Euclid DR1 & SKAO Pathfinders/Precursors

How to synergise between them, now that they all exist

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INAF ISTITUTO NAZIONALE DI ASTROFISICA OSSERVATORIO ASTROFISICO DI TORINO

RESPICE PROSPICE UNIVERSITY of the WESTERN CAPE

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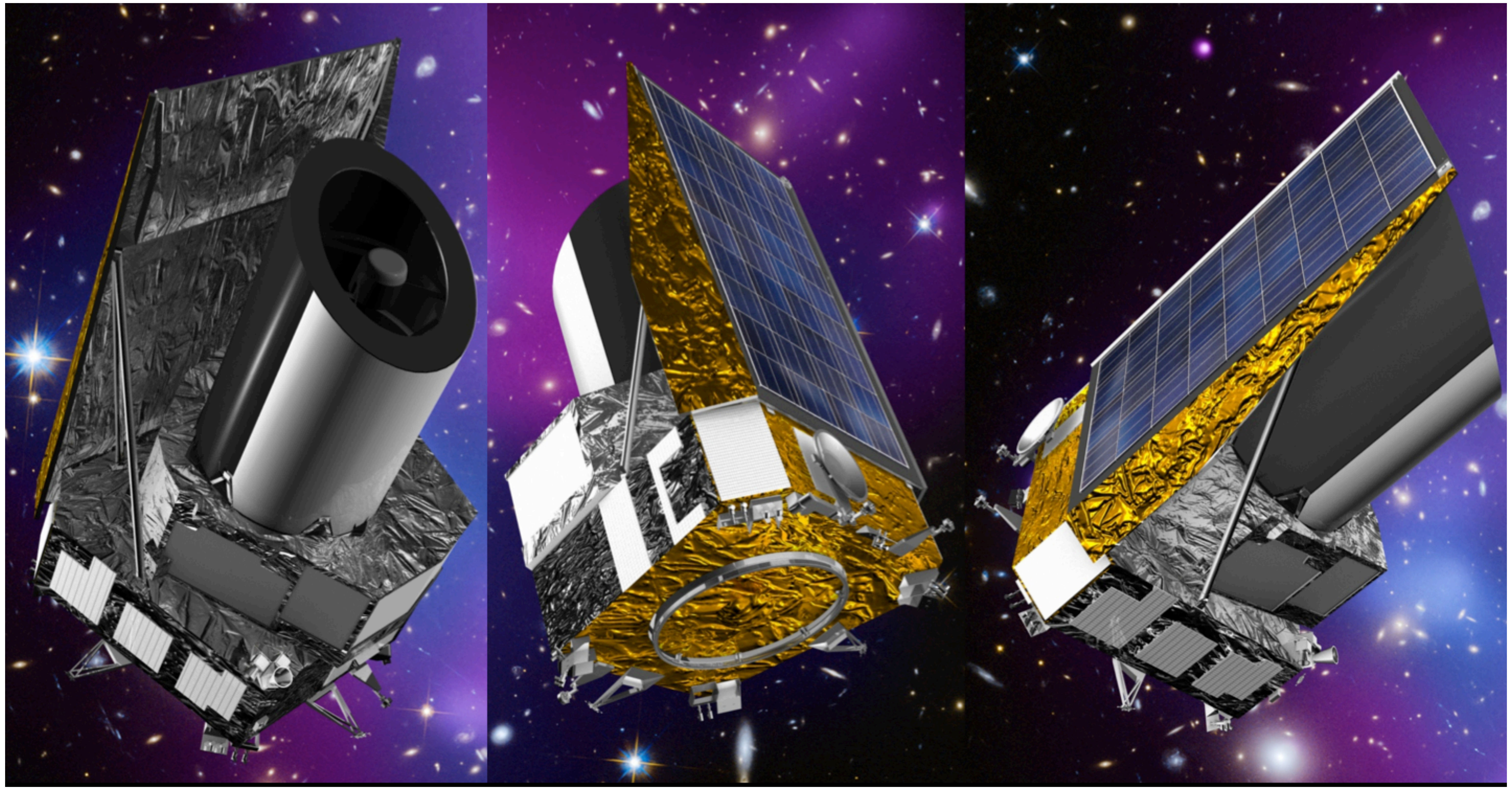
Ministero dell'Università e della Ricerca

Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA

The Euclid Satellite



European Space Agency

Euclid

Turin, November 2019

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Euclid’s specs

[Euclid ‘Red Book’, 2011]

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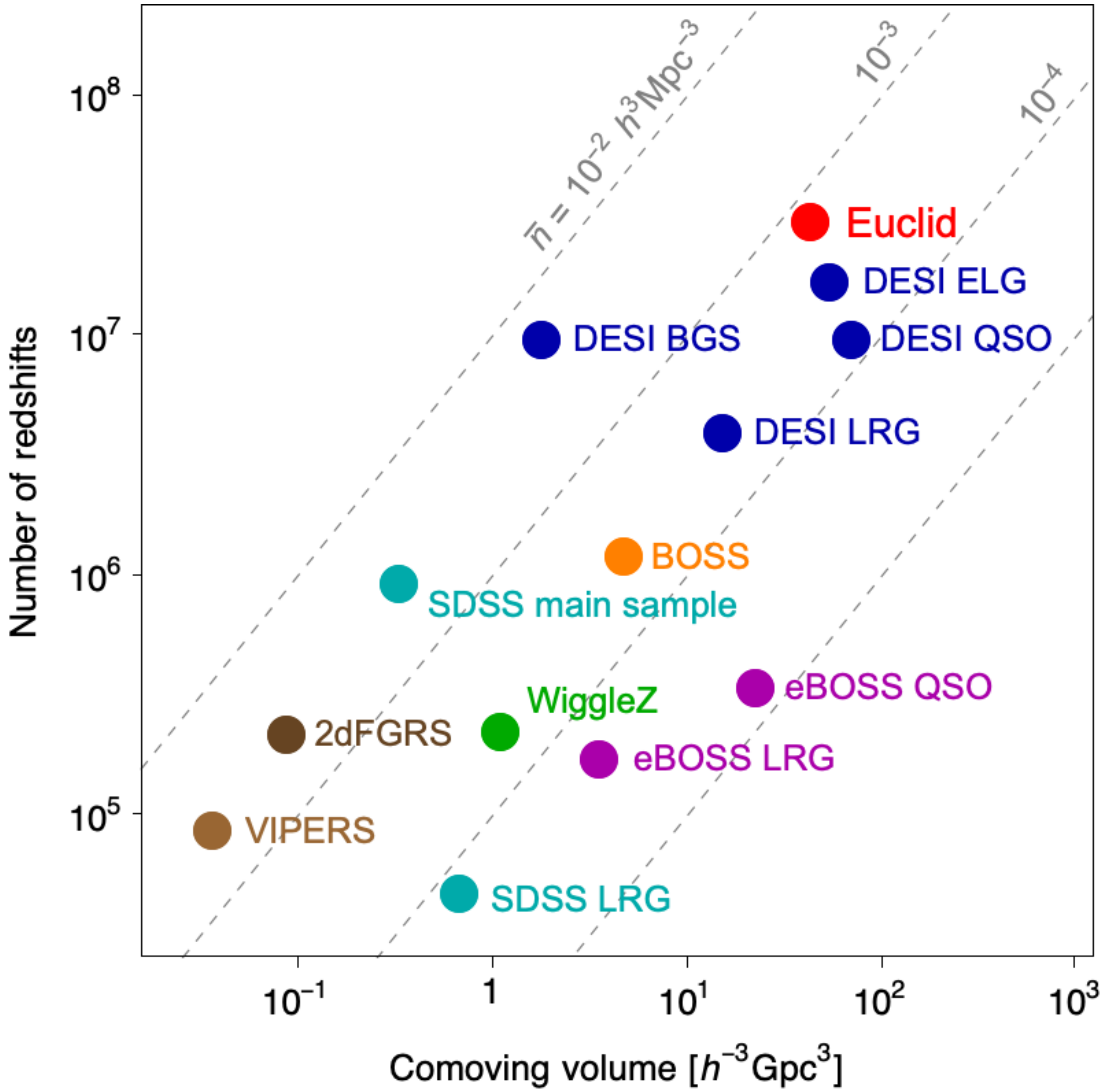
SURVEYS		
	Area (deg2)	Description
Wide Survey	15,000 (required) 20,000 (goal)	Step and stare with 4 dither pointings per step.
Deep Survey	40	In at least 2 patches of > 10 deg^2 2 magnitudes deeper than wide survey

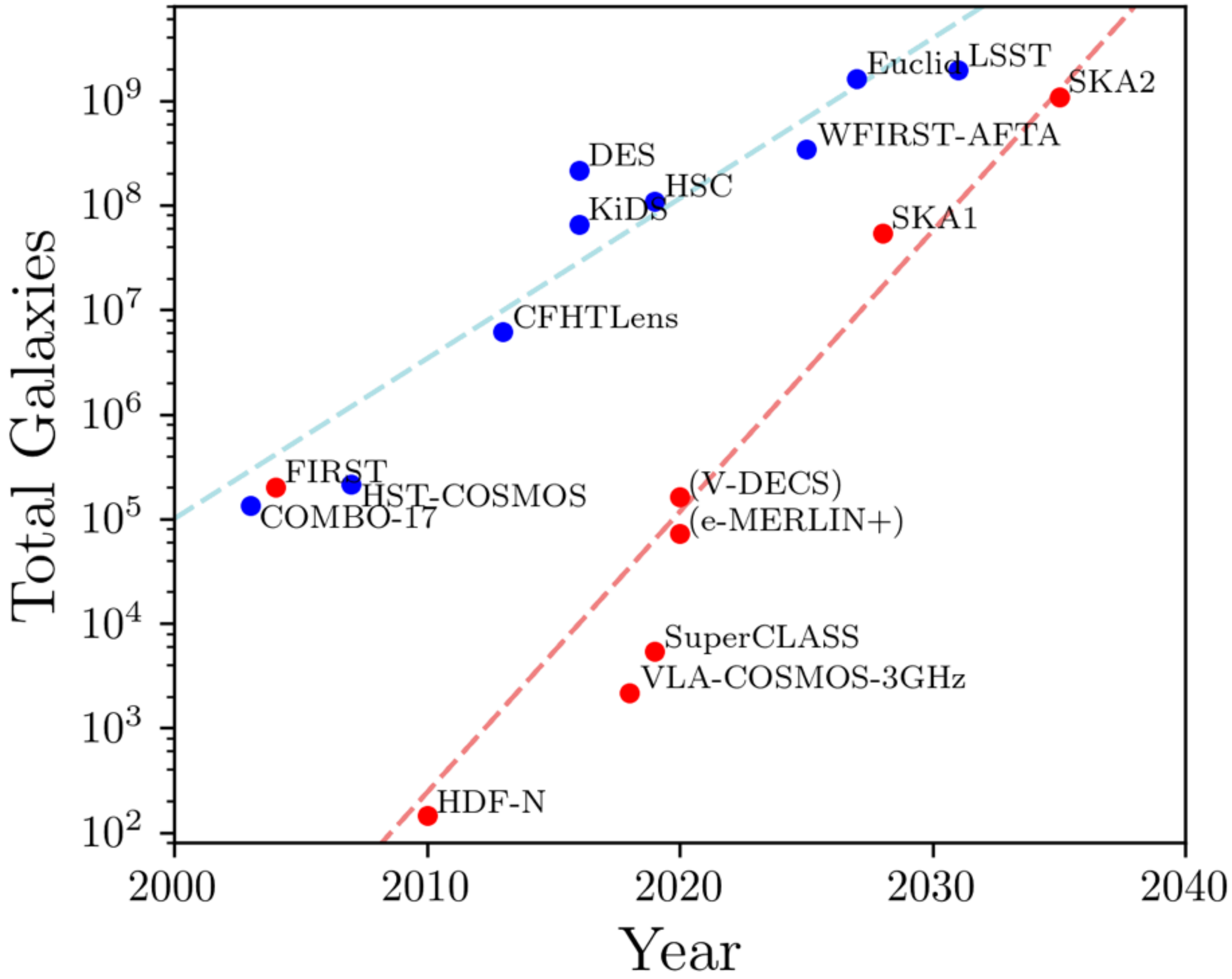
PAYLOAD					
Telescope	1.2 m Korsch, 3 mirror anastigmat, f=24.5 m				
Instrument	VIS	NISP			
Field-of-View	0.787×0.709 deg^2	0.763×0.722 deg^2			
Capability	Visual Imaging	NIR Imaging Photometry			NIR Spectroscopy
Wavelength range	550– 900 nm	Y (920-1146nm),	J (1146-1372 nm)	H (1372-2000nm)	1100-2000 nm
Sensitivity	24.5 mag 10σ extended source	24 mag 5σ point source	24 mag 5σ point source	24 mag 5σ point source	3 10^{-16} erg cm-2 s-1 3.5σ unresolved line flux
Detector Technology	36 arrays 4k×4k CCD	16 arrays 2k×2k NIR sensitive HgCdTe detectors			
Pixel Size Spectral resolution	0.1 arcsec	0.3 arcsec			0.3 arcsec R=250

Euclid’s specs

[Euclid Collaboration: Hoekstra et al. (In prep.)]



[Credits: I. Harrison]



Euclid's science

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- Euclid's main scientific objectives:
  - Reach a precision on dark energy parameters $(w_0, w_a) < (2\,\%, 10\%)$
  - Measure the growth factor exponent γ better than $2\,\%$
  - Measure the sum of neutrino mass better than $0.03\,\mathrm{eV}$
  - Constrain primordial non-Gaussianity amplitude $f_{\rm NL}$ with precision ~ 2

Euclid’s science

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- Euclid’s main probes:
  - Spectroscopic galaxy clustering survey
  - Photometric weak lensing survey
- Euclid’s ancillary probes:
  - Clustering of the photometric galaxy sample (in fact, “3×2 pt” as main probe)
  - Galaxy clusters (number counts and clustering)
  - Cross-correlation with cosmic microwave background
  - Hubble rate measurements with strong lensing

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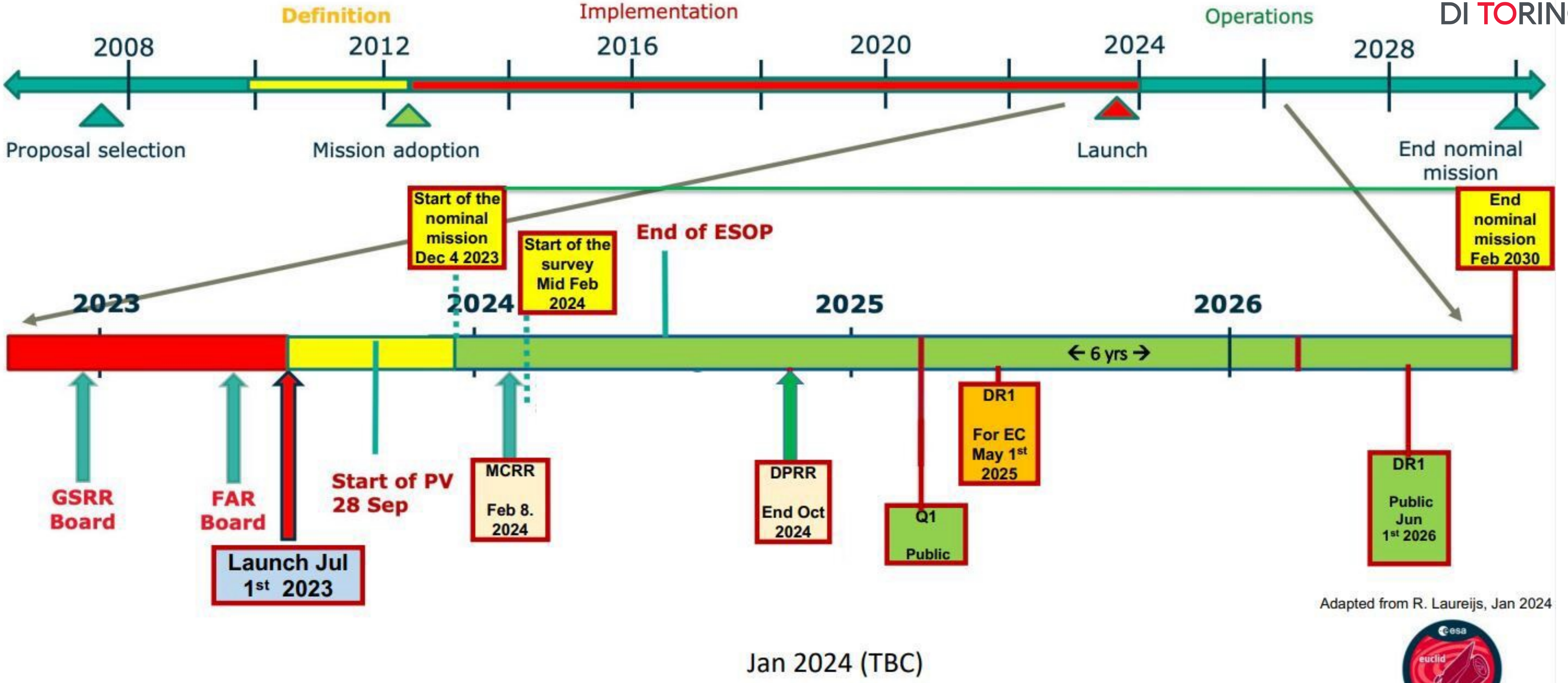
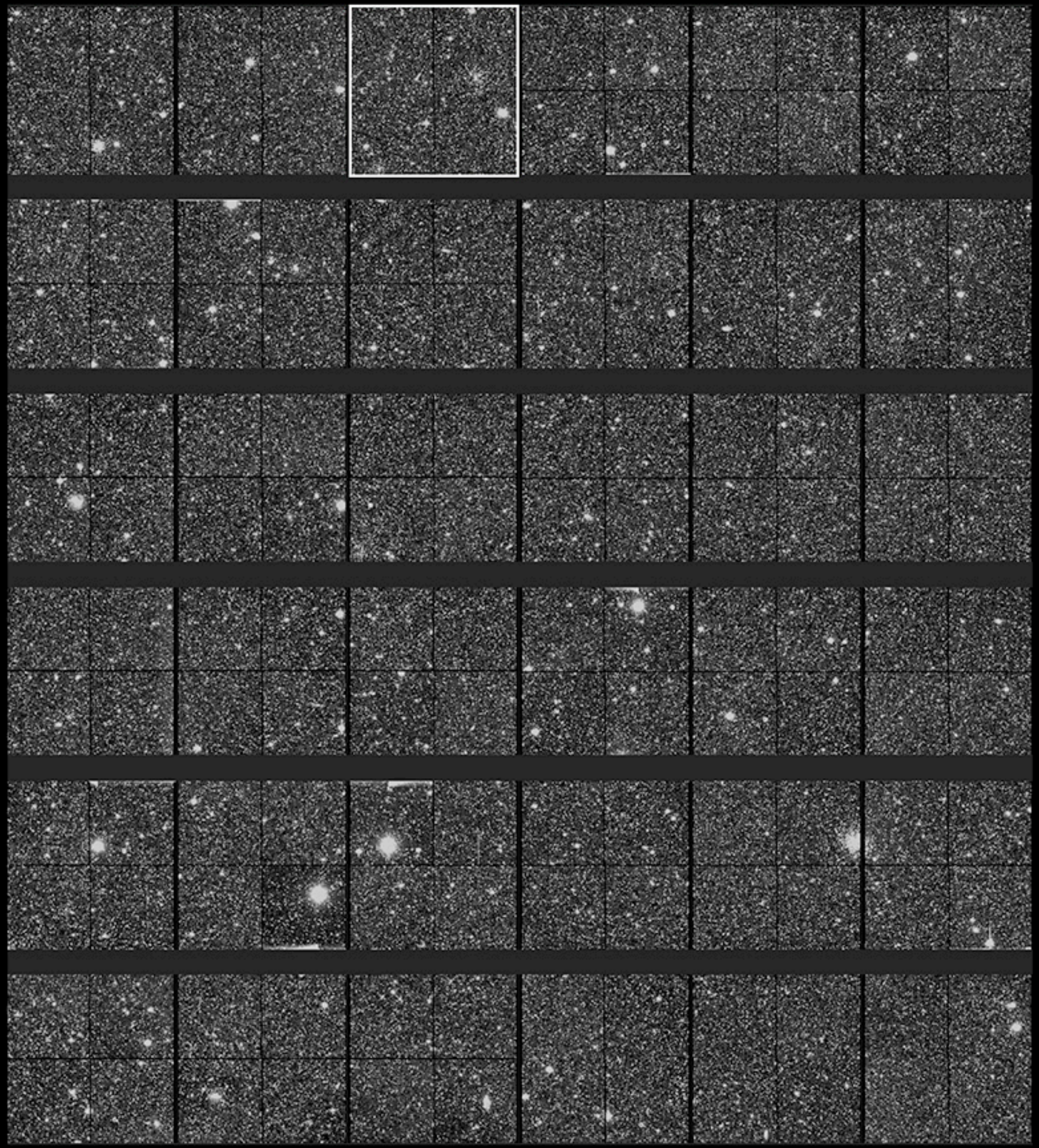
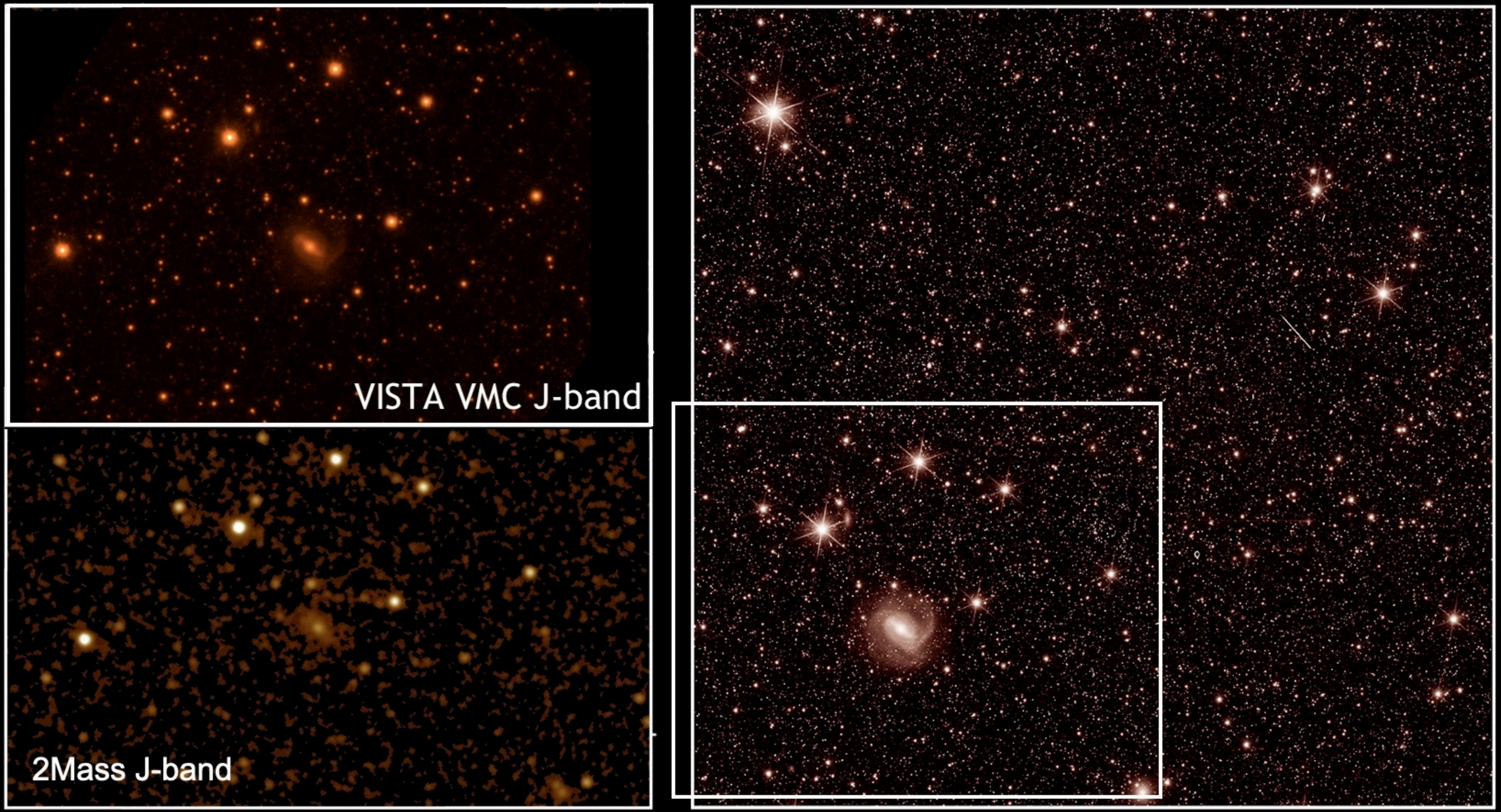
Euclid in a few milestones



[Courtesy of G. Guzzo]

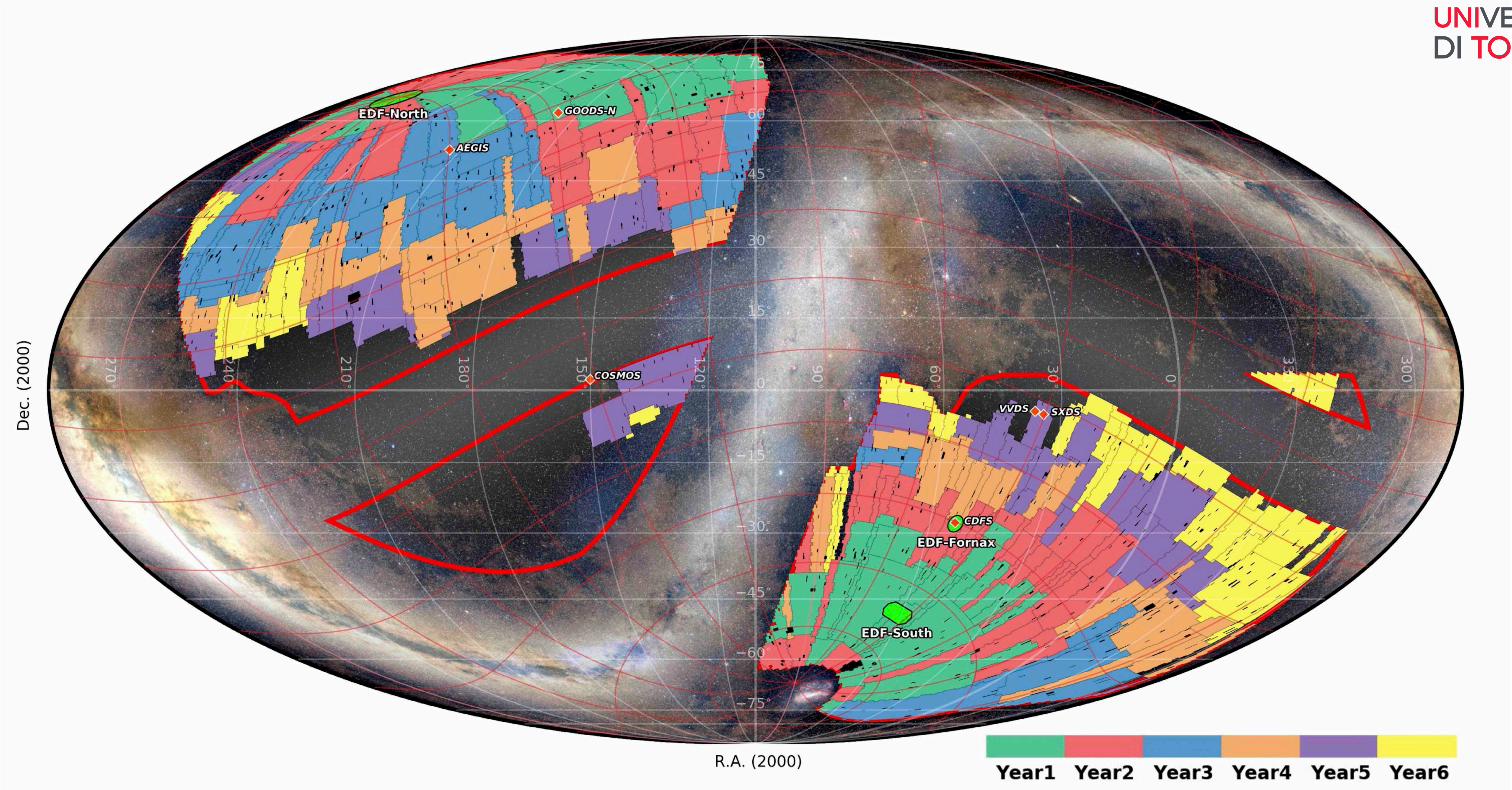
EARLY COMMISSIONING TEST IMAGE, VIS INSTRUMENT





Credit: Ross Collins,
ESA/Euclid/Euclid Consortium

Euclid facts




409″
413″
2802″
2518″
EUCLID VIS
100″
44″
64″
132″
JWST NIRCam
162″
162″
HST WFC3/UVIS
123″
136″
HST WFC3/IR
450″
450″
1495″
2990″
ROMAN WFI (planned 2027)
Credit: Yuzheng Kang

The SKA Observatory

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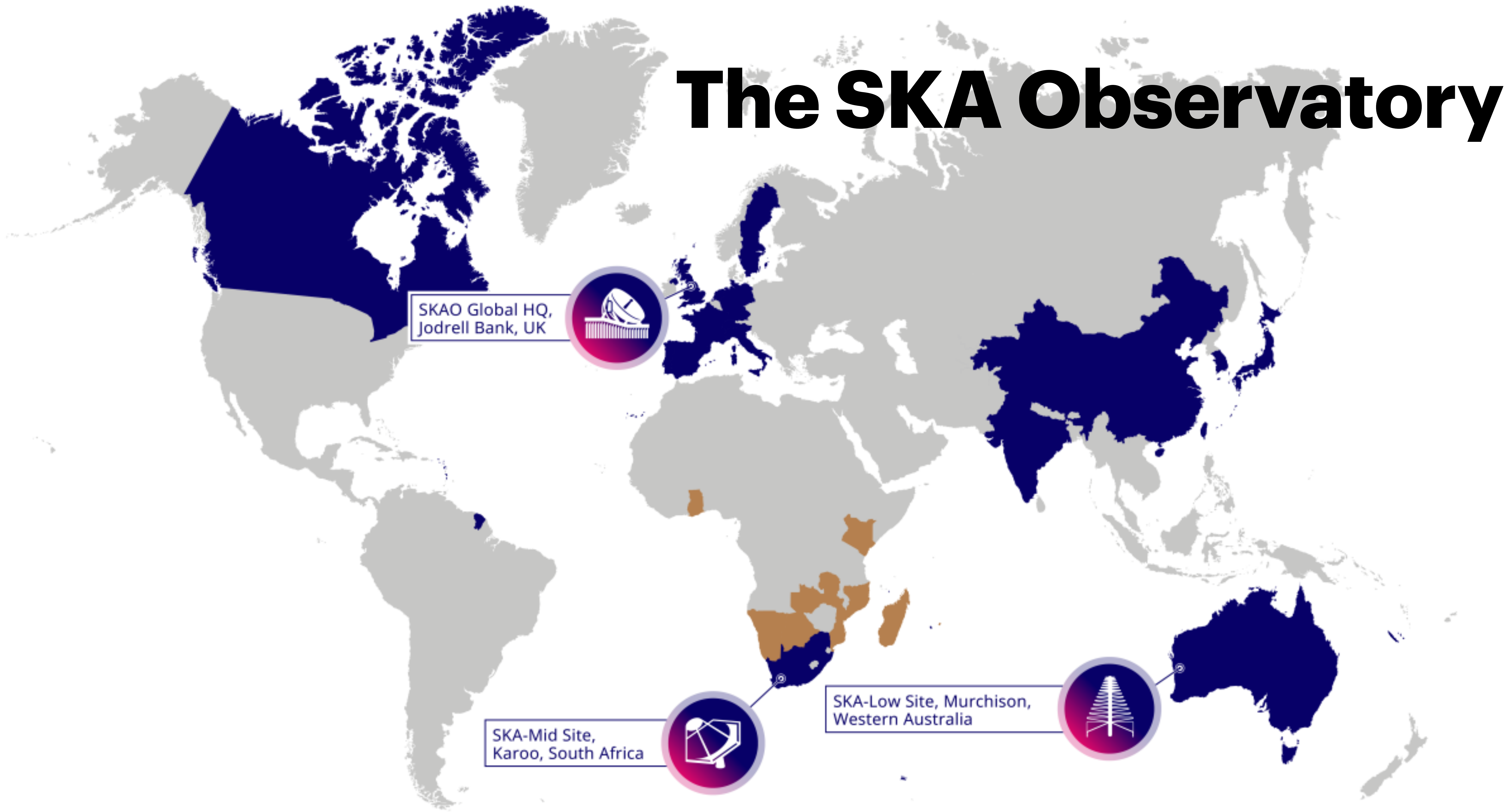
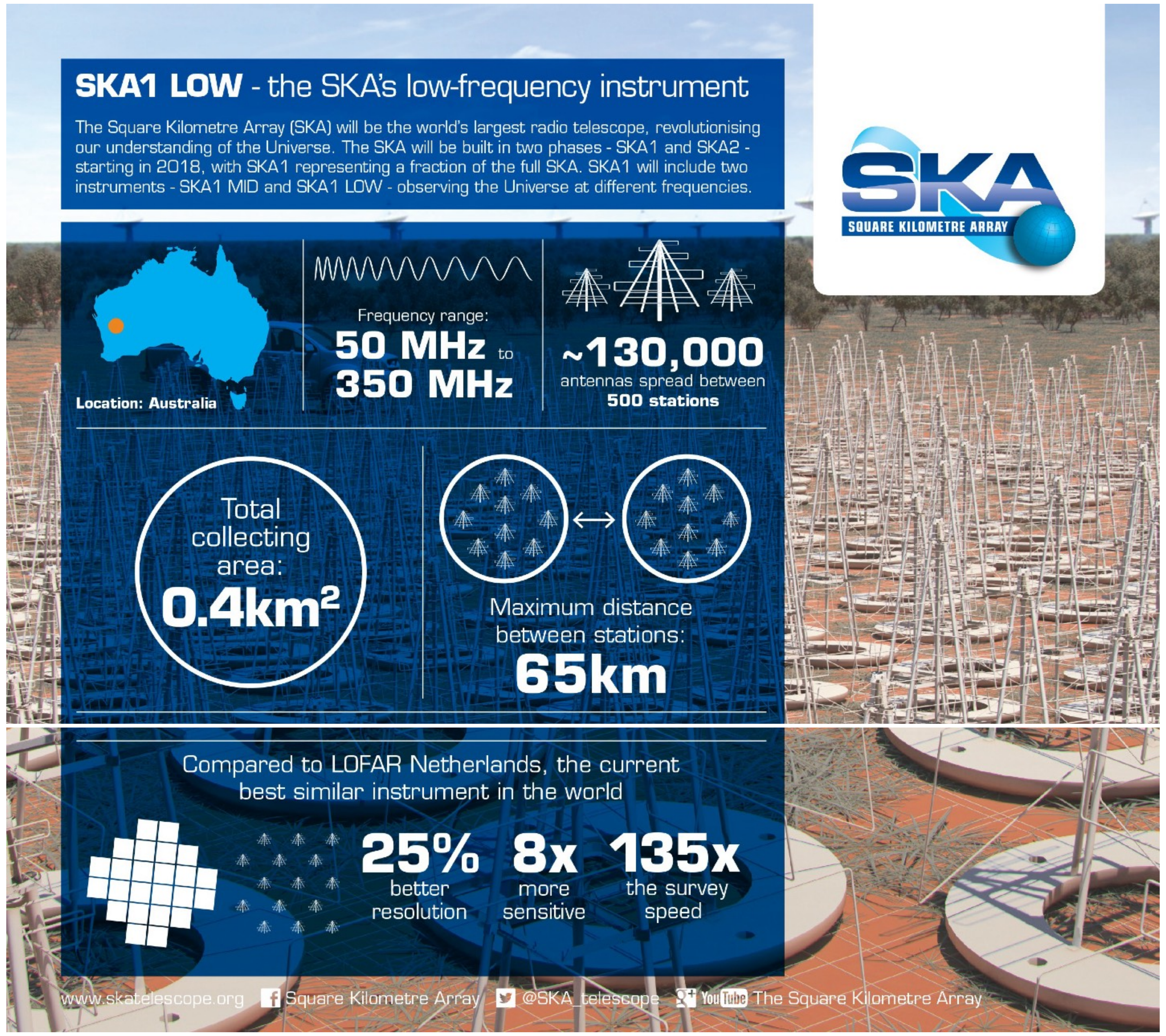
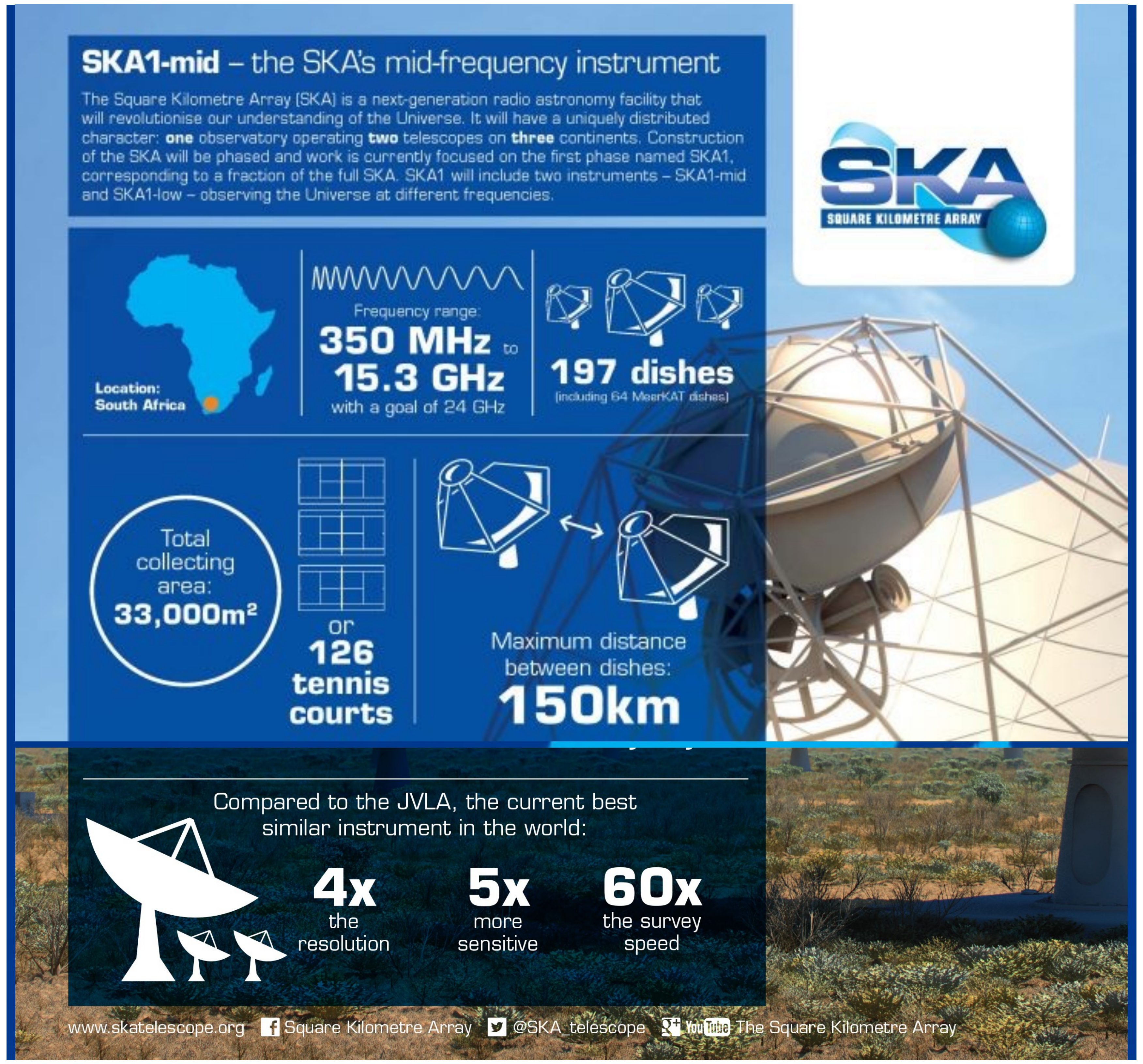


SKAO Partnership - includes SKAO Member States* and SKAO Observers (as of July 2023)

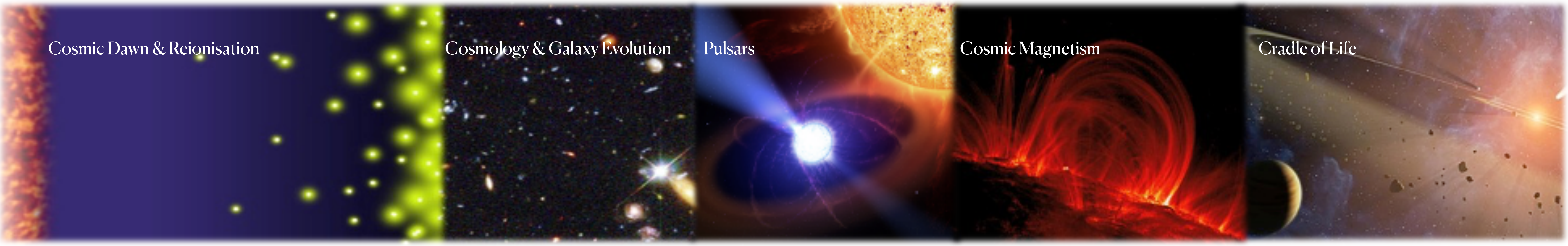
African Partner Countries

The SKA Project





SKAO Science



SKAO's Low telescope

50-350 MHz

SKAO's Mid telescope

Band 1

0.35-1.05 GHz

Band 2

0.95-1.76 GHz

Band 3

1.65-3.05 GHz

Band 5

4.6-24 GHz

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Cosmology at radio wavelengths

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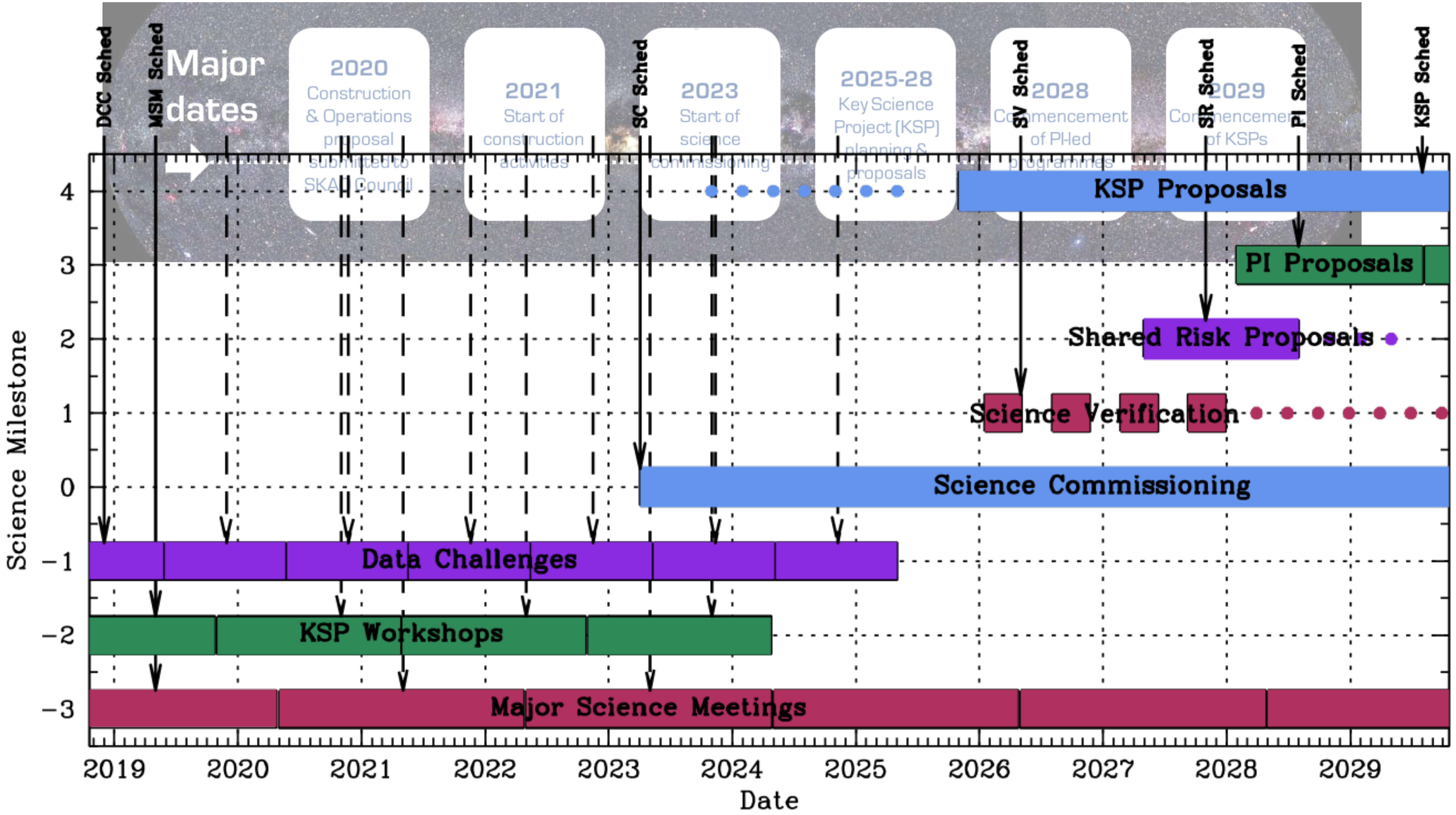
- Surveys carried out at radio wavelengths:
  - HI-line galaxy surveys
  - Continuum galaxy surveys
  - Radio weak lensing surveys
  - HI intensity mapping surveys
- Multi-wavelength synergies

Towards the SKAO

[Credits: R. Braun]



Towards the SKAO

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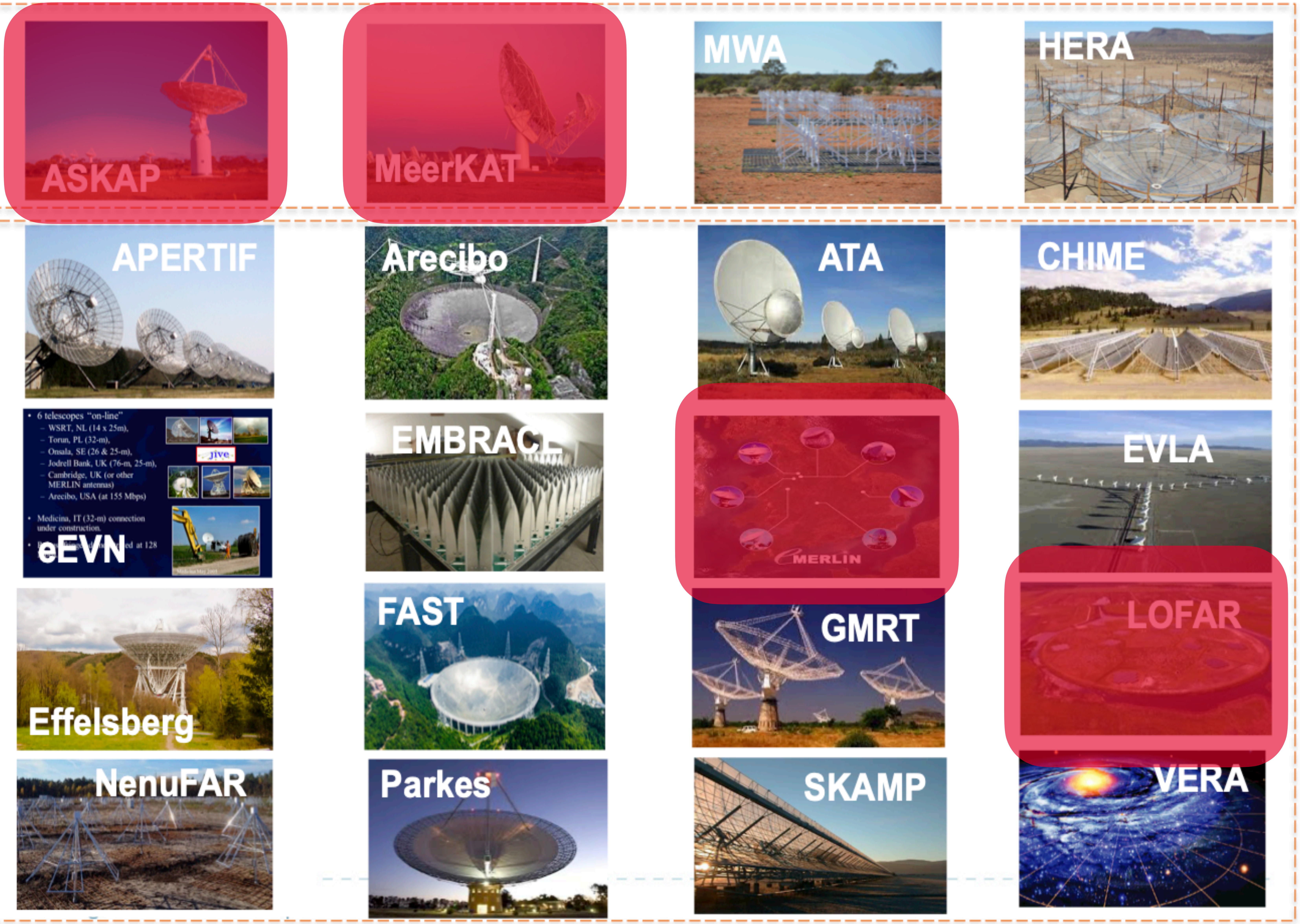
[Courtesy of A. Bonaldi]

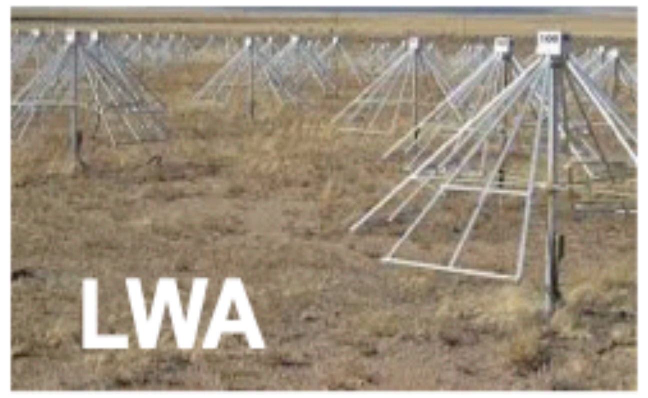
Precursors

Located at future SKA sites (South Africa and Australia)

Pathfinders

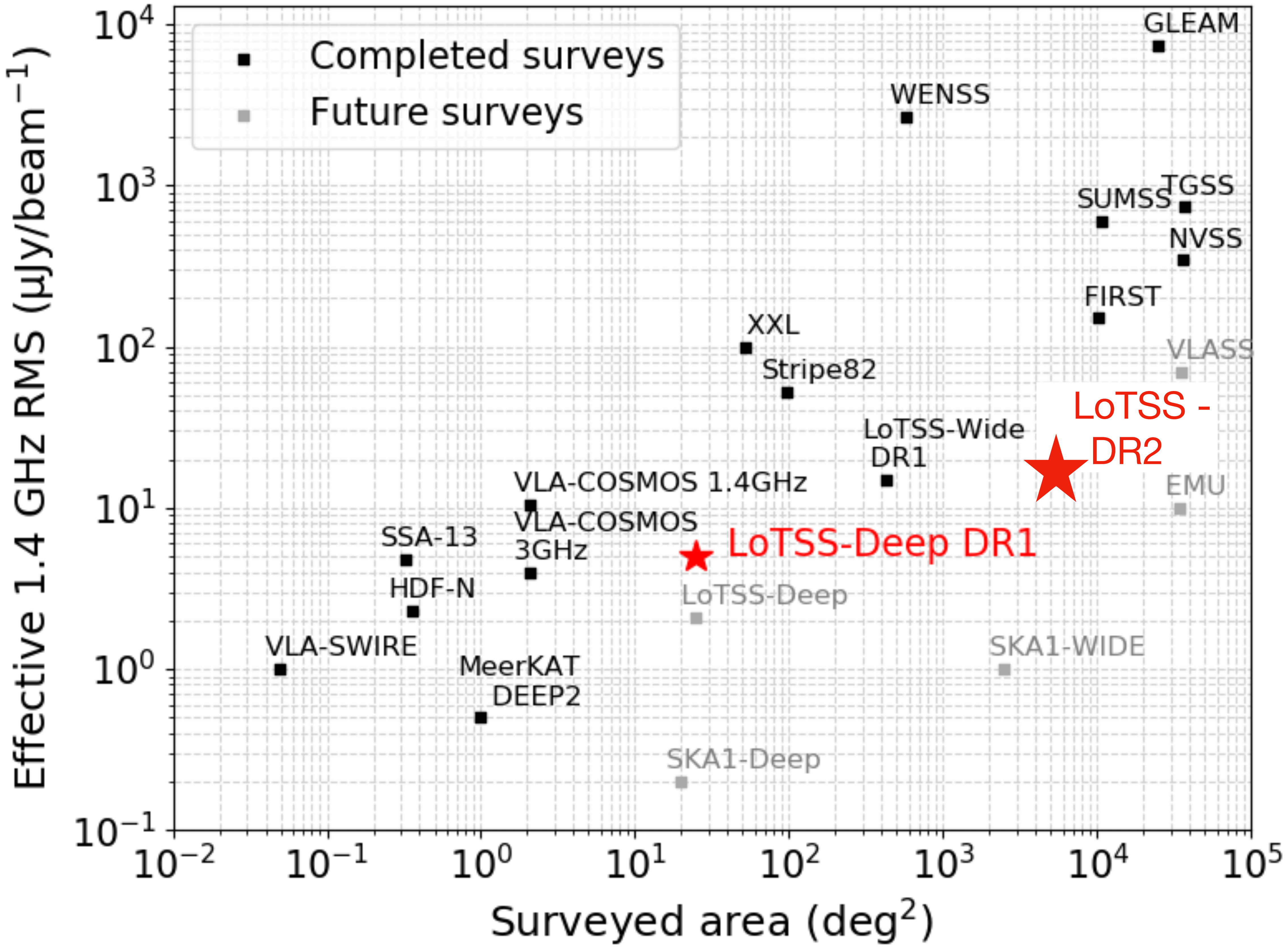
Engaged in SKA related technology and science studies





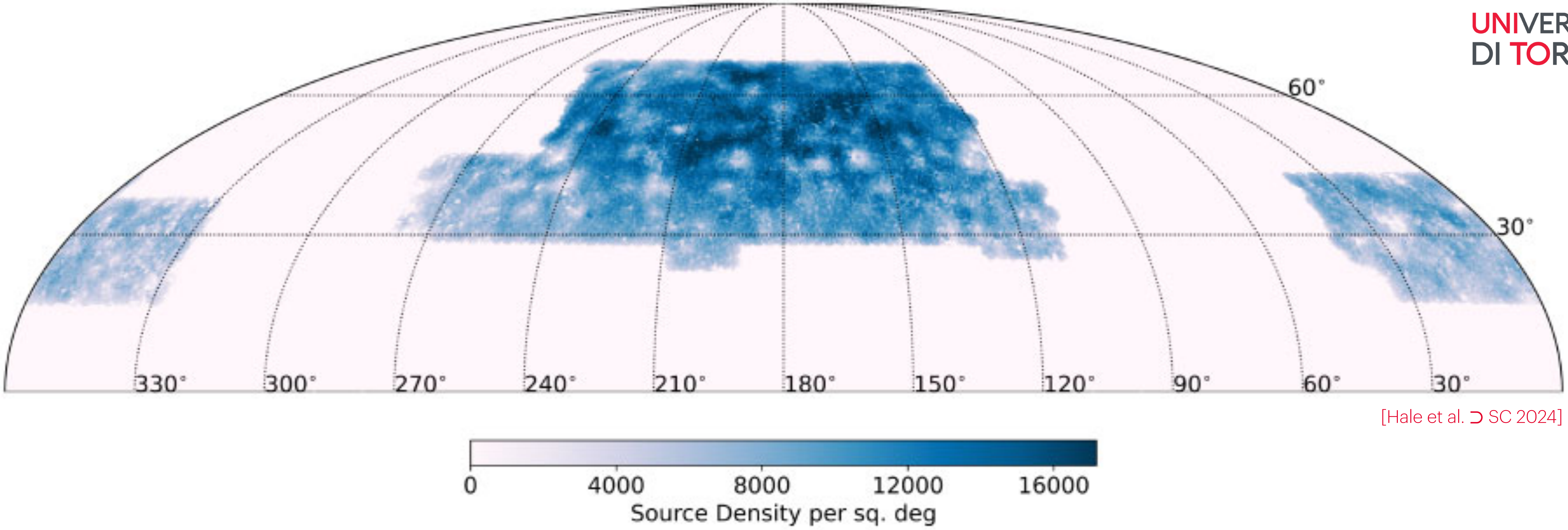
LOFAR

- The LOFAR Two-metre Sky Survey (LoTSS)



- LoTSS-Deep DR1:
  - Boötes, Lockman & Elias N1 fields w/ ~80 μJy/beam rms
  - Multi-frequency coverage leading to ~80k radio sources (~0.9/arcmin²)
- LoTSS DR2:
  - Core and remote station HBA obs: @ 144 MHz, 841 pointings, 5600 sq. deg.
  - Direction dependent calibration: 6" resolution, ~80 μJy/beam rms
  - 4.4M radio sources (~0.2/arcmin²)

LOFAR



[Hale et al. ⊃ SC 2024]

- LOFAR cosmology publications:
- Redshift distribution [Bhardwaj et al. ⊃ SC 2024]
- Counts-in-cell [Pashamourahmadabadi et al. 2024 (TBS)]
- Radio dipole [Böhme et al. 2023]
- Radio-radio correlation [Hale et al. ⊃ SC 2024]
- Radio-CMB correlation [Nakoneczny et al. 2024]
- Radio-optical correlation [Zheng et al. ⊃ SC (in prep.)]
- Cosmological parameters [Heneka et al. (in prep.)]

ASKAP

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- The Rapid ASKAP Continuum Survey (RACS)
  - Deepest radio survey of the Southern sky to date (central frequency 887.5 MHz)
  - Large instantaneous field of view ~31 deg² (~900 pointings with 15 min observations)
  - About 2.1M galaxies (cutting Galactic plane at ±5°)

Publications of the Astronomical Society of Australia (2021), **38**, e058, 25 pages
doi:10.1017/pasa.2021.47

CAMBRIDGE UNIVERSITY PRESS
[Hale et al. 2021]

Research Paper

The Rapid ASKAP Continuum Survey Paper II: First Stokes I Source Catalogue Data Release

Catherine L. Hale[1,2], D. McConnell[3], A. J. M. Thomson[1], E. Lenc[3], G. H. Heald[1], A. W. Hotan[1], J. K. Leung[3,4], V. A. Moss[3], T. Murphy[4], J. Pritchard[4,3], E. M. Sadler[3,4], A. J. Stewart[4] and M. T. Whiting[3]

[1]CSIRO Space and Astronomy, PO Box 1130, Bentley WA 6102, Australia,[2]School of Physics and Astronomy, University of Edinburgh, Institute for Astronomy, Royal Observatory Edinburgh, Blackford Hill, Edinburgh EH9 3HJ, UK,[3]CSIRO Space and Astronomy, PO Box 76, Epping, NSW, 1710, Australia and [4]Sydney Institute for Astronomy, School of Physics, University of Sydney, NSW 2006, Australia

e-MERLIN

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- The Super Cluster Assisted Shear Survey (SuperCLASS)
  - Paving the road to detecting cosmic shear in the radio band
  - 0.06 gal/arcmin^2 (detected, resolved, and at high redshift)
  - ~0.26 deg^2

[Battye, SC et al. (2020)]

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

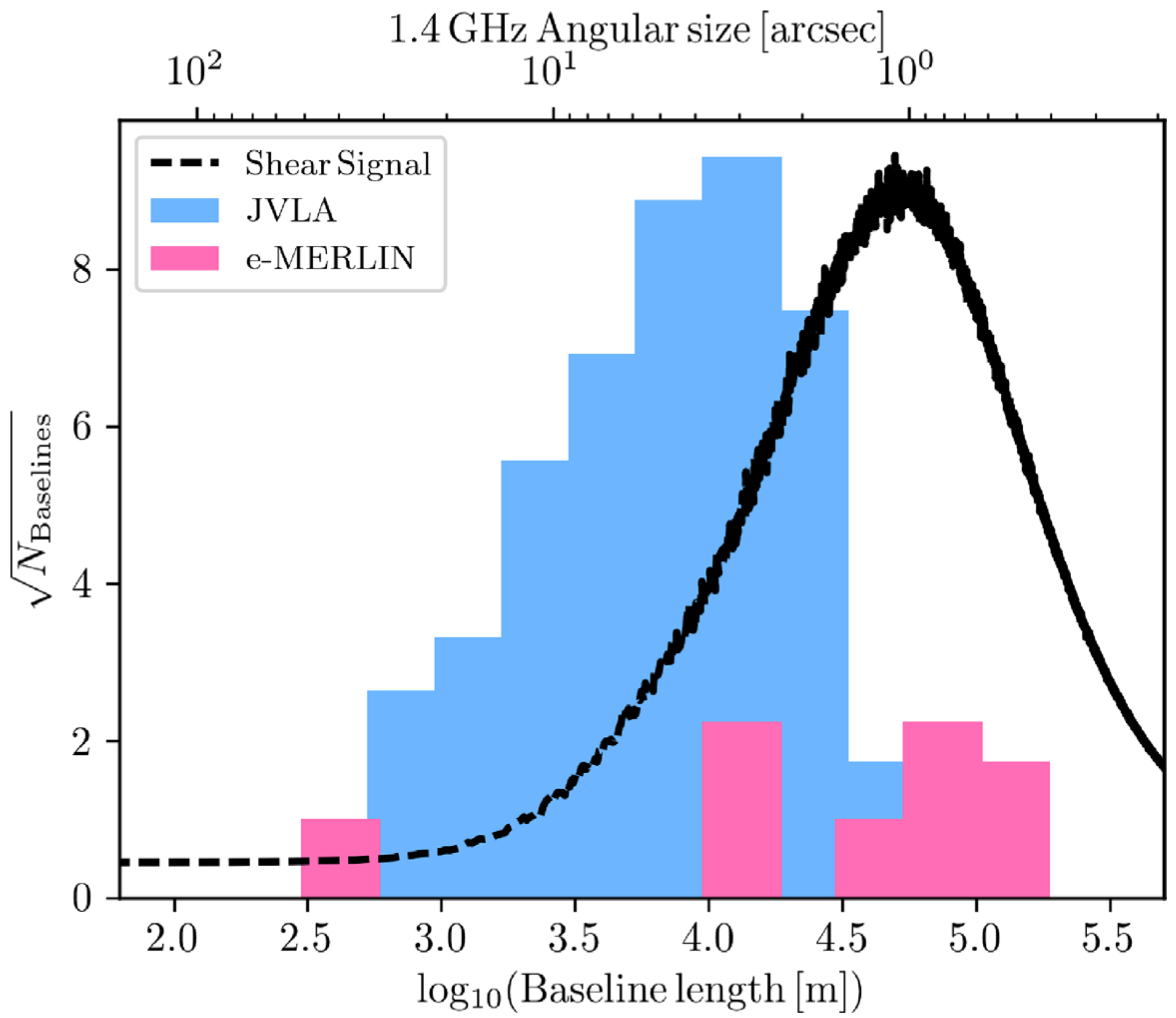
MNRAS **495,** 1706–1723 (2020) doi:10.1093/mnras/staa709
Advance Access publication 2020 April 2

SuperCLASS – I. The super cluster assisted shear survey: Project overview and data release 1

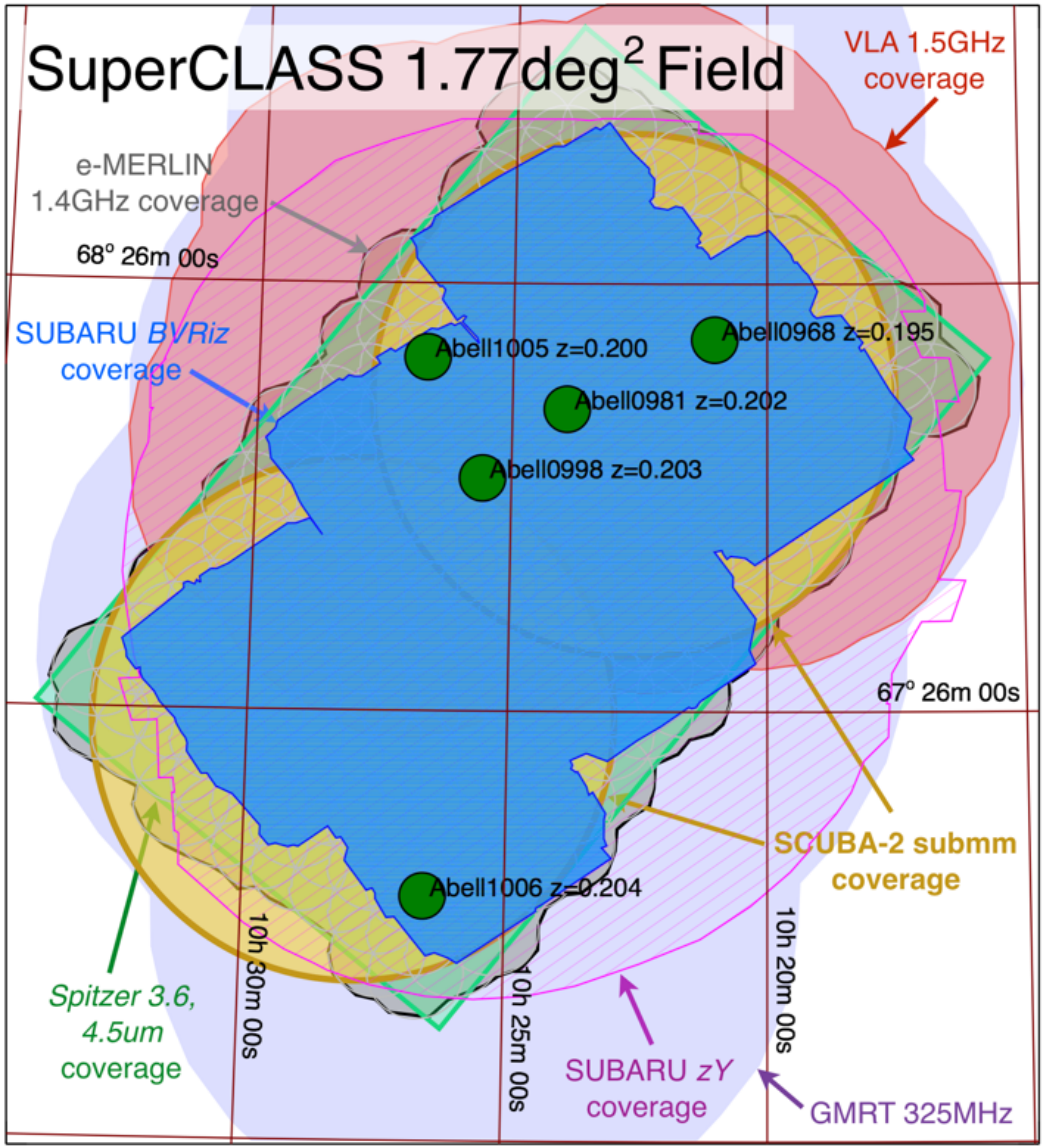
Richard A. Battye,[1★] Michael L. Brown,[1] Caitlin M. Casey,[2] Ian Harrison,[1,3] Neal J. Jackson,[1] Ian Smail,[4] Robert A. Watson,[1] Christopher A. Hales,[5,6] Sinclaire M. Manning,[2] Chao-Ling Hung,[2] Christopher J. Riseley,[7,8,9] Filipe B. Abdalla,[10] Mark Birkinshaw,[11] Constantinos Demetroullas,[1,12] Scott Chapman,[13] Robert J. Beswick,[1] Tom W. B. Muxlow,[1] Anna Bonaldi,[1,14] Stefano Camera,[1,15,16] Tom Hillier,[1] Scott T. Kay,[1] Aaron Peters,[1] David B. Sanders,[17] Daniel B. Thomas,[1] A. P. Thomson,[1] Ben Tunbridge,[1] and Lee Whittaker[1,10] (SuperCLASS Collaboration)

e-MERLIN

- Fully multi-wavelength!



[Courtesy of C. Casey]



MeerKAT

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- The MeerKAT Large Area Synoptic Survey (MeerKLASS)
  - Aiming at HI intensity mapping and continuum cosmology (lots of commensality)
  - Focus of sky patches with multi-wavelength data for cross-correlations
  - L-band: 856-1711 MHz ($z < 0.65$) & UHF-band: 544-1087 MHz ($0.3 < z < 1.6$)

PoS PROCEEDINGS OF SCIENCE

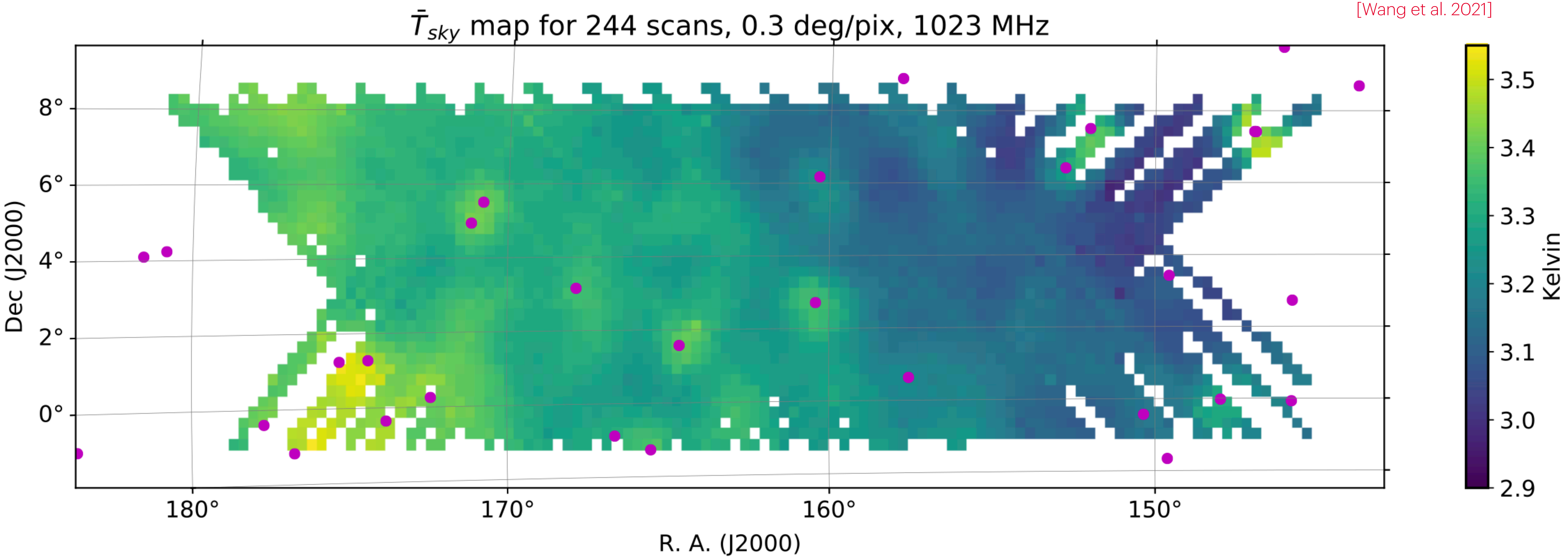
[Santos et al. ⊃ SC 2016]

A Large Sky Survey with MeerKAT

Mário G. Santos*,[1,2] Philip Bull,[3,4] Stefano Camera,[5] Song Chen,[1] José Fonseca,[1] Ian Heywood,[6] Matt Hilton,[7] Matt Jarvis,[1,6] Gyula I. G. Józsa[2,8,9], Kenda Knowles,[7] Lerothodi Leeuw,[10] Roy Maartens,[1,11] Eliab Malefahlo,[1] Kim McAlpine,[1] Kavilan Moodley,[7] Prina Patel,[1,2] Alkistis Pourtsidou,[11] Matthew Prescott,[1] Kristine Spekkens,[12] Russ Taylor,[1,13] Amadeus Witzemann[1] and Imogen Whittam[1]

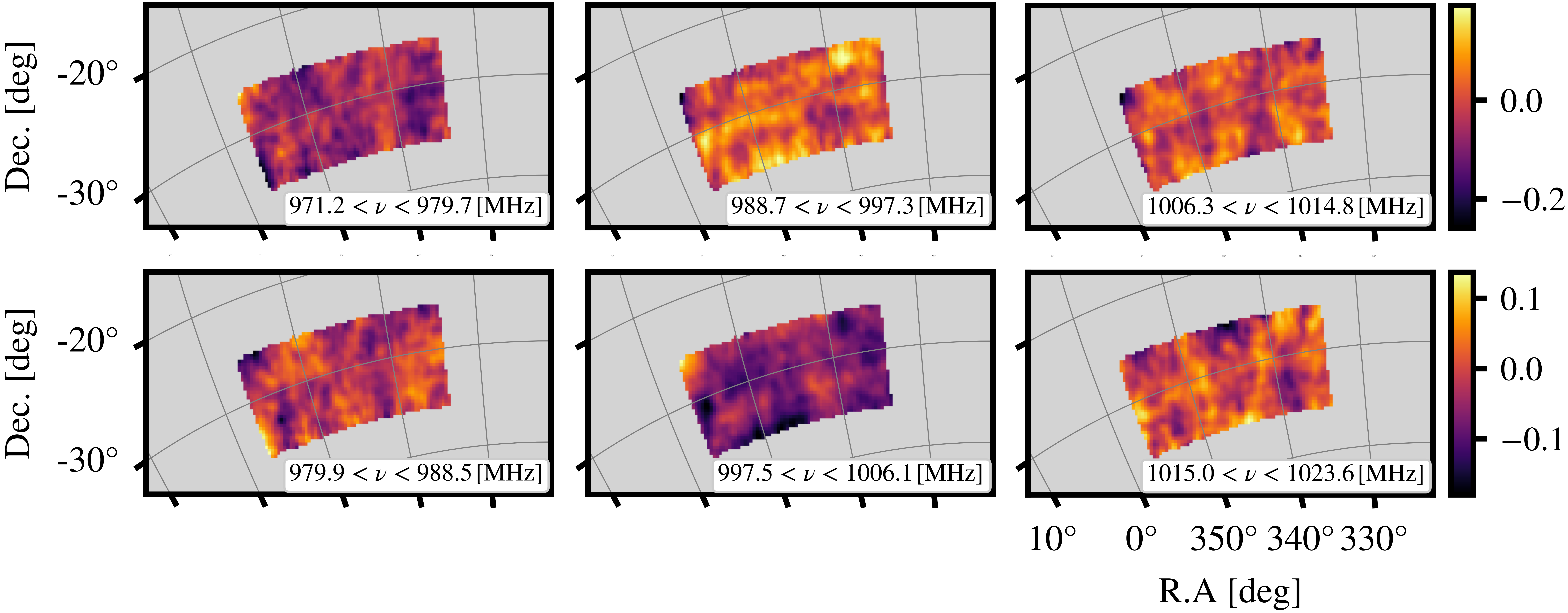
MeerKAT

[Wang et al. 2021]



MeerKAT

[MeerKLASS Collaboration, 2024]



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Synergies

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- Synergies for systematics:
  - Most obvious case, to cross-validate results, remove foregrounds, …
- Synergies for sources:
  - In some cases the same sources must be matched—very much true in non-cosmological science but also for providing e.g. redshifts for cosmological cases
- Synergies in volume:
  - In some cases the main gain is in increased volume probed (IM+Euclid might be such a case in the simplest sense)

Synergies dos and don’ts

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- Public *Euclid* data + external public/non-public data
  - Joint analyses can in principle be done without an EC project—but EC members should not be competing with Euclid internal projects
- Non-public *Euclid* data + external public data
  - EC members can work on these in EC projects; if people external to the EC are to be involved, an MoU should be written (external collaborators can also be defined)
- Non-public *Euclid* + external non-public data
  - MoU is needed

An MoU

Positive

1. Makes things clear and open
2. Allows for science to be done before data releases
3. Could be broader than just cosmology

Could potentially be negative

1. A bit of effort to write
2. Two rule sets so could be less agile
3. Will allow non-SKA members in Euclid to join the joint projects

[Courtesy of J. Brinchmann]

Synergy ideas

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- Synergies for systematics:
  - Radio-optical shear
  - Galaxy number counts × HI intensity mapping
- Synergies for sources:
  - Morphological analysis (for photo-*z* calibration, multi-tracer, ...)
  - Cross-identifications
- Synergies in volume:
  - Fundamental physics on extremely large scales!!