

A New-Generation Near-IR Spectrograph for the Extremely Large Telescope

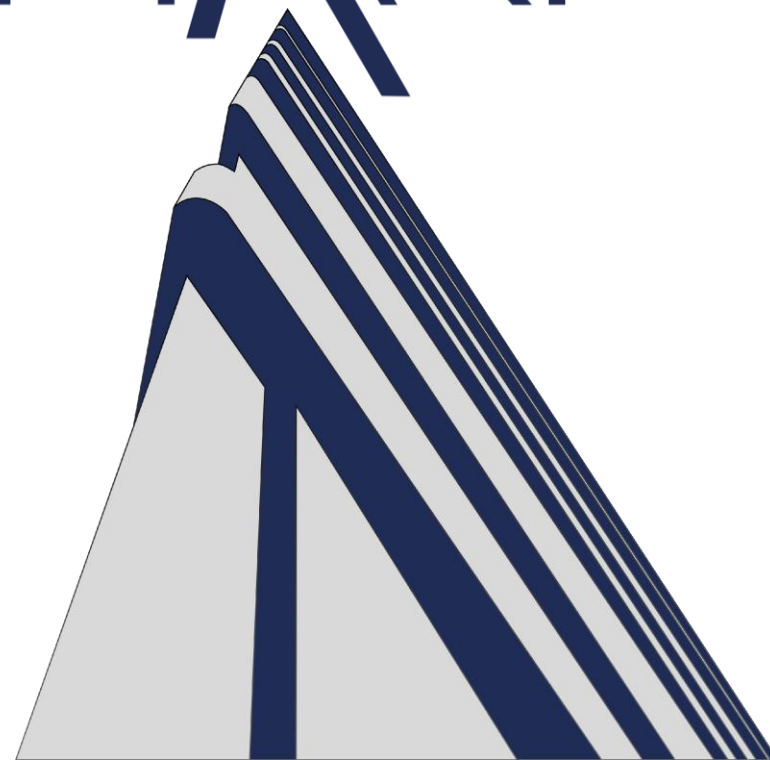
Looking beyond JWST

Paolo Saracco

INAF - Osservatorio Astronomico di Brera

&
the SHARP Team

SHARP

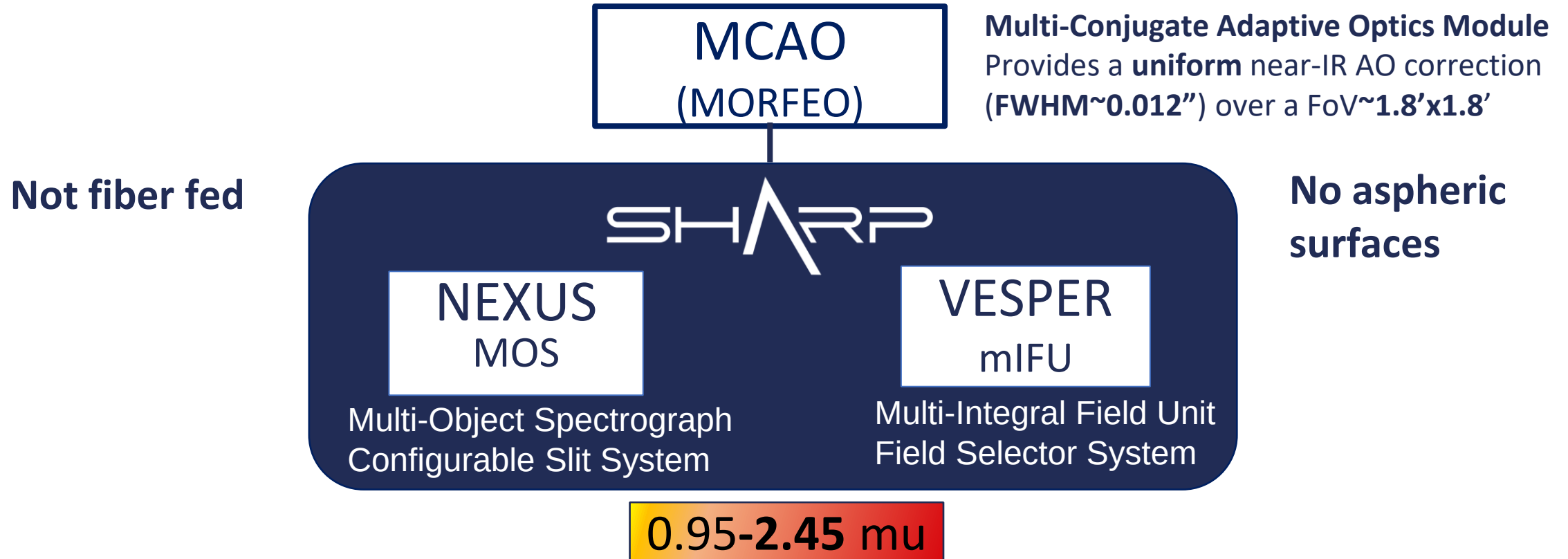


What is SHARP



A Near-IR multi-mode spectrograph

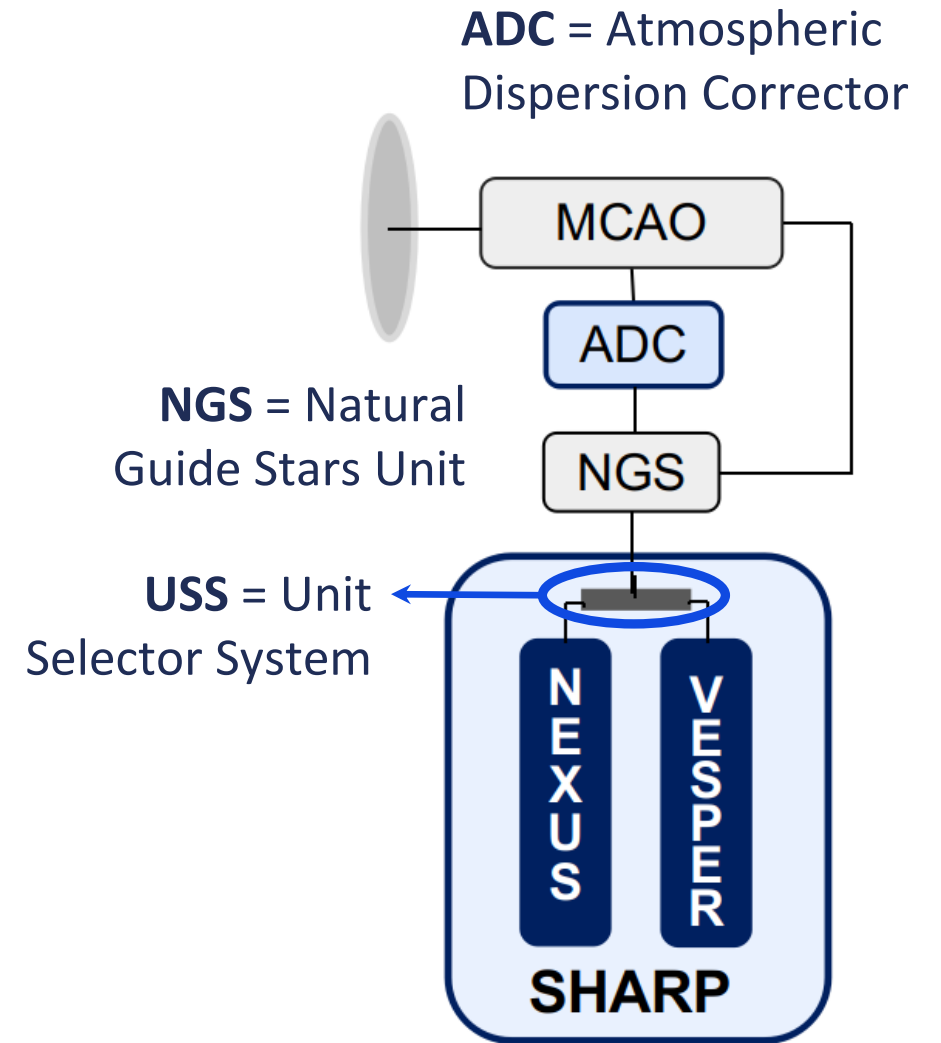
To exploit the ELT capabilities providing spatially resolved multi-object spectroscopy at the sharpest angular resolution over the widest AO corrected field.



Expanding Horizons - **SHARP** proposal for a significant upgrade of ELT

SHARP in a Nutshell

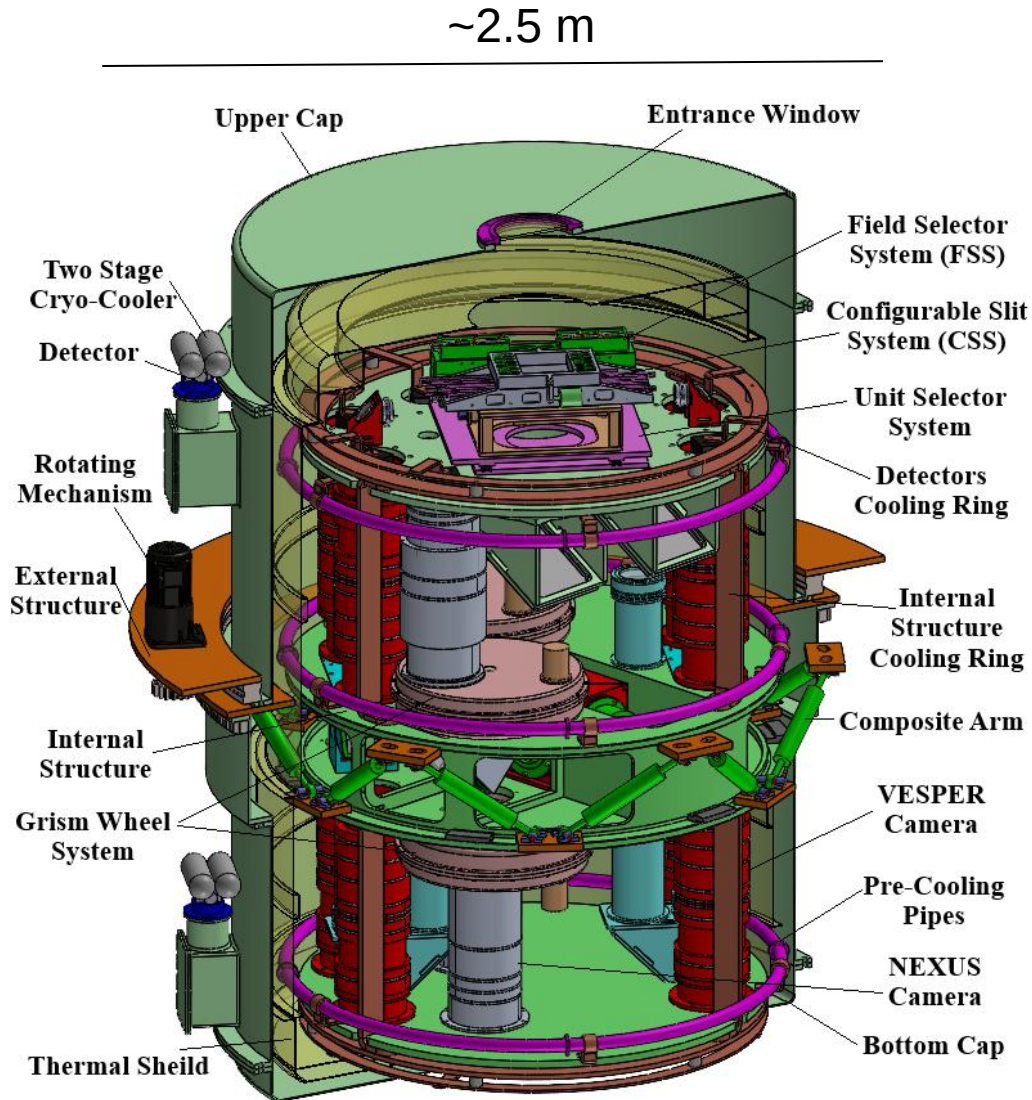
SHARP	NEXUS (MOS)	VESPER (mIFU)
Spectral range	0.95-2.45 μm (Simultaneously)	1.2-2.4 μm (Simultaneously)
Field of View Area probed	1'.2 x 1'.2	21" x 40"
Multiplexing	up to 30 slits (2".4 length)	12 probes (1".7x1".5 each)
Pixel scale	$\sim 0.035''$	$\sim 0.031''$
Resolution $\lambda/\Delta\lambda(0''.2 \text{ ref})$	$\sim 300, 2000, 6000$ (~ 17000 point source)	~ 3000





Key features

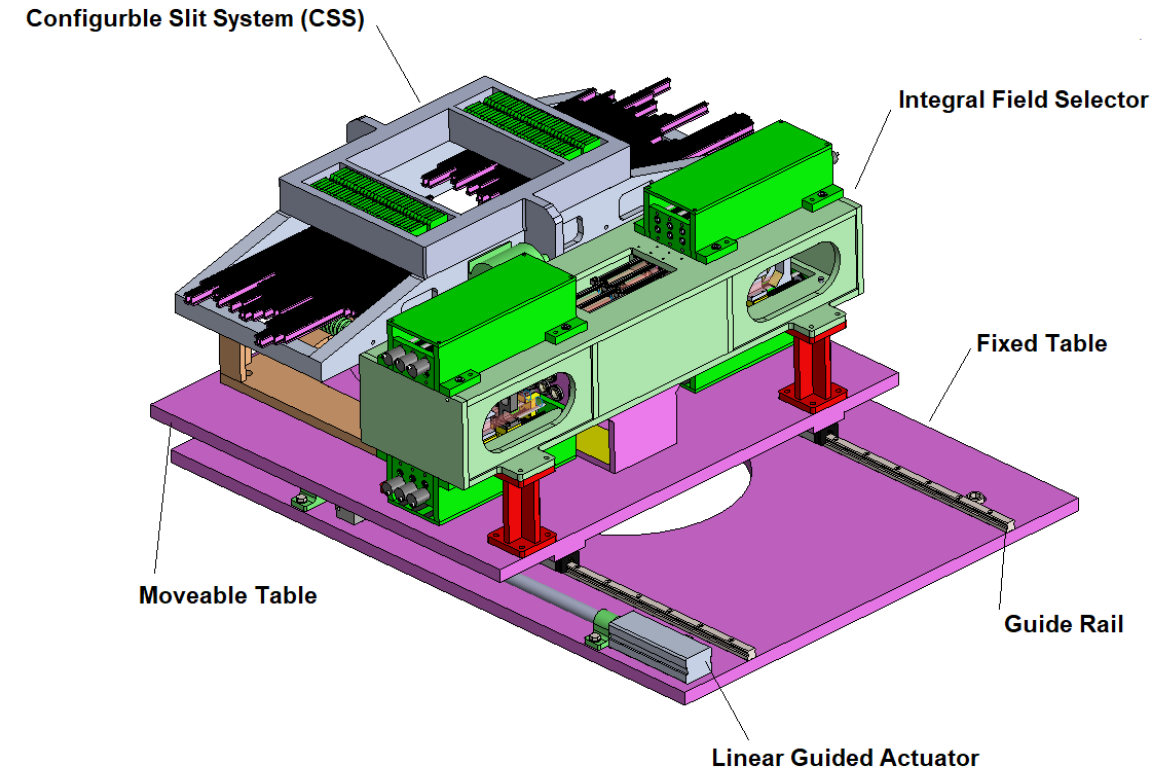
SHARP - Opto-mechanical design



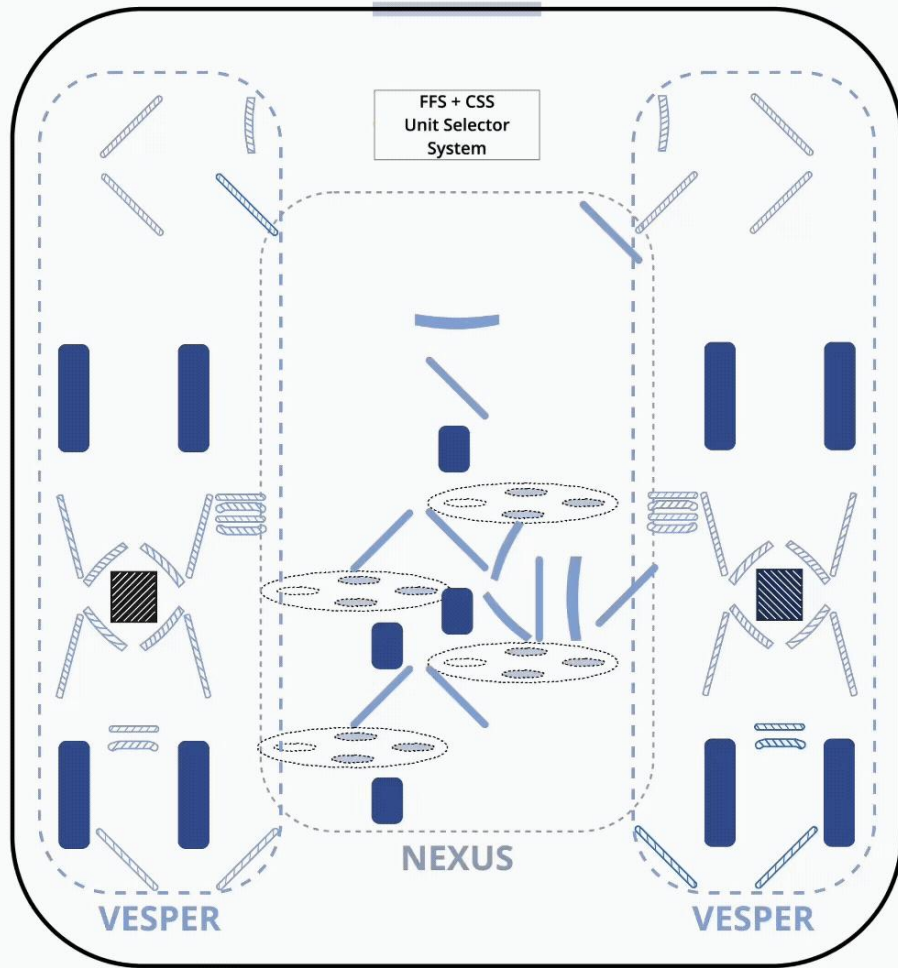
~3.2 m

Unit Selector System

- Configurable Slit System (NEXUS)
- Field Selection System (VESPER)



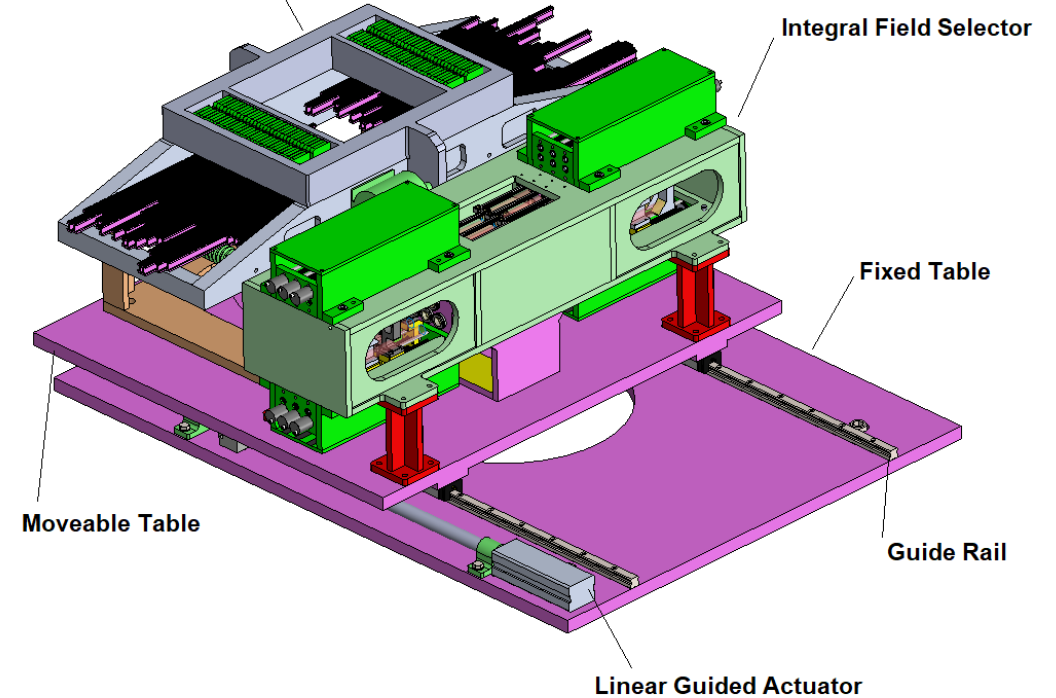
Mahmoodzadeh et al. 2025, 2026



Unit Selector System

- Configurable Slit System (NEXUS)
- Field Selection System (VESPER)

Configurable Slit System (CSS)

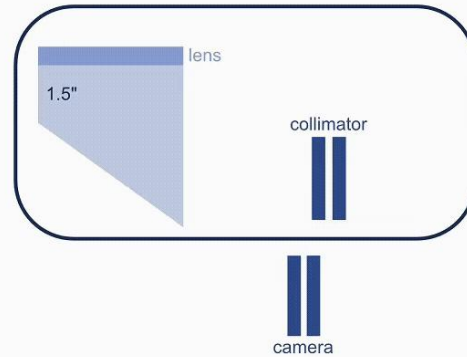
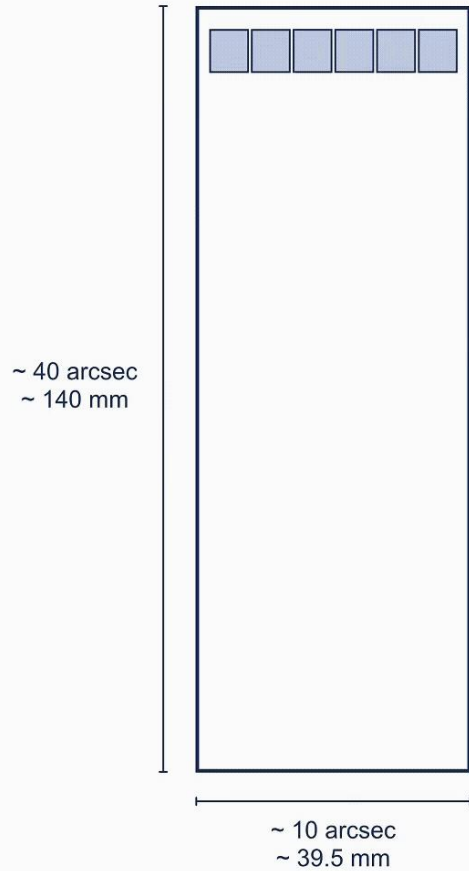


Mahmoodzadeh et al. 2025, 2026

SHARP - VESPER - the Multi-IFU

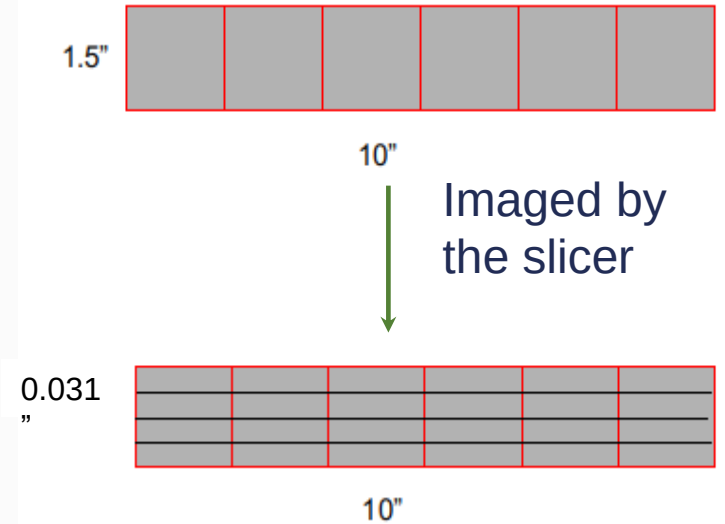
One module of VESPER comprises 6 probes called **Field Selectors** deployable over $\sim 10'' \times 40''$

Field Selector System



Constant Optical path FS-camera
Same focal plane for all FSs

Sky strip resulting from 6 FSs



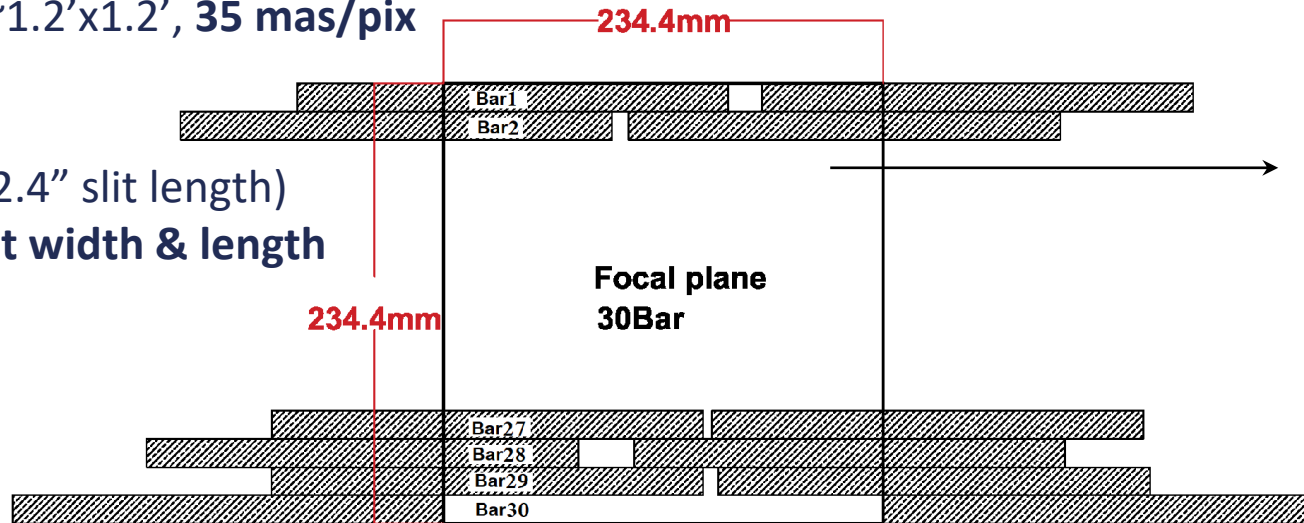
Slicing along the wide direction.
Insensitive to the number of FSs.

SHARP - NEXUS - the Multi-Object Spectrograph

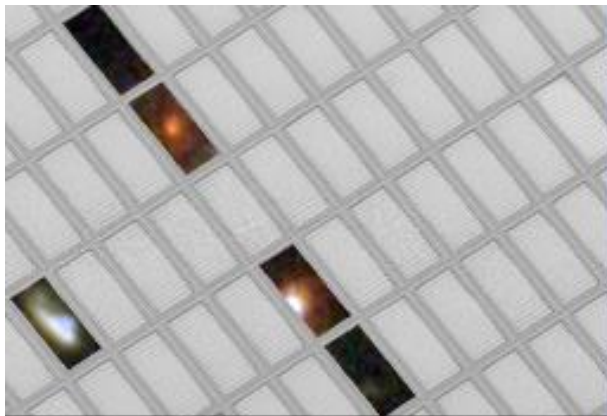
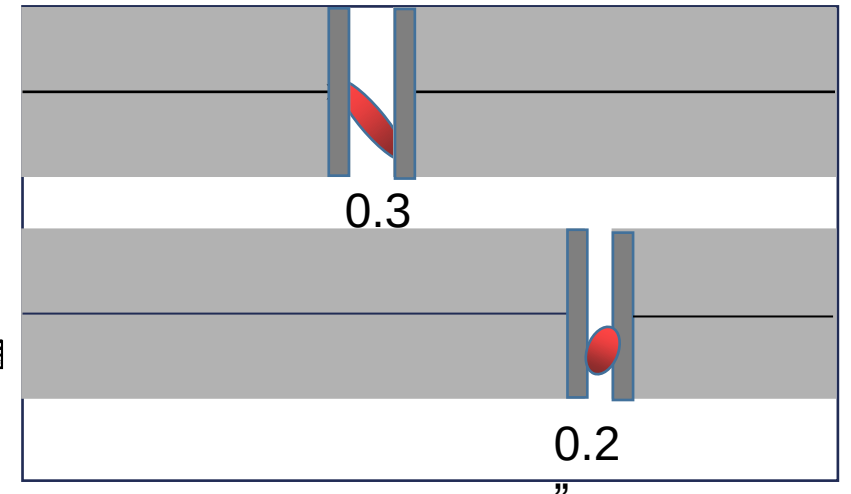
Configurable Slit System

NEXUS FoV $\sim 1.2' \times 1.2'$, 35 mas/pix

~ 30 slits (for 2.4" slit length)
Adjustable slit width & length



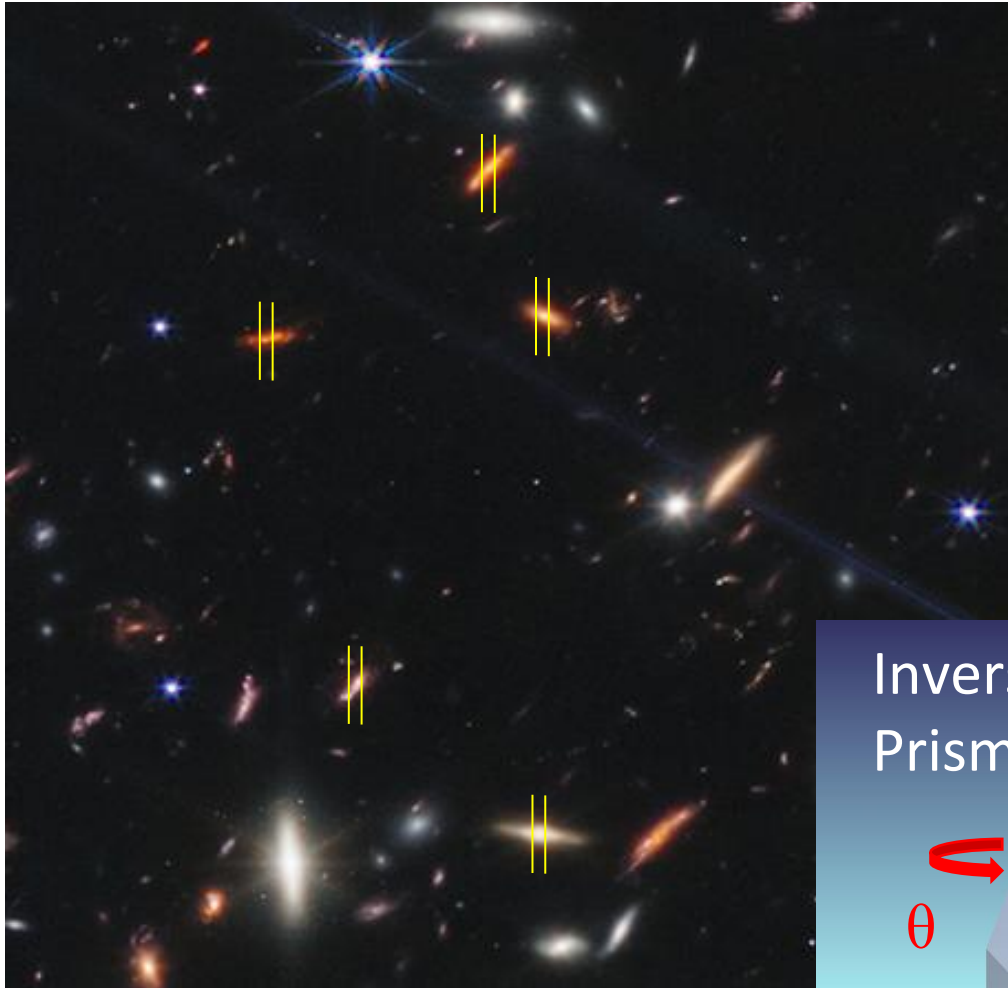
Adjustable slit width & length
Centering of sources



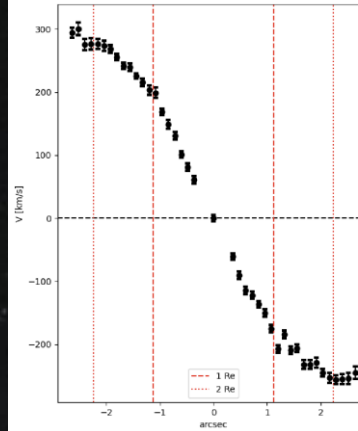
JWST-NIRSpec
MSA (Micro Shutter Array)
0.2" slit width
No centering

SHARP - NEXUS - the Multi-Object Spectrograph

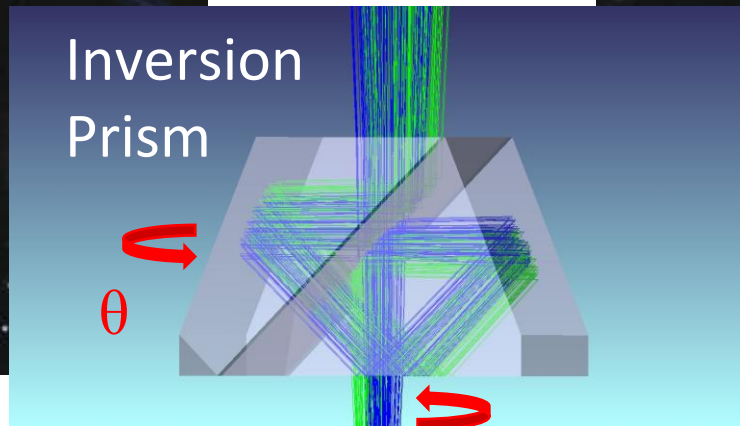
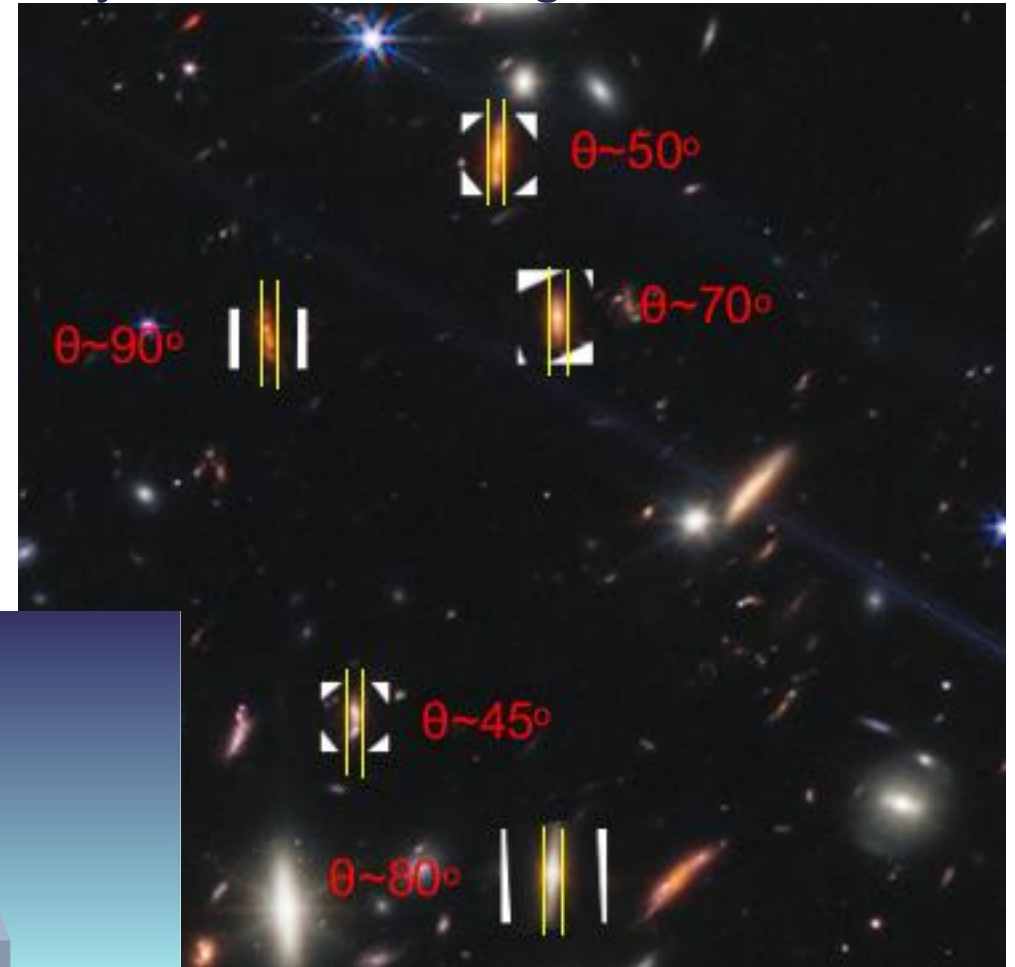
JWST NIRCам image



$z \sim 0.1$ galaxy

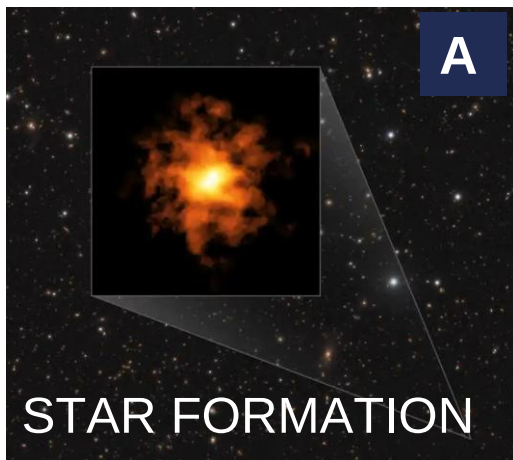


Rotates the field subtended by the slit.
Adjustable rotation angle



Why
SHARP
Scientific Rational

Understanding how baryons assemble to form stars and galaxies over cosmic time.



- Which **physical conditions govern the star formation** in the local and in the early Universe?
- What **regulates** the SF ?
- What triggers the **shutdown** of star formation?
- What is/are the quenching mechanism(s)?
- **Initial Mass Function:** What determines its shape? Transition between low-mass and high-mass stars?

PIAZZI 200



What is the physical interplay between **massive black holes** and galaxies ?

Do MBHs affect SF, quenching and mass accretion?



“Where is” the elusive **PopIII of primordial stars** ?

Searching for the first metal-free star clusters

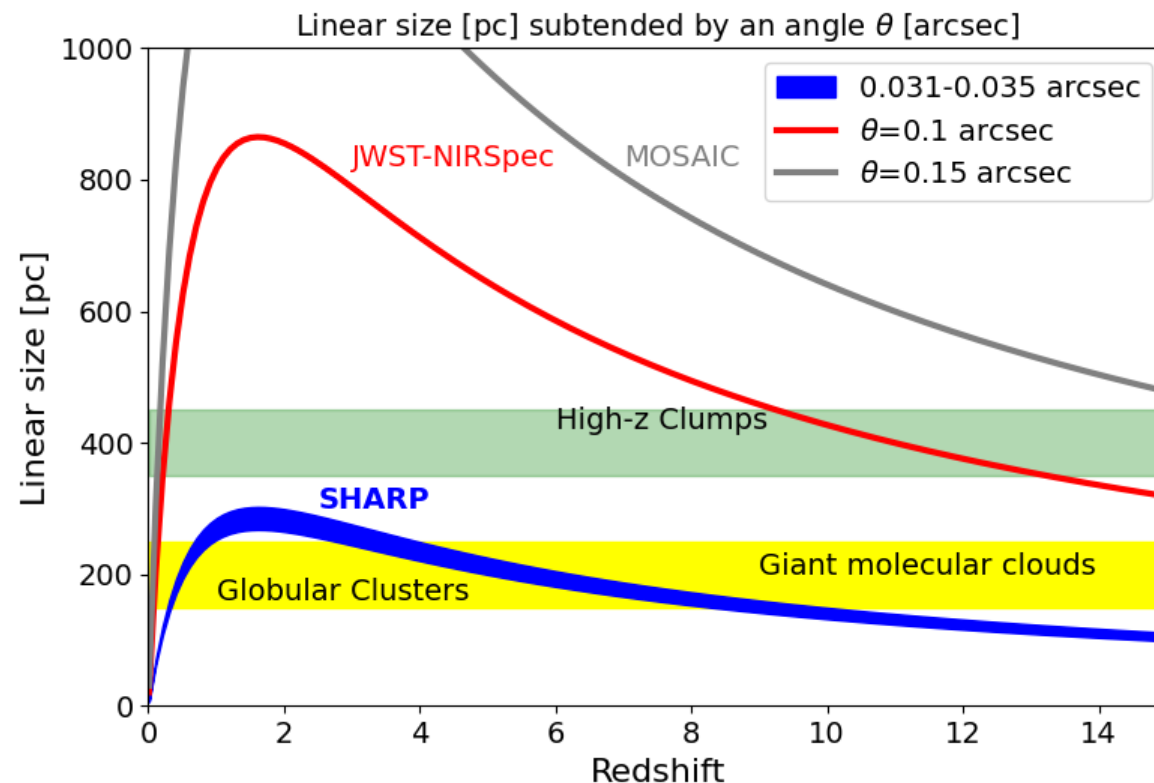
Giant molecular gas clouds ~150-250 pc

Up to $10^6 M_\odot$ of molecular gas

The largest fuel reservoir ==> the place where massive star formation occurs;

- ❖ Main star-forming units
- ❖ Main metal production units
- ❖ Galaxy rotation tracers $\Rightarrow$ DM
- ❖ Cradles of Globular Clusters and
- ❖ of primordial **PopIII** systems?

Resolved at $z < 0.1$ by JWST



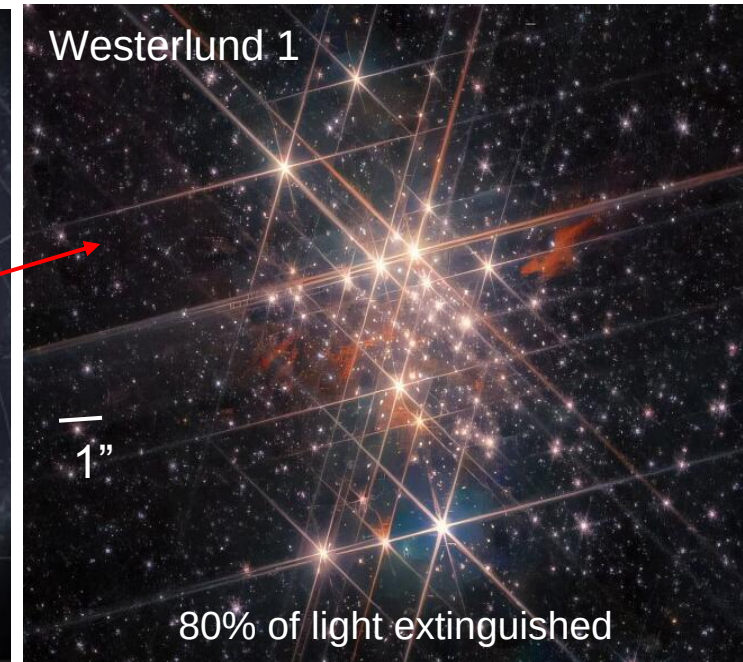
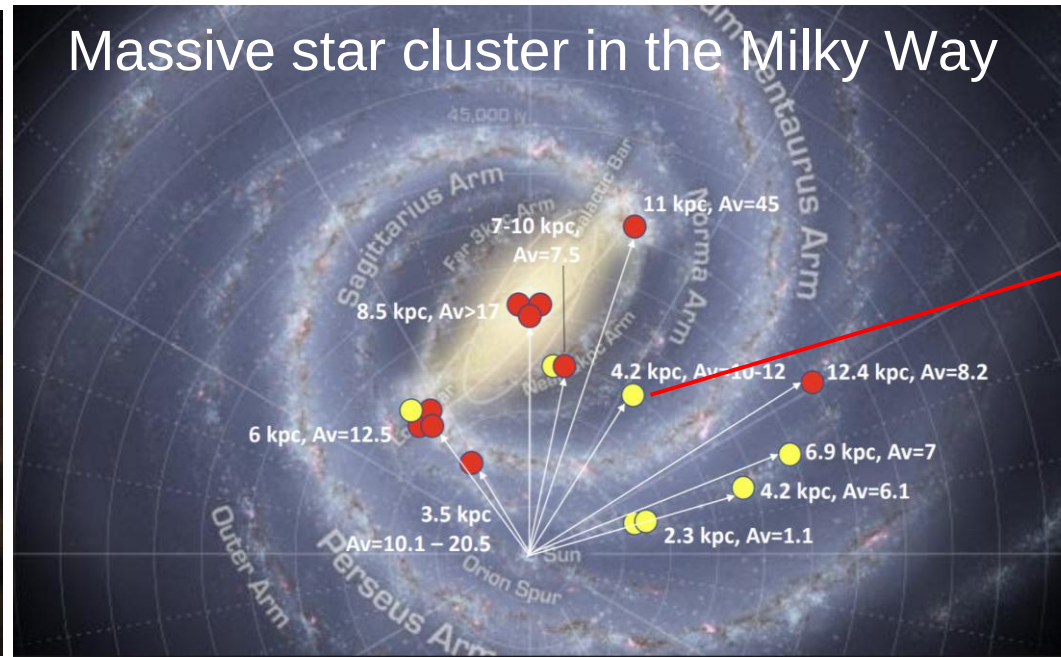
Angular res. $\sim 0.03''$ to sample regions like GMCs over the entire cosmic time

NIR to $\sim 2.45 \mu\text{m}$ to probe dust-shrouded regions and the Universe up to $z \sim 16-17$

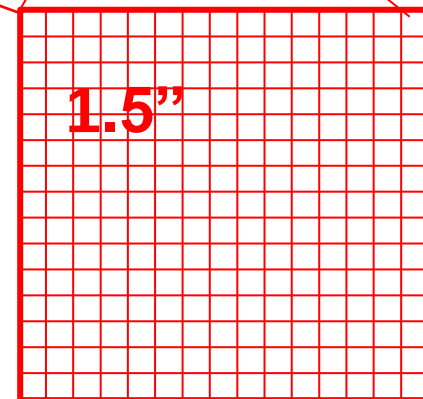
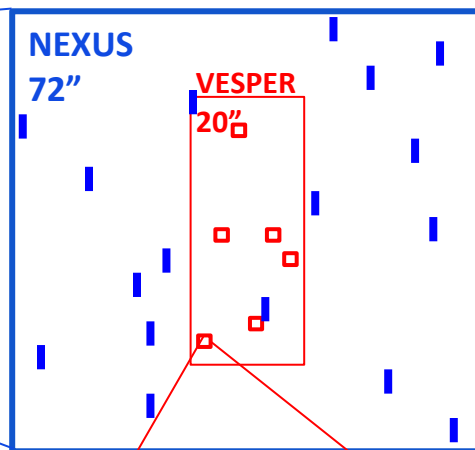
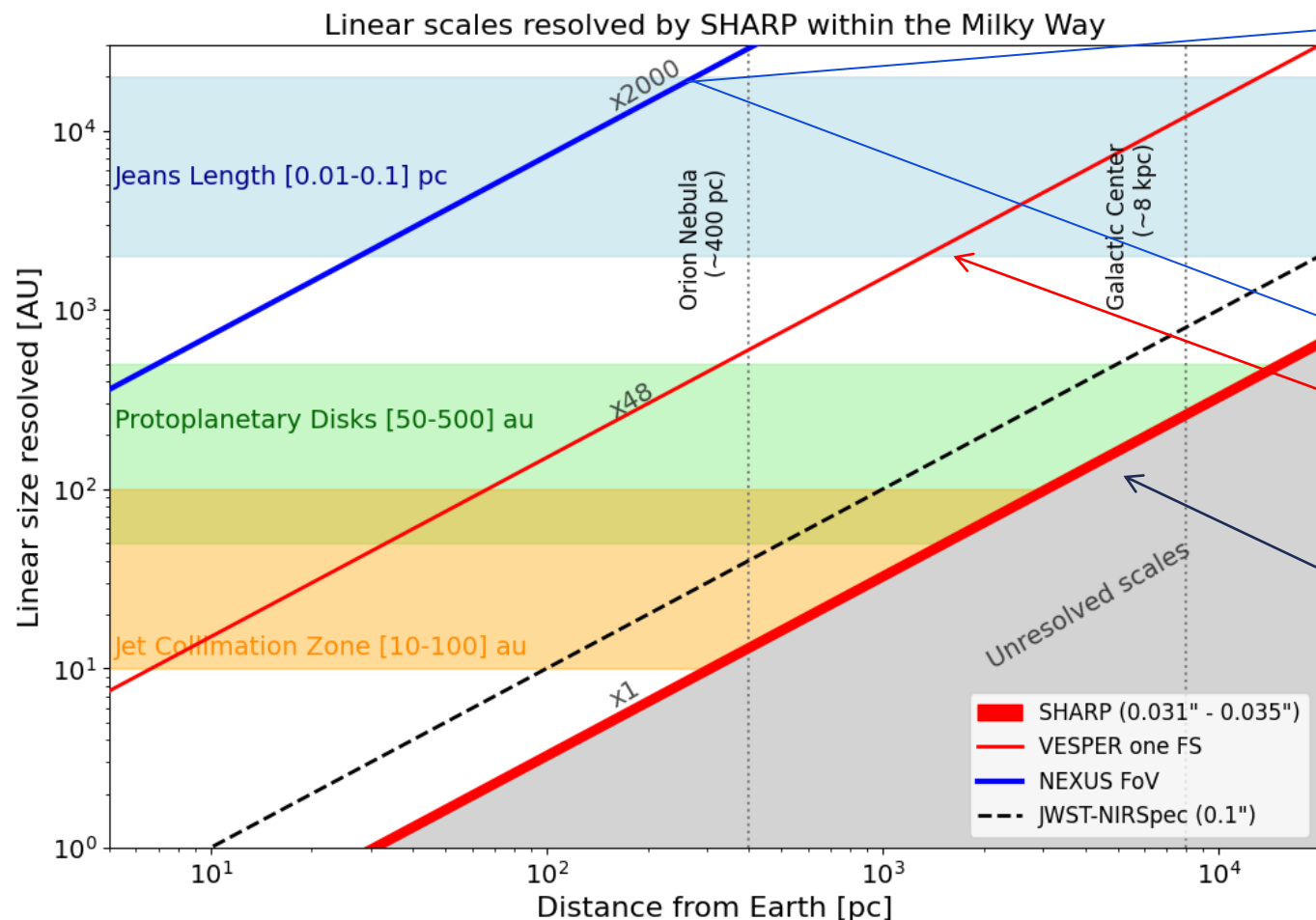
Multiplexing to sample extended and overdensity regions, multiple clumps, clusters, GCs....

Spatially resolved spectroscopy of massive star forming environments

Highly extinguished and crowded



Near-IR is essential for seeing through dust, high angular resolution is necessary to resolve key physical scales.



31 - 35 mas

Solar system resolved scales

- **Mars** (at ~75 million km): **11 km**
- **Jupiter** (at ~630 million km): **92 km**
- **Saturn** (at ~1.27 billion km): **185 km**
- **Pluto** (at ~4.5 billion km): **650 km**

SHARP Proposal

Significant upgrade of ELT

"Facility that enables scientific benefits in a number of areas and serves a large part of the astronomical community."

- A new telescope facility;
- A significant upgrade of an ESO facility;
- Other combinations

- 1st December 2026
Letter of intent
- 1st December 2027
Proposal submission





The ultimate spectrograph

OVERVIEW ▾ PUBLICATIONS & MEETINGS ▾ RESOURCES ▾ FOR THE PUBLIC ▾ JOIN STAFF ▾ Q

SHARP-ETC

SHARP

sharp.brera.inaf.it

A conceptual study for a near-IR
multi-mode spectrograph
for the next generation ELTs



Science Book



Unveiling the Universe with
SHARP
a Spectrograph Proposal
for MORFEO/ELT
30 Sep - 2 Oct 2024



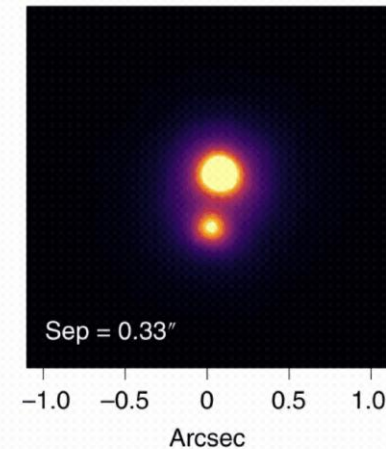
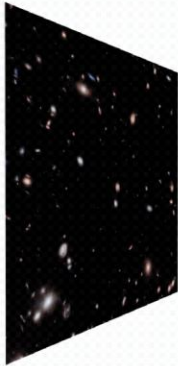
SPIE.



**We welcome expressions of interest from institutes, scientists,
and technologists worldwide.**

sharp_join.oabr@inaf.it

paolo.saracco@inaf.it



**SHARP would allow ELT to overcome the limits of JWST and to pick
up the baton at the end of its mission**

This is SHARP!

"Why Everest?"

"Because it's there"

— G. Mallory, 1924



SHARP Website

Scan the QR code to
explore our research and
updates.

sharp.brera.inaf.it

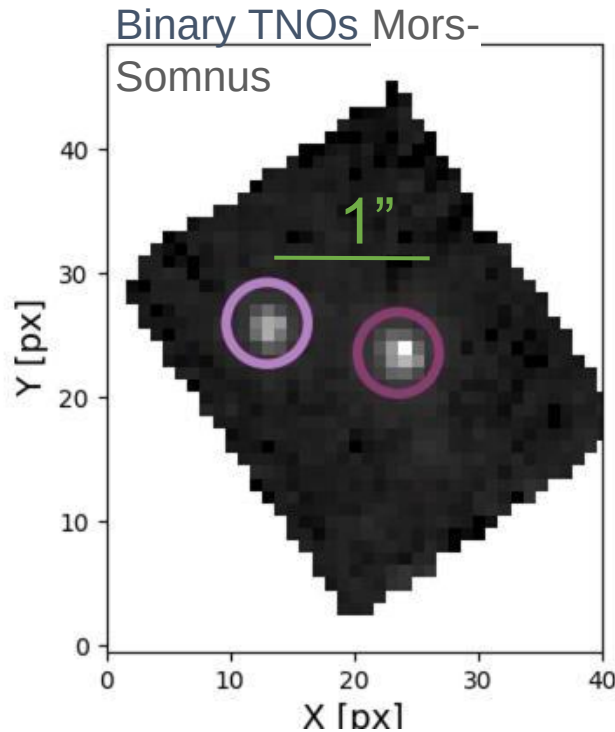
SHARP

Thank you!

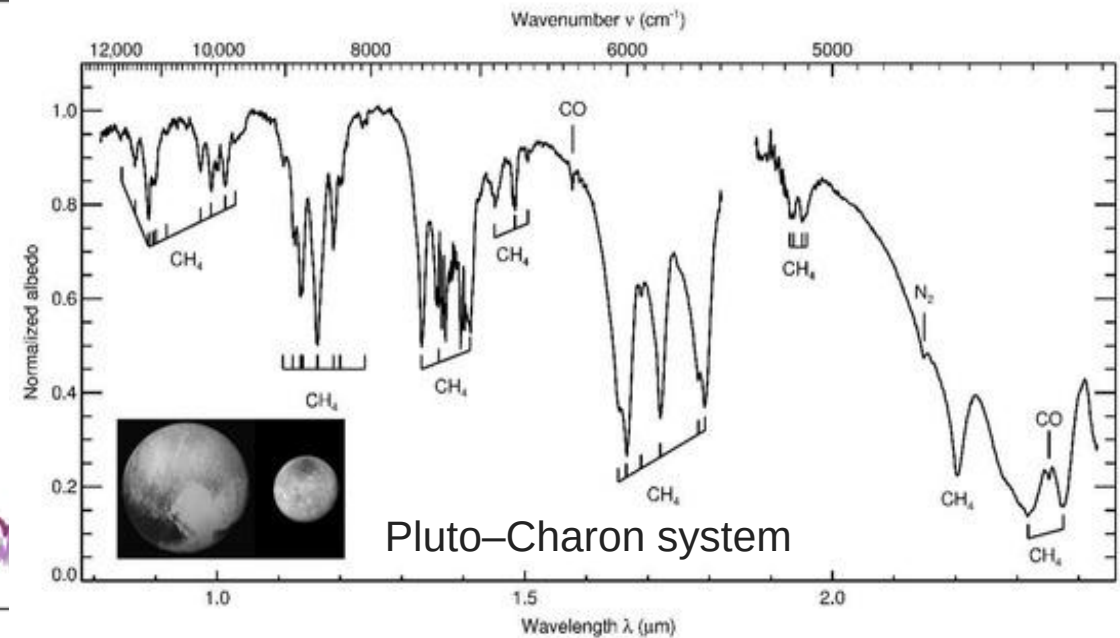
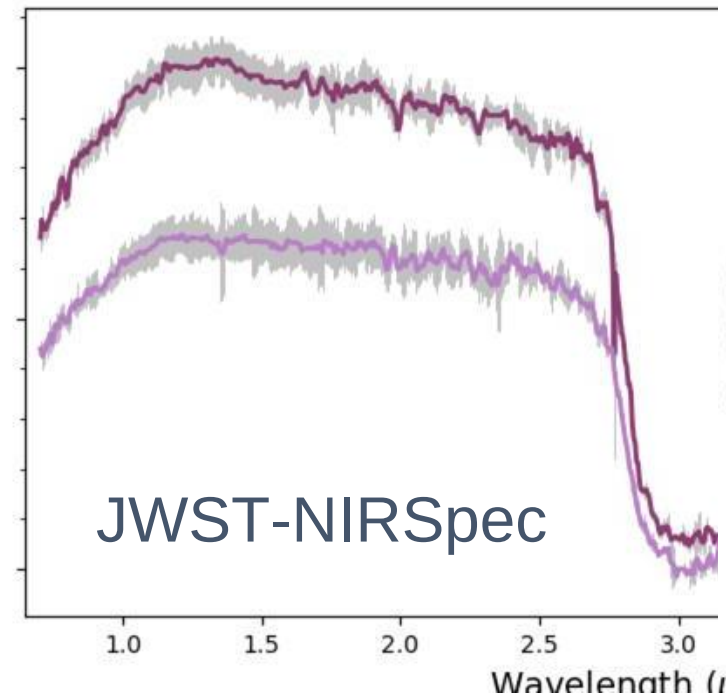
The origins of our planetary system

Chemistry of small bodies/moons surfaces and atmosphere

Searching for **icy** signatures.



Souza-Feliciano+2024

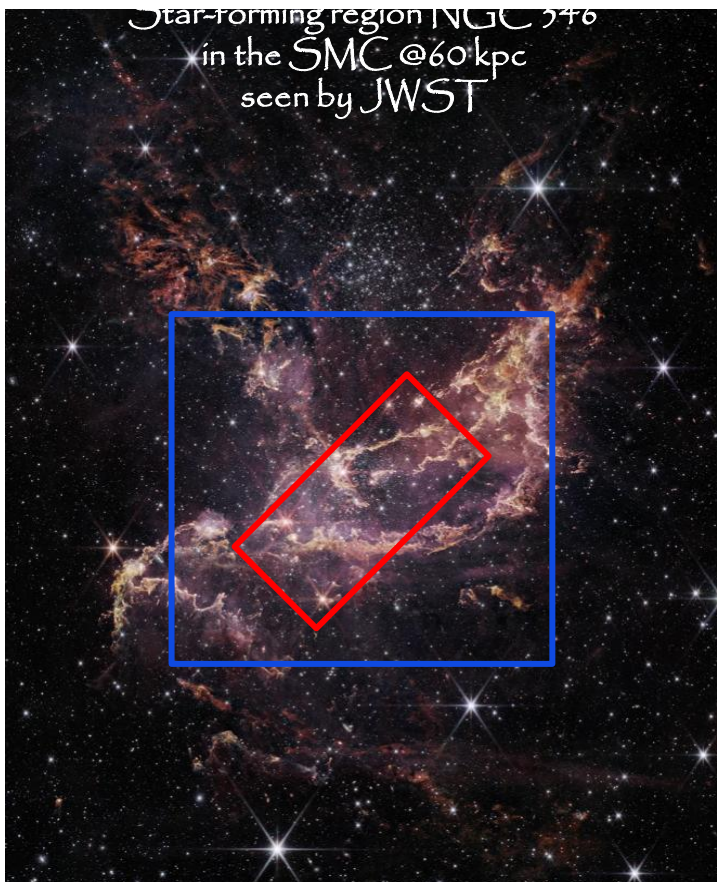


Cruikshank+20

NIR critical for detecting water and organic compounds

Typical cluster sizes: 2" - 16" @50 kpc

VESPER & **NEXUS** allow observing several young stellar objects (YSO) simultaneously in dust-shrouded clusters @low-Z



Credits: L. Podio

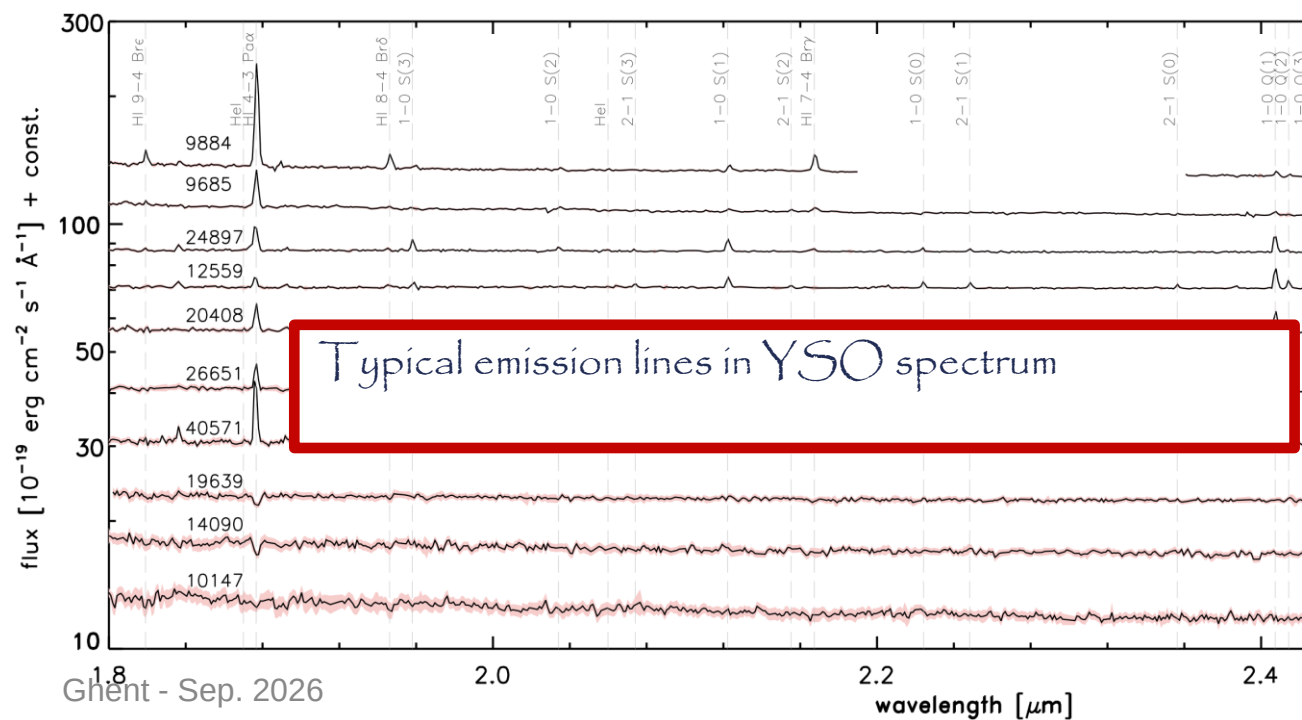
Objectives:

IMF: low-mass ($2 - 0.1 M_{\odot}$) YSO

ACCRETION: from Pa β & Br γ derive M_{acc} from $L_{\text{acc}}-L_{\text{line}}$ correlation calibrated for nearby SFR

EJECTION: through H $_2$, and [Fe II] lines luminosity

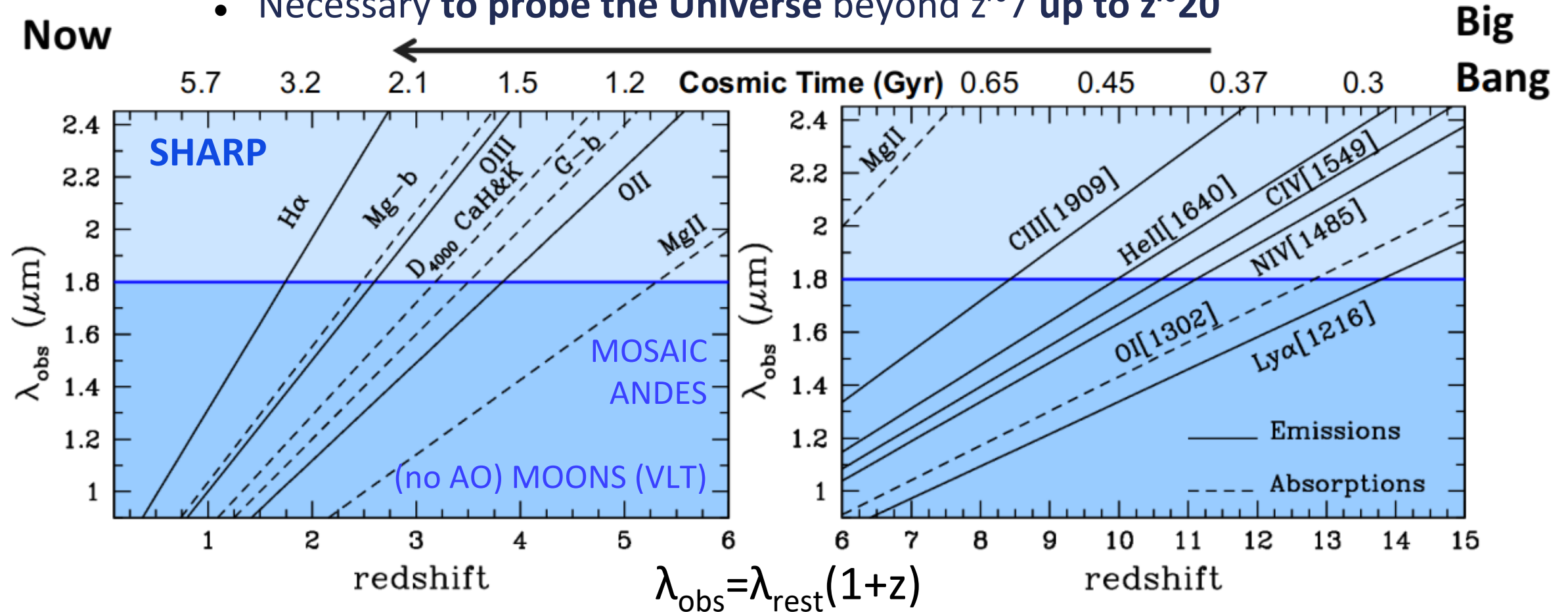
DISK FRACTION: through spectroscopic NIR excess



Backup

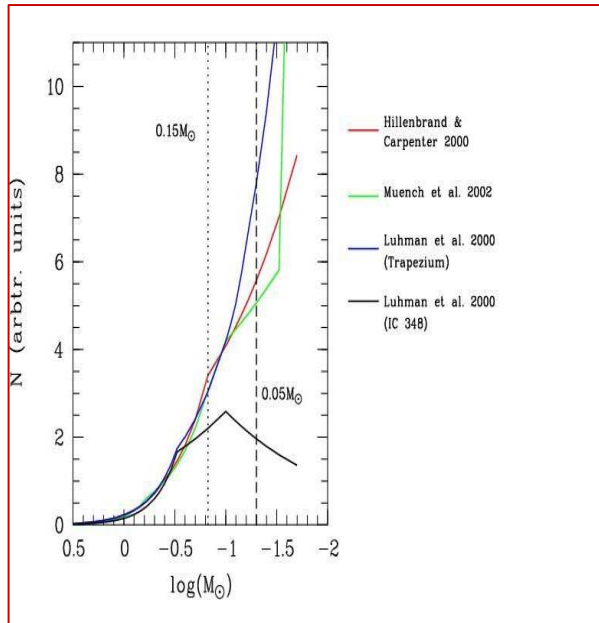
SHARP Why Near-IR

- Critical for detecting **water, organic** compounds exoplanet's atmosphere
- Essential for seeing **through the dust**, nearby star forming regions
- Necessary to **study galaxy properties** beyond $z \sim 1$ up to $z \sim 5$
- Necessary to **probe the Universe** beyond $z \sim 7$ up to $z \sim 20$



What are the effects of the local environment on the forming stars?

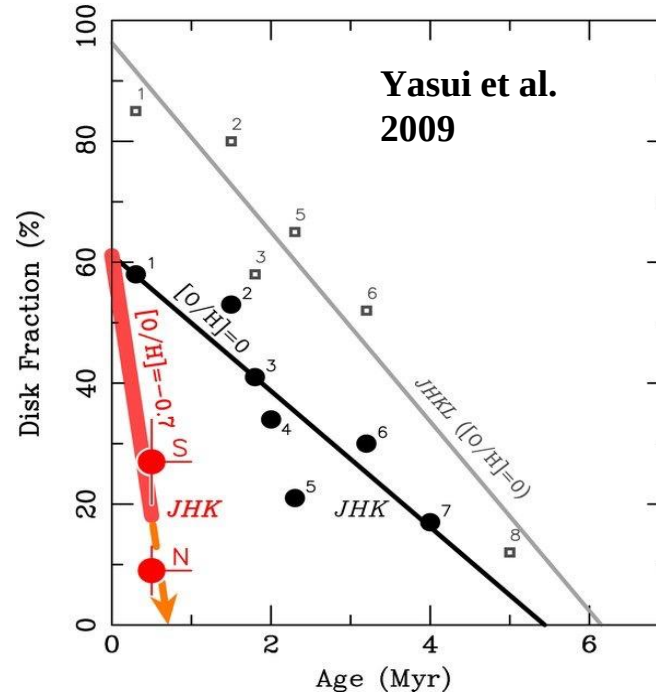
What are the IMF, mass accretion rate & disk lifetime in low-metallicity environments?



IMF at low-Z not determined yet

Agreement with Solar metallicity IMF for $M > 0.3 M_{\odot}$

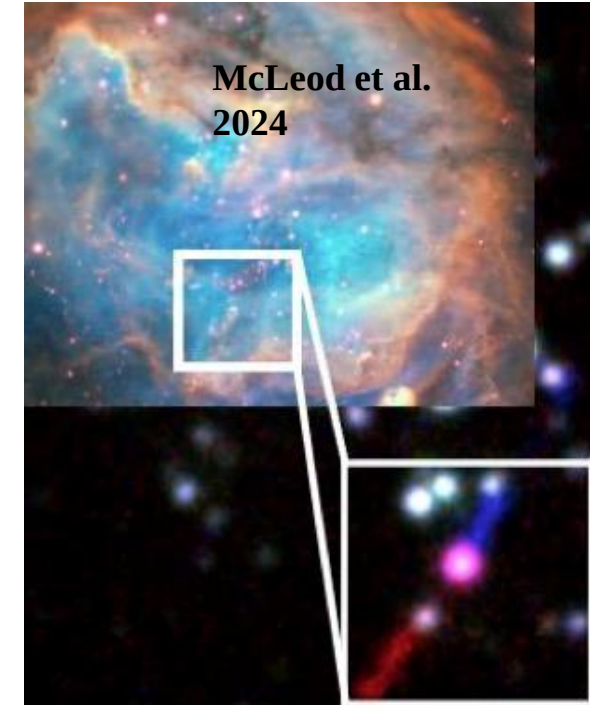
Very uncertain in the low-mass and sub-stellar regimes



Accretion & disk lifetime vs Metallicity

Much lower disk fraction at low Z ($< 0.2 Z_{\odot}$)
indicates shorter disks lifetime

Lower mass accretion rates at low-Z?

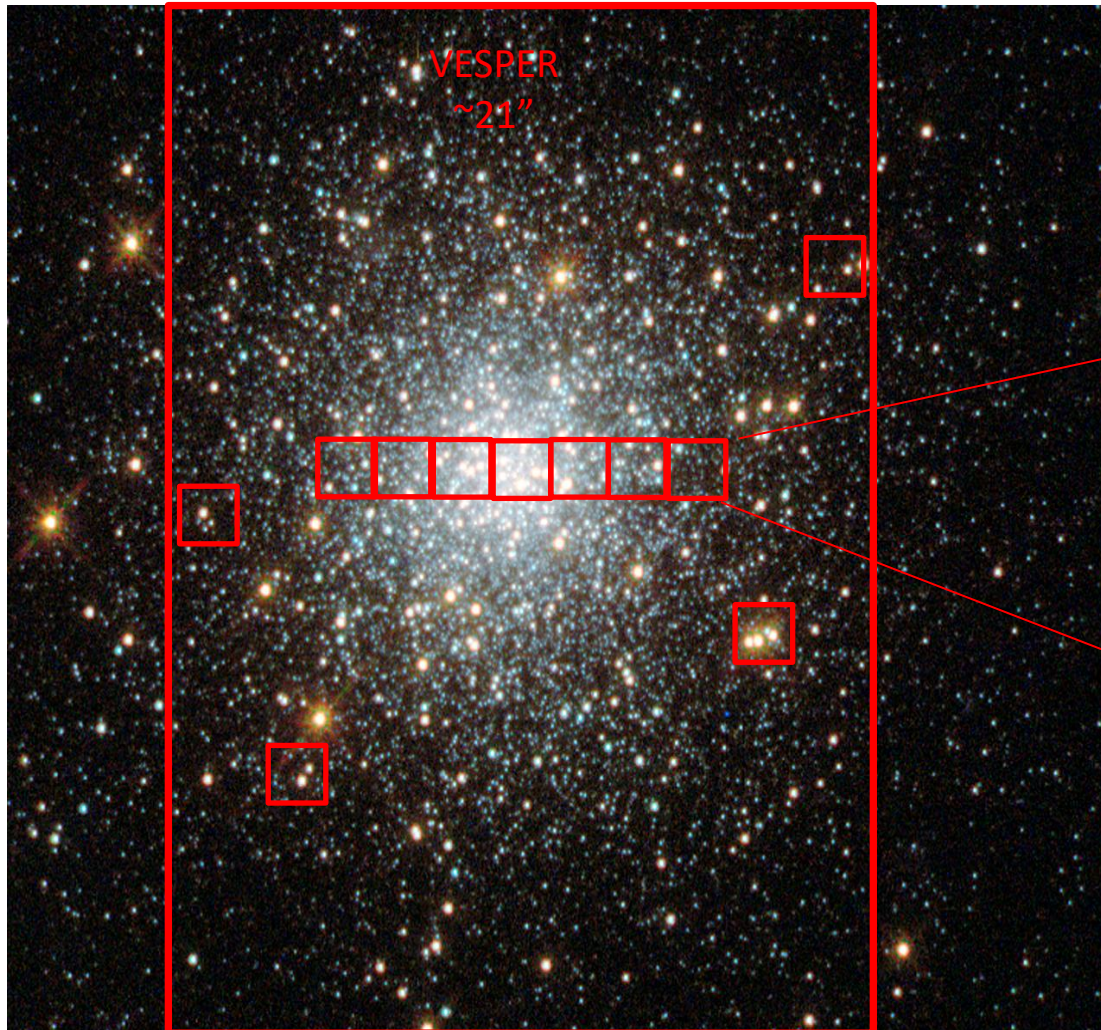


Disks & Jets in low-Z SFRs

Accretion/ejection & disk properties at low-Z

How this affects planet formation?

Globular cluster n.5 in the dwarf galaxy Fornax

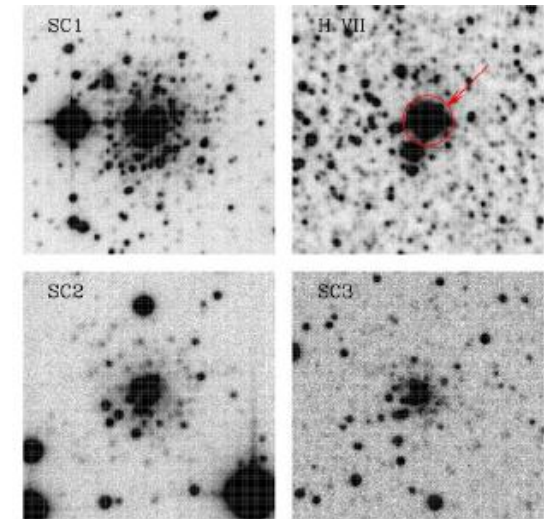


~30 arcsec

How did Globular Clusters assemble ?

Radial gradients stellar properties (kinematics, chemistry) within the Local Group: Fornax at ~150 kpc; NGC6822 at ~500 kpc

Star clusters in the halo of NGC6822



■ 0.031"

Does intermediate MBHs exist?

Accurate kinematics of hundreds stars in GCs (within and outside Local Group).

VESPER velocity resolution ~-45 km/s

NEXUS velocity resolution ~15 km/s

Thanks to WG3&WG4



ScienceDirect

Collection of ~20 scientific papers showcasing the instrument's potential in various areas of astrophysics.



New Astronomy

Supports open access

4.4

CiteScore

2.4

Impact Factor

Articles & Issues ▾

About ▾

Publish ▾

Order journal ↗

Search in this journal



Submit your article ↗

Guide for authors

Special issue

SHARP Science Book

Last update 30 March 2026

SHARP (<http://sharp.brera.inaf.it>) is a conceptual study for a near-IR (0.95–2.45 μm) multimode spectrograph designed to leverage the Multi-Conjugate Adaptive Optics (MCAO) capabilities of the ESO Extremely Large Telescope. Featuring multi-object slit and multi-IFU spectroscopy, SHARP will achieve angular resolutions of ~30 mas, three times better than NIRSpec at JWST, allowing us to address fundamental astrophysical and cosmological questions, from primordial galaxies to exoplanets, connecting the local to the distant Universe. This Special Edition provides an overview of SHARP's scientific capabilities through a collection of papers, each exploring a specific topic where SHARP offers distinct advantages.

Guest Editors:

Dr. Paolo Saracco

(Brera Astronomical Observatory, Milano, Italy)

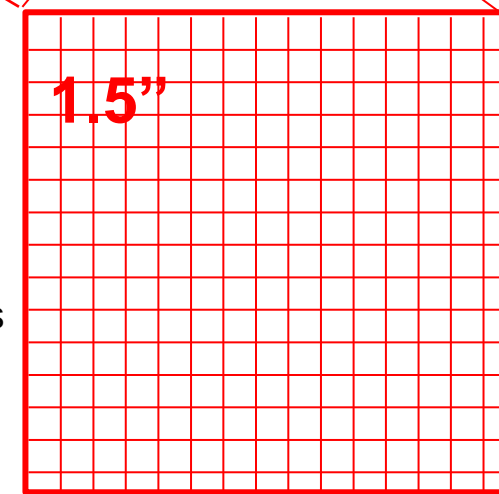
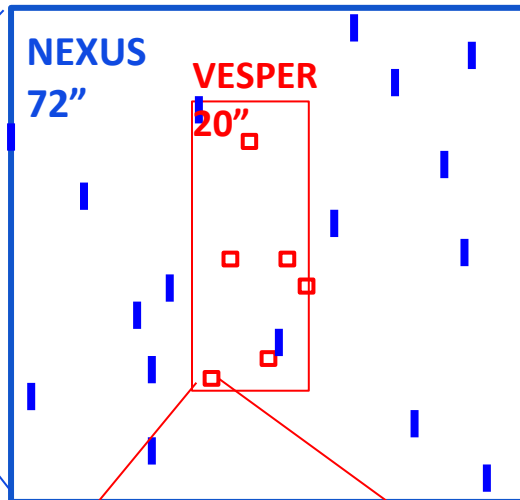
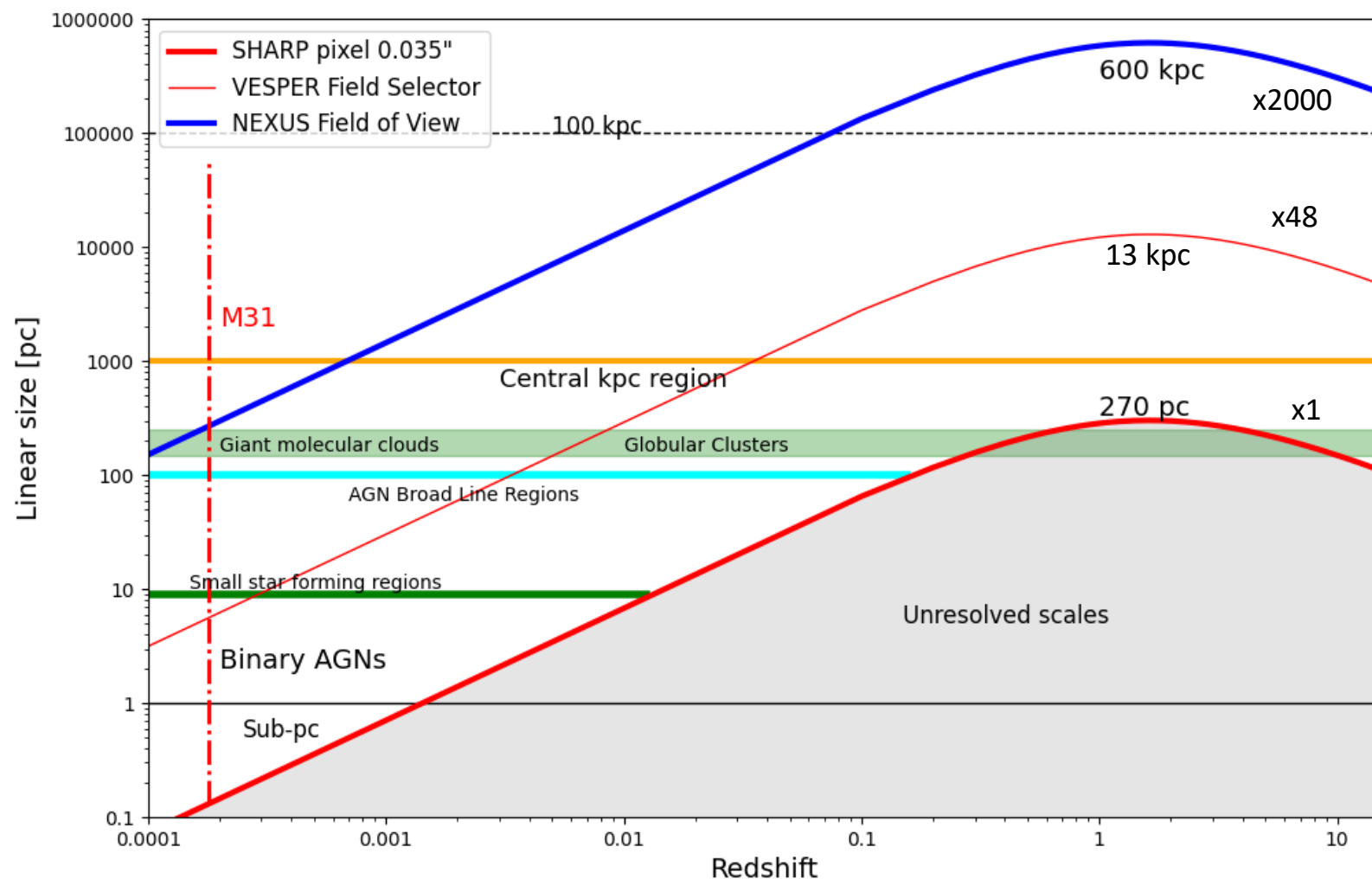
Dr. Maria del Carmen Polletta

(Institute of Space Astrophysics and Cosmic Physics Milan, Milano, Italy)

Dr. Andrea Longobardo

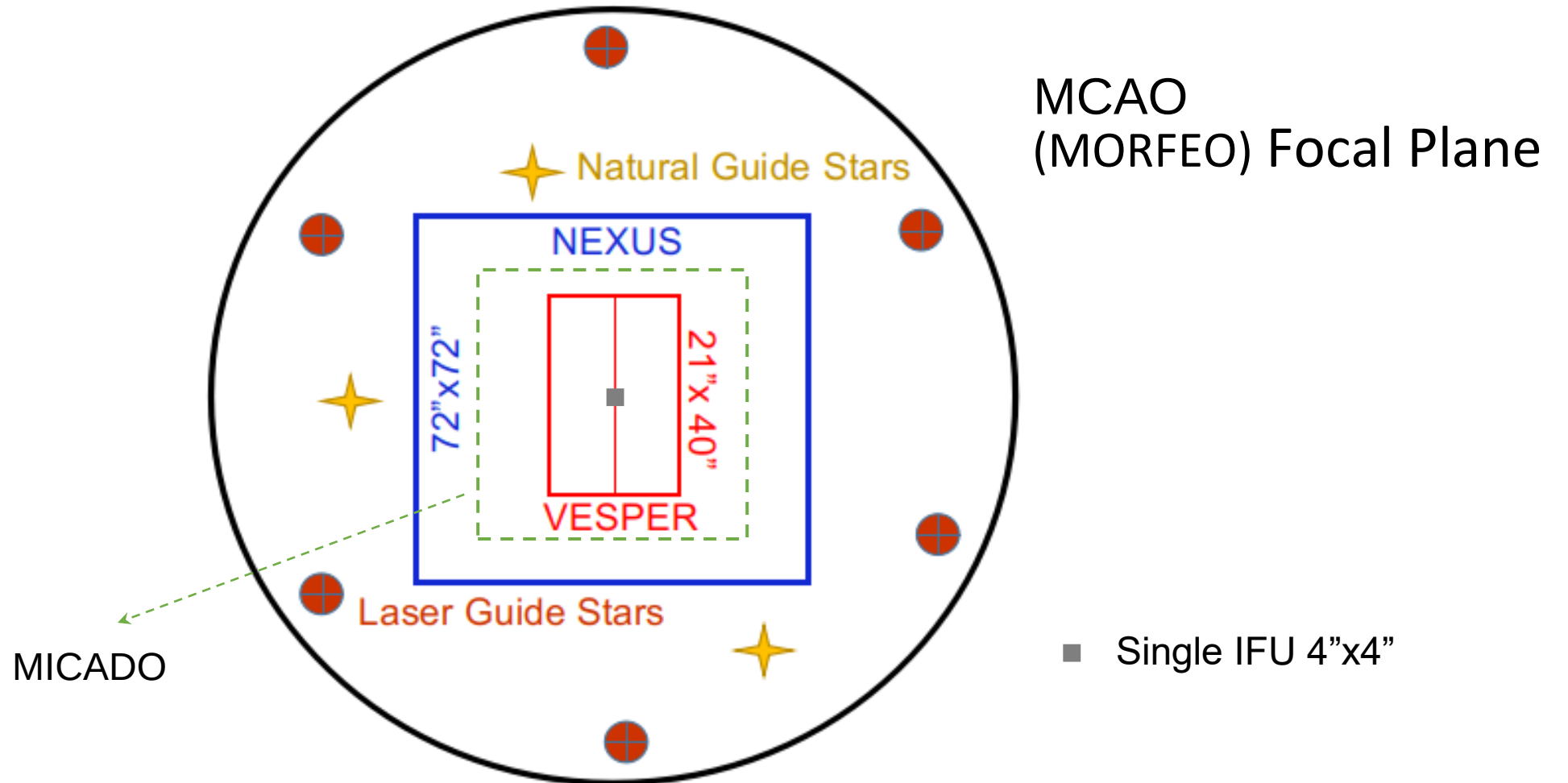
(Institute for Space Astrophysics and Planetology, Roma, Italy)

Angular and linear scales



31 - 35 mas

MCAO corrected area D~160"





SHARP Exposure Time Calculator

Version 0.6

[Documentation](#) [ChangeLog](#)

The ETC is still in beta testing. Report issues to paolo.franzetti@inaf.it

COMPUTE

RESET

SAVE SCENARIO

LOAD SCENARIO

Expand All

Collapse All

Target

☒ SED ☐ Emission Line

Spectrum

☒ Template SSP BC016 Chabrier Zsun 0.1Gy

☐ Upload Choose File No file chosen

☐ Blackbody 11000 K

Magnitude

20.00

K

Flux

1e-18

☒ erg/cm²/sec ☐ erg/cm²/sec/arcsec²

FWHM

30.0

Å

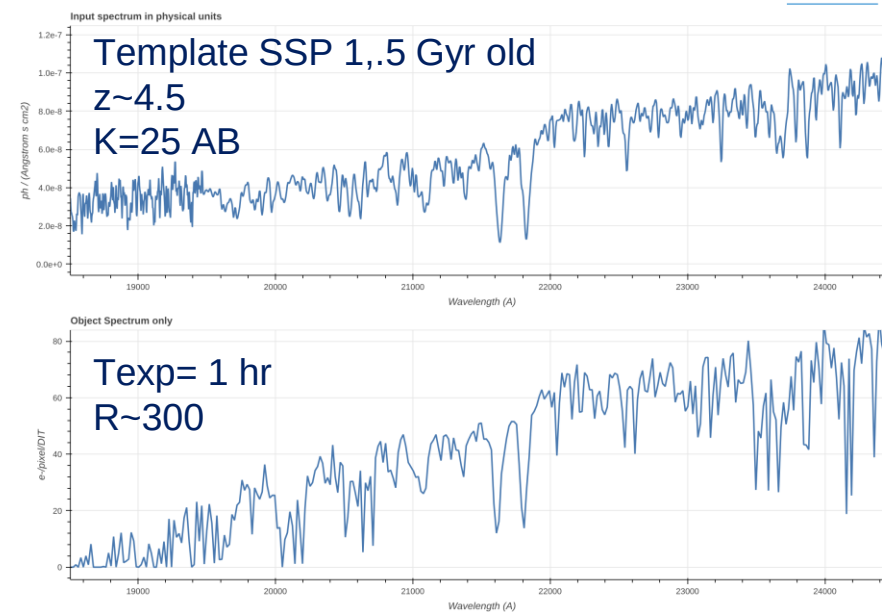
Center

22000.0

Å

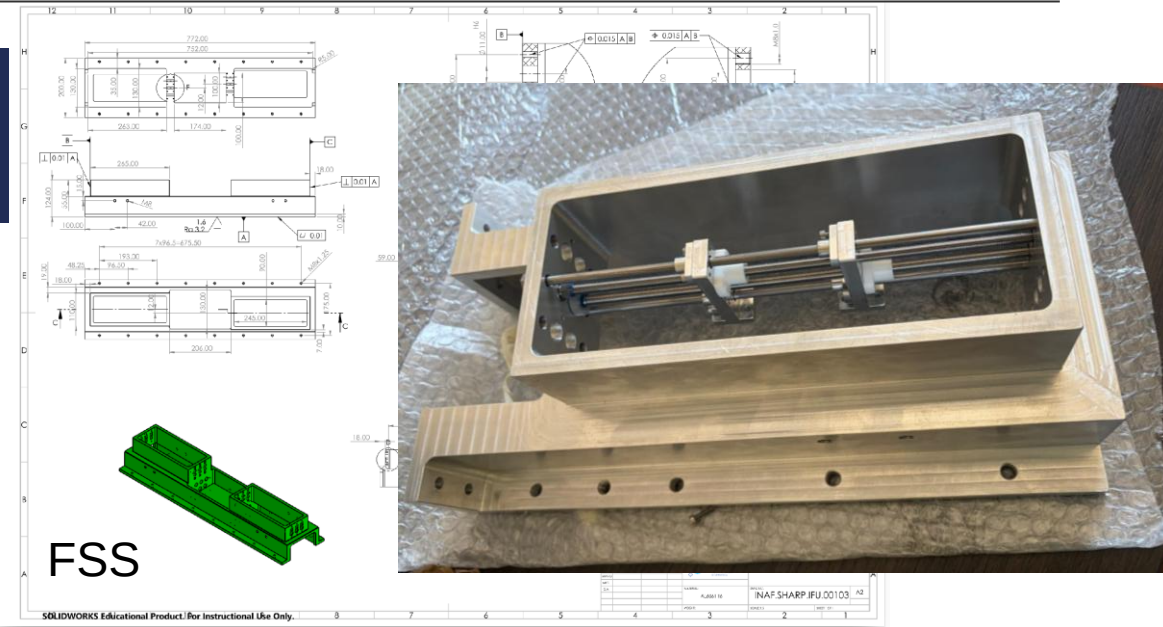
NEXUS spectrum

Slit width 50 mas



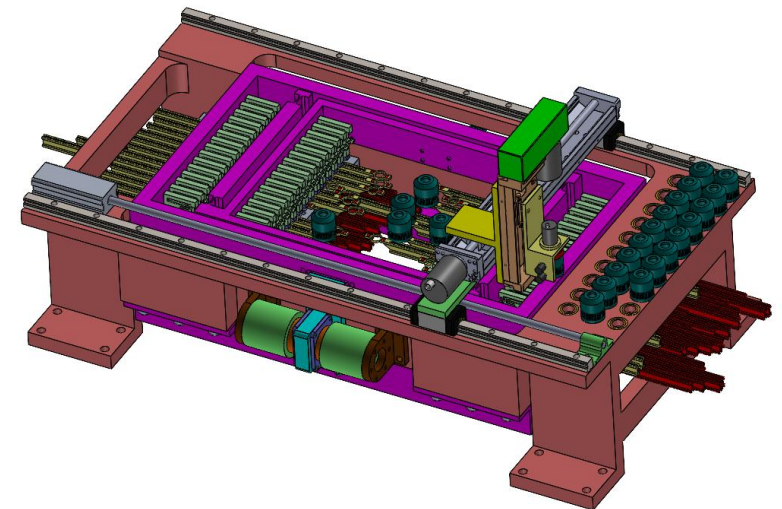
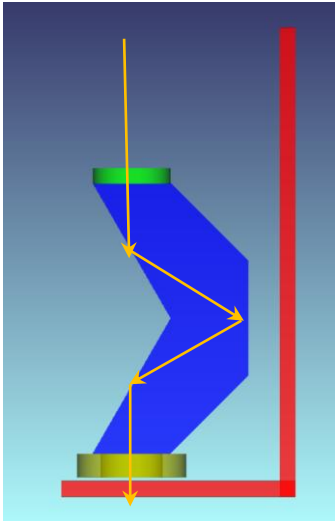
Prototyping of one arm of the Field Selector System of VESPER

- Prototype arrived Early June.
- Tests and measurements ongoing.



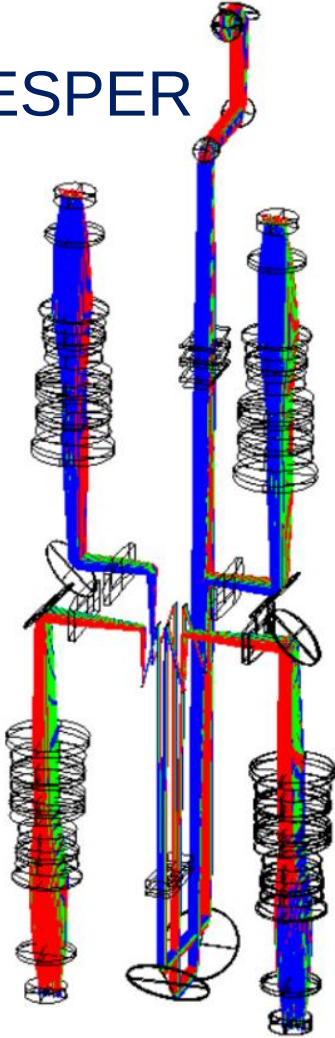
Feasibility assessment of inversion prism system of NEXUS

Ongoing consultancy with companies (e.g. CSEM) experienced in manufacturing of Configurable Slit Systems (e.g., MOSFIRE@Keck telescope)

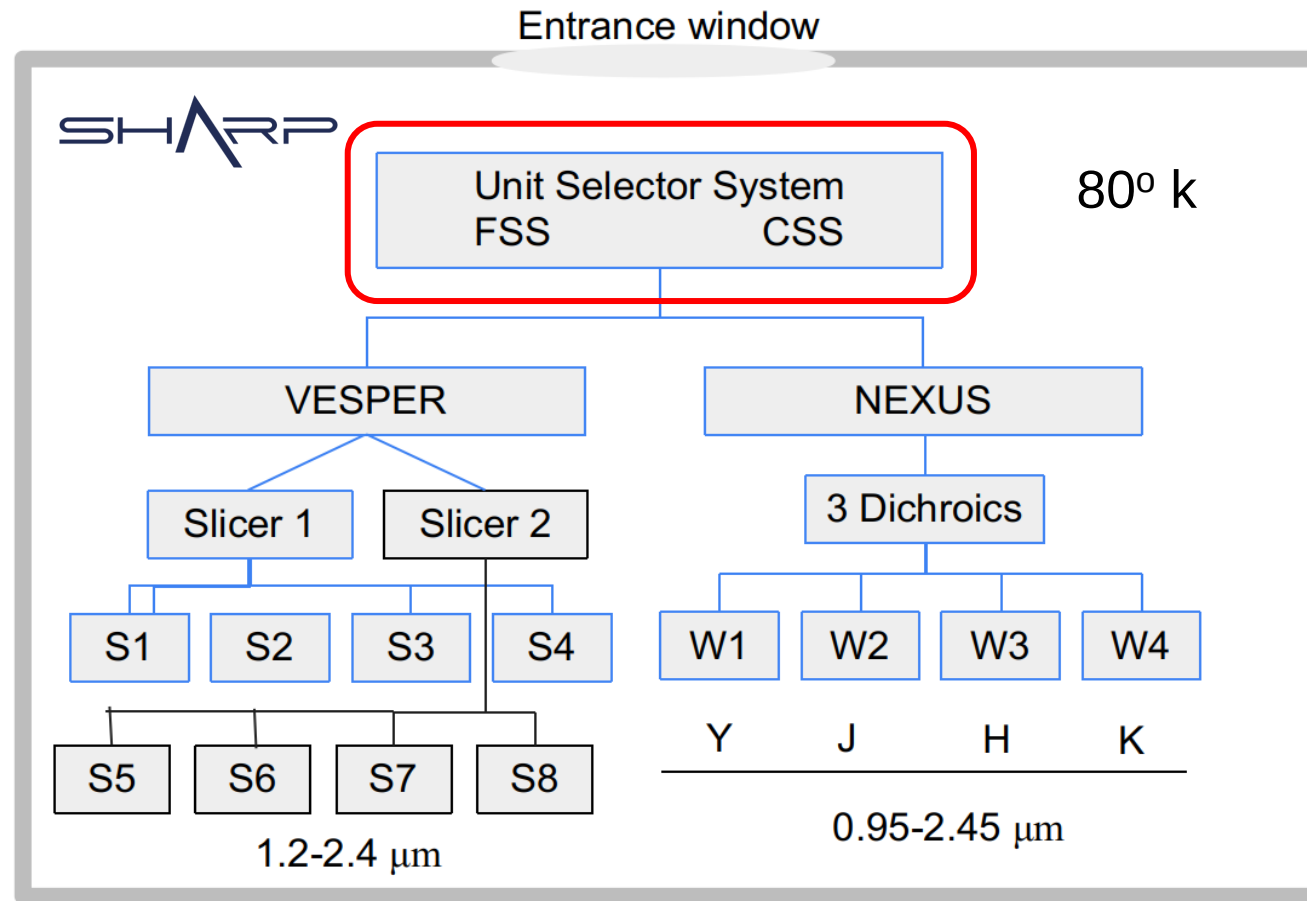


SHARP Architecture

VESPER



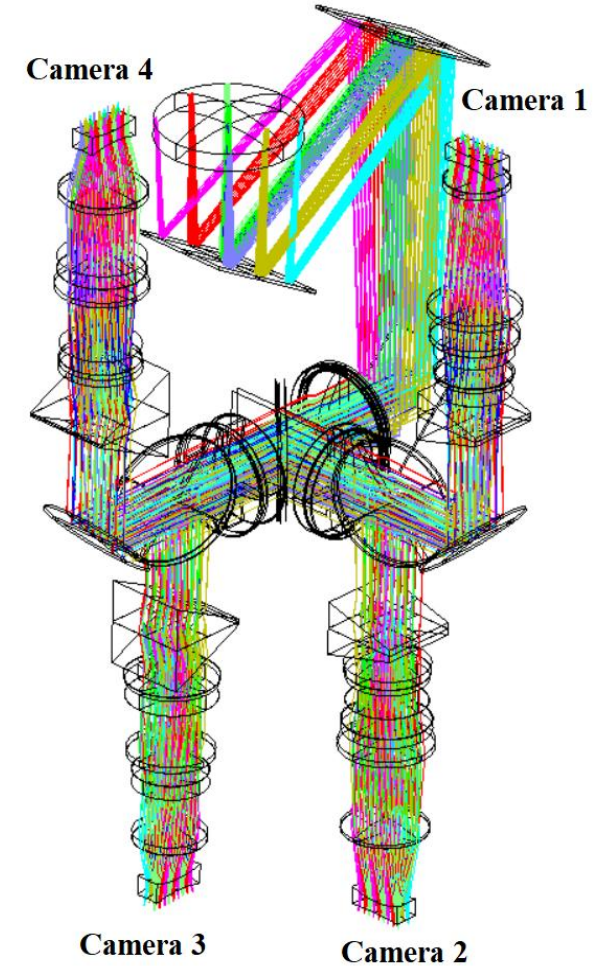
Opt. Design: P. Conconi,
H. Mahmoodzadeh, I. Di Antonio
Paolo Saracco



Unit Selector System (USS)

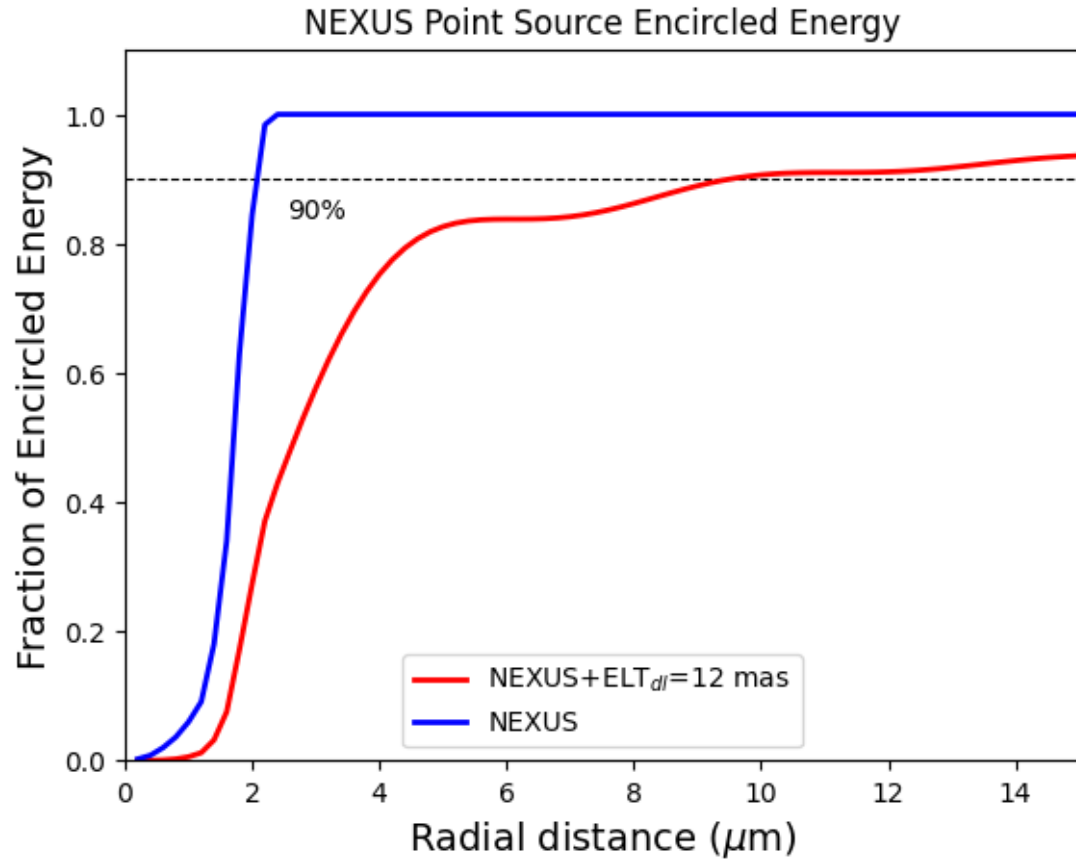
Field Selector System (FSS) + Configurable Slit System (CSS)

NEXUS

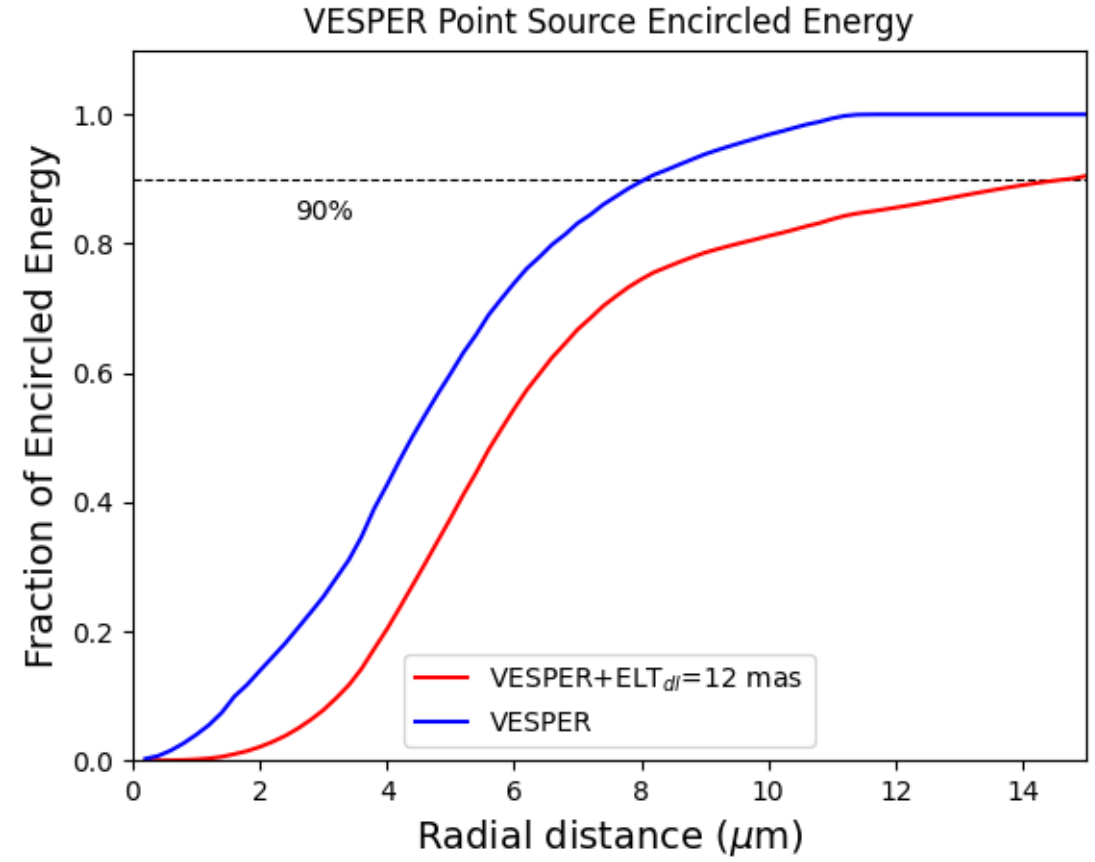


Opt. Design: P. Conconi,
H. Mahmoodzadeh, I. Di Antonio

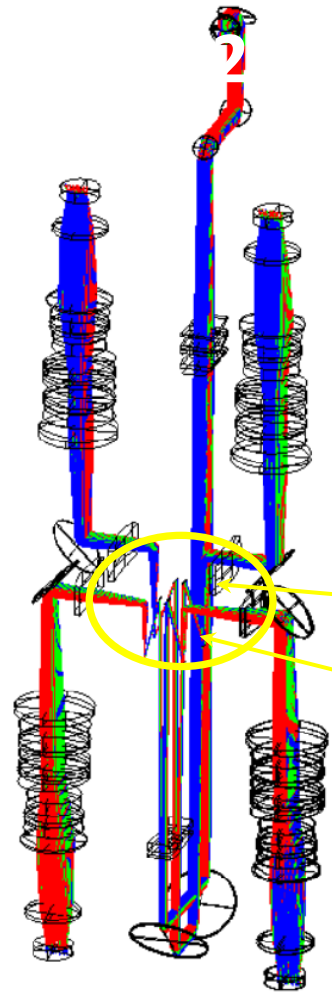
NEXUS



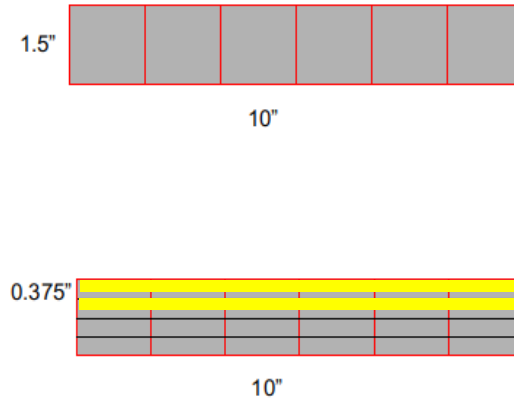
VESPER



SHARP - VESPER - the Multi-IU

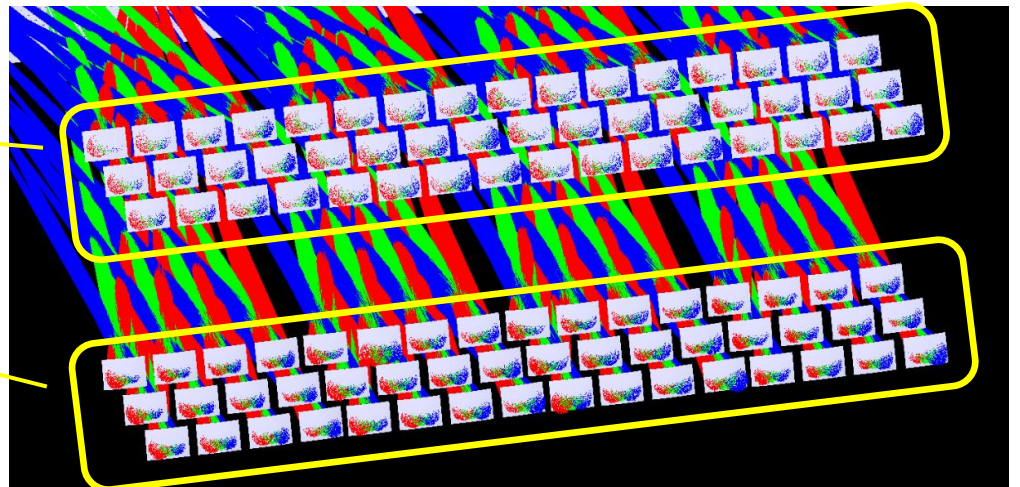
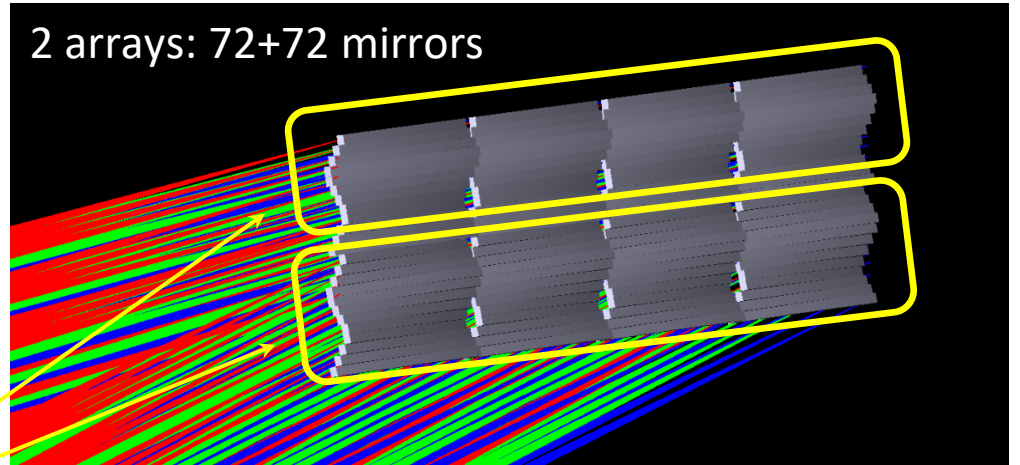


Slicer on the focal plane (similar to MUSE)
288 mirrors, divided into 4 arrays;

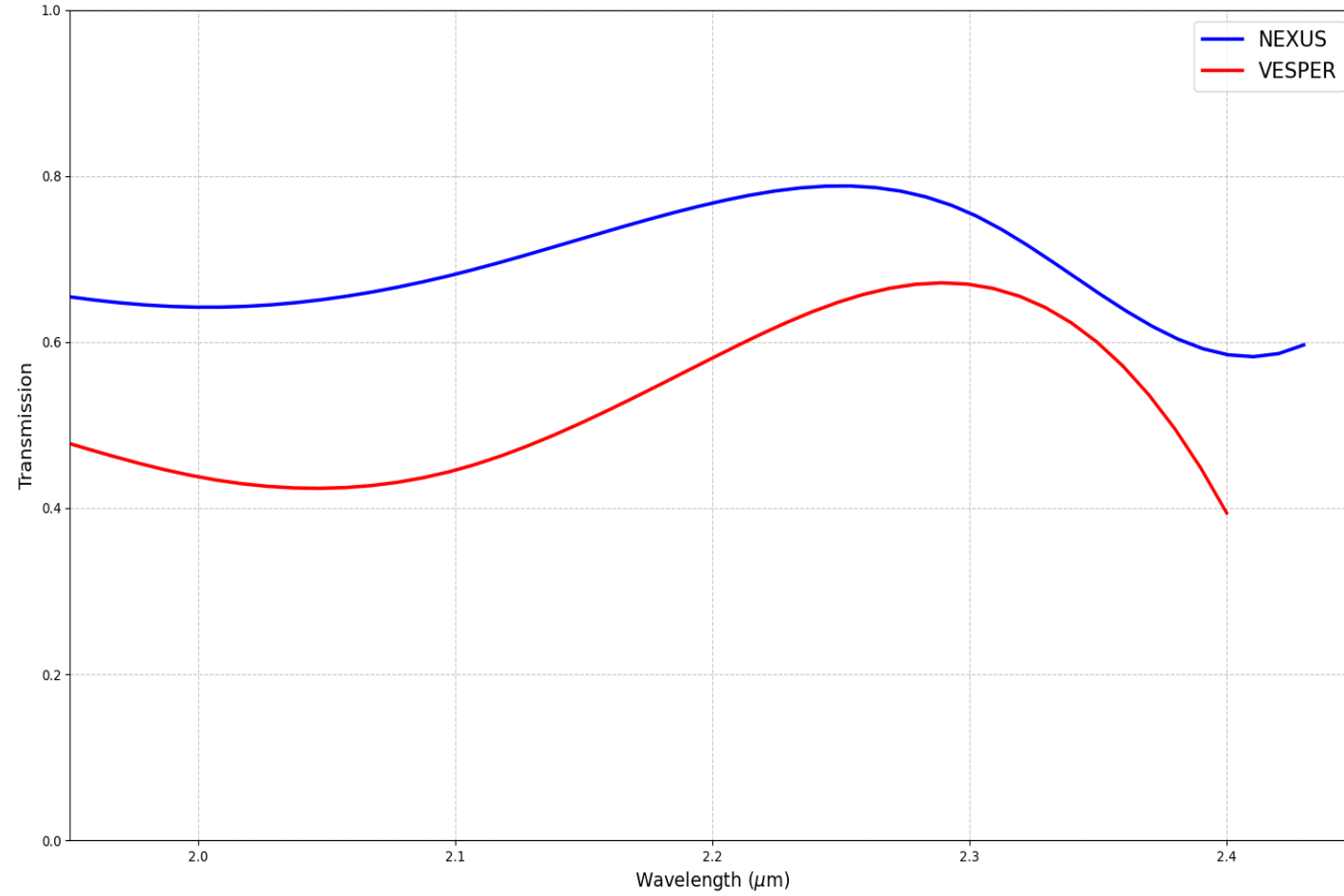


Slicer

Each set samples a stripe of the image :
4 arrays --> 4 stripes --> 4 cameras



Corresponding 72+72 pupil mirrors.

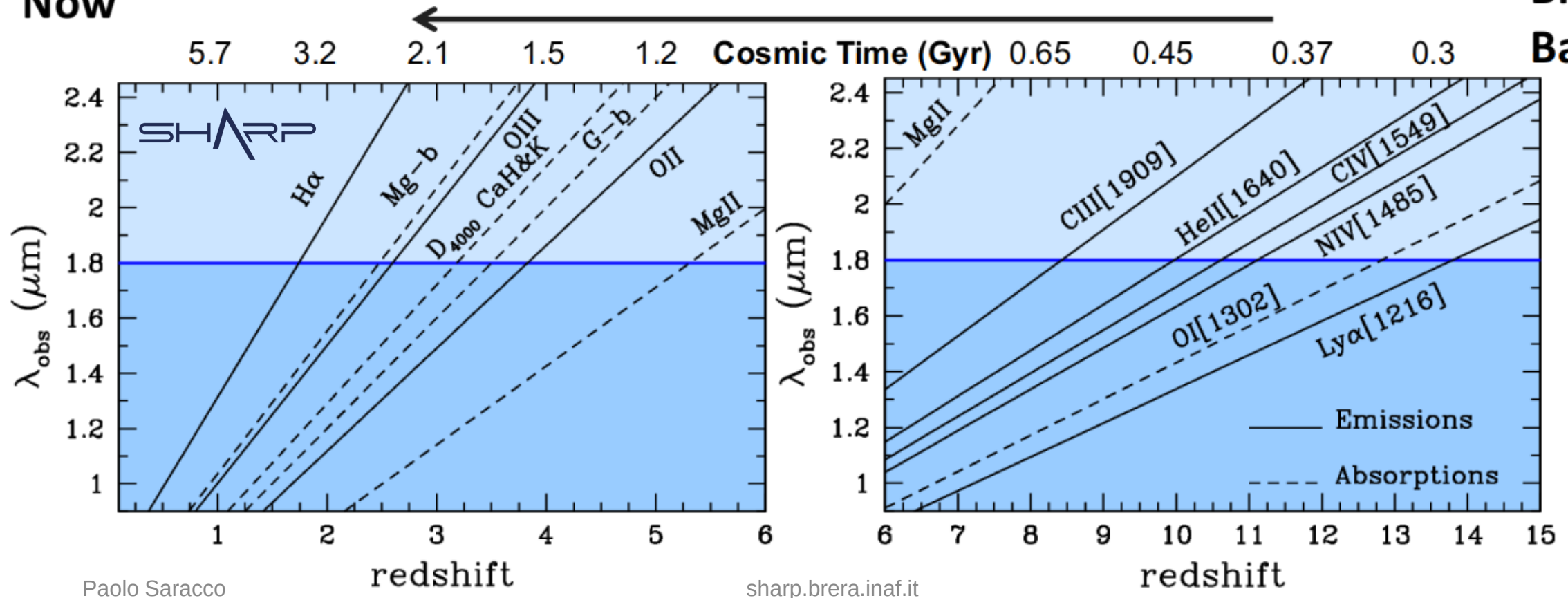


Essential to

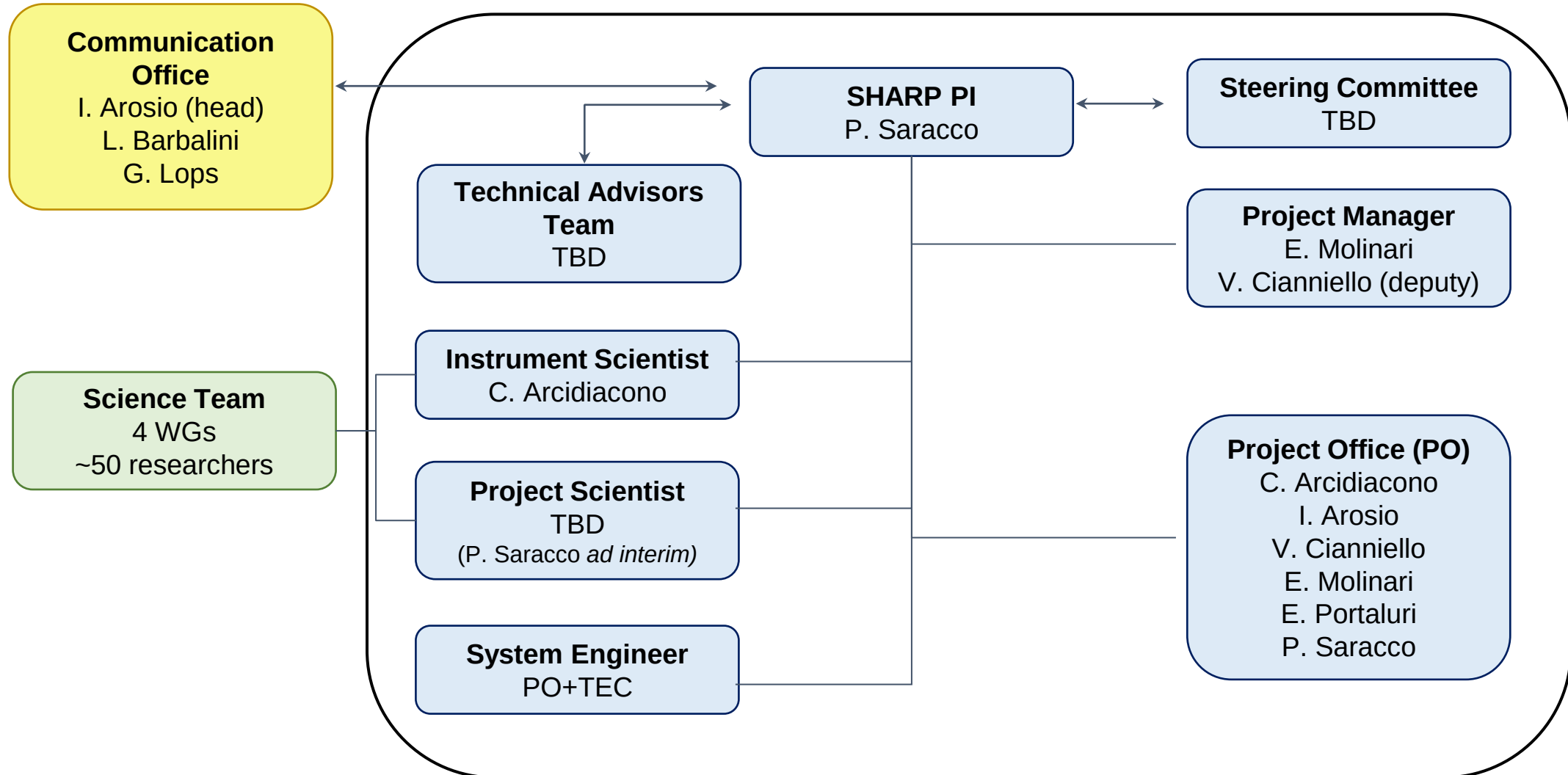
- probe **dust-shrouded regions** (e.g. GC, star forming, AGNs,...)
- study **stellar population properties** up to $z \sim 5$
- probe the **Universe** up to $z \sim 15-16$

Now

Big
Bang



SHARP - Project Management Structure



SHARP Proposal

Significant upgrade of ELT

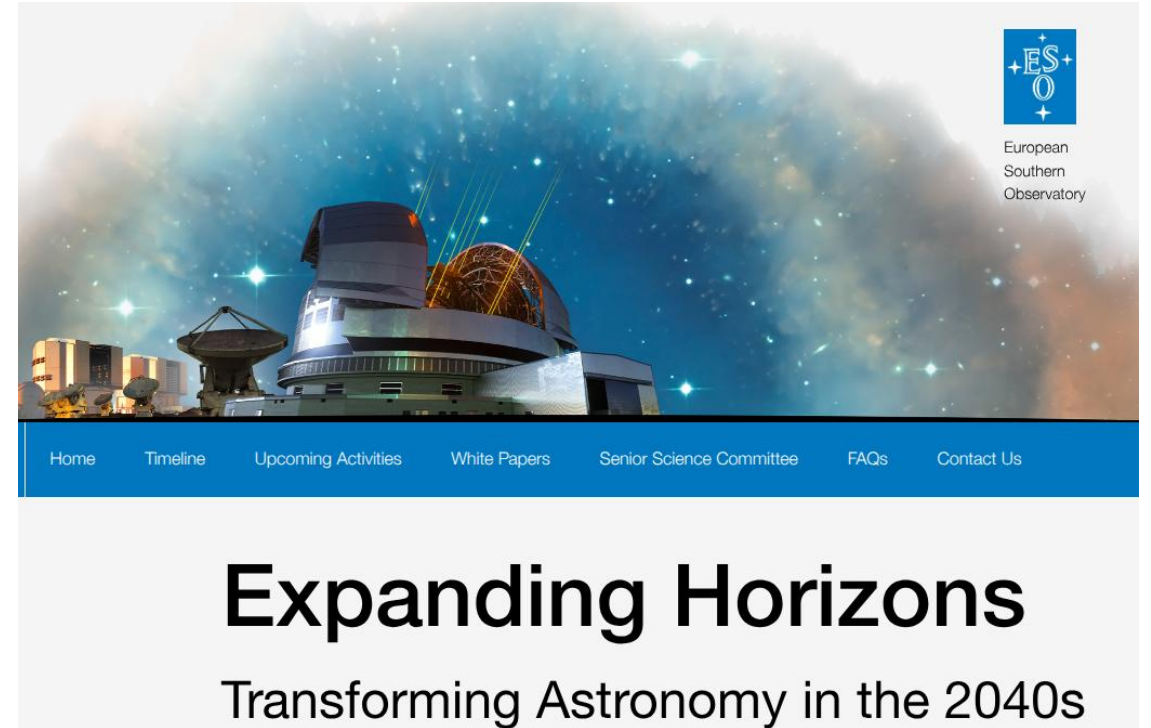
"Facility that enables scientific benefits in a number of areas and serves a large part of the astronomical community."

December 2026

Letter of intent

June 2027

Proposal submission



Scaling SHARP internationally

We welcome expressions of interest from institutes, scientists, and technologists worldwide.

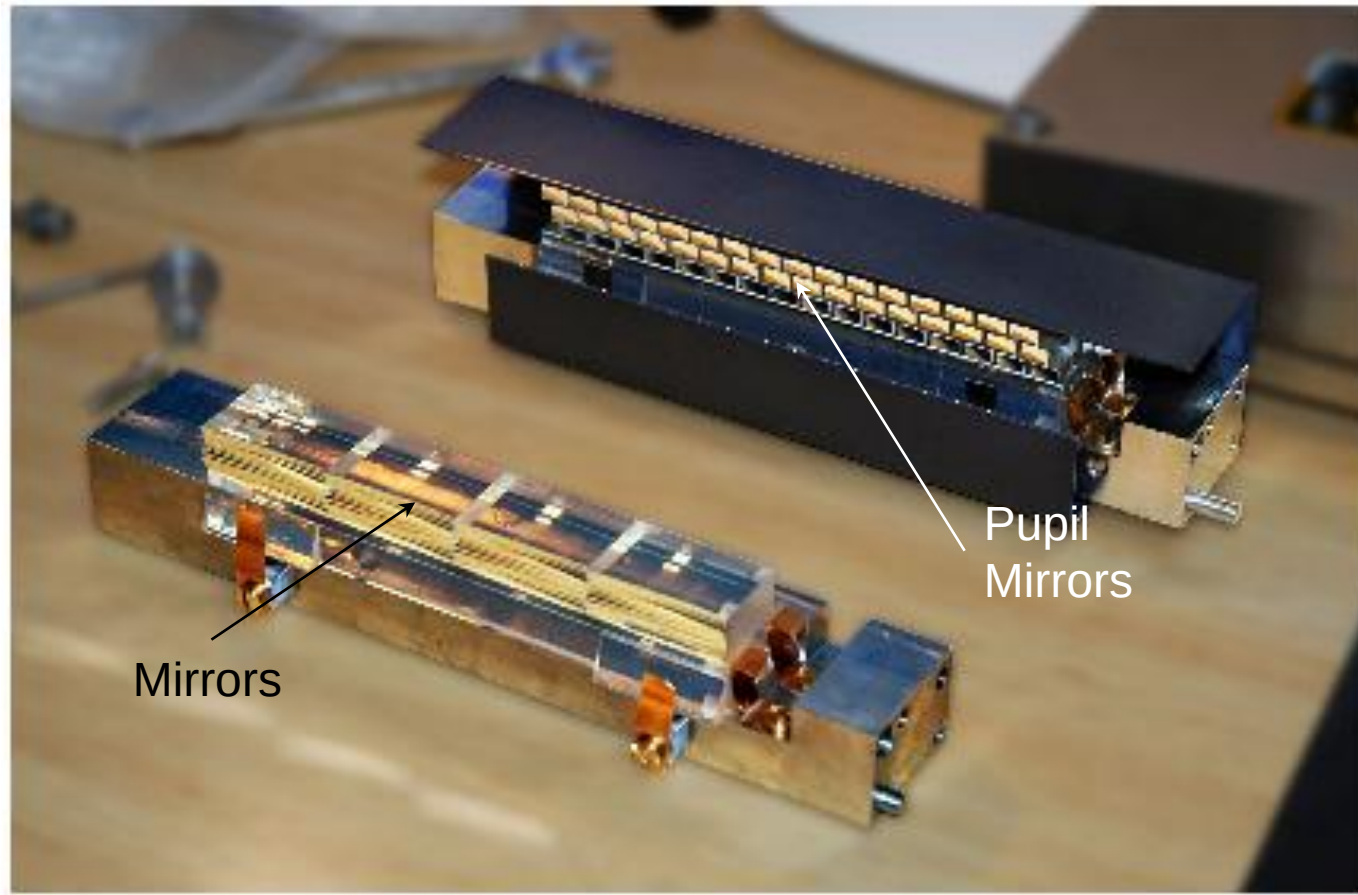
sharp_join.oabr@inaf.it

paolo.saracco@inaf.it

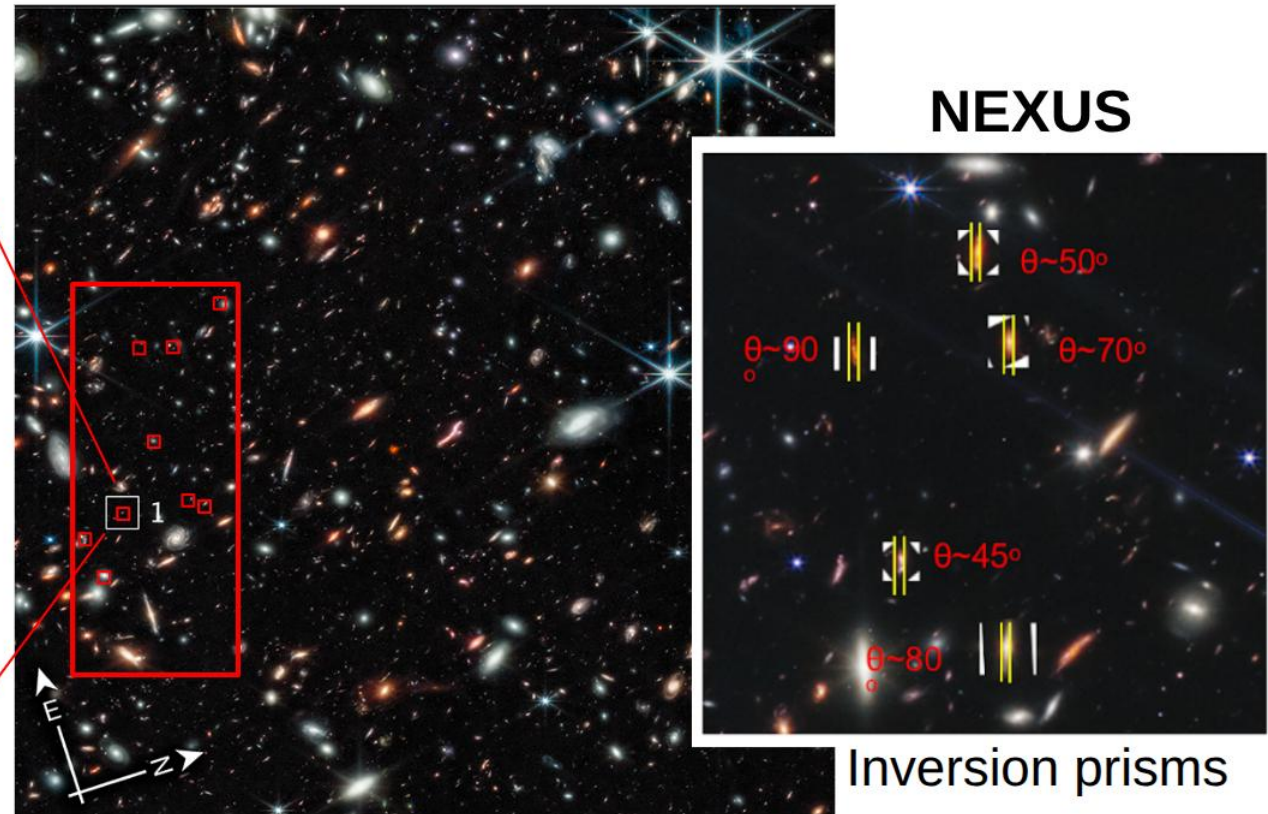
ELTs High-Ang resolution spectrographs in the 2030s-2040s

Spectrograph	AO	Multi Plex	Type FoV	Ang res (mas)	Wavelength (μm)	Comm	$\lambda/\Delta\lambda$	2030 2034	2039	2044
JWST-NIRSpec	-	~100	MSA 3'x3'	100 Pixel size	0.6-5.0		100-2700		?	
JWST-NIRSpec	-	1	IFU 3"x3"	100 Pixel size	0.6-5.0		100-2700		?	
ELT-MICADO	SCAO MCAO	1	Longslit sw<50 mas	12 diff lim ELT	0.85-2.4		20000			
ELT-MICADO	SCAO MCAO	1	IFU ?	12	0.85-2.4		?			
ELT-HARMONY	MCAO	1	IFU 3"x4"	20 pixel size	0.9-2.4		3000-7000?	?		
ELT-ANDES	SCAO	1	IFU 0.5"x0.5"	12 diff lim ELT	1.0-1.8	Fiber	100000			
ELT-MOSAIC	MOAO	8	multi-IFU 2.2"x2.2"	~200 fiber/MOAO	1.0-1.8	Fiber	5000-20000			
GMTIFS	LTAO	1	IFU <3"x4"	50 Pixel size	0.9-2.4		5000-10000			
SHARP-NEXUS	MCAO	~30	MOS 1'.2x1'.2	35 Pixel size	0.95-2.4		~300-6000			
SHARP-VESPER	MCAO	12	multi- IFU 1.7"x1.5"	31 Pixel Size	1.2-2.4		~3000			

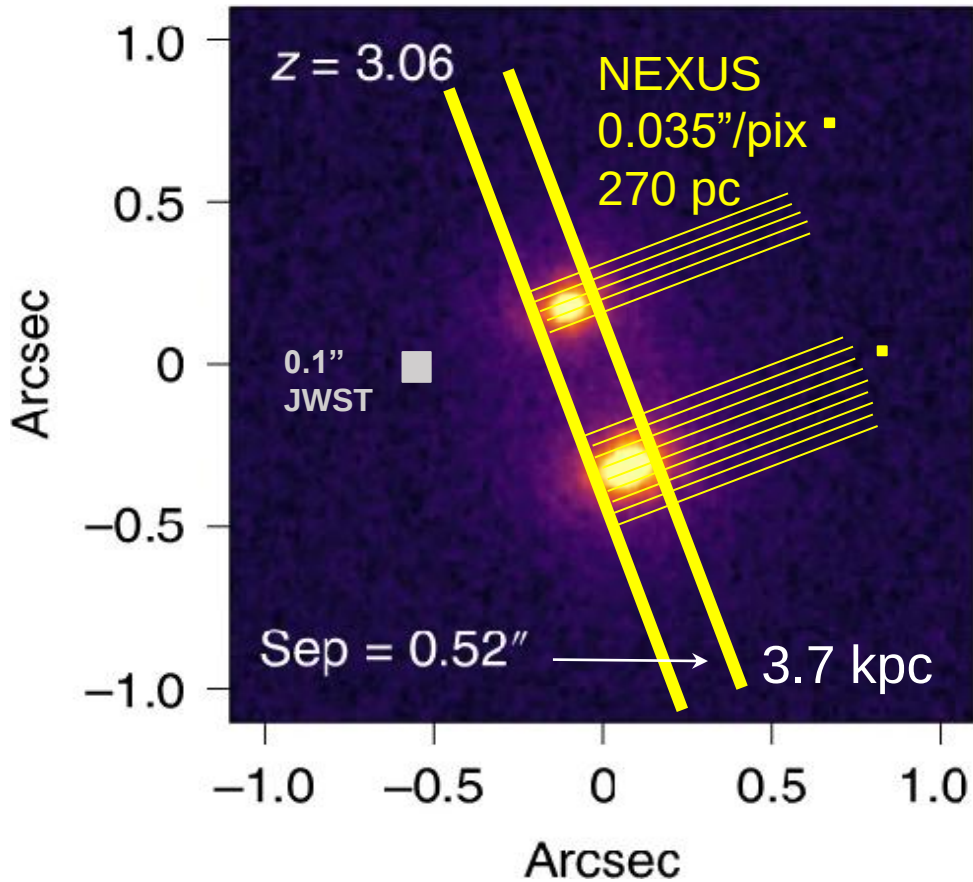
MUSE mirrors (0.8mm) and pupil mirrors



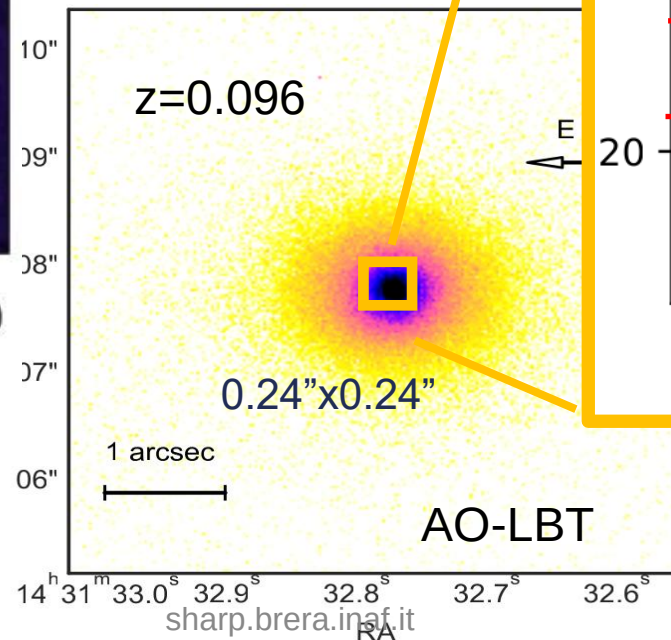
Kinematics and Dark matter of high-z galaxies



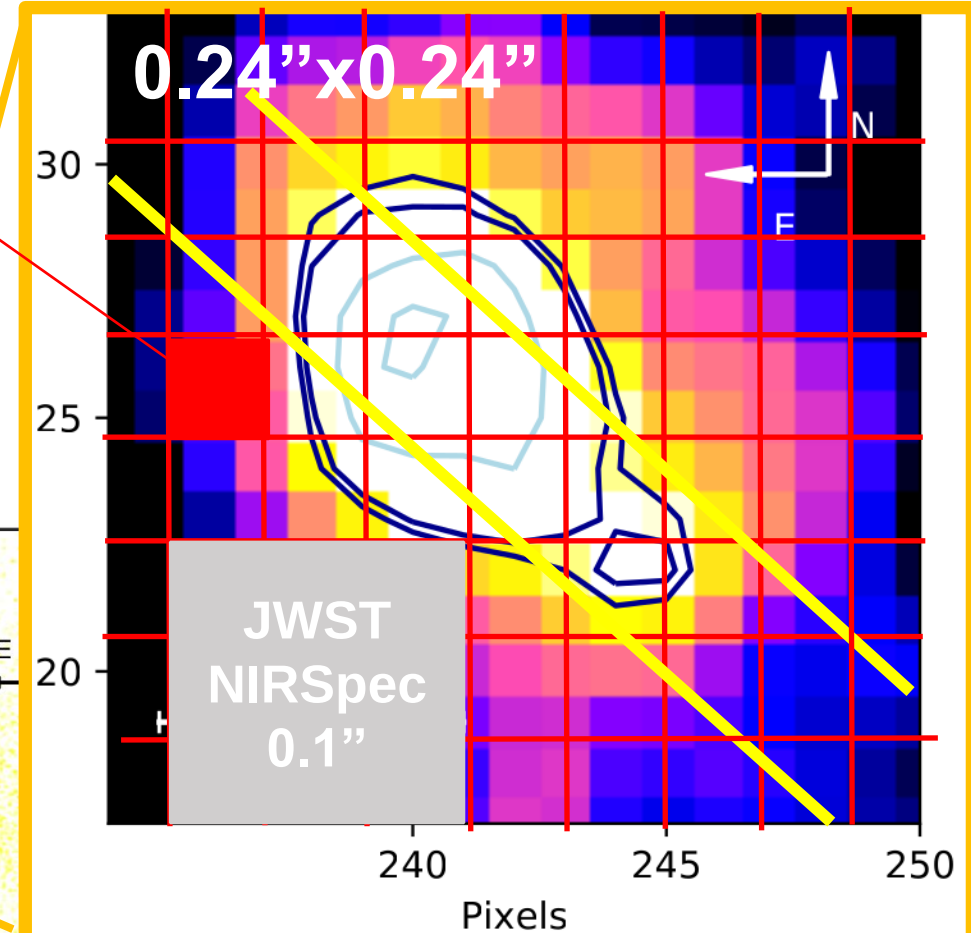
J0732+3533

*Mannucci et al. 2022*

Dual AGNs



VESPER
 $0.031''$
 50 pc

*Severgnini et al. 2021*

Revealing the birth and growth of galaxies with the resolution of the ELT

Looking beyond JWST

Paolo Saracco

INAF - Osservatorio Astronomico di Brera

P. Conconi, C. Arcidiacono, H. Mahmoodzadeh, I. Di Antonio, E. Portaluri, P. Franzetti, A. Gargiulo, I. Arosio, L. Barbalini, G. Lops, E. Molinari, J. M. Alcalá, S. Bisogni, R. Bonito, E. Bortolas, M. Cantiello, A. Caratti o Garatti, E. Cascone, V. Cianniello, E. M. Corsini, F. Damiani, F. D'Ammando, F. D'Alessio, E. Dalla Bontà, M. Dall'Ora, V. De Caprio, G. De Lucia, B. Di Francesco, G. Di Rico, V. D'Orazi, C. Eredia, A. R. Gallazzi, M. G. Guarcello, L. Izzo, F. La Barbera, M. Lippi, M. Longhetti, A. Longobardo, C. Mancini, M. Mirabile, E. Piconcelli, A. Pizzella, L. Podio, L. Prisinzano, C. Tortora, G. Vietri, F. Vitali, H.-F. Wang, S. Zibetti



SHARP	NEXUS (MOS)	VESPER (mIFU)
Spectral range	0.95-2.45 μm (Simultaneously)	1.2-2.4 μm (Simultaneously)
Field of View/Area probed	1'.2 x 1'.2	~20" x 40"
Multiplexing	up to 30 slits (2".4 length)	12 probes (1".7x1".5 each) --> 20"x1".5 (contiguous)
Pixel scale	~0.035"	~0.031"
Resolution $\lambda/\Delta\lambda$	~ 200, 2000, 6000 (0".2 ref) ~17000 Point Source	~3000 ~4000 Point Source