(SKACH) Headline science in SKA1-MID band 6

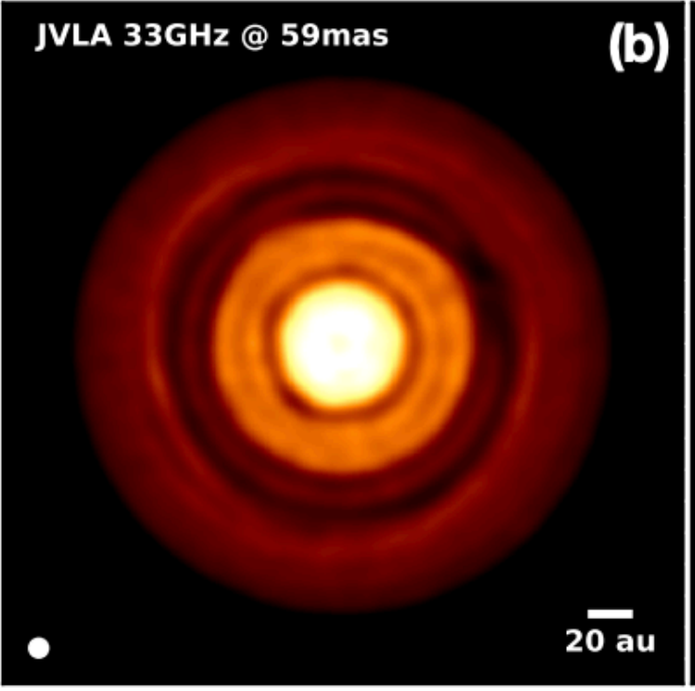
Mark Sargent (ISSI Bern)

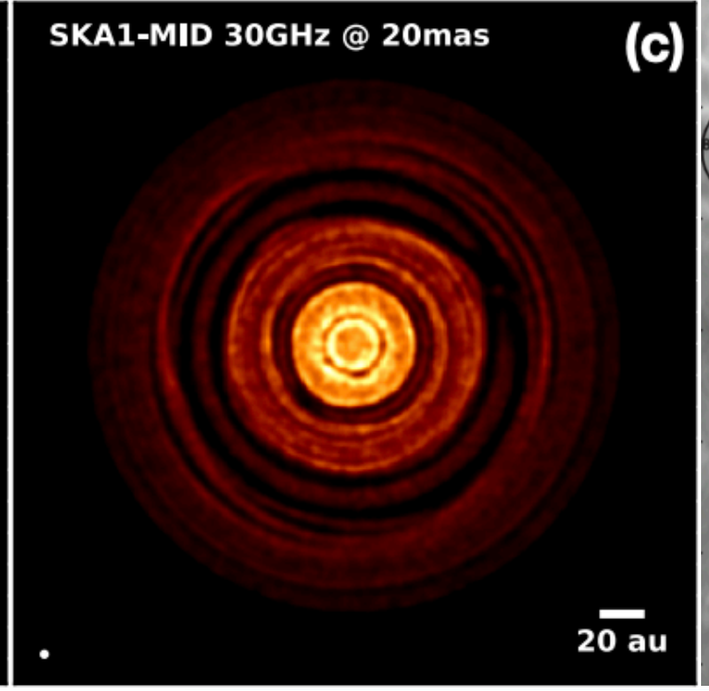
w/ thanks to

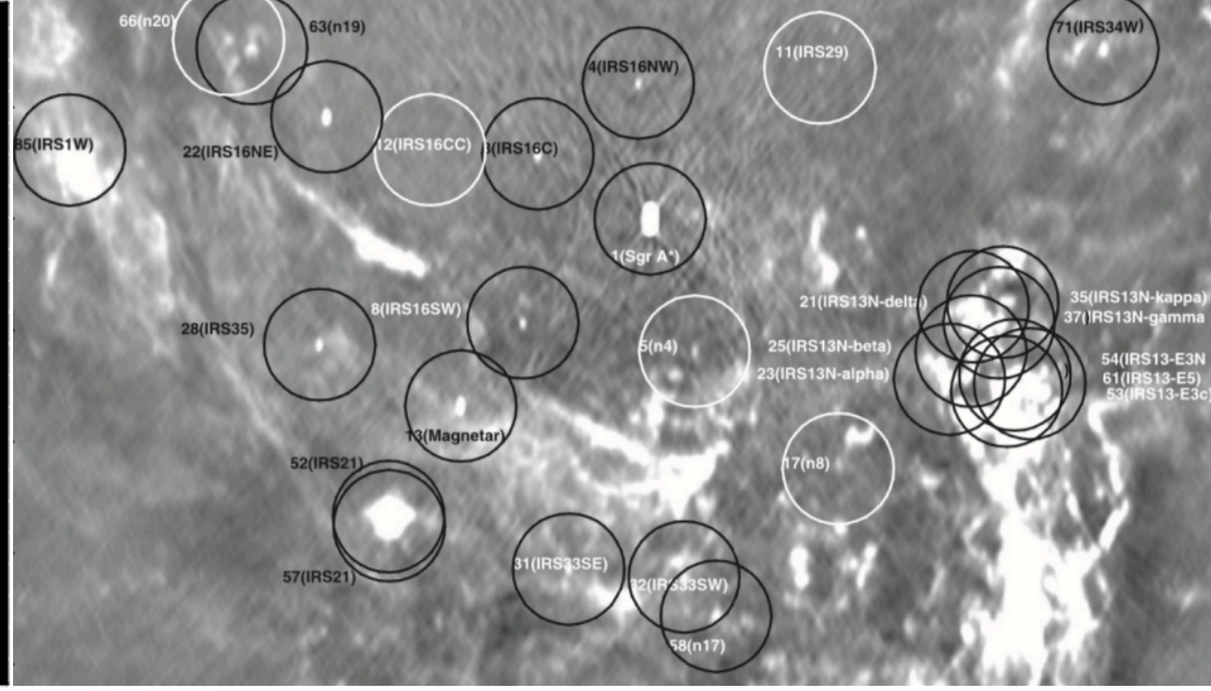
- J. Conway **(for the ASPFR consortium)**
- R. Beswick. M. Coriat, C. Ferrari, I. Jimenez-Serra, S. Mueller **(2019 int'l White Book coordination)**
- T. Bourke, J. Wagg **(for the SKAO)**

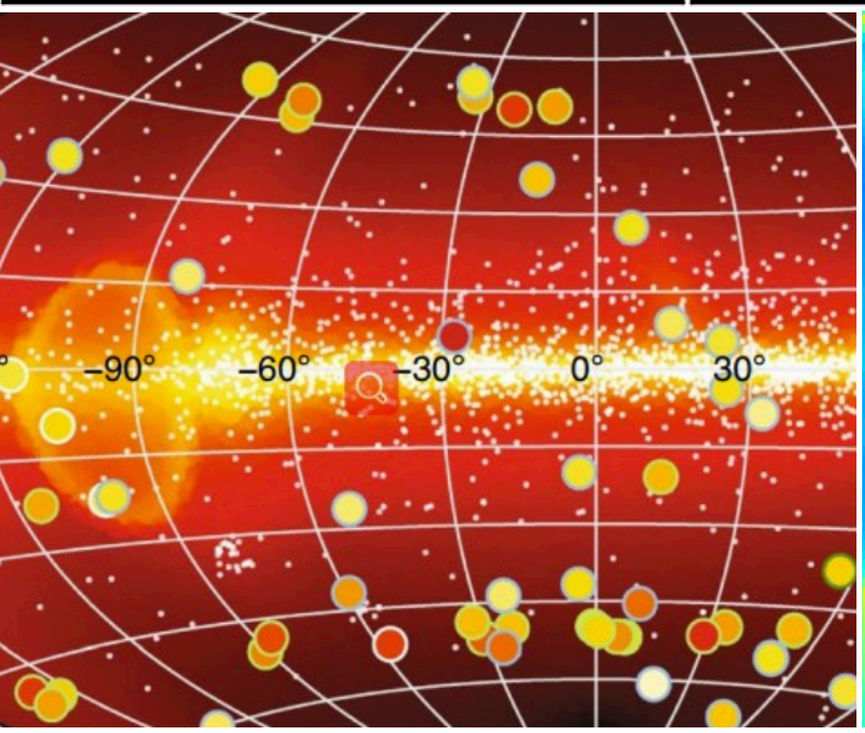
… and many more!

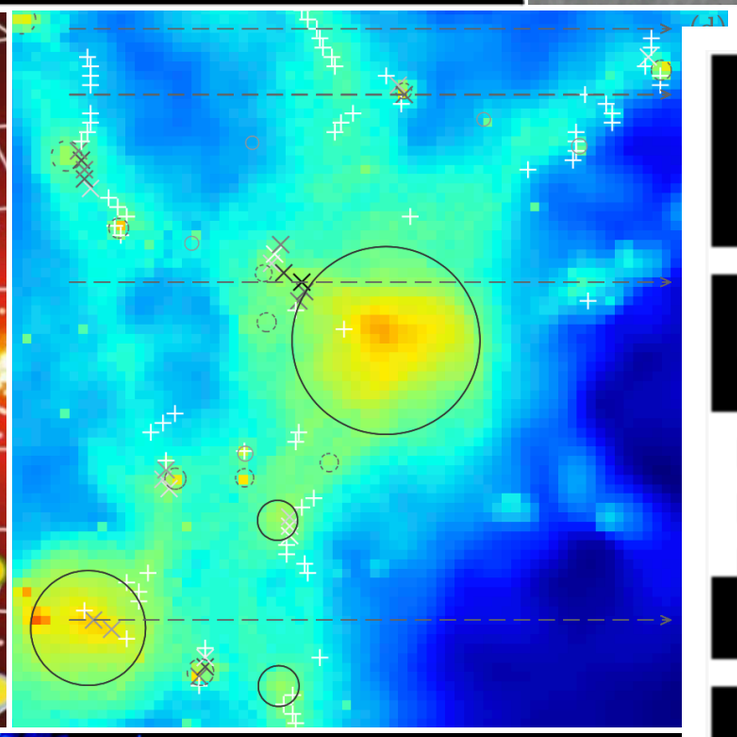
Please complete this survey!

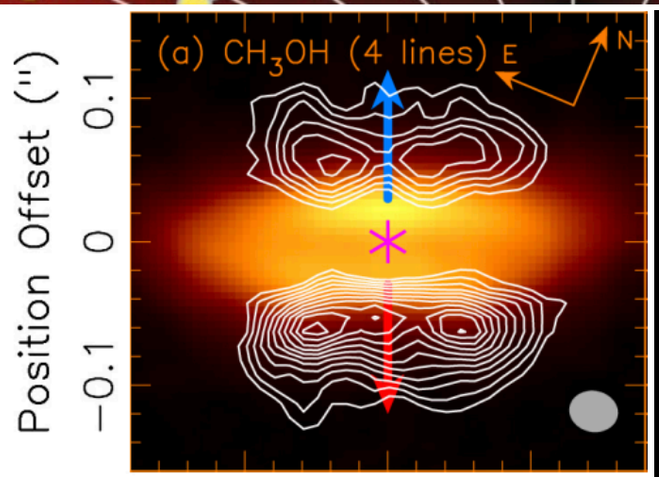


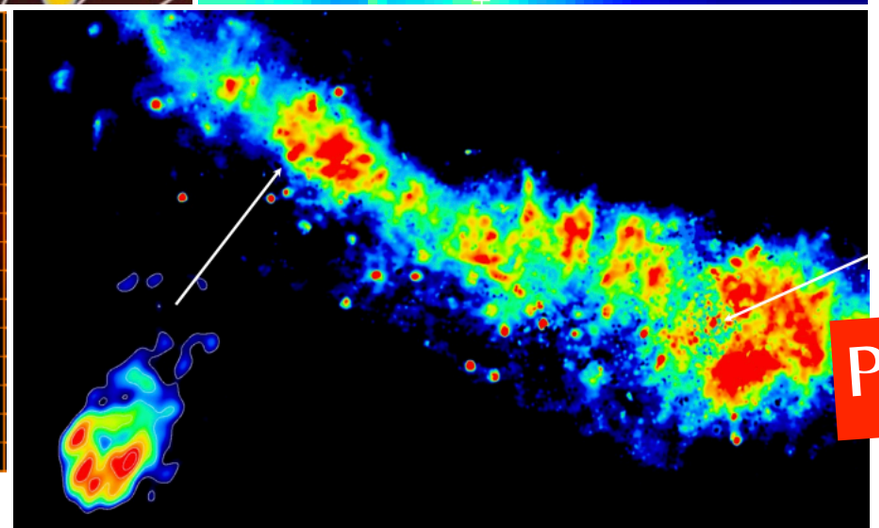










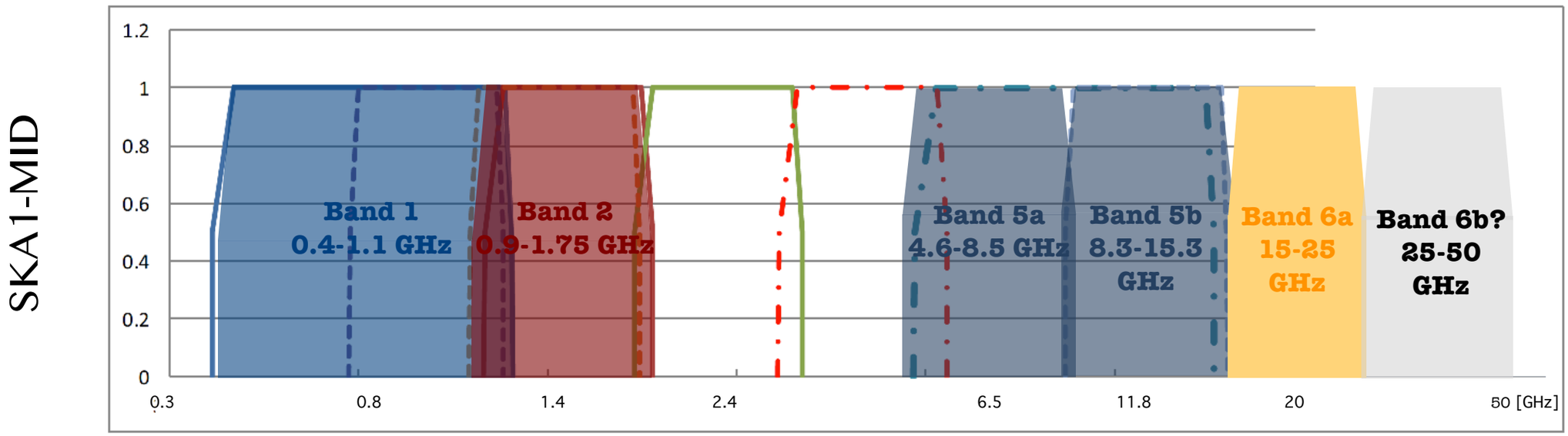


Please complete this survey!

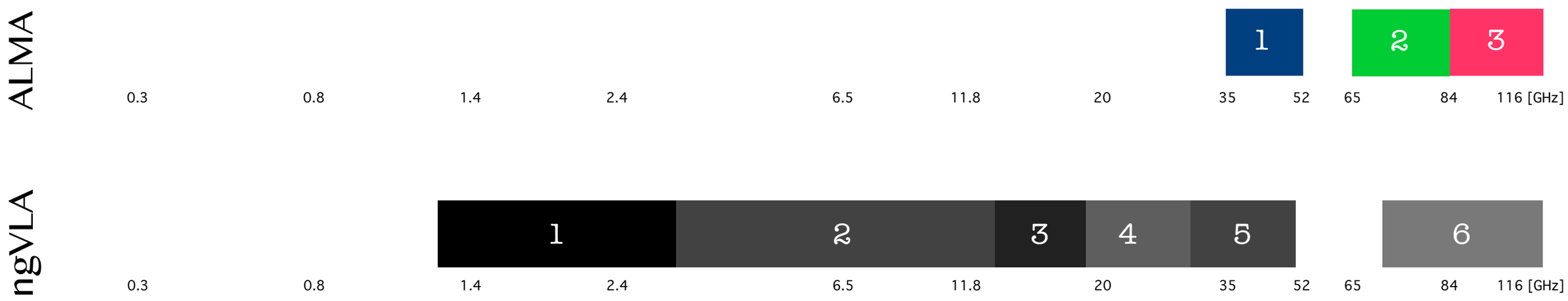
Overview

- Technical context & B6 observational parameter space
- Swiss and international context
- Band 6 science cases
- Next steps for SKACH community

SKA1-MID High-Frequency Coverage



- Band 6a: 15-25 GHz (also investigating a band 6b up to ~50 GHz)
- Instantaneous bandwidths in bands 5a/b, 6a/b, (7): 2x2.5 GHz
- Spectral ‘zoom-mode’ capability: resolution up to 0.2 kHz



Technical Context

- The SKA1-MID dish performance is specified to 20 GHz - will deteriorate gradually toward higher frequencies.

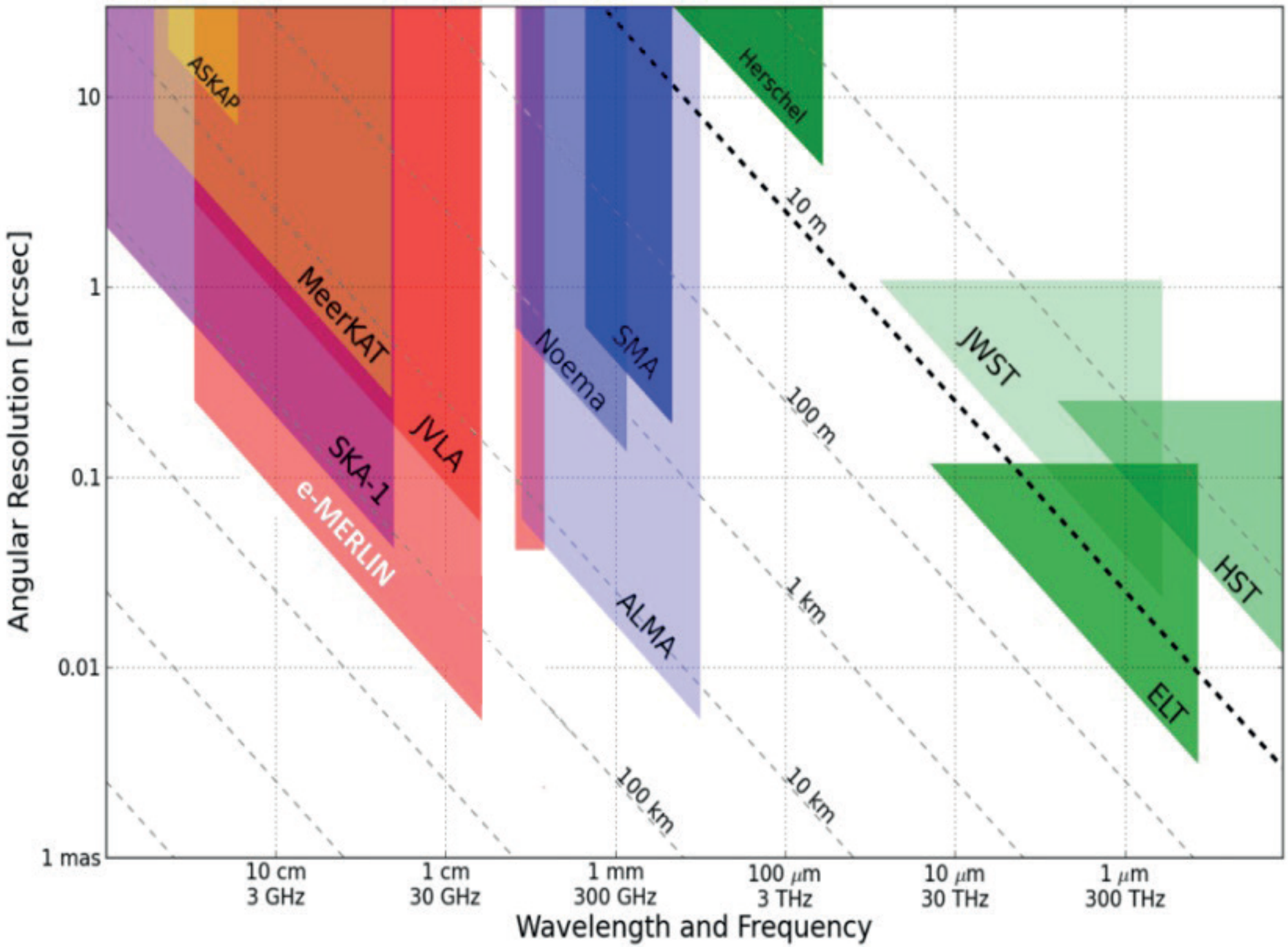
- Anticipated RMS surface error of primary reflector is 280 microns, comparable to VLA dishes. (Needs to be verified by measurements on prototype dish.)

- Zero-th order assumption: would be deployed on 133 MID dishes (but there is potentially still one free slot on the feed indexer of the MeerKAT dishes).

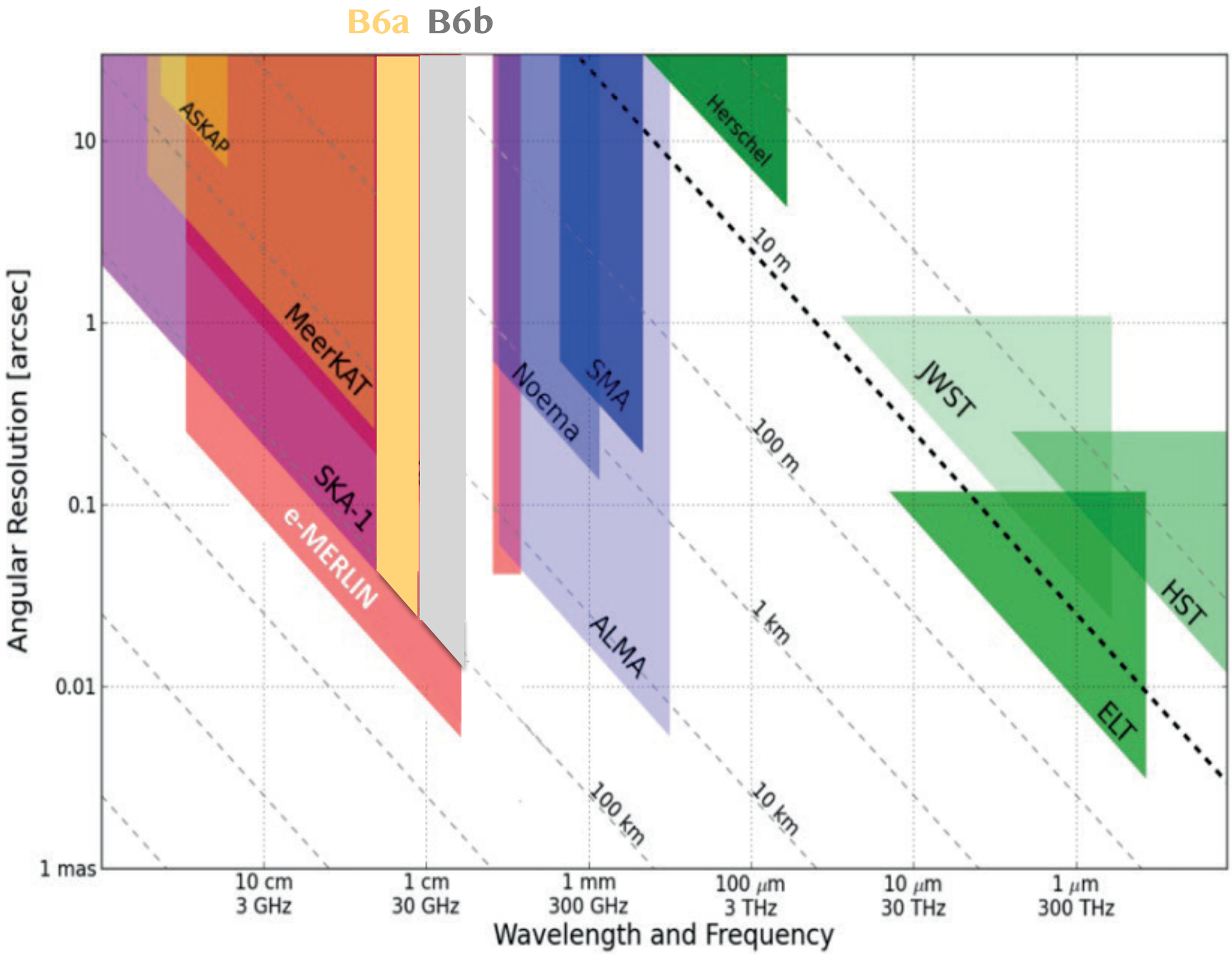
- 15–25 GHz (Band 6a): likely sufficient dish performance. Can be achieved by conventional corrugated horn in existing cartridge slot.

- 25–50GHz (Band 6b) is a ‘stretch goal’: needs verified dish measurements – likely room for only one extra high-freq. feed in indexer, so would need 15–50 GHz WBSPF

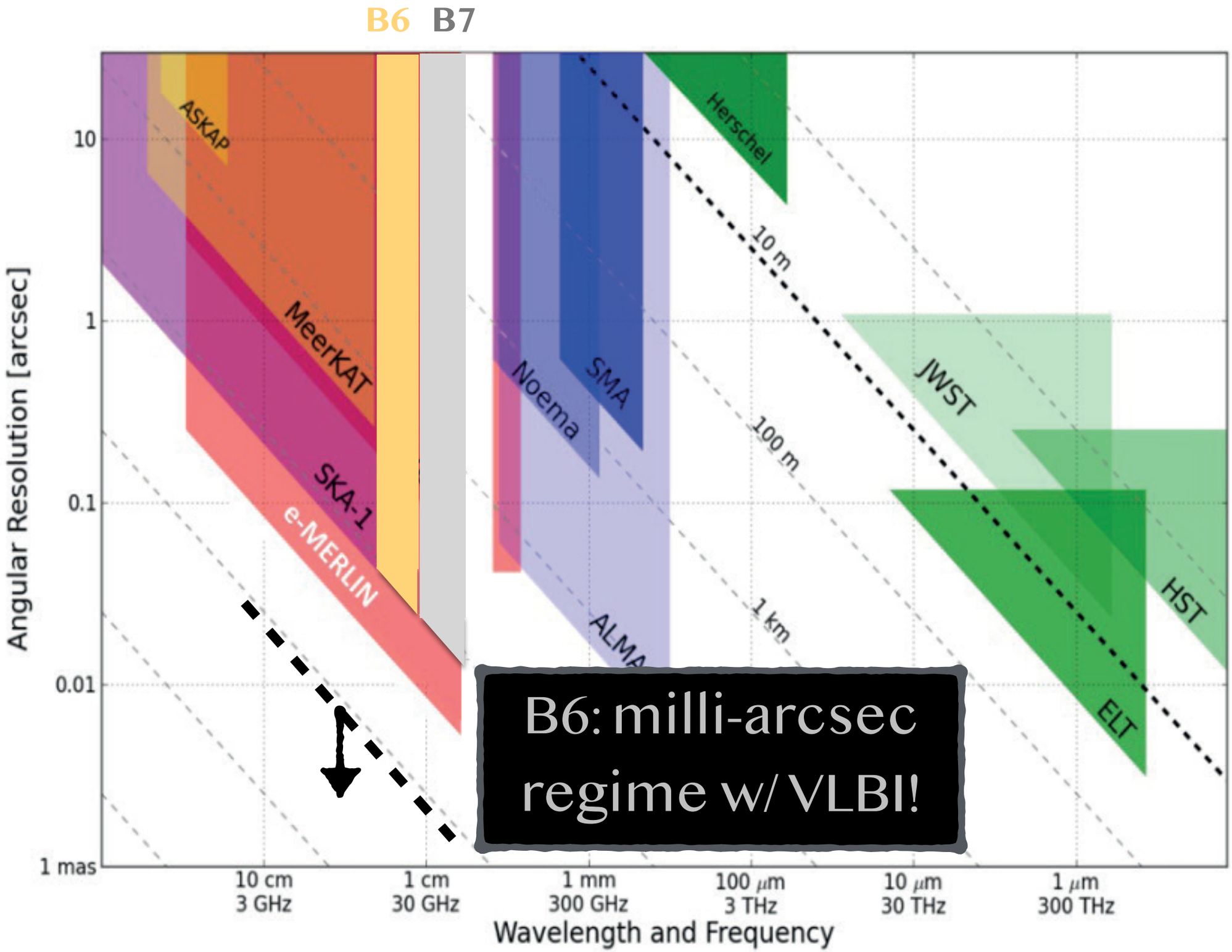
Indicative Band 6 Performance



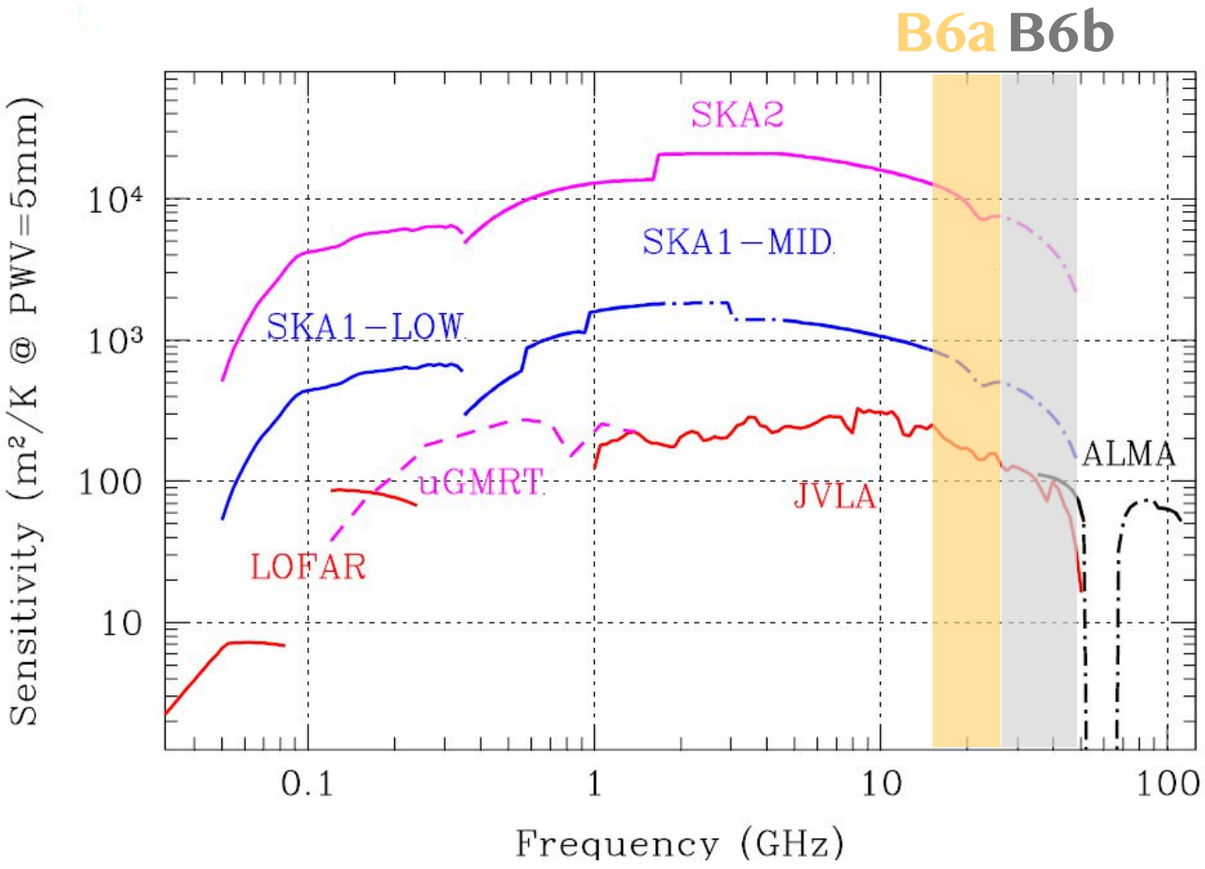
Indicative Band 6 Performance

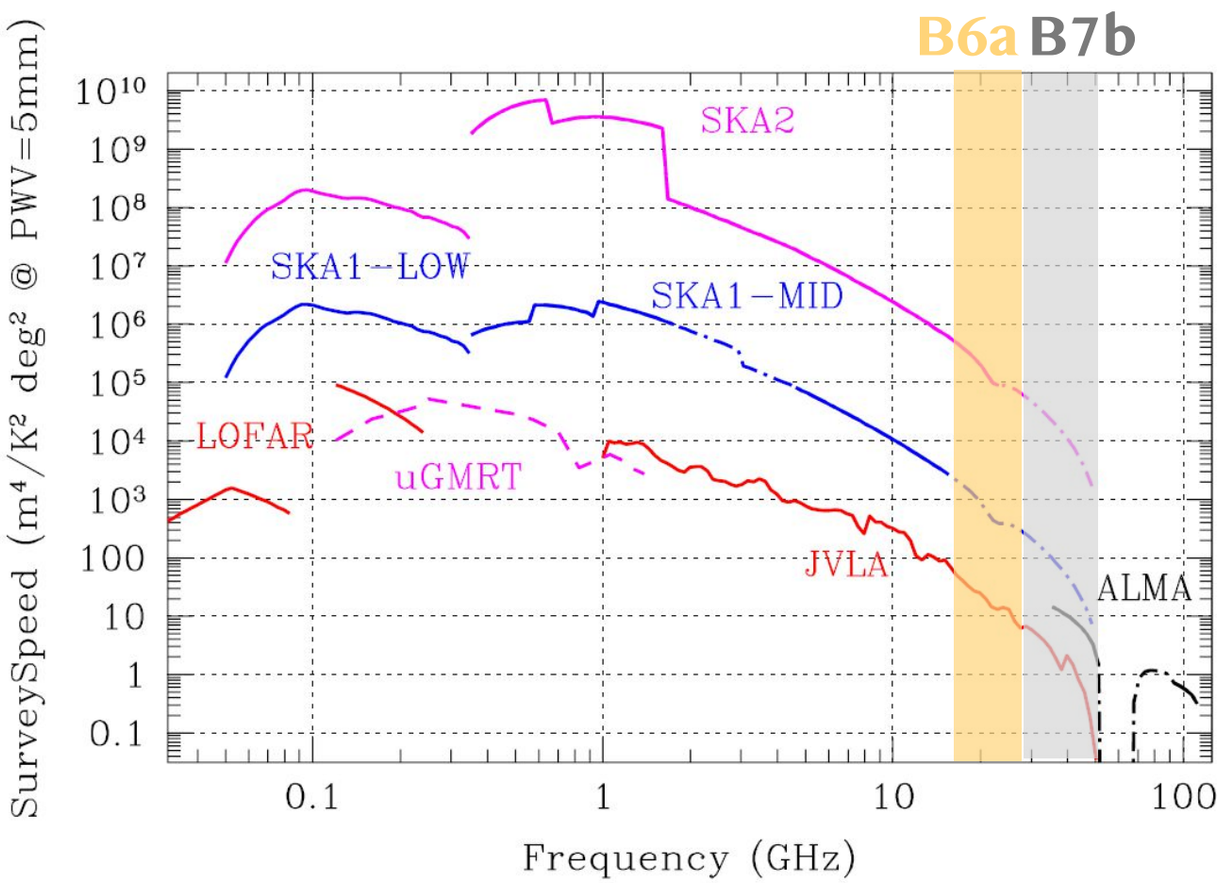


Indicative Band 6 Performance



Sensitivity & Survey Speed Expectations





B6a: ~3x sensitivity improvement (vs. JVLA K-band)

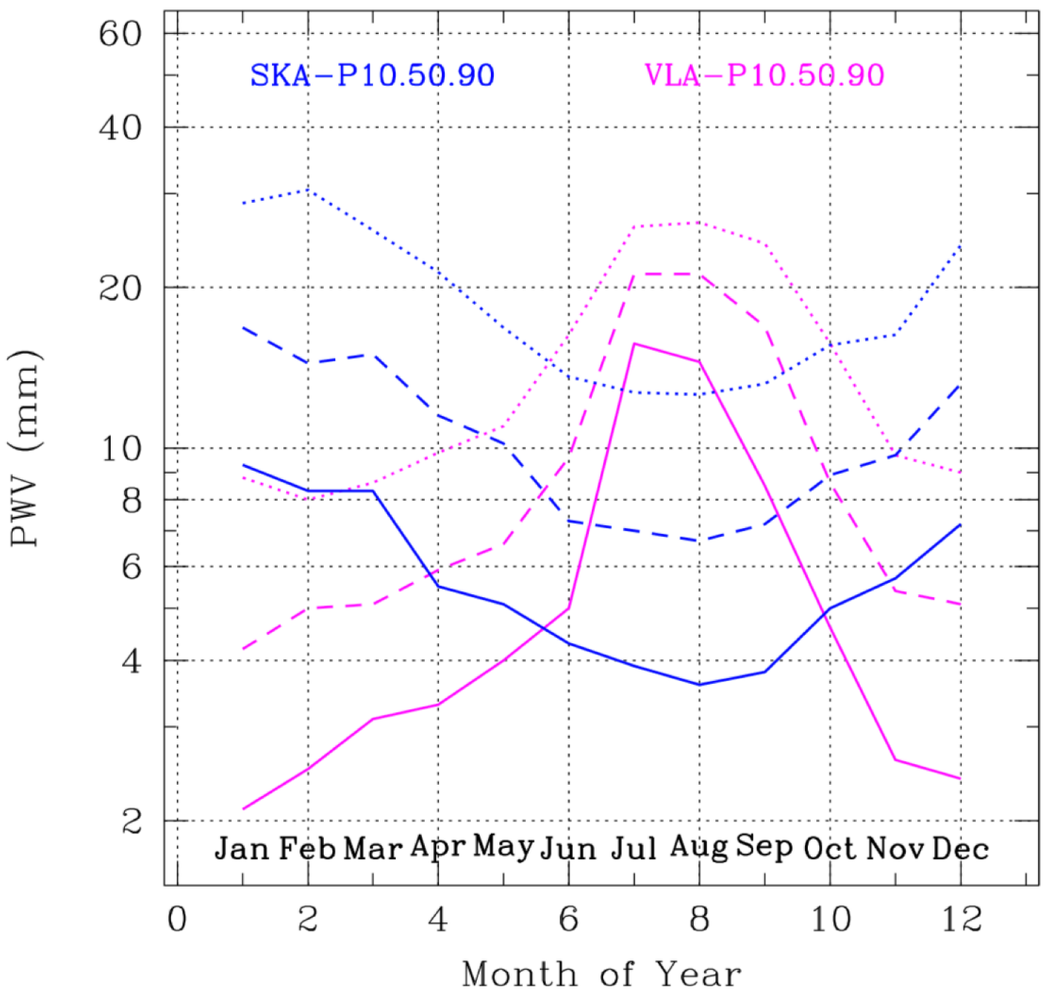
B6b: ~2x sensitivity improvement (vs. ALMA band 1)

B6a: ~20x faster survey speed (vs. JVLA K-band)

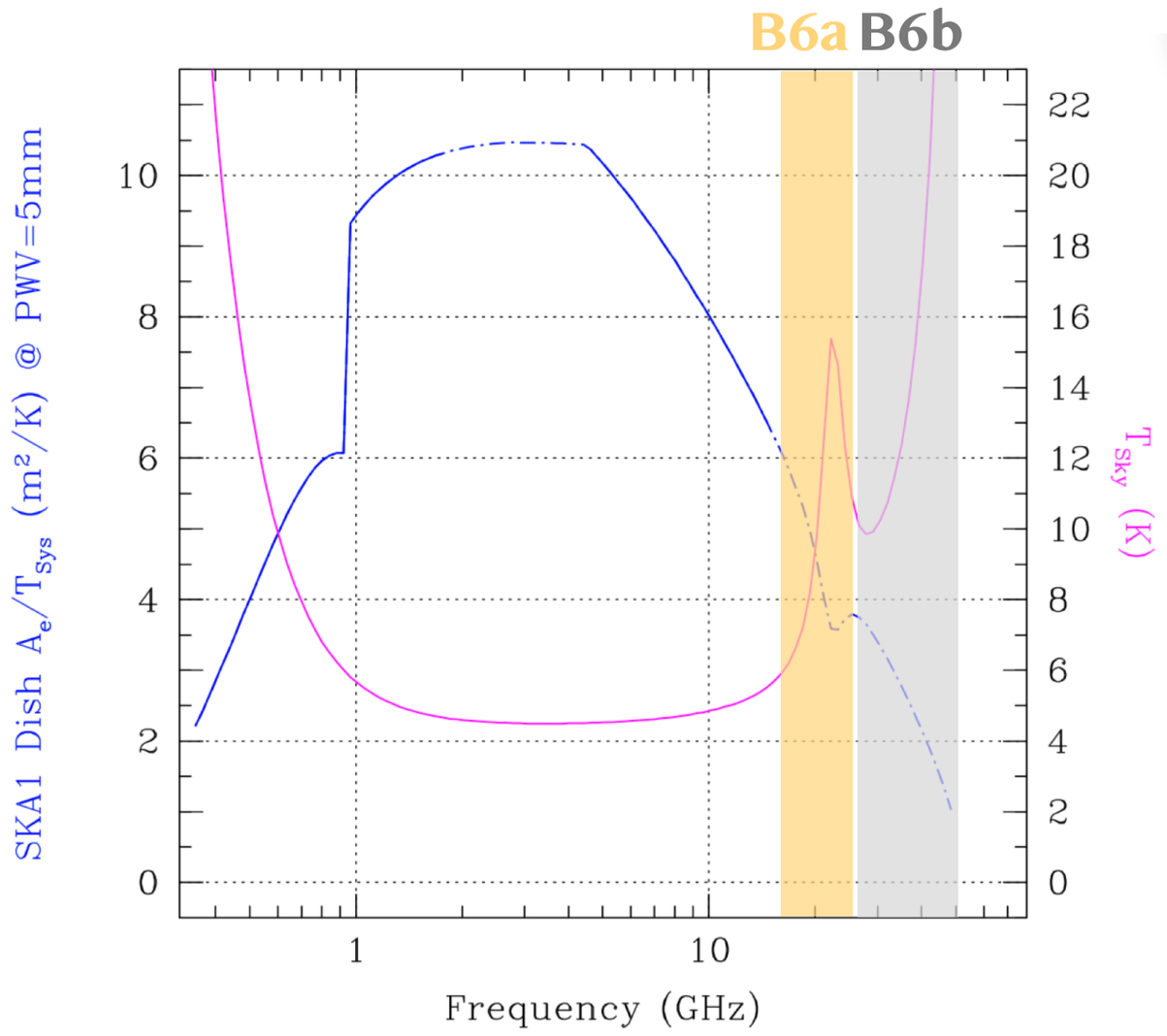
B6b: ~5x (20x) faster survey speed (vs. ALMA band 1 (JVLA Q-band))

B6a/b Performance Estimates: Site & Dish Sensitivity

Avg. seasonal pvw level variation for MID and VLA sites (2010-2015; P. Forkman)

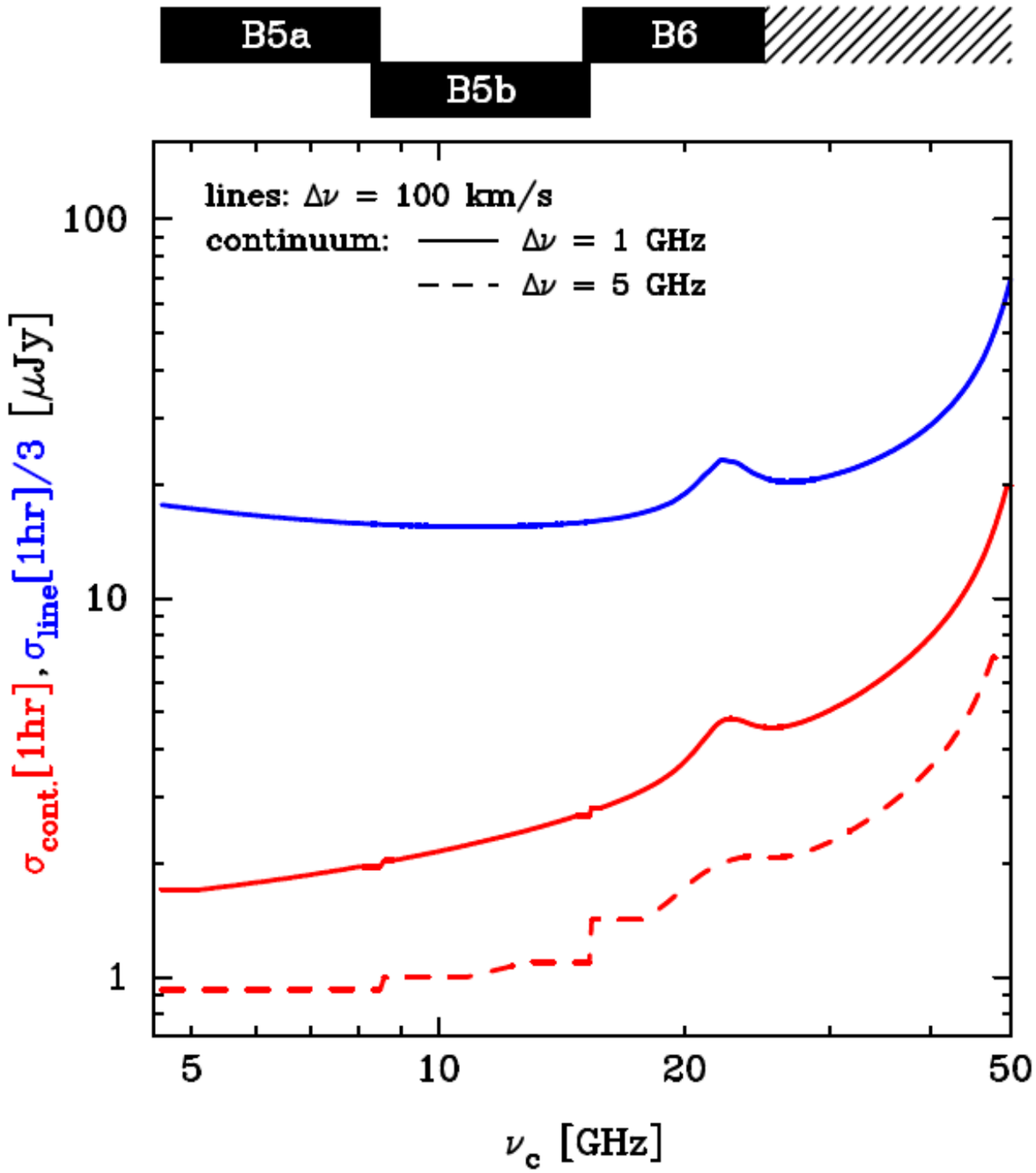


Predicted single-dish sensitivity (zenith, dry weather w/ pwv=5mm)



(see “Anticipated SKA1 Science Performance”, Braun+ 2017, SKA-TEL-SKO-0000818)

B6a/b Performance Estimates: Array Sensitivity



M. Sargent/B6 sensitivity primer (link on final slide)

Indicative 1hr sensitivities (1σ) at ~20 GHz (zenith, pwv=5mm, standard SKAO assumptions on degradation of image noise compared to "natural" array sensitivity):

- line sensitivity (100 km/s channel): 57 uJy
- continuum sensitivity (5GHz BW): 1.7 uJy

At 40 GHz:

- lines: 86 uJy
- continuum: 3.6 uJy

International & Swiss landscape

- Current facilities operating in B6 frequency range: JVLA, ALMA, e-MERLIN, ATCA, several single-dish observatories

- Upcoming facilities: ngVLA - highly ranked in US Astro2020 decadal survey, but NSF funding not yet secured (full science in 2037?)

- B6 is not part of SKA1 deployment baseline (i.e. it's not funded), ODP is proposal-driven
  ➜ SKAO memo/white book on "SKA1 beyond 15GHz" (6 science areas; 35 example sci. cases; 131 pages)

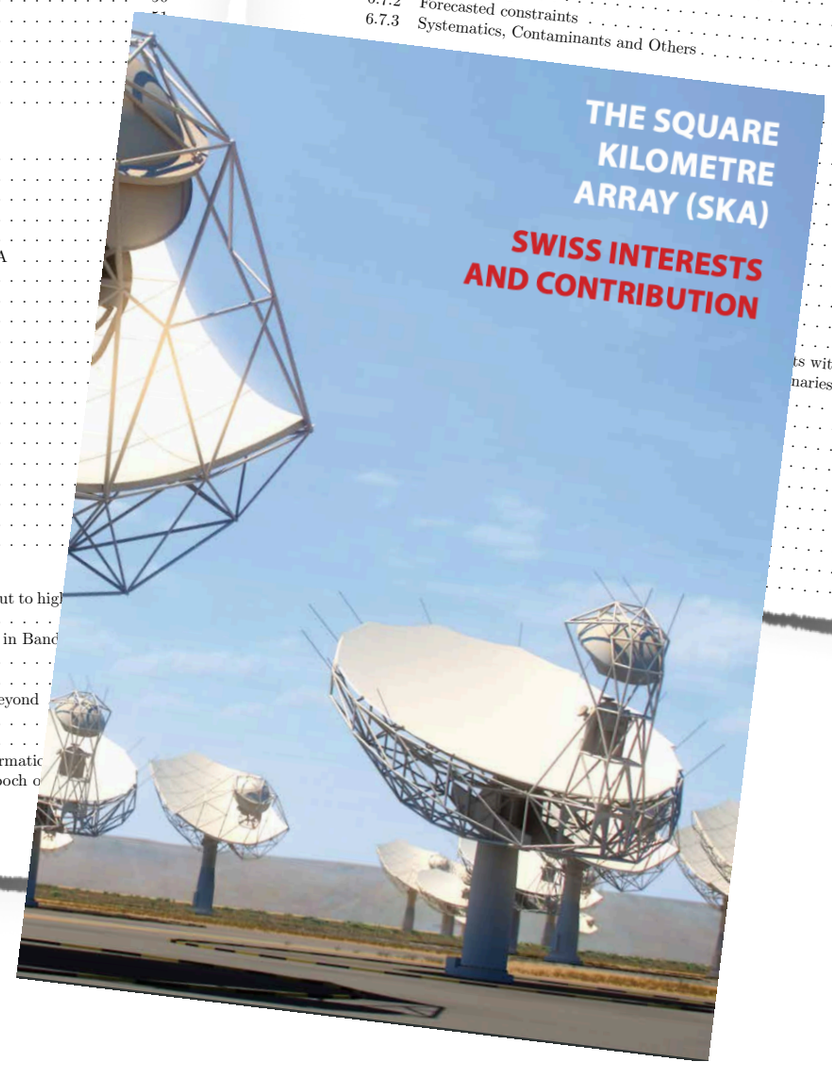
- SERI support for SKACH in a constrained environment
  ➜ funding for hardware development will be easier to secure if backed up by strong community sci. interest

“Beyond Band 5” White Book...

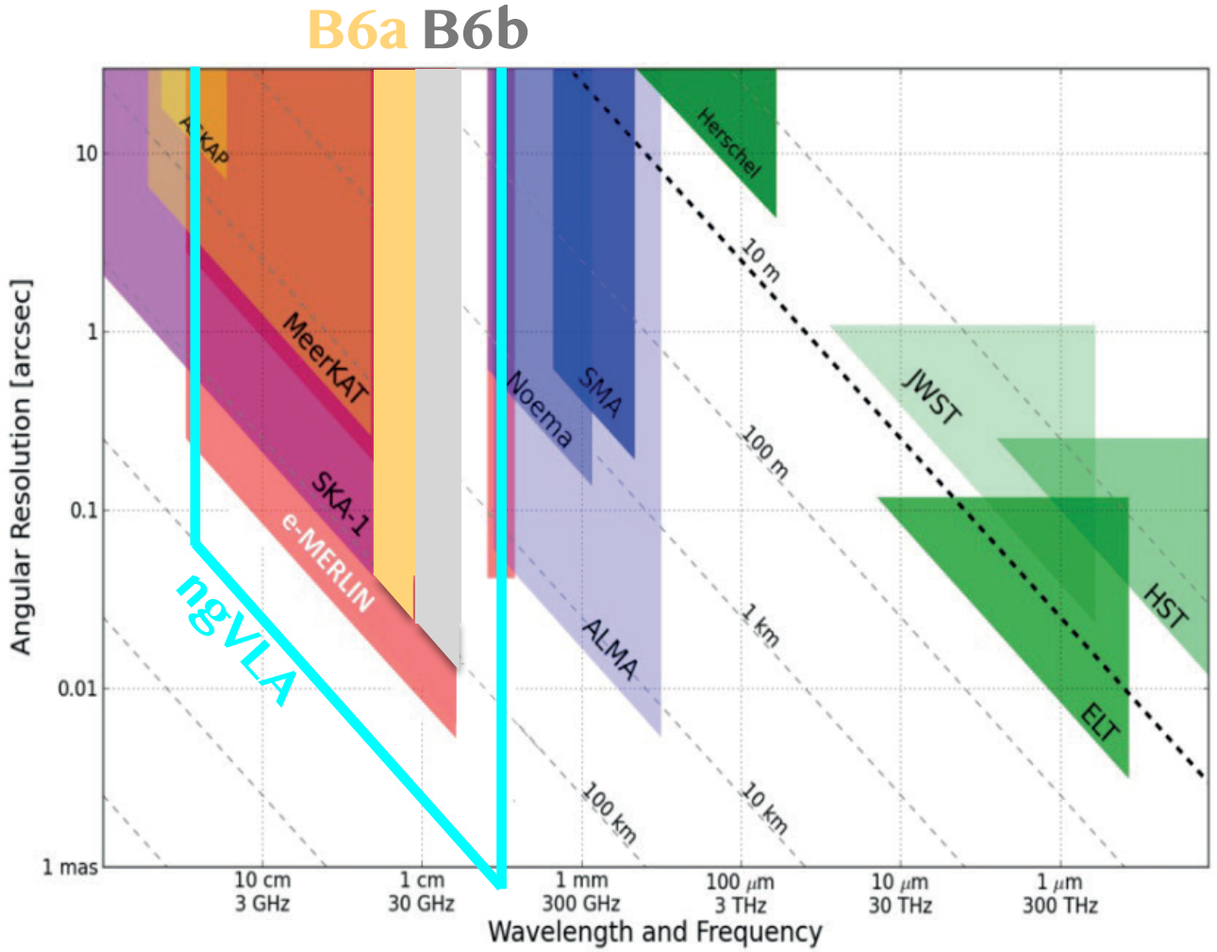
Contents

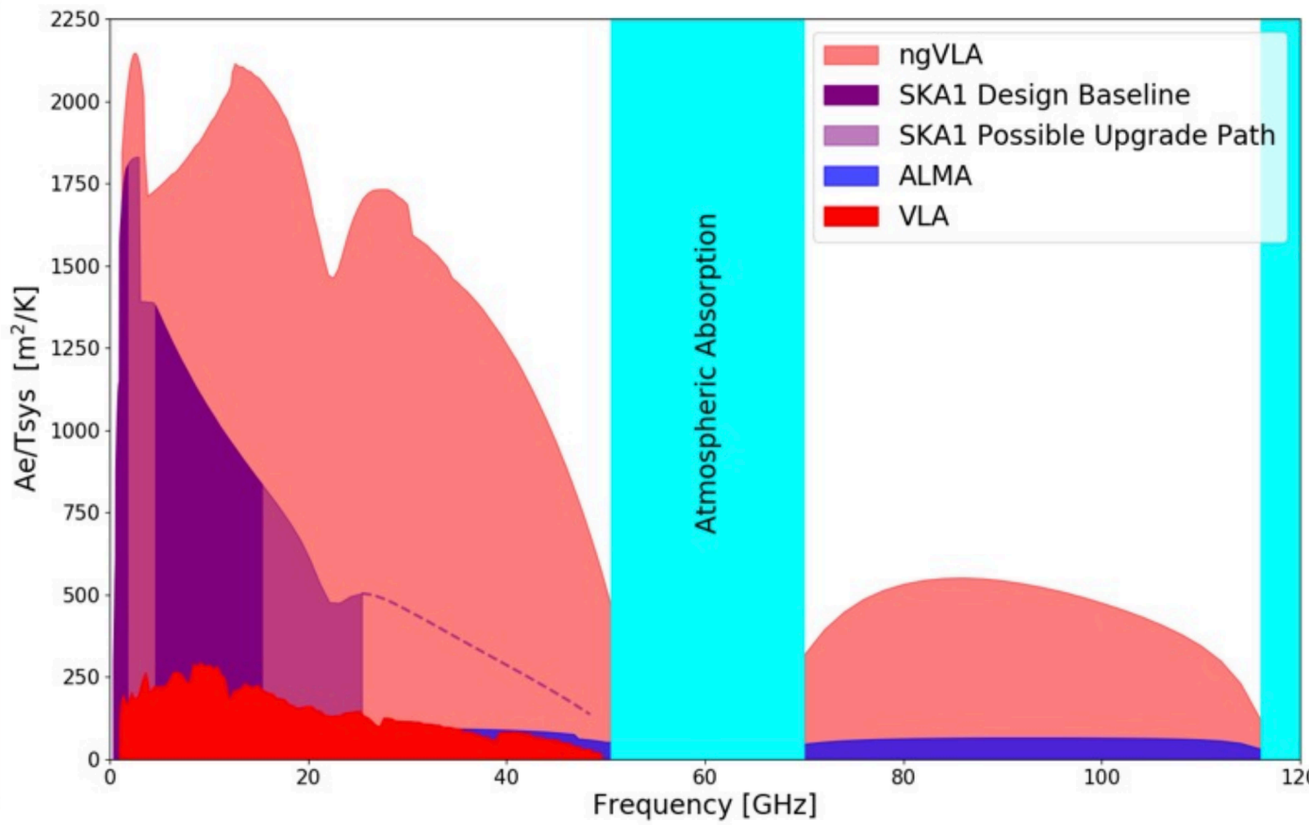
“Beyond Band 5” White Book … and Swiss White Book

Contents



Other show in town: ngVLA





- 1.2-116 GHz
- Hardware optimised for ~30 GHz, higher elevation
- Northern hemisphere
- Full science ~3037?

Emission mechanisms/sources underpinning B6 science

Lines

- Exgal.:
  - redshifted cold/dense molecular lines
  - (mega-)masers
  - …
- Galactic:
  - masers
  - organic/prebiotic molecules
  - dense gas tracers
  - …

Continuum

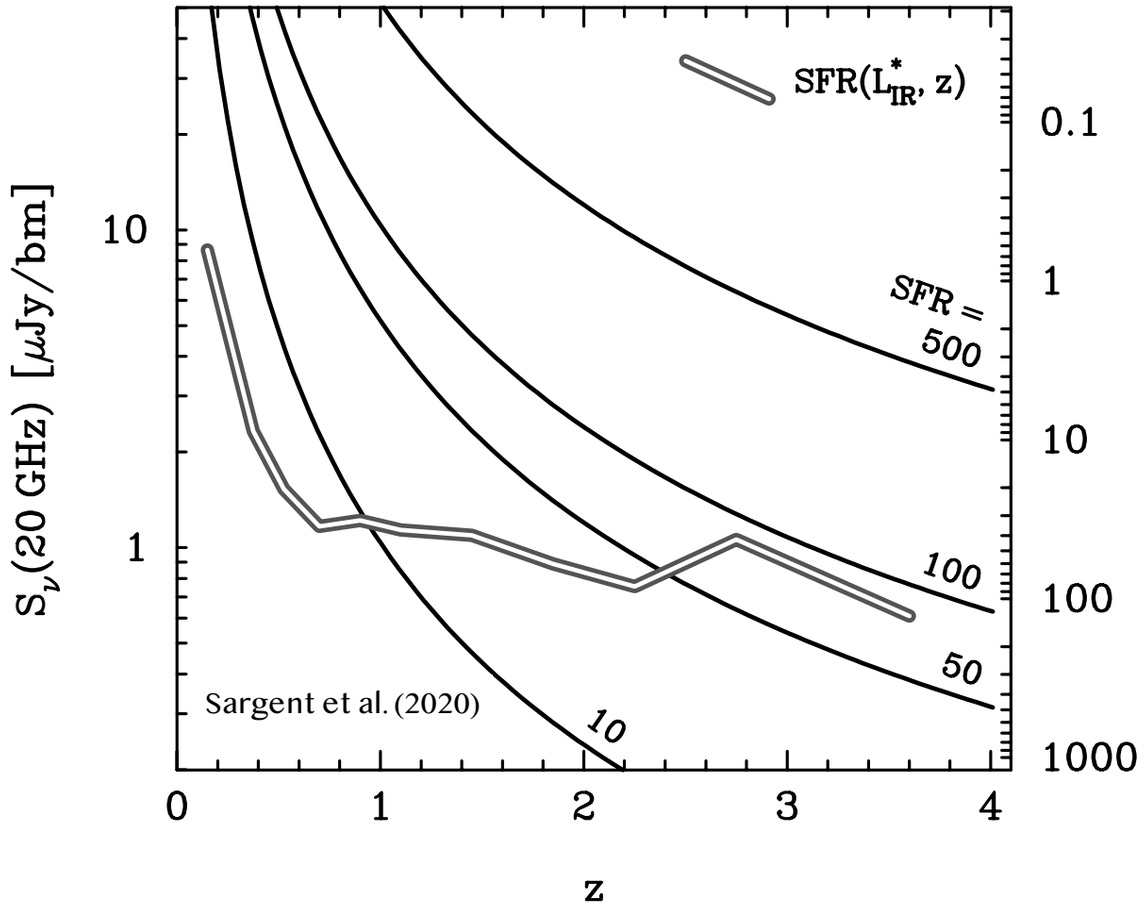
Exgal.:

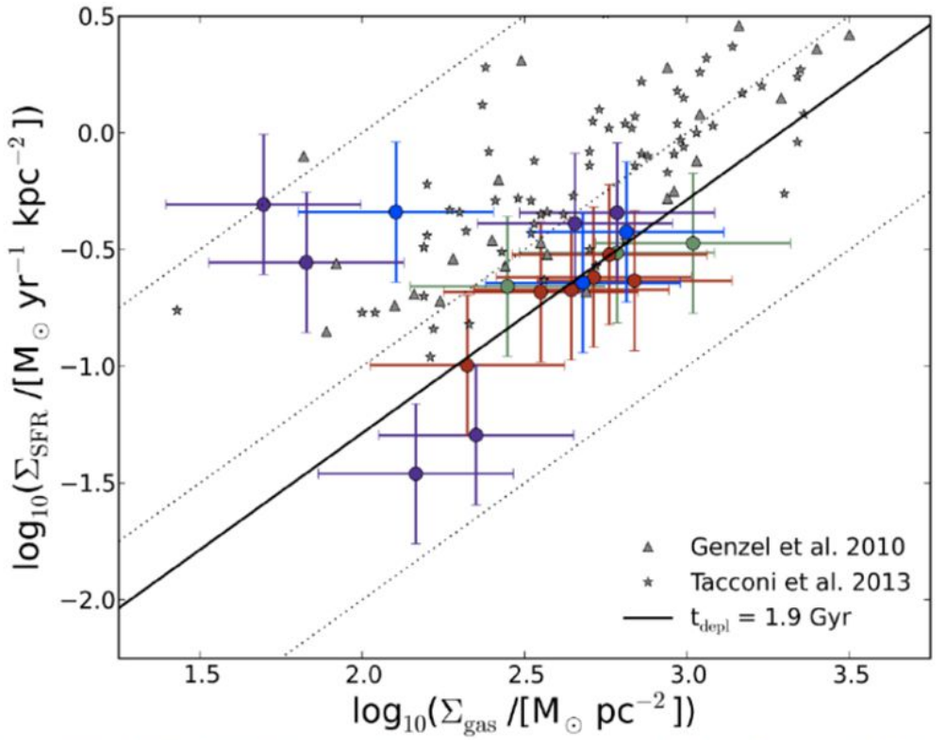
- Star-formation (HII regions): thermal emission
- Spinning Dust: anomalous microwave emission
- AGN
- clusters (S-Z effect)
- …

Galactic:

- proto-planetary disks (cm-sized and smaller particles)
- …

Did you know? - Cosmic star-formation history





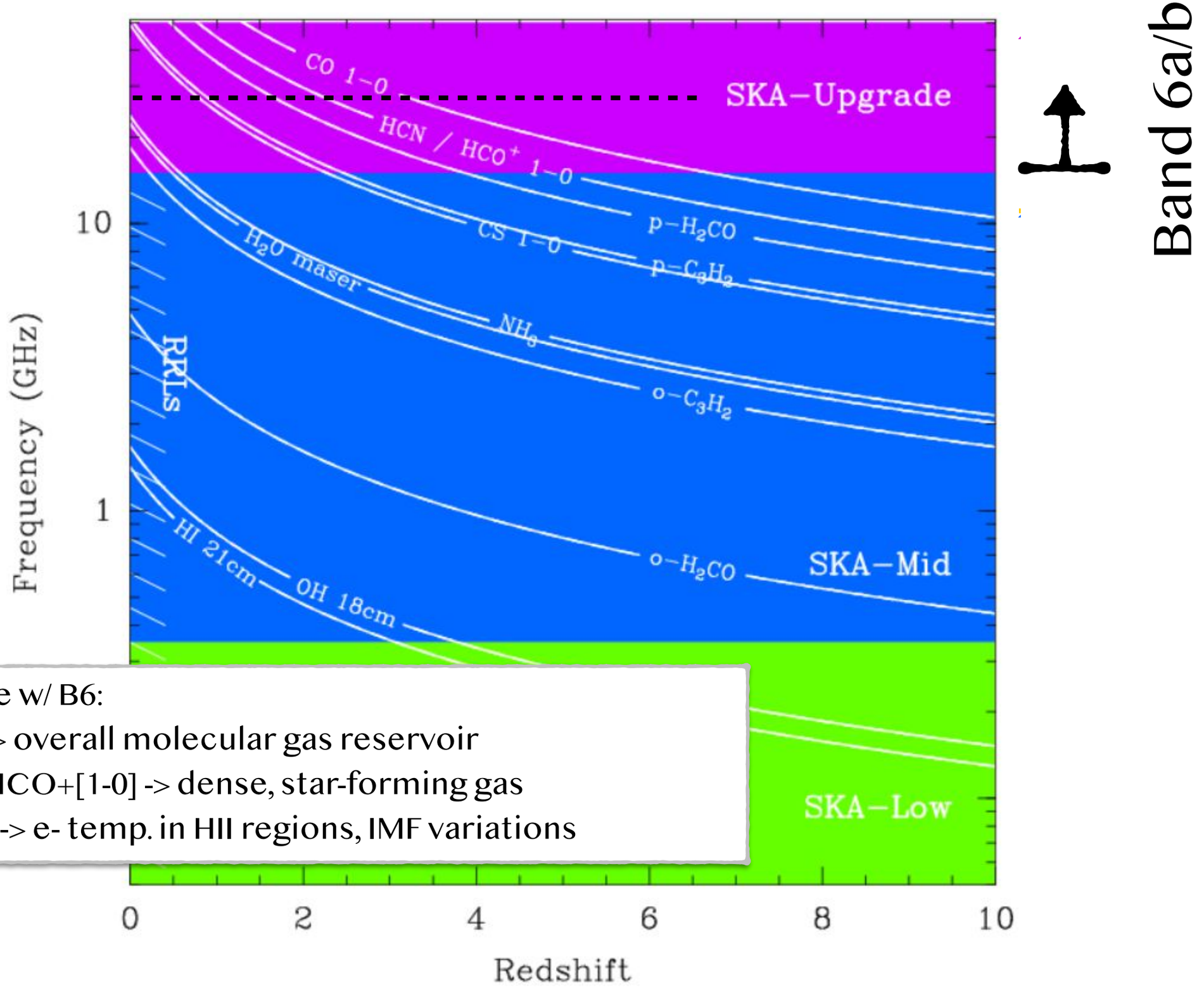
Freundlich et al. (2013)

CSFH science w/ B6:

- probe free-free continuum (directly proportional to production rate of Ly continuum photons)
- 1st measurement of CSFH via dust-unbiased, free-free SF
- calibrate radio-SFRs based on synchrotron continuum
- resolved Schmidt-Kennicutt relations at cosmic noon
- study nuclear jets and feedback

In a single, 100hr pointing at 20 GHz we will be able to observe the free-free continuum of 50+ galaxies (down to L*) in the peak epoch of galaxy formation!

Did you know? - Cosmic star-formation history

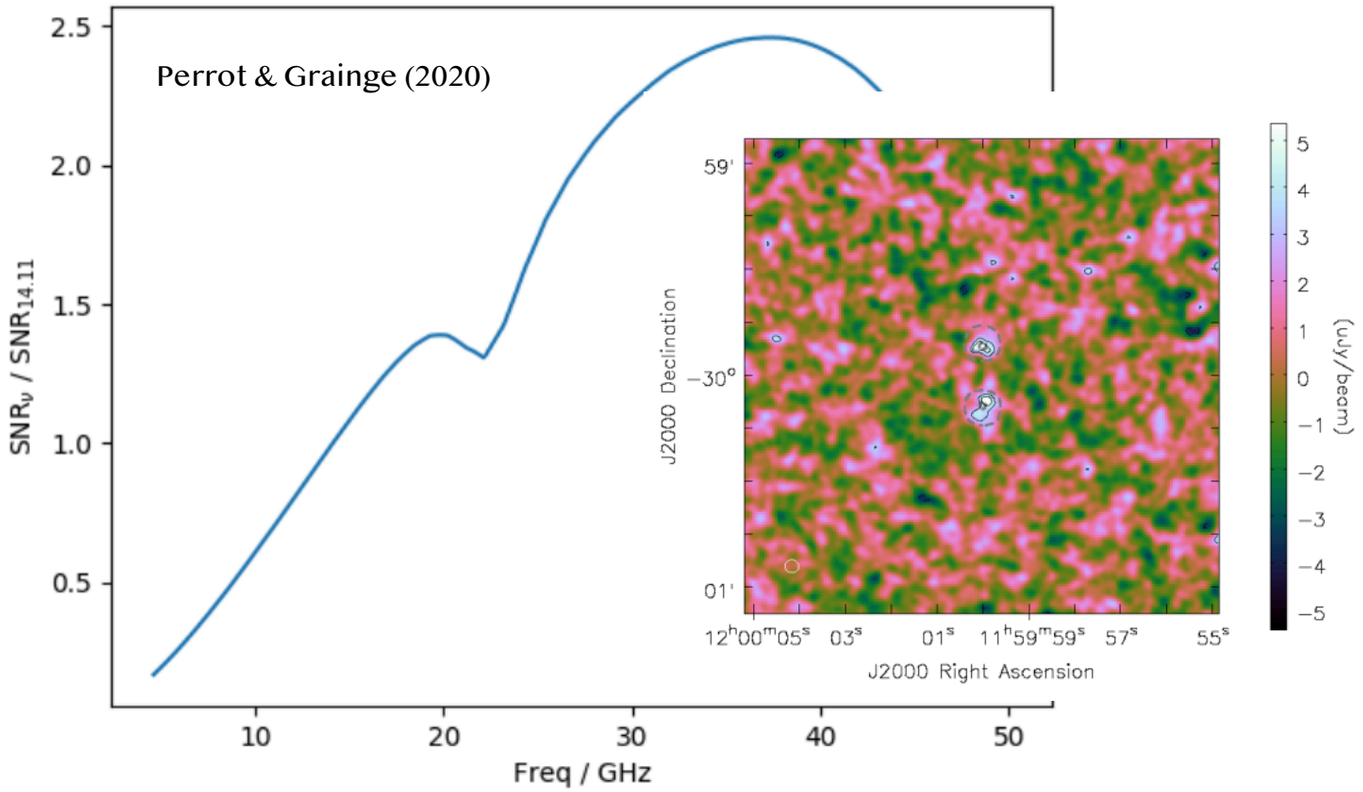


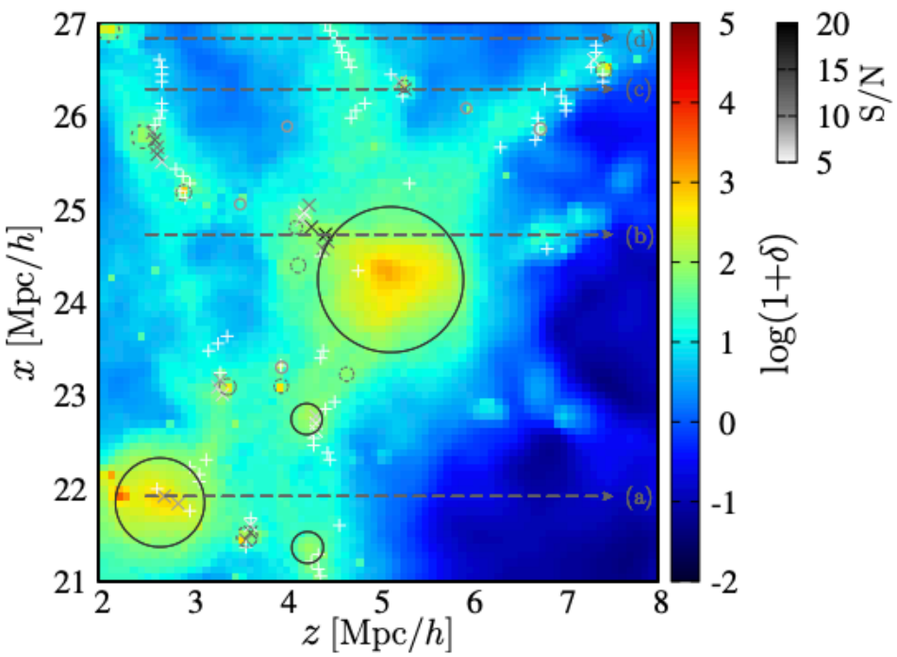
CSFH science w/ B6:

- ^{12}CO[1-0] -> overall molecular gas reservoir
- HCN[1-0], HCO+[1-0] -> dense, star-forming gas
- ^{12}CO/^{13}CO -> e- temp. in HII regions, IMF variations

Did you know? - Cosmology / structure formation

Efficient S-Z cluster detection at z~2, and S-Z signal substructure mapping (X-ray cavities!) on a scale of 10s kpc.





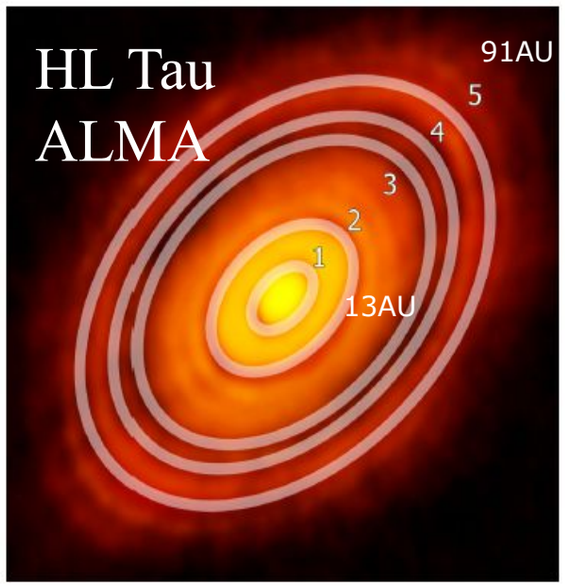
Yoshikawa (2020)

WHIM / missing baryon detection and characterisation (temperature, chemical enrichment) via hyperfine structure transitions of ^{14} NVII detected in absorption against background radio sources.

Did you know? - Cradle of Life science & exoplanets

The University of Manchester
Jodrell Bank
Observatory

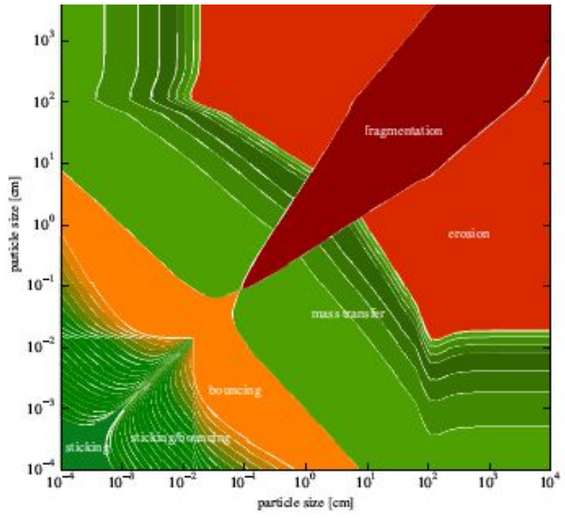
Planet-forming disks/ grain growth

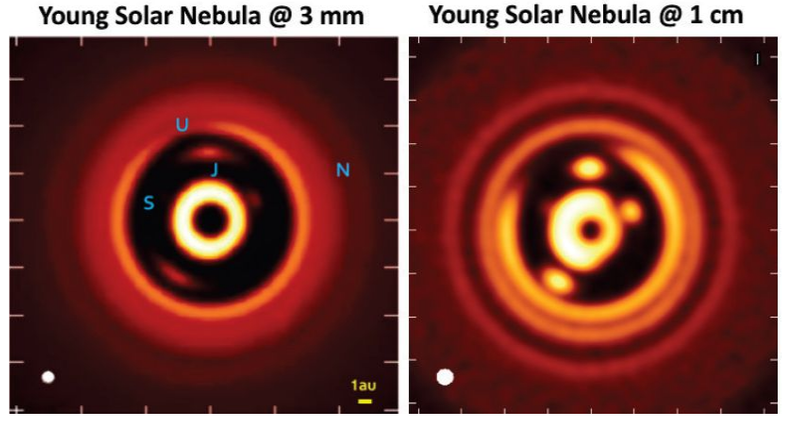


- Inner 10AU (Saturn) opaque to sub-mm [MMSN]
- Need cm wavelengths to see through dust & detect pebble material
- At 1AU need >~ 3 cm
- Jup: 40 mas, Mars 12 mas

Full range of frequencies GHz to 10s of GHz to untangle emission from thermal jets, disk winds, synchrotron

few -10s mas resolution - required





Dust continuum simulation of the young solar system – Ricci et al 2019 (ngVLA science book)

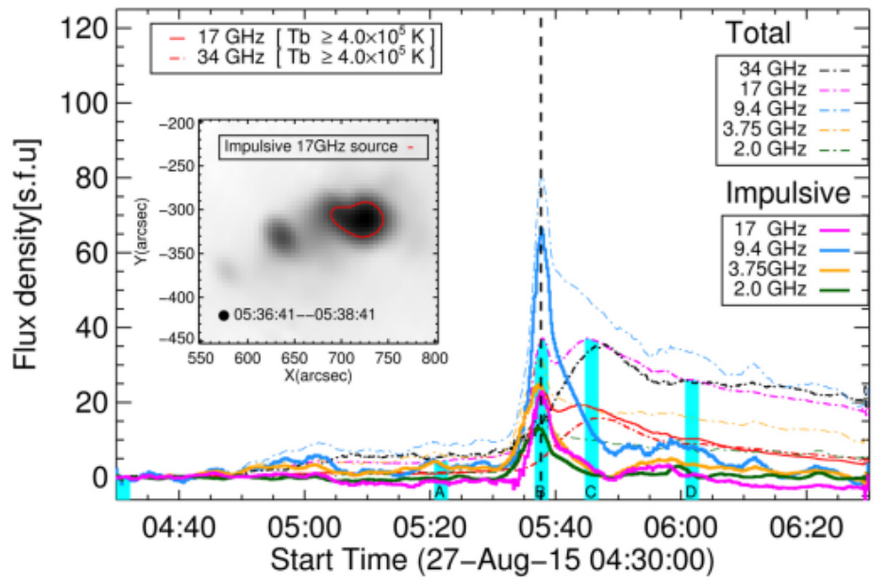
From dust → pebbles → planets

slide credits: Cradle of Life SWG/R. Beswick (SKA SciCon, April 2019)

+ in band 6b: ability to resolve magnetospheric emission from Jupiter-like planets at 10 pc (Guirado et al., 2020)

Did you know? - From the Sun to TNOs

Study electron acceleration via high-resolution microwave emission from different emission regions of solar flares:



Liu et al. (2020)

Formation regions and properties of trans-Neptunian objects:

Table 2: Expected thermal fluxes for 10 of the largest TNOs and Centaurs at a few selected wavelengths of Band 5 and Band 6. **Object** is the name of the TNO/Centaur; **Type** is the dynamical classification of the object; **D** is the area-equivalent diameter in kilometers and milliarcseconds (mas); $\mathbf{F}_{0.7cm}$-$\mathbf{F}_{6.5cm}$ are the estimated thermal fluxes in micro-Jansky (μJy) at these wavelengths; $\mathbf{T}_b$ is the brightness temperature in Kelvin.

Object	**Type**	**D** [km/mas]	$F_{0.7cm}$ [μJy]	$F_{1.2cm}$ [μJy]	F_{2cm} [μJy]	$F_{3.5cm}$ [μJy]	$F_{6.5cm}$ [μJy]	T_b [K]
Pluto	TNO Plutino	2380/100	477.8	120.9	48.4	15.8	4.60	36.5
Eris	TNO Detached	2326/33	28.77	7.35	3.05	1.00	0.29	22.1
Haumea	TNO Classical	1595/43	63.63	16.19	6.70	2.20	0.64	28.3
2007 OR_{10}	TNO SDO	1535/24	18.53	4.72	1.96	0.64	0.19	26.2
Makemake	TNO Classical	1430/38	44.97	11.45	4.75	1.56	0.45	26.6
Quaoar	TNO Classical	1071/34	51.80	13.12	5.26	1.72	0.50	36.4
Chariklo	Centaur	241/21	38.02	9.57	3.95	1.29	0.37	68.4
2002 GZ_{32}	Centaur	237/17	24.78	6.24	2.58	0.84	0.25	66.4
Chiron	Centaur	210/15	18.43	4.64	1.91	0.62	0.18	66.3
Bienor	Centaur	199/16	21.46	5.40	2.23	0.73	0.21	63.5

Santos-Sanz et al. (2020)

Did you know? - Astronometry

The University of Manchester
Jodrell Bank
Observatory

Astrometry with masers (VLBI) with SKA Band 5

- **Masers tied to circumstellar gas clouds:** determination of distance, gas kinematics, density, magnetic fields.

maser	freq	resolution	π accuracy
OH	1612 MHz	20 mas	0.25 mas
CH_3OH	6.7 GHz	6 mas	0.030 mas
CH_3OH	12 GHz	3 mas	0.020 mas
H_2O	22 GHz	2 mas	0.010 mas
SiO	43 GHz	1 mas	?
cf. Gaia	500 THz	100 mas	0.020 mas

Credit: van Langevelde

Work by Rioja & Dodson on multi-View

Links

- White book "SKA1 Beyond 15GHz: The Science case for Band 6" (SKA memo 20-01)
- ngVLA science book: https://ngvla.nrao.edu/page/scibook

- Swiss SKA white book
- SKACH slack channel: #mb6-receiver-science-cases

- B6a/b sensitivity primer (see QR code ➜)

Back-up

ASPFR Consortium: aims & structure

- Provide ‘bridge’ to SKA-ODP (Observatory Development Programme)
- Attract new countries to join SKA
- Development of ‘technology roadmap’ toward an affordable SKA2

Consortium Agreement - Principles

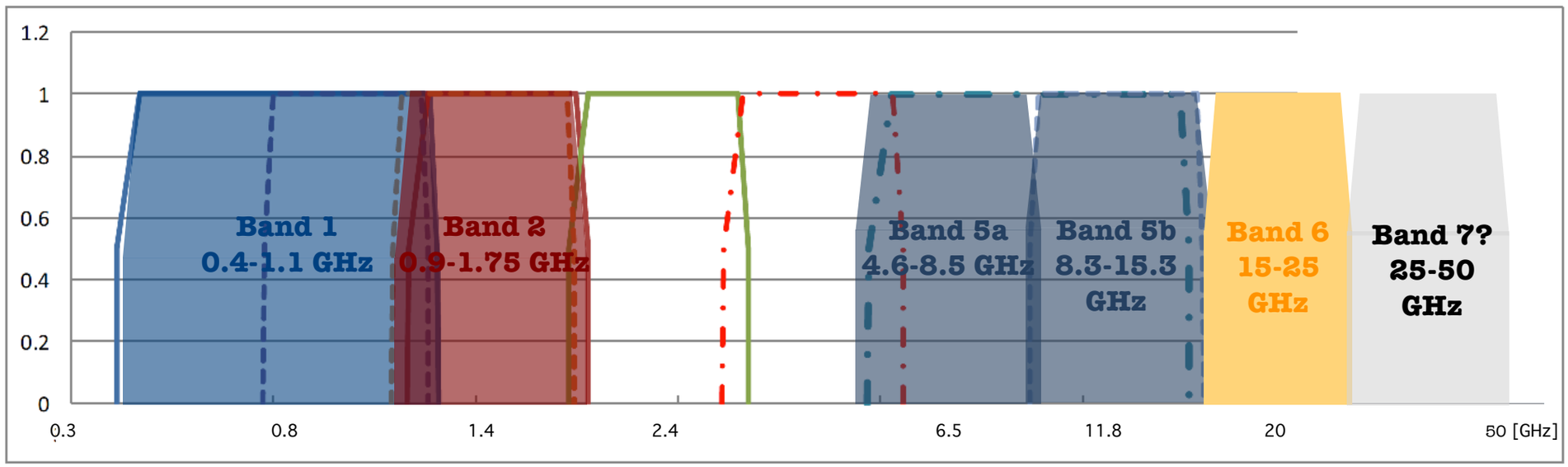
- **Purpose –** Meeting place for institutes/companies work on single pixel technology who wish to explore how this could be used for SKA via design studies, prototypes etc
- SKAO recognises ASPFR as a **conduit into SKAO** planning for advanced Single Pixel Feed/Receivers technology, for planning of SKA1 extensions and for SKA2.
- **Members-** sign a very simple consortium agreement so no problem for all to sign, but also possible to contribute outside of membership.
- **Management Group** and **Board each** one person per member
- **Annual meeting –** This is first one. Keep centred on members plus invited guests or **similar** to PAF, open technology meeting + associated consortium meeting.
- **Simple IP principles -** All IP belongs to partners, the old SKA IP agreement used for baseline design WP *does not* apply. Only when technology selected for deployment will an SKAO IP policy apply (and all development up to that point in ASPFR can be brought as institute owned background IP)
- **Term - Starts -**when 2 members sign **Ends** June 30th 2021 unless extended by Board.

More information:
http://aspfr.pbworks.com/w/page/134188245/ASPFR%20Home

slide credits: J. Conway (ASPFR kick-off meeting, Sep. 2019)

Emission mechanisms/sources underpinning B6 science

SKA1-MID



OH masers

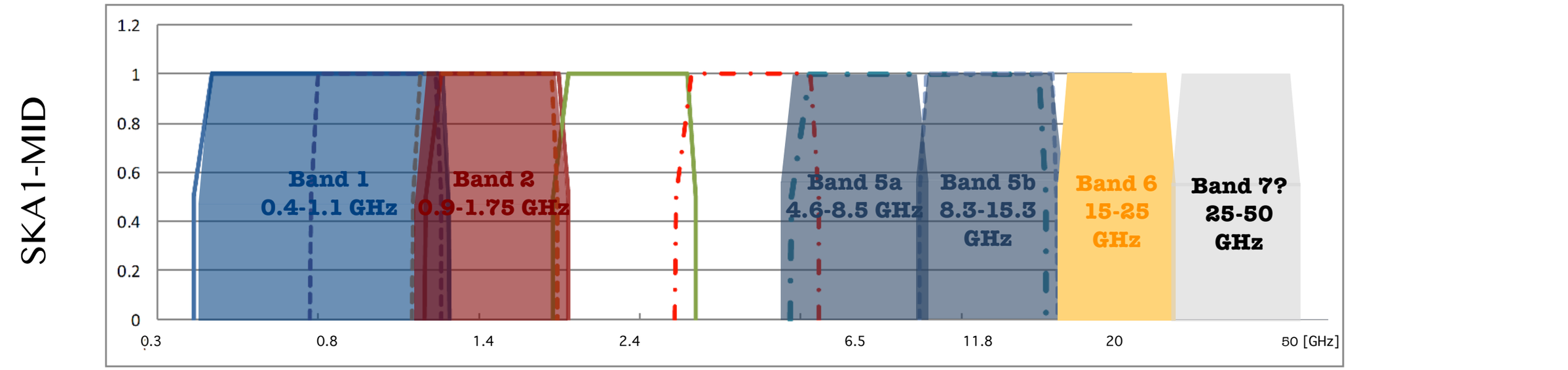
OH* masers formaldehyde maser

OH* masers methanol maser

methanol* maser

H_2O maser

Emission mechanisms/sources underpinning B6 science



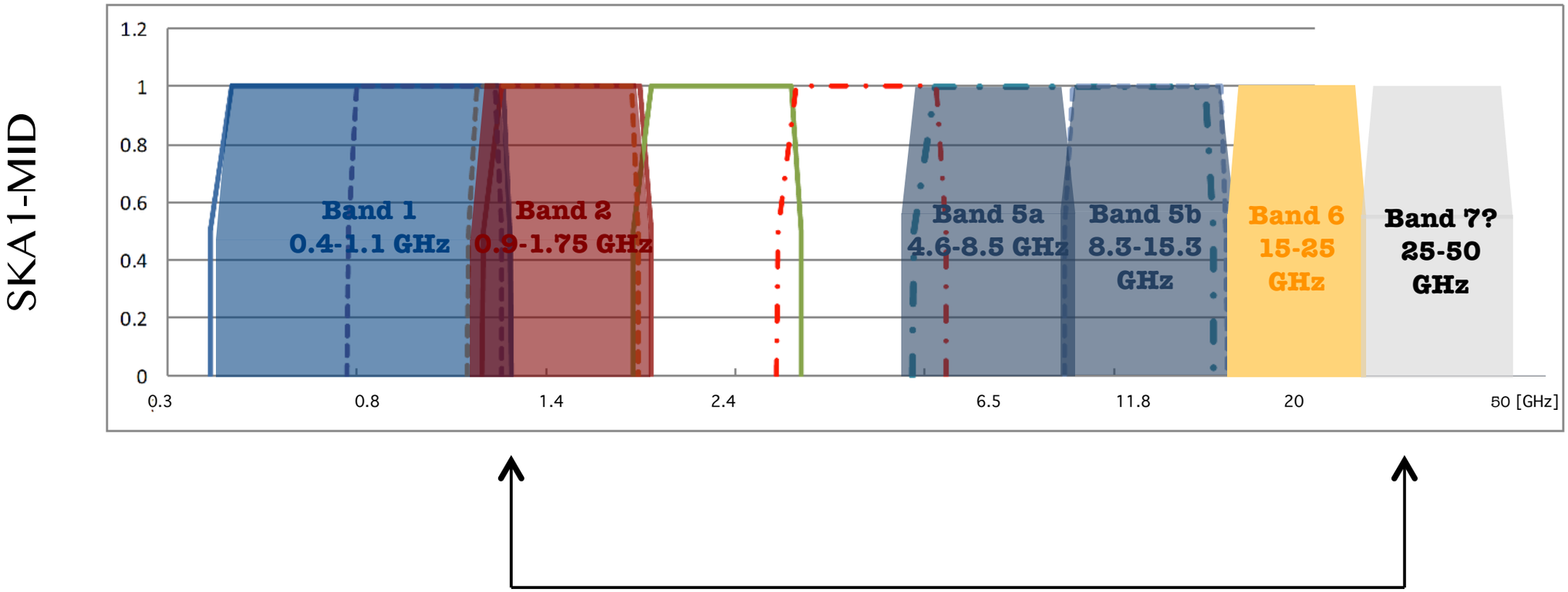
Radio recombination lines

Radio recombination lines

Complex organic/ prebiotic lines

Local dense gas tracers: HCN, HCO+, HNC, etc.

Emission mechanisms/sources underpinning B6 science



Local dense gas tracers: HCN, HCO+, HNC, etc.

CS[1-0]
HCN[1-0]
HCO+[1-0]
CO[1-0]
CS[1-0]
HCN[1-0]
HCO+[1-0]
CO[1-0]

redshift