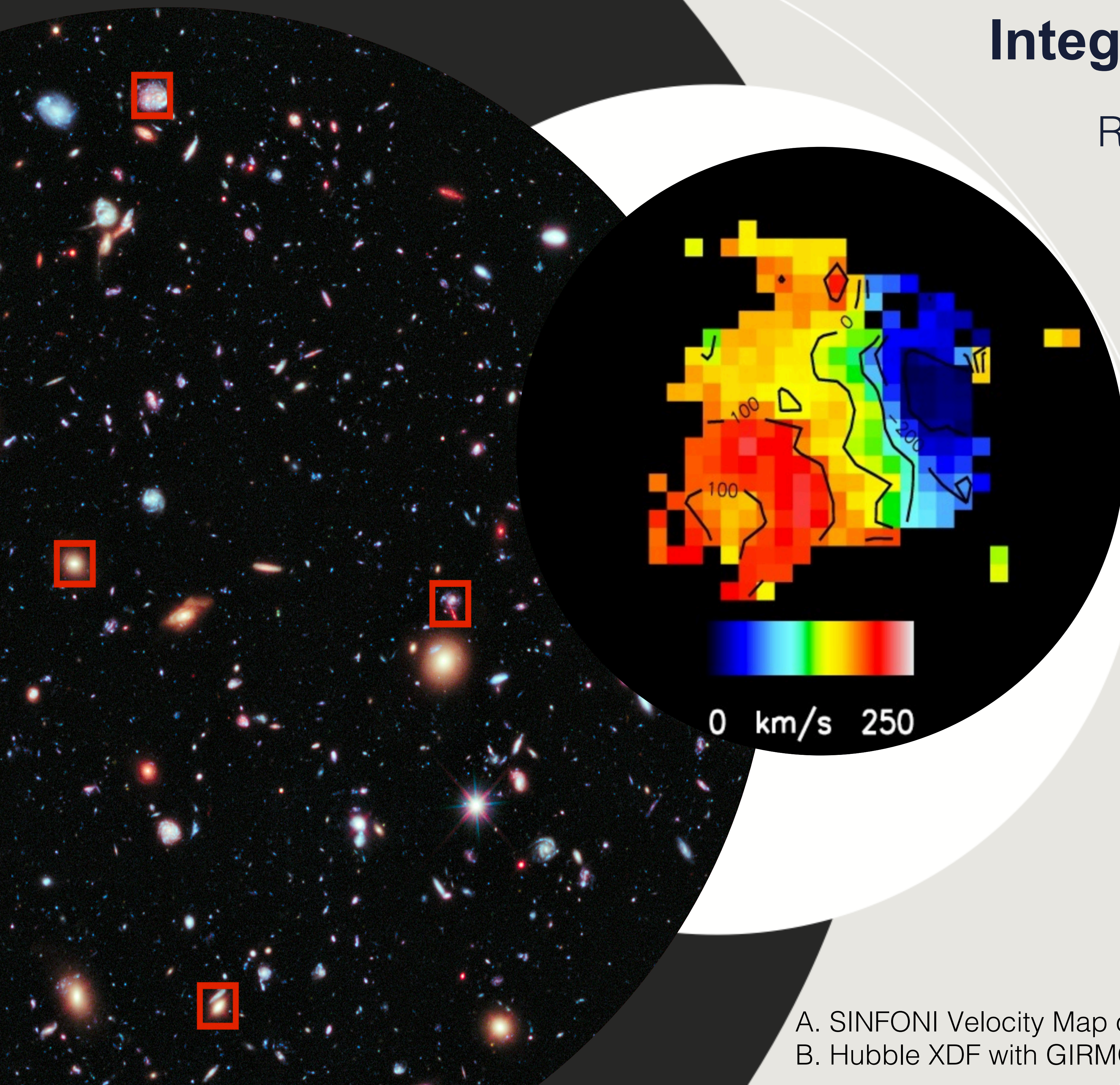
Gemini Infrared
Multi-Object Spectrograph

Science with a Multi-Object Integral Field Spectrograph

Roberto Abraham (Univ. Toronto)
On behalf of the GIRMOS Team



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

DALHOUSIE UNIVERSITY
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UNIVERSITÉ LAVAL
SAINT MARY'S UNIVERSITY SINCE 1802
YORK UNIVERSITÉ UNIVERSITY
University of Victoria
GEMINI OBSERVATORY
Canada
NRC·CNRC
UNIVERSITY OF TORONTO

GIRMOS Science Team

PI: *Suresh Sivanandam*
Deputy-PI: *Scott Chapman*

Project Scientist: *Adam Muzzin*
Project Engineer: *Darren Erickson*

GIRMOS Science

Distant Galaxy Formation and Evolution

Chapman, Sawicki, Damjanov, Abraham, Murray, Man, Ellison, Lemoine-Busserolle, Wisnioski, Mendel

High-z Clusters of Galaxies

Yee, Muzzin

Low Redshift Galaxies and AGN

Sivanandam, Yee, Davidge

Stellar Populations

Sivanandam, Davidge

Globular Clusters and Metal-Poor Stars

Lamb, Webb, Bovy, Turri, Venn, Henault-Brunet

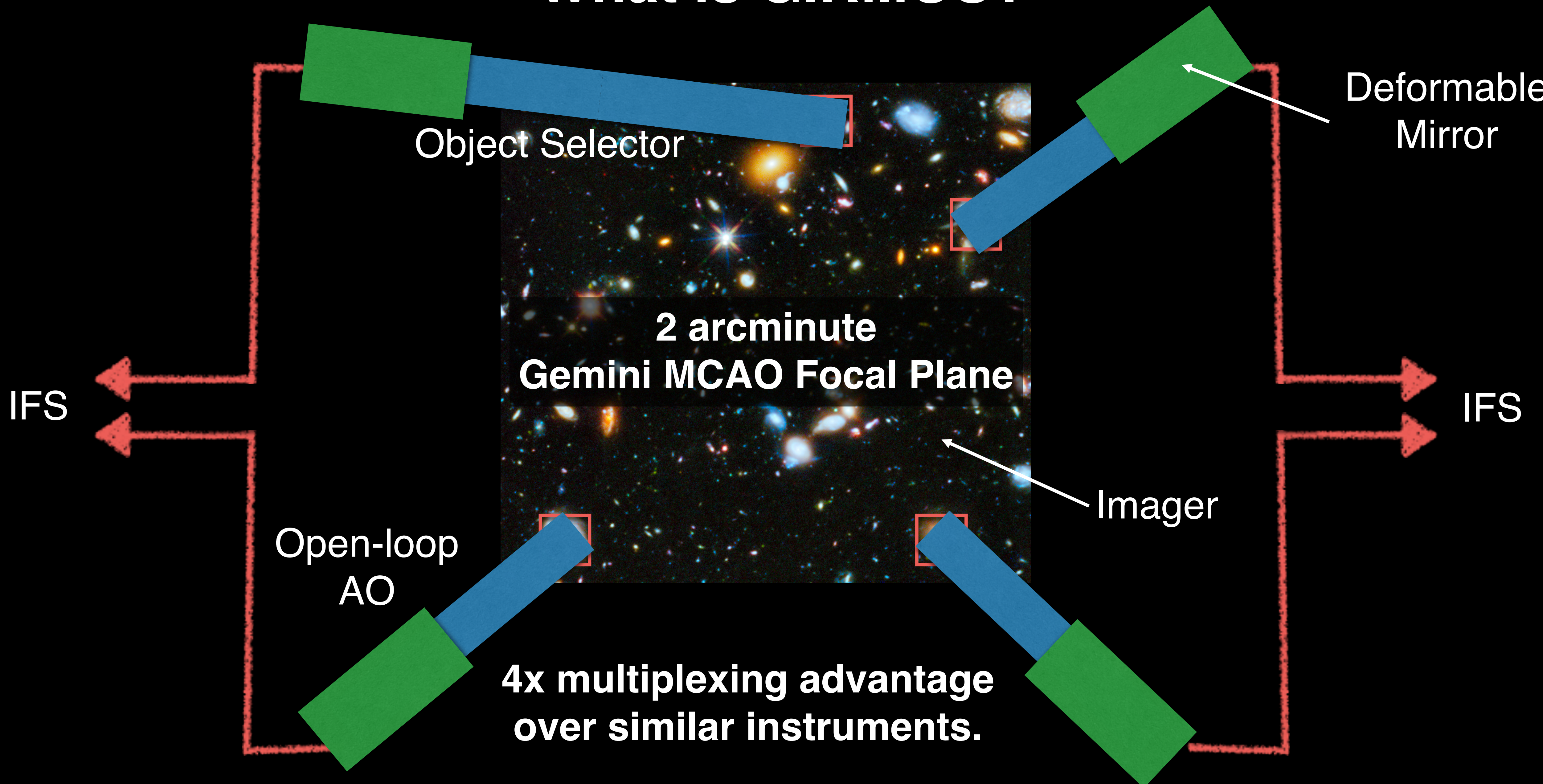
Star Formation

Andersen, McLeod

Gemini Scientific User Community

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

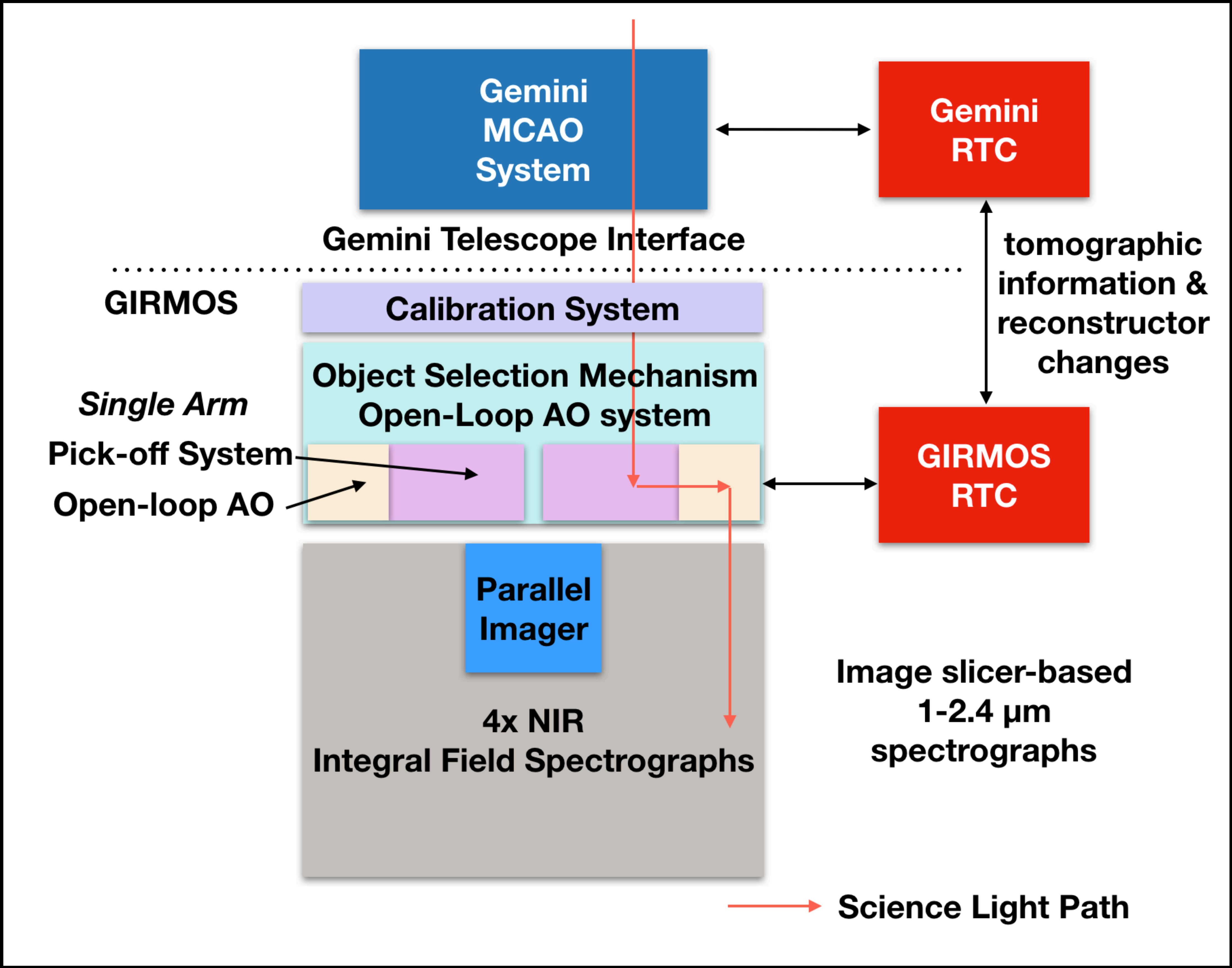
What is GIRMOS?



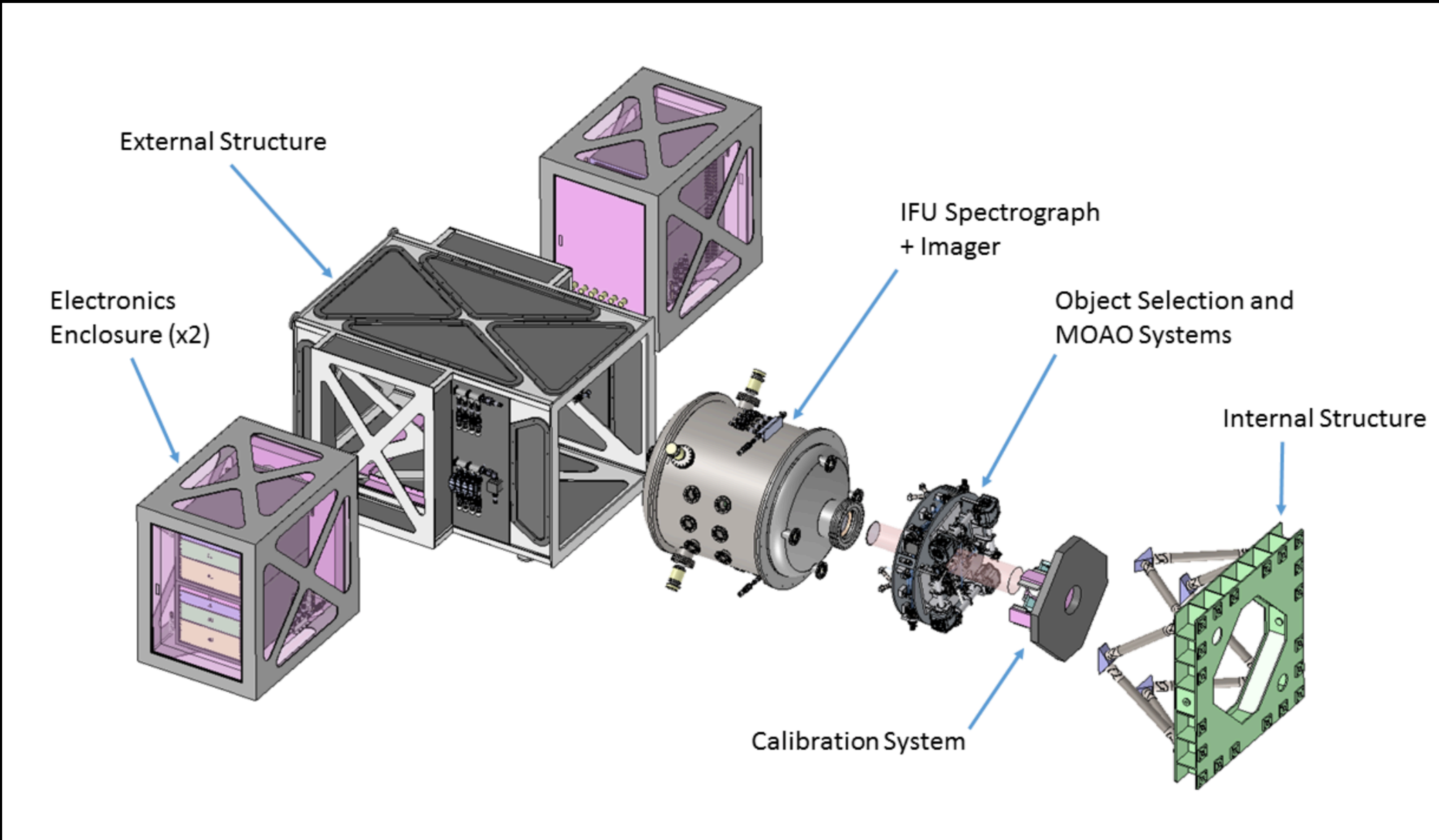
GIRMOS is an AO-fed multi-object integral field spectrograph

- Can simultaneously observe four objects
- Has an additional multi-object AO (MOAO) system that can improve performance over the full MCAO field
- Has a parallel imager that observes the unobscured parts of the field

GIRMOS Block Diagram

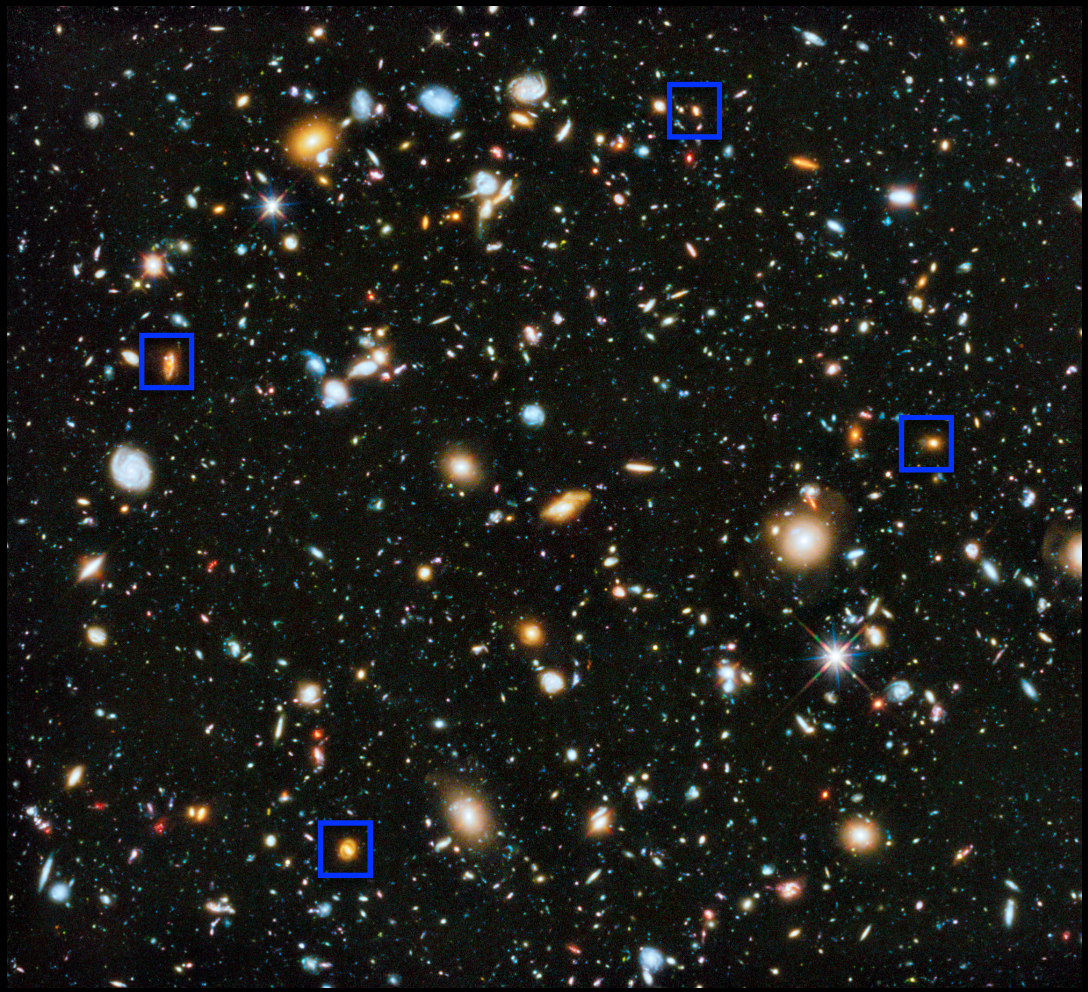


GIRMOS Mechanical Diagram



Successfully completed Conceptual Design Review in Sept. 2019

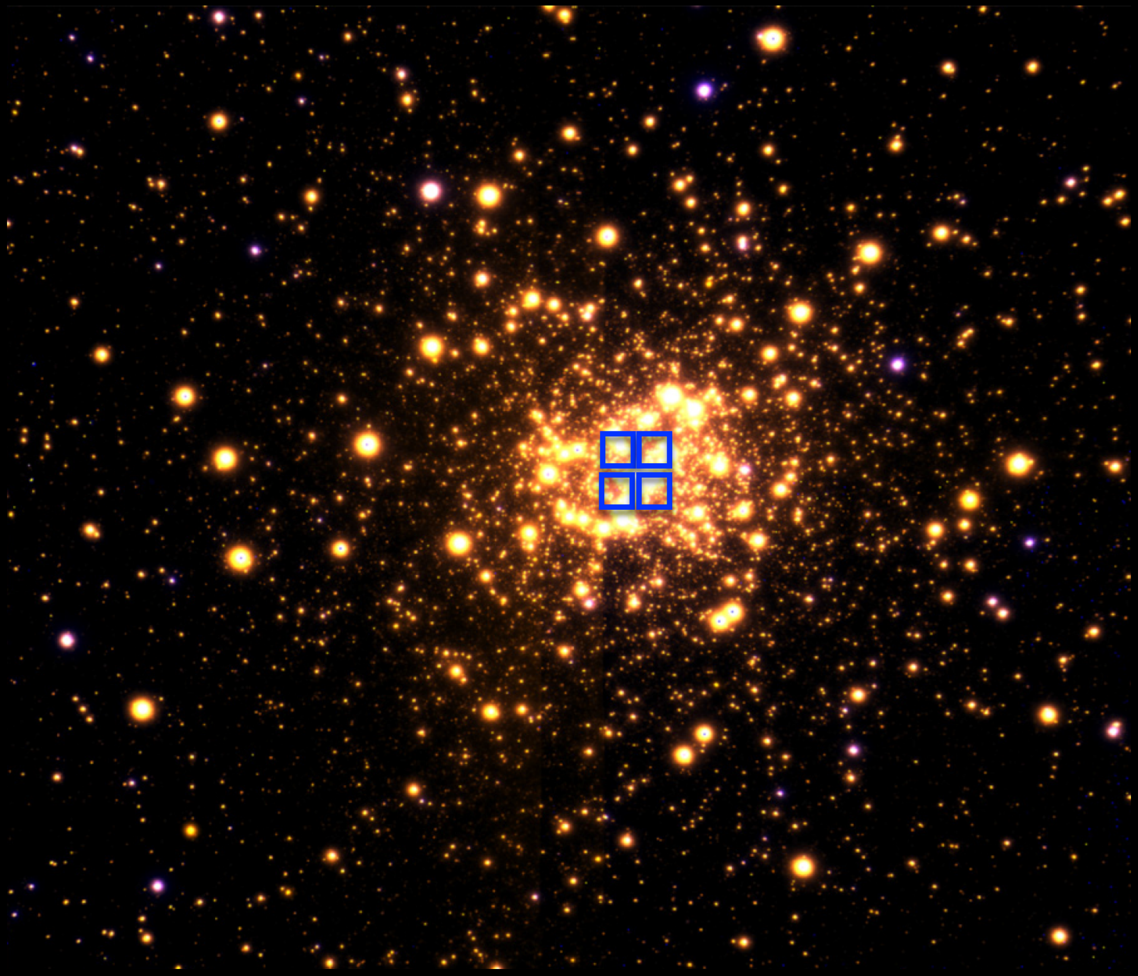
Requested Scientific Modes



Multiple Objects

Pick-off System

MOAO



Single Object

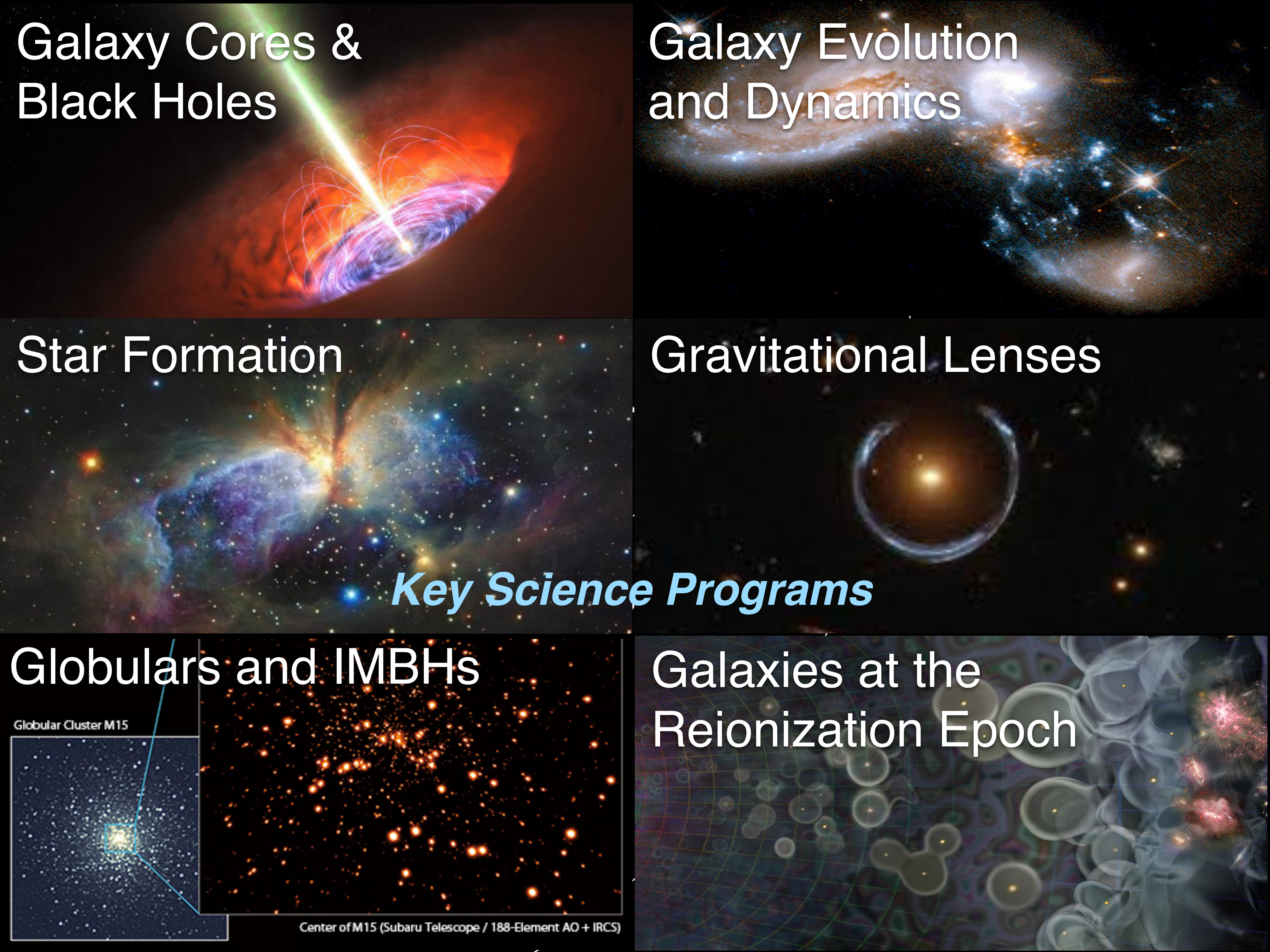
Tiled Super-IFU

LTAO/MCAO

Instrument Parameters

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**	4
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 FOV **(>60% coverage)**	2.0 x 2.0" 4.0 x 4.0" 8.0 x 8.0"	**Spaxel Sampling**	0.025" 0.05" 0.1"
Overall Throughput	35%	**Detectors**	4x HAWAII-2RG 2Kx2K
Imager FOV	85 x 85"	**Imager Plate Scale**	0.025"
Image Wavelength Range	1.1 – 2.4 µm	**Imager Detector**	1x HAWAII-4RG 4Kx4K

Proposal submitted for Phase A study of incorporating GNAOI into GIRMOS


Galaxy Cores & Black Holes
Galaxy Evolution and Dynamics
Star Formation
Gravitational Lenses
Key Science Programs
Globulars and IMBHs
Globular Cluster M15
Center of M15 (Subaru Telescope / 188-Element AO + IRCS)
Galaxies at the Reionization Epoch

GIRMOS Galactic and Nearby Galaxy Science Cases

1. **An AO-assisted survey probing the inner regions of Galactic Globular Clusters (Lamb**, Henault-Brunet, Webb, Bovy, Venn)

2. **Stellar Chemodynamics and the Nuclear Star Cluster Around the SMBH of the Milky Way** (Lamb, Turri, Venn)

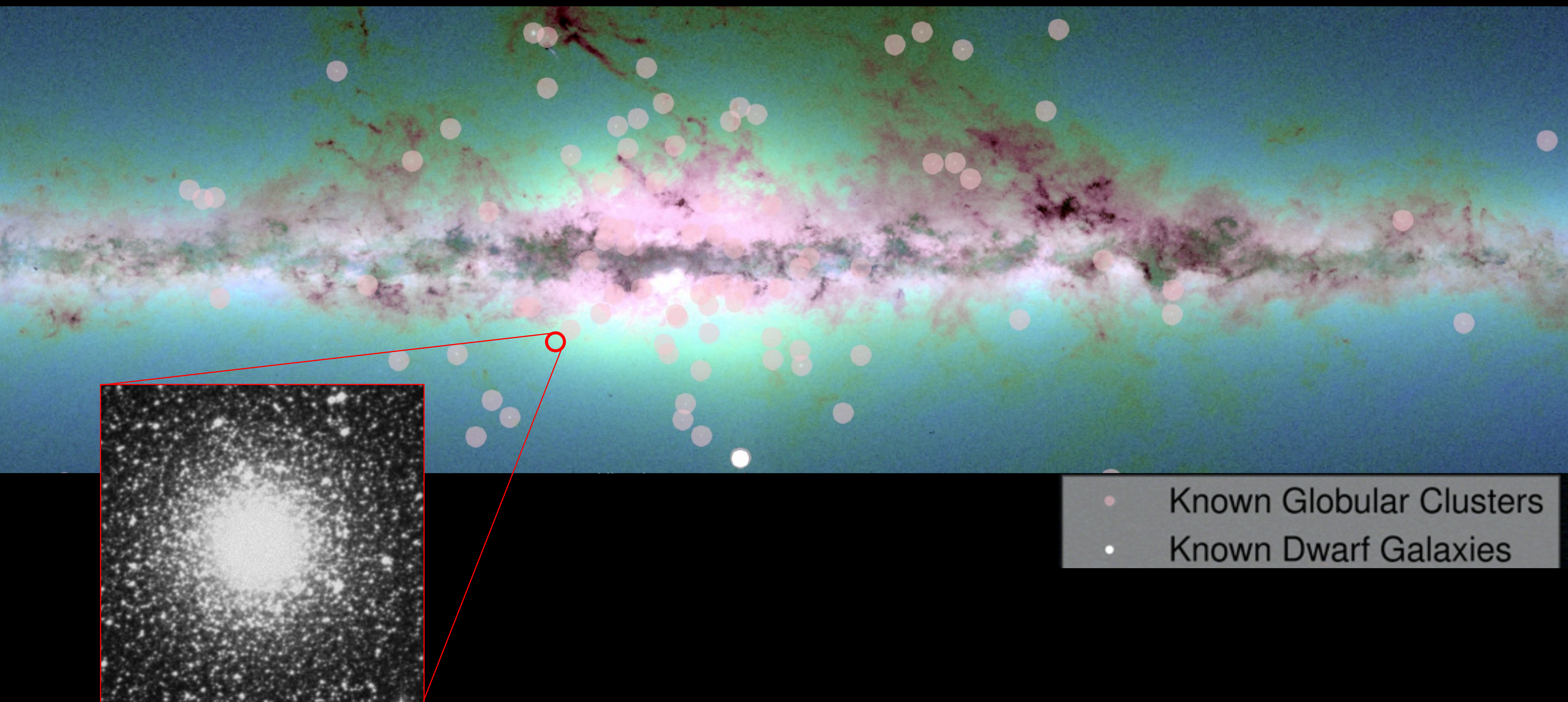
3. **Young Star Clusters and Photo-dissociation Regions** (McLeod)

4. **Young Resolved Massive Star Cluster Formation and Evolution** (Andersen)

5. **Stellar Populations of Nearby Starburst Galaxies** (Davidge)

Globular Cluster Internal Dynamics Survey

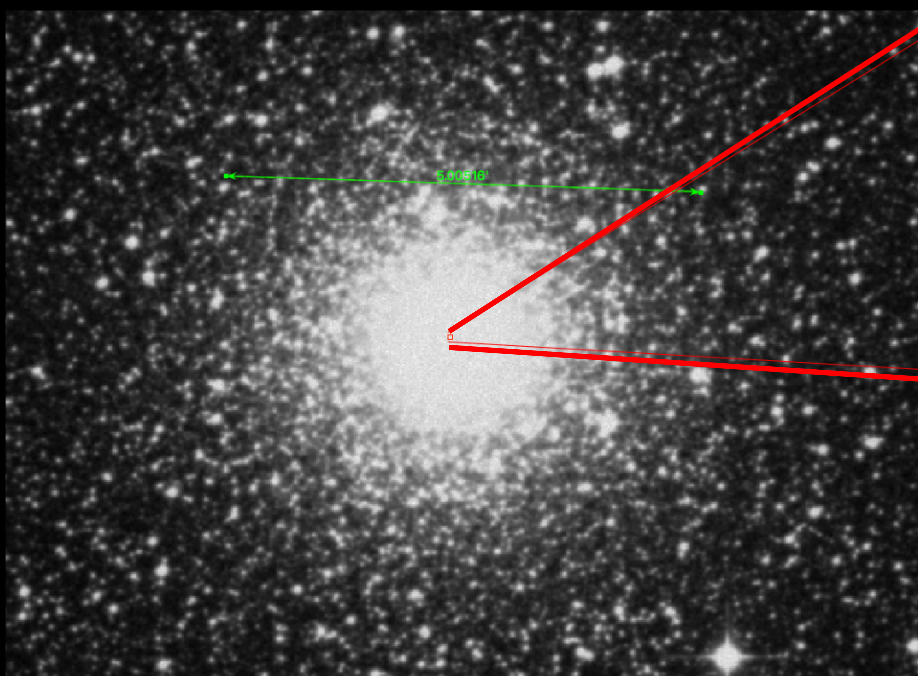
M. Lamb, V. Henault-Brunet, J. Webb, J. Bovy, K.Venn

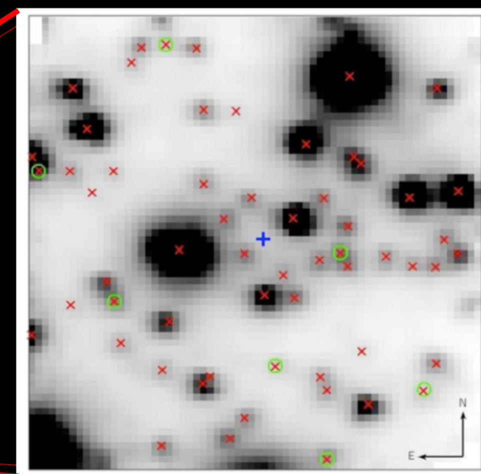


Globular Cluster Science Example: SINFONI + AO

Search for Intermediate Mass Black Holes

Resolved stars in crowded core



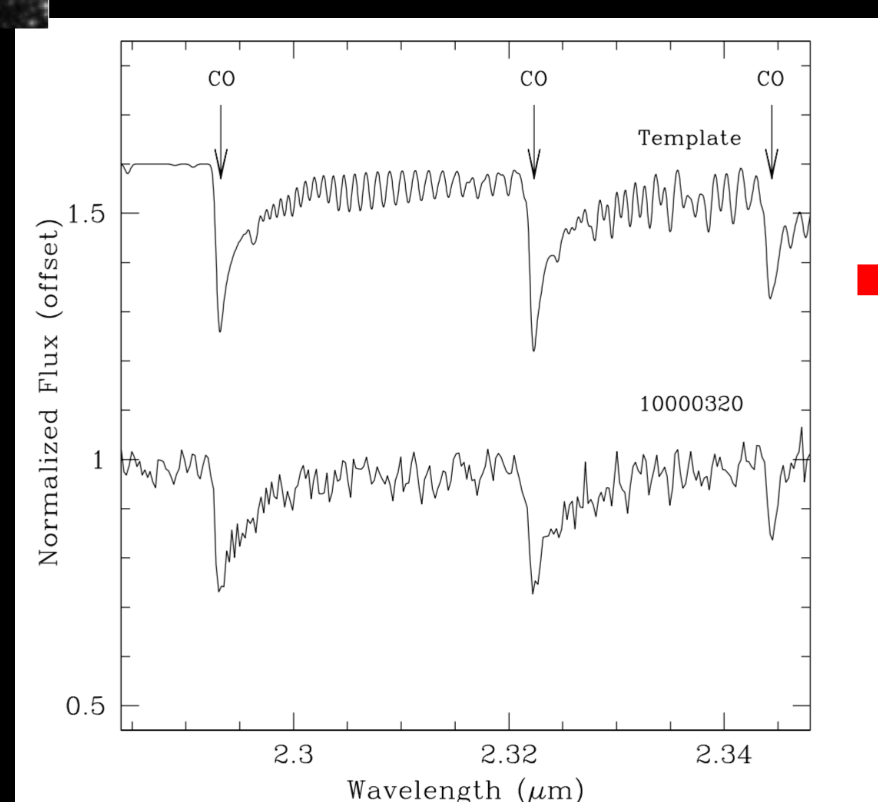


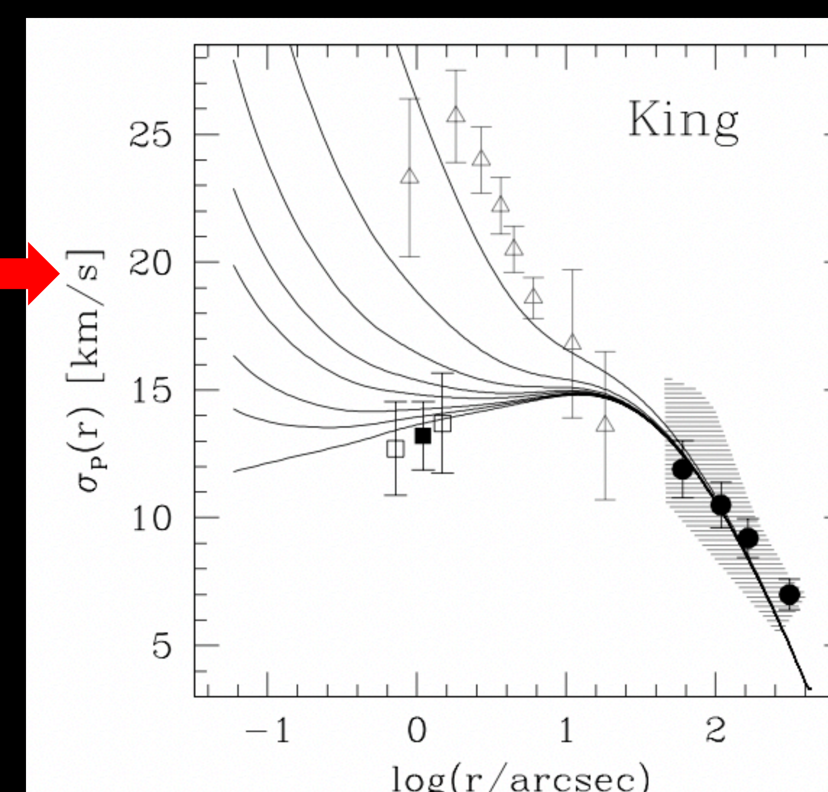
NGC 6388:

- Massive (10^6 M_{sun})
- Bulge Cluster
- Sample: 50+

Search for increased velocity dispersion in cluster cores

e.g. Lanzoni+ 2013

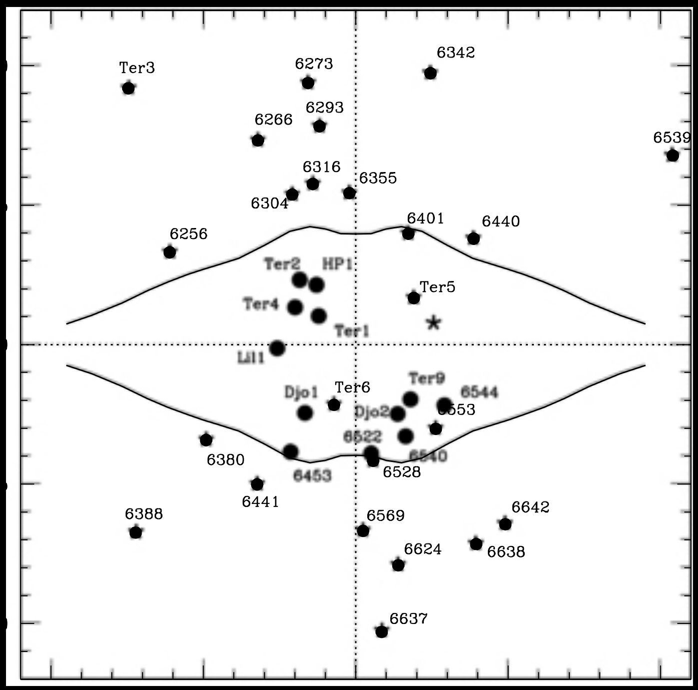




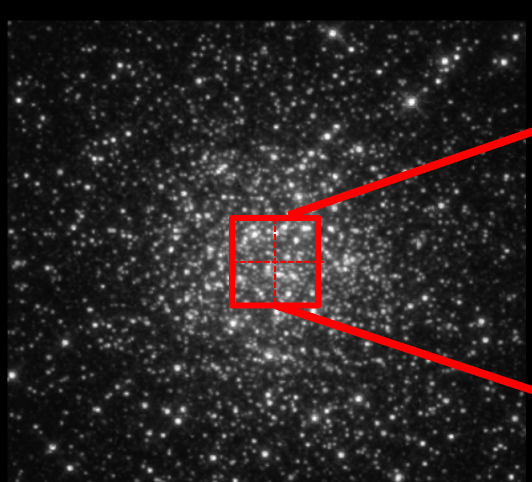
GC Survey Motivation

- IMBHs are a missing link between stellar and SMBHs; so far have proved elusive
- Thought to be in massive GCs
- 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”
    - Little known about GC internal core dynamics: aim to **survey > 20 GCs** with characterized internal dynamics

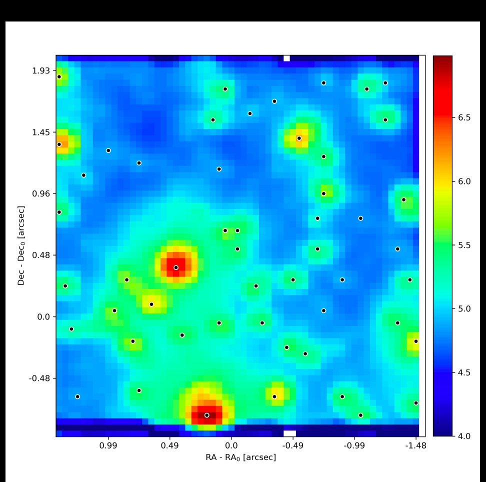
Bulge clusters:



Valenti 2007,2010



NIFS Data



NIFS+ALTAIR Terzan 5 pilot study underway (Butko, Lamb+ in prep)

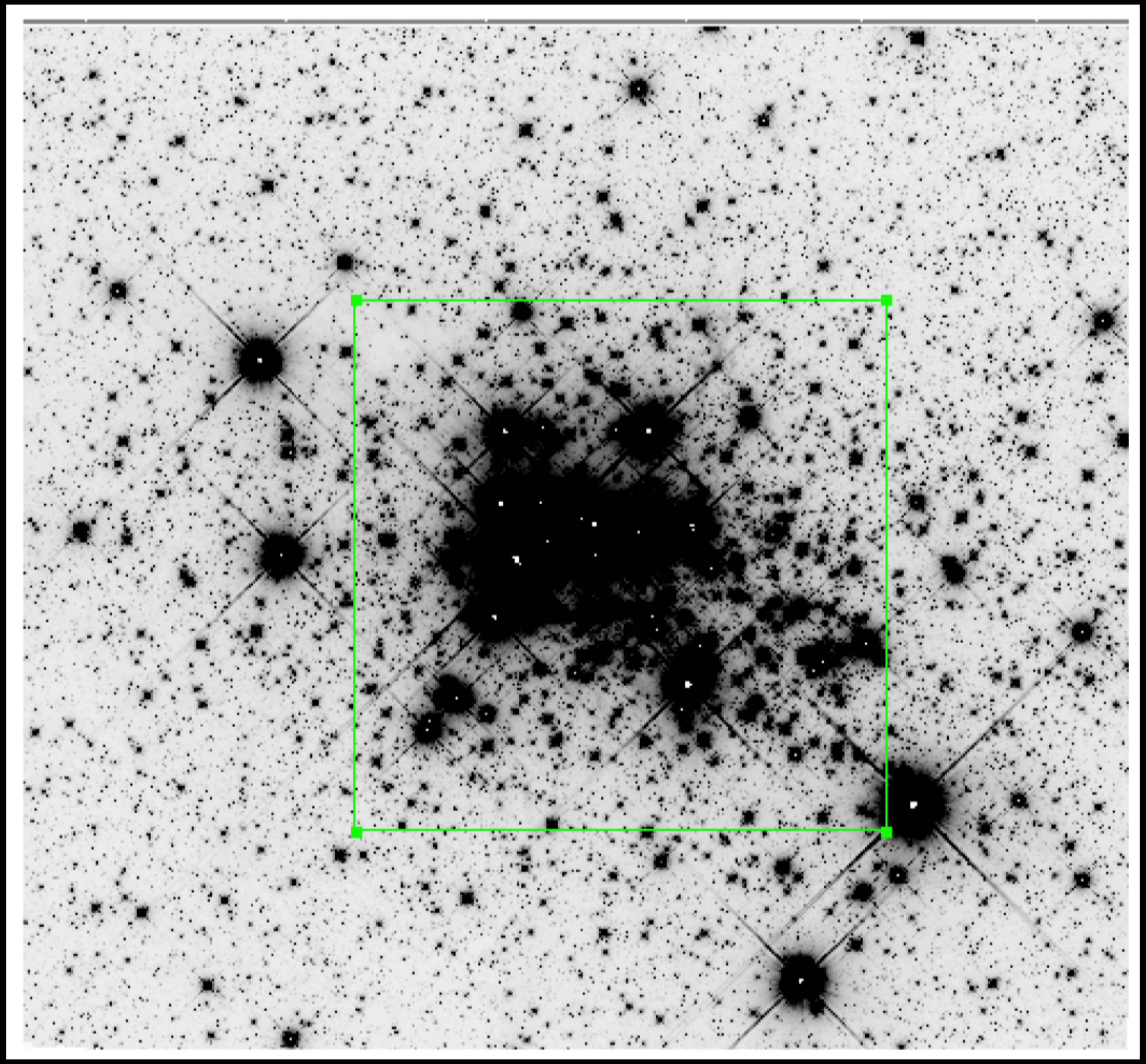
Young, Resolved Massive Star Clusters

M. Andersen

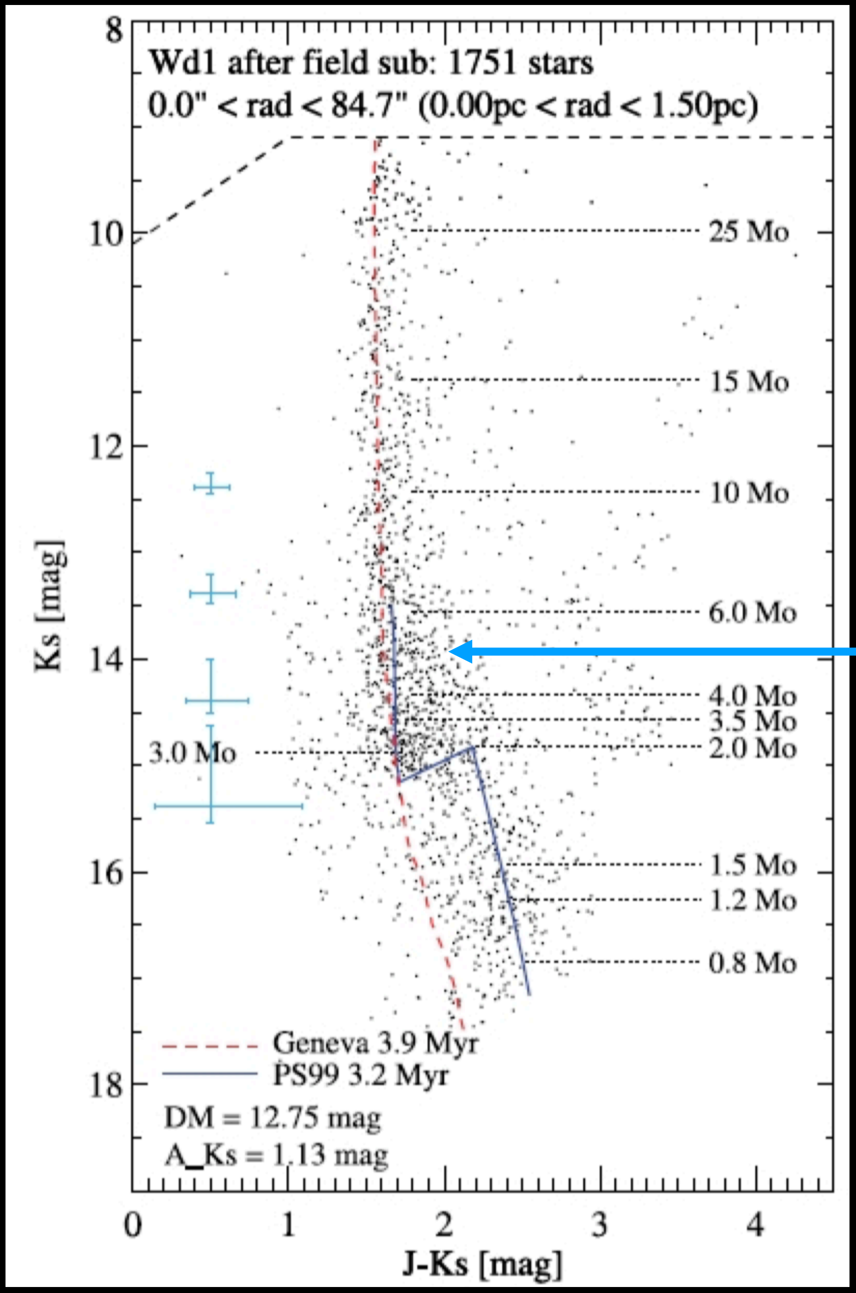
Hodge 301,
NASA/ESA/D. Lennon

Spectral Typing and Age Dating in Massive Clusters

Example YMC target: Westerlund 1



90"



Seeing-limited

GIRMOS can address the noisy HRD

Multi-object spectroscopy can:

Place a representative sample of objects in the HR diagram, instead of relying on colors (spectral typing instead of photometry)

- Will enable a more accurate measure of age spreads within the clusters. Will enable more accurate mass estimates for the individual stars.

-> R=3000, 10+" FOV, 50-100 mas sampling required

- At higher spectral resolutions with high SNR, the velocity dispersion can be estimated. Will the clusters remain bound or disperse into the field?

-> R=8000, 10+" FOV, 50-100 mas sampling required

- Near-IR is crucial due to high extinction, 20 Av or more. Has limited optical studies to only the most massive stars. Optical observations cannot reach the pre-main sequence/main sequence transition where the age information is.

GIRMOS can give age and kinematic information

GIRMOS Extragalactic Science Cases

1. **Kinematics, Star-formation, Metallicities and Stellar Populations of Galaxies at $0.7 < z < 2.7$** (Lemoine-Busserolle, Damjanov, Ellison, Wisnioski, Mendel, Man, Muzzin)

2. **Observations of Distant Galaxy Clusters and Groups: Observing Galaxy Quenching and the Role of Environment at Early Times** (Muzzin, Yee)

3. **Starburst Galaxies at $z > 2$** (Chapman)

4. **A Survey of Massive Quiescent Galaxies at $z > 2$** (Man)

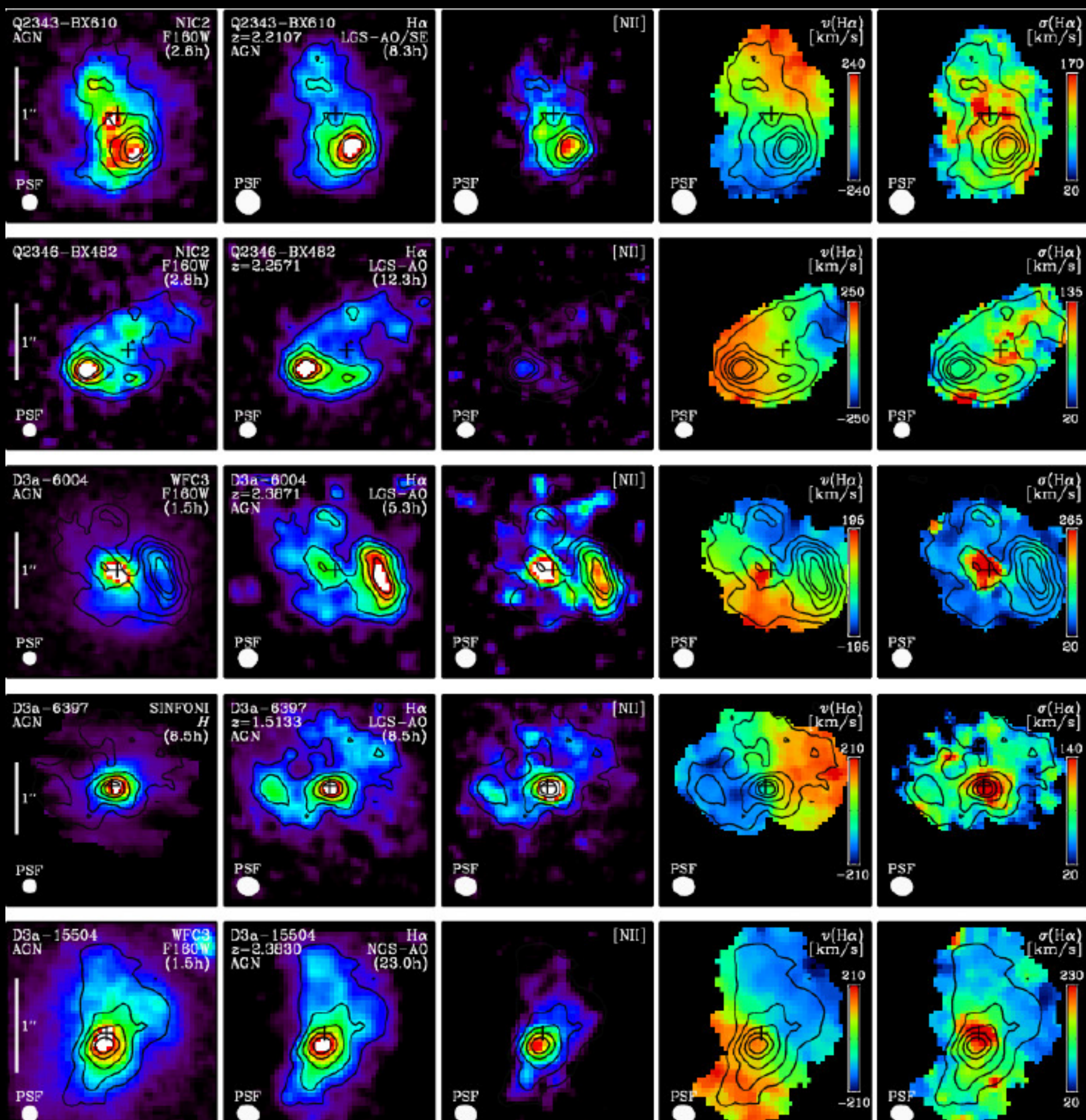
5. **Kinematics, Star-formation, Metallicities and Stellar populations of Gravitationally-Lensed galaxies** (Sawicki, Damjanov, Man)

6. **The Evolution of Disk-Dominated Galaxies at $z > 3$** (Wisnioski)

7. **Galaxies at Cosmic Dawn i.e., $z > 7$** (Muzzin, Sawicki)

Kinematics, star-formation, metallicities and stellar populations of galaxies at 0.7 < z < 2.7

Forster Schreiber+2018

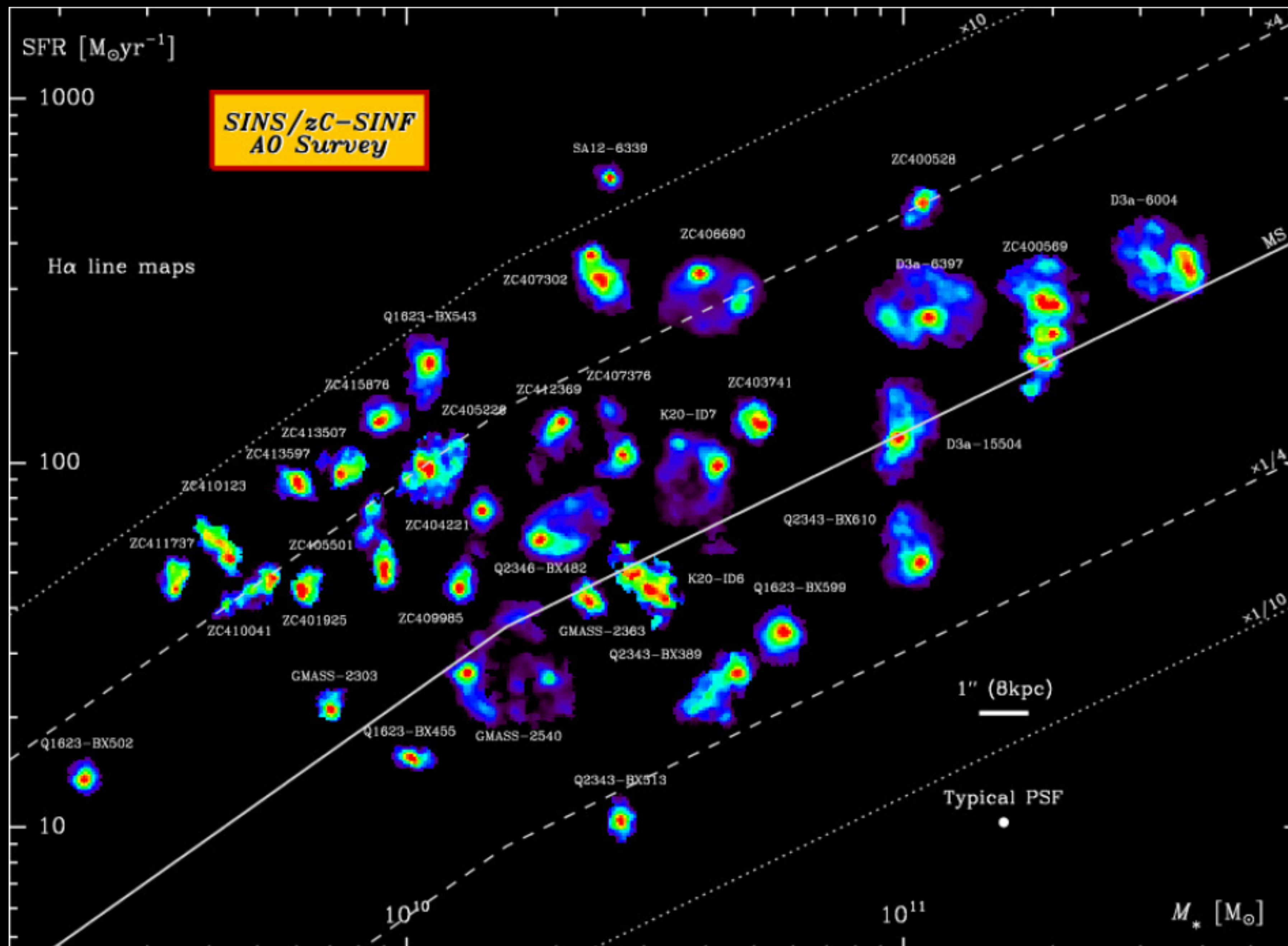


Science Goals

- 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?
- **First large survey will (likely) be GIRMOS's legacy project**

Properties of Galaxy Disks vs. Mass, SFR and Redshift

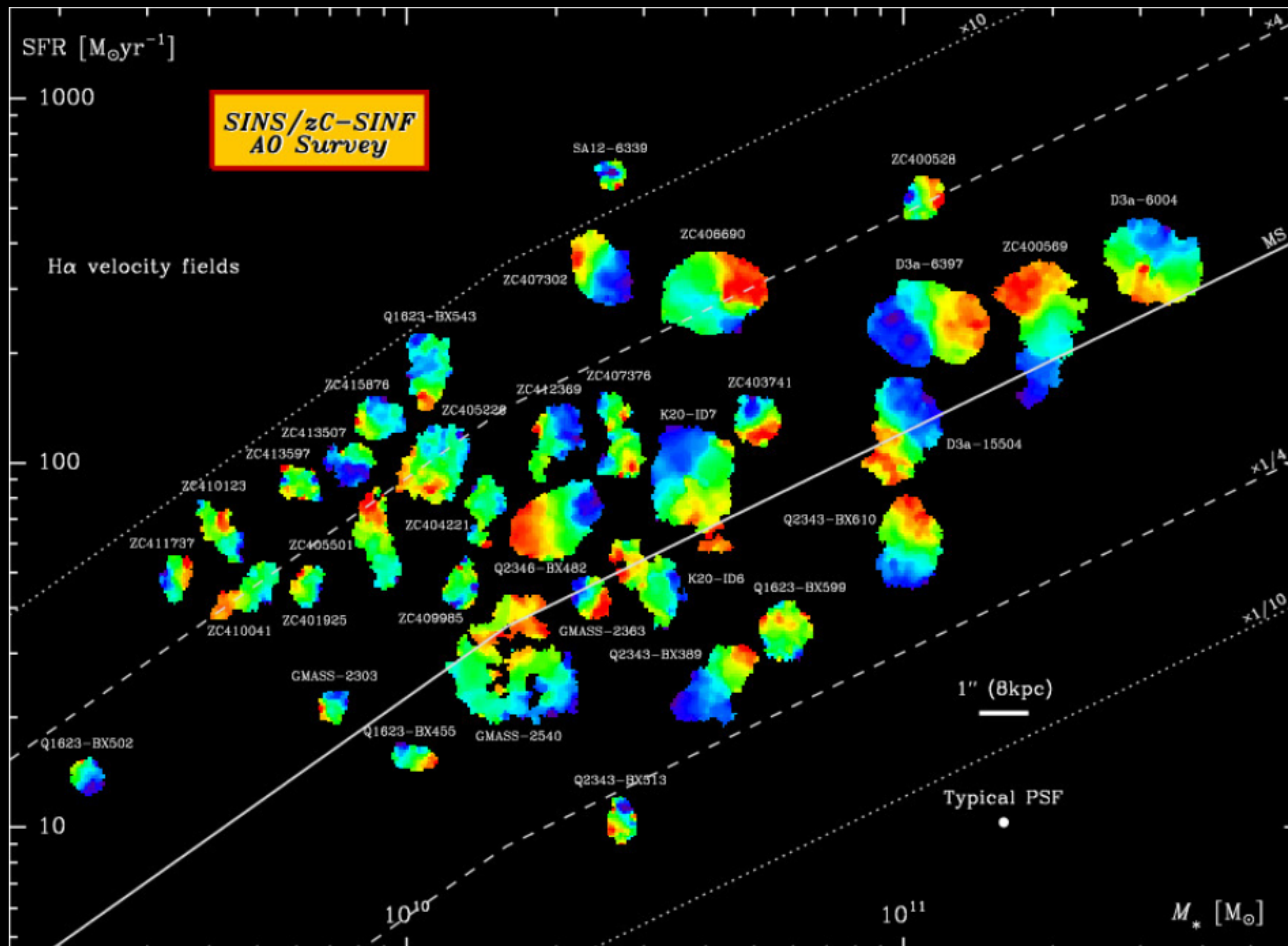
How do disks build up? What is the role of large star-forming clumps?



SINS-cZ-SINF sample is 36 galaxies at z ~ 2, GIRMOS will do a definitive sample of ~150 galaxies at 0.7 < z < 2.7 to get true demographics

Properties of Galaxy Disks vs. Mass, SFR and Redshift

How does the kinematic structure of galaxies evolve over time/with mass?



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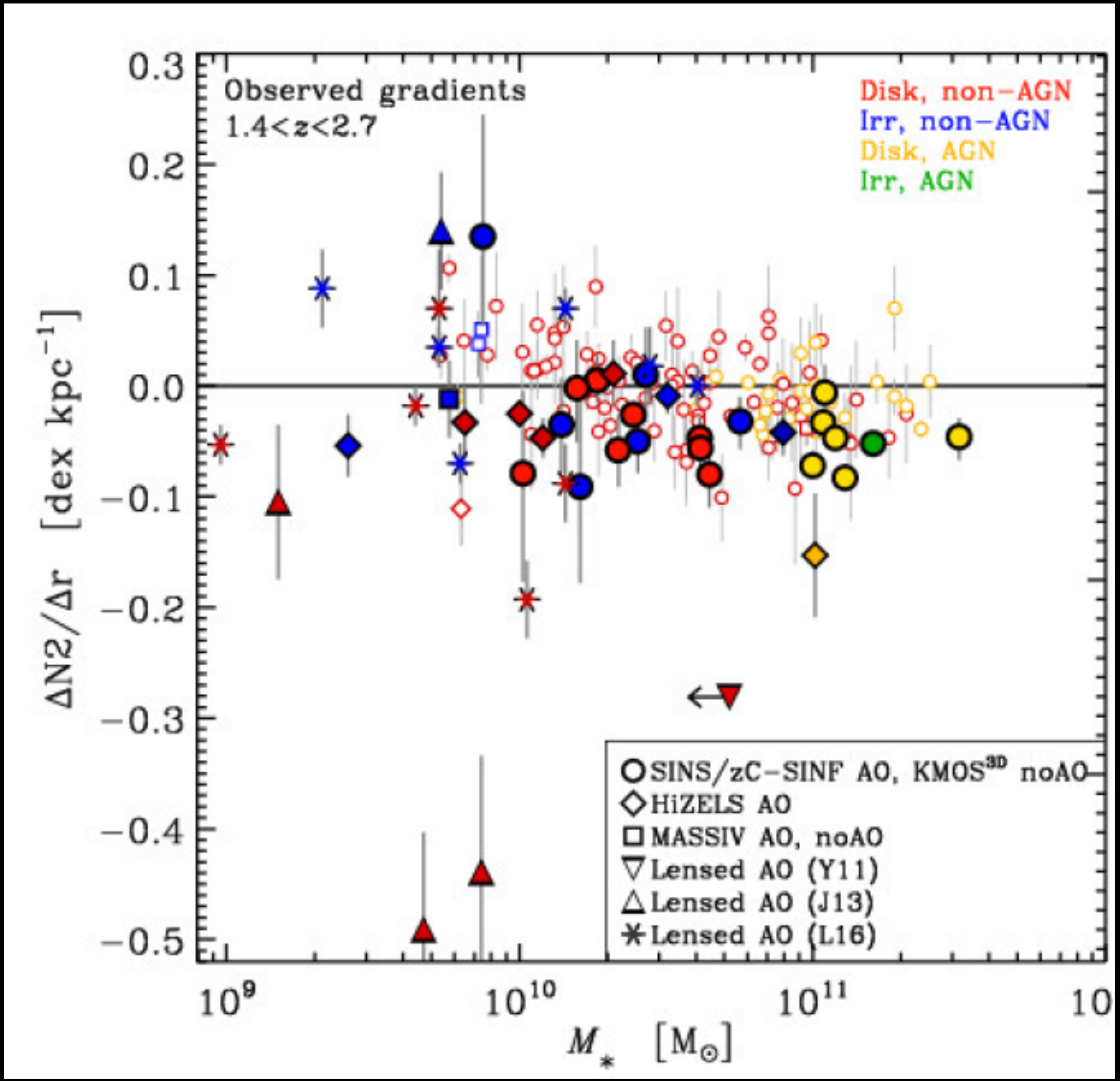
Resolved Gas-Phase Metallicities of Galaxies 0.7 < z < 2.7

How do metallicity gradients evolve with mass/redshift/SFR?

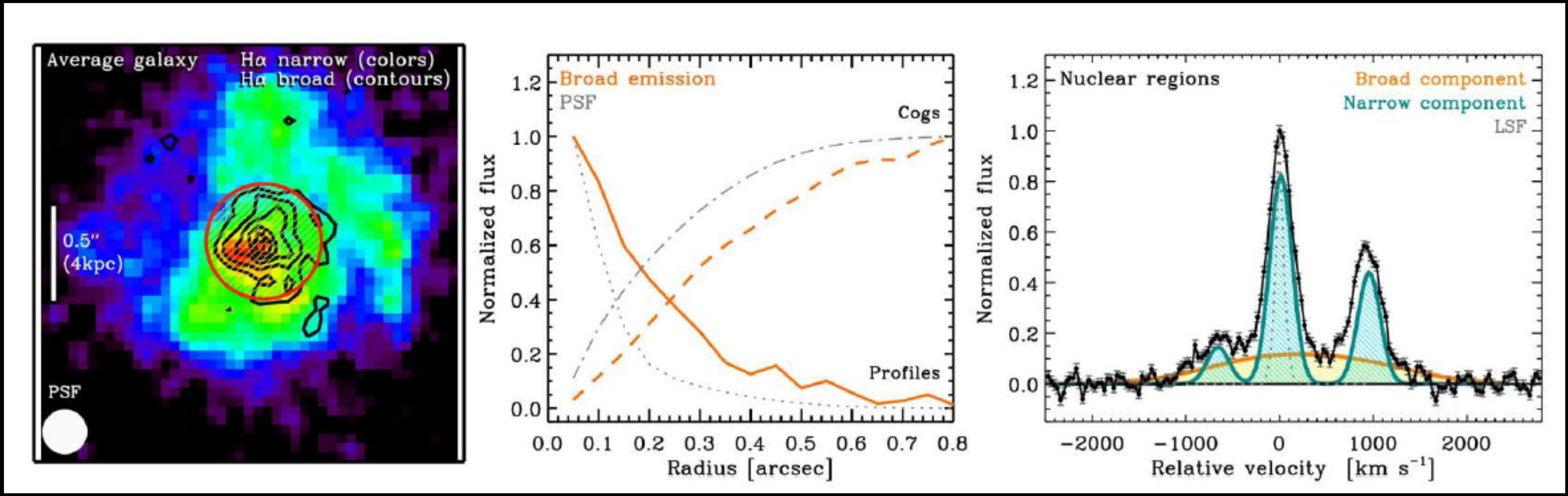


Forster Schreiber+2018

- Current measurements (AO + non-AO) show slightly falling metallicity gradients
- Slight differences between AO (solid points) and non-AO (open points) measurements
- Demographics at high resolution are not well-constrained, GIRMOS will do this very well

Observing AGN Feedback in Action

The smoking gun of galaxy quenching?



Forster Schreiber+2014, Genzel+2014

- Stacking of 7 galaxies shows clear broad component of line emission in center, falling to nothing in the centre.
- Evidence for AGN feedback in central region. What is the incidence of this feedback? How does this evolve with time/mass? GIRMOS will establish the demographics

GIRMOS Science Niches

Galactic Science

Combining all 4 IFUs into an "super" IFU will have the largest-area IR IFU at AO spatial resolutions.

Extragalactic Science

GIRMOS multiplexing will make it a faster survey instrument than existing instrumentation.

R = 8000 mode provides unique resolution to do stellar kinematics & metallicities, but also resolve turbulence scale within galaxies.

Some gaps remain in our science team:
e.g. Solar System, Low mass companions, resolved stellar populations

Summary

- **GIRMOS will be a powerful new AO-fed spectroscopic capability on Gemini**
  - While GIRMOS was originally planned for Gemini-S, the team is in the final stages of making a decision to deploy on Gemini-N and take advantage of its powerful new MCAO system

- **GIRMOS will be designed to be facility-class instrument that addresses a broad range of scientific questions and serve the Gemini scientific community**

- **The GIRMOS scientific team invites interested parties to contact our project scientist, Adam Muzzin (muzzin@yorku.ca)**

- **Current anticipated commissioning date: Late 2024**

Acknowledgements

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