LIGO-II SCIENCE

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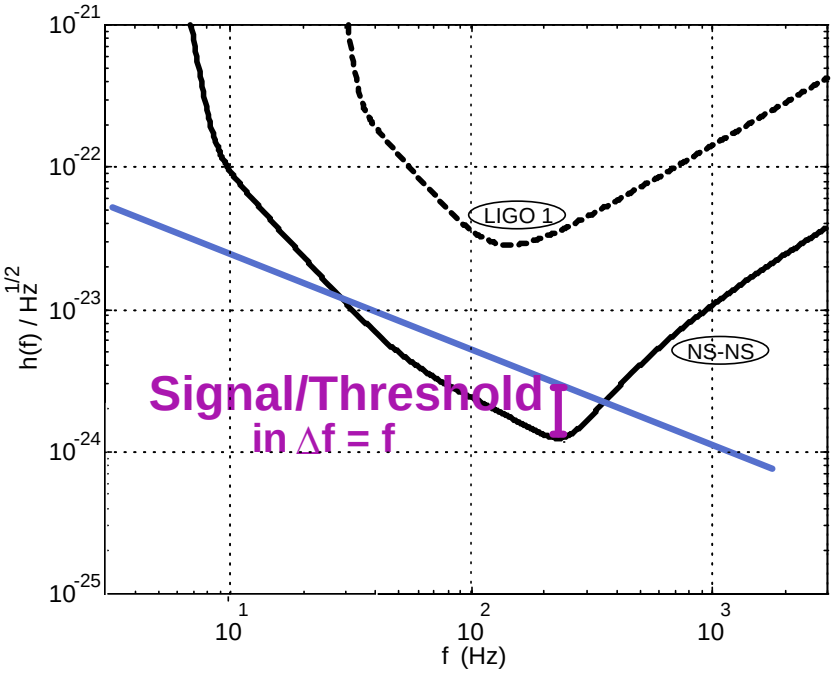
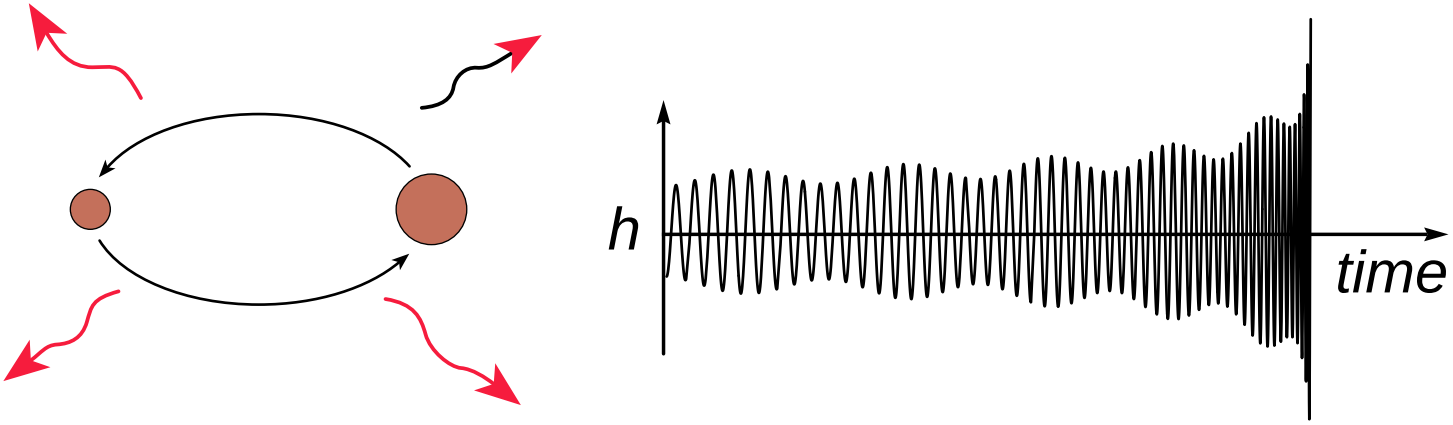
OVERVIEW

- Compact Binaries: Inspiral & Merger
- Neutron-Star Births (supernovae; AIC)
- Neutron-star Spins (pulsars; LMXB's)
- Stochastic Background from Big Bang
- Conclusions:
  - » LIGO-I in domain of plausible detection
  - » LIGO-II likely to see rich variety of sources & science
  - » Tunability of noise curve is key to getting out science
- Conventions:
  - » Threshold set so false alarm probability = 1% in 1 year search.



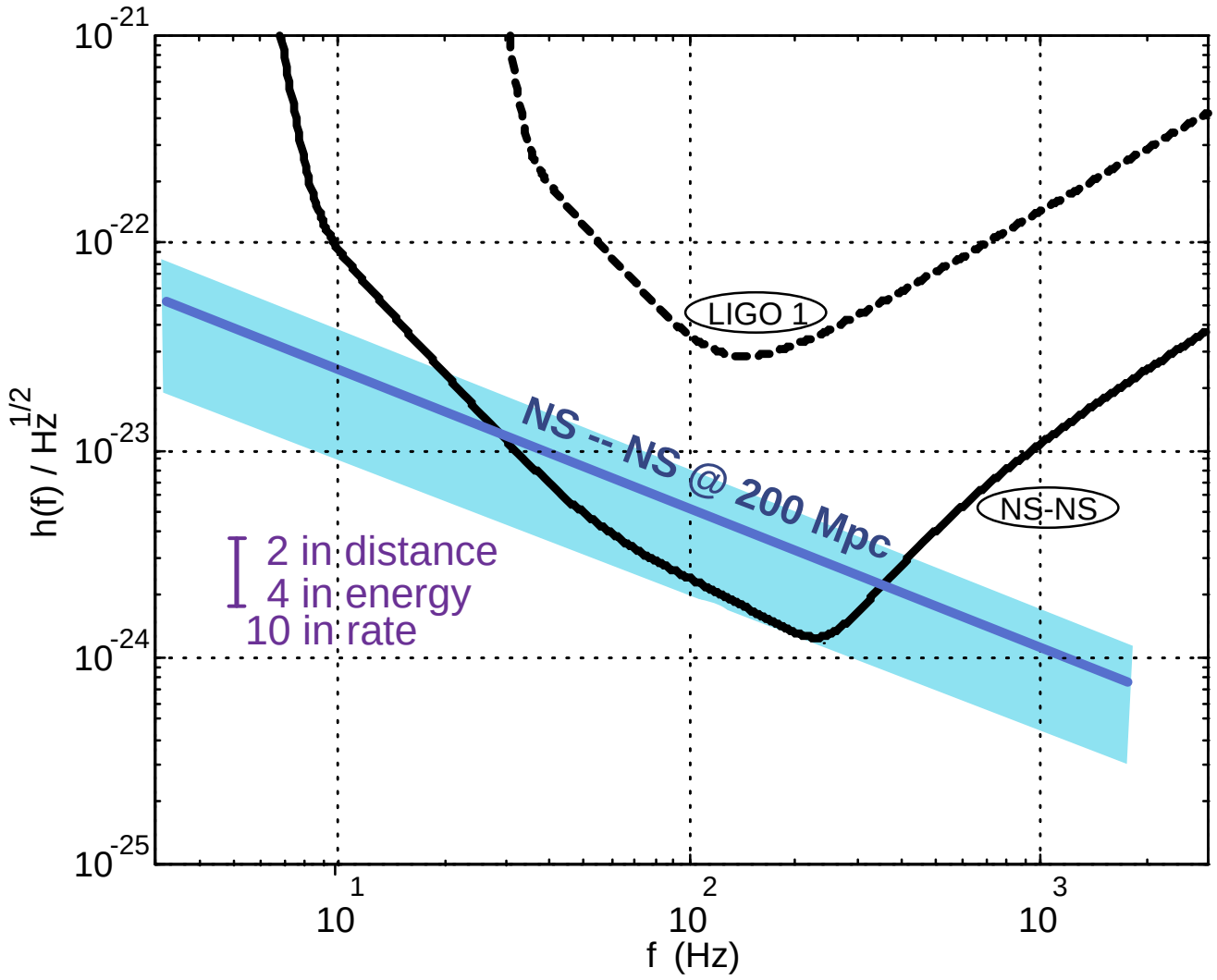
COMPACT-BINARY INSPIRAL



- Several minutes, 1000 -- 10,000 cycles
- Inspiral Science:
  - » Masses, Spins, Distance, Location on sky to ~1 degree
    - – $M_{chirp} = \mu^{3/5} M^{2/5}$ to $\sim 10^{-4}$
  - » Search for EM counterpart (γ-burst?). If found ---
    - – Source of γ-bursts
    - – Measure relative speeds of photons & gravitons to ~ 1 sec / 3×10^9 yrs ~ 10^{-17}
    - – Measure cosmological parameters --
      - GW's: "luminosity distance"
      - EM: red shift

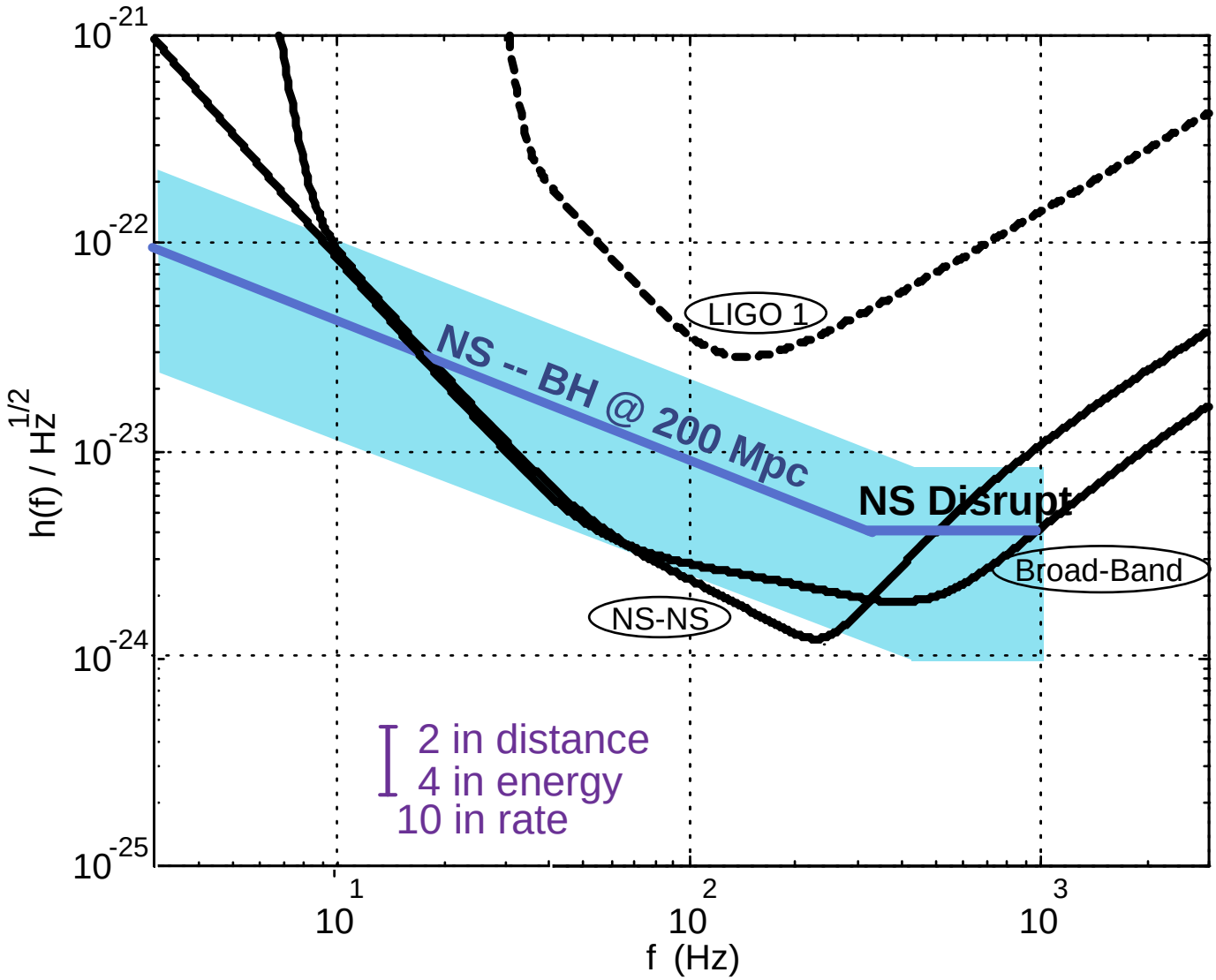
NS-NS INSPIRAL

- Most certain source. Best estimate:
  - ~1/yr @ 200Mpc (3x10^{-6}/yr in our Galaxy)
  - LIGO-II: 450Mpc, 1/month



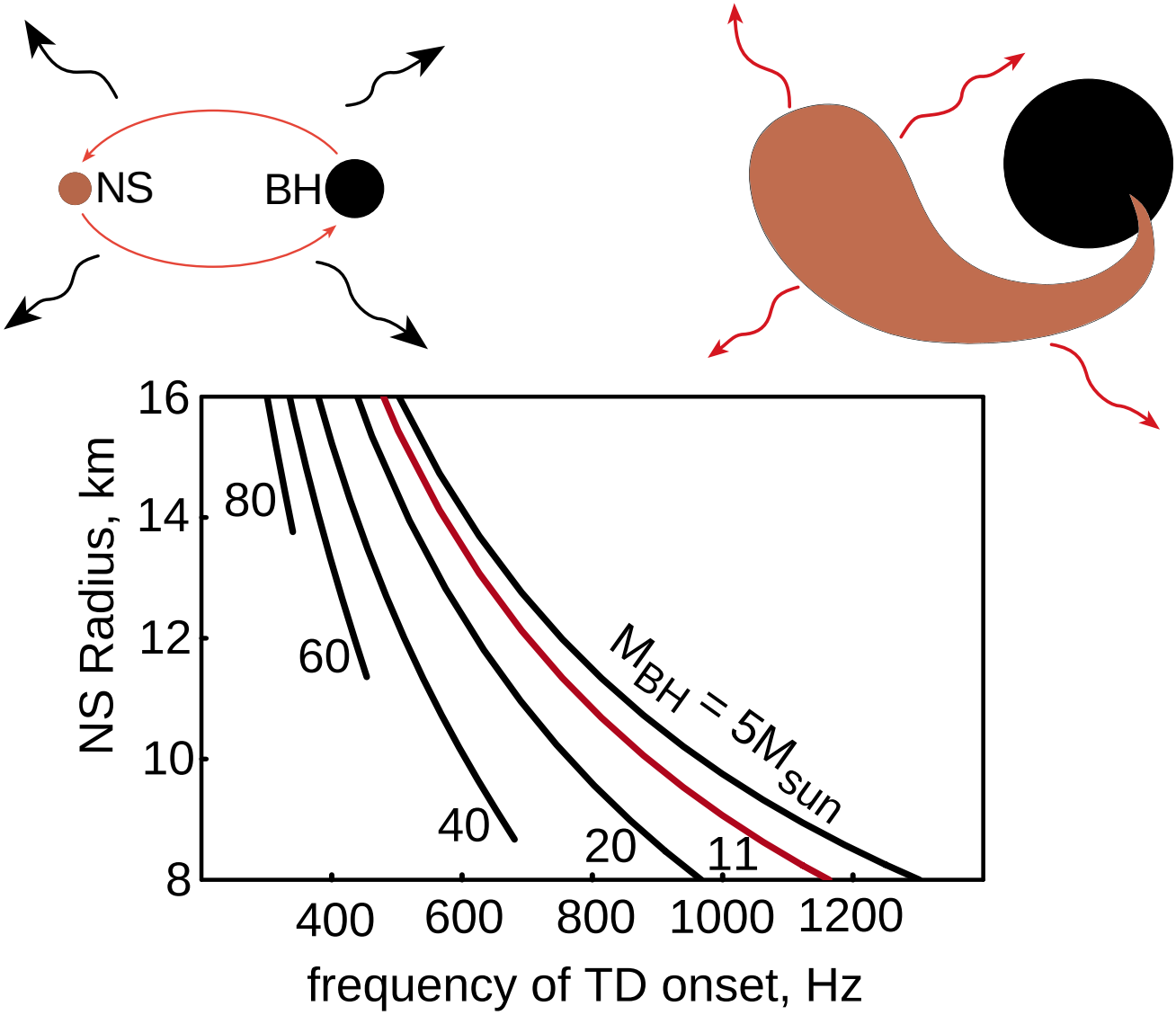
NS-BH INSPIRAL & MERGER

- Rates Highly Uncertain. Best estimate:
  - » ~1/yr @ 200Mpc (~3x10^{-6}/yr in our Galaxy)
  - » LIGO-II: 800Mpc, ~1/week



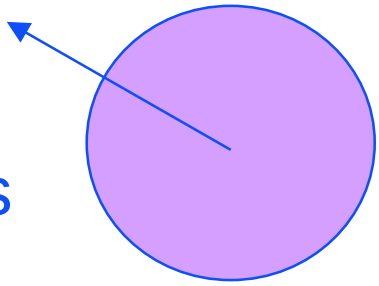
NS-BH MERGER

- NS tidal disruption --> NS radius, equation of state

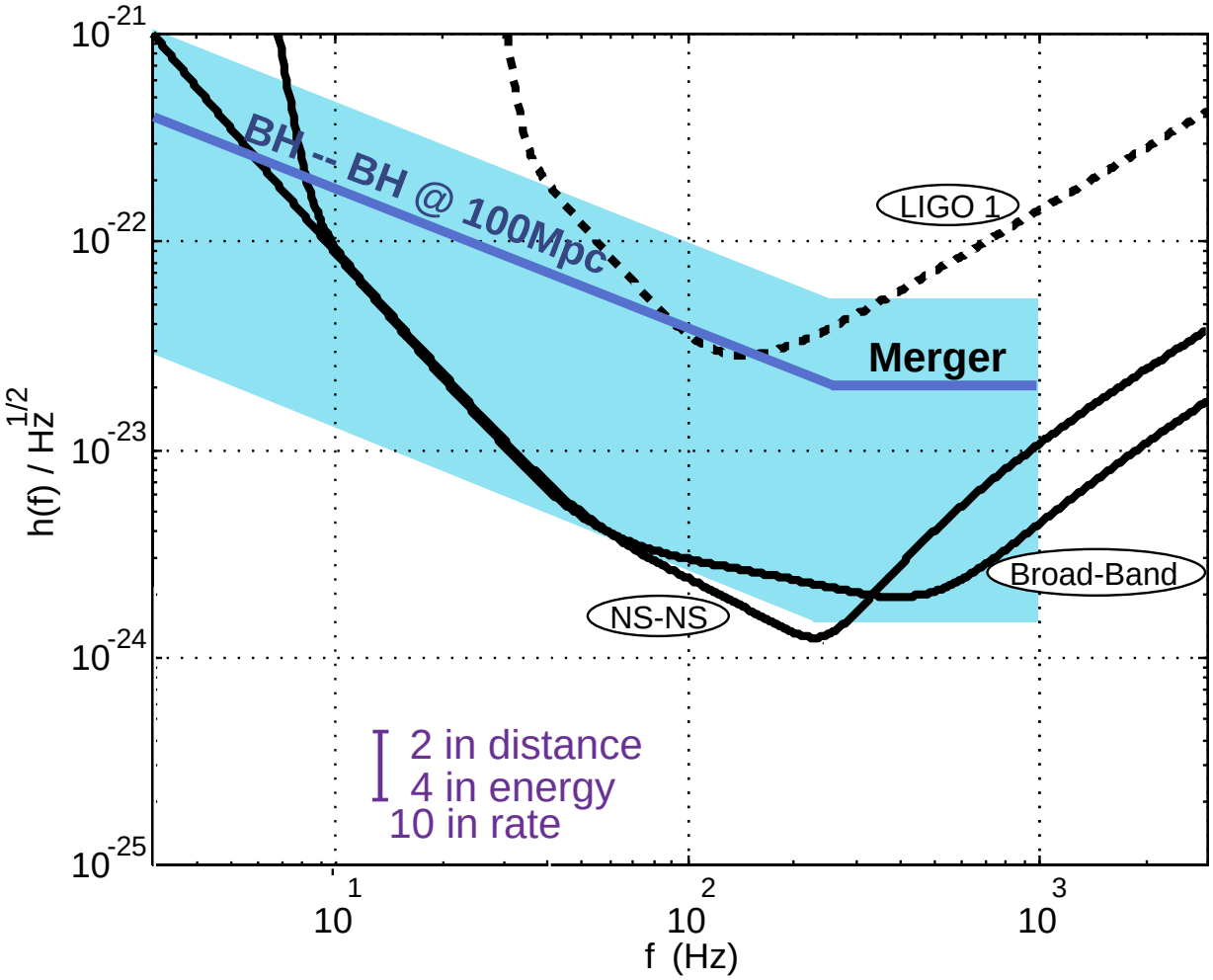


- Broad-band noise curve is crucial

BH-BH INSPIRAL & MERGER

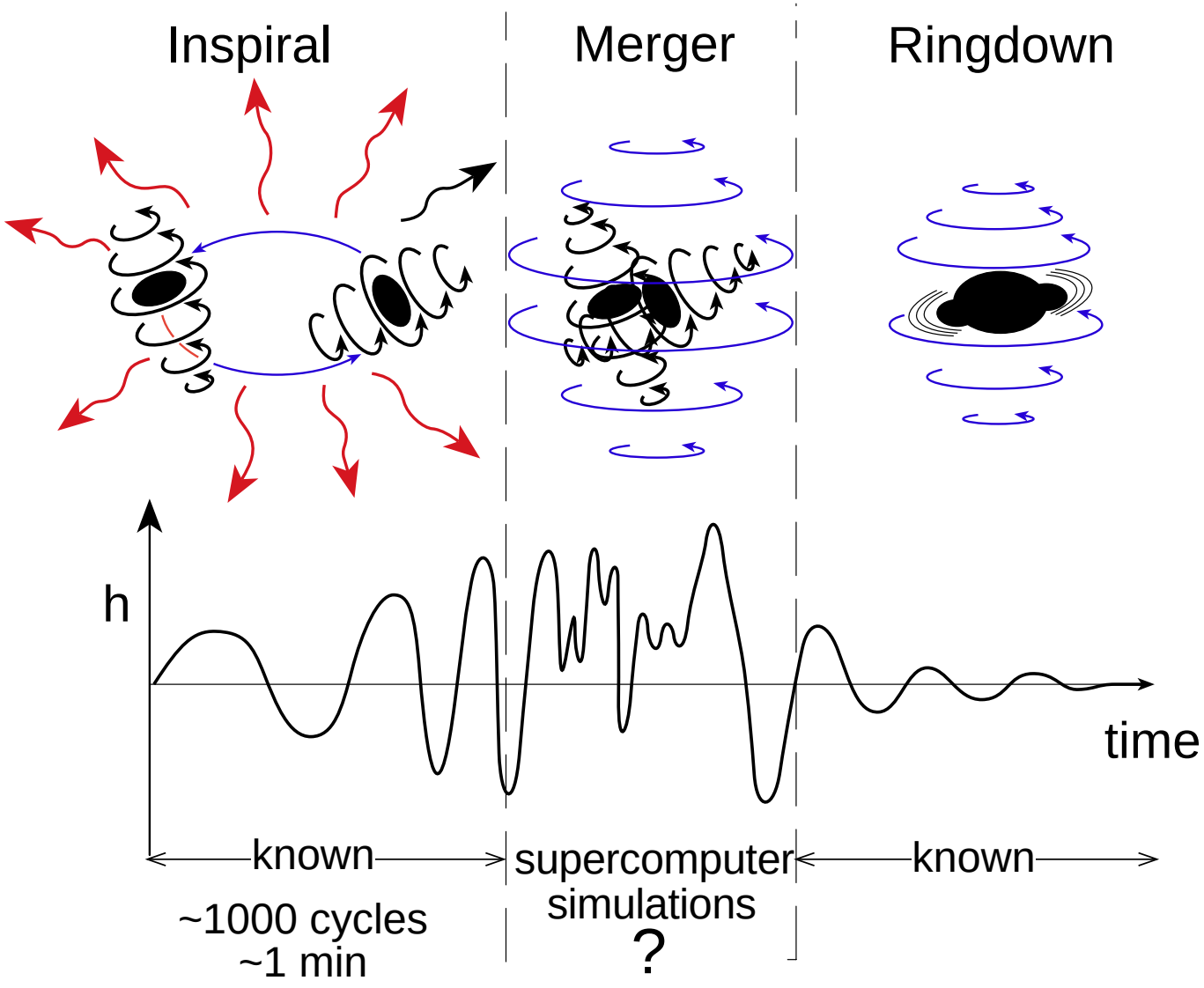


- Globular Clusters: machines for making binary black holes
- Rates Highly Uncertain. Best estimates:
  - » LIGO-I: 100 Mpc, 1/year. LIGO-II: z=0.5, 1/hour



BH-BH INSPIRAL & MERGER (cont)

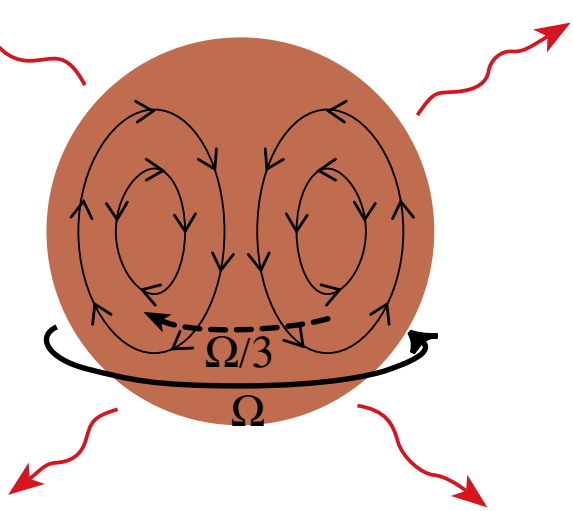
- Merger Science: nonlinear dynamics of spacetime curvature



- Broad-Band Noise Curve is Crucial

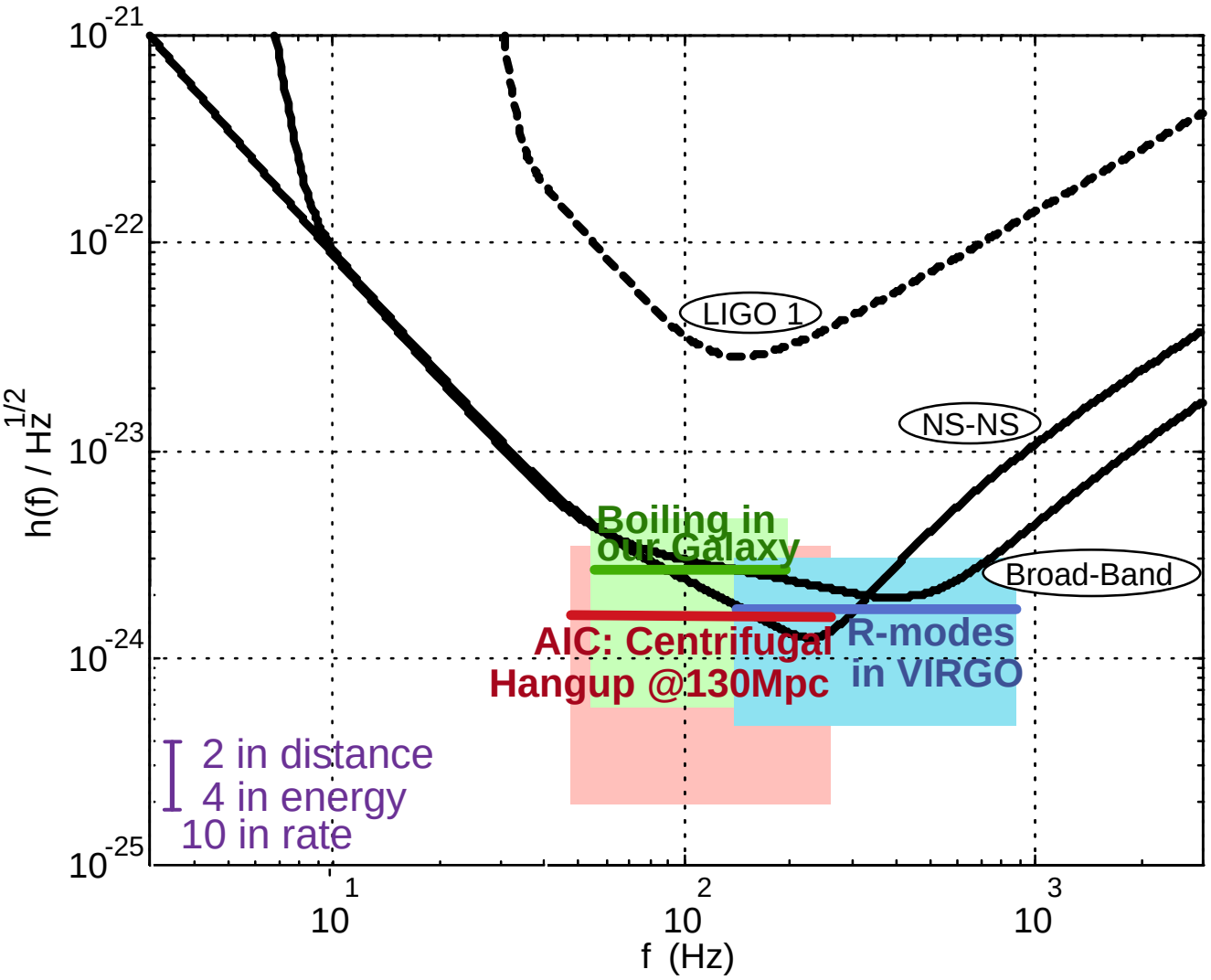
NS BIRTHS

- Supernovae: stellar core collapse -> NS
  - » *If* NS born with P_{spin} < 10 msec: ***R-Mode instability.***
    - – Observations -> Spin evolution, viscosity, mode-mode coupling
    - – LIGO-II: detectable to 20Mpc (VIRGO cluster)



  - » *If* in our galaxy (~1/50 yr):
    - – Boiling -> Neutrinos and Gravitational Waves.
    - – Cross correlate -> dynamics of 1st one sec of NS life
- Accretion-Induced Collapse of White Dwarfs
  - » Only O/Ne/Mg Dwarfs likely to produce NS's (~1/yr at 130Mpc)
  - » Centrifugal hangup at ~ 60 km -> bar-mode instability -> Gravitational Waves [but hydrodynamic losses?]
  - » When shrunk to ~10km -> R-mode instability

NS BIRTHS (cont)

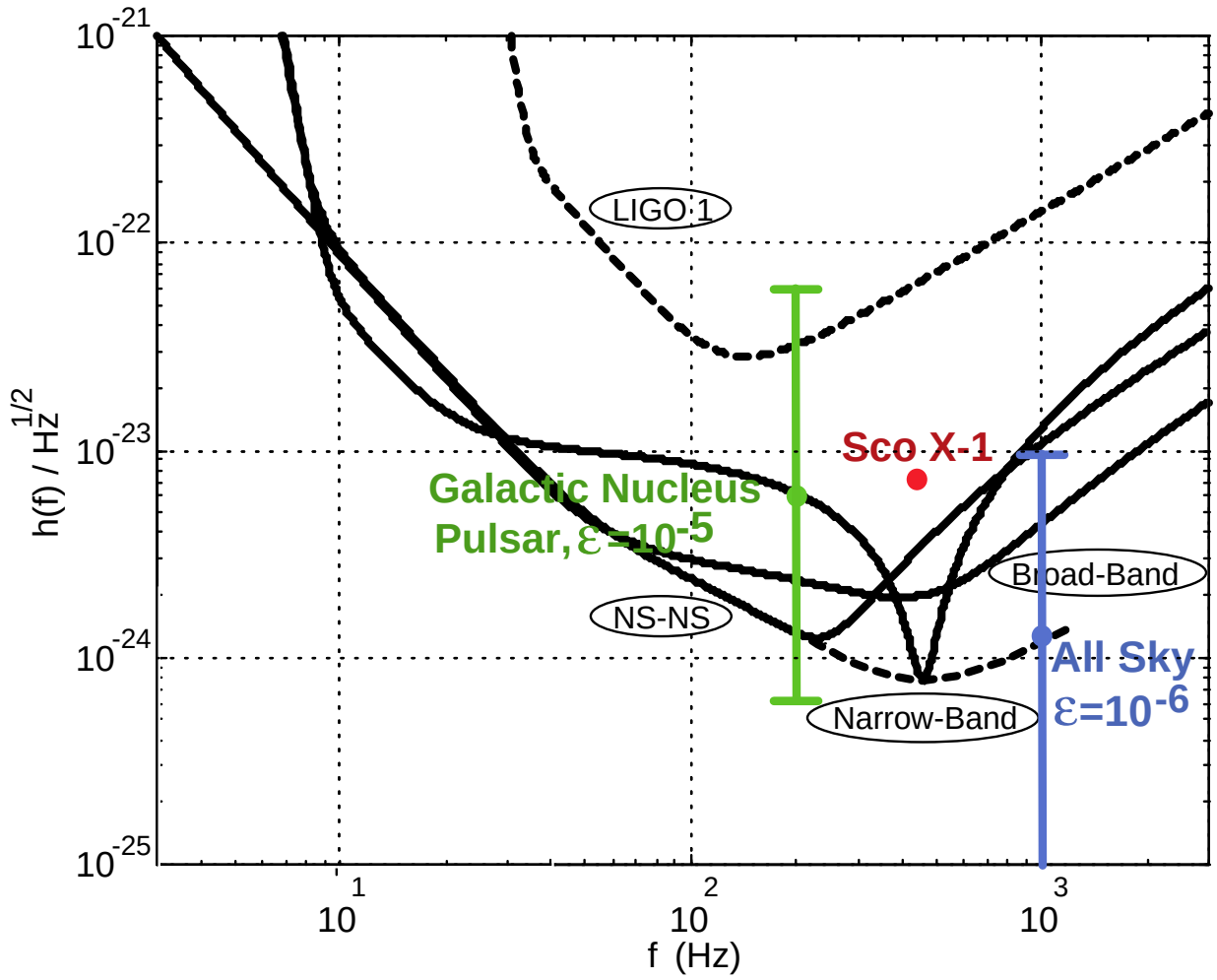


SPINNING NEUTRON STARS

- Pulsars in our Galaxy:
  - » Key uncertainty: NON-axisymmetry
    - – Maximum: $\varepsilon \sim 10^{-4}$ -- 10^{-6}
  - » Science from EM/GW cross correlations:
    - – NS Precession
    - – Physics of NS interiors -- e.g. from spinup after quakes
- LMXB's in our Galaxy (e.g. Sco X-1):
  - » Appear to be buffered at P_{rot} ~ 3-4 msec
  - » Accretion spinup balanced by GW spindown?
    - – R-mode instability? Accretion-induced NON-axisymmetry?
  - » X-ray flux => GW strength
  - » Science Payoff:
    - – NS physics --- viscosity, crustal strength, pycnonuclear reactions, ...

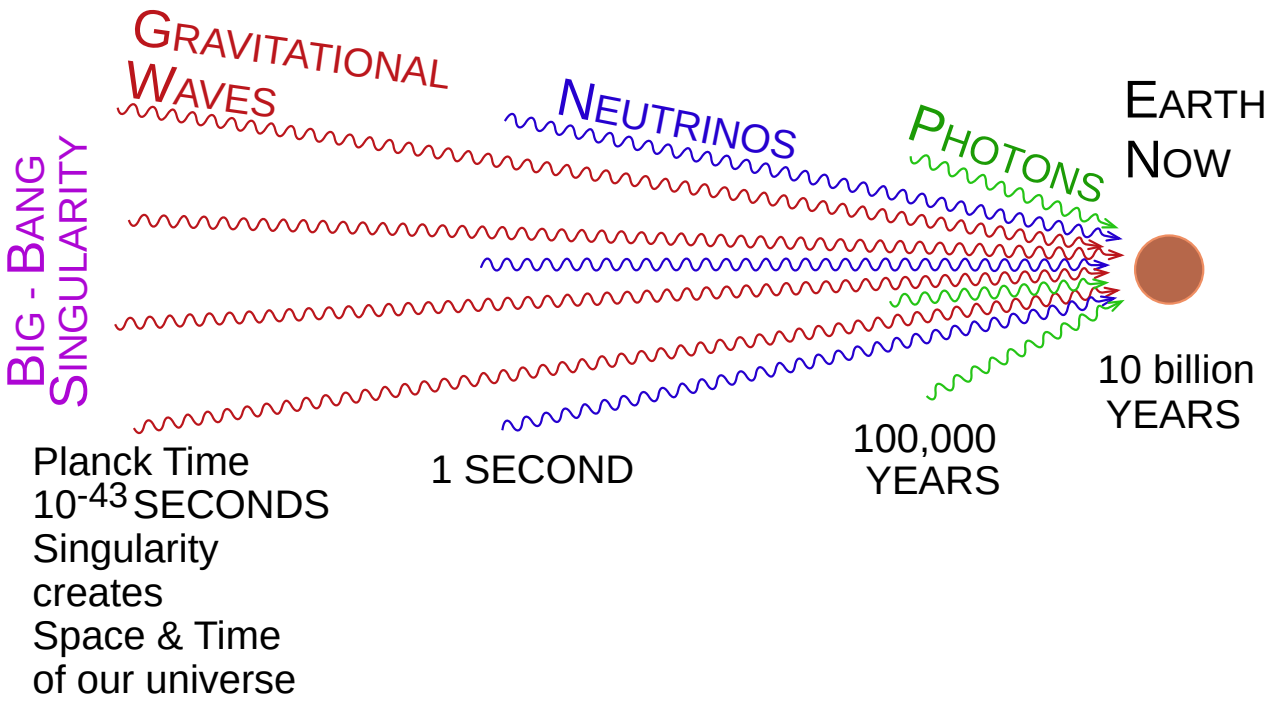
SPINNING NEUTRON STARS (cont)

- Searches: Narrow-Band best; Broad-Band good; NS-NS poor



STOCHASTIC BACKGROUND

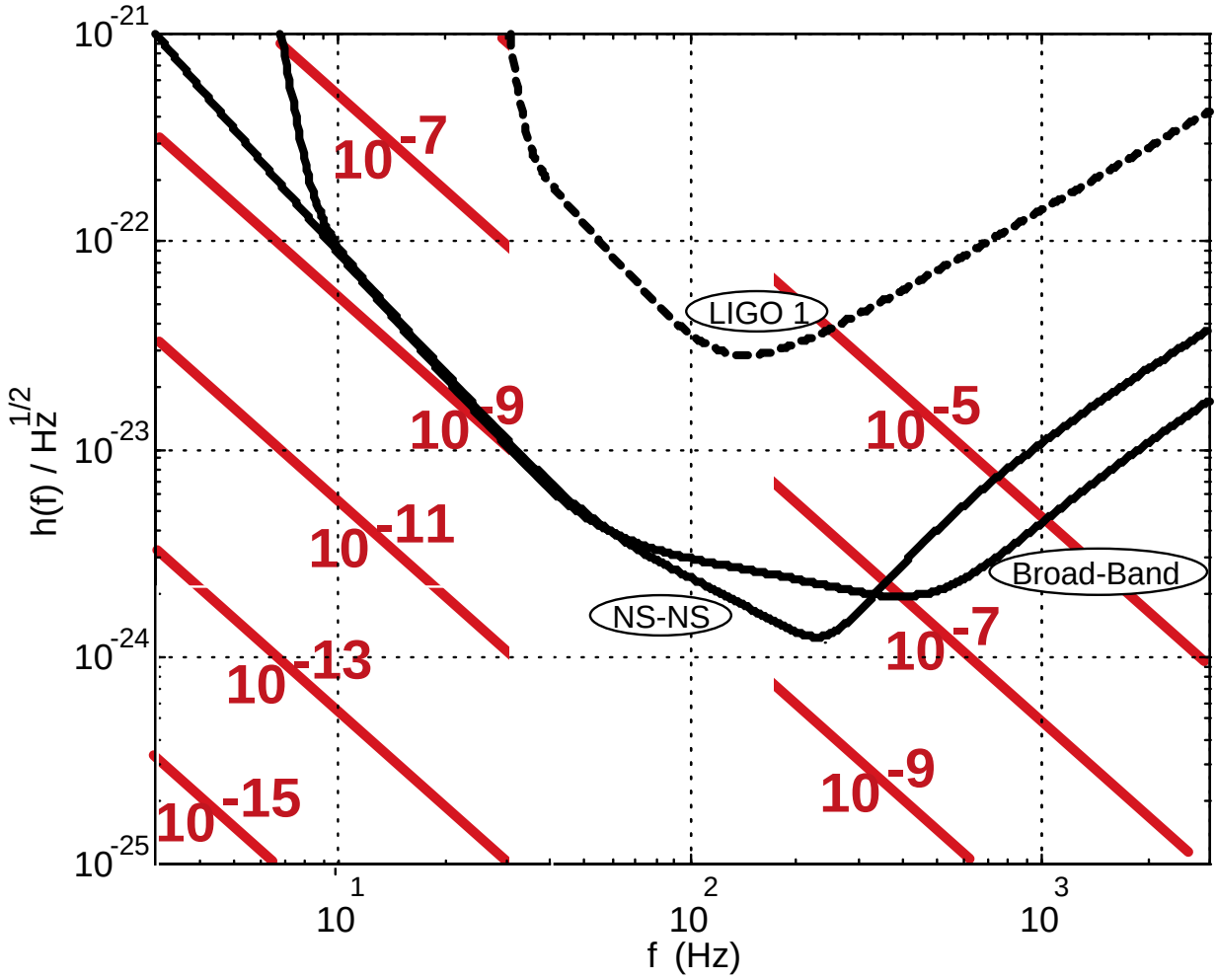
- Big-Bang Birth of Universe



  - » Strength: Ω = (GW energy in $\Delta f=f$)/(closure energy)
  - » Long-term Goal: map spectrum $\Omega(f)$ from f~10^{-17} Hz to f~10^{6} Hz
    - – In LIGO Band: $\Omega(f)$ fixed by physics of era 10^{-43} to 10^{-26} sec
    - – Standard Inflation predicts $\Omega \sim 10^{-15}$ in LIGO band (far too small for LIGO-I, II, III)
    - – Crude String-Theory models suggest Ω *could* be as high as 10^{-5} in LIGO band

STOCHASTIC BACKGROUND

- Search by cross-correlating interferometers
  - » Livingston-Hanford Dead Band: f ~ 70 Hz



- LIGO-I: $\Omega=10^{-5}$ LIGO-II: $\Omega=3\times10^{-9}$

UNKNOWN SOURCES

- Big Surprises are Likely