

# (SKACH) Headline science in SKA1-MID band 6

Mark Sargent (ISSI Bern)

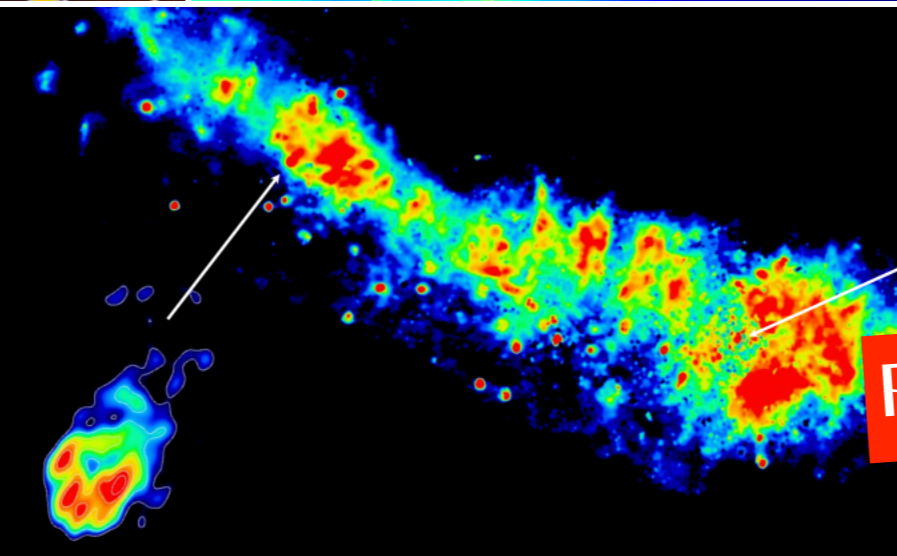
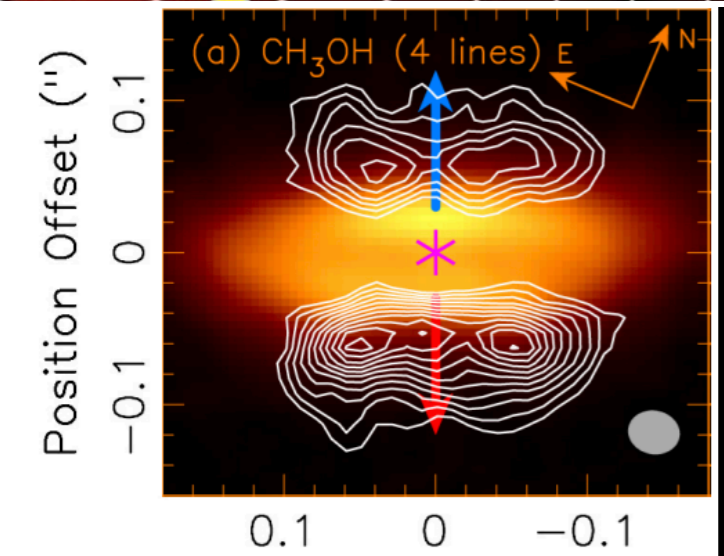
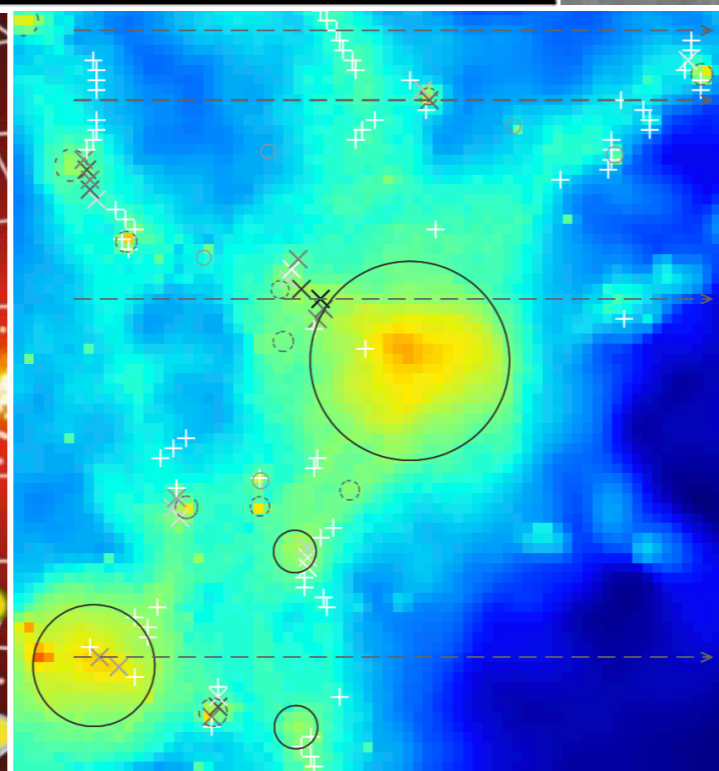
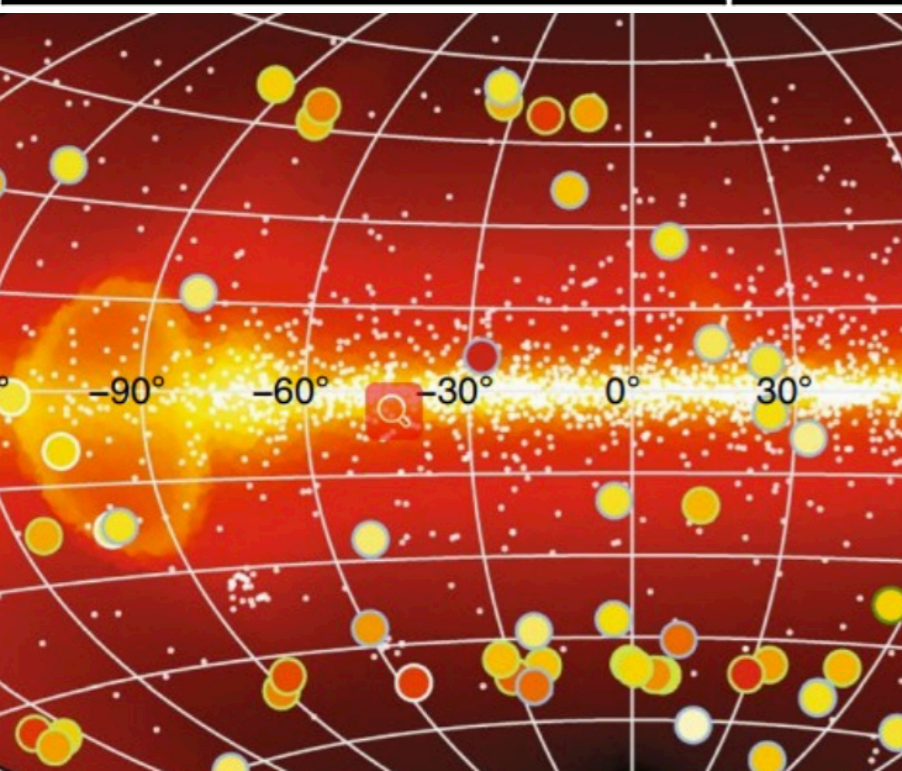
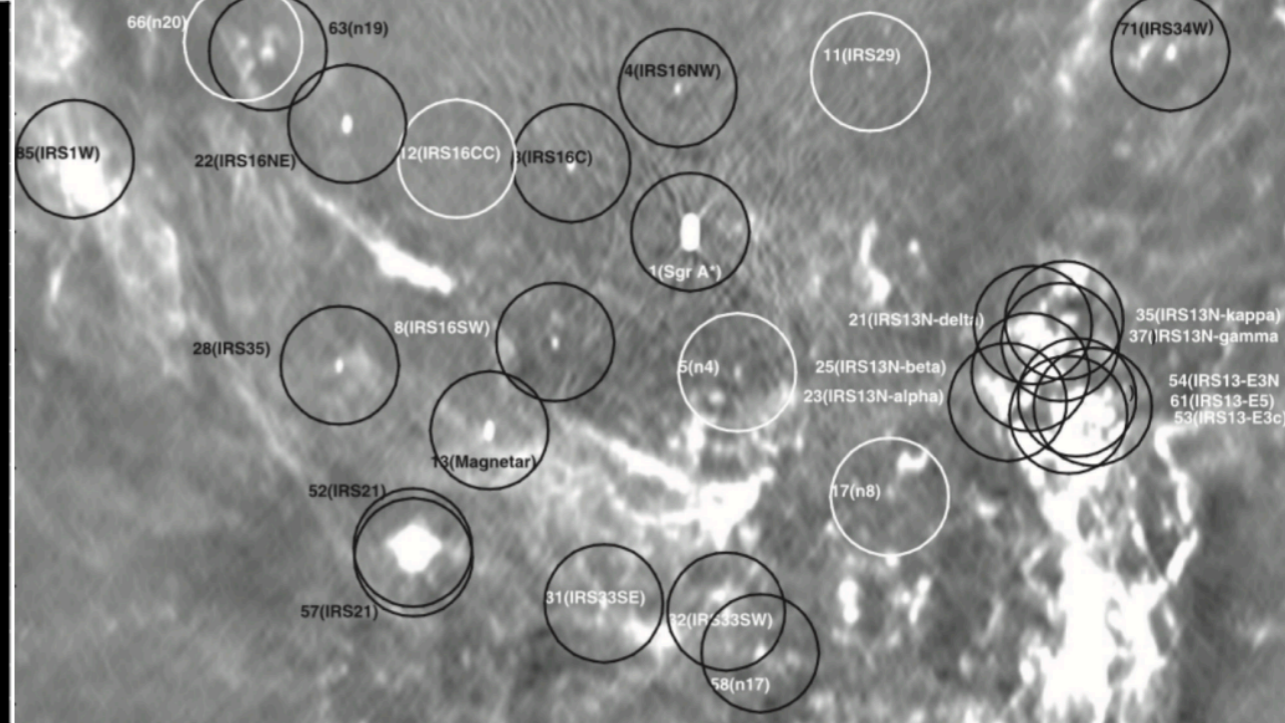
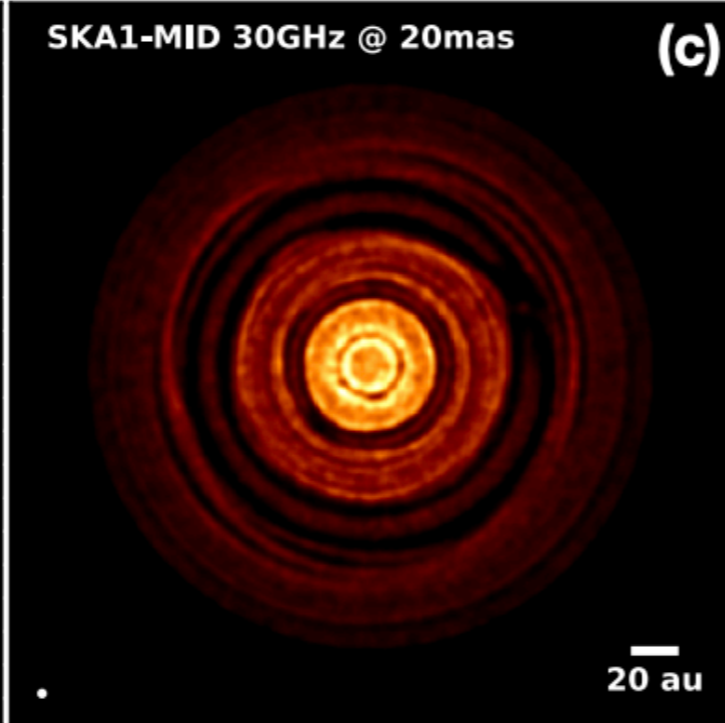
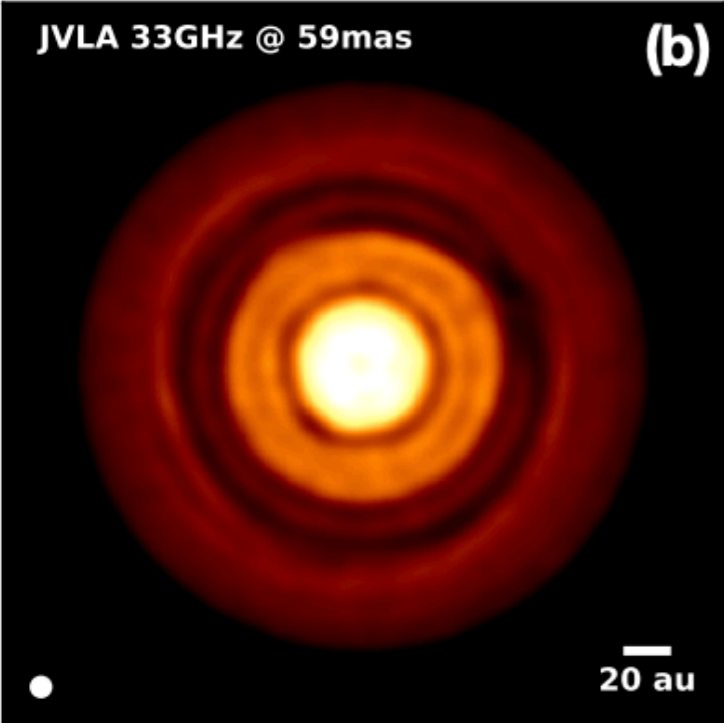
w/ thanks to

- 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!

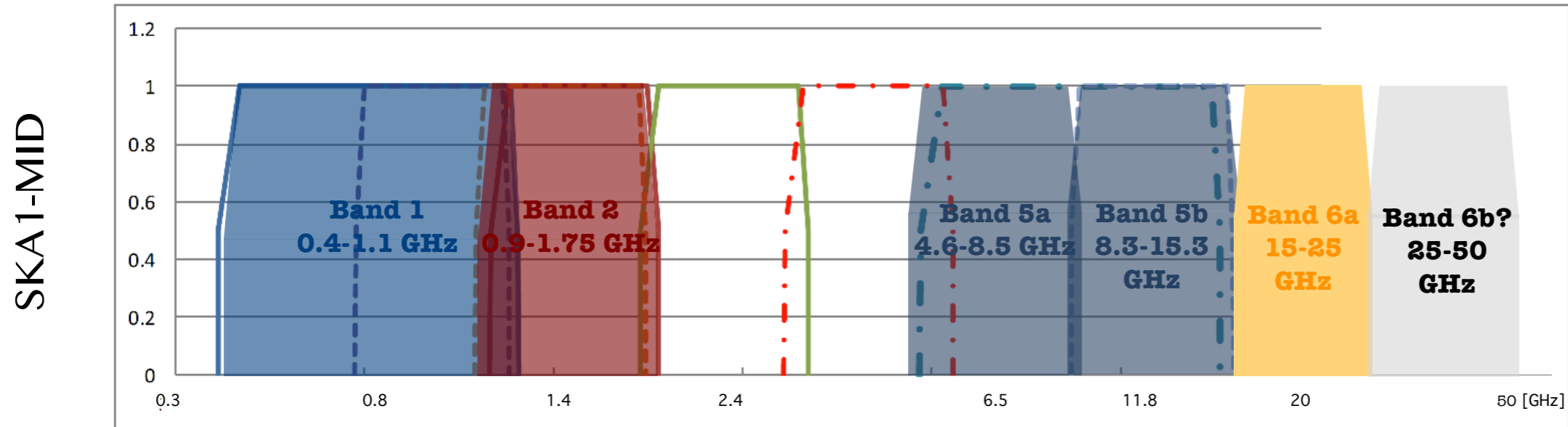


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# Overview

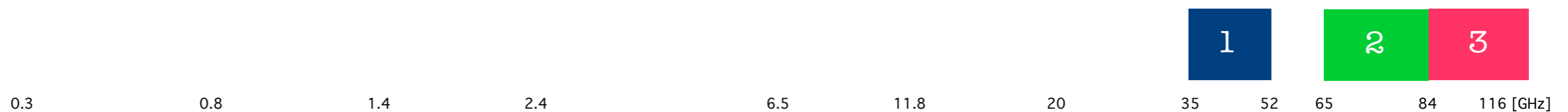
- Technical context & B6 observational parameter space
- Swiss and international context
- Band 6 science cases
- Next steps for SKACH community

# 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

ALMA



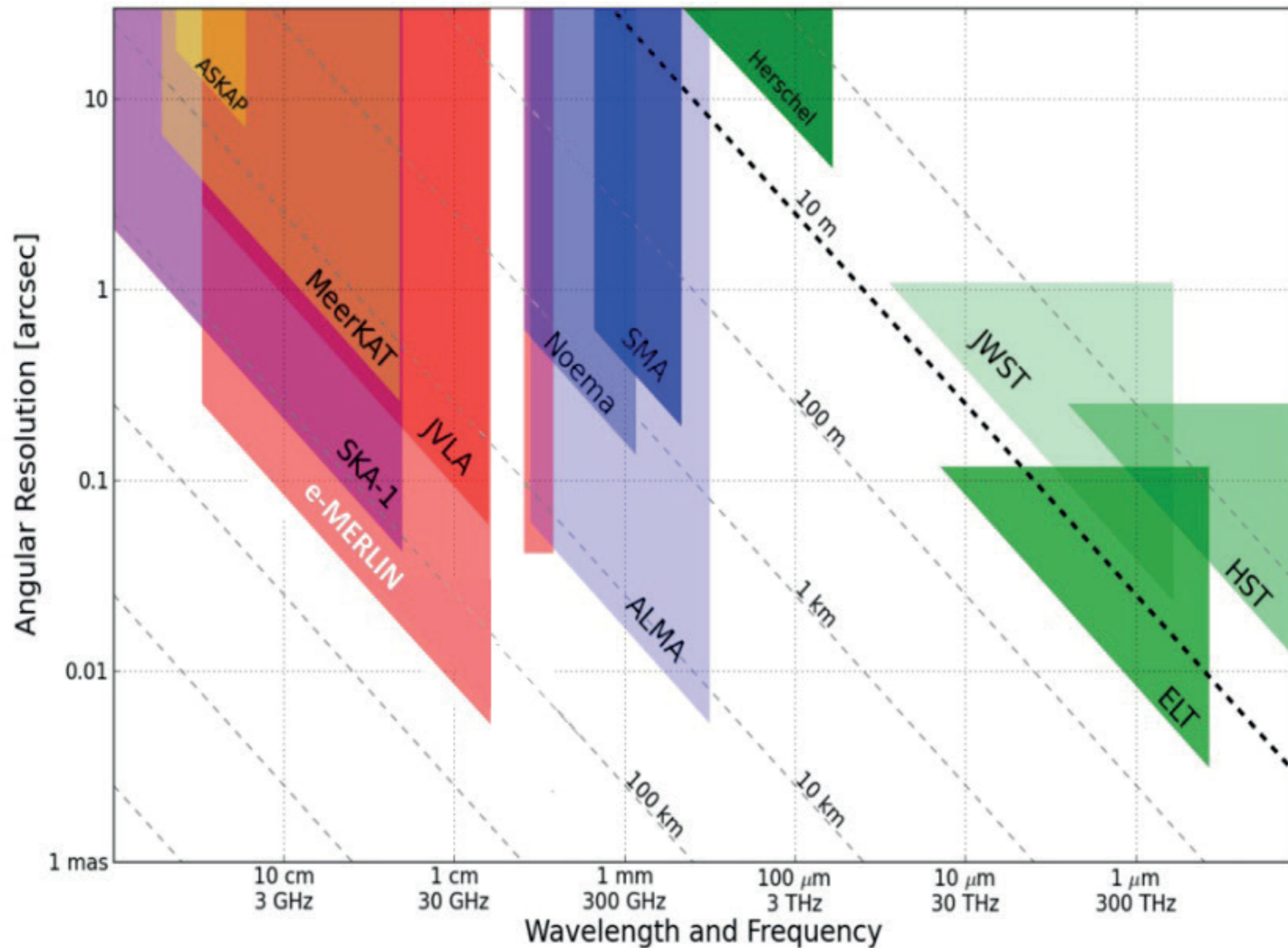
ngVLA



# Technical Context

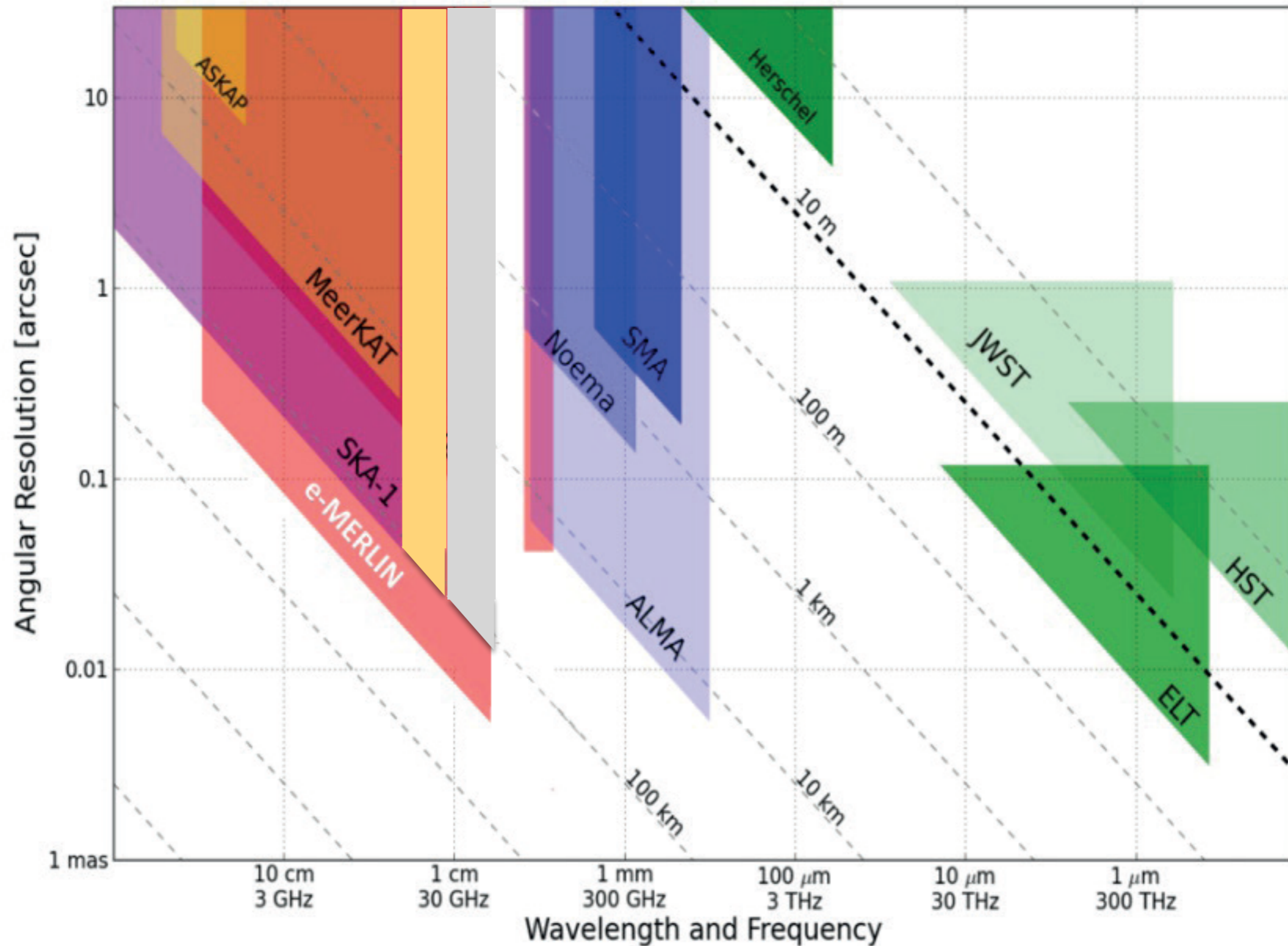
- The SKA1-MID dish performance is specified to 20 GHz - will deteriorate gradually toward higher frequencies.
- Anticipated RMS surface error of primary reflector is 280 microns, comparable to VLA dishes. (Needs to be verified by measurements on prototype dish.)
- Zero-th order assumption: would be 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

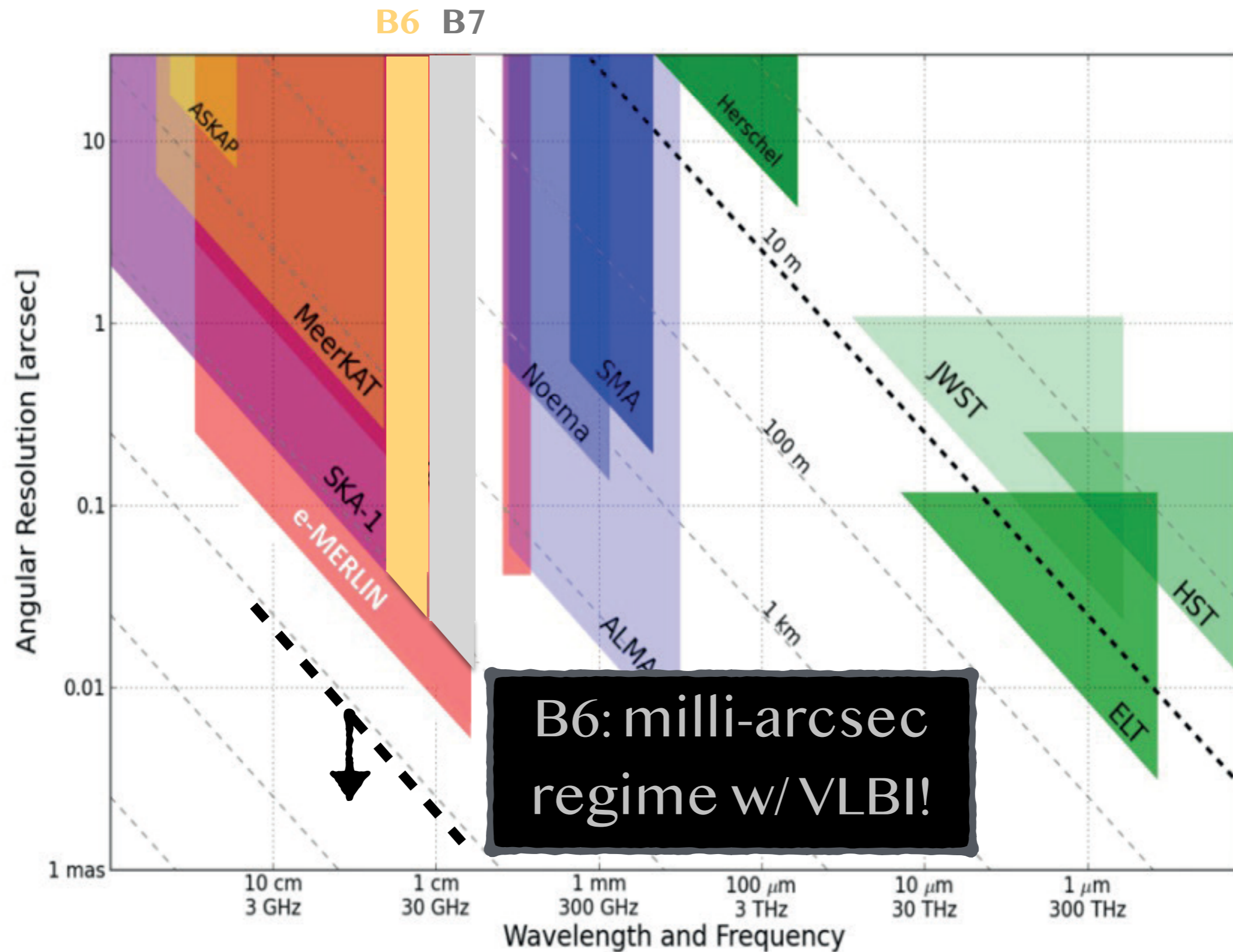


# Indicative Band 6 Performance

B6a B6b

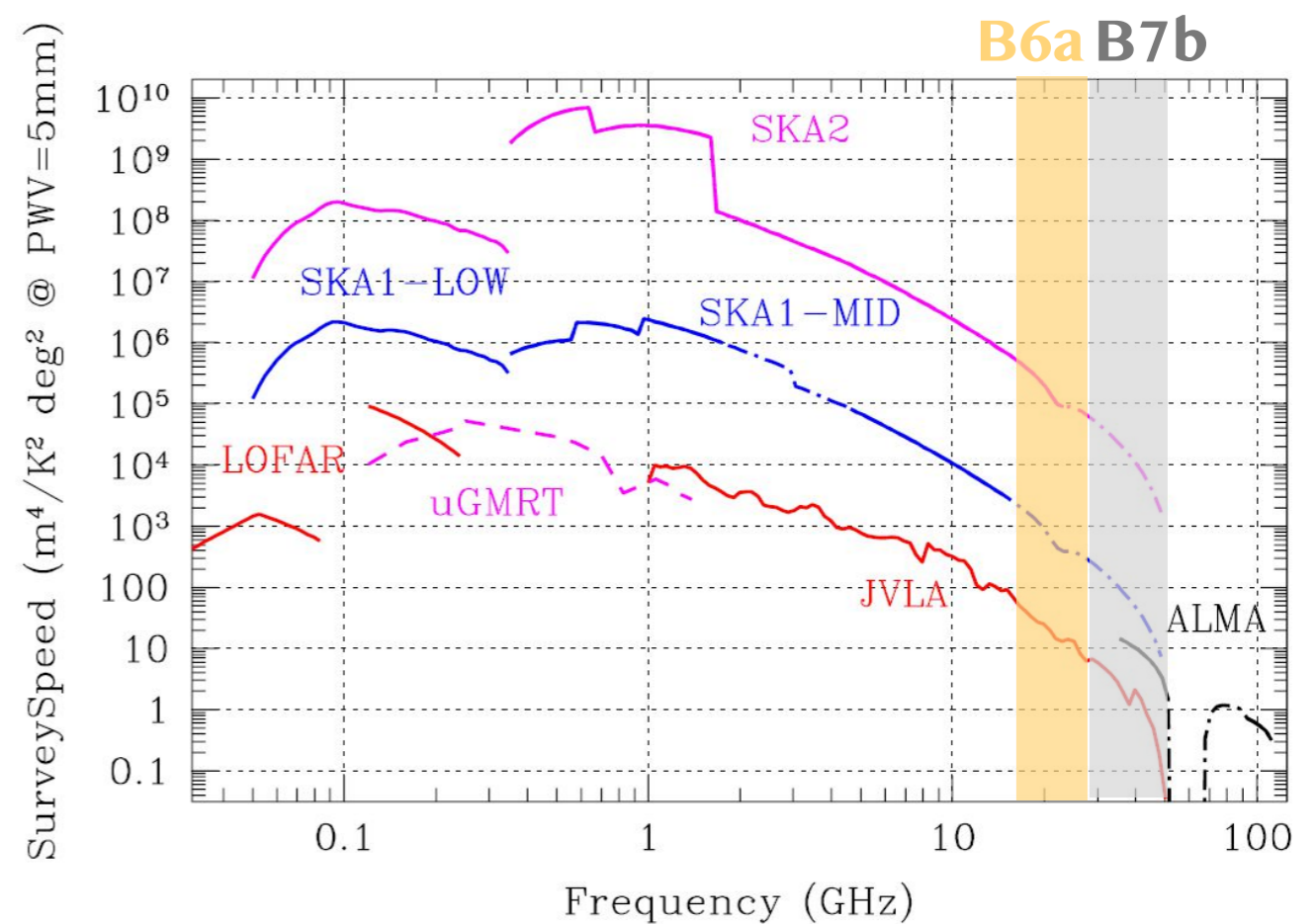
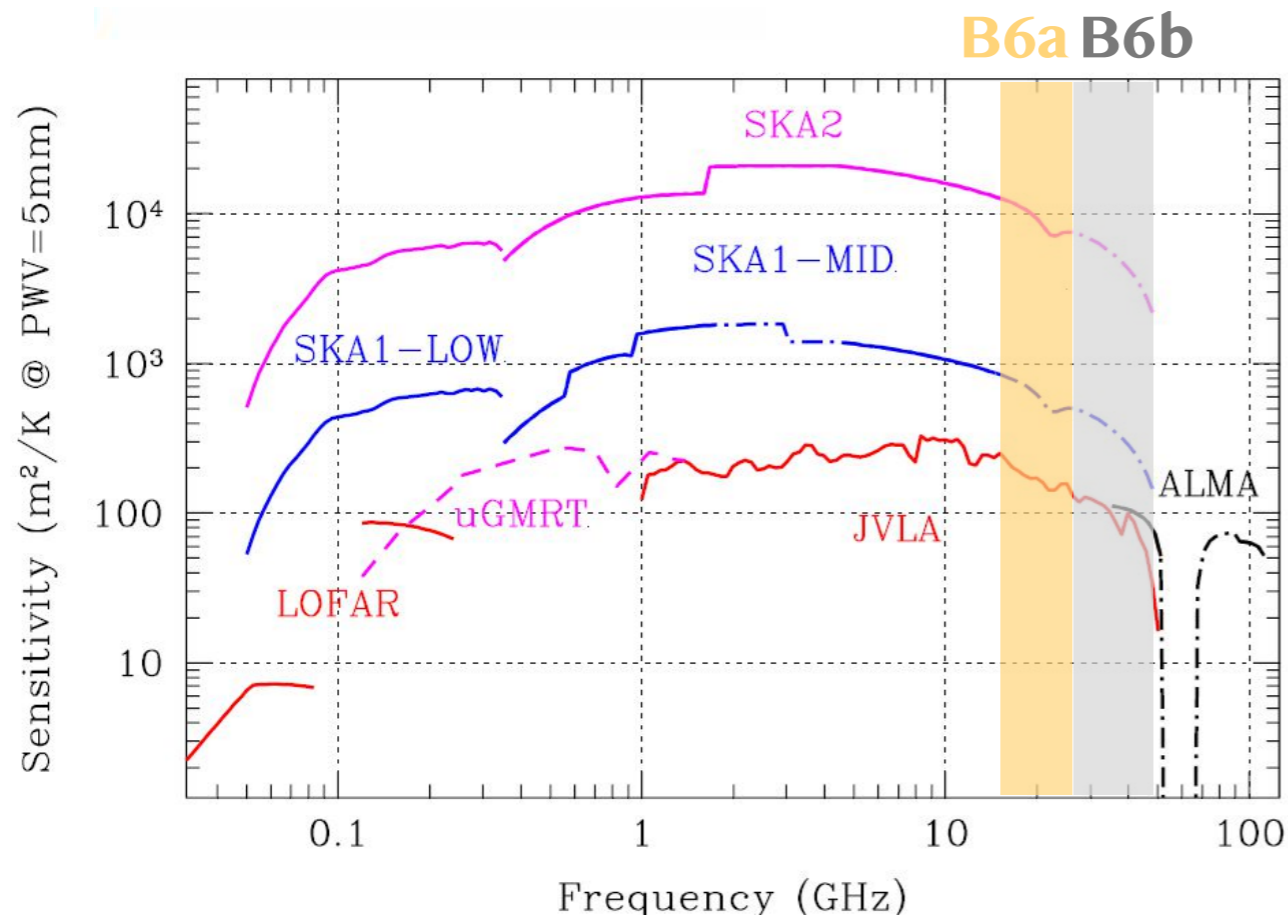


# Indicative Band 6 Performance





# Sensitivity & Survey Speed Expectations



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

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

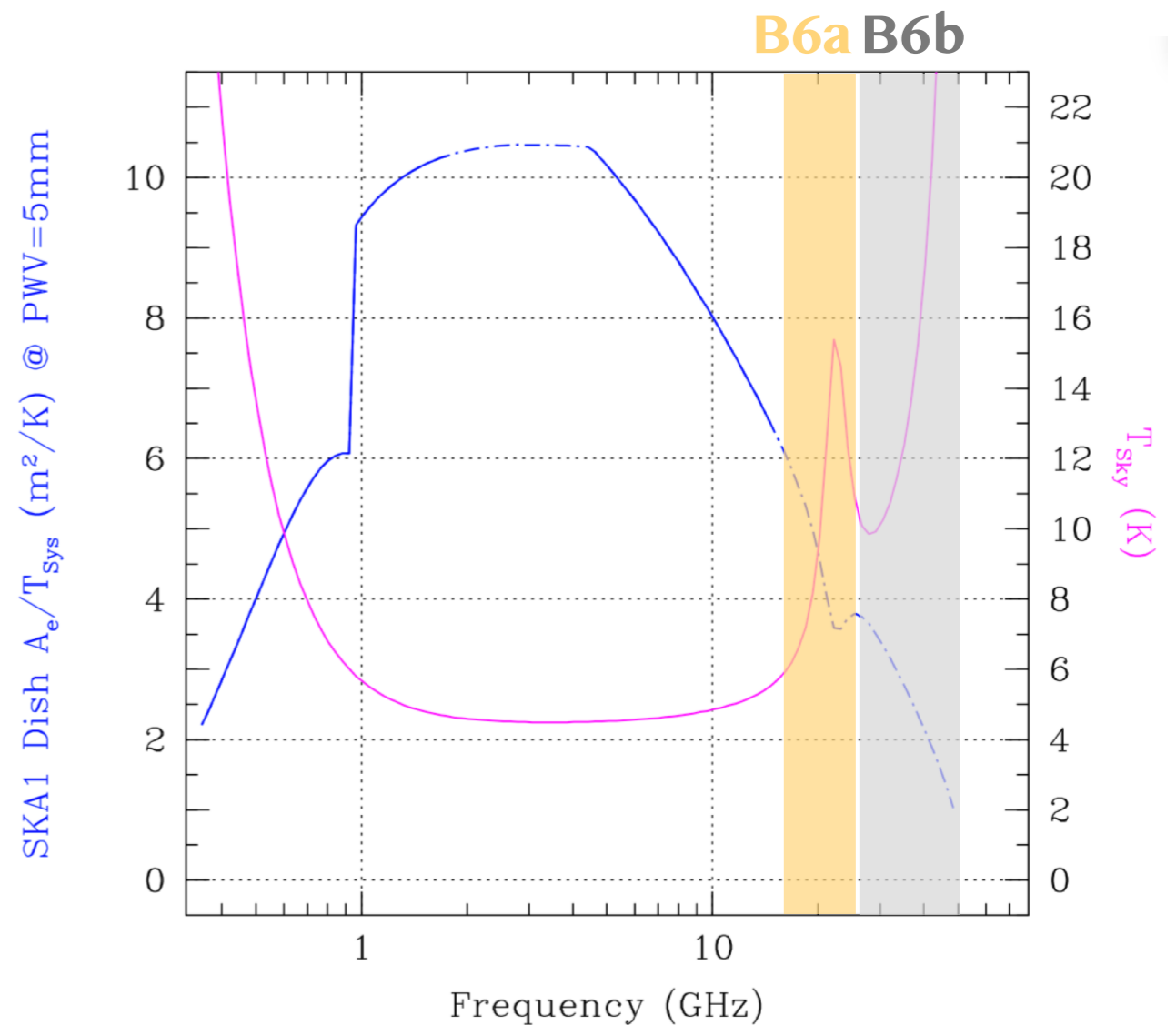
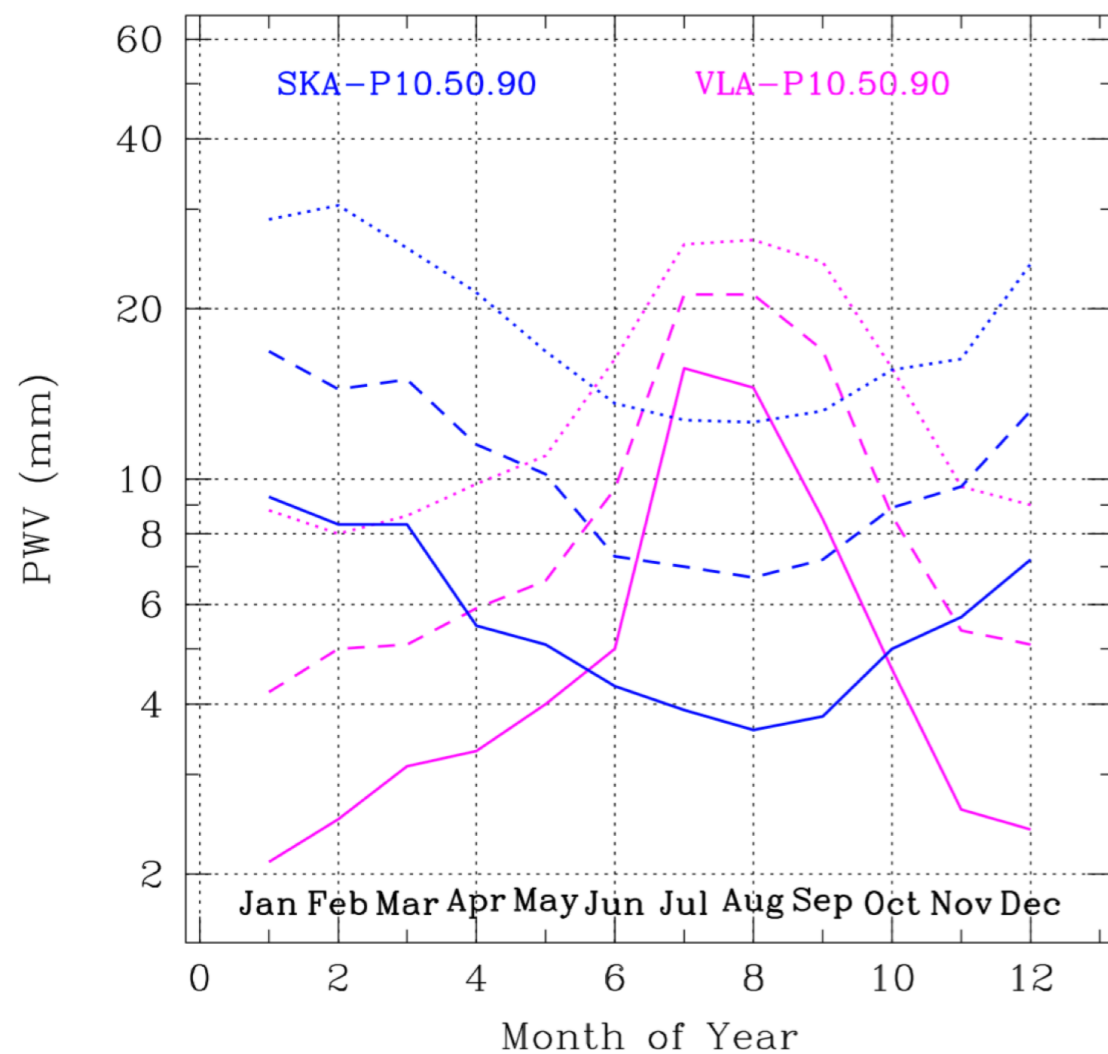
**B6a: ~20x faster survey speed  
(vs. JvLA K-band)**

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

# B6a/b Performance Estimates: Site & Dish Sensitivity

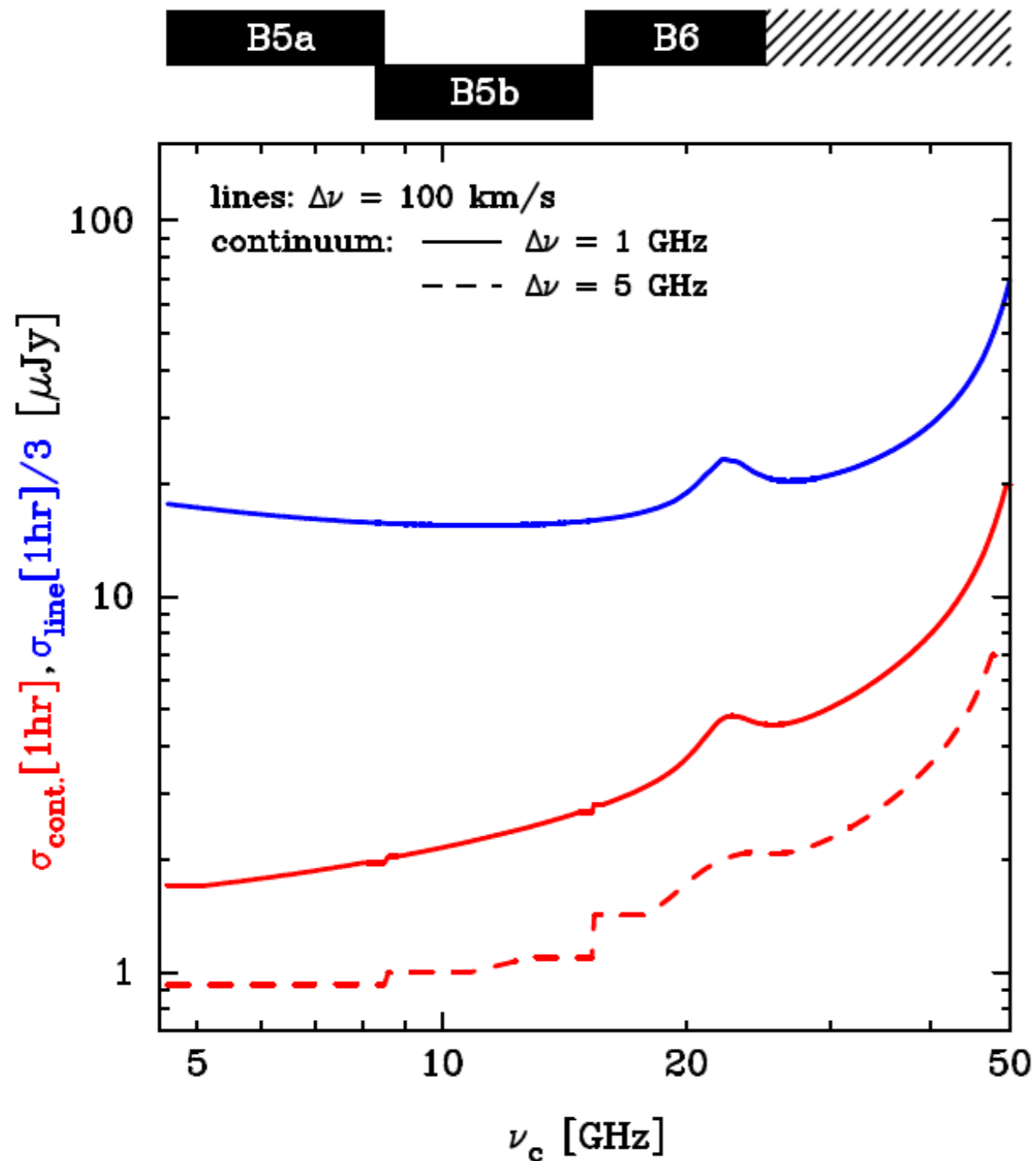
Avg. seasonal pwv level variation for MID and VLA sites (2010-2015; P. Forkman)

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



Indicative 1hr sensitivities ( $1\sigma$ )  
at  $\sim 20 \text{ GHz}$  (zenith, pvw=5mm, standard SKAO assumptions on degradation of image noise compared to “natural” array sensitivity):

- line sensitivity (100 km/s channel): 57  $\mu\text{Jy}$
- continuum sensitivity (5GHz BW): 1.7  $\mu\text{Jy}$

At 40 GHz:

- lines: 86  $\mu\text{Jy}$
- continuum: 3.6  $\mu\text{Jy}$

# 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...

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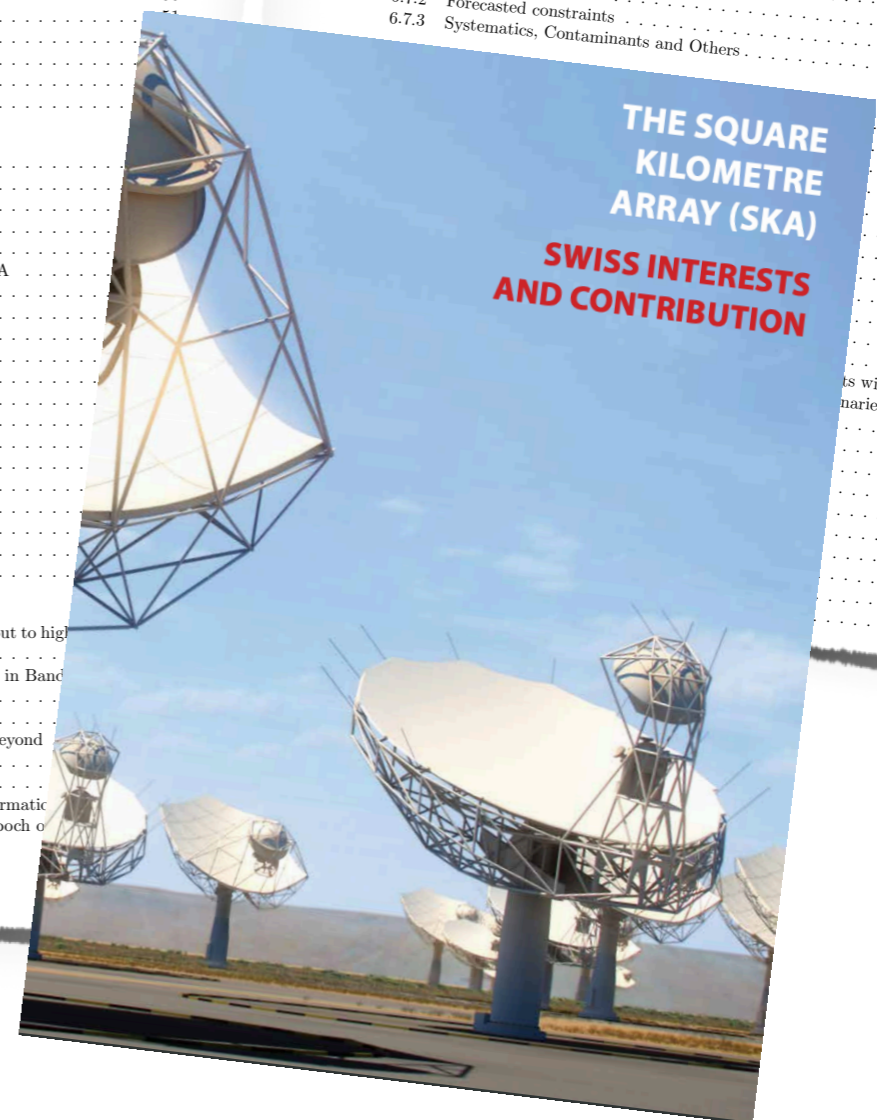
# “Beyond Band 5” White Book ... and Swiss White Book

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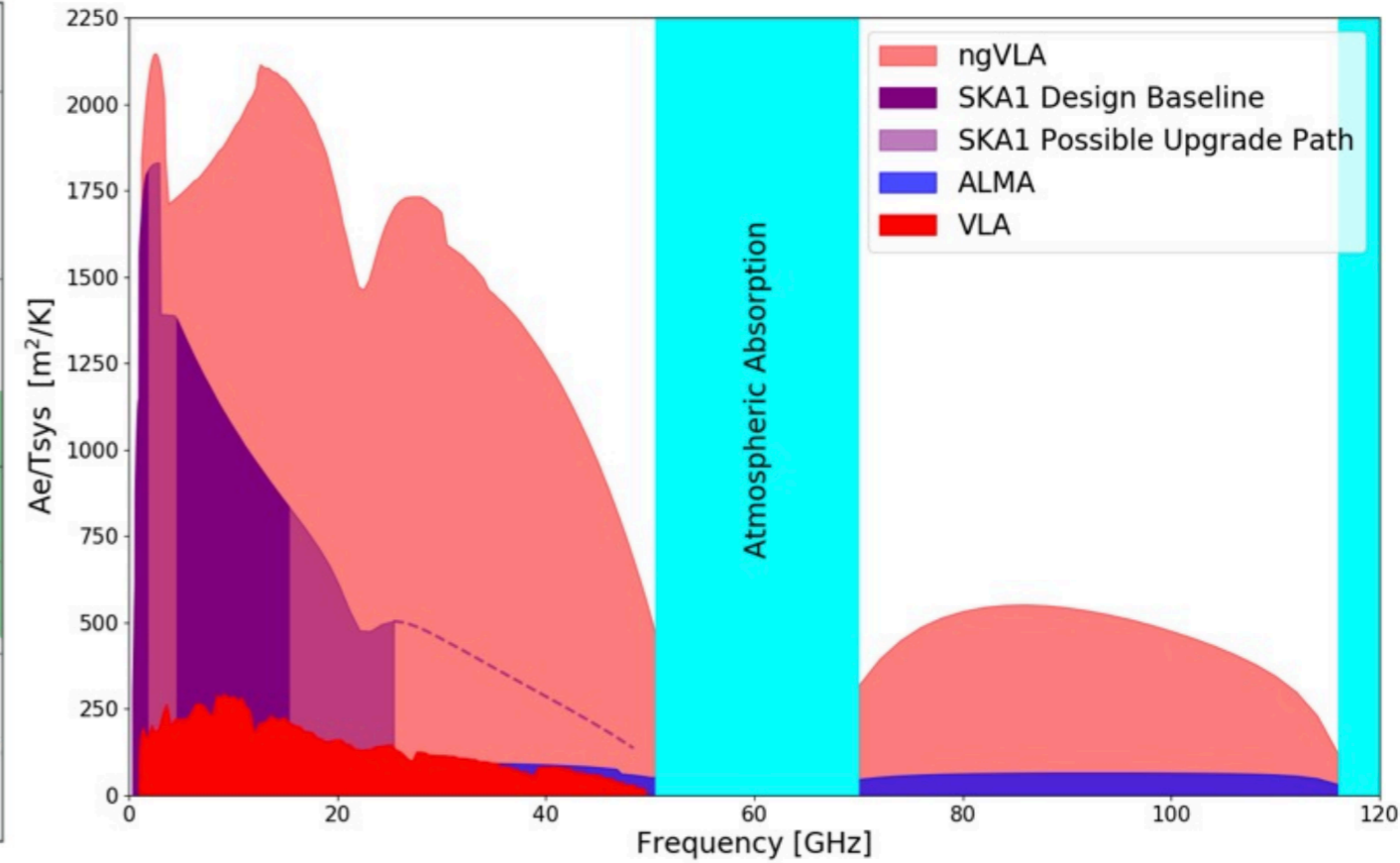
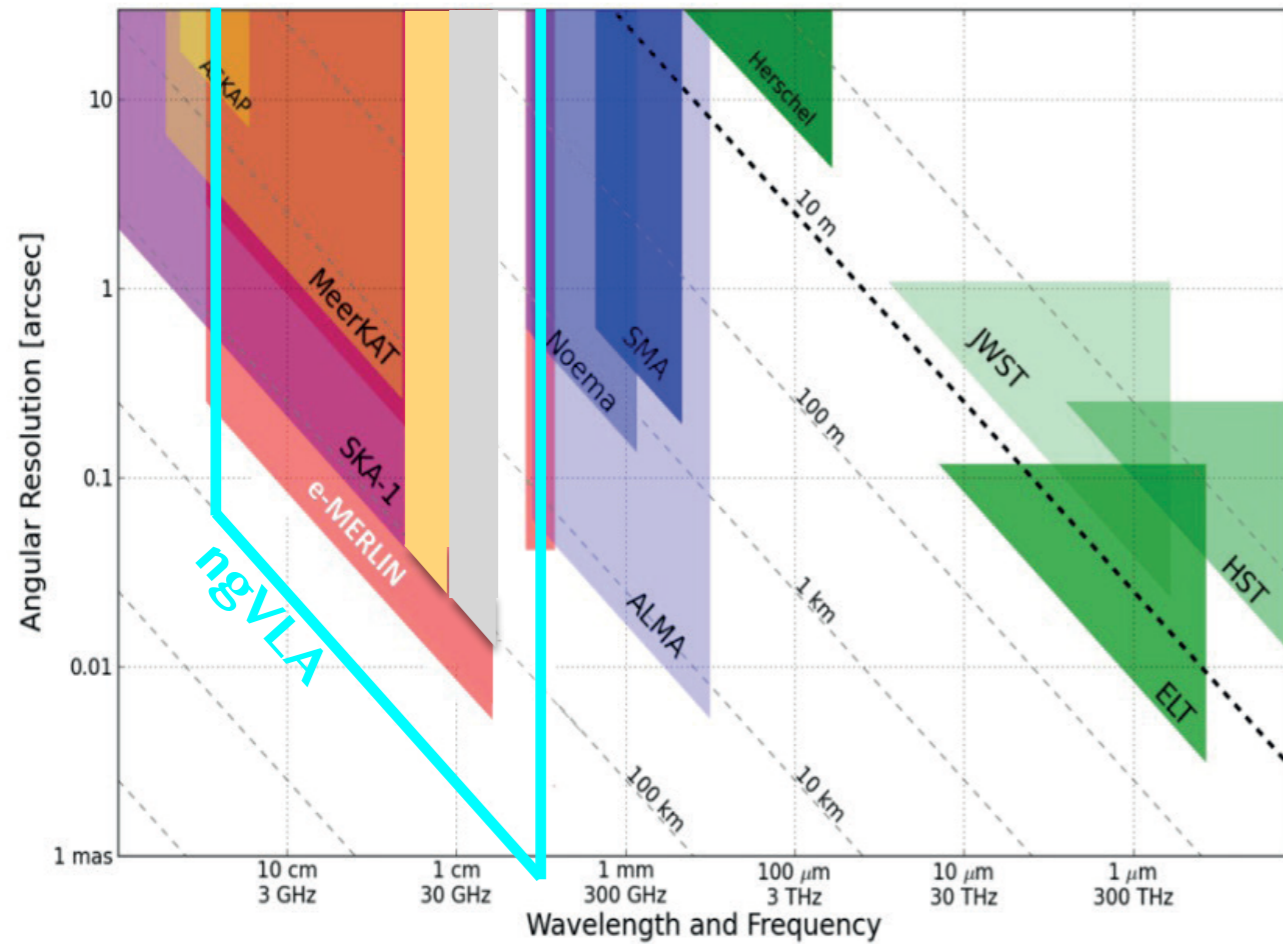
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# Other show in town: ngVLA

B6a B6b



- 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.:

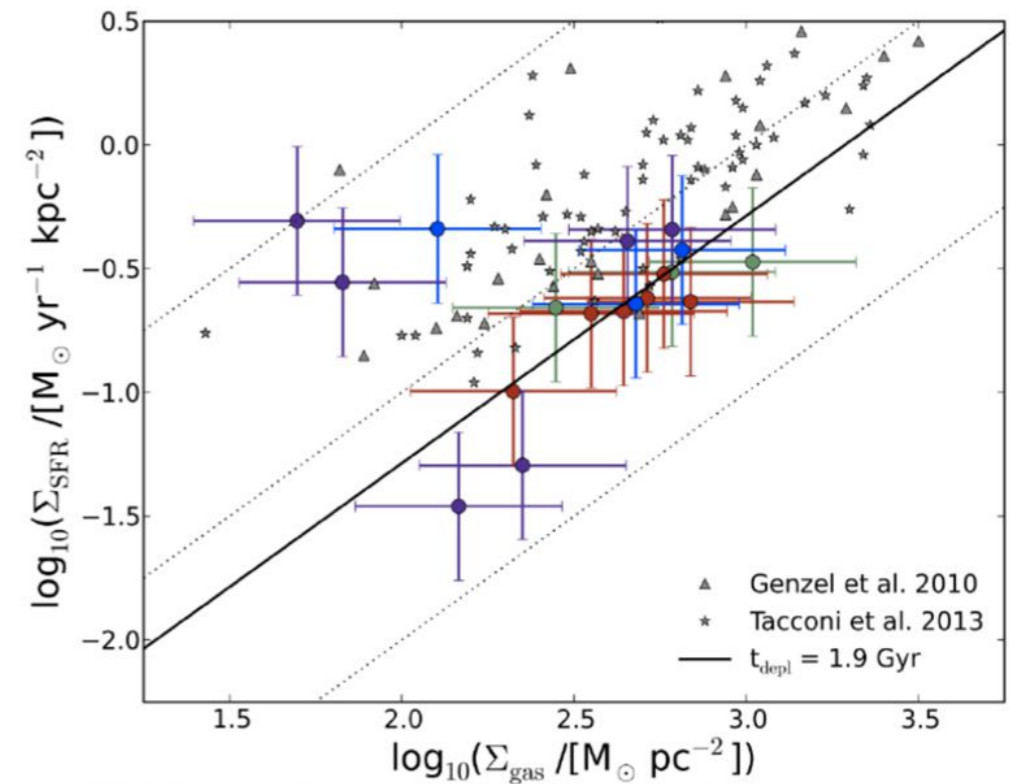
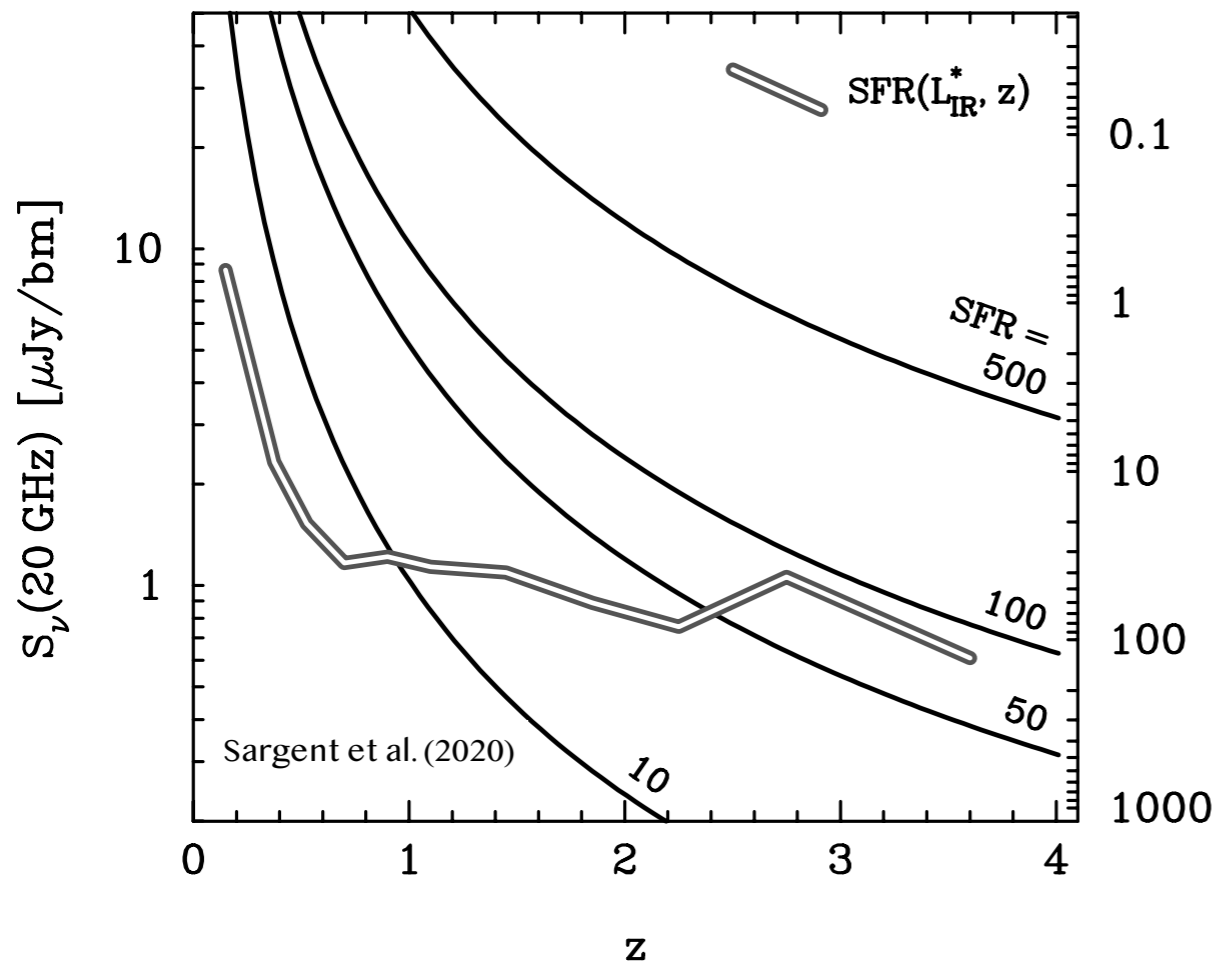
- Star-formation (HII regions): thermal emission
- Spinning Dust: anomalous microwave emission
- AGN
- clusters (S-Z effect)
- ...

### Galactic:

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



# Did you know? - Cosmic star-formation history

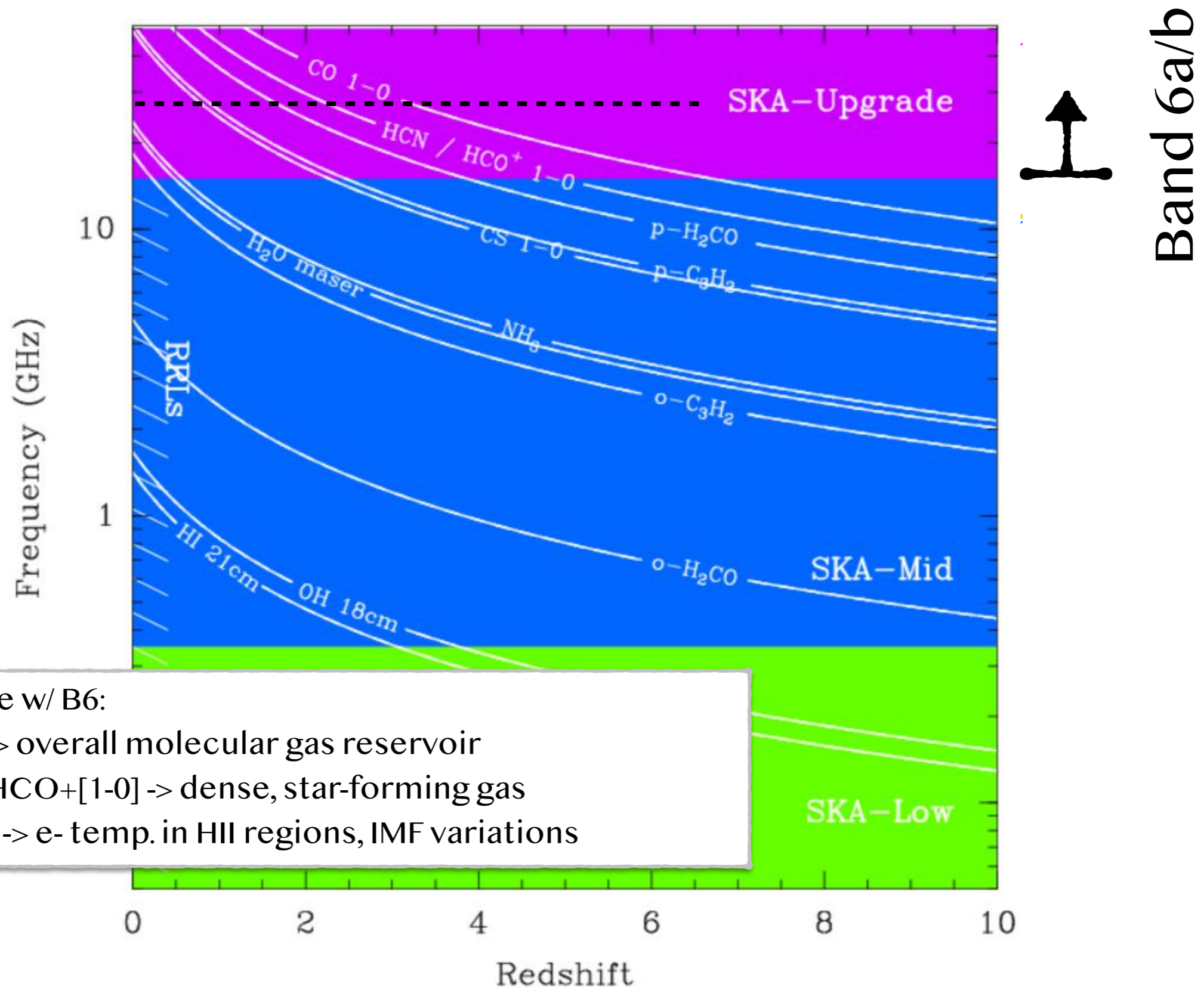


## CSFH science w/ B6:

- probe free-free continuum (directly proportional to production rate of Ly continuum photons)
- 1st measurement of CSFH via dust-unbiased, free-free SFR
- 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

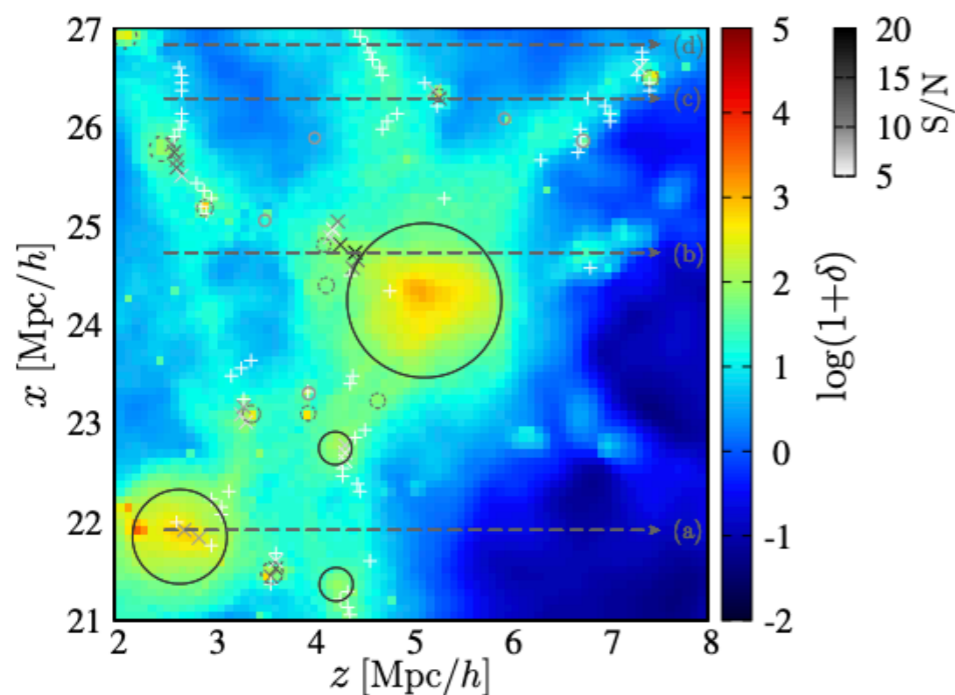
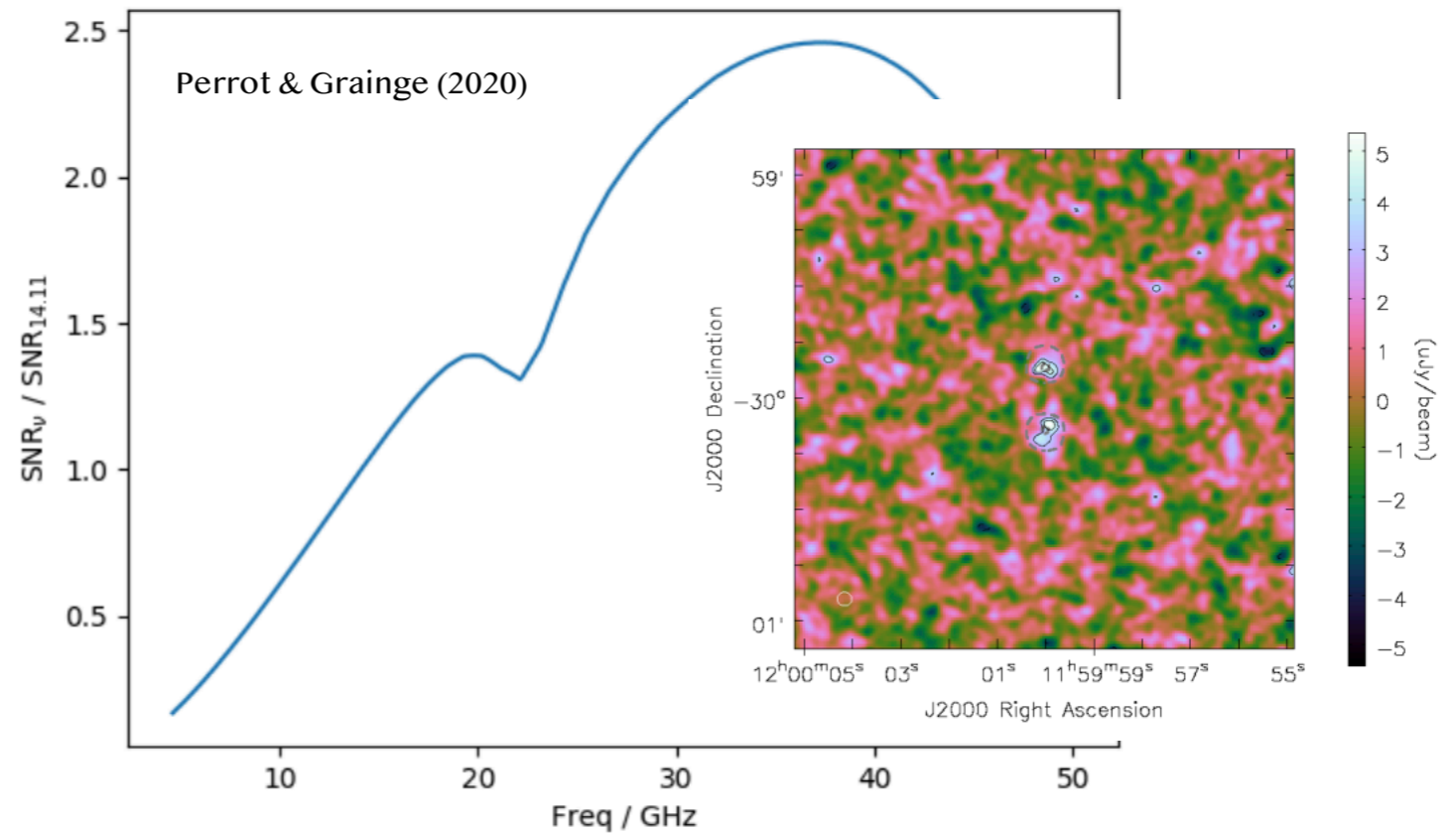


## CSFH science w/ B6:

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

# Did you know? - Cosmology / structure formation

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



Yoshikawa (2020)

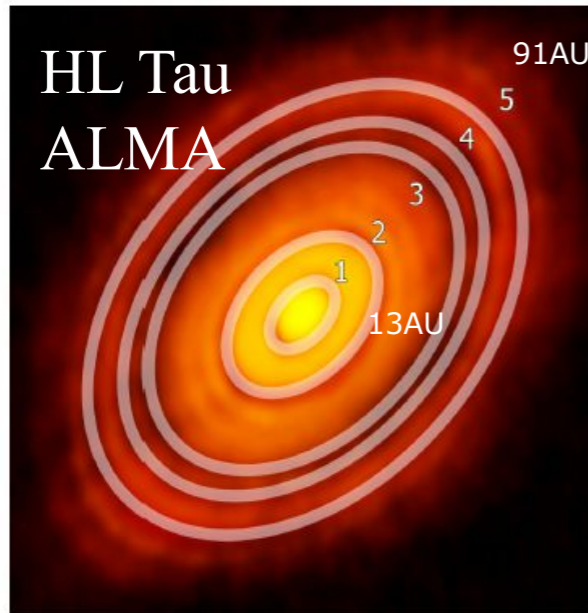
WHIM / missing baryon detection and characterisation (temperature, chemical enrichment) via hyperfine structure transitions of  $^{14}\text{N VII}$  detected in absorption against background radio sources.

# Did you know? - Cradle of Life science & exoplanets

The University of Manchester  
Jodrell Bank  
Observatory

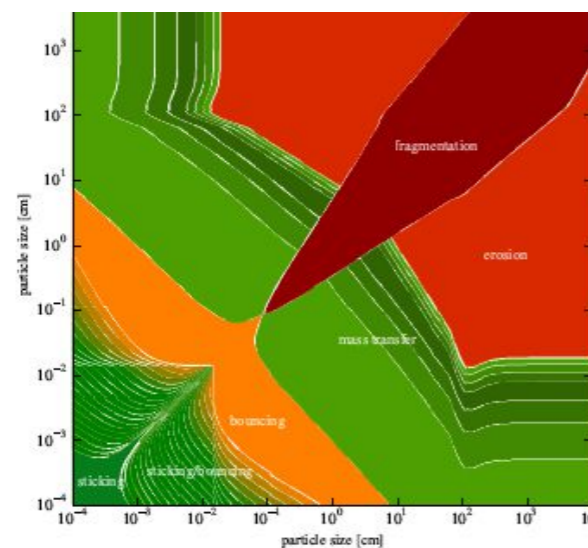


## Planet-forming disks/ grain growth



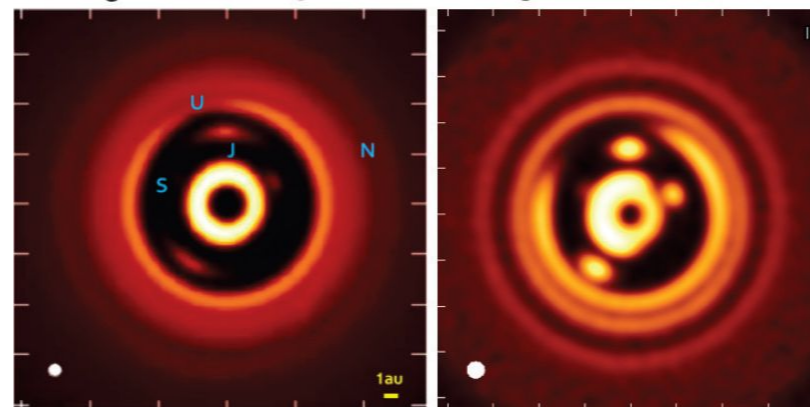
- Inner 10AU (Saturn) opaque to sub-mm [MMSN]
- Need cm wavelengths to see through dust & detect pebble material
- At 1AU need  $> \sim 3$  cm
- Jup: 40 mas, Mars 12 mas

Full range of frequencies GHz to 10s of GHz to untangle emission from thermal jets, disk winds, synchrotron  
few -10s mas resolution - required



Young Solar Nebula @ 3 mm

Young Solar Nebula @ 1 cm



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

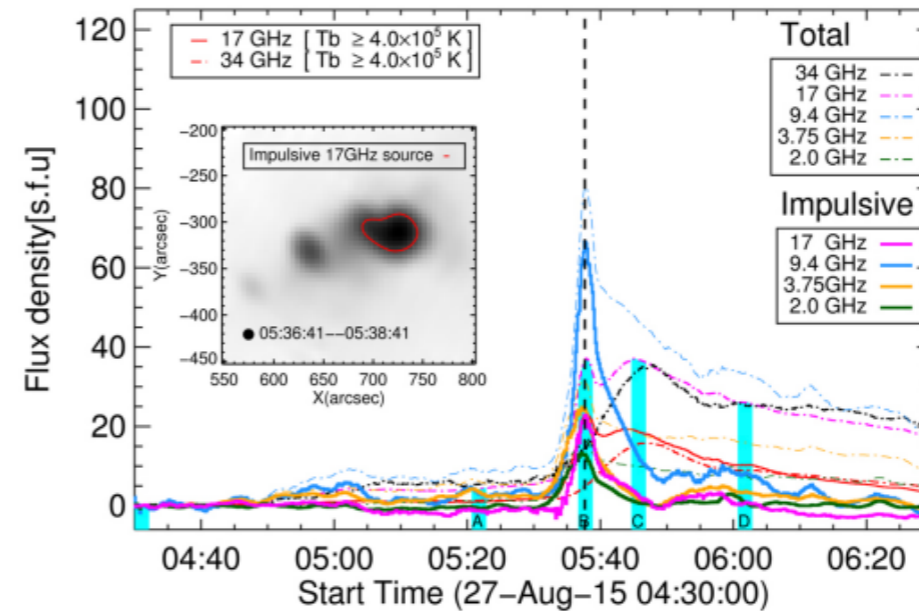
**From dust → pebbles → planets**

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); **F**<sub>0.7cm</sub>-**F**<sub>6.5cm</sub> are the estimated thermal fluxes in micro-Jansky ( $\mu\text{Jy}$ ) at these wavelengths; **T**<sub>b</sub> is the brightness temperature in Kelvin.

Object	Type	D [km/mas]	F <sub>0.7cm</sub> [ $\mu\text{Jy}$ ]	F <sub>1.2cm</sub> [ $\mu\text{Jy}$ ]	F <sub>2cm</sub> [ $\mu\text{Jy}$ ]	F <sub>3.5cm</sub> [ $\mu\text{Jy}$ ]	F <sub>6.5cm</sub> [ $\mu\text{Jy}$ ]	T <sub>b</sub> [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 <sub>10</sub>	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 <sub>32</sub>	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? - Astronomy

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	$\pi$ accuracy
OH	1612 MHz	20 mas	0.25 mas
CH <sub>3</sub> OH	6.7 GHz	6 mas	0.030 mas
CH <sub>3</sub> OH	12 GHz	3 mas	0.020 mas
H <sub>2</sub> O	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

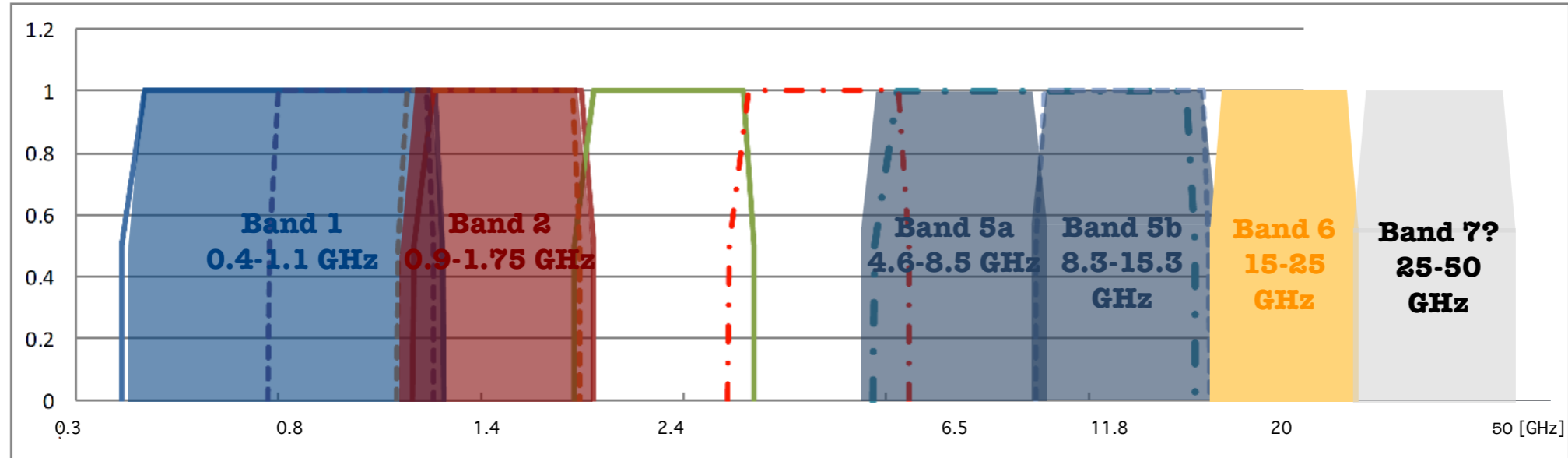
- **Purpose** – Meeting place for institutes/companies work on single pixel technology who wish to explore how this could be used for SKA via design studies, prototypes etc
- SKAO recognises ASPFR as a **conduit into SKAO** planning for advanced Single Pixel Feed/Receivers technology, for planning of 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>

# Emission mechanisms/sources underpinning B6 science

SKA1-MID



***OH masers***

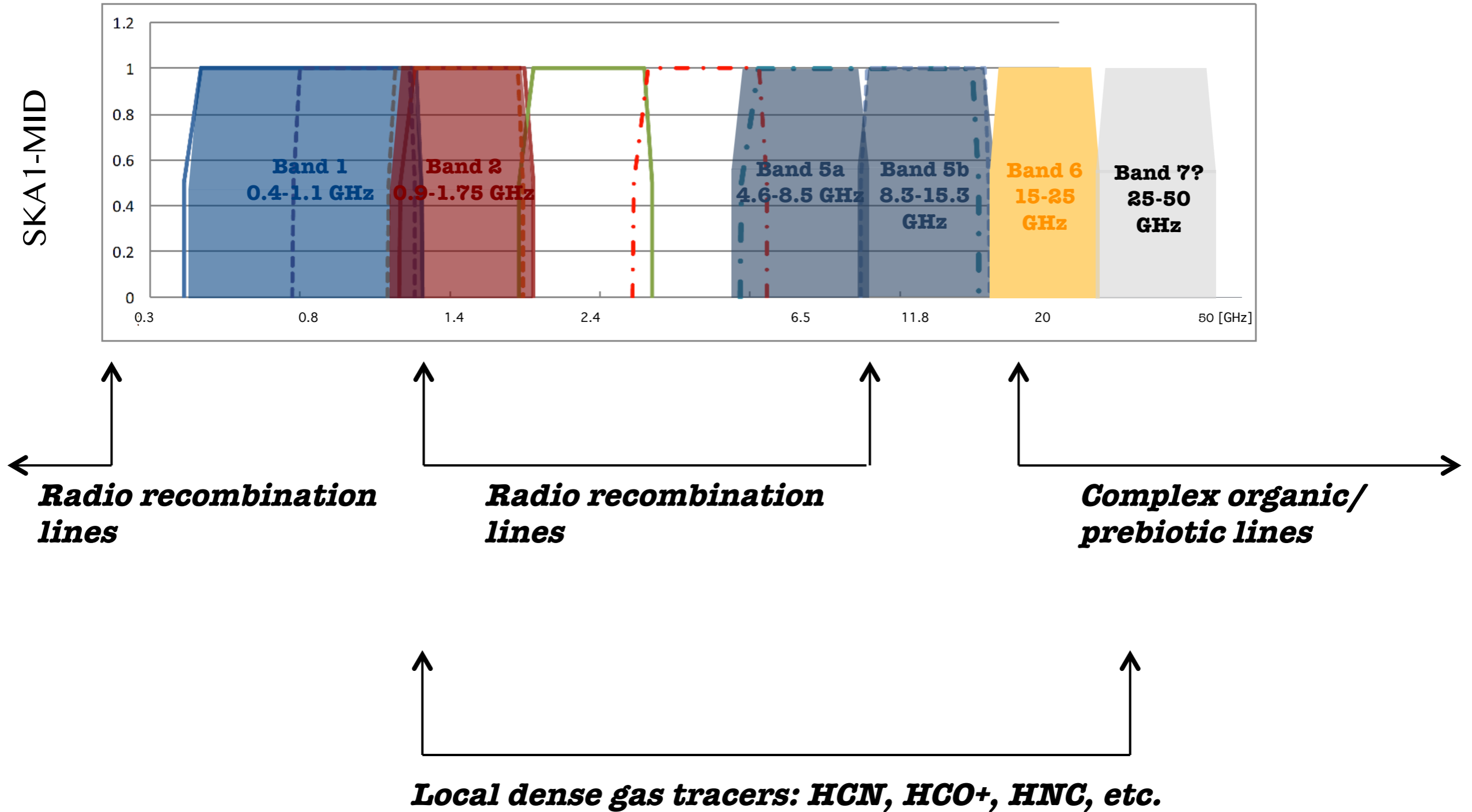
***OH\* masers***  
***formaldehyde***  
***maser***

***OH\* masers***  
***methanol maser***

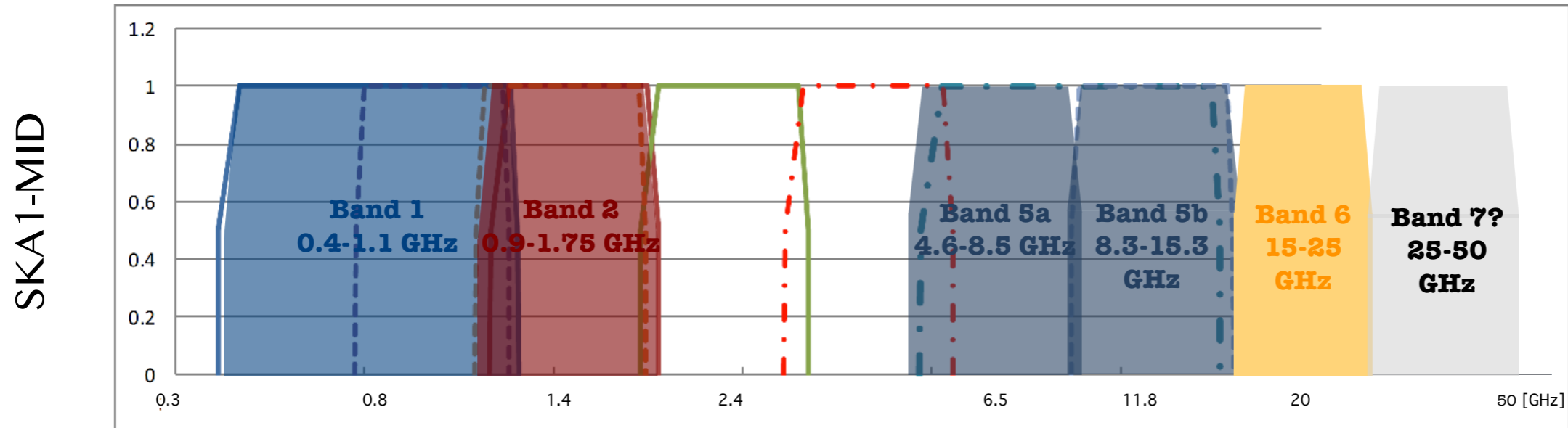
***methanol\* maser***

***H<sub>2</sub>O maser***

# Emission mechanisms/sources underpinning B6 science



# 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**