On the Polarization of Gravitational Waves

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Abstract

It is argued that transversal waves in the geometry of space-time, as postulated by General Relativity, violate translation symmetry within phase planes of a planar wave. Consequently, it is proposed that a corresponding test of transversality is performed, which should have become possible with the increasing number of registered events of gravitational waves. This would provide a independent, new, and essential test of General Relativity.

Remark

A plane wave is characterized by phase planes in which the excitation (a field) is identical within that plane. Thus we have a translation symmetry within a phase plane. This translation symmetry must not only hold for the excitation itself, but also for all measurable quantities derived from it. Clearly, integrals of the excitation, taken along lines within the plane, violate this translation symmetry in general. Such integrals cannot be uniquely measurable quantities, but they are potentials which are only determined up to an arbitrary constant. This is borne out by the dependence of potentials on the origin of integration. An example is the electric potential of a linearly polarized plane electromagnetic wave, which has no absolute meaning but only one given by it's gradient.

This situation is different for the case of gravitational waves of the form postulated by General Relativity [1-3], for which it is claimed that the excitation is a change in the metric tensor. To see that this poses a problem (see also discussion in Ref. 4) we start from a Minkowskian unperturbed situation and take the z-direction as the propagation direction of the plane wave. Now, the position of a test mass in the phase- (x-y-) plane is by itself a potential because we can choose the origin of the x-y-coordinates arbitrarily. If we now consider the change in position of our test mass, caused by the excitation of the wave (change in the metric tensor, constant in the x-y-plane) this is again a quantity with the characteristic of a potential. It is only determined up to a constant and, thus, violates the above stated requirement. The metric tensor yields, on integration, positions which have the nature of a potential. Similarly, the change of the metric tensor, constant in x-y-plane at any instant, yields position changes, again with the nature of a potential, and thus, not unique as required.

It is somewhat difficult not to confuse this latter situation with the freedom of choice of the origin. The problem is most easily illustrated by a commonly used picture to illustrate such waves. This illustration takes test masses arranged in a circle [2,3]. Under the action of a gravitational wave, the circle is supposed to be squeezed or elongated to a ellipse within the phase plane. This is the result of integrating up changes in the metric (the excitation) along the radial directions from the center of the original circle, which yields the instantaneous new positions. However, the movement of any test point would depend on where we choose the center of the circle to which the point should belong to. A point would not move at all if we chose it to be the center itself.

Conclusion

The above argument shows that we must abandon the idea of gravitational waves as transversal geometrical ones. One proposed alternative considers the gravitational field as a scalar quantum-field [5-7]. In this case gravitational waves would be longitudinal and the corresponding accelerating field (force) would point along the direction of wave propagation. Such waves obey the required translation symmetry within phase planes.

The detectors for gravitational waves of the LIGO and VIRGO projects are long-baseline Michelson interferometers with the shape of equilateral right triangles designed to optimally probe waves that propagate perpendicular to the triangles, and hence to the surface of the earth [8,9,3]. However, they would also respond to longitudinal waves, most sensitively for propagation direction along the hypotenuse of the detector triangle, but not at all for a perpendicular alignment. The two LIGO detectors have fairly similar sensitivity to transversal polarized waves due to rather similar alignment of the legs of their interferometers. However, for longitudinal waves their sensitivity can be very different for a particular wave, depending on it’s propagation direction. This, because the direction of the hypotenuses of the two detector triangles are nearly perpendicular to each other [8].

There are now several dozen measurements of gravitational wave events and with these it should become possible to perform an analysis of the signal strengths in the light of wave polarization. I’m not aware of such a analysis, but would welcome it very much in the light of the above expressed skepticism. In other words, such a analysis would provide a strong, independent, and essential test of General Relativity.

References

1. Einstein A., Sitzungsberichte der Koeniglichen Preussischen Akademie der Wissenschaften, part 1, 688 (1916), 154 (1918)
2. Miesner C. W., Thorne K. S., Wheeler J. A., (1973), “Gravitation”, W. H. Freeman, New York
3. https://en.wikipedia.org/wiki/Gravitational_wave
4. Kennefik D., (2007), Traveling at the Speed of Thought, Princeton University Press
5. Gerber P., (1898), Zeitschrift fuer Mathematik und Physik. 43, p. 93–104; english translation: http://www.alternativephysics.org/gerber/Perihelion.htm
6. Gerber P. R., (2013), viXra:1303.0100
7. Gerber P. R., (2019), viXra:111.0010
8. LIGO collaboration; https://www.ligo.caltech.edu
9. Virgo collaboration; http://www.virgo-gw.eu