GRAVITATIONAL WAVE DETECTORS AND GALACTIC BINARIES

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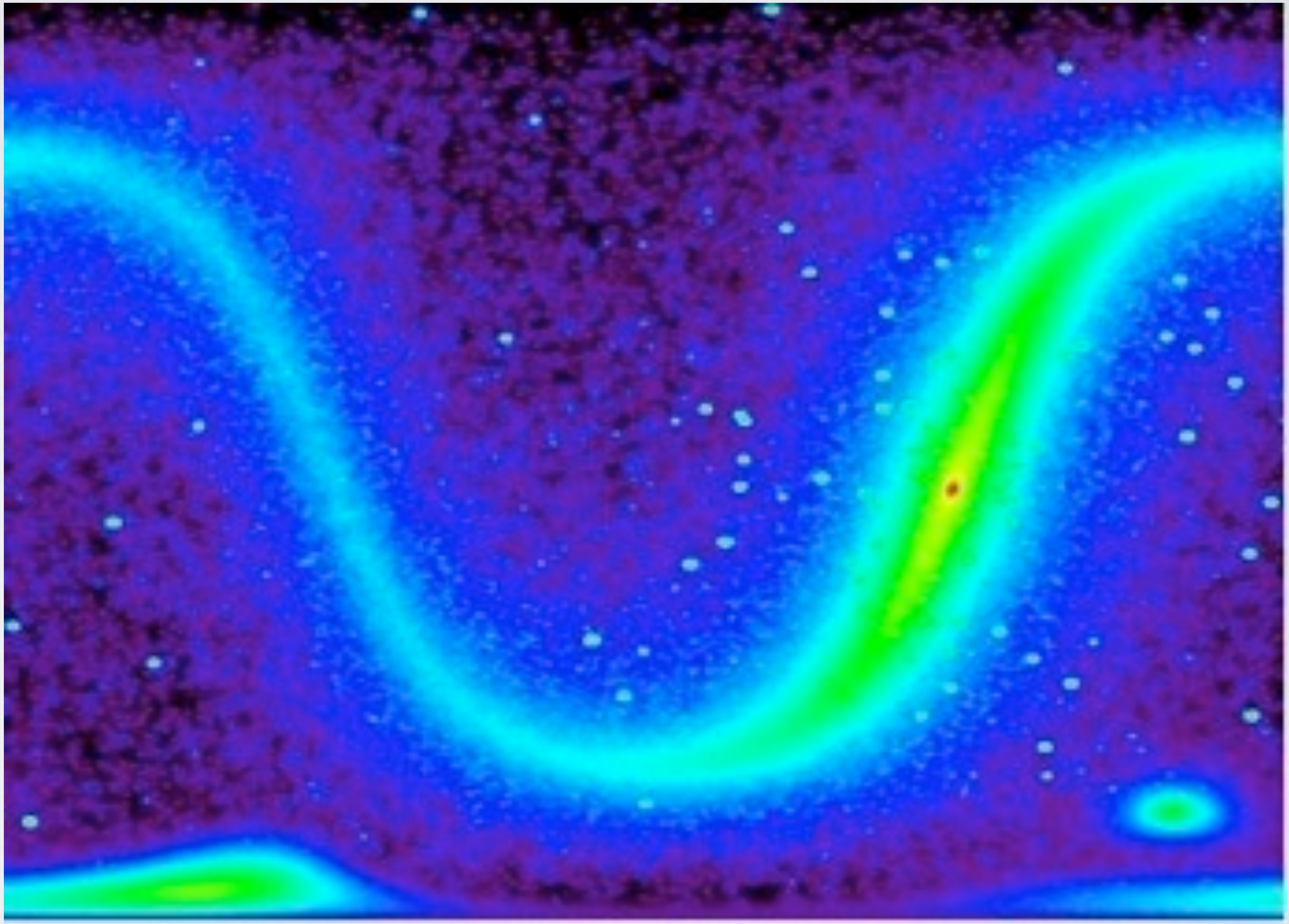
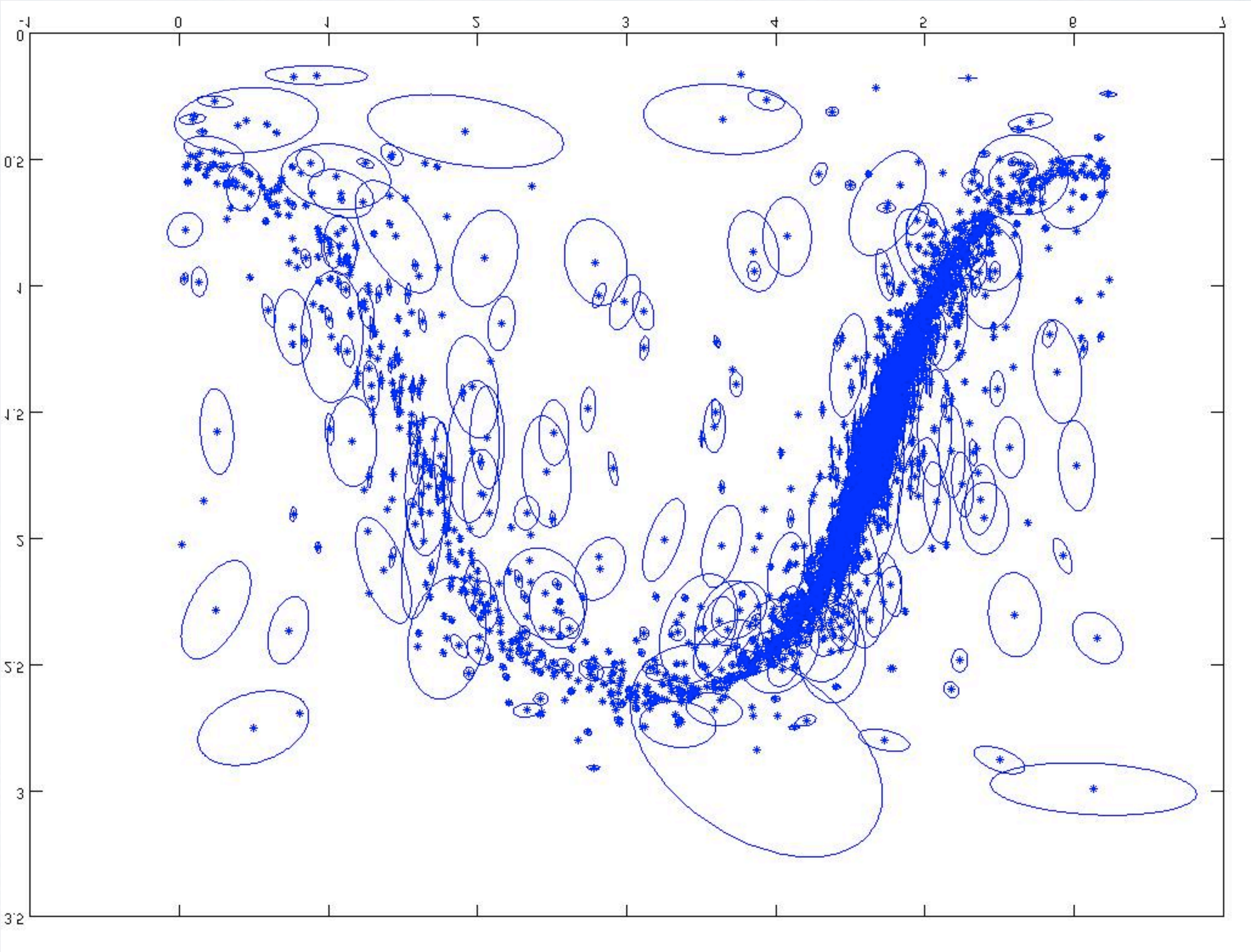
- The gravitational wave Galaxy
- Detector description
- Baseline and alternative configurations

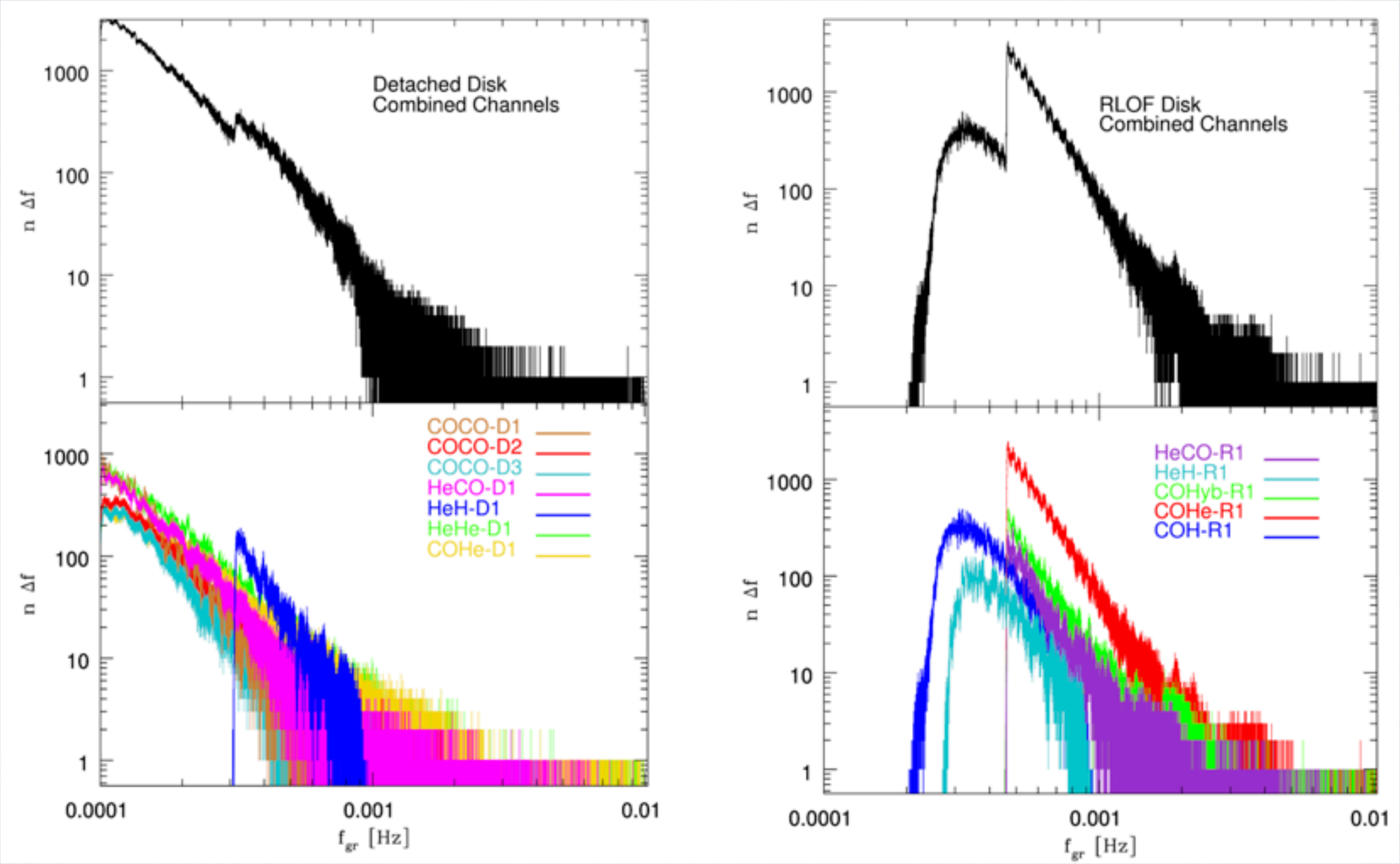
- The gravitational wave signal from the Galactic population of white dwarf binaries will consist of individually resolvable sources and a confusion-limited foreground.



- Individually resolvable means that the parameters describing the binary can be obtained with reasonable precision through data analysis (usually some kind of matched filtering.

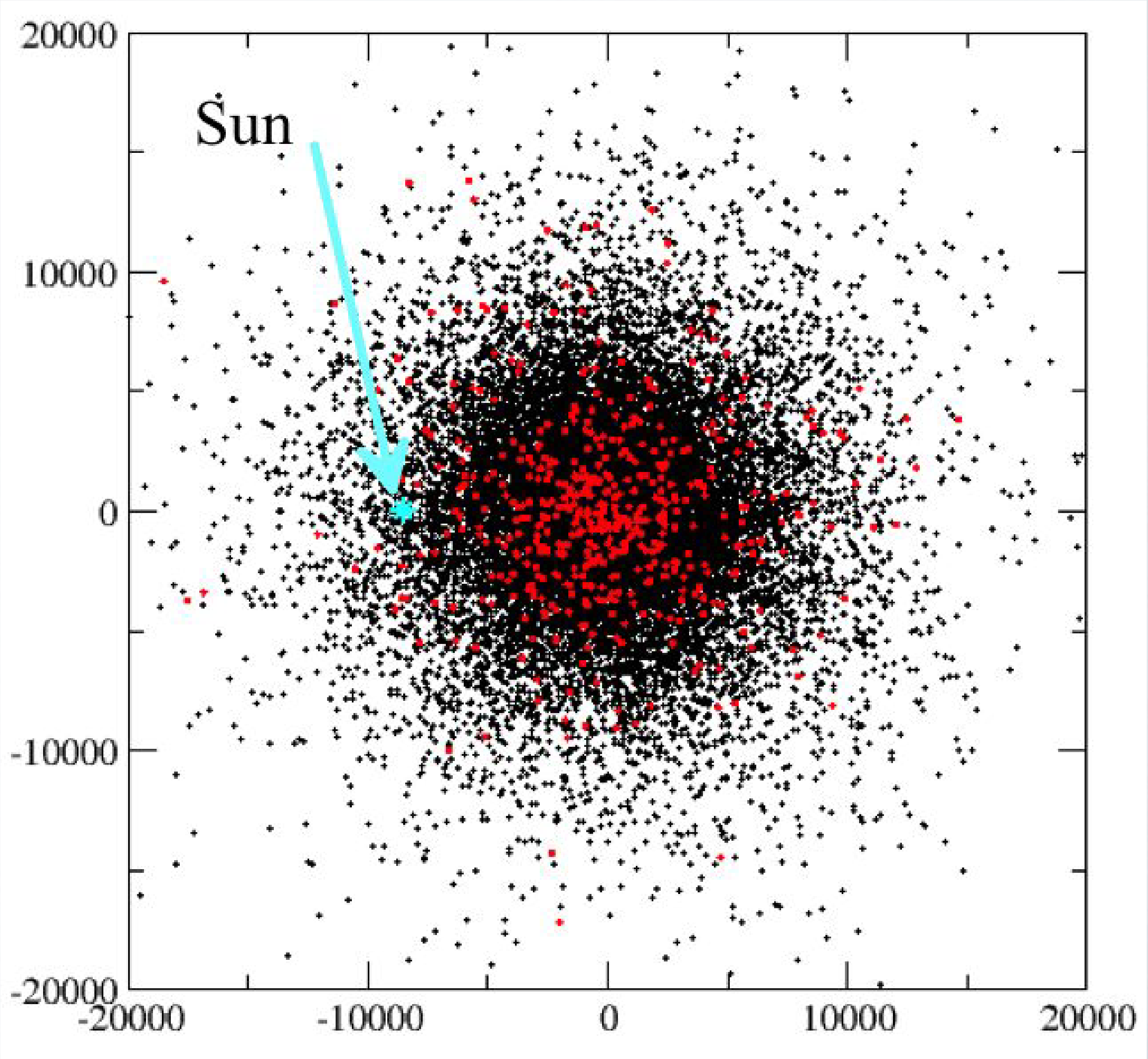


- The confusion-limited foreground is a result of signals from thousands of binaries in each resolvable frequency bin.

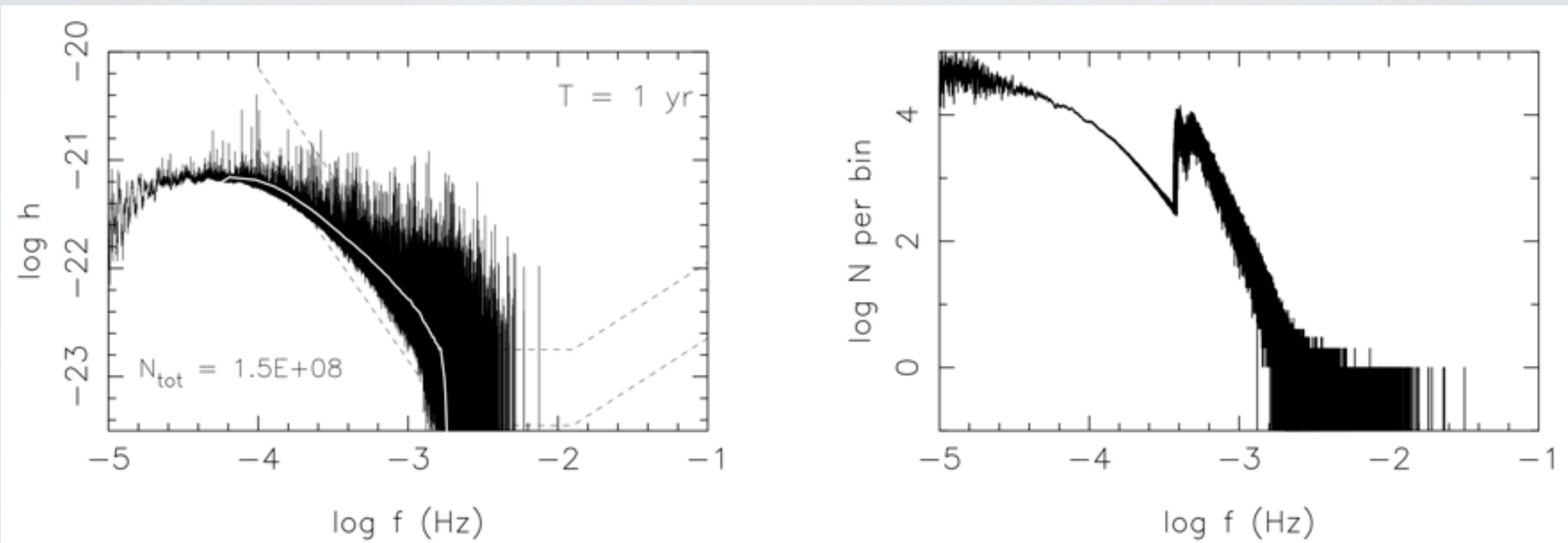


- If the "chirp" of resolvable systems can be measured and the system is driven by gravitational radiation alone, then the distance can be measured and the chirp mass can be obtained.

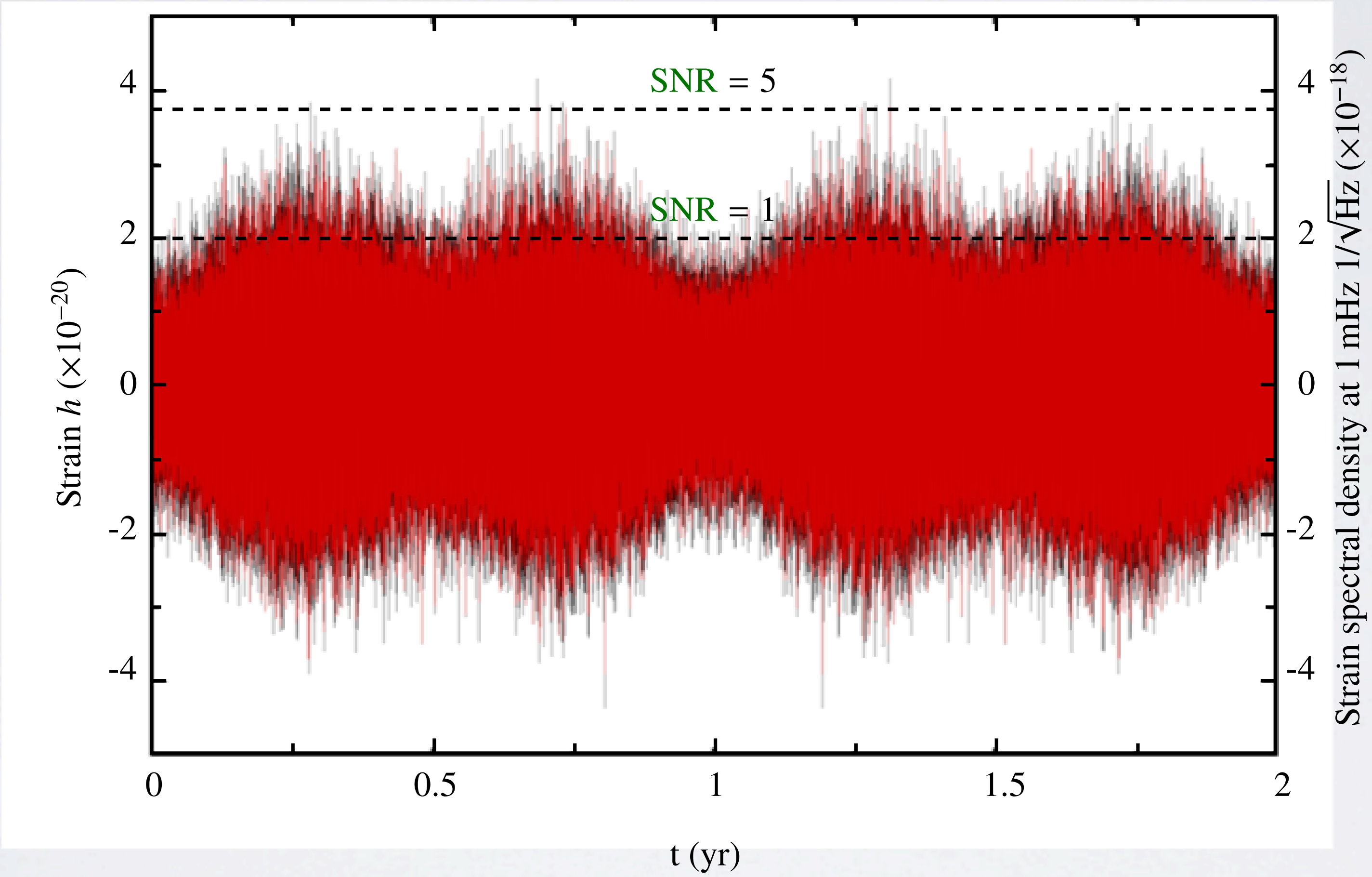
- Sky location and distance can be used to determine the spatial distribution of white dwarf binaries.



- The confusion-limited signal is dominant at low frequencies (f<~3mHz).



- The foreground is based mostly on the disk population and so it is anisotropic.

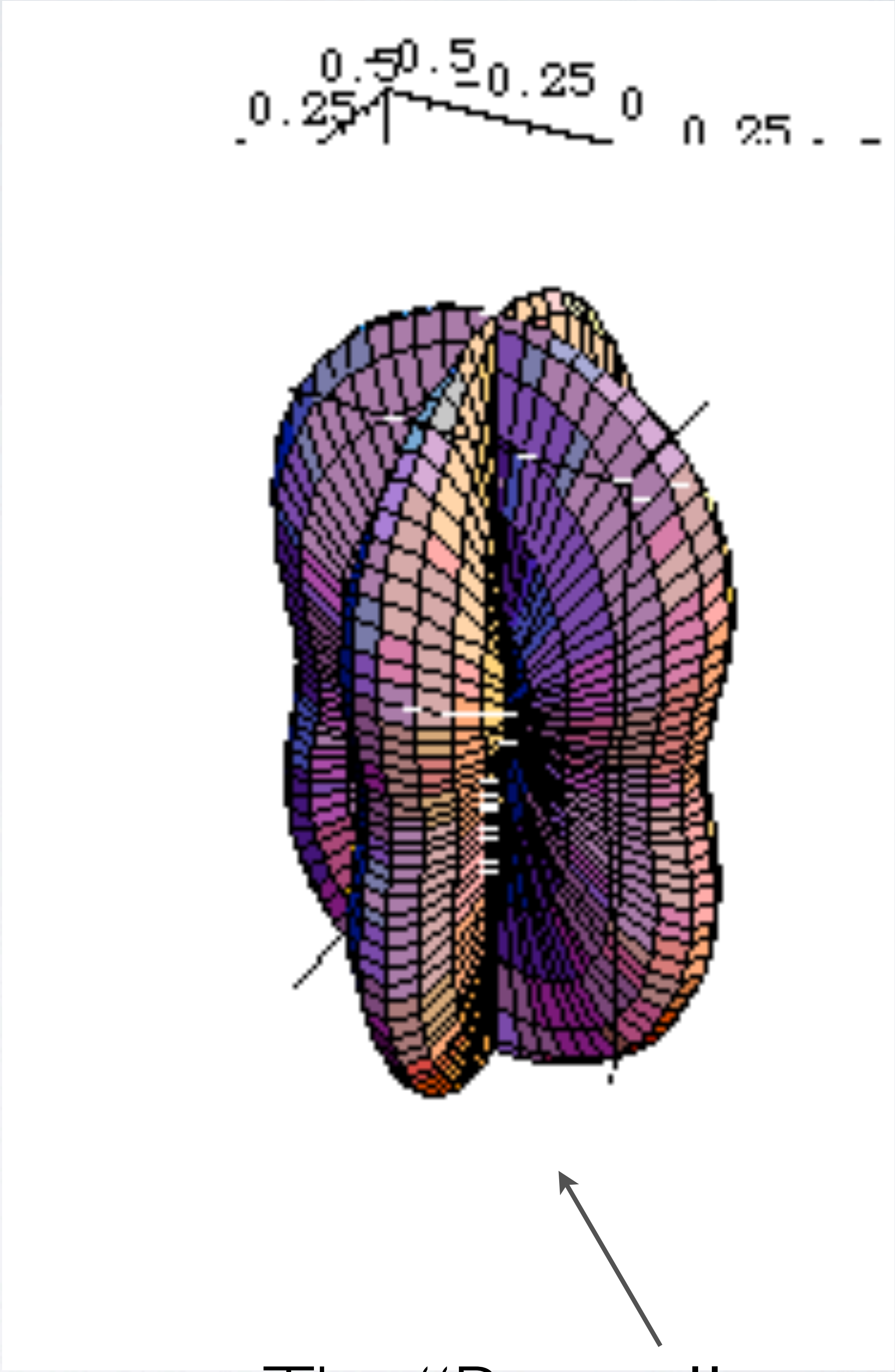


- The spectrum of the foreground may provide probe different star formation rates and different evolutionary scenarios.

- Assuming space-based interferometric gravitational wave detectors, different configurations have different consequences on the ability to extract information from both resolvable sources and the confusion foreground.

- Noises:
  - Acceleration noise: Stray forces on the proof mass.
  - Shot noise: Quantum fluctuations in light intensity.
  - Position noise: Measurement and control noise.

- Motion of the detector influences sensitivity to direction of the sources.
  - Rotation of the detector within its plane.
  - Precession of the plane.
  - Motion of the guiding center of the detector plane relative to the stars.



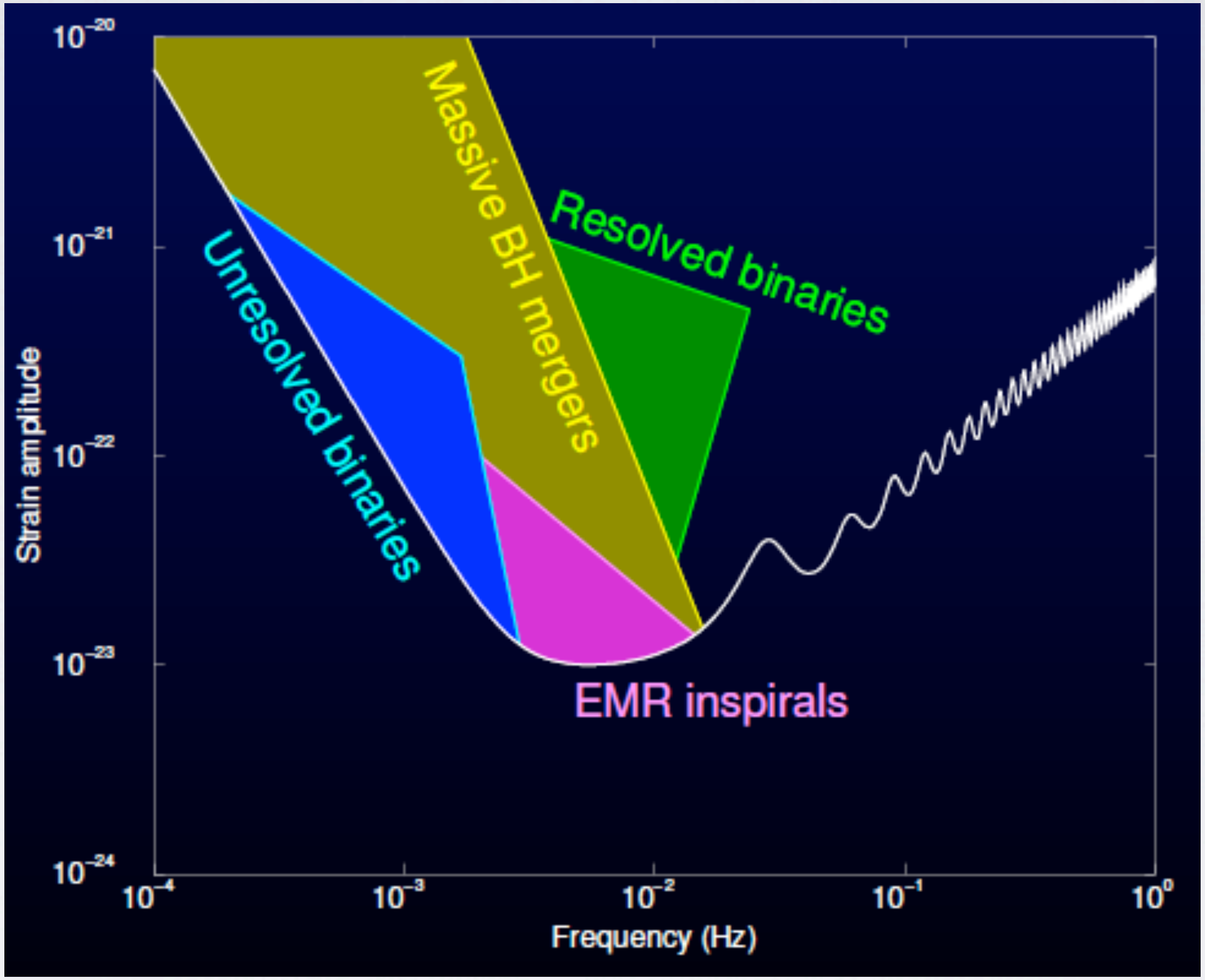
The "Peanut"

- Sensitivity curves are usually plots combining the instrument noise and the transfer function along with some sort of angle/orientation/polarization averaging.

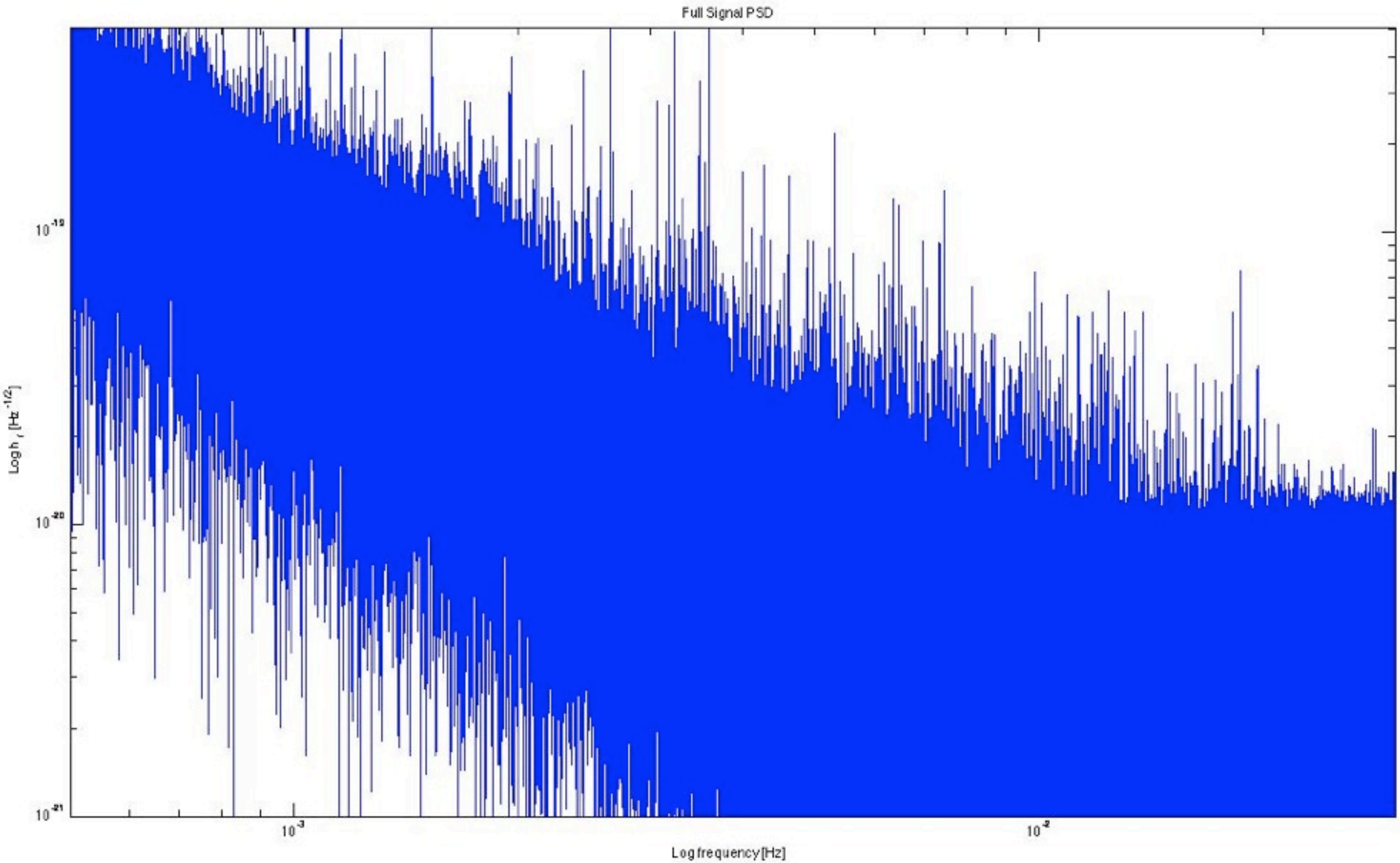
- This allows one to plot the absolute strain amplitude of a suspected source and compare it with the expected noise level.

- Can be misleading due to averaging.

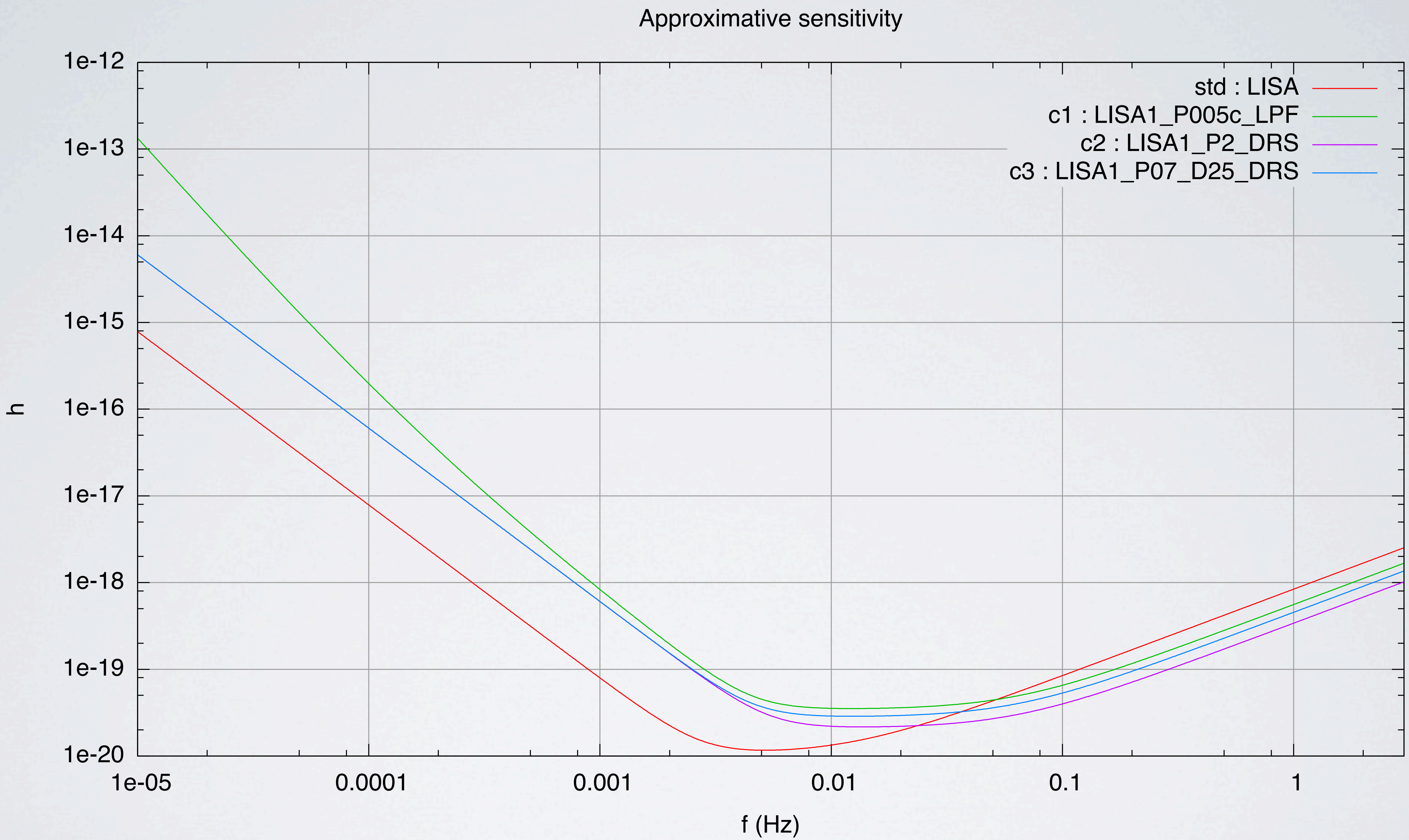
- Require an assumed observation time (usually 1 or 2 years.)

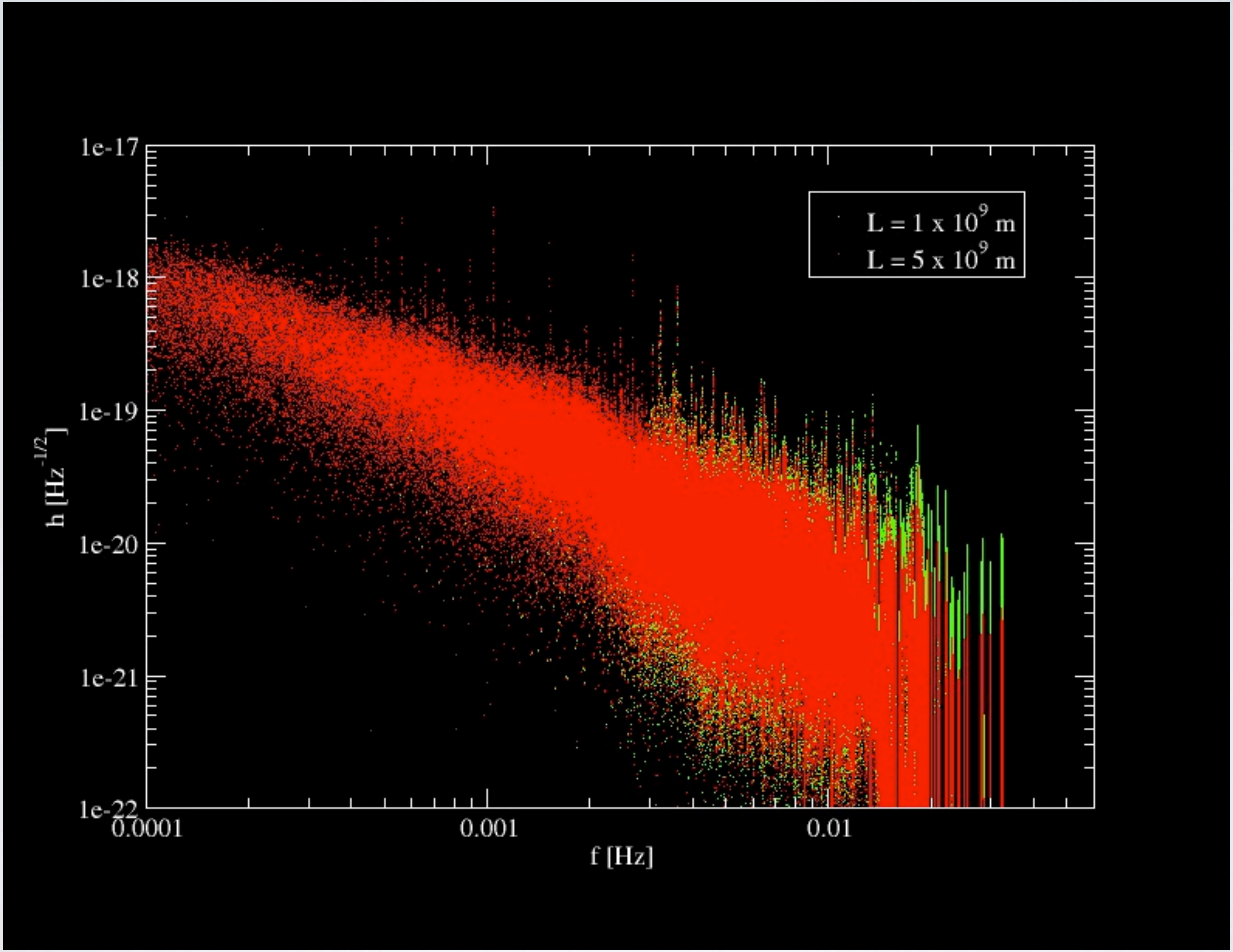


Massive BH mergers
Resolved binaries
Unresolved binaries
EMR inspirals
Strain amplitude
Frequency (Hz)
10^{-20}
10^{-21}
10^{-22}
10^{-23}
10^{-24}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}


Full Signal PSD
10^{-19}
10^{-20}
10^{-21}
Log h [Hz$^{-1/2}$]
10^{-3}
10^{-2}
Log frequency [Hz]

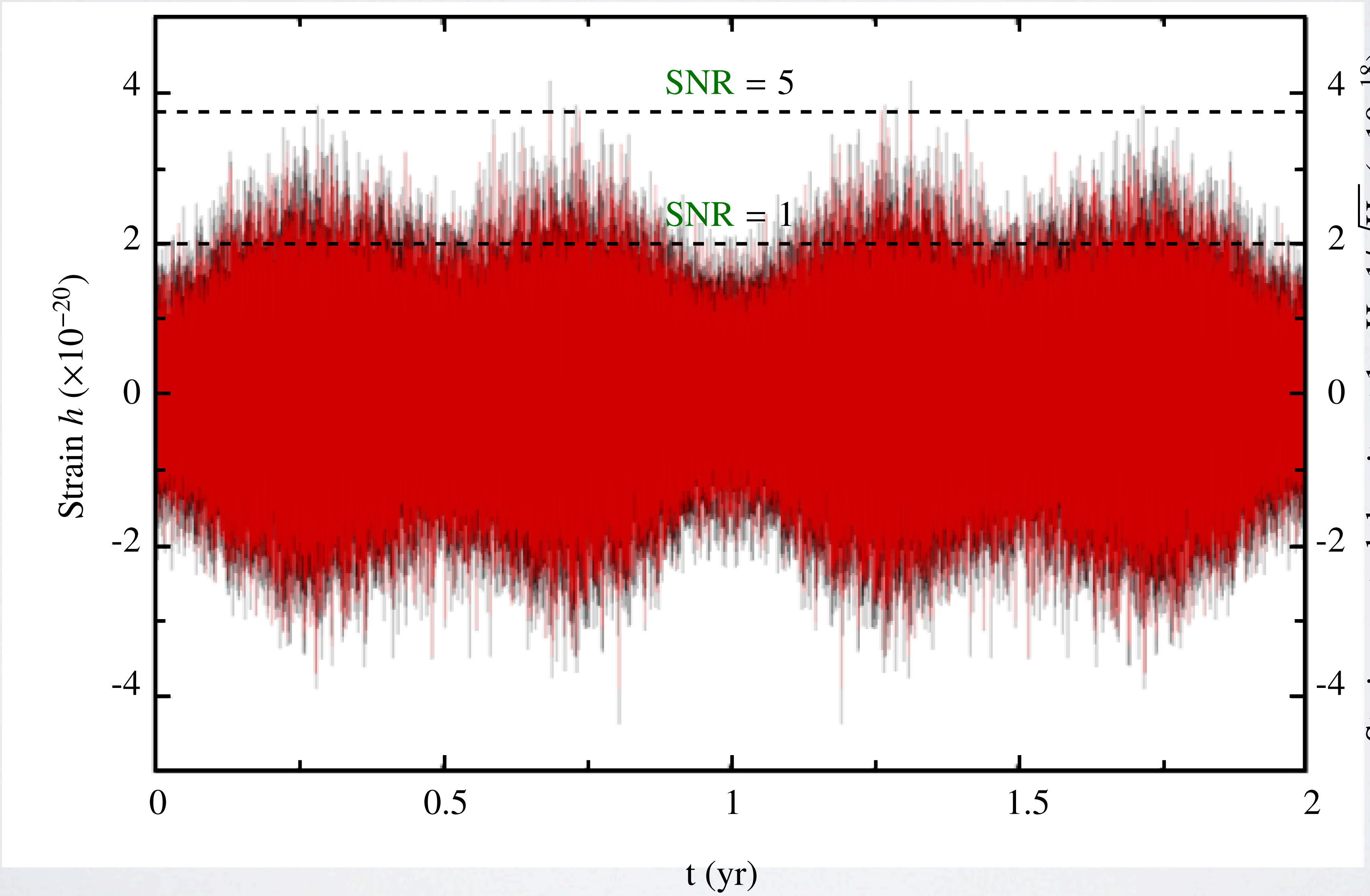
- Shorter armlengths:
  - Increase acceleration noise
  - Decrease shot noise
  - Increase position noise
  - Improve response at high frequencies


Approximative sensitivity
std : LISA
c1 : LISA1_P005c_LPF
c2 : LISA1_P2_DRS
c3 : LISA1_P07_D25_DRS
h
1e-12
1e-13
1e-14
1e-15
1e-16
1e-17
1e-18
1e-19
1e-20
1e-05
0.0001
0.001
0.01
0.1
1
f (Hz)



1e-17
1e-18
1e-19
1e-20
1e-21
1e-22
0.0001
0.001
0.01
f [Hz]
h [Hz$^{-1/2}$]
L = 1 x 10^{9} m
L = 5 x 10^{9} m

- LISA-like orbits:
  - Add annual rotation of the “peanut”
  - Annual variation of polarization phase
  - Annual variation of Doppler phase



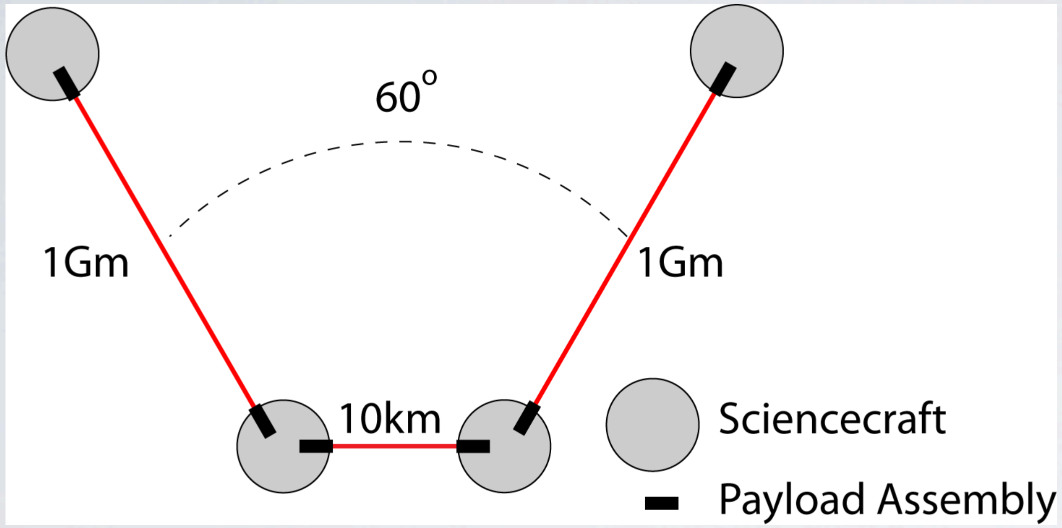
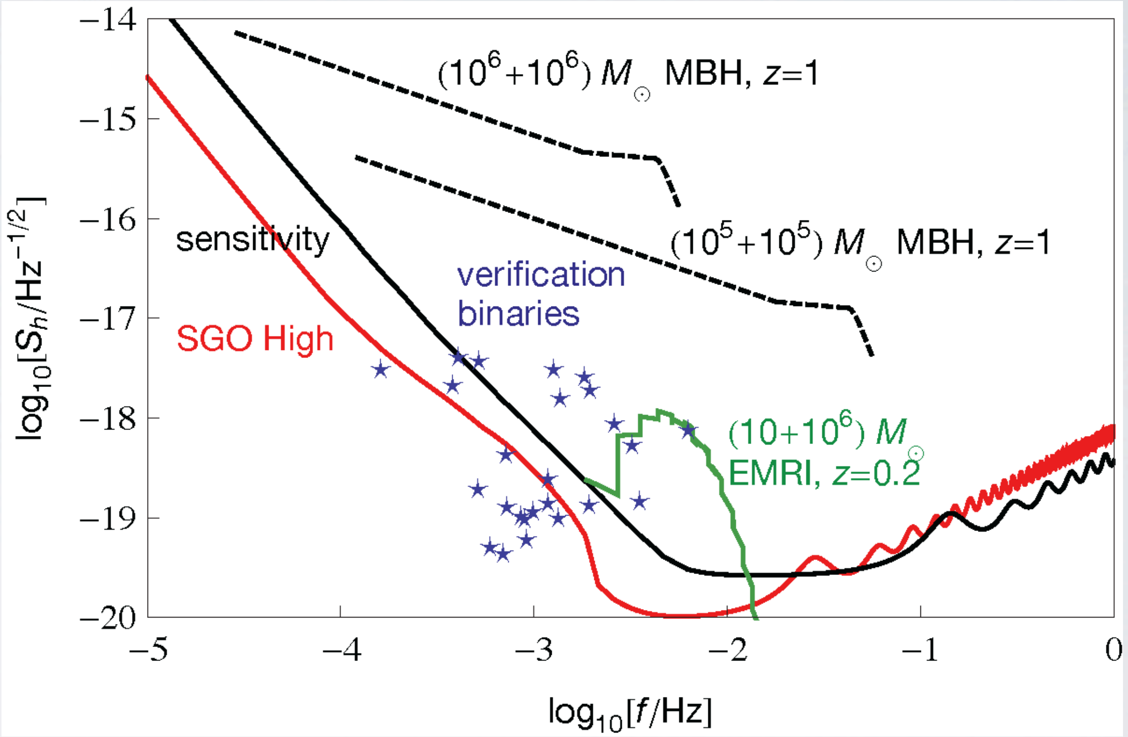


Figure 1: Constellation geometry for SGO Low



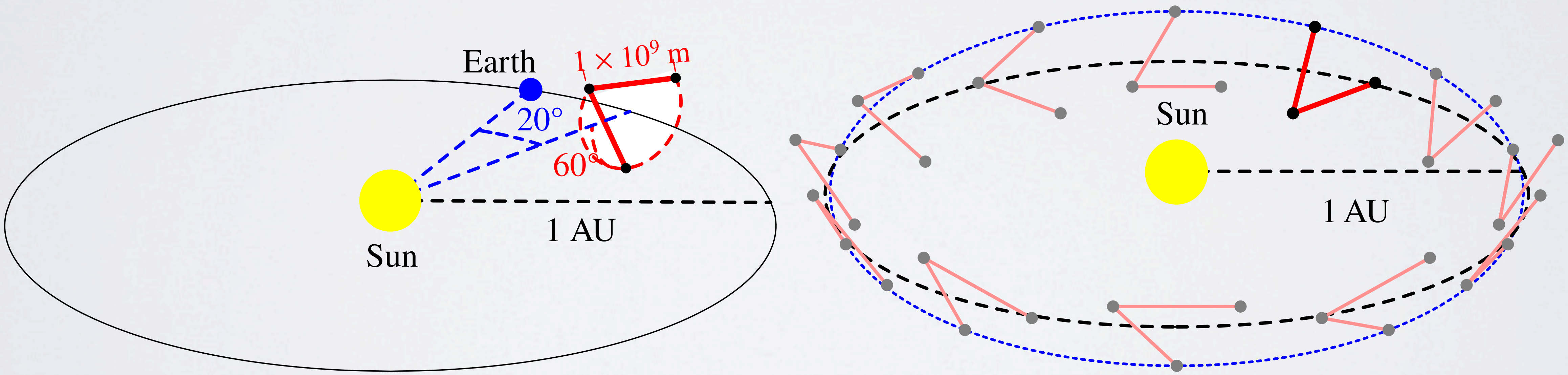
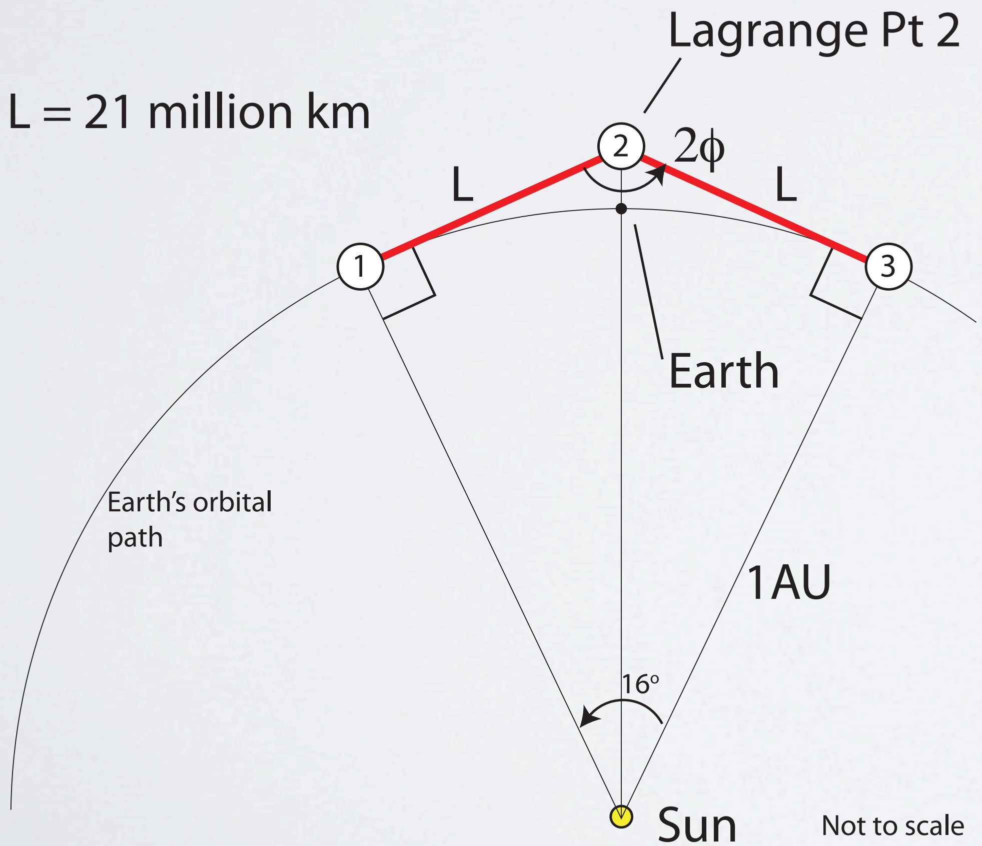
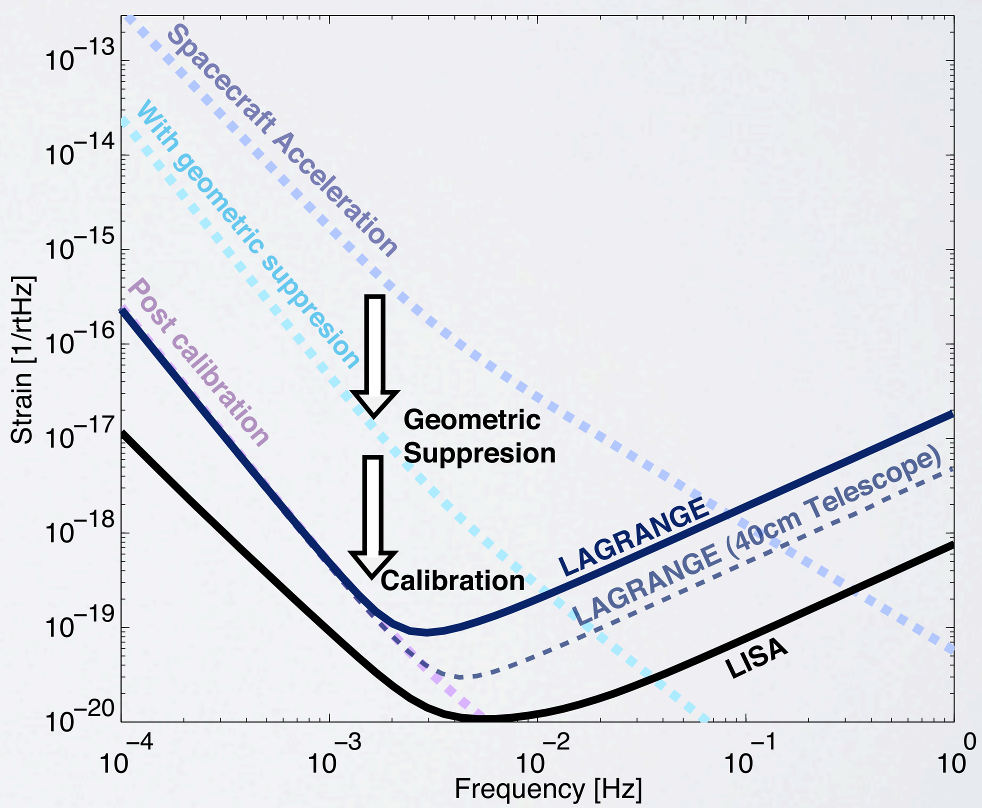


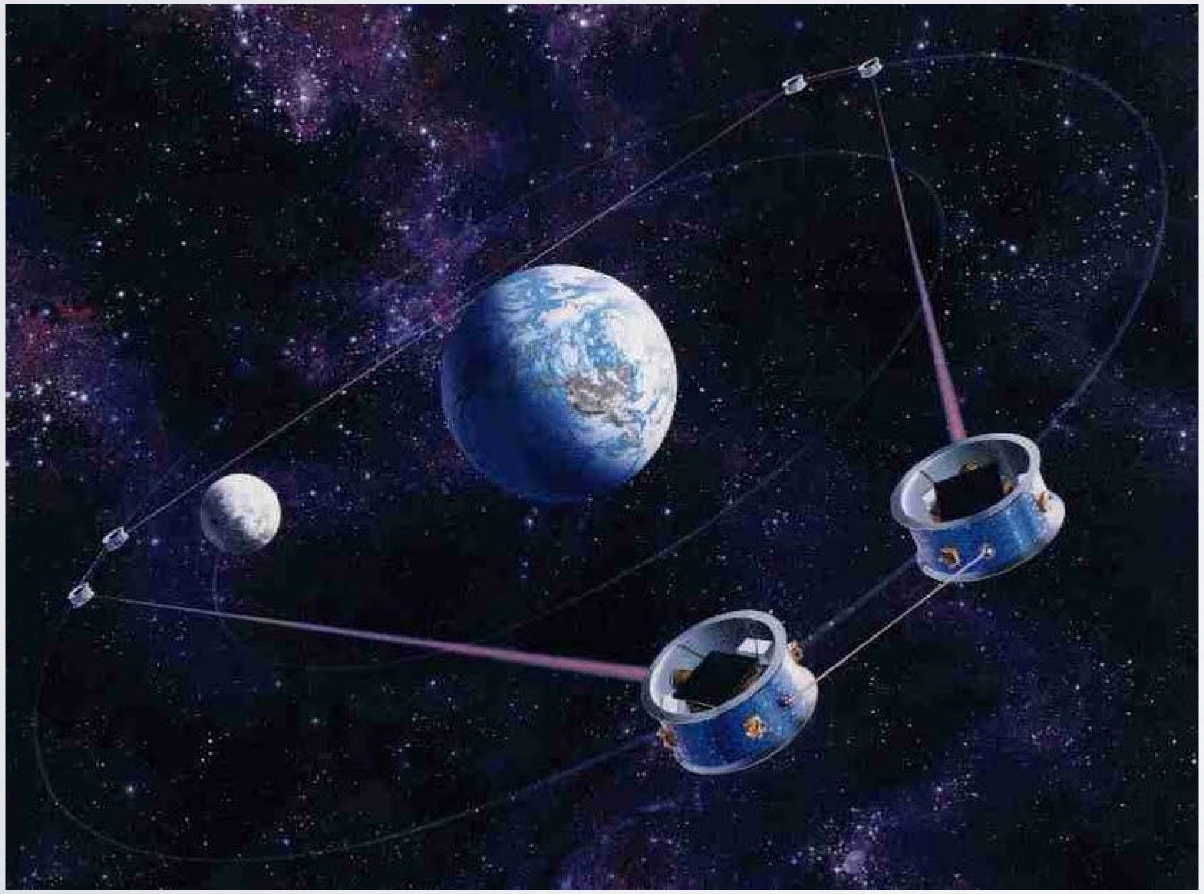
Figure 3.1.: *The NGO orbits: The constellation is shown trailing the earth Earth by about* 20° *(or* 5×10^7 km*) and is inclined by* 60° *with respect to the ecliptic. The trailing angle will vary over the course of the mission duration from* 10° *to* 25°*. The separation between the S/C is* 1×10^6 km.

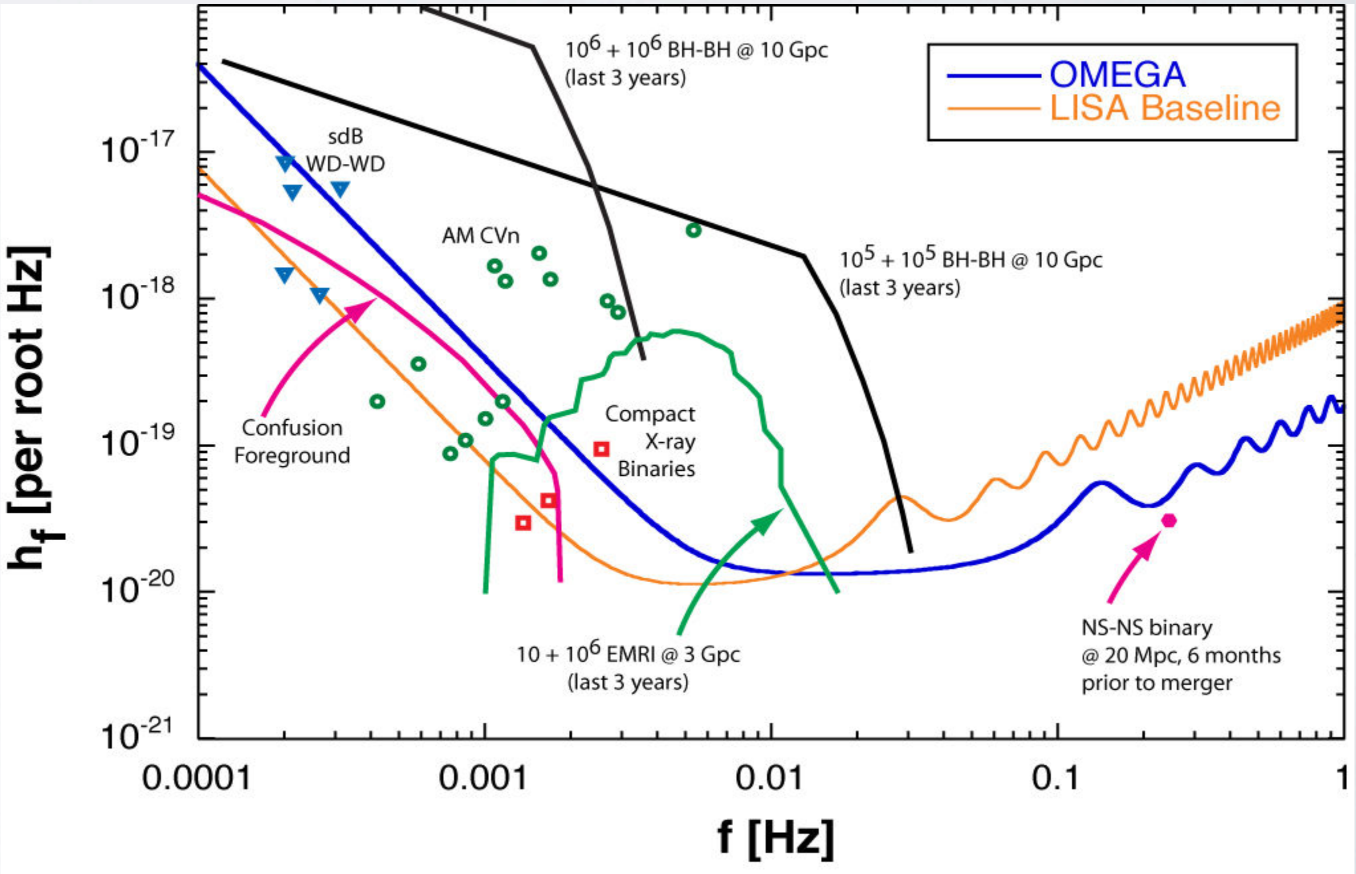
- Other heliocentric orbits:
  - No precession of the orbital plane -> loss of sensitivity pattern variation.
  - Annual polarization phase remains.
  - Annual Doppler phase remains.





- Geocentric orbits
  - Slight plane precession.
  - Polarization phase variation depends on armlength (through orbital radius).
  - Doppler phase variation is still one year.





SUMMARY

- Gravitational wave observations can explore the whole Galaxy.

- Both individual sources and the unresolved foreground contain useful information.

- Mission de-scopes have a variety of consequences on the amount of science recoverable from DWD observations.

GRAVITATIONAL WAVES

- Quadrupole Formula

$$h_+ = 2\frac{G^{5/3}\mathcal{M}^{5/3}}{c^4 d}\left(2\pi f\right)^{2/3}\left(1+\cos^2\iota\right)\cos\left(2\pi f t\right)$$

$$h_\times = -4\frac{G^{5/3}\mathcal{M}^{5/3}}{c^4 d}\left(2\pi f\right)^{2/3}\cos\iota\sin\left(2\pi f t\right)$$

- Chirp mass $\mathcal{M} = \left(M_1 M_2\right)^{3/5}\left(M_1+M_2\right)^{1/5} = \mu^{3/5}M^{2/5}$

- Inspiral $\dot{f} = \frac{96}{5}\frac{G^{5/3}\mathcal{M}^{5/3}}{c^5}f^{11/3}$

- Outspiral — ?

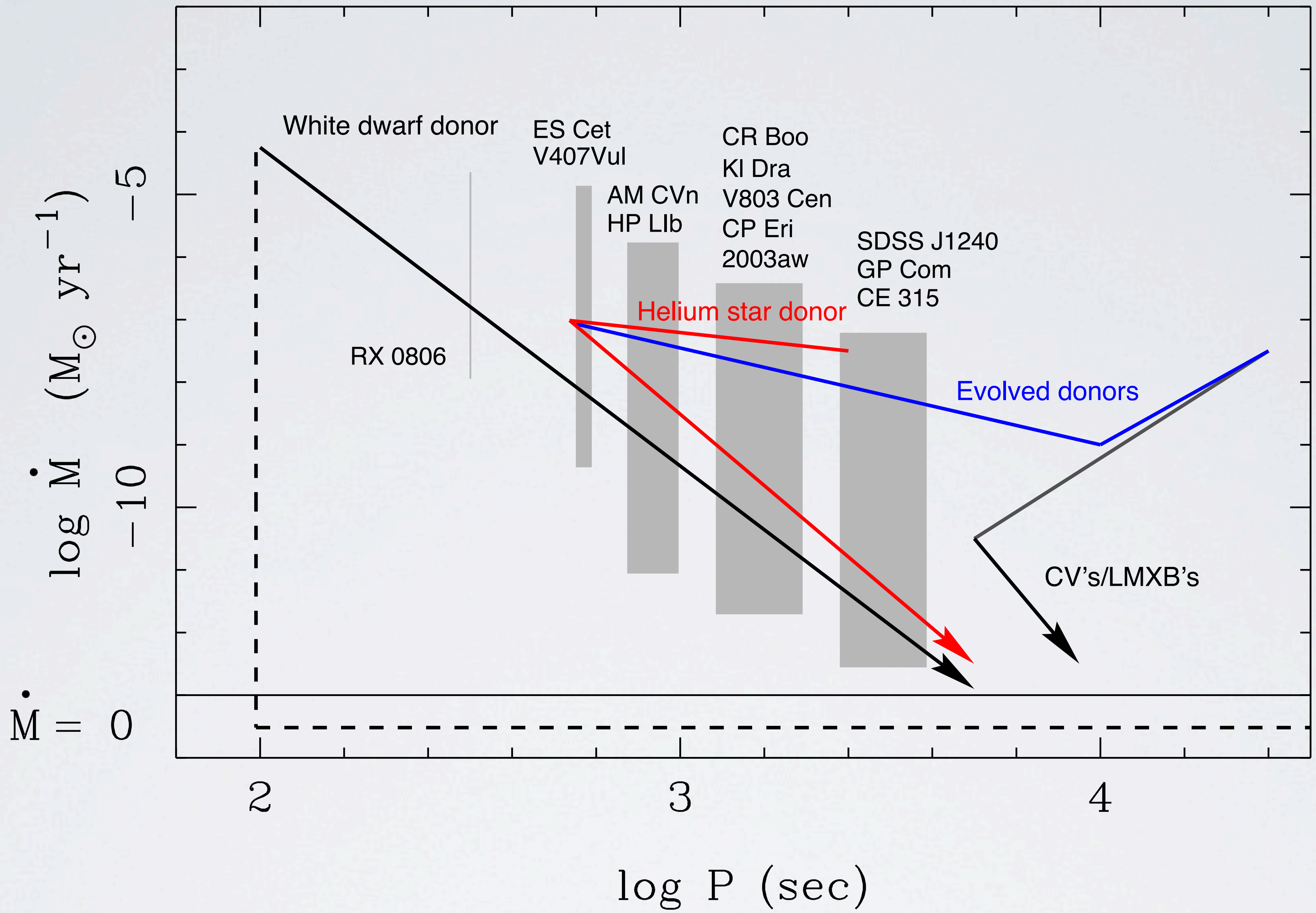
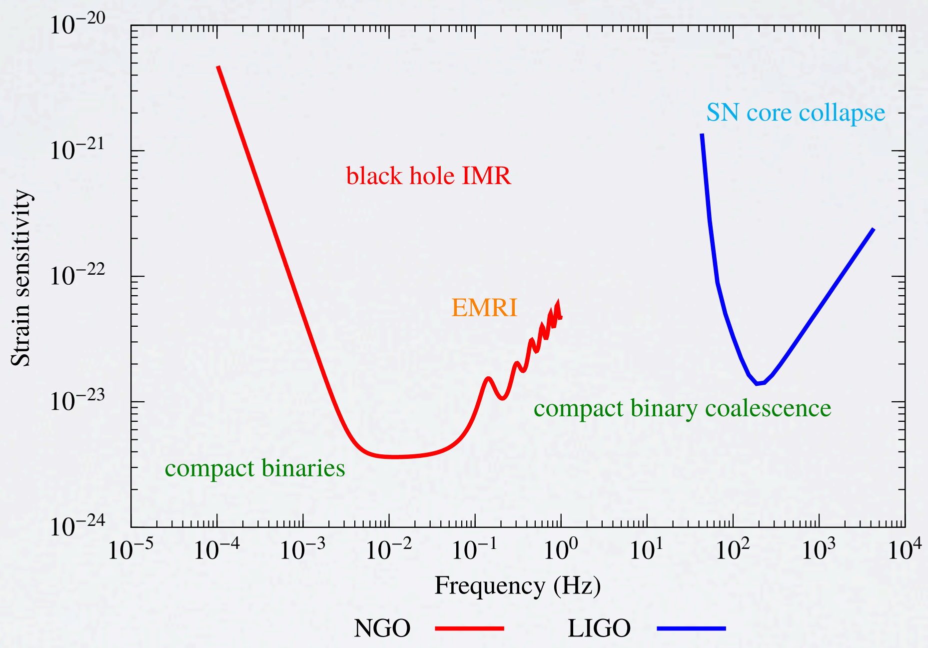
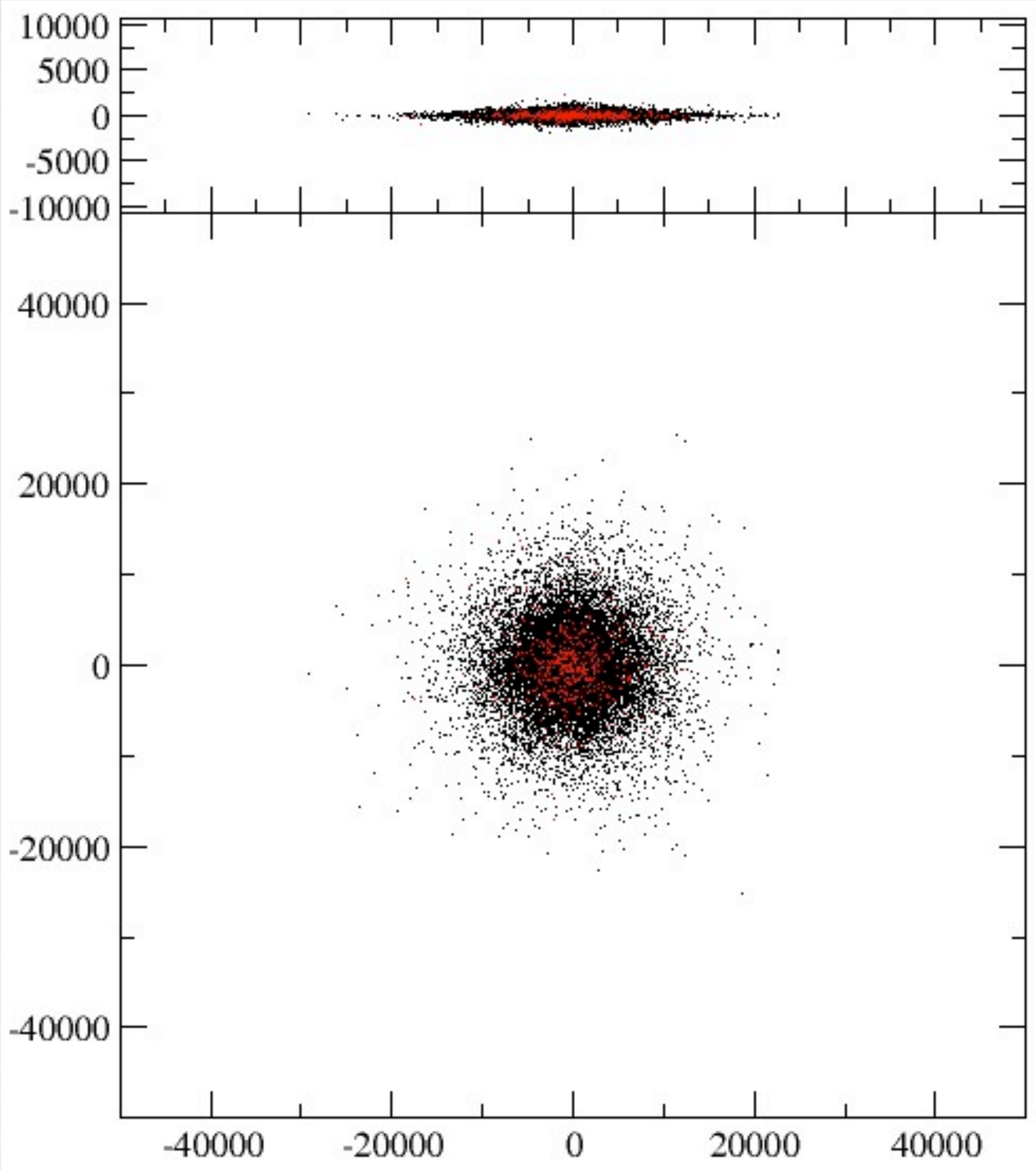


Figure 1. Formation paths of AM CVn stars (see text). The known systems (including the two candidates) are shown at their orbital period.



10^{-20}
10^{-21}
10^{-22}
10^{-23}
10^{-24}
Strain sensitivity
SN core collapse
black hole IMR
EMRI
compact binary coalescence
compact binaries
10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 10^{0} 10^{1} 10^{2} 10^{3} 10^{4}
Frequency (Hz)
NGO
LIGO


10000
5000
0
-5000
-10000
40000
20000
0
-20000
-40000
-40000
-20000
0
20000
40000

AM CVn stars are among the expected 'verification binaries' for a number of proposed space-based gravitational wave missions. I will discuss the expected characteristics of the detectable population of AM CVn stars and other white dwarf binary systems in relation to several proposed mission concepts.