HI intensity mapping in the era of the SKAO

Stefano Camera

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UNIVERSITY of the WESTERN CAPE

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Ministero dell'Università e della Ricerca

Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA

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The SKAO vs the SKA

“SKA” should never be used on its own and should always be qualified by saying “The SKA Project”, while “SKAO” refers to the organisation overseeing the construction and operation of its telescopes. For example: I work on the SKA Project, I work for the SKAO.

Disclaimer(s)

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Square Kilometre Array

We are retiring the use of the full name Square Kilometre Array. A legacy from the initial collecting array believed to be needed to achieve the telescope's original ambition, it no longer reflects today's SKA Project. Its use should be avoided wherever possible and restricted to boilerplate statements and official or legal documents.\

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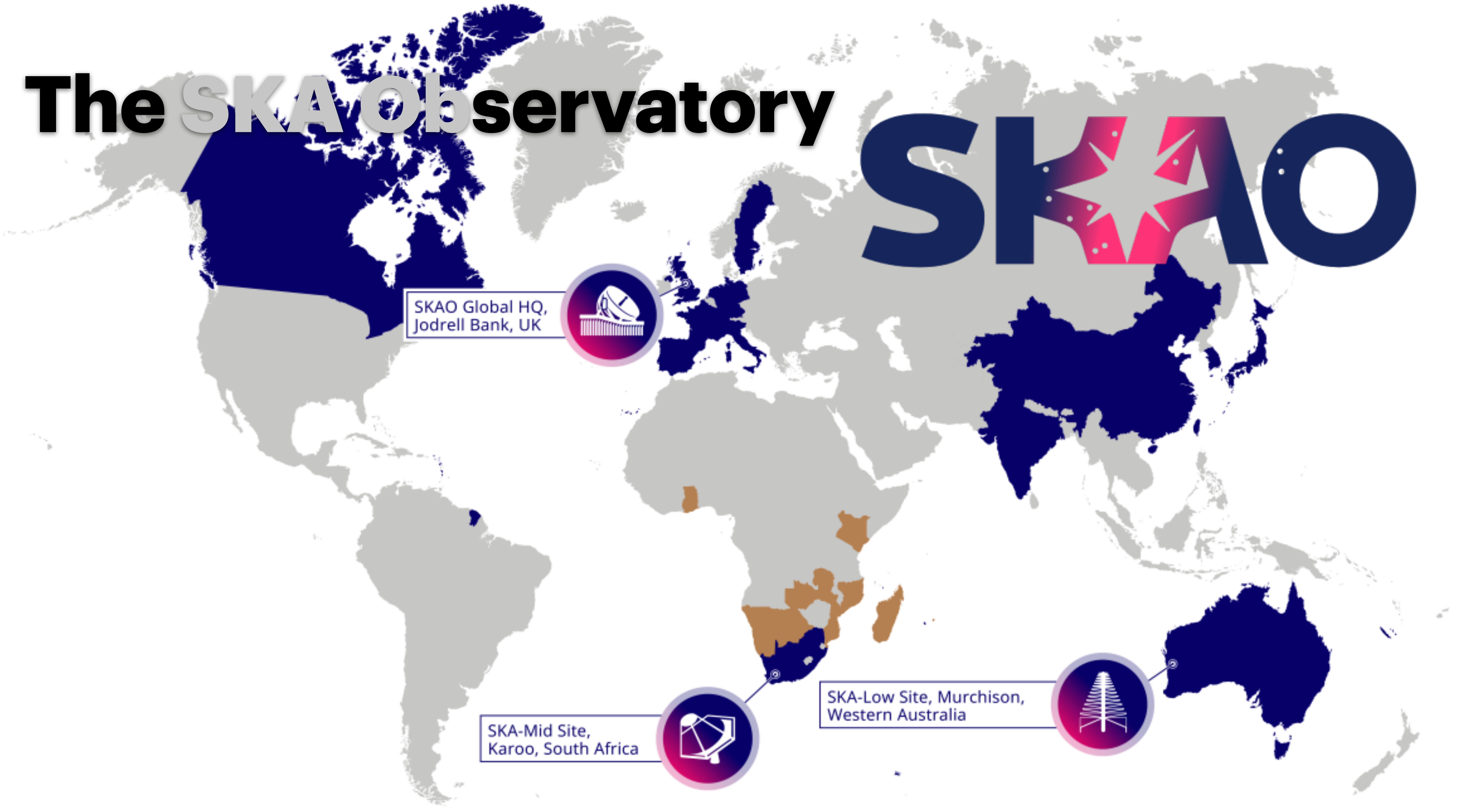
SKA1 and SKA2

The use of SKA1 and SKA2 and all related quantifiers is to be retired in all public communications. The SKAO is delivering the SKA Project, consisting of the current baseline design for the SKAO telescopes, to which there may be a future expansion. That expansion should not be quantified in any way, as exact scope is still to be defined, and engineering and cost-analysis is yet to be conducted.

The SKA Observatory



SKAO Partnership - includes SKAO Member States* and SKAO Observers (as of Nov 2024)

African Partner Countries

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2 · vi · 2025

HI Intensity Mapping wht the SKAO

Stefano Camera

The SKA Observatory

- The SKA Observatory (formerly known as 'Square Kilometre Array') will be the largest radio-telescope on Earth and will be built in two locations

The SKA Observatory

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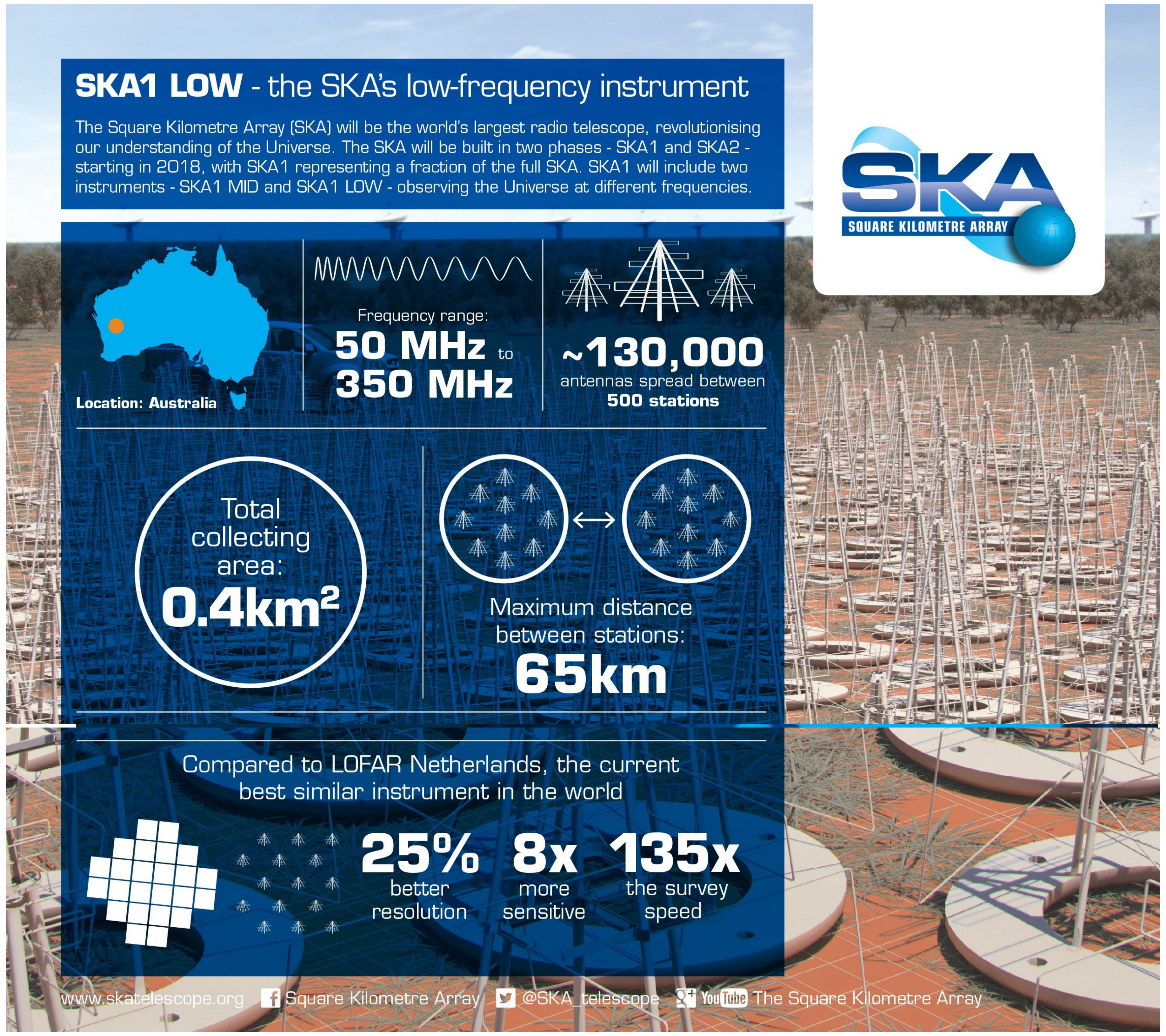
50 MHz  15 GHz



The SKA Observatory

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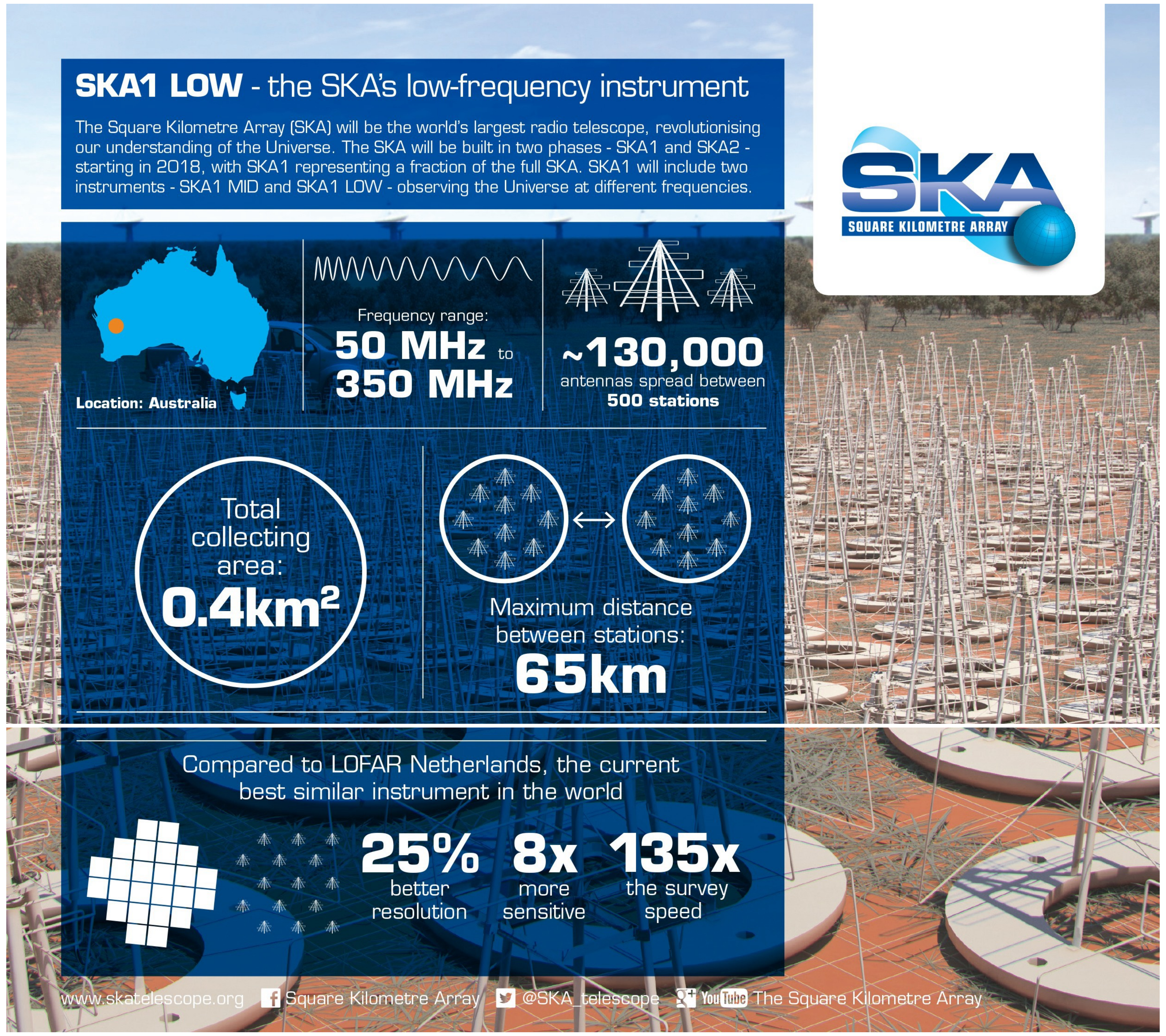
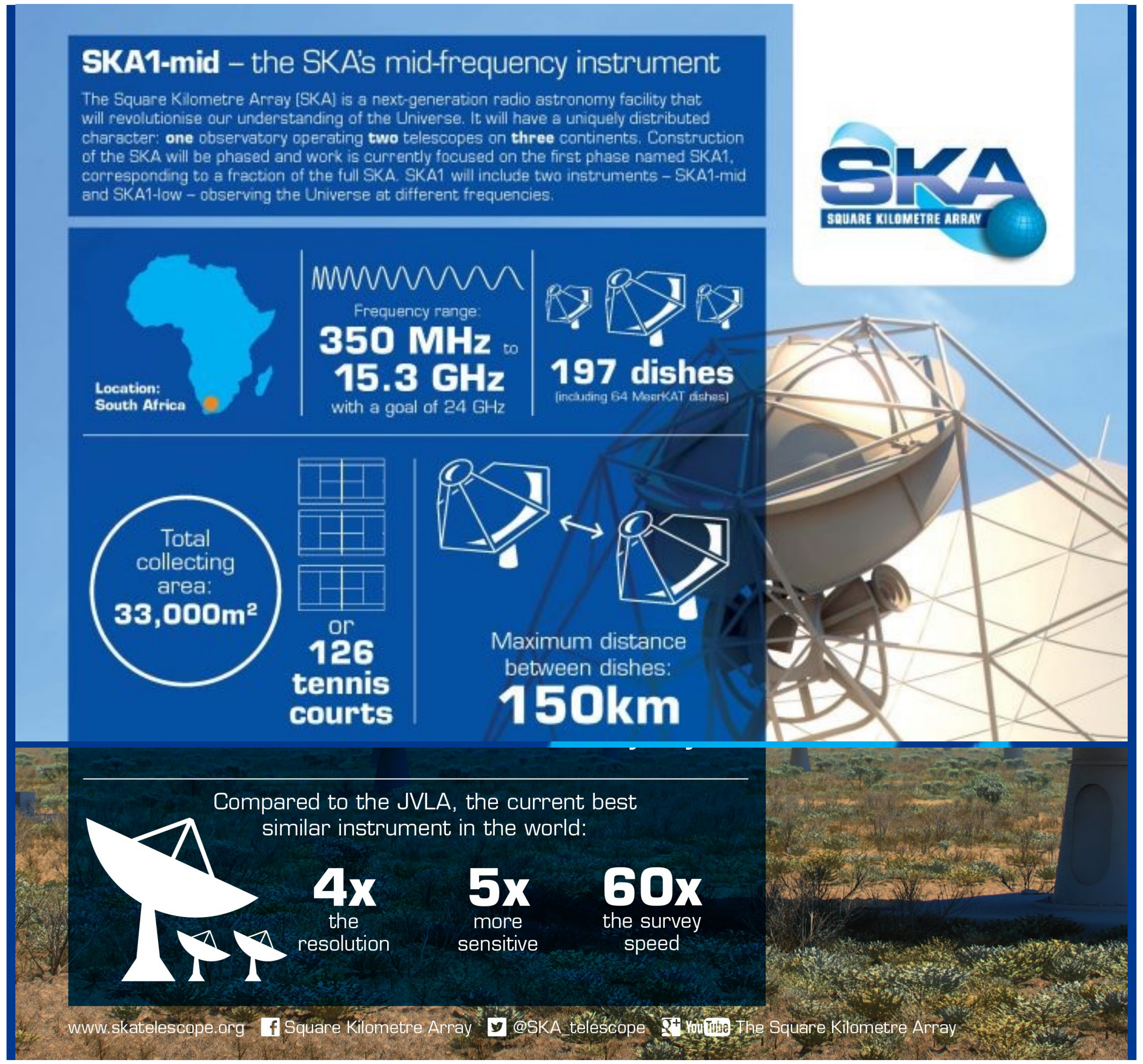
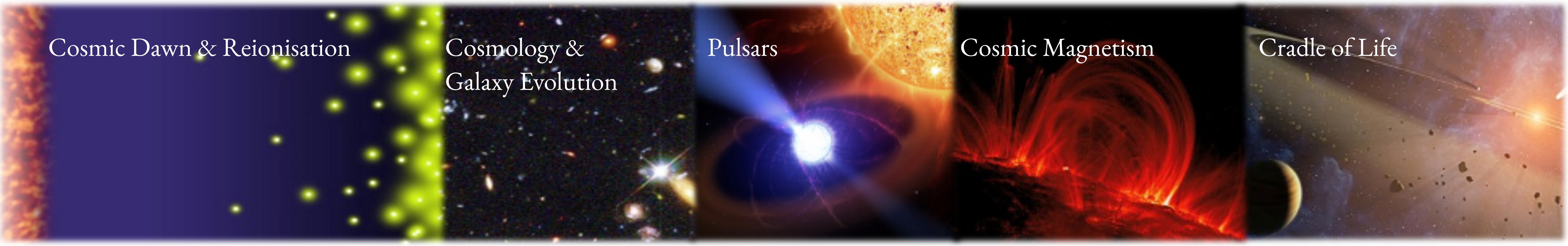
50 MHz

15 GHz

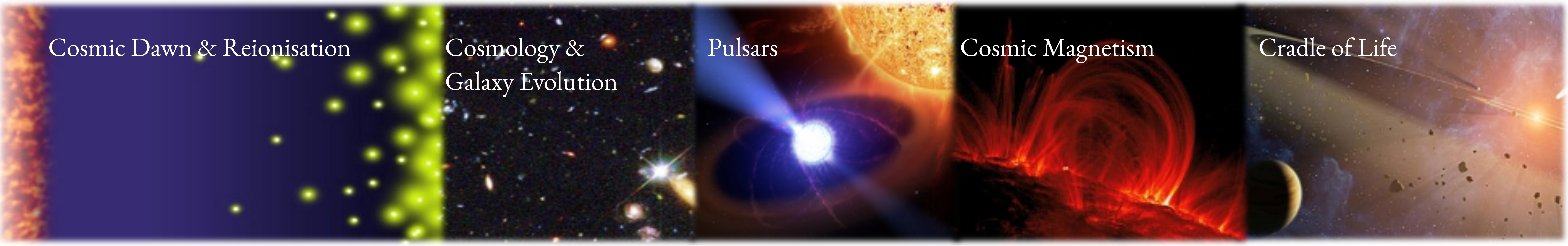




SKAO Science



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

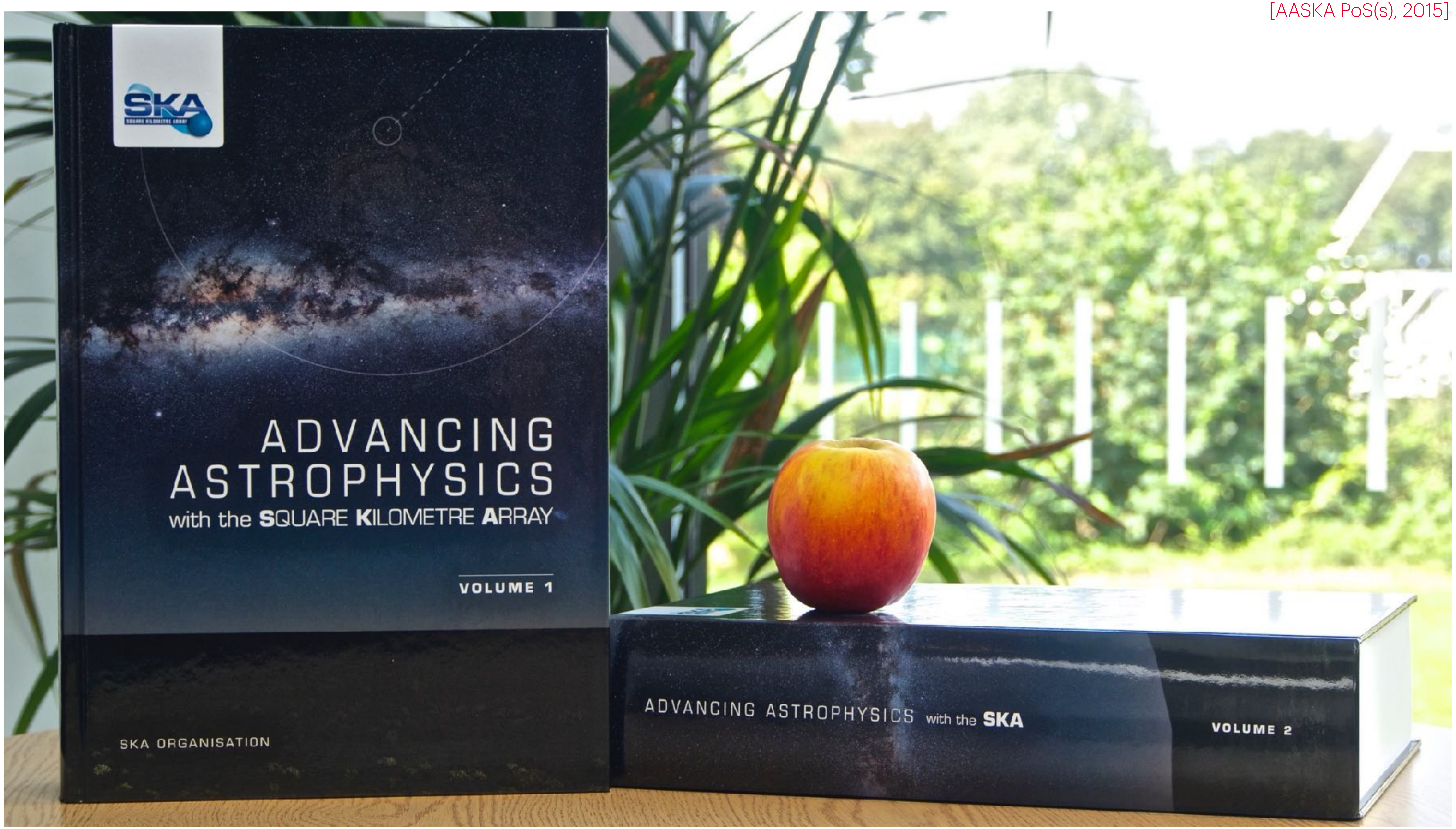
1.65-3.05 GHz

Band 5

4.6-24 GHz

SKAO Science

[AASKA PoS(s), 2015]



SKAO Cosmology

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Publications of the Astronomical Society of Australia (2020), **37**, e007, 31 pages
doi:10.1017/pasa.2019.51

CAMBRIDGE UNIVERSITY PRESS

[SKA Cosmology SWG ⊃ SC 2020]

Research Paper

Cosmology with Phase 1 of the Square Kilometre Array Red Book 2018: Technical specifications and performance forecasts

Square Kilometre Array Cosmology Science Working Group: David J. Bacon [1], Richard A. Battye [2], Philip Bull [3], Stefano Camera [2,4,5,6], Pedro G. Ferreira [7], Ian Harrison [2,7], David Parkinson [8], Alkistis Pourtsidou [3], Mário G. Santos [9,10,11], Laura Wolz [12], Filipe Abdalla [13,14], Yashar Akrami [15,16], David Alonso [7], Sambatra Andrianomena [9,10,17], Mario Ballardini [9,18], José Luis Bernal [19,20], Daniele Bertacca [21,22], Carlos A. P. Bengaly [9], Anna Bonaldi [23], Camille Bonvin [24], Michael L. Brown [2], Emma Chapman [25], Song Chen [9], Xuelei Chen [26], Steven Cunnington [1], Tamara M. Davis [27], Clive Dickinson [2], José Fonseca [9,22], Keith Grainge [2], Stuart Harper [2], Matt J. Jarvis [7,9], Roy Maartens [1,9], Natasha Maddox [28], Hamsa Padmanabhan [29], Jonathan R. Pritchard [25], Alvise Raccanelli [19], Marzia Rivi [13,18], Sambit Roychowdhury [2], Martin Sahlén [30], Dominik J. Schwarz [31], Thilo M. Siewert [31], Matteo Viel [32], Francisco Villaescusa-Navarro [33], Yidong Xu [26], Daisuke Yamauchi [34] and Joe Zuntz [35]

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

HI intensity mapping

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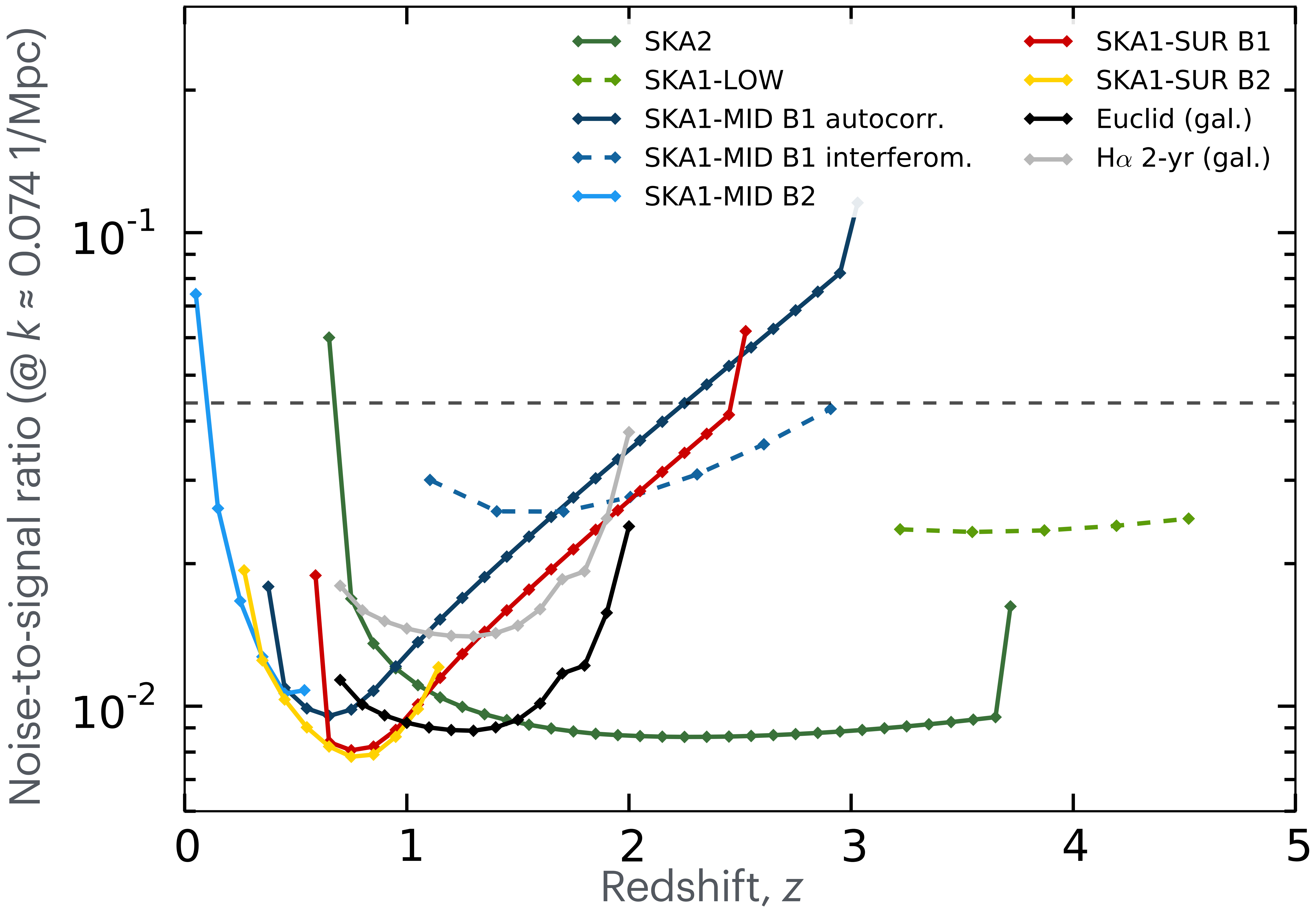
- Origin: integrated emission of 21-cm photons in galaxies (after the EoR ends)
- Pros: no photon lost, better than spectroscopic redshift accuracy
- Cons: poor angular resolution, huge foreground contamination
- Examples:
  - GBT (~1 sq. deg. in cross-correlation w/ WiggleZ @ $0.53 < z < 1.12$) [Chang et al. 2010]
    (~100 sq. deg. in cross-correlation w/ eBOSS & WiggleZ @ $0.6 < z < 1.0$) [Wolz et al. 2021]
  - Parkes (1.3k sq. deg. in cross-correlation w/ 2dFGRS @ $0.057 < z < 0.098$) [Andeson et al. 2018]
  - MeerKAT (~200 sq. deg. in cross-correlation w/ WiggleZ @ $0.400 < z < 0.459$) [MeerKLASS Collaboration 2022]
  - CHIME (three fields stacked against eBOSS LRGs, ELGs, QSOs @ $0.78 < z < 1.43$) [CHIME Collaboration 2022]

SKAO HI intensity mapping cosmology

[Santos ⊃ SC et al. 2015]



SKAO HI intensity mapping cosmology

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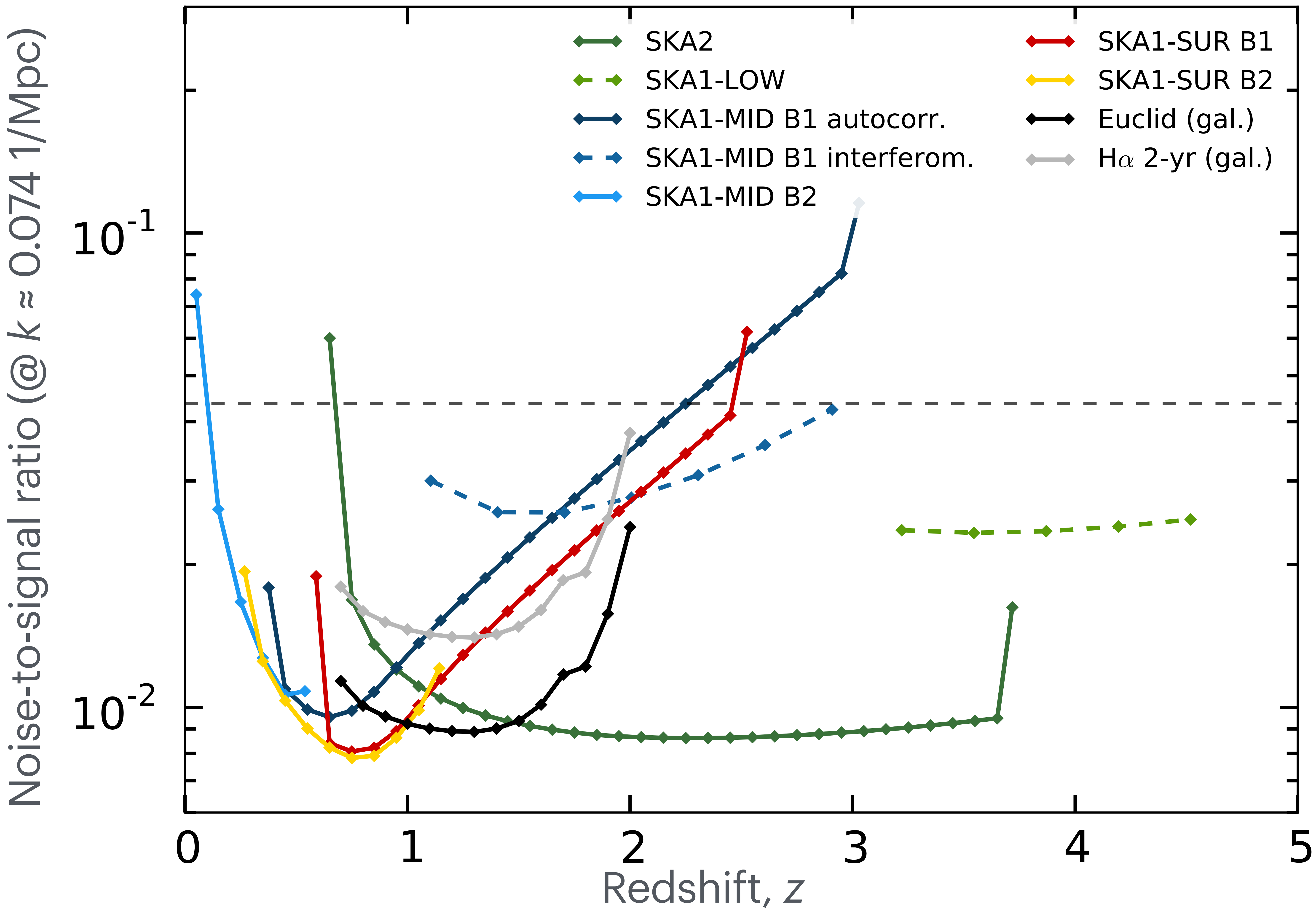
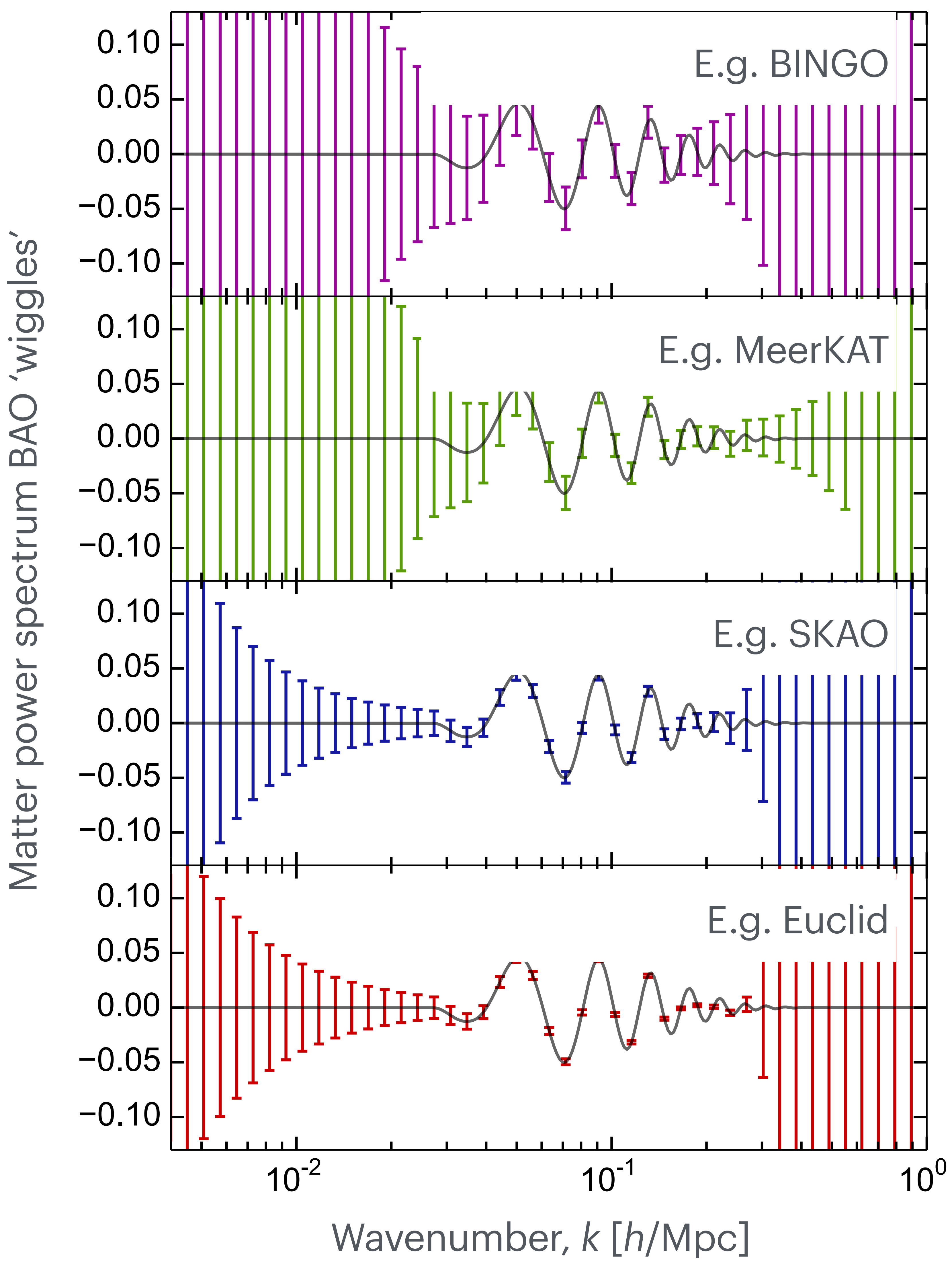
[Santos ⊃ SC et al. 2015]

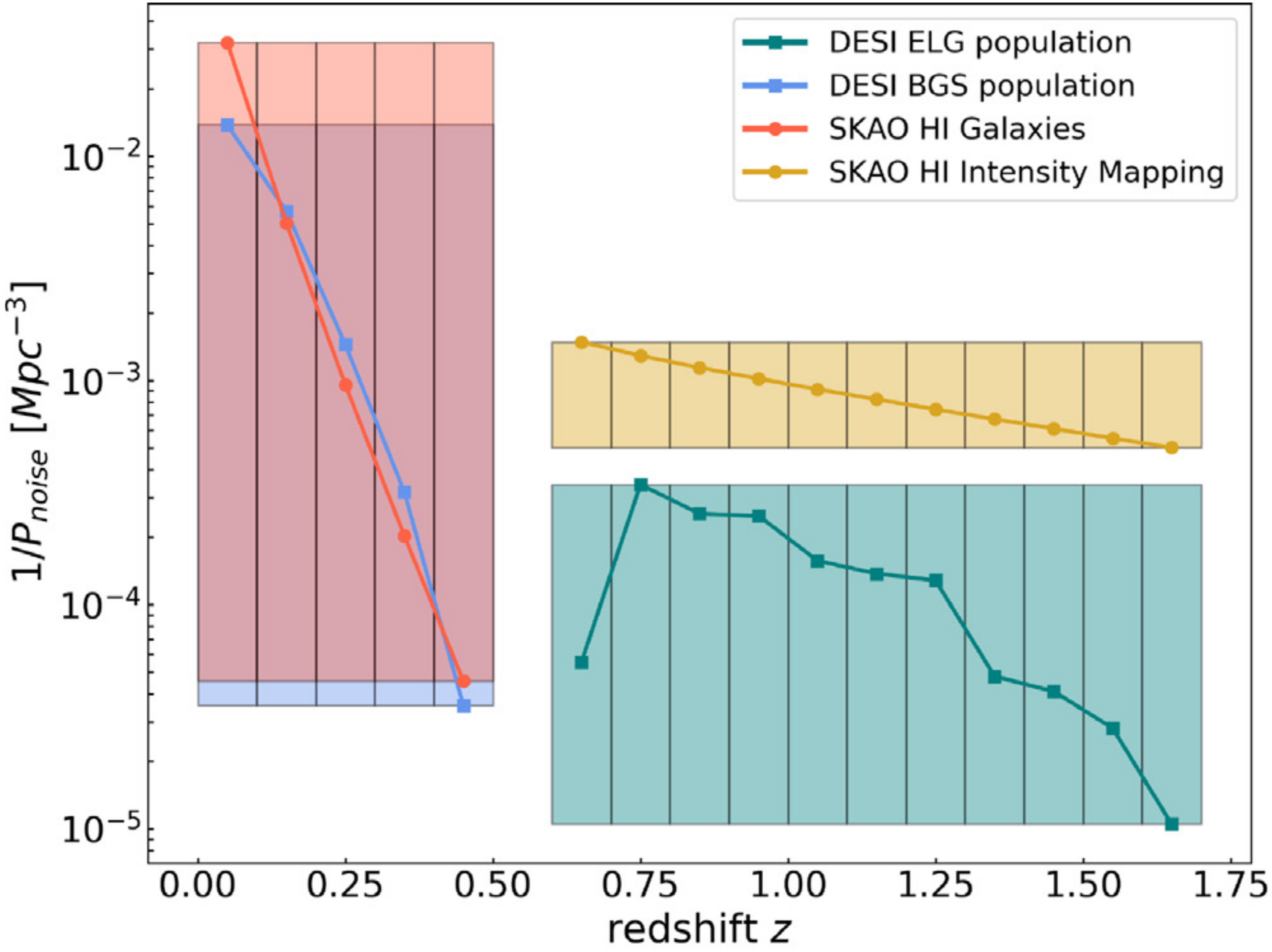


[Bull ⊃ et al. 2015]

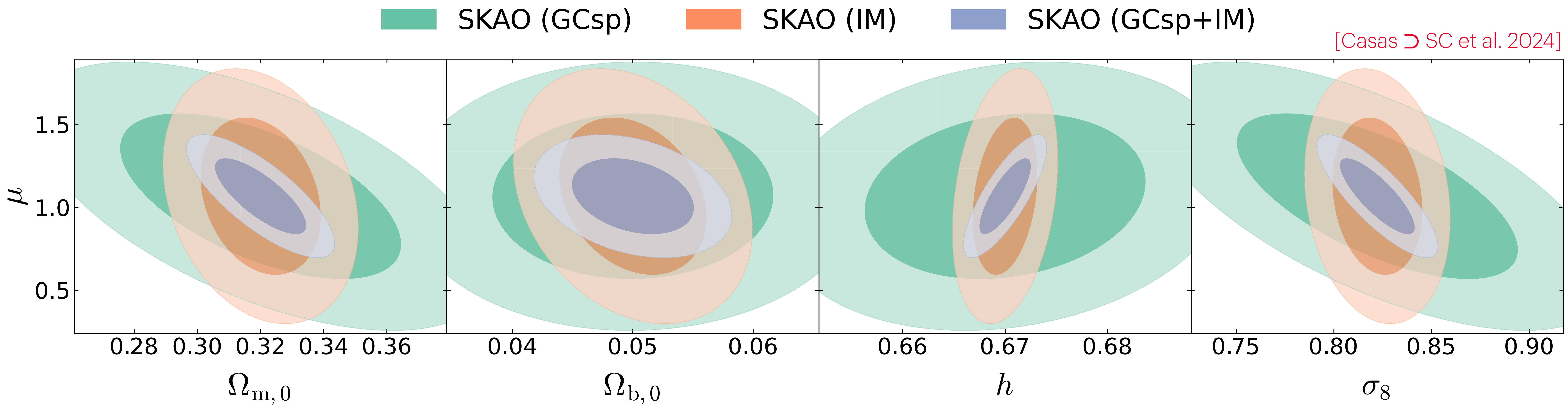


SKAO HI intensity mapping synergies

[Casas ⊃ SC et al. 2024]



SKAO HI intensity mapping synergies



[Casas ⊃ SC et al. 2024]

SKAO HI intensity mapping synergies

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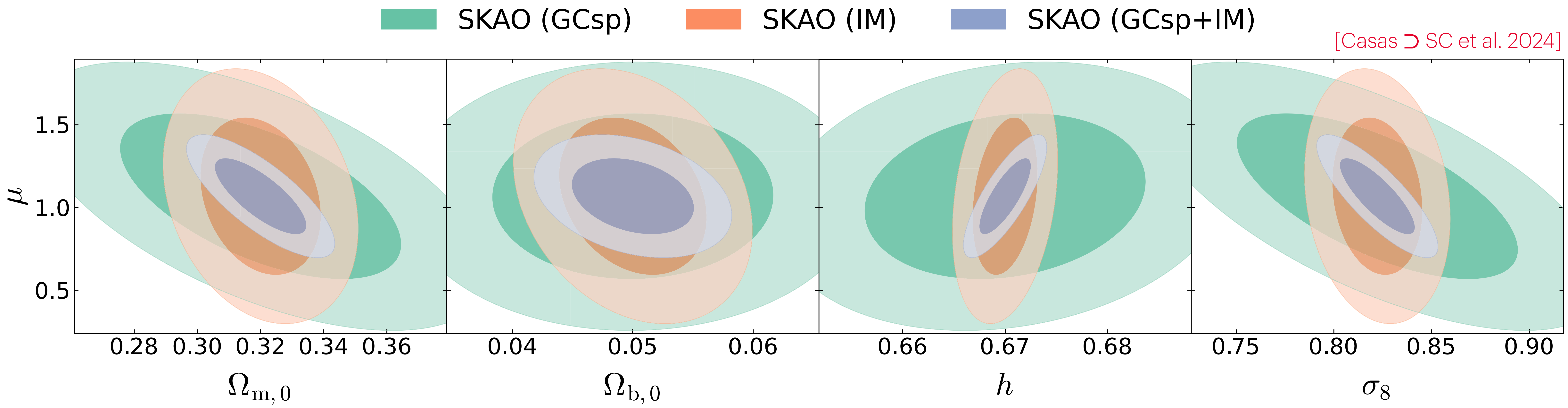
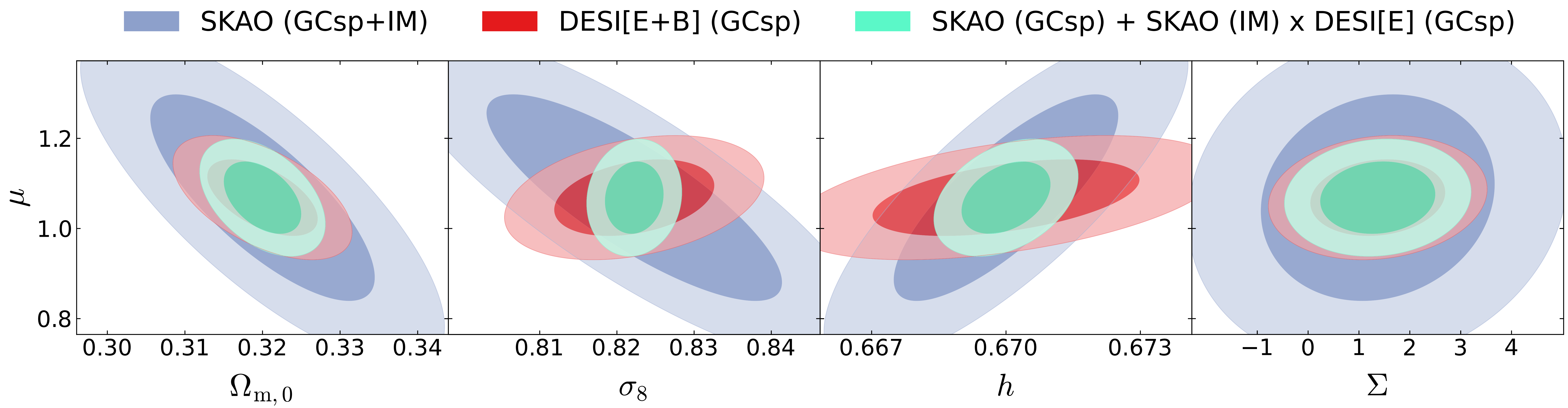
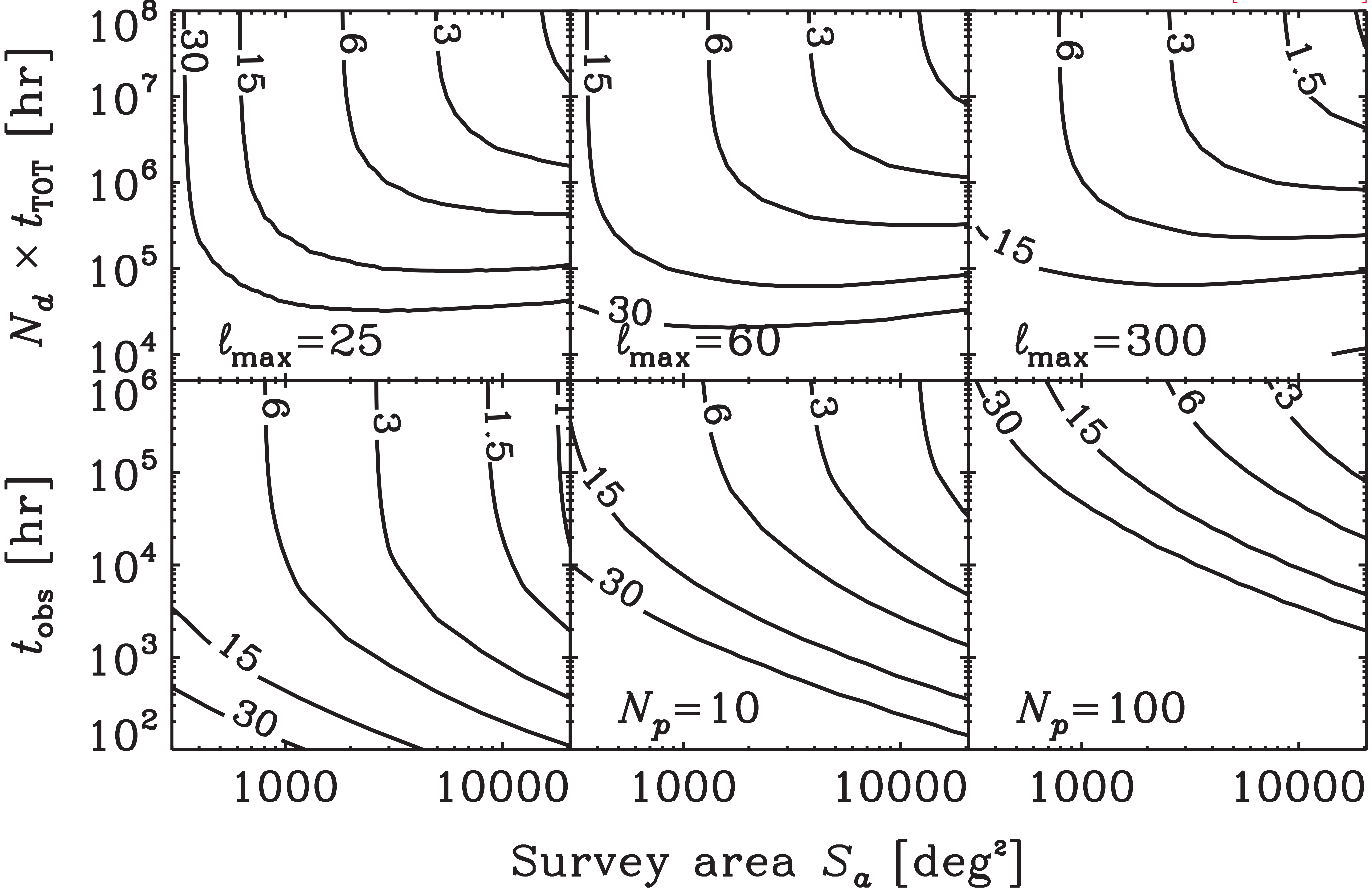
[Casas ⊃ SC et al. 2024]





PNG with SKAO HI intensity mapping

[SC et al. 2013]



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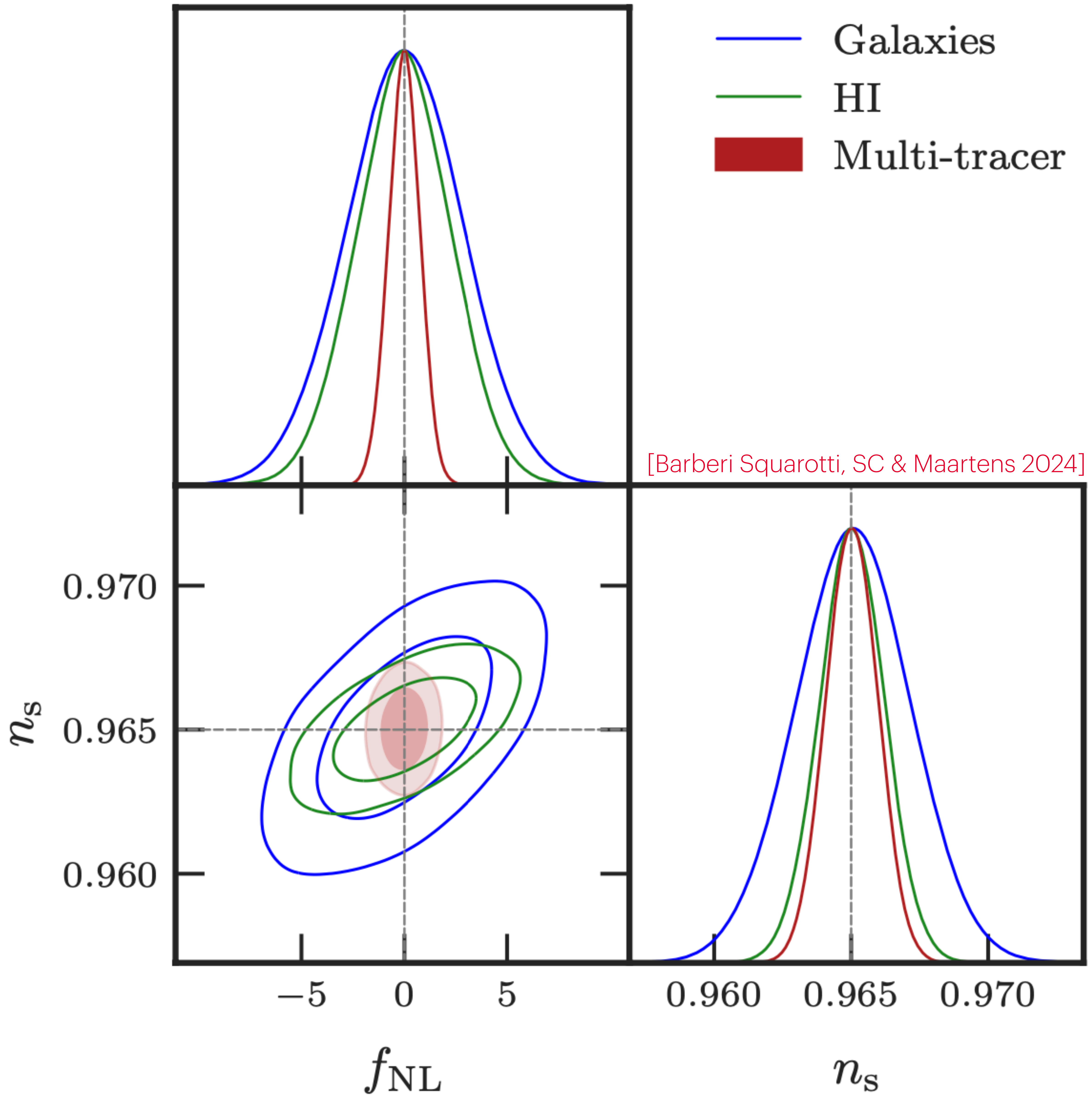
PNG with SKAO HI intensity mapping



[Barberi Squarotti, SC & Maartens 2024]

PNG with SKAO HI intensity mapping

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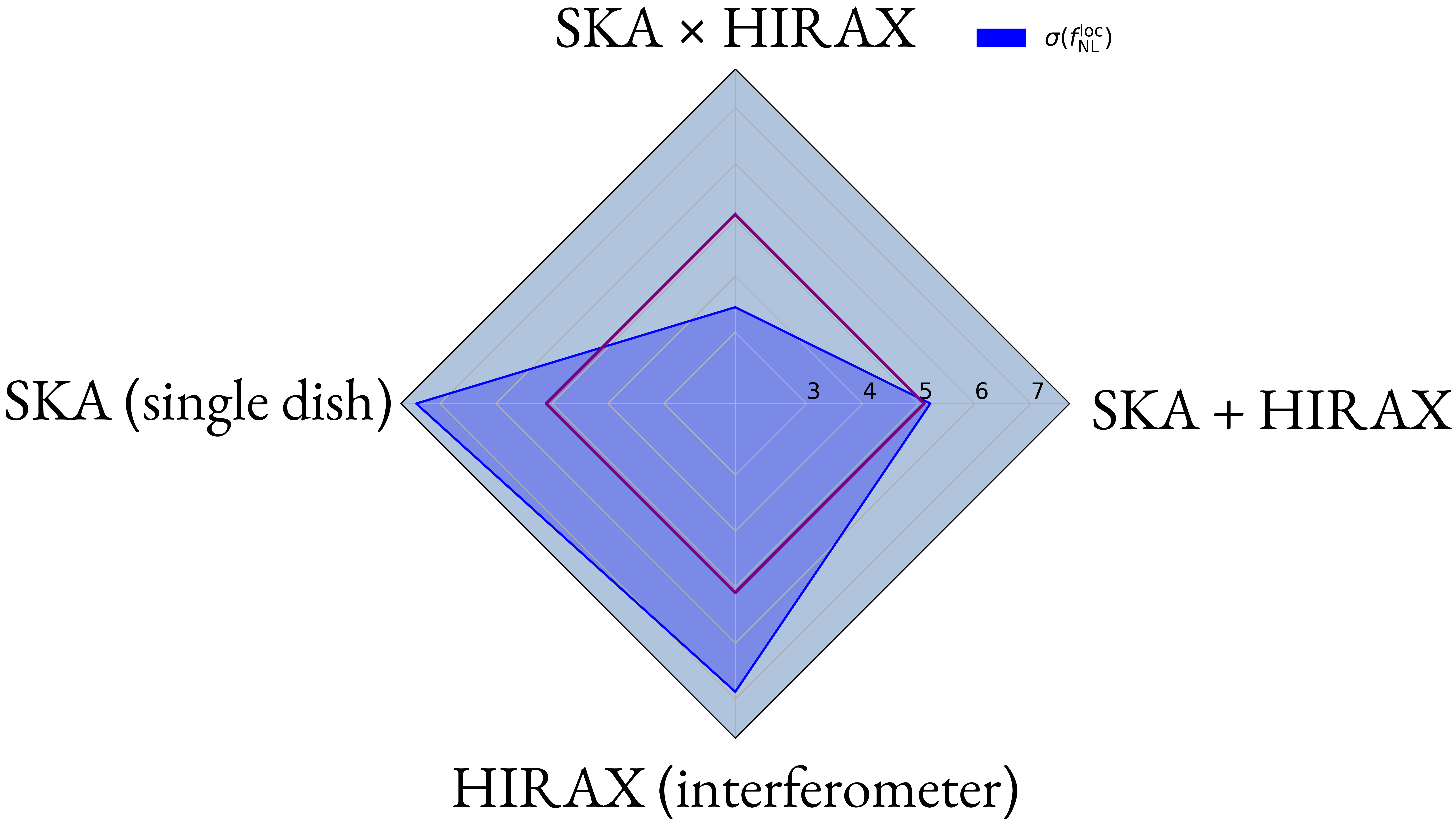
$$\langle \Delta^{\rm IF}(\boldsymbol{k}_1)\,\Delta^{\rm IF}(\boldsymbol{k}_2)\,\Delta^{\rm SD}(\boldsymbol{k}_3)\rangle = (2\,\pi)^3\,\delta_{\rm (D)}(\boldsymbol{k}_{123})\,B_\Delta^{\rm SD\times IF}(\boldsymbol{k}_1,\boldsymbol{k}_2,\boldsymbol{k}_3)$$

[Karagiannis et al. ⊃ SC 2024]

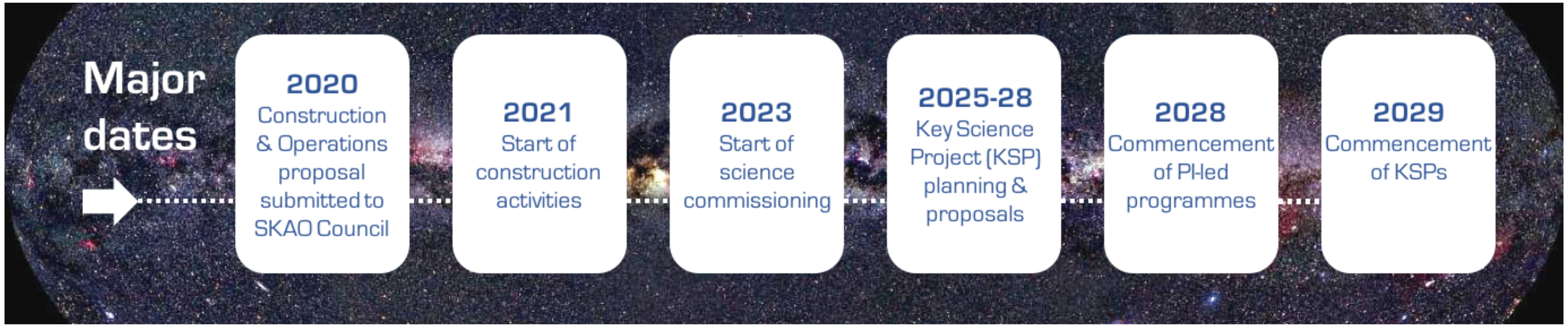
PNG with SKAO HI intensity mapping

$$\langle \Delta^{\rm IF}(\boldsymbol{k}_1)\,\Delta^{\rm IF}(\boldsymbol{k}_2)\,\Delta^{\rm SD}(\boldsymbol{k}_3)\rangle = (2\,\pi)^3\,\delta_{\rm (D)}(\boldsymbol{k}_{123})\,B_\Delta^{\rm SD\times IF}(\boldsymbol{k}_1,\boldsymbol{k}_2,\boldsymbol{k}_3)$$

[Karagiannis et al. ⊃ SC 2024]

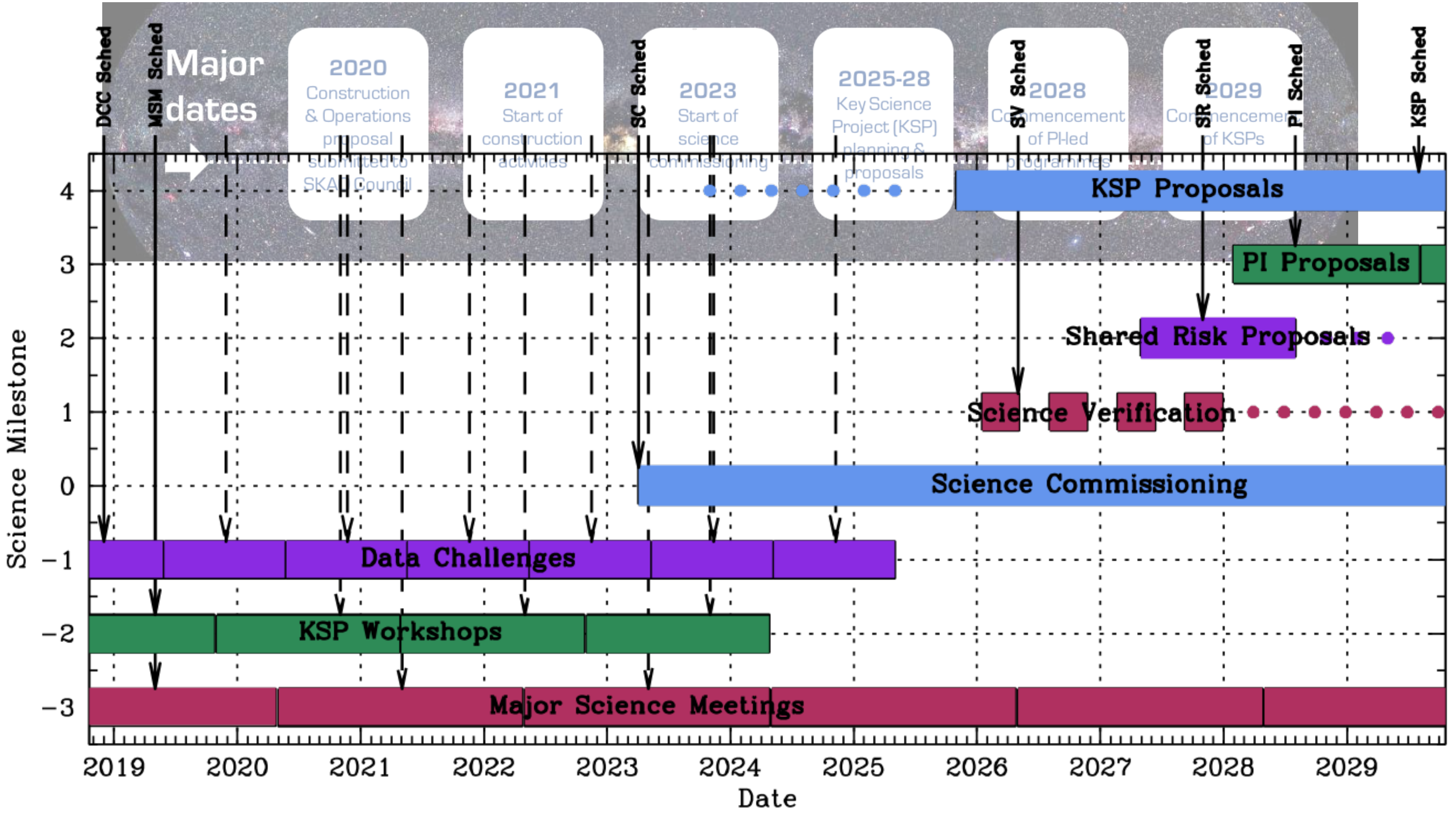


Towards the SKAO



Towards the SKAO

[Credits: R. Braun]



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Towards the SKAO

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[Courtesy of A. Bonaldi]

Precursors

Located at future SKA sites (South Africa and Australia)

Towards the SKAO

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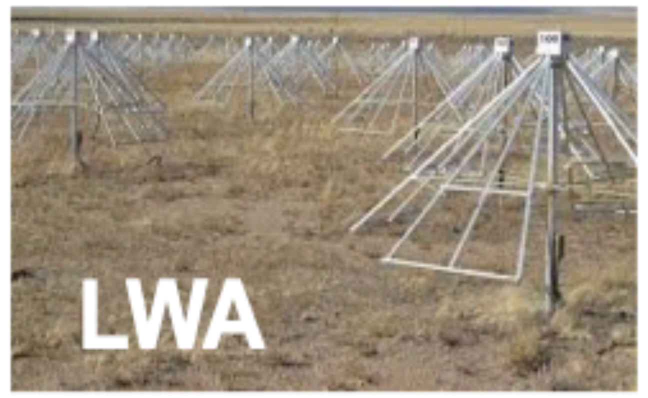
[Courtesy of A. Bonaldi]

Precursors

Located at future SKA sites (South Africa and Australia)

Pathfinders

Engaged in SKA related technology and science studies



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: 900-1670 MHz ($z < 0.58$)

[Santos et al. ⊃ SC 2016]

PoS PROCEEDINGS OF SCIENCE

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

- Detection of baryon acoustic oscillations using HI

[Santos et al. ⊃ SC 2016]