

MAX-PLANCK-INSTITUT
FÜR RADIOASTRONOMIE

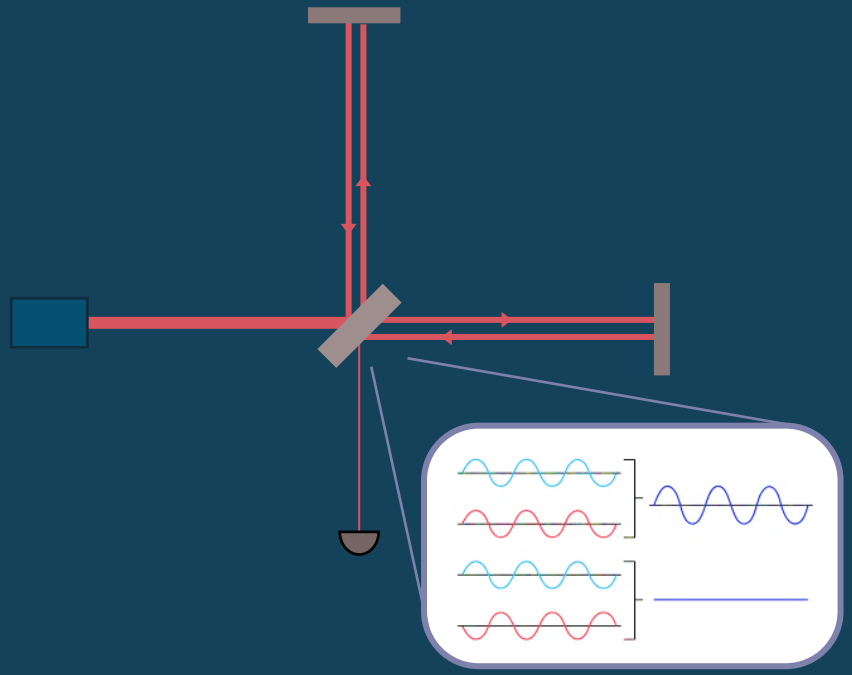
AN SKAO PTA FOR DETECTING NANOHERTZ GRAVITATIONAL WAVES

Kathrin Grunthal for the SKAO Pulsar SWG

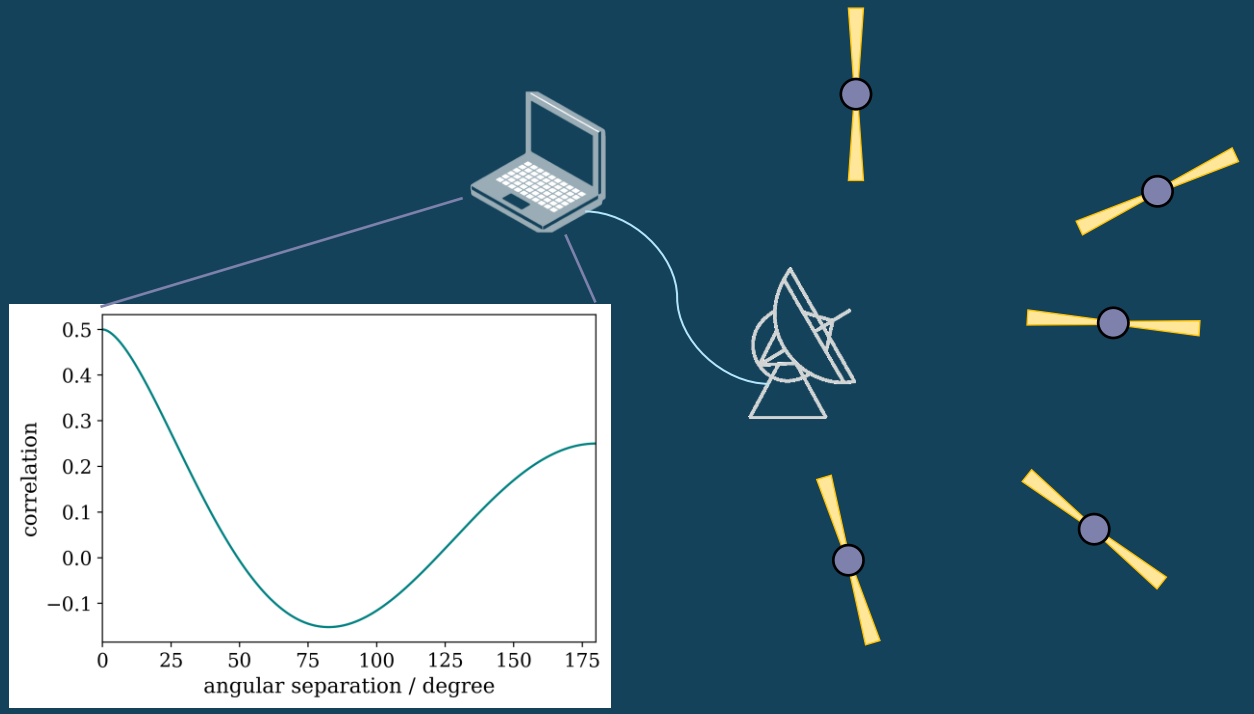
AG Tagung 2026 • 08.09.2026

Pulsars as Gravitational Wave Detectors

Interferometric GW detectors



Pulsar Timing Array (PTA)

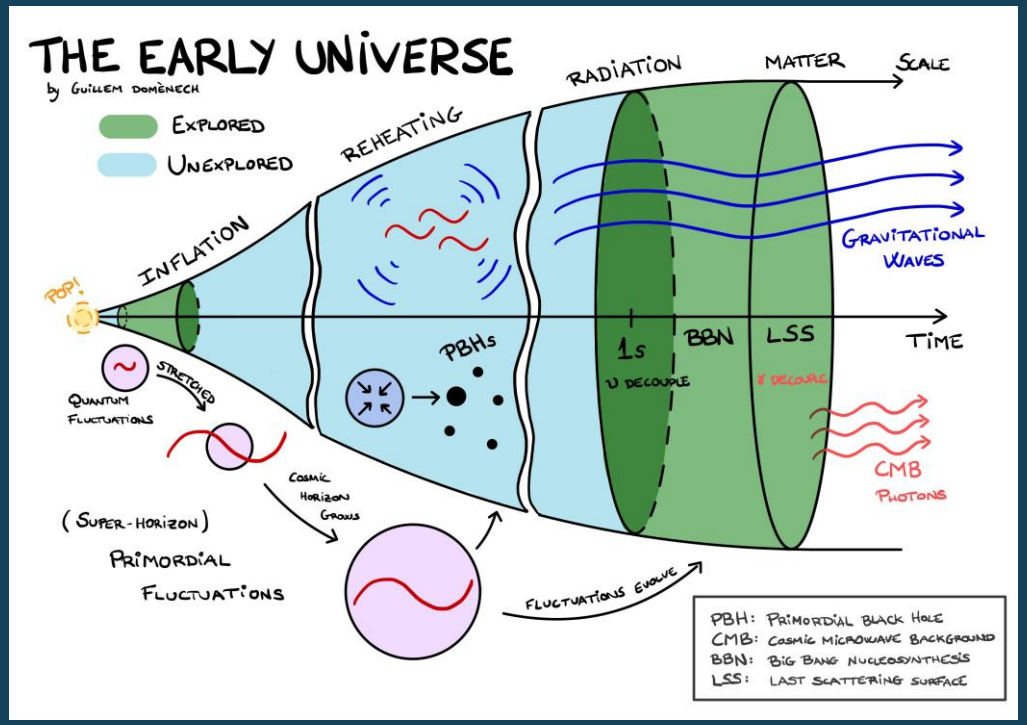


100 Hz — 10 Hz — 100 nHz — 1 nHz

Signals in the PTA GW frequency regime

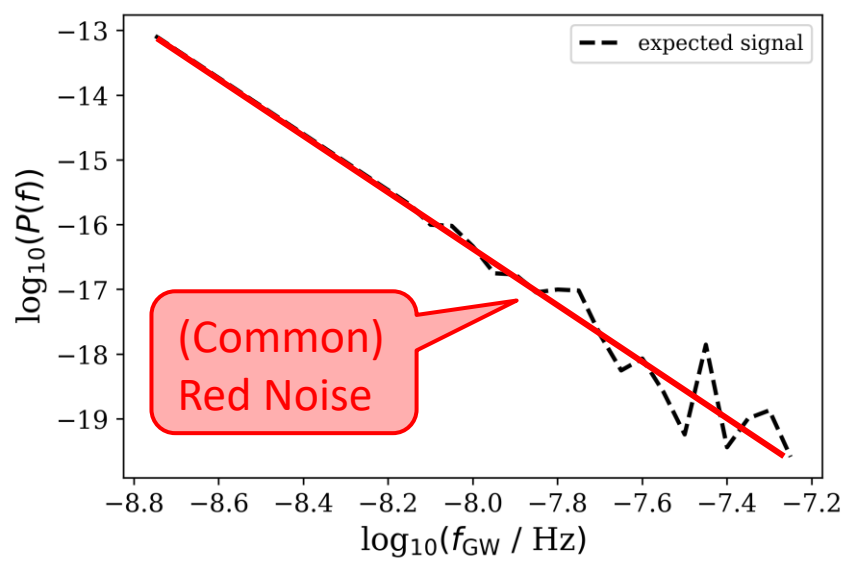


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Finding GW signals in a PTA data set



Noise in pulsar data sets

- Pulsar-intrinsic RN
- ISM-related / Solar wind noise

} spatially uncorrelated

- Clock noise } monopolar
- Solar system ephemeris noise } dipolar
- GW background } quadrupolar

PTA GW analysis deliverables

(A) CRN PSD amplitude
spectral index → **Astrophysics**

(B) Spatial correlations → **GW origin**

PTA science in the SKA era

Where are we now?

Since 2023: compelling evidence for a GWB signal in PTA data sets



In the future:

- What is the origin of this signal?
  - Anisotropy searches / GW sky maps
  - ➢ Number of Pulsars == sky resolution
- What is its spectral shape?
  - Turnover in the power law?
  - ➢ Benefit from high timing precision
- Detect GWs from an individual SMBHB?
- Exotic sources

© Thankful Cromartie

PTA capabilities of the SKAO telescopes

- SKAO telescopes will be 3-4 times more sensitive than similar Southern Hemisphere instruments
  - Observe larger number of pulsars → better sky resolution
  - High timing precision → higher S/N

- Noise in the SKAO PTA
  - High-fidelity pulse profiles → profile variability becomes important
  - Jitter noise → relevant to more pulsars

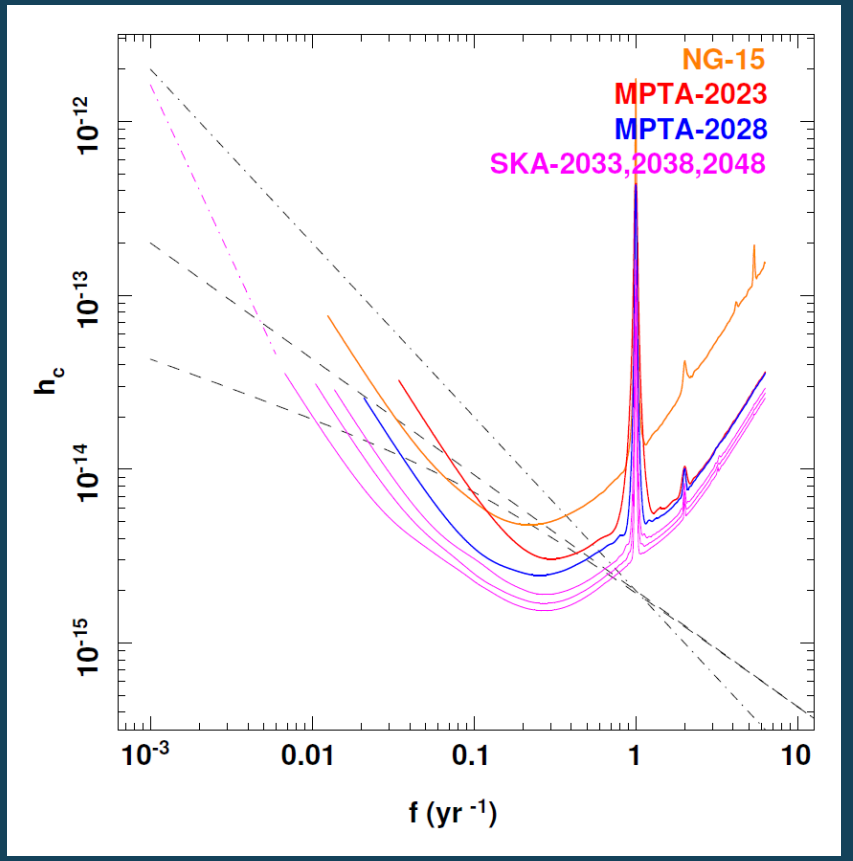
  - ISM noise is chromatic, $\propto f_{\mathrm{obs}}^{-\gamma}$ with $\gamma > 0$
    - SKAO mid + low cover 50 MHz – 15 GHz
    - Broadband observations: → precise DM measurements
→ decouple ISM noise and achromatic RN
    - Study the ISM and the Solar Wind → role of the SKA-low in the PTA operations

A potential SKA-PTA program

- **Estimate pulse S/N and timing uncertainty, σ_{ToA},** based on
  a) the MeerTime MSP census (Spiewak et al. 2022)
  b) assumed sensitivity boost from MeerKAT to … AA*: factor of 3
     … AA4: factor of 4

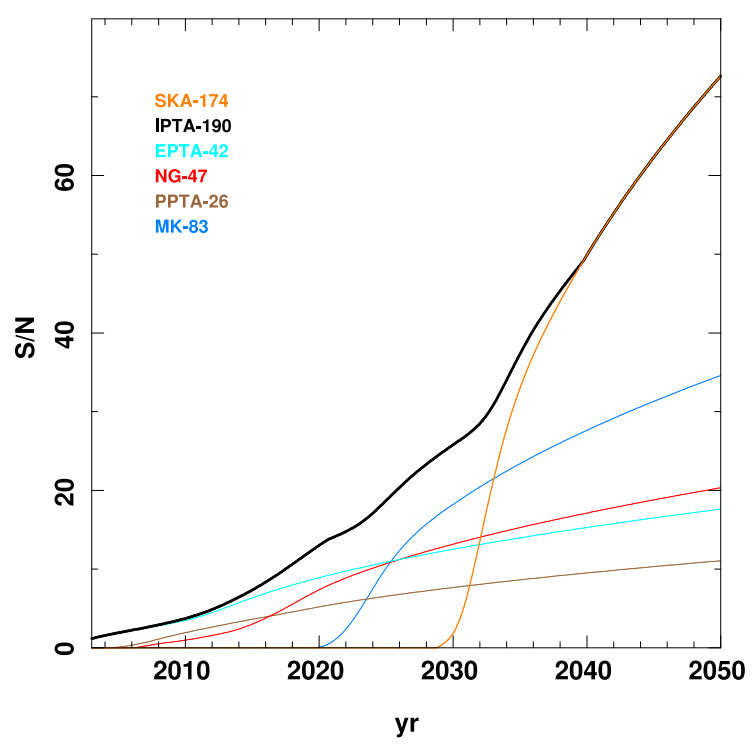
- **Strategy: achieve $\sigma_{\mathrm{ToA}} \leq 1\mu s$** ; allow for up to 3 (4) **sub-arrays**
  - $T_{\mathrm{obs}} < 256$ s with $\left\{\begin{matrix}\text{sub-array}\\ \text{full array}\end{matrix}\right\}$ → Observe 256 s with
  - $T_{\mathrm{obs}} > 2000$ s with AA4 → Discard pulsar

- **Resulting set-up**
  - 174 pulsars
  - Fortnightly cadence – 13 hr/epoch (AA*); 9 hr/epoch (AA4)



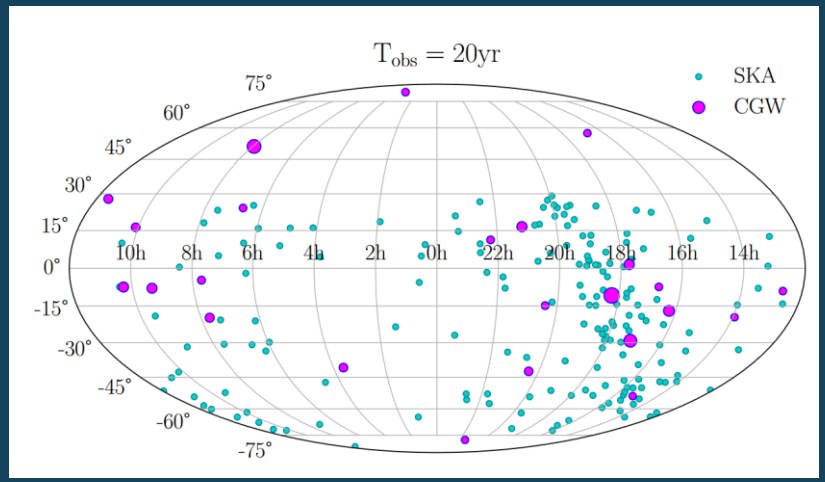
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Forecast of GW analyses performance

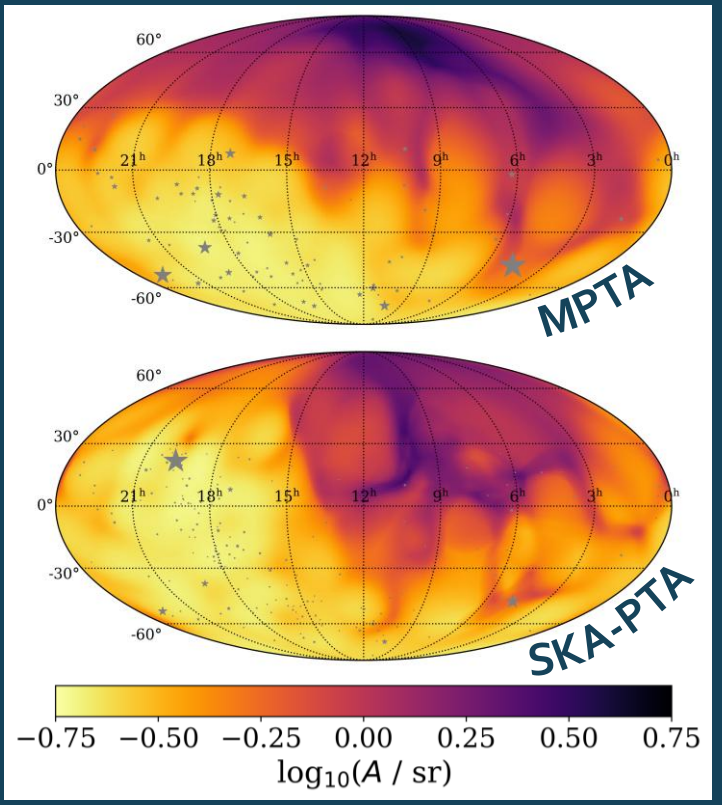


Achievable S/N of GWB signal

Potentially detectable SMBHBs



Improved sky resolution in anisotropy analyses

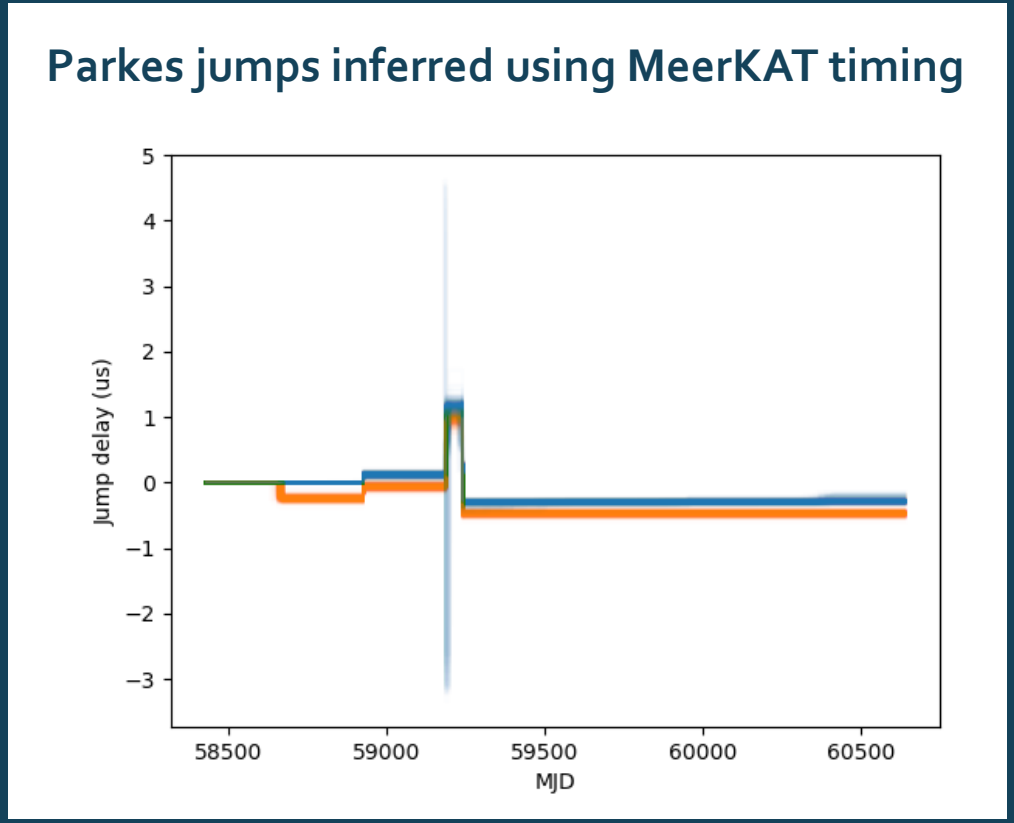


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Requirements for SKA

- **Essential:**
  - Subarrays (at least 4)
  - SKA-mid: bands 1,2,3
  - Data processing
  - Temporal overlap with MeerKAT

- **Desirable:**
  - Flexible/dynamic scheduling
    - Abort sources which are faint
    - Dwell longer when brighter
  - 1-5 GHz wideband receiver



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The SKA-PTA in a broader context…

… of other SKA science

- ISM & Solar Wind studies
  (Tiburzi et al. 2026)
- Structure of Neutron Star interiors
  (Dong et al. 2026, Basu et al. 2026)
- Pulsar emission mechanism
  (Oswald et al. 2026)
- Tests of General Relativity
  (Venkatraman Krishnan et al. 2026)

… of other instruments

- Radio observatories
  - DSA (DSA-2000)
  - ngVLA
- γ-ray pulsar timing array (GPTA)
- Other GW detectors:
  - LISA
  - Cosmic Explorer / Einstein Telescope

Summary and Outlook

SKAO instruments are poised to influence future PTA science

❖ Efficient, high impact PTA experiment

Check me out!

➢ Shannon et al. (2025), *The SKAO Pulsar Timing Array*, arXiv:2512.16163

Future working points

- Optimisation of PTA strategy
- SKAO millisecond pulsar census
- Robust analysis methods