EVN TOG Meeting, 13/14 December 2023
@Institute of Astronomy, in Toruń, Poland.

Thai National Radio Astronomy Observatory Project & the Future Vision

NARIT: National Astronomical Research Institute of Thailand (Public Organization),
Ministry of Higher Education, Science, Research and Innovation, Thailand

Koichiro Sugiyama, Chief Scientist of TNRO Project,

Phrudth Jaroenjittichai, Apichat Leckngam, Wiphu Rujopakarn, Boonrucksar Soonthornthum, Busaba H. Kramer (MPIfR), Nobuyuki Sakai, Taufiq Hidayat (ITB), Zamri Zainal Abidin, Juan Carlos Algaba (Universiti Malaya), Pham Ngoc Diep (VNSC), and Saran Poshyachinda (Executive Director of NARIT),

on behalf of the Project Team Members of *Thai National Radio Astronomy Observatory*

Image credit: D. Singwong, N. Thoonsaengngam, & NARIT / TNRO / CROE.

NARIT Infrastructure

Dr. Saran Poshyachinda | Assoc Prof. Boonrucksar Soonthornthum | Dr. Wiphu Rujopakarn | Dr. Busaba H. Kramer

⌀ 2.4 meters ⌀ 1 meters ⌀ 0.7 meters ⌀ 0.4 meters ⌀ 40 meters ⌀ 13 meters

Members of TNRO Project (project since 2017)

Directors Advisors Project Leaders

S. Poshyachinda; W. Rujopakarn; B. Soonthornthum; B. H. Kramer; P. Jaroenjittichai; A. Leckngam

"Capacity Building Through Radio Astronomy & Geodesy"

Speaker: KS

22 June 2023, Credit: นายศิวรุต พลอยแดง (ดราฟ), CAEP

Acknowledgement

*** Committee from Europe

- International Technical Advisery Committee (ITAC) members:
  - Hideyuki Kobayashi (Chair, NAOJ), **Busaba H. Kramer (Secretariat, MPIfR/**NARIT), Do-Young Byun (KASI), **Francisco P. Colomer (JIVE, retired)**, **Michael Garrett (JBCA)**, Yashwant Gupta (NCRA), Mareki Honma (NAOJ), Kee-Tae Kim (KASI), Jinling Li (SHAO), Zhiqiang Shen (SHAO), Tasso Tzioumis (CASS), **Pablo de Vicente (IGN)**, & **Gundolf Wieching (MPIfR)**.
- International Scientific Advisery Committee (ISAC) members:
  - Michael Bode (Chair, BIUST), Busaba H. Kramer (Secretariat, MPIfR/NARIT), Hideyuki Kobayashi (NAOJ), & **Michael Kramer (MPIfR)**.
- Special thanks to Yebes Observatory, MPIfR, JBCA, and SHAO for constructing the TNRT and VGOS with its receivers developments!

Outline

1. Overview of 40 m Thai National Radio Telescope
2. Science Cases with TNRT
3. Commissioning and Call for Proposal
4. Vision for the Future in Radio Thailand / ASEAN

Image credit: D. Singwong, N. Thoonsaengngam, & NARIT / TNRO / CROE.

Outline

1. **Overview of 40 m Thai National Radio Telescope**
2. **Science Cases with TNRT**
3. **Commissioning and Call for Proposal**
4. **Vision for the Future in Radio Thailand / ASEAN**

Image credit: D. Singwong, N. Thoonsaengngam, & NARIT / TNRO / CROE.

Thai National Radio Astronomy Observatory

Thailand © NordNordWest in Wikipedia

- 40 km away toward NE from NARIT head quarters
- Site is a part of Huai Hong Khrai Royal Development Study Center
- Radio Quiet Zone: less RFI, & Relatively lower water vapor area

Image credit: P. Jaroenjittichai & TNRO/CROE members (NARIT)

The 40 m Thai National Radio Telescope (TNRT)

Big Lift in Feb 2020

L-band
(1.0-1.8 GHz)

K-band
(18-26.5 GHz)

"Upgraded" version of IGN's Yebes 40-m Radio Telescope

With Prime-Focus Tetrapod Head Unit (THU)

0.3 – 115 GHz : P/L/C/X/Ku/K/Q/W-bands

150 um (rms) total surface accuracy

Beam size: 13.4 arcsec – 1.43 degree

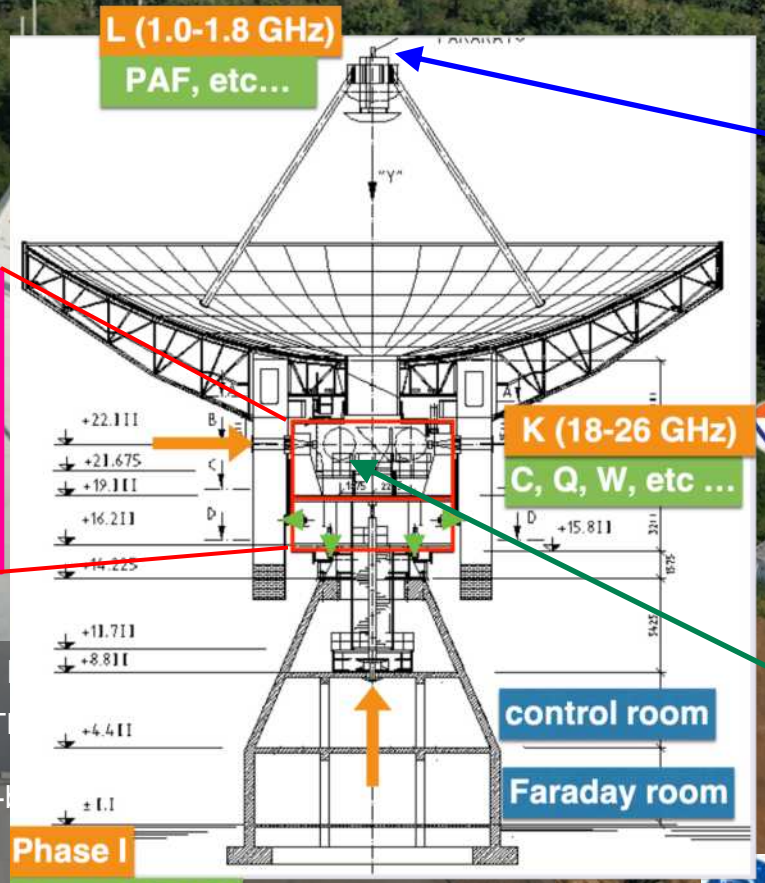
Pointing: 2" (no wind), 6" (5 m/s wind)

Slew: AZ 3 deg/s, EL 1 deg/s

USB: Universal Software Backend Installation & Implementation

Assembly the system in 2021−2022

The 40 m Thai National Radio Telescope (TNRT)



L-band
(1.0-1.8 GHz)

K-band
(18-26.5 GHz)

"Upgraded" version of IGN's Yebes 40-m
With Prime-Focus Tetrapod Head Unit (T

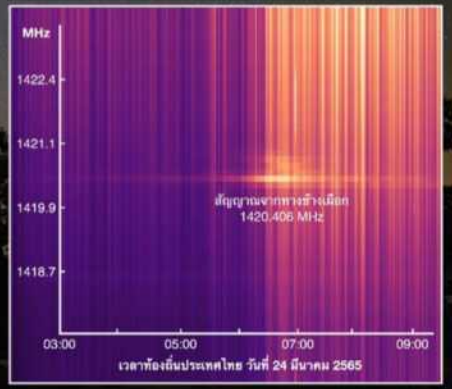
0.3 – 115 GHz : P/L/C/X/Ku/K/Q/W-

150 um (rms) total surface accuracy

Pointing: 2" (no wind), 6" (5 m/s wind)

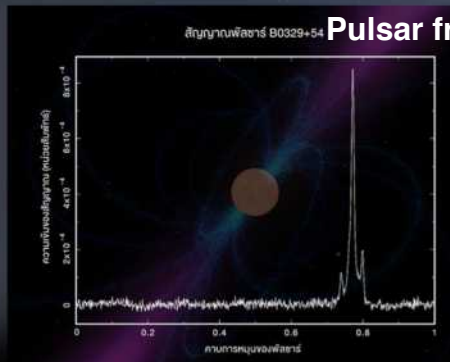
The 1st lights in L-band

HI emission from the Milky Way
on 24 Mar 2022



สัญญาณแรกแห่งห้วงอวกาศ
ของกล้องโทรทรรศน์วิทยุแห่งชาติ

www.NARIT.or.th

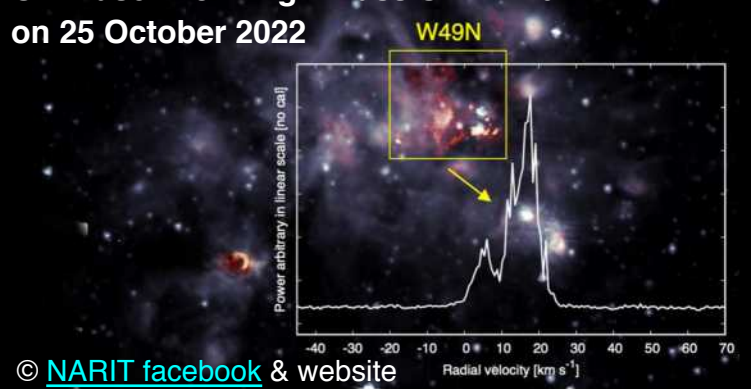


Pulsar from PSR B0329+54
on 15 June 2022

สัญญาณพัลซาร์แรก
จากกล้องโทรทรรศน์วิทยุแห่งชาติ

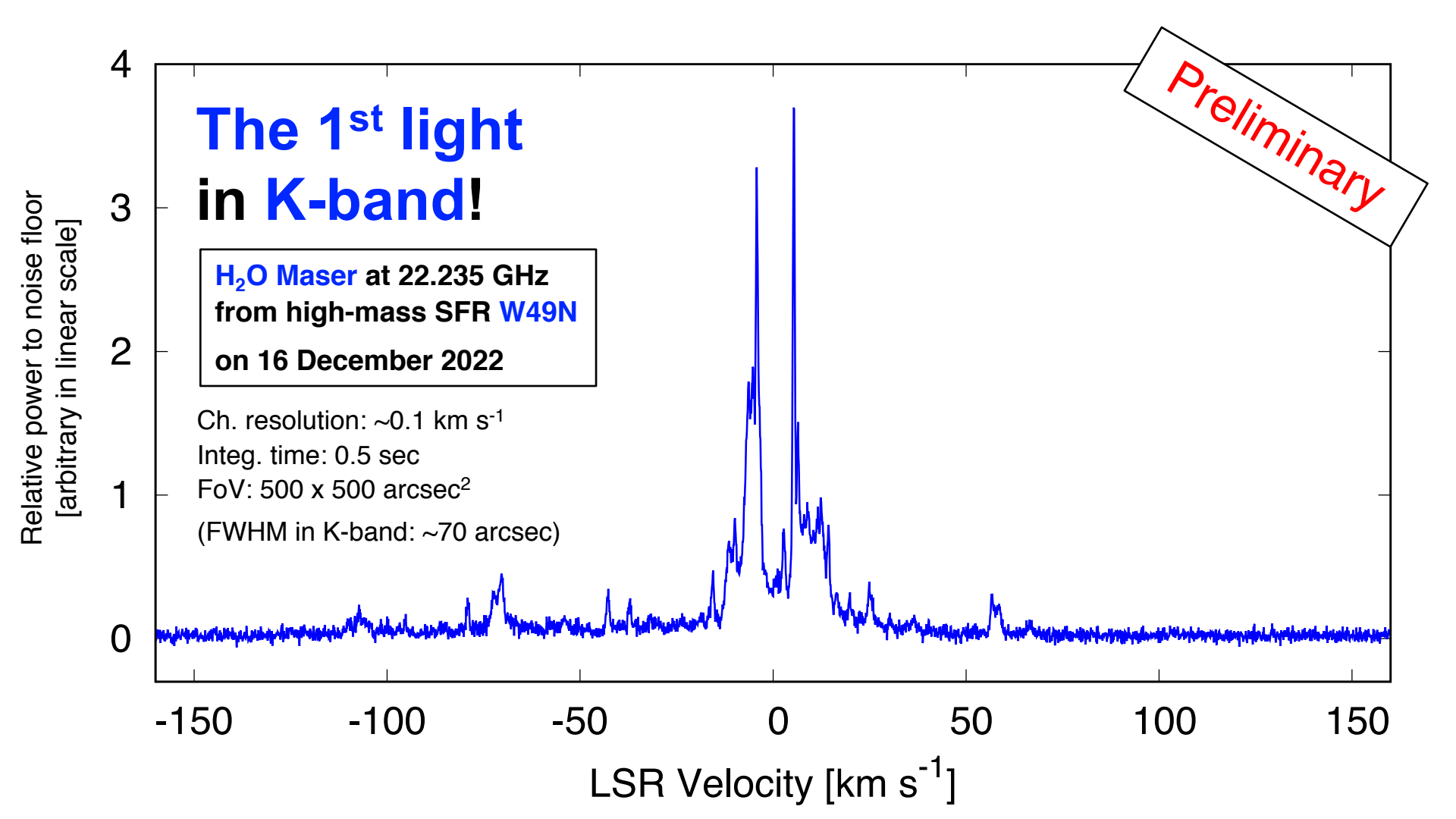
www.NARIT.or.th

OH Maser from high-mass SFR W49N
on 25 October 2022



“สัญญาณเมเซอร์แรก” ของกล้องโทรทรรศน์วิทยุแห่งชาติ

www.NARIT.or.th


The 1st light
in K-band!
H2O Maser at 22.235 GHz
from high-mass SFR W49N
on 16 December 2022
Ch. resolution: ~0.1 km s-1
Integ. time: 0.5 sec
FoV: 500 x 500 arcsec2
(FWHM in K-band: ~70 arcsec)
Preliminary
Relative power to noise floor
[arbitrary in linear scale]
LSR Velocity [km s-1]
4
3
2
1
0
-150
-100
-50
0
50
100
150

Outline

1. Overview of 40 m Thai National Radio Telescope
2. **Science Cases with TNRT**
3. Commissioning and Call for Proposal
4. Vision for the Future in Radio Thailand / ASEAN

Image credit: D. Singwong, N. Thoonsaengngam, & NARIT / TNRO / CROE.

White Paper for TNRT

Sciences with Thai National Radio Telescope

arXiv: arXiv:2210.04926 on 12 Oct 2022

Editors

Jaroenjittichai, Phrudth [1,*], Sugiyama, Koichiro [1,2], Kramer, H. Busaba [3,1], and Soonthornthum, Boonrucksar [1]

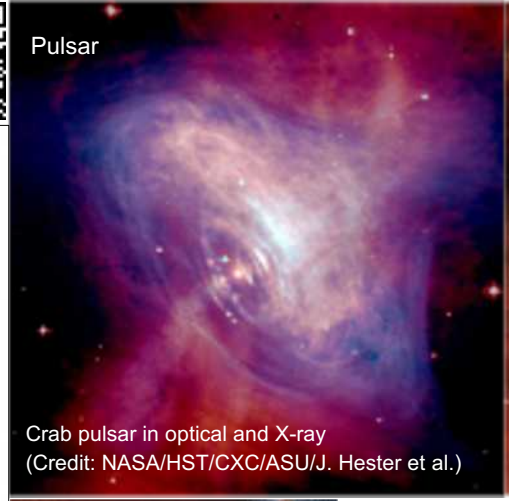
Authors

Akahori, Takuya [2,4], Asanok, Kitiyanee [1], Baan, Willem [5], Bran, Sherin Hassan[1,6], Breen, L. Shari [7], Cho, Se-Hyung [8], Chanapote, Thanapol [1], Dodson, Richard [9], Ellingsen, P. Simon [10], Etoka, Sandra[11], Gray, D. Malcolm[1,11], Green, A. James[12], Hada, Kazuhiro [13], Halson, Marcus[1], Hirota, Tomoya [2], Honma, Mareki [13], Imai, Hiroshi [14], Johnston, Simon [12], Kim, Kee-Tae [8], Kramer, Michael [3,11], Li, Di [15], Macatangay, Ronald[1], Menten, M. Karl [3], Minh, Young Chol [8], Mkrtichian, David [1], Pimpanuwat, Bannawit [11], Richards, M.S. Anita [11], Rioja, Maria [9,16,17], Rujopakarn, Wiphu [1,18], Sakai, Daisuke [13,1], Sakai, Nobuyuki [1,8], Samanso, Nattida[1], Sanpa-arsa, Siraprapa[1], Semenko, Eugene [1], Sunada, Kazuyoshi [13], Surapipith, Vanisa[1], Thoonsaengngam, Nattaporn[1], Voronkov, A. Maxim [12], Wongphecauxson, Jompoj [3], Yadav, Ram Kesh[1], Zhang, Bo [19], Zheng, Xing Wu[20] and Poshyachinda, Saran[1]

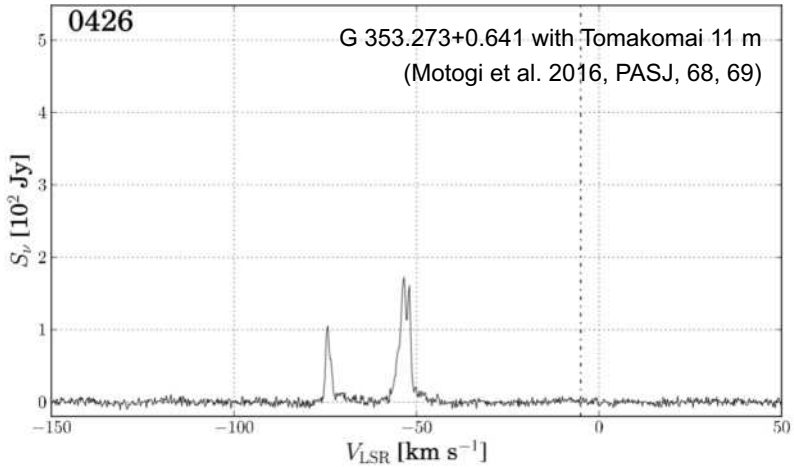
Pulsar / FRB / GW / SFR / Galaxy / AGN / ES / CP stars / Geodesy, & Forecasting system

[1] National Astronomical Research Institute of Thailand (Public Organization), 260 Moo 4, T. Donkaew, A. Maerim, Chiang Mai, 50180, Thailand
[2] Mizusawa VLBI Observatory, National Astronomical Observatory of Japan (NAOJ), Mitaka, Tokyo 181-8588, Japan
[3] Max Planck Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany
[4] SKA Observatory, Jodrell Bank, Lower Withington, Macclesfield, Cheshire SK11 9FT, UK
[5] Netherlands Institute for Radio Astronomy ASTRON, 7991PD Dwingeloo, the Netherlands
[6] Environmental Science Research Center, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand
[7] Sydney Institute for Astronomy (SIfA), School of Physics, University of Sydney, NSW 2006, Australia
[8] Korea Astronomy and Space Science Institute, 776 Daedeok-daero, Yuseong, Daejeon 34055, Republic of Korea
[9] International Centre for Radio Astronomy Research, M468, University of Western Australia, 35 Stirling Highwaym Perth 6009, Australia
[10] School of Natural Sciences, University of Tasmania, Private Bag 37, Hobart, Tasmania 7001, Australia
[11] Jodrell Bank Centre for Astrophysics, School of Physics and Astronomy, University of Manchester, M13 9PL, UK
[12] Australia Telescope National Facility, CSIRO Space and Astronomy, PO Box 76, Epping NSW 1710, Australia
[13] Mizusawa VLBI Observatory, NAOJ, 2-12 Hoshigaoka, Mizusawa, Oshu, Iwate 023-0861, Japan
[14] Amanogawa Galaxy Astronomy Research Center, Graduate School of Science and Engineering, Kagoshima University, 1-21-35 Korimoto, Kagoshima 890-0065, Japan
[15] National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100012, China
[16] CSIRO Astronomy and Space Science, 26 Dick Perry Avenue, Kensington WA 6151, Australia
[17] Observatorio Astronómico Nacional, Alfonso XII, 3 y 5, 28014 Madrid, Spain
[18] Department of Physics, Faculty of Science, Chulalongkorn University, 254 Phyathai Road, Patumwan, Bangkok Thailand. 10330
[19] Shanghai Astronomical Observatory, Chinese Academy of Sciences, Shanghai 200030, China
[20] School of Astronomy and Space Sciences, Nanjing University, Nanjing 210093, China

*E-mail: phrudth@narit.or.th



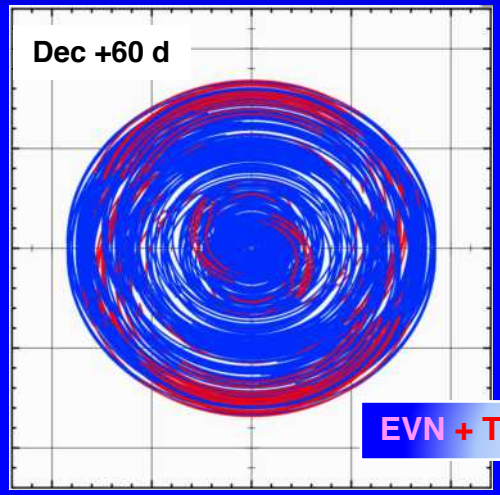
Time-Domain Sciences with TNRT



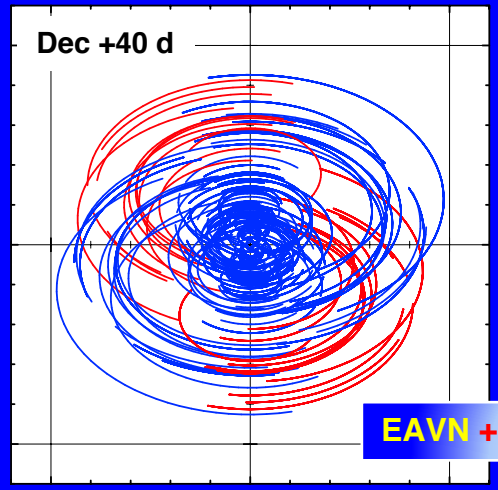
World-wide Collaboration for VLBI

K-band

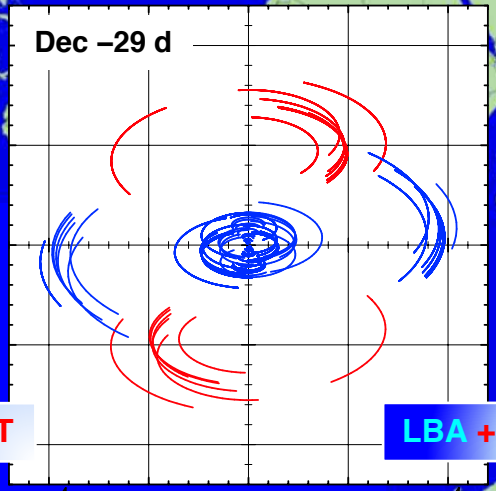
World-wide Collaboration for VLBI



EVN + TNRT



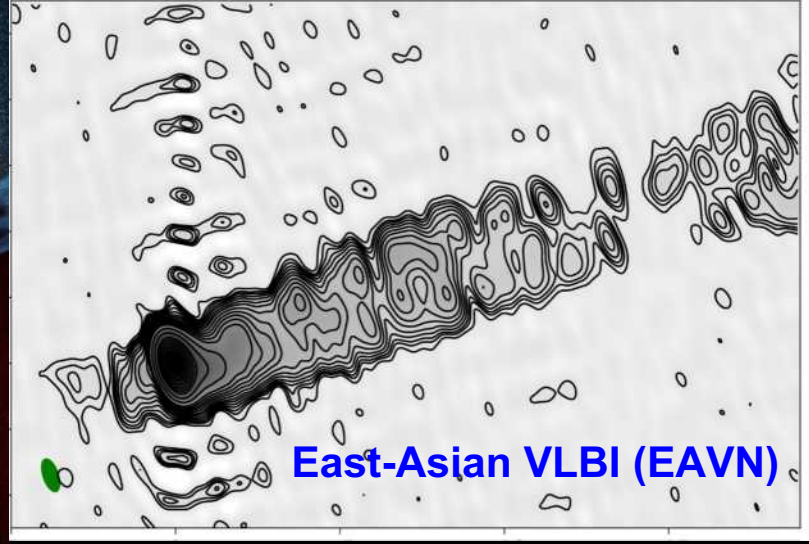
EAVN + TNRT



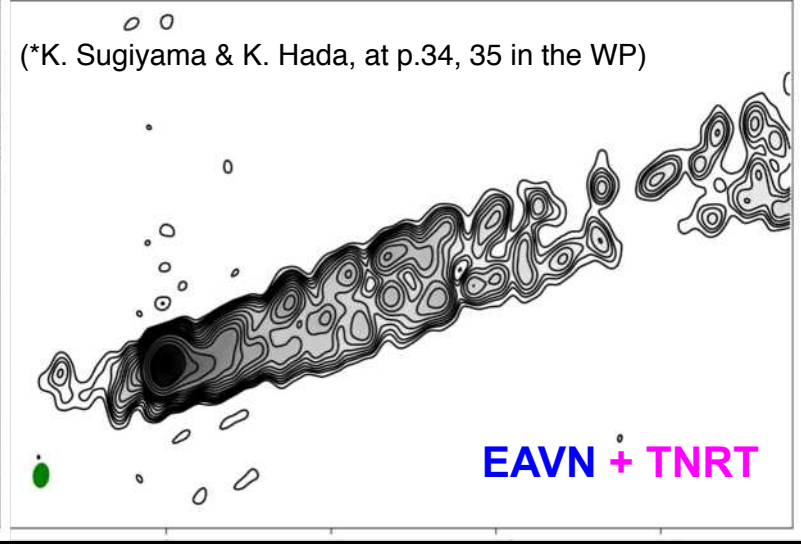
LBA + TNRT

EAVN
EVN
LBA
GMRT

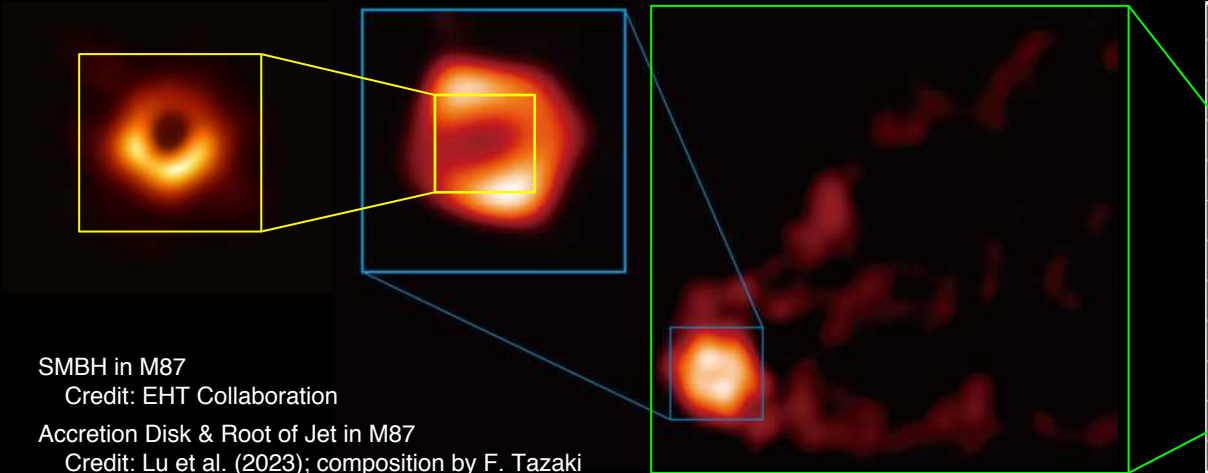
Image credit of background world-map:
Illust AC



(*K. Sugiyama & K. Hada, at p.34, 35 in the WP)

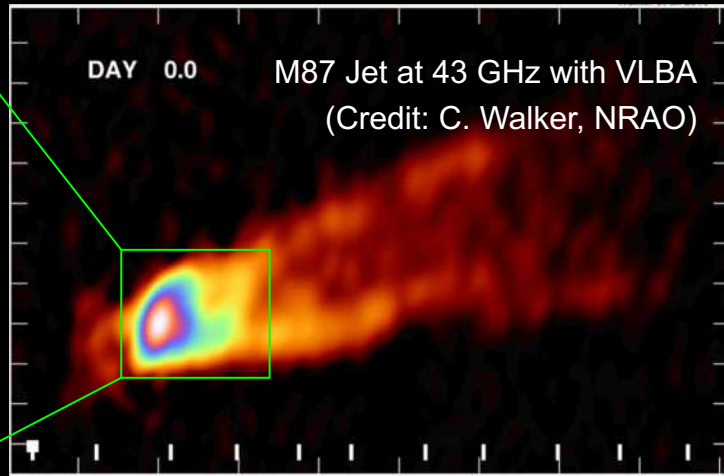


Simulated results of VLBI obs case towards Active Galactic Nucleus M87 at 22 GHz in K-band.



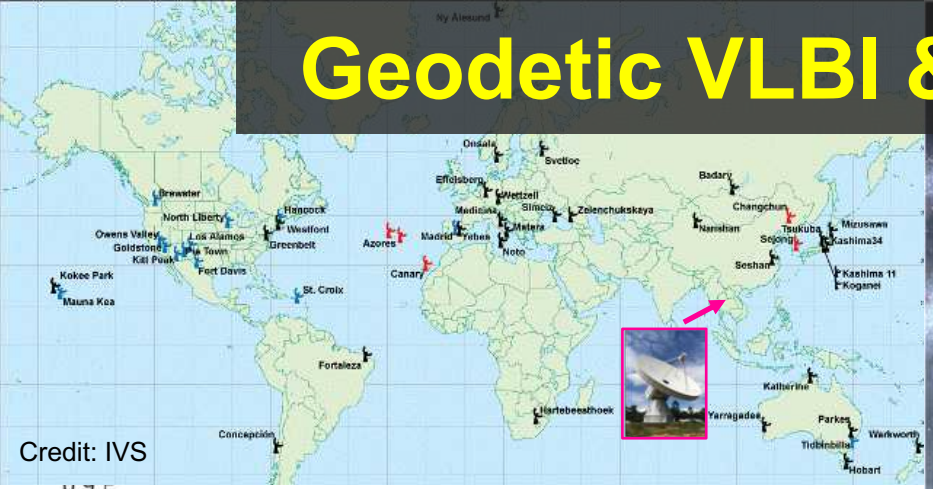
SMBH in M87
Credit: EHT Collaboration

Accretion Disk & Root of Jet in M87
Credit: Lu et al. (2023); composition by F. Tazaki

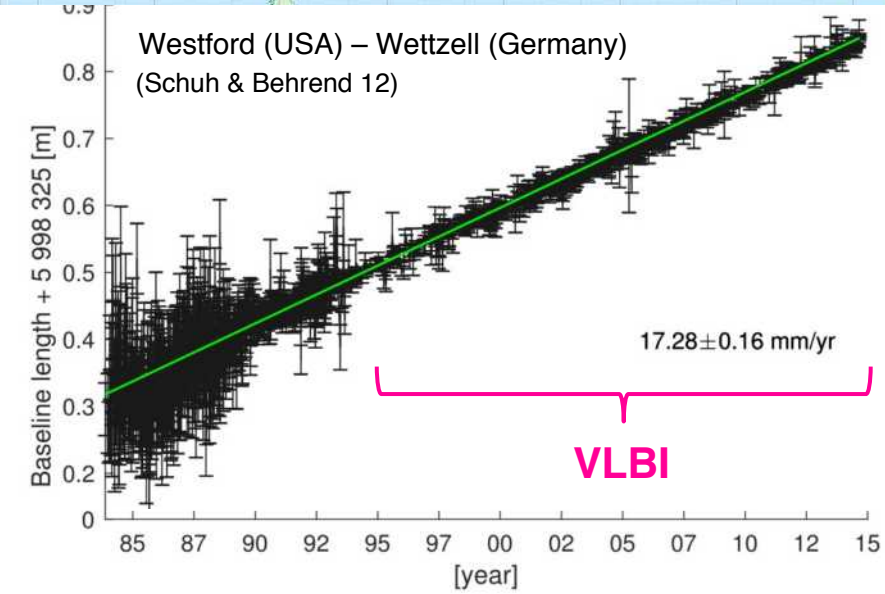


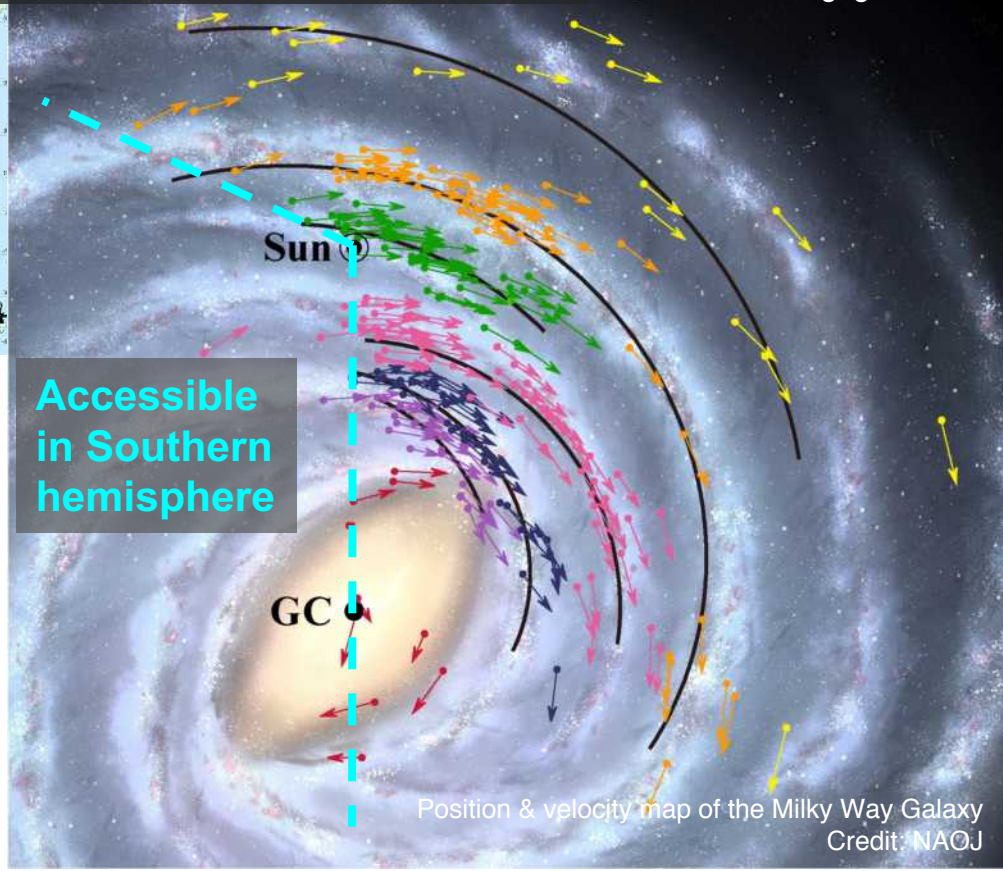
Geodetic VLBI & Astrometry

by Nobuyuki Sakai,
N. Thoonsaengngam, et al.



Credit: IVS





Position & velocity map of the Milky Way Galaxy
Credit: NAOJ

Results of VERA Collaboration, Hirota, + (2020) for 99 srcs and combined with BeSSeL proj. (Reid, Menten, + 2019) in total 224 srcs

Outline

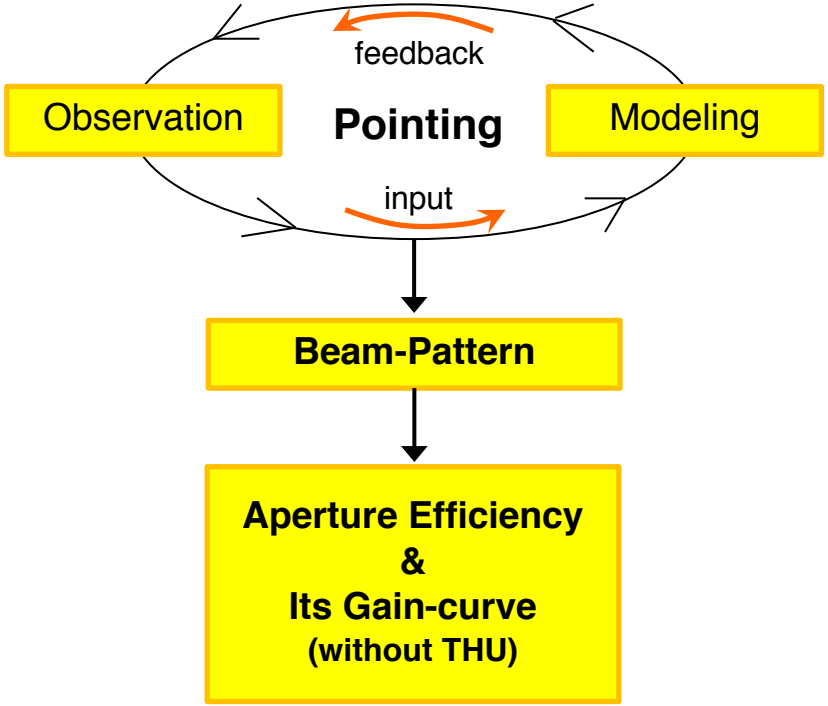
1. Overview of 40 m Thai National Radio Telescope
2. Science Cases with TNRT
3. **Commissioning and Call for Proposal**
4. Vision for the Future in Radio Thailand / ASEAN

Image credit: D. Singwong, N. Thoonsaengngam, & NARIT / TNRO / CROE.

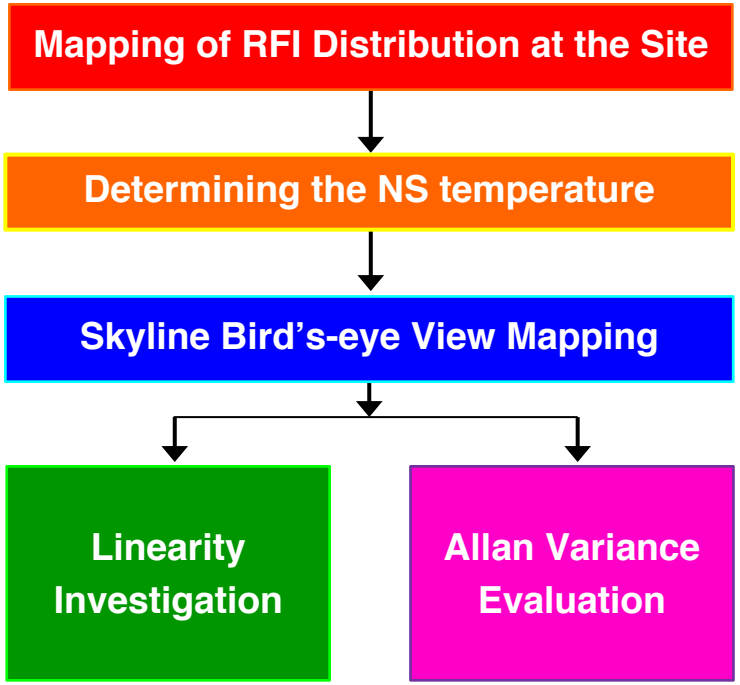
Since November 2022 ~

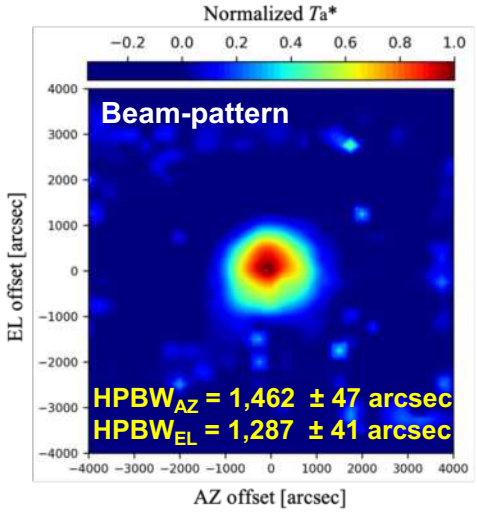
General (Engineering) Commissioning in L-band

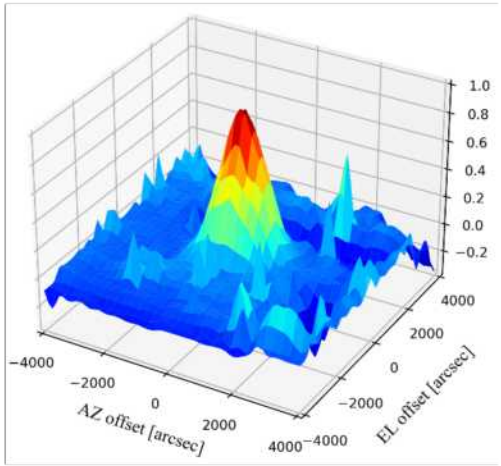
Pointing (relevant) Part

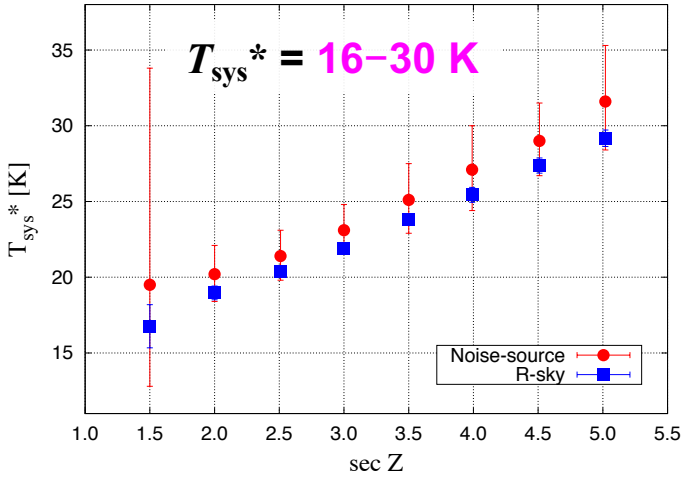


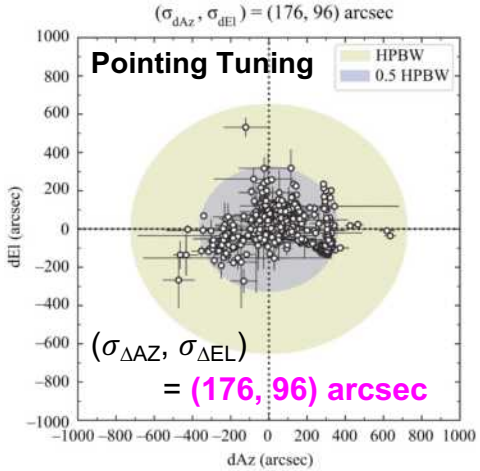
Basic Part

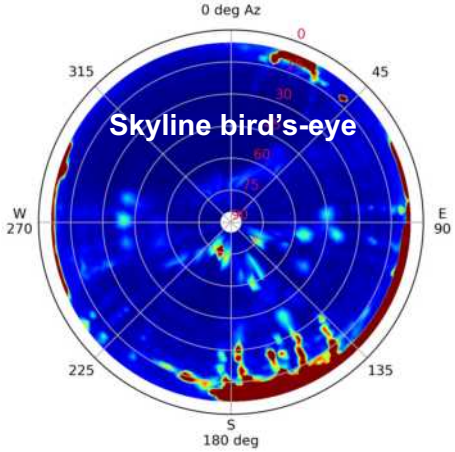


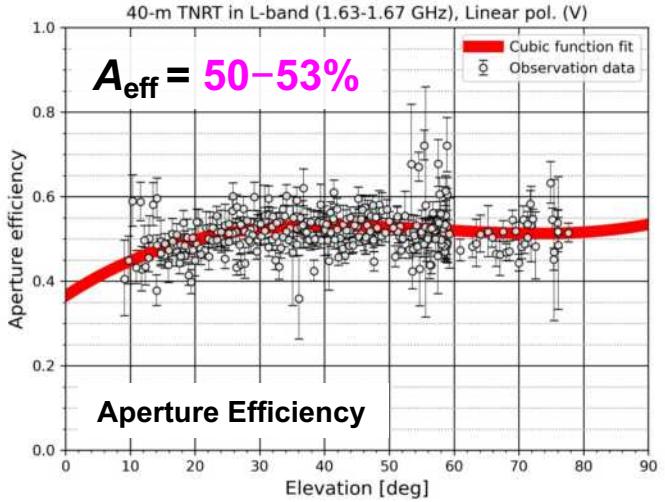












Credit: 1st CfP of the 40-m TNRT (https://indico.narit.or.th/event/197/)

Call for Proposals: 40-m Thai National Radio Telescope, Cycle 0 (Resident Shared Risk Observing)

10 October 2023 to 30 November 2023
UTC timezone

Announced on 10th October 2023 (Tue), 10 TST !! in L-band

https://indico.narit.or.th/event/197/

Deadline of prop. submission: 30th November 2023

Now in the reviewing process, & open-use obs from Jan 2024

Contact
tnrtprop@narit.or.th

TNRO / 40-m TNRT

Photo 1-1: (Left) Chiang Mai, (Middle) Sketch of the TNRO site in Huai Hong Khrai Royal Development Study Centre, and (Right) the 40-m TNRT.

NARIT Facebook with PR

National Astronomical Research Institute of Thailand (NARIT, Public Organization) has established the Thai National Radio Astronomy Observatory (TNRO) in Huai Hong Khrai Royal Development Study Centre, Doi Saket District, Chiang Mai, in the northern part of Thailand 2018, which is 40 km away from NARIT headquarters in the North-East direction. This project was strongly motivated by the importance of the development by ourselves to achieve an empyreal goal of "*Capacity building through radio astronomy and geodesy*" via constructing national radio telescopes in Thailand. This construction has provided precious opportunities to develop engineering / technical / instrumental skills, its technology, unique sciences achieved with these telescopes, and essential experiences on the basis of collaboration with world-wide colleagues at the world-class facilities, as well as contribute to education via cultivating potential young astronomers, engineers, and geodesists. Given a radio quiet zone

Outline

1. Overview of 40 m Thai National Radio Telescope
2. Science Cases with TNRT
3. Commissioning and Call for Proposal
4. **Vision for the Future in Radio Thailand / ASEAN**

Image credit: D. Singwong, N. Thoonsaengngam, & NARIT / TNRO / CROE.

Vision for TNRO Project in Thailand & Regional VLBIs

【Construction】

- Big Lift
- Assembly System
- AZ/EL Movement

2020 ~ 2021

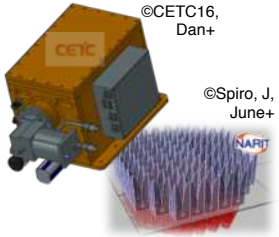
Big Lift Movie:
https://youtu.be/_wmFGBUDjiw

【Installation】

- L/K-band receivers
- Ku Holography

2022 ~ 2023

【Upgrade】



- Upgrade L-band with MPIfR (Gundolf, Christoph, +)
- Develop & Install C/X/Ku-bands receiver
- Prototype L-band PAF
- Develop Q/W-bands receiver

2024 ~ 2025

【VGOS stations】

- VGOS Building
  - Chiang Mai & Songkhla
- Develop Receivers
- Commissioning

2025 ~ 2026

2026 ~ 2027

【Establish Regional VLBI Networks】

- Thai National VLBI Array
- South-East Asia VLBI Network

VGOS in Chiang Mai

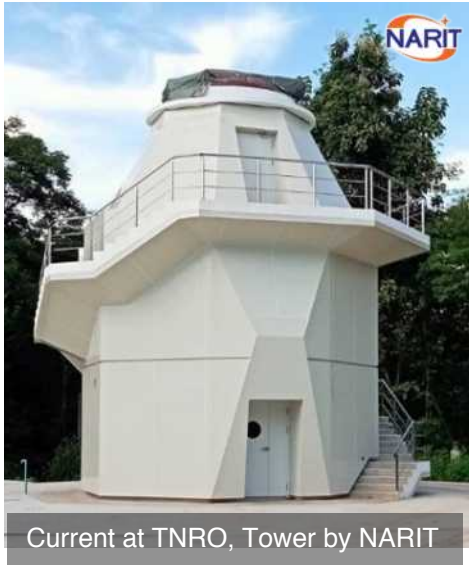
NARIT hosting one of the International Chinese VGOS stations, based on signing MoU with SHAO, CAS (Zhiqiang Shen, Jinling Li, et al.) in 2017, and constructing telescope tower / installing the 13-m VGOS telescope in Chiang Mai.

Special Thanks to SHAO, CAS, Chinese colleagues: **Prof. Zhiqiang Shen, Chao Shen, Prof. Jinling Li, Yuwei Liu, Cong Liu, Chengkai Wan, Zhengxiong Sun, Prof. Jinqing Wang, Prof. Rongbing Zhao, Prof. Fengchun Shu, Zhong Chen, Jiangying Gan, Xuan He, Li Guo**

Image credit: SHAO

Background ©NordNordWest in Wikipedia

Photo credit: Yuwei Liu (SHAO, CAS)



Current at TNRO, Tower by NARIT

VGOS in Chiang Mai & Songkhla

NARIT hosting one of the International Chinese VGOS stations, based on signing MoU with SHAO, CAS (Zhiqiang Shen, Jinling Li, et al.) in 2017, and constructing telescope tower / installing the 13-m VGOS telescope in Chiang Mai.

Besides, another VGOS station will be built in Songkhla (Southern), together with the receiver development at Yebes (**Special thanks to Pablo de Vicente, José A. López-Pérez**, et al.).

Current at TNRO, Tower by NARIT

Background ©NordNordWest in Wikipedia

Artist's illustration of VGOS Songkhla

Refer from A. Leckngam

Vision for the Future: **Thai National VLBI Array (TVA)**

in C/X/Ku/K-bands, 2026 (?) ~

© NordNordWest in Wikipedia, and edited

Chiang Mai (เชียงใหม่)

40-m TNRT

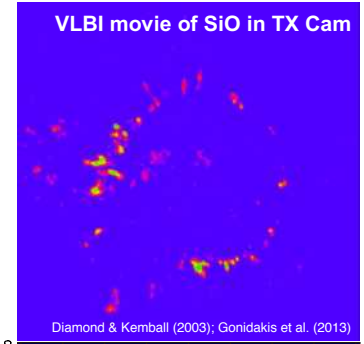
13-m VGOS (*under construction)

Songkhla (สงขลา), 13-m VGOS (*under construction)

Chonburi (ชลบุรี) & Ubon Ratchathani (อุบลราชธานี) (*funding proposal)

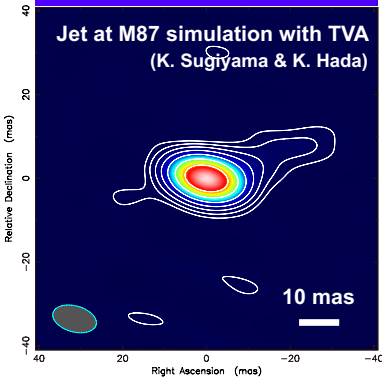
32-m telescopes

VLBI movie of SiO in TX Cam



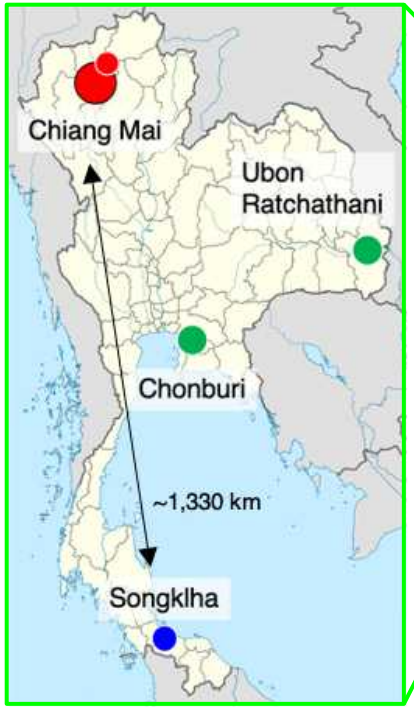
Diamond & Kemball (2003); Gonidakis et al. (2013)

Jet at M87 simulation with TVA (K. Sugiyama & K. Hada)



Vision for the Future: **South-East Asian VLBI Network**

in C/X/Ku/K-bands, 2027 (?) ~



Background © NordNordWest in Wikipedia

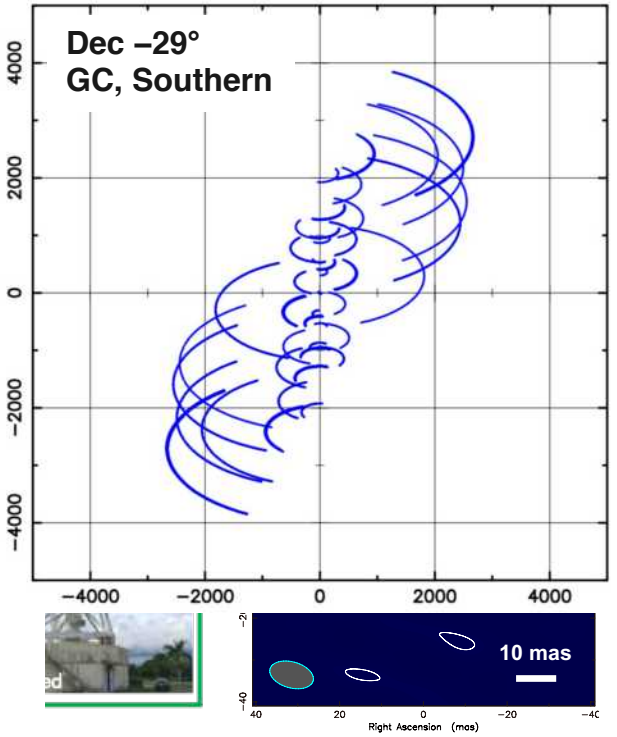
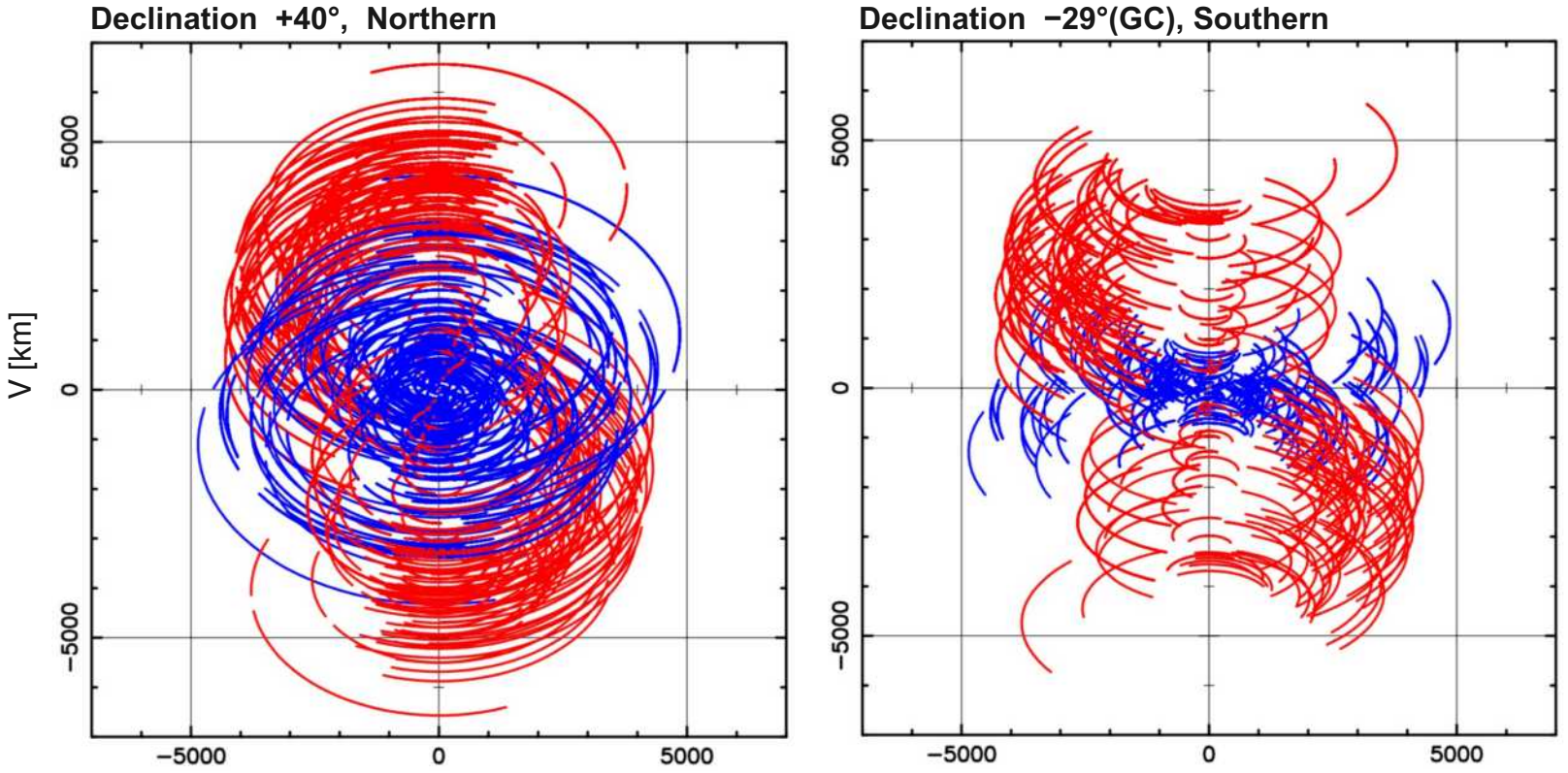


Image Credit: EAVN, Reto Stockli (NASA Earth Observatory), & NARIT / ITB / Univ. of Malaya

Jatiluhur 32-m
©T. Hidayat, I. N. Huda+ in EAVW21

UV-coverage : EAVN + SEAVN in K-band: ngEAVN??

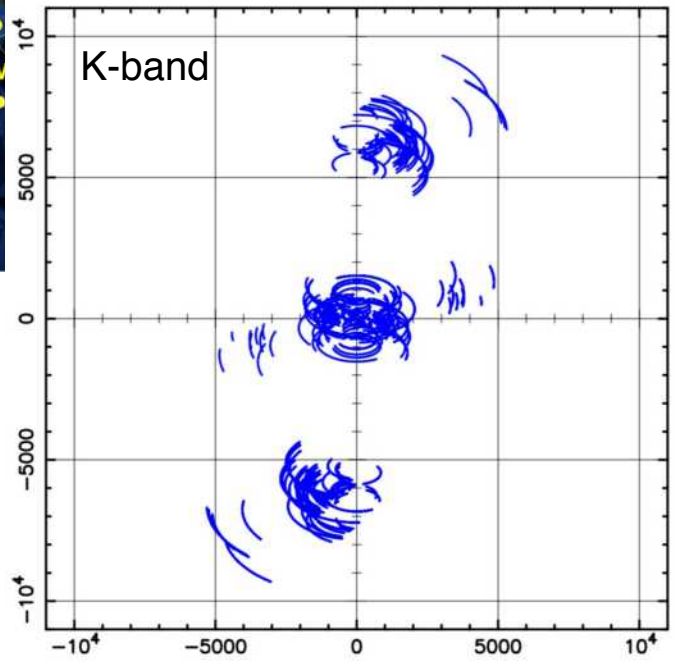


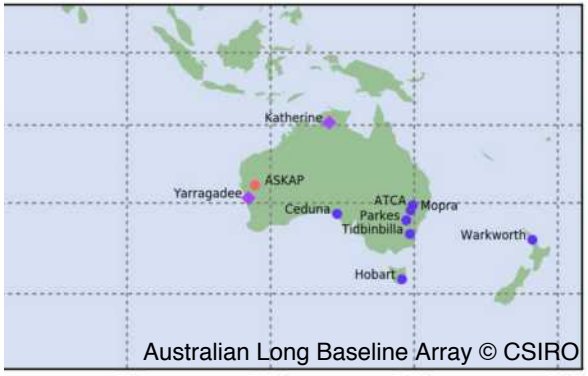
Reboot of Asia-Pacific Telescope (APT)

EAVN + LBA

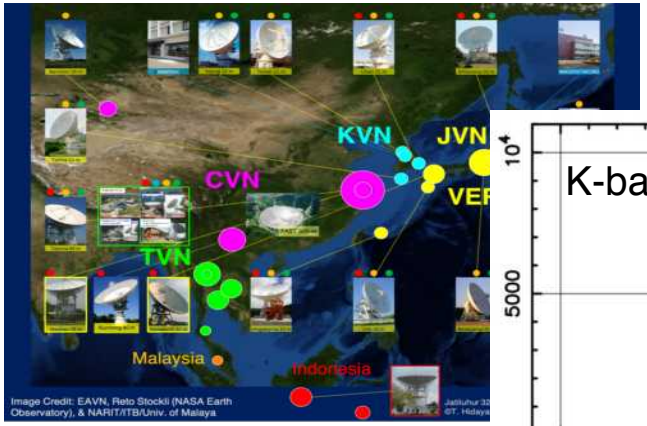
Sgr A* (GC) = **Asia-Pacific Telescope (APT)**

(since ~1990 yrs:
JAXA/ISAS, CSIRO, NAOJ, etc)



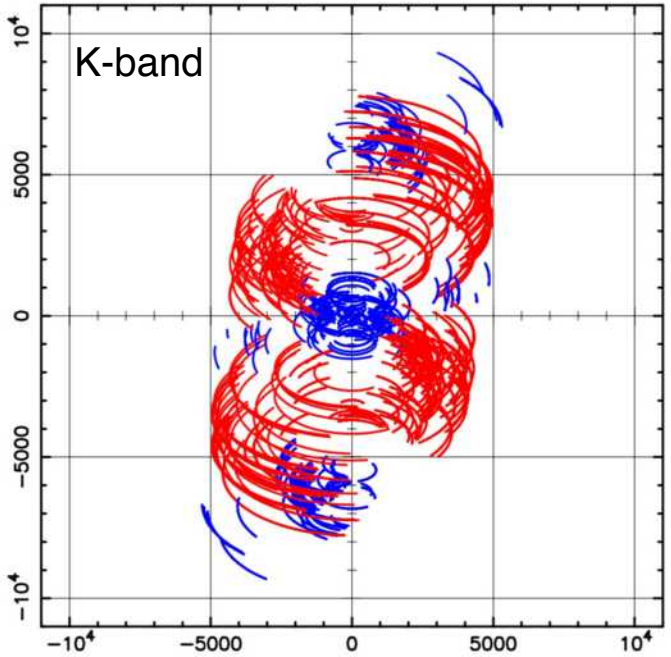


Reboot of Asia-Pacific Telescope (APT)



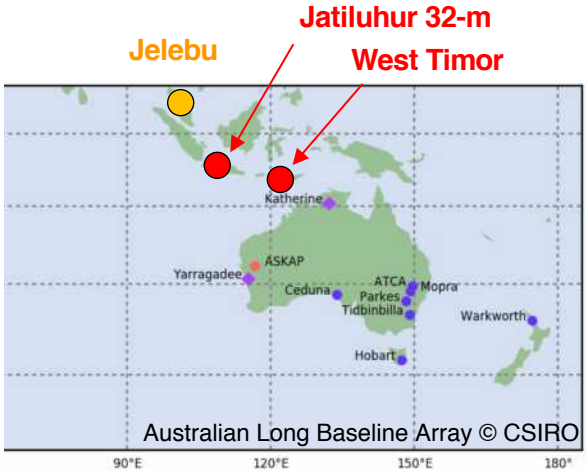
EAVN + LBA **+ SEAVN**

Sgr A* (GC) = **Asia-Pacific Telescope (APT)**



(since ~1990 yrs:

JAXA/ISAS, CSIRO, NAOJ, etc)



➔ Accelerate

Global VLBI Alliance

(Colomer, Kobayashi, et al.)

with **EVN/JIVE** !!

Signing MoU with JIVE on 7 Nov 2019 @Chiang Mai, Thailand

Signing MoU with UM (Malaysia) on 29 Jun 2021

Signing MoU with EAVN on 16 Aug 2022

Signing Letter of Intent with ATNF/CSIRO on 9 May 2018

Renewal of MoU with ITB (Indonesia) on 12 Jan 2023

Summary

[Current Status of 40-m TNRT]

- 1st lights of lines/continuums/pulsar in L/K-bands
- Key science cases with 40-m TNRT … arXiv:2210.04926
  - Single-dish : Time-domain / Unbiased-survey
  - VLBI : Astronomy / Geodesy with drastic better imaging quality

[General Commissioning in L-band at 1st phase]

- Completed in Sep 2023 (Pointing, Beam-pattern, RFI/Skyline bird's-eye view, T_{sys}*, A_{eff}/Gain-curve, etc)
- Call for Proposal (Cycle 0, RSRO style) was announced on 10th Oct 2023, 10 TST at the end!

[Future]

- Upgrade of TNRT (L-/K-bands in a year) & On-going building VGOS x 2
- TVA – Thai National VLBI Array, since 2026 (?):【40-m TNRT】+【VGOS x 2】+【32-m telecom x 2】
- To be foundation of SEAVN: South-East Asian VLBI Network, with Indonesia/Malaysia/Vietnam
  - Upgrade EAVN, Reboot APT, & Accelerate Global VLBI Alliance **with EVN/JIVE** (Colomer, Kobayashi, et al.)

Thank you very much for your attention,
Dziękuję bardzo!

40-m Thai National Radio Telescope
©D. Singwong, N. Thoonsaengngam,
& NARIT / TNRO / CROE

European VLBI Network
©EVN-HP: evlbi.org

East-Asian VLBI Network
©EAVN, Reto Stockli (NASA Earth Observatory), & NARIT/ITB/Univ. of Malaya

Southern Long Baseline Array
©Brian Boyle/CSIRO/IRASR