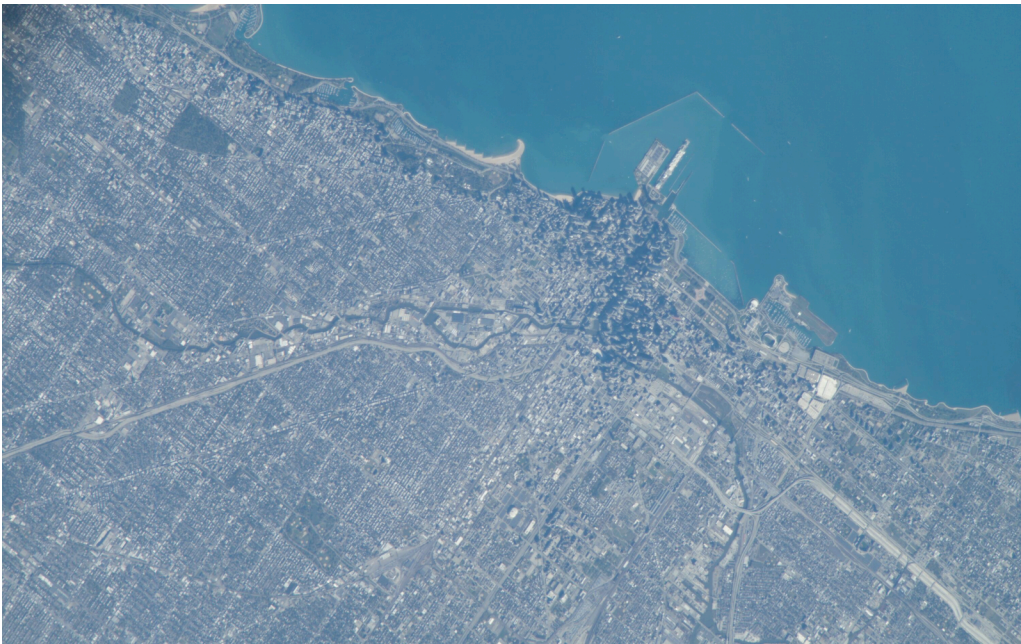


# IBEX: Interstellar Boundary Explorer

An Electronic Resource for Museum Educators

# 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.

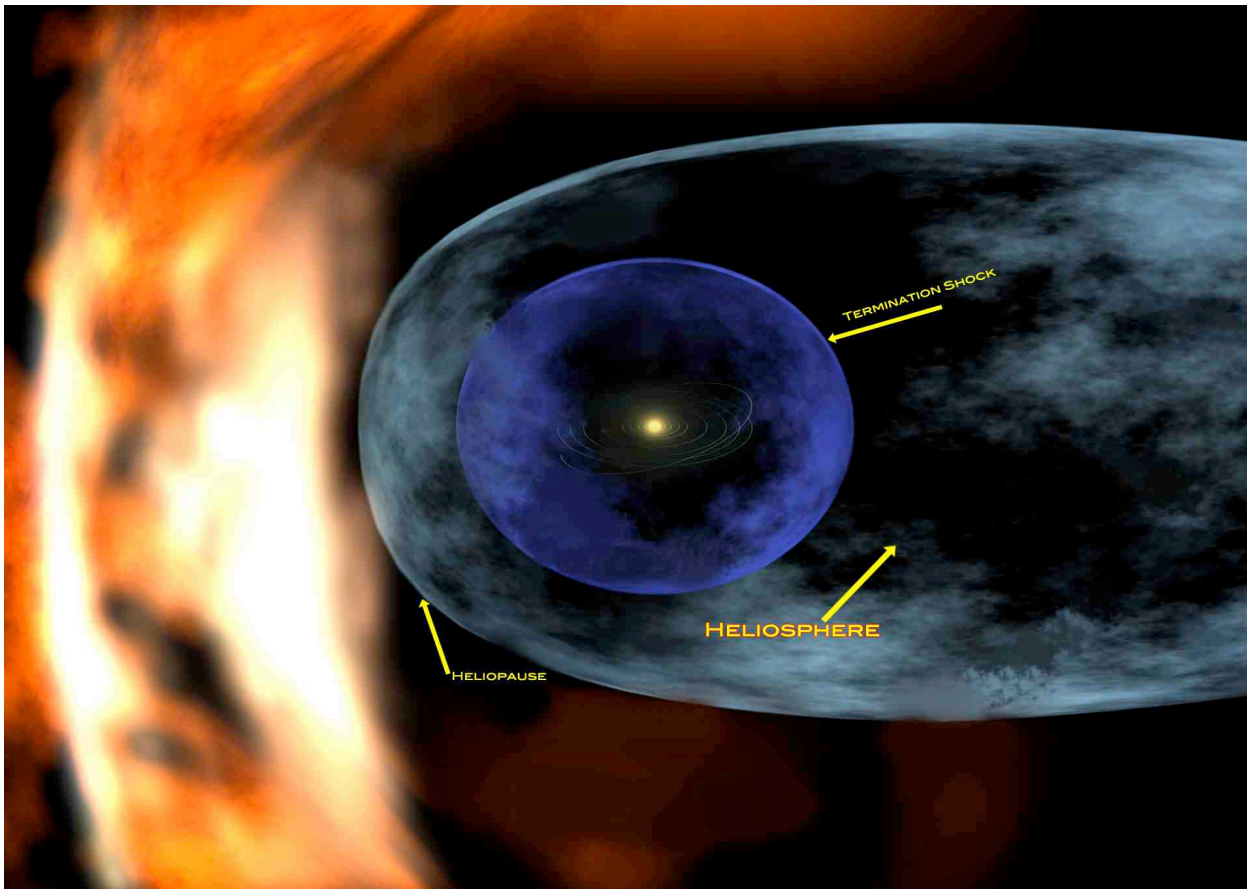
*Chicago, as photographed from the International Space Station. Image Credit: NASA*

# 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 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 weakens. How about gravity? Just like light, the influence of the Sun's gravity extends without limit, although it is weaker farther away from the Sun. There is not a boundary at which it stops.

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



The heliosphere defines one type of boundary of our Solar System.

The boundary of our Solar System is defined by the region where the solar wind and the interstellar medium collide.

*An artist's rendition of our heliosphere.*

*Image credit: Walt Feimer, NASA*

*GSFC*

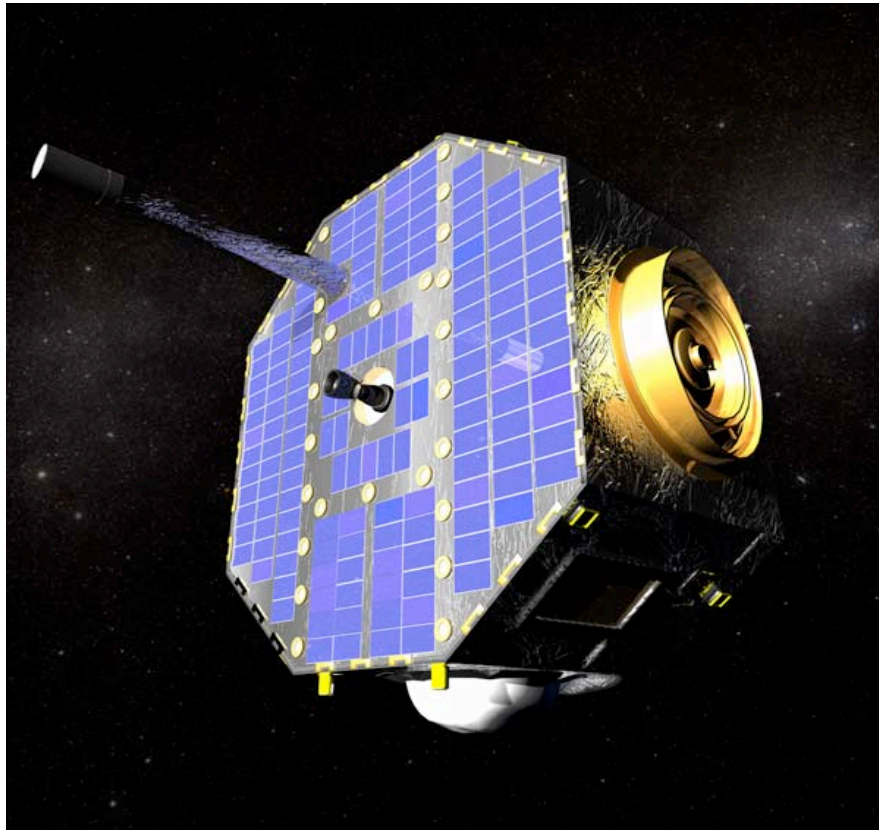
# What tool can we use to study the boundary of our Solar System?



The IBEX spacecraft is designed to collect data about the heliosphere and its boundary. Scientists will use this data to make maps of the heliosphere for the first time.

*Movie Credit: Walt Feimer, NASA GSFC*

# What is **IBEX**?



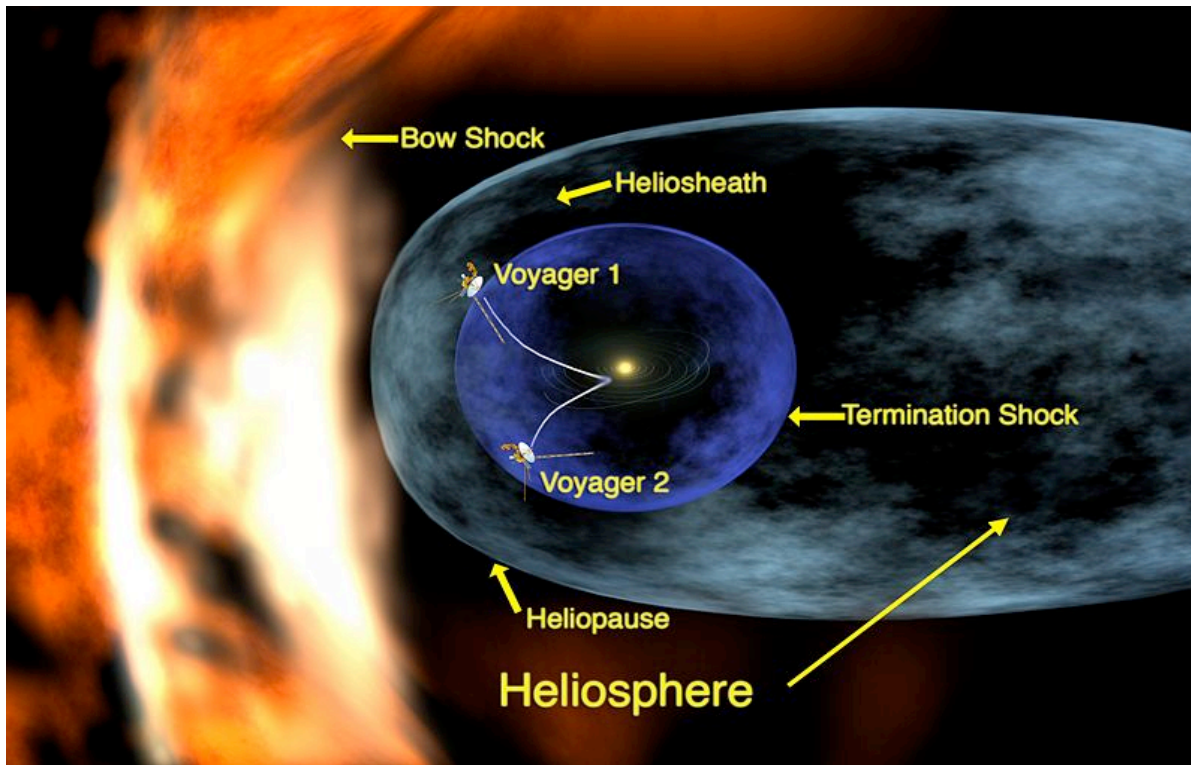
IBEX is a \$134 million NASA-funded Small Explorer satellite mission to orbit Earth and map the boundary of the Solar System.

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

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

# IBEX Science

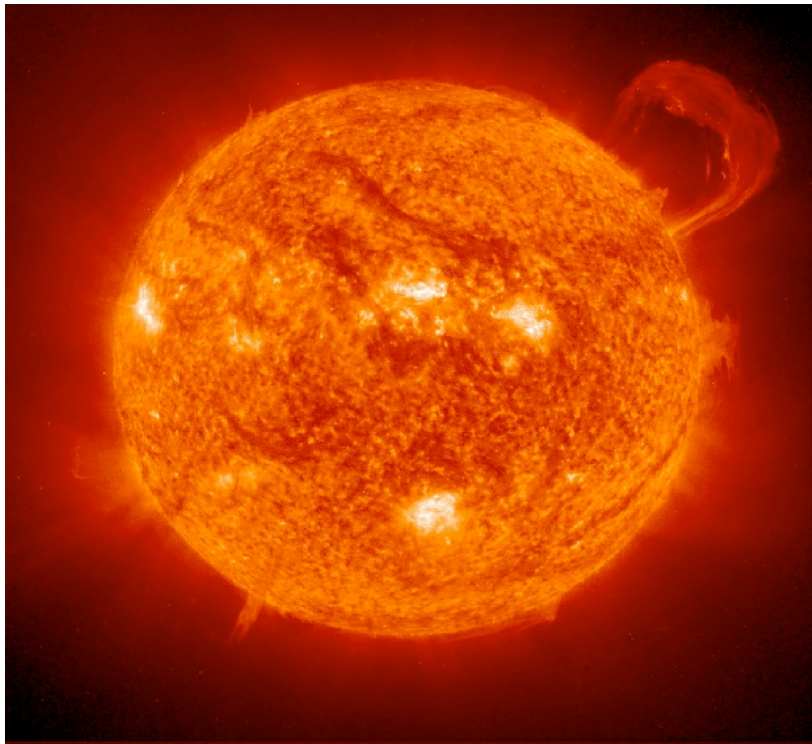
# What is the objective of the IBEX mission?



IBEX's science objective is to discover the global interaction 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**?



The Sun is mainly made of two elements, hydrogen and helium, in a state of matter called **plasma**.

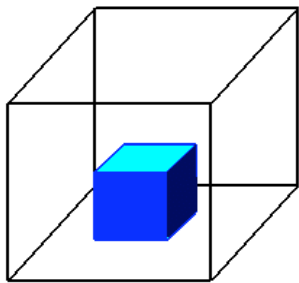
*The Sun, as seen by the SOHO spacecraft. Image credit: SOHO  
(ESA and NASA)*

# What is plasma?



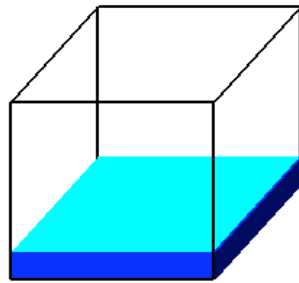
## States of Matter

Glenn  
Research  
Center



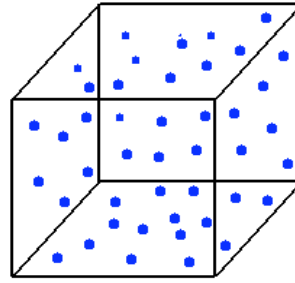
**Solid**

Holds Shape  
Fixed Volume



**Liquid**

Shape of Container  
Free Surface  
Fixed Volume



**Gas**

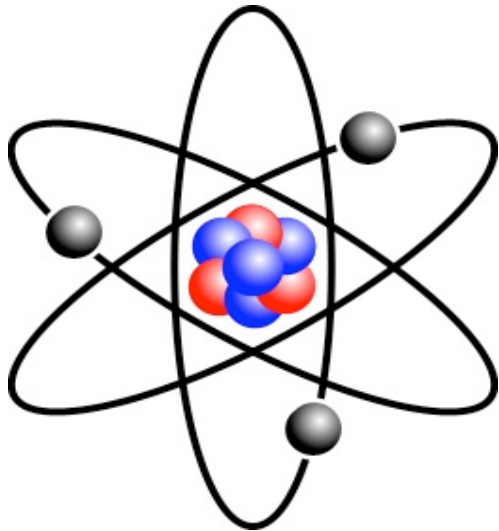
Shape of Container  
Volume of Container

## Plasma is a state of matter.

Everything in the Universe 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.

*Image credit: NASA Glenn Research Center*

# What is plasma?

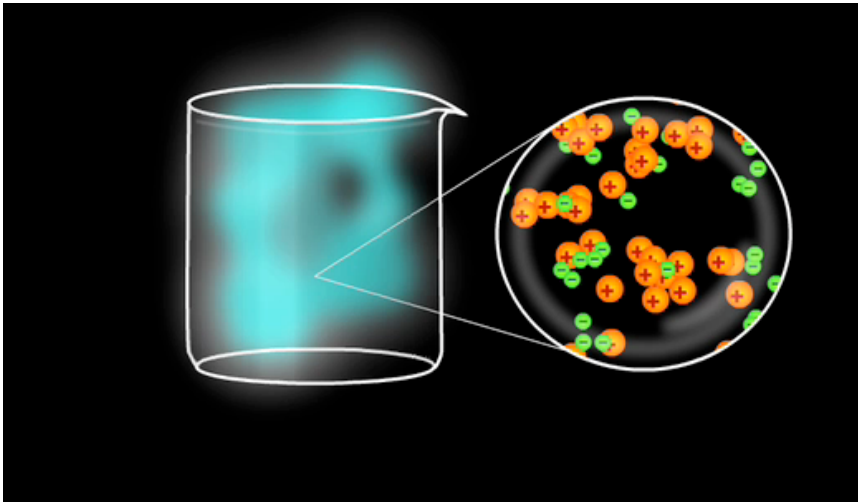


**Atoms are made of protons, neutrons and electrons.** Protons have a positive charge, neutrons have a neutral charge and they both make up the atom's nucleus. Electrons have a negative charge. They surround the nucleus of the atom, roughly pictured here.

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.

*An atom. Image credit: Public domain image*

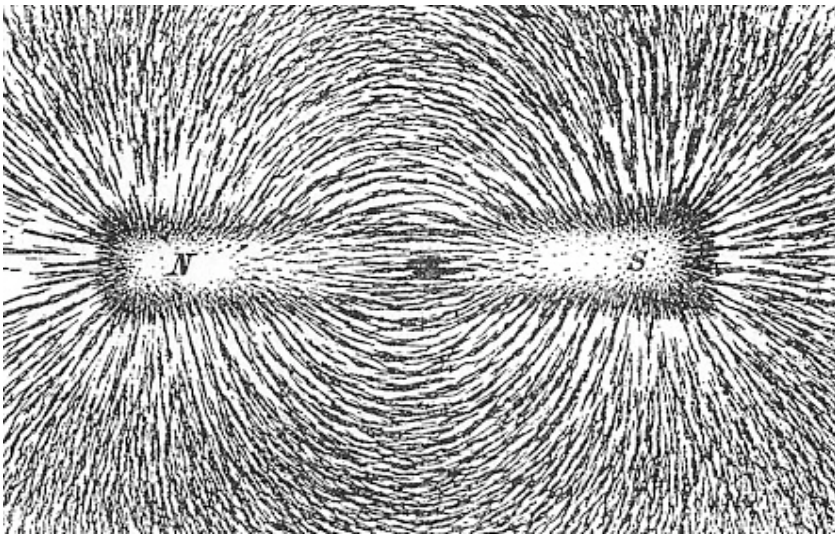
# What is plasma?



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.

*An artist's rendition of protons and electrons in a plasma. Image credit: Adler Planetarium*

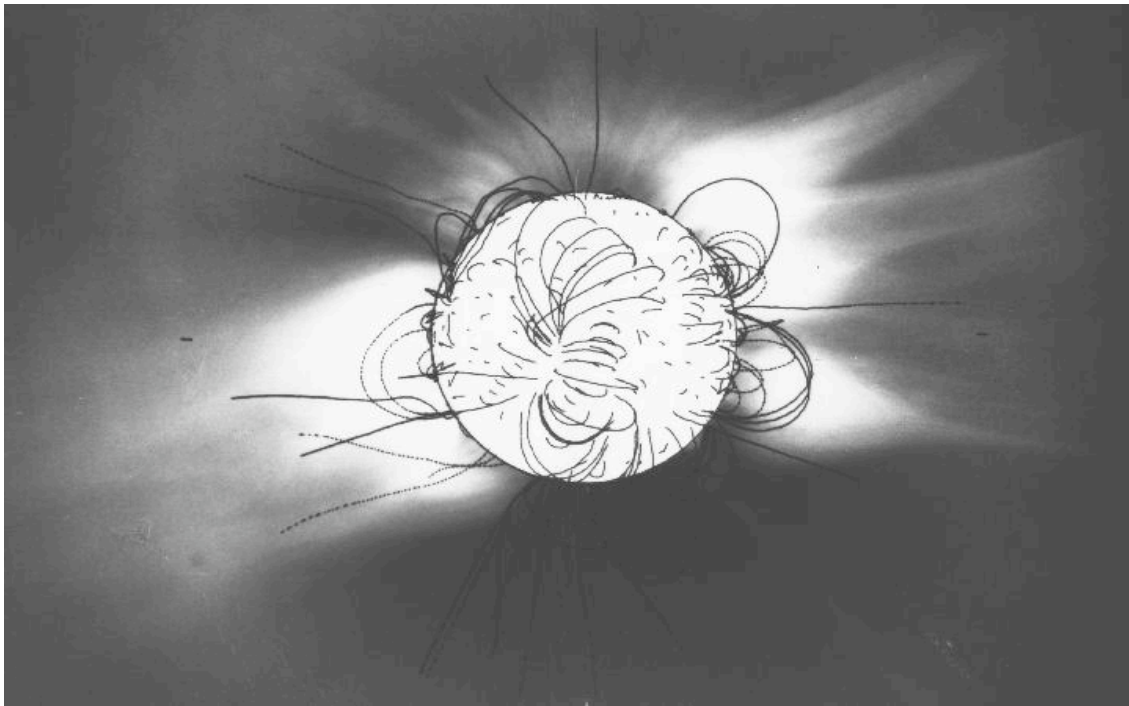
# What is a magnetic field?



Magnetic fields are created by things that are magnetic (like iron magnets) or by moving charged particles. A magnetic field is the description of the force a magnetic object exerts in the space surrounding the magnetic object. A force is a push or pull.

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

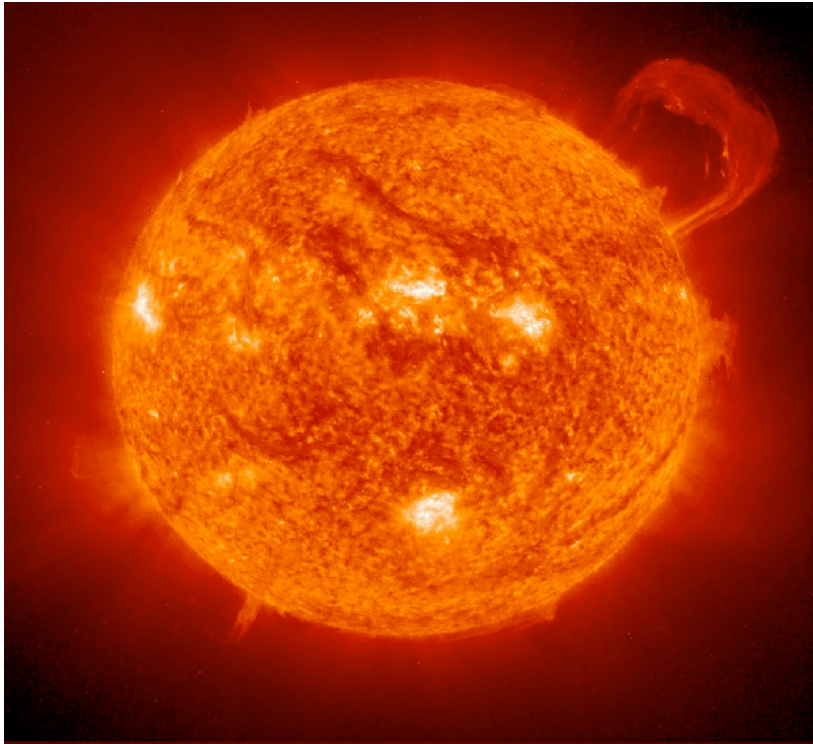
# What is a magnetic field?



When charged particles move around really fast they create magnetic fields. The Sun has a large and complex magnetic field.

*A rendition of the Sun's magnetic field, using actual solar data. Image credit: Kiepenheuer-Institut für 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 Sun, as seen by the SOHO spacecraft. Image credit: SOHO  
(ESA and NASA)*

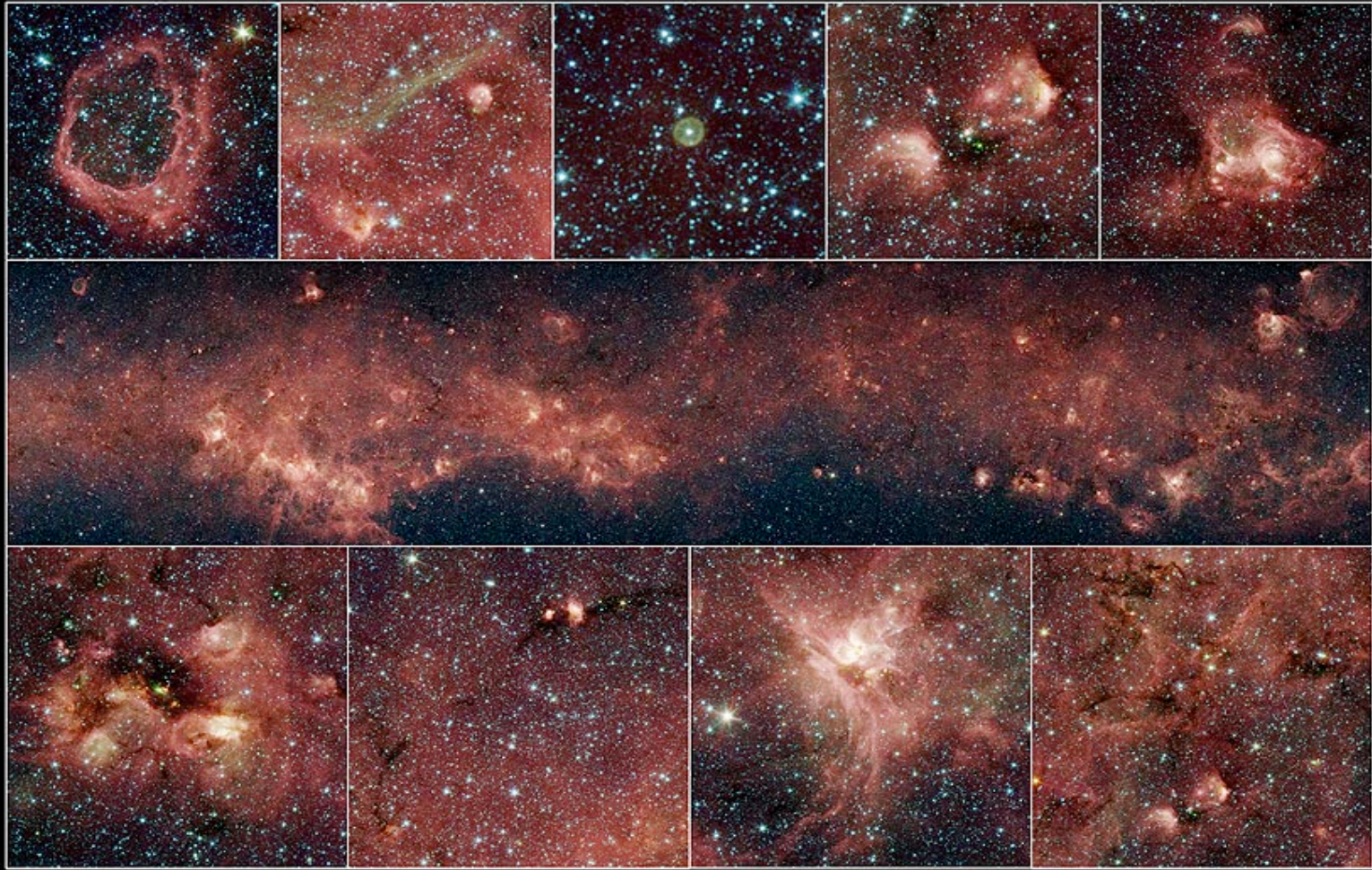
# What is the **interstellar medium**?

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.

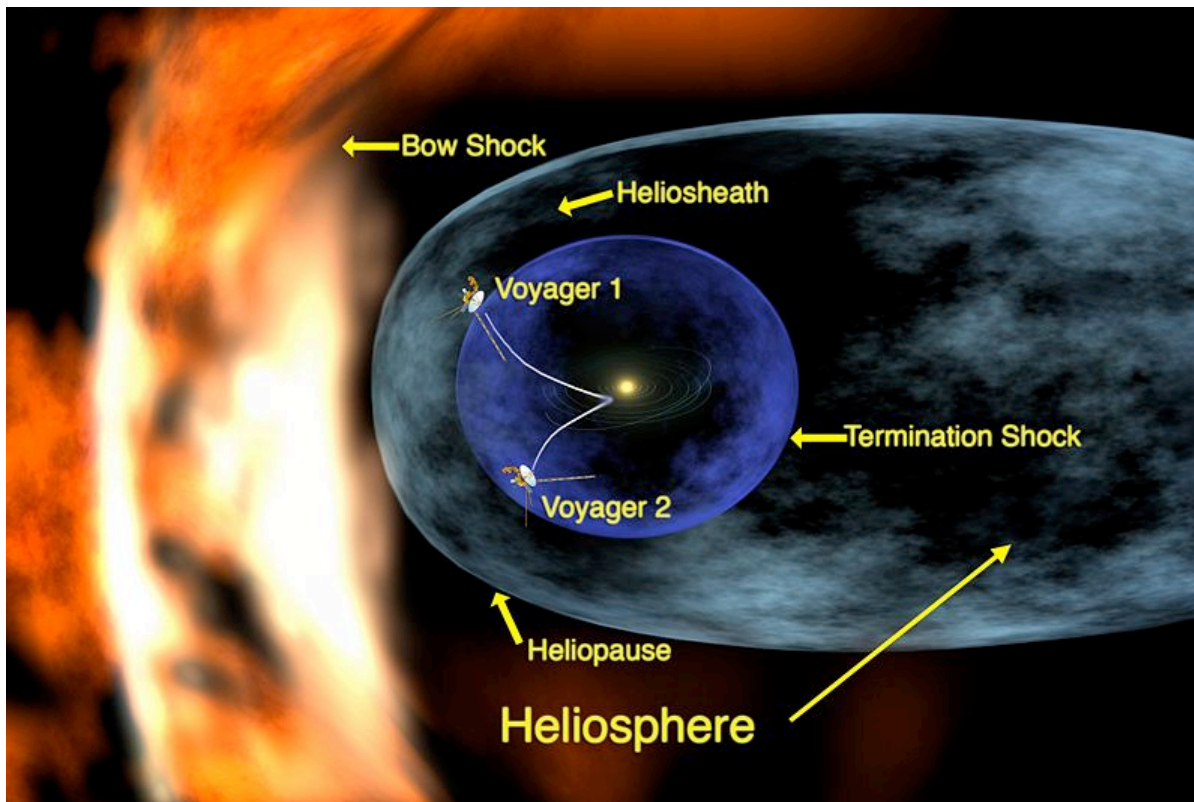
*Slide 17: An infrared image of interstellar material, imaged by the Spitzer Space Telescope. Slide 17 Image credit: NASA/JPL-Caltech/E. Churchwell (University of Wisconsin)*



**A GLIMPSE of the Milky Way**  
NASA / JPL-Caltech / E. Churchwell (University of Wisconsin)

**Spitzer Space Telescope • IRAC**  
sig05-025

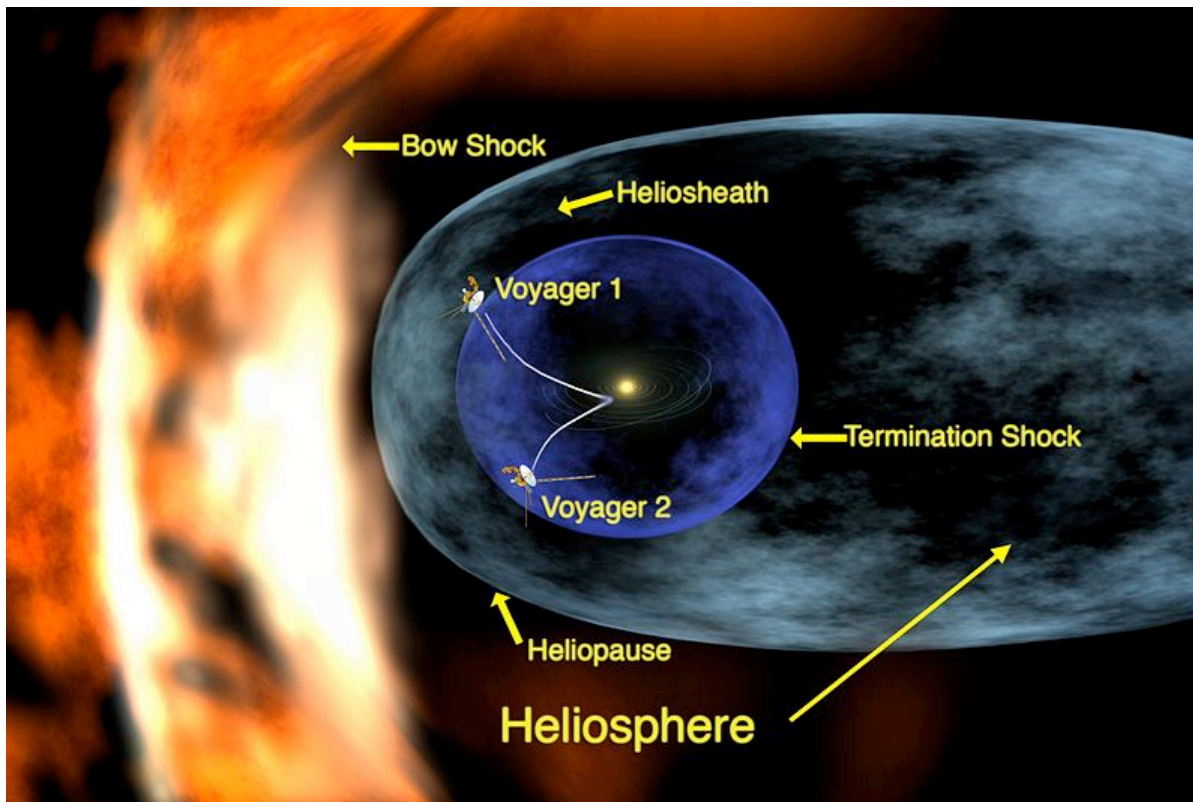
# What happens when the **solar wind** and **ISM** collide?



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.

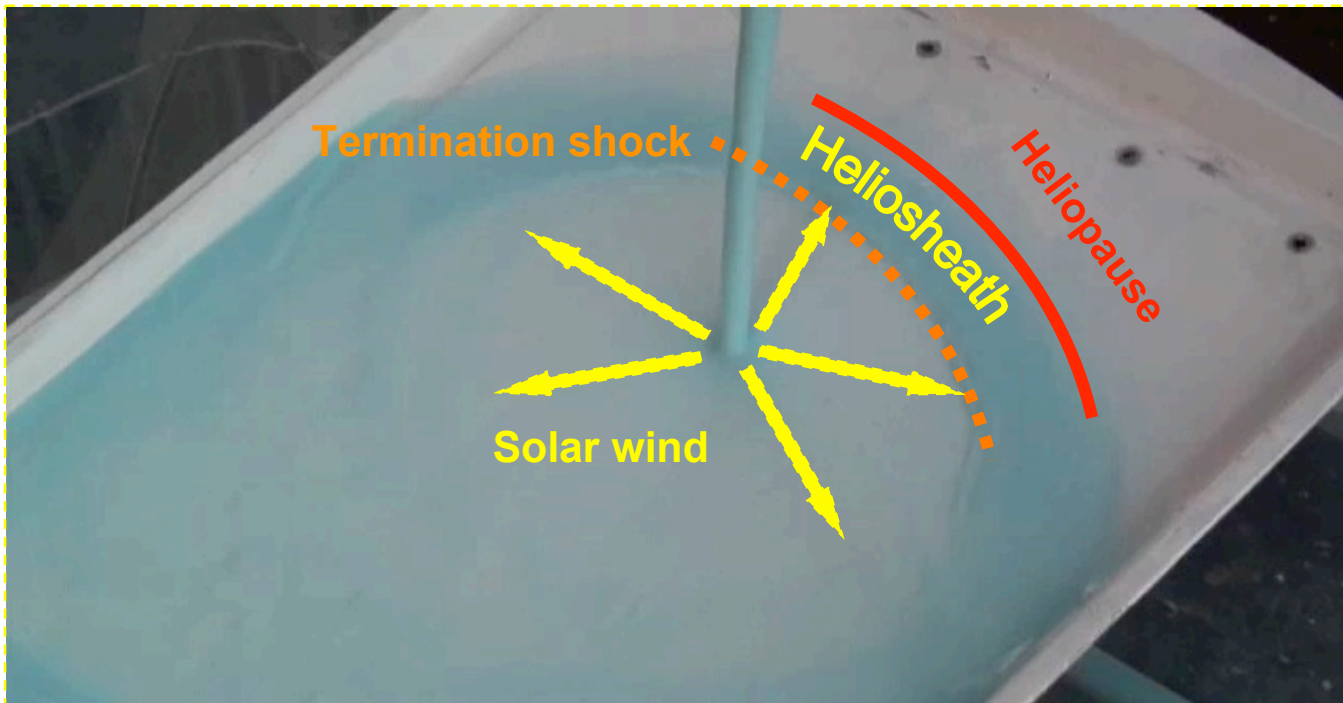
*Image Credit: Walt Feimer, NASA GSFC*

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

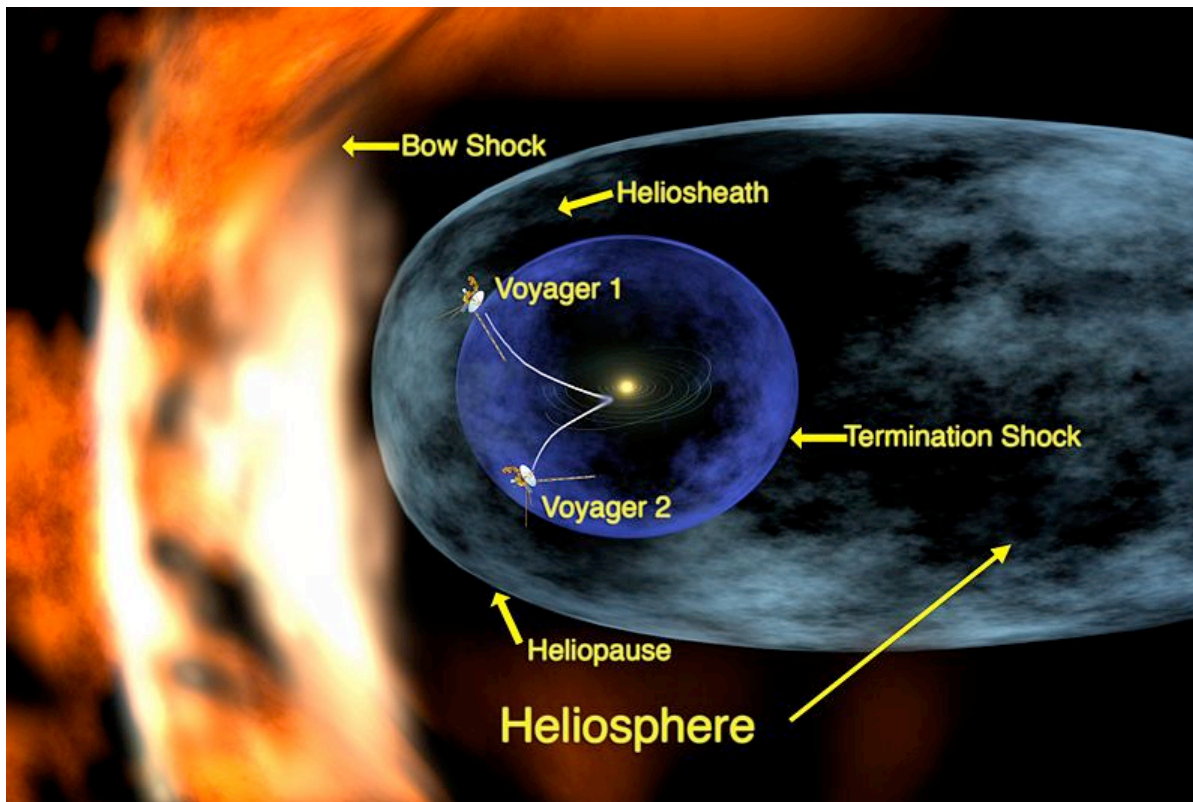


*Movie Credit: IBEX Science Team*

# The “flowing water termination shock model” illustrated:



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



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

*Image Credit: Walt Feimer, NASA GSFC*

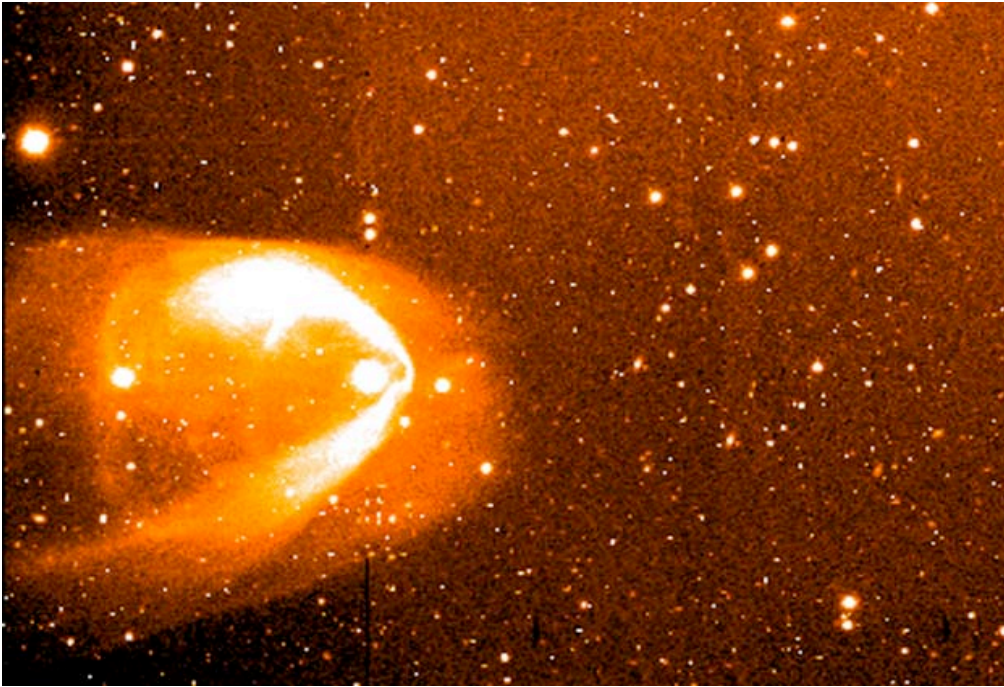
# Images of bow shocks around other stars



**LL Ori**, a star in the Orion Nebula

*Image Credit: Hubble Heritage Team*

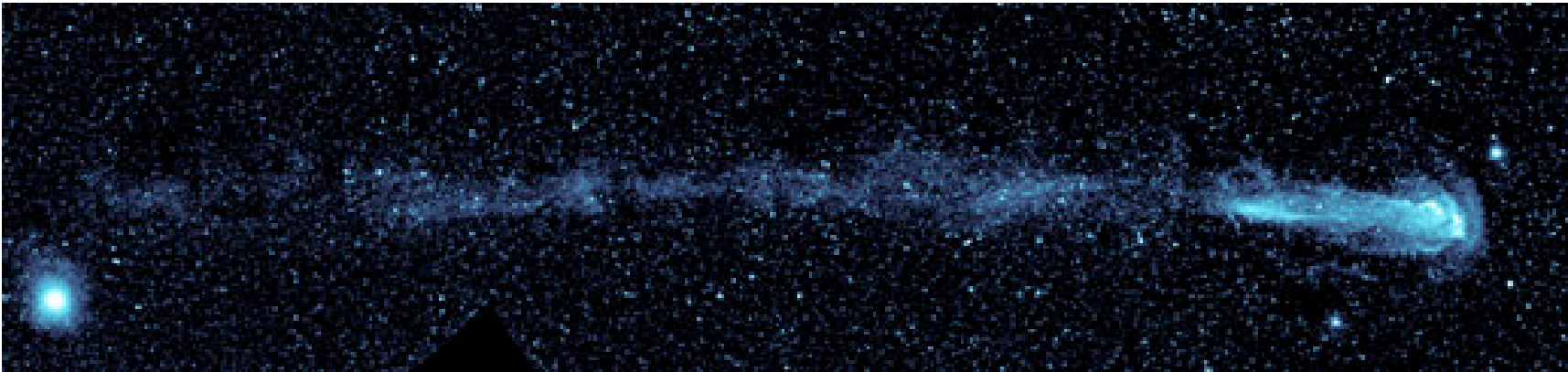
# Images of bow shocks around other stars



**BZ Cam**, a star in the constellation Camelopardalis

*Image Credit: R. Casalegno, C. Conelice et al, WIYN, NOAO, MURST, NSF*

# Images of bow shocks around other stars



**Omicron Ceti (or Mira),** a star in the constellation Cetus

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

# What came before IBEX?



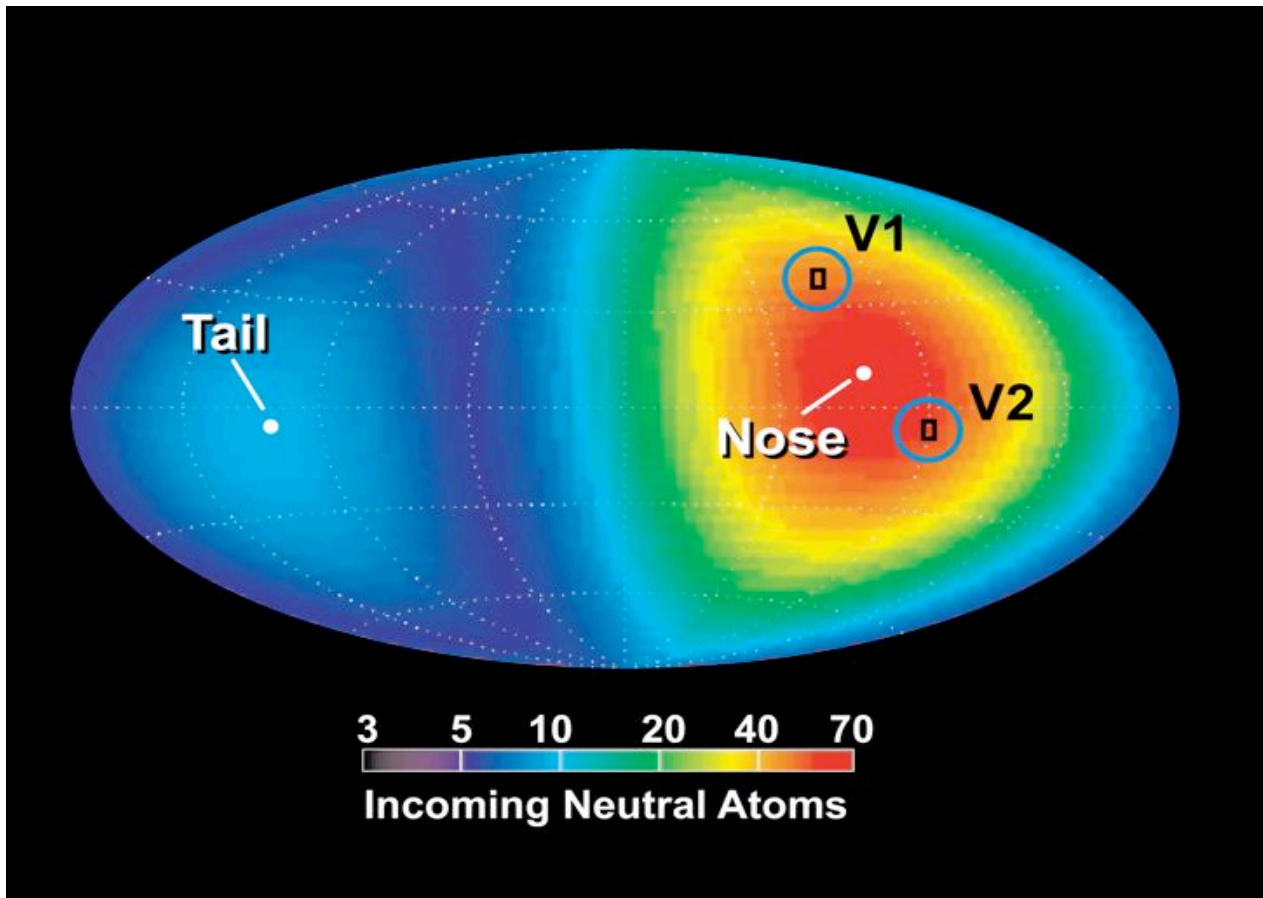
Voyagers 1 and 2 have reached the termination shock. Their information will be combined with IBEX's information to create a more complete model of the boundary of our Solar System.

*An artist's rendition of the Voyager spacecraft. Image*

*Credit: NASA*

# The IBEX Mission

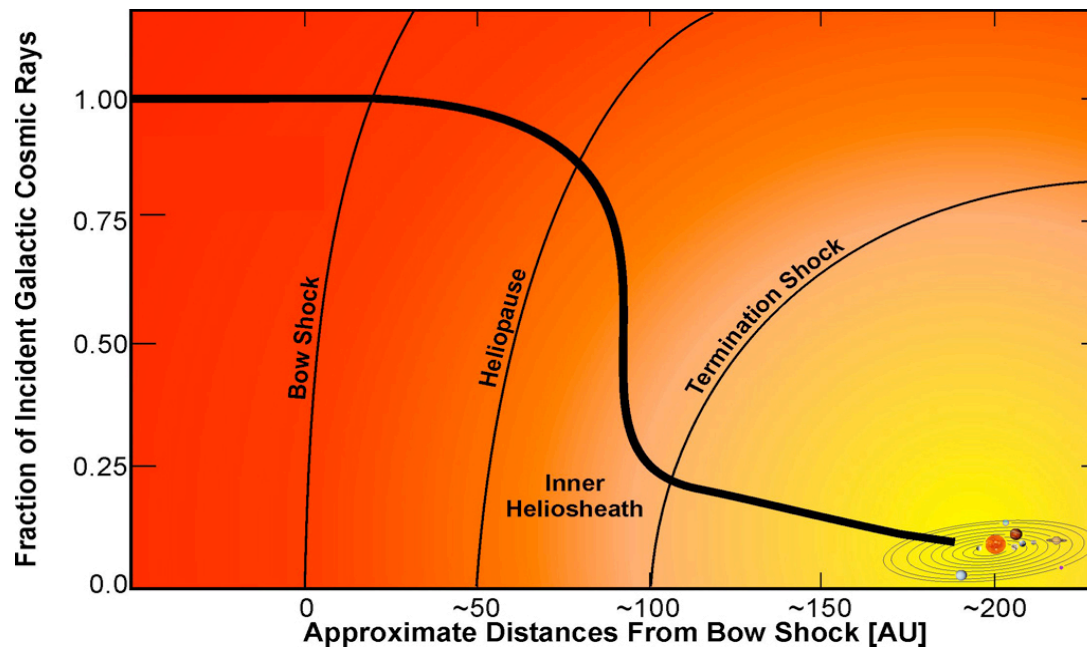
# Why is the IBEX mission important?



IBEX will dramatically increase the amount of data that we have about the boundary of the Solar System.

*Sample Global ENA Map with Voyager 1 and 2 positions inset. Image Credit: IBEX Team*

# 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.

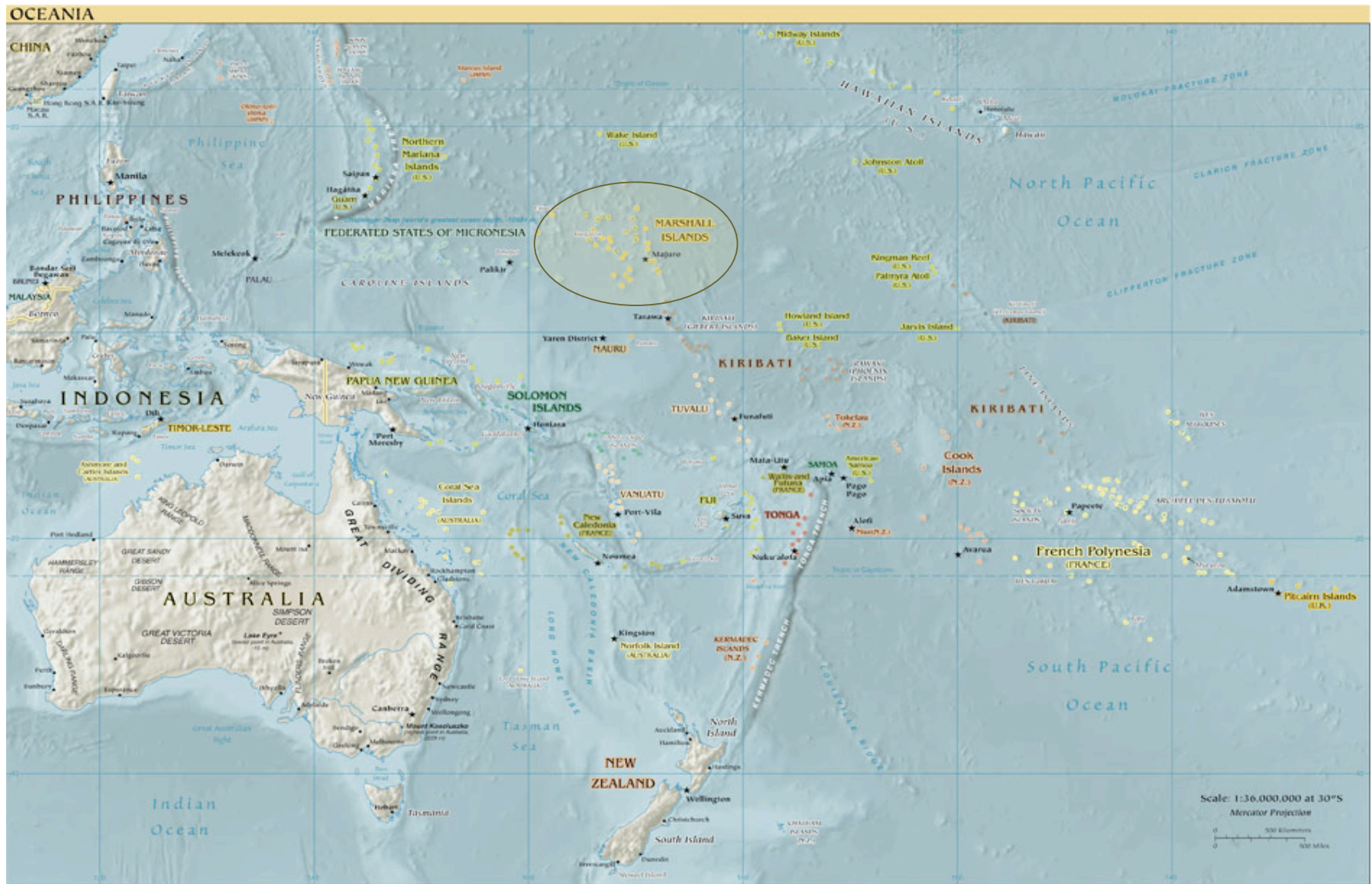
*A graph of the percentages of cosmic rays that reach various parts of our Solar System. Image Credit: IBEX Science Team*

# How does IBEX get to space?



IBEX begins its ride from Kwajalein Atoll, Marshall Islands in the middle of the Pacific Ocean.

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



Kwajalein Atoll is part of the Marshall Islands in the Pacific Ocean, southwest of Hawaii.

Image Credit: CIA website reference maps.

# How does IBEX get to space?

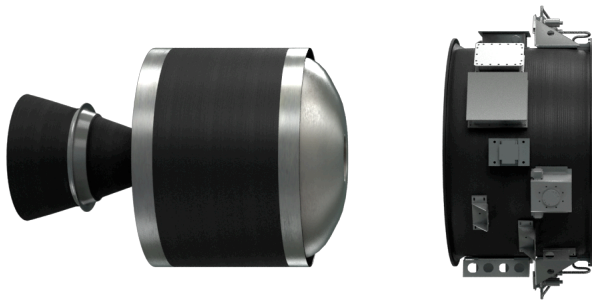


IBEX uses a Pegasus rocket launched from an L-1011 airplane. This is an inexpensive launch option, especially for smaller spacecraft.

*An artist's rendition of the launch of a Pegasus rocket.*

*Image Credit: The Adler Planetarium*

# How does IBEX get to space?



The Pegasus' rockets propel the launch vehicle into space, carrying IBEX on the front/top.

*Image Credit: IBEX Team*

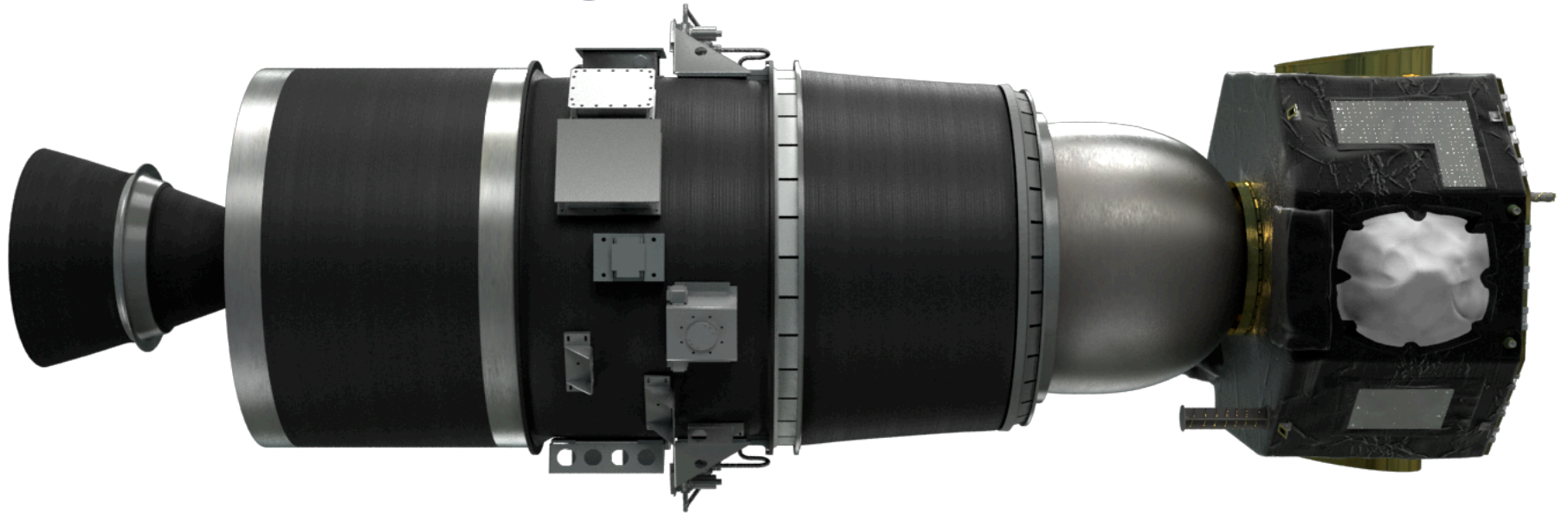
# How does IBEX get to space?



After the Pegasus' rockets are done firing, the smaller rocket on the IBEX spacecraft propels it to its intended orbital location.

*Image Credit: IBEX Team*

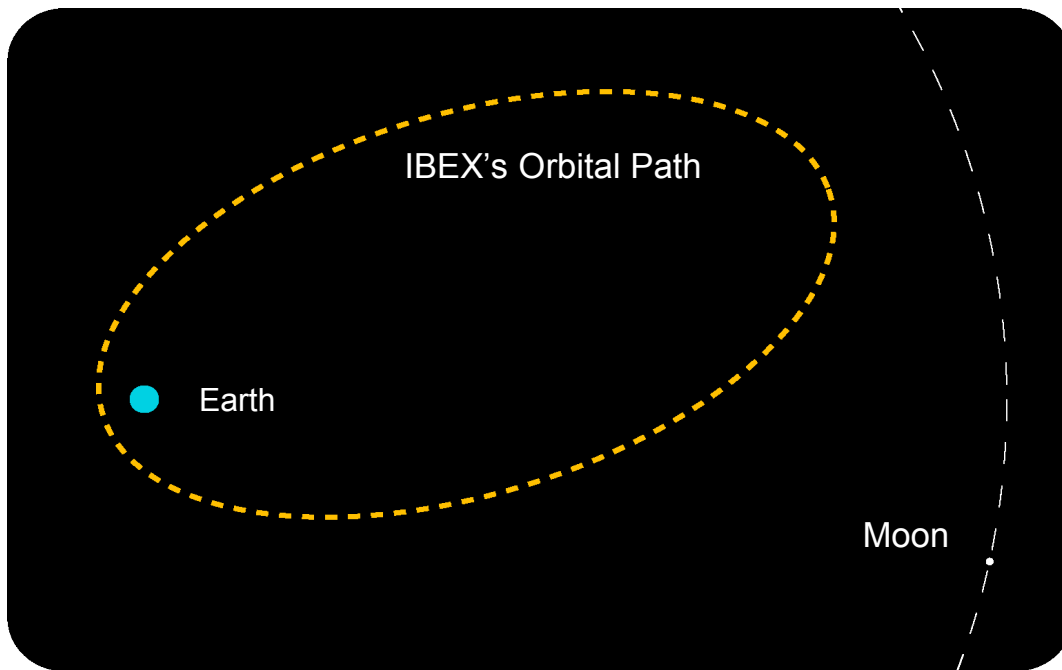
# How does IBEX get to space?



This image shows the entire Pegasus and IBEX launch system, including the satellite itself (far right).

*Image Credit: IBEX Team*

# Where does IBEX orbit?

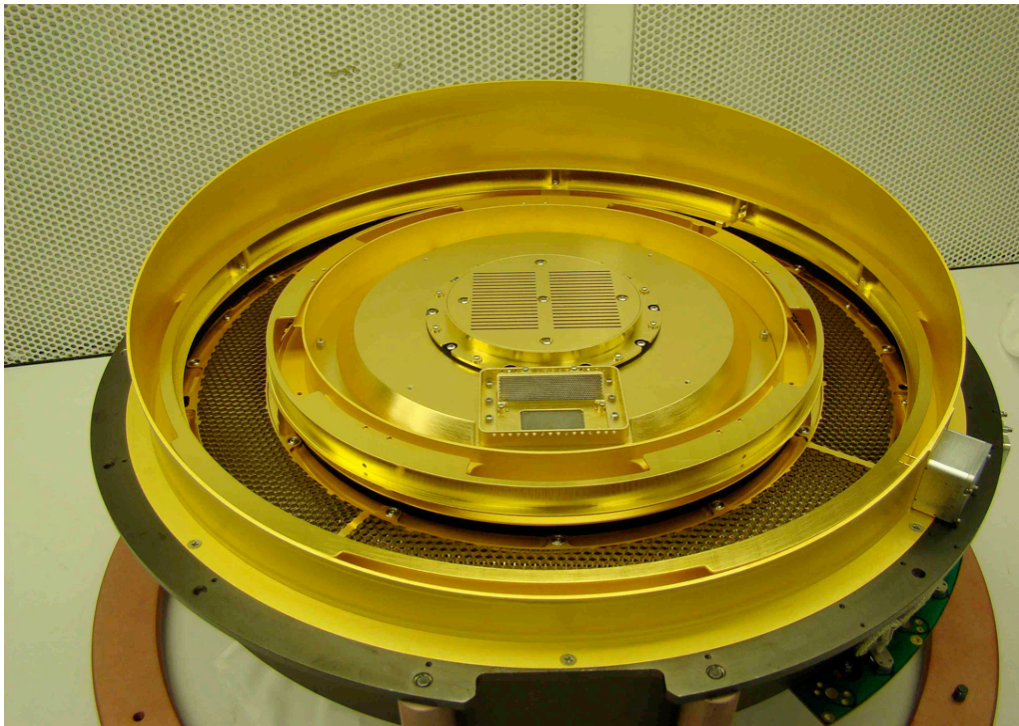


IBEX's orbital location is about 200,000 miles (323,000 kilometers) from Earth.

IBEX spins but always keeps its solar panels aimed at the Sun. Over the course of a year, IBEX's sensors will gather particles from the entire sky.

*Image Credit: IBEX 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-Hi.

*The IBEX-Hi sensor. Image Credit: IBEX Team*

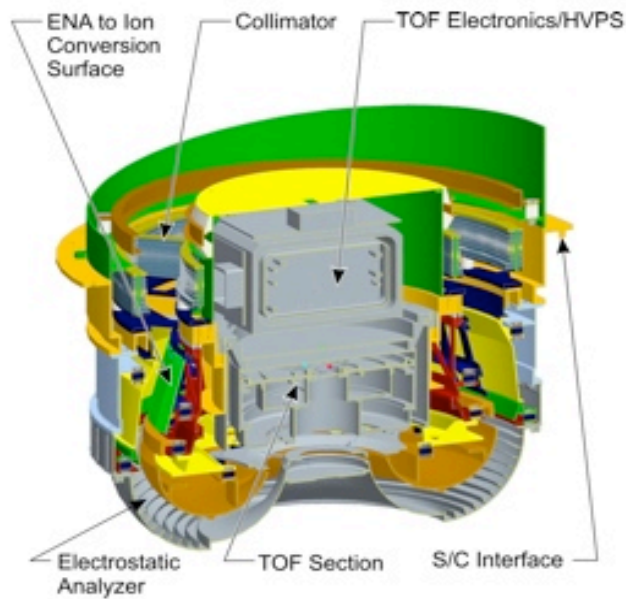
# How does IBEX collect data?

IBEX-Lo is able to detect particles that are of 8 different energy bands. IBEX-Hi is able to detect particles that are of 6 different energy bands. There is a little bit of overlap in the energy bands that each sensor can detect.

The sensors sort the particles and keep track of the direction of origin of the particles, the time they entered the sensor, the mass of the particles, and the amount of energy each particle has. From all of this information, a map of the boundary can be created.

The illustration on the next slide shows more details of IBEX-Hi and IBEX-Lo.

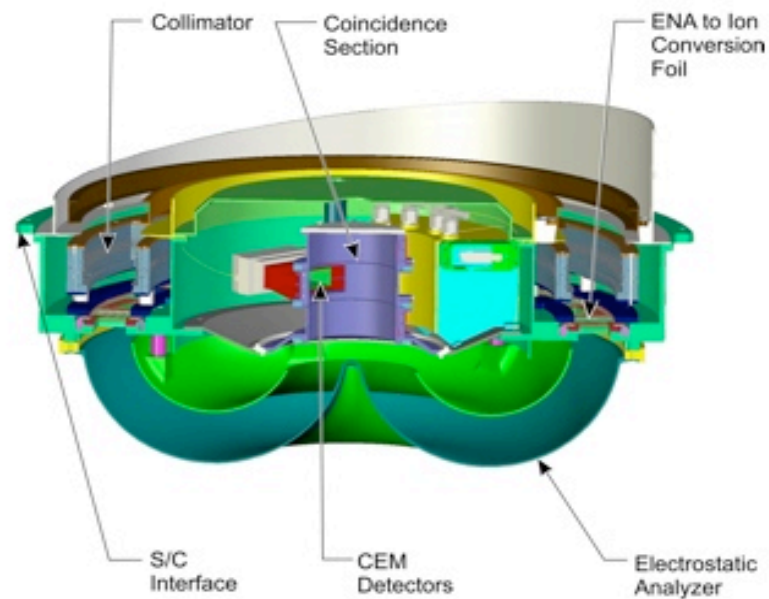
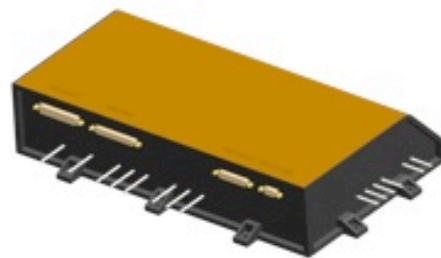
*Slide 39 images: A graphical representation of the IBEX-Hi and IBEX-Lo sensors. Slide 39 Image Credit: IBEX Team*



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### IBEX-Lo:

- Energy range: 0.01-2 keV
- Team: LMATC (Lead), UNH, GSFC, APL



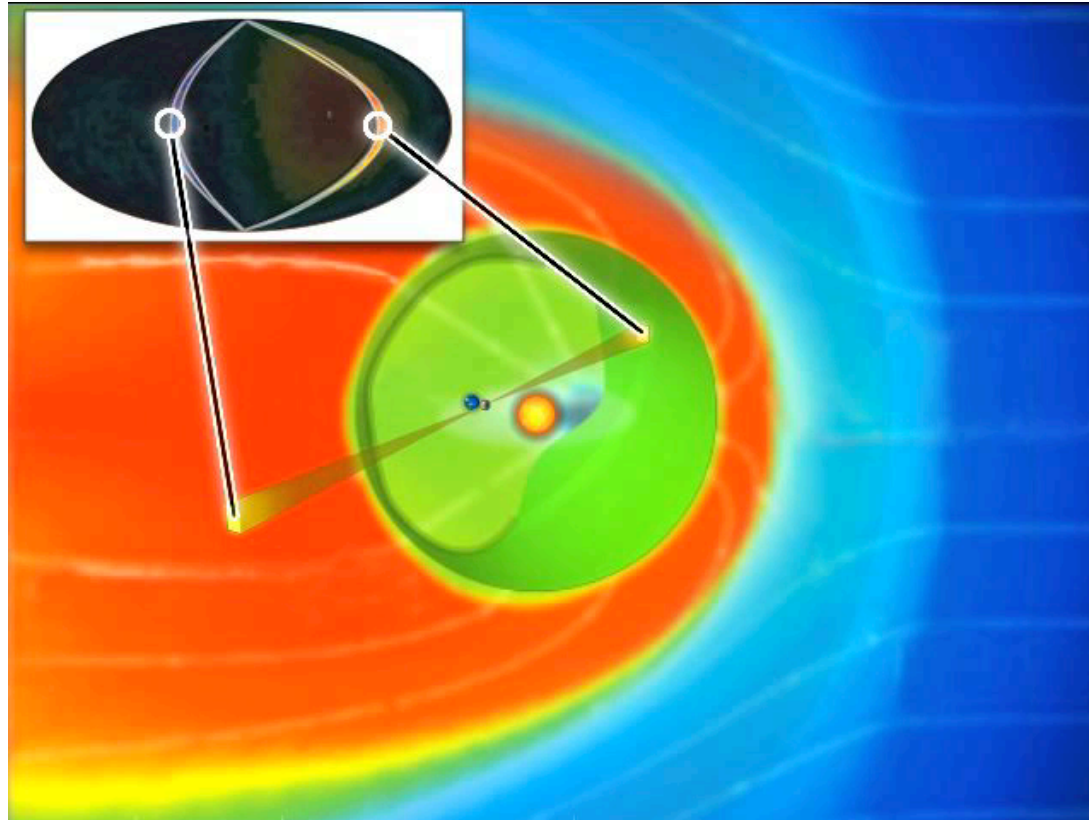
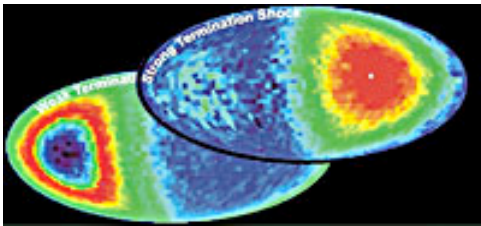
### IBEX-Hi:

- Energy range: 0.3-6 keV
- Team: LANL (Lead), UNH, SwRI

### CEU:

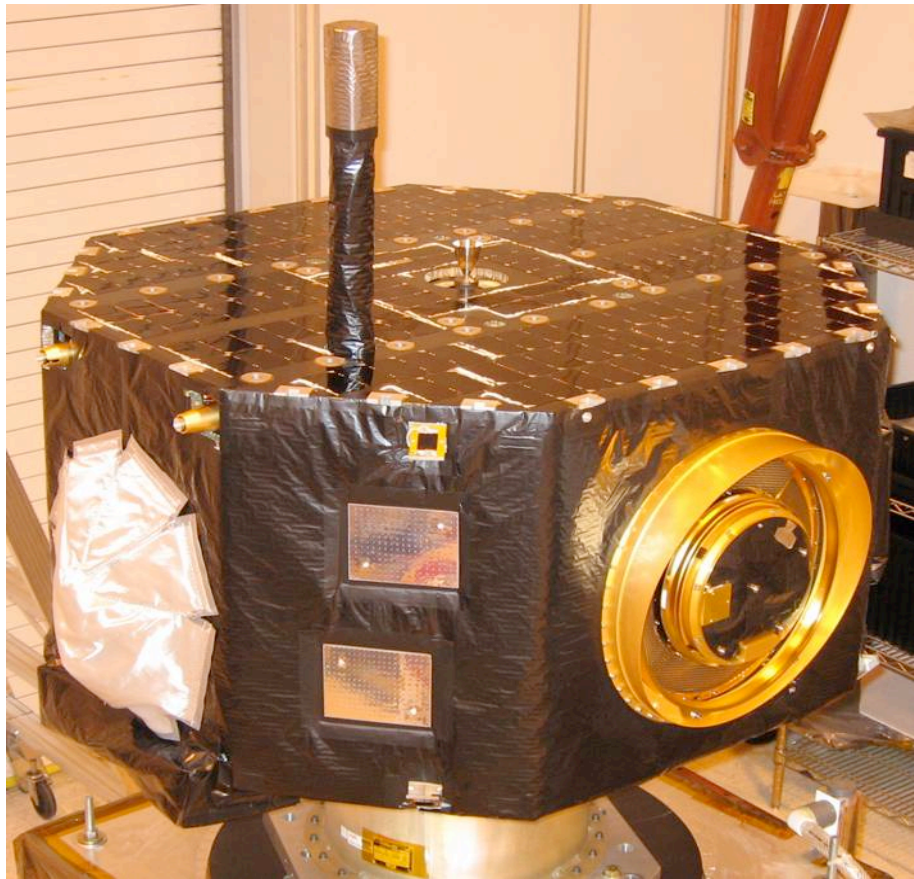
- Provides electronic support and control for payload
- Developed by SwRI

# How will IBEX data create a map of the boundary?



*Movie Credit: IBEX Team*

# From where does IBEX get its power?

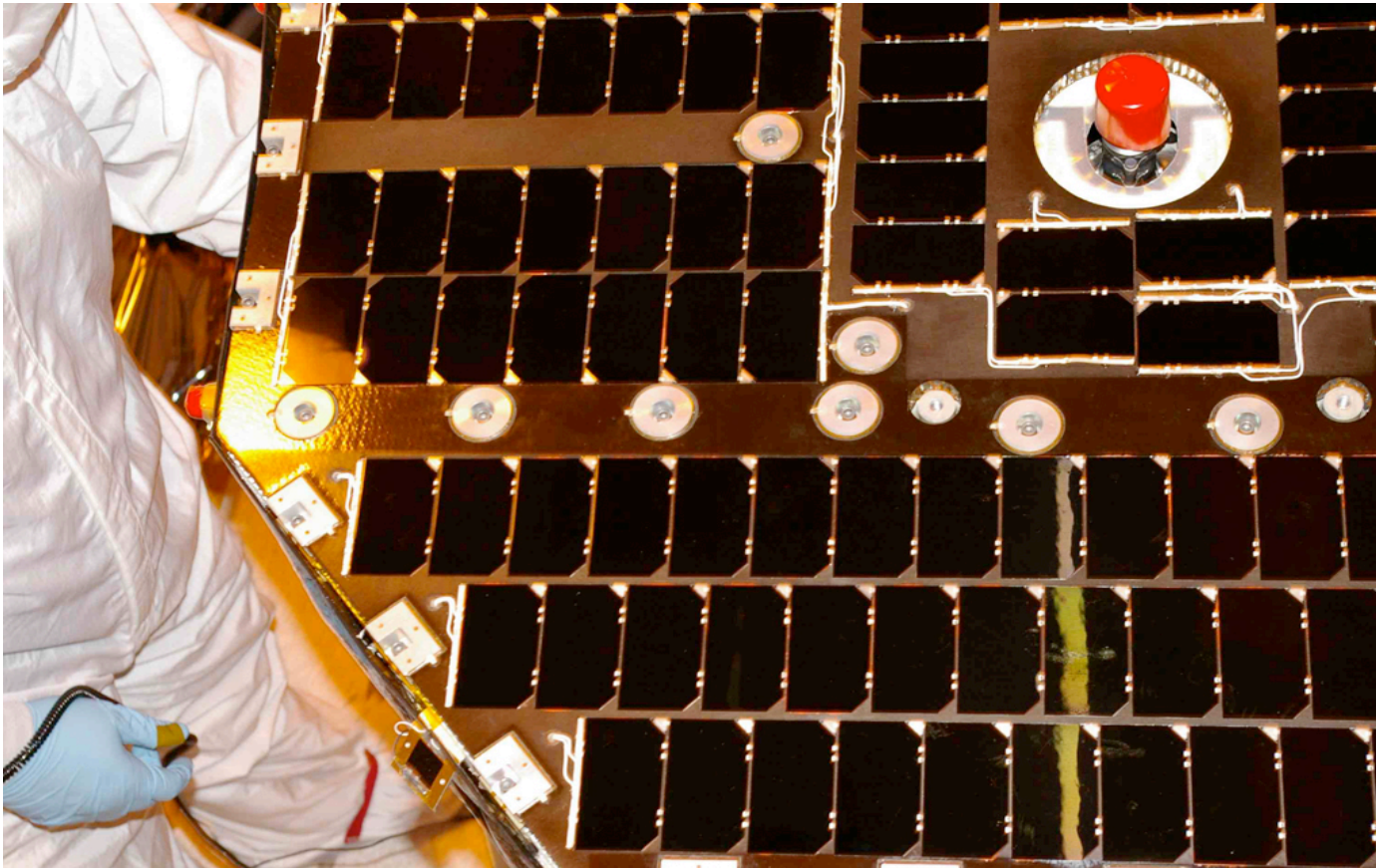


IBEX uses solar panels to collect energy from the Sun.

*The IBEX spacecraft. The solar panels are on the top. Image*

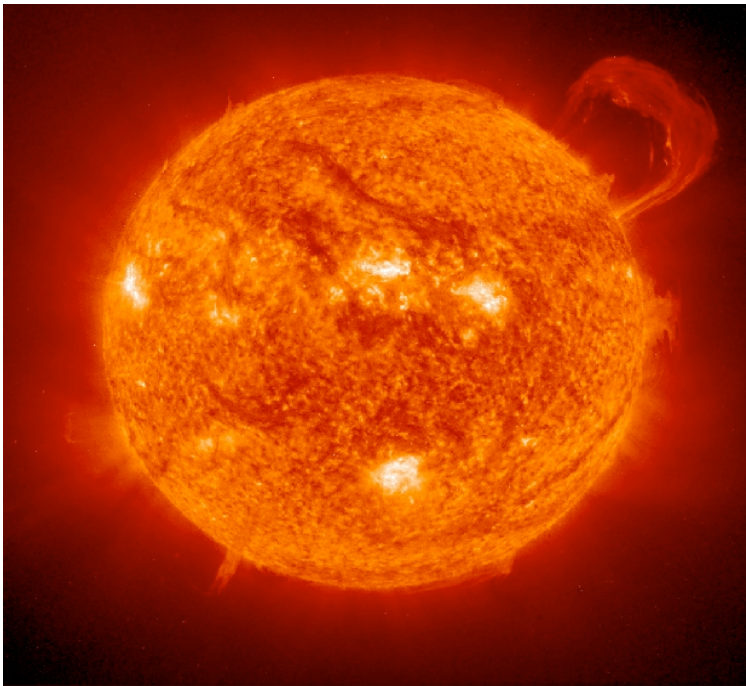
*Credit: Walt Feimer, NASA GSFC*

# From where does IBEX get its power?



*A closeup of the IBEX spacecraft's solar panels. The red object is a spacecraft thruster. Image Credit: Orbital Sciences Corporation*

# What is in store for IBEX's future?



IBEX's primary mission will last for two years. If the spacecraft is healthy in mid-2010, and if NASA's budget permits, then the mission may be extended. From 2008 to 2010, the Sun's activity level will 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 several maps of the heliopause, not just one.

*Image Credit: SOHO (ESA and NASA)*

# How can I get the latest IBEX information?

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

<http://www.nasa.gov/ibex>

or

<http://www.ibex.swri.edu/>

