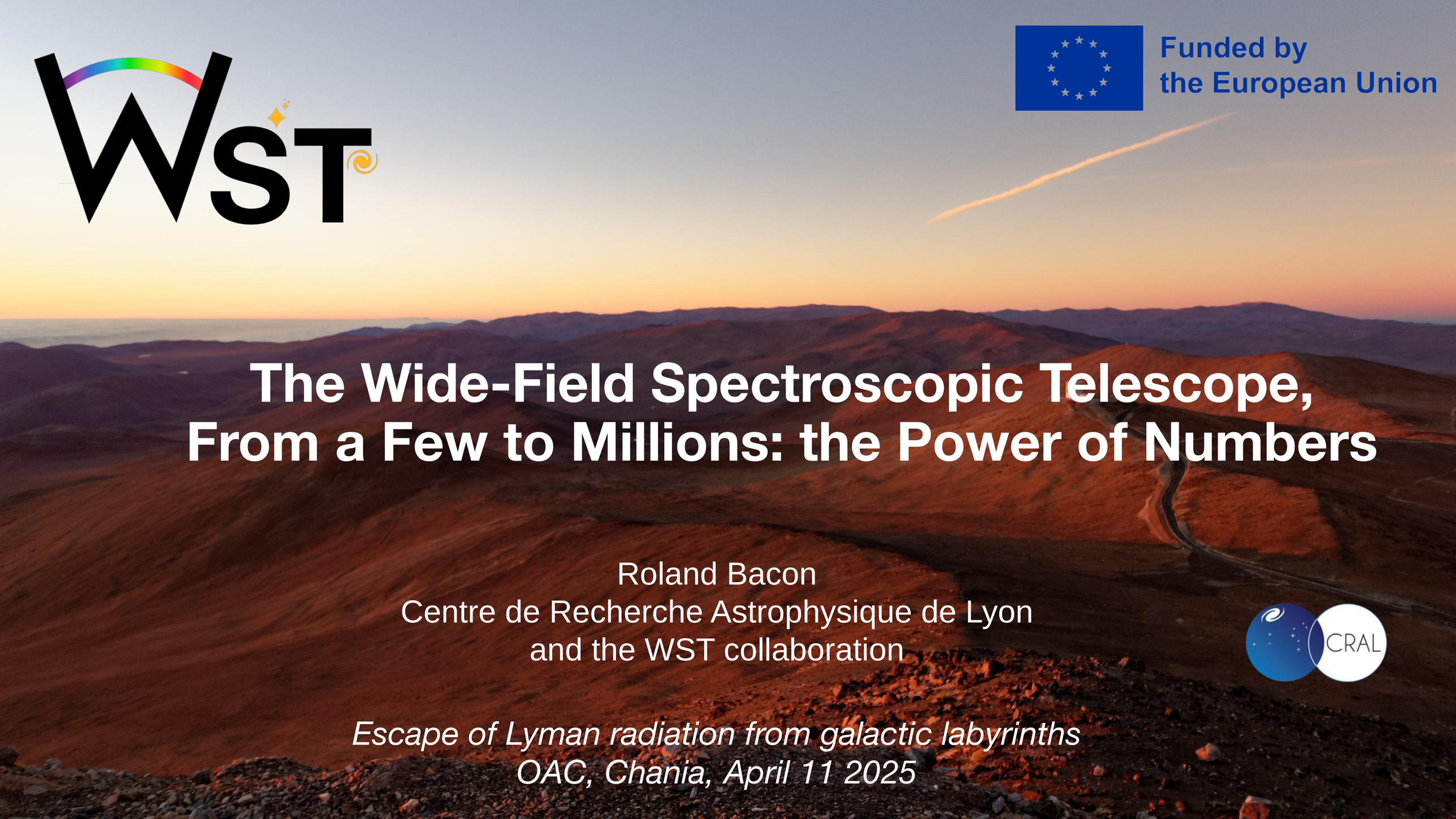


Funded by
the European Union

The Wide-Field Spectroscopic Telescope, From a Few to Millions: the Power of Numbers

Roland Bacon
Centre de Recherche Astrophysique de Lyon
and the WST collaboration

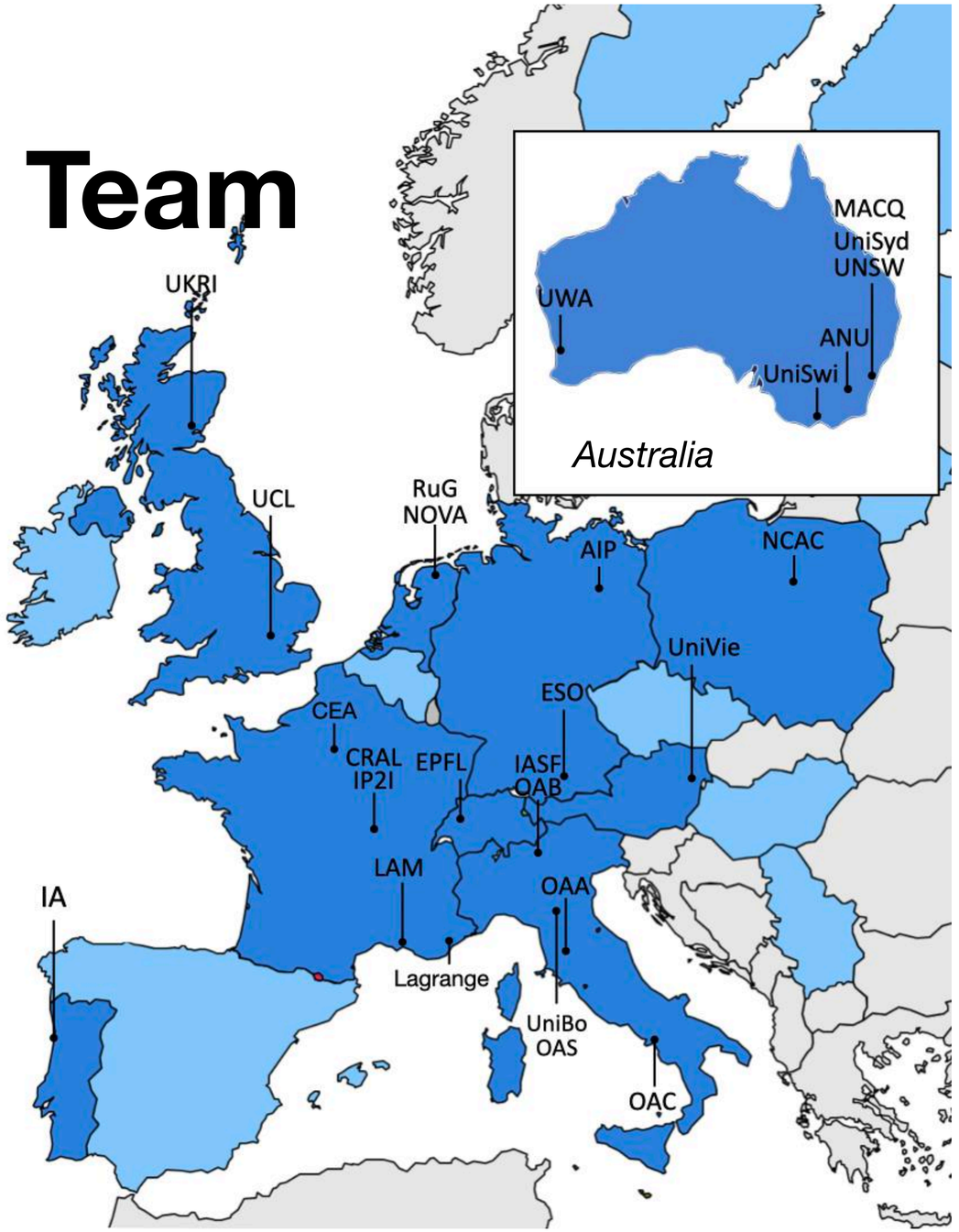
Escape of Lyman radiation from galactic labyrinths
OAC, Chania, April 11 2025

Funded by
the European Union

Consortium & Science Team

- Consortium
  - 26 research institutes or universities, 9 countries in Europe + Australia
  - Participation from many ESO scientists
  - Collective experience
    - 9 optical telescopes, 8 MOS, 10 IFS

- Science Team
  - ~600 members

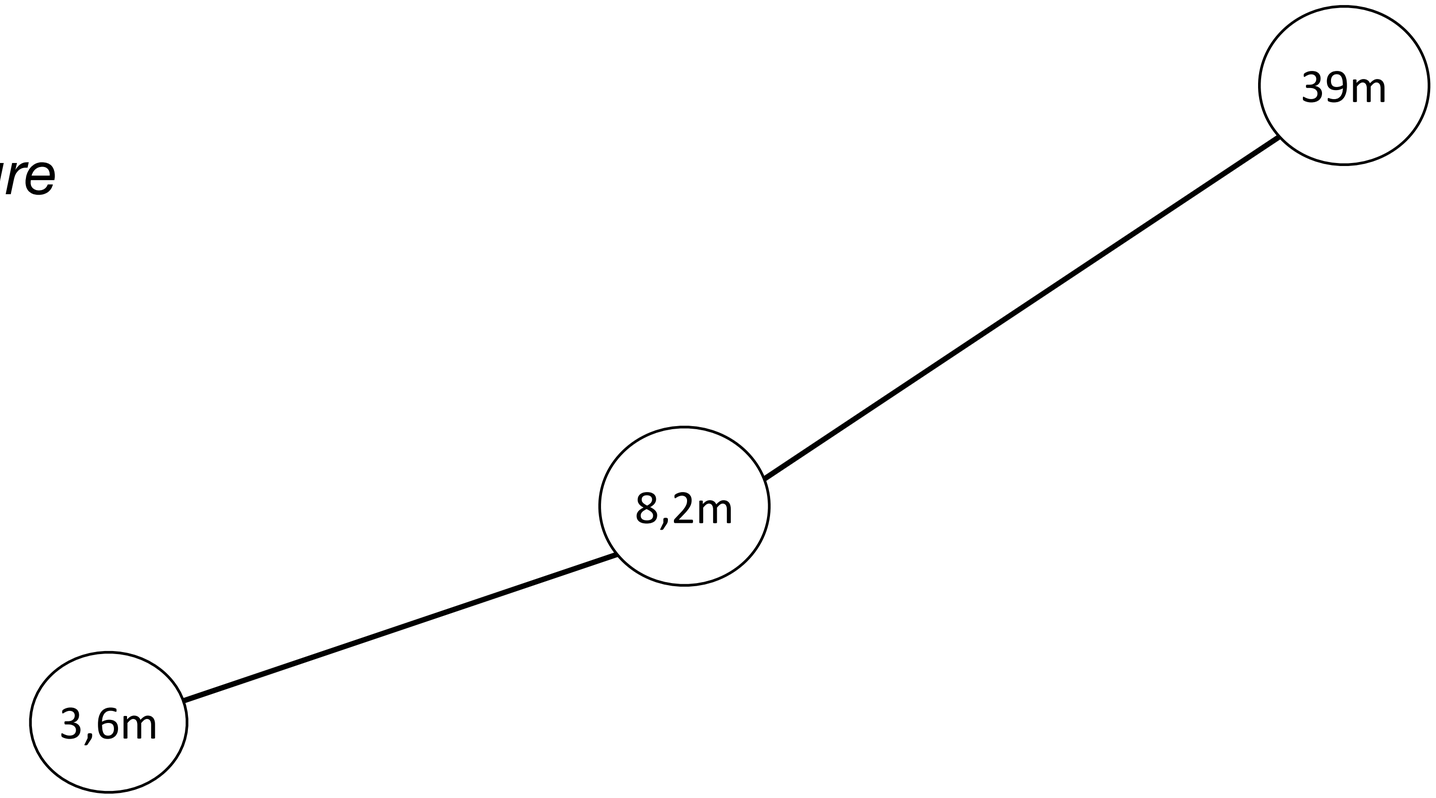


ESO future plans

With **Expanding Horizons**, ESO will search for its next innovative ground-based programme. We aim to identify the next **transformational facility** that will advance humanity's understanding of the Universe whilst fostering international collaboration. ESO will accept proposals from the entire astronomical community.

The evolution of ESO flagship telescopes

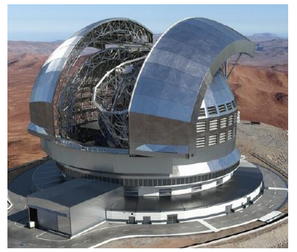
Aperture



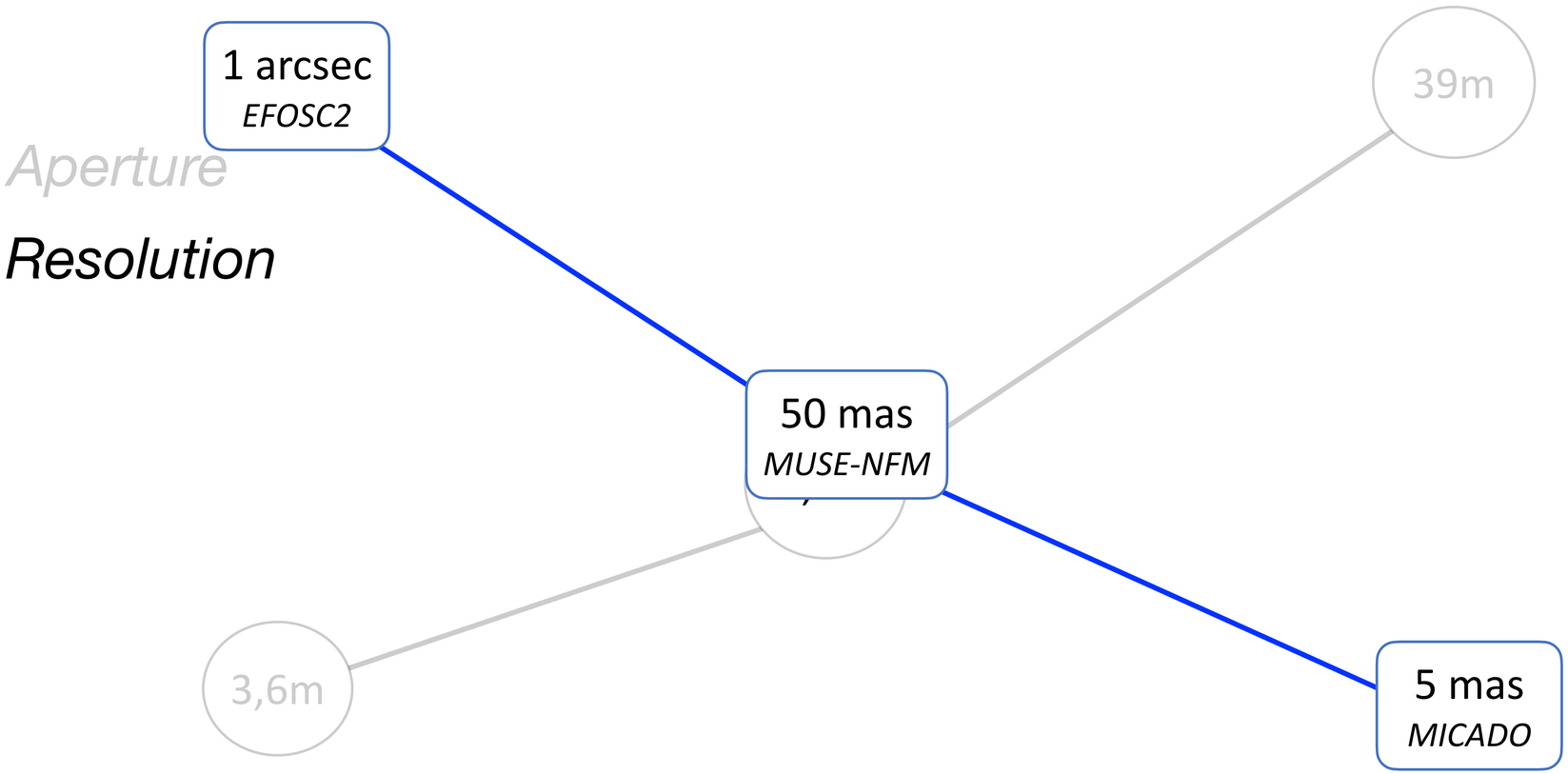
1977
3m60

1998
VLT

2029
ELT



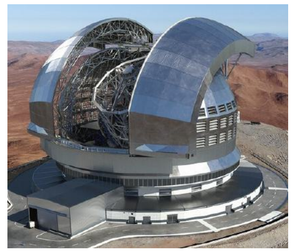
The evolution of ESO flagship telescopes



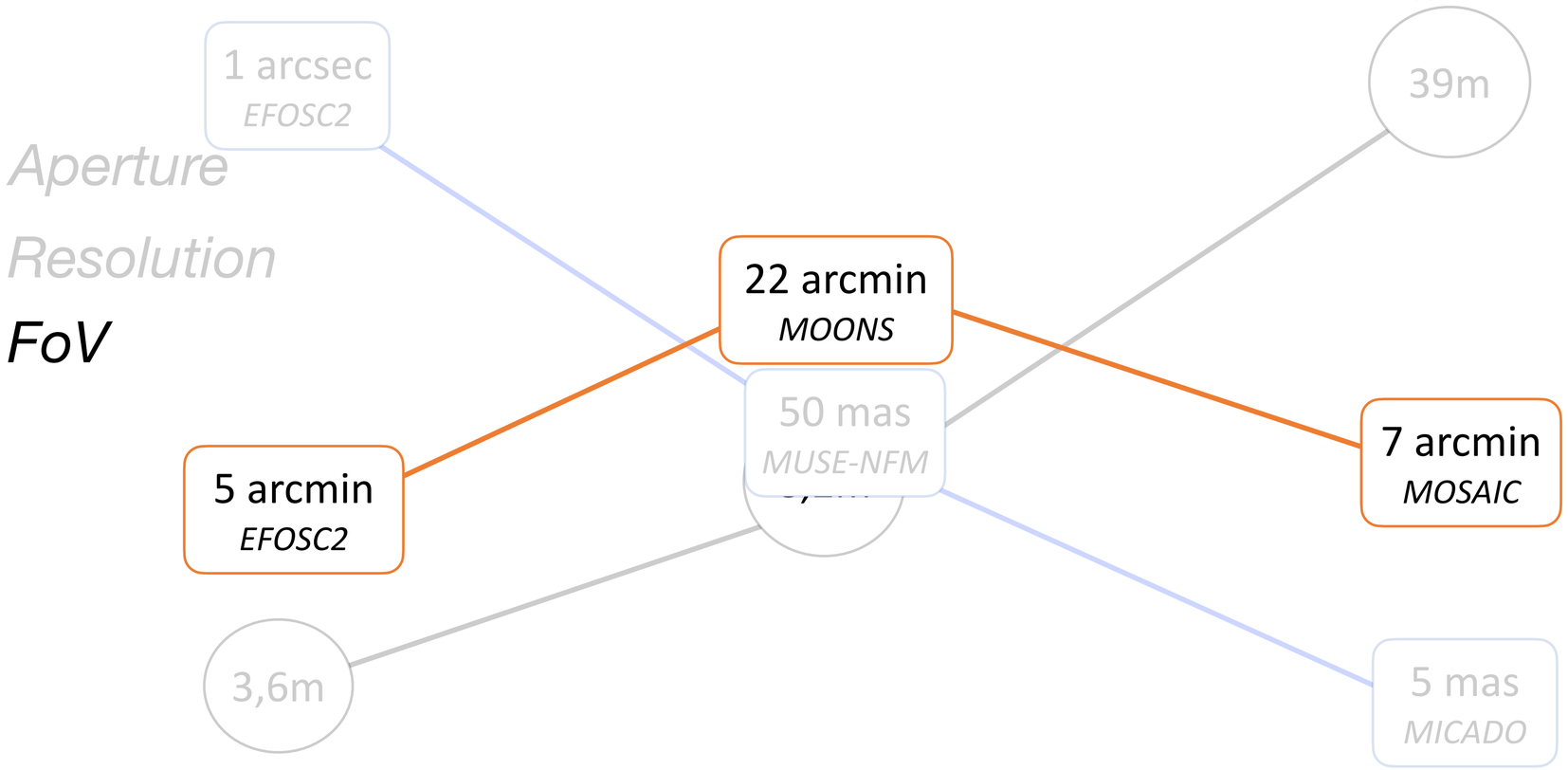
1977
3m60

1998
VLT

2029
ELT



The evolution of ESO flagship telescopes



1977
3m60

1998
VLT

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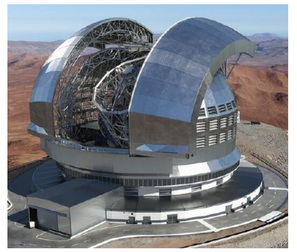
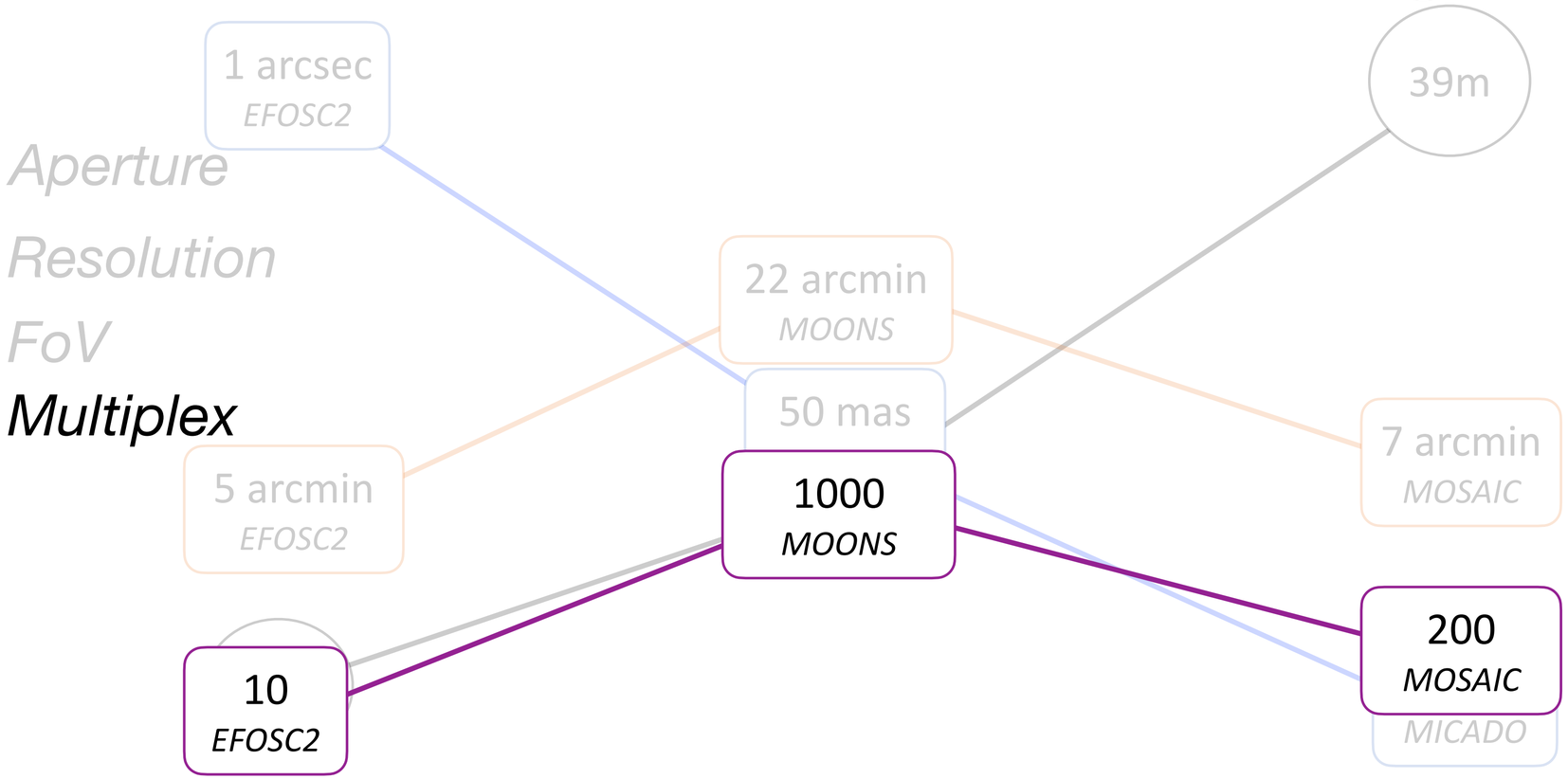
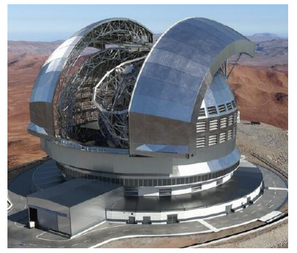
ELT



The evolution of ESO flagship telescopes





The evolution of ESO flagship telescopes

Aperture

Resolution

FoV

Multiplex

1 arcsec
EFOSC2

5 arcmin
EFOSC2

10
EFOSC2

22 arcmin
MOONS

50 mas

1000
MOONS

39m

7 arcmin
MOSAIC

200
MOSAIC

MICADO

2 deg

30,000

0.5 arcsec

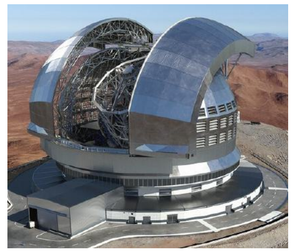
12m

A change of paradigm

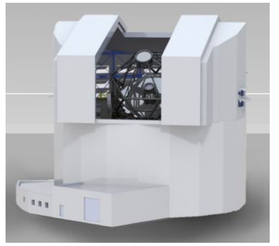
1977
3m60

1998
VLT

2029
ELT



2040+
WST



Astronet Astronomy roadmap 2022-2035

Ground-based facilities

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projects
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- First, the **Cherenkov Telescope Array (CTA)** is an array of telescopes located across two

A **general-purpose, wide-field, high multiplex spectroscopic facility**, for a telescope of the 8-10m class. Such a facility will enable a broad range of science investigations and help capitalise on other large investments by providing follow-up capabilities for facilities such as JWST, VRO and Euclid.

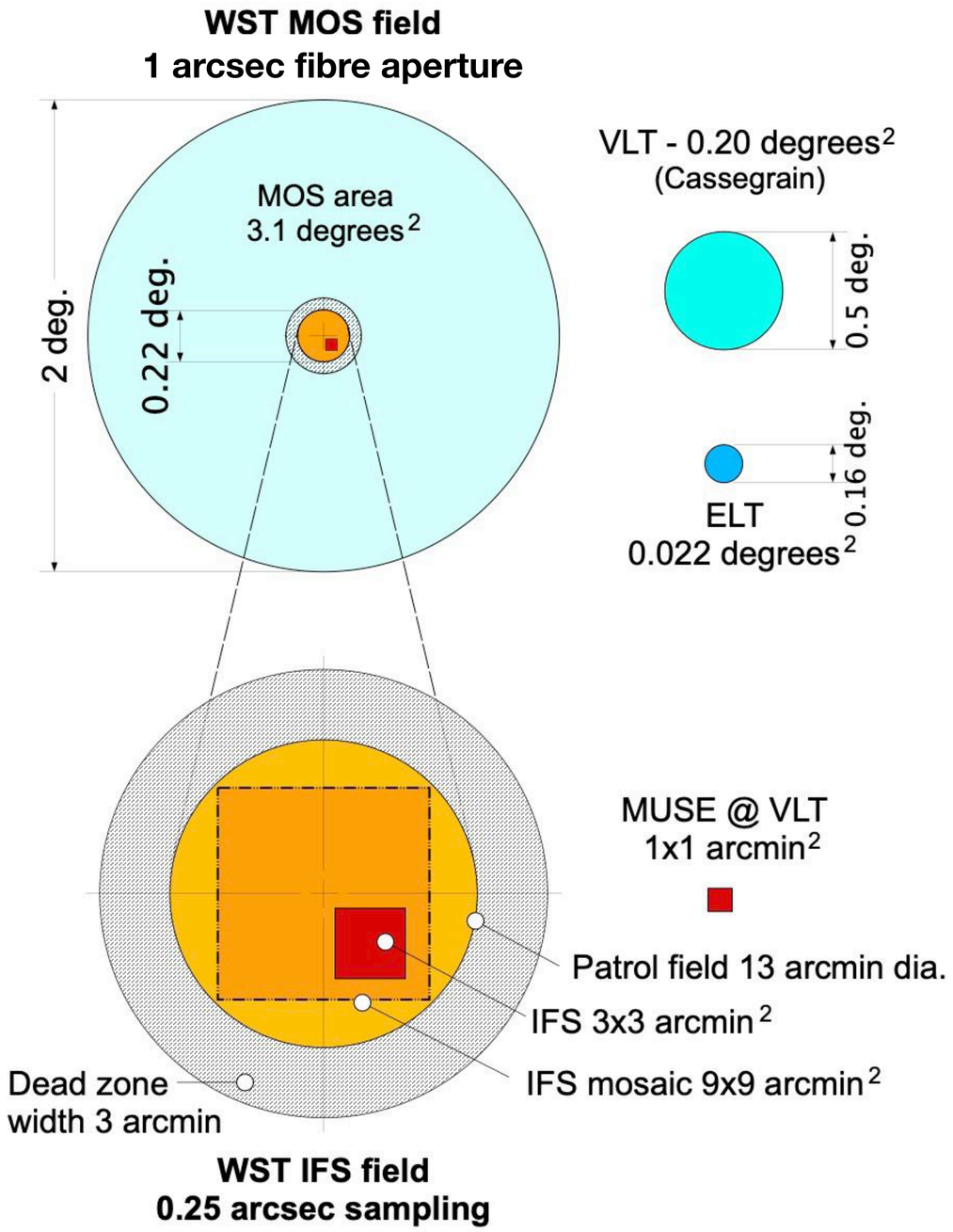
Its completion and scientific exploitation in synergy with the US-based DKIST is a priority.

- A **general-purpose, wide-field, high multiplex spectroscopic facility**, for a telescope of the 8-10m class. Such a facility will enable a broad range of science investigations and help capitalise on other large investments by providing follow-up capabilities for facilities such as JWST, VRO and Euclid.

The Wide-field Spectroscopic Telescope

Unive

Top Level Requirements



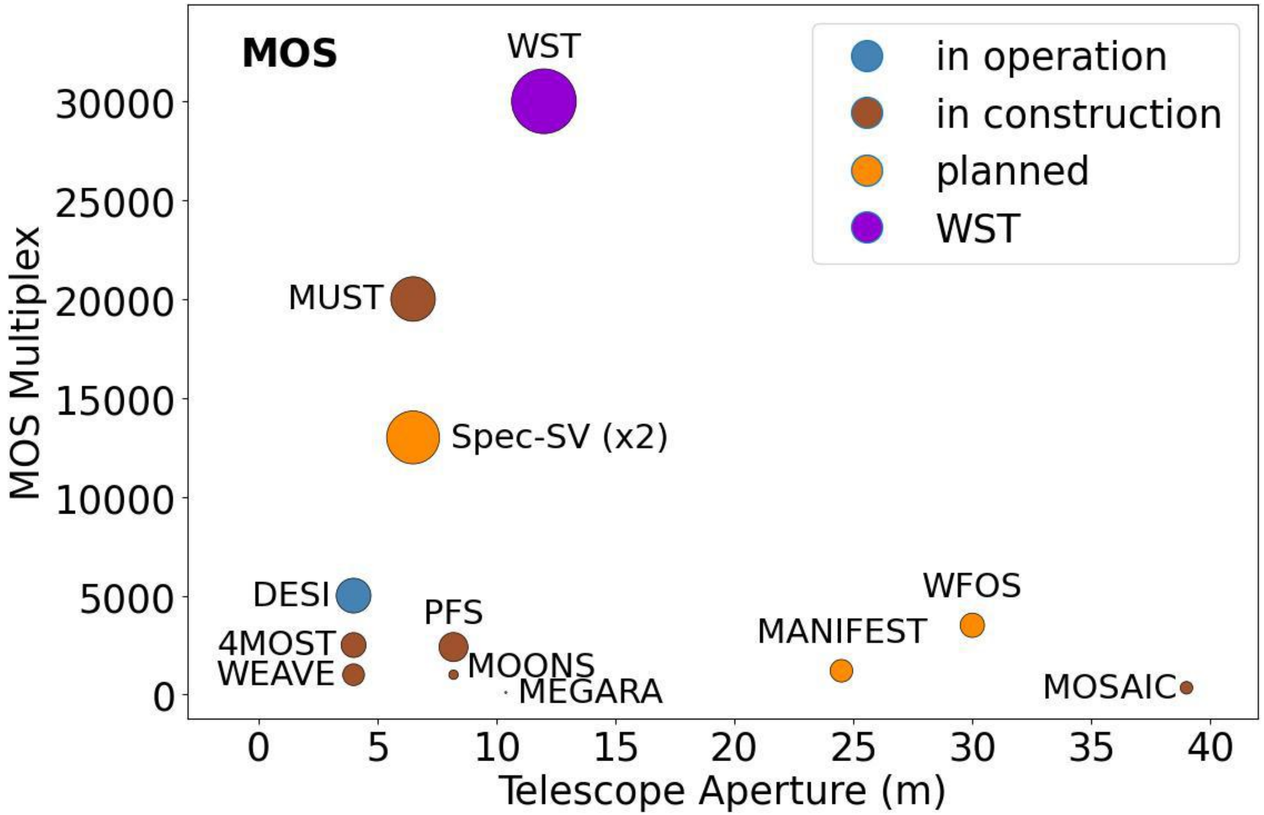
Telescope Aperture	12 m, seeing limited
Telescope FoV	3.1 deg²
Tel. Spec Range	0.35-1.6 µm
MOS LR Multiplex	30,000
MOS LR Resolution	3,000-4,000
MOS LR Spec Range	370-970 nm (simultaneous)
MOS HR Multiplex	2,000
MOS HR Resolution	40,000
MOS HR Spec Range	350-970 nm (3-4 regions)
IFS FoV	3x3 arcmin²
IFS Resolution	3,500
IFS Spec Range	370-970 nm (simultaneous)
IFS Mosaic	9x9 arcmin²
MOS & IFS parallel operation	
ToO implemented at telescope and fibre level	

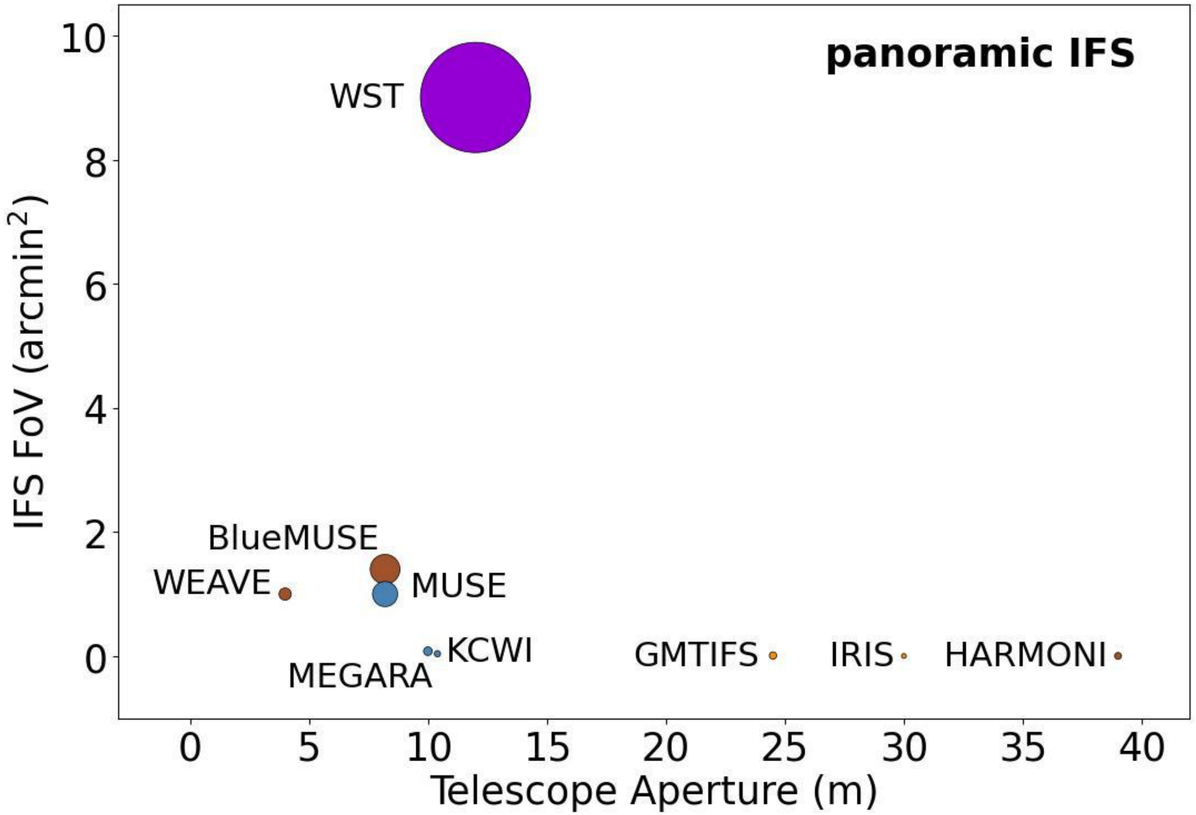
Top Level Requirements

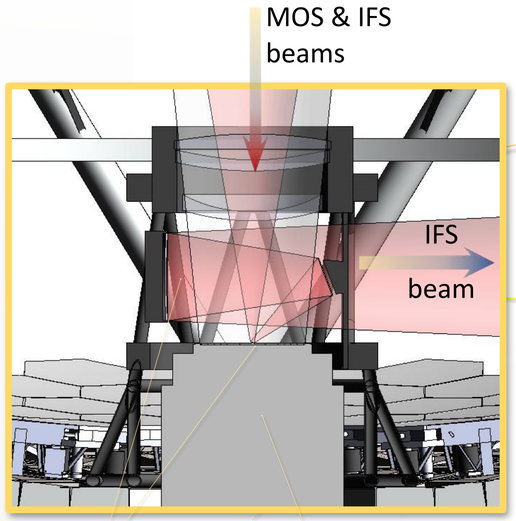
Upgrade Plan

- An IR (1-1.6 μm) extension of the MOS-LR
- A MOS mini-IFUs
- A GLAO for the IFS

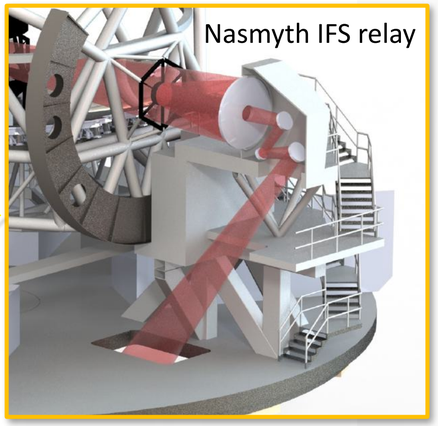
WST capabilities







Field corrector
& ADC



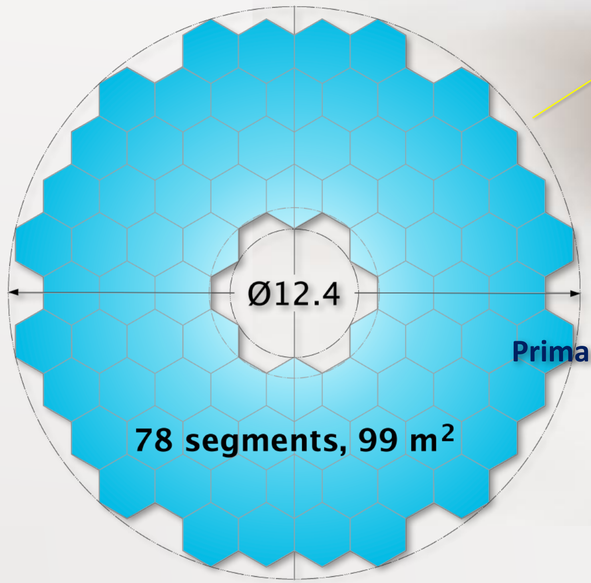
IFS Cassegrain
pick-up & relay
mirrors

MOS f/3 focus
& positioner

MOS instruments

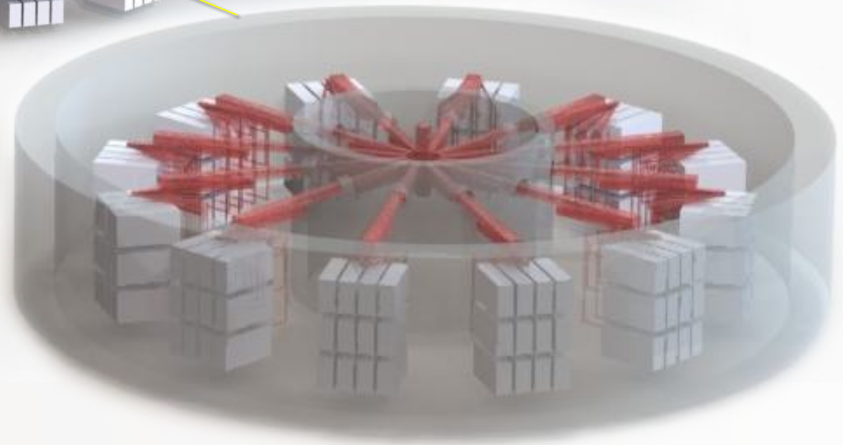
IFS coudé beam &
optical de-rotator

IFS f/35 focus

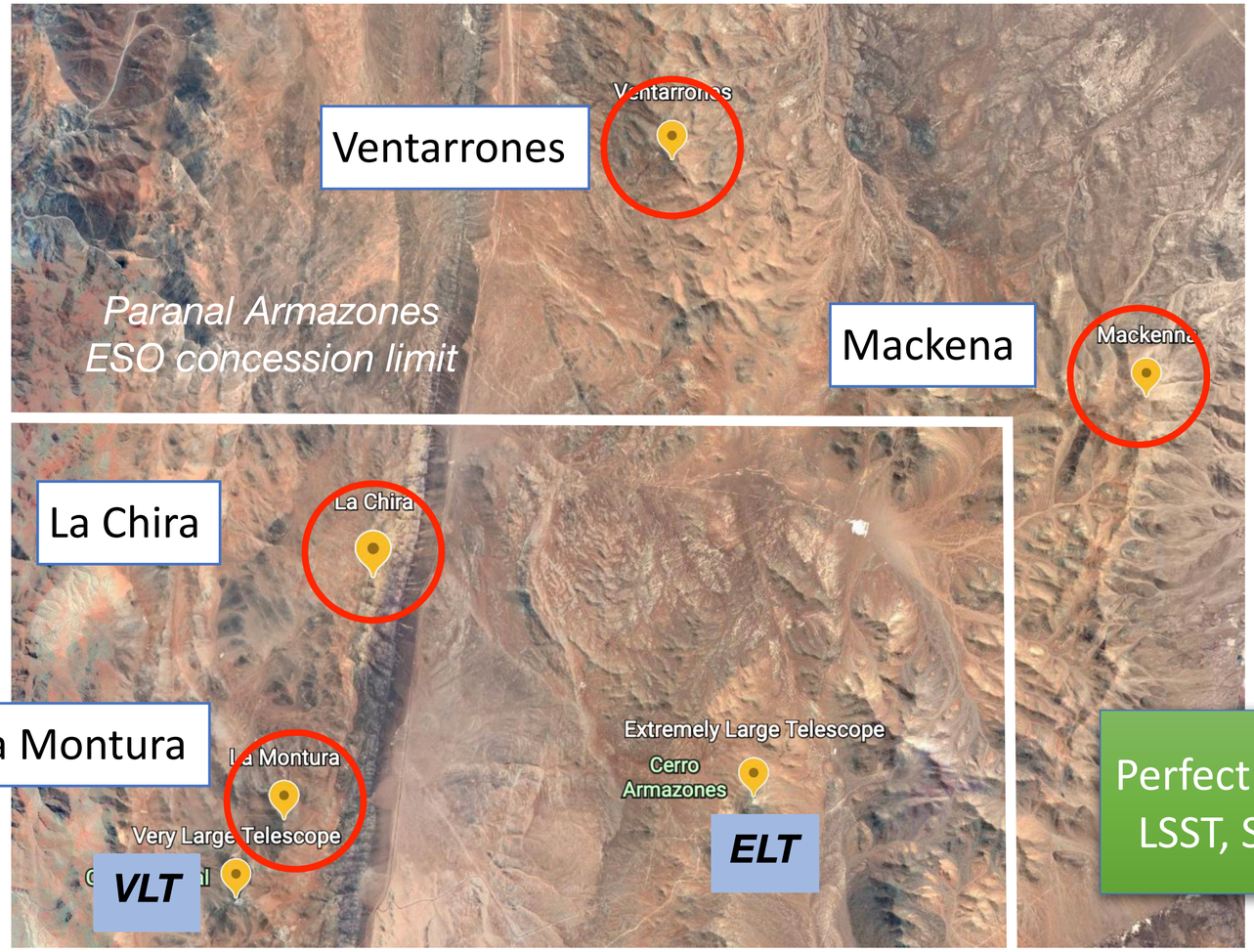


Primary mirror

IFS Station
(144 spectrographs)



Potential sites in ESO areas



Potential sites in and around Paranal-Armazones ESO area

Angel Otarola (ESO)

Sustainability

Paranal solar plant - 9 MW (Filippi et al, 2022)

Perfect match to LSST, SKA, CTA

1700 t of CO2 equivalent

Science Case

Galactic

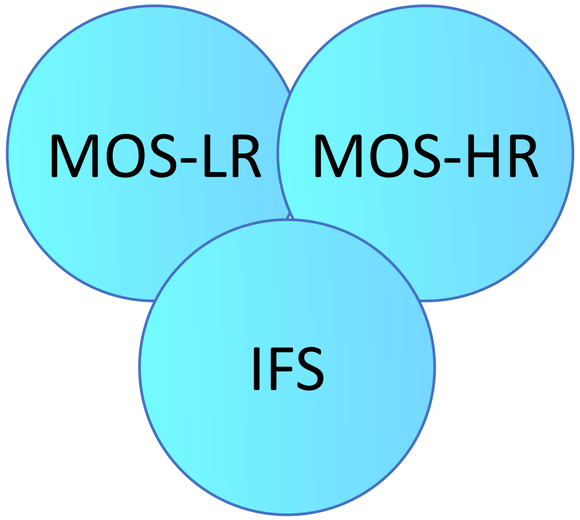
Resolved Stellar Populations

Extragalactic

Cosmology

Time Domain

The WST science white paper v1, Mainieri et al, 2024, astro-ph
194 pages, 214 authors https://arxiv.org/abs/2403.05398
v2 foreseen in 2027-2028



Gaia,
LSST/Rubin,
Euclid, Roman,
SKAO,
HWO,
Einstein Telescope,

In the first 5 years of operation, WST will provide:

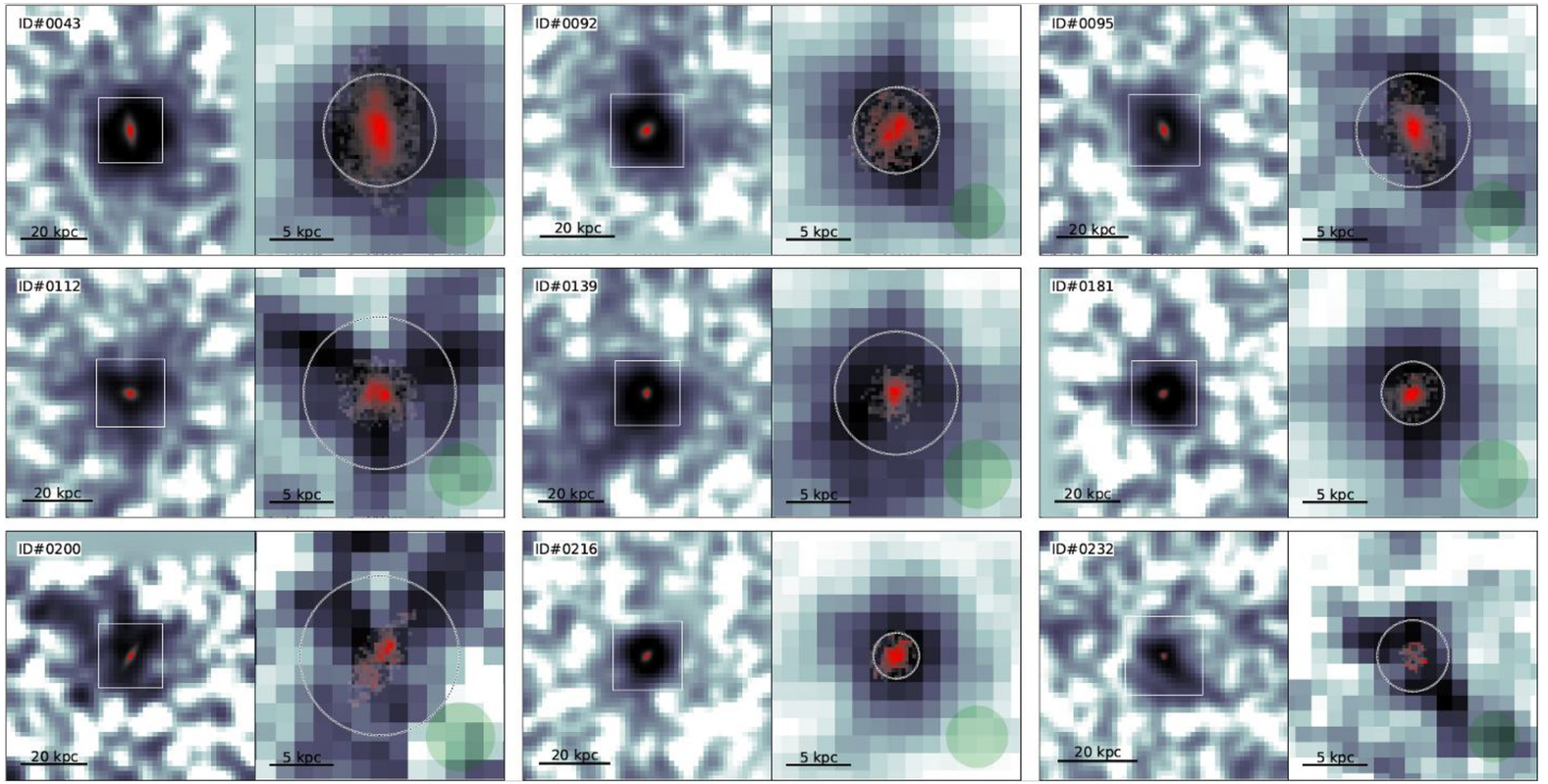
- MOS LR
  - **250 million** galaxies (to AB 24.5) over **14,000 deg²**
  - **25 million** stars (to AB 23.0) over the **entire galaxy and local group**
- MOS HR
  - **A few million** stars (to AB 17.0) over most of the galaxy
- IFS
  - **4 billion** spectra over 30 deg² in diverse environments (low-density fields, galaxy and stars clusters, galactic fields …)

Example of science cases relevant to this conference

- Massive stars & variables stars
- Direct imaging of CGM at high-z
- Direct imaging of the IGM
- End of reionization
- Galactic winds
- LyC leakers
- Lya Luminosity function
- AGN nebulae & feedback

CGM in emission, why we need large sample of Lyman-alpha halos

Floriane Leclercq



First detection of individual Lyman-alpha halos with MUSE, Wisotzki et al 2016

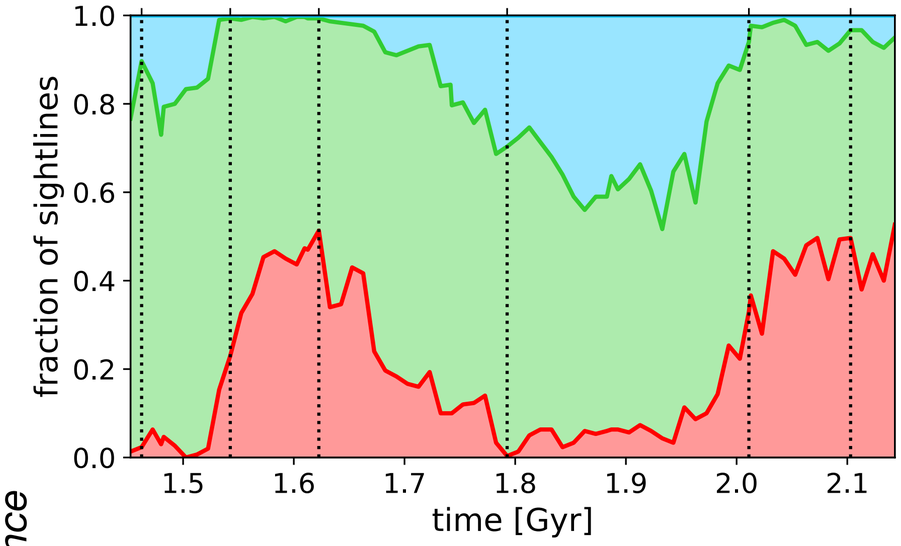
Demography of Lyman-alpha Halos

- z=0 (HST/COS, high-z analogs)
  - 20 LAHs (LARS, Oestlin 2010)
  - 42 LAHs (LaCOS, Hayes 2020, Le Reste this conf)
- z>3 (VLT/MUSE) + a few with KCWI (z>2)
  - 26 LAHs, Wisotzki et al, 2016
  - 145 LAHs, Leclercq et al 2017
  - 268 LAHs, Claeyssens et al 2022

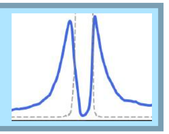
J.,Blaizot

CGM RT Lya simulation Blaizot et al, 2023, MNRAS

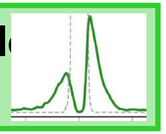
See also John Pharo talk, this conference



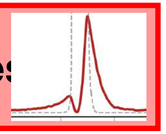
Blue line

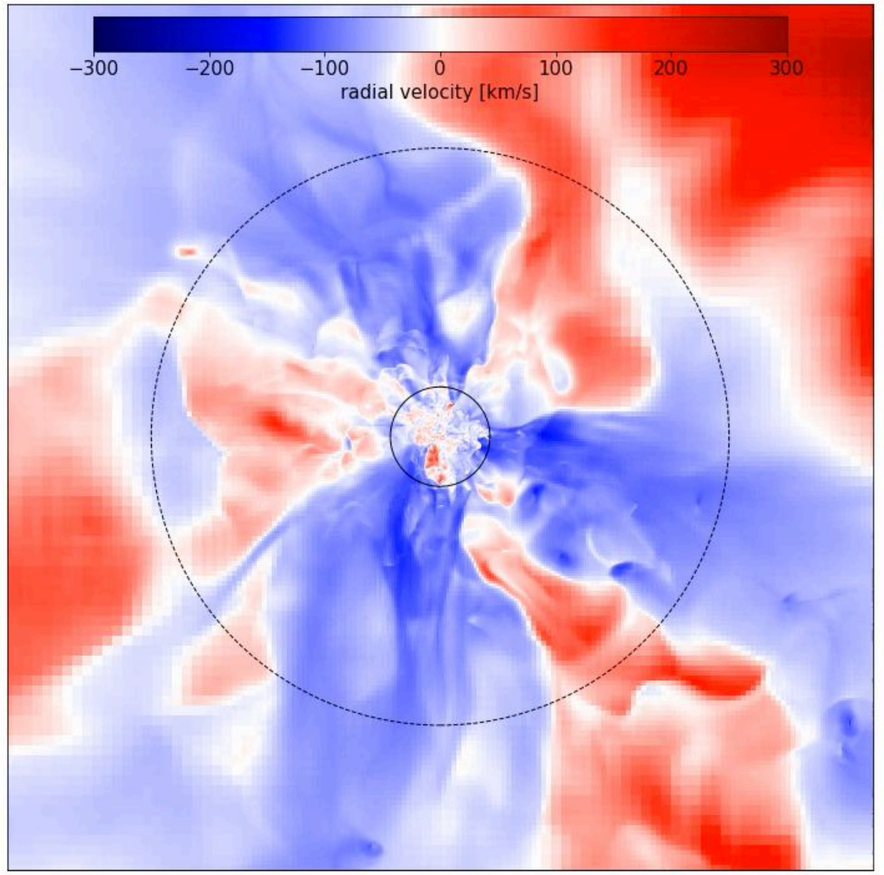


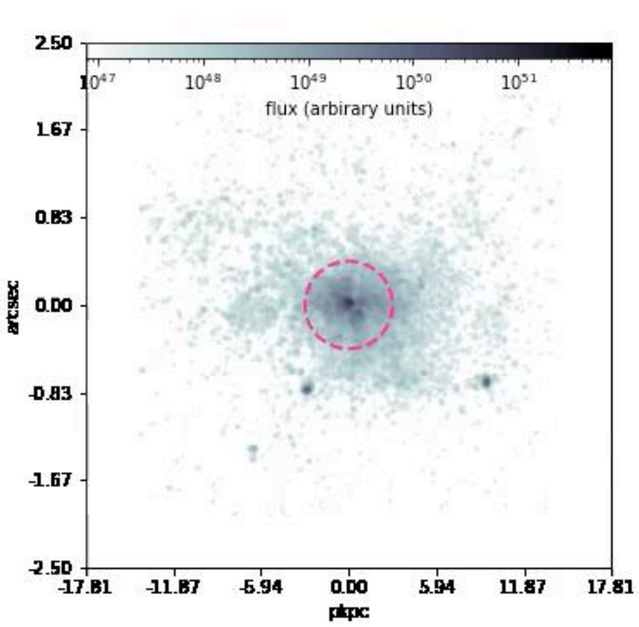
Ordinary double peaks

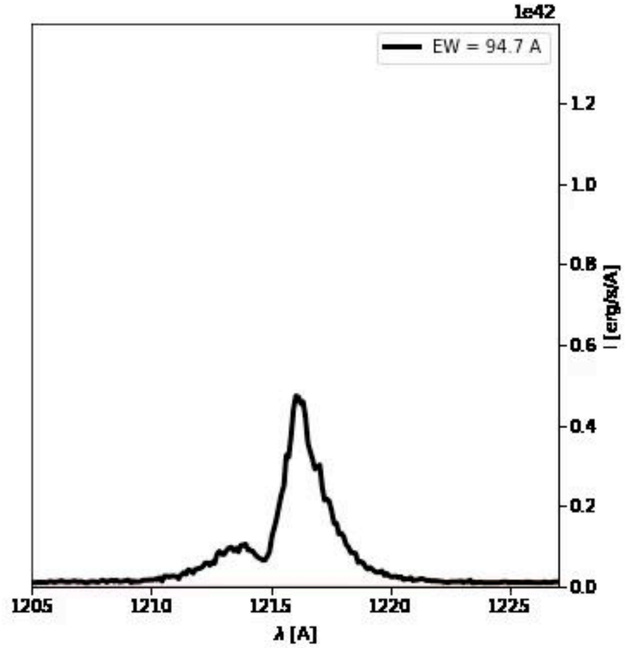


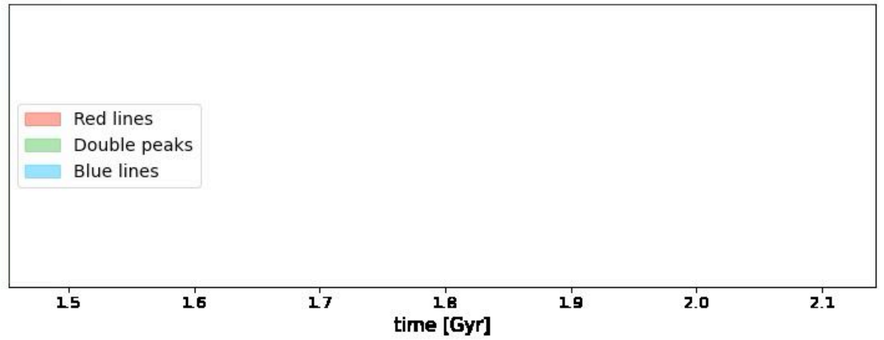
Red line shapes











Outflowing gas

Inflowing gas

Ten years of MUSE & KCWI observations have set strong constraints on the Lya emission from/ through the CGM of star forming galaxies :

(1) Lyα emission extends out to more than $R_{\rm vir}$
(2) line profiles have many shapes
(3) there are systematic variations of the line profile with radius.

Radiation-hydrodynamics simulations that resolve the multiphase ISM reproduce most Lya observations low-mass galaxies at all redshifts. They show that **extreme line profiles are indicative of dominant inflows or outflows**, but the correlation between line shape and flows of gas is generally rather loose.

The volatility of Lya properties, with time and direction, demands **very large samples from both observations and simulations in order to constrain models**. With such samples, we may hope to constrain feedback processes via

- the duty cycle of star formation in low-mass galaxies;
- the geometry (opening angle) of inflows and outflows.

In addition to

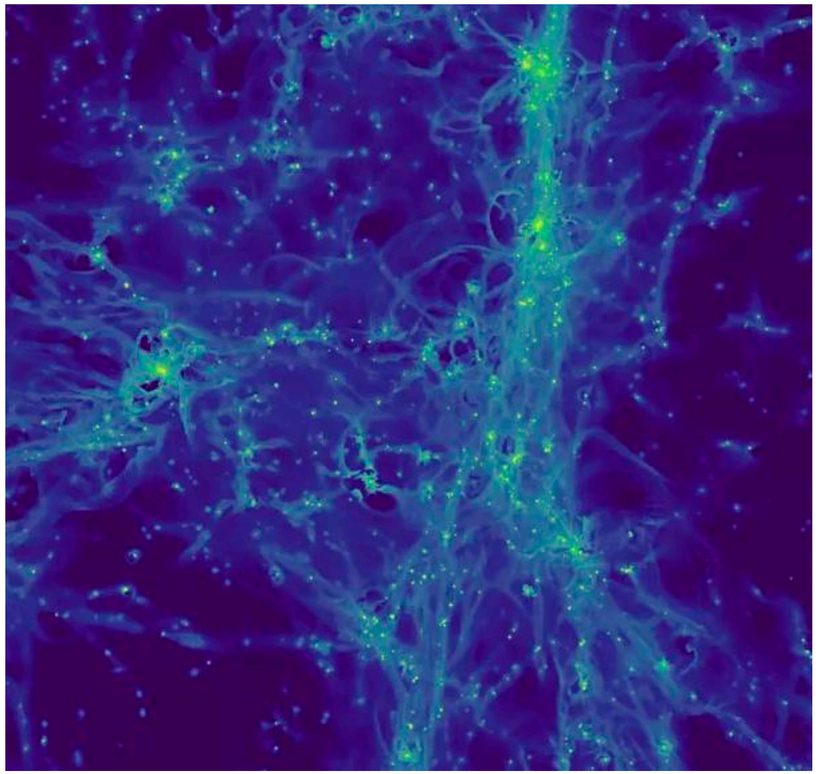
- the impact of environment
- the evolution with redshift

LAEs & LAHs with WST

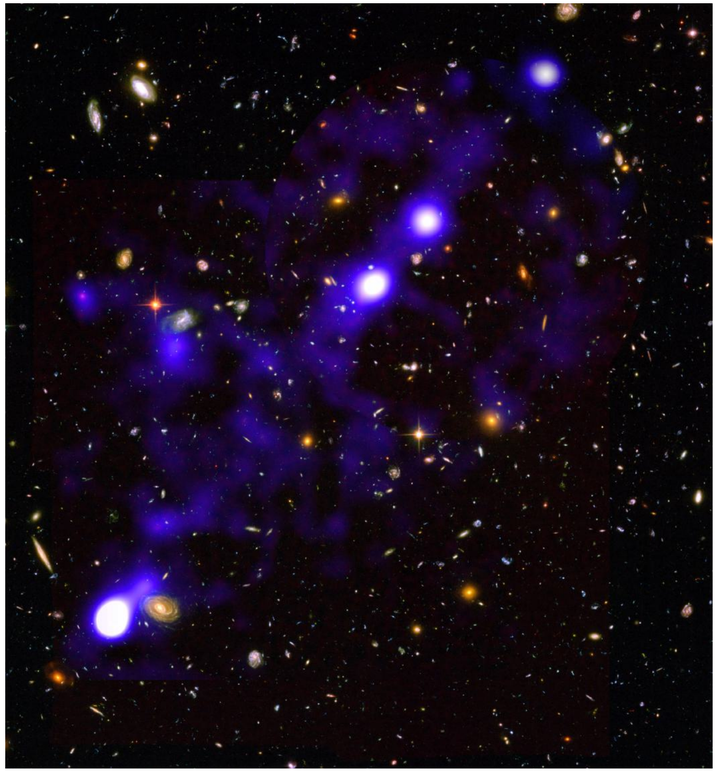
Survey cost: 0

- The **parallel** observations of IFS & MOS ensure that any MOS targeted observations will provide an IFS field (single 3’x3’ field of mosaic up to 9’x9’)
- Except in our galaxy, all other IFS blank fields will have a population of galaxies, including LAEs at z=2-7
- We anticipate in 5 years survey to get
  - **17,000,000** LAEs, including **3,500,000** LAHs
  - over **30 deg²**

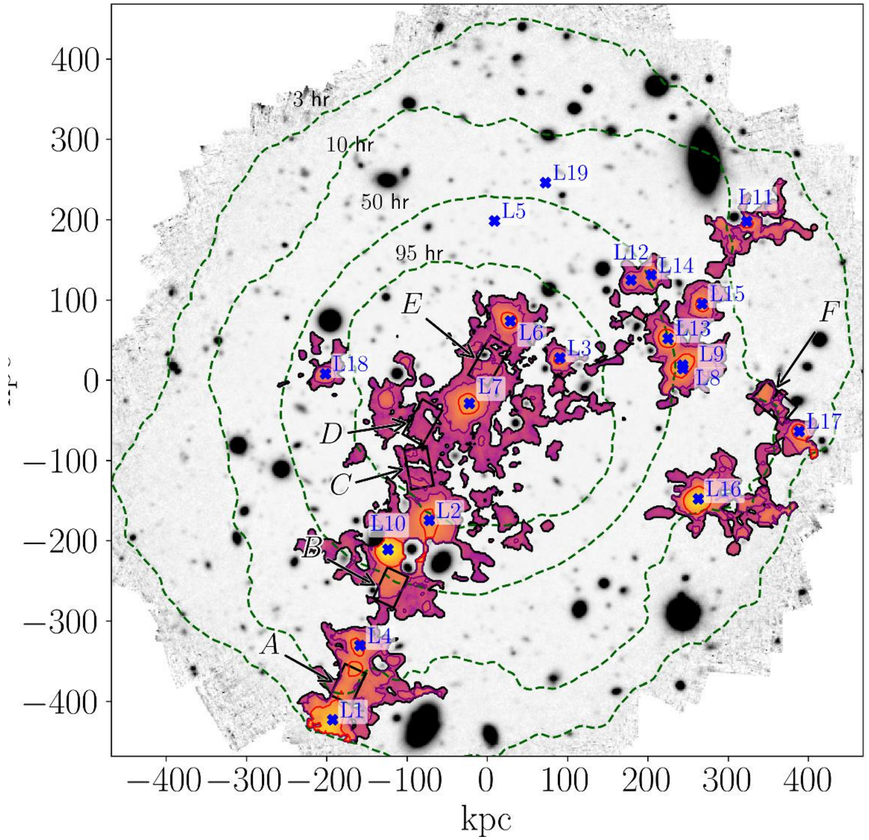
Direct images of the cosmic web



SPHINX simulation



4 cMpc filament at z=3.2 in the MXDF (MUSE, 140h, Bacon et al 2021)



5 cMpc filament at z=4 in the MUDF (MUSE, 142h, Tornotti et al 2025)

The WST cosmic web legacy survey

Davide Tornotti

- Across different redshifts (z=2-4.5) and overdensities (5-20) :
  - Tracing the cosmic web: Lyα emission from filaments on 20 cMpc scales (IFS)
  - Galaxy clustering in overdensities: large scale coeval populations on 150 cMpc scales (MOS)
  - Lyα absorption tomography: mapping the IGM with background galaxies (MOS)

The WST cosmic web legacy survey

Survey cost: 50 nights

- 2 IFS mosaic pointings spine of the filaments on 40 cMpc scales at 30 hours depth, SB = 3-4 10^{-20} erg.s^{-1}.cm^{-2}.arcsec-2
- 7000-9000 MOS fibers for the two major pointings (background galaxies & coeval galaxies)
- 2/3 MOS fibers remain free for additional science cases: galaxy overdensity on 200 cMpc scales and 3D tomography.

Survey design: z~3.3

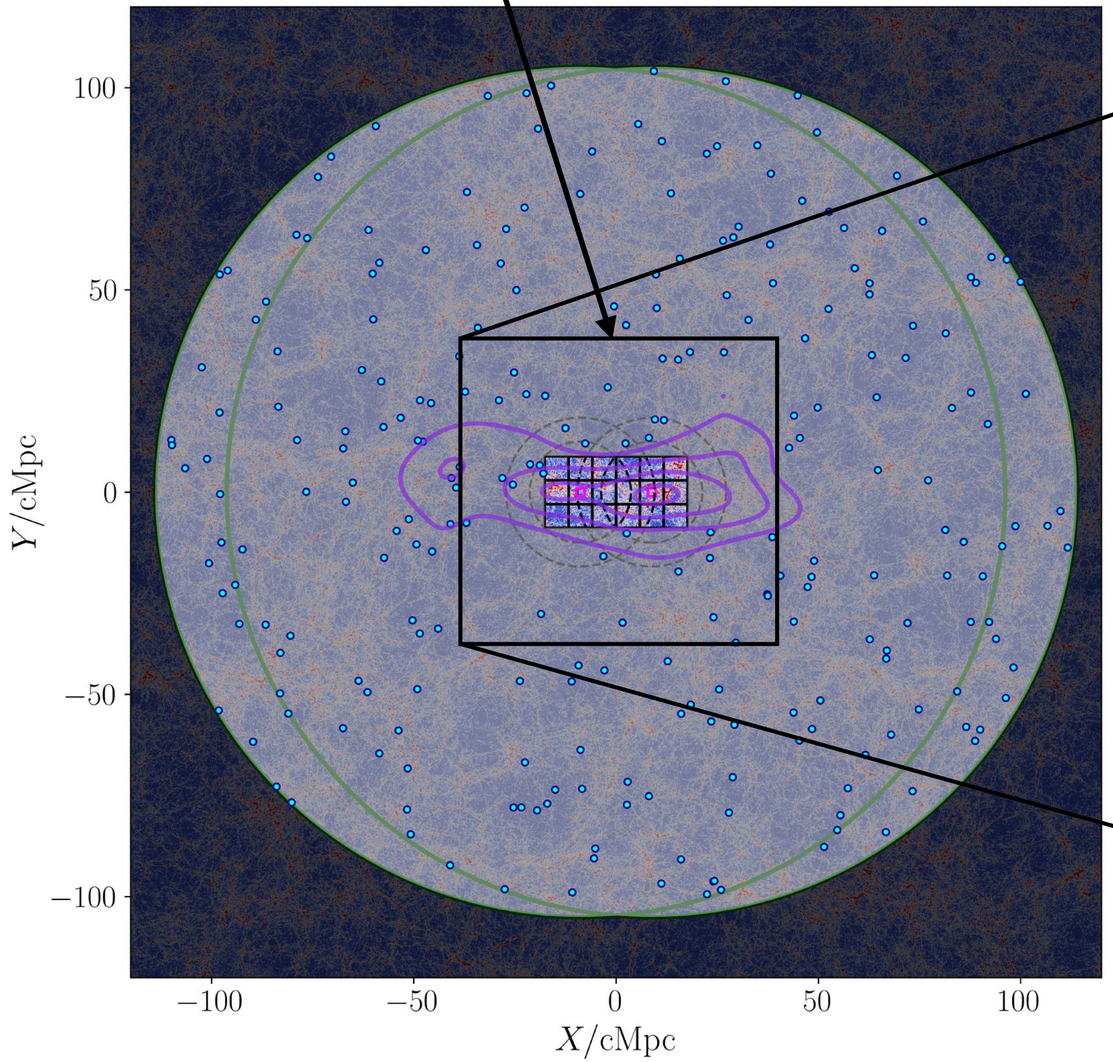
200-300 background massive galaxies up to z~4

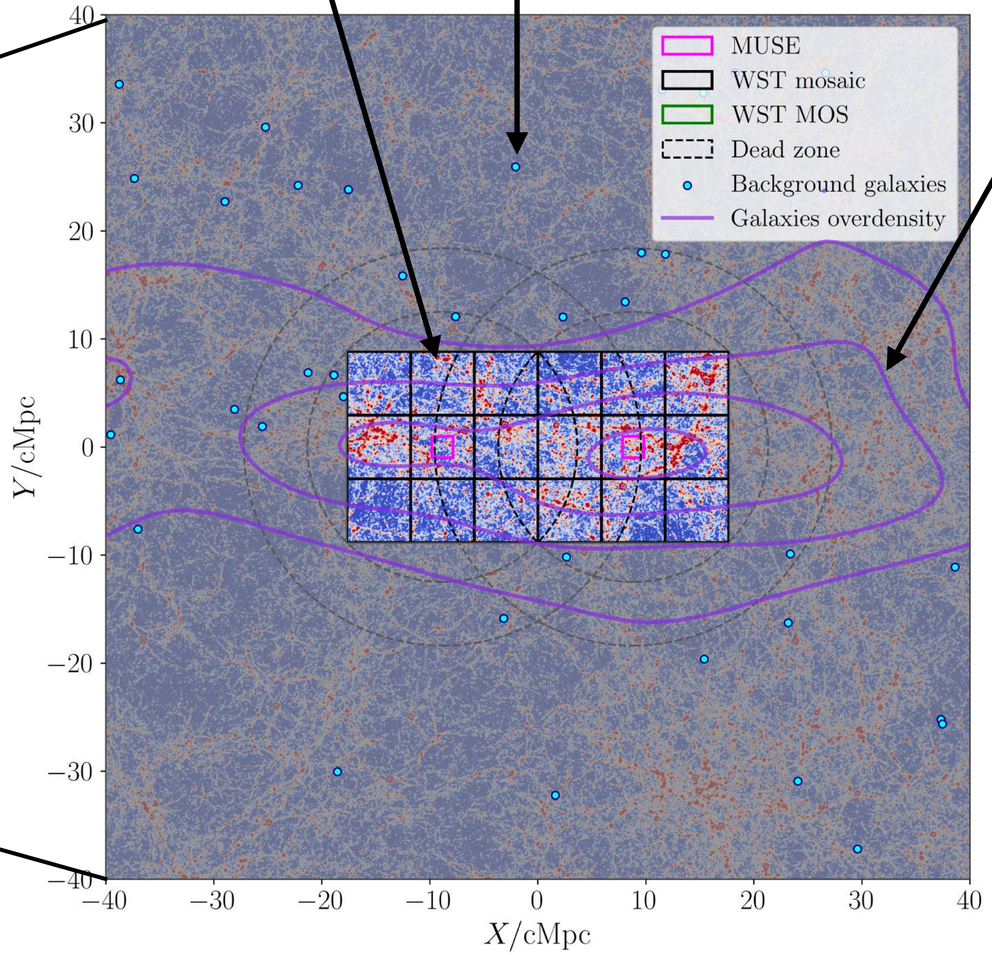
30 hours by single pointing 3x3 arcmin²

7000-9000 co-eval galaxies > 10^{10} $M_\odot$

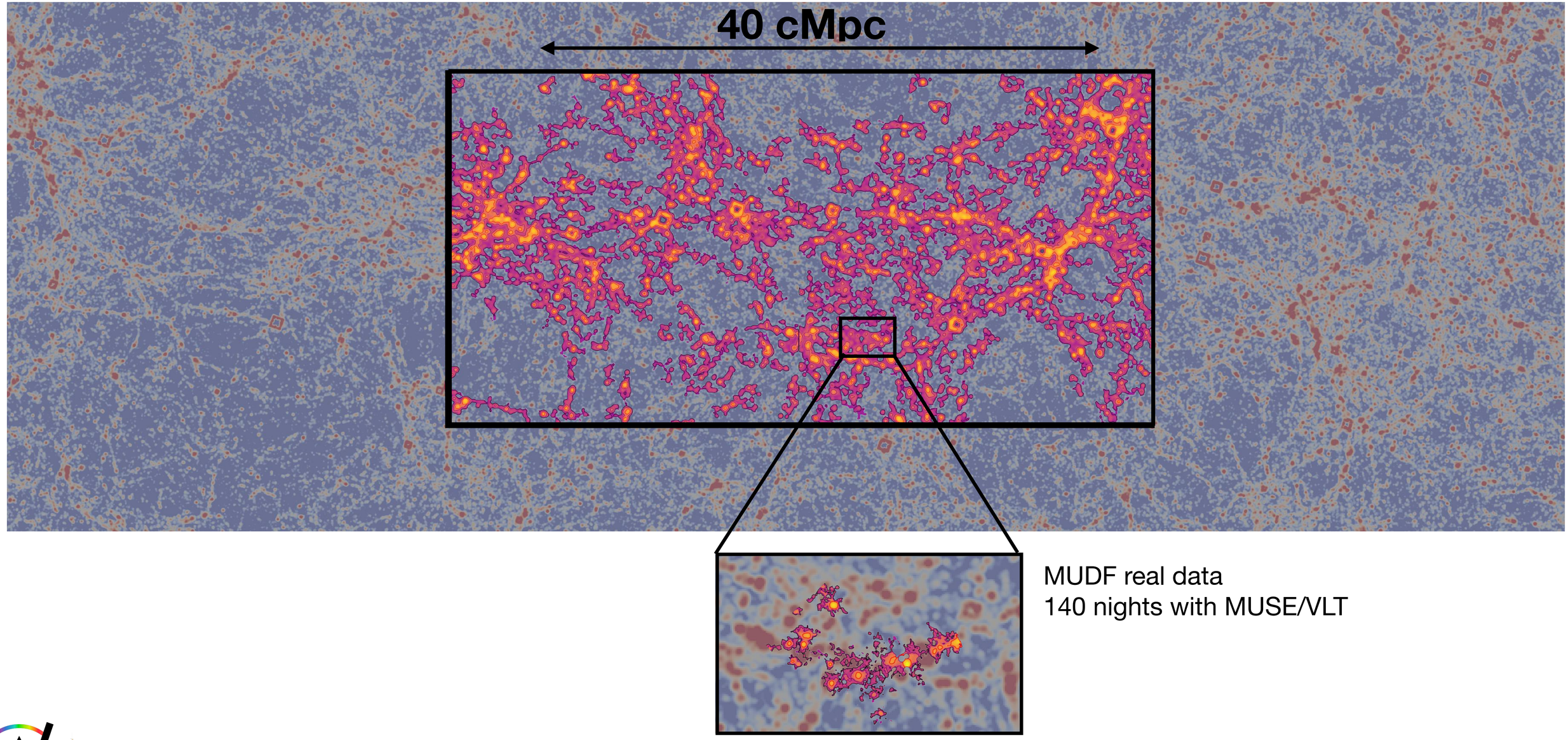
Selected overdense region

MUSE FoV

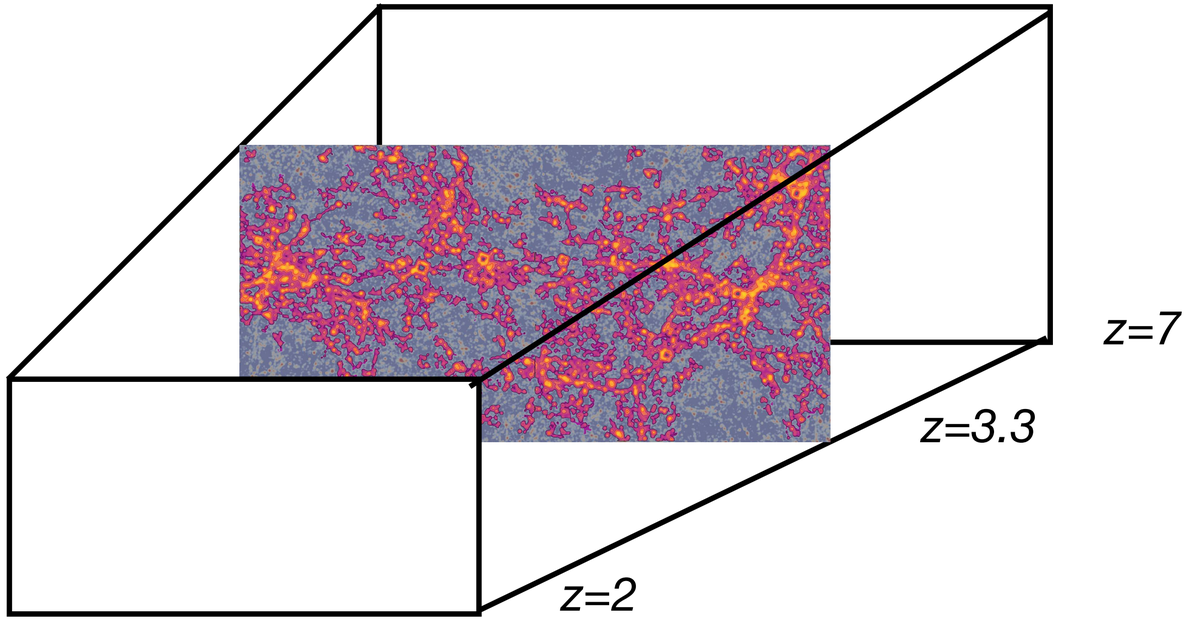




Tracing the cosmic web at unprecedented scale

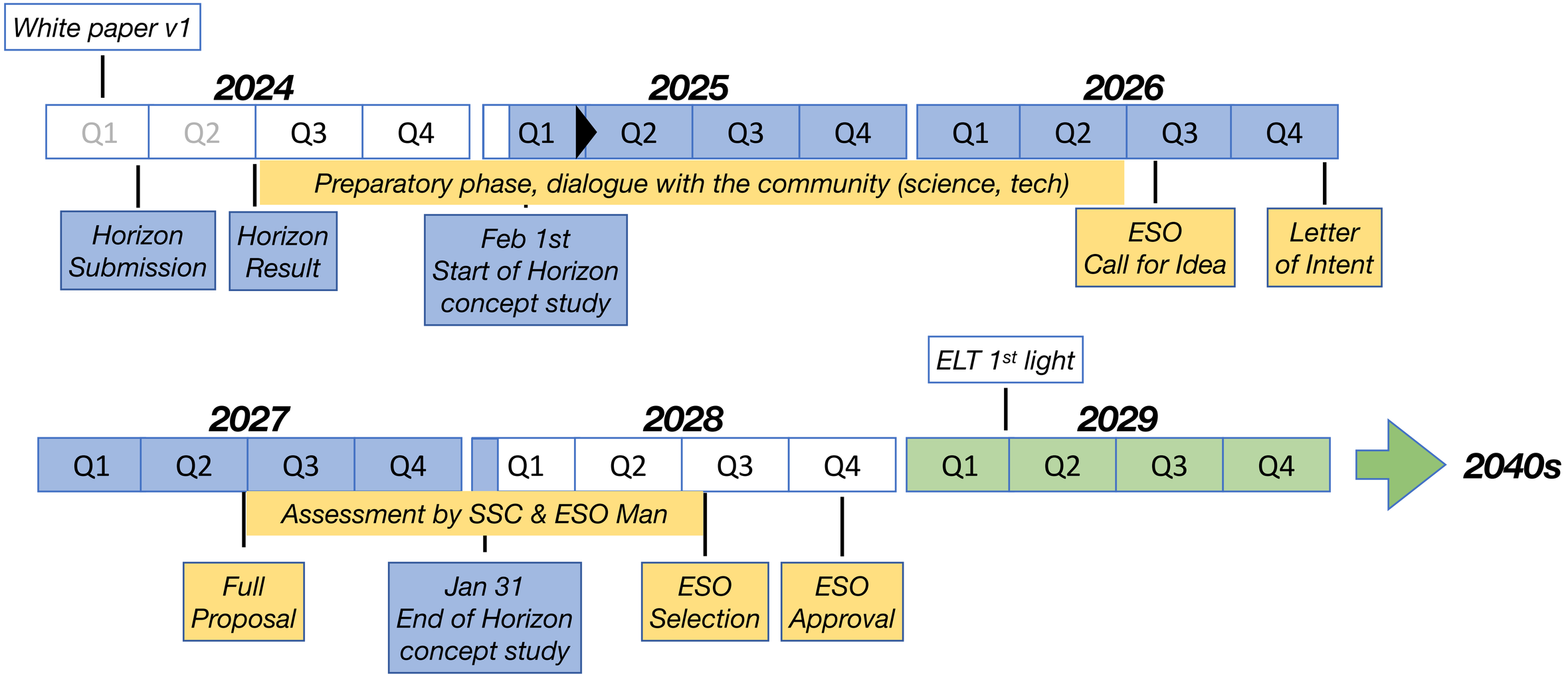


MUDF real data
140 nights with MUSE/VLT



$V = 2.5\ 10^6\ cMpc^3$

WST overall schedule



Thank you

Not yet registered to WST science team ?

Register now at wstelescope.com