Pulsar Timing Array

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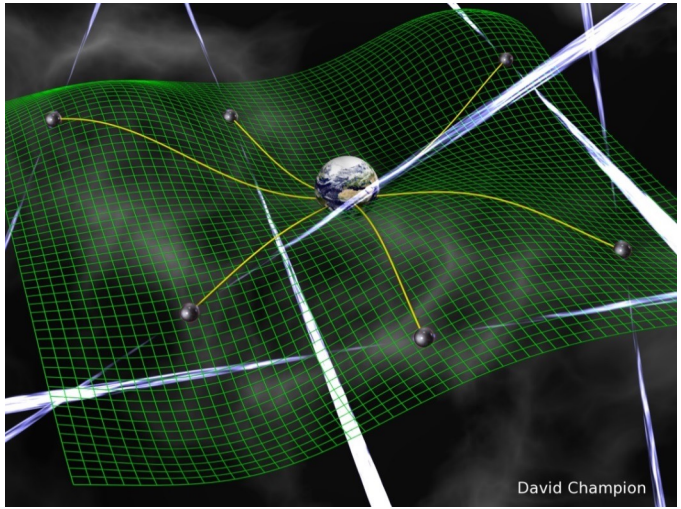
pulsar timing array

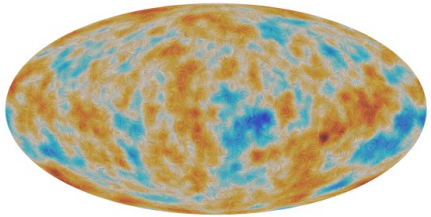
PTA in a nutshell

- direct detection of GWs
- very stable msec pulsars
- precise timing for O(10) years
- GWs affect pulse arrival time
  O(100) nsec
- GW freqency
  → observation period and cadence
  → (1 week)$^{-1}$ ~ (10 years)$^{-1}$
  → 1μHz ~ 1nHz

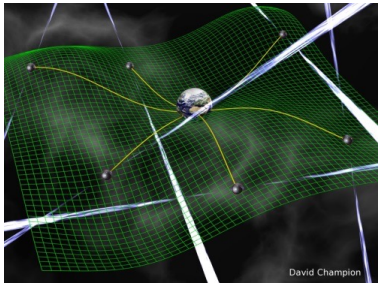


multi-wavelength GW astronomy

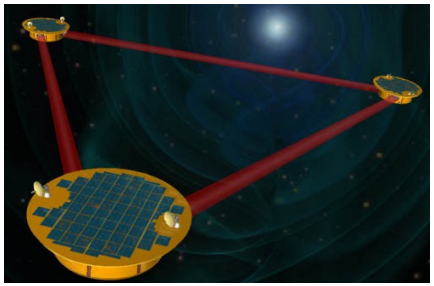
CMB



PTA



space



ground

SMBH binary

supernova

compact binary

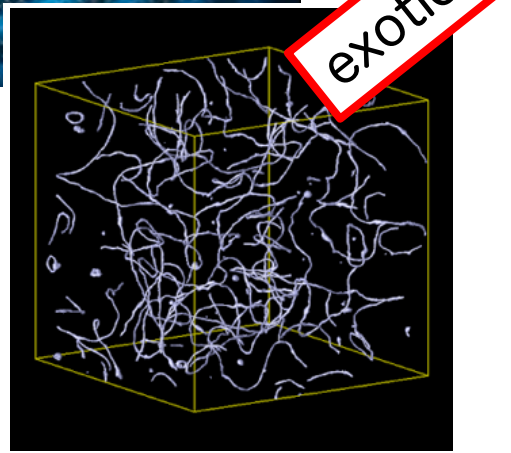
cosmic string

primordial

10^{-17}Hz ～1nHz 1mHz-0.1Hz 100Hz

Nano-Hz GWs

- SMBH binary
- cosmic string
- inflation
- phase transition
- 2nd-order scalar fluctuations



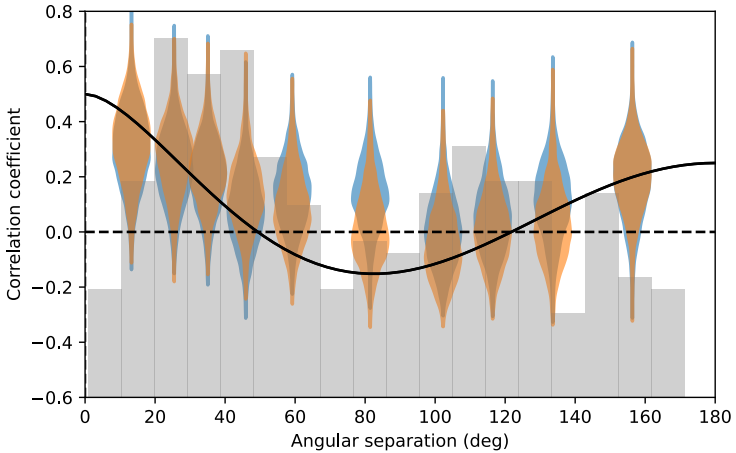
Indian PTA

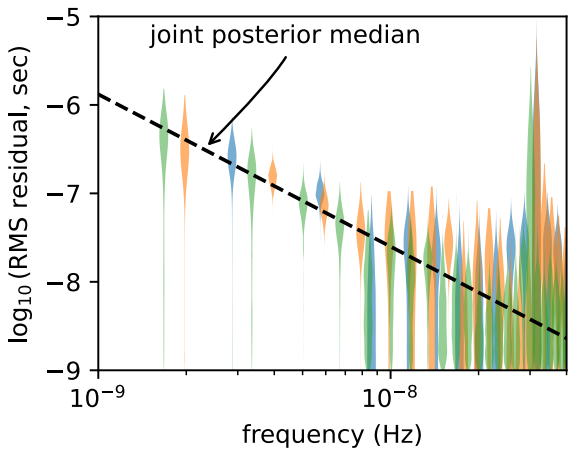
- India + Japan
- uGMRT (SKA pathfinder)
- low frequency (250-1450MHz)
  - uniqueness of InPTA
  - precise dispersion measure
- 2nd data release in 2024

worldwide announcement

6/29 UTC 0:00 : press release

- EPTA + InPTA, NANOGrav, PPTA, CPTA
- GW background signal : 2~4σ → evidence (~~detection~~)
- consistent with that from SMBH binaries
- cannot reject other sources





to improve

- understand systematics better
  - monopole in inter-pulsar correlation?
  - pulse jitter : pulsar intrinsic fluctuations
  - RFI, solar system ephemeris

- longer time baseline
  - just continue observations

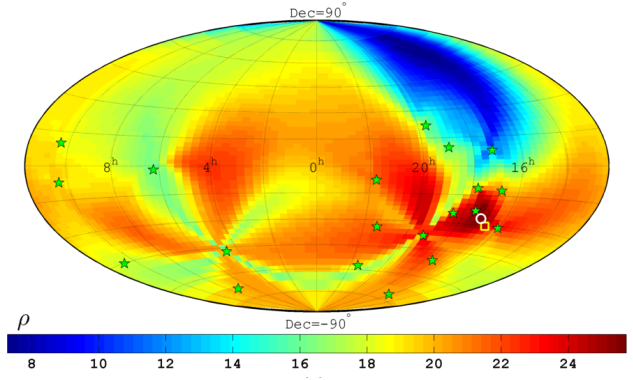
- more pulsars
  - combine different PTAs
  - more sensitive telescope

from detection to astronomy

GW source (□)
most likelihood (○)
pulsar (☆)

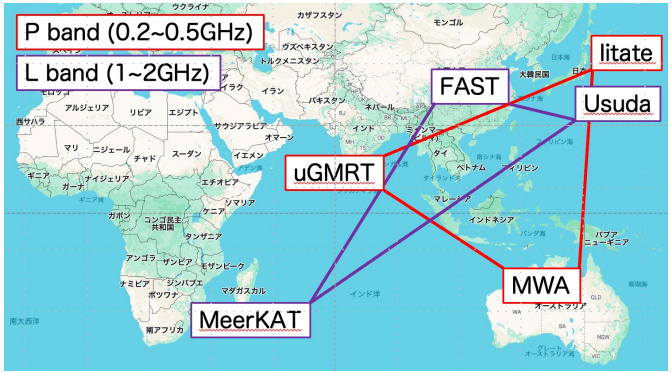
Zhu+ 2015

- angular resolution of GW source
  → > O(10) deg^2
  → GW source cannot be identified



Kato & KT (2023)

- precise pulsar distance from VLBI (< GW wavelength)
- GW angular resolution improves by a few orders
- will do VLBI observation of pulsars



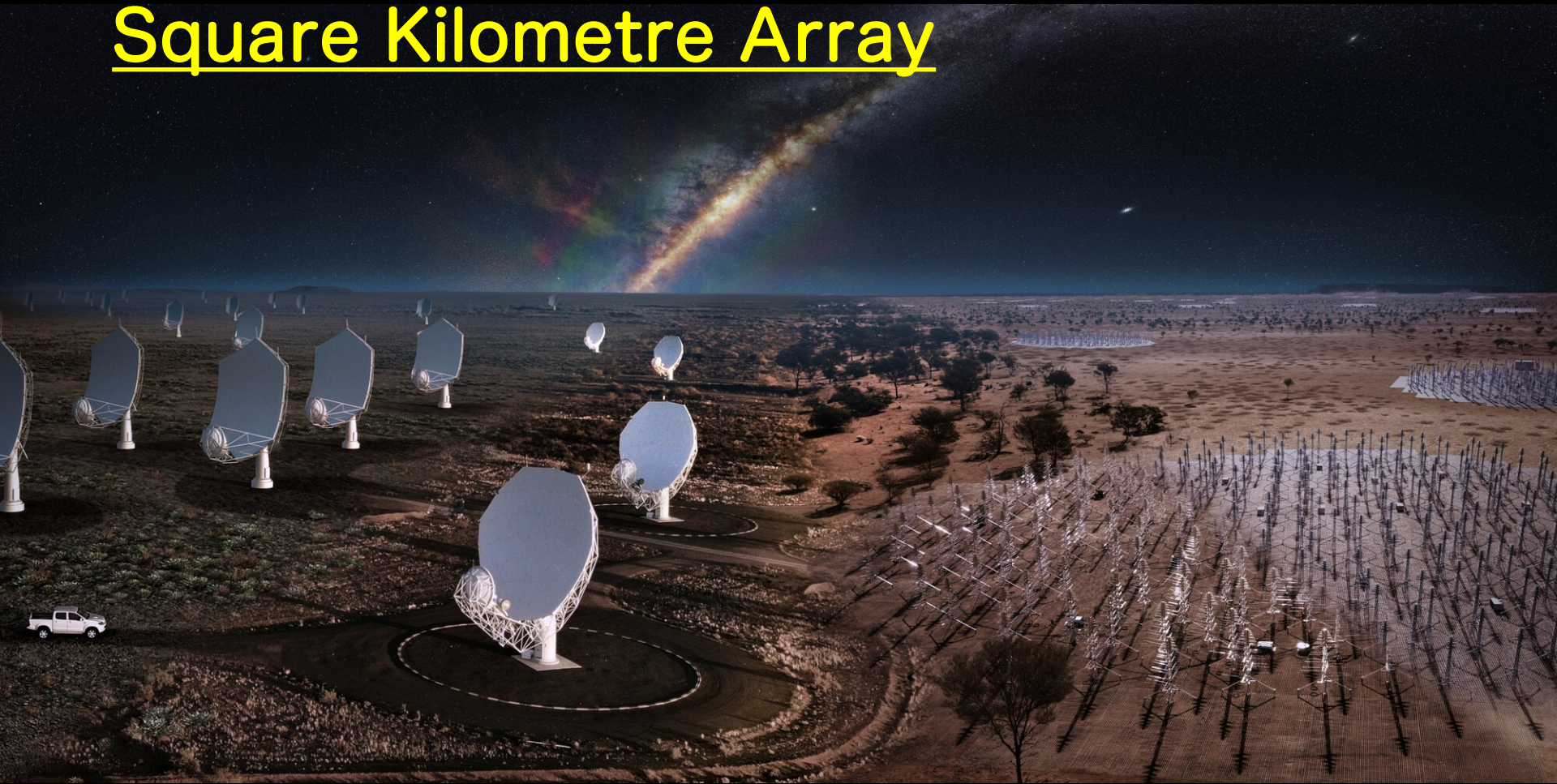
Nano-Hz GW astronomy

D = 85 Mpc
$M_1 = 3.2 \times 10^9\ M_{sun}$
$M_2 = 5.1 \times 10^7\ M_{sun}$
a = 0.35 pc, e = 0.14

D = 156 Mpc
$M_1 = 9.2 \times 10^9\ M_{sun}$
$M_2 = 7.5 \times 10^9\ M_{sun}$
a = 1.3 pc, e = 0.25

D = 245 Mpc
$M_1 = 4.3 \times 10^9\ M_{sun}$
$M_2 = 5.9 \times 10^8\ M_{sun}$
a = 0.12 pc, e = 0.02

Square Kilometre Array



SKA PTA

SKA1 survey
- 9,000 normal pulsars
- 1,400 msec pulsars

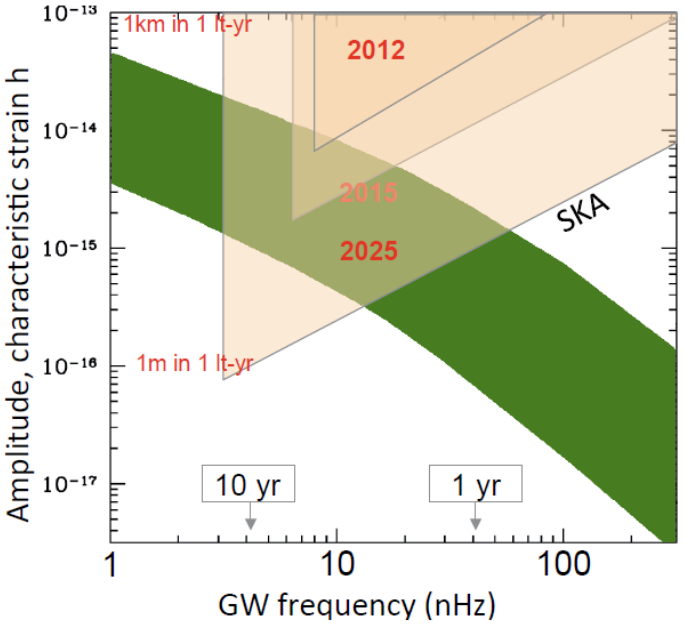
x3 !

SKA2 survey
- 30,000 normal pulsars
- 3,000 msec pulsars

x10 !

SKA-PTA
much more msec pulsars
& much higher sensitivity

SKA1-PTA sensitivity



future prospects

2023 IPTA comparison : arXiv

2024 IPTA combination : ongoing

GWB detection

MeerKAT, FAST join

single source

GWB power spectrum
→ SMBH evolution model

2029 SKA1

precise GWB power spectrum
→ other sources

203? SKA2

GWB anisotropy

SMBH binary catalog

summary

- pulsar timing array
  → direct detection of nano-Hz GWs with msec pulsars
- evidence for GW background
  - statistical significance of HD correlation : $2\sim4\sigma$
  - consistent with GW background from SMBH binaries
  - cannot reject other sources due to low S/N
- future prospects
  - IPTA data combination, SKA1, SKA2
  - nHz GW astronomy
- happy to collaborate on SMBHs, cosmic strings, early universe, GW data analysis