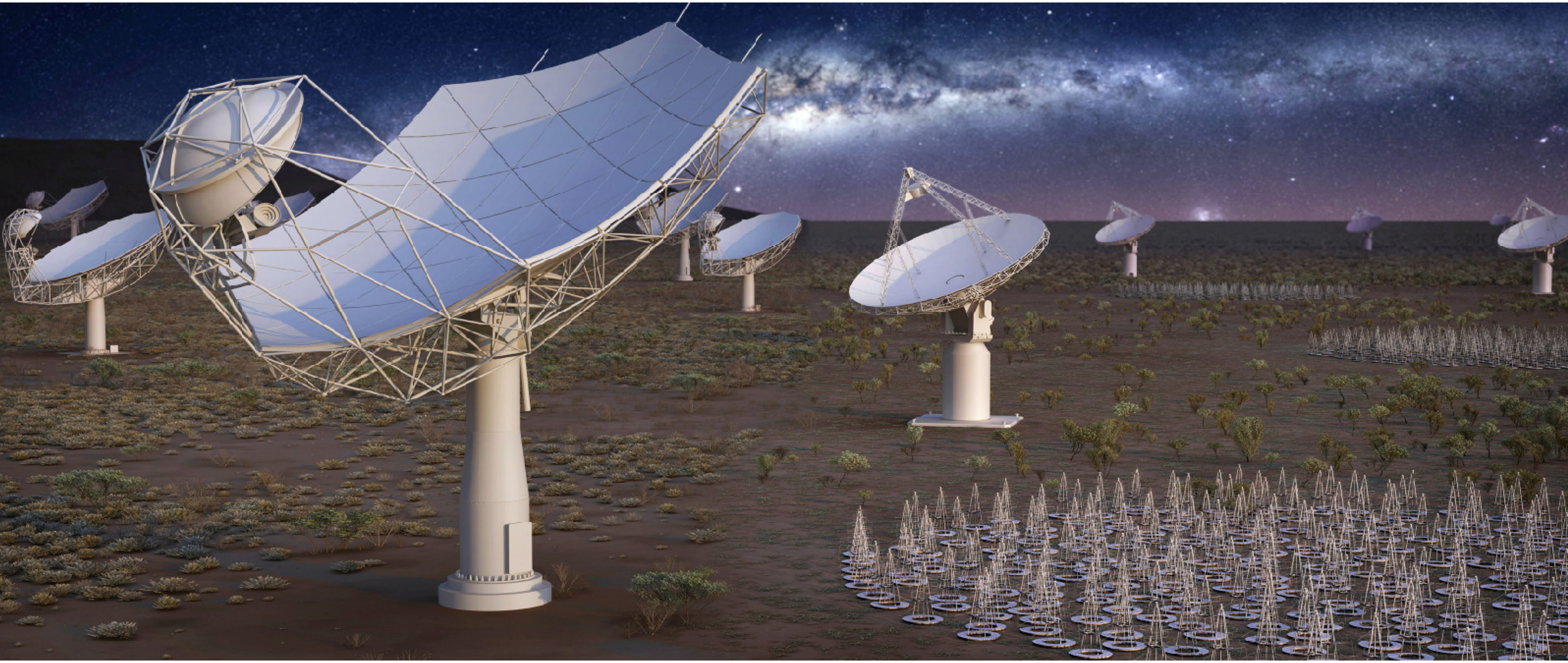
SKA-VLBIの性能とサイエンス事例



NAOJ SKA1 STUDY GROUP
国立天文台SKA1検討グループ

廣田朋也

References

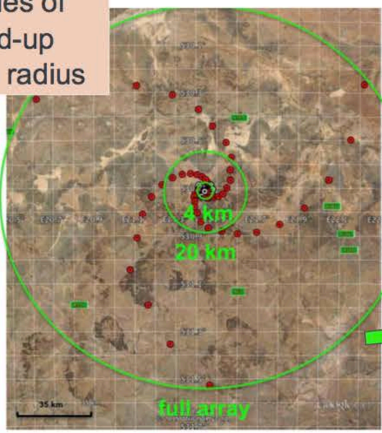
- **SKA Science book (2014)**
  https://www.skatelescope.org/news/ska-science-book/
- **ANTICIPATED SKA1 SCIENCE PERFORMANCE (2017)**
  https://astronomers.skatelescope.org/wp-content/uploads/2017/10/SKA-TEL-SKO-0000818-01_SKA1_Science_Perform.pdf
- **ngVLA Science book (2018)**
  https://ngvla.nrao.edu/page/scibook
- **SKA VLBI KSP WS (2019 October @ Manchester)**
  https://indico.skatelescope.org/event/539/page/280-conference-presentations
- **SKA Science book beyond band 5(2020)**
  https://www.skatelescope.org/wp-content/uploads/2020/02/ScienceCase_band6_Feb2020.pdf
- **SKA-J Science book (2020)**
  http://ska-jp.org/SKAJP_Science_Book_2020.pdf
- **SKA-VLBI性能諸元(2020 September version)**
  https://mwg.sci.kagoshima-u.ac.jp/wiki/pages/m0e1R6Q5/2020.html

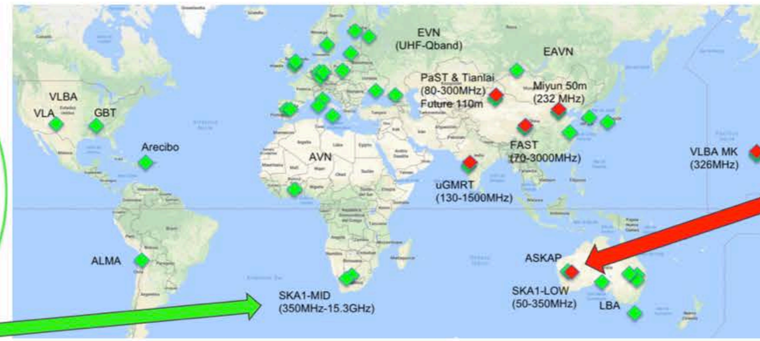
SKA-VLBI overview

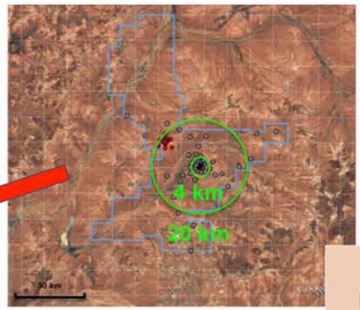
Paragi, SKA-VLBI KSP WS 2019

SKA-VLBI CONFIGURATIONS: networks & sensitivities

SKA1-MID
Examples of phased-up subarray radius

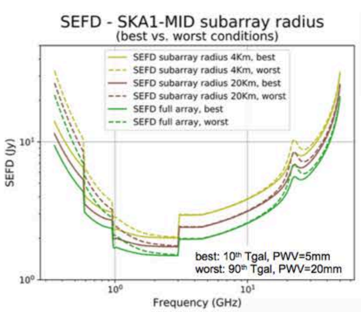


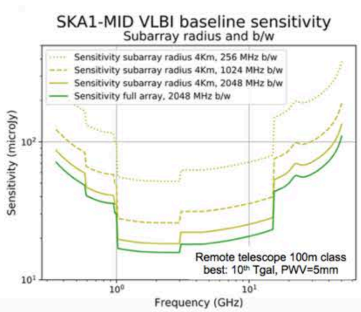


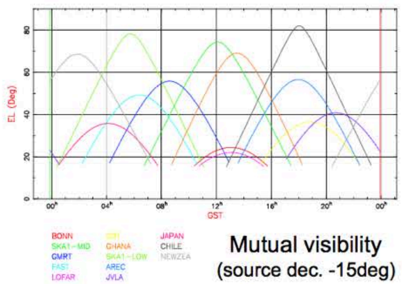


SKA1-LOW
Examples of phased-up subarray radius

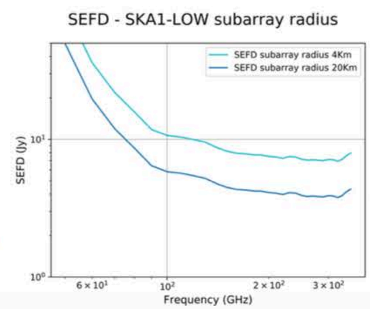
VLBI-MID **VLBI-LOW**

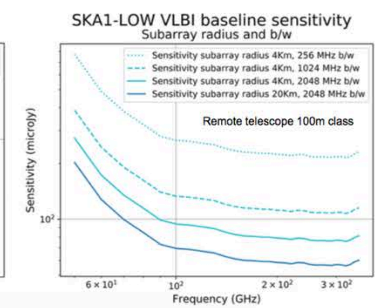






Mutual visibility
(source dec. -15deg)





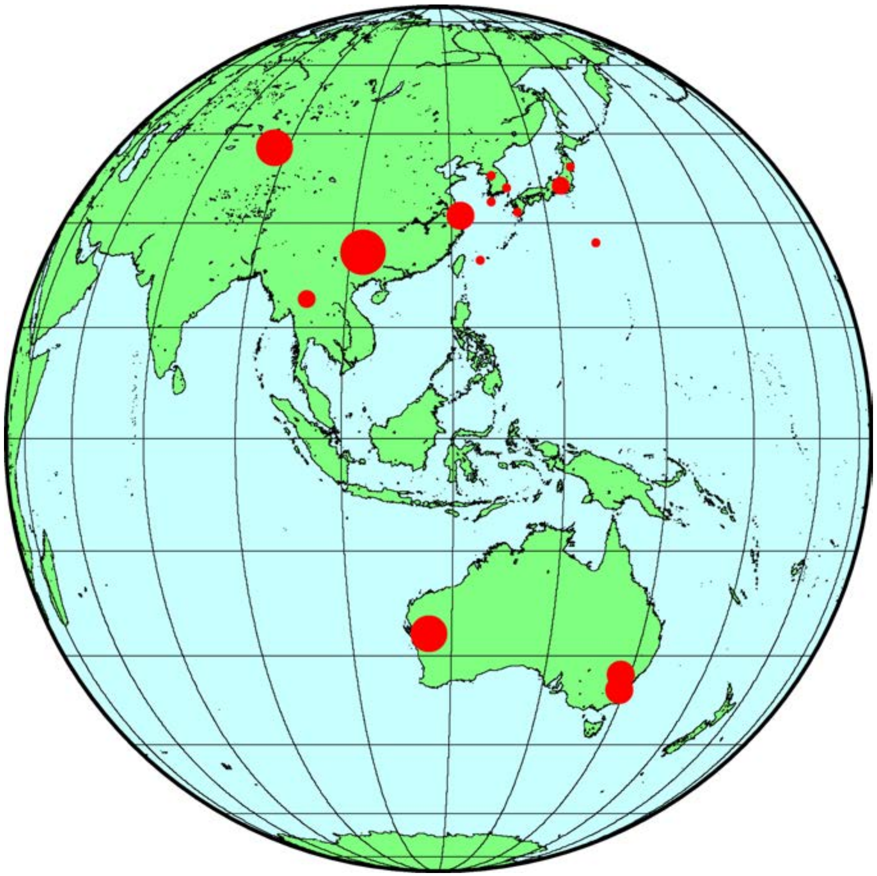
Access to Southern skies, (sub-)uJy sensitivity on mascales, superior calibration

Multi-beam capability: high-precision astrometry!

Simultaneous SKA products: range of angular scales, unique commensal applications

Ultimate *sensitivity* global VLBI

■Possible collaboration for future global VLBI



- Ultimate global VLBI with SKA1
  - Along with a few 100 m-class
  - Several 50 m-class
  - Many 20-30 m antennas

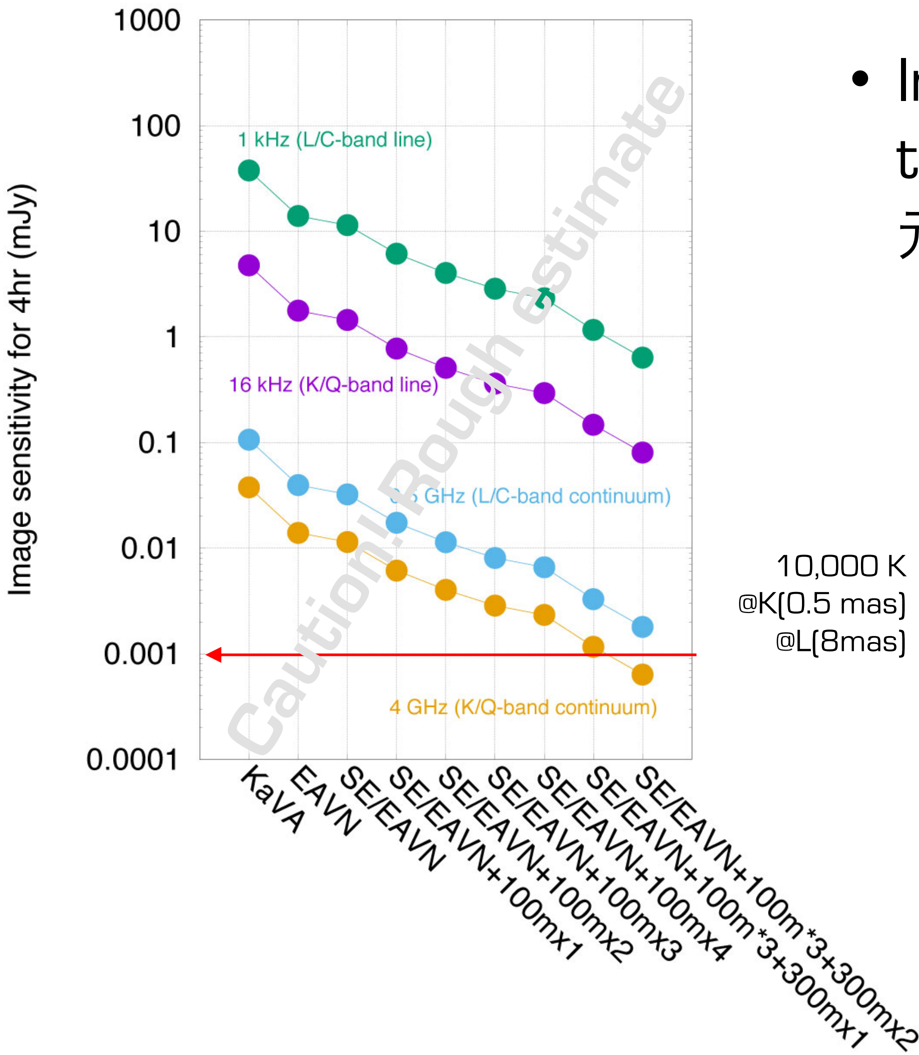
+Phased ALMA Band 1(0?)

+ngVLA LBA

- Common frequency?
- Common sky?
- Need more detailed study

Rough estimate of sensitivity

■Improvement from KaVA by a factor of 100

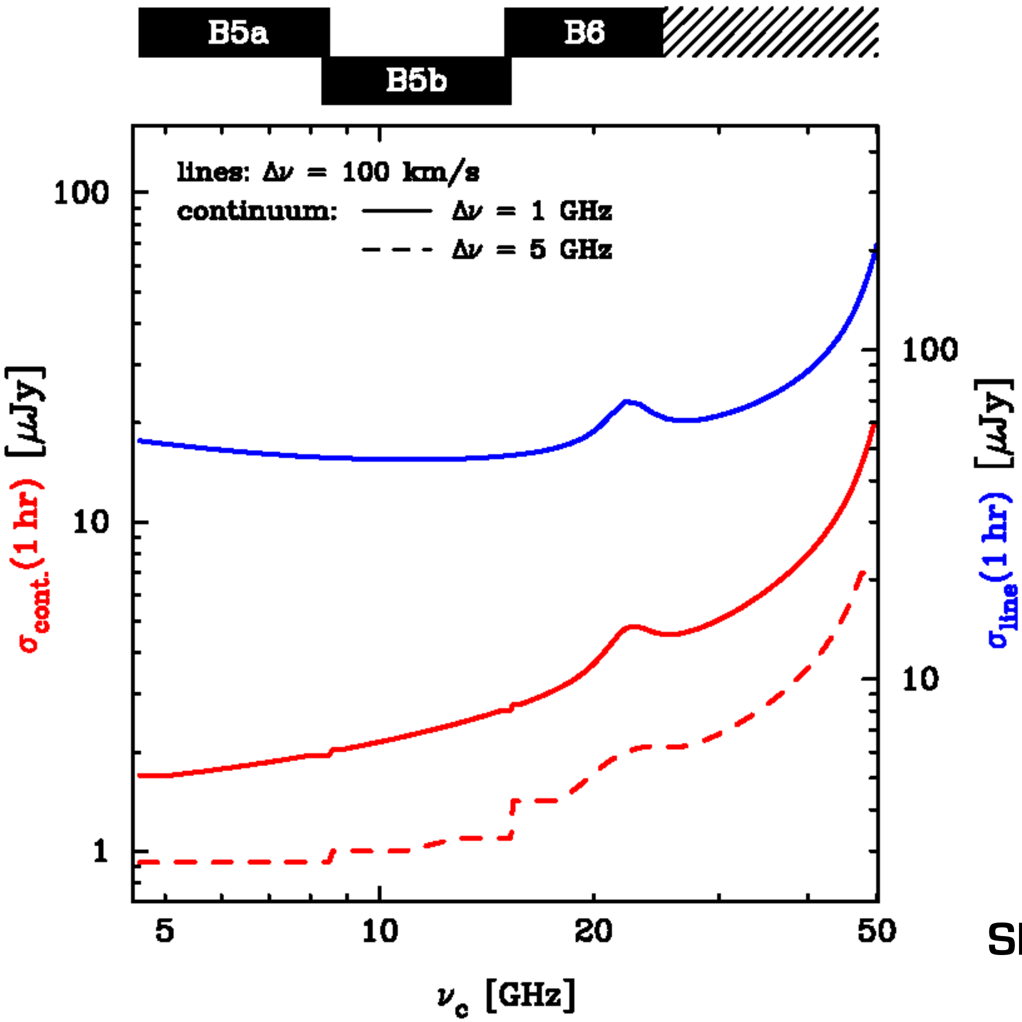


10,000 K
@K(0.5 mas)
@L(8mas)

- Image sensitivity of 4hr on-source time (1σ) based on “SKA-VLBI 性能諸元(2020 September version)”
  - Assuming Tsys=100 K and e=50% if there is no information
  - Rough estimate with uncertainties of a factor of 3-10

Ultimate *sensitivity* global VLBI

■c.f. Image sensitivity at Bands 5 and 6

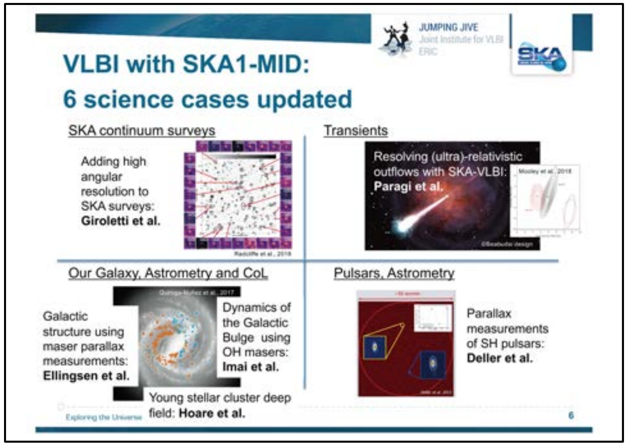


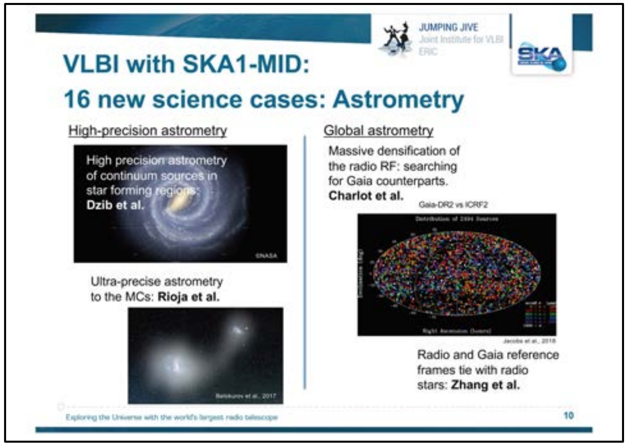
- Parameters are different from my rough estimate
- Still my rough estimate is comparable with that of SKA official document
  - Achieving μJy level

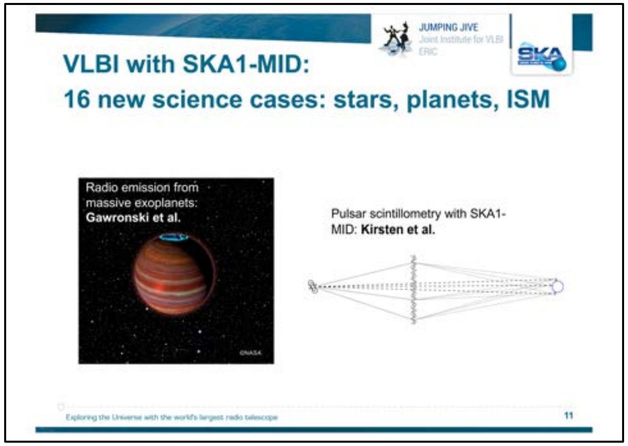
SKA Science book beyond band 5(2020)

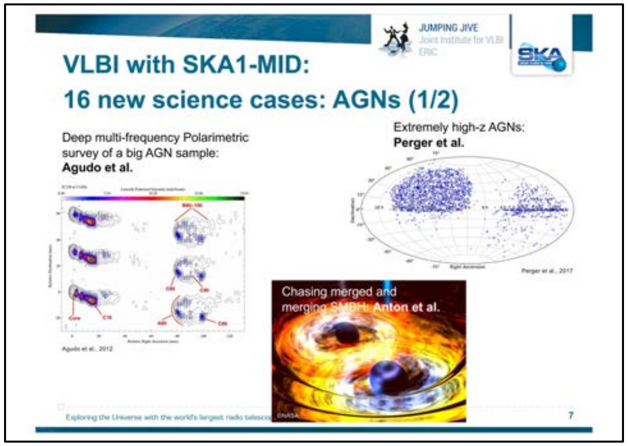
SKA-VLBI science cases

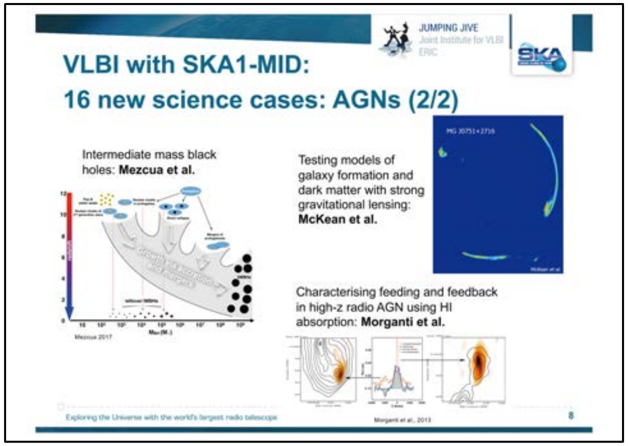
Garcia-Miro, SKA-VLBI KSP WS 2019

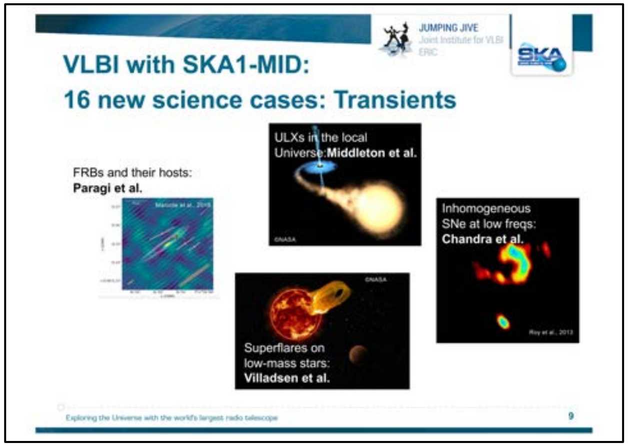








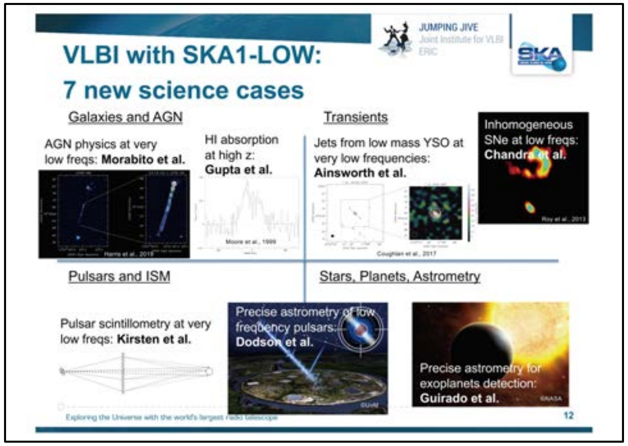




See presentation files in SKA VLBI KSP WS 2019

SKA-VLBI science cases

Garcia-Miro, SKA-VLBI KSP WS 2019



See presentation files in SKA VLBI KSP WS 2019

Maser sciences from VERA

■Increased number of new rare/weak lines

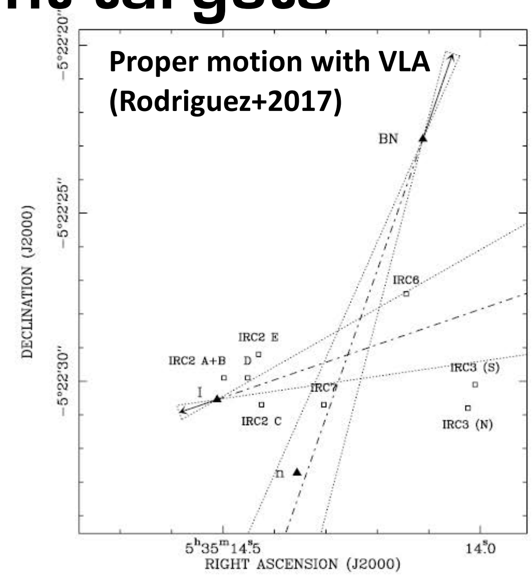
band	Range (GHz)	Species and line frequencies (GHz)	# lines
1	1.2 - 3.5	ground-state OH (1.612, 1.665, 1.667, 1.720)	4
2	3.5 - 12.3	excited OH (4.66, 4.75, 4.765, 6.031, 6.035, 6.049)	6
		CH_3OH Class I (9.936)	1
		CH_3OH Class II (6.668, 12.18)	2
		ortho-H_2CO (4.83)	1
3	12.3 - 20.5	CH_3OH Class II (19.97)	1
		excited OH (13.441, Baudry et al. 1981; Caswell 2004)	1
4	20.5 - 34	H_2O (22.235)	1
		CH_3OH J_2-J_1-series Class I (24.9-30.3)	15
		CH_3OH Class I (23.445, Voronkov et al. 2011)	1
		CH_3OH Class II (23.12, Cragg et al. 2004)	1
		ortho-NH_3 (3,3) (6,6) (9,9) (12,12)	4
		other NH_3 inversion lines (thermal and/or maser)	~dozen
		excited OH (23.8, Baudry et al. 1981)	1
5	30.5 - 50.5	Class I CH_3OH (36.169, 44.069)	2
		Class II CH_3OH (37.7, 38.29, 38.45)	3
		SiO 1-0 v=1,2 (43.12, 42.82)	2
6	70 - 116	CH_3OH Class I (84.521, 95.169, 104.3)	3
		CH_3OH Class II (76.2, 76.5, 85.5, 86.6, 104.1, 107, 108.8)	7
		SiO 2-1 v=1,2 (86.24, 85.64)	2

List of masers from ng-VLA science book (Hunter et al. 2018)

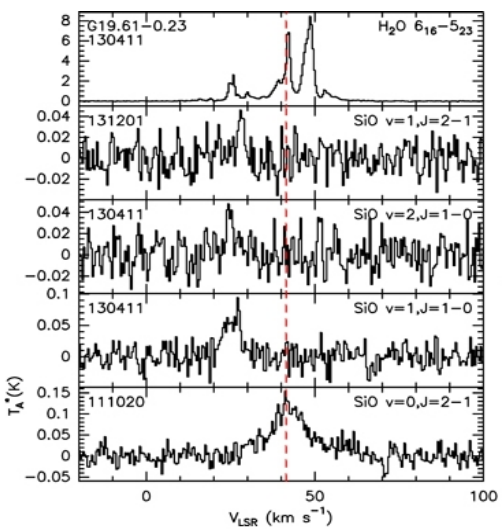
Maser sciences from VERA

■Increased number of new rare/distant targets

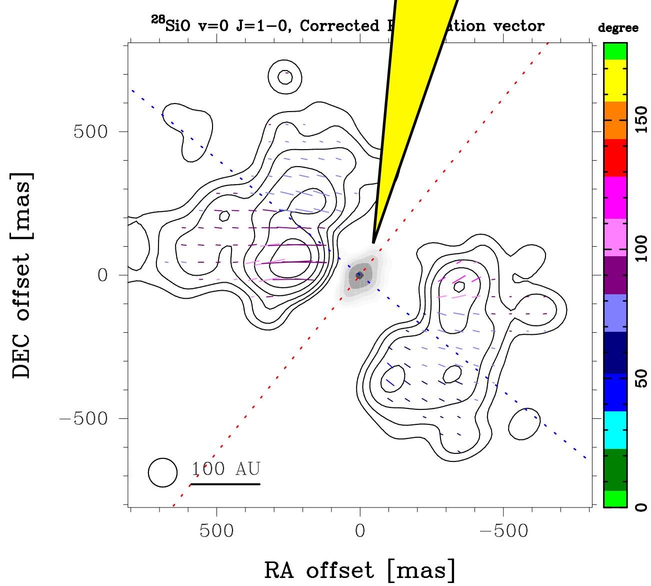
- SiO in SFRs
- Extra-galactic masers
- Polarization
- Combined with continuum



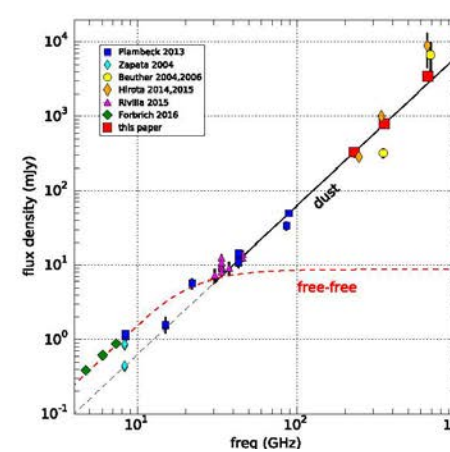
No radio jet?



New SiO maser source G19.61-0.23 detected by ALMA (Cho et al. 2016)



Linear polarization of SiO v=0 J=1-0 maser with VLA (Hirota et al. 2020)

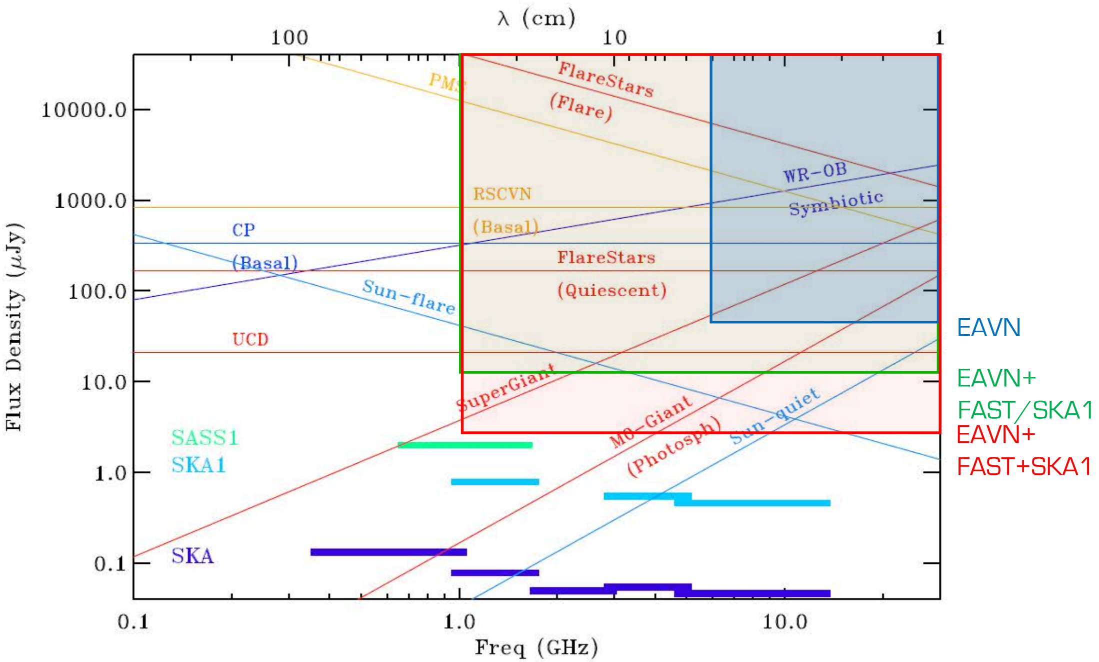


SED of Source I (Plambeck & Wright 2016)

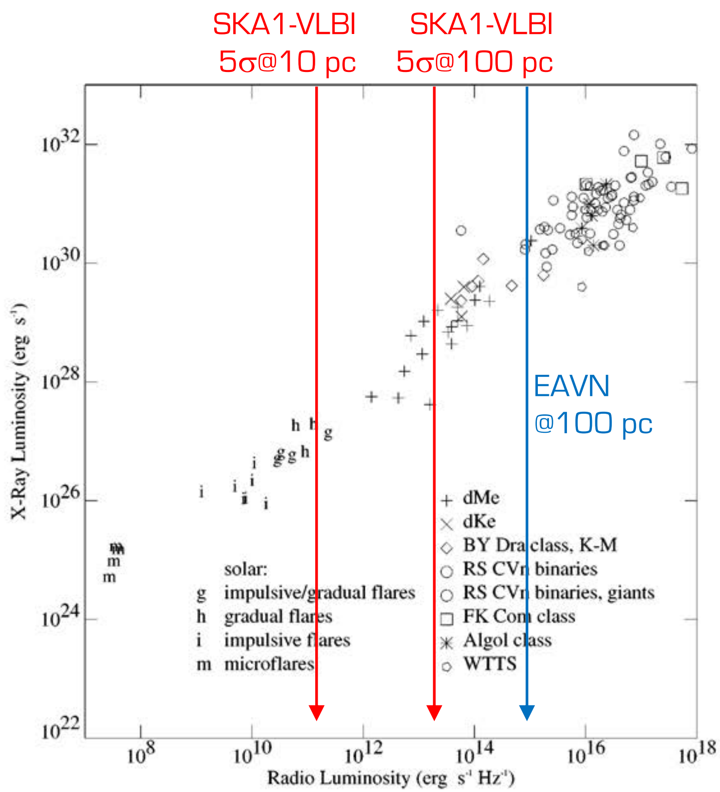
Targets of stellar radio emissions

■Various classes of stars are possible targets

- Planets are also possible targets (mainly at SKA-Low)
- Non-thermal: good targets for VLBI
- Thermal: depending on size



Stellar radio spectra (Umana et al. 2015)

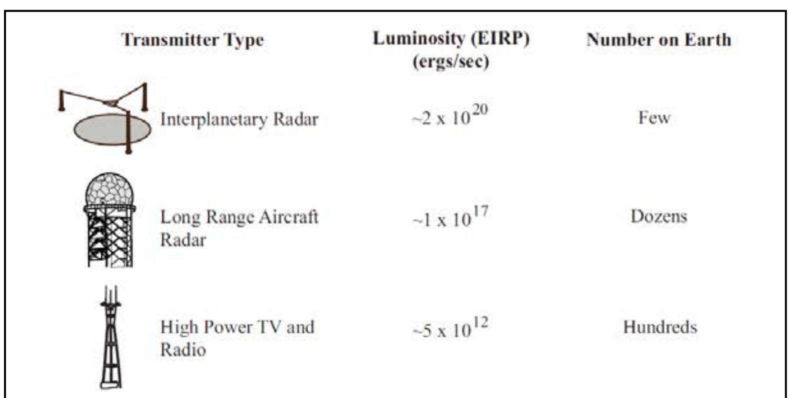


Relationship between X-ray and radio (5-8 GHz) luminosity (Gudel 2002)

SETI?

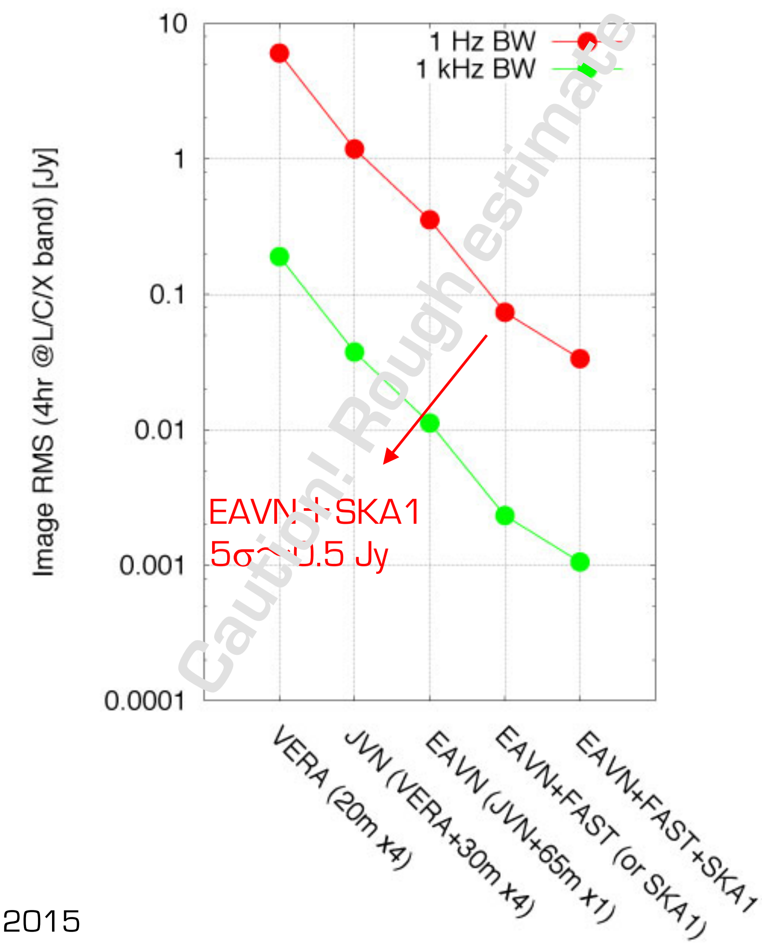
■Recent Unsuccess as Breakthrough Initiatives

- $F\nu = 8\times10^{-16}\,EIRP(D_{pc})^{-2}$ [Jy] for $\Delta\nu$=1 Hz
  - ✓Nearby planets; EIRP<5 10^{19} at L band by GBT (Enriquez+2017)
  - ✓Survey in Orion; EIRP<4 10^{20} at FM by MWA(Tingey+2018)
  - ✓Oumuamua; EIRP< 7kW/100kW (broad/narrow) (Tingey+2018)
- EAVN+SKA can detect airports?



Transmitter Type	Luminosity (EIRP) (ergs/sec)	Number on Earth
Interplanetary Radar	~2 x 10^{20}	Few
Long Range Aircraft Radar	~1 x 10^{17}	Dozens
High Power TV and Radio	~5 x 10^{12}	Hundreds

Siemion et al. 2015



Summary

- SKA-VLBI will provide μJy images at mas resolution
  - New science window will open
  - Thermal emissions can be possible targets
- Collaboration with ALMA Band 1 (0?) and ngVLA will be essential to achieve ultimate sensitivity at currently available EAVN frequency bands
- FAST, LOFAR, etc. will also be essential to achieve ultimate sensitivity at lower frequency (not discussed in this presentation, though)