Search for Compact Binary Coalescences in LIGO's Third and Fourth Science Runs

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For the LIGO Scientific Collaboration (LSC)

G070221-00-Z

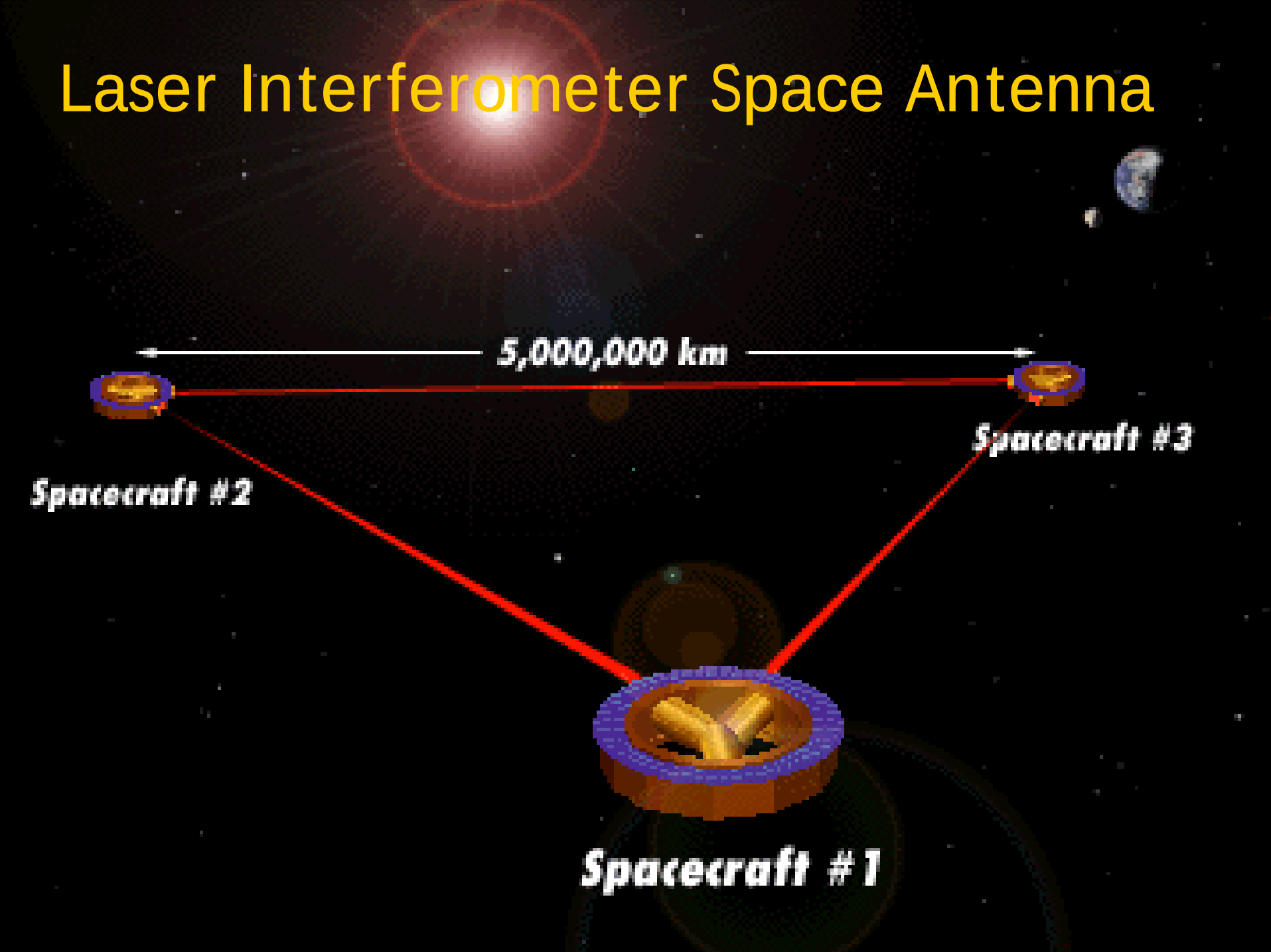

American LIGO at Hanford

American LIGO at Livingstone


British-German GEO

French Italian VIRGO near PISA

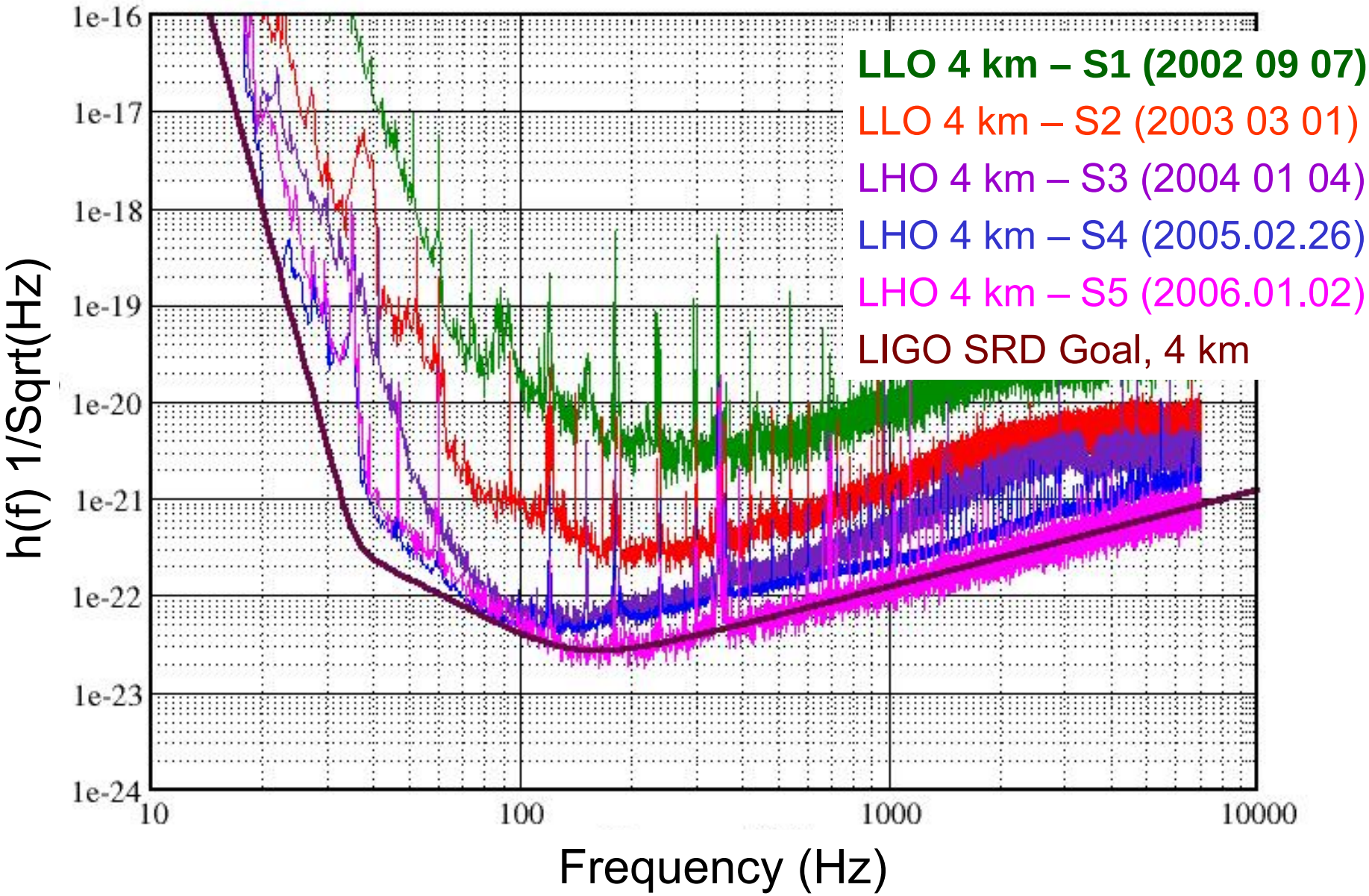
Laser Interferometer Space Antenna



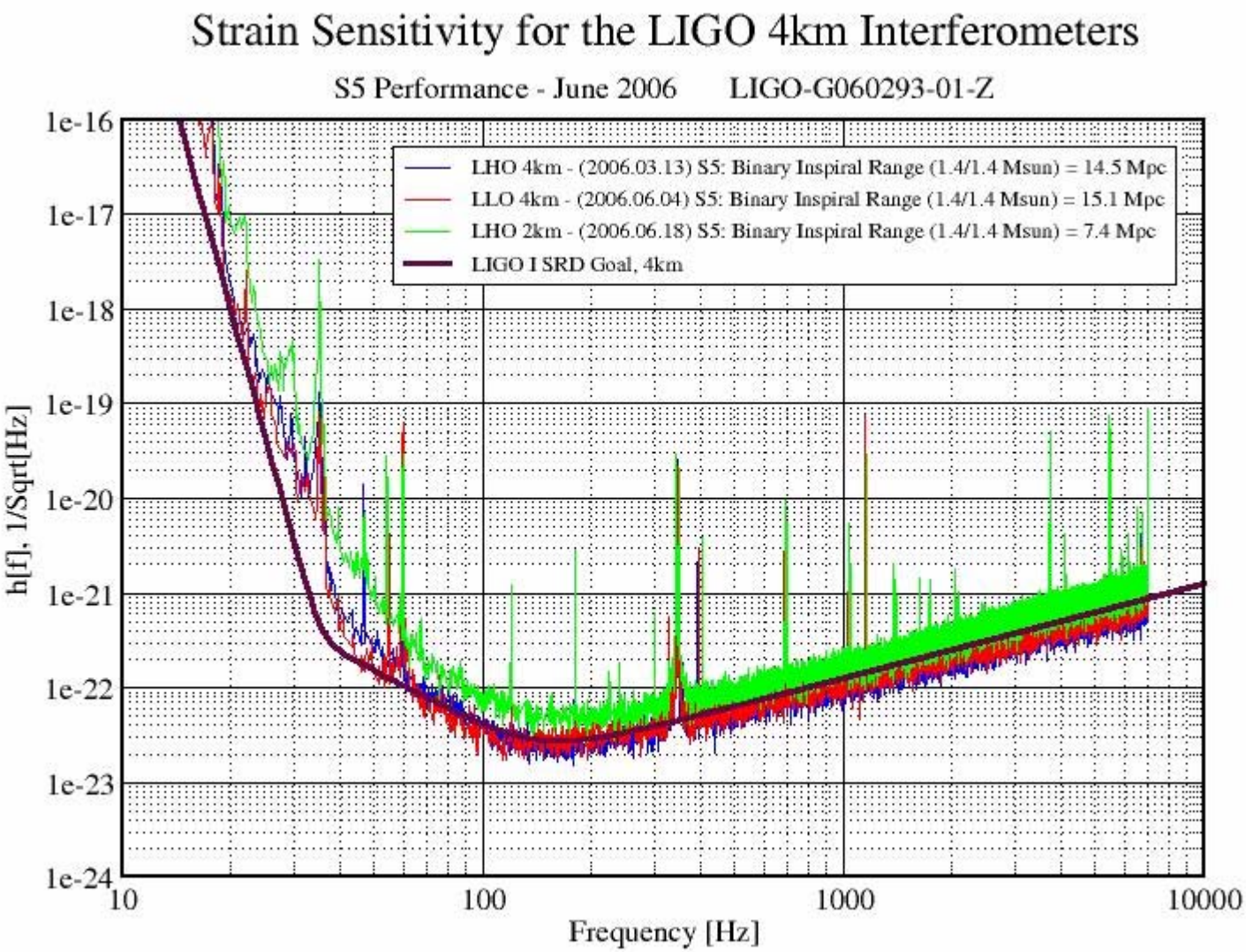
The LIGO Scientific Collaboration

Sensitivity of LSC Interferometers

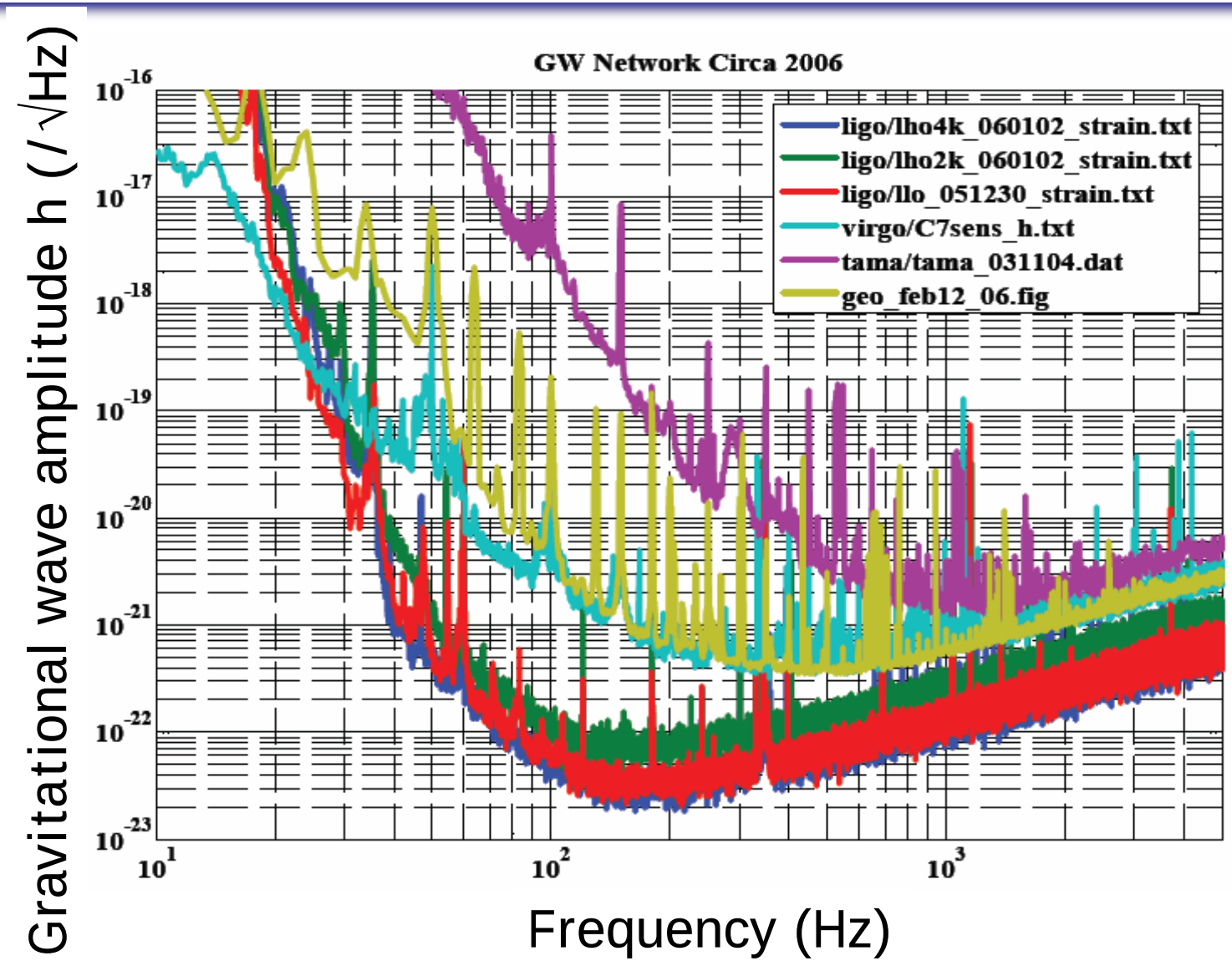
LIGO now at design sensitivity



S5 Sensitivity

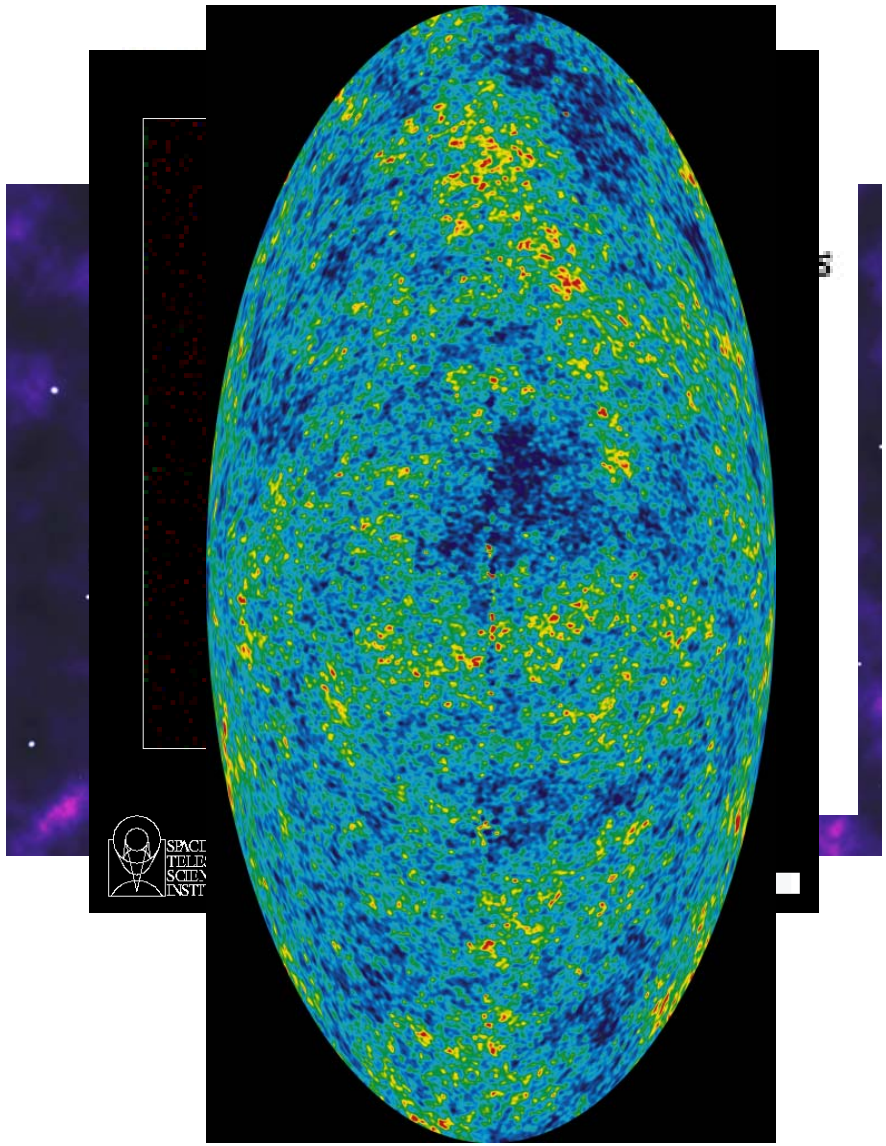


Gravitational wave network sensitivity



LSC Searches

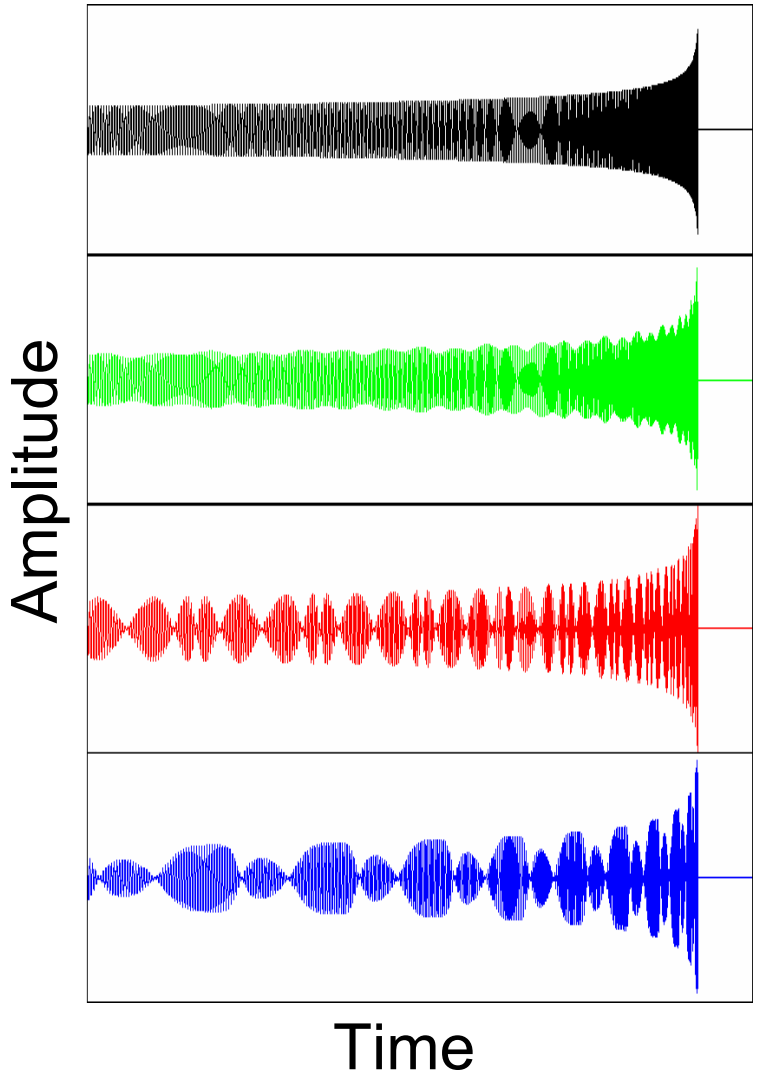
- Compact binary coalescences
  - Binary neutron stars (BNS)
  - Binary black holes (BBH)
  - BH-NS binaries
- Stochastic background
  - Primordial background
  - Astrophysical background
- Continuous waves
  - Rapidly spinning neutron stars or other objects
- Gravitational wave bursts
  - Black hole collisions, supernovae, gamma-ray bursts



Compact binary searches

Compact binary coalescences

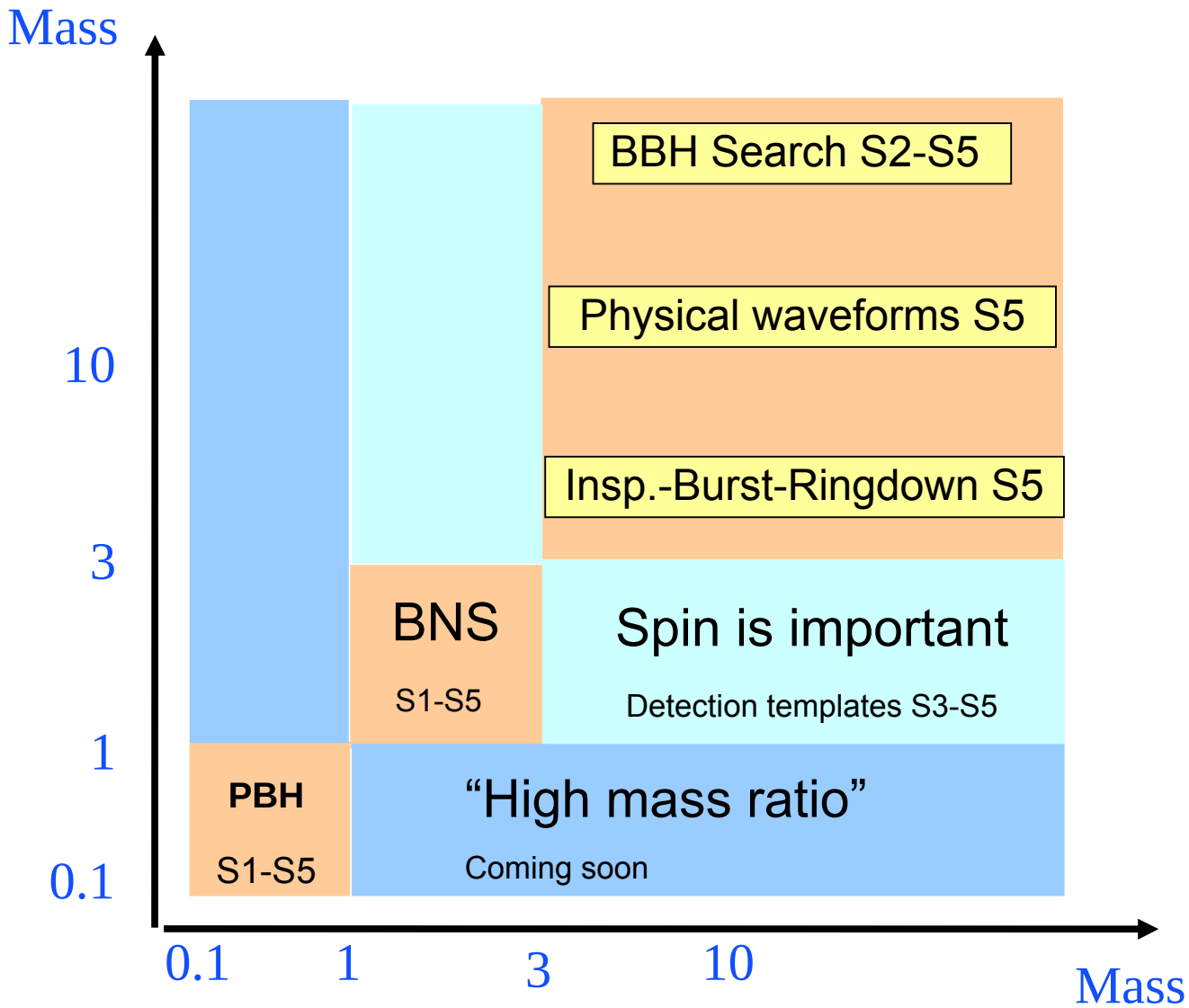
- Late-time dynamics of compact binaries is highly relativistic, dictated by non-linear general relativistic effects
- Post-Newtonian theory, which is used to model the evolution, is now known to $O(v^7)$
- The shape and strength of the emitted radiation depend on many parameters of binary system: masses, spins, distance, orientation, sky location, …



Waveform families

- How reliable are the templates used in the search?
  - Binary neutron stars coalesce well out of the detectors sensitive band – SNR is dominated by the early inspiral part – pretty reliable signal models
  - Binary black holes (of masses in the range 10-50 solar masses) coalesce in the most sensitive part of the detector, SNR has significant contribution from merger but we don't (yet) use merger signal
- Searches reported in this talk use
  - For binary neutron star and primordial black hole binary searches: Standard post-Newtonian templates at $(v/c)^4$ post-Newtonian order
  - For binary black holes: Phenomenological templates that have been shown to have a good overlap with most known waveform families (post-Newtonian families at various orders, effective one-body, P-approximants, etc.)

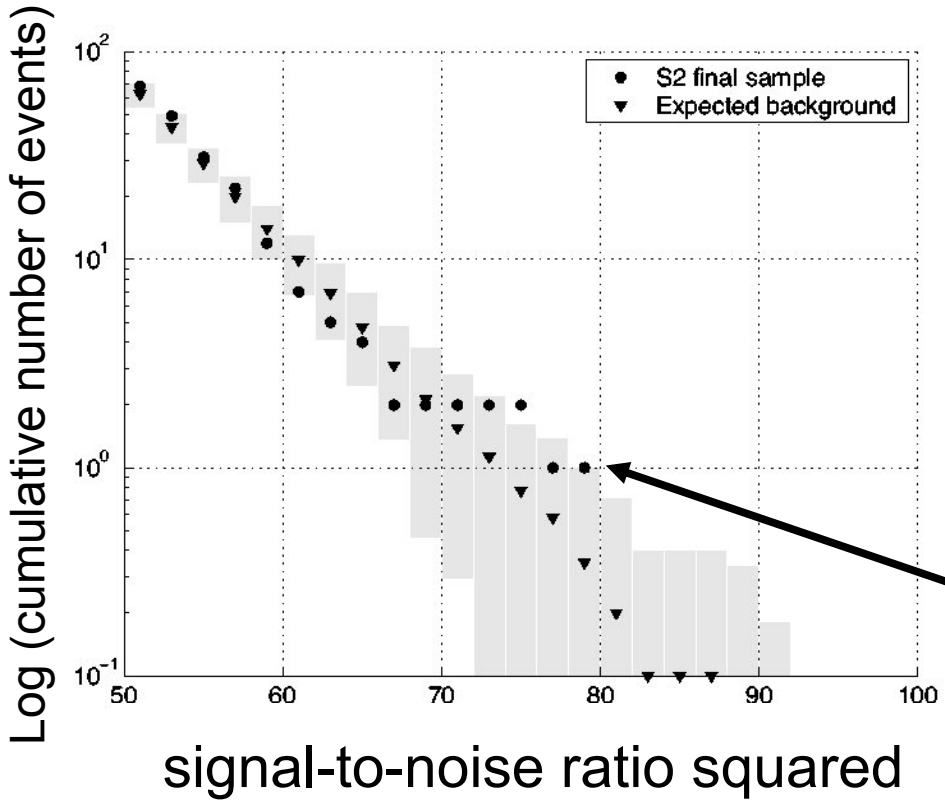
Search parameter space



Binary Neutron Stars

S2 Observational Result

Phys. Rev. D. 72, 082001 (2005)



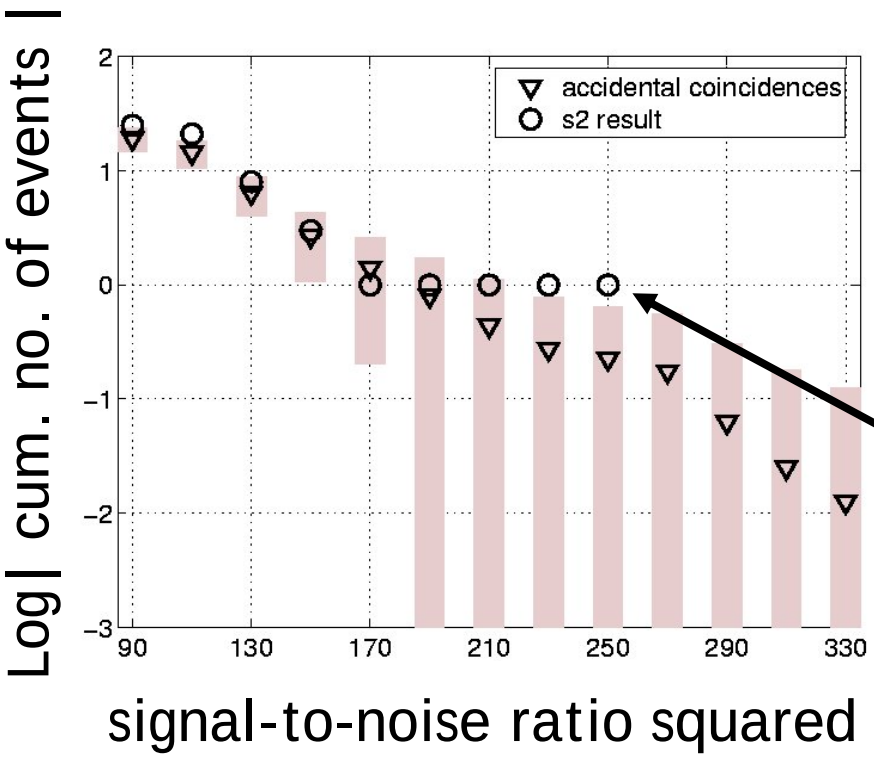
- S3 search complete
  - 0.09 yr of data
  - ~3 Milky-Way like galaxies
- S4 search complete
  - Preliminary results on slide 9
  - 0.05 yr of data
  - ~24 Milky-Way like galaxies

Rate < 47 per year per Milky-Way-like galaxy;
0.04 yr data, 1.27 Milky-Ways

Binary Black Holes

S2 Observational Result

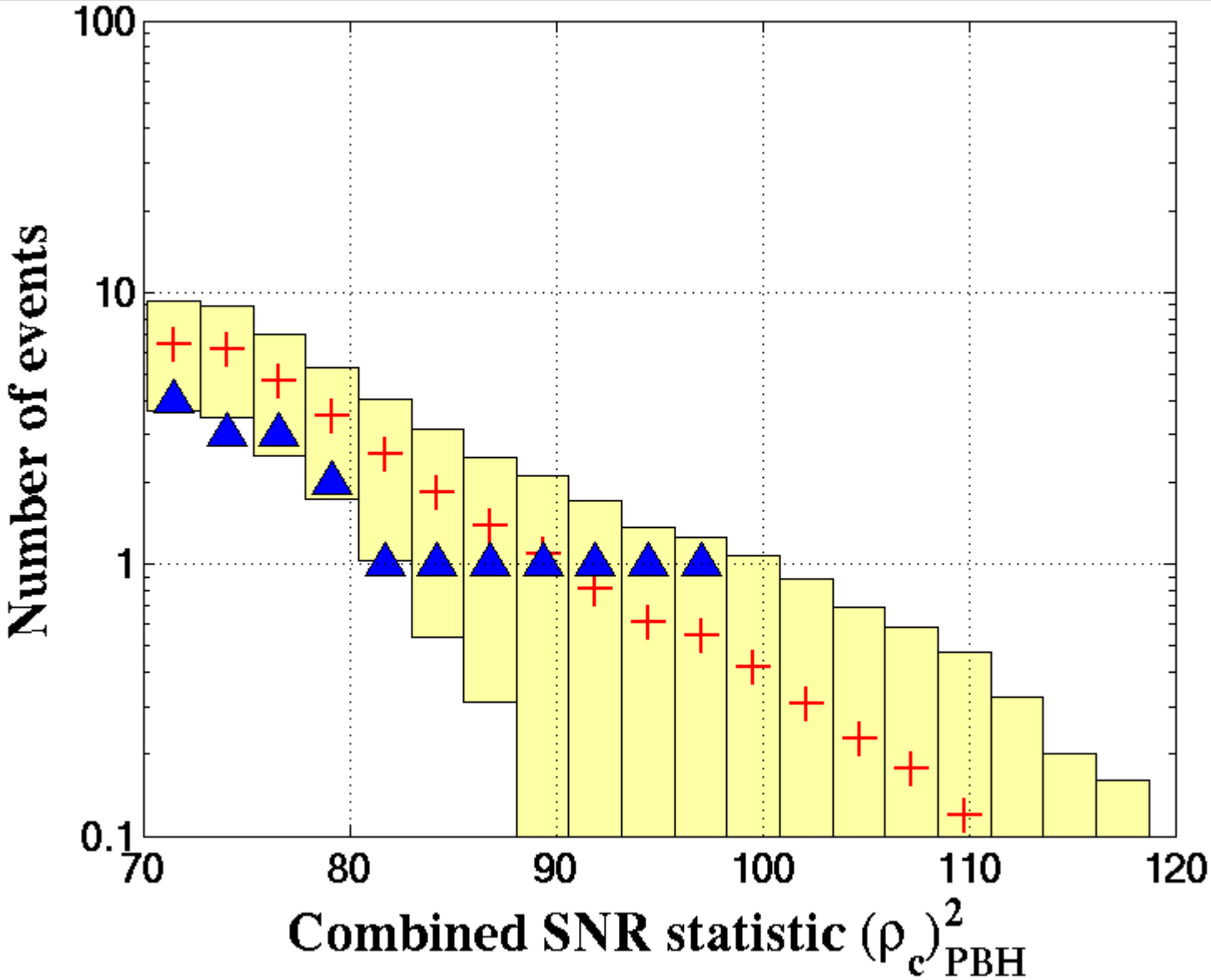
Phys. Rev. D. 73, 062001 (2006)



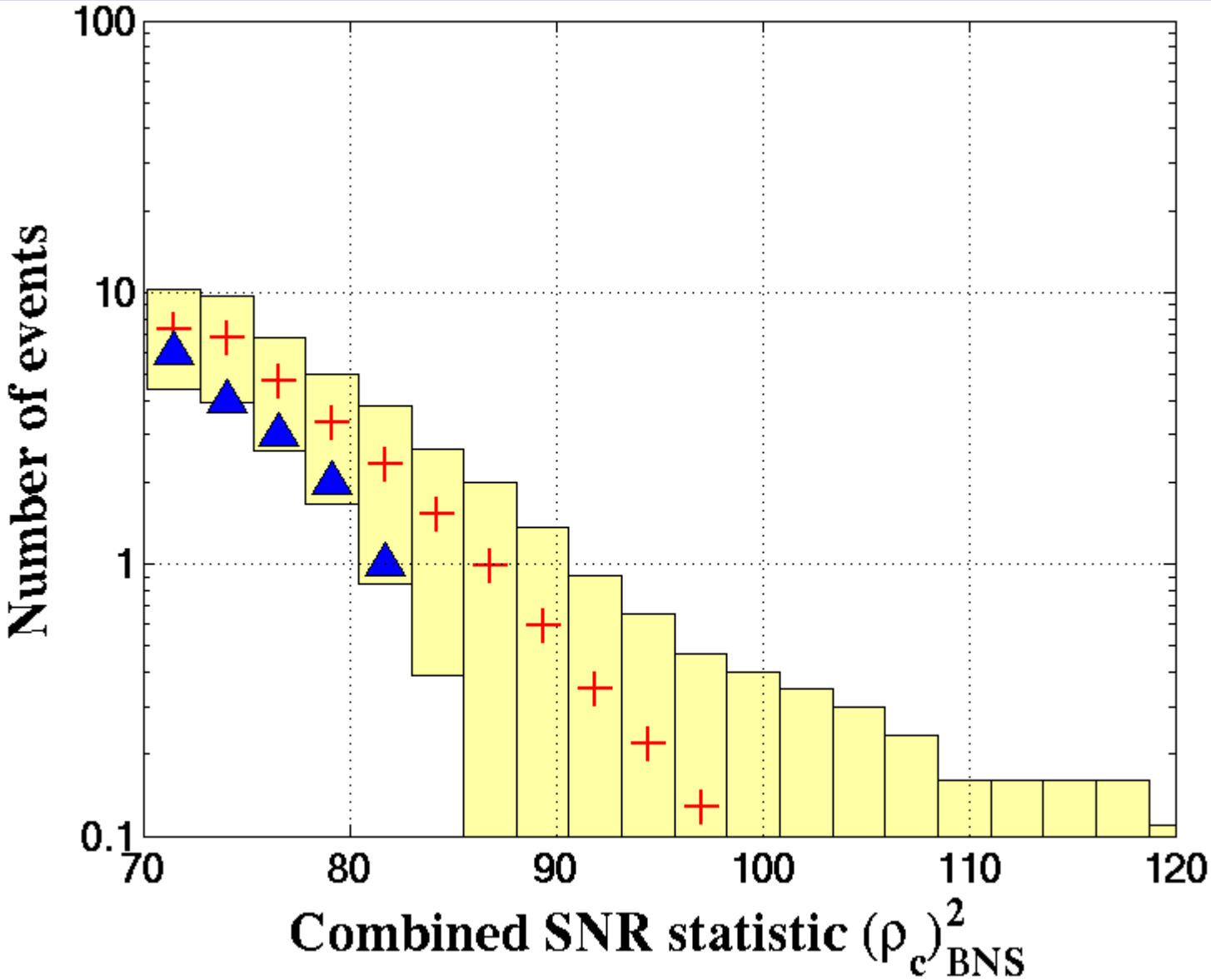
- S3 search complete
  - 0.09 yr of data
  - 5 Milky-Way like galaxies for 5+5 Msuns
- S4 search complete
  - Preliminary results on slide 9
  - 0.05 yr of data
  - 150 Milky-Way like galaxies for 5+5 Msuns

Rate < 38 per year per Milky-Way-like galaxy

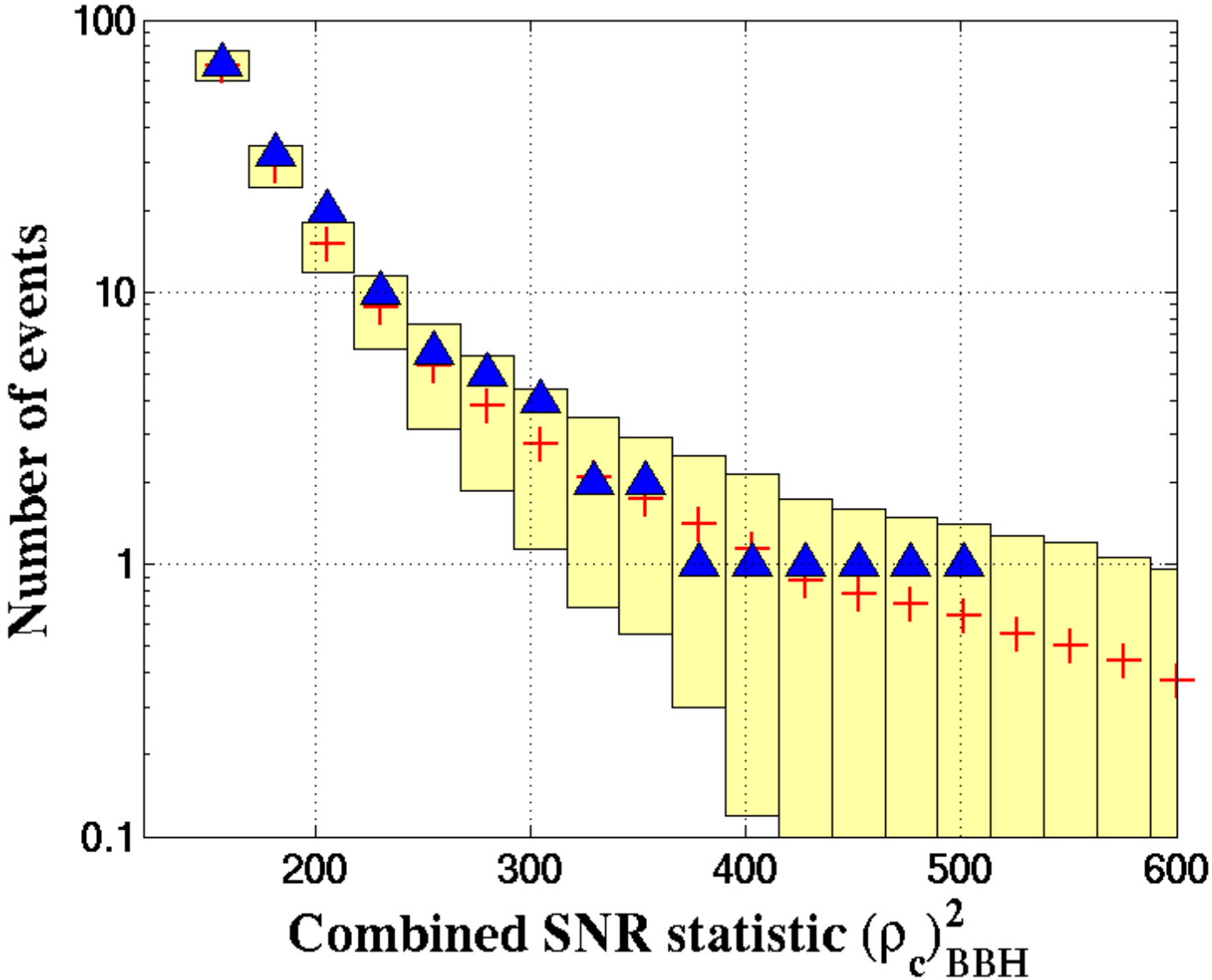
S4: Background Vs Foreground: Primordial Binary Black Holes (Preliminary)



S4: Background Vs Foreground: Binary Neutron Stars (Preliminary)

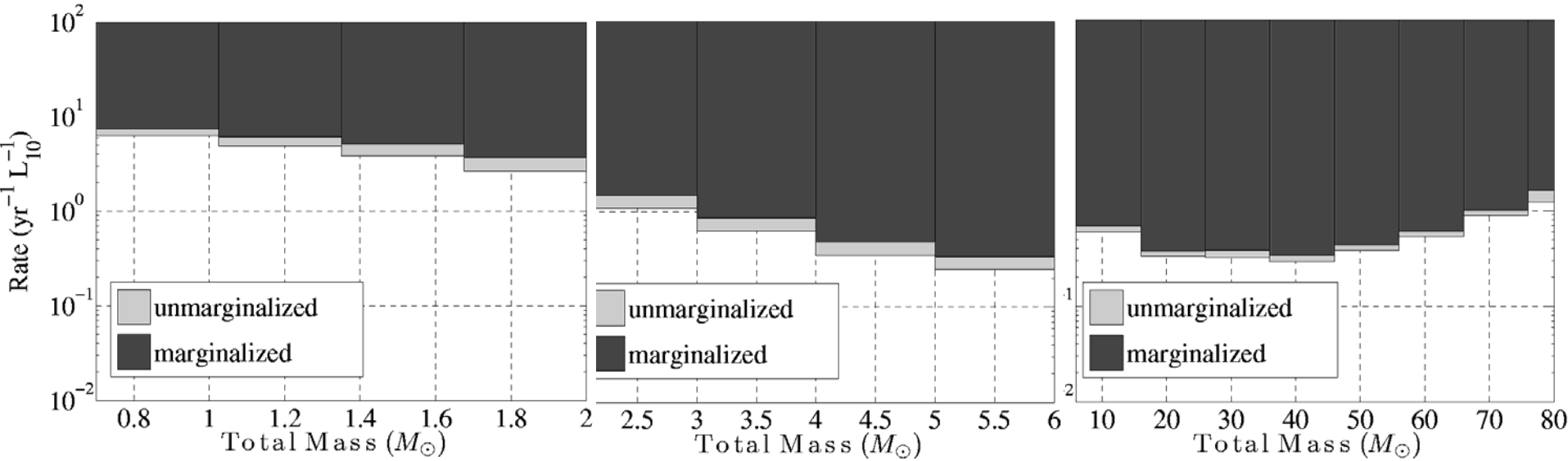


S4: Background Vs Foreground: Binary Black Holes (Preliminary)



S4 Preliminary Rate Upper Limits

Primordial BBH | Binary neutron stars | Binary black holes

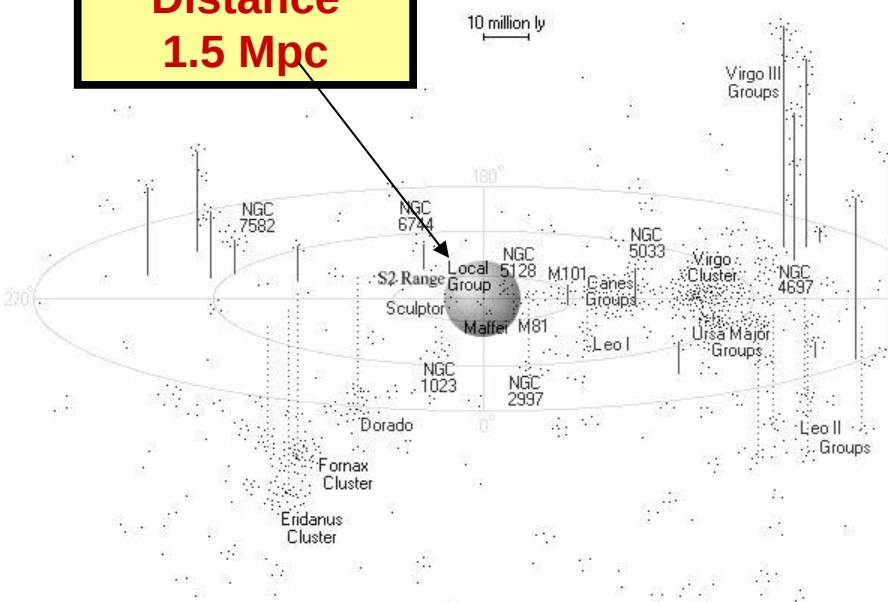


- PBH (0.75/0.75): rate < 4.9 $yr^{-1} L_{10}^{-1}$
- BNS (1.4/1.4): rate < 1.2 $yr^{-1} L_{10}^{-1}$
- BBH (5.0/5.0): rate < 0.45 $yr^{-1} L_{10}^{-1}$

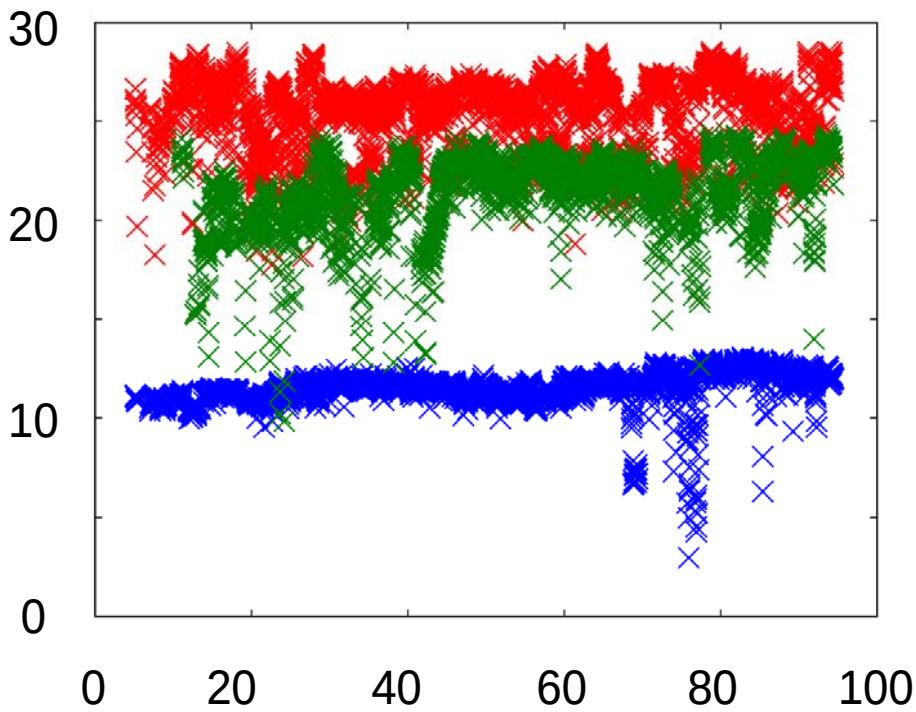
Binary Neutron Stars: S5 Search

- S5 data is being analyzed

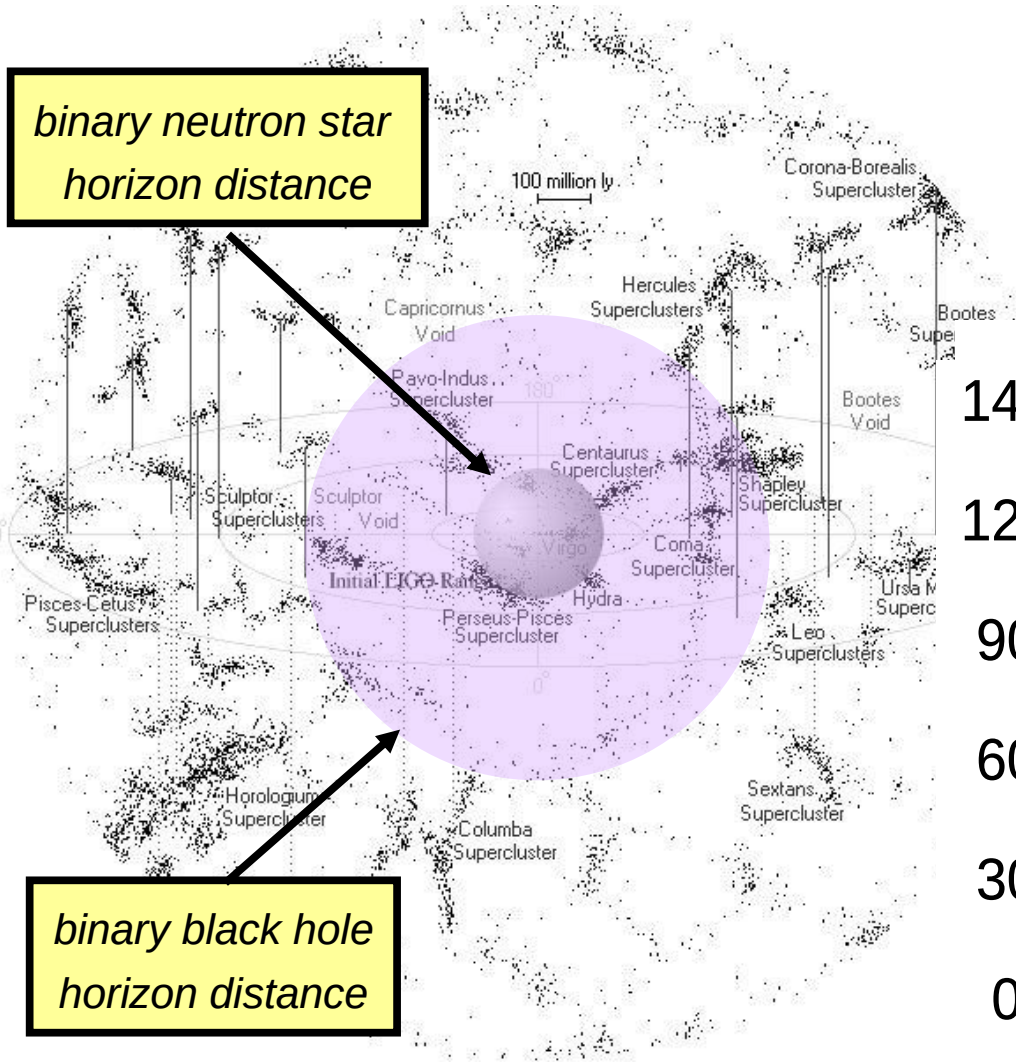
S2 Horizon Distance 1.5 Mpc



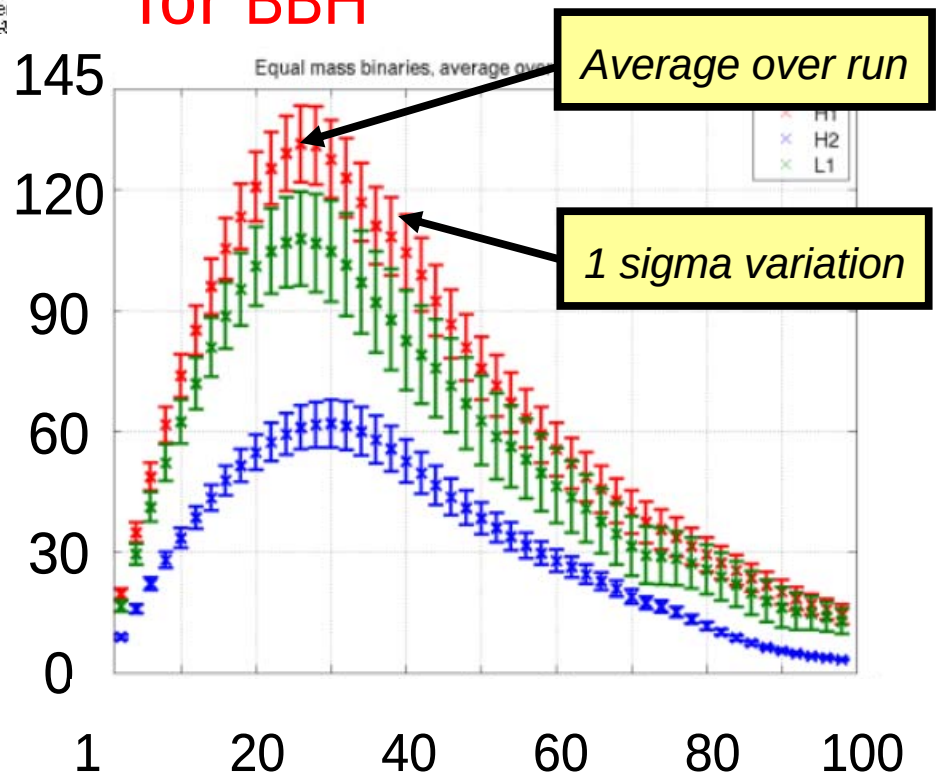
- Distance to 1.4+1.4 Msun optimally oriented & located binary at SNR=8, in Mpc



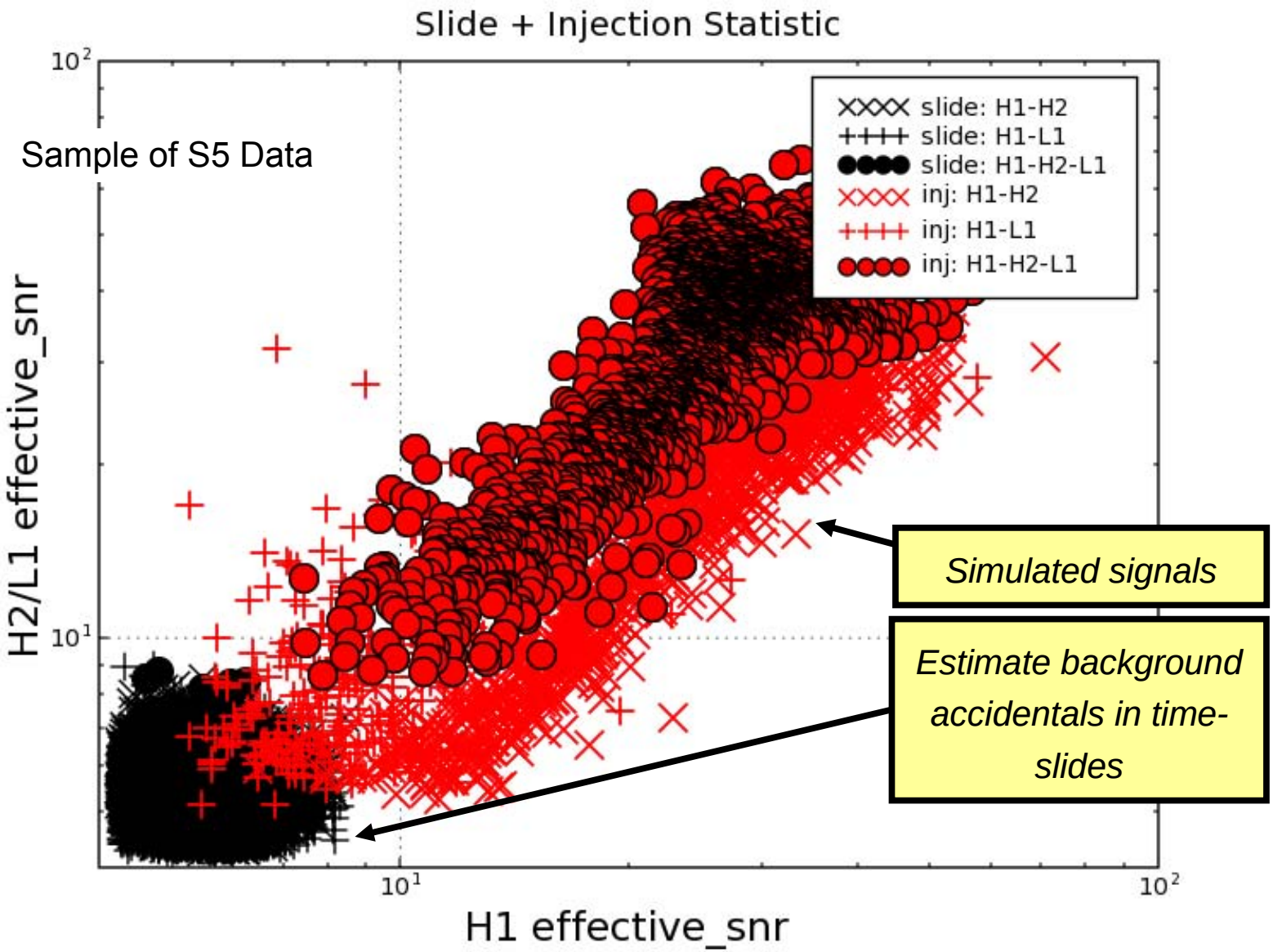
Binary Black Holes: S5 Search



- S5 data being analyzed
- Horizon distance (in Mpc) versus total mass (in $M_{\odot}$) for BBH



Are we capable of detection?



What to expect in the coming years

- 2005-2007: S5 search
  - About 1 year of triple coincident data
  - Search at design sensitivity level
  - Rates are probably about 0.2 per year for BNS
- 2007-2009: Initial detectors will be upgraded to enhanced interferometers
  - GEO will provide coverage: sensitive to Galactic SN
- 2009-2011: Enhanced LIGO and VIRGO
  - About 1 year of data at x 2 sensitivity (8 in volume)
  - BNS rates are at few per year
- 2011-2013: GEO-HF
  - GEO tuned to observe specifically in the high frequency regime
- 2013+: Advanced LIGO and VIRGO
  - Several years of data at x 10 sensitivity (1000 in volume)
  - Expect BNS rates of many per year to several per day