Recent status of SKA Korea Project



With SKA, VLBI astronomy is no longer a niche

한국천문연구원 손봉원
Bong Won Sohn, KASI

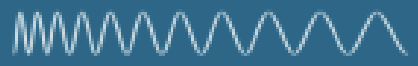
2024/1/30
우주탐사연구회

SKA-mid

SKA 중간 주파수 대역



위치 : 남아프리카 공화국



주파수 범위

350 MHz

에서

15.3 GHz

최종 목표는 24 GHz



197 개의 망원경

(64개의 MeerKat 망원경 포함)



최장 기선 :

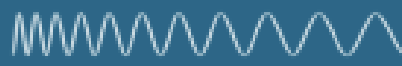
150Km

SKA-low

SKA 낮은 주파수 대역



위치 : 호주

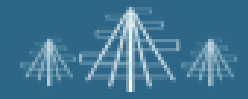


주파수 범위

50 MHz

에서

350 MHz



131,072

512개의 스테이션으로 묶음



최장 기선 :

74km





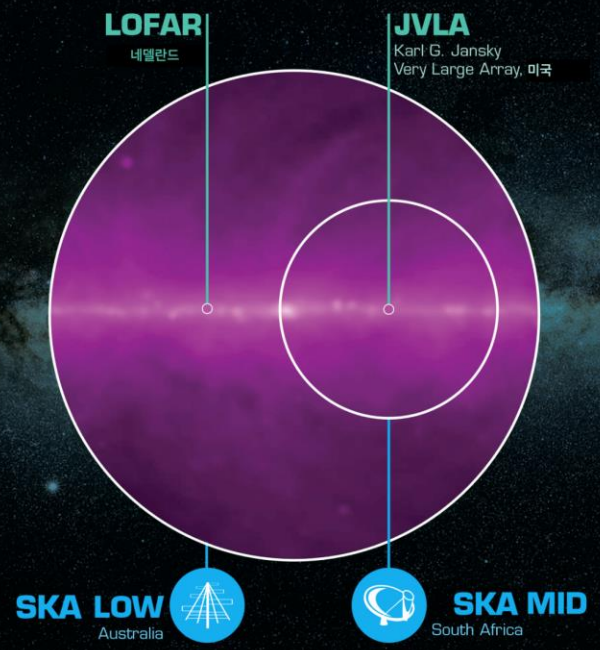
SKA의 우수성 - 현존하는 최고 전파 망원경과 비교

전파망원경의 성능을 나타내는 세가지 핵심요소는 해상도(분해능), 관측속도, 감도이다. SKA는 많은 안테나로 이루어진 거대한 크기의 망원경으로, 현존하는 어떤 망원경 보다도 이 세가지 면에서 뛰어난 성능을 보여줄 것이다. 이를 통해 우주에 대한 더욱 확장된 새로운 지식을 가져다 줄 것이다.

SKA (Square Kilometre Array)는 세계에서 가장 큰 망원경이 될 것이다. SKA는 2021년에 건설이 시작된다. SKA은 높은 주파수 신호를 검출하는 **SKA-MID**와 낮은 주파수 신호를 검출하는 **SKA-LOW**를 설치하여 우주로부터 오는 각각의 신호를 관측할 수 있게 된다.



SKA로 본 모습 (예상도) 현재 전파망원경으로 본 모습 (예상도)





SKA로 본 모습 (예상도) 현재 전파망원경으로 본 모습 (예상도)

SKA LOW x1.2 LOFAR NL

SKA MID x4 JVLA

해상도(분해능)

거대한 크기 덕분에 SKA로 매우 자세하게 우주를 관측할 수 있다. 마치 안경을 끼고 보는 것처럼 뿌연 하늘이 선명하게 보이게 된다.

SKA LOW x135 LOFAR NL

SKA MID x60 JVLA

관측 속도

감도 뿐만 아니라 한번에 관측할 수 있는 영역이 매우 넓어서, SKA는 보다 더 넓은 영역을 보다 더 빨리 관측할 수 있다.

SKA LOW x8 LOFAR NL

SKA MID x5 JVLA

감도

매우 많은 안테나로 만들어지기 때문에, SKA는 구석구석을 보다 더 선명하게 볼 수 있게 한다. 마치 눈으로는 안보이는 깜깜한 하늘을 감도가 좋은 사진으로 관측하면 많은 별들이 보이는 효과와 같다.

As the SKA isn't operational yet, we use an optical image of the Milky Way to illustrate the concepts of increased sensitivity and resolution.

SKA Low (prototype), Murchison desert, W. Australia, 2017



MeerKAT (SKA Mid), Karoo, SA, 2018



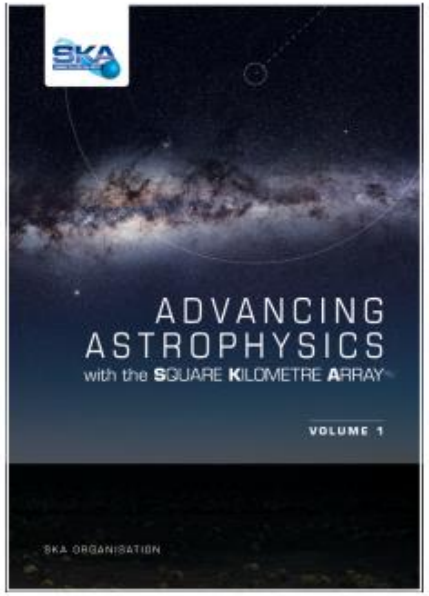
The Science

The unprecedented sensitivity of the thousands of individual radio receivers, combining to create the world's largest radio telescope will give astronomers insight into the formation and evolution of the first stars and galaxies after the Big Bang, the role of cosmic magnetism, the nature of gravity, and possibly even life beyond Earth.

SKAO

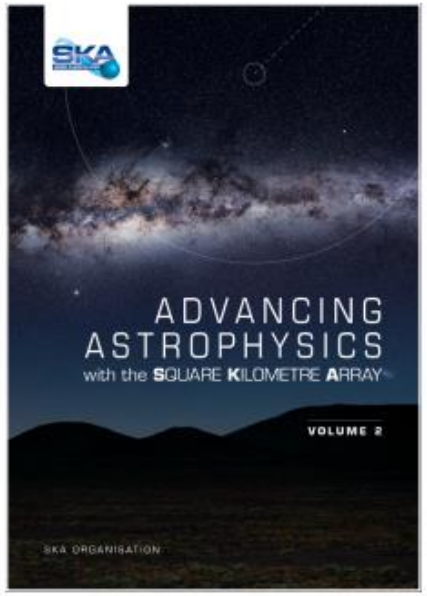
The SKA Science Book

135 chapters, 1300 authors, 2000 pages.



Volume 1

skatelescope.org/books



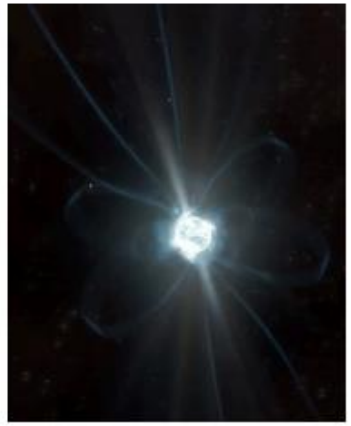
Volume 2

skatelescope.org/books

Case Studies

Gravitational waves

Even in its early deployment phase (SKA1), **the SKA will have the sensitivity to detect around 10,000 normal pulsars and over 1,000 millisecond pulsars in the Milky Way**. When the full SKA is deployed, it will be able to detect all of the pulsars pointed at the Earth in the Milky Way. By detecting the delay in their signals, **the SKA will be able to detect gravitational waves passing through the Milky Way**, produced by the mergers of supermassive black holes at the centres of distant galaxies, complementing the work of LIGO which detects the mergers of stellar mass black holes.



Epoch of Reionisation

One of the last frontiers in cosmology is to explore the formation of the very first stars and galaxies, around 100 million years after the Big Bang, which transformed our Universe from darkness to light and injected enough energy to ionise it, separating atoms into protons and electrons. By observing the most abundant element in the Universe, Hydrogen gas, **the SKA will image the so-called Cosmic Dawn, providing the first detailed measurements ever of the conditions under which the first stars and galaxies formed**, and the Epoch of Reionisation, revealing how their light transformed our Universe into its present ionised state.



SKA Science Working Groups & Focus groups

The Science Working Groups (SWGs) and Focus Groups (FGs) are scientific advisory bodies that provide input to the SKA Organisation on issues related to the design, construction, and future operations of the SKA that are likely to affect the Observatory's scientific capability, productivity and user relations. In addition, the FGs have a more specific, technical focus.

If you are interested in participating in any of the groups, please contact the current chairs or corresponding project scientists via the website link below.

- Cosmology
- Cradle of Life
- Epoch of Reionization
- Extragalactic Continuum (galaxies/AGN, galaxy clusters)
- Extragalactic Spectral Line
- HI galaxy science
- High Energy Cosmic Particles (FG)
- Magnetism
- Our Galaxy
- Pulsars
- Solar, Heliospheric & Ionospheric Physics
- Transients
- VLBI (FG)



www.skatelescope.org

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SKA Observatory

SKA Observatory

SKA Observatory

@skaobservatory

For more, visit

astronomers.skatelescope.org/science-working-groups

March 2023

Case Studies

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SKA1 Telescope Expected Performance – Imaging

Nominal frequency	110 MHz	300 MHz	770 MHz	1.4 GHz	6.7 GHz	12.5 GHz
Range [GHz]	0.05-0.35	0.05-0.35	0.35-1.05	0.95-1.76	4.6-8.5	8.3-15.4
Telescope	Low	Low	Mid	Mid	Mid	Mid
FoV [arcmin]	327	120	109	60	12.5	6.7
Max. resolution [arcsec]	9.7	3.5	0.7	0.3	0.06	0.03
Max. bandwidth [MHz]	300	300	700	810	3900	2 x 2500
Cont. rms, 1hr [μJy/beam] [a]	26	14	4.4	2	1.3	1.2
Line rms, 1hr [μJy/beam] [b]	1850	800	300	140	90	85
Resolution range for cont. & line rms [arcsec] [c]	12-600	6-300	1-145	0.6-78	0.13-17	0.07-9
Channel width (uniform resolution across max. bandwidth) [kHz]	5.4	5.4	13.4	13.4	80.6	80.6
Narrowest bandwidth, zoom mode [MHz]	3.9	3.9	3.1	3.1	3.1	3.1
Finest zoom channel width [Hz]	226	226	210	210	210	210

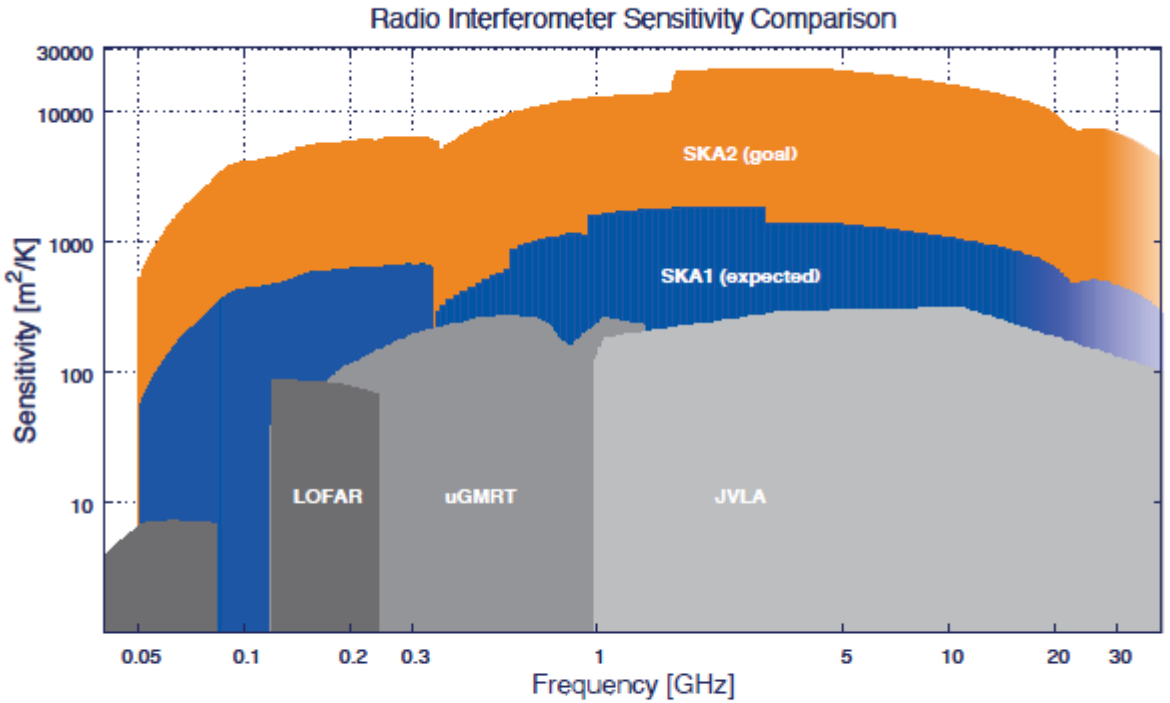
a. Continuum sensitivity at nominal frequency, assuming fractional bandwidth of $\Delta\nu/\nu = 0.3$

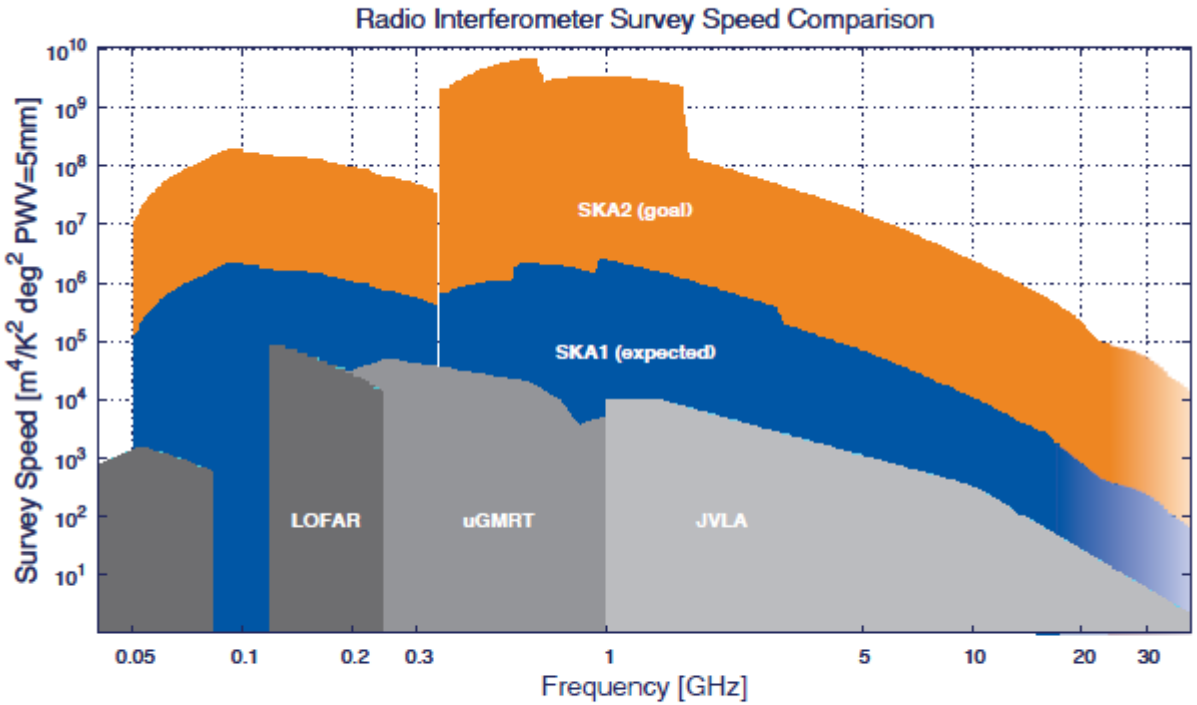
b. Line sensitivity at nominal frequency, assuming fractional bandwidth per channel of $\Delta\nu/\nu = 10^{-4}$ ($>10^{-6}$ will be possible]

c. The sensitivity numbers apply to the range of beam sizes listed

For more details refer to the document "Anticipated SKA1 Science Performance" (SKA-TEL-SKO-0000818 available on astronomers.skatelescope.org and at arxiv.org/abs/1912.12699)

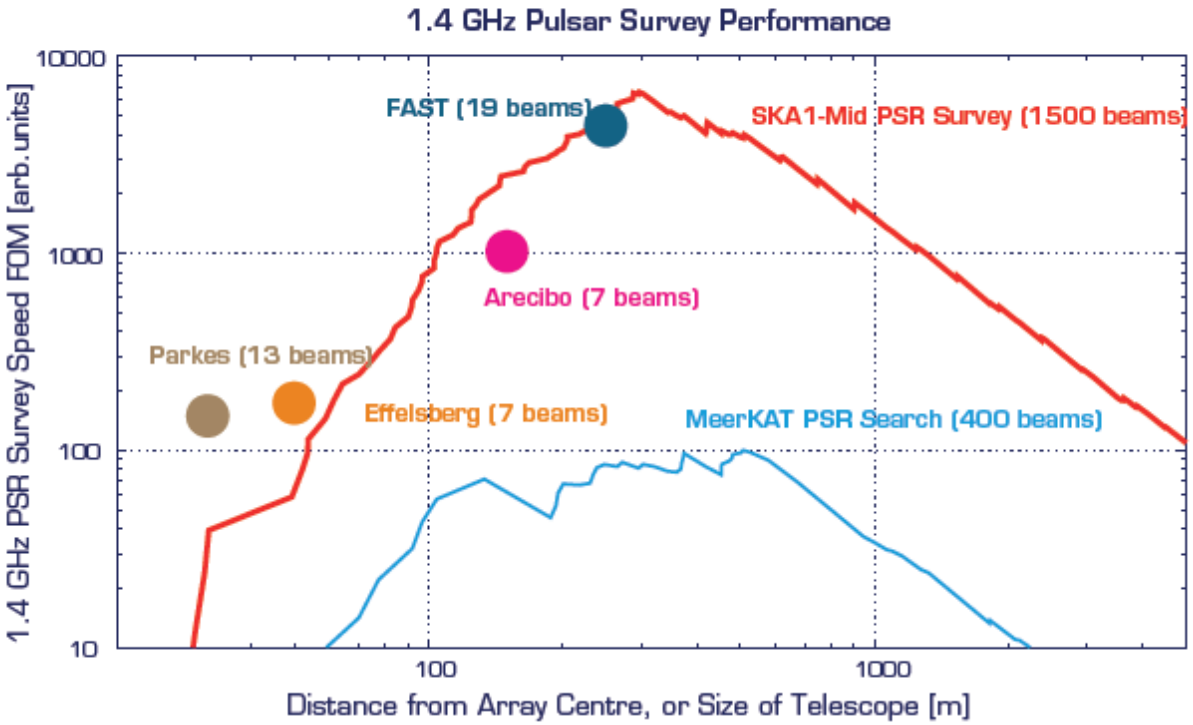
Observing capabilities

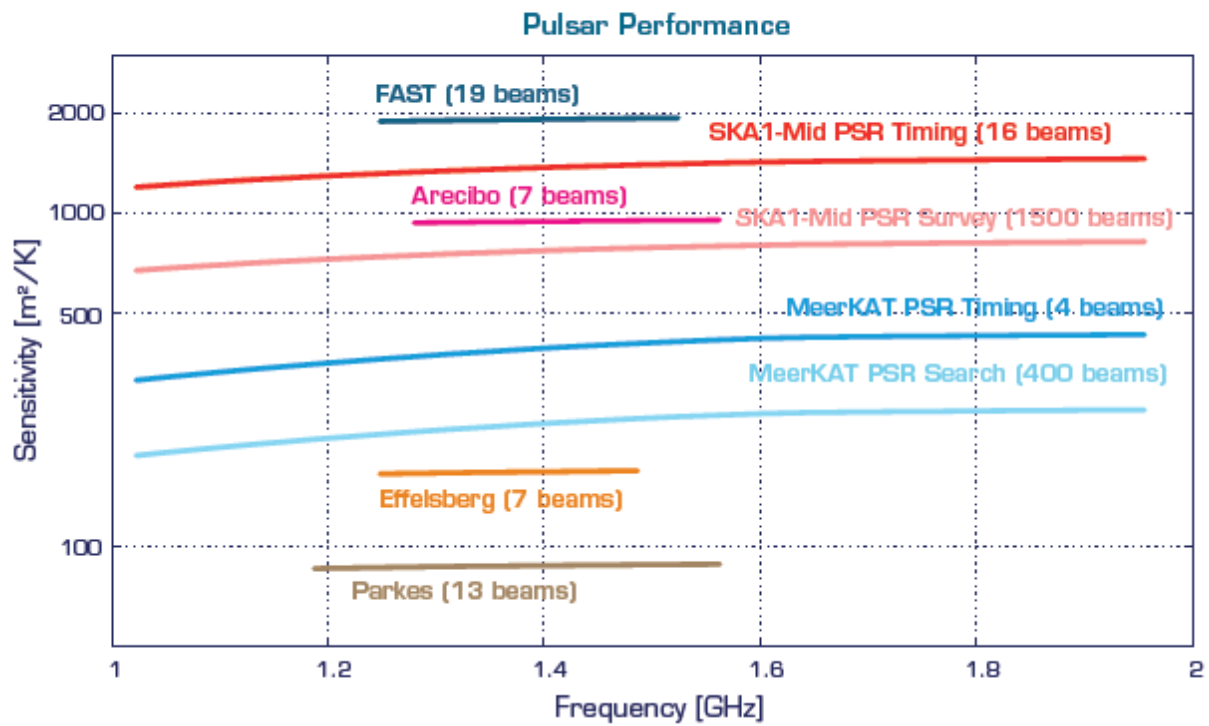


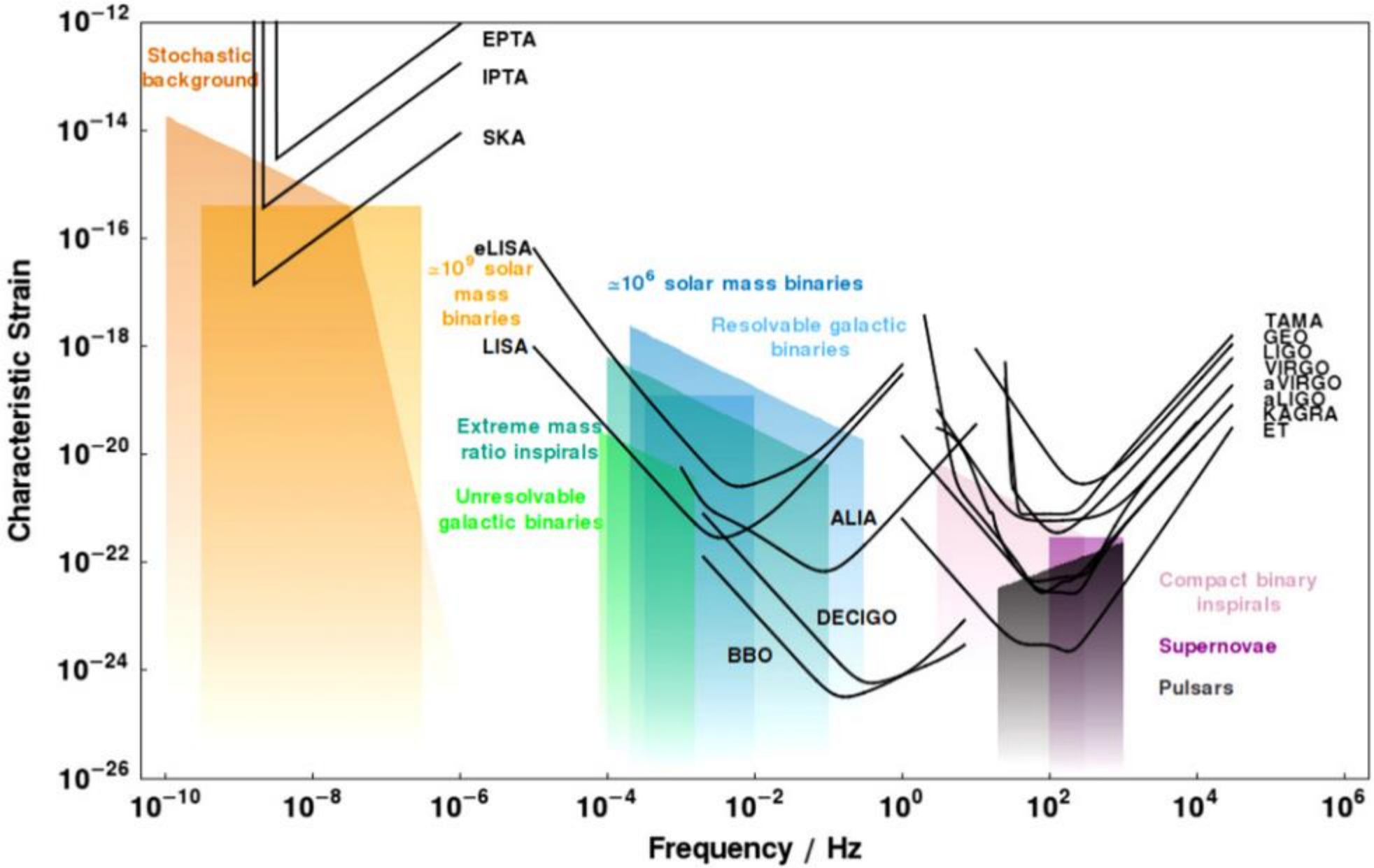


The fading out of SKA1 and SKA2 over 15.3 GHz in the sensitivity and survey speed plots is meant to represent the fact that these are aspirational and not yet part of design work.

Pulsar capabilities

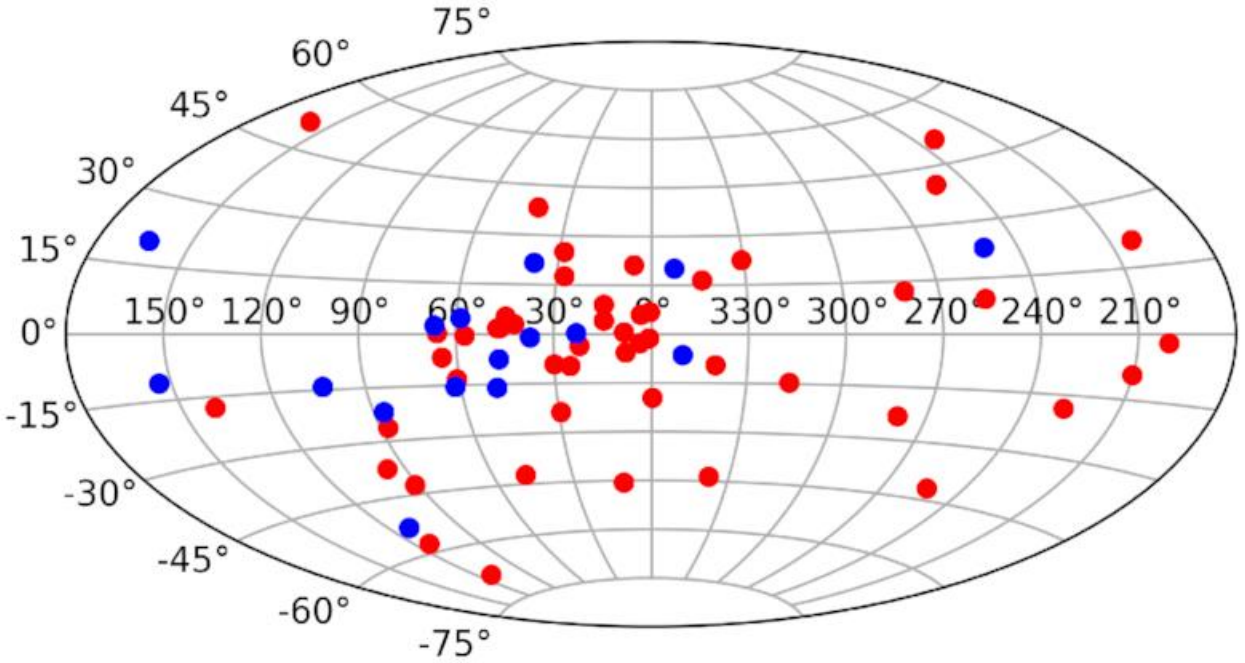






Moore et al (2015)

	J1738+0333
MJD range	54102–56781
Number of ToAs	2941
Weighted rms timing residual (μs)	1.42
Reduced χ^2	0.98
Reference epoch	55000
Units	TCB
Right ascension, RA (J2000)	17:38:53.966385(9)
Declination, Dec. (J2000)	+03:33:10.8723(4)
Proper motion in RA (mas yr^{-1})	7.12(4)
Proper motion in Dec. (mas yr^{-1})	5.0(1)
Spin frequency, f (s^{-1})	170.937369887091(8)
$\dot{f}$ (s^{-2})	$-7.0459(9) \times 10^{-16}$
Parallax, π (mas)	–
Dispersion measure, DM (cm^{-3} pc)	33.777(1)
$\dot{\mathrm{DM}}$ (cm^{-3} pc yr^{-1})	$-1.7(7) \times 10^{-3}$
$\ddot{\mathrm{DM}}$ (cm^{-3} pc yr^{-2})	$2(1) \times 10^{-4}$
Binary model	T2
Orbital period, P_b (d)	0.35479073985(1)
Epoch of periastron, T_0 (MJD)	55441.84(1)
Projected semimajor axis, x (lt-s)	0.34343014(9)
Longitude of periastron, ω_0 (deg)	74(14)
Eccentricity, e	$1.8(4) \times 10^{-6}$
Companion mass, m_c ($\mathrm{M}_\odot$)	–
Derivative of x, $\dot{x}$	–
Epoch of ascending node, T_asc (MJD)	55441.76403507(4)
$\epsilon_1 = e\sin\omega_0$	$1.8(4) \times 10^{-6}$
$\epsilon_2 = e\cos\omega_0$	$5(5) \times 10^{-7}$



The Galactic distribution of 65 pulsars in the data release, including 49 pulsars from the IPTA dr1 (red)

Perera et al (2019), DR2

nature astronomy

Article

https://doi.org/10.1038/s41550-023-02111-9

Evidence for heavy-seed origin of early supermassive black holes from a $z \approx 10$ X-ray quasar

Received: 11 July 2023

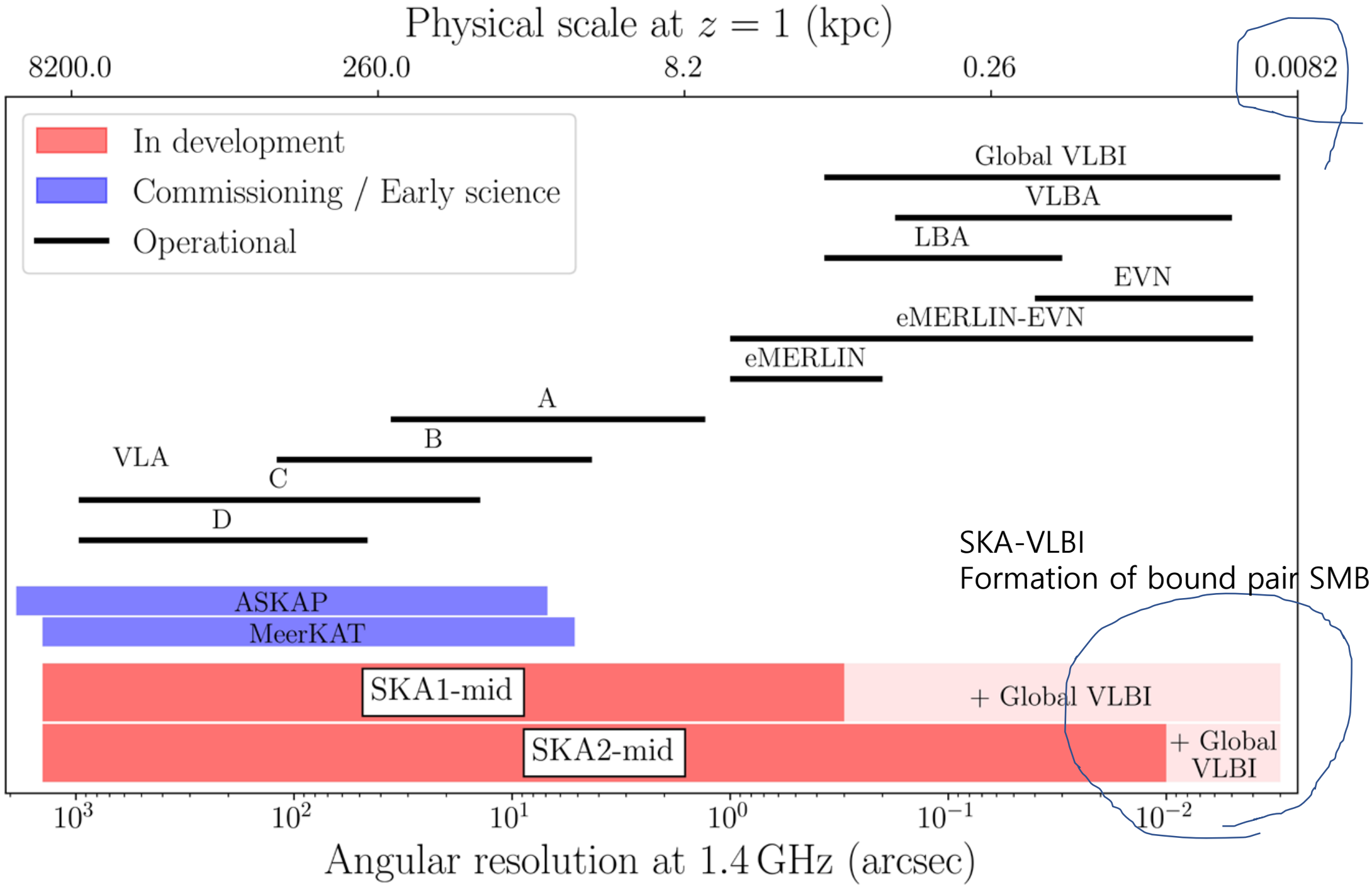
Accepted: 22 September 2023

Published online: 6 November 2023

Check for updates

Ákos Bogdán[1], Andy D. Goulding[2,10], Priyamvada Natarajan[3,4,5,10], Orsolya E. Kovács[6], Grant R. Tremblay[1], Urmila Chadayammuri[1], Marta Volonteri[7], Ralph P. Kraft[1], William R. Forman[1], Christine Jones[1], Eugene Churazov[8] & Irina Zhuravleva[9]

Observations of quasars reveal that many supermassive black holes (BHs) were in place less than 700 Myr after the Big Bang. However, the origin of the first BHs remains a mystery. Seeds of the first BHs are postulated to be either light (that is, 10–100 $M_{\odot}$), remnants of the first stars, or heavy (that is, 10–10^5 $M_{\odot}$), originating from the direct collapse of gas clouds. Here, harnessing recent data from the Chandra X-ray Observatory, we report the detection of an X-ray-luminous massive BH in a gravitationally lensed galaxy identified by the James Webb Space Telescope at redshift $z \approx 10.3$ behind the cluster lens Abell 2744. This heavily obscured quasar with a bolometric



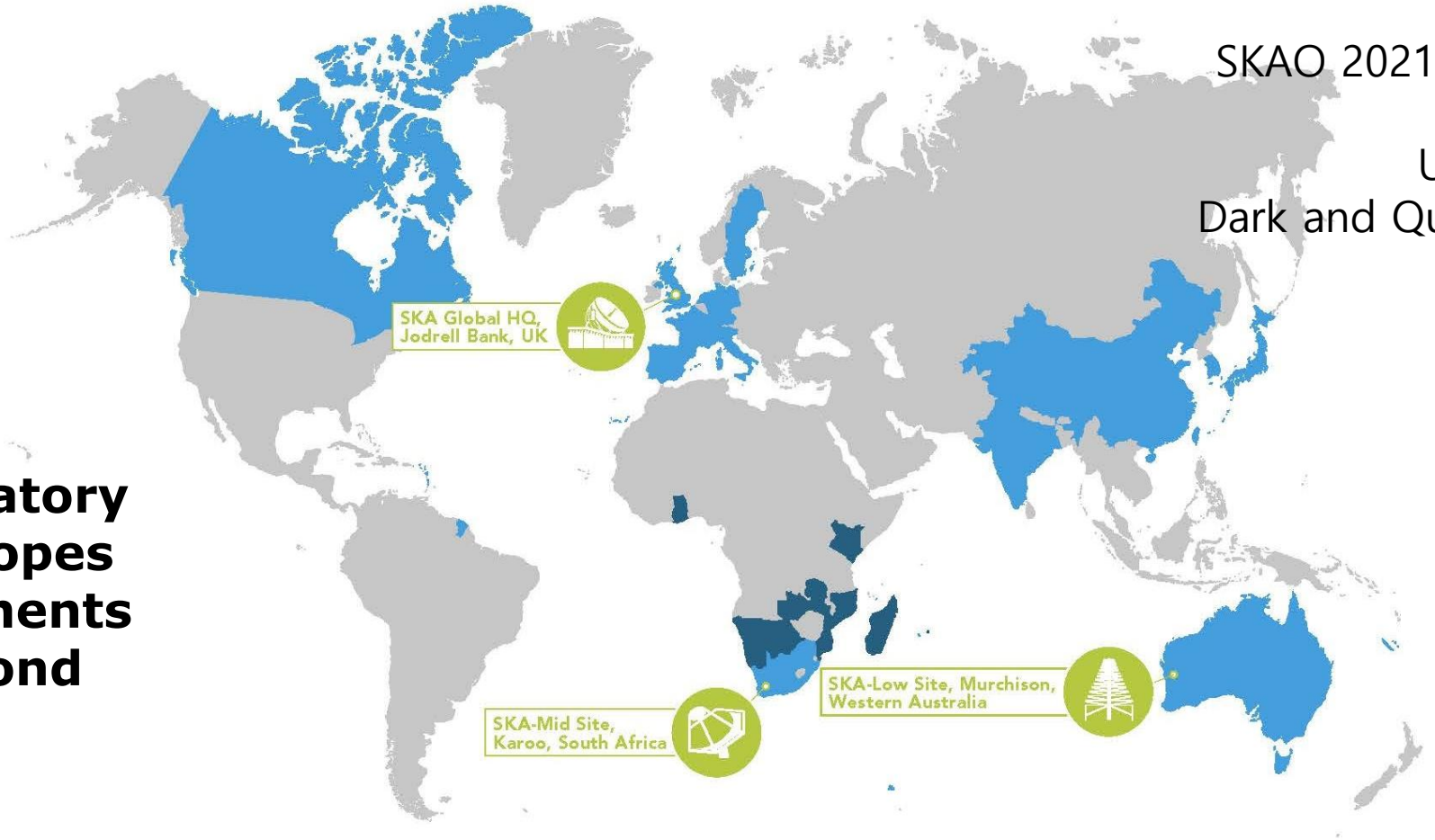
SKA-VLBI
Formation of bound pair SMBH

SKA 건설사업과 한국 참여 현황

SKAO 2021년 국제기구로 전환

UN COPUOS의 멤버
Dark and Quiet Sky Office 운영

One Observatory
Two Telescopes
Three Continents
…and beyond



SKA Partners – includes Members of the SKA Organisation – precursor to the SKAO –, current SKAO Member States*, and SKAO Observers (as of June 2021)

African Partner

Gov. contacts with Ireland, Poland
Discussion with Mexico, Thailand, Singapore
Norway – ionosphere monitoring
미국(NRAO) SKAO 과학기술위원회 복귀

SKAO is an Inter-Governmental Organization (IGO)

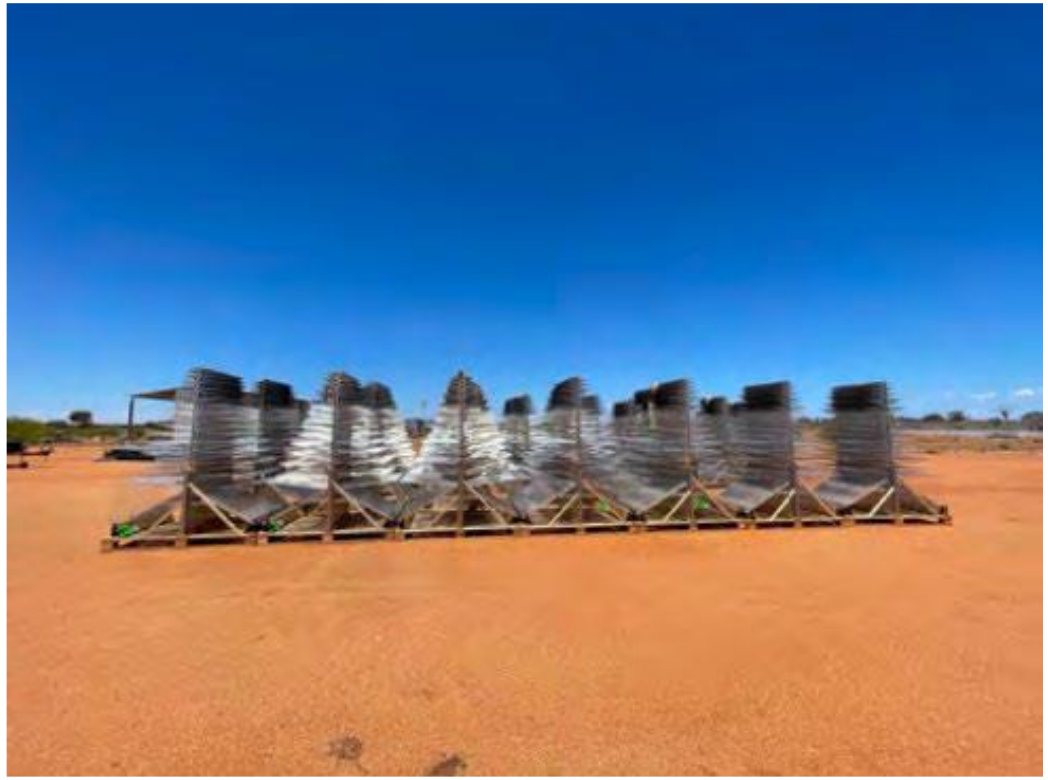
2019 Mar 12	SKA Observatory Treaty signed in Rome
2020 Sep	SKA Construction Proposal endorsed
2021 Jan 15	SKAO Treaty enters-into-force
2021 Feb 4	SKA Observatory born
2021 May 1	Transition from SKA Organisation to SKAO
2021 Jul 1	Start of Construction
2022 Dec 05	Construction Commencement Ceremony











Late 2023

AA0.5 phase
~ early 2025







한국 SKAO 추진 현황



- 2009년 한국 SKA 워킹 그룹 조직
- 2010년 국과위 국가대형연구시설 구축지도 반영, 500억 사업
- 2012~14년 SKA 설계 연구 prepSKA 참여
- 2014년 국과위 국가대형연구시설 구축지도 반영, 1,000억 사업
- 2018~19년 **천문연 기획연구**
- 2021년 **과기부 추인, 국제기구 SKAO이사회 옵서버 자격**
- 2022년 8월 부산 국제천문연맹 총회 SKAO 사무총장 방한
- 2023년 **4차 우주개발진흥 기본계획 반영**
  - 전략3 글로벌 우주개발 협력에서 역할 강화 및 국격 제고
    - 1 국제공동 탐사 및 공동 연구 참여 확대 – 협력 고도화
      - SKA 건설사업 참여, 기술개발 및 관측 접근권 우선 확보
- 2023년 11월 **한영 정상 합의서, SKAO 한국 참여 노력**



SKAO in ROK-UK summit accord



- 한영 정상 합의서
- Building on the continued scientific and research engagements of the two countries, look forward to ROK's potential opportunity to sign a Cooperation Agreement on the Square Kilometre Array Observatory (SKAO).
- 양국간 지속적인 과학 및 연구협력을 바탕으로, 우리는 한국이 국제 전파 망원경 구축(SKAO) 협력 협정에 서명할 기회를 갖기를 고대한다.

SKA 참여 계획

- SKA 건설 및 운영비 (~2030)의 ~1.3% 분담 (+ IkC)
  - 총사업비 1,986M€ (2021년 기준)
  - 한국 사업비 494억원 (23년 과기부 안)
    - 한국 분담금 356억원 (환율에 따라 분담율 변동)
      - 분담금 정부(과기부) 직접 관리, 조약체결 및 국제기구 가입
      - 한국 데이터센터 (SRC Korea) 구축 및 연구개발비 138억원
      - 건설사업 - 천문연+KISTI+국내업체
        - SKAO Fair-Work-Return Low networks tier1 (잠정배정), 건설 분담금의 70% Return
      - 연구, SRC, 인력양성 – 천문연+대학+KISTI; 중점분야 SKA-VLBI
    - 24년 천문연 소속 변경 (우주항공청); 중기재정계획 반영 (25년~)
      - 추진방안, 예산 – 과기부, 우주청 추진단 논의 중

SKA Korea Scientific WGs



SKA in Seoul 2015

- EoR - Ahn (Chosun)
- HI - Oh (Sejong), Chung (Yonsei), MYLee (KASI)
- Pulsar/Gravitation - Park(IBS), JLKim(Ewha), HMLee (SNU)
- Cosmic Magnetism - Ryu (UNIST), Kang (Busan U.)
- AGN
  - Cosmology - Parkinson (KASI)
  - SKA-VLBI – JYKim (KNU), Sohn (KASI)
- And more
  - Dark Matter (Jee, Yonsei), Molecules (H bang, KASI), …



Preparation of SKA regional center (KRSRC)



- Lead by Hyunwoo Kang (KASI)
- Asian-Pacific Blue-Lavender team
  - Korea, Japan, **China, Australia**
- KASI, KISTI, UNIST
  - Supports from KISTI
  - Since PI 18
    - Kubenetes, Rucio, IAA, …



SKA Korea participation of SKA Data Challenge (SDC)

- Participating in SDC3 – finding EoR signal
  - Chosun Univ.(PI), Sejong U., UNIST, KASI
  - Point source removal – Sejong U. (Oh+)
  - Foreground removal – UNIST (Ryu+), KASI (Hong, Parkinson)
  - EoR signal – Chosun U. (Ahn+)





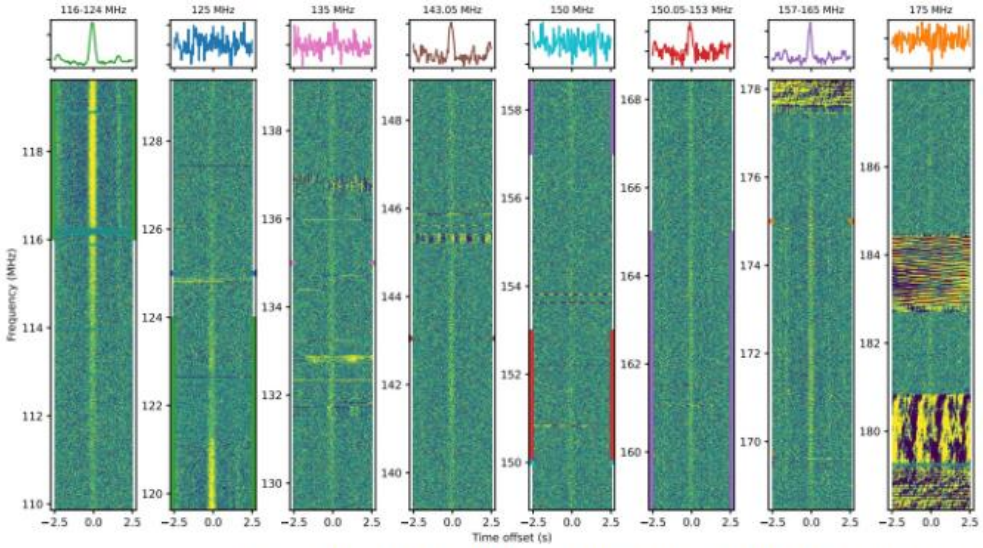


Square Kilometre Array (SKA) 는 천문학, 천체물리학, 우주론은 물론 우주생물학 분야의 전환점이 될 관측 수행을 위한 초대형 전파간섭계 국제협력 프로젝트이다. 1 평방 킬로미터 (square kilometre)에 이르는 넓은 유효 면적을 갖도록 설계된 SKA는 21세기 천문학이 풀어야 할 과제인, 빅뱅 이후 물질과 암흑물질의 분포, 별과 은하의 생성과 진화, 우리 은하의 "모든" 펄사를 이용한 중력파 검출, 우주 자기장의 기원과 진화 연구 그리고 외계 생명체 탐색 및 생명의 기원 규명을 주요 목표로 삼고 있다. 또한 SKA가 만들어낼 방대한 데이터는 최고의 빅데이터 연구 기회를 제공한다.

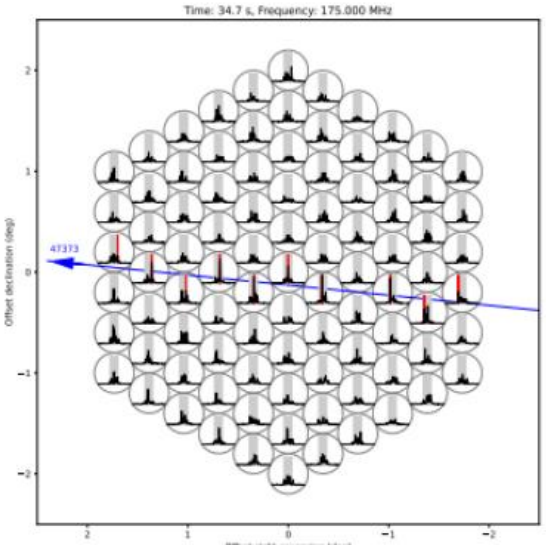
SKA-Korea는 한국의 SKA 사업 참여와 활용 연구를 위한 연구자와 개발자들의 모임이다.

Spectrum Management update

- Observations with LOFAR of Starlink satellites
  - Detected unintentional radiation from satellites in 110-180 MHz
  - Paper to be published in Astronomy & Astrophysics
  - In discussions with SpaceX about this phenomena
  - Planning press release and publication on July 5th (Di Vruno et al. 2023)
  - Approach is to study further, seek technical mitigations with operators and regulatory solutions with ITU

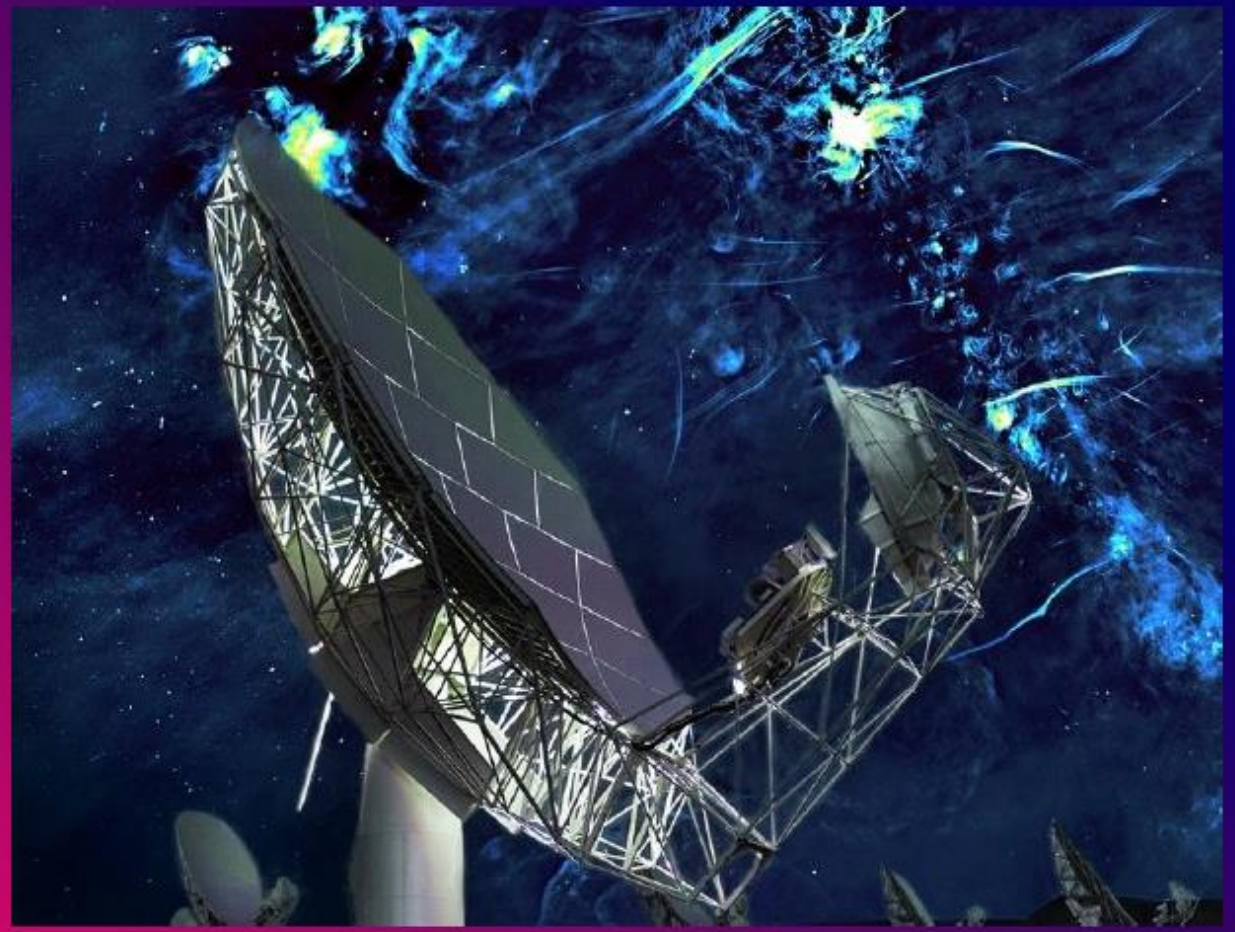


Broadband signal detected in the middle of each panel (horizontal axis is time, vertical is frequency)



Arrangement of Tied Array Beams showing total power in 175 MHz
And satellite crossing in blue

With SKA, VLBI astronomy is no longer a niche





SKAO

We recognise and acknowledge the Indigenous peoples and cultures that have traditionally lived on the lands on which our facilities are located.

www.skao.int