Scientific Background on the Nobel Prize in Physics 2017

The Nobel Committee for Physics, 3 October 2017

https://www.nobelprize.org/nobel_prizes/physics/laureates/2017/advanced-physicsprize2017.pdf

“Distances in space increase and decrease with a steady cadence in two directions at 90 degrees to each other, orthogonal to the direction of motion of the wave.”

“In the case of gravitational radiation, energy conservation forbids monopole radiation, and momentum conservation forbids dipole radiation, leaving the quadrupole as the lowest multipole.”

“It was not until the late 1950‟s that it was rigorously proven that the waves actually exist as solutions to the full non-linear equations, and that they carry energy [16-18].”
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[16] H. Bondi, F.A.E. Pirani and I. Robinson, Gravitational waves in general relativity III. Exact plane waves, *Proc. Roy. Soc. Lond.* A251, 519 (1959)

[17] F.A.E. Pirani, Invariant formulation of gravitational radiation theory, *Phys. Rev.* 105, 1089 (1957)

[18] I. Robinson and A. Trautman, Spherical gravitational waves, *Phys. Rev. Lett.* 4, 431 (1960); I. Robinson and A. Trautman, Some spherical gravitational waves in general relativity, *Proc. Roy. Soc. Lond.* A265, 463 (1962); A. Trautman, Boundary conditions at infinity for physical theories, *Bull. Acad. Polon. Sci.* 6, 403 (1958); A. Trautman, Radiation and boundary conditions in the theory of gravitation, *Bull. Acad. Polon. Sci.* 6, 407 (1958)
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Do gravitational waves (GWs) “actually exist as solutions to the full non-linear (Sic! – D.C.) equations”, and how would they “carry energy [16-18]”? How will you install GW “mirrors” at null-and-spacelike infinity? How will you define spacetime boundaries (cf. R. Penrose) at null-and-spacelike infinity to obtain „gravitationally isolated system‟ and then prove “energy conservation” viz. speculate about “the quadrupole as the lowest multipole” (see above)?

Have you seen pink unicorns dancing with red herrings? The Nobel Committee for Physics will be *very* happy to hear from you.

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Polarization of gravitational waves

A laser interferometric or resonant bar gravitational wave detector measures the local components of a symmetric 3×3 tensor which is composed of the "electric" components of the Riemann curvature tensor, R_{0i0j}, via the equation of geodesic deviation, given for a pair of freely falling particles by $\ddot{x}^i = -R_{0i0j}x^j$, where x^i denotes the spatial separation. In general there are six independent components, which can be expressed in terms of polarizations (modes with specific transformation properties under rotations and boosts). Three are transverse to the direction of propagation, with two representing quadrupolar deformations and one representing a monopole "breathing" deformation. Three modes are longitudinal, with one an axially symmetric stretching mode in the propagation direction, and one quadrupolar mode in each of the two orthogonal planes containing the propagation direction. Figure 9 shows the displacements induced on a ring of freely falling test particles by each of these modes.

General relativity predicts only the first two transverse quadrupolar modes (a) and (b) independently of the source; these correspond to the waveforms h_+ and $h_\times$ discussed earlier (note the cos 2φ and sin 2φ dependences of the displacements). Scalar-tensor gravitational waves can in addition contain the transverse breathing mode (c). More general metric theories predict additional longitudinal modes, up to the full complement of **six** (TEGP 10.2 [147]).

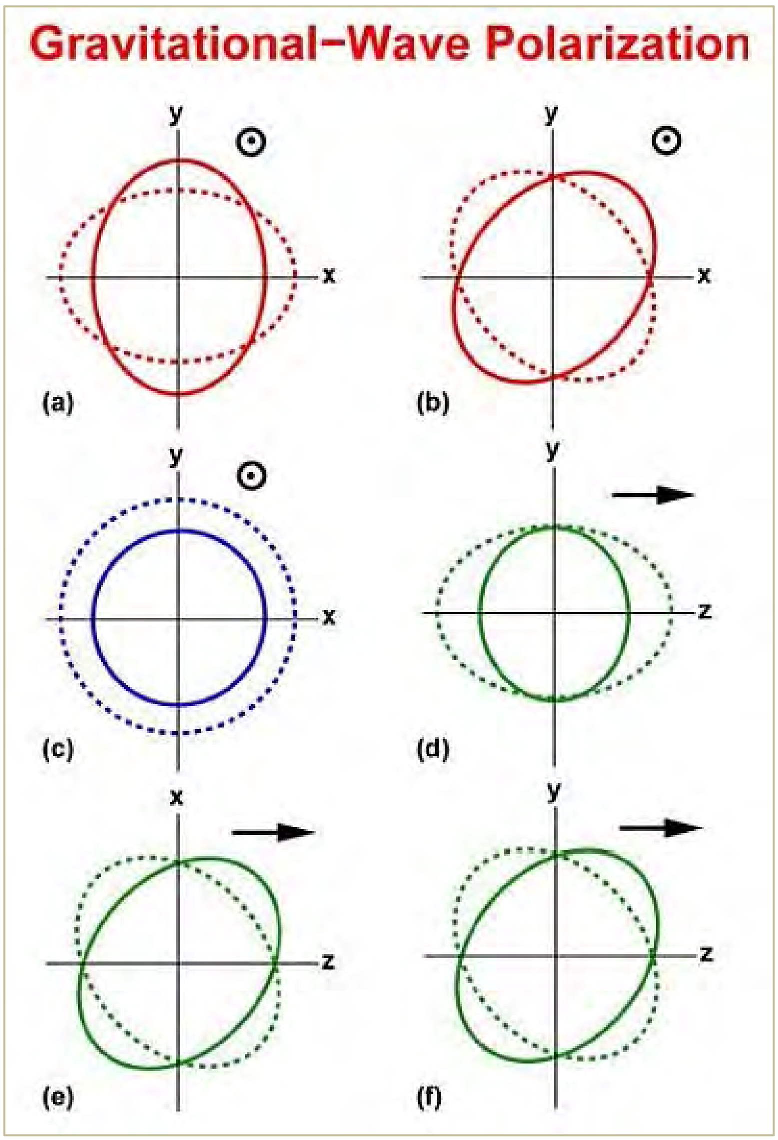

Figure 9

The six polarization modes for gravitational waves permitted in any metric theory of gravity. Shown is the displacement that each mode induces on a ring of test particles. The wave propagates in the +z direction. There is no displacement out of the plane of the picture. In (a), (b) and (c), the wave propagates out of the plane; in (d), (e), and (f), the wave propagates in the plane. In general relativity, only (a) and (b) are present; in scalar-tensor gravity, (c) may also be present.

A suitable array of gravitational antennas could delineate or limit the number of modes present in a given wave. The strategy depends on whether or not the source direction is known. In general there are eight unknowns (six polarizations and two direction cosines), but only six measurables (R_{0i0j}). If the direction can be established by either association of the waves with optical or other observations, or by time-of-flight measurements between separated detectors, then six suitably oriented detectors suffice to determine all six components. If the direction cannot be established, then the system is underdetermined, and no unique solution can be found. However, if one assumes that only transverse waves are present, then there are only three unknowns if the source direction is known, or five unknowns otherwise. Then the corresponding number (three or five) of detectors can determine the polarization. If distinct evidence were found of any mode other than the two transverse quadrupolar modes of GR, the result would be disastrous for GR. On the other hand, the absence of a breathing mode would not necessarily rule out scalar-tensor gravity, because the strength of that mode depends on the nature of the source.

Some of the details of implementing such polarization observations have been worked out for arrays of resonant cylindrical, disk-shaped, spherical and truncated icosahedral detectors (TEGP 10.2 [147], for recent reviews see [87, 133]); initial work has been done to assess whether the ground-based or space-based laser interferometers (or combinations of the two types) could perform interesting polarization measurements [134, 33, 90, 67].

Unfortunately for this purpose, the two LIGO observatories (in Washington and Louisiana states, respectively) have been constructed to have their respective arms as parallel as possible, apart from the curvature of the Earth; while this maximizes the joint sensitivity of the two detectors to gravitational waves, it minimizes their ability to detect two modes of polarization.

The Confrontation between General Relativity and Experiment

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Note: I believe only the first off idea in General Relativity (GR) is correct, namely, that there is no pre-existing 4D background spacetime in Nature. To quote Antonio Machado: "Traveler, there is no path. The path is made by walking." What we call 'spacetime' is being dynamically **re**-created by 'walking' the *consecutive* action (**P** → **Q**) of gravity interacting with the rest of the world, thanks to which (**i**) all gravitating systems are *self-interacting*, and (**ii**) their space***time*** becomes distorted.

Now add the alleged "gravitational-wave polarization" pictured in Fig. 9 above, and try to describe (use math as much as you can) the inevitable *superposition* of all "six independent components" in such a way (try to be creative) that your end result will produce only cases (**a**) and (**b**) above. Your next step will be to prove (recall H. Bondi) that "energy conservation forbids monopole radiation, and momentum conservation forbids dipole radiation", as Kip Thorne speculated and was awarded the Nobel Prize in Physics 2017 for detecting pink unicorns dancing with red herrings. Good luck.

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https://chakalov.net/GWP.pdf