FOR:MPSACngGW subcommittee
Not a whitepaper - some thought and suggestions

FROM: Rainer Weiss May 29, 2023
Emeritus Professor of Physics MIT

FUNDAMENTAL PROPERTIES OF GRAVITATIONAL WAVES THAT COULD LEAD TO SURPRISES

The scientific prospects for gravitational wave research as part of astronomy and astrophysics are bright. The observation of compact binary coalescences of black holes and neutron stars has opened the field. Population modeling indicates that we have only sampled the tail of a distribution of compact binaries and by improving the sensitivity and bandwidth of the detectors, a significant increase in observations is expected. A factor of 10 sensitivity improvement could well yield a 1000 times more sources some with superb signal to noise. The precision measurements would provide exquisite tests of General Relativity and source models. The prospects for the new science coming from improvements of compact binary observations is well represented in several of the white papers being submitted to the committee.

I would like to urge the committee to also consider less well defined but possibly fundamental aspects of gravitational wave science which could yield surprises.
In particular:

- Gravitational waves are the most penetrating probes we have for investigating the universe. They do not become significantly scattered by the medium intervening between source and detector and therby can provide information of all epochs of the universe.

The little scattering that does occur is due to the radiation field induced motions in the intervening matter that then emits induced secondary radiation but at negligible amplitudes relative to the exciting field. Gravitational waves as well as all other fields and particles partake in the lensing distortions of space-time.

The ability of the waves to penetrate makes gravitational wave measurements open to all epochs of the universe starting from the very beginning. Some Inflationary models of the origin predict gravitational waves associated with the mass of the particle causing the inflation. The most generally accepted version makes predictions too small to measure by even the third generation ground based gravitational wave detectors. These would need space based detectors using ground based technology as is described in the BIG BANG OBSERVER and DECIGO space based concepts. Other ideas have been presented for gravitational wave sources in the early universe considering the epochs when the early universe makes transitions from equality of the strengths of the basic interactions in nature to the inequalities in their strengths as we now find them. These phase transitions could well be inhomogeneous and lead to bubbles which generate gravitational waves later in the evolution and which are considerably stronger, possibly detectable by third generation ground based detectors. Even though we are not sure of a detection the possibility of these primordial gravitational waves is so important for cosmology that searches at each improvement in detector sensitivity is warranted.

- Dynamical space-time itself may well be a source of gravitational waves. Changes in the curvature of space-time emit gravitational waves.

We may be able to observe the dynamics in a new source entirely, the fluctuations and distortion that may occur in the space-time of the universe itself. The formation of structure in space-time directly such as black holes and other geometric entities of General Relativity would be accompanied by the emission of gravitational waves. We simply do not know enough about highly curved space-time to invent the possible sources. We need to keep looking.

What are the directions to enhance the possibility for measurement of these fundamental though unknown sources:

1) In ground based detectors aim for the lowest frequencies. Although there are some ideas for cosmological sources at higher frequencies, the red shift makes it more likely that these signals will be at low frequencies. In the ground based detectors make them as long as possible consistent with other science. For CE favor the 40km rather than the 20km length
2) Develop algorithms for more sensitive searches without gravitational wave templatres. Specifically develop algorithms that search for changes in power spectral density.
3) Further develop the idea of modeling the noise sources and making best fits to remove them in the data. Both with new algorithms but also with additional paths in the interferometers specifically designed to measure the noise. The concept is to reduce the contribution of the noise source leaving a residual smaller power spectra in which it could be easier to sense small changes.
4) For space based detectors begin the long term development of high displacement sensitivity detectors on modest length scales such as 1000s of km as envisioned by the DECIGO and BIG BANG OBSERVER concepts to provide sensitivity in the 0.1Hz to 1Hz band.