

LABORATORIO DI TECNOLOGIE ASTRONOMICHE

CUPANI GUIDO, CRISTIANI STEFANO e CESCUTTI GABRIELE

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



Orario prossime lezioni

Oggi dalle 12 --> Cristiani

mer 1° Cescutti

ven 3 Cupani

mar 7 Cescutti

mer 8 Cristiani

ven 10 (empty)

mar 14 (empty)

mer 15 Cristiani

ven 17 Cupani

e dalla settimana successive (orario standard)

mar Cristiani

mer Cescutti

ven Cupani (probabile break in aprile)

Argomenti (mie) lezioni e esercitazioni

Intro su Astronomia Osservativa

Ottiche e Telescopi

Coordinate

Detectors (Cristiani)

Fotometria

Spettrometria

Osservazioni di stelle

Osservazioni di galassie (Cristiani)

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

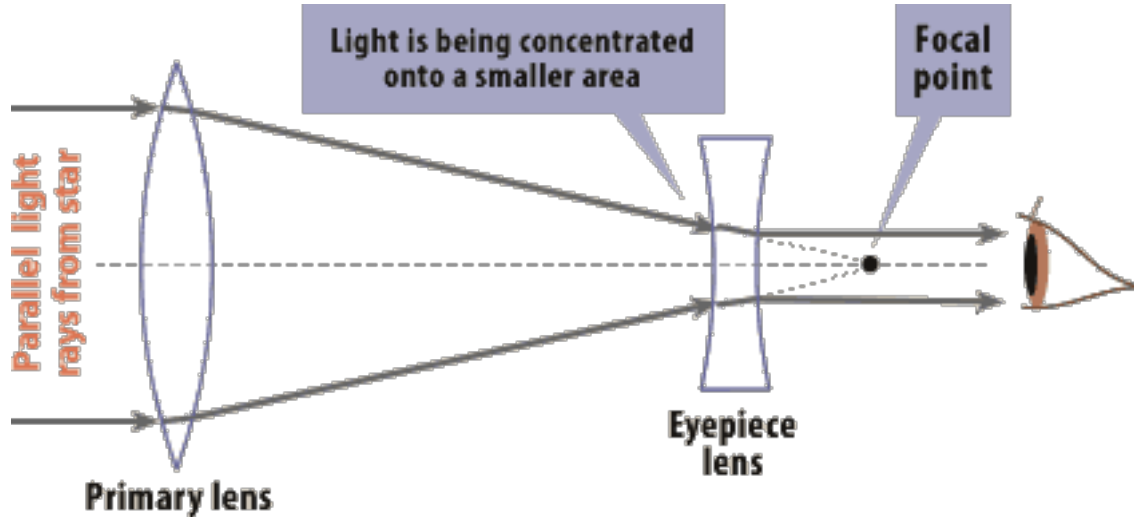


Galilei showing the Chief Magistrate of Venice how to use the telescope.

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?**

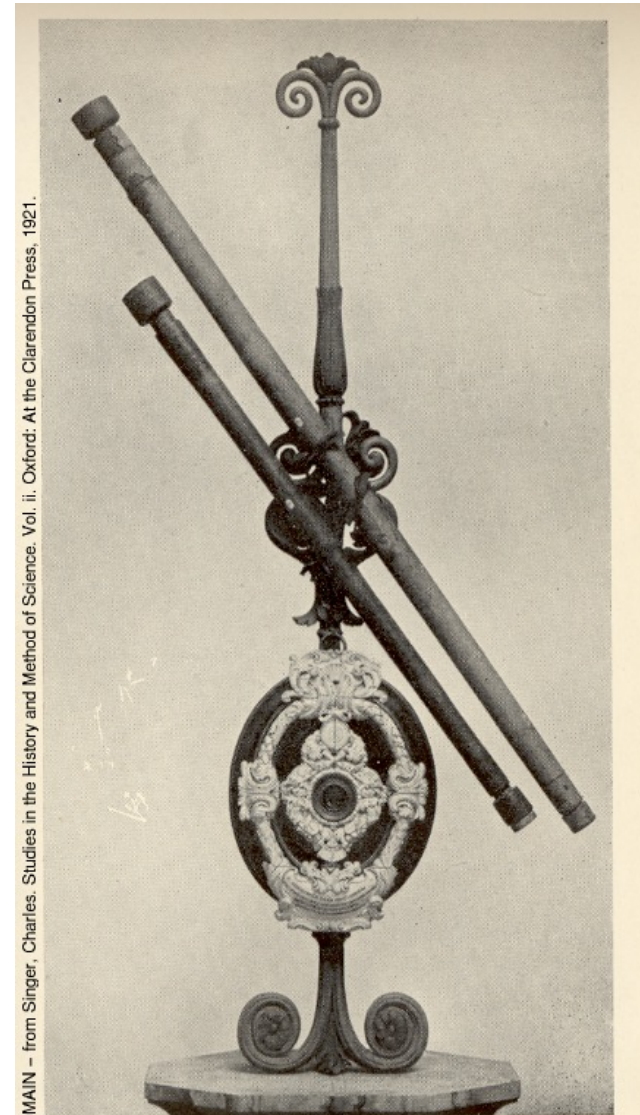
Galilean design



This **convex** spherical lens (called the primary lens) collected and concentrated the light ...

... and this **concave** eyepiece lens made the concentrated light rays parallel again.

PUBLIC DOMAIN – from Singer, Charles. Studies in the History and Method of Science. Vol. ii. Oxford: At the Clarendon Press, 1921.



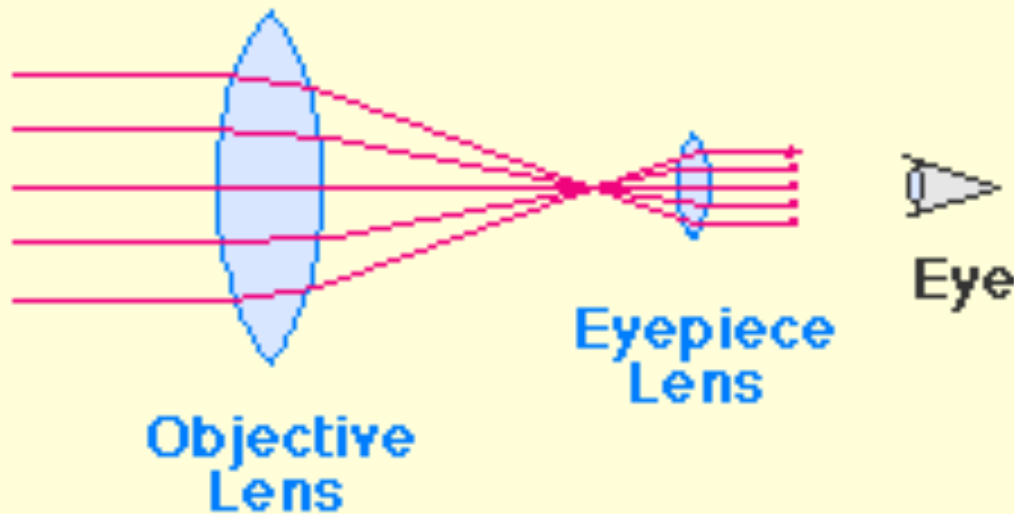
Galileo's Telescopes
The cracked lens is mounted in centre

Beginnings of Modern Observational Astronomy

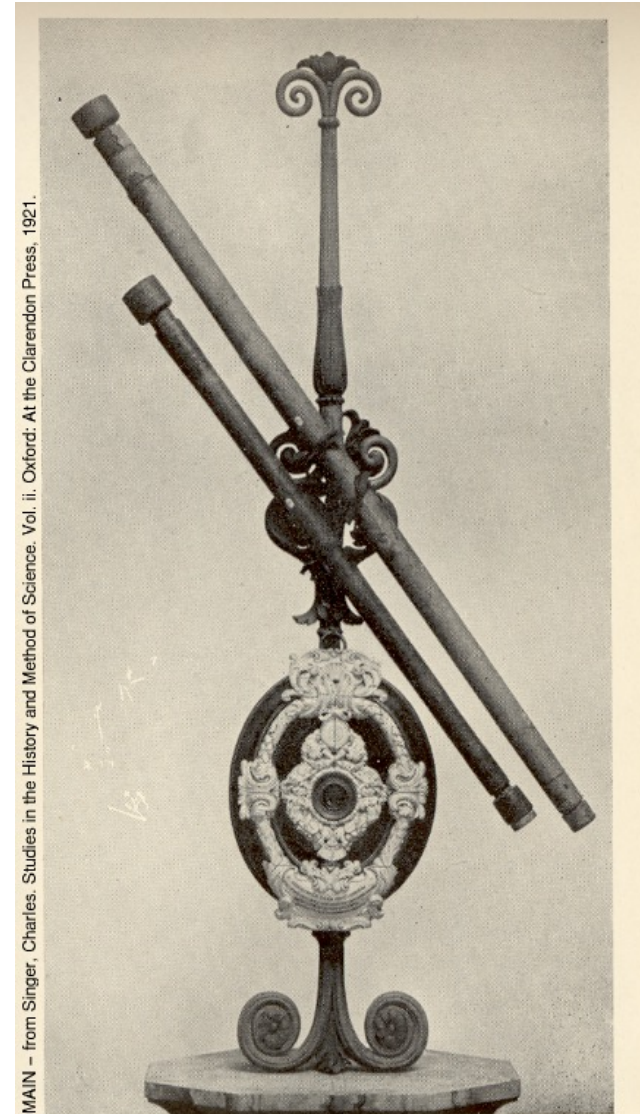
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Modern design

Refracting Telescope



PUBLIC DOMAIN – from Singer, Charles. Studies in the History and Method of Science. Vol. ii. Oxford: At the Clarendon Press, 1921.



Galileo's Telescopes
The cracked lens is mounted in centre

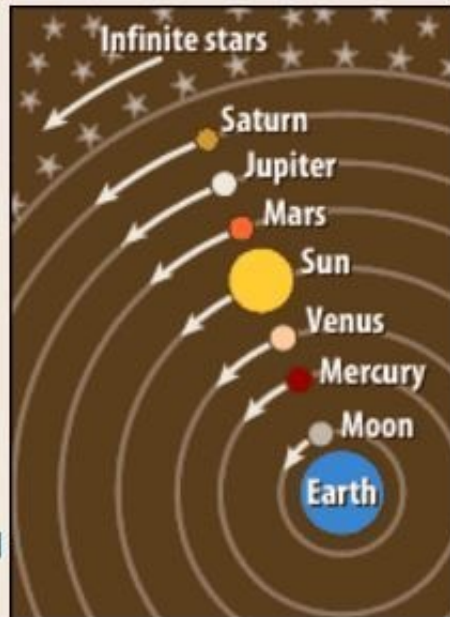
Beginnings of Modern Observational Astronomy

- ◆ 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.

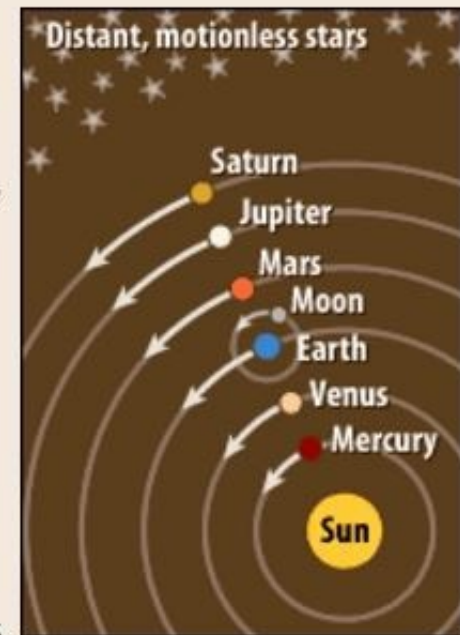
NOTE: The outer planets, like Uranus and Neptune, are missing from both charts because they had not been discovered at the time. The planets are lined up to make the charts easy to read; they never line up this way in nature.



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

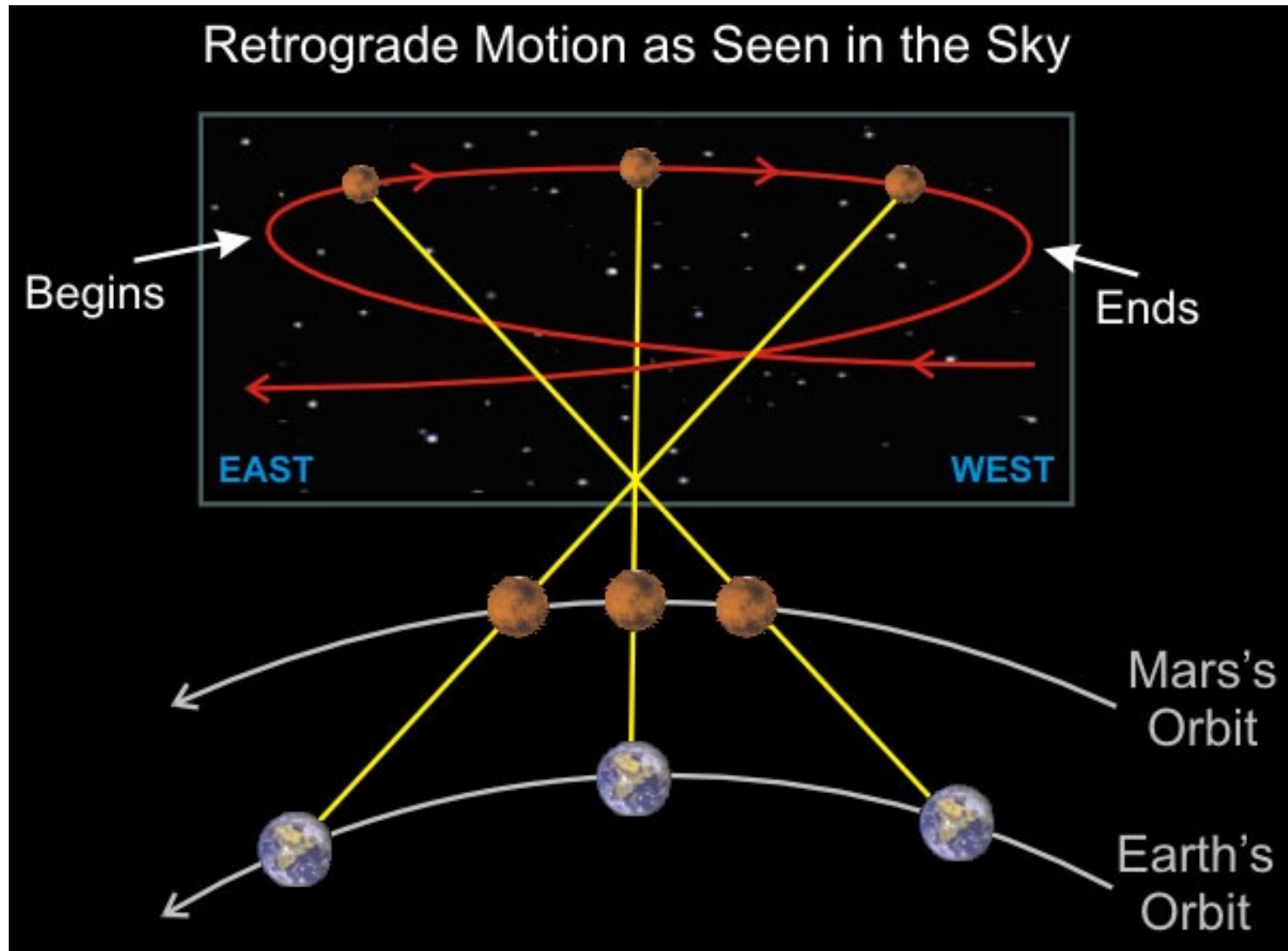
Copernicus thought that the planets orbited the Sun, and that the Moon orbited Earth. The Sun, in the center of the universe, did not move, nor did the stars.

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.



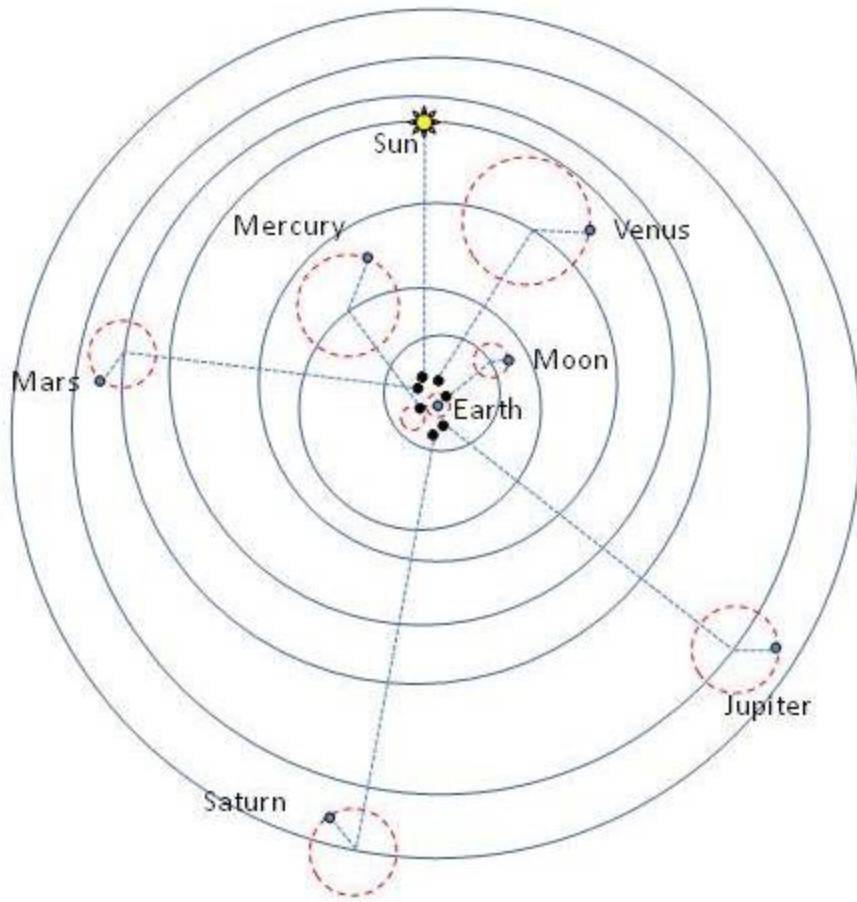
Beginnings of Modern Observational Astronomy

- ◆ How to explain retrograde motion in the Ptolemaic universe?

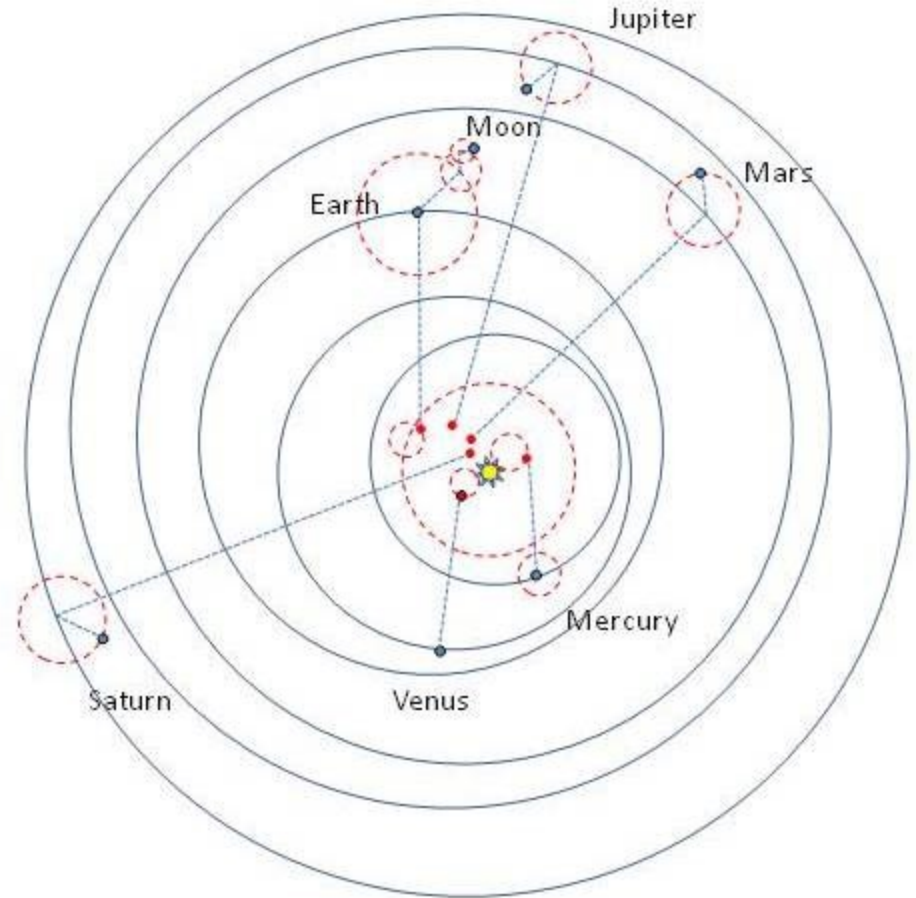


Beginnings of Modern Observational Astronomy

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



Ptolemaic Model



Copernican Model

Beginnings of Modern Observational Astronomy

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



Beginnings of Modern Observational Astronomy

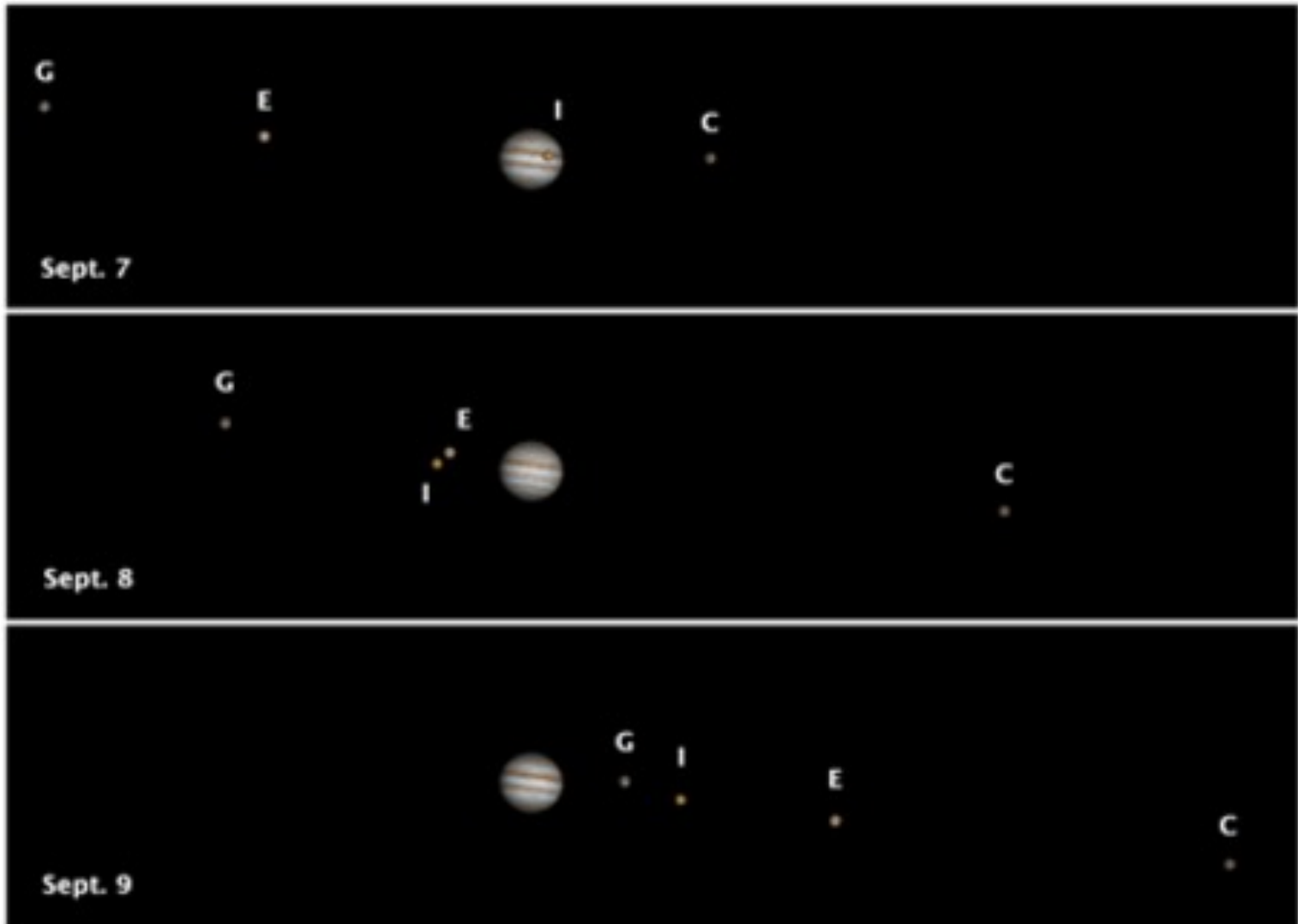
- ◆ Galileo discovered the four largest moons of Jupiter; i.e., heavenly bodies that revolved around Jupiter.

Moons of Jupiter



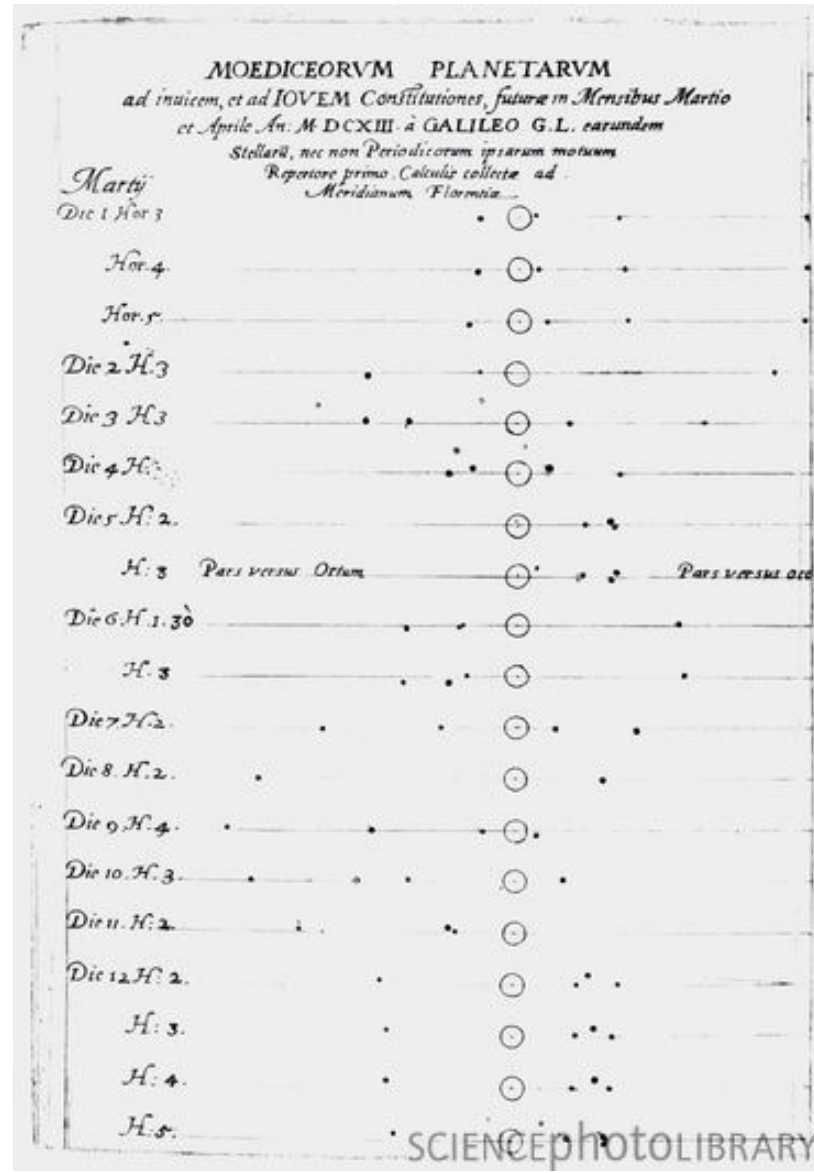
Beginnings of Modern Observational Astronomy

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Beginnings of Modern Observational Astronomy

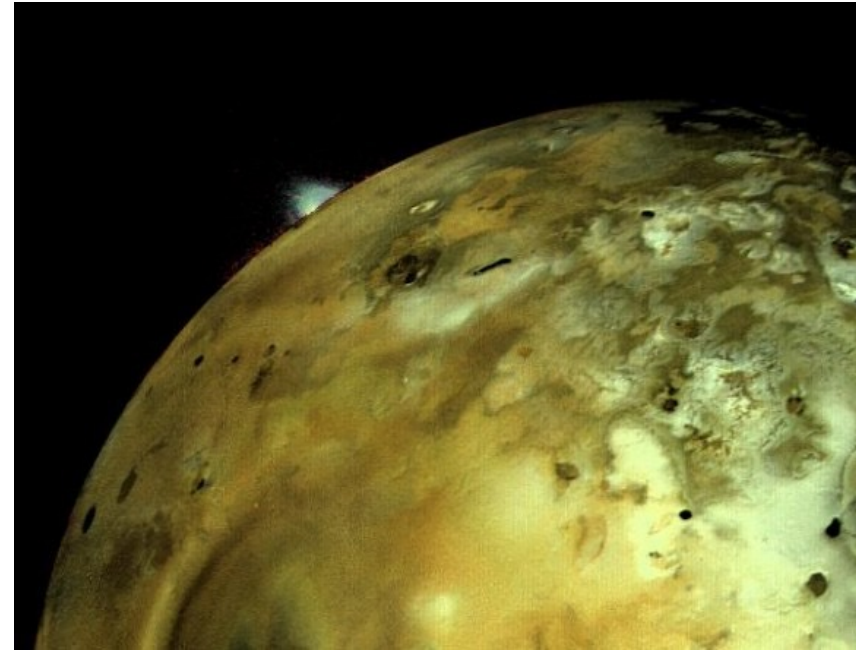
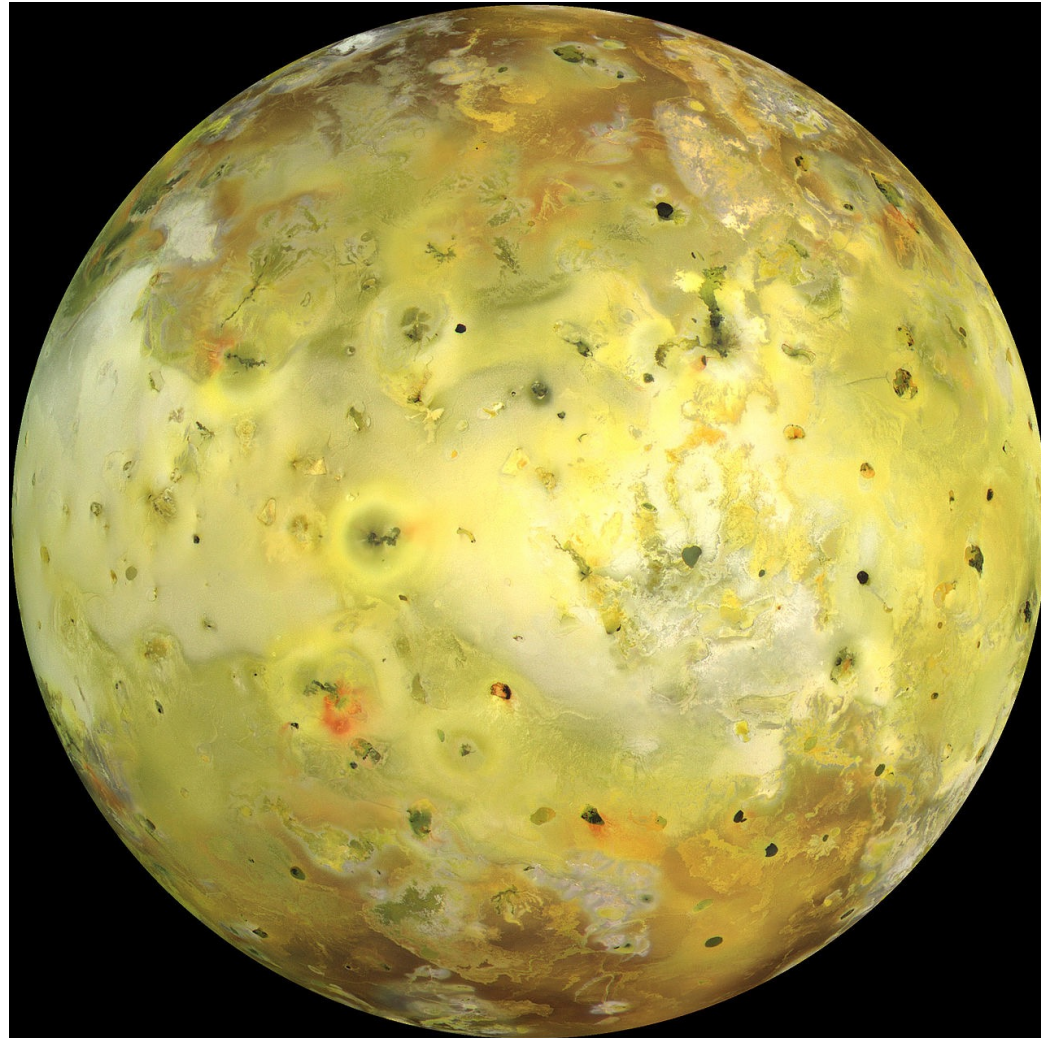
- ◆ Galileo's written record of his discovery of Jupiter's moons. In Latin, Die means day and Hora means hour.



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

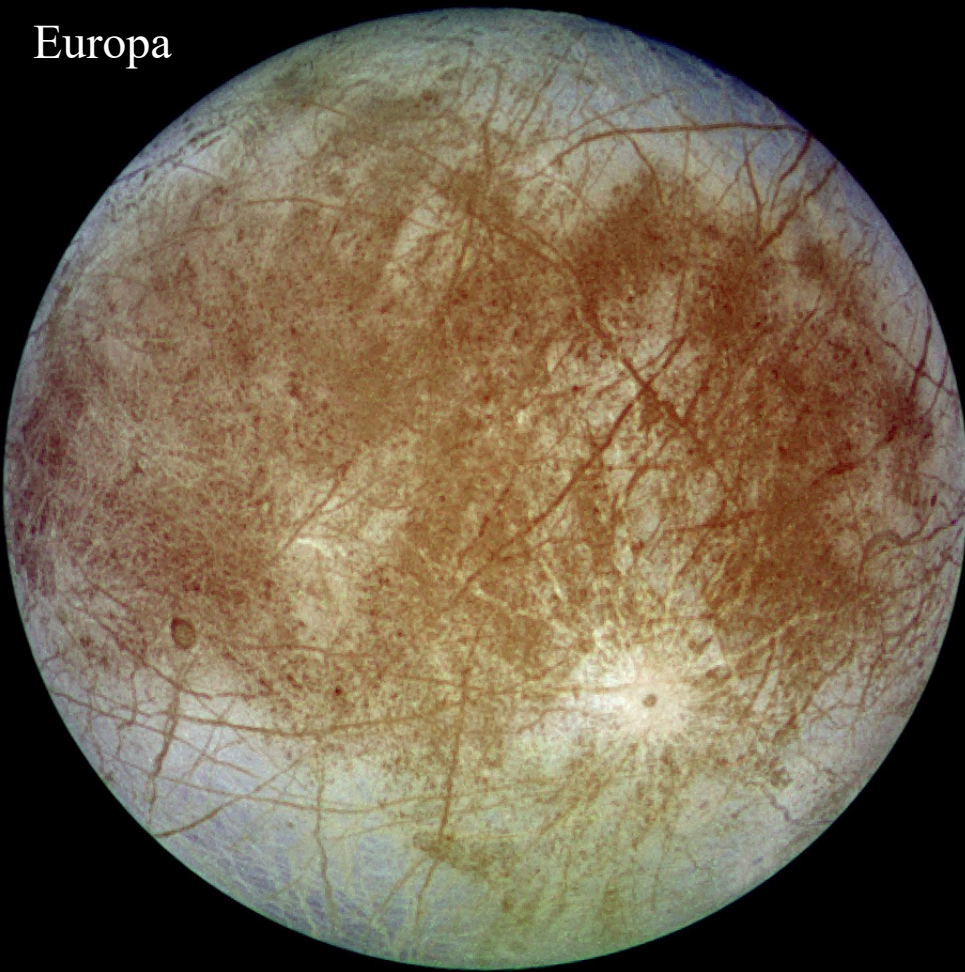


Voyager 1 acquired this image of Io on March 4, 1979. An enormous volcanic explosion can be seen silhouetted against dark space over Io's bright limb. Credit: NASA/JPL.

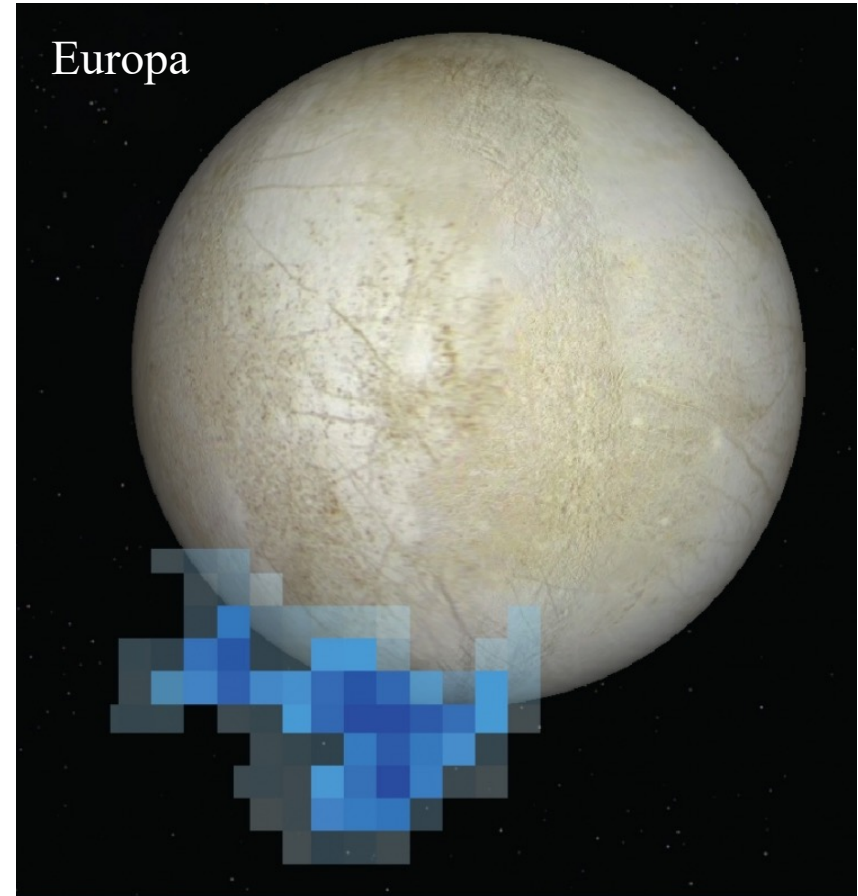
Beginnings of Modern Observational Astronomy

- ◆ 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.

Europa



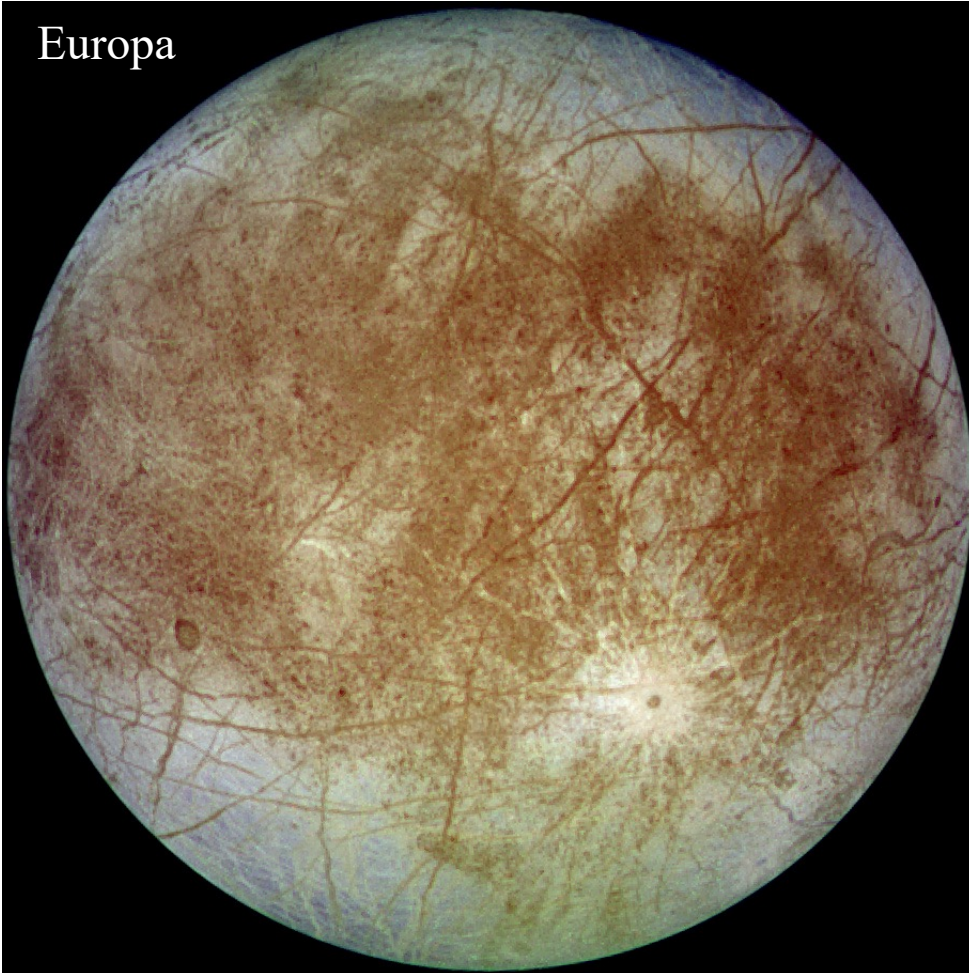
Europa



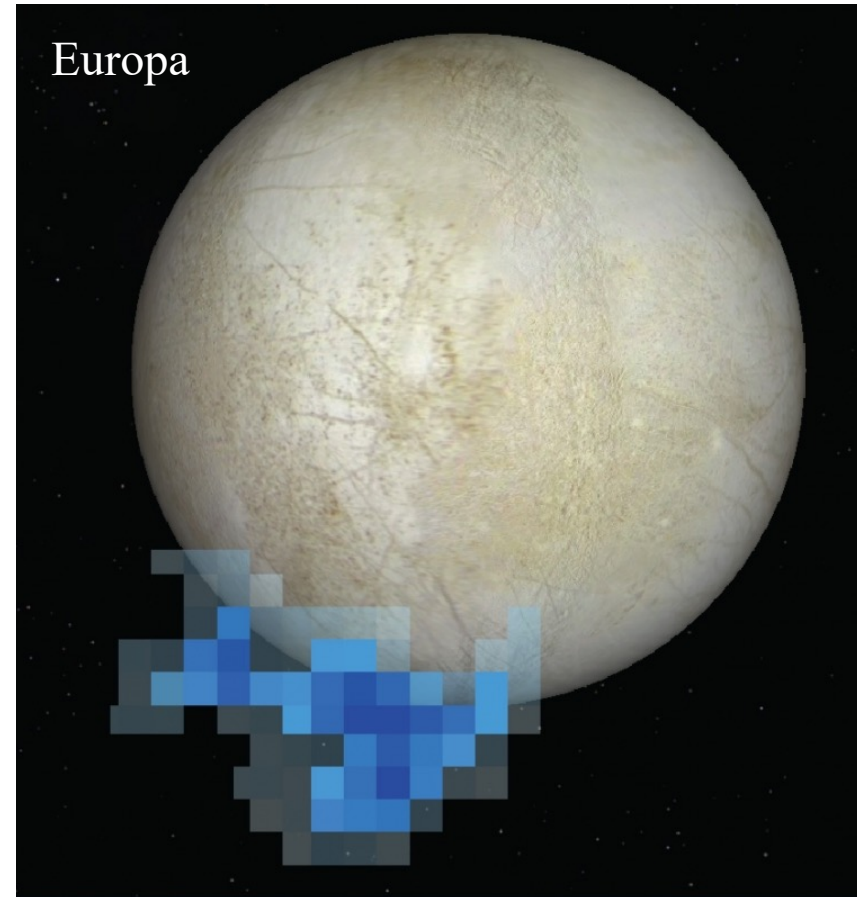
Beginnings of Modern Observational Astronomy

- ◆ 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.

Europa



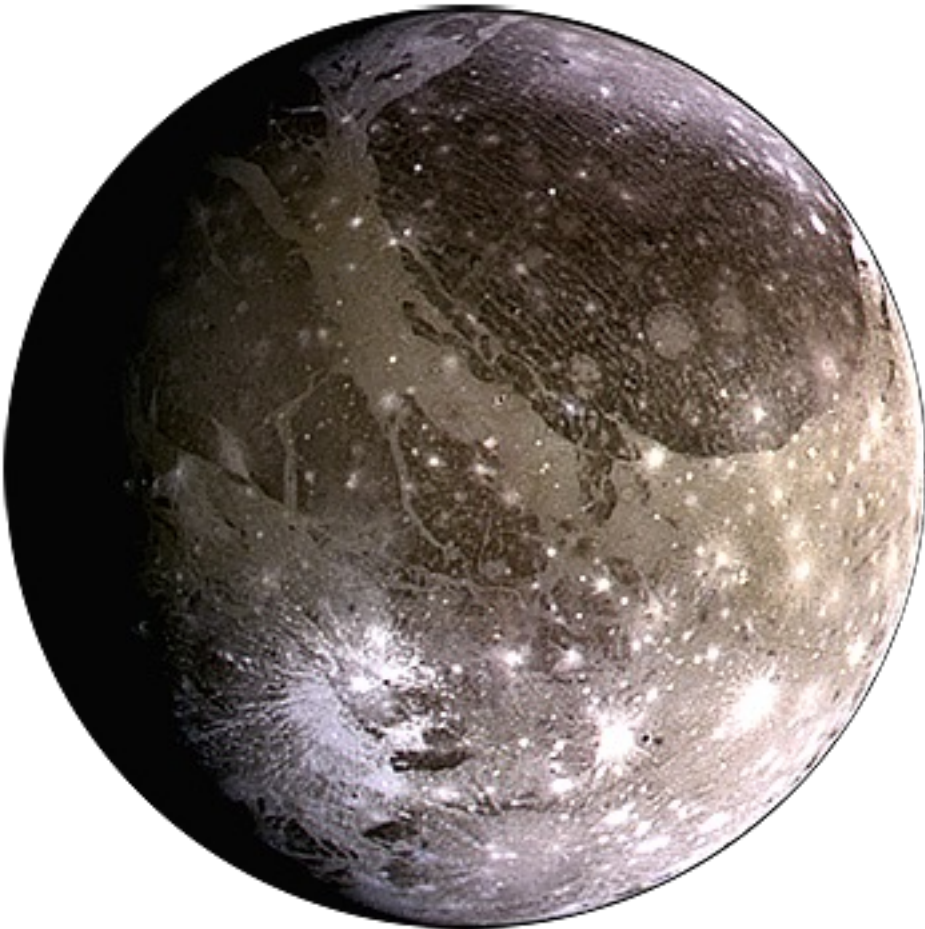
Europa



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

Apparent magnitude of Jupiter's moons during opposition

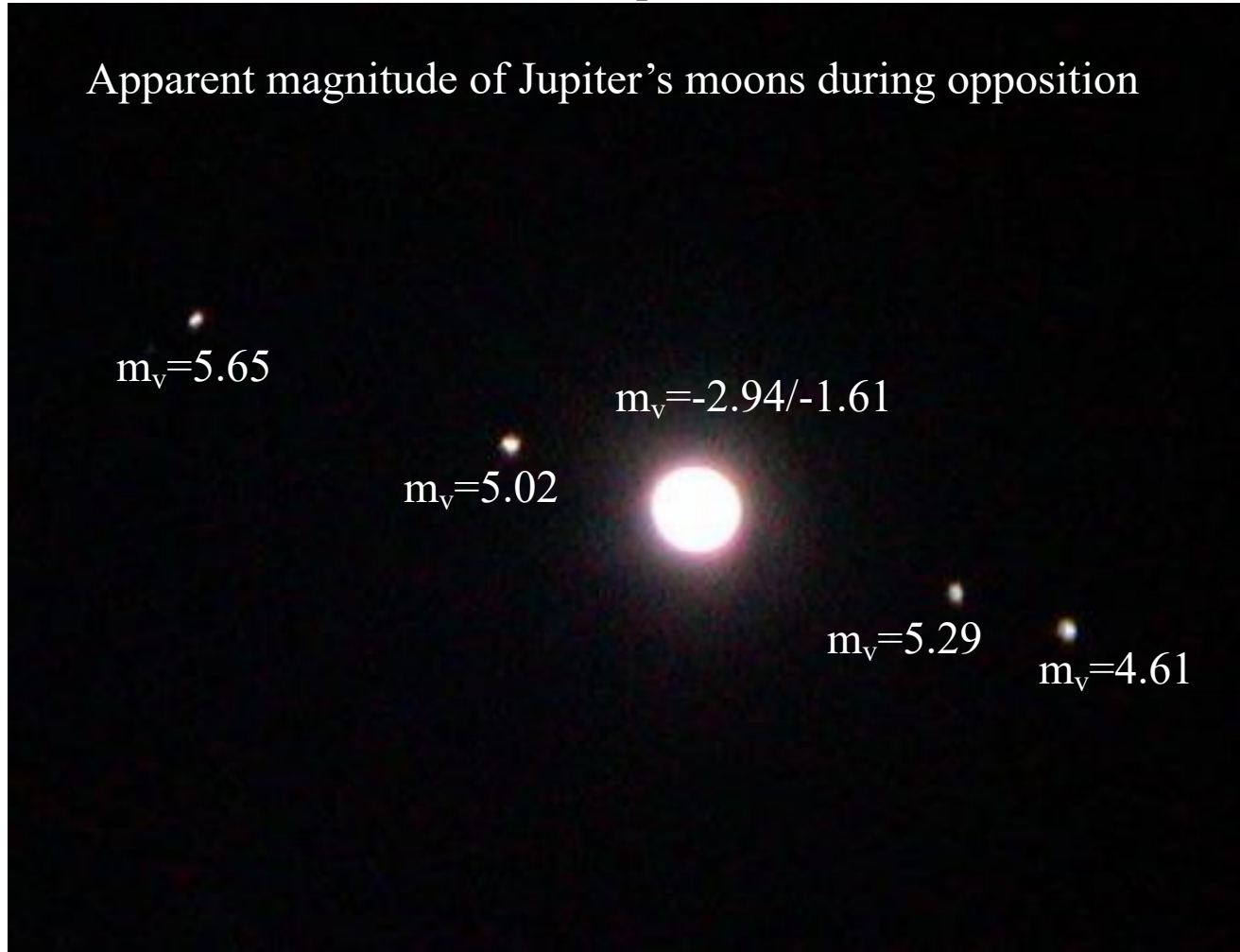
$m_v=5.65$

$m_v=-2.94/-1.61$

$m_v=5.02$

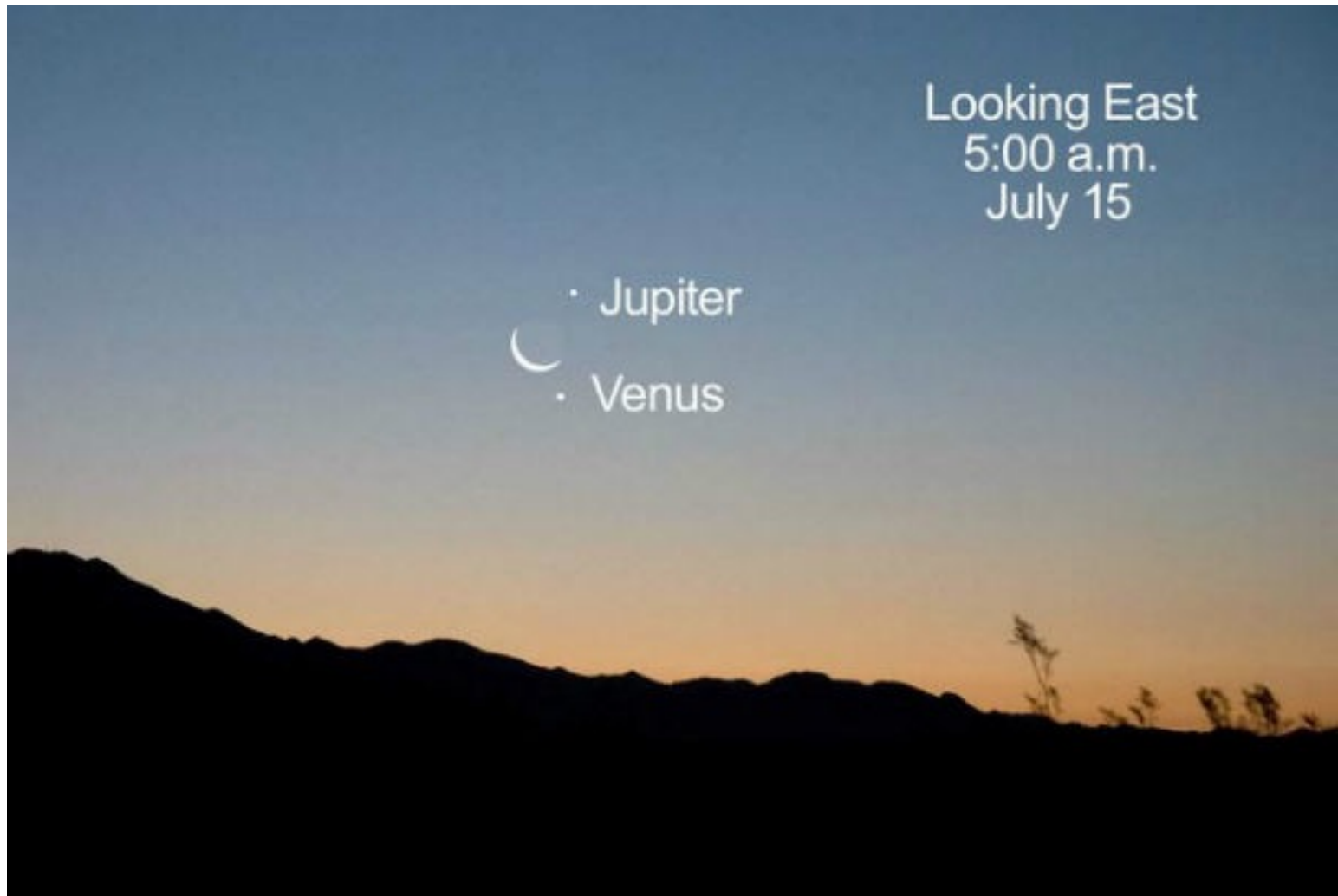
$m_v=5.29$

$m_v=4.61$



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.

Phases of Venus January thru May 2012

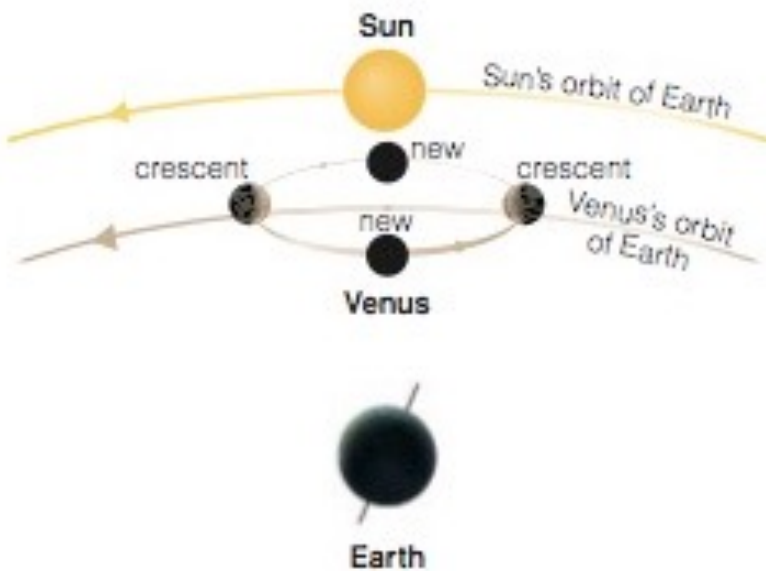


Jan. 17th	Mar. 08th	Mar. 19th	Apr. 11th	May 04th	May 12th	May 20th	May 23rd
78.4 % Ilum.	60.3 % Ilum.	55.0 % Ilum.	41.6 % Ilum.	23.4 % Ilum.	16.8 % Ilum.	7.8 % Ilum.	5.9 % Ilum.
Diam. 13.97	Diam. 19.66	Diam. 21.79	Diam. 28.39	Diam. 39.88	Diam. 44.67	Diam. 51.09	Diam. 53.10

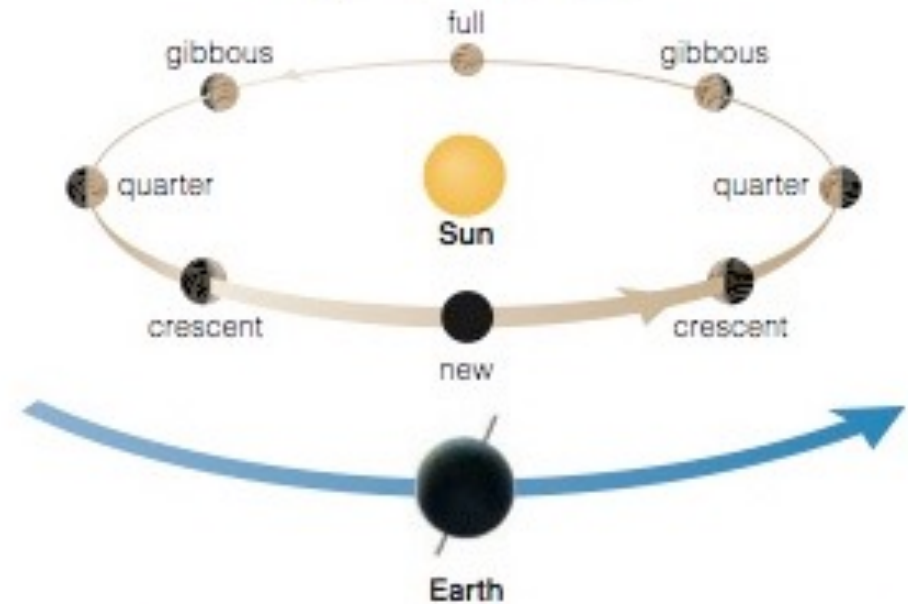
Beginnings of Modern Observational Astronomy

- ◆ 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 Ptolemaic view but supported the Copernican view of Venus? Assignment Question.**

Ptolemaic View of Venus

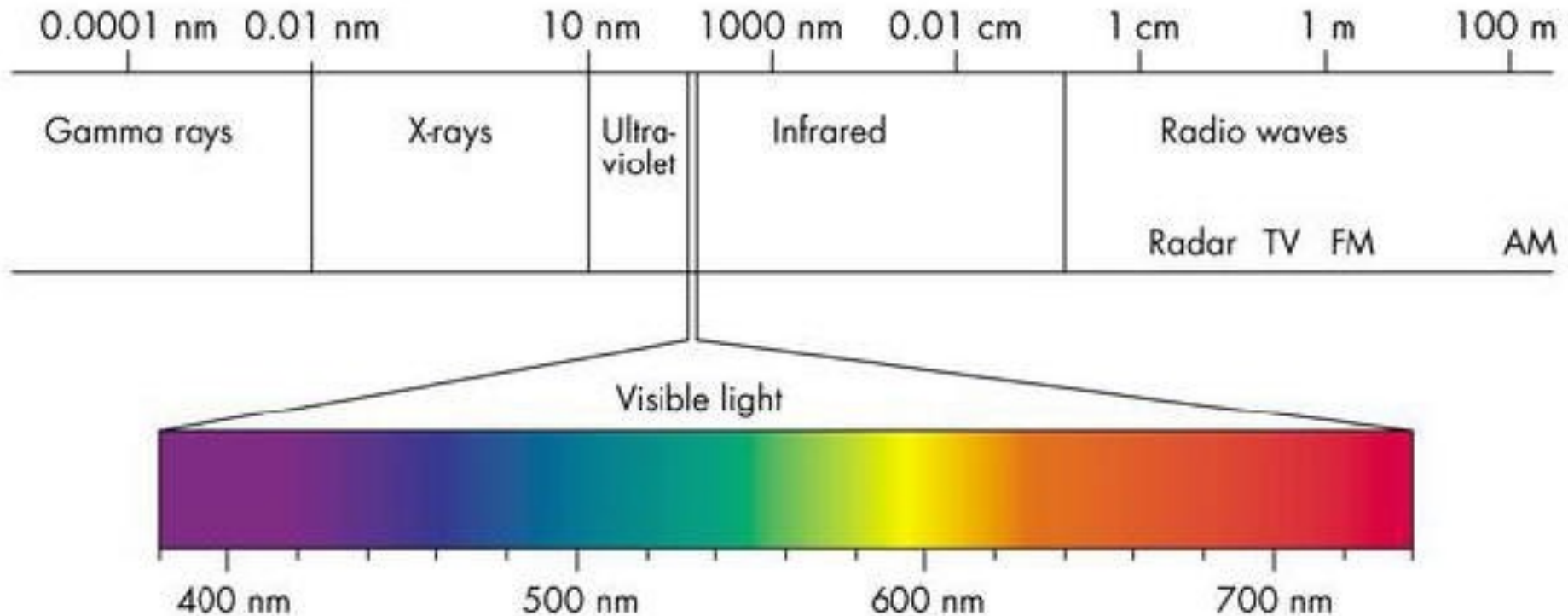


Copernican View of Venus



Beginnings of Modern Observational Astronomy

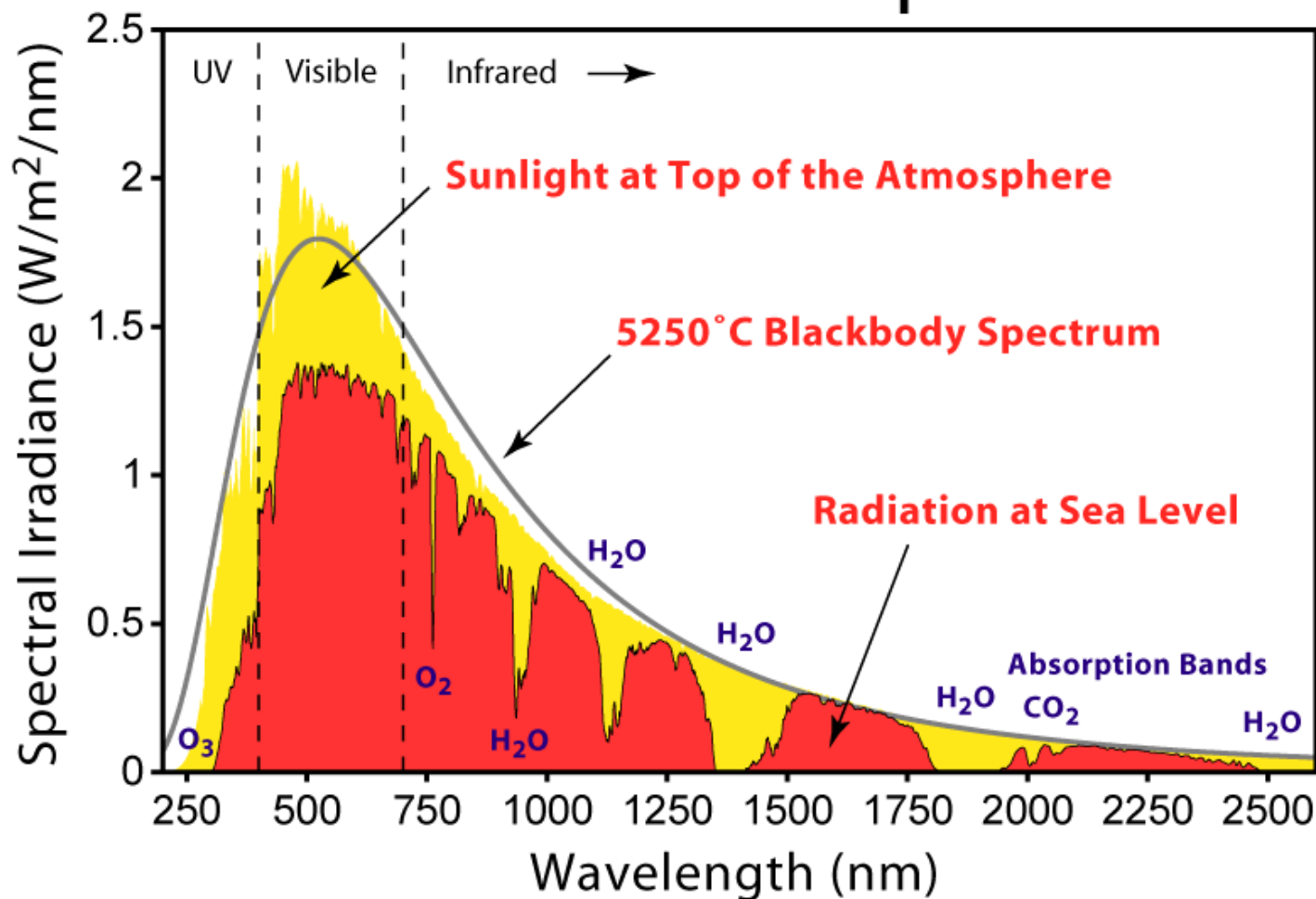
- ◆ Observational astronomy began at optical wavelengths because human eyes are adapted to function in optical light. **Why is that?**



Solar Radiation

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Solar Radiation Spectrum

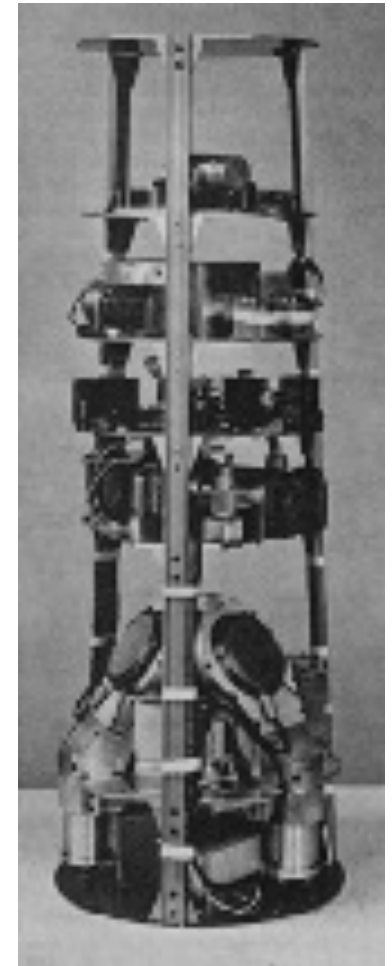
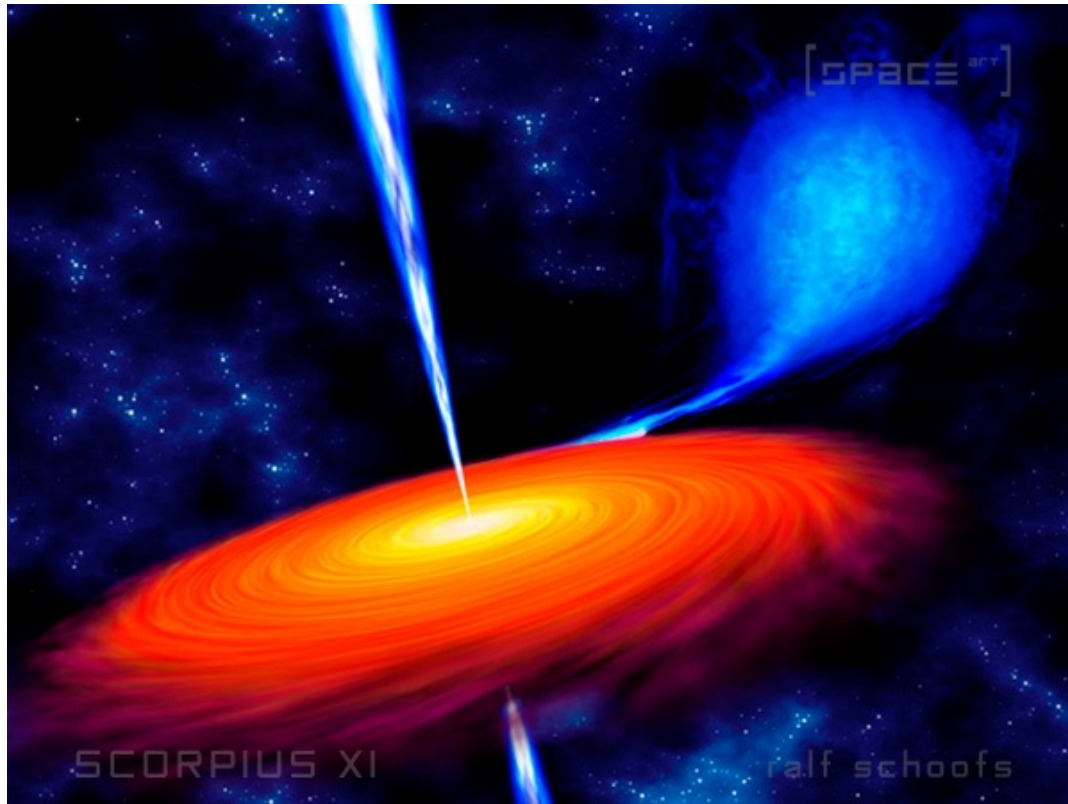


Learning Objectives

- ◆ 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 X-ray Astronomy

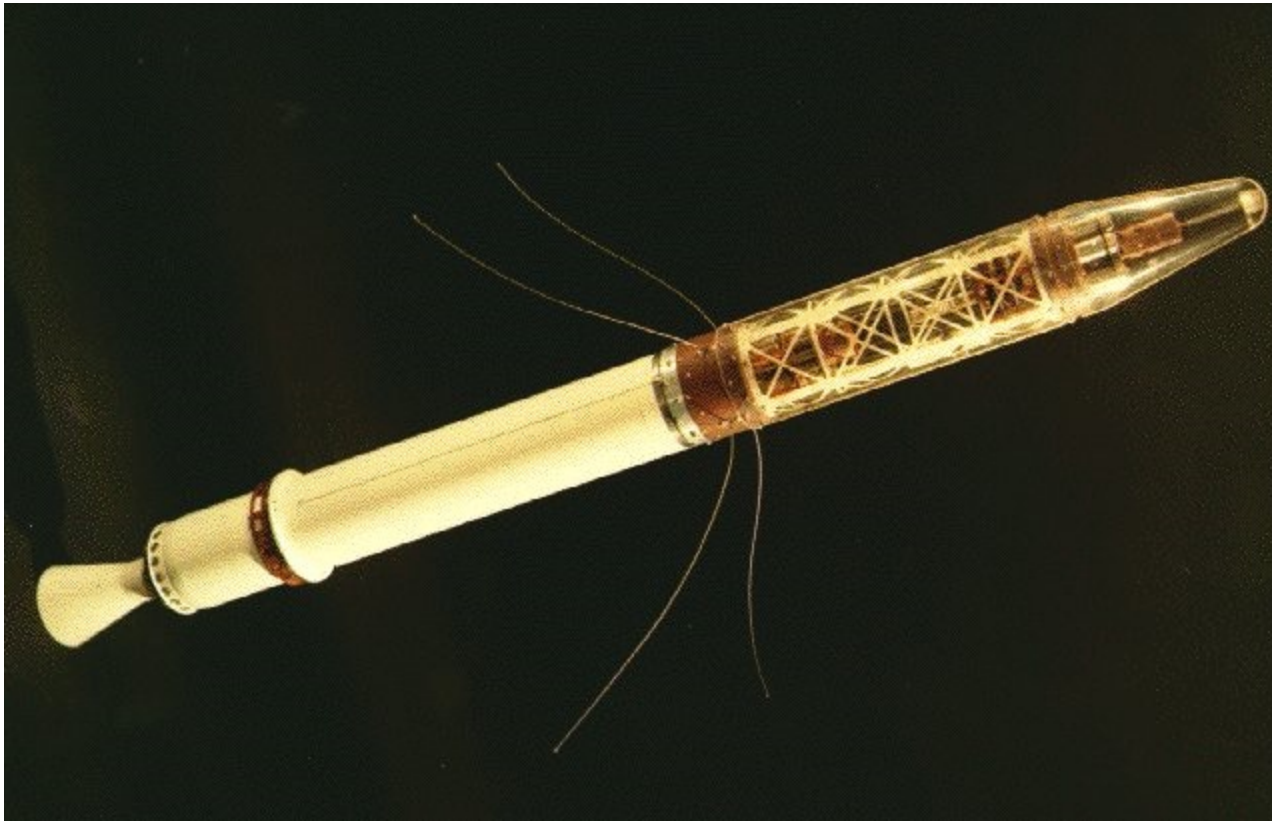
- ◆ The first rocket flight to detect an astronomical source in X-rays, the Sun, occurred in 1949.
- ◆ The first rocket flight to detect an extrasolar astronomical source, Scorpius X-1, occurred in 1962. Scorpius X-1 is now known to be a neutron star accreting from a low-mass main-sequence star.



Experimental Package on the Aerobee rocket launch of June 1962

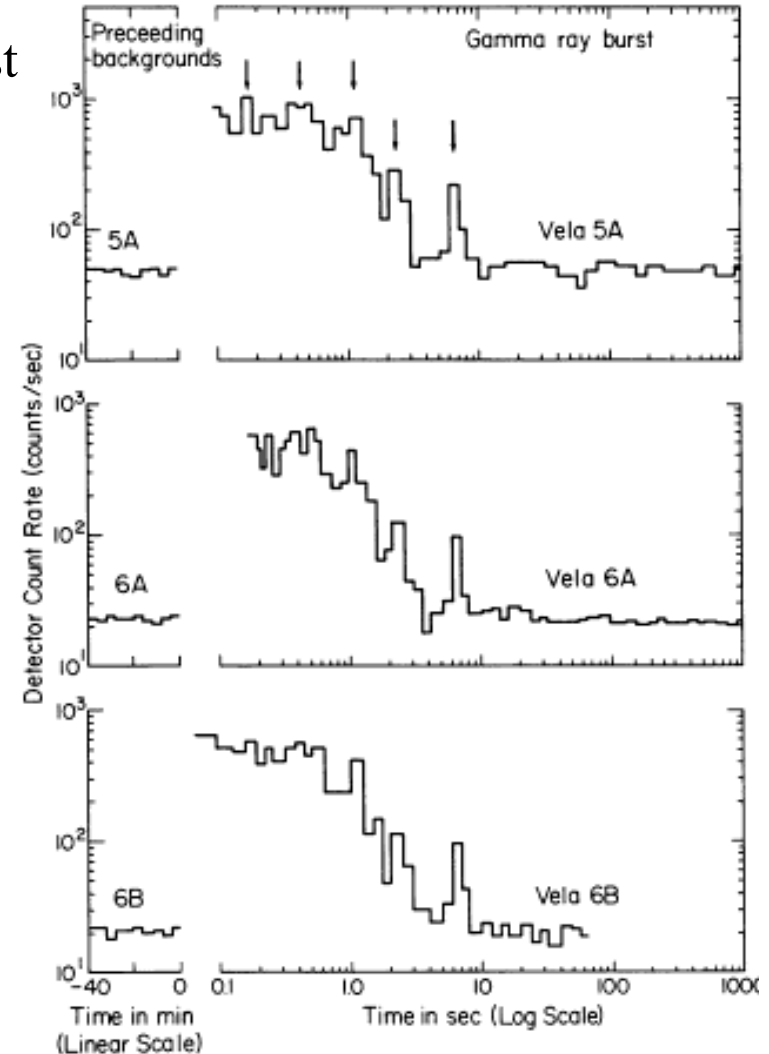
Beginnings of γ -ray Astronomy

- ◆ 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.



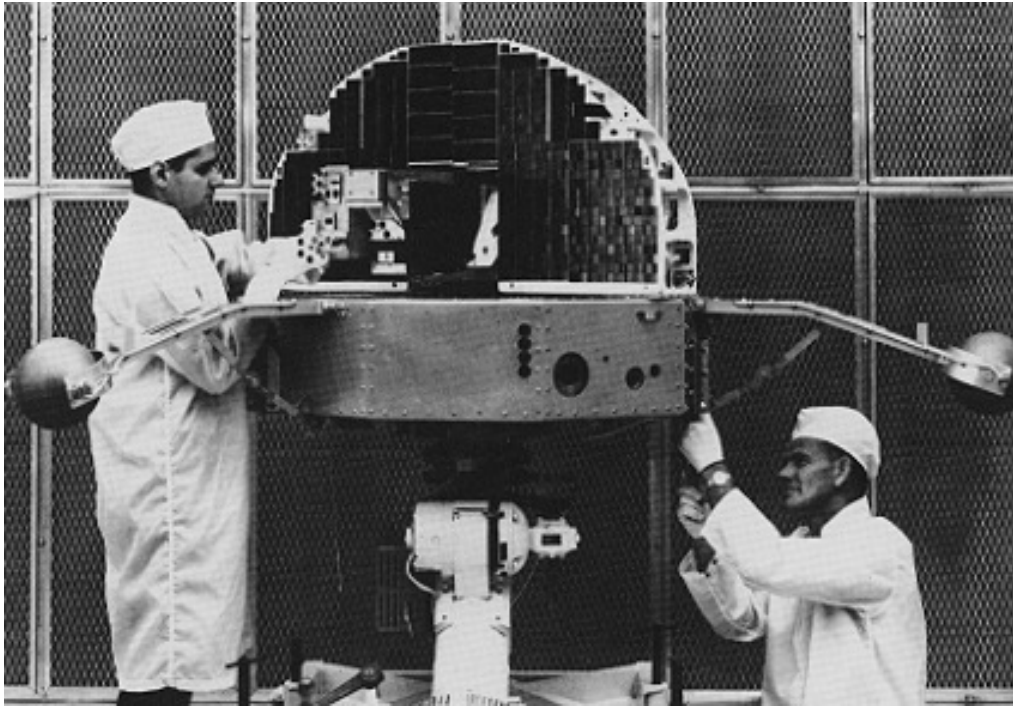
Beginnings of γ -ray Astronomy

- ◆ 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.



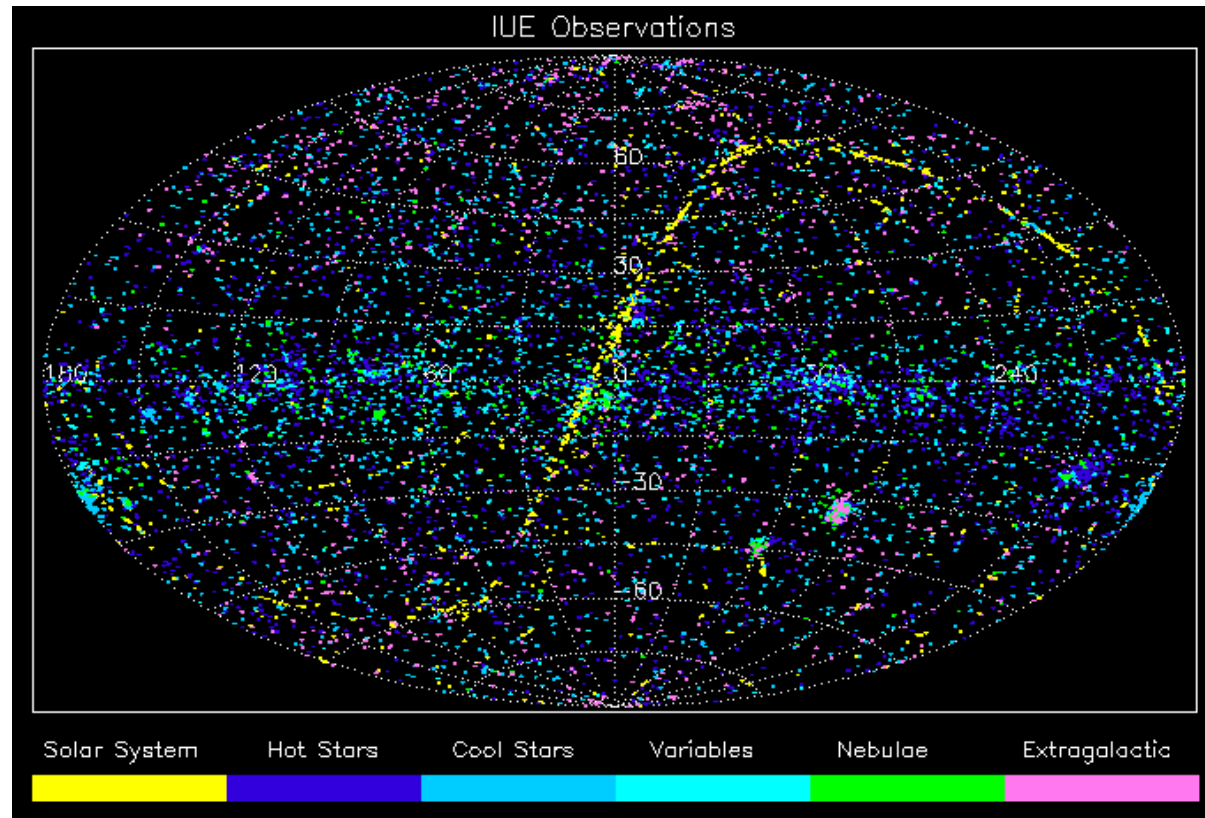
Beginnings of Ultraviolet Astronomy

- ◆ 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.



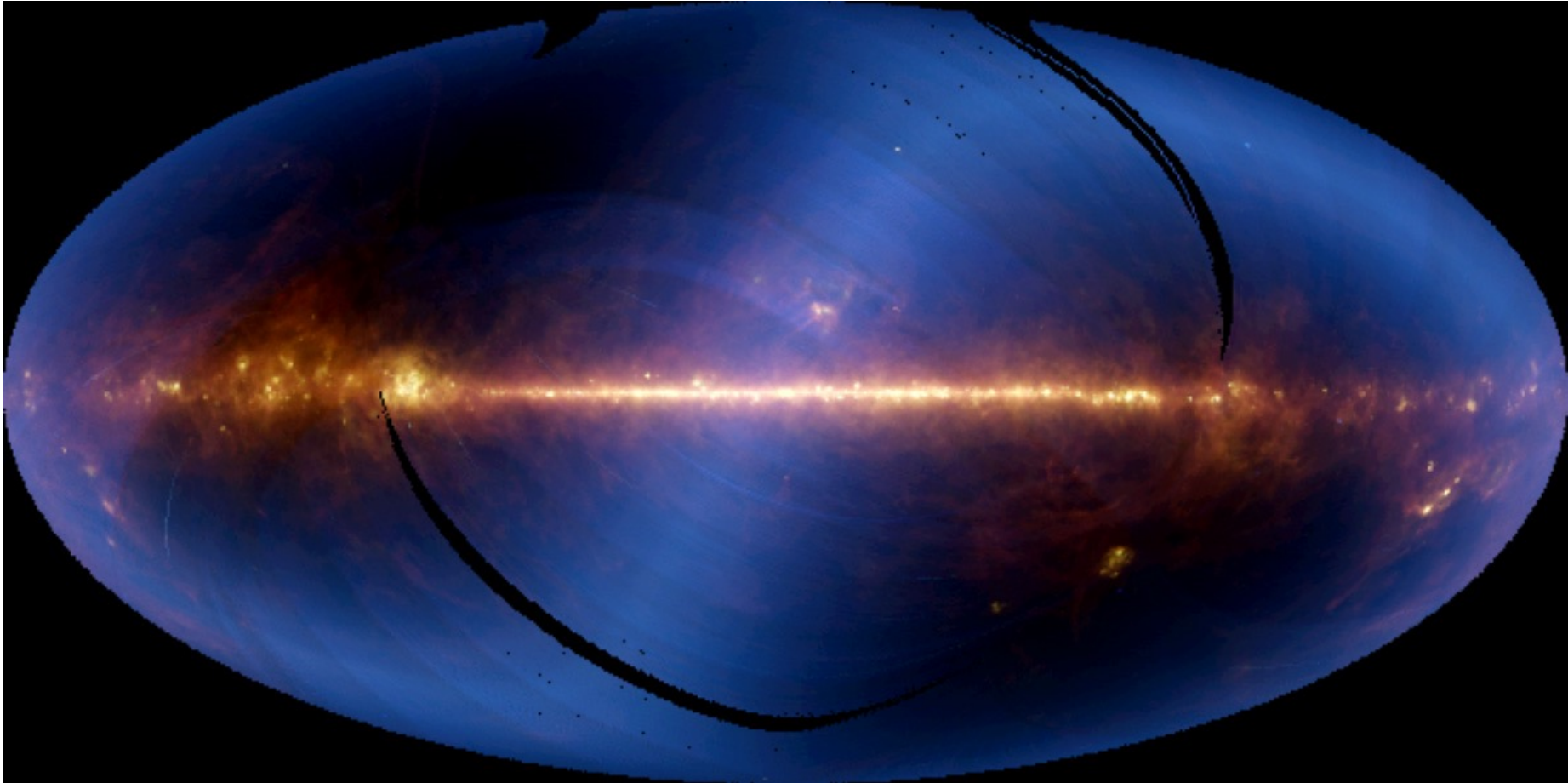
Infrared Astronomy

- ◆ Launched in 1983, the InfraRed Astronomical 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.



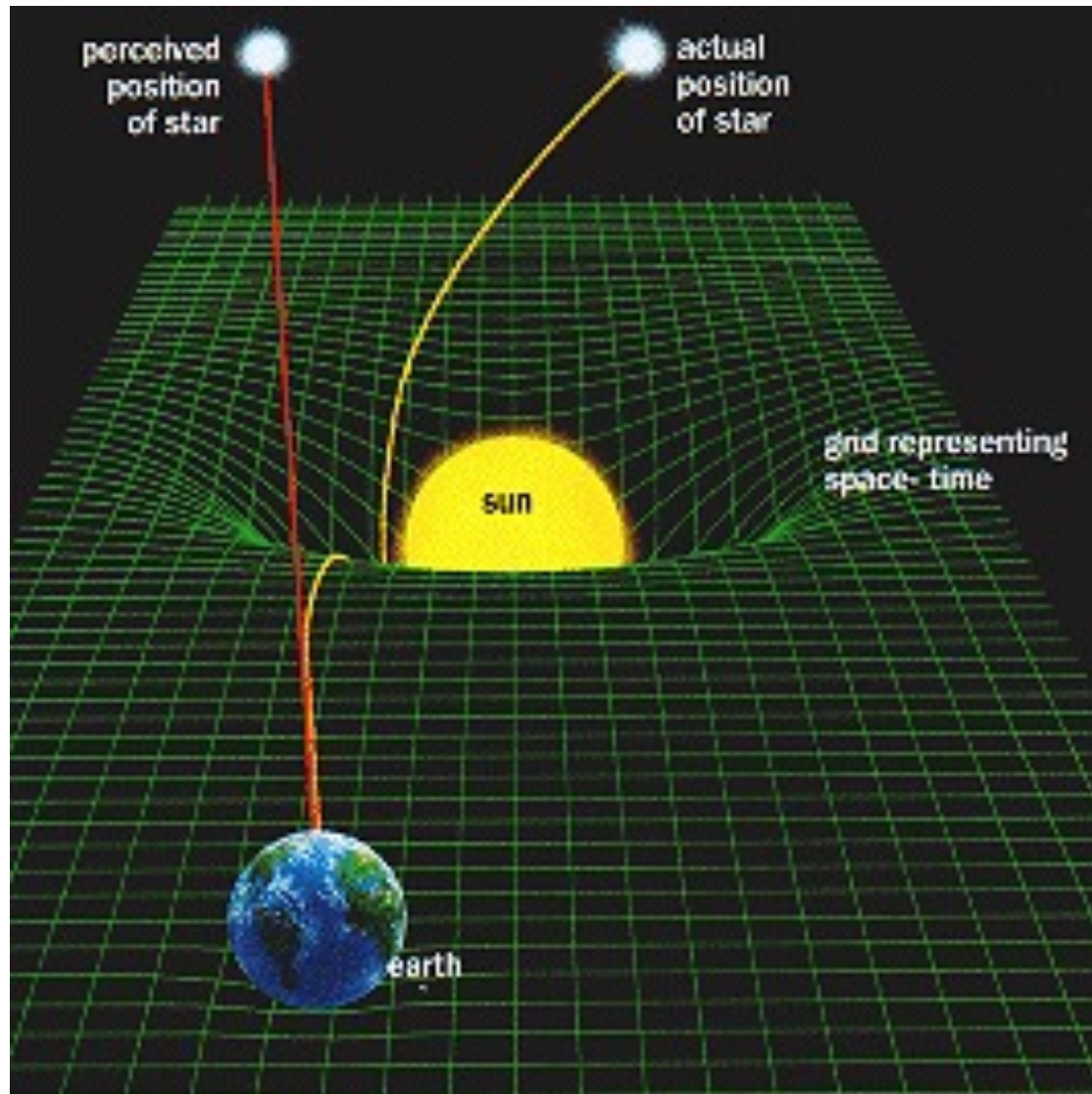
Infrared Astronomy

- ◆ 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.



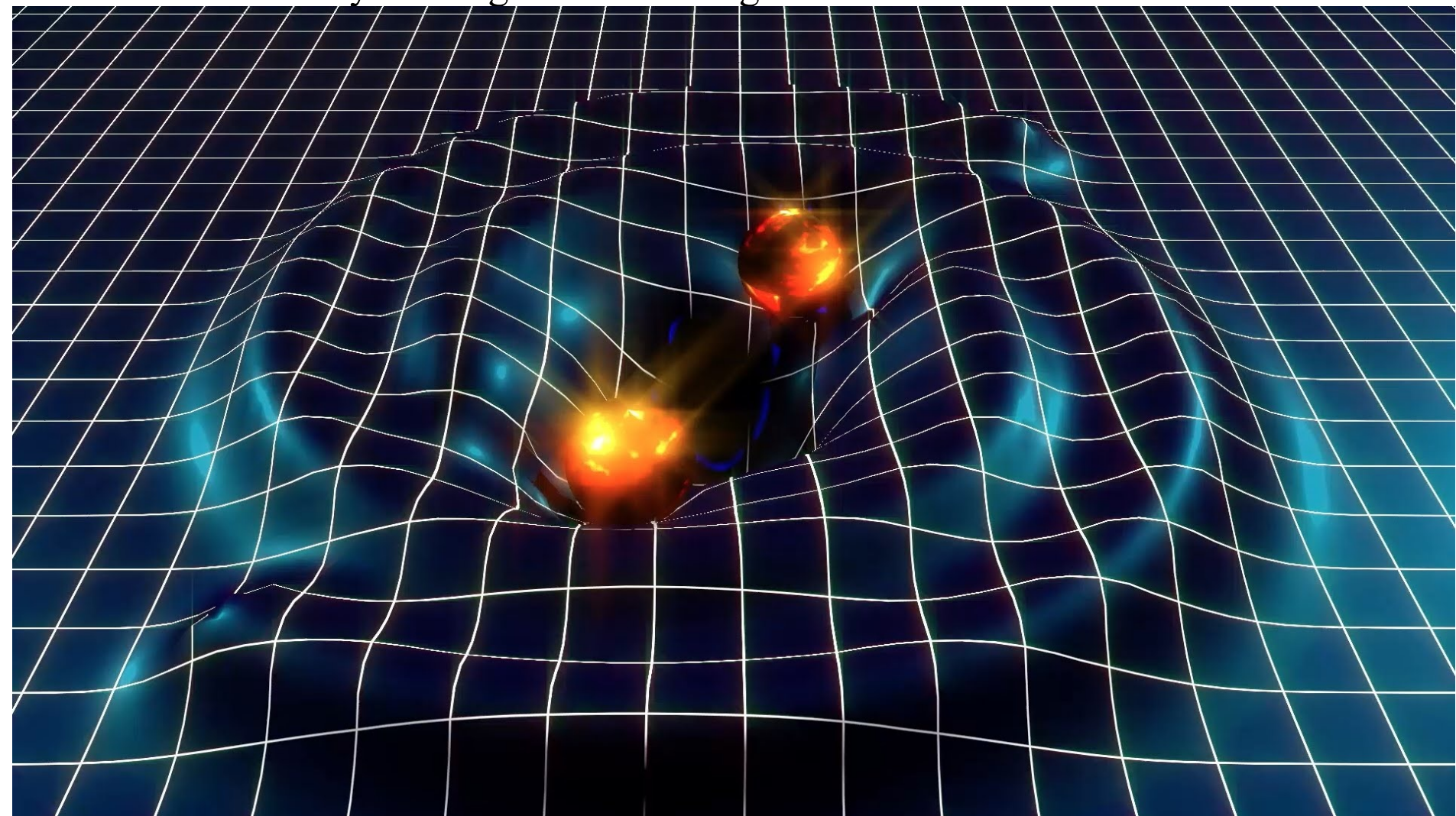
Gravitational Waves

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



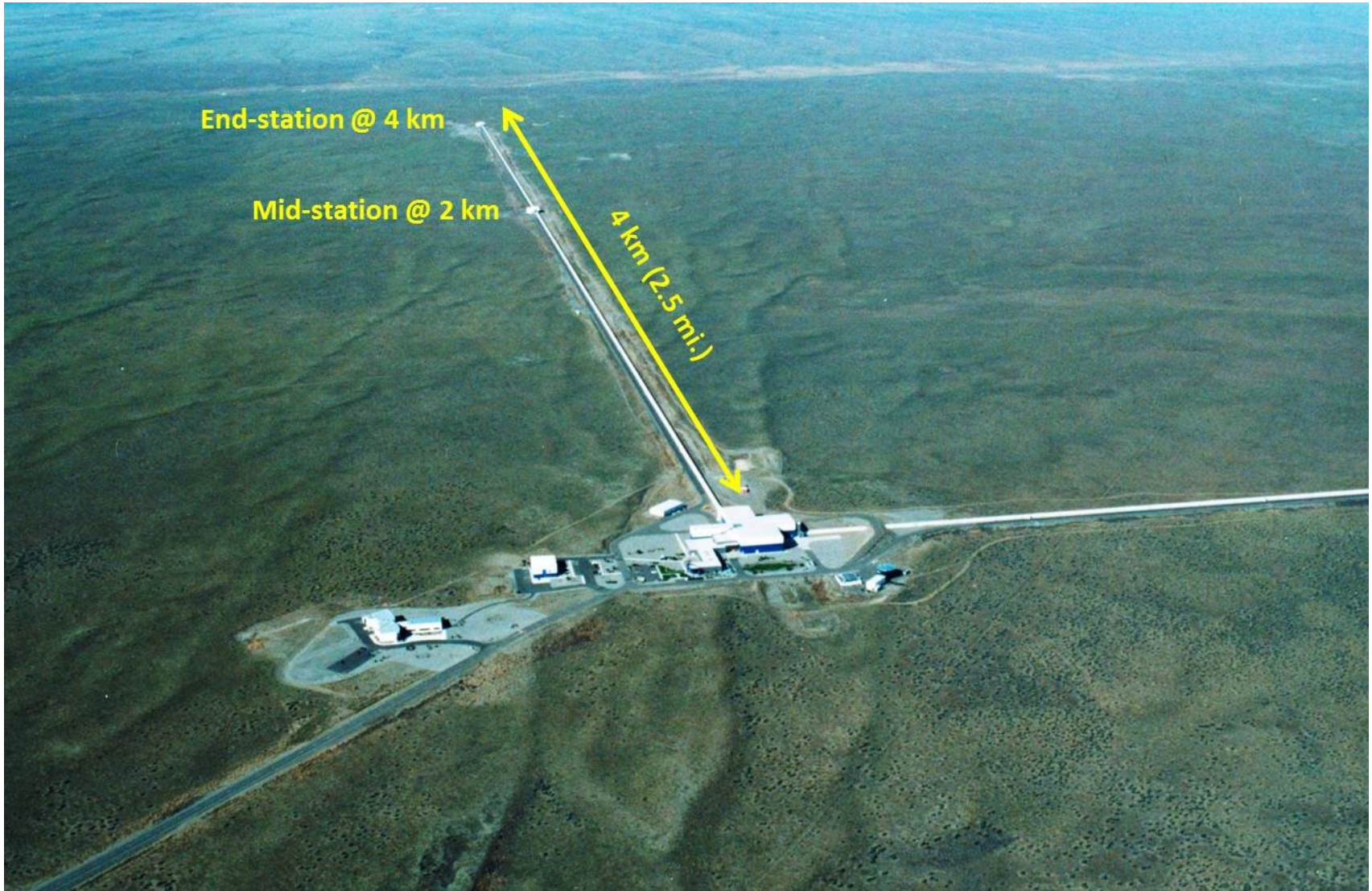
Gravitational Waves

- ◆ 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.



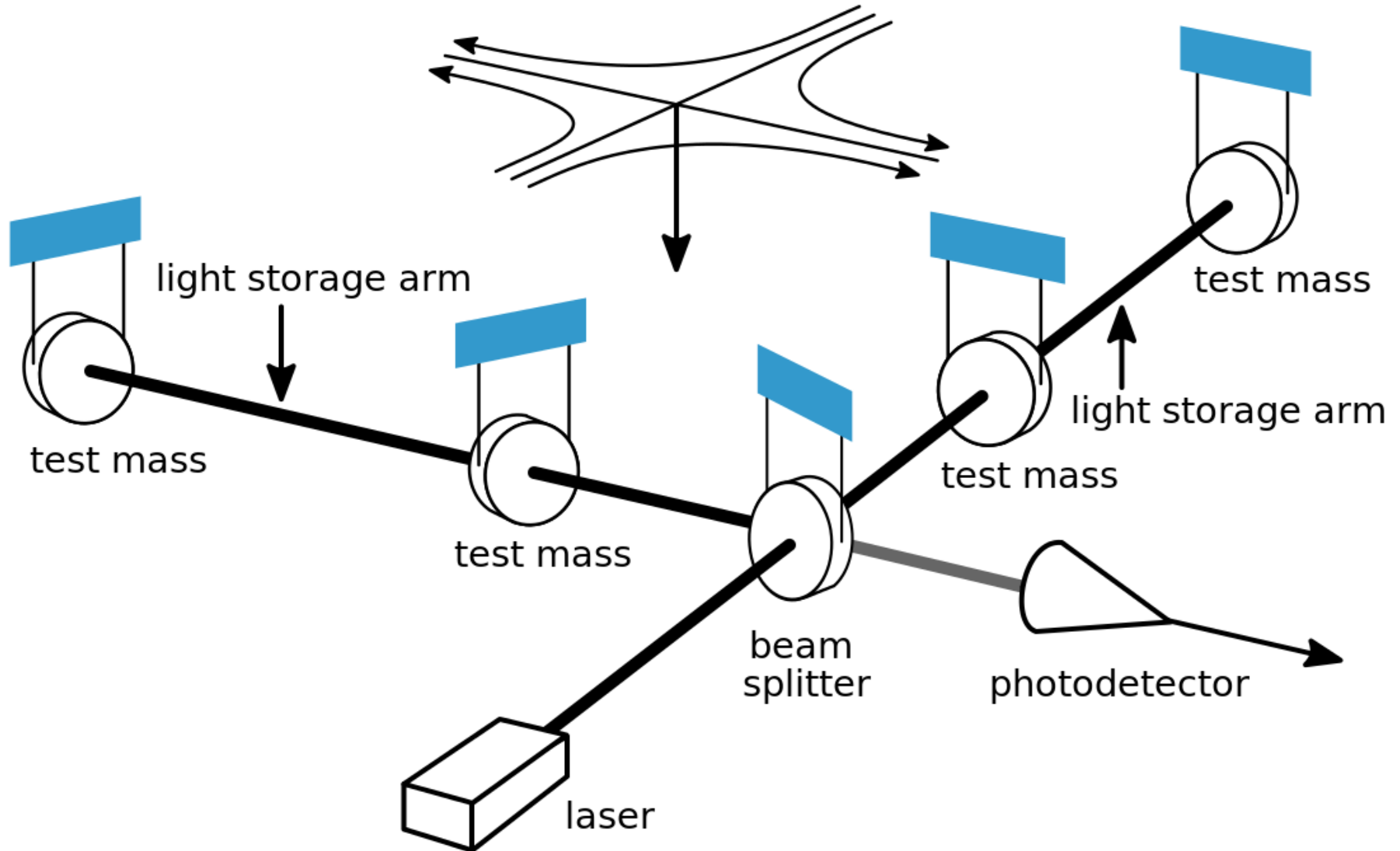
Gravitational Waves

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



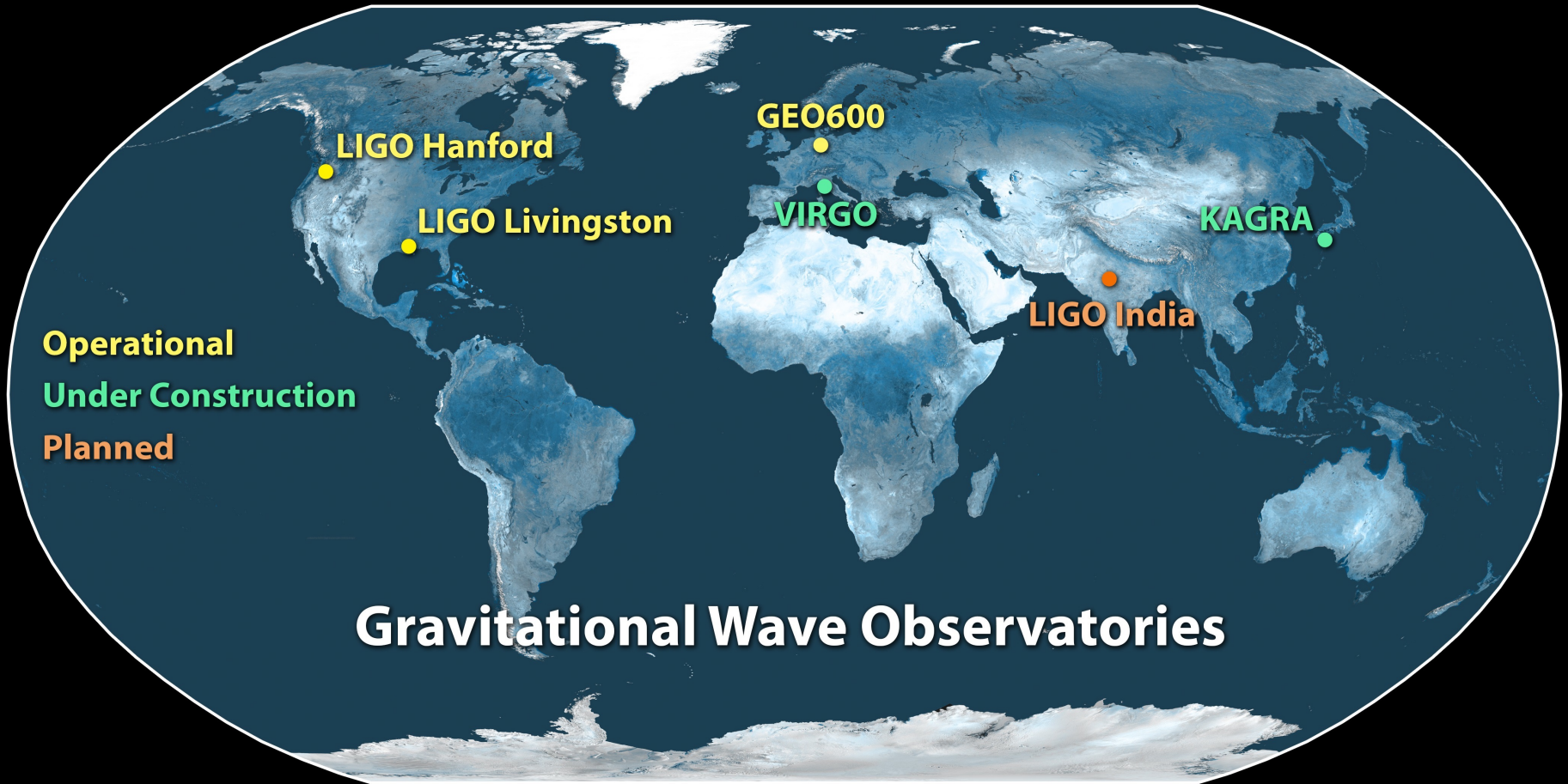
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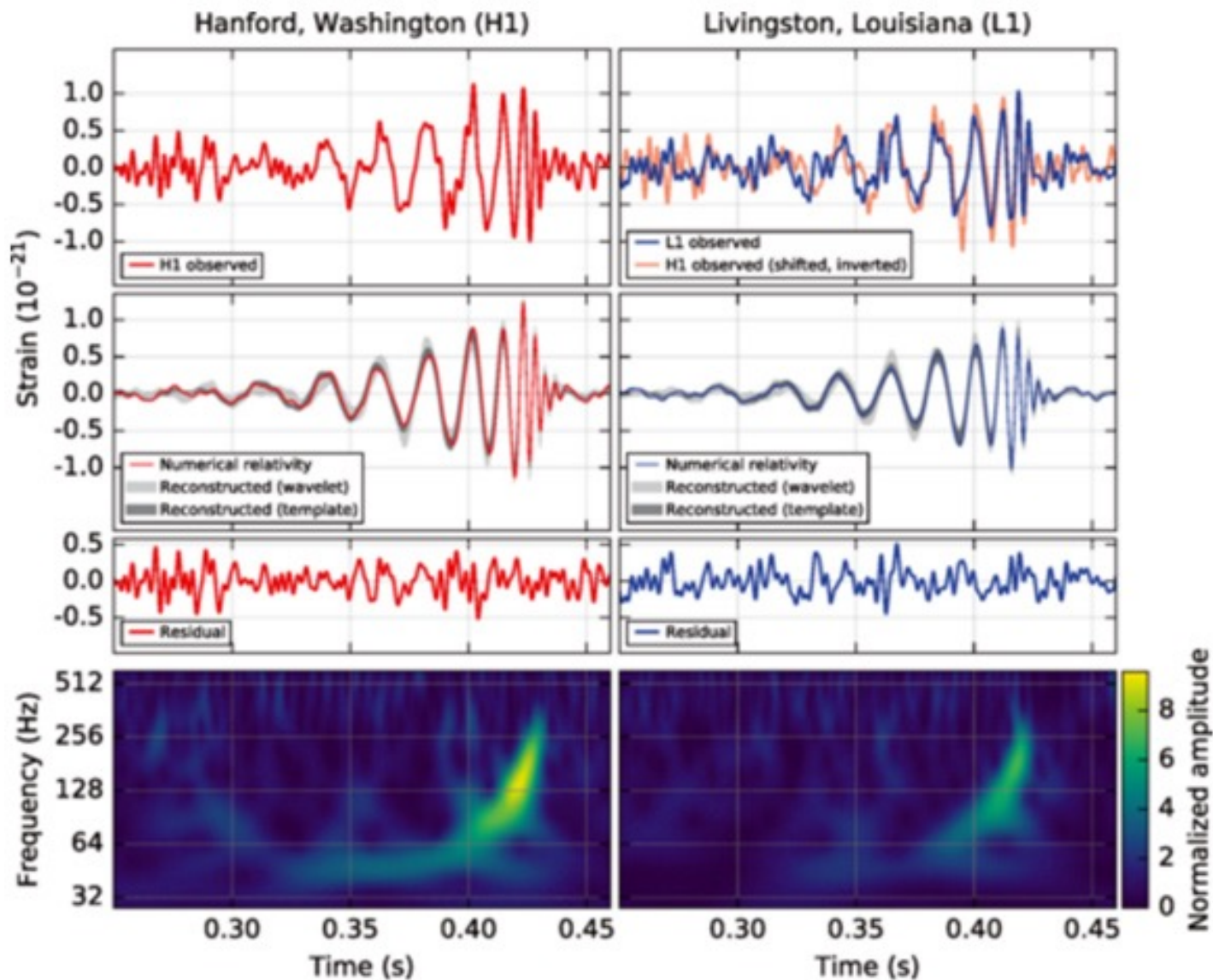
Gravitational Waves

- ◆ 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.

