

Gravitational Waves

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| FREQUENCY | SOURCES | METHOD |
|-----------------------------|---|---------------------------------------|
| 1. $\sim 10^{-16}$ | Primordial | Anisotropy of μ wave background. |
| 2. $\sim 10^{-9}$ | Primordial, Cosmic strings | Timing of milli second pulsars |
| 3. $\sim 10^{-4} - 10^{-1}$ | Binary stars, Super massive black holes | Doppler tracking of space craft, LISA |
| 4. $\sim 10^{-10^3}$ | Inspirals : NS/NS, NS/BH, BH/BH Super novae spinning NS | VIRGO, LIGO, GEO and TAMA |
| 5. $\sim 10^3$ | Inspirals : NS/NS, NS/BH, BH/BH Super novae spinning NS | Cryogenic Resonant bar detectors |

- SIGNALS:-**
1. Primordial sources – Stochastic waveform
 2. Binaries – quasi , sinusoidal sweeping in frequency and amplitude as they spiral towards mutual coalesce.
 3. Supernovae – Gravitational wave bursts.
 4. Pulsars – Periodic waveform due to rotation of non-axis symmetric neutron star.

DETECTORS

WEBER BAR:

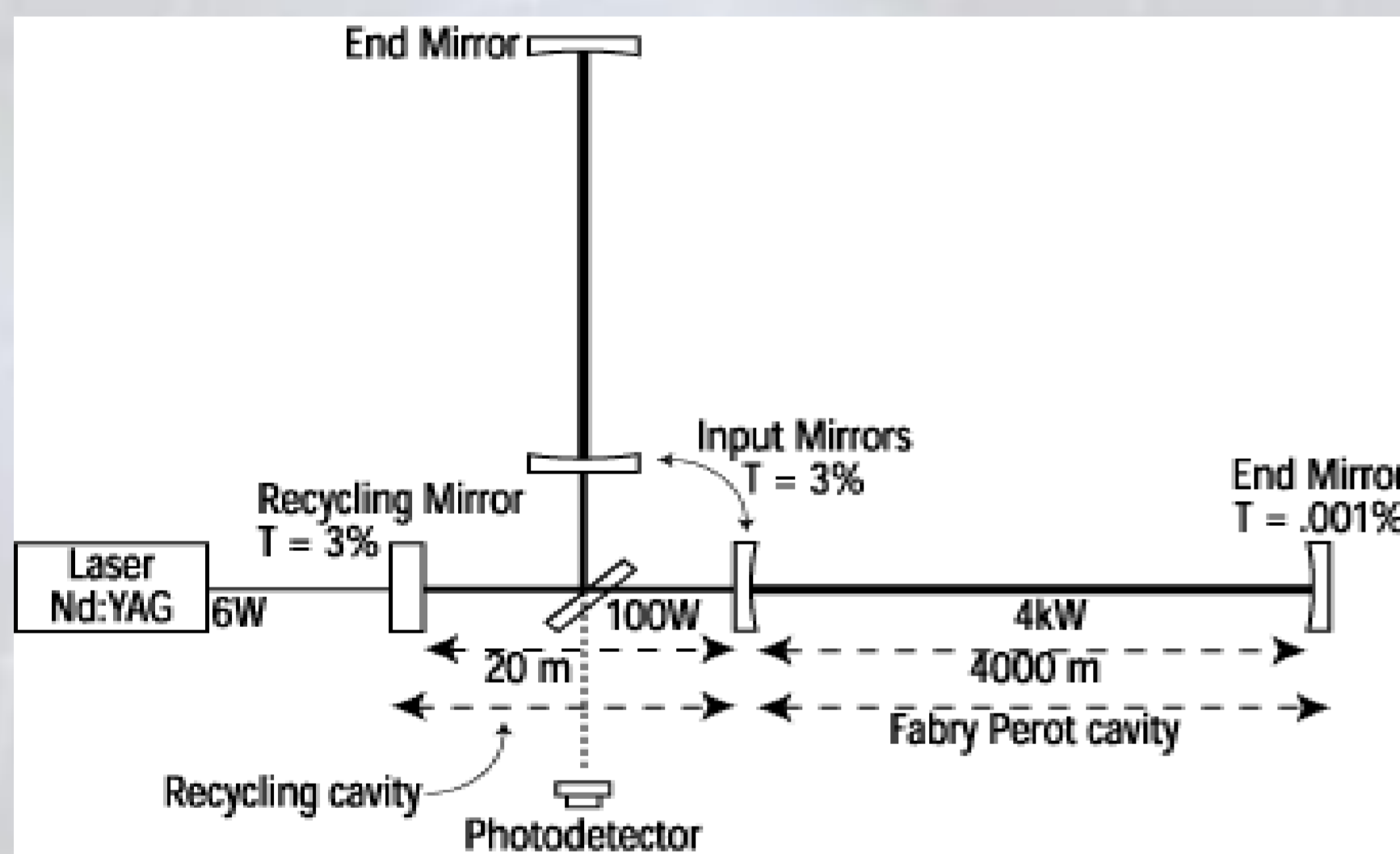
- Massive Aluminium cylinders vibrating at resonance frequency 1660 Hz.
- Very sensitive piezoelectric sensors capable of detecting change of the order of 10^{-19} meters.
- Efforts are being made to develop a detector which can sense the waves in all directions like the Mini Grail.



Credits: bigear.org

LASER INTERFEROMETER:

- The core is a simple Michelson Interferometer
- Main aim – Power amplification



Credits : ligo.caltech.edu

NOISE

SEISMIC NOISE :

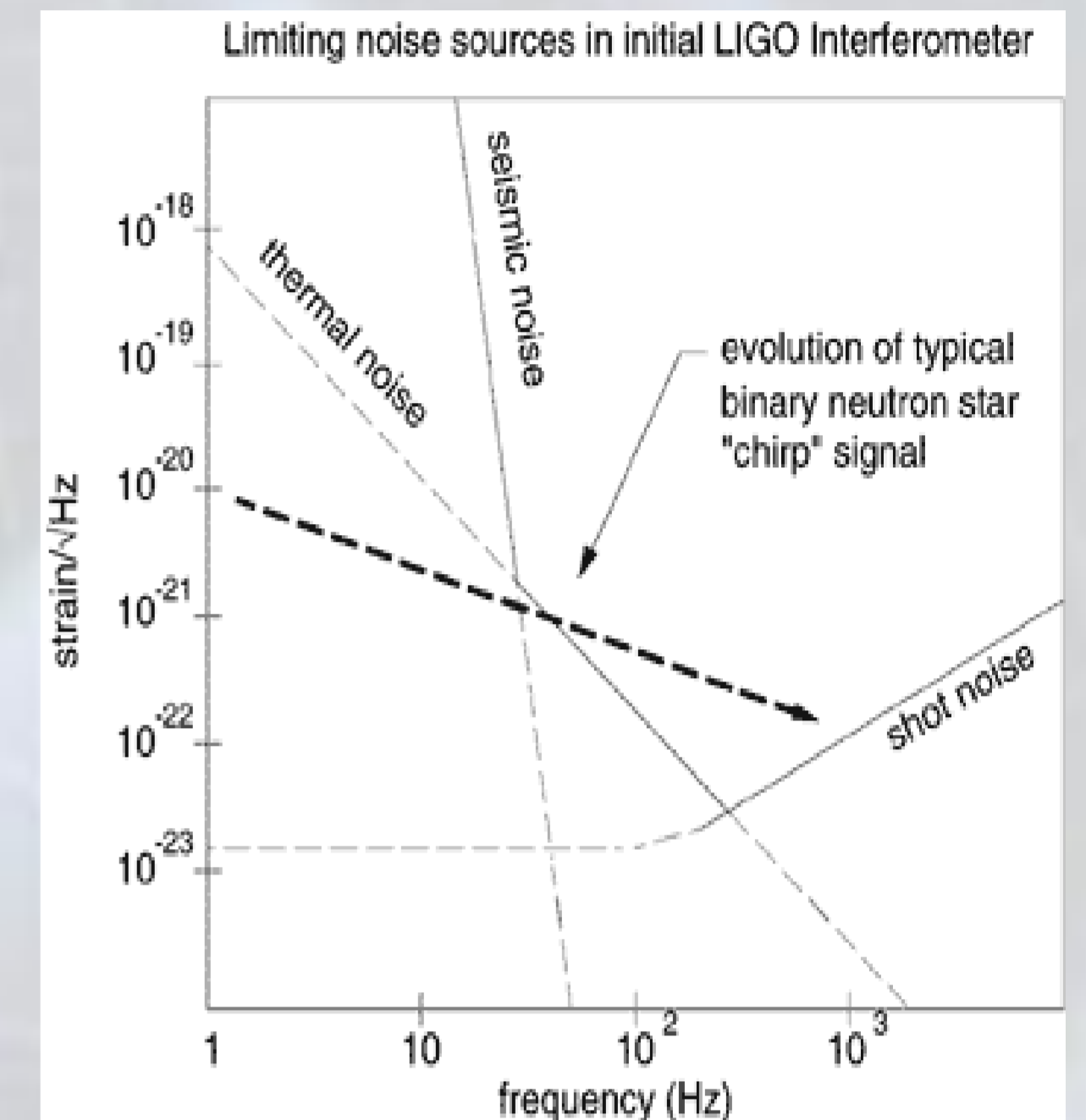
- Seismic activities , ocean waves
- Human activities etc

THERMAL NOISE :

- Brownian motion of particles on the surface of the mirrors & the fused silica that hold the mirrors.

PHOTON SHOT NOISE:

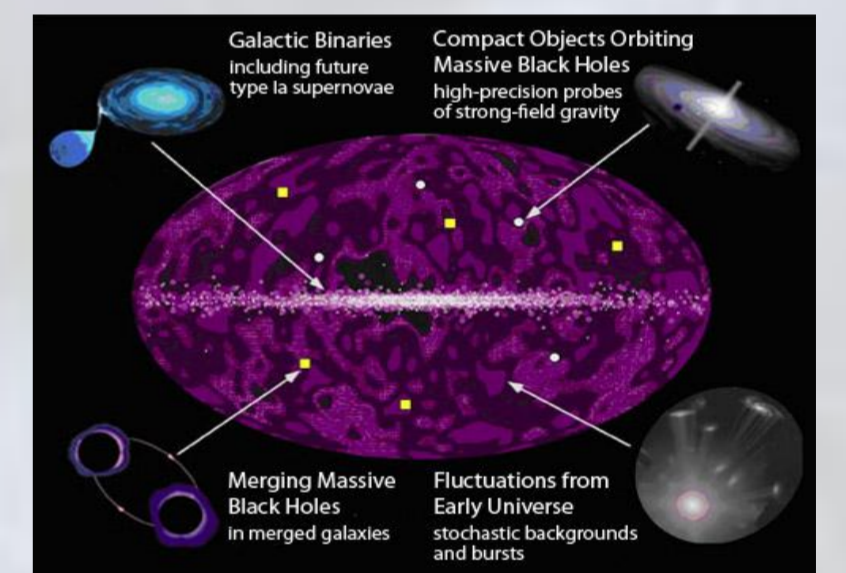
- Production of random photons limits the detectors at high frequency.
- Photons fall at random times causing fluctuations around the average values.



Credits : spie.org

SCIENCE WITH GRAVITATIONAL WAVES :-

1. Test of General Theory of Relativity.
2. Cosmology with gravitational waves :-
 - Test of inflation,
 - Cosmographic measurements
 - Accurate determination of Hubble Constant
 - Characterisation of evolution of dark energy
3. Astronomy - Study of known and unknown pulsars, black holes, neutron stars etc.
4. SURPRISES!!!!!!!!!!!!



Credits-centauri-dreams.org

DATA ANALYSIS

Matched Filter- It is obtained by correlation of a defined template of signal with unknown parameters to detect the presence of the template in the unknown signal. Mass, amplitude etc is not known.

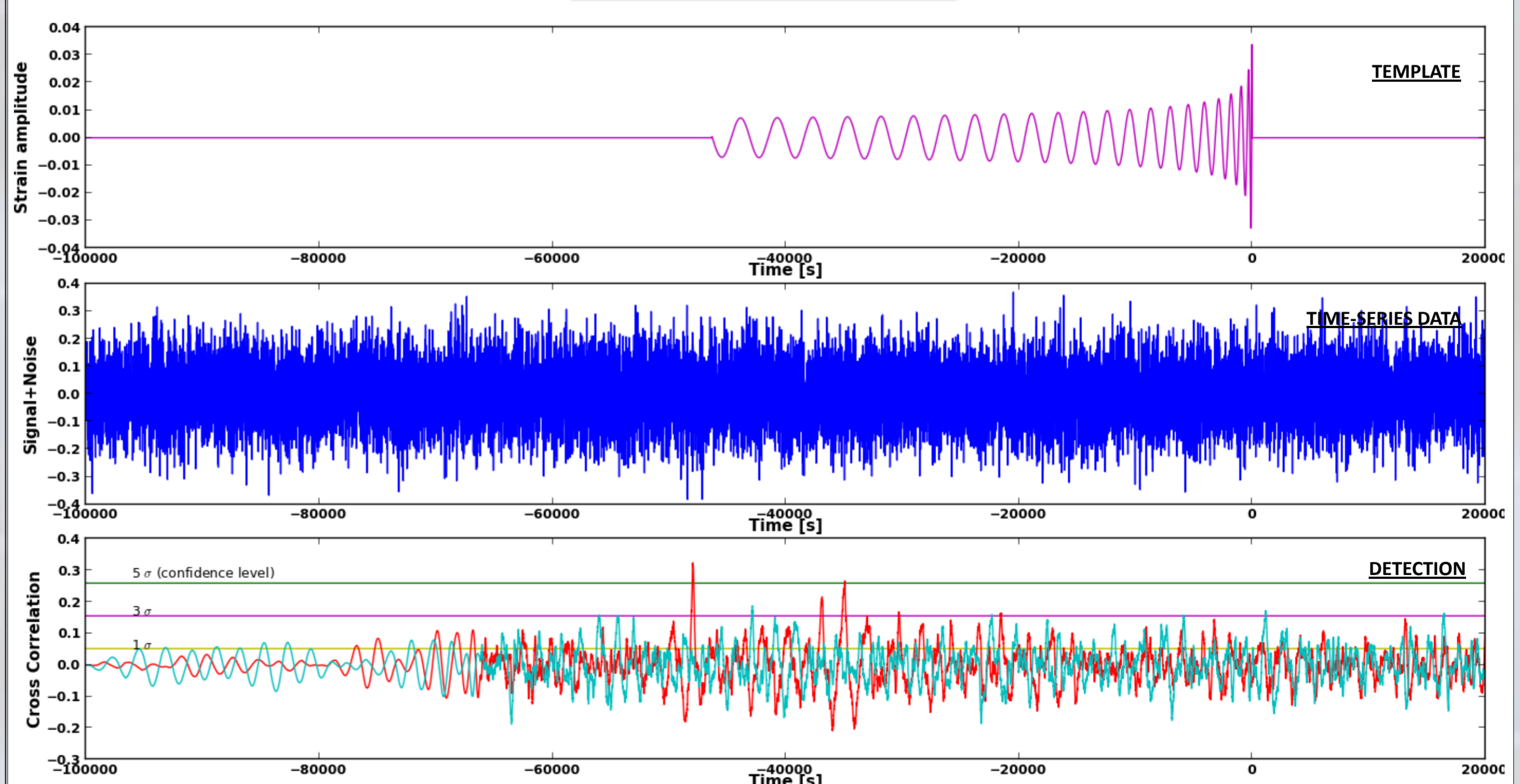
-Template of GW from CBC (Compact Binary Coalesce) is shown in the plot (chirp signal).

-The data we receive from the laser interferometer is a time series data, but GW signal is buried deep under the noise.

-To detect the GW signal from CBC cross correlate the signal with pure noise & check the standard deviation, σ_0

-Now, the template is cross correlated with noise in which the signal is present & check standard deviation, σ_1

MOCK DATA ANALYSIS



-If

$$\sigma_1 > 5 \sigma_0$$

then with 99.9999426697 % confidence we can assure GW signal from CBC has been detected.