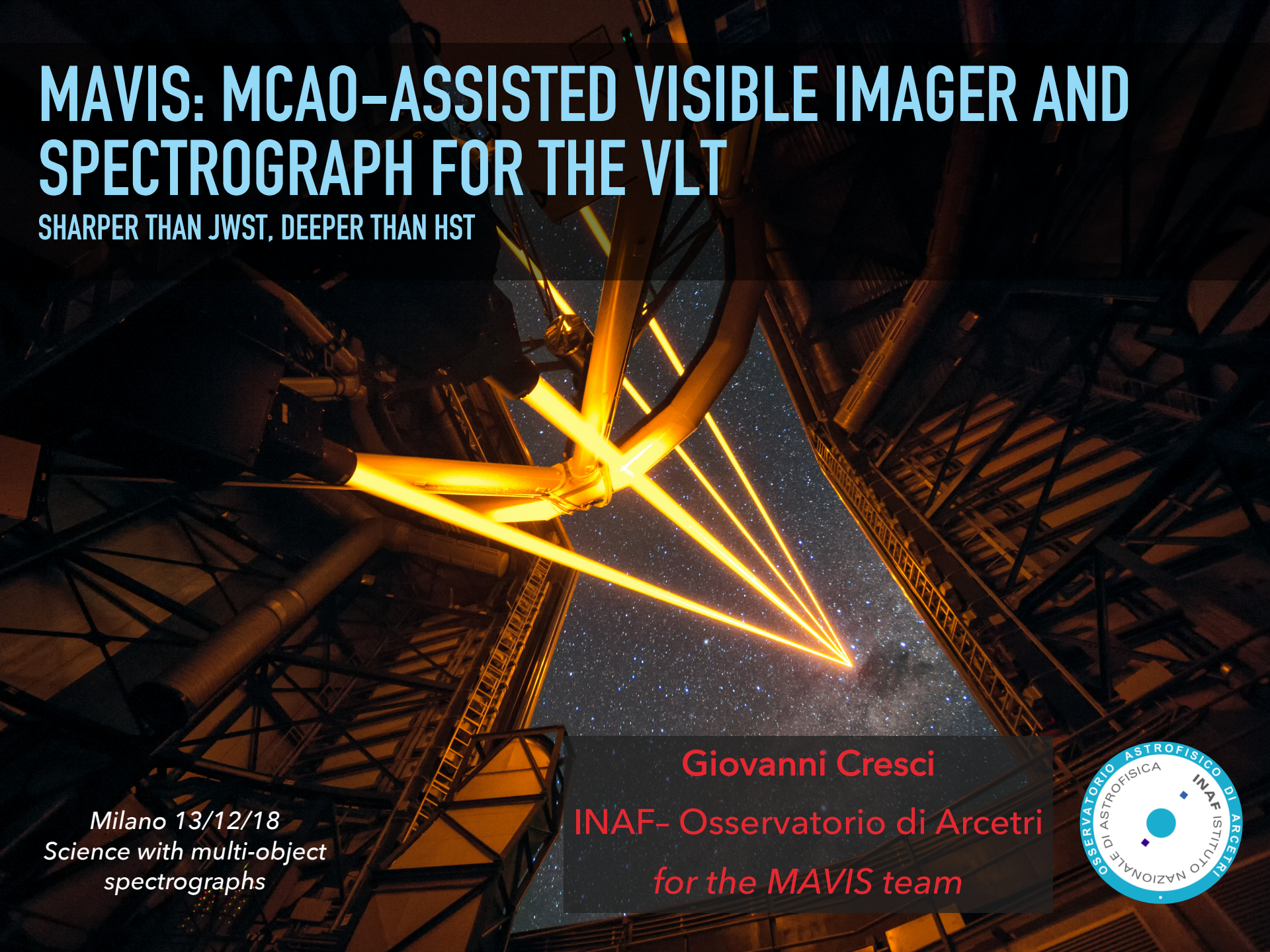
MAVIS: MCAO-ASSISTED VISIBLE IMAGER AND SPECTROGRAPH FOR THE VLT

SHARPER THAN JWST, DEEPER THAN HST



Giovanni Cresci

INAF- Osservatorio di Arcetri

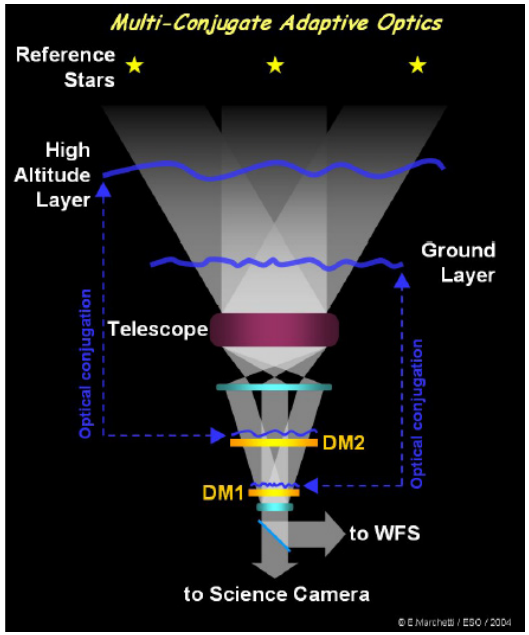
for the MAVIS team

Milano 13/12/18
Science with multi-object spectrographs

WHAT IS MAVIS?

MAVIS (***MCAO-Assisted Visible Imager & Spectrograph***) is a proposed instrument for the VLT AOF (Adaptive Optics Facility).

It will provide near-diffraction limit image quality over a large (~30''x30'') fov using Multi-Conjugate AO



Strawman MAVIS Requirements

Field of view	30"x30"
Angular resolution	FWHM ~ 20mas at V band
Wavelength coverage	VRI, extended to UBz
Strehl ratio	15% at V under median seeing conditions
Sky coverage	> 50% at Galactic Poles
Imager	~ 7mas pixel size. Broad and narrow band filters. Tuneable filters - to be explored
Spectrograph	Fibre + Starbug concepts to be explored: Highly multiplexed point-source capabilities Multiplexed compact IFUs (0.5" FoV) and larger FoV IFUs. R=5,000-10,000. Alternatively, 3"x3" image slicer IFU with 25mas spaxels.

- Blog: www.mavis-ao.org

A BRIEF HISTORY

- **"ESO Community Days"** annual workshop to discuss future instrumentation and upgrades:
  - 2015+2016, a **visible MCAO capability** gathered most interest
  - Concept initially presented by Simone Esposito (INAF Arcetri)
- July 2017: Australia joined ESO as strategic partner
- October 2017: **consortium formed** to address expected ESO phase A call, with INAF (Arcetri, Padova & Roma), Laboratoire d'Astrophysique de Marseille (LAM), and Australian Astronomical Optics (AAO, including ANU, MQ & UniSyd)
- Initial science workshop November 2017 in Sidney
- October 2018: Phase A proposal submitted to ESO
- November 2018: **MAVIS awarded agreement for phase A** conceptual design study by ESO

Australian National University

INAF
ISTITUTO NAZIONALE DI ASTROFISICA
NATIONAL INSTITUTE FOR ASTROPHYSICS

AAO

LAM
LABORATOIRE D'ASTROPHYSIQUE DE MARSEILLE

SWINBURNE UNIVERSITY OF TECHNOLOGY

ONERA
THE FRENCH AEROSPACE LAB

MACQUARIE University
SYDNEY·AUSTRALIA

MAVIS CONSORTIUM

AO system engineering
Opto-mechanics
Instrument Software
NGS WFS

National Optical Astronomical Instrumentation Capability (to come)

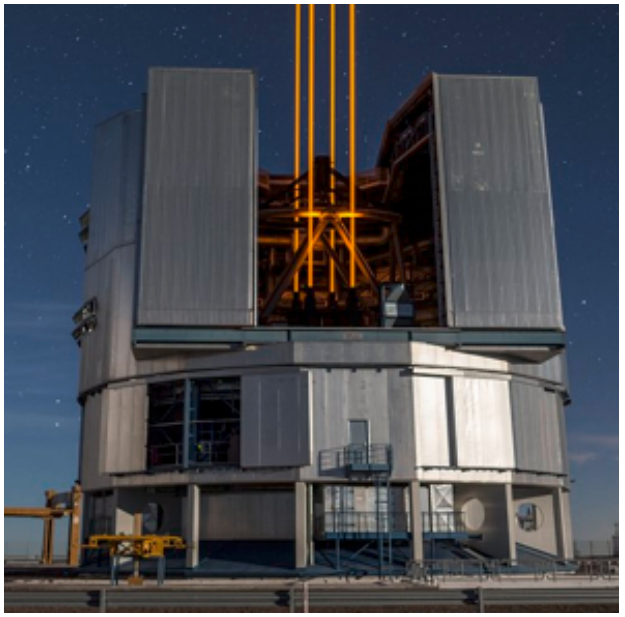
Post-focal instrumentation:
Imagers, spectrograph,
image slicer or fibre pick off
Management
LGS WFS
RTC, AO expertise

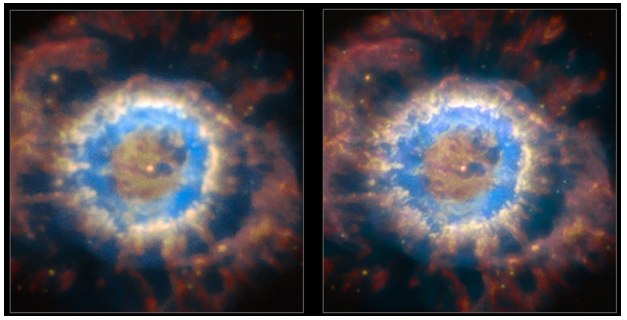
Simulations
Post-processing
AO Control

GTO: 150 nights

ADAPTIVE OPTICS FACILITY (AOF)

- Upgrade of VLT UT4 with AO fully integrated into the telescope
- Key technical components:
  - Deformable secondary mirror with high actuator density
  - Four laser guide stars, 20W each, operating above specifications
  - Both key for high performance in the optical
- Current instrumentation:
  - MUSE: Optical IFU
  - HAWK-I: Wide-field IR imager
  - ERIS (from 2020): 1-5μm imager/IFU
- Mainly ground-layer AO (wide field, low Strehl)
- MUSE narrow field mode gives diffraction limit in optical, but only uses bright guide stars (<15 J-H mag, within 7.5″) and limited performances (Strehl~5%, FWHM~50 mas)

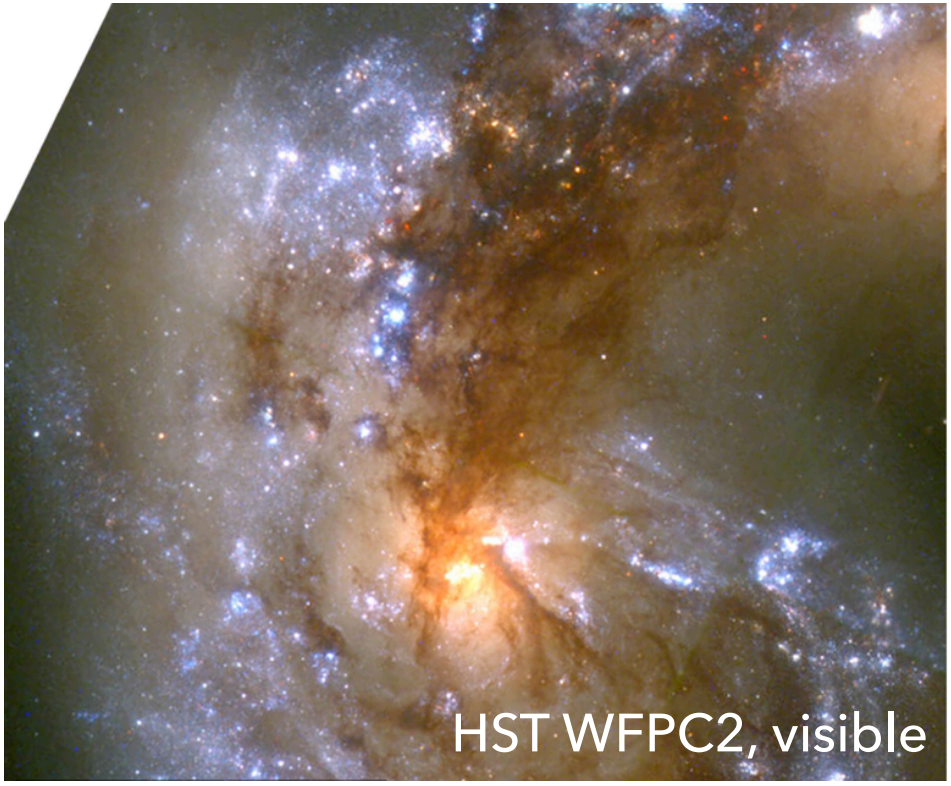




Full AOF science potential not being realized

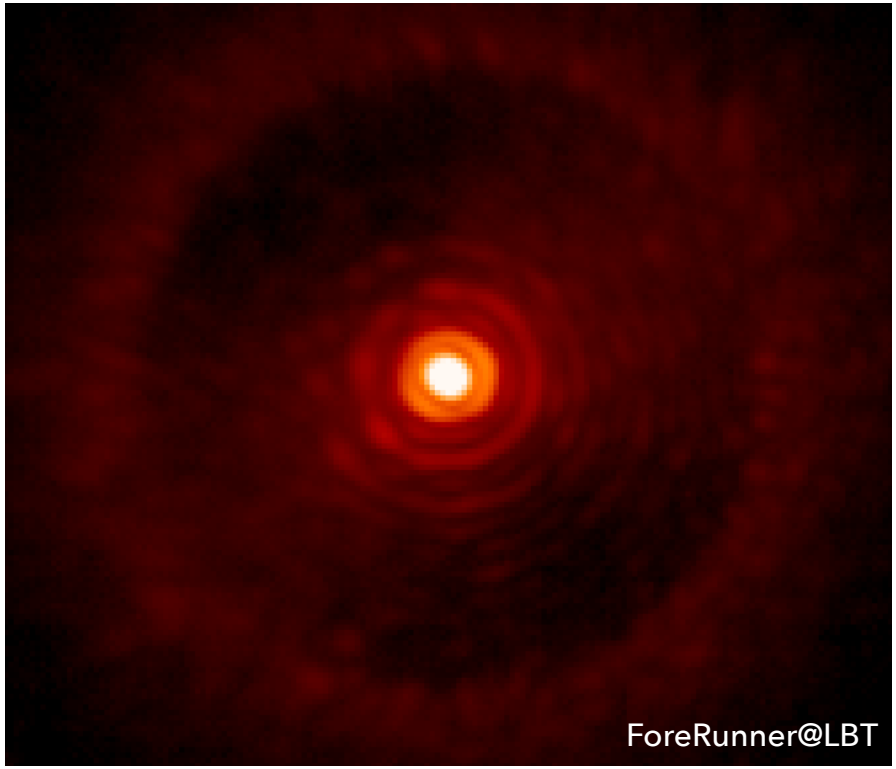
IN THE VISIBLE WITH AO

- Optical wavelengths are information-rich, with many well-understood astrophysical diagnostics
- Sky background is x1,000-10,000 times lower than infrared
- Detectors are larger, lower noise, faster frame rates, and cheaper
- Possible to compete with space facilities
- 500nm on an 8m gives same angular resolution as 2mm on an ELT



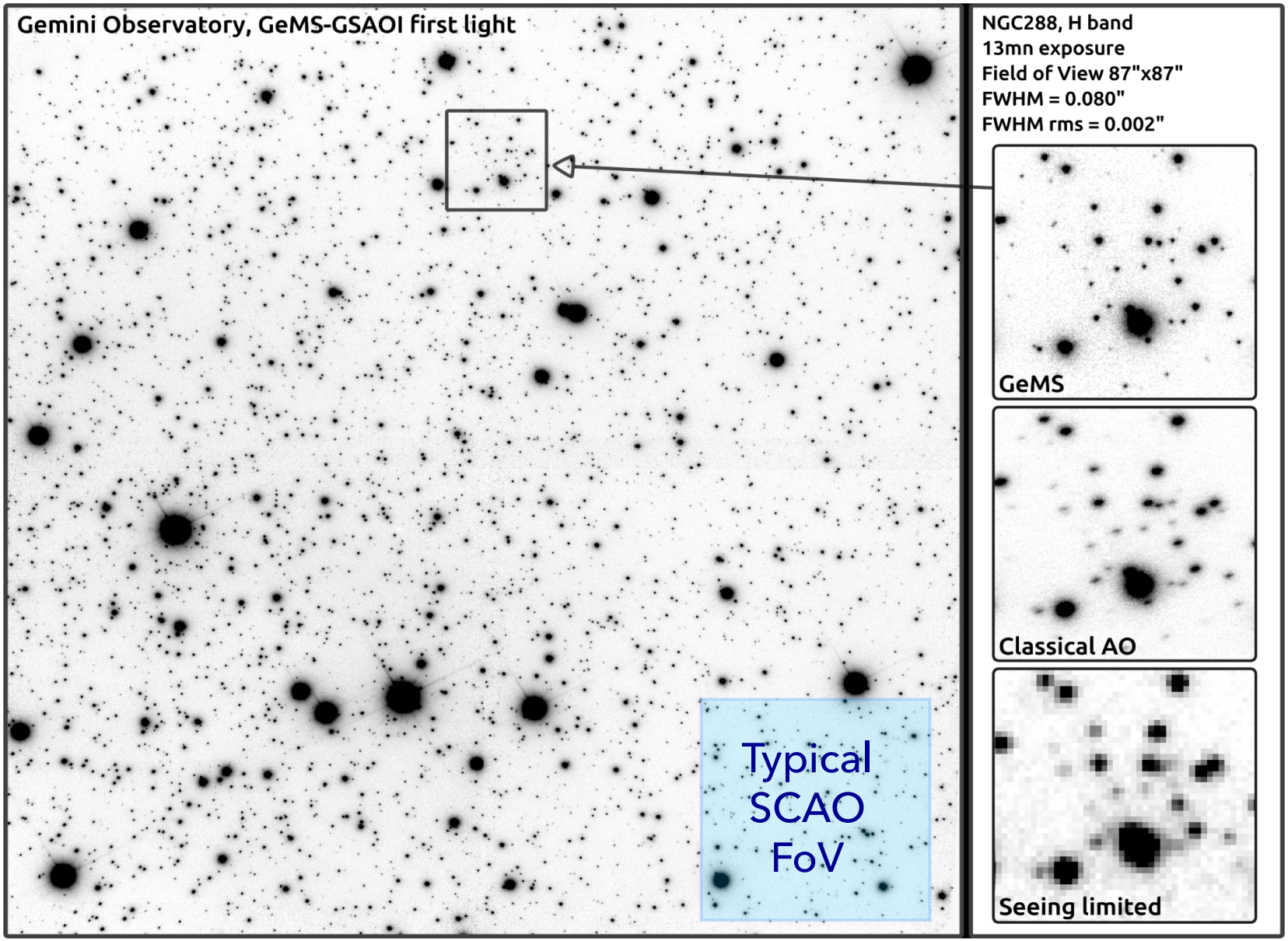
SINGLE CONJUGATE AO IN THE VISIBLE

- 650nm images from SHARK-VIS ForeRunner@LBT
  - Adaptive secondary
  - 0.8″ seeing
  - 50% Strehl ratio!
  - 18 milliarcsec FWHM
- Similar examples from:
  - SPHERE @VLT
  - MAG-AO @Magellan
- Visible AO is feasible!



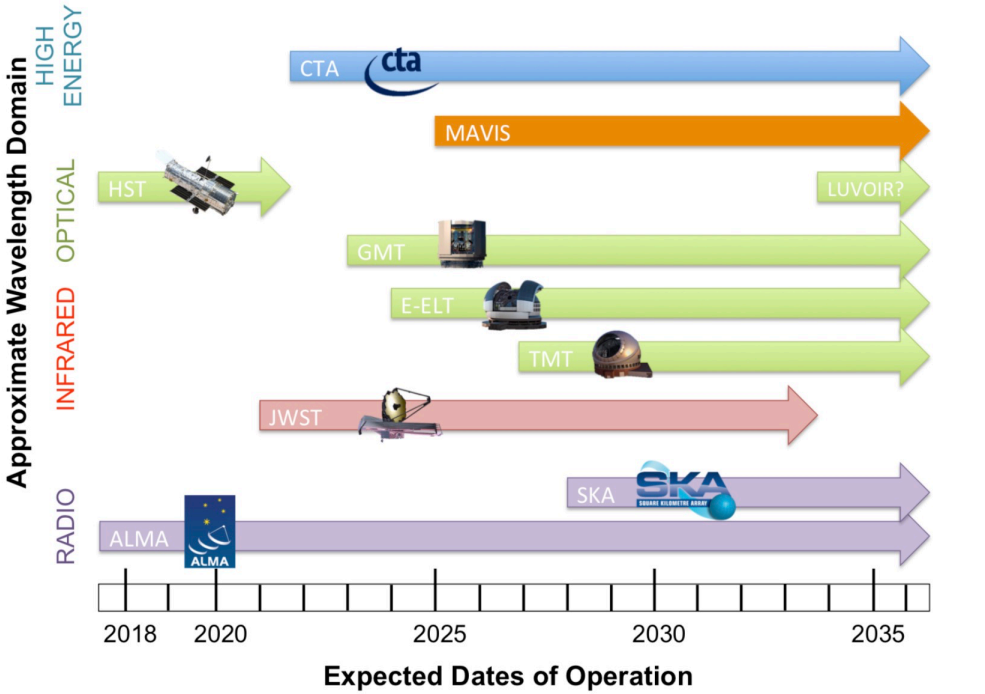
MCAO IN THE NIR

see also MAD@VLT



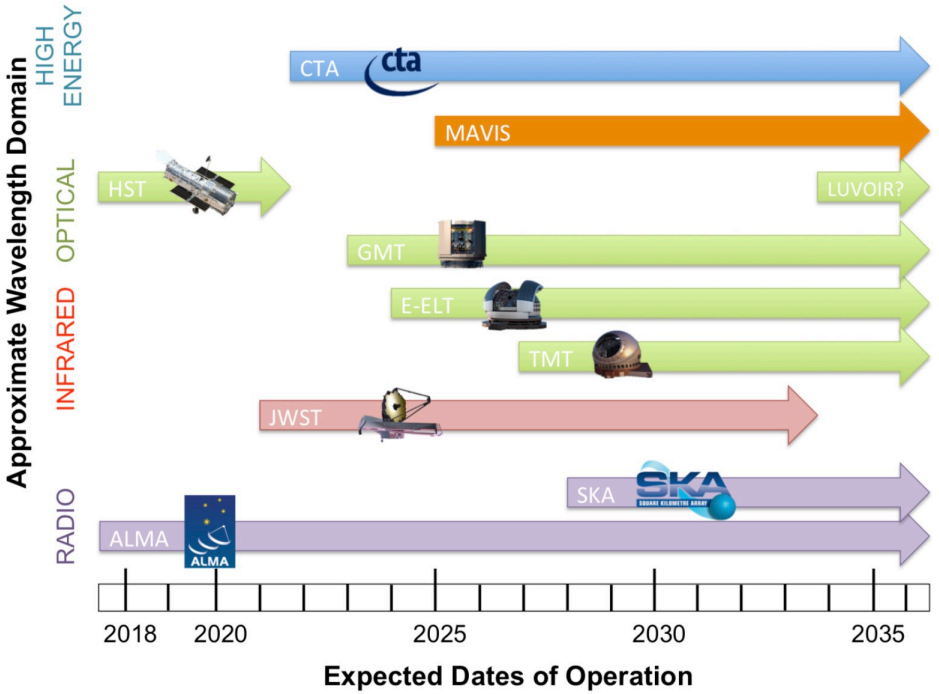
MAVIS IN CONTEXT

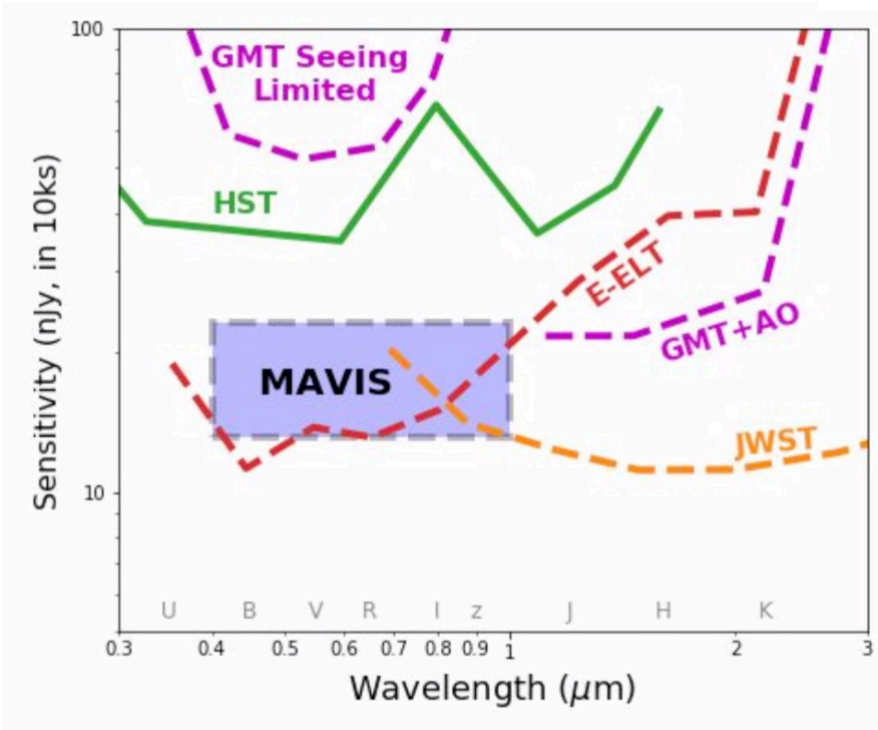
- Forthcoming era of high sensitivity, high resolution astronomy with large telescopes

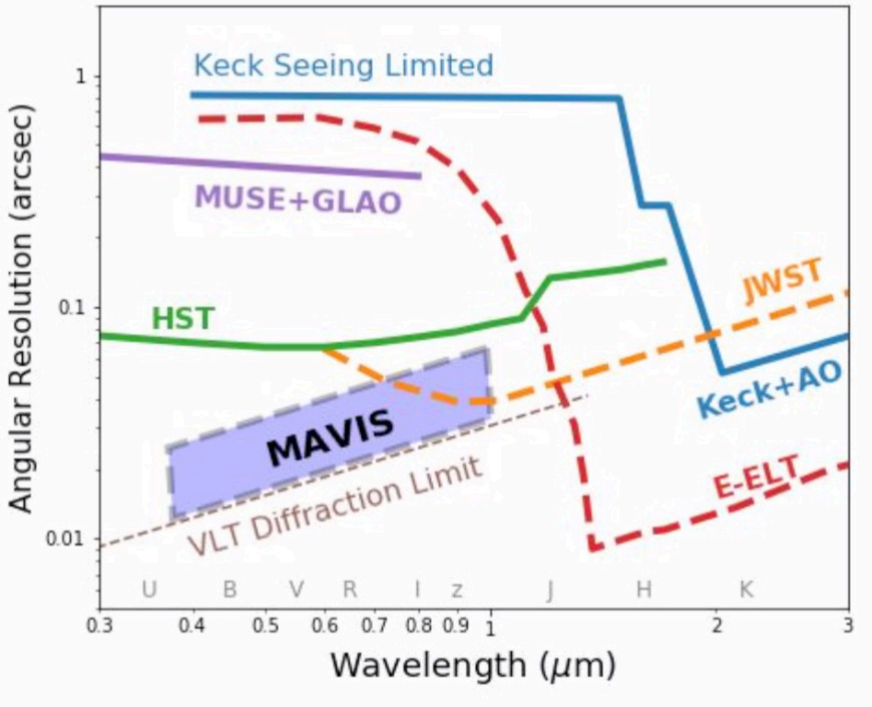


MAVIS IN CONTEXT

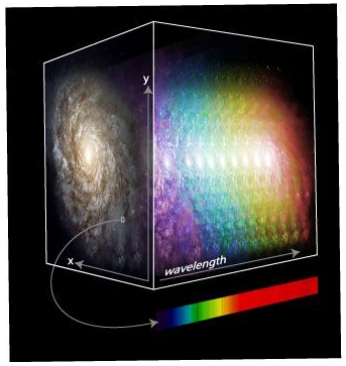
- Forthcoming era of high sensitivity, high resolution astronomy with large telescopes
- Improvement in resolution limited to $\lambda > 1\ \mu m$







A SPECTROGRAPH FOR MAVIS



Two main options being explored

(but still to be defined in Phase A)

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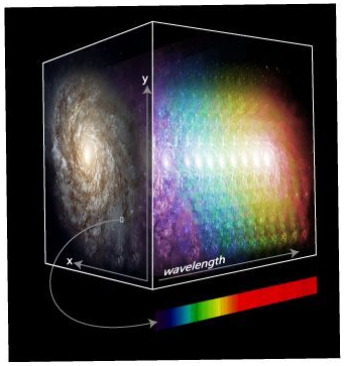

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Monolitic image slicer IFU

- fov ~3″x3″
- R diffraction limit = 19 mas
- spaxel ~25 mas
- R~3000-10000
- $\lambda \sim 350 - 950\ nm$

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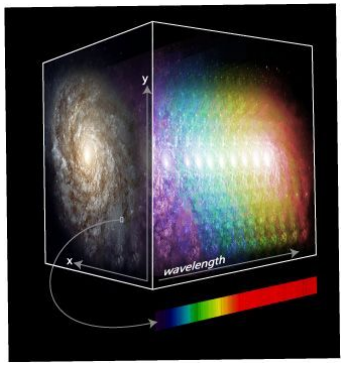

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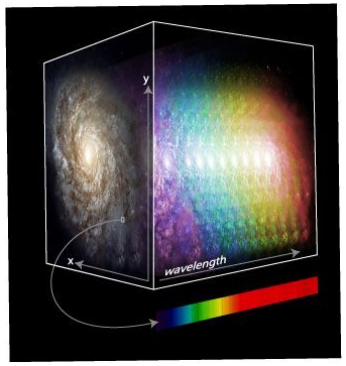
Multiple fiber fed IFU

- ~ 2000 fibers
- multiplicity ~10
- fov ~0.5″x0.5″
- patrol field ~30″x30″
- best use of the large AO corrected field
- spaxel ~ 40 mas

A SPECTROGRAPH FOR MAVIS



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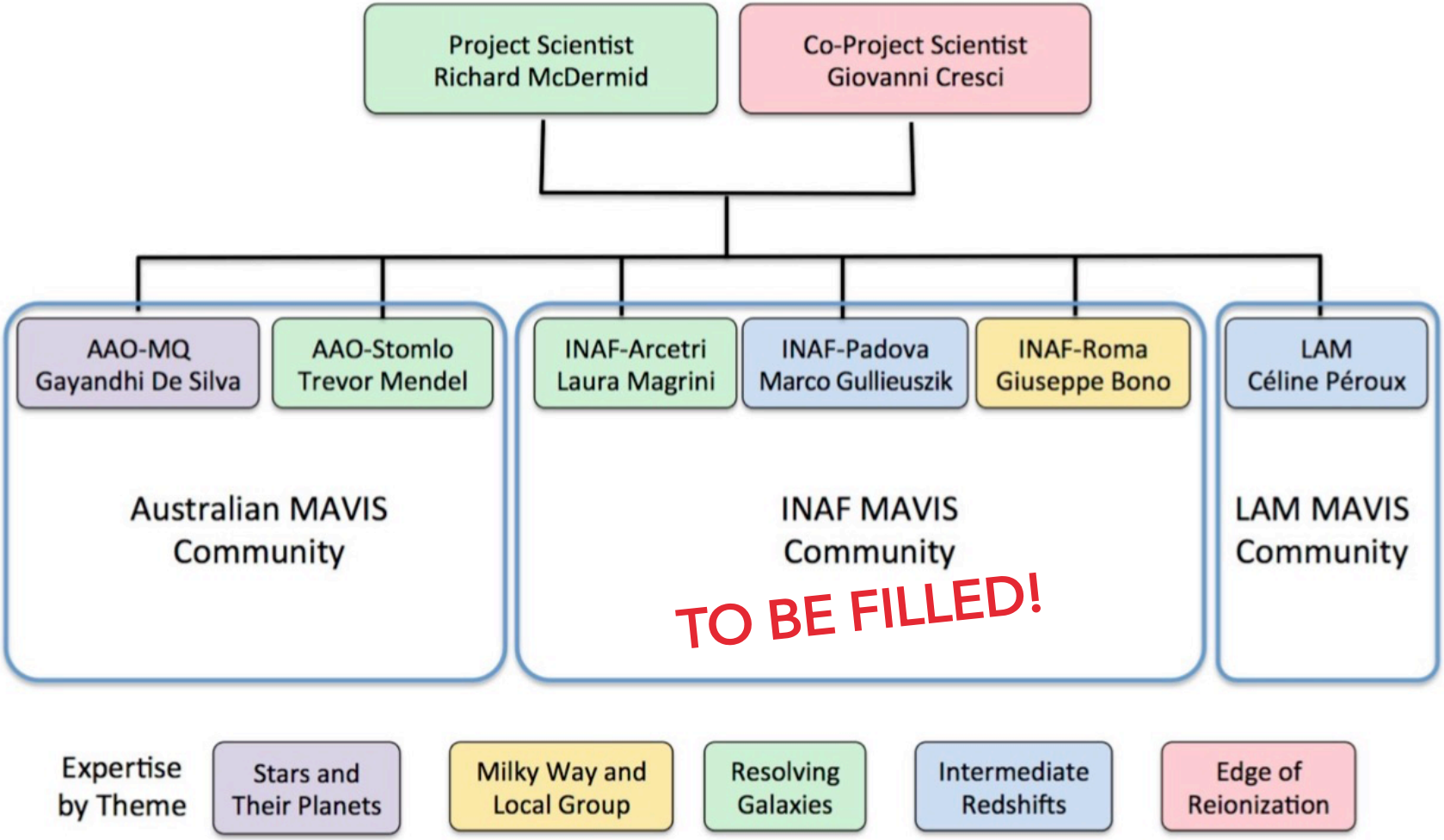
Compared to MUSE/NFM:

- higher **spectral resolution** (R>5000 vs R~2000)
- higher **strehl** and **spatial resolution** (SR~50% and 20mas vs SR~15% and 50mas)
- **blue** coverage (~350 nm vs 460 nm)
- much higher **sky coverage** (~50% sky coverage vs NGS with R<15 J-H mag within 3.25″)
- possible **multiplexity**

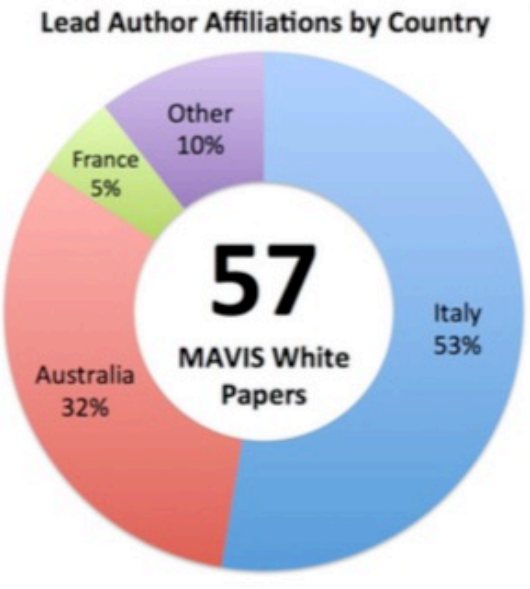
MAVIS SCIENCE TEAM

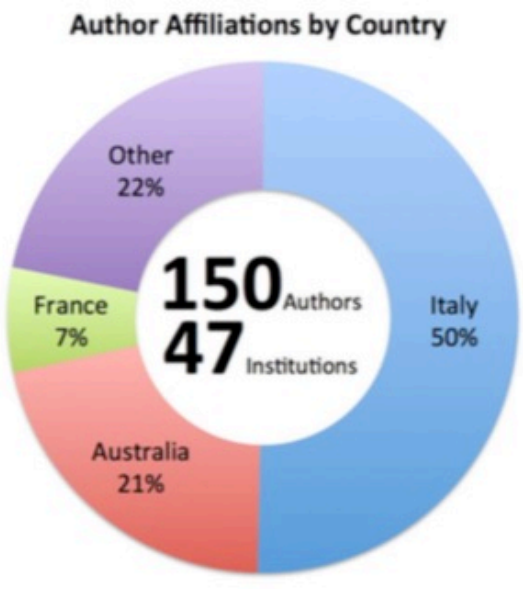


From geographical to scientific structure in phase A

SCIENCE WITH MAVIS: WHITE PAPERS

Call in July 2018





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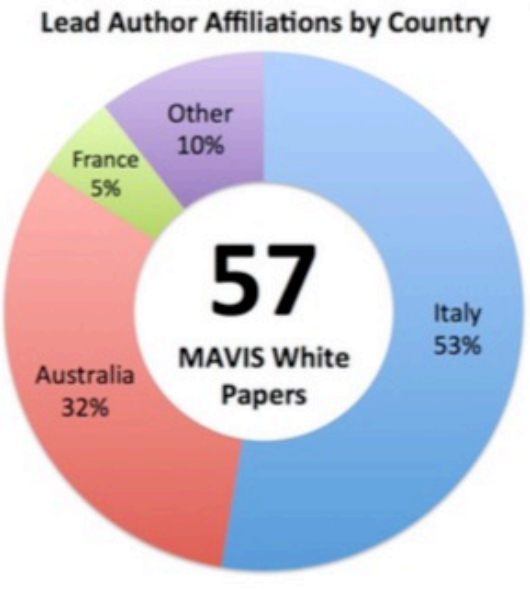

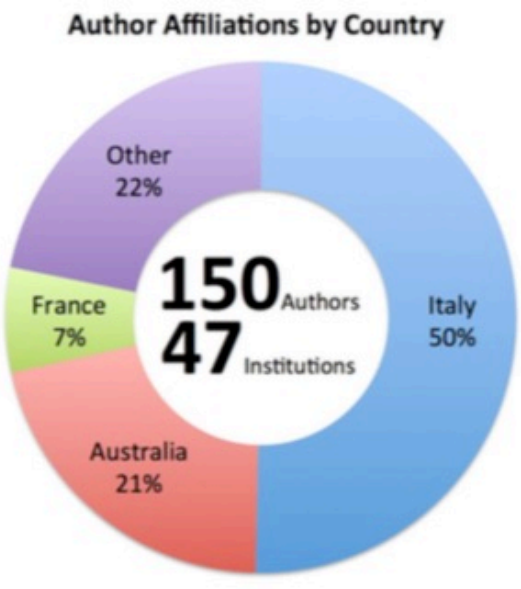

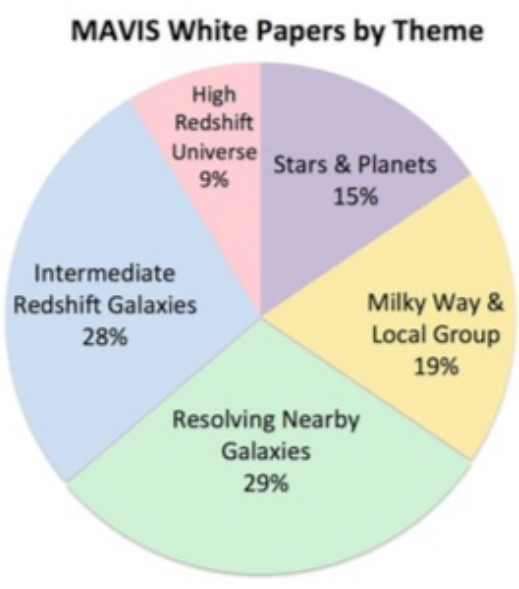

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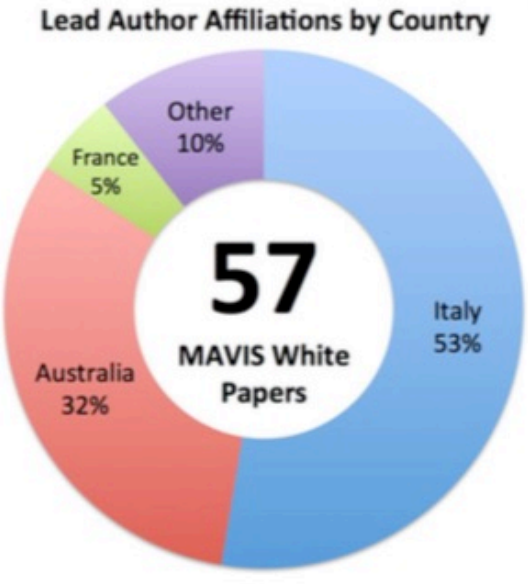
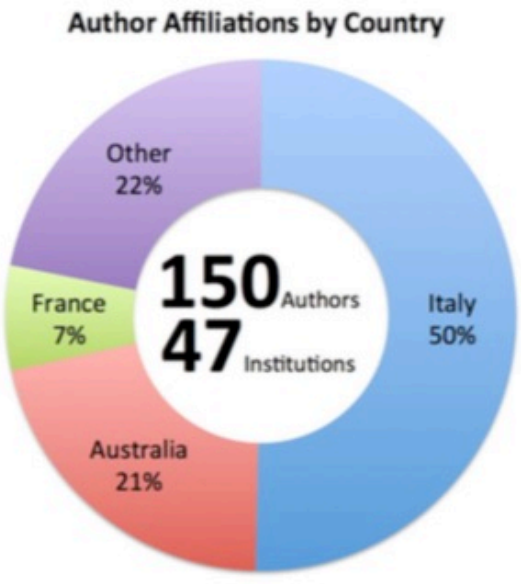
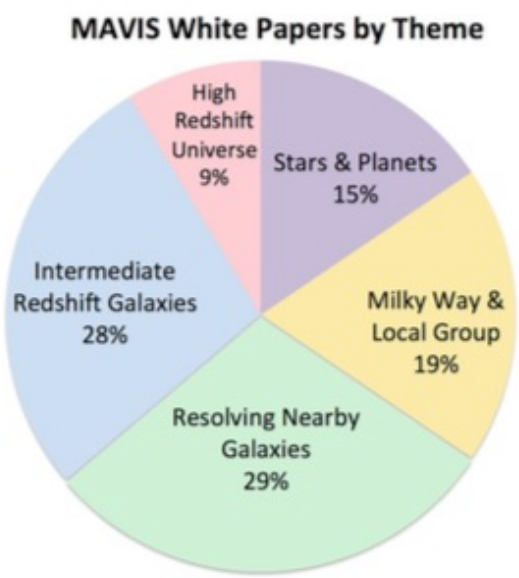
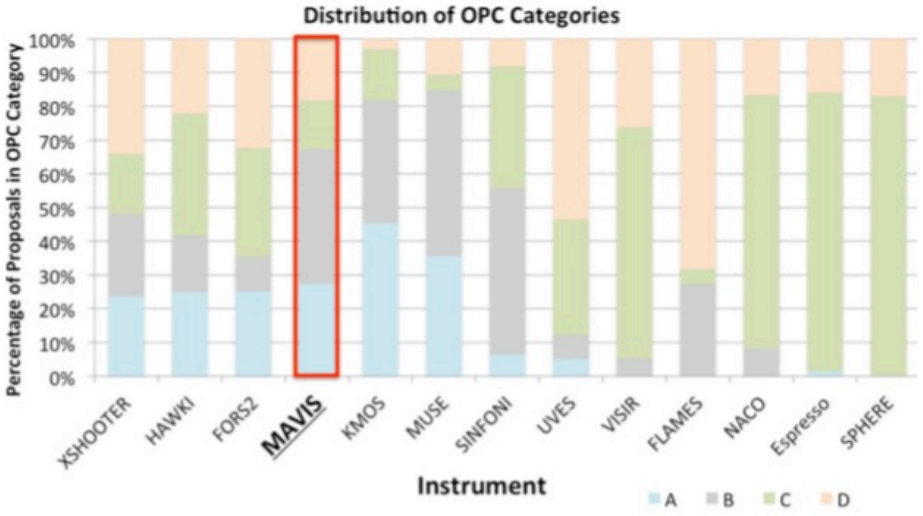
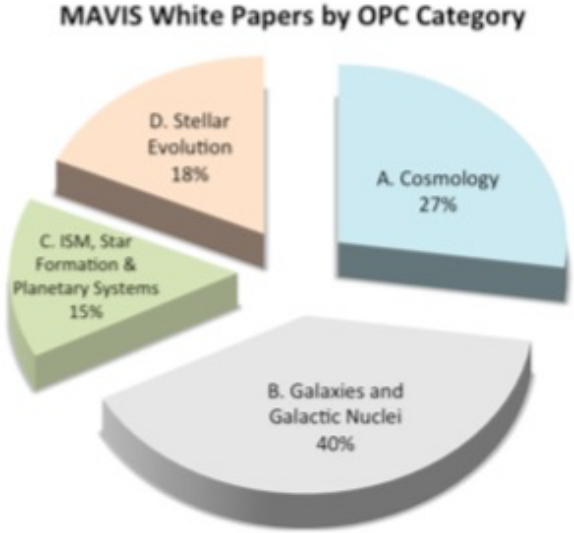






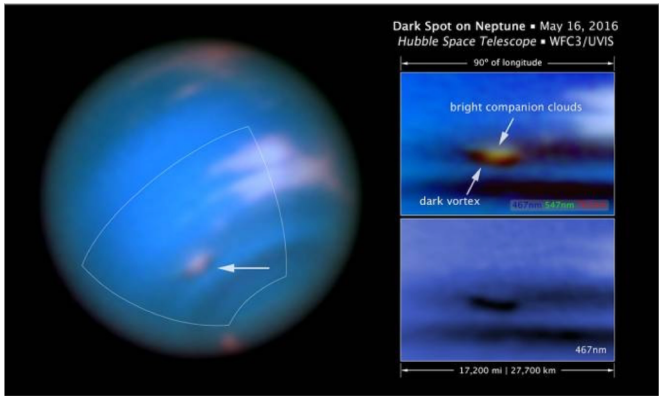


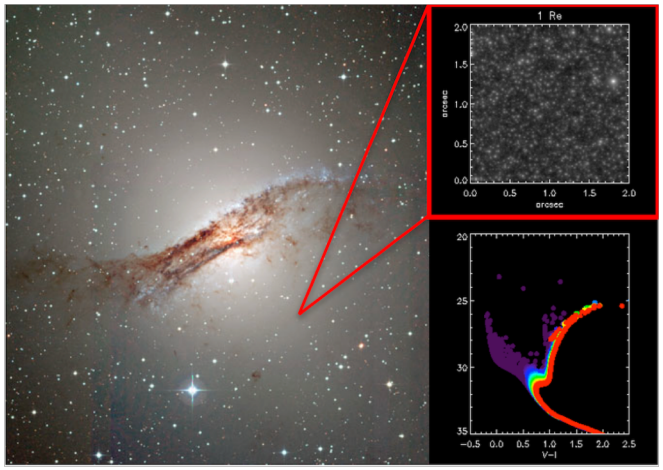


A general purpose instrument!

SCIENCE WITH MAVIS:

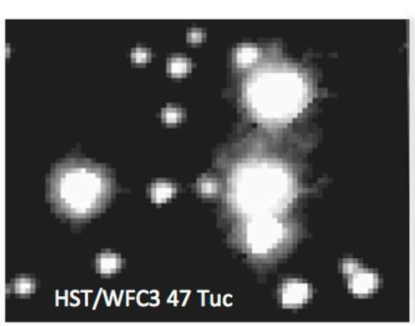
- Crowded Field Photometry & Spectroscopy
- Precision Astrometry and Proper Motions
- Solar System Science
- ExoPlanets
- Initial Mass Function
- Proto-planetary disks
- Stellar jets
- Binary stars and WD
- Galaxy structure and morphology
- Resolved Stellar Populations beyond the Local Group
- Outflows and Feedback
- Morphology of Young Galaxies
- Probing the Edge of Reionization
- Transient follow-ups
- Synergy with future facilities
- …

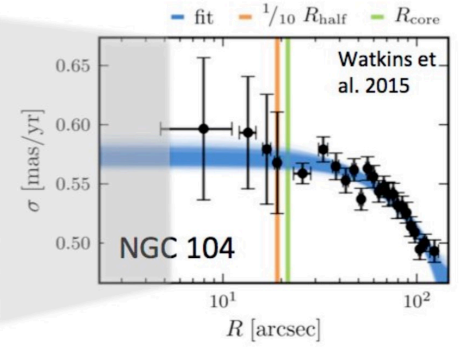


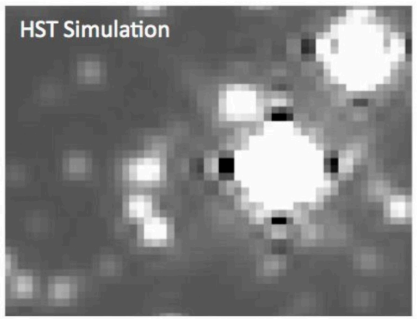


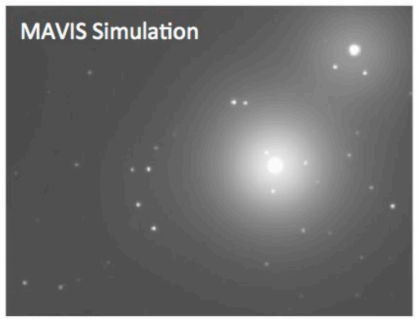
SCIENCE WITH MAVIS

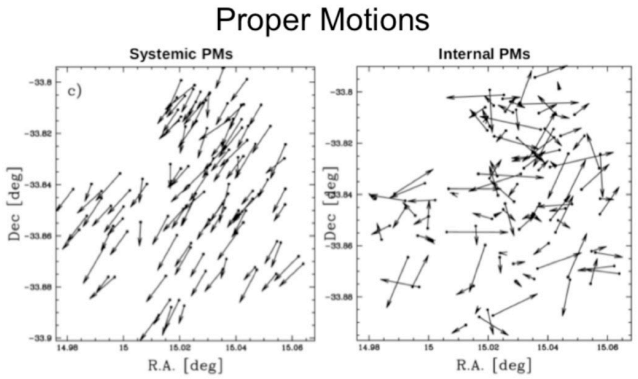
Search for **intermediate mass BH** in nearby dwarf galaxies and globular clusters

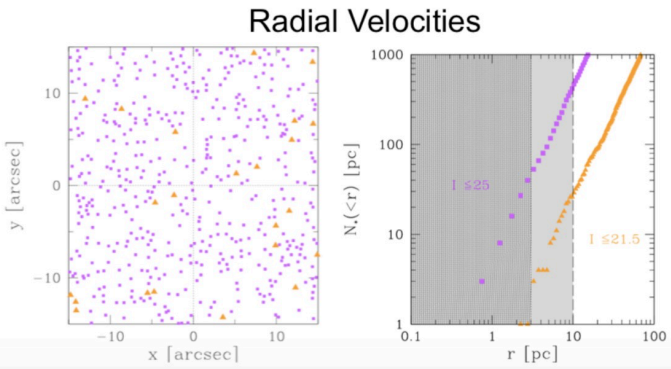


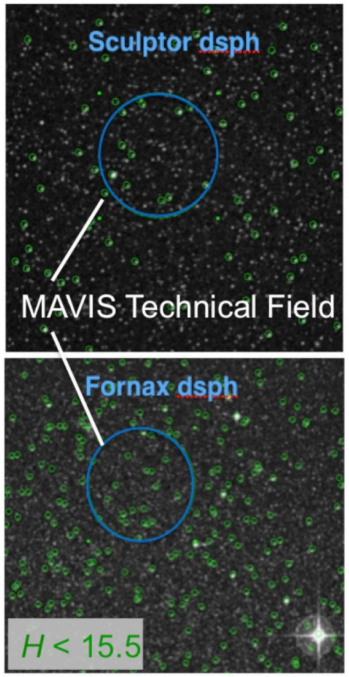








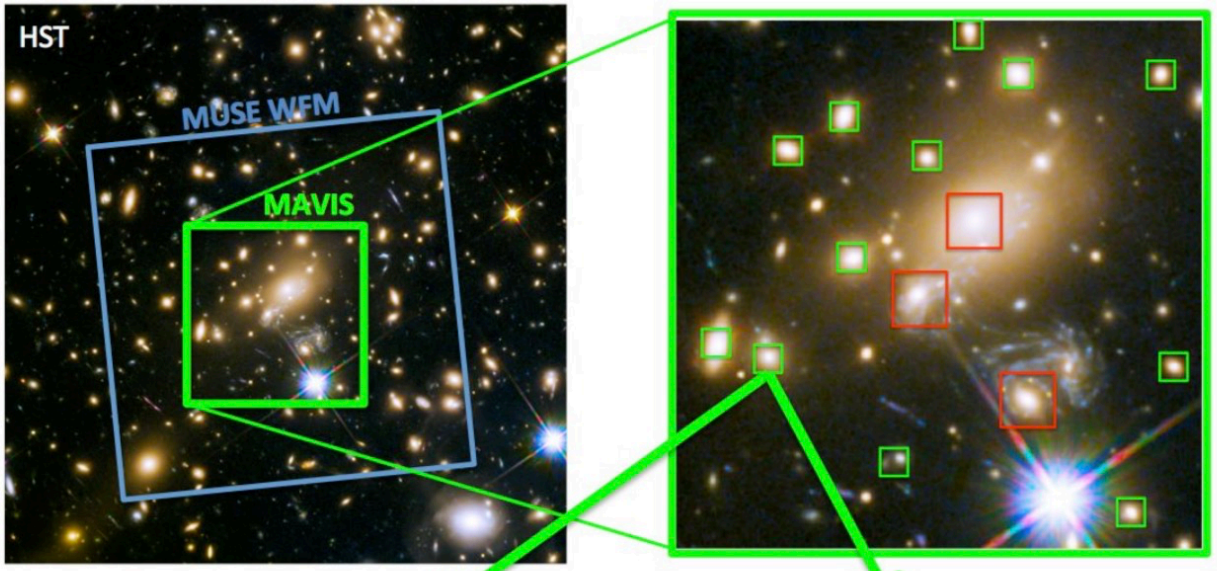


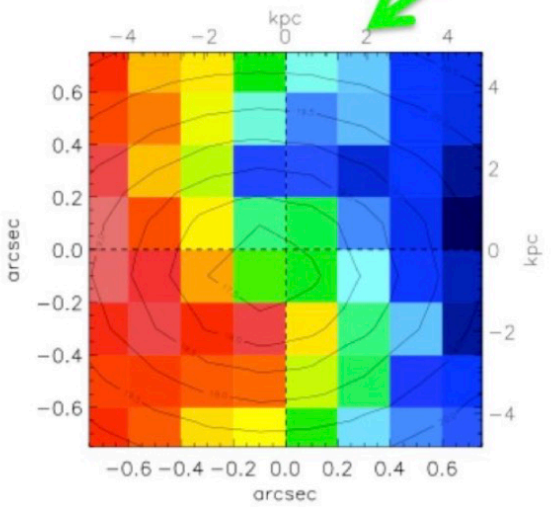


Sculptor dsph

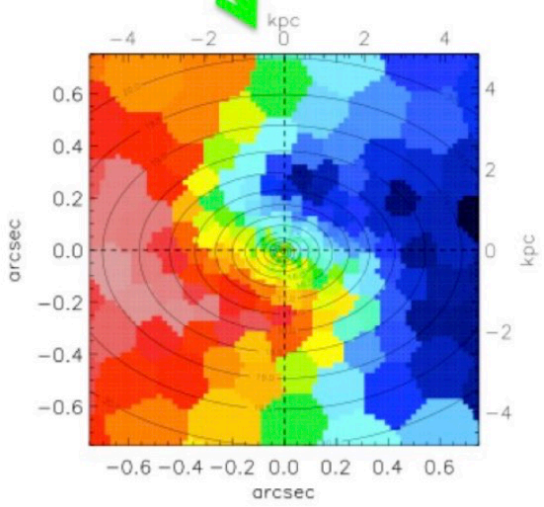
Combining precision astrometry and MOS spectroscopy in crowded fields with unprecedented resolution

SCIENCE WITH MAVIS:





MUSE+GLAO, FWHM=0.4”



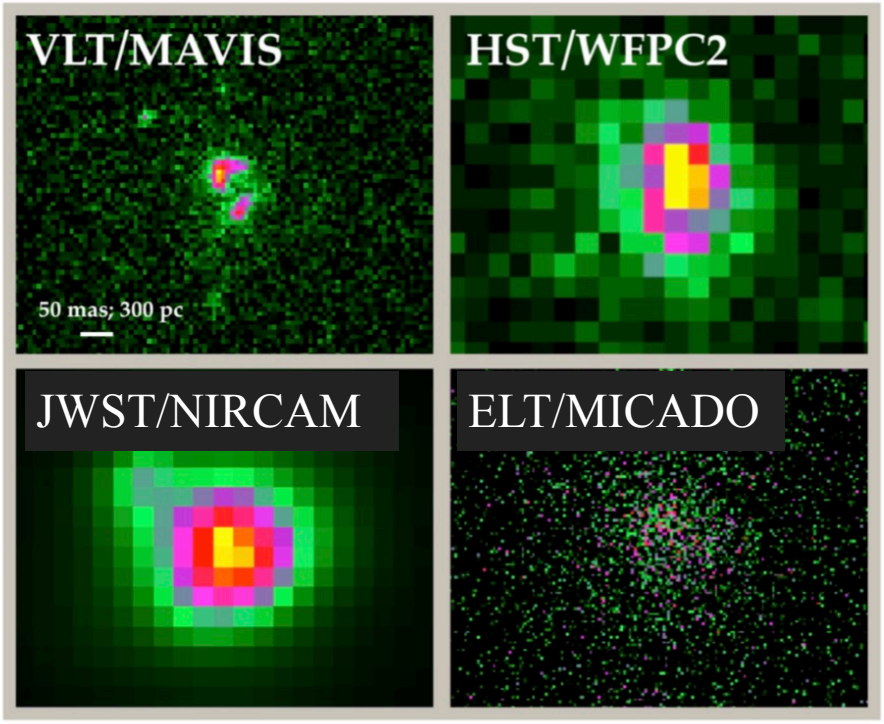
MAVIS, FWHM=30mas

Kinematics on Sub-Kiloparsec Scales at z~0.5:

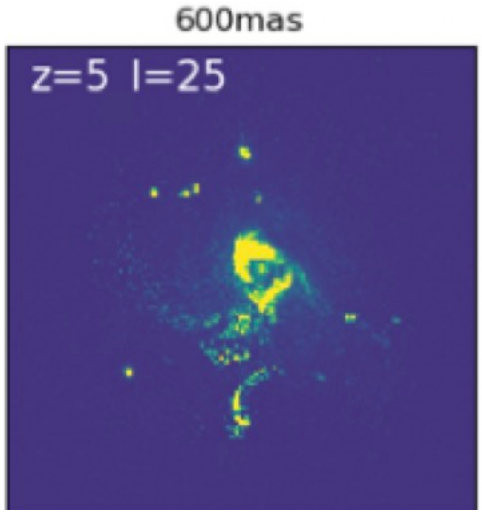
high spatial resolution <0.1” required for precise kinematic classification

SCIENCE WITH MAVIS:

Spatially resolved rest frame UV spectroscopy of z~5-6 galaxies (Re~500 pc ~ 80mas) possible for the first time!



1 hr exposure simulations



Pallottini et al 2017:

- M~ 1.6 · 10^{10} $M_\odot$
- Re ~ 0.6 kpc ~ 100mas at z=5
- high resolution: ~30pc

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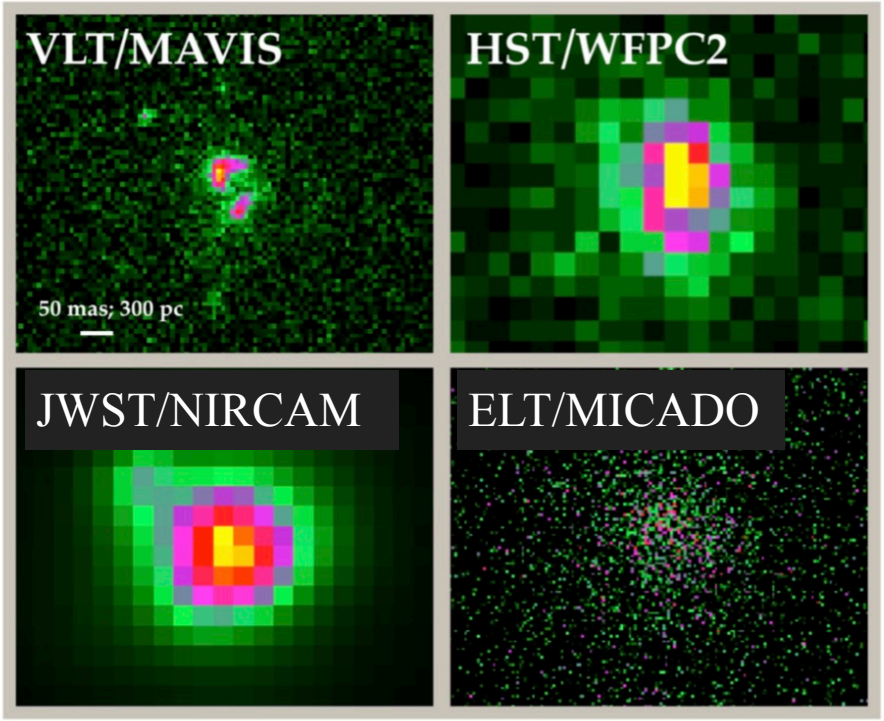

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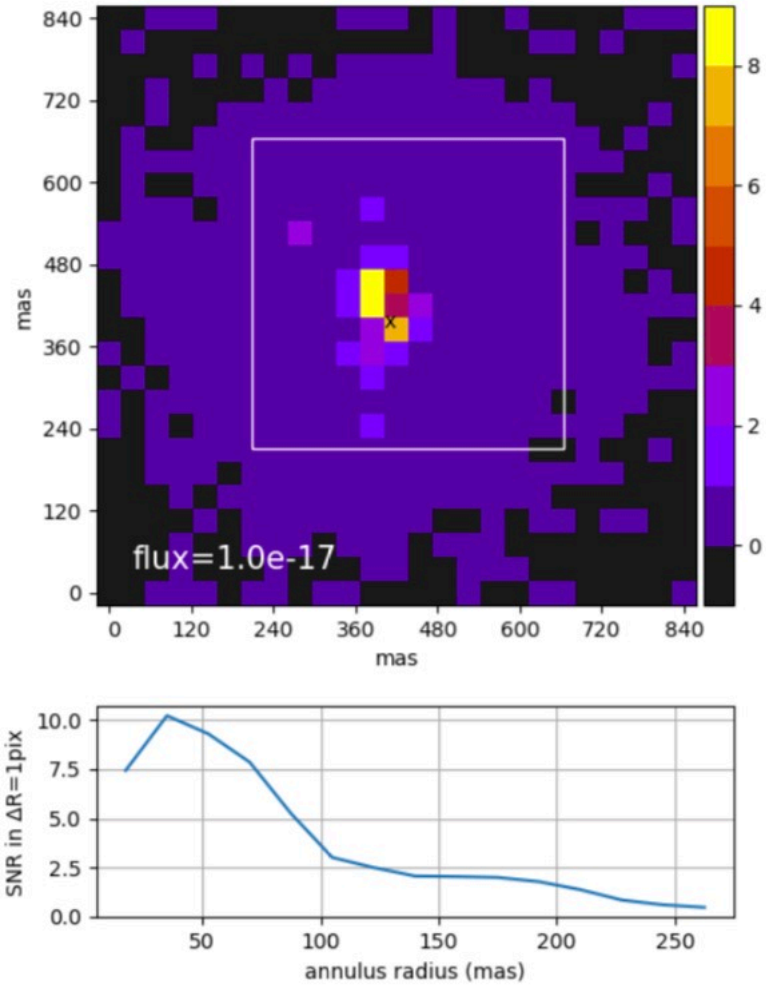
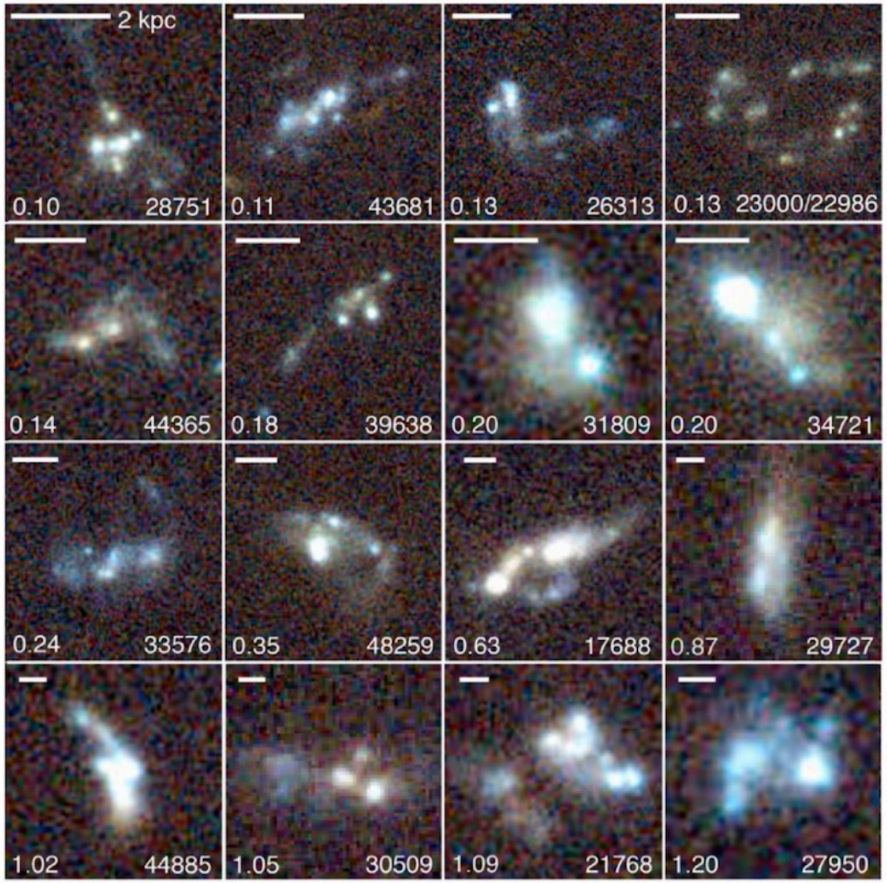


10 hrs Lyα exposure simulations

SCIENCE WITH MAVIS:

The majority of galaxies at z>1 – 2 are dominated by bright star-forming "clumps":

- stellar masses ~10^9 M_{sun}
- typical sizes ≤1 kpc (≤0.1" at z ~2) but unresolved



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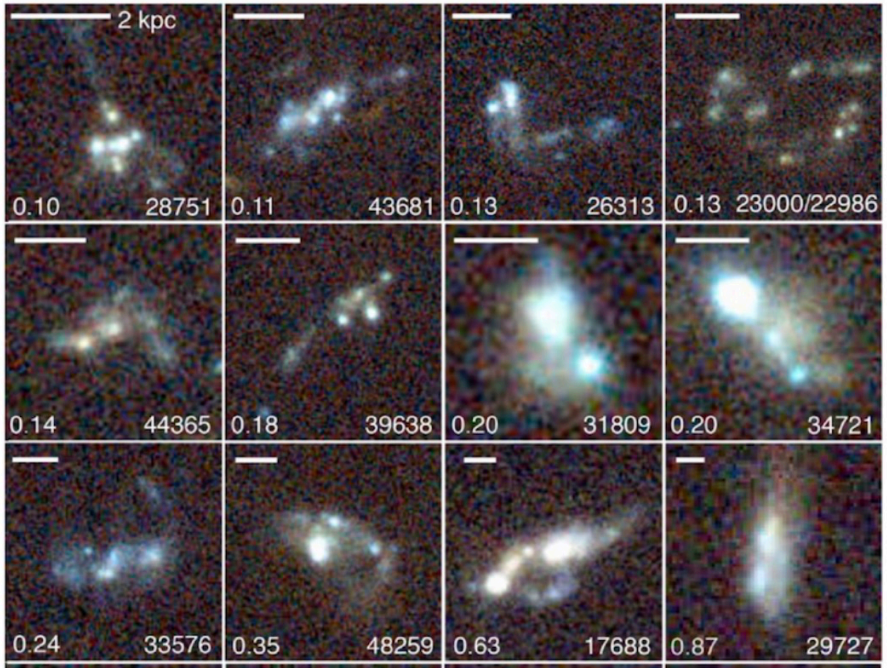
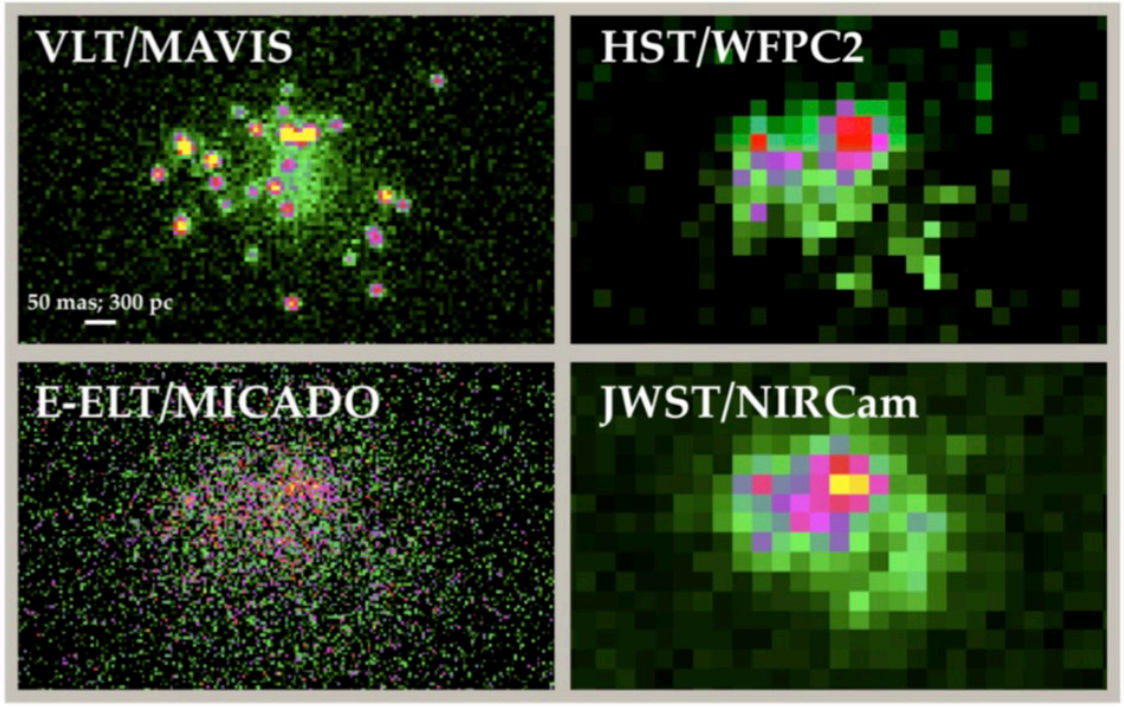
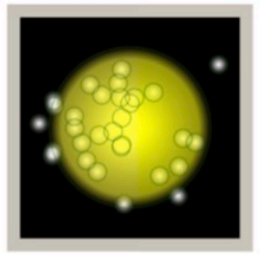


UV spectroscopy:

Lyα, CIII]λ1909, HeIIλ1640, Mg IIλ2798 …

- dynamics
- outflows
- IMF
- escape fraction
- …





I band simulations ($\sigma = 0.1''$ 0.6 kpc at z=5)

CONCLUSIONS

- Diffraction limit optical imaging and spectroscopy
- Phase A starting in January 2019
- Strong INAF involvement in technology and science
- A new discovery window: *sharper than JWST, deeper than HST*
- Inputs required for the definition of the requirements and science cases
- Expected first light ~2025

Interested? Want more info?

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