Q1: NANOGrav's Observing Requirements

As many high precision MSPs as possible observed over a large range of angular separations

100m class or larger telescopes

Large instantaneous receiver bandwidths (> 2 GHz) or widely spaced center frequencies (to correct for dispersion)

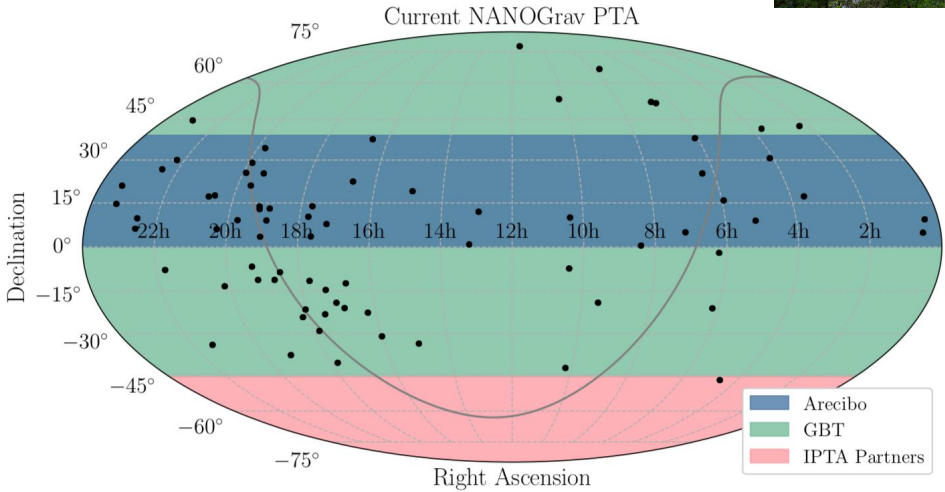
Fast sampling, fine frequency resolution, and robust polarization calibration

At least monthly cadence (to track orbital and astrometric parameters and to maintain high-frequency sensitivity)

At least ~half-hour observations (to mitigate against pulse-to-pulse jitter)

Q1: NANOGrav's Current Program

We observe 79 MSPs at two frequencies (from 800 MHz to 3 GHz) every one to four weeks for roughly 20-30 min using Arecibo (41 MSPs, 5 weekly), the GBT (39 MSPs, 2 weekly), and the VLA (7 MSPs).



The NANOGrav Collaboration, 2018, ApJS, 235, 37

Q1: NANOGrav's Future Program

By 2030, we aim to observe 200 MSPs using wideband receivers (800 MHz to 3 GHz) roughly weekly for roughly 30 min.

This corresponds to roughly 5200 hrs/yr, or ~6000 hrs/yr with overhead. This could be met by a single dedicated telescope or a combination of resources on either single-dish telescopes or arrays.

Ideally this would be accompanied by a pulsar searching program, requiring roughly ~1000 hr/yr.

Q2: Overlaps with new facilities

Overlapping data are required.

- At least few months to a year overlap is required in order to measure any systematic clock offsets and to check calibration through comparison of polarization profiles, flux measurements, etc.
- Would lose low-frequency GW sensitivity if we need to fit an offset between instruments and/or frequency bands via data separated in time.

Q3: Total time allocations

On the GBT and Arecibo, we are currently using a relatively small fraction of the total available astronomy time on each telescope (~10% for GBT and ~20% for Arecibo). There is time available to continue expanding our timing program for at least the next 5-6 years (with ~4 new MSPs/year, although LST=19hr time at AO is tight). We need new facilities if we want to greatly expand the size of the PTA (i.e. pushing for 150-200 MSPs; at least 2-3x size of current program).

We currently use ~1400 hrs/yr for timing, supplemented by roughly ~1000 hrs/yr for searching. The timing time will need to expand significantly, the searching time will likely not.

Q4: Impact of RFI on NANOGrav:

In most cases, RFI requires us to lose (via removing or “zapping”) parts of our bandwidth in frequency or parts of our observation in time, or both.

Affects pulsar timing to some extent, affects search programs more severely. The strong and obvious RFI can be zapped, but weaker RFI can be hard to detect and will cause unknown systematics. Extremely strong RFI can cause a complete loss of an observation.

Timing: RFI can introduce systematics - even when channels are flagged out, for example, they can change the frequency-dependent shape of the pulse profile compared to the template.

Search: un-flagged RFI can badly affect observations, both by introducing spurious candidates and by preventing us from confirming promising candidates. (Last week in PALFA we confirmed zero of 14 promising candidates.)

Q5: US Roles in the IPTA

Currently we have telescopes where we do both pulsar searching and pulsar timing. If we were to give up facilities capable of pulsar searching, say, in favor of keeping timing facilities, then we would be more dependent on international partners to find pulsars that we can time.

This is relevant particularly to the future of Arecibo and GBT - our search telescopes, with ALPACA and FLAG - because neither the ngVLA nor the DSA-2000 is planning for full-field high-time-resolution data products and/or real-time full-field pulsar searches. Whereas LOFAR is running tied-array searches now [*], FAST is doing multi-pixel searches, and SKA is planning for full-field searches at massive computational cost - searching is one of the primary computing cost drivers (US is not directly involved in any of those).

So yes, the roles we can play in future will be affected by available telescopes and instrumentation.

[*] See, e.g., https://arxiv.org/abs/1905.04977 and https://arxiv.org/abs/1910.09668