# Astronomy beyond the visible
# 可见光波段以外的天文学

**Beatriz García, Ricardo Moreno**

***International Astronomical Union***
***ITeDA and Universidad Tecnológica Nacional, Argentina***
***Colegio Retamar de Madrid, Spain***

# Goals 目标

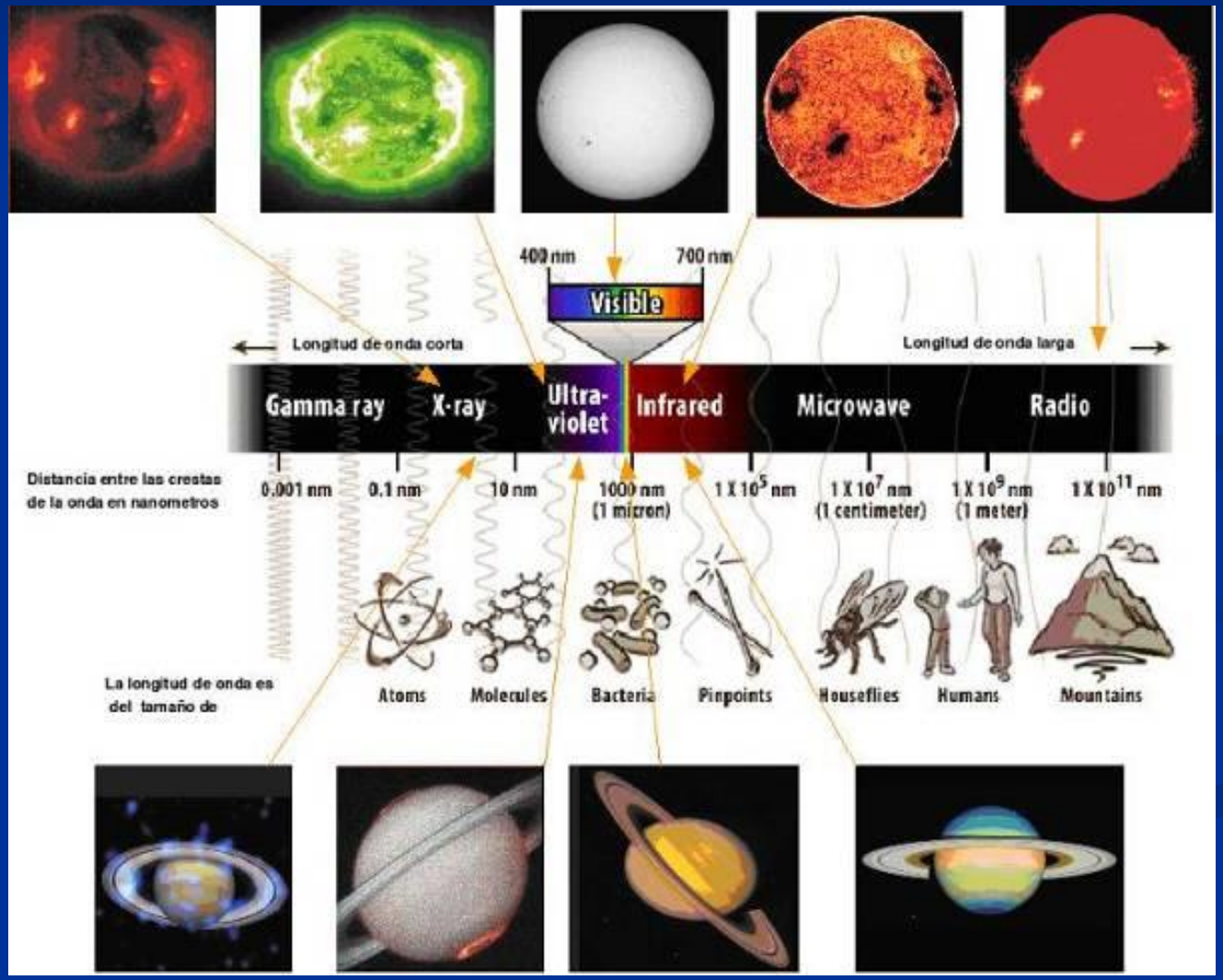
- Show phenomena beyond the visible, e.g. the electromagnetic energy emitted by celestial bodies, but undetectable by the human eye.
- 展示可见光外的现象，例如，天体发出的人眼无法察觉的电磁能量。
- Perform several simple experiments for determining the existence of emission in the wavelength regions of radio waves, infrared, ultraviolet, microwave and X-ray.
- 通过几个简单的实验，探知射电、红外、紫外、微波和X射线波段的辐射特性。

# Presentation 介绍

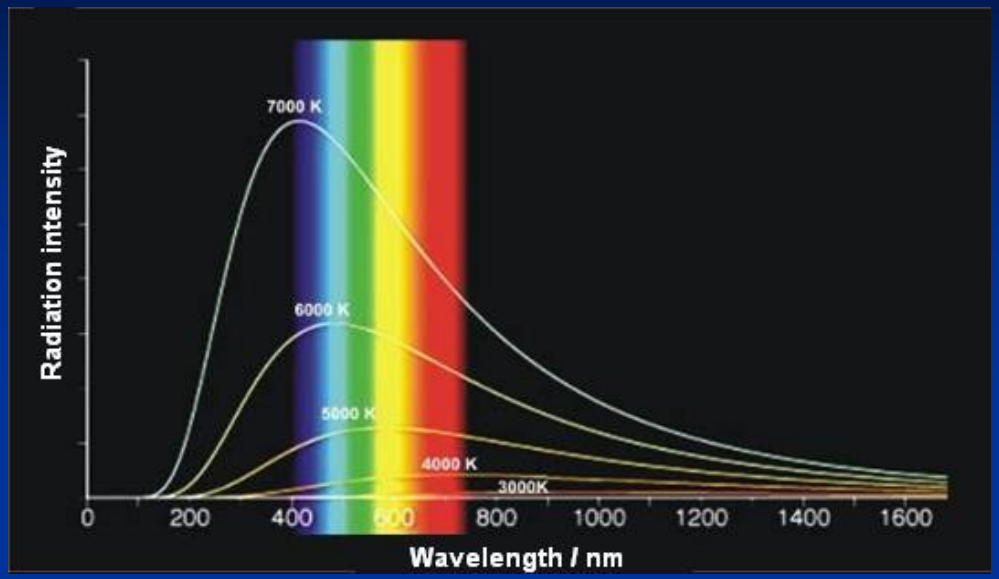
- For centuries, the universe had been studied only with the light detected by the human eye.
- 许多世纪，人类研究宇宙的方式仅限于肉眼能察觉到的可见光。
- There is information that comes from other wavelengths that our eyes cannot see.
- 但天体在可见光波段之外的发出的信息是肉眼看不到的。
- Astronomers observe today in the radio, microwave, infrared, ultraviolet, X-rays and gamma rays as well as visible.
- 如今，天文学家除了在可见光波段观测外，也可以在射电、微波、红外、紫外、X射线、伽玛射线波段研究宇宙。

# Electromagnetic Spectrum 电磁光谱

## All wavelengths of electromagnetic radiation.全波段电磁辐射



# Blackbody Radiation 黑体辐射




By studying the radiation of a distant object, we can measure its temperature without having to go there. This applies for the stars, which are almost black bodies

通过研究远处物体的辐射，我们可以测量它的温度，而不必去那里。这适用于几乎是黑体的恒星

# Blackbody Radiation 黑体辐射

Any "black body" when heated emits light at many wavelengths.

任何"黑体"在加热时都会发出多种波长的光。

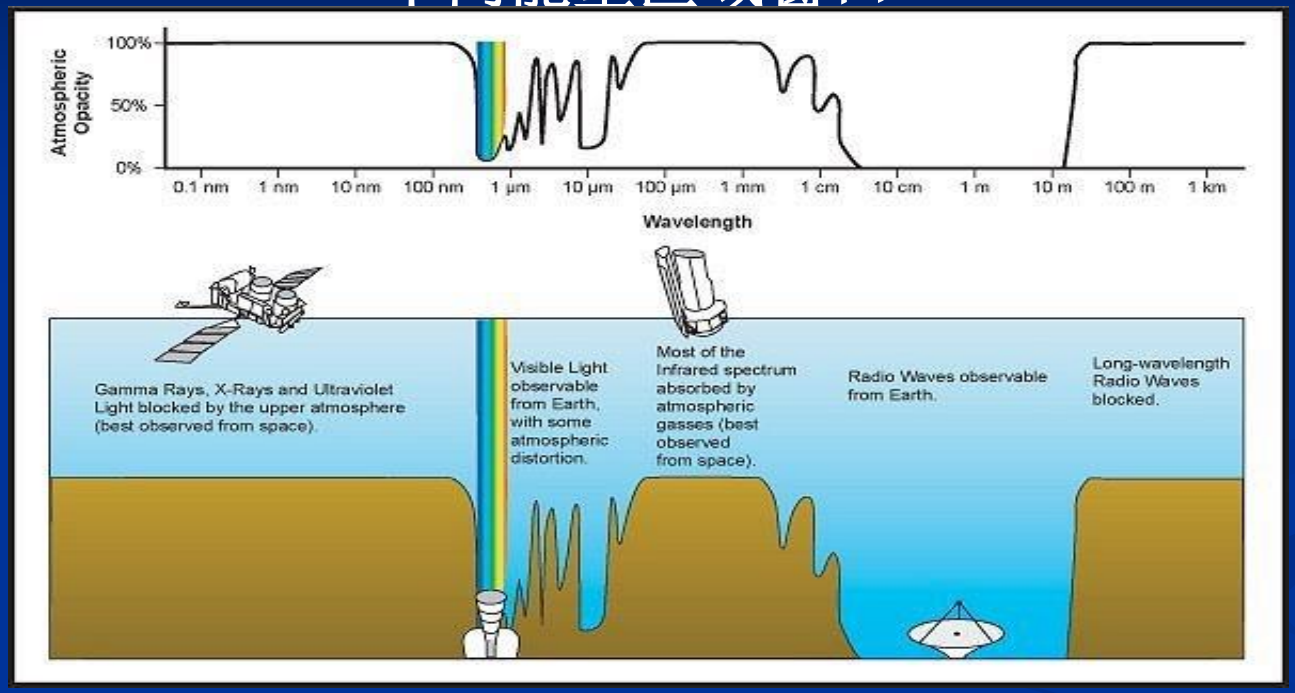
There is $\lambda_{max}$ at which the intensity of radiation is maximum. This $\lambda_{max}$ depends on the temperatura T:

有个 λmax 在该处辐射强度最大。这个 λmax 取决于温度 T:

$$\lambda_{max} = \frac{2.898 \times 10^{-3}}{T} \quad (m)$$

Wien's Law 维也纳法

# Solar radiaton
# Windows for different energy regions
# 太阳辐射
# 不同能量区域窗口



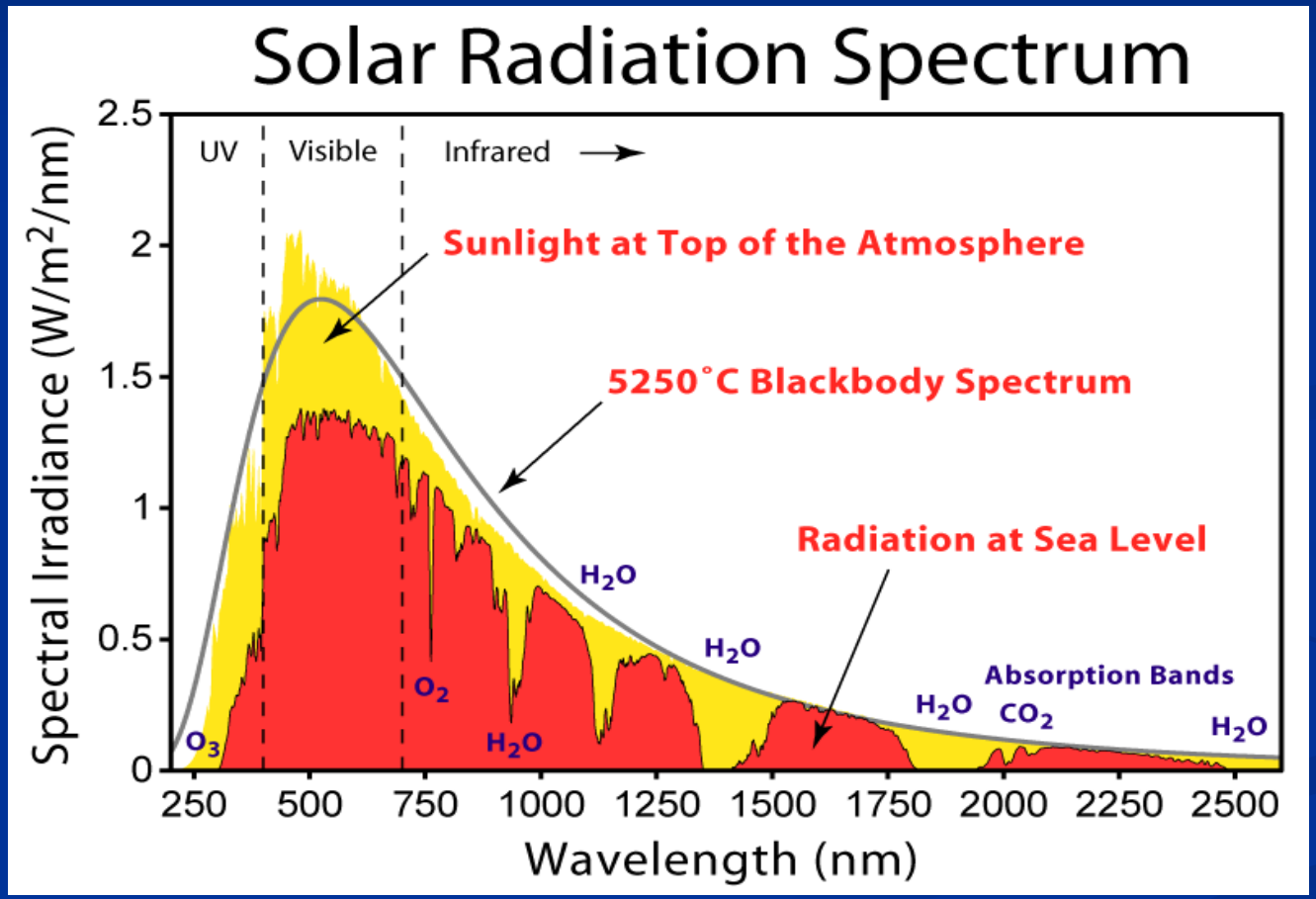

**The Earth's atmosphere is opaque to most wavelengths of radiation. We can detect the hight energies from space and low energies require special detectors.**

地球大气对大多数波段的辐射都是透明的。我们可以在空间探测高能辐射，

利用特殊探测器接收低能辐射。

**When the solar electomagnetic energy goes through the atmosphere, the "black body" radiation change, but the $\lambda_{max}$ at which the irradiance is máximum remains almost without change**

**当太阳的电磁能量穿过大气时，其"黑体"辐射的特征就会发生改变，但辐照度最强的波长值 $\lambda_{max}$几乎没有发生变化**




**太阳辐射谱**
**大气顶层的太阳光强**
5250度的黑体谱
海平面的辐射

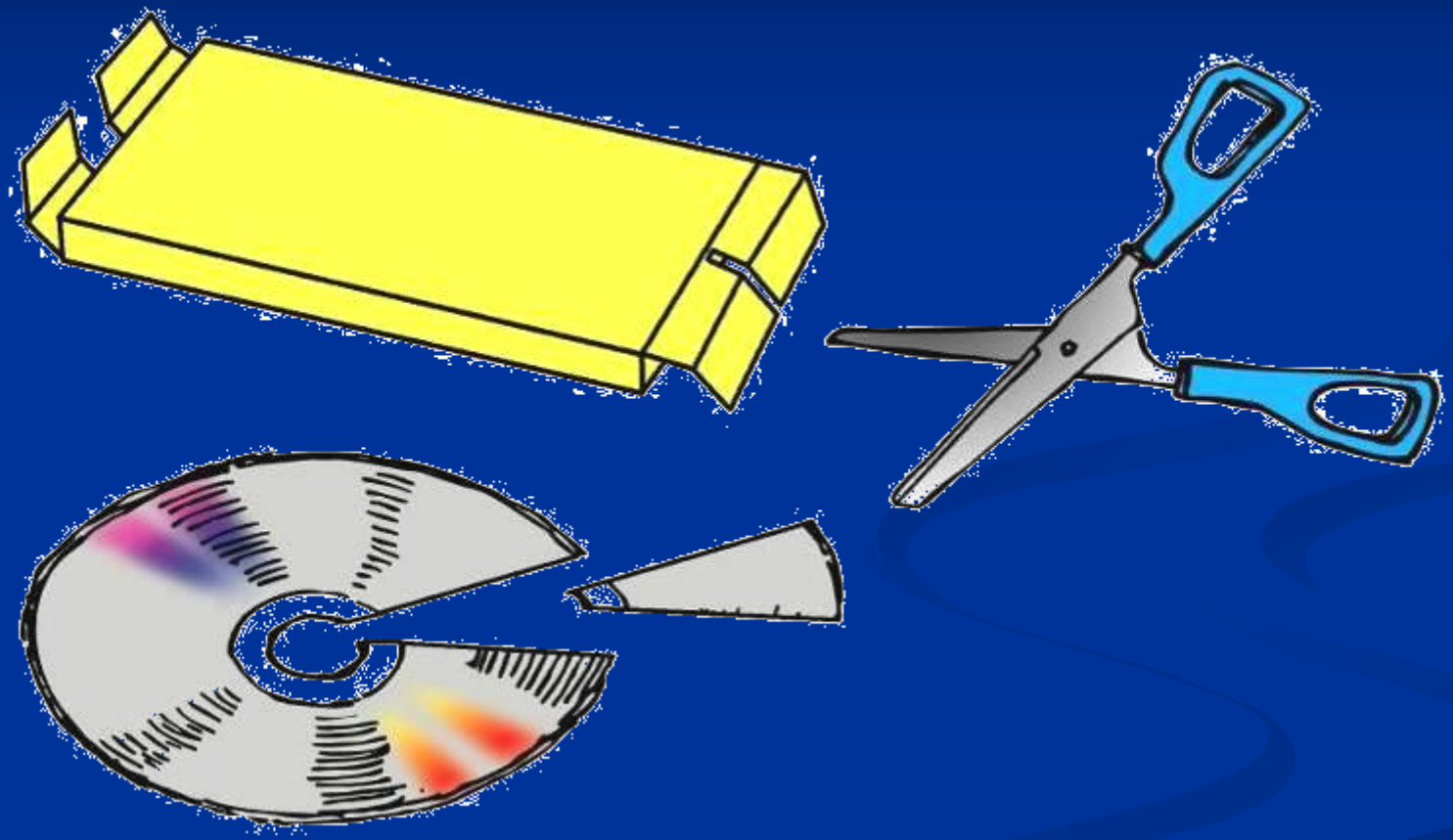
We know that there is $\lambda_{max}$ at which the irradiance or emission is maximum depends on the temperature T, but it does not need to be in a visible region of the spectrum

我们知道辐照度或辐射最强处的波长$\lambda_{max}$ 与温度T有关，但$\lambda_{max}$ 不一定位于可见光谱的区域

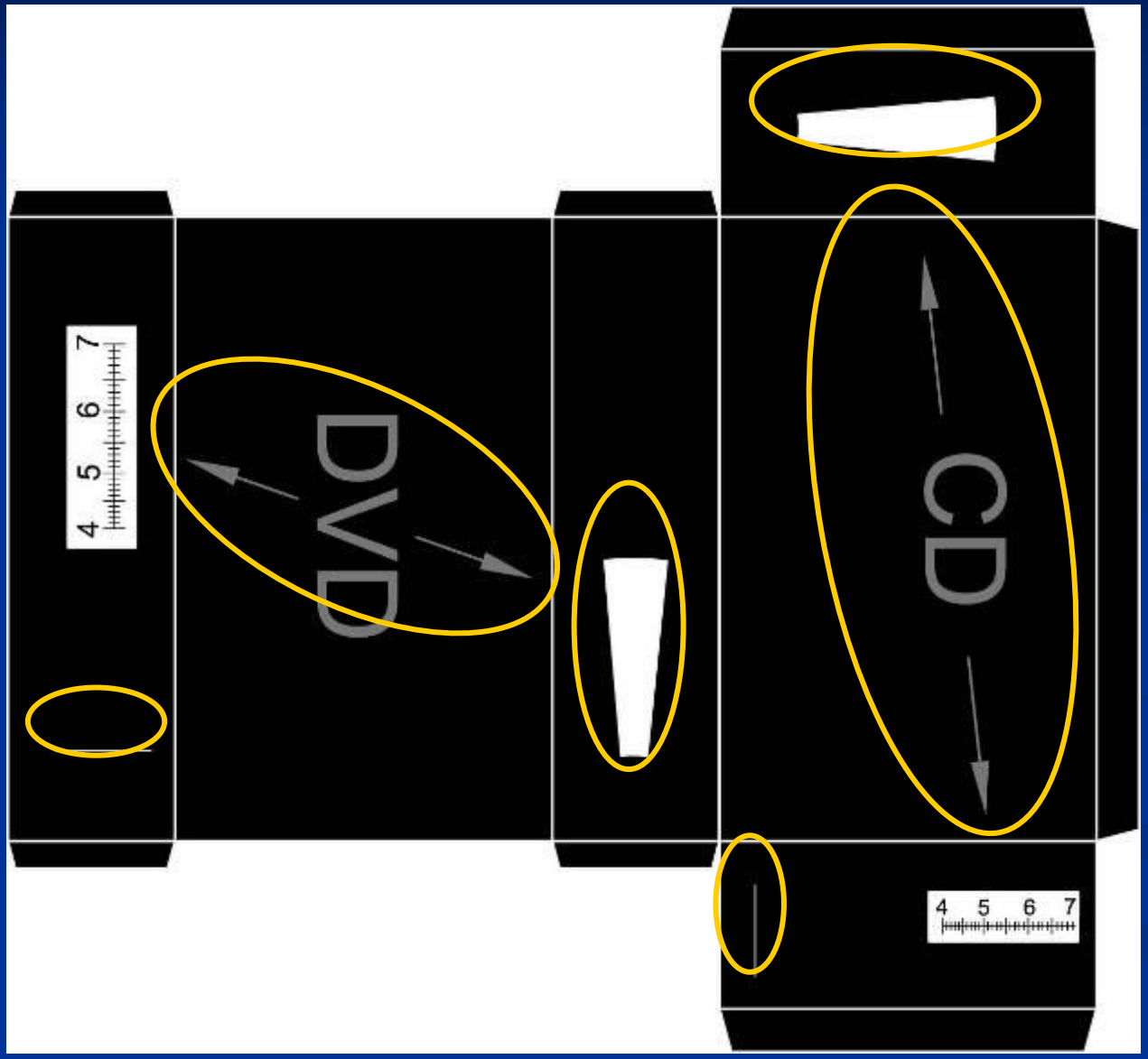
For example, the human body has a temperature of T = 273+37 = 310 K. Then, emits the maximun in $\lambda_{máx}$ = 9300 nm.

例如，人体的温度为T = 273+37 = 310 K. 其对应的最强辐射波长$\lambda_{máx}$ = 9300 nm. 夜视仪就工作在这个波长处

# Activity 1: Building a spectrometer
# 活动1:制作分光仪



# Activity 1: Building a spectrometer
# 活动1:制作分光仪




Depending what you use, DVD or CD, you should cut one or other portion of the template.

根据你使用的是DVD还是CD,剪掉模板中的对应区域。

# Activity 1: Building a spectrometer
# 活动1:制作分光仪


Remove the metal layer of the CD using tape or scratching it.
利用胶带或刮除的方式去掉CD表面的金属层。

NB! The coating will not peel off white or commercial CDs.

# Activity 1: Building a spectrometer
# 活动1:制作分光仪

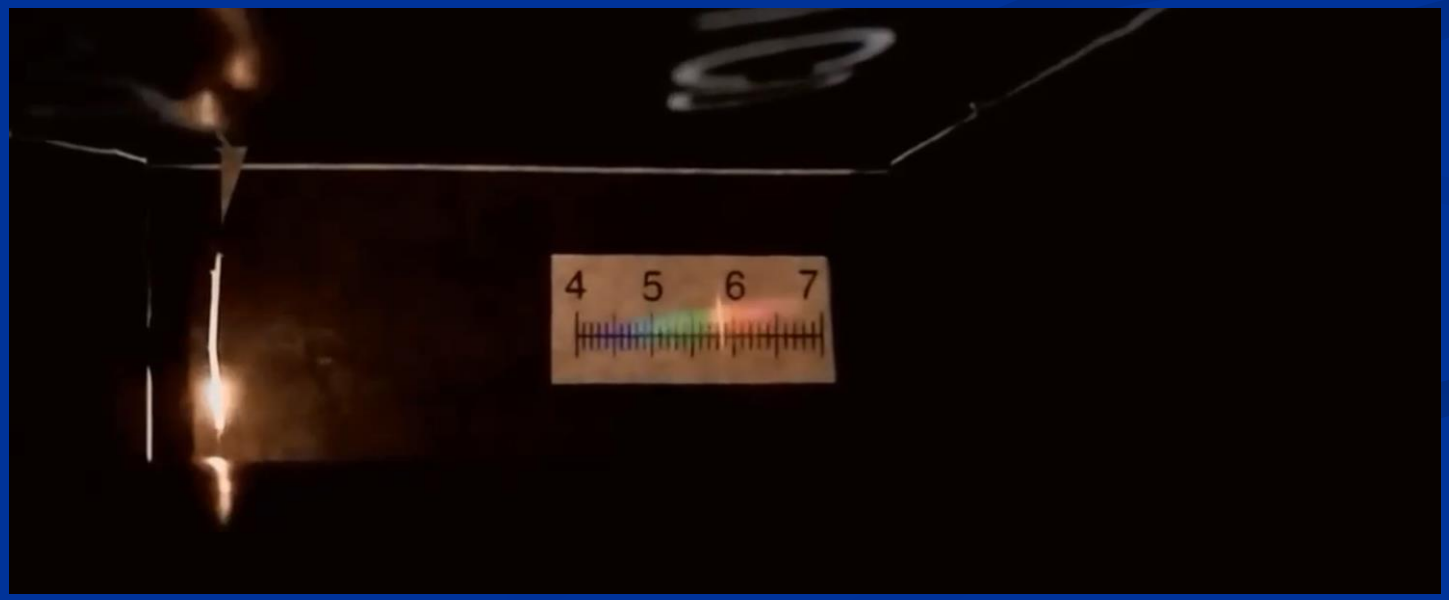
The black surface folded on the inside.
纸模的黑色区域向内。

Compare the light from filament lamps, fluorescent lamps and streetlights.
比较白炽灯、荧光灯和路灯发出的光有何不同。

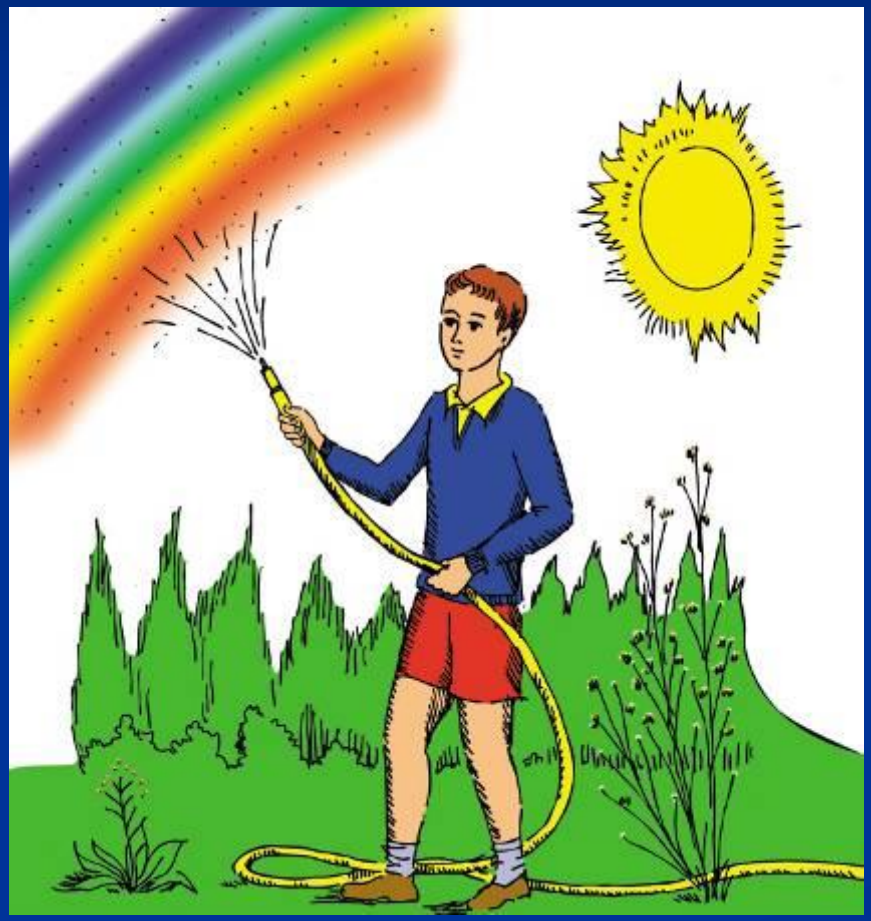
# Activity 2: Sodium lines visualization
# 活动2:钠线的可视化

Spectroscopy allows us to know the chemical composition of stars and exoplanets by studying the spectra that come to us. Let's see an example using a candle where we will impregnate the wick with a little common salt (Na Cl) to see the Sodium emission line that corresponds to a wavelength of 589.

光谱学使我们能够通过研究来到我们身边的光谱来了解恒星和系外行星的化学成分。让我们看一个使用蜡烛的例子，我们将用一点普通的盐(Na Cl)浸渍烛芯，以看到对应于589波长的钠发射线。



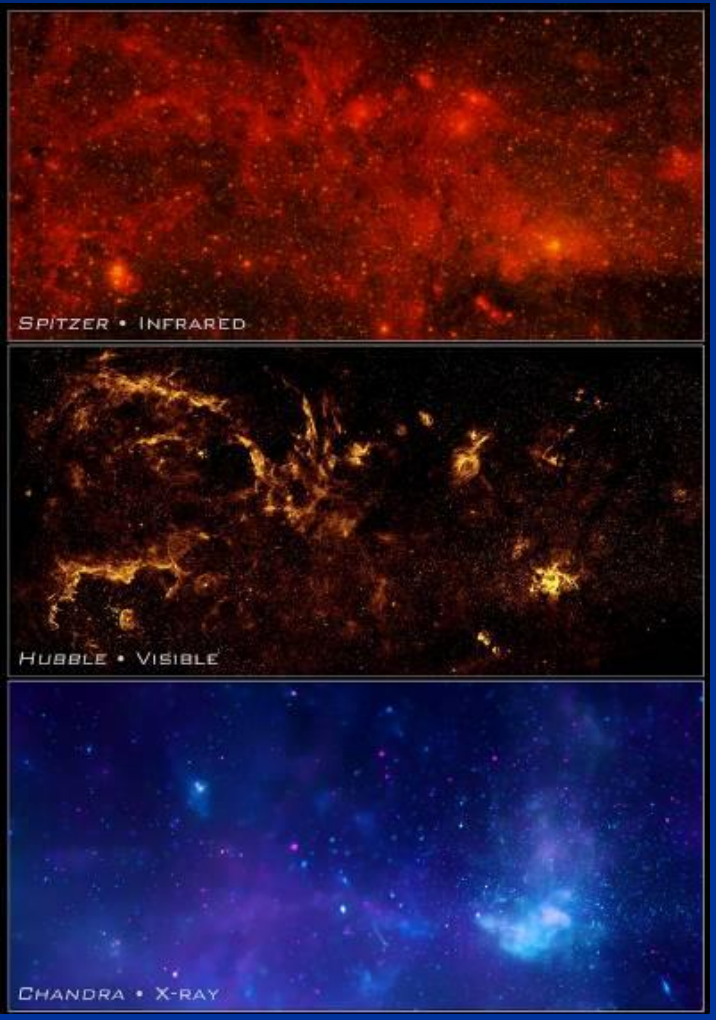
# Activity 3: Decomposing sunlight? With raindrops
# 活动3：利用雨滴分解阳光



Children can split the sunlight and make a rainbow.
孩子们可以分解阳光制造彩虹。

They need a hose with a fine spray. They must have their back to the Sun.
需要一个能喷出细水雾的软管。使用的时候背向太阳。

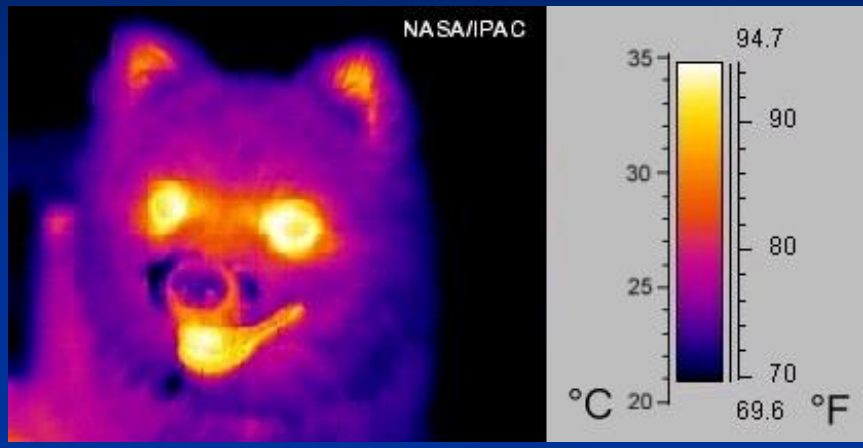
# Other regions of the spectrum
# 光谱的其他区间

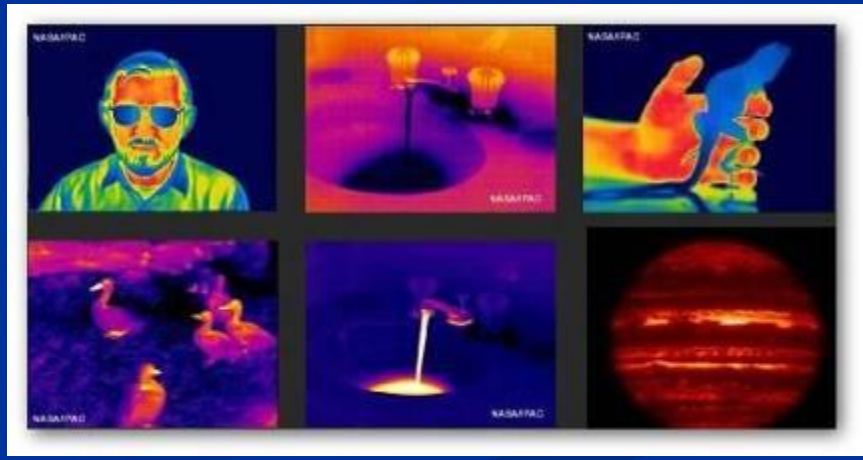



- There is a matter with a temperature much lower than that of the stars, for example, clouds of interstellar matter.
- 有些物质的温度比恒星低，比如星际物质云。
- They do not emit visible radiation, but emit infrared radiation, microwaves and radio waves.
- 它们不会发出可见光辐射，但是会发出红外、微波和射电辐射。
- The type of radiation is associated with the processes that are occurring inside the object. E.g., details in the centre of our galaxy ...
- 辐射的类型与天体内部辐射的产生机制有关，例如，我们星系中心的细节结构。

# The infrared 红外辐射

- William Herschel discovered the infrared using the prism and thermometers.
- 威廉赫歇尔利用三棱镜和温度计发现了红外辐射。
- It is a property of warm bodies, even those not hot enough to emit visible light.
- 任何温热物体都发出红外辐射，即便是那些温度不高不足以发出可见光辐射的物体。
- To help visualize it, we normally establish an equivalence between temperature and colour.
- 为了便于可视化，我们通常会建立一个温度和颜色之间的等效关系。

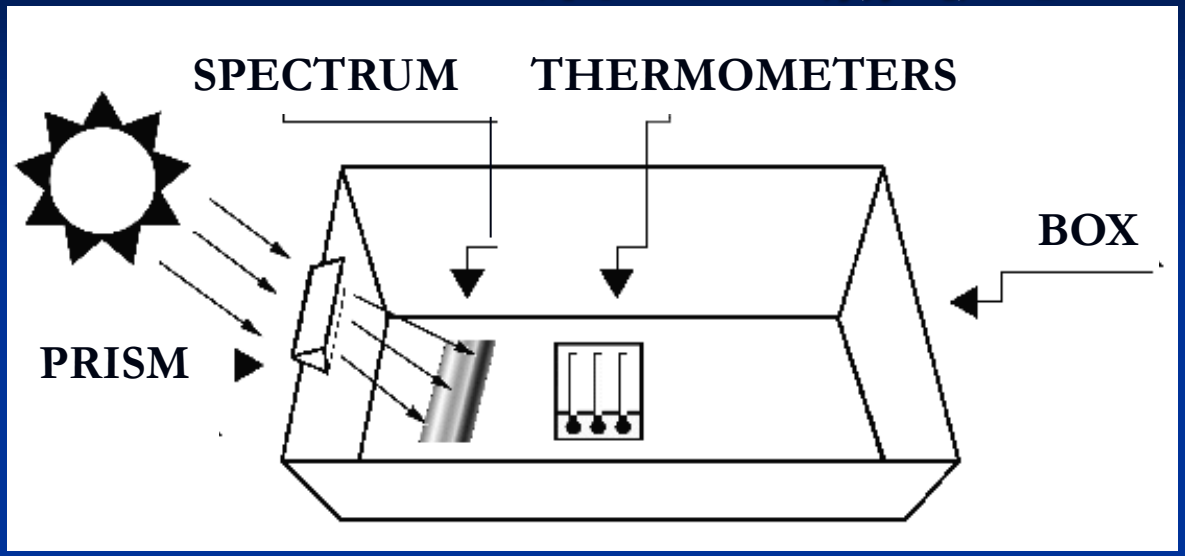


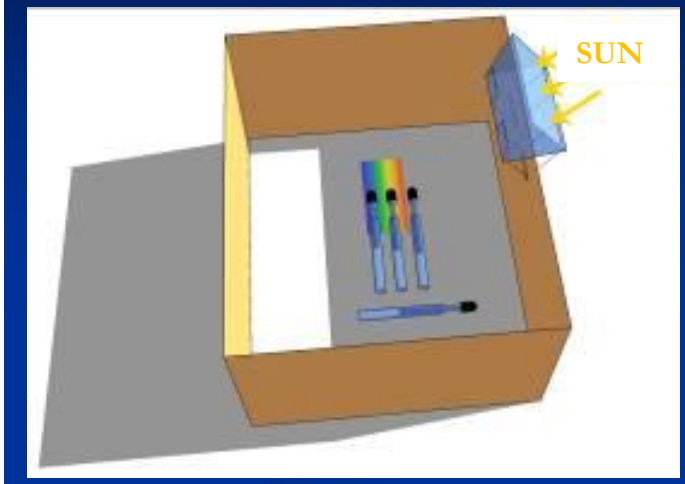



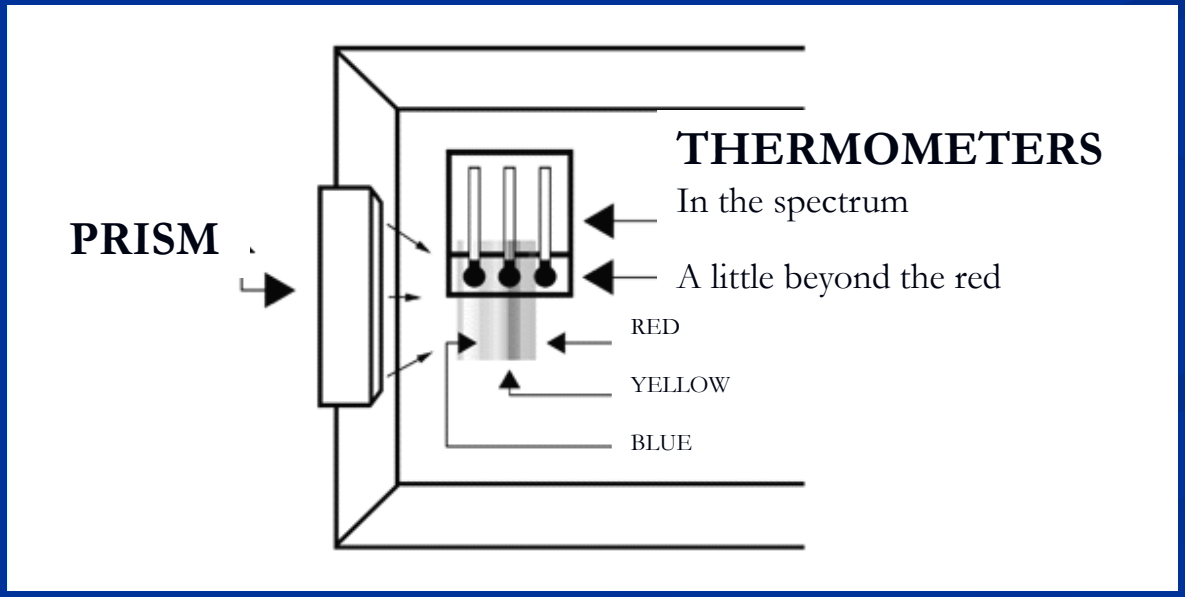
# Activity 4: Herschel Experiment
# 活动4:赫歇尔实验

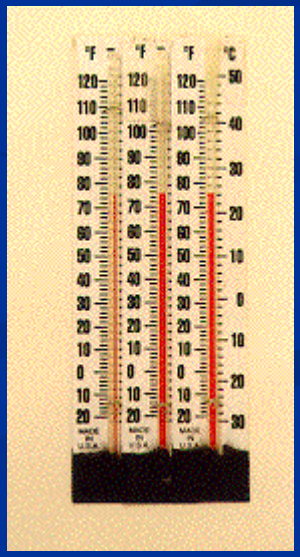
- In 1800, Herschel discovered the infrared in sunlight.
- 1800年，赫歇尔在太阳光中发现了红外辐射。

# Activity 4: Herschel Experiment
# 活动4:赫歇尔实验

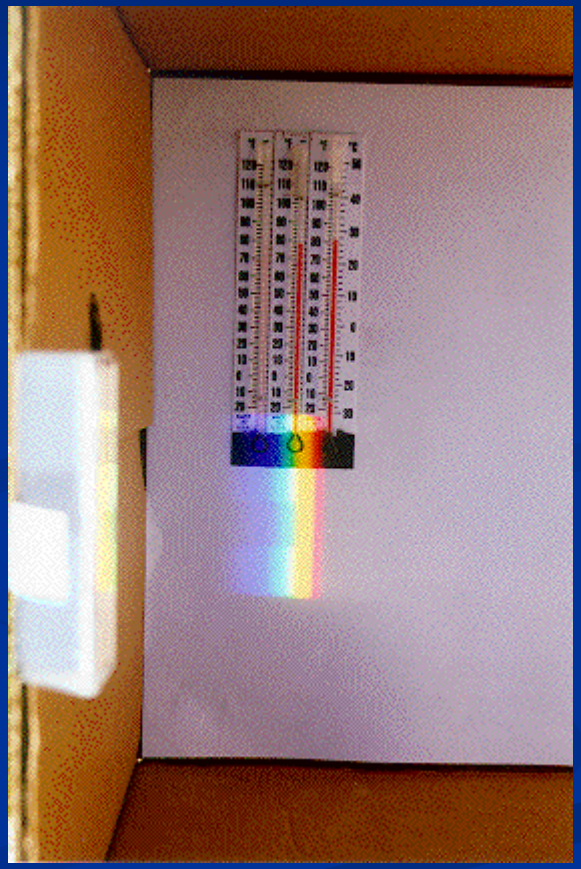


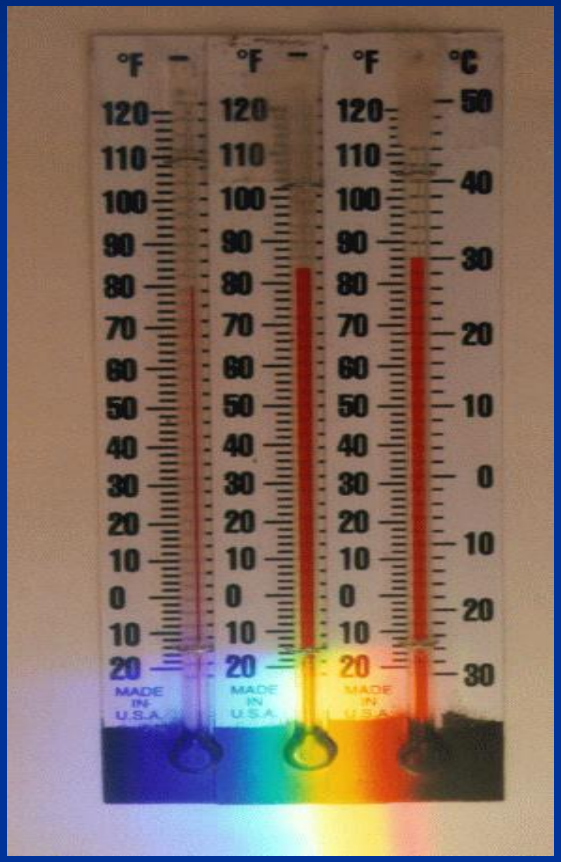



# Activity 4: Herschel Experiment
# 活动4:赫歇尔实验



# Activity 4: Herschel Experiment
# 活动4:赫歇尔实验



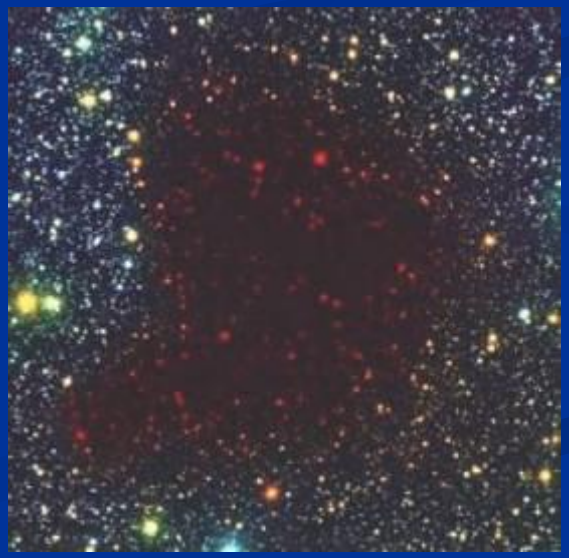

| TABLE OF DATA COLLECTION | | | | |
|---|---|---|---|---|
| | Thermometer No. 1 in the blue | Thermometer No. 2 in the yellow | Thermometer No. 3 beyond the red | Thermometer No. 4 in the shadow |
| After 1 minute | | | | |
| After 2 minutes | | | | |
| After 3 minutes | | | | |
| After 4 minutes | | | | |
| After 5 minutes | | | | |

# Activity 5: IR detection with a phone
# 活动5：利用手机探测红外辐射

- Remote controls emit infrared that our eyes cannot see.
- 遥控器能发射肉眼看不见的红外线
- Many but not all mobile phone cameras are sensitive to IR.
- 许多手机的相机对红外线很敏感


# The power of the infrared
# 红外辐射的能量

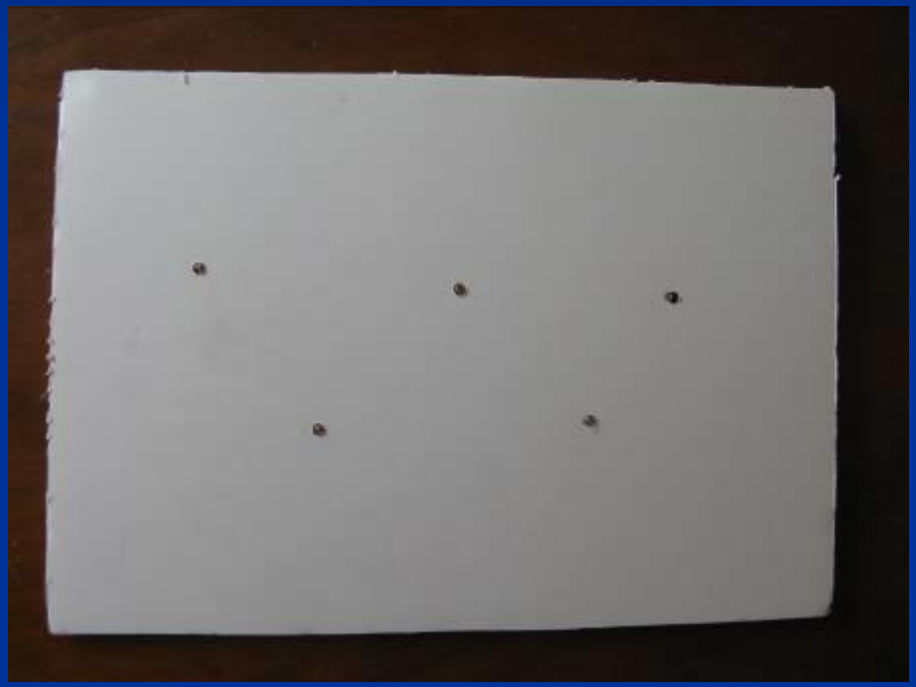
- The interstellar dust absorbs visible light but not infrared so much.
- 星际尘埃吸收可见光，但在红外波段的吸收则比可见光波段少得多。

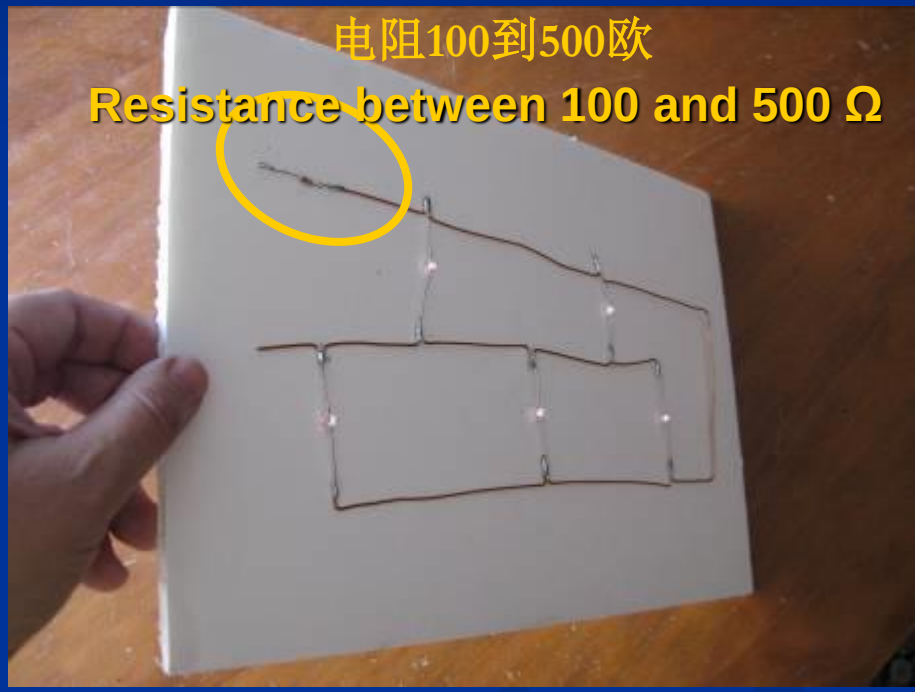


# Activity 6: Detection of IR light of a bulb
# 活动6：探测灯泡的红外辐射

- Most of the energy emitted by an incandescent bulb is in the visible region, but it also emits infrared that can penetrate some fabrics that cannot be penetrated with visible radiation.
- 白炽灯泡发出的能量大部分是在可见光区域，但它也发射红外辐射，红外辐射能穿透可见光辐射无法穿透的织物。
- The same happens with the galactic dust, which can be detected from its infrared emissions, but is opaque in the visible region.
- 同样的情况发生在星系尘埃。红外辐射能够探测到尘埃，但在可见光区域则是不透明的。

# Activity 7: Constellation with IR LEDs
# 活动7：用红外LED灯制作星座





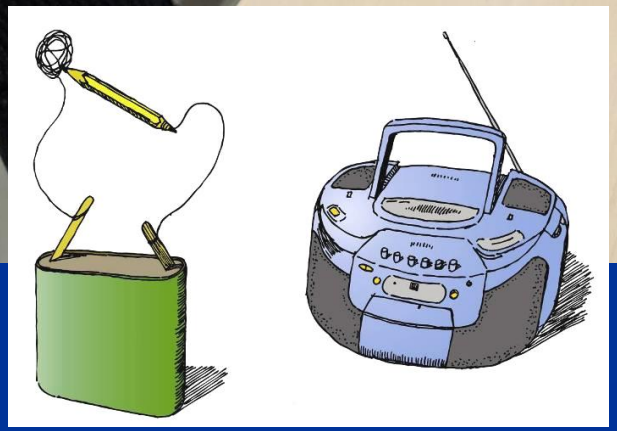

Cassiopeia with IR LEDs.
红外LED灯制成的仙后座

# Activity 8: Constellation with remote controls
# 活动8：用遥控器组成星座

# Emission of radio waves
# 射电辐射

- EM radiation with wavelengths from metres to kilometres is called radio waves.
- 辐射波长从米级直到千米级的电磁辐射被称为射电波。
- They are used for commercial stations.
- 它们可用于商业台站。
- Radio waves also come from space, and thus provide information that cannot be seen at other wavelengths.
- 射电波也来自太空，因此可以提供其它波段无法看到的信息。

# Activity 9: Producing radio waves
# 活动9：制造射电波



# Ultraviolet radiation
# 紫外辐射

- 紫外光子比可见光具有更高的能量。（UV-A黑光用于植物生长）
- UV-C 破坏有机分子之间的化学键。高剂量的紫外线可能会致命。（UV-C用于手术材料消毒）
- UV-C 辐射被大气臭氧过滤。大气中的臭氧是由阳光与O2相互作用形成的，它几乎过滤掉所有的紫外线，只让生命发展所必需的通过。
- UV photons have higher energies than those of visible light. (UV-A black light is used for plant growth)
- UV-C destroys the chemical bonds between organic molecules. At high doses UV can be fatal for life. (UV-C is used for surgical material disinfection)
- UV-C radiation is filtered by atmospheric ozone. The ozone in the atmosphere is formed by the interaction between sunlight and O2, and it filters almost all UV light, allowing only the necessary for the development of life to pass through.

Johann Ritter discovered ultraviolet light in 1801

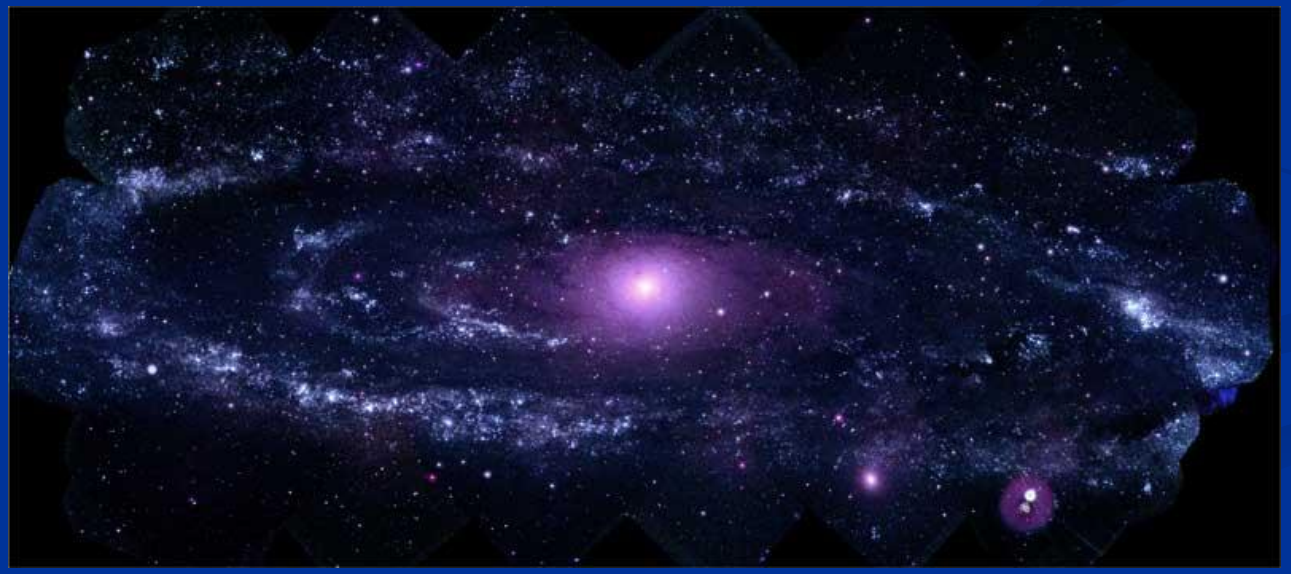
约翰·里特在1801年发现了紫外线

# Ultraviolet radiation紫外辐射

- The Sun emits UV radiation, but most of it is filtered by the ozone layer at the top of our atmosphere; the amount that arrives on Earth is beneficial for life.
- 太阳释放紫外辐射，但大部分被我们大气层内的臭氧层过滤，到达地球上的部分对生命是有益的。
- This radiation is what makes our skin tan.
- 这种辐射是使我们的皮肤晒黑的原因。
- If the ozone layer decreased in thickness, the Earth would receive higher doses and skin cancers would increase.
- 如果臭氧层厚度减少，地球将接收剂量过高的紫外线，皮肤癌会增加。

# Ultraviolet light 紫外光

Andromeda Galaxy in visible light (Hubble)
可见光波段的仙女星系（哈勃）



Andromeda Galaxy in UV light (Swift)
紫外光波段的仙女星系（雨燕卫星）

# Activity 10: Black Light (UV)
# 活动10：黑光（紫外线）

- There is matter that emits light when illuminated with UV. If it is FLUORESCENT, it emits light only while illuminated by UV light.
- 有一些物质在紫外线照射下会发光。如果它是FLUORESCENT，它只有在被紫外线照射时才会发光。

车票或护照上的印记



含有奎宁的滋补水

# Activity 11: Black Light (UV)
# 活动11：黑光（紫外线）

- There is matter that emits light when illuminated with UV. If it is PHOSPHORECENT, it emits visible light for a while.
- 有一些物质在紫外线照射下会发出光。如果它是PHOSORECENT，它就会发出一段时间的可见光。

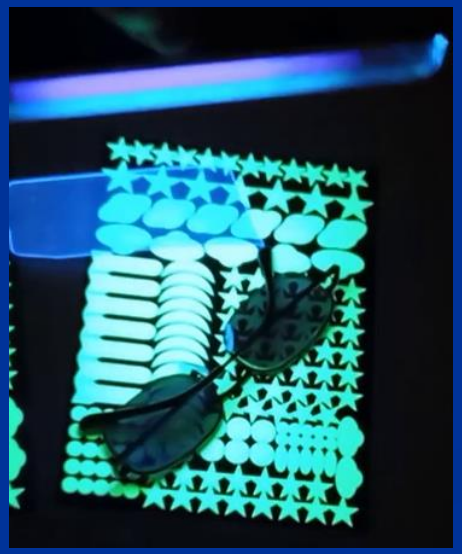
装饰的小星星

紧急海报

# Activity 12: Black Light (UV)
# 活动12：黑光（紫外线）

- There are materials that filter a lot of UV light, such as glass. Sunglasses should be made of glass, not plastic, to protect the retina, which is epithelial tissue. If they are made of plastic (organic), they must have a UV filter
- 有一些材料可以过滤大量的紫外线，例如玻璃。太阳镜应该由玻璃制成，而不是塑料，以保护视网膜，它是上皮组织。如果是塑料（有机）制成的，必须有紫外线过滤器

磷光材料上的玻璃杯，用紫外光照亮



当你摘下眼镜时，你可以看到它们是如何过滤掉紫外线的。

# X-rays X射线

- More energetic than UV is the X-ray radiation.
- 比紫外能量更高的是X射线辐射。

- It is used in medicine for radiographs and other forms of radiology.
- 它被用于射线照相及其他放射医疗用途。

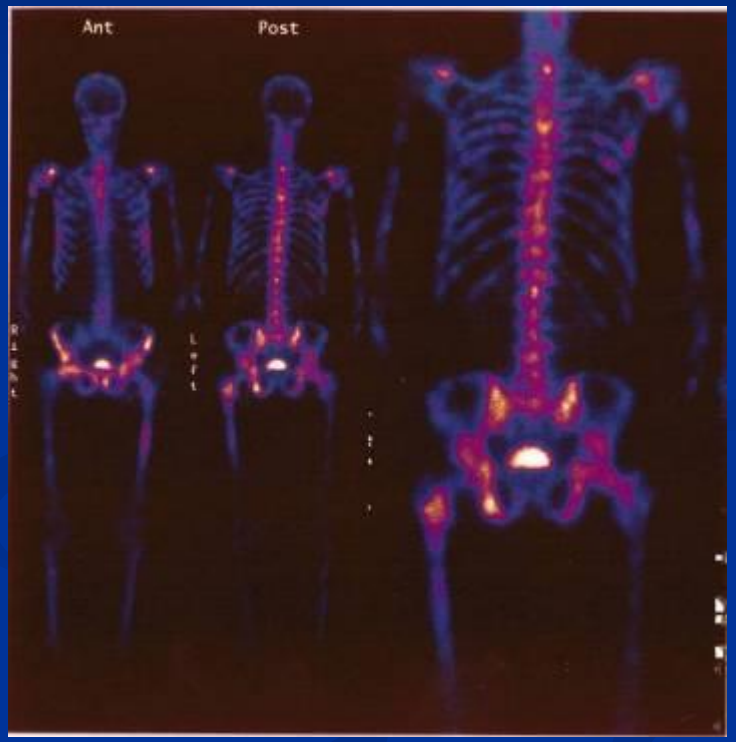
# X-rays X射线

## More energetic than UV
## 比紫外更高的能量

- In the cosmos, X-ray radiation is characteristic of high-energy events and objects: black holes, star collisions, etc..
- 宇宙中，X射线辐射是高能事件和高能天体的特征：黑洞、恒星碰撞等
- The mission of the Chandra Space Telescope is to detect and monitor these kinds of objects
- 钱德拉太空望远镜的任务是探测和监测这类天体

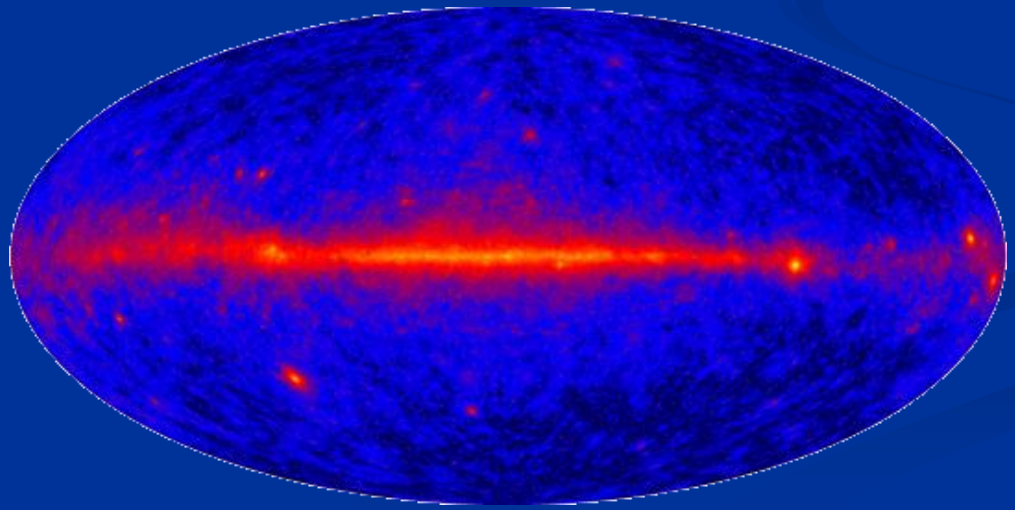
# Gamma rays 伽马射线

- It is the most energetic radiation.
- 这是最高能的辐射。
- On the Earth these rays are emitted by most of radioactive elements.
- 在地球上这种射线可由大多数放射性元素发射。
- Like X-rays, both are used in medicine, in imaging tests and in therapies to cure diseases like cancer.
- 类似X射线，它们都被用于医疗的成像测试和治疗，用于治疗类似癌症的疾病。

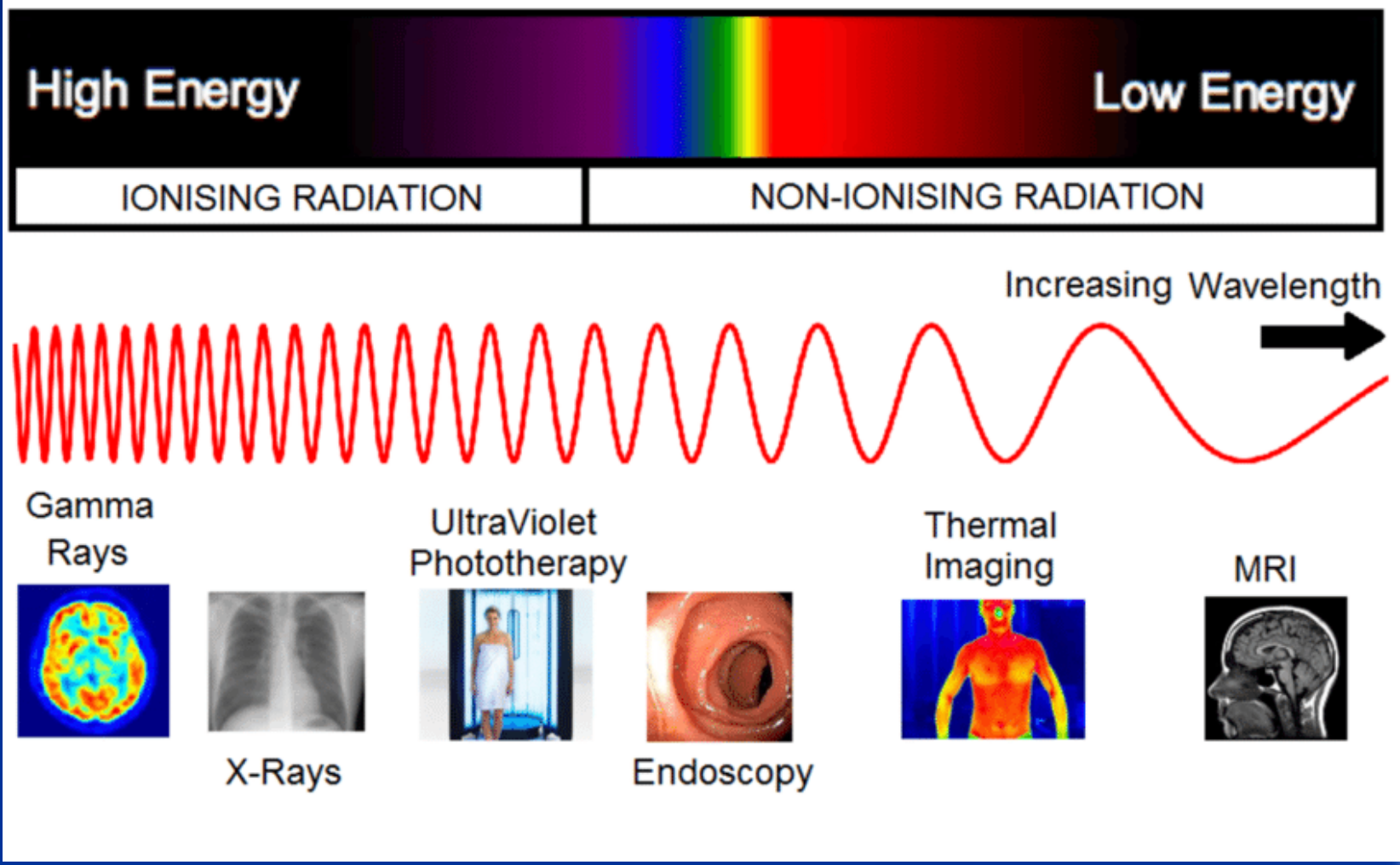


# Gamma rays 伽马射线

- The occasional violent eruptions of gamma rays are not unusual in the sky.
- 偶然产生的剧烈的伽马射线爆发在天空中并不罕见。
- There are different types that last from seconds to hours. One problem is to define their exact location to help identify what objects are producing the radiation.
- 它们有不同的类型，持续时间为数秒到数小时。一个重要问题就是要确定它们的确切位置，以帮助识别是什么天体产生了这样的辐射。



# Uses of EM radiation in Medicine
# 电磁辐射在医学中的应用



## Use of Radio Waves
## 利用射电辐射

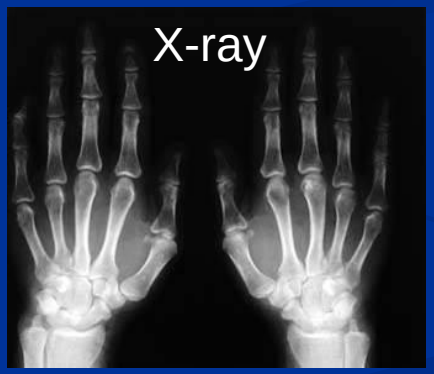
- Magnetic resonance, diagnosis of soft tissues
- 核磁共振，诊断软组织


MRI Human heart


MRI Normal knee

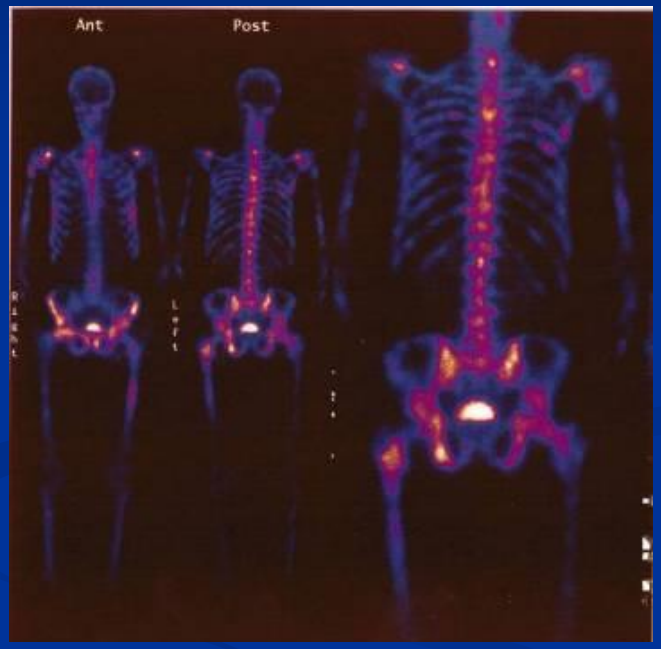
## Use of X-rays
## 利用X射线

- Radiographs and computed axial tomography (CAT scan)
- 射电照相和X射线断层摄影术（CAT扫描）


X-ray


CAT Normal knee

# Use of Gamma-rays
# 利用伽马射线




- Imaging tests and therapies to cure diseases like cancer. Used in positron emission tomography (PET scan)
- 影像学检查和治疗用于治疗癌症等疾病，用于正电子发射体层摄影（PET扫描）

Thank you very much
for your attention!
谢谢！