Mysteries of Stars and Planets Unraveled by Scientific Satellites

Sep. 2014

Today's Lesson（60 minutes）

1. **Astronomical Observation**
   to clarify the mysteries of the Universe.

2. **Solar Observation :**
   to study the Sun, the source of our life.

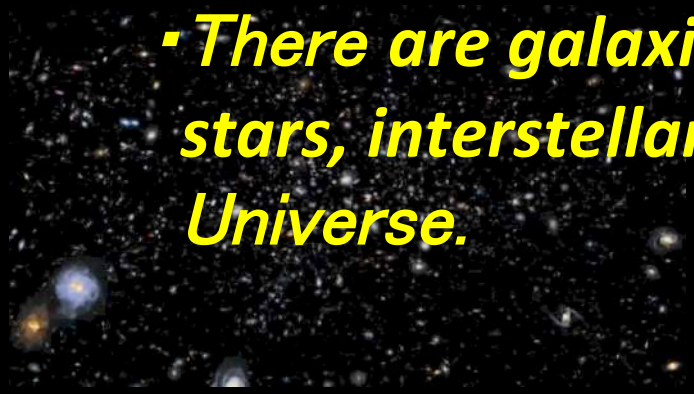
3. **Lunar and Planetary Exploration :**
   to study the origin and evolution of our solar system.

4. **Becoming space scientists or engineers :**
   to work in or with JAXA, for example.

1. Astronomical observation to clarify the mysteries of the Universe.

What we know about the Universe;

- The Universe started with a great explosion of a high-temperature and high-density fireball called "Big Bang" 13.7-13.8 billion years ago.
- The Universe is expanding even now.
- There are galaxies, star clusters, nebulae, stars, interstellar gas, and planets in the Universe.

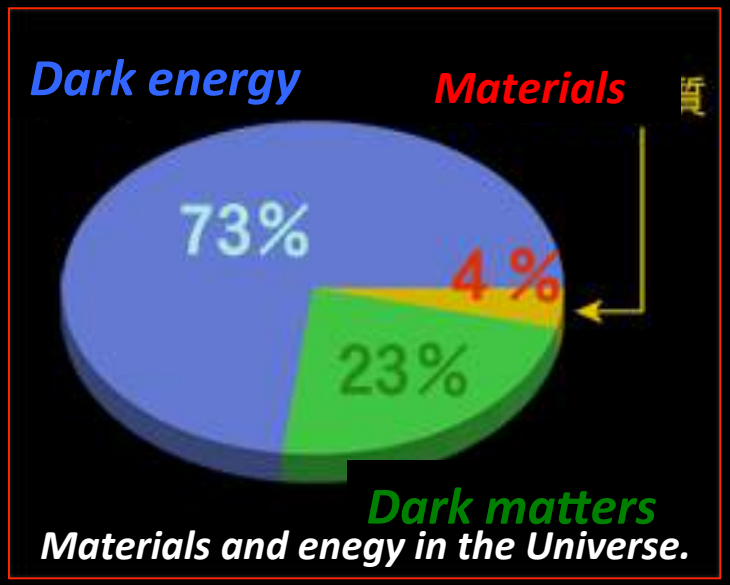


The Universe from its start to today.
（NASA Video）

Still, there are too many questions !

- Where and how the stars are born ?
- What is the mysterious "Black Hole" ?
- What will happen to our Universe in the long future ?
- What roles the dark energy and dark matters are playing ?
- Is there extraterrestrial life ?

....



Materials and enegy in the Universe.

Why we need astronomical observation from satellites? Are ground observations insufficient?

Astronomical observation from satellites without atmospheric effects.

Infrared Telescope (AKARI)

X-ray Telescope (SUZAKU)

Atmosphere has windows for lights and radio waves.

Radio waves with longer wave length

Lights with longer wave length (infrared, etc)

Lights with shorter wave length (X-ray, etc)

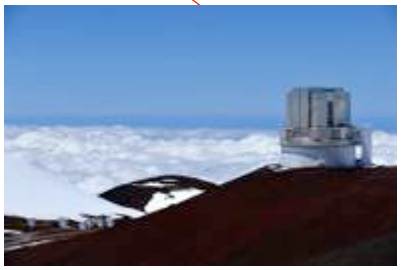
Atmosphere

Radio waves with shorter wave length

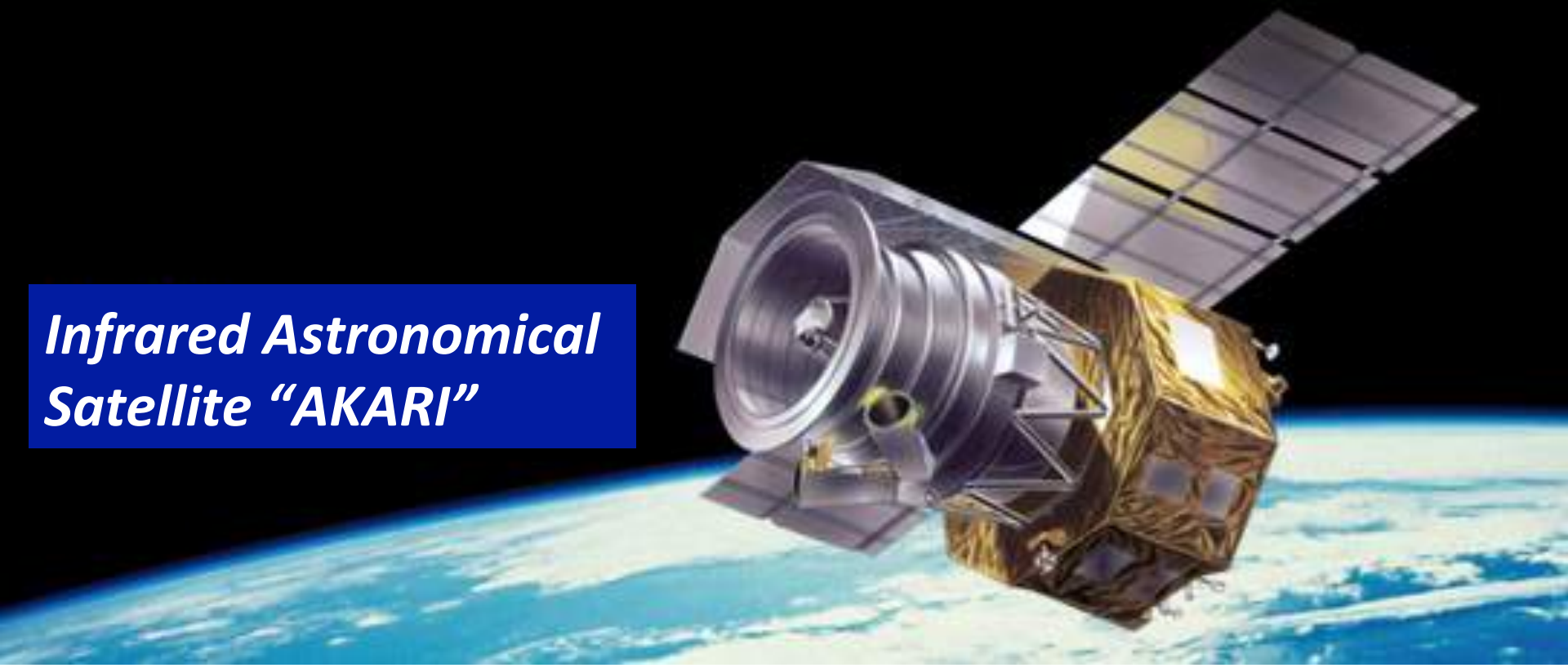
Visible lights

Astronomical observation from the ground with restriction of the atmospheric windows.

Nobeyama Radio Telescope



Subaru Telescope

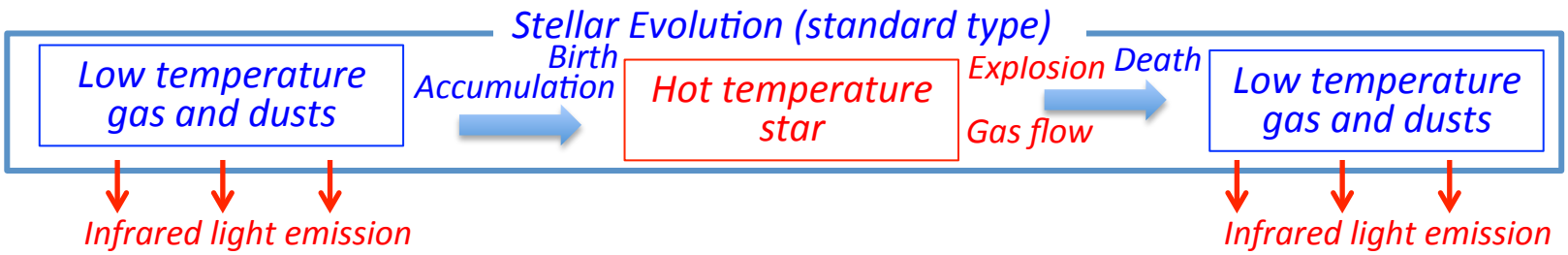


Infrared Astronomical Satellite "AKARI"

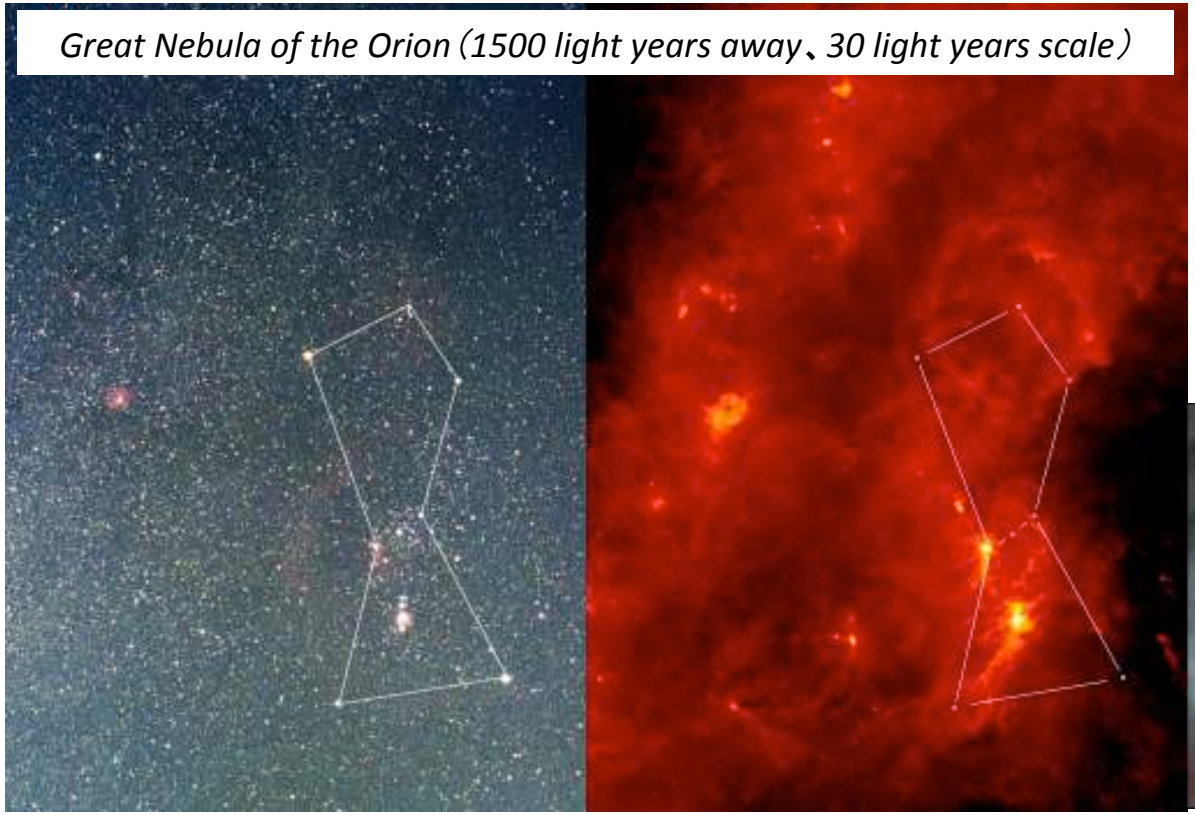
Launch: Feb. 2006
Altitude: 700 km
Weight: 950 kg
Size: 1.9 m x 1.9 m x 3.2 m
Mission: High sensitive infrared astronomical observation
Termination of observation: 2011

Clarification of Mysteries of Evolution of Stars and Galaxies

Using the infrared telescope, the dusts and gas clouds in low temperature that are invisible to the optical telescope can be observed, giving information on the birth, life and death of the stars and galaxies.



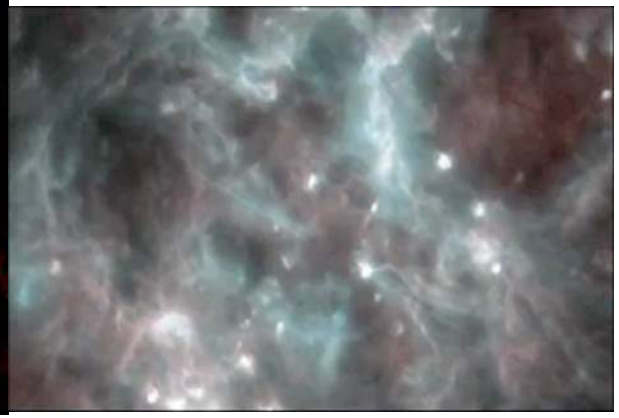
Great Nebula of the Orion (1500 light years away、30 light years scale)



The Orion observed with visible light

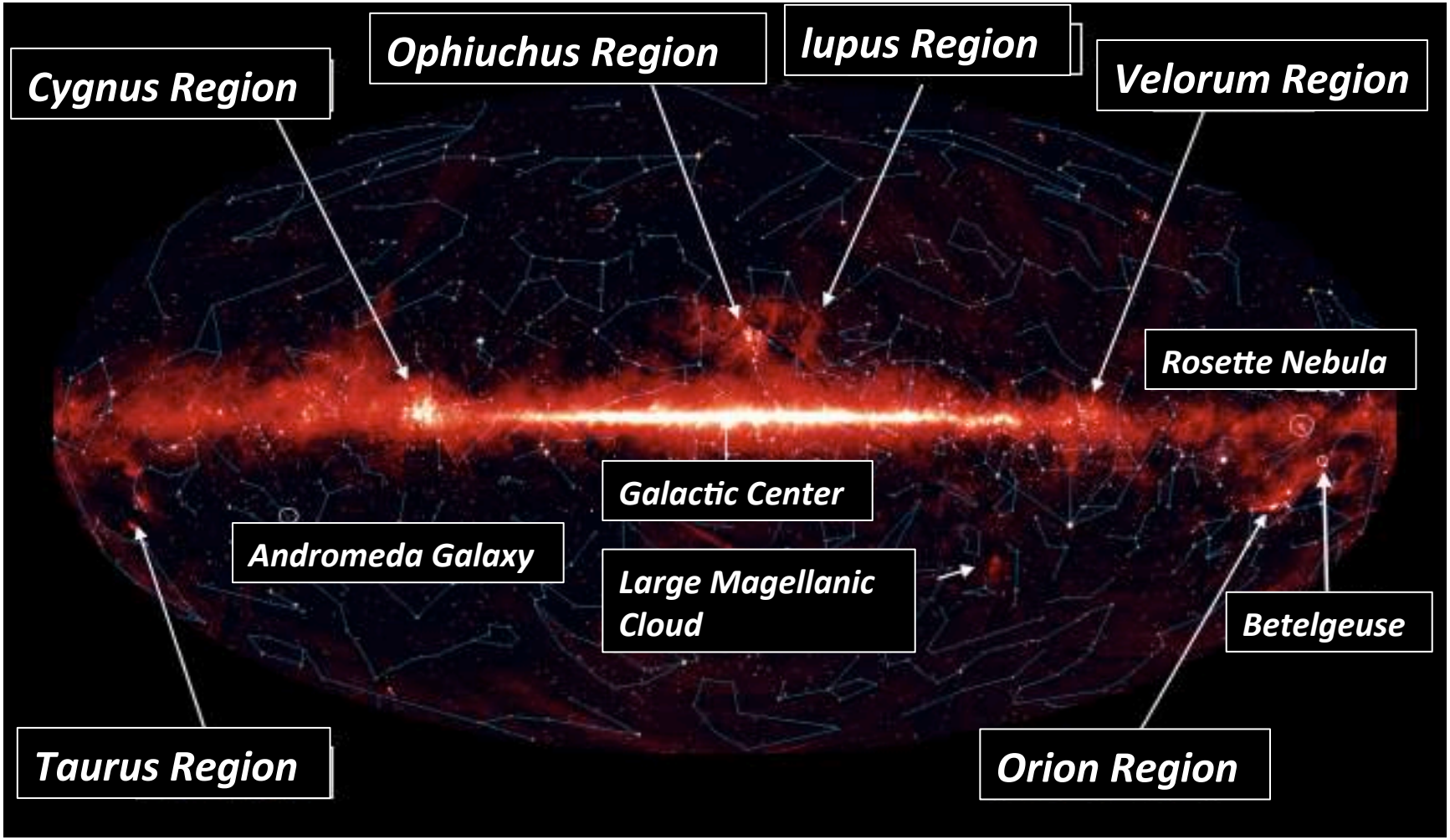
The Orion observed with infrared light

Cygnus X (3000 light years away, 3 light years scale)



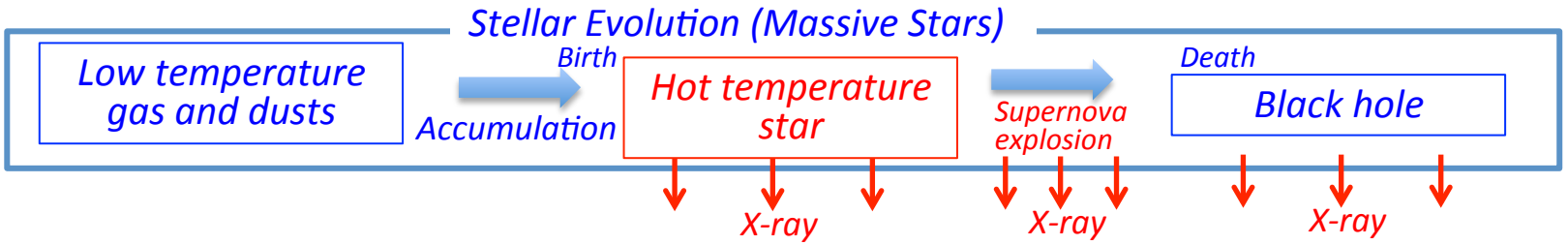
The Swan observed with infrared light

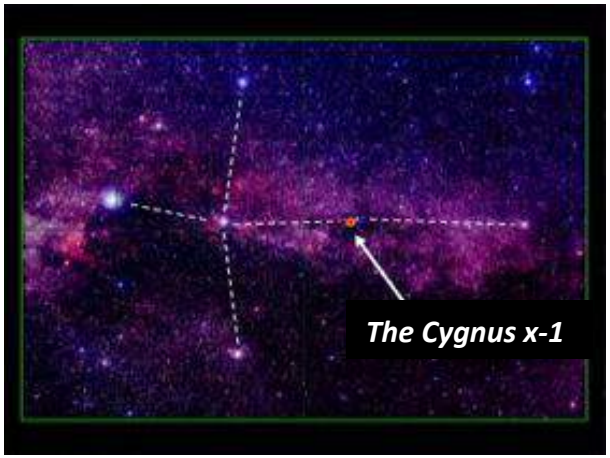
Identification of Star-forming region



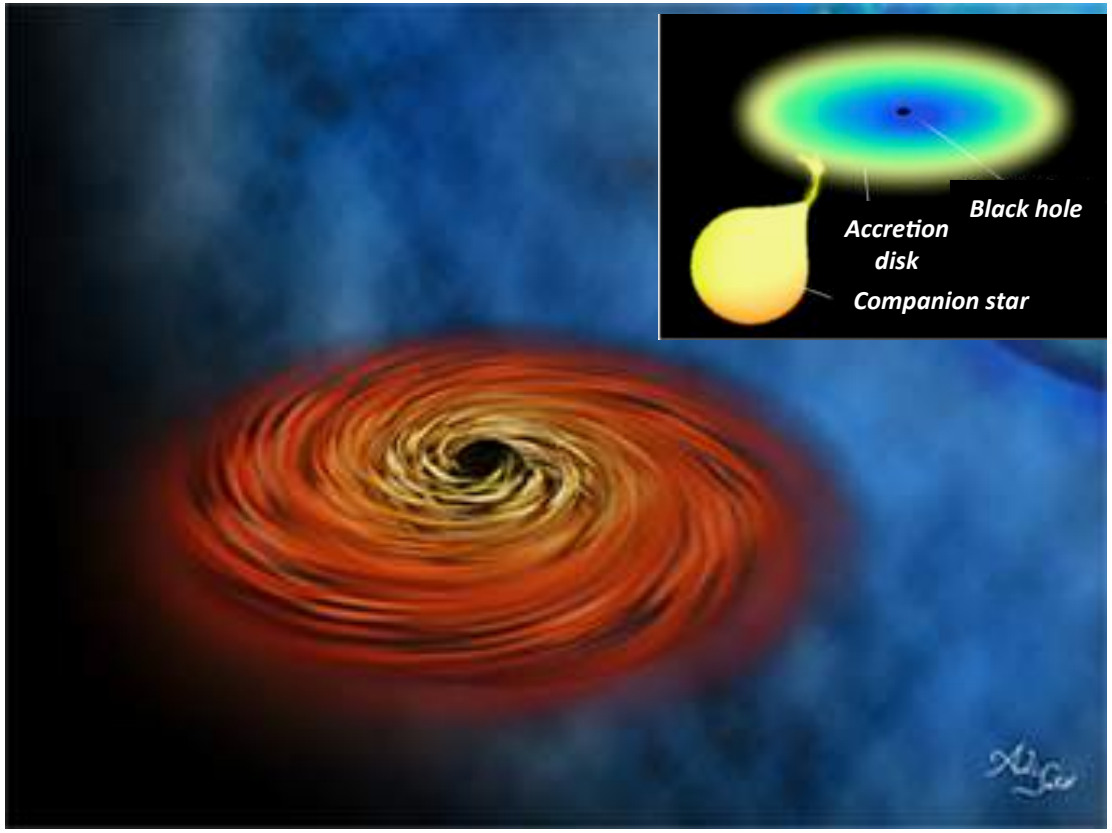
Launch: July 2005
Altitude: 550 km
Weight: 1700 kg
Size: 6.5 m x 2.0 m x 1.9 m
Mission: High performance x-ray observation

Observational Evidence for Black Holes





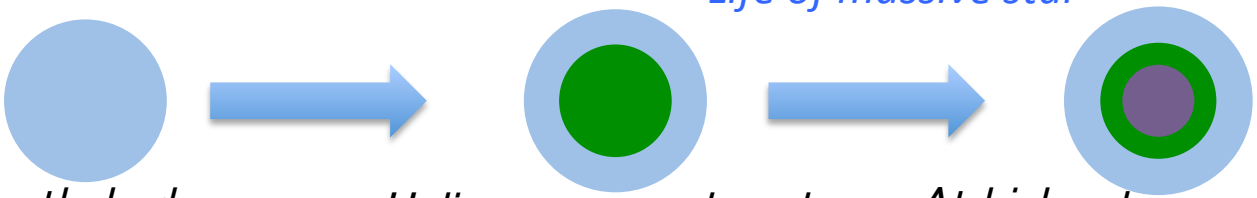
The Cygnus observed with visible lights.



An imaginary picture of the black hole binary "Cygnus x-1", 6000 light years away. "SUZAKU" confirmed the evidence of the black hole binary (one million km across) .

Production of Organic Substance in the Universe

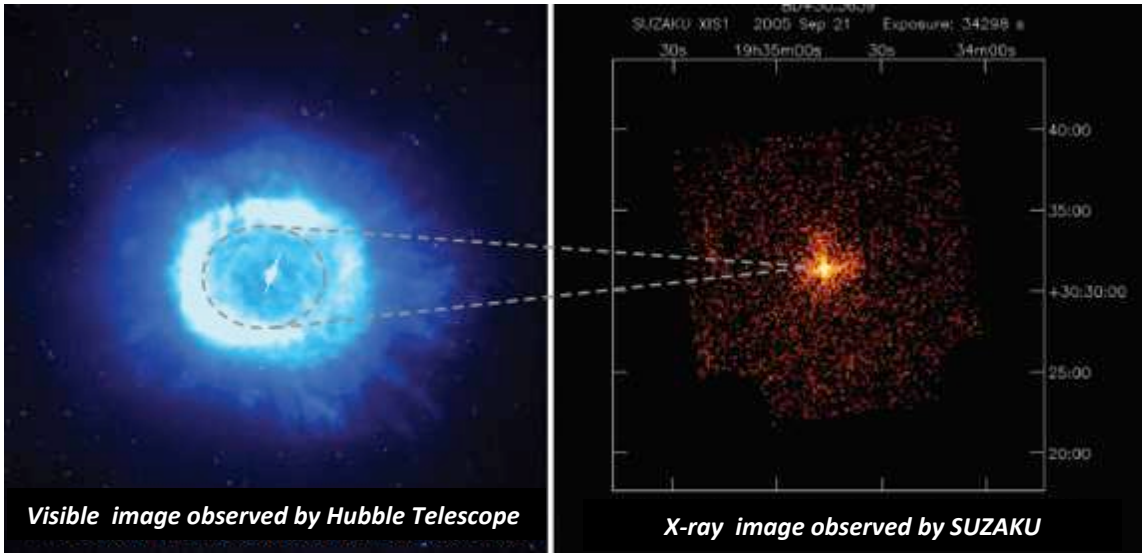
Life of massive star



Mostly hydrogen at birth.

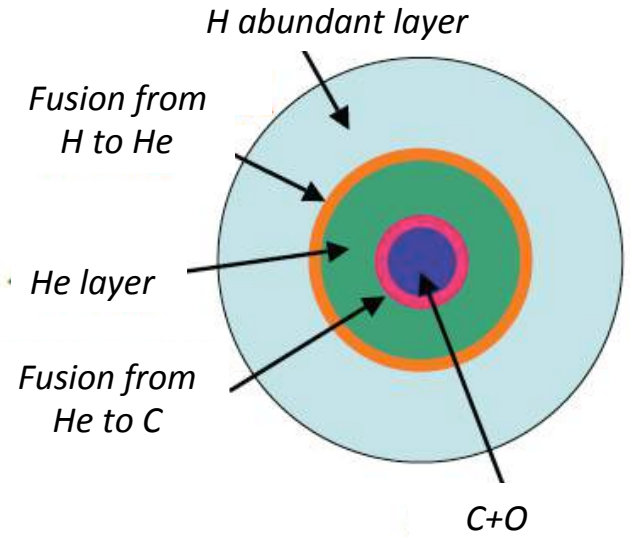
Helium was produced near the center at high temperature.

At higher temperature, carbon and the heavier elements were produced.



Visible image observed by Hubble Telescope

X-ray image observed by SUZAKU



"SUZAKU" x-ray observation of the planetary nebula of the Cygnus shows that carbons are being produced in the nebula and are ejected into space. This is confirmed by detecting the characteristic x-ray from the carbons.

2. Solar Observation :

to study the Sun,
the source of our life.

Importance of Observation of the Sun

The Sun is one of the standard stars in a hundred billion of stars in the galaxy.

➡ It is impossible for us to visit the star, but by studying the Sun, we can know the details of the star.

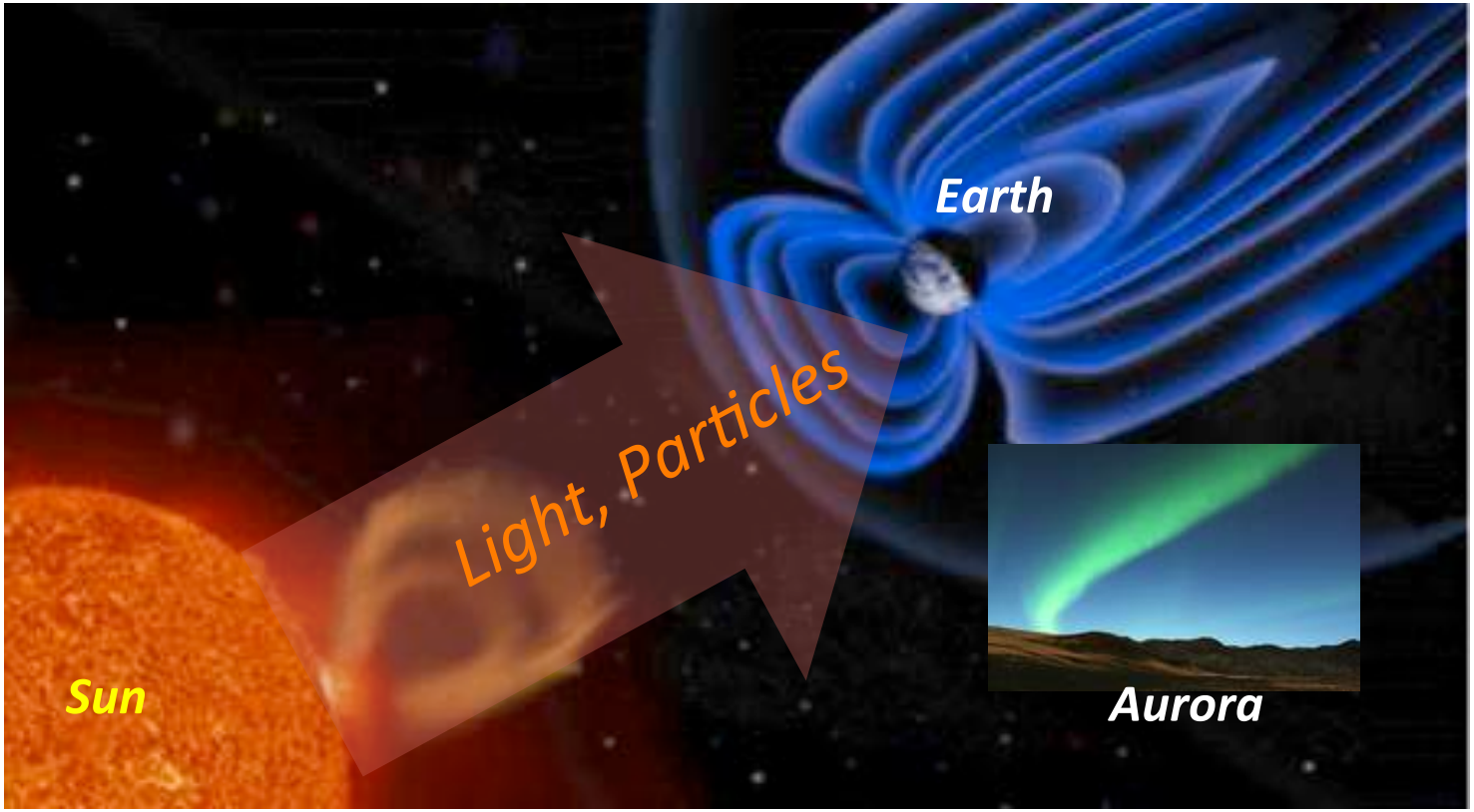
The Sun is the source of almost all activities on the Earth, including atmospheric phenomena and biological activities.

➡ By studying the Sun, we are able to know our past, our present and our future.

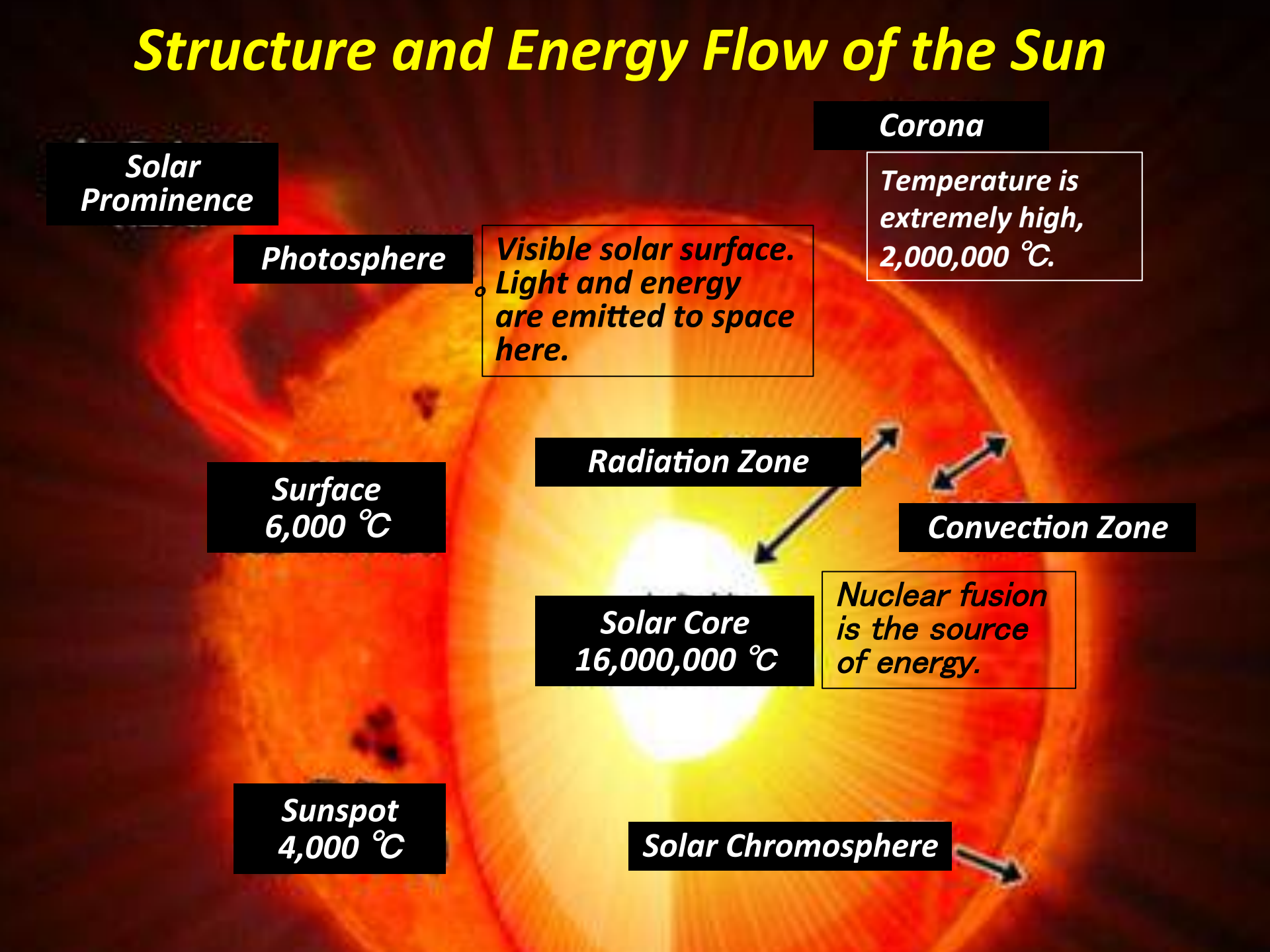
The Sun in Relation to Our Daily Life

Solar lights : *Solar energy reaching the Earth is more than 10,000 times of total human energy consumption.*

Plasma particles from the Sun : *Solar particles generate the magnetosphere surrounding the Earth, producing the aurora and giving important effects to radio communications and astronaut activities in space.*



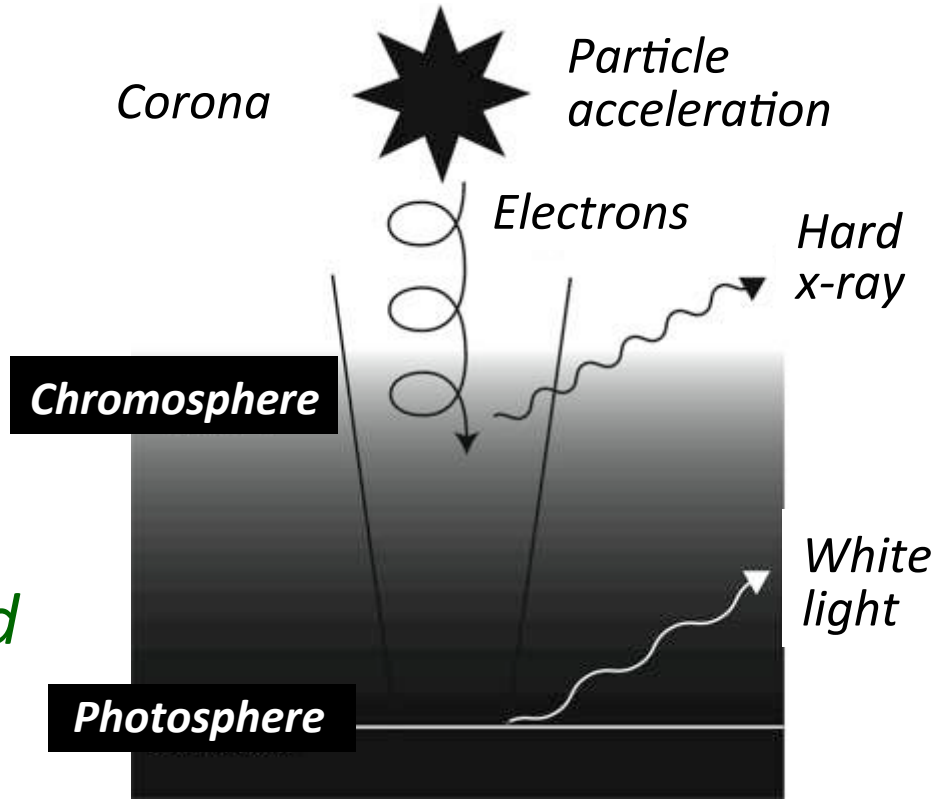
Structure and Energy Flow of the Sun



Mysteries of the Sun

Why the corona can be so high temperature around 2,000,000℃, while the solar surface is only 6,000 ℃ ?

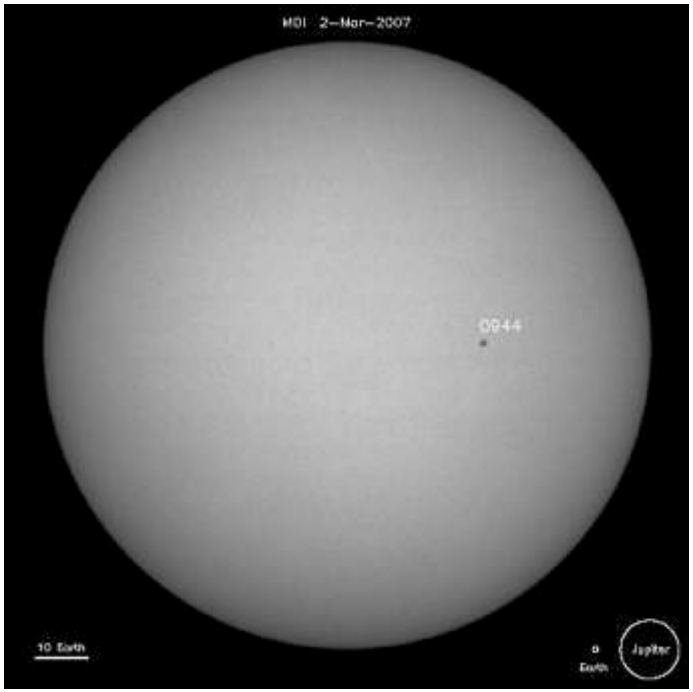
What are the physical mechanisms for the phenomena at the region between the photosphere and the corona, such as the explosive flare, the coronal mass ejection, and the high-speed solar wind ?

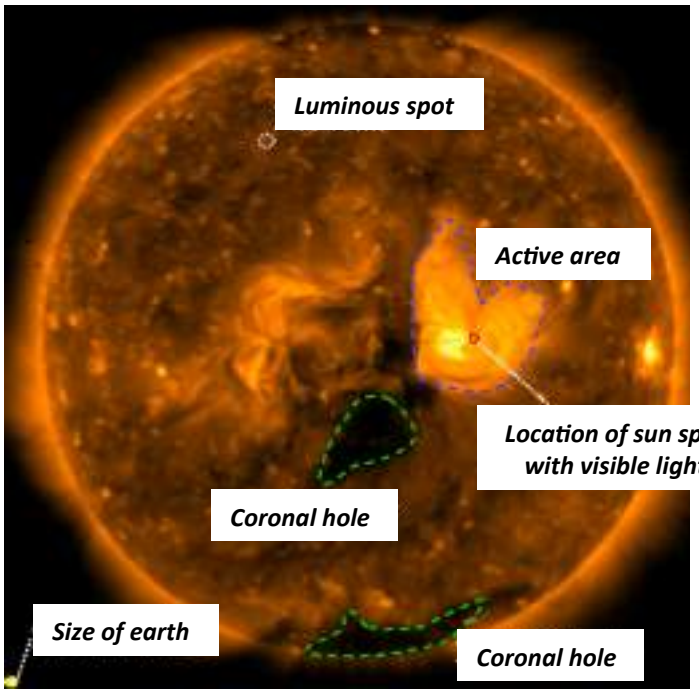


Solar Physics Satellite "HINODE"

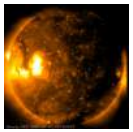
Launch: September 2006
Altitude: 680 km
Weight: 900 kg
Size: 1.6 m x 1.6 m x 4 m
Mission: High performance solar observation with visible light and x-ray telescopes

The Sun Observed by "HINODE" X-ray Telescope





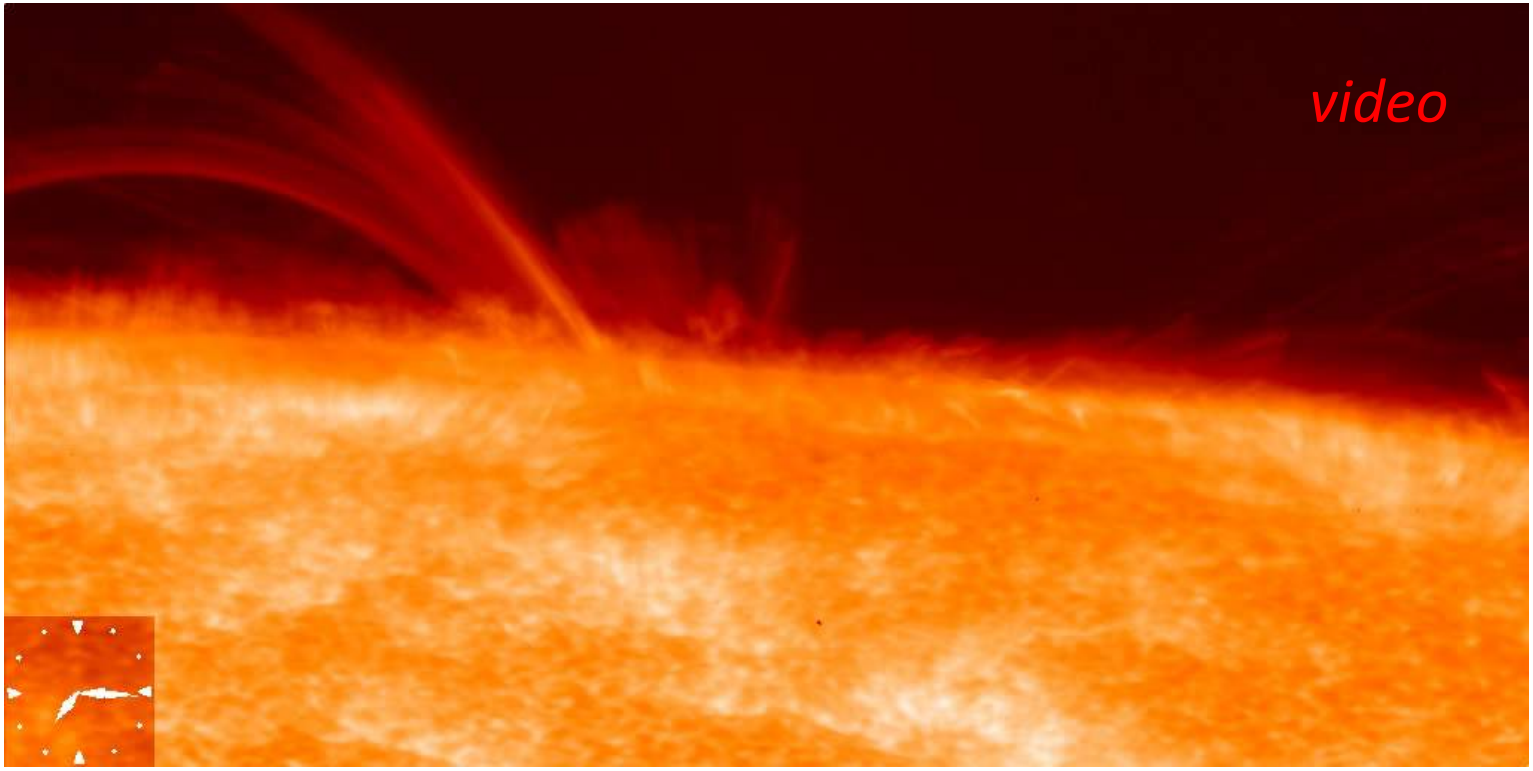
video



The Sun observed with visible lights. The appearance is flattened with several sunspots. The activity seems to be calm and quiet. ***However, ….***

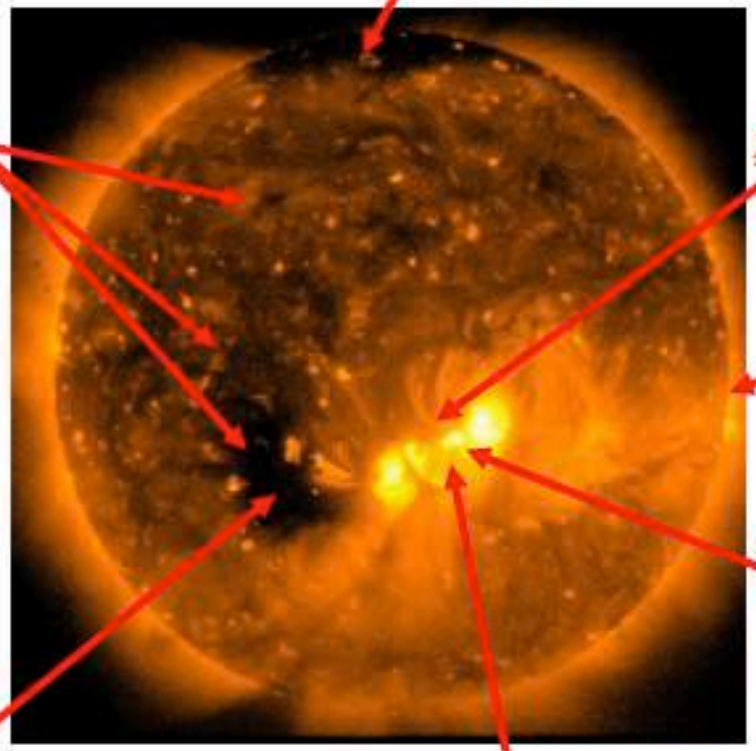
By observing with x-ray, the appearance is completely different from the left image. The areas of high activities are shown in bright color. The explosive flares are excited there, that cause the aurora at earth polar regions. Dark area indicates the coronal hole which is the blow nozzle of solar wind.

The Sun Observed by "HINODE" with Visible Light



Strong light emissions are excited near the sunspot, where the coronal mass is injected upwards. This was first observed by the "HINODE" telescope.

Scientific Achievements in "HINODE" Observation



Solar activities at the polar regions

Magnetic activities during non-active phase

Detailed structure of the sunspot and its dynamics

Discovery of Alfve'n waves

Structure of active areas

Study of heliosphere

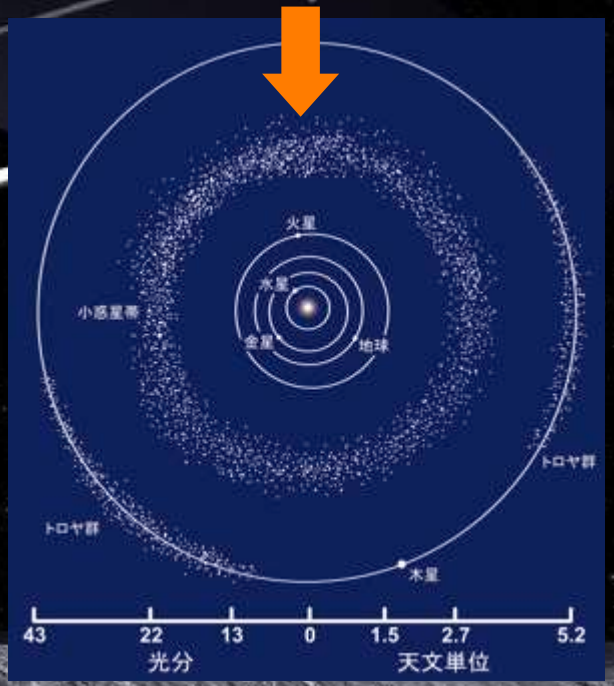
Flares and storage of energy

3. Lunar and Planetary Exploration : to study the origin and evolution of our solar system.

“HAYABUSA” Asteroid Exploration Mission

The objectives are to approach the Asteroid “Itokawa”, to observe it, to get samples from it, and to bring them back to the Earth for analysis.

Asteroids are small bodies orbiting around the Sun, just like the Earth. The size is typically less than 100 km. They are mainly distributed between the orbits of Mars and Jupiter. “HAYABUSA” visited the near-earth asteroid “Itokawa”.



Why "HAYABUSA" explored the asteroid ? (1/2)

To understand the reason, let's look at the birth of the solar system 4.6 billion years ago.

Molecular cloud (a stellar nursery) → *Accretion to protosun and small planets* → *Accretion to larger planets*

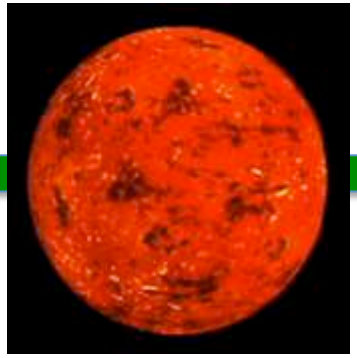
Why "HAYABUSA" explored the asteroid ? (2/2)

Heating by hammering

A lot of collisions

Magma Ocean, heated by collisions to melting temperature

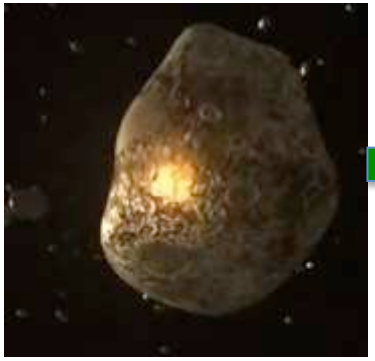
Large planet like Earth



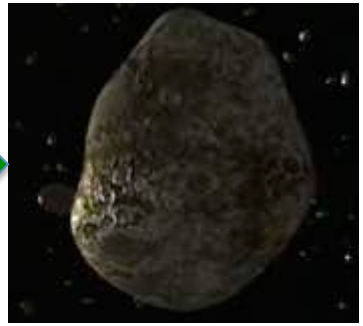
Memories of the early age were lost.

Few collisions

Asteroid



Not heated to melting temperature

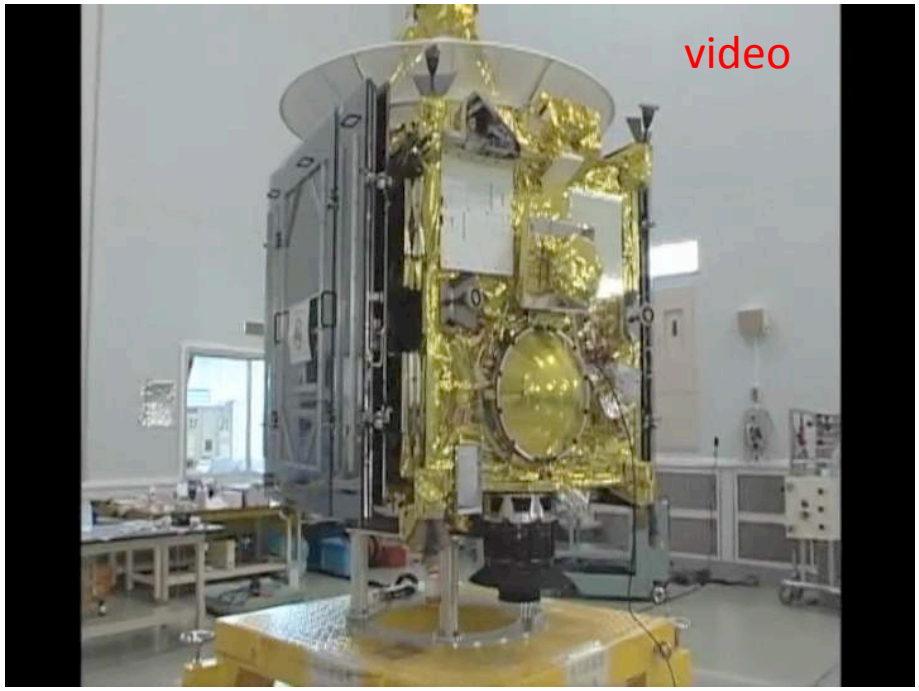


Memories of the early age are kept.

By bringing the samples of the asteroid back to the Earth and by analyzing them, the original materials of the asteroid and the environment of the early solar system are clarified.

Development of "HAYABUSA" and Its Launch

Early studies by scientists started around 1985.
"HAYABUSA" project started in 1996.
"HAYABUSA" departed from the Earth for "Itokawa" in 2003.



Integration of sample return capsule to "HAYABUSA" main spacecraft.

Launch by the M-5 solid rocket from Uchinoura Space Center in 2003.

Observation of "Itokawa" by "HAYABUSA"

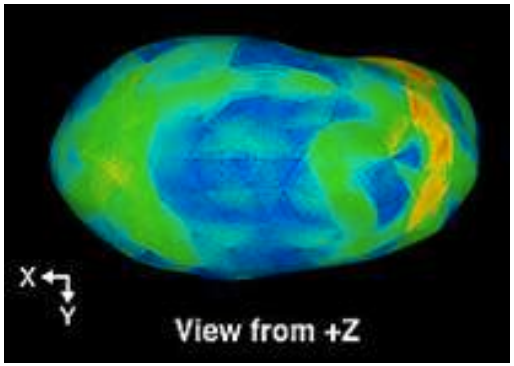
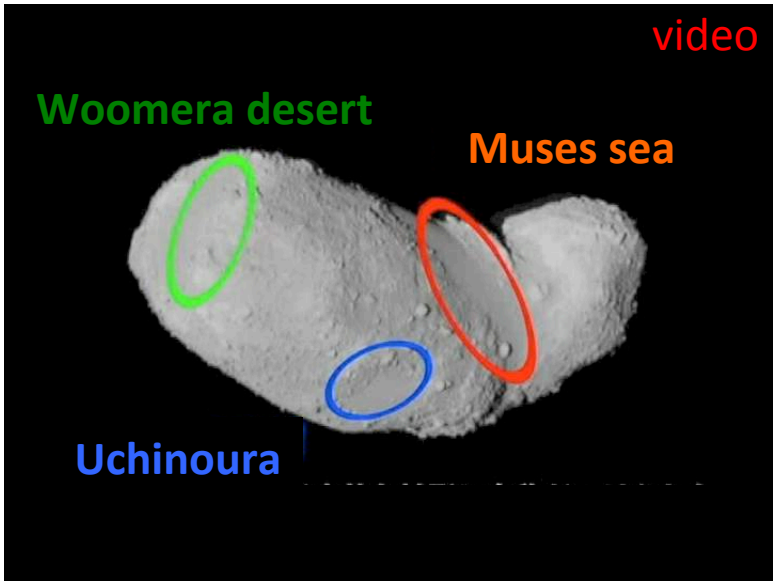


Image of "Itokawa" by ground observation.

Image observed by "HAYABUSA" in close proximity to "Itokawa".

It was called "Itokawa sea otter" as it looed like in shape.

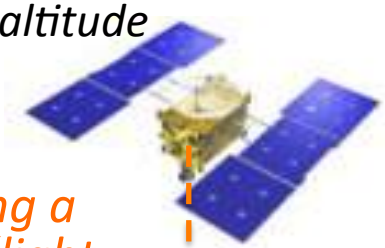


Names were given to major terrains.

Similar in shape!

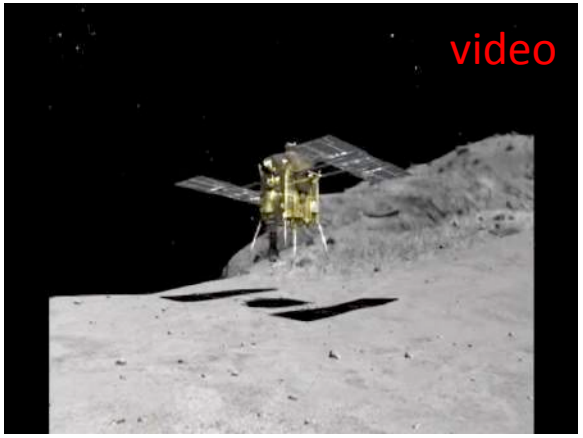
Landing and Sampling

at 30m altitude



Dropping a target (light reflector).

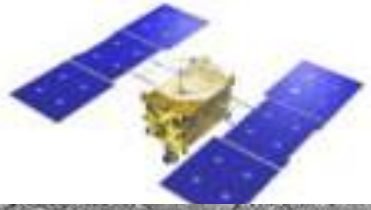
Flashing and detecting the target.

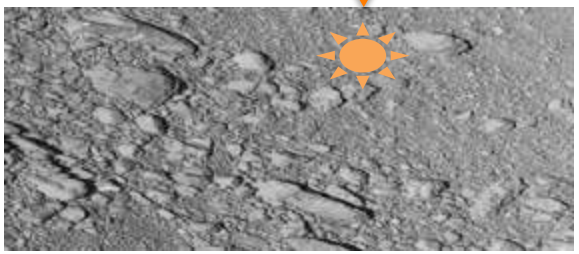


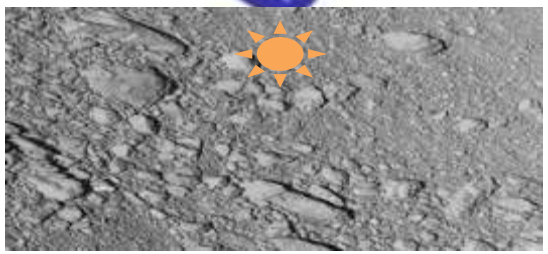
Landing

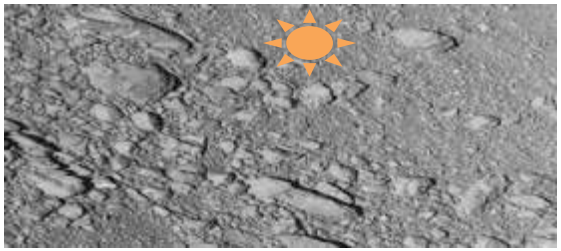
Flying away immediately after sampling.

Landing and sampling.

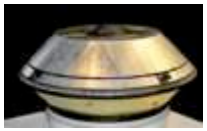








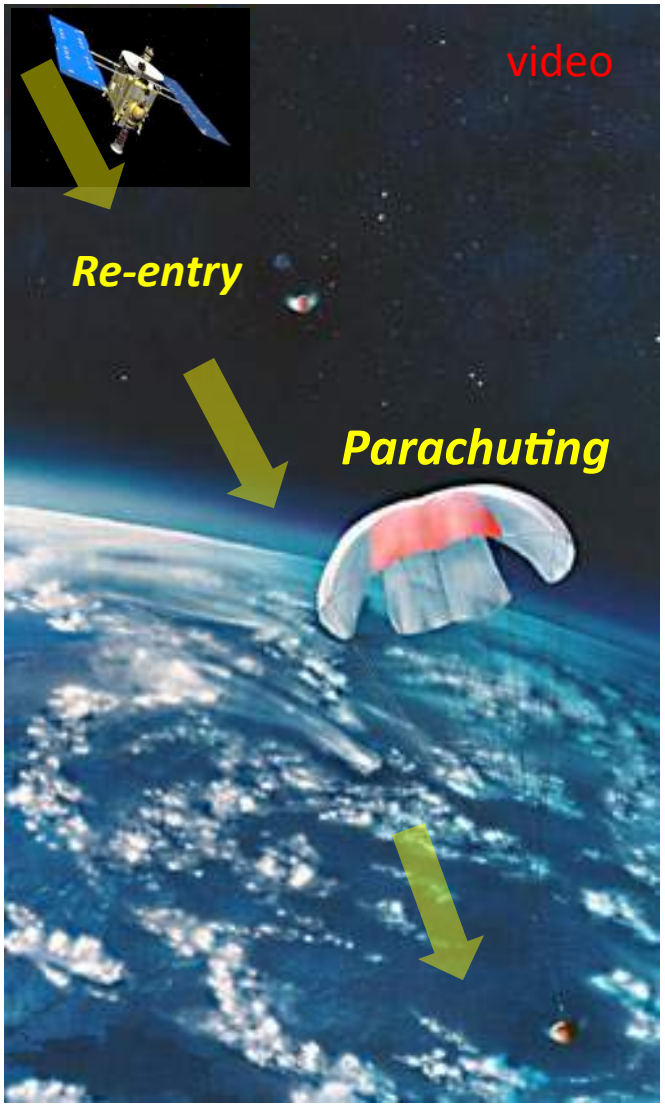
Return to the Earth/Capsule Retrieval



The capsule was separated from "HAYABUSA" just before re-entry and entered the atmosphere at more than 12 km/s.

During descending through the atmosphere, the capsule was enormously heated, but it survived. "HAYABUSA" itself was burned out in the atmosphere.

The capsule ejected a parachute and landed softly on the ground. By detecting the radio waves from the capsule, it was retrieved successfully.

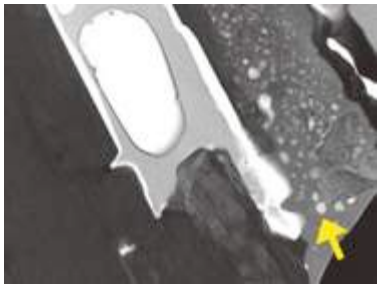


Overcoming Various Difficulties

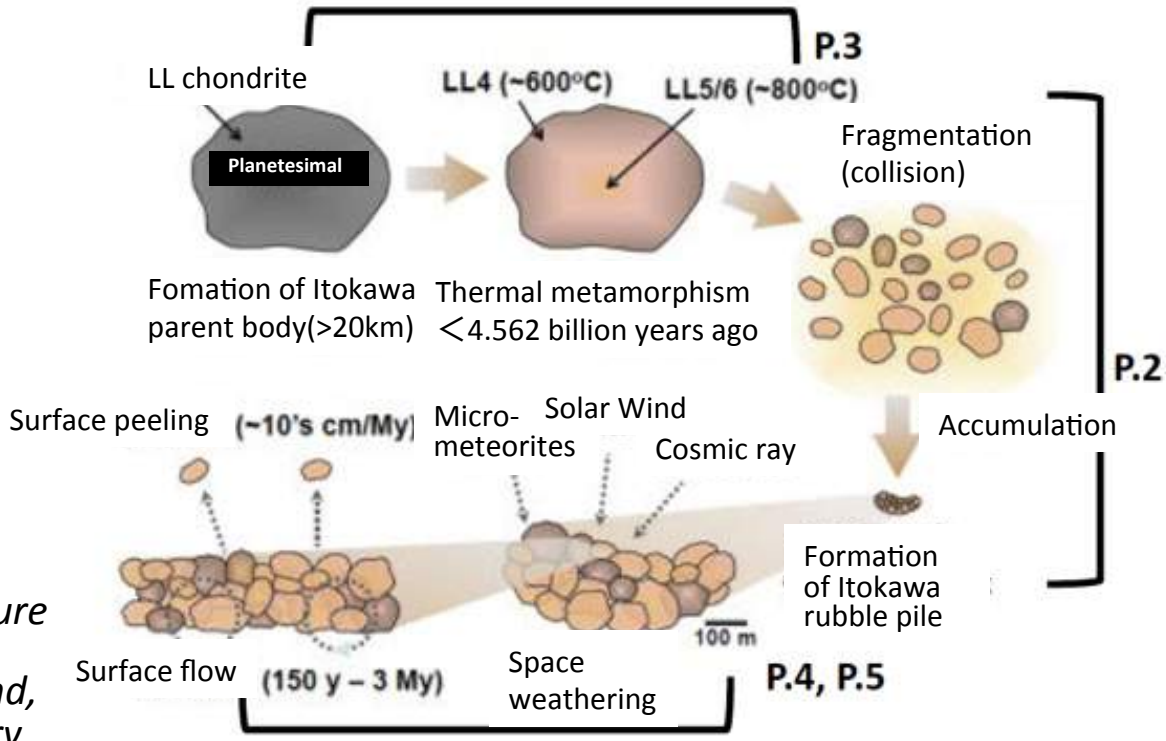
Nov. 2005 *First touch-down on Itokawa (unexpected landing)*
Second touch-down on Itokawa (fuel leak）
Dec. 2005 *Unstable attitude. Communication link to the earth was lost.*
Nov.2009 *Ion engine failed.*

Great advancement in understanding of planet formation/evolution by sample analysis

Sample analysis



Observation of fine structure by electron microscope. Bubble structure was found, showing its thermal history. (Tohoku Univ./JAXA)



The planet evolution process, fragmentation by collision and accumulation of debris after collision, has been clarified.
It was suggested that most small asteroids are rubble piles.

“KAGUYA” Lunar Exploration Mission

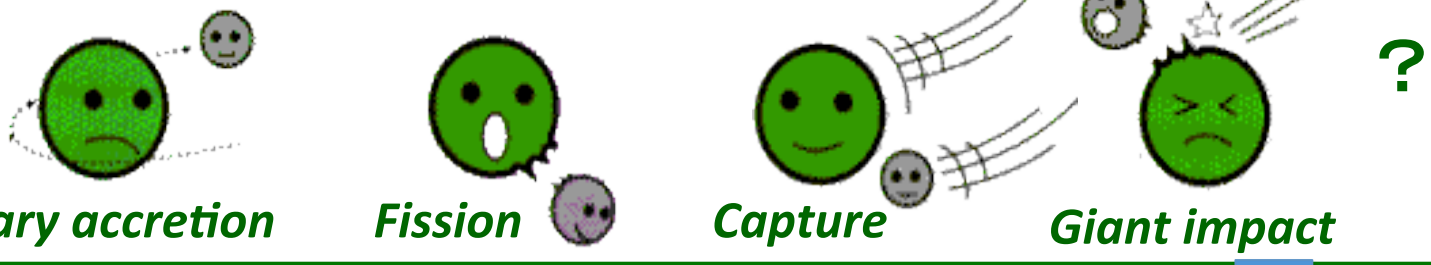
Moon is the most familiar space body and the features are well known;

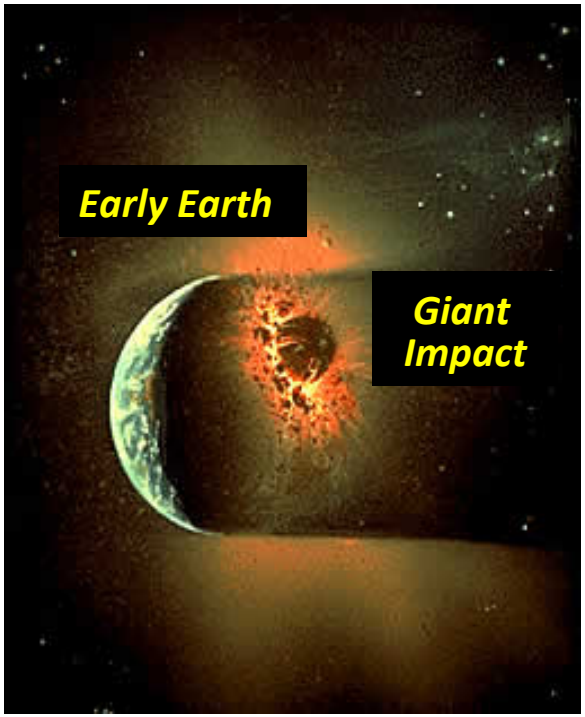
- *The Moon is located at about 30 times of the earth diameter and the size is about ¼ of the earth.*
- *The Moon was born at the same time as the Earth.*
- *As the center of gravity is a little bit out of the geometrical center, the revolution and rotation period is the same. The same lunar hemisphere is always turned towards the Earth.*
- *The surface is covered with a lot of craters produced by collisions of small celestial bodies. The near side is low and flat but the far side has highlands.*
- *The Moon is the only celestial body that has been visited by humans, and its environment is well studied.*

However, there are many mysteries still left !

The Biggest Mystery in Lunar Science
-The Origin of the Moon -

4 Major hypotheses





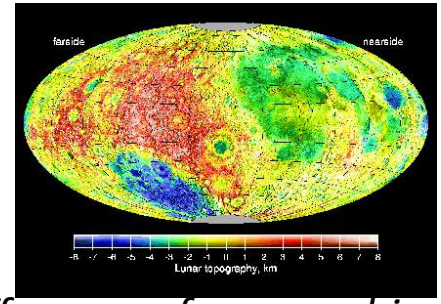
video

Giant impact is the most widely-believed hypothesis, but true?

A Mars-sized body impacted the early Earth?

Mysteries in Evolution of the Moon

1. *There are big differences between the near side and far side. Why ? and How ?*



Difference of geographical features between the far side and near side

2. *Was there a magma ocean in its early phase? If there was, what scale, local or global?*

Magma ocean

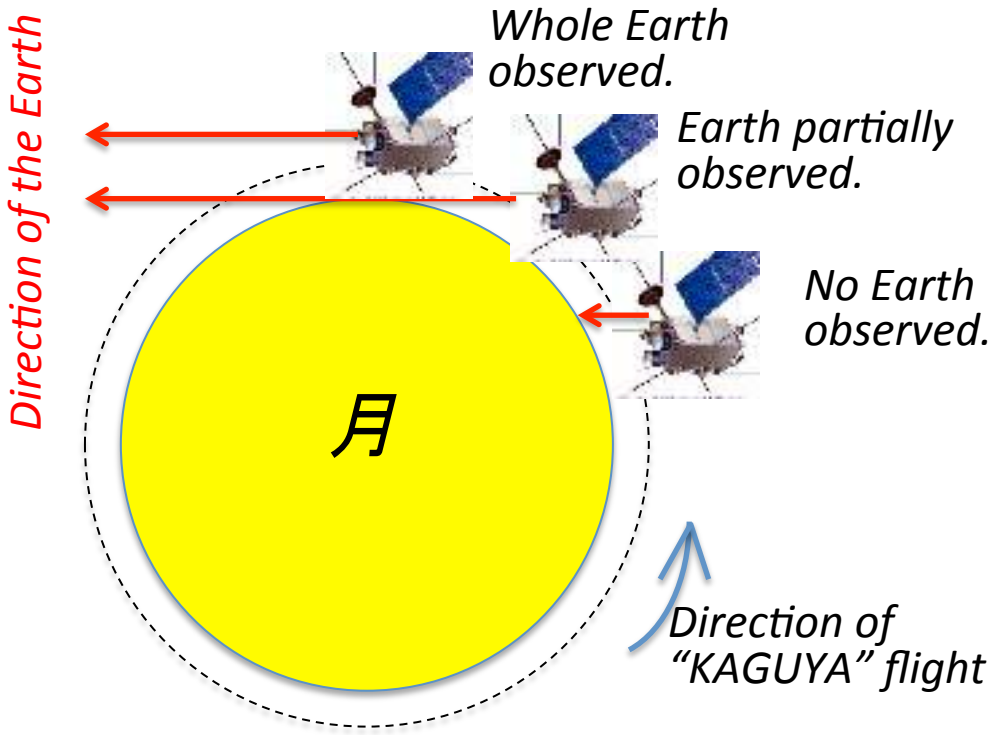
3. *How the topographic and geological features were formed?*

Various types of landforms

Lunar Explorer “KAGUYA”

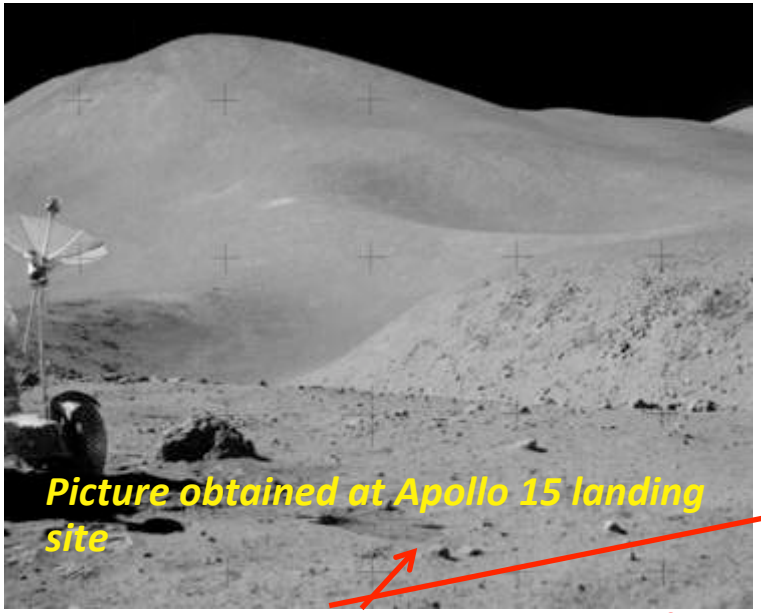
Size : 2.1x2.1x4.8m
(about the same size of minibus)
Configuration: Main satellite and two sub-satellites
Weight: 3 tons in approx.

Earth Rise Observed from "KAGUYA"



Rise of Full Earth

Precise Three-dimensional Topographical Map



Picture obtained at Apollo 15 landing site

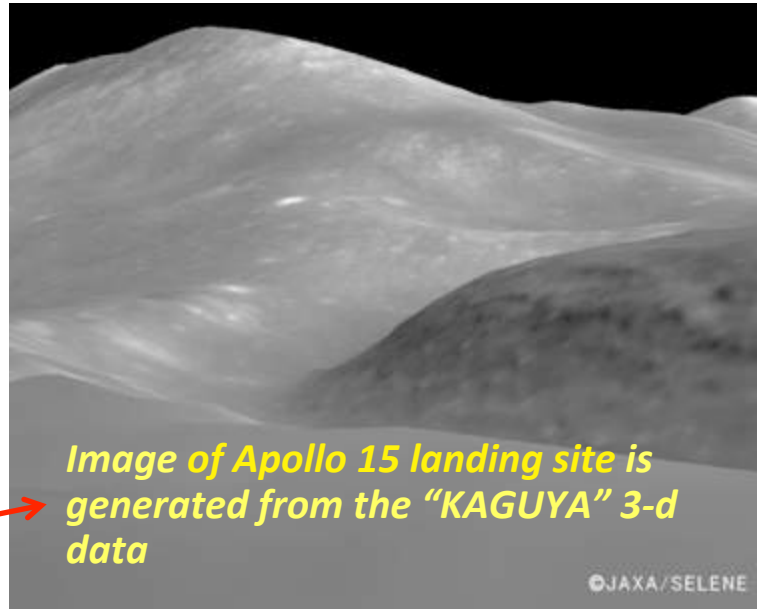
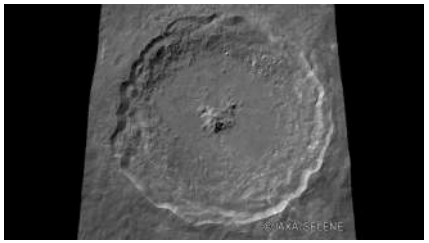


Image of Apollo 15 landing site is generated from the "KAGUYA" 3-d data

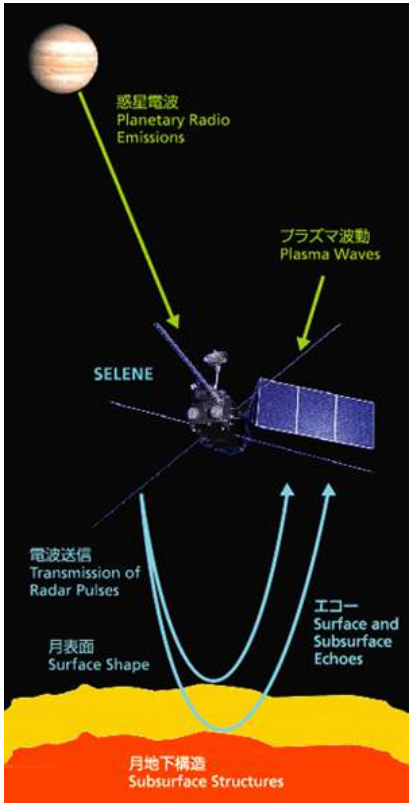
Mons Hadley on the eastern edge of Mare Imbrium

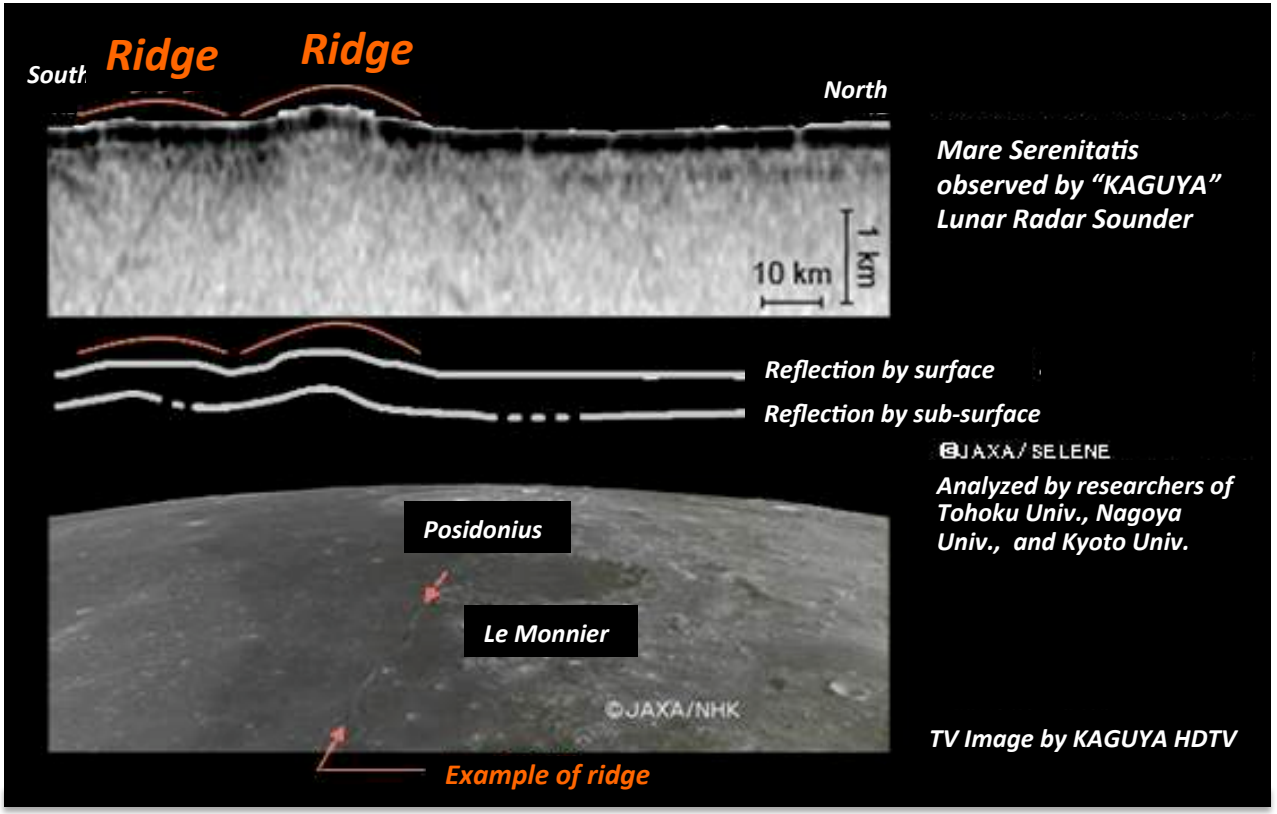


Video

Tycho crater, 85km in diameter with central peaks up to 1.6 km above the floor, is a relatively young crater formed about 110 million years ago. Since it is one of the places of interest on the Moon, sightseeing flights will be planned in future. You can enjoy the simulated experience well in advance using the three-dimensional KAGUYA data (JAXA/ISAS KAGUYA Gallery).

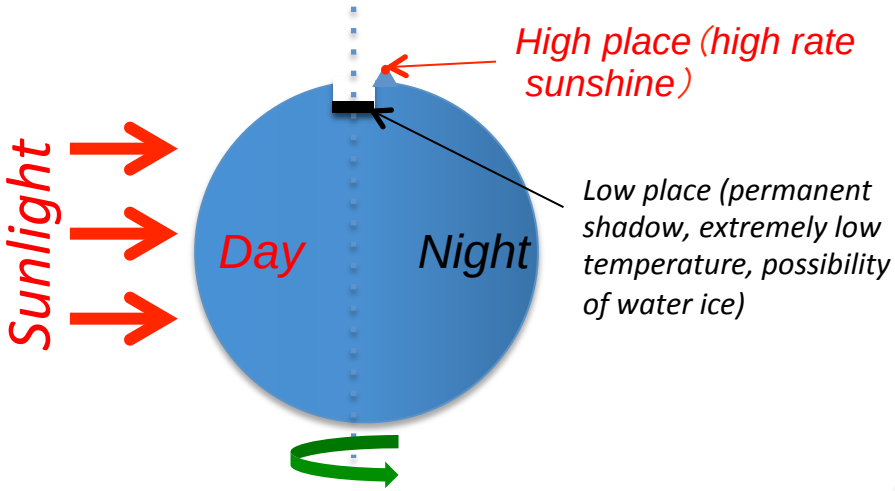
Observation of Sub-surface Structure



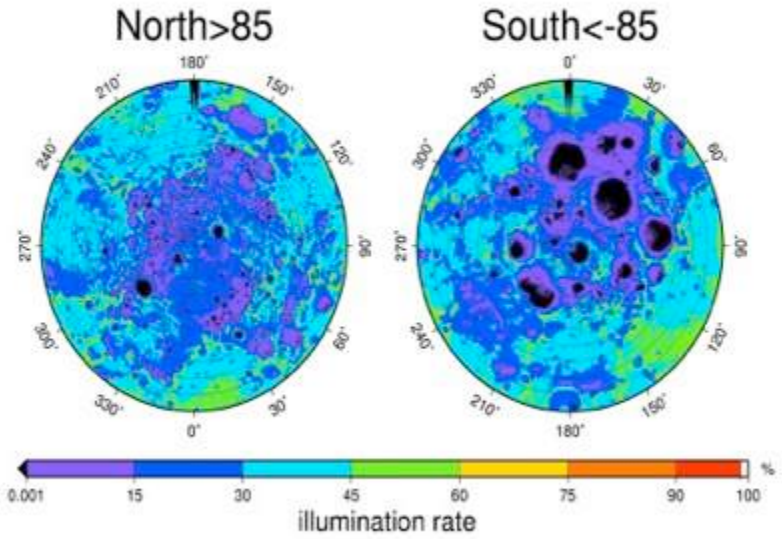


The sub-surface structure had been almost unknown. "KAGUYA" observed the under ground structure up to 5 km from the surface, by transmitting radio waves to the Moon and by receiving the reflected signals from the sub-surface structure. The sub-surface structure above suggests that the "Ridges" of the Moon were formed by shrinking of the lunar surface as it was cooled.

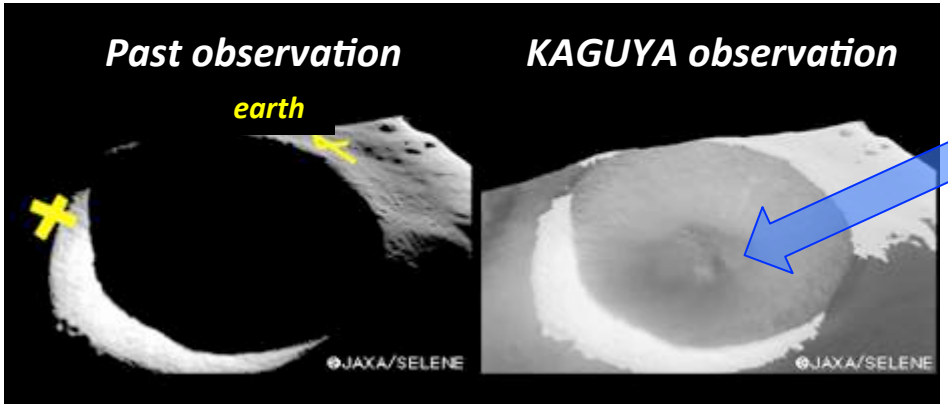
High Rate Sunshine Area and Permanent Shadow Area



Rotation axis almost perpendicular to the plane of the ecliptic

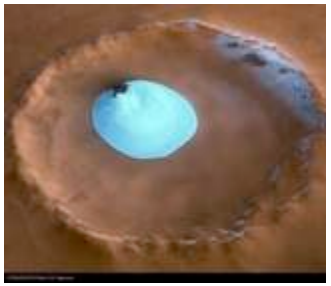


"KAGUYA" observation. "Black" shows "permanent shadow" area. The maximum sunshine rate is 89 % in the north polar region and 86 % in the south polar region. (Noda et al., GRL, 2008) .



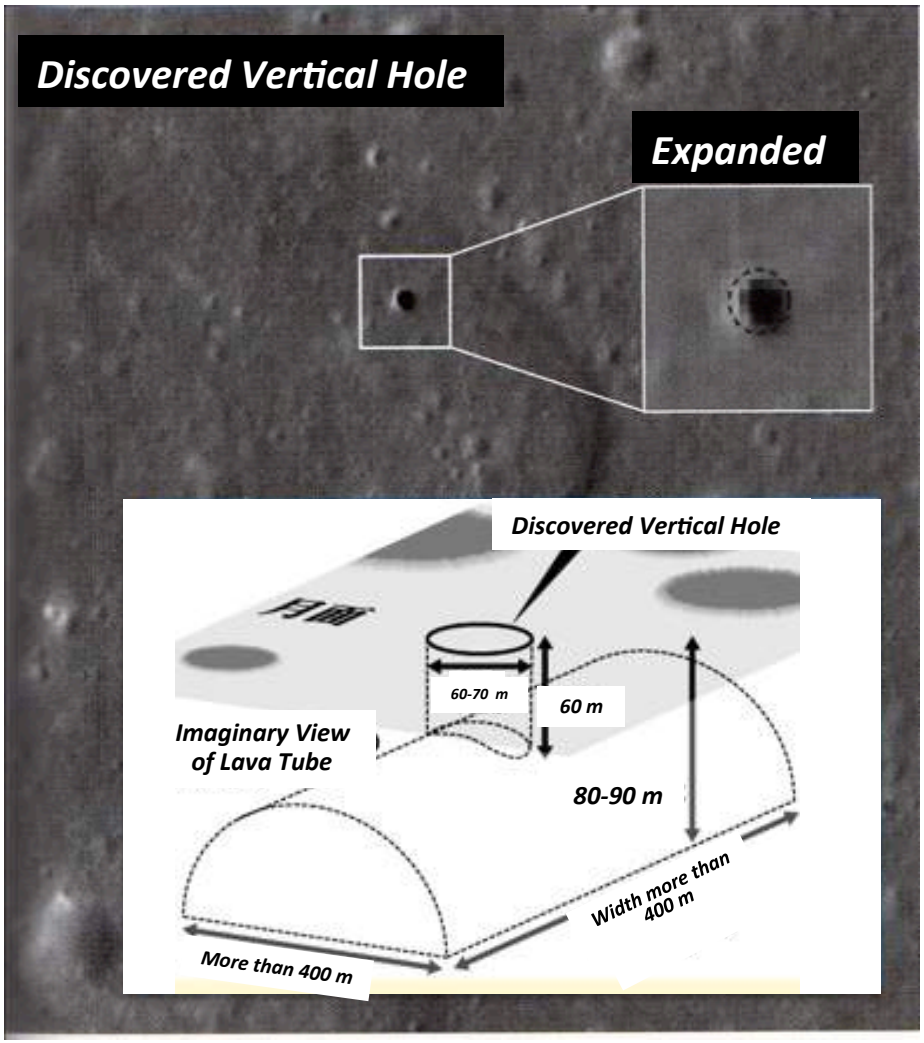
Shackleton crater near the south pole, one of the candidates of the lunar base.

The Inside of the Shackleton crater observed by Terrain Camera. There was no block of water ice exposed inside the crater, rather different from the case of Mars. The amount of water ice is assumed to be several % maximum if any. (Haruyama et al., Science, 2008)。

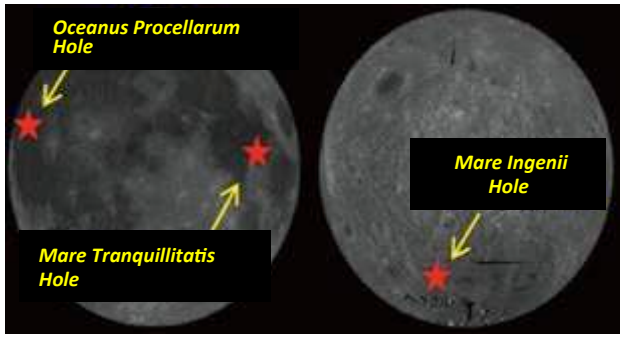


Water ice observed by Mars Express (2005)

Vertical Hole and a Possible Lava Tube



Vertical hole (approx. 70 m diameter) and lava tube (approx. 370 m size) (Haruyama et al., GRL, 2009)



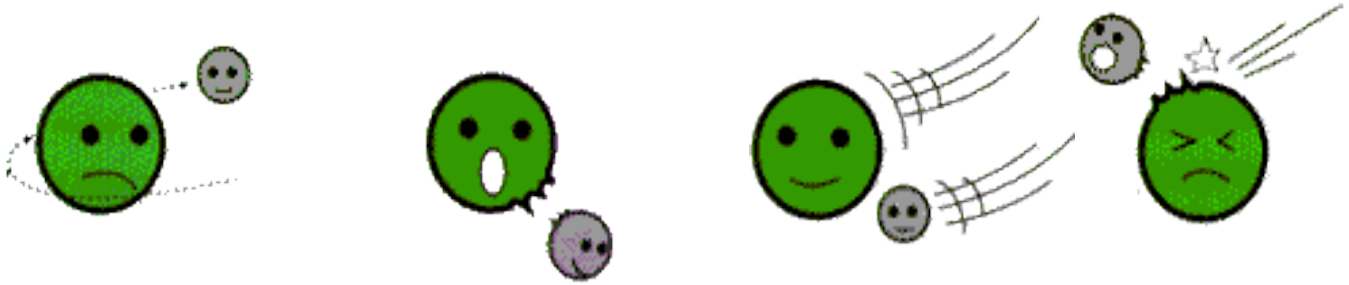
3 Vertical holes discovered by "KAGUYA"

Temperature :-20℃ Constant (Surface: -170～+110℃)

Radiation :same level as the earth surface, approx. 1 mSv/year (at 5 m below the surface) (100-500 mSv/year at the surface)

Protected by meteorite impacts

“KAGUYA” Contribution to “Origin of the Moon”



Binary accretion | **Fission** | **Capture** | **Giant impact**

△ | ○ | △ | ◎

Mechanically feasible?
Global-scale magma ocean?
Material similarity?
Core size?

video

Studied by “KAGUYA” so far.

1. *Under analysis. A certain conclusion will be obtained.*
2. *Under analysis. Some conclusion will be obtained. But, will be finally confirmed by another mission to study the internal structure.*
3. *Evidence obtained.*

Source Material	*Internal Structure*	*Global-scale Magma Ocean*

3 major keys to conclude the origin of the Moon.

"KAGUYA" Contribution to "Evolution of the Moon"

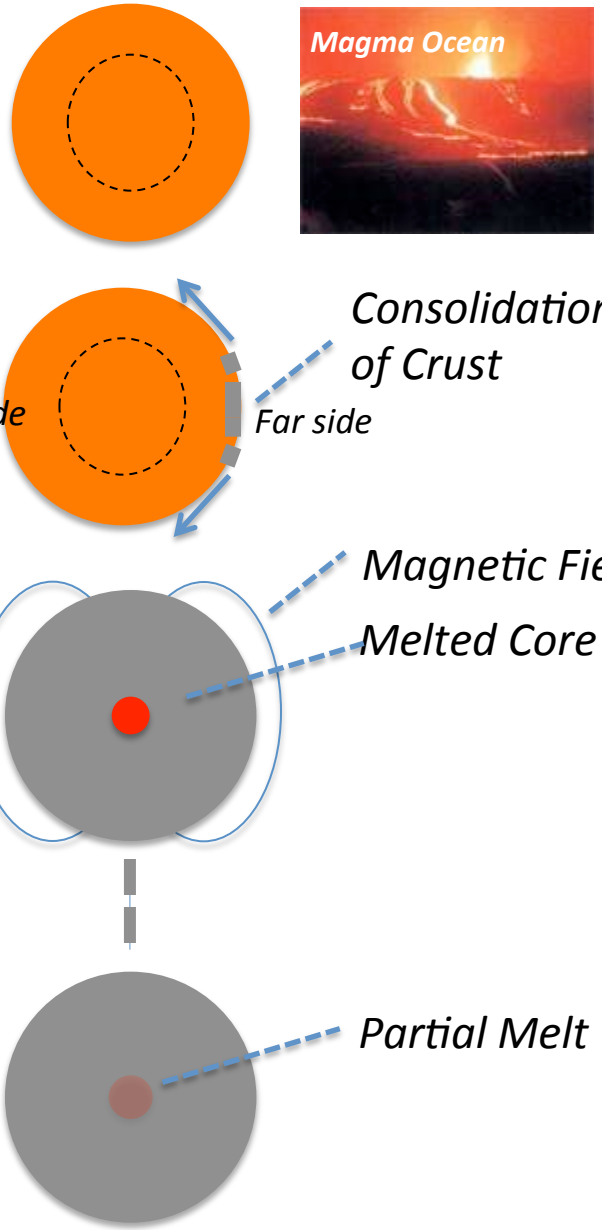
When the Moon was born, the temperature was so high that the surface was globally melted (global-scale magma ocean).

Then, the crust was formed from the far side to the near side.

In the initial stage of evolution, there existed a melted metal core which generated a large scale dipole magnetic field.

The cooling rate of the Moon's far side was slower than previously considered. Volcanic activities existed until more recently

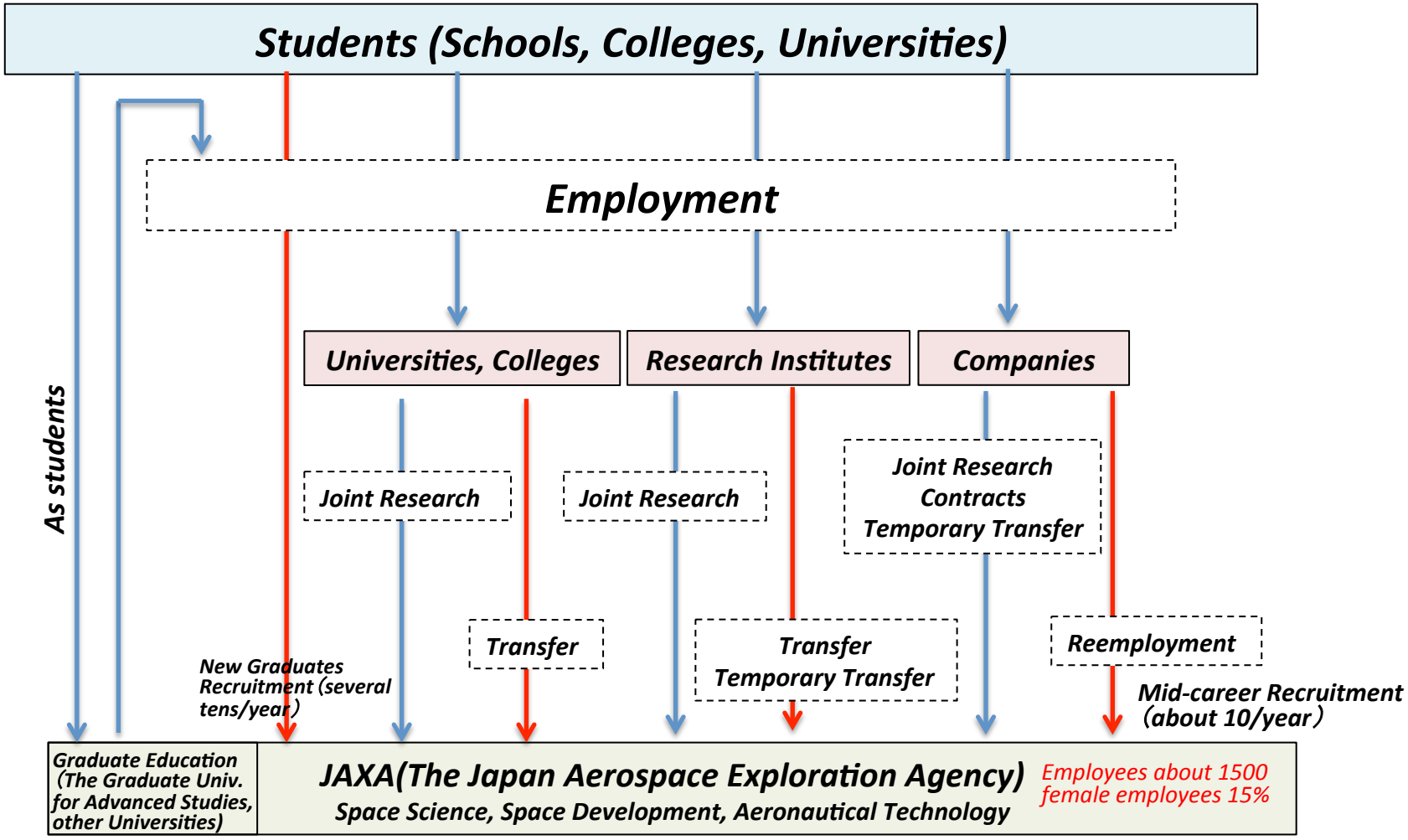
There is a a low-viscosity layer at the core–mantle boundary, suggesting partial melting.



4. Becoming space scientists or space engineers :

to work in or with JAXA, for example.

If you want to work in or with JAXA ...



End of Today's Lesson

One of the important outcomes from the studies of the stars and planets, …….
the Earth, blessed with abundant water and mild atmosphere, is quite a rare planet in the Universe.

Let's preserve this valuable earth environment !