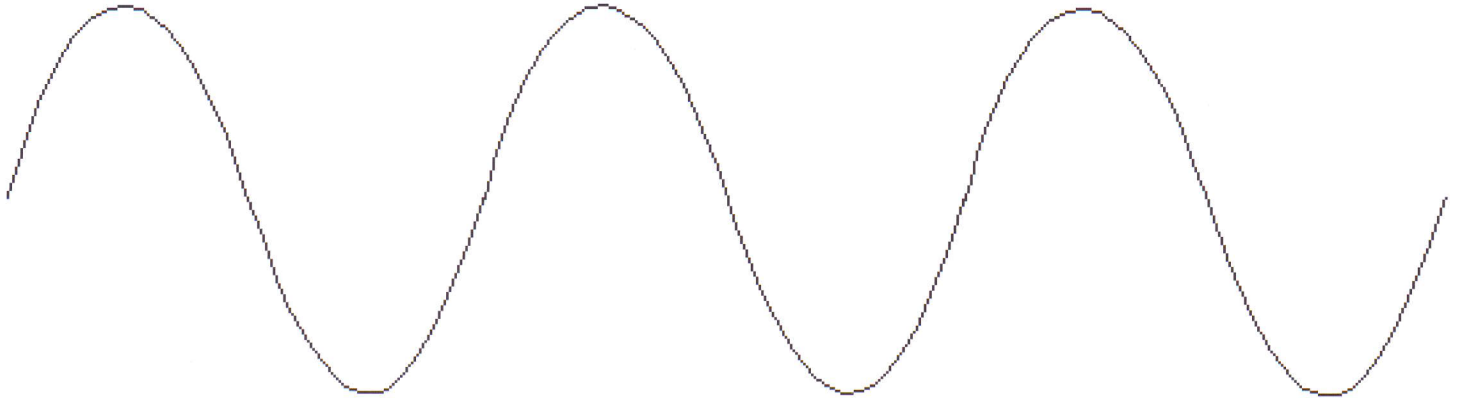
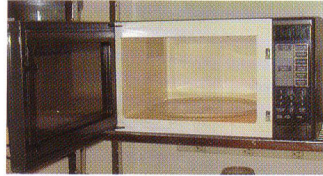


MICROWAVE



Emitted by:

- Gas clouds collapsing into stars
- Microwave ovens
- Radar stations
- Cell phones

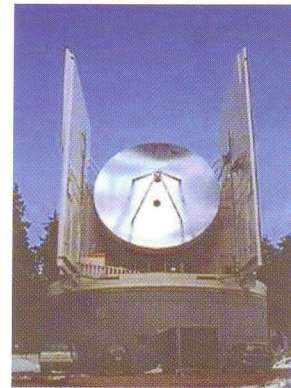


Detected by:

- Ground-and space-based microwave telescopes
- Food (heated)
- Cell phones
- Radar systems



MAP (Microwave Anisotropy Probe) space telescope

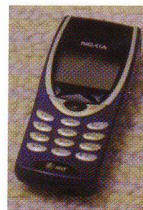


Submillimeter radio telescope in Arizona

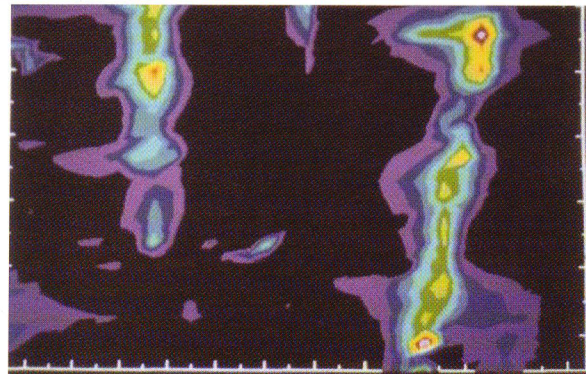
1

Useful for:

- Microwave astronomy
- Cooking
- Radar
- Communications



Cell phone



Map of our Galaxy made with microwaves given off by hydrogen

Harmful Effects: At very high intensities, certain wavelengths can heat up living cells and kill them. Cellular phones have been suspected of affecting the brain, but no strong evidence of this has been found.

2

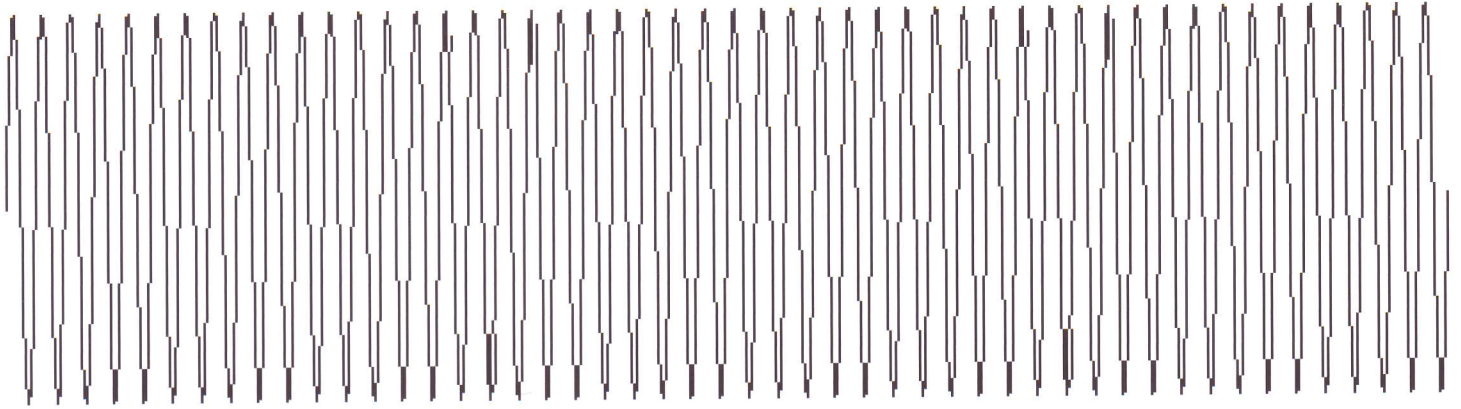
Wavelength: 1 millimeter (mm) to 1 meter

Energy per photon:

One millionth (0.000001 or 10^{-6}) the energy of a visible light photon

3

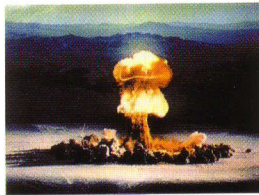
GAMMA RAY



1

Emitted by:

- Radioactive materials
- Exploding nuclear weapons
- Gamma-ray bursts and other astronomical sources
- Solar flares



from <http://www.enviroweb.org/issues/nuketesting/hew/Usa/Tests/Ukgrable2.jpg>

Detected by:

- Gamma detectors on astronomical satellites
- Medical imaging detectors

Compton Gamma Ray Astronomical Observatory satellite
from <http://cossac.gsfc.nasa.gov/>



2

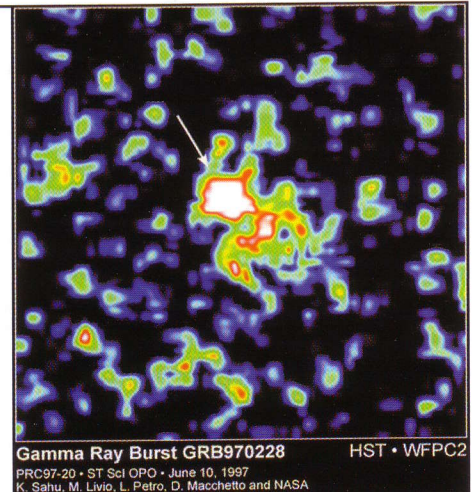
Useful for:

- Studying gamma-ray bursts
- Detecting radioactivity
- Detecting nuclear weapon explosions
- Medical treatments

Harmful Effects: Cancer, radiation sickness.

Hubble Space Telescope image of the visible fireball which accompanied a gamma-ray burst. This image provides evidence that the burst originated in a galaxy seen around the site of the burst.

from <http://www.seds.org/hst/gb970228.html>



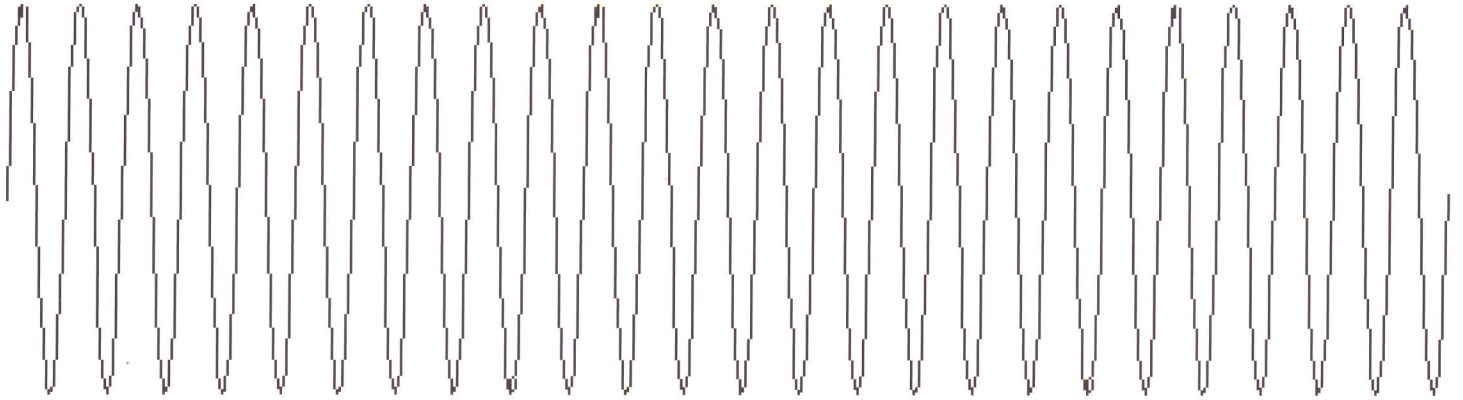
Gamma Ray Burst GRB970228 HST • WFPC2
PRC97-20 • ST ScI OPO • June 10, 1997
K. Sahu, M. Livio, L. Petro, D. Macchetto and NASA

3

Wavelength: 0.001 nanometers and shorter; much smaller than an atom

Energy per photon: more than a million times more energetic than visible light

X-RAY

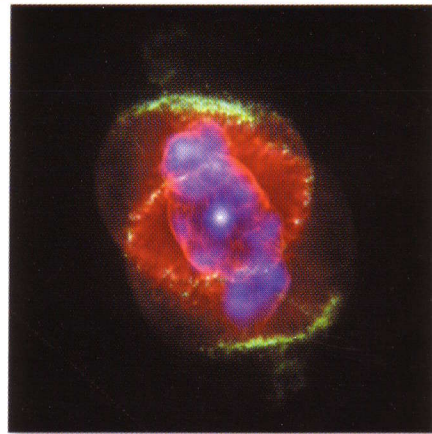


Emitted by:

- Astronomical objects that have temperatures of millions of degrees
- X-ray machines in hospitals
- CAT scan machines
- Older televisions in very low doses
- Radioactive minerals
- Airport luggage scanners

Detected by:

- Space-based X-ray detectors
- X-ray film
- CCD detectors



X-ray: NASA/UIUC/Y. Chu et al., Optical: NASA/HST
Combined X-ray and visible image of Cat's eye planetary nebula

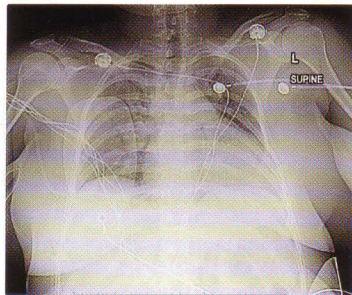
1

Useful for:

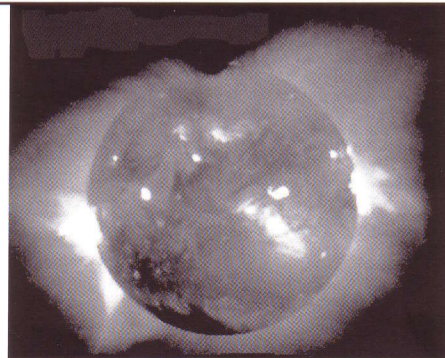
- Astronomical observations
- Medical diagnosis
- Security scanning

Harmful Effects:

DNA mutations, high doses can cause death, lower doses can cause cancer.



<http://www.mmip.mcgill.ca/heart/pages/xr991207r31.html>



X-ray image of the Sun from the Yokoh satellite
from: <http://lasp.colorado.edu/snoe/graphics/solar.html>

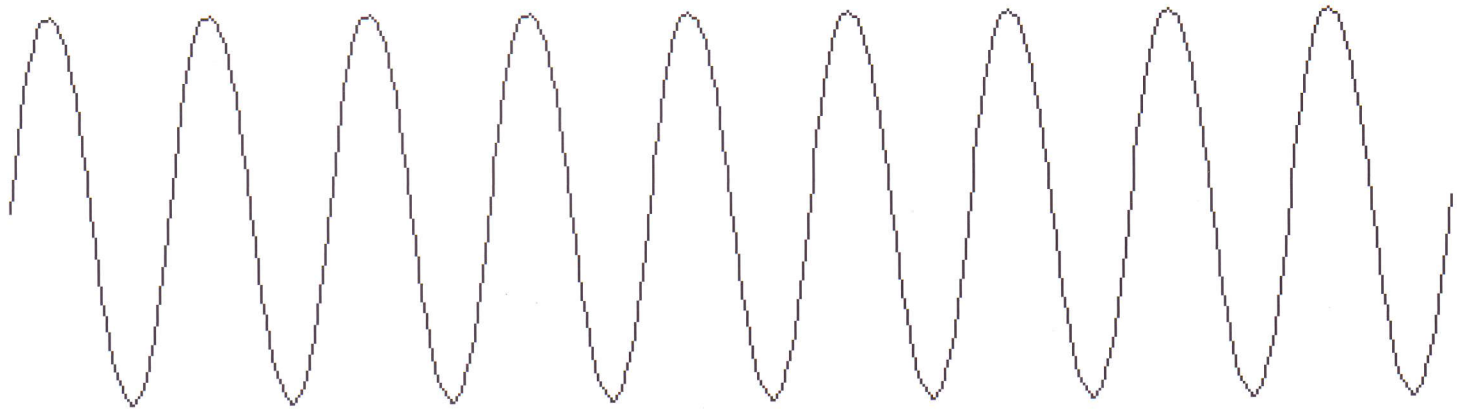
2

Wavelength: From about the length of a water molecule to the length of a large protein molecule

Energy per photon: from about 1,000 to 100,000 times the energy of a visible light photon

3

VISIBLE



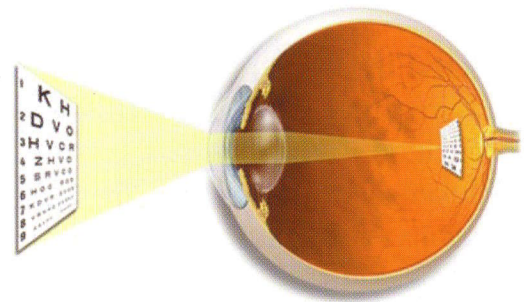
1

Emitted by:

- The Sun and other astronomical objects
- Laser pointers
- Light bulbs
- Heat lamps in restaurants

Detected by:

- Cameras (film or digital)
- Human eye
- Animal eyes
- Plants (chlorophyll absorbs red light)
- Ground- and space-based telescopes and instruments

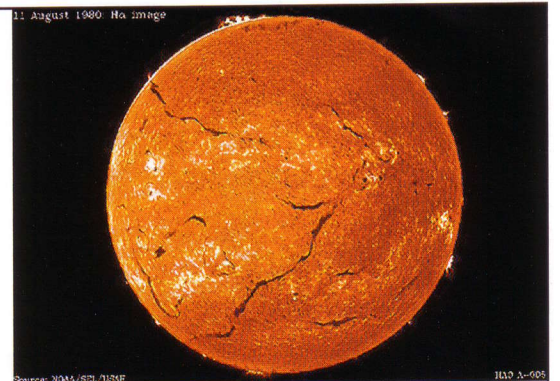


from <http://www.stlukeseye.com/anatomy.htm>

2

Useful for:

- Solar observations
- Plant growth
- Lasers
- Vision
- Photography



11 August 1980 No Image Source: NOAA/ES&I/USNF HAO 3-005

Image of the Sun, taken through a special red filter

from <http://www.hao.ucar.edu/public/slides/slide6.html>

Harmful Effects: Normally harmless, can cause blindness or burn tissue at high intensity (from the Sun or a laser).

3

Wavelength: about the size of bacteria; 1/2 micron (millionth of a meter)
0.6 micron (red); 0.5 micron (yellow/green); 0.4 micron (blue/violet)

1 micron
= 1 micrometer
= 10^{-6} meter
= .000001 meter

Energy per photon: enough to knock electrons off of some atoms.

VERY HIGH FREQUENCY (VHF) RADIO



1

Emitted by:

- Astronomical objects
- FM transmitters

Detected by:

- Ground-based radio telescopes
- FM radios



This image has radio contours superposed on a visible-light Hubble image. From Owens Valley Radio Observatory from <http://www.ovro.caltech.edu/>



2

Useful for:

- Radio astronomy
- Listening to music and talk-radio shows

Harmful Effects: None known.

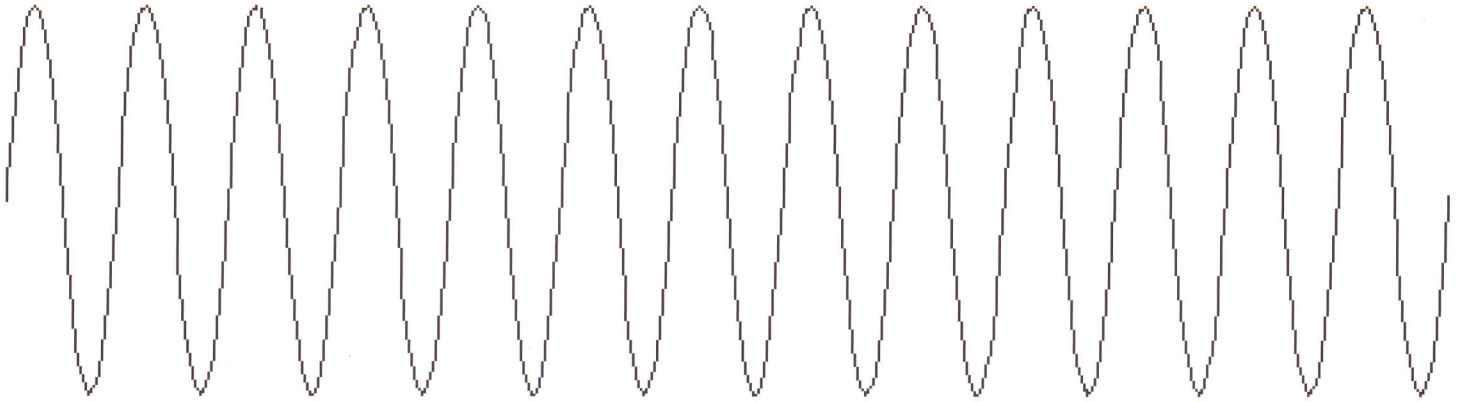


3

Wavelength: 2.8 to 3.4 meters

Energy per photon: One ten-millionth (10^{-7}) the energy of a visible light photon

ULTRAVIOLET A



Emitted by:

- Black light bulbs
- a little by tanning lamps
- UV lamps for rock and mineral identification

Detected by:

- Flying insects, such as house flies
- Black and white film
- Fluorescent paints that are used to convert ultraviolet light to visible colors



from <http://www.pestproducts.com/images/>



1

Useful for:

- Attracting insects
- Illuminating black light posters
- Mineral identification

Harmful Effects:

In high doses may contribute to skin cancer or eye damage.



skin cancer (basal cell carcinoma)



Viceroy Butterfly
(Kentucky state butterfly)

<http://gov.state.ky.us/symbols/butterfly.jpg>

2

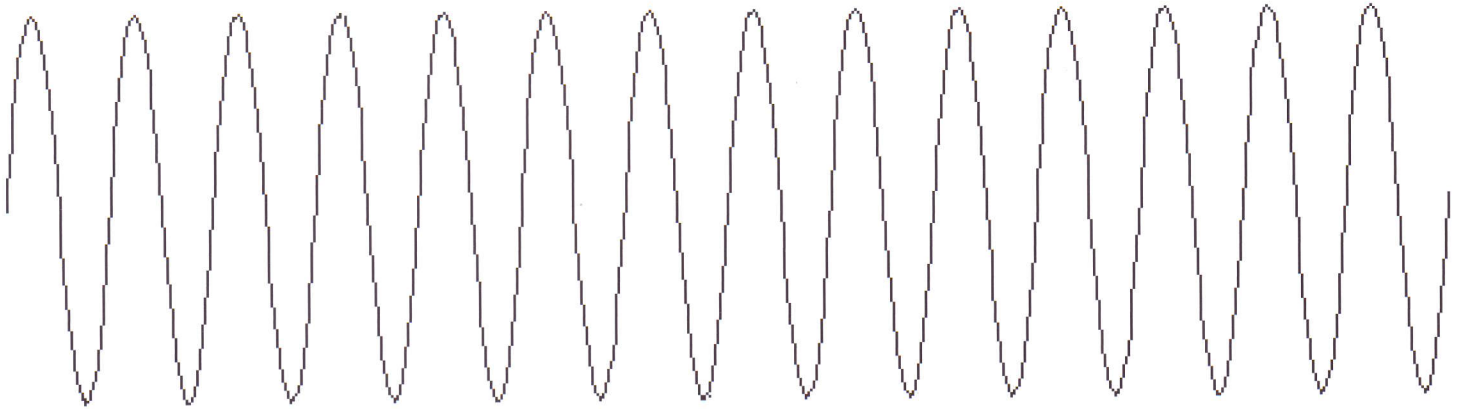
Wavelength: 0.34 to 0.4 microns (millionths of a meter);
the size of a small bacteria

1 micron = 1 micrometer
= 10^{-6} meter
= .000001 meter

Energy per photon: about double the energy of a visible light photon

3

ULTRAVIOLET B



1

Emitted by:

- Tanning booths
- The Sun and hotter stars

Detected by:

- Space-based astronomical ultraviolet detectors
- Ultraviolet cameras



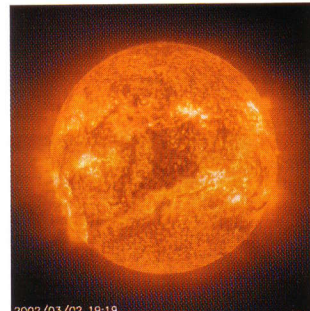
from <http://www.novatan.com/store/prodinfo.asp?number=SOL36175-3F&variation=&aitem=1&mitem=2>

2

Useful for:

- Studying the Sun and hotter stars
- Tanning (but see below)

Harmful Effects: sunburn and skin cancer



The Sun in extreme ultraviolet light, from SOHO spacecraft, March 2, 2002.

Courtesy of SOHO consortium. SOHO is a project of international cooperation between ESA and NASA.

2002/03/02 19:19
<http://sohowww.nascom.nasa.gov/>

Note: There is also **Ultraviolet C** (wavelength 0.1 to 0.29 microns—about the length of a virus) which is very lethal to all living things, and can cause extreme skin burns and cancer. It is used in germicidal lamps to sterilize hospital equipment and water.

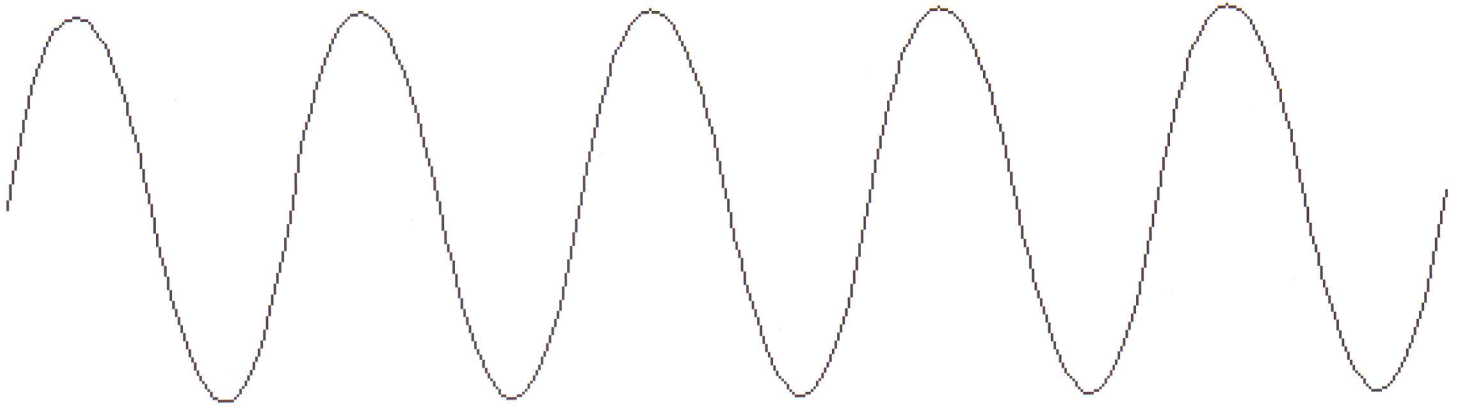
3

Wavelength: 0.29 to 0.32 microns (millionths of a meter)
or 290 to 320 nanometers (billionths of a meter)

Energy per photon: a bit over double the energy of a visible light photon

1 micron = 1 micrometer
= 10^{-6} meter
= .000001 meter

THERMAL INFRARED



1

Emitted by:

- Food warming lights
- Just about everything at room temperature or above
- Lasers
- Bodies of people and animals

A man (right) and a cat (below right) as seen in the infrared

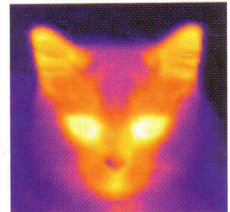


Detected by:

- Infrared telescopes in space and on high-flying airplanes
- Ground-based infrared detectors
- Your skin • Rattlesnakes' eyes
- Night vision devices



NASA's Stratospheric Observatory for Infrared Astronomy has a large infrared telescope on a modified Boeing 747



2

Useful for:

- Restaurants (heating food)
- Hospitals (sterilization)
- Animal vision
- Security cameras
- Radiant space heaters



Harmful Effects: Very high intensity can heat up living tissues and kill them.

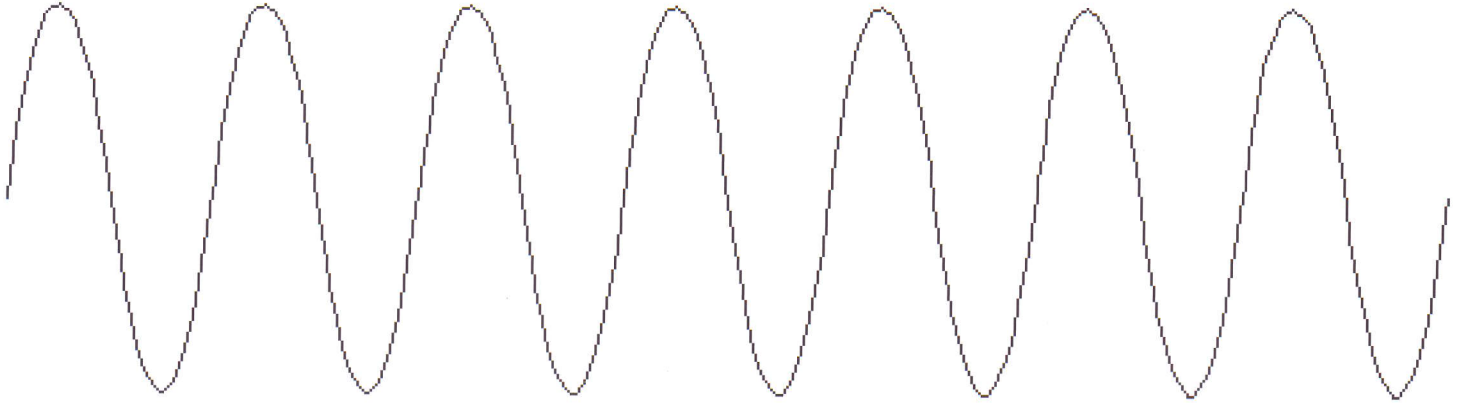
3

Wavelength: 10 microns (or 0.00001 meters or 10^{-5} meters)
(a micron is a millionth of a meter)

1 micron = 1 micrometer
= 10^{-6} meter
= .000001 meter

Energy per photon: 1/20 the energy of a visible light photon

NEAR INFRARED



Emitted by:

- Sun and other stars
- TV remote controls
- Computers with infrared ports
- Laser diodes used in fiber optics for telephone communication
- Plants with chlorophyll



1

Infrared picture of a typical street scene

Detected by:

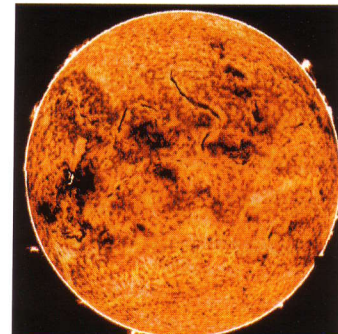
- Ground- and space-based infrared astronomy cameras
- TVs
- Digital cameras
- Many video cameras
- Printers with infrared receivers, computers

Useful for:

- Looking for young stars
- Communication in the air
- Communication over optical fibers



Preparing a satellite equipped with infrared detectors



*Infrared image of the Sun
from <http://solar.physics.montana.edu/YPOP/Spotlight/Today/infrared.htm>*

2

Harmful Effects:

Generally safe, very high intensity can heat tissue.

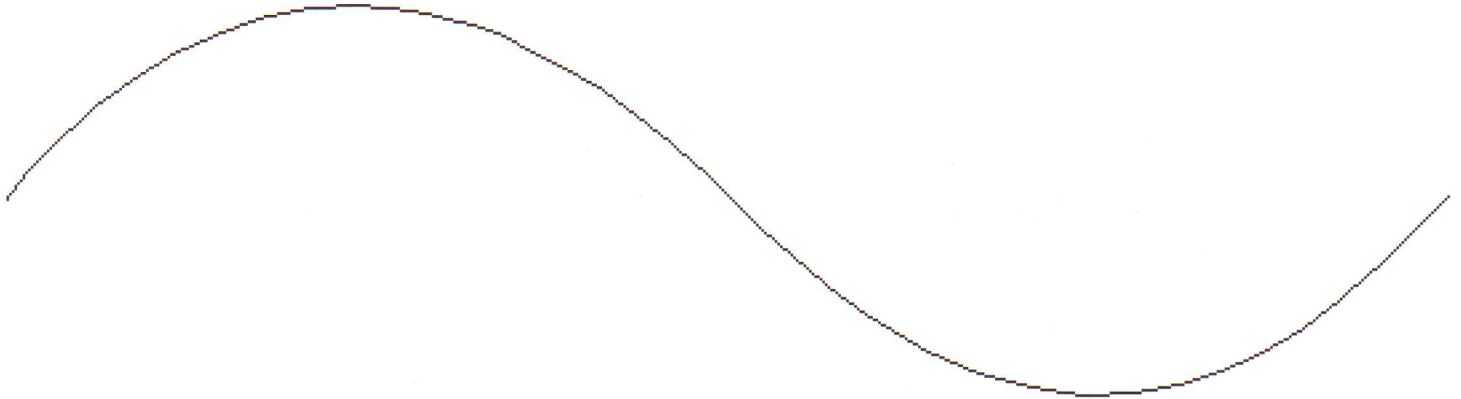
Wavelength: 0.8 to 3 microns (millionths of a meter);
smoke particles are about half a micron in size

Energy per photon: about 1/2 the energy of a visible light photon

1 micron = 1 micrometer
= 10^{-6} meter
= .000001 meter

3

LOW FREQUENCY RADIO



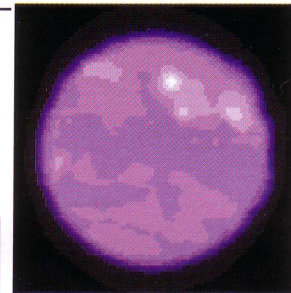
Emitted by:

- Sun
- Astronomical objects
- Radio station transmitters for AM radio

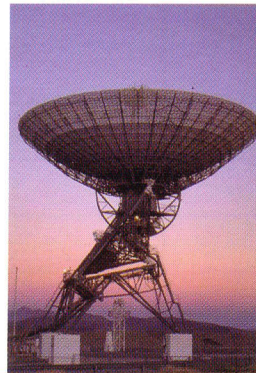
Detected by:

- Ground-based astronomical radio telescopes
- AM radios

*Radio Image of Sun
from the MIT
Haystack Observatory
from [http://
fourier.haystack.mit.edu/
urei/tut8.html#8.1](http://fourier.haystack.mit.edu/urei/tut8.html#8.1)*



1

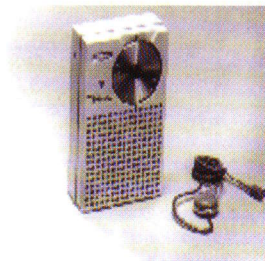


*Radio telescope
at Goldstone
Tracking Center*

Useful for:

- Radio astronomy
- Listening to music and talk-radio shows

Harmful Effects: None known.



2

Wavelength: 200 to 600 meters

Energy per photon: about one billionth (10^{-9}) the energy of a visible light photon

3