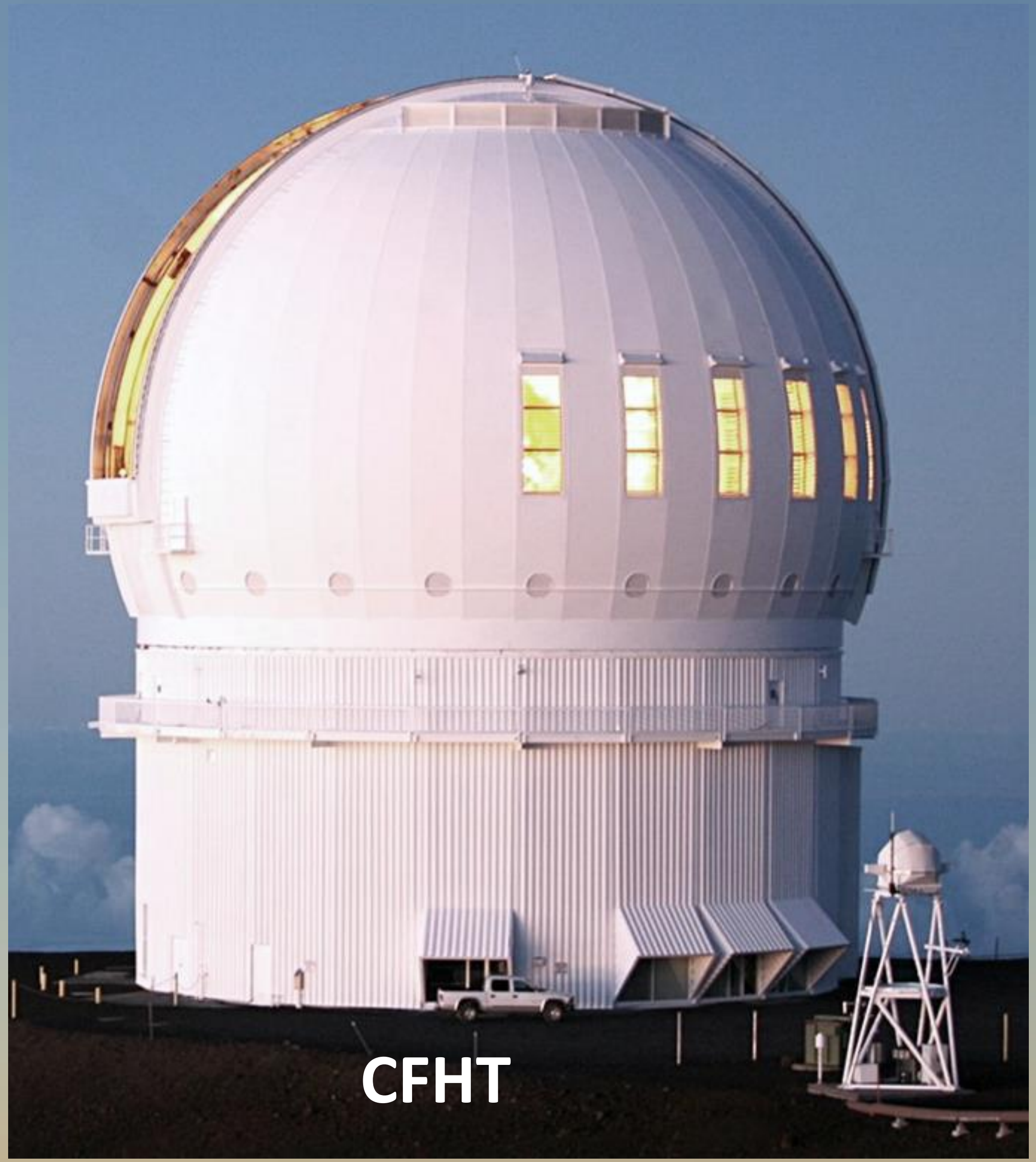
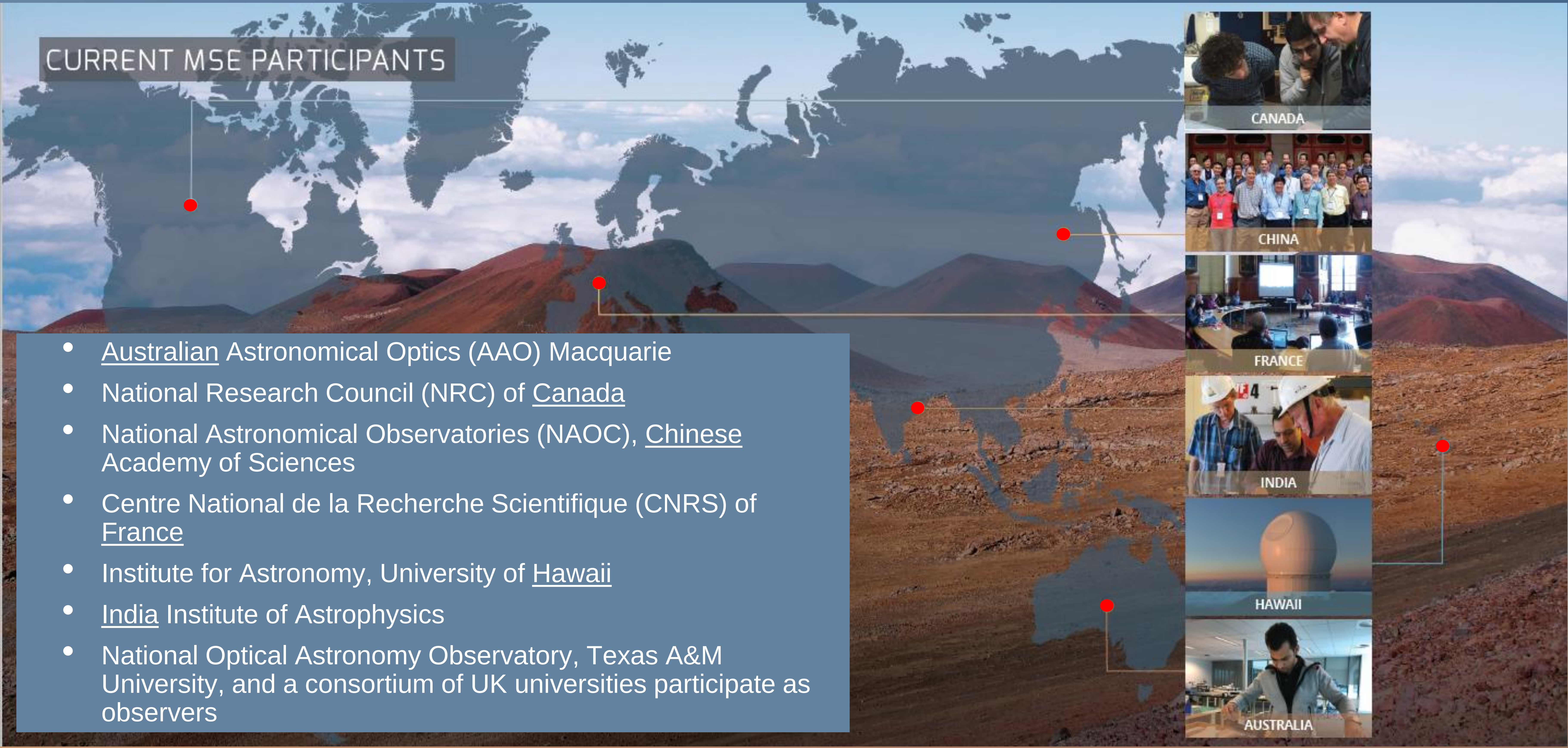


Current MSE partners

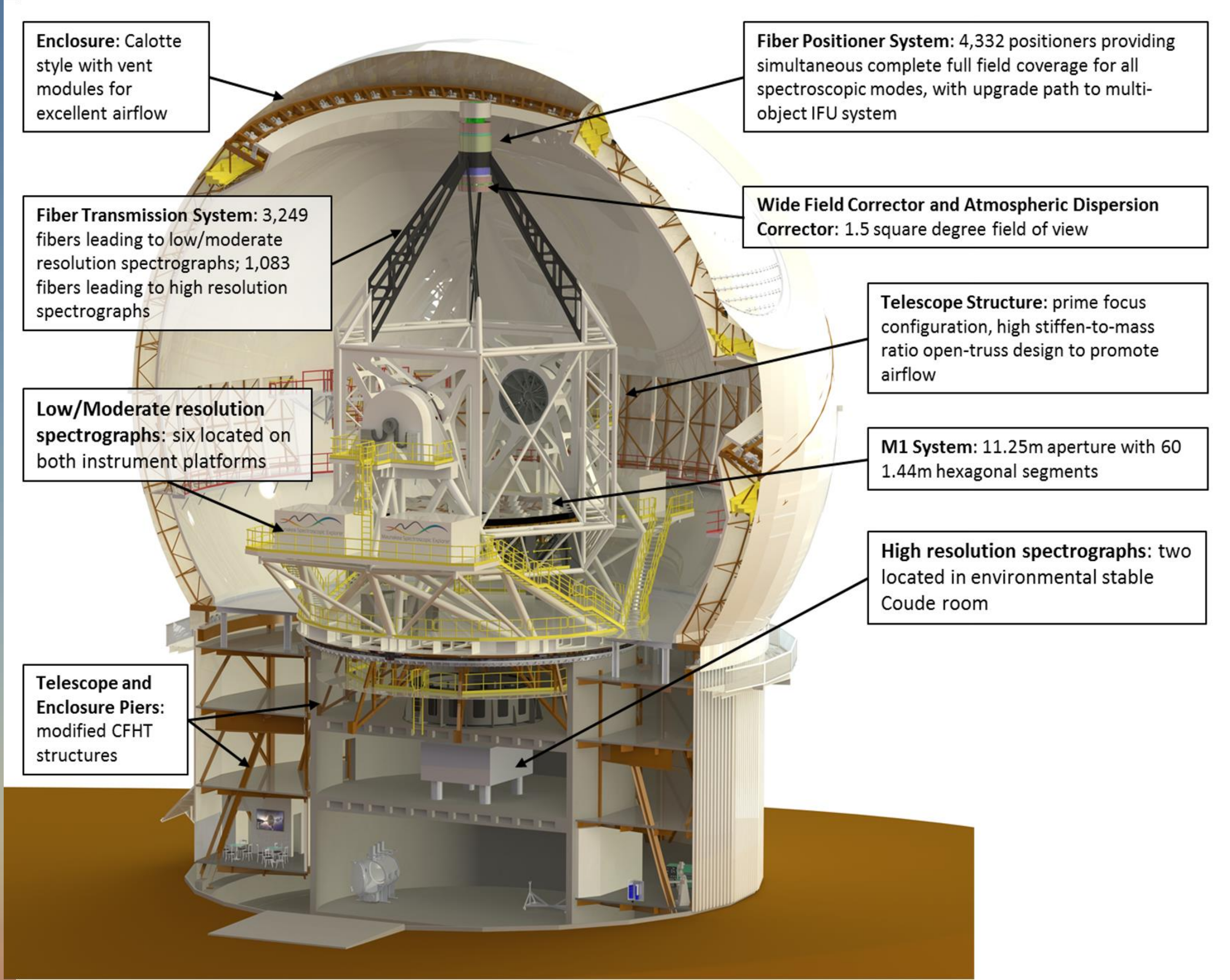
Maunakea Spectroscopic Explorer



- <u>Australian</u> Astronomical Optics (AAO) Macquarie
- National Research Council (NRC) of <u>Canada</u>
- National Astronomical Observatories (NAOC), <u>Chinese</u> Academy of Sciences
- Centre National de la Recherche Scientifique (CNRS) of <u>France</u>
- Institute for Astronomy, University of <u>Hawaii</u>
- <u>India</u> Institute of Astrophysics
- National Optical Astronomy Observatory, Texas A&M University, and a consortium of UK universities participate as observers

Conceptual Design

- 11.25m diameter telescope
- 1.5 square degree field of view
- 4,332 fiber positioner feeds two sets of spectrographs
  - Low/moderate resolution: R~3000 - 6000 / UV to H band / 3249 positioners
  - High resolution: R=40,000 / three windows in optical / 1083 positioners
- **Completely dedicated survey facility**



Maunakea Spectroscopic Explorer

Fiber Positioner System

Conceptual Design by AAO (Australian Astronomical Observatory) Macquarie

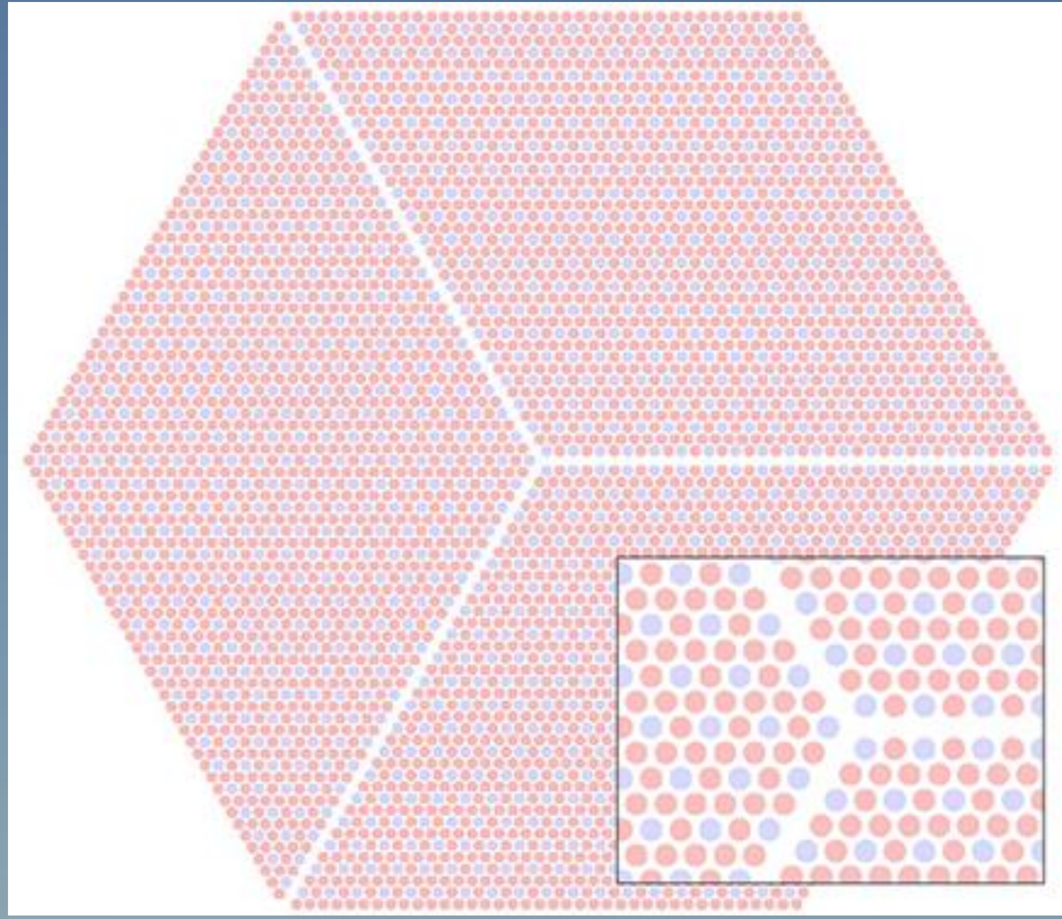
-Sphinx design (based on FMOS/Echidna)

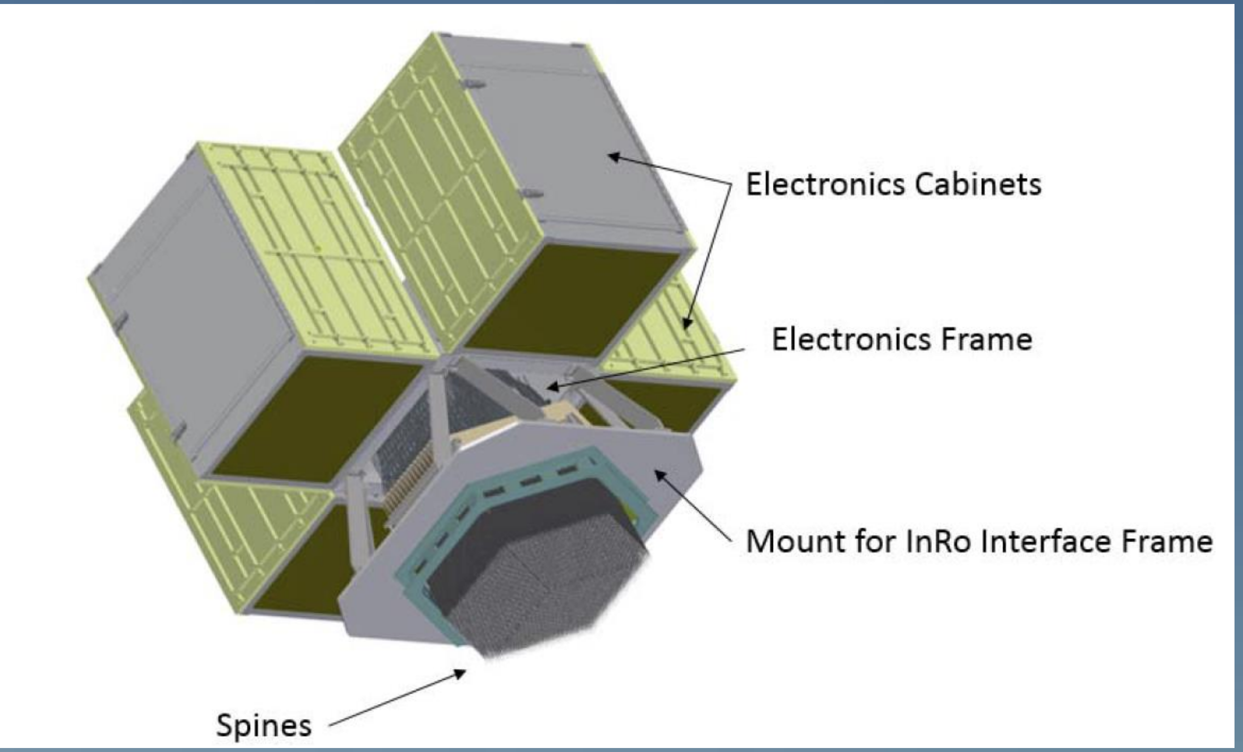
-Hexagonal field of view

- 4,332 piezo actuator positioners

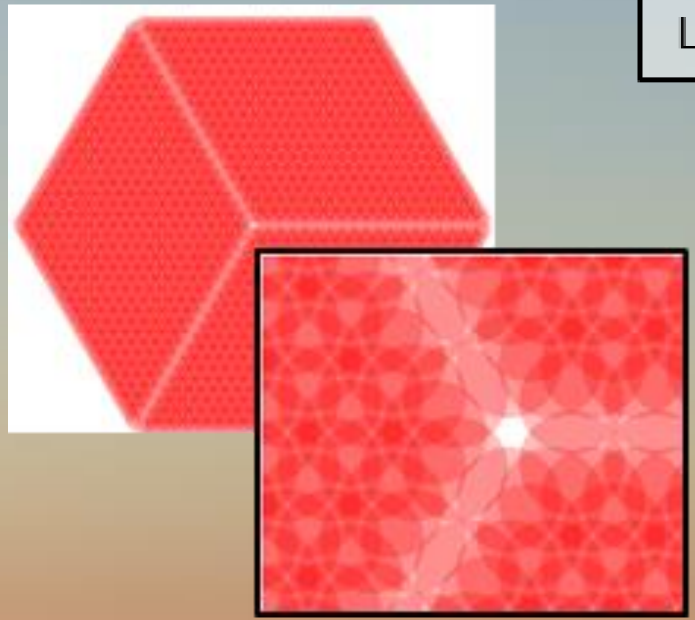
-57 modules/76 positioners each

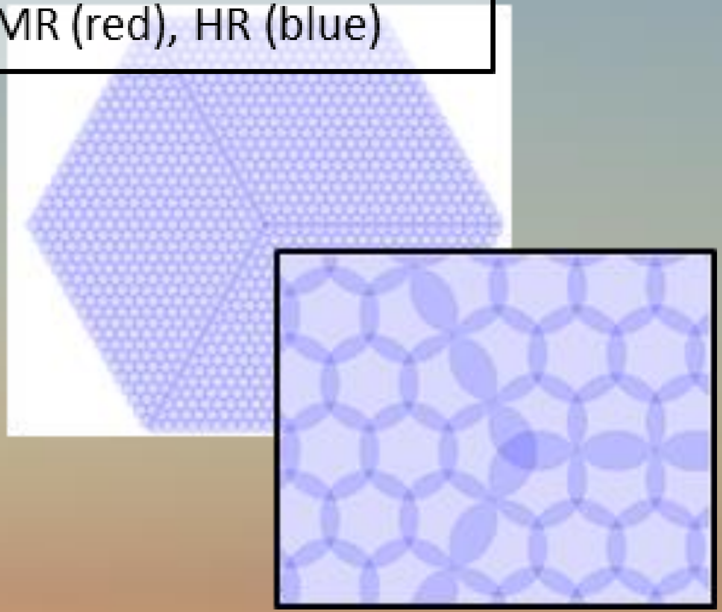
Allows **simultaneous full field** HR and LMR coverage



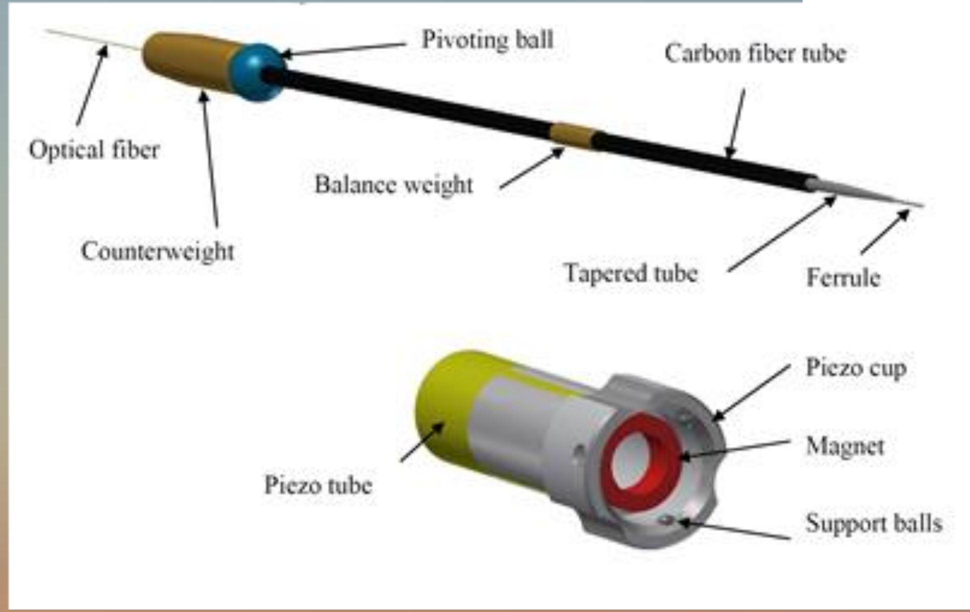


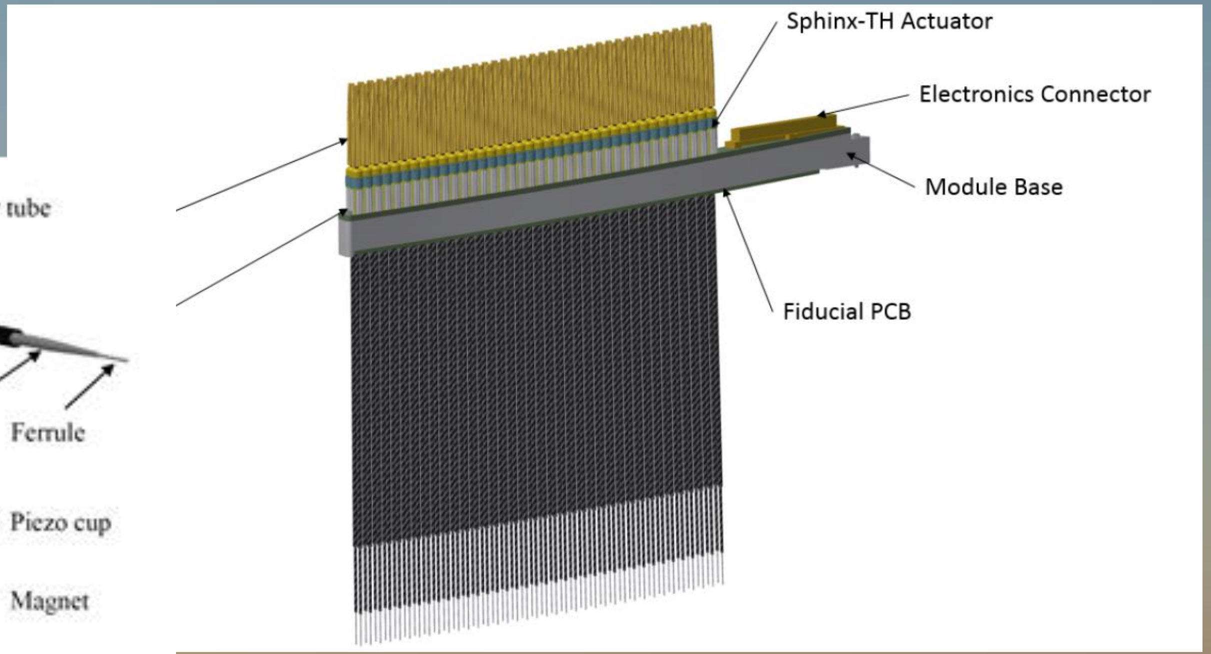
Positioner patrol areas: LMR (red), HR (blue)





Echidna fiber positioner

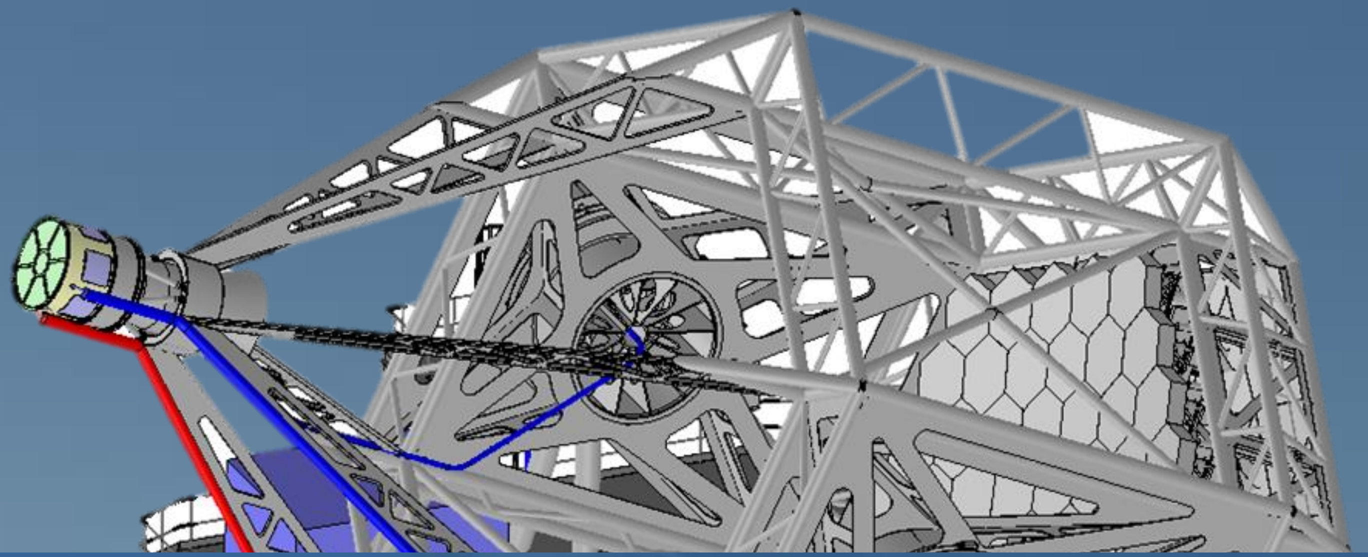




Maunakea Spectroscopic Explorer

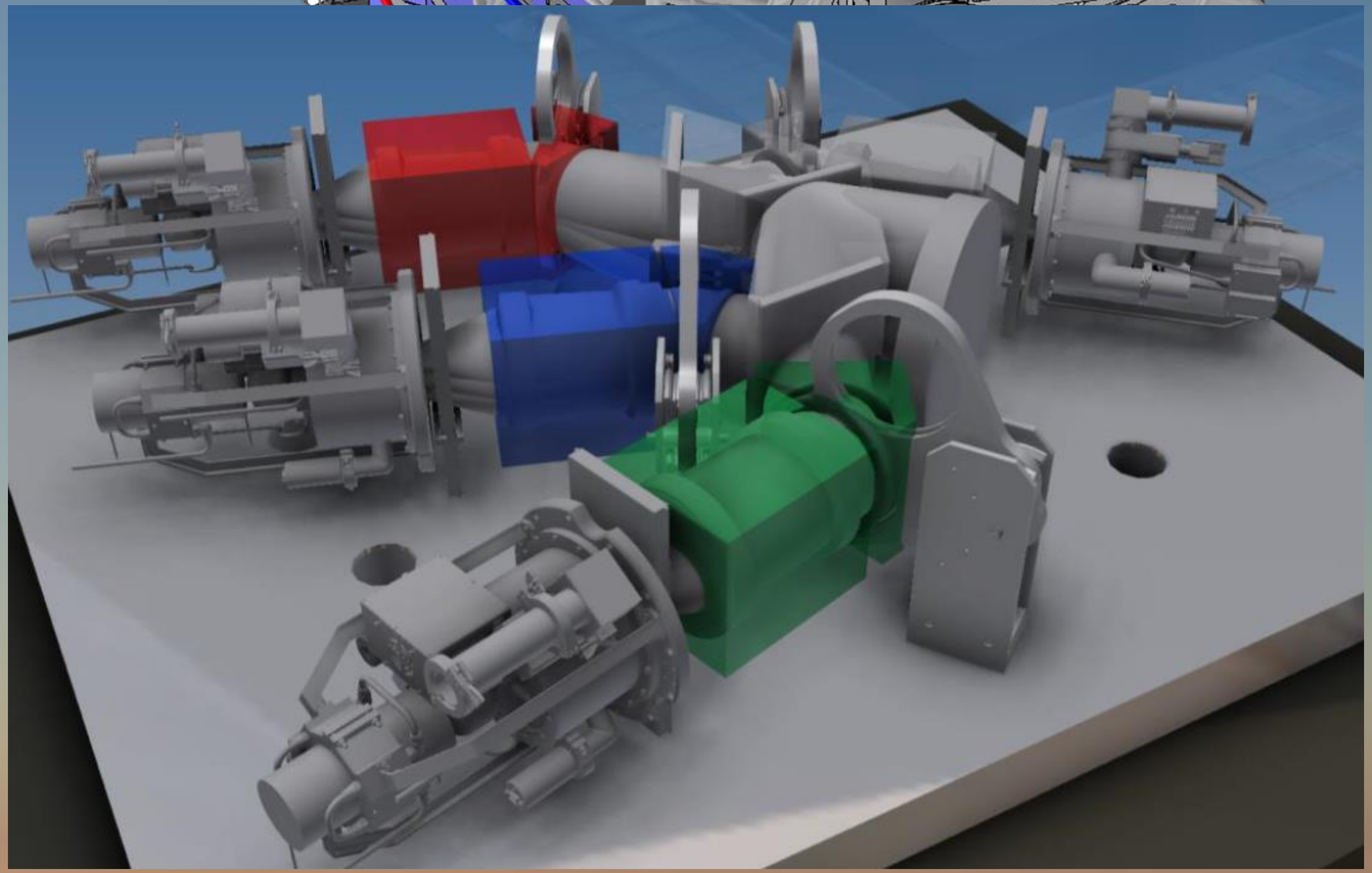
LMR Spectrographs

Conceptual Design by CRAL (Centre de Recherche Astrophysique de Lyon), France



Six identical spectrographs:

- accept 3249 (1” diameter) fibers, divided evenly among spectrographs
- Off-axis Schmidt collimator, f/2
- 3x optical arms (360-950) and 1x NIR (similar to DESI, 4MOST, PFS)
- LR (R = 3000) or MR (R = 6000), ability to switch modes by switching between VPH and VPH plus prism

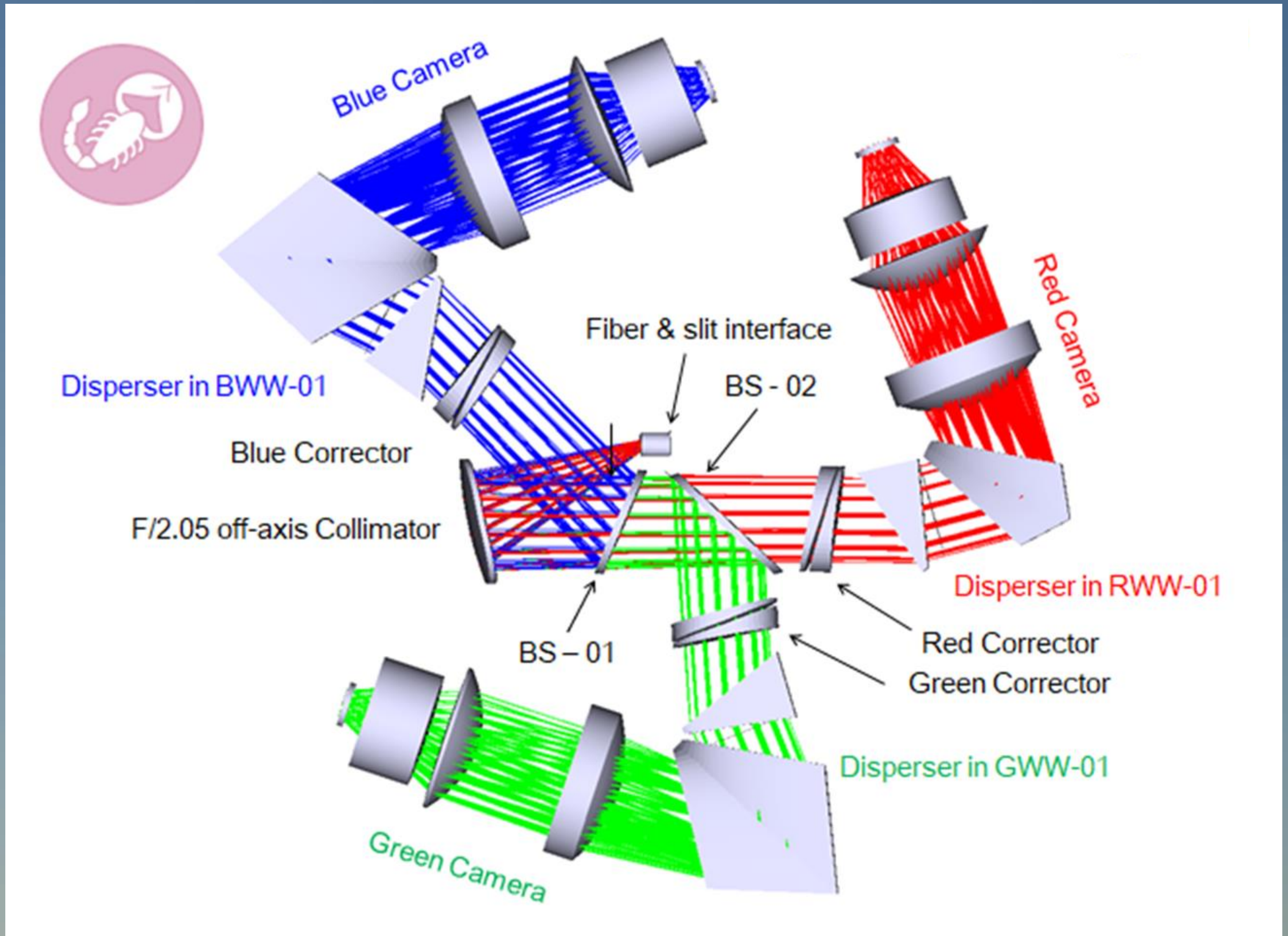


Modes:

- Optical LR + J-band LR
- Optical MR + H-band LR
- All arms of all spectrographs are independently controlled. Possibility of simultaneous LR/MR on different targets in same observing field.

HR Spectrographs

Conceptual Design by NIAOT (Nanjing Institute of Astronomical Optics & Technology)



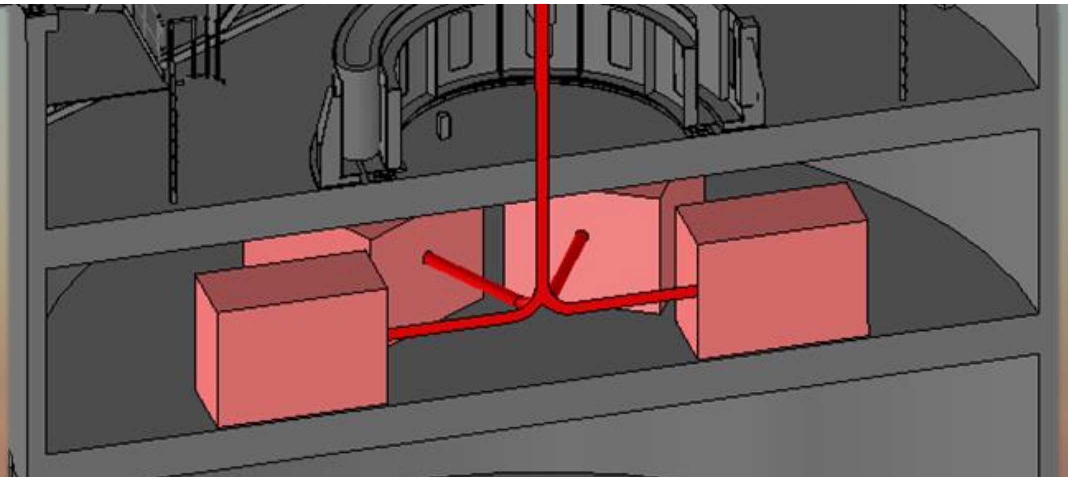
Two identical spectrographs:

- accept 1083 (0.8” diameter) fibers
- Distributed over full field of view
- 3x optical arms (360-950), in three spectral channels (blue green and red), a.k.a. wavelength windows

Blue (401-417nm), R=40k, λ/30

Green (471-489nm), R=40k, λ/30

Red (625-674nm), R=20k, λ/15



MSE instrument specifications

Maunakea Spectroscopic Explorer

See mse.cfht.hawaii.edu:

Low resolution (LR) spectroscopy				
Wavelength range	360 ≤ λ ≤ 560 nm	540 ≤ λ ≤ 740 nm	715 ≤ λ ≤ 985 nm	960 ≤ λ ≤ 1320 nm
Spectral resolution ***(approx. at center of band)***	2,550	3,650	3,600	3,600
Sensitivity requirement ***(pt. source, 1hr, zenith, median seeing, monochromatic magnitude)***	m = 24.0 SNR/res. elem. = 2, λ > 400 nm SNR/res. elem. = 1, λ ≤ 400 nm	m = 24.0 SNR/resolution element = 2	m = 24.0 SNR/resolution element = 2	m = 24.0 SNR/resolution element = 2

Moderate resolution (MR) spectroscopy				
Wavelength range	391 ≤ λ ≤ 510 nm	576 ≤ λ ≤ 700 nm	737 ≤ λ ≤ 900 nm	1457 ≤ λ ≤ 1780 nm
Spectral resolution ***(approx. at center of band)***	4,400	6,200	6,100	6,000
Sensitivity requirement ***(pt. source, 1hr, zenith, median seeing, monochromatic magnitude)***	m = 23.5 SNR/res. elem. = 2, λ > 400 nm SNR/res. elem. = 1, λ ≤ 400 nm	m = 23.5 SNR/resolution element = 2	m = 23.5 SNR/resolution element = 2	m = 24.0 SNR/resolution element = 2

High resolution (HR) spectroscopy			
Wavelength range	360 ≤ λ ≤ 460 nm	440 ≤ λ ≤ 620 nm	600 ≤ λ ≤ 900 nm
Wavelength band	λ / 30 [baseline: 401.0 - 415.0 nm]	λ / 30 [baseline: 472.0 - 488.5 nm]	λ / 15 [baseline: 626.5 - 672.0 nm]
Spectral resolution ***(approx. at center of band)***	40,000	40,000	20,000
Sensitivity requirement ***(pt. source, 1hr, zenith, median seeing, monochromatic magnitude)***	m = 20.0 SNR/resolution element = 10, λ > 400 nm SNR/resolution element = 5, λ ≤ 400 nm	m = 20.0 SNR/resolution element = 10	m = 20.0 SNR/resolution element = 10

Updated Detailed Science Case

Maunakea Spectroscopic Explorer

- Recently the 400-member international MSE Science Team has worked hard to update the MSE Detailed Science Case:

MSE Science Team 2019; arXiv: 1904.04907

Contents

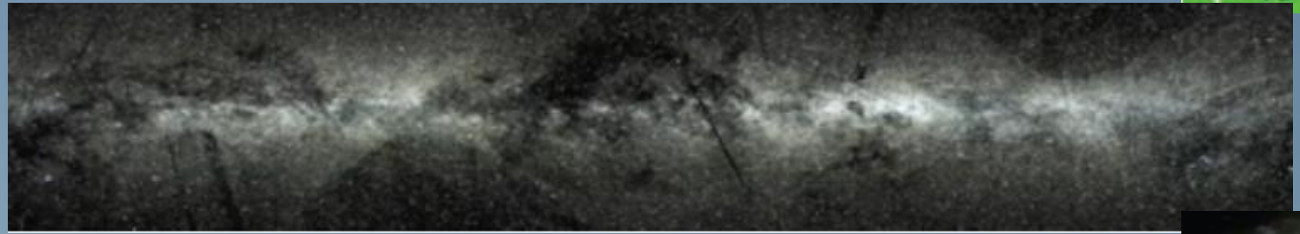
- >300 pages!
- Over 100 active contributors
- Builds on original MSE Detailed Science Case (2016)

Maunakea Spectroscopic Explorer

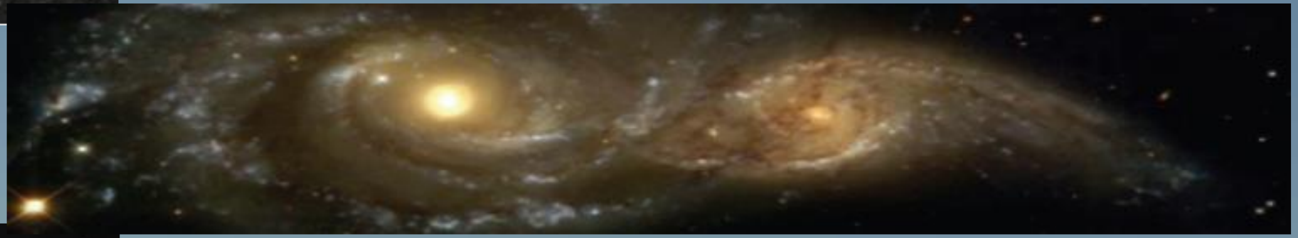
Science Working Groups

Exoplanets and stellar astrophysics
Maria Bergemann & Daniel Huber

Chemical nucleosynthesis
Sivarani Thirupathi & David Yong

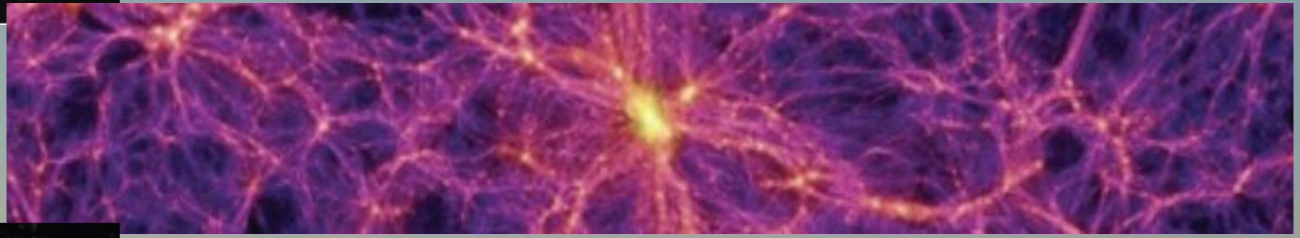


Milky Way and resolved stellar pops
Carine Babusiaux & Sarah Martell

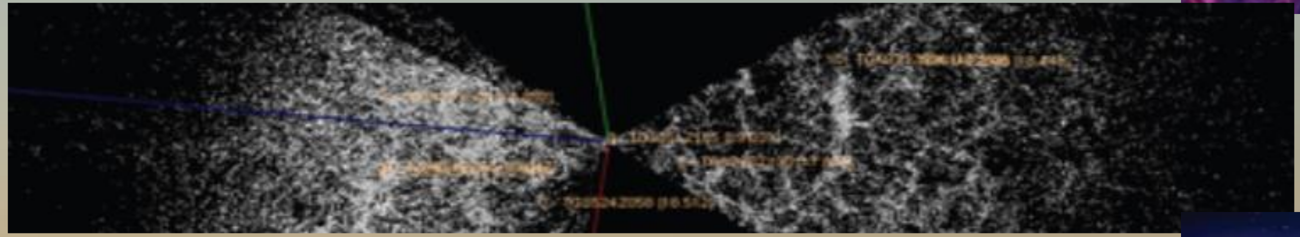


Galaxy Formation and evolution
Kim-Vy Tran & Aaron Robotham

AGN and supermassive black holes
Yue Shen & Sara Ellison



Astrophysical tests of dark matter
Ting Li & Manoj Kaplinghat



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Time domain astronomy and transients
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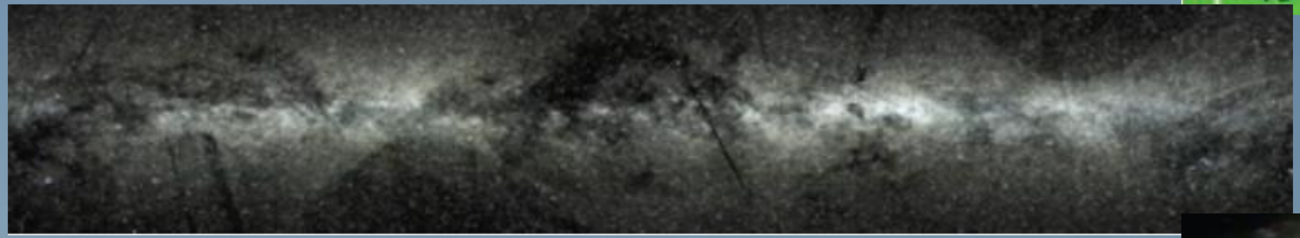

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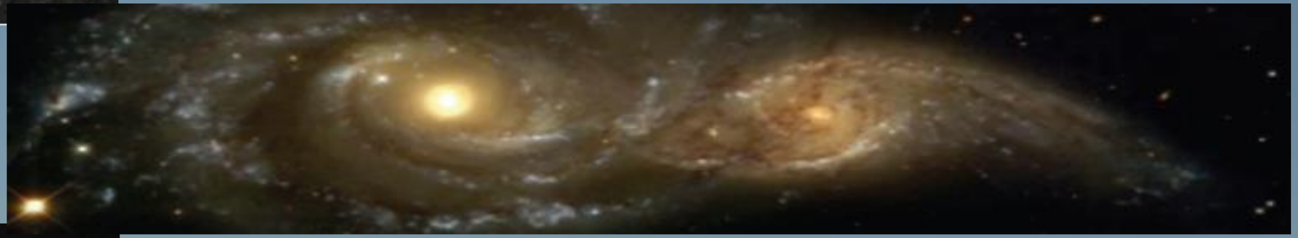

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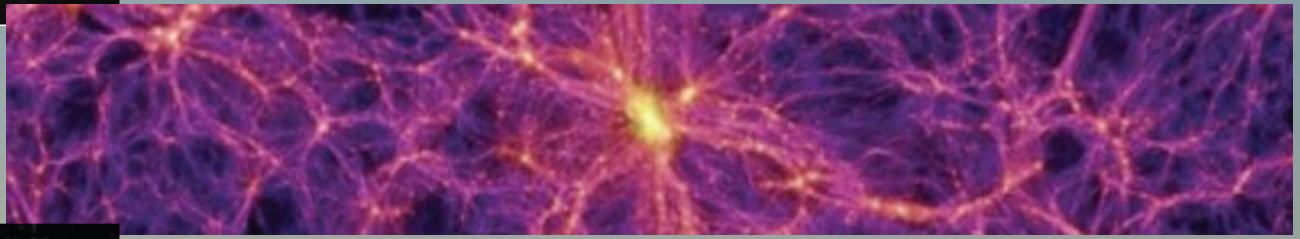

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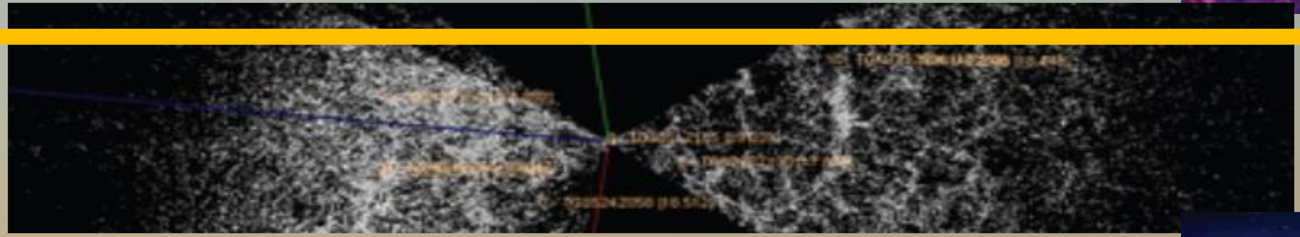
Ting Li & Manoj Kaplinghat

Li, Kaplinghat++
arXiv:1903.03155



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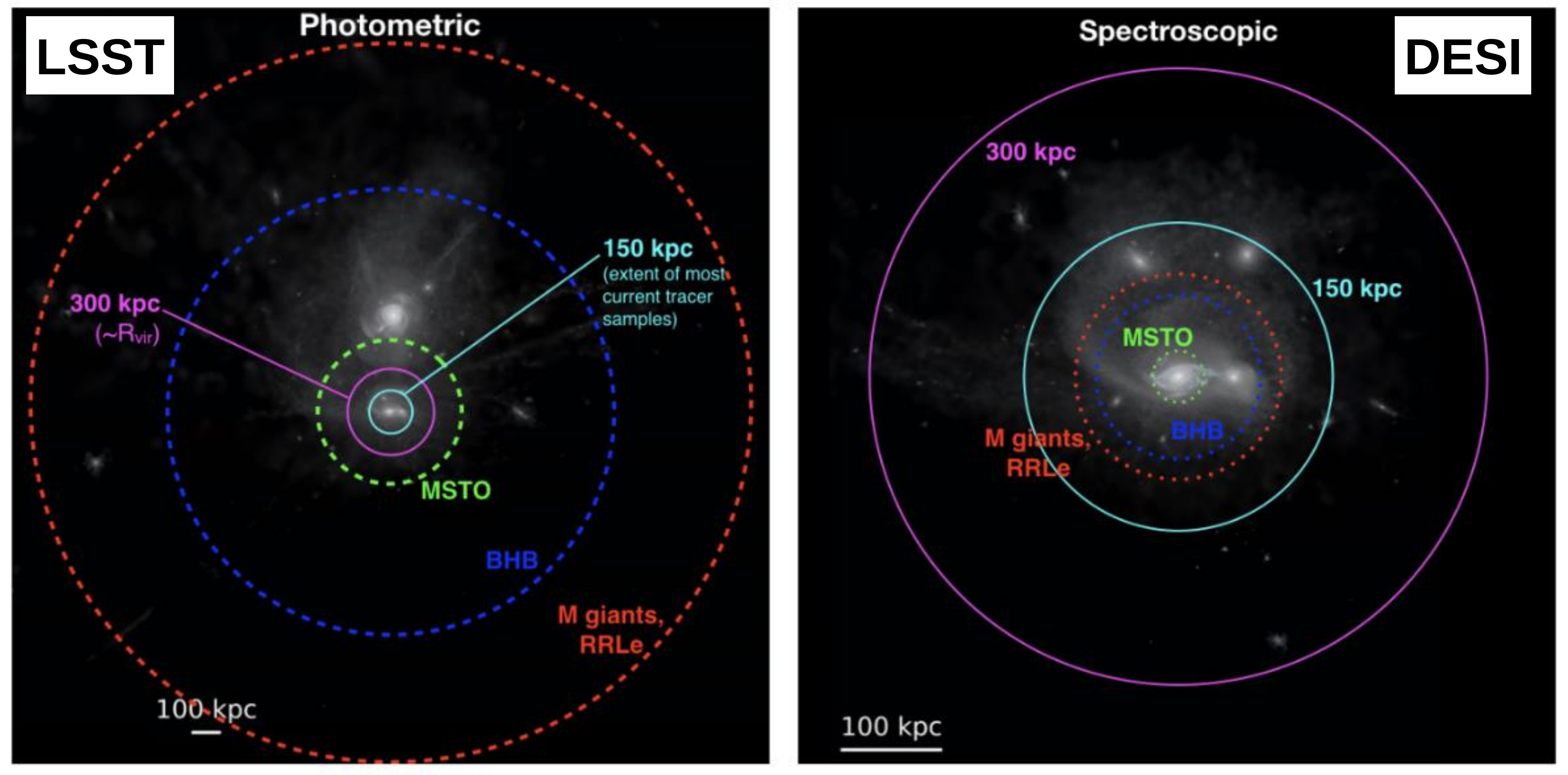
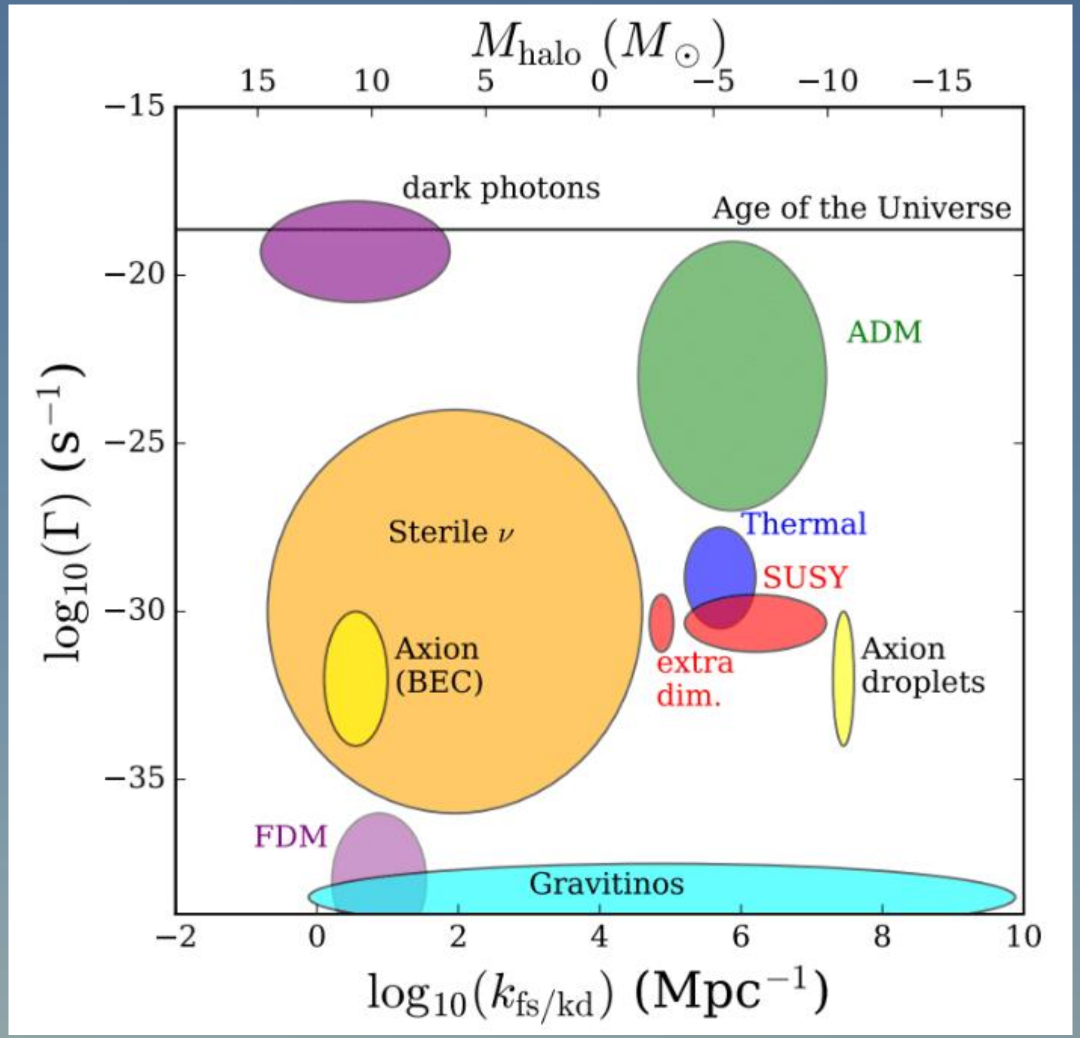
Dark matter science with MSE

Probing the particle nature of dark matter

- By measuring kinematics of stars in the Milky Way and dwarf galaxies, MSE will be able discriminate between different dark matter particles





MSE is the only planned spectroscopic survey that will be able to study the faintest objects discovered by LSST at high and low resolution

MSE Detailed Science Case 2019

Dark matter science with MSE

Maunakea Spectroscopic Explorer

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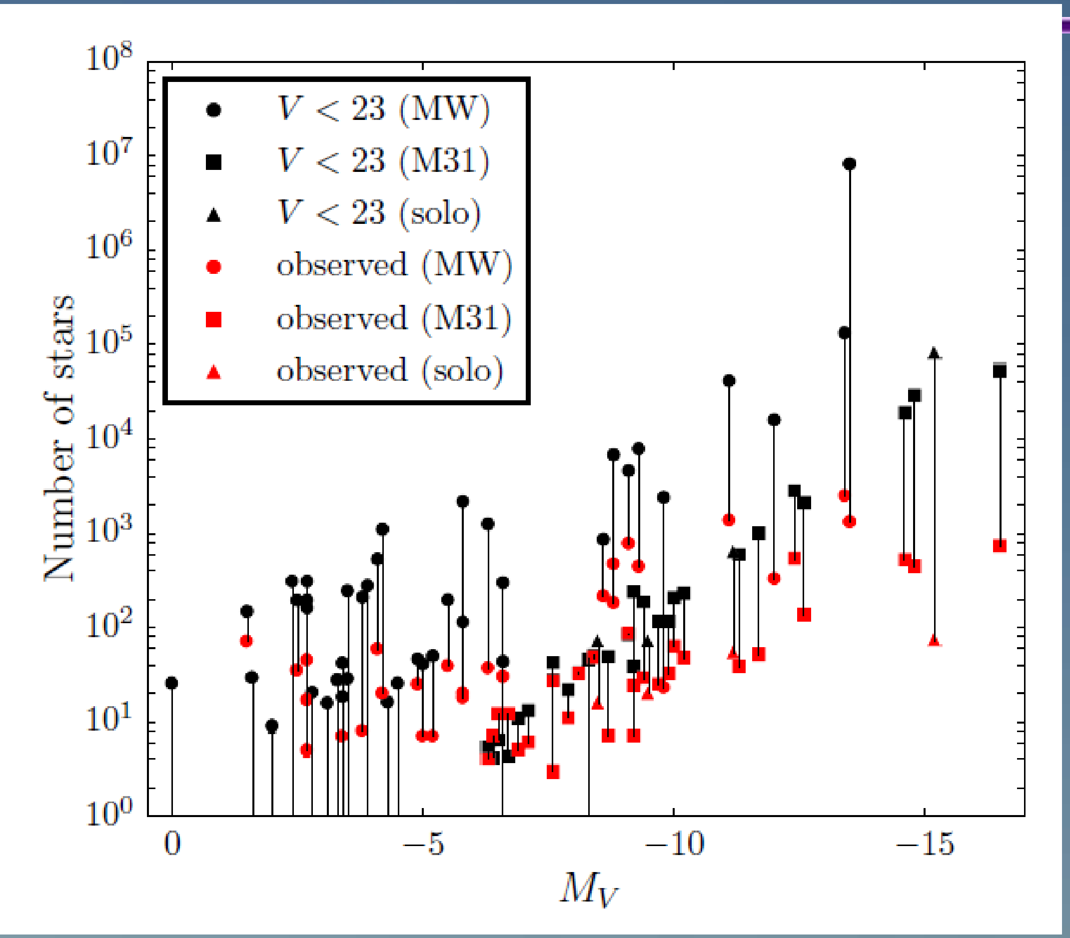
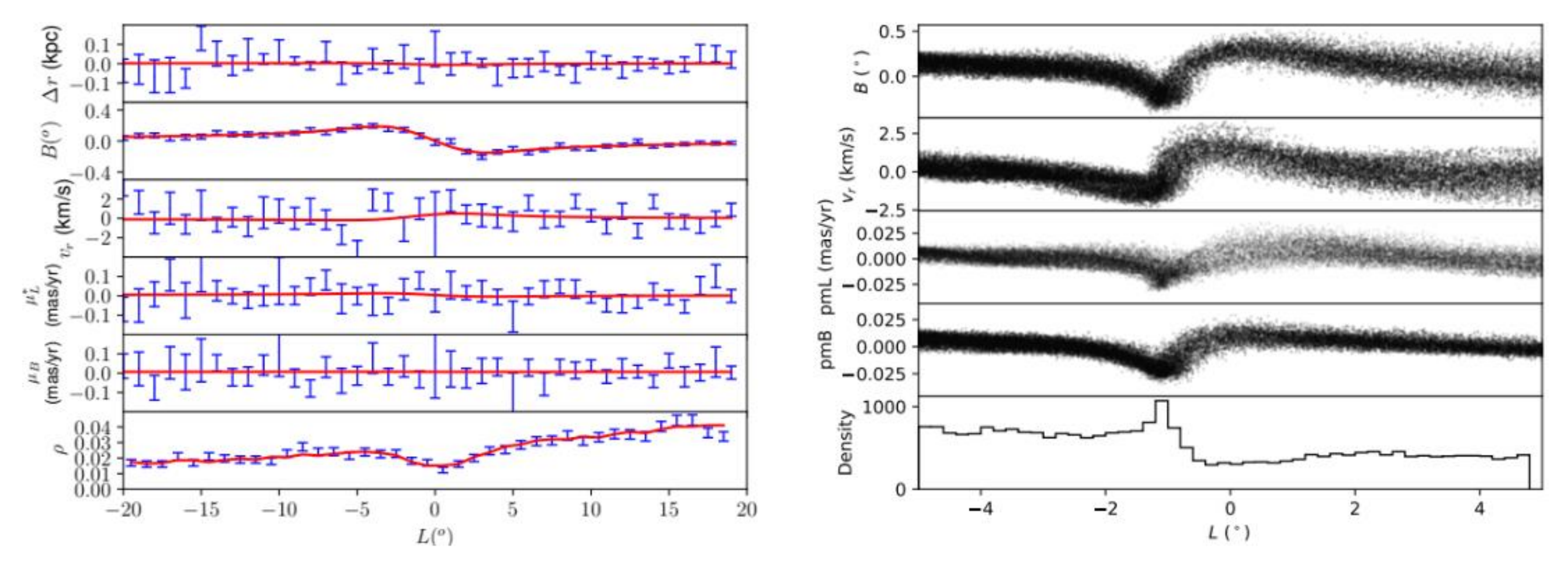
MSE Detailed Science Case 2019



Spectroscopic sample sizes for known dwarf galaxies. Black points indicate number of stars observable with MSE. LSST should find 100s more dwarfs.

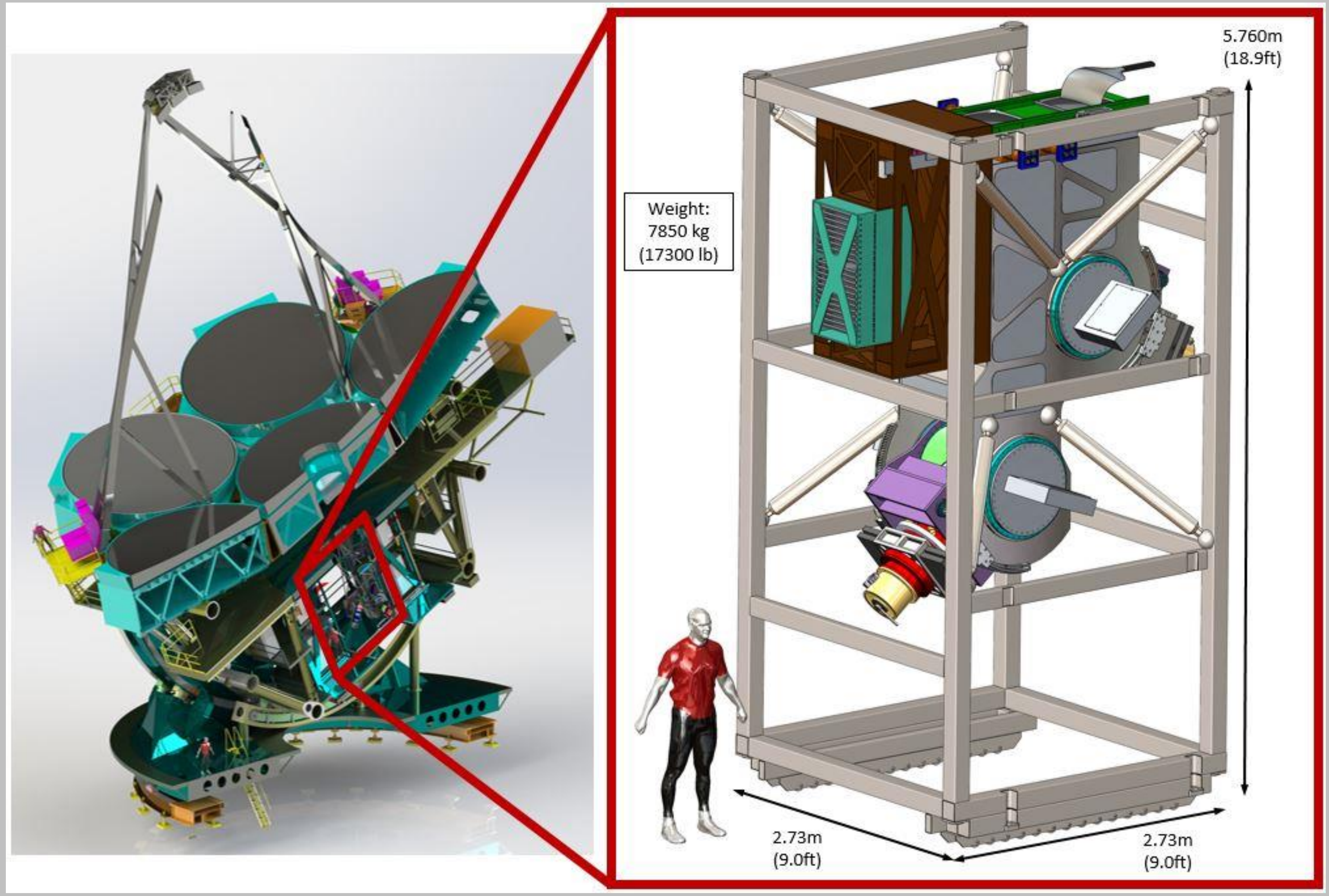


Left: Simulated observations of a $10^7 M_o$ subhalo impact adapted from Erkal & Belokurov 2015. Right: Gap in a simulated GD-1-like stream from a $10^6 M_o$ subhalo. Both are readily detectable by MSE.

GIANT MAGELLAN TELESCOPE

Munnerlyn Astronomical Instrumentation Lab
Texas A&M University

GMACS: The Wide-Field, Multi-Object Spectrograph for the GMT



GMT+GMACS

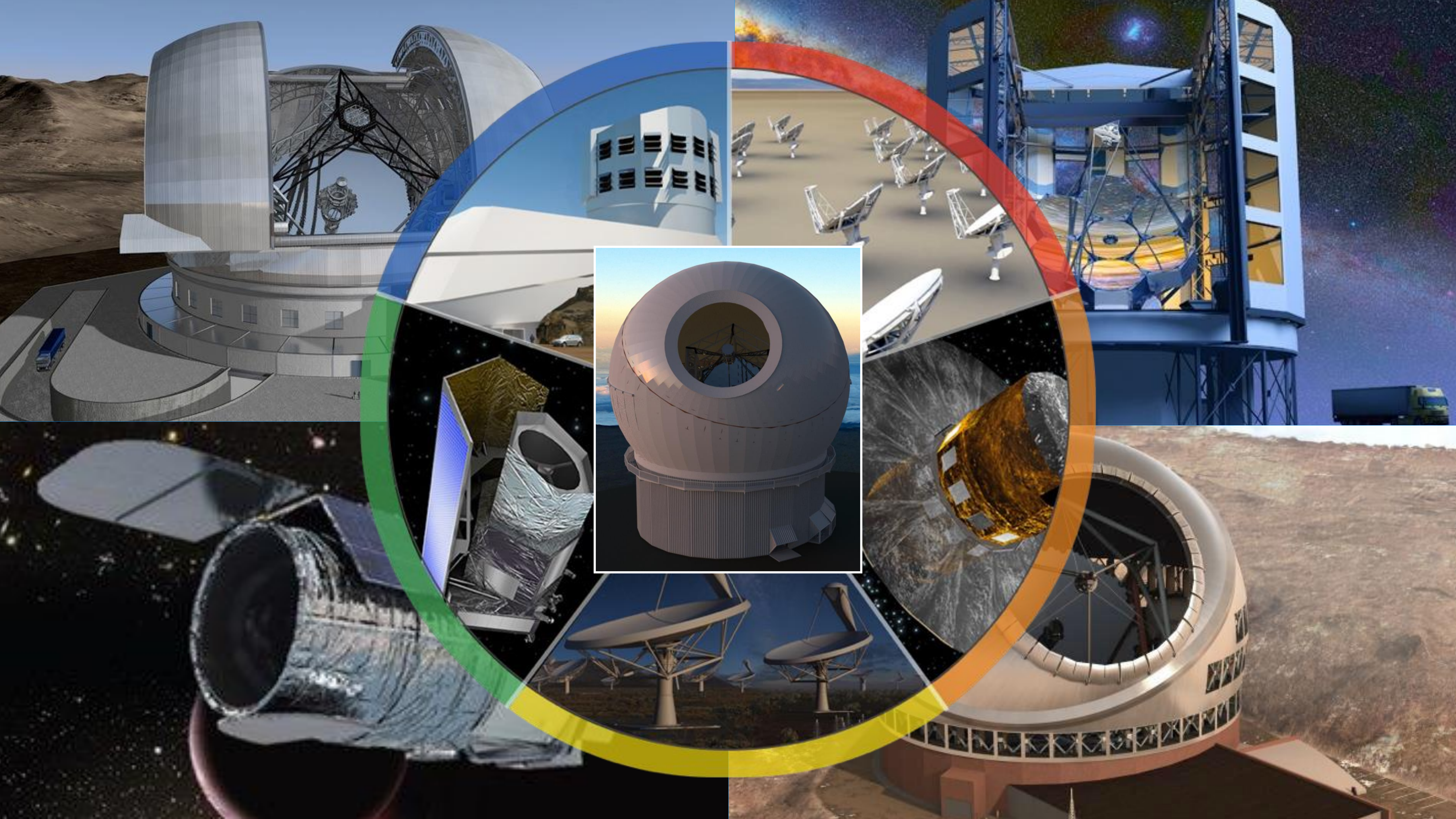
With ~100 nights, GMT+GMACS can

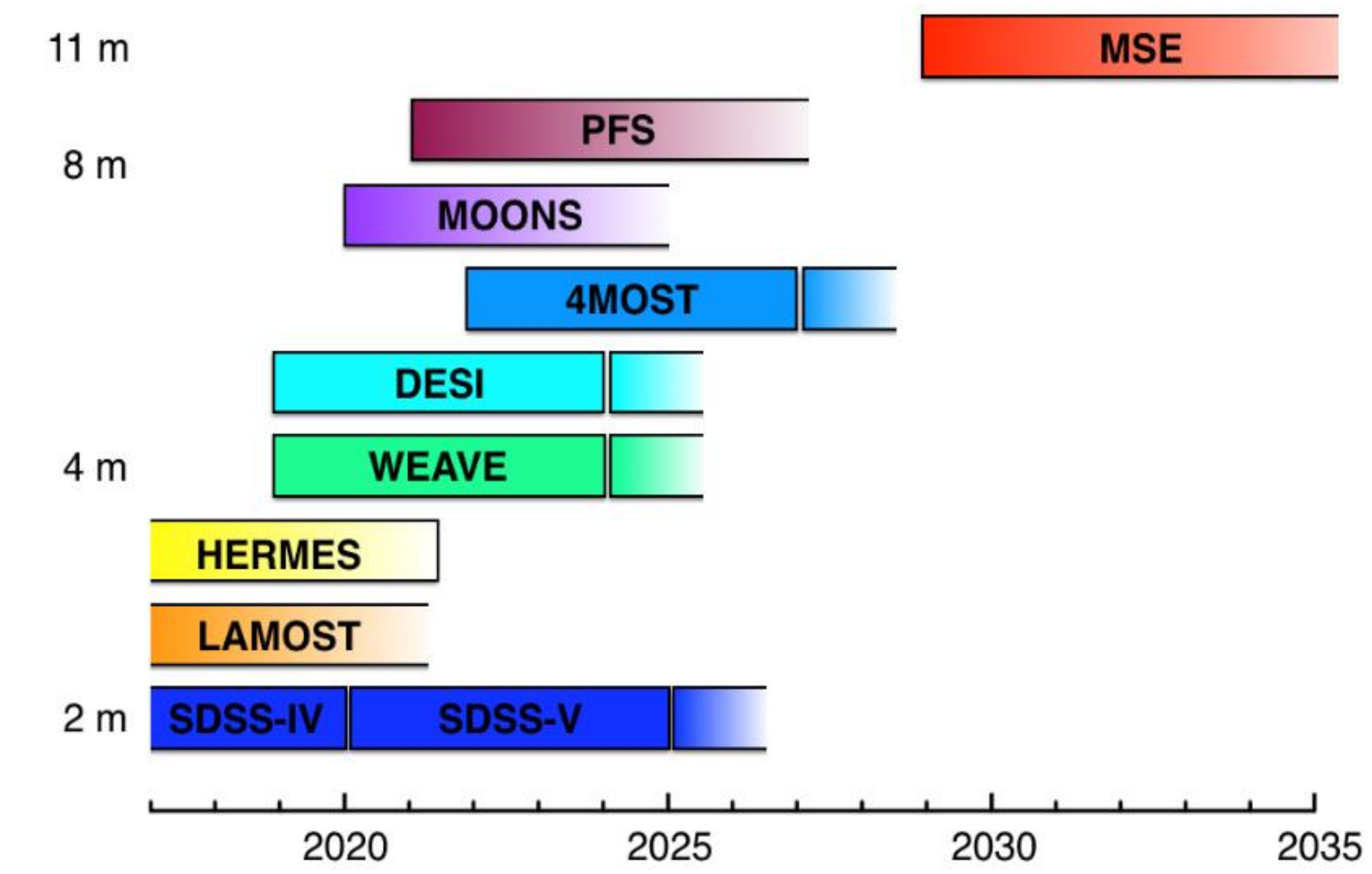
- Fully map Milky Way halo by measuring velocities and rough metallicities of all stars in known halo substructures (satellites, streams, etc.)
- Spectroscopically train photometric redshifts to enhance DETF FOM (Newman Method)
- Measure the mass of the neutrino by measuring galaxy power spectrum at $z > 2.5$

With rapid response capability, GMACS

- Is uniquely able to followup any LSST faint transient
- Can acquire transient observations at the same time as primary science observations

Possibilities are numerous, but only with appropriate coordination between partners/users





MSE Book 2018

Maunakea Spectroscopic Explorer

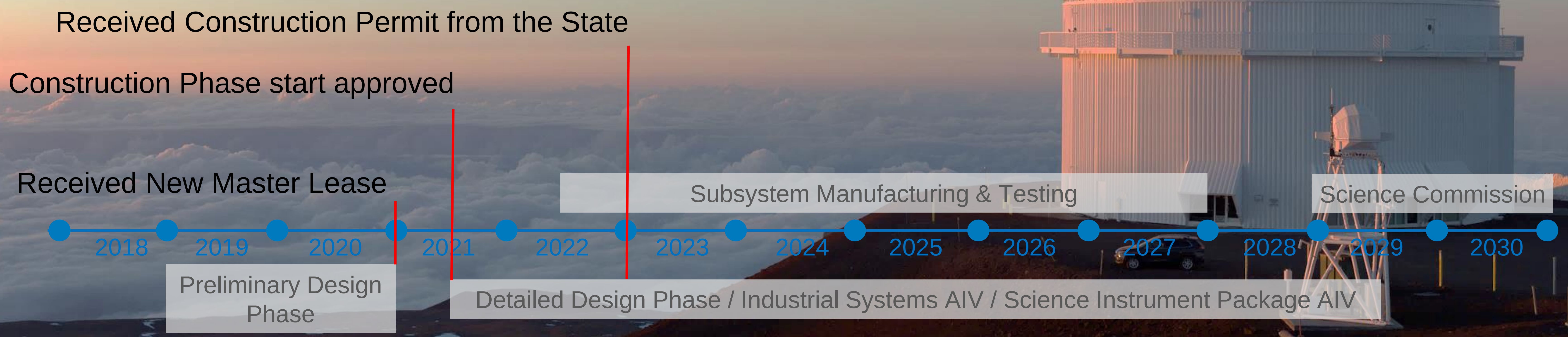
Timeline to Science Operations

Science Commissioning will begin in 2029

- Based on a technically paced schedule with no constraints on resources and cash flow

The project timeline is organized in four major overlapping phases with three milestones:

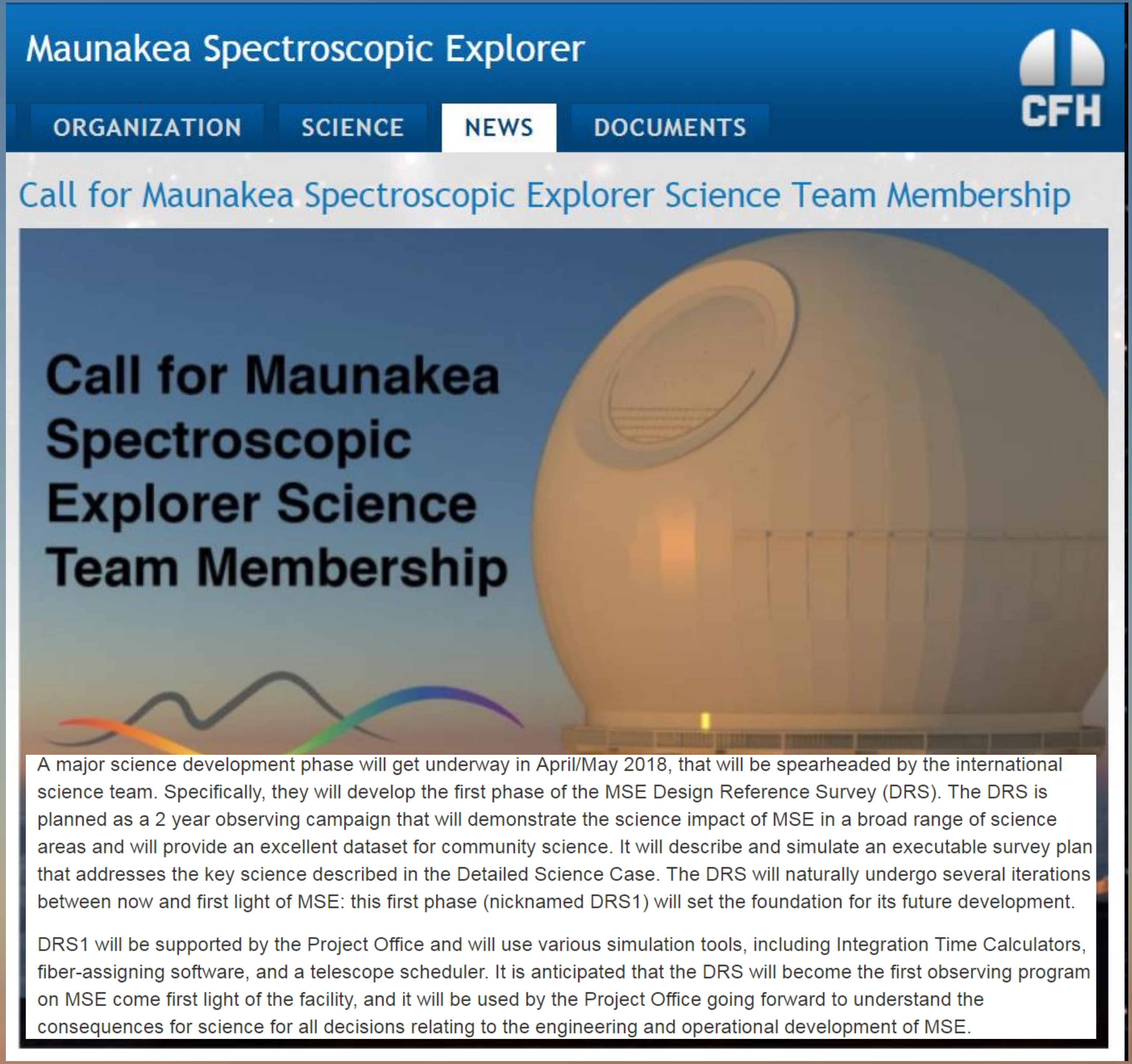
- Preliminary Design Phase - 2 yrs
- Construction Phase - 6.5 yrs duration
- System-Level Assembly, Integration and Verification (AIV) Phase - 5.5 yrs
- Science Commissioning - 2 yrs



Maunakea Spectroscopic Explorer

Join the Science Team!

- Send an email to mseinfo@mse.cfht.hawaii.edu or marshall@mse.cfht.hawaii.edu


Maunakea Spectroscopic Explorer

CFH

ORGANIZATION SCIENCE NEWS DOCUMENTS

Call for Maunakea Spectroscopic Explorer Science Team Membership

A major science development phase will get underway in April/May 2018, that will be spearheaded by the international science team. Specifically, they will develop the first phase of the MSE Design Reference Survey (DRS). The DRS is planned as a 2 year observing campaign that will demonstrate the science impact of MSE in a broad range of science areas and will provide an excellent dataset for community science. It will describe and simulate an executable survey plan that addresses the key science described in the Detailed Science Case. The DRS will naturally undergo several iterations between now and first light of MSE: this first phase (nicknamed DRS1) will set the foundation for its future development.

DRS1 will be supported by the Project Office and will use various simulation tools, including Integration Time Calculators, fiber-assigning software, and a telescope scheduler. It is anticipated that the DRS will become the first observing program on MSE come first light of the facility, and it will be used by the Project Office going forward to understand the consequences for science for all decisions relating to the engineering and operational development of MSE.

Maunakea Spectroscopic Explorer

Thank you!

The Maunakea Spectroscopic Explorer (MSE) conceptual design phase was conducted by the MSE Project Office, which is hosted by the Canada-France-Hawaii Telescope (CFHT). MSE partner organizations in Canada, France, Hawaii, Australia, China, India, and Spain all contributed to the conceptual design. The authors and the MSE collaboration recognize the cultural importance of the summit of Maunakea to a broad cross section of the Native Hawaiian community.