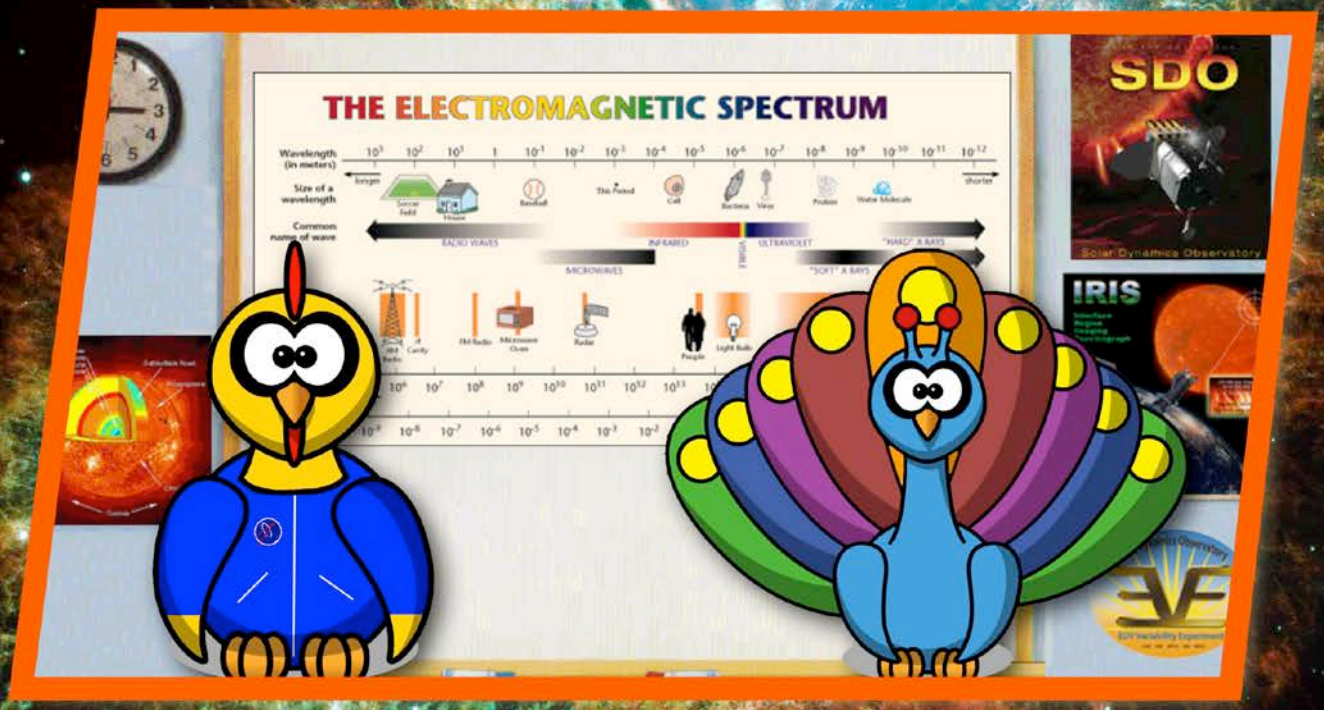
TALES FROM STANFORD SOLAR



LIGHT, ENERGY, AND THE EM SPECTRUM

BY DEBORAH SCHERRER
STANFORD UNIVERSITY

LIGHT, ENERGY, AND THE EM SPECTRUM

HI, I'M CAMILLA!

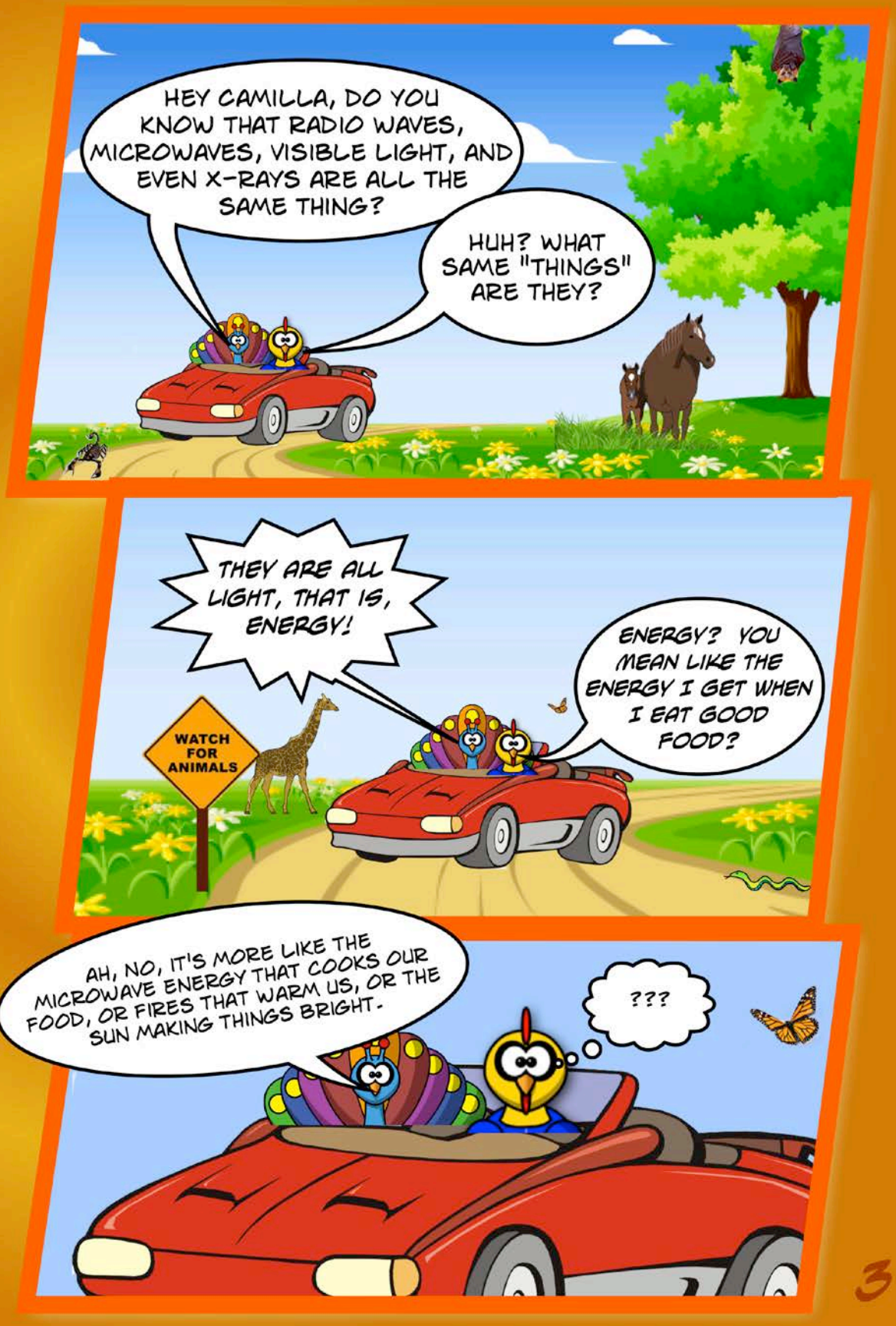
I'M COLOURS!

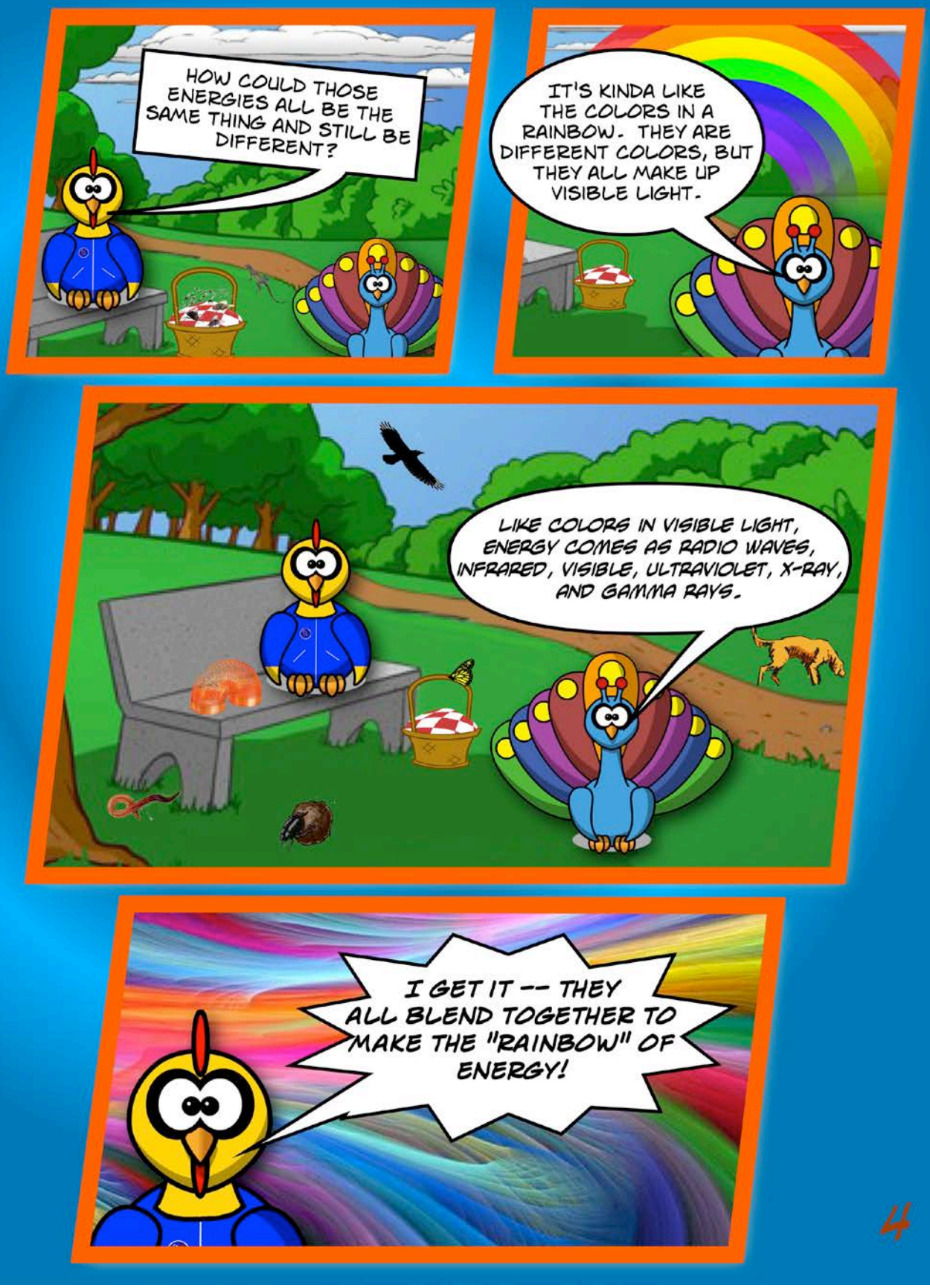
WE ALSO LIKE TO EXPLORE.

DO YOU?

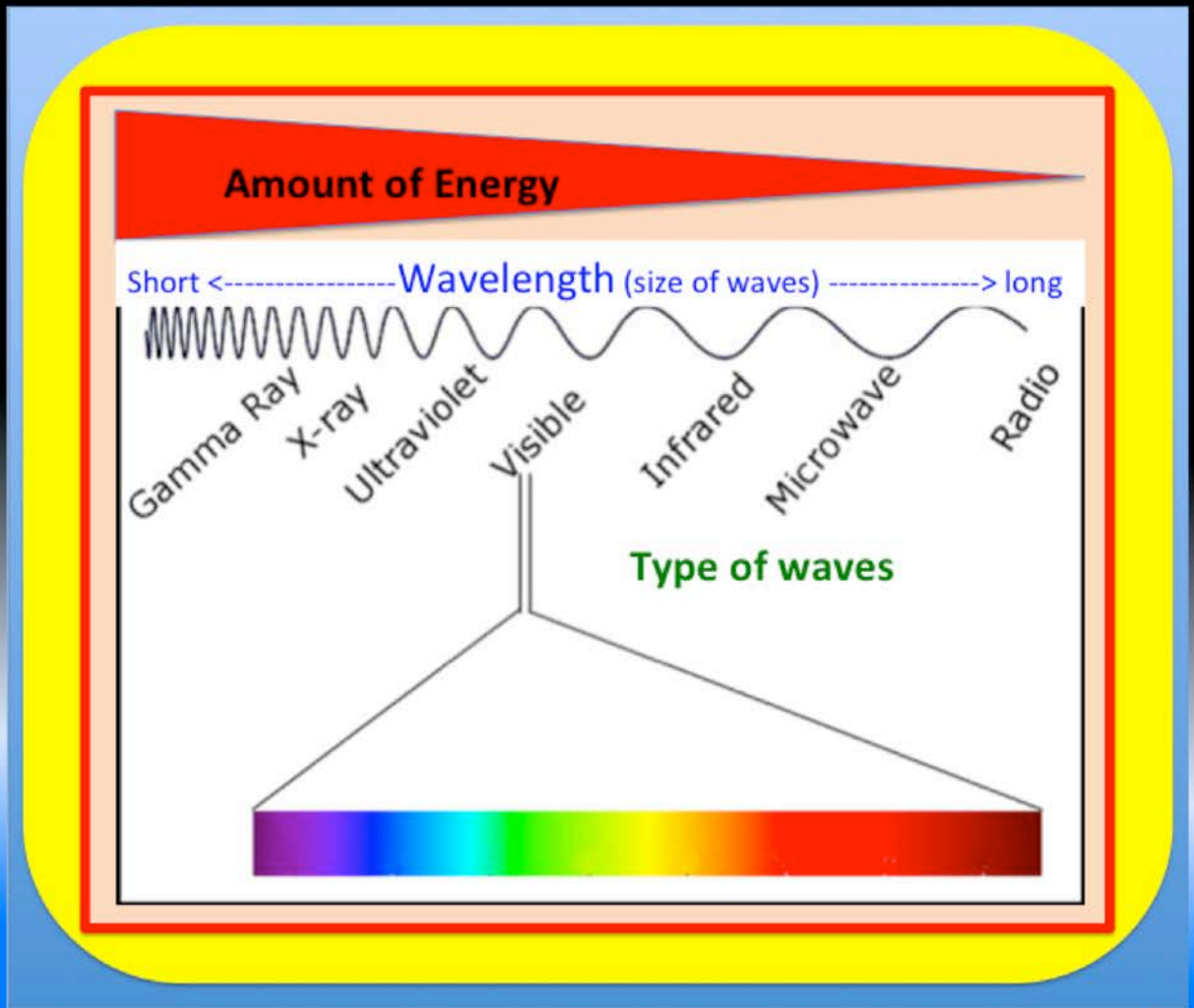
WE WORK AT THE STANFORD SOLAR CENTER, AND WE LOVE NASA SCIENCE!

THIS IS THE CRAB NEBULA, A SUPERNOVA REMNANT FROM A HUGE EXPLODING STAR OBSERVED BY CHINESE ASTRONOMERS IN 1054! WE ARE SEEING IT IN SEVERAL PORTIONS OF THE **ELECTROMAGNETIC SPECTRUM**. WANT TO KNOW WHAT THAT IS?


HEY CAMILLA, DO YOU KNOW THAT RADIO WAVES, MICROWAVES, VISIBLE LIGHT, AND EVEN X-RAYS ARE ALL THE SAME THING?
HUH? WHAT SAME "THINGS" ARE THEY?
THEY ARE ALL LIGHT, THAT IS, ENERGY!
ENERGY? YOU MEAN LIKE THE ENERGY I GET WHEN I EAT GOOD FOOD?
WATCH FOR ANIMALS
AH, NO, IT'S MORE LIKE THE MICROWAVE ENERGY THAT COOKS OUR FOOD, OR FIRES THAT WARM US, OR THE SUN MAKING THINGS BRIGHT.
???


HOW COULD THOSE ENERGIES ALL BE THE SAME THING AND STILL BE DIFFERENT?
IT'S KINDA LIKE THE COLORS IN A RAINBOW. THEY ARE DIFFERENT COLORS, BUT THEY ALL MAKE UP VISIBLE LIGHT.
LIKE COLORS IN VISIBLE LIGHT, ENERGY COMES AS RADIO WAVES, INFRARED, VISIBLE, ULTRAVIOLET, X-RAY, AND GAMMA RAYS.
I GET IT -- THEY ALL BLEND TOGETHER TO MAKE THE "RAINBOW" OF ENERGY!

ELECTROMAGNETIC SPECTRUM



OK, I UNDERSTAND HOW THESE ARE THE SAME. BUT HOW ARE THEY DIFFERENT?

THEY ARE DIFFERENT BY THE ***AMOUNT OF ENERGY*** EACH CARRIES. RADIO WAVES HAVE A SMALL AMOUNT OF ENERGY, X-RAYS AND GAMMA RAYS HAVE A ***LOT!***

YOU CAN LEARN ABOUT WAVES BY PLAYING WITH A SLINKY.

STRETCH OUT A SLINKY AND ANCHOR ONE END. HOLD THE OTHER END IN YOUR HAND AND MOVE YOUR HAND UP AND DOWN.

Slinky waves can be made by vibrating the first coil back and forth in either a horizontal or a vertical direction.

TRY IT!

DON'T HAVE A SLINKY? THEN YOU CAN WATCH THEM MOVE HERE:

https://www.youtube.com/watch?v=lUsjVRy4zaw

AND HERE:

https://www.youtube.com/watch?v=y66PSaiGH7Y

NOTICE THAT THE ENERGY MOVES THROUGH THE SLINKY. THE COILS OF THE SLINKY JUST GO UP AND DOWN.

WAVES ARE THE WAY ENERGY MOVES FROM PLACE TO PLACE!!!

NOW, CHANGE HOW FAST YOU MOVE YOUR HAND. THE FASTER YOU MOVE THE SLINKY, THE HIGHER FREQUENCY OF WAVES YOU GET!

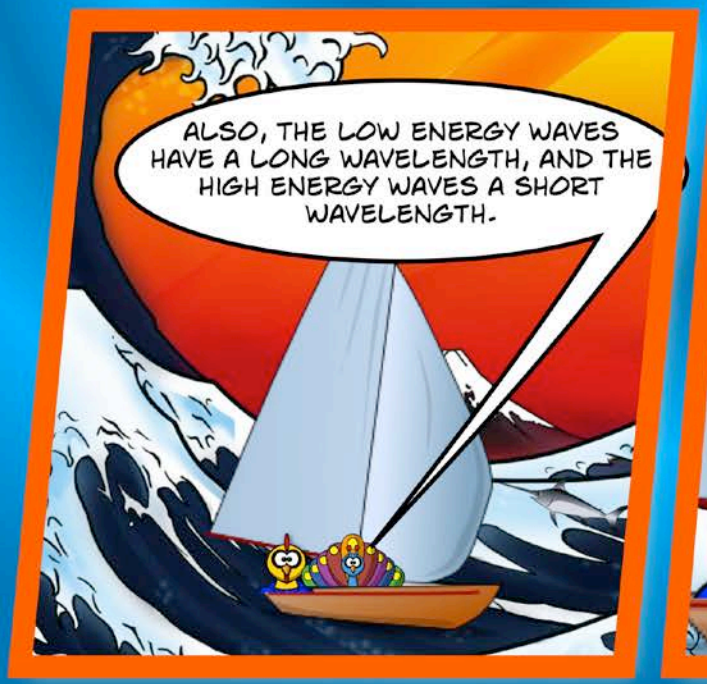
TRY IT!

WHAT'S FREQUENCY?

FREQUENCY IS HOW OFTEN THE WAVES GO BY IN TIME. IF YOU STAND IN THE OCEAN AND A LOT OF WAVES GO BY QUICKLY, THAT'S HIGH FREQUENCY. IF ONLY A FEW WAVES GO BY IN THAT SAME AMOUNT OF TIME, THAT'S LOW FREQUENCY.

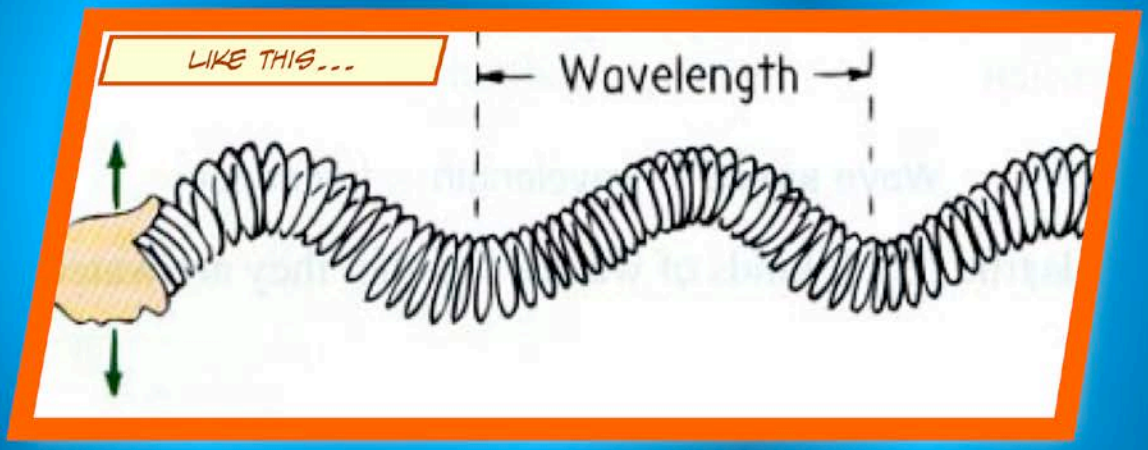
SOMETHING ELSE IS IMPORTANT - HOW MUCH OF THE ENERGY YOU ARE RECEIVING. A LIGHT BULB PRODUCES VISIBLE LIGHT, AND THE SUN PRODUCES VISIBLE LIGHT. BUT YOU GET A **WHOLE** LOT MORE VISIBLE LIGHT ENERGY FROM THE SUN THAN YOU DO FROM THE LIGHTBULB!


I GET IT – A LITTLE ENERGY EQUALS WAVES WITH LOW FREQUENCY. A LOT OF ENERGY EQUALS WAVES WITH HIGH FREQUENCY!


ALSO, THE LOW ENERGY WAVES HAVE A LONG WAVELENGTH, AND THE HIGH ENERGY WAVES A SHORT WAVELENGTH.

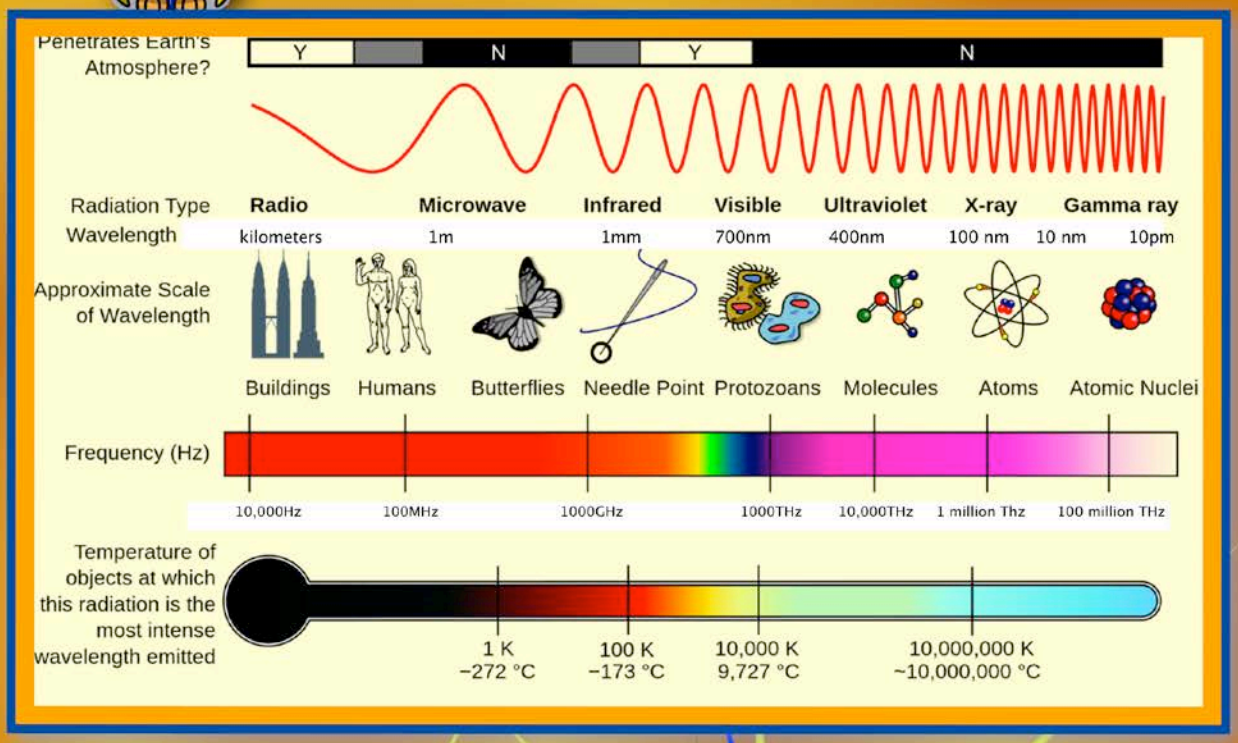

WHAT'S A WAVELENGTH?
ARG....


A WAVELENGTH IS THE DISTANCE BETWEEN 2 CRESTS OR 2 TROUGHS OF A WAVE.


LIKE THIS...
Wavelength


OK, SO FOR LIGHT:
HIGH ENERGY = SHORT WAVELENGTH
LOW ENERGY = LONG WAVELENGTH

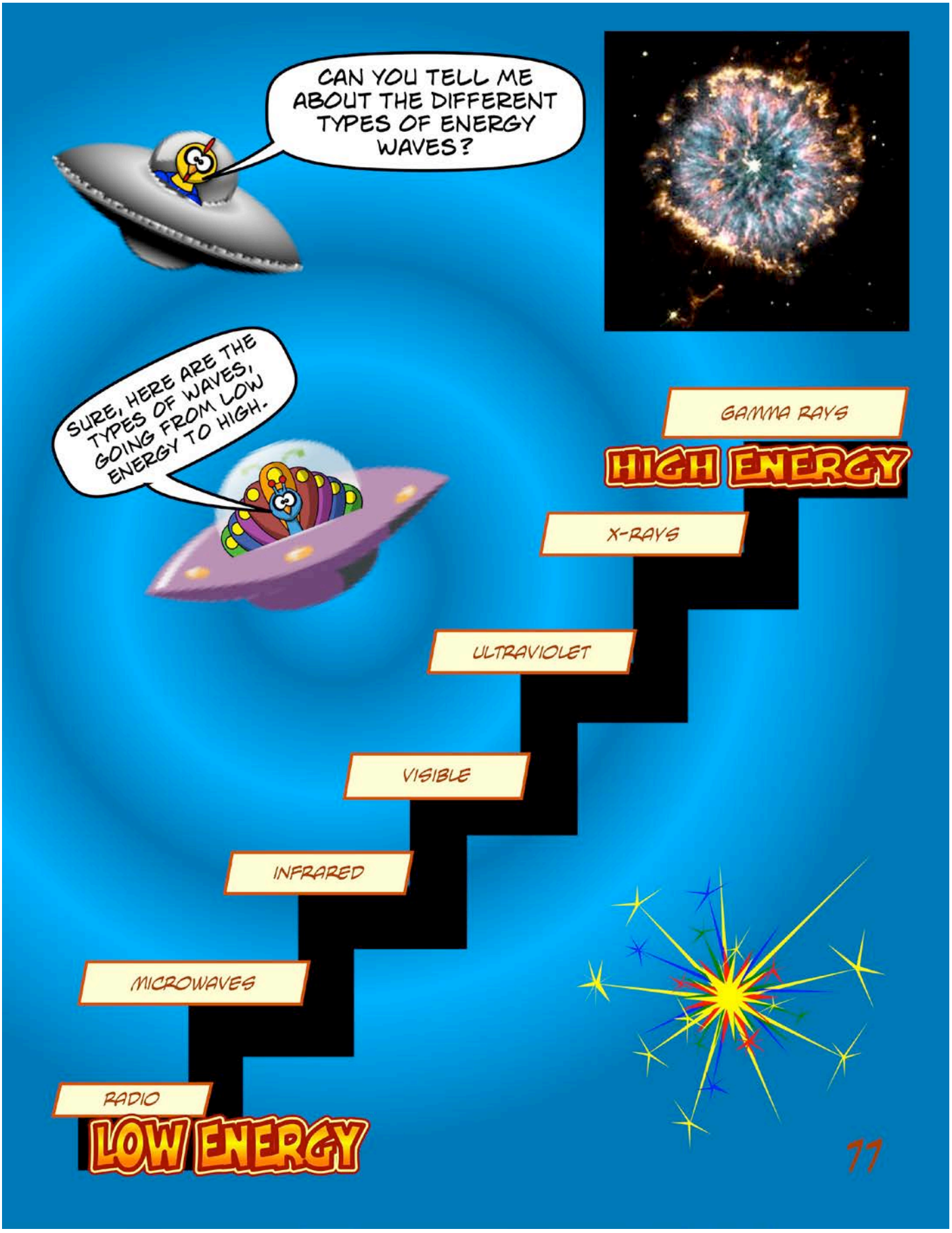
SO, ALL FREQUENCIES OF ENERGY WAVES MAKE UP THE ELECTROMAGNETIC SPECTRUM. VERY AWESOME!

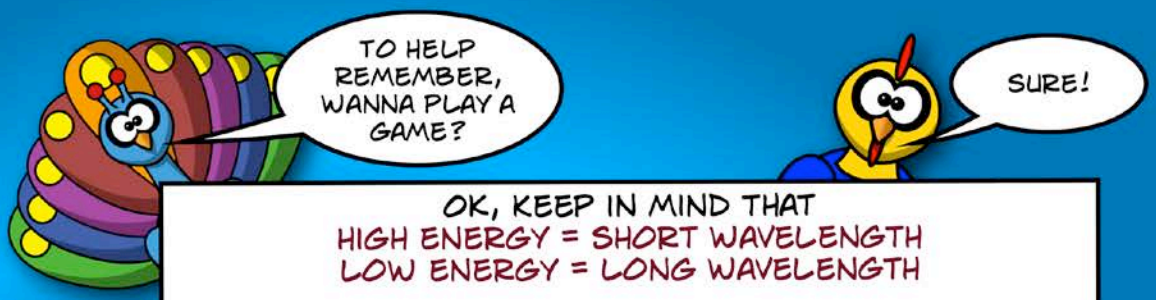


YES, AND NASA HAS A COOL MOVIE THAT TELLS ABOUT IT. WANNA SEE IT?

NASA

http://www.youtube.com/watch?v=IwfJPc-rSXw


CAN YOU TELL ME ABOUT THE DIFFERENT TYPES OF ENERGY WAVES?
SURE, HERE ARE THE TYPES OF WAVES, GOING FROM LOW ENERGY TO HIGH.
GAMMA RAYS
HIGH ENERGY
X-RAYS
ULTRAVIOLET
VISIBLE
INFRARED
MICROWAVES
RADIO
LOW ENERGY



OK, KEEP IN MIND THAT
HIGH ENERGY = SHORT WAVELENGTH
LOW ENERGY = LONG WAVELENGTH

MATCH UP THE WAVES WITH THE OBJECT ABOUT THE SIZE OF THEIR WAVELENGTH:

GAMMA RAY

INFRARED

MICROWAVE

RADIO WAVE

VISIBLE LIGHT

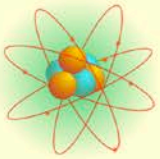
X-RAYS

ULTRAVIOLET

MOLECULE

BUILDINGS

NEEDLE POINT



ATOM

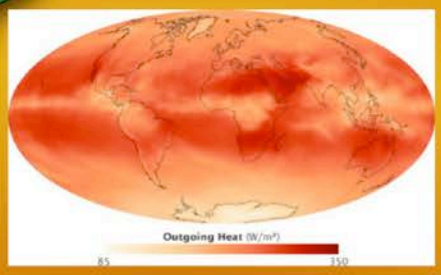
BUTTERFLY

NUCLEUS

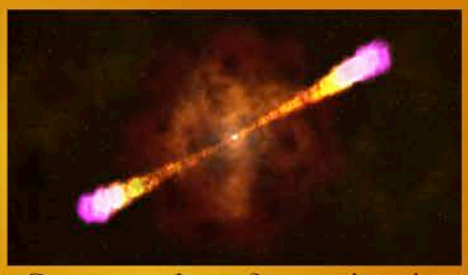
PROTOZOA

FOR ANSWERS SEE:
http://solar-center.stanford.edu/comics/Light-Energy-EM-Spectrum/em-properties.pdf

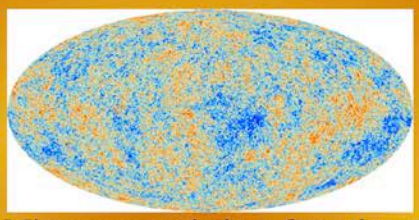
ARRANGE THESE ASTRONOMICAL IMAGES IN ORDER OF THE ENERGIES THEY REPRESENT, FROM LOW TO HIGH.



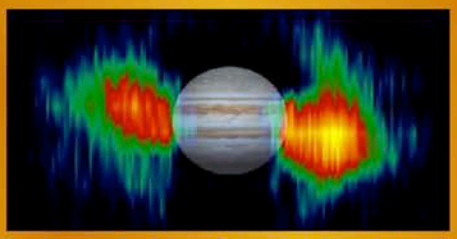
1. Infrared emissions from the Earth (*false color*)



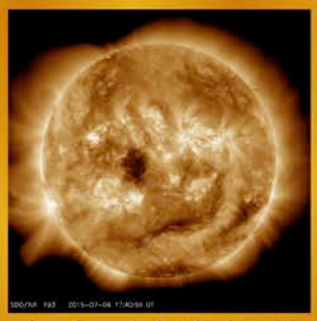
2. Gamma ray burst from a gigantic star collapsing into a black hole (*false color*)



3. Microwave emissions from the early universe (*false color*)



4. Radio emissions from Jupiter (*false color*)



5. Sun in ultraviolet light (*false color*)

6. Sun in visible light (*true color*)

7. Supernova (a giant exploding star) in X-rays (*false color*)

Put your answers here:

_____ *(lowest energy)*

_____

_____

_____

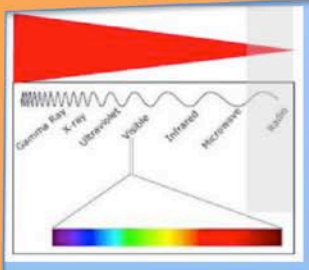
_____

_____

_____ *(highest energy)*

FOR ANSWERS AND MORE INFORMATION ABOUT THESE OBJECTS, SEE:
http://solar-center.stanford.edu/comics/Light-Energy-EM-Spectrum/em-energies.pdf

NOW, HERE'S MORE ABOUT THE DIFFERENT KINDS OF WAVES



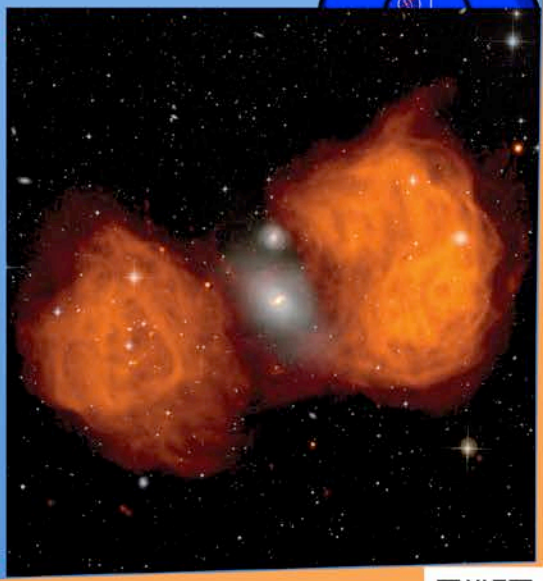
Radio Waves

Radio waves have very long wavelengths with a relatively small amount of energy.

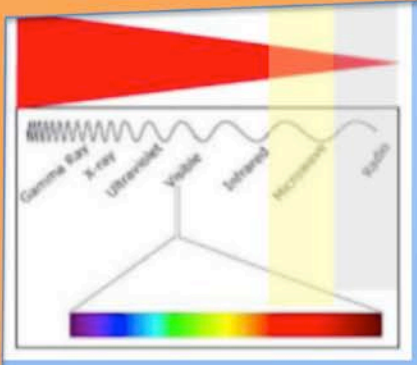
Wavelengths can be from meters to many kilometers long. In fact, in theory they could be as long as the universe!

On Earth we use radio waves to transmit information, which we can convert to sound when we hook up a radio receiver to a speaker.

Astronomers use radio telescopes to study supernova remnants, radio galaxies, quasars, and pulsars.



http://www.youtube.com/watch?v=OzDmEA8x0nQ

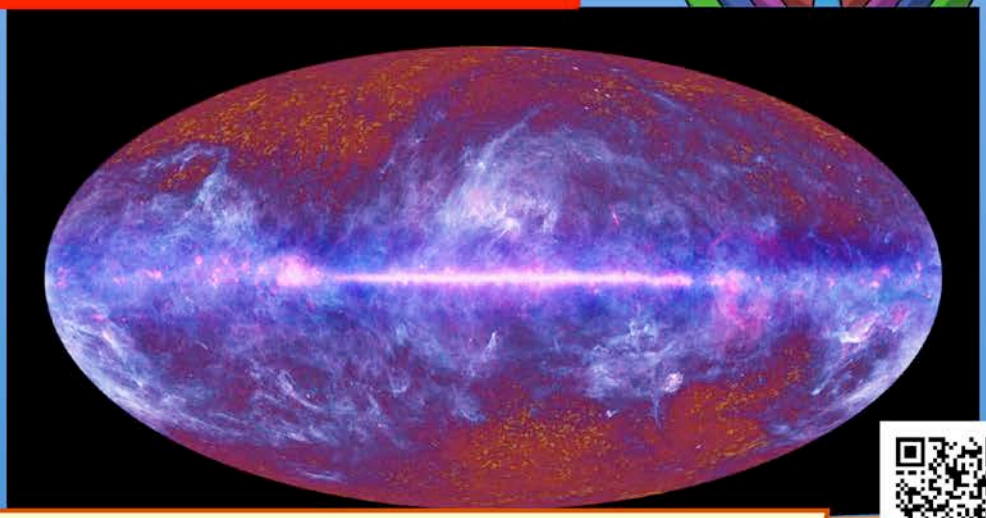


Microwaves

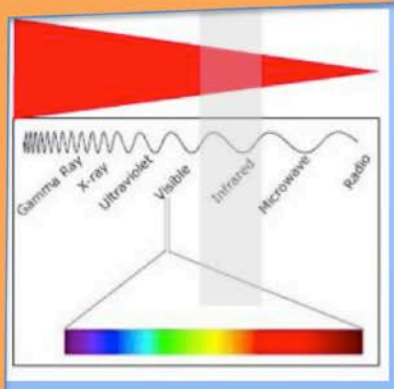
Microwaves have wavelengths about the size of 1 mm to 1 meter, and a relatively small amount of energy.

On Earth we use microwaves to "jiggle" atoms in our food to make it warm, for communications, and for radar.

Astronomers use microwave telescopes to create images of the universe beyond clouds of dust and gas.



HTTPS://WWW.YOUTUBE.COM/WATCH?V=YGQQB1BVNU8

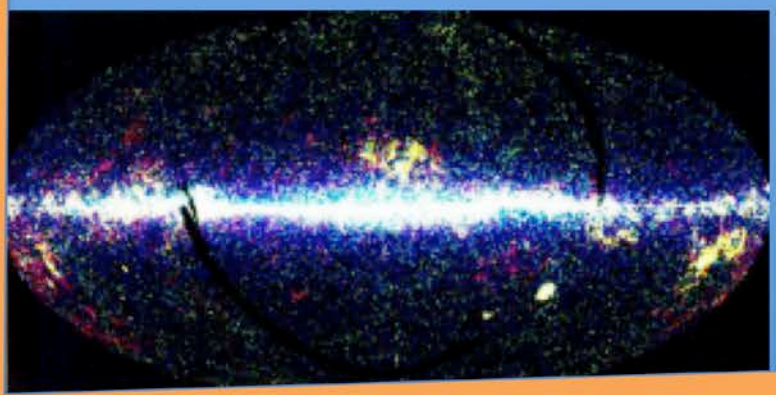


Infrared

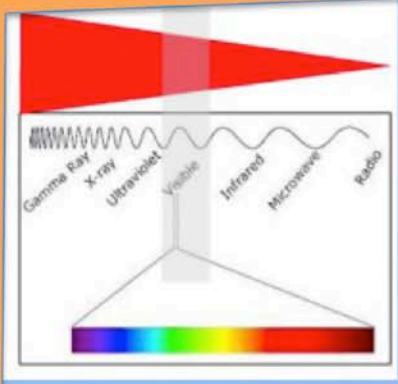
Infrared waves feel like heat to us. We can't see them, but snakes can sense them with their tongues. Infrared wavelengths are smaller than the thickness of a human hair.

On Earth, night vision goggles and special heat-sensing cameras sense infrared waves and turn them into something we can see.

Infrared radiation can pass through dusty regions of space, allowing astronomers to study objects hidden by gas and dust, such as the center of our galaxy and regions of newly forming stars.



http://www.youtube.com/watch?v=i8caGm9Fmh0



Visible Light

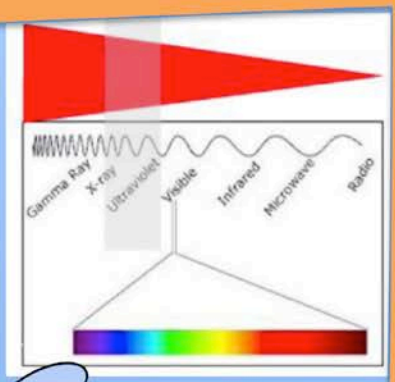
Visible light is what our eyes detect. It includes all the colors of the rainbow, which when mixed together appear to us as white.

Astronomers use visible light to study the Sun and stars. Often they separate the visible light back into its colors, since by using a spectrograph (an instrument that breaks light up into its colors) they can learn much about the composition, movement, temperature, and magnetism of the star.

http://www.youtube.com/watch?v=PMtC34pzKGc

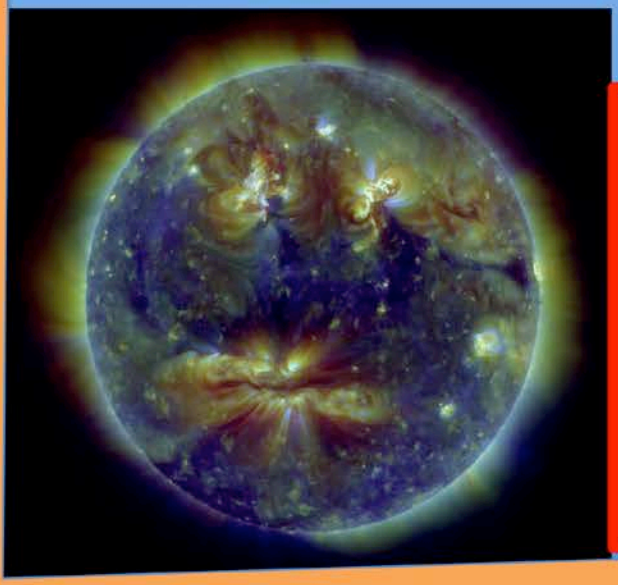
Ultraviolet Light

Ultraviolet light is more energetic than visible light. We cannot see it, but some insects can.



UV light from the Sun can cause sunburn, damage our eyes, and even cause cancer. Most UV is blocked out by Earth's ozone layer and atmosphere.

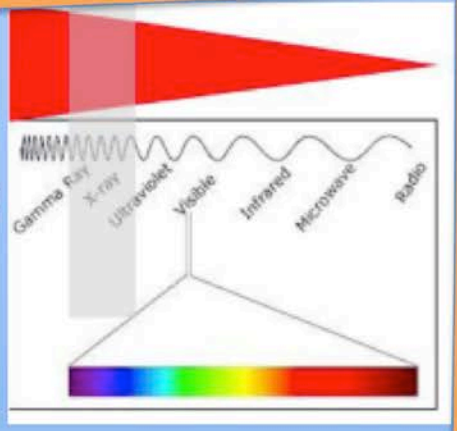
Help – Camilla didn't use enough sunscreen!!!



Because UV light comes from areas that are very, very hot, astronomers use UV to study activity on the Sun. NASA's Solar Dynamics Observatory studies the Sun in ultraviolet light!

http://www.youtube.com/watch?v=QW5zeVy8aE0

X-rays



X-rays have a LOT of energy, so much that they can go right through the soft parts of our bodies but not our bones. That's why doctors use X-rays to look for bone damage.

Our Sun produces X-rays during big solar flares. These don't get through our atmosphere, but can damage satellites and hurt astronauts in space.

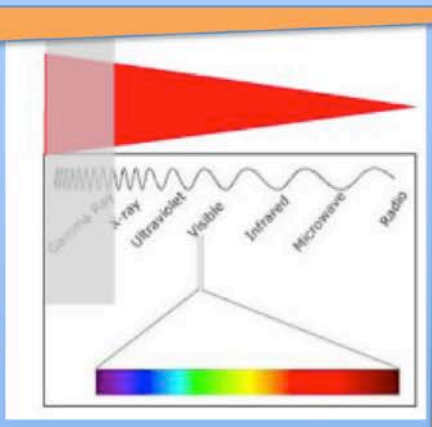
X-rays are emitted from astronomical objects that have extremely hot gases.

SCIENTISTS LOOK AT X-RAY EMISSIONS NOT ONLY TO STUDY THE SUN AND STARS, BUT ALSO NEUTRON STARS AND THE GASES FALLING INTO BLACK HOLES!

http://www.youtube.com/watch?v=CCAYcuCWOnM

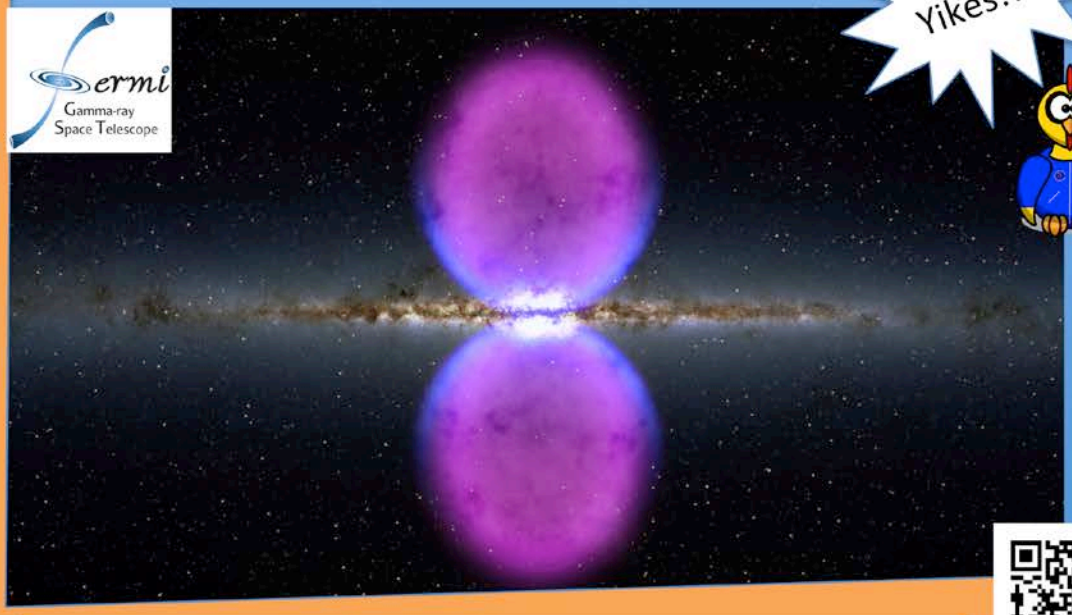
Gamma Rays

GAMMA RAYS HAVE A HUGE AMOUNT OF ENERGY, AND THE SMALLEST WAVELENGTH (SMALLER THAN AN ATOM). GAMMA RAYS ARE PRODUCED BY THE MOST GIGANTIC EXPLOSIONS IN THE UNIVERSE, INCLUDING EXPLODING STARS (SUPERNOVAE), STARS THAT ARE COLLIDING, RAPIDLY ROTATING NEUTRON STARS (PULSARS), EMISSIONS FROM SUPERMASSIVE BLACK HOLES, AND THE COLLAPSE OF STARS.



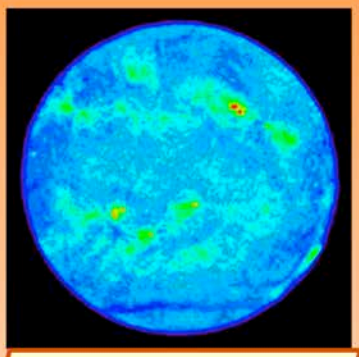
NASA's FERMI mission studies the universe in gamma rays!

Fermi Gamma-ray Space Telescope

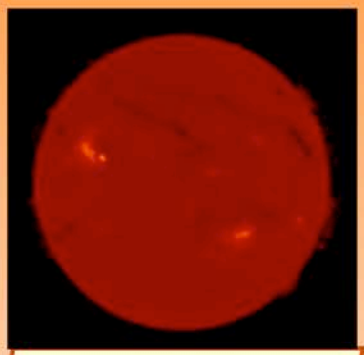


http://www.youtube.com/watch?v=TA5SLDiIUWs

WE CAN STUDY THE SUN BY LOOKING AT THE RADIO WAVES, MICROWAVES, INFRARED LIGHT, VISIBLE LIGHT, ULTRAVIOLET LIGHT, X-RAYS, AND GAMMA RAYS IT PRODUCES.

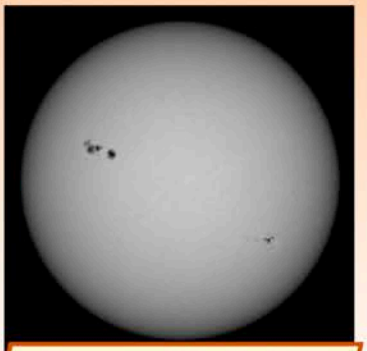


SUN IN RADIO WAVES

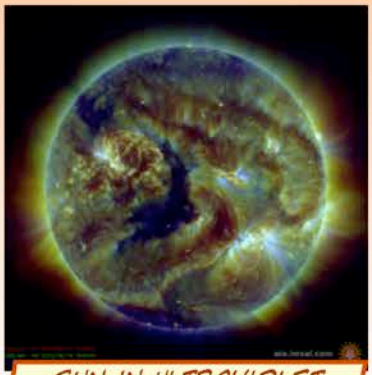


SUN IN MICROWAVES

SUN IN INFRARED LIGHT

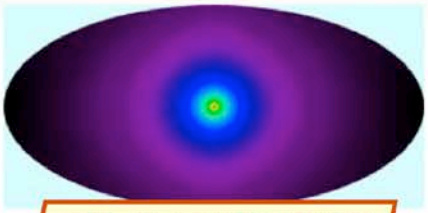


SUN IN VISIBLE LIGHT



SUN IN ULTRAVIOLET LIGHT

SUN IN X-RAYS



SUN IN GAMMA WAVES

WANT TO LEARN MORE?

http://solar-center.stanford.edu/comics/Light-Energy-EM-Spectrum/em-sunspectrum.pdf


---AND WAVES AND ENERGY AND THE DIFFERENT TYPES OF WAVES LIKE---
WOW, COLOURS! THANKS FOR TEACHING ME ABOUT THE ELECTROMAGNETIC SPECTRUM
RADIO, MICROWAVES, INFRARED, VISIBLE, ULTRAVIOLET, X-RAYS, AND GAMMA RAYS AND---
AND HOW THEY ARE THE SAME THING BUT WITH DIFFERENT AMOUNTS OF ENERGY, AND ABOUT THE DIFFERENT THINGS WE CAN LEARN WITH THE DIFFERENT WAVES AND----


AW SHUCKS---

THERE ARE LOTS OF ANIMALS SHOWN IN THIS BOOK. MOST OF THEM HAVE SOMETHING TO DO WITH ASTRONOMY OR SPACE. CAN YOU FIND & NAME THEM ALL?

WHICH ANIMALS NAVIGATE BY THE SUN, BY THE STARS, BY THE EARTH'S MAGNETIC FIELD?

WHICH ANIMALS ARE REPRESENTED BY CONSTELLATIONS IN THE SKY?

WHICH ANIMAL DID AN ANCIENT CULTURE LINK TO THE SUN?

Answers:
http://solar-center.stanford.edu/comics/Light-Energy-EM-Spectrum/em-animals.pdf

RESOURCES

VIDEO TOUR OF THE ELECTROMAGNETIC SPECTRUM
HTTP://MISSIONSCIENCE.NASA.GOV/EMS/EMSVIDEO_01INTRO.HTML

IMAGINE THE UNIVERSE! THE ELECTROMAGNETIC SPECTRUM:
HTTP://IMAGINE.GSFC.NASA.GOV/SCIENCE/TOOLBOX/EMSPECTRUM1.HTML

INTRODUCTION TO THE ELECTROMAGNETIC SPECTRUM:
HTTP://MISSIONSCIENCE.NASA.GOV/EMS/01_INTRO.HTML

NASA'S FERMI MISSION:
HTTP://WWW.NASA.GOV/CONTENT/FERMI-GAMMA-RAY-SPACE-TELESCOPE

NASA'S SOLAR DYNAMICS OBSERVATORY
HTTP://SDO.GSFC.NASA.GOV/

NASA'S IRIS MISSION
HTTP://IRIS.GSFC.NASA.GOV/

FOR MORE COMICS:
HTTP://SOLAR-CENTER.STANFORD.EDU/COMICS

STORY & DESIGN BY DEBORAH SCHERRER
INSPIRATION FROM EMILY KELLAGHER

STANFORD SOLAR CENTER
http://solar-center.stanford.edu/

THIS PROJECT WAS A COLLABORATION BETWEEN NASA'S SDO/HMI AND IRIS EDUCATION PROGRAMS