

(My) Highlights* from the New SKA Science Book

* extragalactic

Mark Sargent



Collaborators: I. Prandoni (INAF-IRA), H. Algera (ASIAA), O. Bait (NRAO), D. Schaerer (UniGE), J. Moldon (IAA Granada), R. Coogan (U. of Sussex/CEA)

OUTLINE

Part I – single-band, multi-tiered surveys for galaxy evolution:

- Revisiting the “reference survey” scenario (feasibility, target populations)

Part II - multi-band surveys for galaxy evolution:

- Requirements
- A scenario for a resolution-matched (and partially area-matched) LOW+MID survey
- Depth & confusion noise
- Some science nuggets

TIERED (SINGLE-BAND) CONTINUUM SURVEYS WITH SKA

Reference scenario: still viable

PoS PROCEEDINGS OF SCIENCE

Revealing the Physics and Evolution of Galaxies and Galaxy Clusters with SKA Continuum Surveys*

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In this chapter we provide an overview of the science enabled by radio continuum surveys in the SKA era, focusing on galaxy/galaxy cluster physics and evolution studies, and other relevant continuum science in the > 2020 scientific framework. We outline a number of reference radio-continuum surveys for SKA1 that can address such topics, and comprehensively discuss the most critical science requirements that we have identified. We highlight what should be achieved

Prandoni & Seymour (2015)

Draft contribution to Advancing Astrophysics: Preparing for Science with the SKAO



Opening new parameter space windows on galaxy/AGN co-evolution with SKA radio continuum surveys

Isabella Prandoni,¹ Mark T. Sargent,² Matteo Bonato,^{1,3} Dharam V. Lal,⁴ Masoumeh Ghasemi-Nodehi,⁵ Mahdiyar Mousavi-Sadr,⁶ Nicholas Seymour,⁷ Fatemeh S. Tabatabaei,⁶ Gianfranco De Zotti,⁸ Ivano Baronchelli,^{1,3} Elisabetta Liuzzo,^{1,3} Nicola Marchili,^{1,3} Marcella Massardi^{1,3} and Rosita Paladino^{1,3}
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In this chapter we provide an overview of the science enabled by extragalactic radio continuum surveys in the SKA era, focusing on galaxy/AGN co-evolution

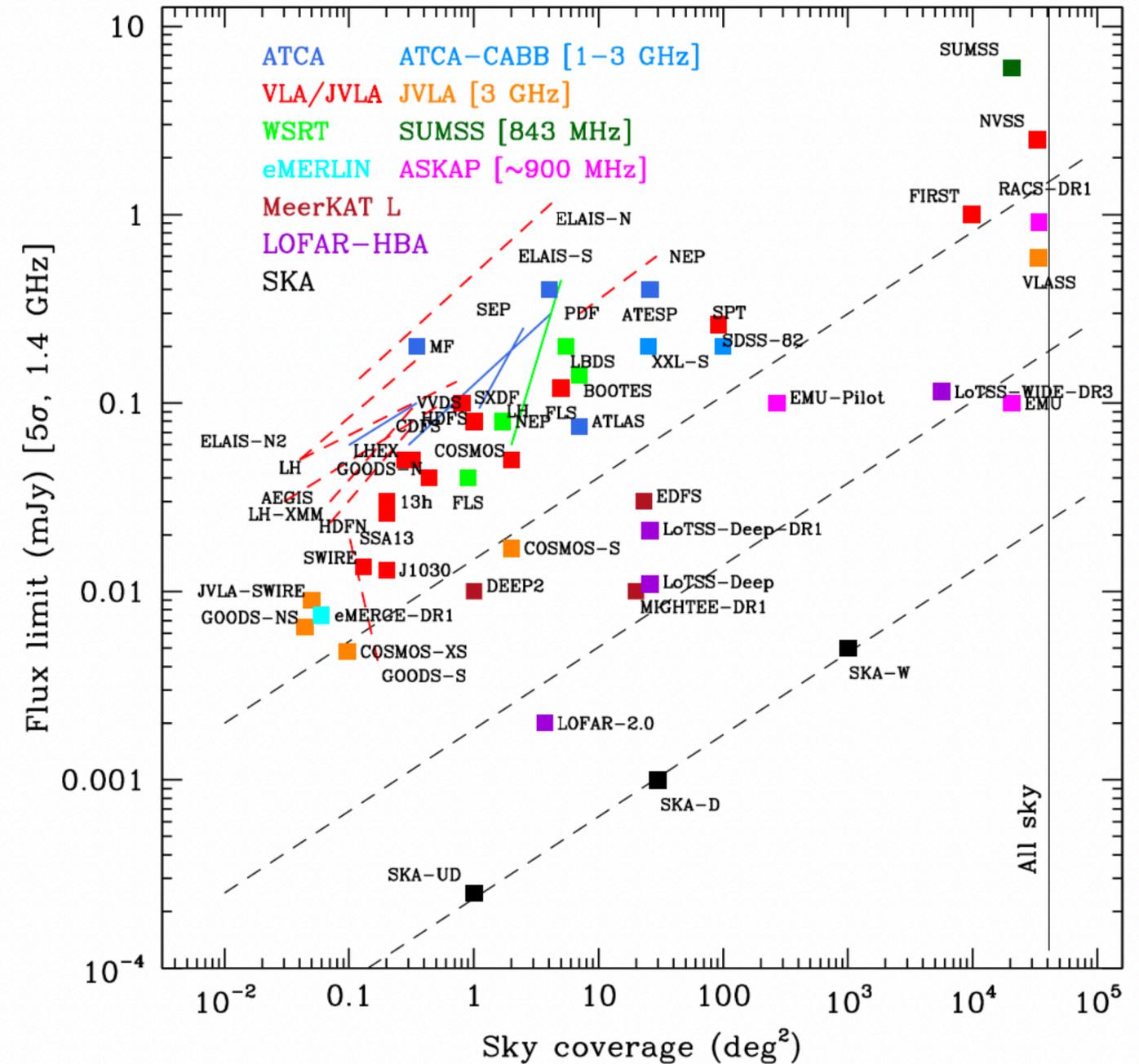
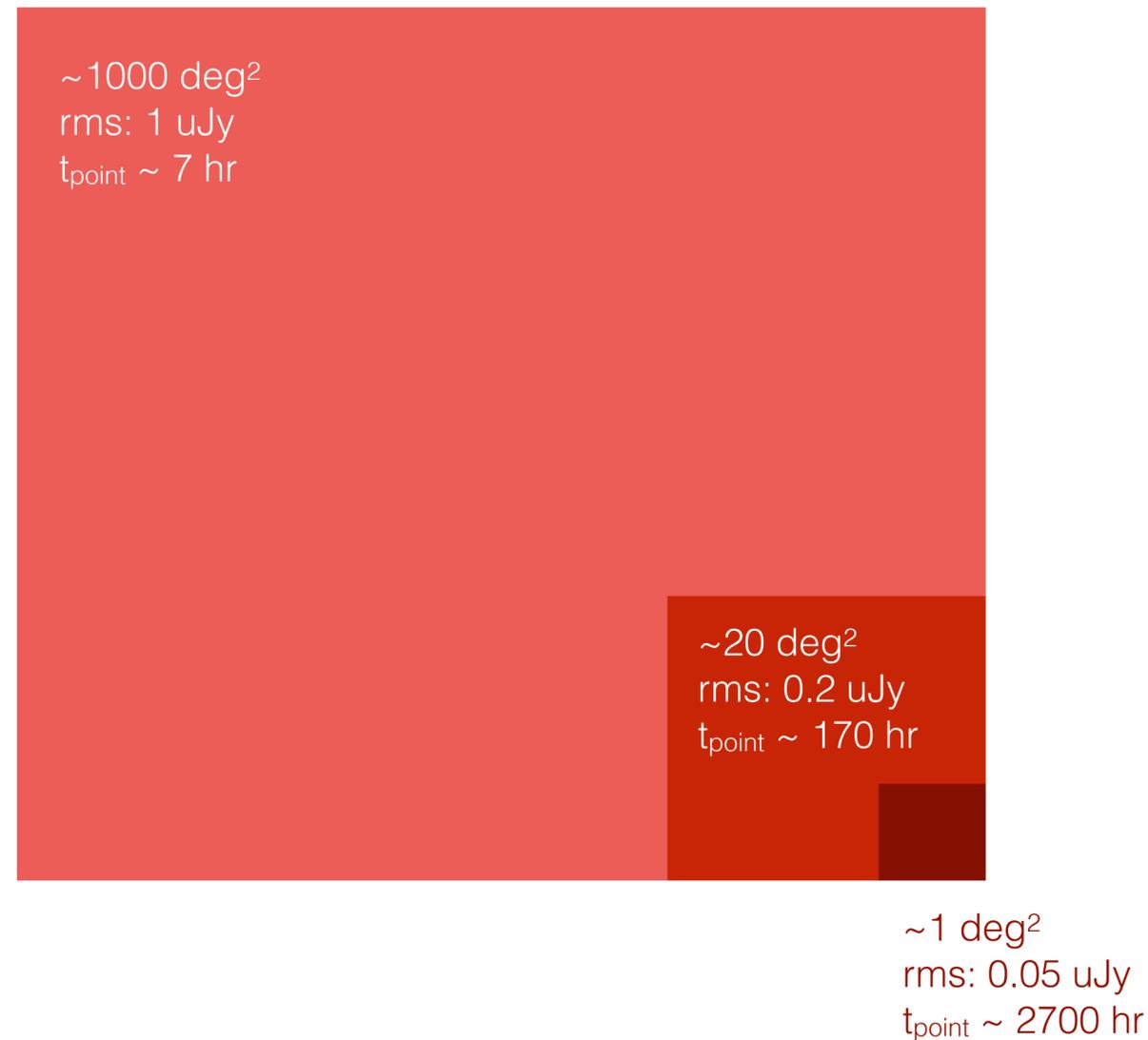
Prandoni, Sargent et al. (2026)

TIERED (SINGLE-BAND) CONTINUUM SURVEYS WITH SKA

Reference scenario: still viable

Band 2 (1.4 GHz)

$\leq 0.5''$ resolution; BW = 0.34 GHz



TIERED (SINGLE-BAND) CONTINUUM SURVEYS WITH SKA

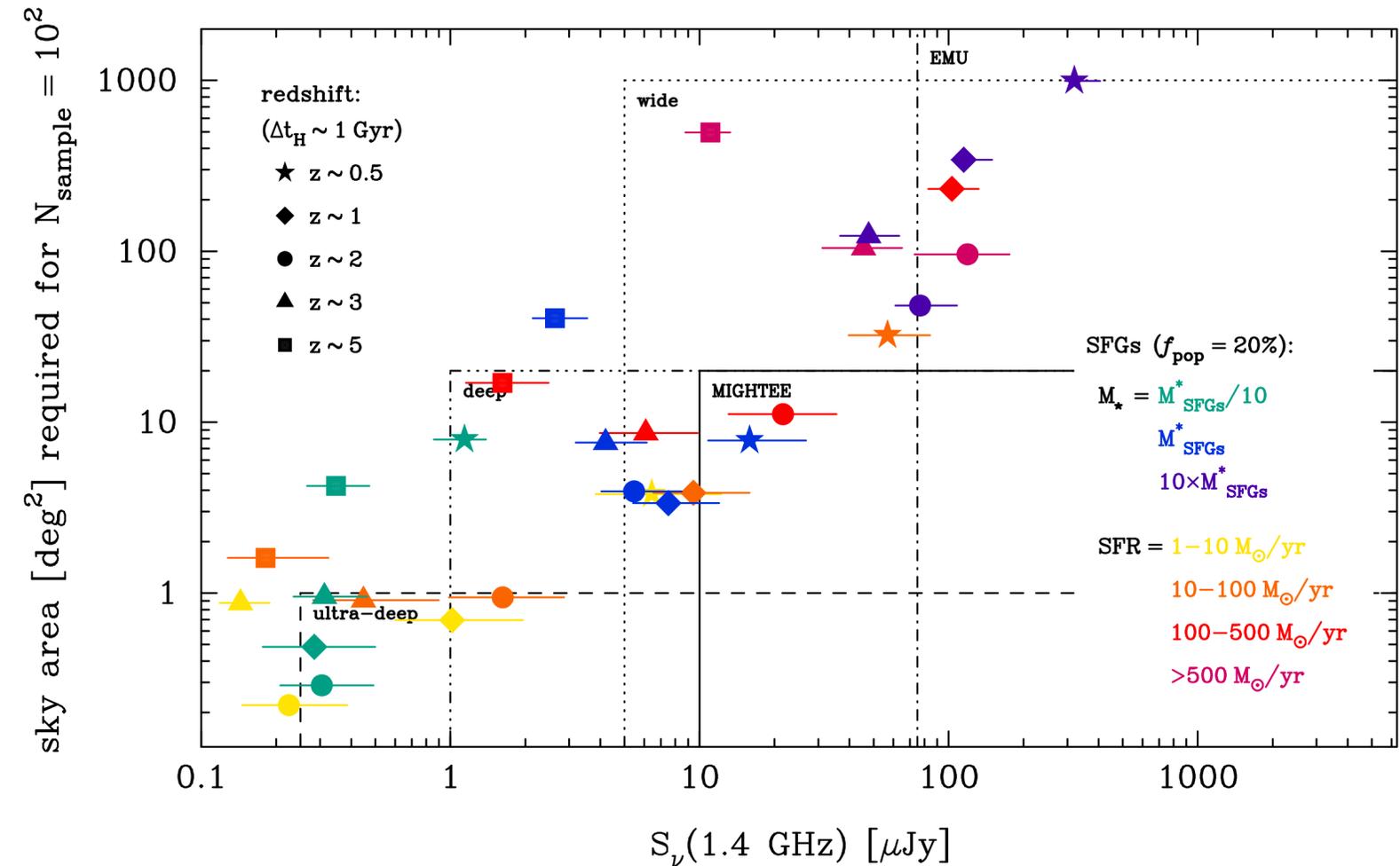
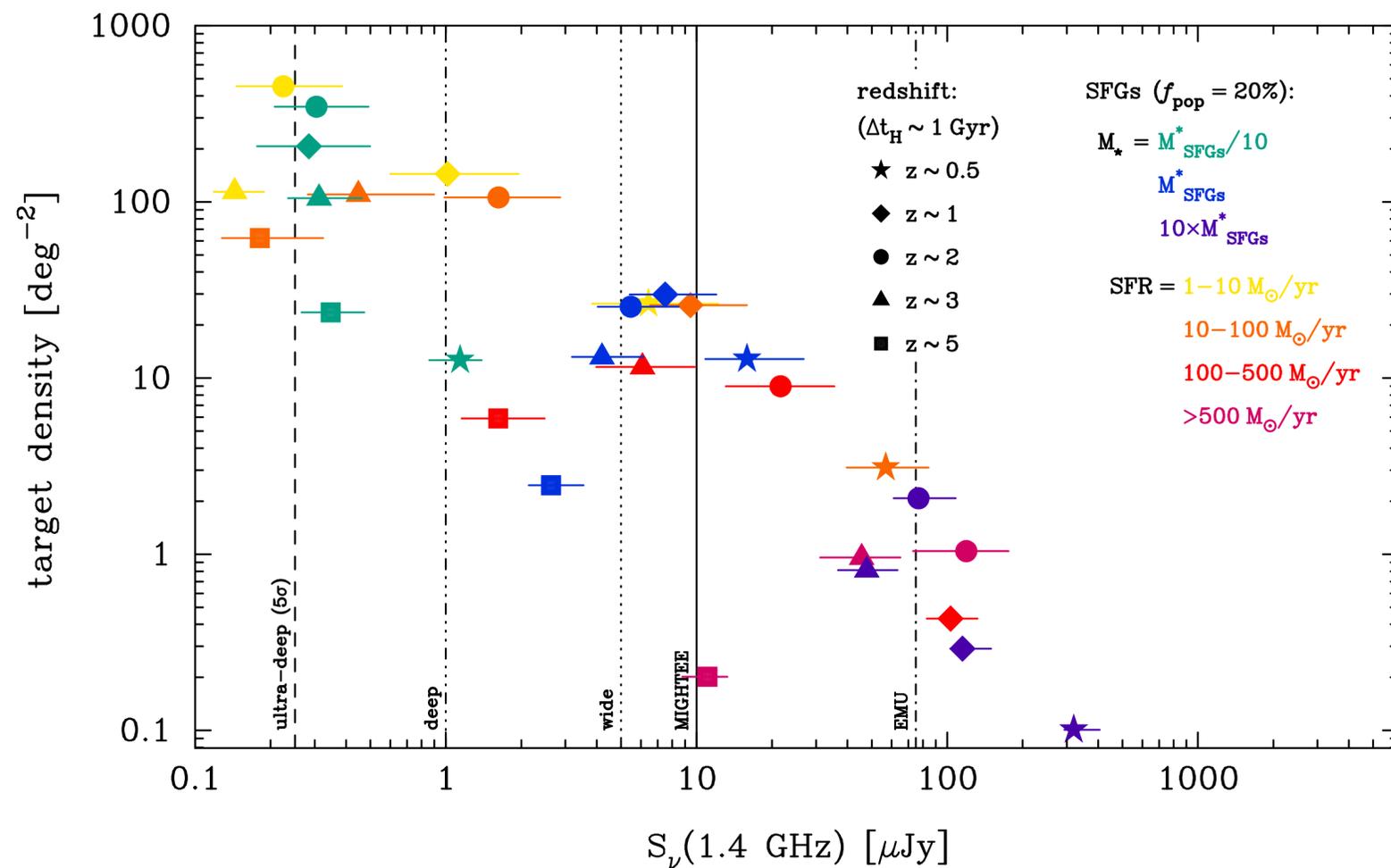
Which populations will we detect*? - Star-forming galaxies (SFGs)...

*This prediction is based on the T-RECS simulations; Bonaldi et al. (2023)

TIERED (SINGLE-BAND) CONTINUUM SURVEYS WITH SKA

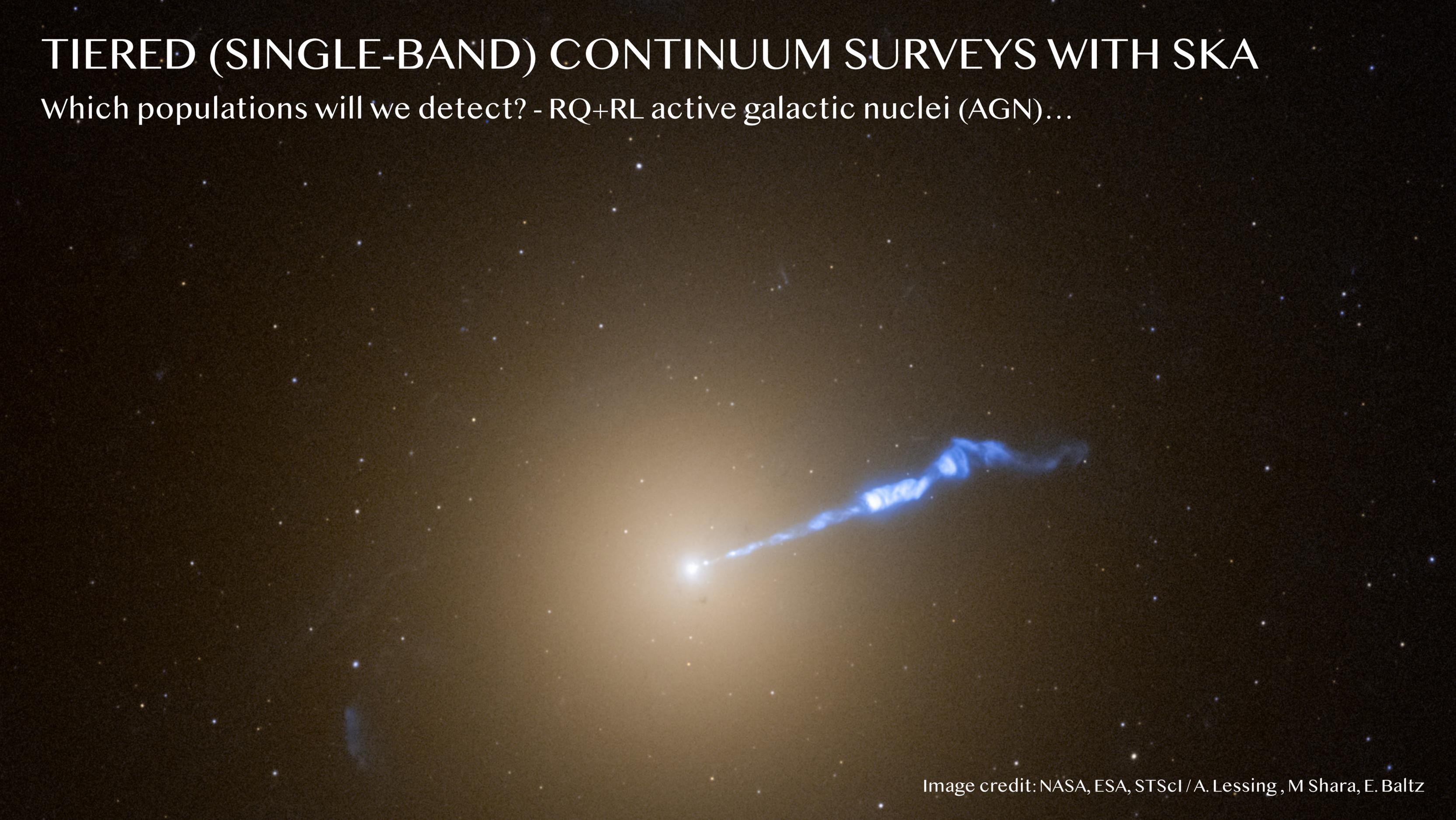
Which populations will we detect? - Star-forming galaxies (SFGs)...

- “Normal” SFGs even well below the knee of the stellar mass function can be detected throughout the peak epoch of galaxy formation (i.e. out to $z \sim 3$)
- Simultaneous increase of depth & area w.r.t. precursor surveys is key for multivariate studies of SFGs!



TIERED (SINGLE-BAND) CONTINUUM SURVEYS WITH SKA

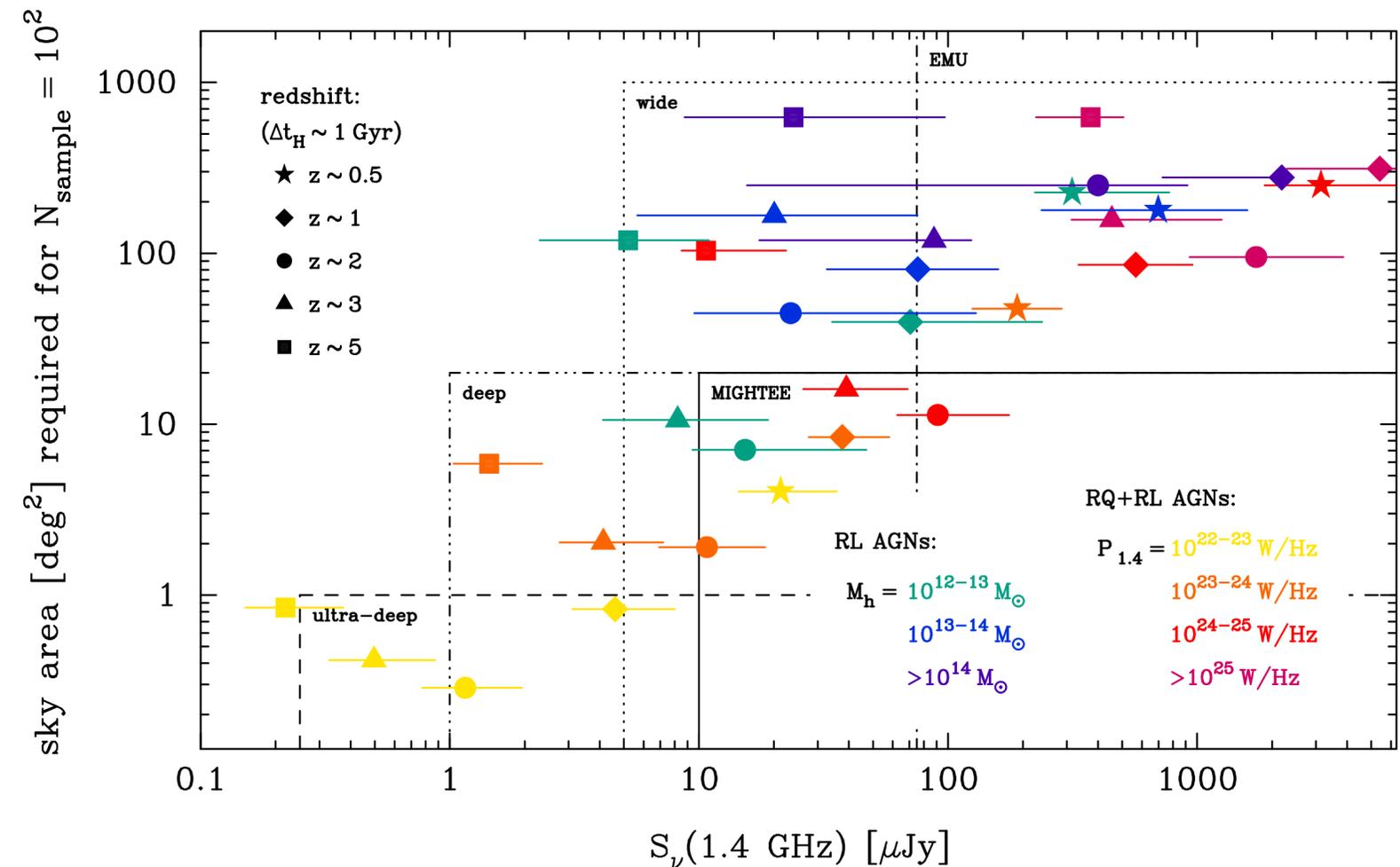
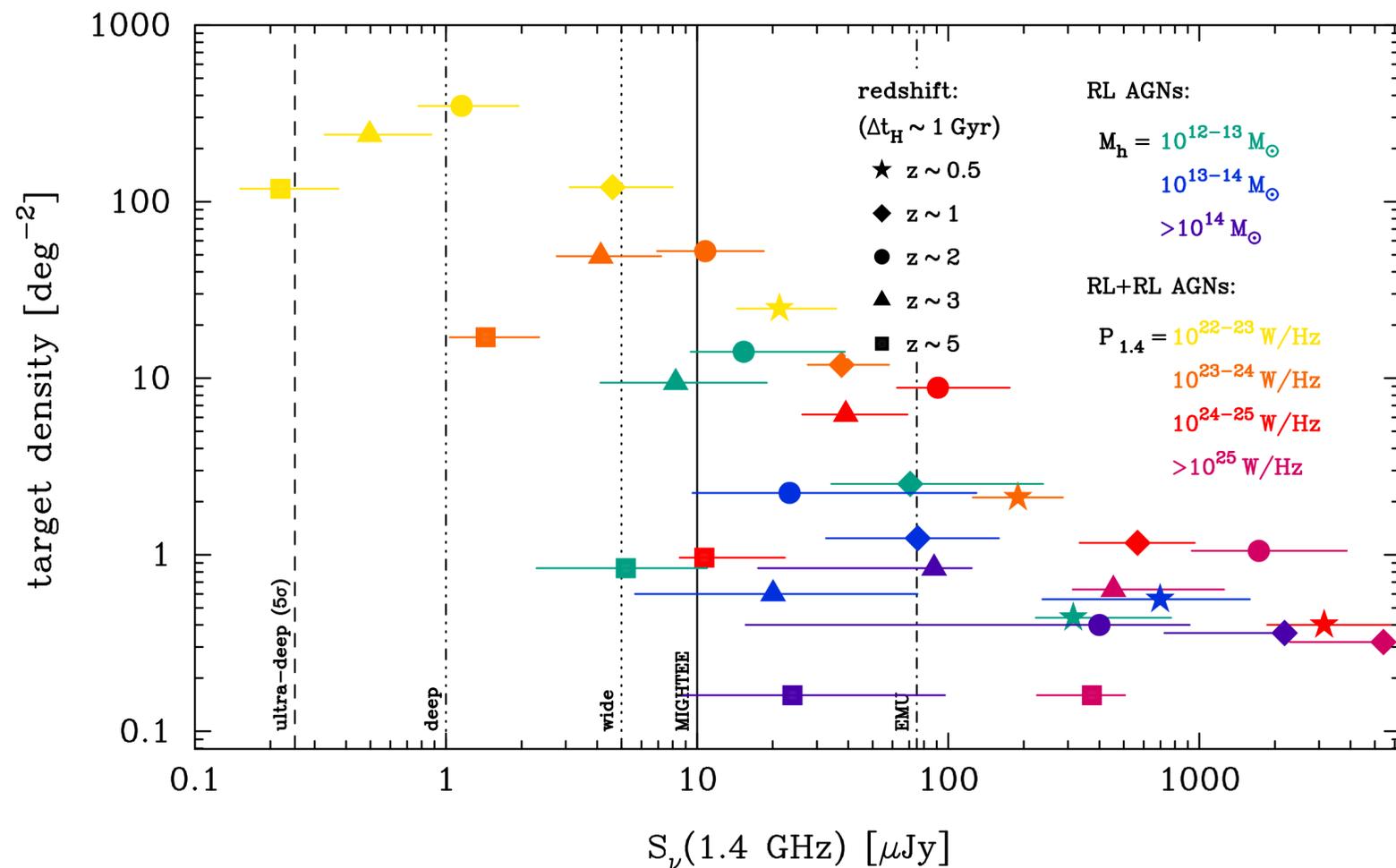
Which populations will we detect? - RQ+RL active galactic nuclei (AGN)...



TIERED (SINGLE-BAND) CONTINUUM SURVEYS WITH SKA

Which populations will we detect? - RQ+RL active galactic nuclei (AGN)...

- ASKAP EMU traces the most luminous AGN and extreme environments, but only the SKA deep and wide tiers can fully sample fainter RL AGN and investigate radio-AGN feedback in lower mass DM halos.
- MIGHTEE can fully sample radio AGN up to redshifts $z \sim 2$, but only the SKA deep tier can push their study to higher redshift.



MULTI-FREQUENCY CONTINUUM SURVEYS WITH SKA

Wider range of astrophysical processes/properties & better precision of “core” observables

Draft contribution to Advancing Astrophysics: Preparing for Science with the SKAO

Star formation and Accretion in Nearby Galaxies

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Sargent³, E. Brinks⁴, R. D. Baldi⁵, S. Dey⁶, F. Tabatabaei⁷, K. Rubinur⁸,
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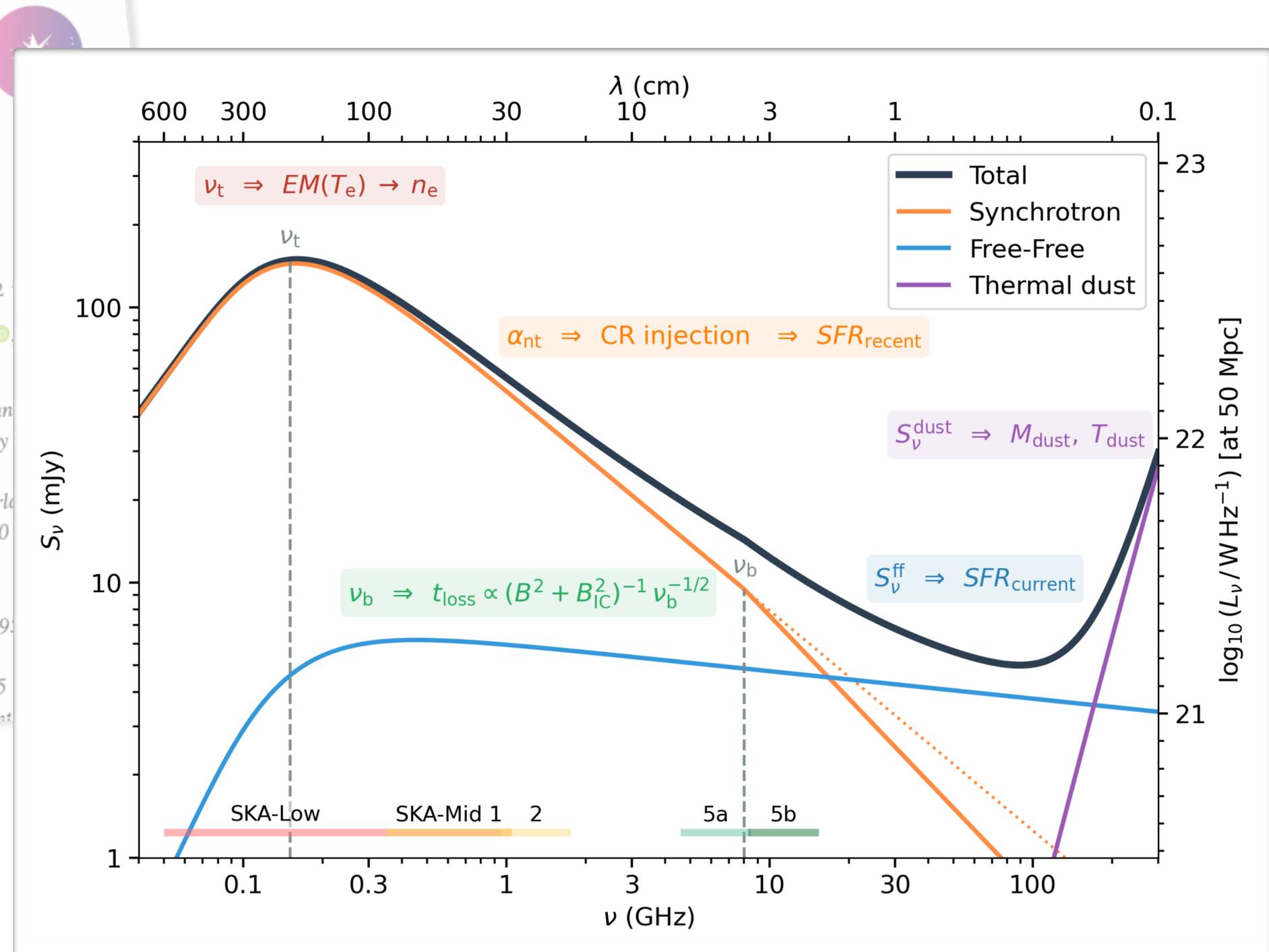
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Moldon, Beswick et al. (2026)

MULTI-FREQUENCY CONTINUUM SURVEYS WITH SKA

Wider range of astrophysical processes/properties & better precision of “core” observables

Draft contribution to *Advancing Astrophysics: Preparing for Science with the SKAO*



Probing the nature of Lyman continuum emitting and low-metallicity galaxies using the SKA

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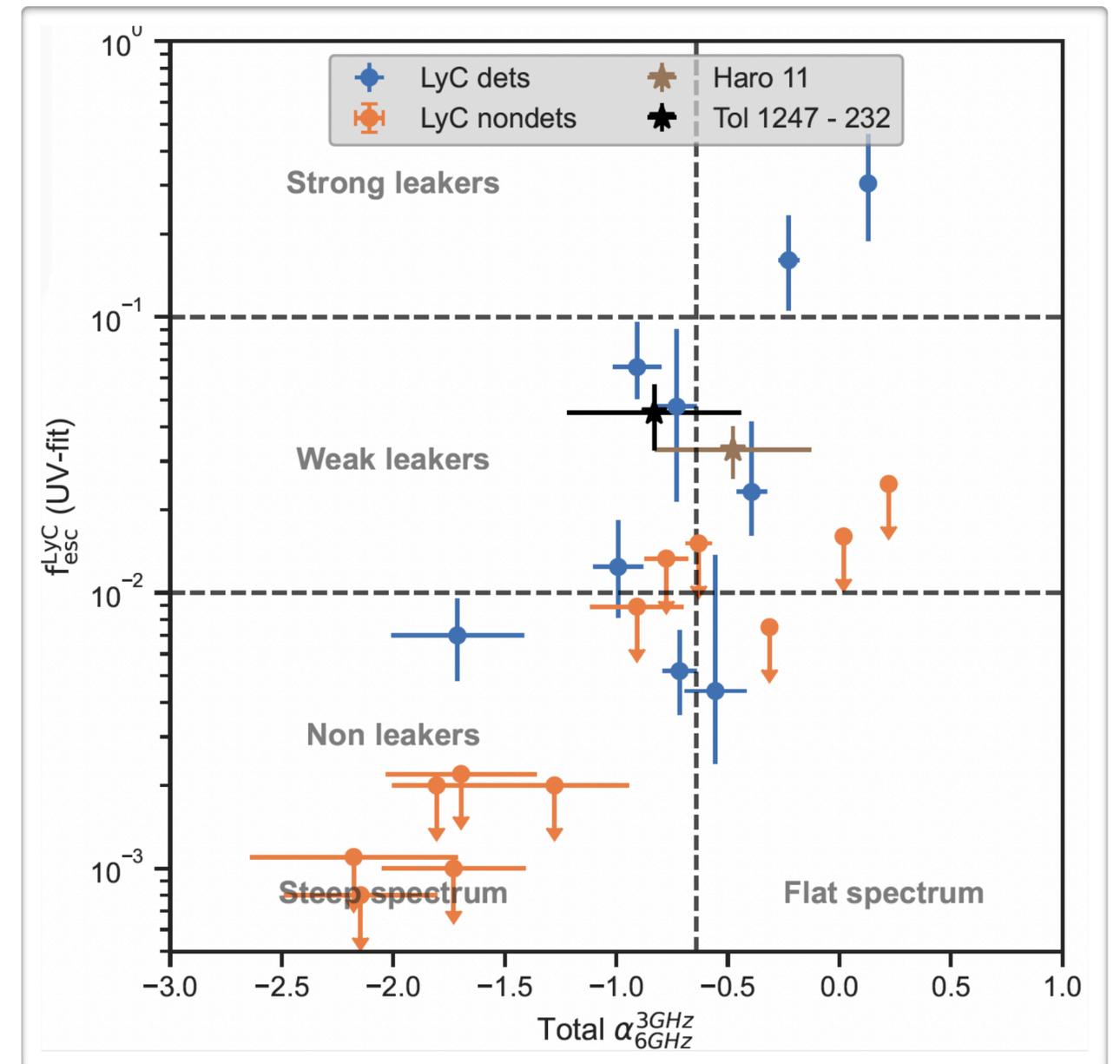
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The nature of the sources responsible for cosmic reionization remains a key open question in observational cosmology. Recent JWST results increasingly suggest

Bait, Schaerer & Sargent (2026)

(see also: Bait et al. 2024)

E.g., low-*z* EoR galaxy analogues – LyC escape fractions anti-correlate with starburst age:



MULTI-FREQUENCY CONTINUUM SURVEYS WITH SKA

Concepts for a deep, multi-band survey in AA4 for galaxy evolution science

Requirements.

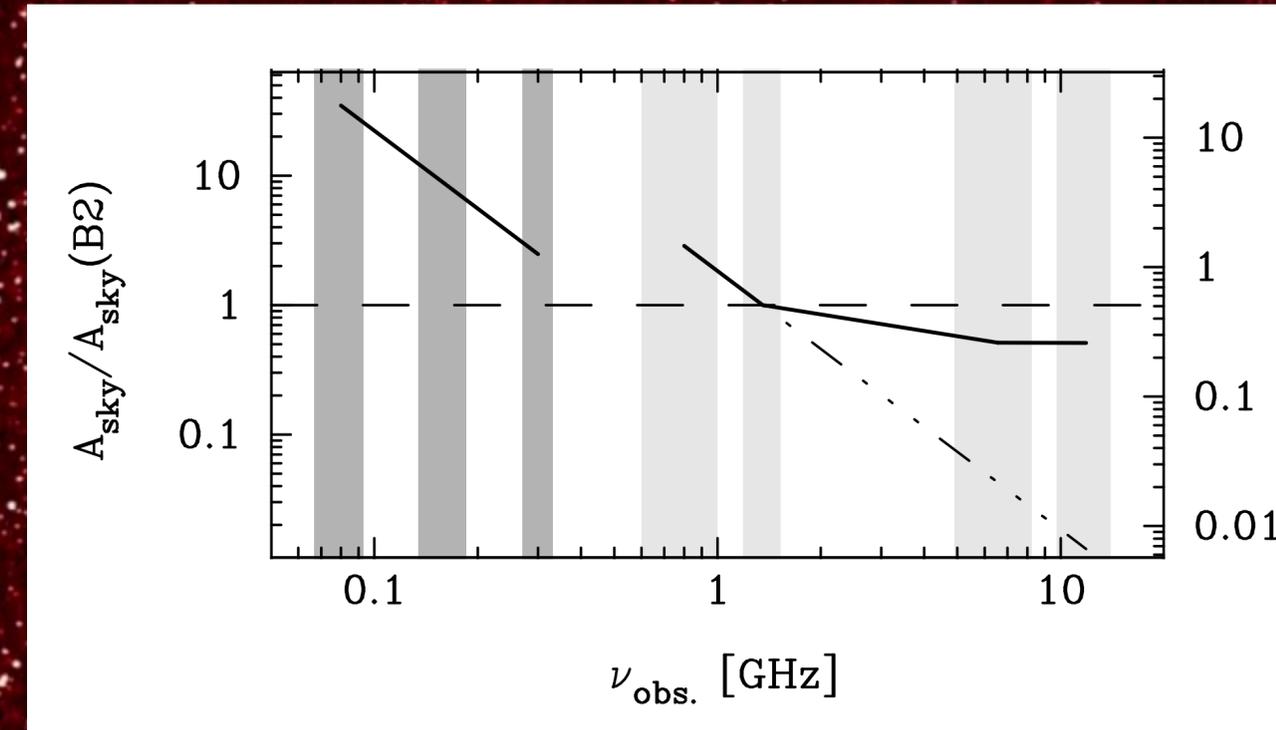
1. Span ~ 2 dex in frequency (0.15–15 GHz), with no more than 50% variation in angular resolution (and beam sizes varying no more than 10% between 300MHz and Band 5b),
2. Ensure that thermal noise remains at least a factor 1.5 above the confusion noise in all bands (i.e. confusion noise contributes $\lesssim 30\%$ to the total noise budget at the flux limit),
3. Achieve a sensitivity sufficient for a robust characterisation of the radio SEDs of (i) M^* galaxies ($\sim 5 \times 10^{10} M_{\odot}$) throughout the peak era of the cosmic SFH (out to $z \sim 3$), thereby jointly constraining the cosmic SFR density through both radio free-free and synchrotron emission, and (ii) galaxies with Milky Way-like SFRs ($1\text{--}10 M_{\odot}/\text{yr}$) out to $z \sim 1$, and
4. Cover at least 50% of the noise-equivalent field-of-view in band 2, i.e. a minimum of 0.25 deg^2 .

MULTI-FREQUENCY CONTINUUM SURVEYS WITH SKA

Concepts for a deep, multi-band survey in AA4 for galaxy evolution science

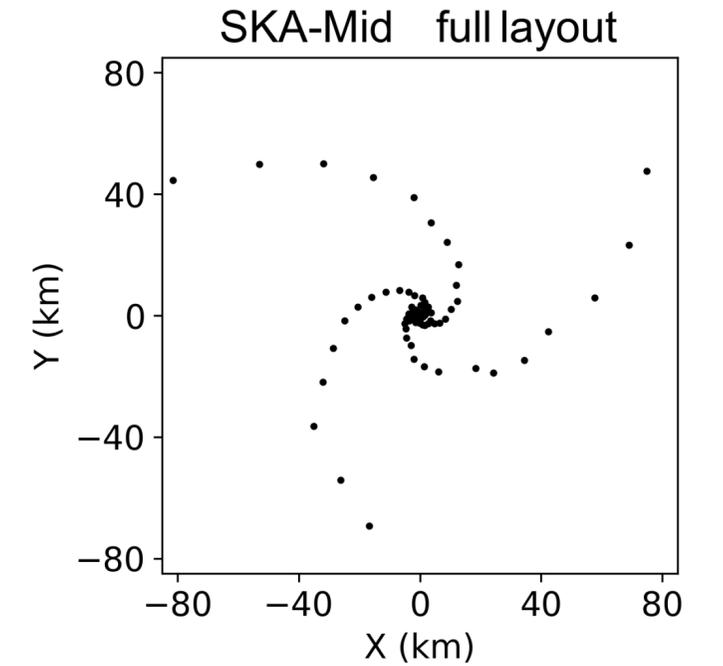
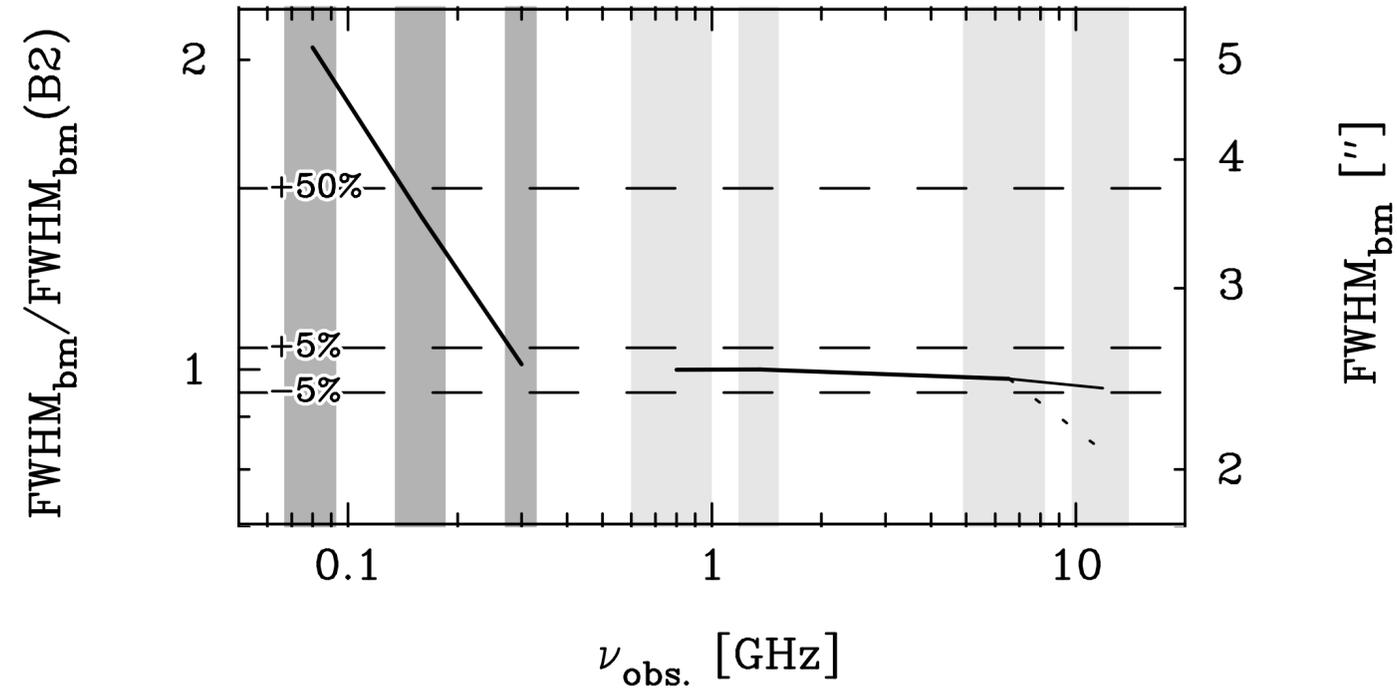
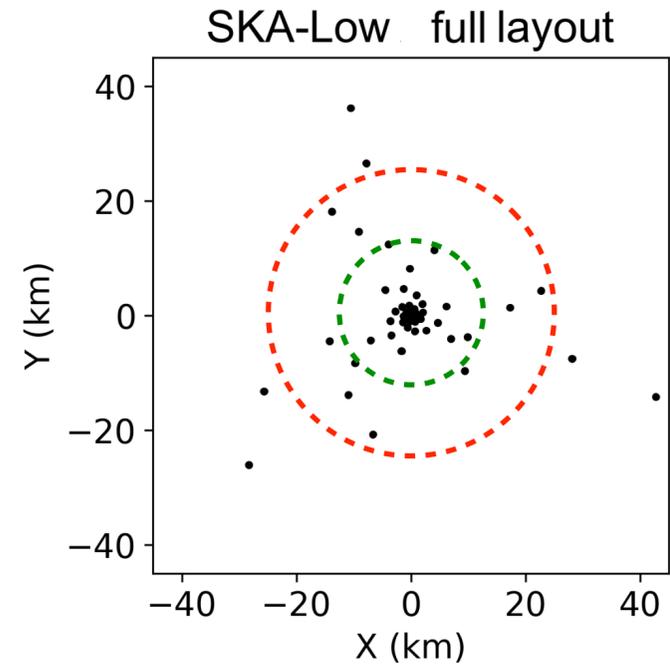
Set-up:

1. 7 bands distributed in ~ 0.3 dex increments in log frequency space across the full LOW and MID tuning ranges, with the exception of a larger gap at ~ 3 GHz (i.e. the inexistant band 3/4):
2. $d\nu = [0.3-0.5]*\nu$ if possible, taking into account (i.e. avoiding) known RFI regions
3. Survey field centred at Dec. = -45 deg (e.g., Euclid Deep Field-South)
4. Minimal sky area of 0.25 deg^2 : ~ 3 x the size of the combined GOODS-N/S fields, or about 10% of COSMOS. Requires a mosaic of 12 (39) pointings in Band 5a (5b).



MULTI-FREQUENCY CONTINUUM SURVEYS WITH SKA

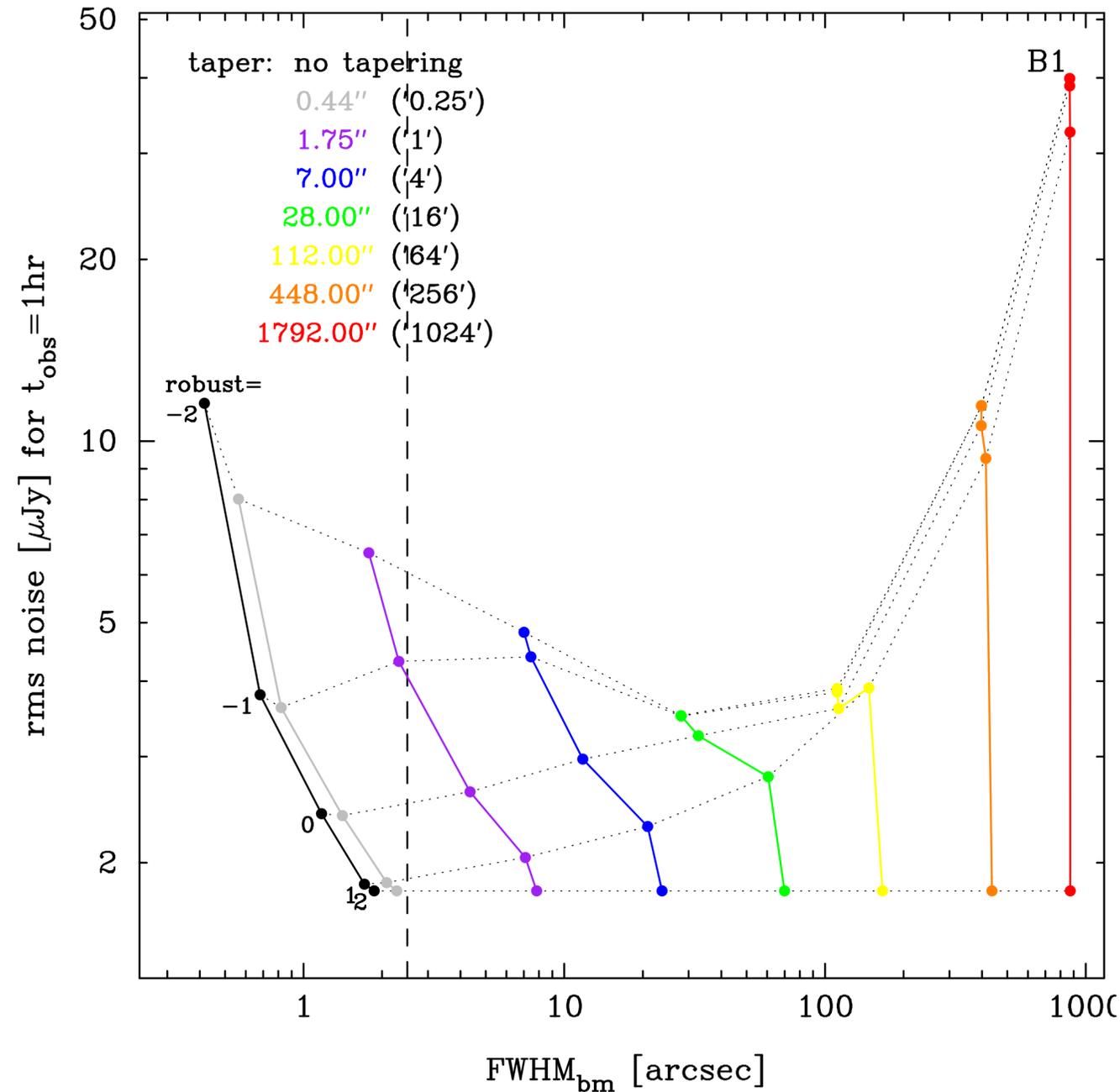
Angular resolution



telescope	array config.	tuning freq. ν_{ref} [GHz]	$\Delta\nu$ [GHz]	FWHM_{bm} [arcsec]	robust	taper [arcsec]
LOW	AA4 (outer 24 km)	0.080	0.026	5.14	-1	–
	AA4 (outer 12 km)	0.160	0.051	3.51	-1	–
	AA4	0.300	0.060	2.53	-1.5	–
MID	AA4	0.800 (B1)	0.400	2.50	1	0.54 (‘0.31’)
	AA4	1.355 (B2)	0.340	2.50	1	0.58 (‘0.56’)
	AA4	6.550 (B5a)	3.300	2.45	1	0.86 (‘4’)
	AA4	11.850 (B5b)	4.200	2.40	1	0.81 (‘6.82’)

MULTI-FREQUENCY CONTINUUM SURVEYS WITH SKA

Angular resolution: weighting followed by tapering best approach to minimizing noise



Uniform weighting (robust=-2):

Gives each scale the same weight by gridding. If multiple visibilities fall in one uv cell, they are down-weighted by the number of visibilities in that cell.

-> Finer angular res. at expense of higher image noise.

Natural weighting (robust=2):

Visibilities are not weighted before gridding, causing scales that have more baselines (usually: short baselines) to dominate the image.

-> Noise minimised, but poorer image resolution and side lobes.

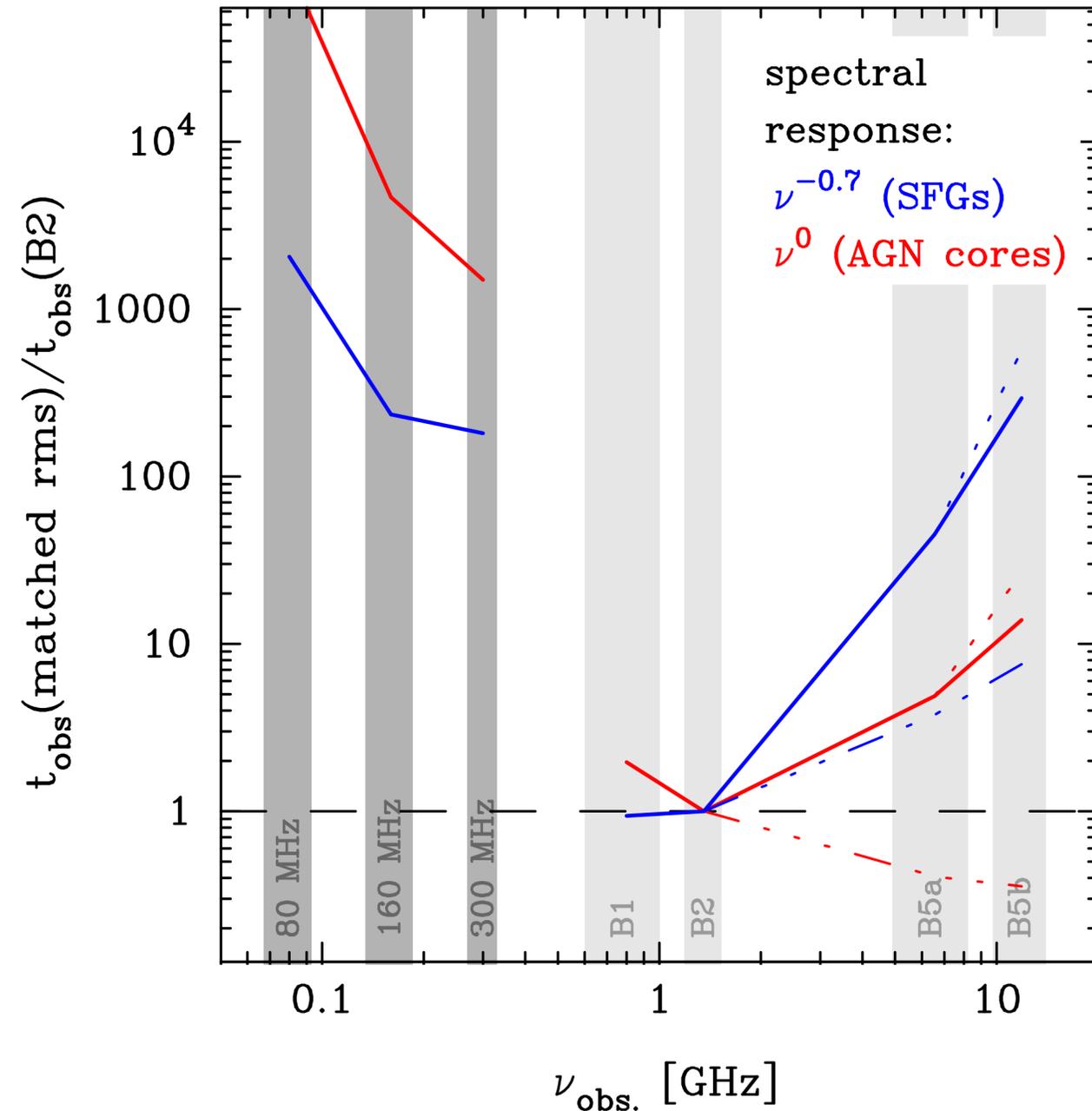
MULTI-FREQUENCY CONTINUUM SURVEYS WITH SKA

Observing times

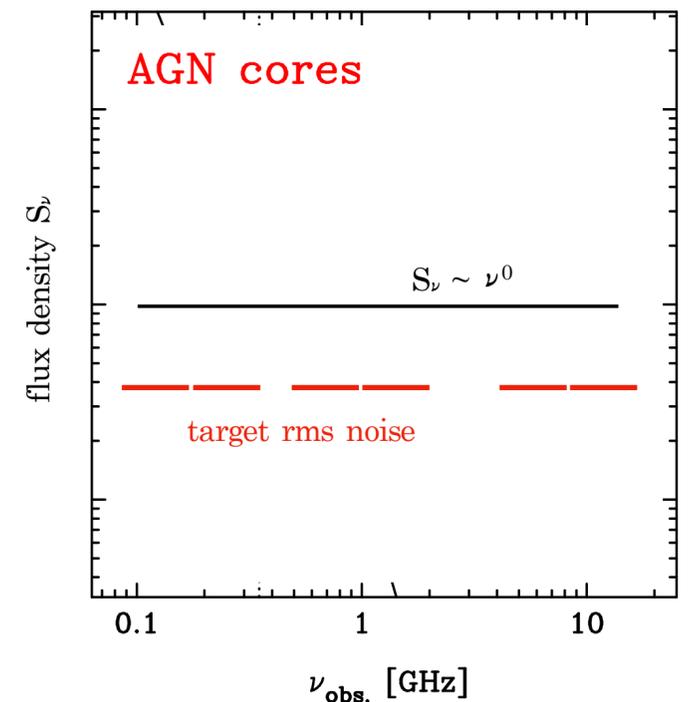
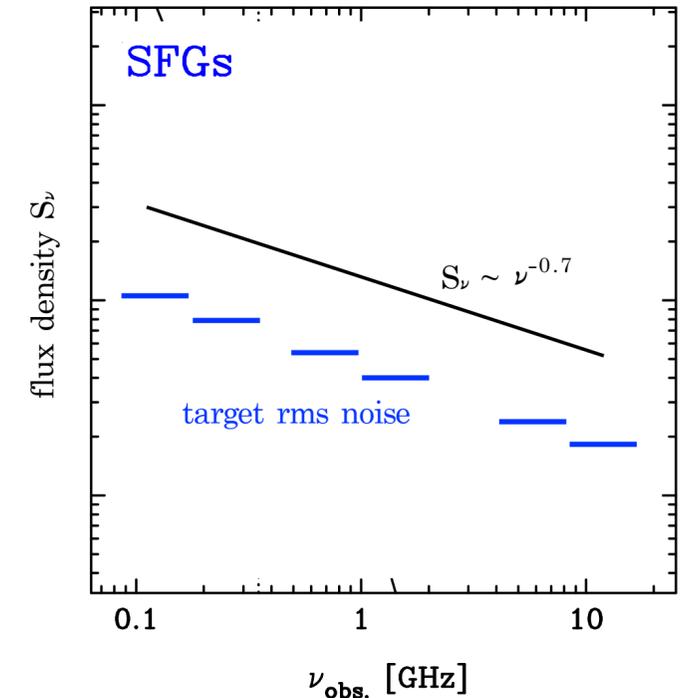
Total predicted survey times are dominated by:

- The LOW bands (due to sensitivity penalties when pushing the telescope to its high-resolution limit (through \sim uniform weighting and/or limitation to data from outer stations),
- Band 5a/b coverage (overcoming the intrinsically small FoV at high frequencies requires mosaicking).

N.B.: All LOW bands can be observed at once. (Inst. BW=300 MHz.)

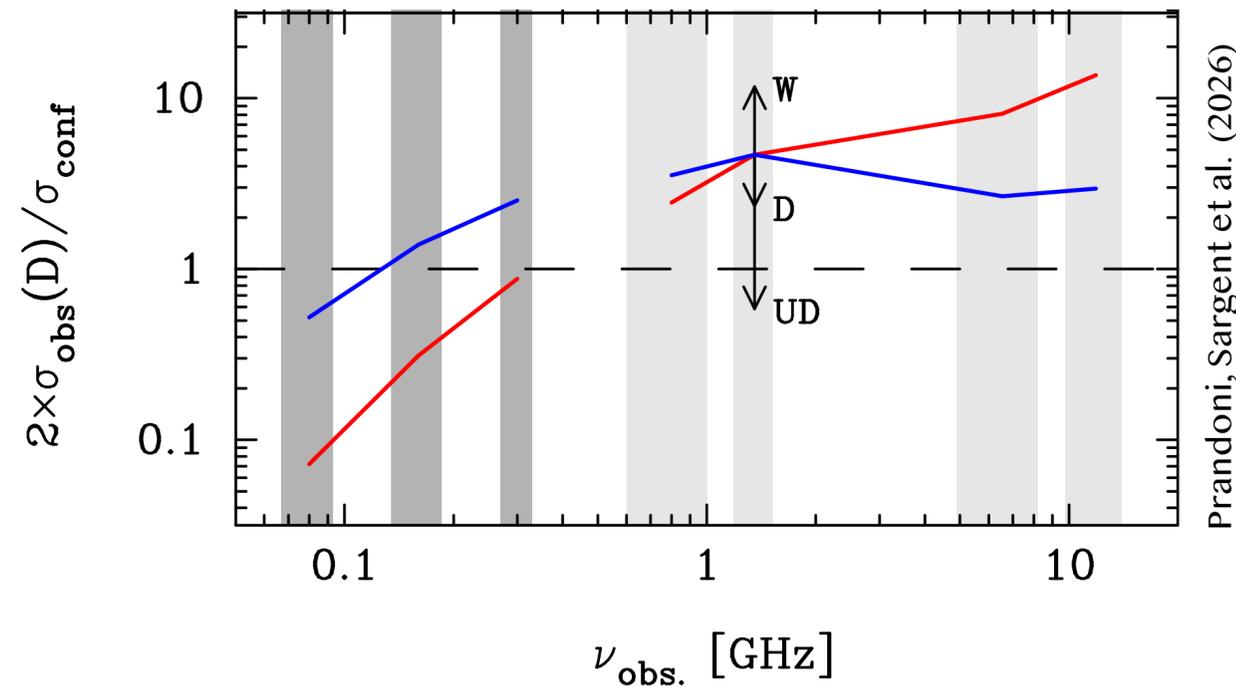


Prandoni, Sargent et al. (2026)



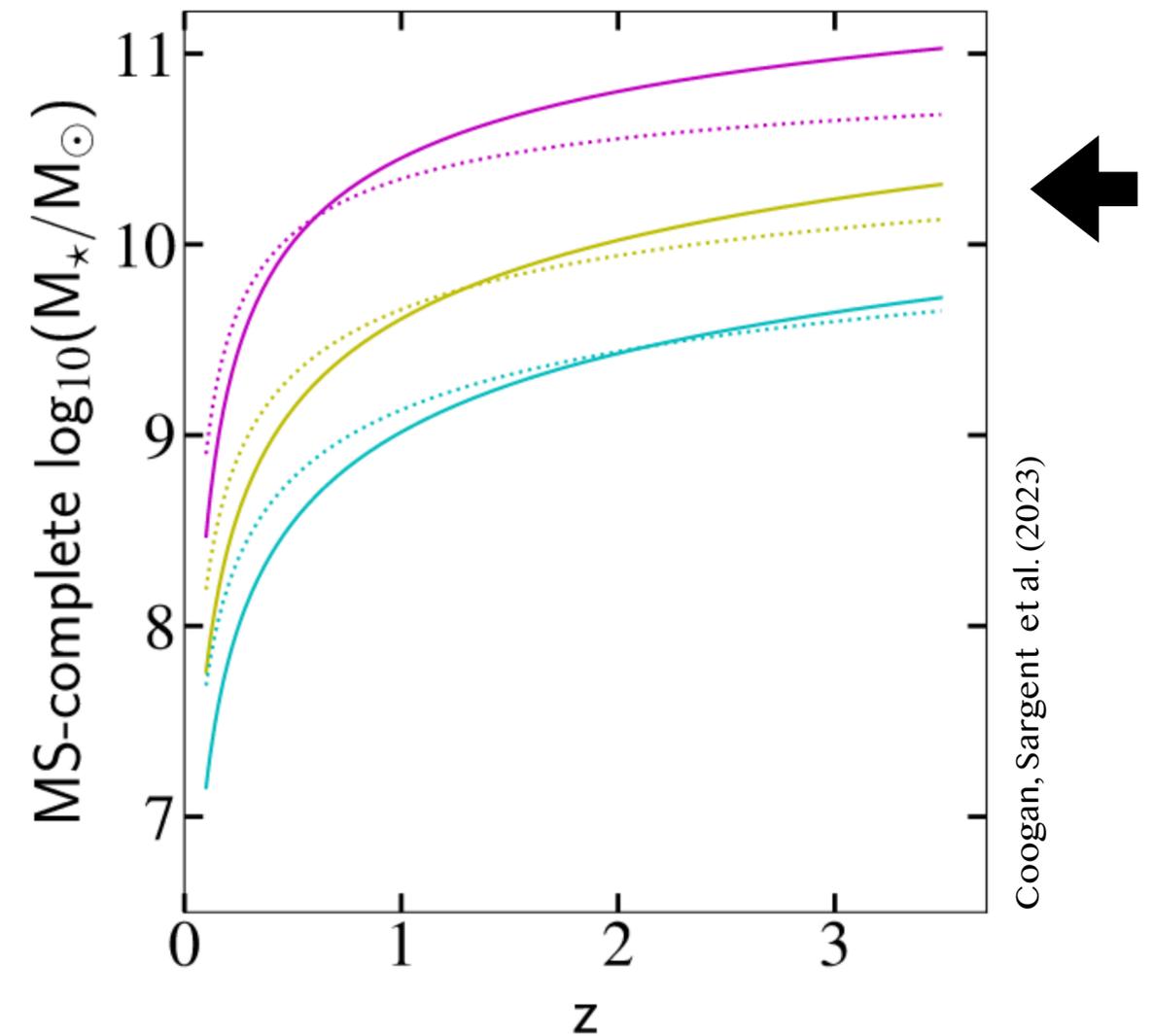
MULTI-FREQUENCY CONTINUUM SURVEYS WITH SKA

Depth & confusion noise



- Threshold $1.5 \times \sigma_{\text{conf}}$ is reached at an rms noise of $\sim 1.9 \mu\text{Jy/bm}$ at 160 MHz, corresponding to $0.4 \mu\text{Jy/bm}$ in band 2 for a $\nu^{-0.7}$ response.
This is 2x the nominal depth of the 'Deep' tier (with prior information, approx. equiv. sensitivity).
- Avoiding source confusion down to 160 MHz under a flat spectral response is only feasible in shallow fields.

Accounting for the evolution of galaxy SFRs to higher values, galaxies with Milky Way-Like masses are detectable in the Deep tier out to $z \sim 4$.



MULTI-FREQUENCY CONTINUUM SURVEYS WITH SKA

Wider range of astrophysical processes/properties & better precision of “core” observables

The knee of the SFR-function is constrained by free-free emission out to $z \sim 4$, facilitating a measurement of the cosmic star-formation history via thermal processes.

Chapter in *Advancing Astrophysics with the SKA - II*

Tracing the Star Formation History of the Universe through Thermal Free-Free Emission with the SKA

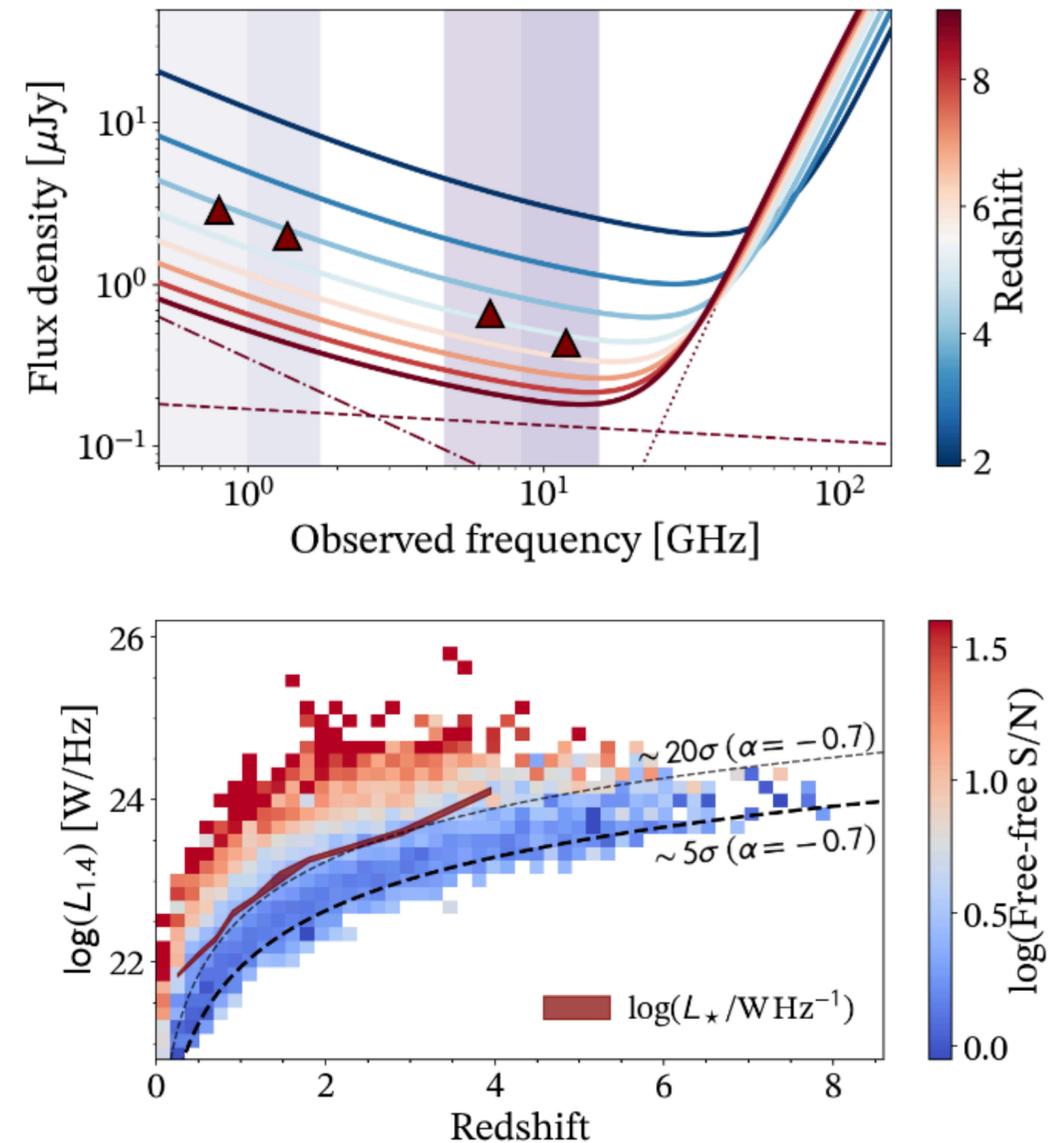
Hiddo S. B. Algera,¹ Mark Sargent,² Eric J. Murphy³ and Fangxia An⁴

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One of the major scientific aims of the SKA is to trace the history of star formation across cosmic time. High-frequency radio surveys are indispensable in this regard,

Algera, Sargent et al. (2026)



MULTI-FREQUENCY CONTINUUM SURVEYS WITH SKA

Some final thoughts

1. Legacy proposal requiring approx. ~5000 hrs. ➡ Value of each band needs to be thoroughly justified. E.g., could settle for just one high-resolution LOW band at 300MHz (with ~3'' resolution, via weighting with robust = -1). This would reduce the overall survey time by ~30%, but would still constrain the low-freq. spectral turn-over for cosmic noon galaxies.
2. Would make sense to begin work on such a multi-band survey by observing band 1 and band 2 already in AA*. This would change the overall project time minimally, but constitute close-to-optimal usage of AA* capabilities, in that survey speed is maximized for angular scales 1–2'' in AA* with band 1 & 2.
3. Multi-band & multi-tier? – Could add an AGN-focused wide tier (~10deg²) spanning 1-10 GHz with just 10% extra observing time.

SUMMARY

1. Multi-tier “reference surveys” for galaxy evolution in band 2:
 - Depth/sky coverage proposed ~10 yrs ago remain key to breach genuinely new parameter space.
 - Observing time requirements remained roughly the same also with new ETC.
2. Resolution-matched (and partially area-matched) LOW+MID multi-band surveys:
 - Focusing on galaxy-integrated (spatially unresolved) photometry over ~2 dex in frequency, for galaxy populations out to cosmic noon epoch ($z \sim 1-3$).
 - Employs sub-arraying and optimized weighting/tapering to achieve matched resolution ($\sim 2.5''$).
 - Avoidance of source confusion sets depth to intermediate (“Deep”) tier of multi-tiered reference survey for star-forming galaxies. A wide-area, shallower tier for AGN science could be added at quite small cost.
 - A legacy project (several 1000 hrs) for science currently in its infancy. — There’s much to be learned! Would also play key role for exploitation of single-band “workhorse” surveys.