Andrzej Trautman, Ivor Robinson, and the Foundations of Gravitational Radiation Theory

Donald Salisbury, Austin College Department of Physics and Max Planck Insitute for the History of Science

Abstract

It is especially pertinent following the momentous detection of gravitational waves by LIGO and the death of Ivor Robinson in 2016 that we investigate the central role played by the Polish physicist Andrzej Trautman and his dear collaborator Robinson in helping to establish the foundations of gravitational wave research. Trautman was a student of Leopold Infeld who had famously rejected the reality of gravitational waves. Yet Trautman's intuition, informed in part by his training as a radio engineer, led him to be the first to correctly pose asymptotic boundary conditions that described the mass loss of an isolated system through emitted gravitational radiation. His series of papers announcing these results were published in a then obscure Polish journal. Fortunately, though, Felix Pirani visited Warsaw in1957 and he was so impressed with Trautman that he arranged for him to visit his group at King's College in London. Trautman's lectures in London won him wide admiration, and significantly affected the subsequent work on gravitational wave solutions of Einstein's equations in the group led by Hermann Bondi. This was also the occasion in which Trautman and Robinson discovered a deep and abiding mathematical affinity, resulting in the discovery of exact solutions of Einstein's equations that could be interpreted as representing gravitational radiation.

Andrzej Trautman

- Born 1933 in Warsaw, Poland
- High school following the war in France
- Studied radio engineering at the Politechnika Warszawska
- Began doctoral work under Leopold Infeld in 1955
- After publishing several articles on equations of motion and gravitational radiation, delivered lectures at King's College, London, in 1958
- With extensive appointments abroad – including Syracuse, London, and Chicago – Professor of Physics at Warsaw.

Andrzej Trautman
Warsaw, 2016

Ivor Robinson

- Born 1923 in Liverpool, England
- Bachelor degree in Mathematics from Cambridge
- Visited Infeld and Trautman in Warsaw, 1959
- Visits and temporary appointments at Copenhagen, Stockholm, Hamburg, Syracuse, Chapel Hill
- Appointed Head of Relativity Group at the Southwest Center for Advanced Study in Dallas in 1963 – later to become the University of Texas at Dallas.

Joanna and Ivor Robinson
Dallas, 2011

Prior International Relativity Collaborations Related to Radiation

- Albert Einstein (1879-1955) – German émigré to Princeton, NJ, 1933-1955
- Leopold Infeld (1898-1968) – Polish Einstein assistant at Princeton, University of Toronto , then 1951 to Warsaw.
- John Lighton Synge (1897-1995) – Irish professor at Toronto 1920-25, 1930-43, Dublin Institute for Advanced Studies 1948-95
- Peter Gabriel Bergmann (1915-2002) – German German émigré Einstein Assistant 1936 – 41, Syracuse University 1948-82
- Hermann Bondi (1919-2005) – Austrian professor at King's College, London, 1954-85

Einstein and Bergmann in Princeton, 1941

The Role of Symmetries in the work of Trautman and Robinson

Symmetry and Particle Equations of Motion

Trautman was encouraged in 1955 by his teacher in Warsaw, Jerzy Plebański (1928-2005), to undertake a Ph. D. thesis on gravitational radiation with Infeld – even though until close to his death Infeld did not believe such waves existed.

Infeld and Plebański in Warsaw, 1951

Bergmann in 1949, and later in 1953, his student Joshua Goldberg (1925-), showed how to obtain the equations of motion directly exploiting the `strong' conservation laws that resulted from the symmetry of Einstein's field equations under general coordinate transformations.

Joshua Goldberg
Syracuse, 2011

The EIH, Bergmann, Goldberg approach employed the symmetry identity on the left-hand side of the field equations, assuming that particles were represented by singularities in the gravitational field.

Infeld, Plebański – and Trautman beginning in 1956 – exploited the identity that resulted from the invariance of the material action under the general covariance symmetry.

Trautman showed in 1958 that the so-called slow motion iterative method for obtaining the particle equations of motion could not be reliably extended to the far wave zone – and that it was apparently not yet possible to relate corrections to the particle motions to wave emission.

Symmetry and Gravitational Waves

Inspired by his background in radio engineering, in 1958 Trautman exteded to gravitational waves asymptotic boundary conditions that Arnold Sommerfeld had employed for outgoing electromagnetic waves

The asymptotic Riemann-Christoffel curvature tensor turned out to be of Petrov type II, thus exhiting a special symmetry that was shared by Robinson's exact plane gravitational waves.

Also in 1958 Trautman was the first to prove that gravitational waves extract energy from compact gravitational bound systems. (Bondi mass loss should properly be called Trautman-Bondi mass loss. See Chruściel, Jezierski, MacCallum 1998). He also showed in 1958 that emitted waves could carry encoded information, anticipating by four years the Bondi news function.

The Robinson – Trautman Collaboration

Felix Pirani (1928-20150), a student of Infeld and Alfred Schild (1921-77) in Toronto, visited Infeld in Warsaw in 1957. Pirani had argued for a spacetime curvature-based reality of gravitational waves – building upon geodesic deviation principles learned from Synge and Schild.

Pirani invited Trautman to King's College where he delivered an instrumental series of lectures on equations of motion and gravitational radiation. Ivor Robinson attended and they struck up a lifelong friendship and collaboration.

Each brought experience and intuition to the relation between mathematically special solutions of Einstein's equations and gravitational radiation. Joint papers published beginning in 1960 were the first to display exact radiation-like solutions that exhibited the fall-off `peeling' properties that had been identified by Ray Sachs (1932-), a student of Bergmann.

The Link Between Equations of Motion and Radiation

Róża Michalska-Trautman (1932-2015) published in 1969 , following the death of her advisor Infeld, a co-authored derivation of the radiation reaction of two bodies in motion. Subrahmanyan Chandrasekhar (1910-1995) showed one year later in a generalized post-Newtonian formalism how to get this decaying quadrupole and more. Applied to the Hulse-Taylor neutron binary, these calculations form the basis of their 1993 Nobel prize-winning period decay observations

William Burke (1941-1996) and Kip Thorne (1940 -) began in 1969 to develop techniques for systematically combining iterative expansions in the near and wave zones. Today the continuing improvement of these matching techniques, combined with numerical techniques has made it possible to compute characteristic template gravitational signals from a variety of astrophysical sources. Thus it was possible to find and interpret the LIGO signal of 2016 as emerging from coalescence of two black holes at a distance of one billion light years from the earth!

See Daniel Kennefick for more details of the history of the quadrupole formula