(Switzerland). They stopped operation, respectively, in 2001, 2007, and 2010.

Data from four of these bars have already been analyzed together with data from LIGO and VIRGO over the last decade, when they had similar sensitivities with the interferometers. Finally, there are two detectors composed of resonant-mass spherical antennas: Mini-GRAIL and Mario SCHENBERG to which I will return later.

There are also interferometer projects in space, such as the NASA-ESA LISA (Laser Interferometer Space Antenna), the Japonese DECIGO (Deci-hertz Interferometer Gravitational wave Observatory) and BBO (Big Bang Observer). Because they are free from the seismic motions of Earth's crust, which couples mechanically and also gravitationally to the detectors, they are able to cover a much lower range of frequencies. While the ground interferometers, resonant-bars and resonant-spheres, cover the frequency range of 10 Hz–10 kHz, the space interferometers will cover the 10^{-4} Hz–10^{2} Hz frequency band.

Pulsar Timing Arrays is a new way of searching for the detection of gravitational waves. The pulse time series of dozens of extremely regular single pulsars are monitored every once in a while by radio telescopes and compared with their respective theoretical pulse time series models in the hope of finding discrepancies (residuals) between the time arrivals of the measured pulses and the model pulses. These discrepancies would be caused by the passage of a long wavelength gravitational wave in the space between Earth and these better-than-nuclear-clock-pulsars.

Three major groups were formed for these searches: NANOGrav (North American Nanohertz Observatory of Gravitational Waves), the Parkes Pulsar Timing Array (PPTA), and the European Pulsar Timing Array (EPTA). They cover GW frequencies between 10^{-9} and 10^{-8} Hz – complementary to LIGO and LISA.

Current data sets are ruling out a few cosmic string (CS) models, and the Square Kilometer Array (SKY) should detect GWs or rule out most CS models.

Covering the very low frequency band, from 10^{-18} to 10^{-15} Hz, there are the electromagnetic CMB (Cosmic Microwave Background) detectors searching (on land or onboard satellites, such as Planck) for electromagnetic B-mode polarization. Here the principle of detection is simple: these almost Universe size wavelength gravitational waves leave an imprint on the electromagnetic CMB.

All this effort is to fill up the maps of the sky in the different frequency bands (from 10^{-18} to 10^{10} Hz) of the gravitational wave window as the scientific community has done in the past 400 years for the electromagnetic window.

3. GRAVITATIONAL WAVE ASTRONOMY: A NEW WINDOW TO OBSERVE THE UNIVERSE

Gravitational Wave Astronomy will open a new window to observe the Universe, which will probably revolutionize our knowledge of it.

There is a host of possible astrophysical sources of gravitational waves: namely, supernovae, the collapse of a star or star cluster to form a black hole, inspiral and coalescence of compact binaries, MACHOs as primordial black holes (PBHs), pulsars and rotating neutron stars, quark stars, boson stars, neutron star modes, the fall of stars and black holes into supermassive black holes, rotating neutron stars, ordinary binary stars, relics of the Big Bang, vibrations or collisions of monopoles, cosmic strings and cosmic bubbles, and other exotic events, anticipated from theory, which may be confirmed when gravitational wave astronomy becomes a reality, besides phenomena not yet known or even anticipated, and other surprises.

If nature has more dimensions than the four of spacetime, gravity will have "transit" in these extra dimensions, and special effects on the intensity, propagation and polarization of gravitational waves may occur differently from the ones anticipated by the General Relativity. The study of these effects on the gravitational waves would be, therefore, a tool for the investigation of extra dimensions in the Universe and to formulate an auto consistent theory of quantum gravity.

Gravitational Waves will tell us even if there was or was not a Big Bang. If there was no Big Bang, gravitational waves will provide us with important details of this or these previous phases of our bouncing Universe.

4. SPHERICAL ANTENNAS AND THE SCHENBERG DETECTOR

One can increase the sensitivity of a resonant-mass detector by maximizing signal-to-noise ratio. Maximization of the signal to noise ratio can go in two directions: the minimization of noise or the maximization of signal. If it is hard to decrease the noise, one can try to increase the signal. A GW antenna with a spherical shape (massive or hollow) seems to be the best solution for a given choice of frequency;