National Aeronautics and Space Administration

IBEX: Interstellar Boundary Explorer

An Electronic Resource for Informal Educators

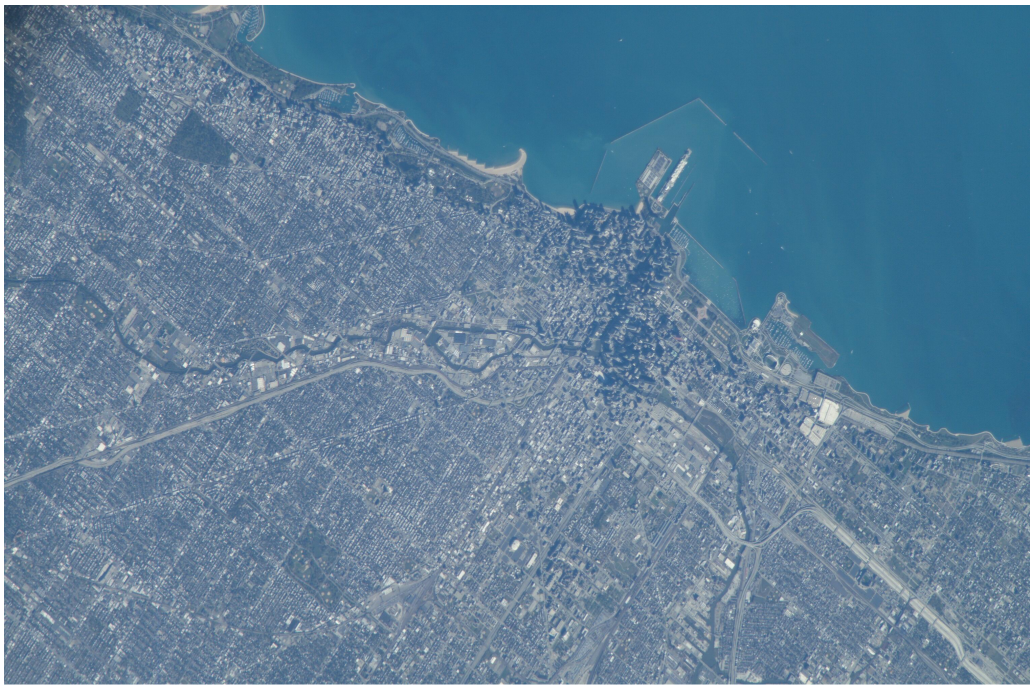
(Revised Spring 2011)

How to use this resource:

Thank you for your interest in NASA's Interstellar Boundary Explorer (IBEX) spacecraft mission. This PowerPoint was designed as a comprehensive guide to the IBEX mission, background science, and results to date as of mid-2011. There are images and text boxes on the following slides that will give you an overview of these topics, but there is also much more information contained in the Notes section below each slide that was included based on the questions and requests from informal (i.e. museum) educators who reviewed this material in 2008 and 2011. We recommend that if you are perusing these slides for your own information, you should keep the PowerPoint in "Normal" view so that you can see the slide and the Notes sections at the same time. If you wish to show some portion of this material to others, please keep in mind that you may have to make significant alterations to one or more slides so that they are appropriate for your audiences. Thanks, again, for your interest in IBEX, and we hope you enjoy learning about the mission!

- Sincerely, the IBEX Education and Public Outreach Team

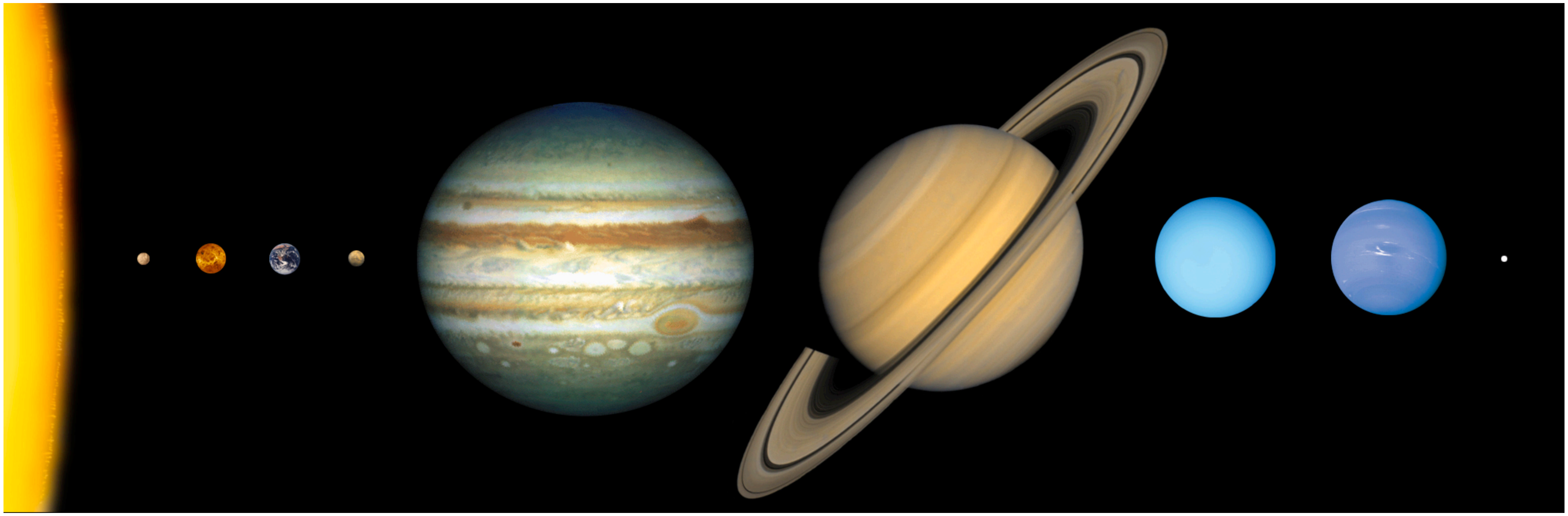
What does it mean for something to have a boundary?



Some things, like a table or a soccer field have clear edges and boundaries. Other objects, like cities and towns, have boundaries that aren't as easy to see. It is hard to say where they end and something else begins if you are looking at them from a distance.

Chicago, as photographed from the International Space Station. Image Credit: NASA

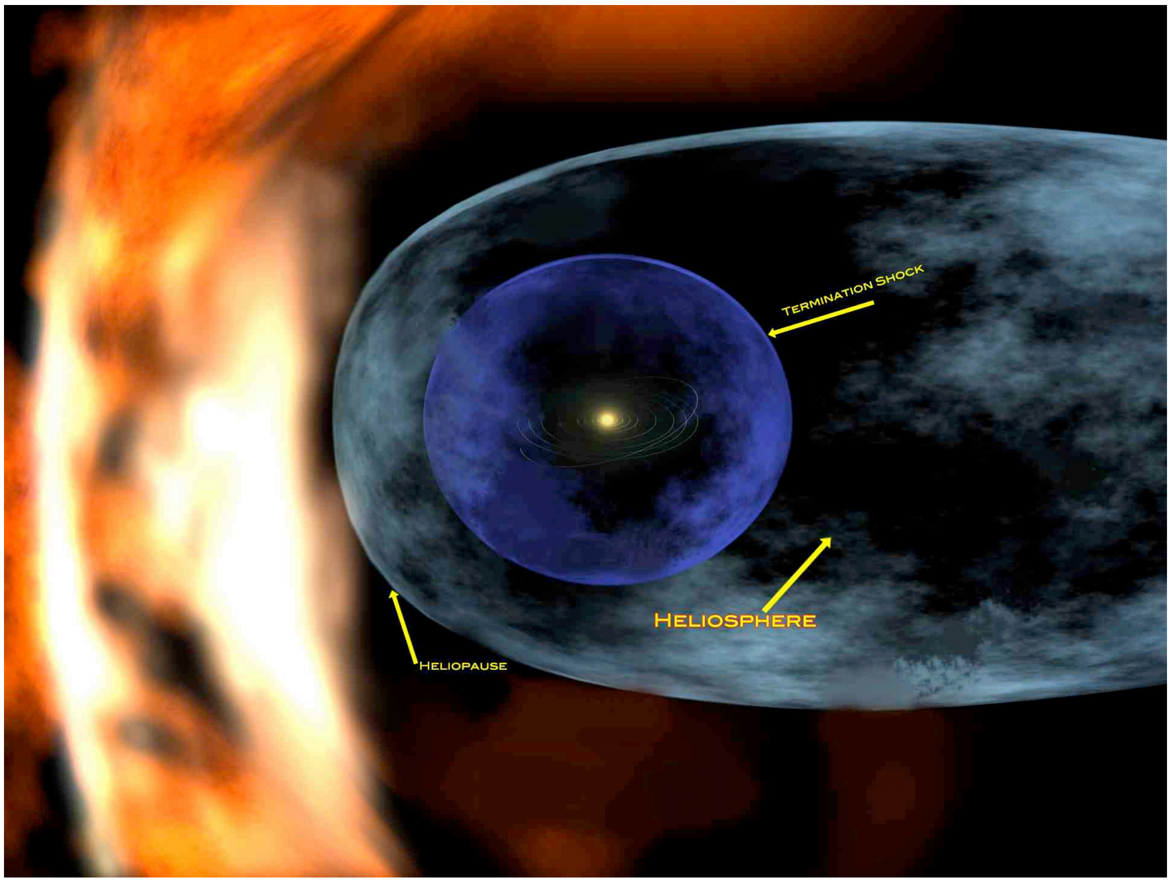
What defines the boundary of our Solar System?



You could say that the Solar System extends as far as the influence of the Sun. Could the reach of the Sun's light or the extent of the Sun's gravity help us decide how far the Solar System extends? The light from the Sun gets fainter as you move farther away, but there is no specific place where the light stops or where it suddenly weakens. Also, the influence of the Sun's gravity extends without limit, although it is weaker the farther away from the Sun that you travel. There is no boundary at which either light or gravity stops. Neither of these would seem to help us define our Solar System's "edge".

Image Credit: NASA

What *else* can we use to define the boundary of our Solar System?



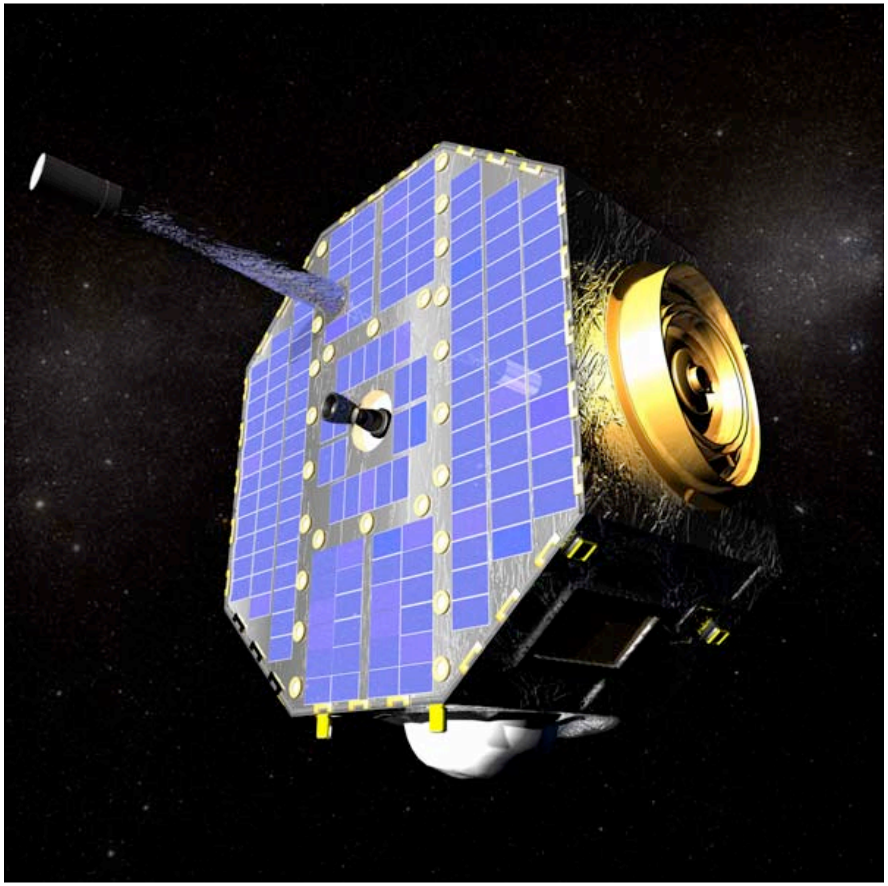
The **heliosphere** helps define one type of boundary of our Solar System. The solar wind from our Sun blows outward against the material between the stars, called the **interstellar medium**, and clears out a bubble-like region. This bubble that surrounds the Sun and the Solar System is called the **heliosphere**. It is a definable, measureable region in space. But what tool can we use to study this region?

An artist's rendition of our heliosphere. Image credit: Walt Feimer, NASA GSFC

What tool can we use to study the boundary of our Solar System?

IBEX was the first spacecraft designed to collect data across the entire sky about the heliosphere and its boundary. Scientists have used this data to make the first maps of our heliosphere boundary. This movie clip shows an artist's rendition of the IBEX spacecraft in orbit around Earth. *Movie Credit: Walt Feimer, NASA GSFC*

What is **IBEX**?



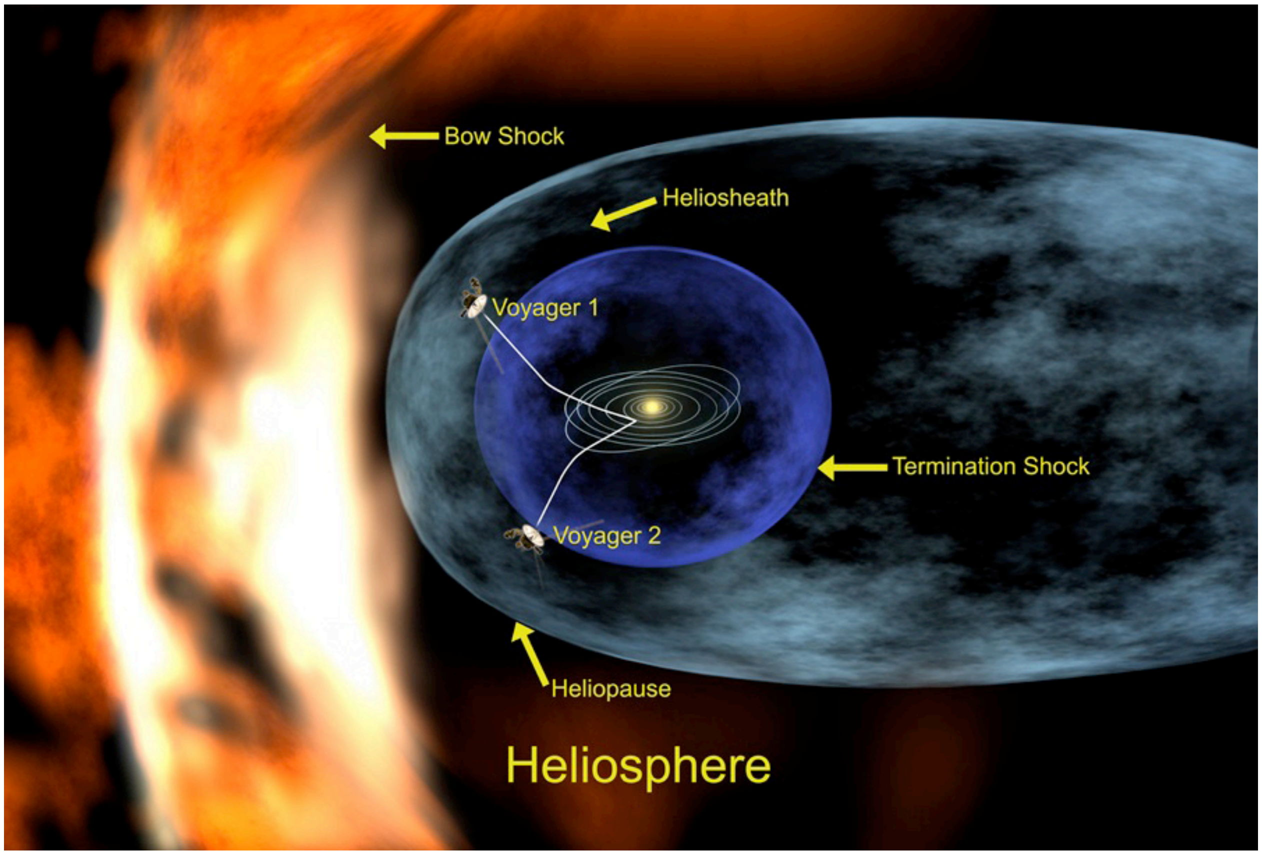
IBEX is a $134 million NASA-funded Small Explorer satellite mission that orbits Earth and maps the boundary of the Solar System. The IBEX spacecraft itself is about the size of a large bus tire.

The acronym **IBEX** stands for **Interstellar Boundary Explorer**.

An artist's rendition of the IBEX spacecraft. Image Credit: Walt Feimer, NASA GSFC

IBEX Science

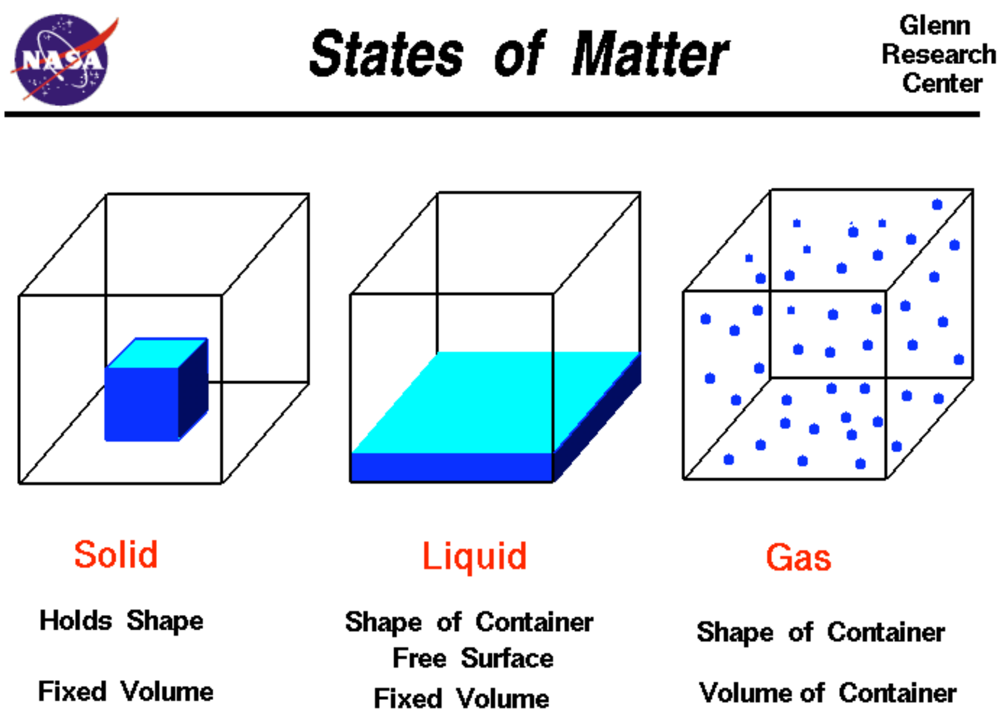
What is the objective of the IBEX mission?



IBEX's science objective is to discover the global interaction (i.e., the interaction across the entire sky) between **plasma** from the **solar wind** and the **interstellar medium**. This distant region is called the **boundary of our Solar System** and is created, in part, by plasma.

Image credit: Walt Feimer, NASA GSFC

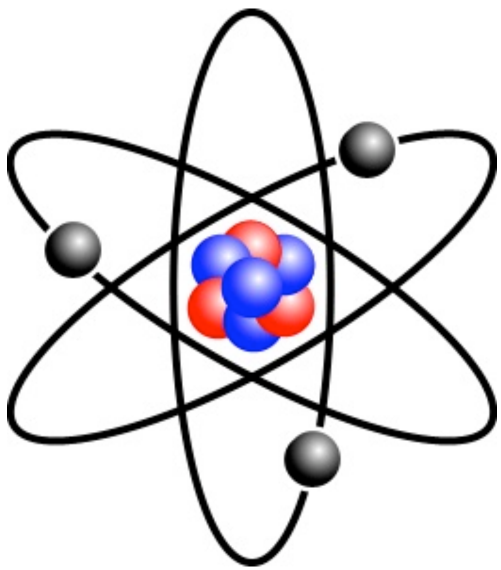
What is **plasma**?



Plasma is a state of matter. Everything in the Universe that we can see is made of "stuff" called matter. All matter is made of atoms, and it can exist in different states. Many people are familiar with three states of matter: solid, liquid, and gas. Plasma, as a state of matter, may be unfamiliar to most people, even though it actually makes up most of the Universe: all of the stars and most of the matter between the stars.

Image credit: NASA Glenn Research Center

What is **plasma**?

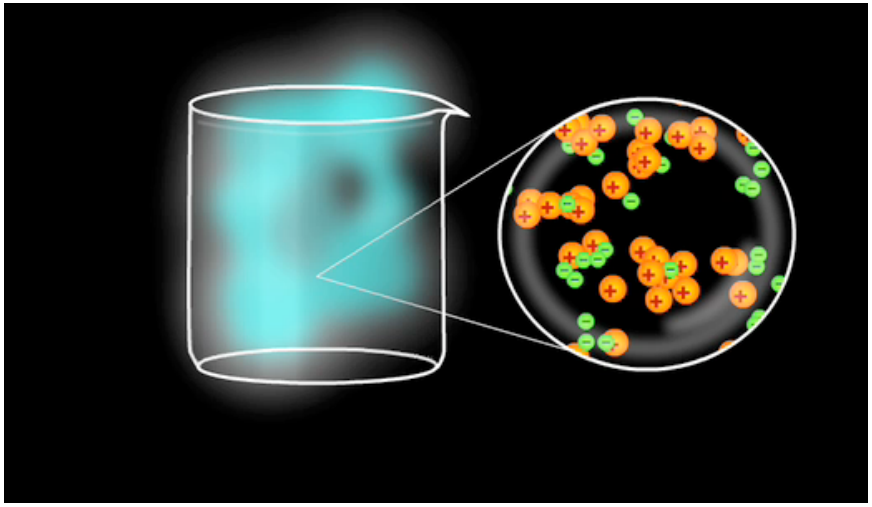


Atoms are made of protons, neutrons and electrons.

Protons have a positive charge, neutrons have a neutral charge and they both make up the atom's nucleus. Electrons have a negative charge. They surround the nucleus of the atom, roughly pictured here.

A simplified artist's rendition of an atom. Image credit: Public domain image

What is **plasma**?



When heat energy is added to a gas, the particles forming the gas begin to move around faster. When enough heat energy is added to a gas, protons and electrons separate, forming a **plasma**. Plasma can react to magnetic fields. This movie clip shows an artist's rendition of protons and electrons in a plasma.

Movie credit: Adler Planetarium

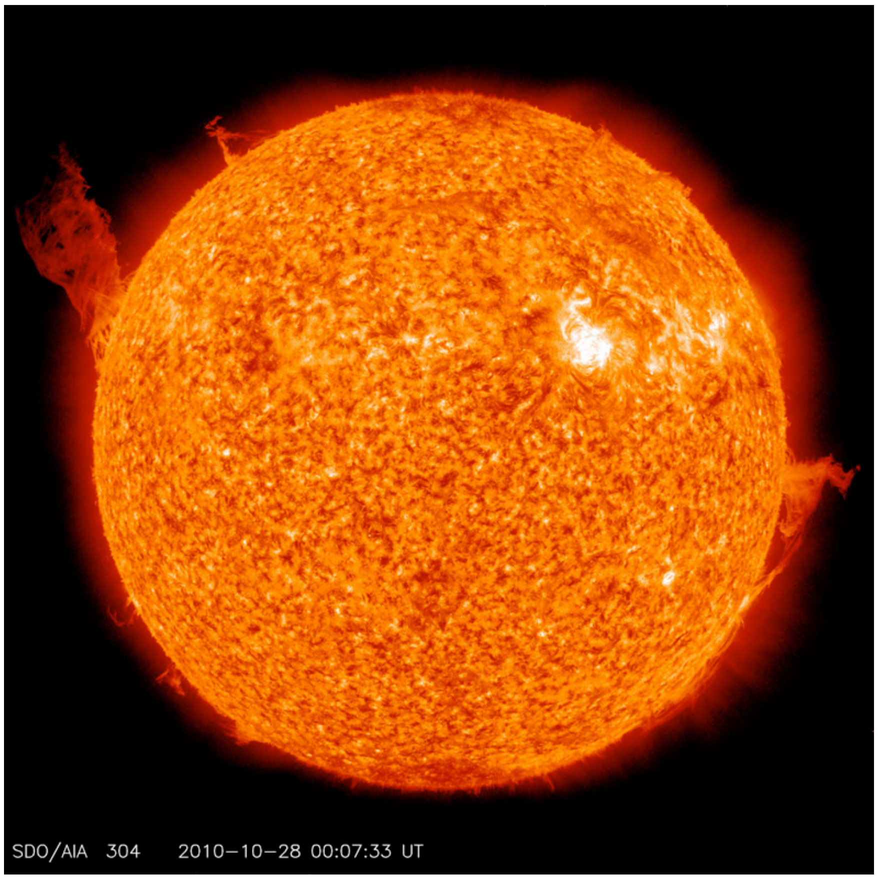
Where can I find examples of **plasma**?

Some examples of plasma that may be familiar to you include:

- a flame
- lightning
- our Sun

Cloud-to-ground lightning. Image credit: NOAA Photo Library, NOAA Central Library; OAR/ERL/National Severe Storms Laboratory

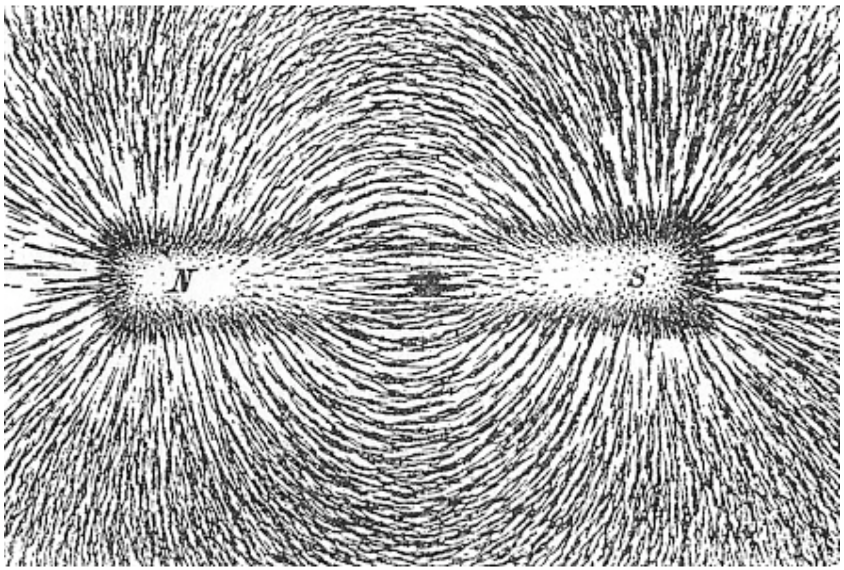
What is **plasma**?



The Sun is mainly made of two elements, hydrogen and helium, in a state of matter called **plasma**. When a heated gas has enough energy to make its electrons detach from the nucleus, it becomes a plasma.

The Sun, as seen by the Solar Dynamics Observatory (SDO) spacecraft on October 28, 2010. Image credit: Courtesy of NASA/SDO and the AIA science team

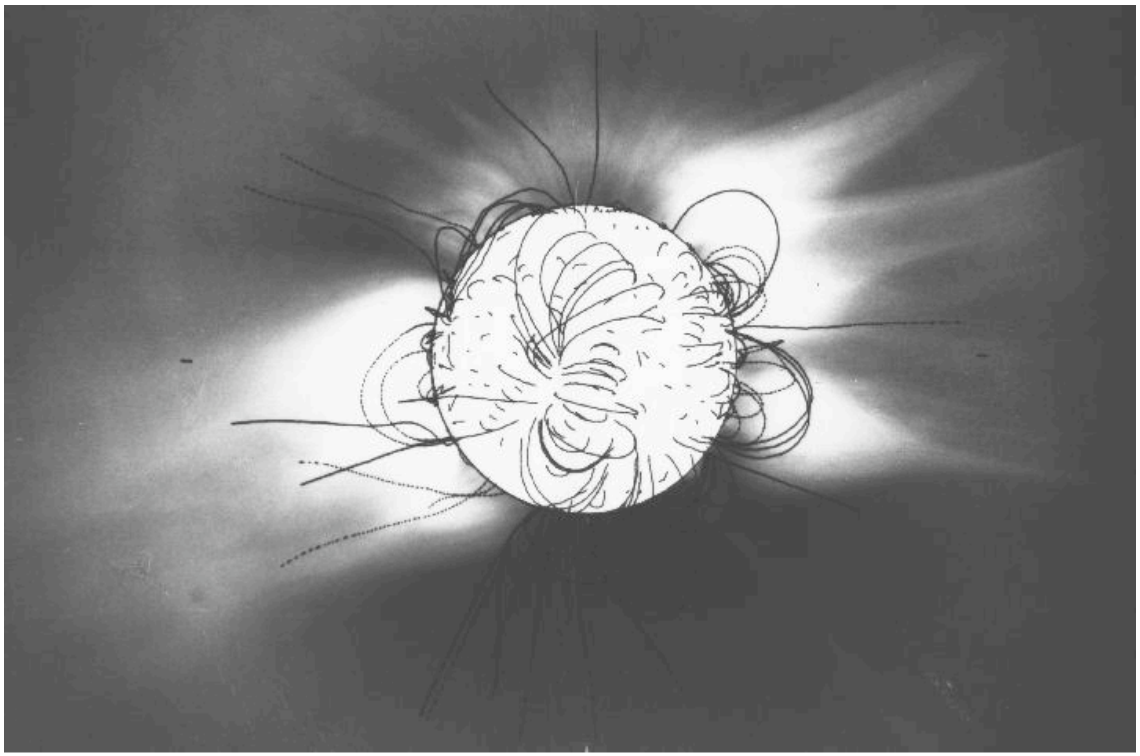
What is a **magnetic field**?



Magnetic fields are created by things that are magnetic or by moving electric charges. A magnetic field is a field, or map, that describes the strength and direction of magnetism at each point in space. The magnetic field at a particular location can be used to determine the force felt by other magnetic objects or electric charges at that location.

Iron filings around a bar magnet highlighting the magnetic fields.
Image credit: Public domain image

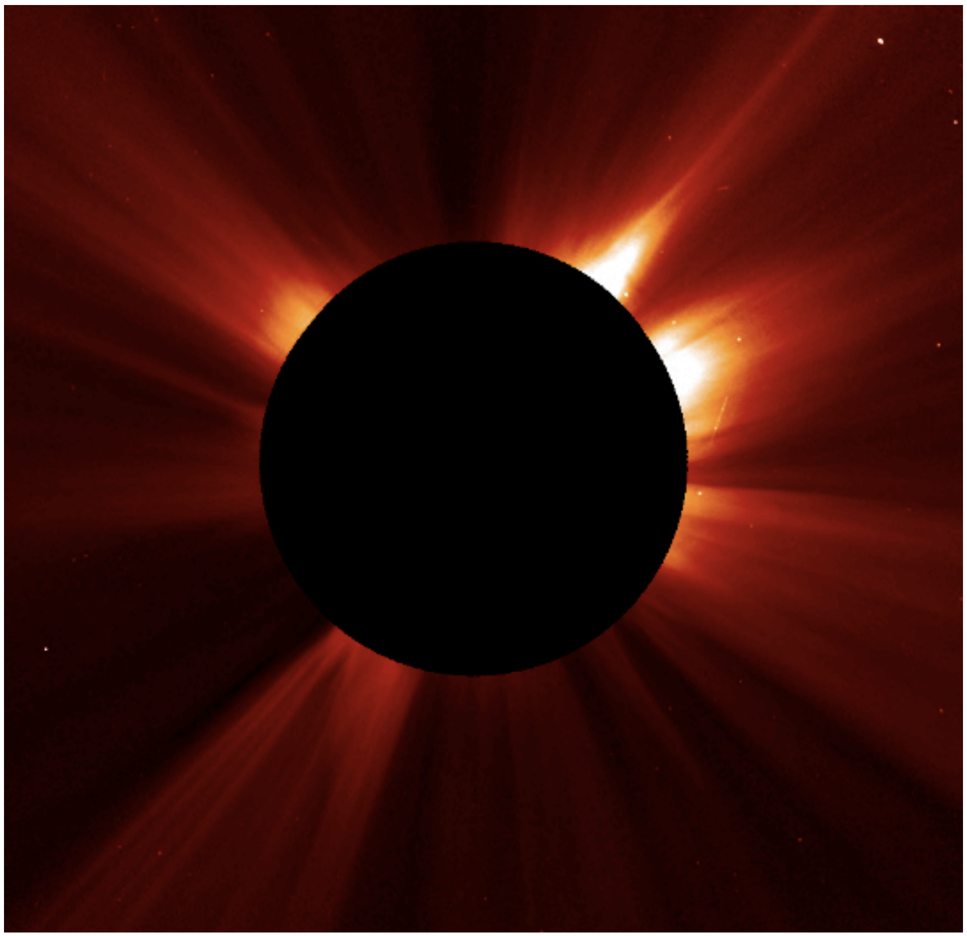
What is a **magnetic field**?



When charged particles move around really fast, they create magnetic fields. The Sun has a large and complex magnetic field formed by moving charged particles – mostly ions and electrons.

A rendition of the Sun's magnetic field, using actual solar data. Image credit: Kiepenheuer-Institut fur Sonnenphysik

What is the **solar wind**?



The **solar wind** is a stream of charged particles (plasma) that flow off the Sun at about one million miles per hour (400 kilometers per second)! These particles come from the outermost layer of the Sun, called the corona.

The solar corona, as seen by the LASCO instrument on the SOHO spacecraft. The Sun itself is blocked by a "screen" so that the much dimmer corona can be imaged. Image credit: SOHO (ESA and NASA)

What is the **interstellar medium**?

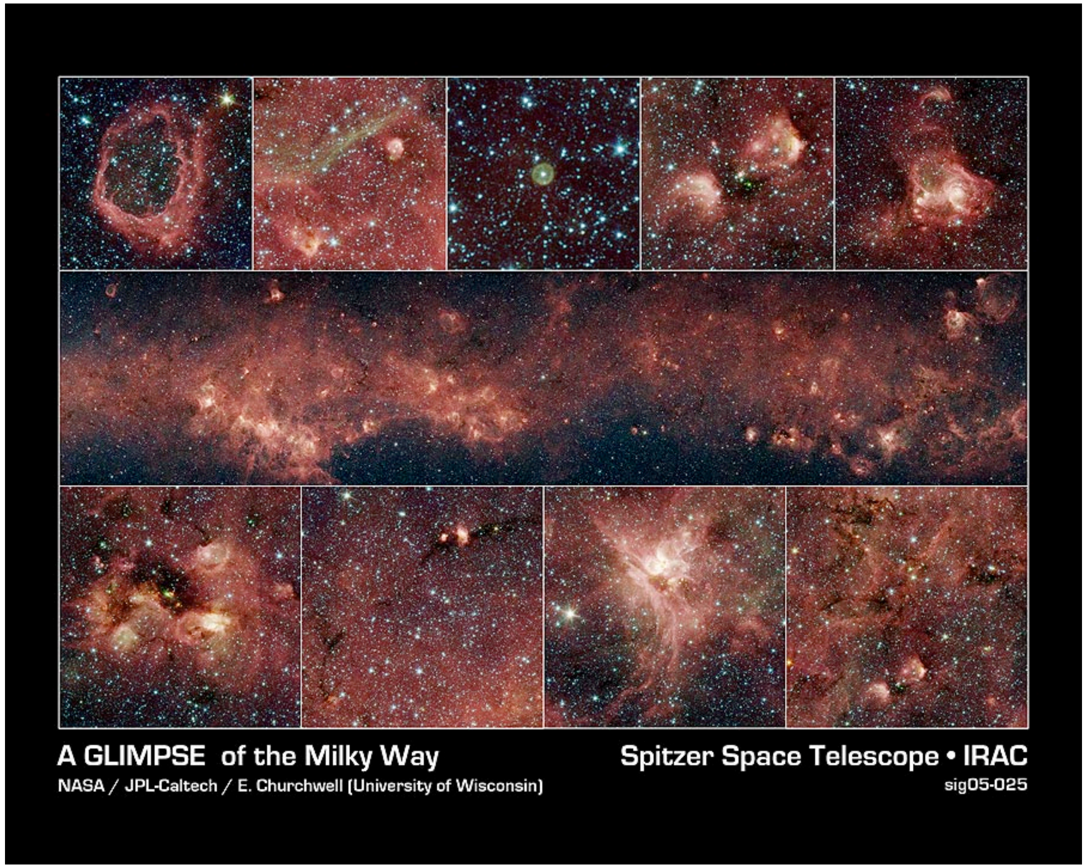
The **interstellar medium** (ISM) is the name for the material that is in space between stars in our Milky Way Galaxy:

- mostly hydrogen and helium
- heavier elements such as carbon
- dust, mostly silicates

The next slide shows examples of dust and gas clouds between the stars in our Milky Way Galaxy.

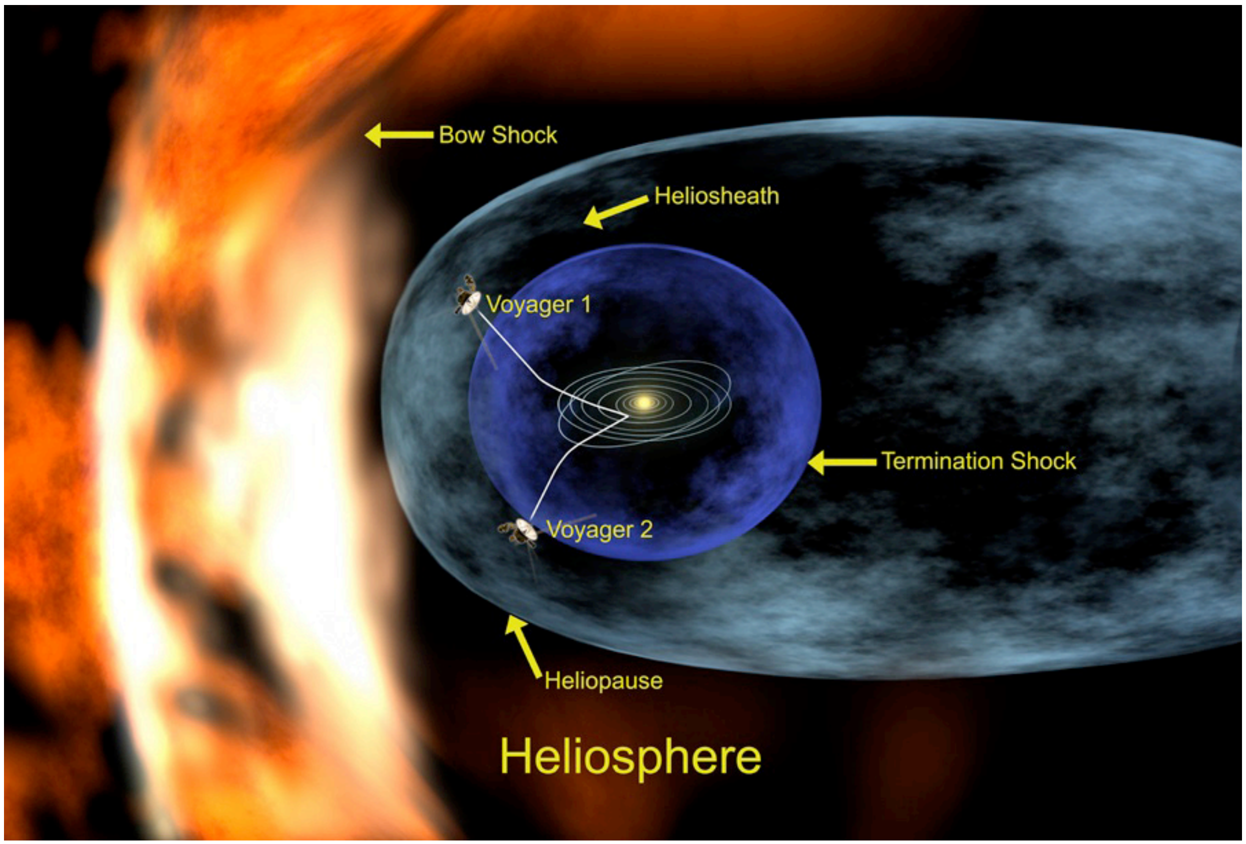
Next slide: An image of interstellar material, imaged by the Spitzer Space Telescope. Slide 18 Image credit: NASA/JPL-Caltech/E. Churchwell (University of Wisconsin)

What is the **interstellar medium**?



This image shows material of the interstellar medium shining in infrared light. The red clouds indicate the presence of large molecules mixed with the dust, which have been illuminated by nearby star formation. White arcs in several of the images show regions where stars are forming. The bubble-shaped dust clouds are created by powerful stellar winds that blow aside the interstellar dust around massive groups of forming stars. Green wisps show the presence of hot hydrogen gas. The small bubble in the top-middle is a planetary nebula – a feature that forms when a red giant star has blown off its outer layers into space, leaving the core of the star, known as a white dwarf, in the middle.

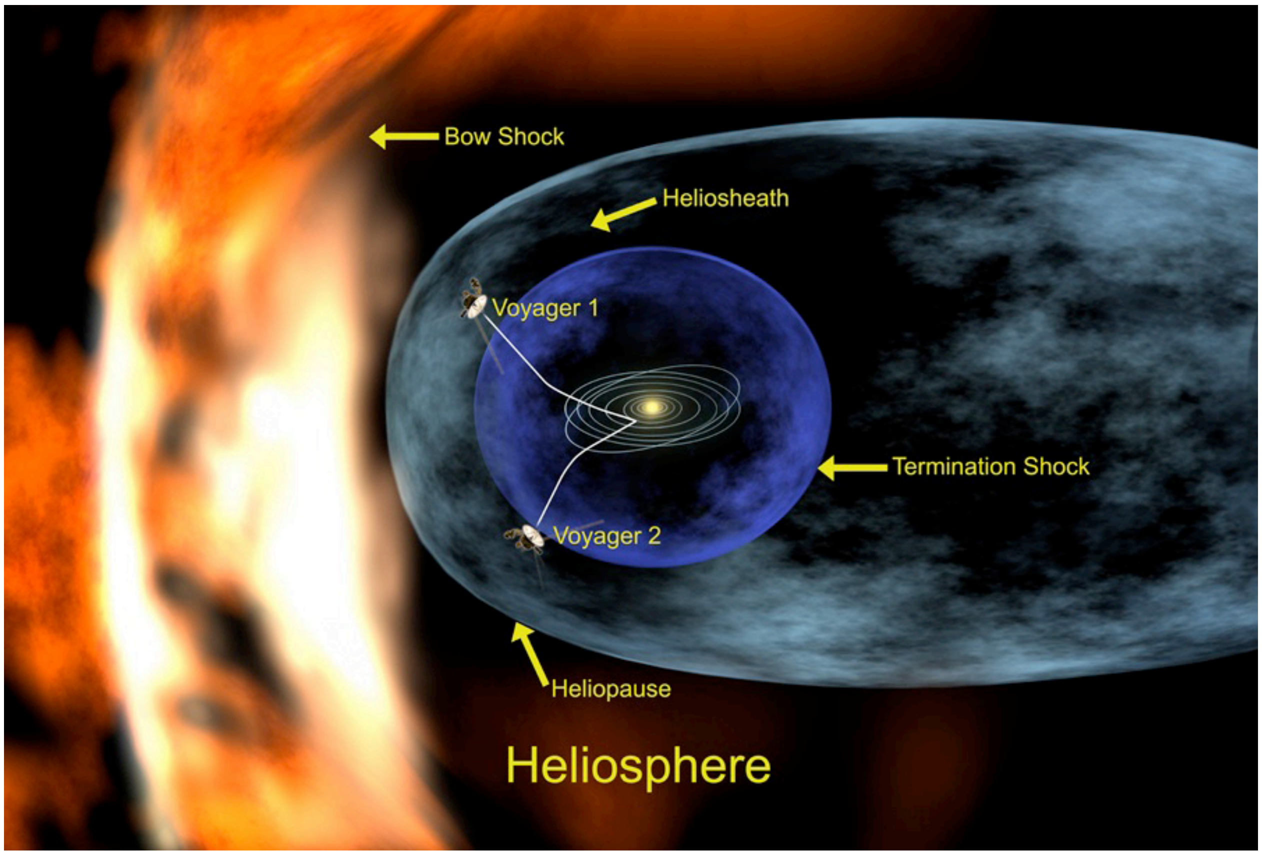
What happens when the **solar wind** and **ISM** collide?



The solar wind blows outward against the ISM and clears out a bubble-like region in this gas. This bubble that surrounds the Sun and the Solar System is called the **heliosphere**.

Image Credit: Walt Feimer, NASA GSFC

What are the parts of the **heliosphere**?



The heliosphere consists of:

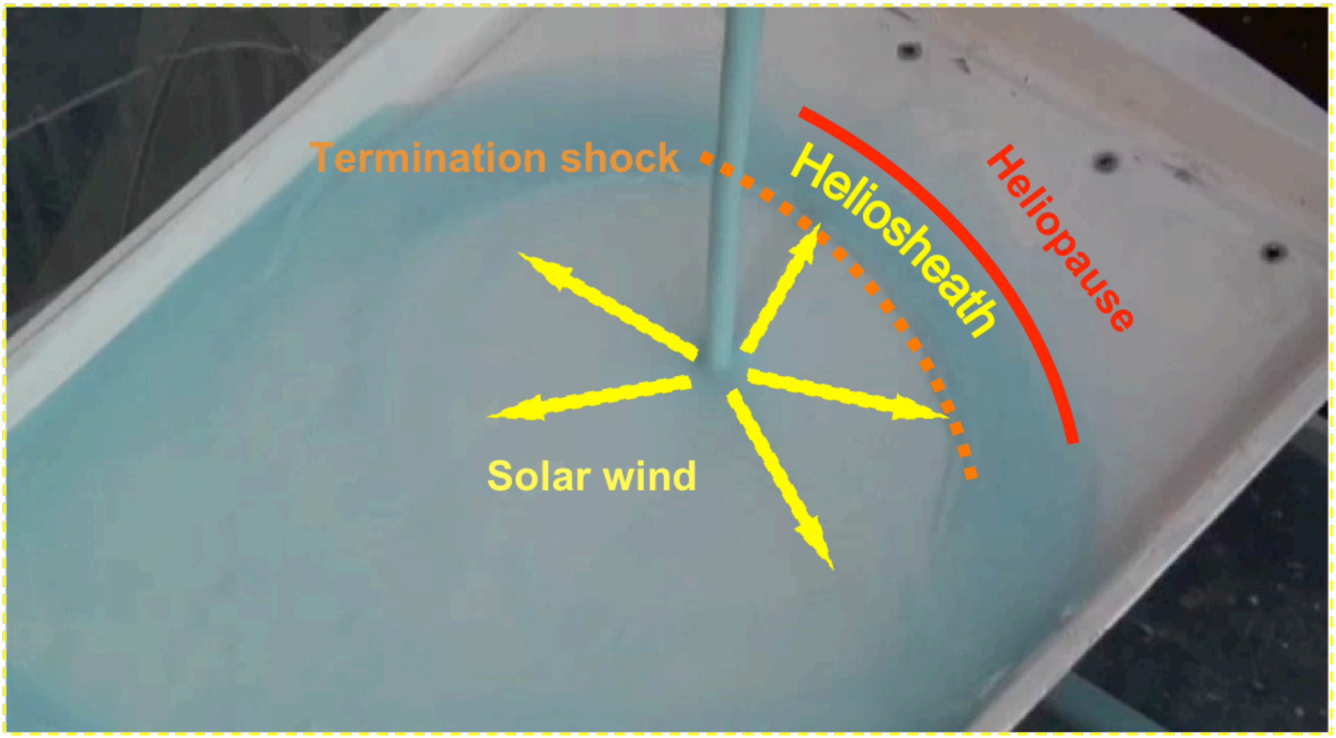
- the **heliopause**, the outermost part of the boundary
- the **termination shock**, the innermost part of the boundary
- the **heliosheath,** the part in between the heliopause and the termination shock.

Image Credit: Walt Feimer, NASA GSFC

A simple 2-D demonstration of the **termination shock**

This movie clip shows a simple 2-dimensional demonstration of the “flowing water termination shock” model. *Movie Credit: IBEX Science Team*

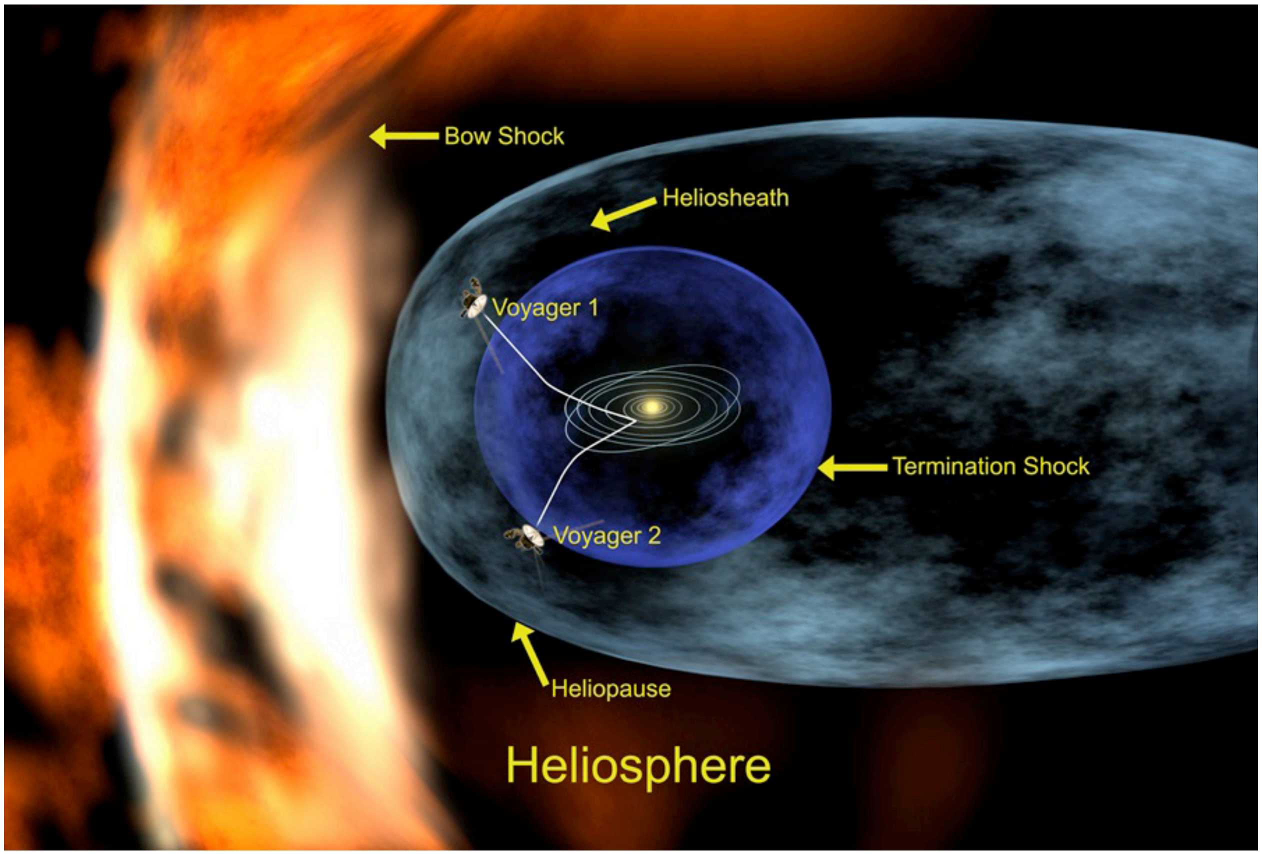
The “flowing water termination shock model” illustrated:



This is an illustrated version of the “flowing water termination shock” model.

Image credit: IBEX Team

What is the **bow shock** or **bow wave**?



Because the Sun is moving relative to the interstellar medium around it, the heliosphere forms a structure in the interstellar medium like the wave formed in front of a moving boat in the ocean or the shock formed by air piling in front of a supersonic airplane. This is called the **bow wave** or **bow shock**.

Image Credit: Walt Feimer, NASA GSFC

Images of bow shocks around other stars

LL Ori, a star in the Orion Nebula

The bright dot near the center of the image is the star. The curved region to its right is its bow shock, stretching about a half light-year in length. LL Orionis is a young star, with stellar winds that are stronger than the solar wind from our middle-aged Sun. These winds collide with material from the center of the Orion Nebula, forming the bow shock.

Image Credit: Hubble Heritage Team

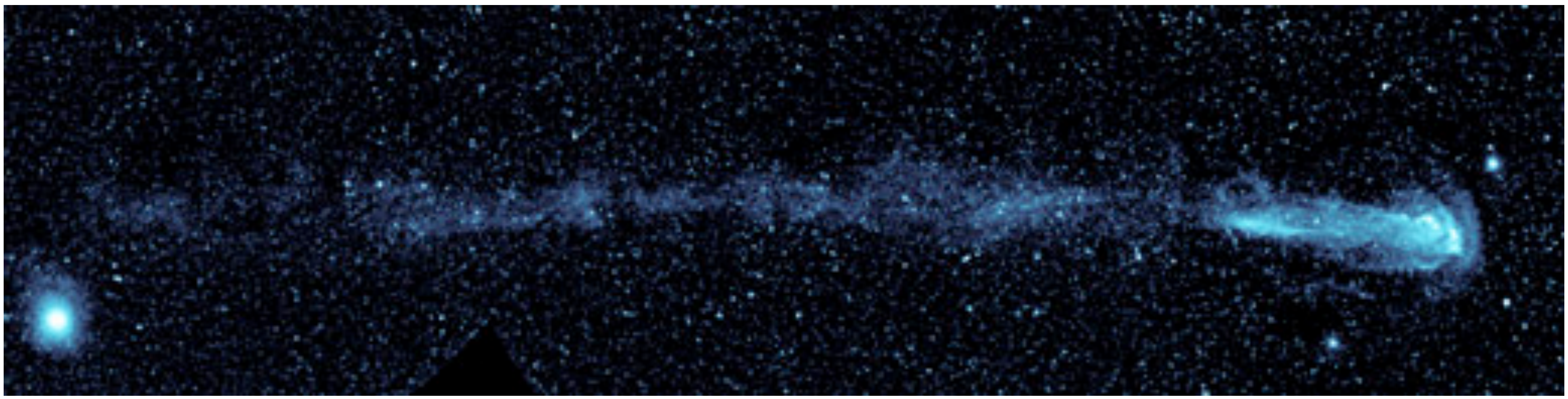
Images of bow shocks around other stars

Zeta Ophiuchi, a star in the constellation Ophiuchus

The blue-white dot in the center of the image is the star Zeta Ophiuchus. Zeta Ophiuchus is a fast-moving young, very hot star that is plowing through a region of interstellar gas and dust (moving from lower right to upper left). The curved orange structure is the bow shock in front of the star.

Image Credit: NASA/JPL-Caltech/UCLA

Image of a bow wave around another star



Omicron Ceti (or Mira), a star in the constellation Cetus. While this structure looks like a comet, the “head” (to the right) is actually the bow wave created by the interstellar gas that piles up in front of Omicron Ceti. The “tail” is bow wave material that is left behind as the star moves extremely quickly through our galaxy.

Image Credit: NASA/JPL-Caltech/C. Martin (Caltech)/M. Seibert (OCIW)

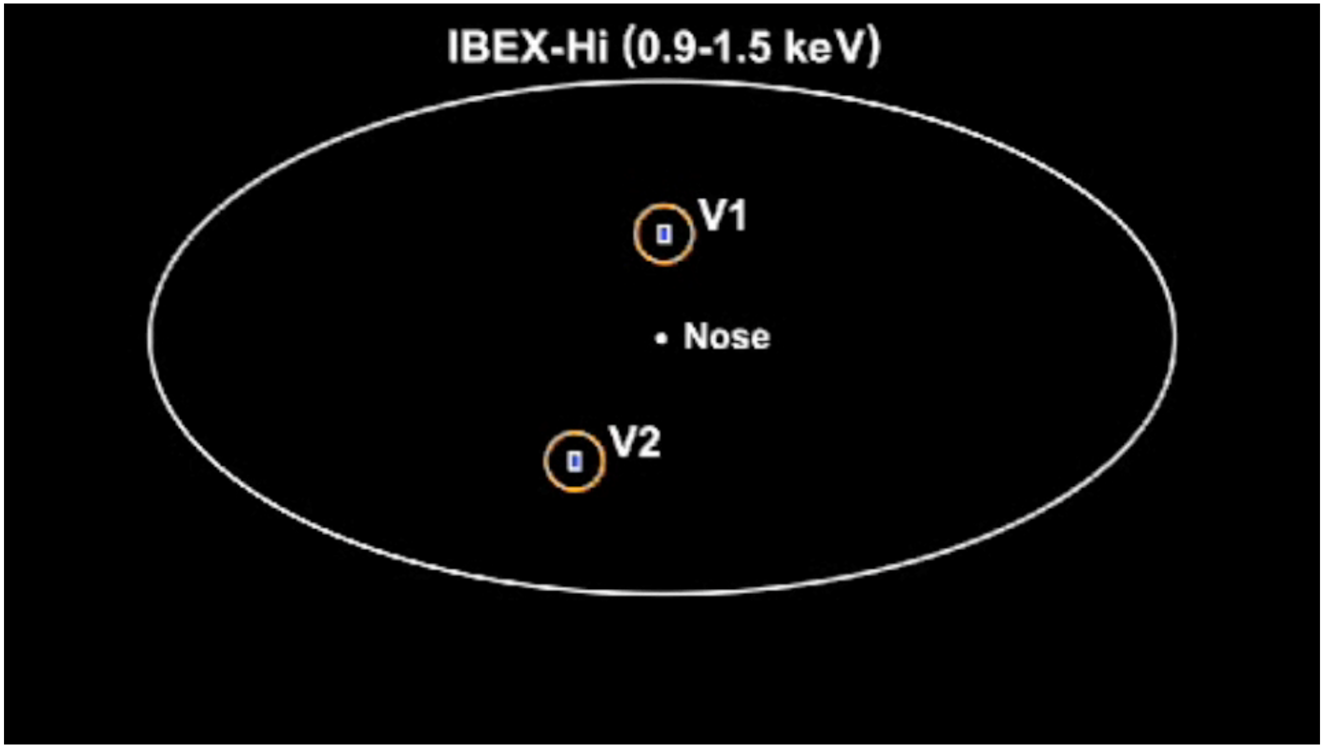
The IBEX Mission

What came before IBEX?

Voyagers 1 and 2 have passed the termination shock. The data from the Voyagers is combined with IBEX's information to create a more complete model of the boundary of our Solar System.

An artist's rendition of the Voyager spacecraft. Image Credit: NASA

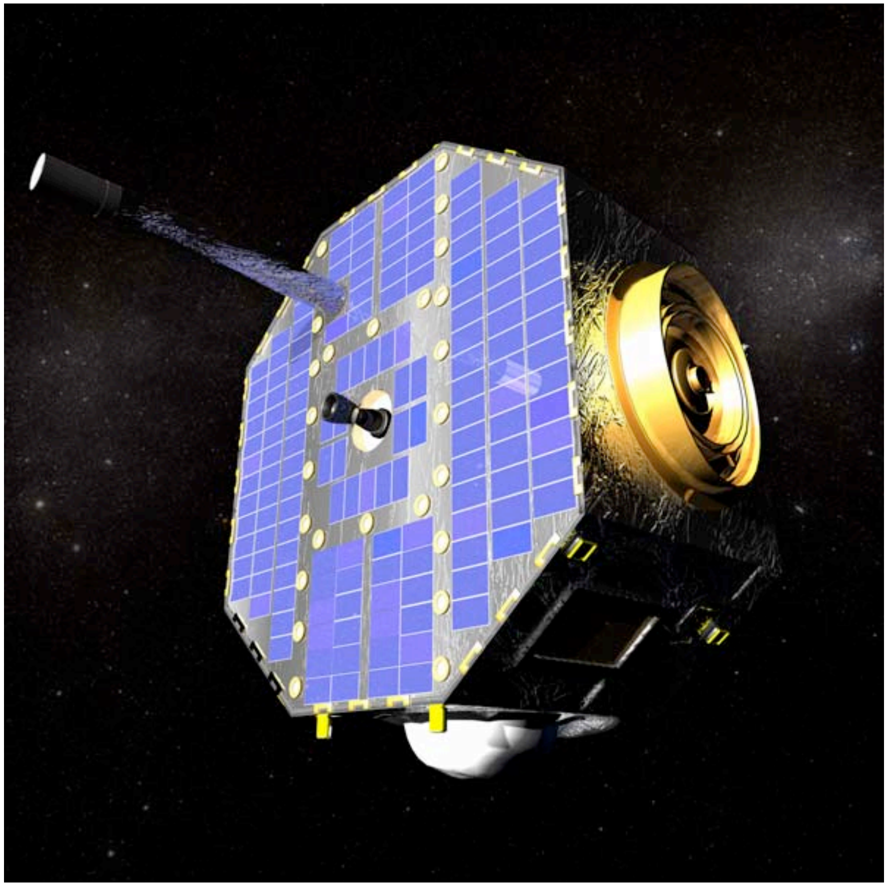
Why is the IBEX mission important?



This movie clip illustrates how the Voyager spacecraft are at our Solar System's boundary but can only sample the conditions at those two specific points. IBEX images the entire sky, giving us an all-sky view of the boundary.

Movie Credit: IBEX Team

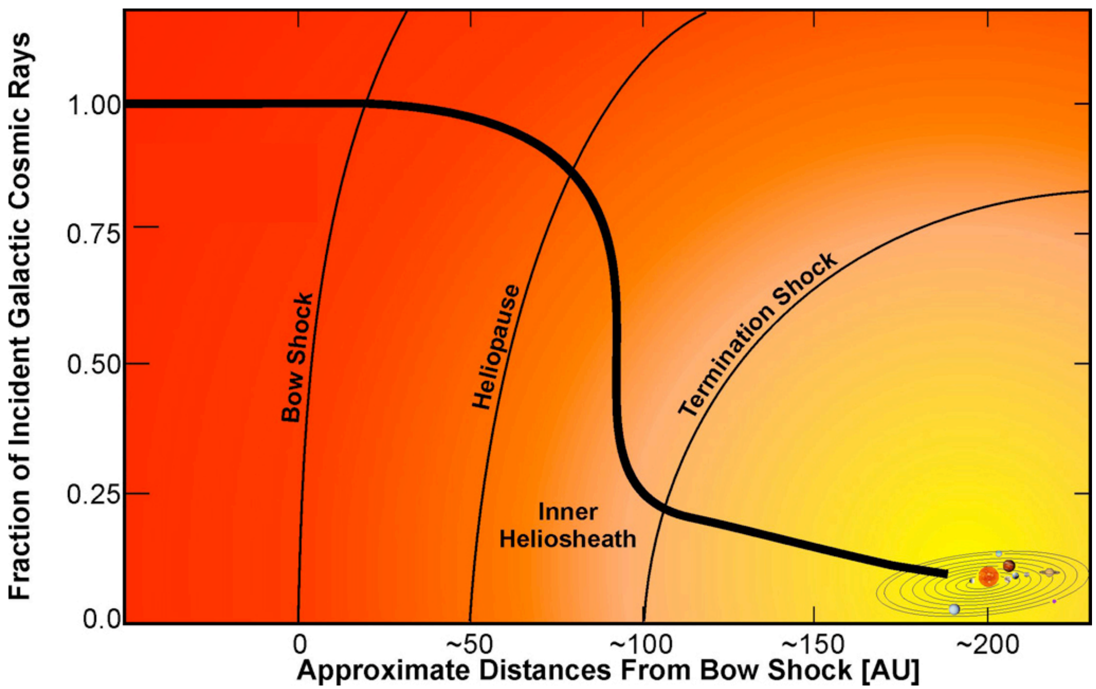
Why else do we need IBEX?



Unlike the images shown in Slides 25, 26, and 27, our heliosphere boundary does not emit light that we can detect, which means it would be impossible to image using conventional telescopes. Instead of collecting light, like other telescopes do, IBEX collects particles coming from the boundary so that we can learn about the processes occurring there.

An artist's rendition of the IBEX spacecraft. Image Credit: Walt Feimer, NASA GSFC

Why is the IBEX mission important?



The boundary of the Solar System protects us from harmful cosmic rays. Without it, four times more cosmic rays would enter our Solar System and potentially damage our ozone layer and DNA. It is important to study this region to know how this protective region works.

A graph of the percentages of cosmic rays that reach various parts of our Solar System. Image Credit: IBEX Science Team

How did IBEX get into space?

IBEX began its ride from Kwajalein Atoll, Marshall Islands in the middle of the Pacific Ocean on October 19, 2008.

Kwajalein Atoll, Marshall Islands. Image Credit: Dirk HR Spennemann, Digital Micronesia

How did IBEX get to space?

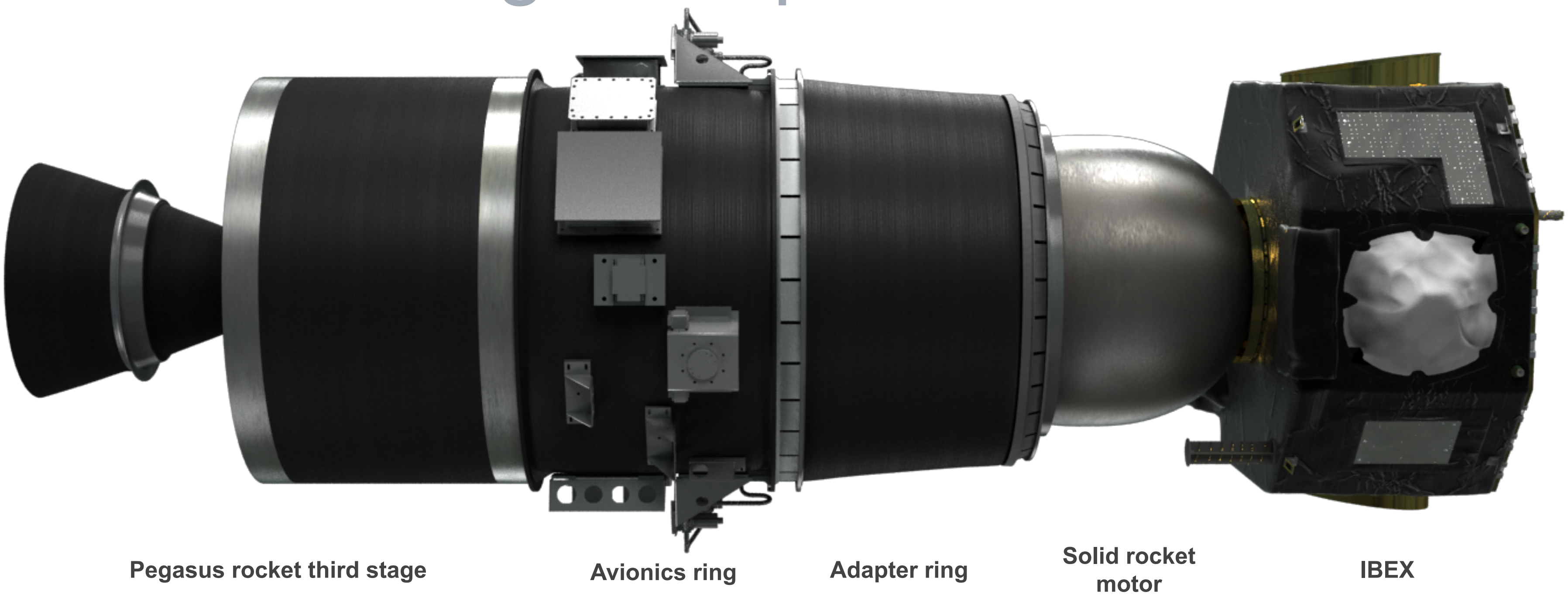
Kwajalein Atoll is part of the Marshall Islands in the Pacific Ocean, southwest of Hawaii. *Image Credit: CIA website reference maps.*

How did IBEX get to space?

IBEX used a Pegasus rocket launched from an L-1011 airplane. This is an inexpensive launch option, but can only be used for smaller spacecraft.

An artist's rendition of the launch of a Pegasus rocket. Image Credit: The Adler Planetarium

How did IBEX get to space?



This image shows a digital rendering of the third stage of the Pegasus rocket (far left), the avionics ring (the portion with the attached cube-shapes), the adapter ring that connected the Pegasus third stage to the solid rocket motor & IBEX, the IBEX solid rocket motor (the gray bell-shaped portion and the ring to its right), and the IBEX satellite itself (far right). Not shown in this rendering are the first and second stages of the Pegasus launch system and the rocket fairing that covered the entire system.

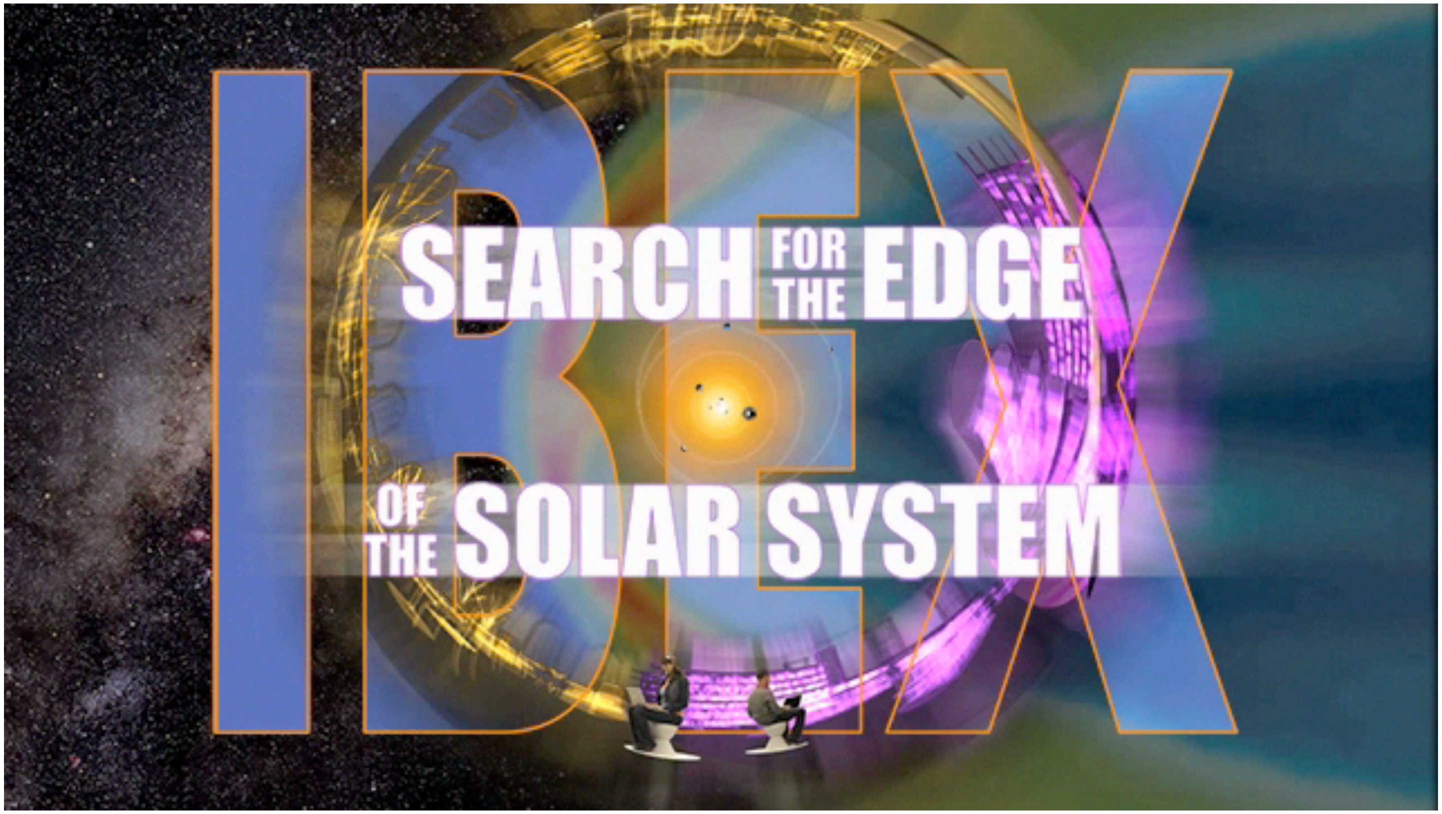
Image Credit: *IBEX Team*

How did IBEX get to space?

After the Pegasus' rockets were done firing and were jettisoned, the smaller solid rocket motor (left) propelled the IBEX spacecraft (right) to its intended orbital location.

Image Credit: IBEX Team

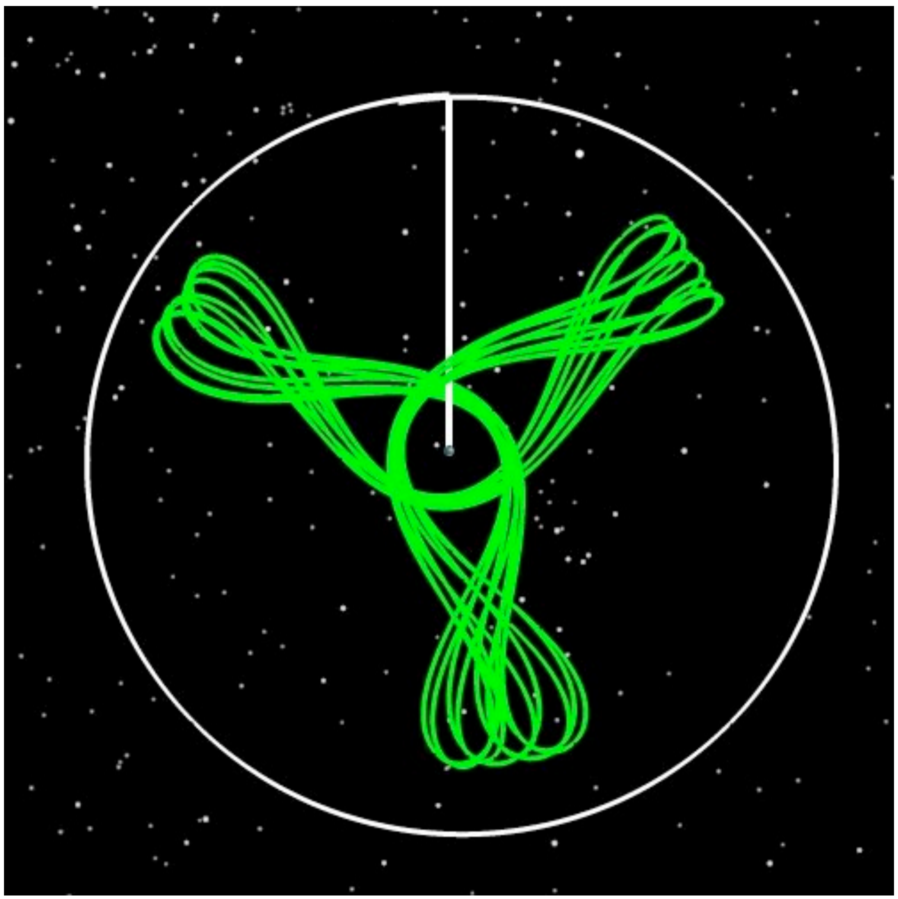
How did IBEX get to space?



This movie clip shows an animation of the launch of the IBEX spacecraft on October 19, 2008. (*Please note that most of the clip contains no narration, only accompanying music.)*

Movie Credit: IBEX Team/Adler Planetarium, from the "IBEX: Search for the Edge of the Solar System" planetarium show

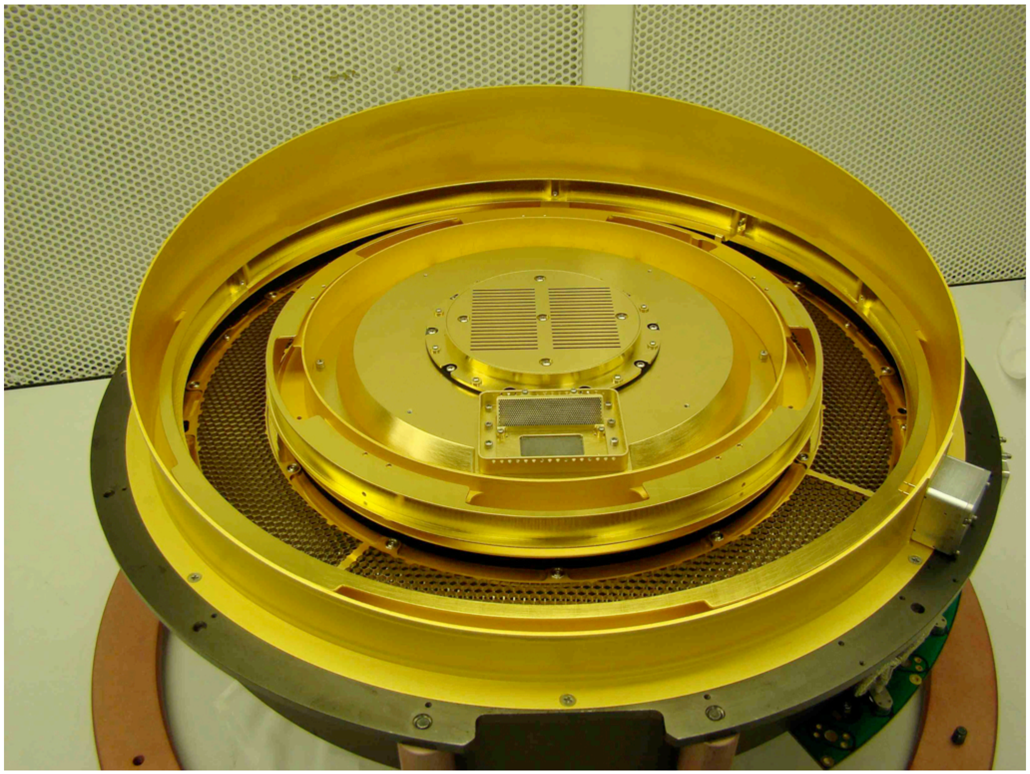
Where does IBEX orbit?



IBEX orbits Earth. In June 2011, IBEX concluded a maneuver that placed it into a new orbital configuration, represented by the image to the left. The farthest point of IBEX's orbit is still around 200,000 miles (320,000 kilometers) from Earth. The closest point of IBEX's orbit is now about 30,000 miles (48,000 kilometers) from Earth, above the harsh environment of Earth's radiation belts. IBEX completes one of these orbital "lobes" in 9.1 days, and completes three orbits every 27.3 days, which is the same amount of time for the Moon to orbit Earth once. The benefit of this new orbit is that the spacecraft's orbit is incredibly stable and is not affected by the Moon's gravitational pull, as it was to a large extent prior to the maneuver.

Image Credit: Applied Defense Solutions

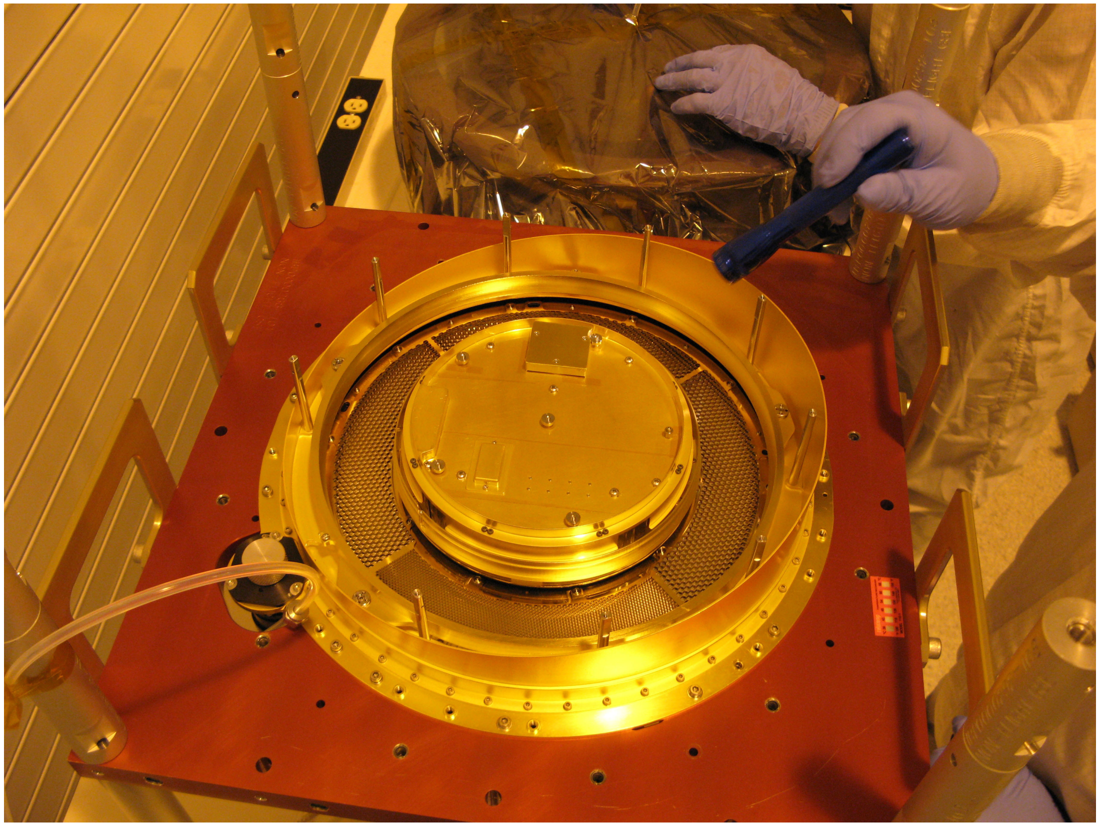
How does IBEX collect data?



IBEX uses two sensors, IBEX-Hi and IBEX-Lo, to collect energetic neutral atoms made from solar wind particles. This is an image of IBEX-Hi, prior to its integration with the rest of the IBEX spacecraft.

Image Credit: IBEX-Hi team

How does IBEX collect data?

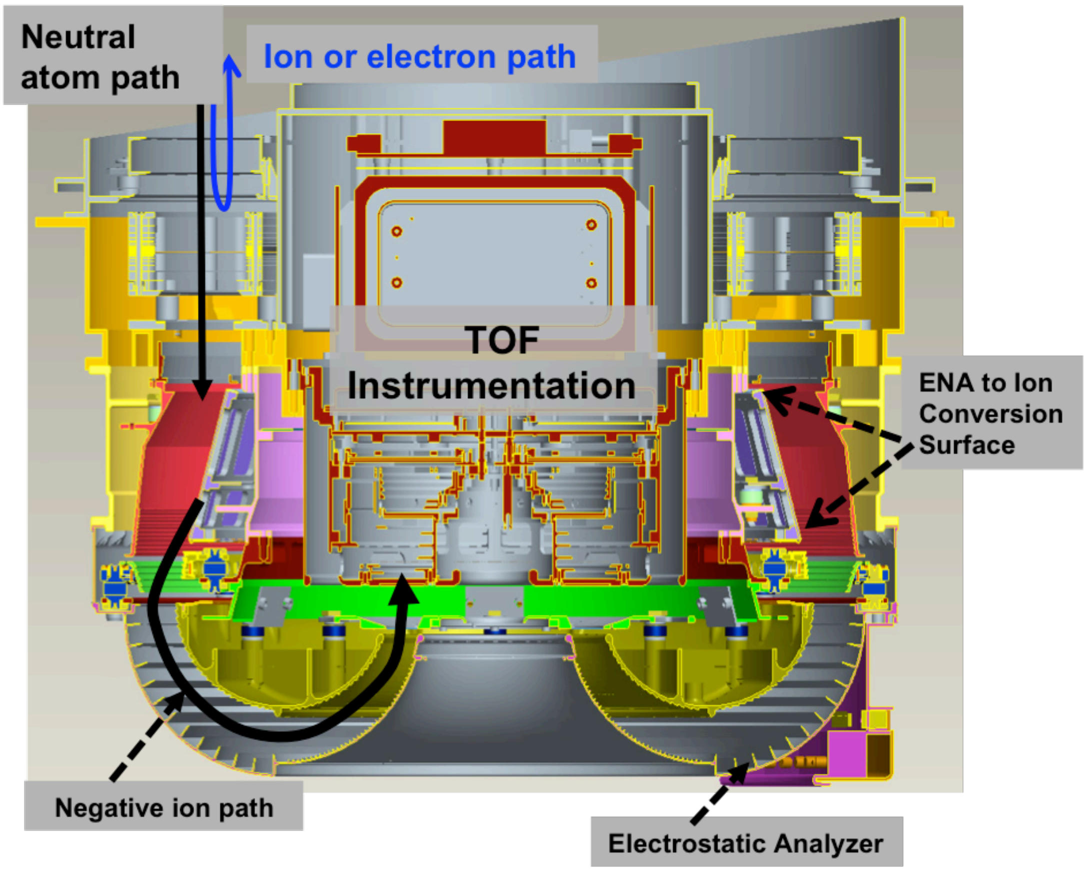


IBEX uses two sensors, IBEX-Hi and IBEX-Lo, to collect energetic neutral atoms made from solar wind particles. This is an image of IBEX-Lo, prior to its integration with the rest of the IBEX spacecraft.

Image Credit: IBEX-Lo Team

How does IBEX collect data?

Cross Section of IBEX-Lo

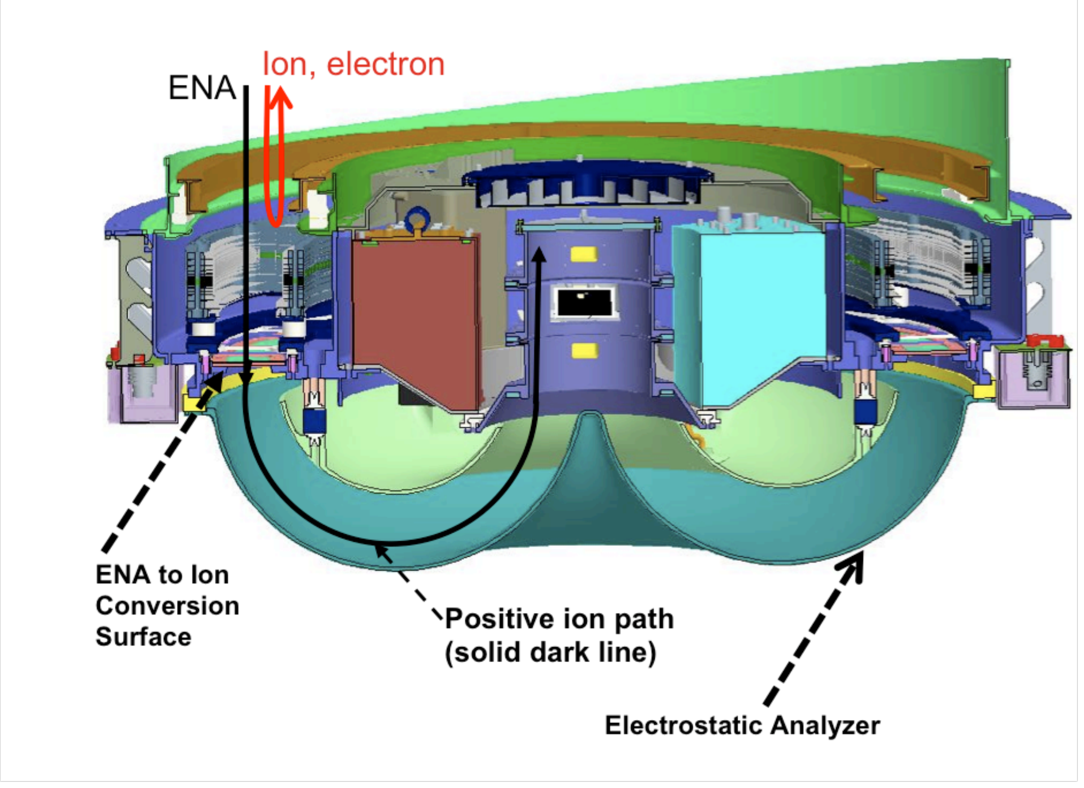


This is a cutaway drawing of the IBEX-Lo sensor.

Image Credit: IBEX-Lo Team

How does IBEX collect data?

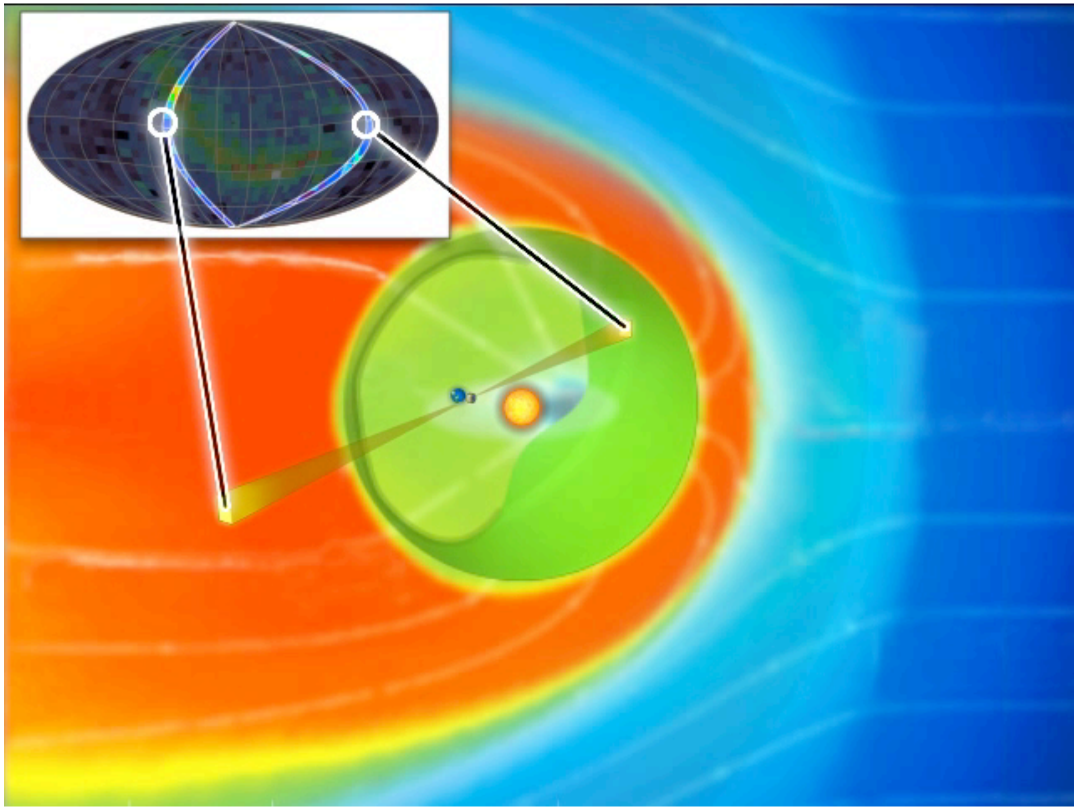
Cross Section of IBEX-Hi



This is a cutaway drawing of the IBEX-Hi sensor.

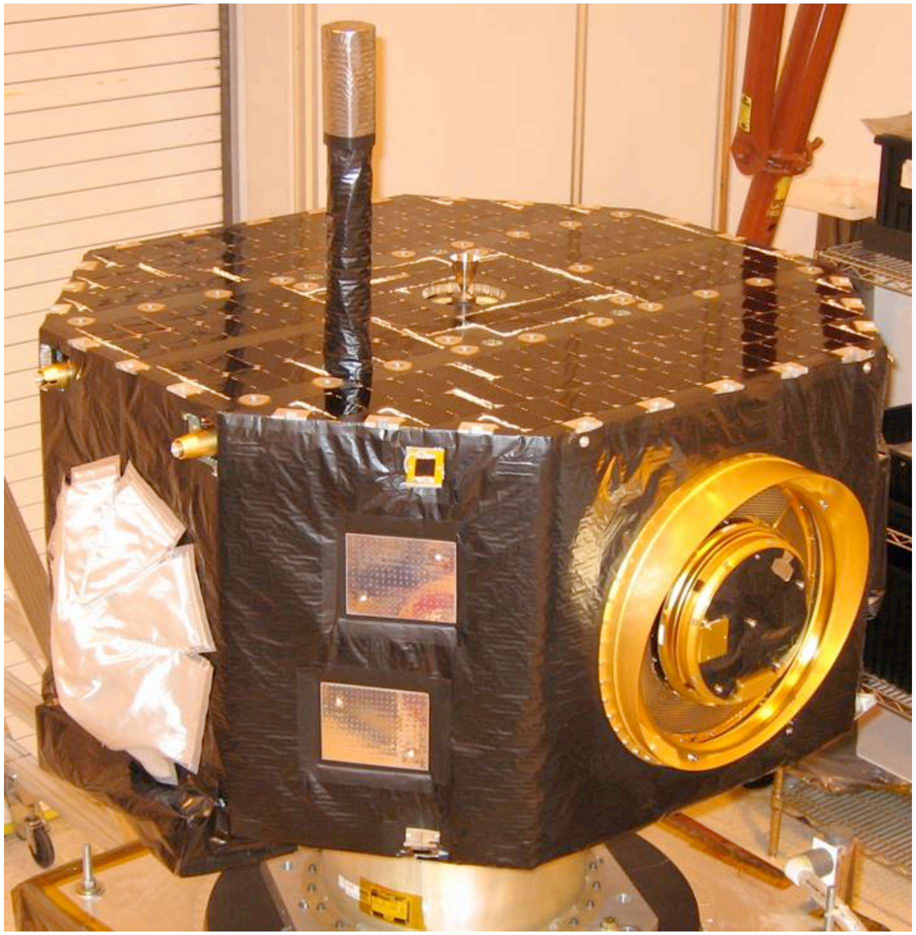
Image Credit: IBEX-Hi Team

How does IBEX data create a map of the boundary?



This movie clip shows an artist's rendition of how IBEX makes a map of our Solar System boundary. *Movie Credit: IBEX Team*

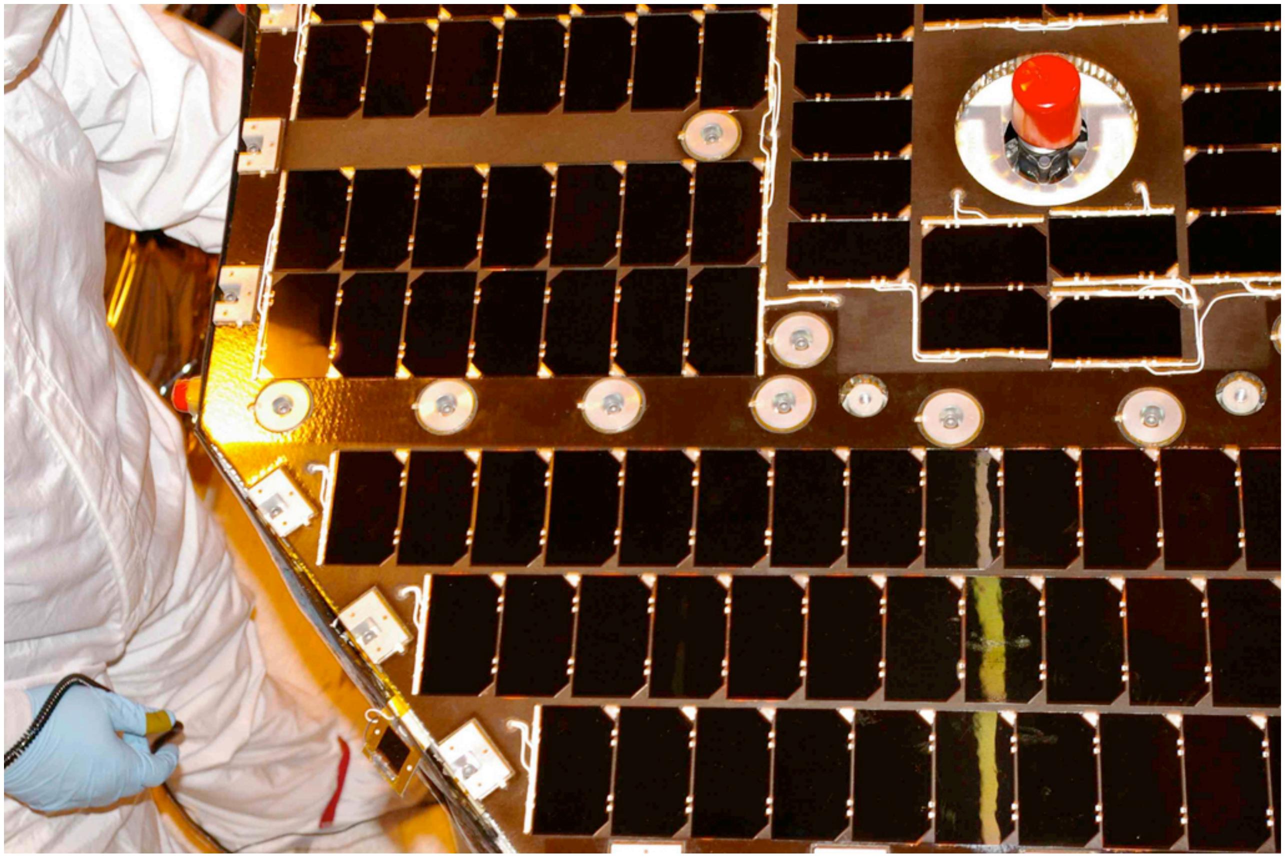
From where does IBEX get its power?



IBEX uses a solar panel consisting of many solar cells to collect energy from the Sun.

The IBEX spacecraft. The solar panel is on the top.
Image Credit: Walt Feimer, NASA GSFC

From where does IBEX get its power?



This is a close-up image of the IBEX spacecraft's solar panel with its individual solar cells. The red object in the middle is a protective cap on a small thruster (rocket) that was removed prior to launch.

Image Credit: Orbital Sciences Corporation

IBEX Science Results

The next slide illustrates the science results anticipated prior to the IBEX mission, and the six slides following it show several of the heliosphere boundary images released so far. Please refer to the Notes section of each slide for additional information.

What did the science team predict?

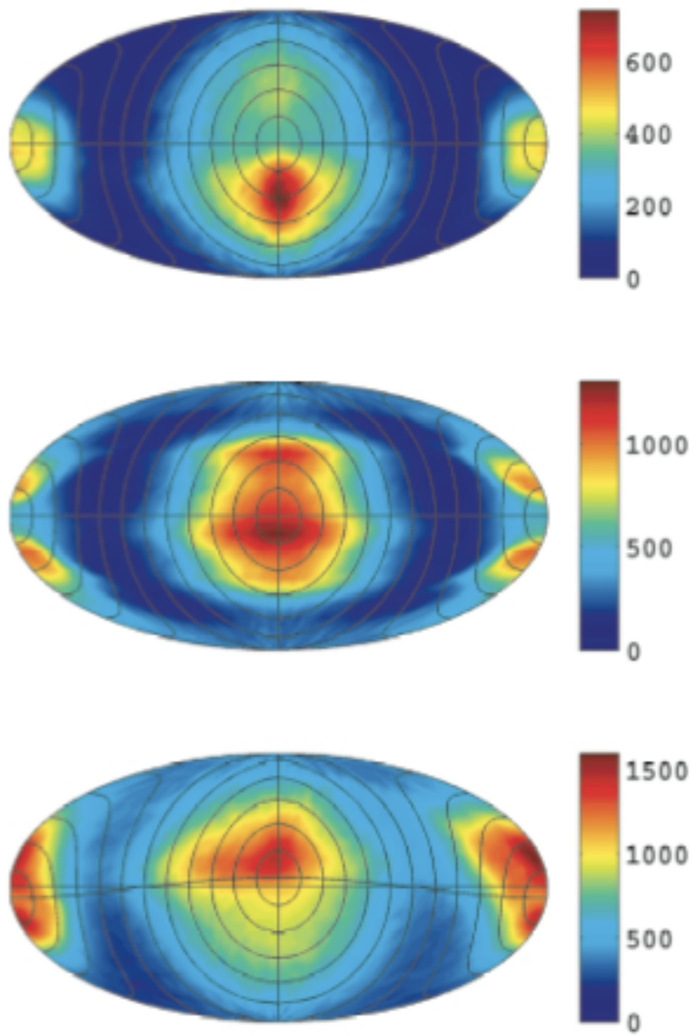
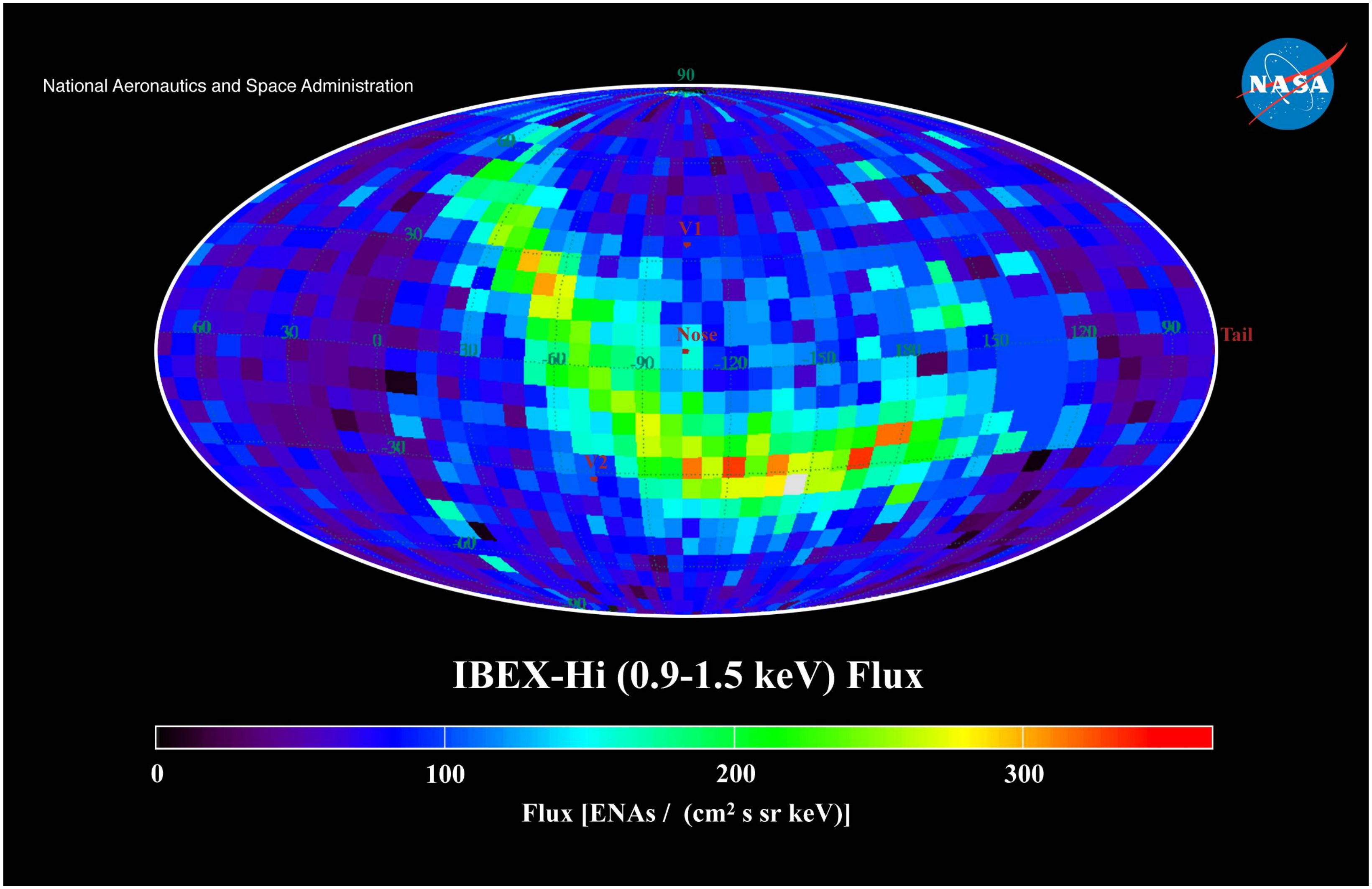


FIG. 3.—All-sky ENA maps (Mollweide projection; see Fig. 1 for details) for the three plasma profiles shown in Fig. 2. Units of ENA flux are $(cm^2\ s\ sr\ keV)^{-1}$.

Before the IBEX mission, scientists used computers to make these models and simulations (based on the <u>very scant</u> evidence that they already had) to describe the processes occurring at the boundary of our Solar System. These illustrations show several possible simulations of the distribution of Energetic Neutral Atoms that scientists thought they might see in the IBEX heliosphere boundary images.

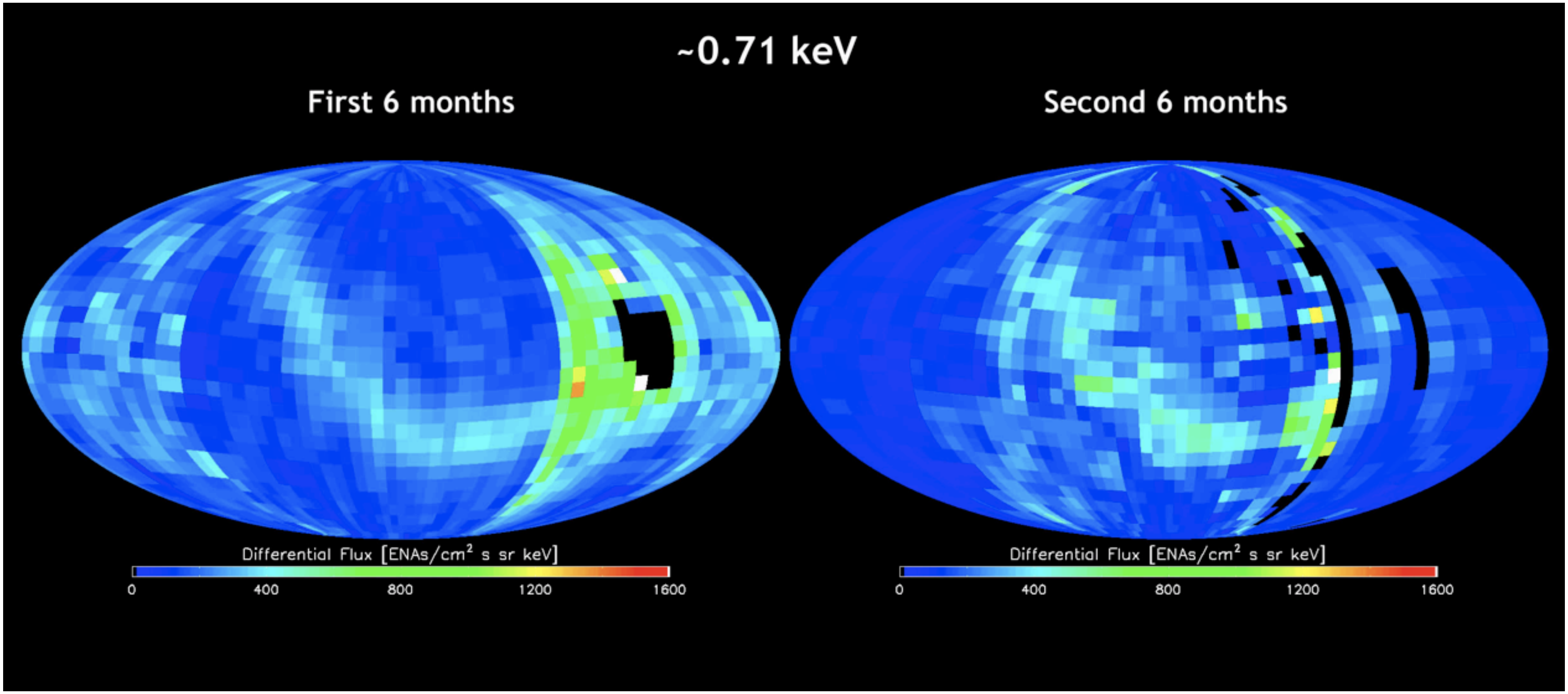
Image Credit: From Heerikhuisen, J., et al published in the Astrophysical Journal, 655: L53-56, 2007 January 20.

What did IBEX observe?



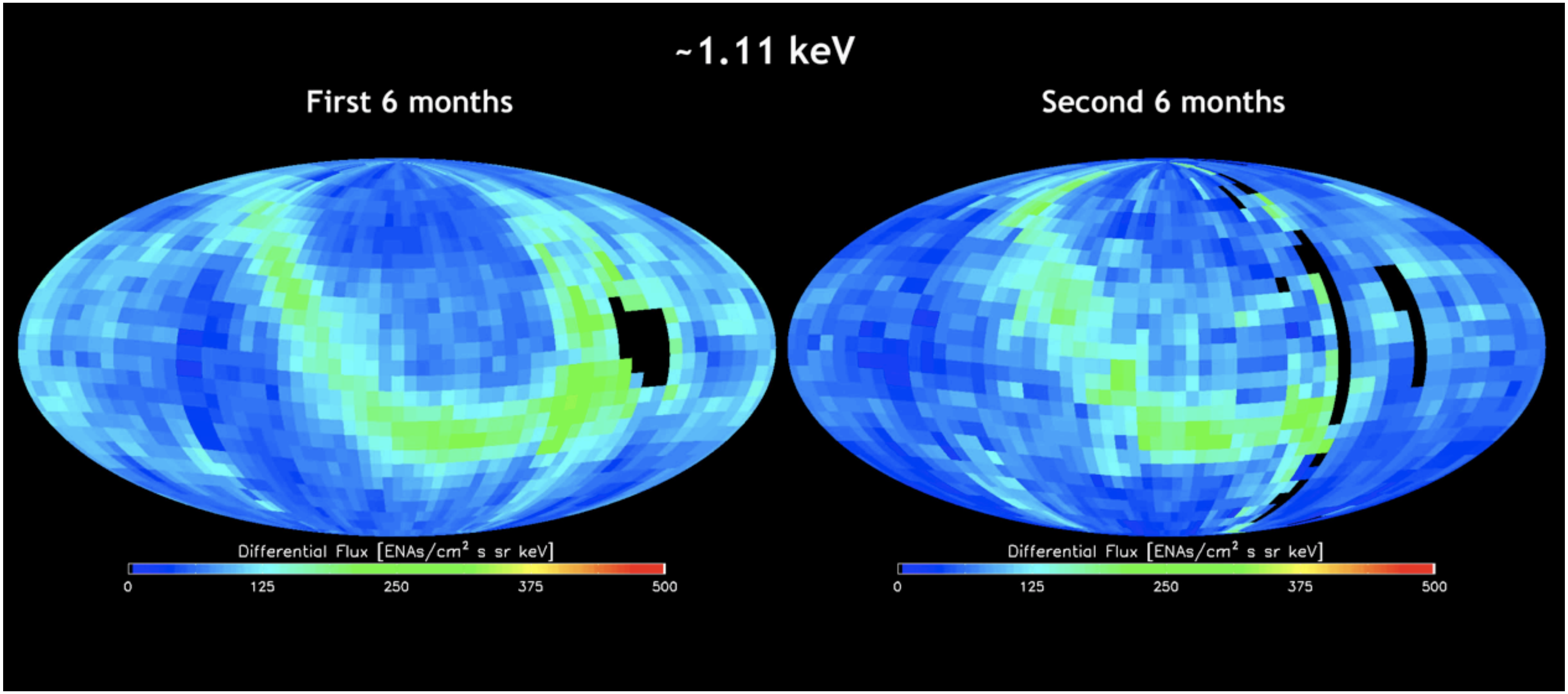
This is one of the first five IBEX heliosphere boundary images released in October 2009. It shows an unexpected feature, called the “IBEX Ribbon”, which is a region of enhanced ENA emissions shown by the light blue, green, yellow, and red areas.
Image Credit: *SwRI/IBEX team*

What did IBEX observe?



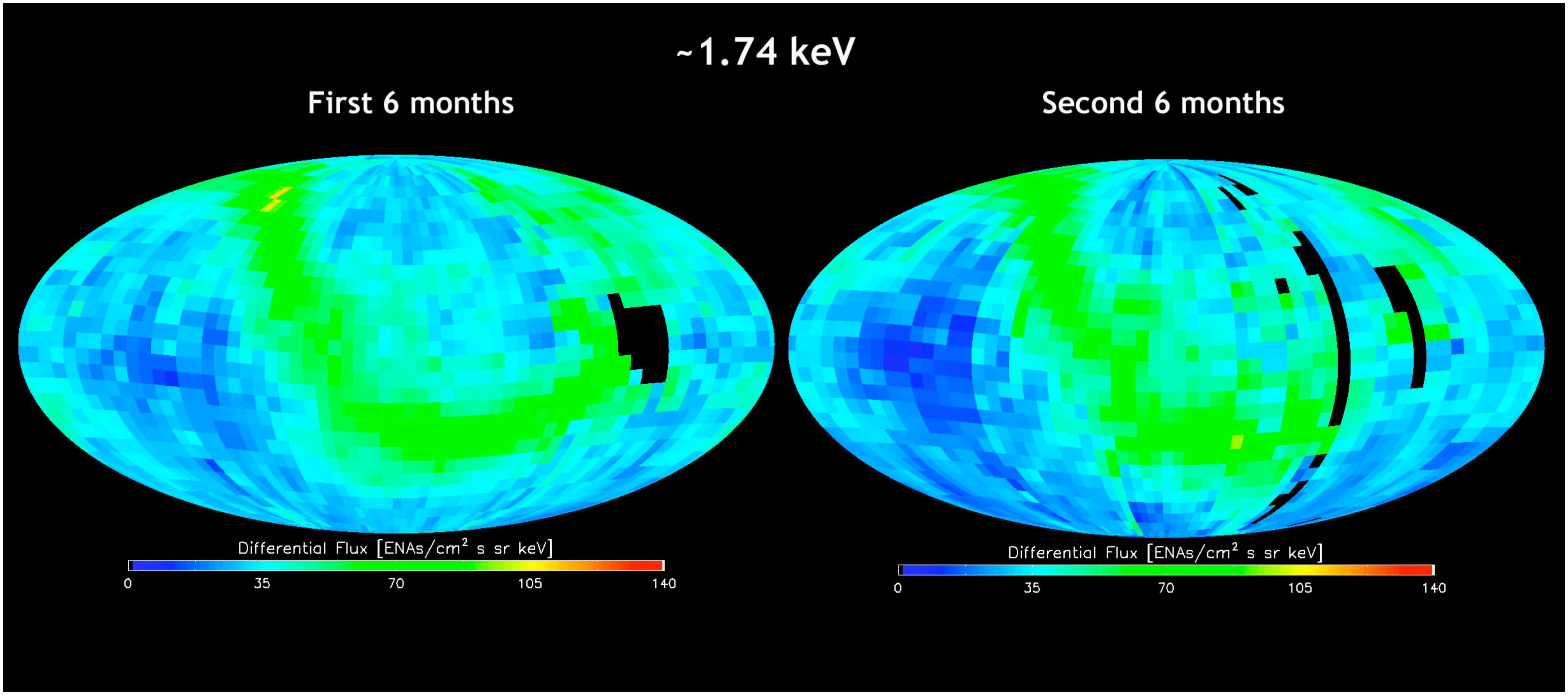
The images on this slide show a comparison of one image from the first set of IBEX heliosphere boundary maps (left) and one image from the second set of maps (right) at the same energy level (~. 71 keV), six months apart. The large-scale IBEX Ribbon structure and the overall sky pattern of ENAs are visible in both maps, though the IBEX team noted that the ribbon feature does not look exactly the same in both maps. This suggests that the region producing the ribbon evolved, even over this short six-month timescale. *Image Credit: SwRI/IBEX team*

What did IBEX observe?



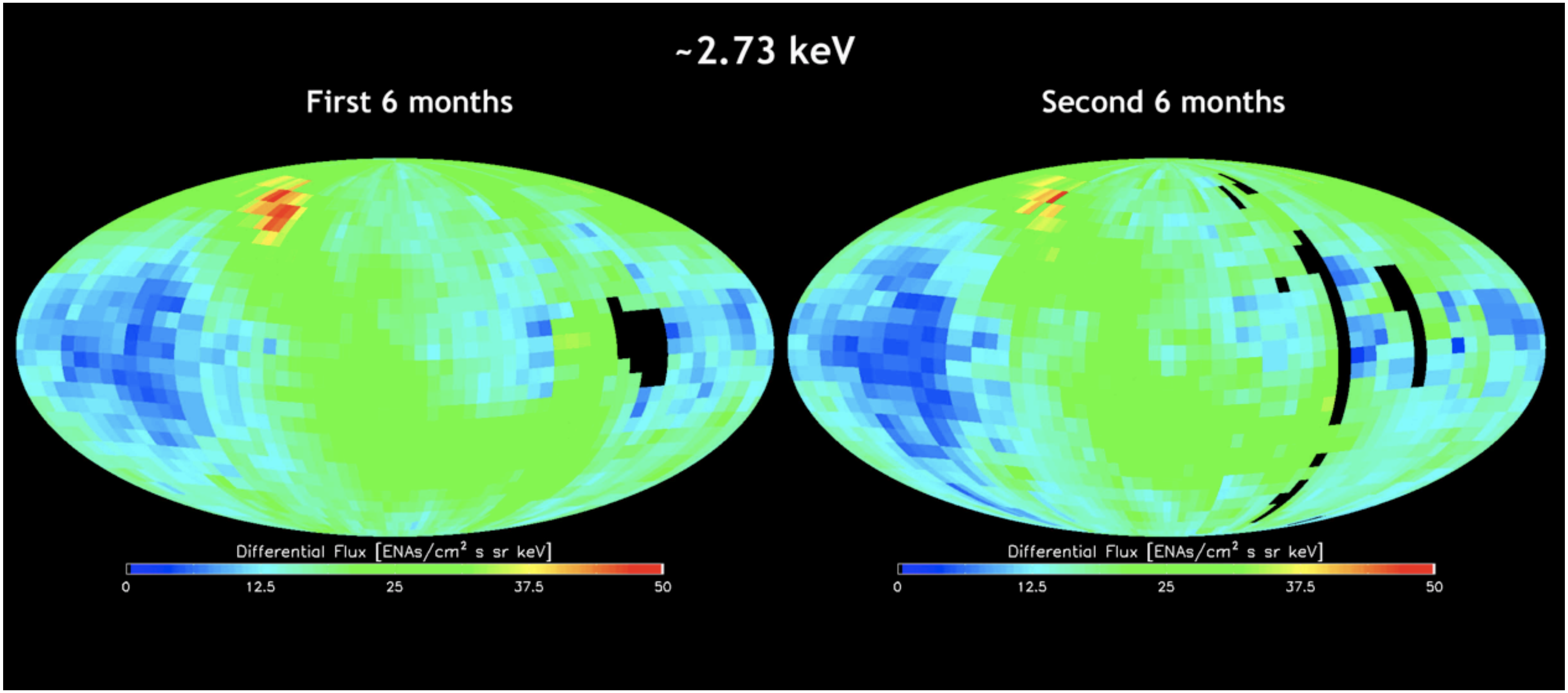
The images on this slide show a comparison of one image from the first set of IBEX heliosphere boundary maps (left) and one image from the second set of maps (right) at the same energy level (~1.11 keV), six months apart. The large-scale IBEX Ribbon structure and the overall sky pattern of ENAs are visible in both maps, though the IBEX team noted that the ribbon feature does not look exactly the same in both maps. This suggests that the region producing the ribbon evolved, even over this short six-month timescale. *Image Credit: SwRI/IBEX team*

What did IBEX observe?



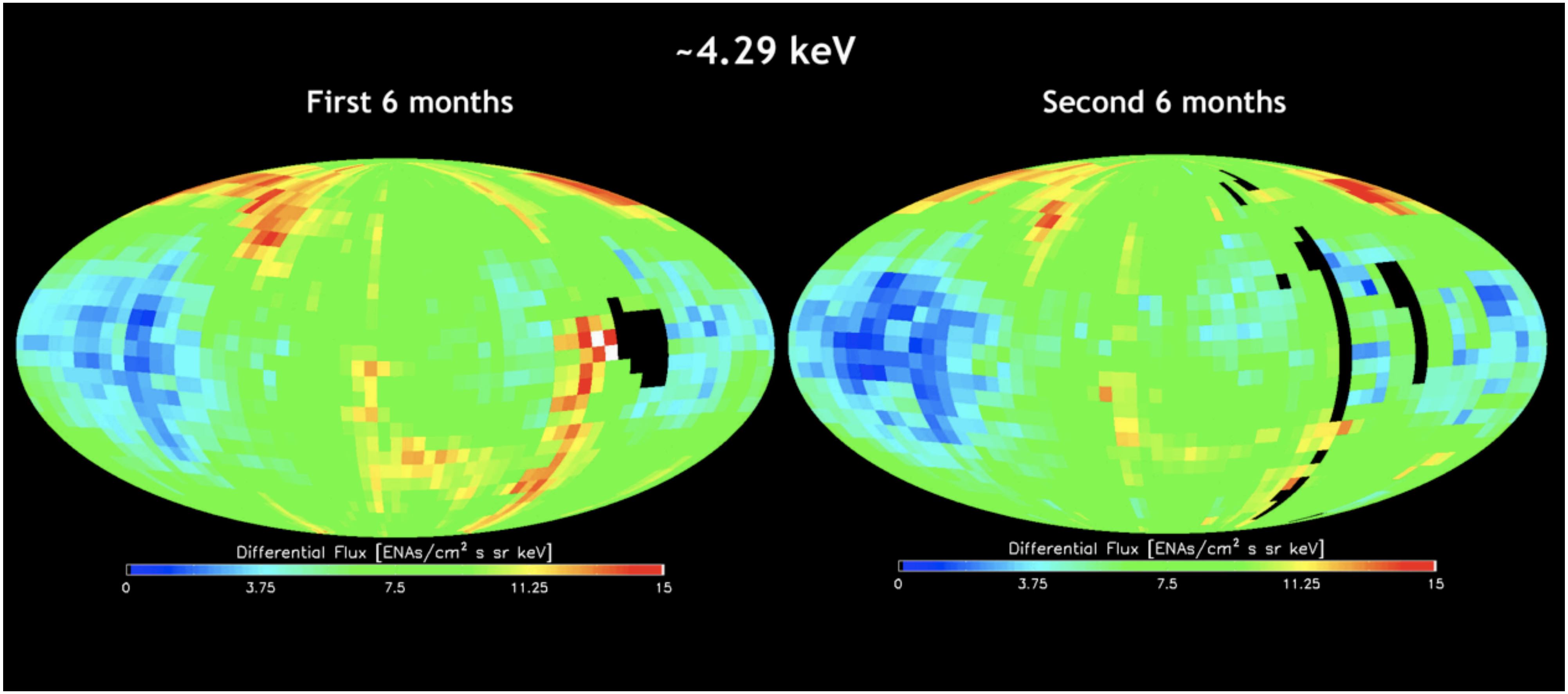
The images on this slide show a comparison of one image from the first set of IBEX heliosphere boundary maps (left) and one image from the second set of maps (right) at the same energy level (~1.74 keV), six months apart. The large-scale IBEX Ribbon structure and the overall sky pattern of ENAs are visible in both maps, though the IBEX team noted that the ribbon feature does not look exactly the same in both maps. This suggests that the region producing the ribbon evolved, even over this short six-month timescale. *Image Credit: SwRI/IBEX team*

What did IBEX observe?



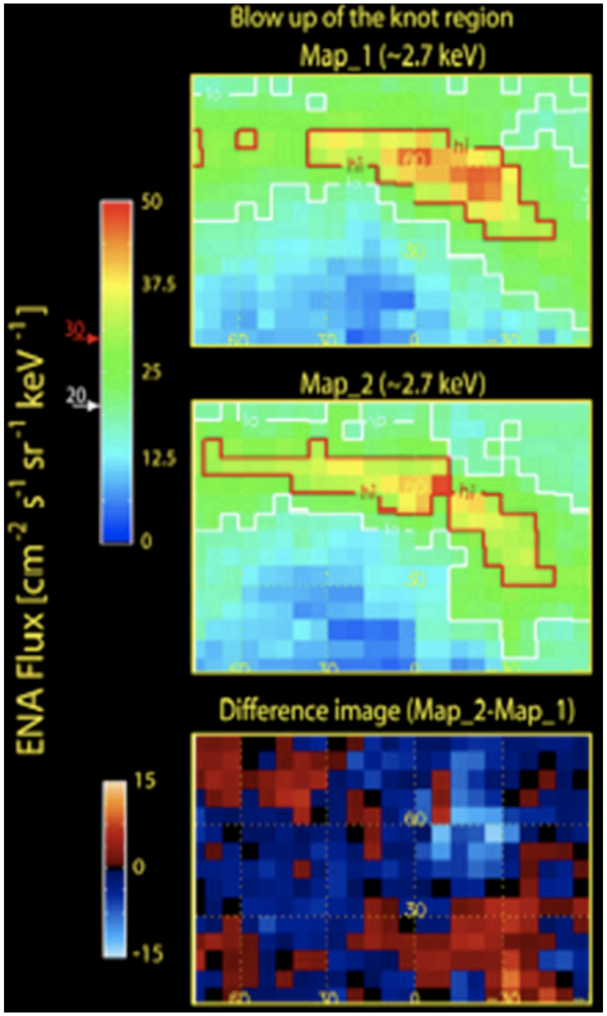
The images on this slide show a comparison of one image from the first set of IBEX heliosphere boundary maps (left) and one image from the second set of maps (right) at the same energy level (~2.73 keV), six months apart. The large-scale IBEX Ribbon structure and the overall sky pattern of ENAs are visible in both maps, though the IBEX team noted that the ribbon feature does not look exactly the same in both maps. This suggests that the region producing the ribbon evolved, even over this short six-month timescale. *Image Credit: SwRI/IBEX team*

What did IBEX observe?



The images on this slide show a comparison of one image from the first set of IBEX heliosphere boundary maps (left) and one image from the second set of maps (right) at the same energy level (~4.29 keV), six months apart. The large-scale IBEX Ribbon structure and the overall sky pattern of ENAs are visible in both maps, though the IBEX team noted that the ribbon feature does not look exactly the same in both maps. This suggests that the region producing the ribbon evolved, even over this short six-month timescale. *Image Credit: SwRI/IBEX team*

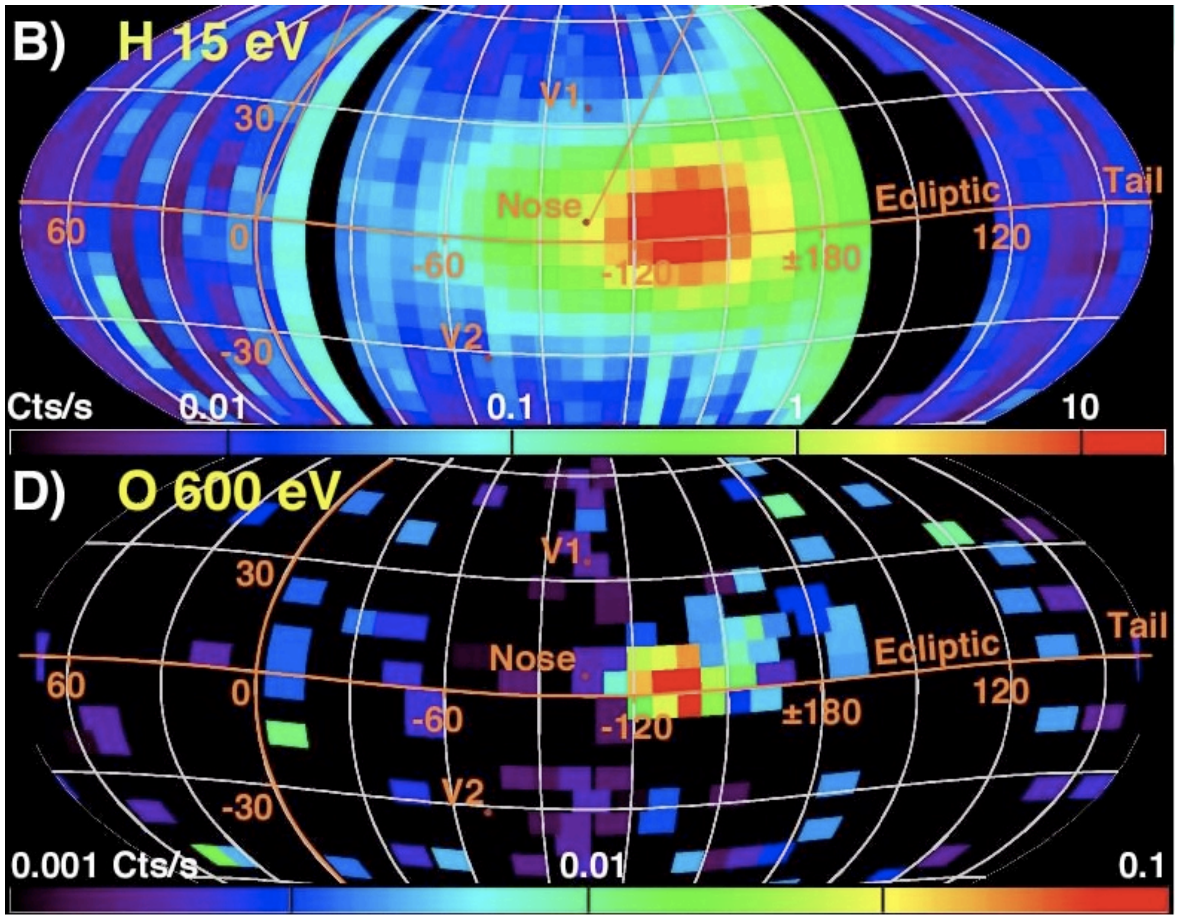
What else have the IBEX maps shown us?



This is a close-up of a portion of the heliosphere boundary images showing change over time in the amount of energetic neutral atoms detected in one part of the IBEX Ribbon. In just six months, the “knot” region (here, outlined in red) showed decreased ENA emissions and appeared to have spread out a bit.

Image Credit: McComas, et al. (2010), Journal of Geophysical Research

What else have the IBEX maps shown us?



This image shows the first detections of interstellar hydrogen and oxygen drifting in from the interstellar medium. The concentration of red and yellow in this image shows the hydrogen (top image) and oxygen (bottom image) detected by IBEX.

Image Credit: McComas, et al. (2009) and Science

What is causing the "IBEX Ribbon"?

We do not yet know. The IBEX science team is considering several different explanations for the IBEX ribbon based on the data gathered to date. One of them is that the magnetic field in our area of the Milky Way Galaxy (represented by the black lines in the image) is pushing the hardest on the portion of the heliosphere boundary where the ribbon has been detected, producing more energetic neutral atoms in that region. More data is needed from IBEX, however, to determine whether this theory, or one of the others, fits the observed data best.

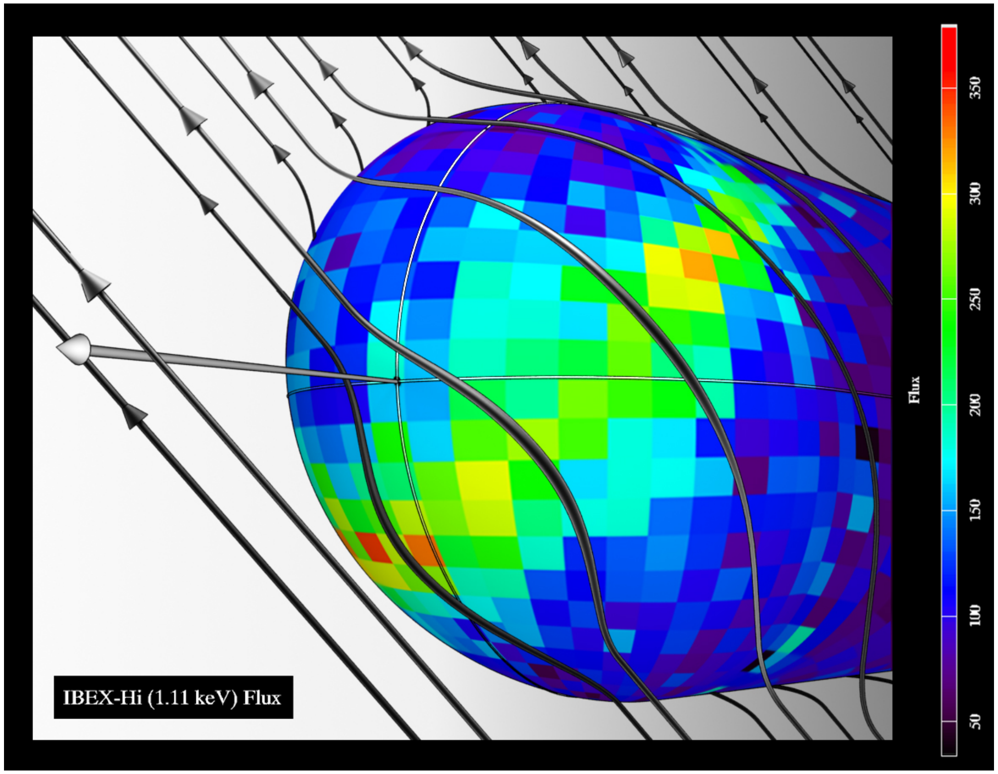
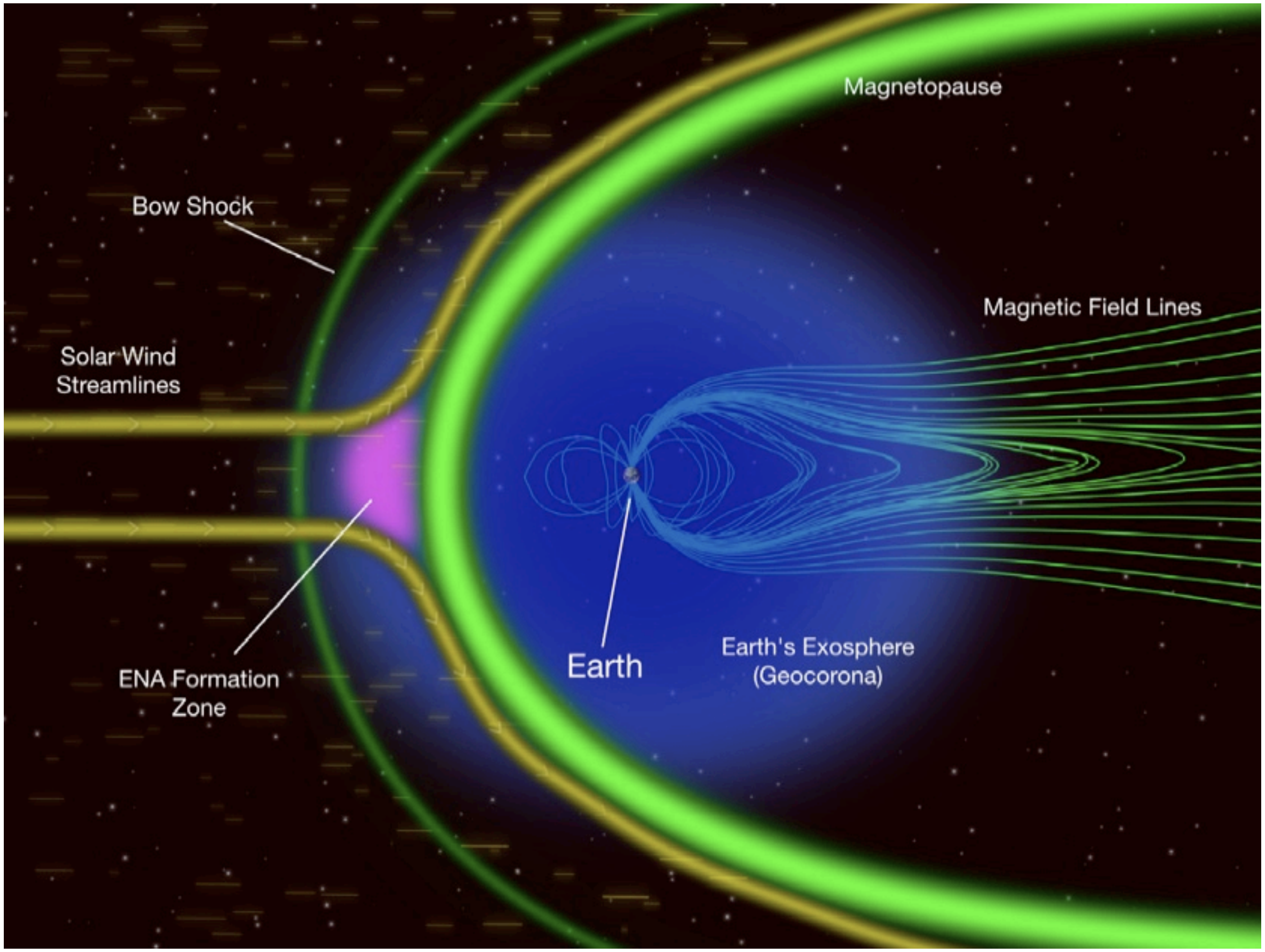


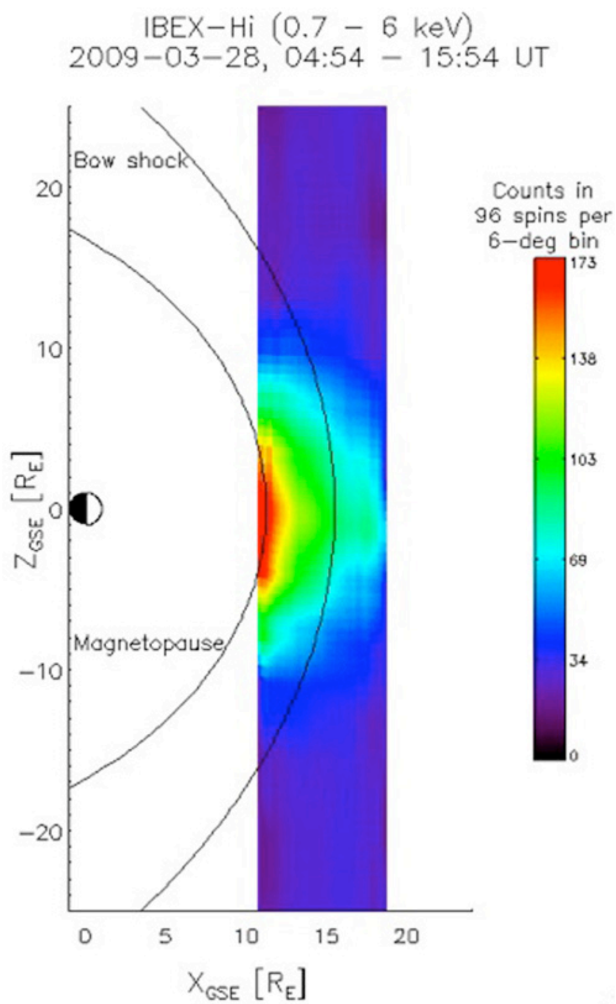
Image Credit: IBEX Team and Adler Planetarium

Where else can IBEX observe ENAs?



Energetic neutral atoms are produced as a result of interactions between the solar wind and the Earth's magnetosphere. IBEX can help us learn more about this region, as well. This is an artist's illustration of the Earth's magnetosphere as seen from the side; the ENA-producing region is shown in pink. *Image Credit: NASA/Goddard Space Flight Center*

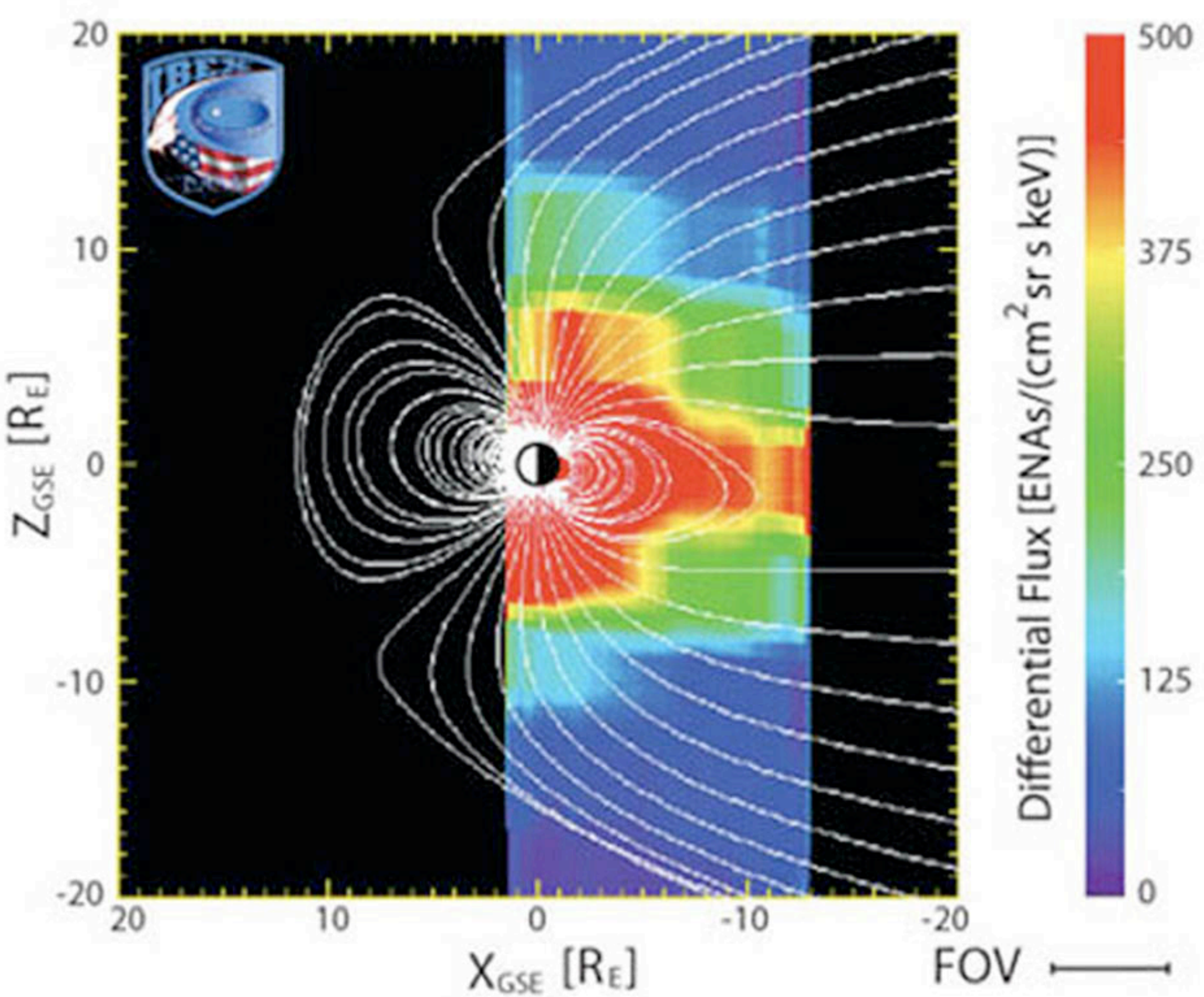
Where else can IBEX observe ENAs?



This is IBEX's image of Energetic Neutral Atoms produced as the solar wind interacts with Earth's magnetosphere.

Image Copyright: American Geophysical Union
Image Credit: IBEX Team

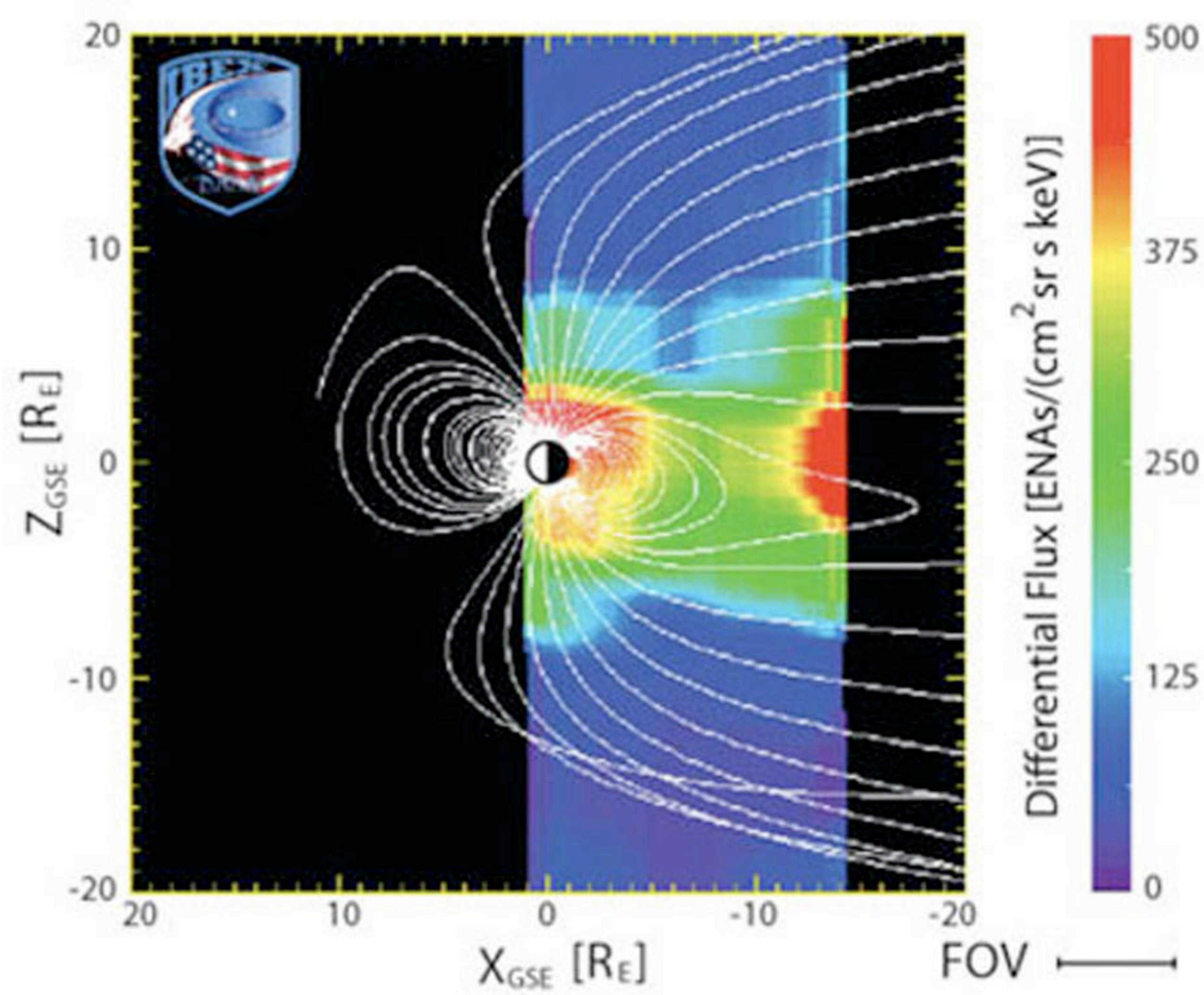
Where else can IBEX observe ENAs?



This image is the first-ever composite image of the plasma sheet in the Earth's magnetotail. It is important to note that this ENA image is an average of the ENAs detected over the course of about two days.

Image Credit: NASA/IBEX Science Team

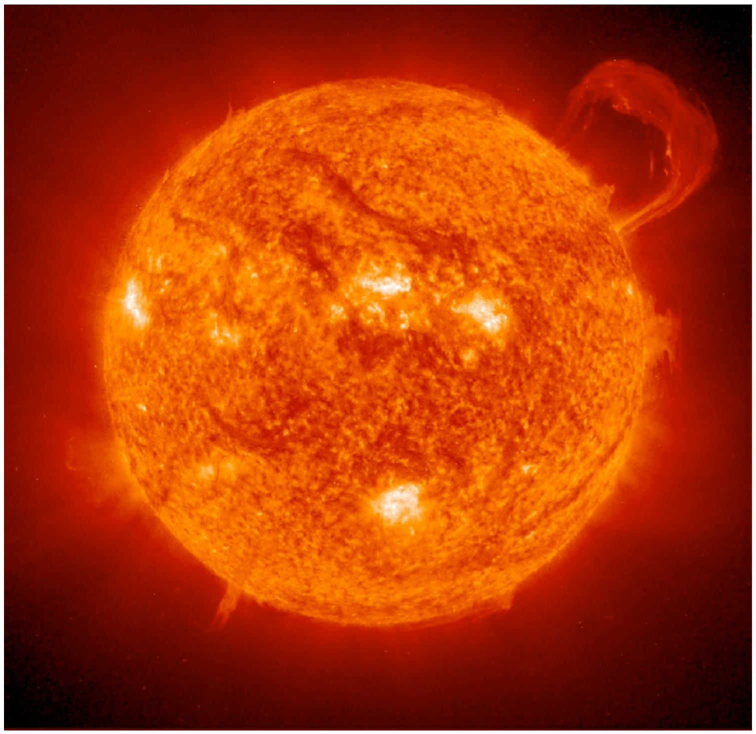
Where else can IBEX observe ENAs?



This image is a composite image of the plasma sheet in the Earth's magnetotail and shows more ENAs in the most distant part of the plasma sheet, an observation that would be consistent with dynamic changes in the magnetotail.

Image Credit: NASA/IBEX Science Team

What is next for IBEX's future?

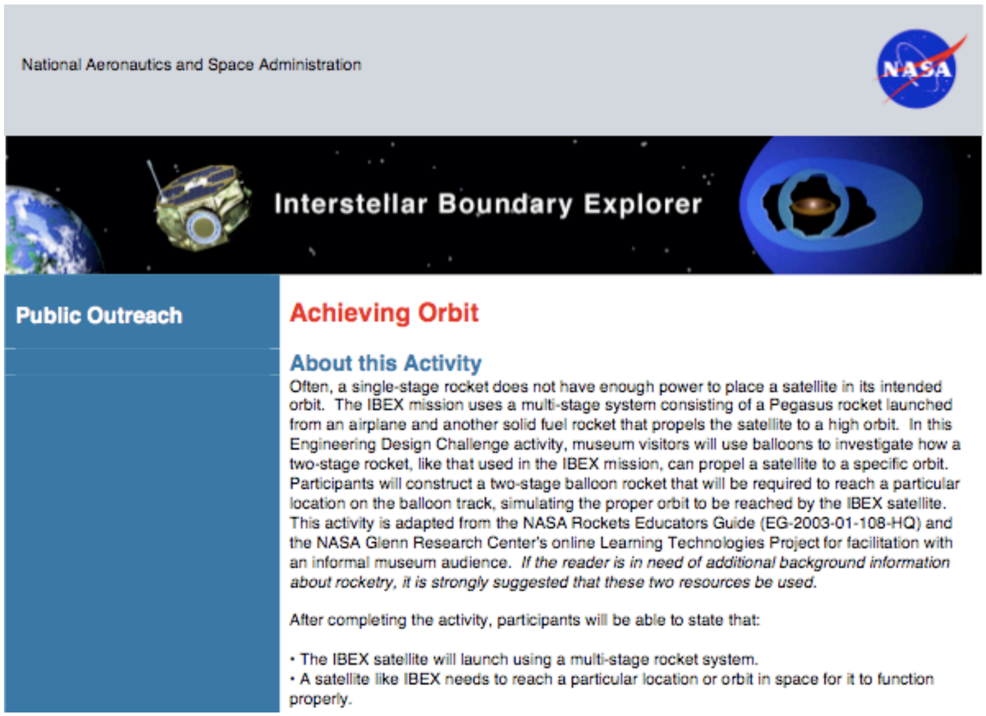


IBEX's primary mission lasted for two years (Feb. 1, 2009 to Feb. 1, 2011). The mission has been extended at least through September 30, 2013. Currently, the Sun's activity level has begun to increase, which may push the heliosphere outward and/or change its shape. Because the amount of solar wind particles streaming from the Sun depends, in part, on how active the Sun is, scientists are eager to make many more maps of the heliopause, not just the four sets created during IBEX's prime mission phase.

Image Credit: SOHO (ESA and NASA)

IBEX Activities for Informal Education Audiences

IBEX Activity Recommendation:


National Aeronautics and Space Administration

Interstellar Boundary Explorer

Public Outreach

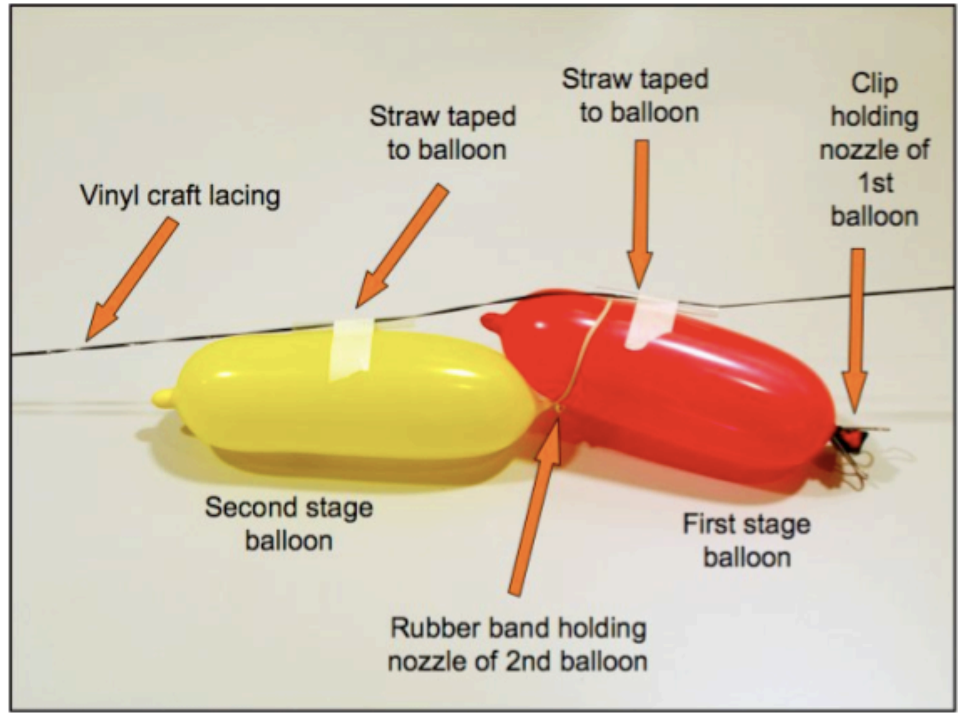
Achieving Orbit

About this Activity

Often, a single-stage rocket does not have enough power to place a satellite in its intended orbit. The IBEX mission uses a multi-stage system consisting of a Pegasus rocket launched from an airplane and another solid fuel rocket that propels the satellite to a high orbit. In this Engineering Design Challenge activity, museum visitors will use balloons to investigate how a two-stage rocket, like that used in the IBEX mission, can propel a satellite to a specific orbit. Participants will construct a two-stage balloon rocket that will be required to reach a particular location on the balloon track, simulating the proper orbit to be reached by the IBEX satellite. This activity is adapted from the NASA Rockets Educators Guide (EG-2003-01-108-HQ) and the NASA Glenn Research Center's online Learning Technologies Project for facilitation with an informal museum audience. *If the reader is in need of additional background information about rocketry, it is strongly suggested that these two resources be used.*

After completing the activity, participants will be able to state that:

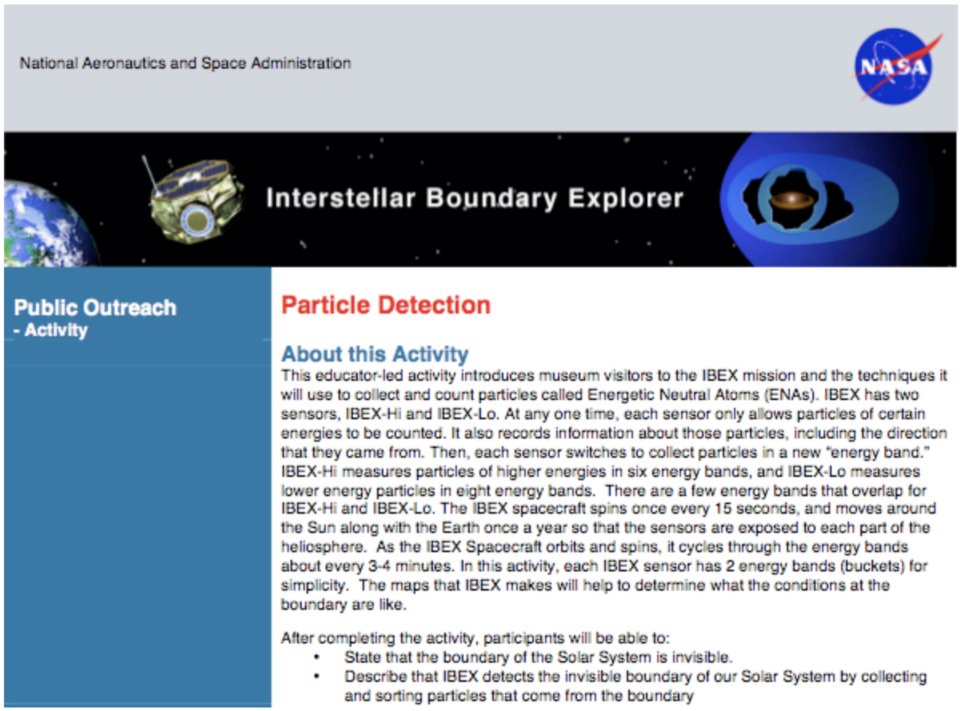
- The IBEX satellite will launch using a multi-stage rocket system.
- A satellite like IBEX needs to reach a particular location or orbit in space for it to function properly.



To illustrate a multi-stage rocket system, such as the one used to launch IBEX, the engineering design challenge "Achieving Orbit" activity is recommended.

Image Credits: NASA/IBEX/Adler Planetarium

IBEX Activity Recommendation:


National Aeronautics and Space Administration

NASA

Interstellar Boundary Explorer

Public Outreach
- Activity

Particle Detection

About this Activity

This educator-led activity introduces museum visitors to the IBEX mission and the techniques it will use to collect and count particles called Energetic Neutral Atoms (ENAs). IBEX has two sensors, IBEX-Hi and IBEX-Lo. At any one time, each sensor only allows particles of certain energies to be counted. It also records information about those particles, including the direction that they came from. Then, each sensor switches to collect particles in a new "energy band." IBEX-Hi measures particles of higher energies in six energy bands, and IBEX-Lo measures lower energy particles in eight energy bands. There are a few energy bands that overlap for IBEX-Hi and IBEX-Lo. The IBEX spacecraft spins once every 15 seconds, and moves around the Sun along with the Earth once a year so that the sensors are exposed to each part of the heliosphere. As the IBEX Spacecraft orbits and spins, it cycles through the energy bands about every 3-4 minutes. In this activity, each IBEX sensor has 2 energy bands (buckets) for simplicity. The maps that IBEX makes will help to determine what the conditions at the boundary are like.

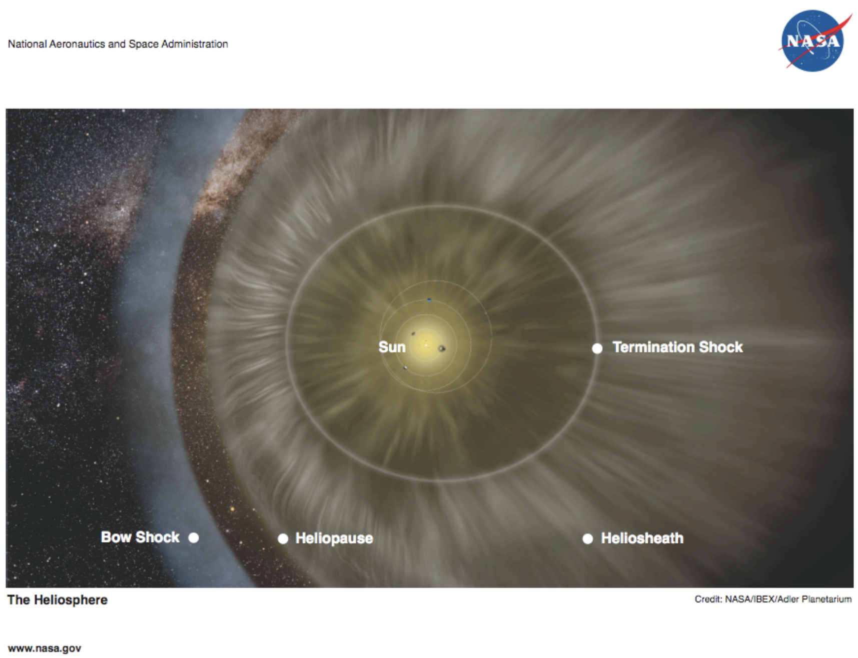
After completing the activity, participants will be able to:

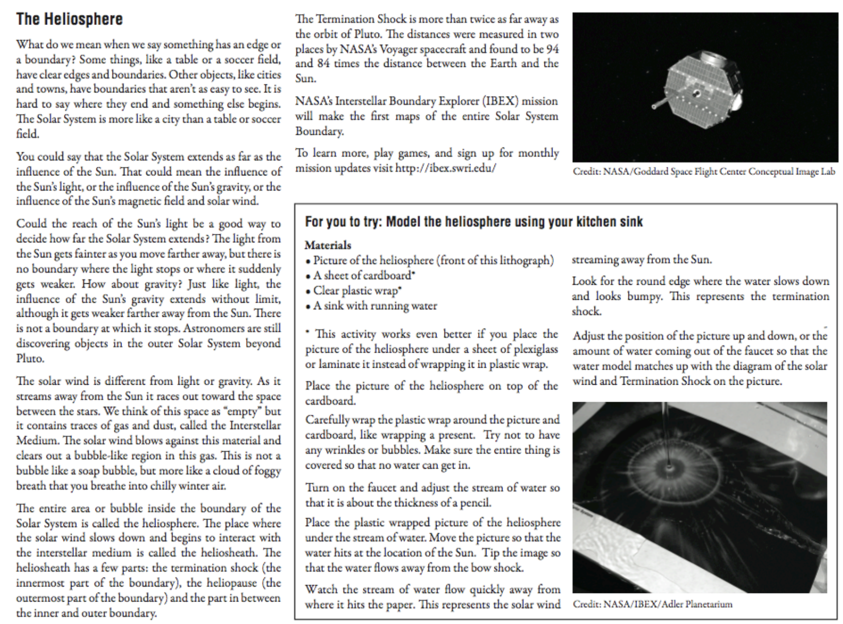
- State that the boundary of the Solar System is invisible.
- Describe that IBEX detects the invisible boundary of our Solar System by collecting and sorting particles that come from the boundary

To illustrate how the IBEX spacecraft collects energetic neutral atoms and how the IBEX team creates a map of our Solar System's boundary from this information, the "Particle Detection" activity is recommended.

Image Credits: NASA/IBEX/Adler Planetarium

IBEX Activity Recommendation:





The Heliosphere

What do we mean when we say something has an edge or a boundary? Some things, like a table or a soccer field, have clear edges and boundaries. Other objects, like cities and towns, have boundaries that aren't as easy to see. It is hard to say where they end and something else begins. The Solar System is more like a city than a table or soccer field.

You could say that the Solar System extends as far as the influence of the Sun. That could mean the influence of the Sun's light, or the influence of the Sun's gravity, or the influence of the Sun's magnetic field and solar wind.

Could the reach of the Sun's light be a good way to decide how far the Solar System extends? The light from the Sun gets fainter as you move farther away, but there is no boundary where the light stops or where it suddenly gets weaker. How about gravity? Just like light, the influence of the Sun's gravity extends without limit, although it gets weaker farther away from the Sun. There is not a boundary at which it stops. Astronomers are still discovering objects in the outer Solar System beyond Pluto.

The solar wind is different from light or gravity. As it streams away from the Sun it races out toward the space between the stars. We think of this space as "empty" but it contains traces of gas and dust, called the Interstellar Medium. The solar wind blows against this material and clears out a bubble-like region in this gas. This is not a bubble like a soap bubble, but more like a cloud of foggy breath that you breathe into chilly winter air.

The entire area or bubble inside the boundary of the Solar System is called the heliosphere. The place where the solar wind slows down and begins to interact with the interstellar medium is called the heliosheath. The heliosheath has a few parts: the termination shock (the innermost part of the boundary), the heliopause (the outermost part of the boundary) and the part in between the inner and outer boundary.

The Termination Shock is more than twice as far away as the orbit of Pluto. The distances were measured in two places by NASA's Voyager spacecraft and found to be 94 and 84 times the distance between the Earth and the Sun.

NASA's Interstellar Boundary Explorer (IBEX) mission will make the first maps of the entire Solar System Boundary.

To learn more, play games, and sign up for monthly mission updates visit http://ibex.swri.edu/

Credit: NASA/Goddard Space Flight Center Conceptual Image Lab

For you to try: Model the heliosphere using your kitchen sink

Materials
- Picture of the heliosphere (front of this lithograph)
- A sheet of cardboard*
- Clear plastic wrap*
- A sink with running water

* This activity works even better if you place the picture of the heliosphere under a sheet of plexiglass or laminate it instead of wrapping it in plastic wrap.

Place the picture of the heliosphere on top of the cardboard.

Carefully wrap the plastic wrap around the picture and cardboard, like wrapping a present. Try not to have any wrinkles or bubbles. Make sure the entire thing is covered so that no water can get in.

Turn on the faucet and adjust the stream of water so that it is about the thickness of a pencil.

Place the plastic wrapped picture of the heliosphere under the stream of water. Move the picture so that the water hits at the location of the Sun. Tip the image so that the water flows away from the bow shock.

Watch the stream of water flow quickly away from where it hits the paper. This represents the solar wind streaming away from the Sun.

Look for the round edge where the water slows down and looks bumpy. This represents the termination shock.

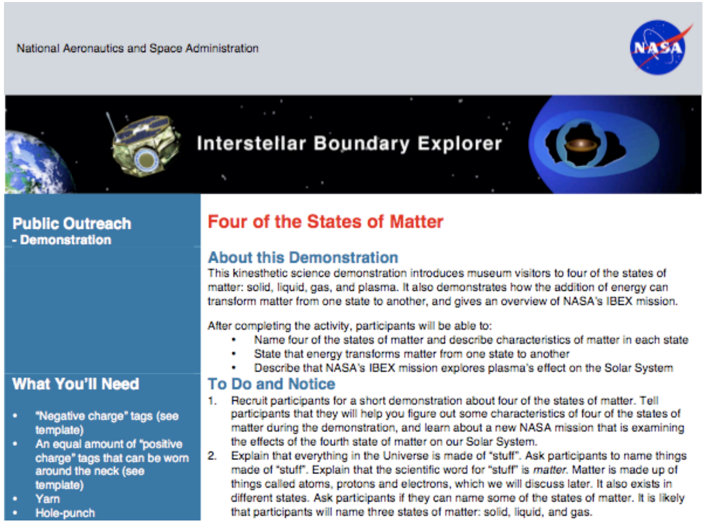
Adjust the position of the picture up and down, or the amount of water coming out of the faucet so that the water model matches up with the diagram of the solar wind and Termination Shock on the picture.

Credit: NASA/IBEX/Adler Planetarium

A lithograph is available on the IBEX website to conduct the "flowing water heliosphere" demonstration using the image on the front of the lithograph itself. Instructions are on the reverse side.

Image Credits: NASA/IBEX/Adler Planetarium

IBEX Activity Recommendations:


National Aeronautics and Space Administration

Interstellar Boundary Explorer

Public Outreach - Demonstration

Four of the States of Matter

About this Demonstration

This kinesthetic science demonstration introduces museum visitors to four of the states of matter: solid, liquid, gas, and plasma. It also demonstrates how the addition of energy can transform matter from one state to another, and gives an overview of NASA's IBEX mission.

After completing the activity, participants will be able to:

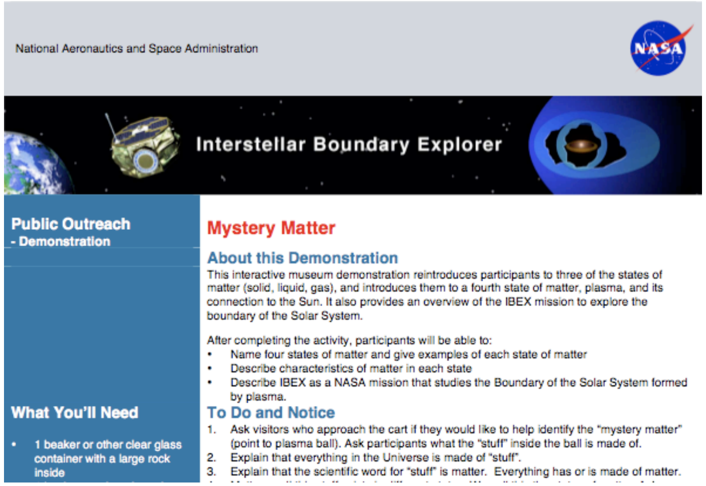
- Name four of the states of matter and describe characteristics of matter in each state
- State that energy transforms matter from one state to another
- Describe that NASA's IBEX mission explores plasma's effect on the Solar System

What You'll Need

- "Negative charge" tags (see template)
- An equal amount of "positive charge" tags that can be worn around the neck (see template)
- Yarn
- Hole-punch

To Do and Notice

1. Recruit participants for a short demonstration about four of the states of matter. Tell participants that they will help you figure out some characteristics of four of the states of matter during the demonstration, and learn about a new NASA mission that is examining the effects of the fourth state of matter on our Solar System.
2. Explain that everything in the Universe is made of "stuff". Ask participants to name things made of "stuff". Explain that the scientific word for "stuff" is *matter*. Matter is made up of things called atoms, protons and electrons, which we will discuss later. It also exists in different states. Ask participants if they can name some of the states of matter. It is likely that participants will name three states of matter: solid, liquid, and gas.


National Aeronautics and Space Administration

Interstellar Boundary Explorer

Public Outreach - Demonstration

Mystery Matter

About this Demonstration

This interactive museum demonstration reintroduces participants to three of the states of matter (solid, liquid, gas), and introduces them to a fourth state of matter, plasma, and its connection to the Sun. It also provides an overview of the IBEX mission to explore the boundary of the Solar System.

After completing the activity, participants will be able to:

- Name four states of matter and give examples of each state of matter
- Describe characteristics of matter in each state
- Describe IBEX as a NASA mission that studies the Boundary of the Solar System formed by plasma.

What You'll Need

- 1 beaker or other clear glass container with a large rock inside

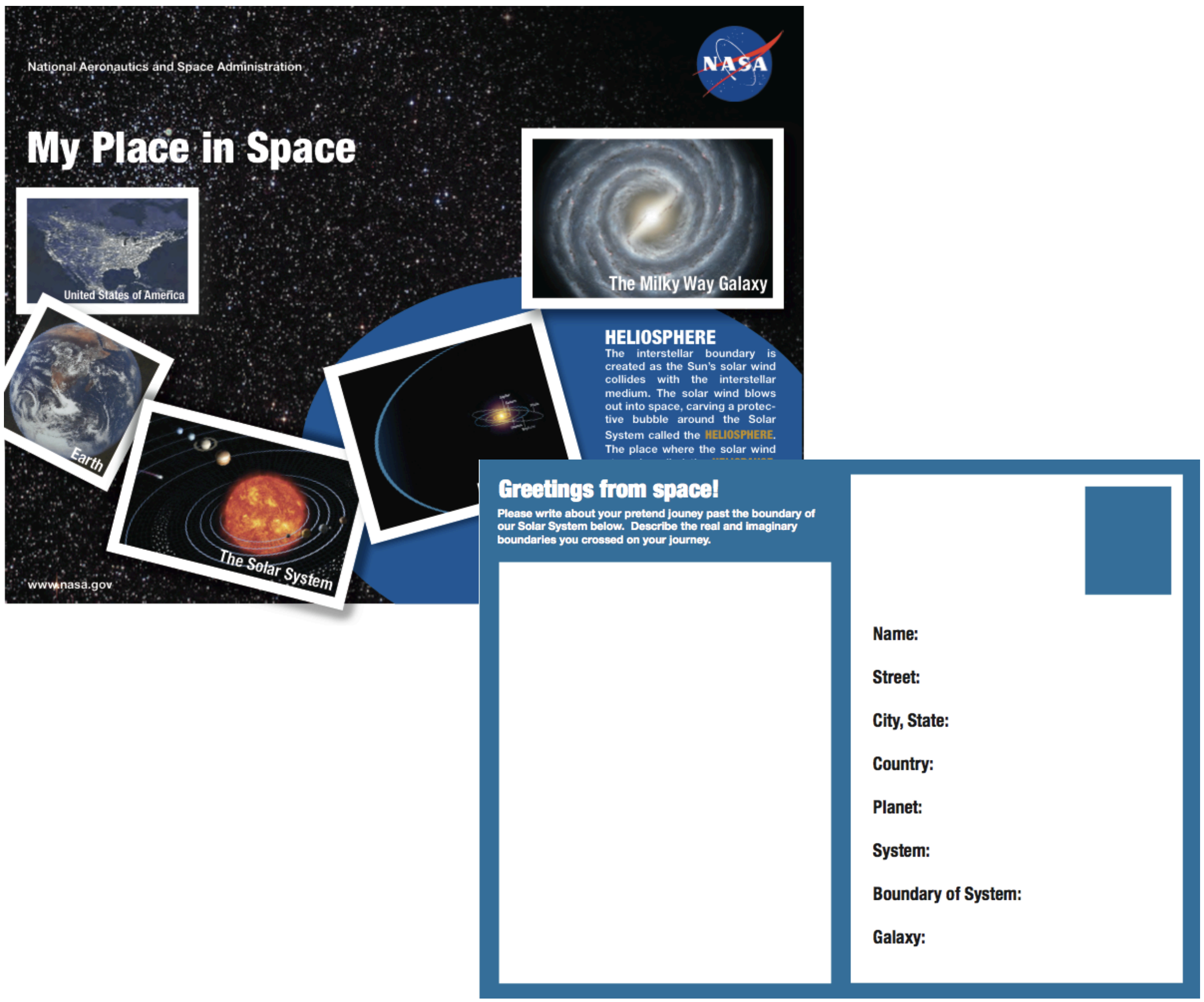
To Do and Notice

1. Ask visitors who approach the cart if they would like to help identify the "mystery matter" (point to plasma ball). Ask participants what the "stuff" inside the ball is made of.
2. Explain that everything in the Universe is made of "stuff".
3. Explain that the scientific word for "stuff" is matter. Everything has or is made of matter.

To investigate more about plasma and its relationship to solids, liquids, and gases, the "Four of the States of Matter" and/or "Mystery Matter" activities are recommended.

Image credits: NASA/IBEX/Adler Planetarium

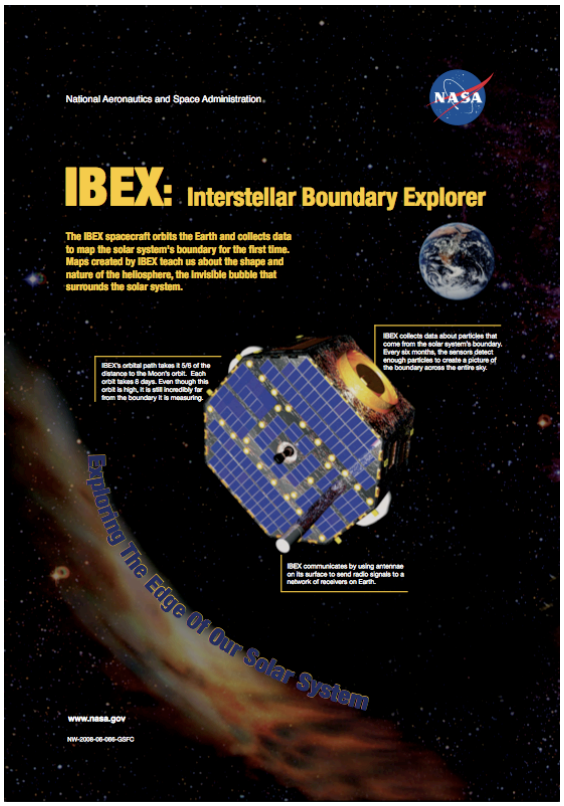
IBEX Activity Recommendation:

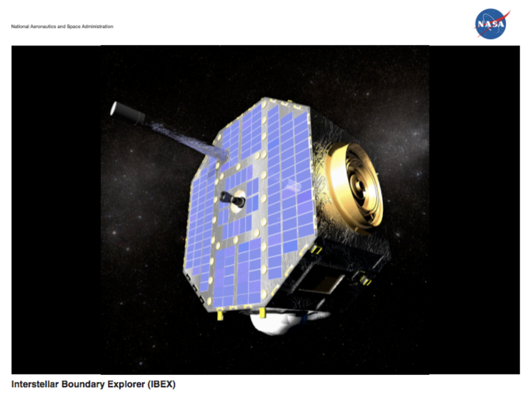


To help participants visualize the location of our Solar System's boundary in relation to other more familiar locales, such as street, city, state, etc., the "Postcards from Space" activity is recommended.

Image credit: IBEX/NASA/Adler Planetarium

IBEX Resources:





Posters and lithographs explaining more about the IBEX mission are available for download in both English and in Spanish. *(A selection is shown here for illustrative purposes only.)* The IBEX website includes information about the *IBEX: Search for the Edge of the Solar System* planetarium show, as well as online games and activities.

Image credit: IBEX/NASA/Adler Planetarium

How can I get the latest IBEX information?

Check out the IBEX website for the latest news, information, resources, and images from the mission:

NASA Portal Page web address

IBEX Mission Site web address