DUNLAP INSTITUTE
for ASTRONOMY & ASTROPHYSICS

GIRMOS: Gemini Infrared Multi-Object Spectrograph A TMT Pathfinder Instrument

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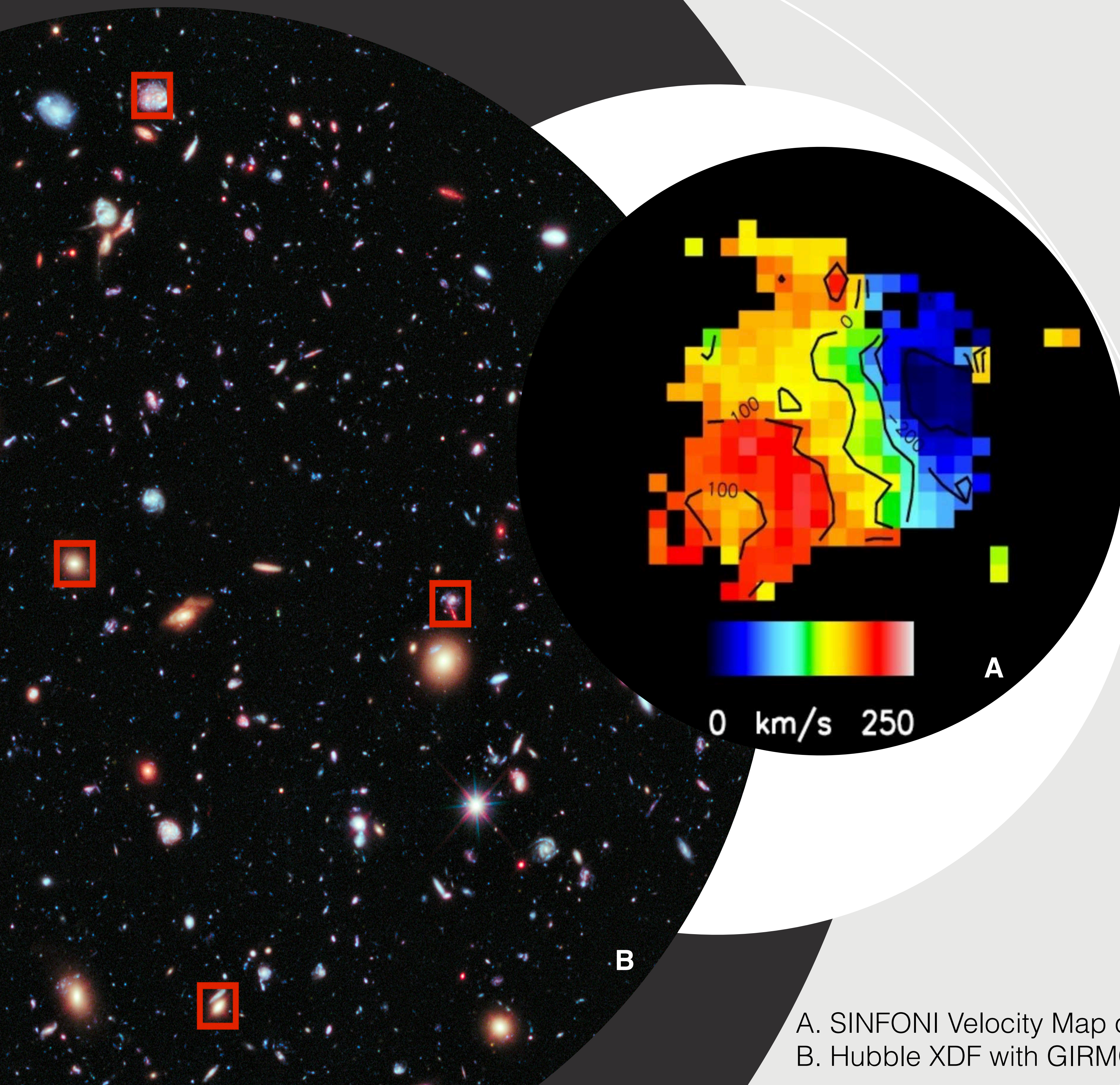


A. SINFONI Velocity Map of z~2 Galaxy
B. Hubble XDF with GIRMOS Fields Overlaid

Team

GIRMOS Technology

Project Engineer: Darren Erickson
AO Lead: Scott Chapman

Adaptive Optics

Andersen, Lardiere, Veran, Bradley, Hickson, Lamb, Sivanandam, Correia, Akiyama

MEMS Deformable Mirrors

Chapman, El-Sankary, Shafai

NIR Spectrographs

Lead: Sivanandam

Moon, Andersen, Simard, Thibault, Akiyama

Calibration

Lead: Hickson

Optical Design and Fabrication

Lead: Thibault

Chen, Sivanandam, Moon

Data Management and Pipeline

Lead: Sawicki

GIRMOS Science

Project Scientist: Adam Muzzin

Distant Galaxy Formation and Evolution

Chapman, Sawicki, Abraham, Murray, Ellison, Simard

High-z Clusters of Galaxies

Yee, Muzzin

Observational Cosmology

Carlberg

Low Redshift Galaxies and AGN

Sivanandam, Yee, Andersen, Davidge, Akiyama

Stellar Populations

Sivanandam, Davidge

Metal Poor Stars

Venn

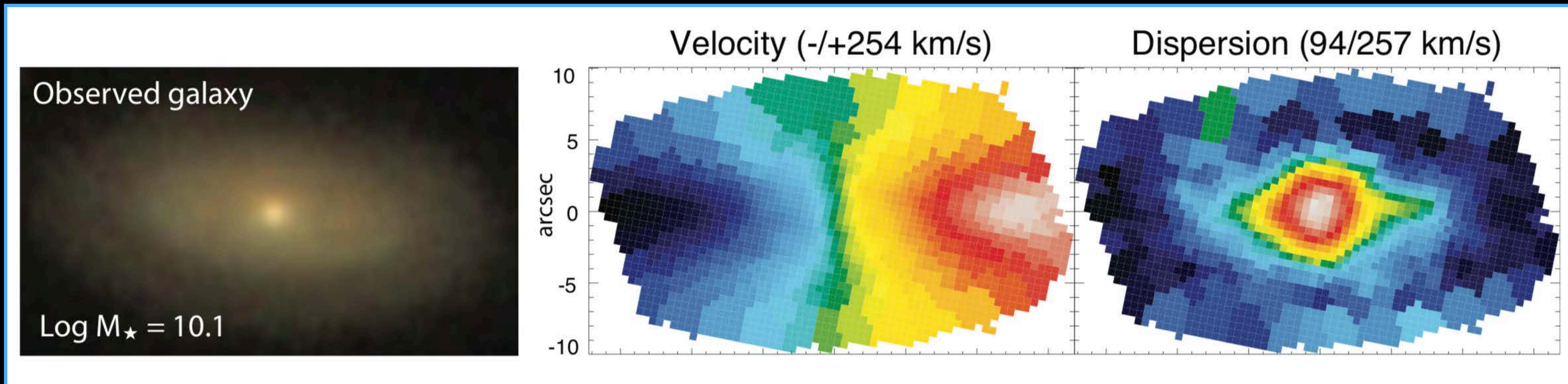
Star Formation

Murray

Gemini Scientific User Community

Partners: University of Toronto, Dalhousie, UBC, UVic, Laval, Saint Mary's, NRC-Herzberg, UManitoba, York U, Gemini Obs., International Institutions.

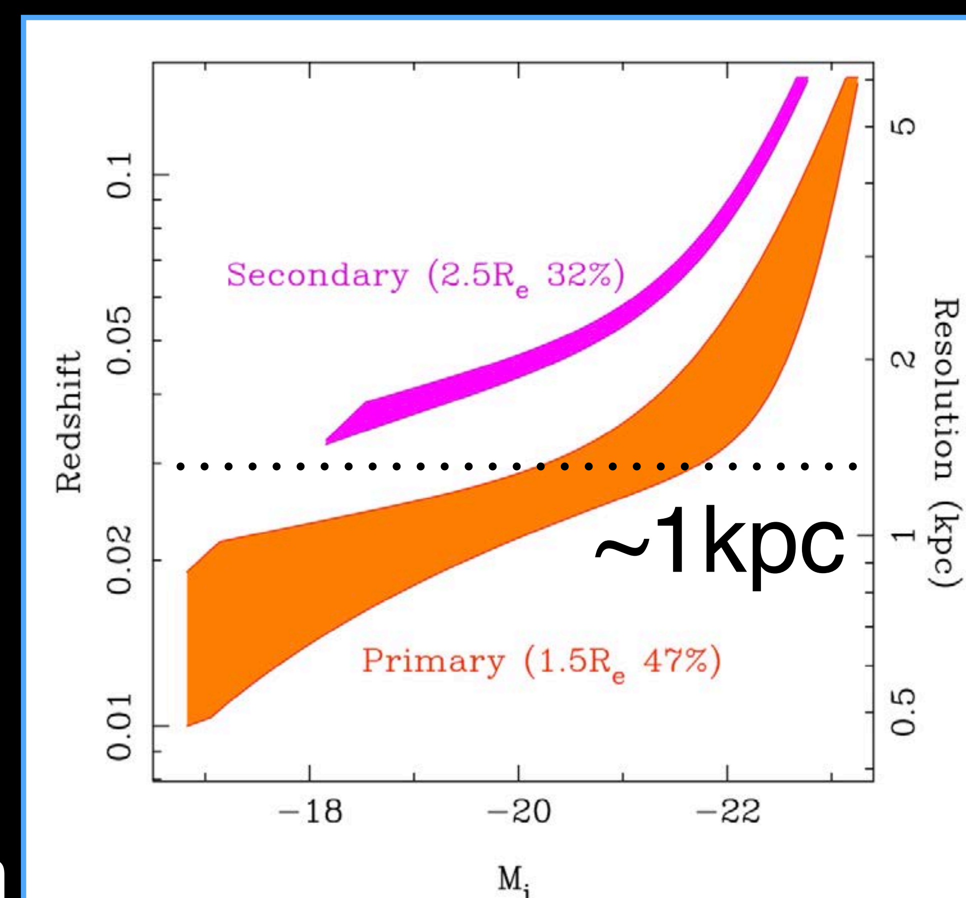
Age of Integral Field Spectroscopy of Nearby Galaxies



1. **How do galaxy disks grow?**
2. **How do bulges and ellipticals grow?**
3. **What affects star formation?**
4. **How have galaxies assembled and what are the relative contributions of their components?**

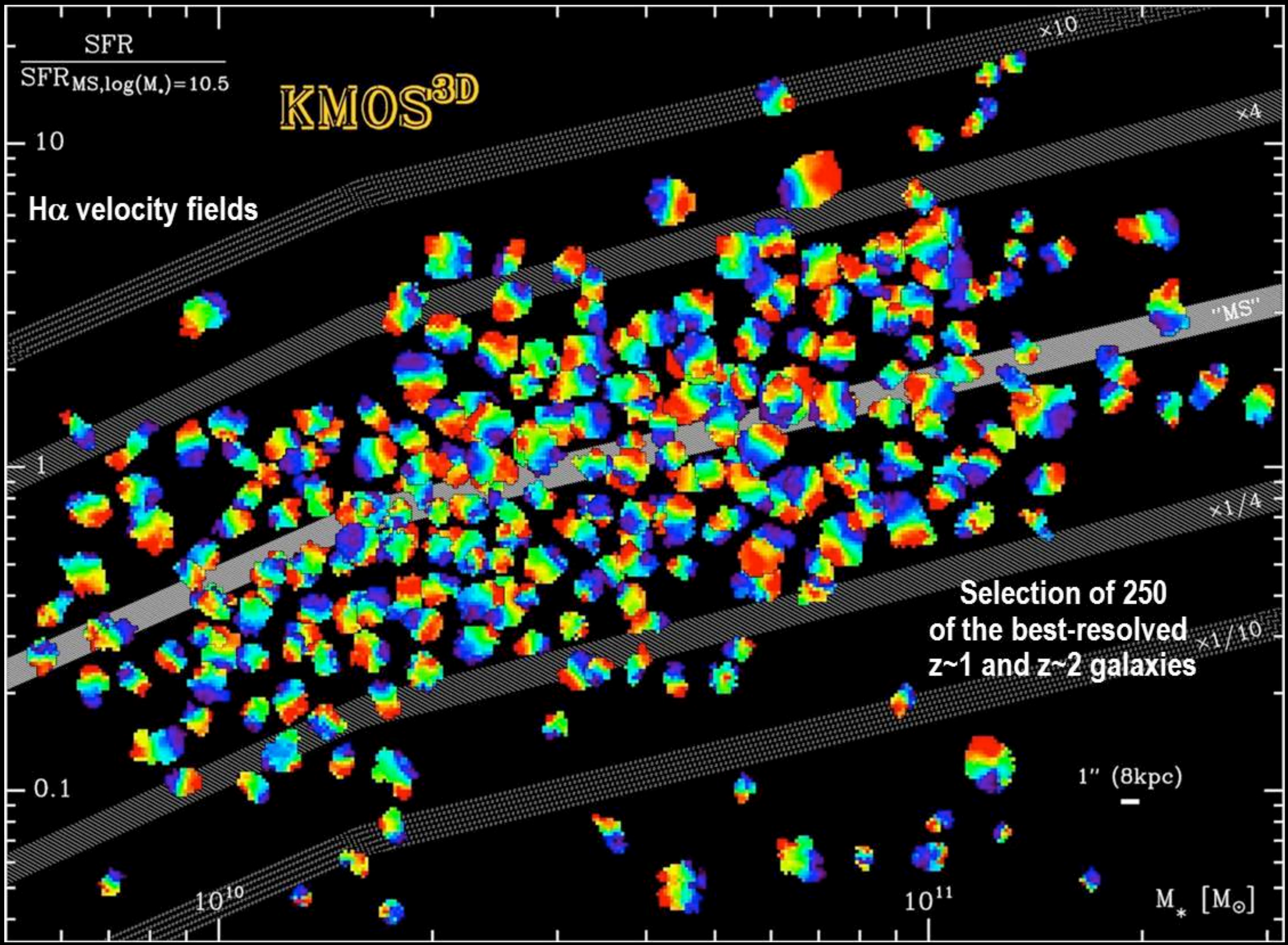
MaNGA

Bundy et al. (2015)



Spatial Resolution

Age of High-z Integral Field Spectroscopy



Wisnioski et al. (2014)

Age of Large Scale IFS Surveys

Visible

★ Several wide integral
spectroscopic surv

★ Focus mainly on n

- SAURON (N$_{g}$
- ATLAS^{3D} (N$_{ga}$
- CALIFA (N$_{gal}$ =
- SAMI (Ongoing)
- MaNGA (Ongoing,

★ **Increasing utility of 2-4 m**
telescopes

?

Infrared

ntegral field
veys

laxies (z~1-4) or
alaxies

0)

g-limited)

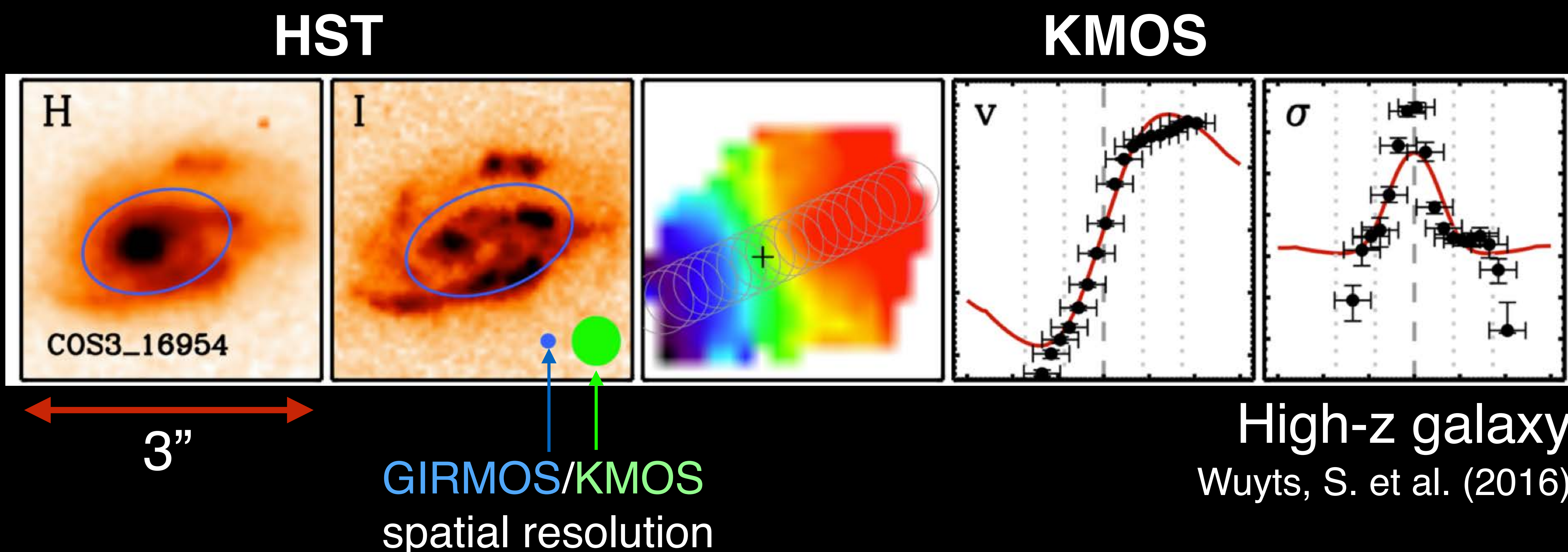
(N$_{gal}$ = 600)

S (N$_{gal}$ = 1000)

s.

re large aperture 8-10 meter class
or larger telescopes and long
integration times

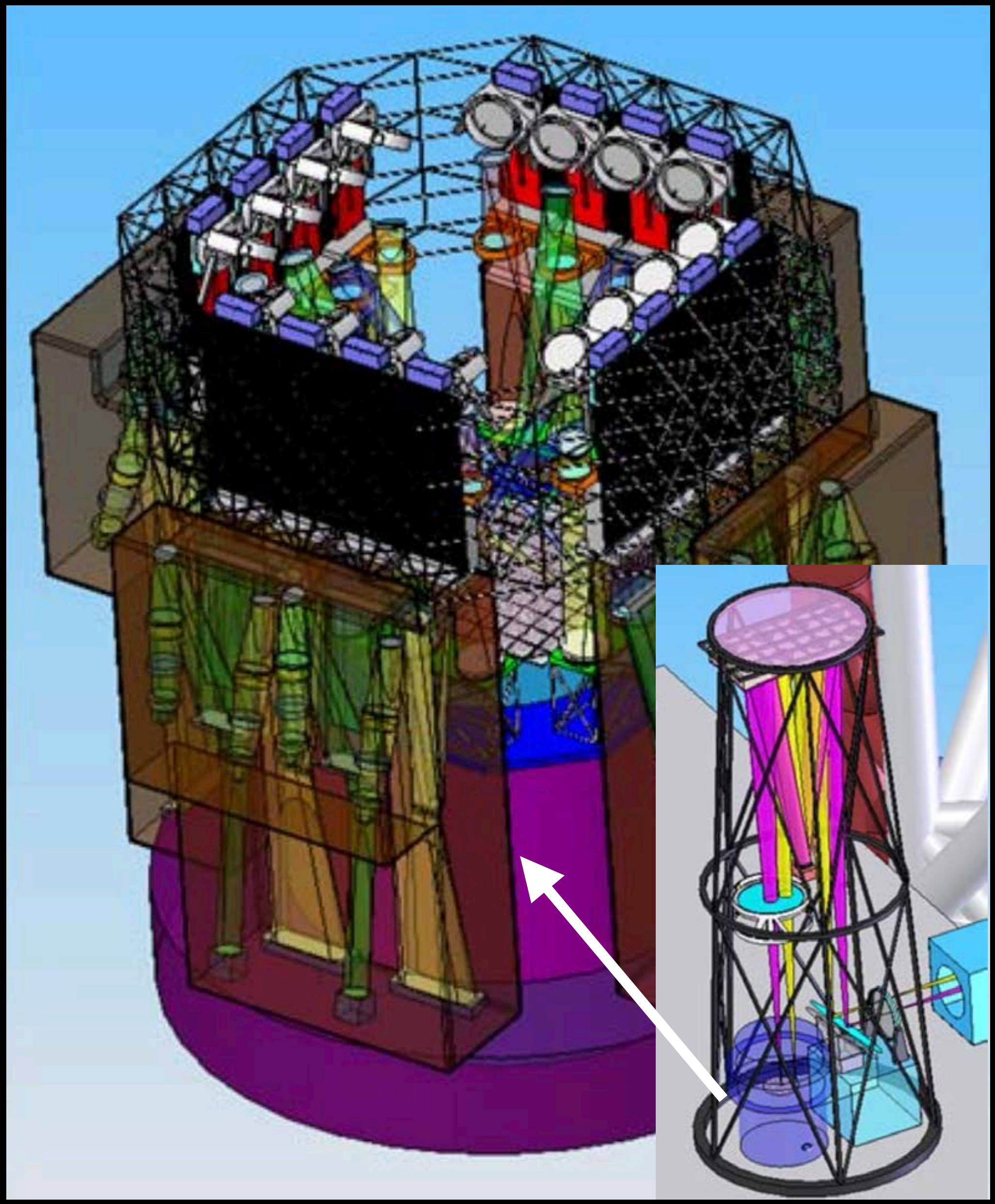
The Need for High Angular Resolution and High Sensitivity



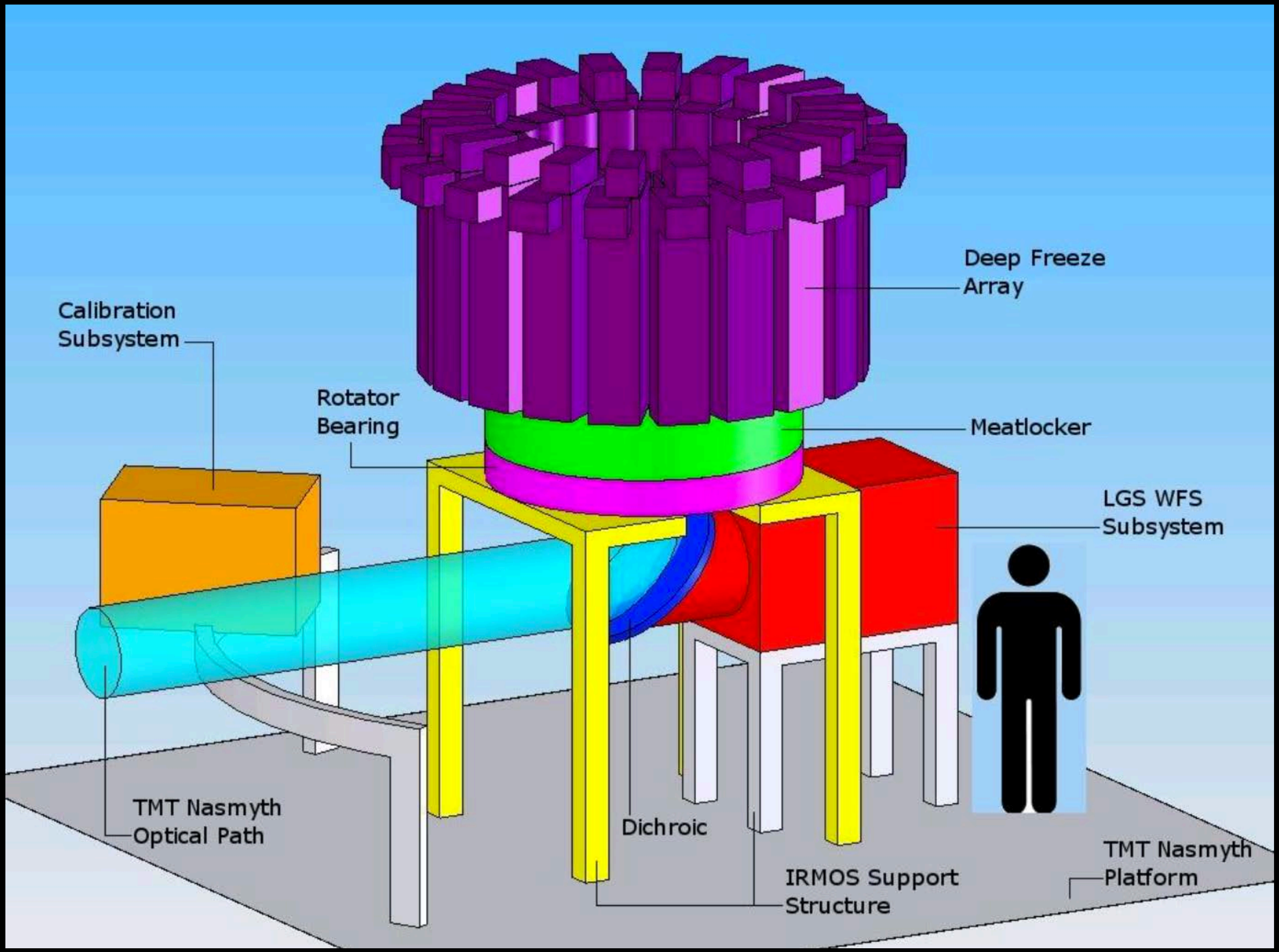
High-z galaxy
Wuyts, S. et al. (2016)

- Existing Multi-IFU instrument (KMOS) does not have sufficient spatial resolution to resolve high-z galaxies in detail
  - SINFONI SINS survey a benchmark for high-z galaxy science
- Increased spatial resolution can resolve individual HII regions at increased sensitivity so long as system throughput is sufficient

Context: Filling the Science and Technology Gap



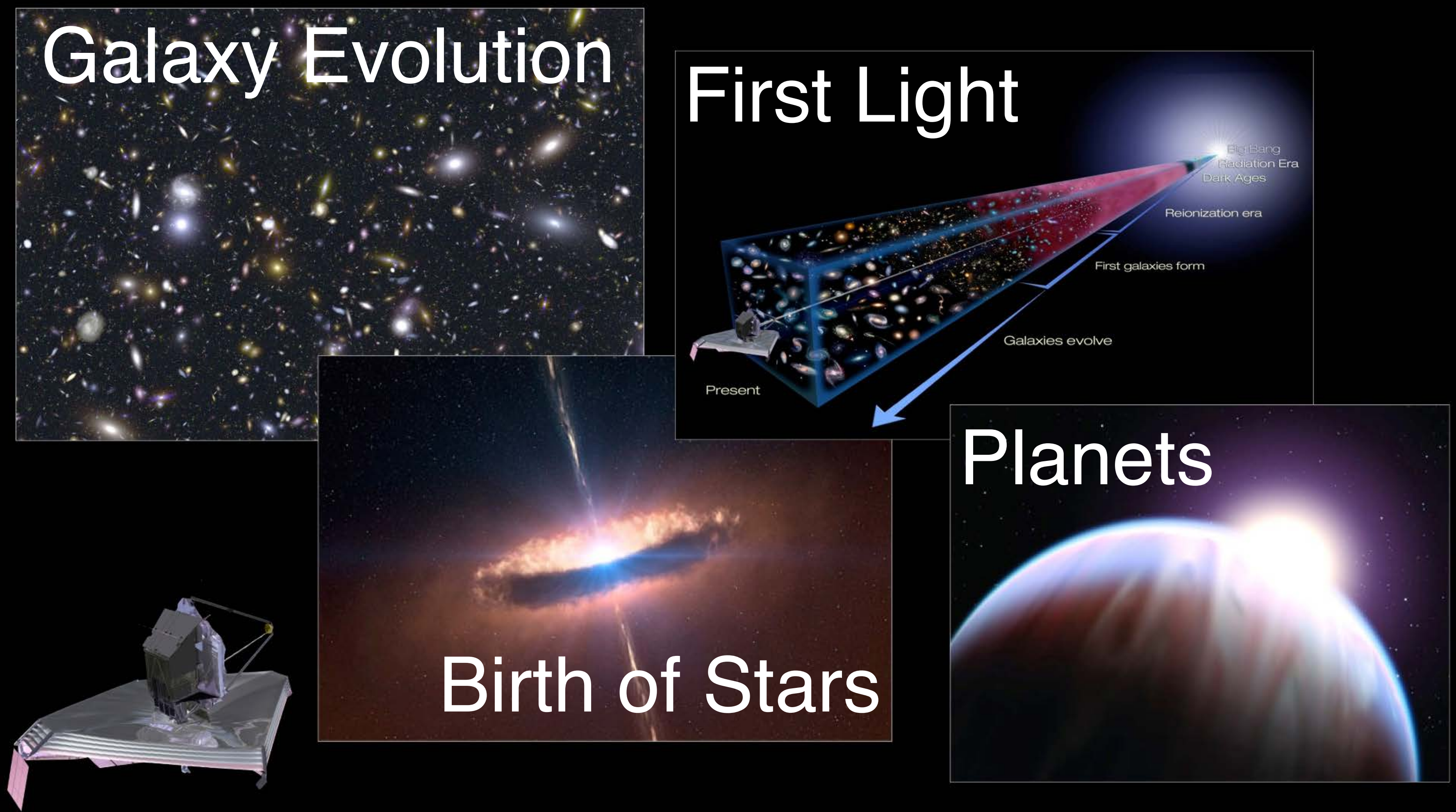
IRMOS-TiPi (Ellis et al. 2006)



IRMOS-UF (Eikenberry et al. 2006)

- **No. 1 in TMT Science Advisory Committee's Priority Ranking**
- **Tall tent poles: Adaptive Optics Feasibility, Complexity, and Cost**
- **Spawned Canadian/Japanese Effort to Develop Multi-Object Adaptive Optics (RAVEN)**

Context: Filling the Science and Technology Gap



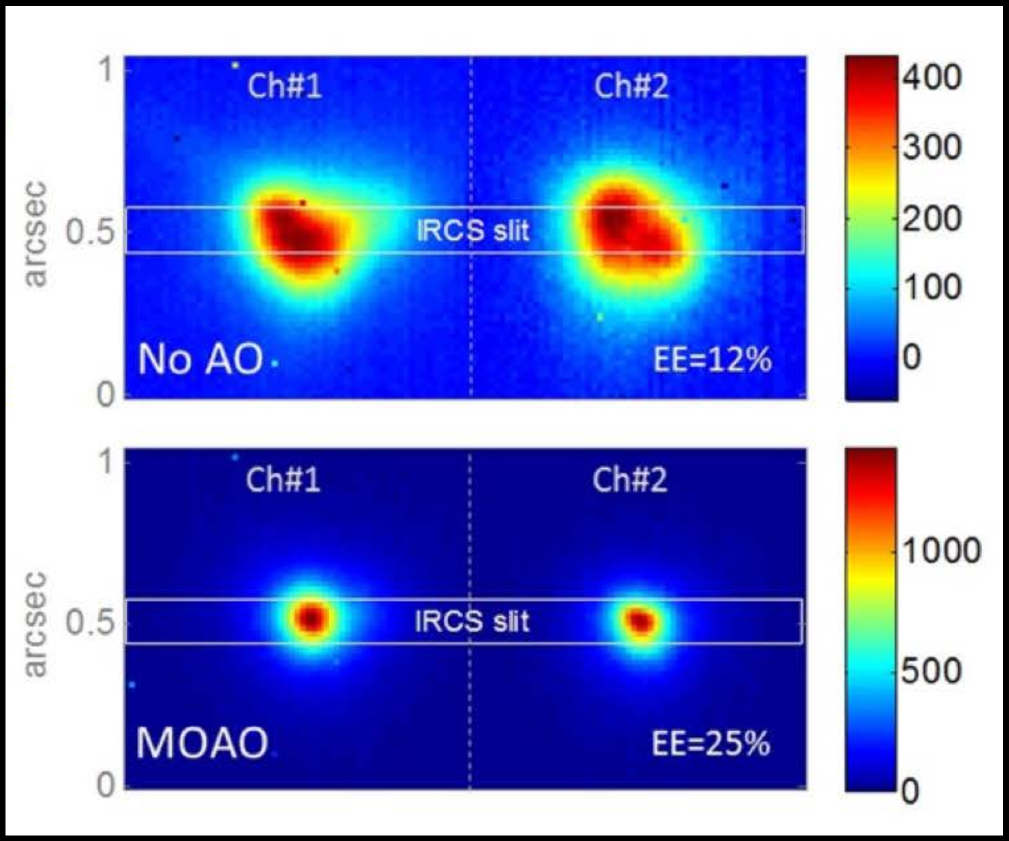
JWST Science Themes (Credit: NASA)

EUCLID Wide-Field Telescope

- **Detailed follow-up observations of exciting JWST and EUCLID targets will be required from the ground in the next decade**
- **Most compelling workhorse instrument: AO-fed, multi-object integral field spectrograph with high spatial resolution and sensitivity**
- **GIRMOS is a pathfinder that can lead to an MOAO-fed TMT instrument**

Leveraging Gemini AO infrastructure and Canadian MOAO expertise

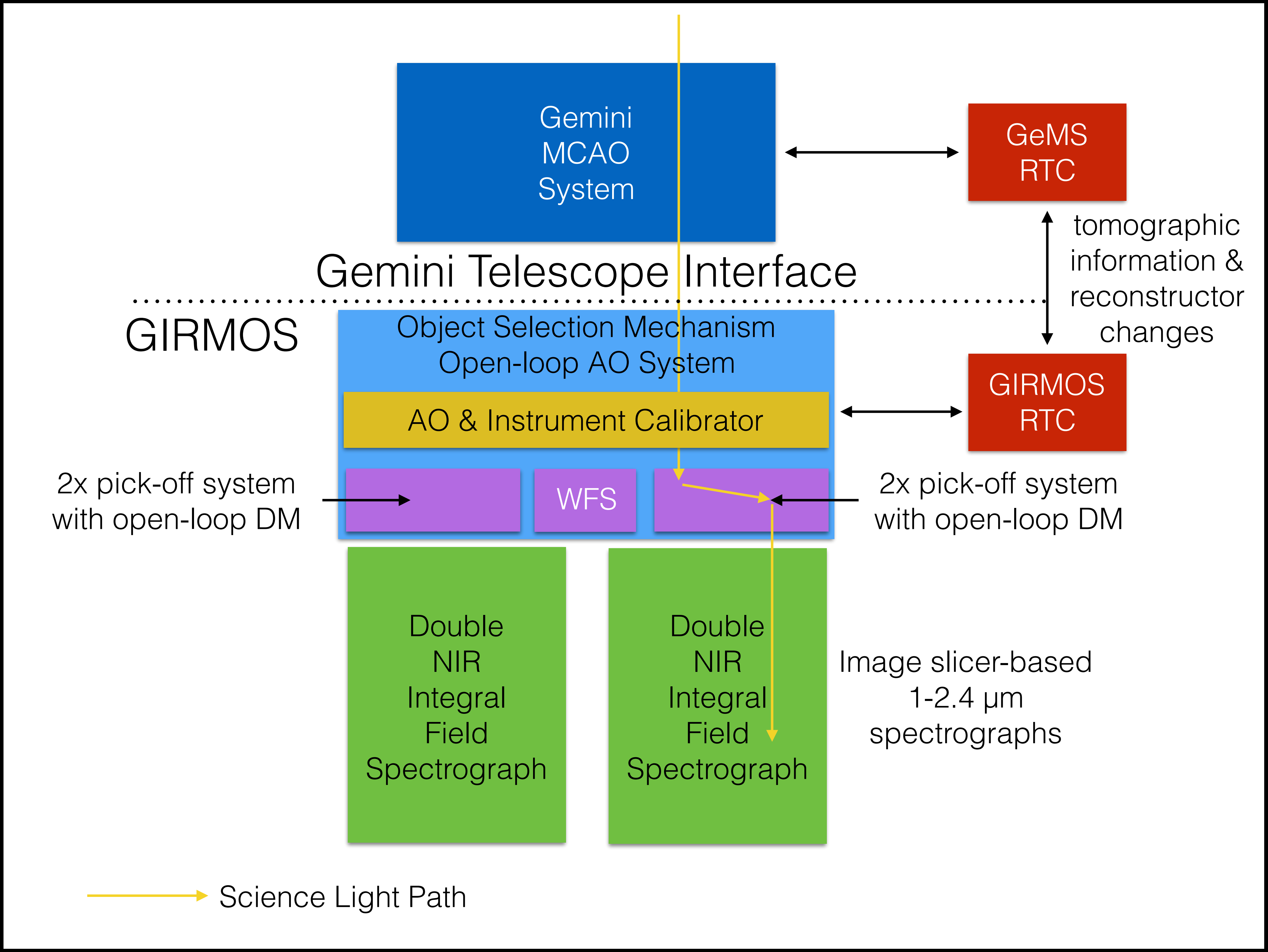
Gemini GeMS MCAO Observation of NGC288
Credit: Gemini



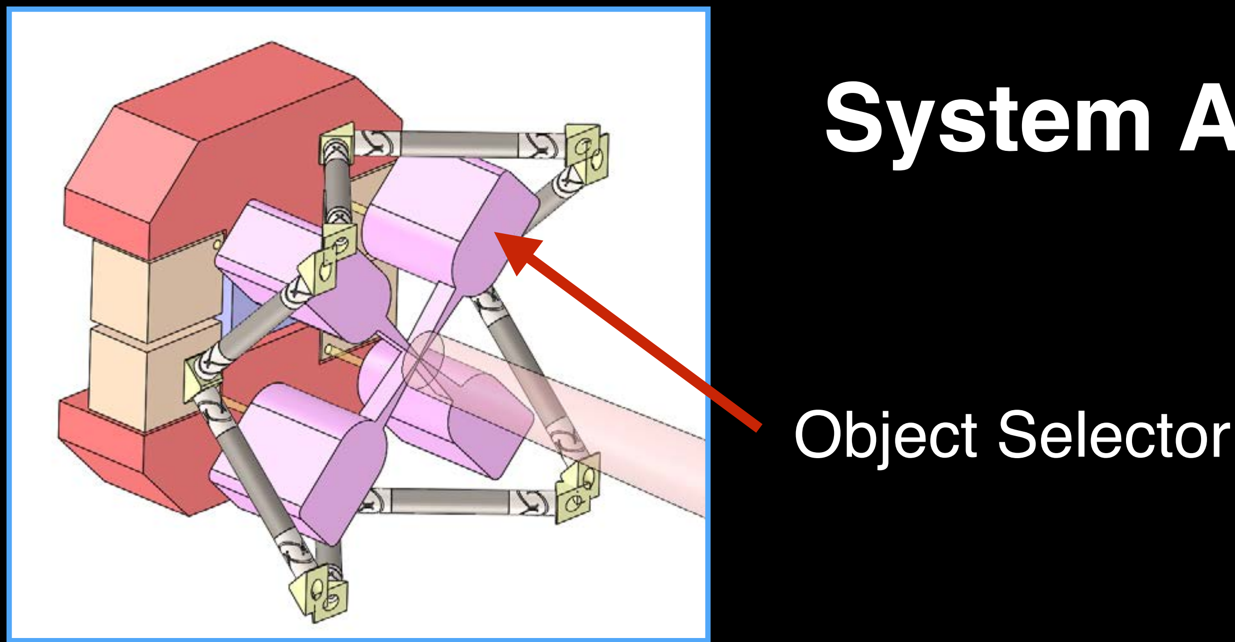
RAVEN MOAO performance on Subaru

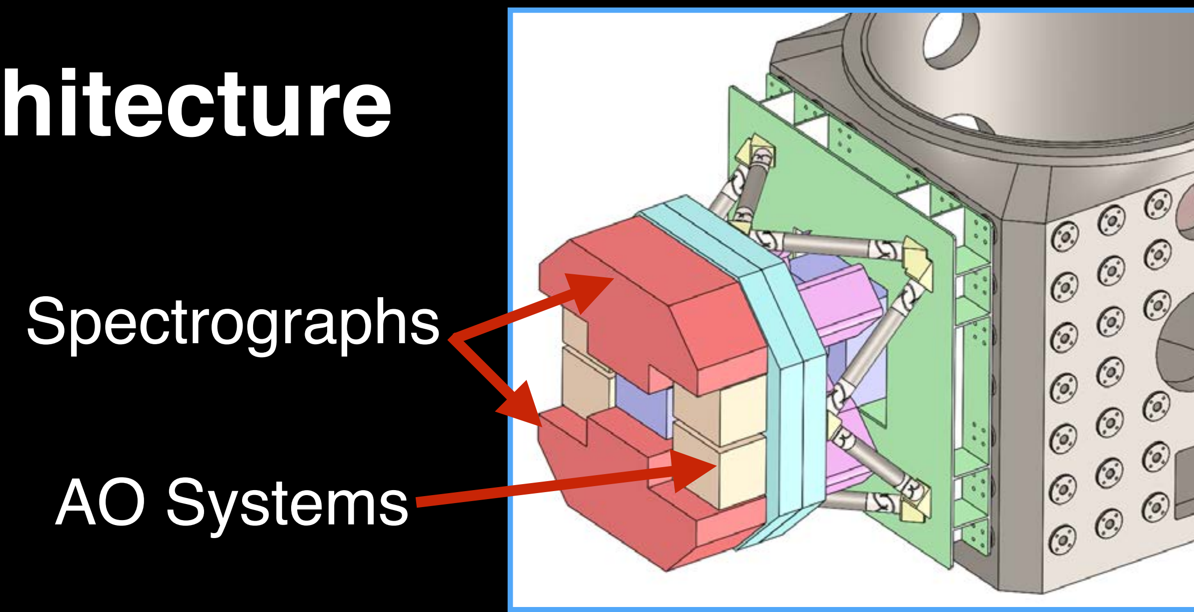
- **GeMS MCAO can correct over a 2' field-of-view with Strehl ratios of ~20-30% in H and K-bands**
  - **Significant upgrades planned over the next year to improve sky coverage and laser performance**
- **Additional MOAO corrections to enhance imaging performance by building upon our RAVEN work on Subaru**

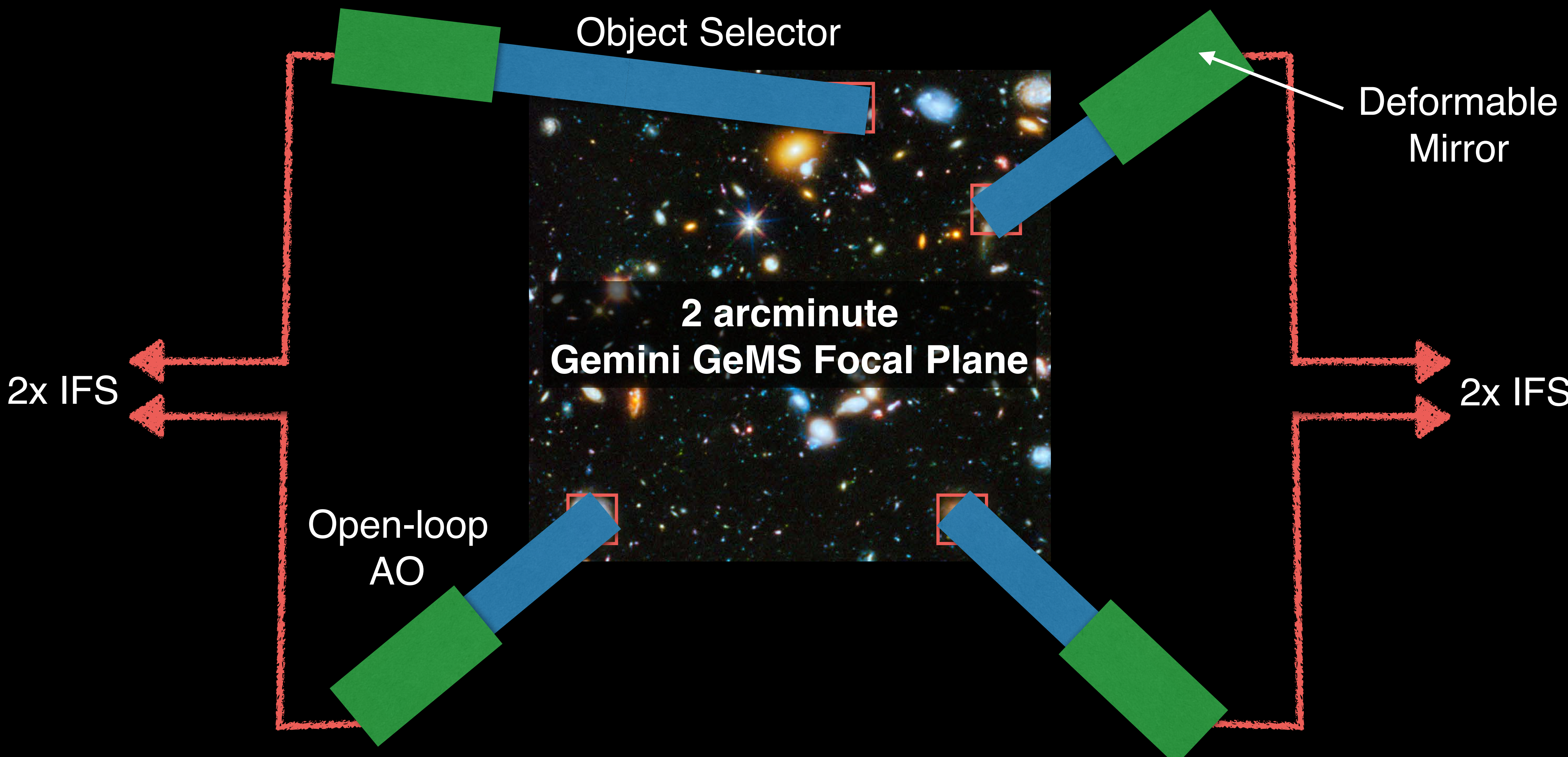
Instrument Block Diagram



System Architecture





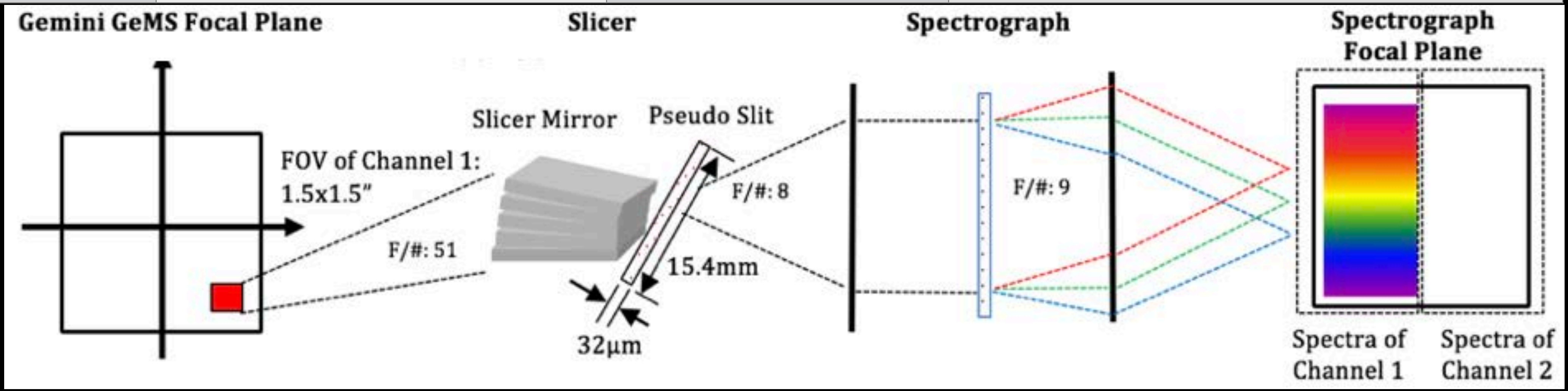


$15M budget

System Parameters

Parameter	*Requirement*	*Parameter*	*Requirement*
Telescope Feed	Gemini-South 8.1-meter MCAO f/33 beam	**Individual IFU Field-of-view (arcsecs)**	0.75x0.75 1.5x1.5 3.0x3.0 6.0x6.0 (Combined)
MOAO Performance	~50% Encircled Energy within 0.1” (H and K-bands)	**Spatial Pixel Size (milli-arcsecs)**	25x25 50x50 100x100 100x100 (Combined)
Field-of-regard	2 arcminute diameter patrol field	**Spectral Resolution R**	3000 or 6000
Wavelength Range	1.1-2.4 µm (J, H, or K-bands)	**Spectrograph Throughput**	>45%
Number of IFUs	4 with possibility for more	**Detector**	2Kx2K HAWAII-2RG for every two spectral channels

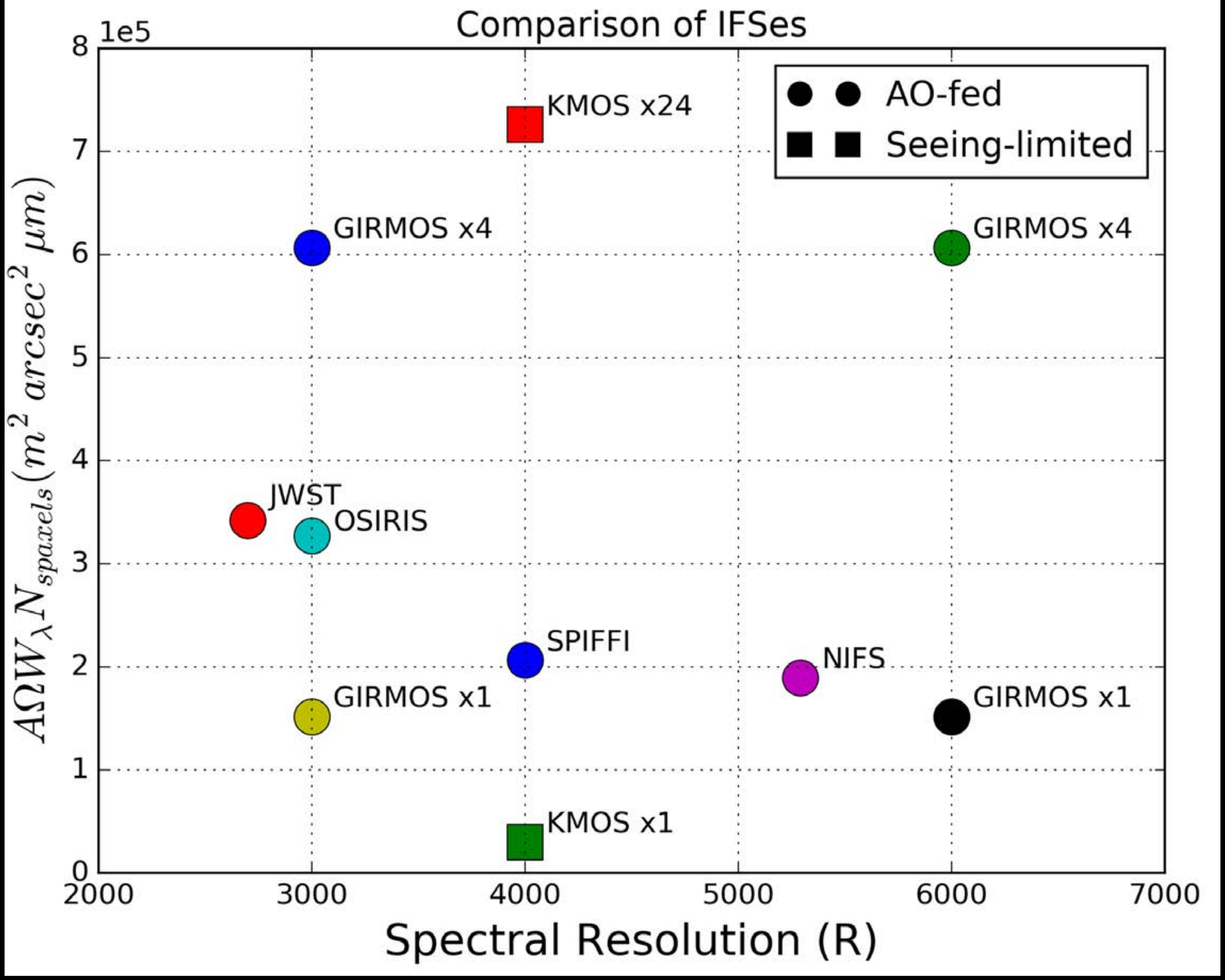
Modular Spectrographs



Comparison with Existing and Future Capabilities

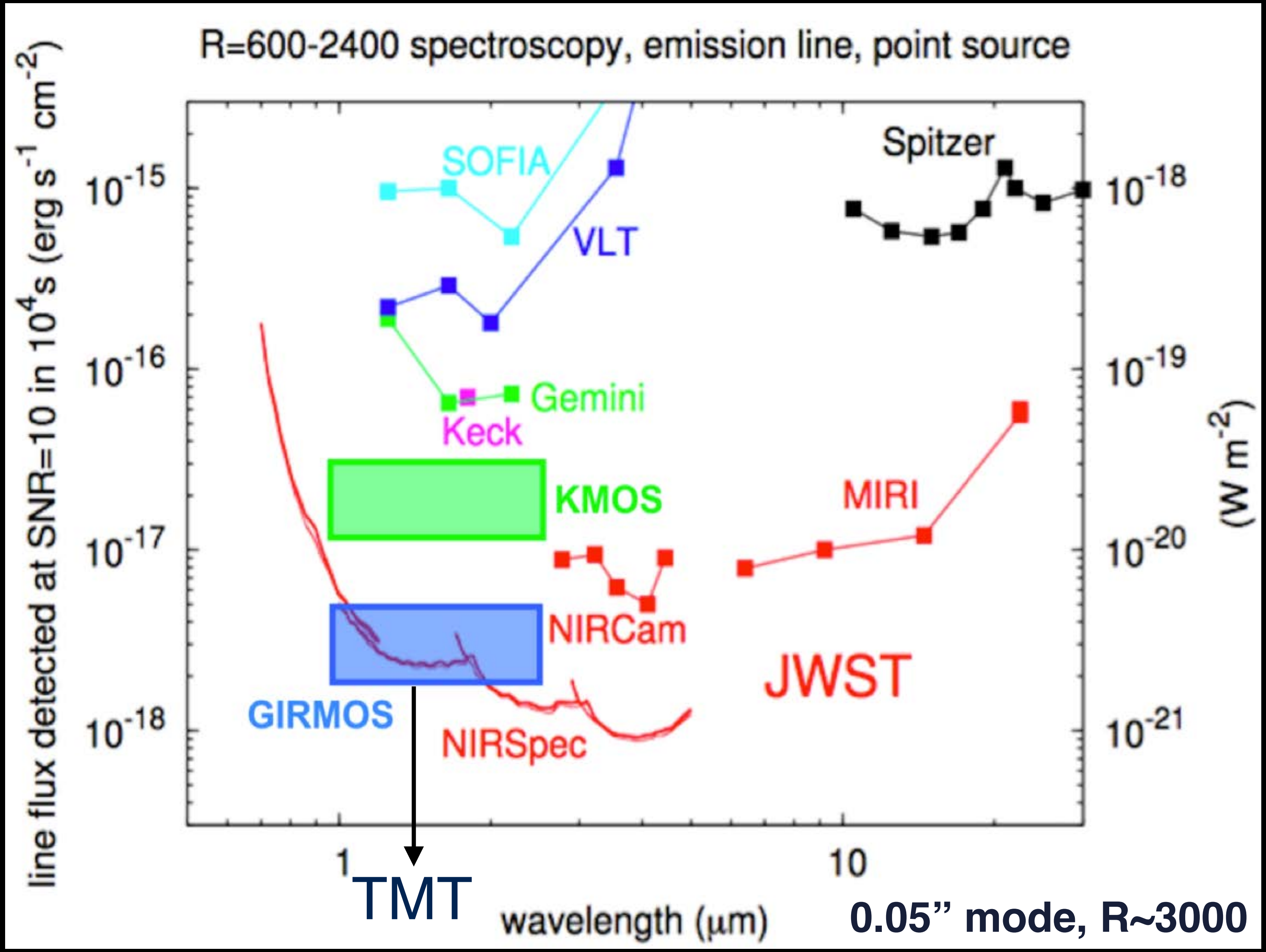
- **Largest field-of-view optimized for maximal information content from z~2-3 galaxy.**
- **GIRMOS is competitive with KMOS in terms of information content despite having 6x less multiplexing.**
    - Upgrade path for additional arms included.
- **GIRMOS will be the most powerful AO-fed instrument for integral-field spectroscopy in the foreseeable future.**
    - GIRMOS can inform ELT instrument development with on-sky scientific and technical experience.

Information Grasp



Information Grasp =
Étendue (Collecting Area * FOV)
x **Wavelength Coverage**
x **# of Spaxels**
(measured for H-band)

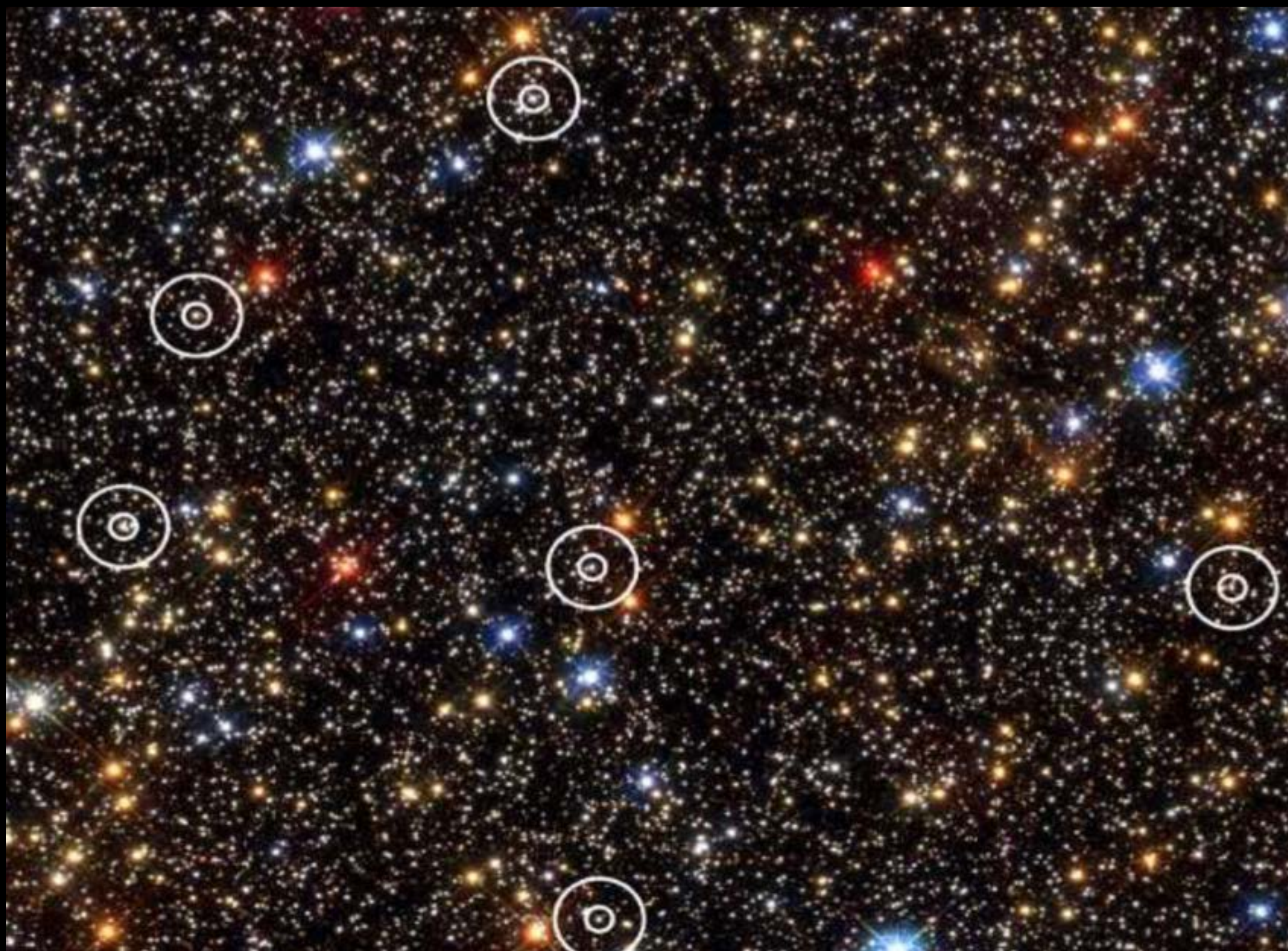
Overall Sensitivity Comparisons



Sensitivity Comparison in between OH lines

- Able to resolve and detect individual star forming regions in typical z~2 galaxies
  - Sensitivity limits reach 1 $M_\odot$ yr^{-1} within a ~0.1" HII region

Key Science Drivers: Galactic Science



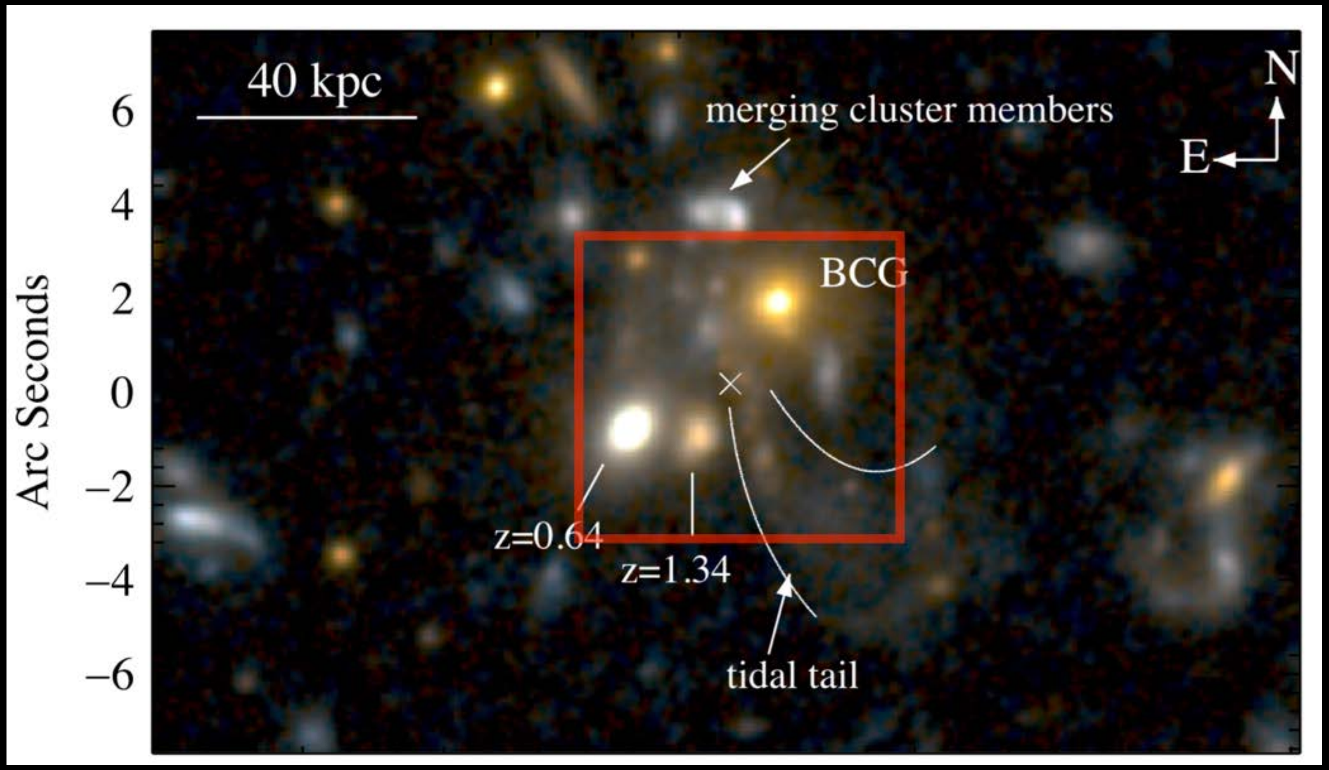
75”x50” field of within the galactic bulge with low metallicity candidates selected from HST SWEEPS WFC3 field. Prime targets are encircled at 2” and 4” to show lack of crowding.

- Near-field cosmology in the Galactic Bulge
  - Low metallicity stars
- Low-mass companion/ exoplanet searches in star clusters
- Star formation within the Milky Way

Key Science Drivers: High-z Science

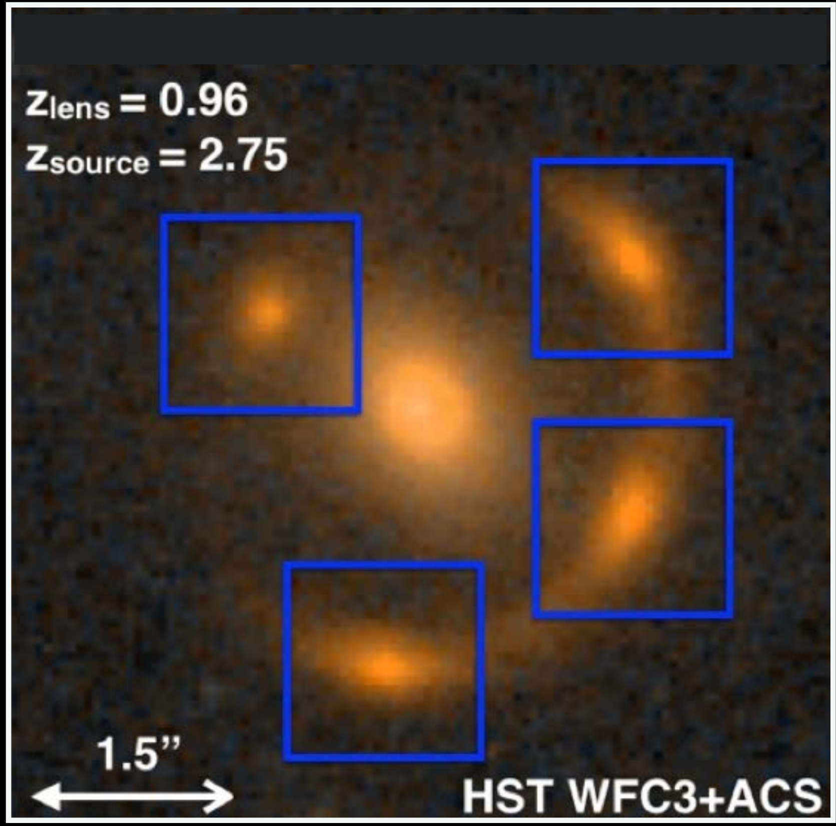
Clusters

Brightest Cluster Galaxy Formation



Hubble Space Telescope (HST) image of SpARCS1049 Cluster, showing the complex morphology of the core (Webb et al. 2015a). The combined GIRMOS field is shown.

Galaxy Lenses



Serendipitously discovered strong lens system, where GIRMOS can excel at obtaining spectra of distant lensed galaxies.

- **In addition to being able to resolve 4 galaxies within each pointing, multiplexing other unique advantages**

Summary

- **Multi-object AO integral field spectroscopy critical for future large surveys**
- **GIRMOS will be the most powerful AO-fed instrument for integral-field spectroscopy in the foreseeable future until ELT multiplexed spectroscopy becomes available**
  - GIRMOS can inform TMT instrument development with on-sky scientific and technical experience
  - Upgrade path for additional arms considered
- **Project consists of an ambitious scientific and technology development plan that will directly benefit a second generation TMT instrument**
- **Expected Commissioning Date: Early 2023**

Gear Moss

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