

Module 4: Radiation and the Electromagnetic Spectrum

Topic 2 Content: The Electromagnetic Spectrum

Introduction

The Electromagnetic Spectrum

Introduction

There are several types of radiation, with wavelengths varying from the size of buildings to as small as the nucleus of an atom.

Click on the buttons on the electromagnetic spectrum to learn more about the various types of radiation emitted by stars and other celestial bodies. As you explore the spectrum, notice the size of the waves for each type of radiation.

EM SPECTRUM

Visible Ultraviolet X-ray Gamma Ray

10^{-6} 10^{-8} 10^{-10} 10^{-12}

About the size of...

Buildings Humans Honey Bee Pinpoint Protozoans Molecules Atoms Atomic Nuclei

Frequency (Hz)

10^4 10^8 10^{12} 10^{15} 10^{16} 10^{18} 10^{20}

Temperature of bodies emitting the wavelength (K)

1 K 100 K 10,000 K 10 Million K

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Radio Waves

The Electromagnetic Spectrum

Radio Waves

The longest wavelengths are radio waves. One wavelength can be hundreds of kilometers long. This type of radiation is the weakest in the electromagnetic spectrum. Radio emissions from space tell astronomers about clouds of cool hydrogen that rest between stars. Cool hydrogen is invisible to the naked eye but is extremely important in astronomy because this is where stars are formed. Radio waves can penetrate clouds of dust, allowing scientists to see through these dust clouds. Some of the most distant objects in the universe are detected only at radio wavelengths.

THE

Wavelength (meters) **Radio** 10^3

About the size of: Buildings

Frequency (Hz) 10^4

Temperature of bodies emitting the wavelength (K)

RUM

X-ray 10^{-10} **Gamma Ray** 10^{-12}

Atoms Atomic Nuclei

Million K

(Note: The central image is the Crab Nebula, a supernova remnant, shown with a radio wavelength overlay.)

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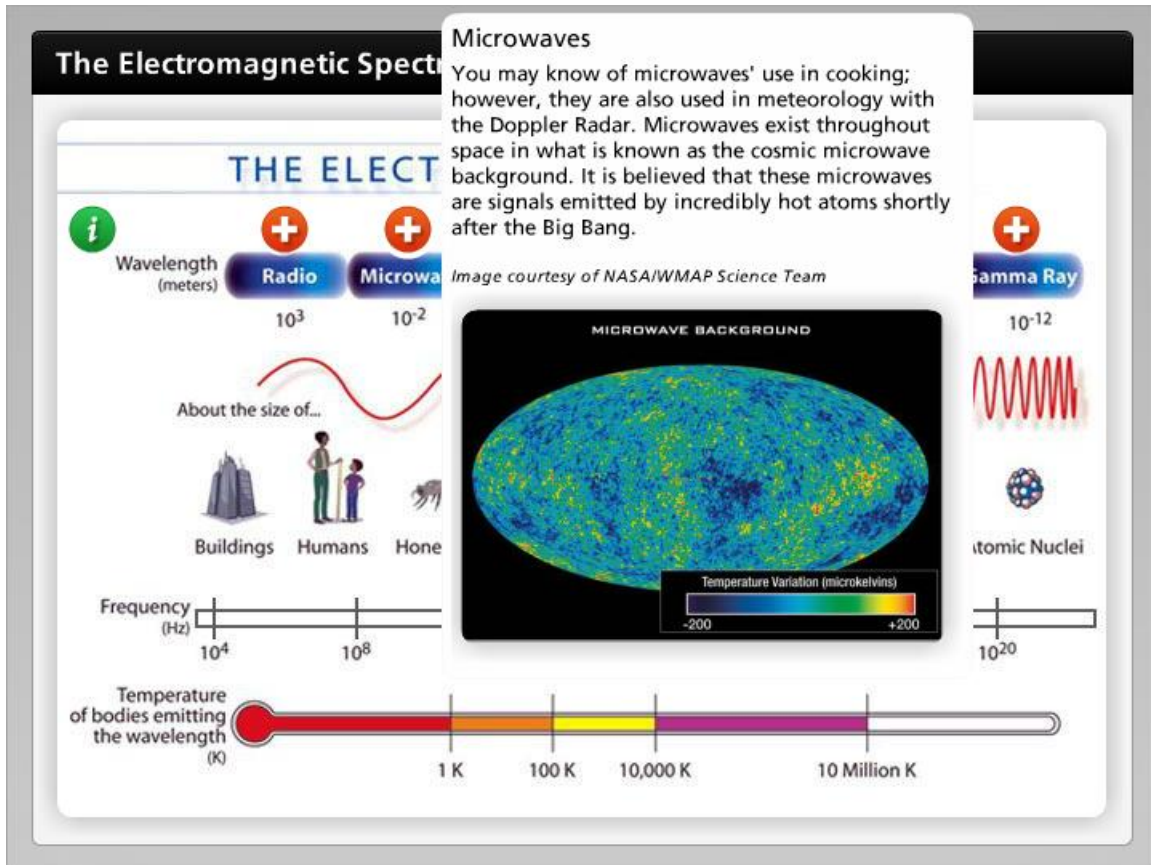
This is an image of the Crab Nebula shown with radio wavelength.

Image courtesy of NRAO/AUI and M. Bietenholz

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Microwaves



You may know of microwaves' use in cooking; however, they are also used in meteorology with the Doppler Radar. Microwaves exist throughout space in what is known as the cosmic microwave background. It is believed that these microwaves are signals emitted by incredibly hot atoms shortly after the Big Bang.

Image courtesy of NASA/WMAP Science Team

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Infrared

The Electromagnetic Spectrum

THE ELECTROMA


Wavelength (meters)


Radio **Microwave** **Infrared**


10^3 10^{-2} 10^{-5}


+ **+** **+**


About the size of...




Buildings


Humans


Honey Bee



Pinpo

Frequency (Hz)

10^4 10^8 10^{12}

Temperature of bodies emitting the wavelength (K)

1 K 100




Infrared

With wavelengths around one-tenth of a meter, infrared radiation has longer and less energetic waves. You cannot see this part of the spectrum, but you can feel this part as heat. Your brain can estimate the temperature of an object because you can detect it with your nerve cells. Infrared radiation is used to detect cool areas that are not emitting visible light but are emitting energy that is less intense such as that from planets, comets, and newly forming stars.

Notice how much infrared reveals in the image and allows astronomers to "see" the invisible.

Image courtesy of NASA/JPL-Caltech/T.Bourke (Harvard-Smithsonian CfA)



Protostellar Jet in BHR 71 Dark Cloud
NASA / JPL-Caltech / T. Bourke (Harvard-Smithsonian CfA) Spitzer Space Telescope • IRAC
sig07-005

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Visible Light

Th **Visible Light**
Your eyes can only see visible light, which makes up a small part of the spectrum as the colors red, orange, yellow, green, blue, indigo, and violet, or ROYGBIV.

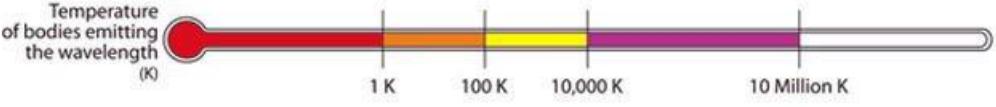
Here is an image of the Crab Nebula in visible light.
Image courtesy of NASA/CXC/SAO



ELECTROMAGNETIC SPECTRUM

Visible	Ultraviolet	X-ray	Gamma Ray
$.5 \times 10^{-6}$	10^{-8}	10^{-10}	10^{-12}
10^{15}	10^{16}	10^{18}	10^{20}

Temperature of bodies emitting the wavelength (K)



1 K 100 K 10,000 K 10 Million K

Your eyes can only see visible light, which makes up a small part of the spectrum as the colors red, orange, yellow, green, blue, indigo, and violet, or ROYGBIV.

Here is an image of the Crab Nebula in visible light.

Image courtesy of NASA/CXC/SAO

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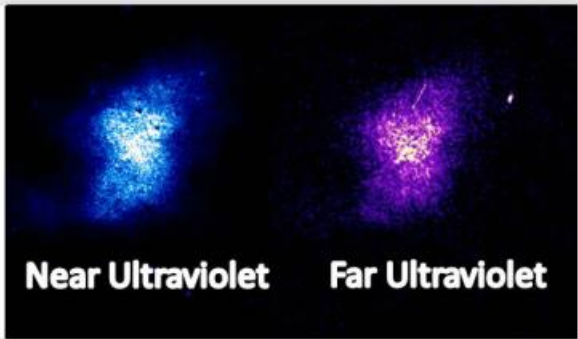
Ultraviolet

Ultraviolet

Although this type of radiation is less harmful than X-rays and gamma rays, ultraviolet radiation is still very dangerous to humans. Earth's atmosphere helps to protect you from some of the harmful effects of ultraviolet radiation. Ultraviolet radiation allows astronomers to learn about hot, excited regions of the universe like hot stars and areas of hot nebula.

These images show the Crab Nebula in two types of ultraviolet wavelengths.

Images courtesy of NASA



Near Ultraviolet **Far Ultraviolet**

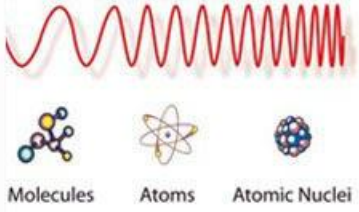
of t
t

1 K 100 K 10,000 K

SPECTRUM

Ultraviolet X-ray Gamma Ray

10^{-8} 10^{-10} 10^{-12}



Molecules Atoms Atomic Nuclei

10^{16} 10^{18} 10^{20}

10 Million K

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These images show the Crab Nebula in two types of ultraviolet wavelengths.

Images courtesy of NASA

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X-rays

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THE SPECTRUM

Radio
Wavelength (meters) 10^3

About the size of...
Buildings Human

X-rays
Wavelength (meters) 10^{-10}

Frequency (Hz) 10^{18}

Temperature of bodies emitting the wavelength (K) 10^7

Gamma Ray
Wavelength (meters) 10^{-12}

Frequency (Hz) 10^{20}

Temperature of bodies emitting the wavelength (K) Billion K

Atoms **Atomic Nuclei**

X-rays
As the waves become more stretched out in the electromagnetic spectrum, the longer the wavelength becomes and the less energy is emitted. X-rays emit less energy than gamma rays; however, X-rays are very intense and emit a tremendous amount of energy because they have a wavelength of around one ten-millionth of a meter. When you think of X-rays, you usually think of going to the doctor. When you get an X-ray, the waves can pass through your skin and muscles but not through your bones because they are denser. X-rays tell astronomers about hot areas in the universe like black holes and nuclear fusion in the cores of stars.

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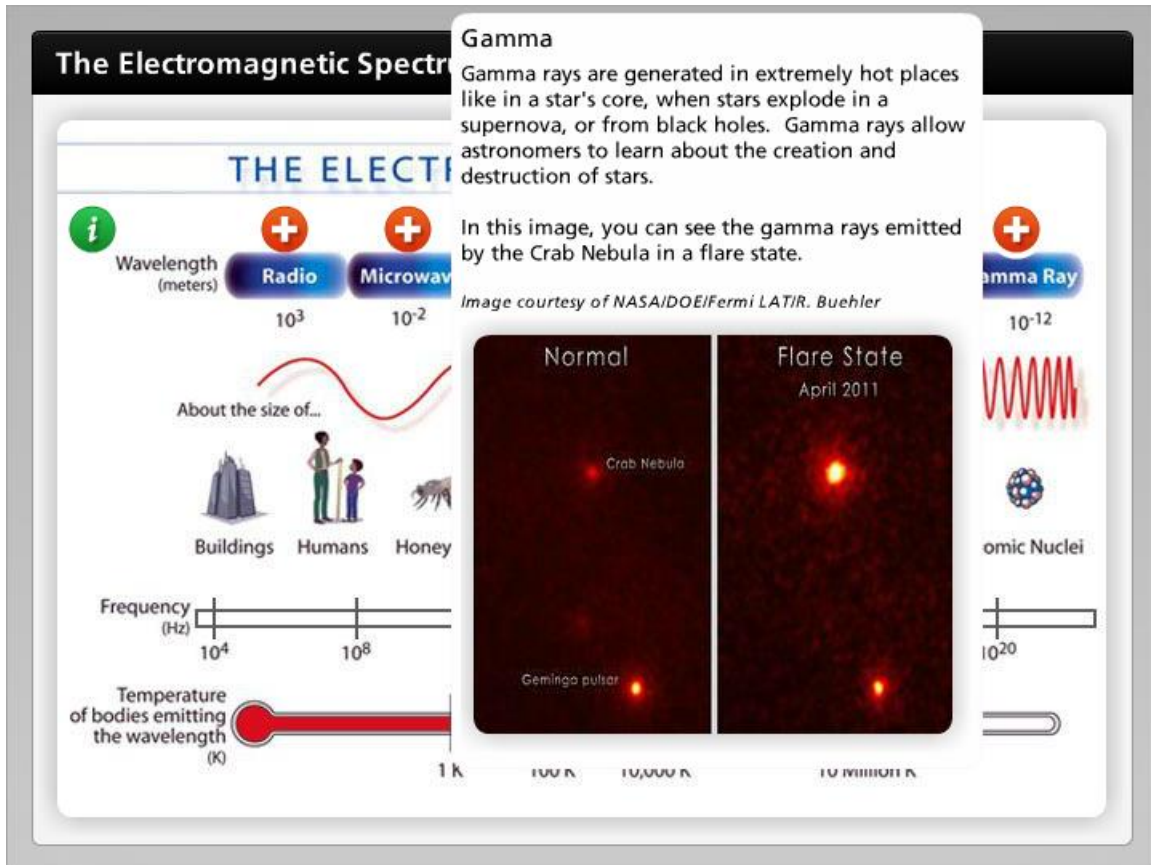
Here is an image of the Crab Nebula in X-ray and how it would look in the visible part of the spectrum.

Image courtesy of NASA/CXC/SAO

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Gamma



Gamma rays are generated in extremely hot places like in a star's core, when stars explode in a supernova, or from black holes. Gamma rays allow astronomers to learn about the creation and destruction of stars.

In this image, you can see the gamma rays emitted by the Crab Nebula in a flare state.

Image courtesy of NASA/DOE/Fermi LAT/R. Buehler