



En cosmic voyage through the Universe

Pål Brekke
Norwegian Space Centre

New book



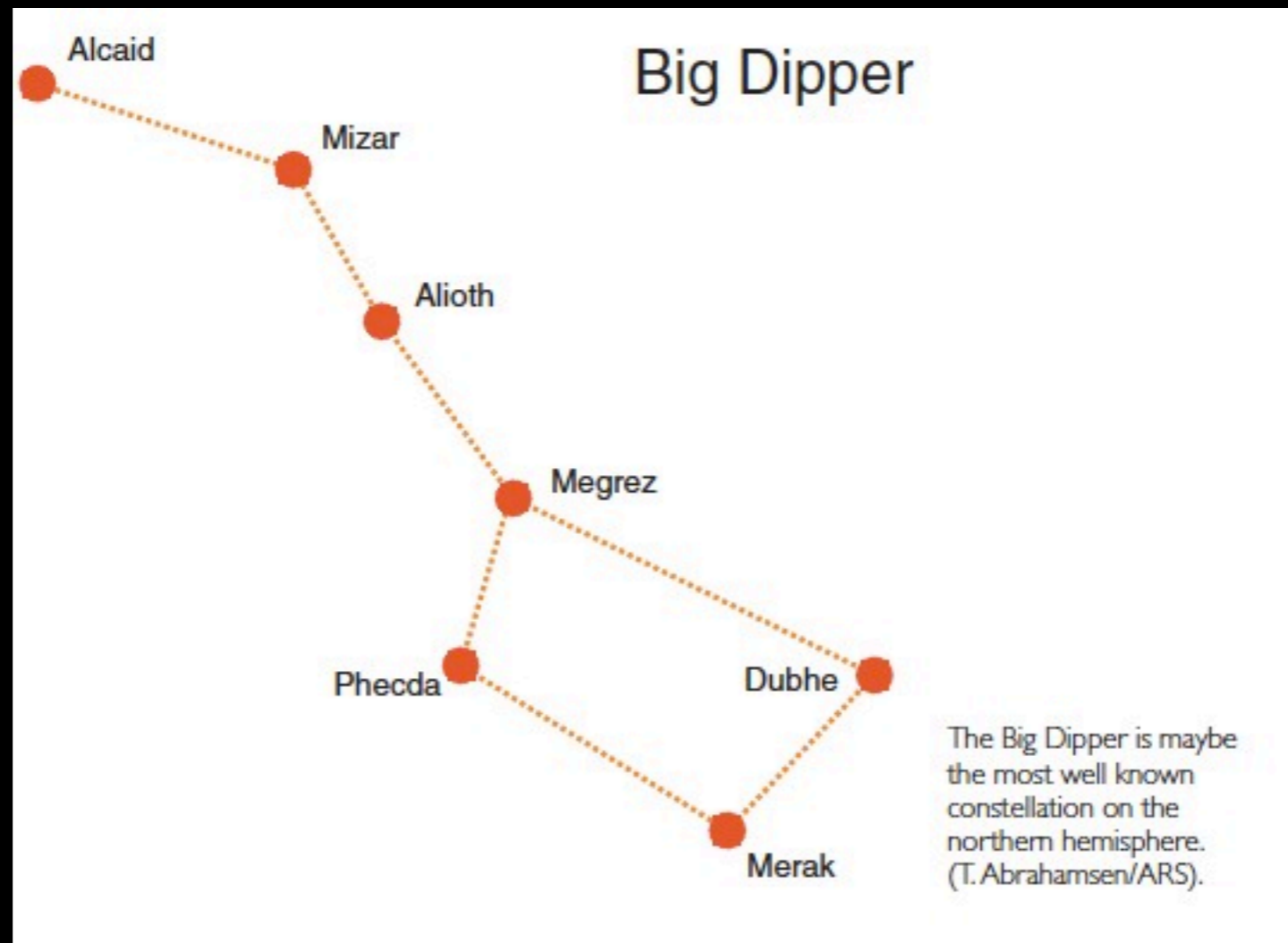
Available on Springer.com and Amazon.com

<http://www.solarmax.no/>

Contact: paal@spacecentre.no

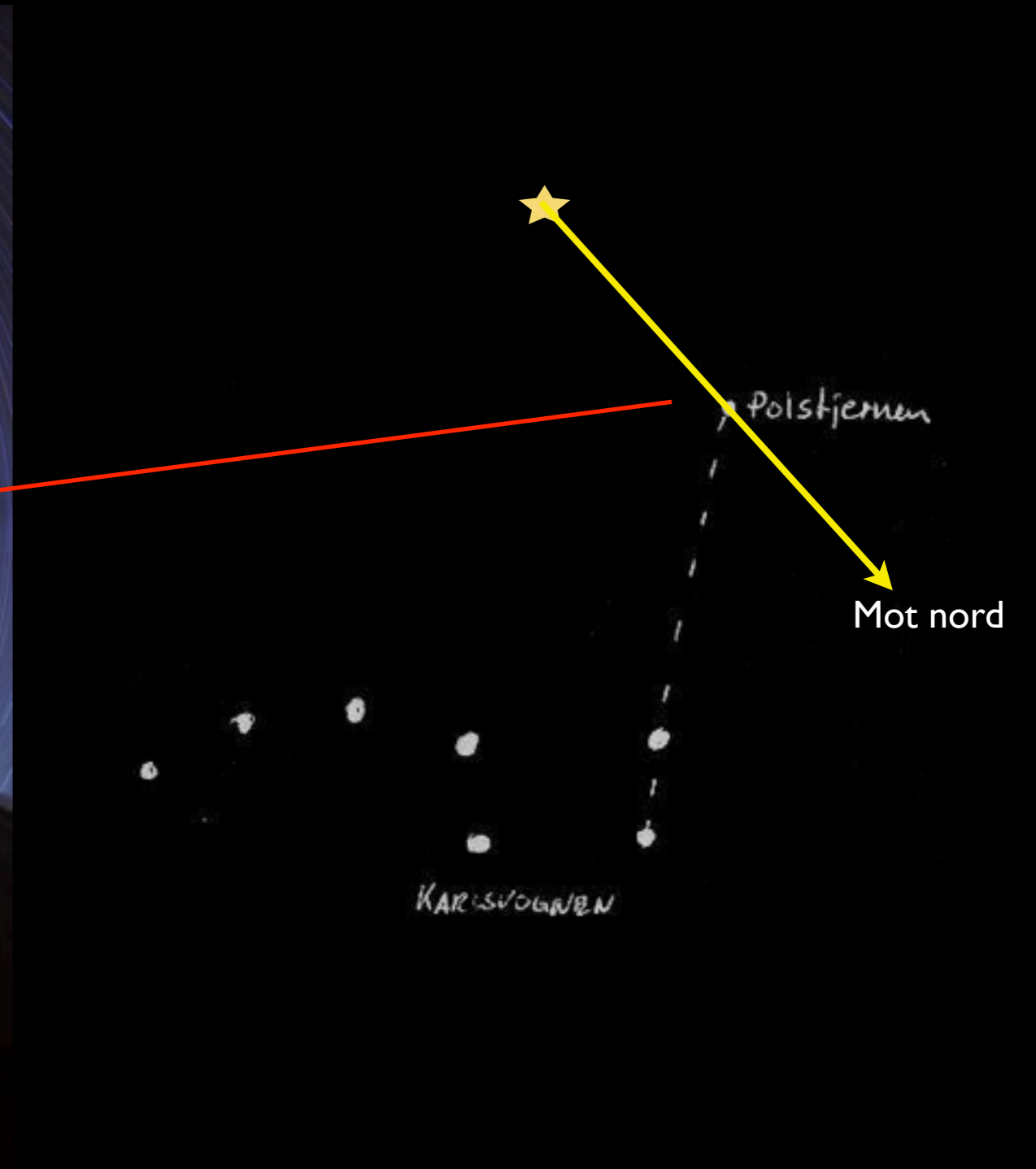
Big Dipper

- Alcaid - 210 light years away
- Mizar - 88 light years - thus 122 closer (> 100 trillion kilometer)
- Dubhe - 100 light year - strongest of them - 45 x brighter than the Sun



The Polar Star

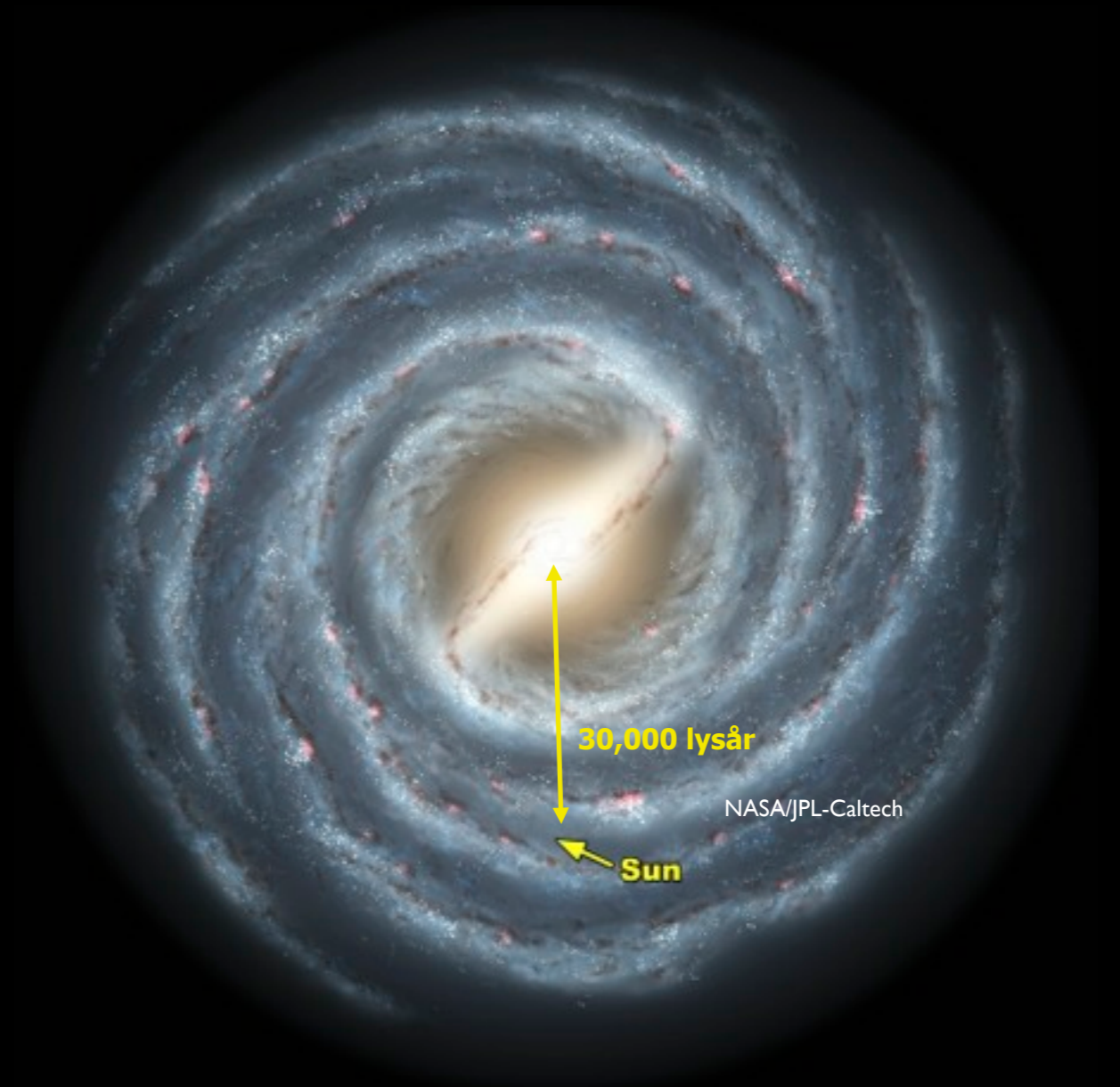
- Big Dipper - a navigational tool



THE MILKY WAY – OUR NEIGHBOURHOOD



NASA/CXC/M.Weiss



All stars that can be seen with the naked eye belong to our galaxy – the Milky Way. It is so big that the light spends hundred thousand years to travel across it. Our solar system is located in one of the spiral arms in the Milky Way.

We are one of more than 200 billion other stars in the galaxy. Including billions of other galaxies the number of stars in the Universe is almost unthinkable.

How many stars in the Universe?

Thimble = 8000 sandgrains

Milk carton = 8 000 000 sandgrains

- Scientist at Hawaii have estimated the total number of sand grains on Earth:
 - 7,500,000,000,000,000 (7.5 billion billion!) sandgrains - Or 7.5×10^{18} sandgrains
- How many stars? A crude estimate:
 - 300,000,000,000,000,000,000 (300 000 billion billion) stars
- Thus, there are about 3000 stars for each sandgrain on Earth



Andromeda-galaxy

- Located about 2,3 million light years away.
- Travelling towards us with a speed of 120 km/s (432.000 km/h)
- Will collide with our Milky Way in about 3 billion years.



Galileo Galilei (1564-1642)



Galileo - observing Saturn



1610

He wrote to the Duke of Tuscany that "[t]he planet Saturn is not alone, but is composed of three, which almost touch one another and never move nor change with respect to one another." He also described Saturn as having "ears".

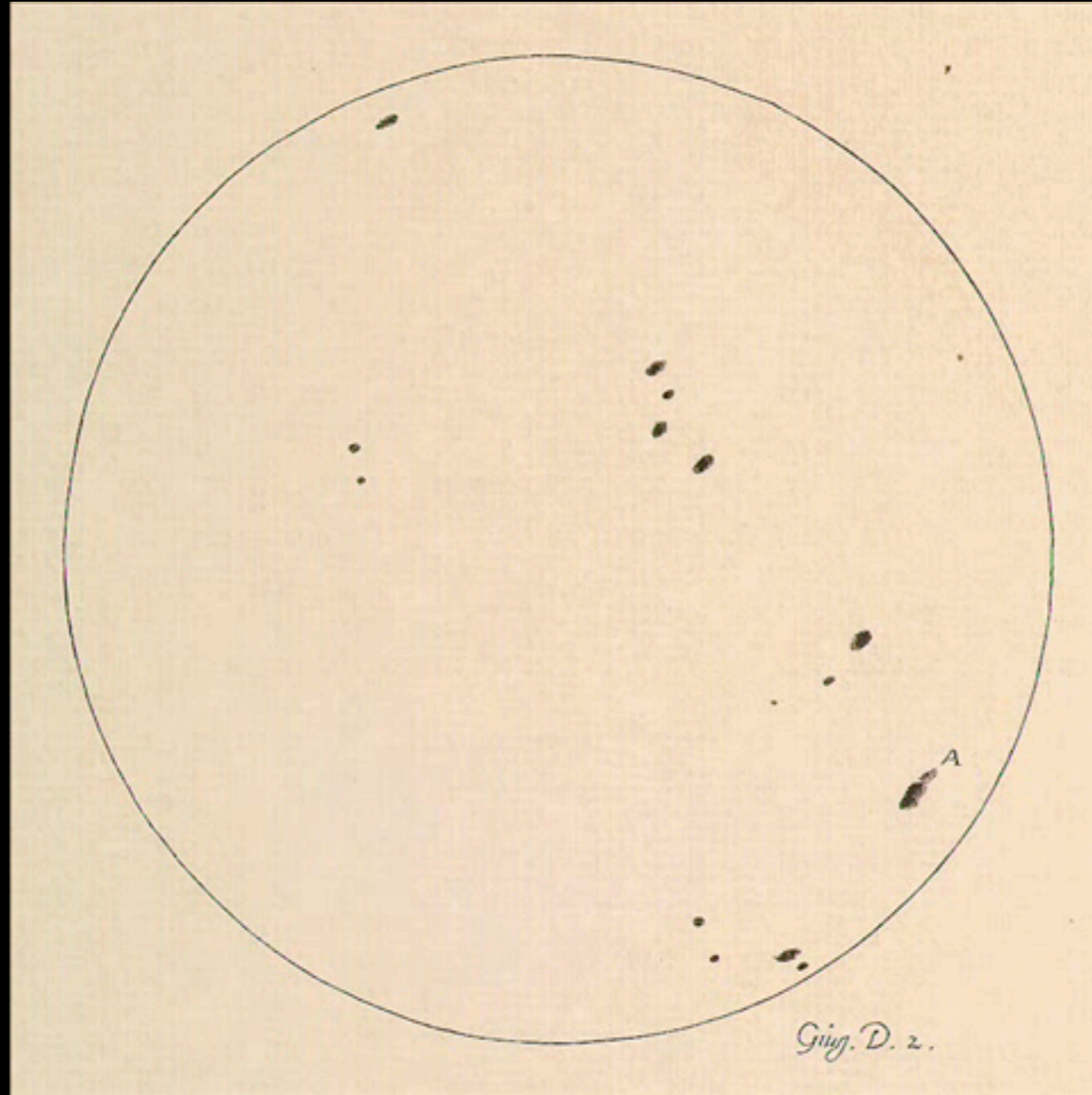
In 1612, the plane of the rings was oriented directly at the Earth and the rings appeared to vanish. Mystified, Galileo wondered, "has Saturn swallowed his children?"

They reappeared again in 1613, further confusing Galileo.[5]



1616

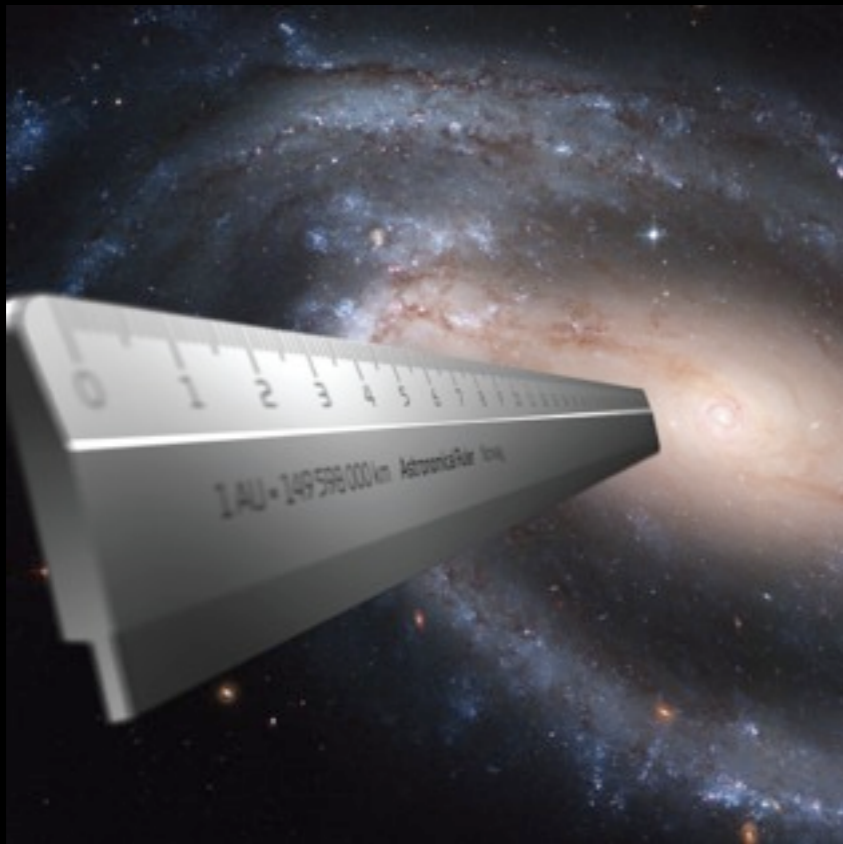
Solflekker observert av Galileo (1612)



Galileo looks at the Pleiads

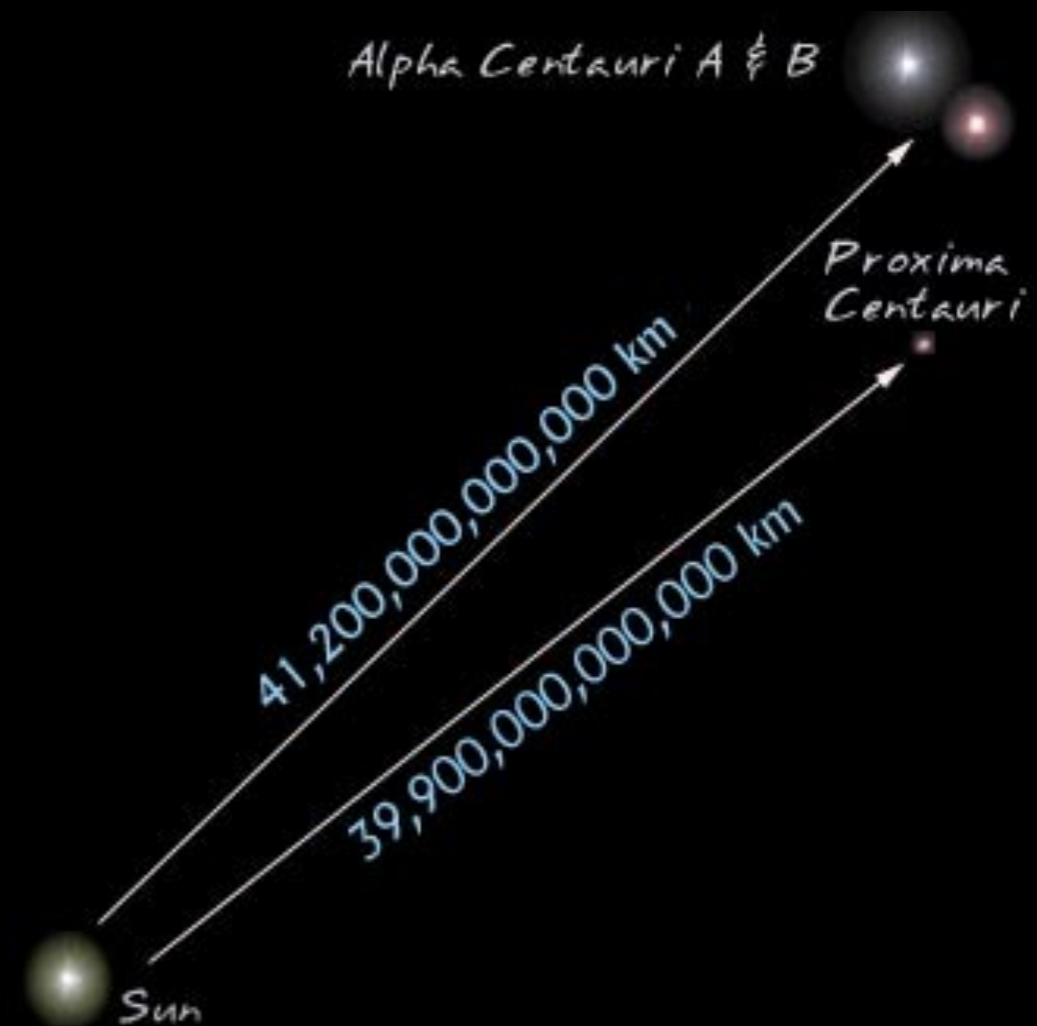
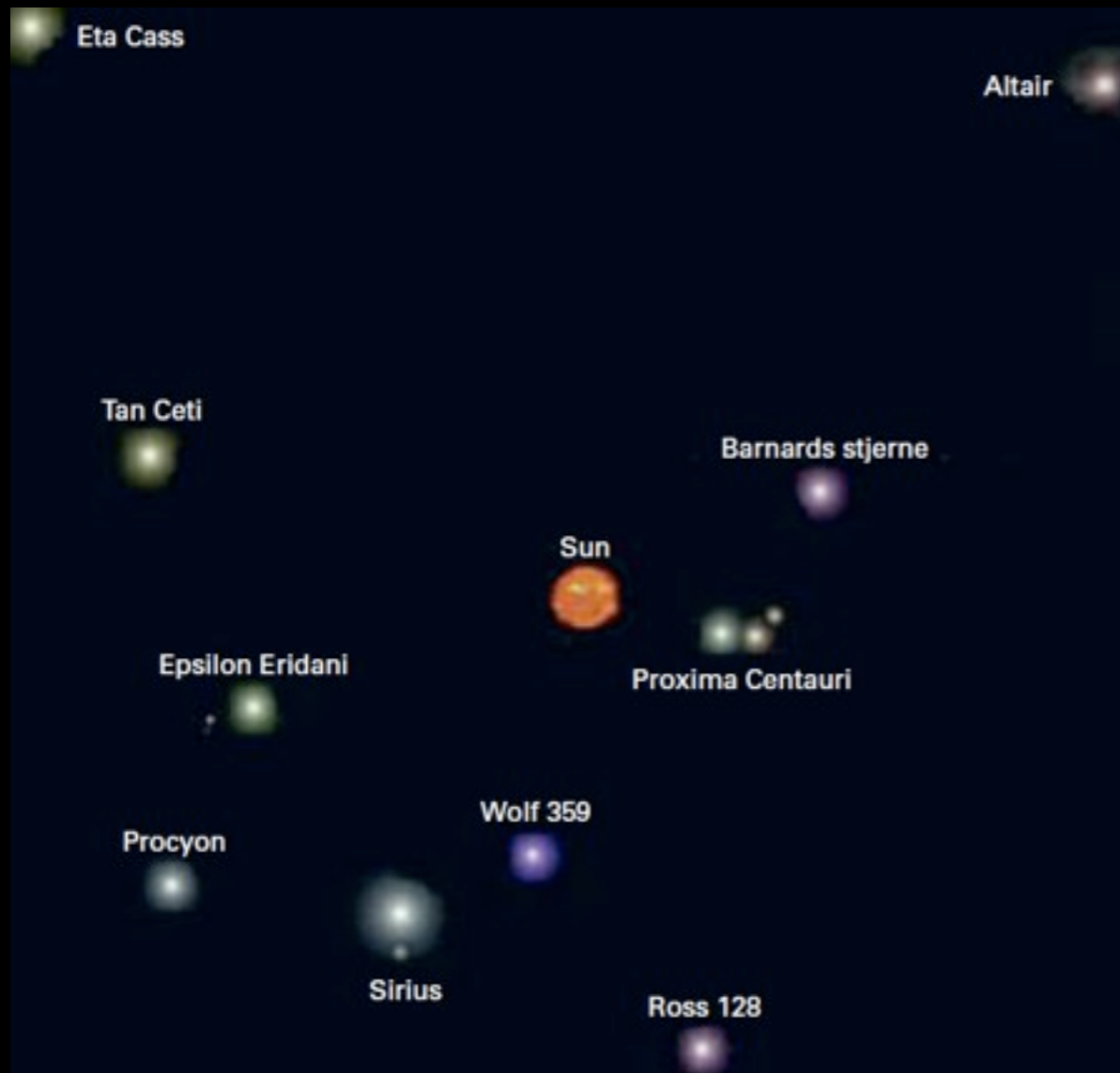
- Large distances - unpractical to use km.
- We use «light years»
- Light travels 300 000 km per second.
- How many km is a light-year?

1 light-year = $299\,792\text{ km/s} \times 60\text{s} \times 60\text{m} \times 24\text{t} \times 365\text{d} = 9\,460\,000\,000\,000\text{ km}$



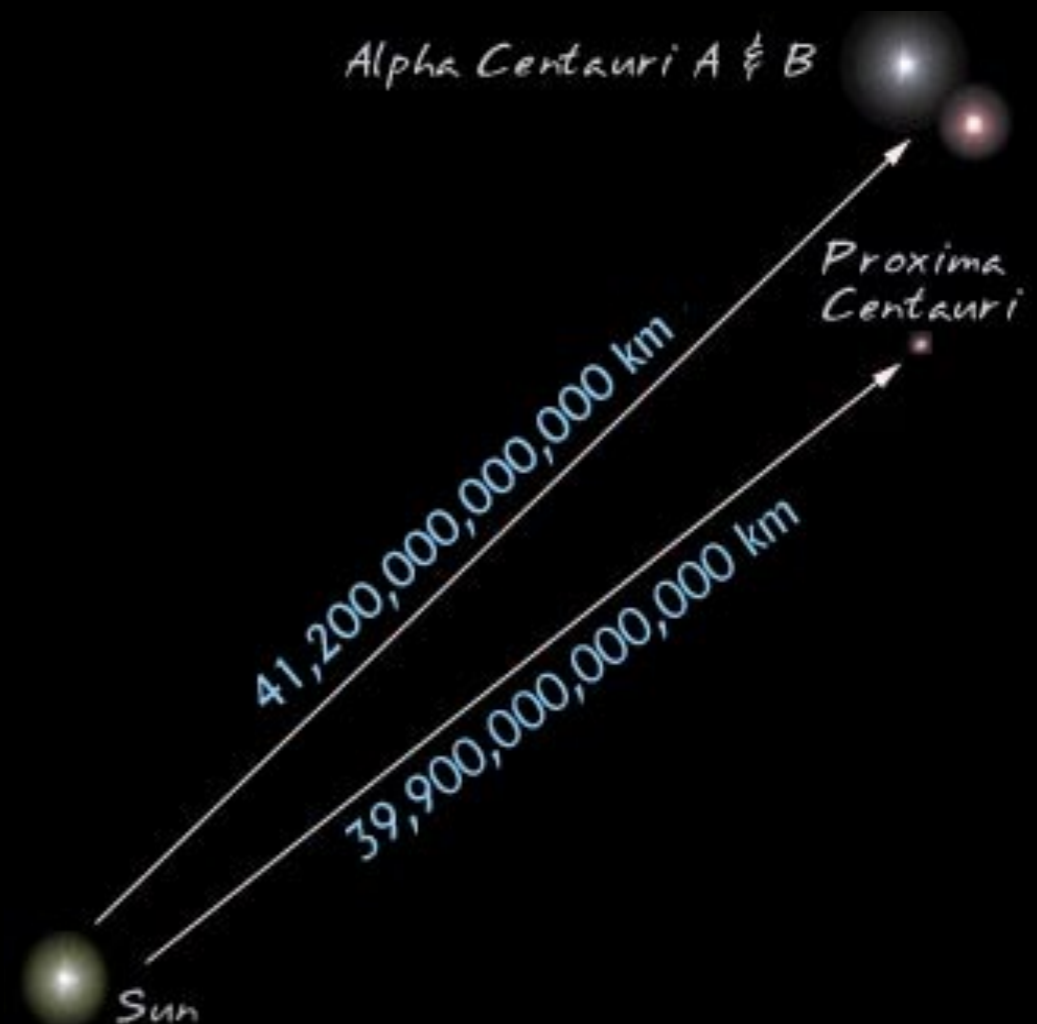
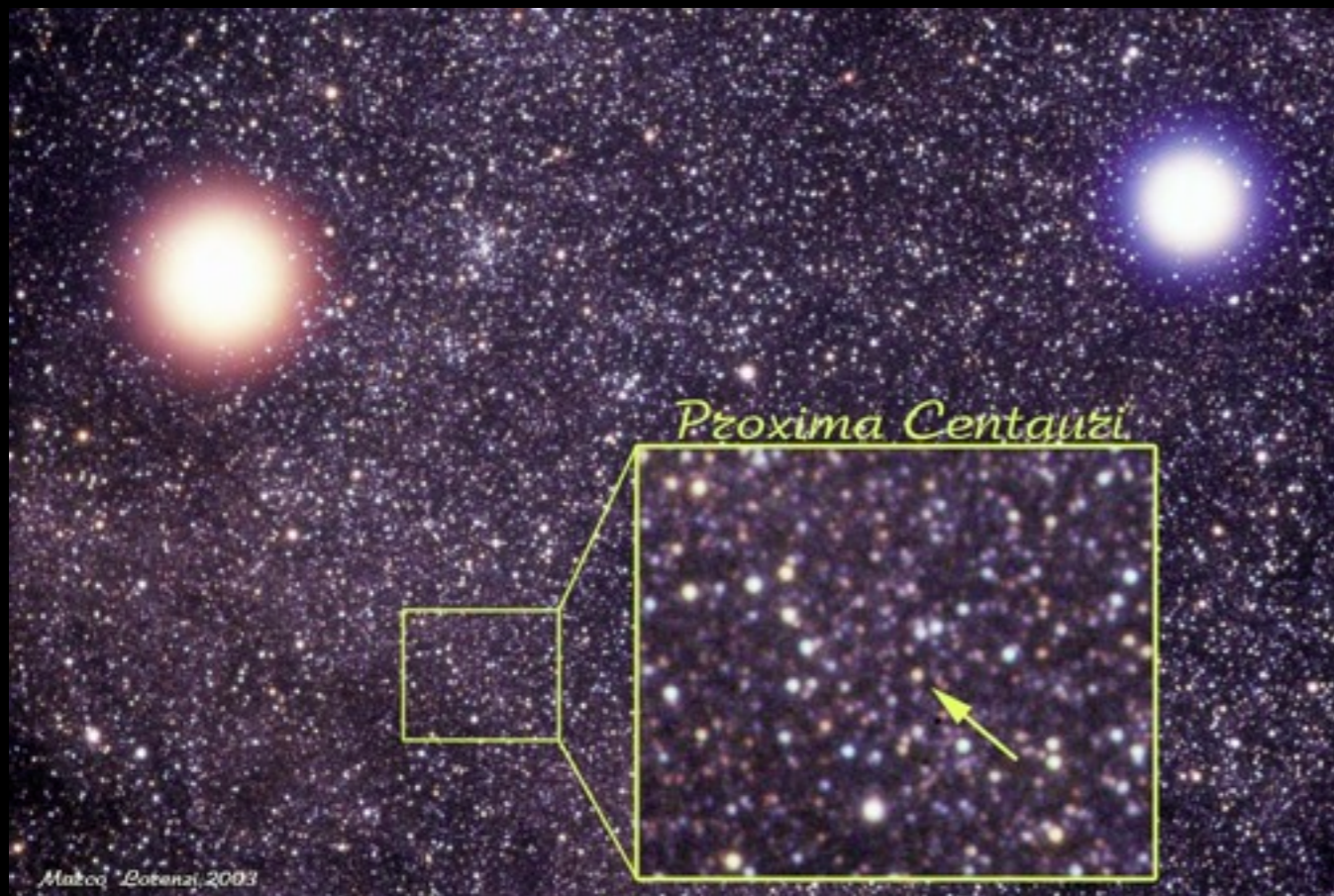
The Sun's neighbourhood

- Proxima Centauri and Alpha Centauri is about 4 light years away.
- The distance is about 40,000,000,000,000 km (40,000 billion km)
- If the Sun was a sand grain, the nearest star would be located 30 km away.



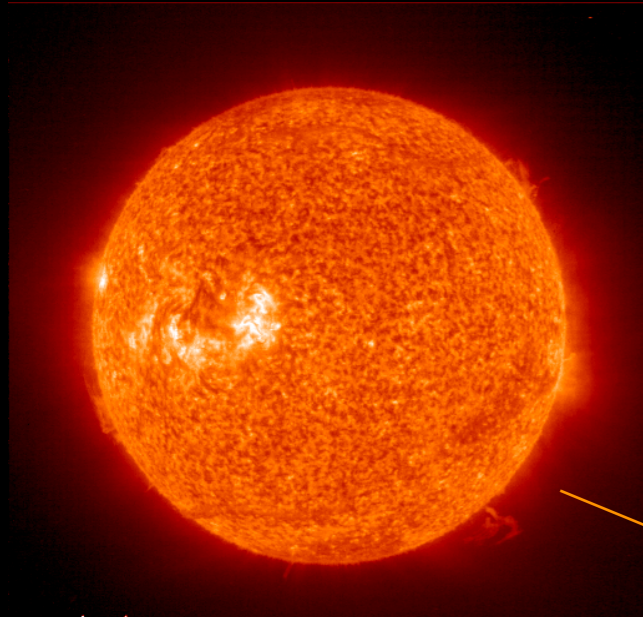
The Sun's neighbourhood

- Proxima Centauri and Alpha Centauri is about 4 light years away.
- The distance is about 40,000,000,000,000 km (40,000 billion km)
- If the Sun was a sand grain, the nearest star would be located 30 km away.



How long time would it take you with the Space Shuttle?

The distance to the Sun



150 000 000 km - 150 million km

How long time would it take to fly there?



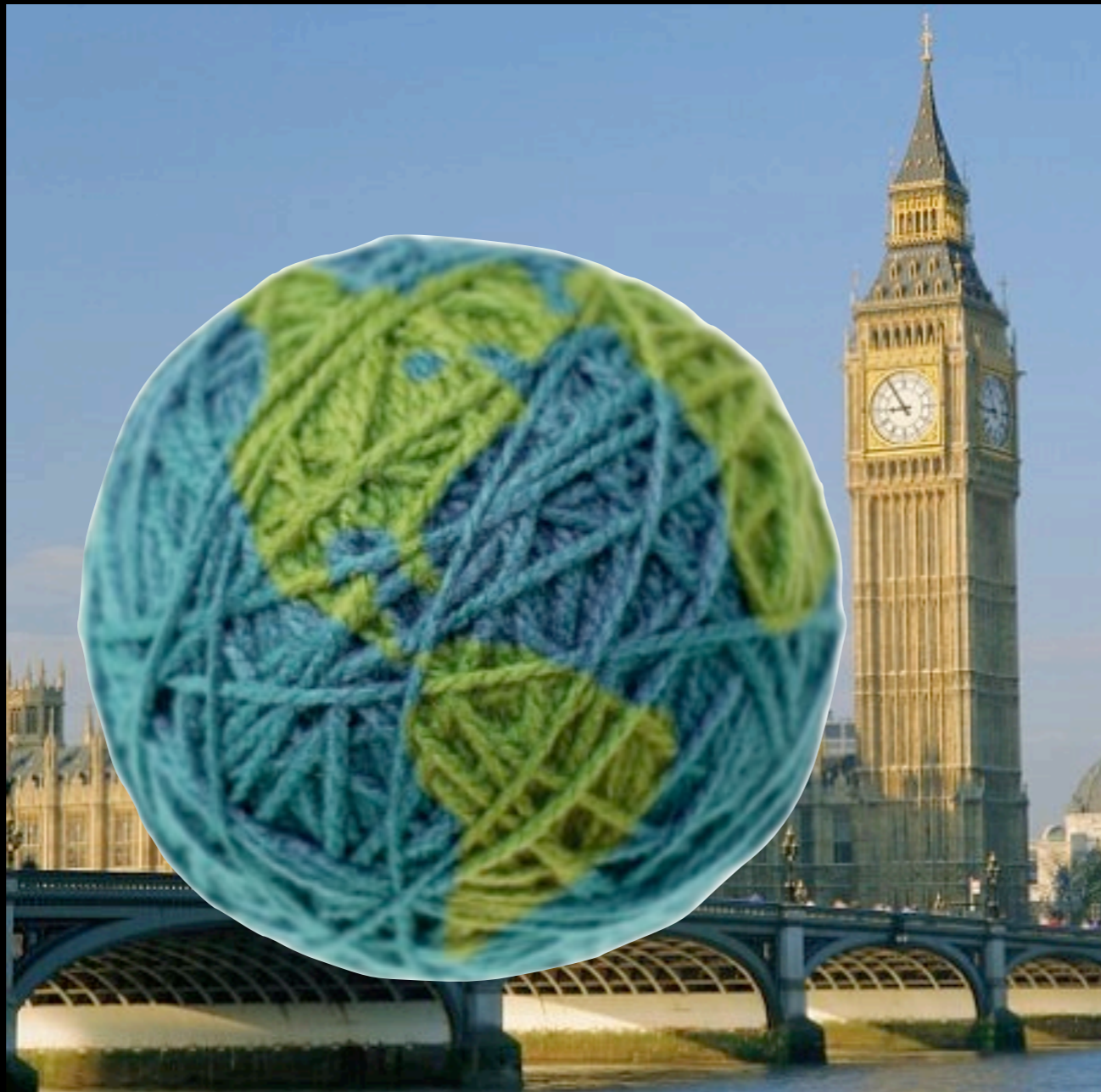
The distance to the Sun

150 million km with yarn would be:

Diameter: 75 m

Weight: 60 000 tonnes (equals 30 fully loaded space shuttles)

Enough yarn to knit sweaters for 250 million people



THE LIFE SPAN OF THE SUN

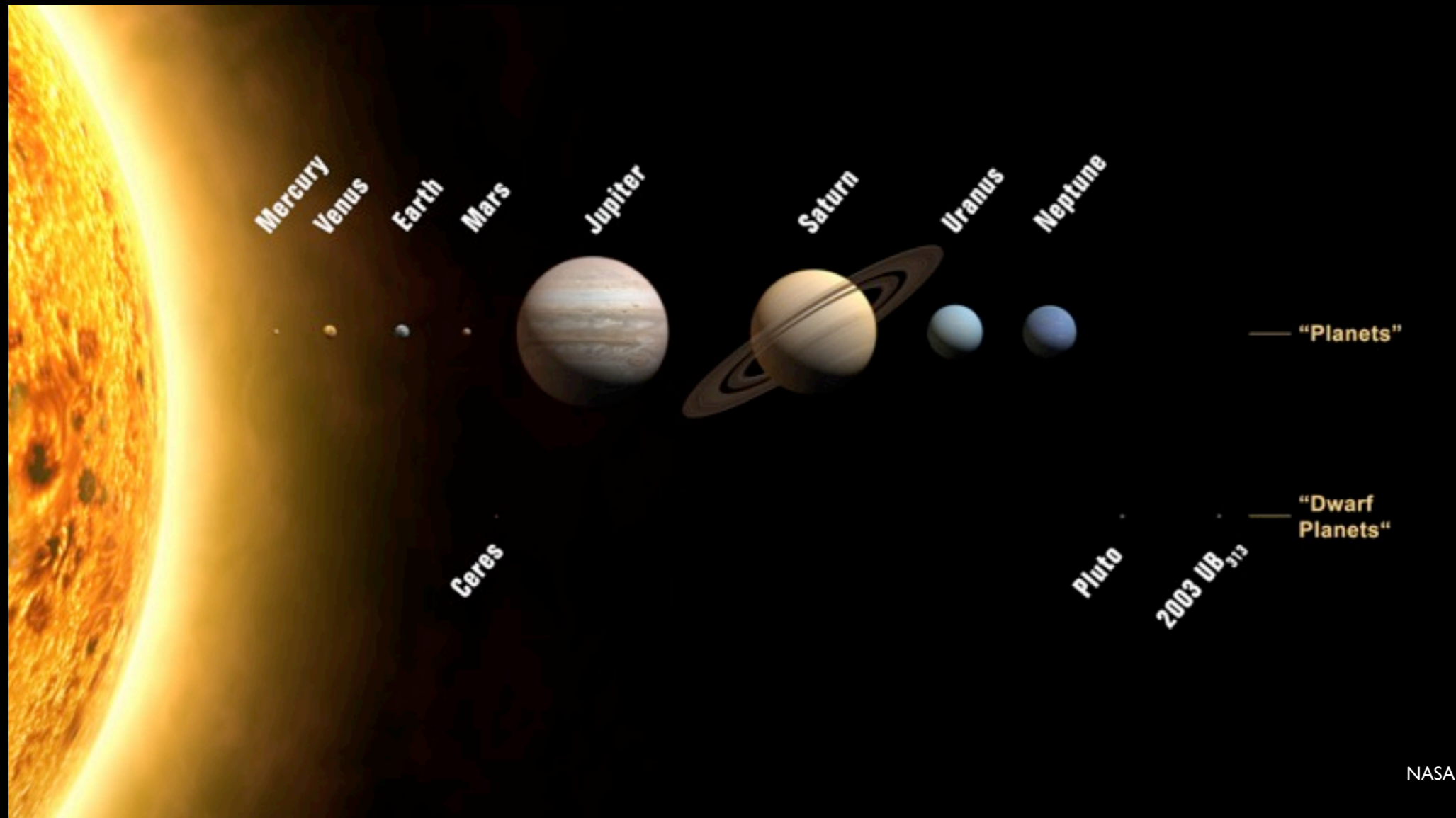


NOAA/T.Abrahamsen/ARS

The Sun is 4.5 billion years old and born out of a cloud of gas. The cloud contracted and when the pressure and temperature in the central part got high enough the nuclear reactions started and the Sun was born.

In the next 5 billion years more and more of the “fuel” Hydrogen will be converted to Helium and the temperature of the Sun will increase. When all the Hydrogen is spent, the Sun will expand to a red giant and swallow Mercury, Venus and maybe also the Earth. It will be 250 times bigger than today.

THE SOLAR SYSTEM



The Sun is the centre of the solar system and also the largest object containing more than 99.8% of the total mass of the solar system. The eight planets rotate around the Sun in separate orbits kept in place by the gravitational forces from the Sun. In addition there are billions of other objects orbiting such as asteroids, comets, moons and dwarf planets.

The four inner planets, Mercury, Venus, Earth, and Mars are called the rocky planets and are all relatively small. Further out are the big gaseous planets Jupiter, Saturn, Uranus and Neptune. Outside Neptune is the small and strange dwarf planet Pluto. Pluto was earlier regarded as a planet but was degraded to a dwarf planet.

THE ROCKY PLANETS



The innermost planets are all quite similar to the Earth consisting mainly of rock and metals and with a hard crust. They have a relatively high density, rotates very slowly, no rings and few moons orbiting them.

The Earth is the largest and the only one with liquid water. Mars is the one most similar to the Earth. Here we find old canyons where water may have flowed. Its polar caps are covered with ice. Several orbiters, landers and robotic rovers have explored Mars in great detail. The ultimate question is if some sort of life has existed on Mars.

The Moon is born



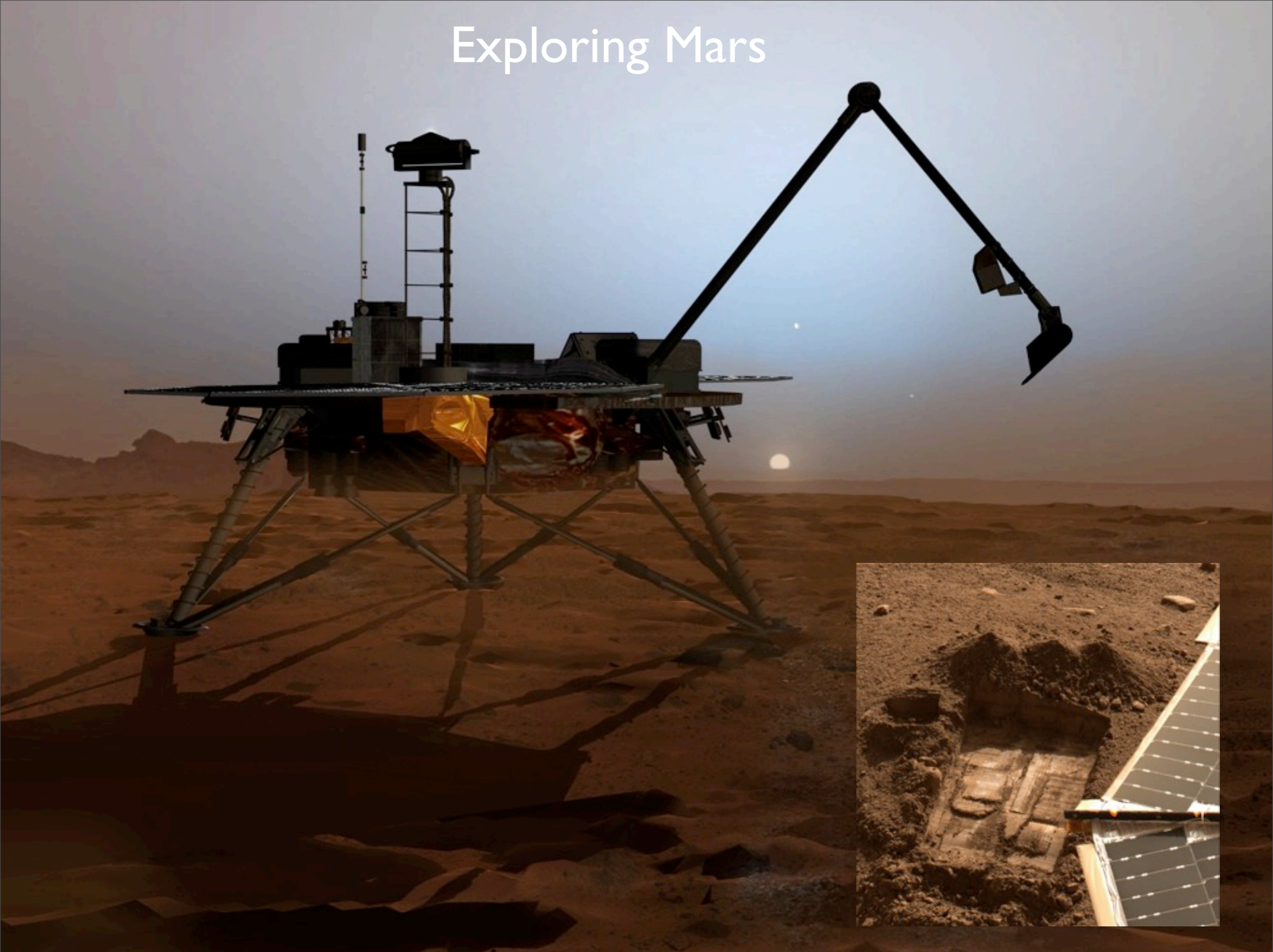
THE GASEOUS PLANETS



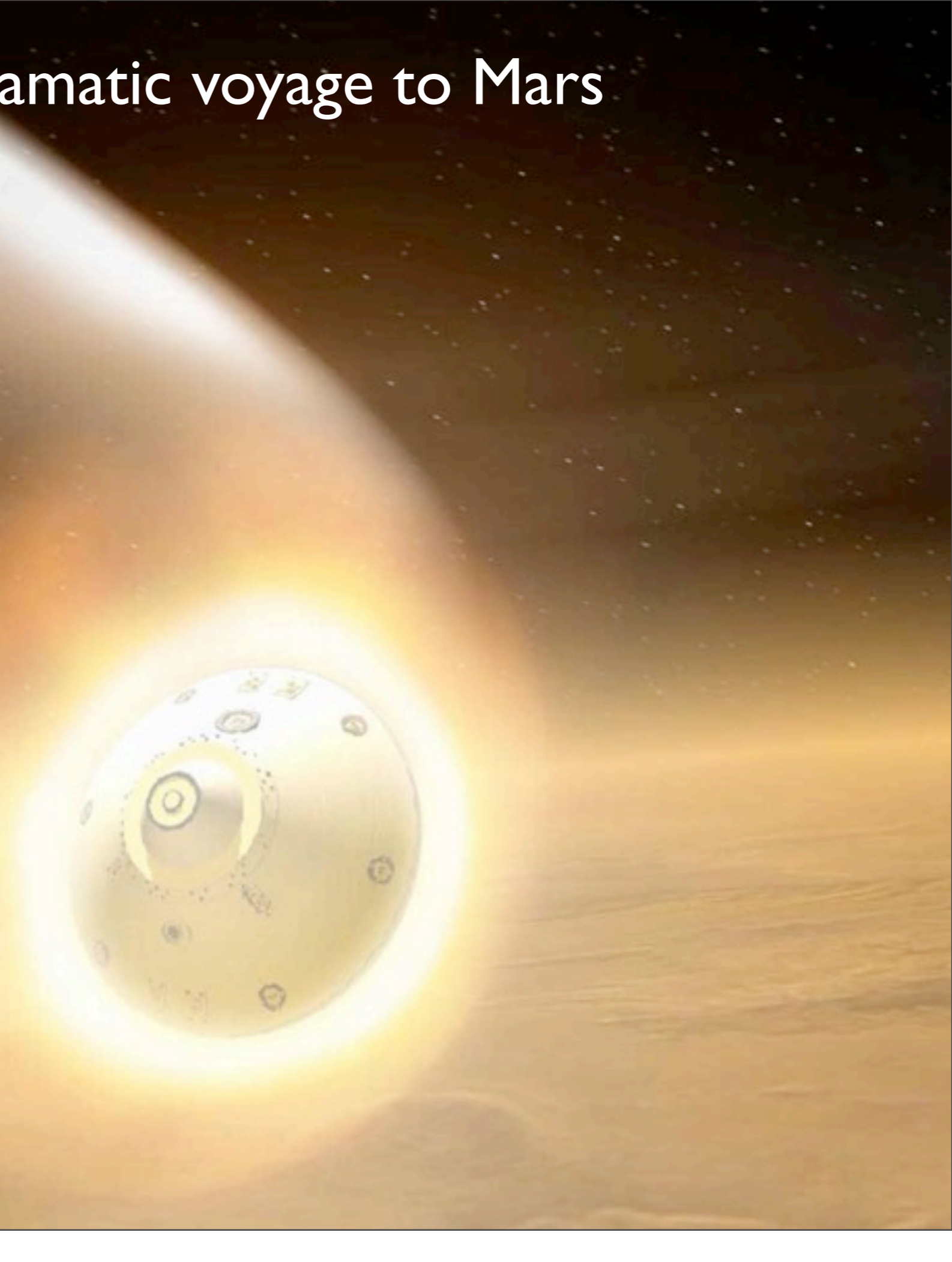
The outer planets are often called the gaseous planets (Jupiter, Saturn, Uranus, Neptune) even if they both consist of gas, liquid and ice. They mainly consist of hydrogen and helium and their density is fairly low. Uranus and Neptune also contain large amounts of compressed water deep inside. They rotate much faster than the inner planets and have extensive atmospheres. Saturn is known for its amazing ring systems, but the other gas planets also have rings.

These giant planets all have a large number of moons. Jupiter has 64 known moons, while Saturn has 34 moons. One of Saturn's moons, Titan, is quite mysterious, covered by a thick layer of clouds. In January 2005 the Huygens probe landed on Titan and sent back the first pictures to show us how it looks like on the surface.

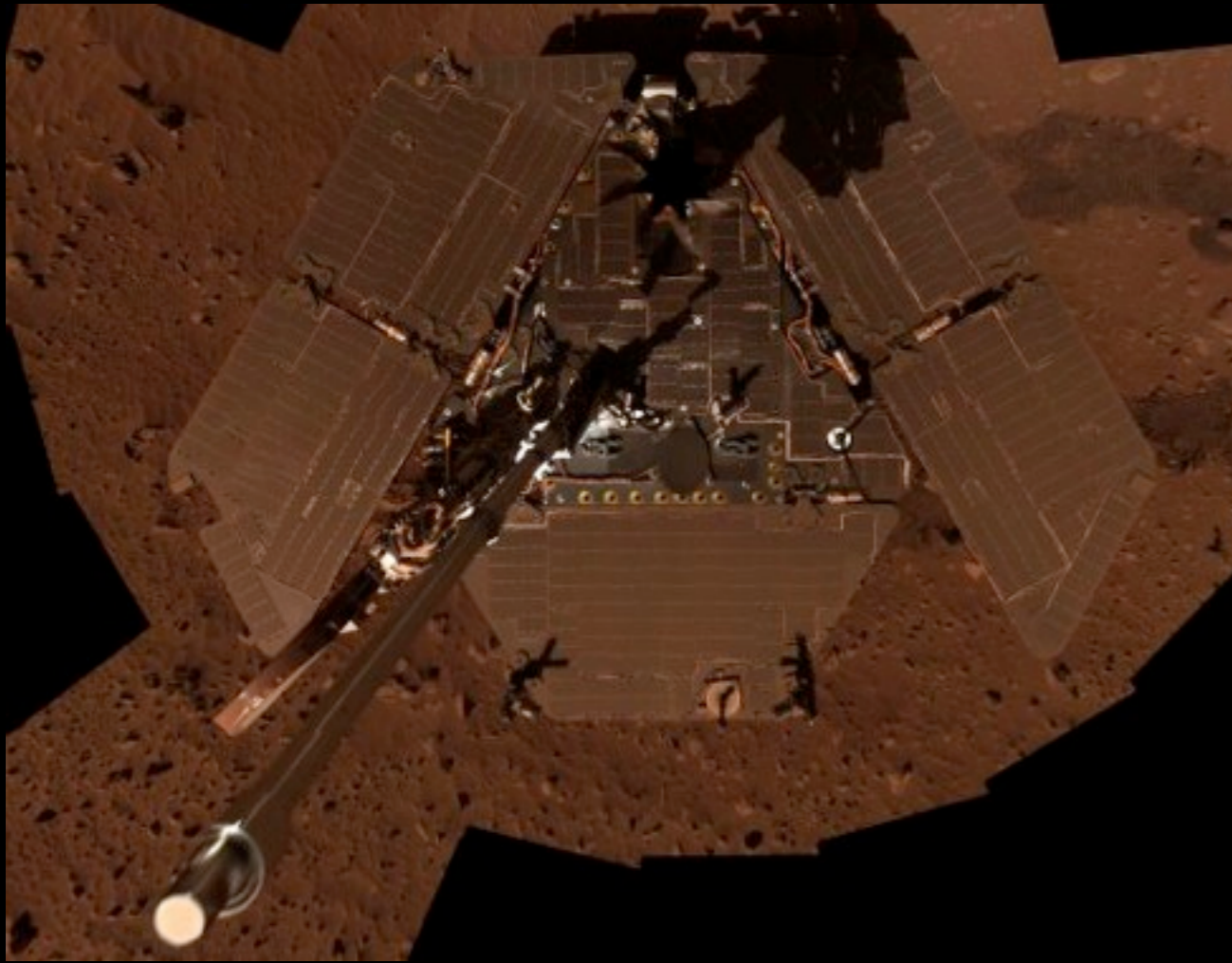
Exploring Mars



Mars-rovers dramatic voyage to Mars



Who cleaned the solar panels?

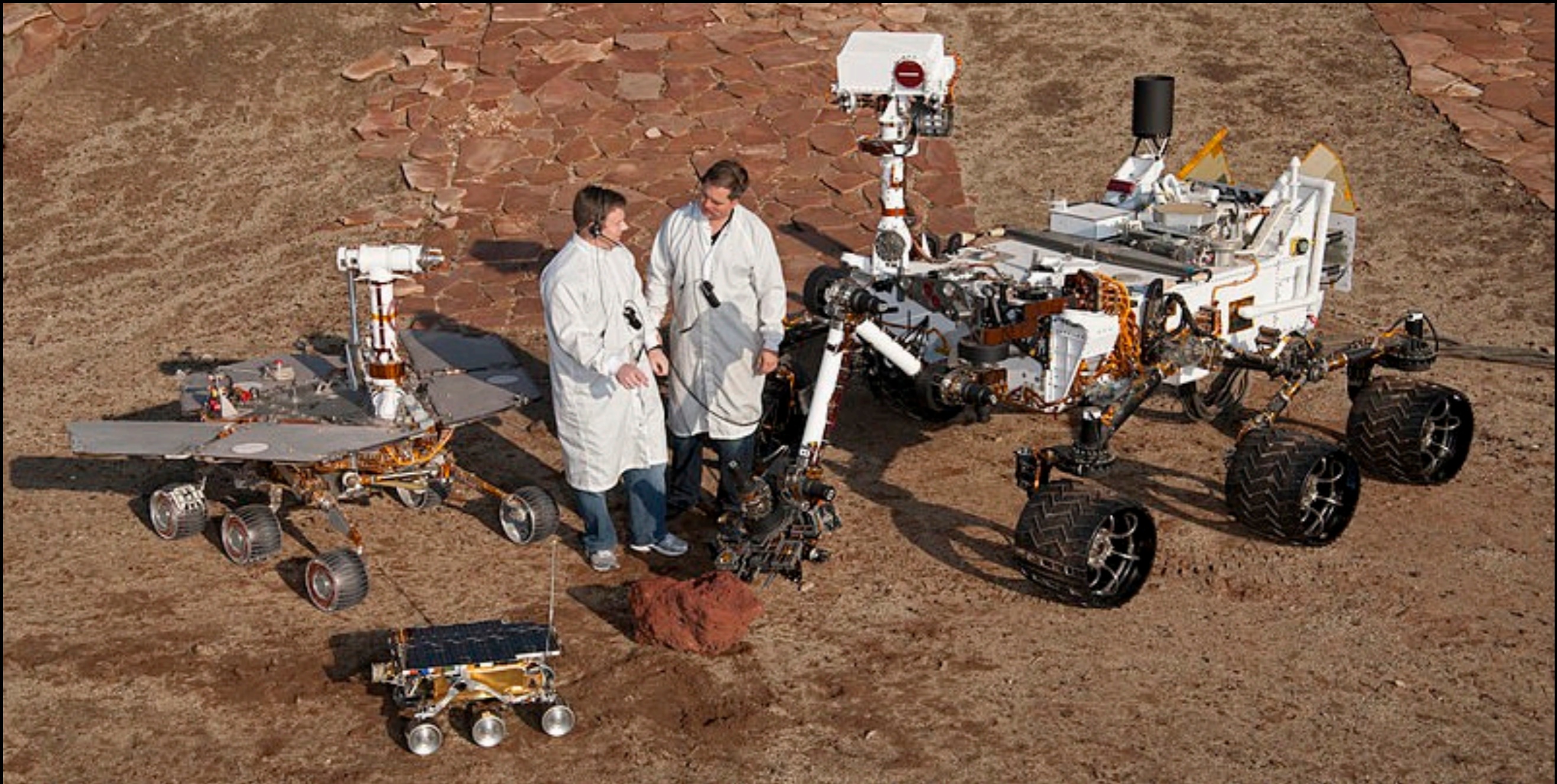


Curiosity - MSL

Sojourner - Mars Pathfinder Project (1997)

Spirit/Opportunity - Mars Exploration Rover Project (- 2004)

Curiosity - Mars Science Laboratory 2012



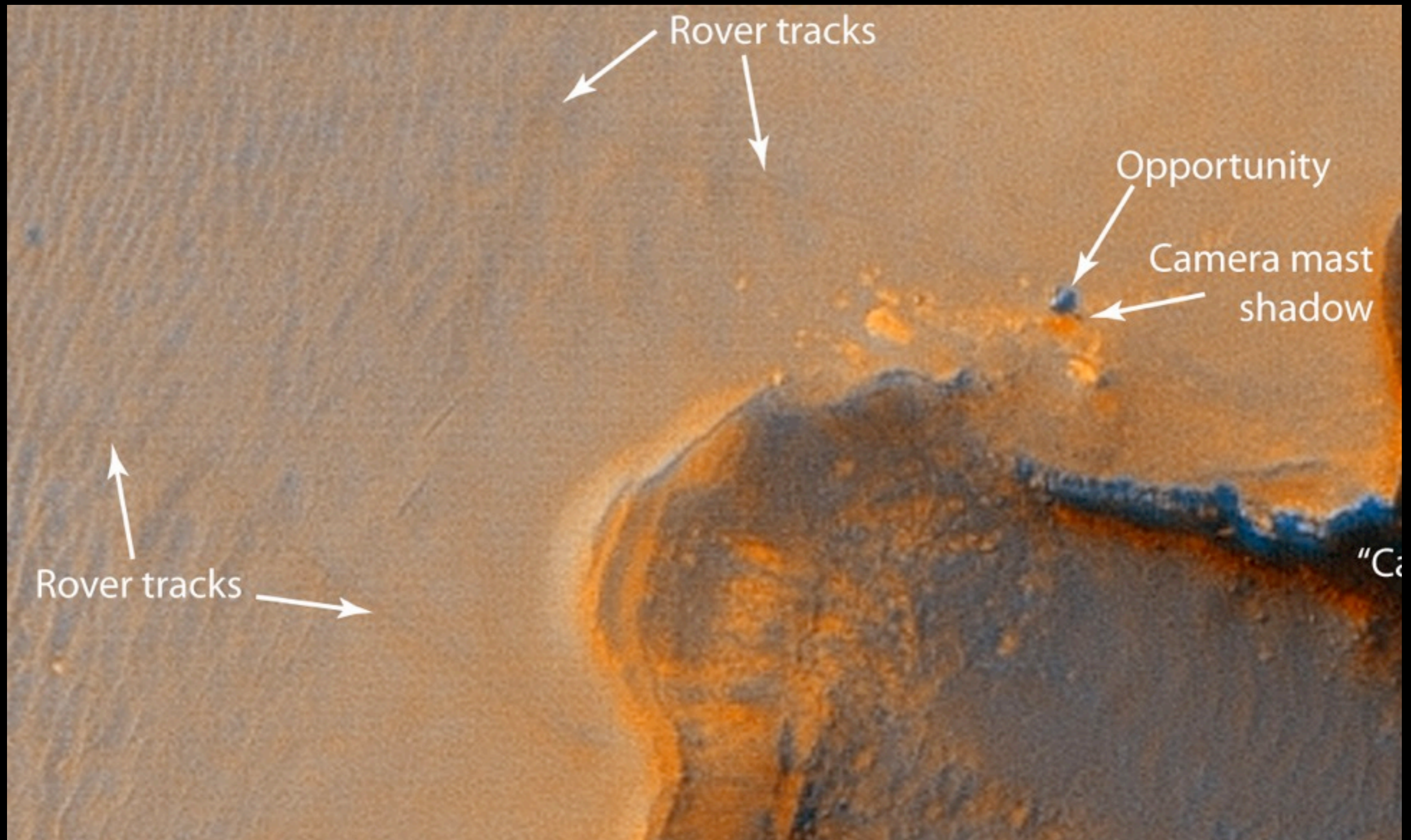
Mars Reconnaissance Orbiter



Mars Reconnaissance: skutt opp i 2005 for å lete etter spor av vann

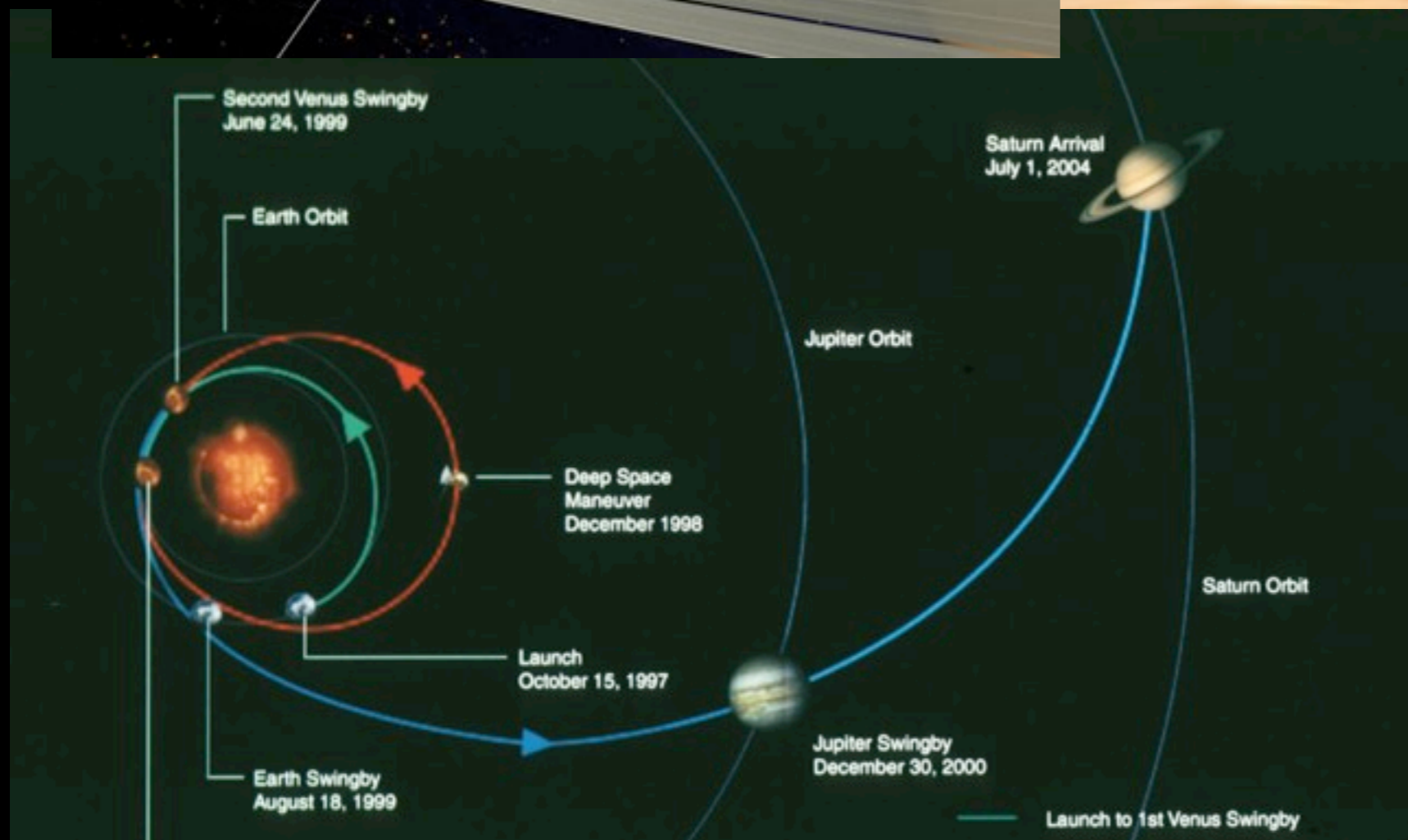
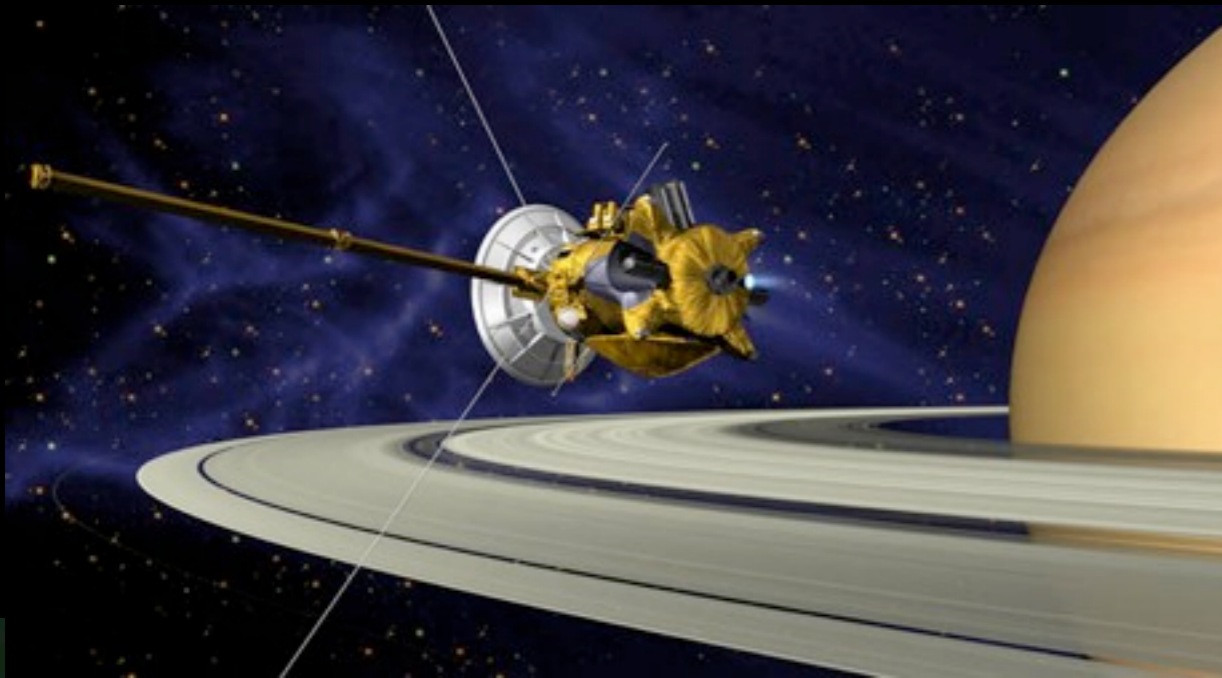


Rover-spor

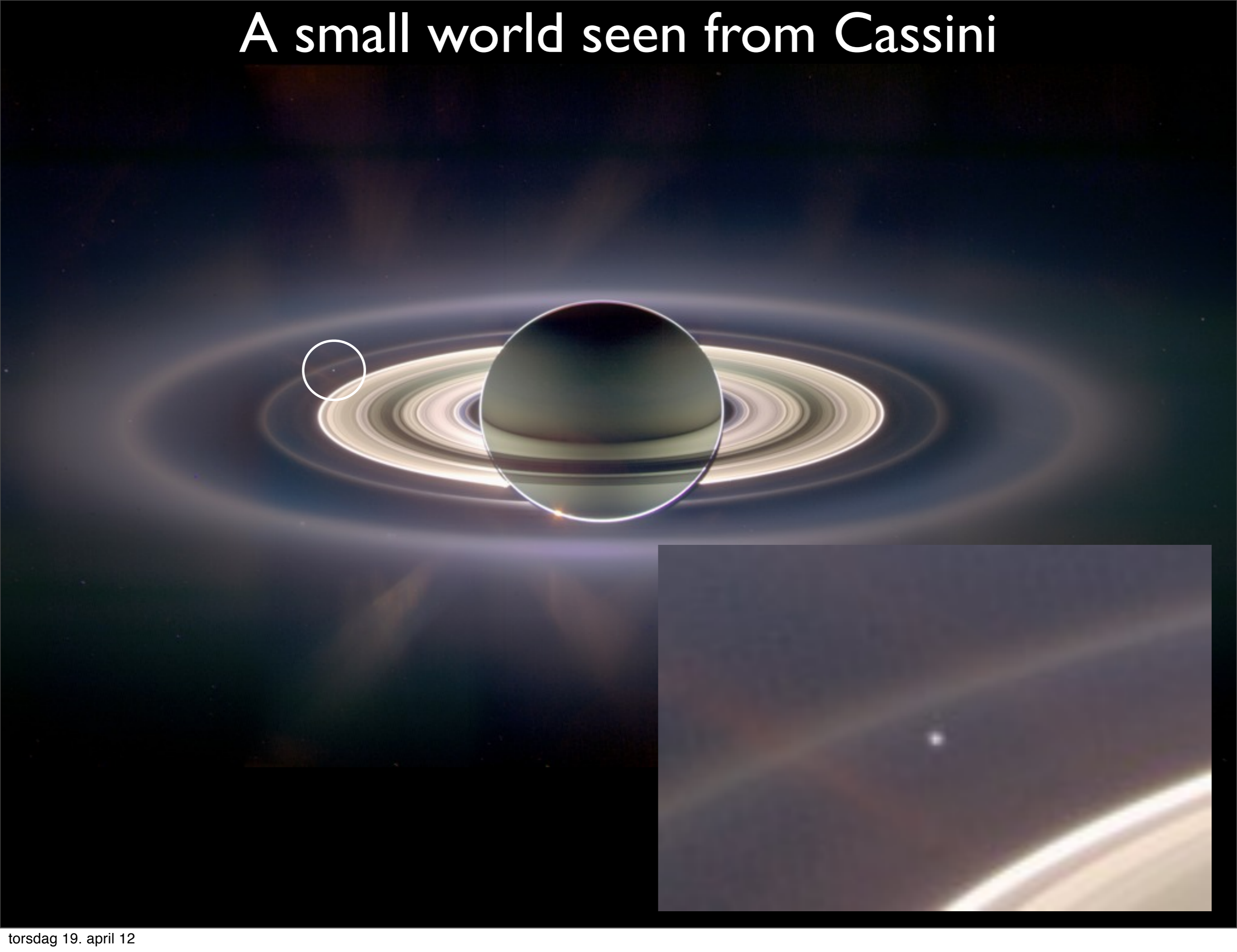


Cassini Huygens

Launched in 1997 - reached Saturn in 2004



A small world seen from Cassini



Modern telescopes



European Extremely Large Telescope

Finished in 2020?

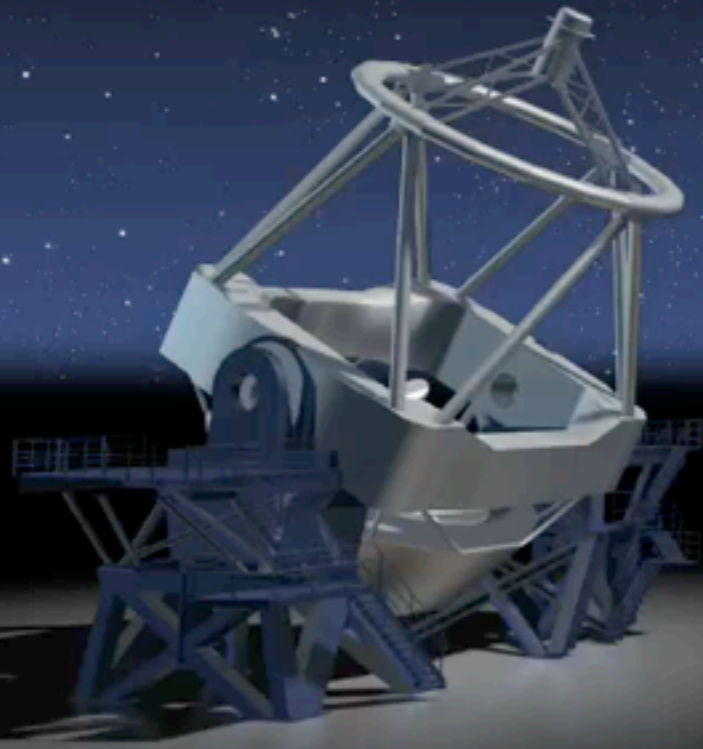
Diameter: 40 m (1200 kv-meter)



Astronomers “don’t like” the Earths Atmosphere



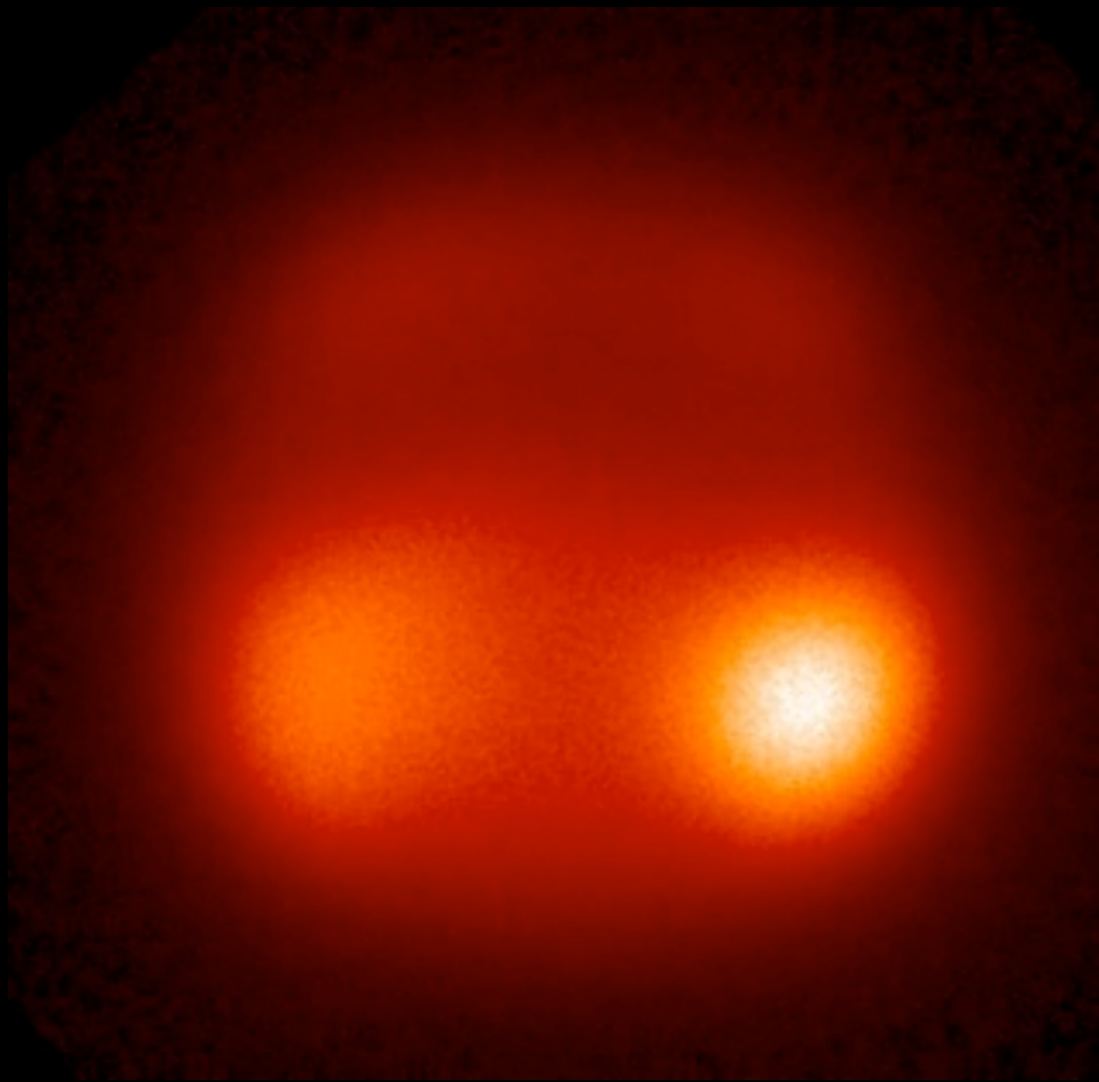
Smart optics



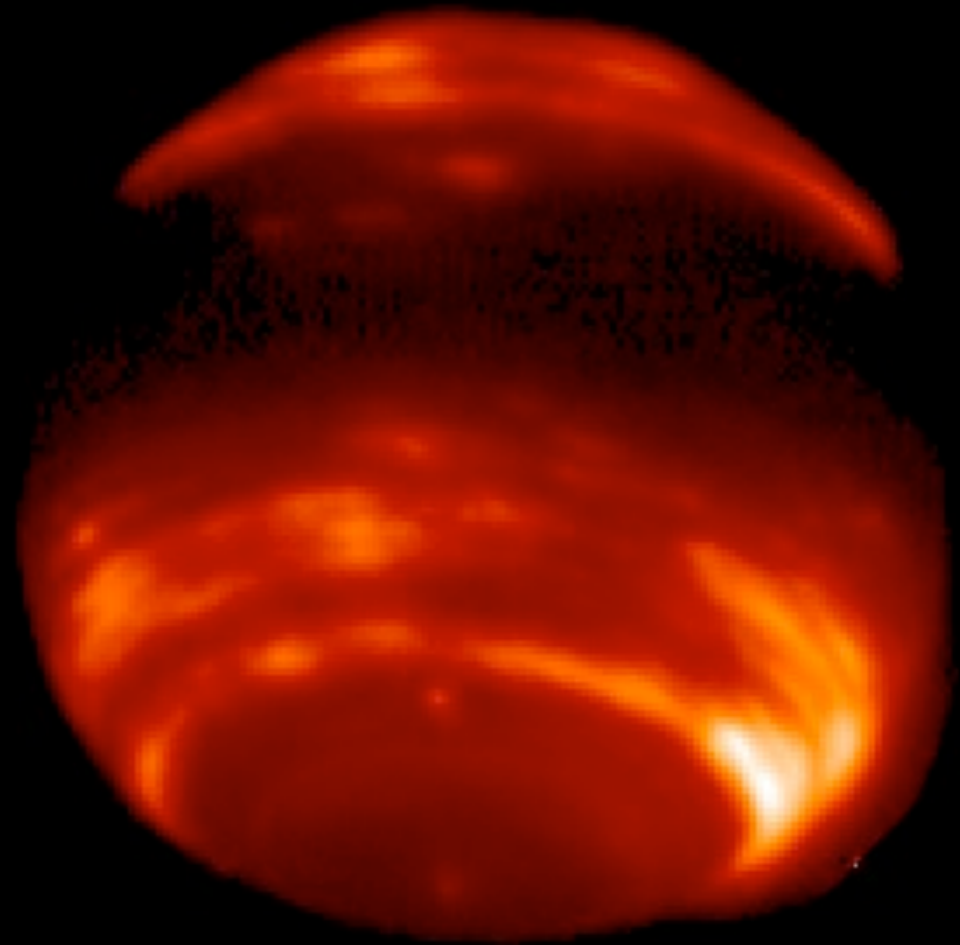
Neptune at 1.65 microns

Without adaptive optics

With Keck adaptive optics



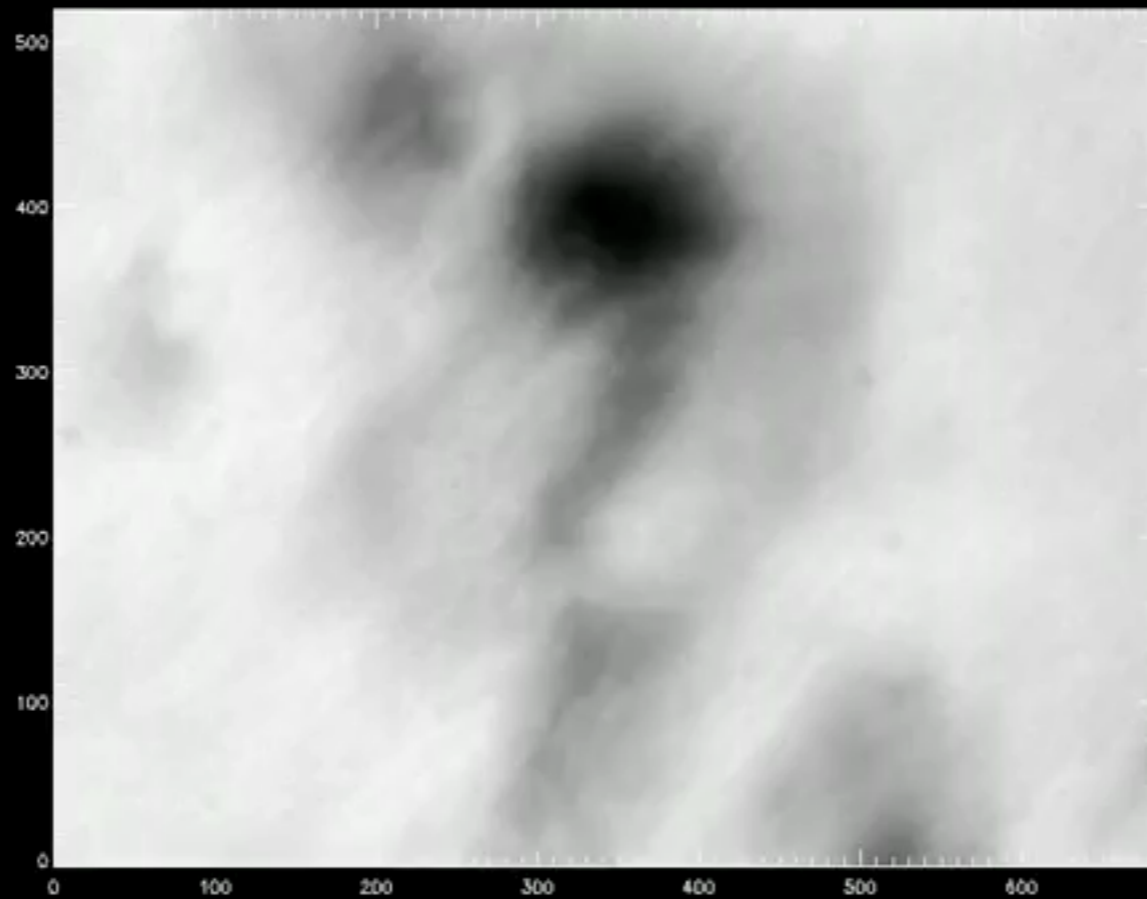
2.3 arc sec



May 24, 1999

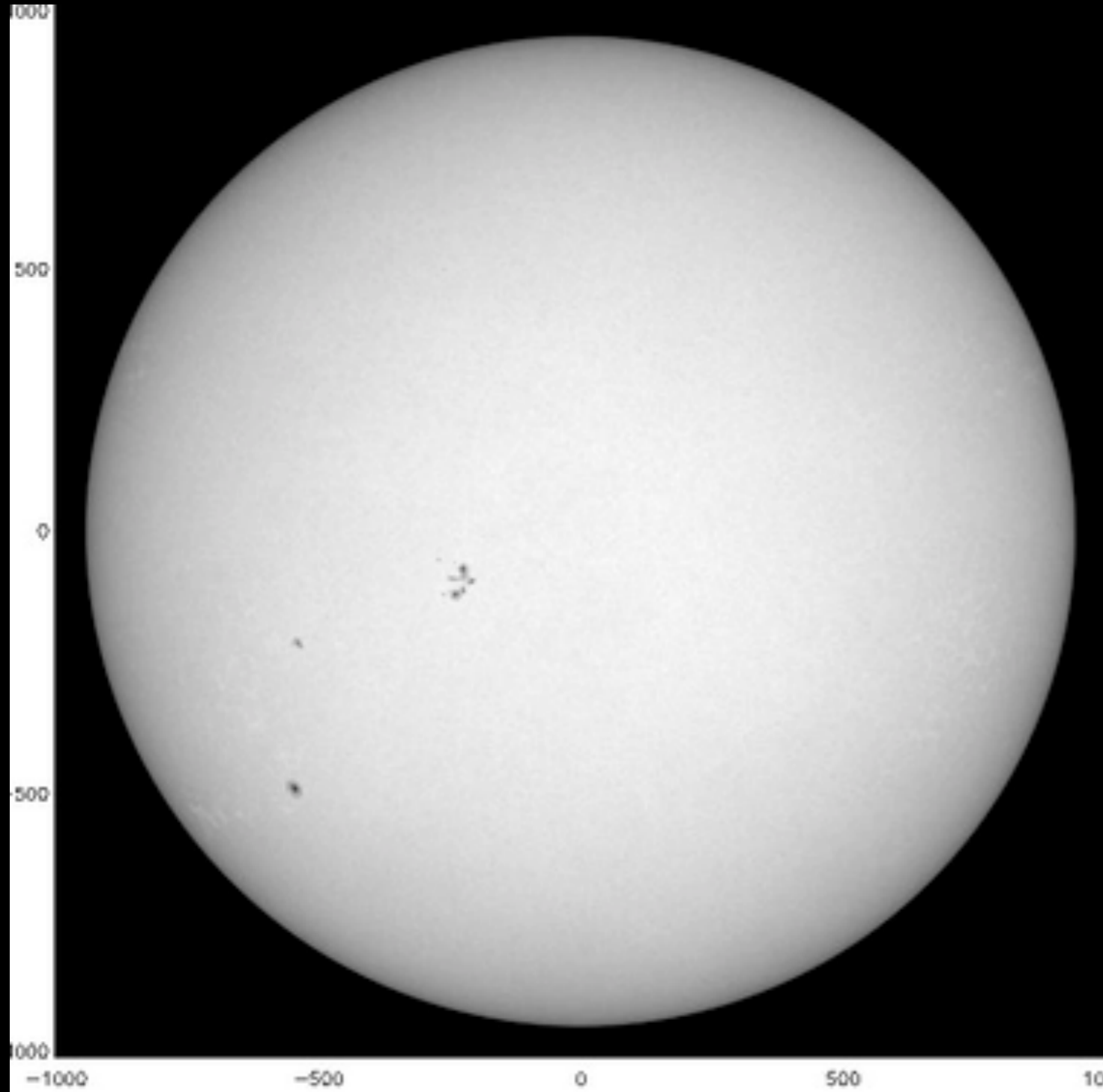
June 27, 1999

Tenerife Adaptive Optics



World best telescope

Sharpest ever pictures of the Sun – SWT LaPalma

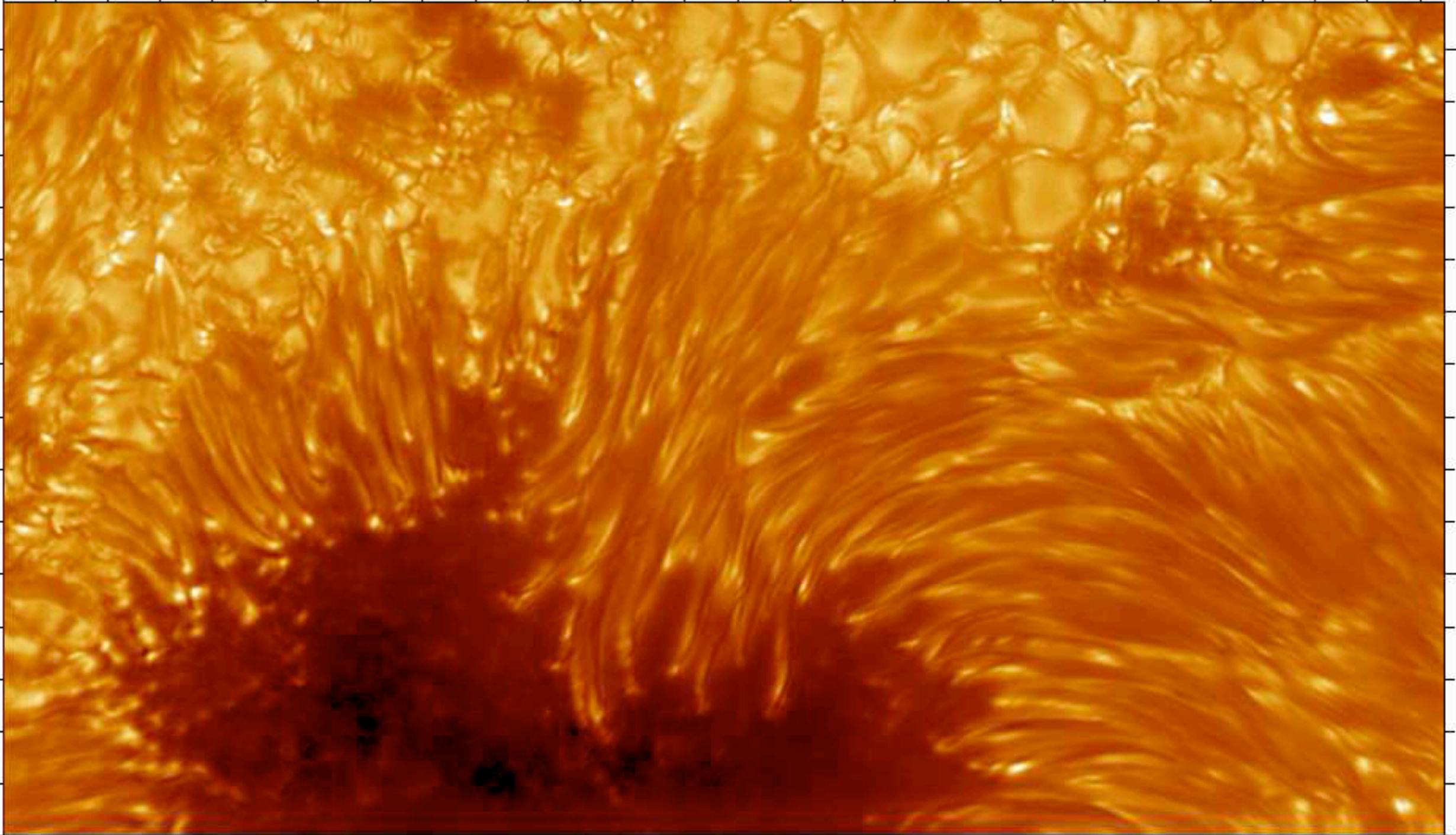


Sunspots

Sharpest ever pictures of the Sun – SWT LaPalma

G-Band, 15 July 2002, Swedish 1-m solar telescope

00:00:00



distance in units of 1000 kilometers

Exploring the human body (visible, X-rays, IR-thermal imaging)

← Different views of a biking kid



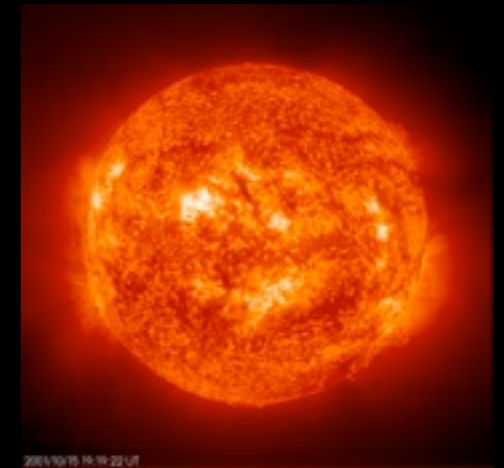
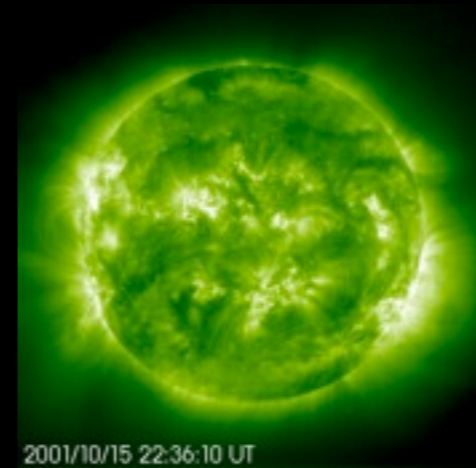
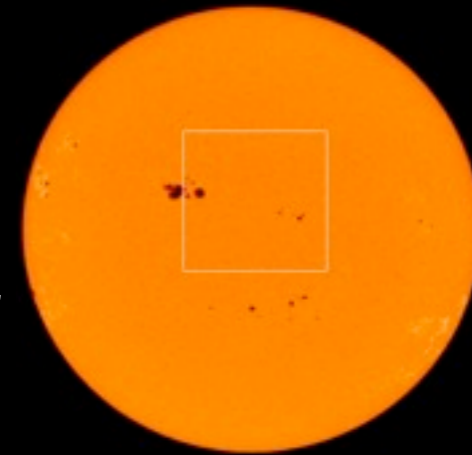
Exploring the Sun at different wavelengths



← Different views of a biking kid



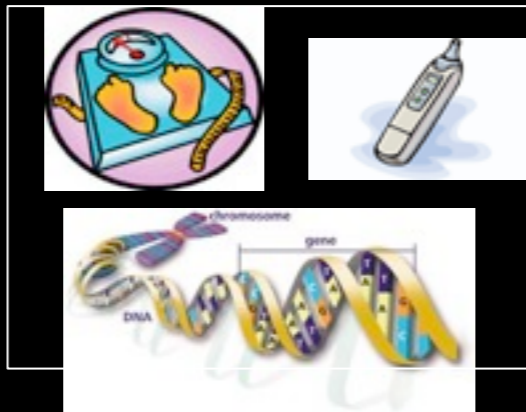
Different views of the Sun →



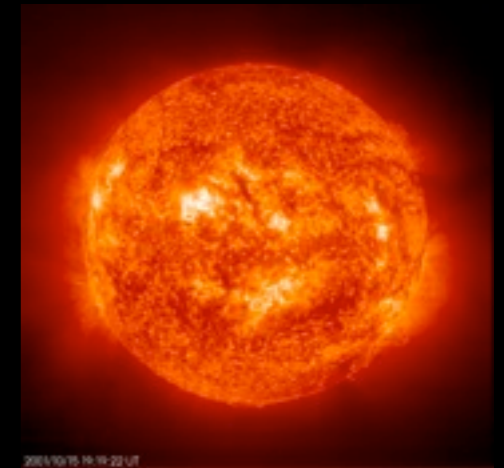
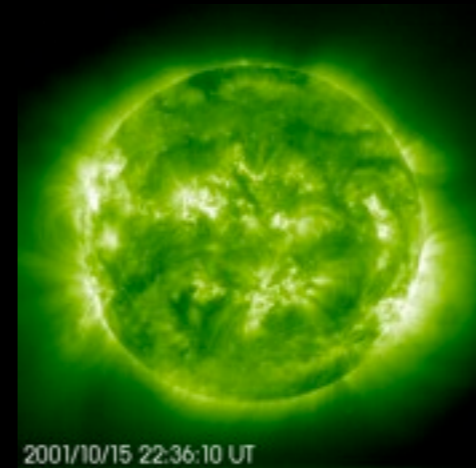
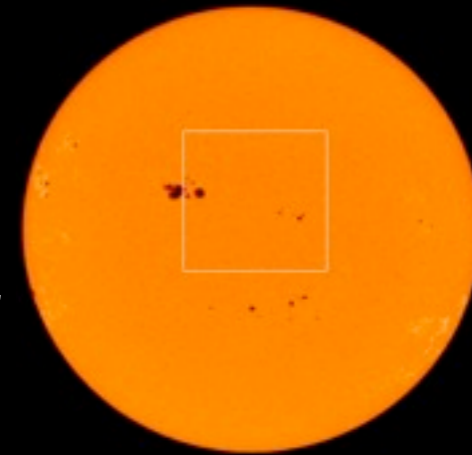
Exploring the Sun at different wavelengths



← Different views of a biking kid



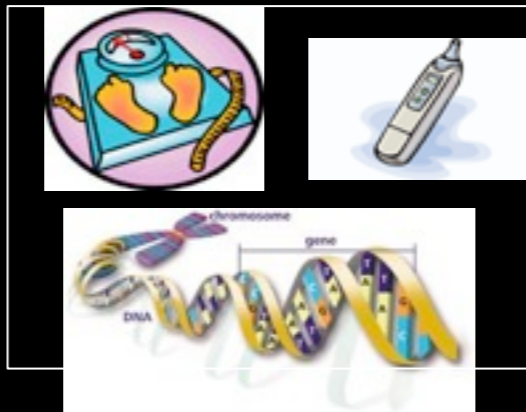
Different views of the Sun →



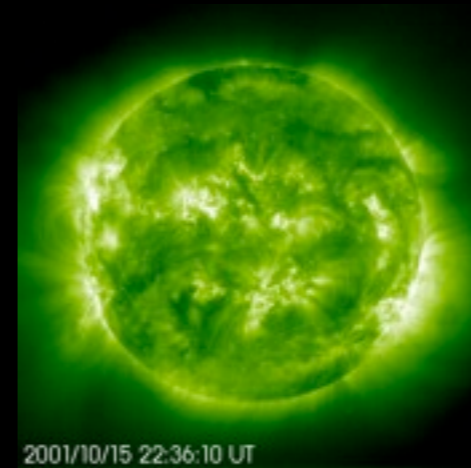
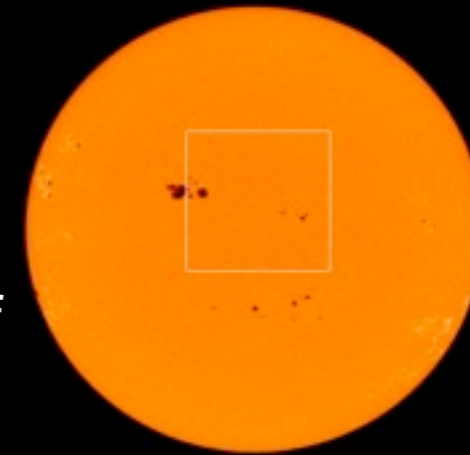
Exploring the Sun at different wavelengths



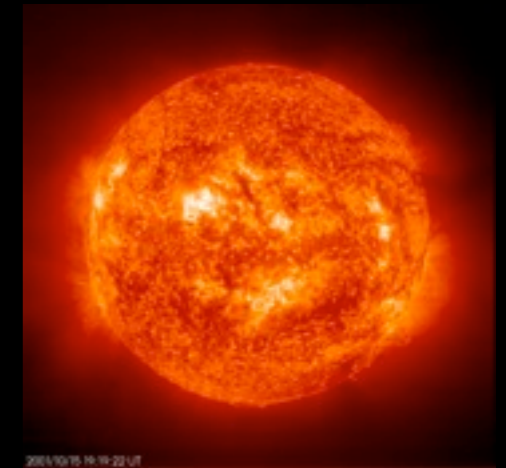
← Different views of a biking kid



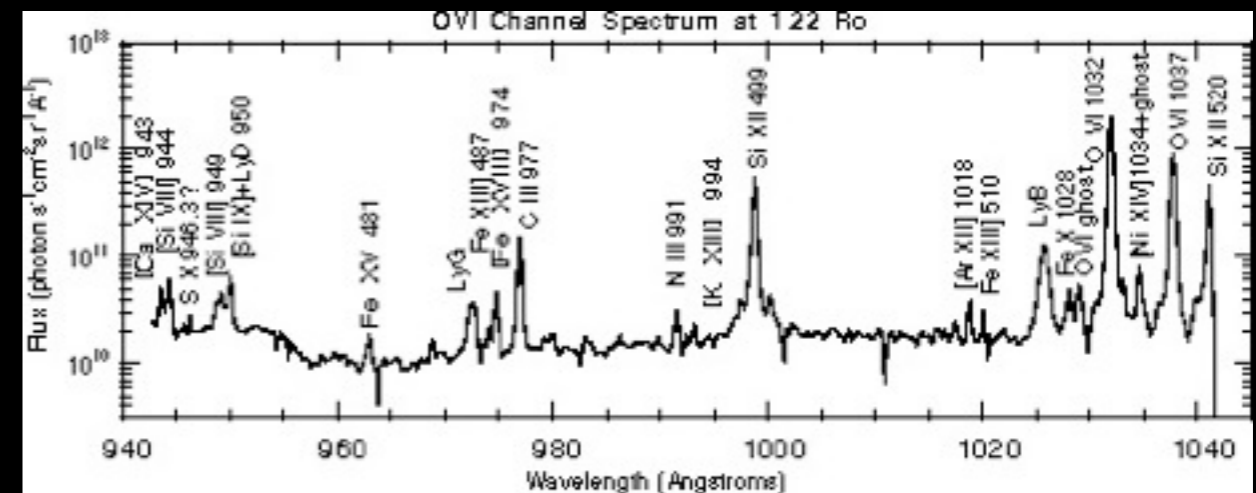
Different views of the Sun →



2001/10/15 22:36:10 UT



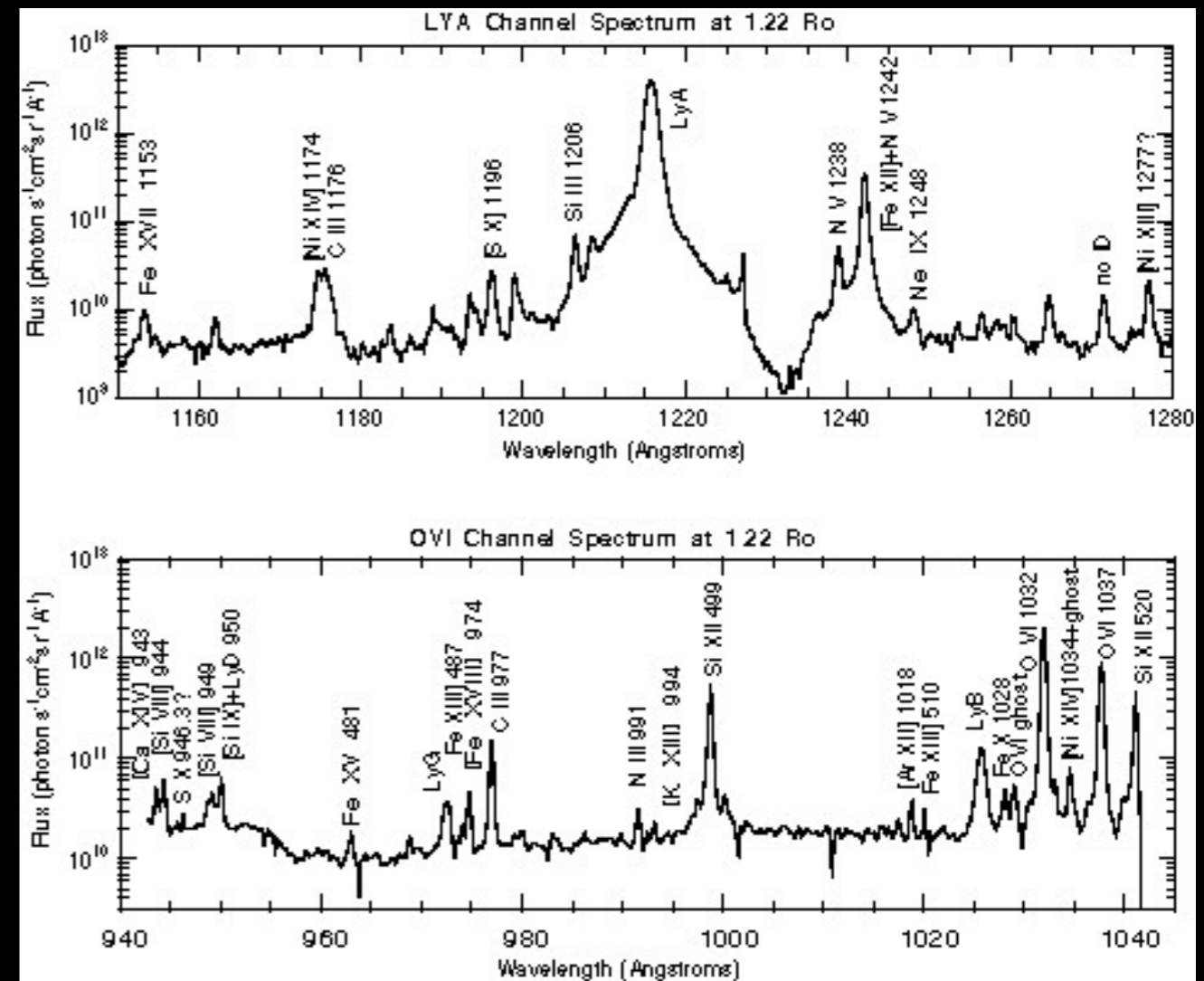
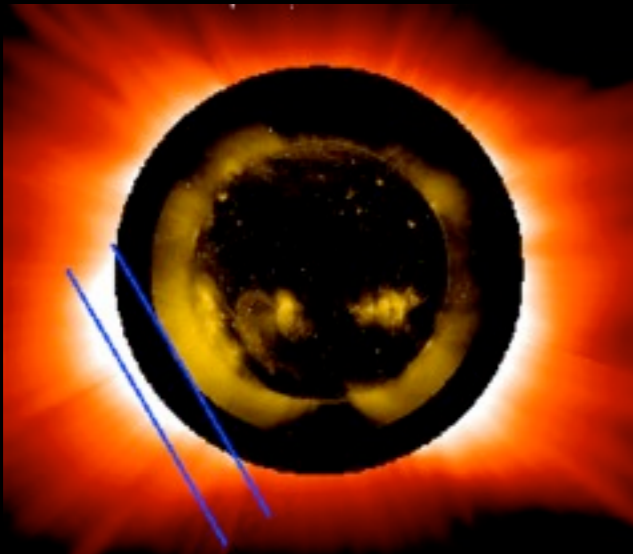
2001/10/15 19:19:22 UT



Spectrum is like fingerprints of a star

Spectrum is like fingerprints of a star.

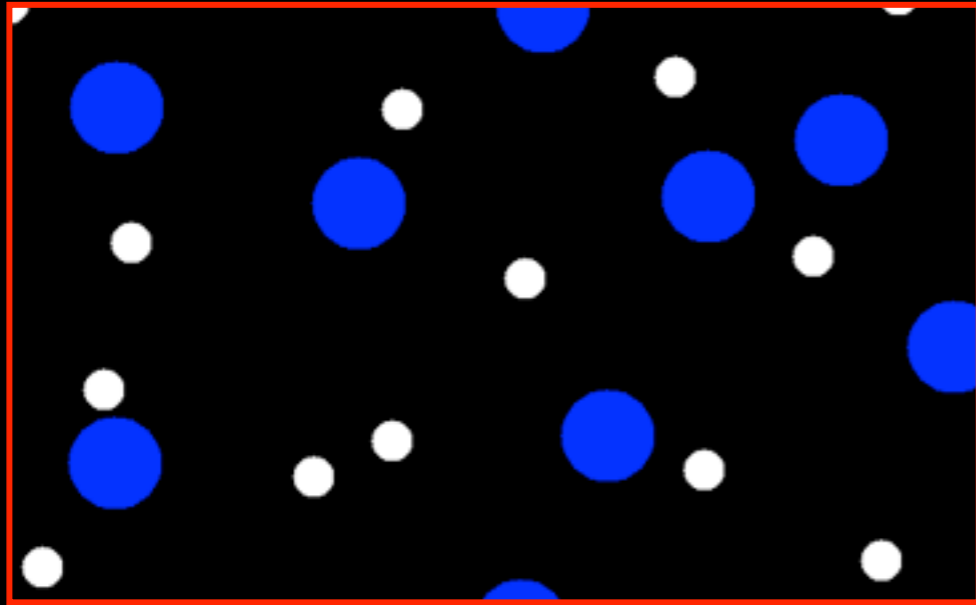
- It provides information about the physical properties of the star:
 - composition, abundance, temperature, density and
 - line-of-sight motions, etc.
- Once we have these information, we can develop models and
- theories to understand how a star works.



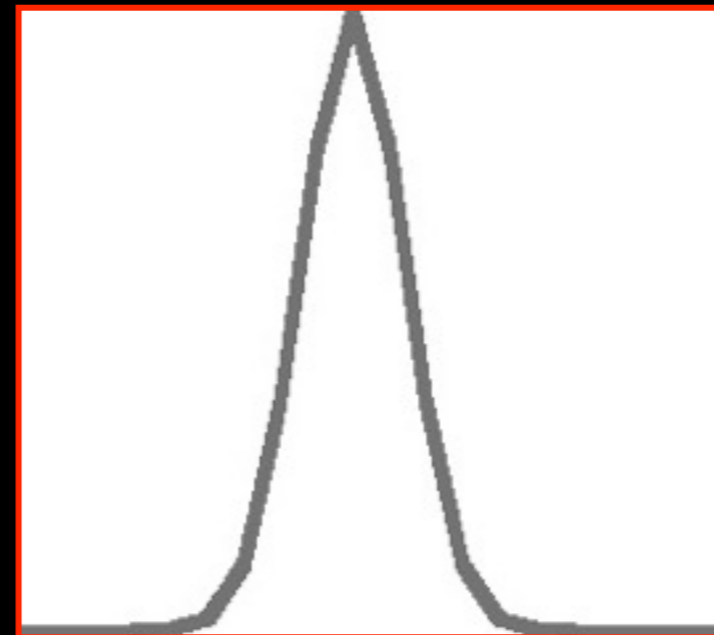
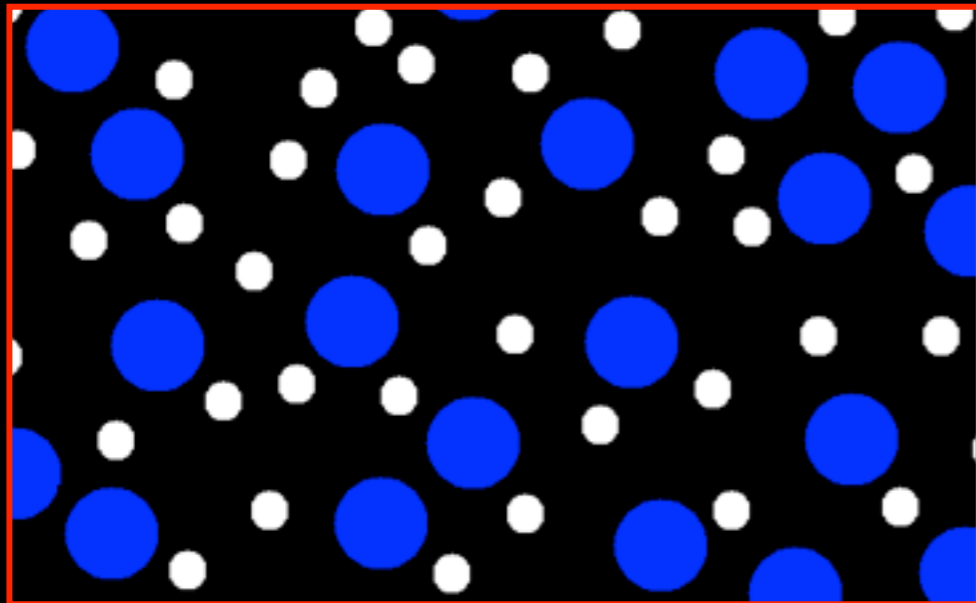
SOHO/UVCS Observations of the corona above an active region

What can we learn from a spectrum

#1: Line Intensity

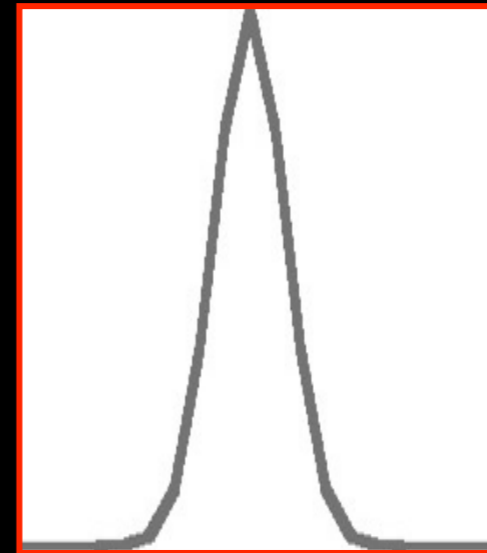
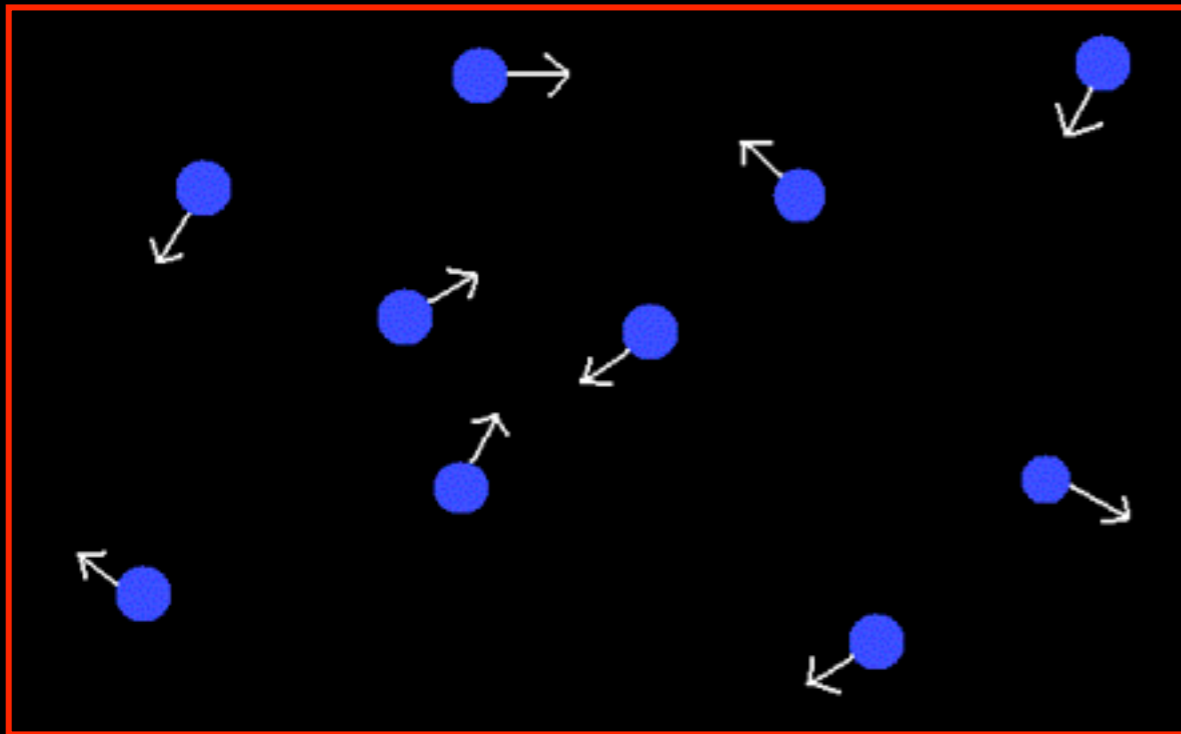


Less particles
→ lower intensity
(fainter line)

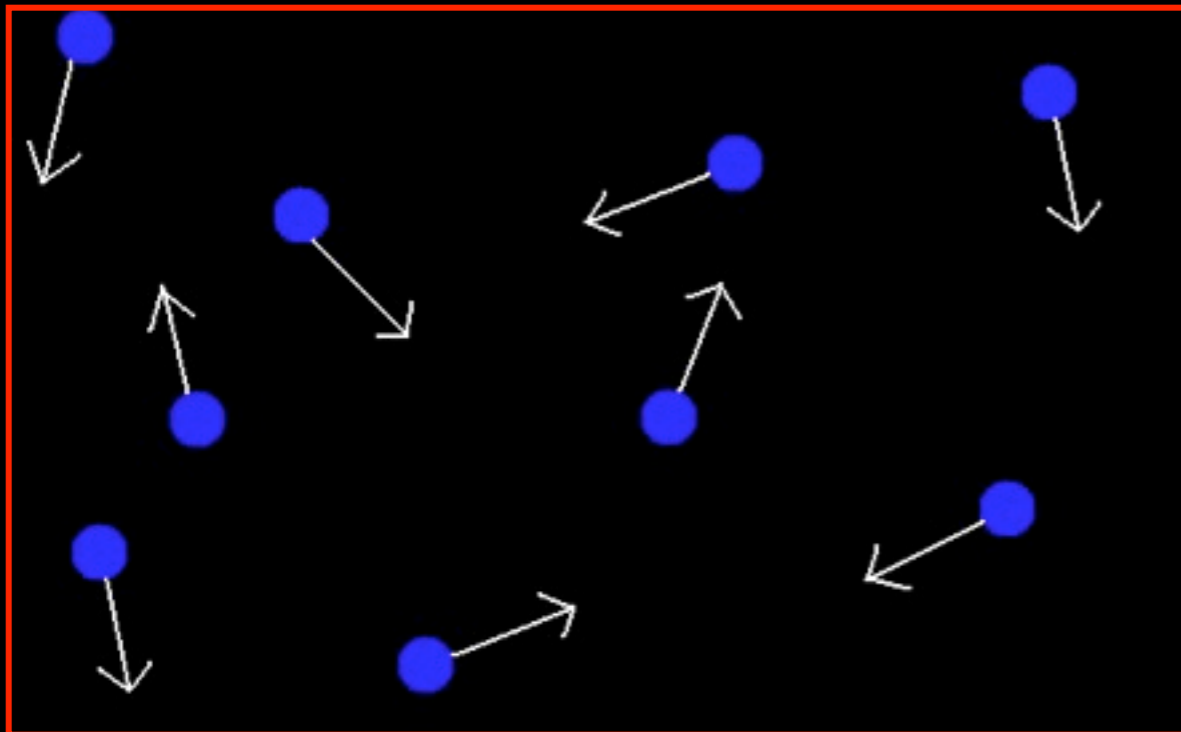


More particles
→ higher
intensity
(brighter line)

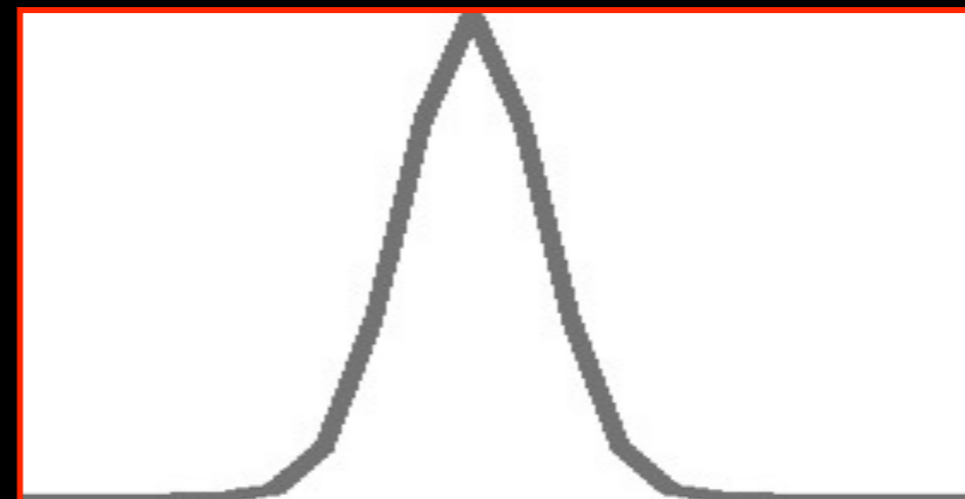
What can we learn from a spectrum #2: Line Profile



Slower random motion
→ narrower width

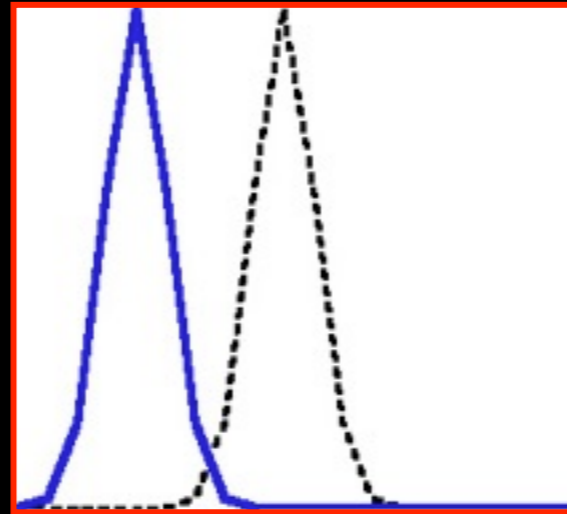
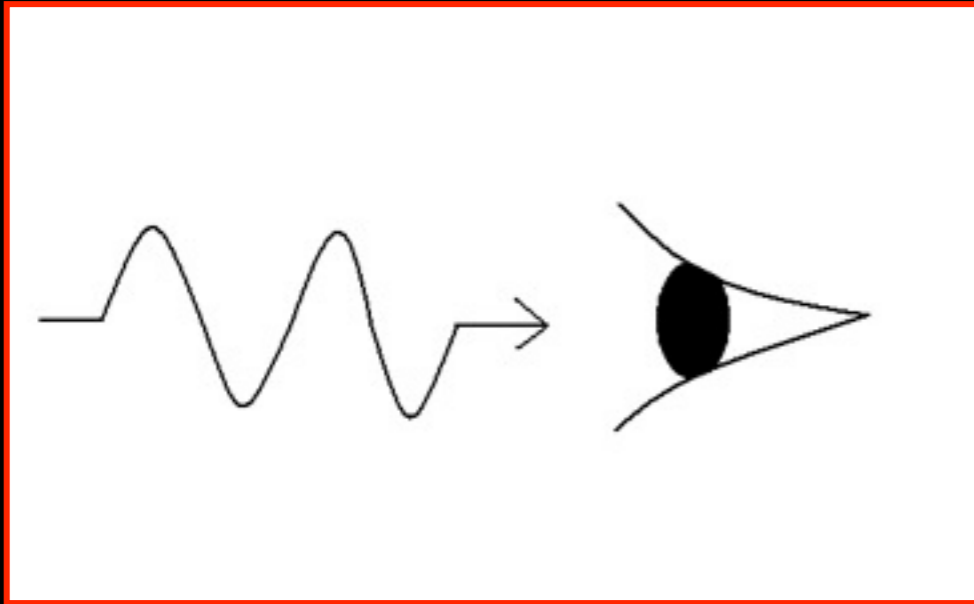


Faster random motion
→ wider width

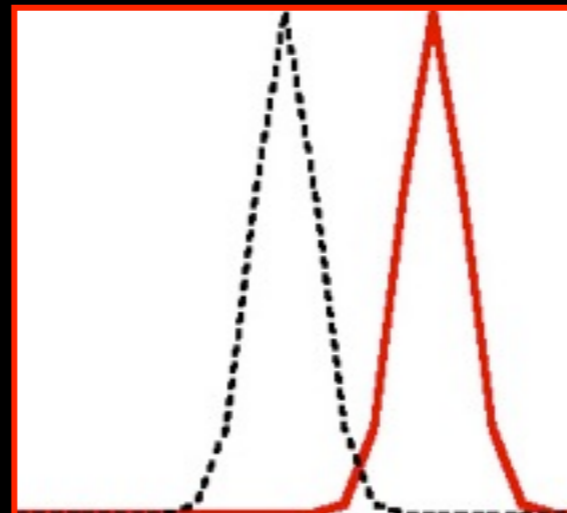
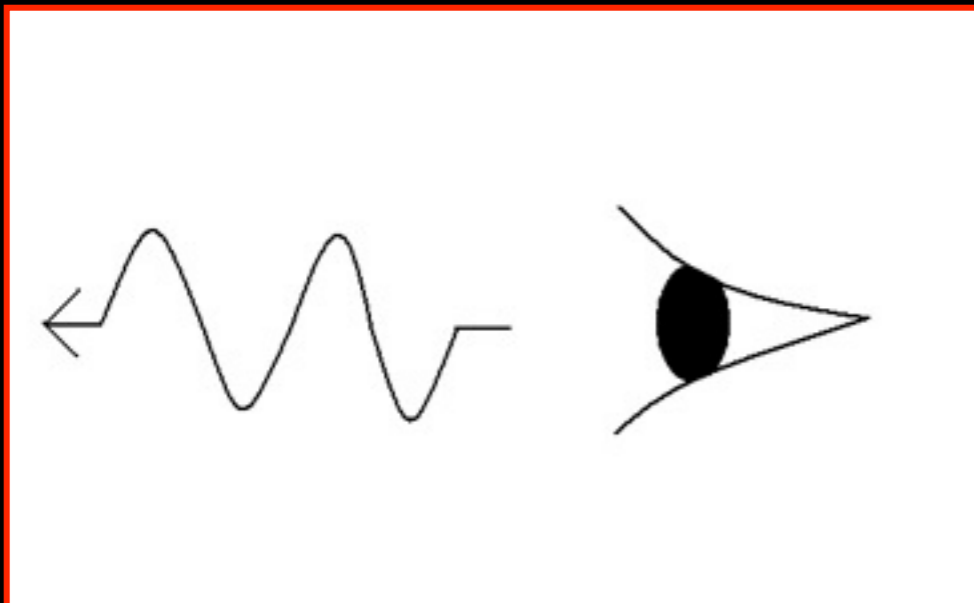


What can we learn from a spectrum

#3: Line Shift

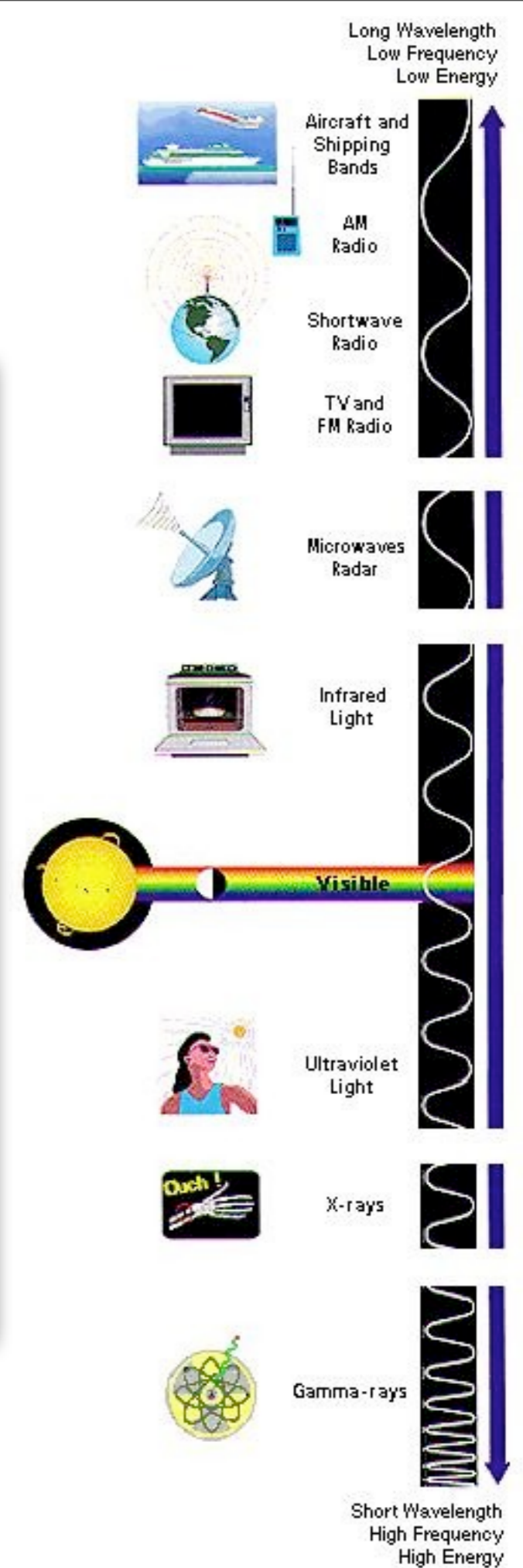
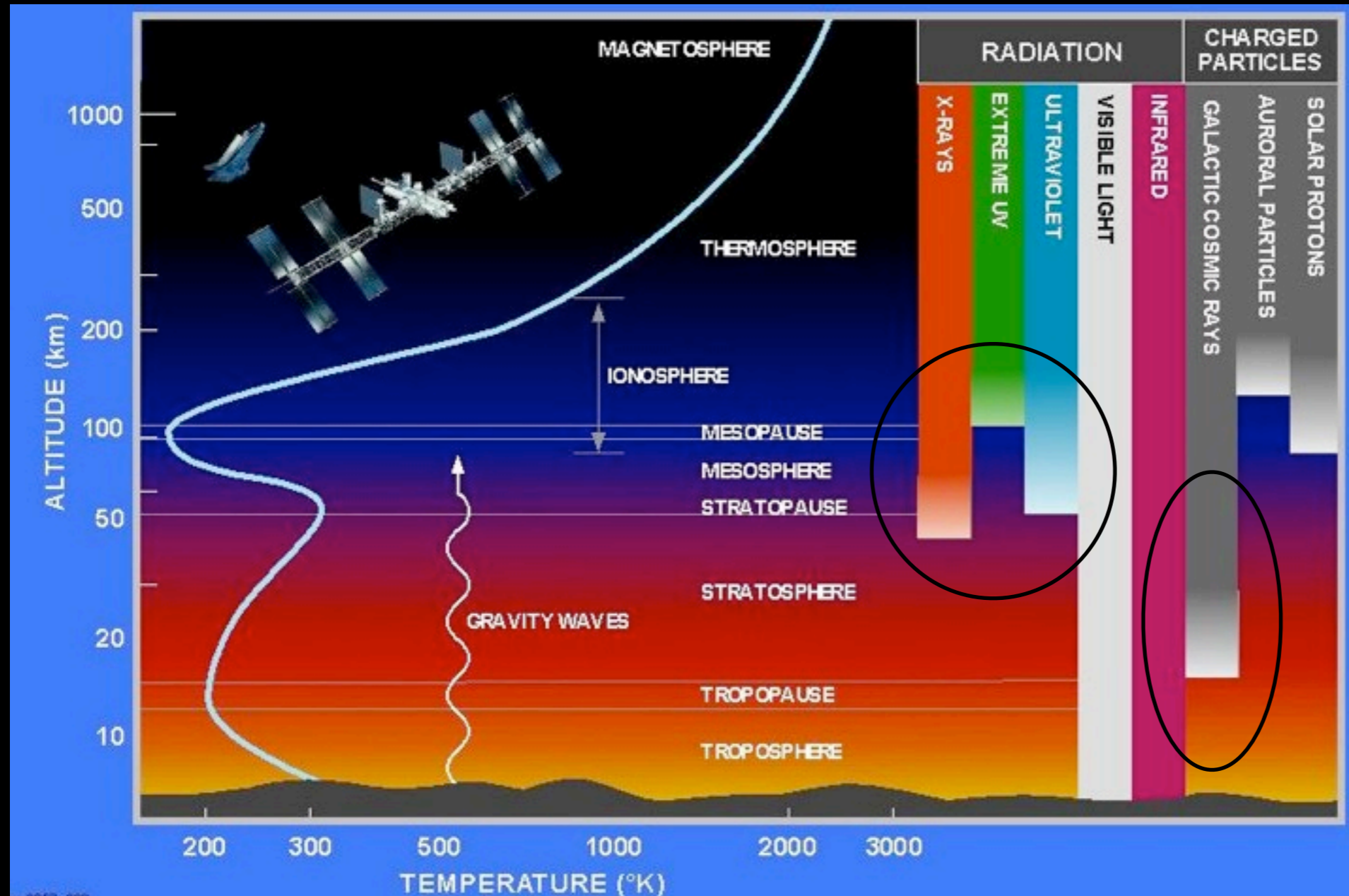


Source moving toward us
→ blue shift (shorter wavelength)



Source moving away from us
→ red shift (longer wavelength)

Electromagnetic radiation

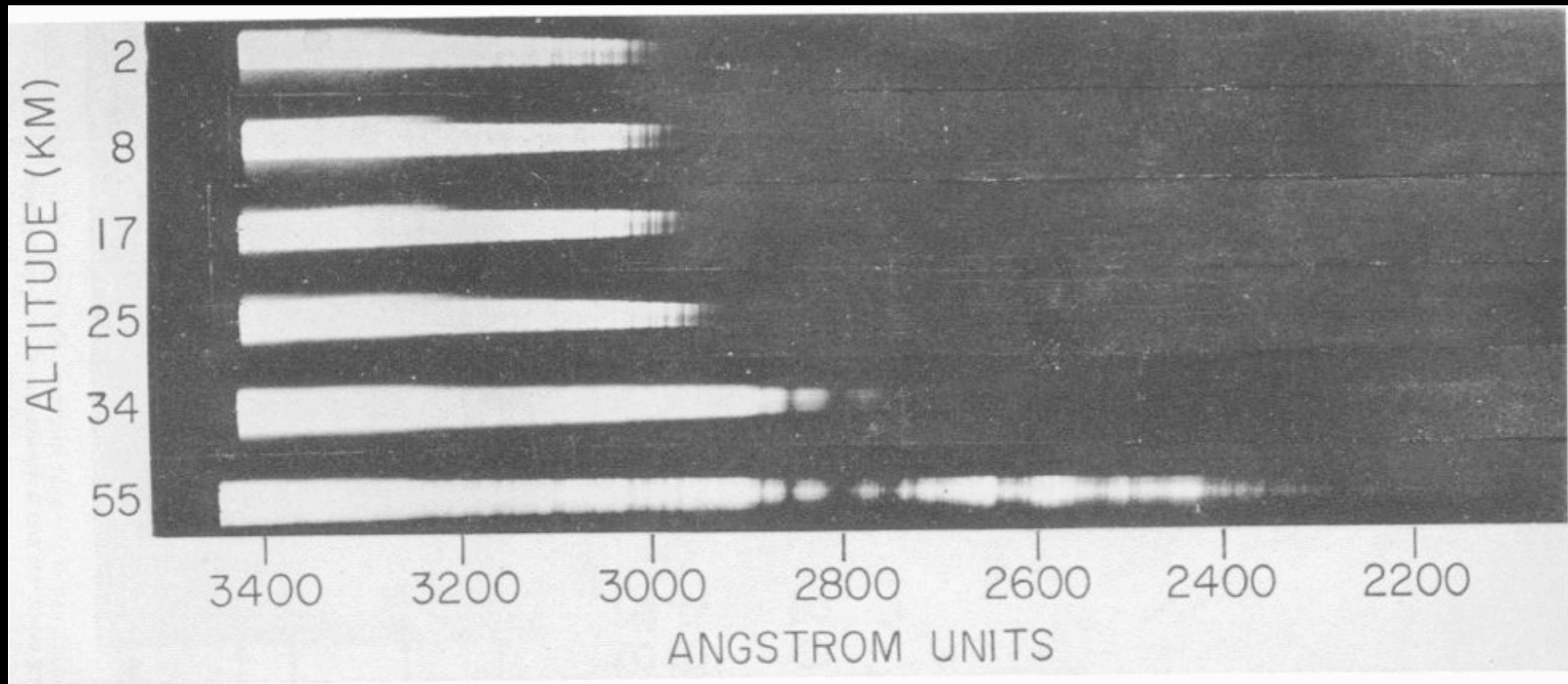


First Glimpse of the Sun from Space

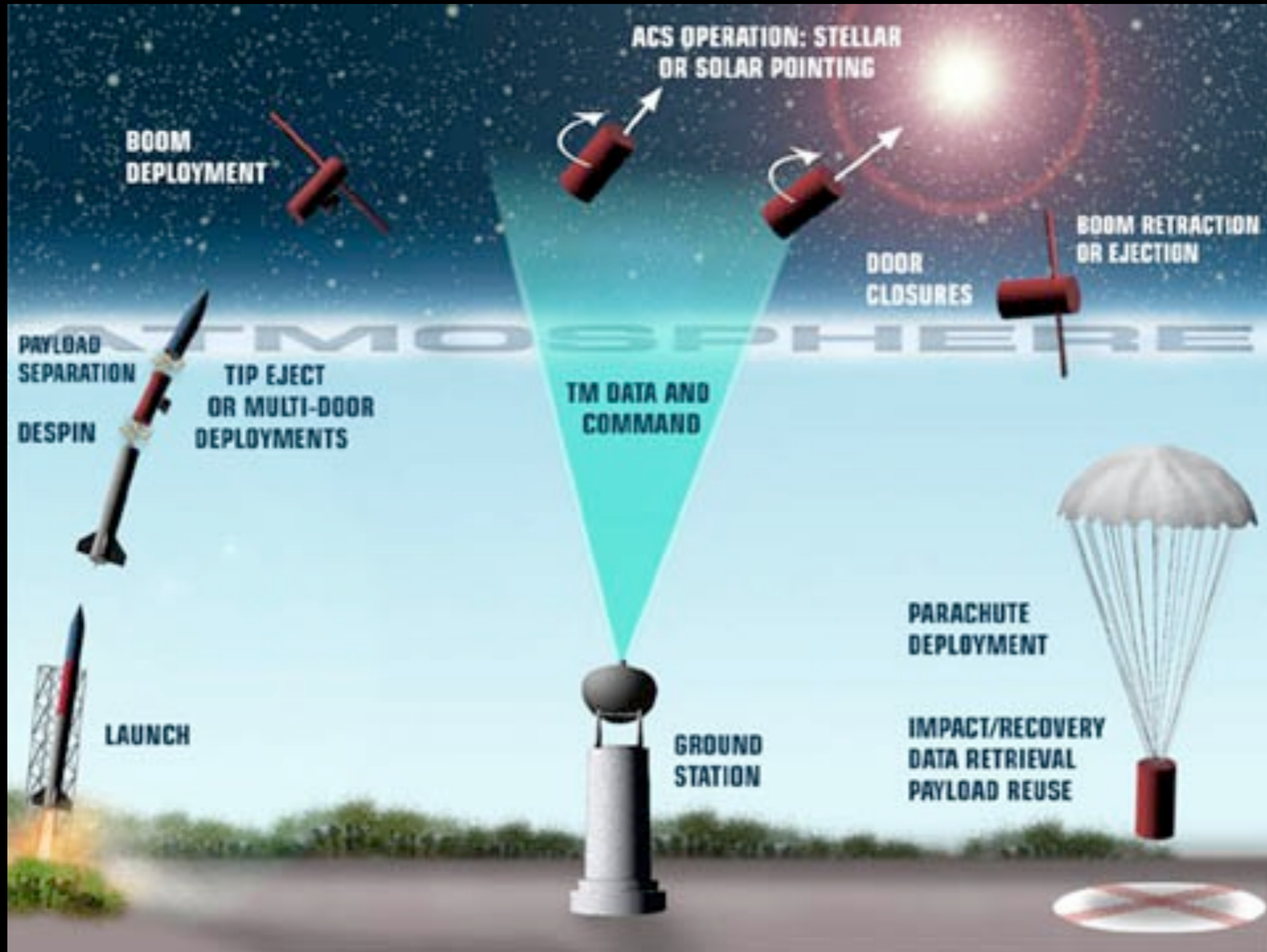
- After World War II, captured V2 rockets provided a means for sending scientific instruments above the bulk of the earth's atmosphere, which absorbed ultraviolet (UV) radiation.
- To study the nature of that absorption, and to examine the ultraviolet portion of the solar spectrum, a group at the Naval Research Laboratory (NRL) in Washington D.C. led by physicist Richard Tousey designed a rugged solar spectrograph to fly in the V2 warhead. 12 spectrometers were built
- The first spectrograph was placed in the warhead of the missile for a flight in June 1946 and confirmed that recovery was going to be a major problem.
- The spectrographs were then placed in the tail fins, and explosive bolts were added break the vehicle into two pieces on descent, destroying its aerodynamic form.
- The first successful flight of the NRL UV spectrograph was on October 10, 1946. The missile reached an altitude of 173 km and the series of spectra obtained during ascent showed the decrease in UV absorption with altitude and helped set the upper limit to the Earth's ozone layer.



First UV spectrum of the Sun

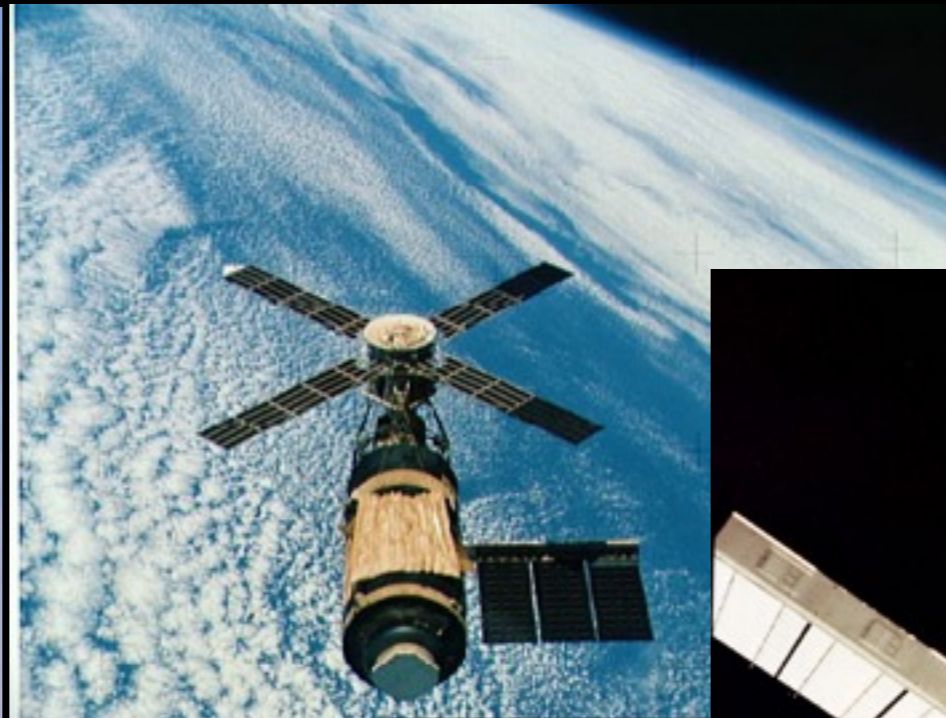


Sounding rockets still useful for Solar Observations



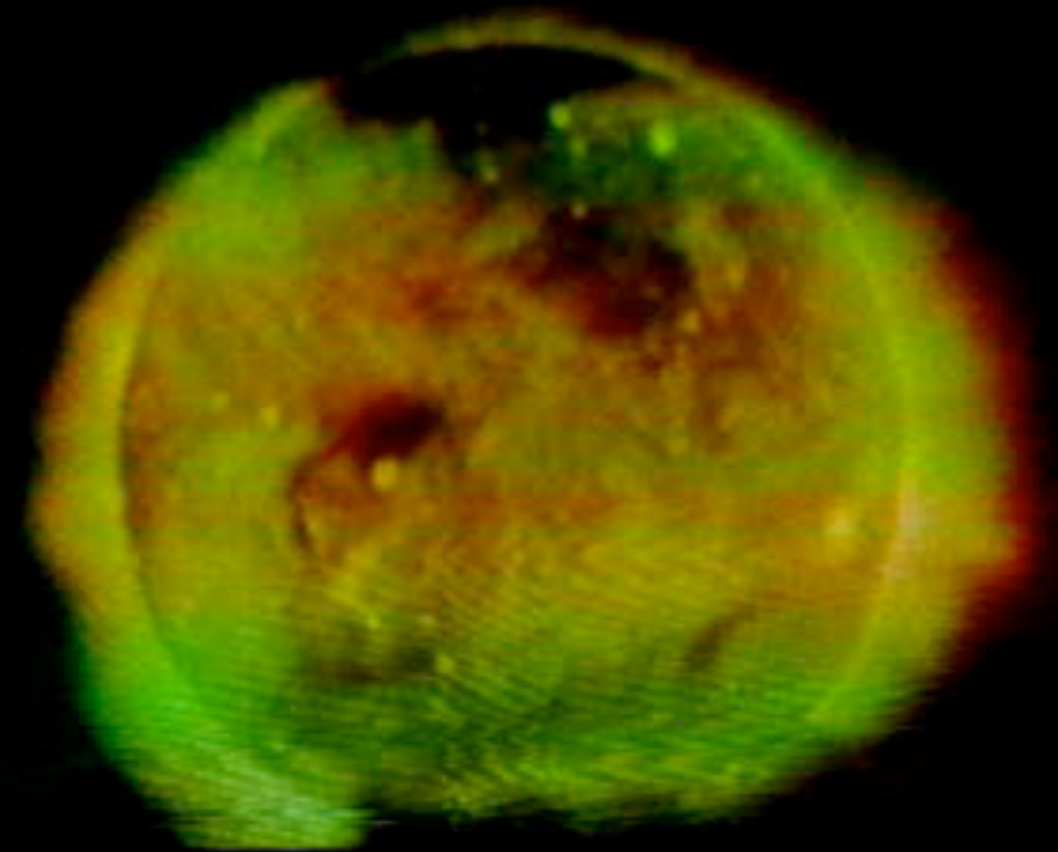
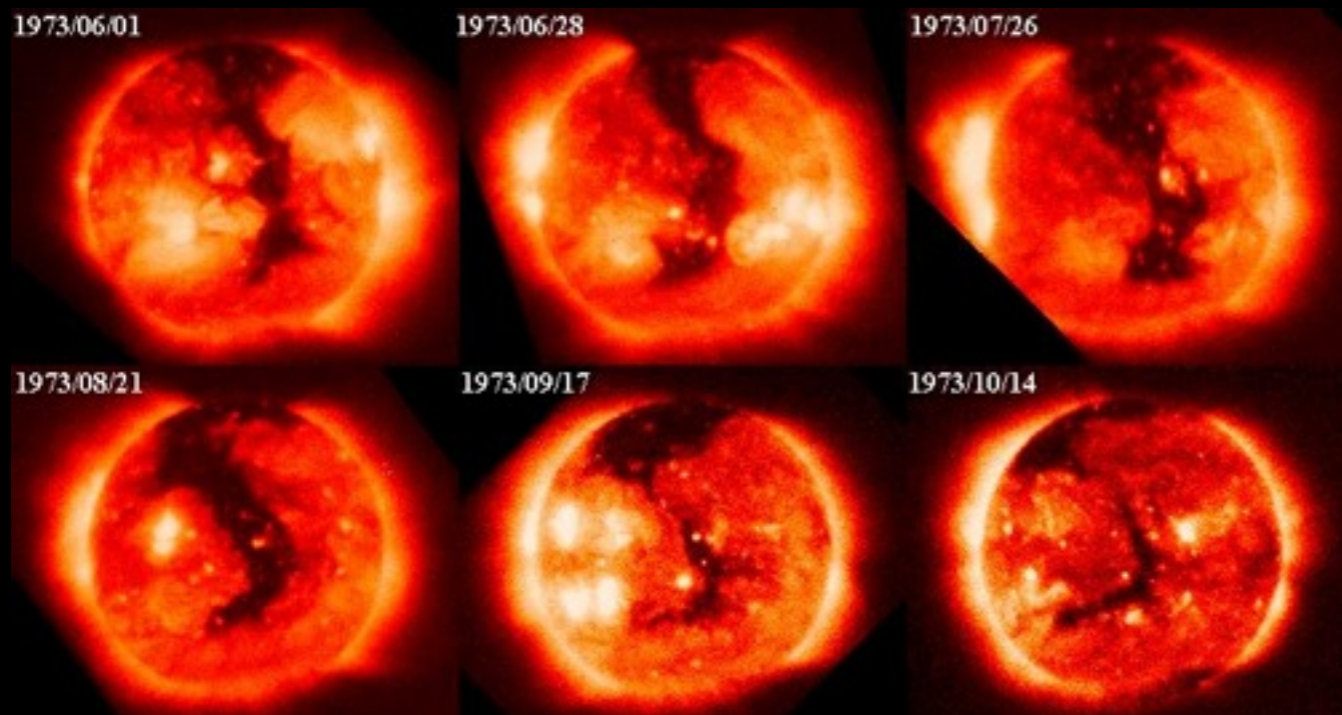
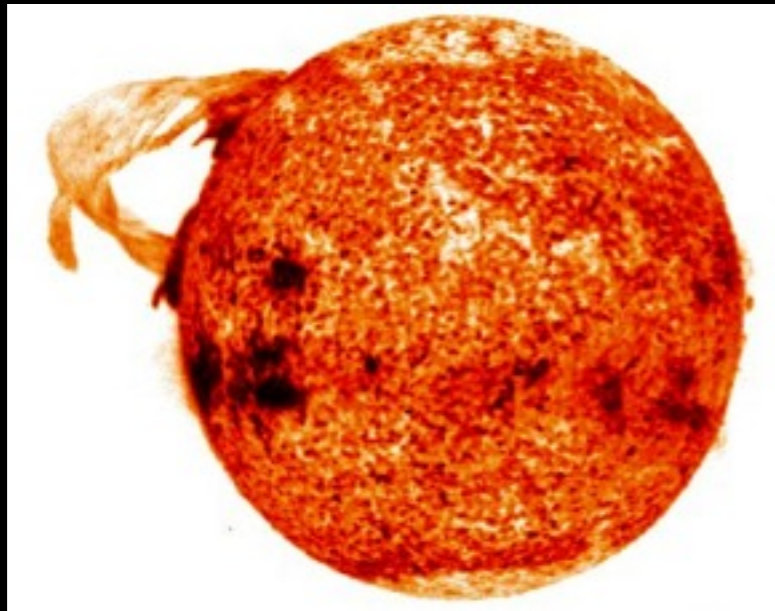
Skylab – Apollo Telescope Mount

- *Skylab*, the first US space station, was launched into orbit on May 14, 1973 as part of the Apollo program. This 91 metric ton structure was 36 meters (four stories) high, 6.7 meters in diameter and flew at an altitude of 435 km (270 miles).
- When Skylab was launched it lost a solar panel and part of its external shielding. Skylab astronauts had to rig a "golden umbrella" to keep their habitat comfortable. Skylab re-entered the Earth's atmosphere in 1979 over Australia. This re-entry was a year or two earlier than expected.

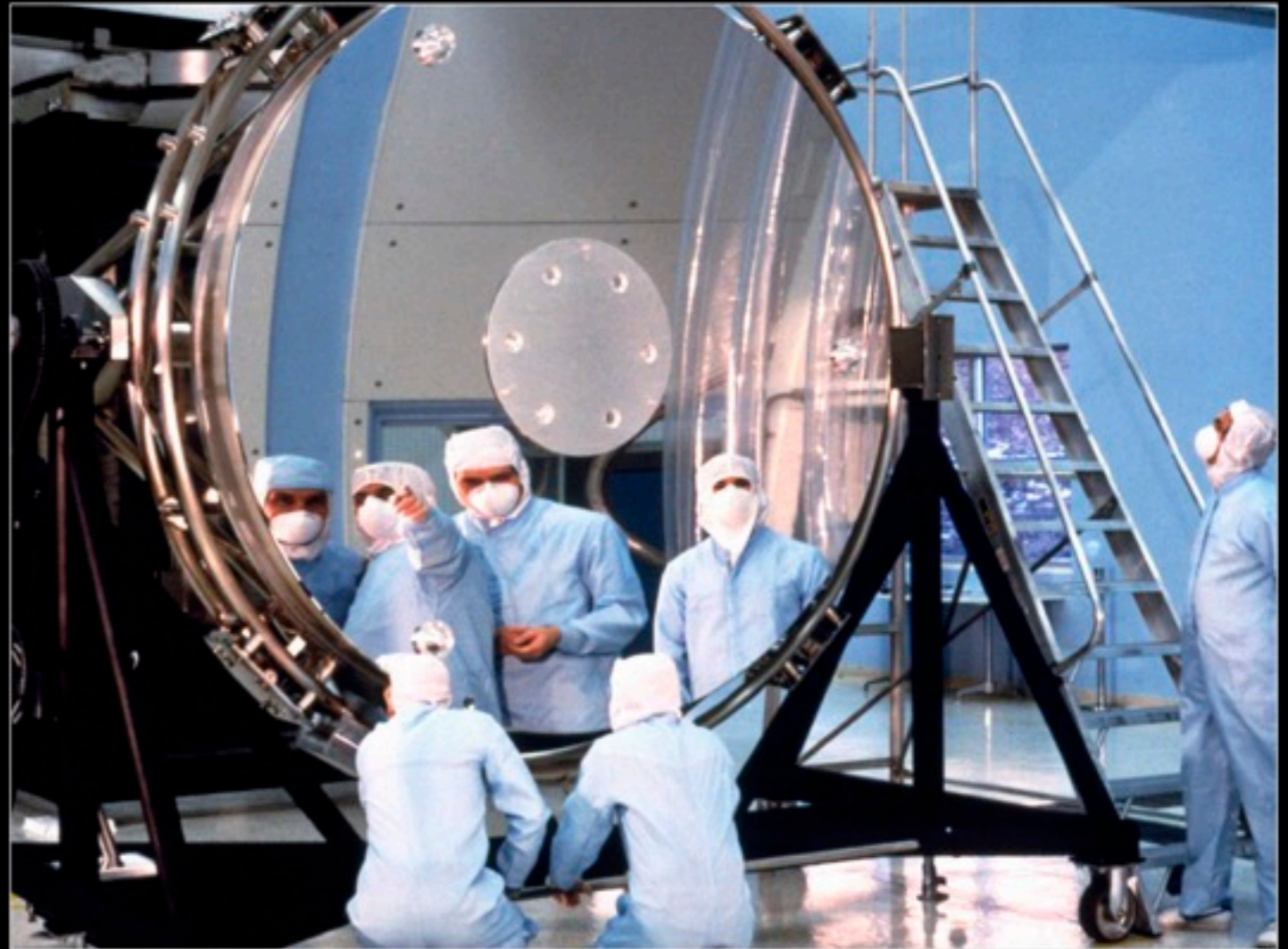


Skylab – Apollo Telescope Mount

- *Skylab* included eight separate solar experiments on its Apollo Telescope Mount: two X-ray telescopes (an X-ray and extreme ultraviolet camera); an ultraviolet spectroheliometer; an extreme ultraviolet spectroheliograph and an ultraviolet spectroheliograph; a white light coronagraph; and two hydrogen-alpha telescopes



Hubble Space Telescope



Working on Hubble's Main Mirror

Image Credit: NASA, 1990

Hubble Space Telescope - close to failure



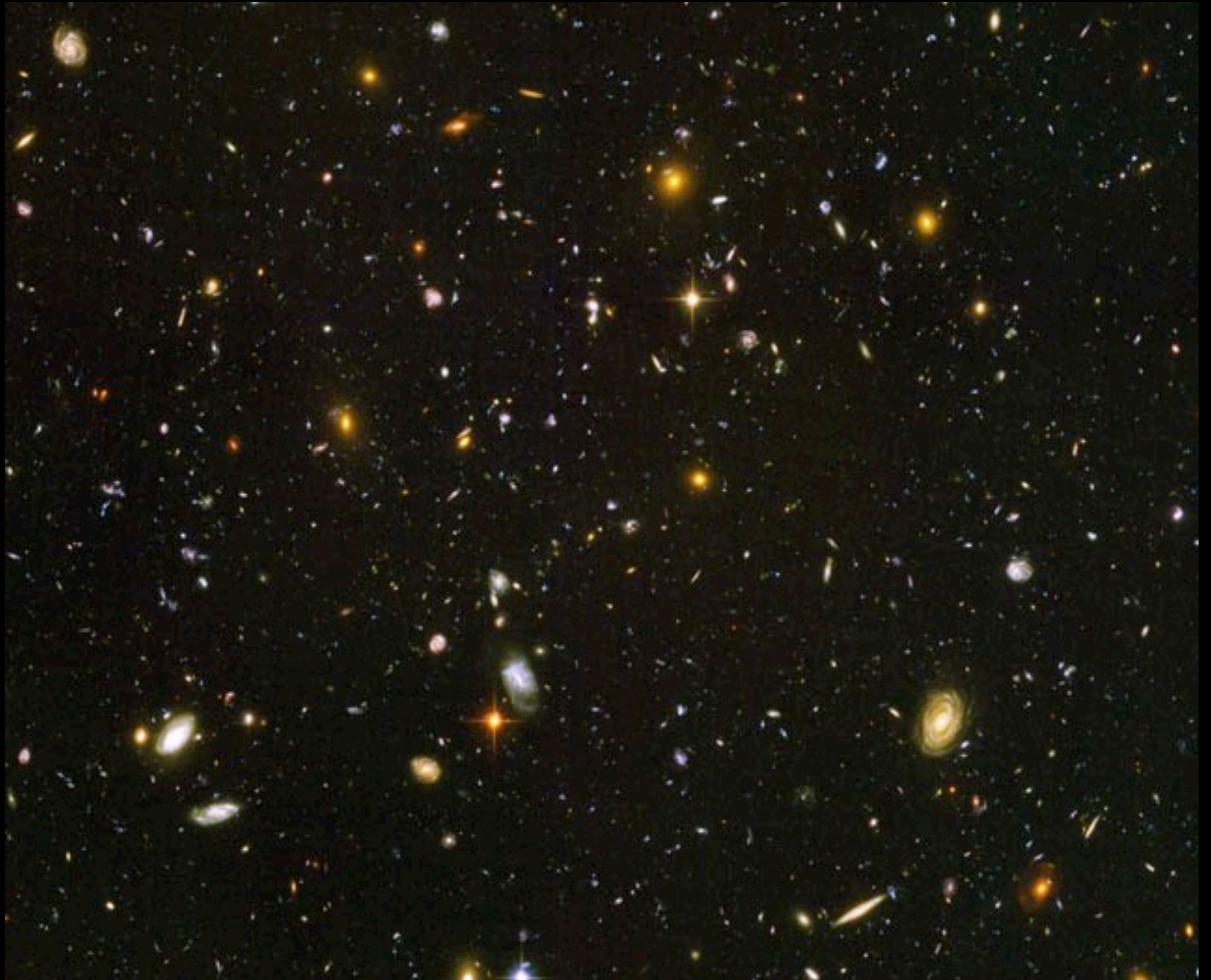
Hubble Space Telescope



Hubbel Ultra Deep Field Exposure



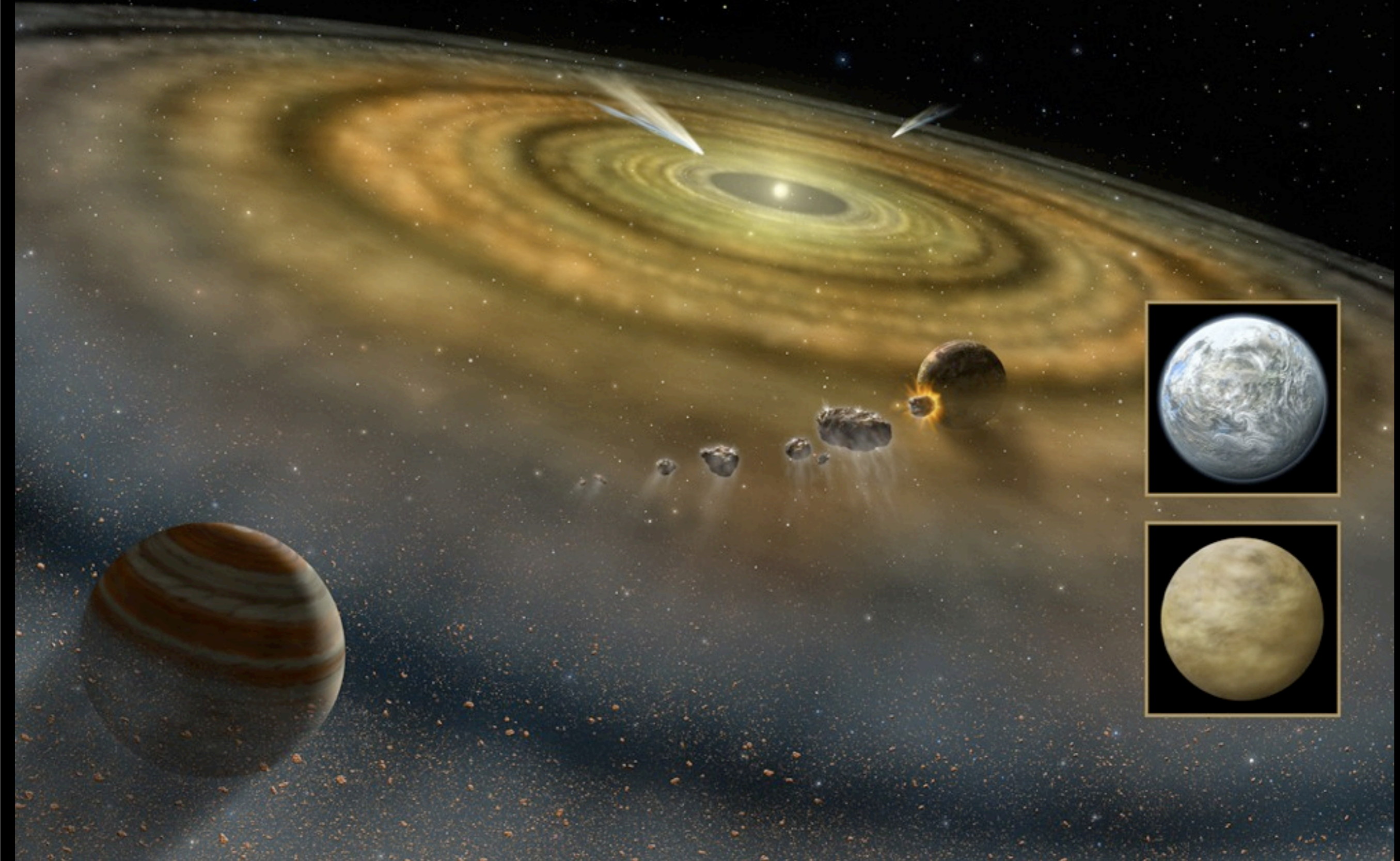
Hubbel Ultra Deep Field Exposure



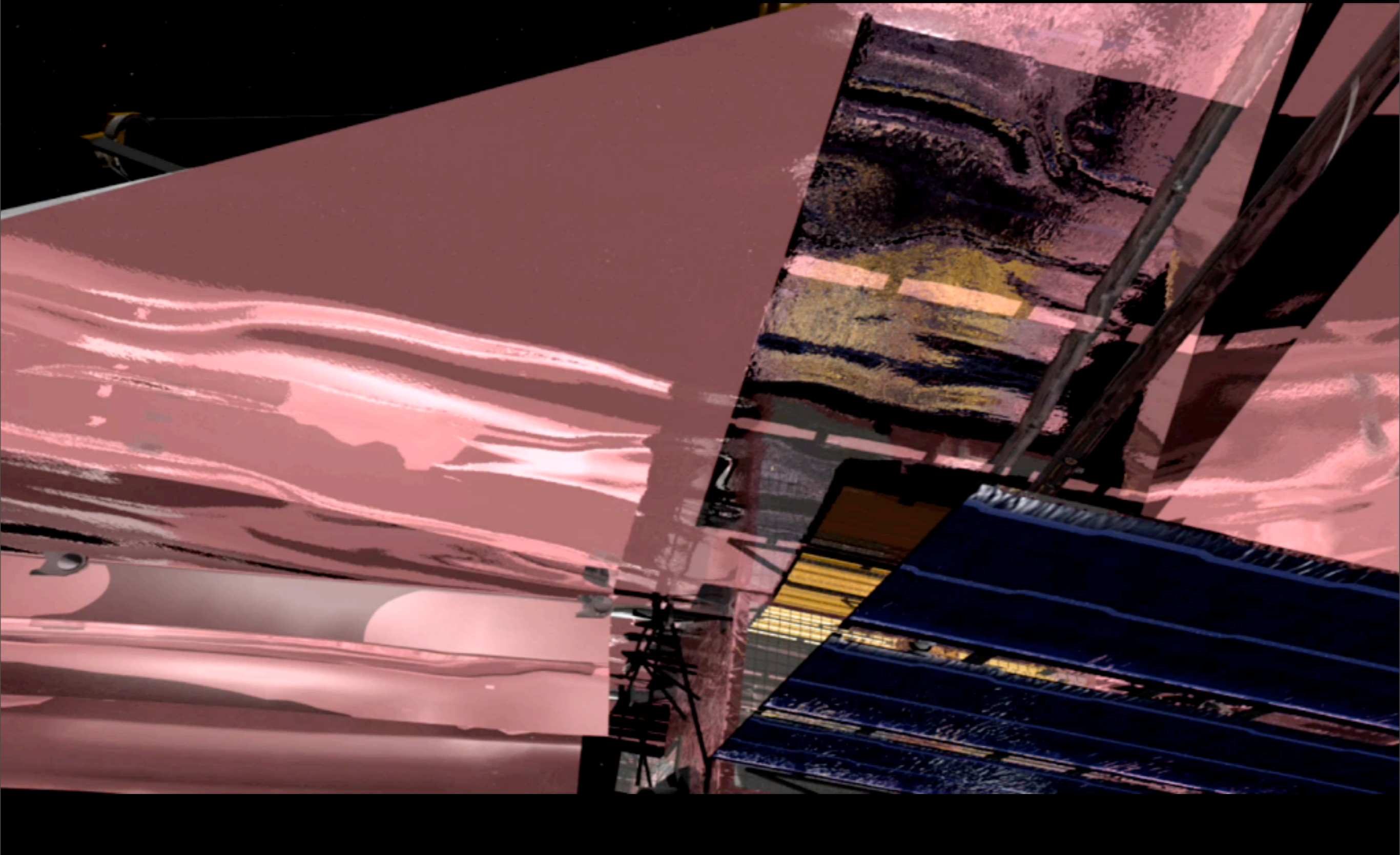
Hubble - 22 years in space



A solar system is born



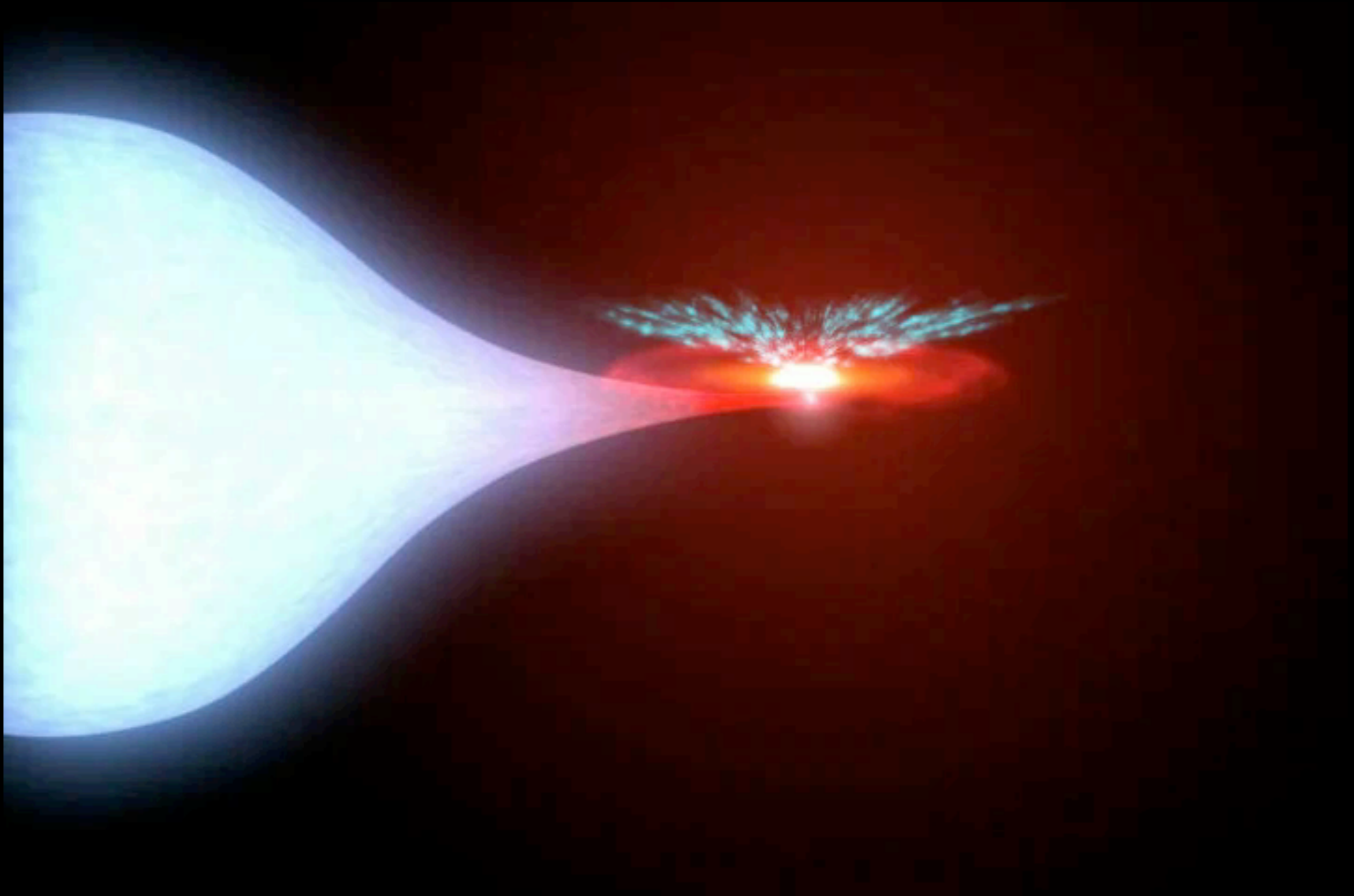
James Webb Telescope



Black holes



Black holes



Supermassive Black Hole

- *Real observations of so-called S-stars at the center of our galaxy circling like flies around a flower (15 years per orbit - 14 million km/h). The Sun: 200 million years - 950 000 km/h.*
- *From the orbits one can calculate the mass of the object they circle: 4 million times the Sun!!*



KEPLER

- Kepler (launched 7 March 2009) is observing 150 000 stars every day.



The night sky tonight



Jorda, Longyearbyen, 10m

FOV 60°

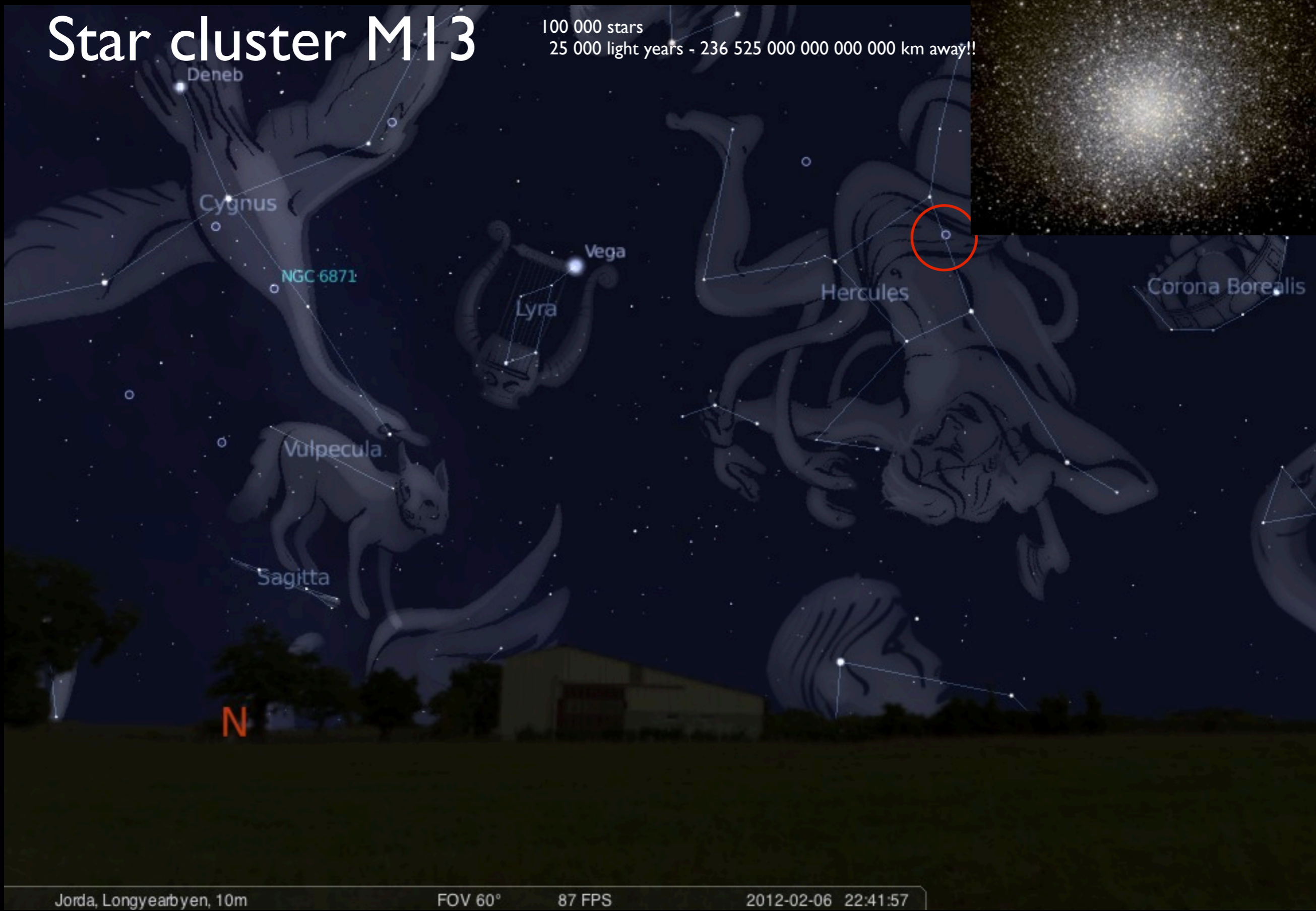
75.5 FPS

2012-02-06 16:07:21

www.stellarium.org

Star cluster M13

100 000 stars
25 000 light years - 236 525 000 000 000 000 km away!!



N

Jorda, Longyearbyen, 10m

FOV 60°

87 FPS

2012-02-06 22:41:57

www.stellarium.org

Useful resource



Article: <http://www.solarmax.no/Aurora/>

Contact: paal@spacecentre.no

Thanks to ESA and NASA for images/animations