Teasing out the Cosmic Light

The importance of light in astronomy

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for ESA – European Space Agency

International Year of Light session at World Science Forum 2015, Budapest

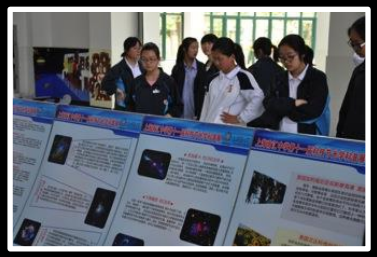
Light: it’s (almost) all we have to investigate the Universe

International Astronomical Union:
IYL2015 Cosmic Light Cornerstone Projects

INTERNATIONAL
YEAR OF LIGHT
2015

COSMIC
LIGHT

IAU



INTERNATIONAL YEAR OF LIGHT 2015

COSMIC LIGHT

IAU

Instruments: naked eye

Instruments: telescope – 1609

One of Galileo's telescopes in Padova (normally at Museo Galileo - Istituto e Museo di Storia della Scienza, Firenze)

Photography

The Orion Nebula by H. Draper, 1880

Image from the Harvard College Observatory Plate Collection

By A.A. Common, 1883

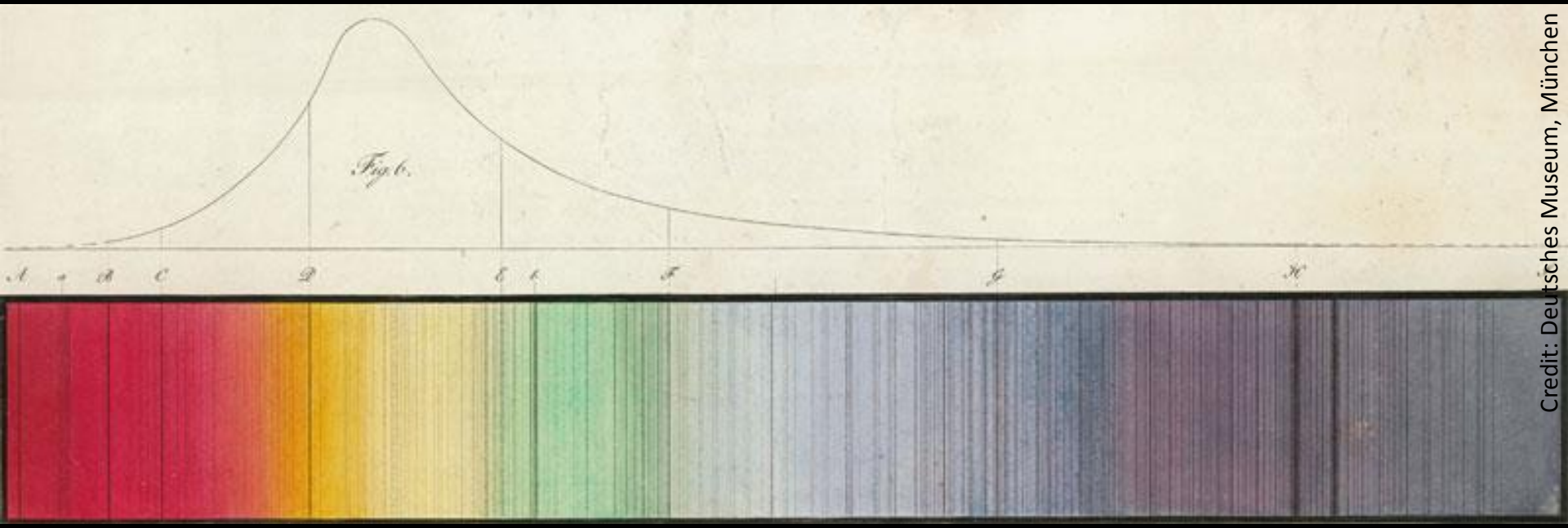
Credit: Agnes M. Clerke

Image from the Harvard College Observatory, 1888

Photography: record light + automatic + higher sensitivity


Harvard College Observatory, circa 1890
Side effect: need more/new labour to analyse data

Spectroscopy: split the light to study the chemistry of stars



Credit: Deutsches Museum, München

Spectrum of the Sun by J. Fraunhofer, 1814

Spectroscopy + Photography: the birth of Astro*physics*

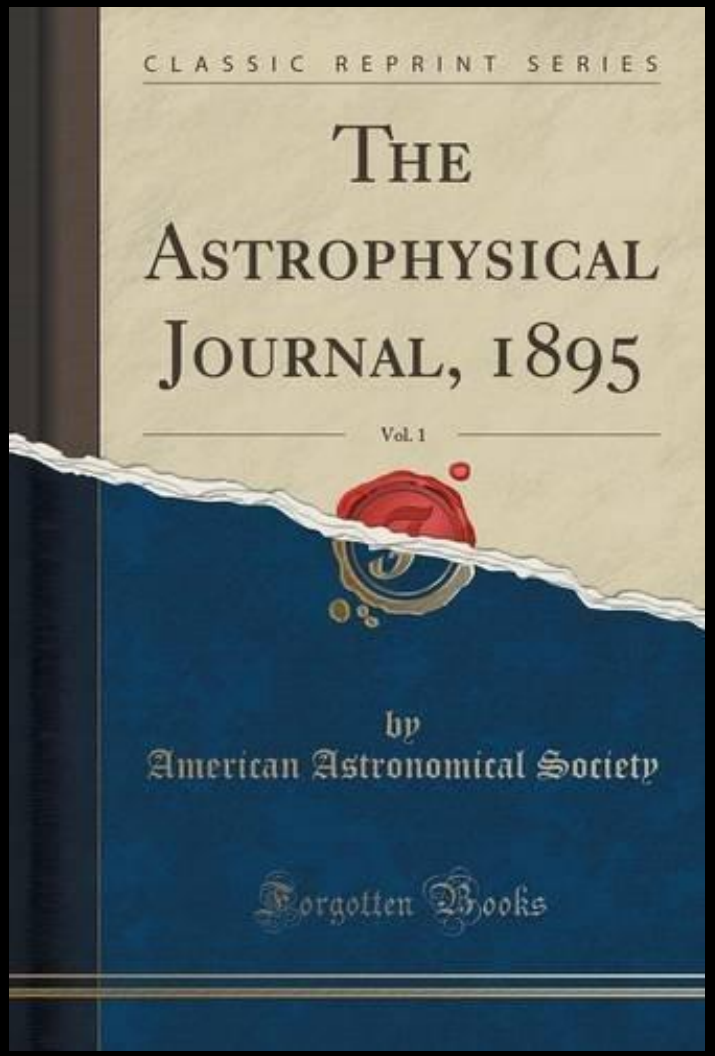
→ What are stars made of?

→ What powers stars?

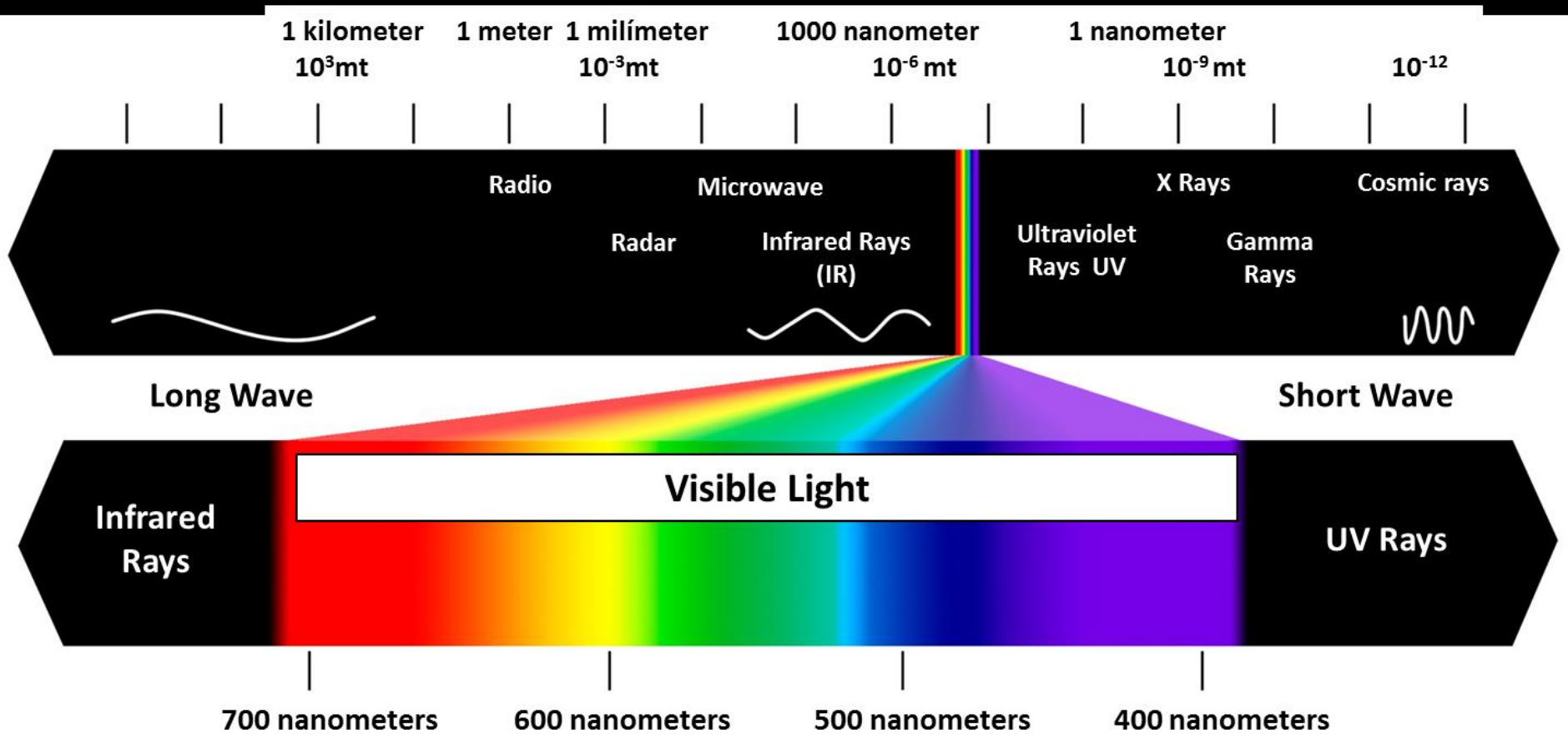
→ How big is the Universe?

→ Is our ‘Galaxy’ all there is?

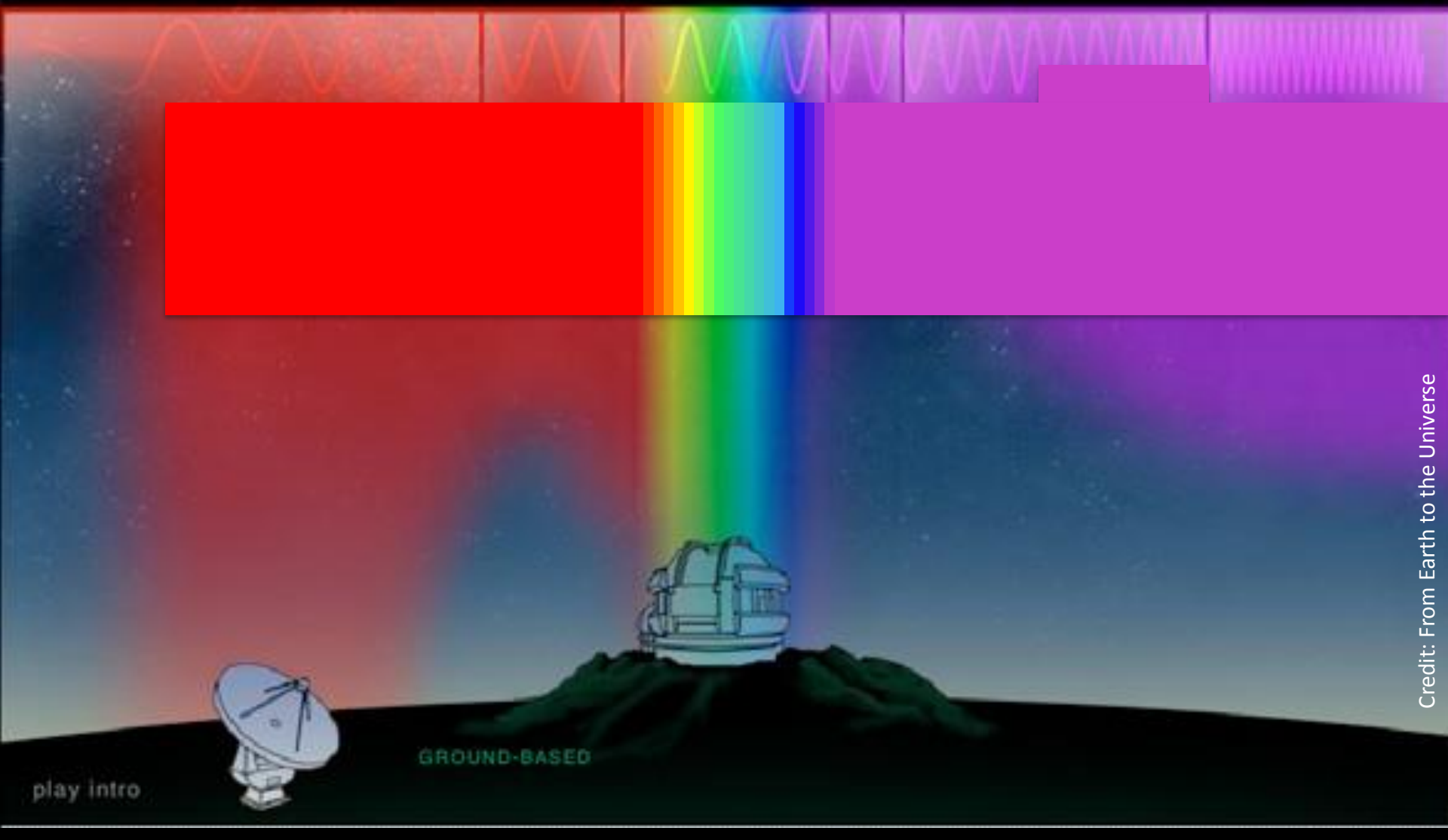
→ Is the Universe evolving?



Visible light: only a fraction of the Electromagnetic Spectrum

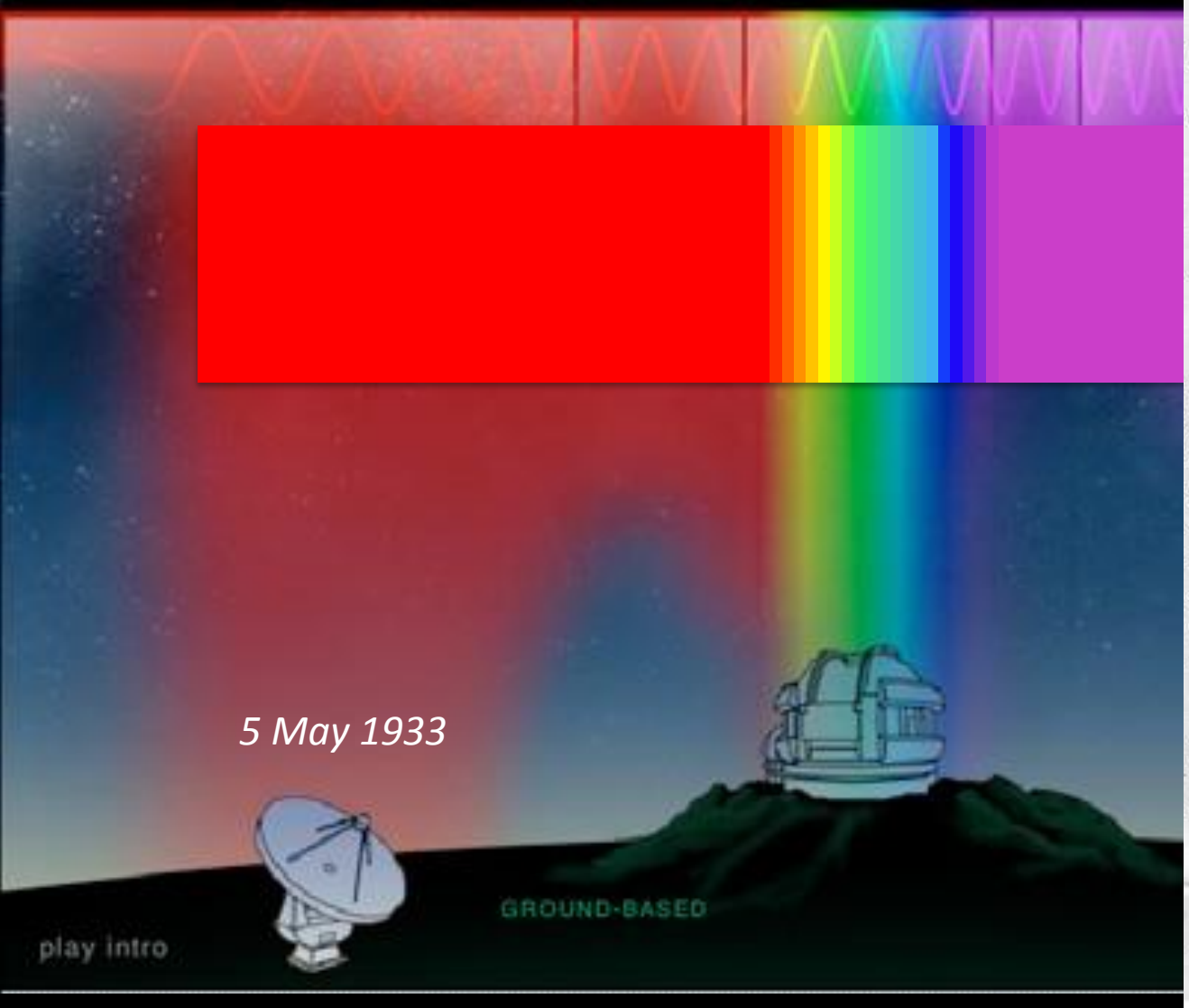


Astronomy beyond visible light?



Credit: From Earth to the Universe

Astronomy beyond visible light?



NEW RADIO WAVES TRACED TO CENTRE OF THE MILKY WAY

Mysterious Static, Reported by K. G. Jansky, Held to Differ From Cosmic Ray.

DIRECTION IS UNCHANGING

Recorded and Tested for More Than Year to Identify It as From Earth's Galaxy.

ITS INTENSITY IS LOW

Only Delicate Receiver Is Able to Register—No Evidence of Interstellar Signaling.

Discovery of mysterious radio waves which appear to come from the centre of the Milky Way galaxy was announced yesterday by the Bell Telephone Laboratories. The discovery was made during research studies on static by Karl G. Jansky of the radio research department at Holmdel, N. J., and was described by him in a paper delivered before the International Scientific Radio Union in Washington.

The galactic radio waves, Mr. Jansky said, differ from the cosmic rays and also from the phenomenon of cosmic radiation, described last week before the American Philosophical Society at Philadelphia by Dr. Vesto M. Slipher, director of the Lowell Observatory at Flagstaff, Ariz.

Unlike the cosmic ray, which comes from all directions in space, does not vary with either the time of day or the time of the year, and may be either a photon or an electron, the galactic waves, Mr. Jansky pointed out, seem to come from a definite source in space, vary in intensity with the time of day and time of the year, and are distinctly electro-magnetic waves that can be picked up by a radio set.

New Waves Have High Frequency.

The cosmic radiation discovered by Dr. Slipher is a mysterious form of light apparently radiated independently of starlight, originating, Dr. Slipher concluded, at some distance above the earth's surface, and possibly produced by the earth's atmosphere.

The galactic radio waves, the announcement says, are short waves, 14.6 meters, at a frequency of about 20,000,000 cycles a second. The intensity of these waves is very low, so that a delicate apparatus is required for their detection.

Unlike most forms of radio disturbances, the report says, these newly found waves do not appear to be due to any terrestrial phenomena, but rather to come from some point far off in space—probably far beyond our solar system.

If these waves came from a terrestrial origin, it was reasoned, then they should have the same intensity all the year around. But their intensity varies regularly with the time of day and with the seasons, and they get much weaker when the earth, moving in its orbit, interposes itself between the radio receiver and the source.

A preliminary report, published in the Proceedings of the Institute of Radio Engineers last December, described studies which showed the presence of three separate groups of static: Static from local thunderstorms, static from distant thunderstorms, and a "steady hiss type static of unknown origin." Further studies this year determine the unknown origin of this third type to be from the direction of the centre of the Milky Way, the earth's own home galaxy.

Direction of Arrival Fixed.

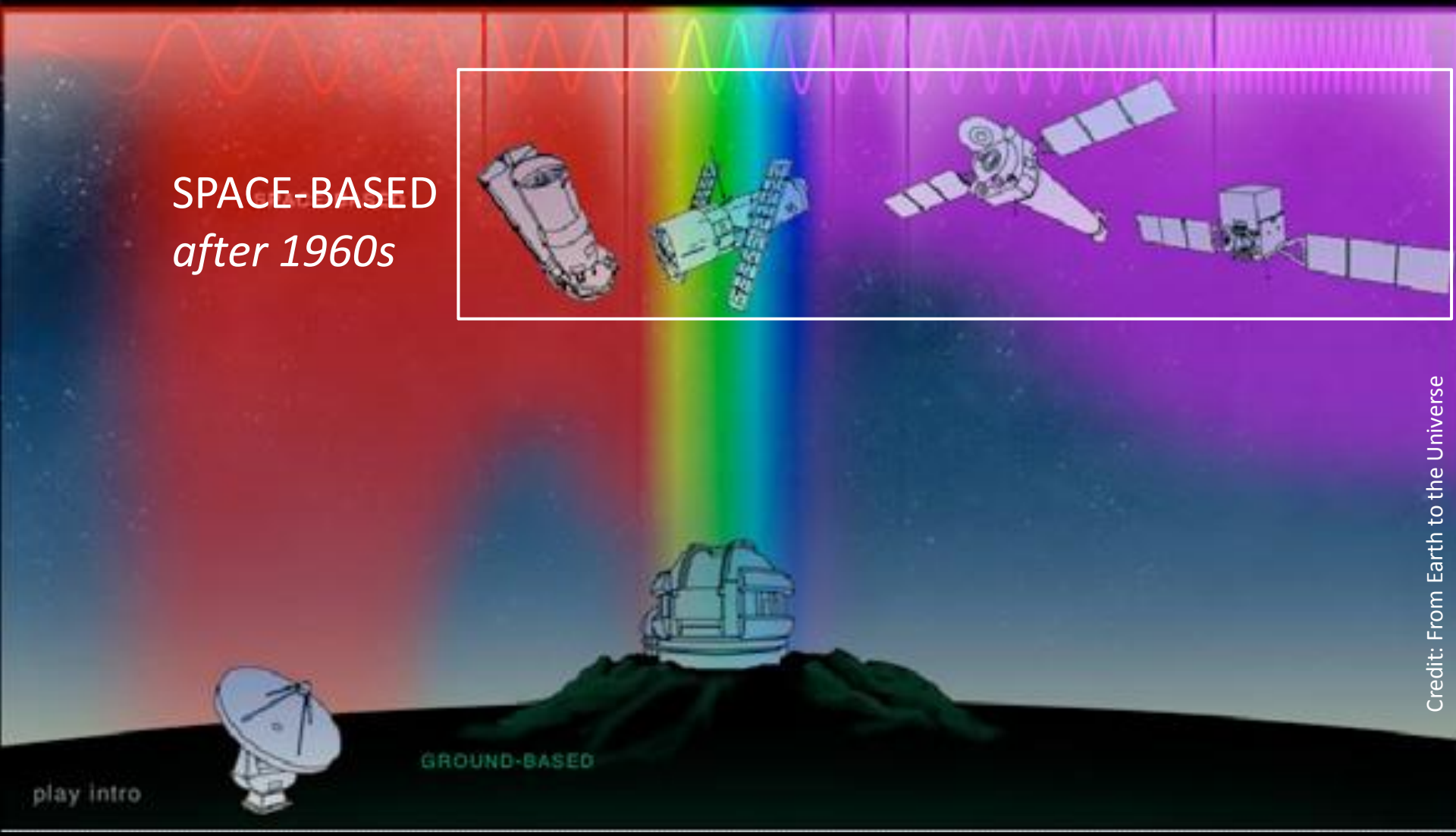
The direction from which these waves arrive, the announcement asserts, has been determined by investigations carried on over a considerable period. Measurements of the horizontal component of the waves were taken on several days of each month for an entire year, and by an analysis of these readings at the end of the year their direction of arrival was disclosed.

"The position indicated," it was explained, "is very near to the point where the plane in which the earth revolves around the sun crosses the centre of the Milky Way, and also to that point toward which the solar system is moving with respect to the other stars.

"Further verification of this direction is required, but the discovery, like that of the cosmic rays and of cosmic radiation, raises many cosmological questions of extreme interest."

There is no indication of any kind, Mr. Jansky replied to a question, that these galactic radio waves constitute some kind of interstellar signalling, or that they are the result of some form of intelligence striving for intra-galactic communication.

Astronomy beyond visible light?



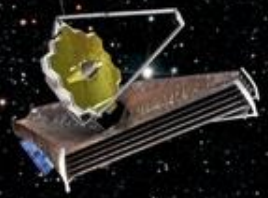
Credit: From Earth to the Universe

→ ESA'S FLEET ACROSS THE SPECTRUM

esa

Thanks to cutting edge technology, astronomy is unveiling a new world around us. With ESA's fleet of spacecraft, we can explore the full spectrum of light and probe the fundamental physics that underlies our entire Universe. From cool and dusty star formation revealed only at infrared wavelengths, to hot and violent high-energy phenomena, ESA missions are charting our cosmos and even looking back to the dawn of time to discover more about our place in space.

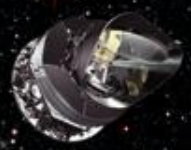
jwst
Observing the first light



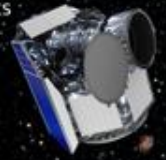
gaia
Surveying a billion stars

herschel
Unveiling the cool and dusty Universe

planck
Looking back at the dawn of time



cheops
Sizing and first characterisation of exoplanets

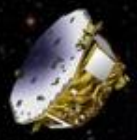


euclid
Exploring the dark Universe

hst
Expanding the frontiers of the visible Universe

xmm-newton
Seeing deeply into the hot and violent Universe

lisa pathfinder
Testing the technology for gravitational wave detection

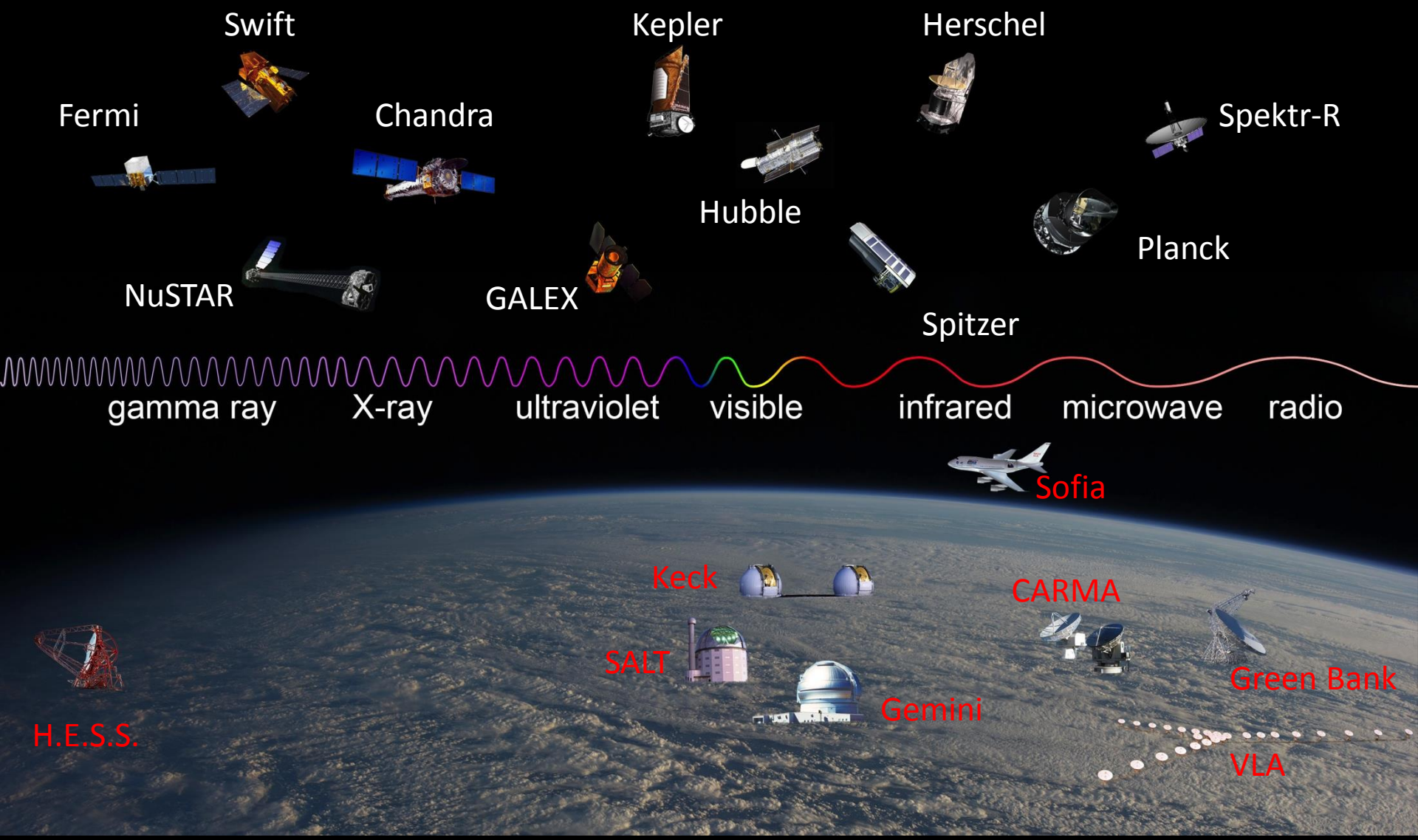


microwaves
sub-millimetre
infrared
optical
ultraviolet
x-rays
gamma rays

integral
Seeking out the extremes of the Universe

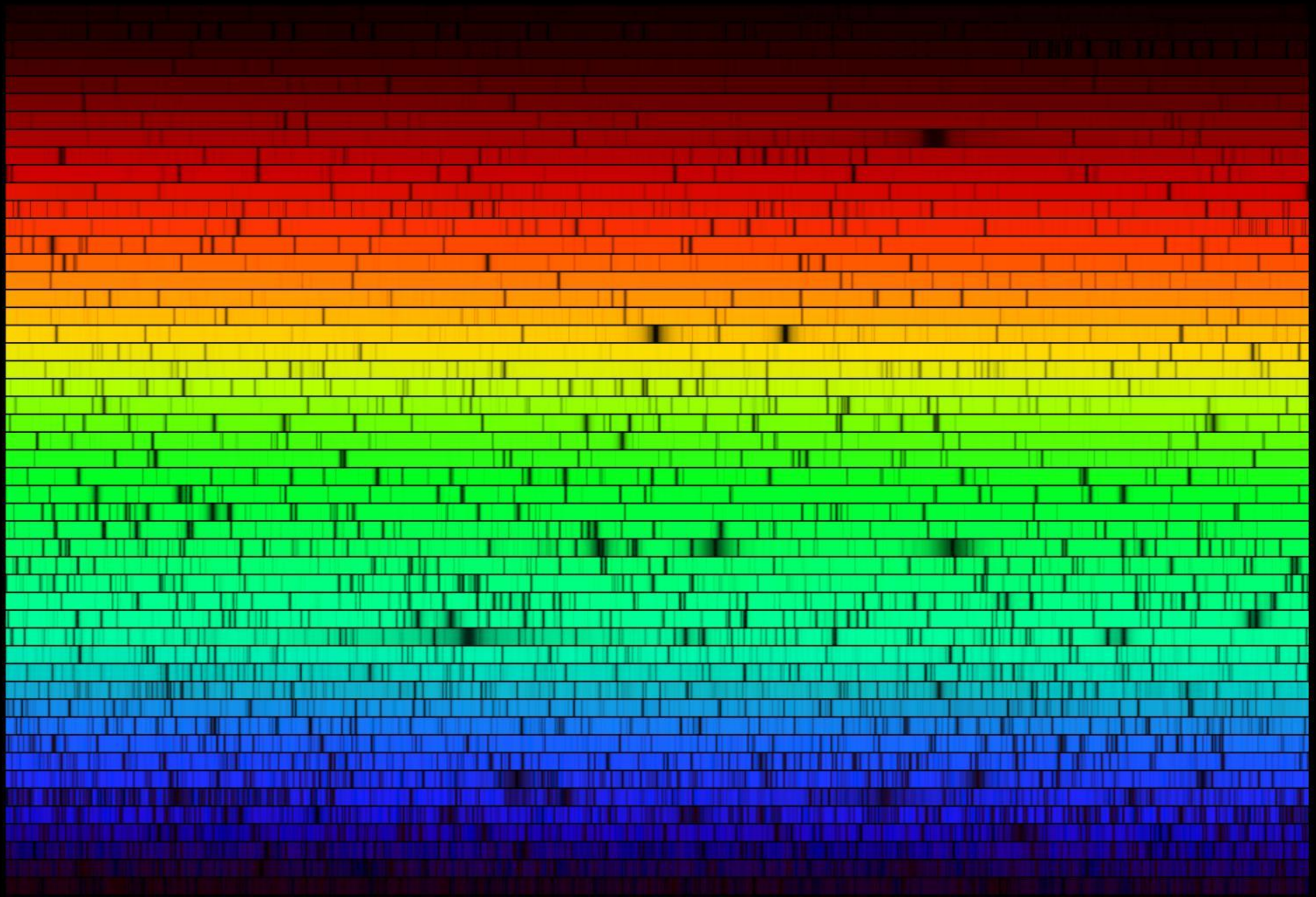
www.esa.int

European Space Agency

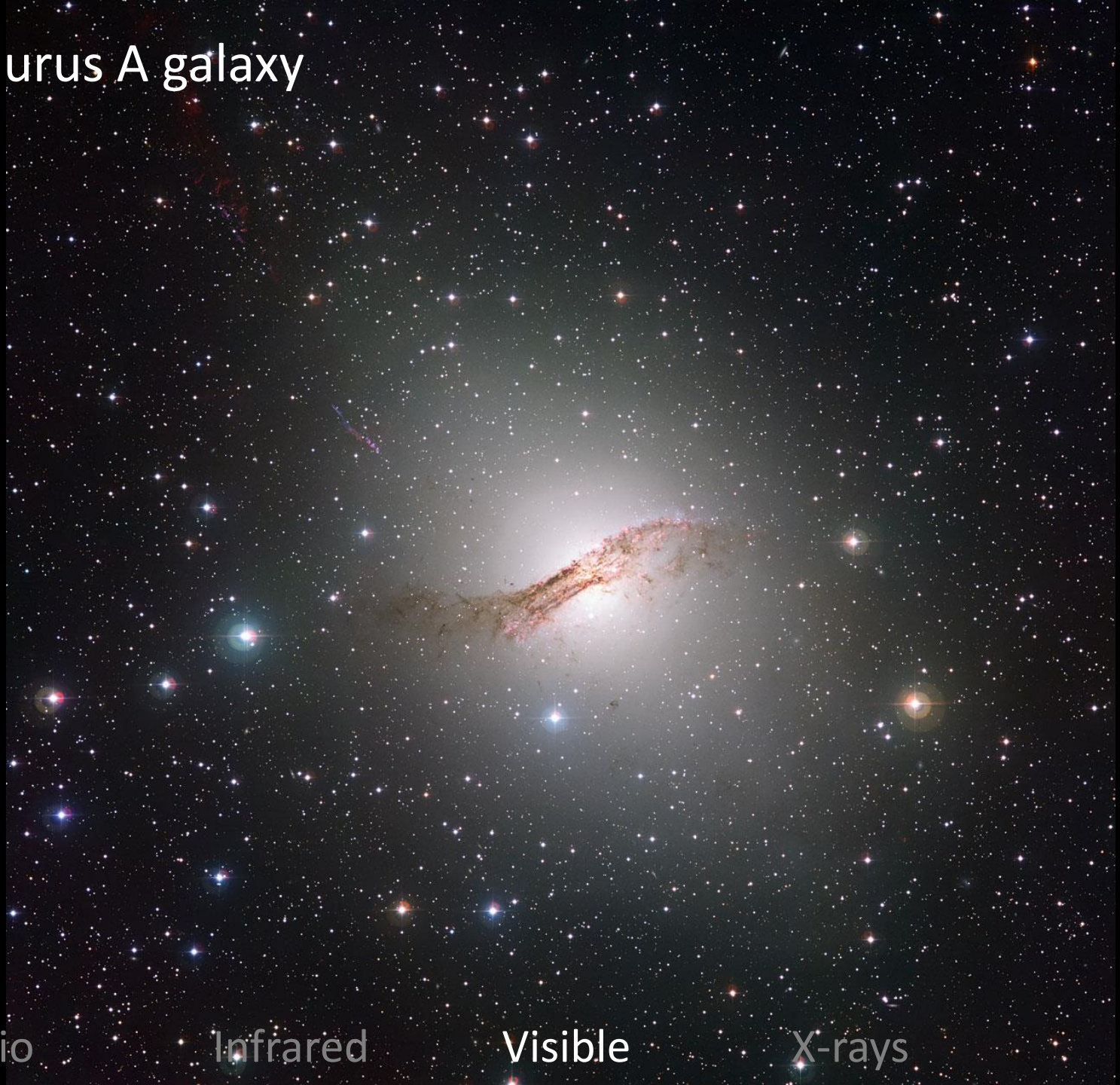


Astronomy across the spectrum: from space and ground

Why?



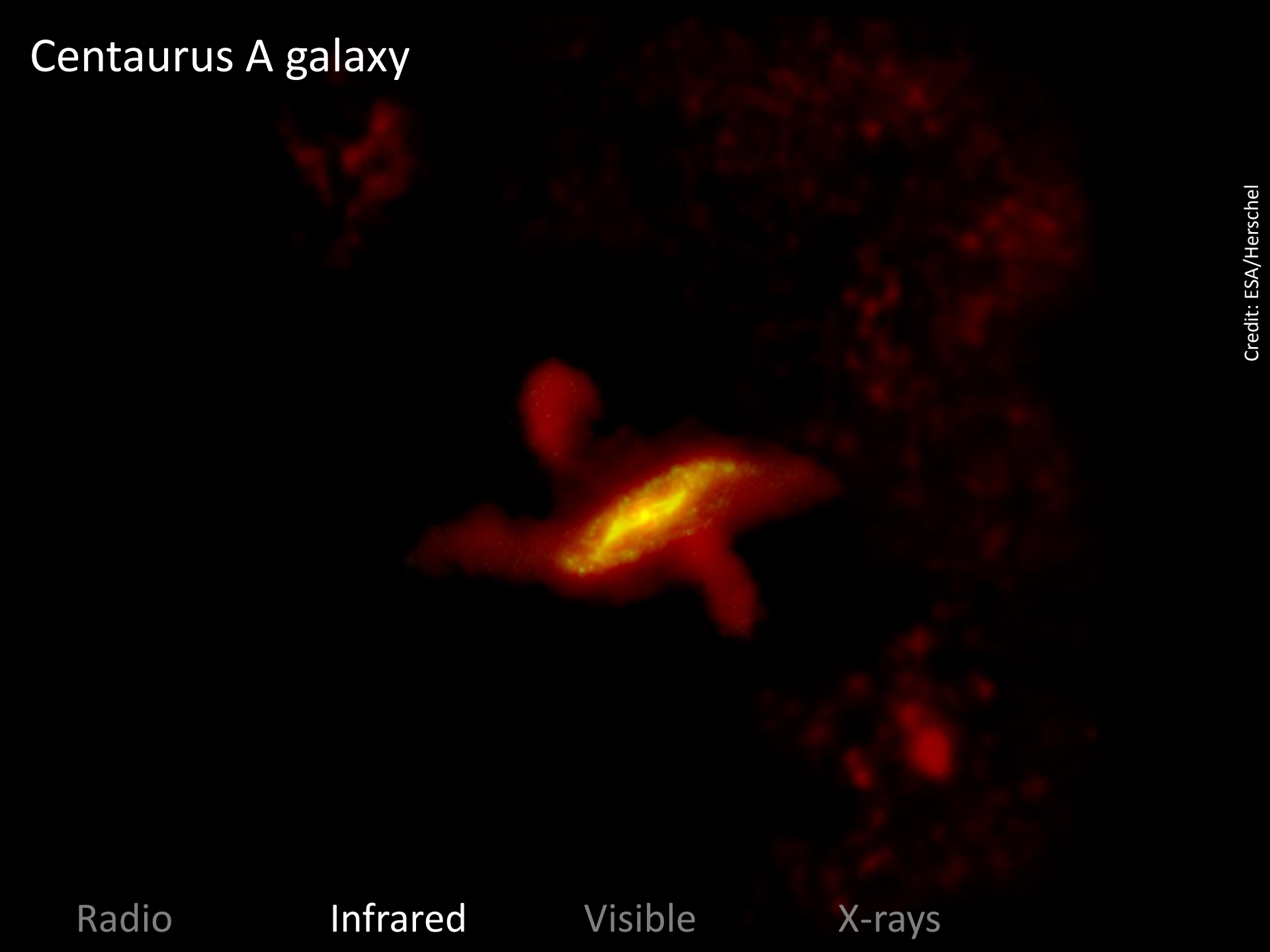
Centaurus A galaxy



Radio Infrared Visible X-rays

Credit: ESO

Centaurus A galaxy



Credit: ESA/Herschel

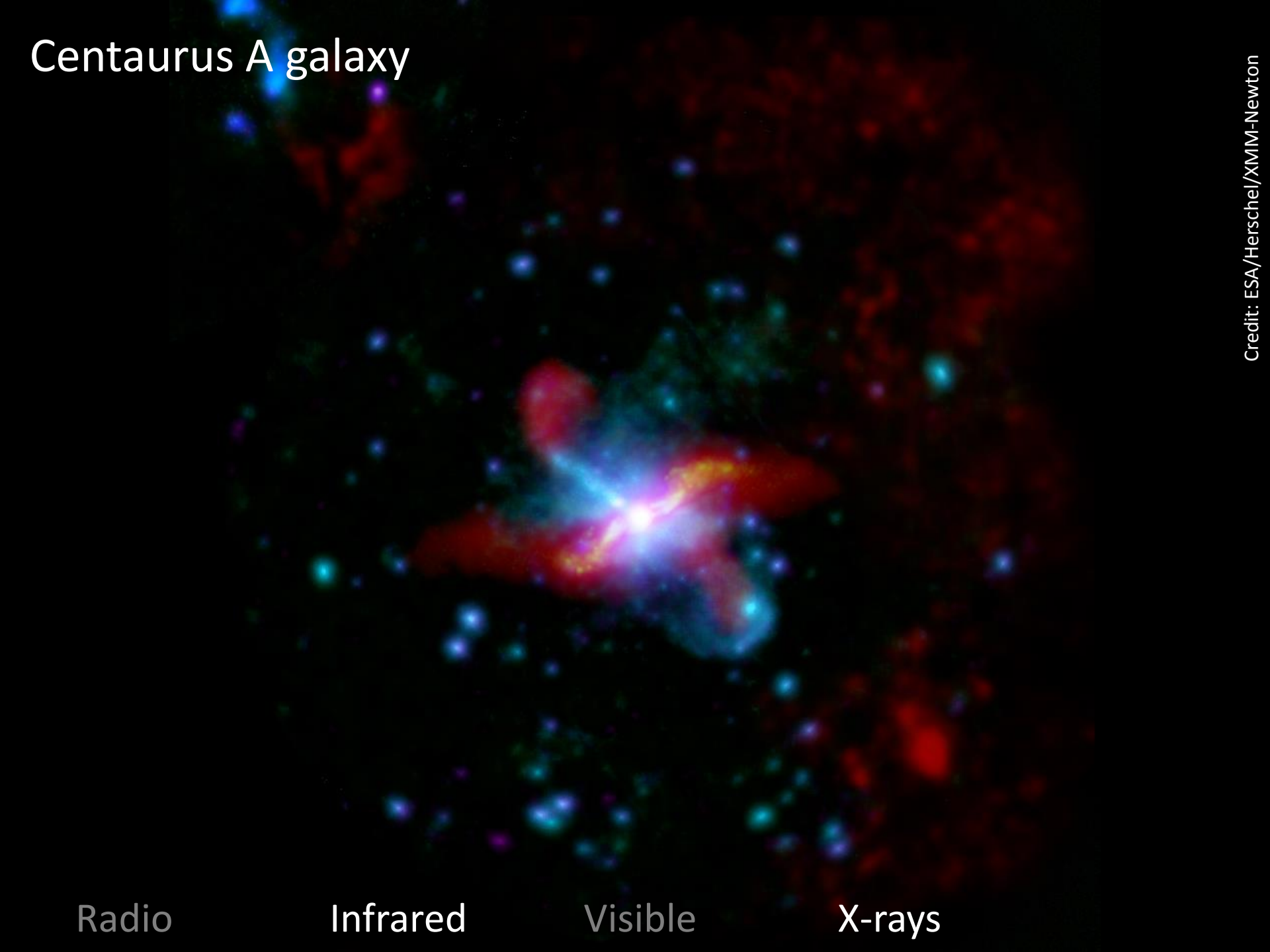
Radio Infrared Visible X-rays

Centaurus A galaxy

Radio Infrared Visible X-rays

Credit: ESA/XMM-Newton

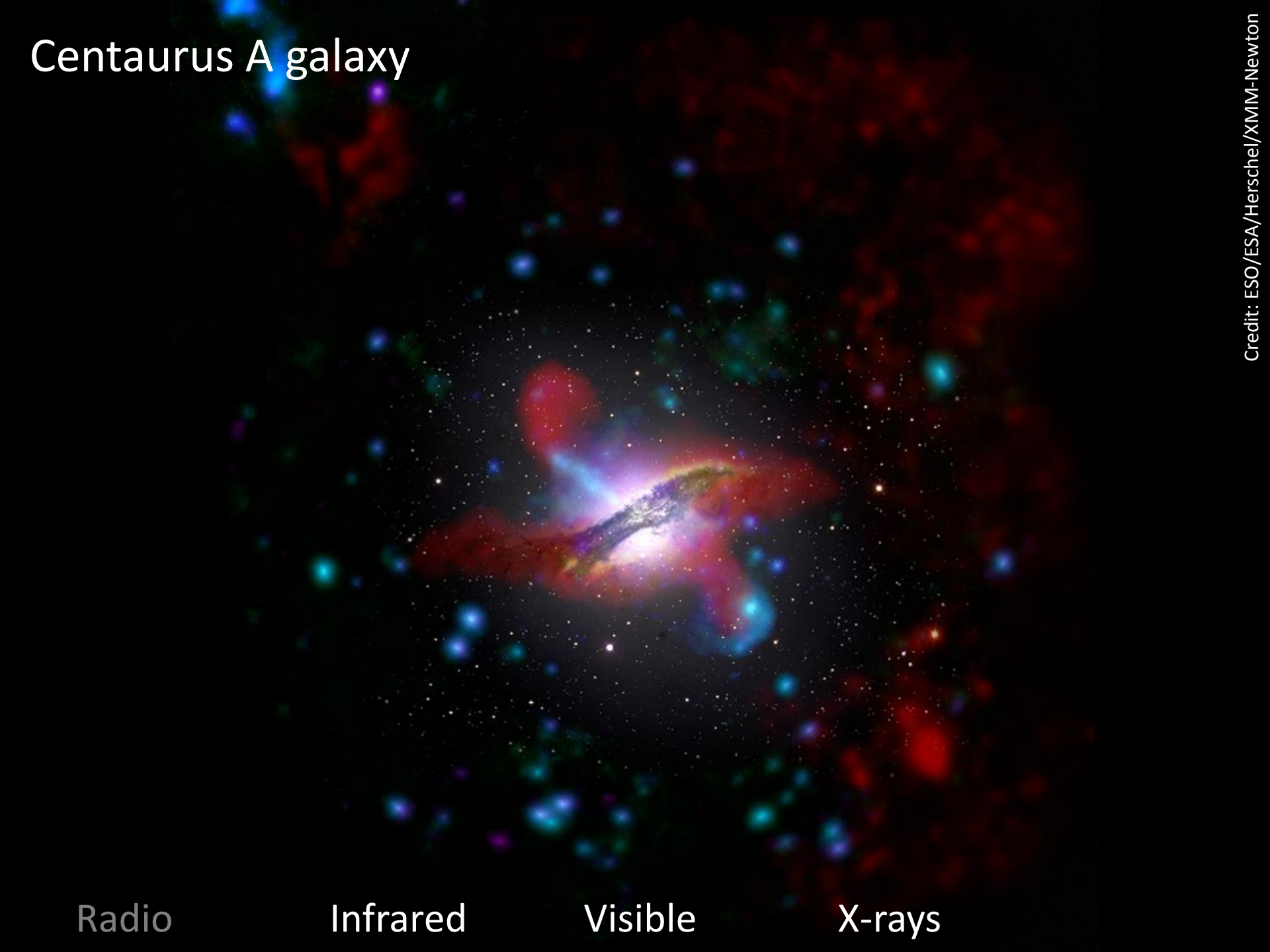
Centaurus A galaxy



Radio Infrared Visible X-rays

Credit: ESA/Herschel/XMM-Newton

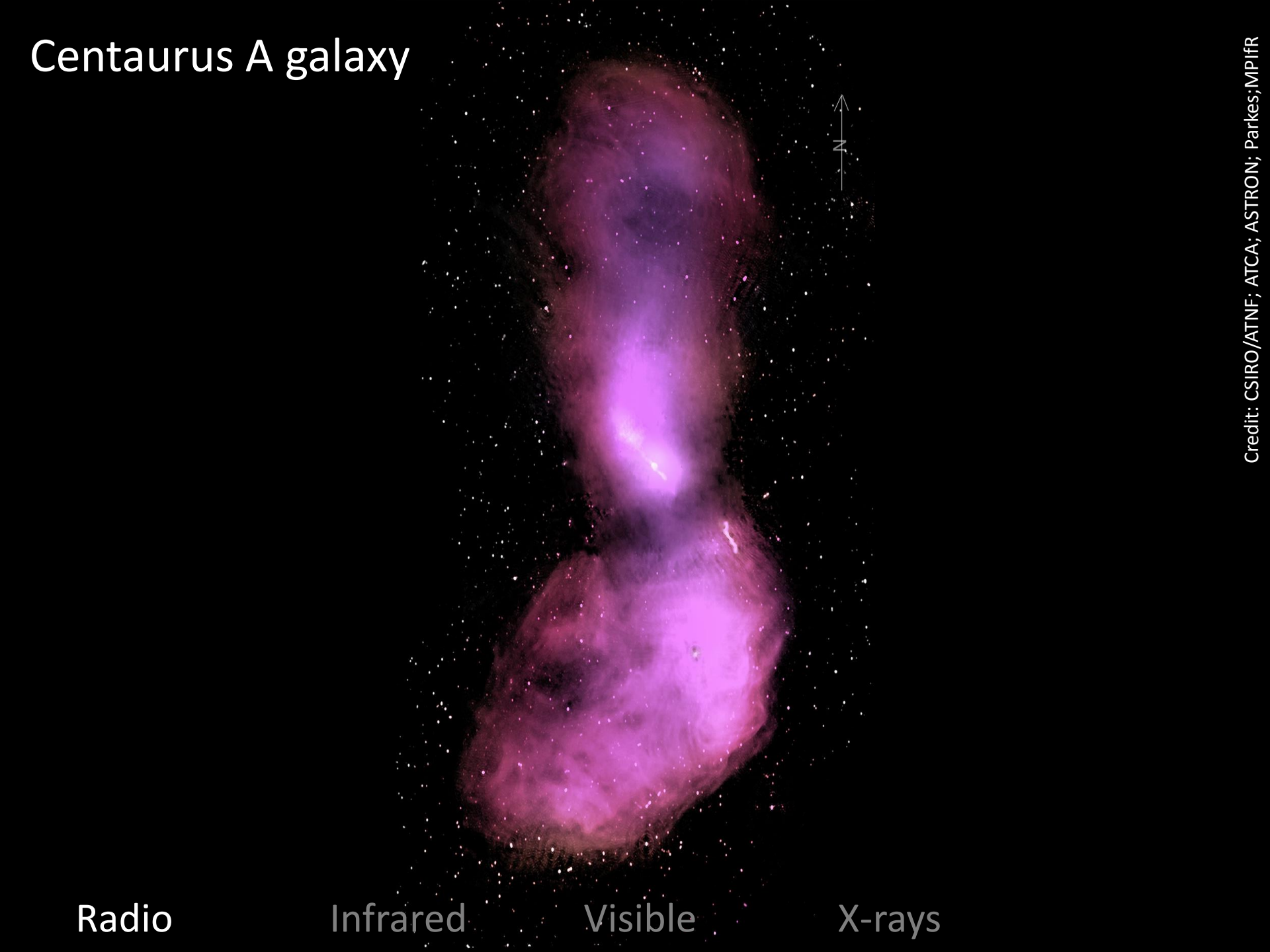
Centaurus A galaxy



Radio Infrared Visible X-rays

Credit: ESO/ESA/Herschel/XMM-Newton

Centaurus A galaxy



Radio Infrared Visible X-rays

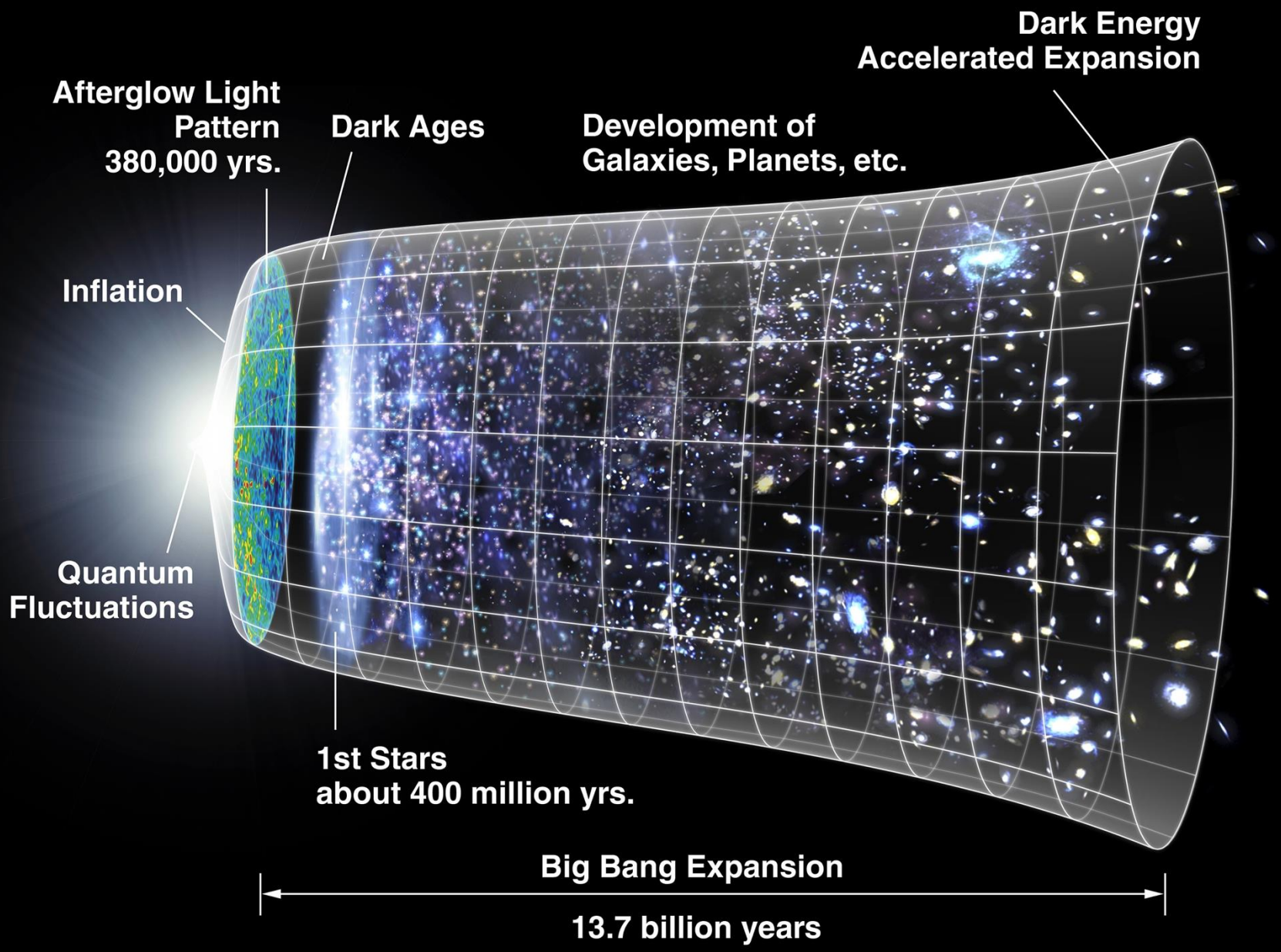
Credit: CSIRO/ATNF; ATCA; ASTRON; Parkes;MPIfR

Centaurus A galaxy

Radio Infrared Visible X-rays

Credit: CSIRO/ATNF; ATCA; ASTRON; Parkes;MPIfR; ESO/WFI/AAO (UKST); MPIfR/ESO/APEX; NASA/CXC/CfA

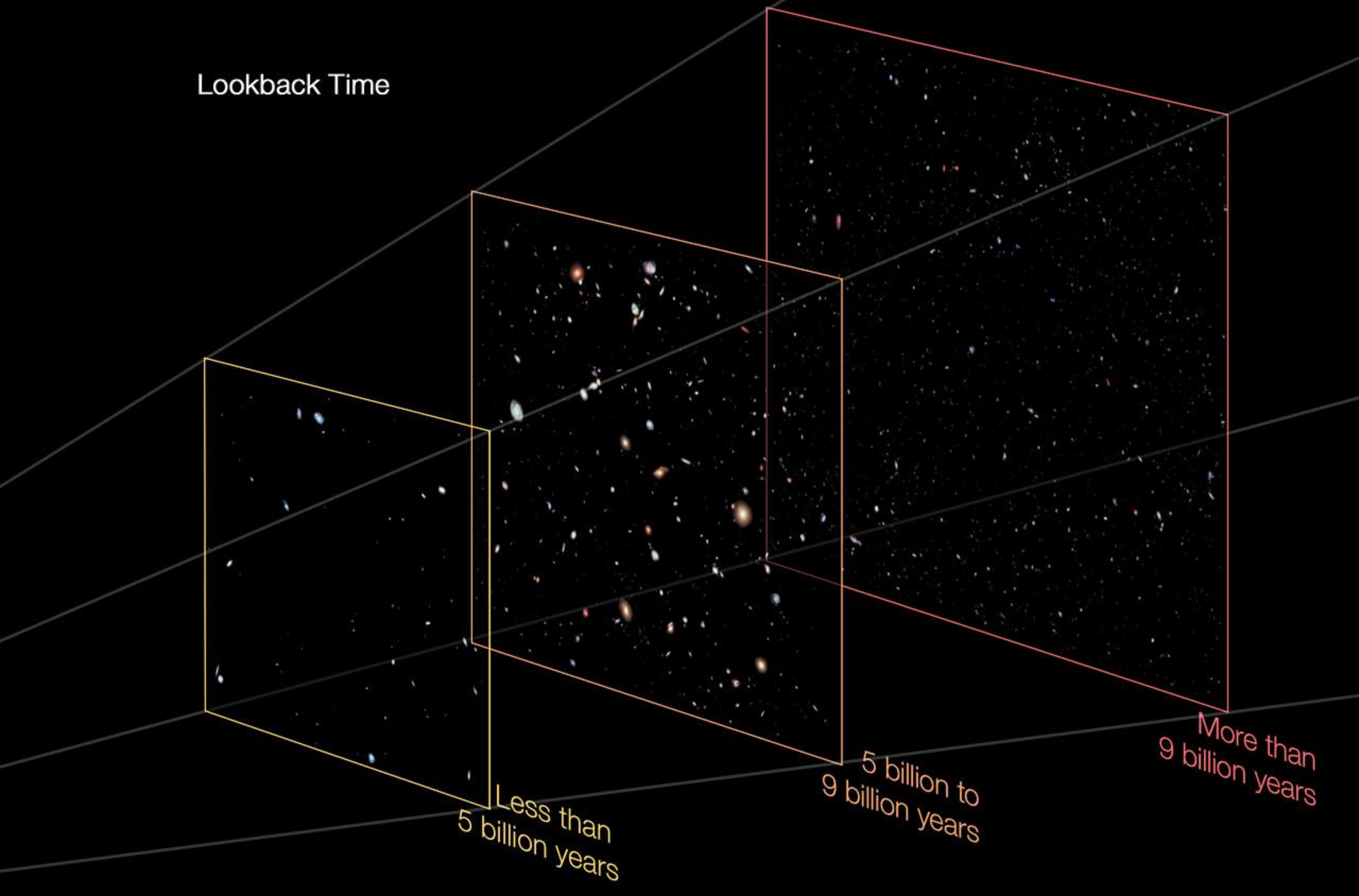
The history of the Universe



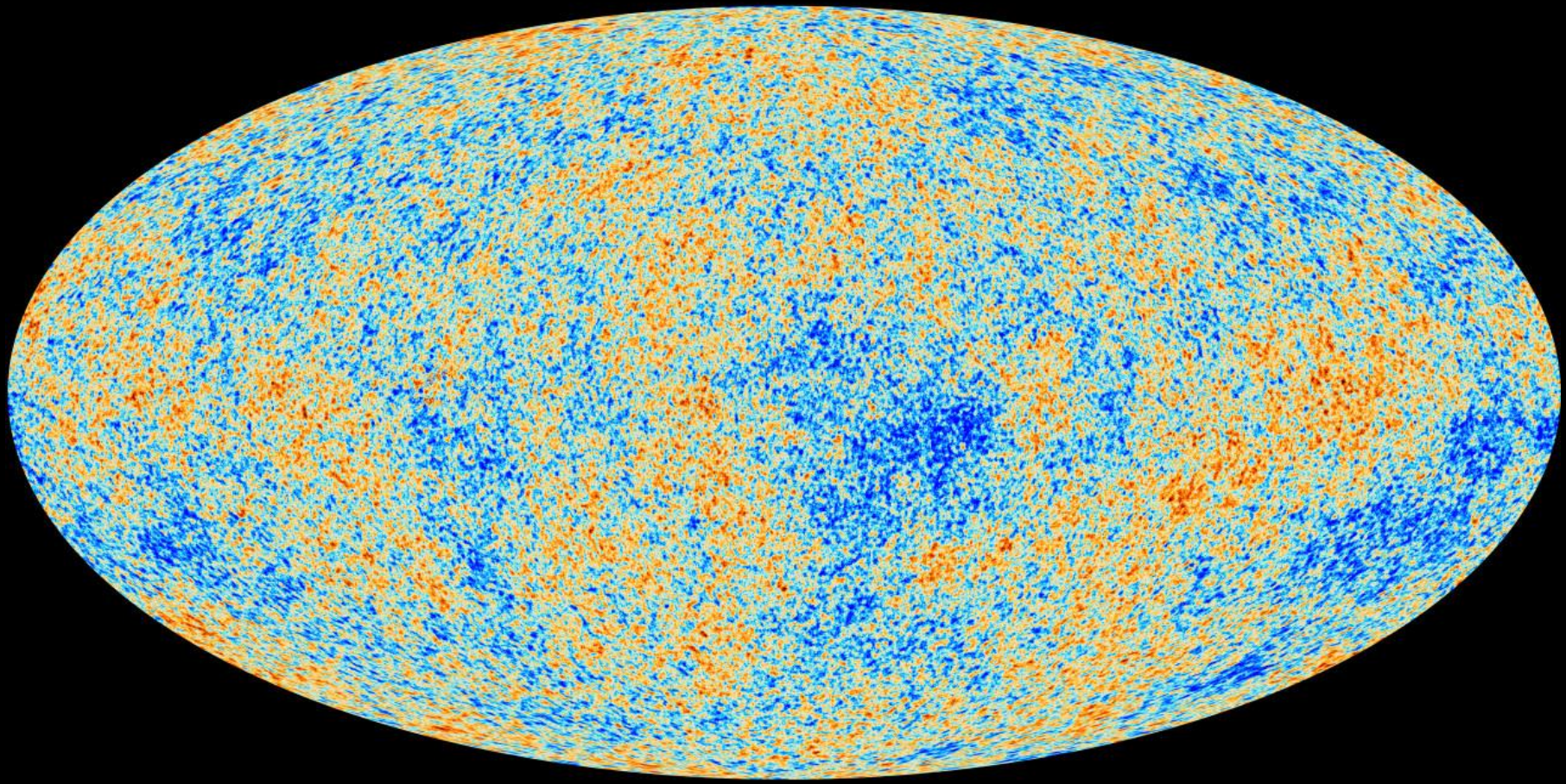
The history of the Universe: searching for the first galaxies

Credit: NASA, ESA, G. Illingworth, D. Magee, and P. Oesch (University of California, Santa Cruz), R. Bouwens (Leiden University), and the HUDF09 Team

The history of the Universe: searching for the first galaxies



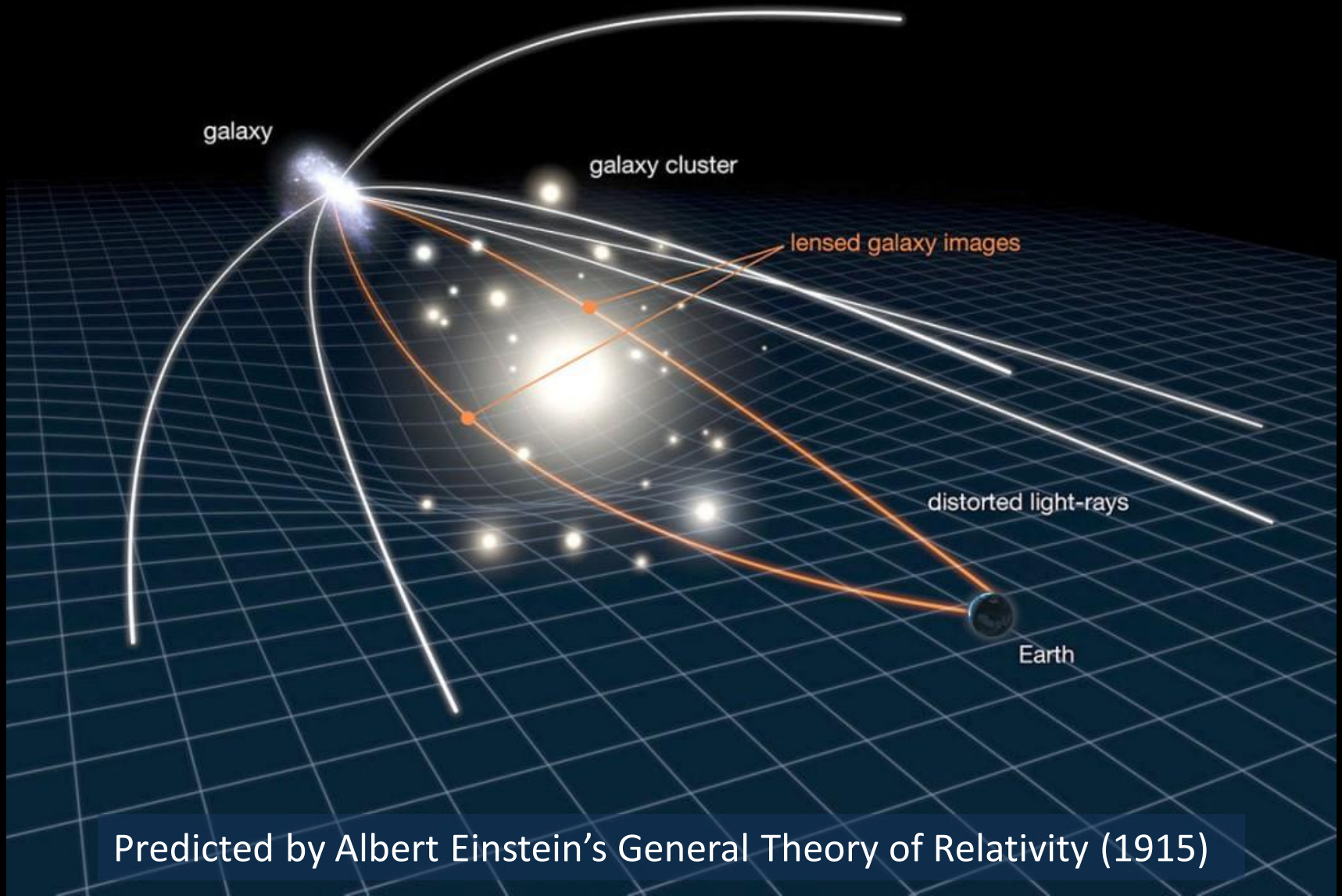
The history of the Universe: the first cosmic light



Credit: ESA & the Planck Collaboration

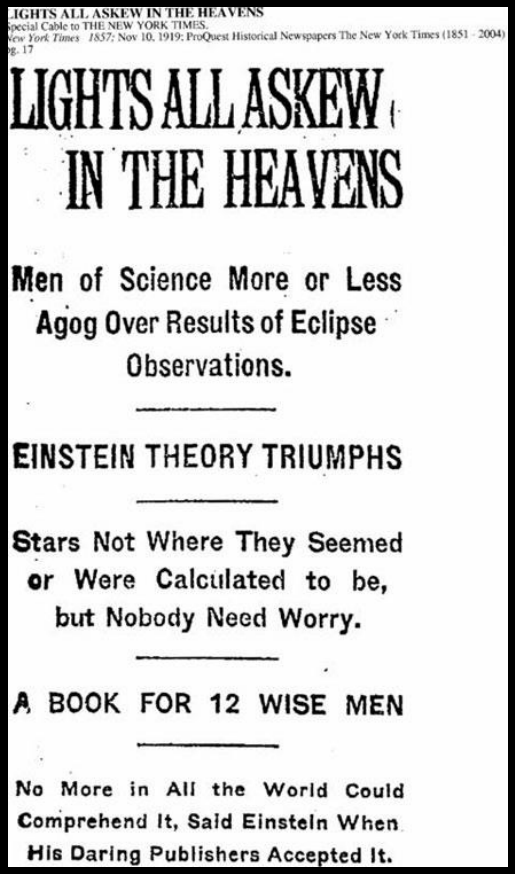
The Cosmic Microwave Background, first discovered by Penzias & Wilson in 1965

Light to see the invisible: gravitational lensing



Predicted by Albert Einstein's General Theory of Relativity (1915)

Light to see the invisible: gravitational lensing



LIGHTS ALL ASKEW IN THE HEAVENS

Special Cable to THE NEW YORK TIMES.

pg. 17

LIGHTS ALL ASKEW IN THE HEAVENS

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

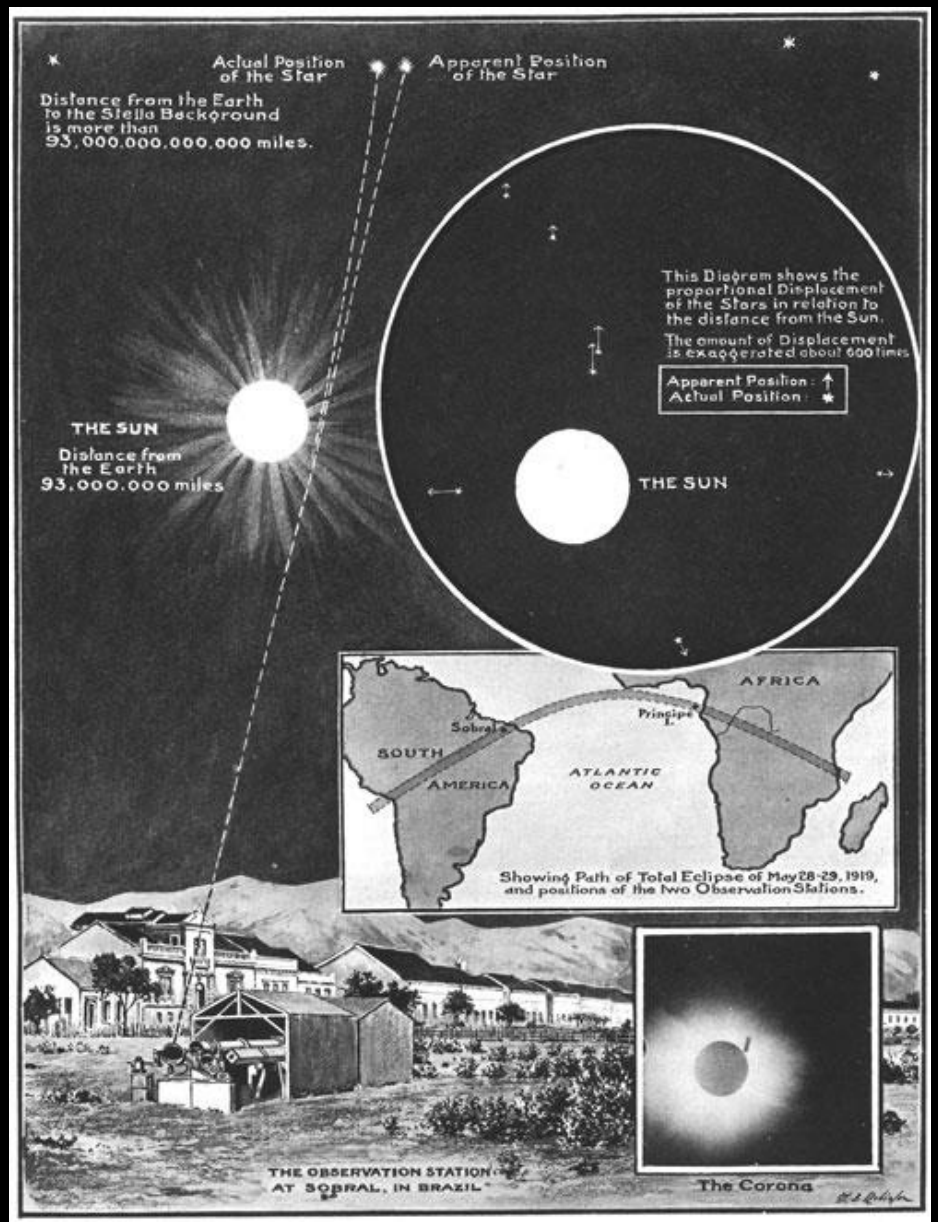
EINSTEIN THEORY TRIUMPHS

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

A BOOK FOR 12 WISE MEN

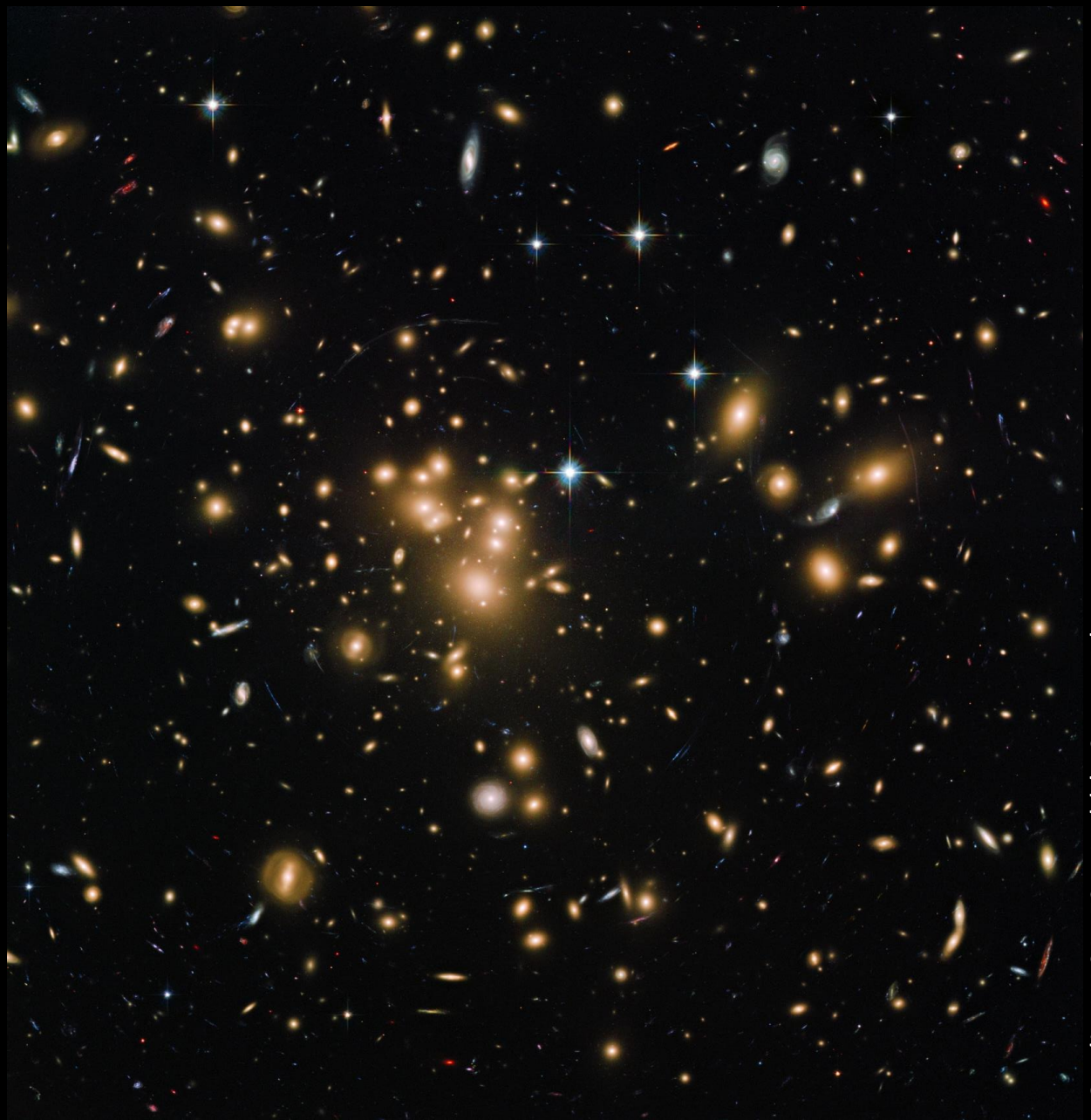
No More in All the World Could Comprehend It, Said Einstein When His Daring Publishers Accepted It.

New York Times
10 November 1919



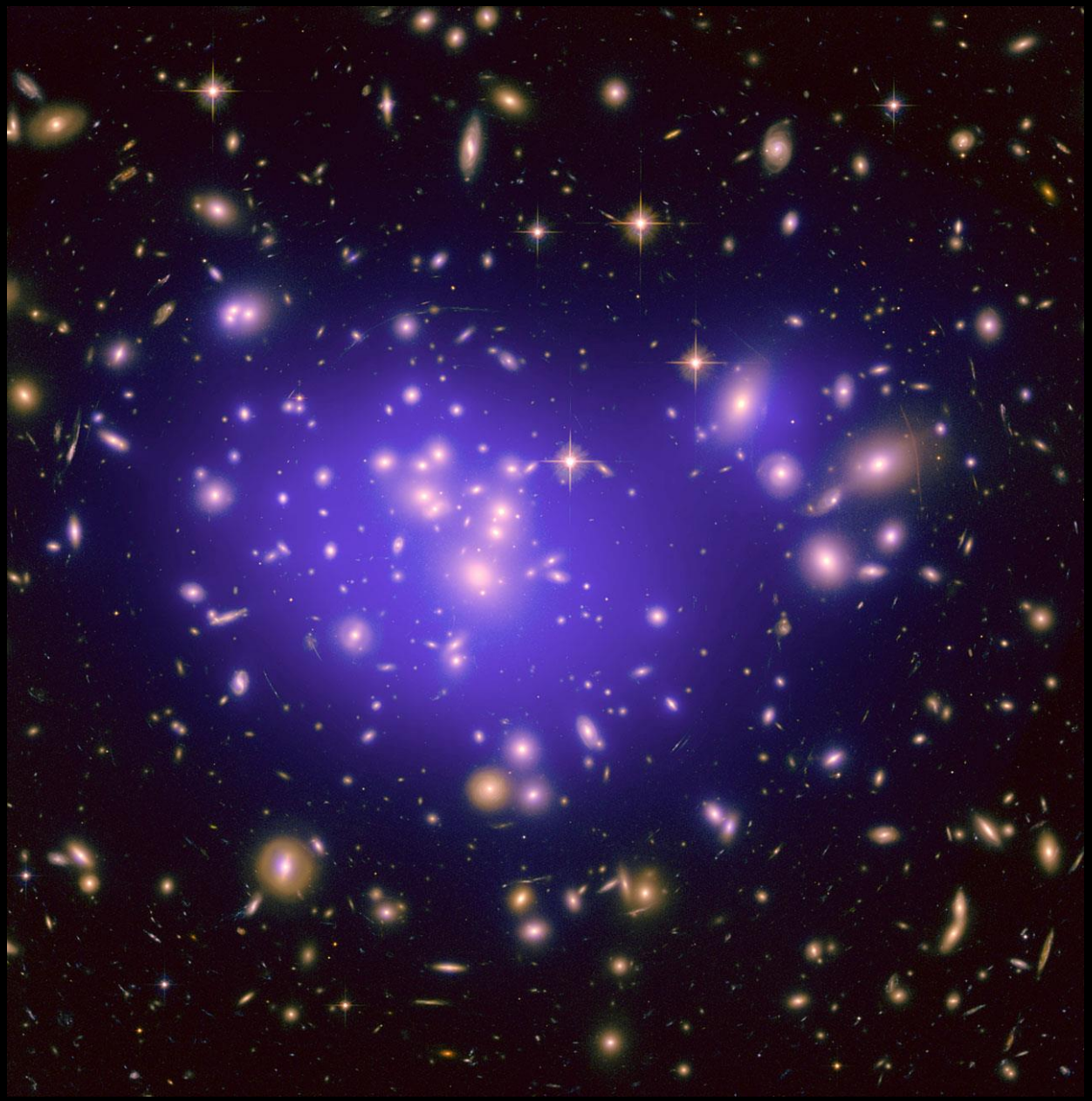
Illustrated London News, 22 November 1919

Light to see the invisible: gravitational lensing



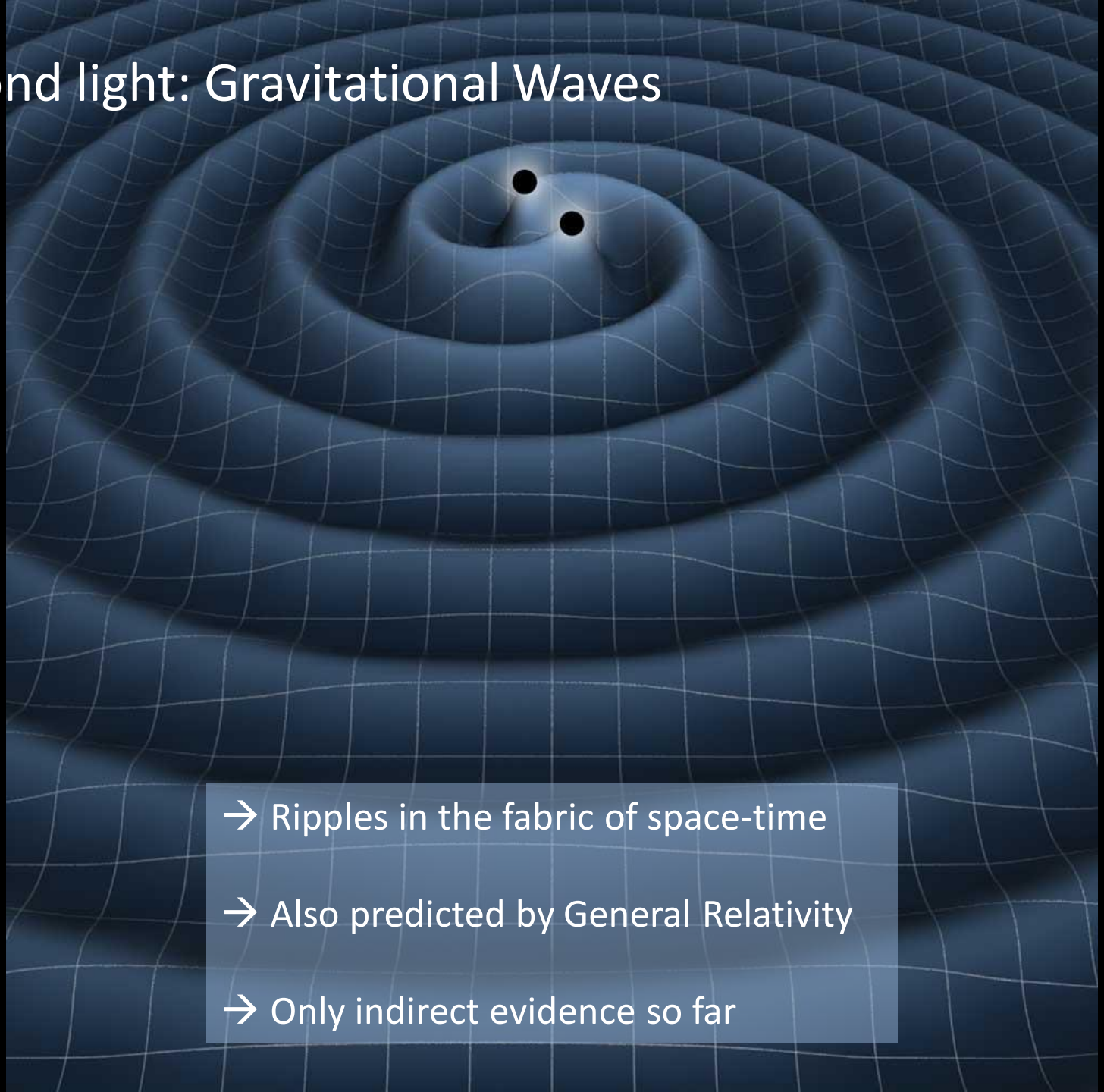
Credit: NASA, ESA, Hubble Space Telescope

Light to see the invisible: gravitational lensing



Credit: NASA, ESA, E. Jullo (JPL/LAM), P. Natarajan (Yale) and J-P. Kneib (LAM)

Beyond light: Gravitational Waves



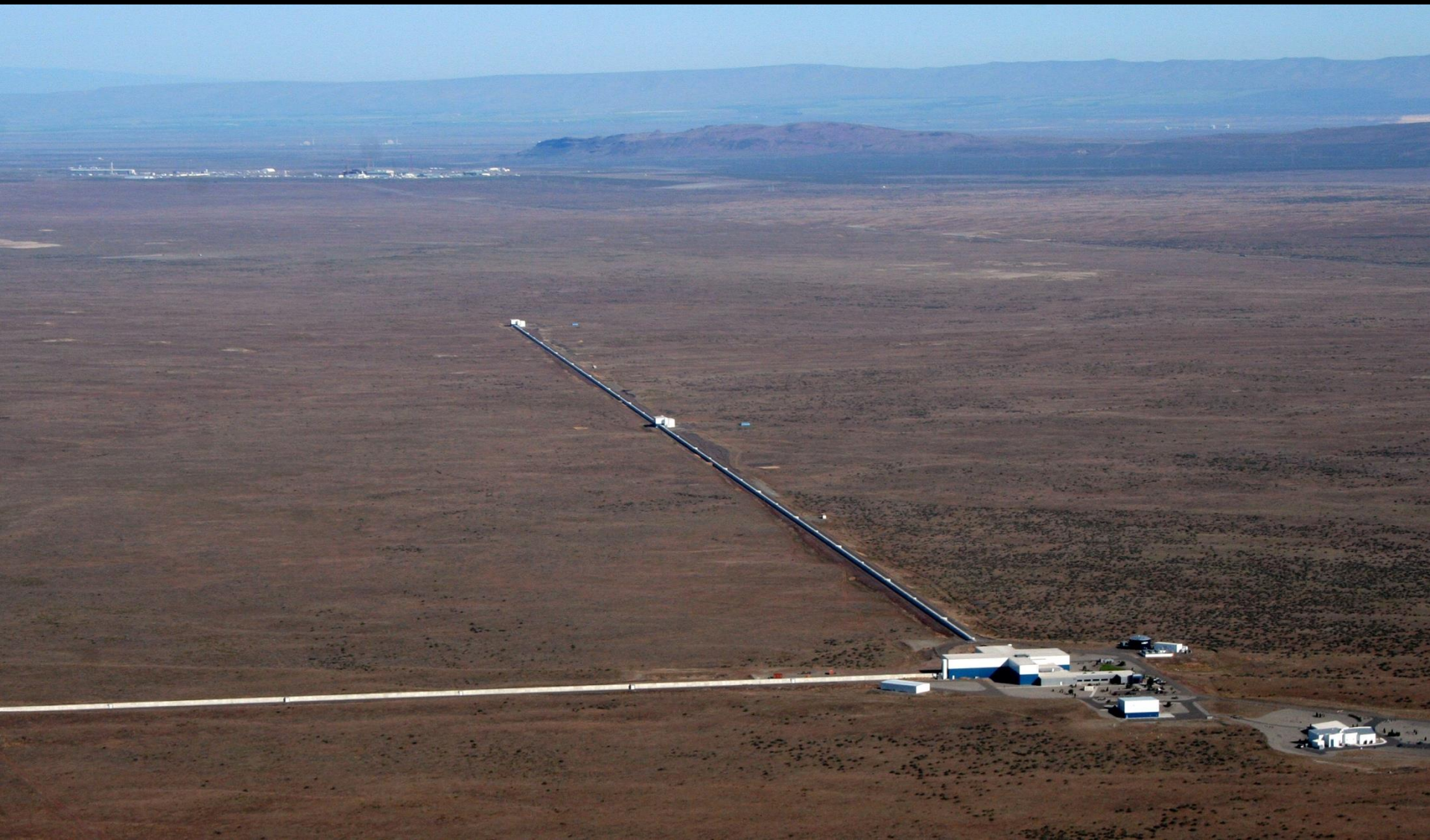
→ Ripples in the fabric of space-time

→ Also predicted by General Relativity

→ Only indirect evidence so far

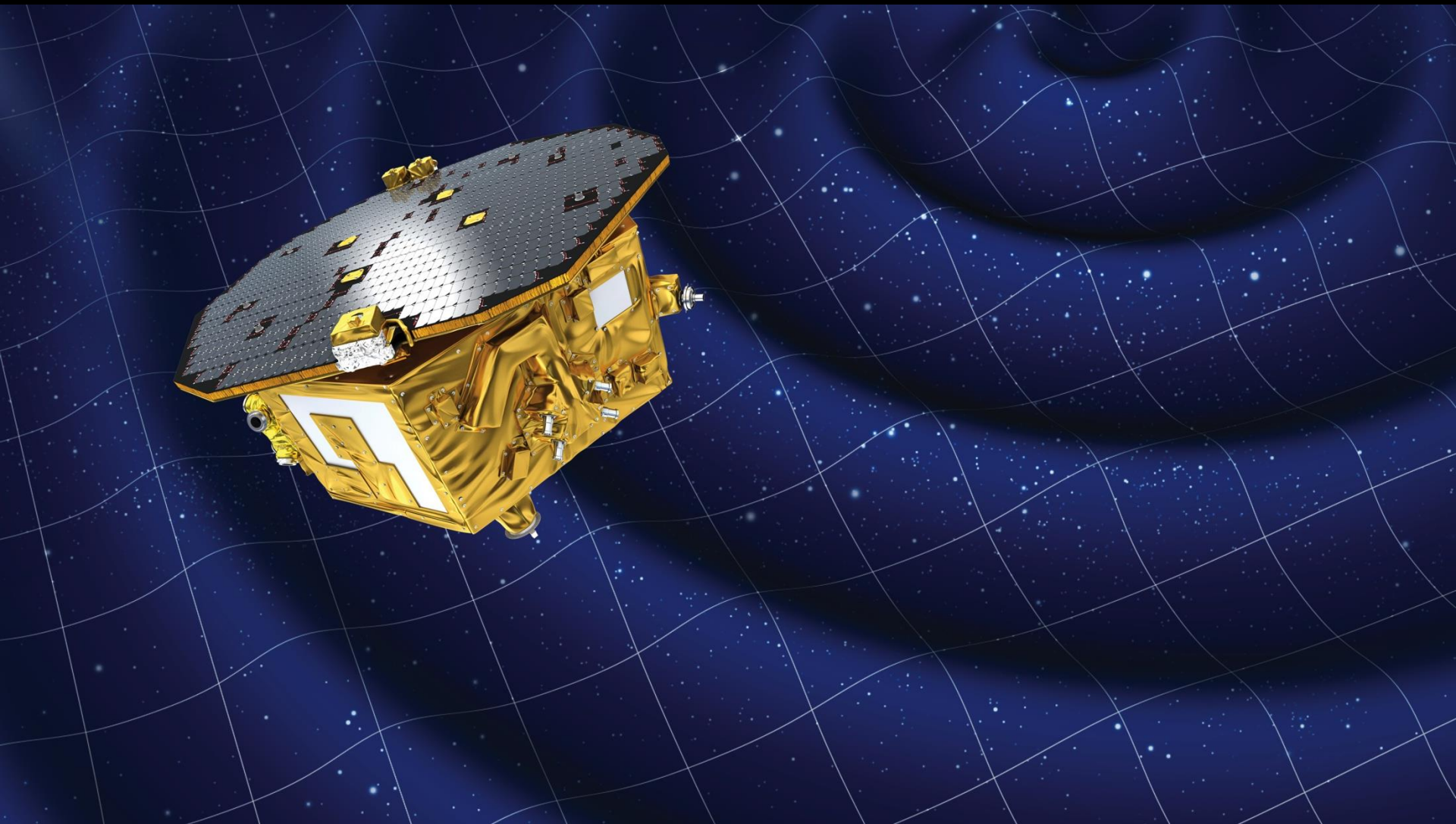
Beyond light: Gravitational Waves

PRESENT: Laser Interferometer Gravitational-Wave Observatory (*LIGO*), USA



Beyond light: Gravitational Waves

COMING SOON: ESA's LISA Pathfinder – Launch: 2 December 2015
Demonstrating the technology to detect gravitational waves from space



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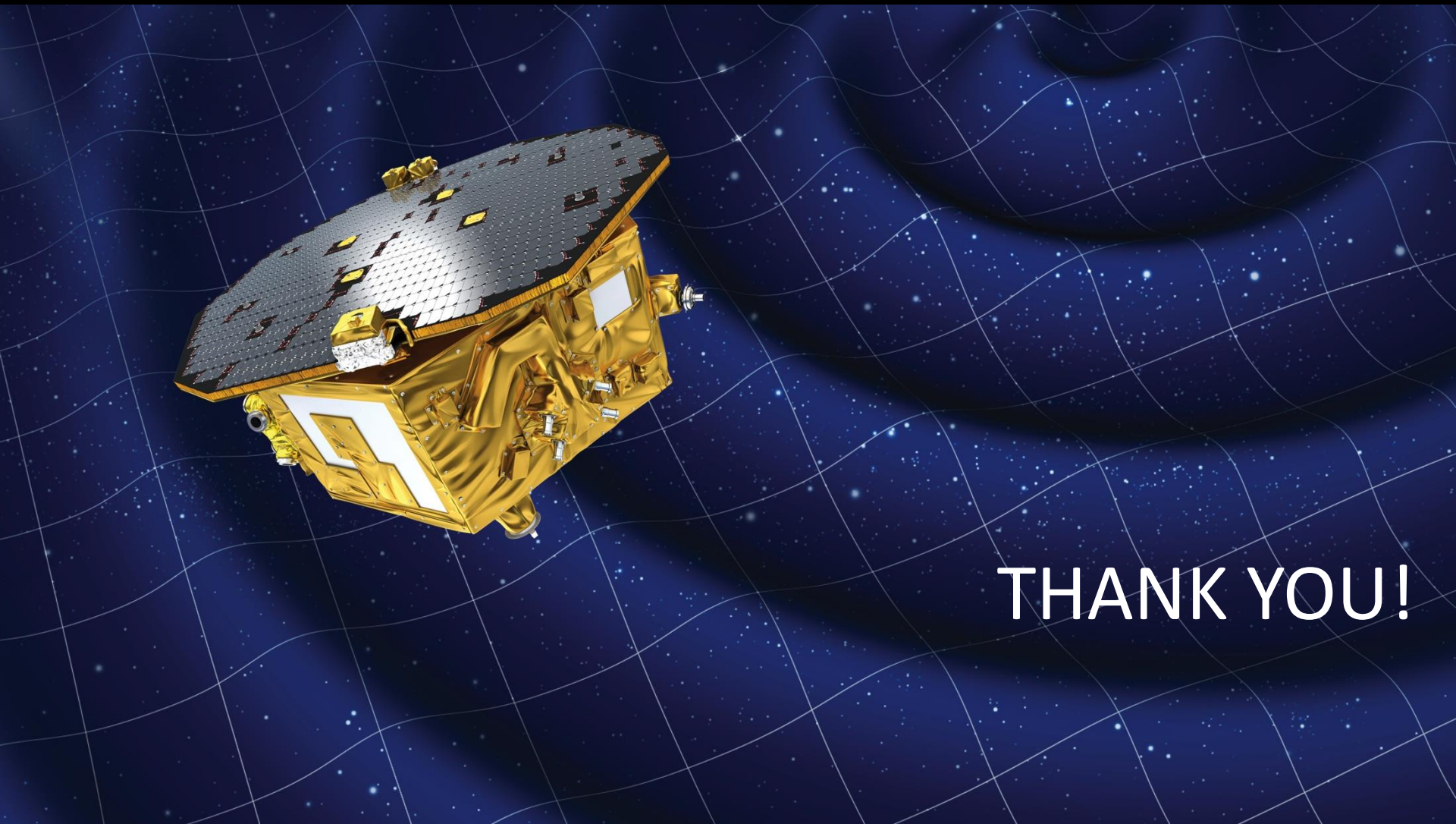
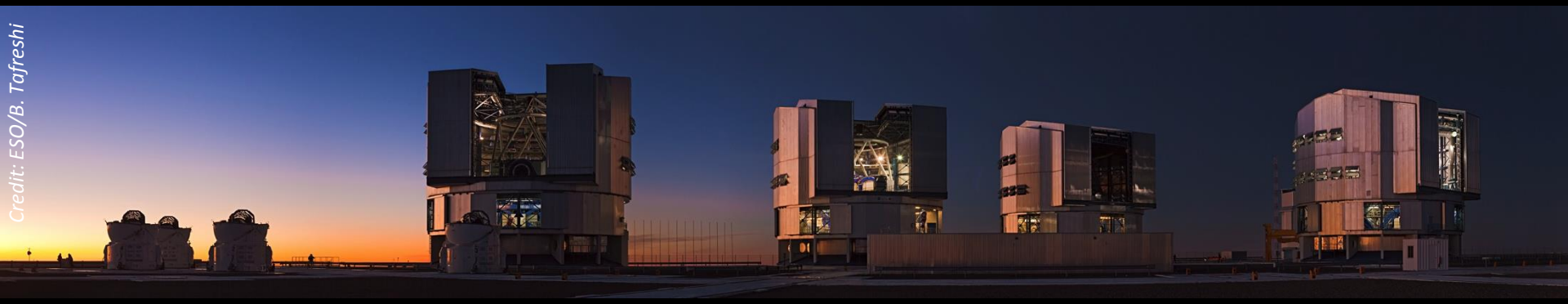


THANK YOU!

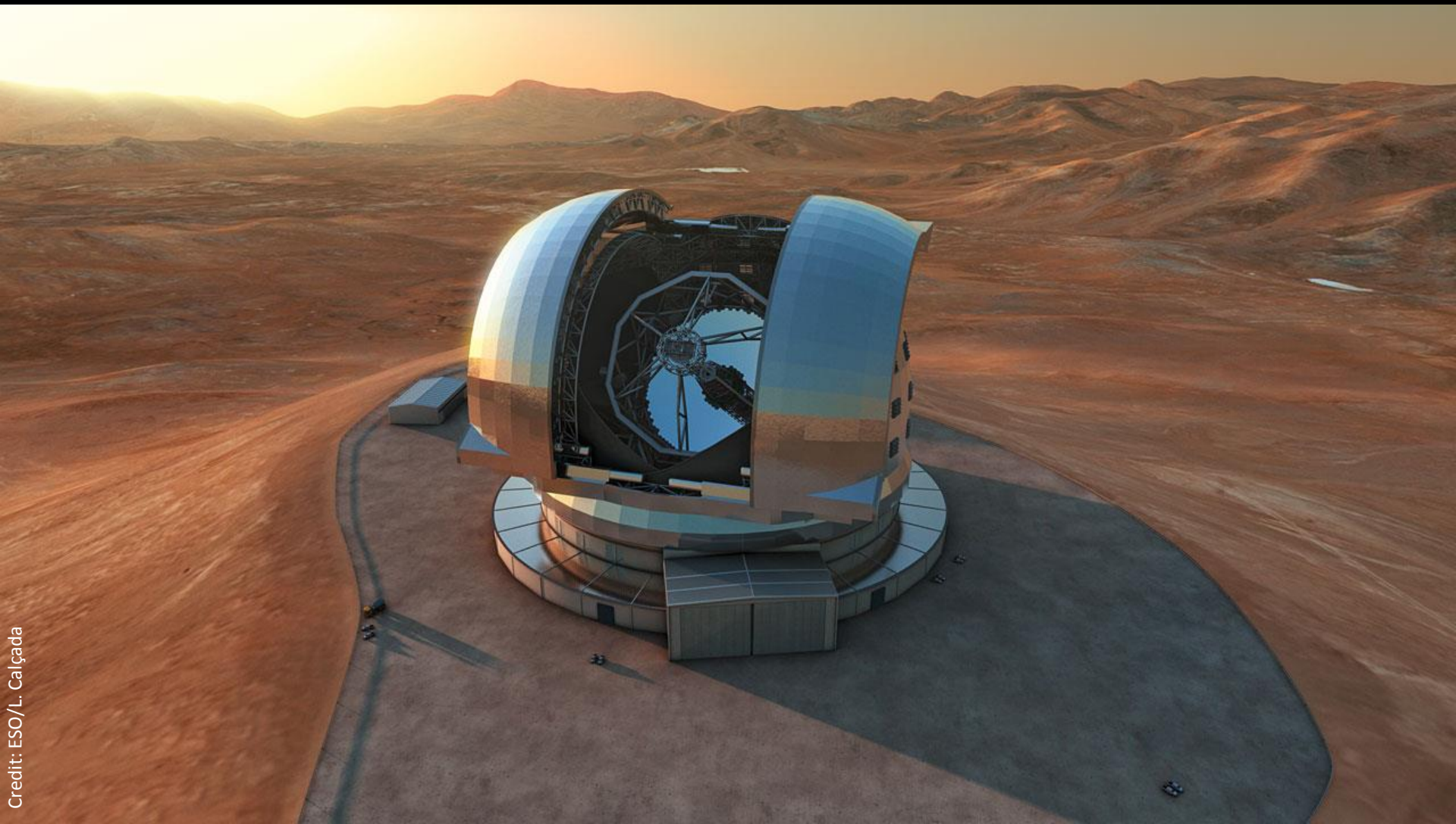
Visible light



PRESENT: ESO’s Very Large Telescope, Chile

Visible light

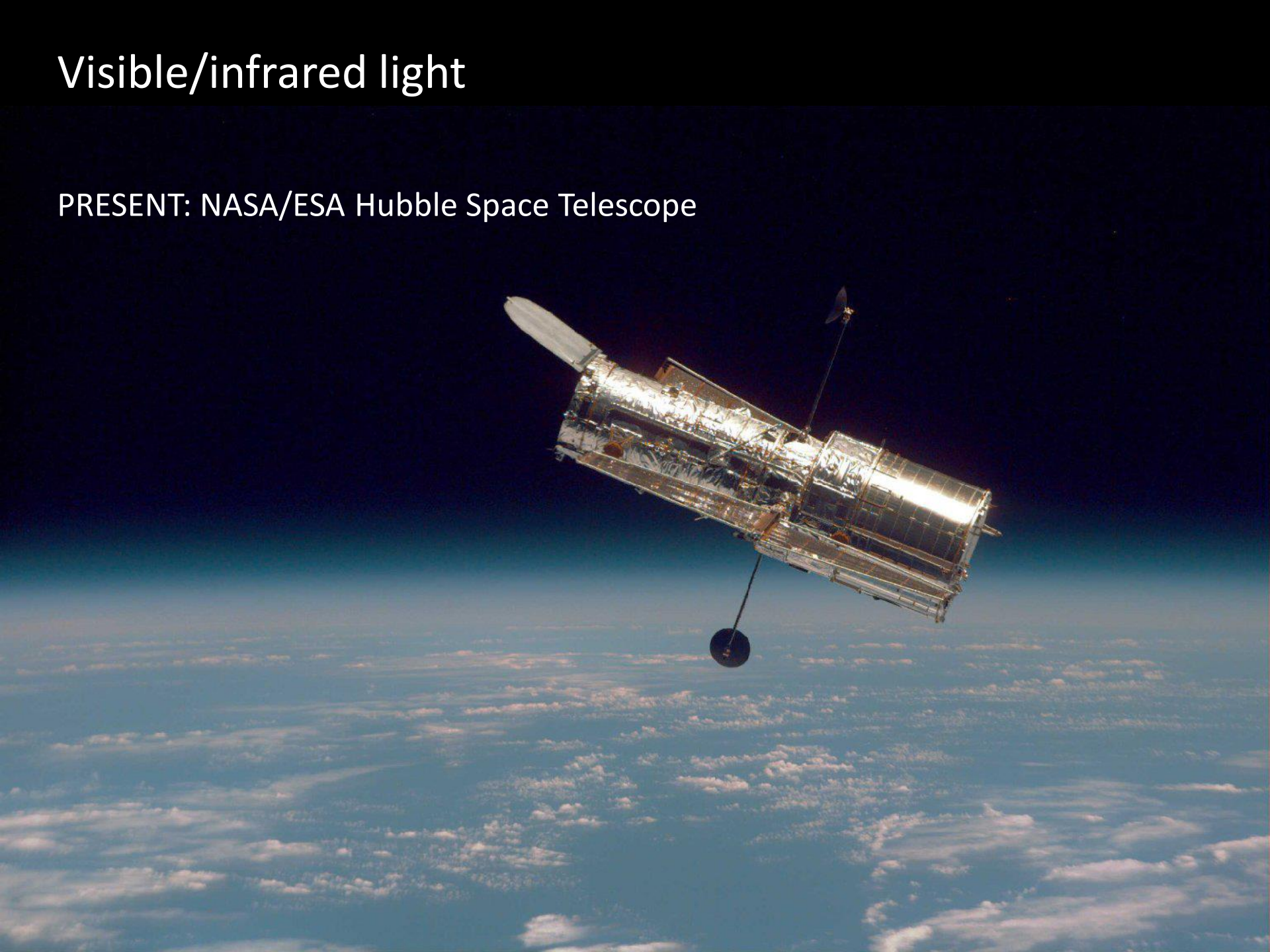
FUTURE: ESO's European Extremely Large Telescope, Chile



Credit: ESO/L. Calçada

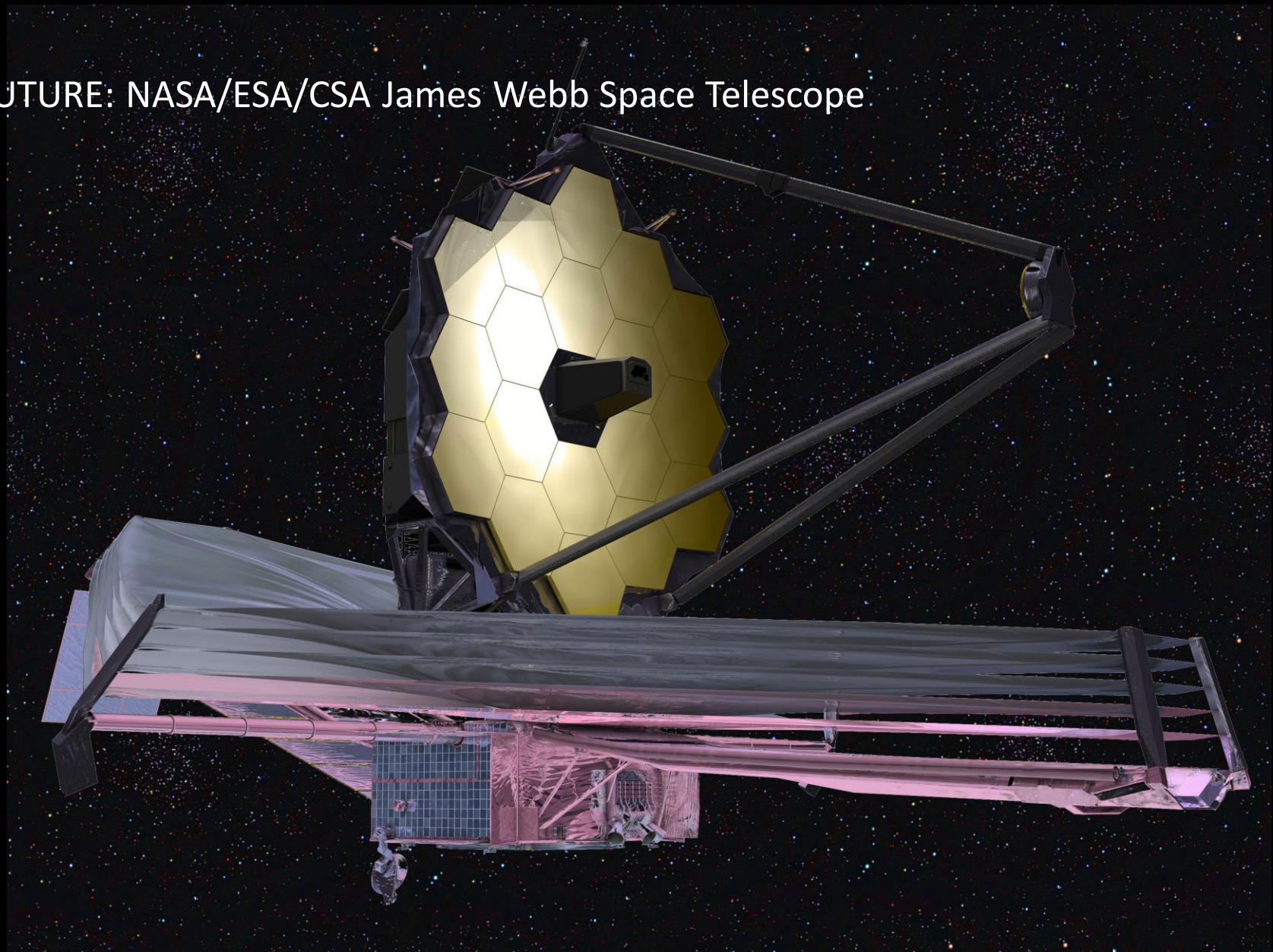
Visible/infrared light

PRESENT: NASA/ESA Hubble Space Telescope



Visible/infrared light

FUTURE: NASA/ESA/CSA James Webb Space Telescope



Radio waves

Credit: Dave Finley, AUI, NRAO, NSF

PRESENT:
NRAO's Very Large Array,
New Mexico, USA

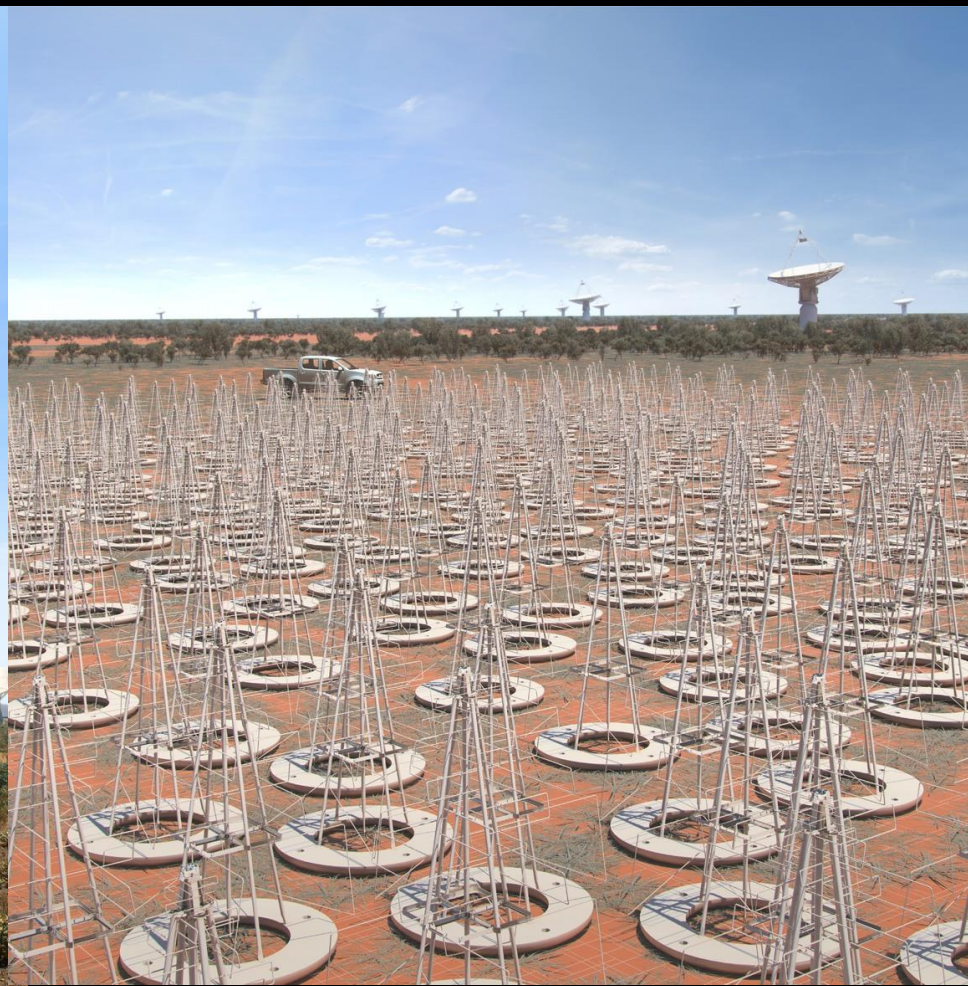
ESO, NRAO & NAOJ's Atacama Large Millimeter/submillimeter Array (ALMA), Chile

Credit: ESO/B. Tafreshi

Radio waves

FUTURE: Square Kilometre Array (SKA)
Two arrays of radio telescopes covering 1 km^2 in South Africa & Australia

Credit: SKA Organisation



Very high-energy gamma rays

Credit: MPG / MPI für Physik / Robert Wagner

PRESENT:
MAGIC Collaboration, La Palma, Canary Islands

H.E.S.S. Collaboration, Namibia

Credit: H.E.S.S. Collaboration

Very high-energy gamma rays

FUTURE: Cerenkov Telescope Array (CTA), at 2 locations: Canary Islands & Chile