

Einstein's Gravity in War and Peace

Prof. David Kaiser

Wednesday, November 17, 2010, STS.003

Heavens unit

Overarching questions:

Are representations of astronomical phenomena *true* or merely *useful*?

How does scientific knowledge travel?



I. War and Spacetime

Große Naturforscher

Eine Geschichte der Naturforschung
in Lebensbeschreibungen

Von
Philipp Lenard
Geiselberg

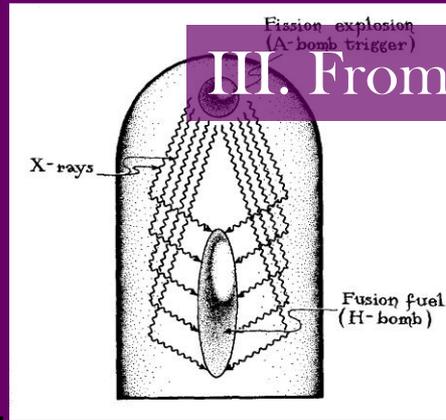
„Alle Fortschritte und alle Kultur
der Menschheit sind nicht aus der
Majorität geboren, sondern beruhen
ausschließlich auf der Genialität
und der Tatkraft der Persönlichkeit.
Der Führer.“

Sechste Auflage · Mit 70 Bildnissen



J. F. Lehmanns Verlag / München 1943

II. Fame and Backlash



III. From Bombs to the Cosmos

Readings: Einstein, “What is the theory of relativity?,” 227 – 232;
Kaiser, “General relativity primer”

Screen shots of online articles removed due to copyright restrictions. To read these articles, see "[Counterexamples to Relativity](#)" on Conservapedia and "[Defending Einstein from the New Barbarians](#)".

Late last week...

Einstein and Politics

Freedom of Information and Privacy Acts

Subject: ALBERT EINSTEIN
File Number: 61-7099
Section: 1



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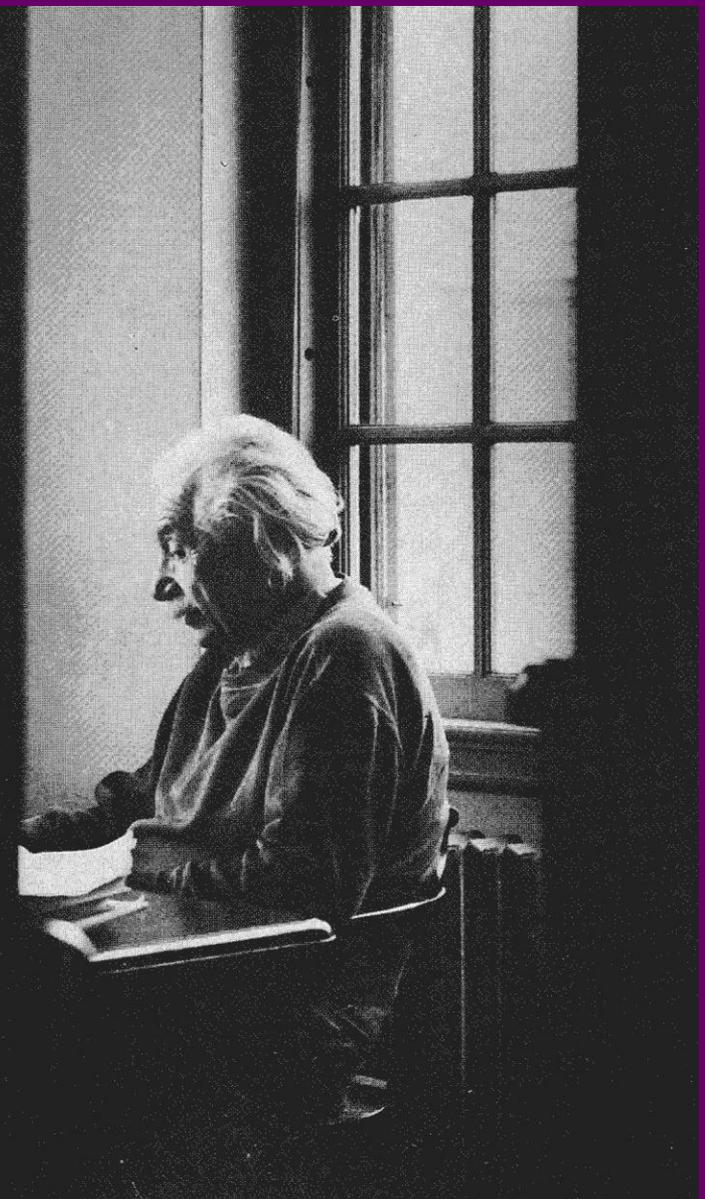
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OF ALBERT EINSTEIN TO THE UNITED STATES

Honorable A. Dana Hodgdon, Chief
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Washington, D.C. DEC 2 - 1932

61-7099 -1
REC 1 1932 P.M.
November 19, 1932
MAN

Dear Sir:

It is respectfully requested, in view of the mandatory Alien Exclusion Laws of the United States, and the laws making it a felony for any person knowingly to assist or permit certain classes of inadmissible aliens to enter the United States, that the American Consul General at Berlin, or Geneva, or any other American consular office at which application by Professor Albert Einstein for a passport visa may be made, be instructed to refuse and withhold such passport visa to Professor Einstein; or, if such passport visa has been issued, to suspend or revoke the same, in accordance with the laws and facts hereinafter set forth.



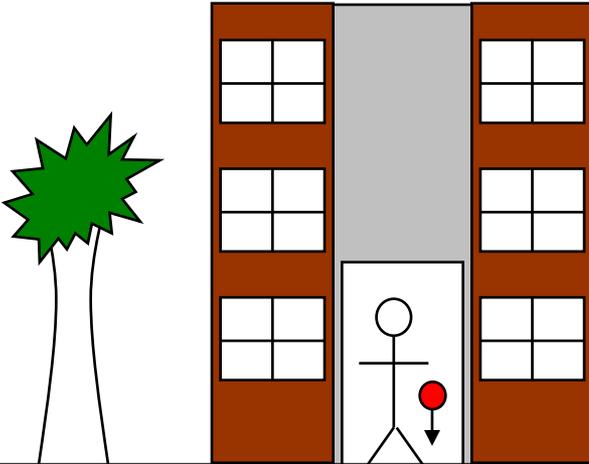
Photos of "Einstein on Politics: His Private Thoughts and Public Stands on Nationalism, Zionism, War, Peace, and the Bomb," David Rowe and Robert Schulmann, and "The Einstein File: J. Edgar Hoover's Secret War Against the World's Most Famous Scientist," Fred Jerome, removed due to copyright restrictions.

“Temple of Relativity”

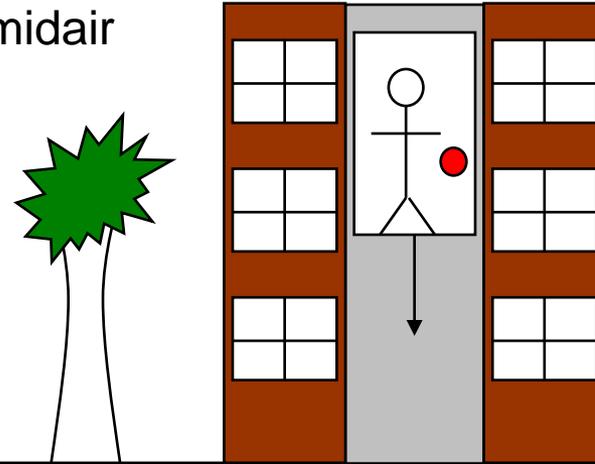
Cartoon of the Taj Mahal with equations on it removed due to copyright restrictions.

Thought Experiment: Dropping the Ball

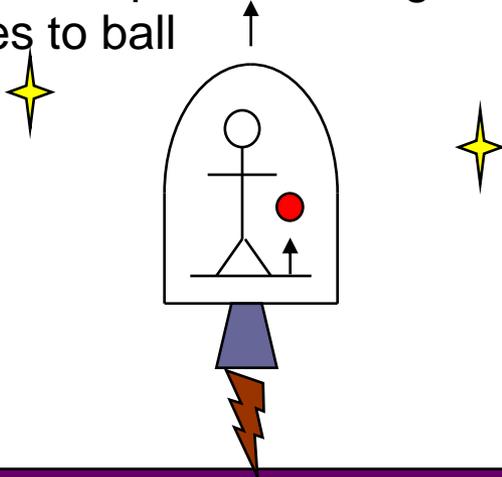
Elevator at rest: ball falls to floor



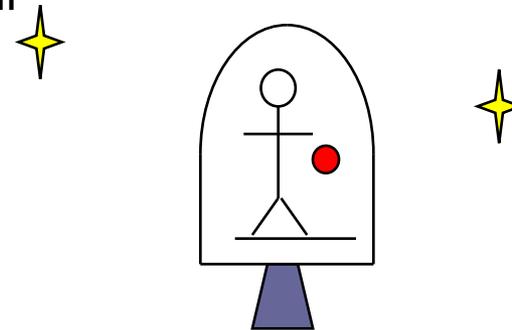
Elevator in free fall: ball hangs in midair



Spaceship accelerating: floor rises to ball



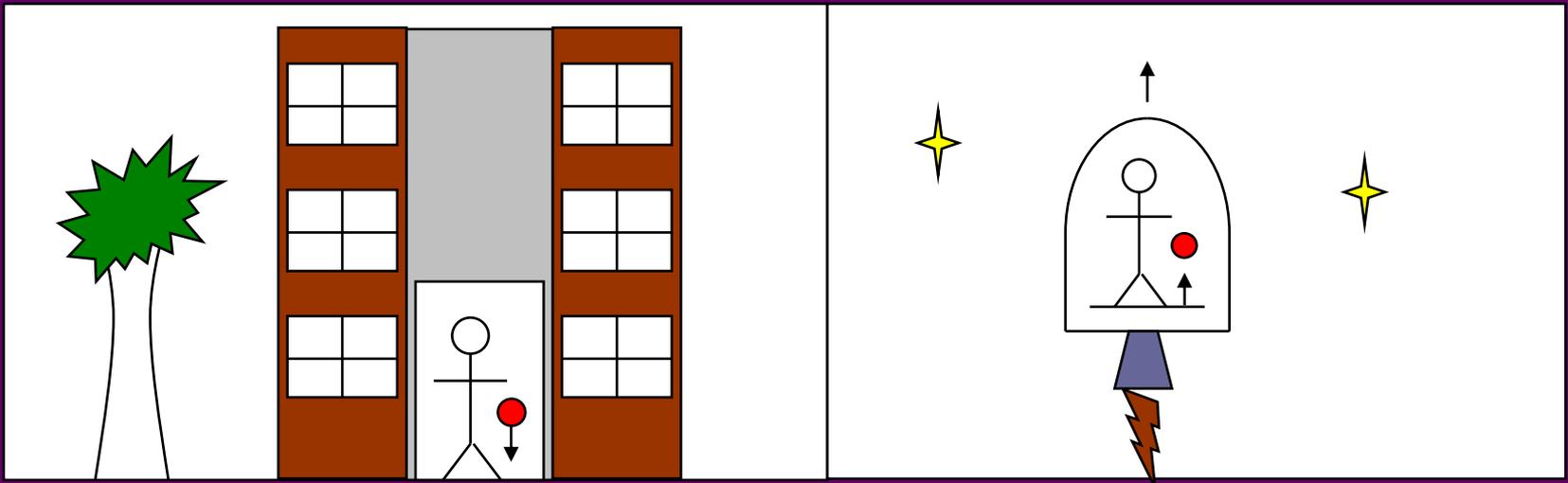
Spaceship at rest: ball hangs in midair



An “Asymmetry in the Explanation”

Einstein: There aren't really 4 phenomena — only 2! The ball either falls toward the floor or it doesn't.

The same phenomenon had been given separate descriptions:



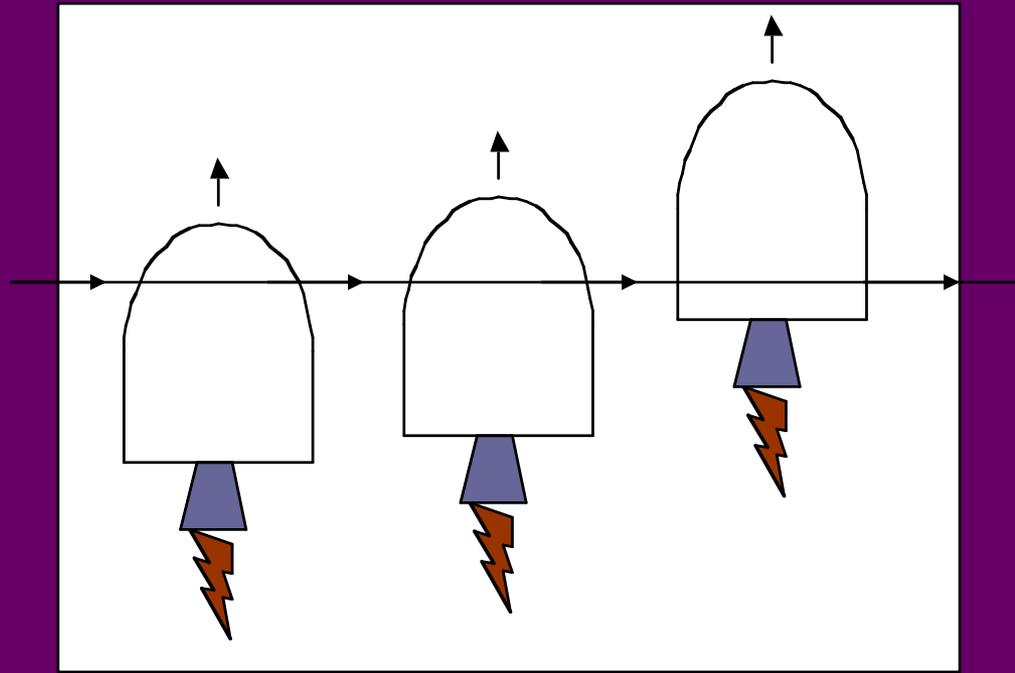
The earth's **gravitational attraction** pulls the ball downward.

No forces push on the ball, so it stays at rest, while the floor **accelerates** upward.

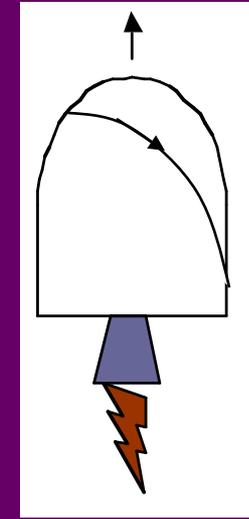
But no experiment could *distinguish* between the two descriptions.

Gravity and acceleration are interchangeable.

Follow the Light Beam



View outside spaceship



View inside spaceship

Inside the accelerating spaceship, the light beam appears to bend toward the floor. Enter the *Equivalence Principle*: the same phenomenon must occur when the spaceship is *at rest* in a *gravitational field*.

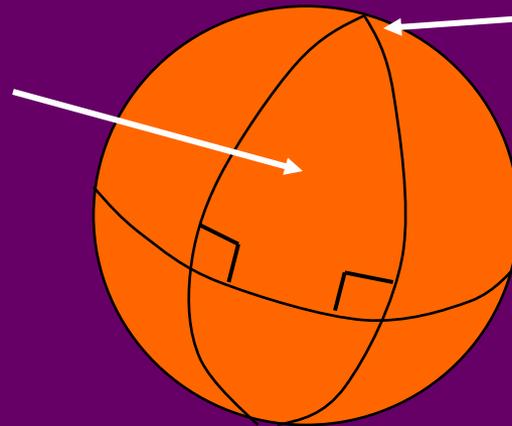
Gravity must bend the path of light.

Spacetime is Curved

Light is special: nothing travels faster than light, and everyone agrees on its speed. So people can use light to chart the *shortest distances* between two points. Light becomes a *mapping tool*.

If a light beam's path is curved by gravity, this is like saying that spacetime itself is curved by gravity. The geometry of spacetime need *not* be *Euclidean*.

interior angles of a triangle $> 180^\circ$



parallel lines intersect

surface of a sphere

A little help from his friends

After several years of false starts, Einstein eventually arrived at the field equations of *General Relativity*.



Marcel Grossmann, 1920

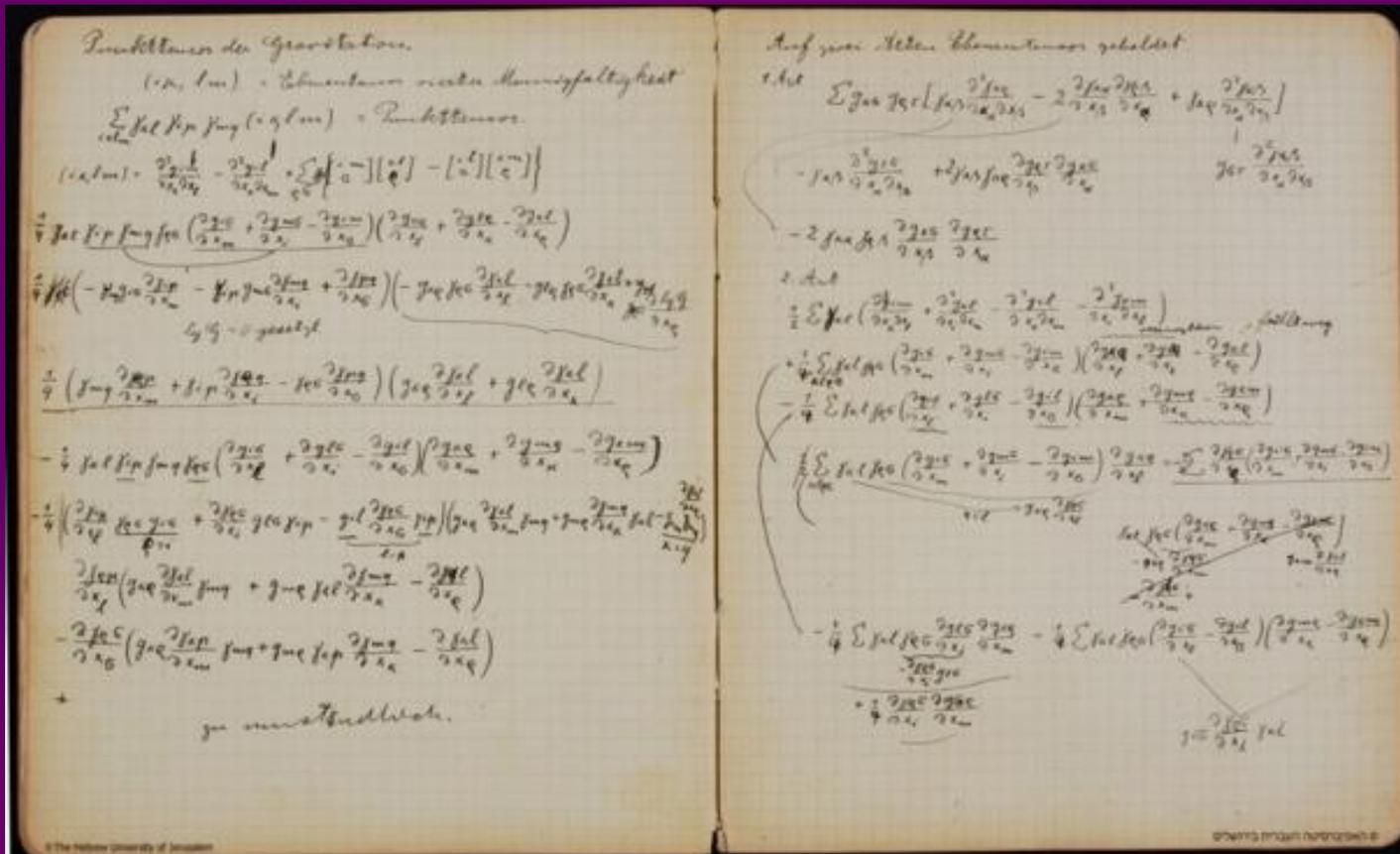
$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = \frac{8\pi G}{c^2} T_{\mu\nu}$$

curvature of spacetime = distribution of matter and energy

Long Gestation

Einstein labored for 10 years on his theory of gravitation. After several false starts, he arrived at his equations in November 1915 — right in the midst of World War I.

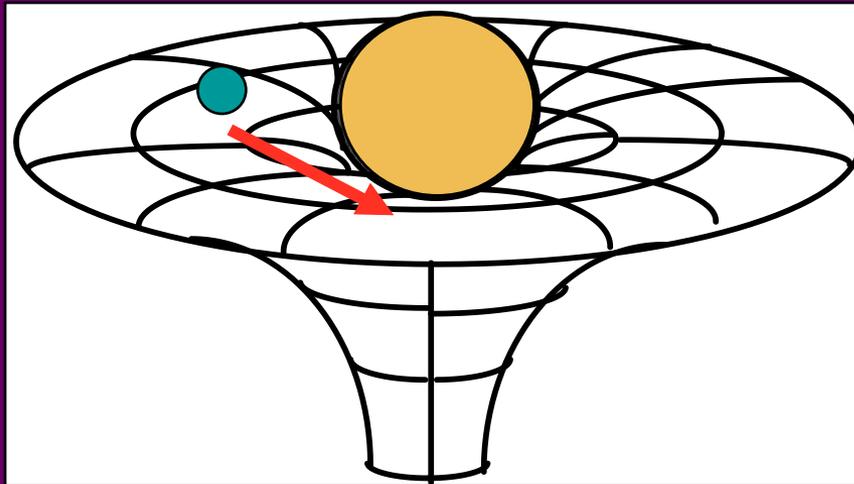
Image of "The Genesis of General Relativity: Sources and Interpretations," Jürgen Renn, removed due to copyright restrictions.



Einstein's Zurich notebook, ca. 1913

Geometry Supreme

To Einstein, gravitation was *nothing but geometry*. There was no “force” of gravity: objects simply followed the shortest paths through curved spacetime.



The earth “falls” in its orbit around the sun because the sun makes a bigger “dent” in the surrounding spacetime than does the earth.

The Relativity Virus

Einstein's work was so novel — relying on difficult mathematics and unfamiliar concepts — that virtually no scientists worked on it without direct, personal contact with Einstein himself. General relativity spread like a *virus*.

Map of Europe in 1914 removed due to copyright restrictions. See: [europe1914.gif](#).



Einstein with W. Pauli, 1926

“The theory of gravitation will not find its way into my colleagues’ heads for a long time yet, no doubt.”

Einstein to H. Zangger, 1915

Relativity on the Eastern Front

The war shaped how news of Einstein's work spread. One of the first converts was the Russian mathematician, *Vsevolod Frederiks*, who had been studying in Göttingen.



Göttingen Institute for Theoretical Physics

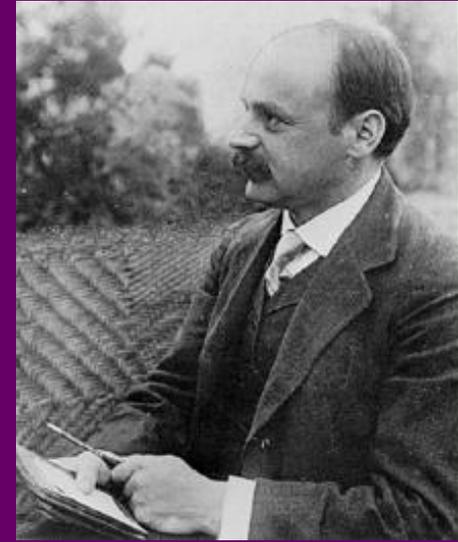


Aus dem großen Gefangenenlager Weinberge bei Jossen: Gefangene vor der Postanstalt. Sep. 19. 1914.

Soon after hearing Einstein lecture on the new theory, Frederiks was detained as a civilian prisoner of war. Upon his release, he returned to his native St. Petersburg and helped train Russia's first experts in general relativity.

Equations in the Trenches

Another Göttingen colleague, *Karl Schwarzschild*, discovered his now-famous solution to Einstein's equations as a diversion while serving in the German Army.



K. Schwarzschild,
ca. 1908

Image of "On the Gravitational Field Of A Mass Point According to Einstein's Theory," K. Schwarzschild. See: [Arxiv.org](https://arxiv.org).

Image of Karl Schwarzschild's grave removed
due to copyright restrictions.

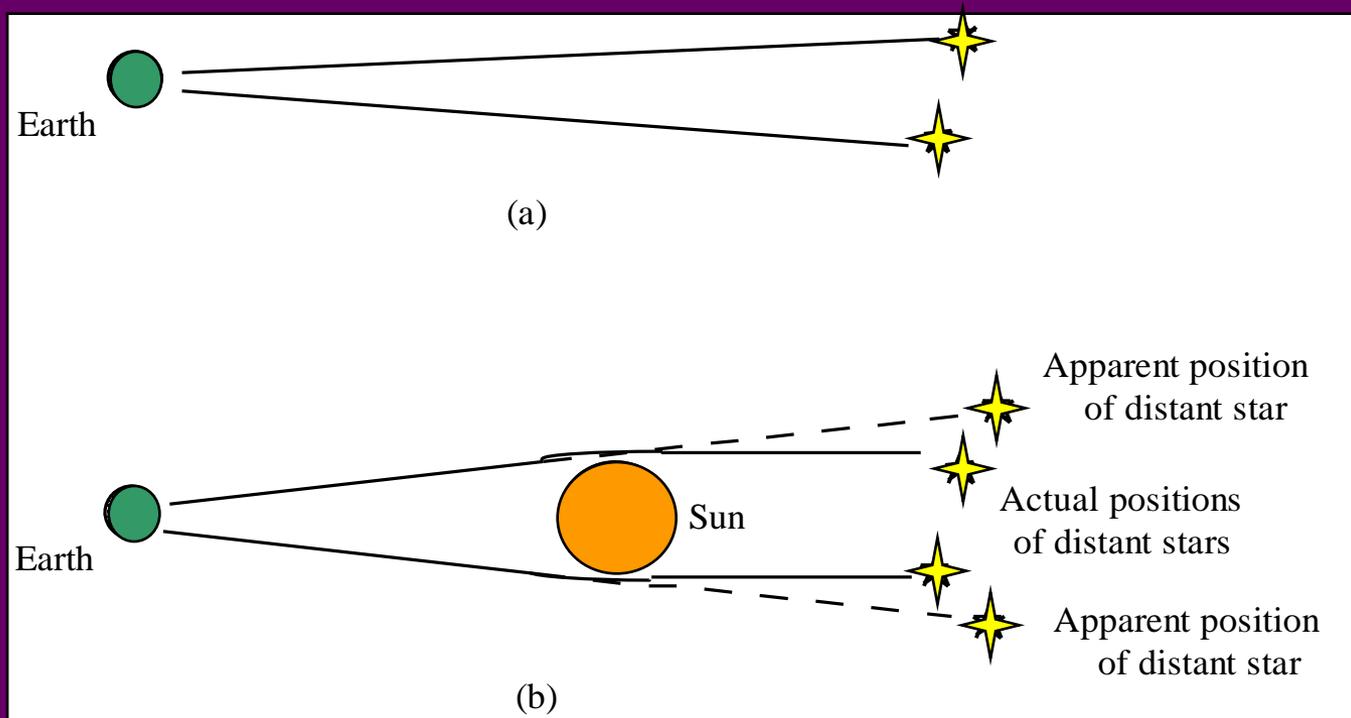
Soon after publishing his paper, he died
from a rare skin disease contracted on the
Russian front.

Eclipse and Imprisonment

Still another of Einstein's colleagues, the German astronomer *Erwin Freundlich*, tried to test a crucial prediction of Einstein's theory: that gravity could bend the path of starlight.



E. Freundlich



Einstein letter, 1913

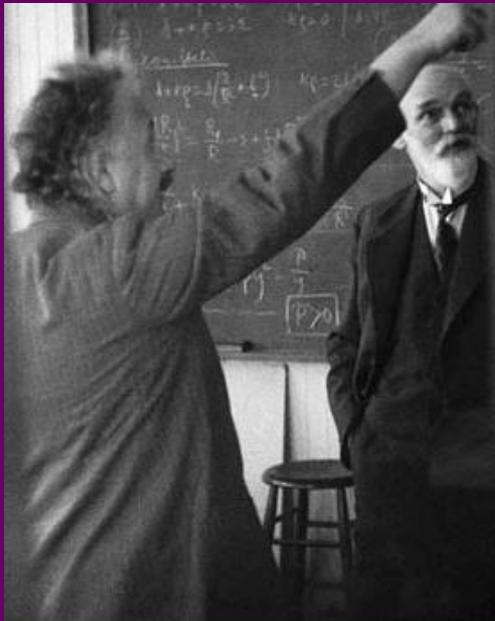
Freundlich found himself on the wrong side of the Russian border when war broke out, and was sent to a prison camp.

Relativity on the Western Front

Even after war had broken out, Einstein made several trips to visit colleagues in Leiden, since the Netherlands was still a neutral country.



Einstein visiting Paul Ehrenfest's group in Leiden, 1920s



Einstein and de Sitter, ca. 1932

He coached astronomers like *Willem de Sitter* in the intricacies of his new theory.

Beyond the Blockade

The war choked off all direct contact between scientists in Germany and Britain. *Arthur Eddington* learned about general relativity from Willem de Sitter, who sent him extensive English-language primers.



A. S. Eddington, ca. 1920

Eddington, a Quaker and conscientious objector, completed his wartime national service by preparing a new eclipse expedition to test Einstein's prediction about the bending of starlight.

Images of "Masters of Theory: Cambridge and the Rise of Mathematical Physics," Andrew Warwick," and "Practical Mystic: Religion, Science, and A.S. Eddington," Matthew Stanley, removed due to copyright restrictions.

Eddington's Announcement

Immediately after the war, a British expedition led by *Eddington* was successful.



Nov 1918: *Armistice*

May 1919: *Eclipse expedition*

Nov 1919: *Results announced*

Einstein was greeted by a ticker-tape parade in New York City in 1921.

(In this case, the war actually accelerated interest and research into Einstein's work.)

LIGHTS ALL ASKEW IN THE HEAVENS

Men of Science More or Less
Agog Over Results of Eclipse
Observations.

EINSTEIN THEORY TRIUMPHS

Stars Not Where They Seemed
or Were Calculated to be,
but Nobody Need Worry.

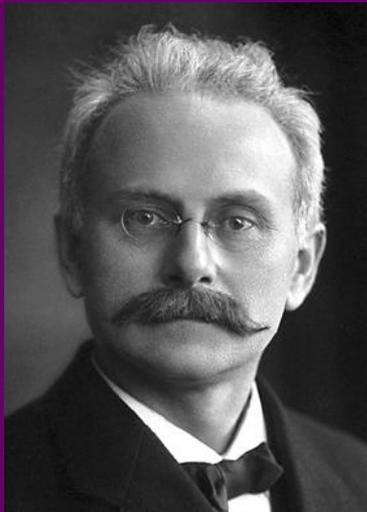
A BOOK FOR 12 WISE MEN

No More in All the World Could
Comprehend It, Said Einstein When
His Daring Publishers Accepted It.

Special Cable to THE NEW YORK TIMES.
LONDON, Nov. 9.—Efforts made to
put in words intelligible to the non-
scientific public the Einstein theory of

Backlash: deutsche Physik

Einstein told the London *Times*, 1919:
“Today I am described in Germany as a ‘German servant,’ and in England as a ‘Swiss Jew.’ Should it ever be my fate to be represented as a *bête noire*, I should, on the contrary, become a ‘Swiss Jew’ for the Germans and a ‘German savant’ for the English.”



Johannes Stark



Philipp Lenard

Große Naturforscher

Eine Geschichte der Naturforschung
in Lebensbeschreibungen

Von
Philipp Lenard
Heidelberg

“Aller Fortschritt und alle Kultur
der Menschheit sind nicht aus der
Majorität geboren, sondern beruhen
ausschließlich auf der Genialität
und der Tatkraft der Persönlichkeit.
Der Führer.”

Sechste Auflage • Mit 70 Bildnissen



J. F. Lehmanns Verlag / München 1943

Stark and Lenard Attack

Two-part strategy: 1. Einstein's work was repugnant to the Aryan sensibility. 2. Key results had been plagiarized from early Aryan researchers. (*"First of all, you're wrong, and second of all, we got there first!"*)

"The concept of force, which was introduced by Aryan scientists [like Newton and Galileo!], obviously arises from the personal experience of human labor, of manual creation, which has been and is the essential content of the life of Aryan man."

94 Molekularkräfte.

Das Umfassende seiner „Principia“ gibt Newton selbst zu erkennen aus seiner kurzen Mit-Anführung derjenigen Teile der Naturerkenntnis, die erst ganz in den Anfängen oder überhaupt nur andeutungsweise vorhanden waren, von denen er sagt, daß „nicht genügende Erfahrung (copia experimentorum) vorliege, um festbestimmtes darüber aufweisen zu können“¹⁾. Er nennt hier die Kräfte, mit welchen die be-



Bild 17. Isaac Newton.

nachbarten Teile der Körper in kleinsten Abständen einander anziehen, so daß sie zusammengehalten werden, wobei ersichtlich wird, daß er diese Kräfte — die Molekularkräfte und die chemischen Kräfte in heutiger Ausdrucksweise — nicht mehr wie Galilei (und auch noch Huygens) auf einen äußeren Druck zurückzuführen sucht, sondern daß er sie ähnlich der Gravitation wirkend, aber doch von derselben verschiedenen ansieht. Er nennt auch die elektrischen Anziehungen und Ab-

¹⁾ Schluß des „Scolium generale“ am Ende der „Principia“.

The little-known Johann Soldner had written a paper in 1803 (which Stark and Lenard republished in 1921), in which he had used Newtonian gravity to derive the bending of light near the sun. (Soldner's result was one-half of Einstein's value.)

General Relativity Recedes

Graph showing the number of worldwide publications on general relativity between 1920 and 1945 removed due to copyright restrictions. Between the mid-1920s and 1930, when there were about eighty. There was a steep rise in publications, which quickly dropped in 1930.

General Relativity Reborn

Number of publications on *GR* worldwide, 1920-90

What had changed?

Graph showing the number of worldwide publications on general relativity between 1920 and 1990 removed due to copyright restrictions. After a low base line, in the mid-1950s publication rates began to rise, more steeply beginning in the 1970s. They peaked at over 750 in the late 1980s.

New Patrons

Photo of Roger Babson removed due to copyright restrictions.

This monument is to remind students of the blessings forthcoming when a semi-insulator is discovered in order to harness gravity as a free power and reduce airplane accidents.

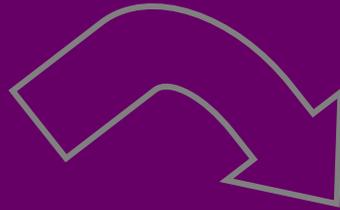
Announcement from the Gravity Research Foundation's 1951 Awards for Essays on Gravity removed due to copyright restrictions.
See: [Gravity Research Foundation](#).



Photo courtesy of [graysky](#) on Flickr.

Seeding a Community

Photo of the Gravity Research
Foundation removed due to copyright
restrictions.



Program from the Conference on the Role of
Gravitation in Physics at the University of North
Carolina, Chapel Hill, January 18023, 1957,
removed due to copyright restrictions.

New Tools

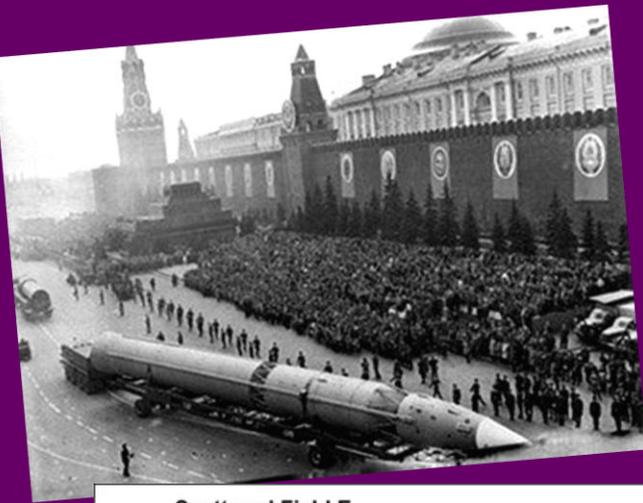
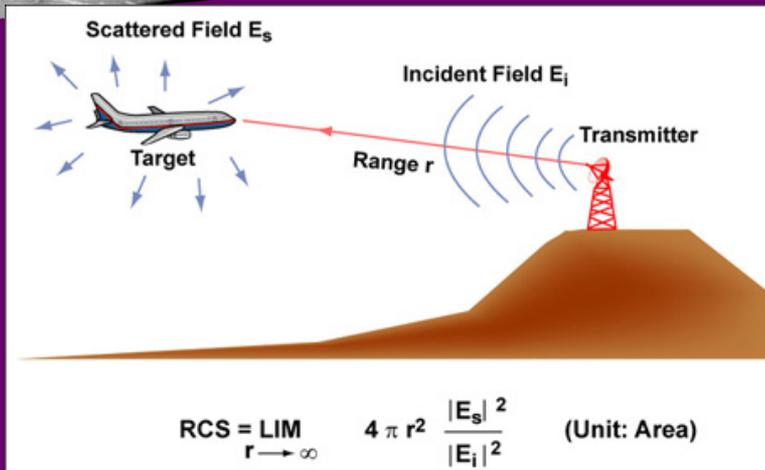


Image of "The Prediction of Ballistic Missile Trajectories from RADAR Observations," I.I. Shapiro, Technical Report No. 129, 27 February, 1957, removed due to copyright restrictions.



Radar research during and after World War II put a premium on finding tiny objects in the sky and separating signal from noise.

Targeting Venus

Image demonstrating conjunction with Earth, Mercury, and the Sun removed due to copyright restrictions.
See: [Positional Astronomy](#).

Image of paper removed due to copyright restrictions.
Shapiro, I.I., et al. "Fourth Test of General Relativity: Preliminary Results." *Physical Review of Letters*, 20 no. 20 (1968)

Graph of "excess" delay between April and September in 1967 removed due to copyright restrictions. See: Page 4 of "[Fourth Test of General Relativity](#)."

New high-precision tests of *GR* became possible: bounce radar signals off of Mercury and Venus and measure their return times. **Irwin Shapiro** led a group at MIT's *Lincoln Laboratory*, a postwar spin-off of MIT's wartime radar lab.

From H-Bombs to the Cosmos

A Numerical Method for Two-Dimensional Lagrangian Hydrodynamics

Bryce DeWitt

Radiation Laboratory, University of California, Livermore, California

With the increasing availability of high speed computing machines having large fast-memory storage it becomes possible to undertake the numerical investigation of hydrodynamic shock problems in two dimensions. Here is presented in outline a simple scheme for setting up the difference equations of such problems in purely Lagrangian form.

Introduce the following notation: x, y = Lagrangian coordinates, X, Y = Eulerian coordinates, U, V = velocity components, P = pressure, Q = artificial longitudinal viscous pressure⁽¹⁾, and G = specific volume. Then the basic hydrodynamical equations are

$$\dot{U} = -G\partial(P + Q)/\partial X \quad (1)$$

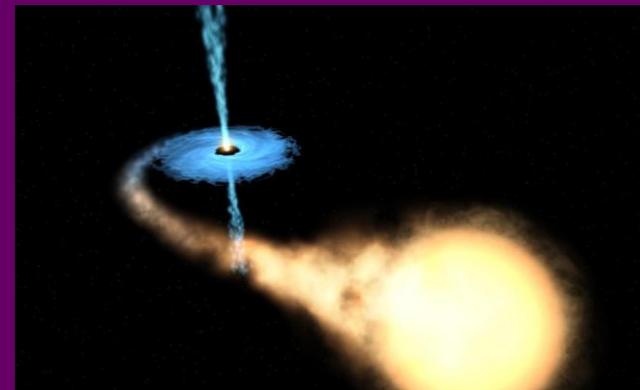
$$\dot{V} = -G\partial(P + Q)/\partial Y \quad (2)$$

$$\dot{X} = U, \quad \dot{Y} = V, \quad (3)$$

$$\dot{G} = G[\partial U/\partial X + \partial V/\partial Y], \quad (4)$$

$$d(PGY) = -(\gamma - 1)Q G^{\gamma-1} dG \quad (4)$$

Bryce DeWitt mastered early computer simulation codes for H-bombs at Livermore Lab during the early 1950s, then used the same approach to help invent numerical relativity during the 1960s. The method has been used to model black holes, cosmology, and more.



War, Peace, and Gravity

During the 1950s and 1960s, new patrons, new tools and techniques, and new discoveries (quasars, pulsars, microwave background radiation) brought Einstein's *general relativity* back to physicists' attention. Today it is at the heart of cutting-edge developments.

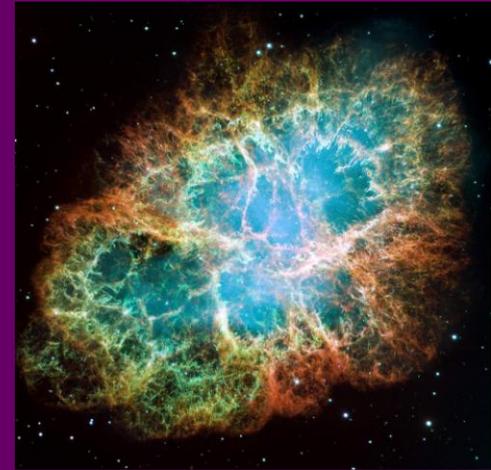


Photo courtesy of [koolkay](#) on Flickr.

The fortunes of Einstein's “temple of relativity”—erected during World War I, rejected by the Nazis, and reborn during the Cold War—rose and fell with the political tides. Even the most abstract theory could not escape “the fetters of everyday life.”

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STS.003 The Rise of Modern Science
Fall 2010

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