Gravitational Waves as a unique window on the Universe

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Humanity's view of the Universe has been dominated by visible light for millennia. Over the past century, astronomers have gradually opened up additional regions of the electromagnetic spectrum and also gathered some information from astrophysical particles. Beginning this decade, humanity will gain access to the unexplored spectrum of gravitational radiation.

What does this spectrum have to offer astrophysics in the era of multi-messenger astronomy?

- Gravity dominated sources are generally "clean" with few relevant parameters.
- Gravitational waves propagate with negligible interaction and obscuration other than weak lensing, from the earliest moments of the Big Bang.
- Sources are coherent and "bright" because the "charges"/masses are large.
- The sources dominate their physical systems, are coherent on a vast scale by comparison to light-emitting charges.
- The fundamental parameters of an astrophysical system like a binary (masses, spins, luminosity distance, orientation, orbits, etc.) are encoded into the gravitational radiation polarization and waveform.
- Signal strengths drop off as 1/r because detectors measure amplitude rather than power. This means that first or second generation instruments may already probe to great cosmological distances.
- Detection is naturally all-sky, but sky location is more difficult.
- In the low-frequency band (0.1 mHz to 1 Hz) accessible from space, most sources are long lived and their signal evolution can be followed over thousands to millions of cycles with fractional cycle accuracy.
- Expected sources are numerous and have high SNR in the low-frequency band.
- Where electromagnetic and gravitational wave observations of the same object are possible, the information to be gleaned from each is high complementary.
- Examples of expected sources are: massive black hole mergers of the earliest seeds in proto-galaxies to the present day supermassive black hole mergers, compact stars spiraling into central engines, merging intermediate-mass black holes, and compact binaries in the Milky Way.
- Examples of speculative sources are: phase transition at the Electro-weak scale, cosmic strings and the cosmological background.
- The gravitational wave spectrum will undoubtedly reveal revolutionary discoveries not foretold by the electromagnetic spectrum.