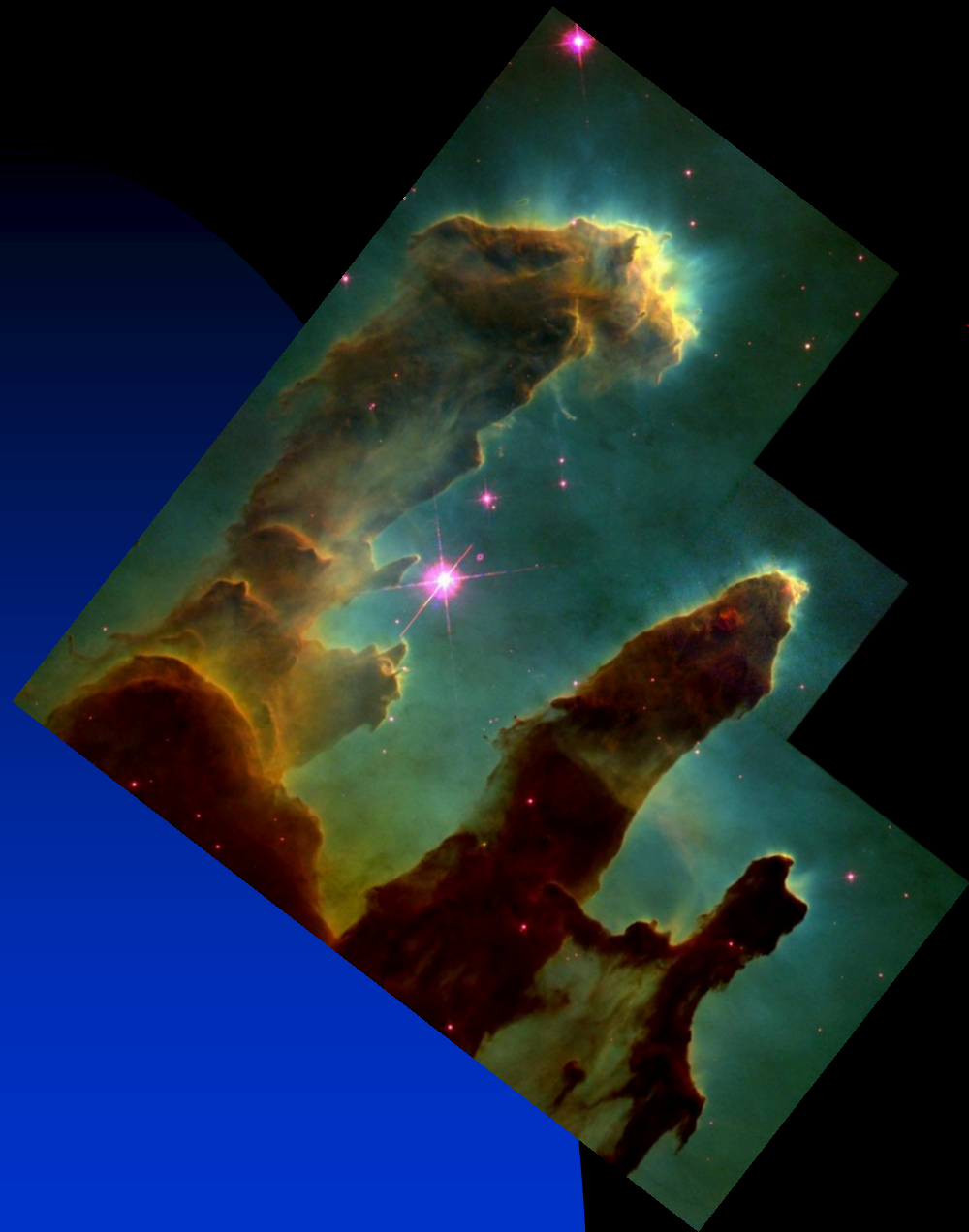


# 天體輻射



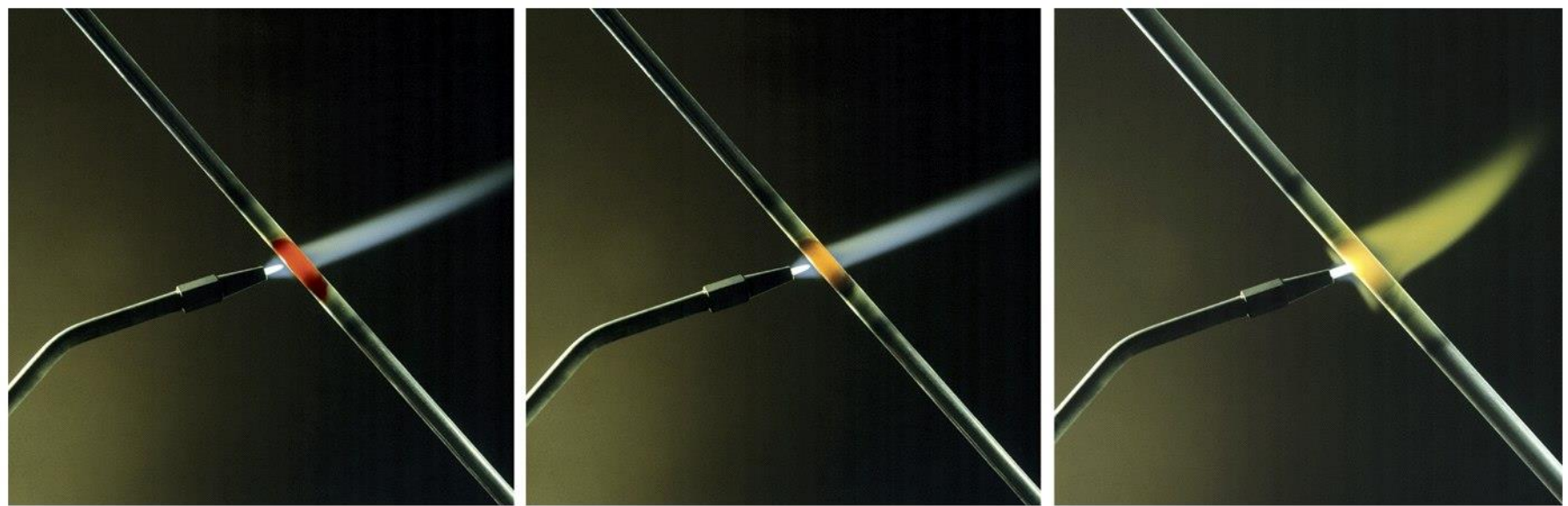
輻射體——靠自己熱度發光

越熱→越明亮、顏色越白熾

溫度低



溫度高



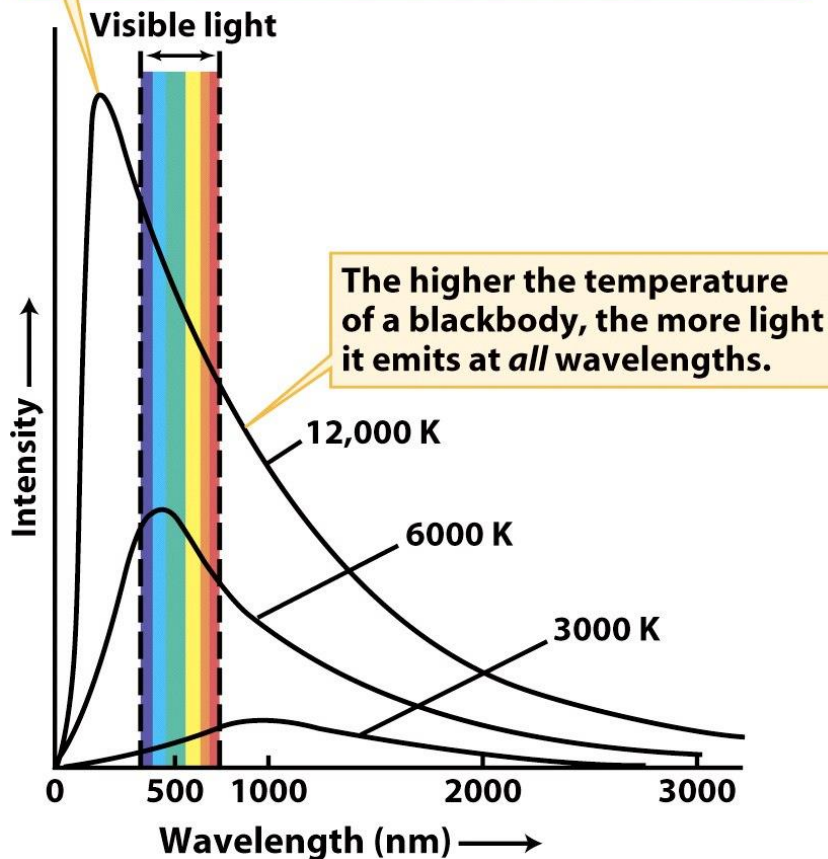
紅橙

黃綠

藍白

# Planck Function

The higher the temperature of a blackbody, the shorter the wavelength of maximum emission (the wavelength at which the curve peaks).



$$B_\nu(T) d\nu = \frac{2h\nu^3}{c^2} \frac{1}{e^{\frac{h\nu}{kT}} - 1} d\nu$$

The Planck's constant  $h = 6.626 \times 10^{-34}$  [J s]  
 $= 4.135 \times 10^{-15}$  [eV s]

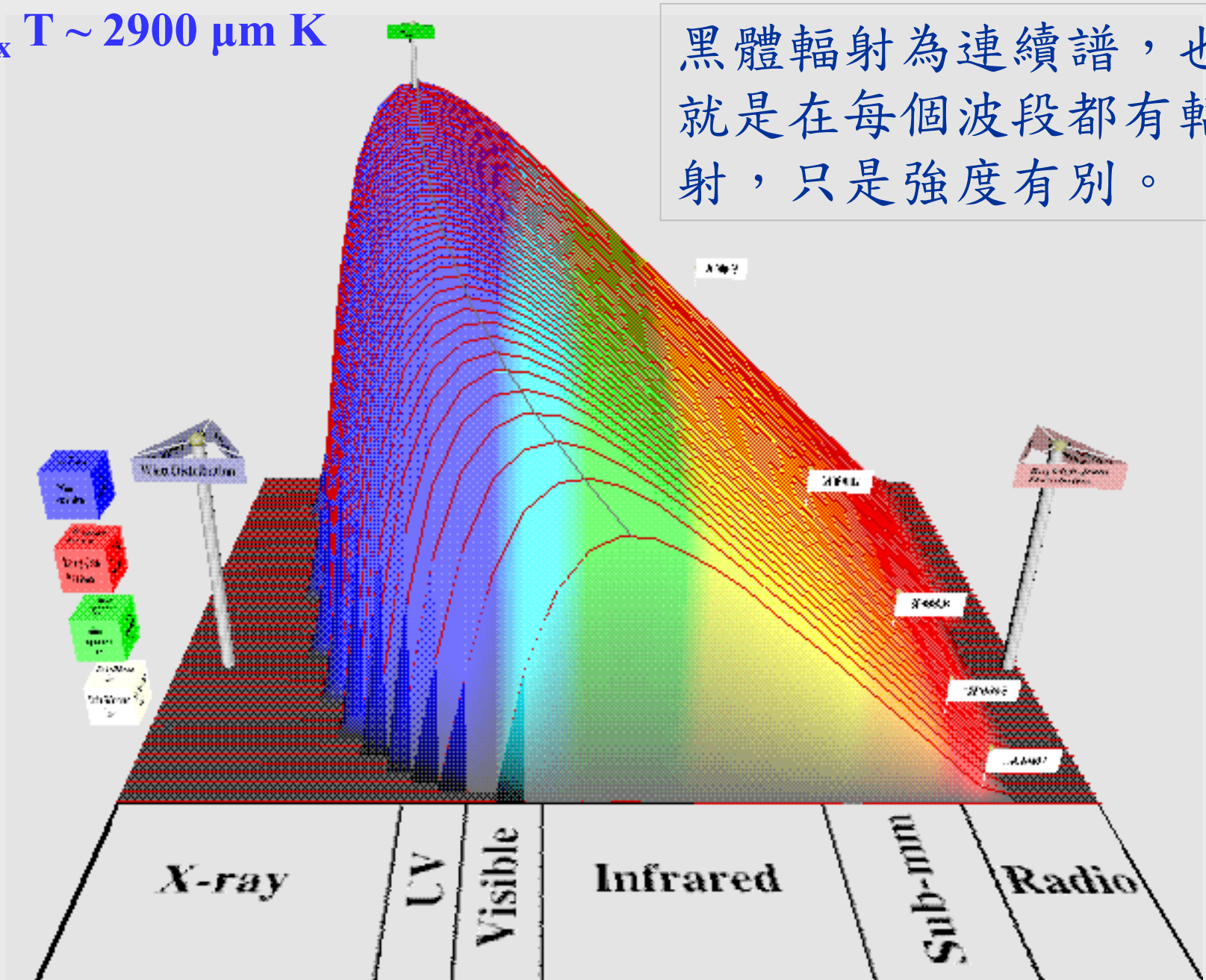
The Boltzmann's constant  $k = 1.38 \times 10^{-23}$  [J/K]

Wien's displacement law ---  
wavelength of the peak of the  
emission of a black body and  
its temperature

$$\lambda_{\max} T \approx 2900 [\mu\text{m K}]$$

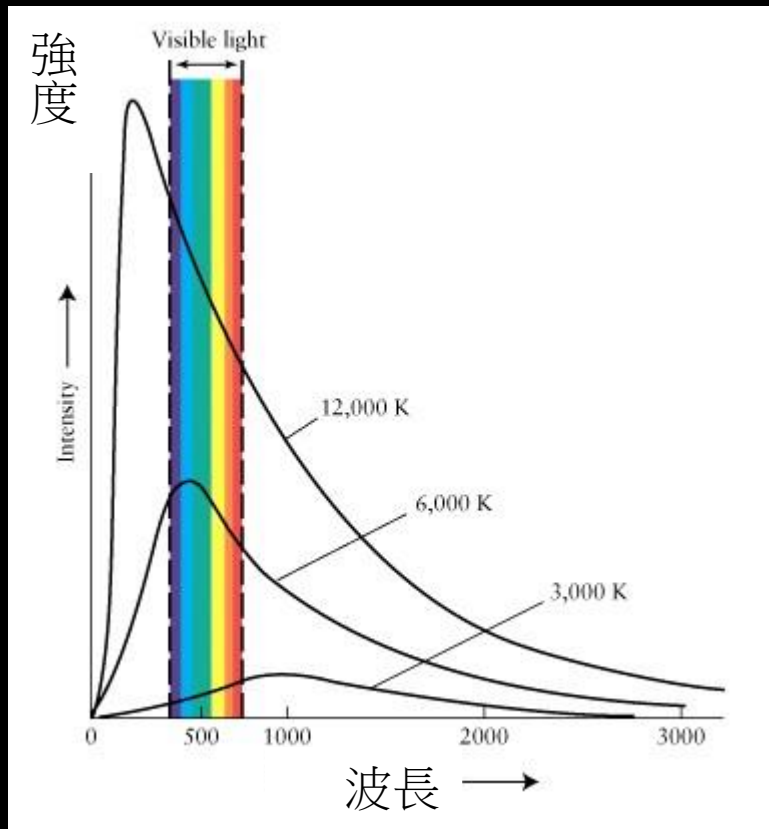
$$\lambda_{\max} T \sim 2900 \mu\text{m K}$$

黑體輻射為連續譜，也就是在每個波段都有輻射，只是強度有別。



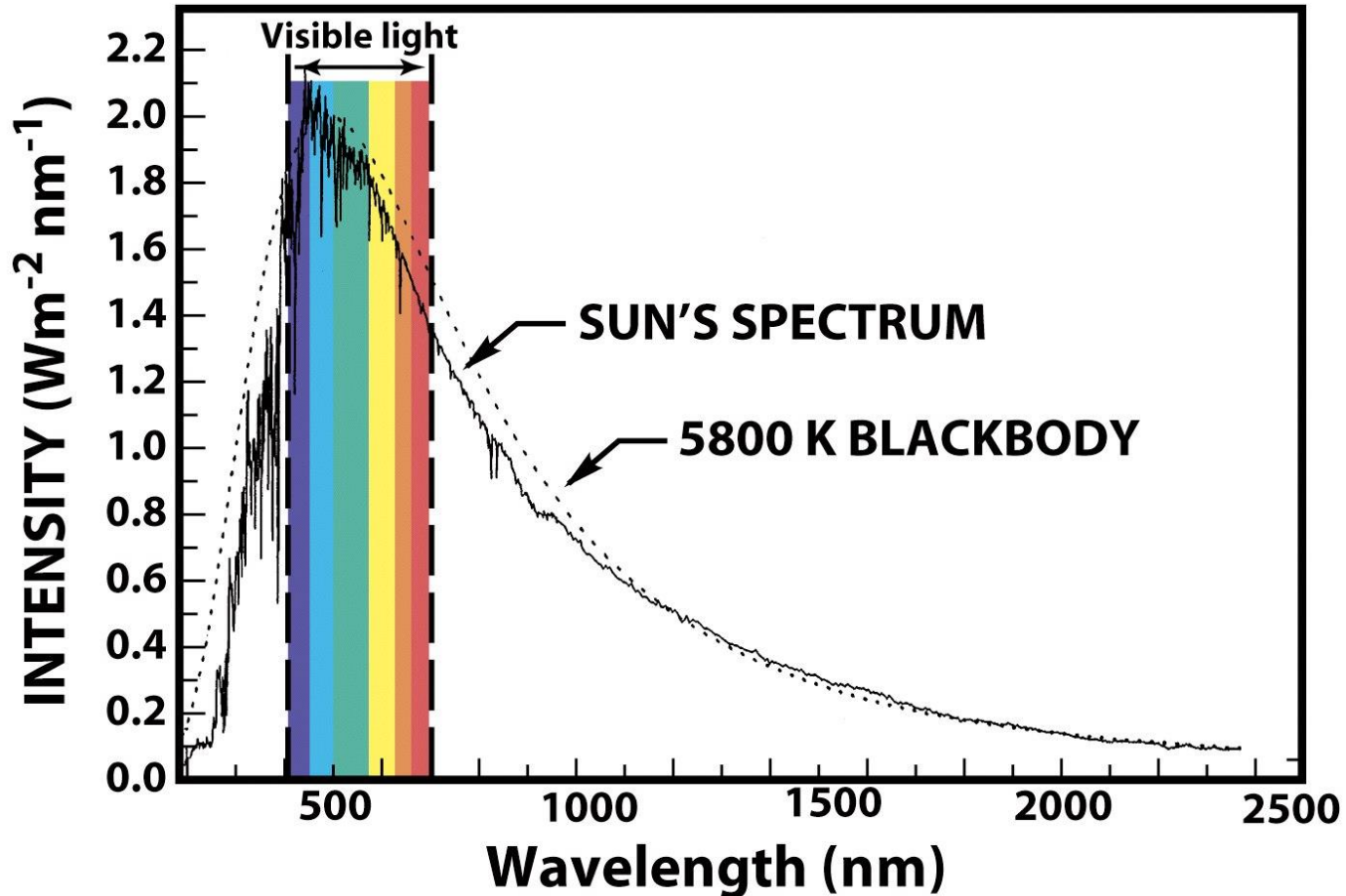


© 1998 Jerry Lodriguss



恆星（自行發光）  
表面溫度高 → 藍白  
表面溫度低 → 紅黃  
→ 從恆星的顏色可以估計其輻射溫度

我們的太陽是顆黃綠色的恆星  
表面輻射溫度大約為5800K



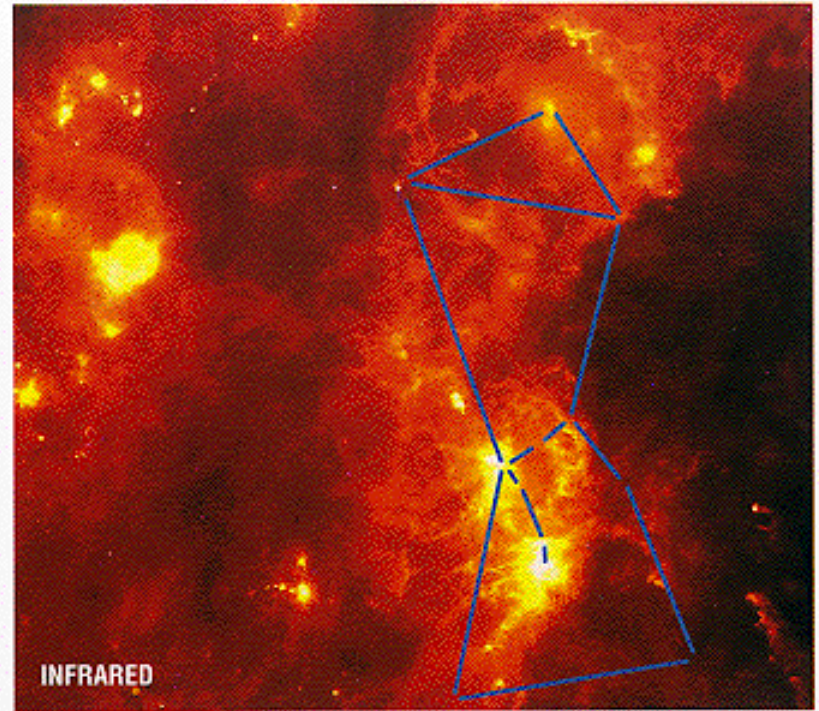
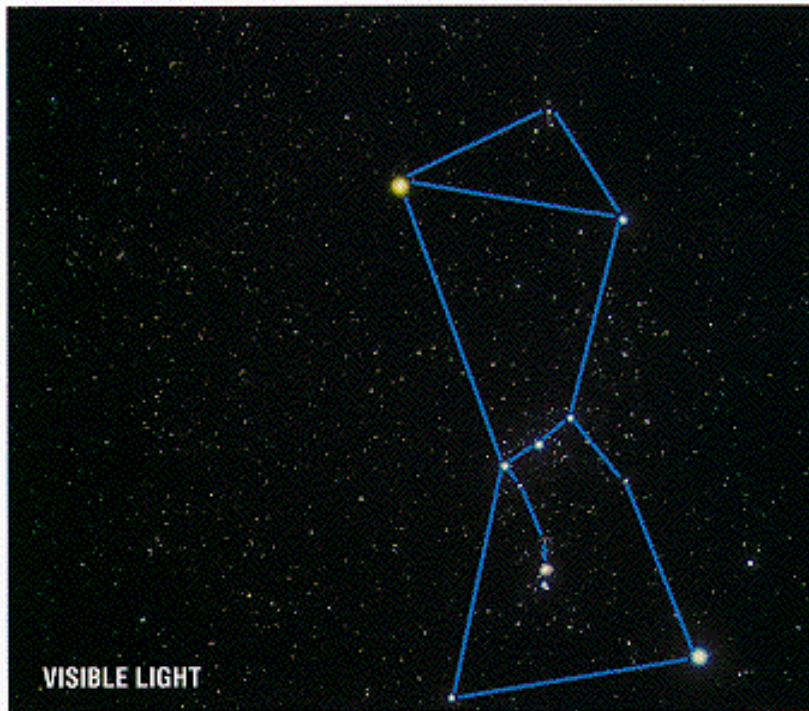
$$T \approx 5800\text{K}, \lambda_{\text{max}} \approx 0.5\mu\text{m} = 5000\text{\AA}$$



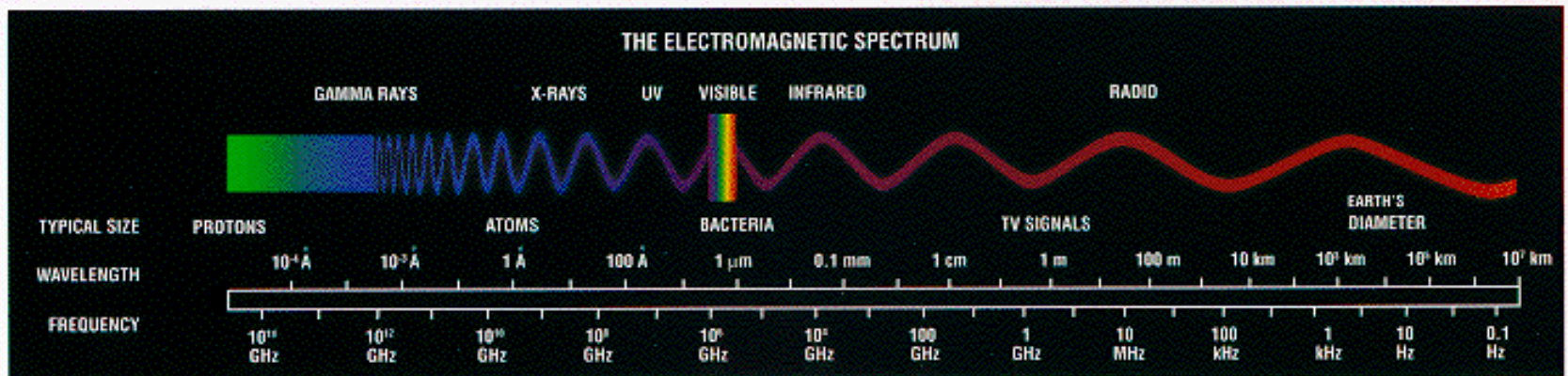
$$T \approx 300\text{K}, \lambda_{\text{max}} \approx 10\mu\text{m}$$



## Infrared Astronomy: More than Our Eyes Can See



*These views of the constellation Orion dramatically illustrate the difference between the familiar, visible-light view and the richness of the universe that is invisible to our eyes, though accessible in other parts of the electromagnetic spectrum.*





可見光

近紅外

中紅外

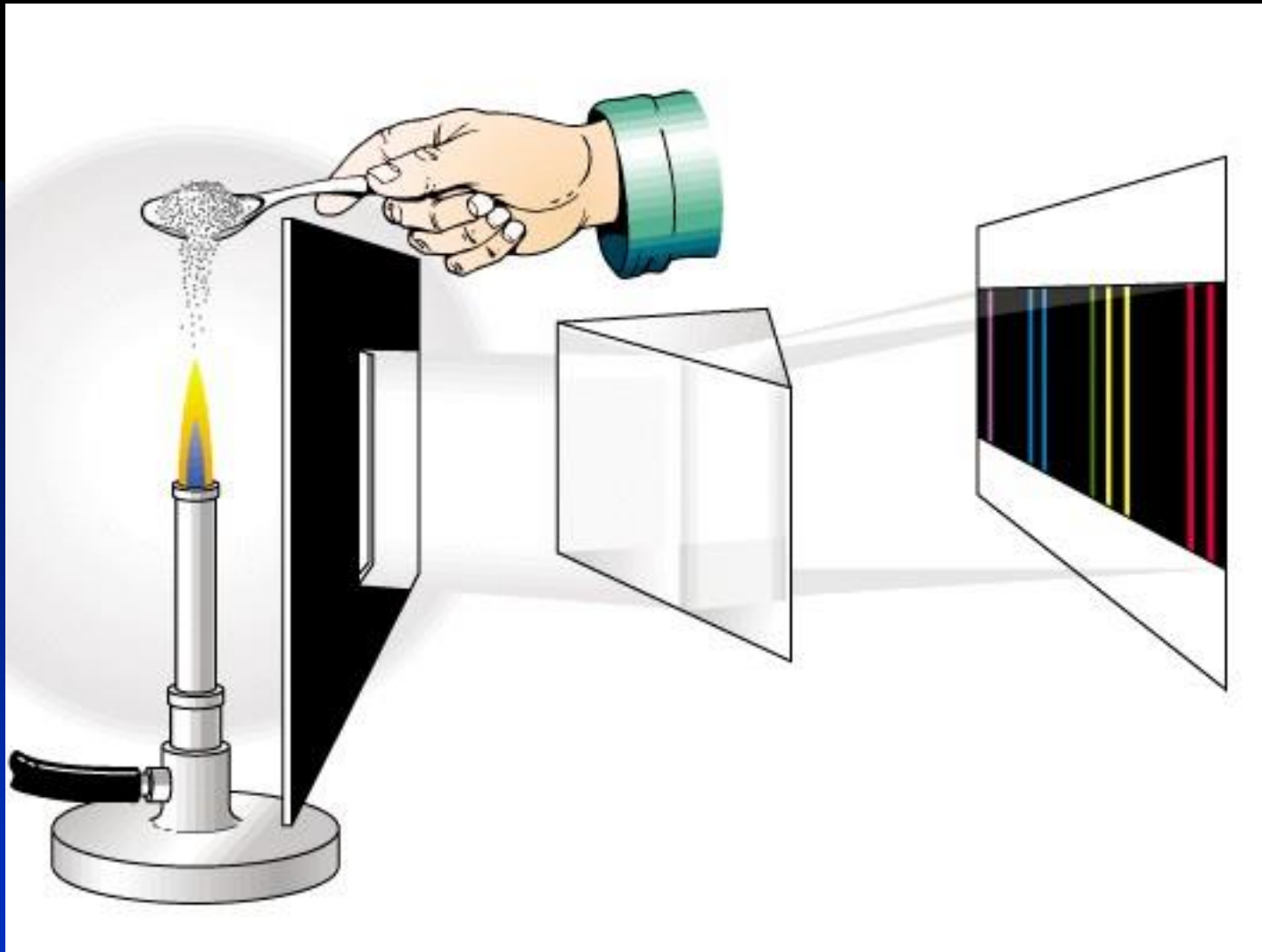


恆星

熱灰塵

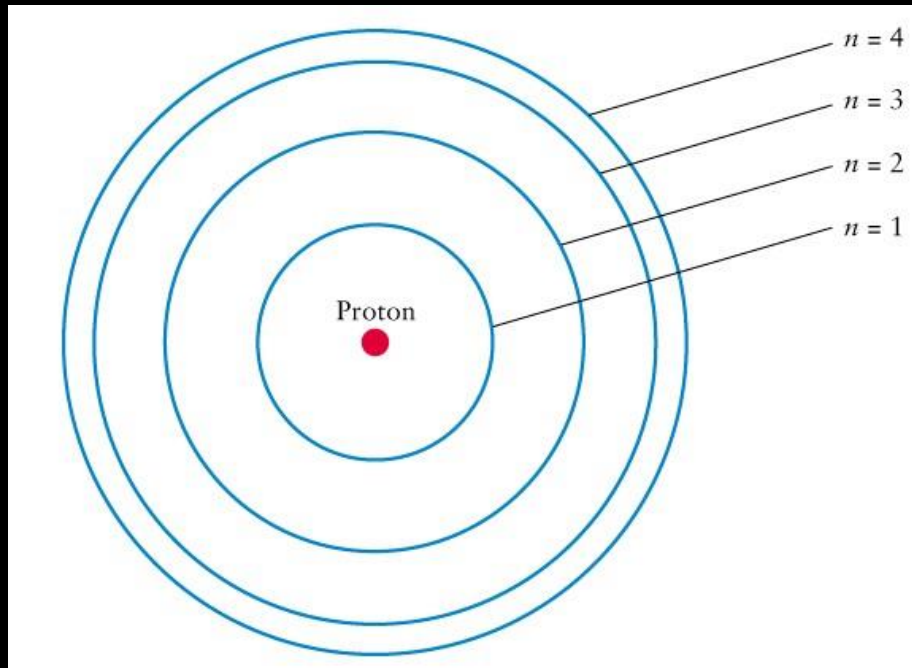
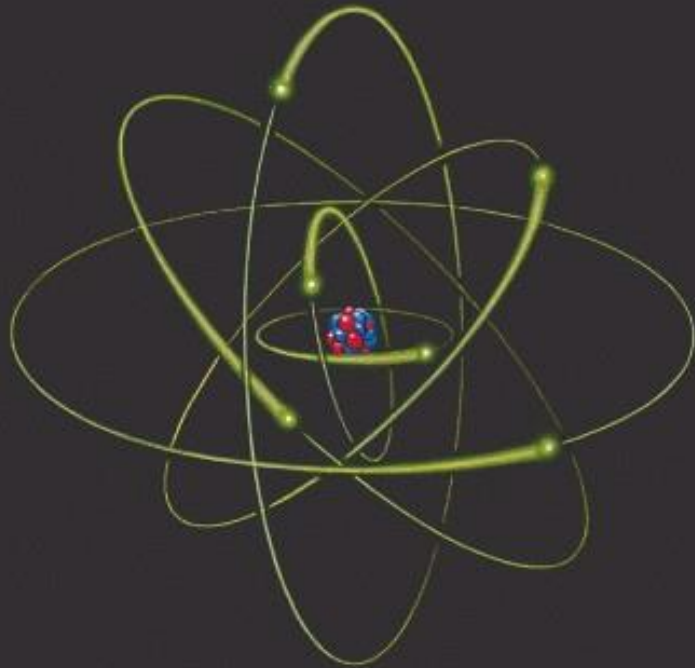
溫灰塵

獵戶座馬頭星雲（恆星誕生之處）  
在不同波段呈現的影像



Robert Bunsen and Gustav Kirchhoff in the 19<sup>th</sup> century  
Emission spectra of heated elements → chemical analysis

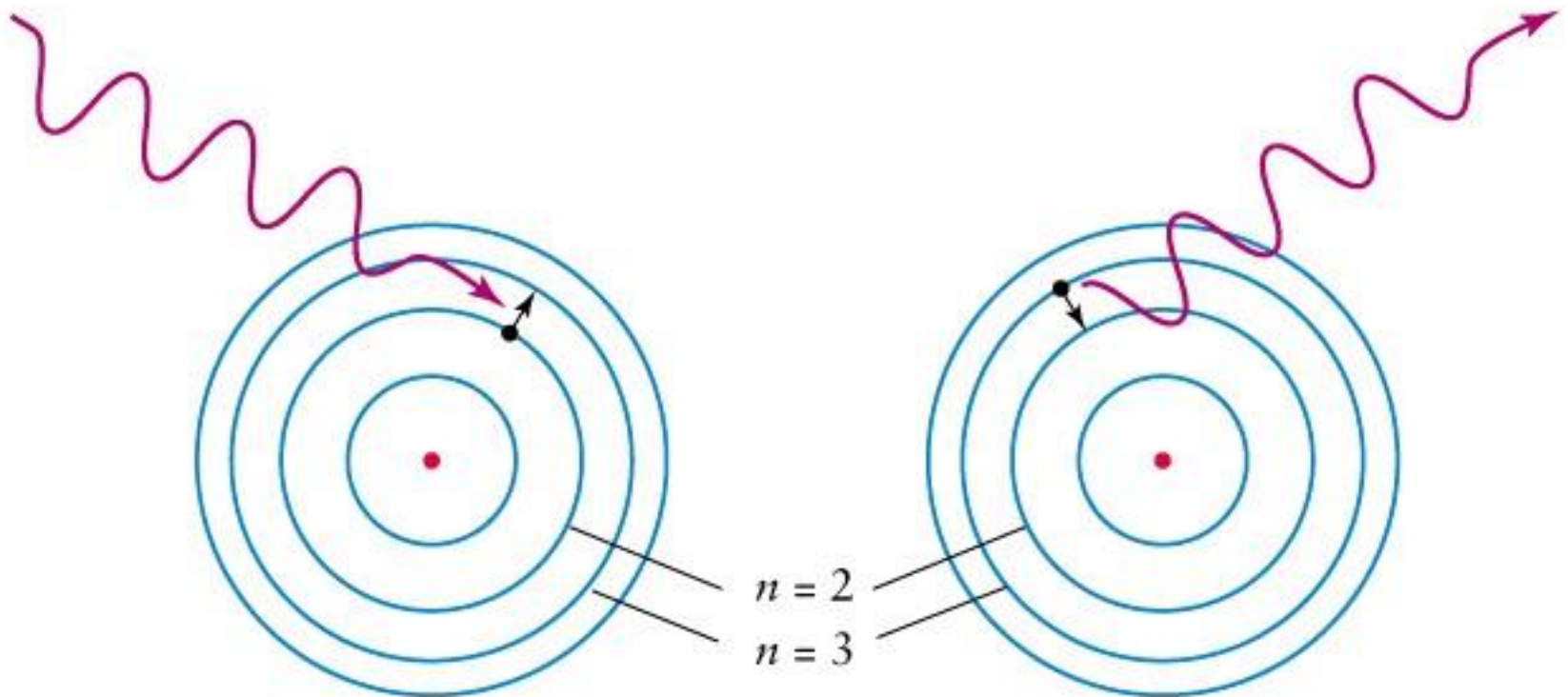
電子繞著原子核，在一定的軌道區域運行，每個軌道能量不同



變換軌道 → 能量改變

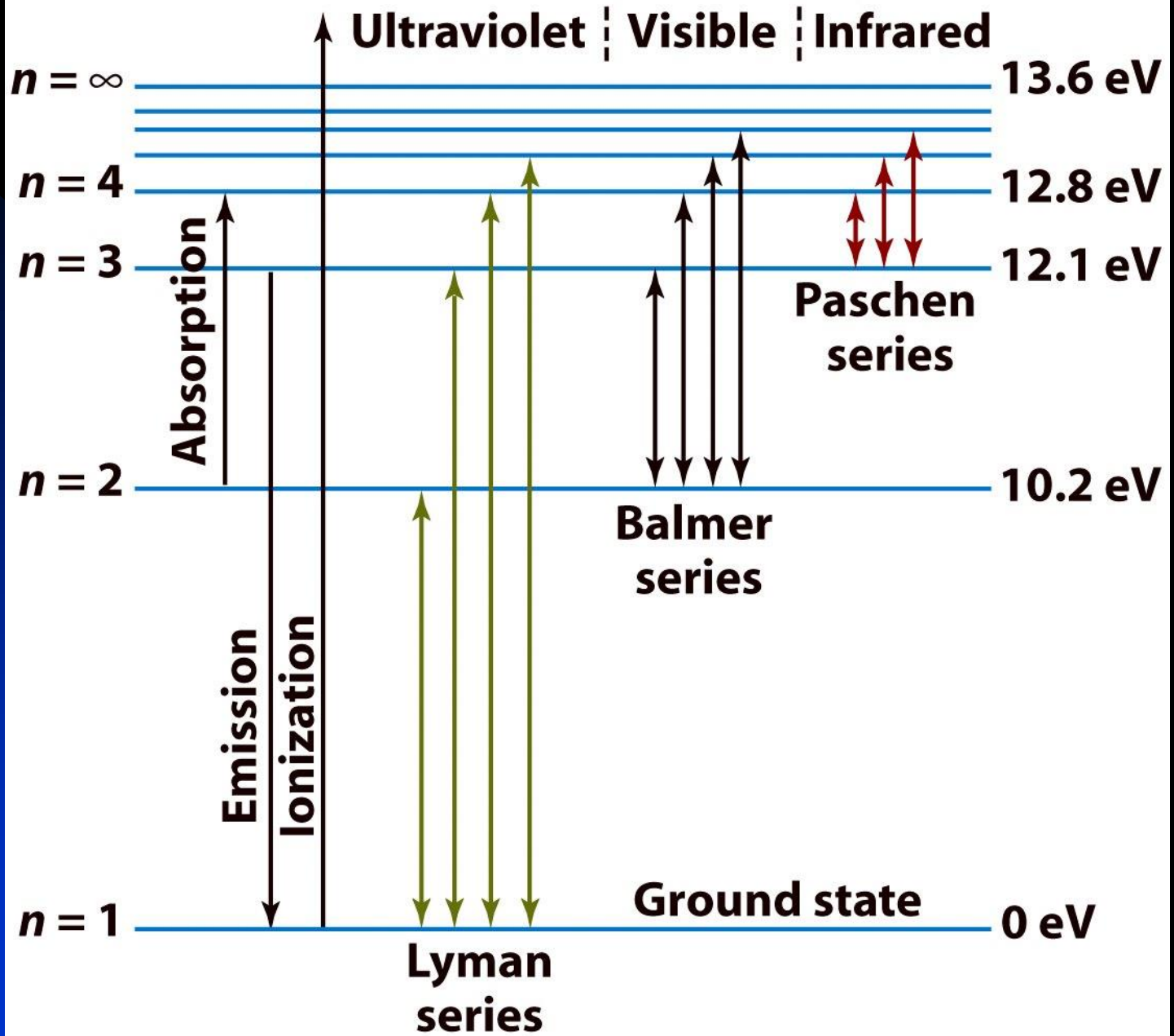
低 → 高能量軌道 → 吸收能量

高 → 低能量軌道 → 放出能量



a Absorption

b Emission



熱輻射體

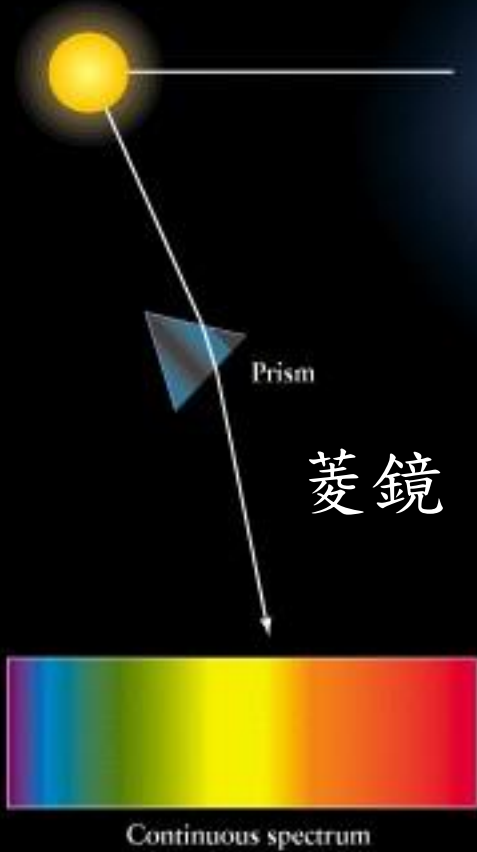
Hot blackbody

低溫氣體

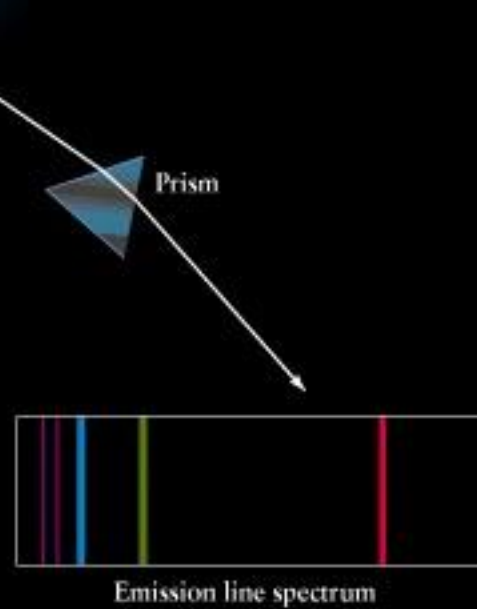
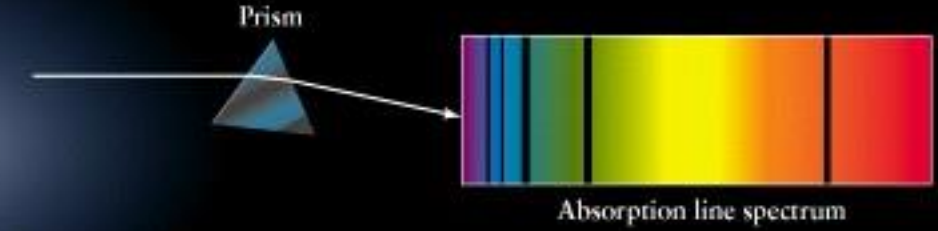
Cloud of cooler gas

這裡看到連續譜加上個別吸收暗線

菱鏡（分光）

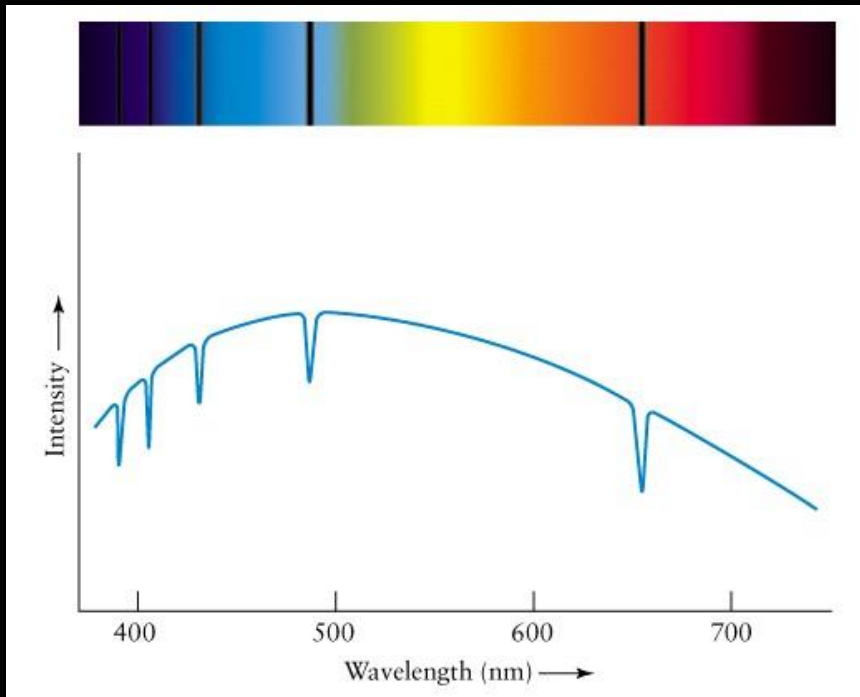


這裡看到如彩虹般連續譜

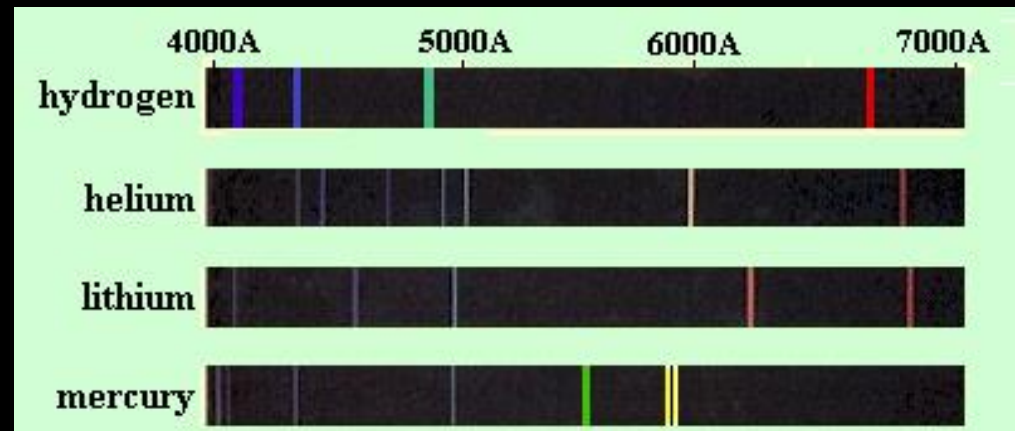


這裡看到個別發射亮線

原來各個能量（波長）都有的輻射，要是某個能量的光被吸收，便產生吸收（暗）線。



不同元素有不同躍遷  
→ 不同譜線。



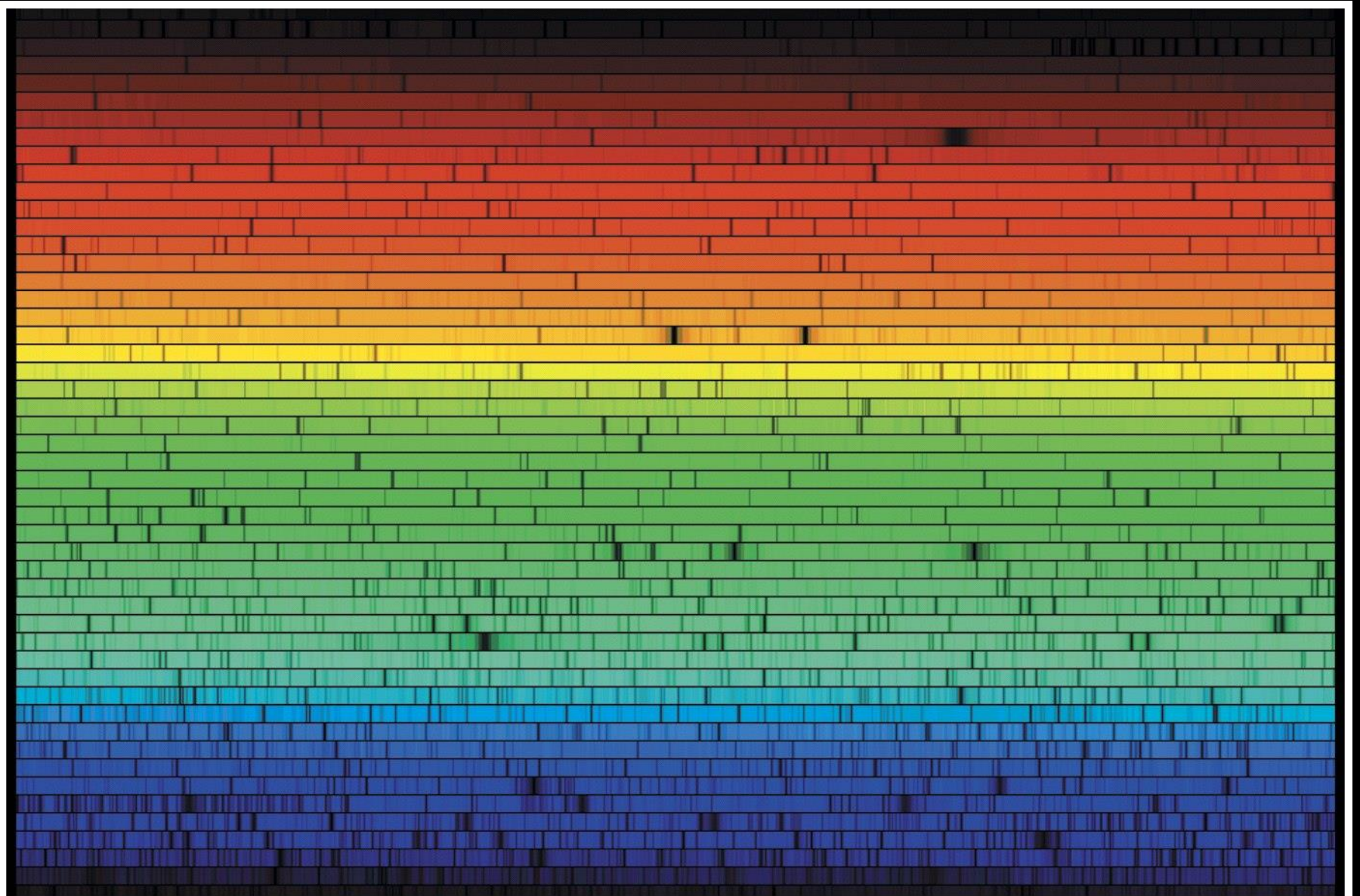
氫、氦、鋰、汞等元素的光譜  
[web.fccj.org/~ethall/thallium/spectra.gif](http://web.fccj.org/~ethall/thallium/spectra.gif)

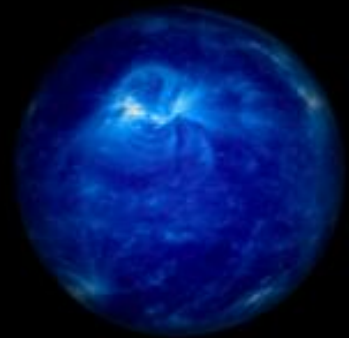
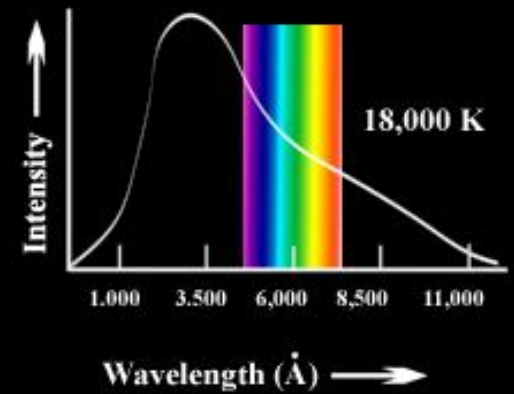
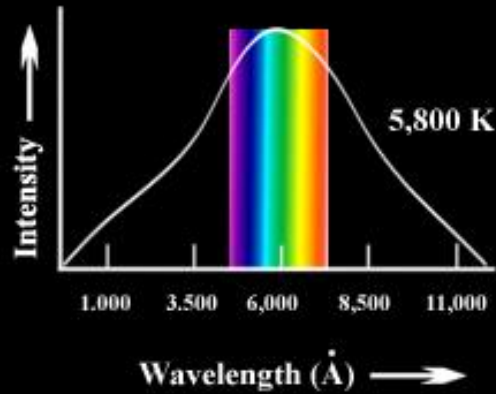
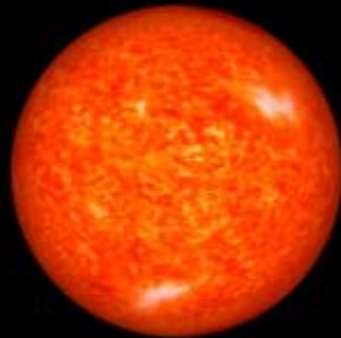
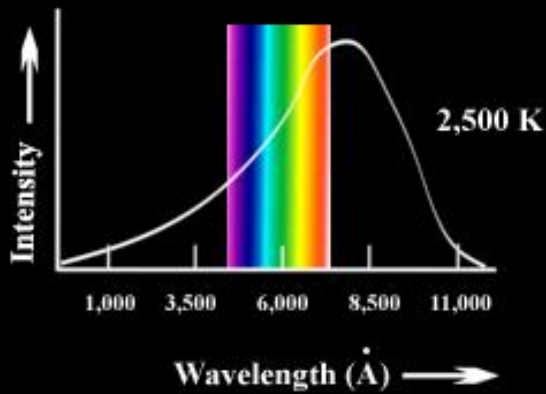


太陽內部很熱，發出高能量的光，經過較冷的外層氣體，部分能量被吸收

太陽光譜中可以看到很多吸收線







Colors are exaggerated

# 熾熱年輕恆星 組成的星團



月全食的月球



各種恆星正在雲氣中誕生



恆星之間太空中的雲氣

太陽系當中的彗星

# The Entire Sky at Five Wavelength Ranges

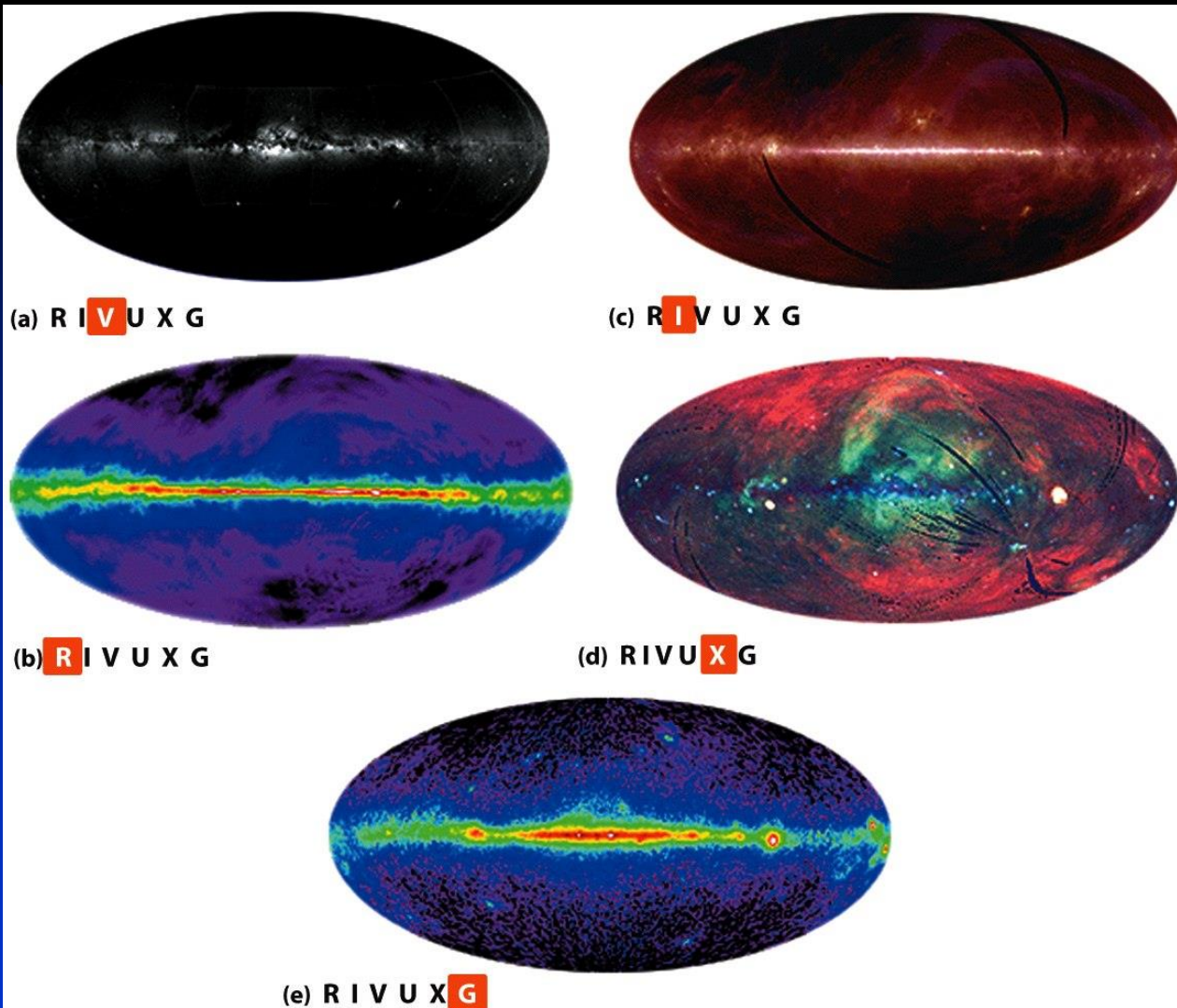
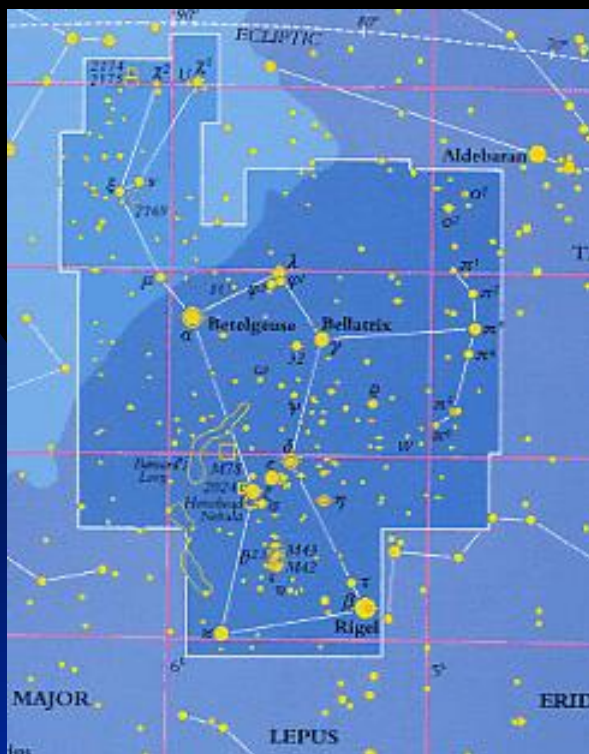


Figure 6-32  
*Universe, Eighth Edition*  
© 2008 W. H. Freeman and Company

# Orion

## 獵戶座





**Starry Night Pro - untitled** [ \_ ] [ 5 ] [ X ]

File Edit Go Settings Selection Sky Guides Window Help

2001/8/10 18:41:01 UT (UT)  
 Gaze: Az: 266° 50.030' Alt: 9° 9.485'  
 Chart centre (J2000): RA: 5h 33.774m Dec: 3° 27.710'

**Orion**

**12 Tau**  
5.53  
Taurus  
RA: 3h 39'  
Dec: 3° 3'

Celestial Distance:

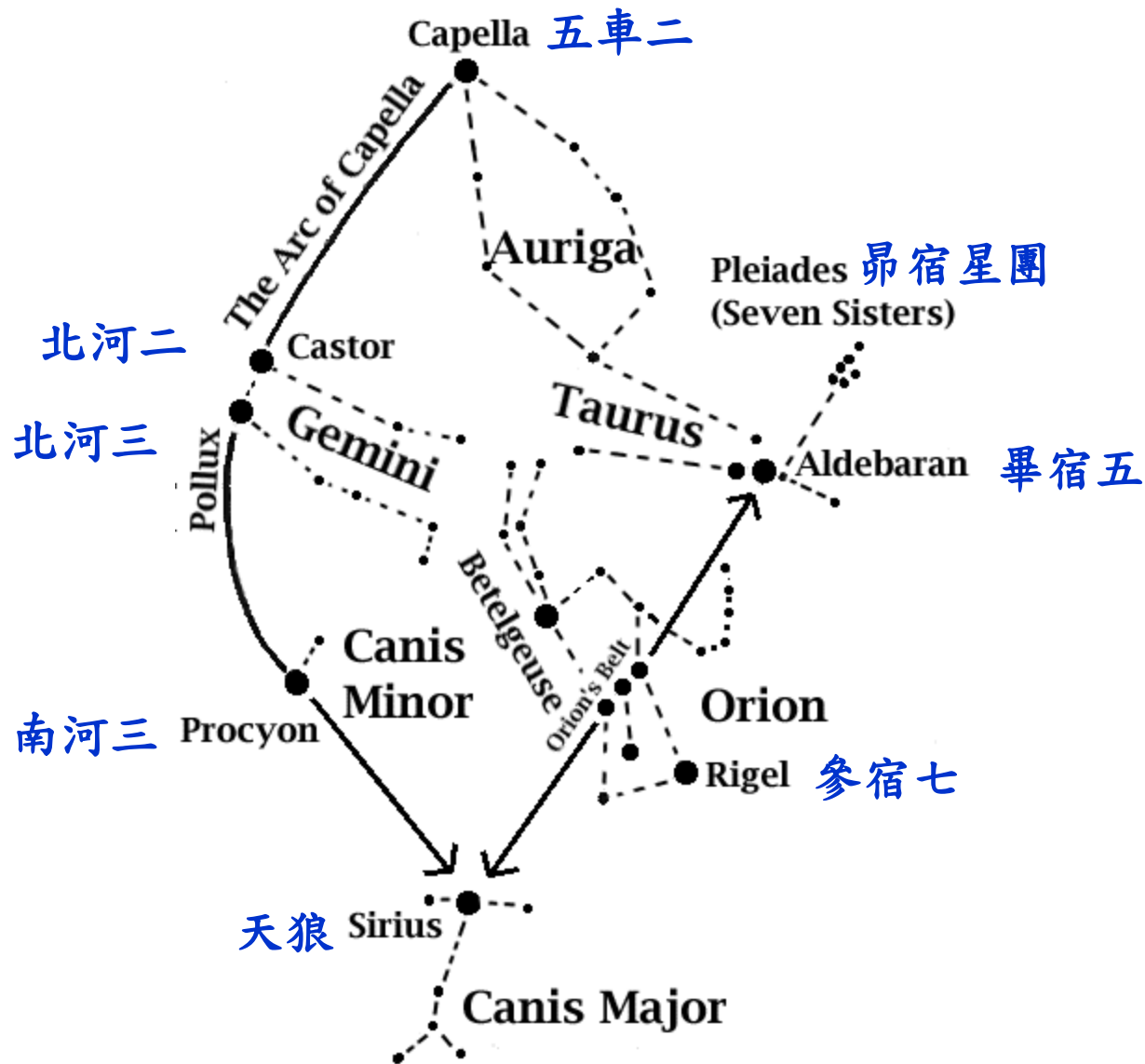
Time: 003 days 8/10/ 2001 AD  
 Sync All Windows 2:41:01 PM  
 Now Julian...

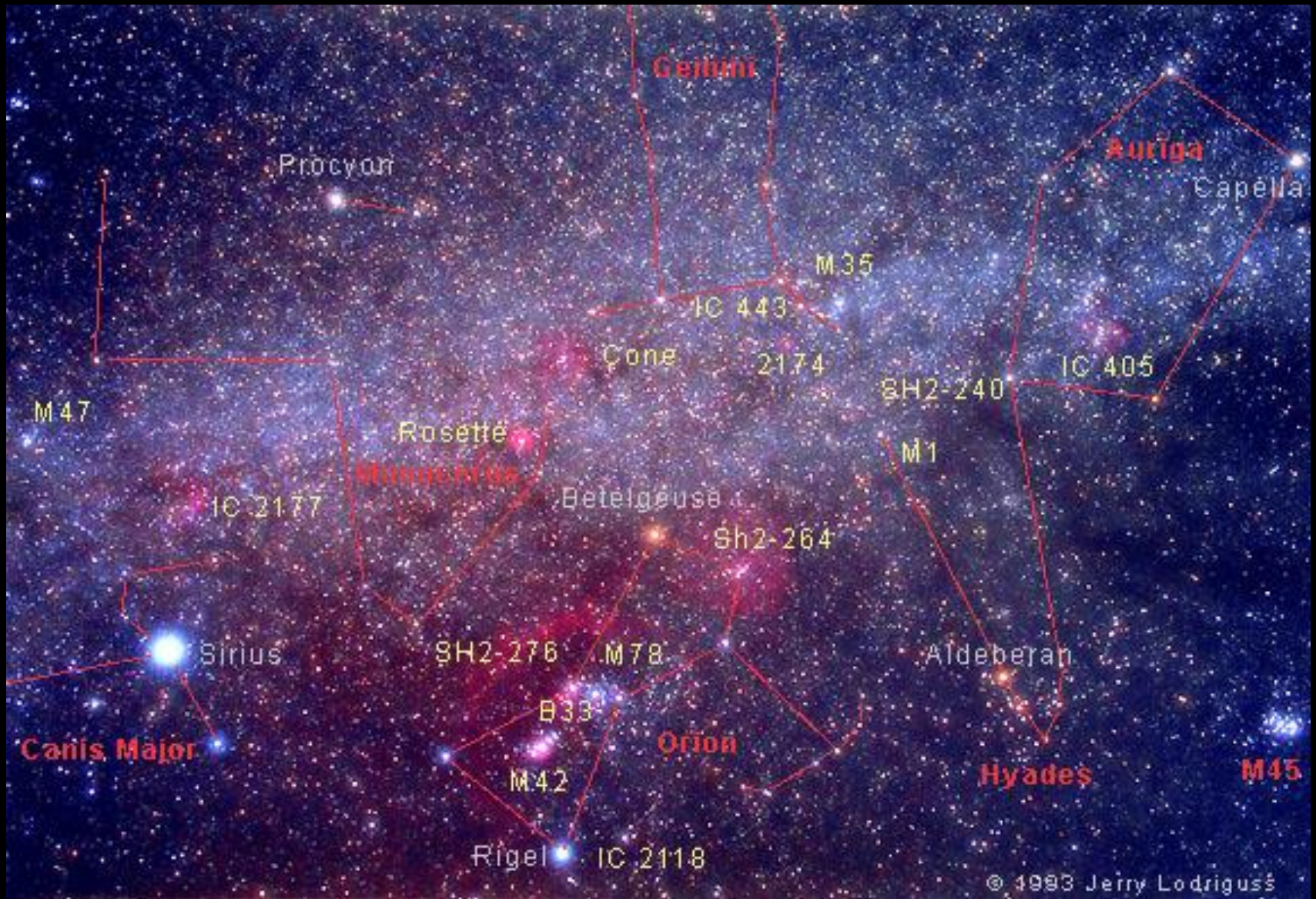
Philade...  
 Lat 40 N  
 Lon 75 W  
 3 m  
 72°

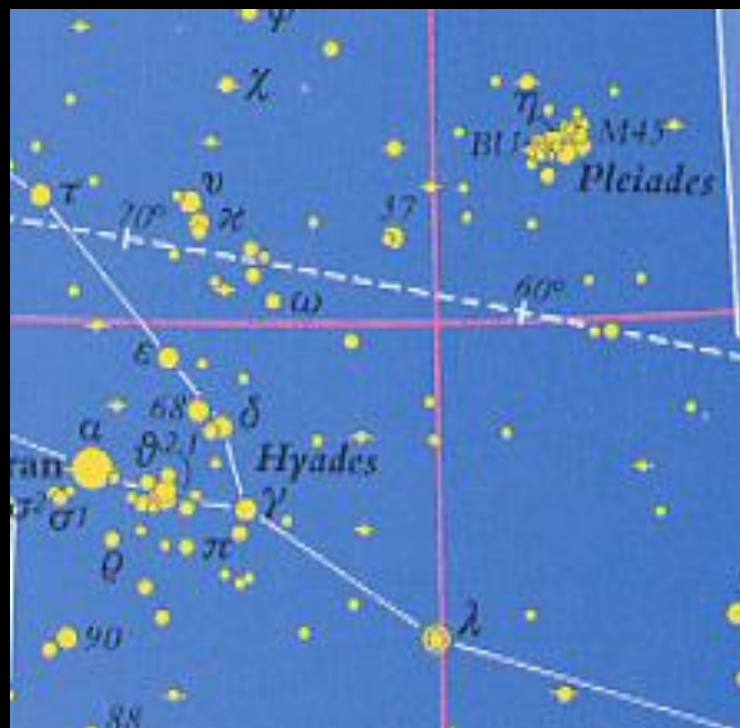
Philadelphia, U.S.A. 8/10/2001 2:41:01 PM



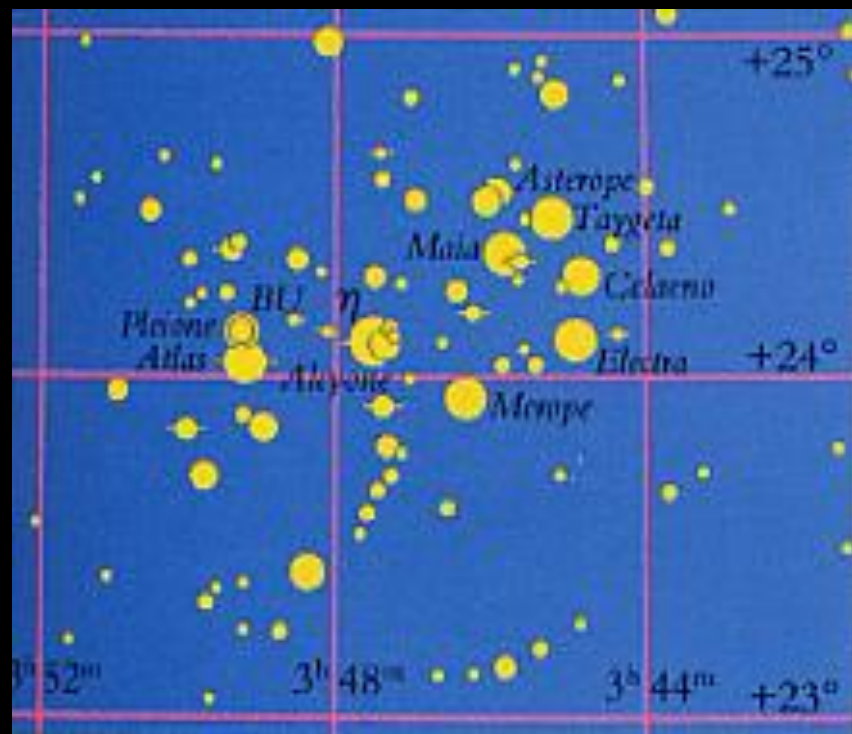
# Using Orion as a Sky Guide



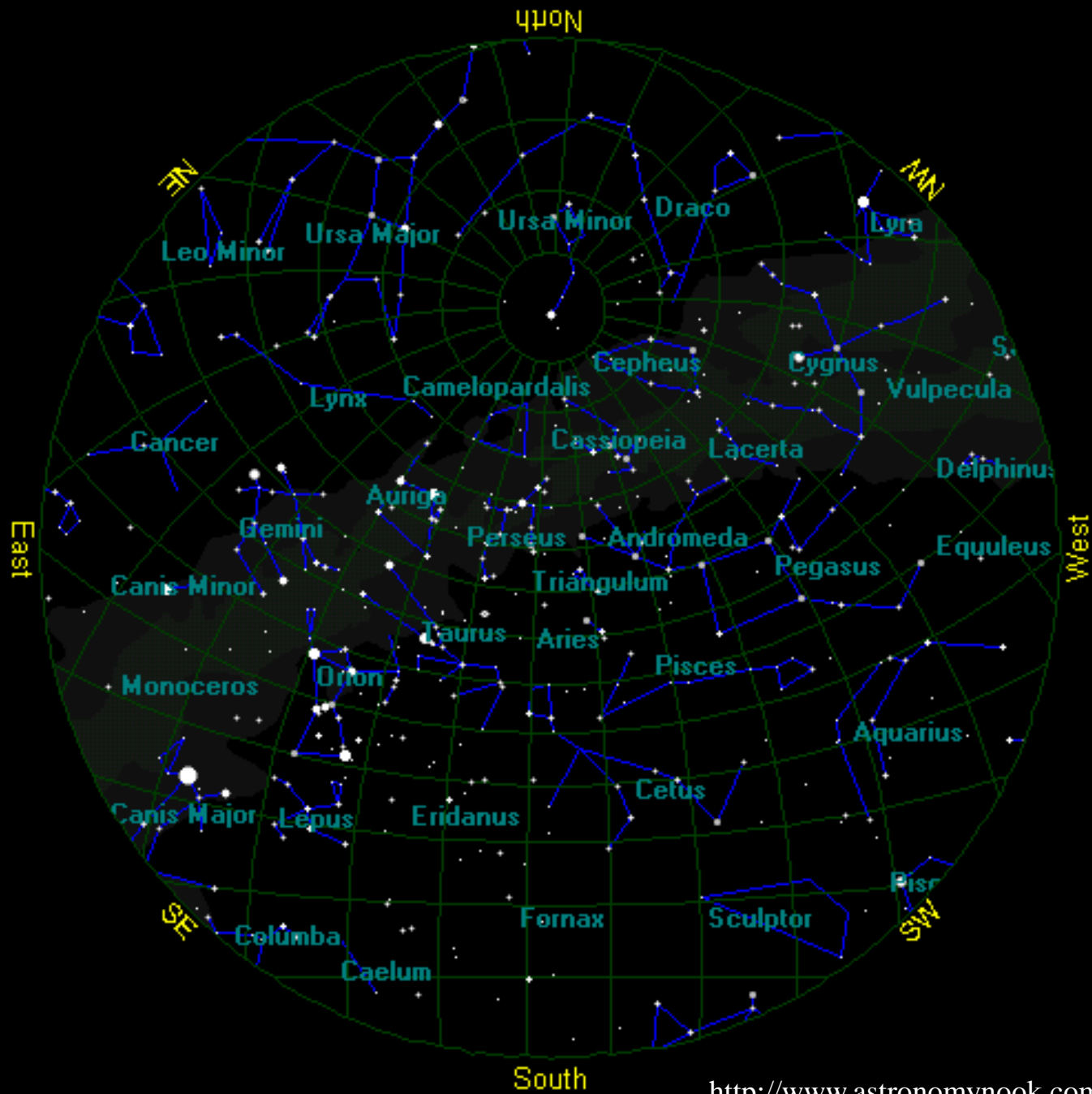




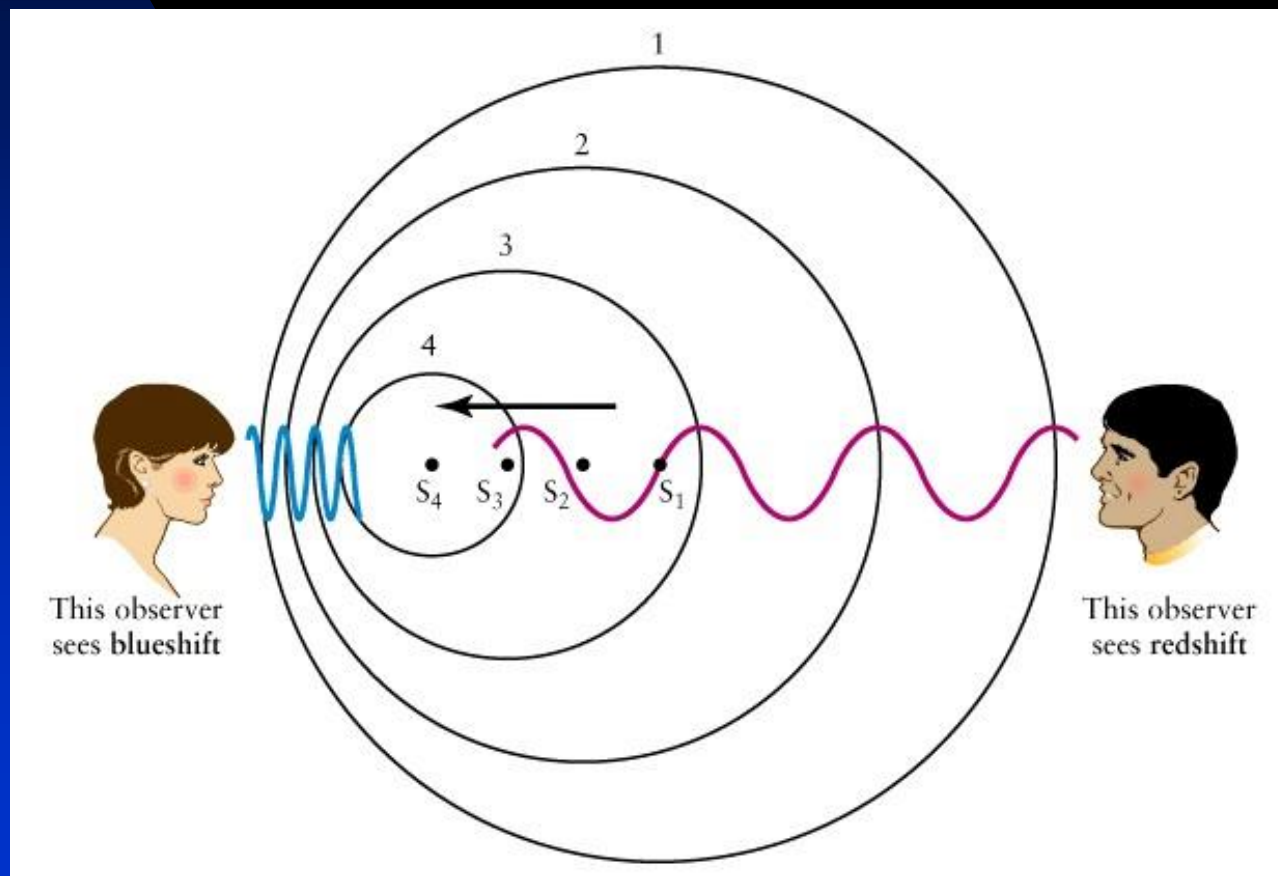
畢宿星團 (Hyades) 位於金牛頭部，距離我們只有150光年。Aldebaran (阿拉伯文「追隨者」) 乃金牛眼睛，距離60光年)。

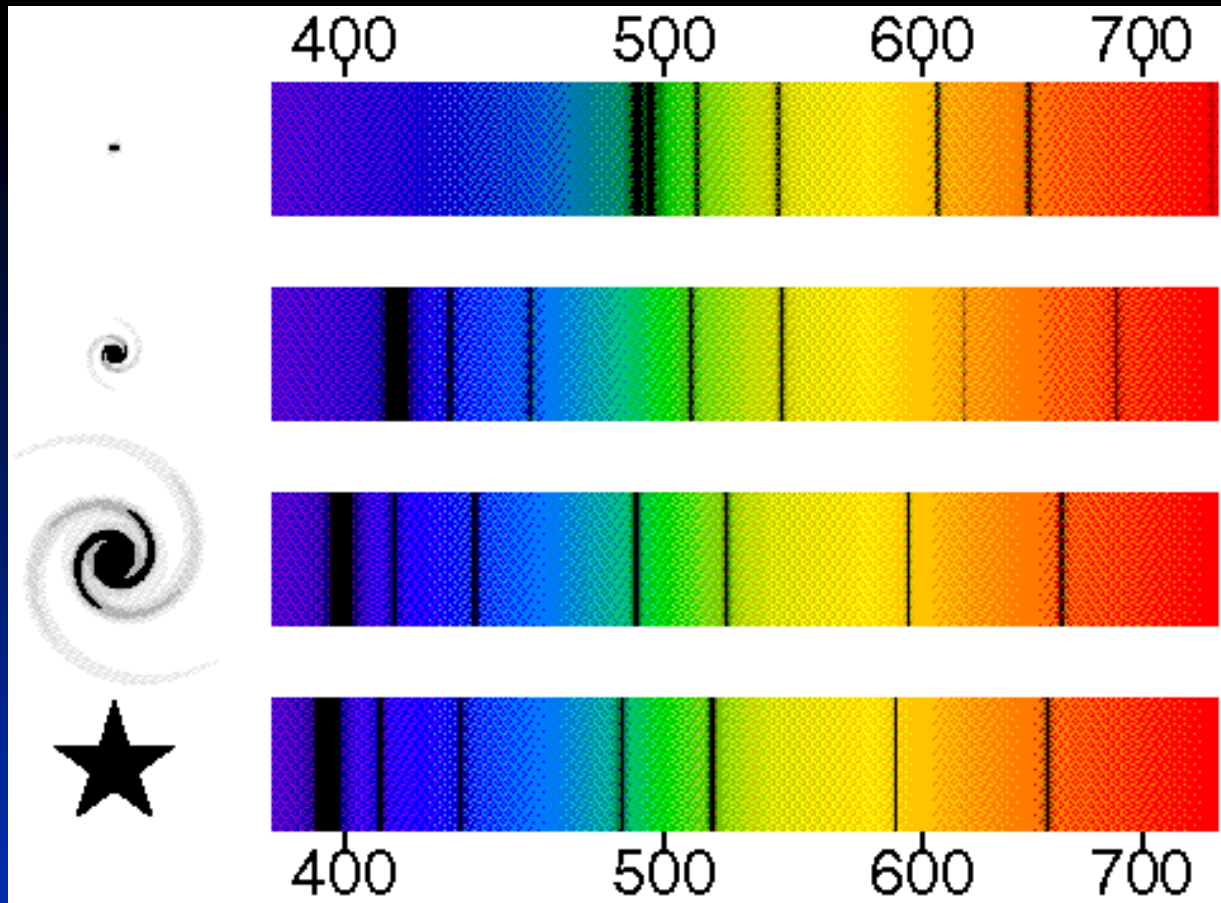


昴宿星團 (Pleiades) 位於金牛肩膀，裸眼可見6~7顆，故也稱「七姊妹」。透過雙筒望遠鏡可見9顆，全部星團約500顆星



**都卜勒效應 (Doppler effect)** —— 測量  
波動頻率（振動快慢）的改變，可以  
知道我們和波源之間的速度





<http://www.astro.ucla.edu/~wright/doppler.htm>

$$\frac{\Delta\lambda}{\lambda_0} = \frac{v}{c}$$

$v$ : speed of the source along the line of sight  
 $c$ : speed of light =  $3 \times 10^8$  km/s

$$\frac{\Delta\lambda}{\lambda_0} = \frac{v}{c} \quad \text{is valid only when } v \ll c$$

When the speed is approaching the speed of light,  $v \rightarrow c$ , the formula becomes the general form

$$\lambda_{\text{obs}} = \lambda_0 \left( \frac{c+v}{c-v} \right)^{1/2} \quad (v \text{ along the line of sight})$$

= radial velocity

The Doppler shift  $z = (\lambda_{\text{obs}} - \lambda_0) / \lambda_0$

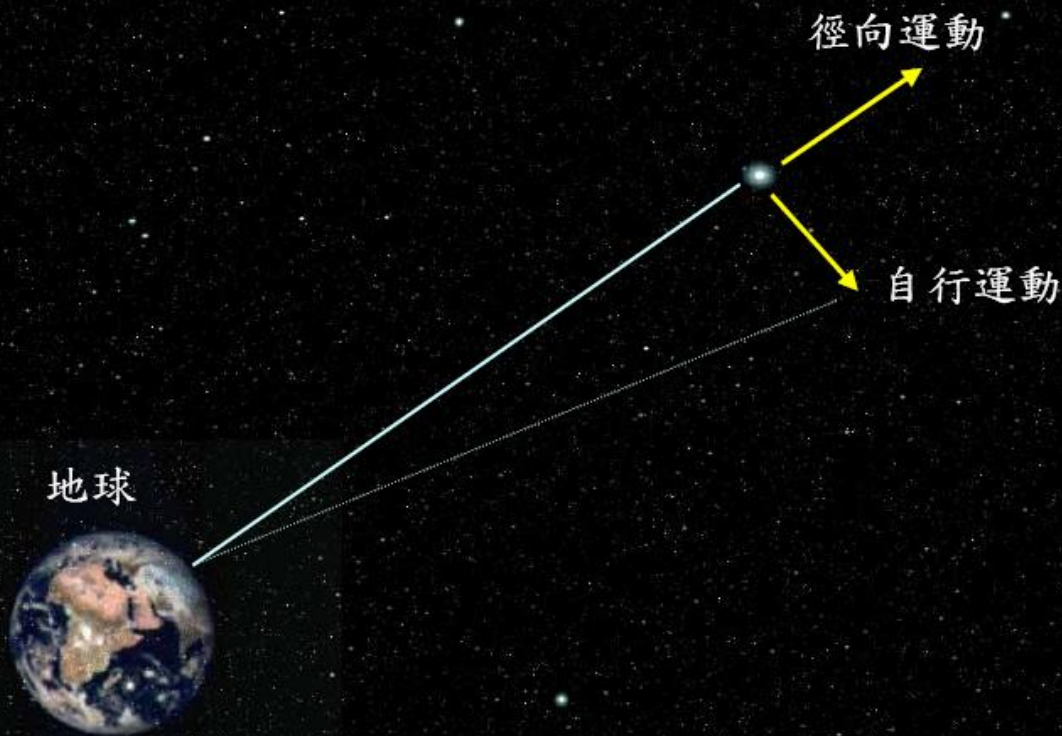
$$= \left( \frac{c+v}{c-v} \right)^{1/2} - 1$$
$$\approx v/c$$

- 都卜勒效應 —— 駛近與遠離的火車鳴笛
- 利用此原理可以
  - ★ 觀察心臟跳動情形
  - ★ 判斷高速公路上的車速
  - ★ 測知天體**沿視線方向**的運動
    - 太陽表面震盪的情形
    - 恆星在銀河系中運動情形
    - 雙星互繞、繞行恆星的行星
    - 星系運動的情形（宇宙膨脹）
    - ...



天體在太空的運動可以分成兩個分量，一個  
投影在天球上的**自行運動** (proper motion)，另  
一個為垂直的**徑向運動** (radial velocity)。

Measured by  
Doppler shift



巴納德星為離我們第三近的恆星（最近的是太陽，其次是毗鄰星），距離地球約6光年，它的proper motion 為每年10.3角秒，以其距離換算，也就是速度每秒90公里。經由Doppler effect 測量光譜線，得到Barnard's Star 的radial velocity 為每秒111公里，因此其在太空中實際運動的速度為142 km/s。

Q: 直徑10公里的小行星，若以每秒140公里的速率撞向地面，動能有多大？要是這些動能全部都轉換成熱能，撞擊點的溫度有多高？這樣的能量對周遭環境會造成怎樣的影響？