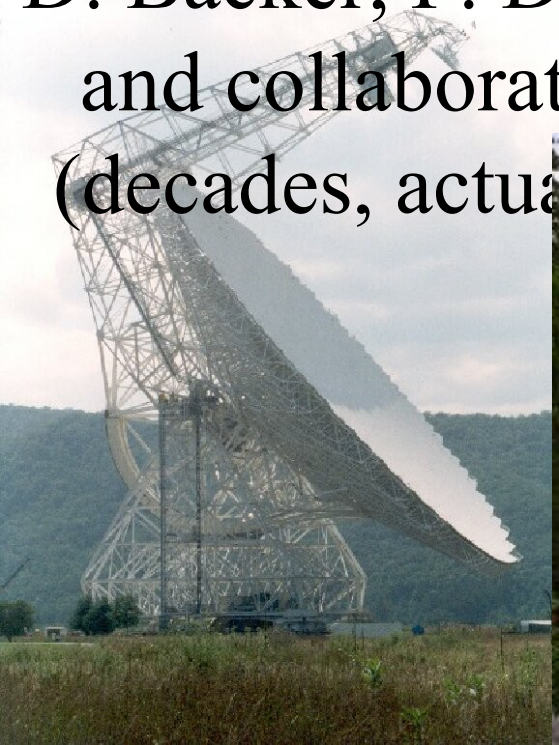
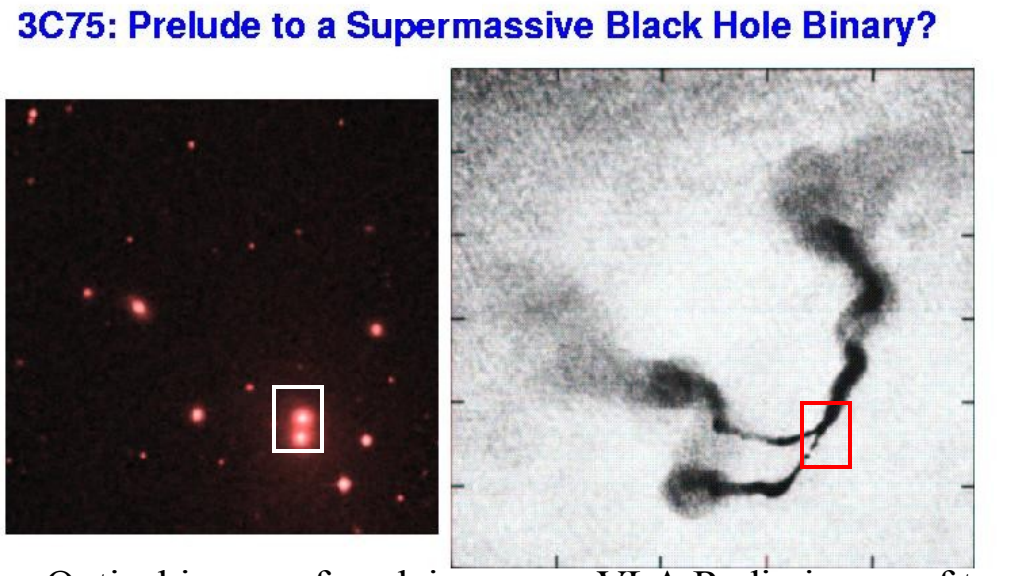
PULSAR TIMING ARRAY: A NANOHERTZ GRAVITATIONAL WAVE TELESCOPE

D. Backer, P. Demorest, I. Stairs, R. Ferdman, D. Nice and collaborators and observatory staffs from years (decades, actua

, NSF funding



Galaxy Mergers Binary Massive Black Holes



Optical image of nuclei of two galaxies

VLA Radio image of two jets, and cores

- ***Many galaxies contain Massive Black Holes*.**
- ***All galaxies grow by mergers.***
- When two galaxies with MBHs merge, the two holes will sink to a common center.
- ***Compact Massive Black Hole binaries are inevitable!***
- MBH binary orbit will eventually decay via GW emission

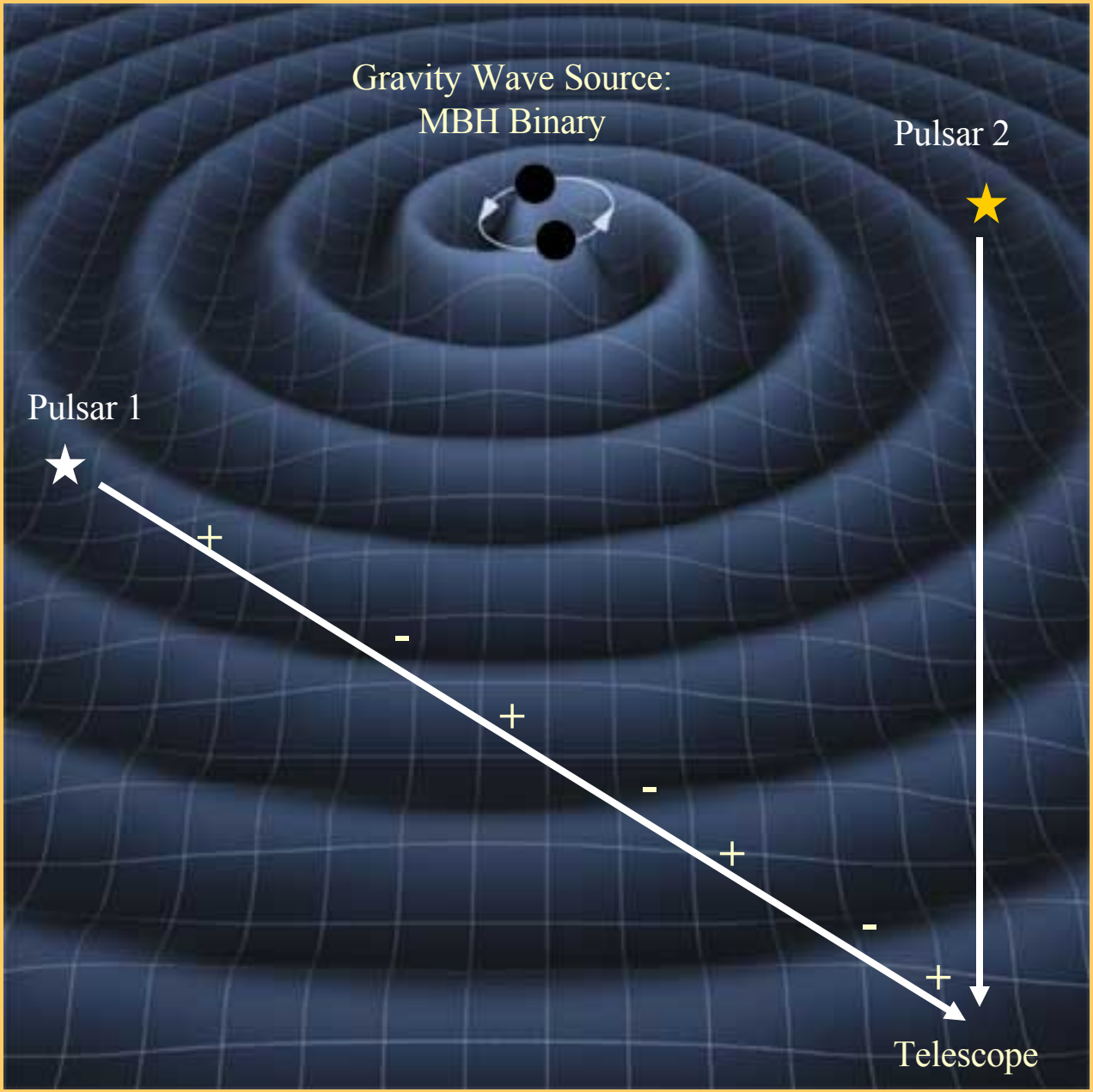
Other Sources

There is renewed interest in *cosmic strings* resulting from phase transitions in an early Universe with many dimensions (11):

- Damour & Vilenkin (2005) *Phys Rev D*, 71, 063510
- Hogan (2006) *Phys Rev D*, 74, 043526
- Also see Hogan *astro-ph*/0608567 "Gravitational Wave Sources from New Physics

Pulsar observations provide the best limit on this fundamental physics phenomenon.

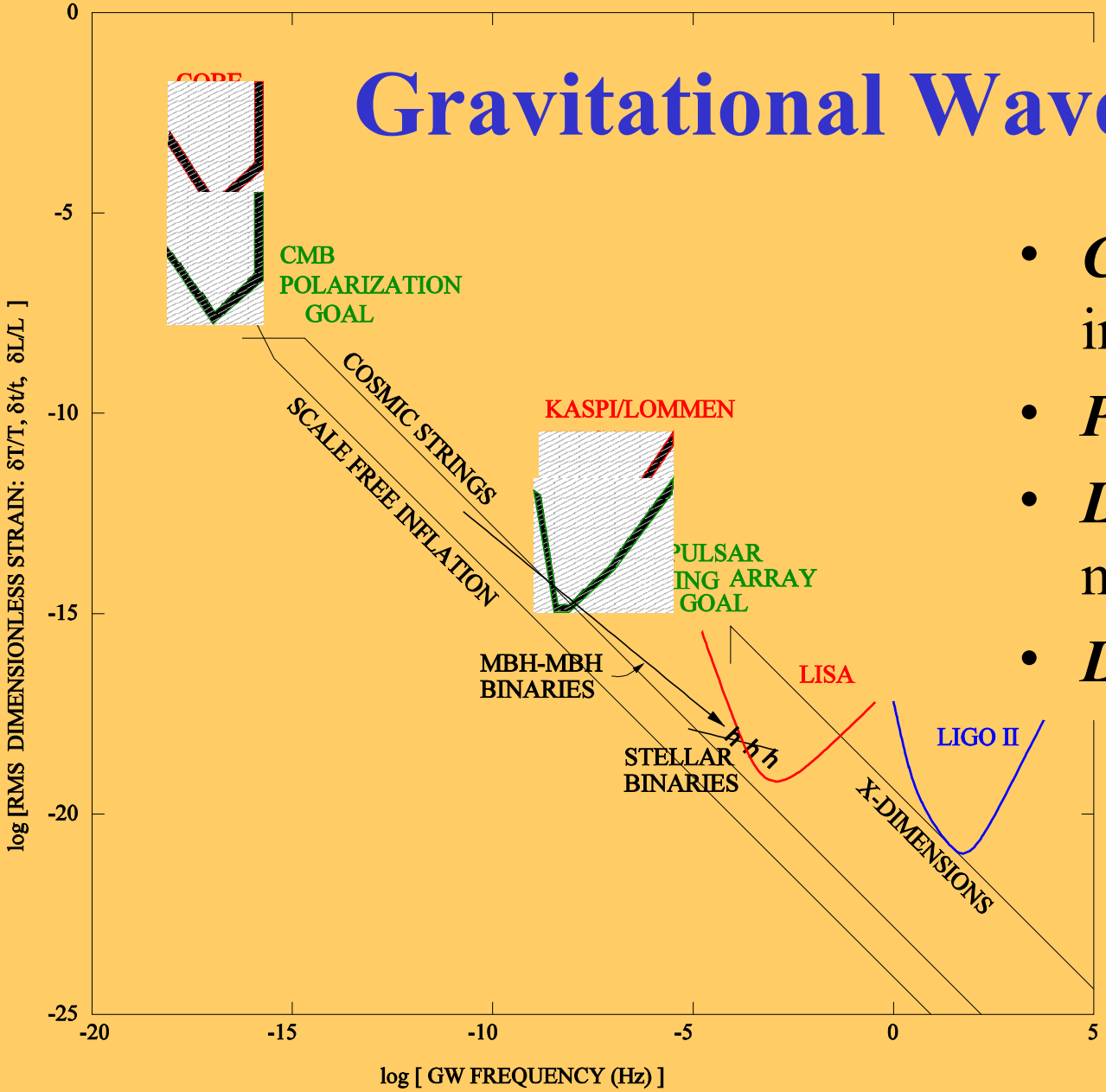
Gravity Wave Detection



$$h_c \sim (rms_{TOA})/T^{1.5}$$

- **Lower rms_{TOA}: more "*Bt*" per obs more/better PSRs better *G/Tsys***
- **Increase *T***

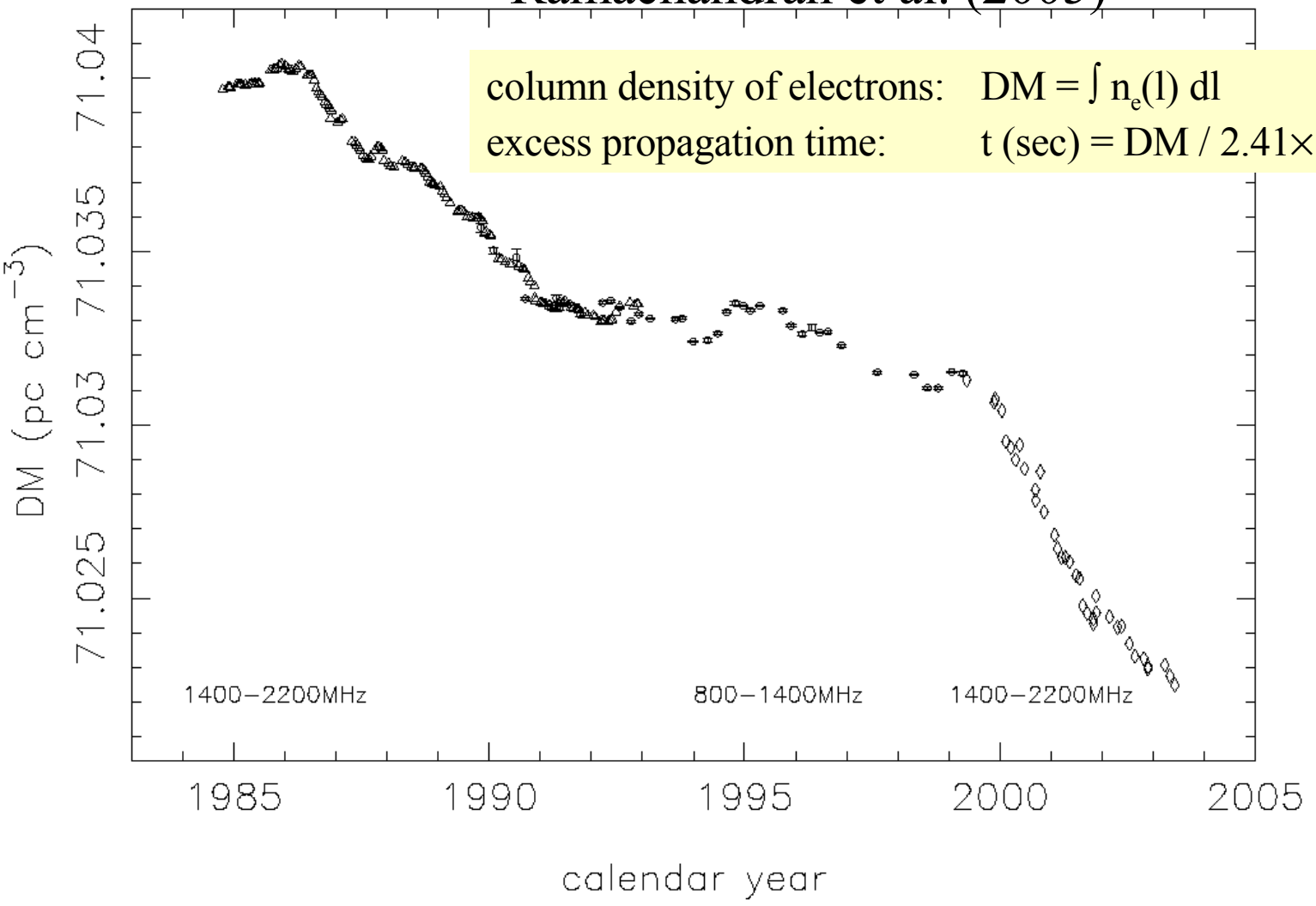
Gravitational Wave Spectrum



- ***CMB*** Polarization: inflation era probe
- ***Pulsars***: MBH-MBH
- ***LISA***: MBH-MBH + mBH-MBH
- ***LIGO***: Nstar-Nstar

Interstellar Plasma "Weather"

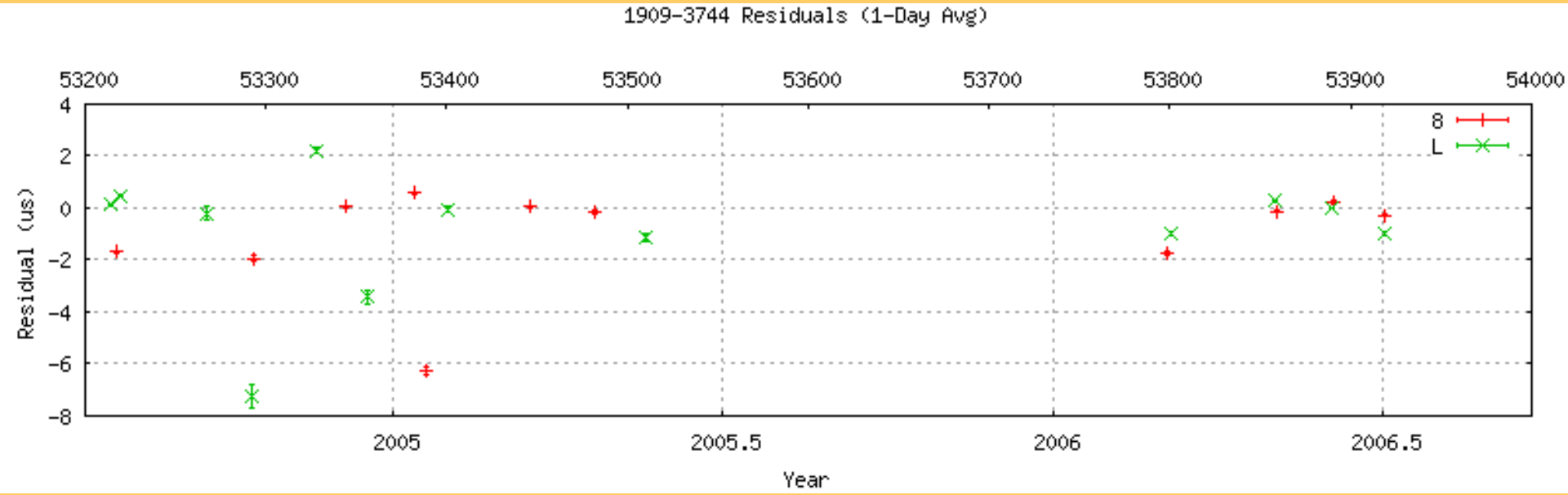
Ramachandran et al. (2005)

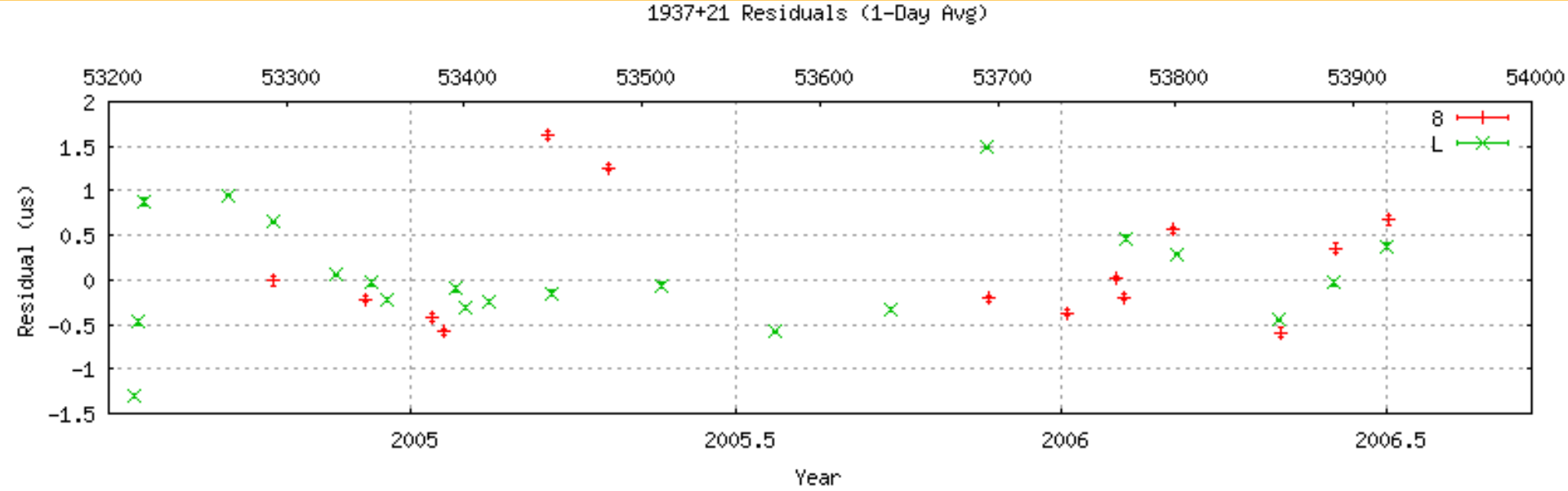


column density of electrons: $DM = \int n_e(l)\, dl$

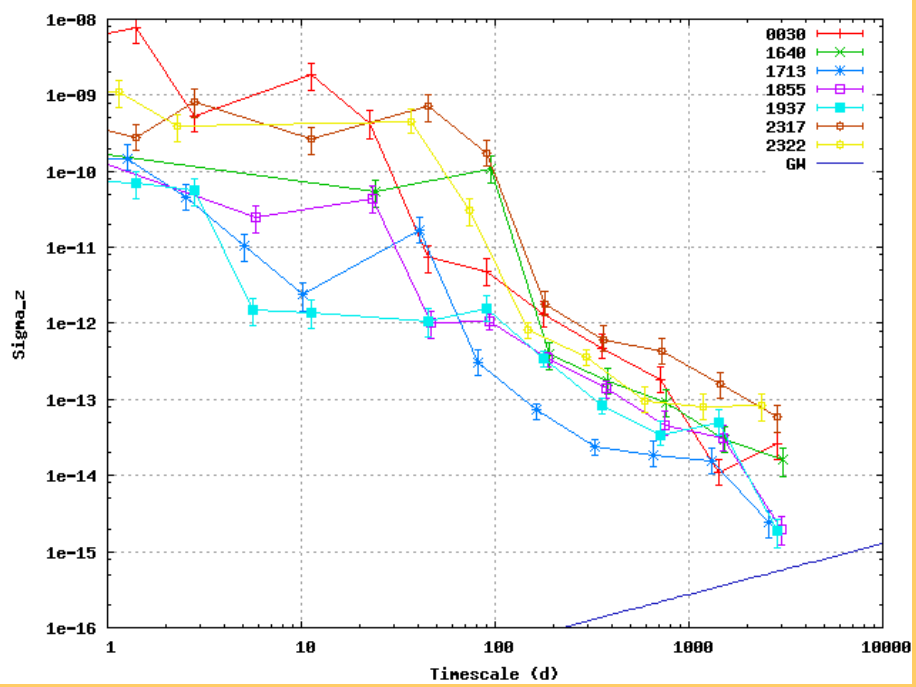
excess propagation time: $t\,(\mathrm{sec}) = DM / 2.41\times10^{-4}\,[f(\mathrm{MHz})]^2$

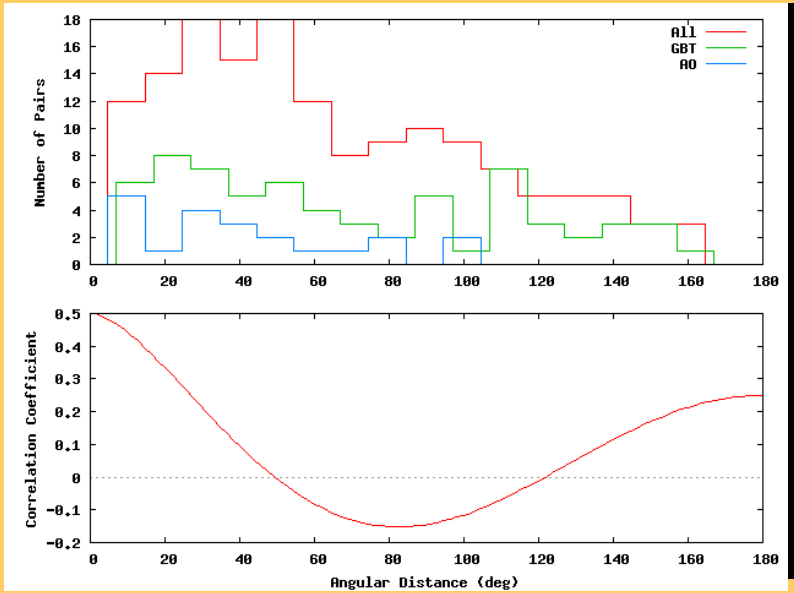
GBT Precision Timing—Demorest PhD

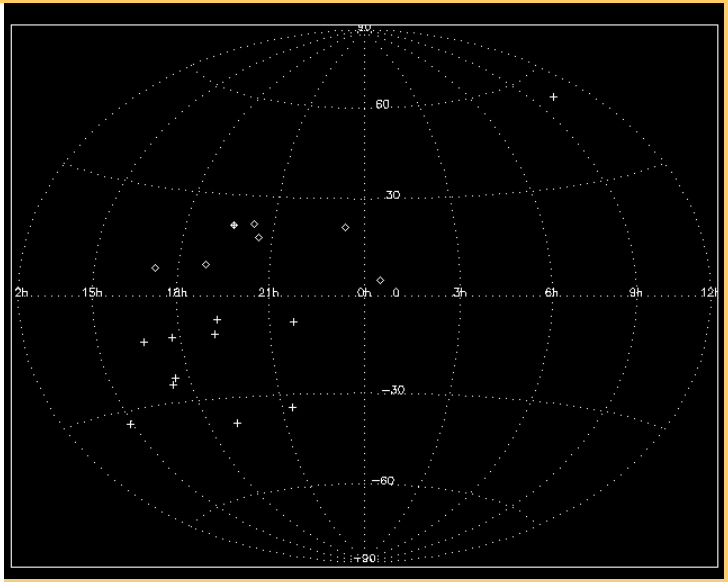




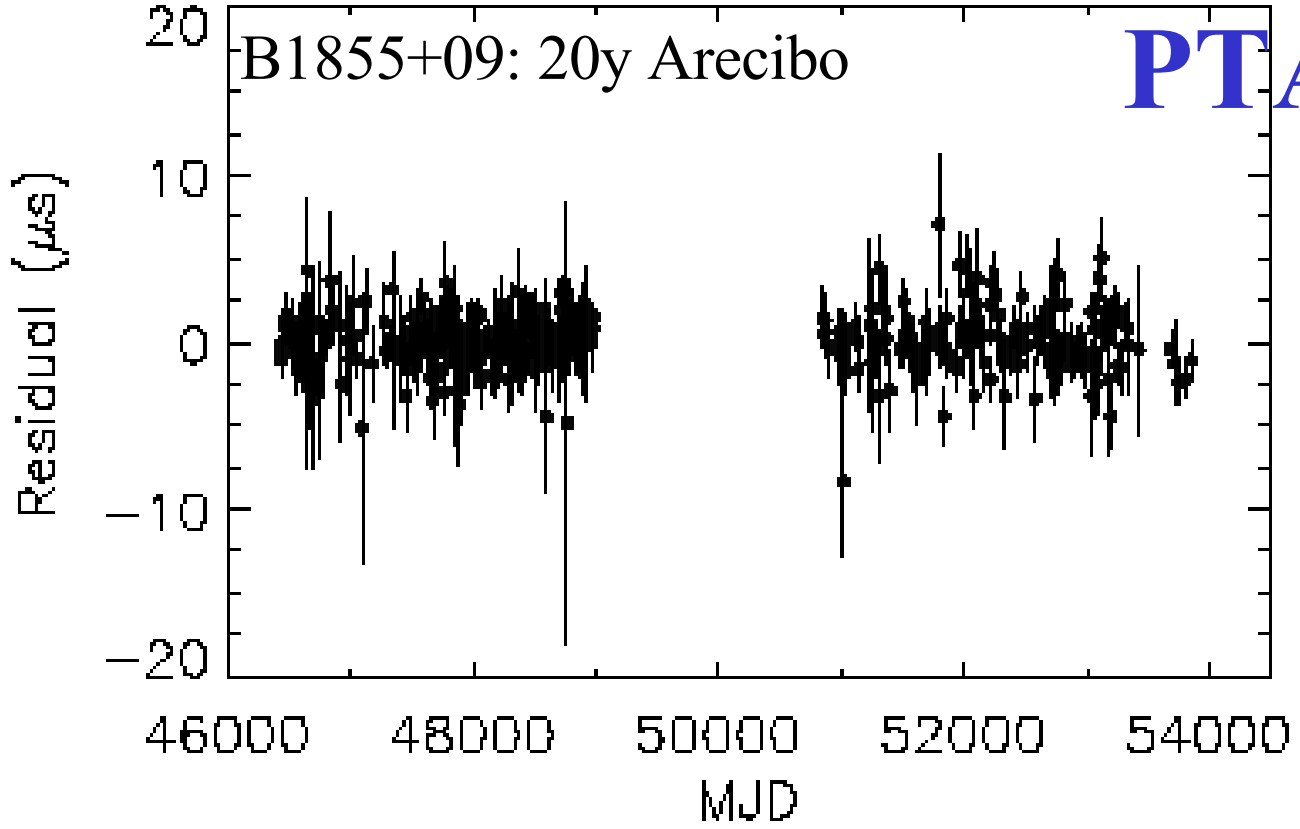
Pulsar Timing Array – Demorest PhD



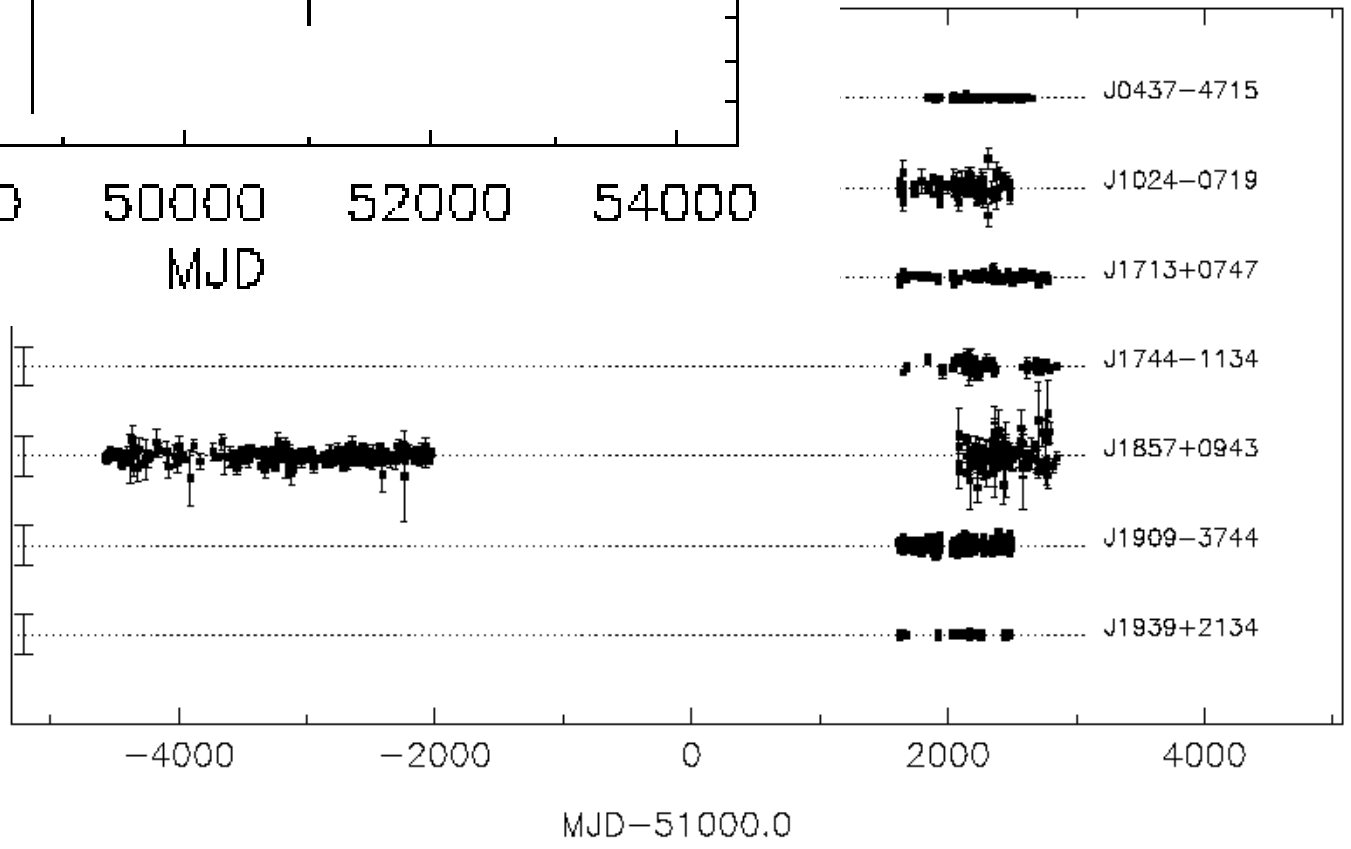




PTA Results

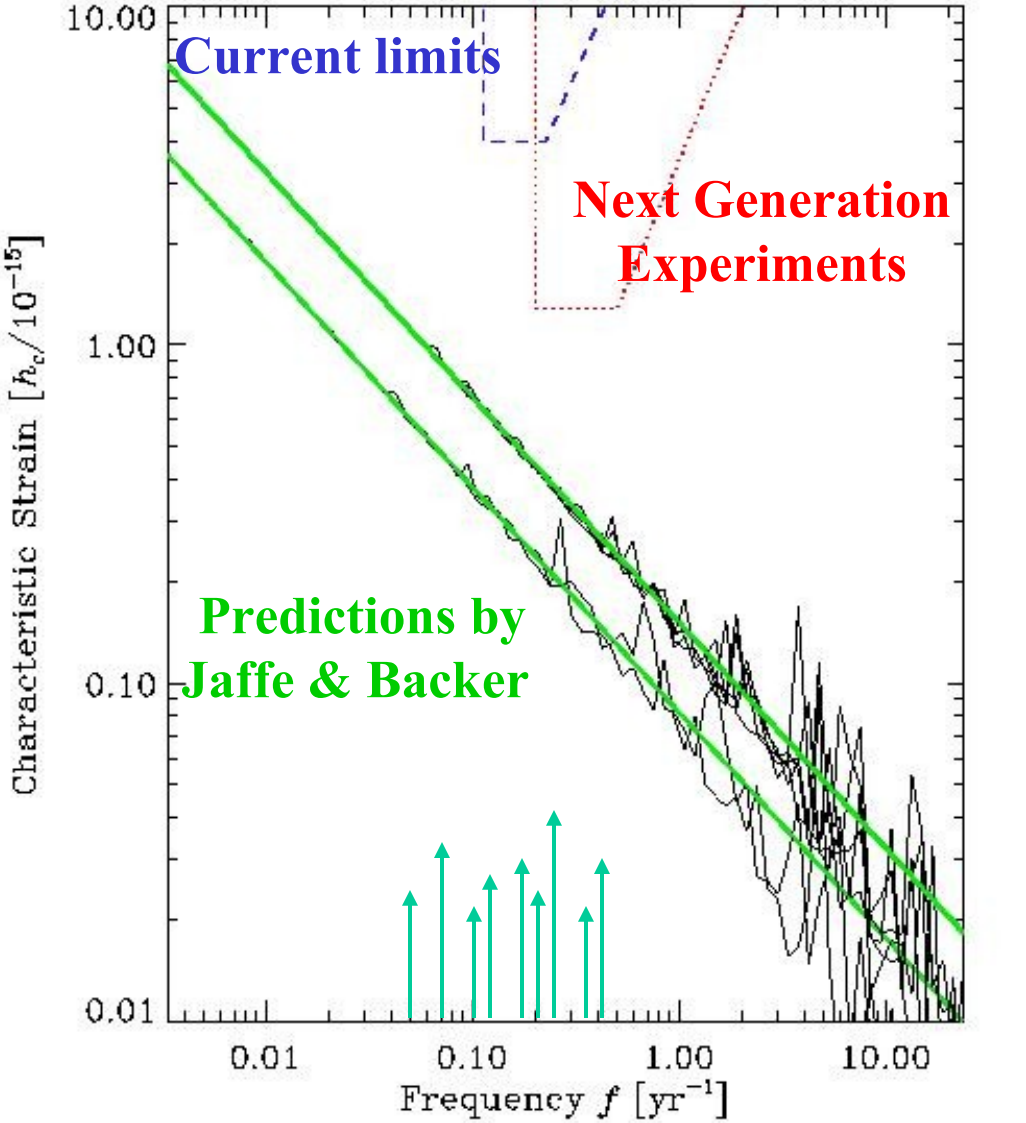


Lommen et al. (2006)



Jenet et al. (2006)

2006 September 8



Pulsar Timing Limits on the Stochastic Gravitational Wave Background from Massive Black Hole Binaries

Observational Issues

- Sensitivity: $(G/Tsys)(Bt)^{0.5}$
- Cadence: monthly (or more often); scheduling important
- Amplitude Calibration: variable gains & polarization apparent profile variations; linearity of system important
- Multi-frequency over more than 2 octaves: *DM* goes as RF^{-2}; scattering as $RF^{\sim -4}$; *DM(T,RF);* simultaneous obs important
- Duration: exceed 5y to get beyond 1/y fit "absorption"; $h_c \sim (rms_{TOA})/T^{1.5}$
- Phase Calibration: Integrity of clock backend; cable delay from rcvr backend at 10 ns...over 10y
- Size/Integration: large *D*/small *T* vs smaller *D*/larger *T*?
- Complementarity of global programs: *RF*, sky coverage