Topic around Gravitational wave

JC38 sp. topic

General relativity and the prospect of gravitation waves by Einstien (1916)

Näherungsweise Integration der Feldgleichungen der Gravitation.

Von A. Einstein.

Bei der Behandlung der meisten speziellen (nicht prinzipiellen) Probleme auf dem Gebiete der Gravitationstheorie kann man sich damit begnügen, die $g_{\mu\nu}$ in erster Näherung zu berechnen. Dabei bedient man sich mit Vorteil der imaginären Zeitvariable $x_4 = it$ aus denselben Gründen wie in der speziellen Relativitätstheorie. Unter »erster Näherung« ist dabei verstanden, daß die durch die Gleichung

$$g_{\mu\nu} = -\delta_{\mu\nu} + \gamma_{\mu\nu} \qquad (1)$$

definierten Größen $\gamma_{\mu\nu}$, welche linearen orthogonalen Transformationen gegenüber Tensorcharakter besitzen, gegen 1 als kleine Größen behandelt werden können, deren Quadrate und Produkte gegen die ersten Potenzen vernachlässigt werden dürfen. Dabei ist $\delta_{\mu\nu} = 1$ bzw. $\delta_{\mu\nu} = 0$, je nachdem $\mu = \nu$ oder $\mu \neq \nu$.

Wir werden zeigen, daß diese $\gamma_{\mu\nu}$ in analoger Weise berechnet werden können wie die retardierten Potentiale der Elektrodynamik. Daraus folgt dann zunächst, daß sich die Gravitationsfelder mit Lichtgeschwindigkeit ausbreiten. Wir werden im Anschluß an diese allgemeine Lösung die Gravitationswellen und deren Entstehungsweise untersuchen. Es hat sich gezeigt, daß die von mir vorgeschlagene Wahl des Bezugssystems gemäß der Bedingung $g = |g_{\mu\nu}| = -1$ für die Berechnung der Felder in erster Näherung nicht vorteilhaft ist. Ich wurde hierauf aufmerksam durch eine briefliche Mitteilung des Astronomen de Sitter, der fand, daß man durch eine andere Wahl des Bezugssystems zu einem einfacheren Ausdruck des Gravitationsfeldes eines ruhenden Massenpunktes gelangen kann, als ich ihn früher gegeben hatte[1]. Ich stütze mich daher im folgenden auf die allgemein invarianten Feldgleichungen.

[1] Sitzungsber. XLVII, 1915, S. 833.

Gleichwohl müßten die Atome zufolge der inneratomischen Elektronenbewegung nicht nur elektromagnetische, sondern auch Gravitationsenergie ausstrahlen, wenn auch in winzigem Betrage. Da dies in Wahrheit in der Natur nicht zutreffen dürfte, so scheint es, daß die Quantentheorie nicht nur die Maxwellsche Elektrodynamik, sondern auch die neue Gravitationstheorie wird modifizieren müssen.

Nachtrag. Das seltsame Ergebnis, daß Gravitationswellen existieren sollen, welche keine Energie transportieren (Typen a, b, c), klärt sich in einfacher Weise auf. Es handelt sich nämlich dabei nicht um »reale« Wellen, sondern um »scheinbare« Wellen, die darauf beruhen, daß als Bezugssystem ein wellenartig zitterndes Koordinatensystem benutzt wird. Dies sieht man bequem in folgender Weise ein. Wählt man das Koordinatensystem in gewohnter Weise von vornherein so, daß $\sqrt{g} = 1$ ist, so erhält man statt (2) als Feldgleichungen bei Abwesenheit von Materie

$$\sum_\alpha \frac{\partial^2 \gamma_{\mu\alpha}}{\partial x_\nu \partial x_\alpha} + \sum_\alpha \frac{\partial^2 \gamma_{\nu\alpha}}{\partial x_\mu \partial x_\alpha} - \sum_\alpha \frac{\partial^2 \gamma_{\mu\nu}}{\partial x_\alpha^2} = 0 .$$

Führt man in diese Gleichungen direkt den Ansatz

$$\gamma_{\mu\nu} = \alpha_{\mu\nu} f(x_1 + ix_4)$$

ein, so erhält man zwischen den Konstanten $\alpha_{\mu\nu}$ 10 Gleichungen, aus denen hervorgeht, daß nur α_{22}, α_{33} und α_{23} von null verschieden sein können (wobei $\alpha_{22} + \alpha_{33} = 0$). Bei dieser Wahl des Bezugssystems existieren also nur diejenigen Wellentypen (d, e, f), welche Energie transportieren. Die übrigen Wellentypen lassen sich also durch diese Koordinatenwahl wegschaffen; sie sind in dem angegebenen Sinne nicht »wirkliche« Wellen.

Wenn es also auch in dieser Untersuchung sich als bequem herausgestellt hat, die Wahl des Koordinatensystems von vornherein keiner Beschränkung zu unterwerfen, wenn es sich um die Berechnung der ersten Näherung handelt, so zeigt unser letztes Ergebnis doch, daß der Koordinatenwahl gemäß der Bedingung $\sqrt{-g} = 1$ eine tiefe physikalische Berechtigung zukommt.

Ausgegeben am 29. Juni.

Discovery of pulsar

The Nobel Prize in Physics 1974
Martin Ryle, Antony Hewish

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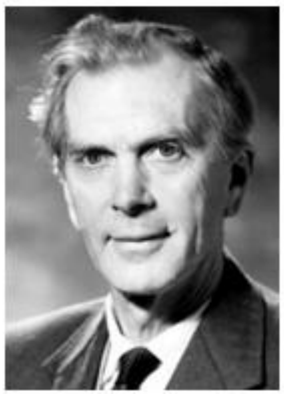
The Nobel Prize in Physics 1974



Sir Martin Ryle
Prize share: 1/2

Antony Hewish
Prize share: 1/2

The Nobel Prize in Physics 1974 was awarded jointly to Sir Martin Ryle and Antony Hewish *"for their pioneering research in radio astrophysics: Ryle for his observations and inventions, in particular of the aperture synthesis technique, and Hewish for his decisive role in the discovery of pulsars"*

discovery was in 1967

The Nobel Prize in Physics 1993

"for the discovery of a new type of pulsar, a discovery that has opened up new possibilities for the study of gravitation"

Russell A. Hulse

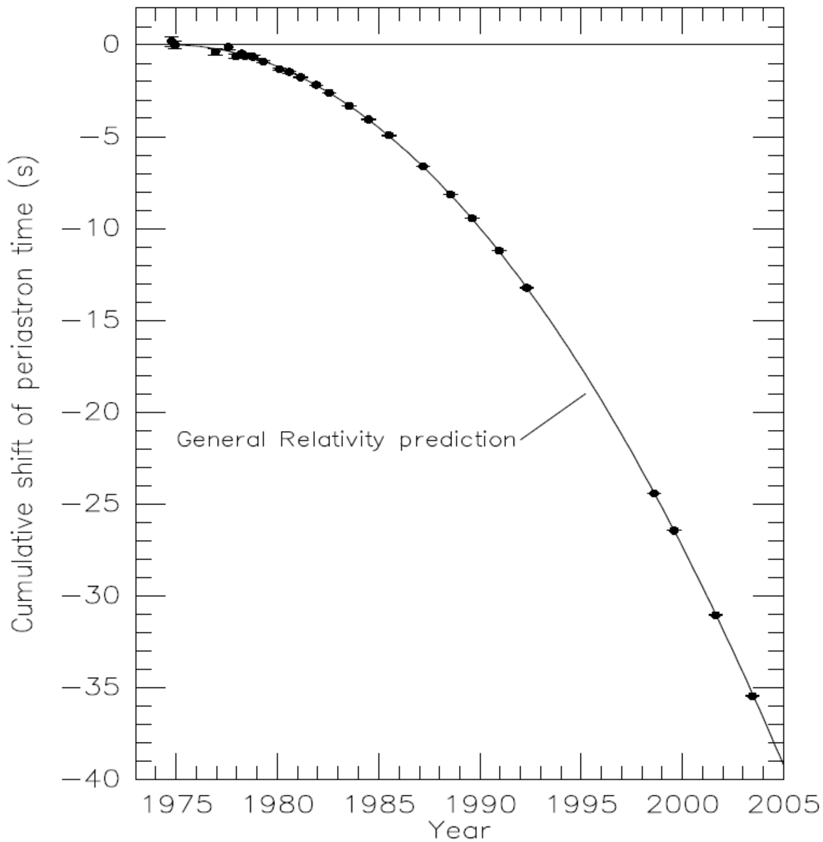
Joseph H. Taylor Jr.

discovery was in 1974

Relativistic Binary Pulsar B1913+16: Thirty Years of Observations and Analysis

1. Introduction

Pulsar B1913+16 was the first binary pulsar to be discovered (Hulse & Taylor 1975). Thirty years of subsequent observations have enabled us to measure numerous relativistic phenomena. We have used these measurements for funda-



J.M. Weisberg and J.H. Taylor, ASP Conference Series, 328 (2005) 25 (arXiv:astro-ph/0407149).

1st-generation detector

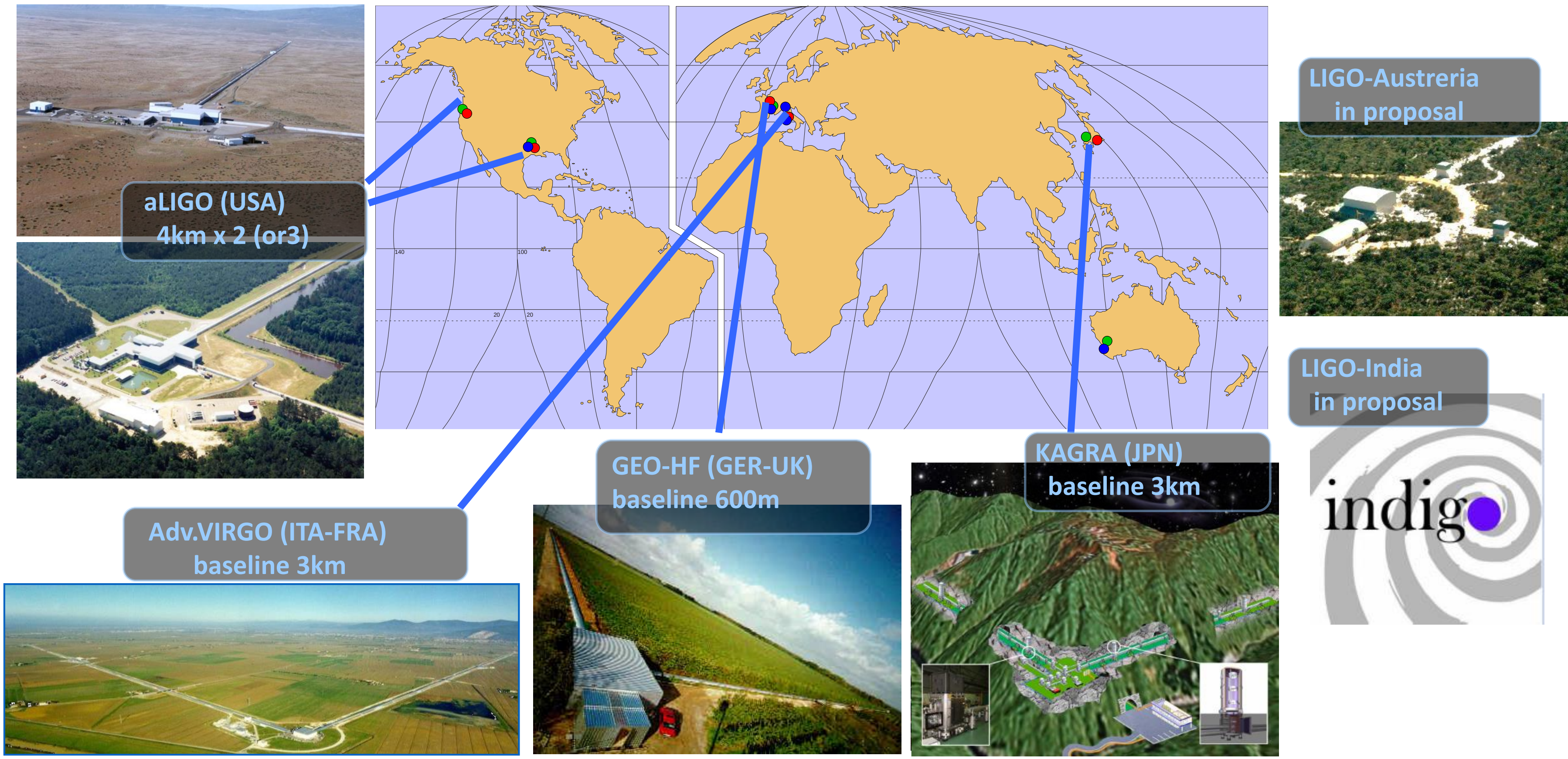
~2000, those big scale detectors have started their operation

Here, I can add remarks (from my impression after reading several reports)

・ From 90's , numerical (computing) method to calculate the Einstein equation shows progress

・ From 05~07(?) , treatment of black holes etc... can be well done for this topic.

2nd-generation detector



Sensitivity and the expected event rate is more than 1 order higher than 1st generation's .

Direct observation of GW (2016)

Selected for a Viewpoint in *Physics*
PRL **116**, 061102 (2016) PHYSICAL REVIEW LETTERS week ending 12 FEBRUARY 2016

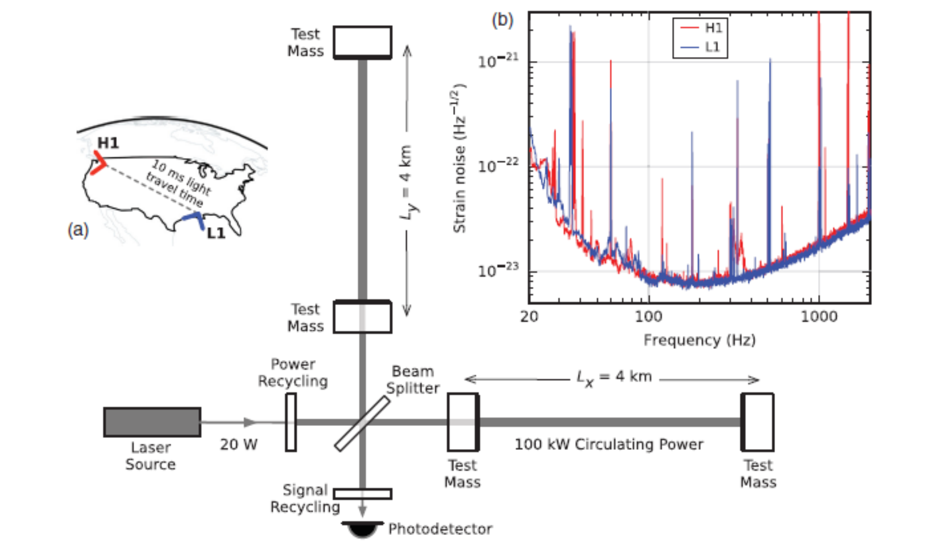
Observation of Gravitational Waves from a Binary Black Hole Merger

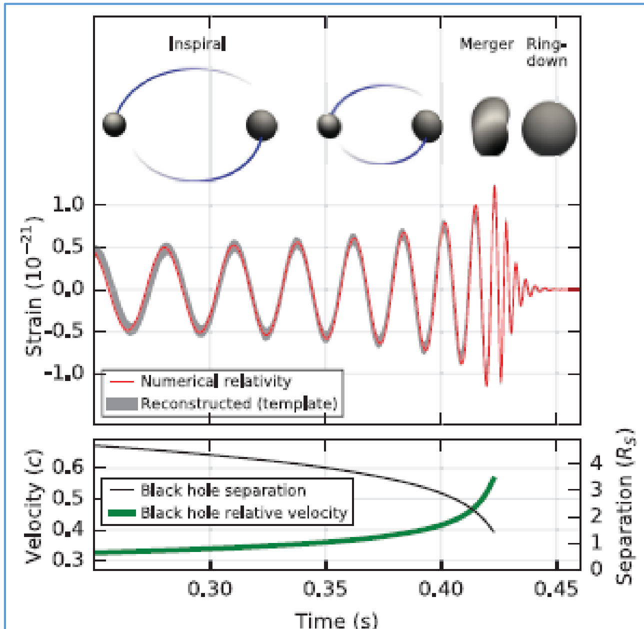
B. P. Abbott *et al.**
(LIGO Scientific Collaboration and Virgo Collaboration)
(Received 21 January 2016; published 11 February 2016)

On September 14, 2015 at 09:50:45 UTC the two detectors of the Laser Interferometer Gravitational-Wave Observatory simultaneously observed a transient gravitational-wave signal. The signal sweeps upwards in frequency from 35 to 250 Hz with a peak gravitational-wave strain of 1.0×10^{-21}. It matches the waveform predicted by general relativity for the inspiral and merger of a pair of black holes and the ringdown of the resulting single black hole. The signal was observed with a matched-filter signal-to-noise ratio of 24 and a false alarm rate estimated to be less than 1 event per 203 000 years, equivalent to a significance greater than 5.1σ. The source lies at a luminosity distance of 410^{+160}_{-180} Mpc corresponding to a redshift $z = 0.09^{+0.03}_{-0.04}$. In the source frame, the initial black hole masses are $36^{+5}_{-4} M_\odot$ and $29^{+4}_{-4} M_\odot$, and the final black hole mass is $62^{+4}_{-4} M_\odot$, with $3.0^{+0.5}_{-0.5} M_\odot c^2$ radiated in gravitational waves. All uncertainties define 90% credible intervals. These observations demonstrate the existence of binary stellar-mass black hole systems. This is the first direct detection of gravitational waves and the first observation of a binary black hole merger.

DOI: 10.1103/PhysRevLett.116.061102

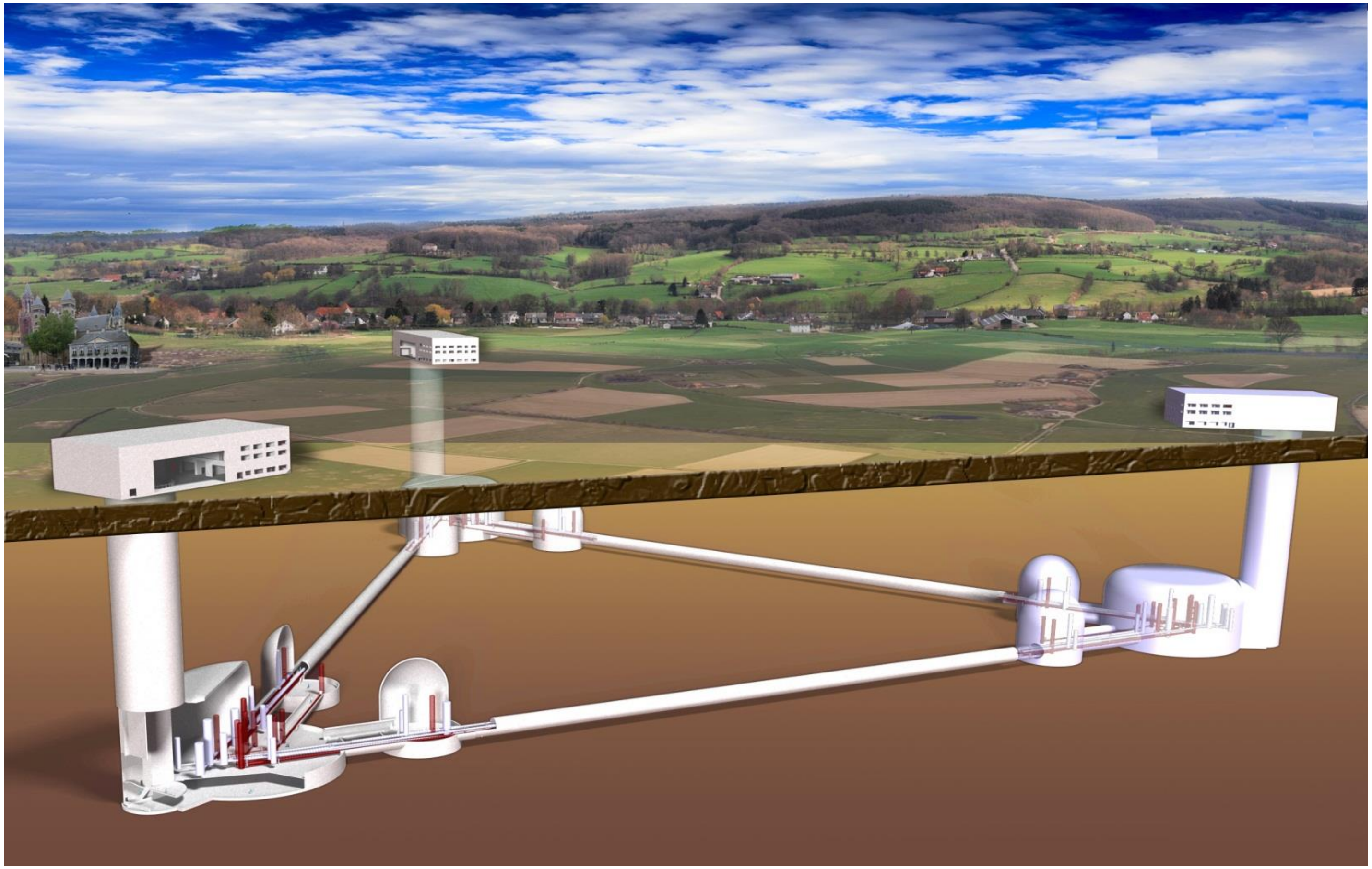
PRL **116**, 061102 (2016) PHYSICAL REVIEW LETTERS week ending 12 FEBRUARY 2016





3rd-generation detector : ET (Einstein Telescope)

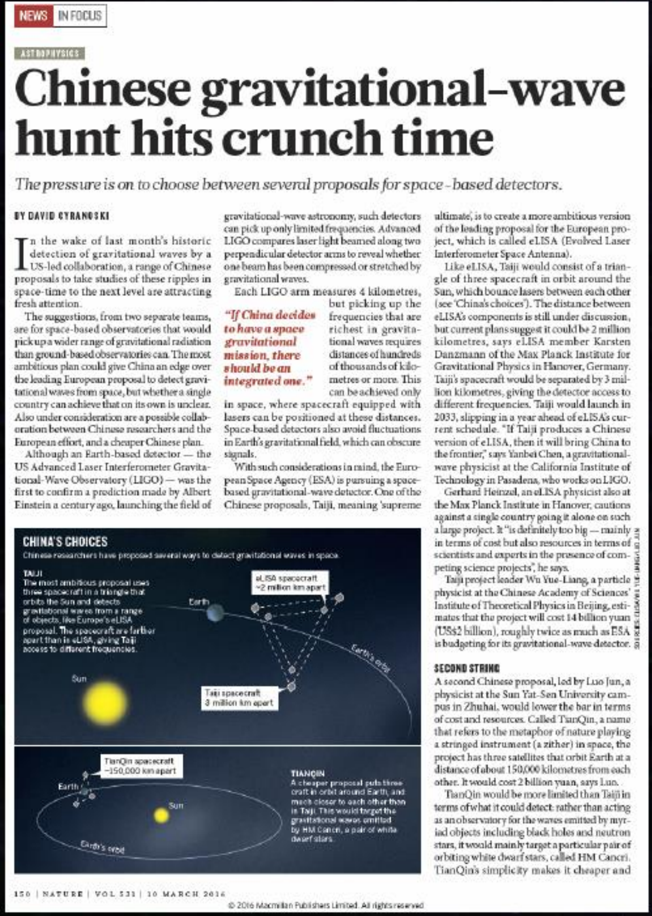
~2026 ? . L ~10km, undergraound, w cold temperature



GW experiments proposed in China ?

Chinese GW Mission

Nature 531, 150 (March 2016)



NEWS IN FOCUS

ASTROPHYSICS

Chinese gravitational-wave hunt hits crunch time

The pressure is on to choose between several proposals for space-based detectors.

BY DAVID CYRANOSKI

In the wake of last month's historic detection of gravitational waves by a US-led collaboration, a range of Chinese proposals to take studies of these ripples in space-time to the next level are attracting fresh attention.

The suggestions, from two separate teams, are for space-based observatories that would pick up a wider range of gravitational radiation than ground-based observatories can. The most ambitious plan could give China an edge over the leading European proposal to detect gravitational waves from space, but whether a single country can achieve that on its own is unclear. Also under consideration are a possible collaboration between Chinese researchers and the European effort, and a cheaper Chinese plan.

Although an Earth-based detector — the US Advanced Laser Interferometer Gravitational-Wave Observatory (LIGO) — was the first to confirm a prediction made by Albert Einstein a century ago, launching the field of gravitational-wave astronomy, such detectors can pick up only limited frequencies. Advanced LIGO compares laser light beamed along two perpendicular detector arms to reveal whether one beam has been compressed or stretched by gravitational waves.

Each LIGO arm measures 4 kilometres, but picking up the frequencies that are richest in gravitational waves requires distances of hundreds of thousands of kilometres or more. This can be achieved only in space, where spacecraft equipped with lasers can be positioned at these distances. Space-based detectors also avoid fluctuations in Earth's gravitational field, which can obscure signals.

"If China decides to have a space gravitational mission, there should be an integrated one."

With such considerations in mind, the European Space Agency (ESA) is pursuing a space-based gravitational-wave detector. One of the Chinese proposals, Taiji, meaning 'supreme ultimate', is to create a more ambitious version of the leading proposal for the European project, which is called eLISA (Evolved Laser Interferometer Space Antenna).

Like eLISA, Taiji would consist of a triangle of three spacecraft in orbit around the Sun, which bounce lasers between each other (see 'China's choices'). The distance between eLISA's components is still under discussion, but current plans suggest it could be 2 million kilometres, says eLISA member Karsten Danzmann of the Max Planck Institute for Gravitational Physics in Hanover, Germany. Taiji's spacecraft would be separated by 3 million kilometres, giving the detector access to different frequencies. Taiji would launch in 2033, slipping in a year ahead of eLISA's current schedule. "If Taiji produces a Chinese version of eLISA, then it will bring China to the frontier," says Yanbei Chen, a gravitational-wave physicist at the California Institute of Technology in Pasadena, who works on LIGO.

Gerhard Heinzel, an eLISA physicist also at the Max Planck Institute in Hanover, cautions against a single country going it alone on such a large project. It "is definitely too big — mainly in terms of cost but also resources in terms of scientists and experts in the presence of competing science projects", he says.

Taiji project leader Wu Yue-Liang, a particle physicist at the Chinese Academy of Sciences' Institute of Theoretical Physics in Beijing, estimates that the project will cost 14 billion yuan (US$2 billion), roughly twice as much as ESA is budgeting for its gravitational-wave detector.

SECOND STRING

A second Chinese proposal, led by Luo Jun, a physicist at the Sun Yat-Sen University campus in Zhuhai, would lower the bar in terms of cost and resources. Called TianQin, a name that refers to the metaphor of nature playing a stringed instrument (a zither) in space, the project has three satellites that orbit Earth at a distance of about 150,000 kilometres from each other. It would cost 2 billion yuan, says Luo.

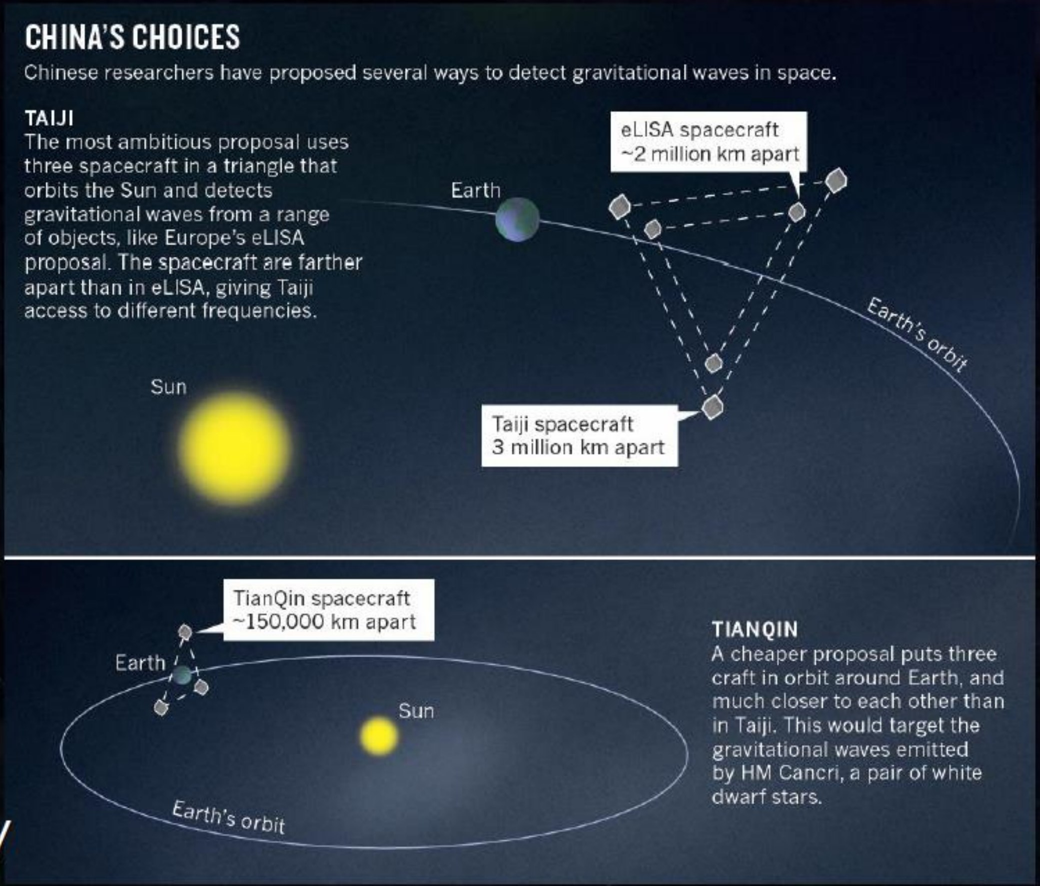
TianQin would be more limited than Taiji in terms of what it could detect: rather than acting as an observatory for the waves emitted by myriad objects including black holes and neutron stars, it would mainly target a particular pair of orbiting white dwarf stars, called HM Cancri. TianQin's simplicity makes it cheaper and

- Just after the LIGO's announcement of the first discovery in Feb. 2016, China decided to launch space GW mission.

Chinese GW Missions

- Taiji (太極)
  * Slightly longer than LISA
  * Heliocentric orbit
  * Proposed by Chinese Academy of Science

- TianQin (天琴)
  * ~10 times shorter
  * Geocentric orbit
  * Proposed by Sun Yat-Sen University



Paper for the JC 39

[Motivation for this selection]

- (I want to know or) feel interesting how to distinguish from SM tt->h
- Can we connect it with future dark matter search ?

Search for heavy Higgs bosons A/H decaying to a top quark pair in pp collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector

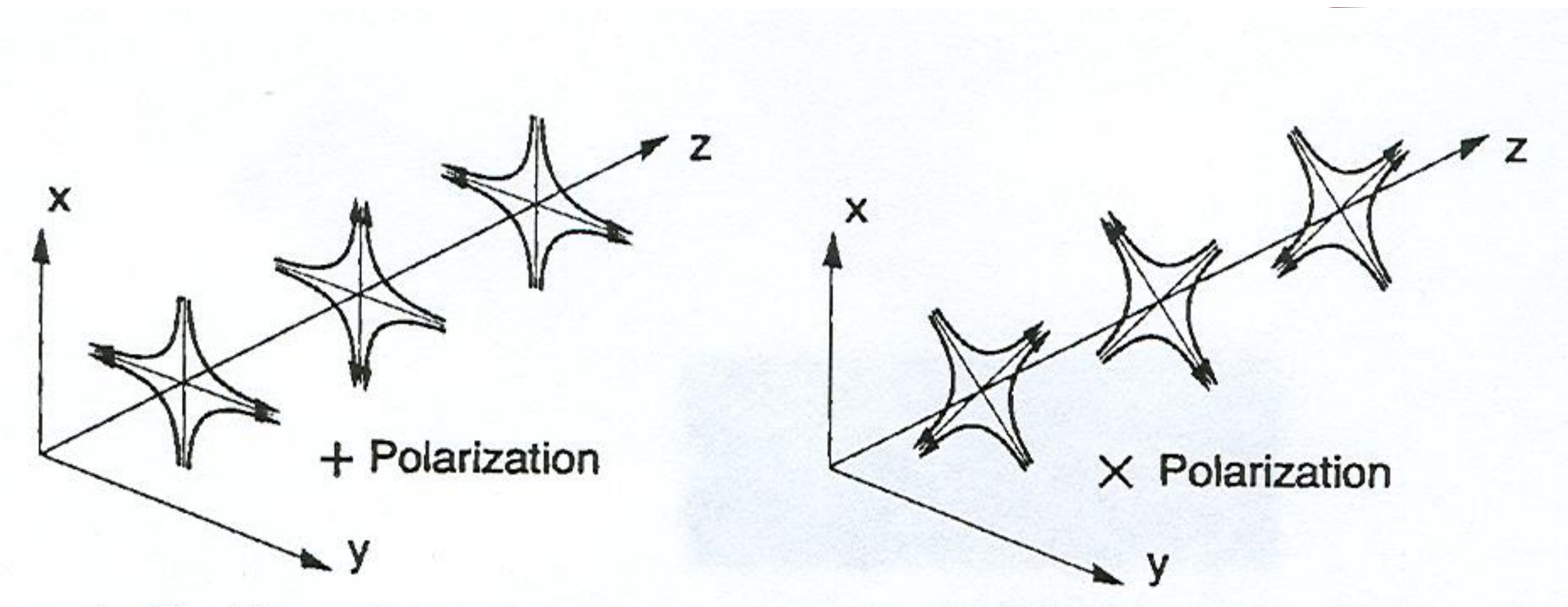
ATLAS Collaboration

A search for heavy pseudoscalar (A) and scalar (H) Higgs bosons decaying into a top quark pair ($t\bar{t}$) has been performed with 20.3 fb^{-1} of proton–proton collision data collected by the ATLAS experiment at the Large Hadron Collider at a center-of-mass energy of $\sqrt{s}$ = 8 TeV. Interference effects between the signal process and Standard Model $t\bar{t}$ production, which are expected to distort the signal shape from a single peak to a peak–dip structure, are taken into account. No significant deviation from the Standard Model prediction is observed in the $t\bar{t}$ invariant mass spectrum in final states with an electron or muon, large missing transverse momentum, and at least four jets. The results are interpreted within the context of a type-II two-Higgs-doublet model. Exclusion limits on the signal strength are derived as a function of the mass $m_{A/H}$ and the ratio of the vacuum expectation values of the two Higgs fields, $\tan\beta$, for $m_{A/H} > 500$ GeV.

arXiv:1707.06025v1 [hep-ex] 19 Jul 2017

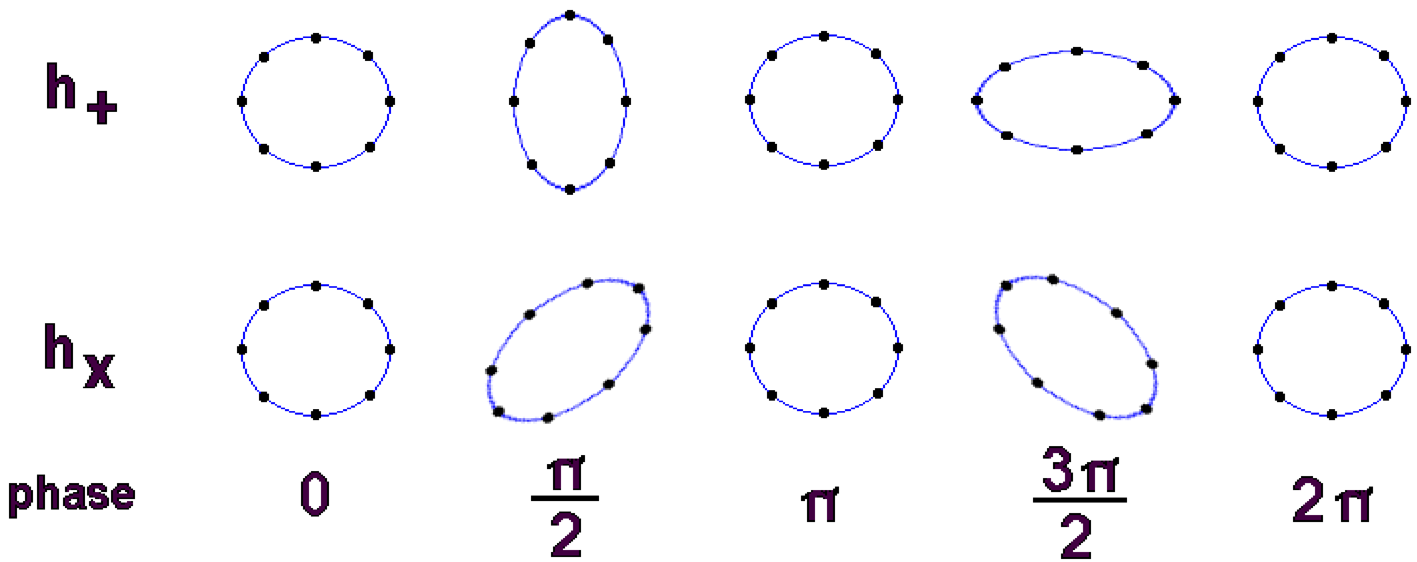
Quadrupole Field

- An oscillating dipole produces EM waves.
- A time varying mass-quadrupole produces GWs



Gravitational-waves

- GWs stretch and compress the space-time in two directions (polarizations): ‘+’ and ‘x’.



- h_+ & h_x are time-varying and their amplitude depend on the source that is emitting GWs.