Pulsar Observation with the SKA

Shinichiro Asayama
SKA Observatory
Neutron Star Observation and Theory Workshop 2023, Kyoto, Japan, 08 September 2023

The SKA: a global collaboration to build and operate the next-generation radio astronomy observatory

Prime Science Motivation: Study the history of the Universe in Hydrogen

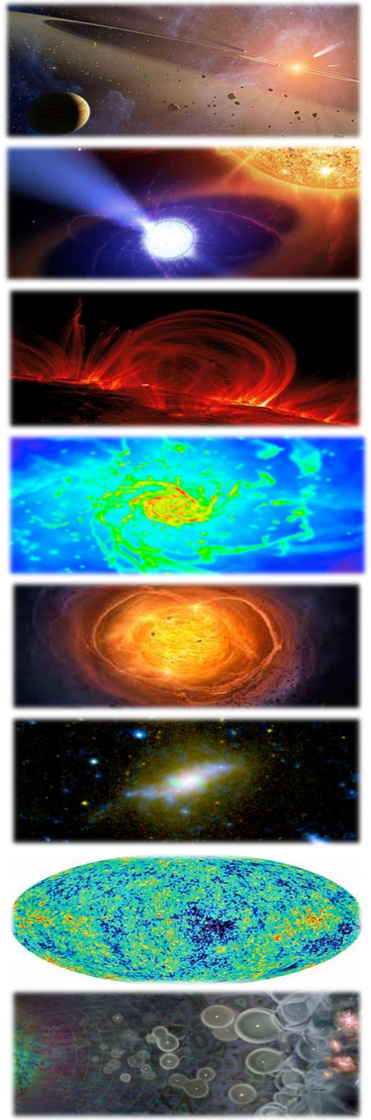
Will enable transformational science in many other areas

South Africa – Karoo region

Western Australian Outback

SKA Big Questions

- **The Cradle of Life & Astrobiology**
  How do planets form? Are we alone?
- **Strong-field Tests of Gravity with Pulsars and Black Holes**
  How accurate is Einstein's General Relativity?
- **Our Galaxy, The Milky Way**
  How does matter cycle between stars and the Interstellar Medium?
- **The Origin and Evolution of Cosmic Magnetism**
  What is the role of magnetism in galaxy evolution and the structure of the cosmic web?
- **Galaxy Evolution probed by Neutral Hydrogen and Radio Continuum**
  How do normal galaxies form and grow? What is their star-formation history?
- **The Transient Radio Sky**
  What are Fast Radio Bursts and how can we utilise them? What haven't we discovered?
- **Cosmology & Dark Energy**
  What is dark matter? What is the large-scale structure of the Universe?
- **Cosmic Dawn and the Epoch of Reionisation**
  How and when did the first stars and galaxies form?



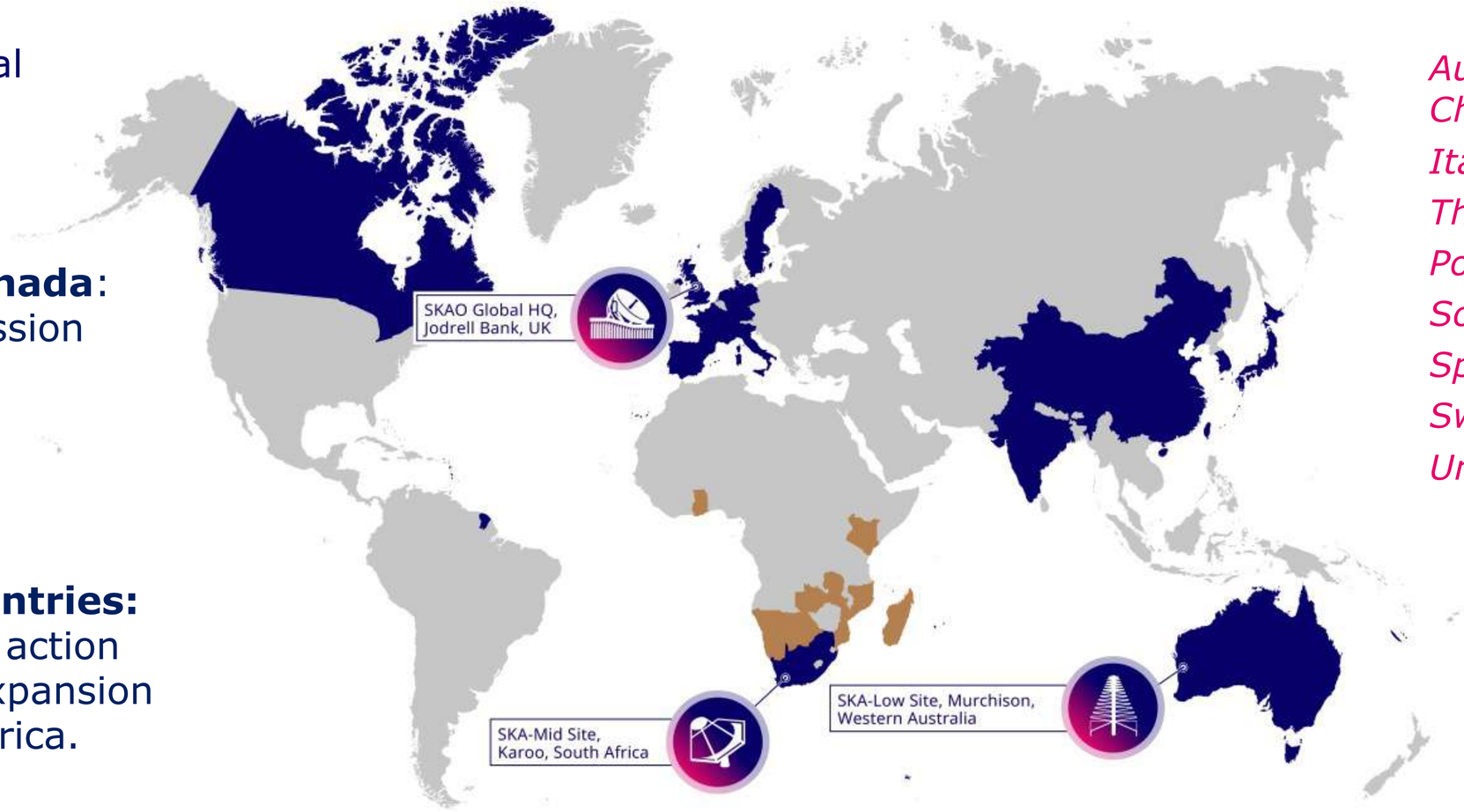
The most important discoveries in the anticipated 50-year lifespan cannot be envisaged!

SKAO – global partnership

One Observatory Two Telescopes Three Continents

SKAO is the world's second intergovernmental organisation to be dedicated to astronomy

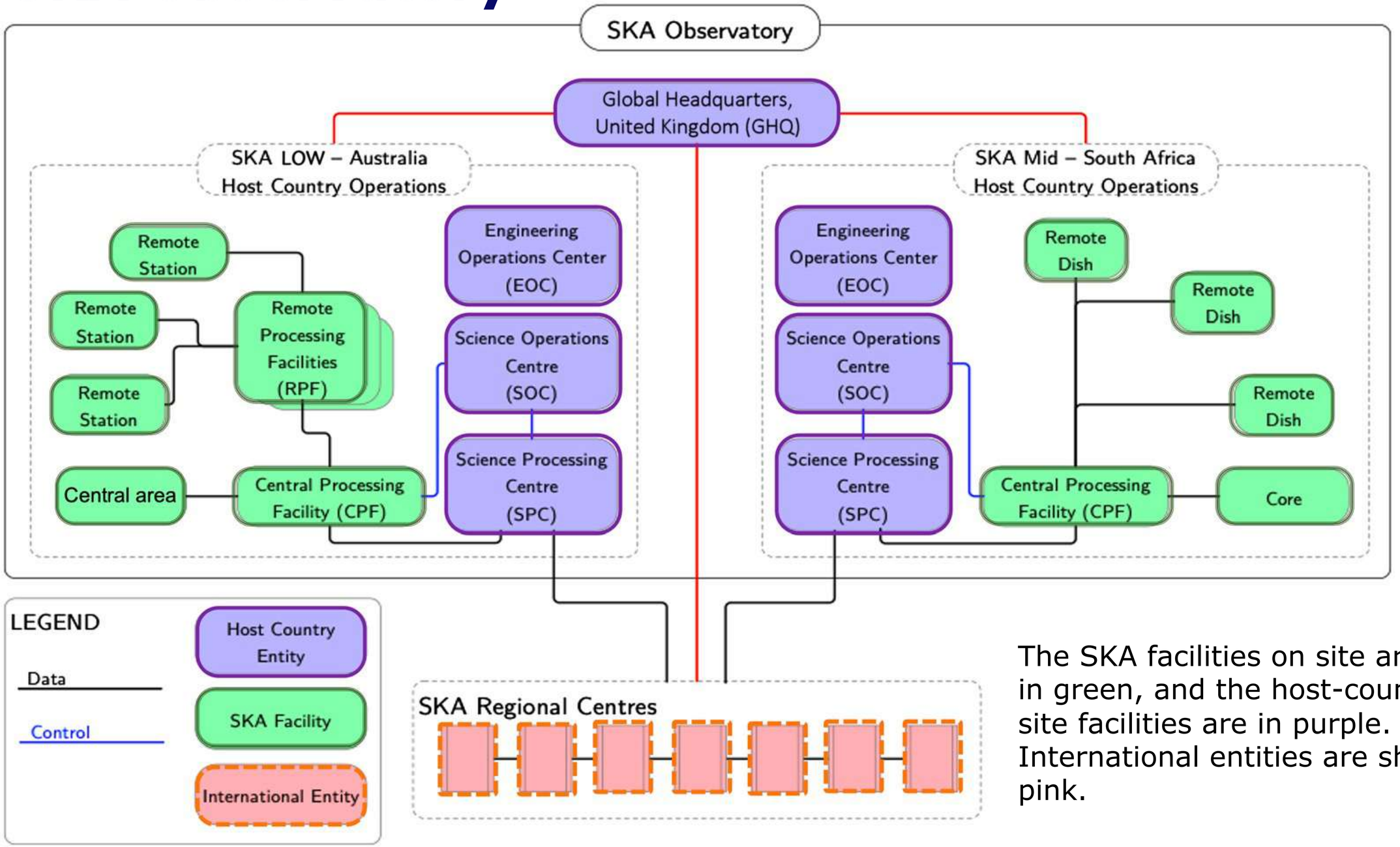
- **France, Germany, Canada**: in negotiations on accession agreement
- **Sweden & India**: interim arrangements
- **Japan & S. Korea**: early stages
- **8 African partner countries:** involved in coordinated action to support the future expansion of the SKA project in Africa.



Australia
China
Italy
The Netherlands
Portugal
South Africa
Spain
Switzerland
United Kingdom

Other members welcome!

The SKA Observatory



The SKA facilities on site are shown in green, and the host-country off-site facilities are in purple. International entities are shown in pink.

SKA-LOW

THE SKAO'S LOW-FREQUENCY TELESCOPE

FREQUENCY RANGE:
50 MHz–
350 MHz

131,072
ANTENNAS
SPREAD ACROSS **512** STATIONS

MAXIMUM BASELINE:
~74km

SKA-MID

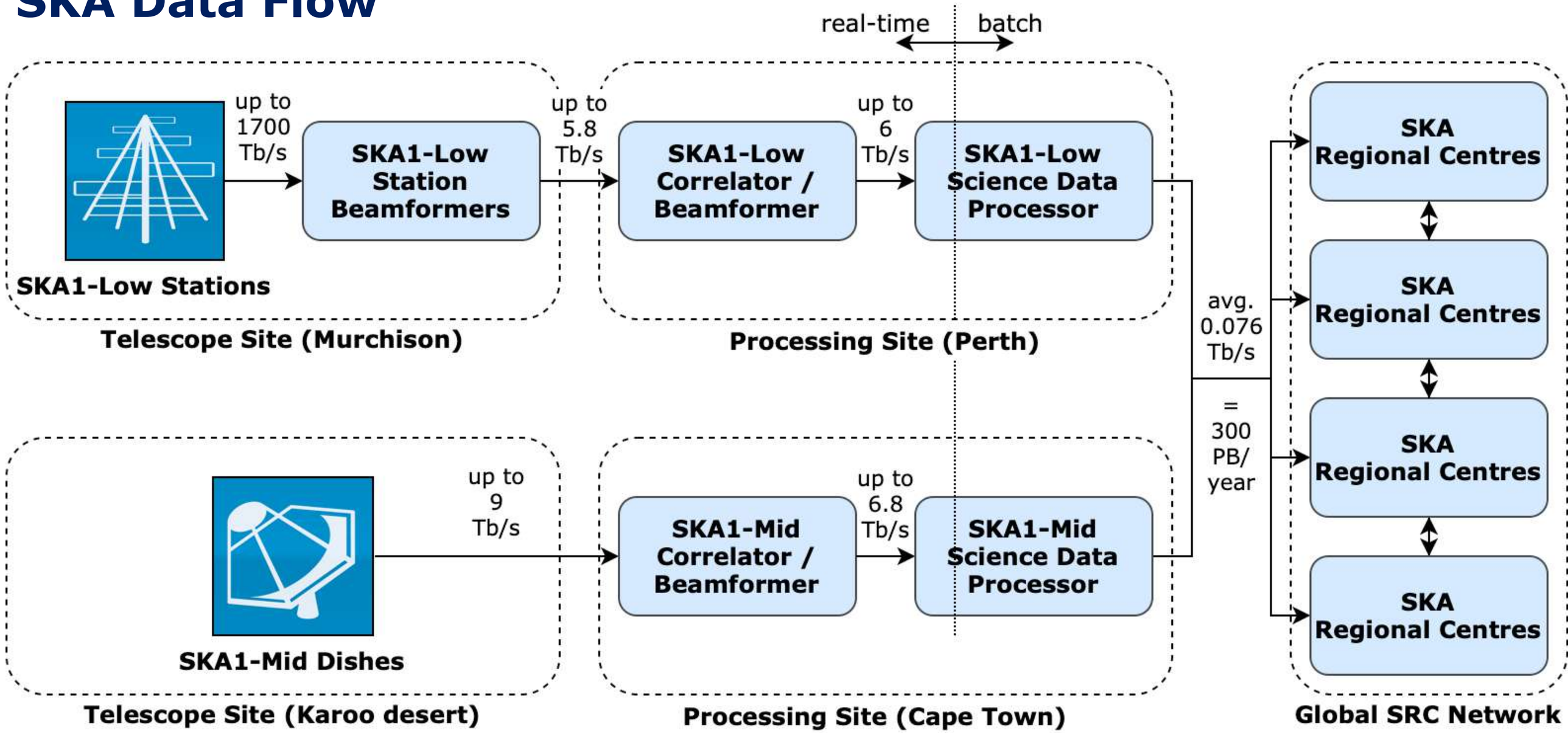
THE SKAO'S MID-FREQUENCY TELESCOPE

FREQUENCY RANGE:
350 MHz–
15.4 GHz
WITH A GOAL OF 24 GHz

197 DISHES
(INCLUDING 64 MEERKAT DISHES)

MAXIMUM BASELINE:
150km

SKA Data Flow



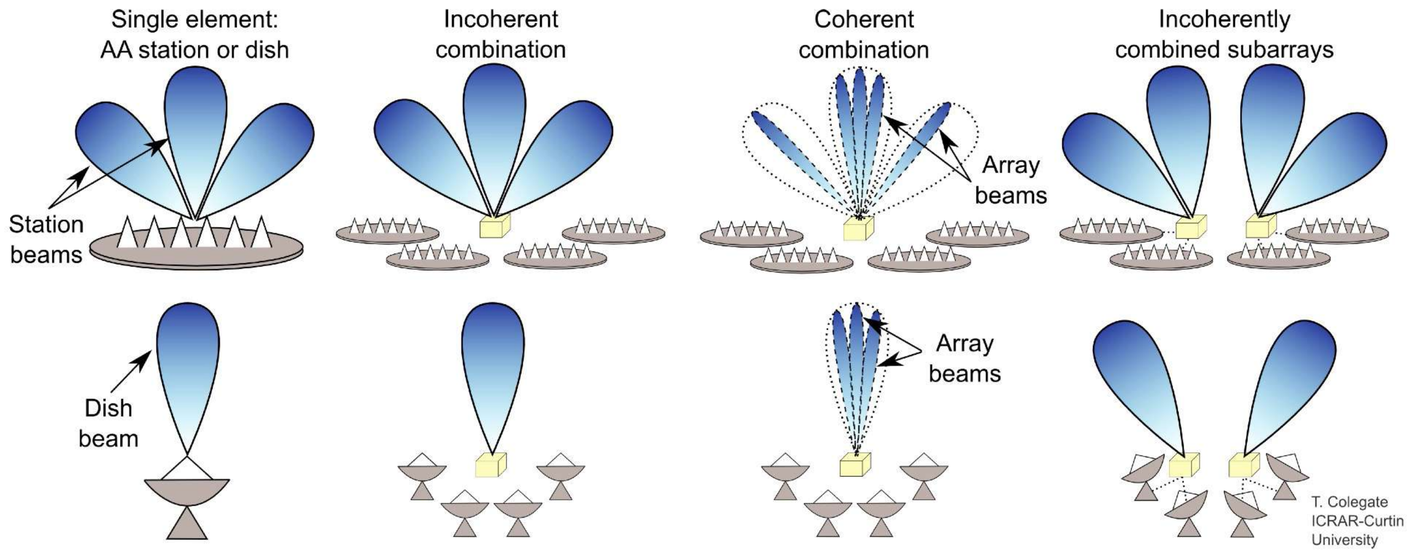
Non-imaging (Pulsars, Fast Radio Bursts, VLBI, ...)

	Search		Timing		Bandwidth (Max)
Telescope	Beams	Subarrays	Beams	Precision (1 sigma)	
SKA1-Mid	1500	up to 16	16 (8 on B5)	5 ns	300 MHz
SKA1-Low	500	up to 16	16	10 ns	300 MHz

Possible simultaneously:

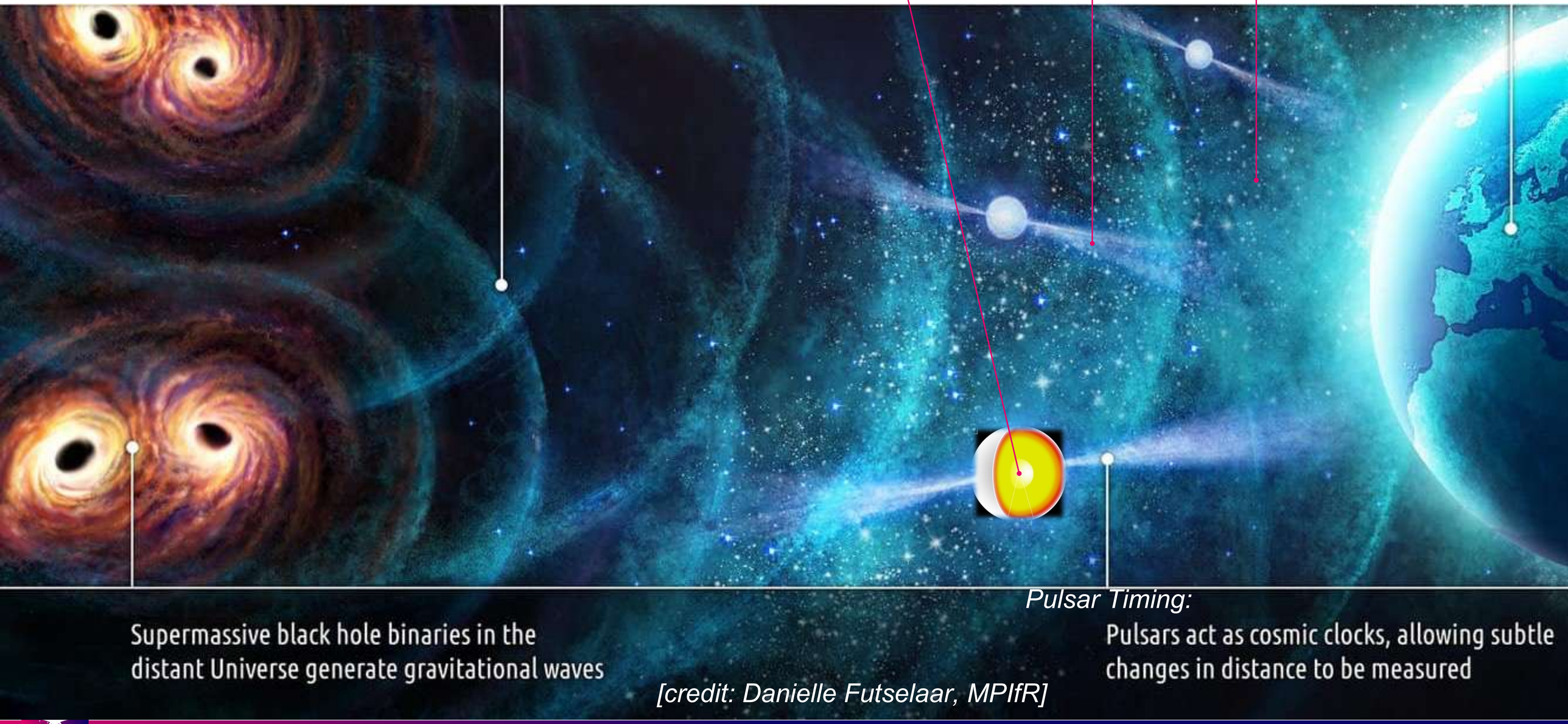
- imaging
- VLBI
- pulsar search
- pulsar timing

via commensal / sub-arrays



Pulsar science

From interior equation of state and plasma physics… to magneto-ionised ISM



[credit: Danielle Futselaar, MPIfR]

Pulsar Science with the SKA

Pulsar Science with the SKA

Pulsar Searching

Can we find new and interesting pulsars?...

Credit : Dr Charlotte Sobey

Pulsar Science with the SKA

Pulsar Timing

Can we prove Einstein's theory of gravity wrong?...

Credit : Dr Charlotte Sobey

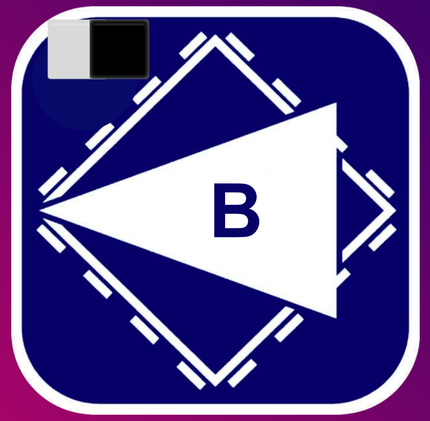
Pulsar Science with the SKA

Pulsar Location

Can we measure their distances?

Credit : Dr Charlotte Sobey

Magnetism Science with the SKA



Pulsar Polarisation + Extragalactic sources

How does the Universe's magnetism evolve over time?

Credit : Dr Charlotte Sobey

In Short…

1. Find ‘em
2. Time ‘em (with full polarisation)
3. VLBI ‘em… (measure distances)

… science ensues!

Pulsar observations and Amateur radio astronomical activities in Japan

Brief Introduction of pulsar observations in Japan

Usuda 64m at JAXA

- Preliminary trials of millisecond pulsars (1990-1994)

Kashima 34m at NICT

- Millisecond Pulsar for high a precision time standard (1992-2005)
- VLBI application (2012-)

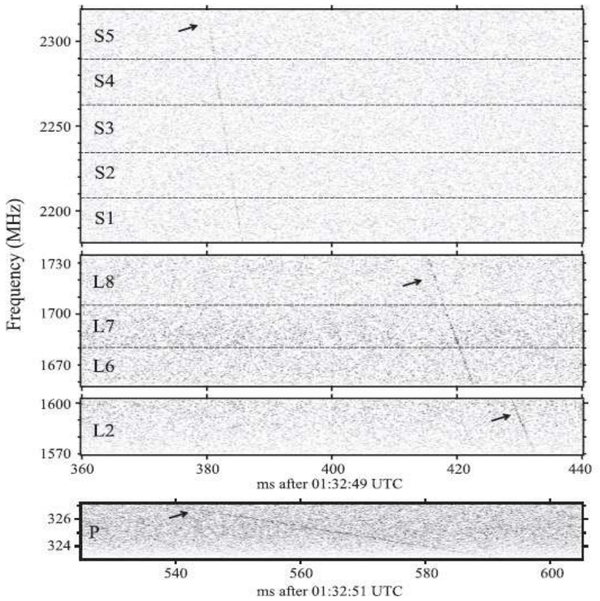
Iitate Planetary Radio Telescope (IPRT): Tohoku University

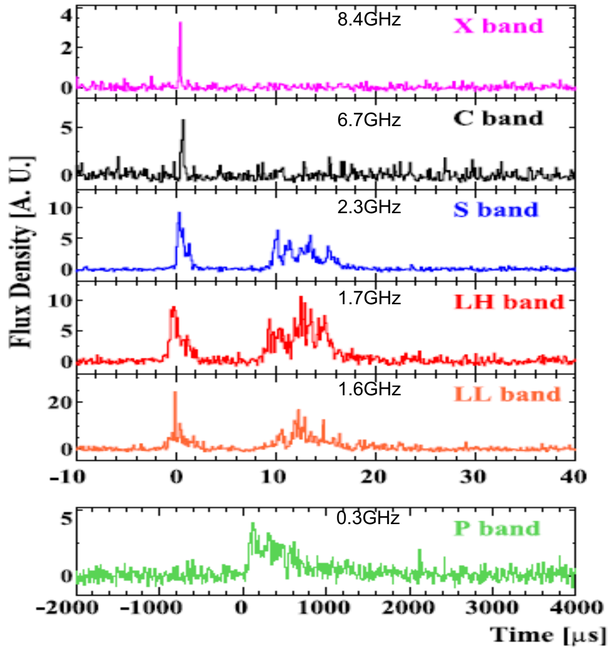
- Observing jovian synchrotron emission

Toyokawa observatory, ISEE, Nagoya Univ.

- Observing interplanetary scintillation of radio sources for the solar wind study

*Simultaneous Multi-frequency radio observations of giant radio pulses of Crab pulsar(*Mikami et al. 2016 ApJ, 832:212)

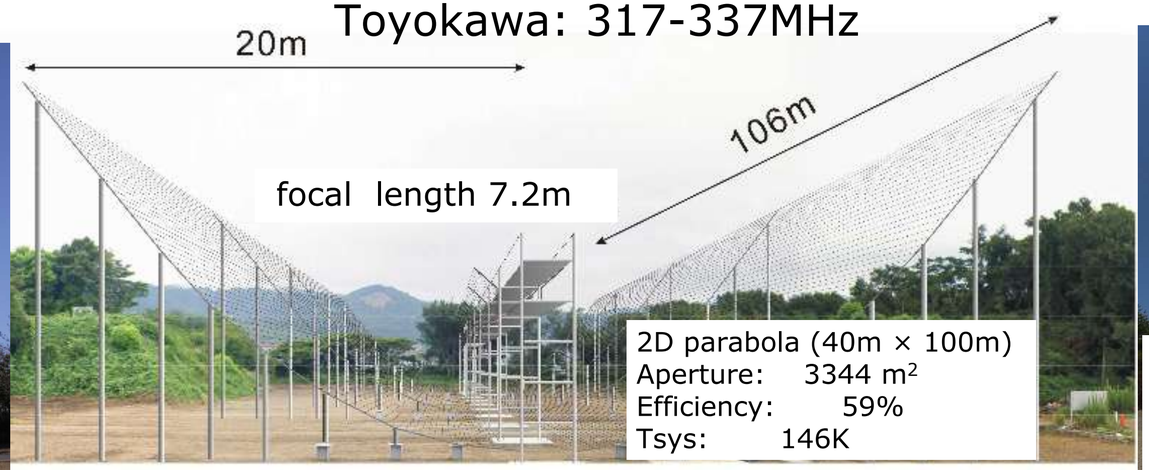




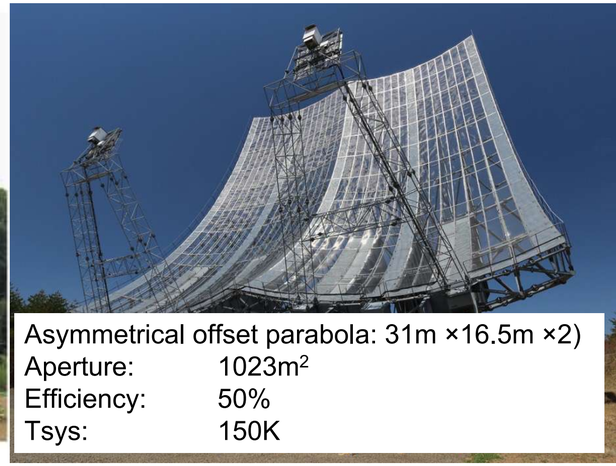
Usuda 64m

Kashima 34m

Toyokawa: 317-337MHz



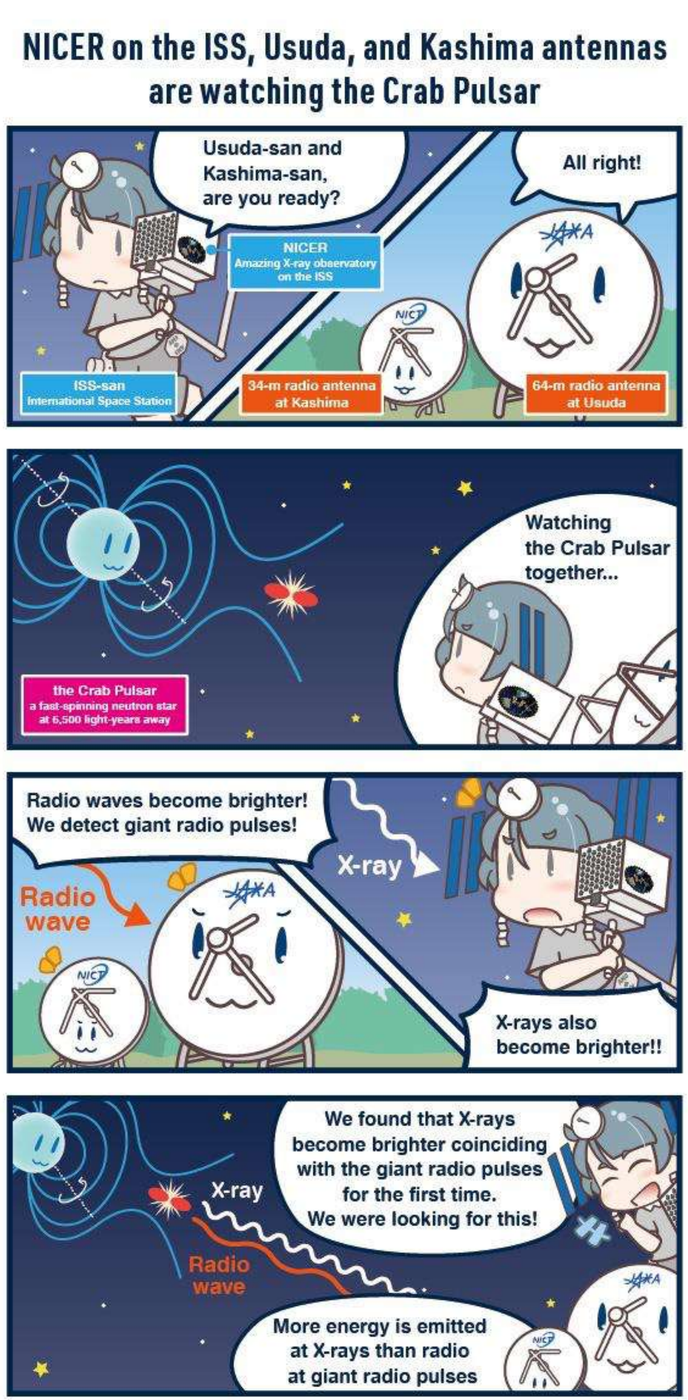
Iitate: 317.1-333.1MHz



Enhanced X-ray Emission Coinciding with Giant Radio Pulses from the Crab Pulsar

Enoto et al., Science, 372, 187-190 (2021) [arXiv: 2104.03492]

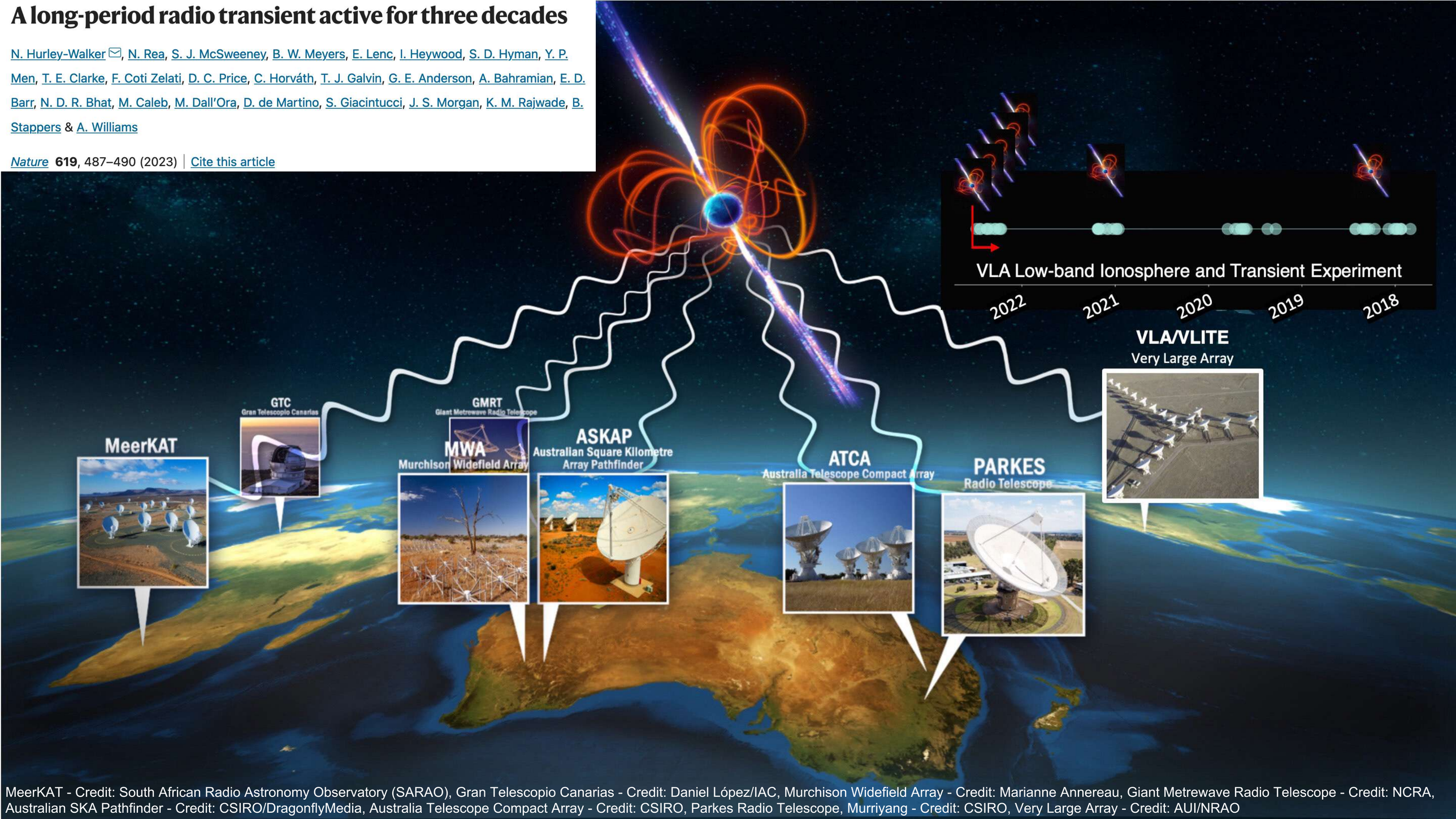
Toshio Terasawa, Shota Kisaka, Chin-Ping Hu, Sebastien Guillot, Natalia Lewandowska, Christian Malacaria, Paul S. Ray, Wynn C.G. Ho, Alice K. Harding, Takashi Okajima, Zaven Arzoumanian, Keith C. Gendreau, Zorawar Wadiasingh, Craig B. Markwardt, Yang Soong, Steve Kenyon, Slavko Bogdanov, Walid A. Majid, Tolga Guver, Gaurava K. Jaisawal, Rick Foster, Yasuhiro Murata, Hiroshi Takeuchi, Kazuhiro Takefuji, Mamoru Sekido, Yoshinori Yonekura, Hiroaki Misawa, Fuminori Tsuchiya, Takahiko Aoki, Munetoshi Tokumaru, Mareki Honma, Osamu Kameya, Tomoaki Oyama, Katsuaki Asano, Shinpei Shibata and Shuta J. Tanaka



A long-period radio transient active for three decades

N. Hurley-Walker ✉, N. Rea, S. J. McSweeney, B. W. Meyers, E. Lenc, I. Heywood, S. D. Hyman, Y. P. Men, T. E. Clarke, F. Coti Zelati, D. C. Price, C. Horváth, T. J. Galvin, G. E. Anderson, A. Bahramian, E. D. Barr, N. D. R. Bhat, M. Caleb, M. Dall'Ora, D. de Martino, S. Giacintucci, J. S. Morgan, K. M. Rajwade, B. Stappers & A. Williams

Nature **619**, 487–490 (2023) | Cite this article



MeerKAT - Credit: South African Radio Astronomy Observatory (SARAO), Gran Telescopio Canarias - Credit: Daniel López/IAC, Murchison Widefield Array - Credit: Marianne Annereau, Giant Metrewave Radio Telescope - Credit: NCRA, Australian SKA Pathfinder - Credit: CSIRO/DragonflyMedia, Australia Telescope Compact Array - Credit: CSIRO, Parkes Radio Telescope, Murriyang - Credit: CSIRO, Very Large Array - Credit: AUI/NRAO

Don’t you want your Pulsar telescope(s)?

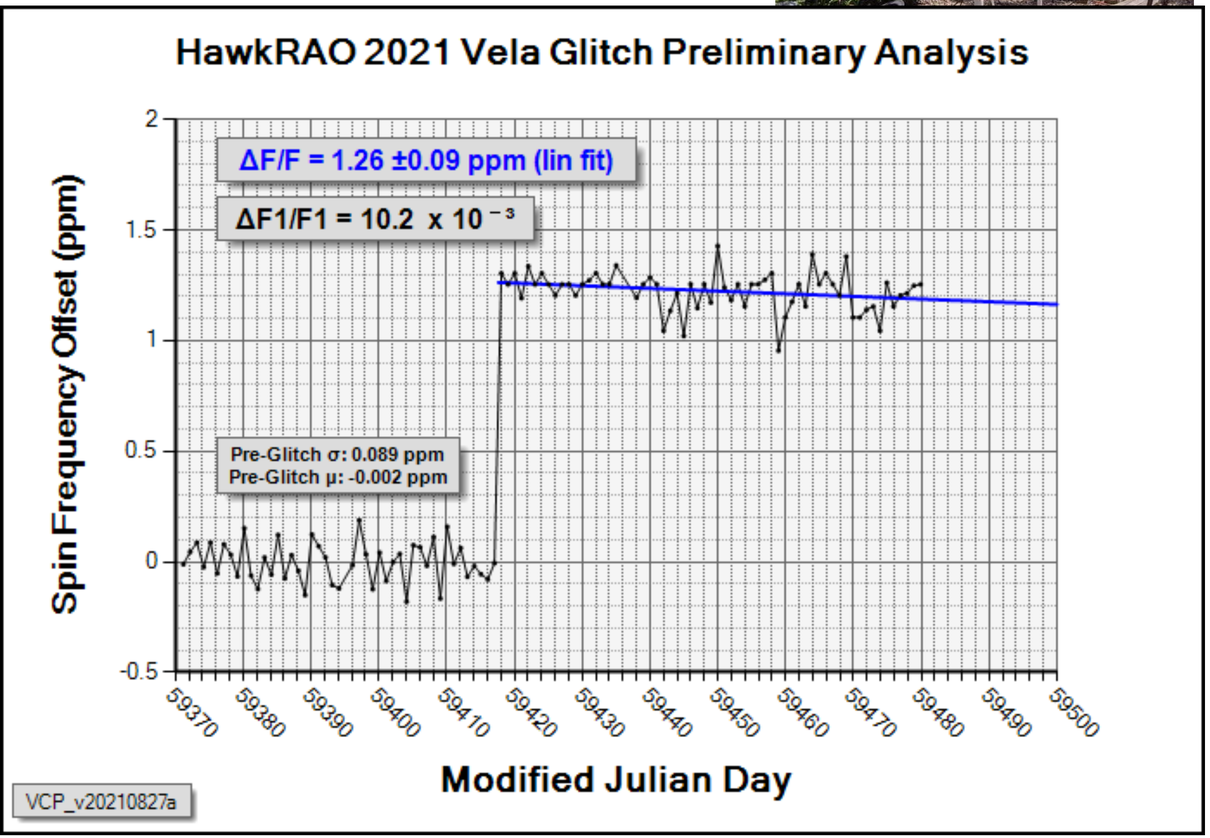
Amateur Pulsar Detection

- Pulsars are faint radio sources requiring large antennas, complex receivers and data processing to detect them.
- It has long been believed that pulsar detection by amateur radio-astronomers is extremely difficult.
- Recent advancement in Information and communications technology (ICT) has enabled to observe pulsars with a small parabola or an array of high gain antennas.
- In the past decade, some amateur radio astronomers achieved detection of pulsars using Software Defined Radio (SDR) receivers.

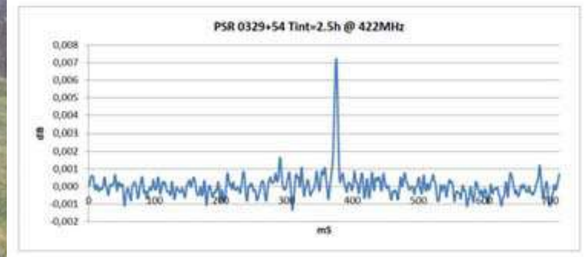
Amateur Pulsar Detection

Glitch event in the Vela pulsar (PSR J0835-4510) observed at HawkRAO

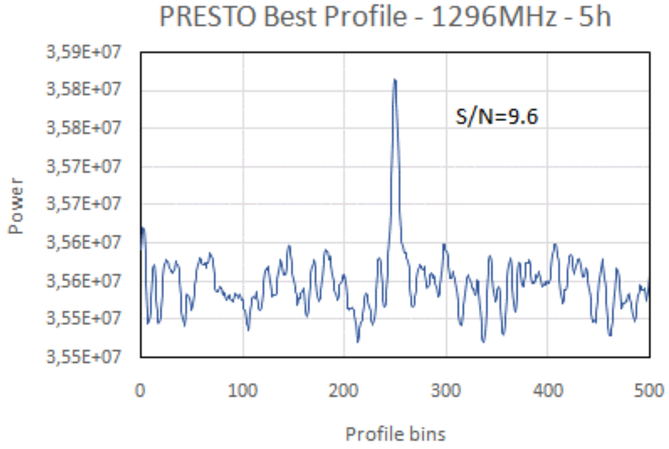
ATel #14808; *Steve Olney (Hawkesbury Radio Astronomy Observatory)*
on 26 Jul 2021; 08:08 UT



Andrea - Italy
422MHz + 2.4MHz + 3Hrs
2m Corner reflector



Hannes - Austria
1296MHz + 2MHz + 5Hrs
3m offset dish



Figures from: Amateur Pulsar Detection on a shoestring Introduction (Peter East)

2-3時間の観測でB0329+54を観測

Amateur pulsar observations using cheap equipment

天球儀

アマチュア無線技術を用いたパルサー観測

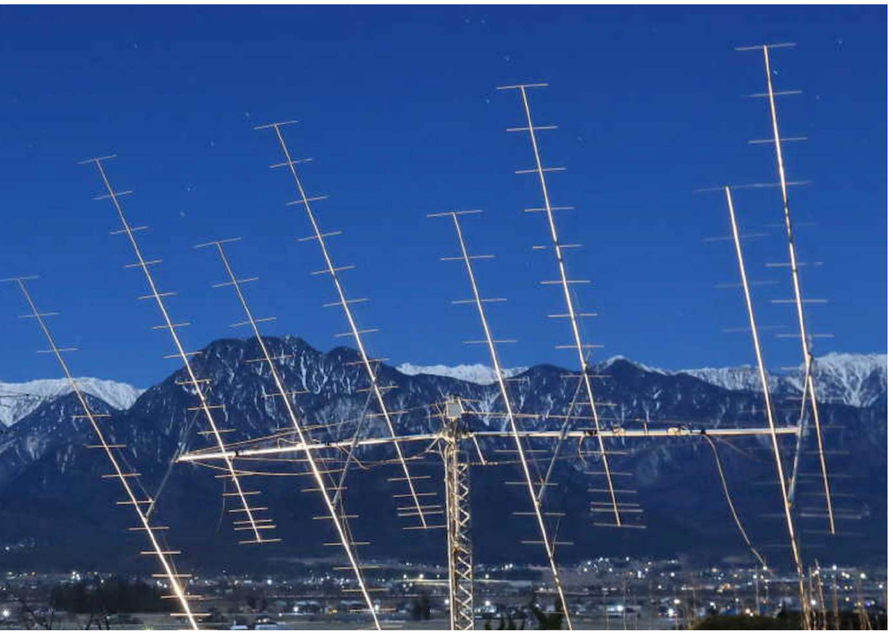


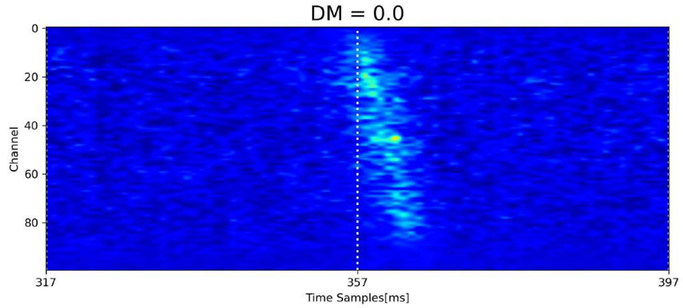
矢口徳之[1]・臼居隆志[1]・
横川英彰[1]・吉田英人[2]・寺澤敏夫[3]・浅山信一郎[4]

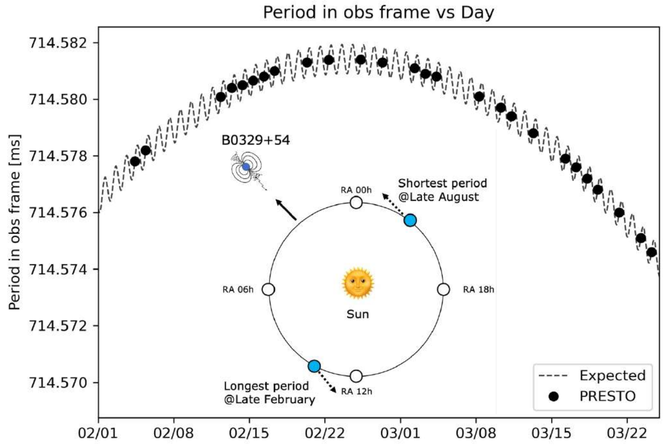
〈[1] 日本流星研究会〉
〈[2] 東京大学理学系研究科地球惑星科学専攻 〒113-0033 東京都文京区本郷 7-3-1〉
〈[3] 東京大学宇宙線研究所 〒277-8582 千葉県柏市柏の葉 5-1-5〉
〈[4] SKA Observatory, Jodrell Bank, Lower Withington, Macclesfield, SK11 9FT, UK〉

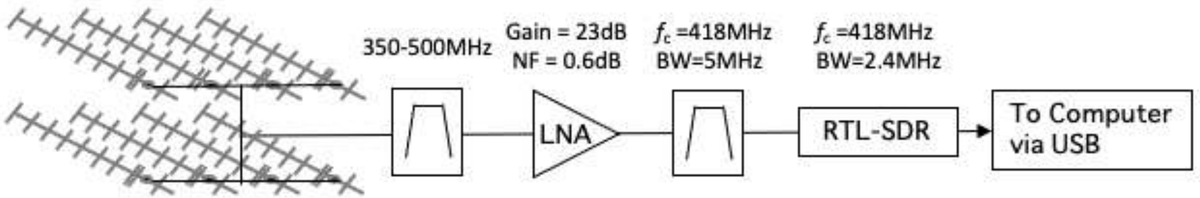
2023年
8月号

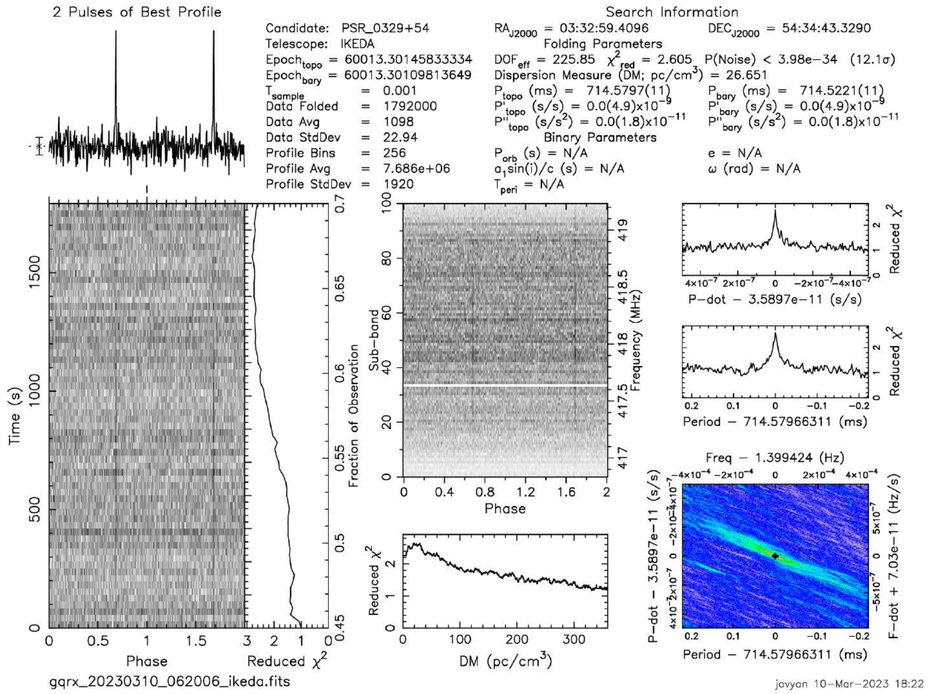
これまで電波パルサーの観測は大規模な施設が必要なためアマチュアでは観測困難であると考えられてきた．ネット通販等で誰でも安価（～数千円）に入手可能なソフトウエア無線（SDR）受信機を用い，アマチュア無線家と天文学研究者がタッグを組みパルサーの受信に成功した本邦初の結果を報告する．SDRを用いたパルサー観測は，教育研究機関や科学館等での実習課題や広報普及活動にも活用できるだろう．





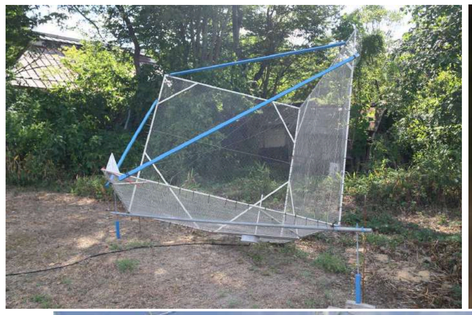


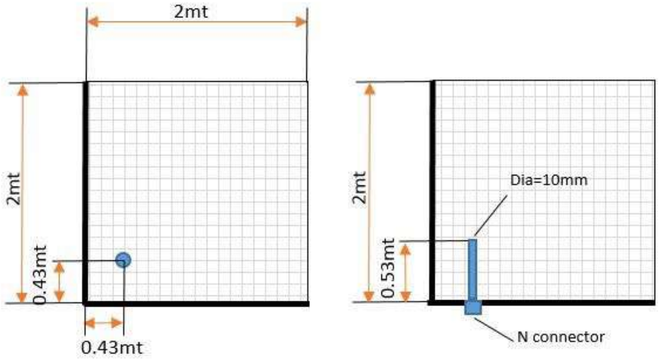


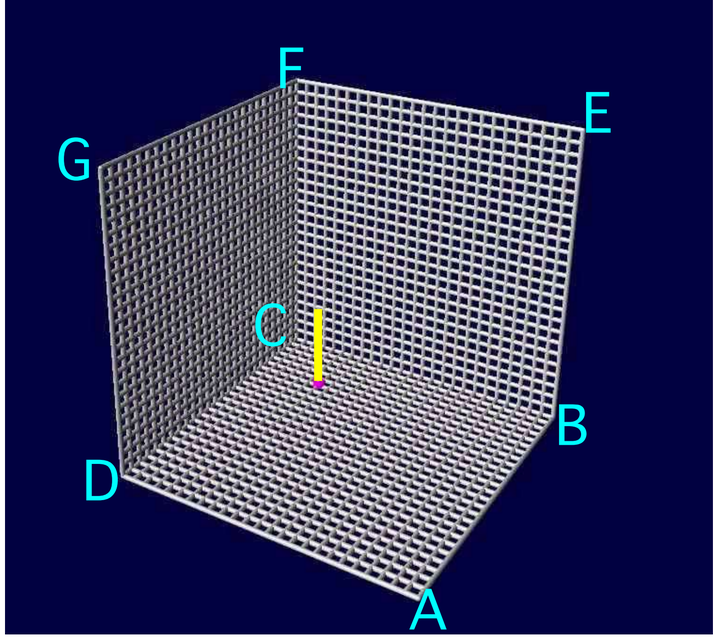


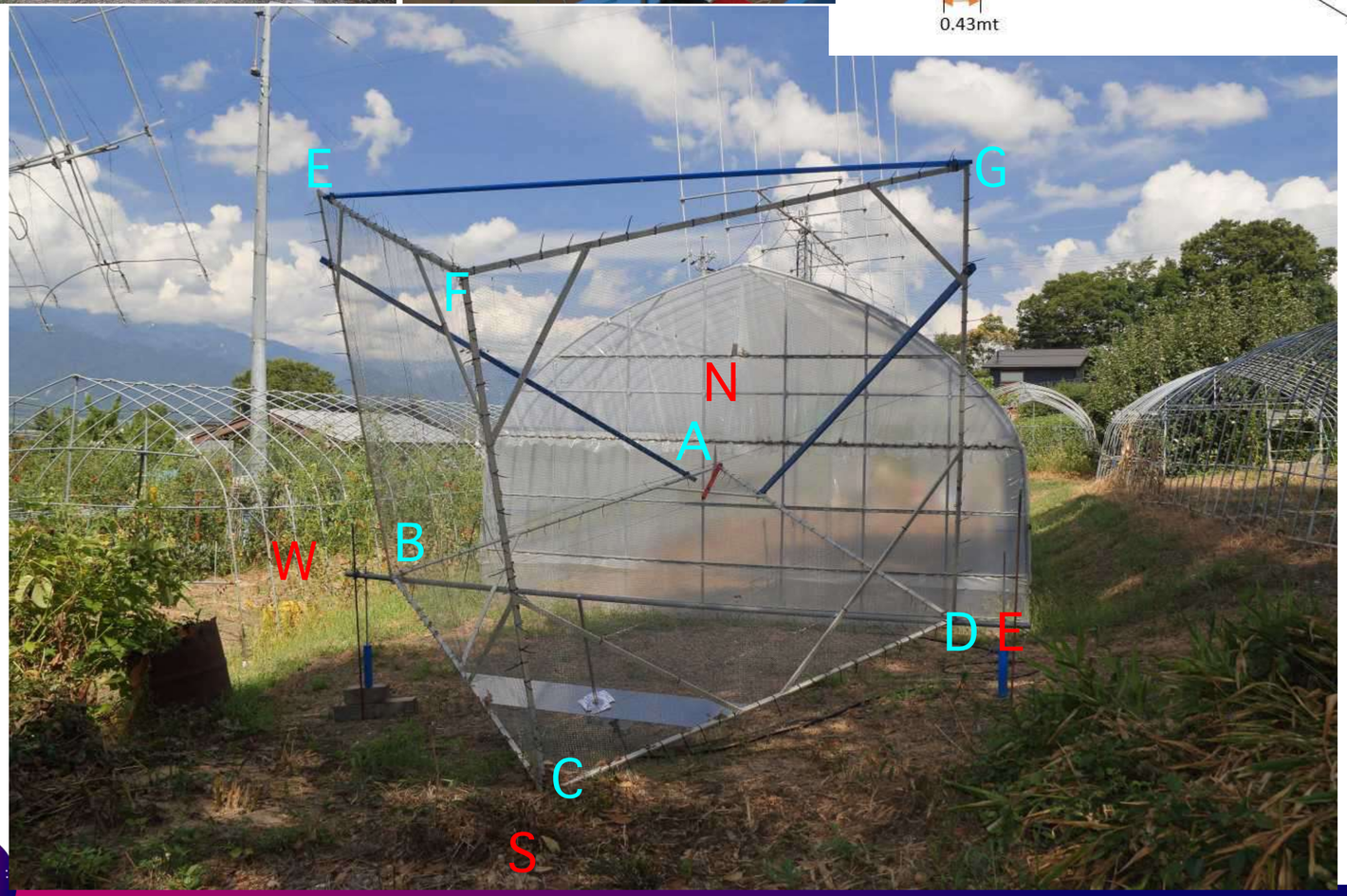
2-3時間の観測でB0329+54を観測

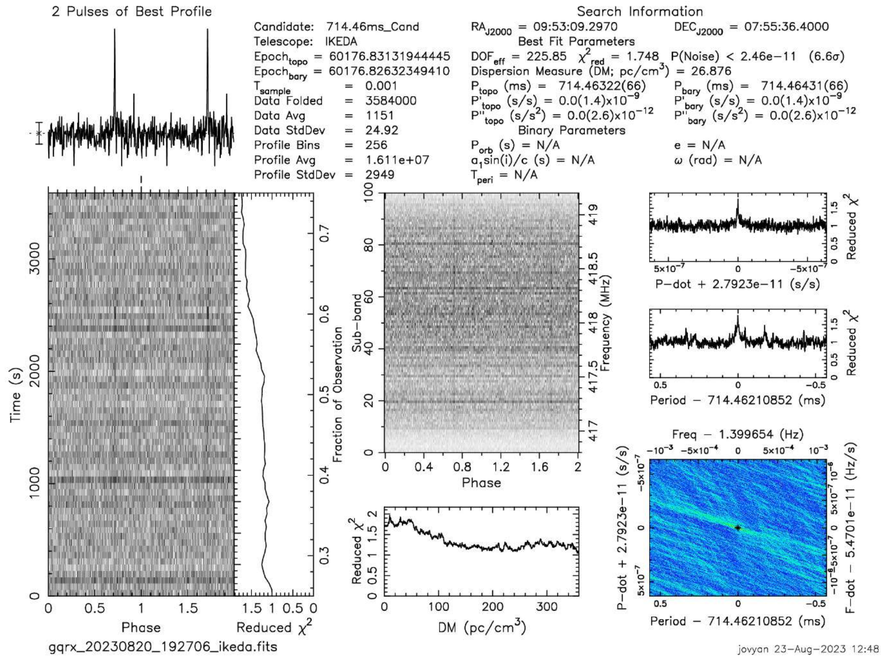
Pulsar Detection with a 3D Corner reflector











First Detection @ 2023-08-21 ☺

Thank you

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

SKAO

www.skao.int