What Has Einstein Ever Done for You?

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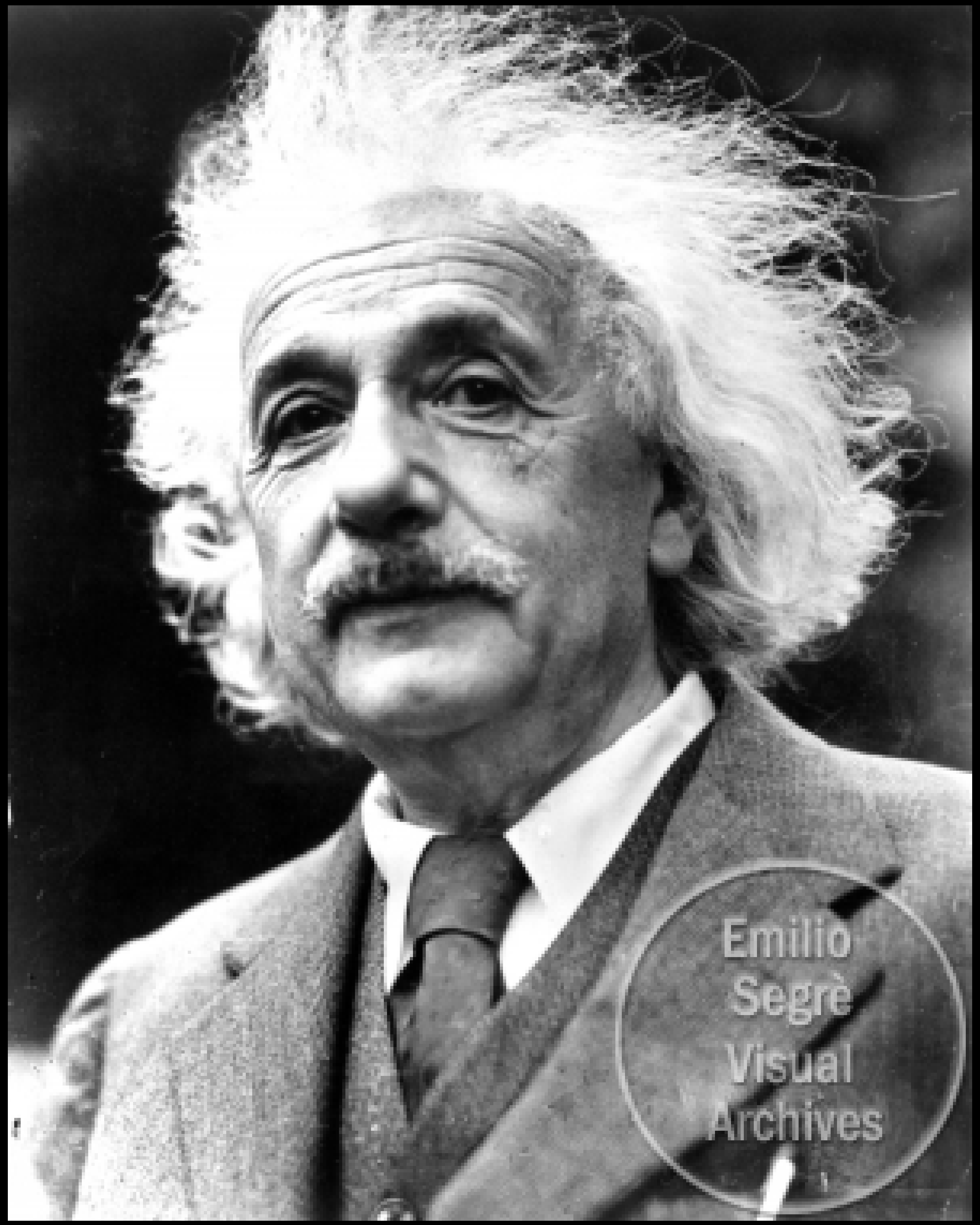
www.robertotrotta.com

@R_Trotta



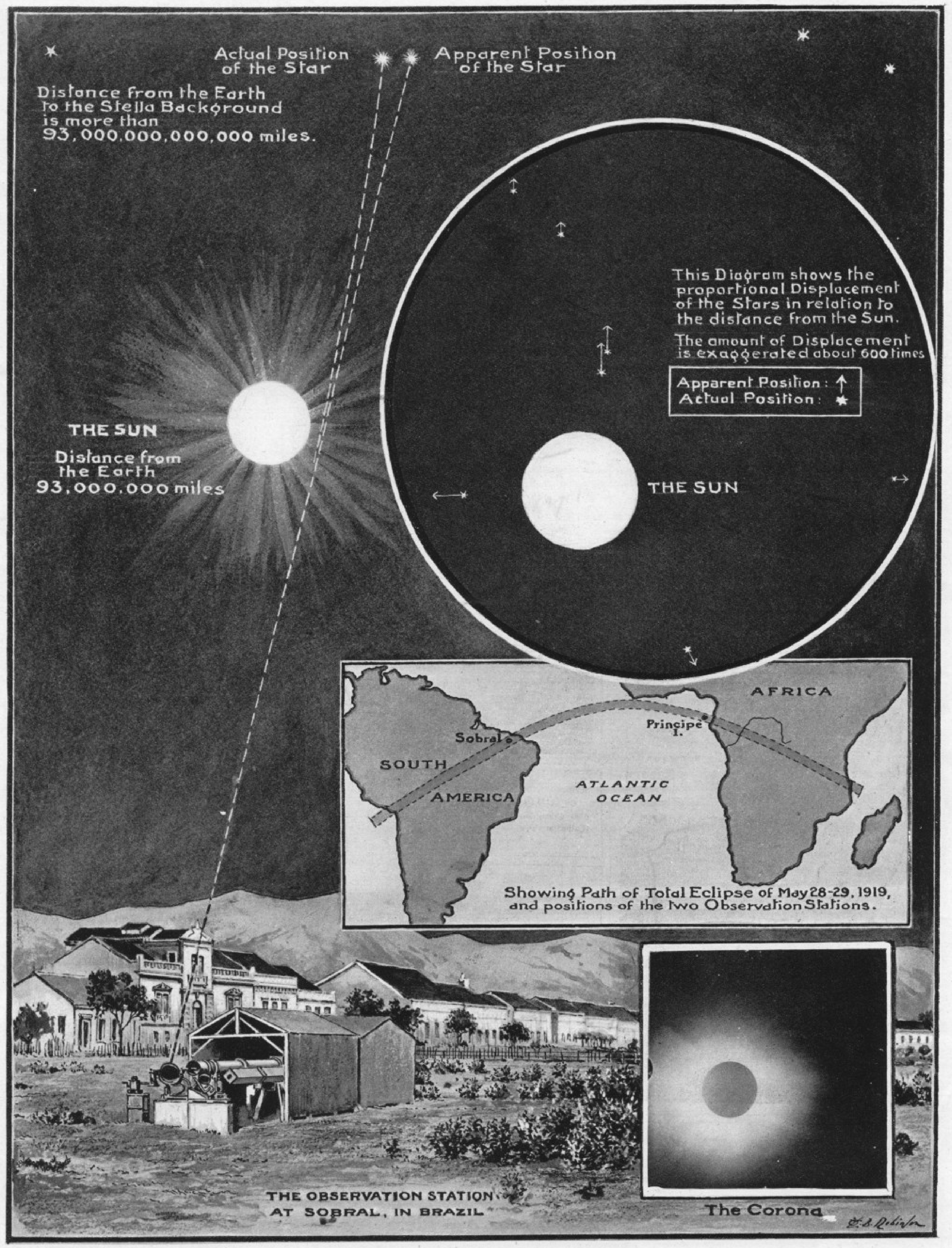
Albert Einstein in 1948

Credit: Emilio Segrè Visual Archives & Culver Pictures, Inc.

The Illustrated London News
Nov 22nd 1919

"STARLIGHT BENT BY THE SUN'S ATTRACTION": THE EINSTEIN THEORY.

DRAWN BY W. B. ROBINSON, FROM MATERIAL SUPPLIED BY DR. CROMMELIN.



THE CURVATURE OF LIGHT: EVIDENCE FROM BRITISH OBSERVERS' PHOTOGRAPHS AT THE ECLIPSE OF THE SUN.

The results obtained by the British expeditions to observe the total eclipse of the sun last May verified Professor Einstein's theory that light is subject to gravitation. Writing in our issue of November 15, Dr. A. C. Crommelin, one of the British observers, said: "The eclipse was specially favourable for the purpose, there being no fewer than twelve fairly bright stars near the limb of the sun. The process of observation consisted in taking photographs of these stars during totality, and comparing them with other plates of the same region taken when the sun was not in the neighbourhood. Then if the starlight is bent by the sun's attraction, the stars on the eclipse plates would seem to be pushed outward compared with those on the other plates. . . . The second Sobral camera and the one used at Principe agree in supporting (Einstein's theory). . . . It is of profound philosophical interest. Straight lines in Einstein's space cannot exist; they are parts of gigantic curves."—*[Drawing Copyrighted in the United States and Canada.]*

The New York Times
November 10th 1919

LIGHTS ALL ASKEW IN THE HEAVENS
Special Cable to THE NEW YORK TIMES.
New York Times 1857; Nov 10, 1919; ProQuest Historical Newspapers The New York Times (1851 - 2004)
pg. 17

LIGHTS ALL ASKEW IN THE HEAVENS

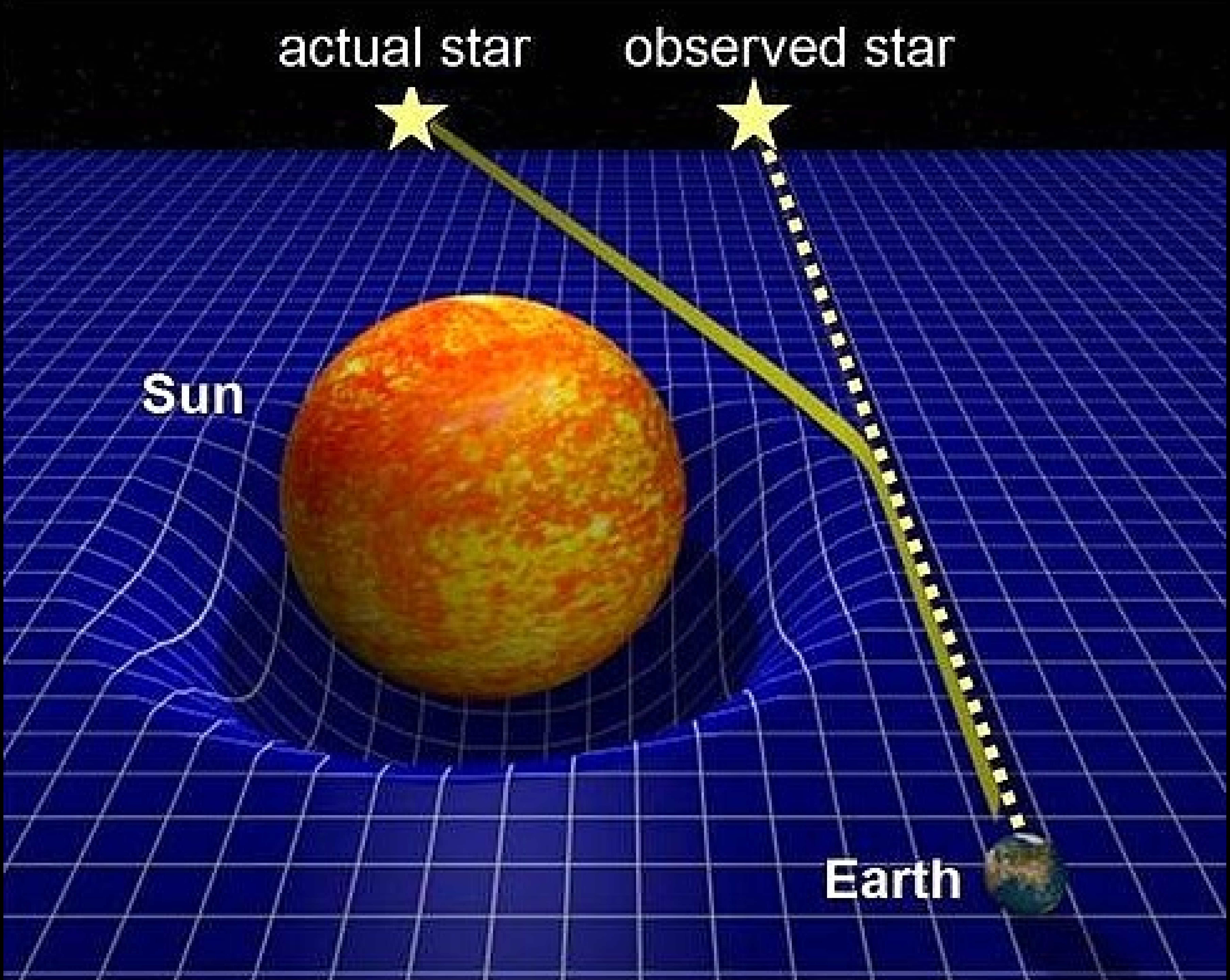
Men of Science More or Less Agog Over Results of Eclipse Observations.

EINSTEIN THEORY TRIUMPHS

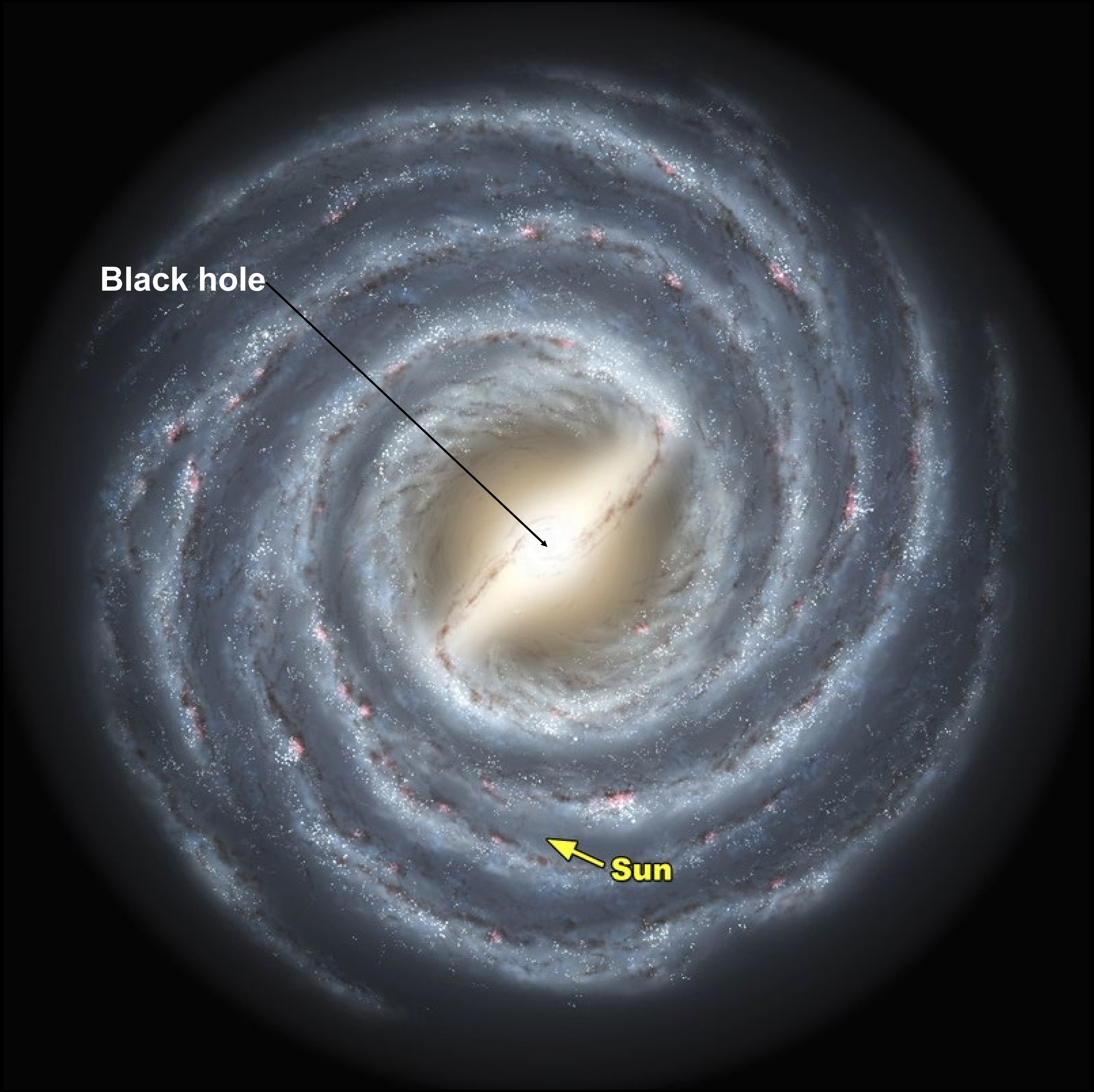
Stars Not Where They Seemed or Were Calculated to be, but Nobody Need Worry.

A BOOK FOR 12 WISE MEN

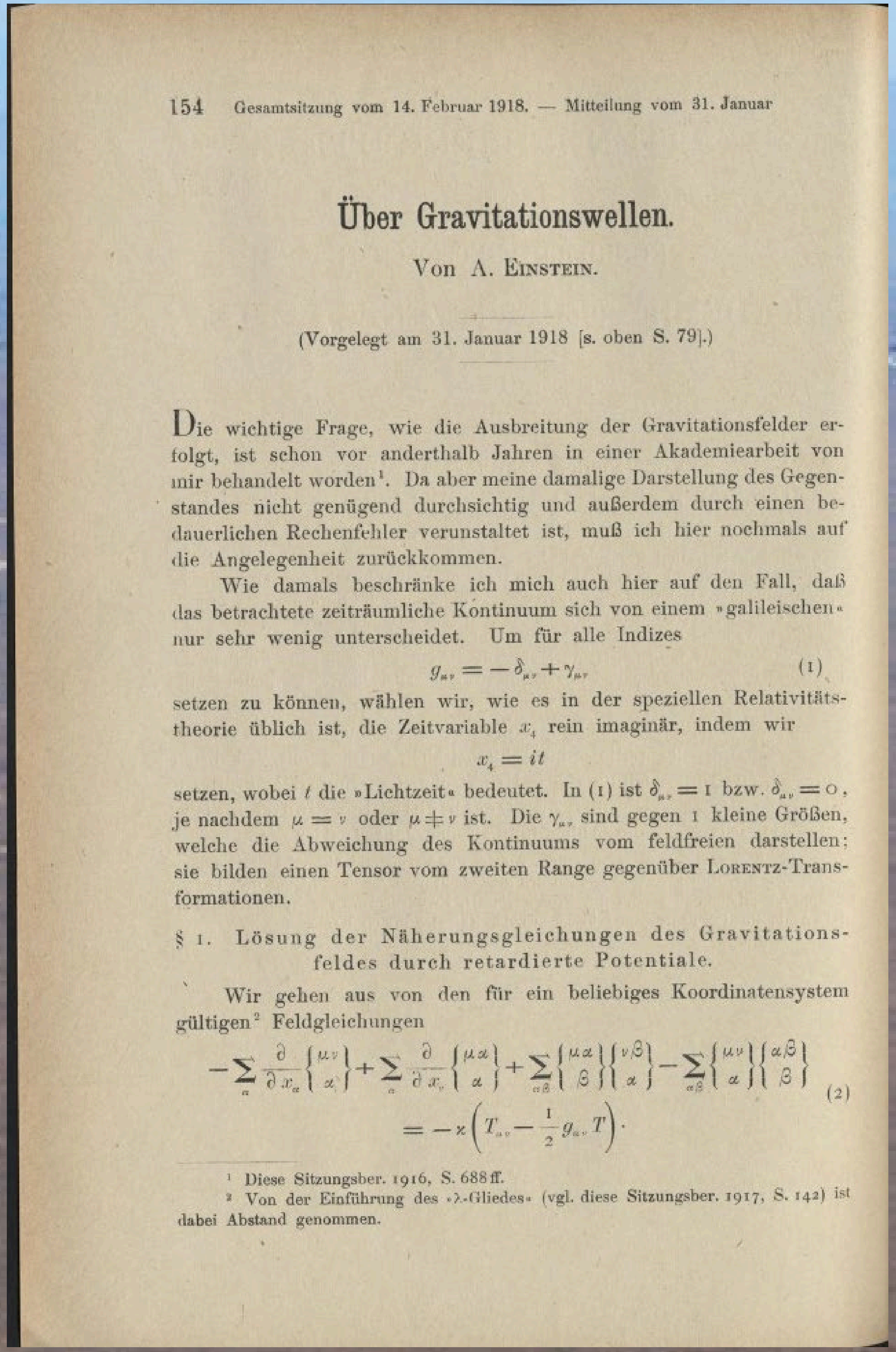
No More in All the World Could Comprehend It, Said Einstein When His Daring Publishers Accepted It.


actual star
observed star
Sun
Earth

Black hole


Black hole
Sun

The Supermassive Black Hole at the centre of our Galaxy



Über Gravitationswellen.

Von A. Einstein.

(Vorgelegt am 31. Januar 1918 [s. oben S. 79].)

Die wichtige Frage, wie die Ausbreitung der Gravitationsfelder erfolgt, ist schon vor anderthalb Jahren in einer Akademiearbeit von mir behandelt worden[1]. Da aber meine damalige Darstellung des Gegenstandes nicht genügend durchsichtig und außerdem durch einen bedauerlichen Rechenfehler verunstaltet ist, muß ich hier nochmals auf die Angelegenheit zurückkommen.

Wie damals beschränke ich mich auch hier auf den Fall, daß das betrachtete zeiträumliche Kontinuum sich von einem »galileischen« nur sehr wenig unterscheidet. Um für alle Indizes

$$g_{\mu\nu} = -\delta_{\mu\nu} + \gamma_{\mu\nu} \tag{1}$$

setzen zu können, wählen wir, wie es in der speziellen Relativitätstheorie üblich ist, die Zeitvariable x_4 rein imaginär, indem wir

$$x_4 = it$$

setzen, wobei t die »Lichtzeit« bedeutet. In (1) ist $\delta_{\mu\nu} = 1$ bzw. $\delta_{\mu\nu} = 0$, je nachdem $\mu = \nu$ oder $\mu \neq \nu$ ist. Die $\gamma_{\mu\nu}$ sind gegen 1 kleine Größen, welche die Abweichung des Kontinuums vom feldfreien darstellen; sie bilden einen Tensor vom zweiten Range gegenüber Lorentz-Transformationen.

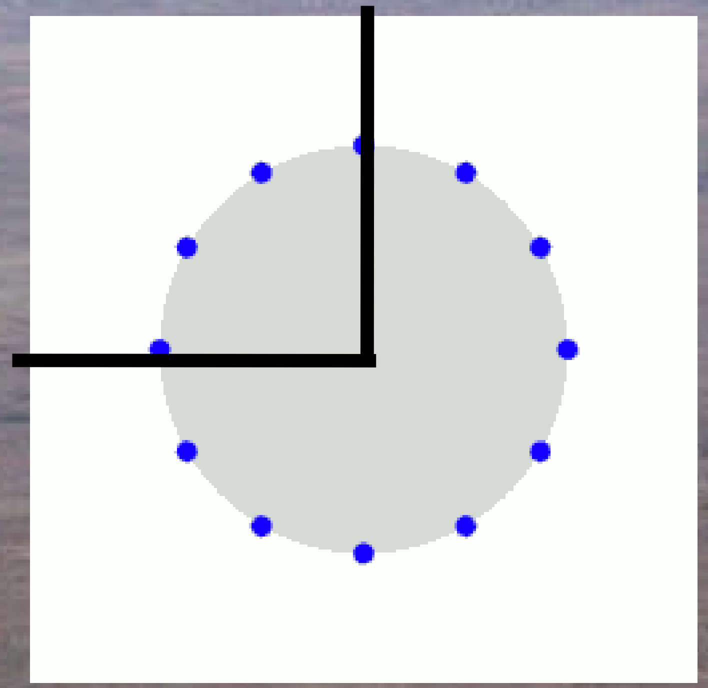
§ 1. Lösung der Näherungsgleichungen des Gravitationsfeldes durch retardierte Potentiale.

Wir gehen aus von den für ein beliebiges Koordinatensystem gültigen[2] Feldgleichungen

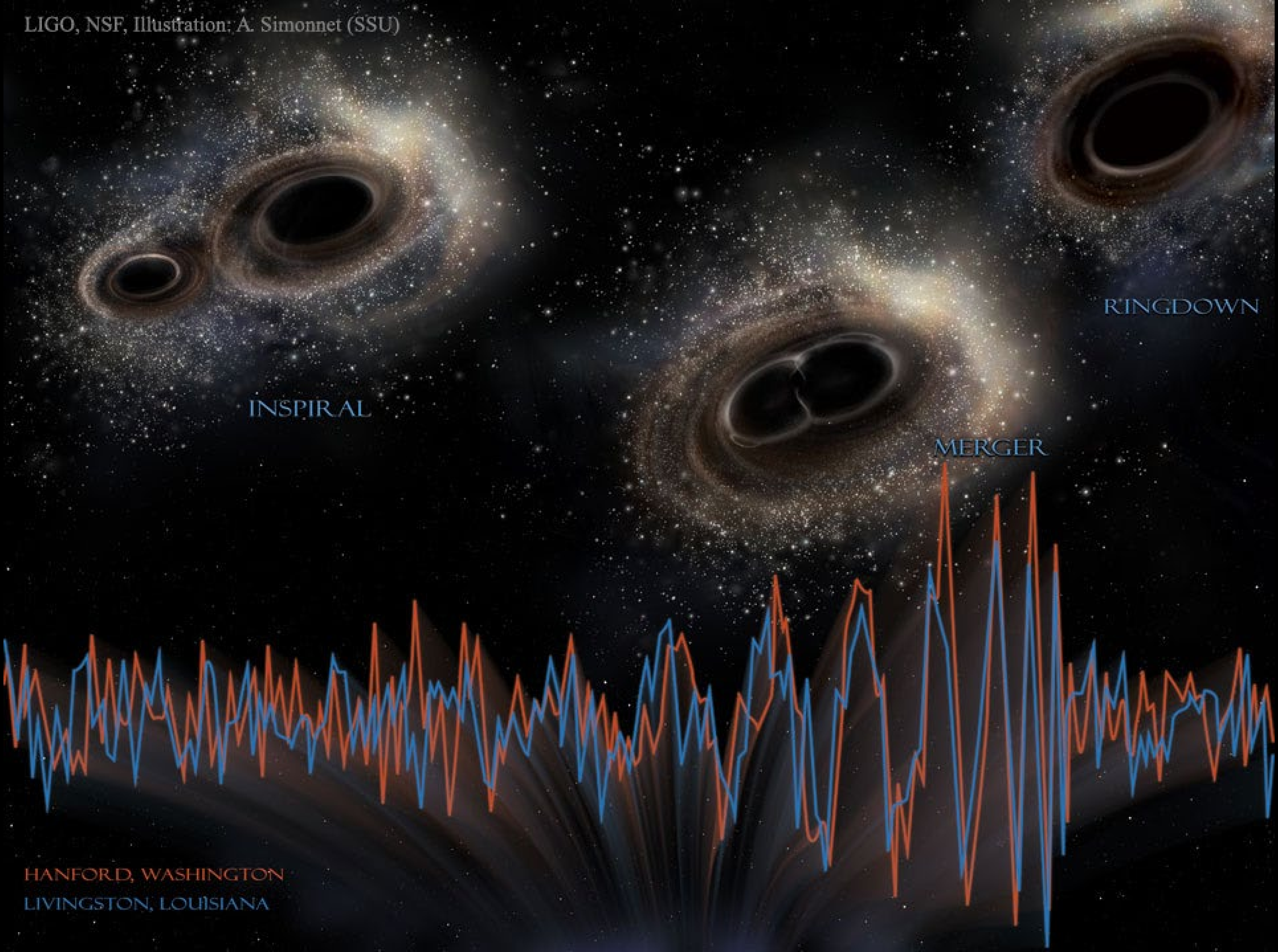
$$-\sum_\alpha \frac{\partial}{\partial x_\alpha}\begin{Bmatrix}\mu\nu\\ \alpha\end{Bmatrix} + \sum_\alpha \frac{\partial}{\partial x_\nu}\begin{Bmatrix}\mu\alpha\\ \alpha\end{Bmatrix} + \sum_{\alpha\beta}\begin{Bmatrix}\mu\alpha\\ \beta\end{Bmatrix}\begin{Bmatrix}\nu\beta\\ \alpha\end{Bmatrix} - \sum_{\alpha\beta}\begin{Bmatrix}\mu\nu\\ \alpha\end{Bmatrix}\begin{Bmatrix}\alpha\beta\\ \beta\end{Bmatrix} = -\varkappa\left(T_{\mu\nu} - \frac{1}{2}g_{\mu\nu}T\right). \tag{2}$$

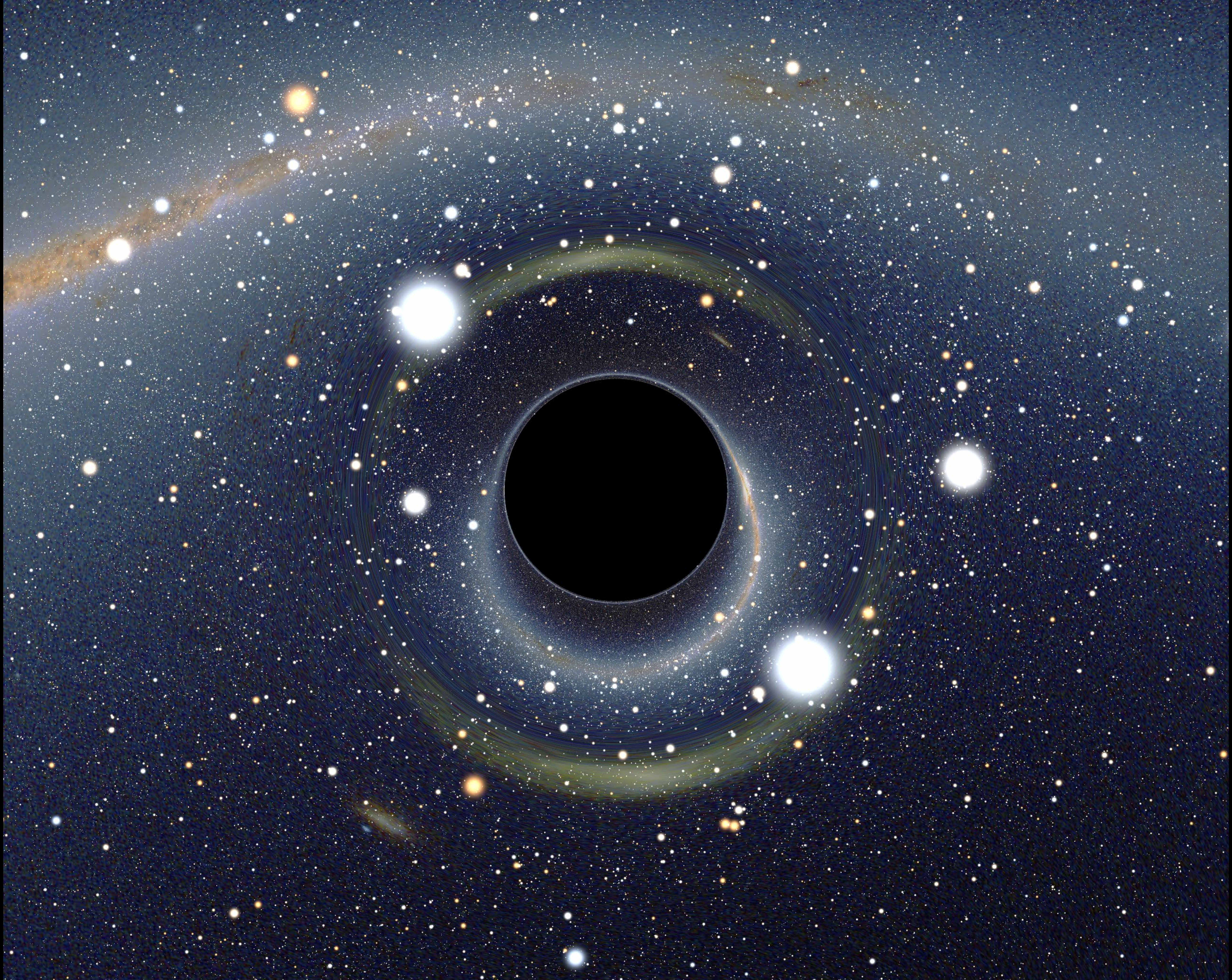
[1] Diese Sitzungsber. 1916, S. 688 ff.

[2] Von der Einführung des »λ-Gliedes« (vgl. diese Sitzungsber. 1917, S. 142) ist dabei Abstand genommen.



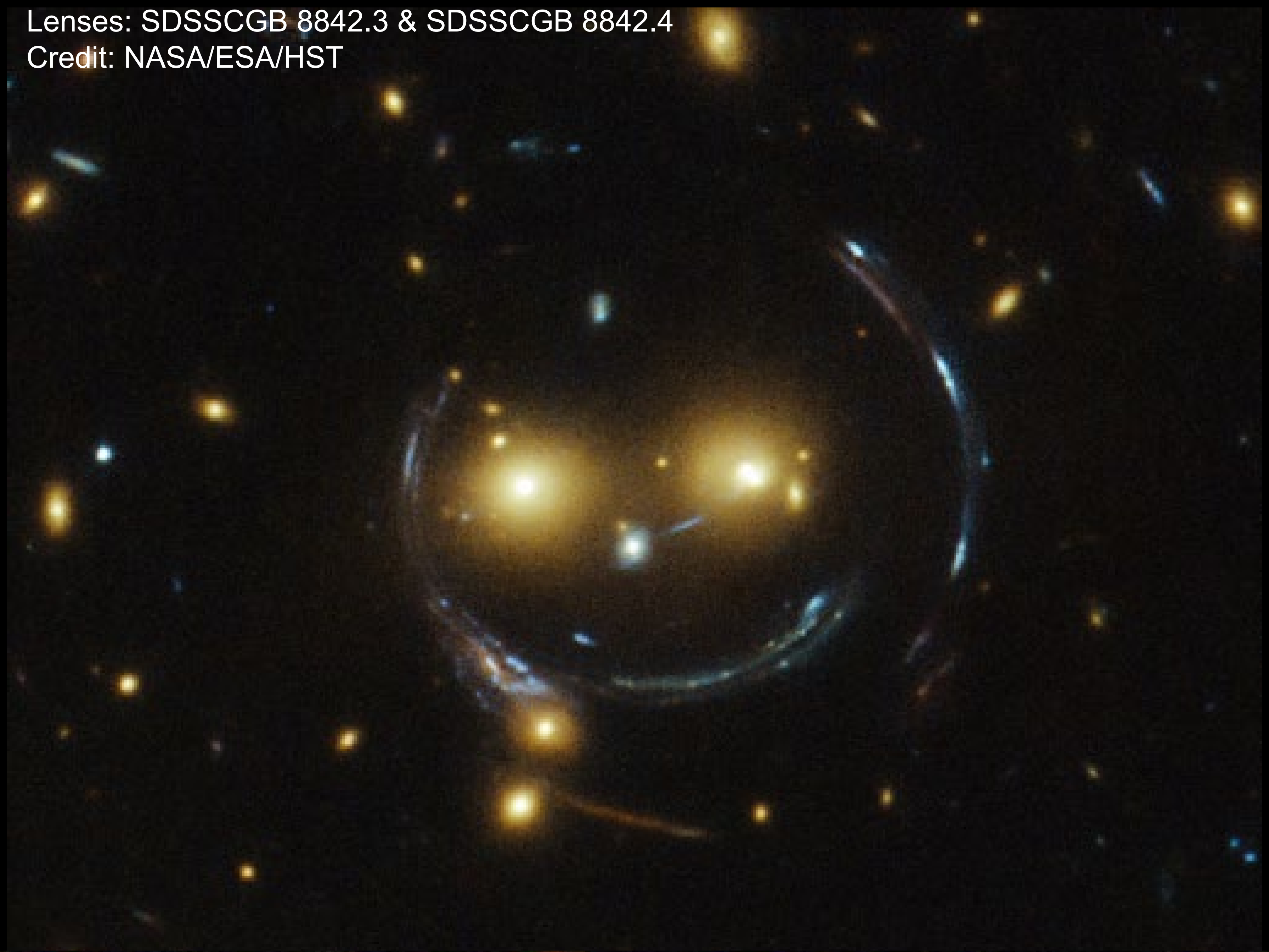
Credit: LIGO Observatory

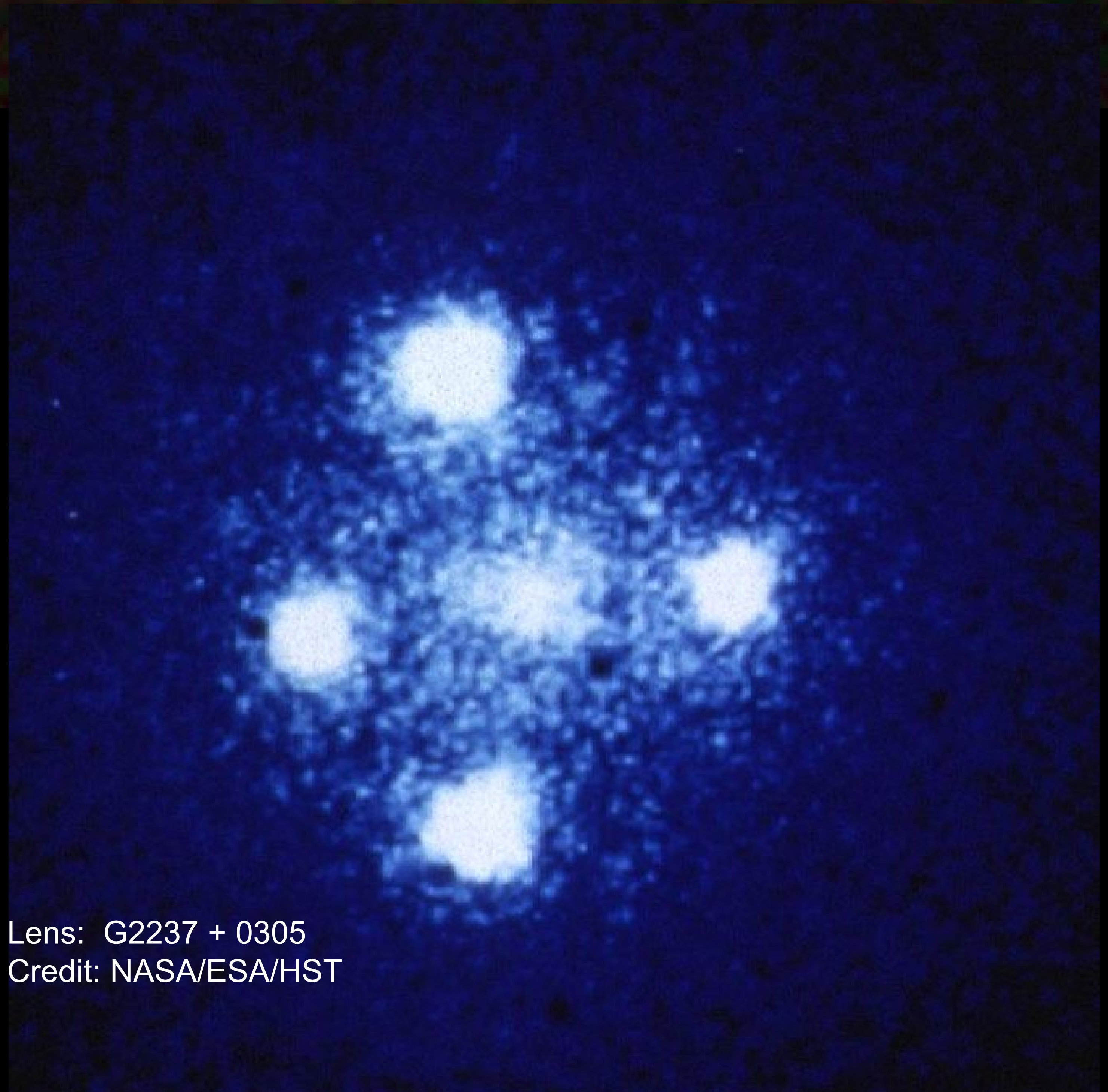

LIGO, NSF, Illustration: A. Simonnet (SSU)
INSPIRAL
MERGER
RINGDOWN
HANFORD, WASHINGTON
LIVINGSTON, LOUISIANA

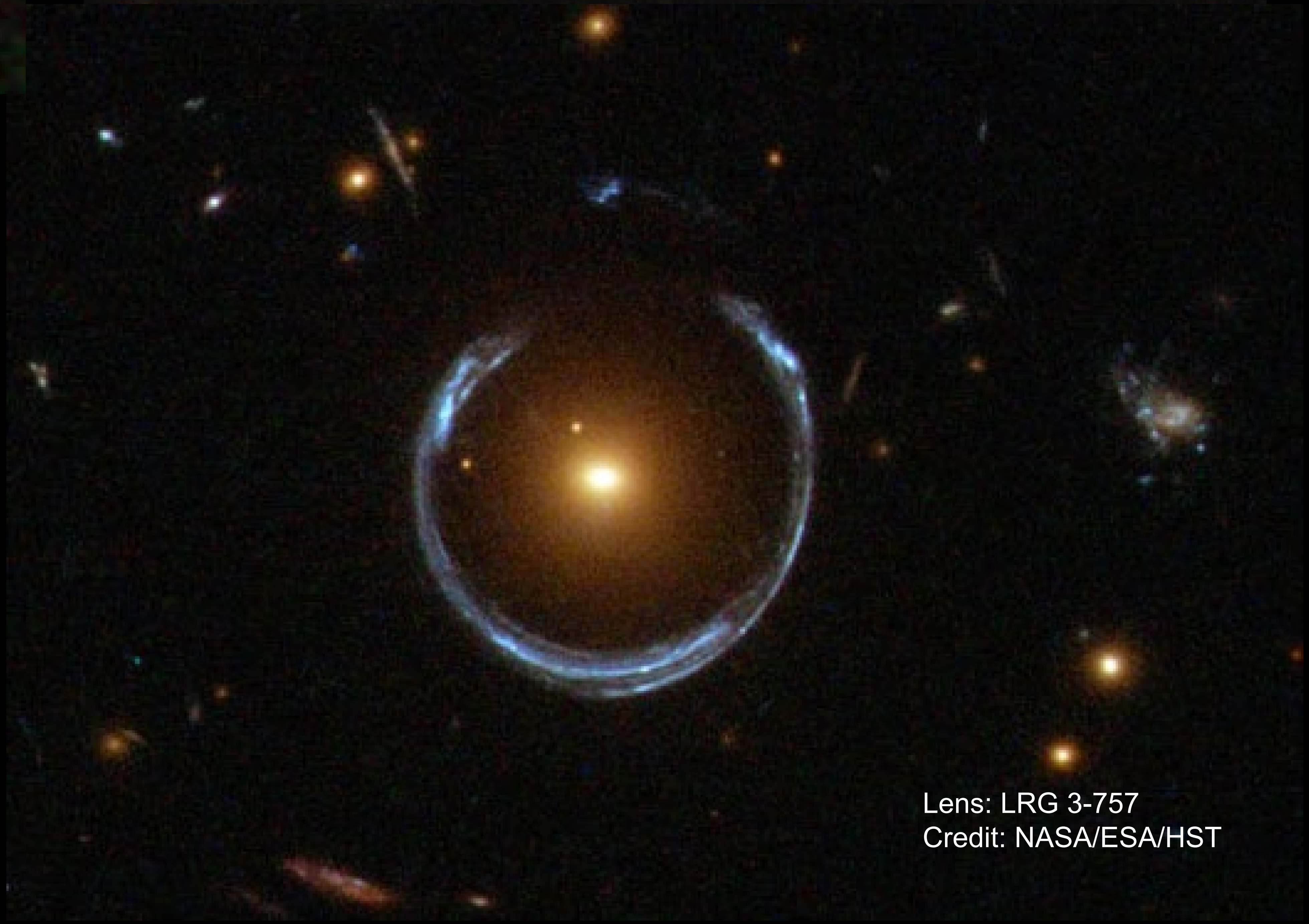


Credit: Alain Riazuelo


Lens: UZC J224030.2+032131
Credit: NASA/HST


Lenses: SDSSCGB 8842.3 & SDSSCGB 8842.4
Credit: NASA/ESA/HST

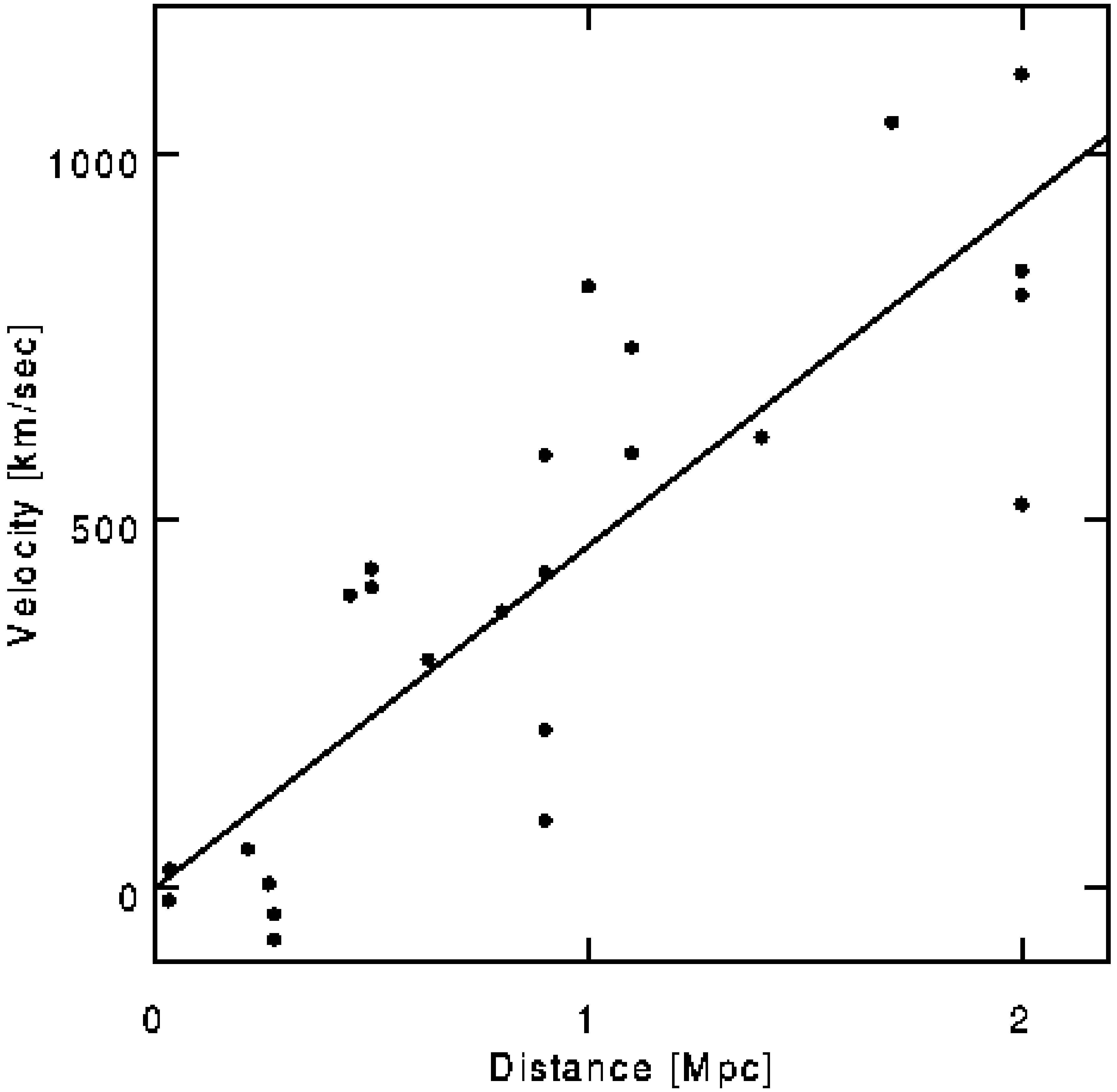

Lens: G2237 + 0305
Credit: NASA/ESA/HST

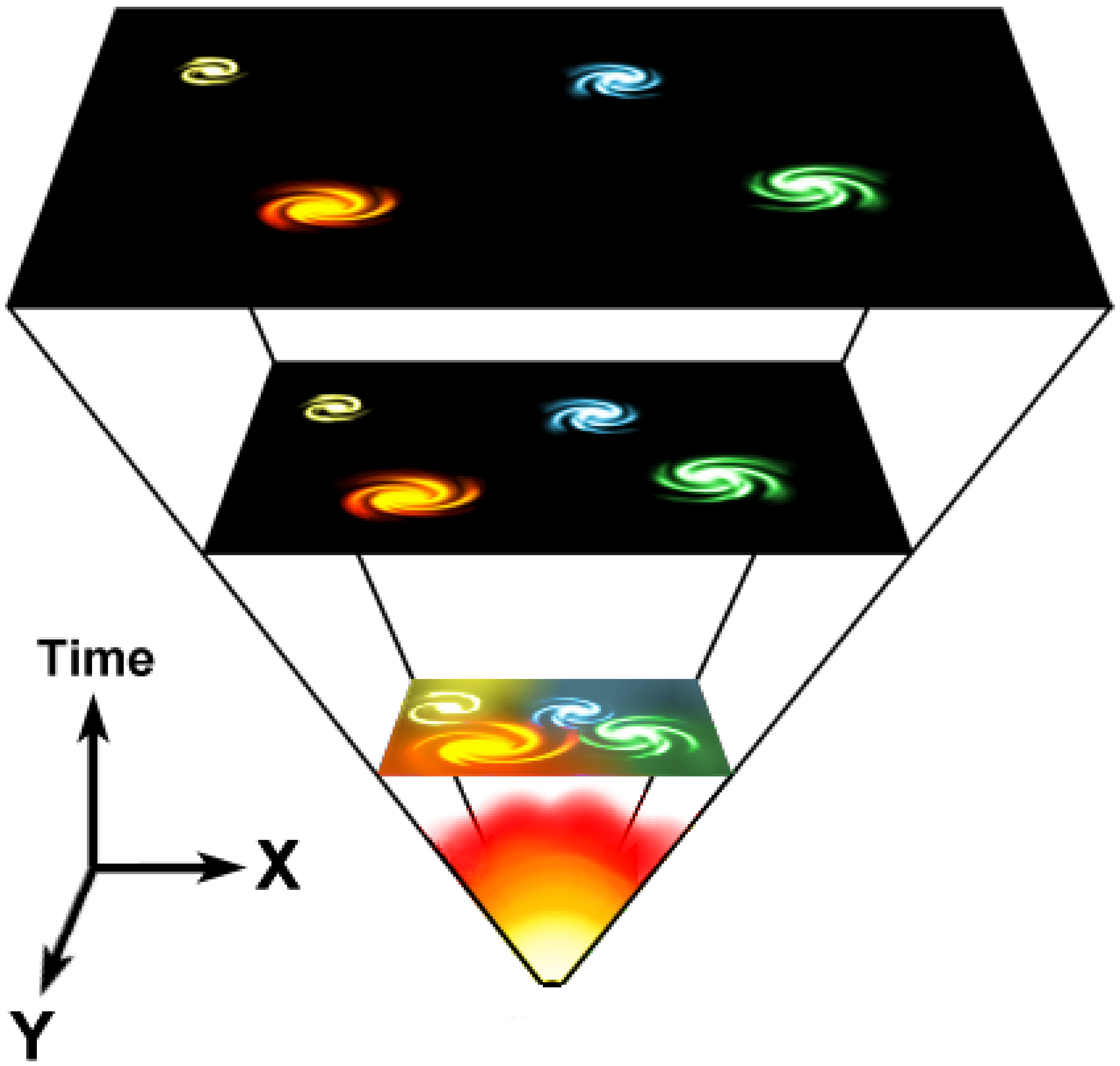

Lens: LRG 3-757
Credit: NASA/ESA/HST

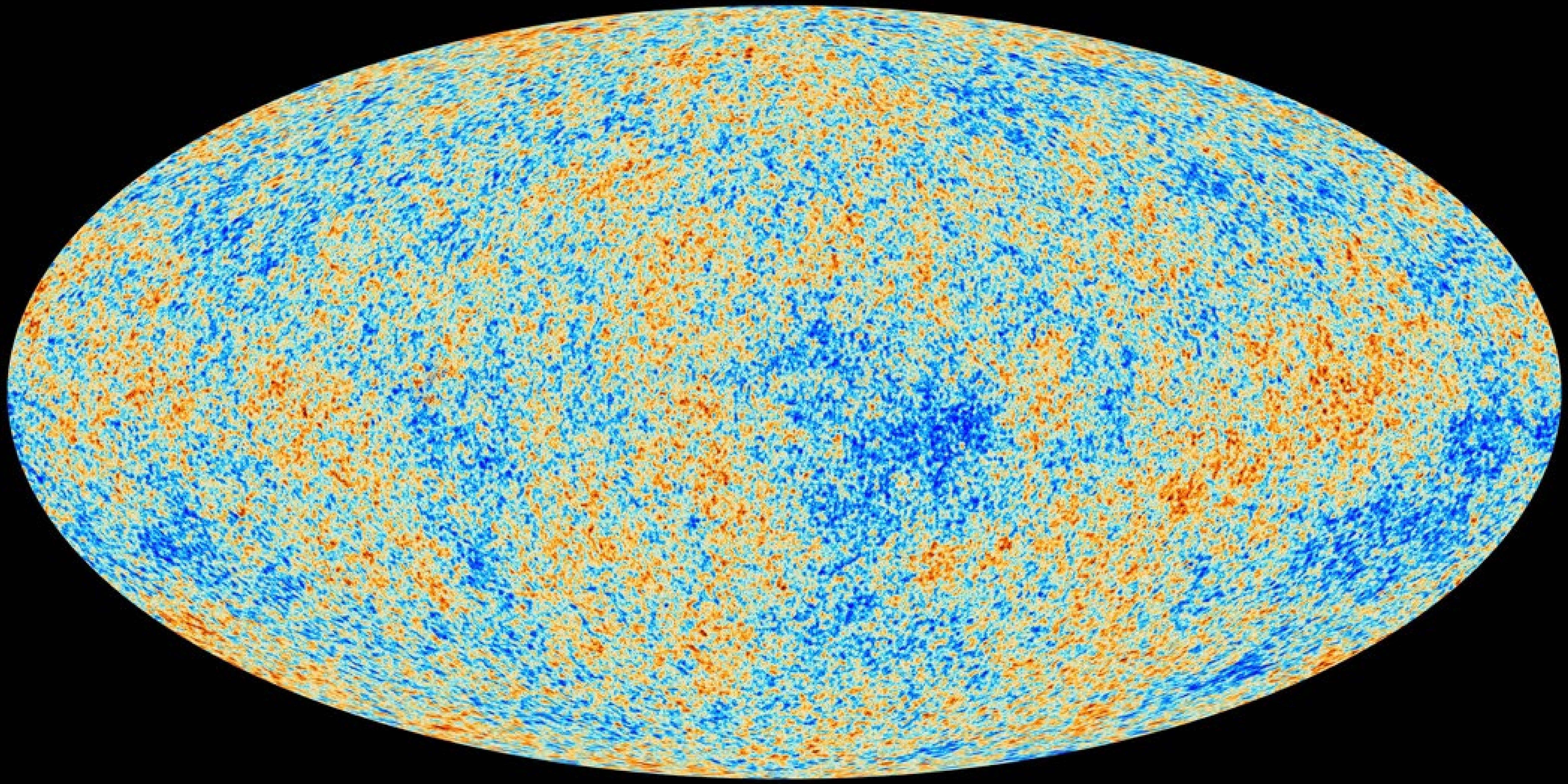
Galaxy Cluster Abell 2218 **HST • WFPC2**

NASA, A. Fruchter and the ERO Team (STScI) • STScI-PRC00-08

1929
Hubble-Lemaître Law




Time
X
Y




London
D:Wave

Credit: The National Trust

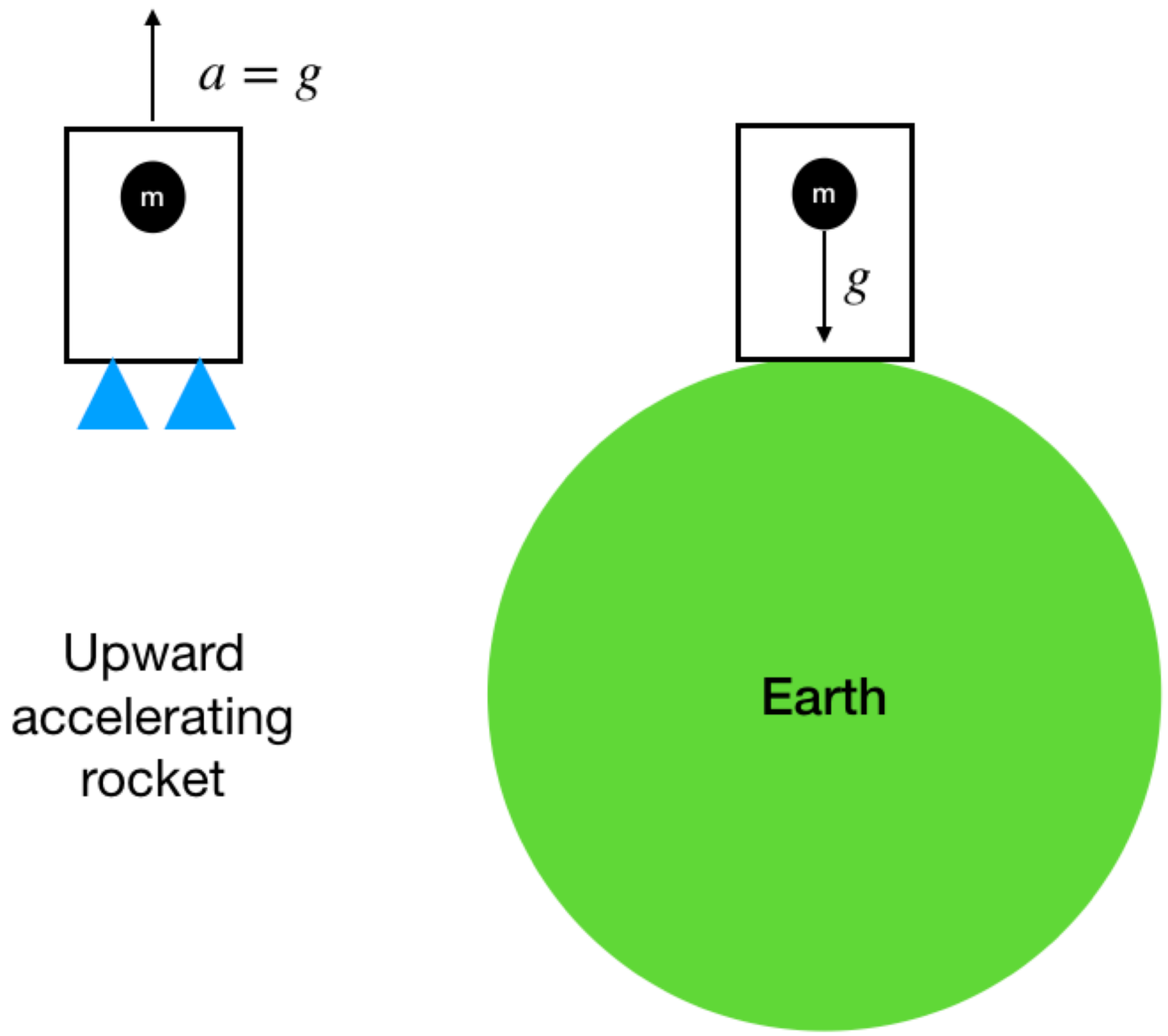
Source: Wikimedia

Source: U.S. Navy/Wikimedia

The Equivalence Principle

Imperial College London

Massive particle

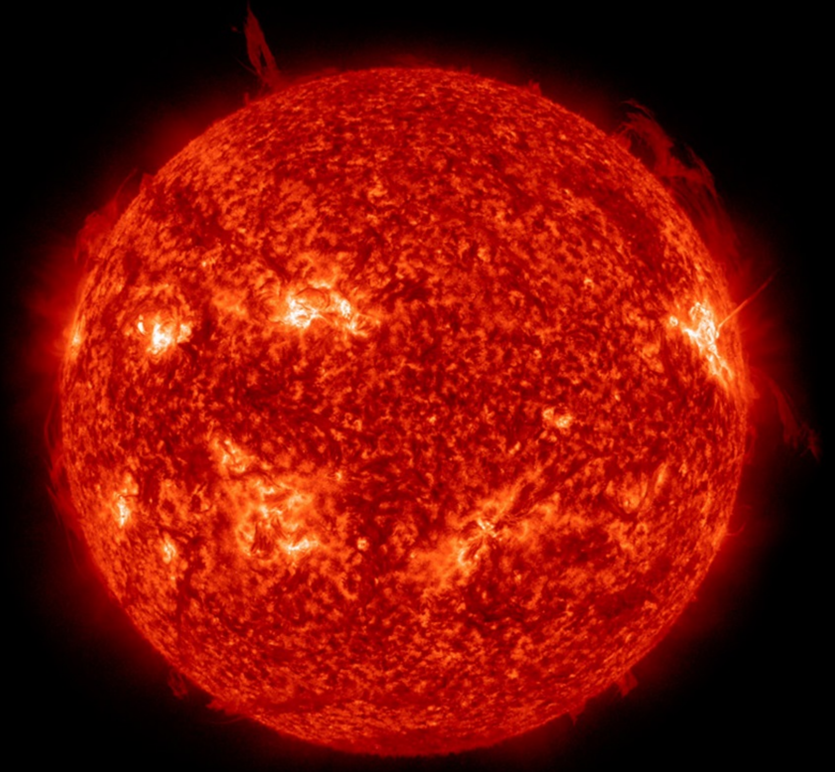



g

Source: JPL/NASA

1 year

364 days
23hrs, 58’30’’



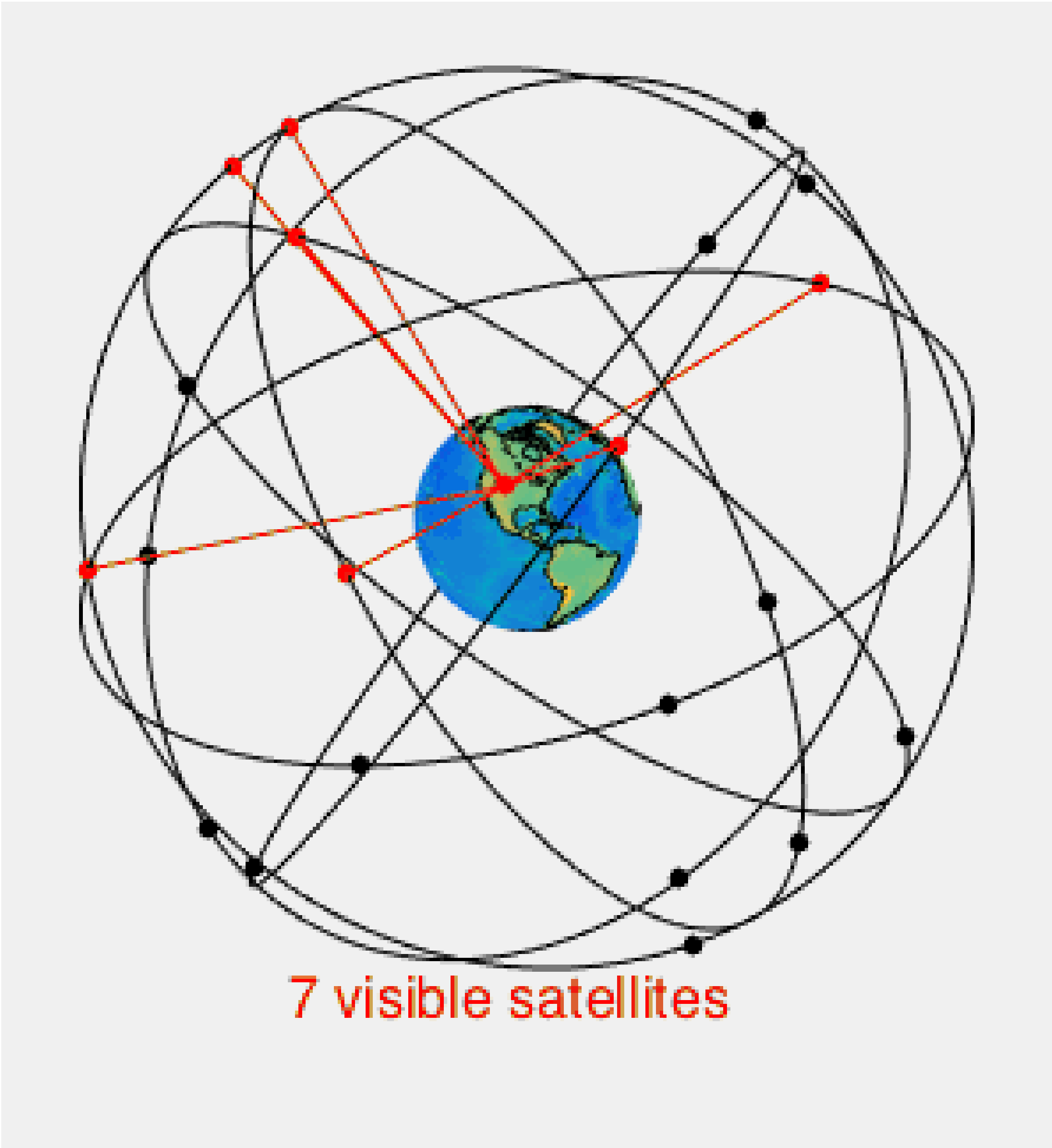
364 days
22hrs, 30’00’’

Tempus Fugit

Imperial College London

1.00000000000008 second

1 second



Credit: Wikimedia

On the ground:

On the satellite:

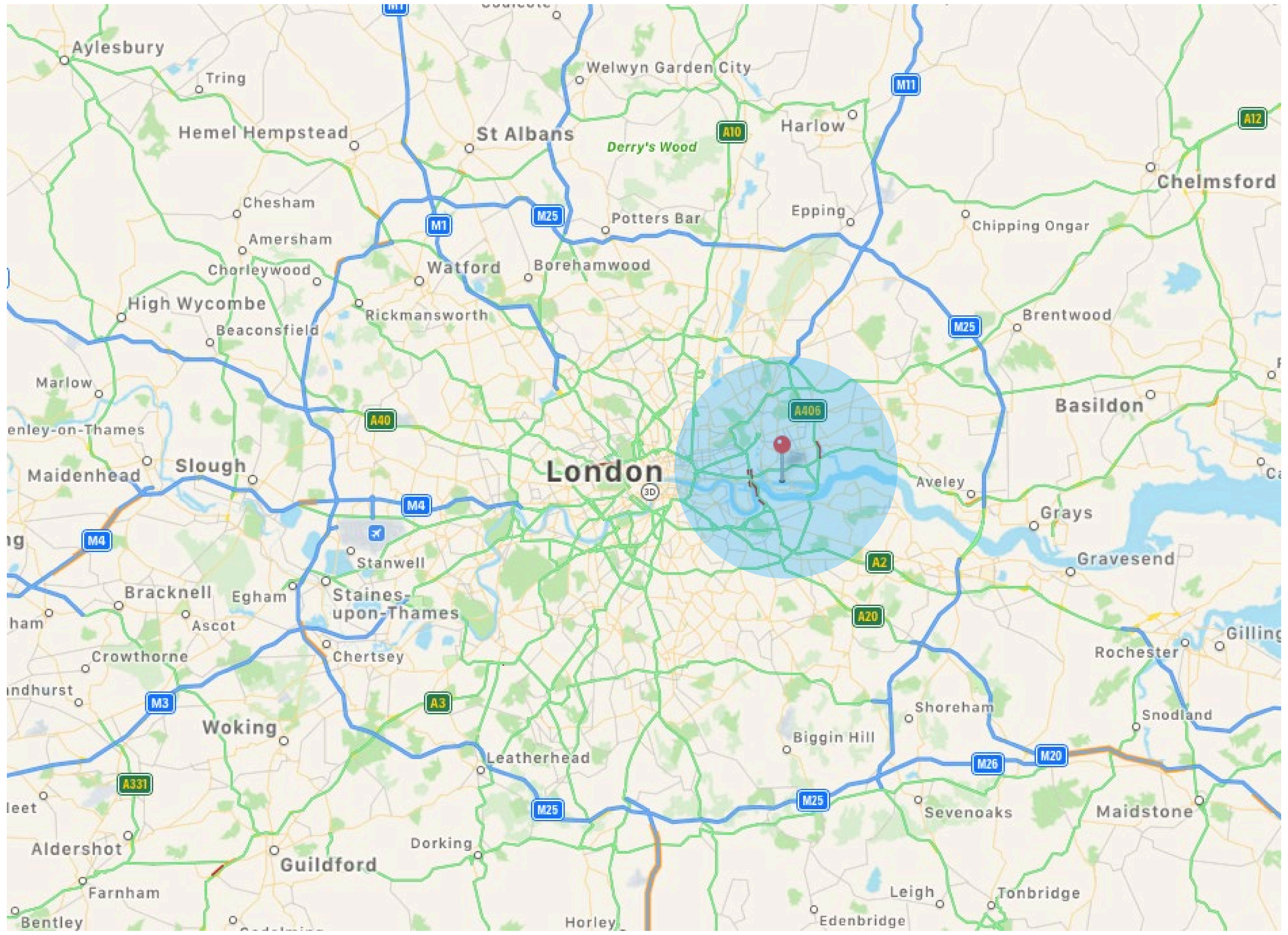
11:59:59:007:000 (Special relativity)

12:00:00:045:000 (General relativity)

12:00:00:000:000

12:00:00:038:000

1 day later…



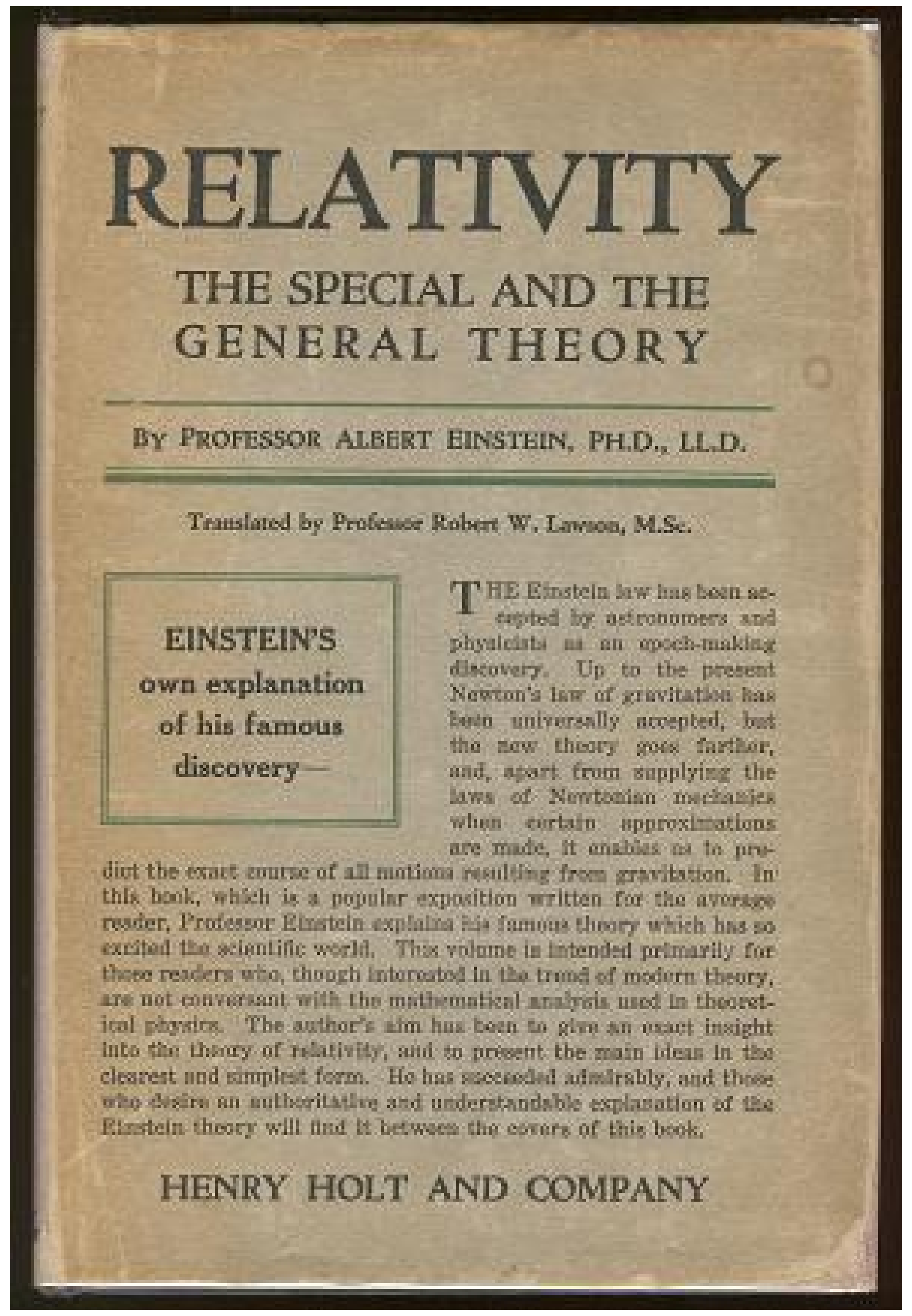
Apple Maps

Einstein
1915

Schwarzschild
1916

Hawking
1974

John O'Sullivan
1992


RELATIVITY

THE SPECIAL AND THE GENERAL THEORY

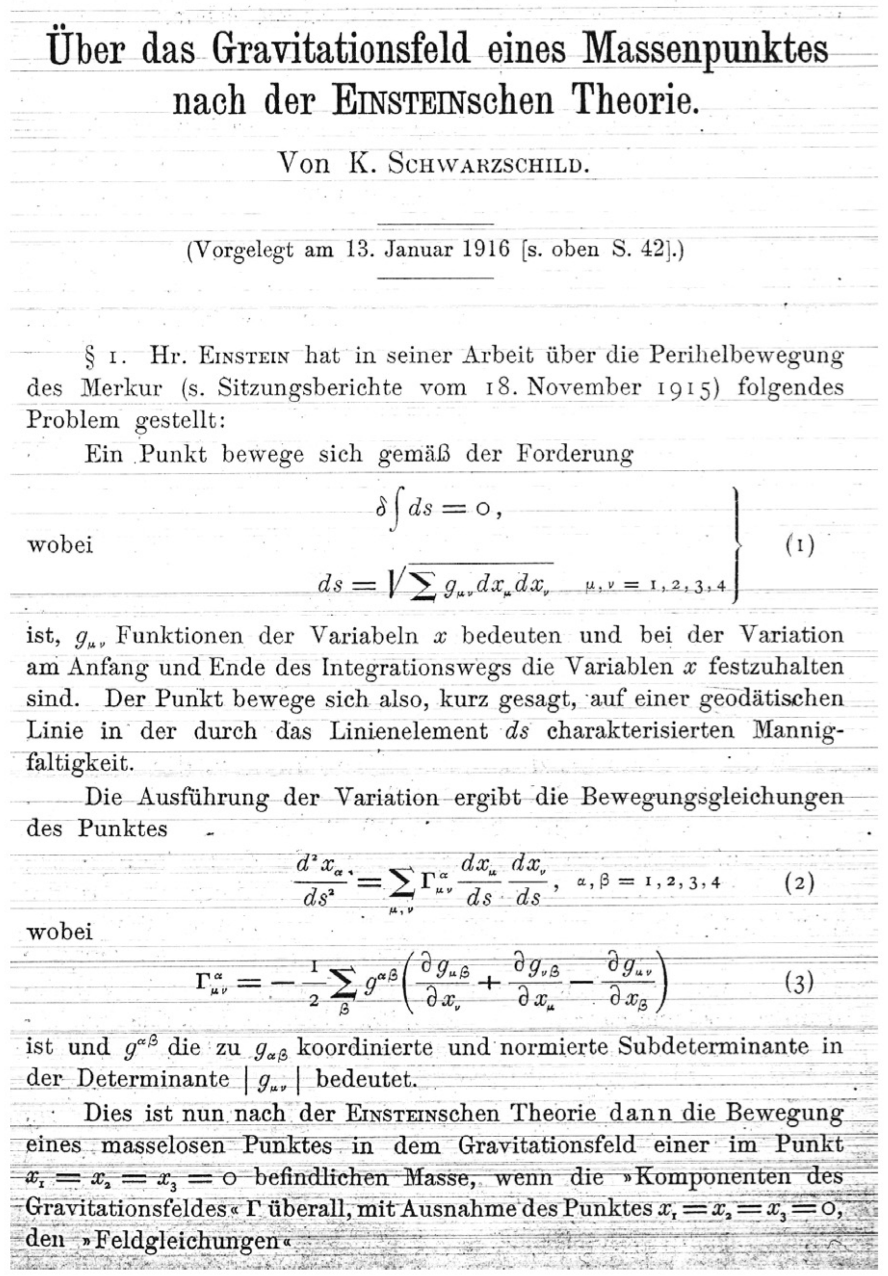
BY PROFESSOR ALBERT EINSTEIN, PH.D., LL.D.

Translated by Professor Robert W. Lawson, M.Sc.

EINSTEIN'S own explanation of his famous discovery—

THE Einstein law has been accepted by astronomers and physicists as an epoch-making discovery. Up to the present Newton's law of gravitation has been universally accepted, but the new theory goes farther, and, apart from supplying the laws of Newtonian mechanics when certain approximations are made, it enables us to predict the exact course of all motions resulting from gravitation. In this book, which is a popular exposition written for the average reader, Professor Einstein explains his famous theory which has so excited the scientific world. This volume is intended primarily for those readers who, though interested in the trend of modern theory, are not conversant with the mathematical analysis used in theoretical physics. The author's aim has been to give an exact insight into the theory of relativity, and to present the main ideas in the clearest and simplest form. He has succeeded admirably, and those who desire an authoritative and understandable explanation of the Einstein theory will find it between the covers of this book.

HENRY HOLT AND COMPANY


Über das Gravitationsfeld eines Massenpunktes nach der Einsteinschen Theorie.

Von K. Schwarzschild.

(Vorgelegt am 13. Januar 1916 [s. oben S. 42].)

§ 1. Hr. Einstein hat in seiner Arbeit über die Perihelbewegung des Merkur (s. Sitzungsberichte vom 18. November 1915) folgendes Problem gestellt:

Ein Punkt bewege sich gemäß der Forderung

$$\left.\begin{aligned} &\delta\int ds = 0, \\ \text{wobei} \quad & \\ &ds = \sqrt{\sum g_{\mu\nu}\, dx_\mu\, dx_\nu} \qquad \mu, \nu = 1, 2, 3, 4 \end{aligned}\right\} \qquad (1)$$

ist, $g_{\mu\nu}$ Funktionen der Variabeln x bedeuten und bei der Variation am Anfang und Ende des Integrationswegs die Variablen x festzuhalten sind. Der Punkt bewege sich also, kurz gesagt, auf einer geodätischen Linie in der durch das Linienelement ds charakterisierten Mannigfaltigkeit.

Die Ausführung der Variation ergibt die Bewegungsgleichungen des Punktes

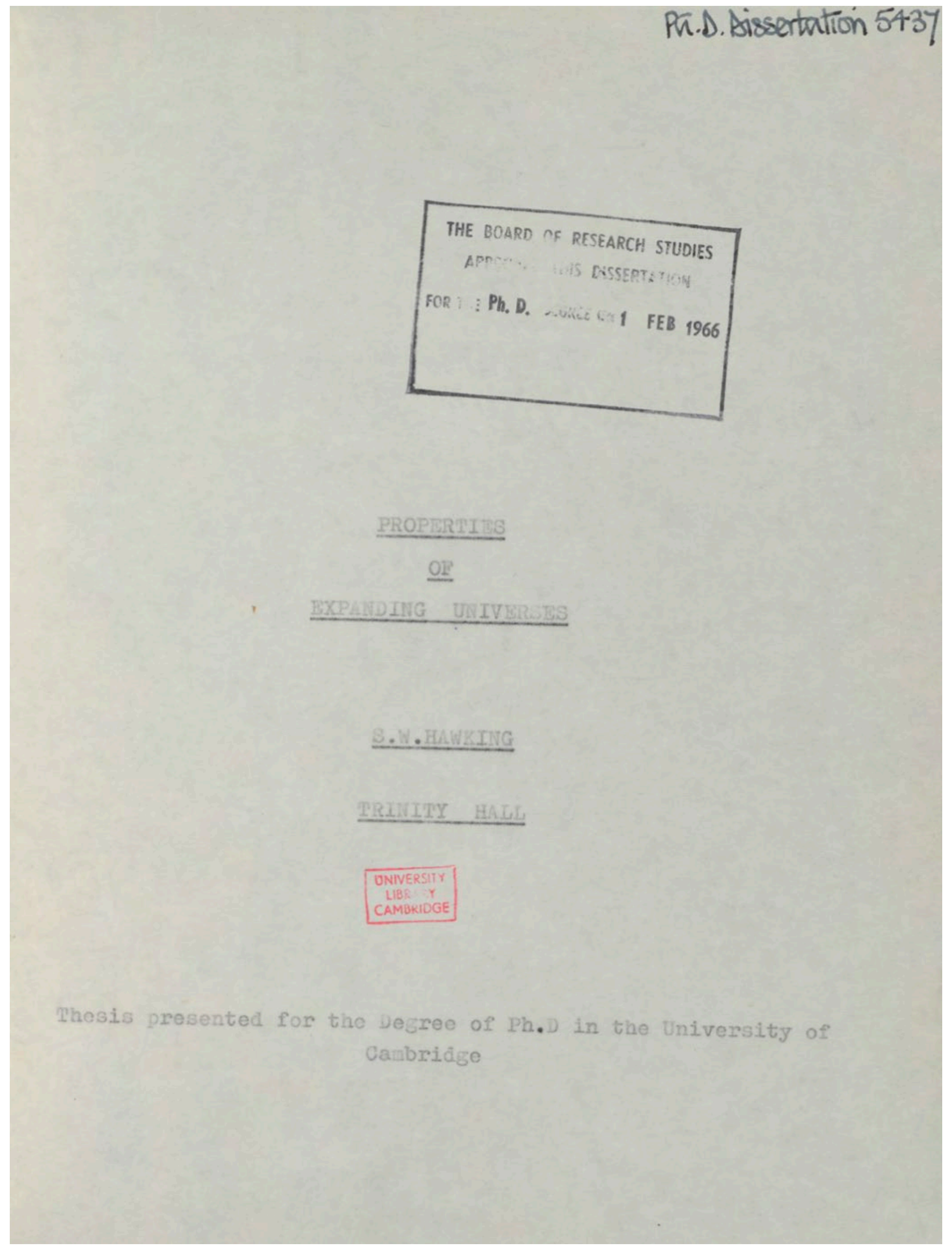
$$\frac{d^2 x_\alpha}{ds^2} = \sum_{\mu,\nu} \Gamma^\alpha_{\mu\nu} \frac{dx_\mu}{ds} \frac{dx_\nu}{ds}, \quad \alpha, \beta = 1, 2, 3, 4 \qquad (2)$$

wobei

$$\Gamma^\alpha_{\mu\nu} = -\frac{1}{2} \sum_\beta g^{\alpha\beta} \left(\frac{\partial g_{\mu\beta}}{\partial x_\nu} + \frac{\partial g_{\nu\beta}}{\partial x_\mu} - \frac{\partial g_{\mu\nu}}{\partial x_\beta} \right) \qquad (3)$$

ist und $g^{\alpha\beta}$ die zu $g_{\alpha\beta}$ koordinierte und normierte Subdeterminante in der Determinante $|g_{\mu\nu}|$ bedeutet.

Dies ist nun nach der Einsteinschen Theorie dann die Bewegung eines masselosen Punktes in dem Gravitationsfeld einer im Punkt $x_1 = x_2 = x_3 = 0$ befindlichen Masse, wenn die »Komponenten des Gravitationsfeldes« Γ überall, mit Ausnahme des Punktes $x_1 = x_2 = x_3 = 0$, den »Feldgleichungen«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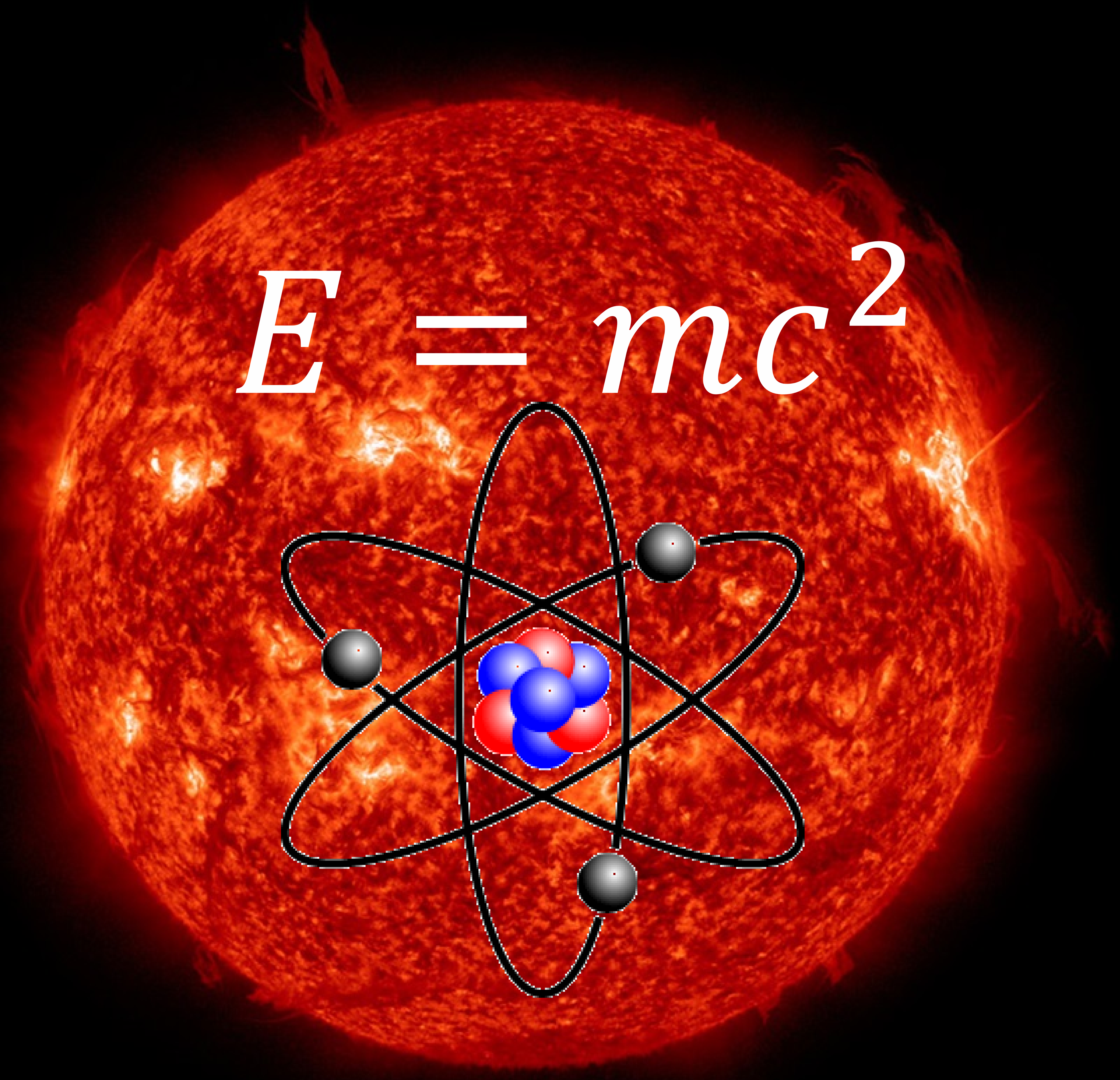
$E = mc^2$


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iter
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&PLANT SYSTEMS

"In the course of the last four months it has been made probable […] that it may become possible to set up a nuclear chain reaction in a large mass of uranium […] This new phenomenon would also lead to the construction of bombs, and it is conceivable – though much less certain – that extremely powerful bombs of a new type may thus be constructed.

America - that it may become possible to set up a nuclear chain reaction in a large mass of uranium,by which vast amounts of power and large quant-

private persons who are willing to make contributions for this cause, and perhaps also by obtaining the co-operation of industrial laboratories

(Einstein to Roosevelt, 1939)

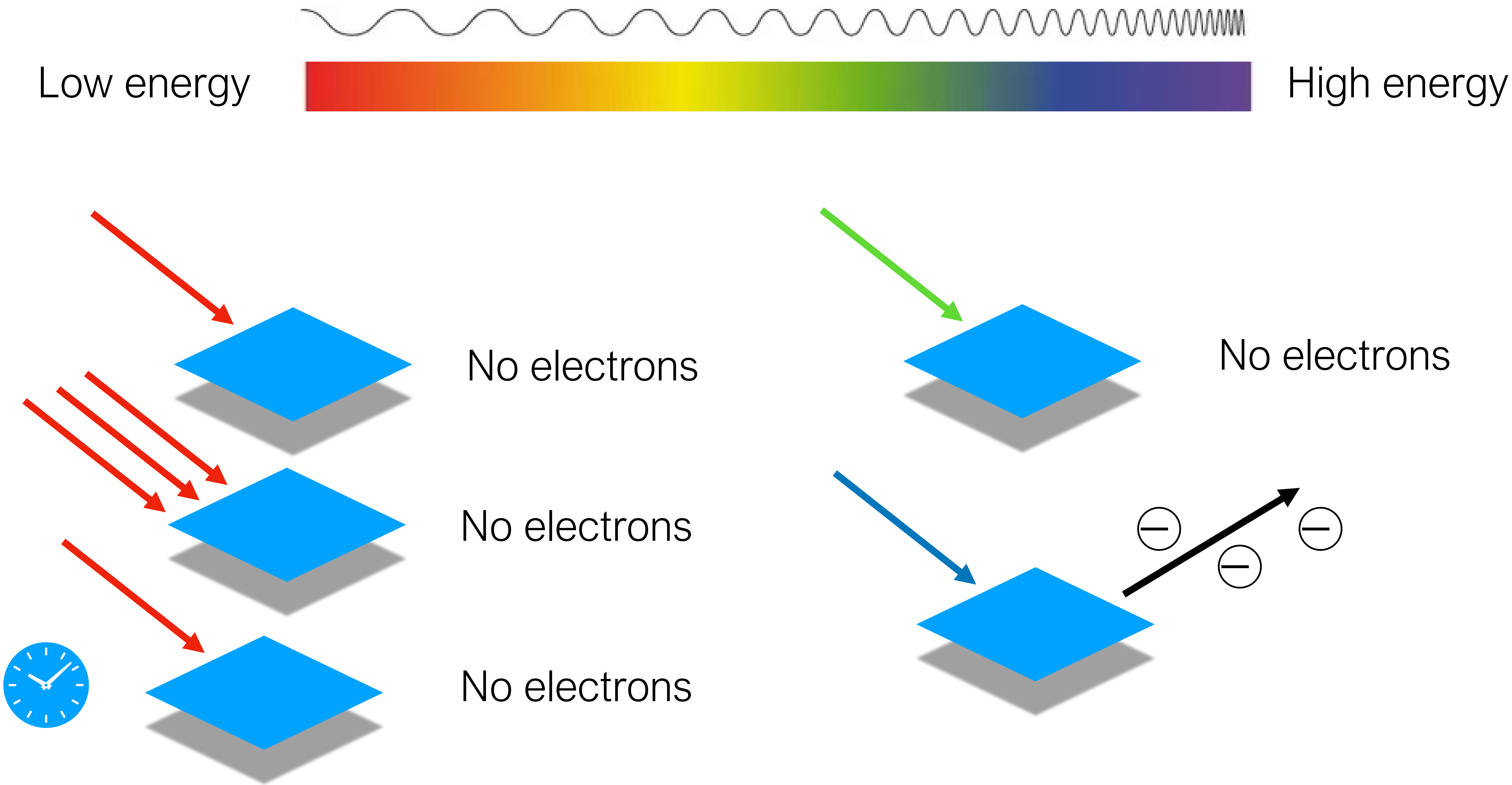
"Had I known that the Germans would not succeed in developing an atomic bomb, I would have done nothing." (Einstein, 1947)

such bombs might very well prove to be too heavy for transportation by air.

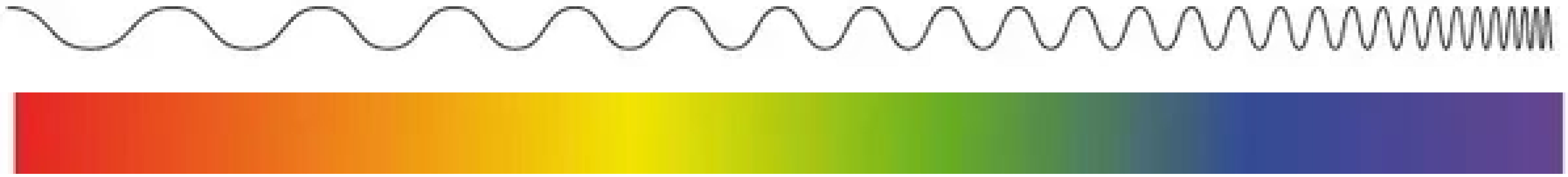
Yours very truly,

A. Einstein

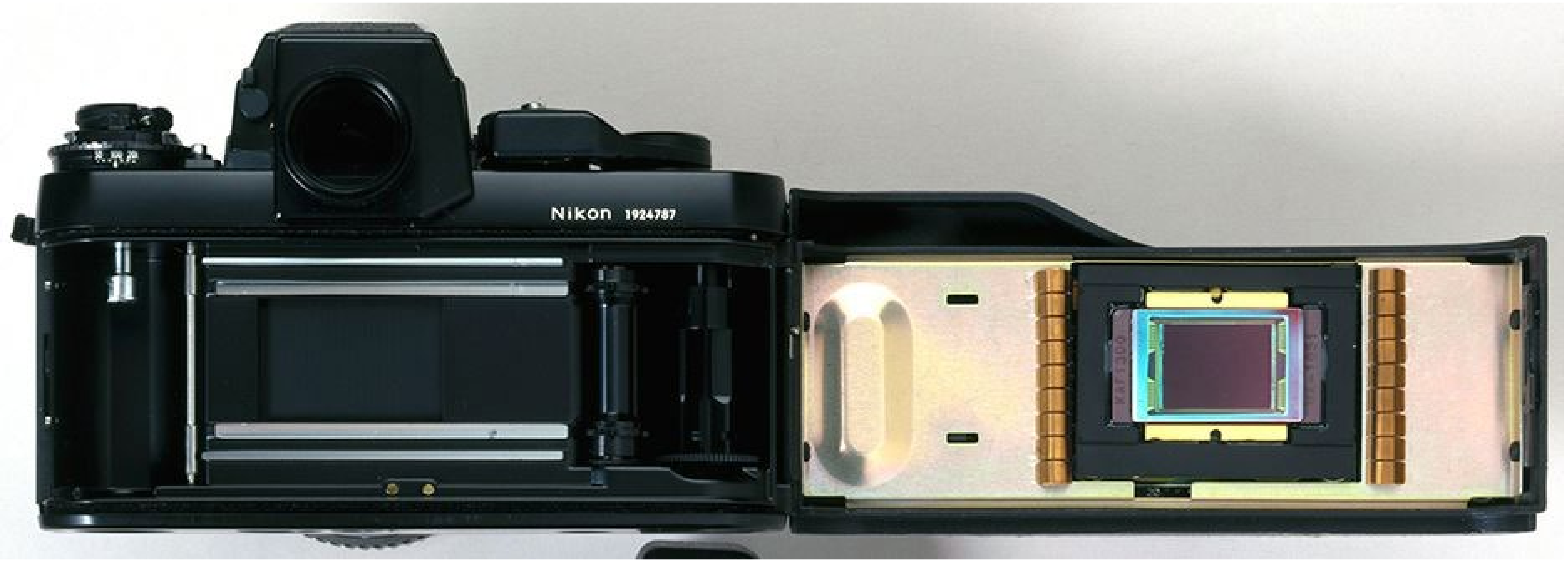
(Albert Einstein)

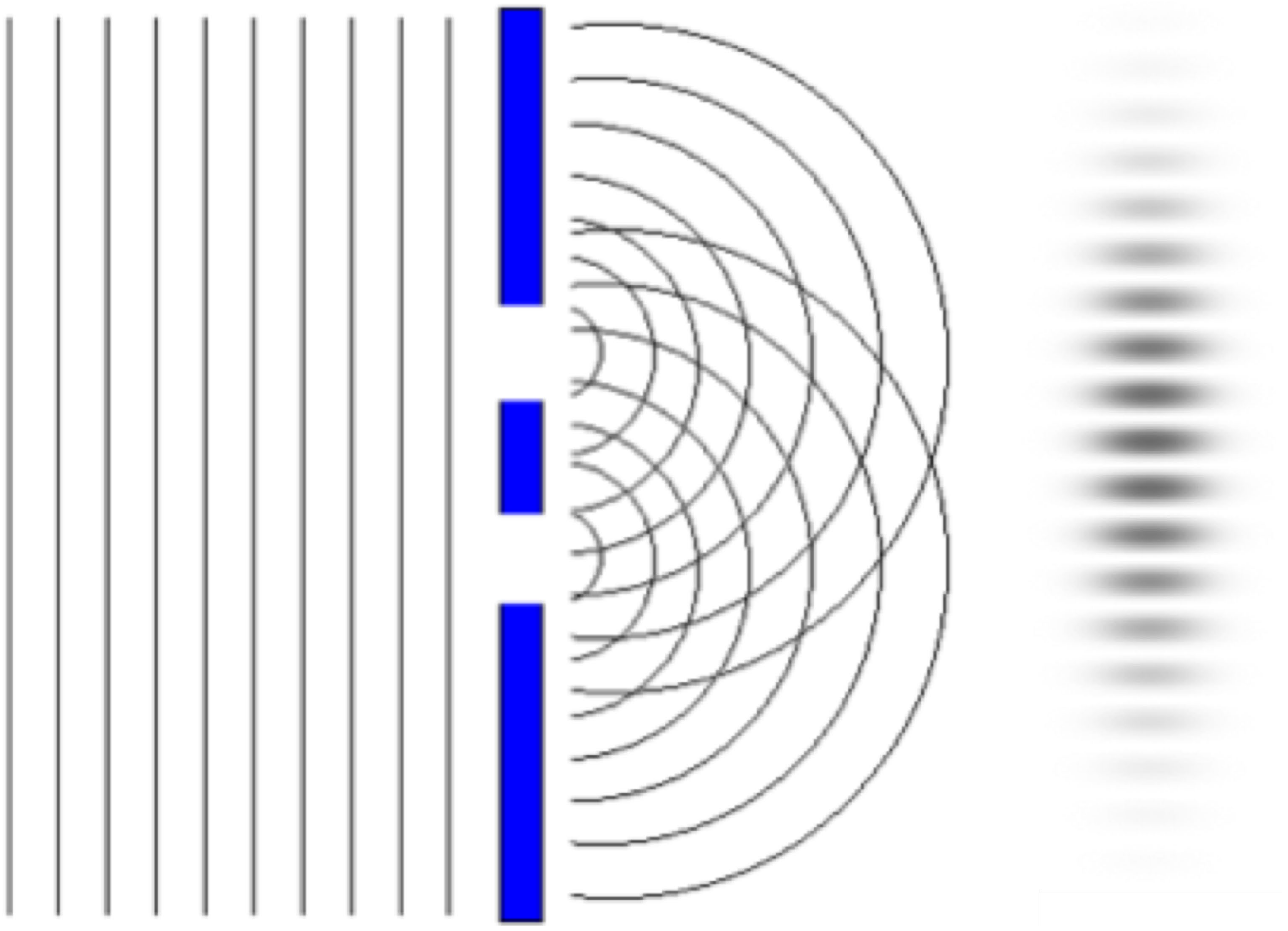

Low energy
High energy
No electrons
No electrons
No electrons
No electrons

Low energy



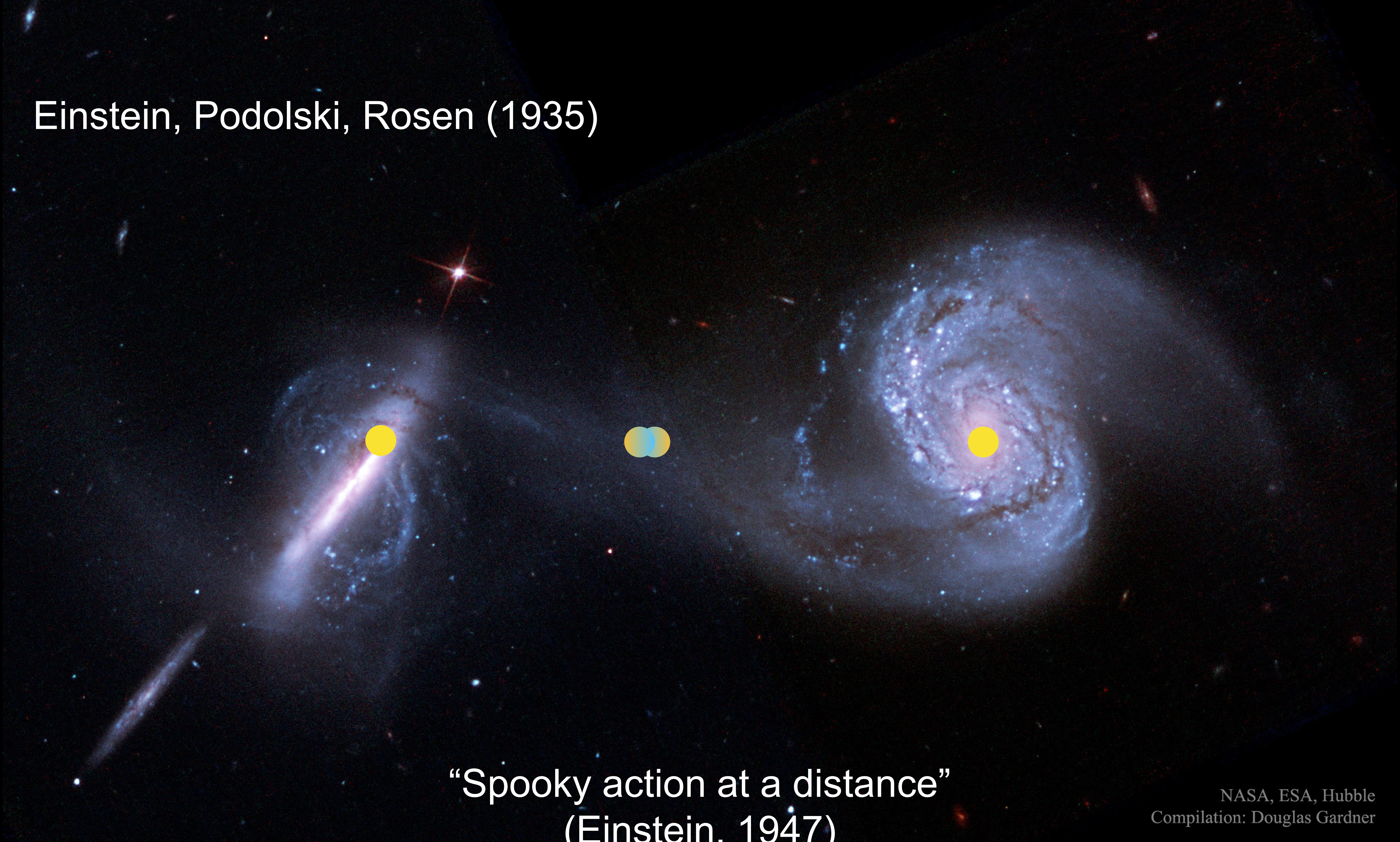
High energy





Credit: Akira Tonomura (Hitachi Ltd)

Einstein, Podolski, Rosen (1935)

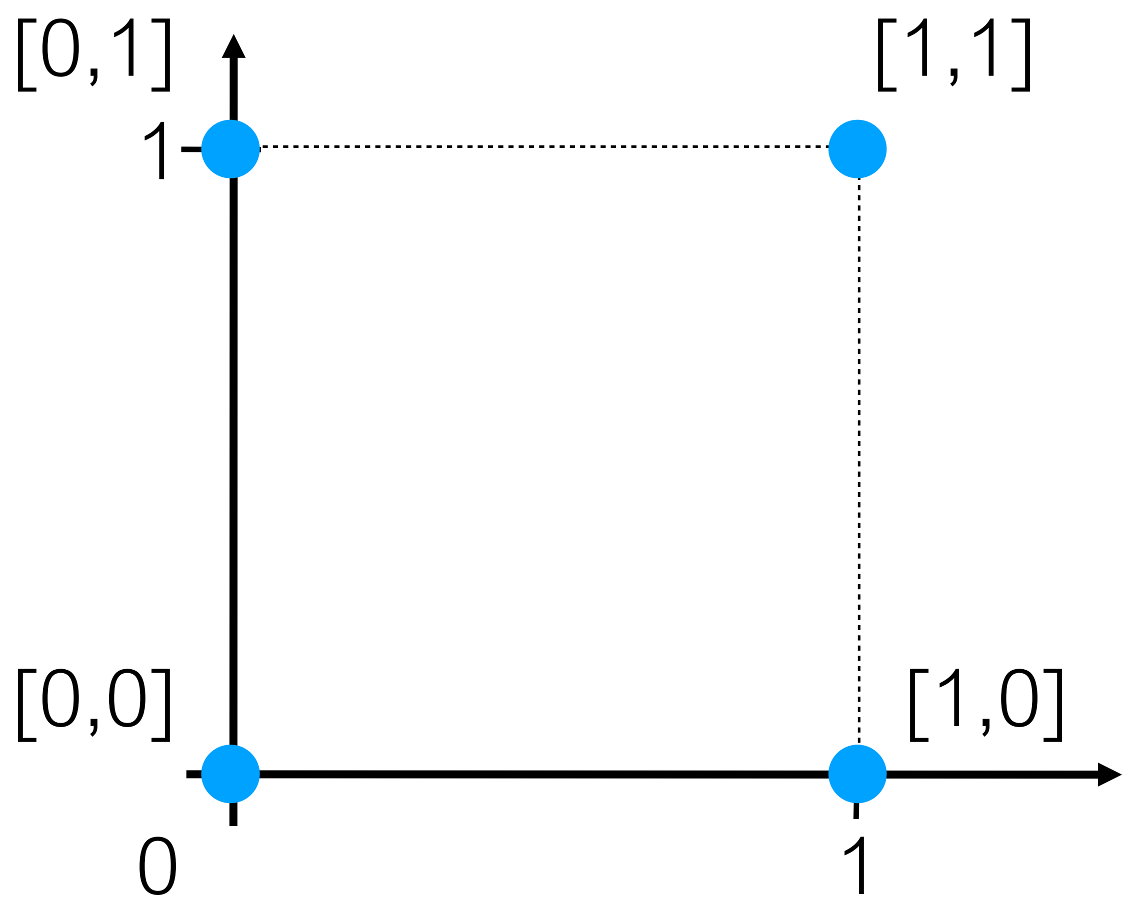


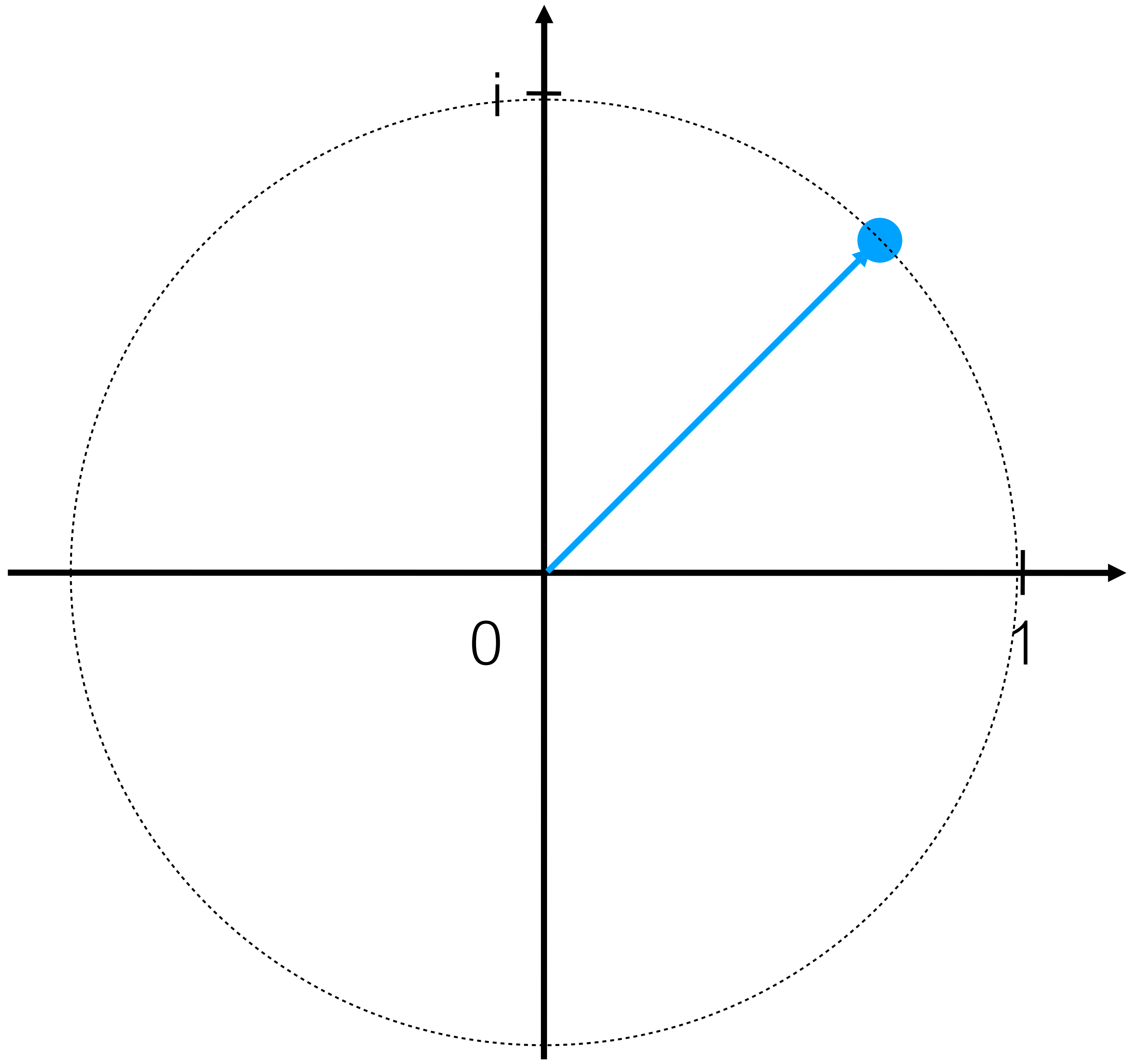
“Spooky action at a distance”
(Einstein, 1947)

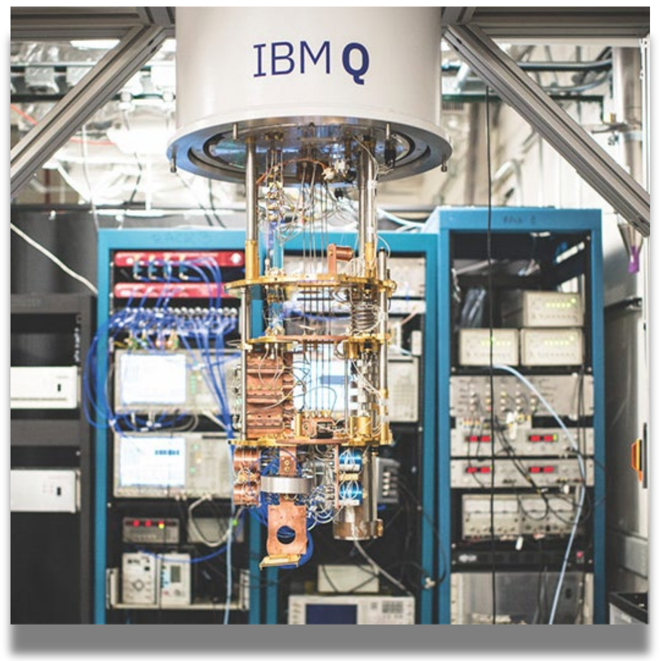
NASA, ESA, Hubble
Compilation: Douglas Gardner

Classical bits [0,1] [0,1]

Quantum bits (‘qbits’)







64-bits: 1 out of
18,446,744,073,709,551,616 states

16-qbits: in all of
65,536 states at the same time

“Quantum theory yields much, but it hardly brings us close to the Old One’s secrets. I, in any case, am convinced He does not play dice with the universe.” (Einstein to Born, 1926)

What Has Einstein Ever Done for Me?!

Thank You!

www.robertotrotta.com

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