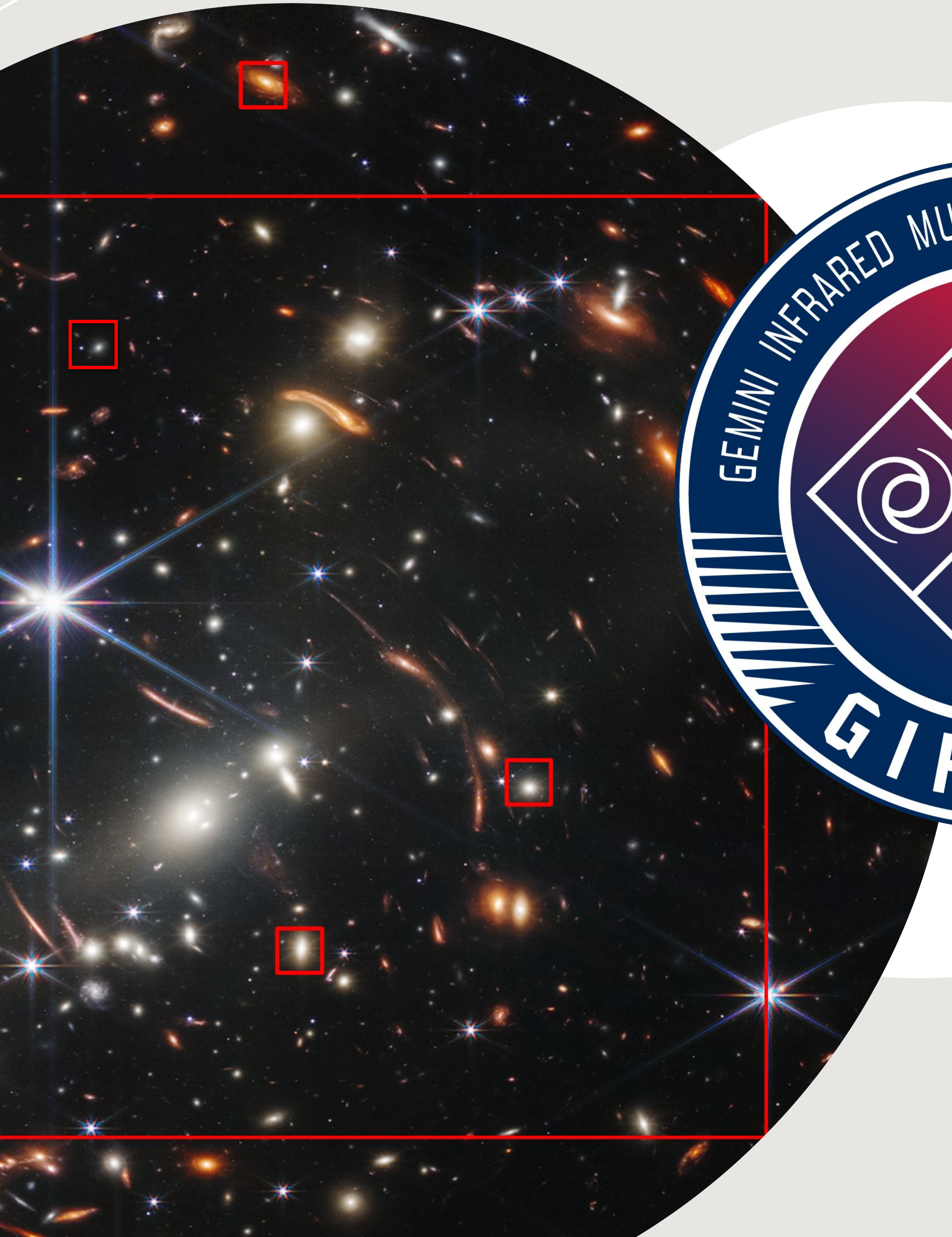
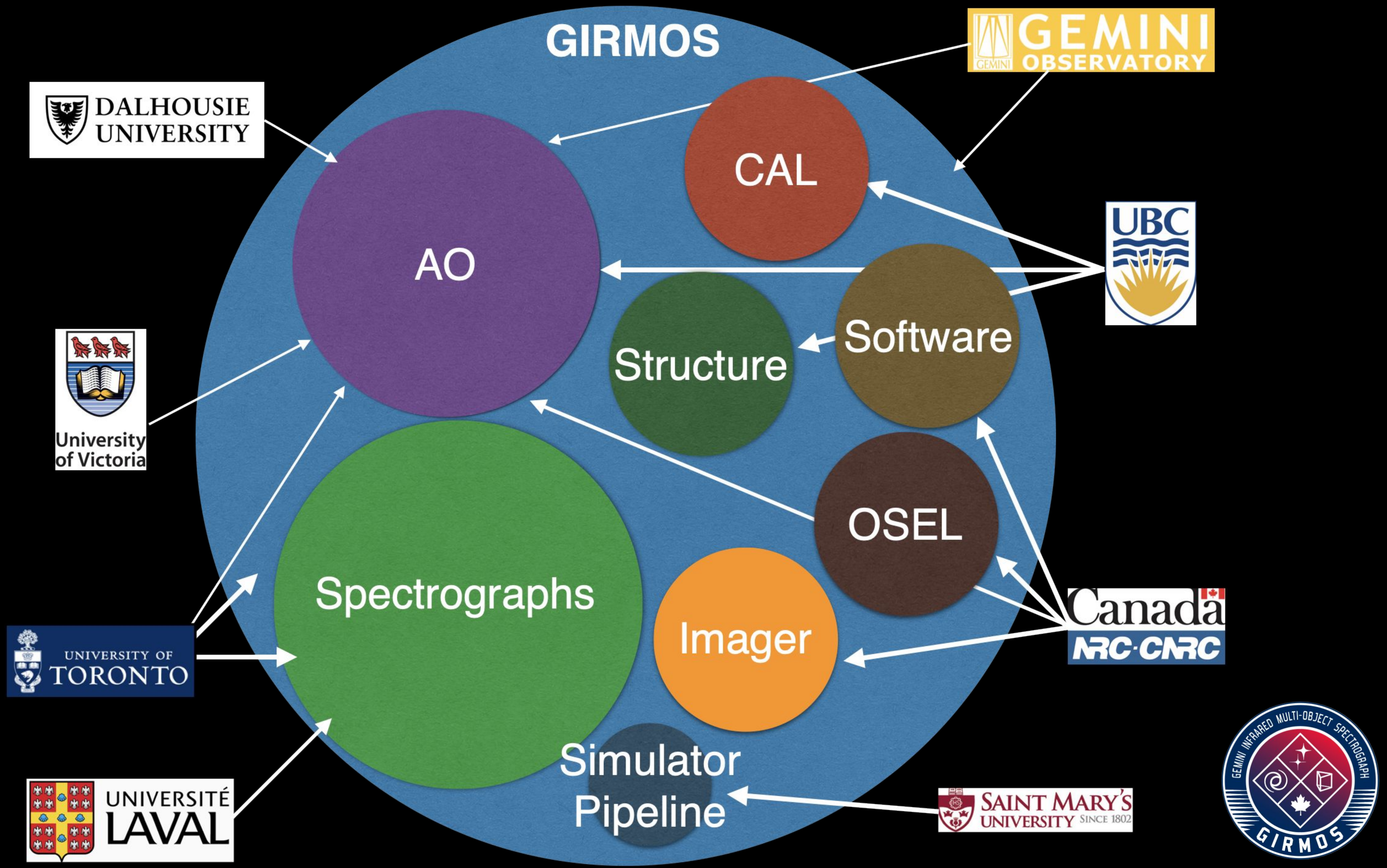


JWST SMACS 0723 Observation
with GIRMOS Fields Overlaid

Gemini Infrared
Multi-Object Spectrograph

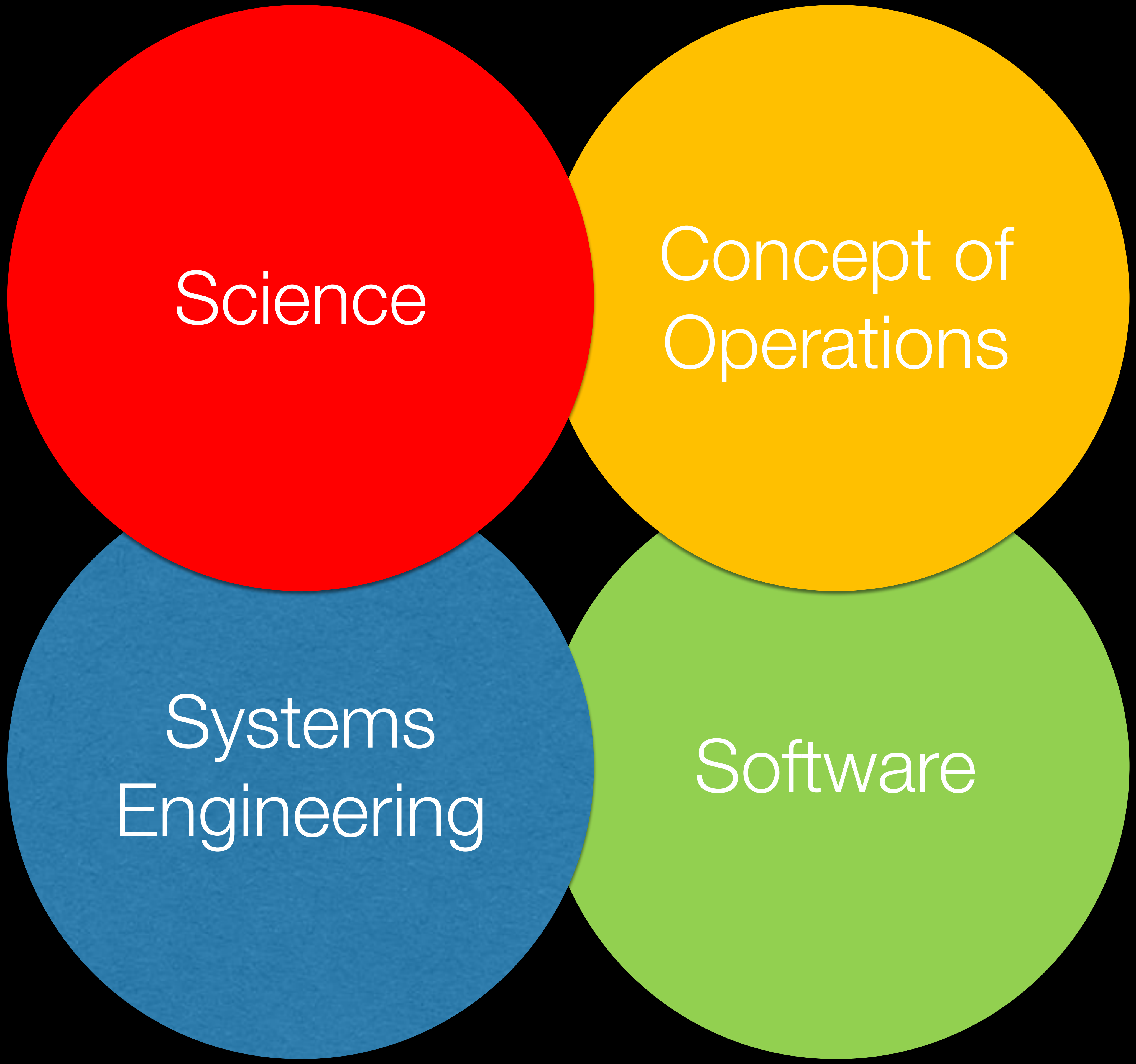
Instrument Overview

Suresh Sivanandam
GIRMOS Principal Investigator
University of Toronto
Project Scientist: A. Muzzin
Imaging Project Scientist: A. McConnachie
Co-Is:
S. Chapman, P. Hickson, S. Thibault, M. Sawicki, A. Muzzin, S. Christie, J. Atwood, J. Dunn, S. Roberts, K. Venn, A. Anthony, M. Barnet, **M. Tschimmel, G. Sivo, J. Scharwaechter, S. Barbod**, M. Lamb, S. Chen, S. Dutt, P. Nkwari, O. Lardiere
+ GIRMOS Team


GIRMOS
GEMINI OBSERVATORY
DALHOUSIE UNIVERSITY
CAL
AO
UBC
Structure
Software
University of Victoria
OSEL
Spectrographs
Imager
Canada
NRC·CNRC
UNIVERSITY OF TORONTO
Simulator
Pipeline
UNIVERSITÉ LAVAL
SAINT MARY'S UNIVERSITY SINCE 1802
GEMINI INFRARED MULTI-OBJECT SPECTROGRAPH
GIRMOS

GNAO+GIRMOS

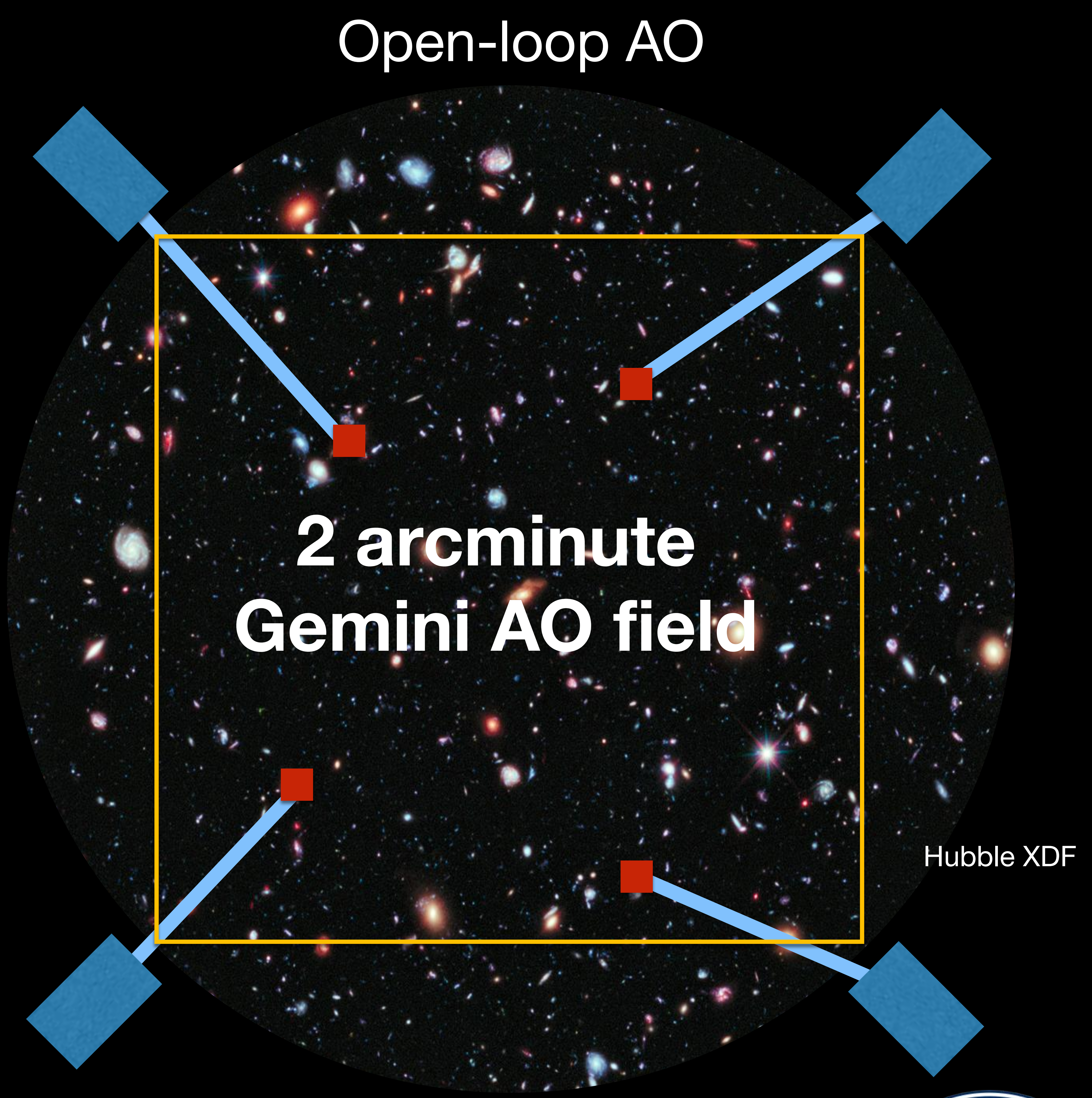
- **Moving towards a unified system view due to highly coupled performance metrics**



GIRMOS Overview

Tightly coupled with the upcoming Gemini-North AO system, GIRMOS provides:

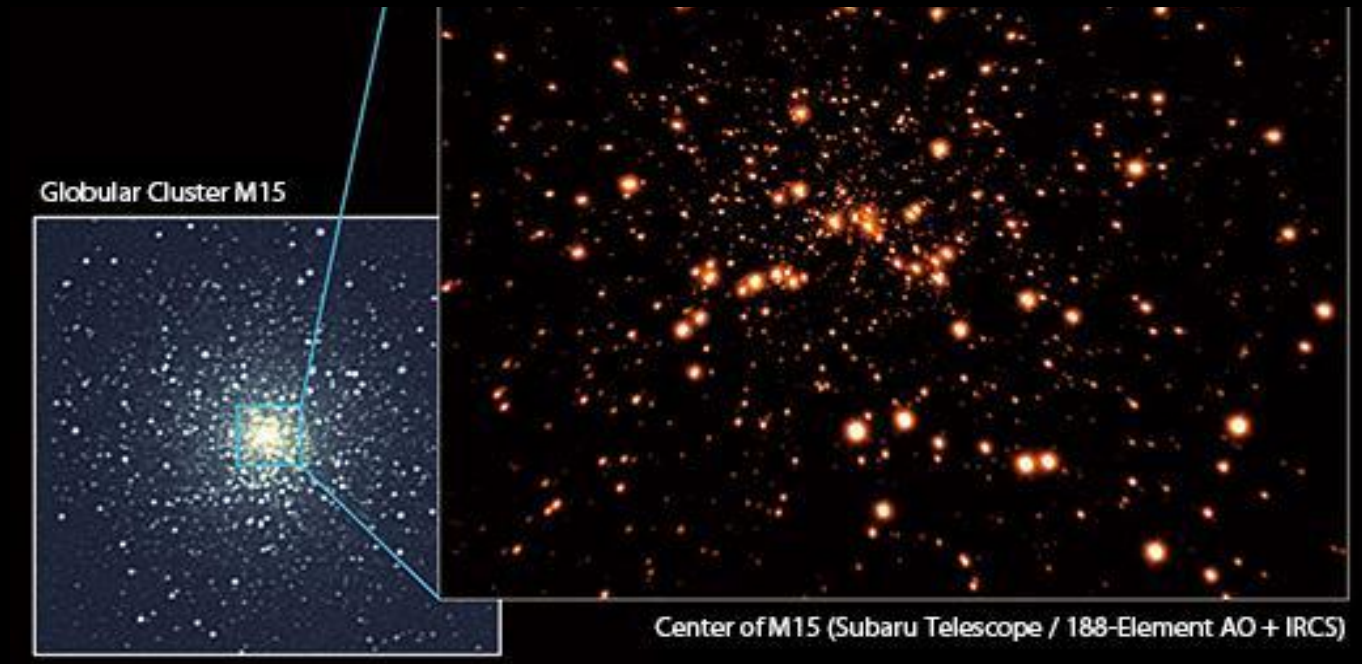
- High angular resolution infrared imaging spectroscopy of up to 4 objects within the 2' FOV through multi-object AO correction
- Parallel imaging of the Gemini AO corrected field



Science Drivers

Star Formation

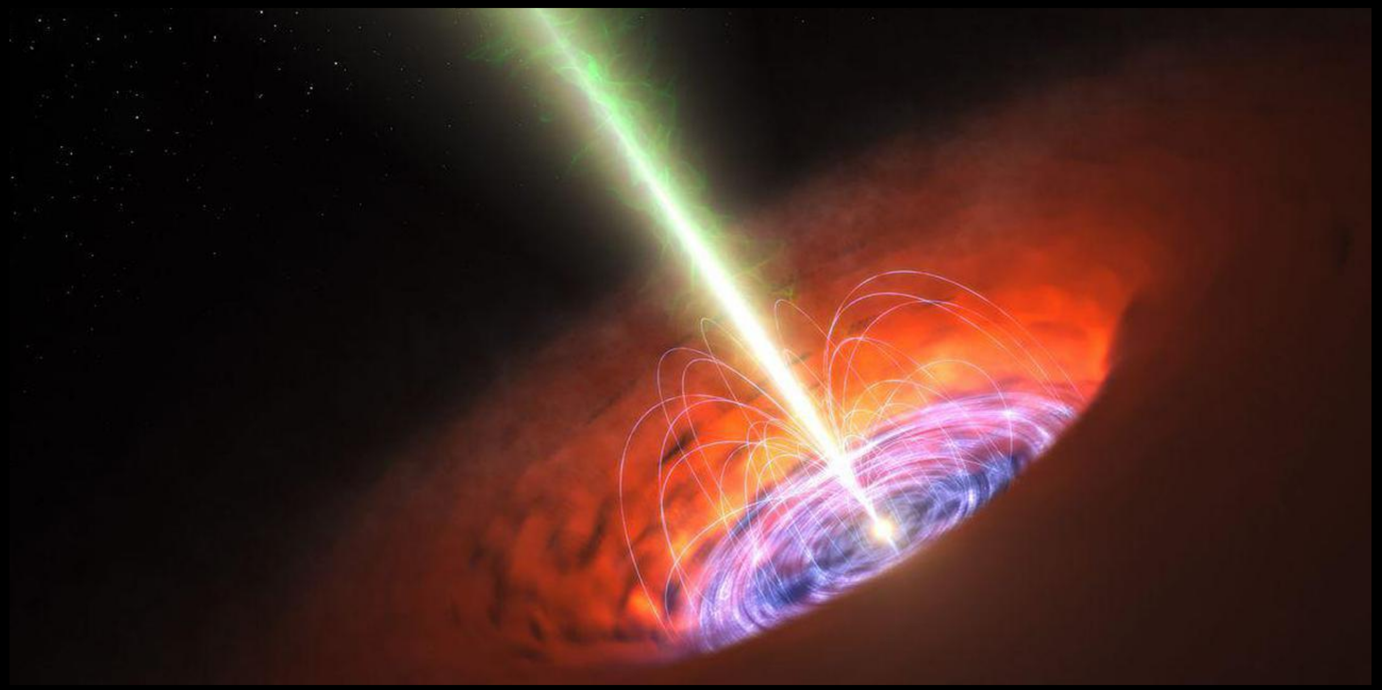
Galaxy Evolution & Dynamics

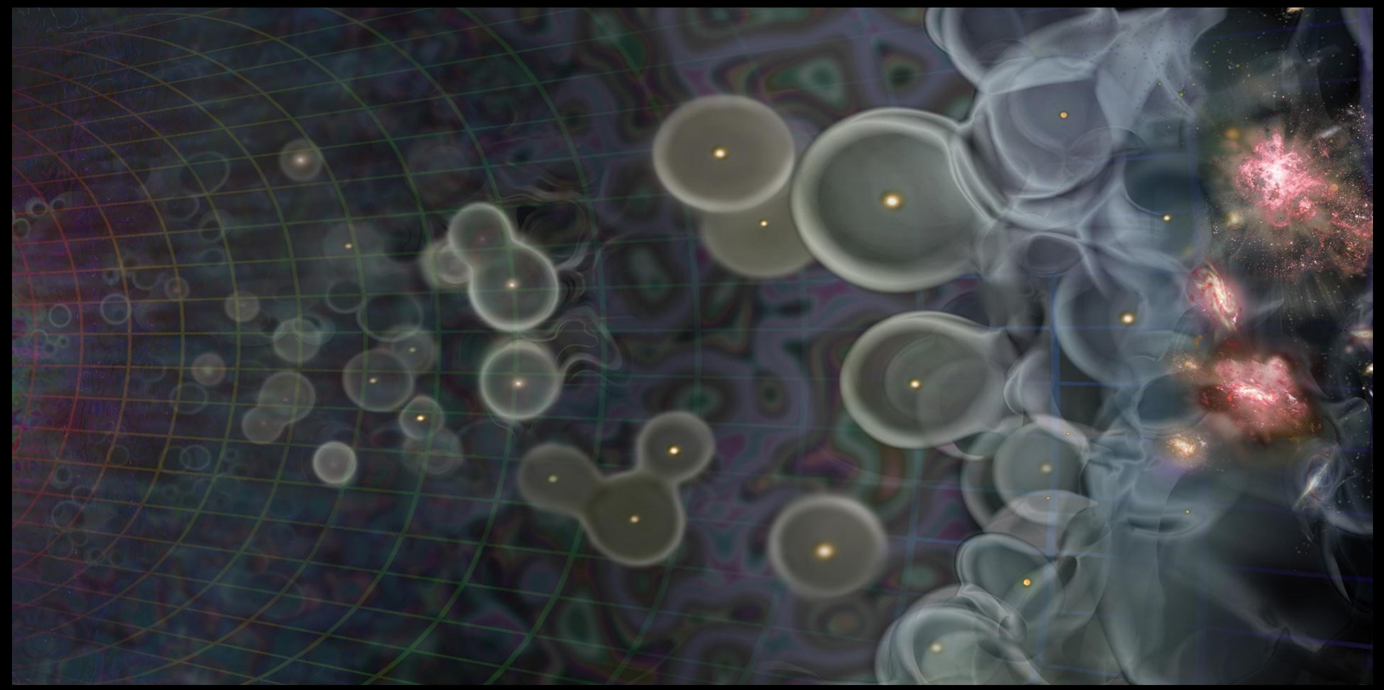


Globulars & IMBHs

Gravitational Lenses

Galaxy Cores & Black Holes





Reionization & Galaxies

JWST Follow-up & Transients

GIRMOS Science Cases

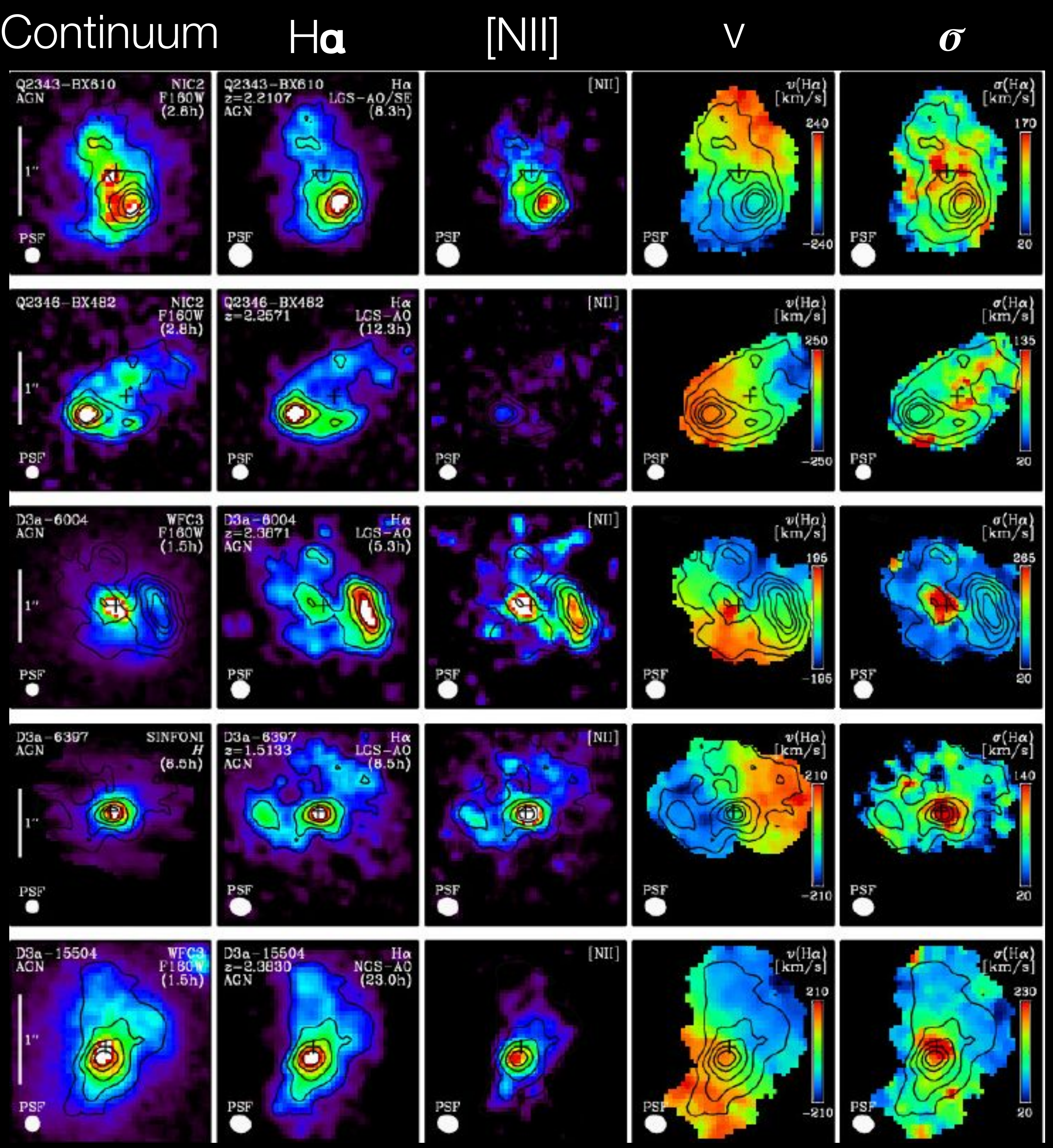
Galactic and Nearby Galaxy Science

- An AO-assisted survey probing the inner regions of Galactic Globular Clusters
- Stellar Chemodynamics and the Nuclear Star Cluster Around the SMBH of the Milky Way
- Young Star Clusters and Photo-dissociation Regions
- Young Resolved Massive Star Cluster Formation and Evolution
- Stellar Populations of Nearby Starburst Galaxies
- Broad-band Follow-up of Multi-Messenger Events

Extragalactic Science Cases

- Kinematics, Star-formation, Metallicities and Stellar Populations of Galaxies at $0.7 < z < 2.7$
- Observations of Distant Galaxy Clusters and Groups: Observing Galaxy Quenching and the Role of Environment at Early Times Starburst Galaxies at $z > 2$
- A Survey of Massive Quiescent Galaxies at $z > 2$
- Kinematics, Star-formation, Metallicities and Stellar populations of Gravitationally-Lensed galaxies
- The Evolution of Disk-Dominated Galaxies at $z > 3$
- Galaxies at Cosmic Dawn ($z > 7$)

Reference Science Program – High Redshift (1 < z < 3) Galaxy Survey



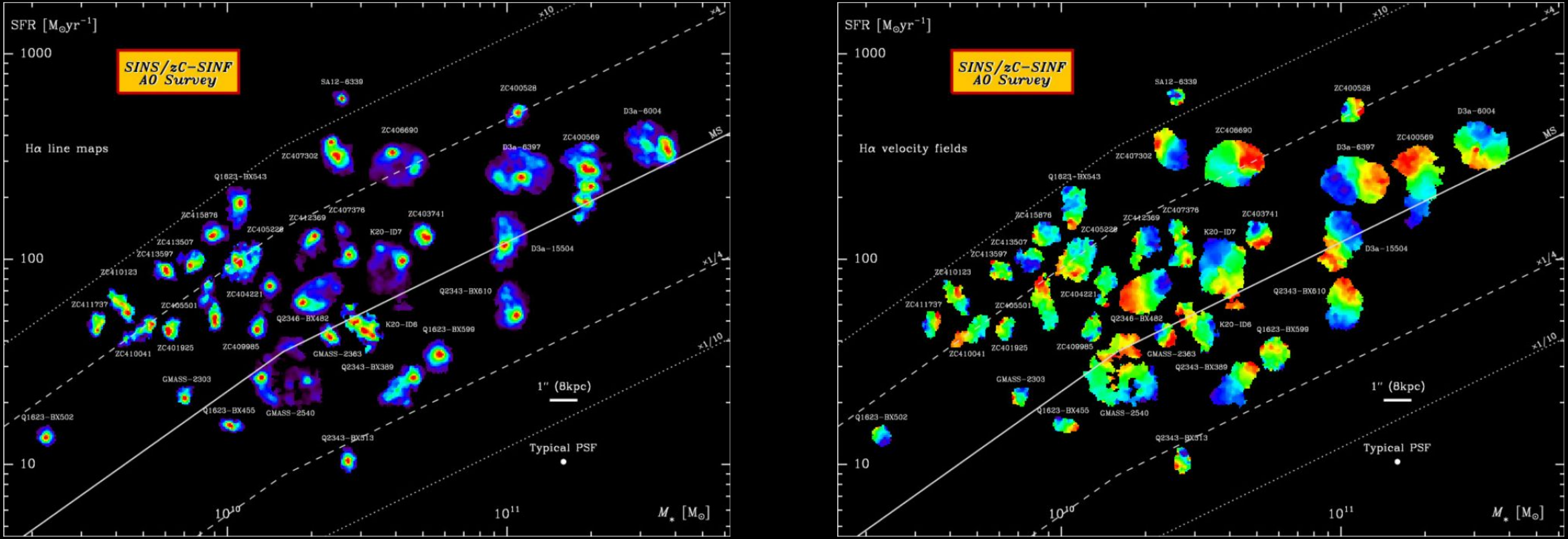
Forster Schreiber+2018

Science Goals

- Understand the basic properties of galaxy disks over a wide range of redshift and halo mass at kpc resolution
- How, when and where do galaxies build up their mass: mergers (kinematics) or star formation?
- Do galaxies keep their metals, what is the role of feedback? AGN vs. stellar?

500-hour (250 galaxy) reference survey primarily drives GIRMOS top level spectroscopic requirements

Reference Science Program – High Redshift (1 < z < 3) Galaxy Survey



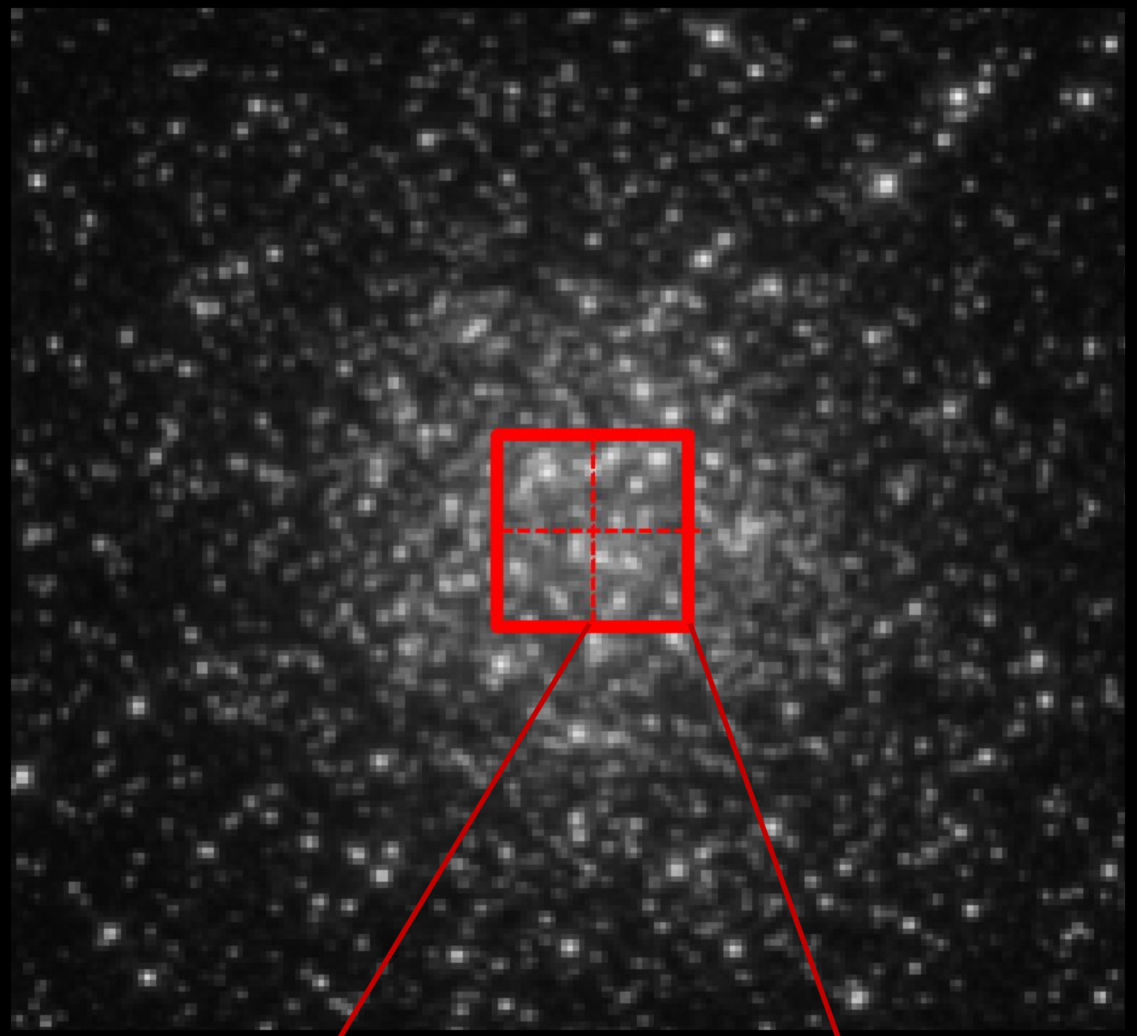
Forster Schreiber+2018

State-of-the art high angular resolution survey SINS-cZ-SINF’s sample only 36 galaxies at z ~ 2. GIRMOS aims to improve sample size by ~10x by significantly increasing survey throughput compared to existing AO instruments.

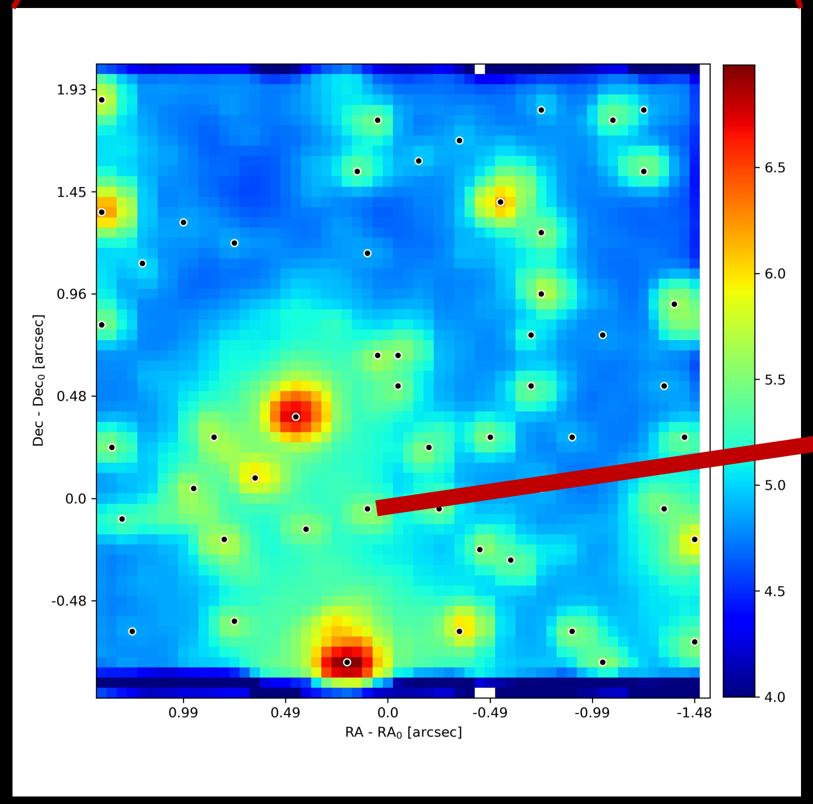
GEMINI INFRARED MULTI-OBJECT SPECTROGRAPH
GIRMOS

Reference Science Program – Chemodynamics of Globular Clusters

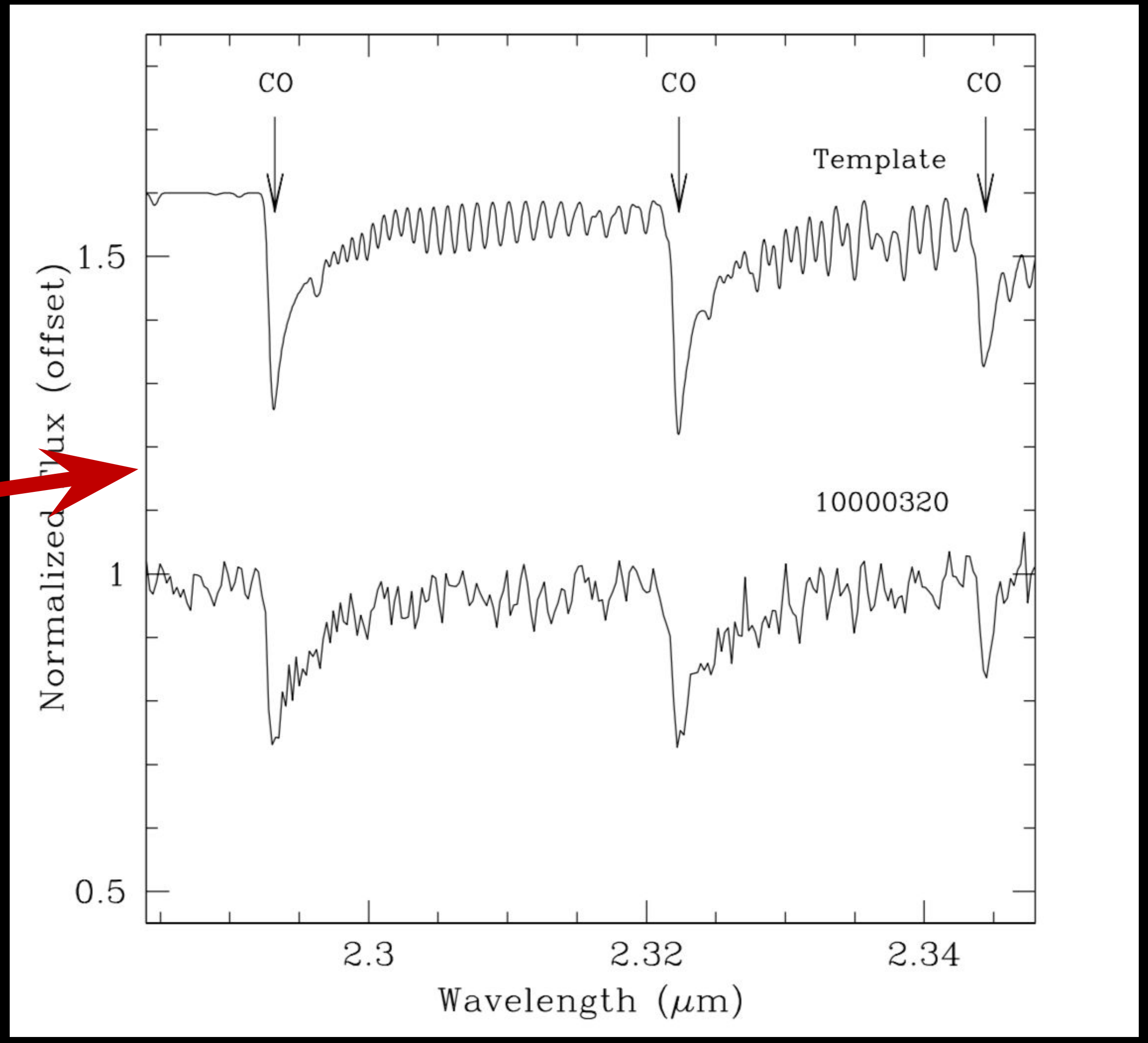
Terzan 5

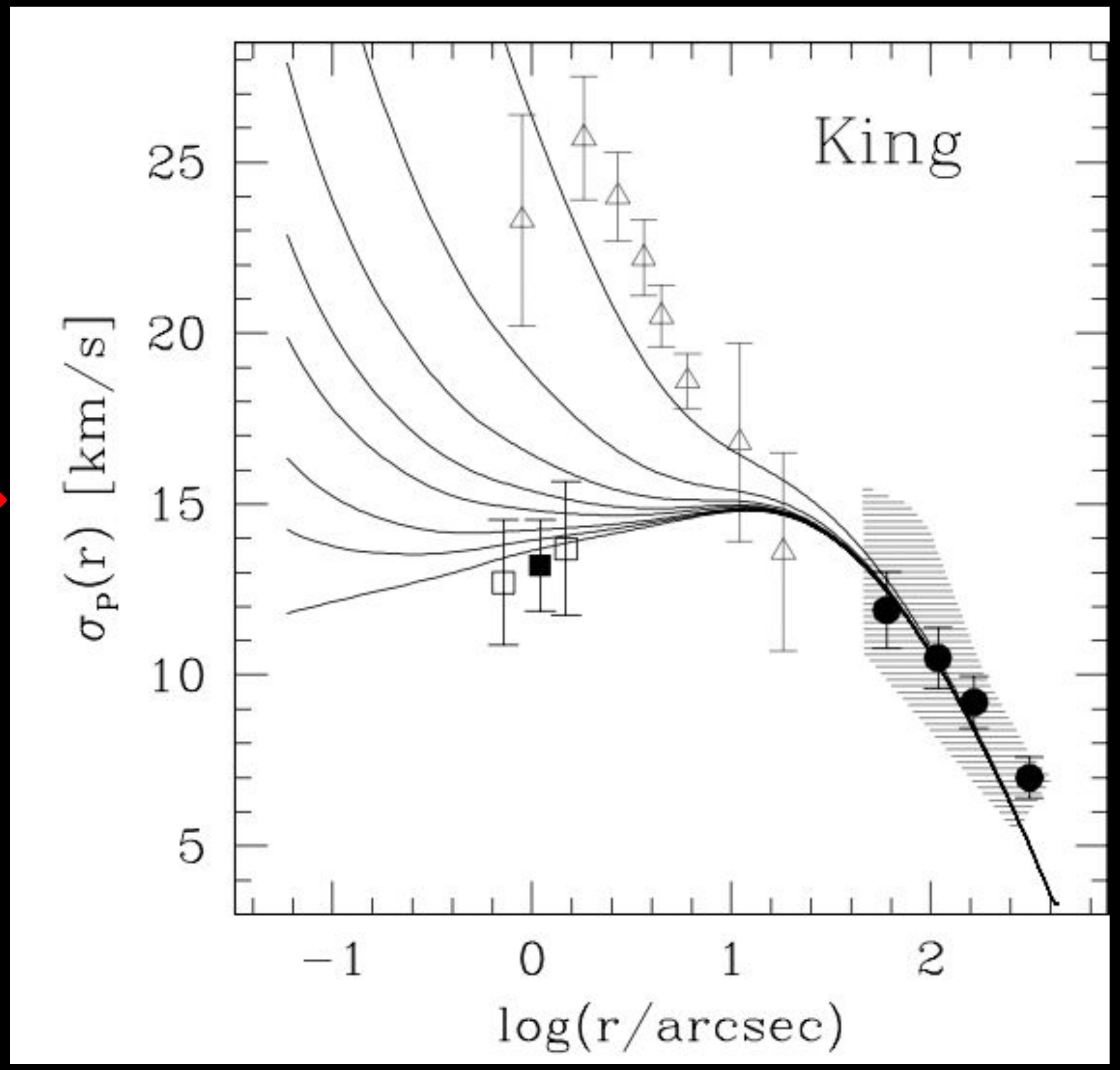


- **Intermediate Mass Black Holes** (IMBHs) are a missing link between stellar and Supermassive Black Holes
- Many GCs distributed around dusty Galactic centre
- Such a survey is **ideal for GIRMOS**:
  - Dusty and crowded: need **AO + infrared**
  - Massive bulge GCs have IMBH sphere of influence ~ 3”
  - Aim to **survey > 20 GCs** with characterized internal dynamics
  - Additionally, chemical abundances of these stars can also be extracted to study formation histories

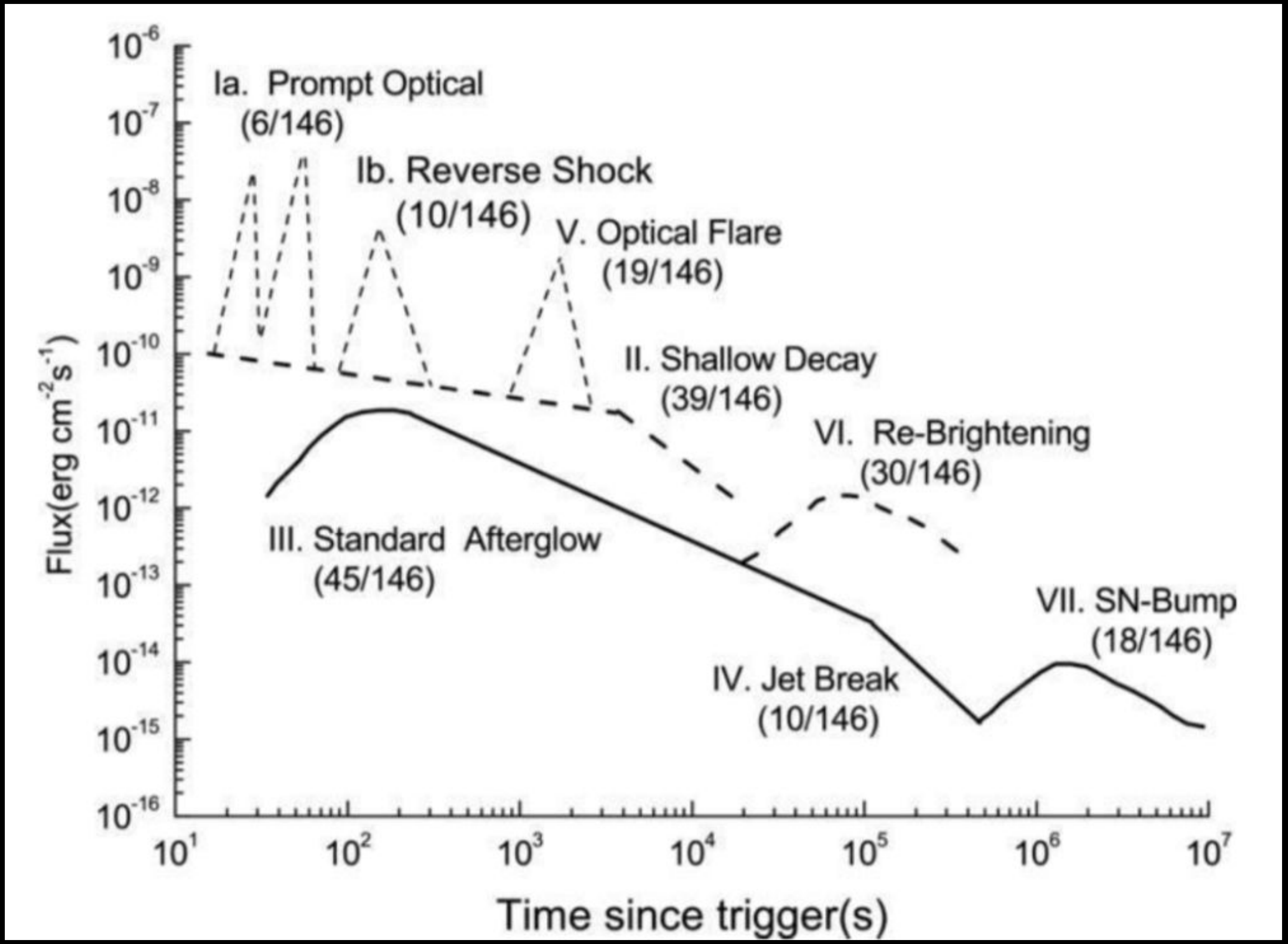


Gemini NIFS Data (Lamb+ in prep.)

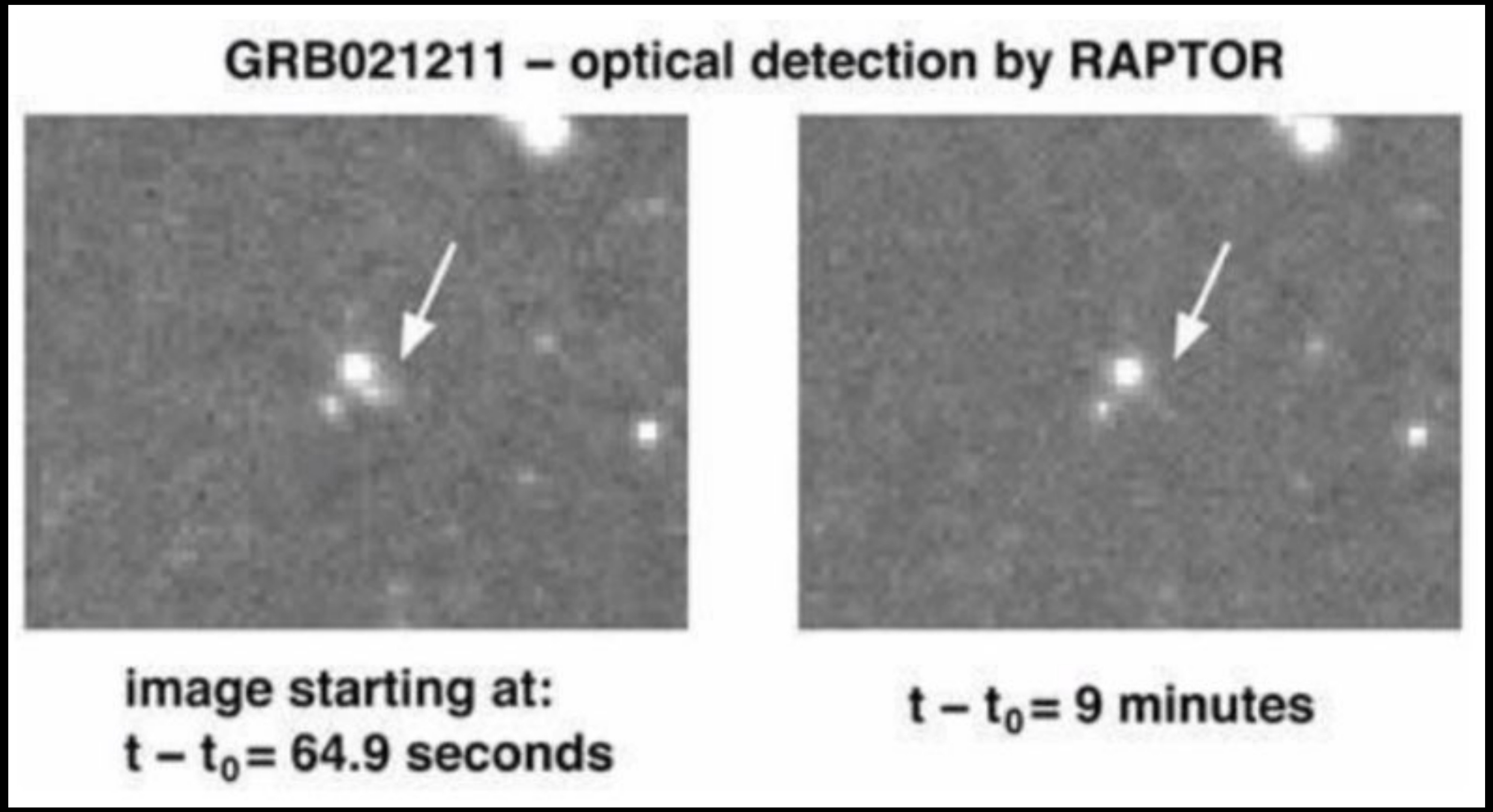




Reference Science Program – AO-Assisted Imaging of Transients



Li et al. (2012)

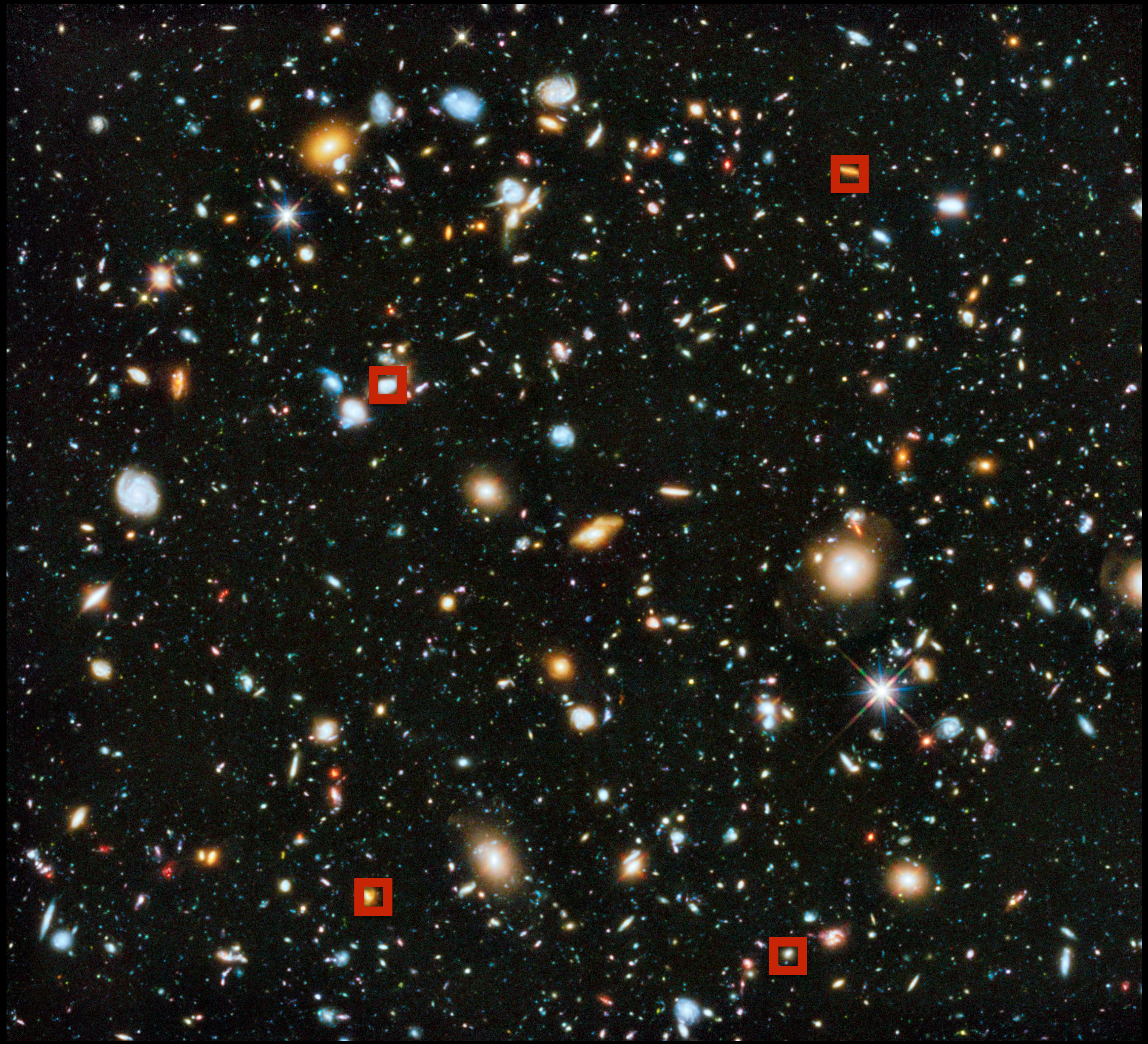


Credit: RAPTOR Team

- IR observations of GW/GRB kilonovae afterglows require both high angular resolution and fast turnaround.
- GNAO+GIRMOS and Gemini are the only facility in the world that can provide this combination.
- 10 minute response

A wide range of transients are expected in the coming years with ongoing surveys as well as the Vera Rubin Telescope and Multi-Messenger events

Requested Spectroscopic Instrument Modes

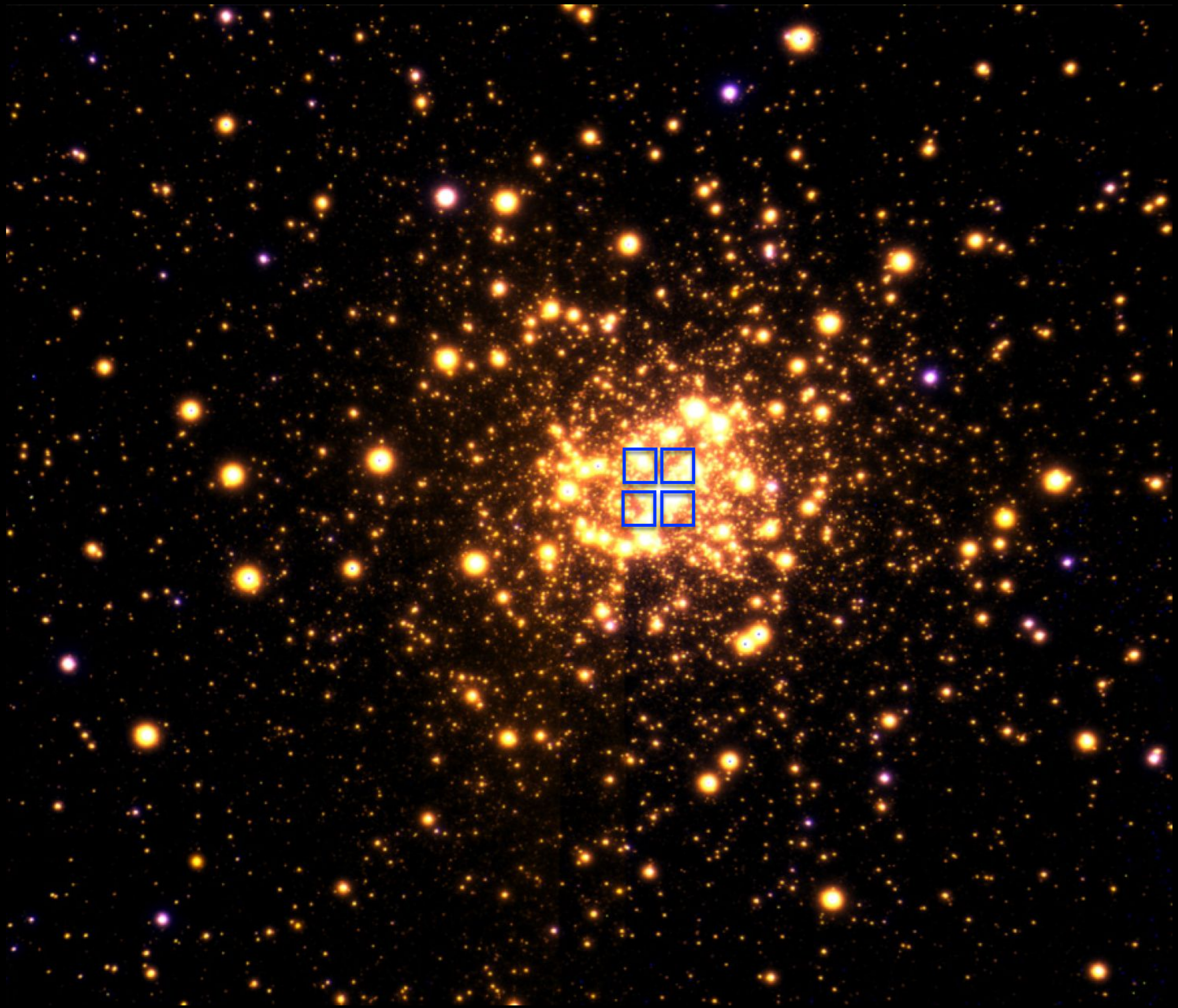


Multiple Objects

Pick-off System

Multi-Object AO

(GIRMOS MOAO)



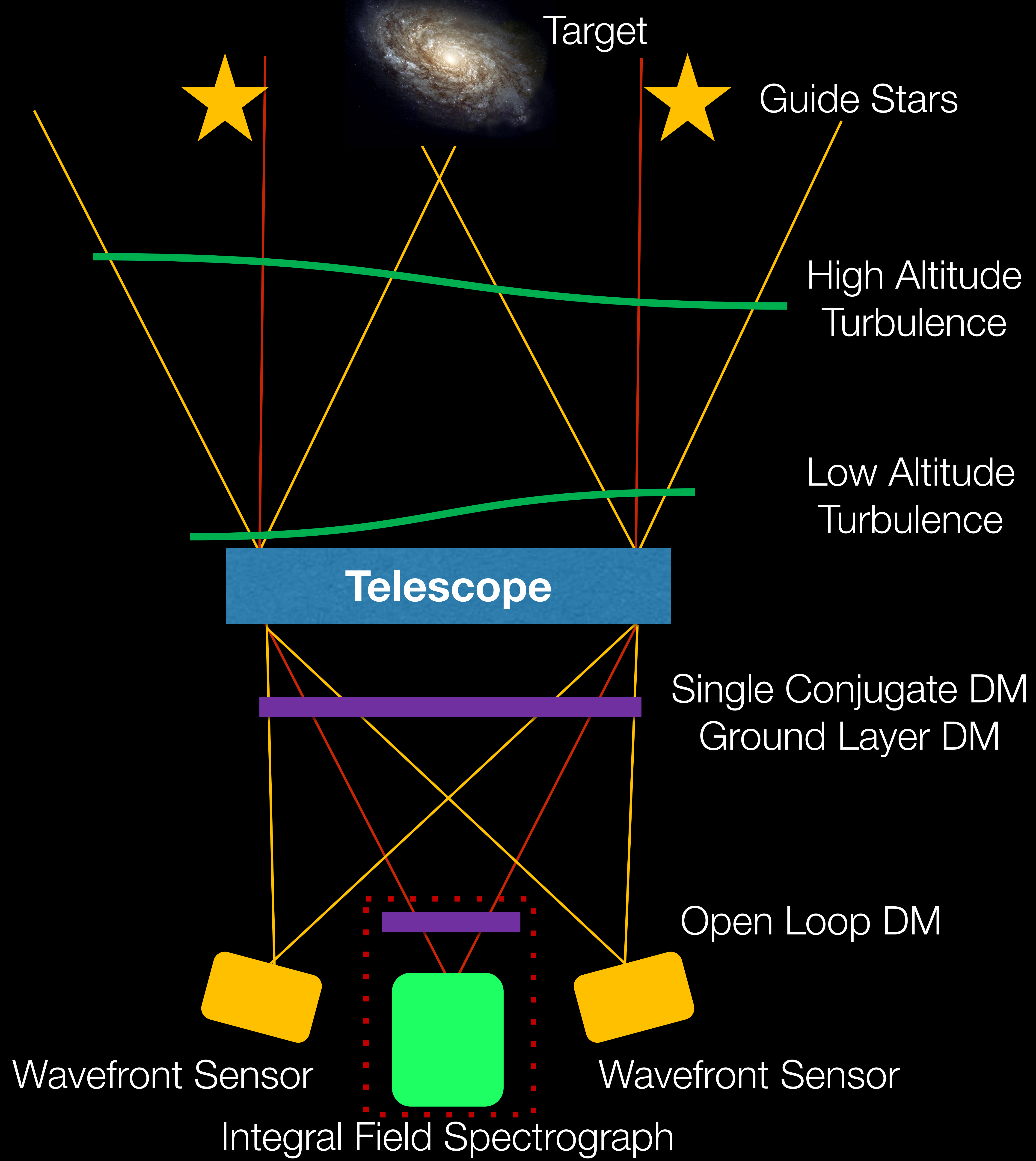
Single Object

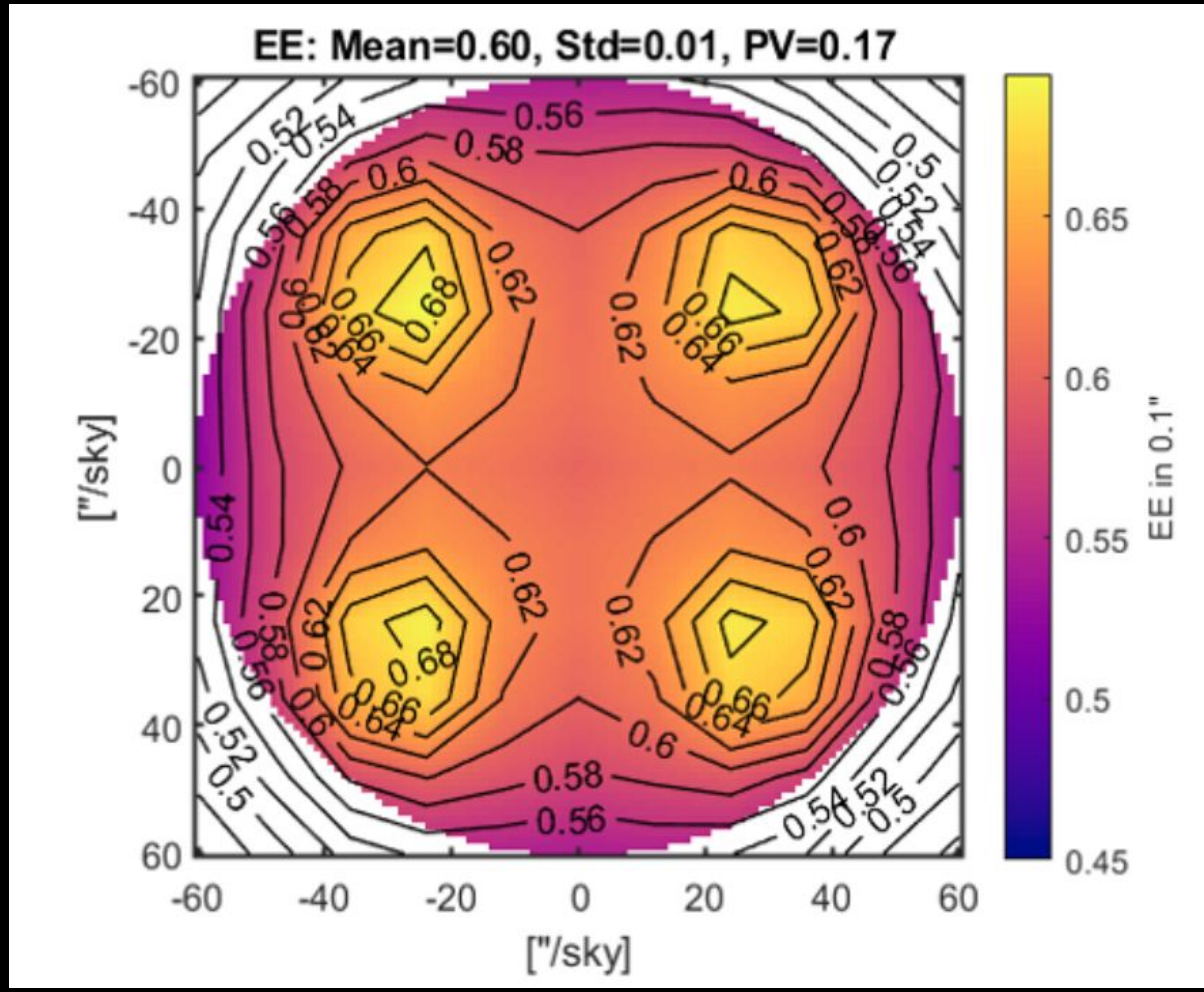
Tiled Super-IFU

Laser Tomographic AO

(Gemini LTAO)

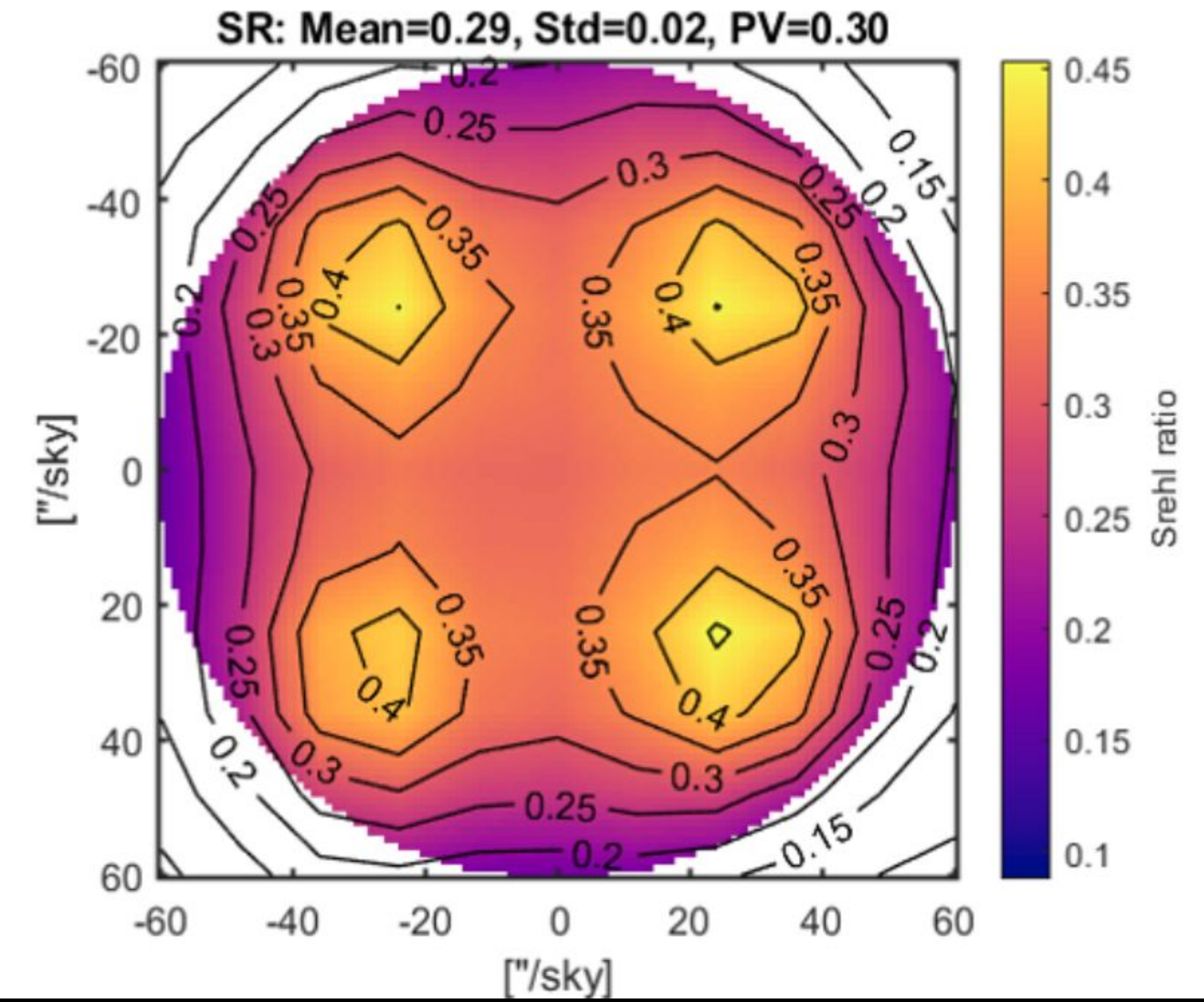
Multi-Object Adaptive Optics





Encircled Energy within 0.1”

Simulated GIRMOS Performance



Strehl Ratio

- Heritage from MOAO Technical Pathfinder (Subaru RAVEN)
- Risk retirement AO testbed operational
- Preliminary design AO peer review this week

System Parameters

Sivanandam et al. (2020), Proc. SPIE

AO Image Quality	50% EE in 0.05” in H-band (LTAO) 50% EE in 0.1” in H-band (MOAO) 50% EE in 0.4” in H-band (GLAO)	**Field-of-Regard for MOAO**	2’ diameter patrol field
Wavelength Range	0.95 – 2.4 μm	**Number of IFSes**	Up to 4
Spectral Bands	0.95 – 1.35, 1.25 – 1.8, 1.63 – 2.35 μm (R~3,000) 1.194 – 1.35, 1.5 – 1.706, 2.11 – 2.379 μm (R~8,000)	**Spectral Resolving Power (R)**	3,000 and 8,000
Individual IFS FOV (100% coverage)	1.0 x 1.0” 2.0 x 2.0” 4.0 x 4.0”	**Spaxel Sampling**	0.025” 0.05” 0.1”
Single Object Mode IFS Observable FOV (~2” gaps between IFU fields)	~2.0 x 2.0” ~4.0 x 4.0” ~8.0 x 8.0”	**Spaxel Sampling**	0.025” 0.05” 0.1”
Overall Spectrograph Throughput	35%	**Detectors**	HAWAII-2RG 2Kx2K per spectrograph
Imager FOV	85 x 85”	**Imager Plate Scale**	0.021”
Imager Wavelength Range	0.9 – 2.4 μm	**Imager Detector**	1x HAWAII-4RG 4Kx4K

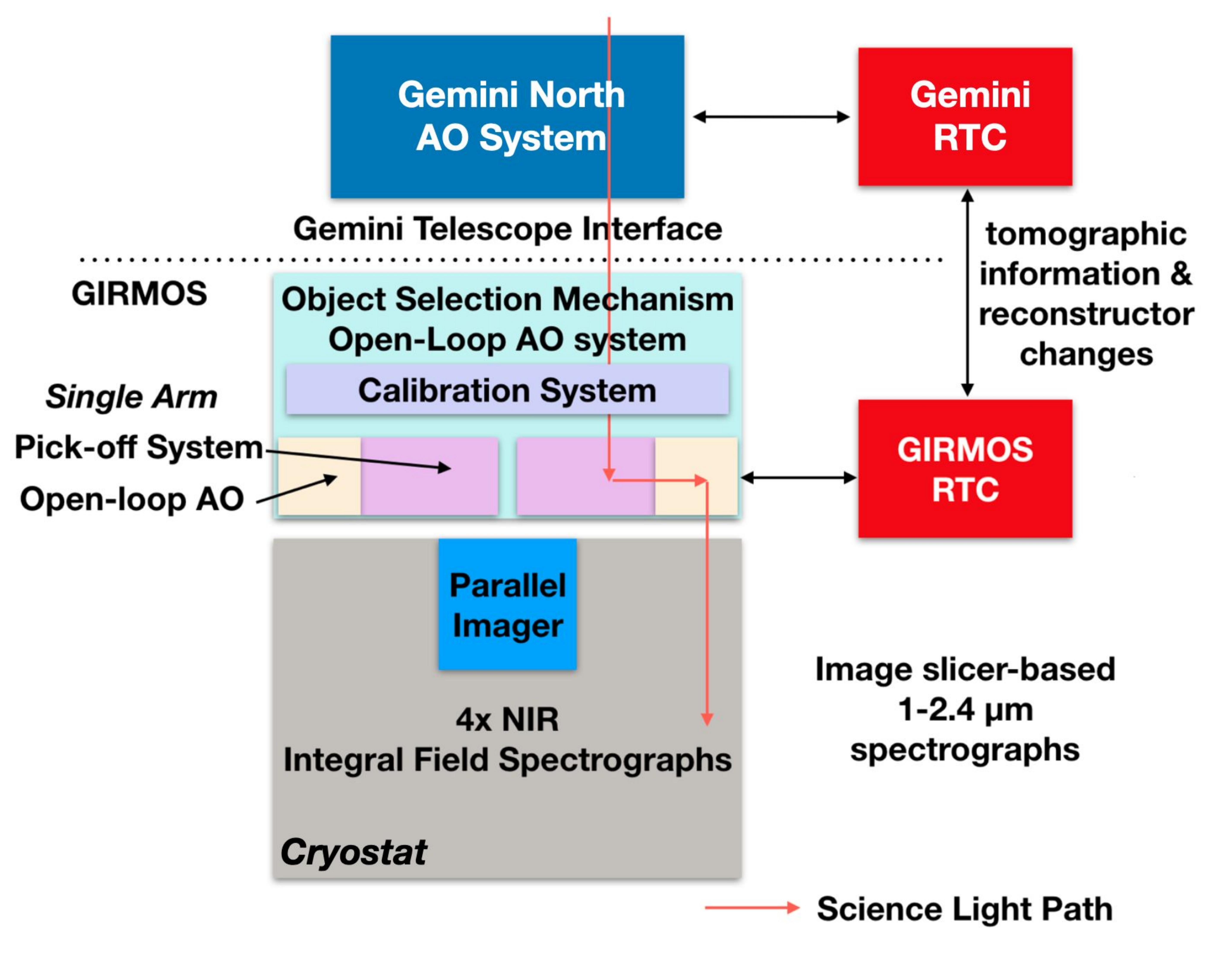
JWST NIRSpec IFU – 3x3” (0.1”/spaxel) @ R_{MAX} ~ 2700

Image slicer-based for best low surface brightness performance

Three spatial and two spectral modes

Simultaneous imaging and spectroscopy possible

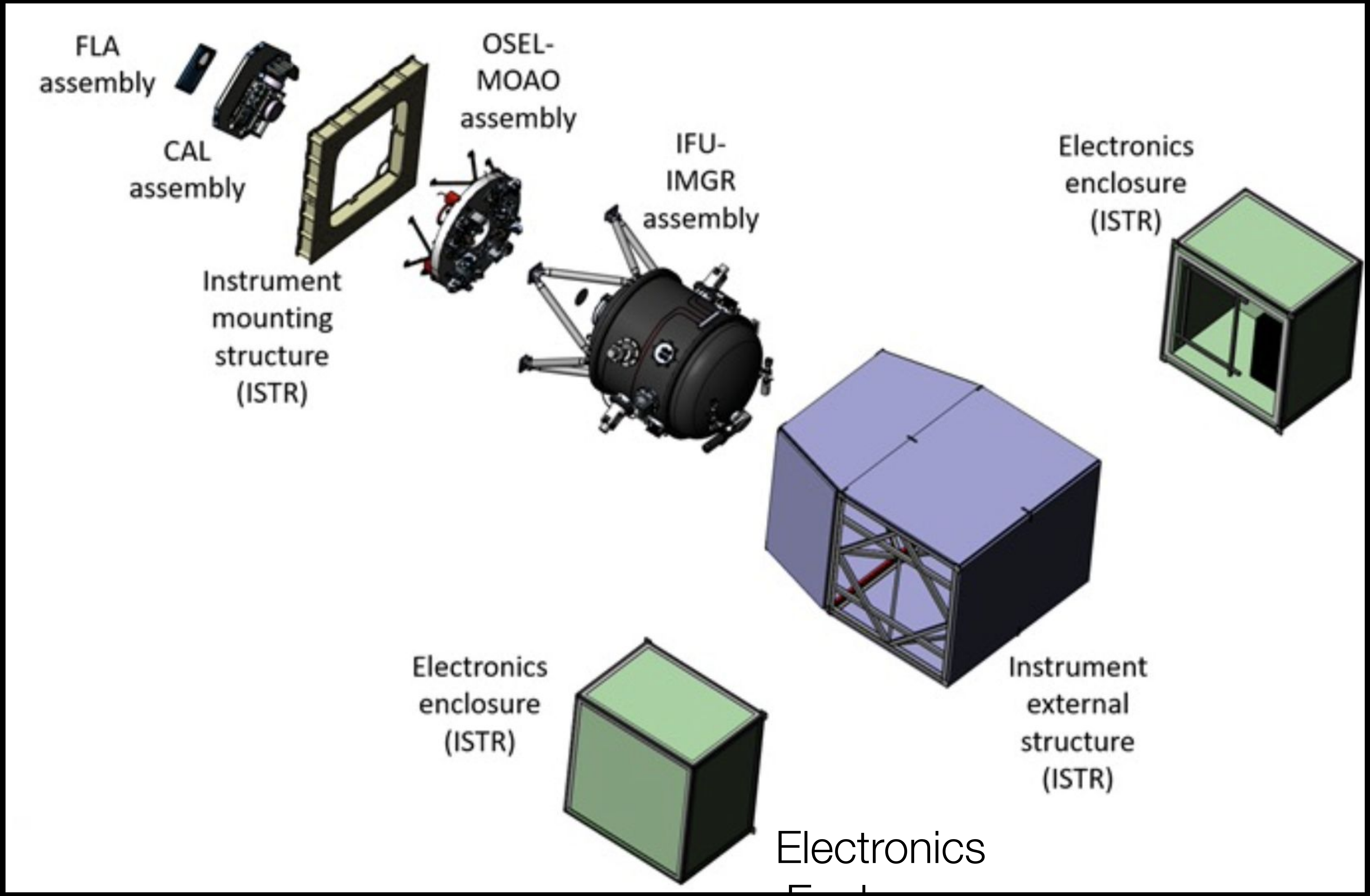
GIRMOS Architecture



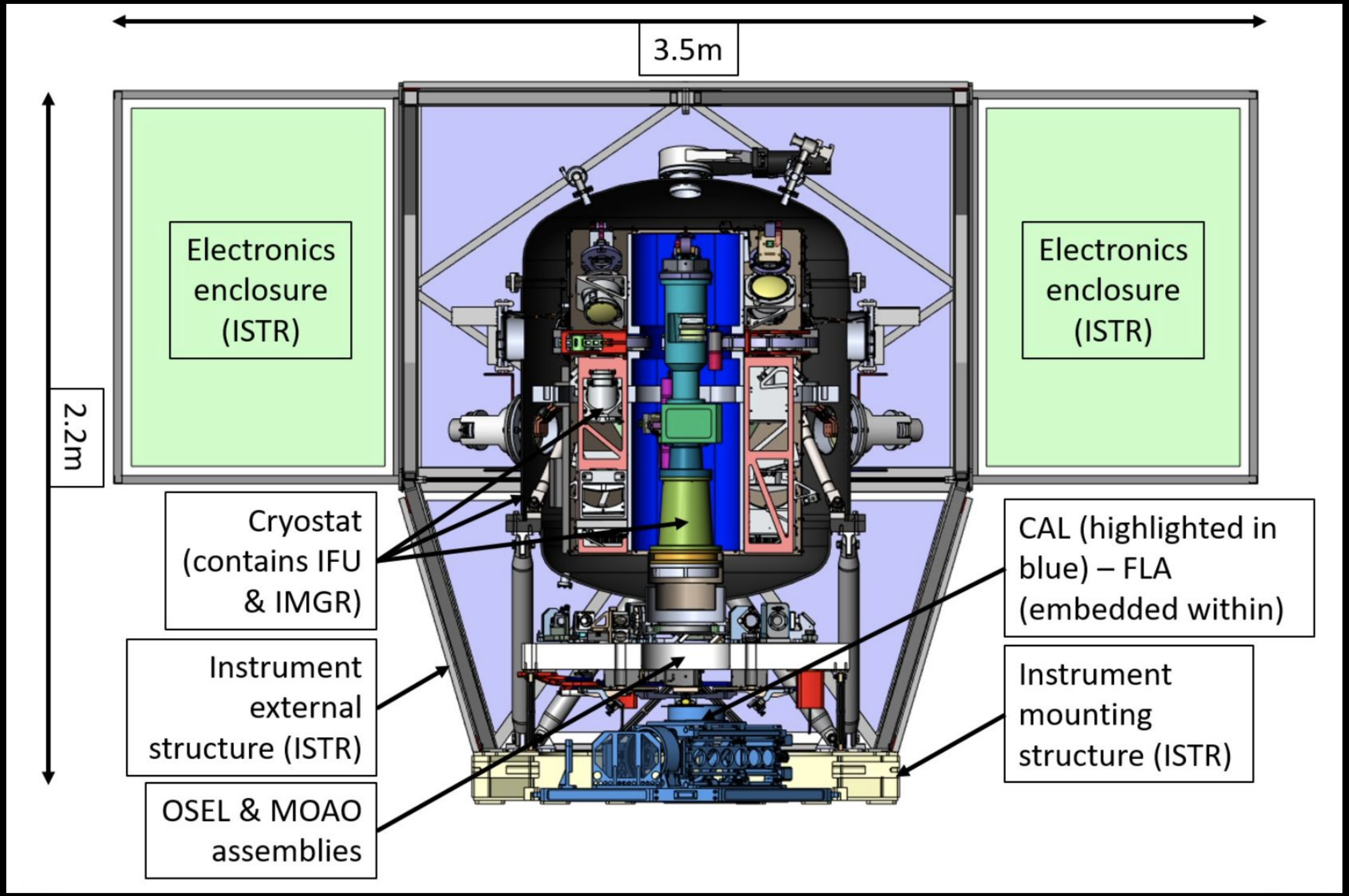
- GIRMOS is implemented through **five** major optical subsystems
- The instrument will be jointly developed with the new AO facility at Gemini-North
- Our MOAO system will require a close integration with the GNAO system, through their real-time controller (RTC), which will share the tomographic information derived from GNAO laser constellation (LGS) and natural guide star (NGS) wavefront sensors (WFS)
- The GIRMOS AO system will operate for multi-object science cases

Overall Design

Assembled View



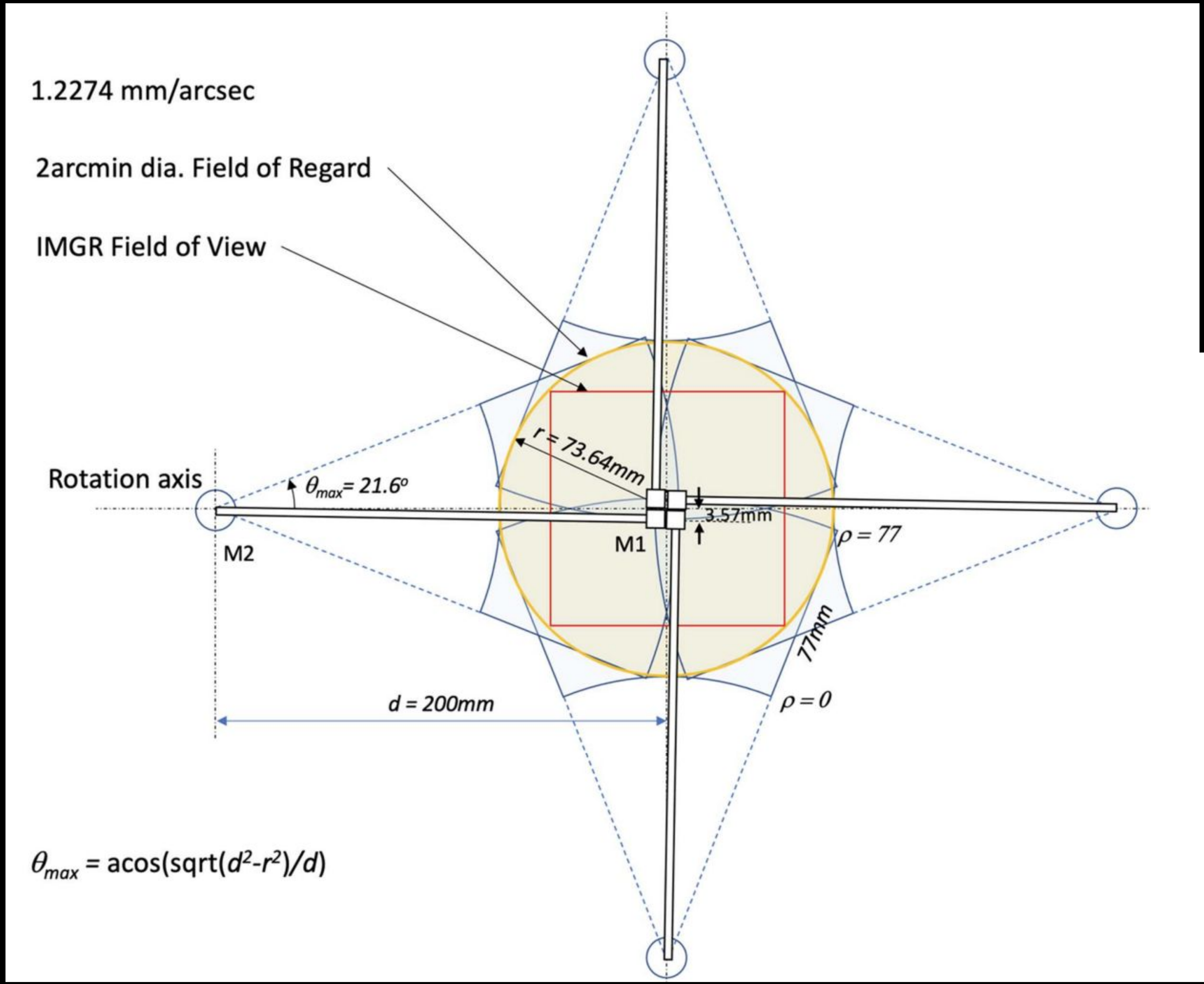
GIRMOS Exploded View

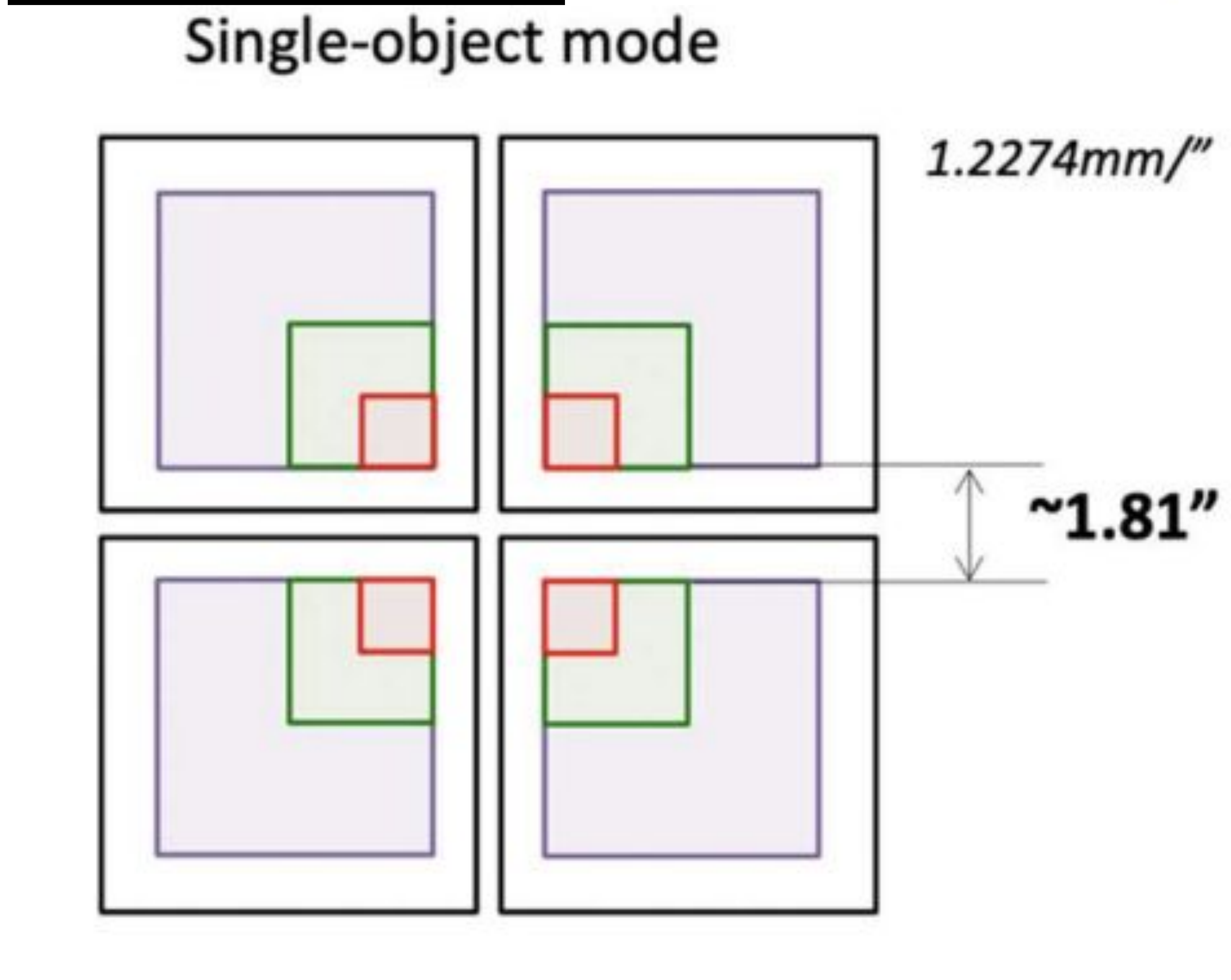


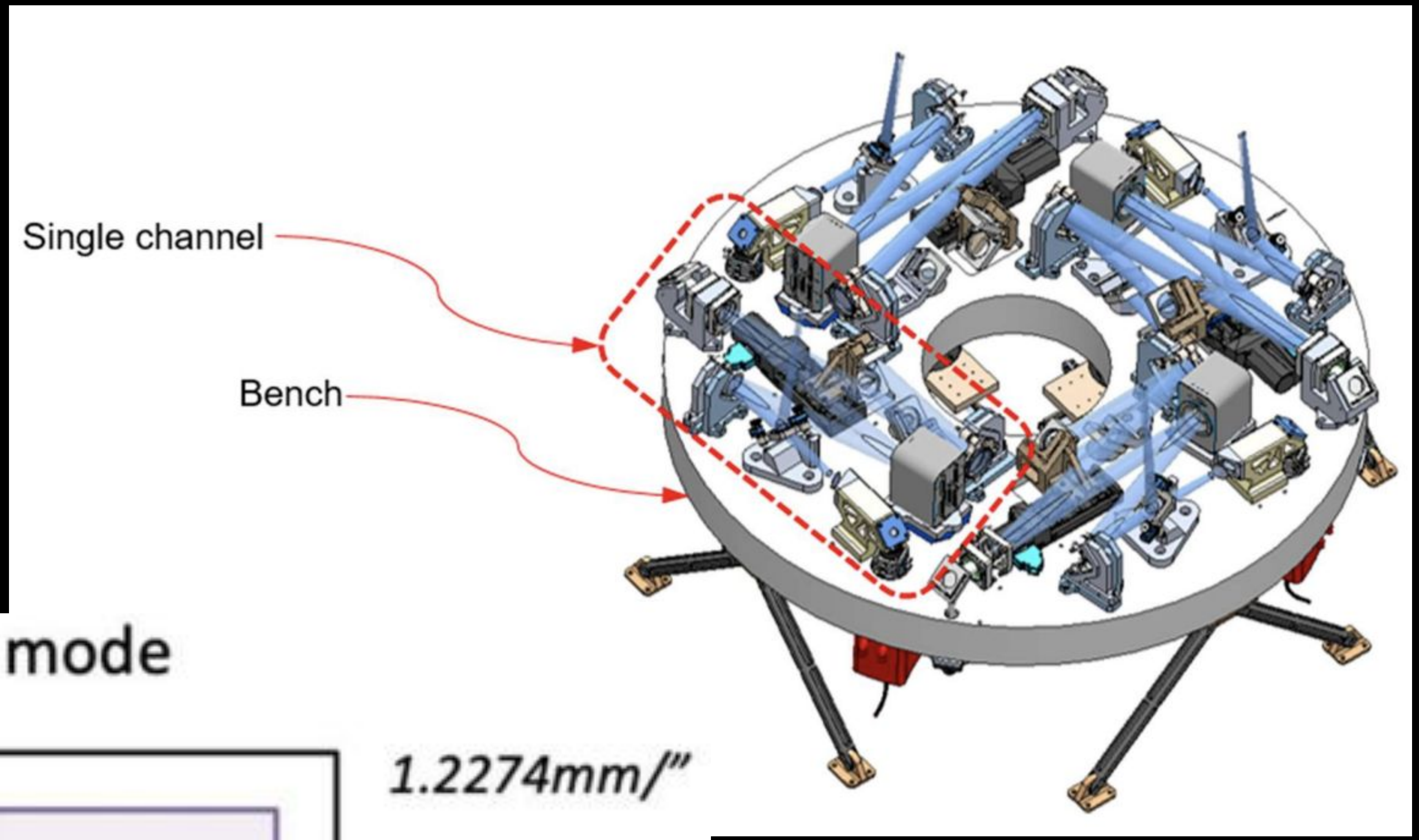
CAL – Calibration System
OSEL/MOAO – 4x Object Selection & MOAO Systems
IMGR/IFU – Imager & 4x Integral Field Spectrographs

Successful Preliminary Design Review in May 2022

System Components – OSEL & MOAO

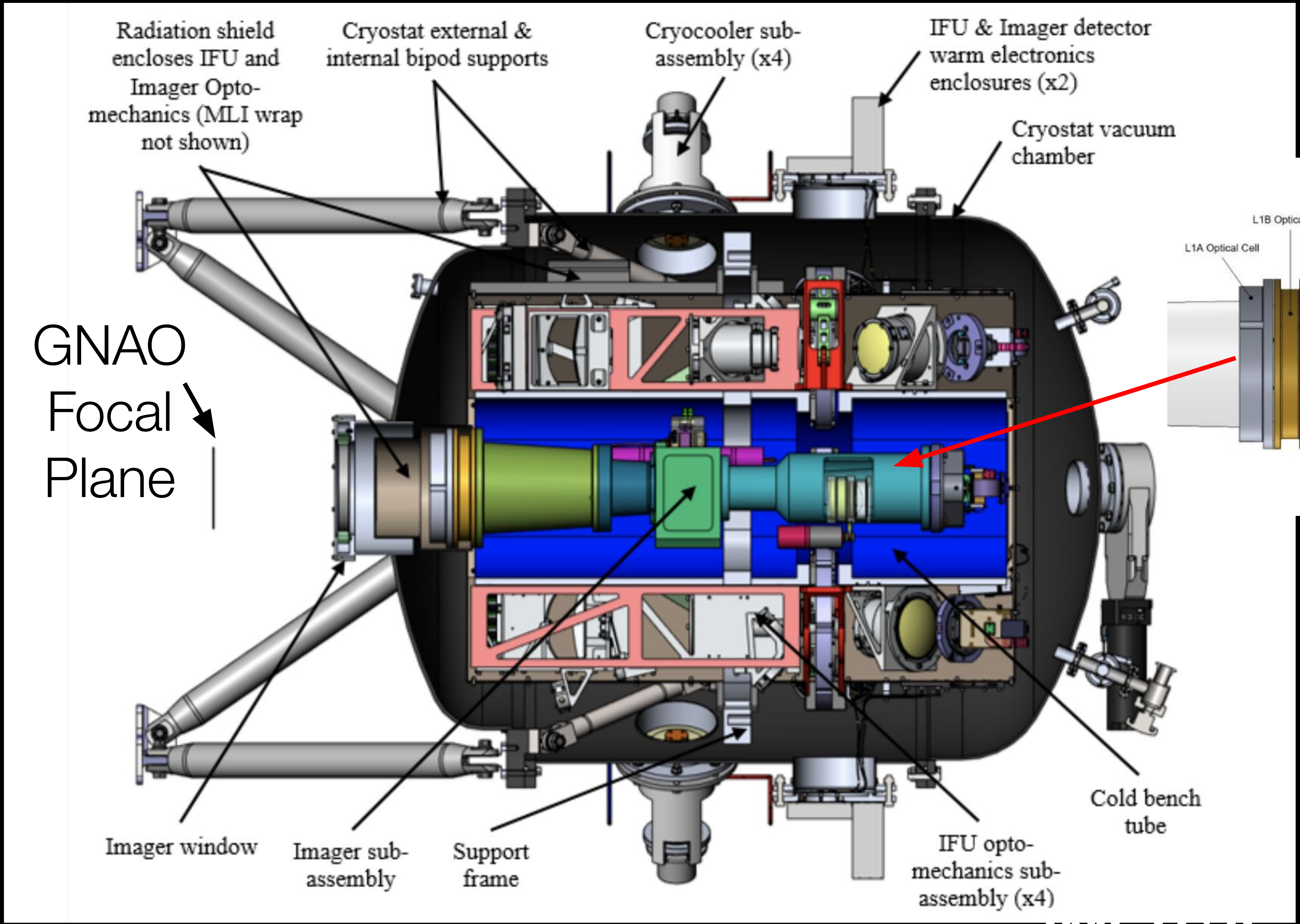




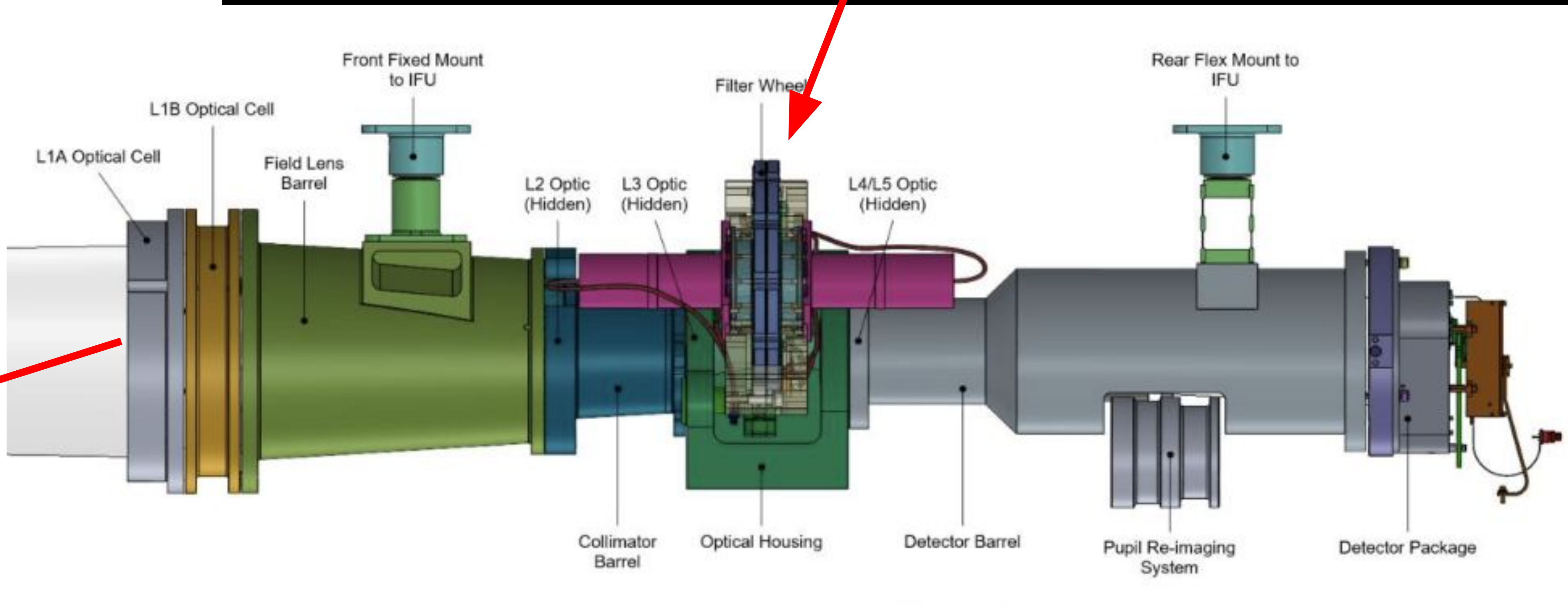


- R-θ pick-offs for source selection
- AO system fully integrated
- Pick-offs with pinholes visible to imager for acquisition and flexure compensation

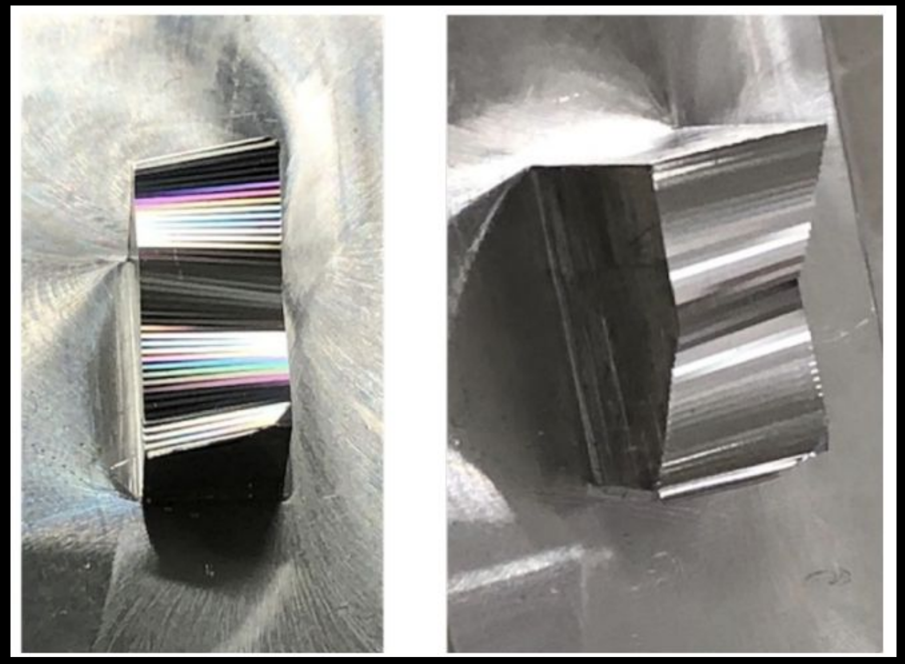
System Components – IFUs & IMGR



20 position filter wheel



IMG
R



Prototype GIRMOS Slicer

IMGR+IF
U

Conclusions

- Multi-object AO integral field spectroscopy critical for future large extragalactic surveys
- GIRMOS is being closely developed with GNAO and will serve as its first light instrument
- GIRMOS will be the most powerful AO-fed instrument for integral-field spectroscopy in the foreseeable future until ELT multiplexed spectroscopy becomes available
- Project consists of an ambitious scientific and technology development plan that will directly benefit a future US-ELT instrument
- Currently in early Critical Design Phase with completion in Fall 2023
- Expected delivery to Gemini late 2026/early 2027 with commissioning plan that ***coincides with GNAO first light in FY2028***

Acknowledgements

The GIRMOS project gratefully acknowledges its financial support from the Canada Foundation for Innovation (CFI), Ontario Research Fund (ORF), British Columbia Knowledge Development Fund (BCKDF), Fonds de Recherche du Quebec (FRQ), Nova Scotia Research and Innovation Trust (NSRIT), University of Toronto and in-kind and cash contributions from the National Research Council Canada (NRC) and the Association of Universities for Research in Astronomy (AURA) through its Gemini Observatory.

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