Vesmírné teleskopy – ten největší a první český

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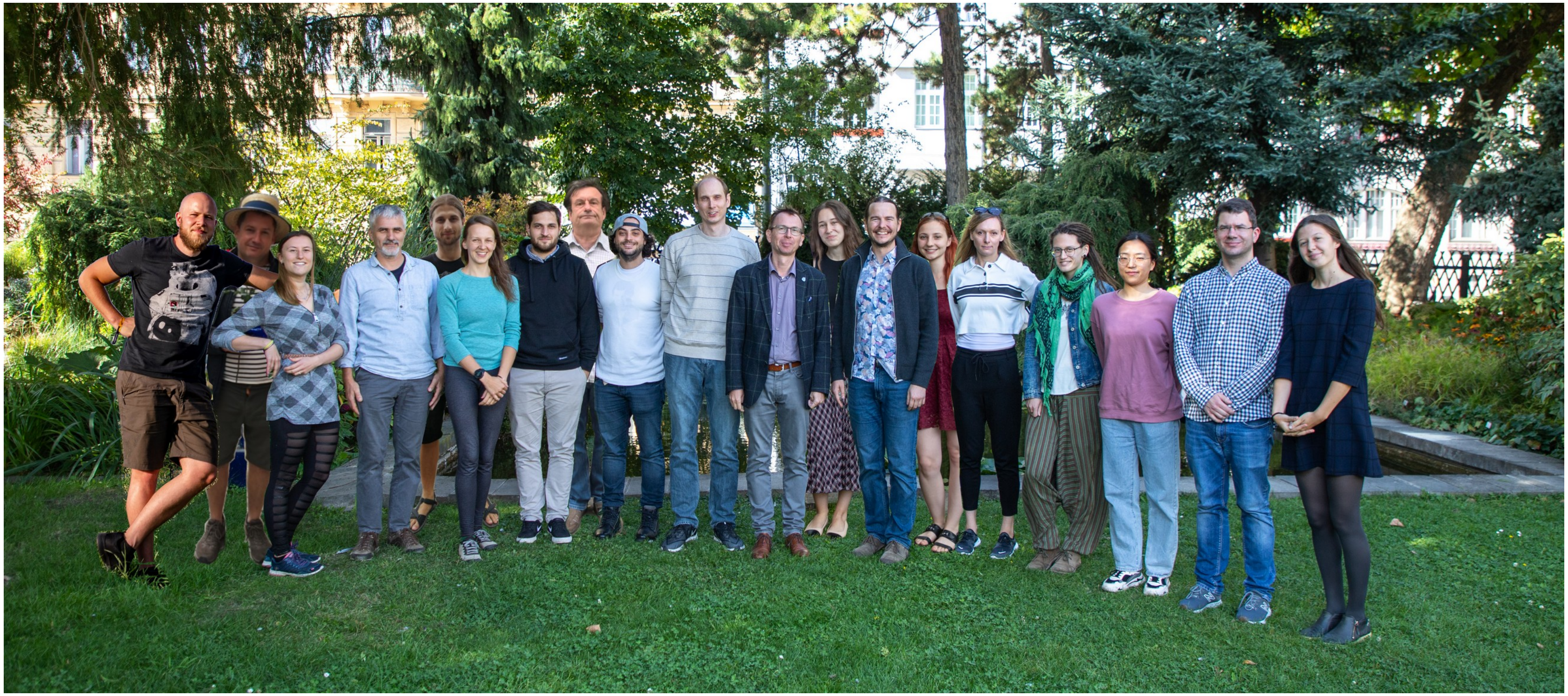
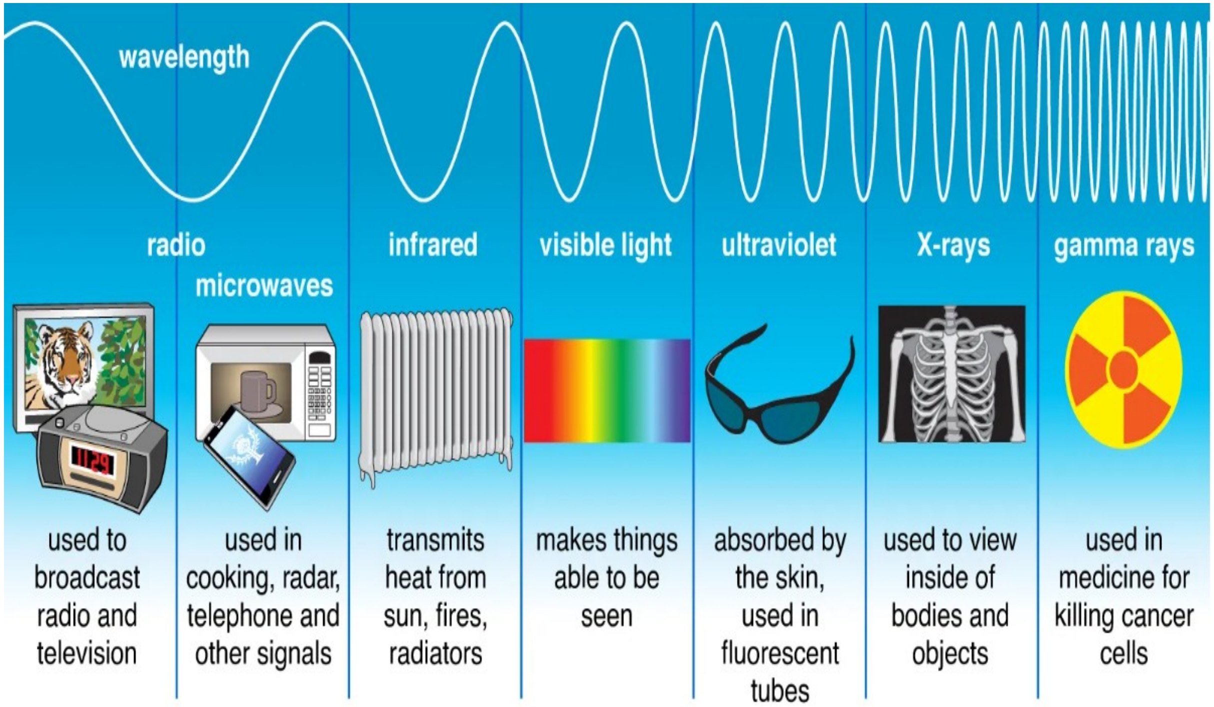
High energy astrophysics group (HEA)

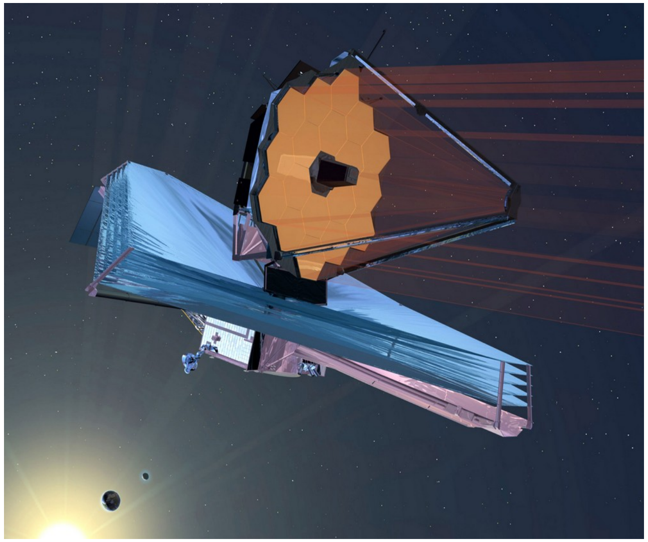


https://hea.physics.muni.cz/

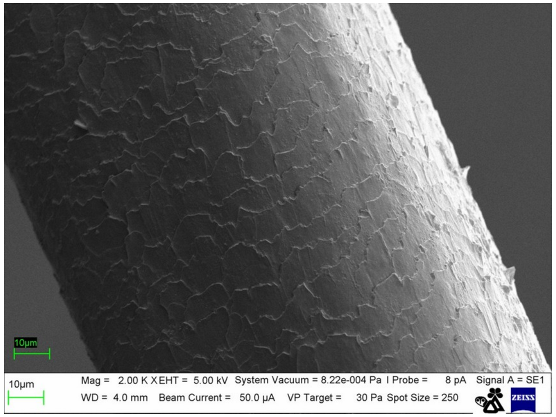
Brief characteristics

Biggest and most sensitive infrared telescope





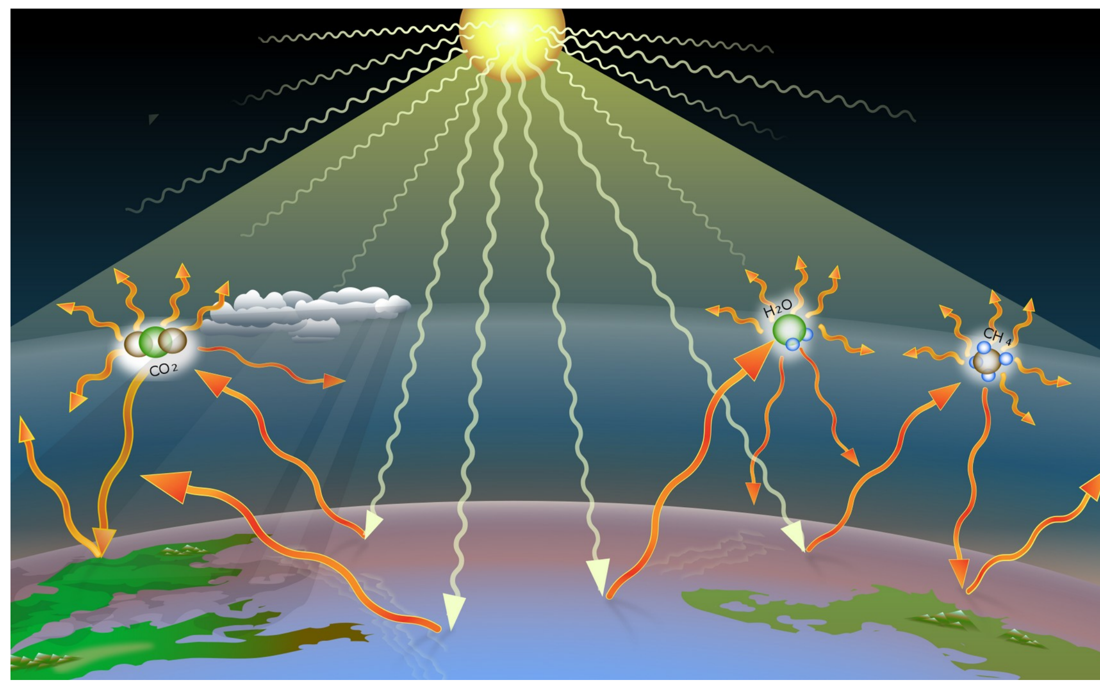
JWST observes at wavelengths from 0,6 to 28 micrometers
Comparable to a human hair



Infrared radiation

- **Longer wavelength than the radiation that we observe**
- **Shorter wavelength than radio waves**

Everything “warm” radiates at infrared wavelengths: atmosphere, Earth, Moon, Sun

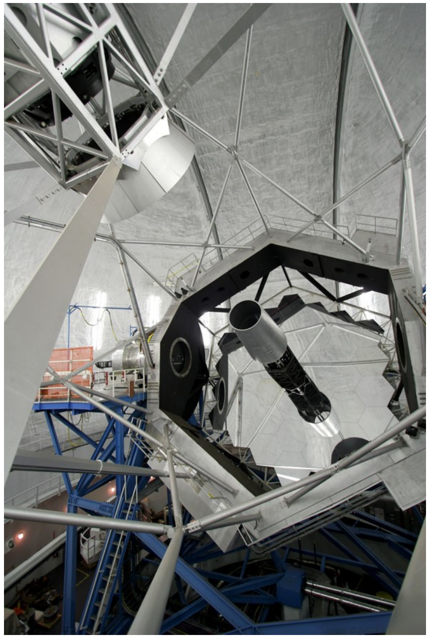


James Webb Space Telescope
Largest space telescope

Full scale model at NASA Goddard

Infrared radiation

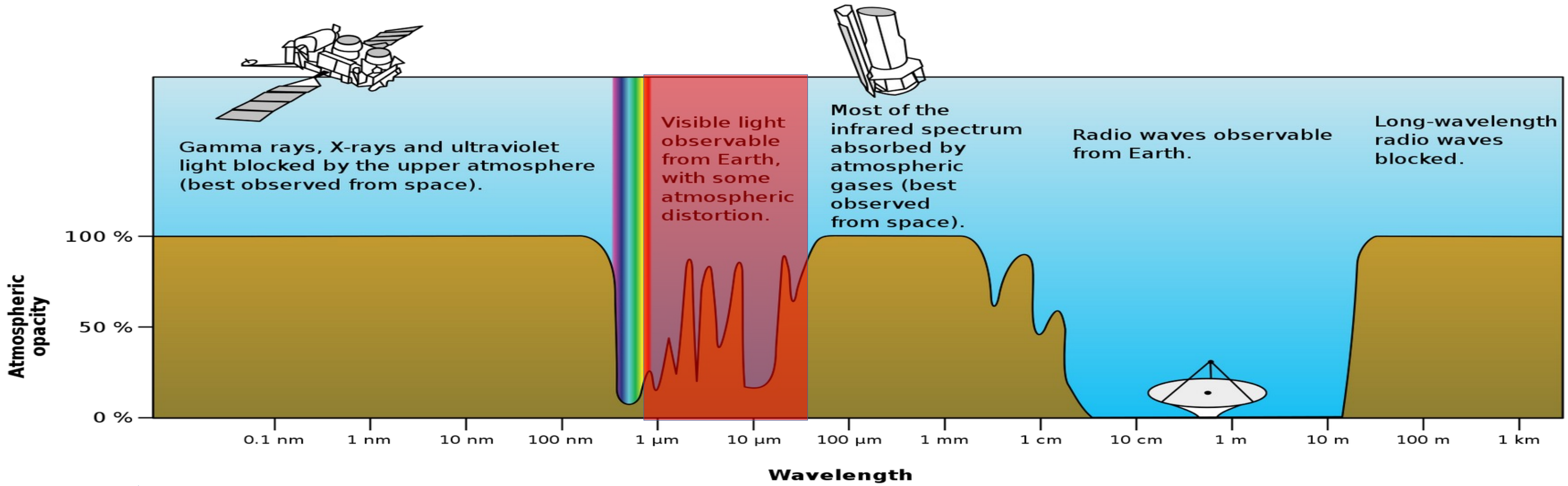
- **Longer wavelength than the radiation our eyes “detect”**
- **Shorter wavelength than radio waves**
- **astronomer Kris Sellgren (Galactic center observations)**



Detector OSIRIS (2 .2 microns, Keck observatory)

Detection of infrared radiation

- **With Earth-bound telescopes we can observe at specific wavebands where the absorption by atmosphere water vapor and other molecules is small**
- **“Warm” atmosphere is also the source of noise**



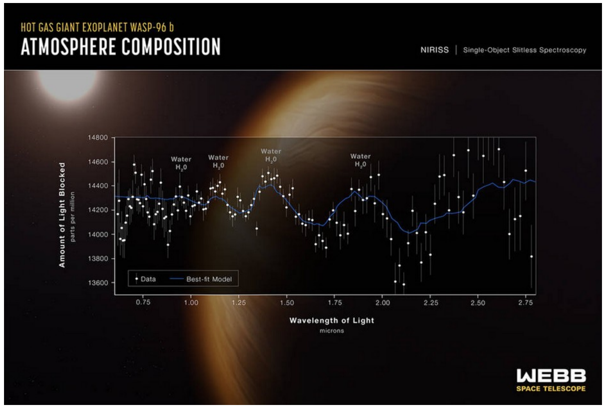
Infrared space telescope avoids the disturbing effects of the atmosphere

Telescope is also a bit warm, which is still a source of noise → necessary passive and active cooling

Infrared radiation in astronomy

Reasons to construct a big (infrared) space telescope:

- Distant galaxies have their spectrum “redward” shifted – the emission peak in the infrared domain
- Infrared radiation penetrates more easily through dense and cool gas and dust clouds (detection of young, forming stars)
- Cooler objects like protoplanetary disks and planets radiate mostly in the infrared domain
- Infrared radiation, when observed from the Earth, is affected by the atmosphere → put it into space



James Webb telescope beginnings

- **1946 – Lyman Spitzer** created the concept of **space telescope (RAND Co.)**

Document title: Lyman Spitzer, Jr., "Astronomical Advantages of an Extra-terrestrial Observatory," Project RAND, July 30, 1946.

Source: The RAND Corporation, reprinted with permission.

Prior to World War II, Earth-orbiting telescopes only existed in science fiction stories. The advent of guided missiles by Germany during the war, however, made a few astronomers optimistic that this new rocket technology would soon be able to loft telescopes and other astronomical instruments into space. Among the believers, Princeton University's Lyman Spitzer authored a paper for the Douglas Aircraft Company's Project RAND (the think tank established by the Army Air Corps after World War II) on the scientific benefits of a space-based telescope. The paper became part of a larger 1946 RAND report on the feasibility of developing and launching a scientific spacecraft. Originally classified, the Spitzer study was unknown to other astronomers for several years. When his ideas became known, many astronomers remained skeptical of the worth of space-based instruments. Over time, however, astronomers began to embrace the astronomical studies Spitzer described in his paper and eventually attributed the Hubble Space Telescope's development to Spitzer's efforts.

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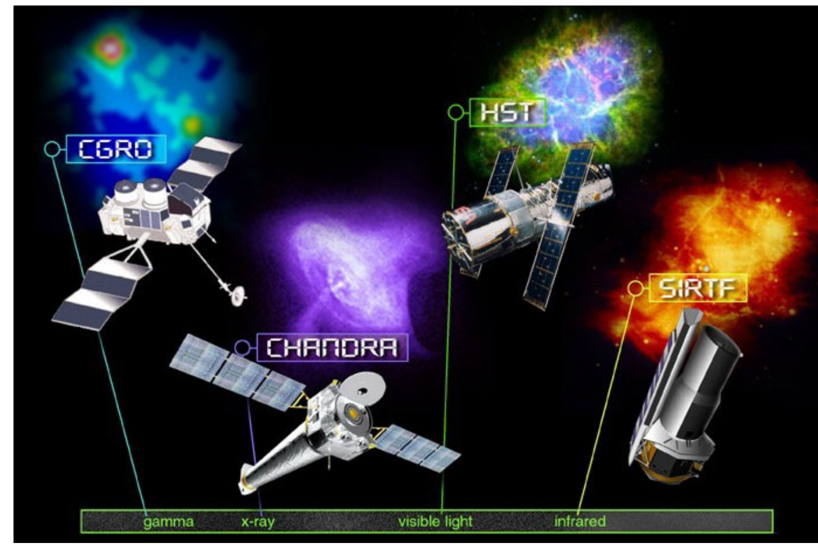
YALE UNIVERSITY OBSERVATORY
PROSPECT AND CANNER STREETS
NEW HAVEN 11, CONNECTICUT

July 30, 1946.

ASTRONOMICAL ADVANTAGES
OF AN
EXTRA-TERRESTRIAL OBSERVATORY

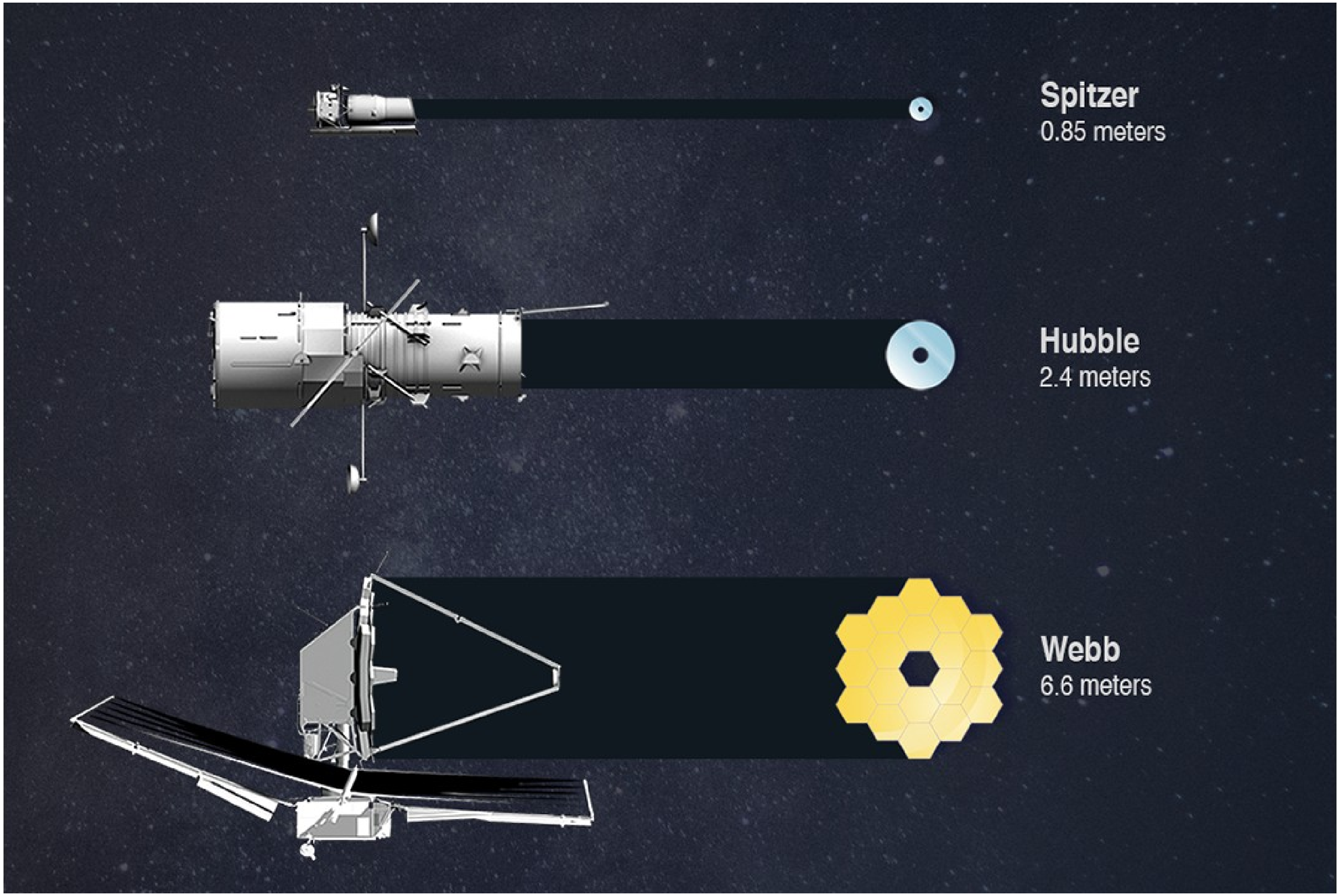
It has been proposed that rockets be used to accelerate a small mass, containing scientific equipment, up to a speed of 5 miles a second, at which speed the mass could revolve around the earth indefinitely, forming a small satellite. Such a development is certainly not out of the question within the next few decades, in view of the rapid strides already made in rocket research, and the emphasis now being placed on research in this field. The present memorandum points out, in a very preliminary way, the results that might be expected from astronomical measurements made with such a satellite. The discussion is divided into three parts, corresponding to three different assumptions concerning the amount of instrumentation provided. In the first section it is assumed that no telescope is provided; in the second a 10-inch reflector is assumed; in the third section some of the results obtainable with a large reflecting telescope, many feet in diameter, and revolving about the earth above the terrestrial atmosphere, are briefly sketched.

It should be emphasized that this is only a preliminary survey of the scientific advantages that astronomy might gain from such a development. The many practical problems,



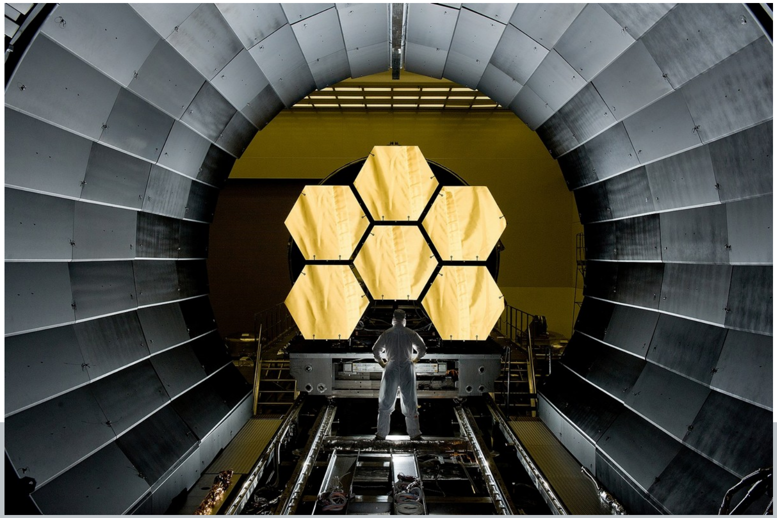
- **Launching of 4 big space telescopes "Great Observatories" between 1990 and 2003**
- **Compton GRO (1991-2000), Chandra X-ray Observatory (1999-), Hubble Space Telescope (1990-), Spitzer Infrared Telescope (2003-2020)**

James Webb telescope beginnings



James Webb telescope beginnings

- **1996 –** the concept of **Next Generation Space Telescope**
- **2002 –** naming after **James E. Webb (1906-1992), second administrator of NASA (1961-1968) during the era of the first human space missions Mercury and Gemini**
- **July 2011 – project nearly cancelled**
- **November 2011 –** project saved
- **2013-2014 –** integration of 4 detectors into the Integrated Science Instrument Module (ISIM)



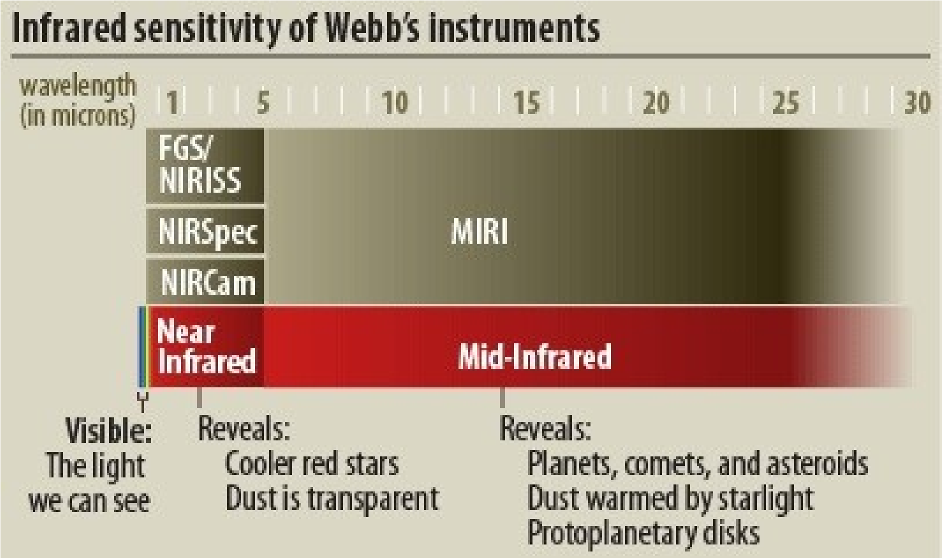
James Webb telescope beginnings

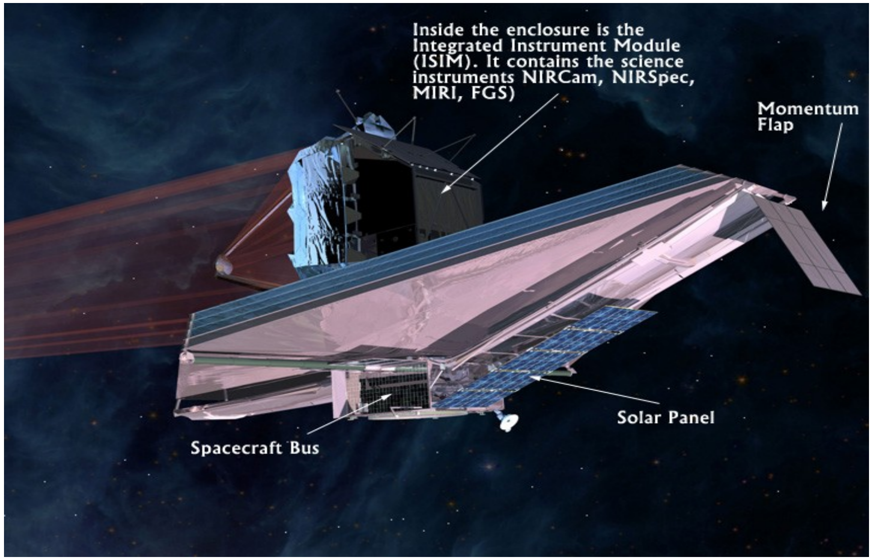
- **2013-2014 –** integration of 4 detectors into

  Integrated Science Instrument Module (ISIM)

- Observation modes: **imaging, spectroscopy (decomposition into "rainbow"), coronography (direct exoplanet imaging by blocking the stellar light), combination of imaging and spectroscopy (IFU – integral field unit), aperture interferometry**

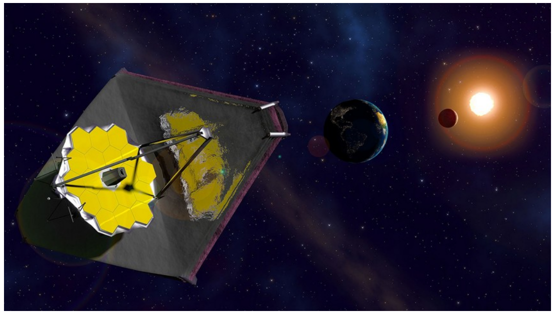
- **NIRcam, NIRspec, FGS/NIRISS, MIRI**

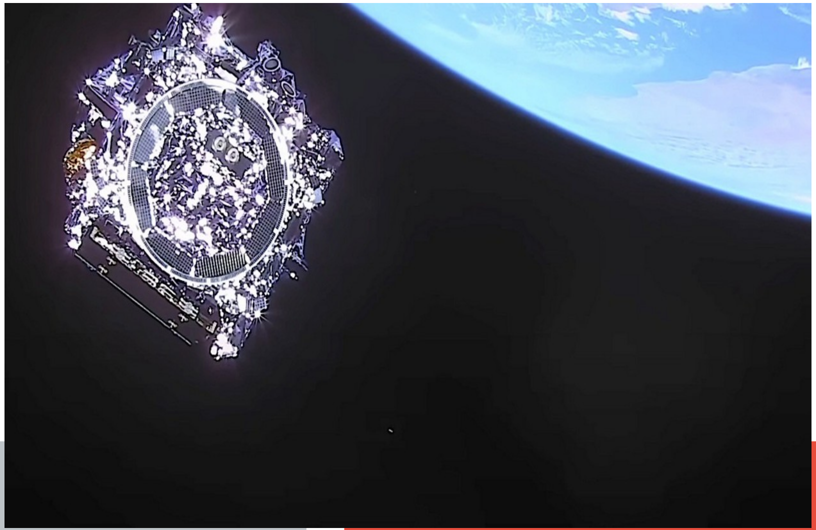




James Webb telescope beginnings

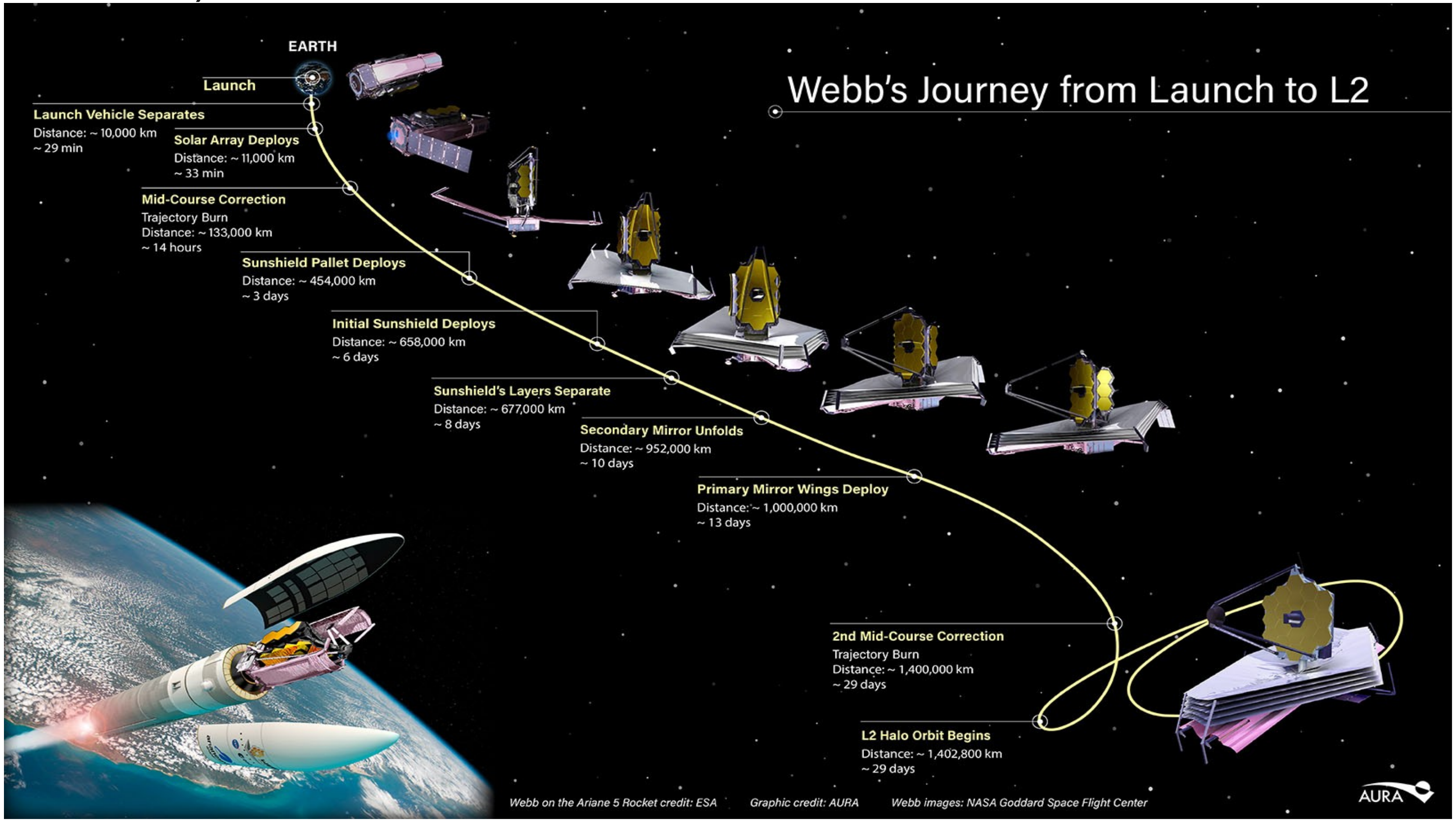
- **June 2014 –** cryogenic test with all the four detectors at the Goddard space center
- **2015** – hexagonal mirror segments completed
- **2016** – cryogenic test of mirrors and other instruments
- **November, 2016** – basic telescope construction completed
- **December, 2016** – anomaly during vibration tests
- **2018** – launch postponed until 2020, problems during the propulsion tests and fracture of the antisolar shield
- **2020-2021** – delays due to COVID19, rocket Ariane 5
- **December 25, 2021** – 12:20 UTC: rocket Ariane 5 with JWST launched from Kourou, French Guiana





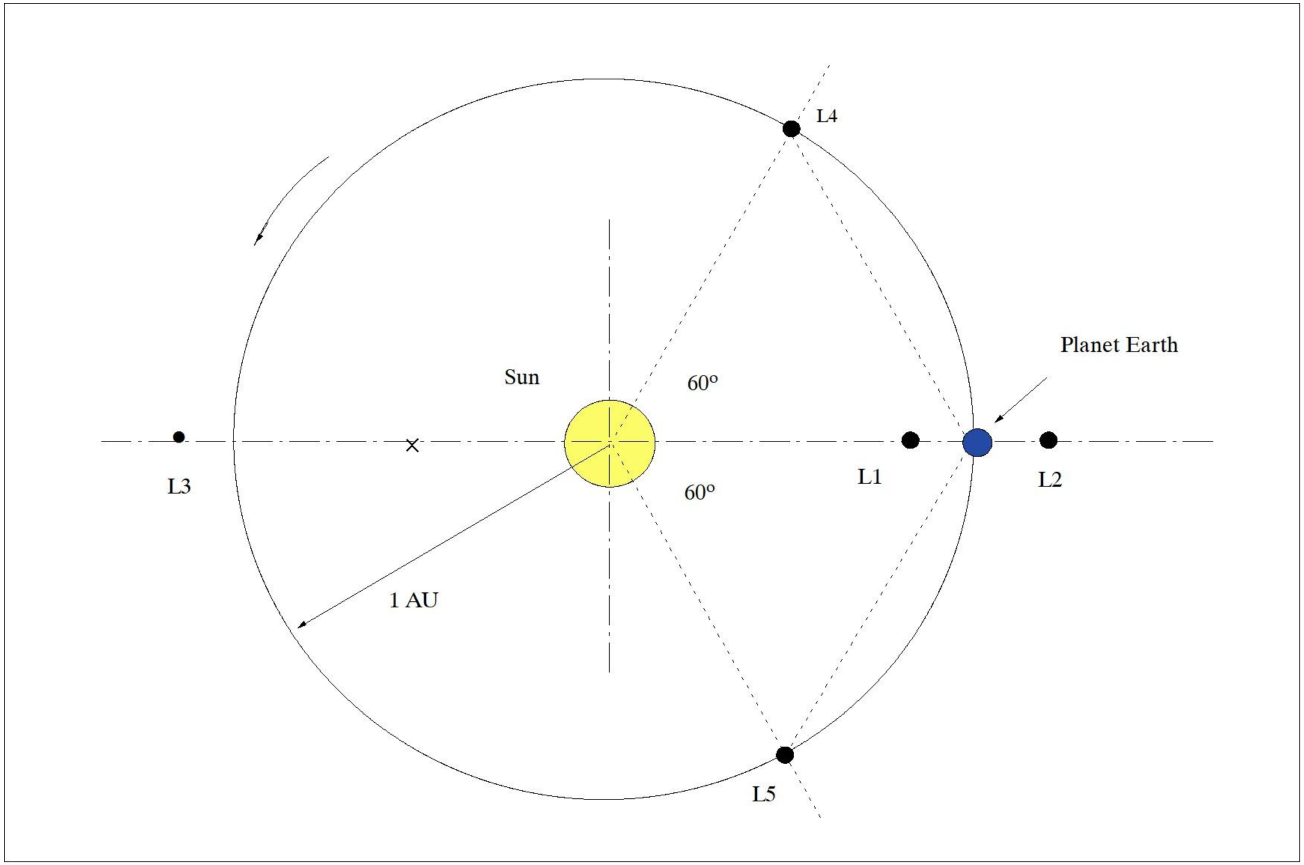
Launch and journey to the point L2

- **December 25, 2021** – 12:20 UTC: rocket Ariane 5 with JWST launched from Kourou, French Guiana
- **January 24, 2022 –** JWST is inserted into the orbit around the L2 point of the Sun-Earth system, 1.5 million kilometers from the Earth (3-4 times more distant than the Moon from the Earth)



Lagrange equilibrium points

- **5 points: L1, L2, L3 along the Sun-Earth line (unstable); L4 and L5 at the peaks of the equilateral triangle (stable)**



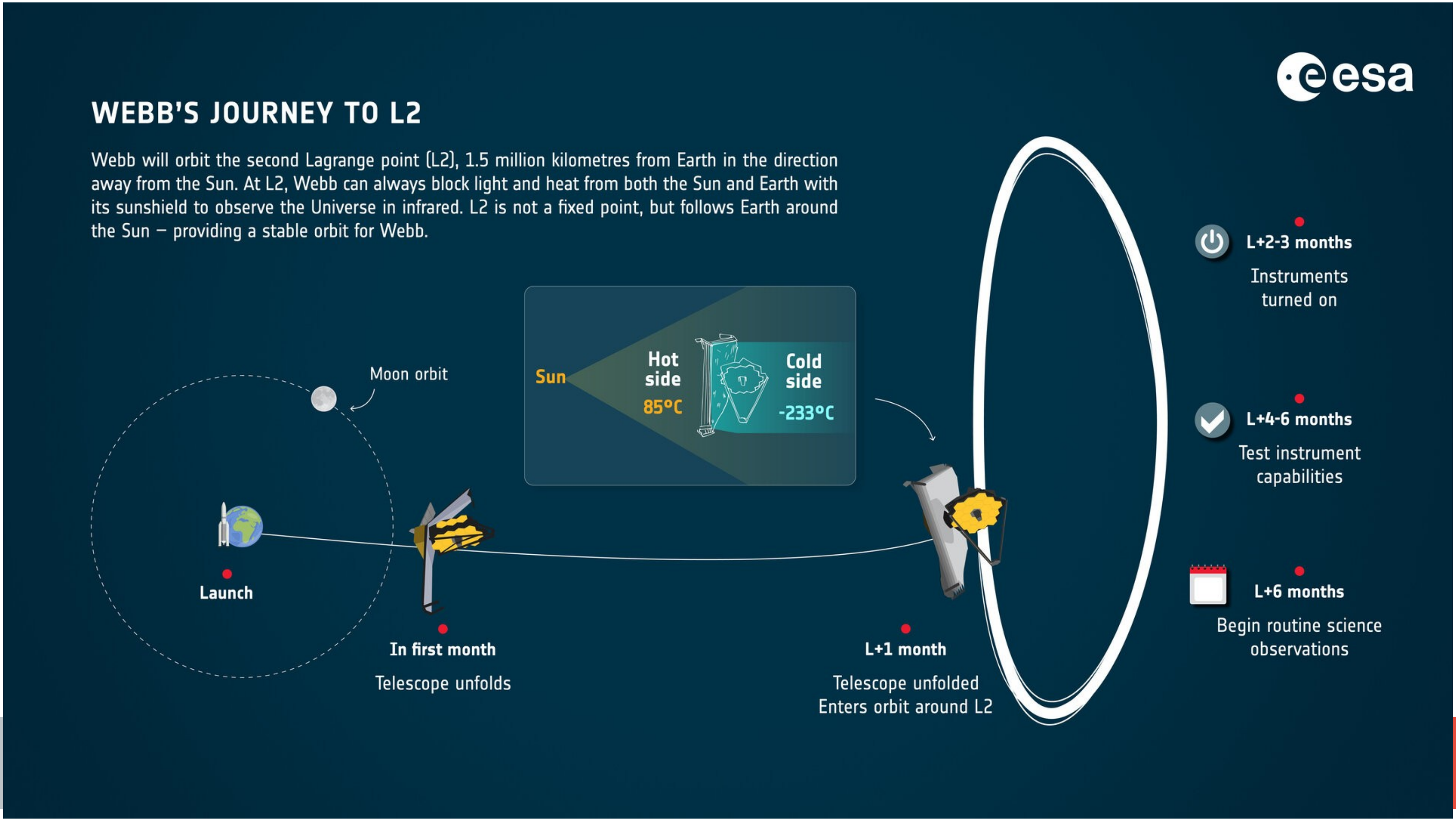
Joseph-Louis Lagrange

(1736-1813)

3-body problem → Langrange points

JWST orbits around the L2 point

- **JWST orbits around the L2 point once in every ~6 months**
- **Orbital corrections every 3 months**
- **Stable temperature conditions, detectors are passively and actively cooled**



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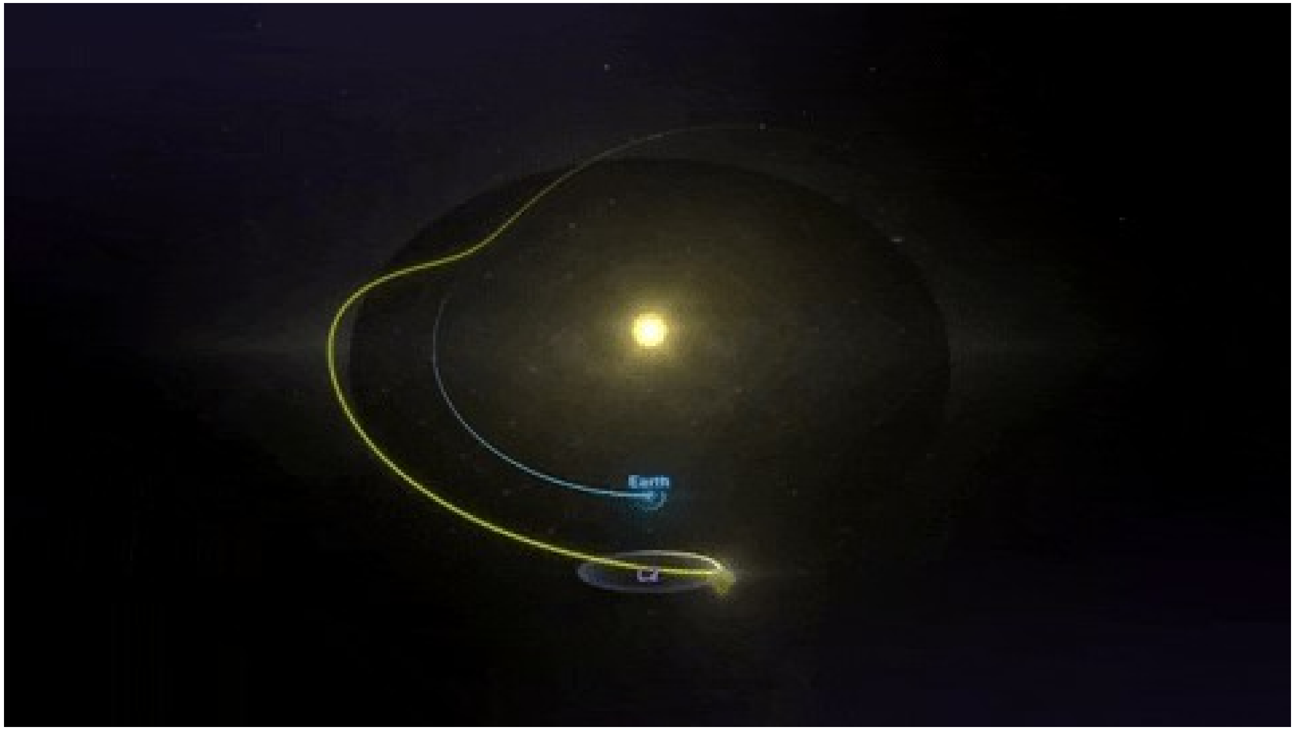
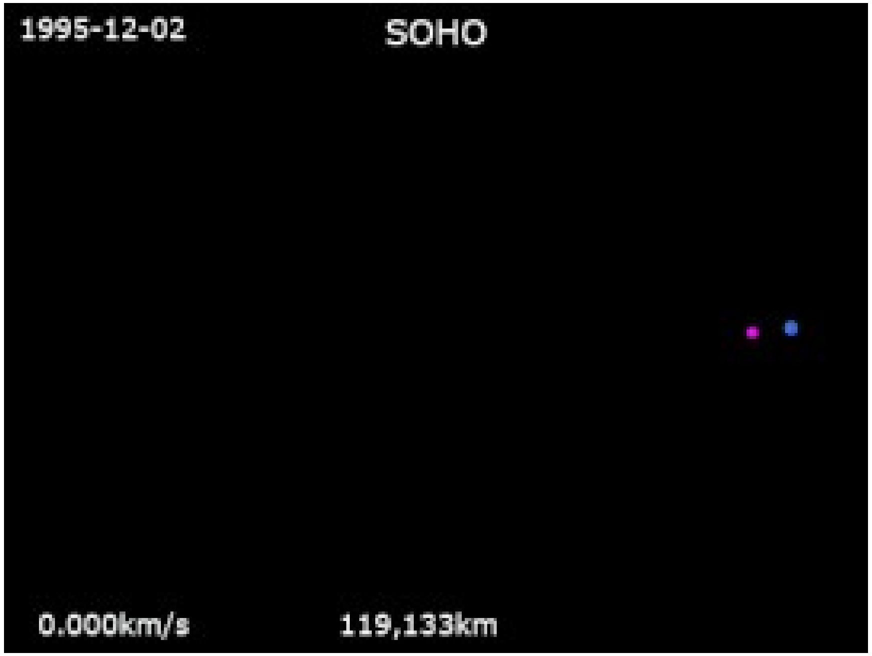


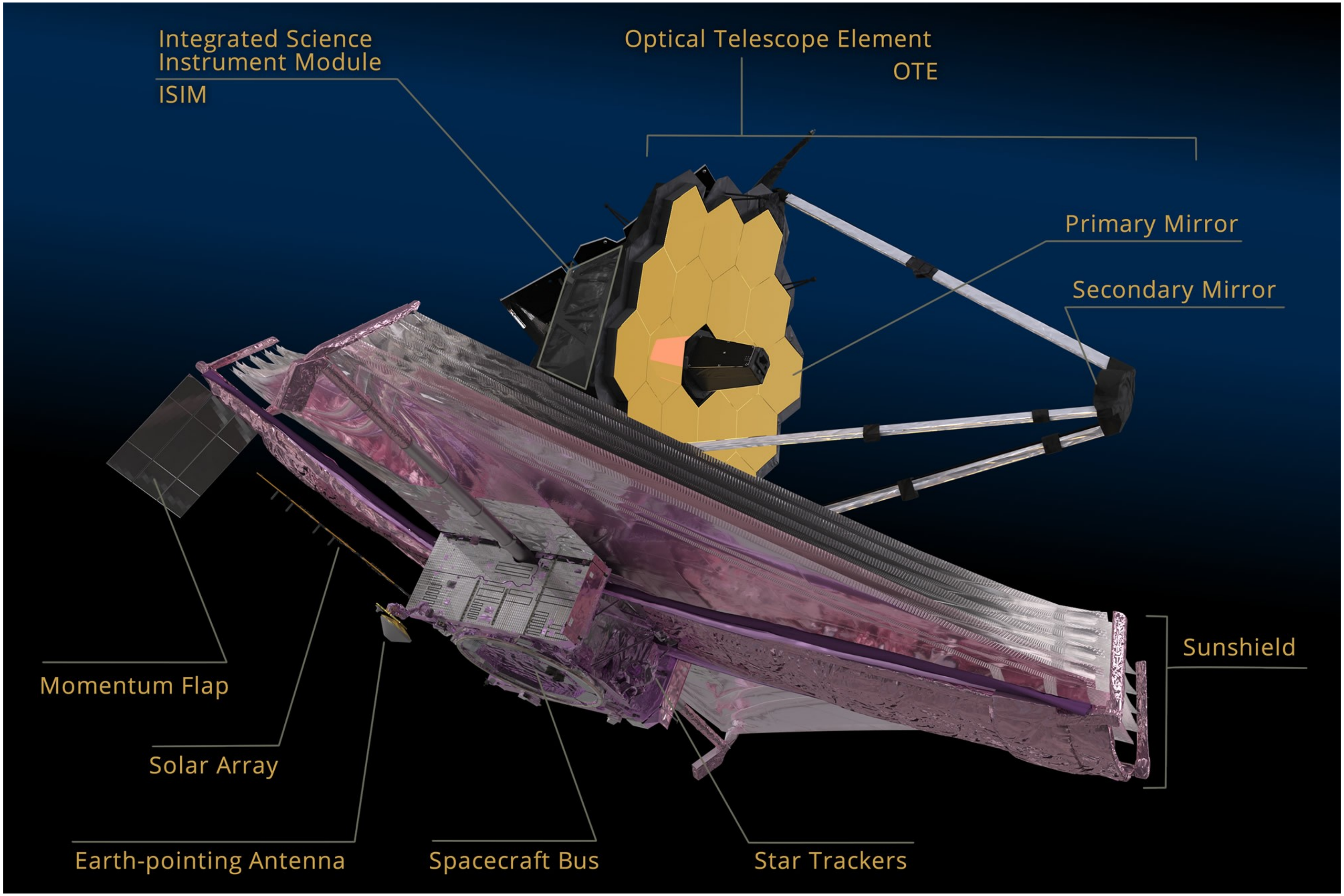
JWST orbits around the L2 point

- **JWST orbits around the L2 point once in every ~6 months**
- **Orbital corrections every 3 months**
- **Halo orbit –** **periodic 3D orbit around the Lagrangian points. Top view for SOHO:**



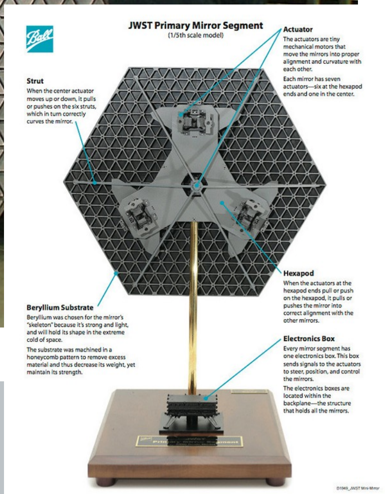
Robert Farquhar
(1932-2015)
“Father of halo orbits”

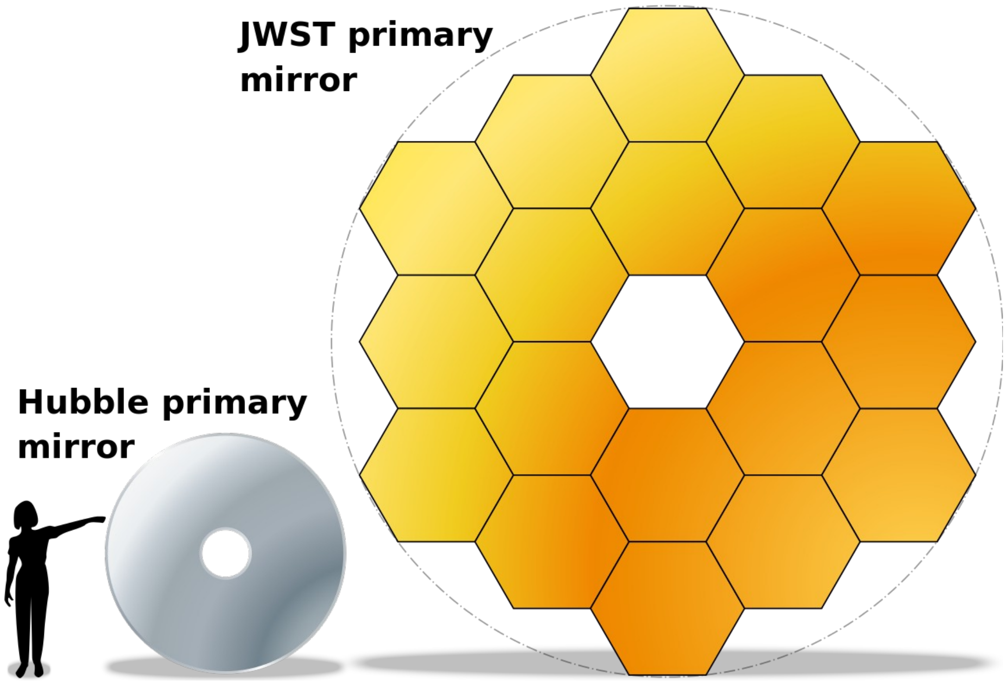
Telescope construction



Primárne zrkadlo

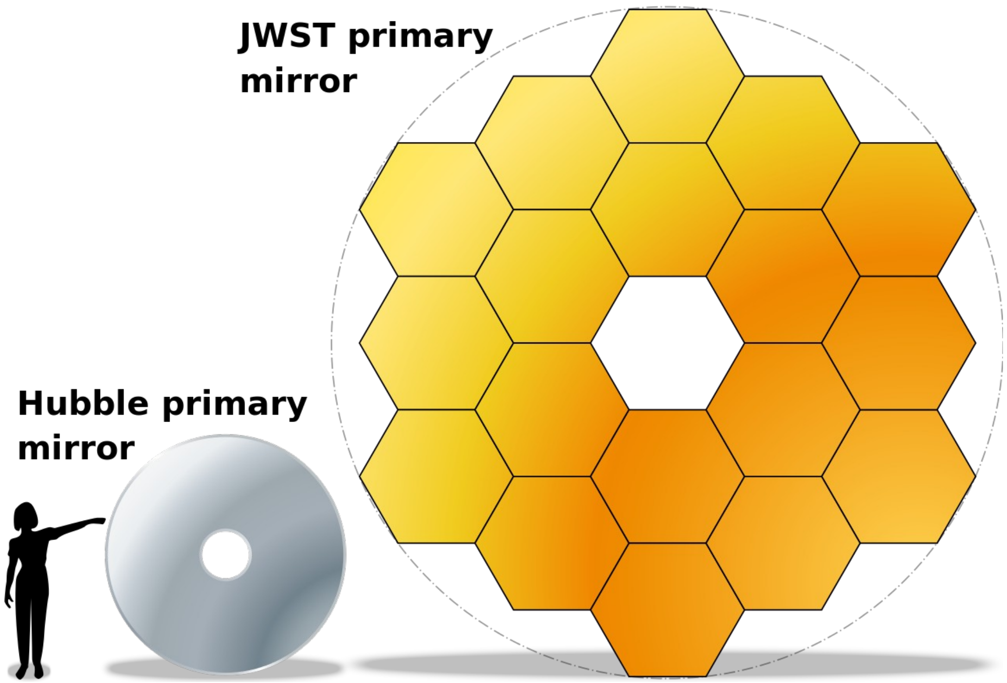
- Overall diameter 6.5 meters, composed from 18 hexagonal segments made of beryllium with the gold coat
- Golden layer is only 100 nm thick – altogether 48 grams (golf ball has 46 grams)
- Beryllium is a rare metal, it is light as well as flexible
- Each segment has only 20 kg and it is about 1 mm thick

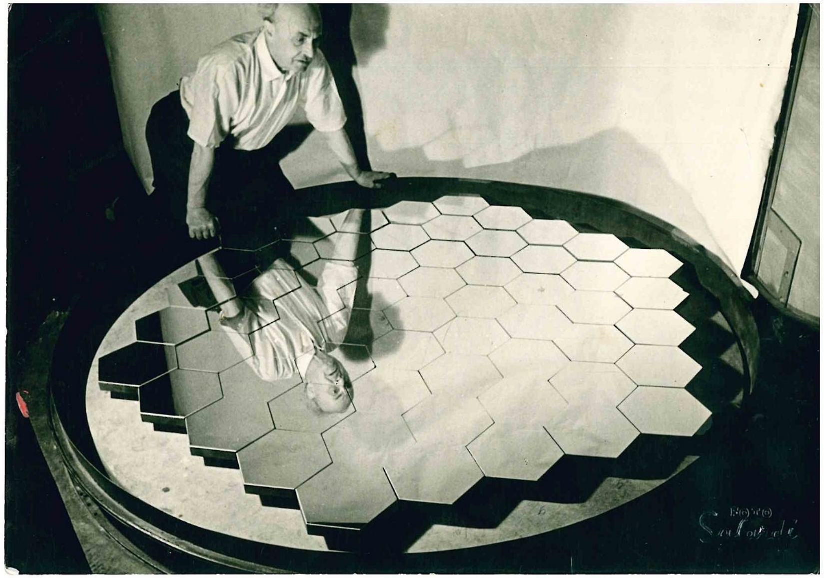




Primary (segmented) mirror

- **Development Guido Horn D'Arturo (Bologna, 1952) and Jerry Nelson (Lawrence Berkeley National Laboratory)**





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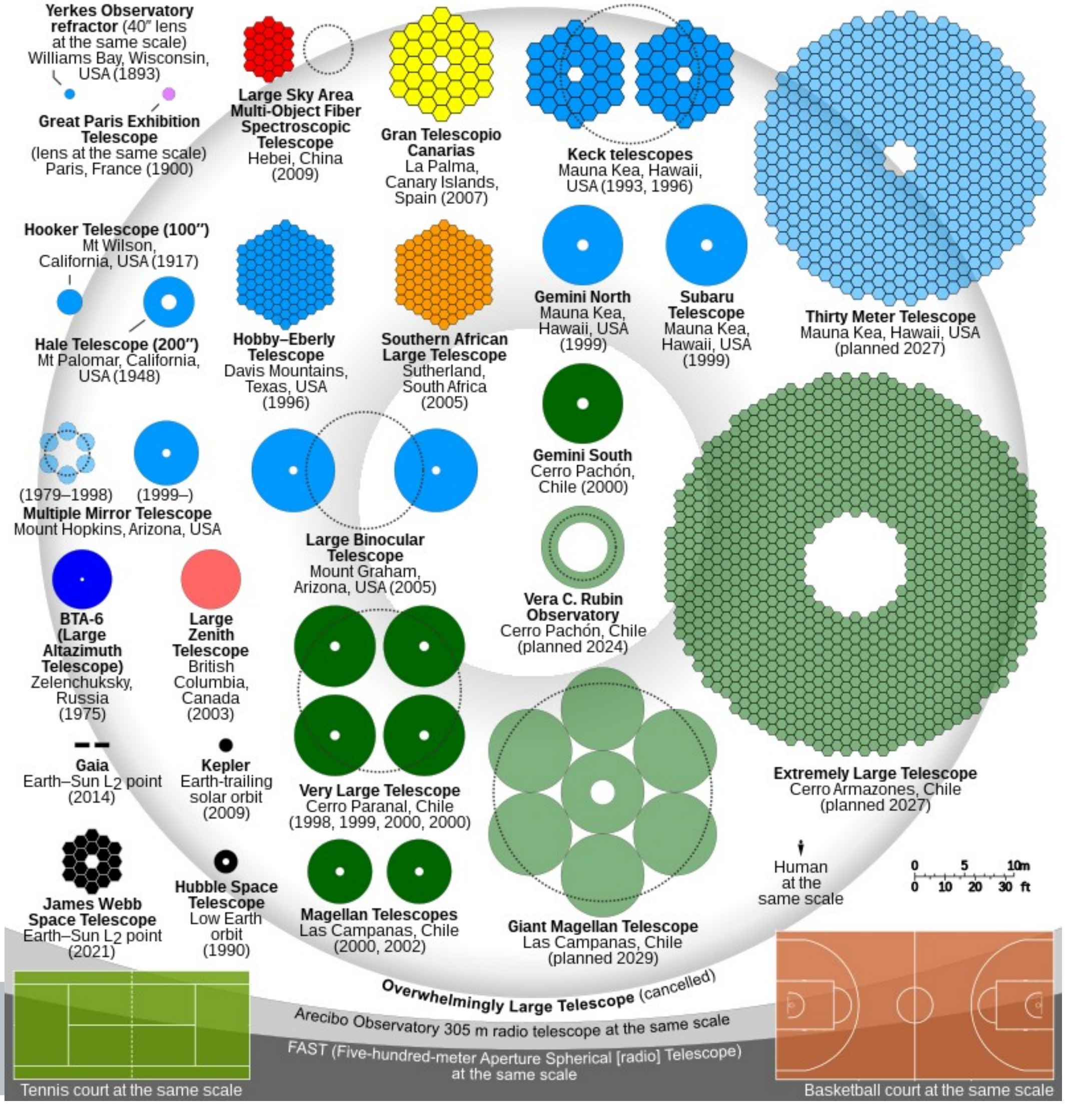
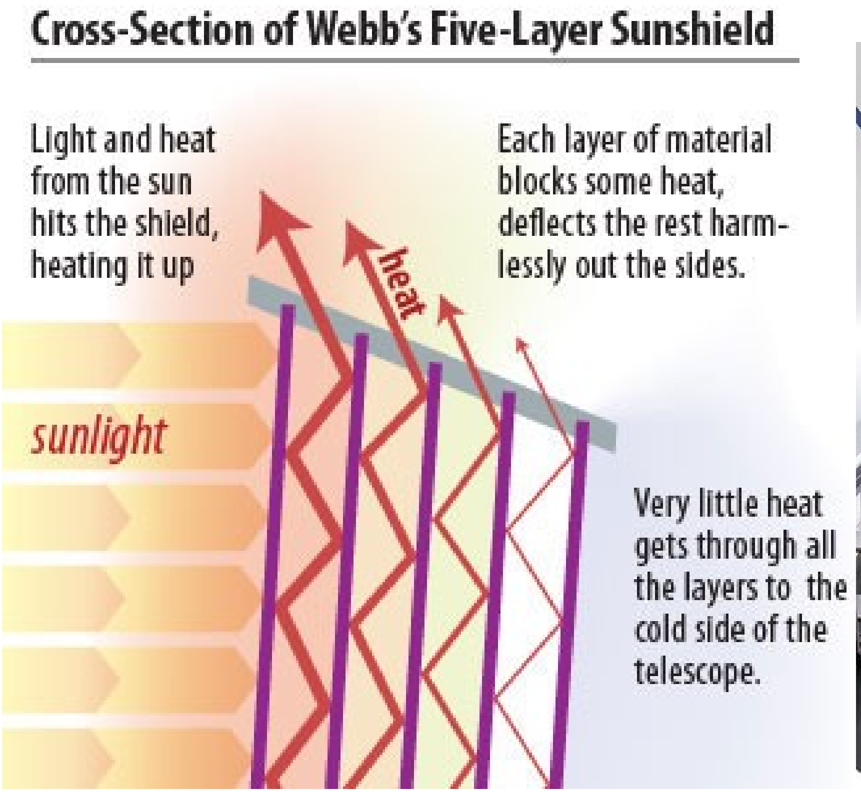
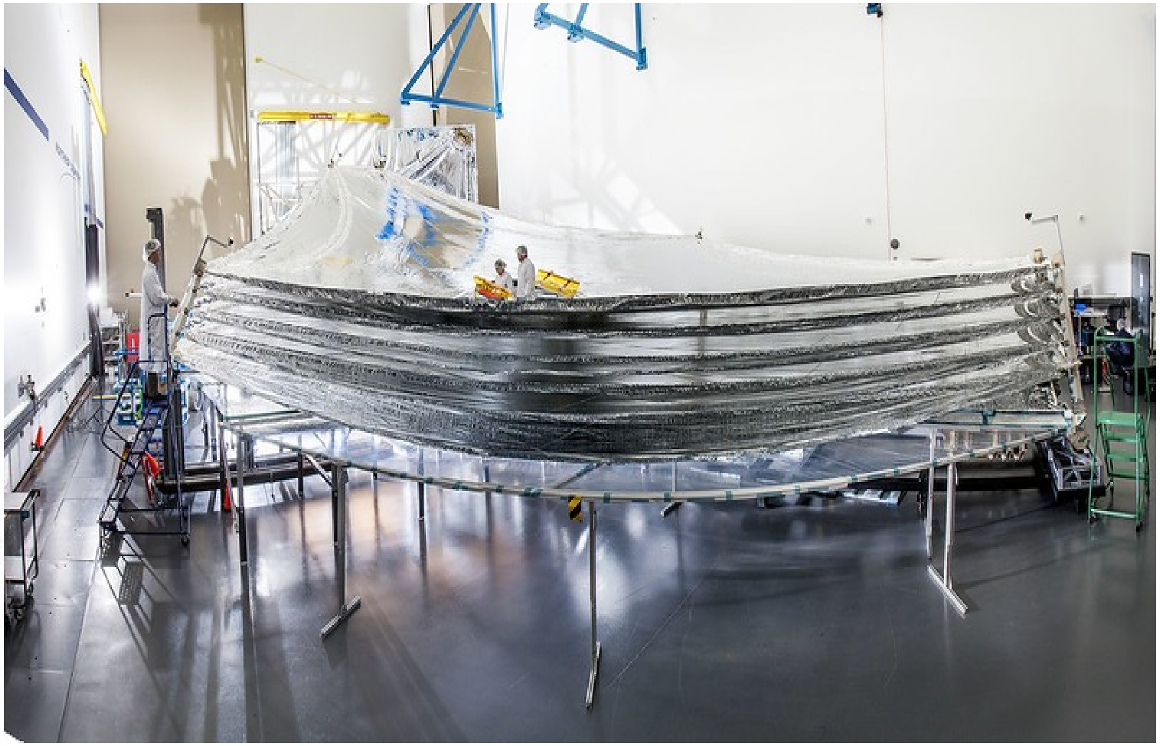


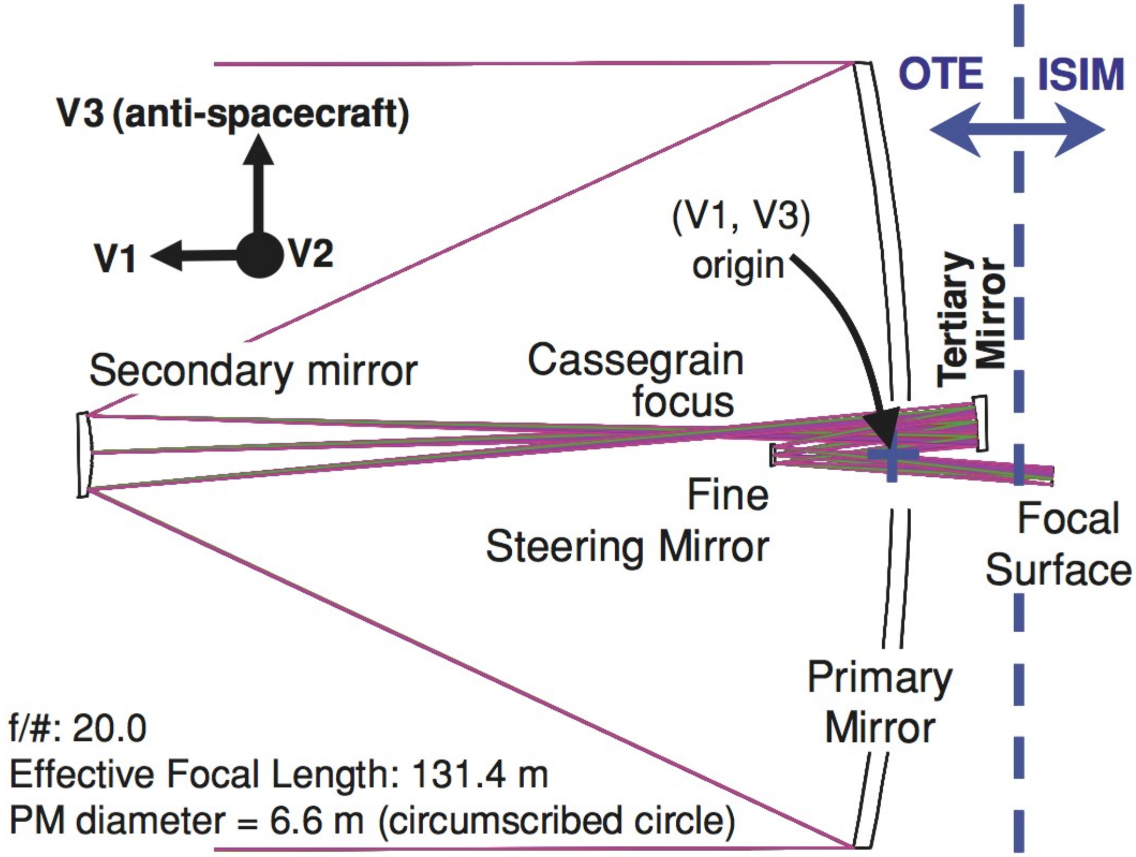
Antisolar shield

- **Big as a tennis court: 14 x 21 meters**
- **Five thin layers with vacuum in between – good insulation properties**
- **Material: kapton E covered with the layer of aluminum and silicon**





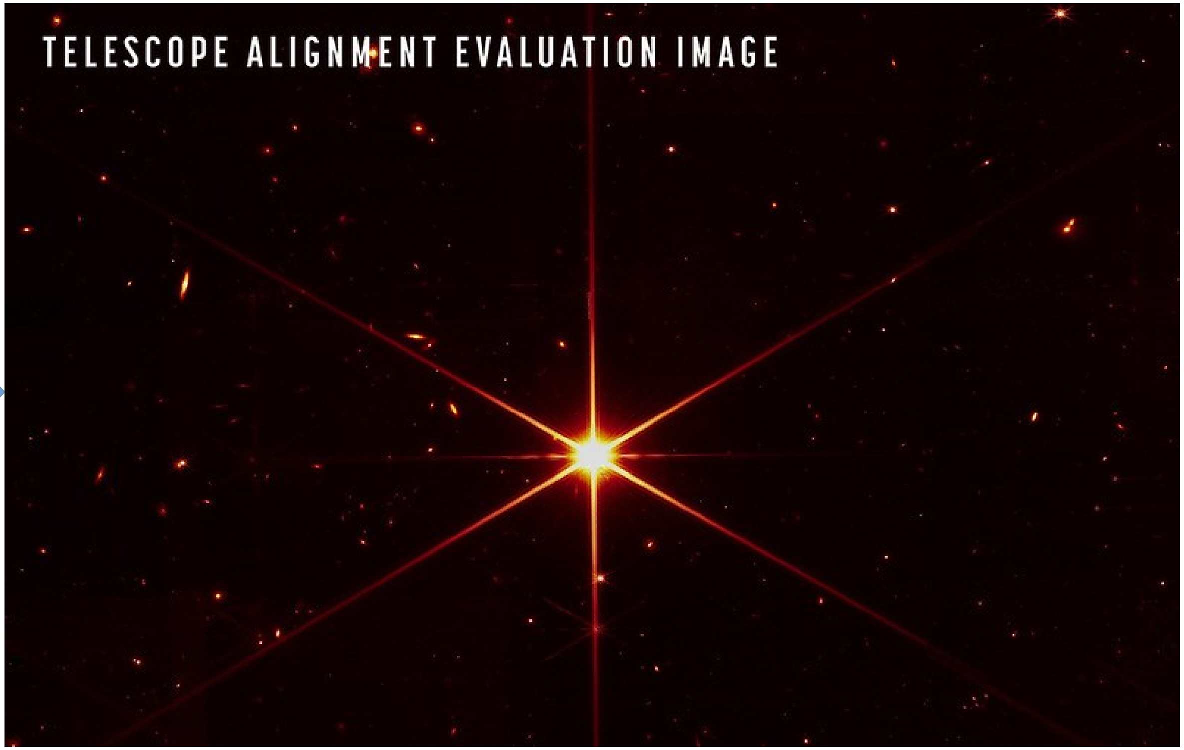
Optical system of JWST



Anastigmatic 3-mirror system

- Primary mirror 6.5 m from 18 segments
- Secondary mirror 0.74 m
- Tertiary mirror
- 132 small engines - actuators – to fine-tune the segment position

Image of a star provided by the optical system

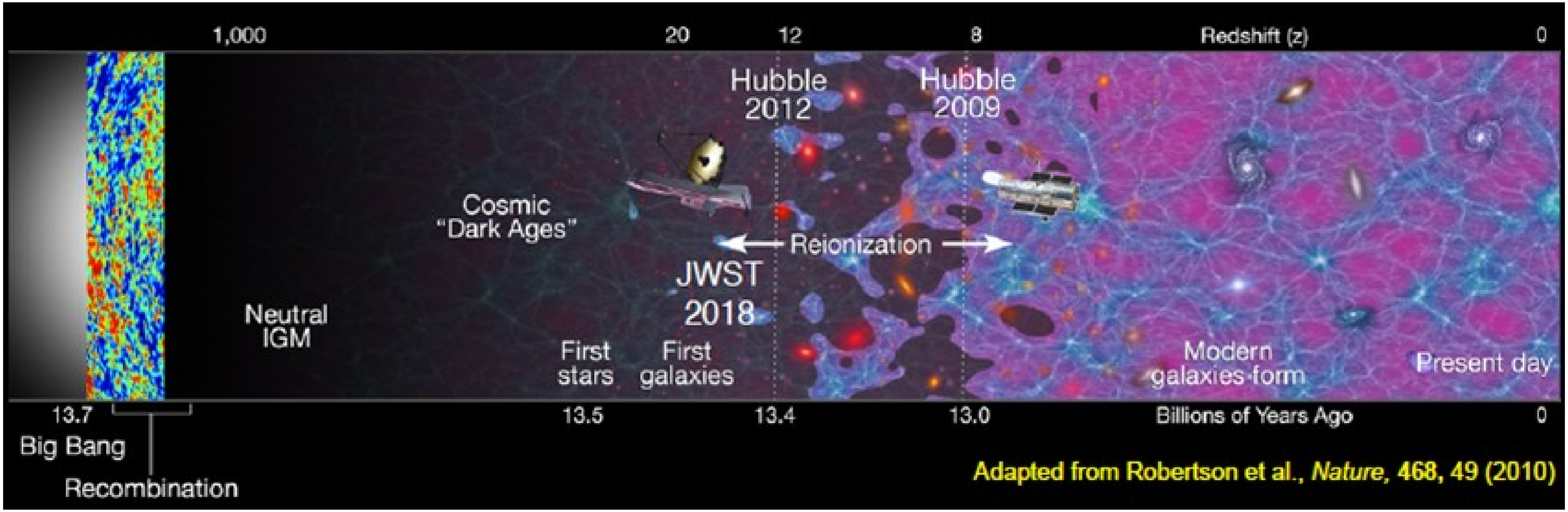


Scientific focus

- **Origin of stars and planets, their evolution in the Universe across the galaxy and time**

Scientific focus

- JWST has been studying formation and evolution of galaxies from 180 million years after the Big Bang (hot and dense origin of our Universe)
- First stars formed only 100 million years after the Big Bang
- From ~100 million years (z=30) till ~914 million years (z=6), the neutral hydrogen was *reionized*
- In our Galaxy, we will study star formation, exoplanets, and the Galactic center



Scientific focus

- **JWST has been studying formation and evolution of galaxies from 180 million years after the Big Bang (hot and dense origin of our Universe)**
- **First stars formed only 100 million years after the Big Bang**
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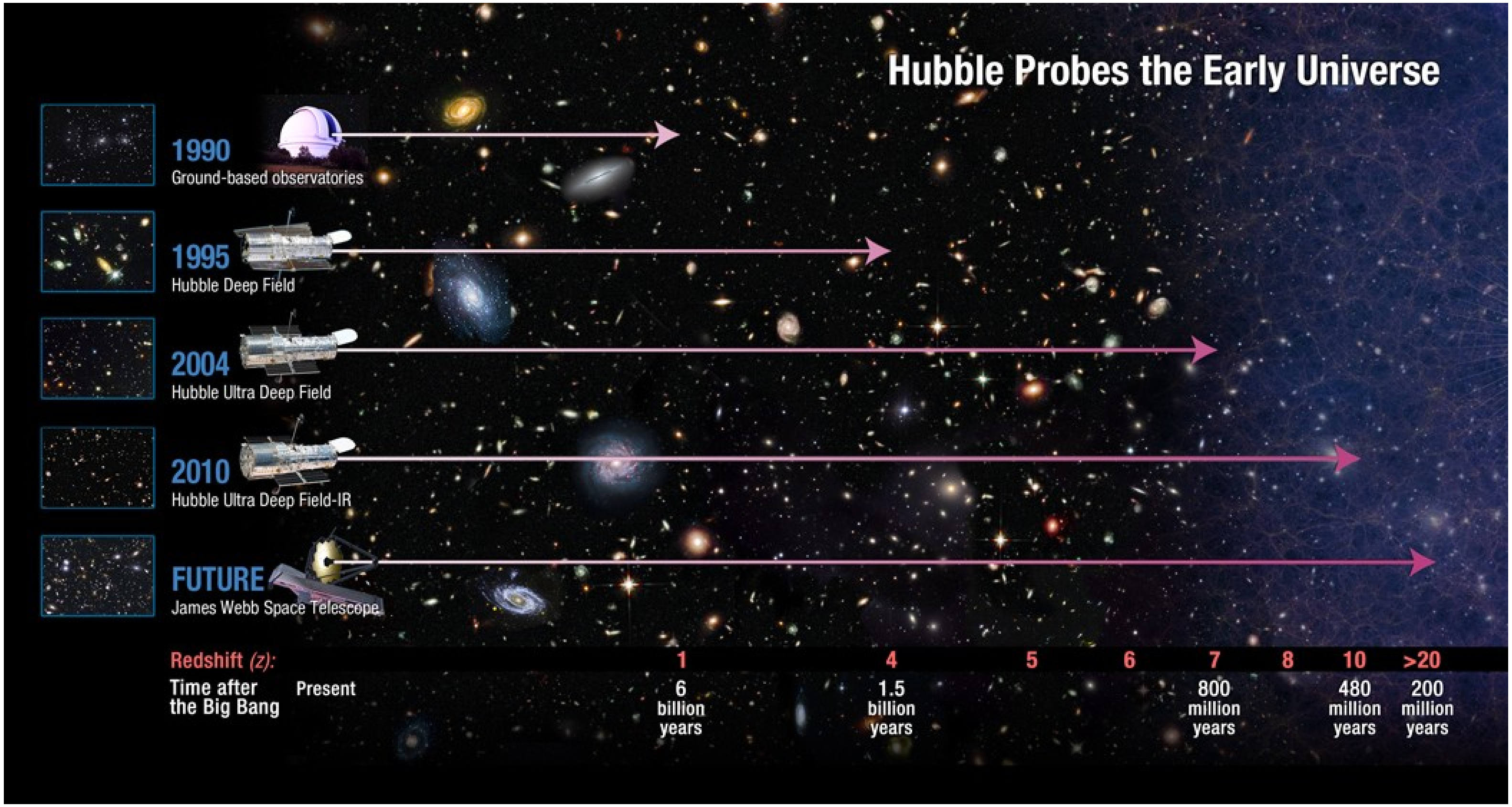

First scientific results

Webb’s First Deep Field SMACS J0723.3-7327

Galaxy cluster - 4.6 billion light years distant, some “red” galaxies ~13.1 Gly

MIRI NIRCam

First scientific results

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NIRISS

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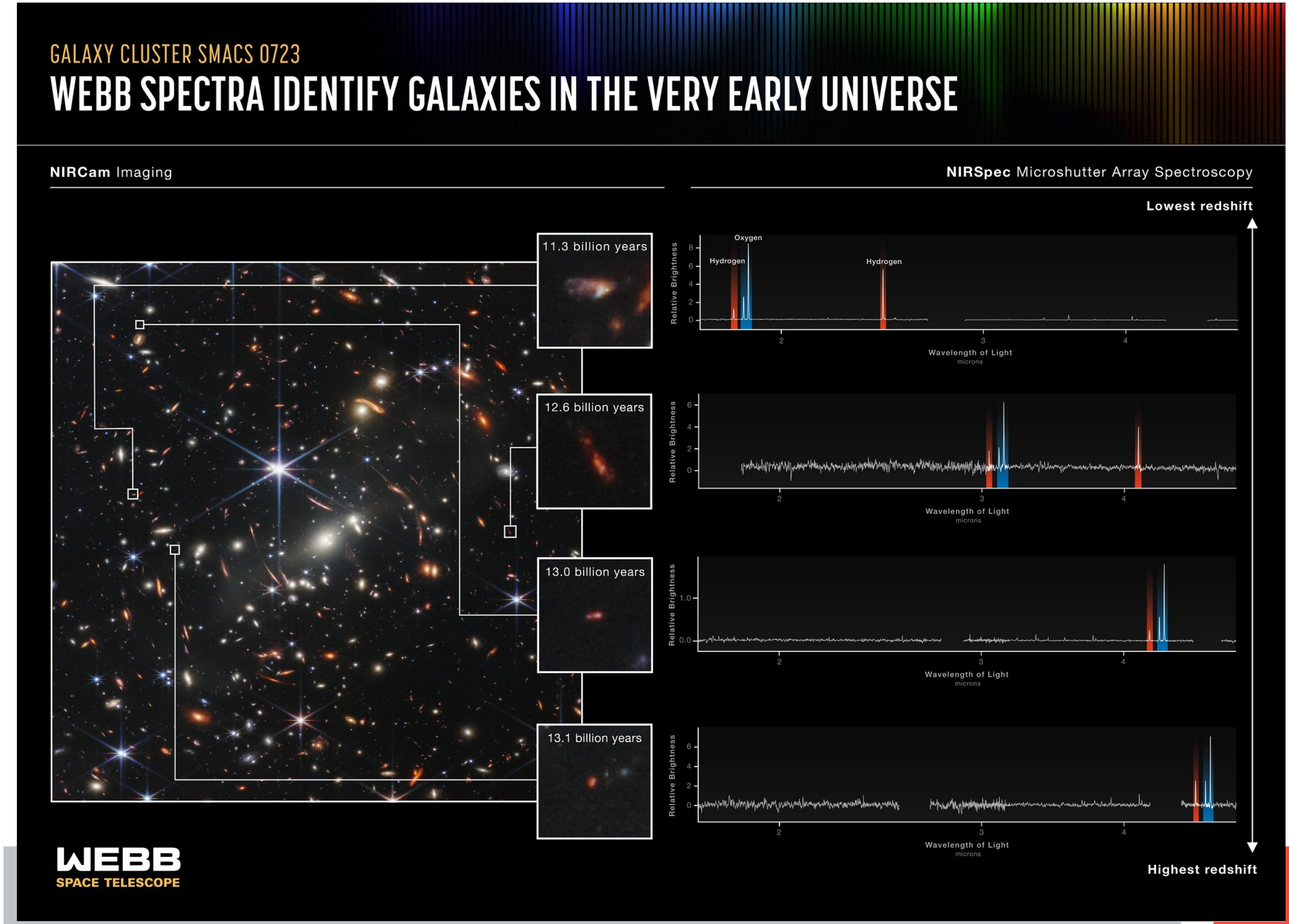


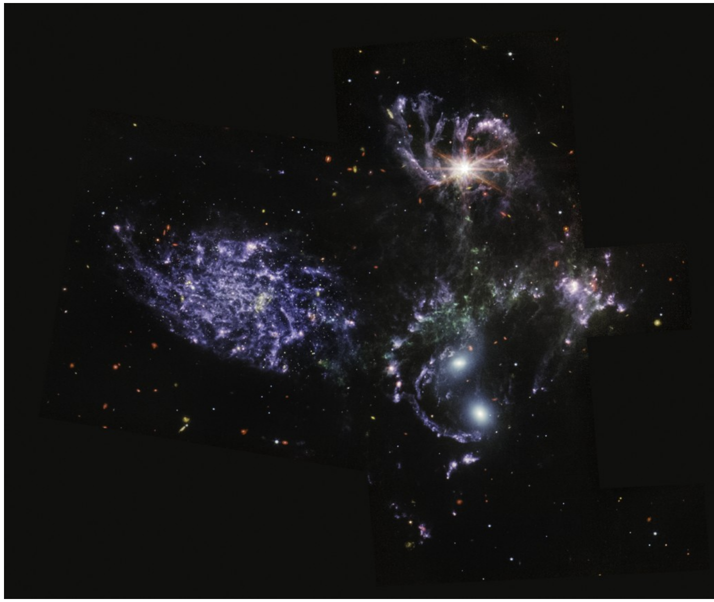
NIRSpec Microshutter Array Spectroscopy

First scientific results

Stephan's quintet
4 colliding galaxies - 290 million light years from the Earth

NIRCam/MIRI

NIRCam



MIRI

First scientific results

Carina nebula
8500 light years from the Earth, star-formation region (NGC3324)

NIRCam

MIRI

First scientific results

Southern Ring Nebula (NGC 3132)
Gas and dust expelled by a dying star (2500 light years from the Earth)

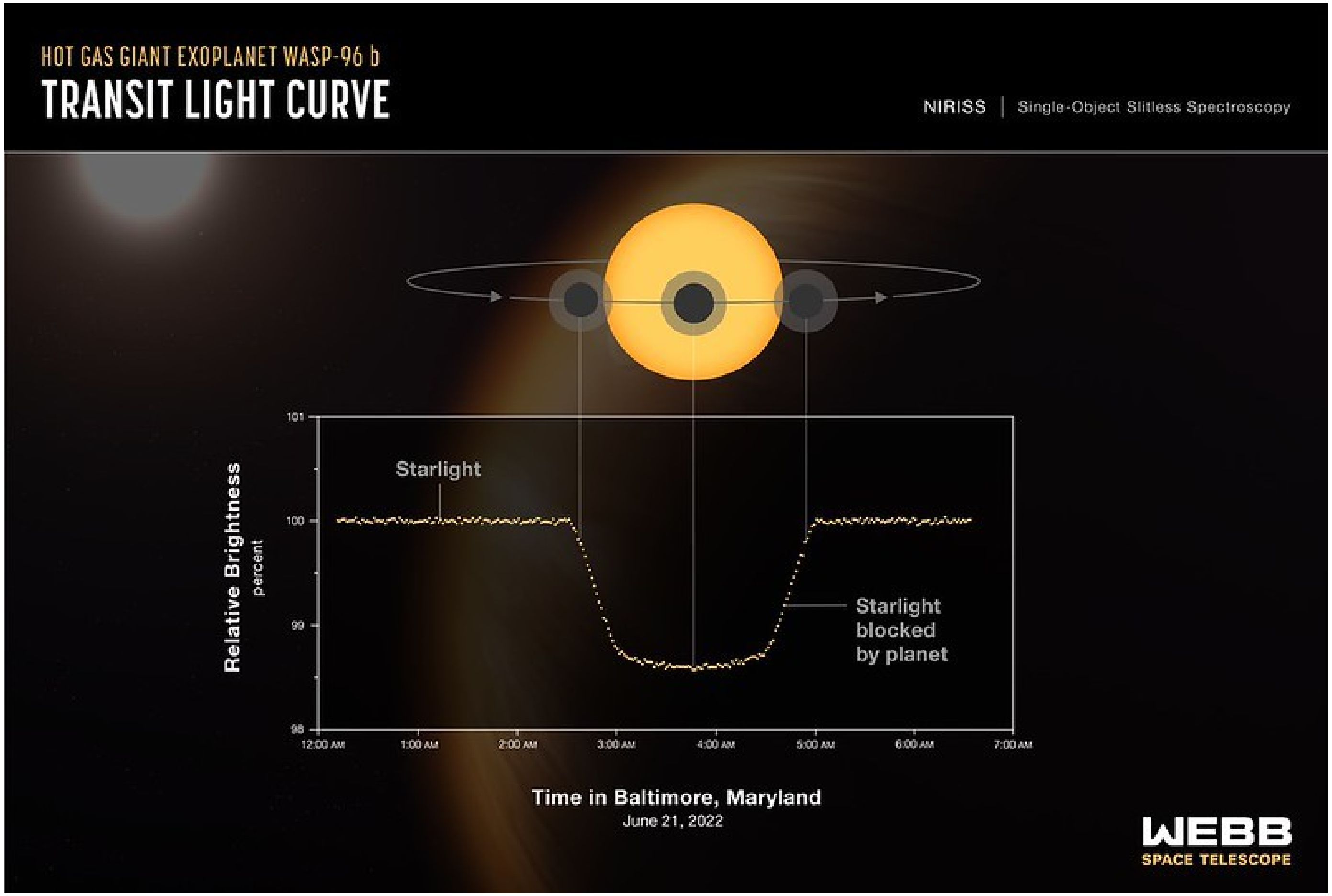
NIRCam

MIRI

First scientific results

WASP-96b

Analysis of the exoplanet atmosphere spectrum, detection of water and clouds (1120 ly)



NIRISS

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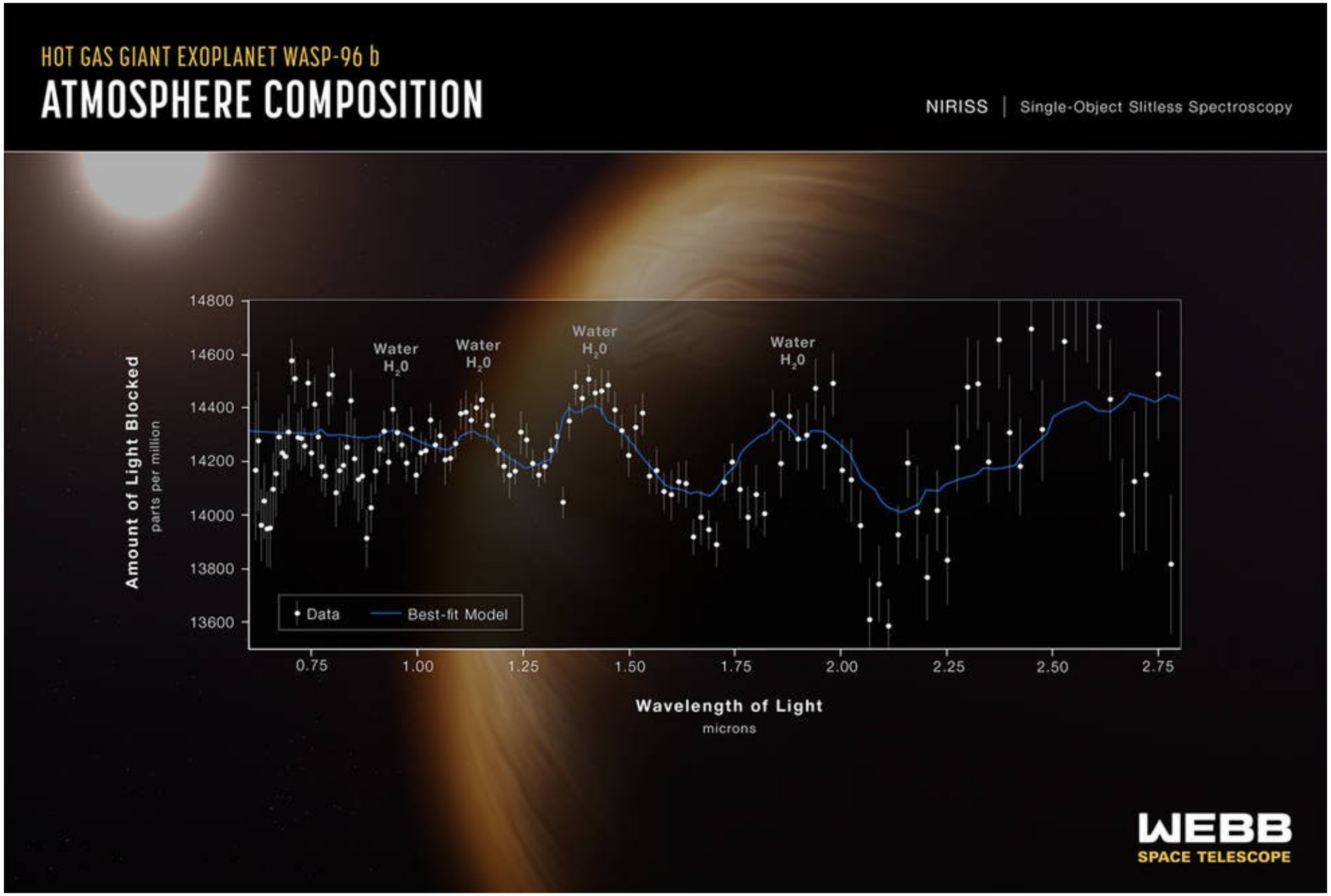


NIRISS

Selected other results

Cartwheel galaxy
~ 500 milion light years

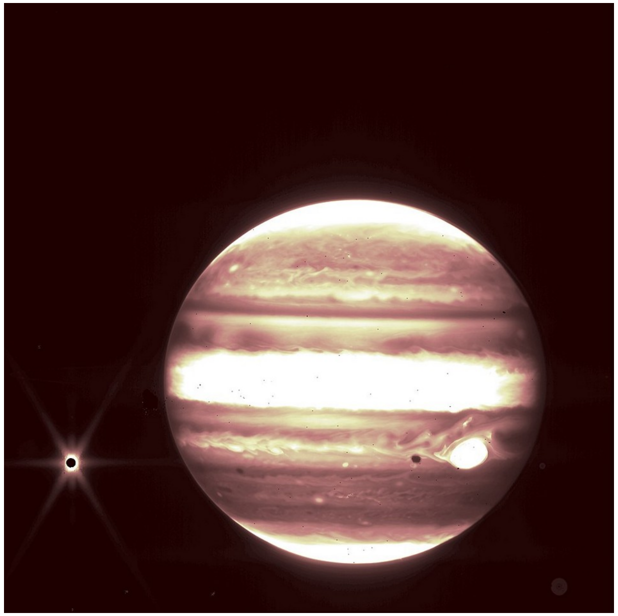
NIRCam/MIRI

NIRCam

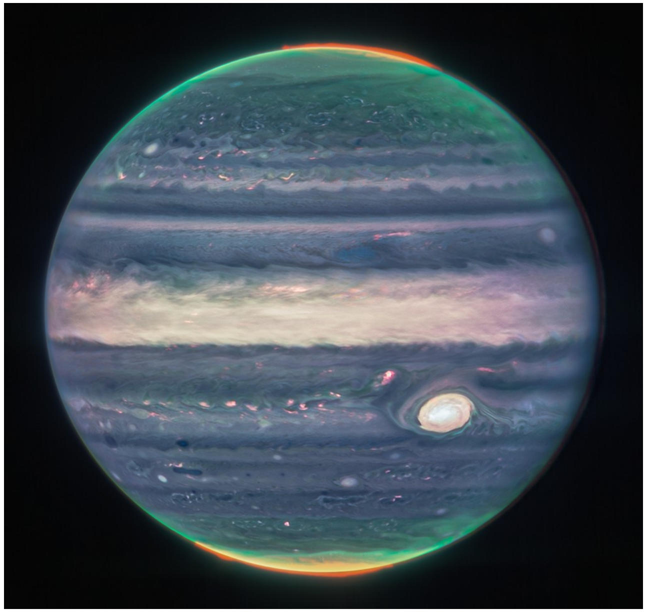
MIRI

Selected other results

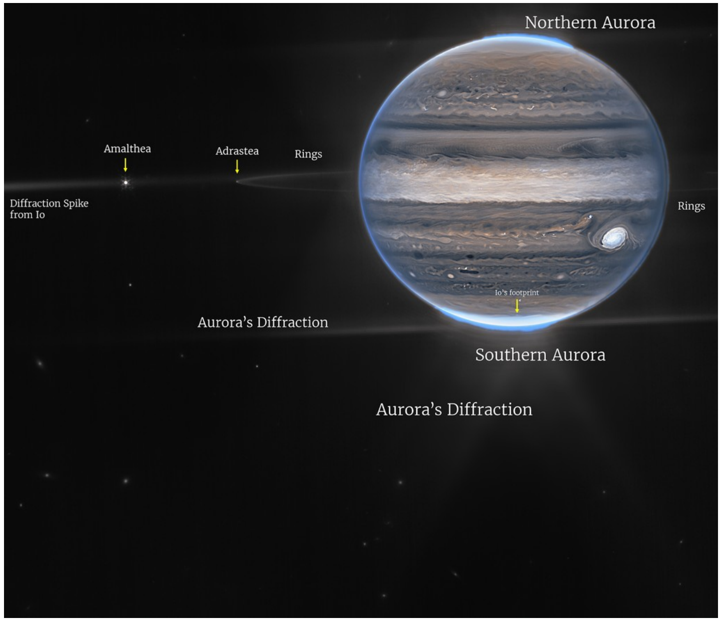
Jupiter with moons and the ring



NIRCam



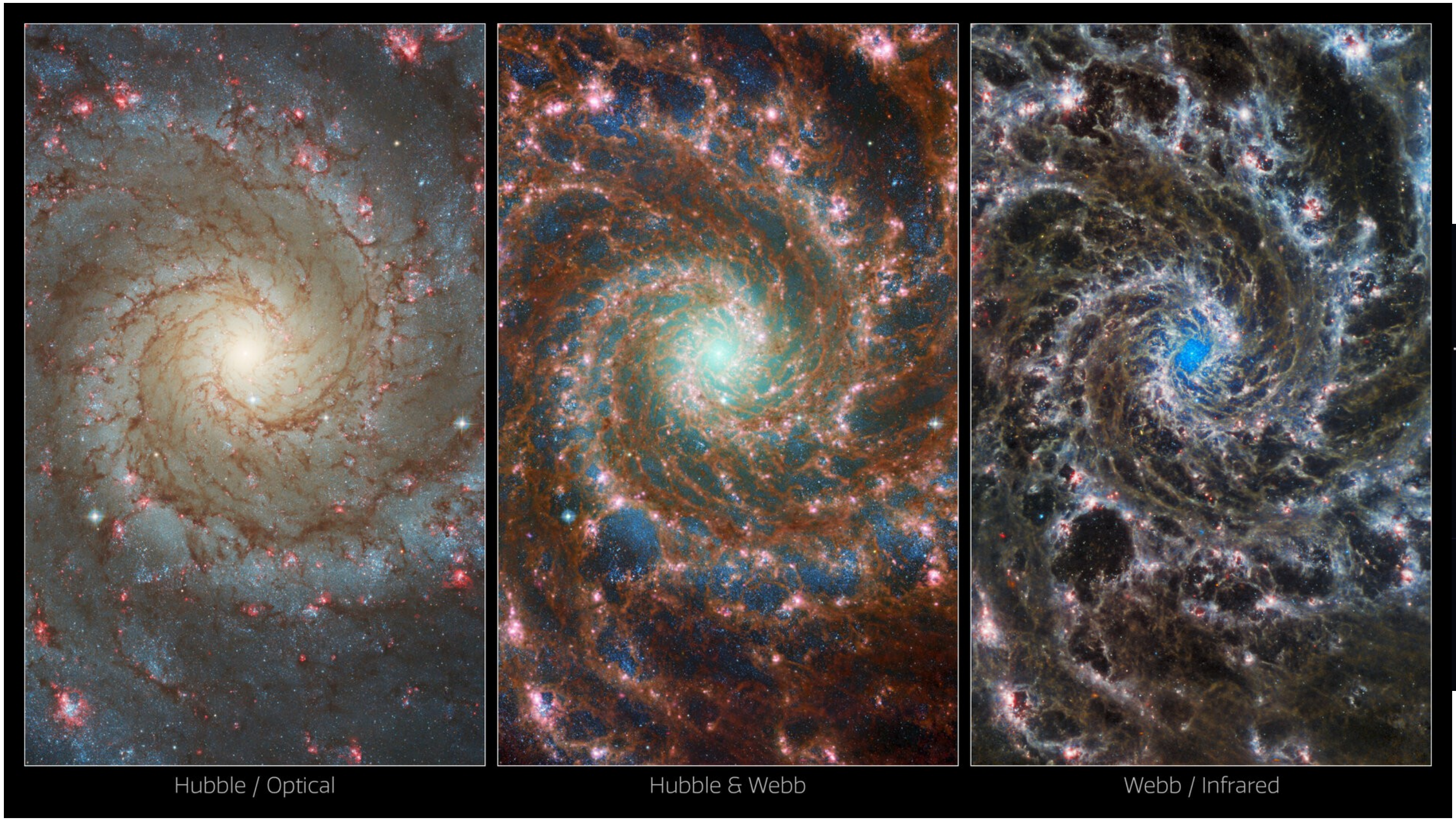
NIRCam

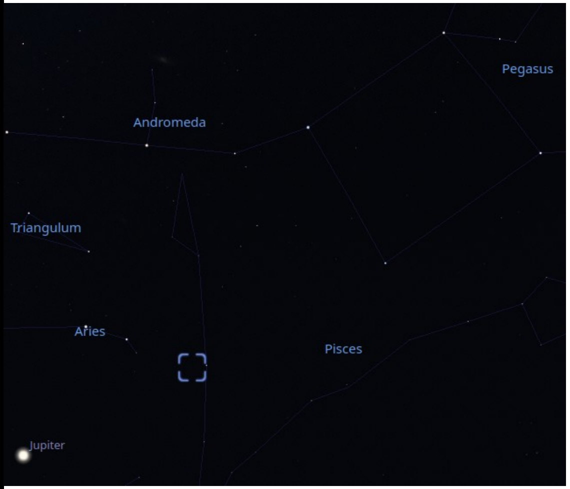


NIRCam

Selected other results

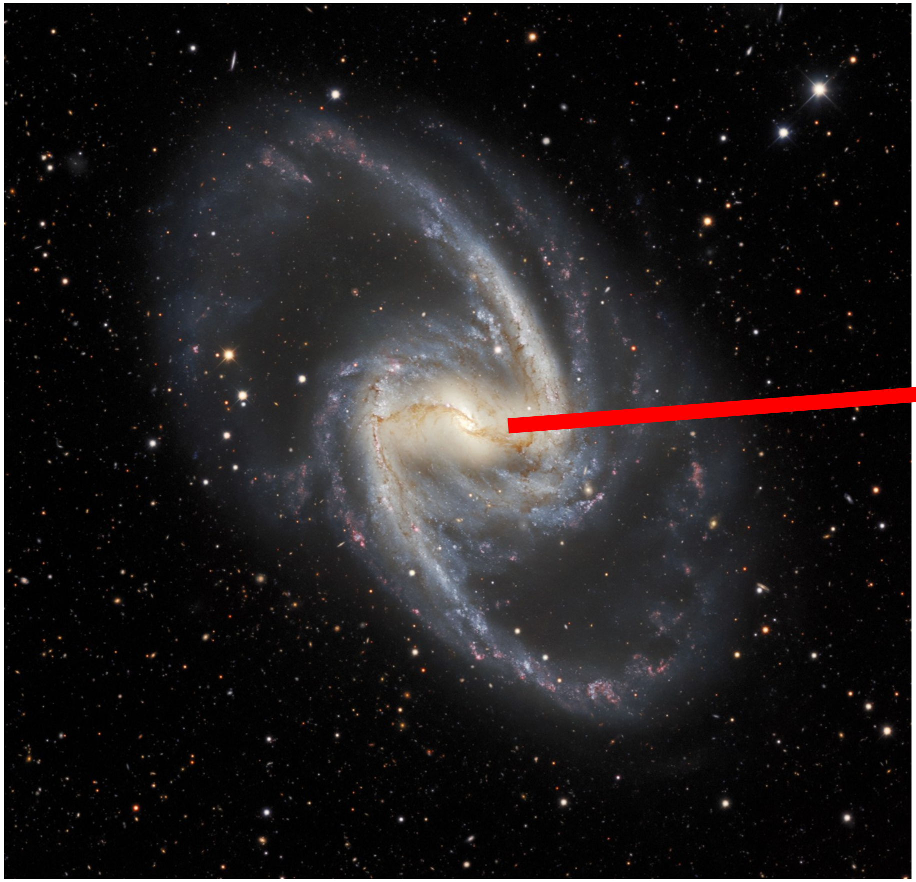
M74 – Fanthom galaxy – 32 million light years from the Earth





Selected other results

NGC1365 – Great Barred Spiral Galaxy – 56 million light years



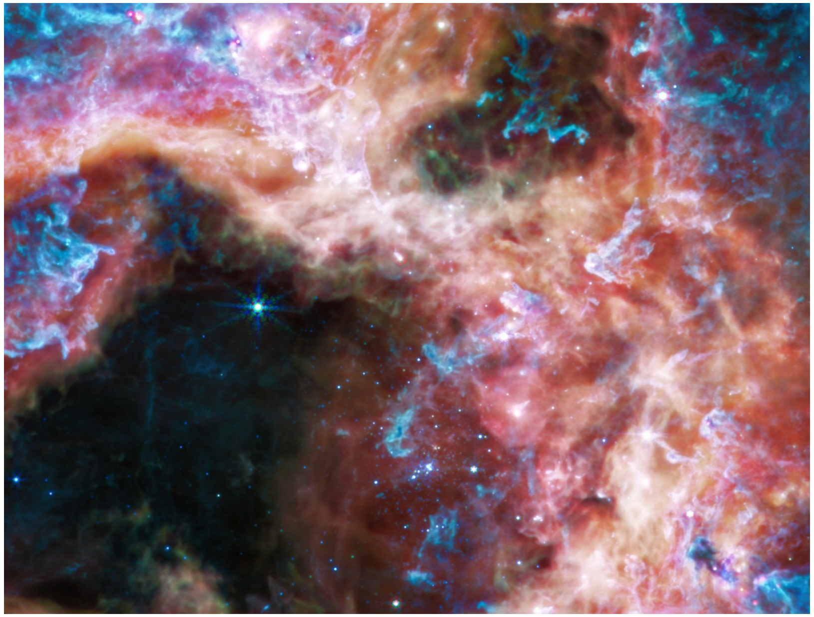
Visible light (DESCam)

MIRI

Selected other results

Tarantula nebula (30 Doradus) – HII region in Giant Magellanic cloud – 160 000 light years from the Earth

NIRCam

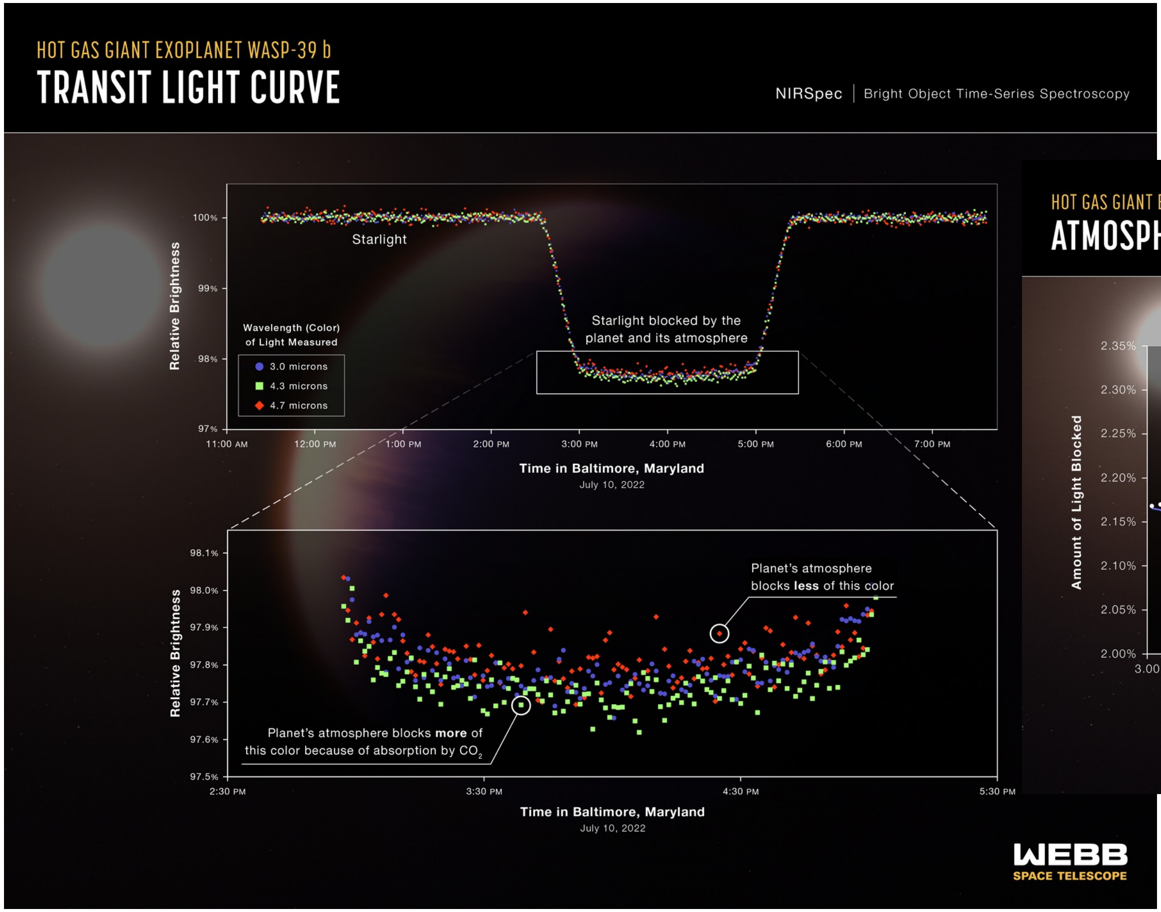


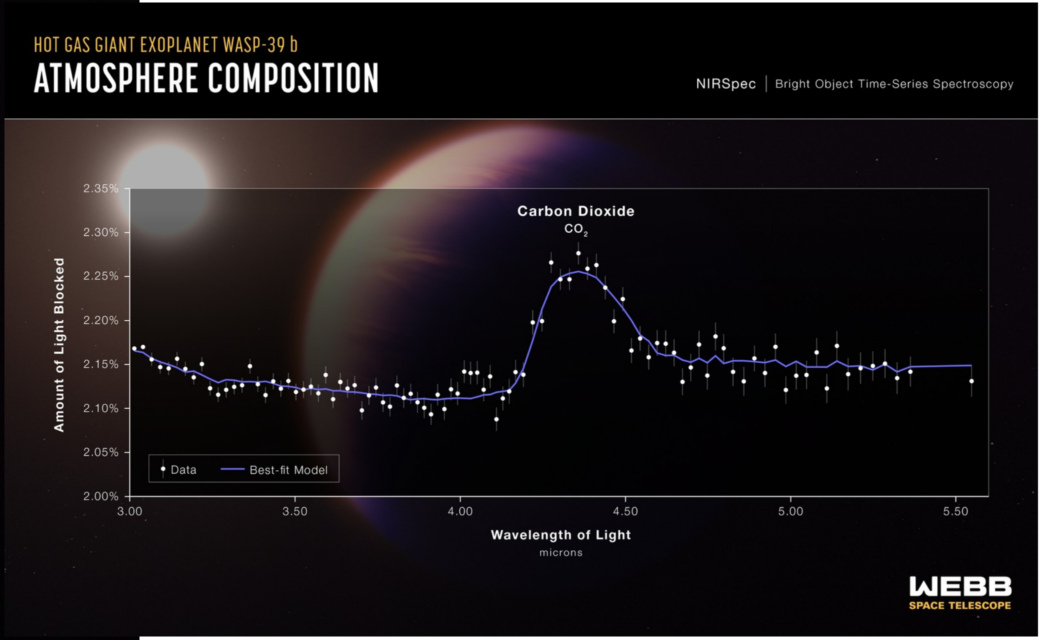
MIRI

Selected other results

First detection of carbon dioxide in the exoplanet atmosphere

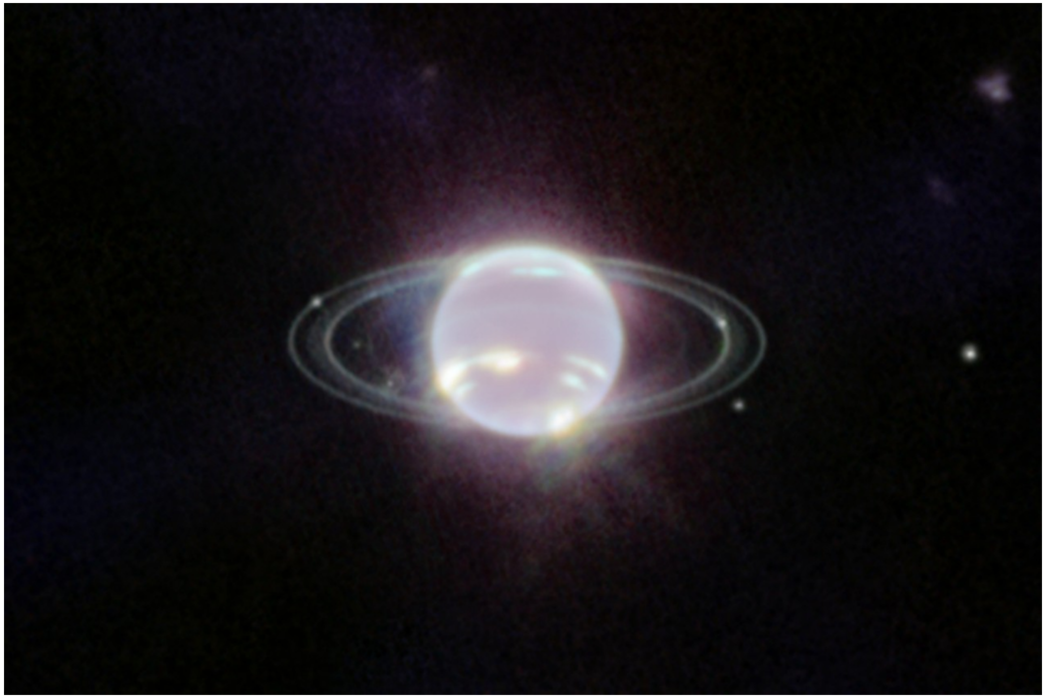
WASP-39b: 700 light years distant, temperature 900 degrees Celsius, 4-day orbit around the star



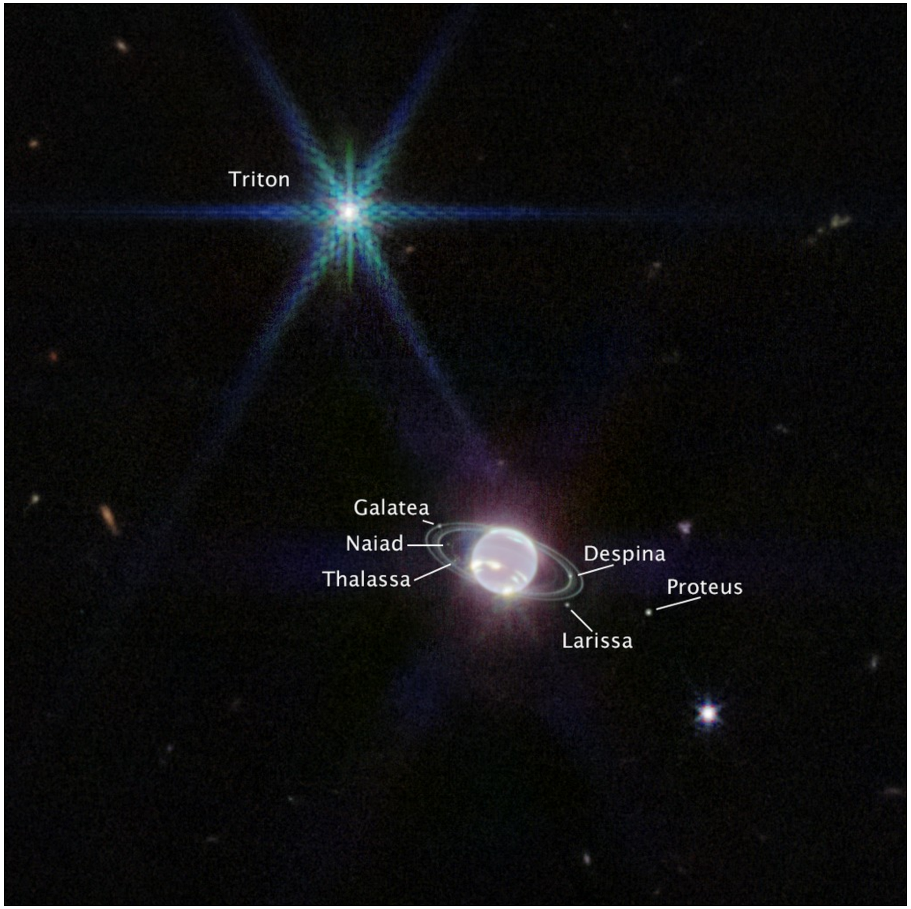


Selected other results

Neptune with rings and moons



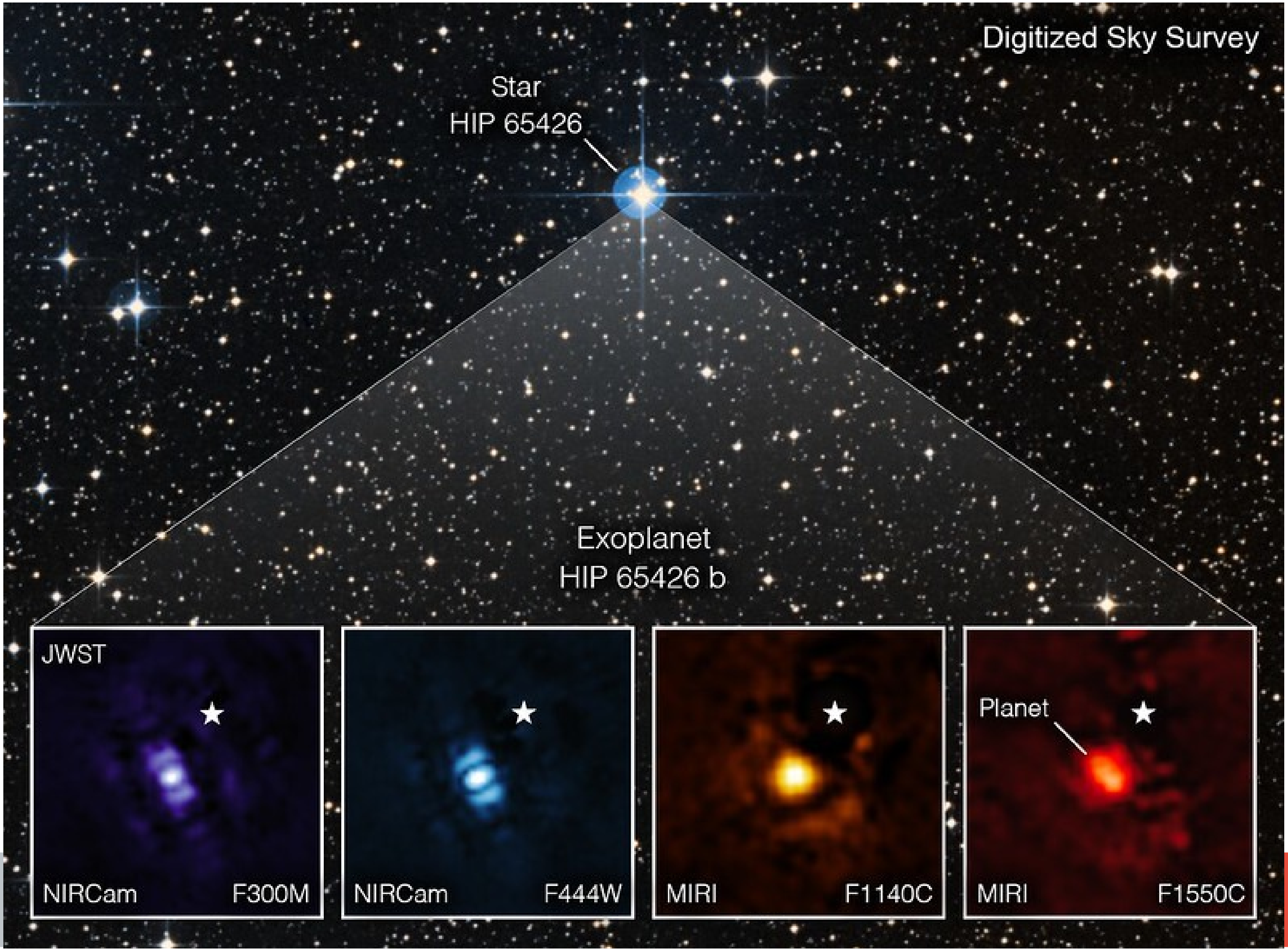
NIRCam



NIRCam

Selected other results

Exoplanet imaging by blocking the stellar light



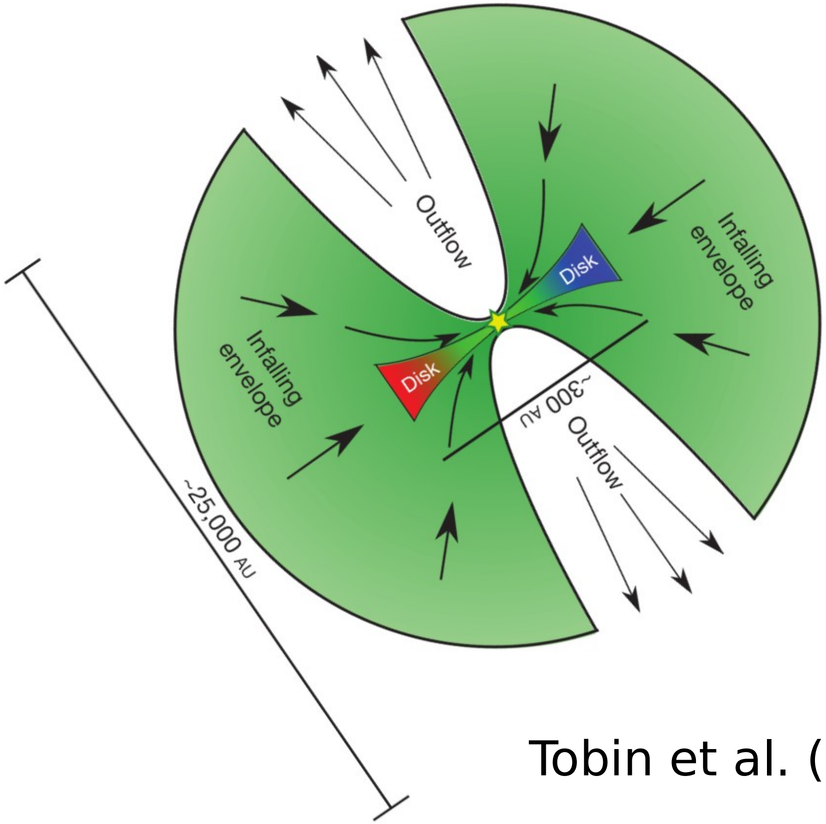
Selected other results

Protostar – forming star in the dark cloud L1527 at 460 light years in the Taurus star-forming region

NIRCam

Star ~0.2 M_{sun}

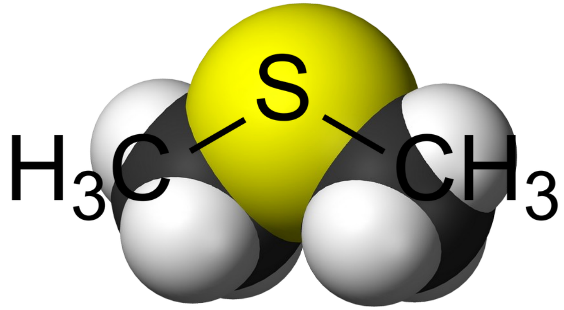
Envelope ~0.1 M_{sun}

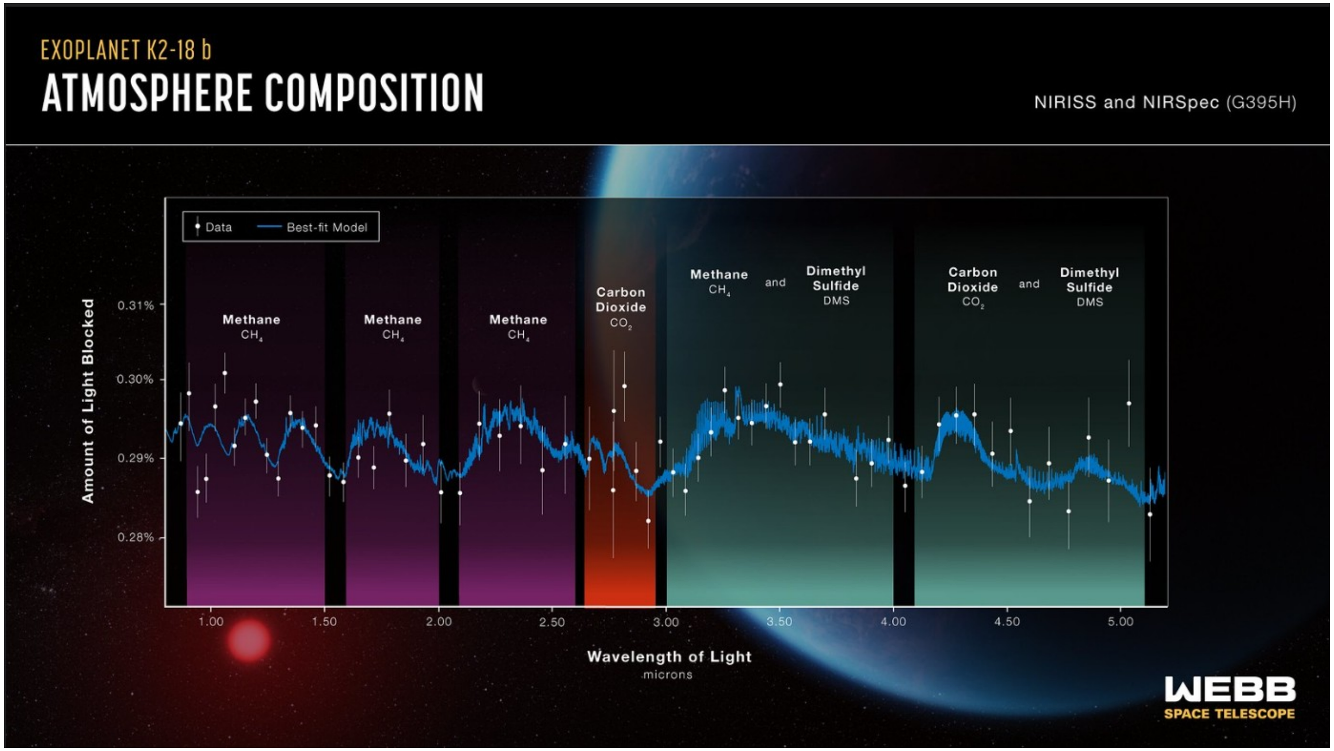


Tobin et al. (2012)

Potential biosignature?

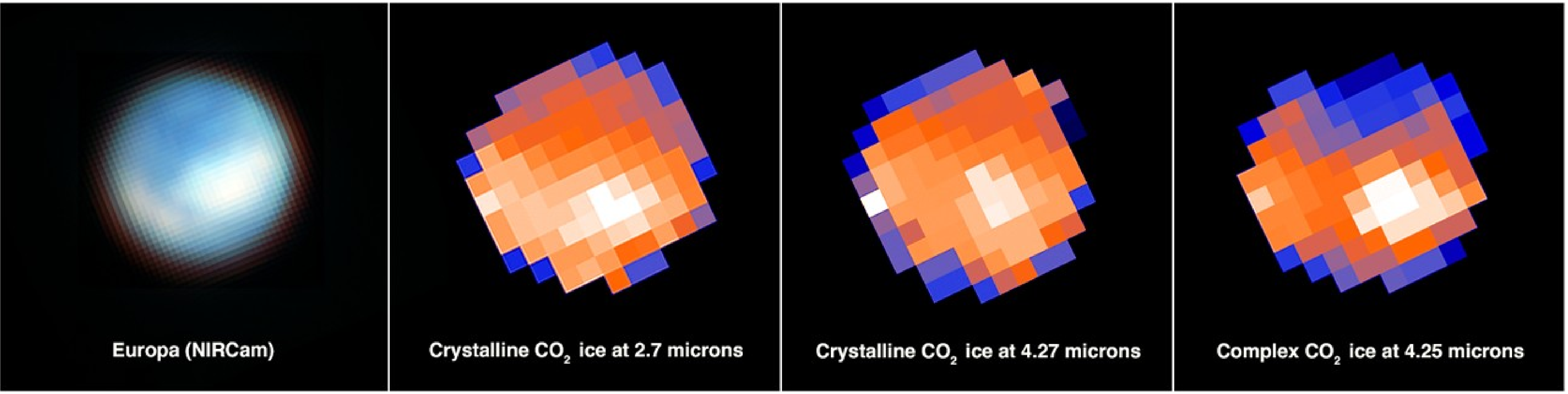
- Detection of methane, carbon dioxide, and traces of dimetyl sulfide in the atmosphere of the transiting exoplanet K2-18b
- Subneptune, **Hycean (hydrogen+ocean)** planet with potentially water ocean and hydrogen atmosphere (lack of ammonia)
- 120 light years from the Earth





Potential biosignature?

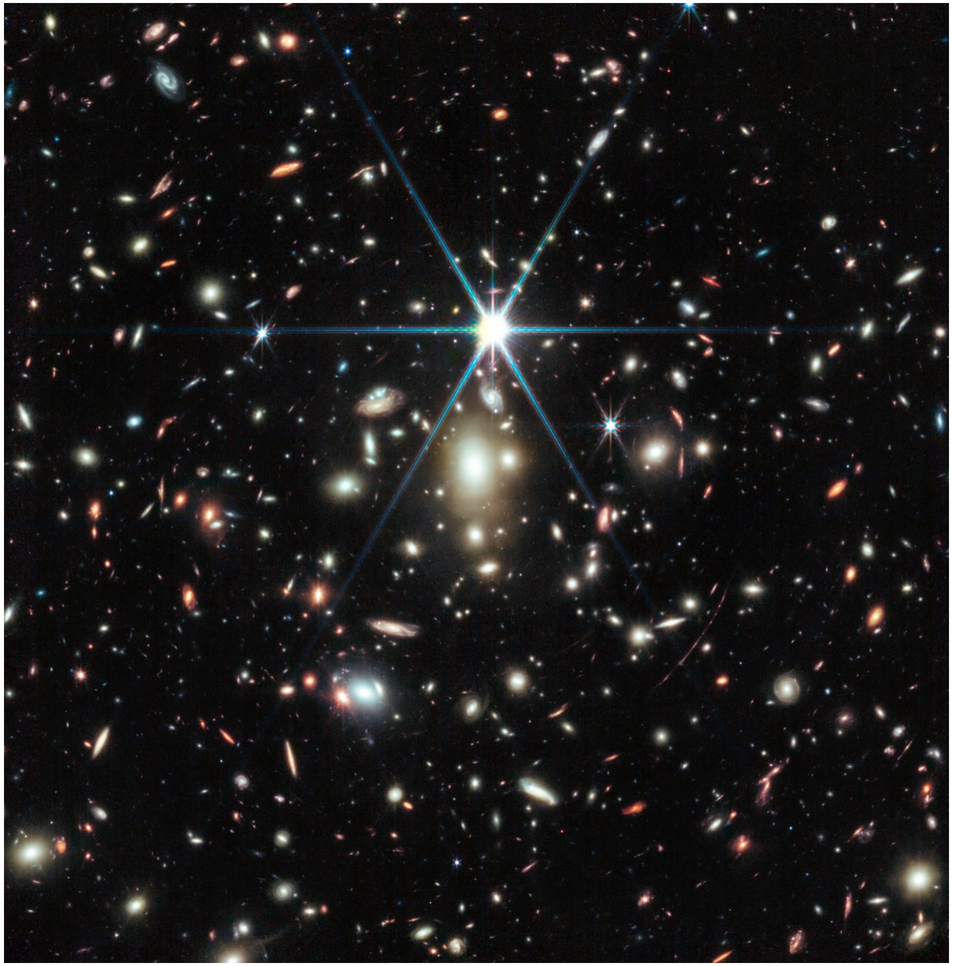
- Detection of CO2 on Europa’s surface



NIRSpec/IFU

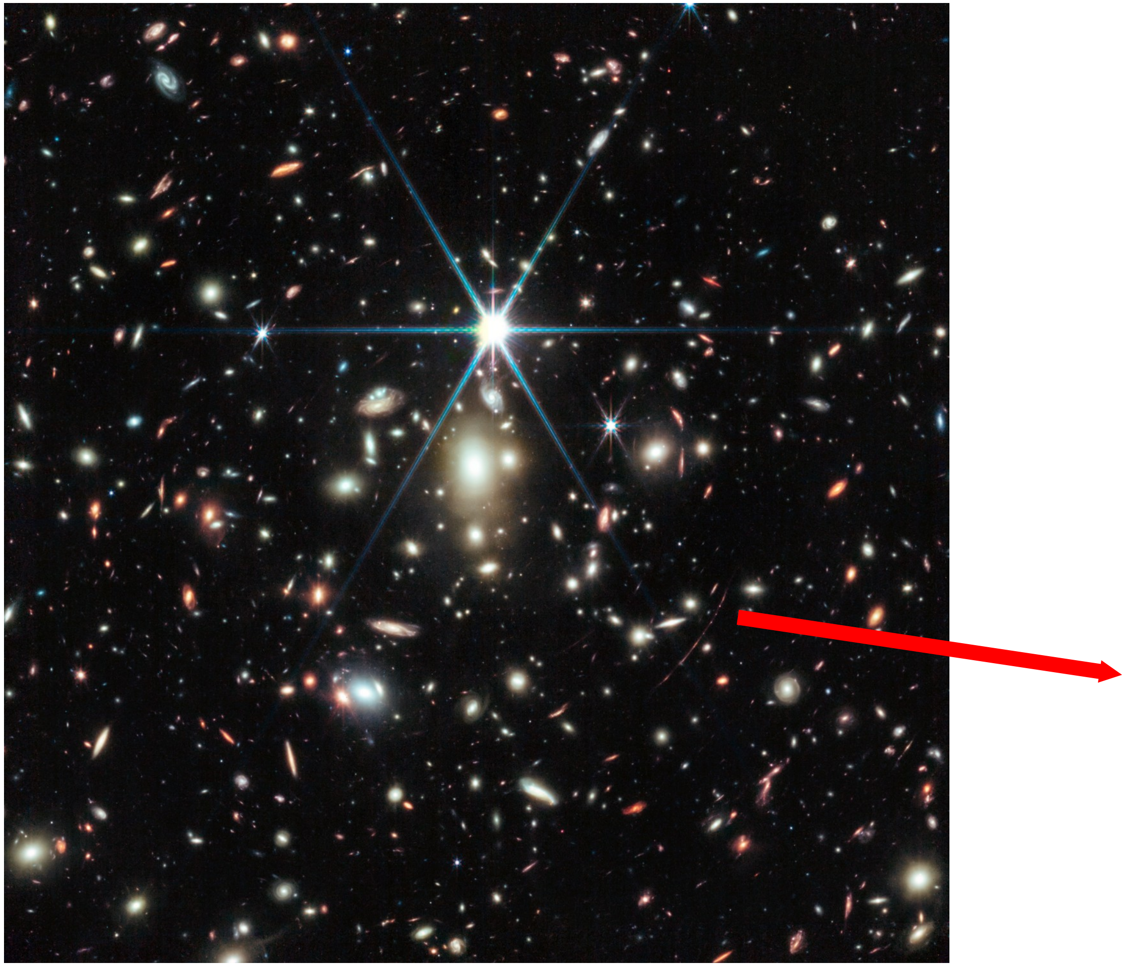
Selected other results

Oldest and most distant single star – Earendel (1 billion years after the Big Bang). B-type star, temperature 2x Solar, 10^6 Solar luminosities



Selected other results

Oldest and most distant single star – Earendel (1 billion years after the Big Bang). B-type star, temperature 2x Solar, 10^6 Solar luminosities



Sunrise Arc

Selected other results

Oldest and most distant single star – Earendel
Extreme magnification by 4000, likely a binary with a cooler companion

Anniversary image

Nearest star-forming region at 390 ly (Rho Ophiuchi)

NIRCam

Another star-forming region

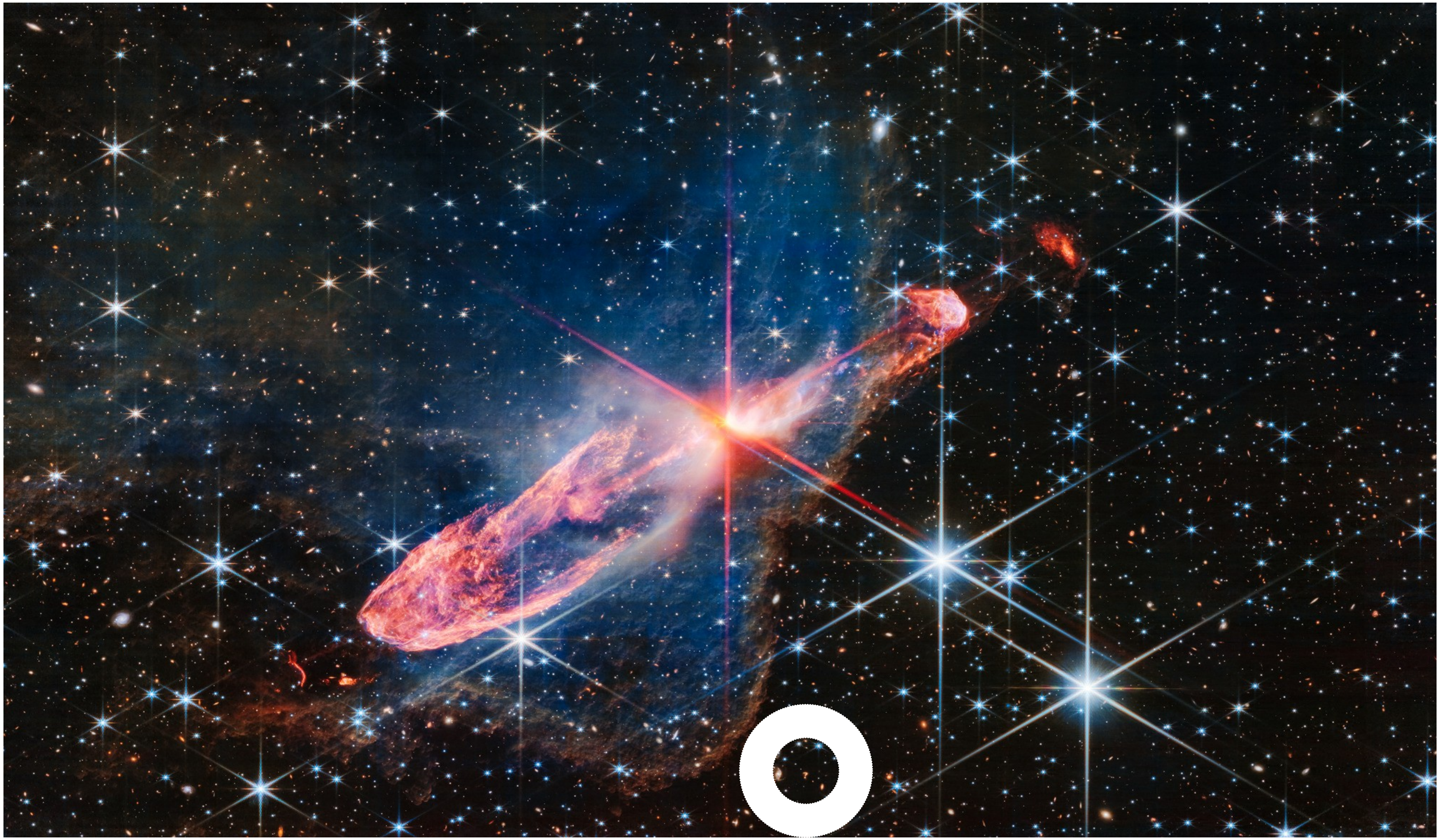
Herbig-Haro object 46/47 at 1470 ly
Jet from a forming binary star colliding with a dark nebula (Bok nebule)

New Technology Telescope (ESO)

Near-infrared image (JWST)

Another star-forming region

Herbig-Haro object 46/47 at 1470 ly
Jet from a forming binary star colliding with a dark nebula (Bok nebule)



Another star-forming region

Herbig-Haro object 46/47 at 1470 ly

Mysterious object in the background

Another star-forming region

Herbig-Haro object 46/47 at 1470 ly

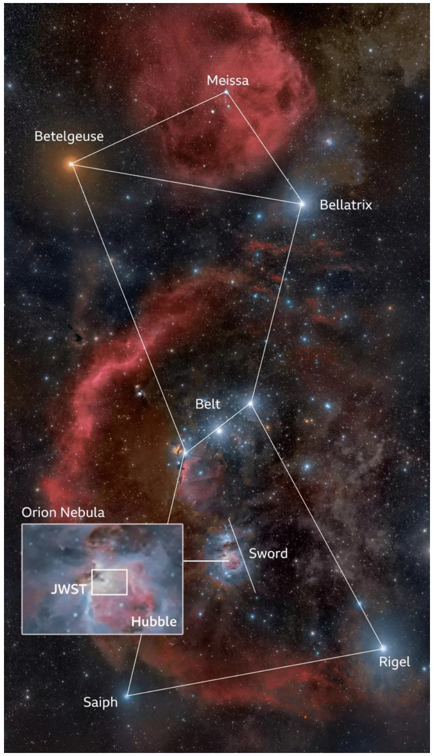
Mysterious object in the background

Another star-forming region

Herbig-Haro object 46/47 at 1470 ly

Mysterious object in the background

Mysterious objects in Orion



M42: 1400 light years distant

JuMBOs – Jupiter-Mass Binary Objects

Planned/ongoing observations

Galactic center – our project of investigating young stars in the vicinity of the supermassive black hole (Sgr A*)

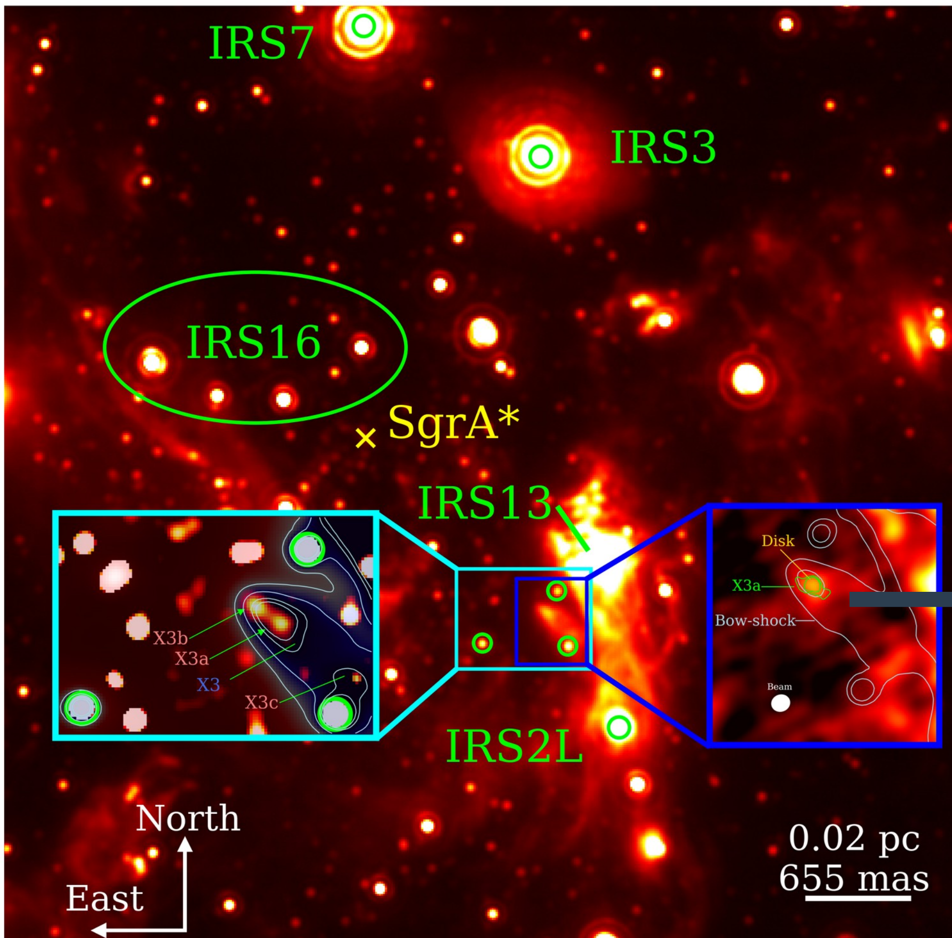
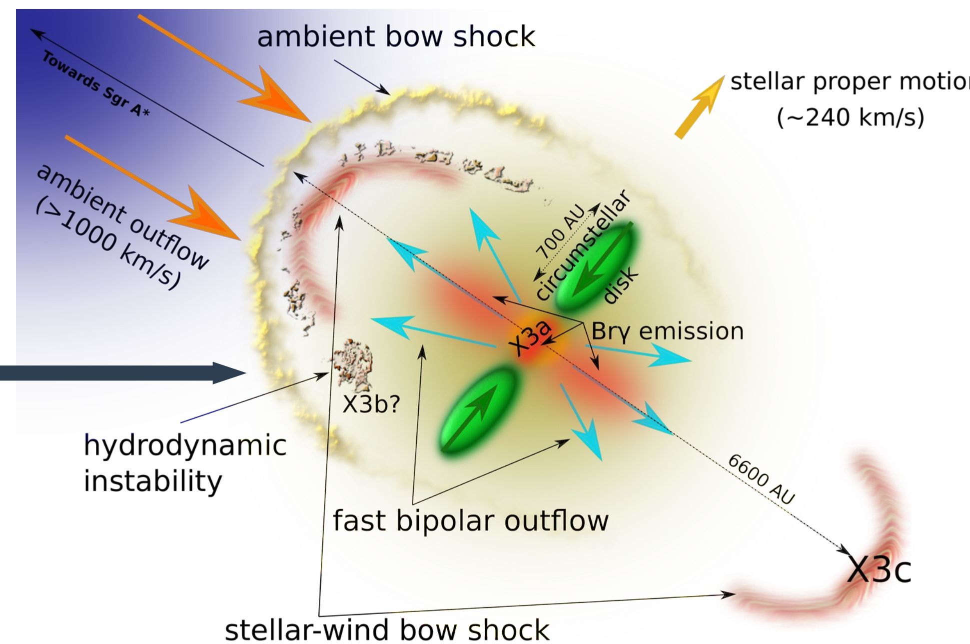


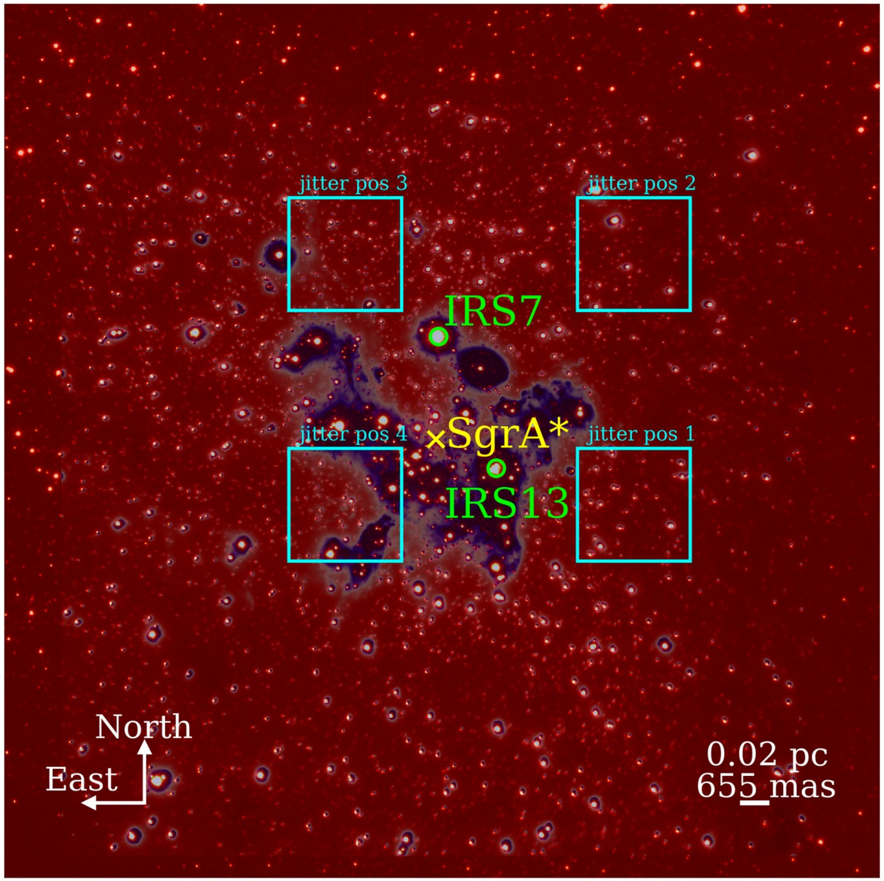
Image in the *L band* (3.7 microns) taken with 8-m the ESO VLT telescope

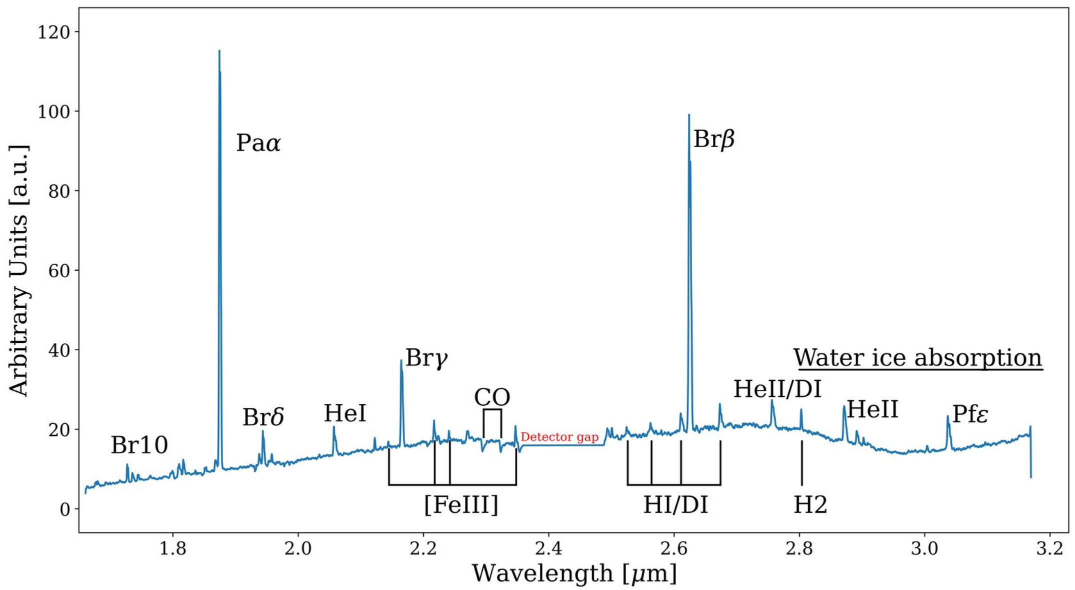


Planned/ongoing observations

Galactic center – our project of investigating young stars in the vicinity of the supermassive black hole (Sgr A*)

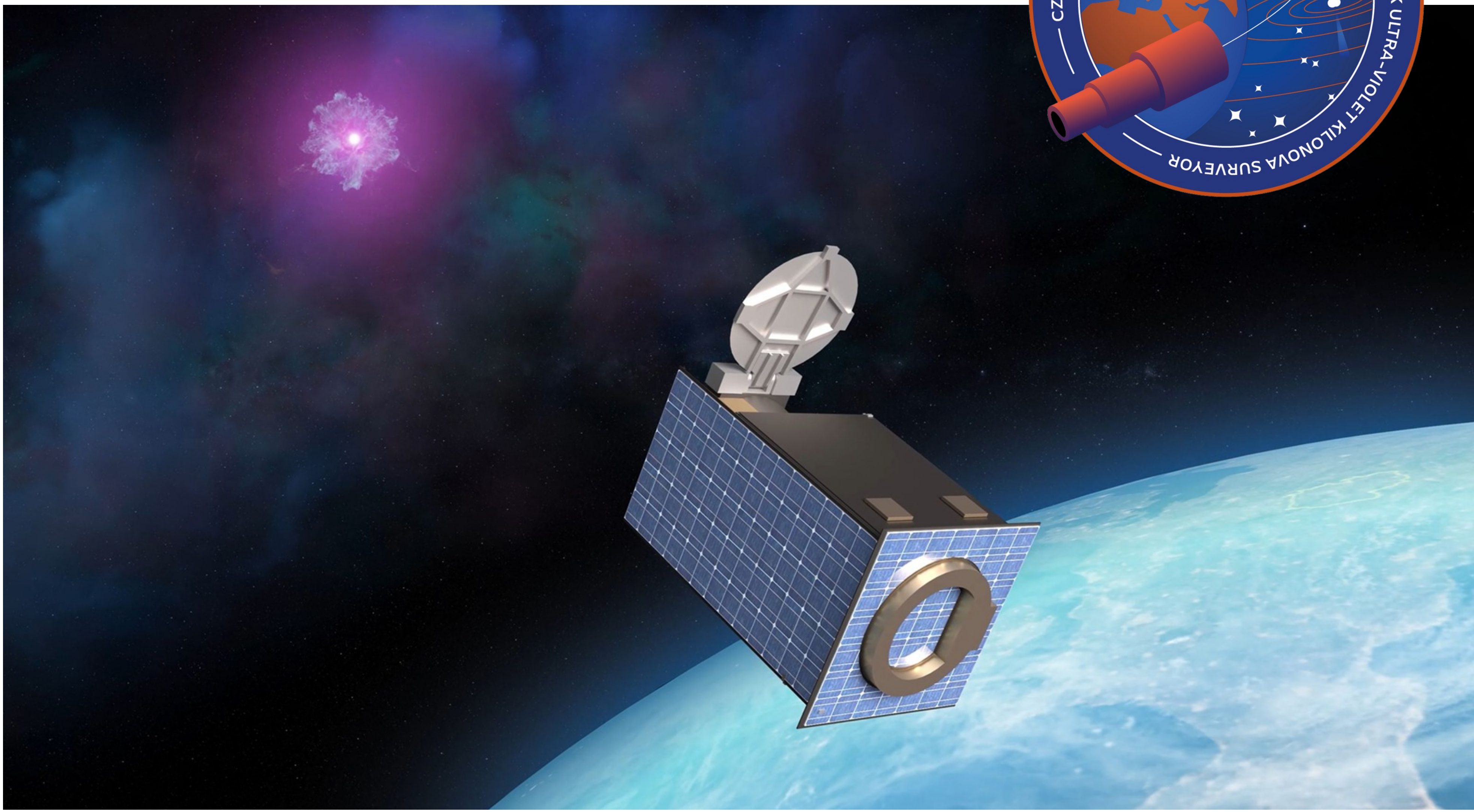
K/L-band, 2.2/3.6 μm



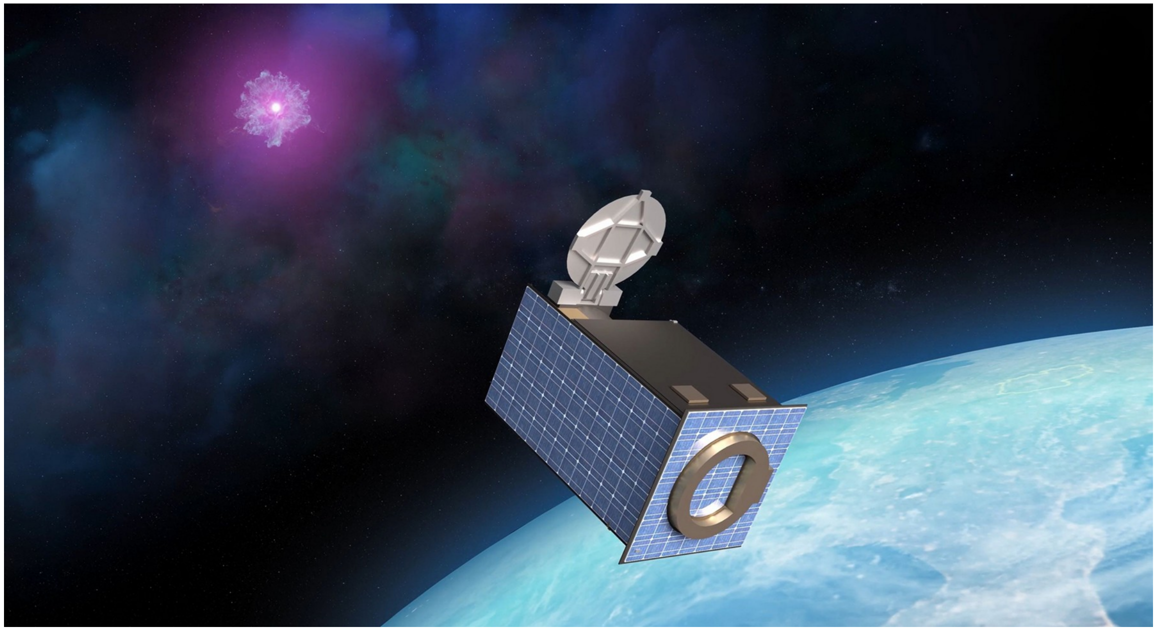


NIRSPEC spectrum

QUVIK
Small space telescope



QUVIK
Small space telescope



UV astronomy

- Two UV bands (near and far UV)
- Main research focus: **kilonovae** (mergers of 2 neutron stars)
- Other areas
  Stars (supernovae, hot stars)
  Active galactic nuclei
  (tidal disruption events)
- **Planned launch: 2028**

https://quvik.cz/

Ďakujem za pozornosť!!!