LABORATORIO DI TECNOLOGIE ASTRONOMICHE

CUPANI GUIDO, GIRARDI MARISA e CESCUTTI GABRIELE

con l’aiuto di GIULIA IAFRATE
per le esperienze al telescopio a Basovizza
(da determinare le date!)

Orario prossime lezioni

oggi 4 Marzo Cescutti
gio 7 Marzo Cescutti (solo 14-16)
ven 8 Marzo Cupani

e dalla settimana successive (orario standard)

lun 11 Marzo Girardi
gio 14 Marzo   Cescutti
ven 15 Marzo Cupani

(12h Girardi, 24 Cupani e 36 Cescutti)

Argomenti (mie) lezioni e esercitazioni

Intro su Astronomia Osservativa
Ottiche e Telescopi
Coordinate
Fotometria
Spettrometria
Osservazioni di stelle

Detectors e riduzione dati (Cupani)
Esercizi di uso DS9 (Girardi)

	Titolo	Tipo Attività
	Introduzione al corso	lezione
	Telescopi ottici: Introduzione e base di Ottica + ADS e ArXiv	lezione
	Telescopi ottici: Ottica dei telescopi e aberrazioni ottiche	lezione
	Lezione finale su Telescopi (configurazioni e montatura)	lezione
	Osservazioni in Basovizza I	laboratorio
	Osservazioni in Basovizza II	laboratorio
	Intro sulle coordinate - Uso di GAIA DR3 e TOPCAT	laboratorio
	Coordinate concluso - Altri esempi con GAIA DR3 e TOPCAT	laboratorio
	Misure larghezze equivalenti in uno spettro stellare I	laboratorio
	Misure larghezze equivalenti in uno spettro stellare II	laboratorio
	Misure larghezze equivalenti in uno spettro stellare III	laboratorio
	Calcolo delle abbondanze di alcuni elementi chimici	laboratorio
	Calcolo delle abbondanze di alcuni elementi chimici e esempi di sintesi spettale	laboratorio

Elenco delle mail degli studenti

How to Basovizza

Sentire per Asiago

Esami finale:

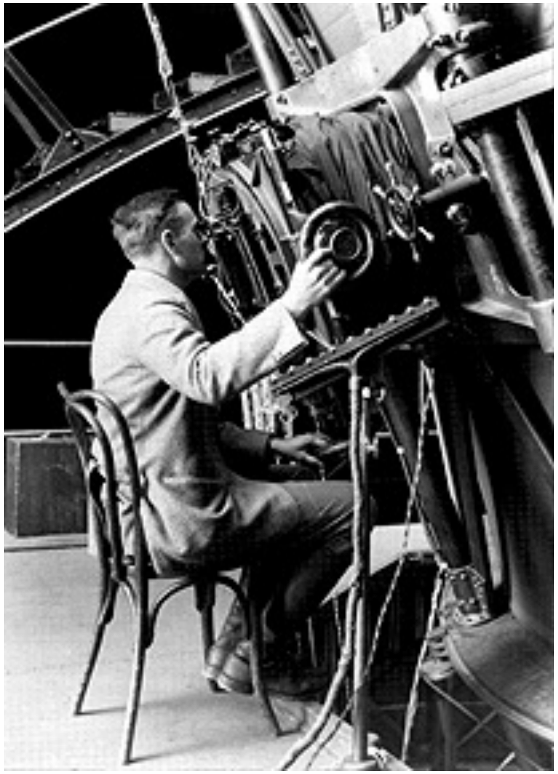
Discussione di un proposal osservativo
e di un articolo scientifico (con domande collegate!)

Esercizi richiesti debitamente svolti

Circa quando volete

Observational Astronomy

An Introduction



Learning Objectives

- Beginnings of modern observational astronomy at optical wavelengths.
- The electromagnetic window:
  Causes of scattering or absorption of electromagnetic radiation by the Earth's atmosphere
- Beginnings of modern observational astronomy at other wavelengths:
  2. Radio
  3. X-ray
  4. γ-ray
  5. Ultraviolet
  6. Infrared

  Gravitational Waves

Beginnings of Modern Observational Astronomy

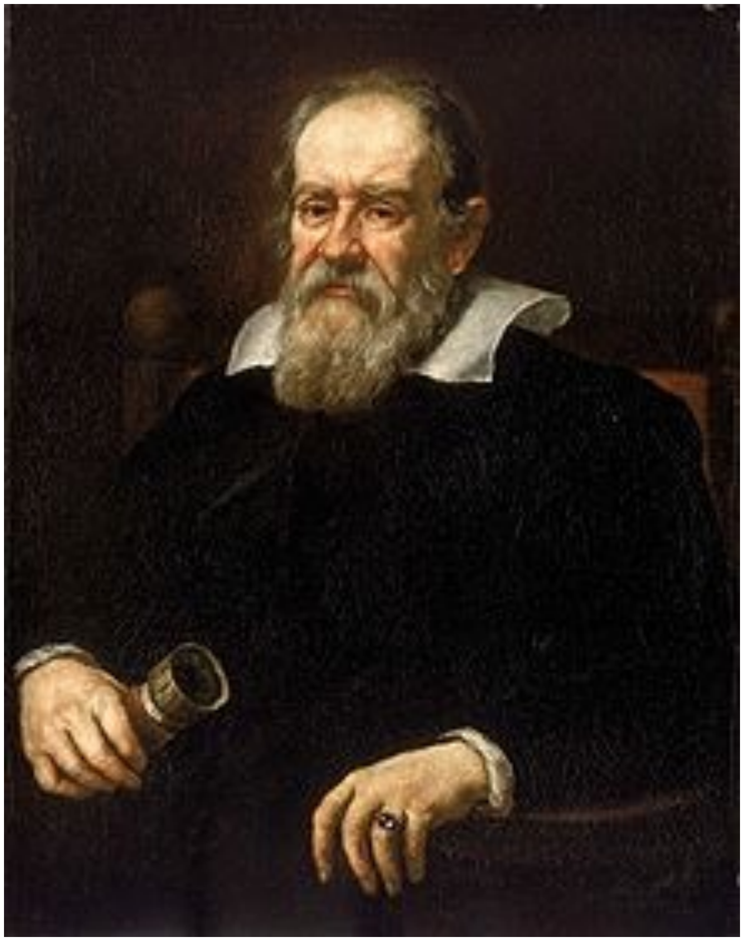
◆ In 1608, two spectacle makers* in Netherlands, one of whom was Hans Lippershey (born in Germany, lived in the Netherlands), filed for a patent for a "Dutch perspective glass." Neither was granted a patent. Nevertheless, because Lippershey was able to financially exploit his invention to the Dutch military, he is widely credited for inventing the telescope.

Early depiction of a "Dutch telescope" from 1624.

*The spectacle industry started in Venice and Florence (Italy) in the thirteenth century, and later expanded to the Netherlands and Germany.

Beginnings of Modern Observational Astronomy

- In 1609, Galileo Galilei, an Italian scientist, improved on Lippershey's design to build a telescope to observe the heavens for the first time.



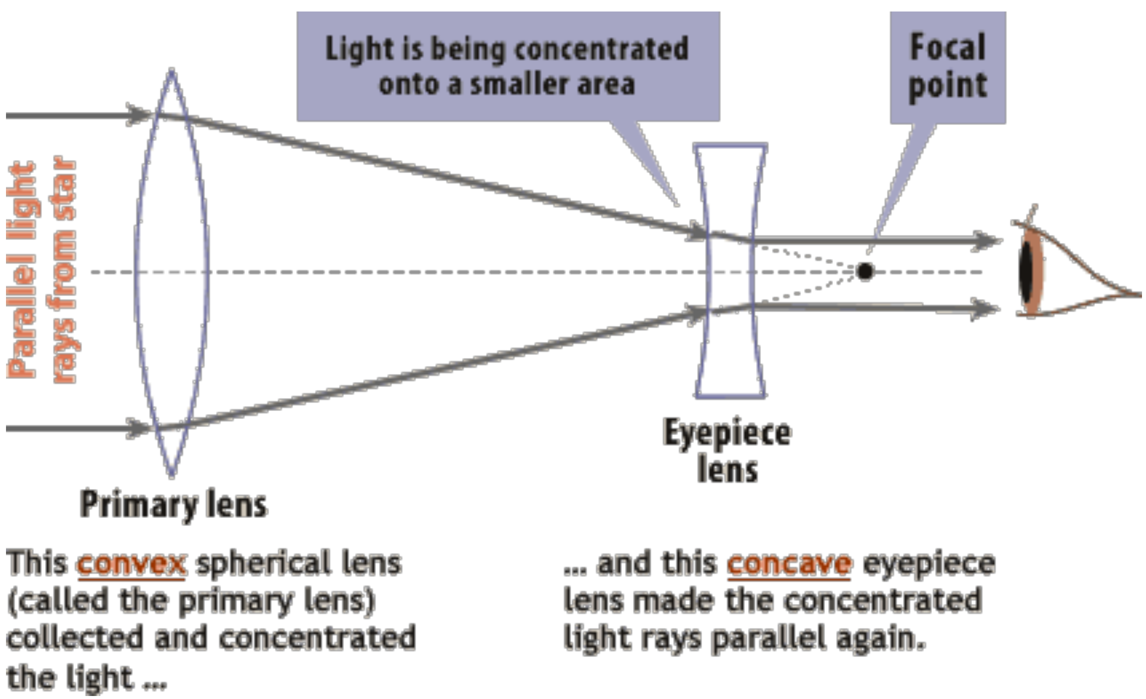
Galileo Galilei, 1564-1642

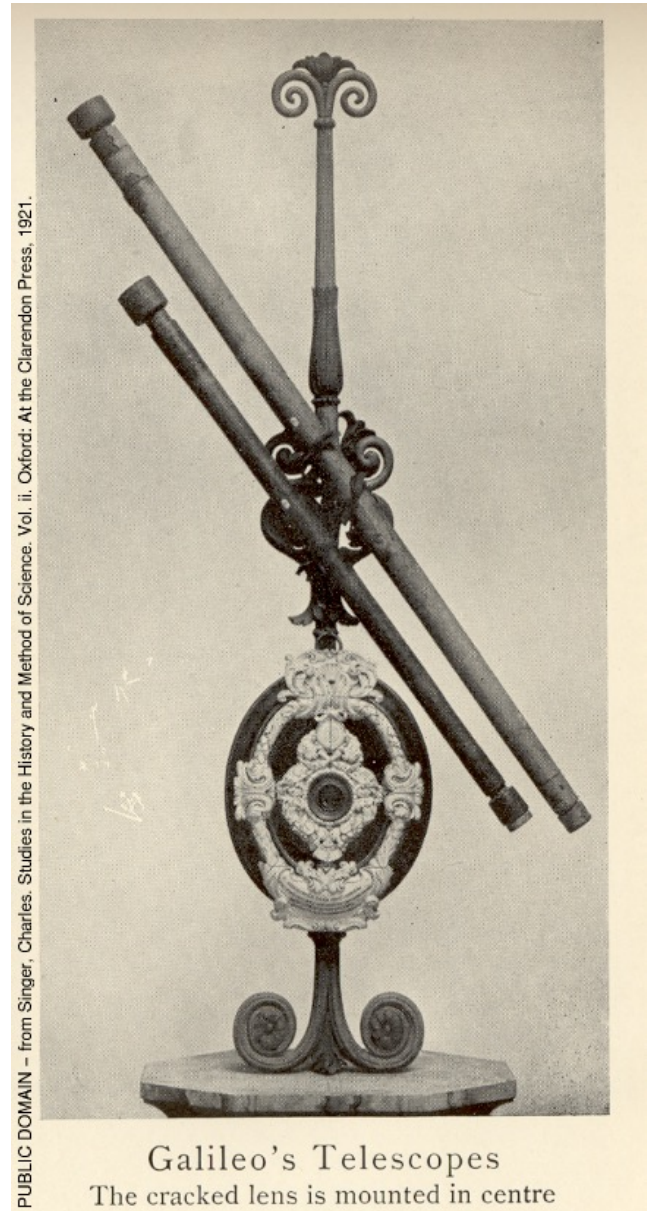
Galilei showing the Chief Magistrate of Venice how to use the telescope.

Beginnings of Modern Observational Astronomy

- Galileo’s telescope employed an objective lens and an ocular lens to refract light to a focus at his eye, starting with a magnification of 3 and later improved to 30.
- Galileo’s observations of the heavens revolutionized astronomy. In what ways are the telescope superior to the naked eye?

Galilean design





Beginnings of Modern Observational Astronomy

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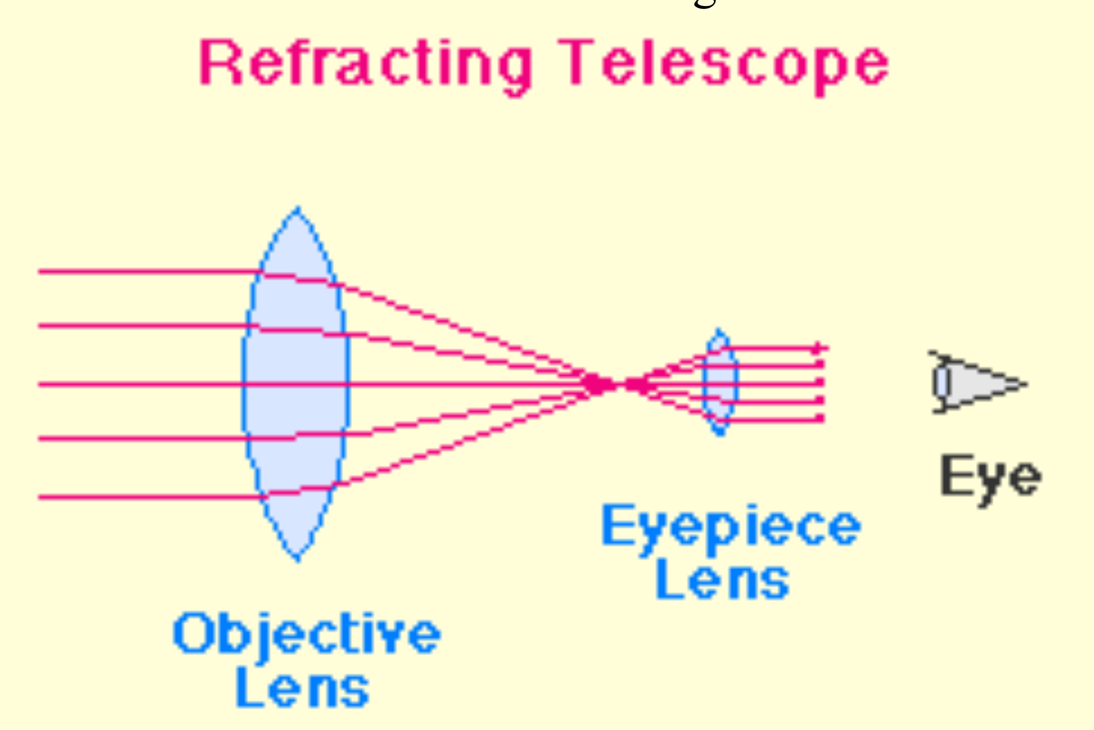
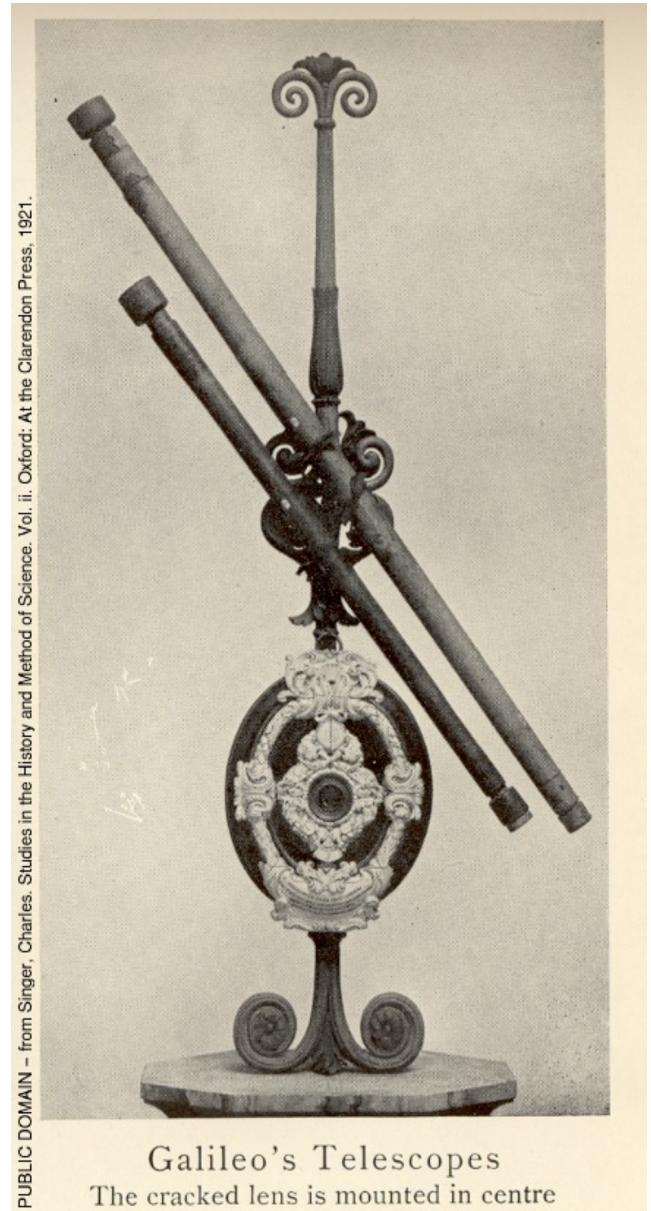
Modern design



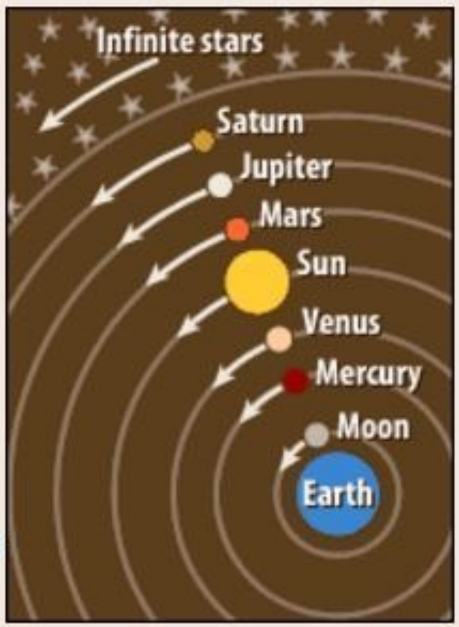


Beginnings of Modern Observational Astronomy

- At the time of Galileo, there were two hypotheses for the motion of the heavens based on (naked eye) astronomical observations:

Ptolemy's model: "Earth-centered," or "geocentric"

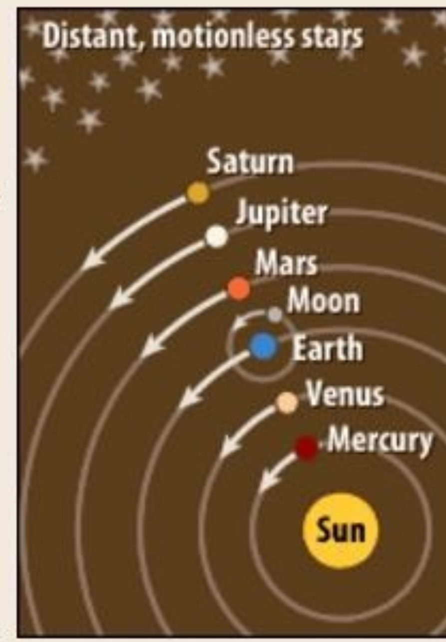
Ptolemy thought that all celestial objects – including the planets, Sun, Moon, and stars – orbited Earth. Earth, in the center of the universe, did not move at all.



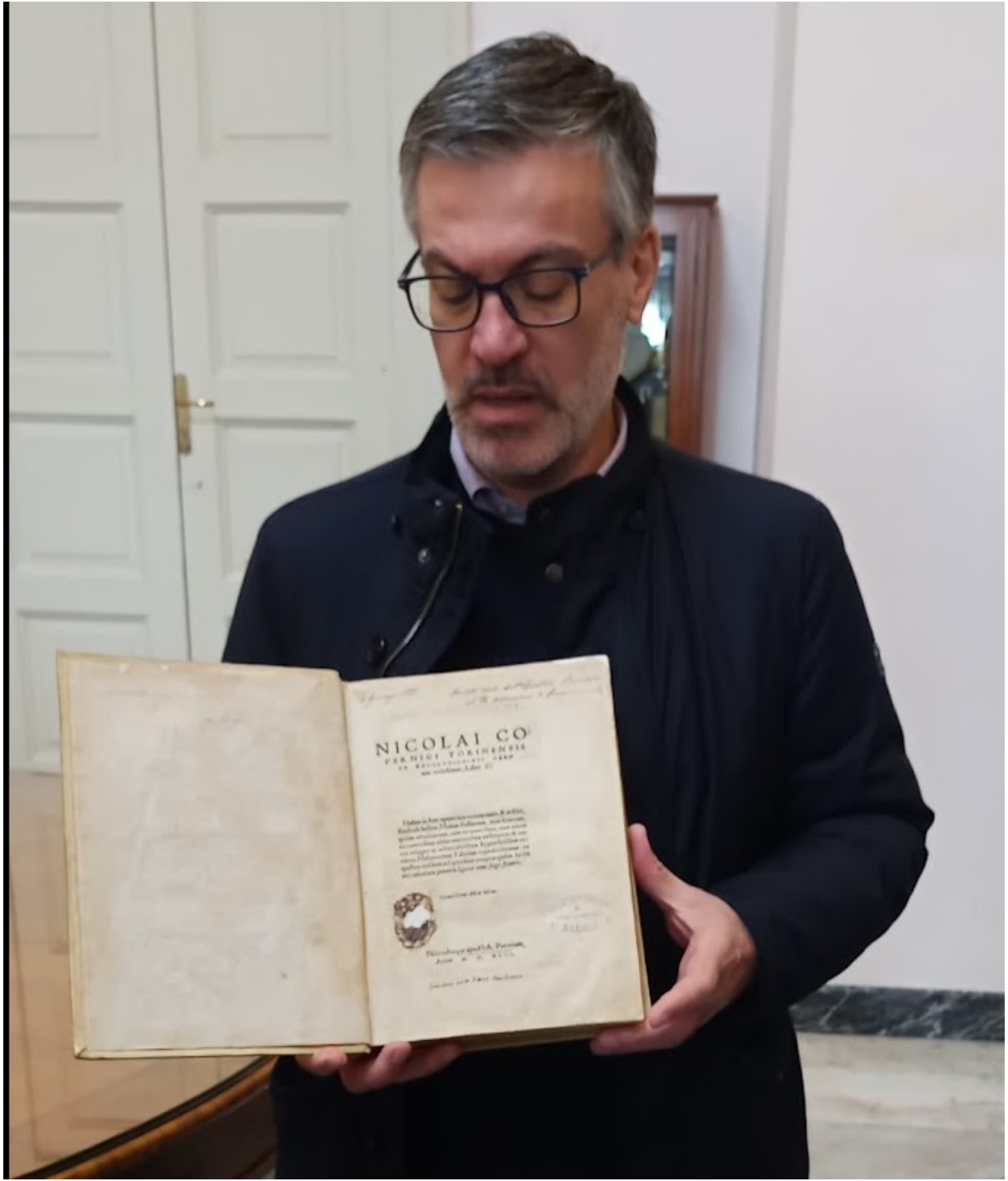
NOTE: The outer planets, like Uranus and Neptune, are missing from both charts because they had not been discovered at the time. The planets are lined up to make the charts easy to read; they never line up this way in nature.

Copernicus' model: "Sun-centered," or "heliocentric"

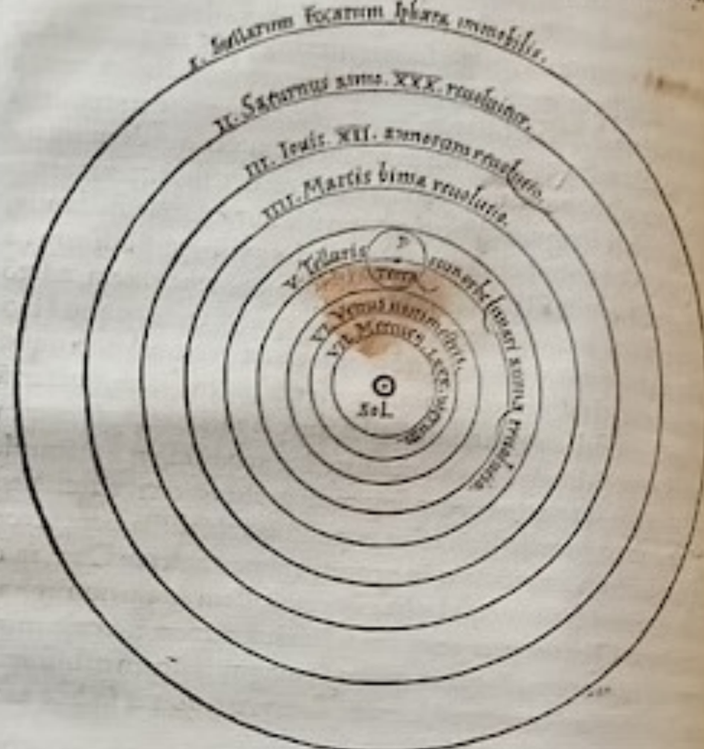
Copernicus thought that the planets orbited the Sun, and that the Moon orbited Earth. The Sun, in the center of the universe, did not move, nor did the stars.



Copernicus was correct about some things, but wrong about others. The Sun is not in the center of the universe, and it does move, as do the stars. Also, both Copernicus and Ptolemy thought the orbits of the planets were circular, but we now know they are elliptical.


NICOLAI CO
PERNICI TORINENSIS

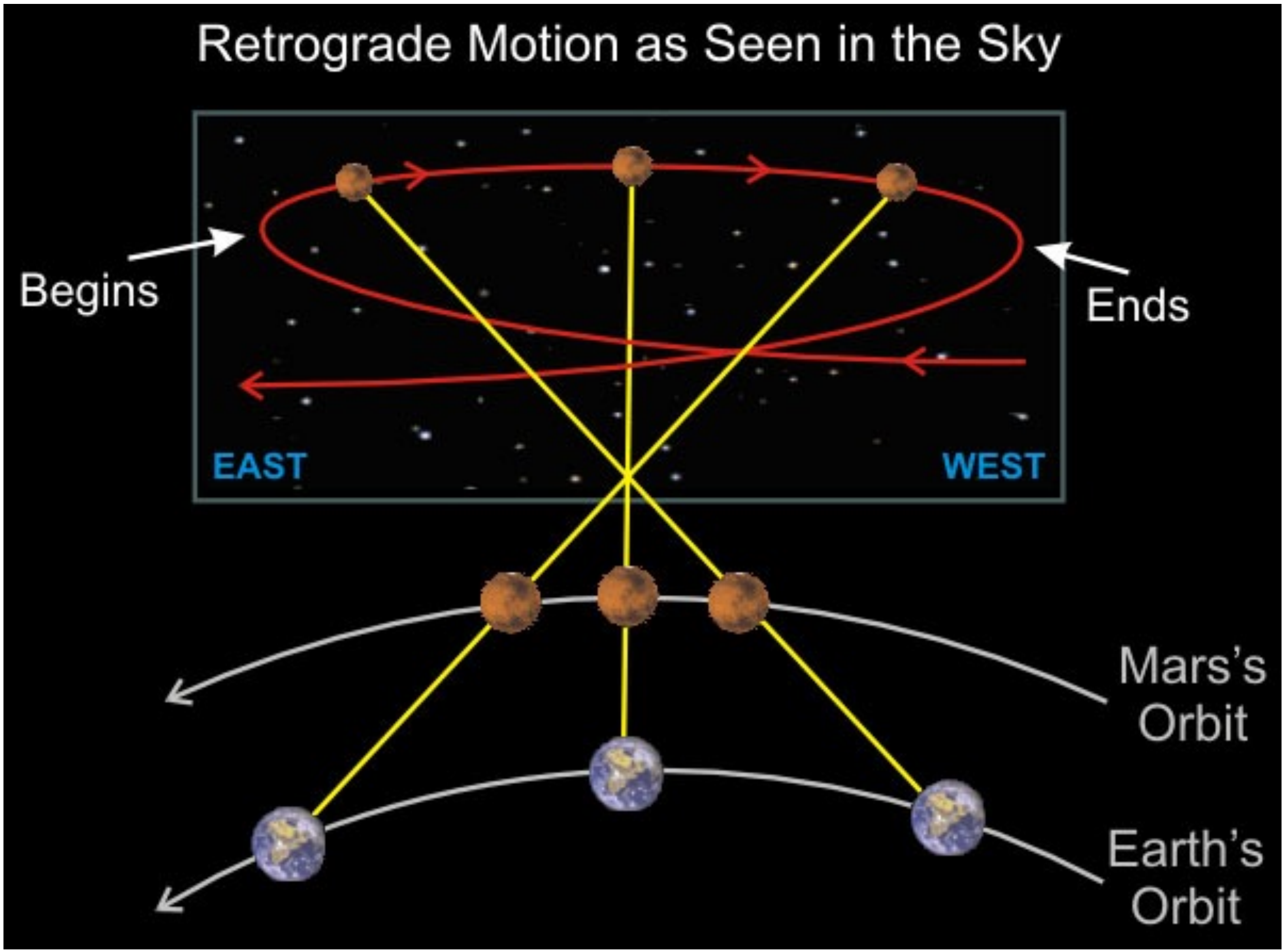
net, in quo terram cum orbe lunari tanquam epicyclo contineri diximus. Quinto loco Venus nono menſe reducitur. Sextum deniq; locum Mercurius tenet, octuaginta dierum ſpacio circũ currens. In medio uero omnium reſidet Sol. Quis enim in hoc



pulcherimo templo lampadem hanc in alio uel meliori loco poneret, quàm unde totum ſimul poſsit illuminare? Siquidem non inepte quidam lucernam mundi, alij mentem, alij rectorem uocant. Trimegiſtus uiſibilem Deum, Sophoclis Electra intuentẽ omnia. Ita profecto tanquam in ſolio regali Sol reſidens circum agentem gubernat Aſtrorum familiam. Tellus quoq; minime fraudatur lunari miniſterio, ſed ut Ariſtoteles de animalibus ait, maximã Luna cũ terra cognationẽ habet. Concipit interea à Sole terra, & impregnatur annuo partu. Inuenimus igitur ſub hac

Beginnings of Modern Observational Astronomy

- How to explain retrograde motion in the Ptolemic universe?



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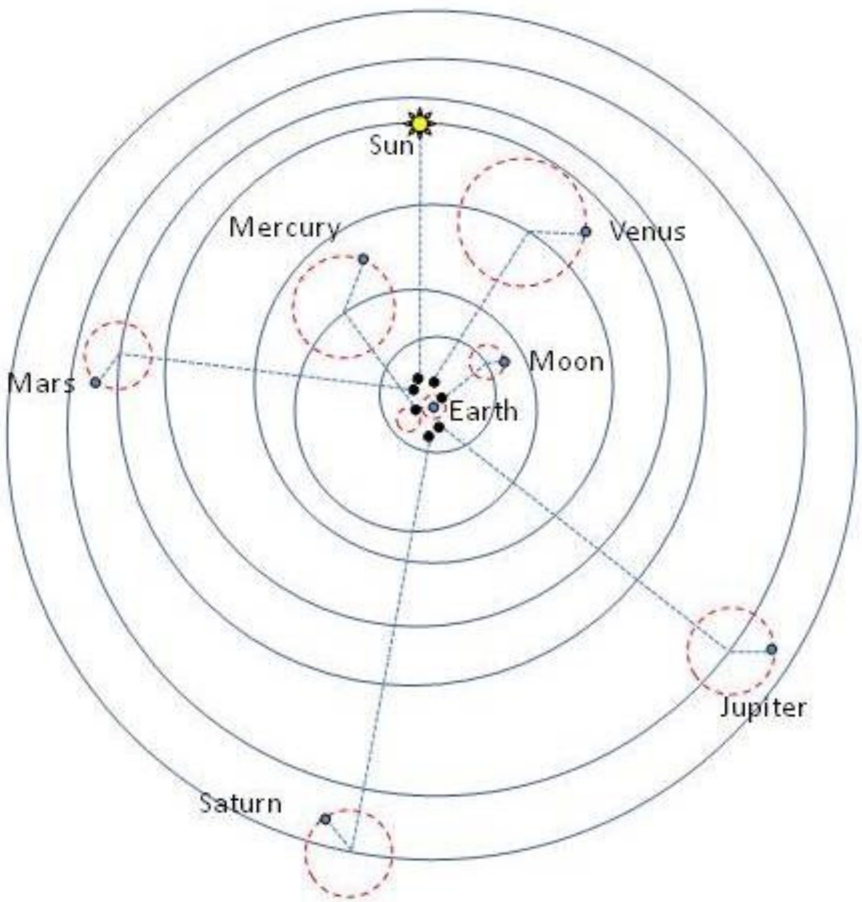
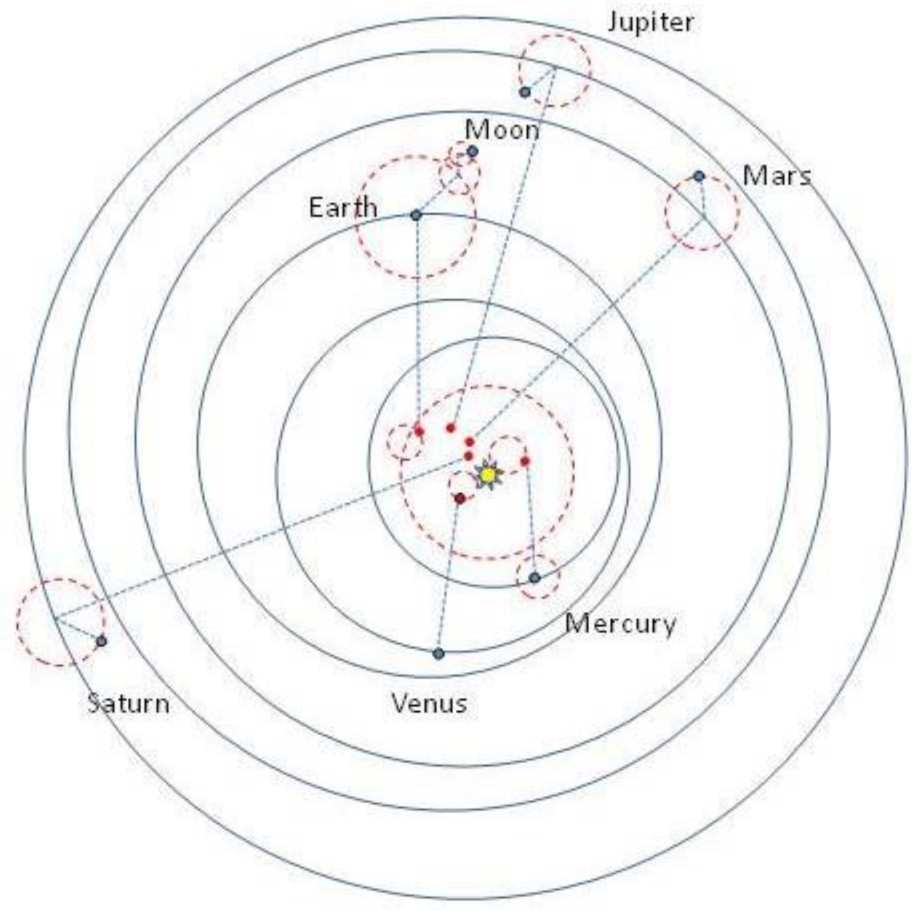


Ptolemaic Model



Copernican Model

Beginnings of Modern Observational Astronomy

- Ptolemic view of planetary motions seeked to explain retrograde motion (for all the planets) in a geocentric view of the heavens.

Beginnings of Modern Observational Astronomy

- Galileo discovered the four largest moons of Jupiter; i.e., heavenly bodies that revolved around Jupiter.

Moons of Jupiter

Beginnings of Modern Observational Astronomy

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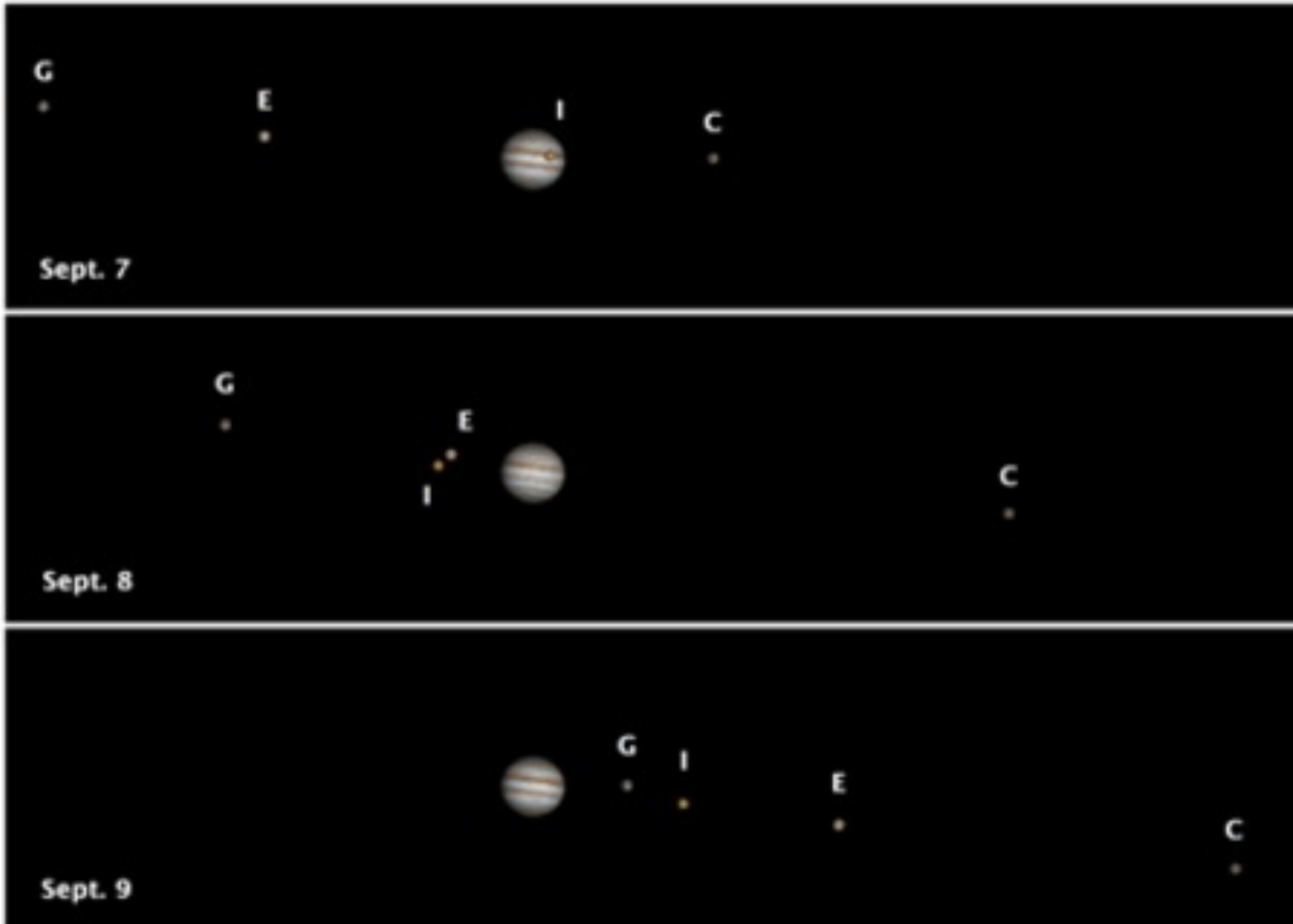
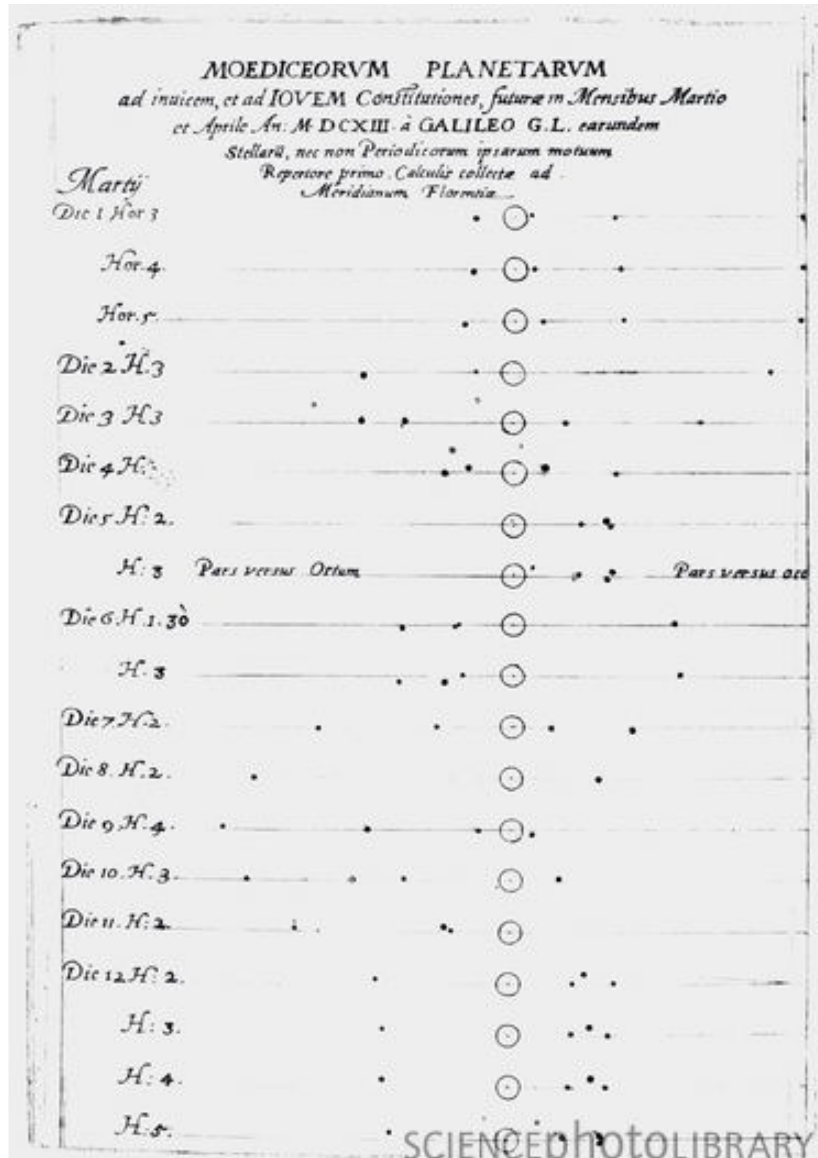


Beginnings of Modern Observational Astronomy

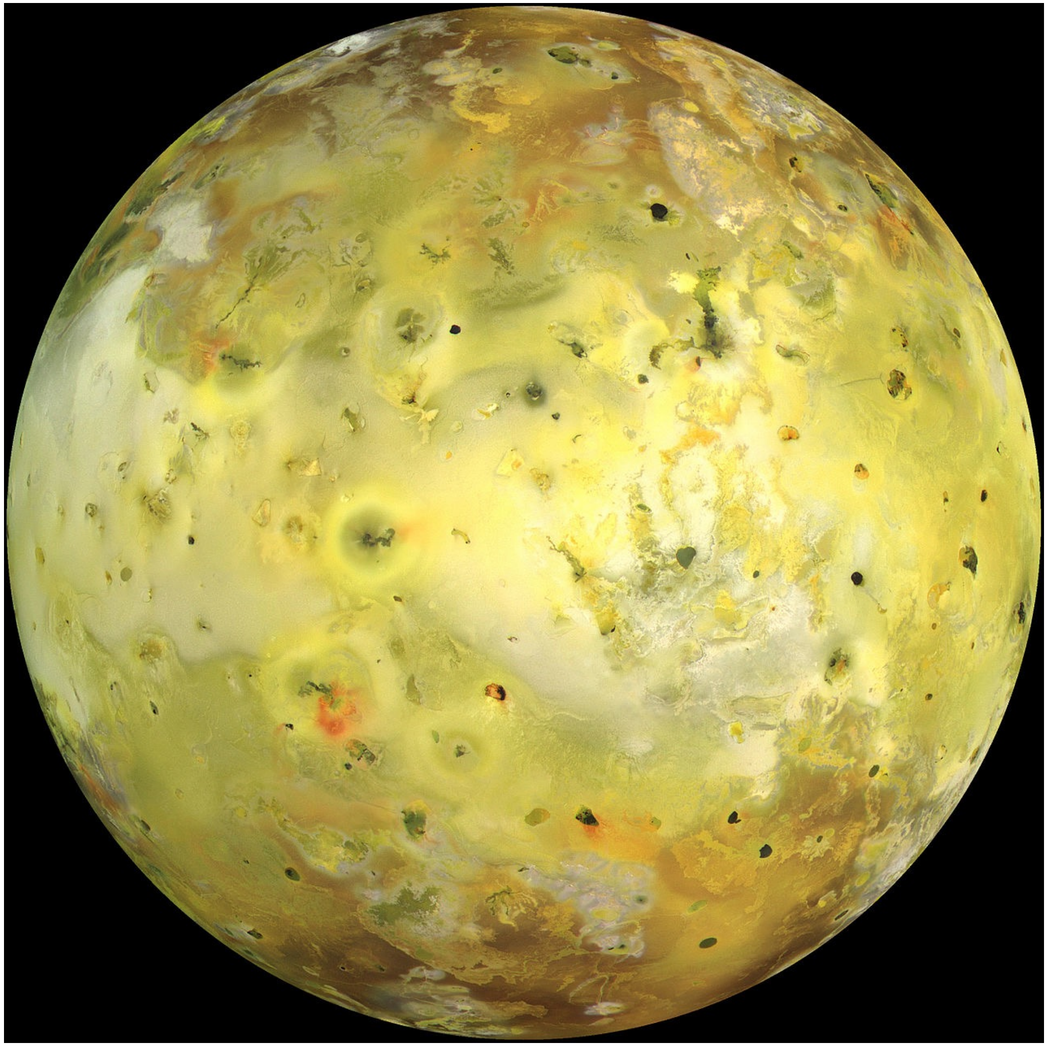
- Galileo's written record of his discovery of Jupiter's moons. In Latin, Die means day and Hora means hour.

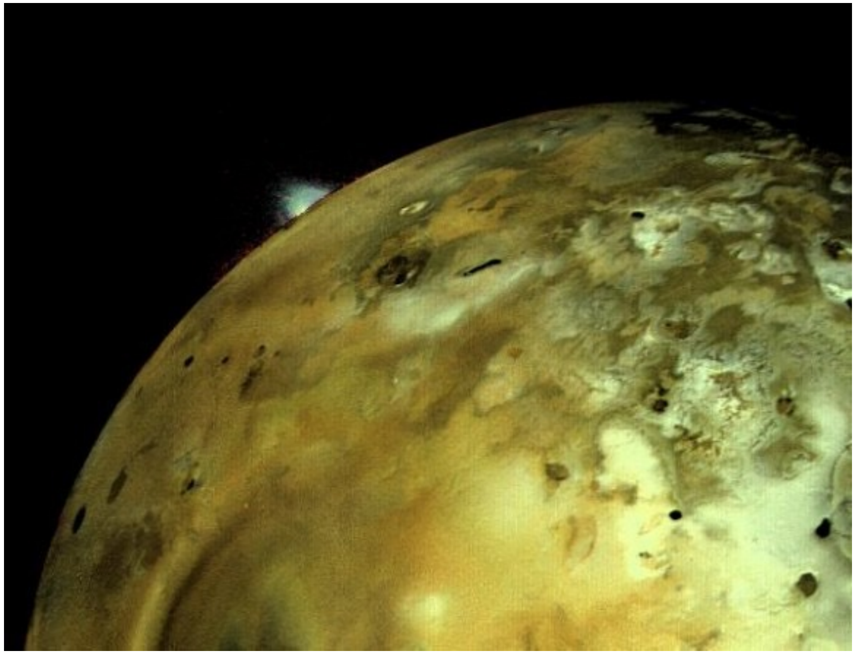


Beginnings of Modern Observational Astronomy

- Io was the first body outside the Earth discovered to have active volcanoes. What powers the volcanoes of Io? Assignment Question.

Io

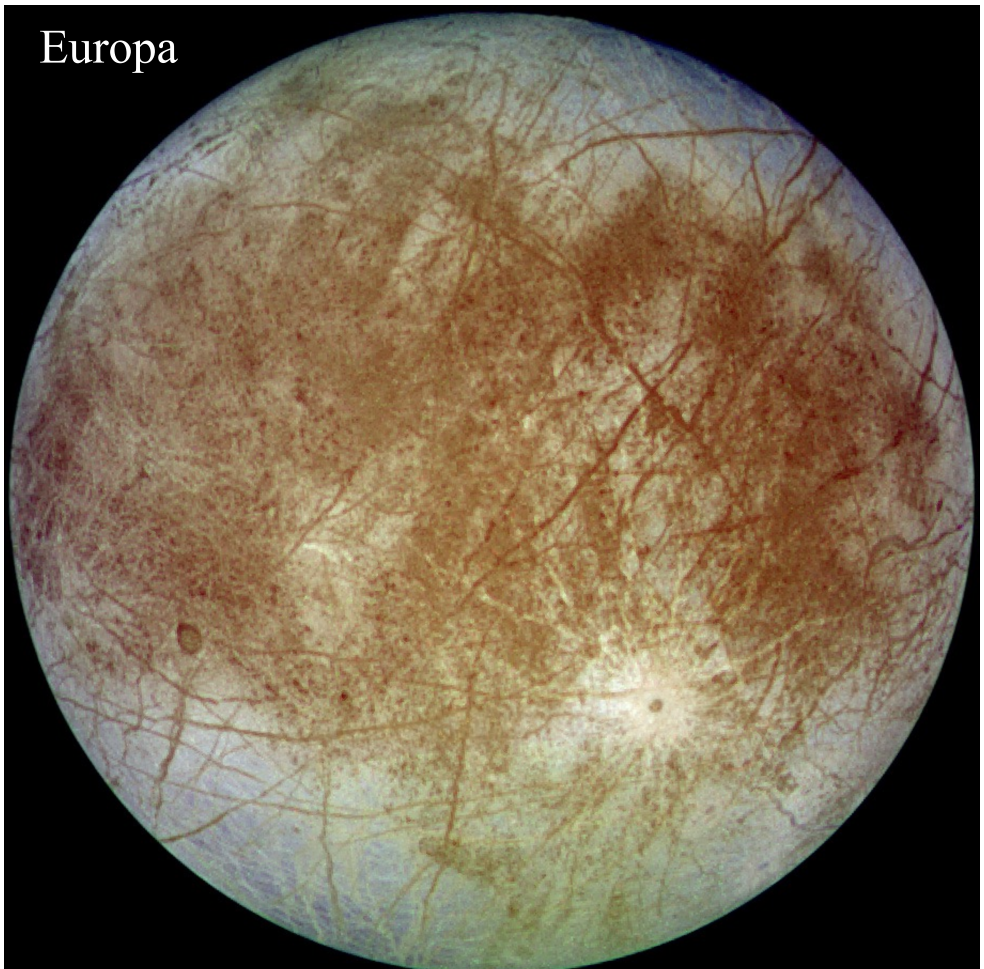


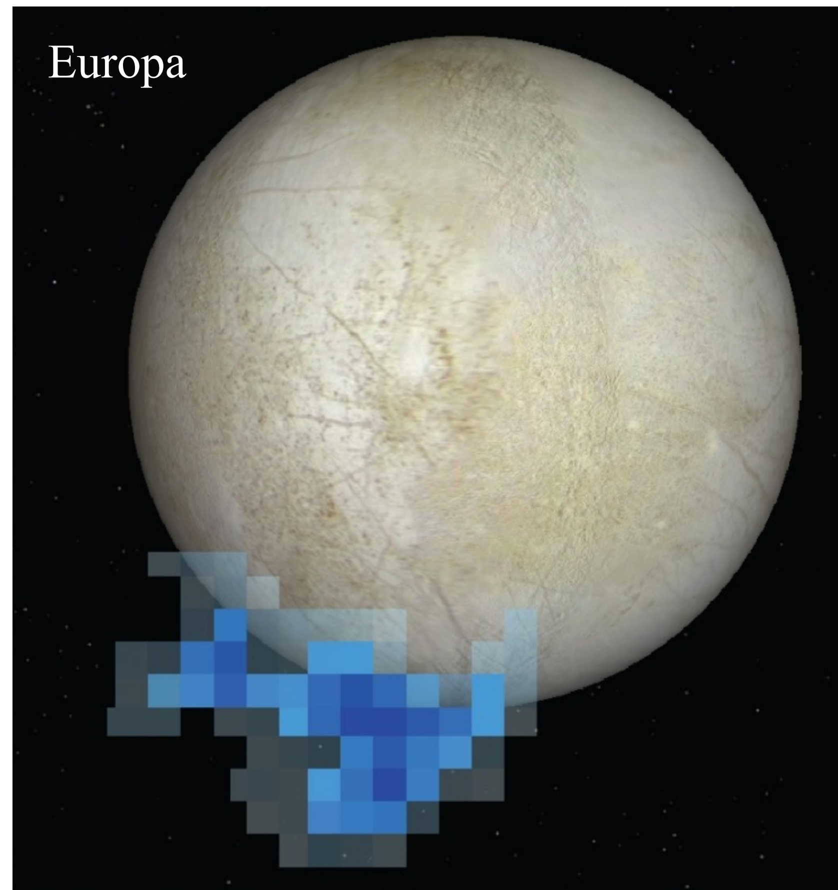


Voyager 1 acquired this image of Io on March 4, 1979. An enormous volcanic explosion can be seen silhouetted against dark space over Io's bright limb. Credit: NASA/JPL.

Beginnings of Modern Observational Astronomy

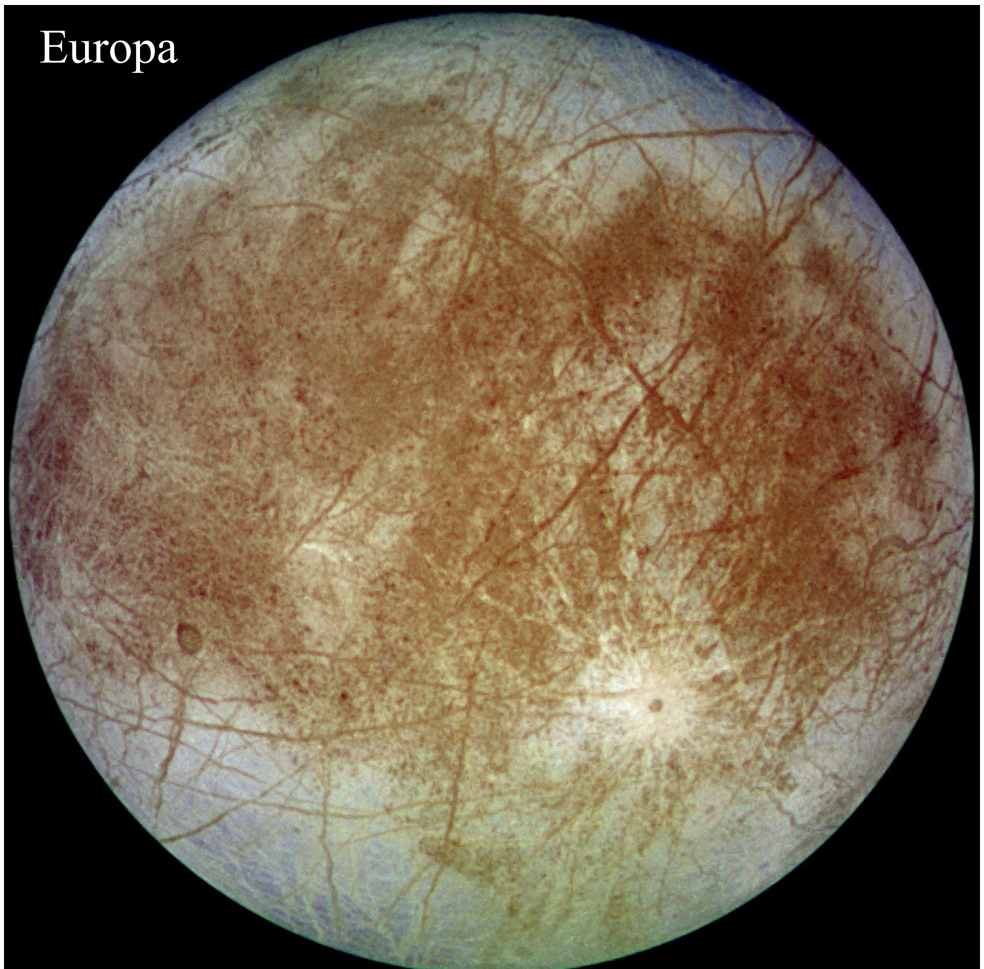
- Europa, covered by ice, is thought to have a liquid ocean. The graphic on the right shows the location of water vapor detected over Europa's south pole in observations taken by NASA's Hubble Space Telescope (HST) in December 2012. This is the first strong evidence of water plumes erupting off Europa's surface.

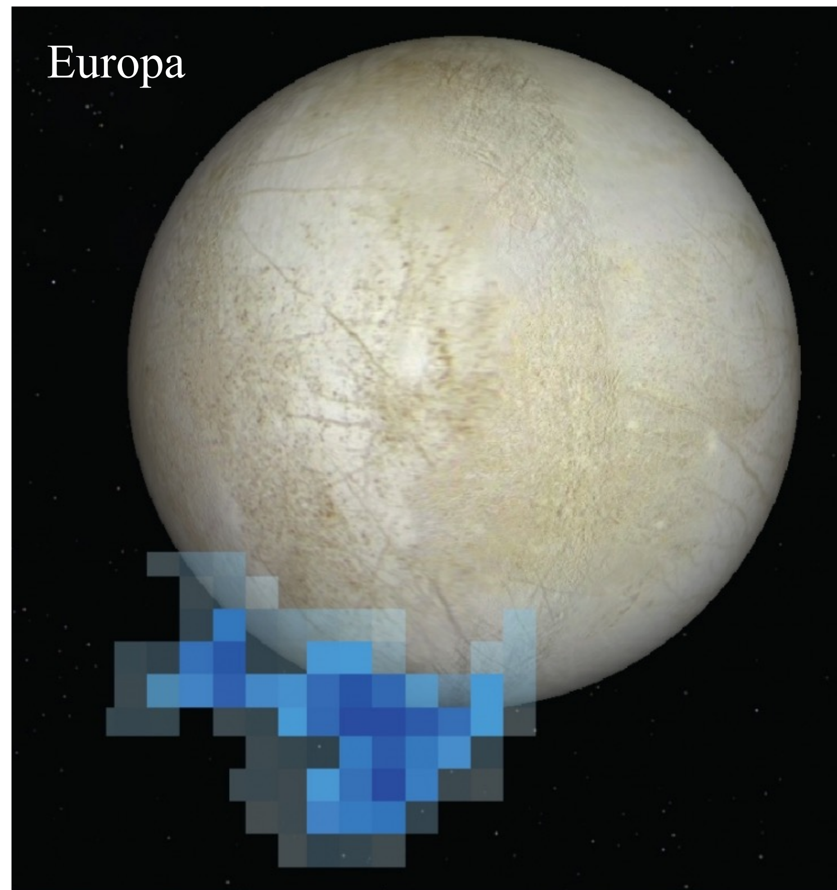




Beginnings of Modern Observational Astronomy

- The HST did not actually photograph water plumes, but detected emission lines from oxygen and hydrogen in the plume. Charged particles moving at high speeds in Jupiter's magnetic field strike and dissociate water molecules in the plume, resulting in excited hydrogen and oxygen atoms.

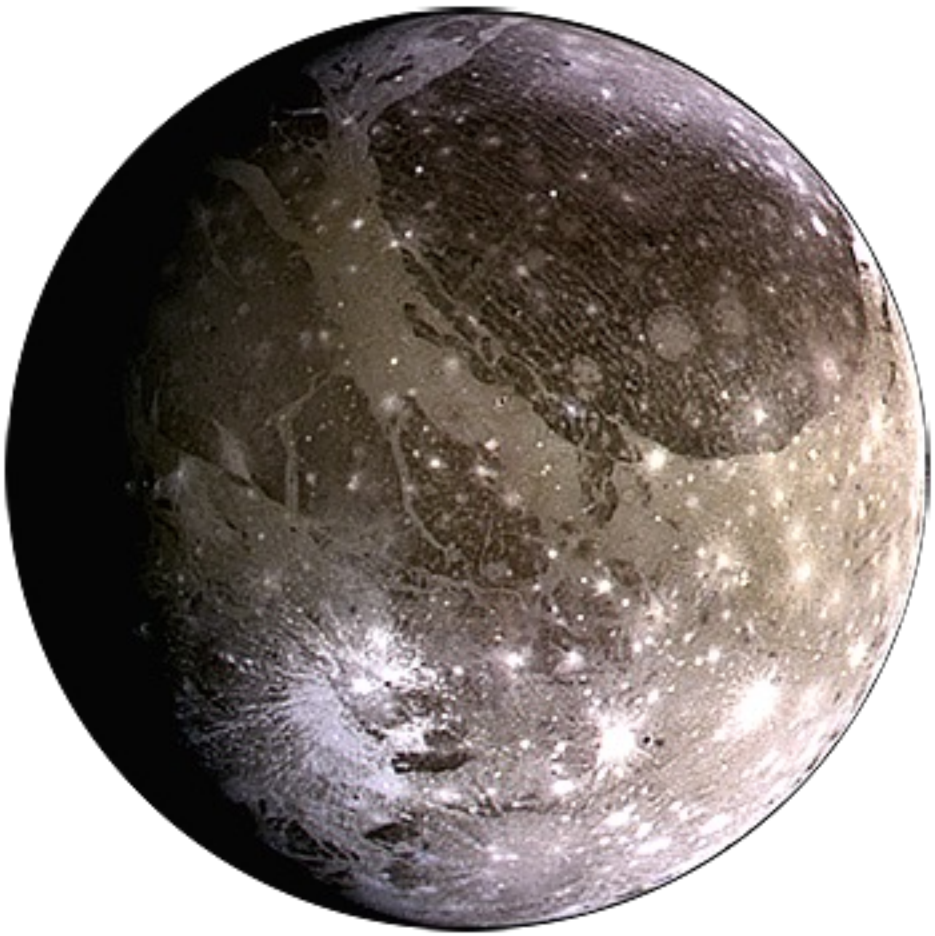




Beginnings of Modern Observational Astronomy

- Ganymede, the largest moon in the Solar System, and Callisto. Both bear scars from bombardment by asteroids and comets thought to have occurred about 4 billion years ago. Like Europa, Ganymede also is thought to have a liquid ocean.

Ganymede

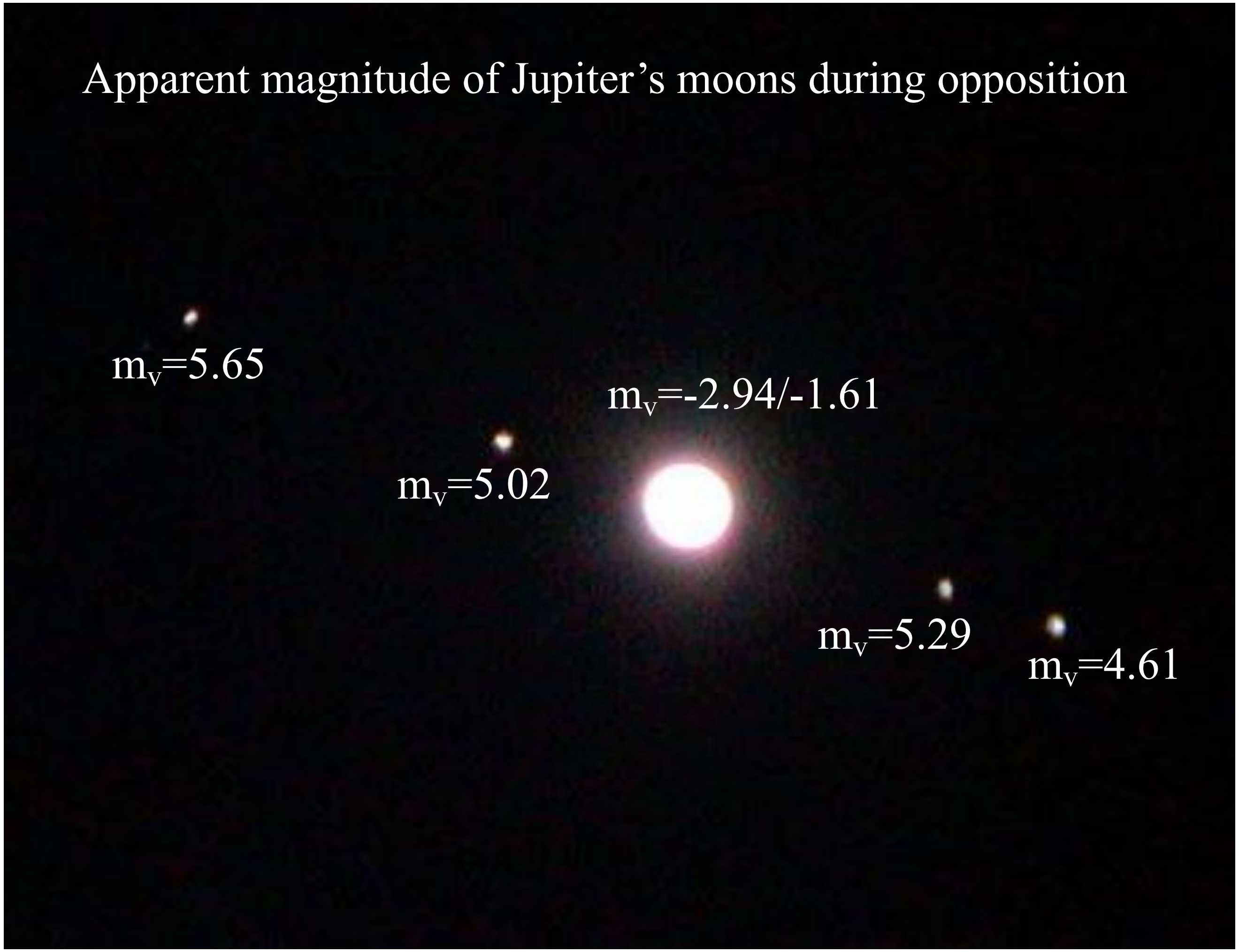


Callisto

Beginnings of Modern Observational Astronomy

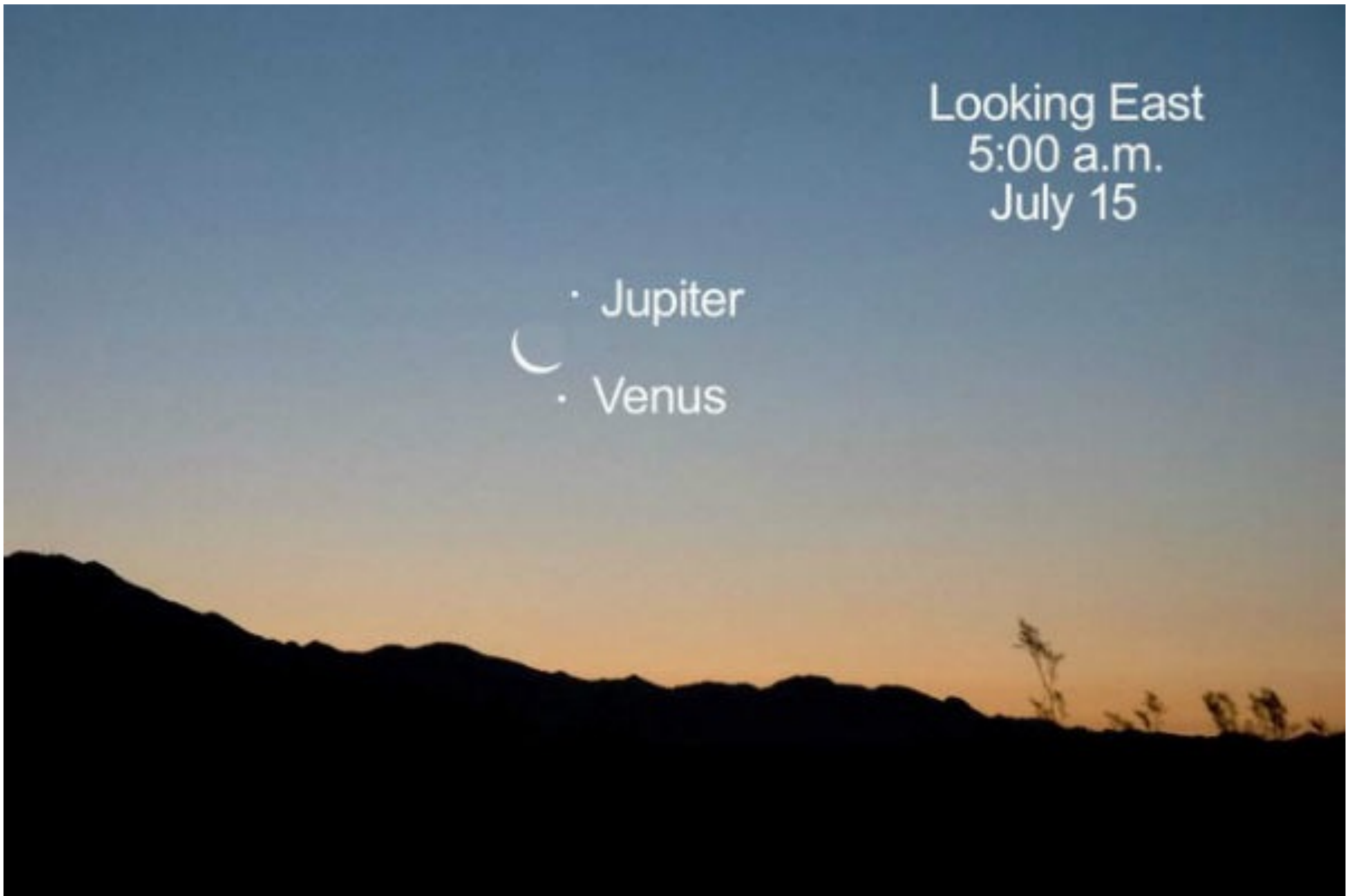
- Galileo discovered the four largest moons of Jupiter; i.e., heavenly bodies that revolved around Jupiter. Why were these moons not previously discovered? Assignment Question.

Moons of Jupiter



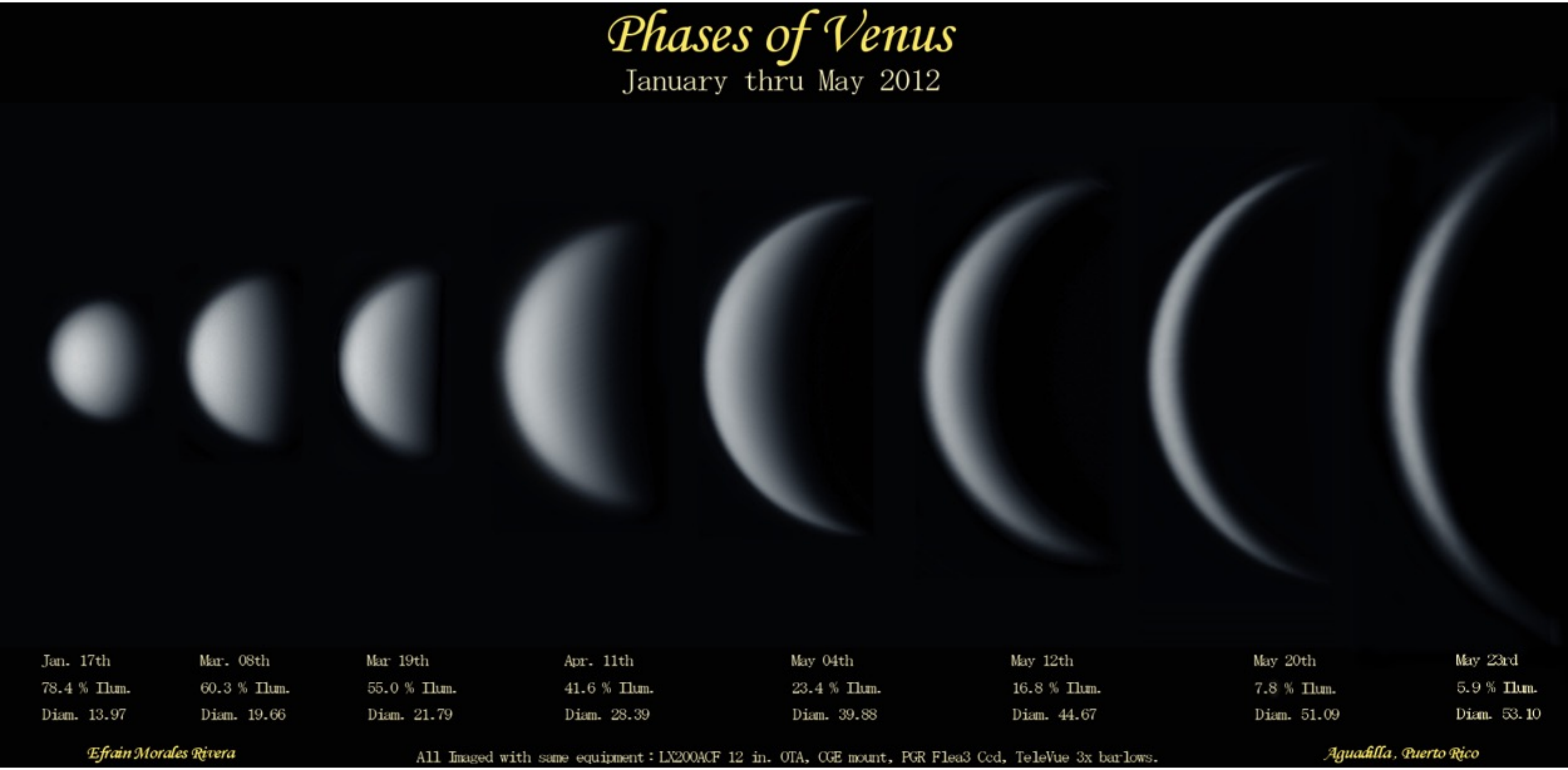
Beginnings of Modern Observational Astronomy

- Venus can be seen in the morning or evening sky, with apparent magnitudes ranging from about -4.9 (crescent) to -3.8 (full). The angular diameter of Venus ranges from about 9″.6 to 66″.0.



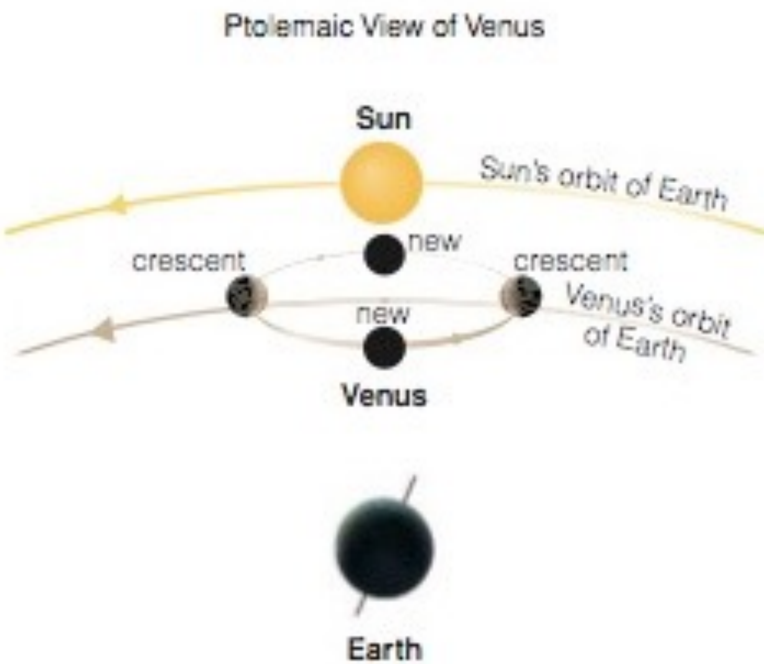
Beginnings of Modern Observational Astronomy

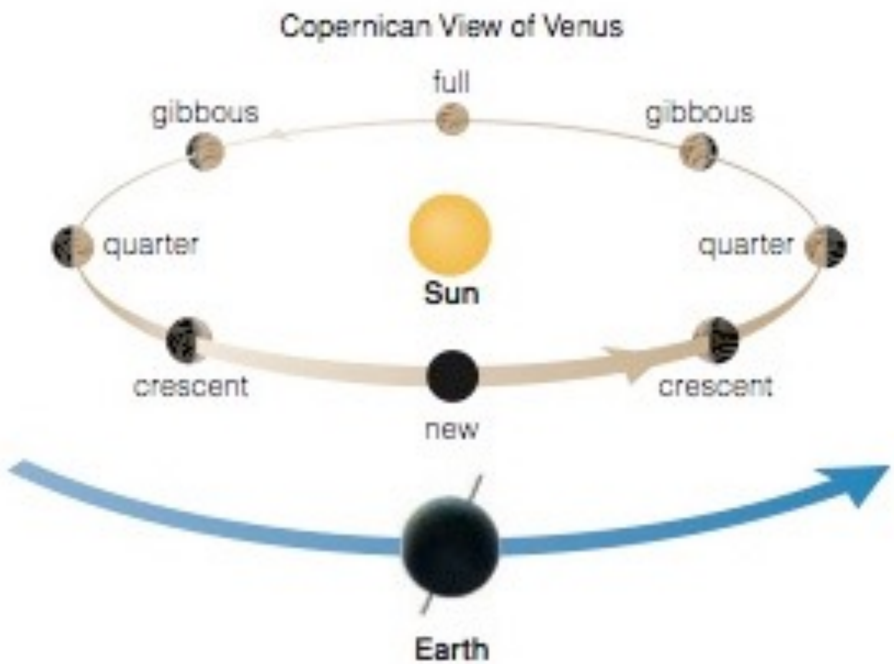
- Galileo also discovered that Venus goes through phases just like the Earth's Moon, from gibbous to new.



Beginnings of Modern Observational Astronomy

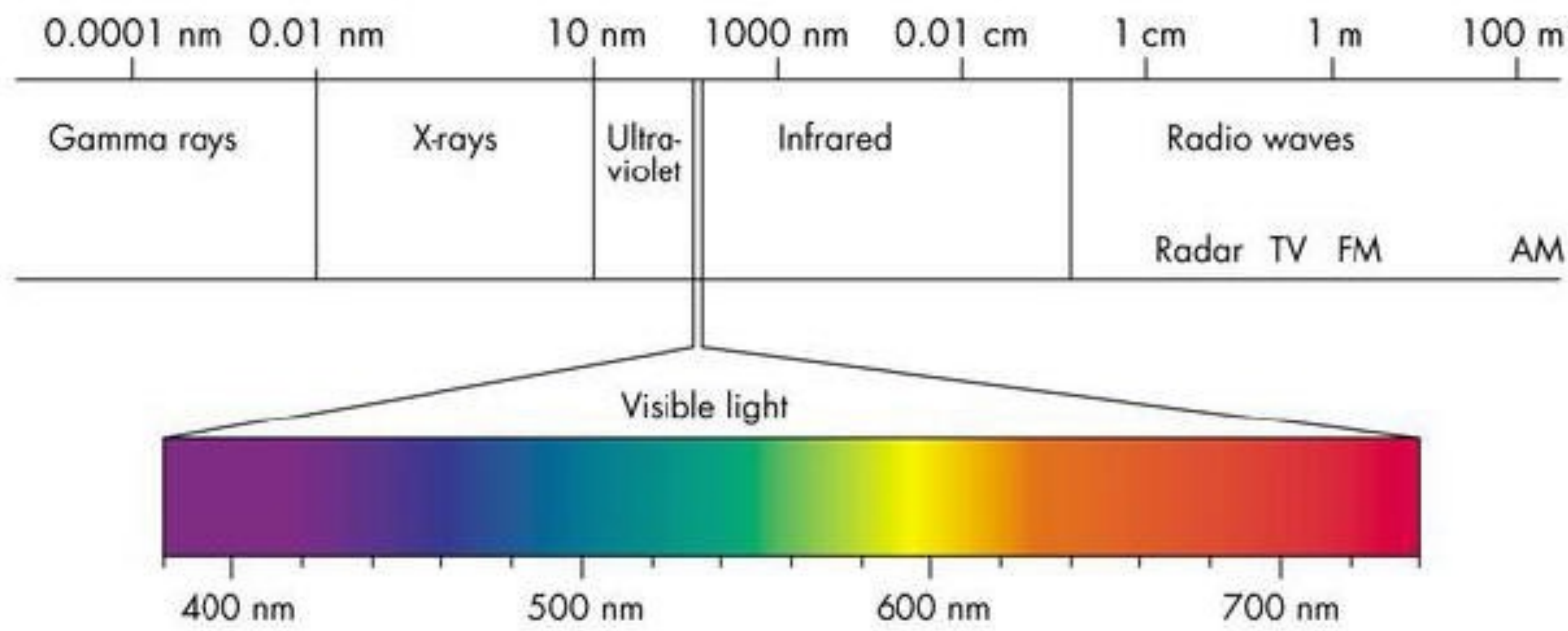
- Galileo also discovered that Venus goes through phases just like the Earth's Moon, from gibbous to new. Why did Galileo's observation disprove the Ptolemic view but supported the Copernican view of Venus? Assignment Question.





Beginnings of Modern Observational Astronomy

- Observational astronomy began at optical wavelengths because human eyes are adapted to function in optical light. Why is that?



Solar Radiation

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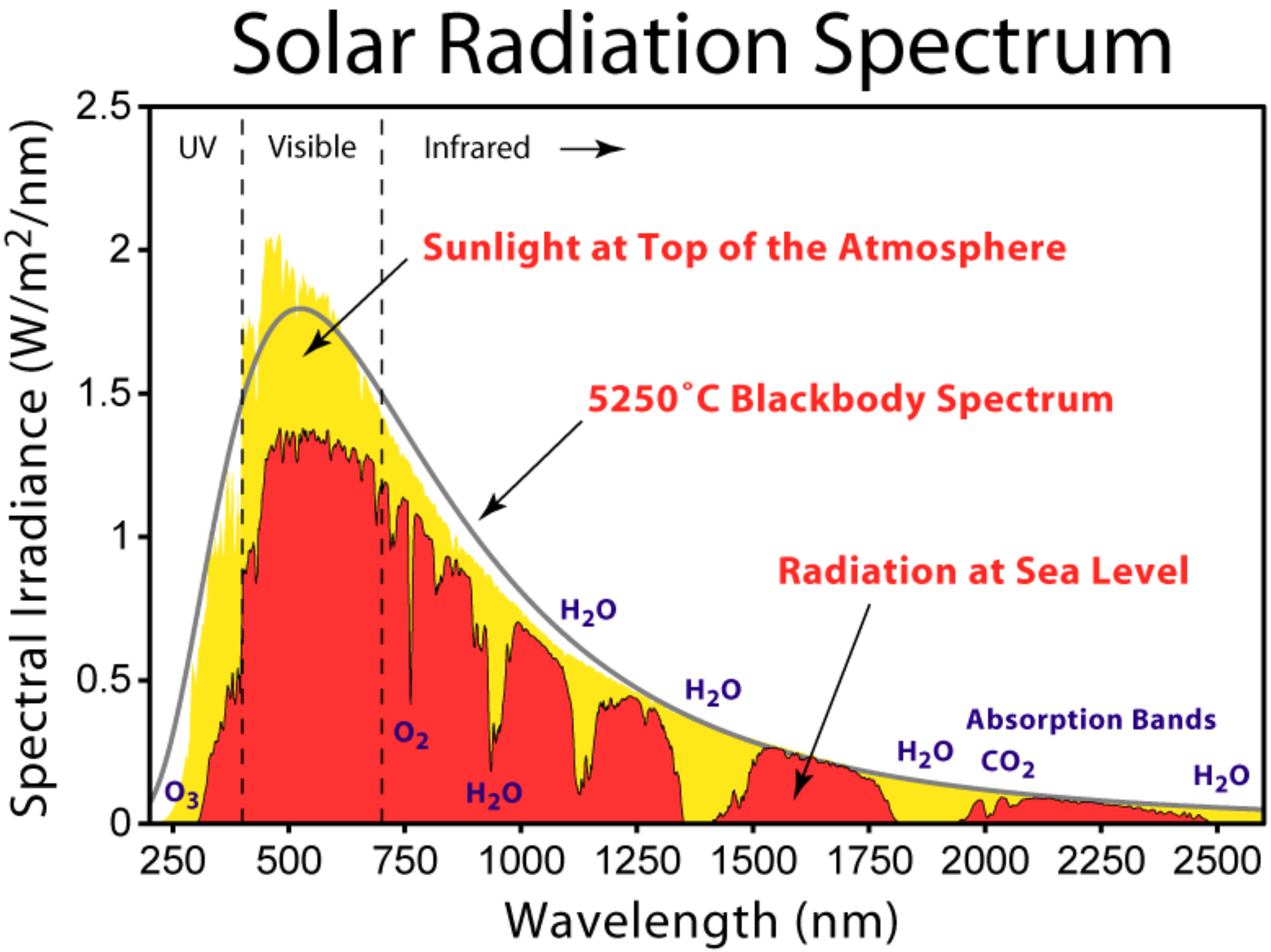
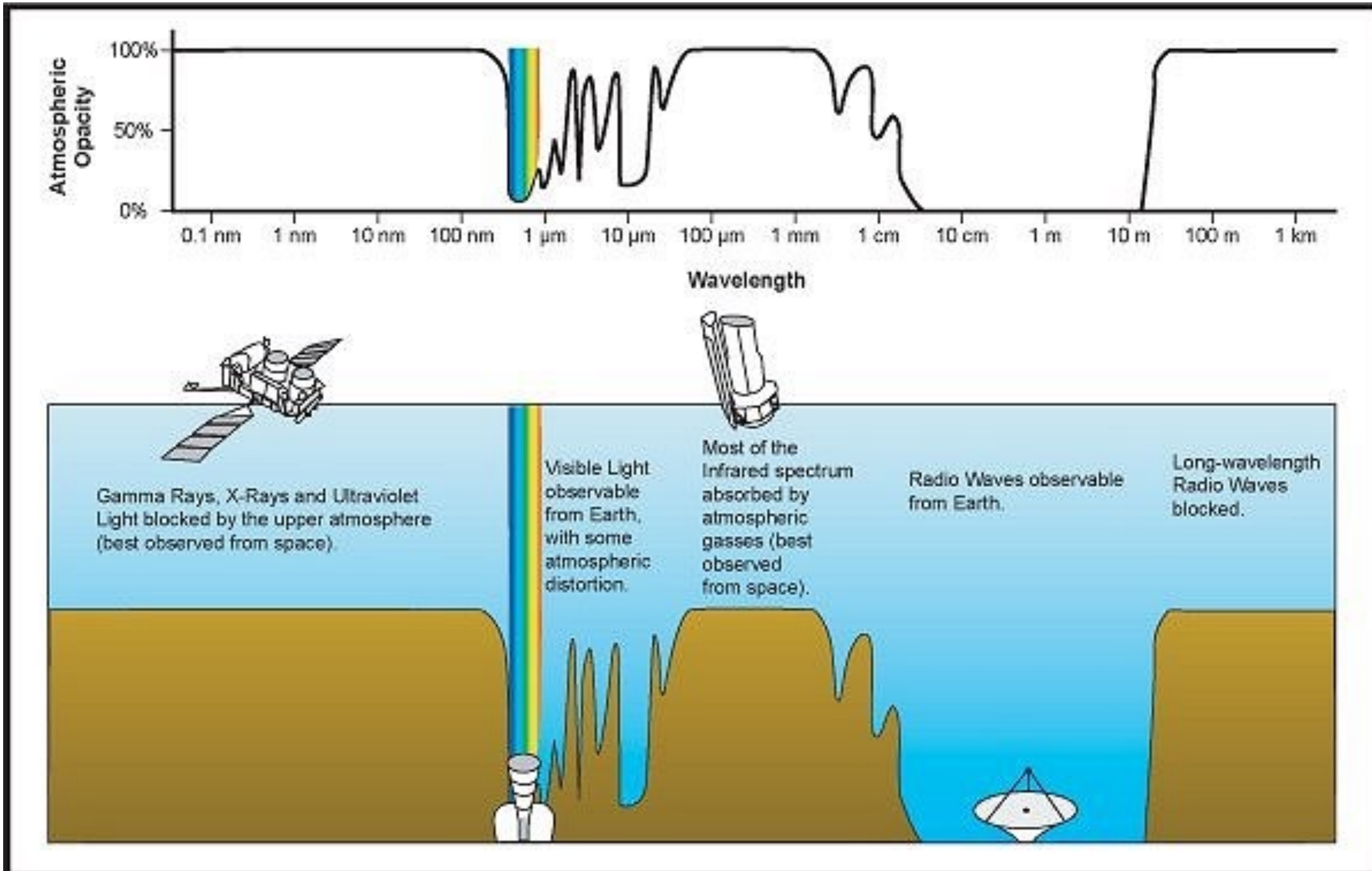


Learning Objectives

- Beginnings of modern observational astronomy at optical wavelengths.
- The electromagnetic window:
  Causes of scattering or absorption of electromagnetic radiation by the Earth's atmosphere
- Beginnings of modern observational astronomy at other wavelengths:
  2. Radio
  3. X-ray
  4. γ-ray
  5. Ultraviolet
  6. Infrared
  7. Gravitational Waves

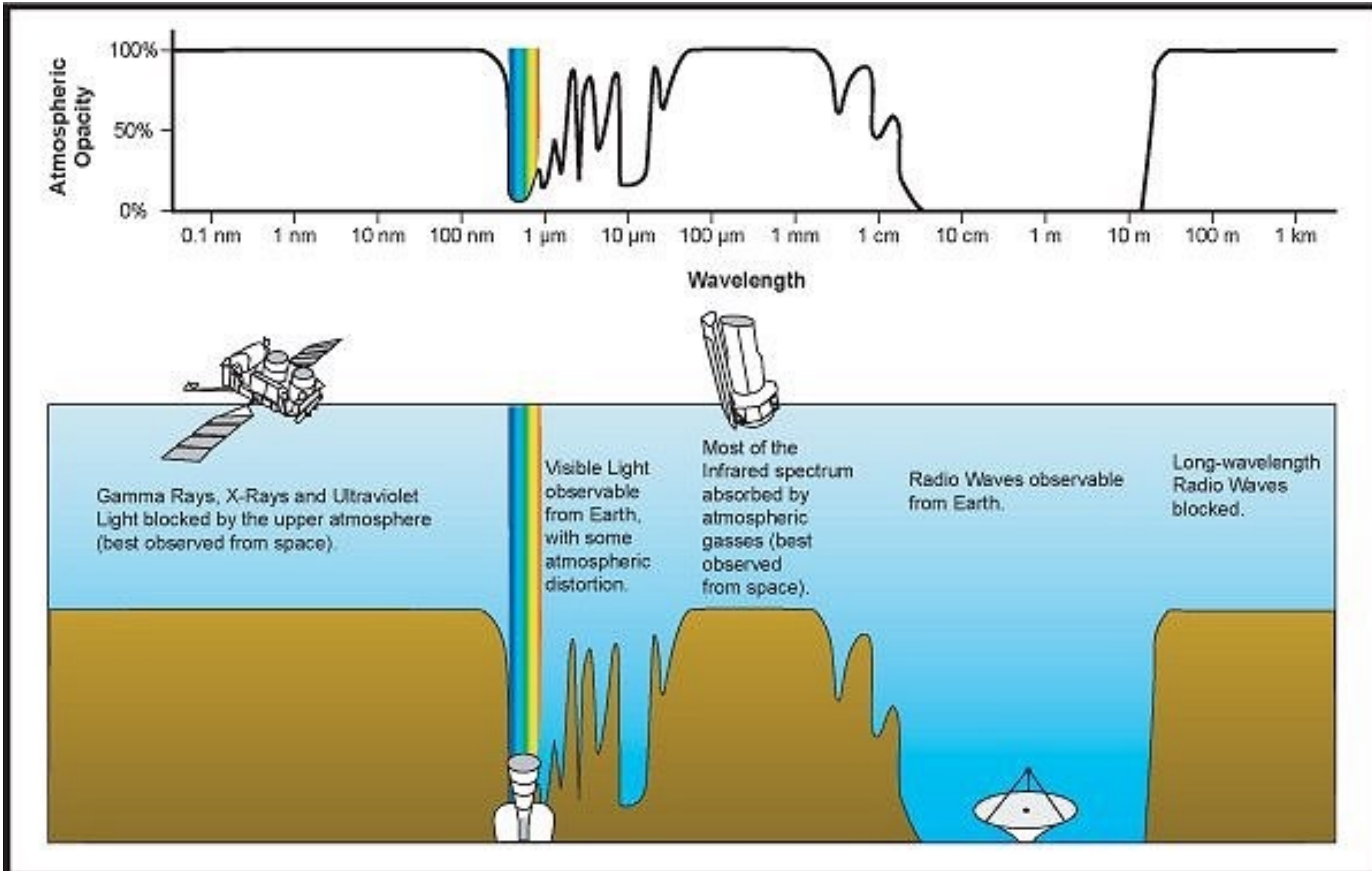
Absorption by Earth's Atmosphere

- Absorption by the Earth's atmosphere (as measured at sea level) throughout the electromagnetic spectrum.



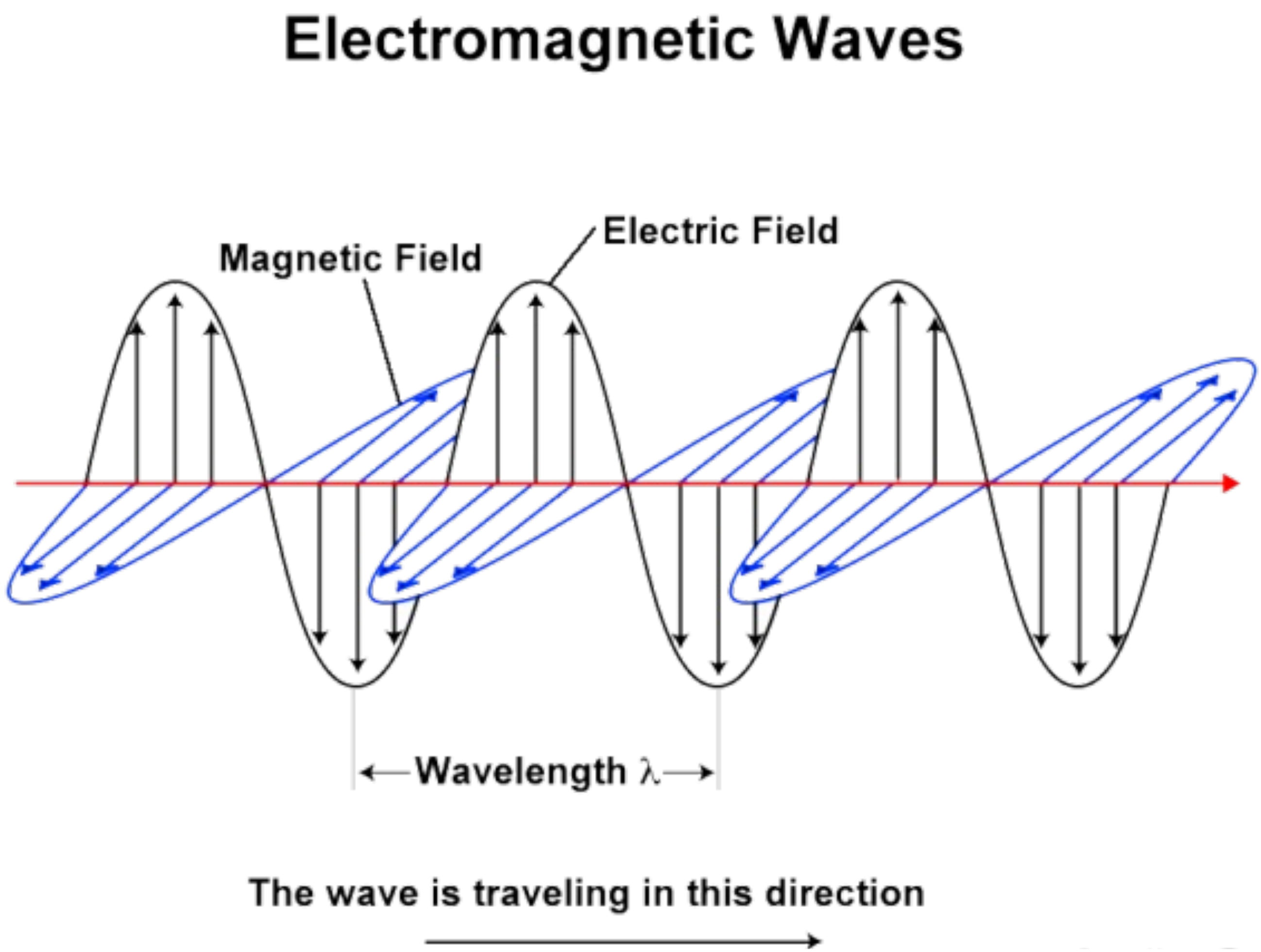
Absorption by Earth's Atmosphere

- Why does the Earth's atmosphere block or absorb electromagnetic radiation at long radio wavelengths (>10 m)?



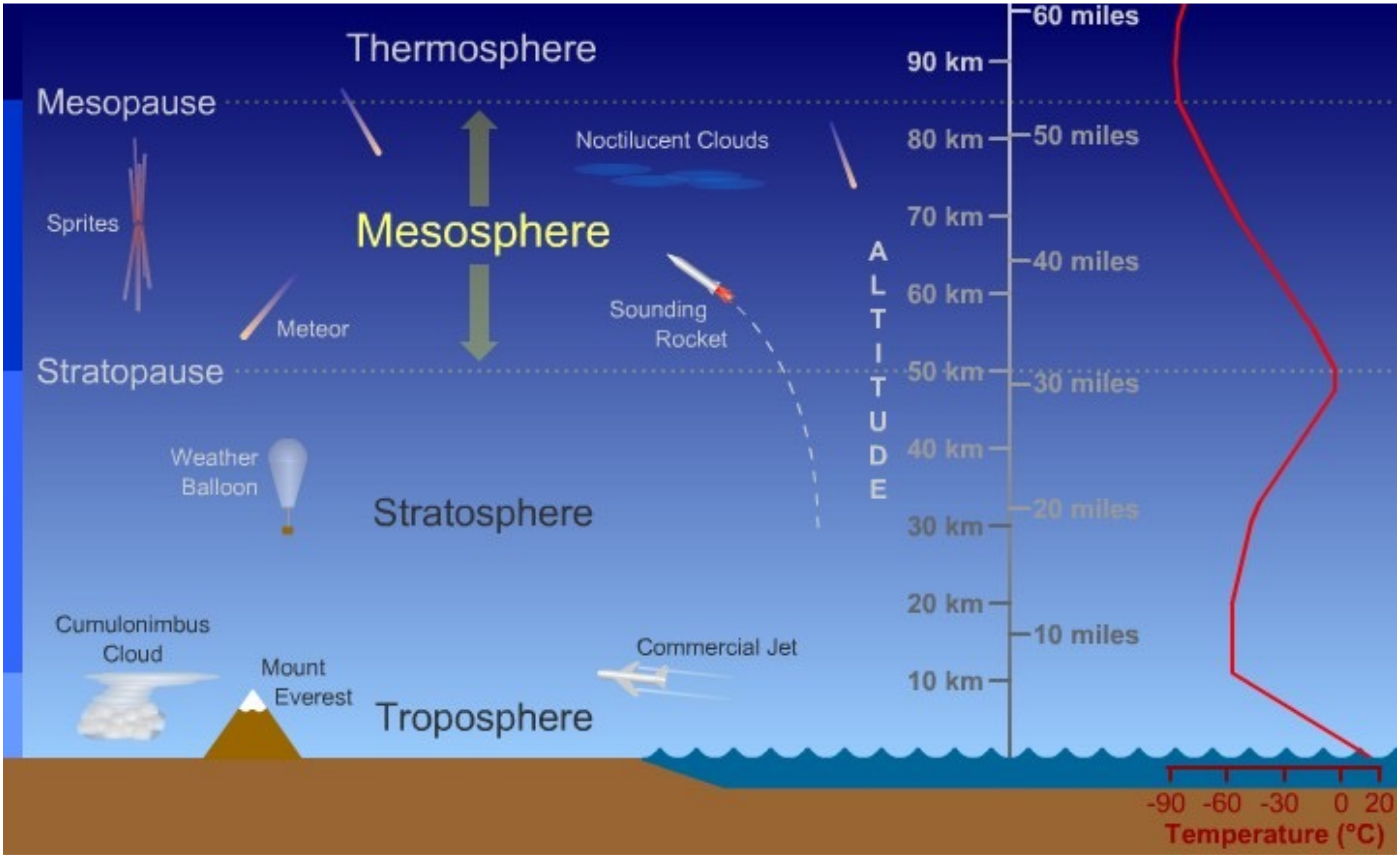
Absorption by Earth's Atmosphere

- Electromagnetic waves – light – has both electric and magnetic field components, which stand in a fixed ratio of intensity to each other, and which oscillate in phase perpendicular to each other and perpendicular to the direction of energy and wave propagation.



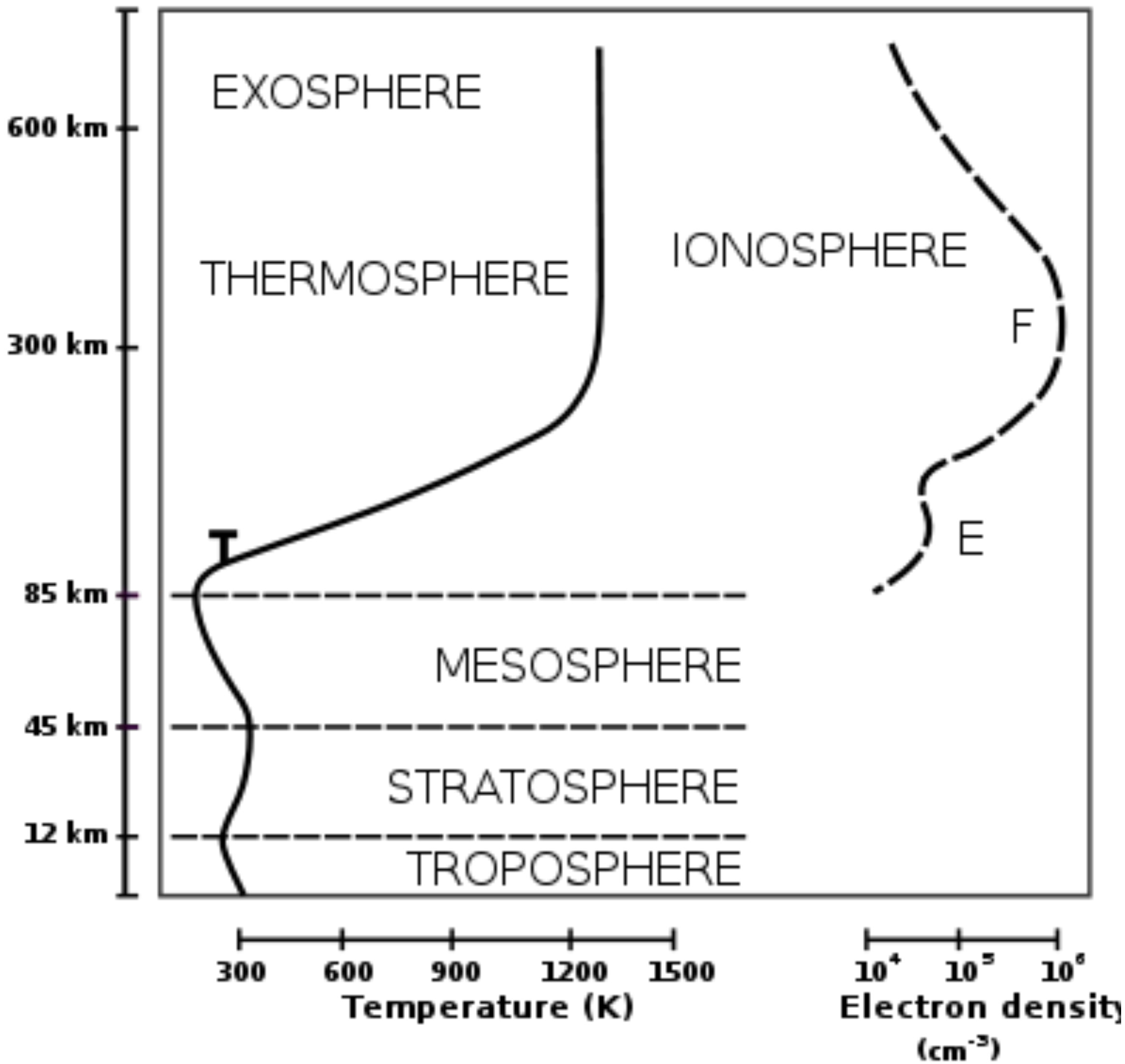
Absorption by Earth's Atmosphere

- A schematic of the lower portion of the Earth's atmosphere.



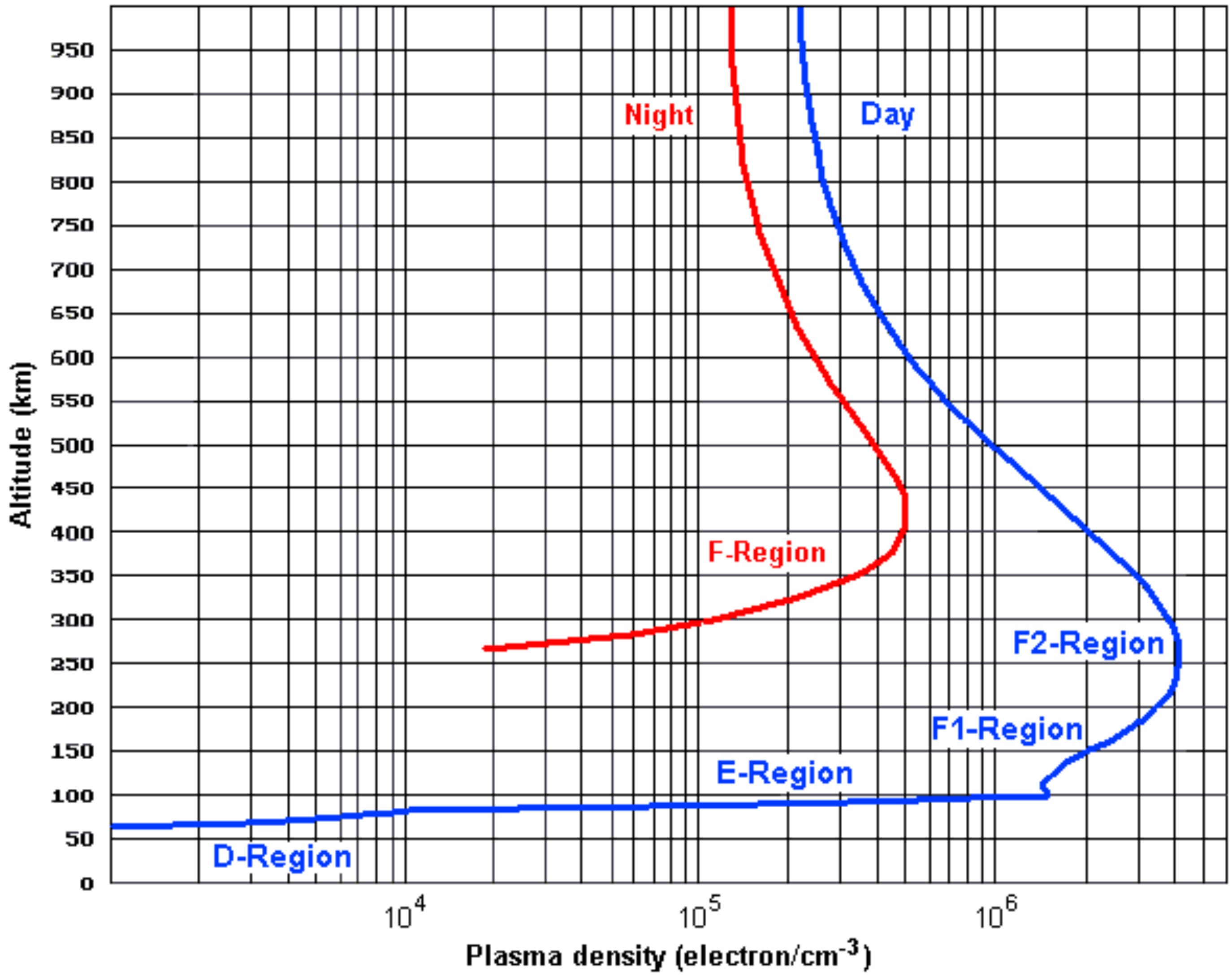
Absorption by Earth's Atmosphere

- The ionosphere comprises a part of the mesosphere, the entire thermosphere, and a part of the exosphere, spanning altitudes of about 85-600 km. Notice that the ionosphere is highly ionized (hence its name).



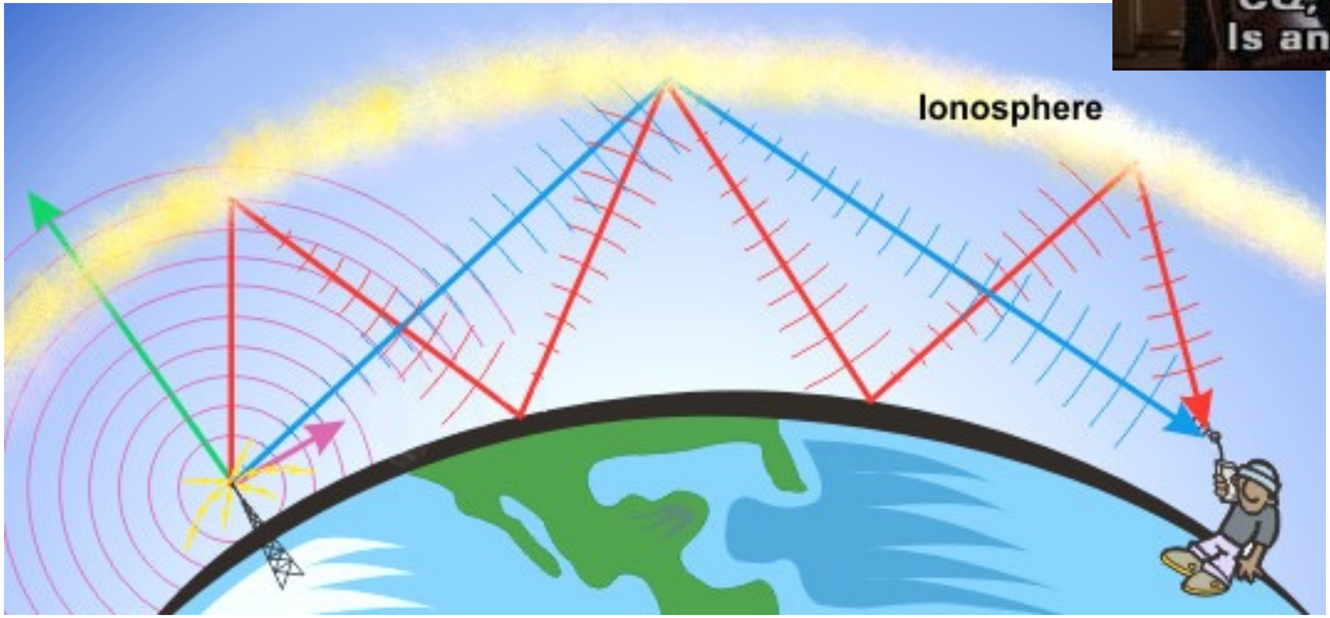
Absorption by Earth's Atmosphere

- What is responsible for ionizing atoms/molecules in the ionosphere to produce ions and free electrons?



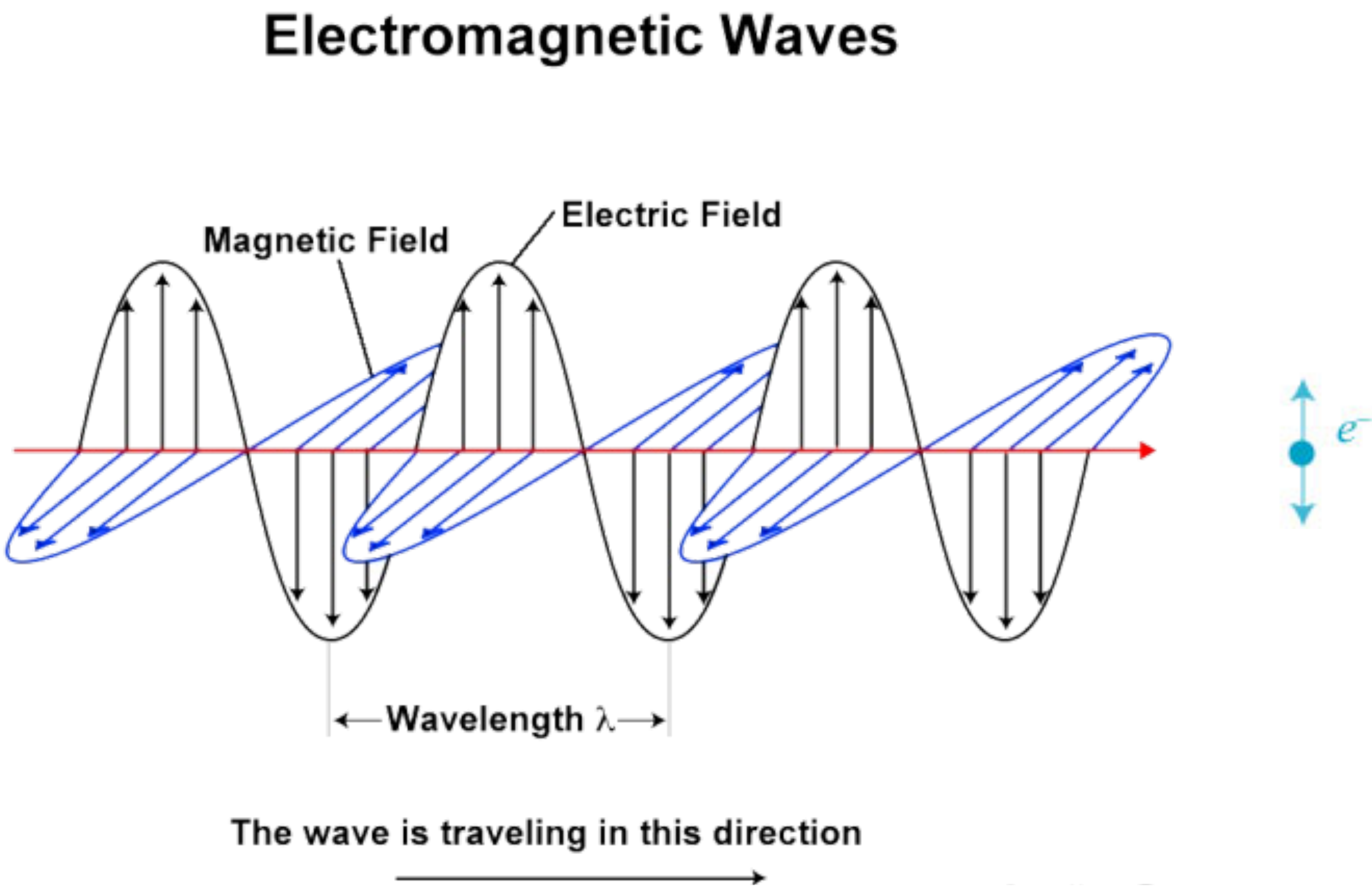
Absorption by Earth's Atmosphere

- Radio waves at wavelengths >10 m reflected by free electrons in the Earth's ionosphere, but why? This effect is used for ground communication at long radio wavelengths (e.g., amateur or ham radio).



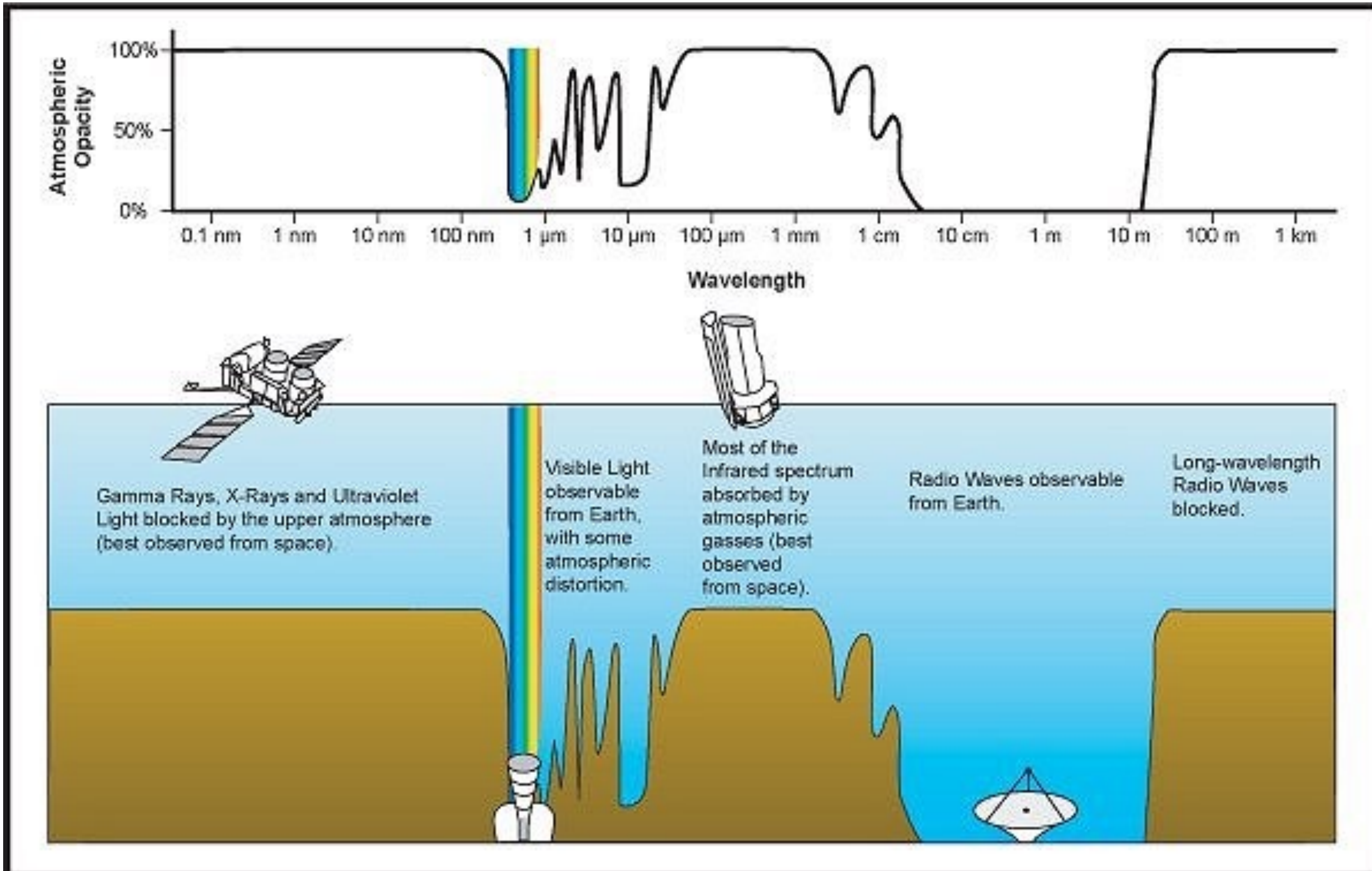
Absorption by Earth's Atmosphere

- Radio waves at wavelengths >10 m reflected by free electrons in the Earth's ionosphere, but why?



Absorption by Earth's Atmosphere

- Why then does the Earth's atmosphere not block or absorb electromagnetic radiation at radio wavelength shorter than ~10 m (until about 2 cm)?



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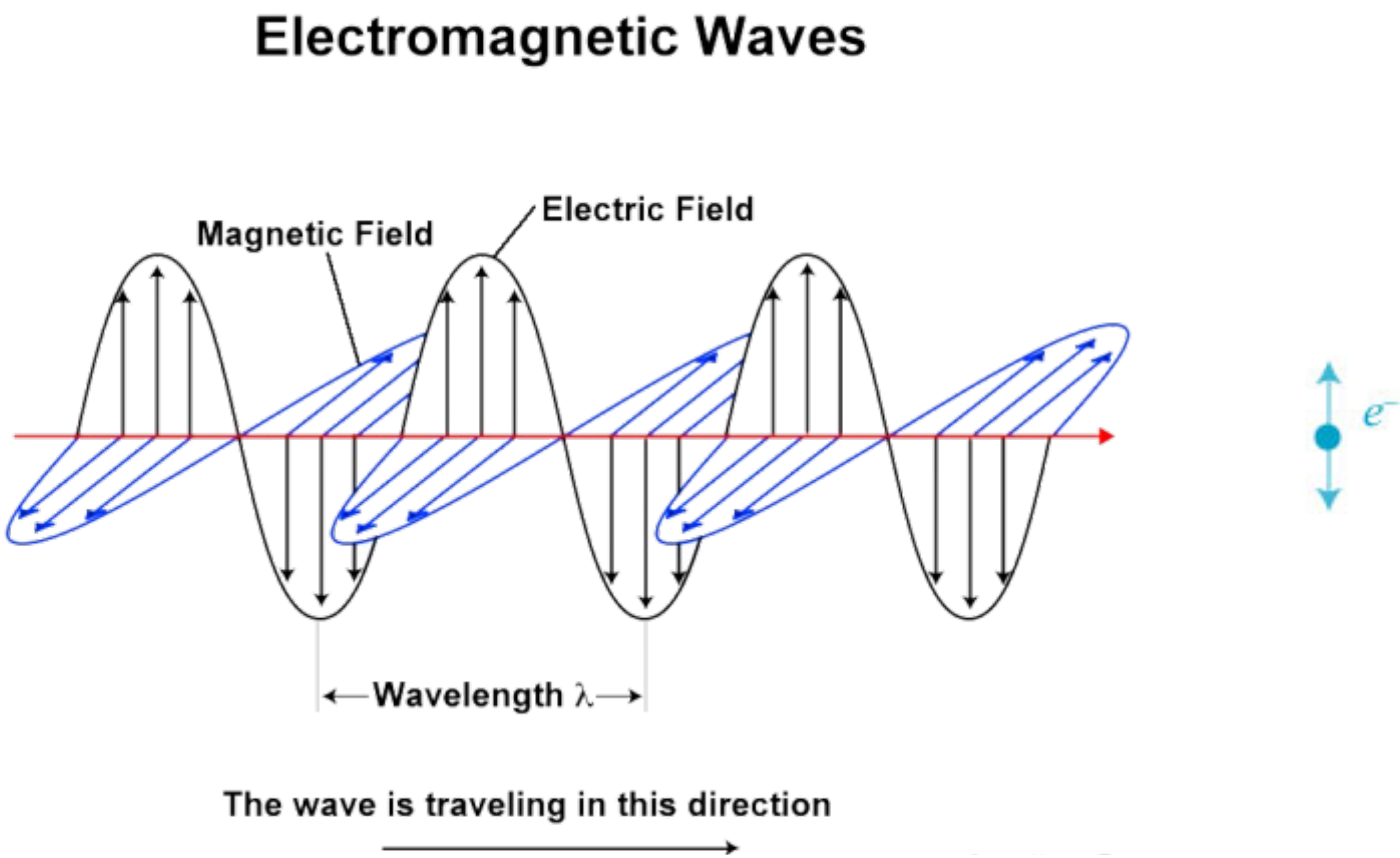
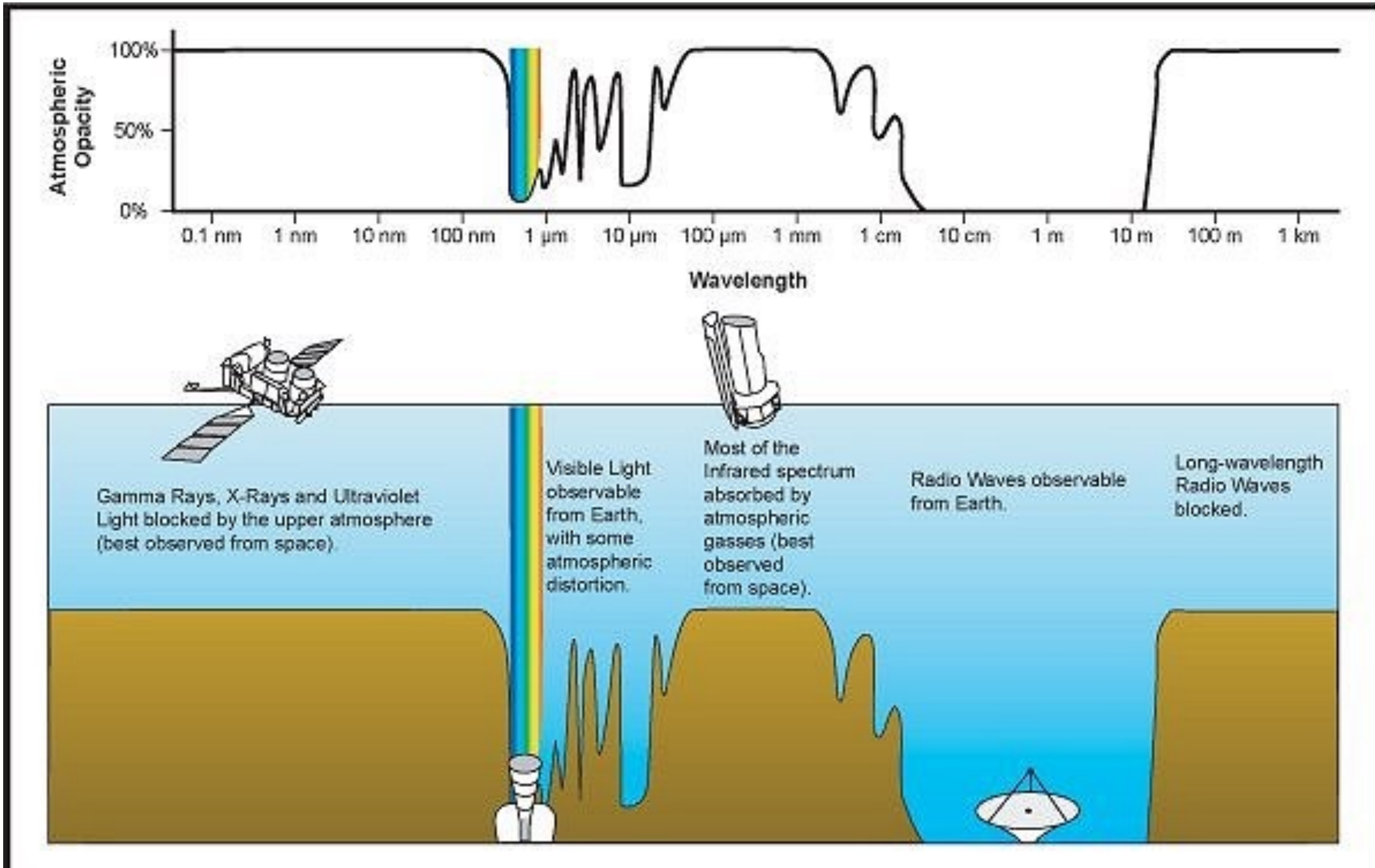
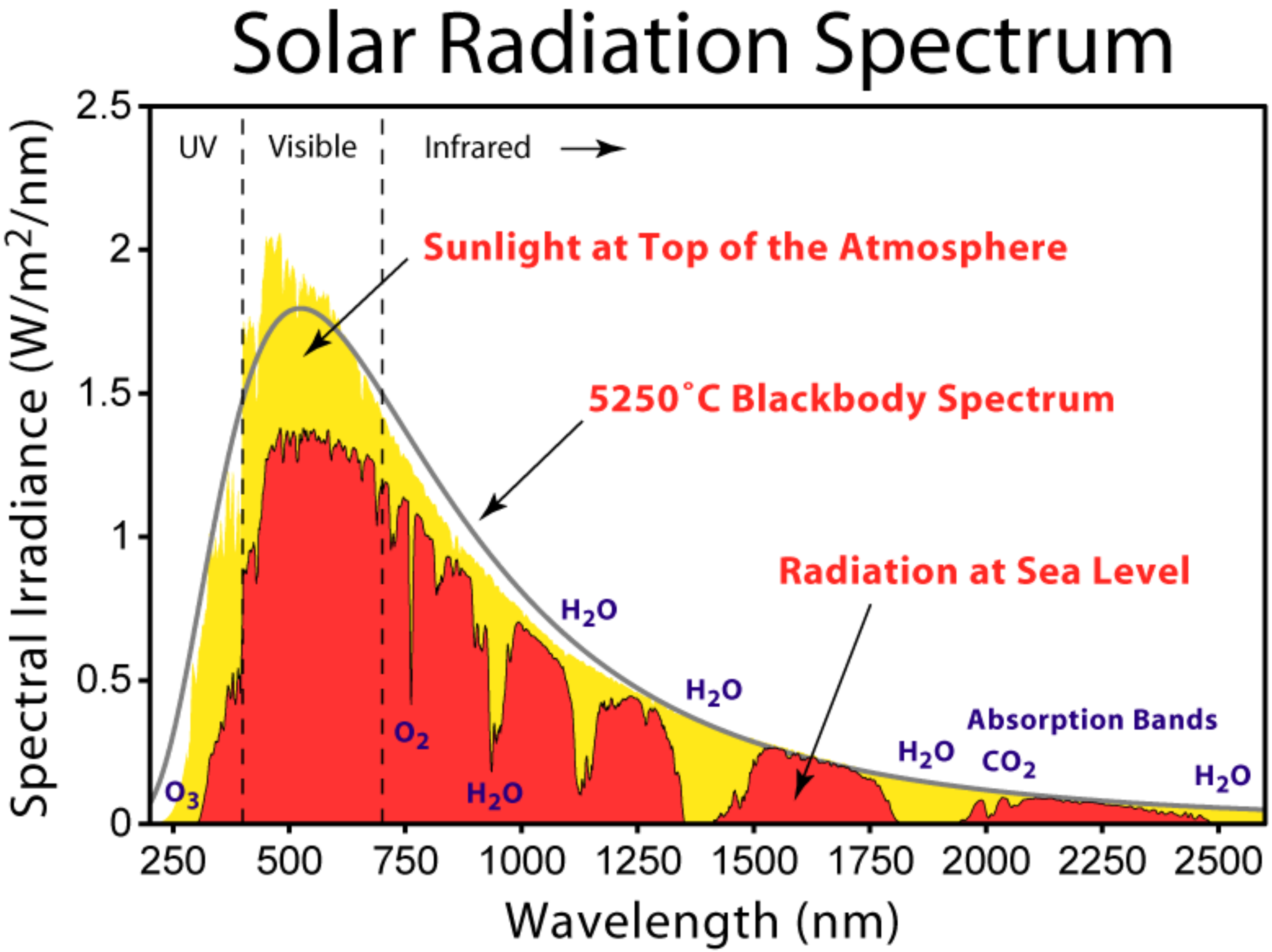


Absorption by Earth's Atmosphere

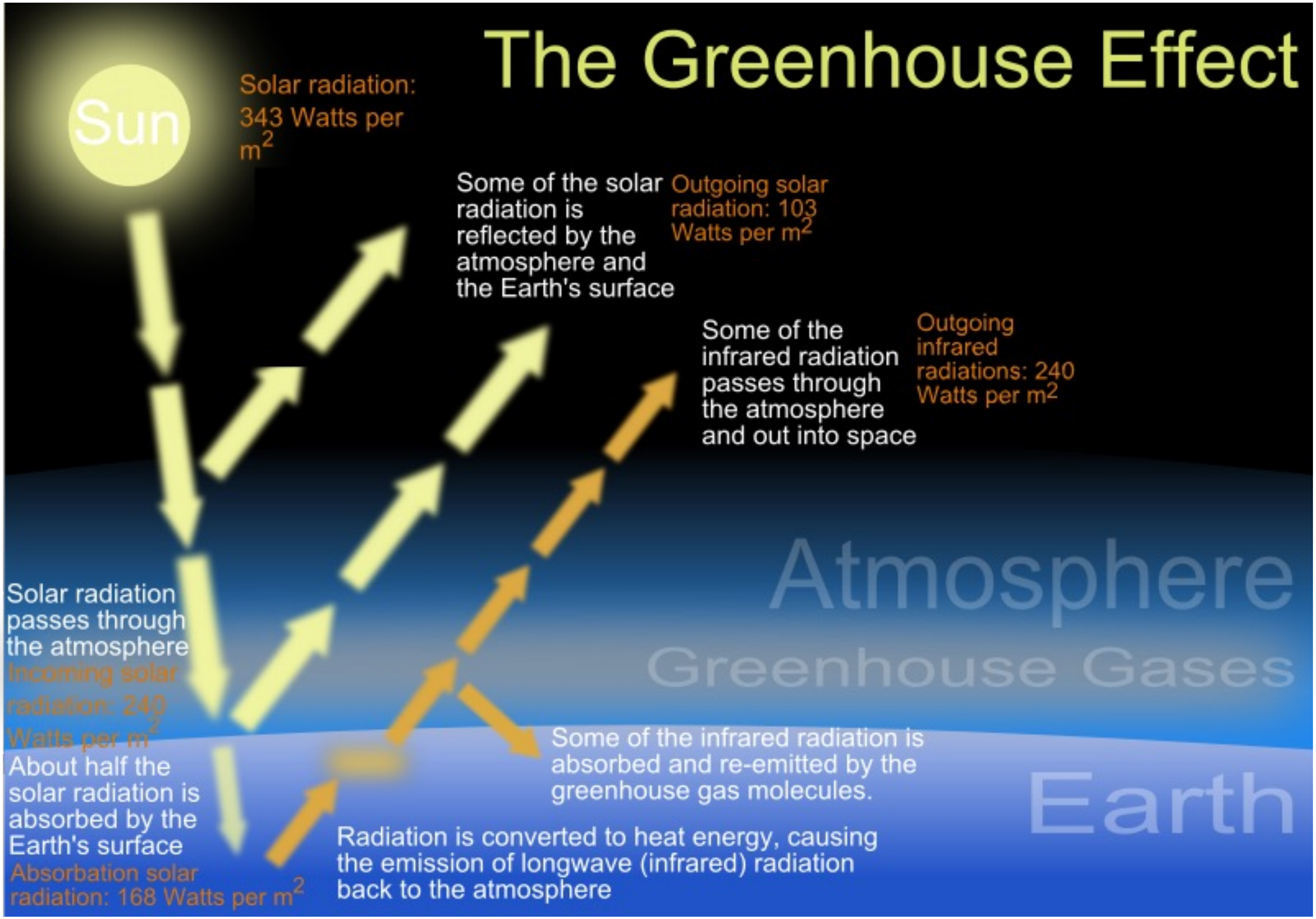
- Why does the Earth's atmosphere block or absorb electromagnetic radiation at very short radio and infrared wavelengths?



Absorption by Earth's Atmosphere

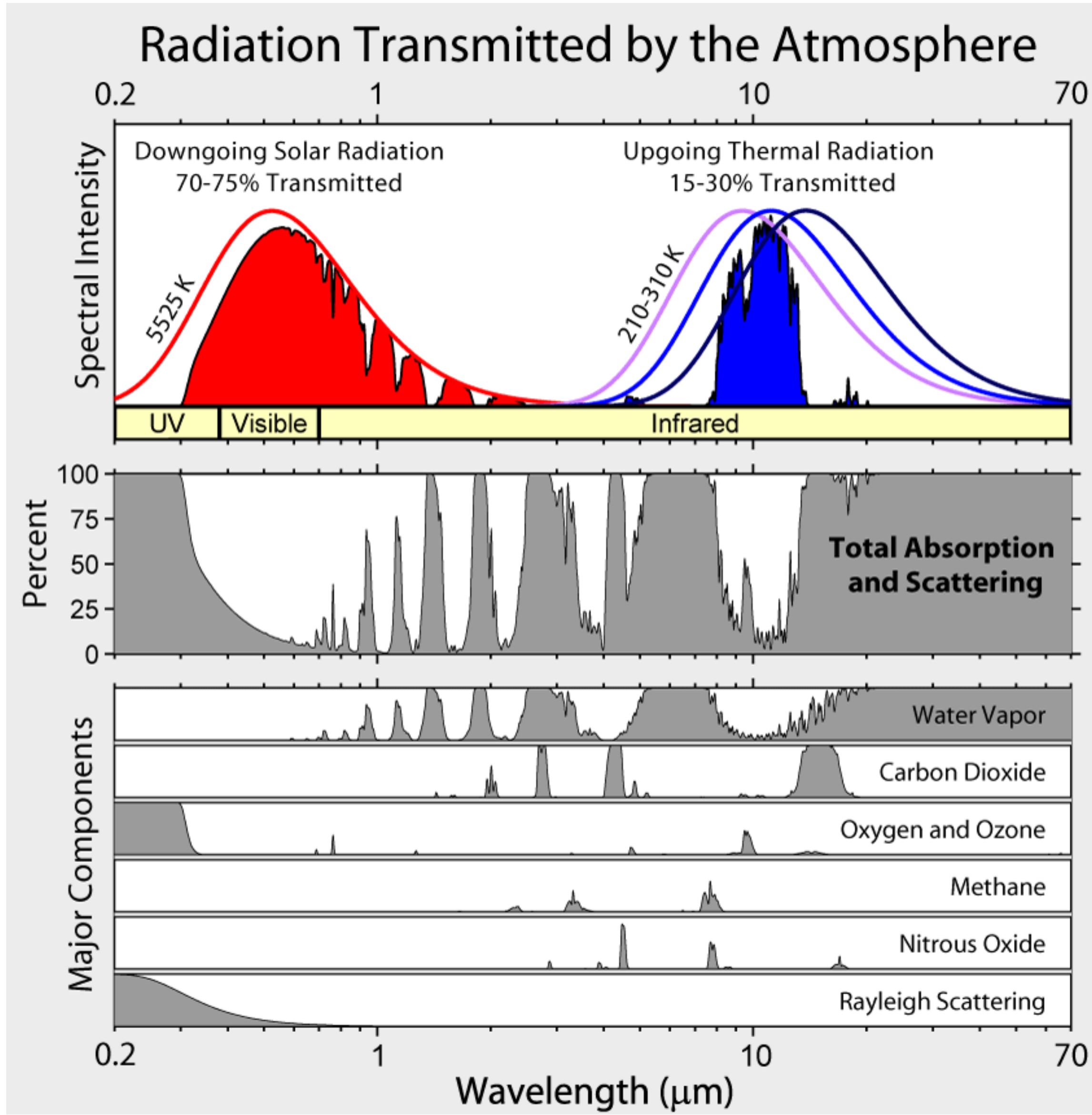


Absorption by Earth's Atmosphere



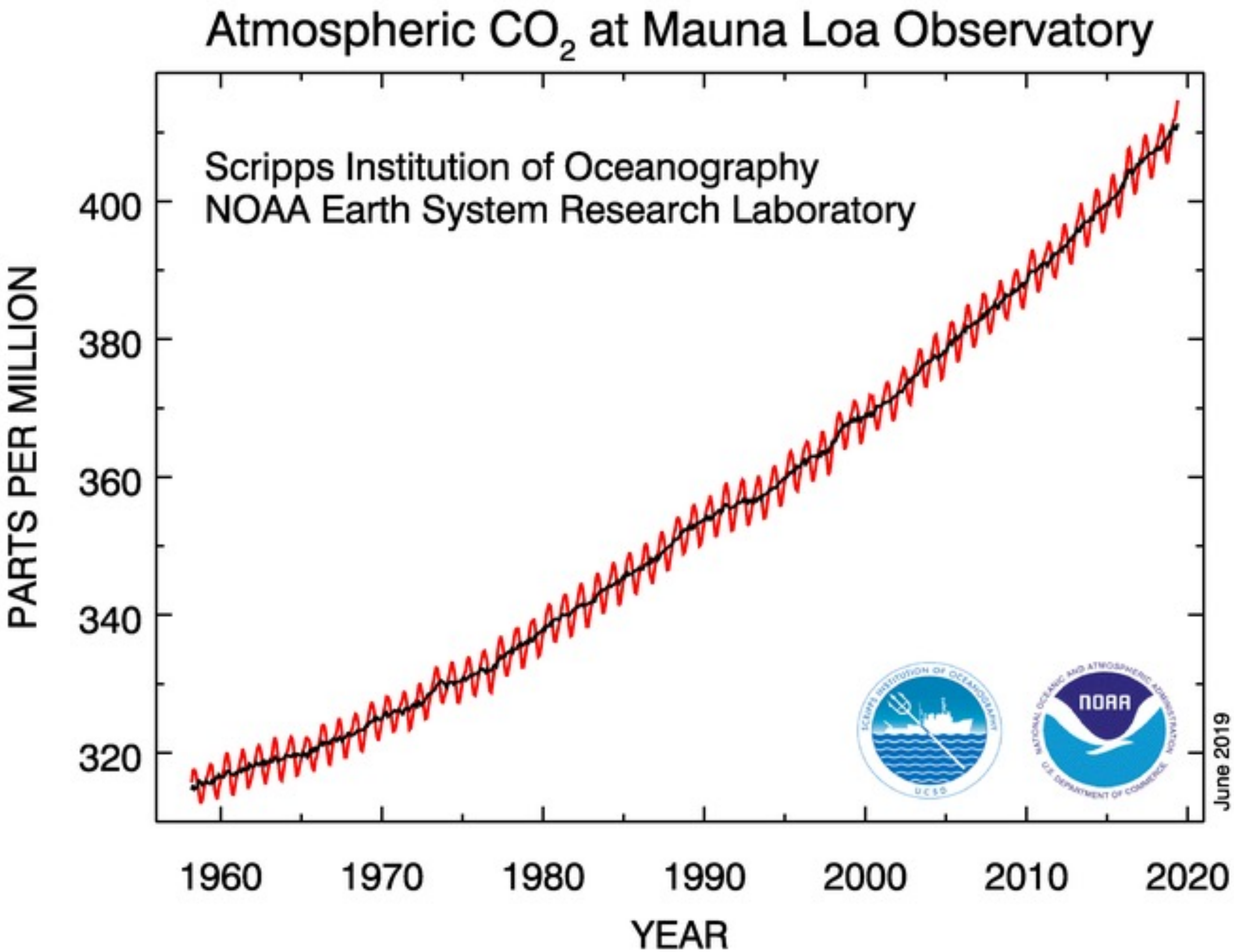
Absorption by Earth's Atmosphere

- Gases responsible for the Greenhouse effect.
- Water vapor and carbon dioxide responsible for bulk of absorption at infrared wavelengths. Methane is a particular powerful greenhouse gas, responsible for ~25% of manmade global warming. Why? Assignment Question.



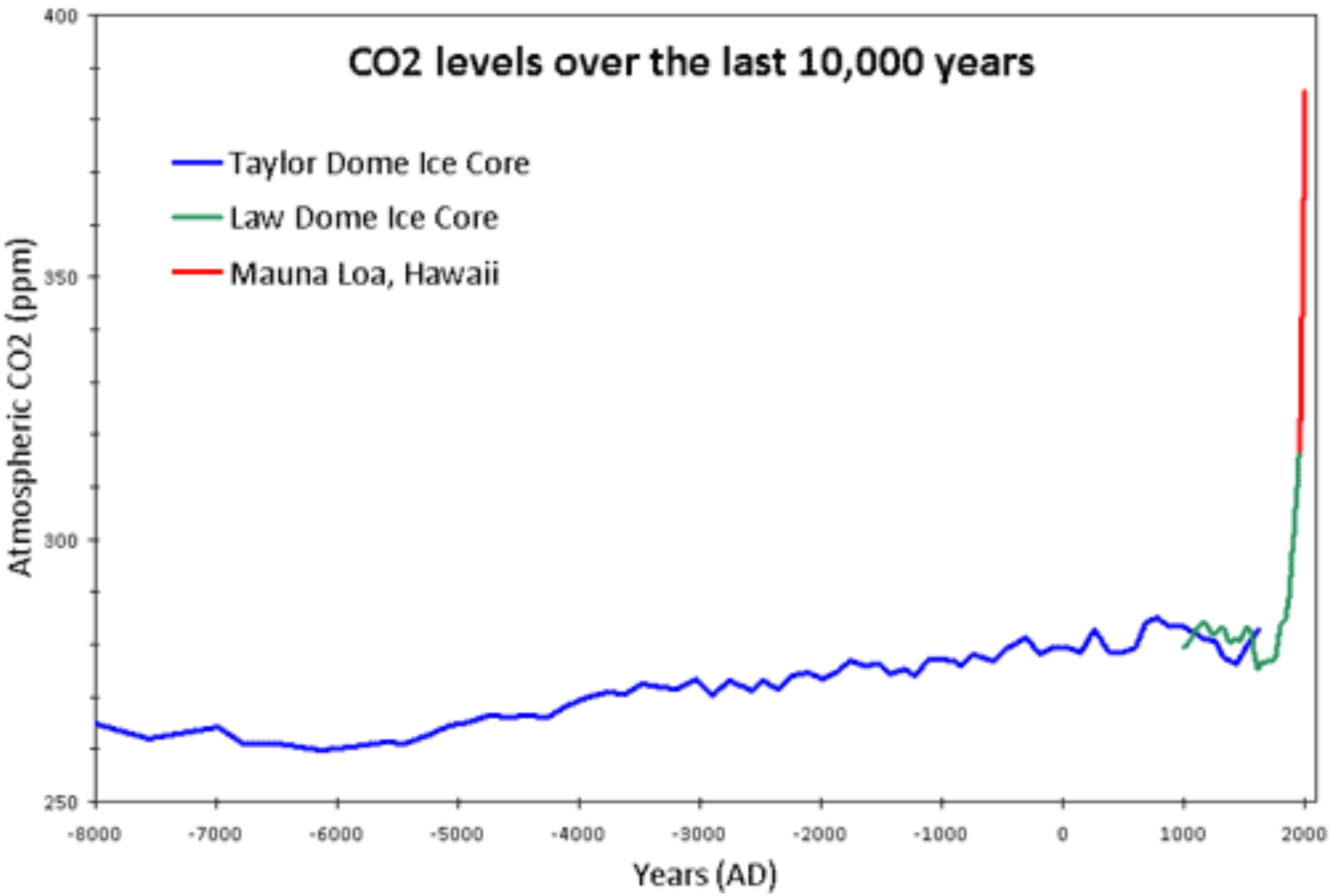
Absorption by Earth′s Atmosphere

- Rising concentration of CO_2 in the Earth's atmosphere.



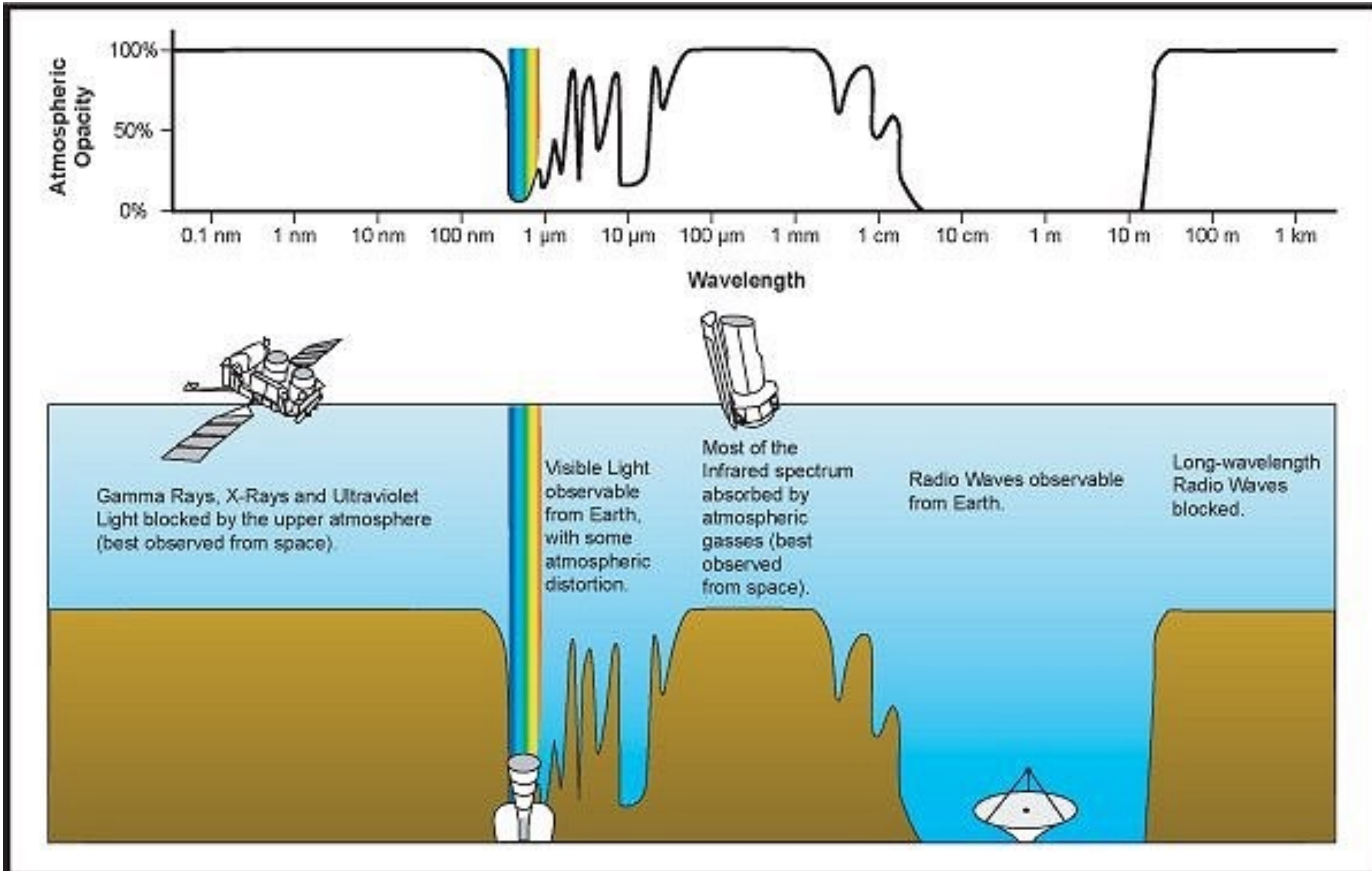
Absorption by Earth's Atmosphere

- Alarming rise in concentration of CO_2 in the Earth's atmosphere since industrial age.

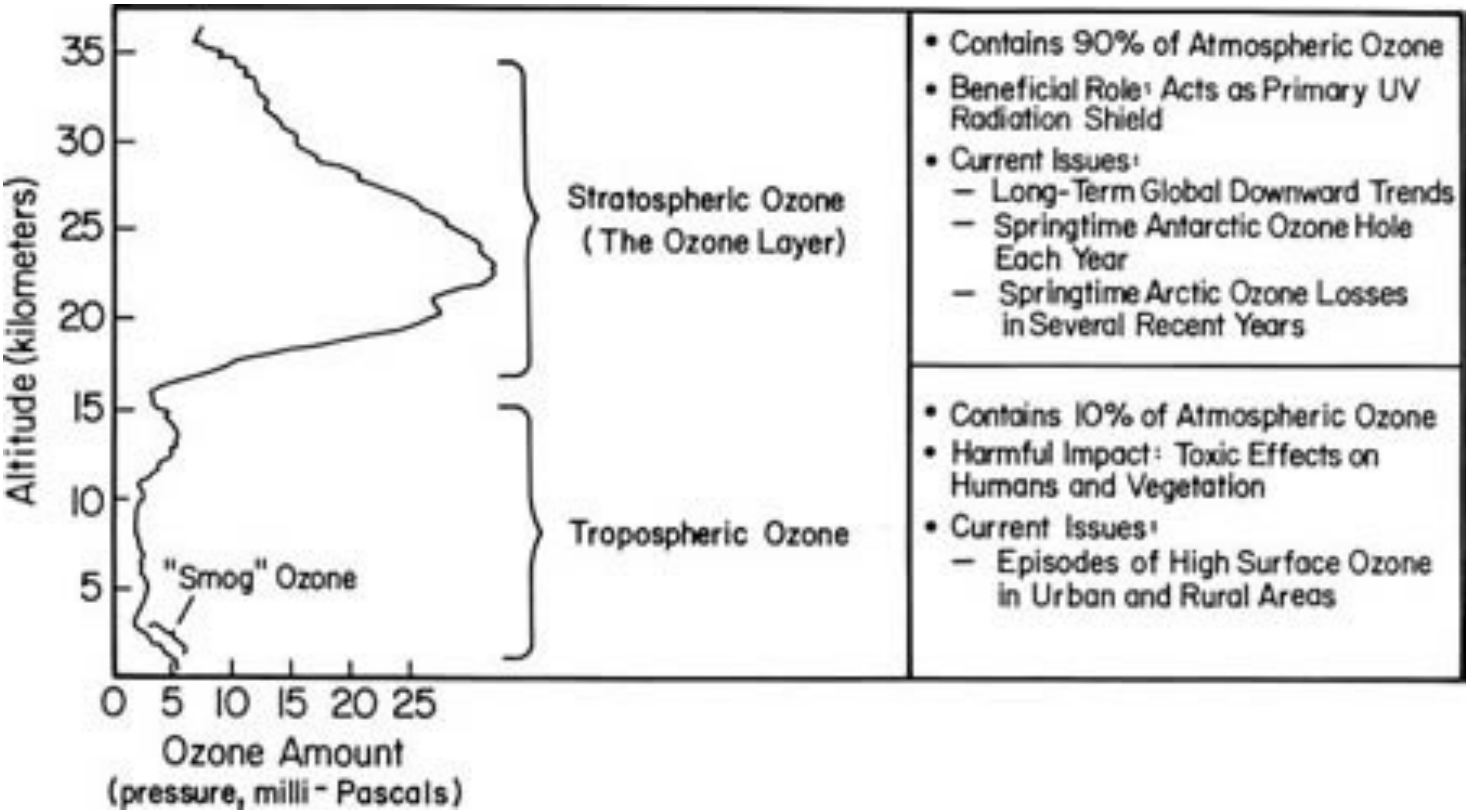


Absorption by Earth's Atmosphere

- Why does the Earth's atmosphere block or absorb electromagnetic radiation at ultraviolet wavelengths?



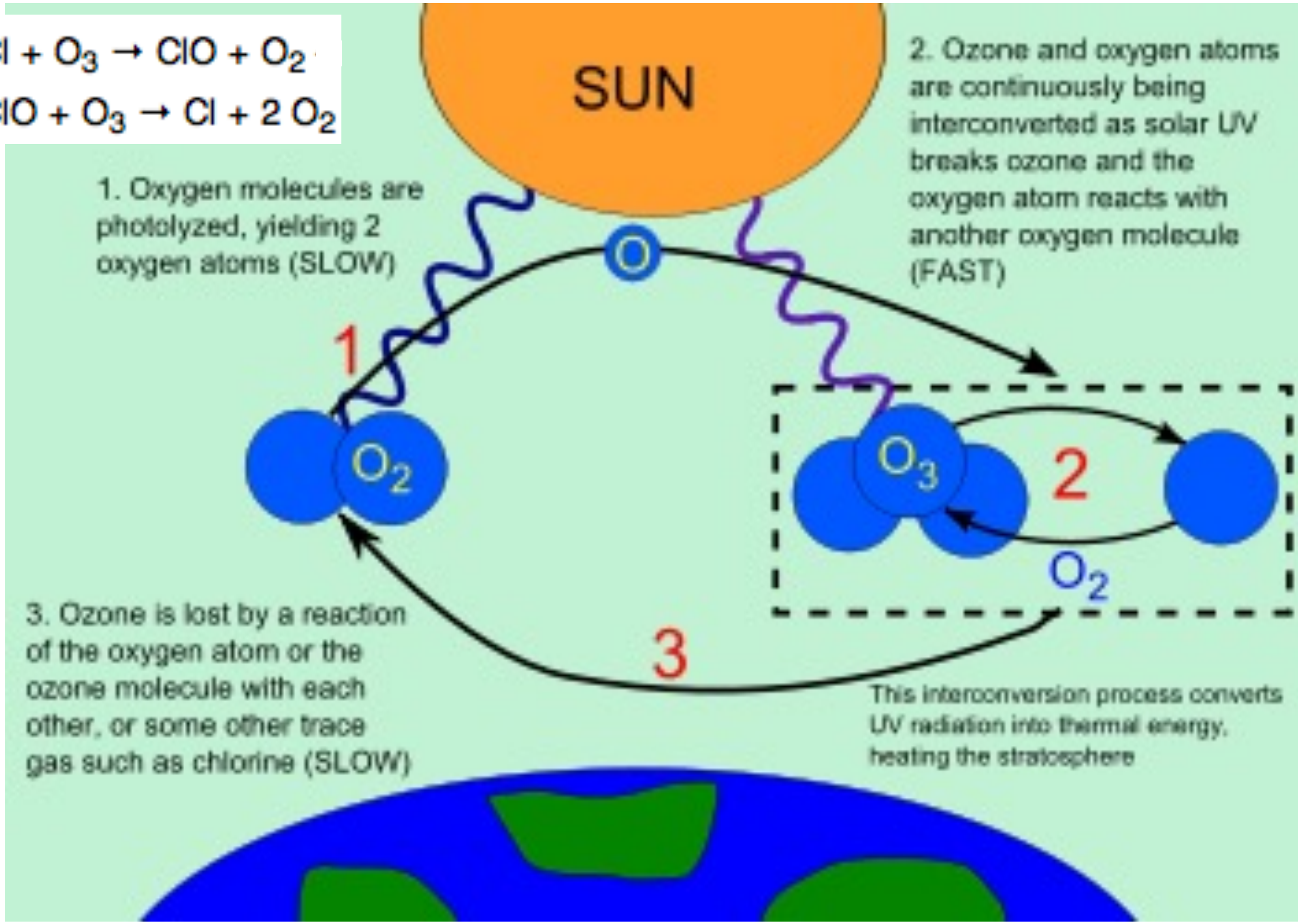
Absorption by Earth's Atmosphere



Absorption by Earth's Atmosphere

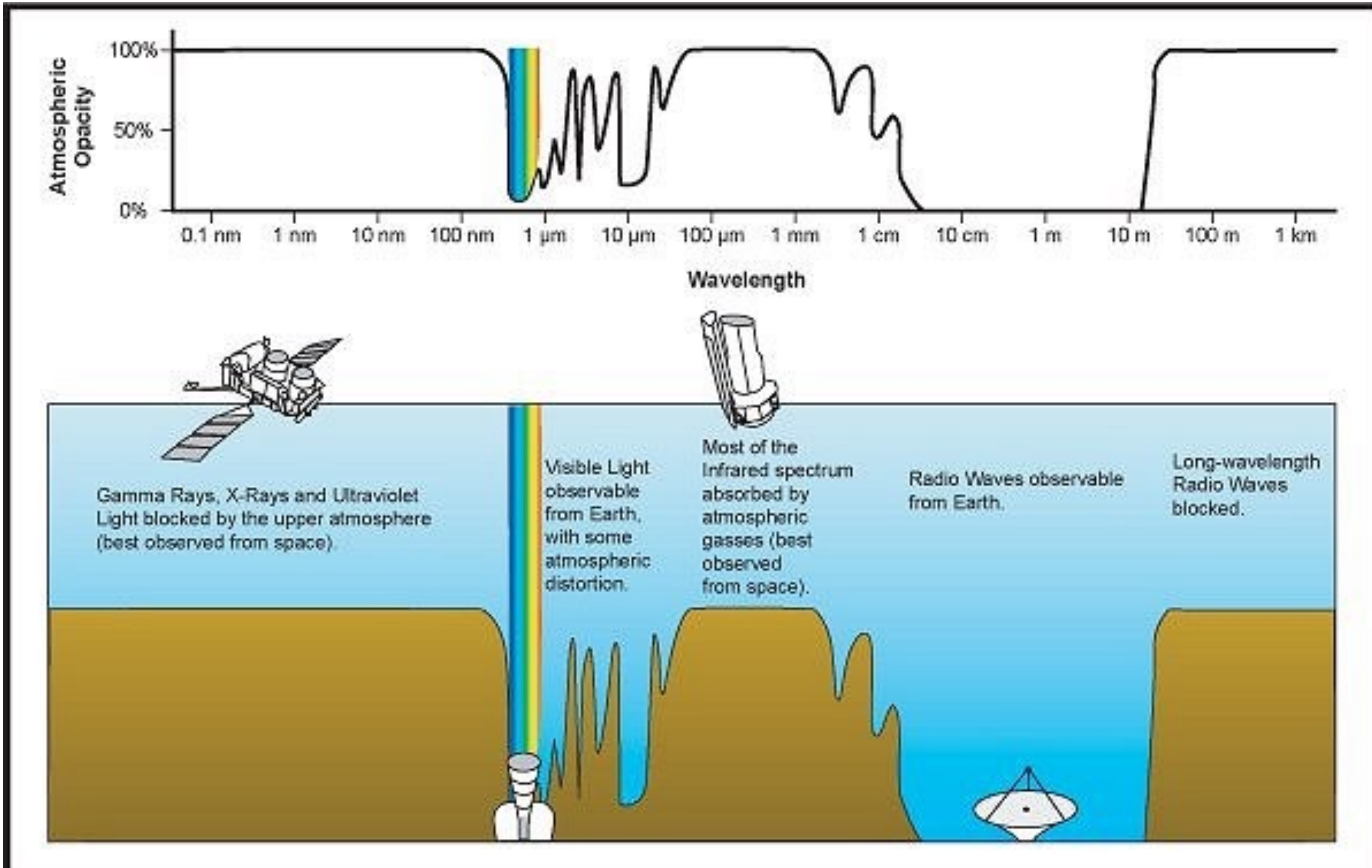
- .

- $Cl + O_3 \rightarrow ClO + O_2$
- $ClO + O_3 \rightarrow Cl + 2\,O_2$

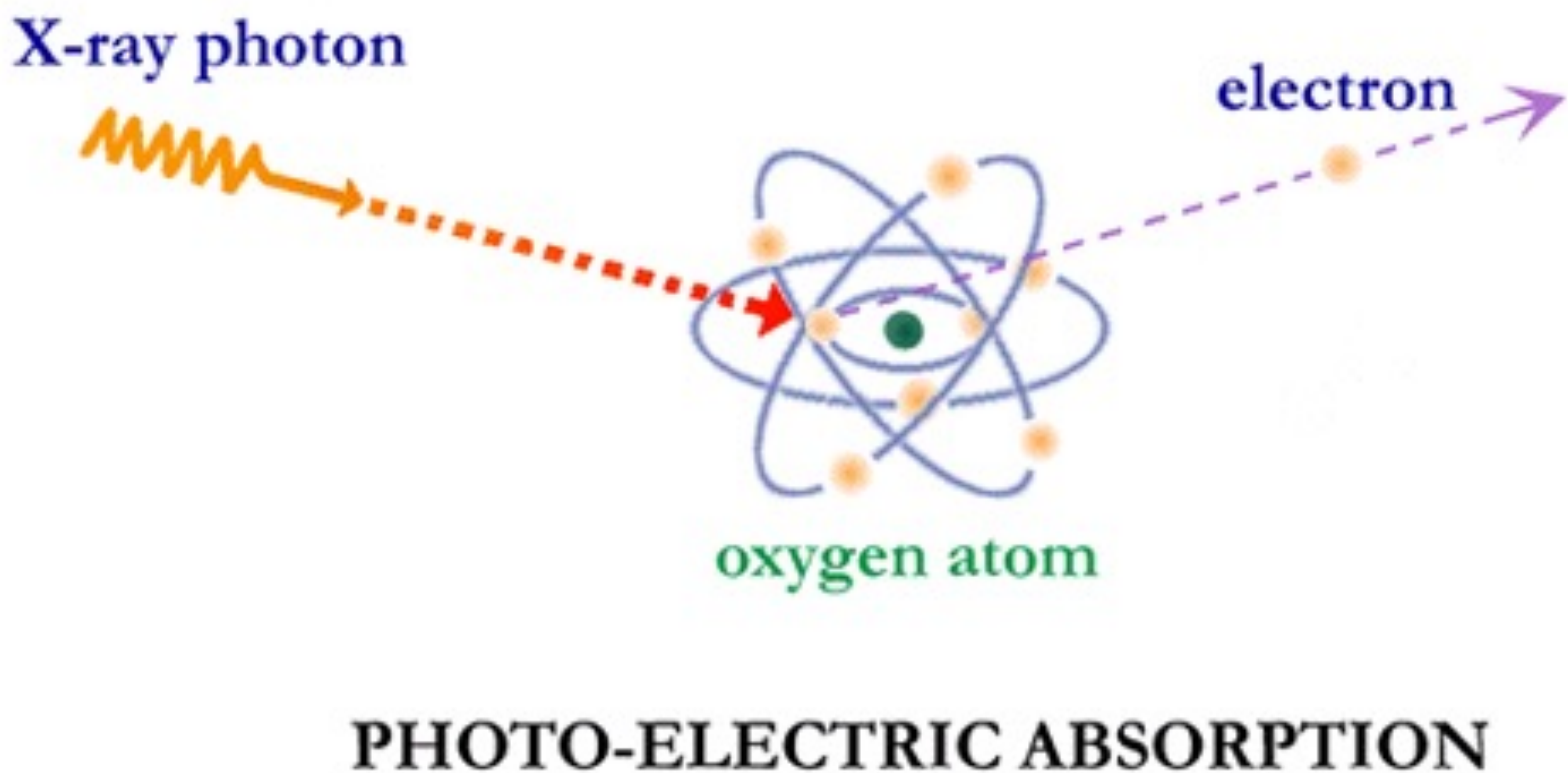


Absorption by Earth's Atmosphere

- Why does the Earth's atmosphere block or absorb electromagnetic radiation at X-ray and γ-ray wavelengths?



Absorption by Earth's Atmosphere



Learning Objectives

- Beginnings of modern observational astronomy at optical wavelengths.
- The electromagnetic window:
  Causes of scattering or absorption of electromagnetic radiation by the Earth's atmosphere
- Beginnings of modern observational astronomy at other wavelengths:
  2. Radio
  3. X-ray
  4. γ-ray
  5. Ultraviolet
  6. Infrared
  7. Gravitational Waves

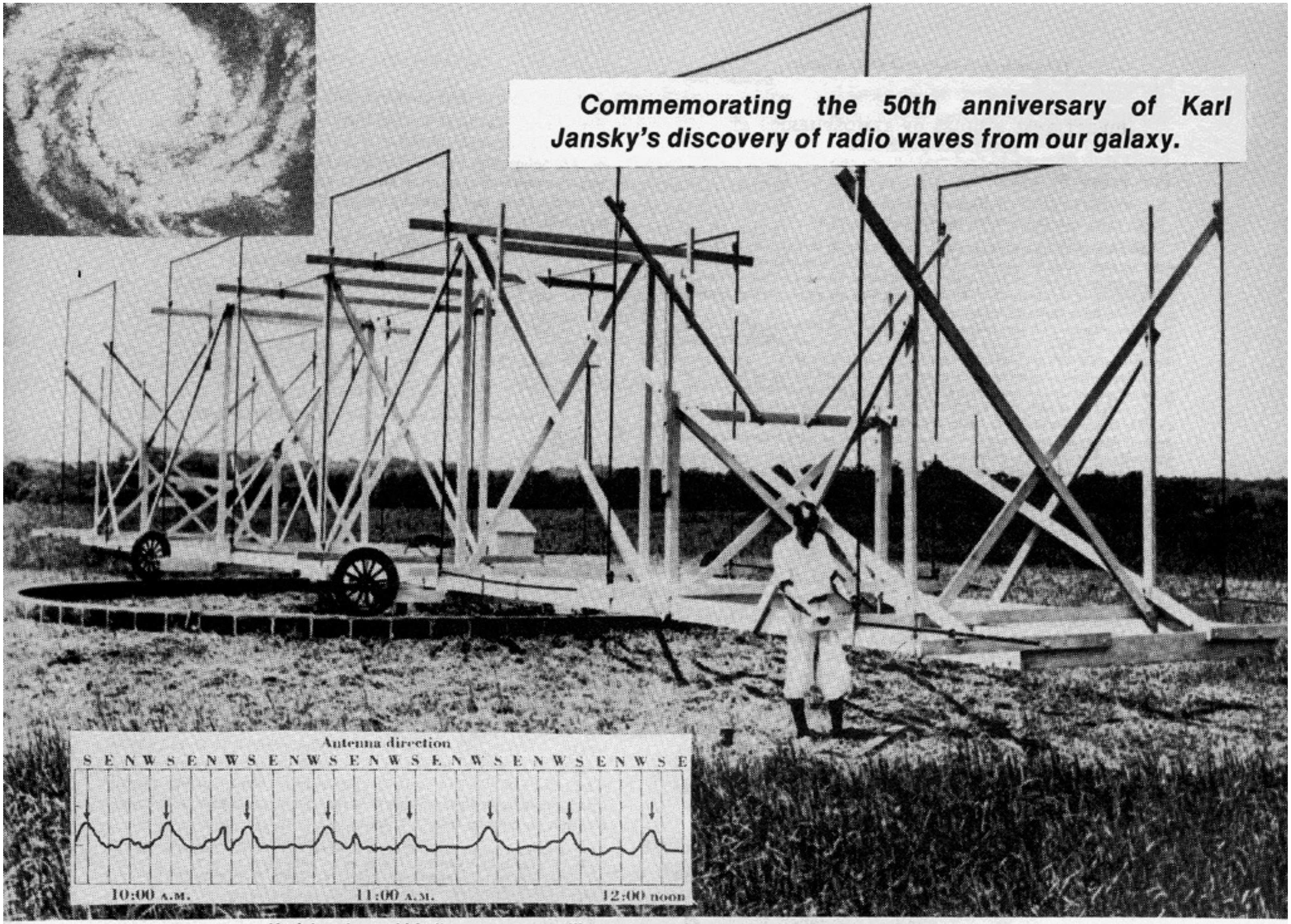
Beginnings of Radio Astronomy

- In 1895, Marconi built a wireless system capable of transmitting and receiving signals at long distances.
- In 1928, Karl Guthe Jansky, trained as a radio engineer, was employed at the Bell Telephone Laboratories to investigate sources of static that might interfere with radio voice transmissions. In 1932, he built an antenna operating at a radio frequency of 20.5 MHz (wavelength of 14.6 m) for this study.

Karl Jansky, 1905-1950

Full-size replica of Jansky's antenna

Beginnings of Radio Astronomy



Karl Jansky and his "merry-go-round" antenna — the first radio telescope with record of hiss noise he detected from our galaxy as indicated by small bumps, one for each revolution of the antenna every 20 minutes.

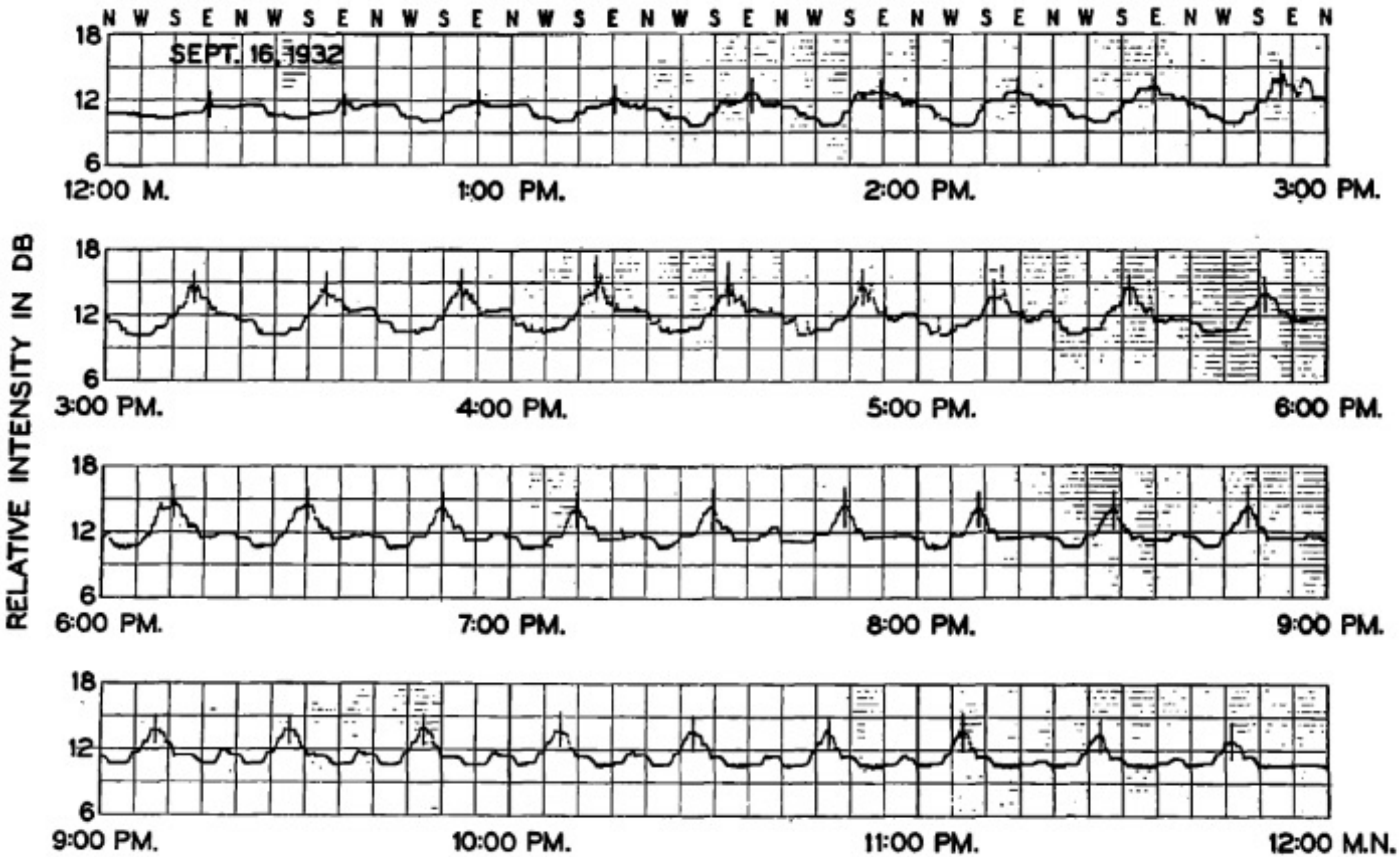
Beginnings of Radio Astronomy

- Jansky detected static from nearby and distant thunderstorms, together with a persistent faint hiss of unknown origin.
- Jansky found that the intensity of the faint hiss rose and fell once a day, with maximum intensity coinciding with the position of the Sun. He therefore surmized that the source of the faint hiss was the Sun.
- After a few months, however, Jansky found that the position of maximum intensity moved away from the Sun and the time of maximum intensity repeated every 23 hours 56 minutes (the sidereal period) rather than 24 hours.
- By 1933, Jansky had concluded that the signal was coming from our own Milky Way galaxy and was strongest in the direction of the Galactic center.

The Sun is the brightest radio source in the daytime sky over a broad range of wavelengths. At 20 MHz, however, the Galactic center is usually brighter, especially at solar minimum as was the case in 1932/1933.

Beginnings of Radio Astronomy

- Jansky's original recordings.

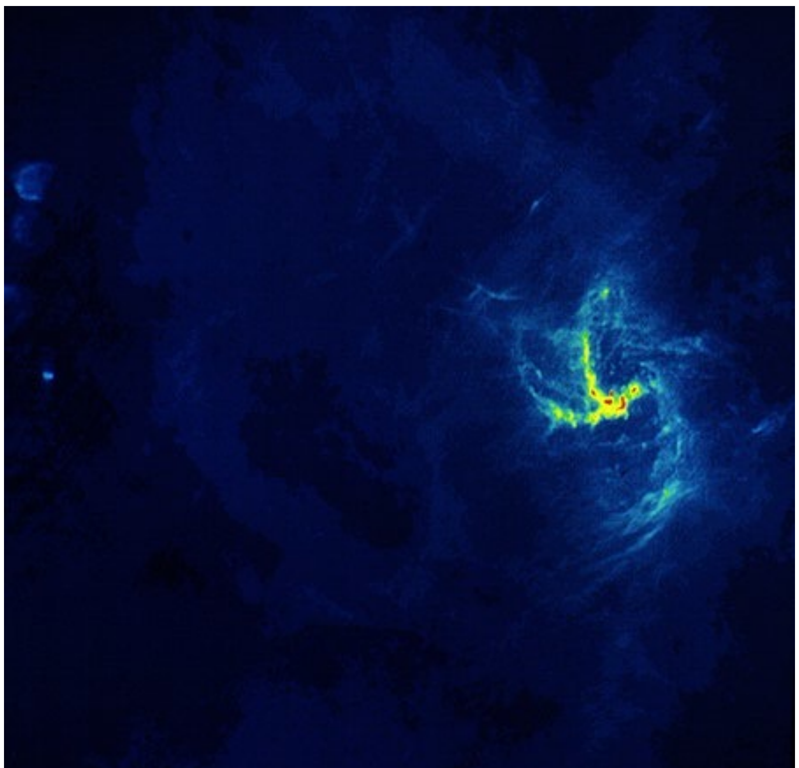


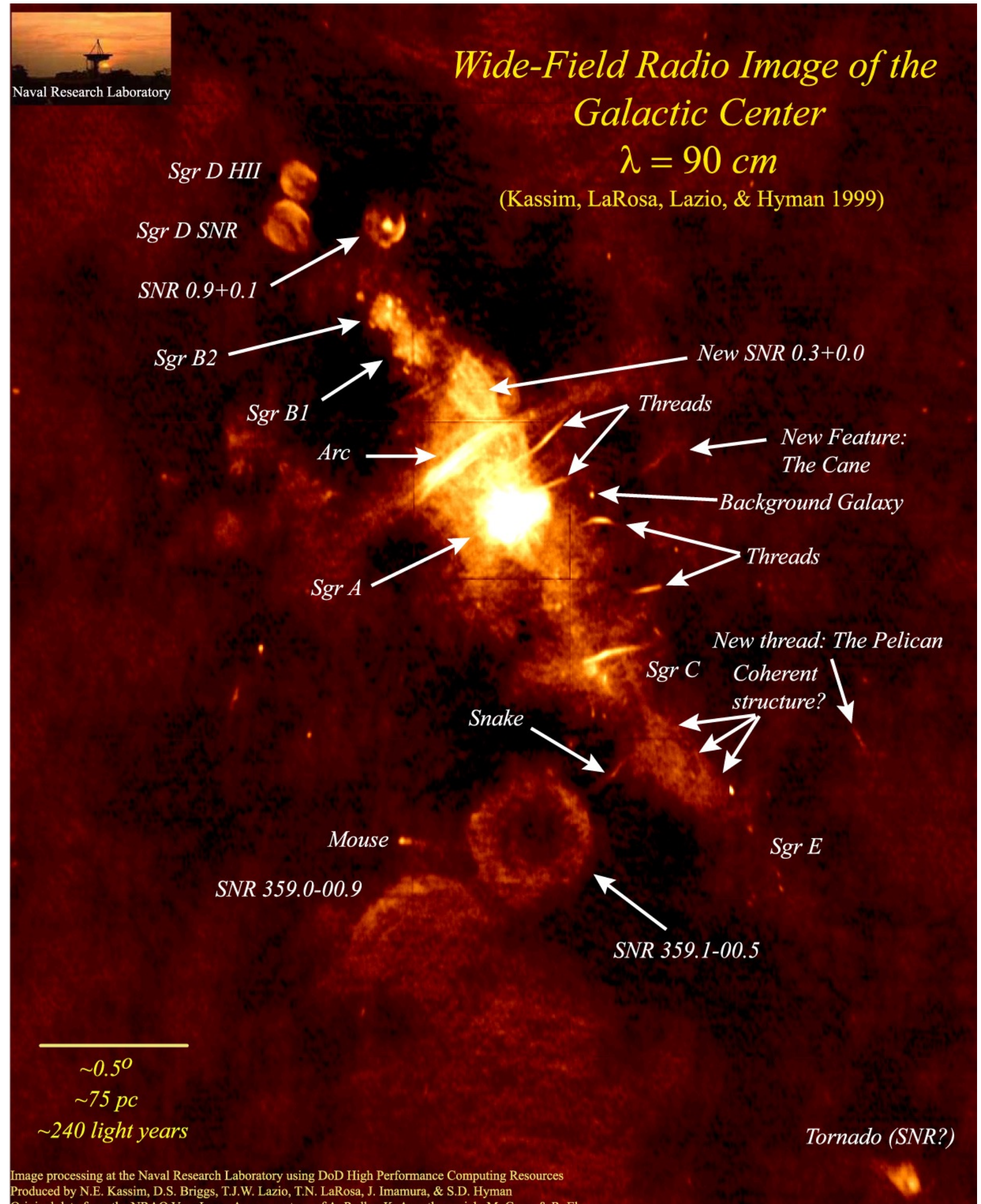
SAMPLE RECORD OF WAVES OF INTERSTELLAR ORIGIN.

Beginnings of Radio Astronomy

- An image towards the center of our Galaxy at a radio wavelength of 90 cm. The supermassive black hole at the Galactic center is located within Sgr A.

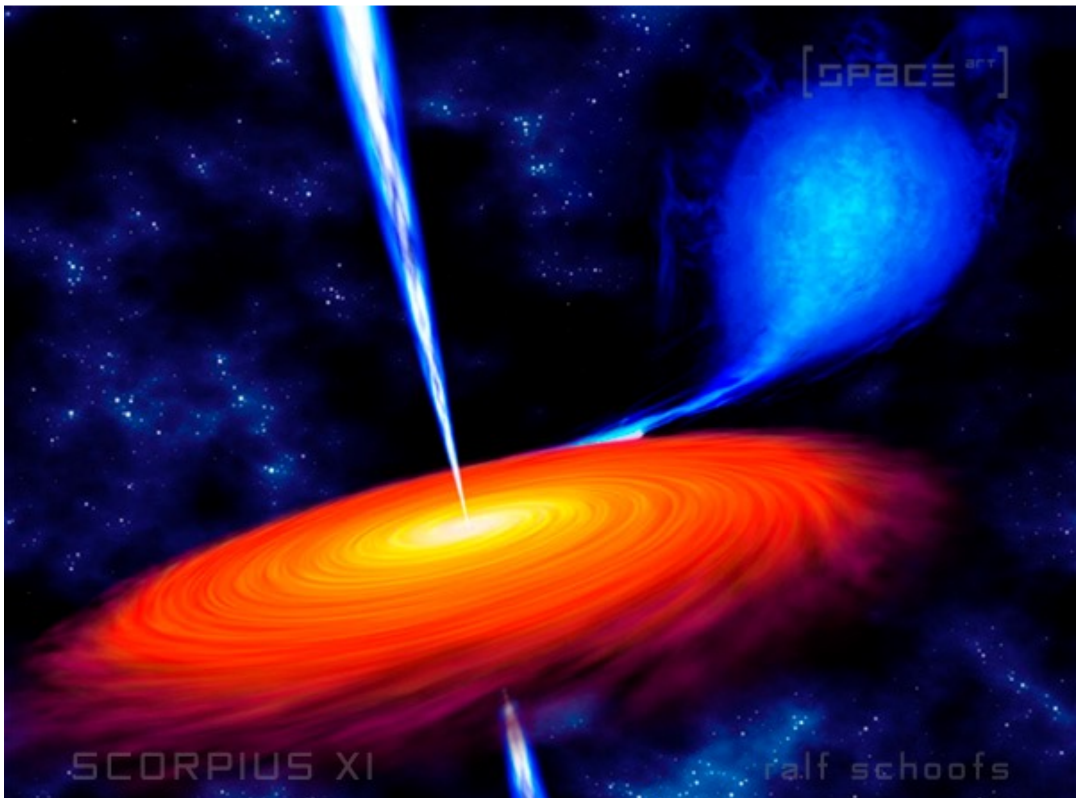
Closeup of Sgr A

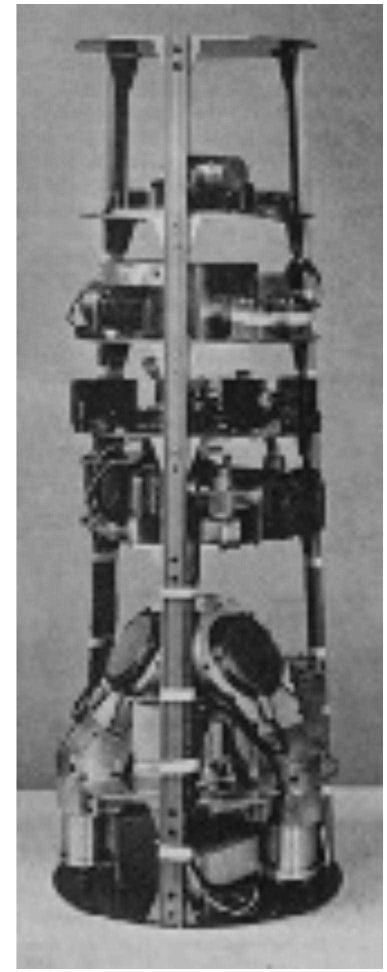




Beginnings of X-ray Astronomy

- The first rocket flight to detect an astronomical source in X-rays, the Sun, occurred in 1949.
- The first rocket flight to detect an extrasolar astronomical source, Scorpius X-1, occurred in 1962. Scorpious X-1 is now known to be a neutron star accreting from a low-mass main-sequence star.

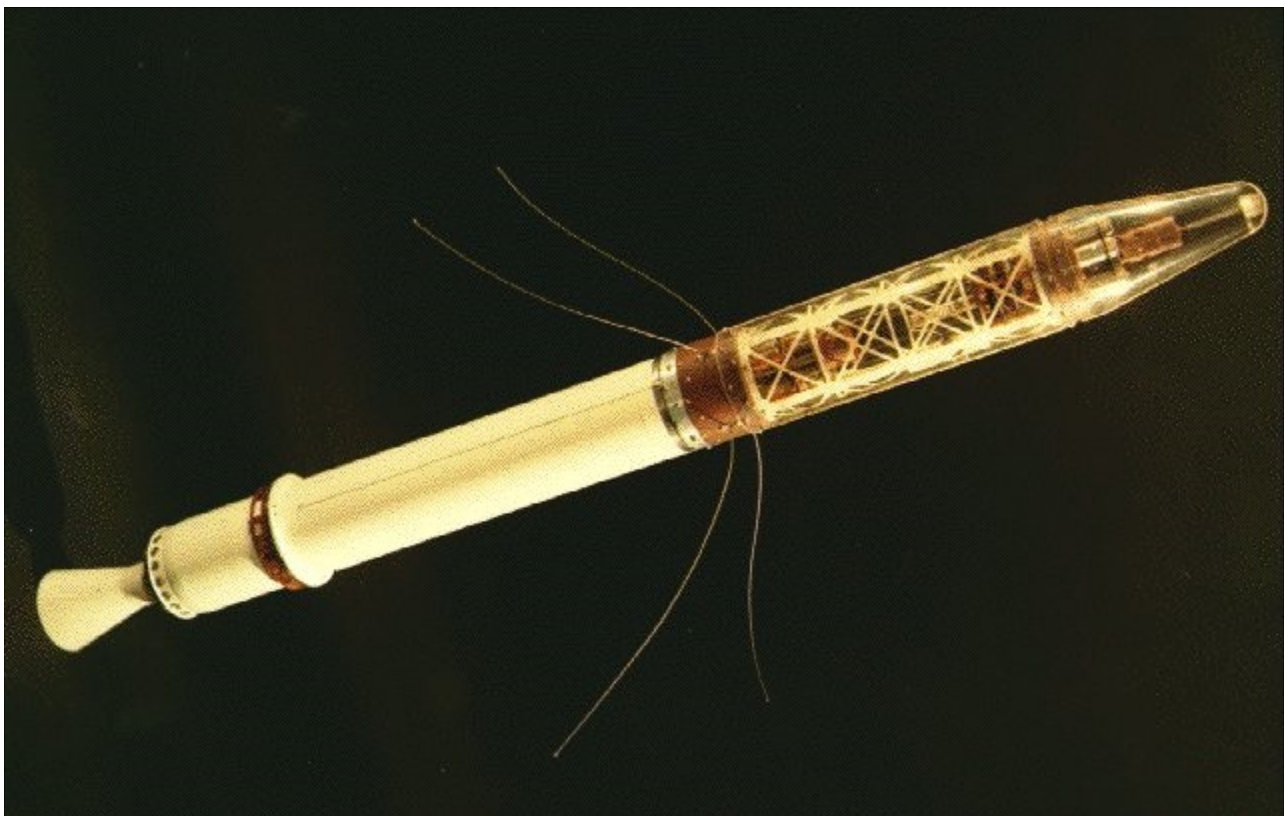




Experimental Package on the Aerobee rocket launch of June 1962

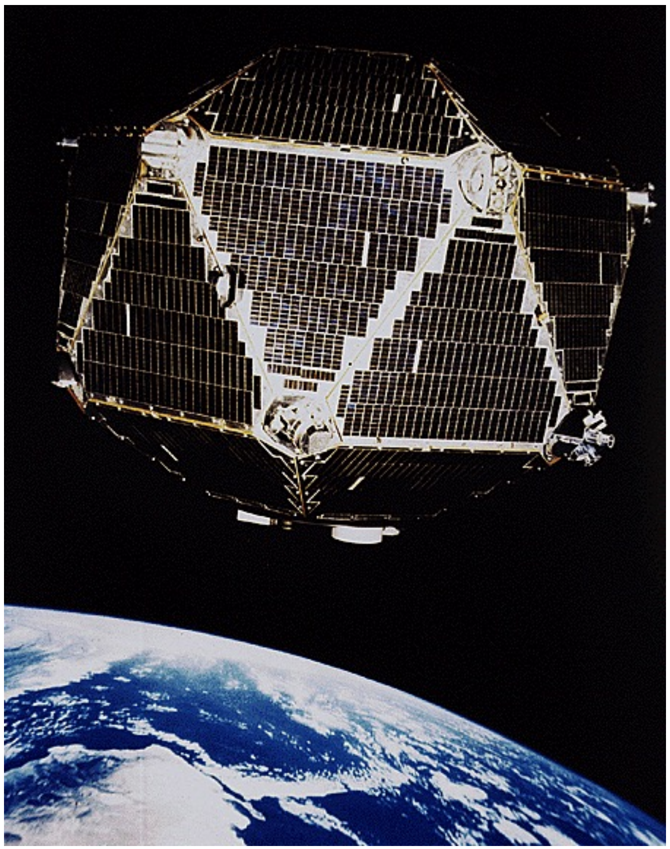
Beginnings of γ-ray Astronomy

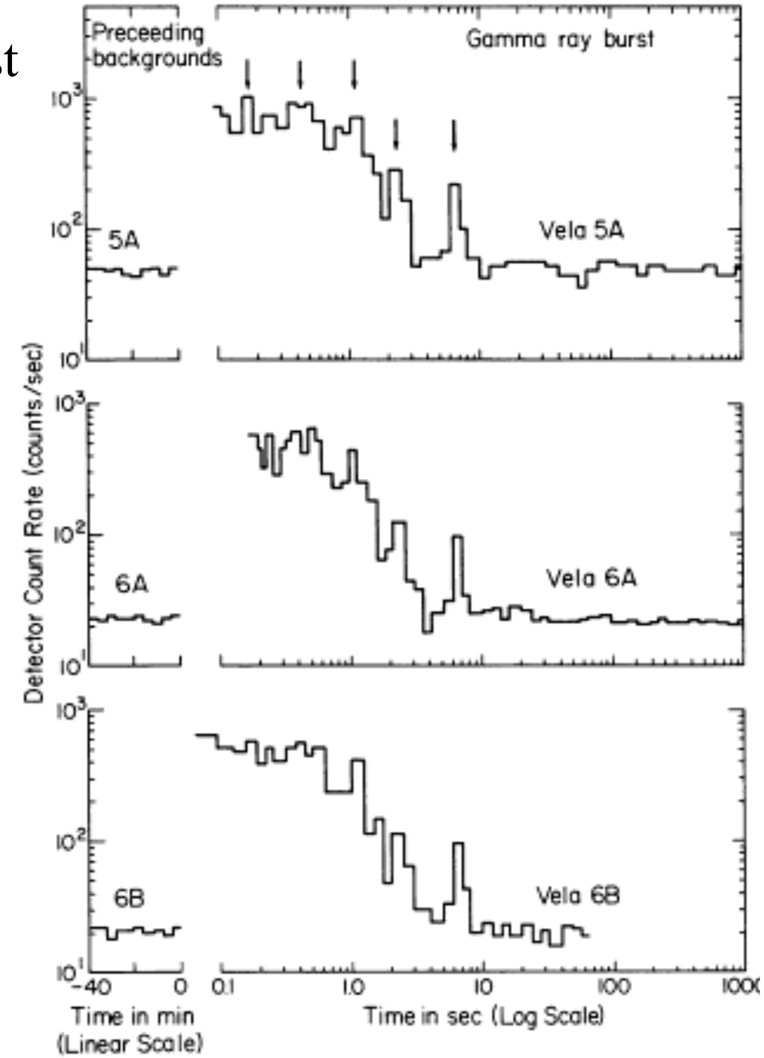
- The USA satellite program began with the Explorer series of satellites, with Explorer 1 launched in 1954.
- Explorer 11, launched in 1961, carried the first γ–ray telescope into space. During its 7-month lifespan, it detected a total of 22 γ–ray photons.



Beginnings of γ-ray Astronomy

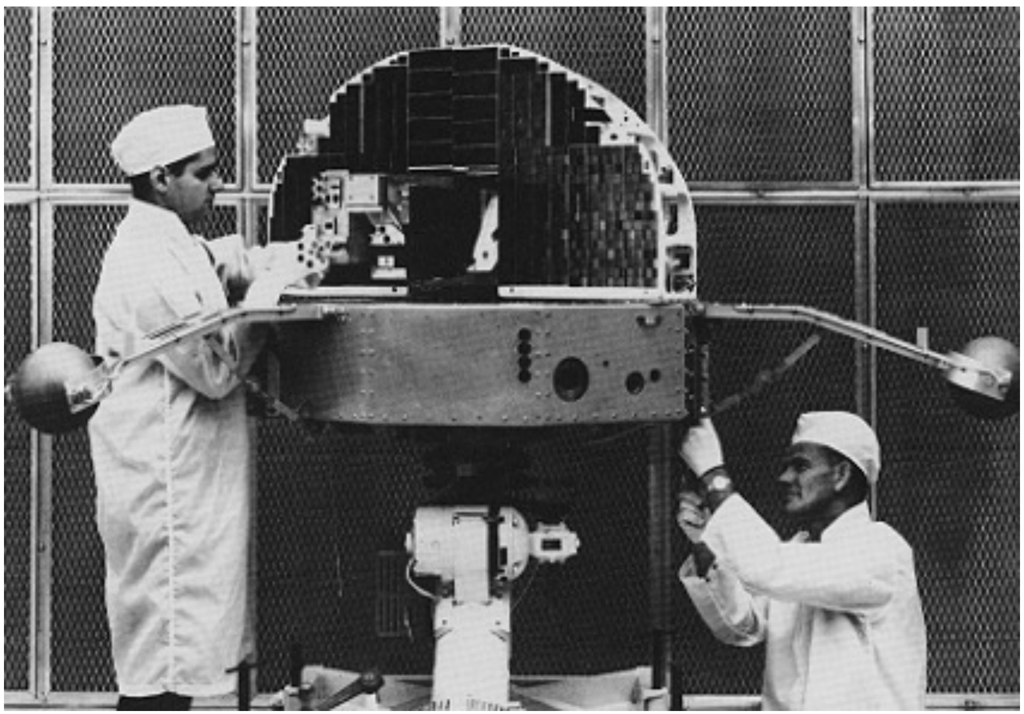
- Vela was the name of a group of satellites developed by the USA to monitor compliance with the 1963 Partial Test Ban Treaty by the Soviet Union and other nuclear-capable states. It means *vigil* or "watch" in Spanish.
- Serendipitously, the Vela satellites were the first devices ever to detect cosmic γ-ray bursts.





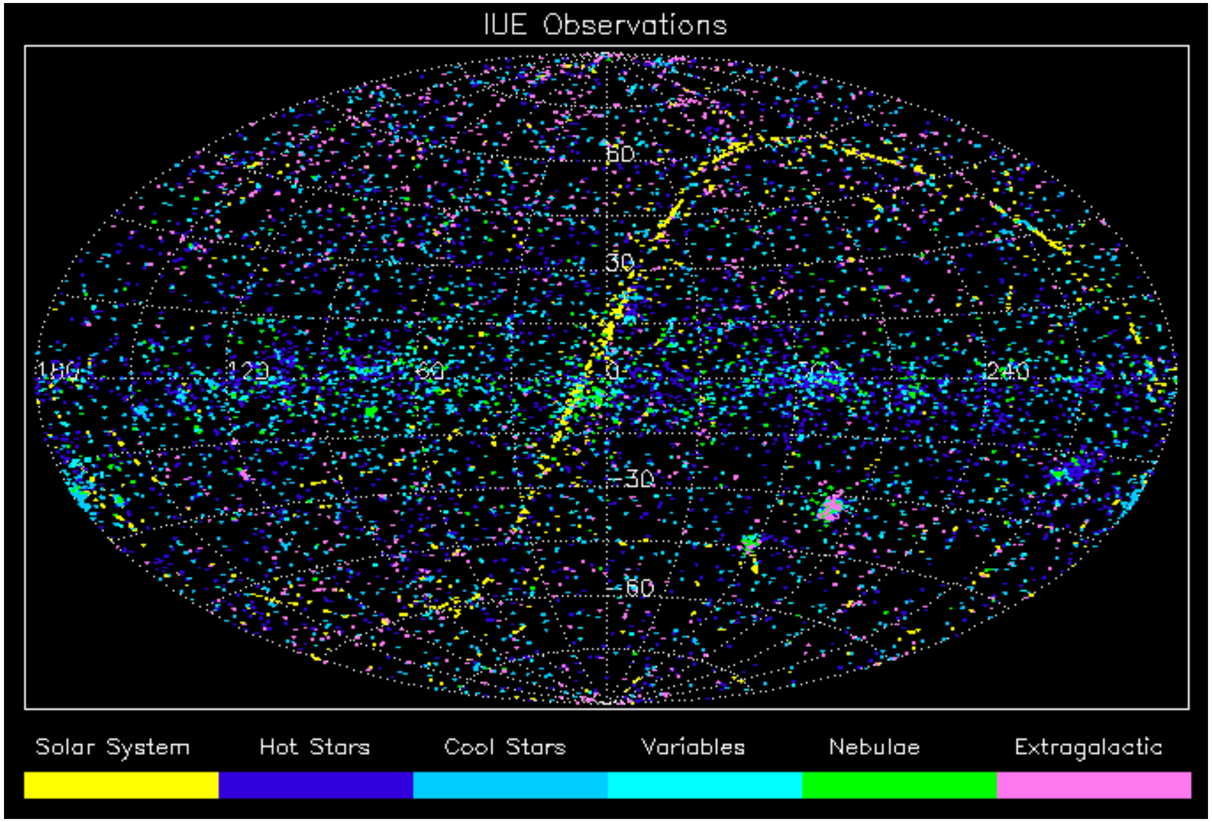
Beginnings of Ultraviolet Astronomy

- The Orbiting Solar Observatory (OSO) Program was a series of nine NASA satellites primarily intended to study the Sun. These satellites were launched between 1962 and 1975.



Beginnings of Ultraviolet Astronomy

- The International Ultraviolet Explorer (IUE), launched in 1978, was designed to take ultraviolet spectra. The original minimum mission lifetime was 3 years, but the satellite operated for nearly two decades before being switched off in 1996 for budgetary reasons while still functioning at near original efficiency.

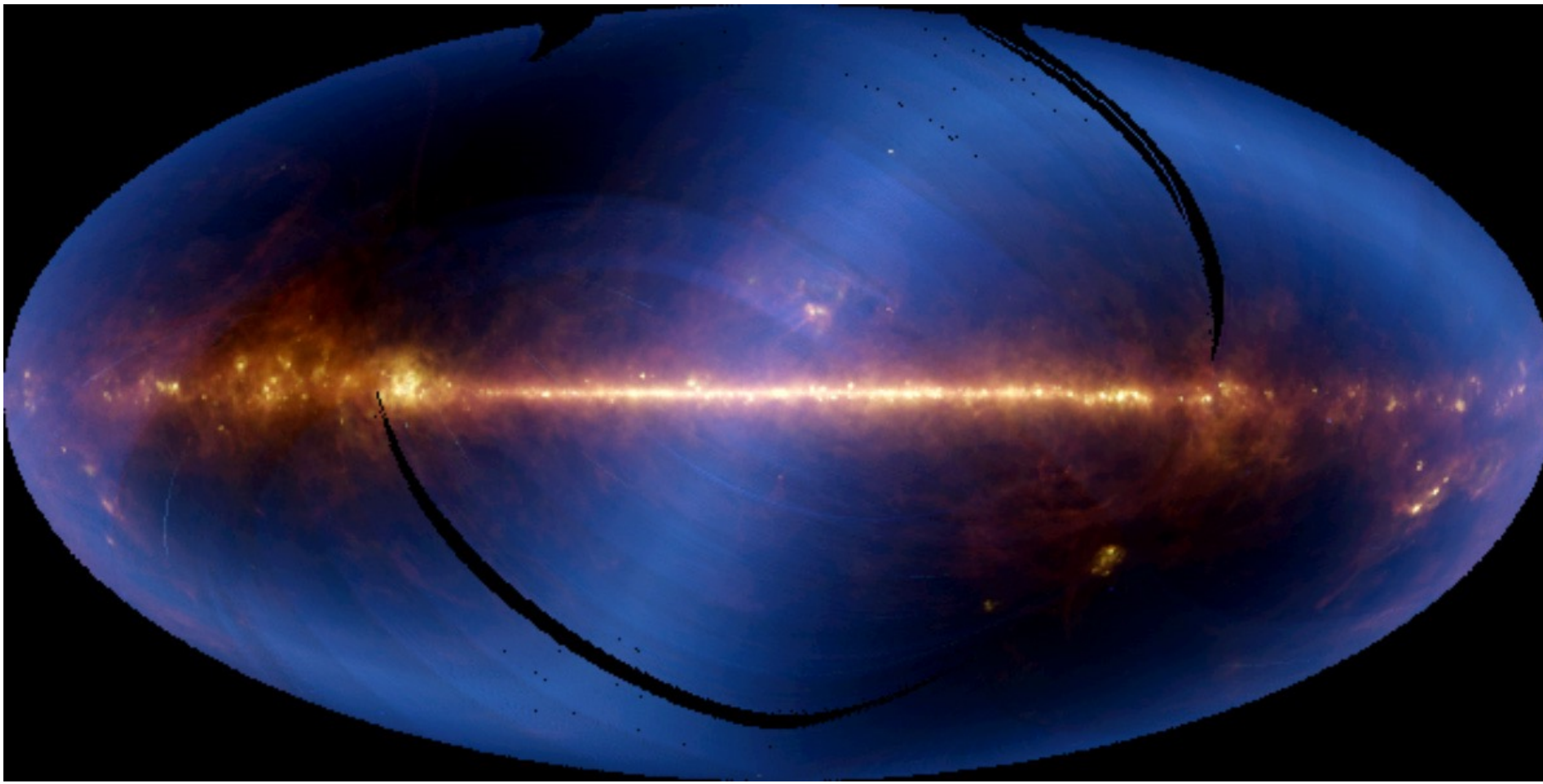


Infrared Astronomy

- Launched in 1983, the InfraRed Astronomial Satellite (IRAS) was the first infrared telescope in space.
- IRAS comprised a 60-cm telescope operating at 12, 25, 50, and 100 μm with a field of view of 63.6 arcmin and angular resolutions ranging from 25″ to 100″.
- IRAS made the first all-sky survey at infrared wavelengths.

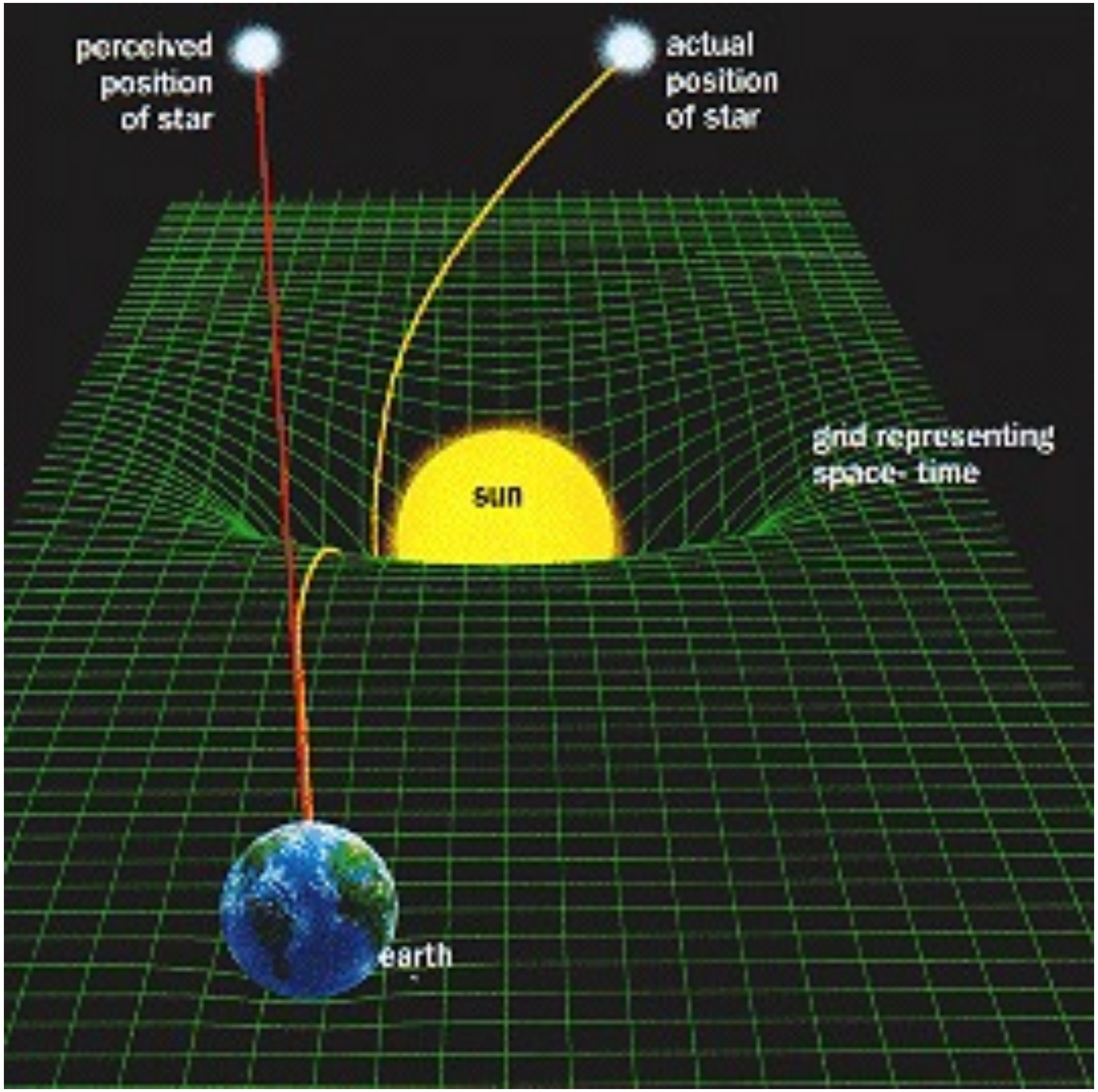
Infrared Astronomy

- IRAS all-sky image with emissions at 12 μm in blue, 60 μm in green, and 100 μm in red. Hazy horizontal S-shaped structure is zodiacal dust (in the plane of the Solar System). Black stripes are regions of the sky not scanned.



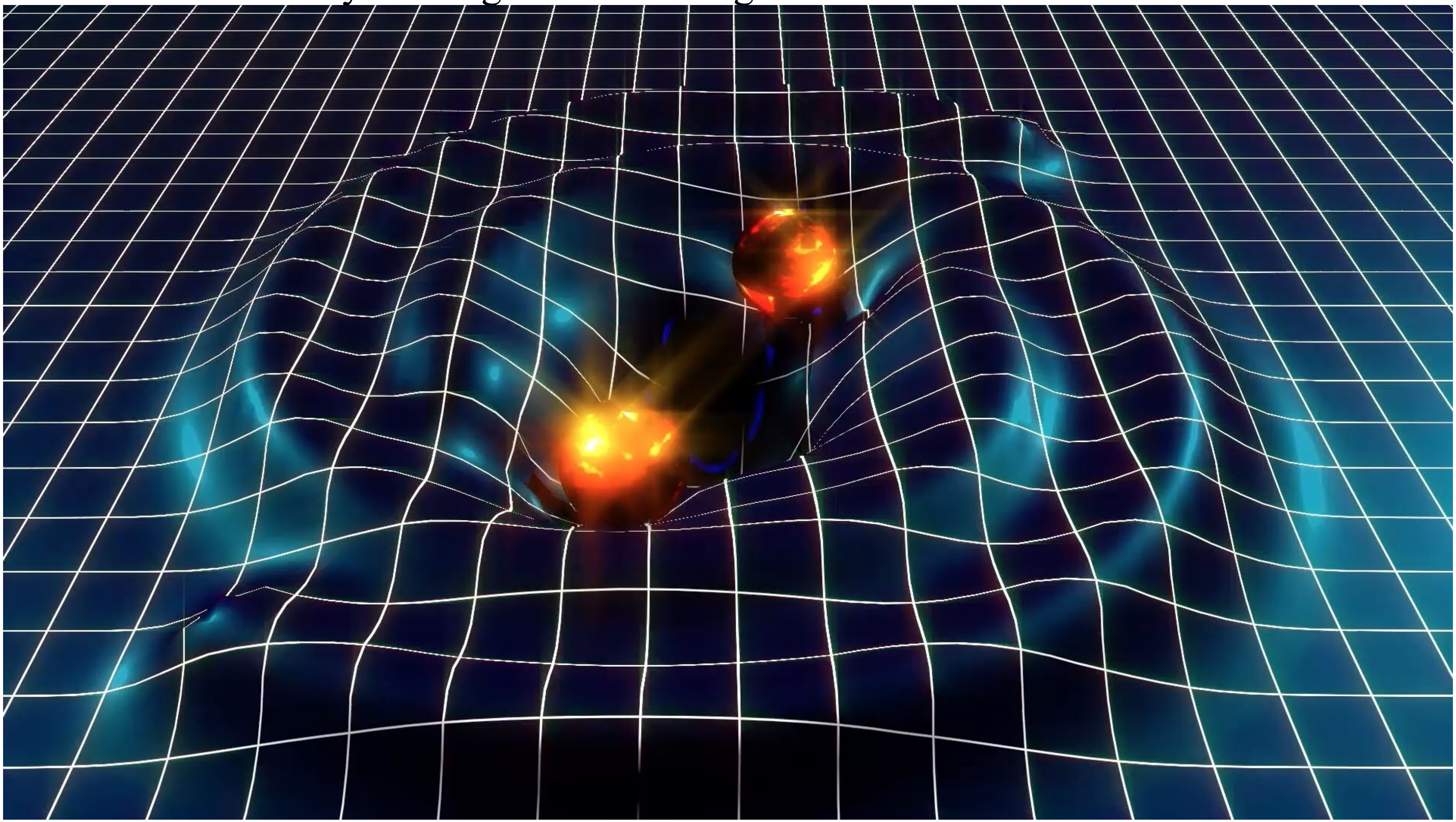
Gravitational Waves

- Gravitational waves are ripples in the curvature of spacetime that travel as waves, transporting energy as gravitational radiation.



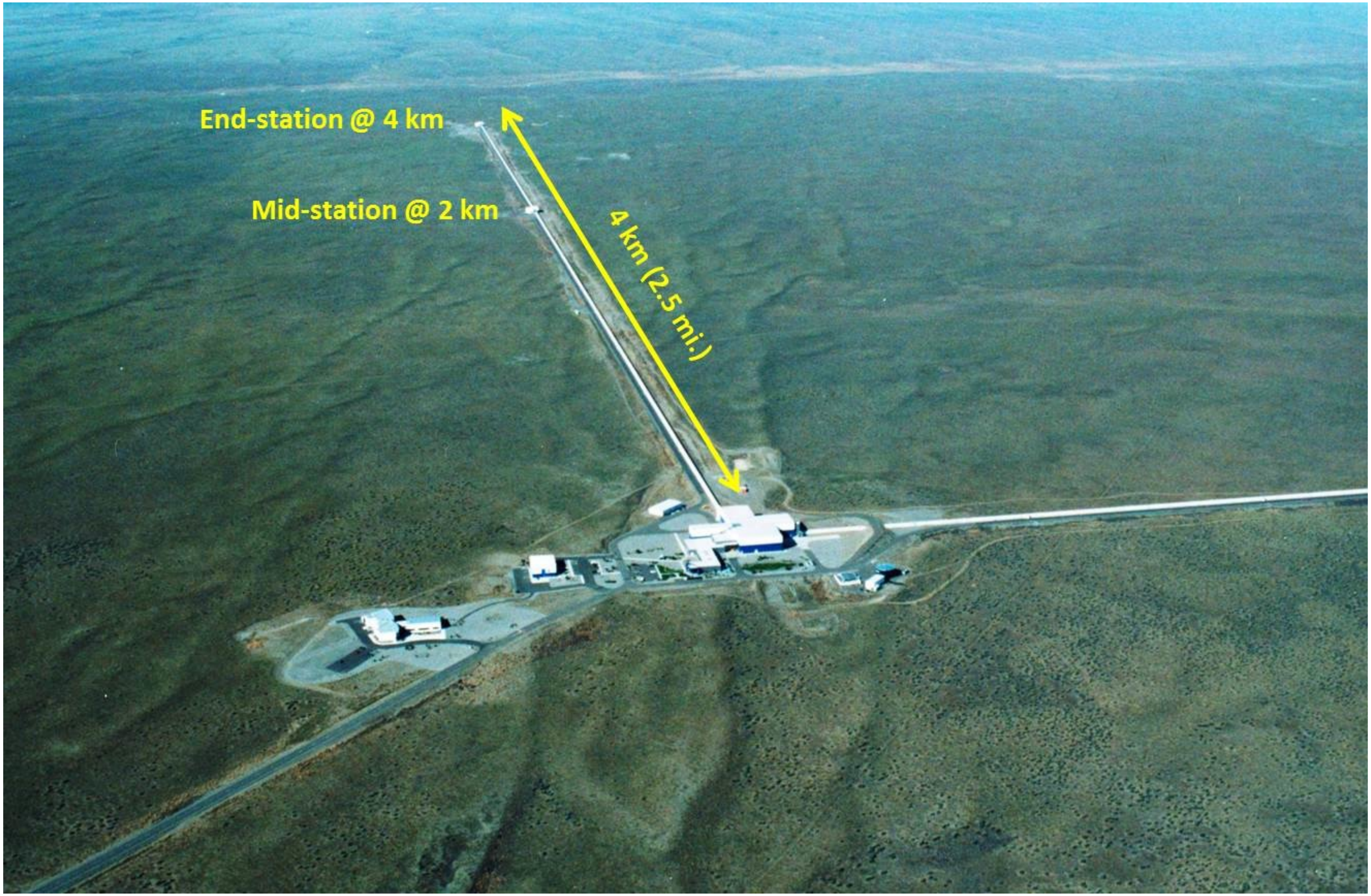
Gravitational Waves

- Gravitational waves are ripples in the curvature of spacetime that travel as waves, transporting energy as gravitational radiation. Possible sources of gravitational waves are closely orbiting and coalescing neutron stars and black holes.



Gravitational Waves

◆ Gravitational waves were detected as small (~1/10000 size of proton) changes in arm lengths at the Laser Interferometer Gravitational-wave Observatory (LIGO).



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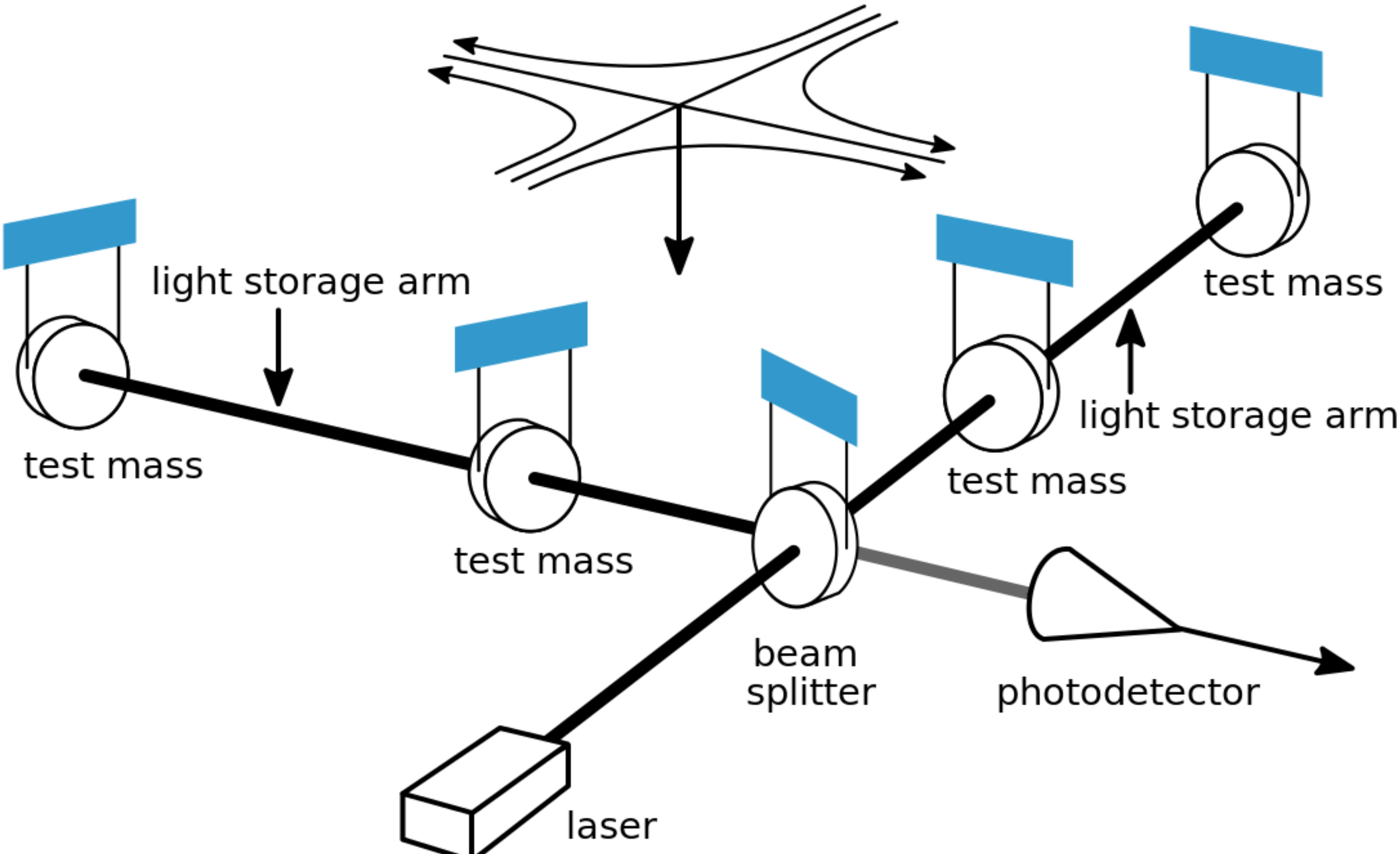
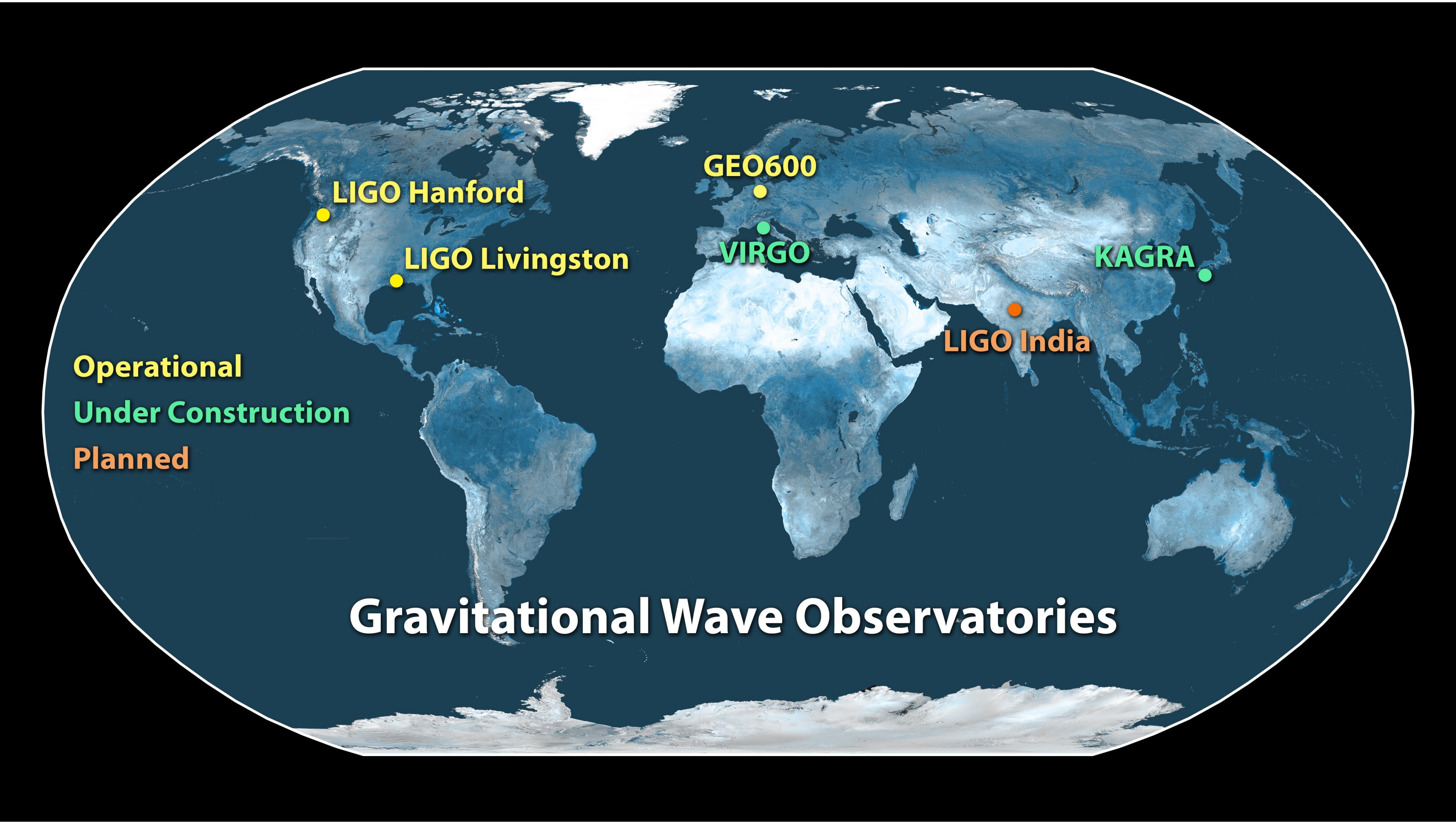


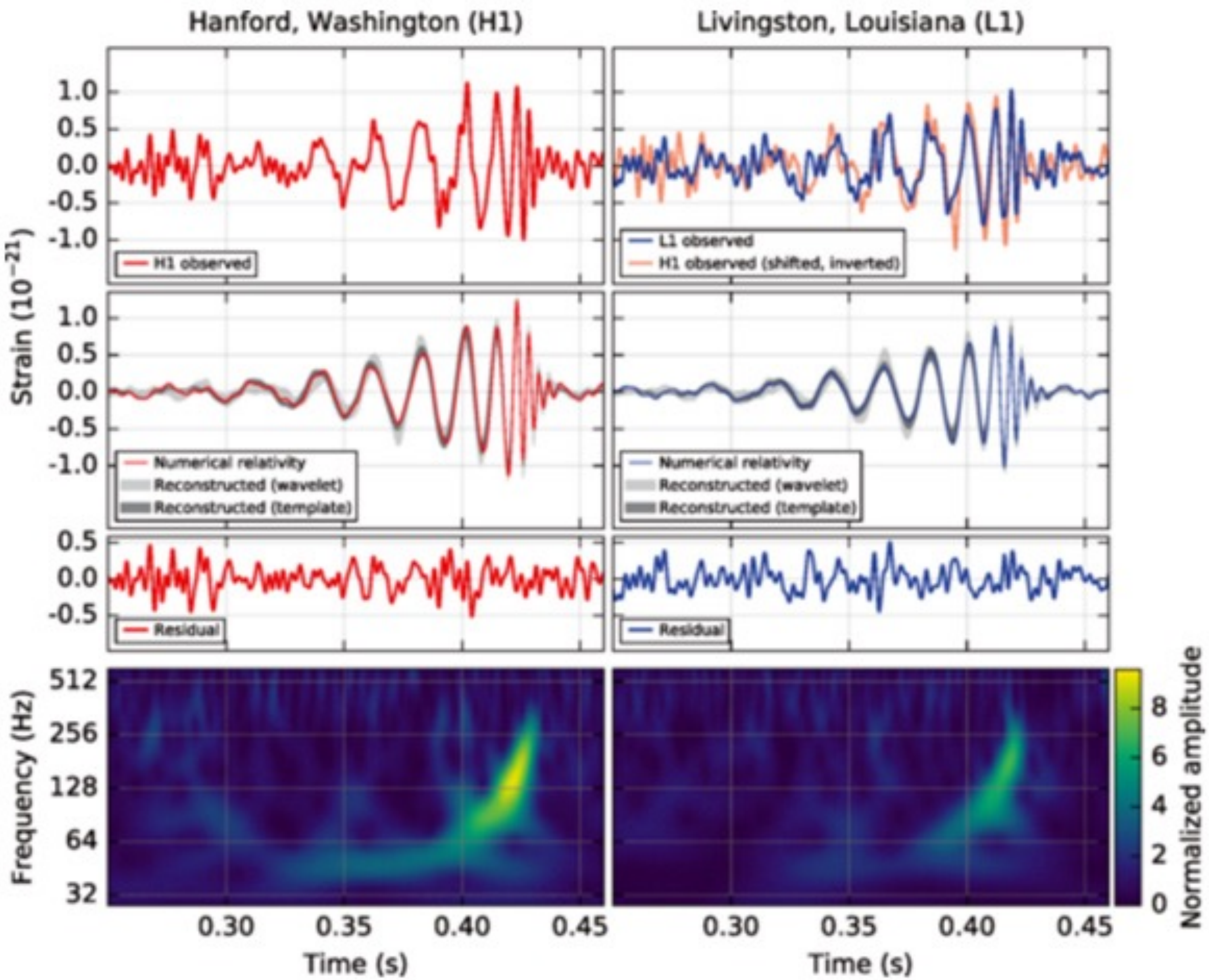
Gravitational Waves

- LIGO is located at Hanford, Washington, and Livingston, Louisiana.



Gravitational Waves

- First detected event (14 Sep 2015). Strain = $\Delta L/L$, where L is the arm length.



Gravitational Waves

- Sound corresponding to waveform of gravitational wave, first two animations at original frequency and next two animations at a higher frequency more audible to human ear, and then repeated.