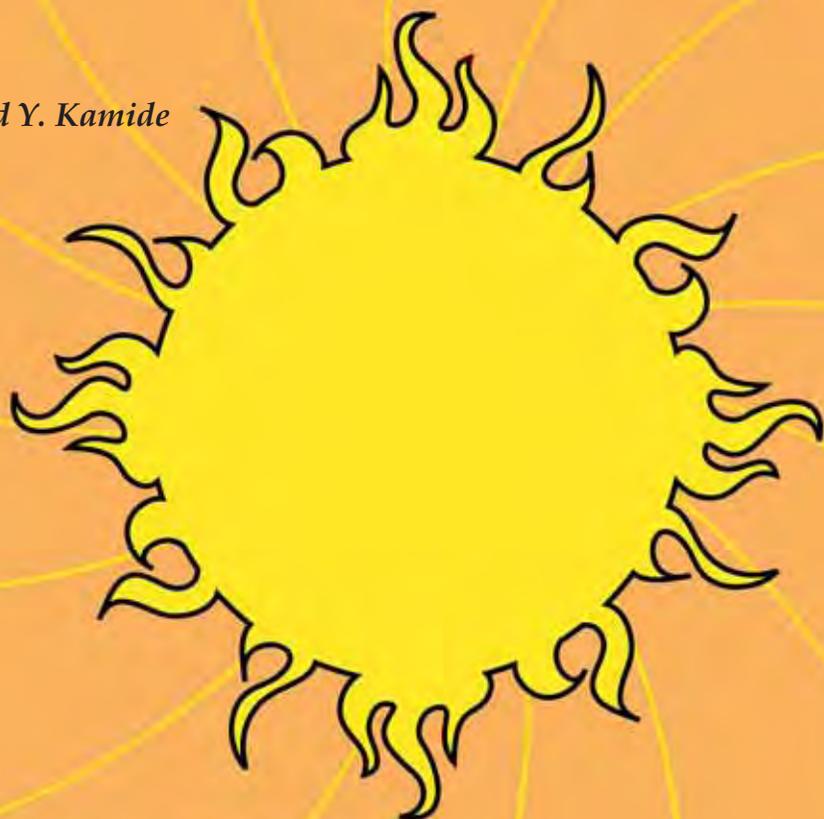


What is the Solar Wind ?!

By Hayanon

Translated by Y. Noda and Y. Kamide

Supervised by M. Kojima





Seeing the Invisible Solar Wind

Solar activity changes with an approximately 11-year cycle. The number of sunspots peaks during an active period of the Sun called the "solar maximum" and sunspots almost vanish during a quiet period, the "solar minimum."

It has been known that the Sun's light energy output also varies in step with solar activity. However, its variation is only 0.1%; so small that we could hardly be aware of the Sun's becoming brighter or darker through the 11-year cycle.

Of the energy given off by the Sun, light carries the largest part, followed by neutrinos and solar wind. The neutrino is now a famous subject, thanks to the 2002 Nobel Prize in Physics. This elementary particle has a unique character of being noninteractive with other substances. This allows them even to pass through the Earth! Despite the huge solar energy that neutrinos have, their influence on the Earth is thought to be negligible.

The energy of the third largest carrier, the solar wind, is only one-millionth that of light. Still, if the solar wind were visible to us, it would show surprisingly dynamic changes over the solar cycle.

The figure below was obtained by observations made in a specific way, explained on the last page. It shows the speed and distribution of the solar wind during a solar cycle. The high-speed solar wind of 700-800 km per second is

indicated by a dark blue color. The warmer the color is, the slower the solar wind blows. The red color is the low-speed solar wind of 300-400 km per second. Each figure of the Sun has information on the annual solar wind corresponding to the respective years from 1991 to 2000.

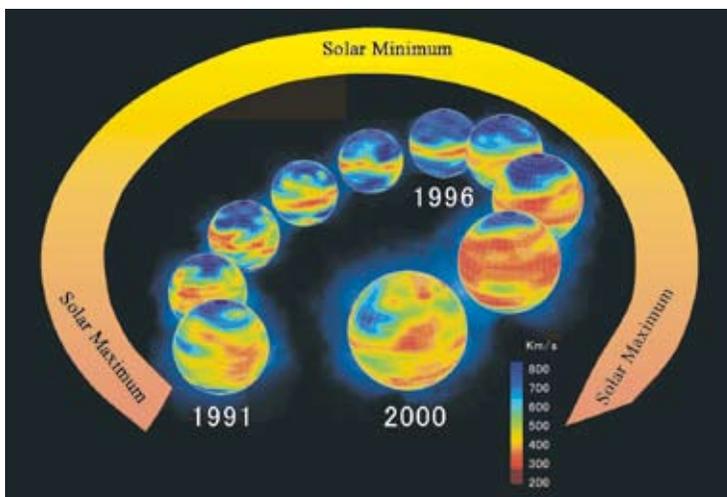
As for the solar activity, the sunspot number began to decrease starting from 1991 during the solar maximum and almost disappeared in 1996 in the solar minimum. Then, it began to increase through 2000, the next maximum.

When you look at the Sun image for 1996, you will notice the low-speed solar wind blew along the solar equatorial zone in a belt-like shape, while the high-speed solar wind was in wide areas of midlatitude and polar regions.

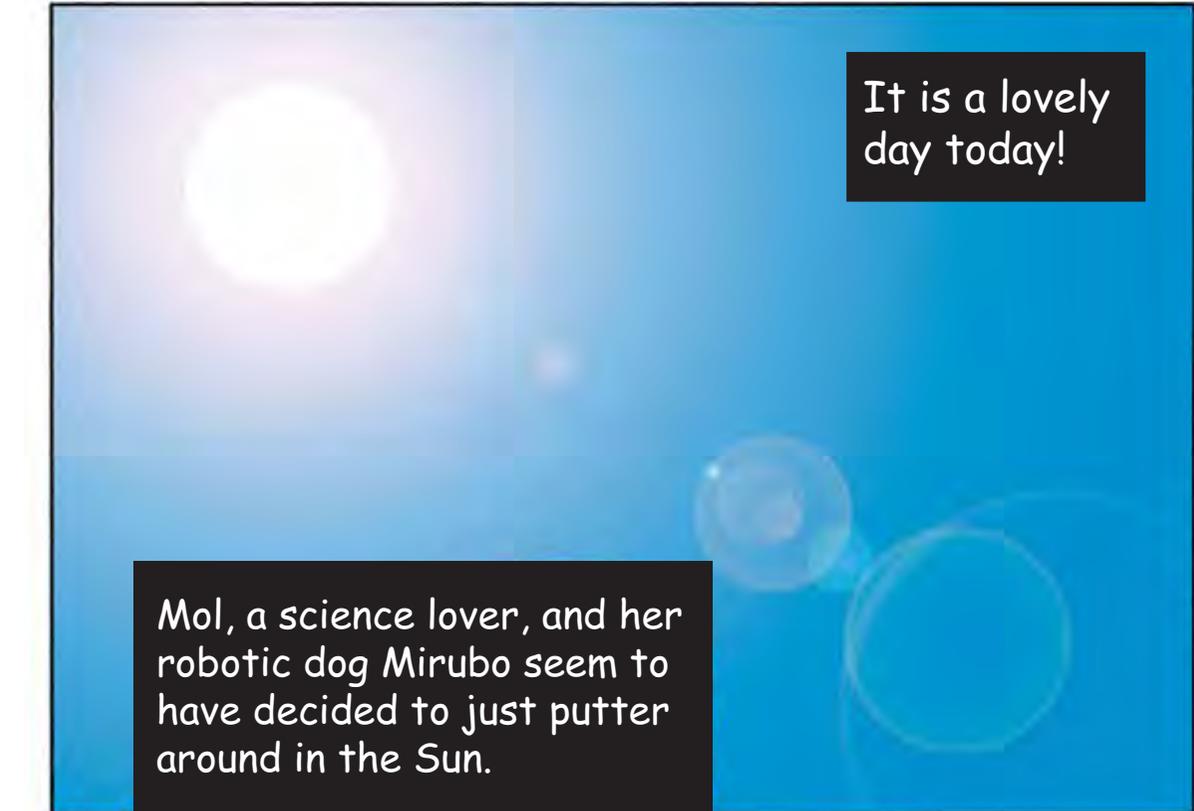
When the Sun became active, the areas of the low-speed solar wind advanced to cover wider parts of the solar surface. To the contrary, the high-speed solar wind areas were confined in the polar regions. At solar maximum, the low-speed solar wind was emitted from the Sun's whole surface.

The solar wind streams out into the vast interplanetary space. Along with solar activity it affects planets and interplanetary space.

Now, let's examine how the solar wind has an influence on our life as well.

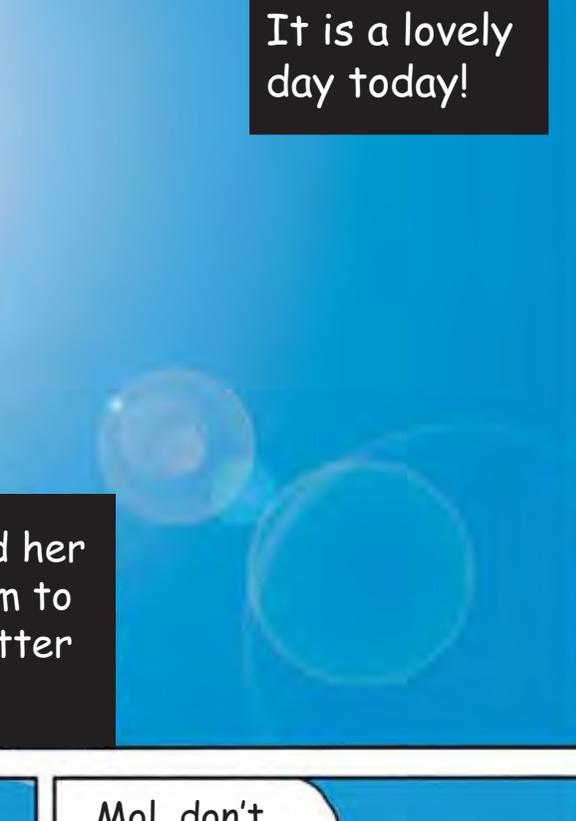


Annual change of the solar wind speed distribution. <Observation and data processing by the Solar-Terrestrial Environment Laboratory >



It is a lovely day today!

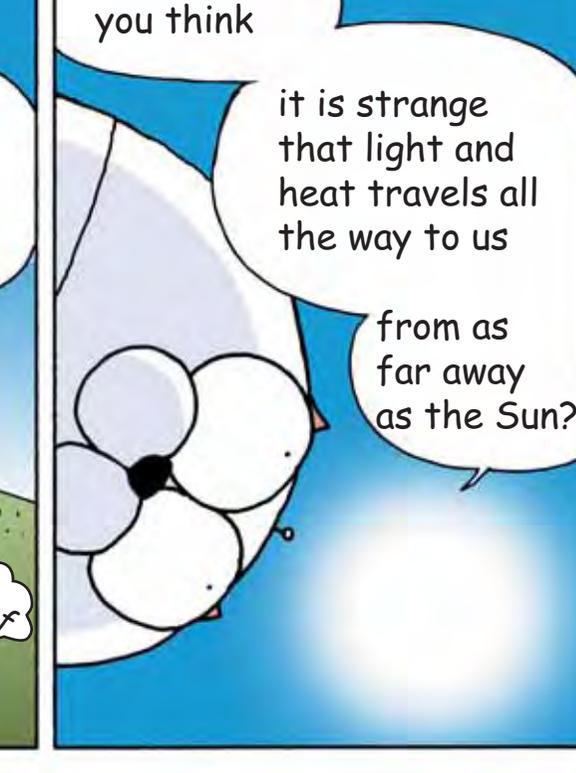
Mol, a science lover, and her robotic dog Mirubo seem to have decided to just putter around in the Sun.



I feel great!!

So do I!
I love basking in the Sun.

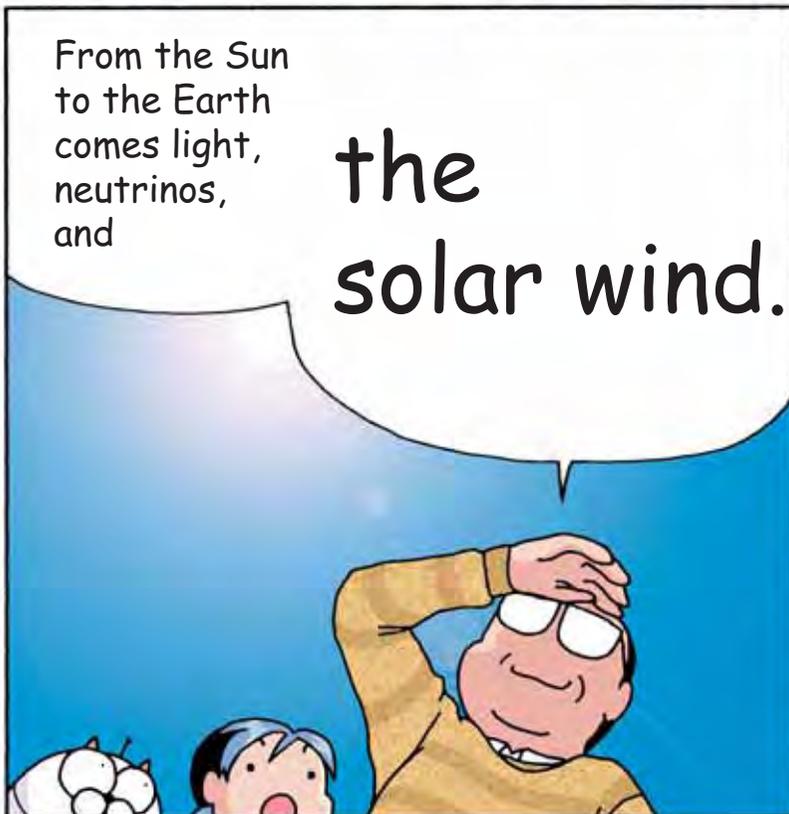
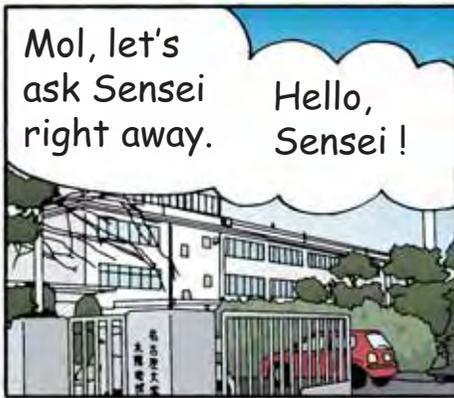
Whoof



Mol, don't you think

it is strange that light and heat travels all the way to us

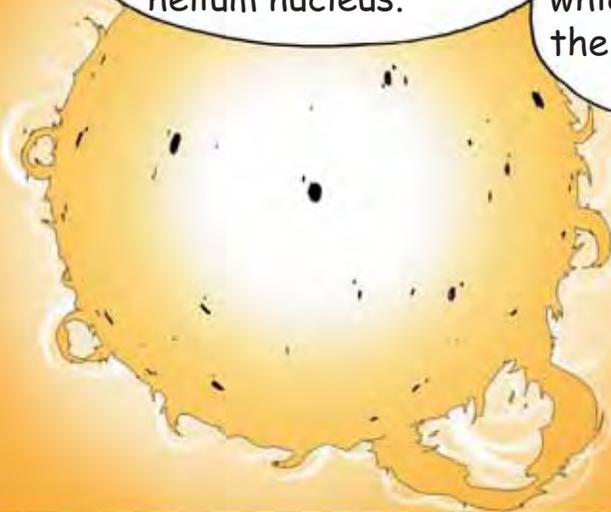
from as far away as the Sun?



First of all, let me explain what happens in the Sun.

Inside the Sun, a process called nuclear fusion takes place. Four hydrogen nuclei transform into a helium nucleus.

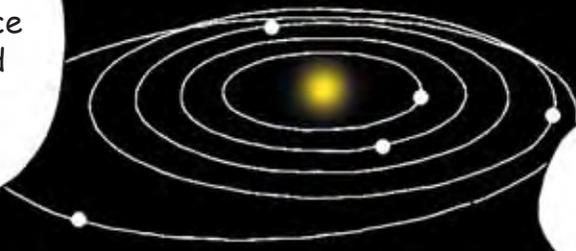
This reaction produces energy, which travels up to the Sun's surface.



Hydrogen atoms heat up to more than 1 million °C on the solar surface, then decompose into electrons and protons.

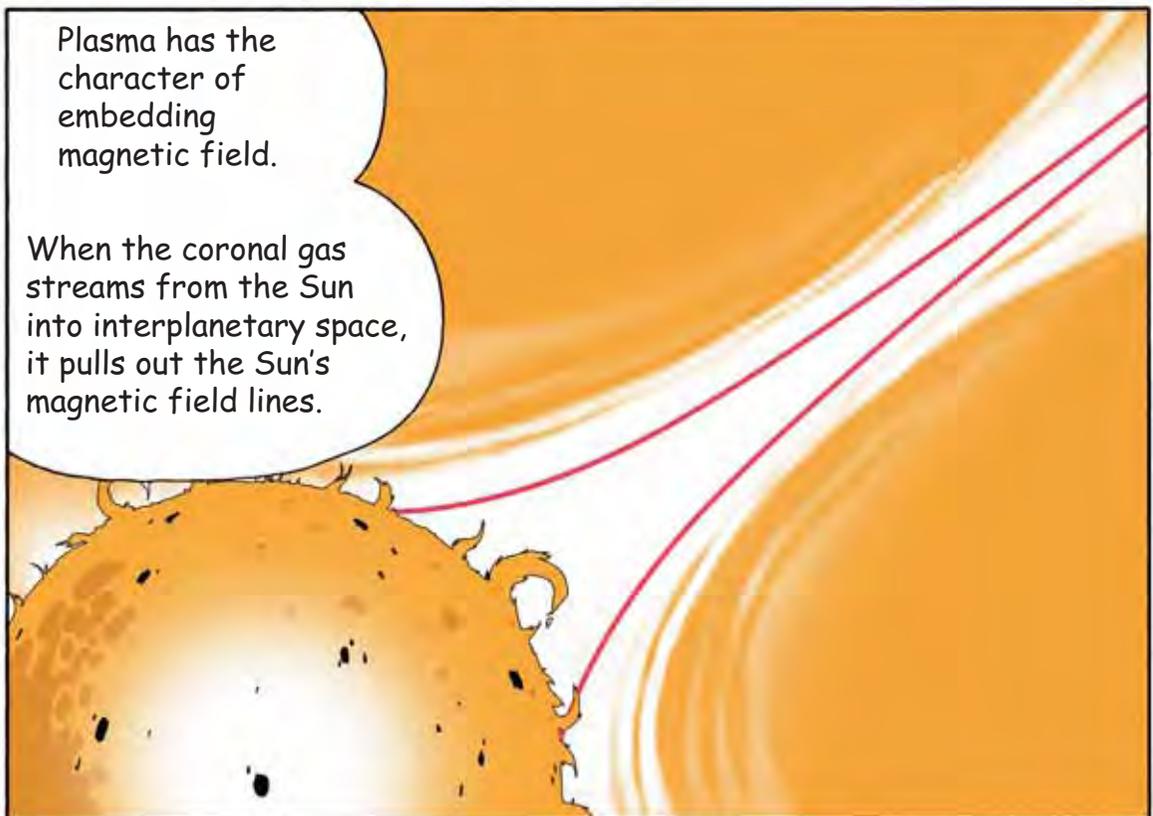
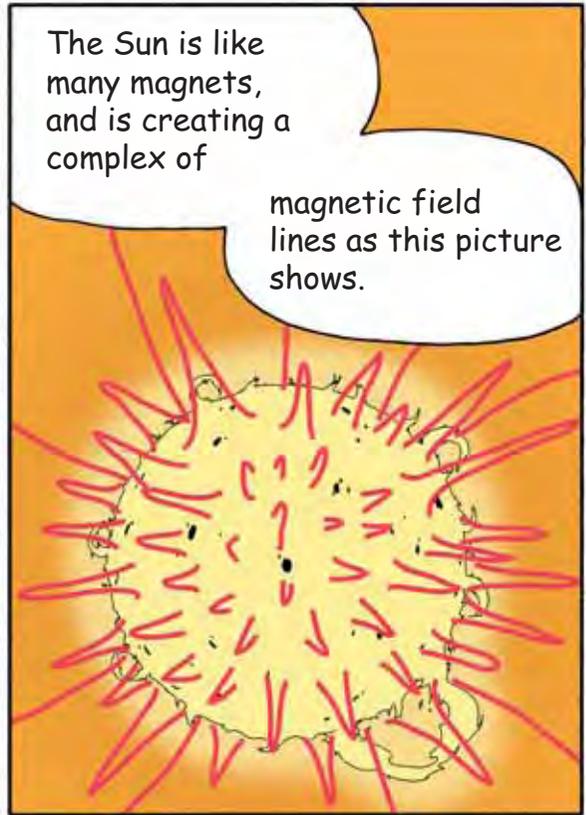
They are called plasmas. The plasma gas is forced to burst out from the solar surface by the high pressure it has.

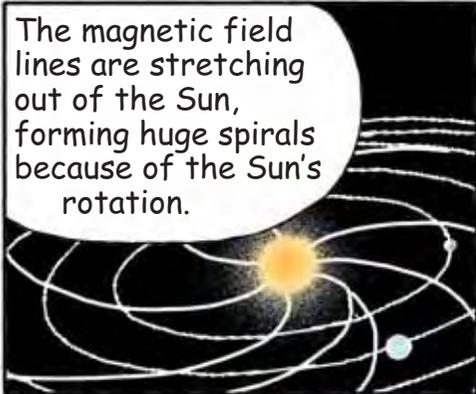
The plasma gas then runs through interplanetary space at ultra-high-speed as fast as 300-800 km per second!



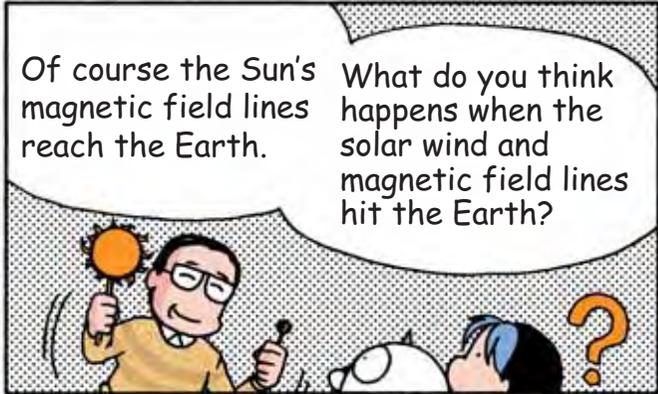
That is the solar wind.





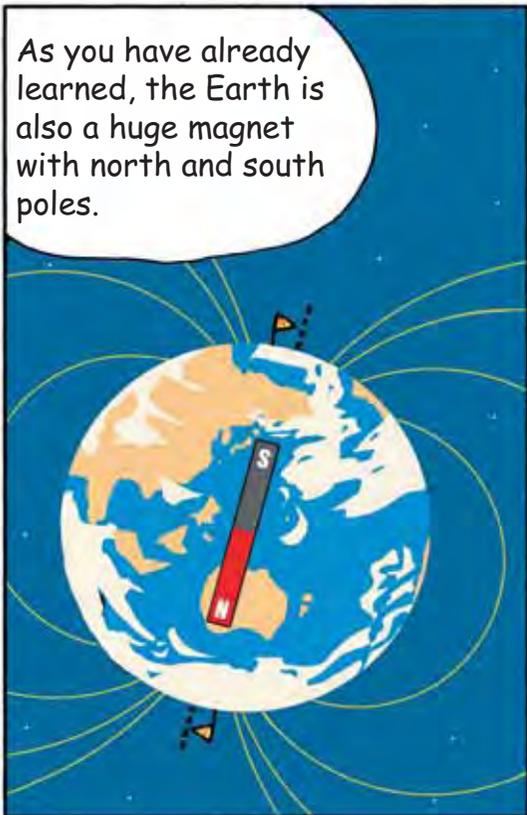


The magnetic field lines are stretching out of the Sun, forming huge spirals because of the Sun's rotation.

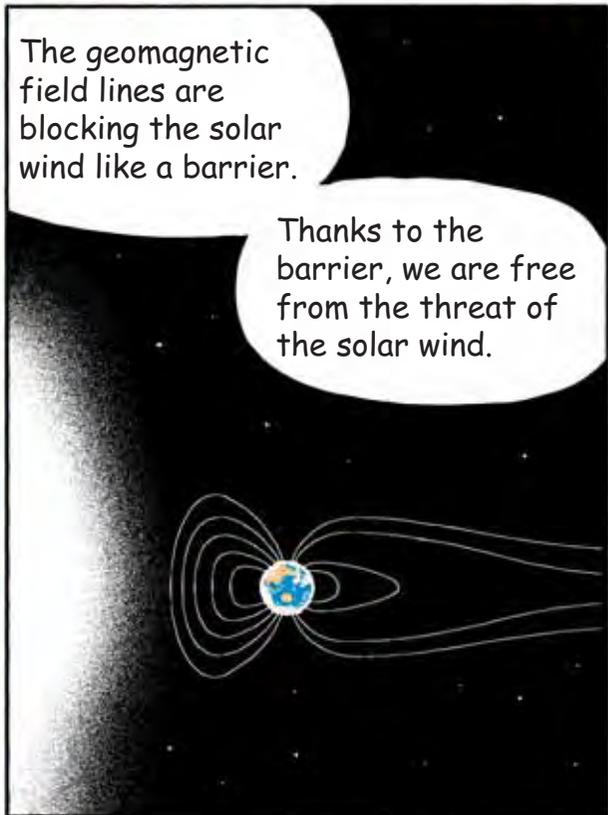


Of course the Sun's magnetic field lines reach the Earth.

What do you think happens when the solar wind and magnetic field lines hit the Earth?



As you have already learned, the Earth is also a huge magnet with north and south poles.



The geomagnetic field lines are blocking the solar wind like a barrier.

Thanks to the barrier, we are free from the threat of the solar wind.



This barrier, however, cannot entirely shield the solar wind.

When the solar wind buffets the geomagnetic field, its huge energy penetrates into the Earth's magnetosphere in various forms.

Aurora is one of the phenomena caused by the energy from the Sun!

The solar wind, the flow of plasmas, creates the aurora by colliding with the atoms and molecules of the Earth's upper atmosphere.

The status of the solar wind can abruptly be changed according to solar activity.

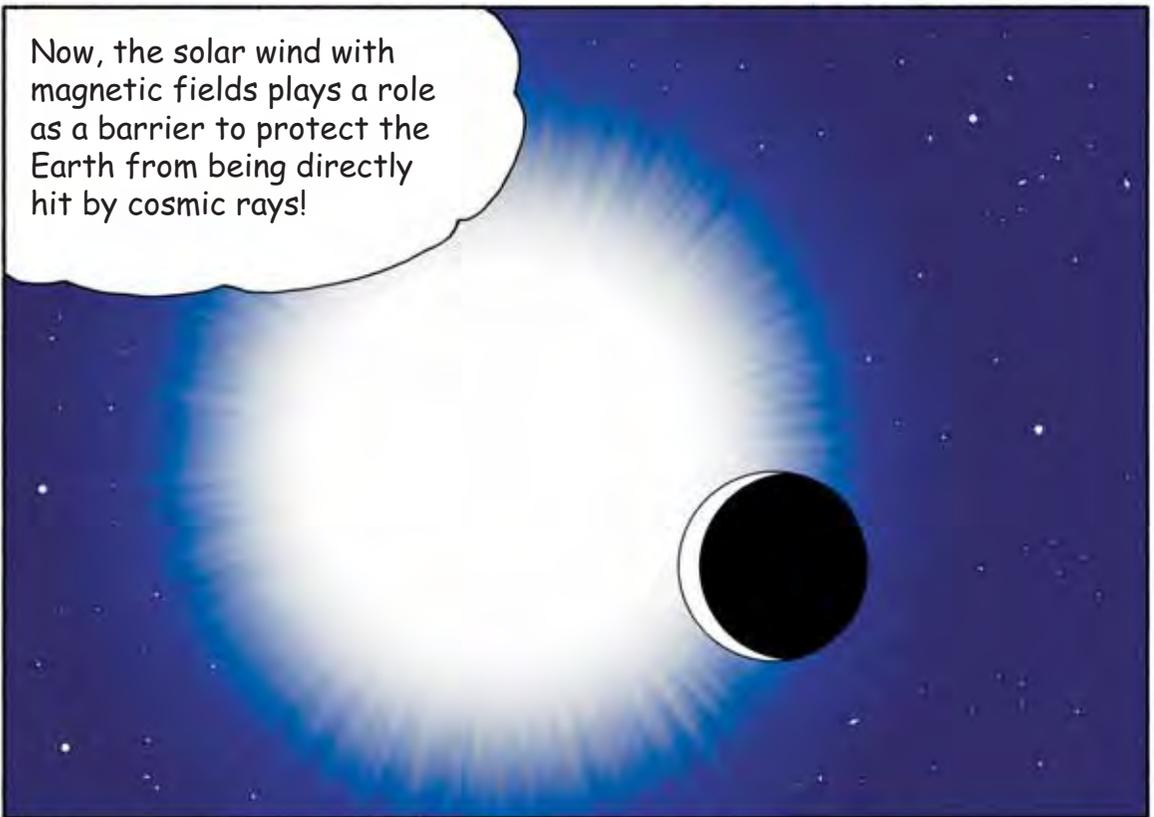
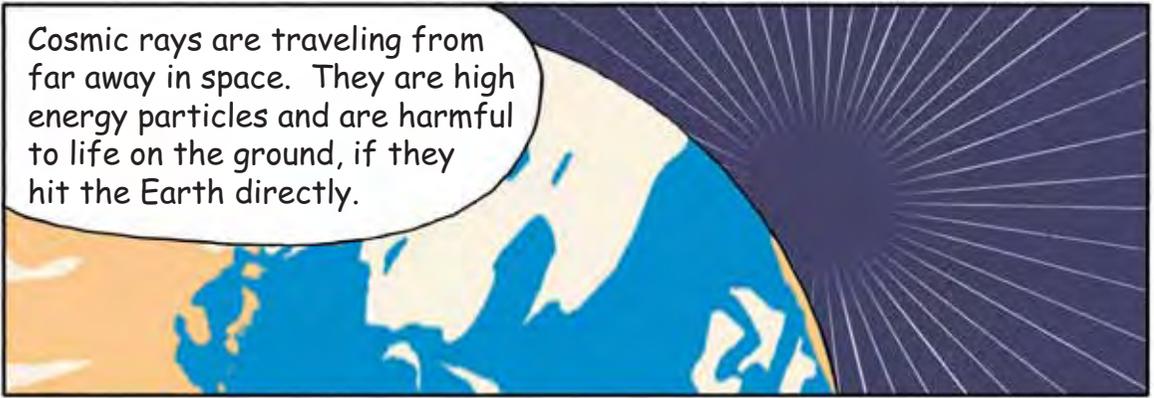
This change could damage satellites and even harm electric systems on the ground by inducing abnormally intense currents.

Although the solar wind is invisible and cannot be detected on the ground,

its influences on our life and environment are seen in many ways.

The solar wind has a negative impact indeed.

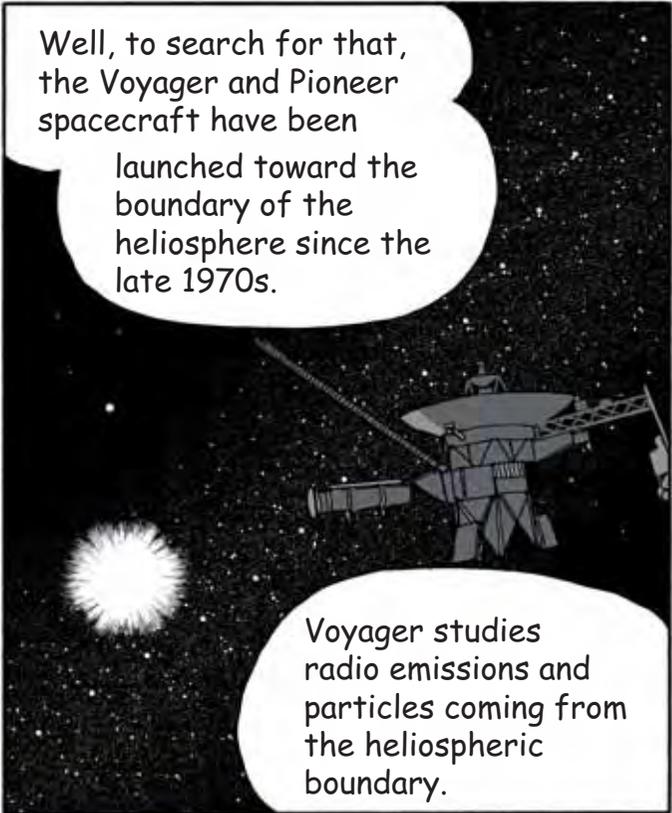
However, it could be worse without the solar wind!





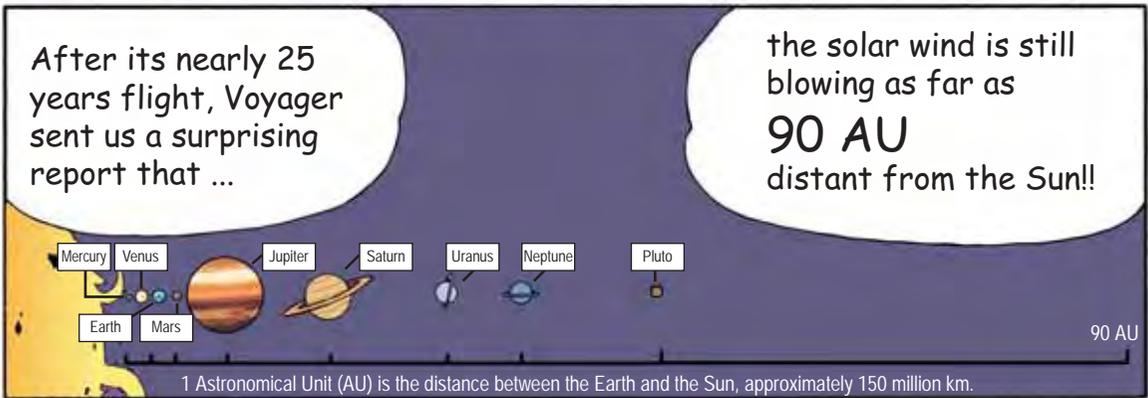
How far does the solar wind reach?

Does it go far beyond the Earth?



Well, to search for that, the Voyager and Pioneer spacecraft have been launched toward the boundary of the heliosphere since the late 1970s.

Voyager studies radio emissions and particles coming from the heliospheric boundary.



After its nearly 25 years flight, Voyager sent us a surprising report that ...

the solar wind is still blowing as far as **90 AU** distant from the Sun!!

1 Astronomical Unit (AU) is the distance between the Earth and the Sun, approximately 150 million km.

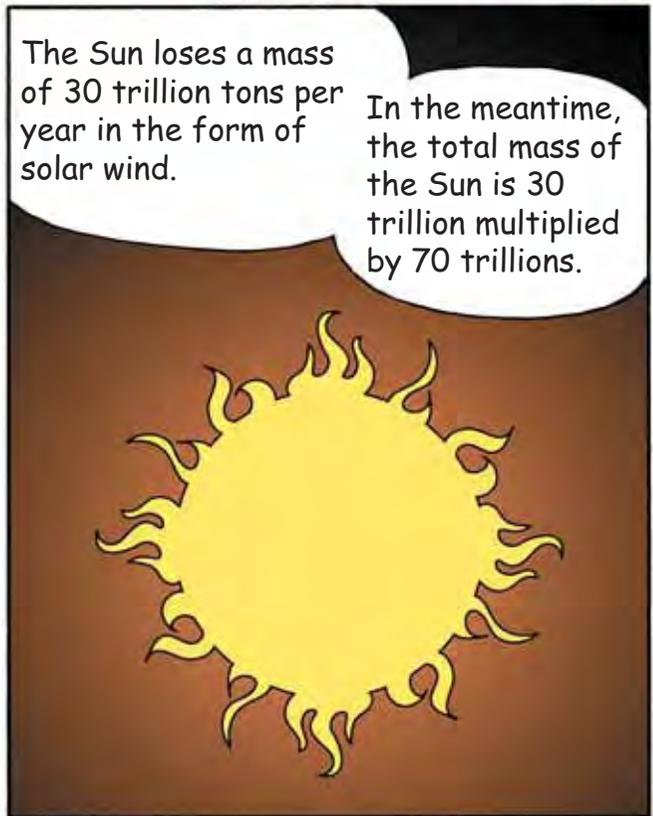
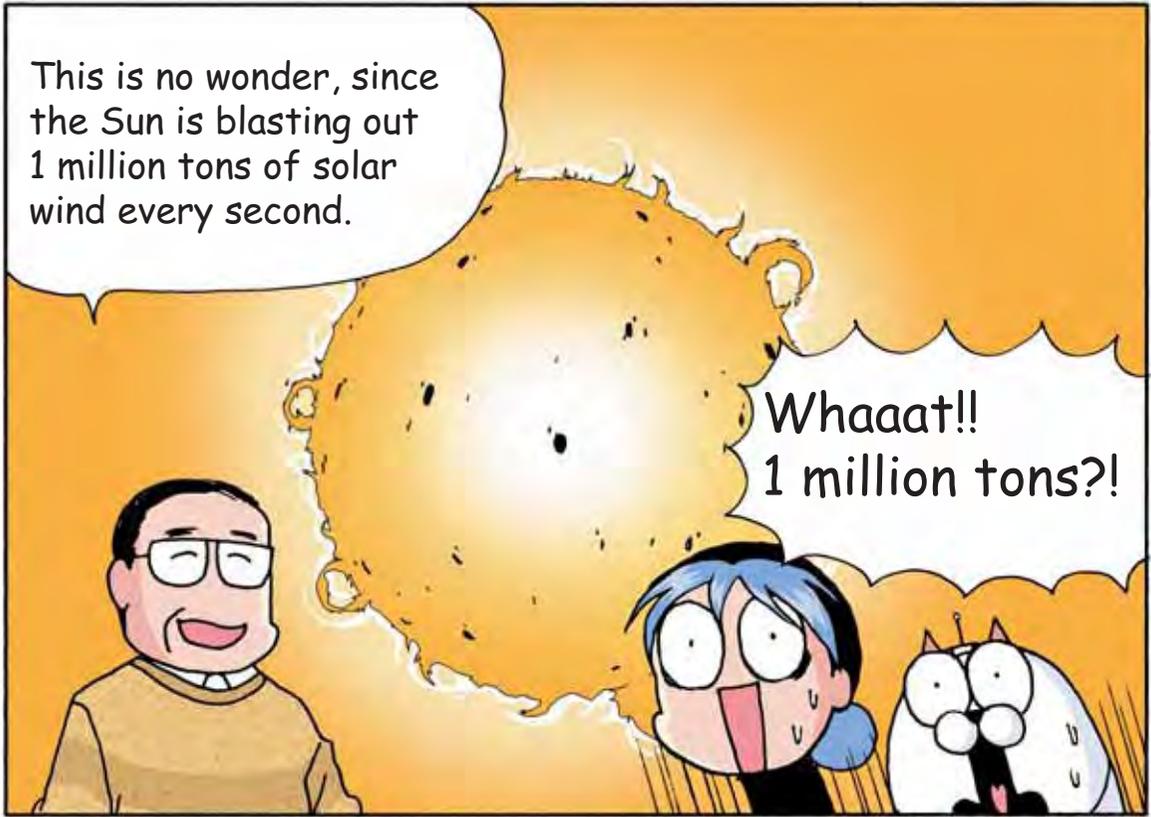


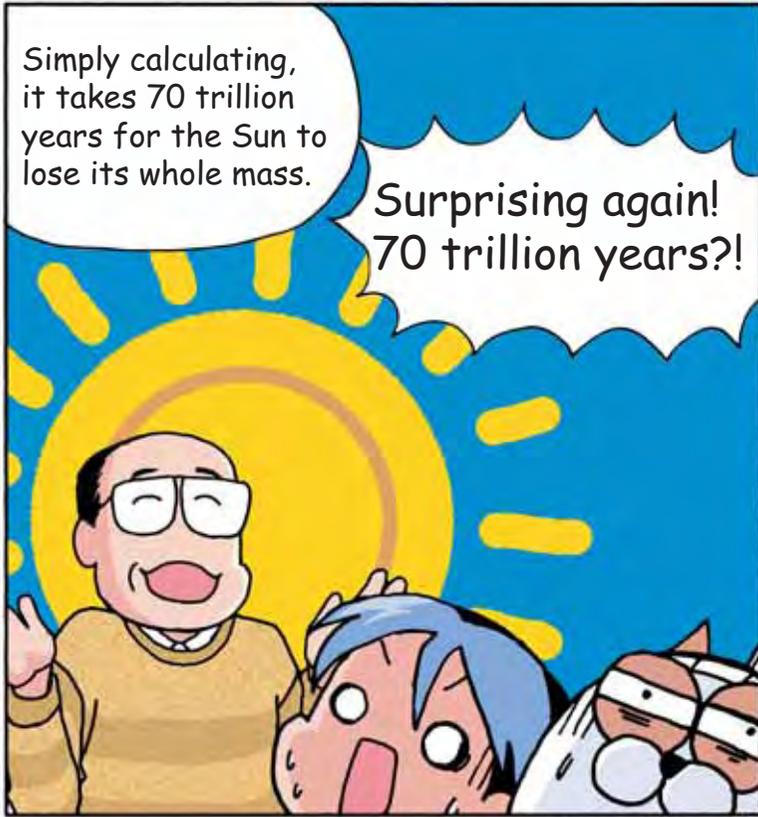
Wow, the solar wind travels so far?!

One hundred fifty million km multiplied by 90 is ... Um.

Anyway, it must be a heavy, mighty wind!!

Incredible!





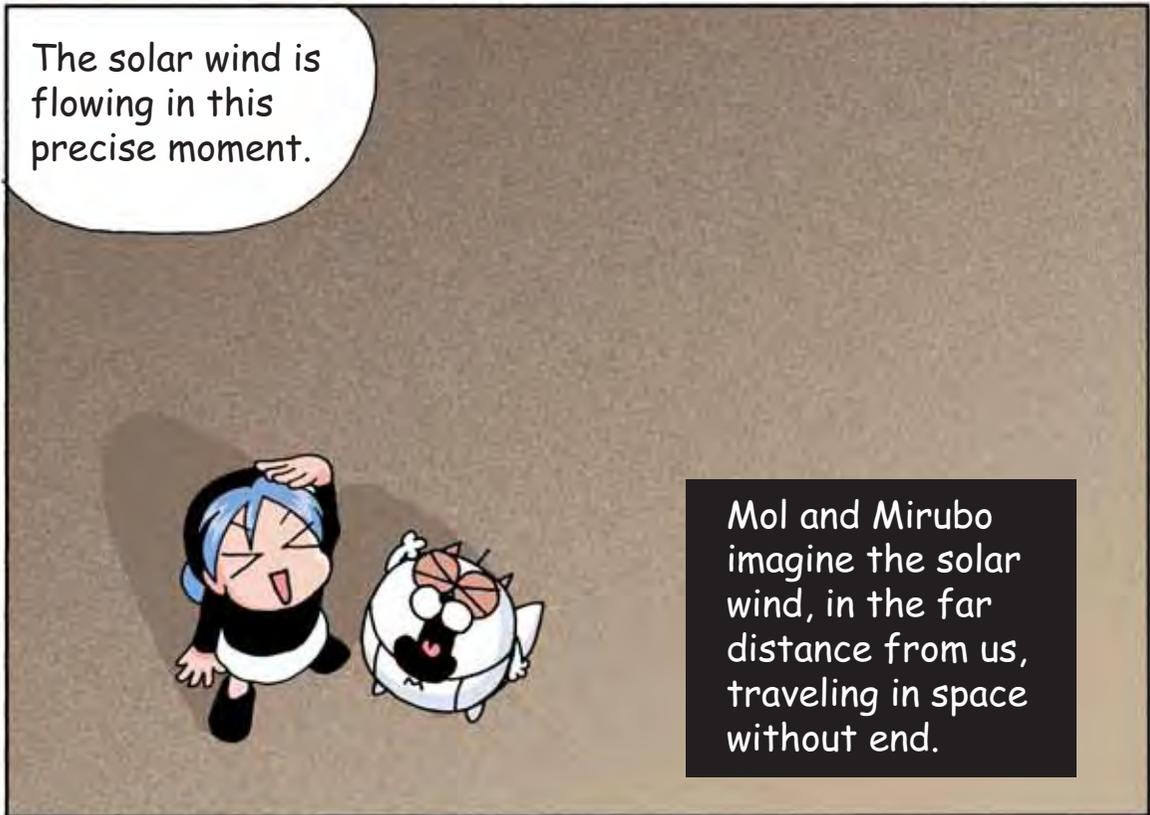
Simply calculating, it takes 70 trillion years for the Sun to lose its whole mass.

Surprising again! 70 trillion years?!



Despite the enormous amount of the solar wind, the Sun will not disappear.

The Sun is really something.



The solar wind is flowing in this precise moment.

Mol and Mirubo imagine the solar wind, in the far distance from us, traveling in space without end.

What is the Solar Wind?!



Hello, sensei. Today I have a question about the wind blowing from the Sun. Can it be seen from a space station?



The solar wind blowing near the earth contains only about 10 particles per a sugar cube in volume. It is a very thin gas, almost a vacuum, not emitting light strong enough to be seen by the naked eye.



When was the solar wind discovered? How was that unseen presence found? Even I have no clue at all.



In the 1900s, people thought that something along with light came from the Sun to the Earth because the geomagnetic field was disturbed or auroras occurred a few days later after the sunspots and flares appeared.



The solar wind does not blow when sunspots disappear?



Oh, yes it does. It flows anytime. Actually, the solar wind is the solar atmosphere itself. Around 1950, a German scientist named L. Biermann studied comet tails and found that solar wind always blew even when there was no sunspot observed.



The tail of a comet is something like a streamer flapping in the wind.



When was the solar wind observed directly?



It was not until 1962 that solar wind was proved to exist. The spacecraft Mariner II succeeded in directly detecting the solar wind on its way to Venus.



It was a great discovery, wasn't it?



In fact, an American scientist E. Parker had developed a theory of the solar wind 4 years before the success of Mariner II. He predicted its speed to be as fast as a few hundred kilometers per second. The name of the solar wind was given by him.



How far does the solar wind go beyond the Earth?



It travels beyond Saturn and Uranus, then finally collides with interstellar gas. Until then the solar wind has become thinner, colder, and weaker. The region where the pressure of the solar wind and the interstellar gas is in balance is the heliosphere's boundary.



What is it like beyond the heliosphere?



The temperature just outside the heliosphere is extremely high, about 8000 K. This region contains both ionized hydrogen like solar wind and neutral hydrogen, but it is very thin. Those atoms have a density as low as less than one-tenth that of the solar wind flowing near the Earth.



The heliosphere is expected to have a huge tail streaming in the interstellar gas just like a comet has.



I now am assured that a tail is really something. Look at my tail! Do you want to have one, Mol?



Not really...

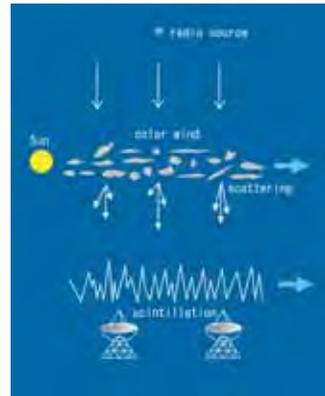


Cast Eyes Skywards to Observe the Solar Wind



A number of satellites have been launched to observe the solar wind, but their trajectories cannot escape from the orbital plane. Only the solar probe named Ulysses, which was launched in 1990, has succeeded in going out of the orbital plane by changing the inclination of its trajectory by nearly 90 degrees with the help of Jupiter's immense gravity! However, there were not many probes working on the satellite around that time. It was almost impossible to get the whole picture of the solar wind blowing in the vast interplanetary space.

Actually, ground-based observations are the way to fill-in the solar wind observations made by spacecraft. In 1964, A. Hewish and his colleagues at the University of Cambridge discovered that radio waves coming from outer space became stronger and weaker in a few-second cycle. This is just like starlight twinkling in the night sky, the phenomenon caused by the turbulence in the Earth's atmosphere. The light from a star is scattered in different directions

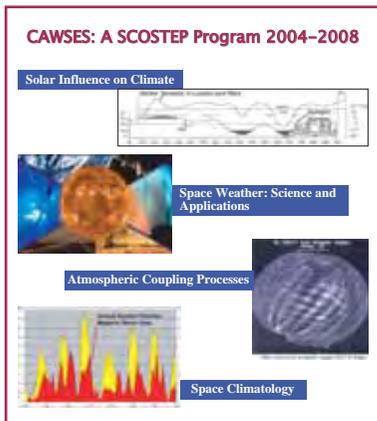


when it passes through the atmosphere, which makes the star seem to twinkle.

For radio waves from a radio source, scattering is caused by the charged particles, or solar wind plasma (see above figure). There are countless radio sources in all directions in the sky as seen from the Earth. The "twinkling" of their radio waves gives us on the ground vital clues in a short time to understand how solar wind exists in various areas such as the near- and far-orbital plane and around the Sun.



The Solar-Terrestrial Environment Laboratory carries out solar wind observations by radio telescopes set up in 4 different sites in Japan. One of them is at the foot of Mt. Fuji (picture above). This telescope has 100 m long (EW) and 20 m wide (NS) antenna, which is operated at 327 MHz. A thousand pieces of thin stainless steel wires welded between the parabolic structures create a huge reflecting surface.



Climate and Weather of the Sun-Earth System (CAWSES)

CAWSES is an international program sponsored by SCOSTEP (Scientific Committee on Solar-Terrestrial Physics) and has been established with the aim of significantly enhancing our understanding of the space environment and its impacts on life and society. The main functions of CAWSES are to help coordinate international activities in observations, modeling and theory crucial to achieving this understanding, to involve scientists in both developed and developing countries, and to provide educational opportunities for students at all levels. The CAWSES office is located at Boston University, Boston, MA, USA. The four science Themes of CAWSES are shown in the figure.

<http://www.bu.edu/cawses/>

<http://www.ngdc.noaa.gov/stp/SCOSTEP/scostep.html>



Solar-Terrestrial Environment Laboratory (STEL), Nagoya University

STEL is operated under an inter-university cooperative system in Japan. Its purpose is to promote "research on the structure and dynamics of the solar-terrestrial system," in collaboration with a number of universities and institutions both in Japan and abroad. The Laboratory consists of four research Divisions: Atmospheric Environment, Ionospheric and Magnetospheric Environment, Heliospheric Environment, and Integrated Studies. The Geospace Research Center is also affiliated to the Laboratory to coordinate and promote joint research projects. At its seven Observatories/Stations, ground-based observations of various physical and chemical entities are conducted nationwide.

<http://www.stelab.nagoya-u.ac.jp/>

はやのん Hayanon

Graduated from the Department of Physics of Ryukyu University, Hayanon, a writer and cartoonist, has contributed a number of serials in popular magazines on the basis of her strong background in science and computer games. Her consistent writing style, expressing a love for science, is well accepted.

<http://www.hayanon.jp/>

子供の科学

Kodomo no Kagaku (Science for Children)

Kodomo no Kagaku, published by the Seibundo Shinkosha Publishing Co., Ltd. is a monthly magazine for juniors. Since the inaugural issue in 1924, the magazine has continuously promoted science education by providing various facets of science, from scientific phenomena in everyday life to cutting edge research topics.

<http://www.seibundo.net/>

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