Impedance of Spacetime

The most frequently mentioned objection to the proposed spacetime-based model of the universe is it does not seem reasonable that spacetime should have an energy density in excess of the critical energy density observed by cosmological observations and theoretically predicted by GR. Part of the problem is that in our experience we are only familiar with energy that possesses quantized angular momentum (fermions and bosons). Therefore, we accept the statement that energy in any form creates gravity. We cannot easily imagine a form of energy which is fundamentally different from the various forms of observable energy. Even though the standard model has numerous "fields", many physicists reject any model which purports to quantify and analyze the underlying structure of these fields. Changing a long held concept is always a difficult task, but fortunately physicists are more open to reason so here goes.

The first step is to prove that spacetime is an elastic medium with a definable impedance. This proof requires a discussion of gravitational waves. Gravitational waves are transverse waves that are generated by the unsymmetrical acceleration of mass. The easiest to visualize source of strong gravitational waves are rapidly rotating binary star systems, especially a binary neutron star systems. The gravitational waves generated by binary stars remove angular momentum from the rotating stars and cause the stars to spiral towards each other and eventually merge. The emitted gravitational waves modulate the two space dimensions transverse to the propagation direction. A spherical volume is caused to become an oscillating ellipsoid where the distance between two transverse points increases while the orthogonal distance between points decreases. These effects offset so there is no change in the volume and no change in the rate of time.

It is very difficult to detect gravitational waves. A large radiated power produces a very small distortion of spacetime. This is discussed by D. G. Blair in the 1991 book *Detecting Gravitational Waves* and his 2012 book *Advanced Gravitational Wave Detectors.* In his 1991 book Blair says, "A gravitational wave is a wave in a medium with an extremely large stiffness. Since the propagation velocity is c, we can, by analogy to acoustic waves, identify the quantity of c^3/G ($4\text{x}10^{35}$ kg/s) with the characteristic impedance of the medium." In his 2012 book he also says that "The rigidity of normal matter is so low compared with that of spacetime that the stiffness of matter is utterly negligible" (p 7). Later he also says that resonant mass detectors of gravitational waves "suffer from an extremely poor impedance matching. The highest acoustic impedance achievable in a detector is about 10^{10} kg/s. This is 25 orders of magnitude below the impedance of spacetime - 10^{35} kg/s."

Blair does not reveal the calculation that led him to identifying the impedance of spacetime, but I independently also identified this impedance and here is the reasoning that I used. Gravitational wave equations can be complex because of nonlinearities and emission patterns. But the equation for the intensity (I) of a plane wave with amplitude $A = \Delta L/L$ and frequency ν at the low power limit is:

$$I = \left(\frac{\pi c^3}{4G}\right) A^2 \nu^2 \quad \text{equivalent to:} \quad I = kA^2\omega^2\left(\frac{c^3}{G}\right) \qquad (1)$$

A standard equation from acoustics is: $I = kA^2\omega^2 Z$ where Z is the impedance of the acoustic medium. It is obvious comparing equation (1) with the acoustic equation that the impedance term must be:

$Z_s = c^3/G \approx 4.04 \text{x} 10^{35}$ kg/s. The reason for introducing the impedance of spacetime into a discussion of the energy density of spacetime is because it implies energetic properties of spacetime. If spacetime was an empty void, it would not have a specific impedance. A gravitational wave propagating in spacetime is interacting with something that is 25 orders of magnitude larger impedance than osmium or tungsten carbide. If the impedance of spacetime were infinite or zero, then it would not be capable of wave propagation. Instead, as Blair said, spacetime is a very stiff elastic medium. Waves propagate in this medium at the speed of light. The large impedance permits a tremendous energy density to be transmitted with a very small wave amplitude.

If a black hole had a mass of $4.04\text{x}10^{35}$ kg, how big would it be? The answer is that it would be $3\text{x}10^8$ meters (1 light second) in radius if it was maximally rotating. If it was not rotating, then it would be twice this radius. Therefore, the units kg/s for the impedance of spacetime are understandable.

Suppose that we do another numerical example which illustrates equation 1. If we assume an intensity of: $I = 1$ w/m^2 and a gravitational wave with frequency of about 1 Hz, then using equation 1, the gravitational wave's dimensionless strain amplitude is about $A \approx 10^{-18}$. A spherical volume 1 meter in diameter is being deformed by about 10^{-18} m. An intensity of about 1 w/m^2 is about the intensity of the sun's light at Pluto. The point is that something physical is happening in spacetime. The gravitational wave is interacting with something and a physical change is taking place.

I do not want to proceed further because I first need the following question to be answered.

Do you accept that spacetime has impedance of about c^3/G?

I would like a yes or no answer from John W. and anyone else that is interested in this subject.