



MUST
MULTIPLEXED
SURVEY TELESCOPE

A Stage-V Spectroscopic Survey
in the Northern Hemisphere

& its

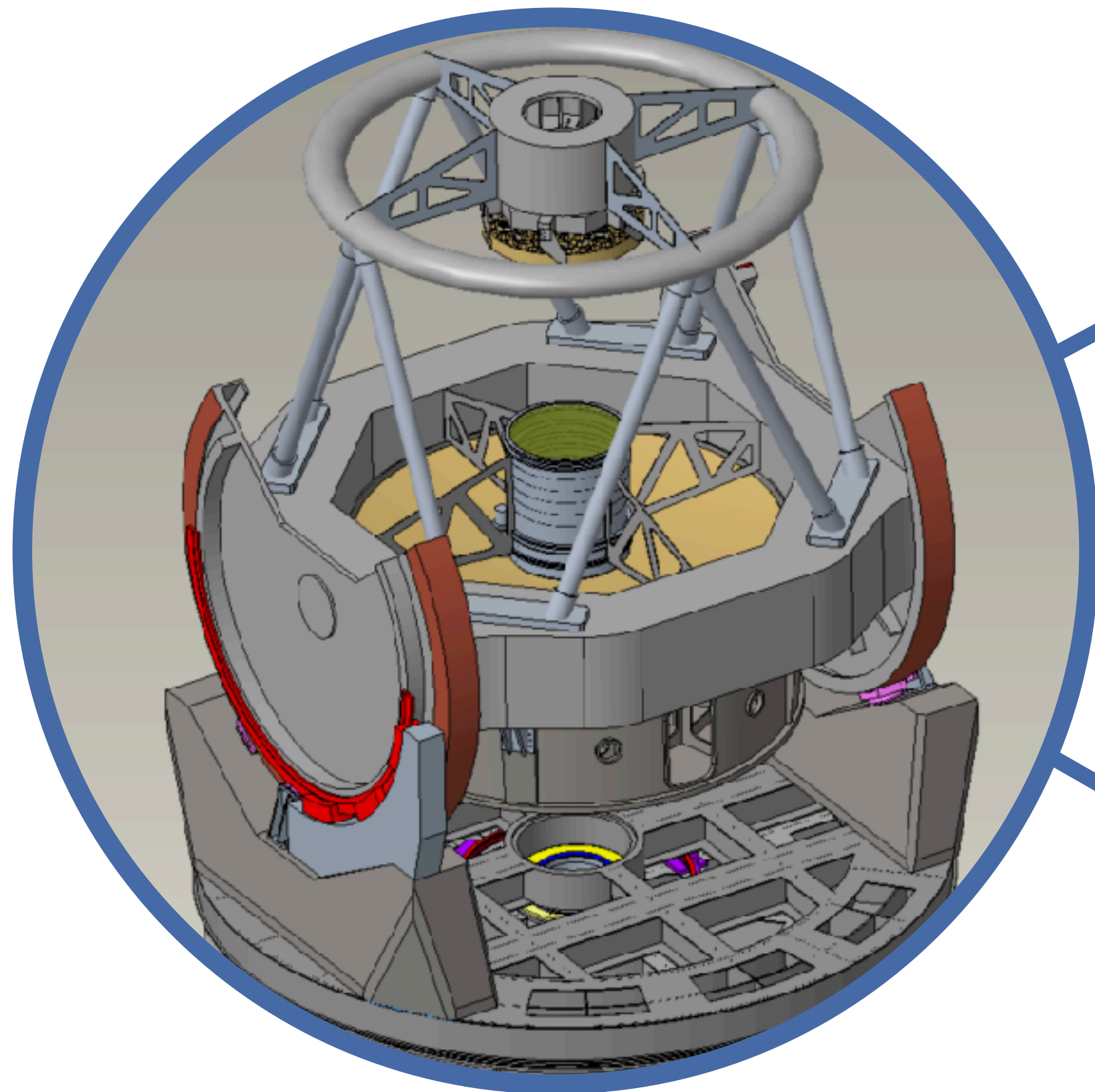
Synergy with Euclid

Song Huang (Tsinghua)
on behalf of the MUST team



My Goals Today

- First, I am here on behalf of a large team of scientists and engineers from many institutes in China today. This project is led by Tsinghua University



1

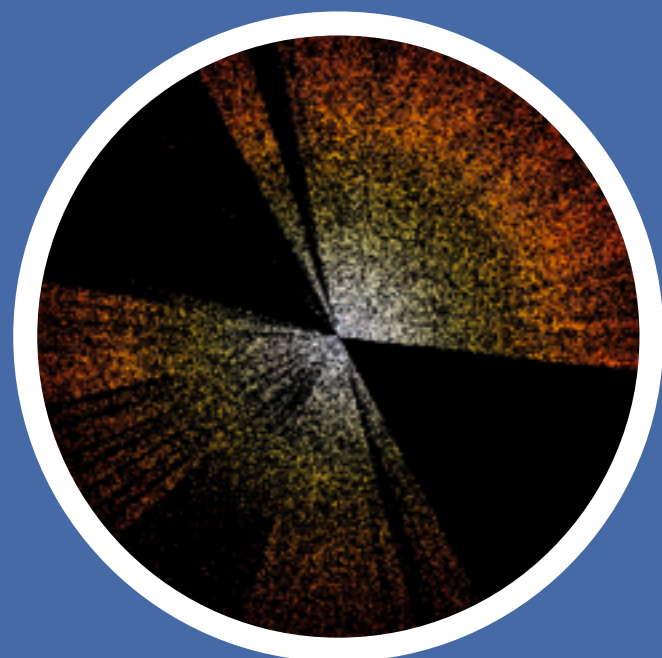
Put this 6.5-m spectroscopic survey telescope on your map

2

Why are we closely following the development of *Euclid*?

3

What can we help with *Euclid* in the long run?



The Main Scientific Driver for MUST

The international astrophysics and cosmology community recognized that we are facing **a significant gap** in multiplexed spectroscopic capability in the next 10-20 years. Large spectroscopic survey still has the potential to revolutionize different fields in astronomy.

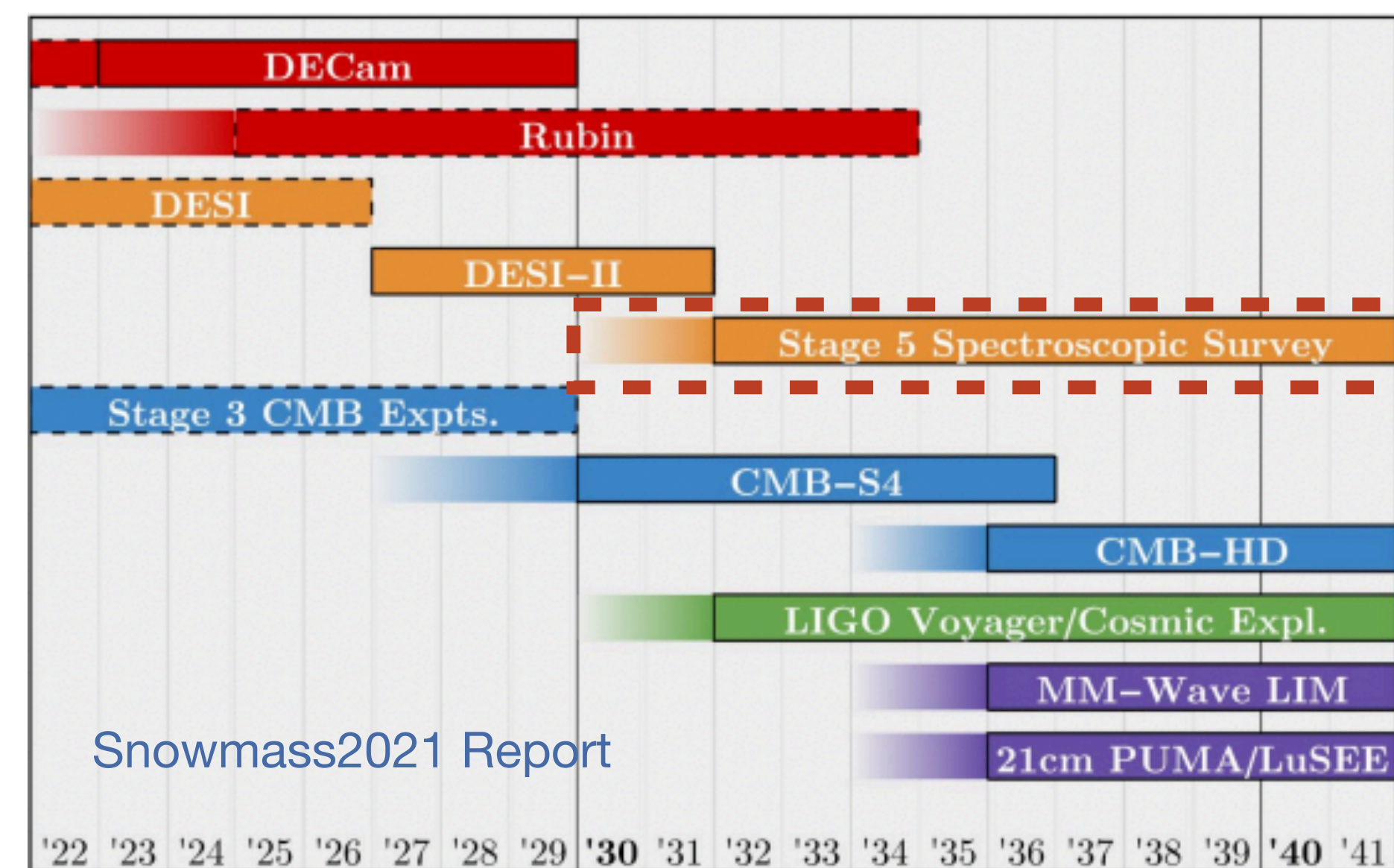
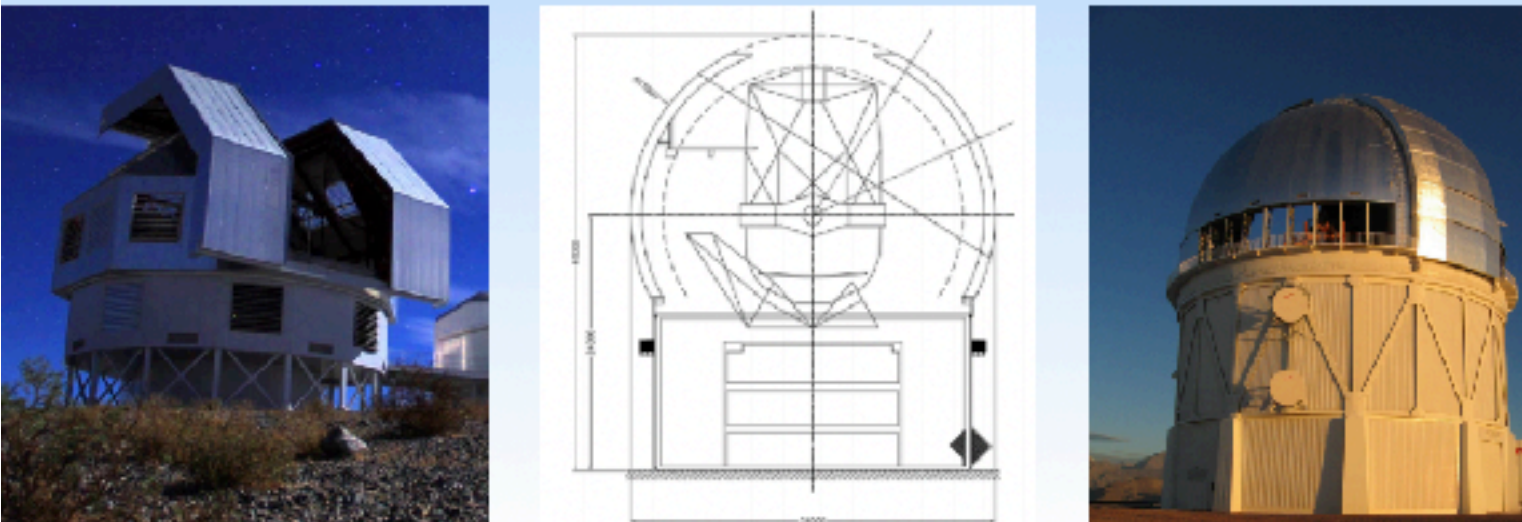
- **MUST** was scientifically inspired by both the **SSSI** (or SSST) concept and the **MegaMapper** project.
- It is our answer to the call for a **Stage-V spectroscopic survey** in the northern hemisphere.

SSSI

**A Southern Spectroscopic Survey Instrument:
Synergies with WFIRST**

Jeff Newman, U. Pittsburgh/PITT PACC

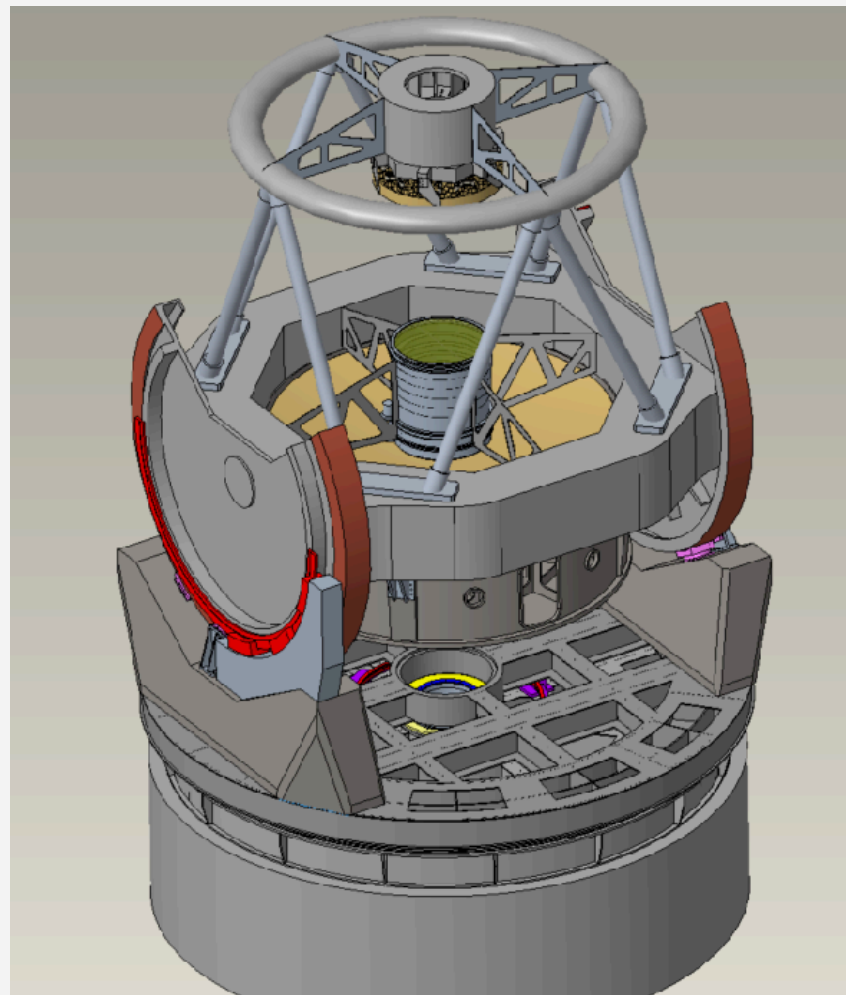
with contributions from Katrin Heitmann, Josh Frieman, Lindsey Bleem and Elisabeth Krause



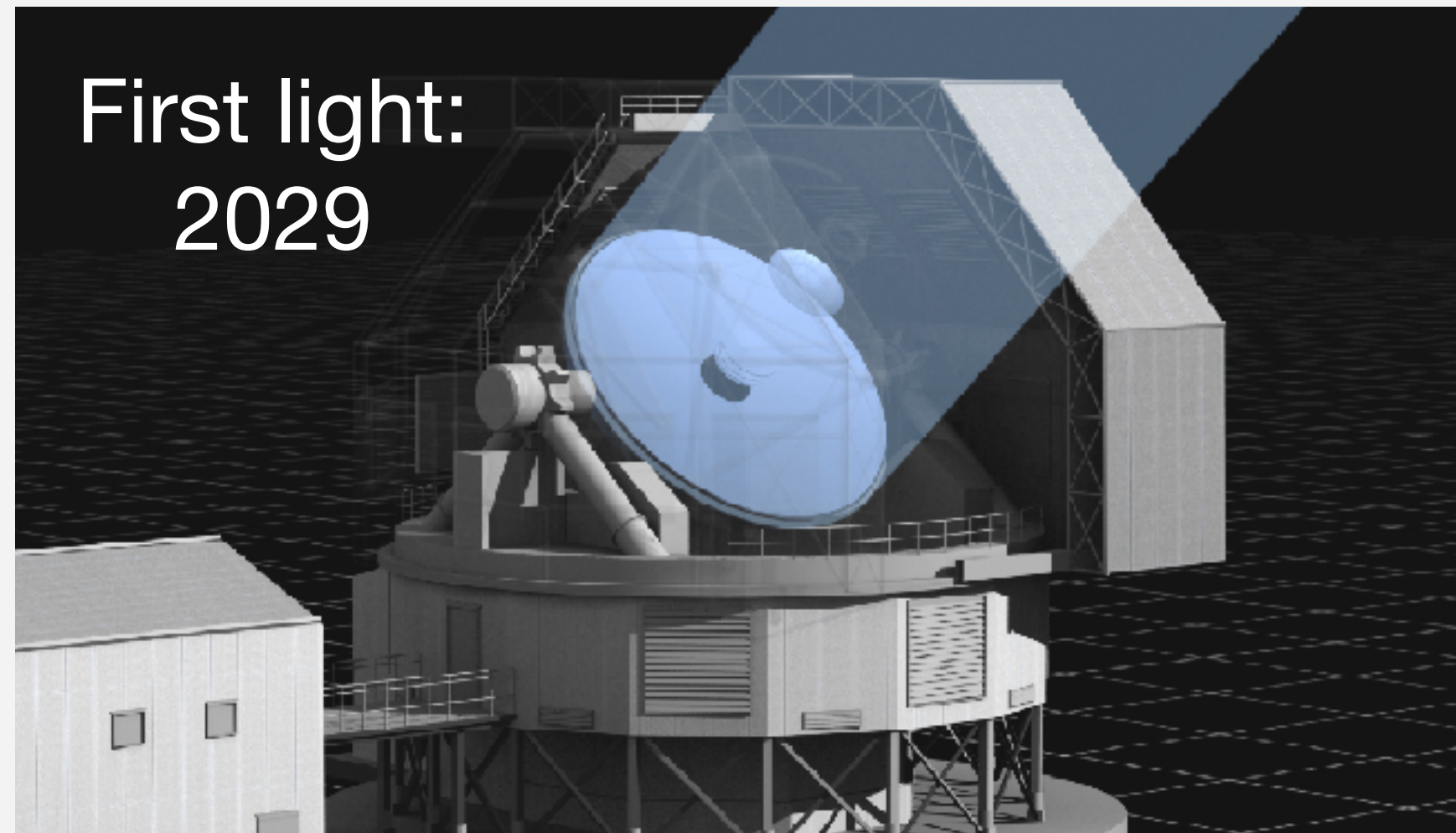


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MUST: Introduction



First light:
2029



Parameter	Current Design
Diameter	6.5 m
FoV	7 deg ²
No. Spectra	~ 20,000
Wavelength	0.36-1.0 (1.4) micron
Resolution	R~5000

Our Vision for MUST

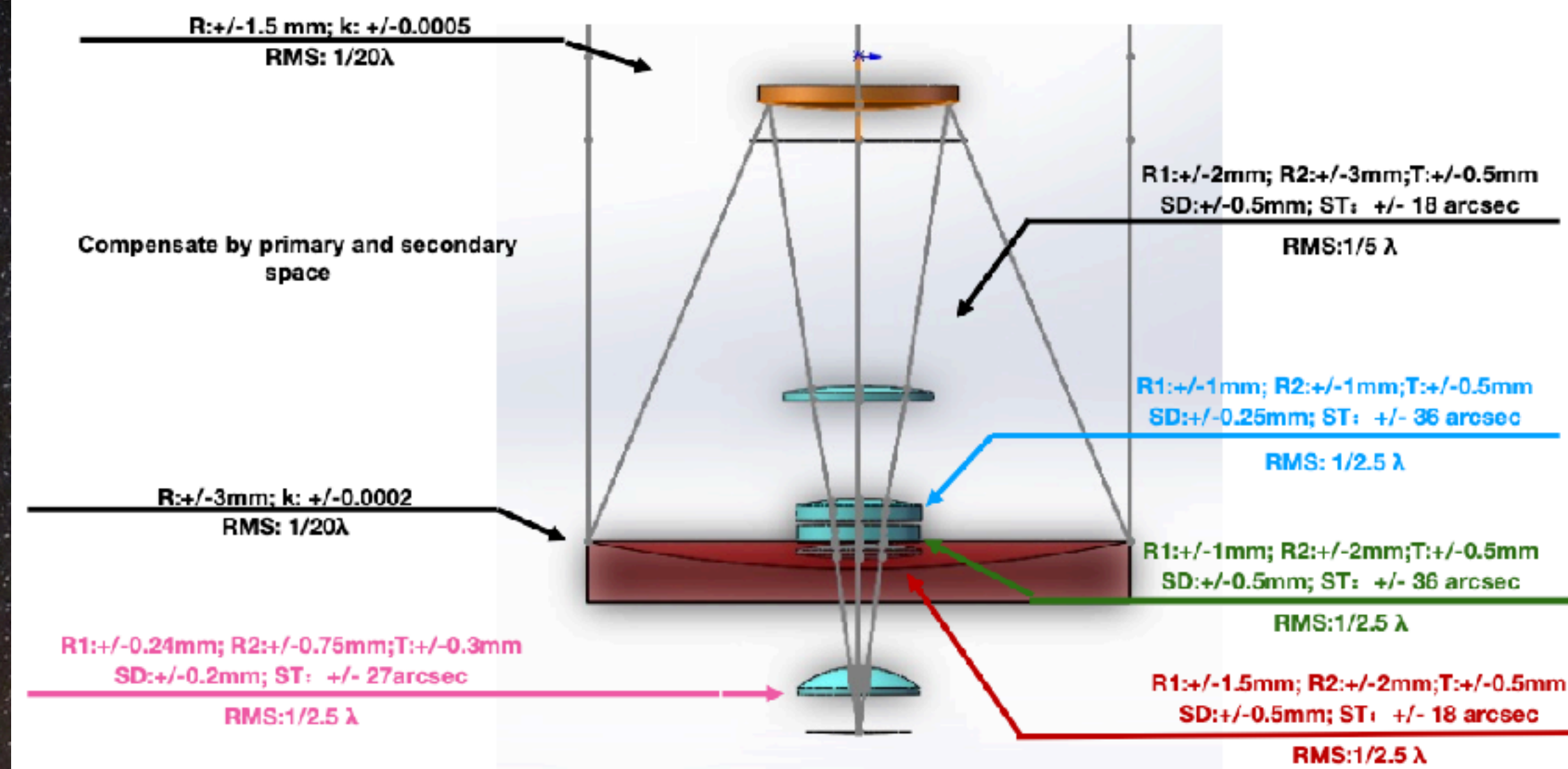
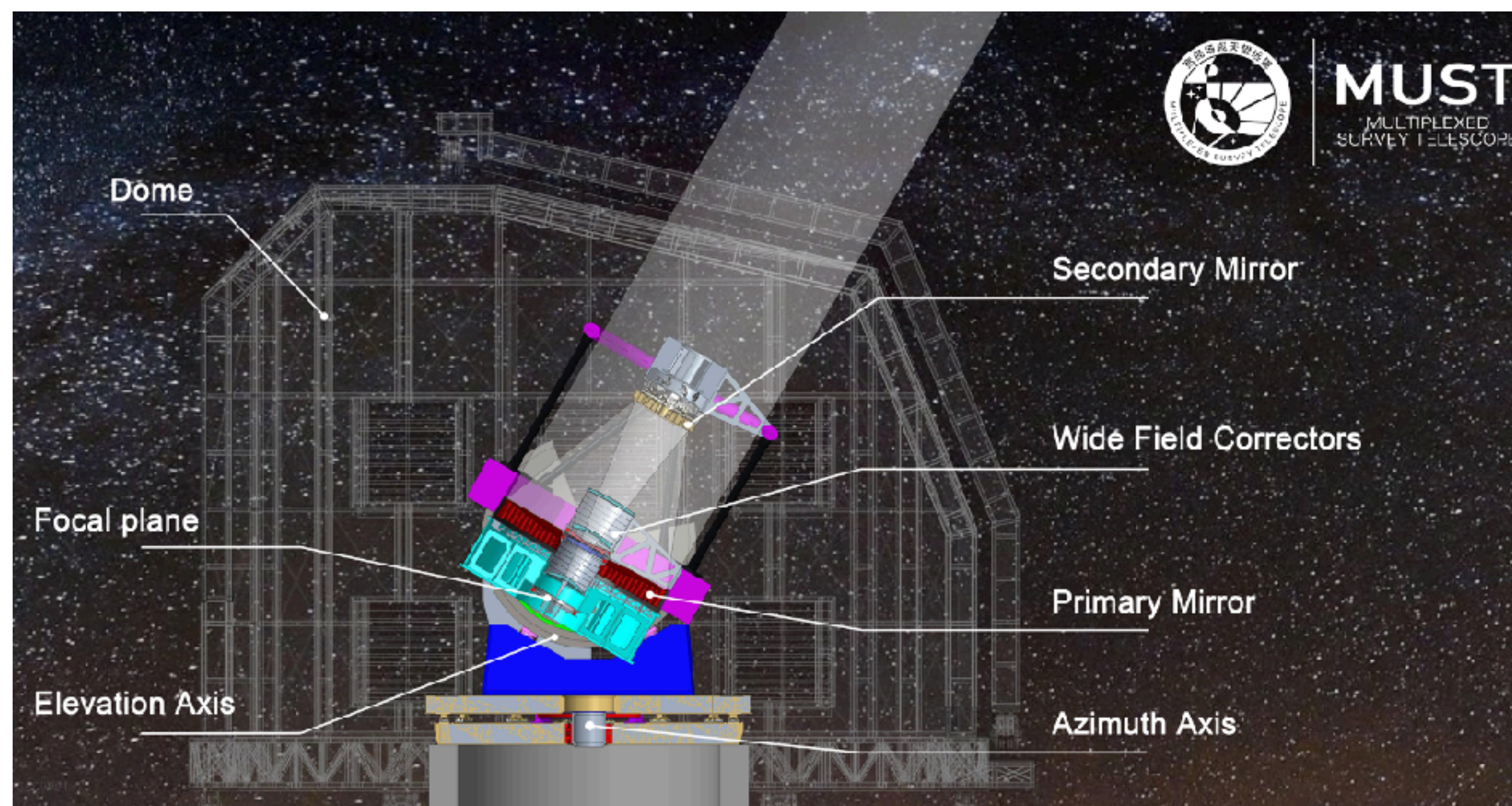
- Next-gen, **Stage-V** spectroscopic survey facility.
- A long-term **platform** to support the Chinese astronomy community.
- Opportunities for international **collaboration**.



Conceptual Design is Almost Done

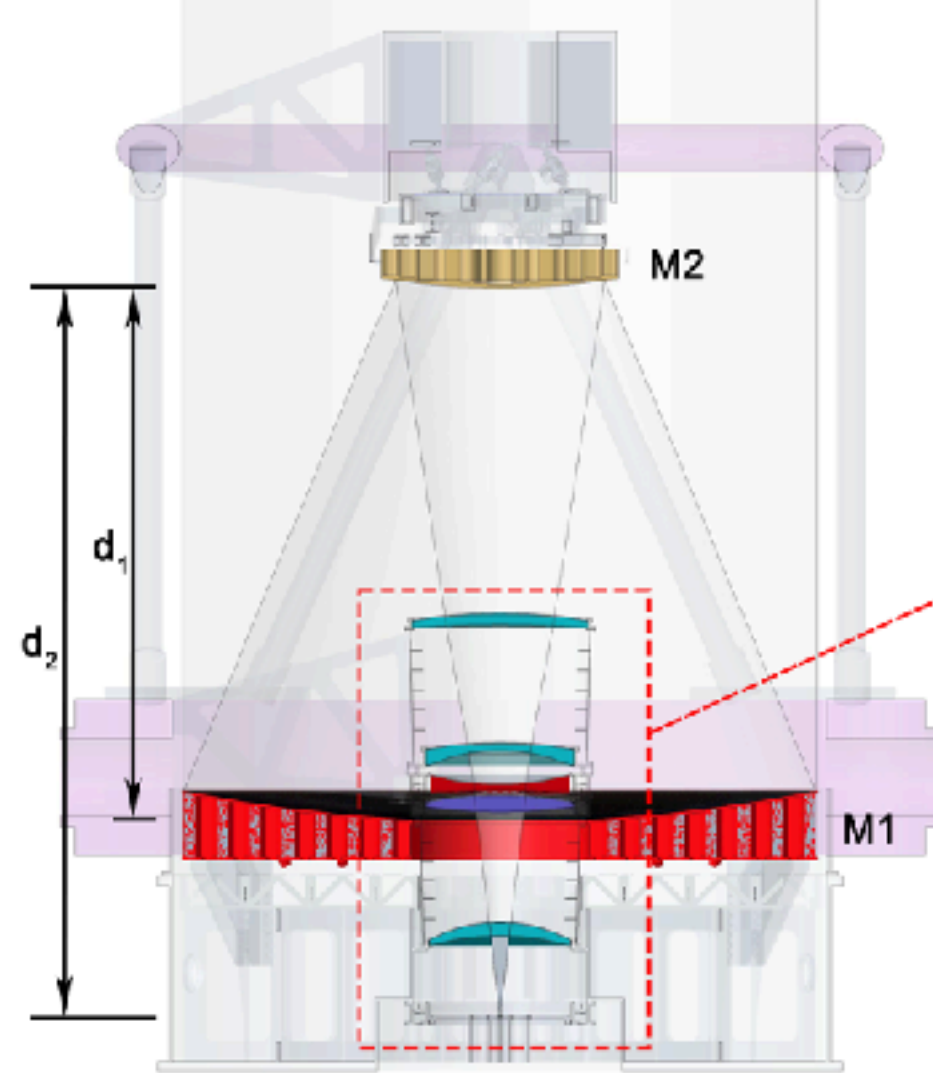
- ◉ We are about to finish the first draft of the conceptual design report (> 400 Pages)
- ◉ With the help of a very experienced international advisory committee, we will release the English version on arXiv in **2023**.

<https://must.astro.tsinghua.edu.cn/must/> ◉ Still under construction

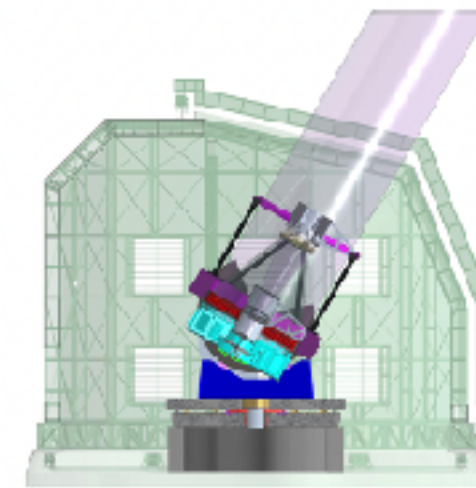
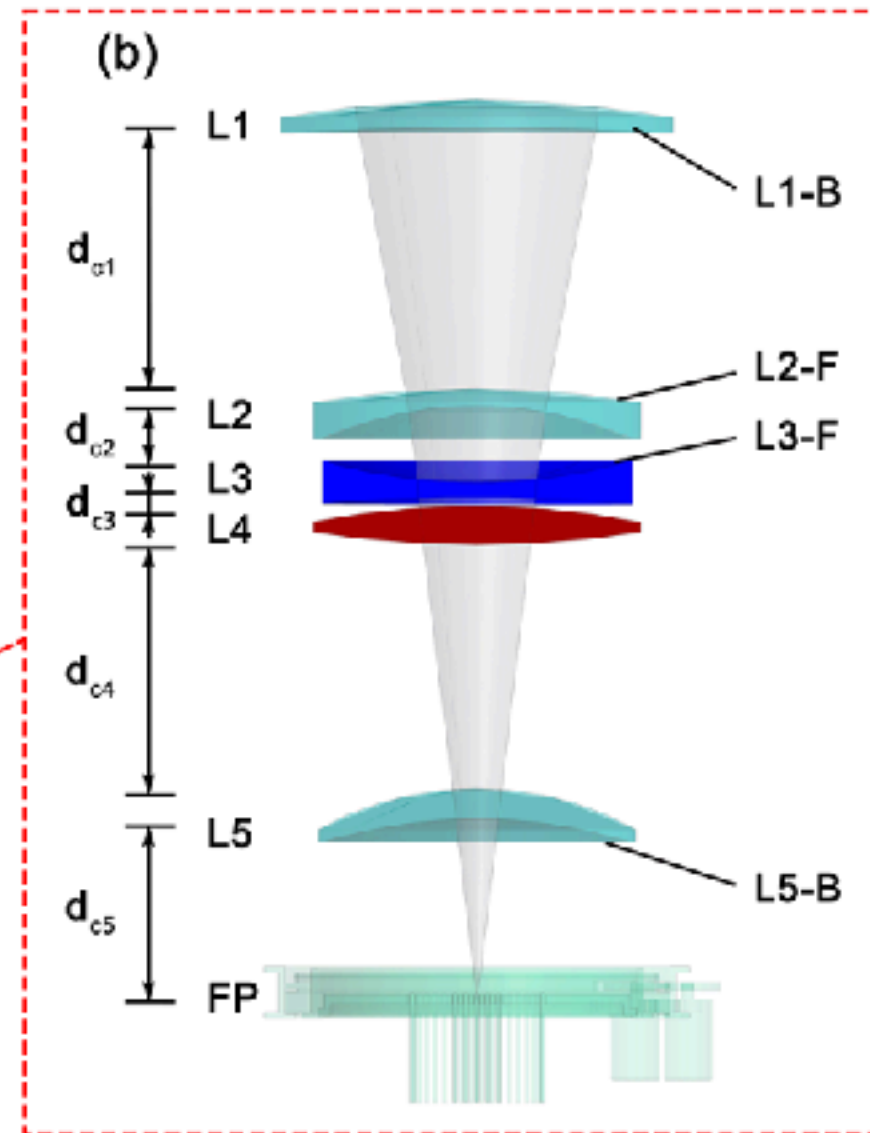




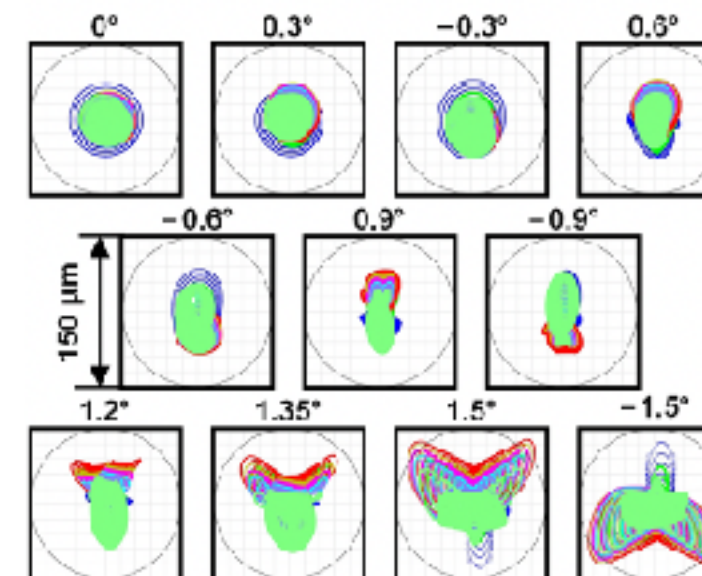
(a) Zhang et al. submitted



(b)



(b)



Optical Design

- A 6.5-m **R-C** design with a 2.45-m secondary.
- Carefully designed **WFC** to achieve **7 deg²** FoV.
- For a spectroscopic telescope, MUST has excellent imaging quality: **EE80 < 0.6 arcsec**
- **Optical design paper submitted!** Will be on arXiv.

Fundraising

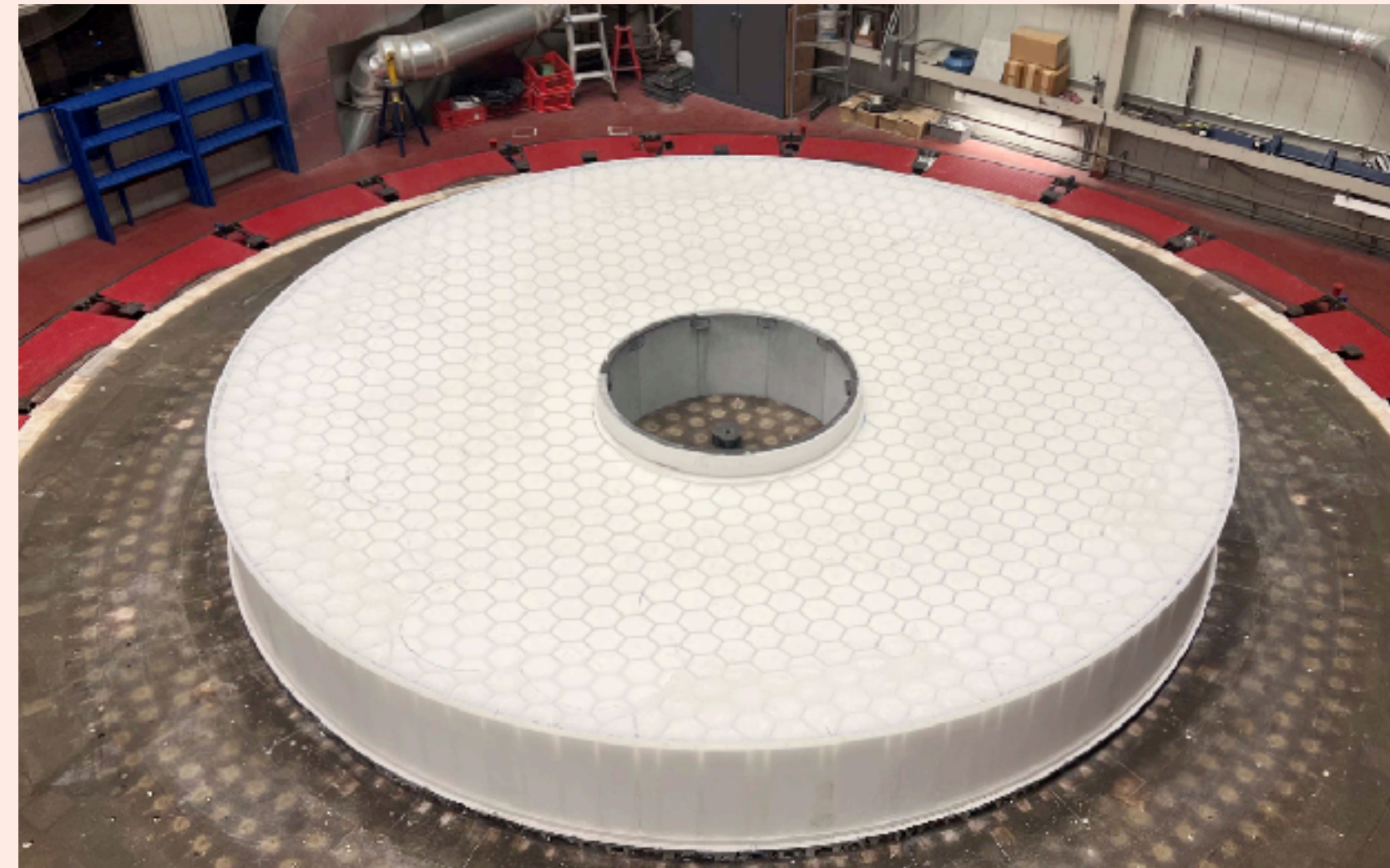
- Made great progress! At **~55%** line now
- Total cost for construction is **~200M €**
- Great support from Tsinghua University.





Construction

- ◎ The blank of the primary mirror has been cast at Arizona Mirror Lab.
- ◎ Contracts for several major components are under negotiation.



Pathfinder

- ◎ Finish building a 65cm pathfinder.
- ◎ Will start to observe on the MUST site in 2023



Infrastructure

- ◎ Local government has made great progress on the summit



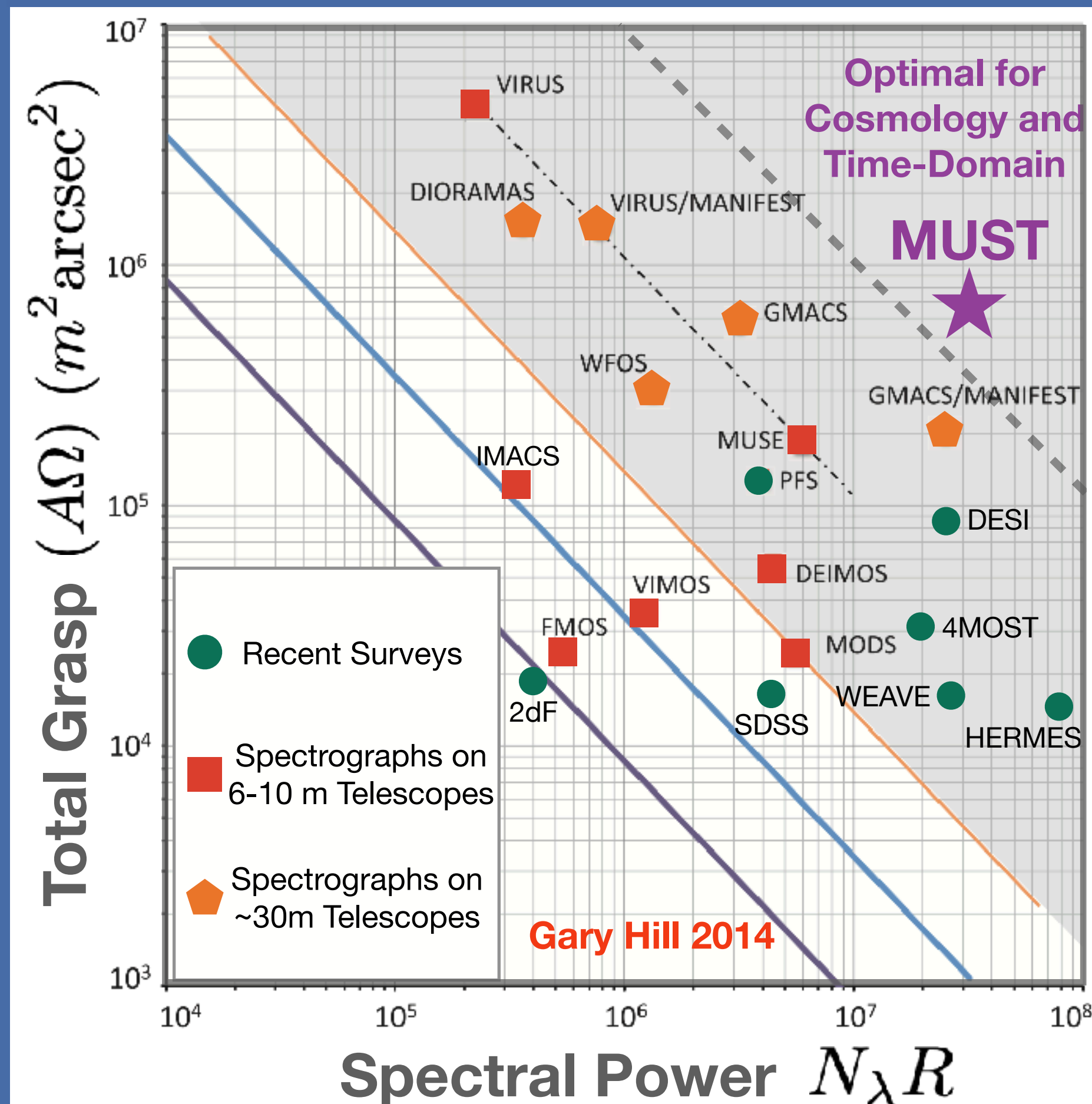
MUST: Scientific Vision

We have Gathered Broad Community Inputs

- ◉ We have organized the first scientific planning meeting in 2021 to hear the community inputs from very different fields, ranging from cosmology to Solar system science.
- ◉ These inputs have become the foundation of our initial scientific vision.



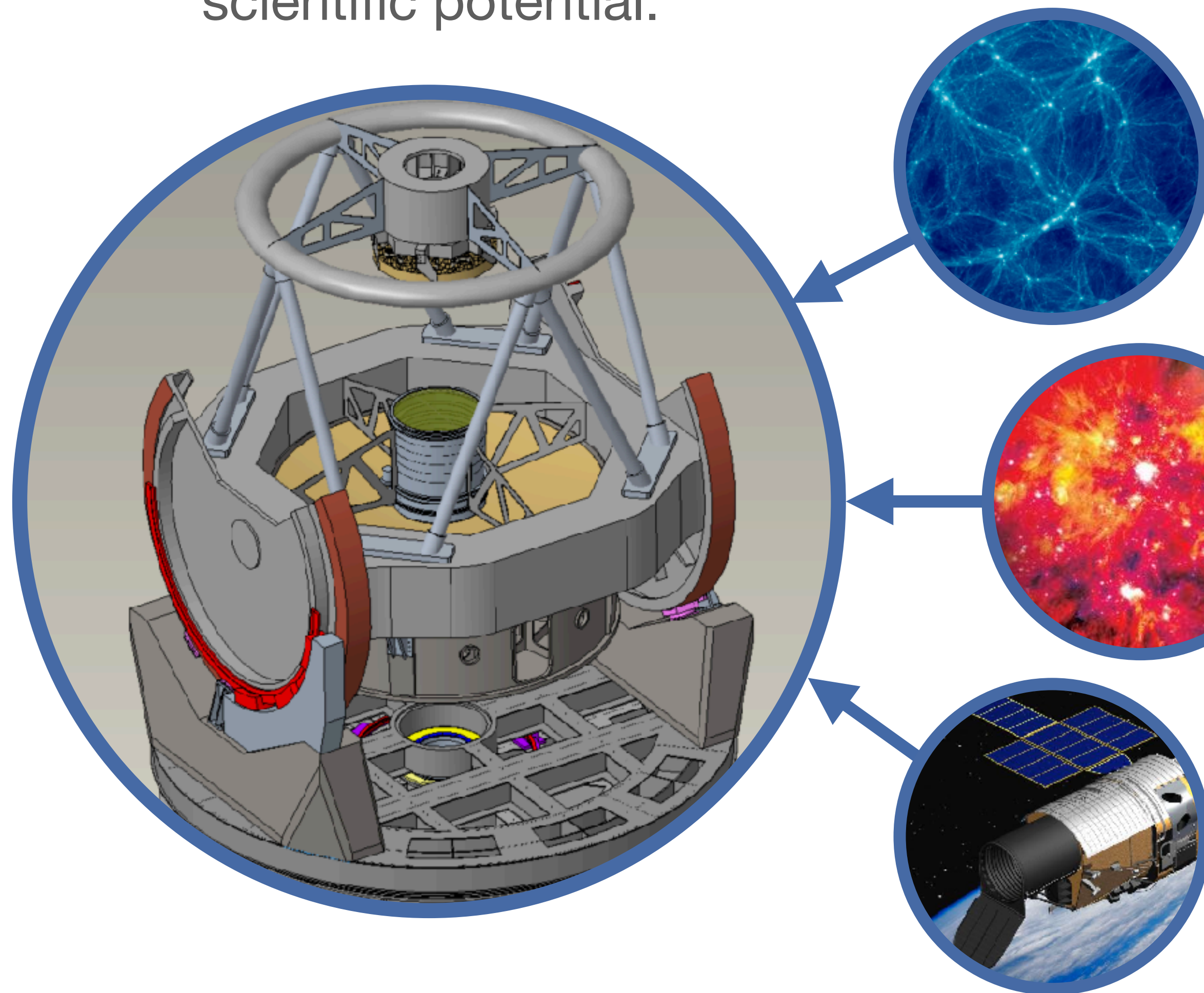
Aiming for the Unique Parameter Space





MUST: Three Main Themes

- While in a very early stage, we have identified three main themes to develop MUST's scientific potential.



Stage-V Cosmology Survey: capable of conducting the **next-generation** spectroscopic surveys for cosmology.

Time-Domain Spectroscopic survey: help depict a more **dynamic** Universe using time-domain spectra.

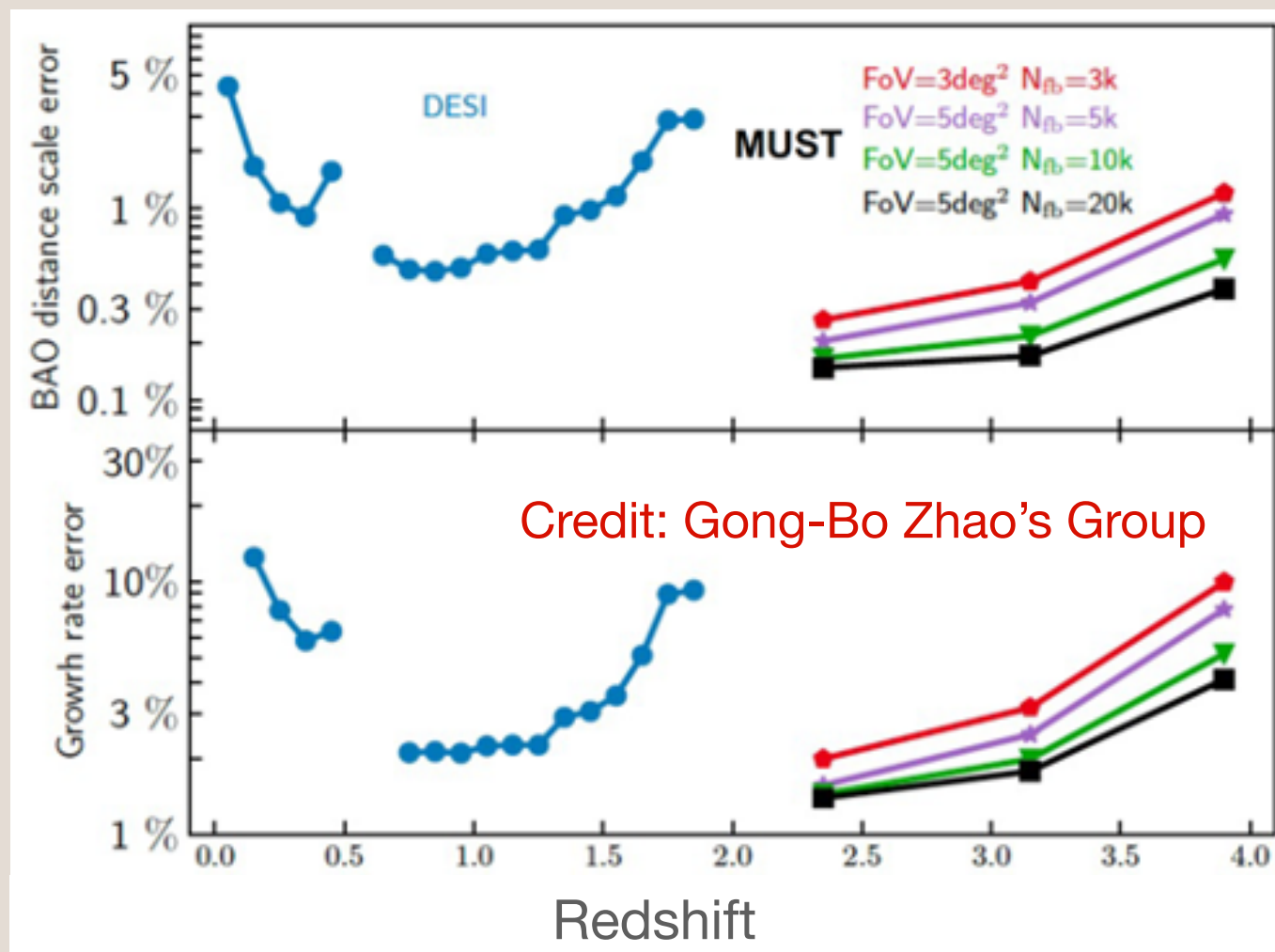
A Flexible Scientific Platform: to facilitate synergy with a series of domestic and **international** projects.



Keys to the Next-Gen Spectroscopic Cosmology Survey: High-redshift, Multi-Probe, Small-Scale

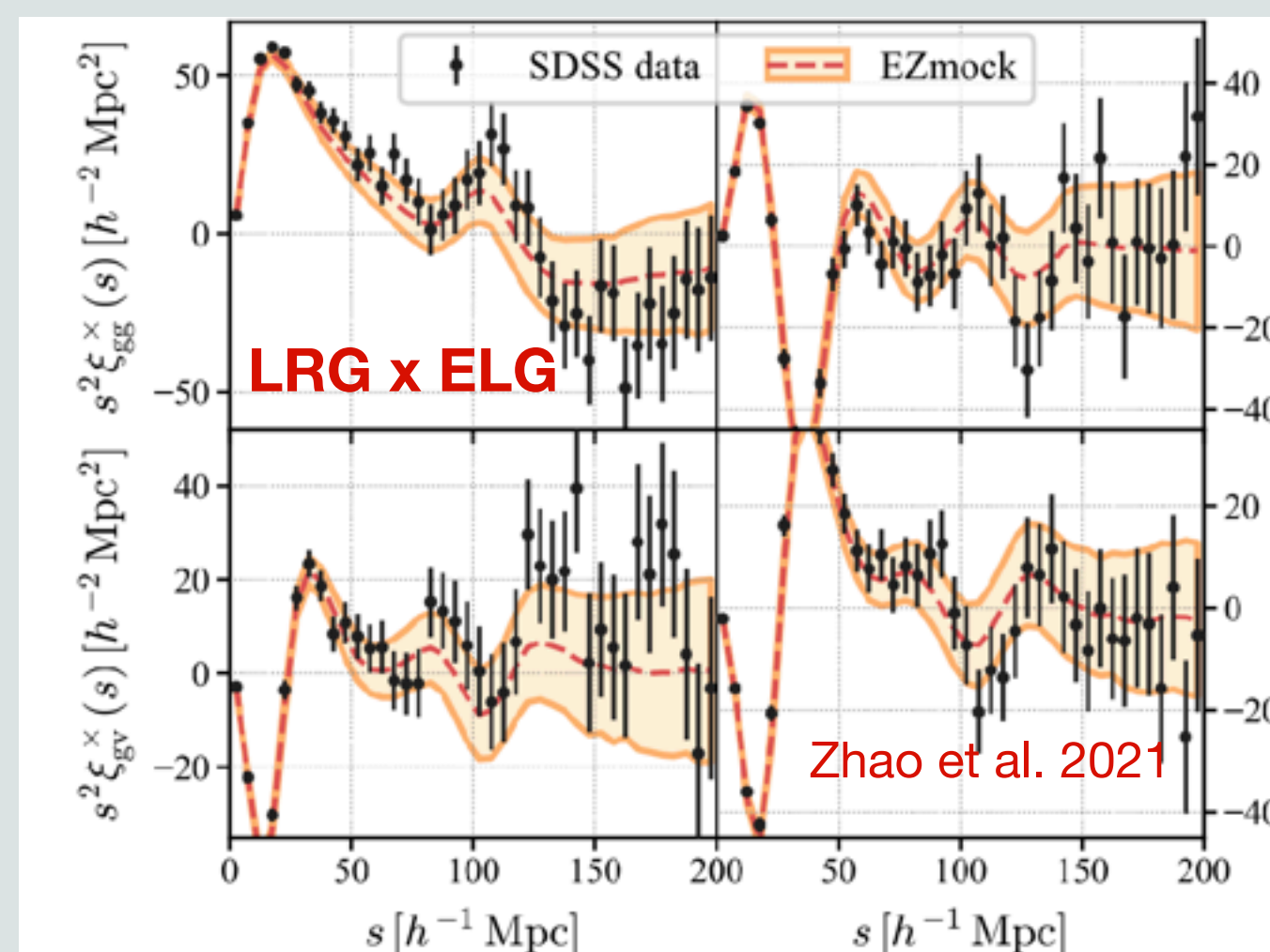
High-Redshift Cosmology

- Investigate the evolution of dark energy and other essential cosmological questions in a larger volume using Lyman break galaxy (LBG), Lyman- α emitter (LAE), and QSOs as tracers.



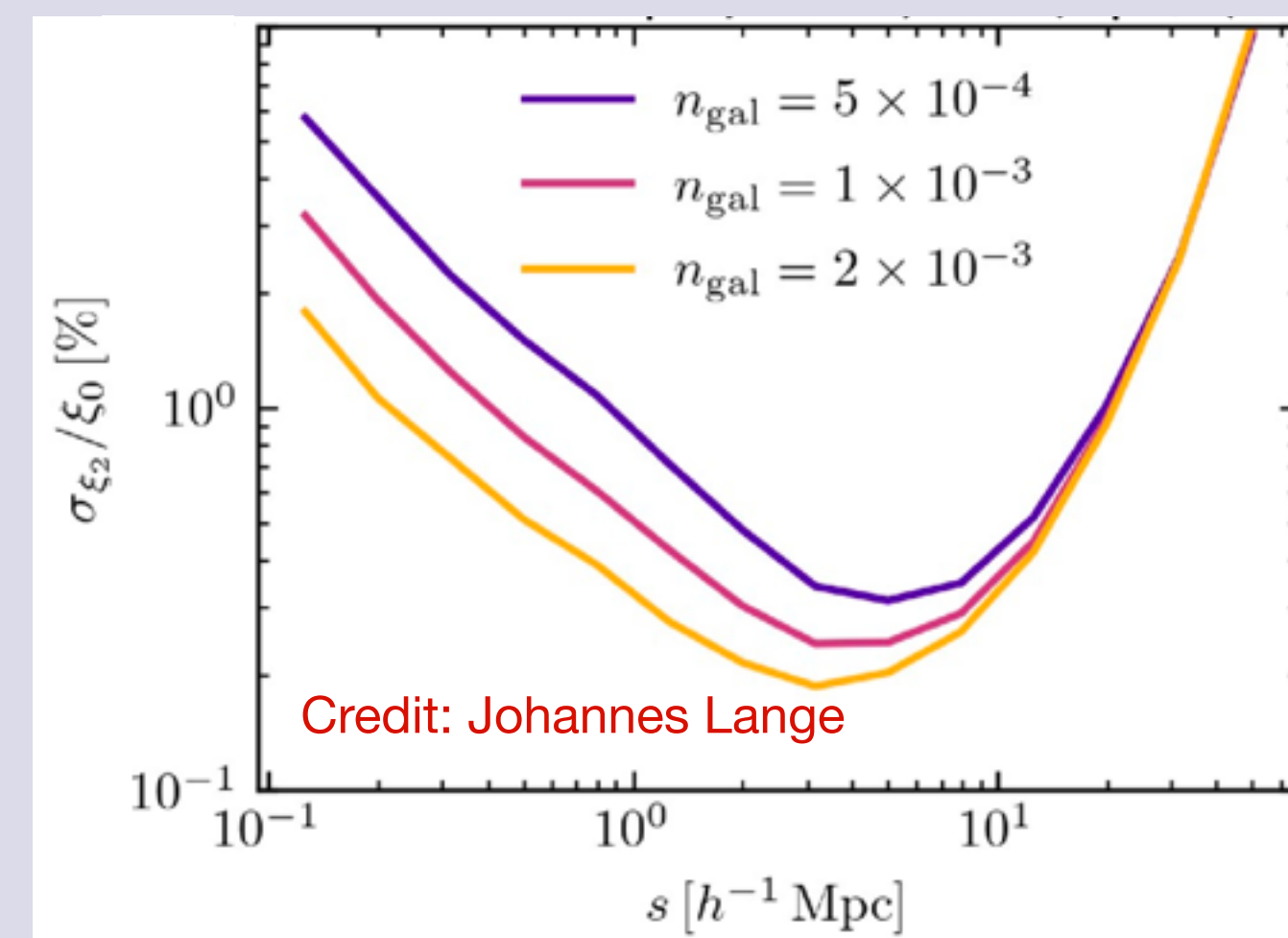
Multi-Probes & Cross-Correlation

- Within $z < 1$, multi-probe strategy has the potential of breaking the limitation of cosmic variance to achieve more precise cosmological constraint.



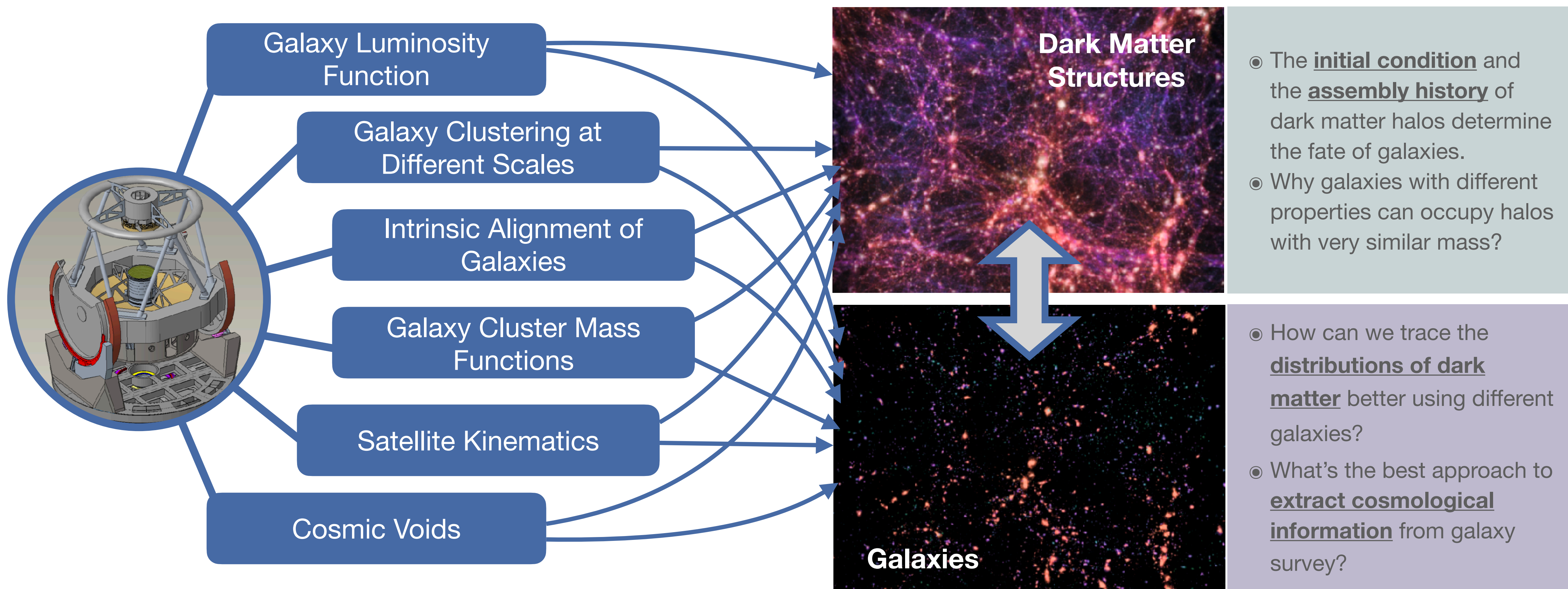
Small, Non-Linear Scale

- The non-linear regime possess great cosmological potential including information about the baryonic effect.
- High sampling density is required to retrieve this information



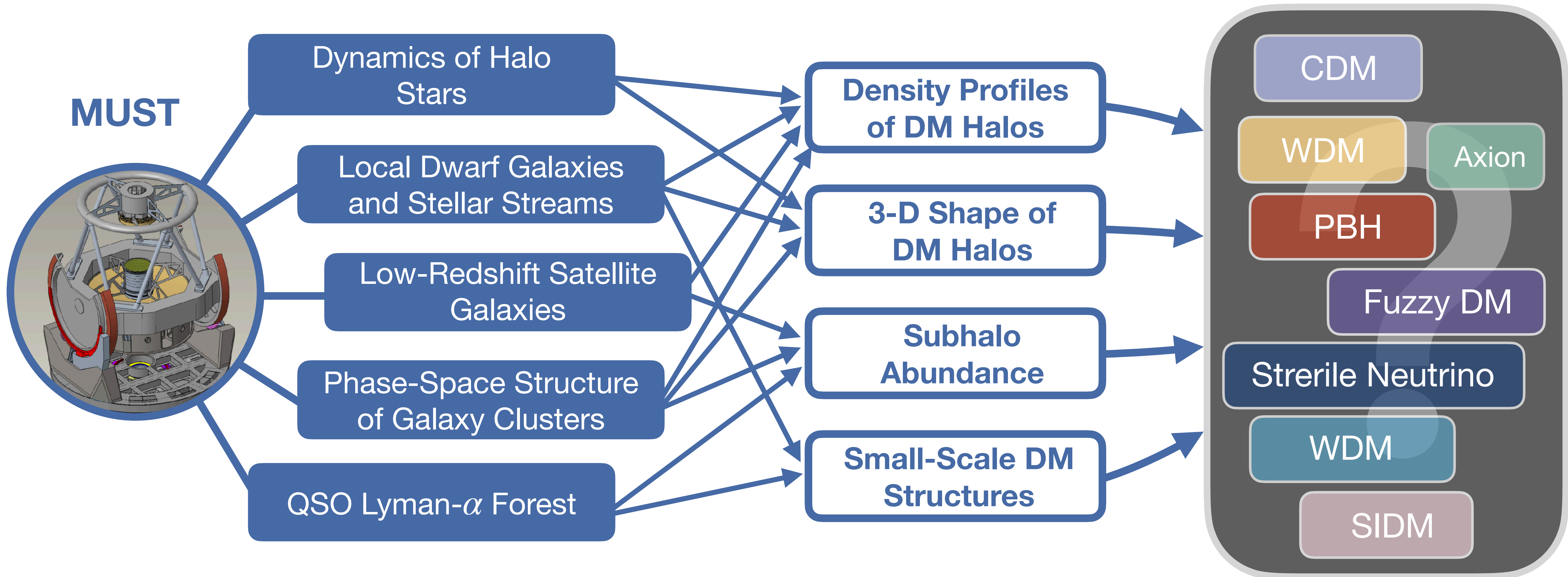
Scientific Focus: **Galaxy-Halo Connection**

Better **galaxy-halo connection** model is crucial for both cosmology and galaxy formation



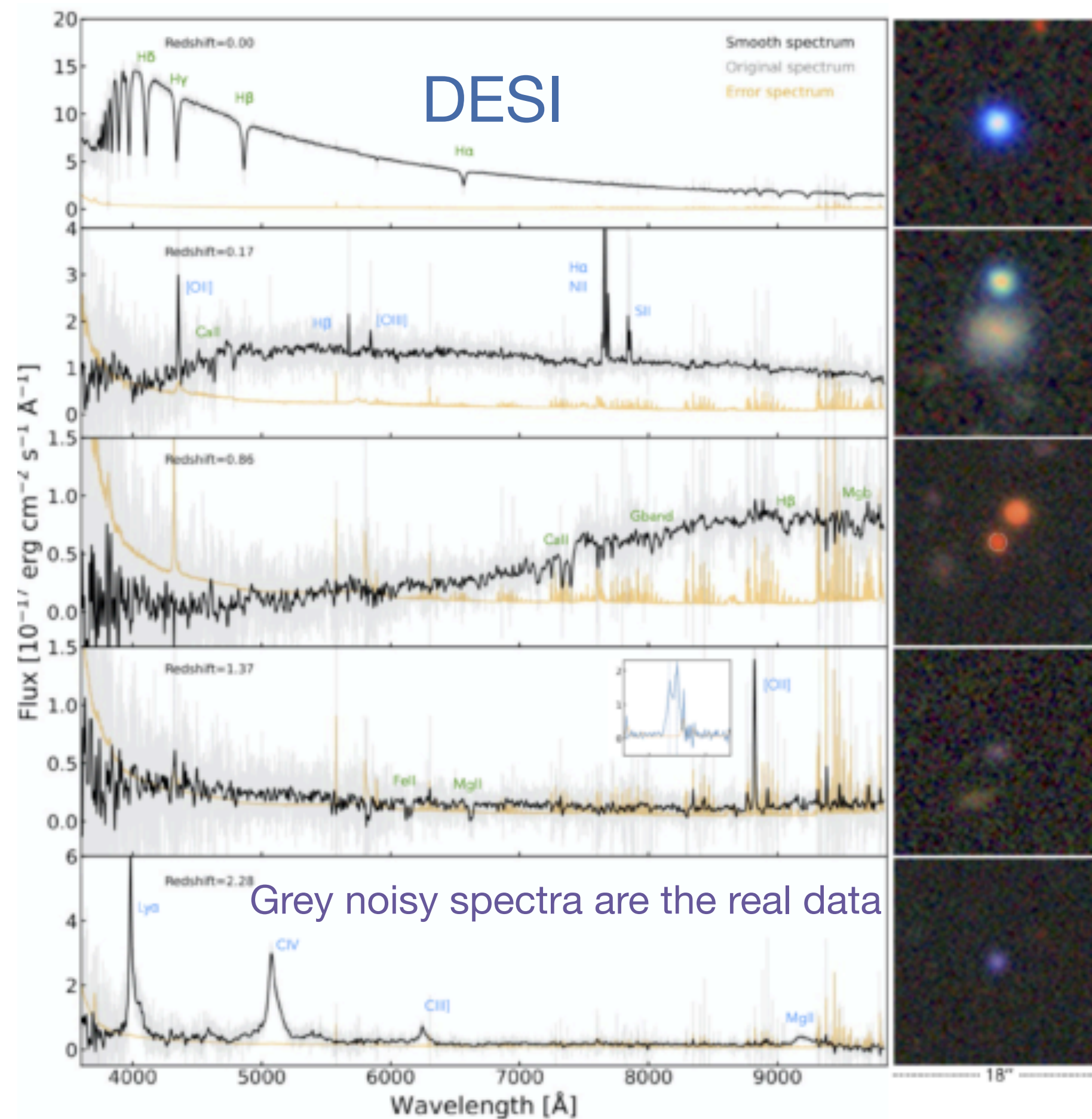


MUST can also act like a “Dark Matter Observatory”

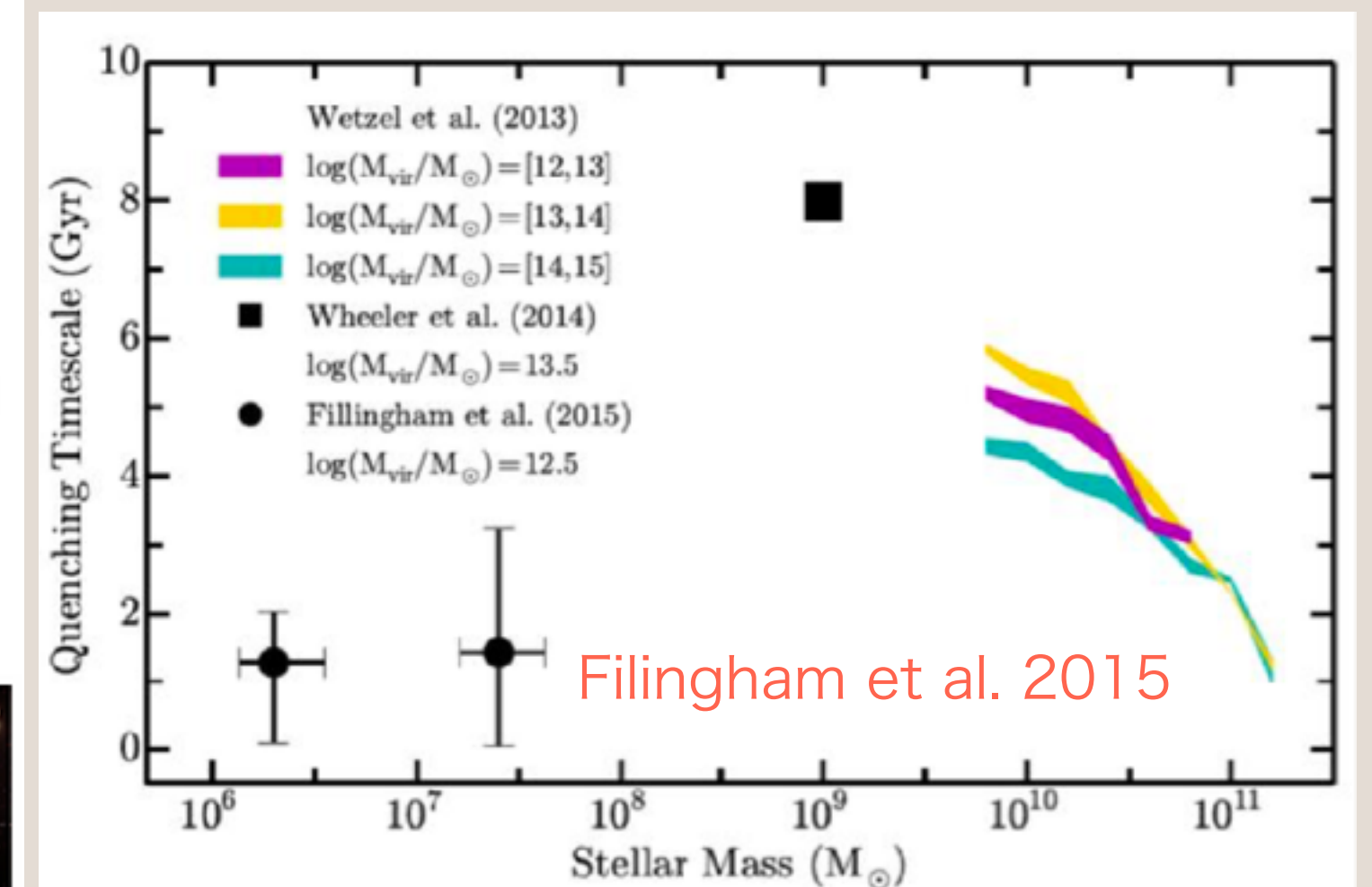
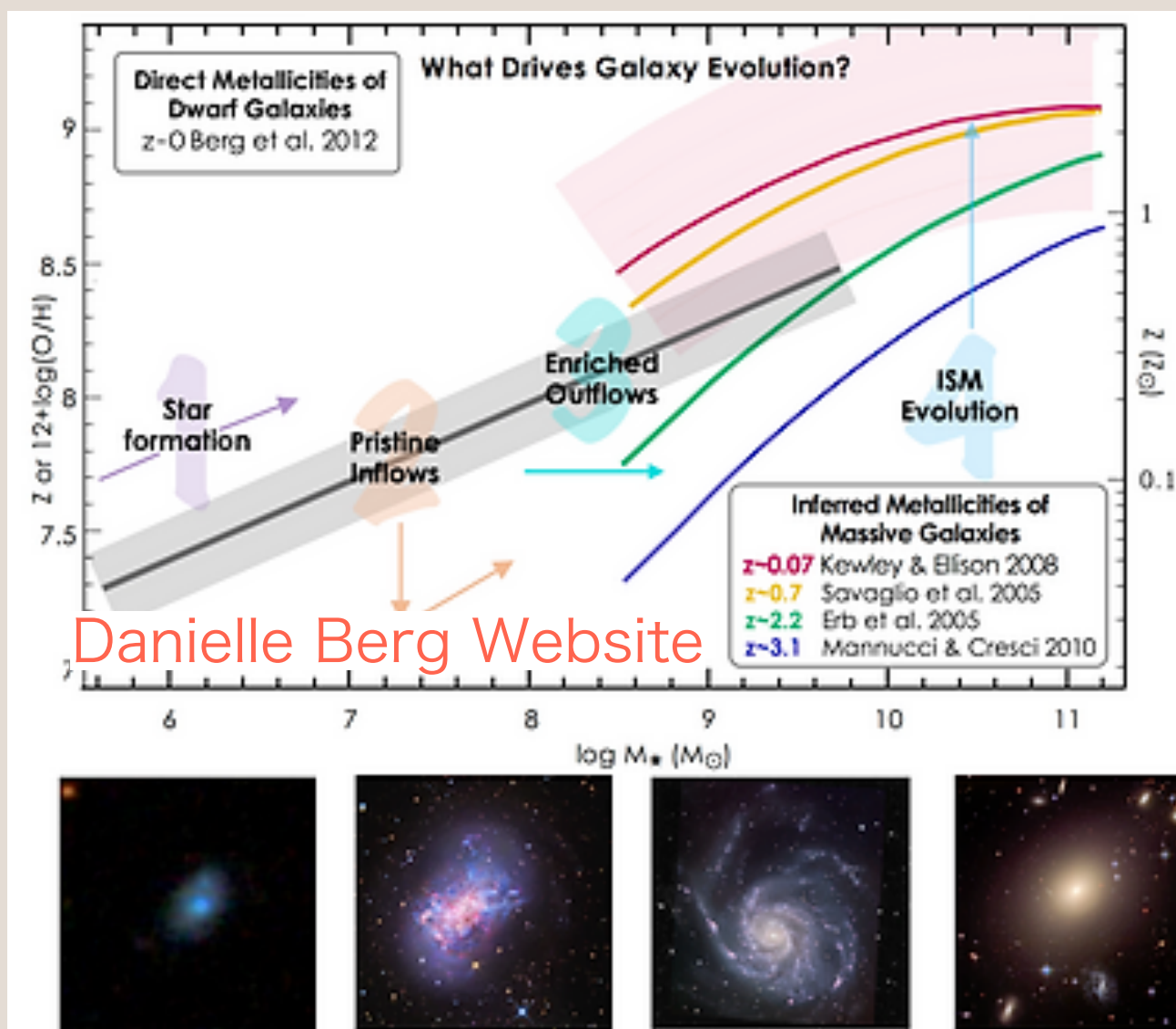


Scientific Focus: Galaxy Formation

MUST is not just a “cosmology experiment” but also an engine for extragalactic research



- Compared to the typical spectral S/N from the cosmology surveys, MUST will provide **high-S/N spectra of a large sample of $z < 1$ galaxy**, especially the ones not well-represented in current surveys, such as **dwarf galaxies** or galaxies in **dense environments** to address vital questions such as the **quenching mechanism & timescale** of different galaxies.





Scientific Focus: **Time-Domain Spectroscopy**

Transient Follow-up

Of high-value time-domain targets

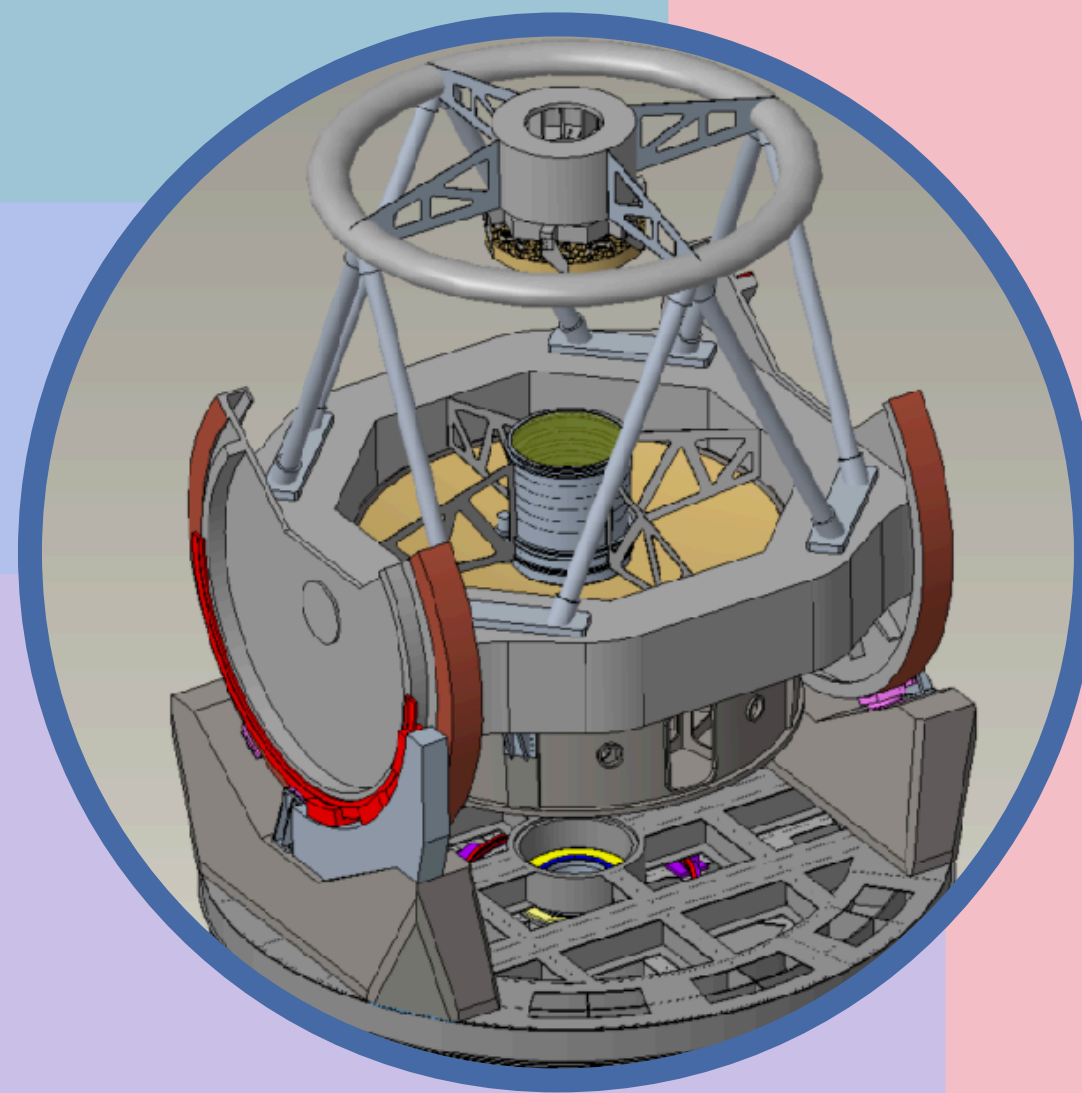
- The confirmation and classification of supernovae, TDEs, and other transient events.
 - The search and confirmation of optical counterparts of GW events
- Survey of SN and TDE host galaxies
 - Peculiar velocity survey of SN host galaxies
- RM surveys of AGNs and QSOs
 - Time-domains spectroscopic surveys of MW Stars

Spectroscopic Survey Time-Domain Survey

When combined with multi-messenger search and large photometric surveys, time-domain spectroscopic surveys can open up new windows to the dynamic Universe.

Serendipity Discoveries

- The careful mining of the MUST data could help uncover rare or ignored types of transient events (e.g., see the discovery of changing face AGN)
- Explore the “Unknown unknown”





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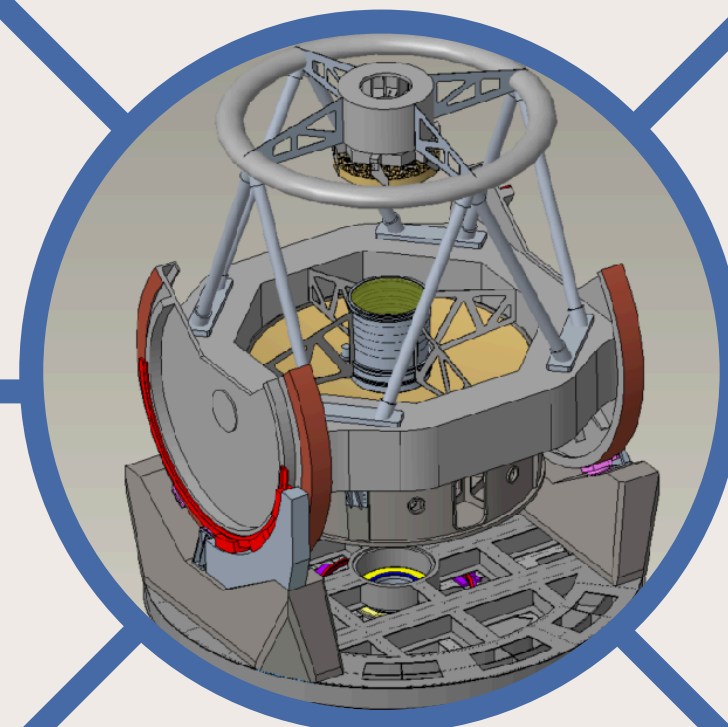
Scientific Synergy: Domestic Projects

FAST

- ◉ Spectroscopic confirmation of FRB hosts
- ◉ Low-z galaxy+HI surveys

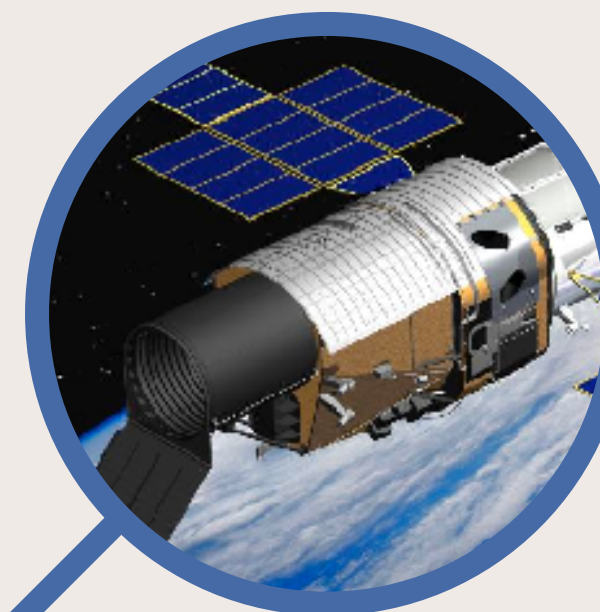


MUST



CSST

- ◉ Photometric redshift calibration
- ◉ Joint cosmology & extragalactic studies



ALiCPT

- ◉ Joint cosmology analysis
- ◉ Joint galaxy cluster studies



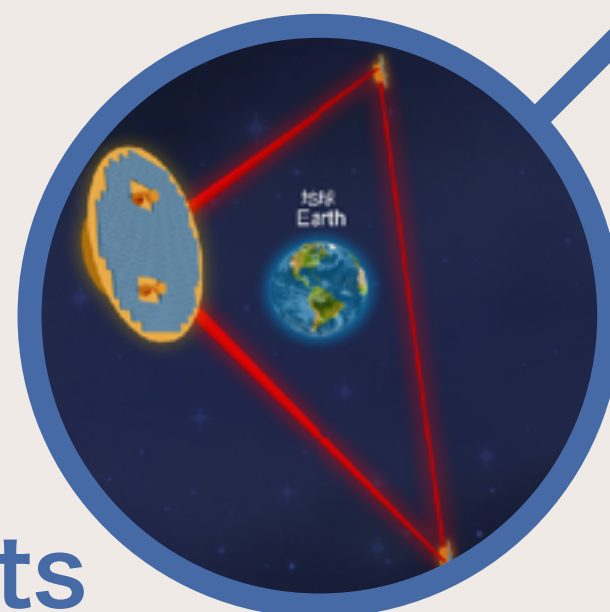
WFST

- ◉ High-value ToO follow-up
- ◉ SN TDE hosts surveys
- ◉ Joint time-domain surveys



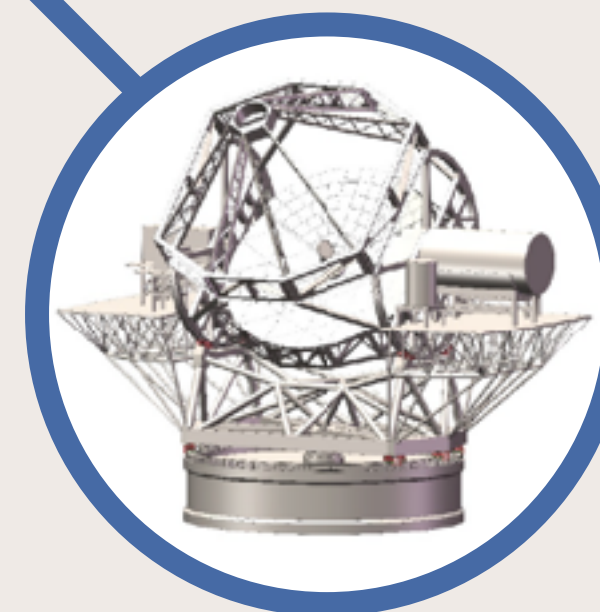
- ◉ Evolution of SMBH
- ◉ Gravitational wave cosmology

TianQin, Taiji Space Gravitational Wave Projects



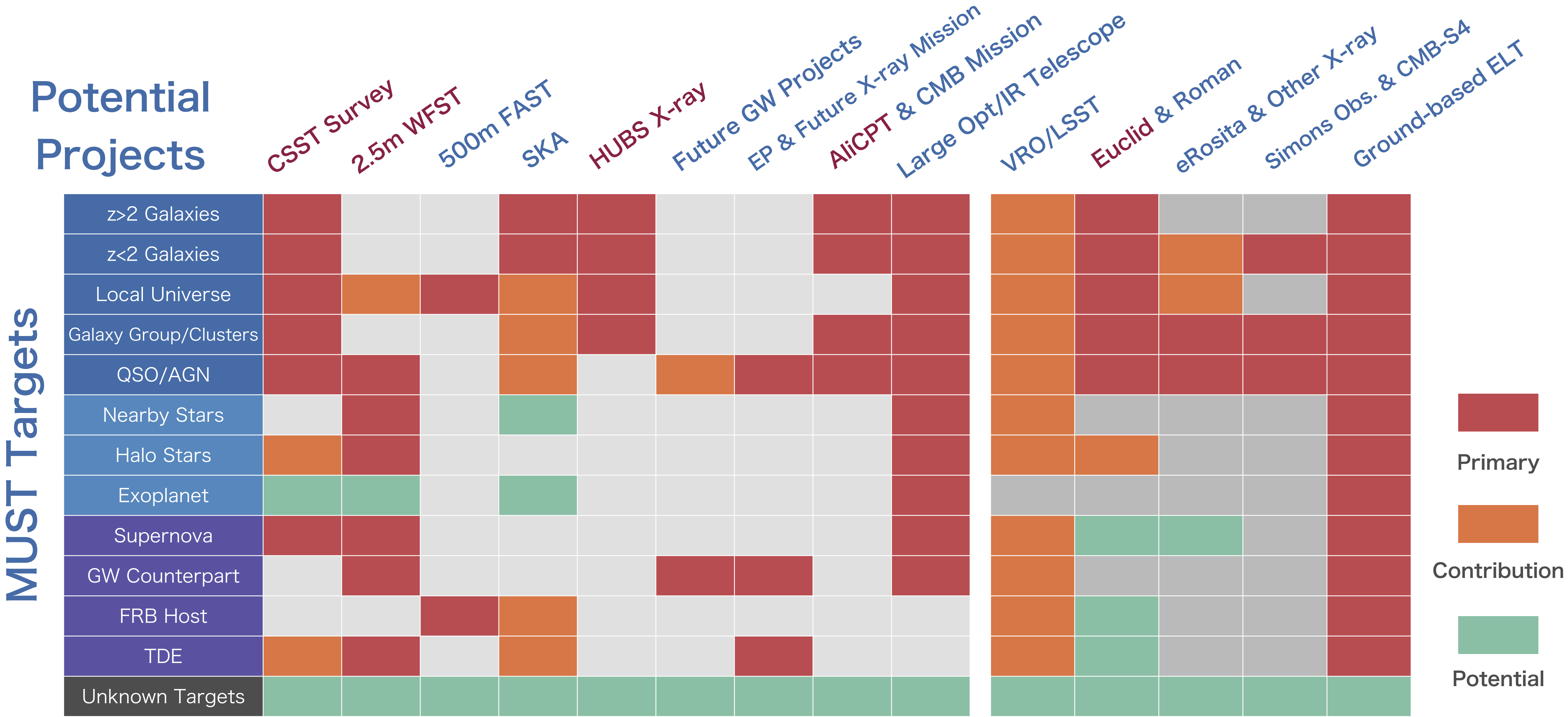
- ◉ Joint investigations of a variety of targets
- ◉ MUST will provide large number of follow-up opportunities

Large Optical Telescope



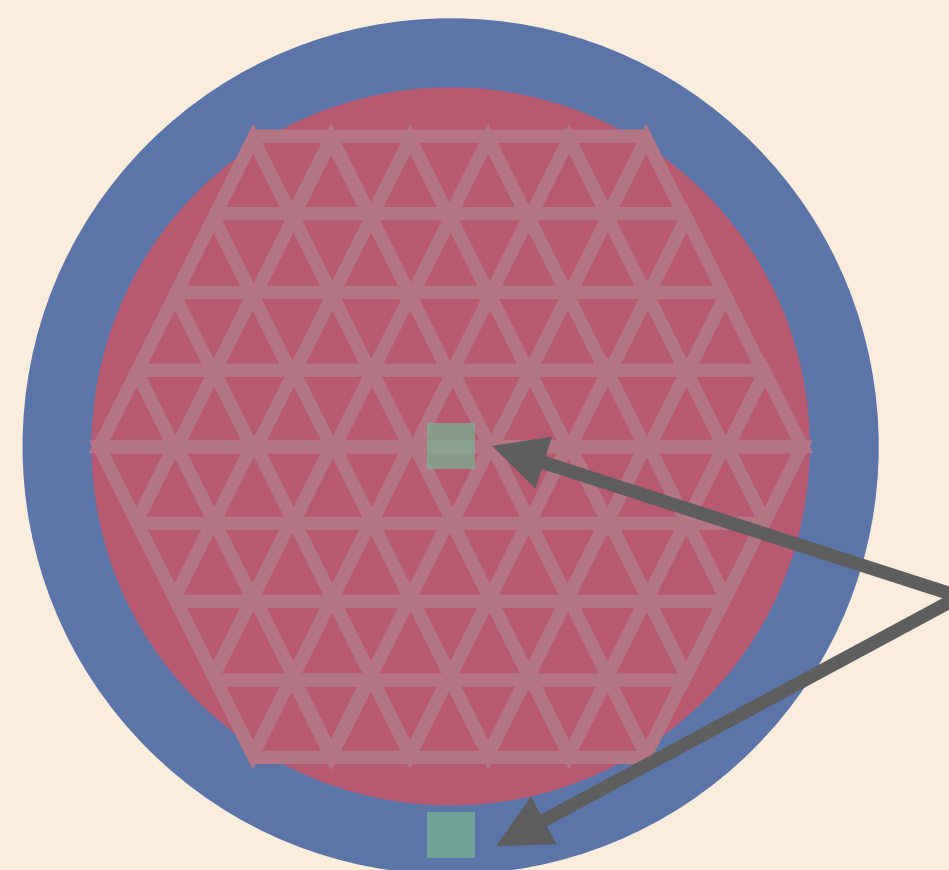
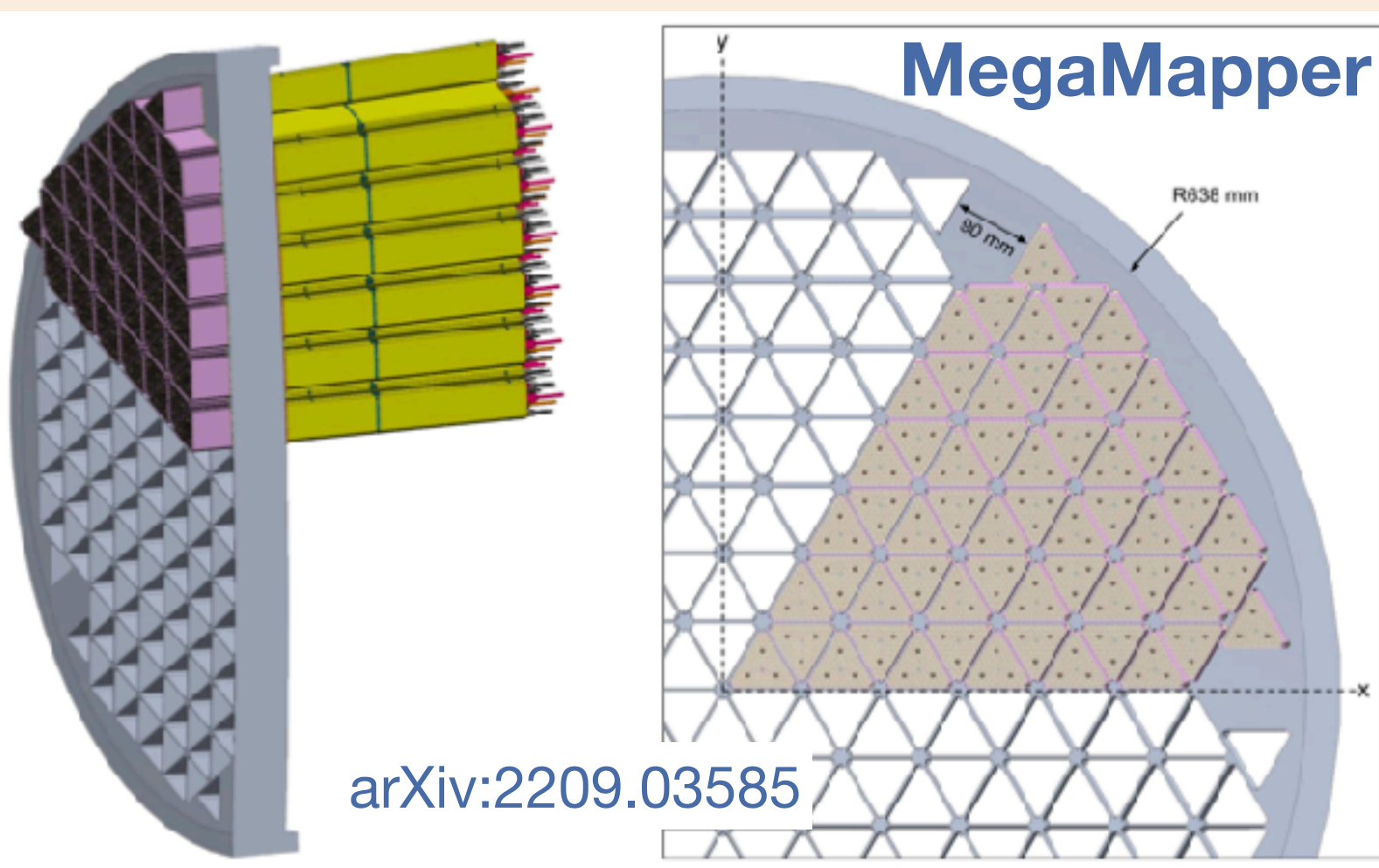
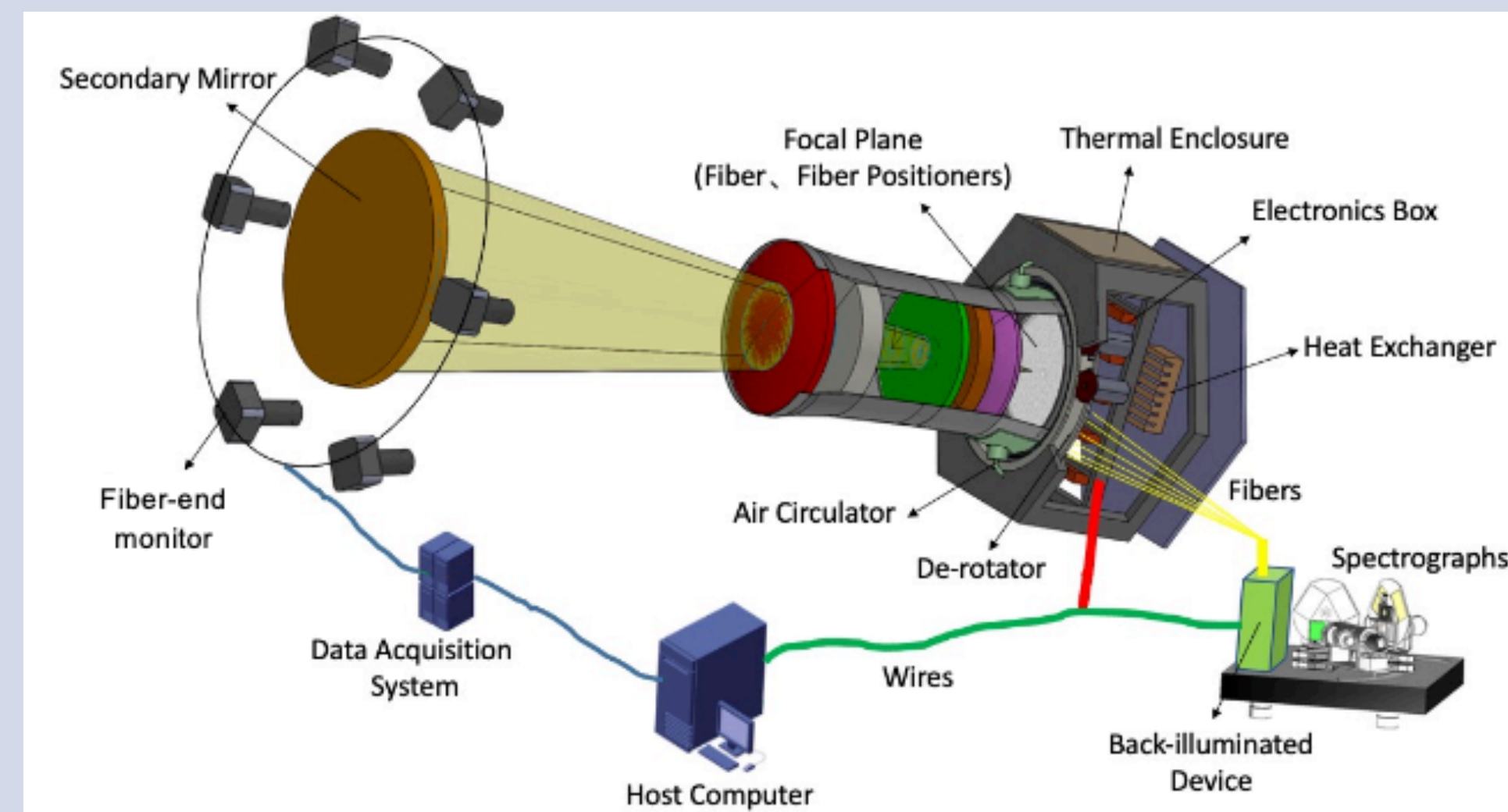


Scientific Synergy: Domestic and International



Current Design

- ◉ The focal plane will host **~20,000 fiber** positioners in 7 deg² FoV
- ◉ Working with the **USTC** team, we are starting with a baseline design focusing on cosmological applications:
 - ◉ We are using traditional **theta-phi** positioners with **8mm pitch**



Our Goals

- ◉ In discussion with **EPFL** for a more **modular** design with **higher fiber density**.
- ◉ Also, we are exploring the potential of including more **flexible** instrument combinations on the focal plane (e.g., IFU)

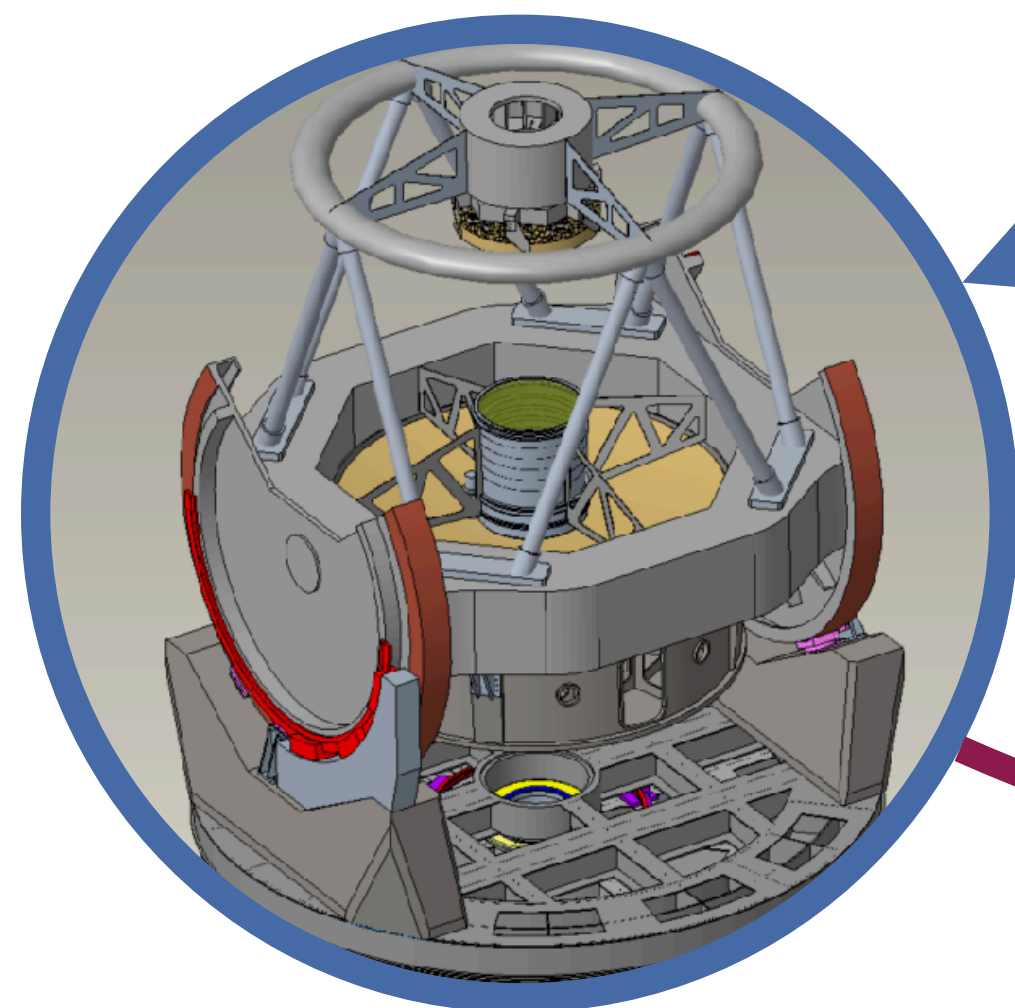
Euclid - MUST Synergy

1

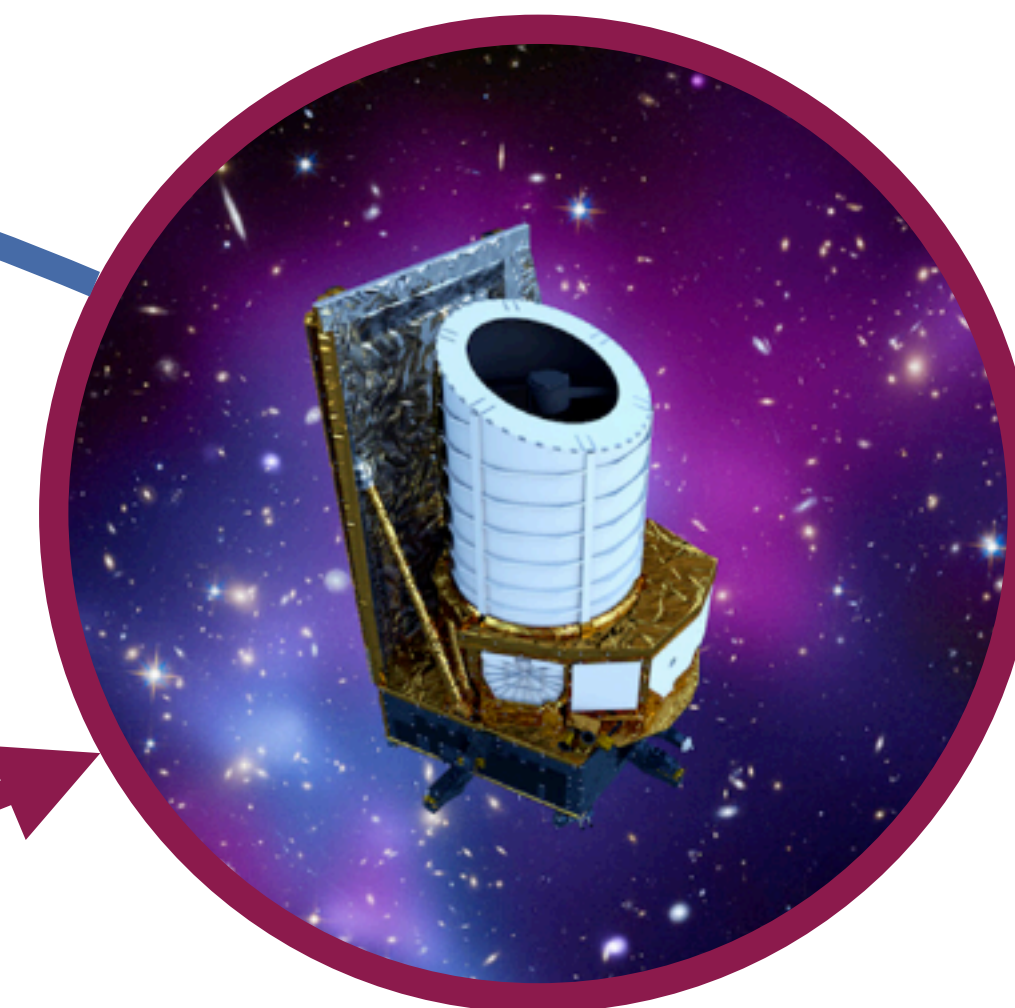
- ◉ ***Euclid*** and its ground-based imaging surveys are crucial for MUST's **target selections**

2

- ◉ ***Euclid*'s cosmology & extragalactic achievements** will shed light on a promising path for MUST



We can do a
lot of science
together!



3

- ◉ In the long run, MUST can help ***Euclid*** achieve its full potential through synergy in many aspects.



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Scientific Collaboration

Scientific Collaboration Policy

- We have drafted an initial version of the [scientific collaboration policy](#) and [code of conduct](#).
- We aim to make it as friendly as possible to the [junior members](#) of the community including the [international](#) ones.



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多目标光谱巡天望远镜科学合作规范

MUST 科学合作组织 (MUST Science Collaboration)

October 9, 2022

**We sincerely welcome your
participation and involvement!**

Scientific Discussion and Communications

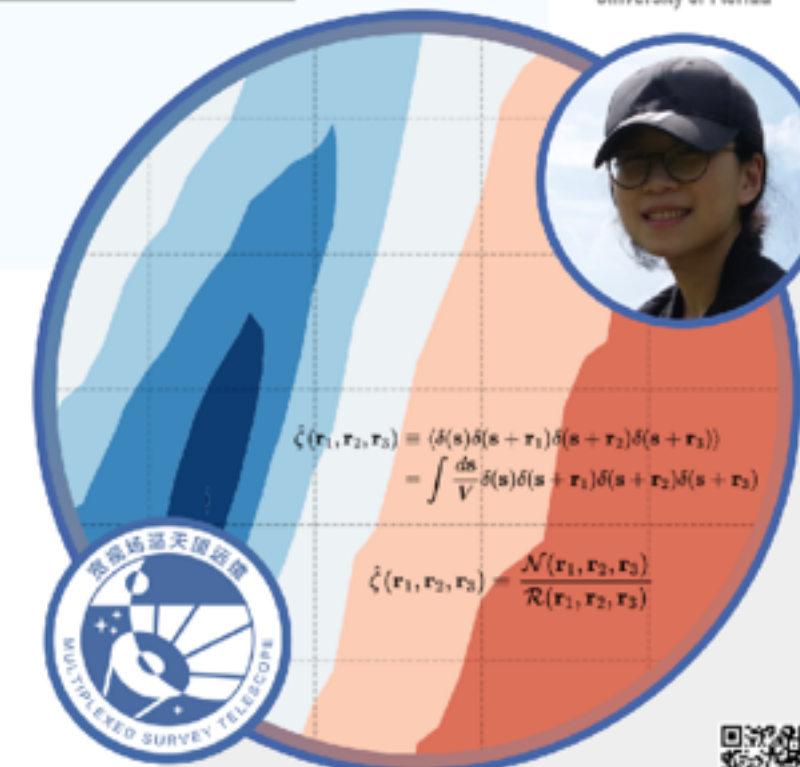
- We are organizing different types of [on-line talks & discussions](#) on different scientific topics related to MUST.
- The first few [“We MUST Talk”](#) seminars have drawn broad domestic attention.

We MUST Talk **AUG 4**

Higher-Order Correlation Function of Large Scale Structures
and Parity Violation Search

Aug 4 (Thu) 9:00 AM Beijing

Jia-Min Hou (侯佳旻)
University of Florida



Zoom ID: [274 322 2637](#) PW: MUST

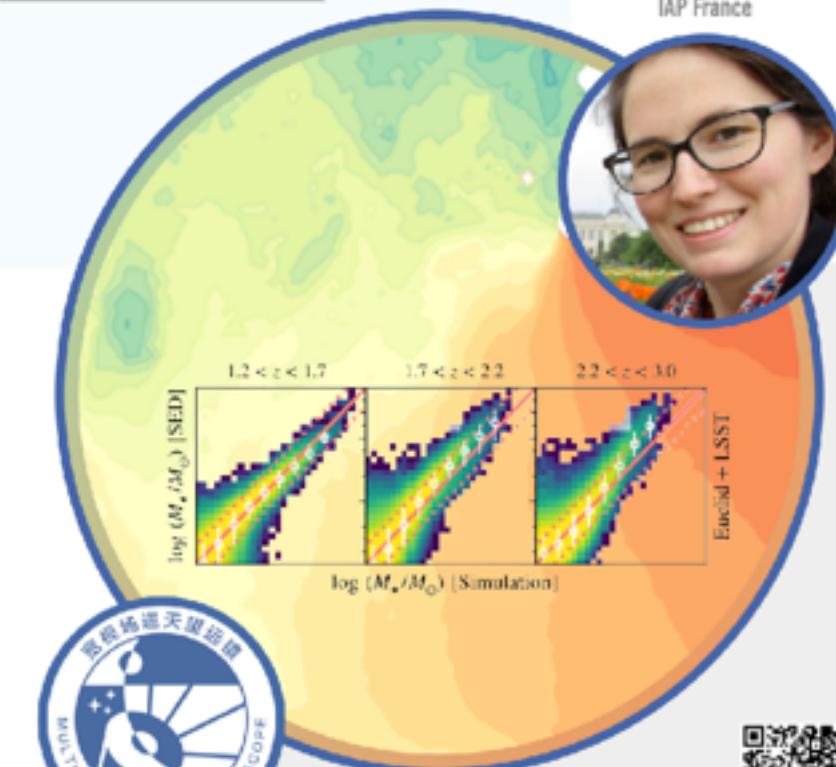


We MUST Talk **AUG 25**

The Panchromatic Sky: SED-fitting performances and
forecast for future imaging surveys

Aug 25 (Thu) 16:00 Beijing

Clotilde Laigle
IAP France



Zoom ID: [274 322 2637](#) PW: MUST



Summary

- ◎ **MUST** is a 6.5m telescope developed for next-generation spectroscopic surveys in the northern hemisphere.
- ◎ In addition to playing a major role in the **Stage-V** cosmology endeavor, **MUST** can support various extragalactic topics.
- ◎ *Euclid*'s data and science are invaluable to us. Meanwhile, MUST will help *Euclid* exhaust its scientific potential in the 2030s.



Looking Forward to Your Comments and Advice !



Scientific Potential: Flexibility

Important Topics

Cosmology & Dark Energy
DM Distribution and Nature
Galaxy-Halo Connection
Gravitational Theory
Distribution of Baryons
Star Formation and Quenching
Origin of the Milky Way
Stellar BH and SMBH
Stellar Physics
Searching Earth 2.0

Targets

z>2 Galaxies	Primary	Secondary	Secondary	Primary	Primary	Primary	Potential	Potential		
z<2 Galaxies	Primary	Primary	Primary	Primary	Primary	Primary	Potential	Potential		
Local Universe	Potential	Primary	Primary	Primary		Primary	Secondary	Secondary		
Galaxy Group/ Clusters	Primary	Primary	Primary	Primary	Secondary	Primary				
QSO/AGN	Primary	Secondary	Primary		Primary	Primary		Primary		
Nearby Stars		Potential					Primary	Secondary	Primary	Secondary
Halo Stars		Secondary	Potential			Secondary	Primary	Secondary	Secondary	
Exoplanets									Potential	Primary
Supernova	Primary		Secondary			Potential			Primary	
GW Counterparts	Primary			Primary				Secondary	Primary	
FRB Hosts	Potential			Potential	Primary	Potential				
TDE						Potential	Secondary	Primary	Secondary	
Unknown Targets	Potential	Potential	Potential	Potential	Potential	Potential	Potential	Potential	Potential	Potential

❖ A Simplified Version





Scientific Potential: **Milky Way**

“Renaissance” of Galactic Science

- The large diameter, large FoV, highly multiplexed instrument, and the potential high-res capability of MUST could be very valuable for Galactic archaeology, near-field cosmology, physics of ISM, and more!
- High-resolution MUST can conduct a complete survey of nearby $G < 12$ mag stars ($\sim 0.8M$)
 - ➔ Accurate abundance and kinematic information will help us reconstruct the local accretion history.
 - ➔ These data can contribute to the search of Earth 2.0 and the study of stellar evolution in binary systems.
- MUST can also conduct large and deep surveys of Galactic halo stars.

Proposed by Yuan-Sen Ting (ANU), Ting Li (Toronto), and Haining Li (NAOC)

