



UNIVERSITY OF TARTU

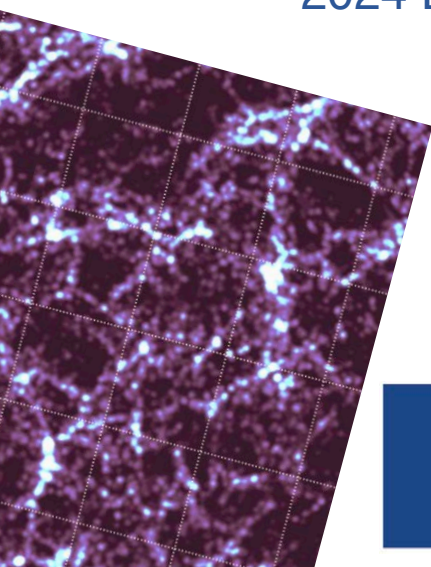
Overview of the 4MOST surveys

Elmo Tempel

2024 EXCOSM kick-off



Funded by
the European Union



BUILDING EXCELLENCE IN THE STUDY OF GALAXIES AND COSMOLOGY AT THE UNIVERSITY OF TARTU (EXCOSM)



**Funded by
the European Union**

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Leibniz-Institut für
Astrophysik Potsdam



university of
 groningen



UNIVERSITÉ
DE LORRAINE



UNIVERSITY OF TARTU
Tartu Observatory



REPUBLIC OF ESTONIA
MINISTRY OF EDUCATION
AND RESEARCH



Estonian
Research Council

4MOST Consortium

17 full members, 10 minor participants





4
MOST

4MOST

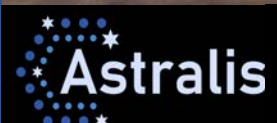
4-metre Multi-Object Spectroscopic Telescope



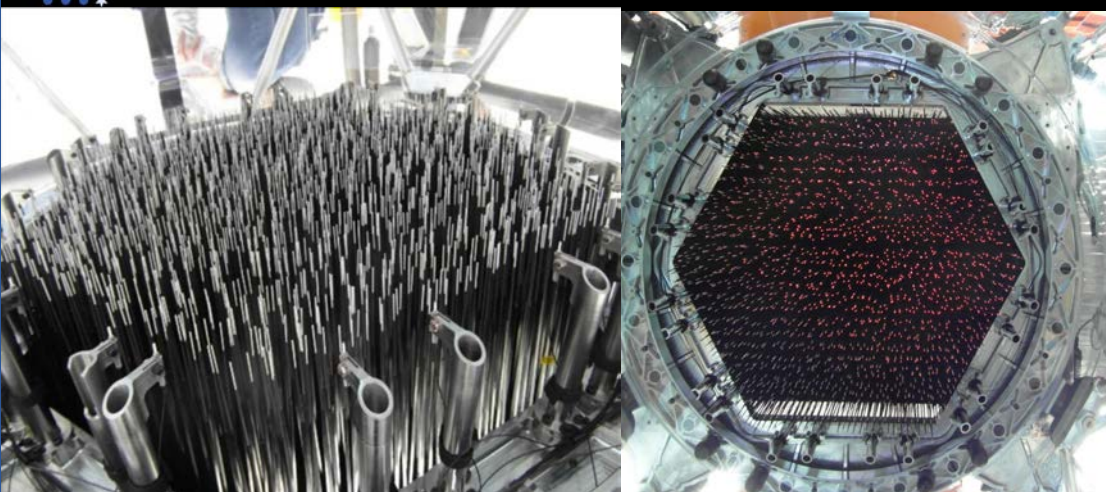


European Southern Observatory

ESO VLT



Australian ESO Positioner (AESOP)

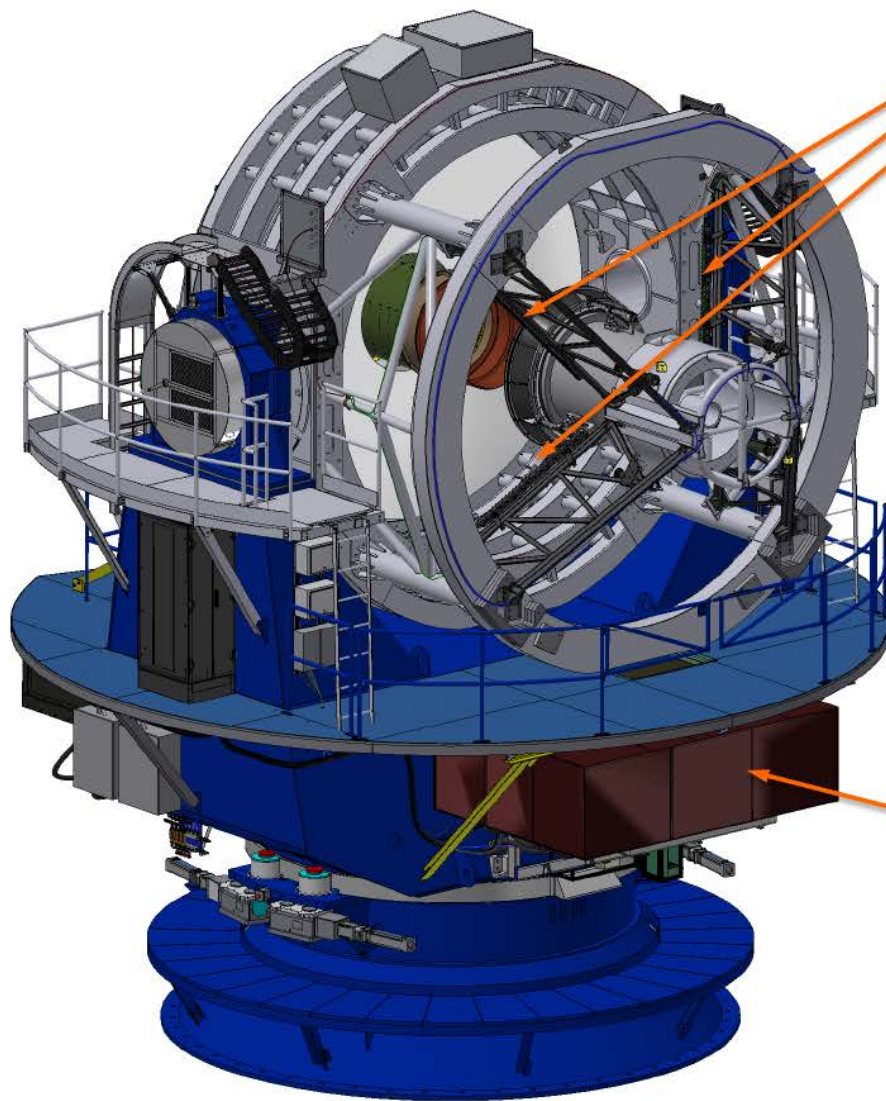


ESO VISTA → 4MOST



4MOST

ESO/VISTA 4-metre telescope

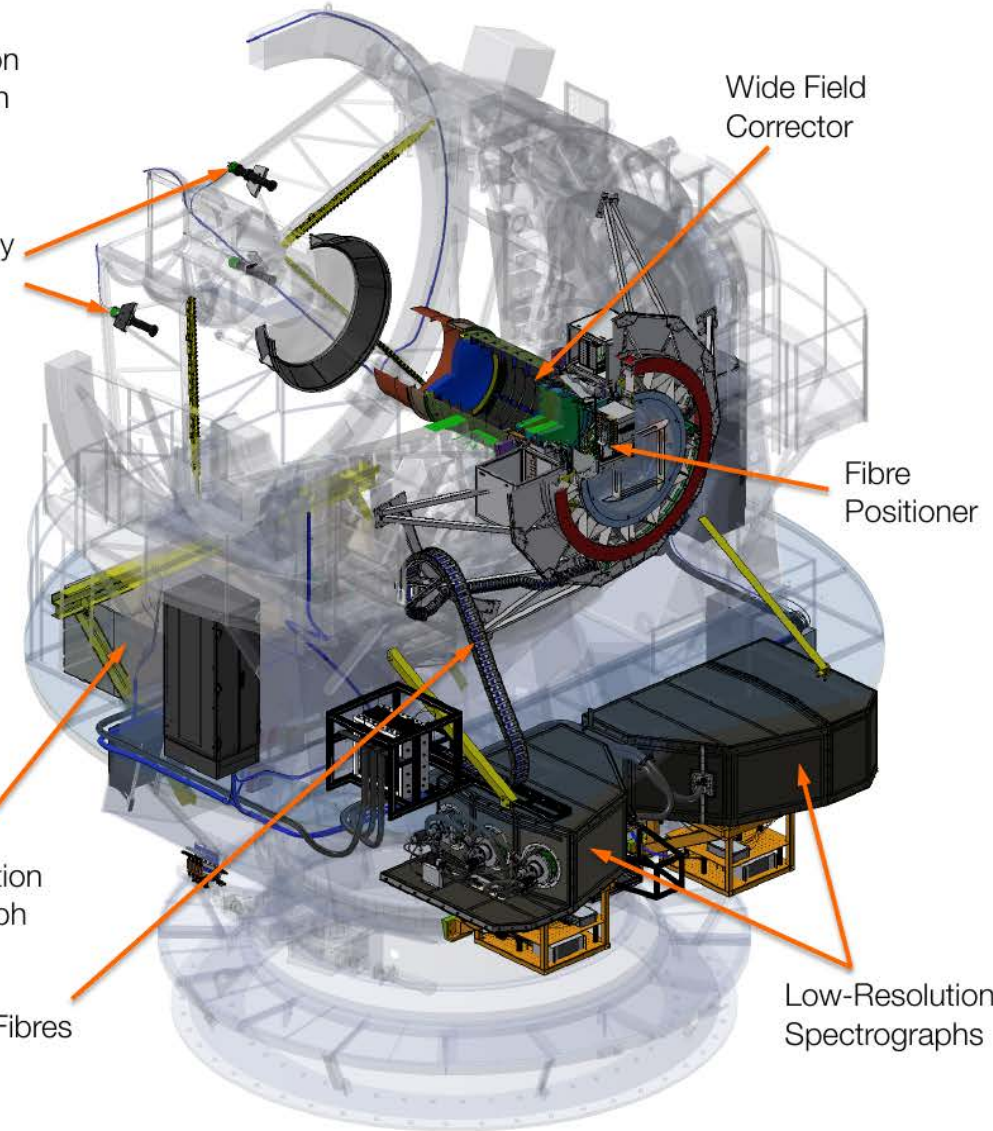


4 Calibration
Illumination
Units

4 Metrology
Cameras

High-Resolution
Spectrograph

2436 Science Fibres

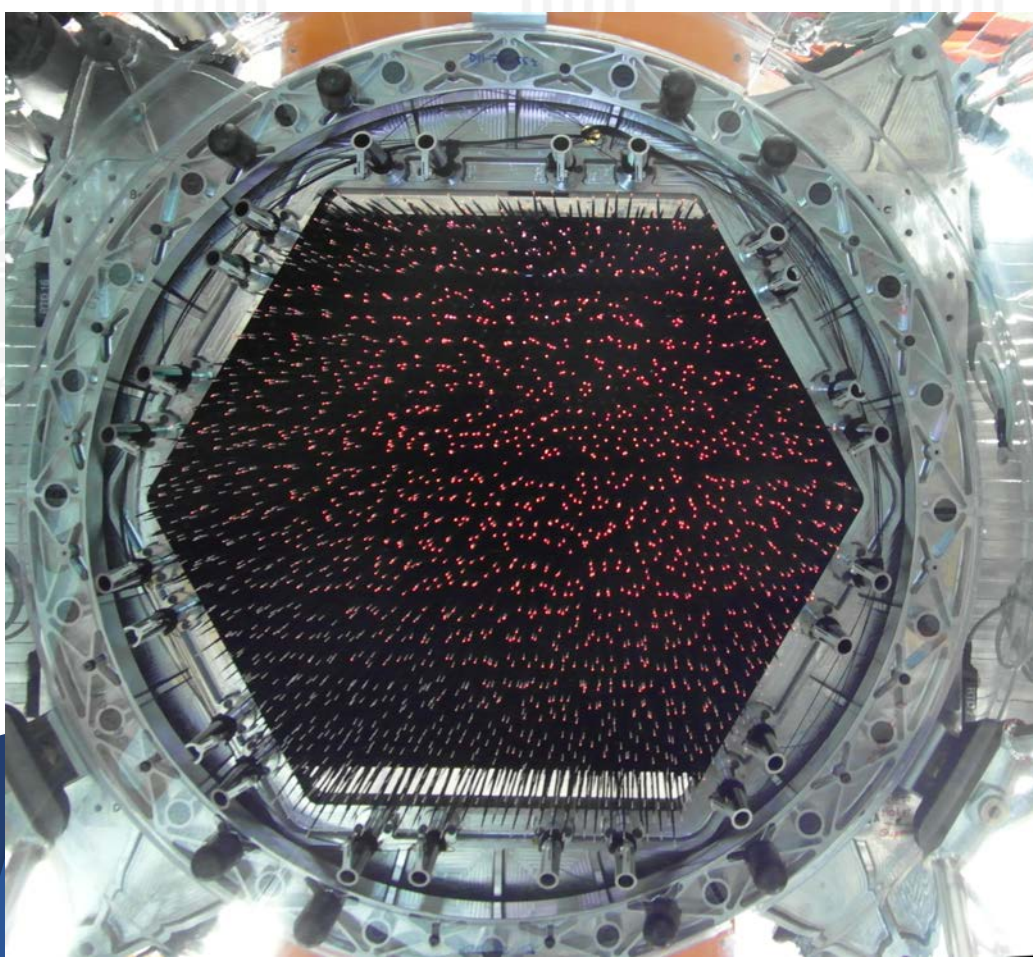


Wide Field
Corrector

Fibre
Positioner

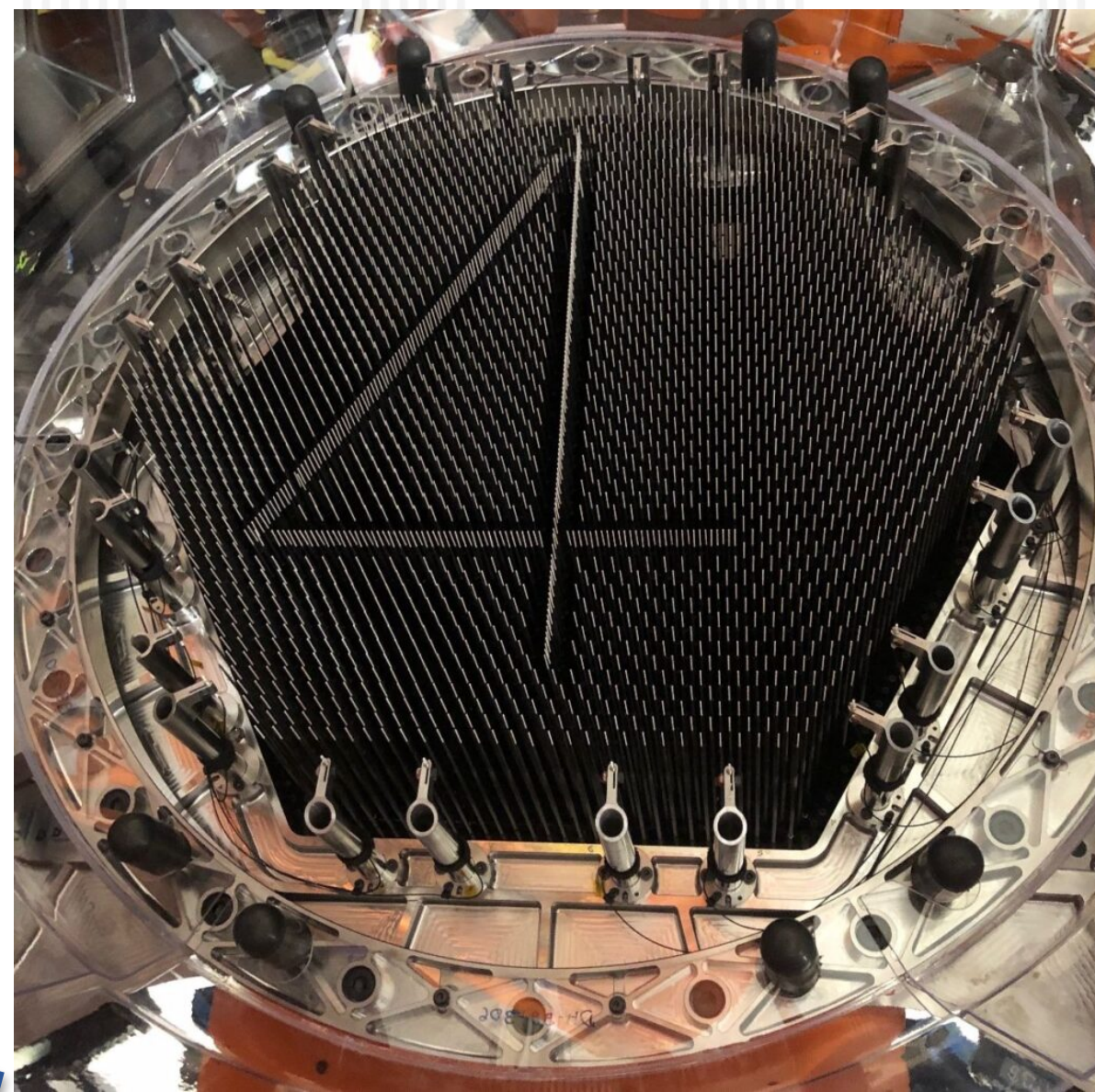
Low-Resolution
Spectrographs

Credit: 4MOST



4MOST

AESOP fibre positioner





4MOST survey

- Upgrade to the 4m VISTA telescope to become large field of view fibre-fed spectroscopic survey facility
- Consortium of Universities/Institutes working with ESO (approved June 2015). 17 full members & 10 minor participants. **PI: Roelof de Jong**
- Operations start mid 2025 (at least 2x5 year surveys)
- Simultaneously run 10 consortium surveys (70% time) and community proposed surveys (30% time) contiguously over 5yrs
- 10+ surveys will share the focal plane in a given pointing

18 independent surveys on 1 telescope embedded in 1 observing program

WAVES is the largest of the extragalactic programs

Instrument capabilities

4.2 deg² hexagonal field of view

30000 deg² accessible sky area (70% of full sky)

1624 low and **812** high-resolution fibres

Minimum distance between fibres: **15 arcsec**

4.8 million hours fibre-hours per year

Wavelength range (LR): 370 - 950 nm

... (HR): 392.6 – 435.5, 516 – 573, 610 – 679 nm

Spectral resolution: 5000 (LR), 20000 (HR)

Radial velocity accuracy: < 1 km/s



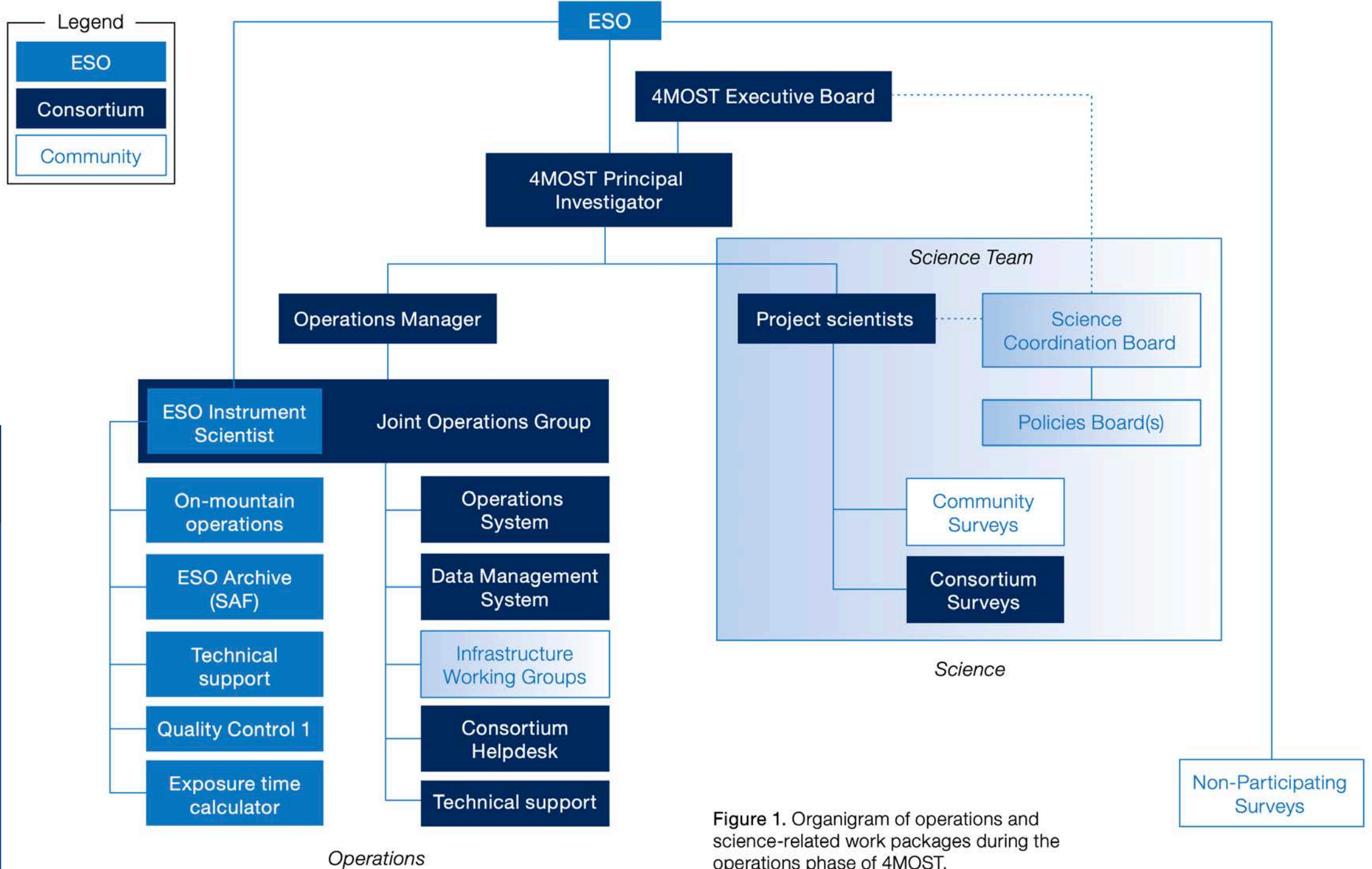
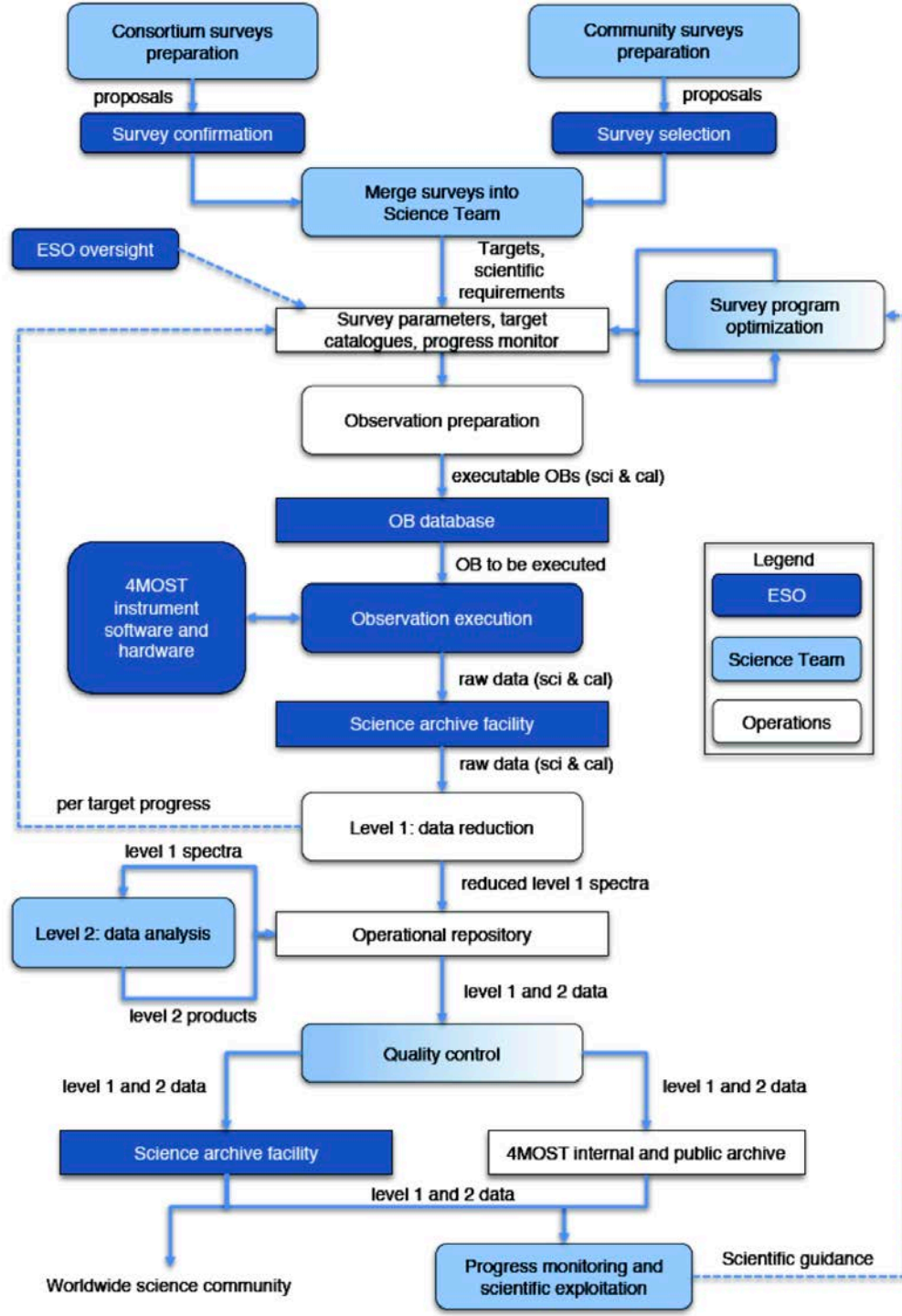


Figure 1. Organigram of operations and science-related work packages during the operations phase of 4MOST.

4MOST

Operations model



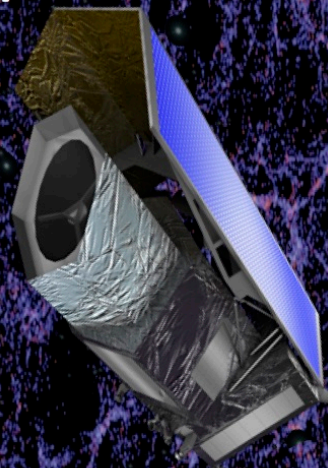
Galactic Archeology
Gaia complement



High-energy sky
eROSITA complement



Cosmology and galaxy evolution
Euclid complement
LSST/SKA/Etc.



4MOST

Science program

4
MOST

Credit: 4MOST

4MOST science program (18 surveys)

Milky Way archeology (Gaia follow-up)

Magellanic Clouds

Stellar clusters in MW

White dwarf binaries, young stars, RRLyrae

Dwarf galaxies and stellar streams

Galaxy clusters (eRosita follow-up)

AGN (eRosita follow-up)

Cosmology

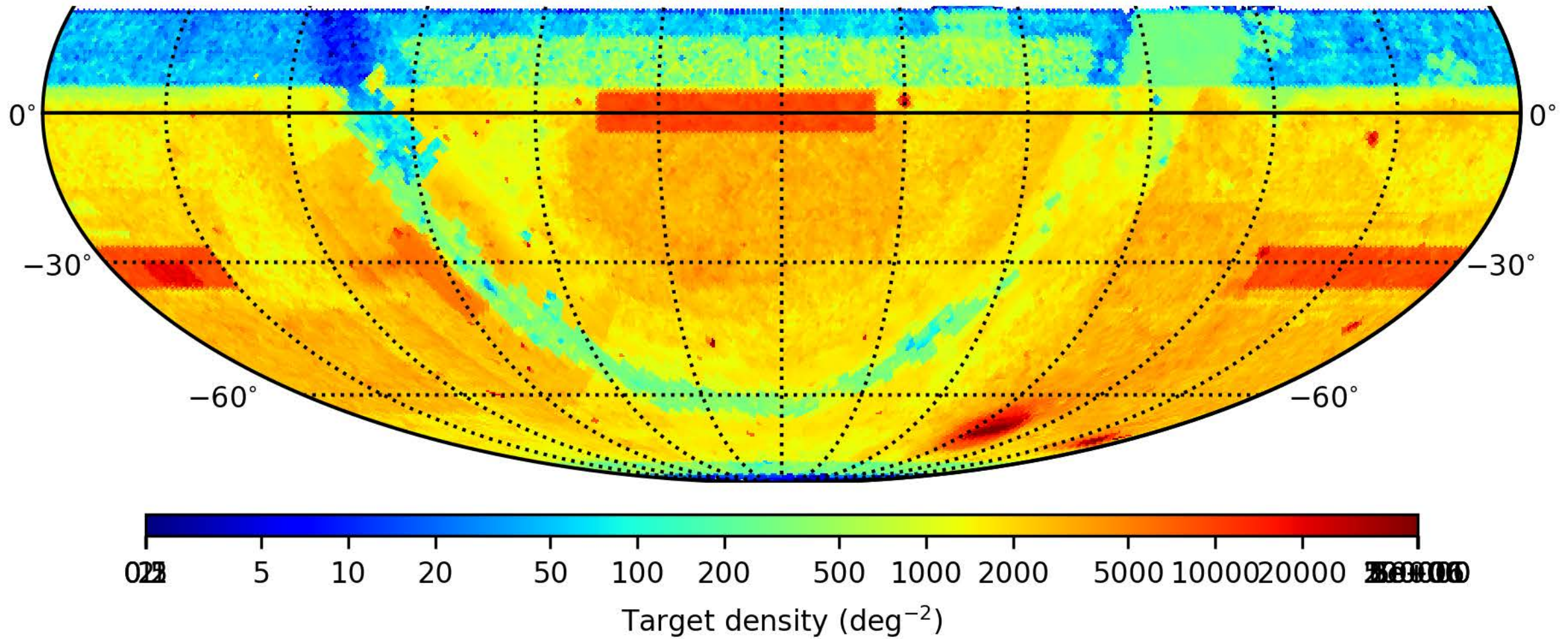
Galaxy evolution

Transients in LSST (live supernovae spectra)

Strong lens survey (Euclid follow-up)

HI deep spectroscopy

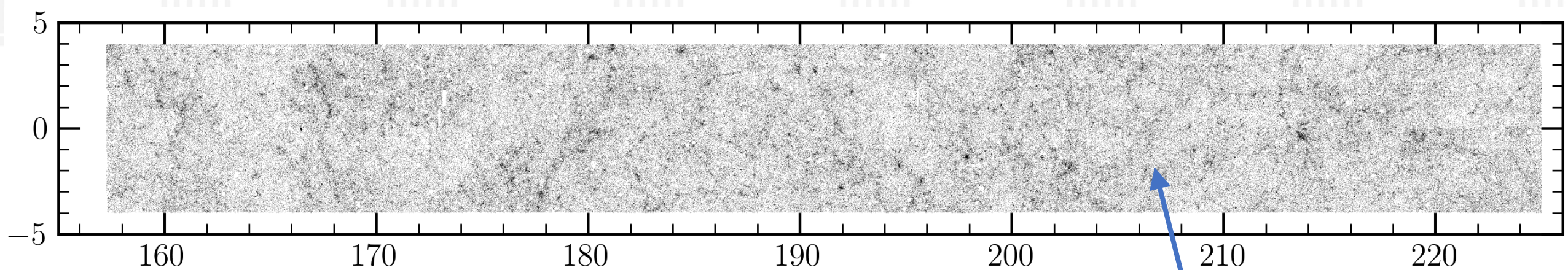




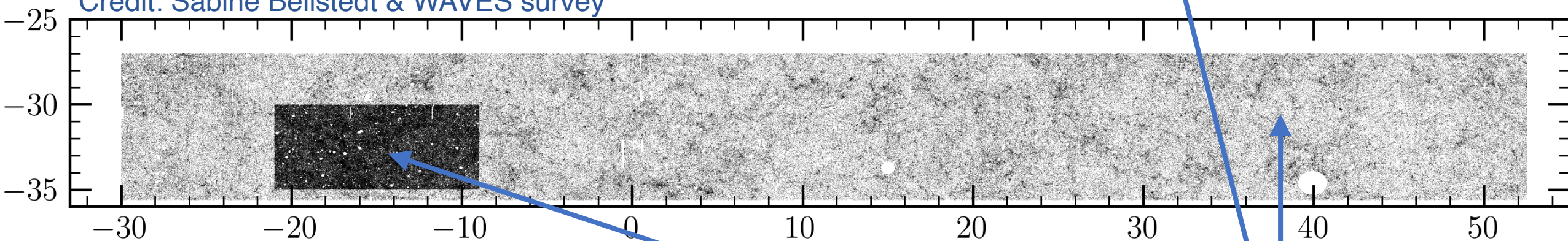
4MOST

Target density in the sky

59 million low-resolution targets
13 million high-resolution targets



Credit: Sabine Bellstedt & WAVES survey



WAVES deep

60 deg²

0.5M galaxies

no z limit

WAVES wide

1200 deg²

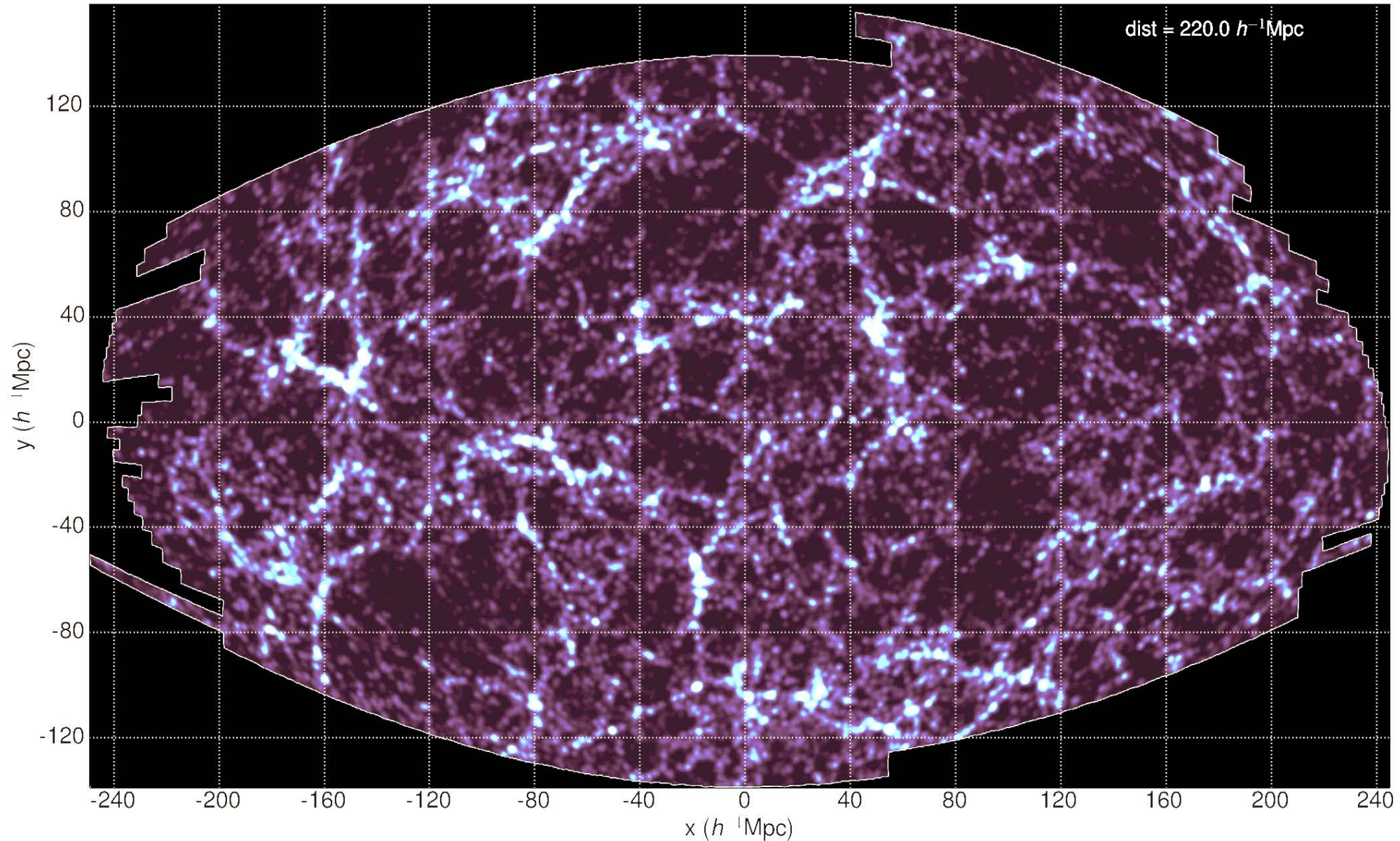
1.5M galaxies

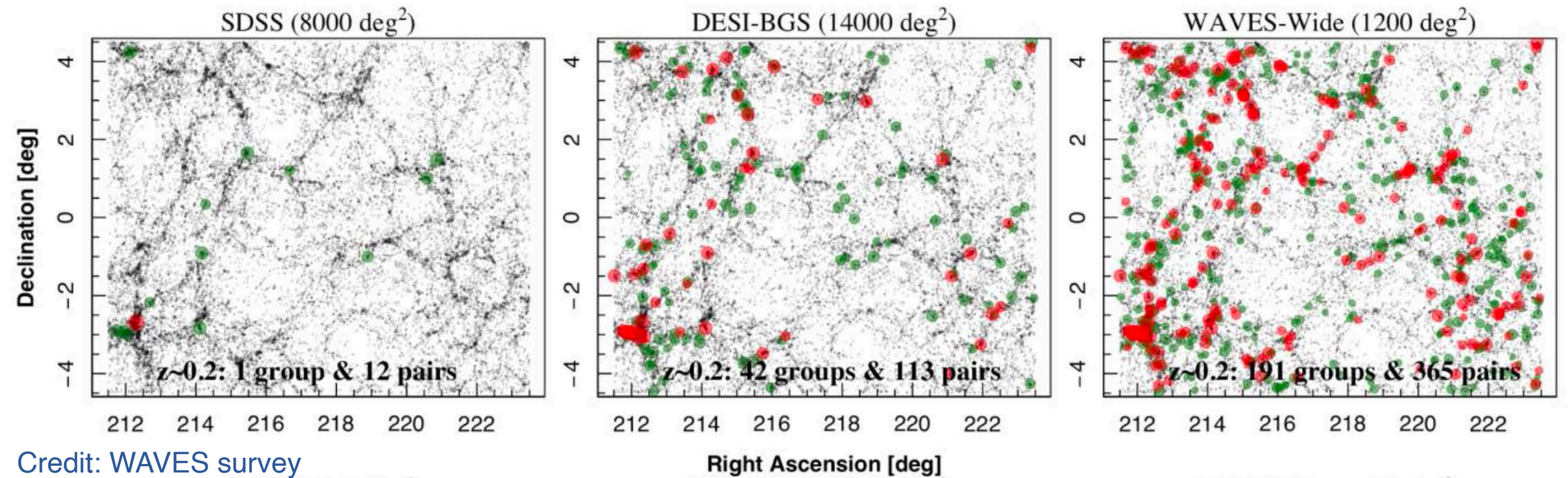
$z < 0.2$

WAVES survey

Photometry is based on VISTA KiDS

Cosmic Web in the SDSS





Credit: WAVES survey

WAVES survey

Galaxy density in WAVES is ~10 times higher than in SDSS

SDSS main

7200 deg²

0.5M galaxies

mag_r < 17.77

z < 0.2

WAVES wide

1200 deg²

1.5M galaxies

mag_i < ~22

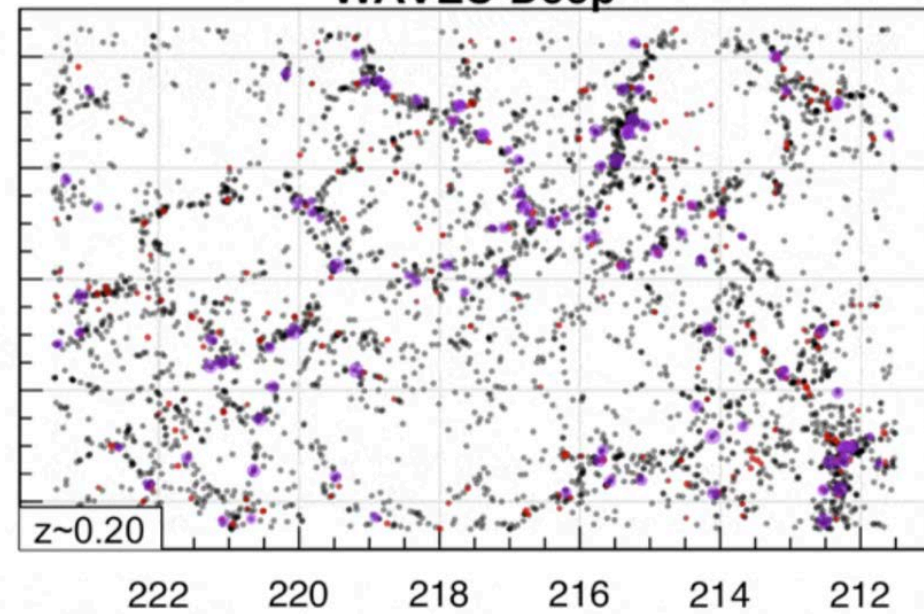
z < 0.2

6x smaller

3x redshifts

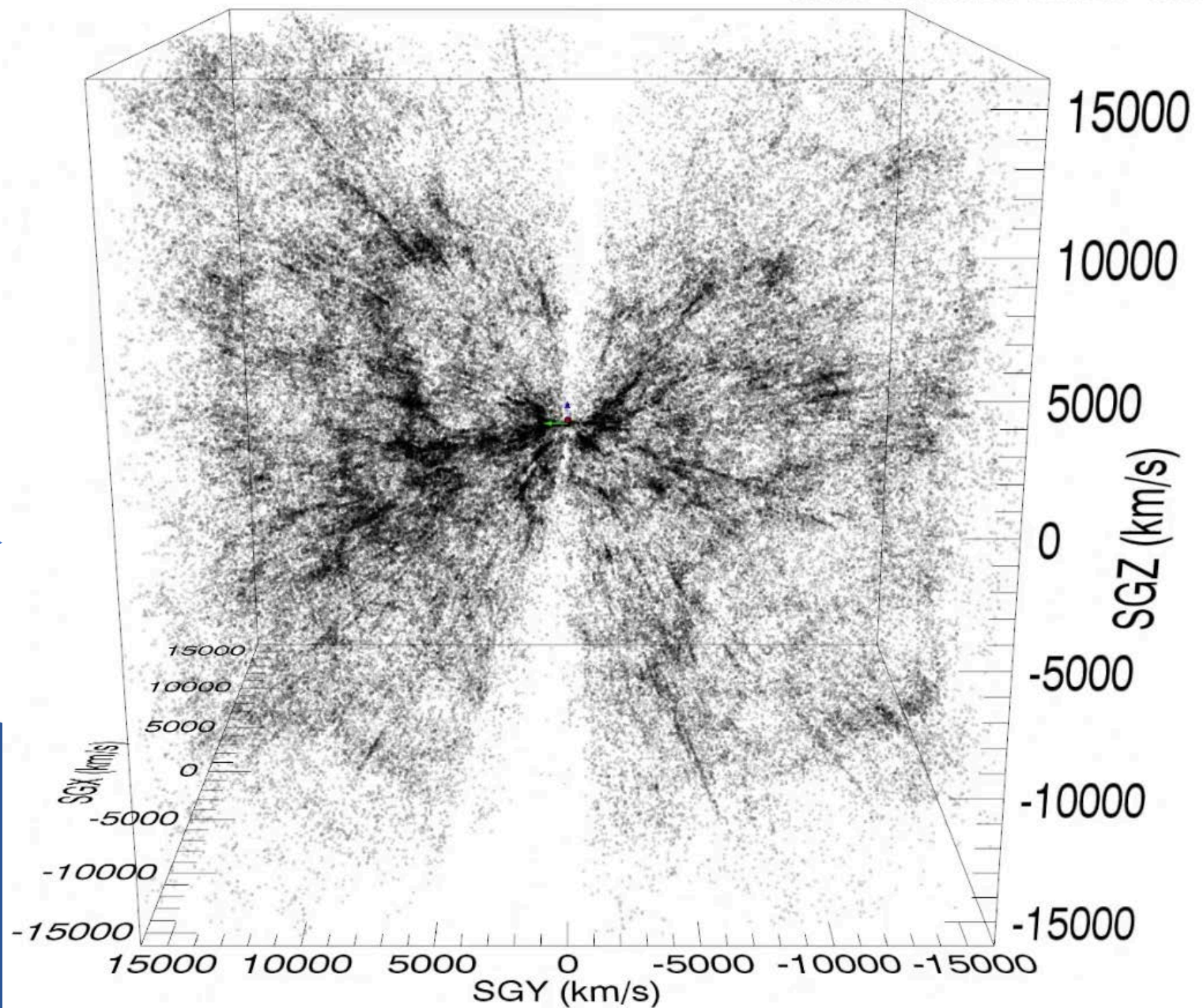
more than
10 times denser

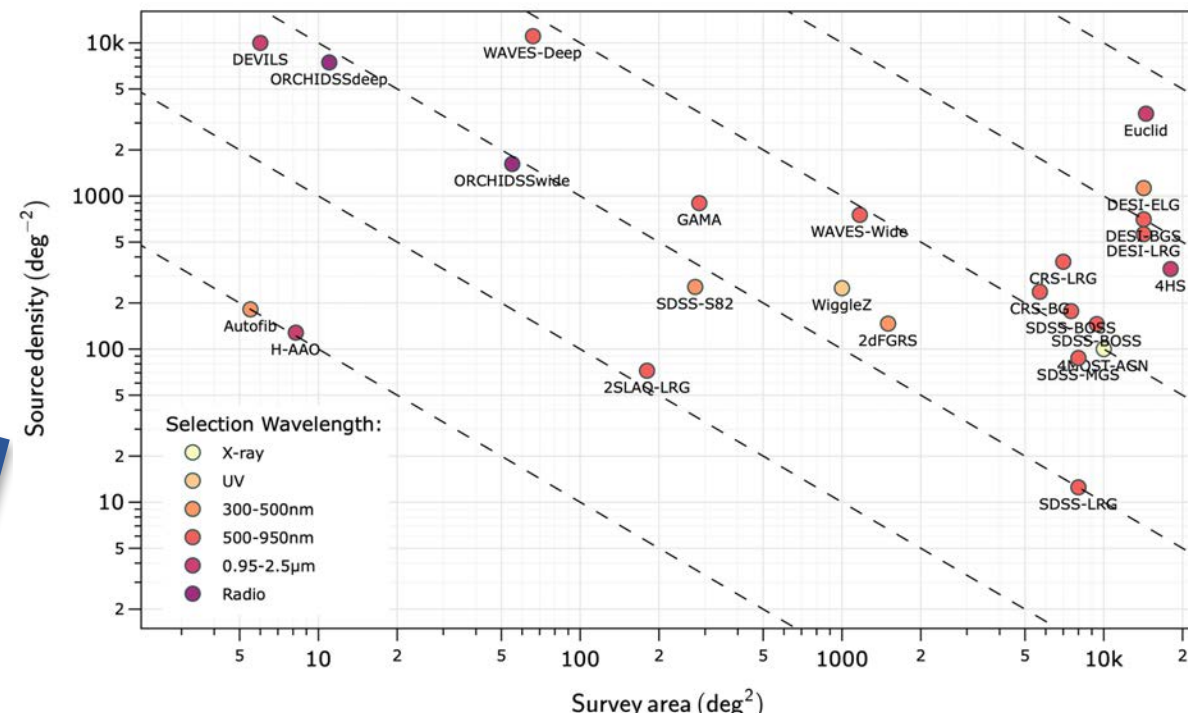
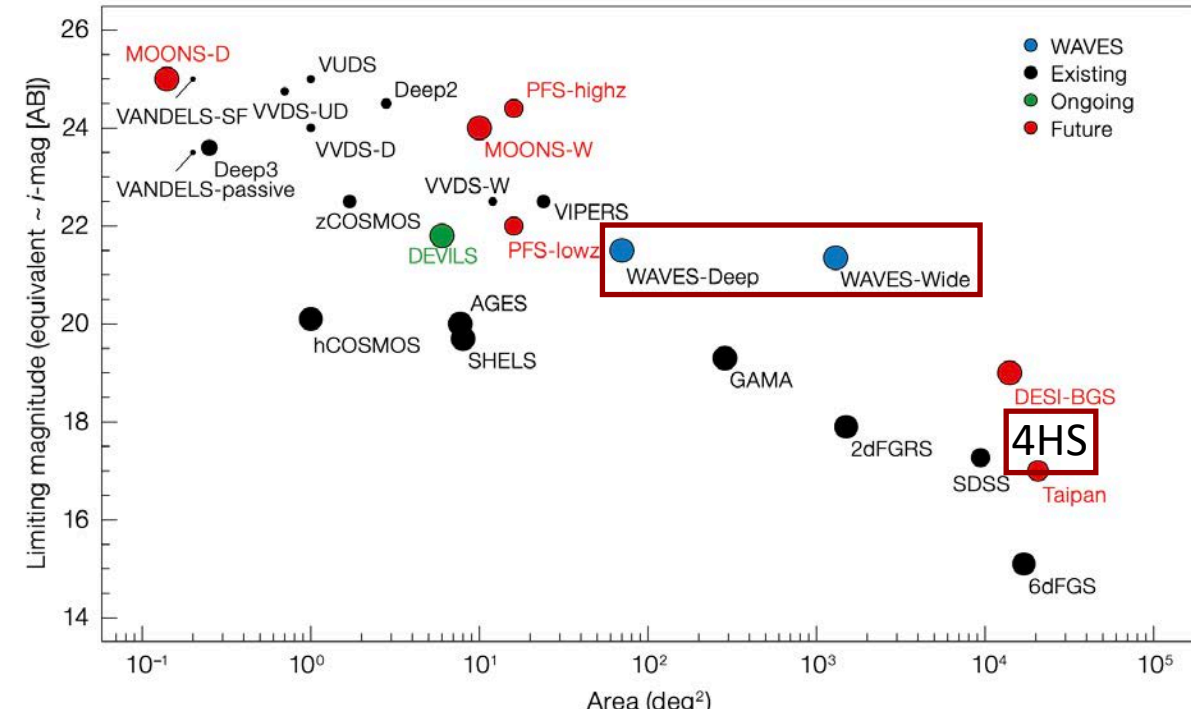
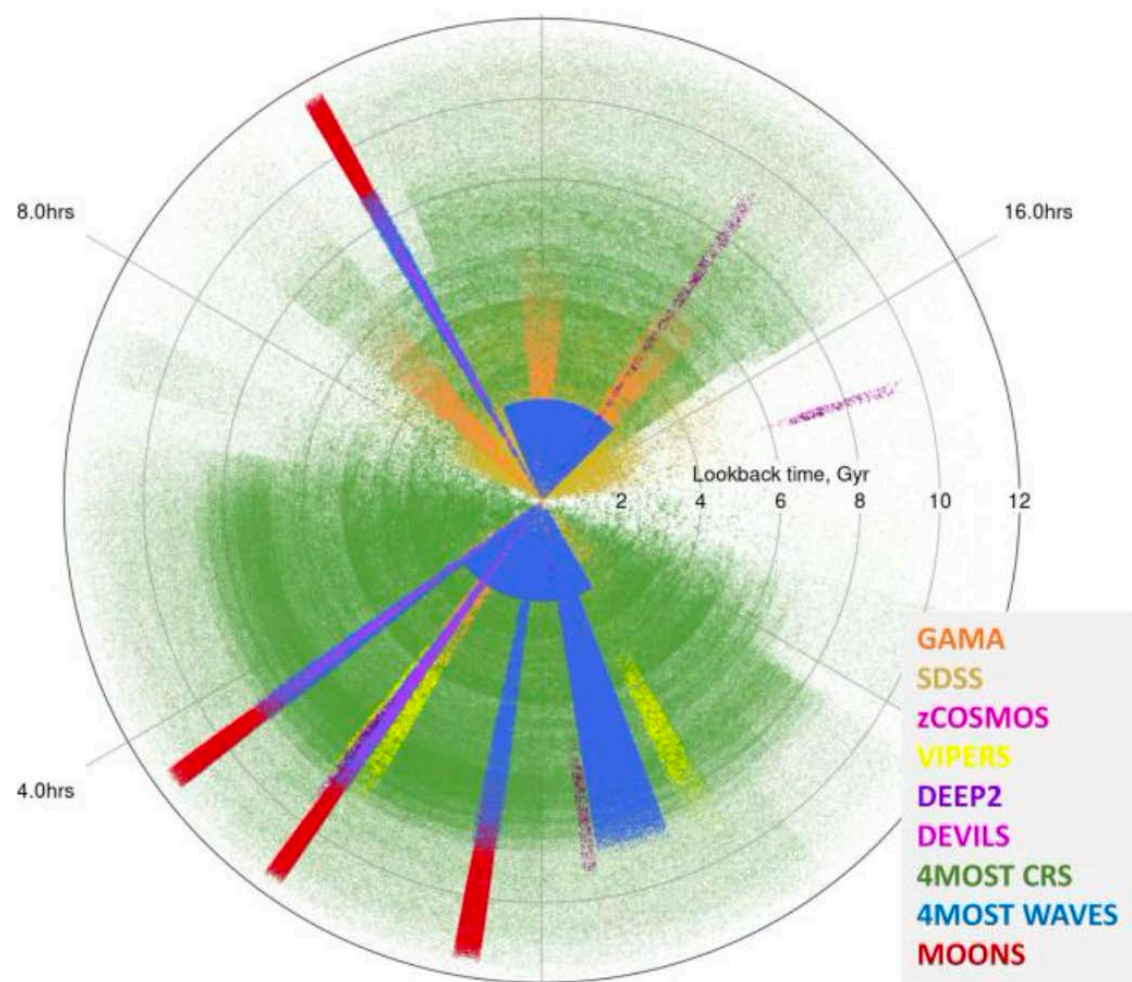
WAVES-Deep



Cosmic Web in 3D

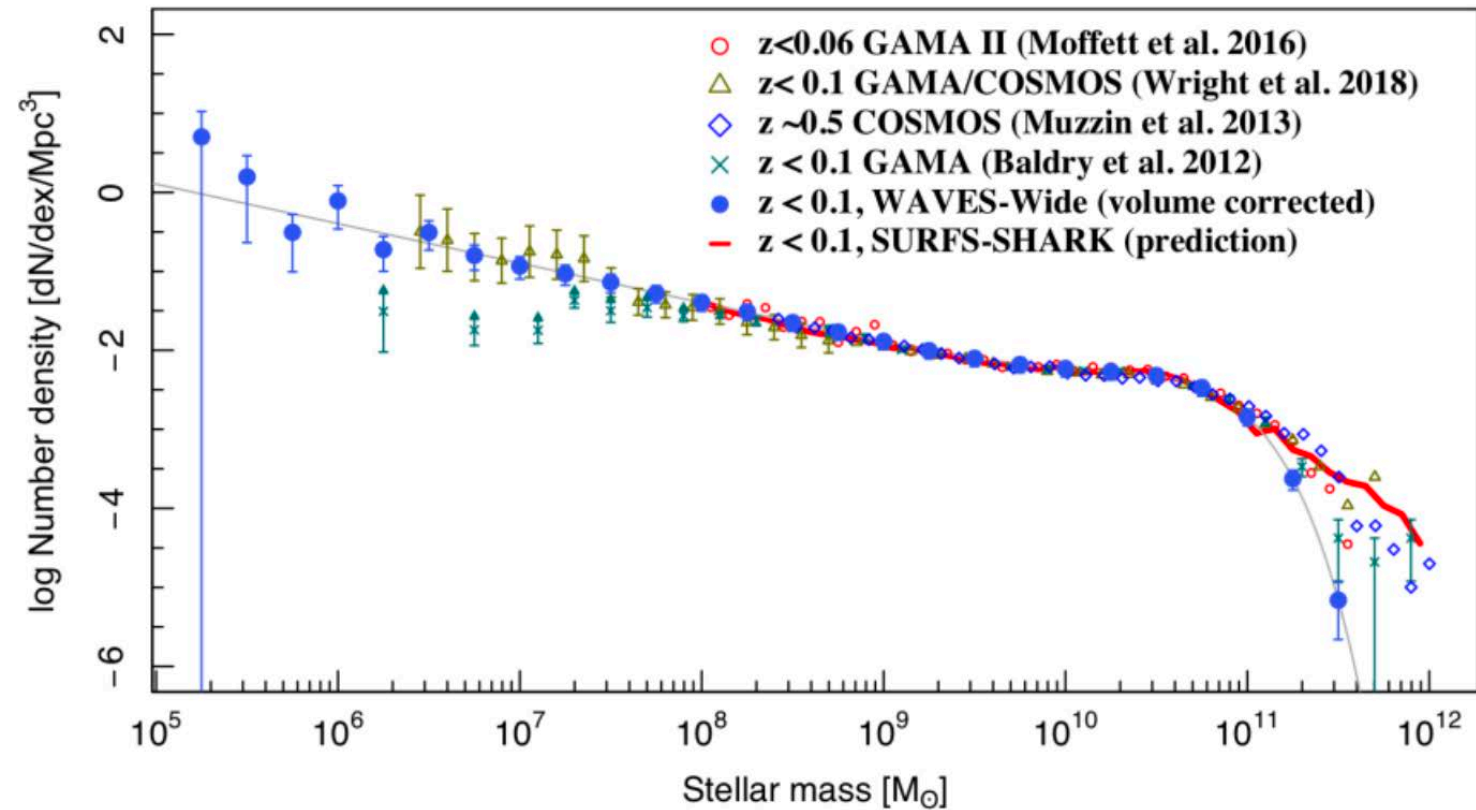
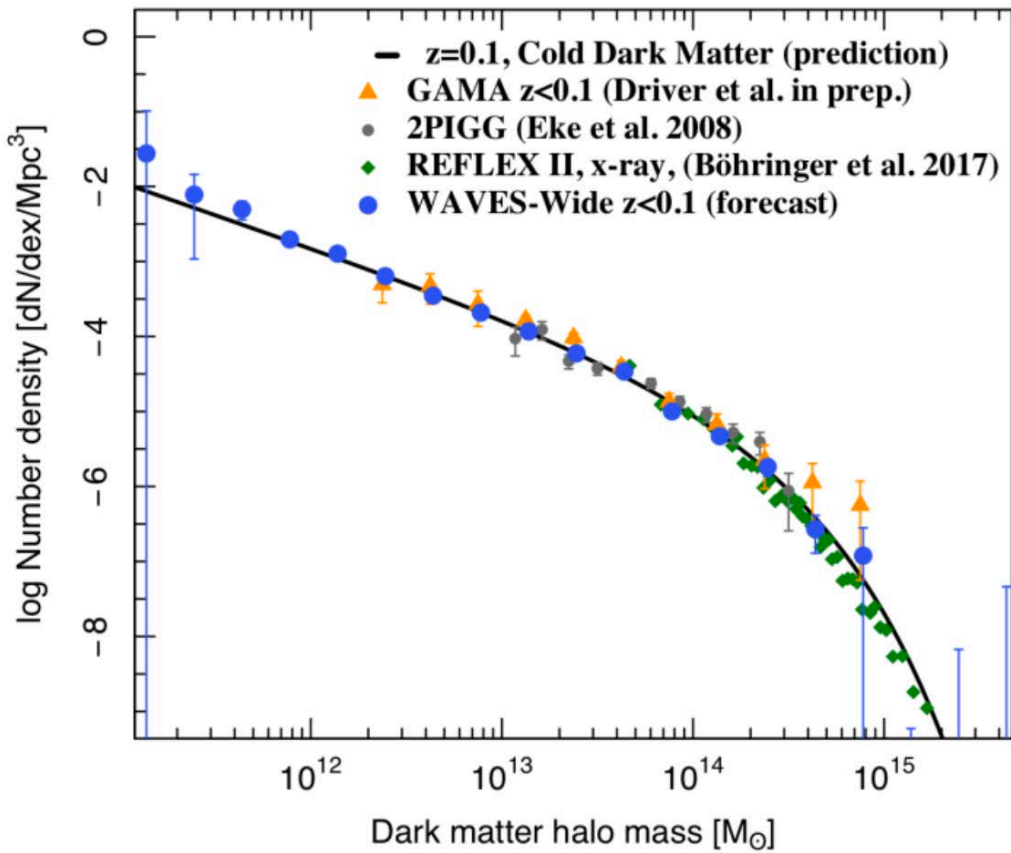
Cosmic web in the Local Universe





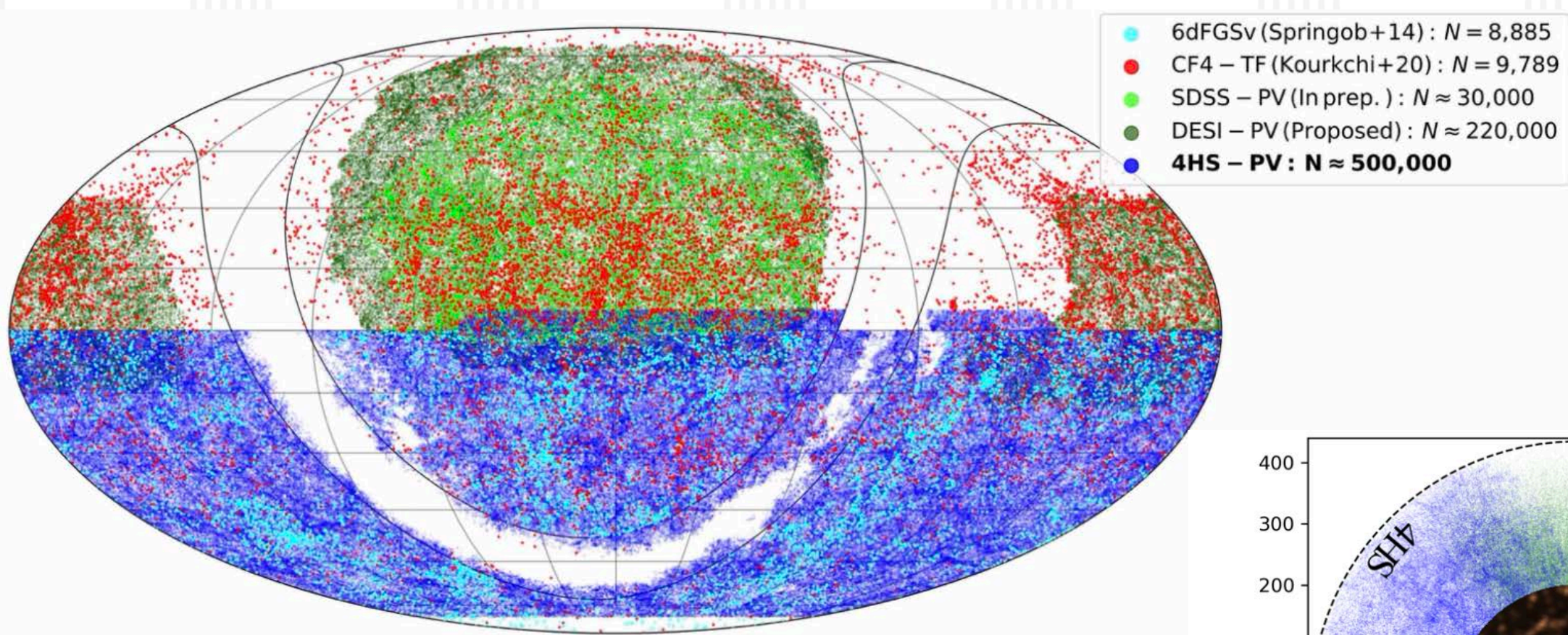
WAVES survey

Galaxy evolution in low redshift ($z < 0.2$)

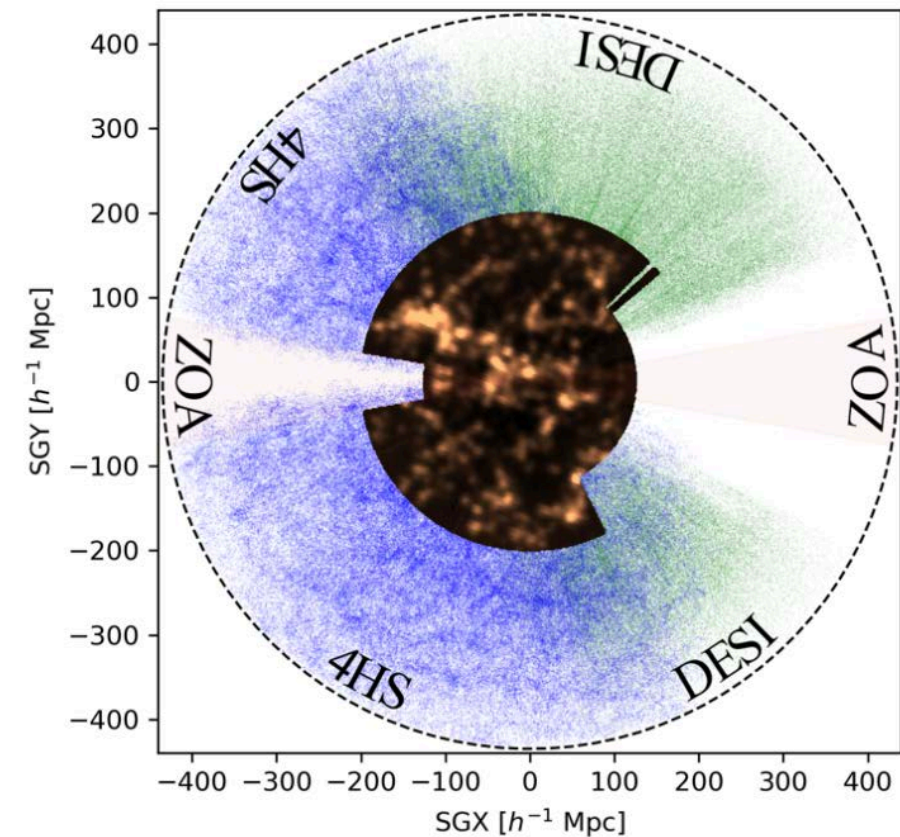


WAVES survey

Mass function down to small halo masses



4HS: 4MOST Hemisphere Survey
of nearby Universe ($z < 0.2$)



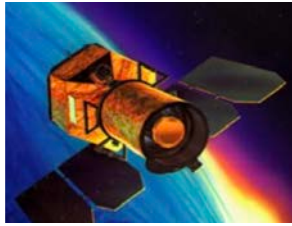
Credit: 4MOST

Data Fusion Centre

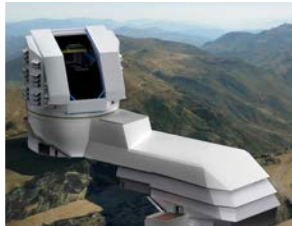
PLASMA, STARS, AGN & DUST



eROSITA



GALEX



LSST (2024)



EUCLID (2023)



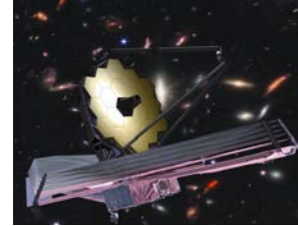
Roman (2026)



WISE

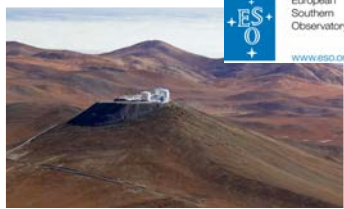


Herschel



JWST (2023)

DISTANCES, GROUPS & DARK MATTER



MOONS (2024)



4MOST (2024)

DESI (2023)

GROUND
& SPACE
IMAGING

OPTICAL
SPECTROSCOPY

Data
Fusion
Centre

RADIO
SURVEYS

COLLABORATION & SCIENCE

NEUTRAL GAS & CHARGED PARTICLES



ASKAP (2023)

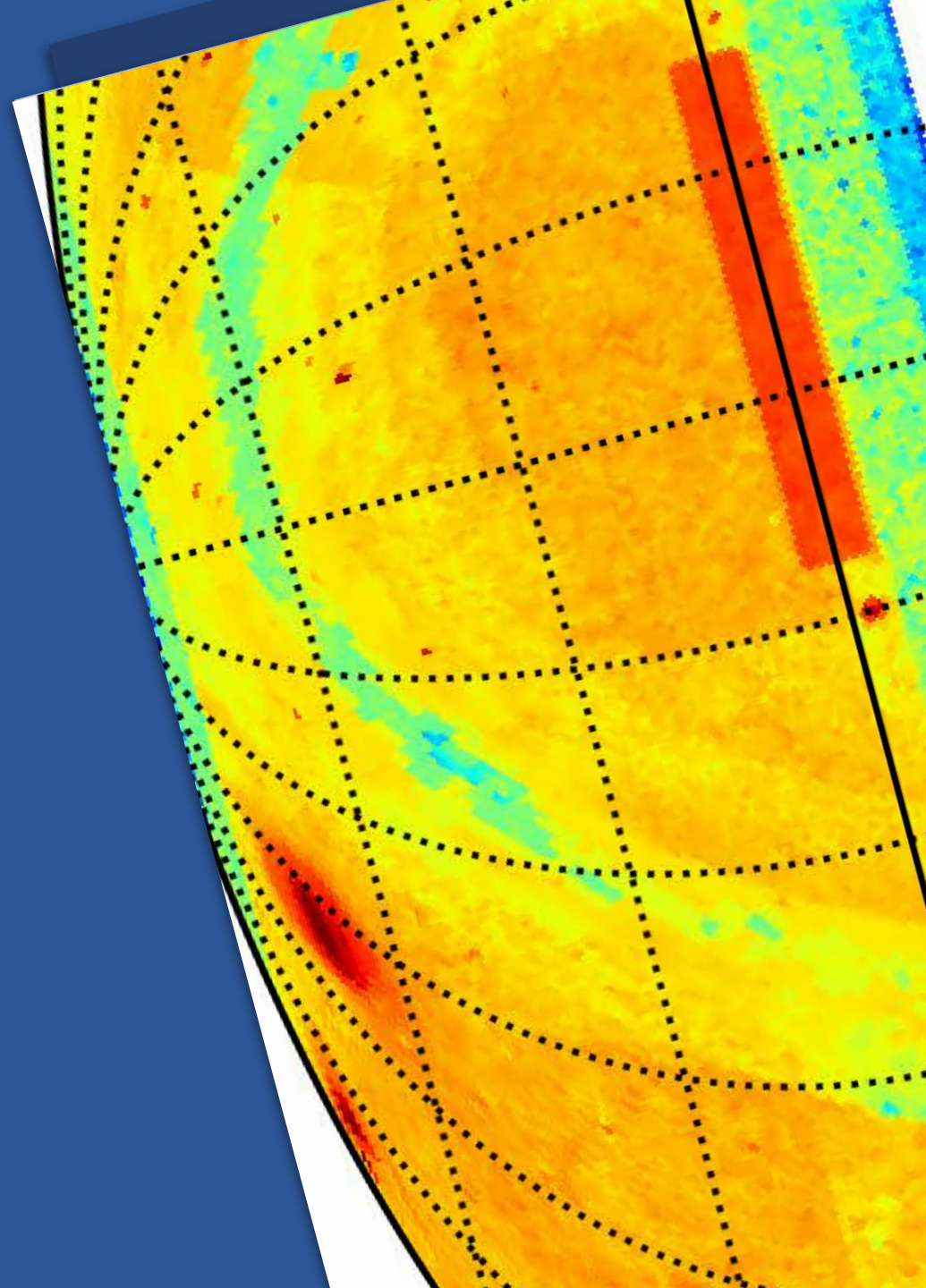


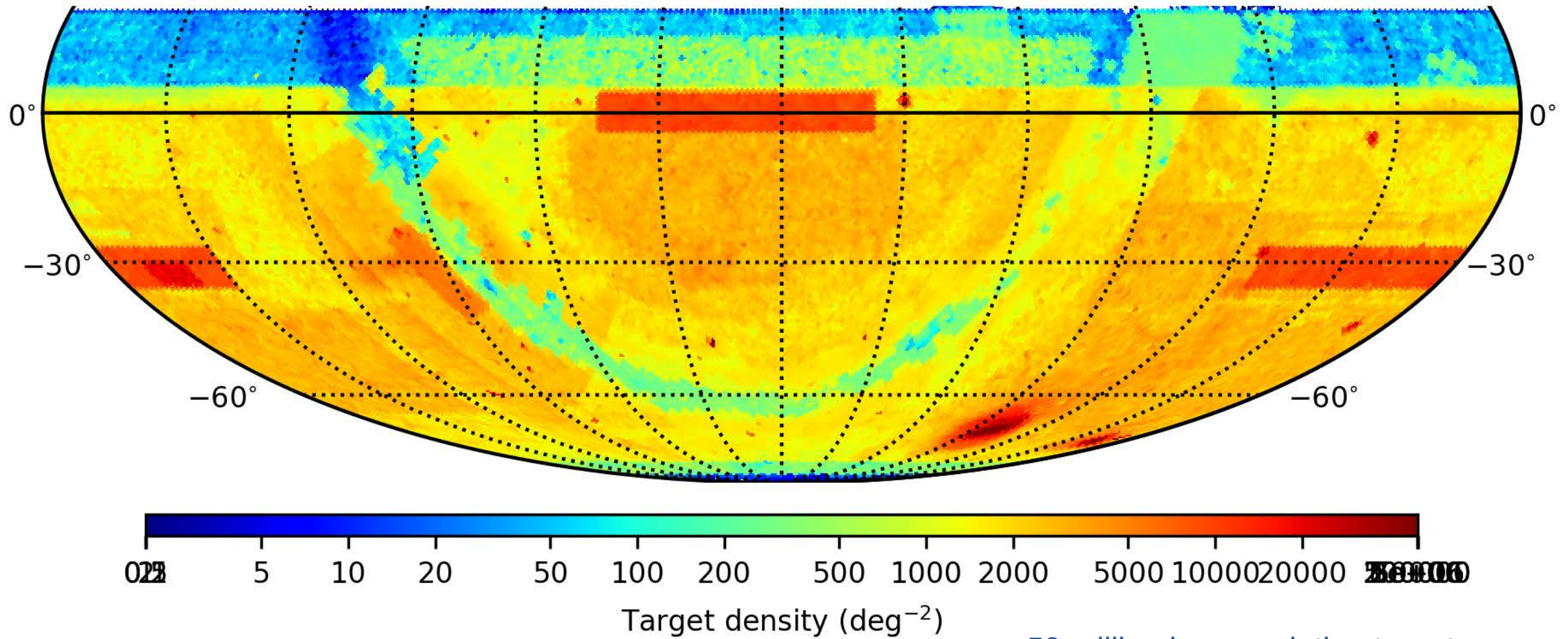
SKA (2029)



4MOST

Survey preparation





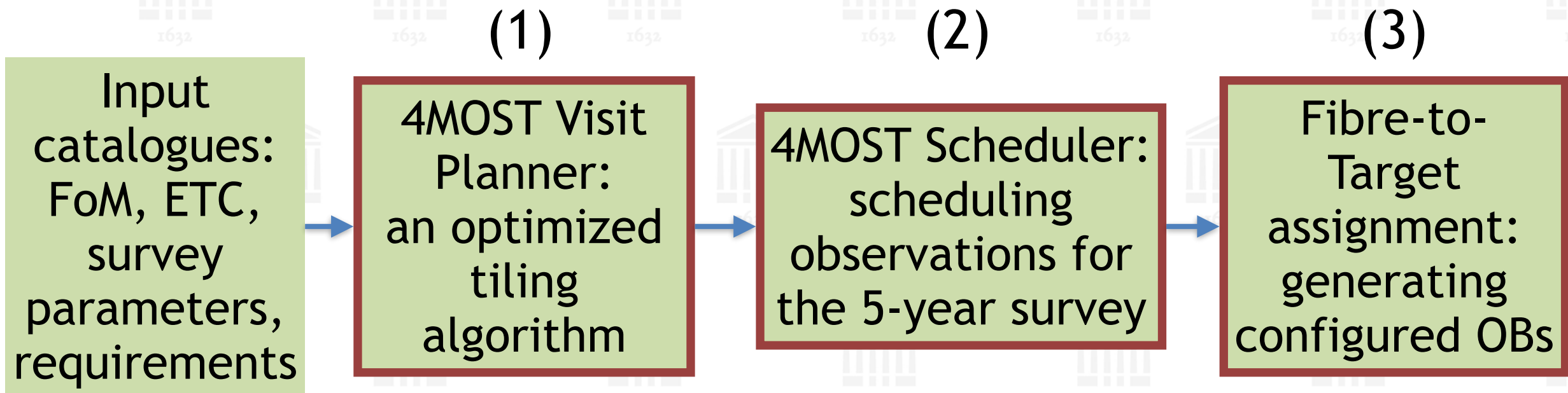
59 million low-resolution targets
13 million high-resolution targets

4MOST

Target density in the sky

How to observe those targets most efficiently?

Credit: 4MOST



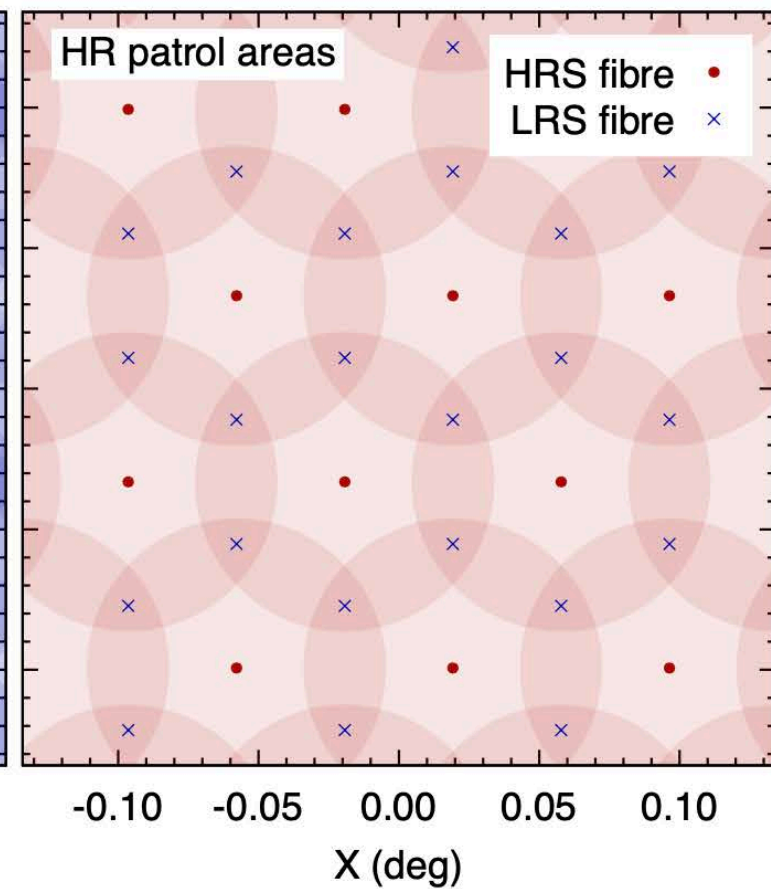
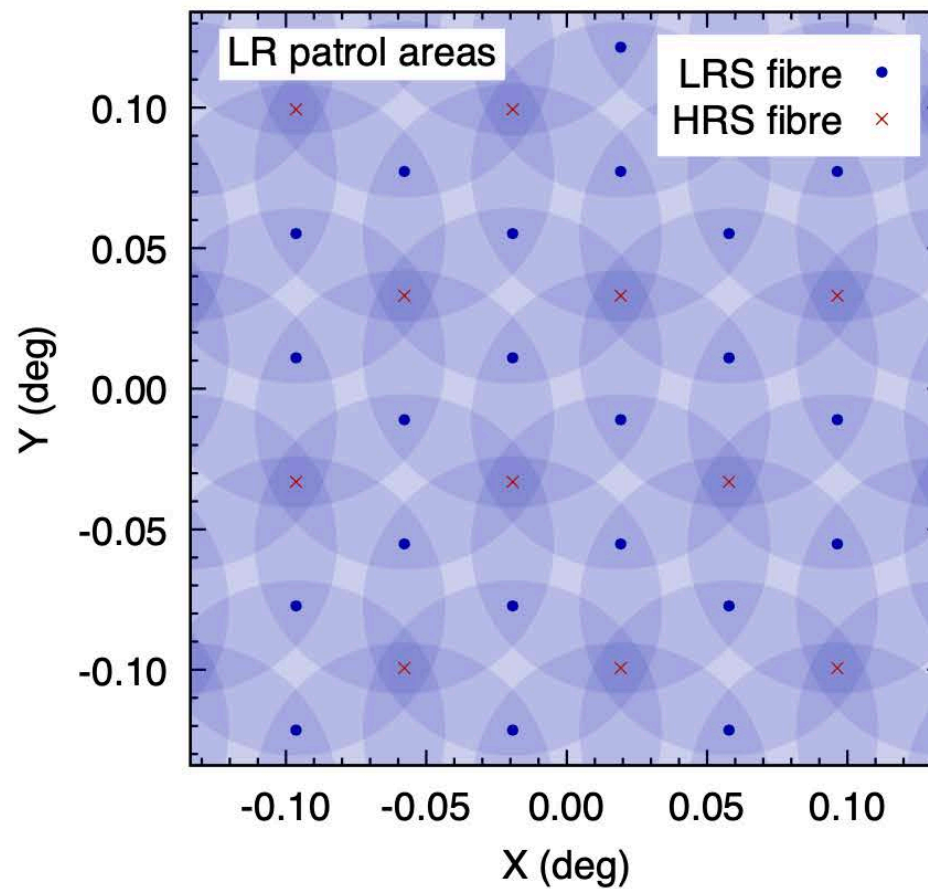
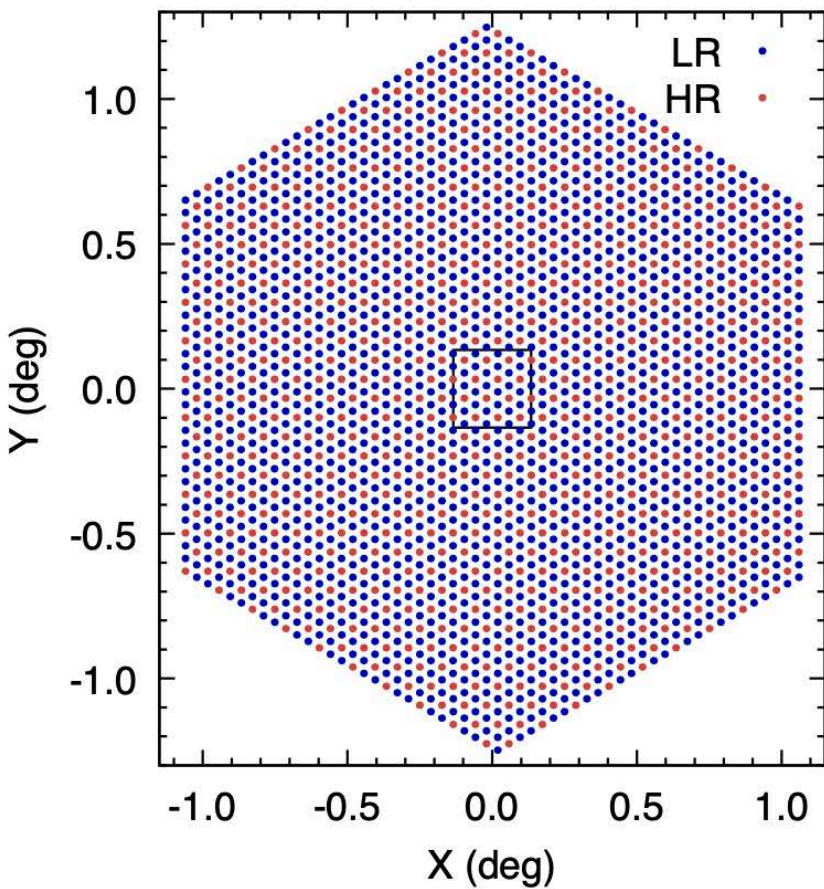
(1) ET et al. (2020) “An optimised tiling pattern for multi-object spectroscopic surveys: application to the 4MOST survey”

(2) paper in prep

(3) ET et al. (2020) “Probabilistic fibre-to-target assignment algorithm for multi-object spectroscopic surveys”

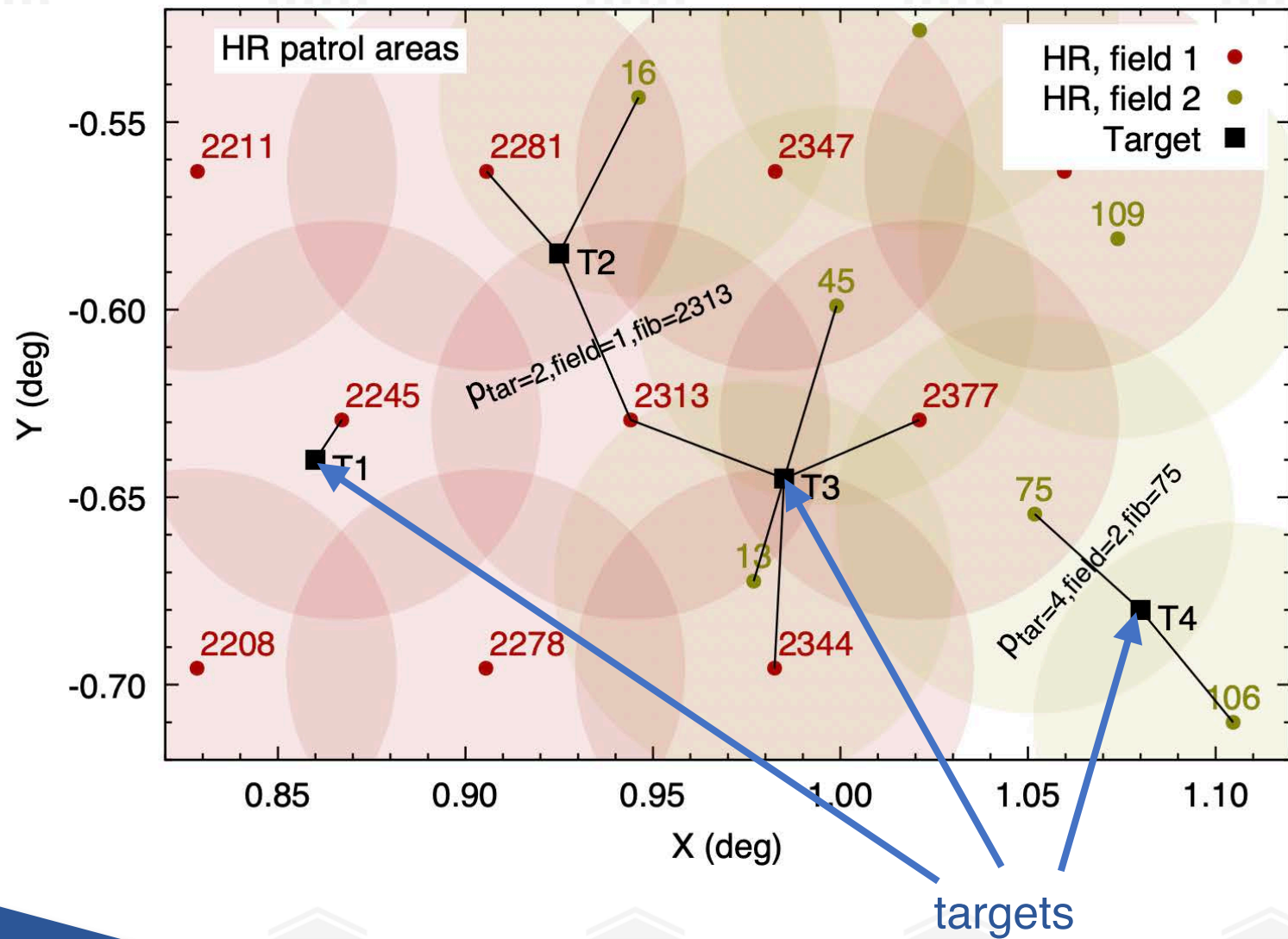
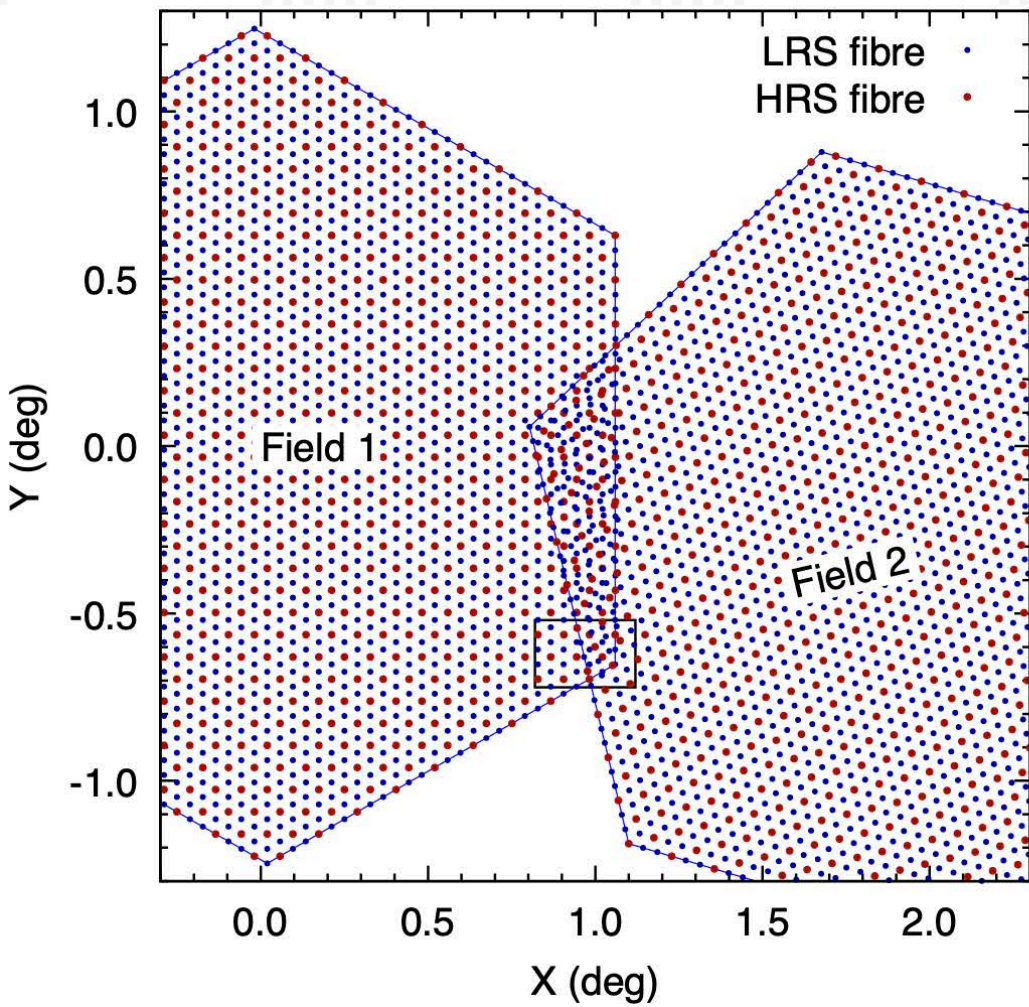
Preparing observations

General flowchart



4MOST fibre pattern

2/3 low-resolution and 1/3 high-resolution fibres

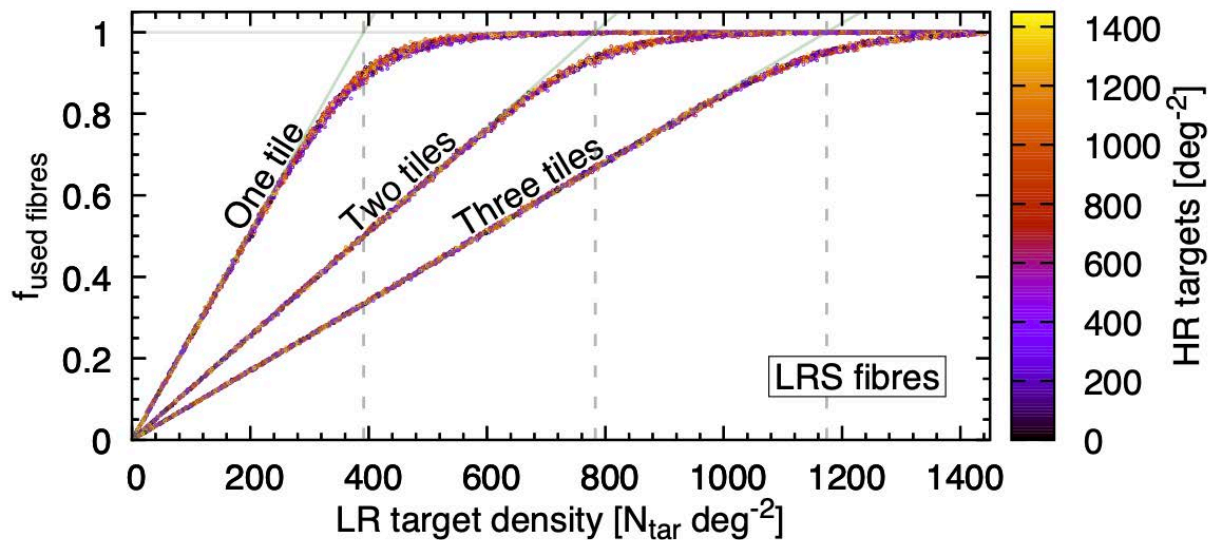


4MOST fibre pattern

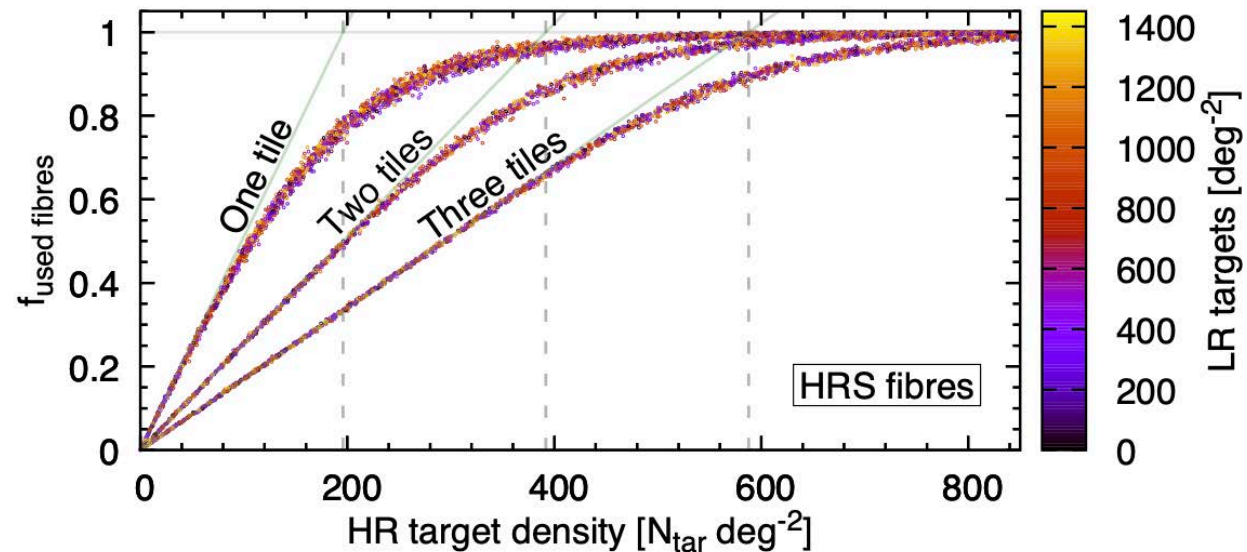
Probabilistic fibre assignment

We assign a probability for each fibre-target pair

Low-resolution fibres



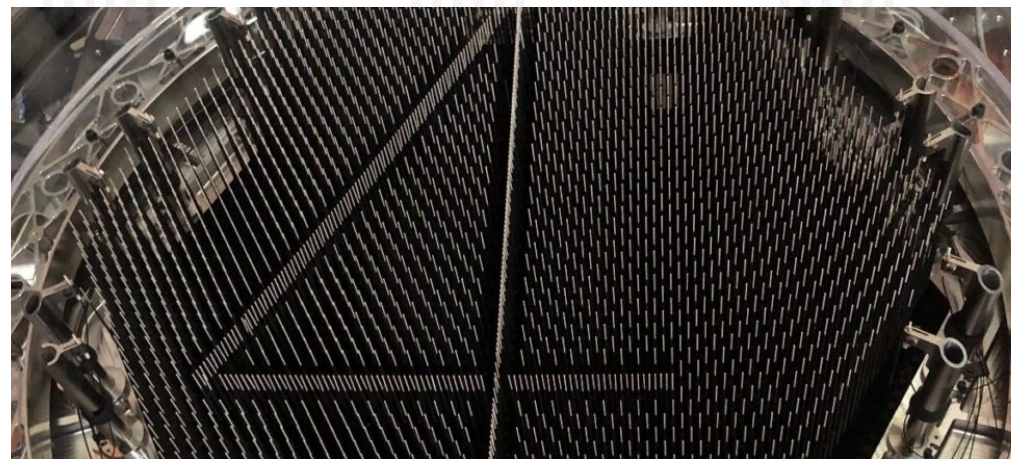
High-resolution fibres



For efficient survey, it is important to have more targets in the catalog than are required for the science goals

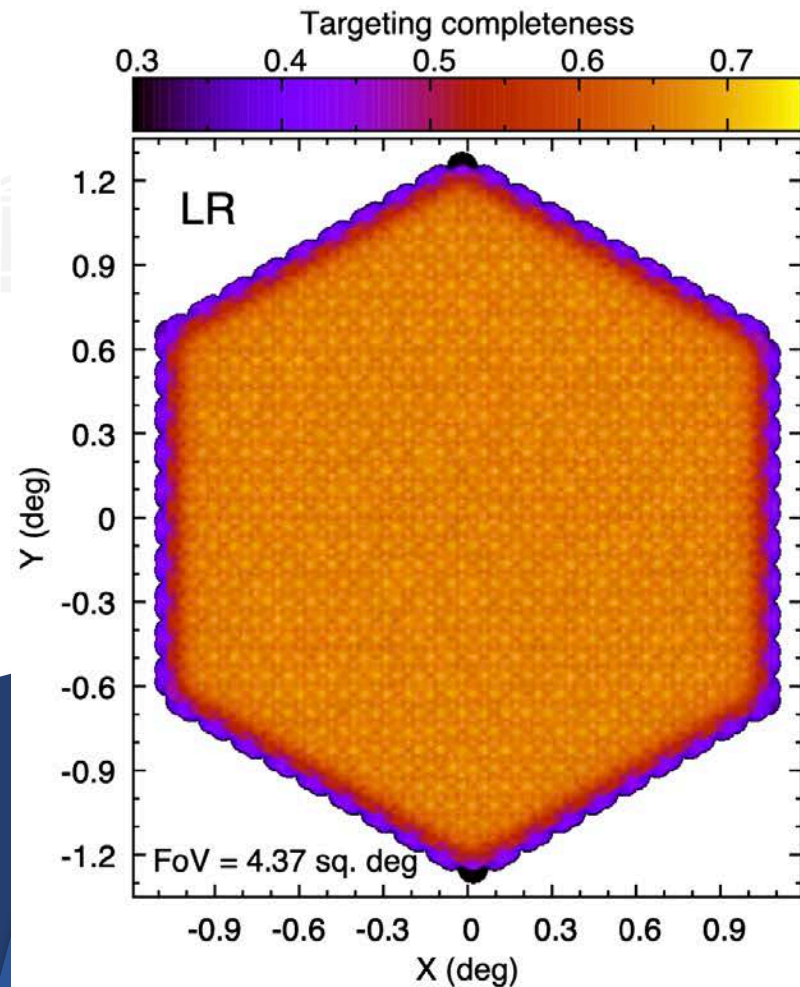
4MOST fibre pattern

fibre assignment efficiency

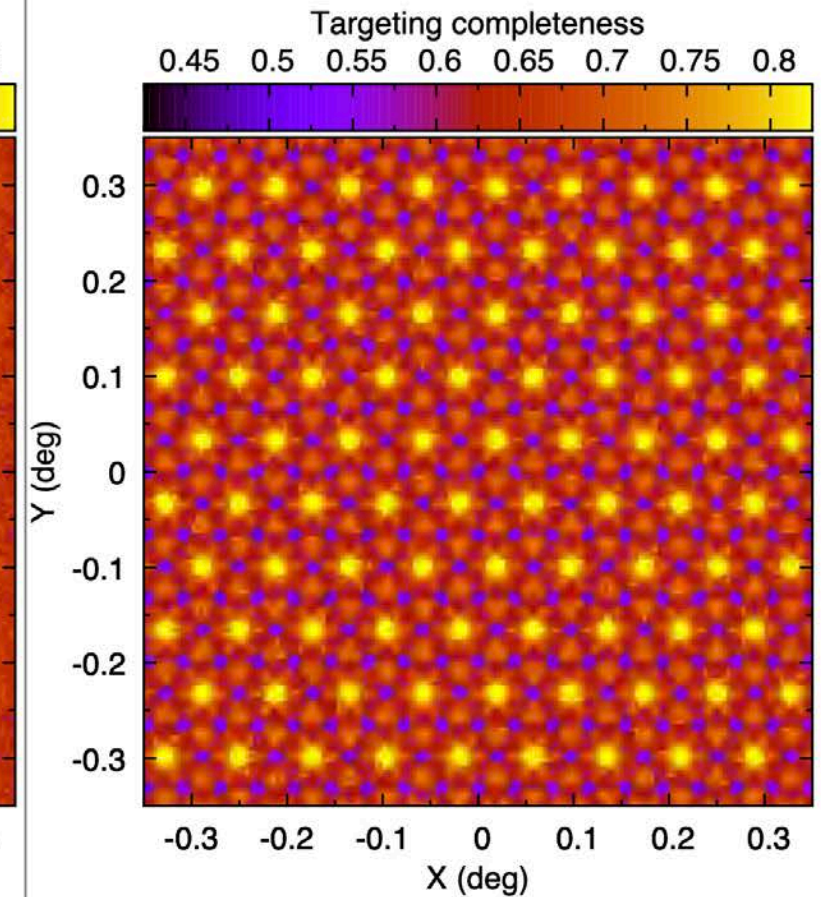
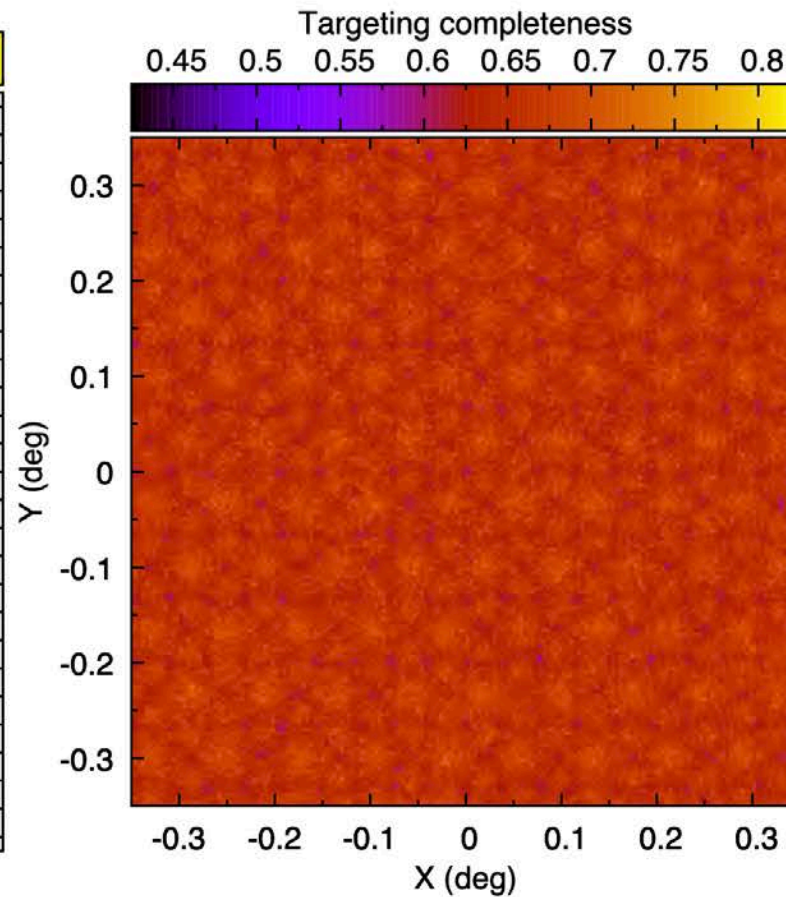


ET et al. 2020

Probabilistic fibre to target allocation

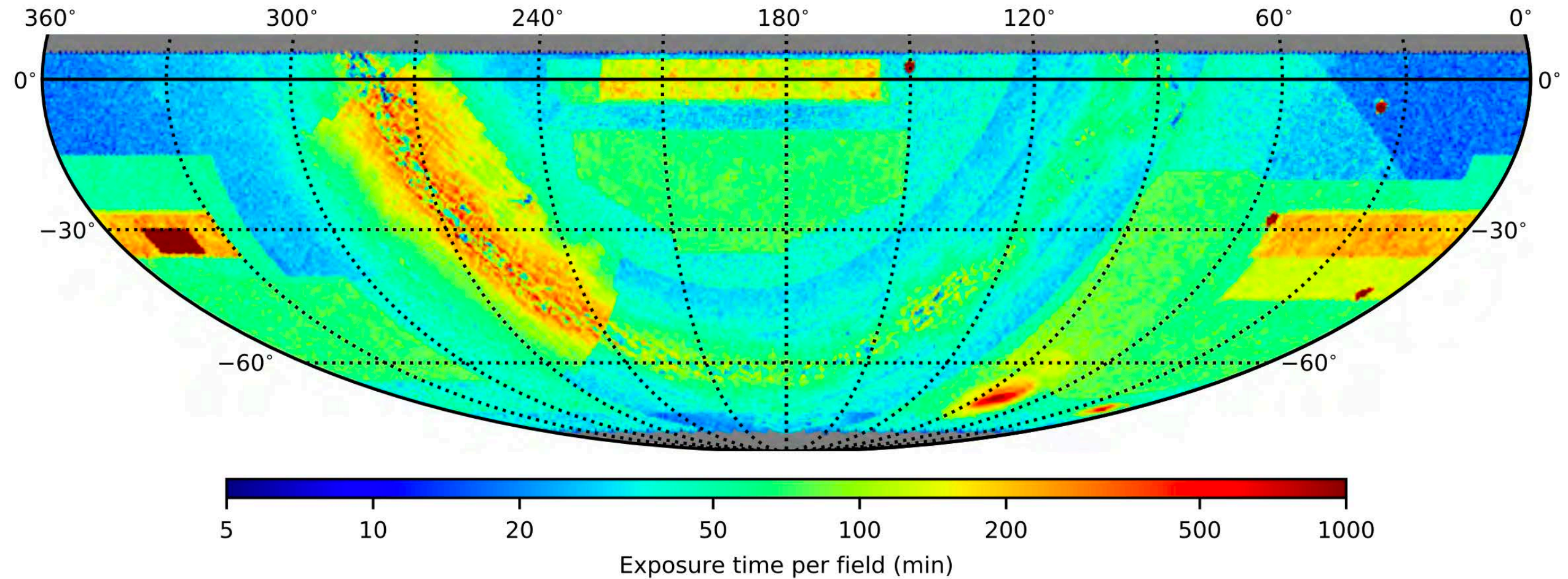


Random targeting



4MOST fibre pattern

Random vs probabilistic targeting

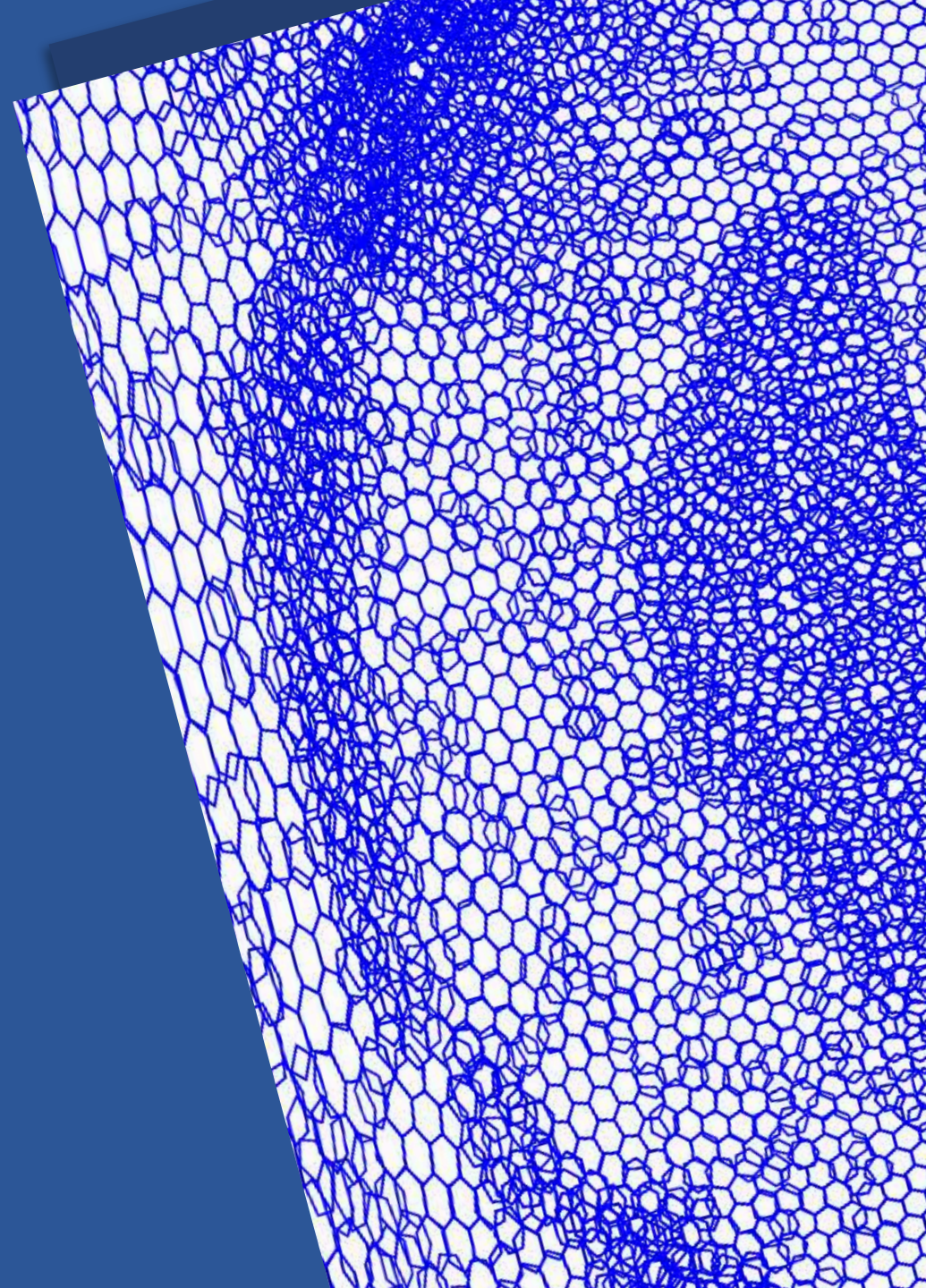


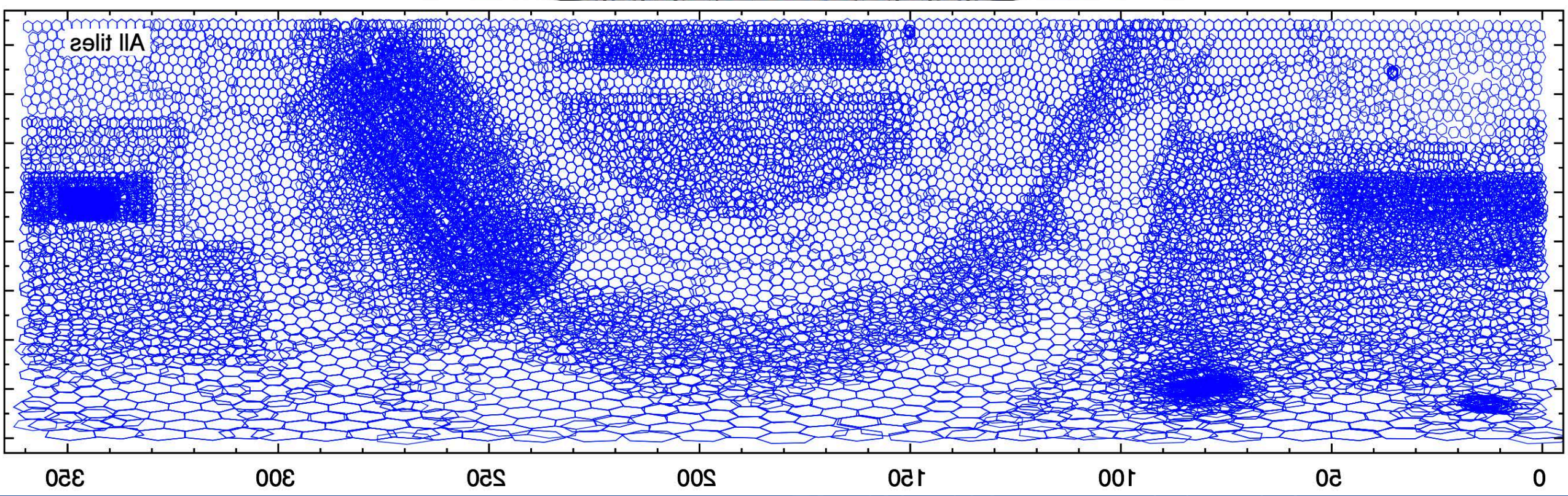
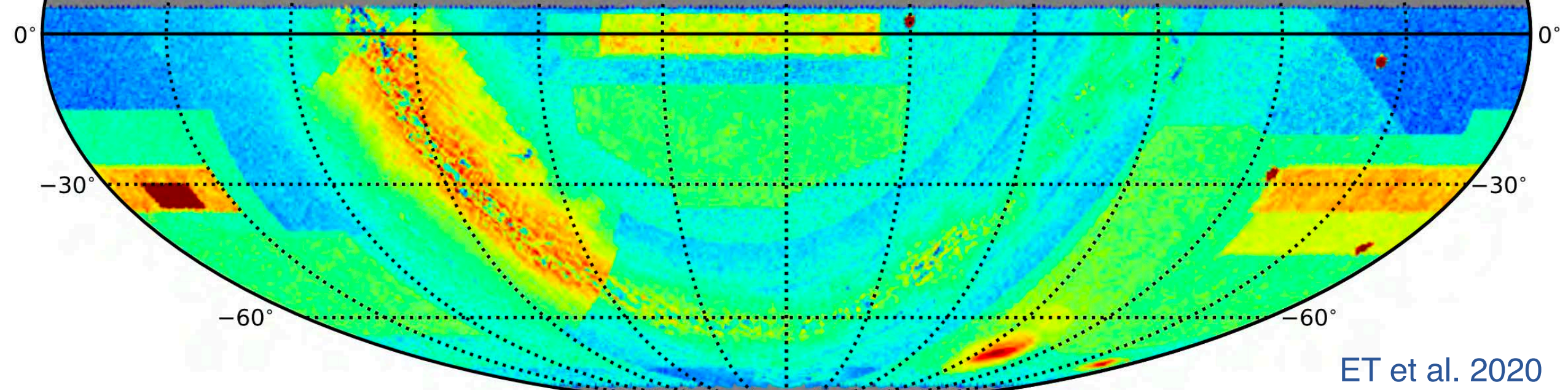
4MOST Visit Planner

Why do we need a Visit Planner?

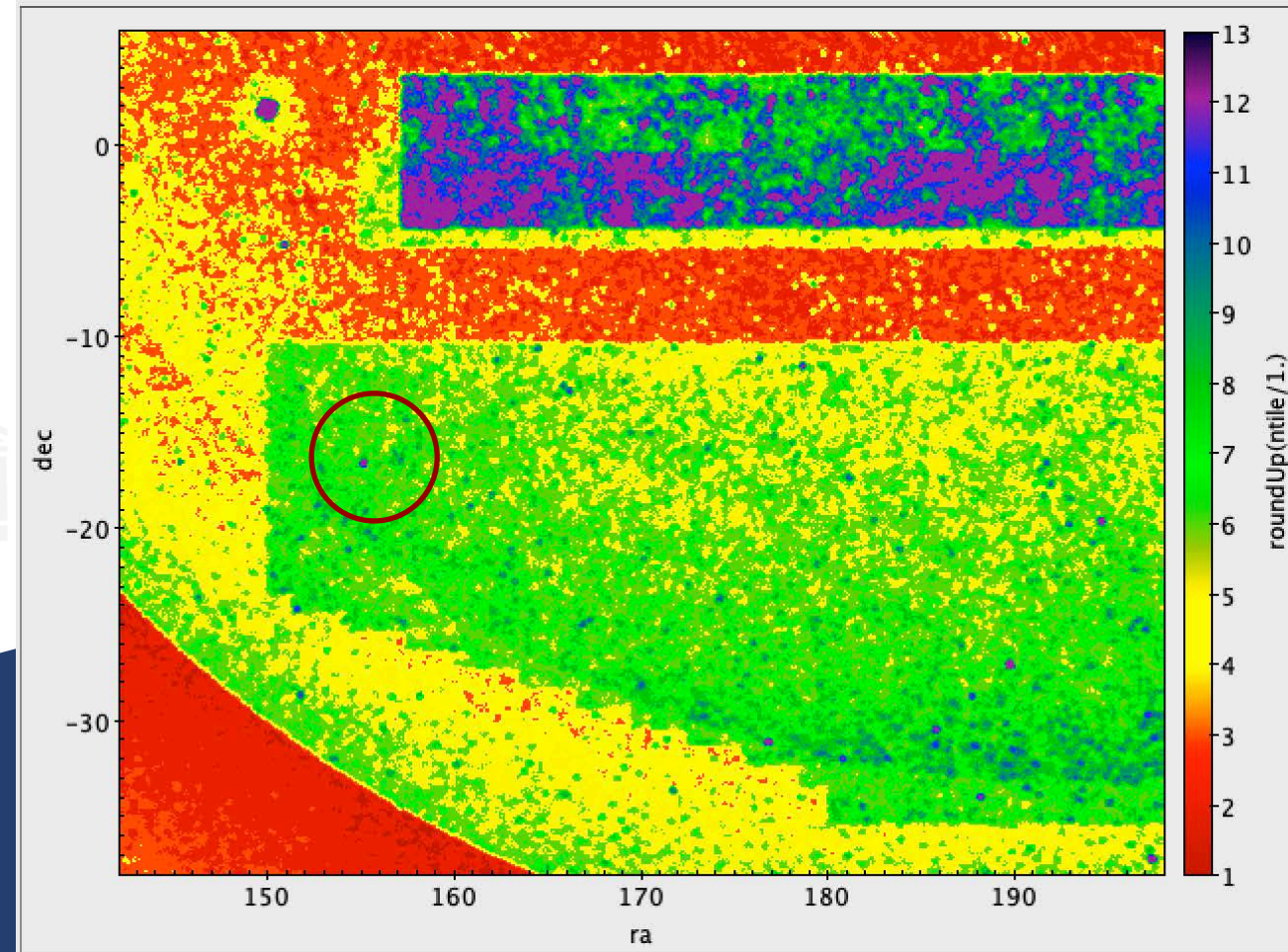
Tiling challenge

- Where to point the telescope? The list of tile centres and orientation angles that are needed to effectively observe the given list of targets.
- What is the exposure time of each tile? Attach an exposure time for each tile so that the targets are observed efficiently.
- Divide the tiles between D/G/B sky conditions.
- Include survey requirements, e.g. contiguous area (no gaps between tiles).

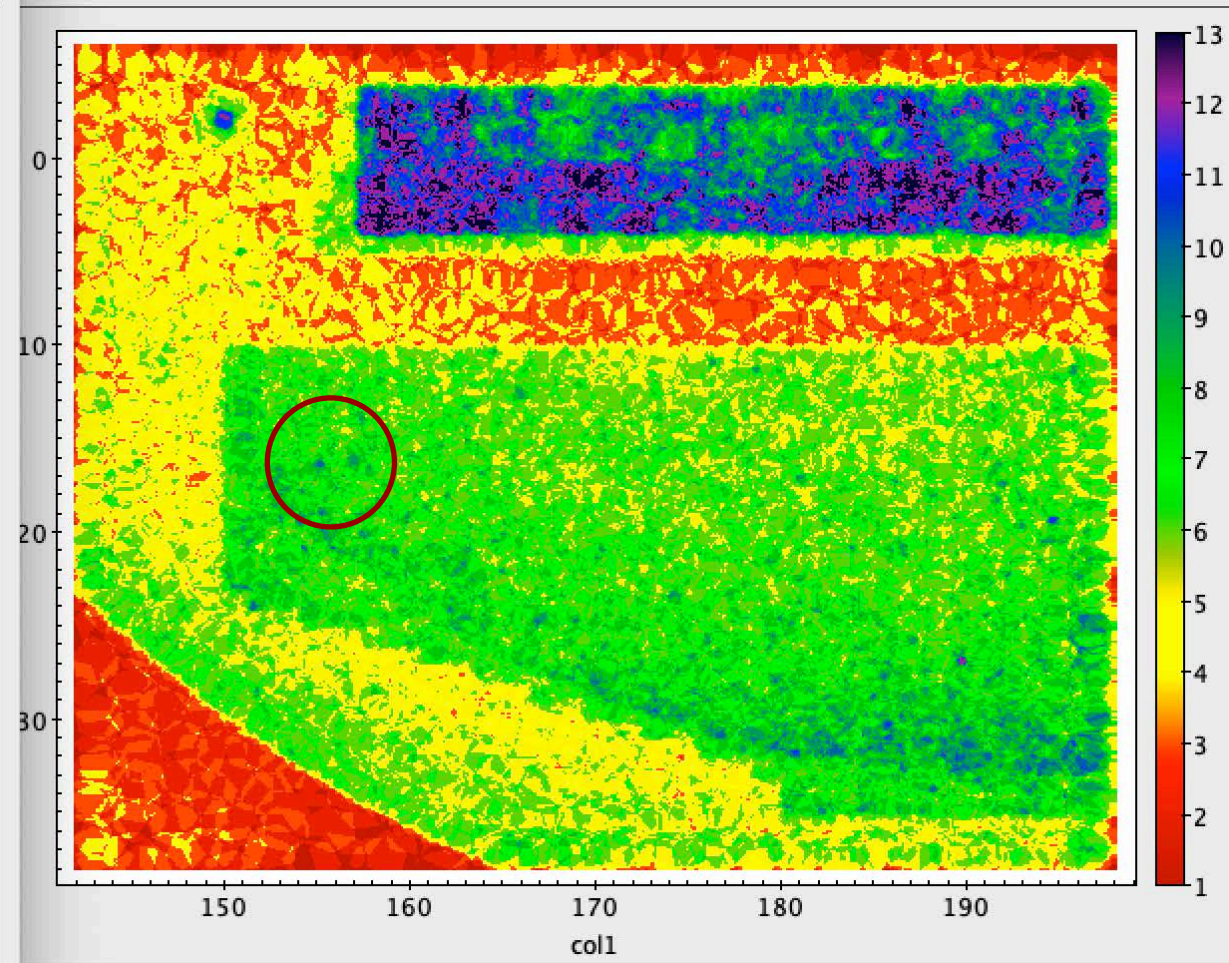




Required exposure time

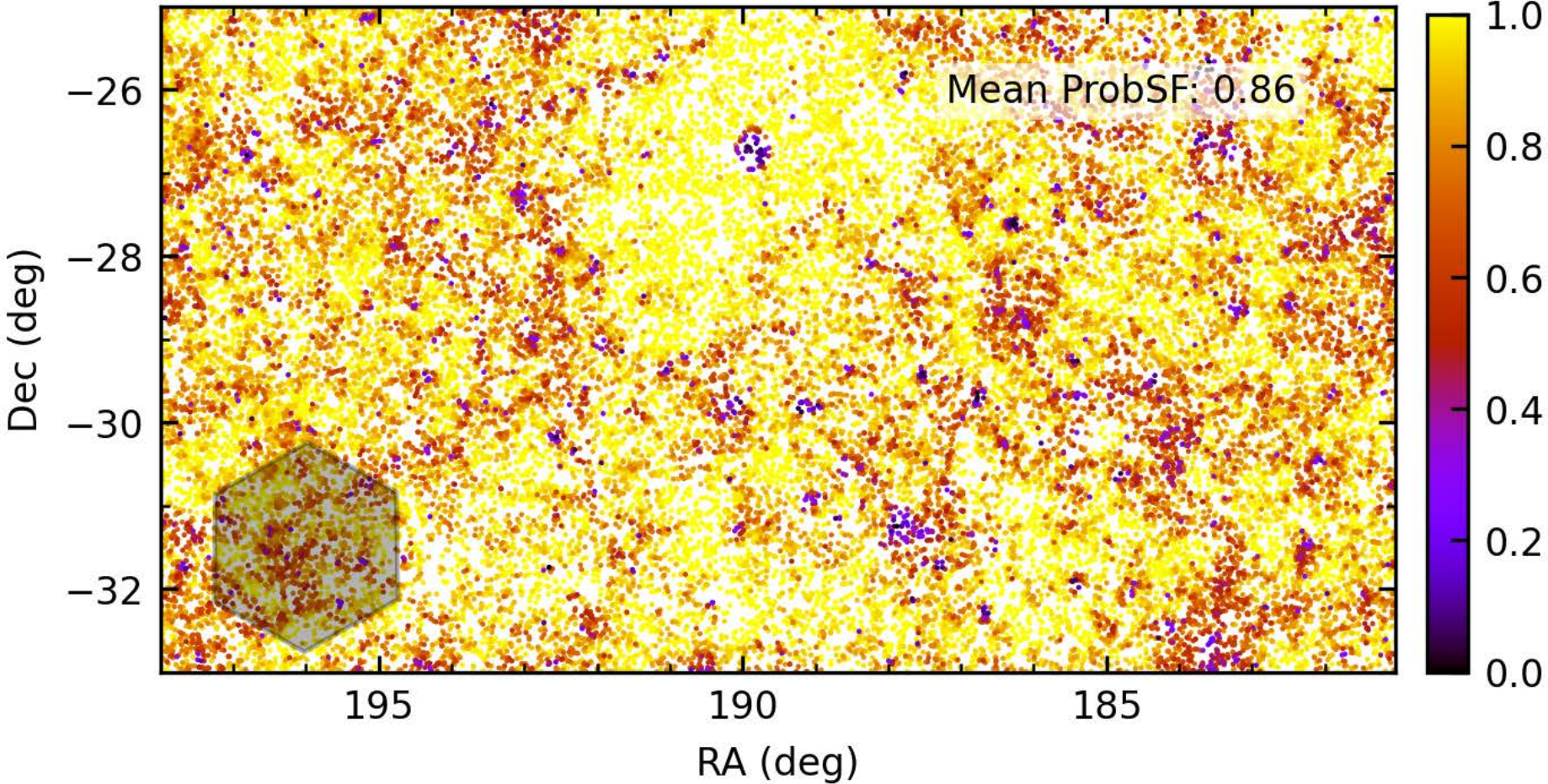


Exposure time from tiling



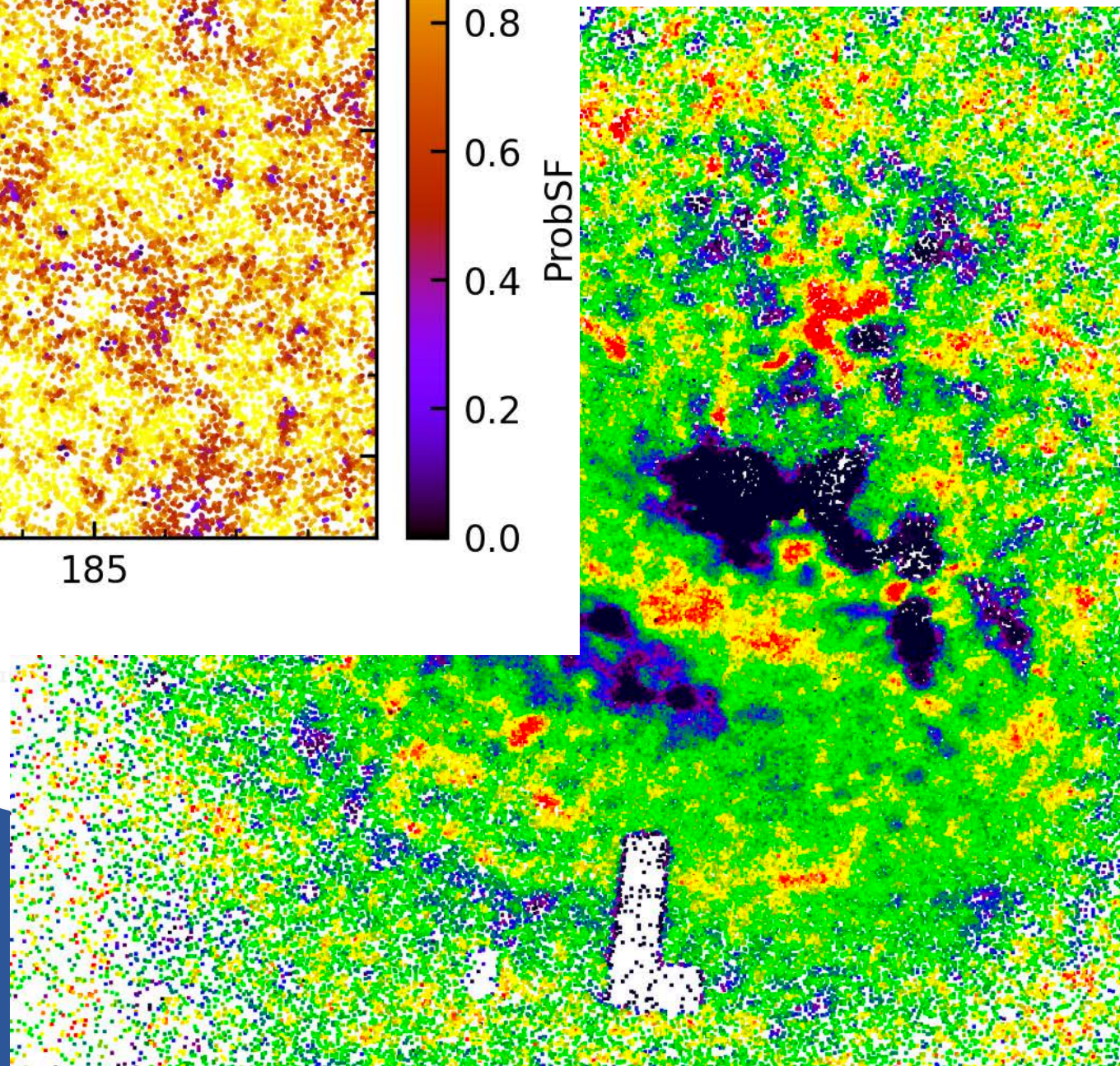
4MOST Visit Planner

A small sky area



Probabilistic selection function

Probability that target is successfully observed



Thank you!



ut.ee



info@ut.ee



tartuylikool
tartuuniversity



unitartu
unitartuscience
unitartutiksu

