Multi -Messenger Coordination on the Supermassive Scale

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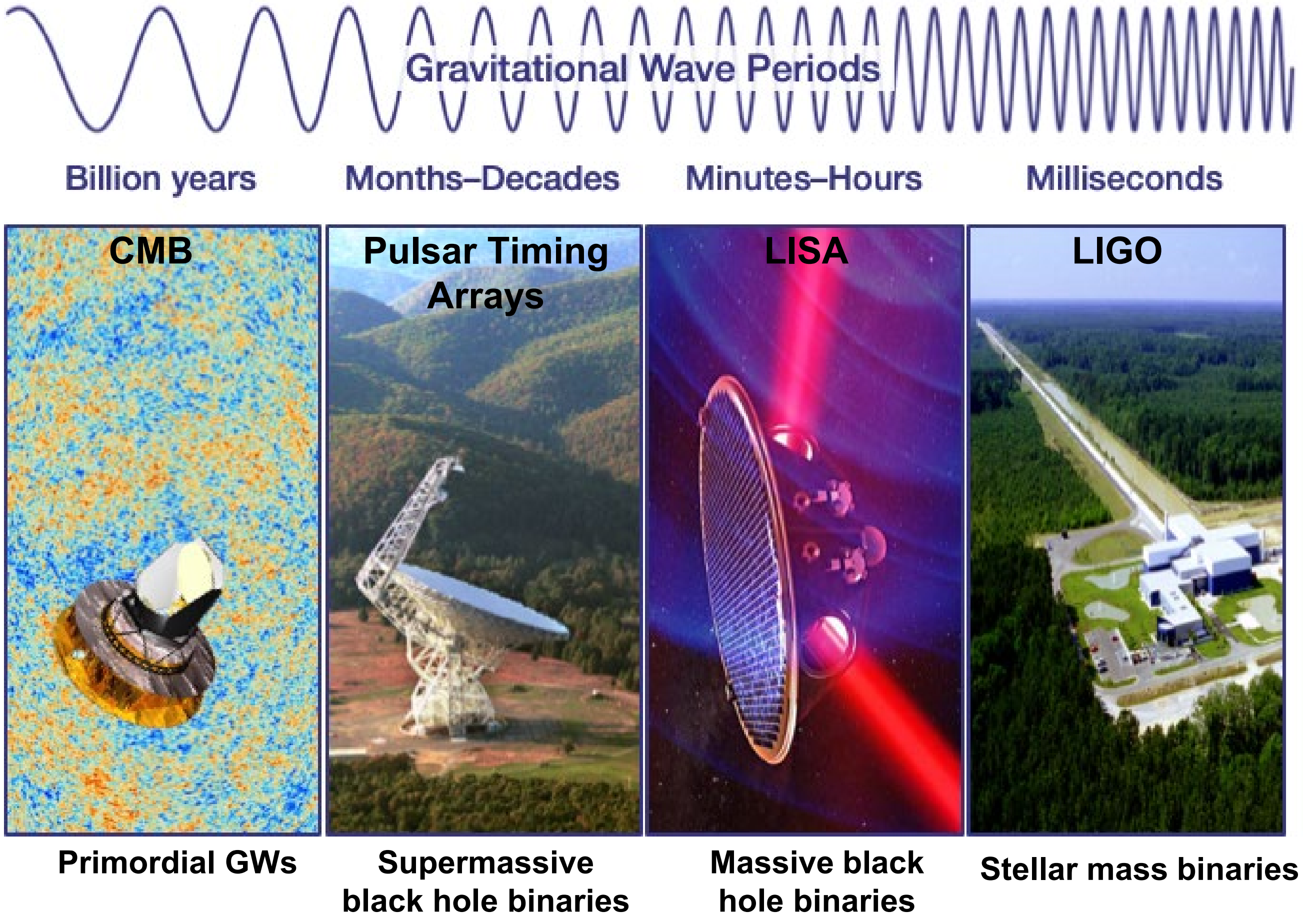


Lower frequencies, Higher masses

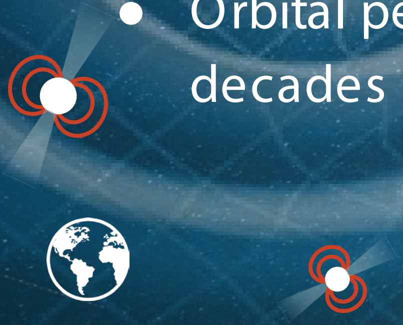
Higher frequencies, Lower masses

Figure Credit: NANOGrav PFC

GWs from SMBHBs

Continuous waves (CWs) from single SMBHBS

- Deterministic, modelable signal affects the earth and the pulsar while evolving
- Orbital periods of months to decades



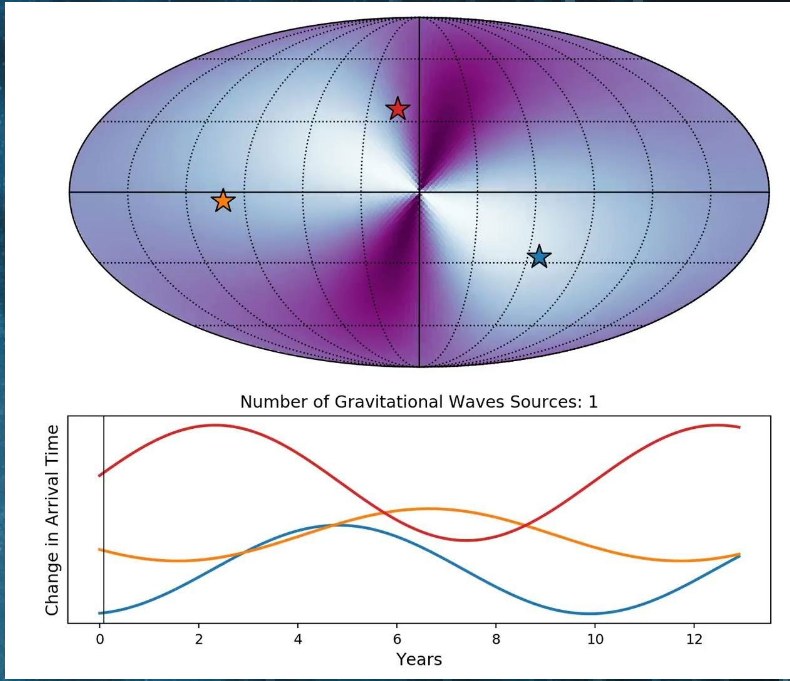
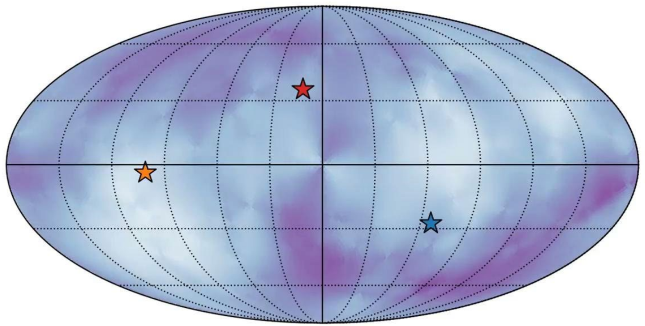


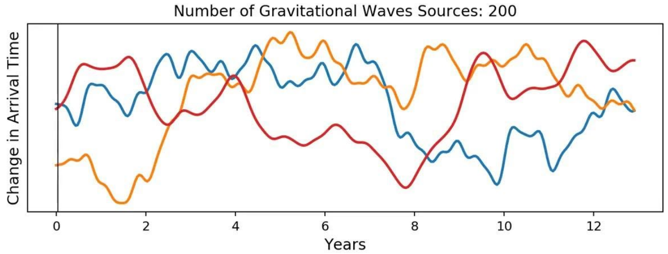
Figure Credit: Jeff Hazboun

GWs from SMBHBs

The **stochastic gravitational wave background (GWB)**

- Induces spatially correlated red noise with a common spectrum (A_{CRN}, γ_{CRN}) in all pulsars





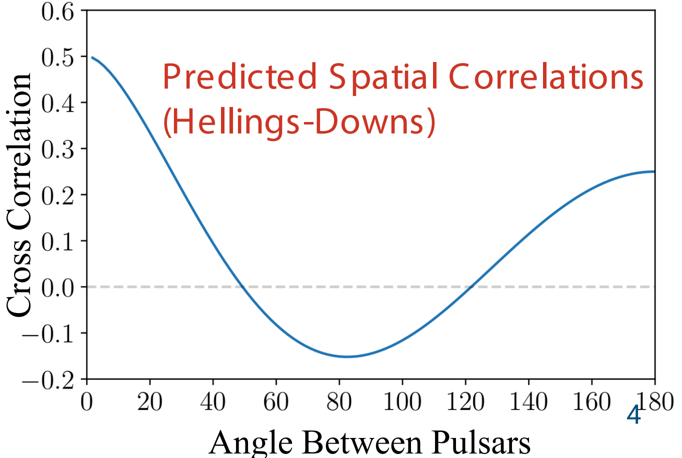
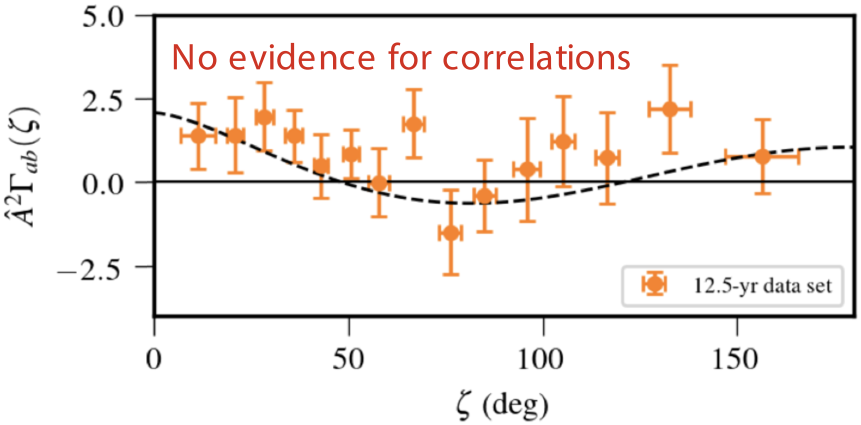


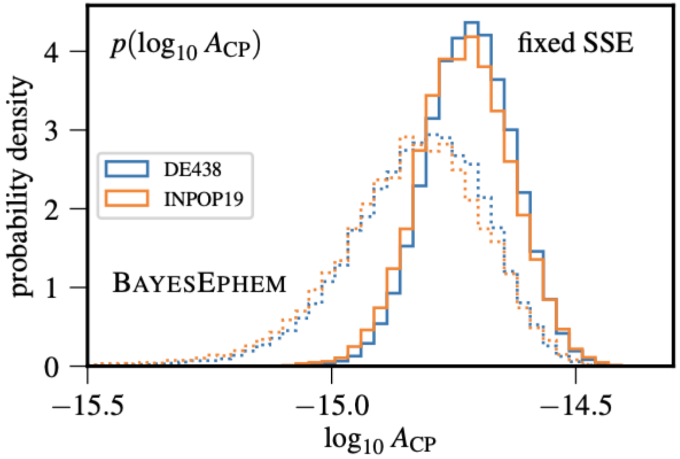
Figure Credit: Jeff Hazboun

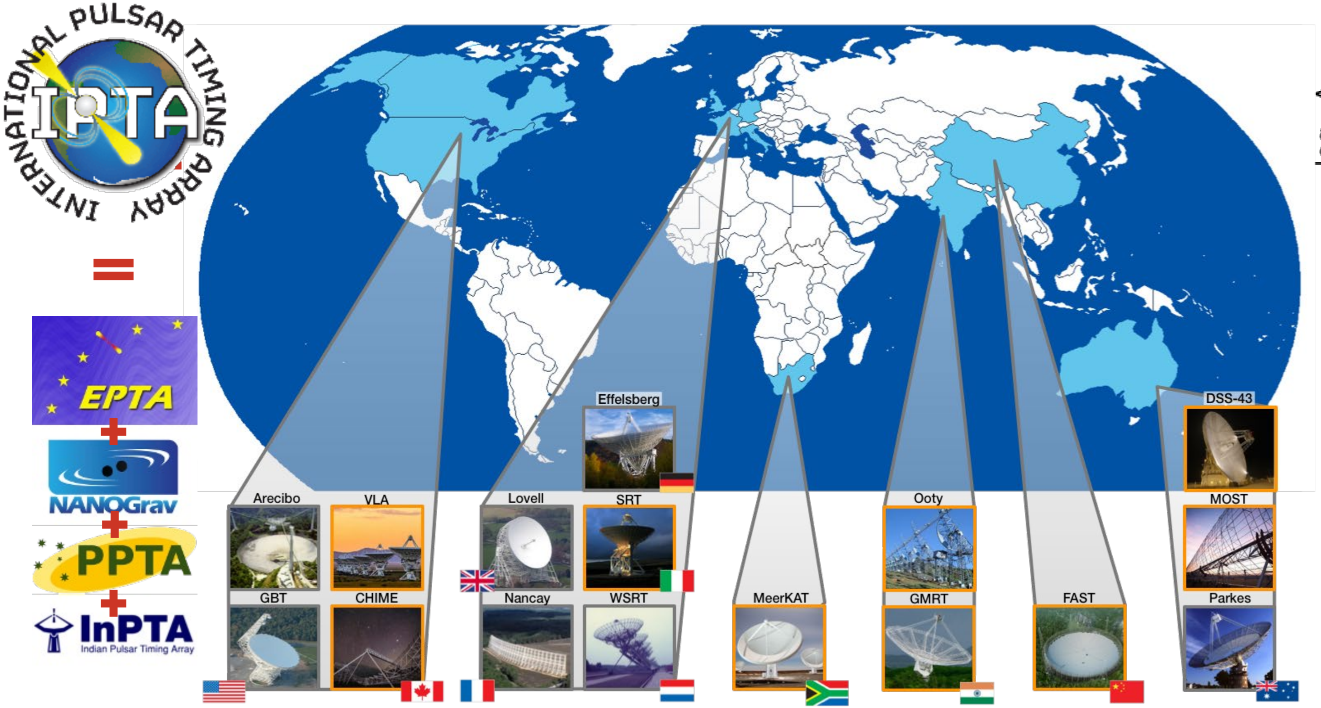
12.5-year GWB Searches

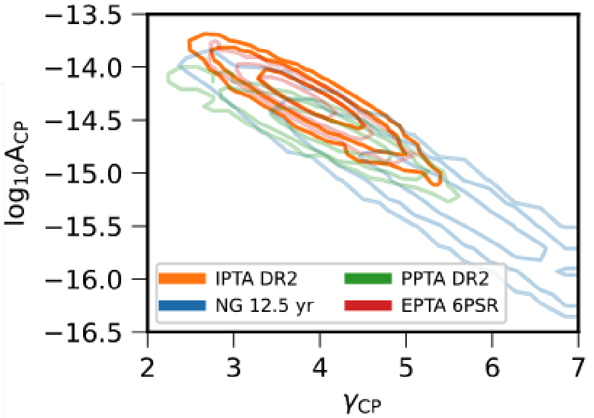
- NANOGrav's 12.5-year data set shows strong evidence of an **uncorrelated** common-spectrum red noise process



Strong evidence for CRN



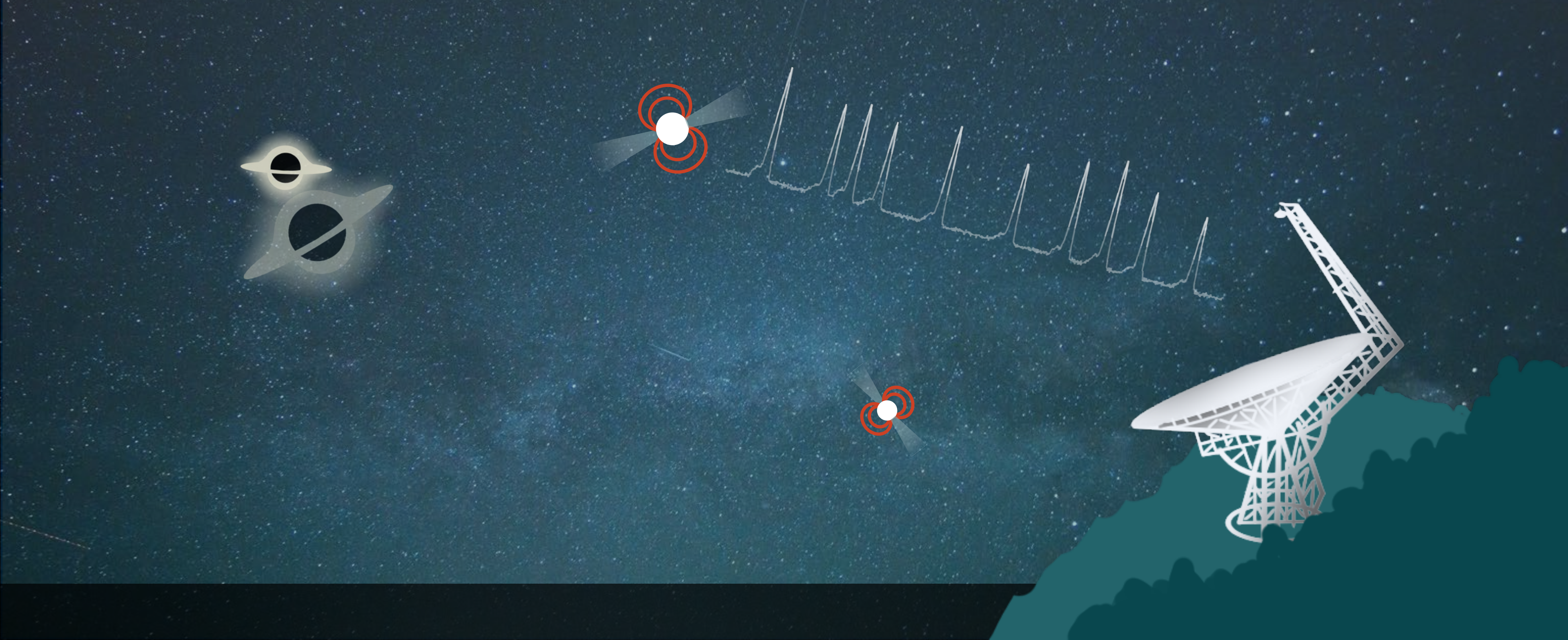




Supported by international collaborators!

Figure Credit: Antoniadis+ 2022

So what’s next?



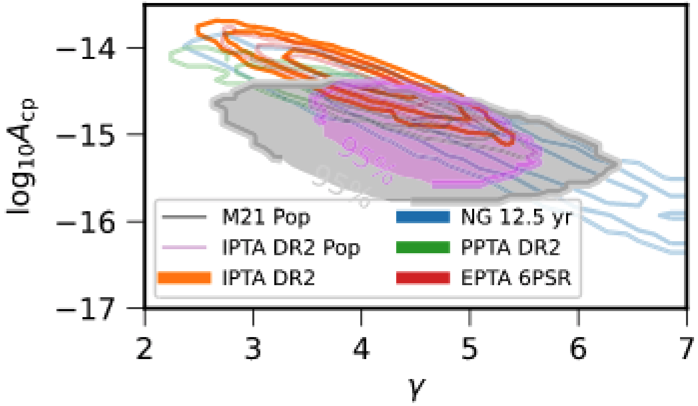
In Progress: New Data Sets!

All PTAs are increasing data time spans and adding pulsars to hopefully reach a GWB detection in the coming years

→ DR3

Detection • Characterization • SMBHB population!

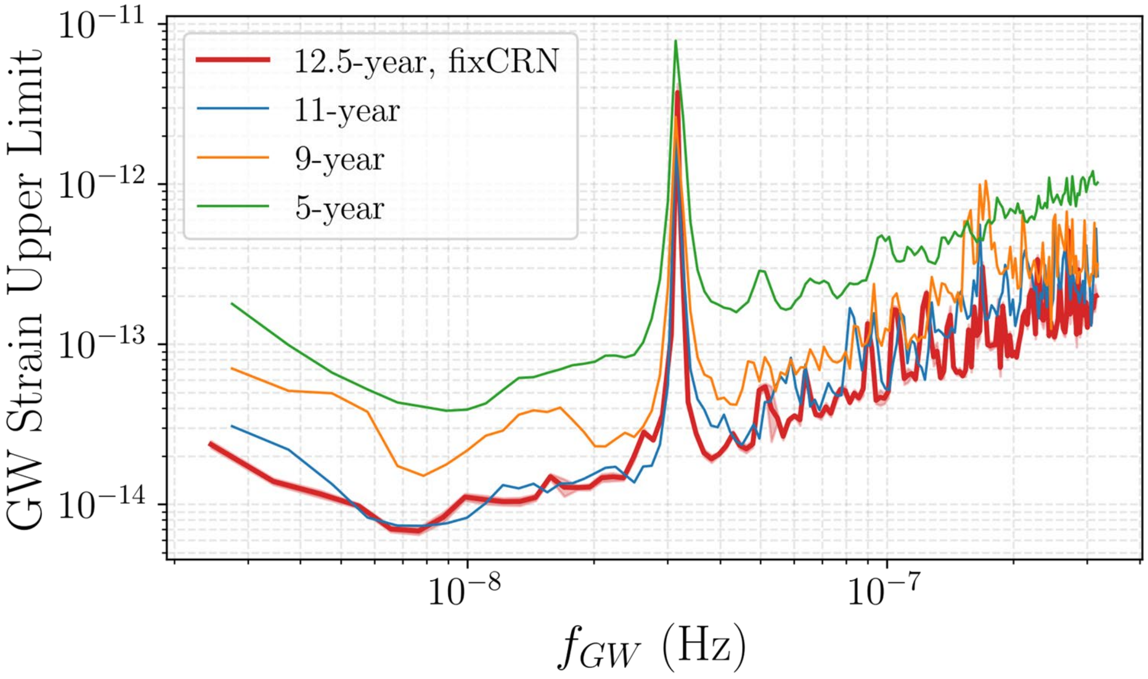
- DR2
- 15-year
- DR3
- DR1



Next Up: Continuous Waves

CWs could be detectable soon after the GWB

All-sky upper limits are continuing to decrease (but need to account for presence of red noise)



Next Up: Continuous Waves

D_{95} is the lower distance limit to a $10^9\ M_\odot$ binary at $f_{GW} = 7.65$ nHz

Can place limits on individual SMBHB candidates

◇ SMBHB candidate or galaxy cluster

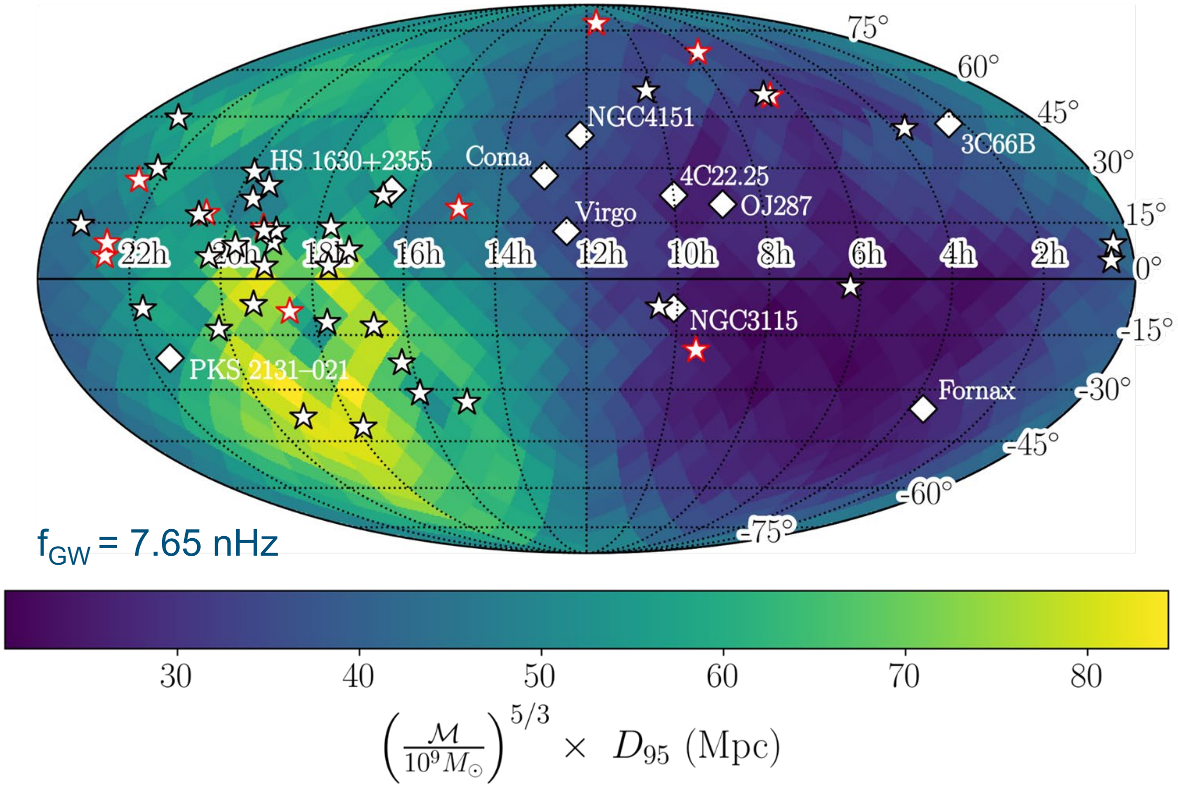
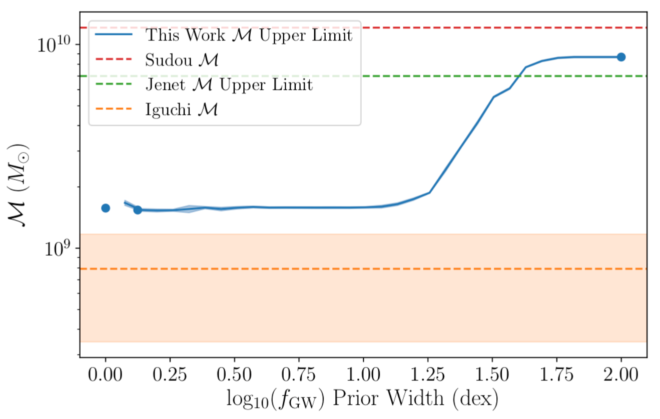
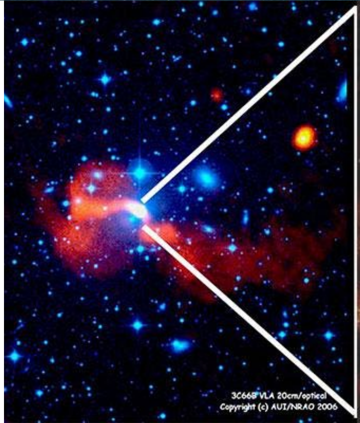


Figure Credit: Arzoumanian+ (in prep.)

One Step Further: Multi-Messenger Searches

- Even without a detection, we can learn a lot about SMBHB candidates
- Much less expensive than all-sky all-frequency CW searches
- Can set better limits and have better detection prospects than all-sky searches (Arzoumanian+ 2020, Liu+ 2021)





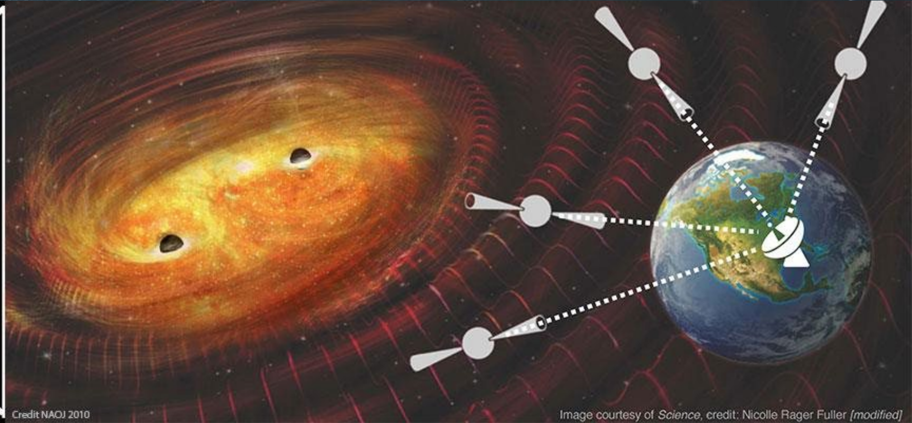


Figure Credit: Arzoumanian+ (2020)

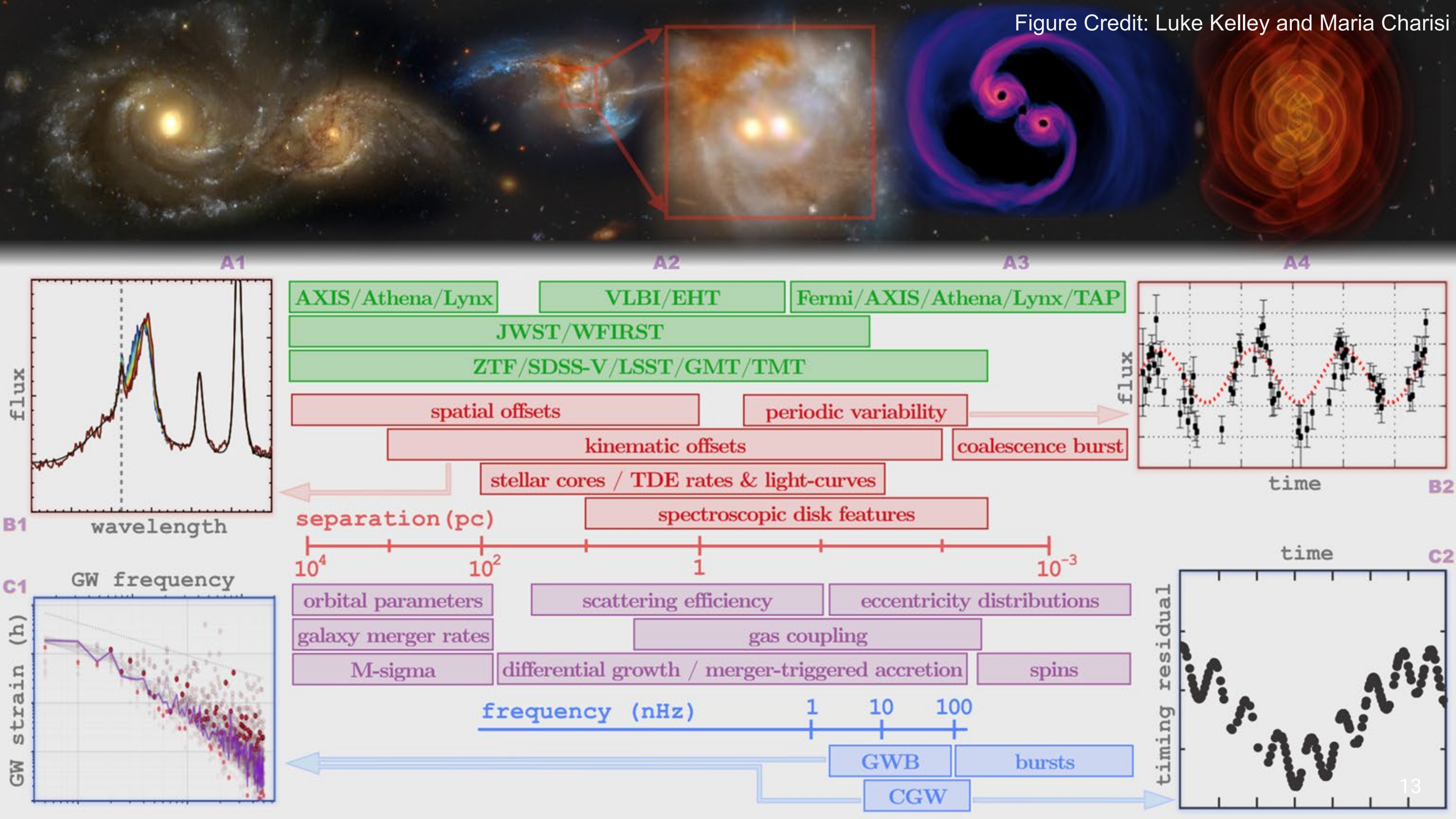
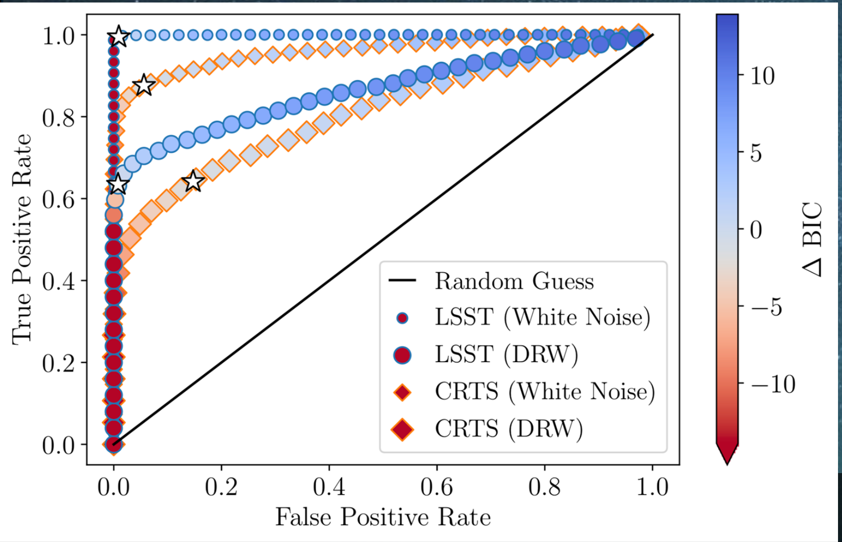
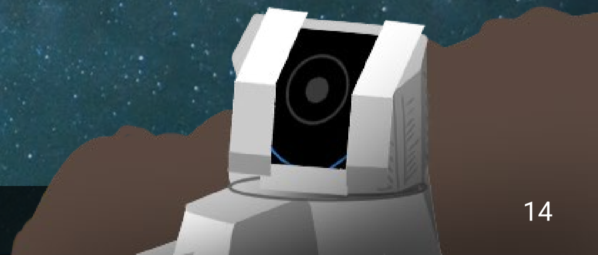


Figure Credit: Luke Kelley and Maria Charisi
A1
A2
A3
A4
AXIS/Athena/Lynx
VLBI/EHT
Fermi/AXIS/Athena/Lynx/TAP
JWST/WFIRST
ZTF/SDSS-V/LSST/GMT/TMT
spatial offsets
periodic variability
kinematic offsets
coalescence burst
stellar cores / TDE rates & light-curves
spectroscopic disk features
separation (pc)
10^4
10^2
1
10^-3
flux
wavelength
B1
flux
time
B2
orbital parameters
scattering efficiency
eccentricity distributions
galaxy merger rates
gas coupling
M-sigma
differential growth / merger-triggered accretion
spins
frequency (nHz)
1
10
100
GWB
bursts
CGW
C1
GW frequency
GW strain (h)
C2
time
timing residual

We Need:

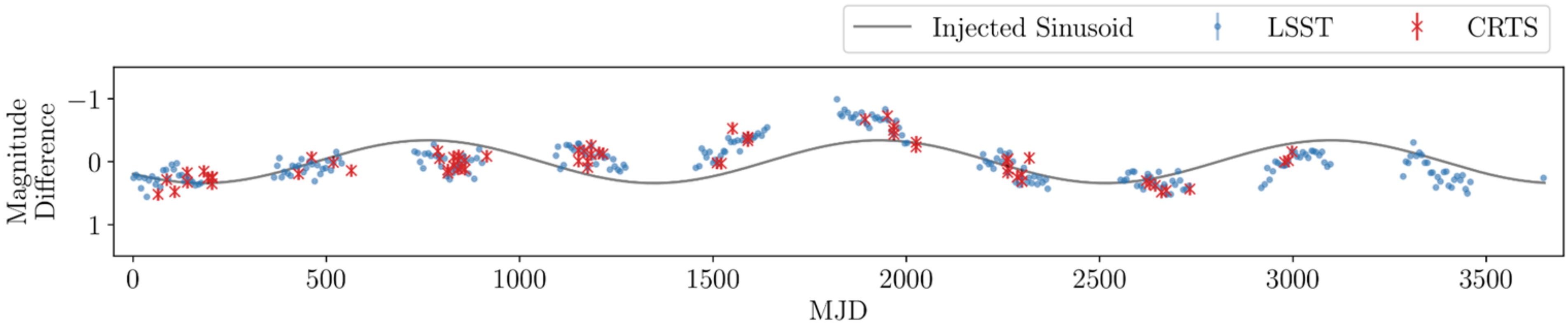
- Efficient tools to identify SMBHB candidates in big data sets
  - Next generation telescopes and surveys will be more effective!





We Need:

- Efficient tools to identify SMBHB candidates in big data sets
- Ongoing monitoring of existing (and future) candidates
  - Long-period binaries need long data sets to confirm



We Need:

- Efficient tools to identify SMBHB candidates in big data sets
- Ongoing monitoring of existing (and future) candidates
- Coordinated efforts to share SMBHB candidates
  - BOBcat: Black holes Orbiting Black holes catalog (Sydnor & Burke-Spolaor - see their poster!)

Display By: source model

Parameter Errors: show hide

Search:

Select all | Deselect all | Column visibility | Export selected: CSV | Export selected: JSON

Show 50 entries

Previous 1 2 3 4 5 ... 1658 Next

Source	Rating	Models	Host RA	Host Dec	z	Evidence
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OJ287		7 models	08:54:48.9	+20:06:31	0.305	
0402+379		1 model	10:44:50.030	+21:31:18.15	0.701	
SDSS J032223.02+		1 model	22:18:17.60	+40:34:09.6	2.03	
PG1302-102		1 model	09:20:34.38	+50:41:47.7	0.054	
NGC 4151		1 model	03:33:35.99	-36:07:37.7	0.1254	
NGC 5548		2 models	22:23:08.3	-28:56:52	0.0321	
SDSS J095656.42+		4 models	01:24:46.19	+09:30:31.3	0.04867	

Remember:

The multimessenger future of SMBHBs is incredibly bright!

- GWs from SMBHBs are nearly within reach, and multimessenger techniques can help
- Infrastructure is needed to coordinate abundant future data
    - How can GW and EM astronomers better collaborate to reach a multimessenger detection of an SMBHB?

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