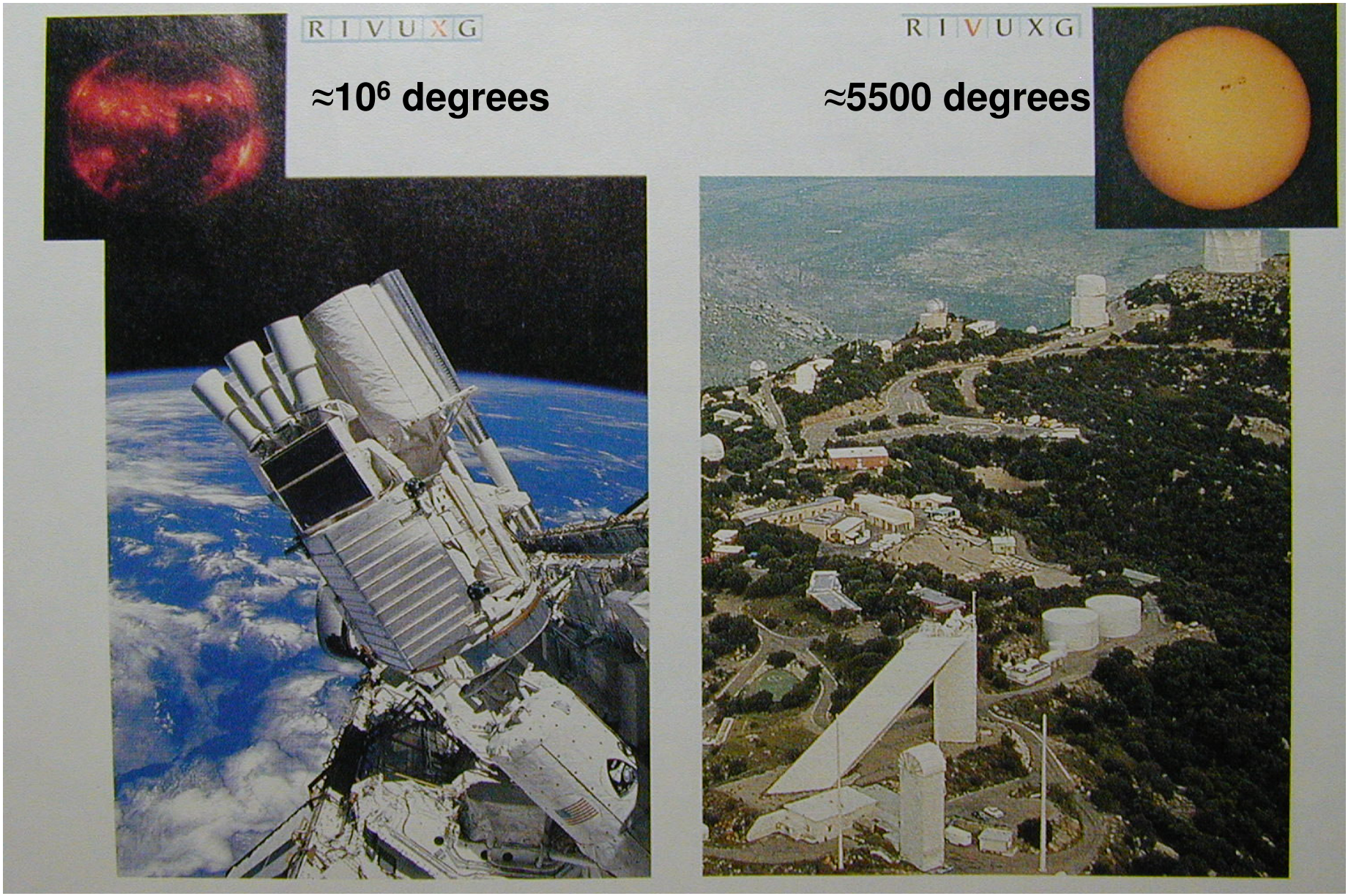
天文狗仔的報料裝備：望遠鏡
(observations, not too many lab works)

辜品高
師大地科系
中研院天文所

visible & invisible



Prism (三稜鏡) & Spectrum

refraction (折射) → 色散(分光)

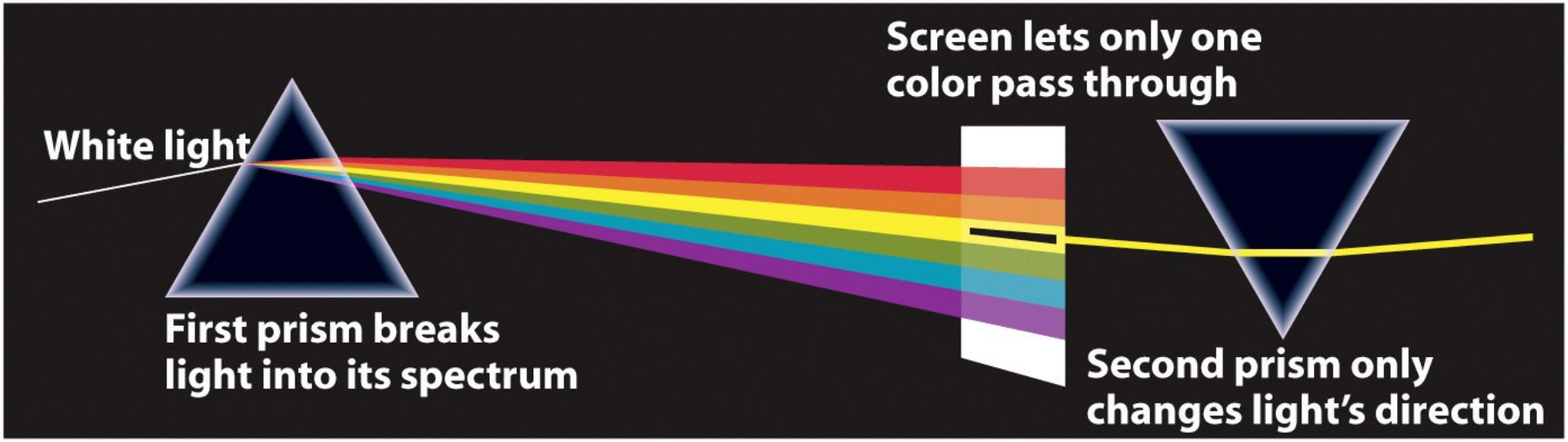


Figure 3-1
Discovering the Universe, Seventh Edition

rainbow

Sunlight comes from the other side of the rainbow

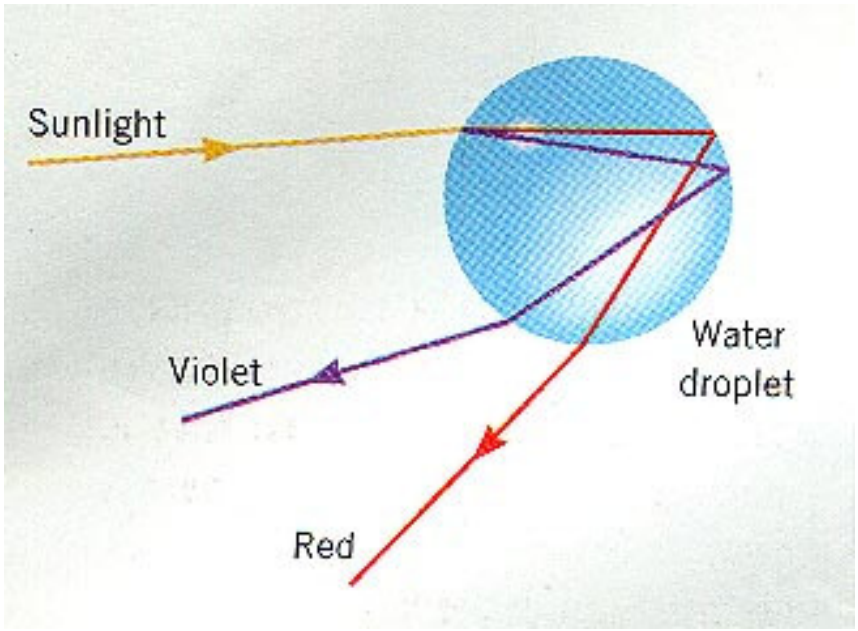
West

East

Examples of Refraction

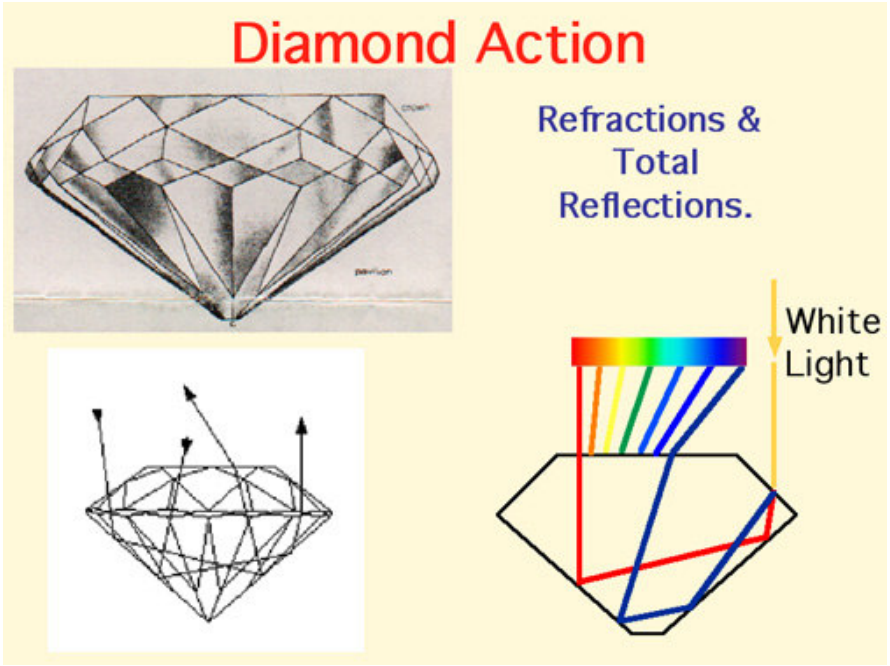
折射率(index of refraction)越大，光速越低

Index of refraction = 1.33



http://sol.sci.uop.edu/~jfalward/refraction/refraction.html

Index of refraction = 2.41



http://boomeria.org/physicslectures/secondsemester/light/refraction/refraction.html

4 C's

Light is Electromagnetic Radiation

電磁波

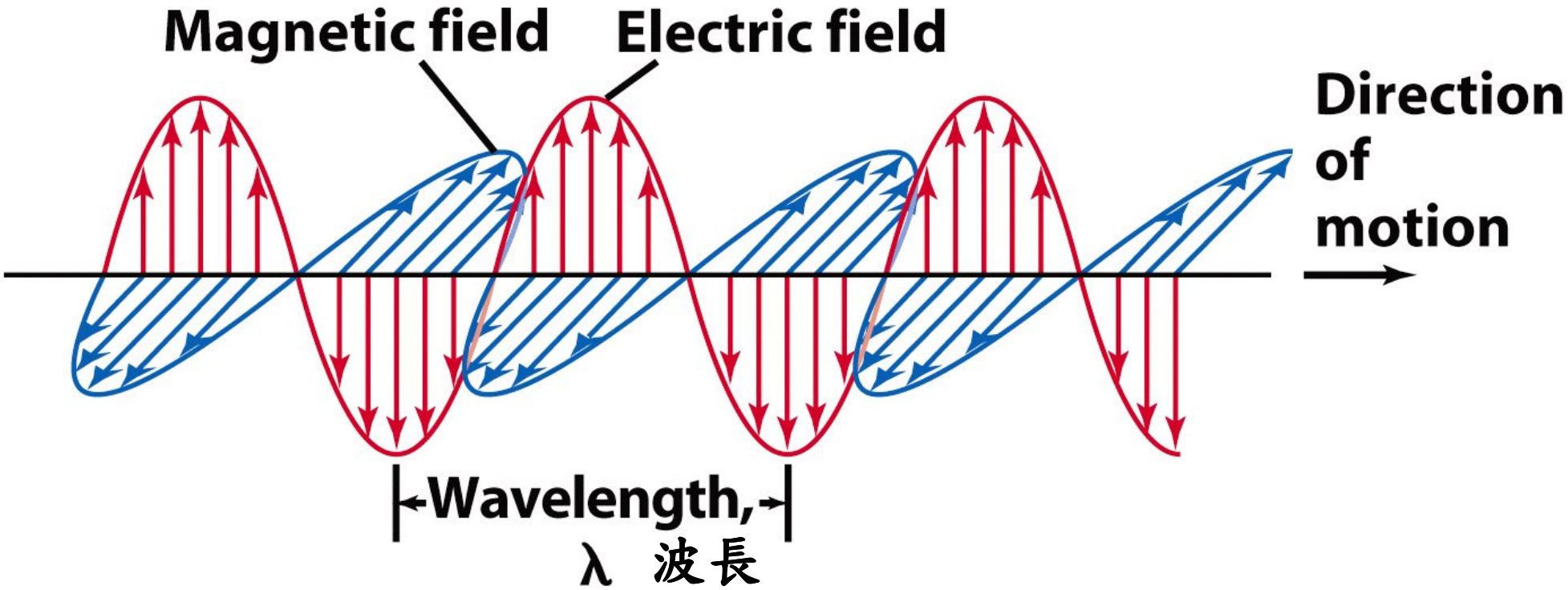


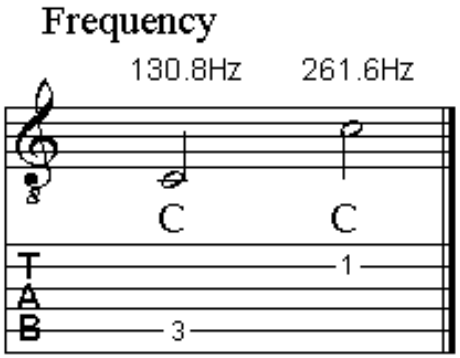
Figure 3-3
Discovering the Universe, Seventh Edition

wavelength= speed of light x period
= speed of light / frequency

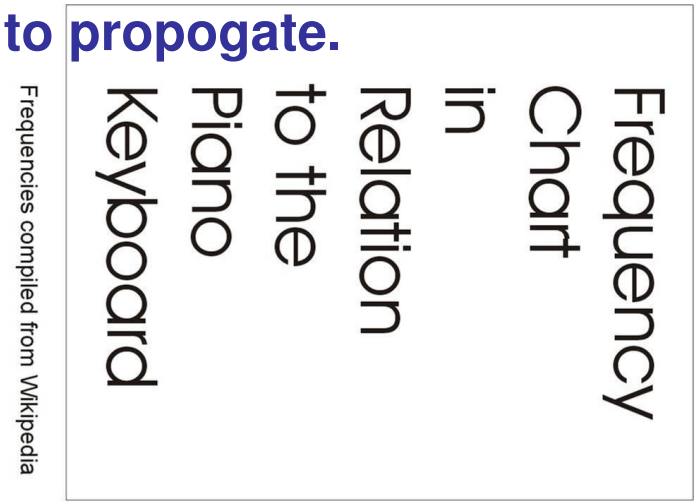
speed of light in vacuum = 3×10^8 m/s
speed of light is slower in other media determined by index of refraction

Music & Sound waves

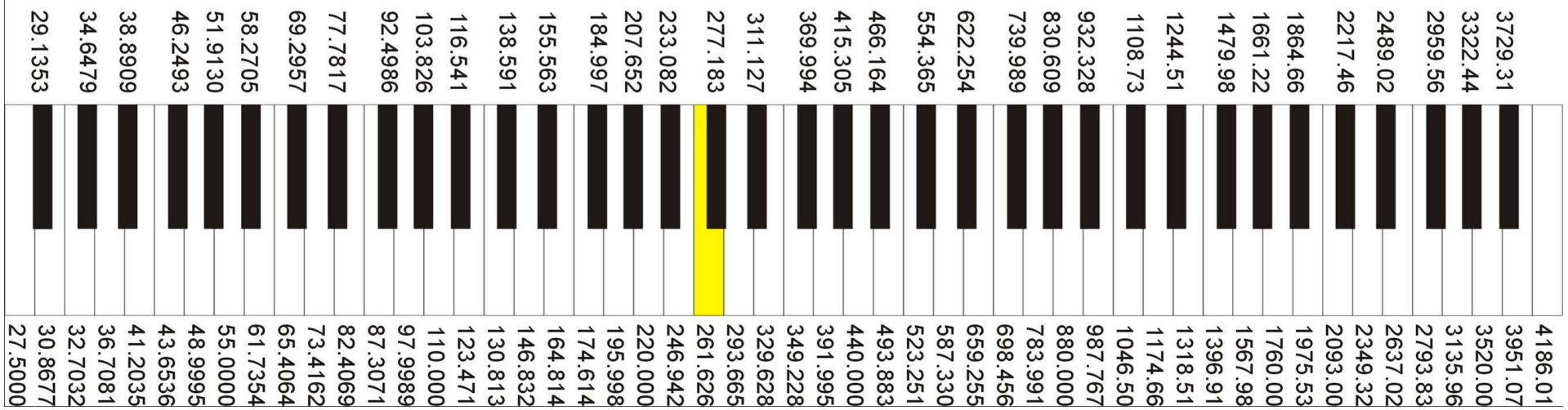
Note that sound waves require a medium to propogate.



音譜



Hertz (Hz， 赫) = how many vibration per second



Spectrum of light

光譜

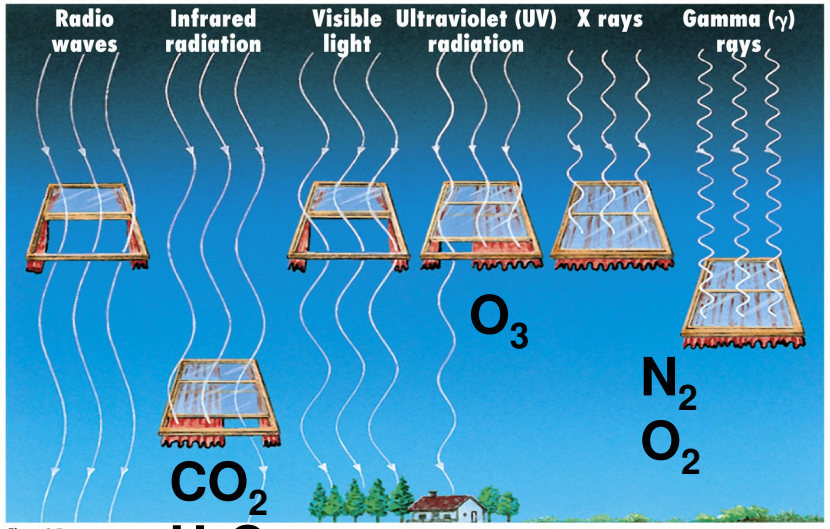
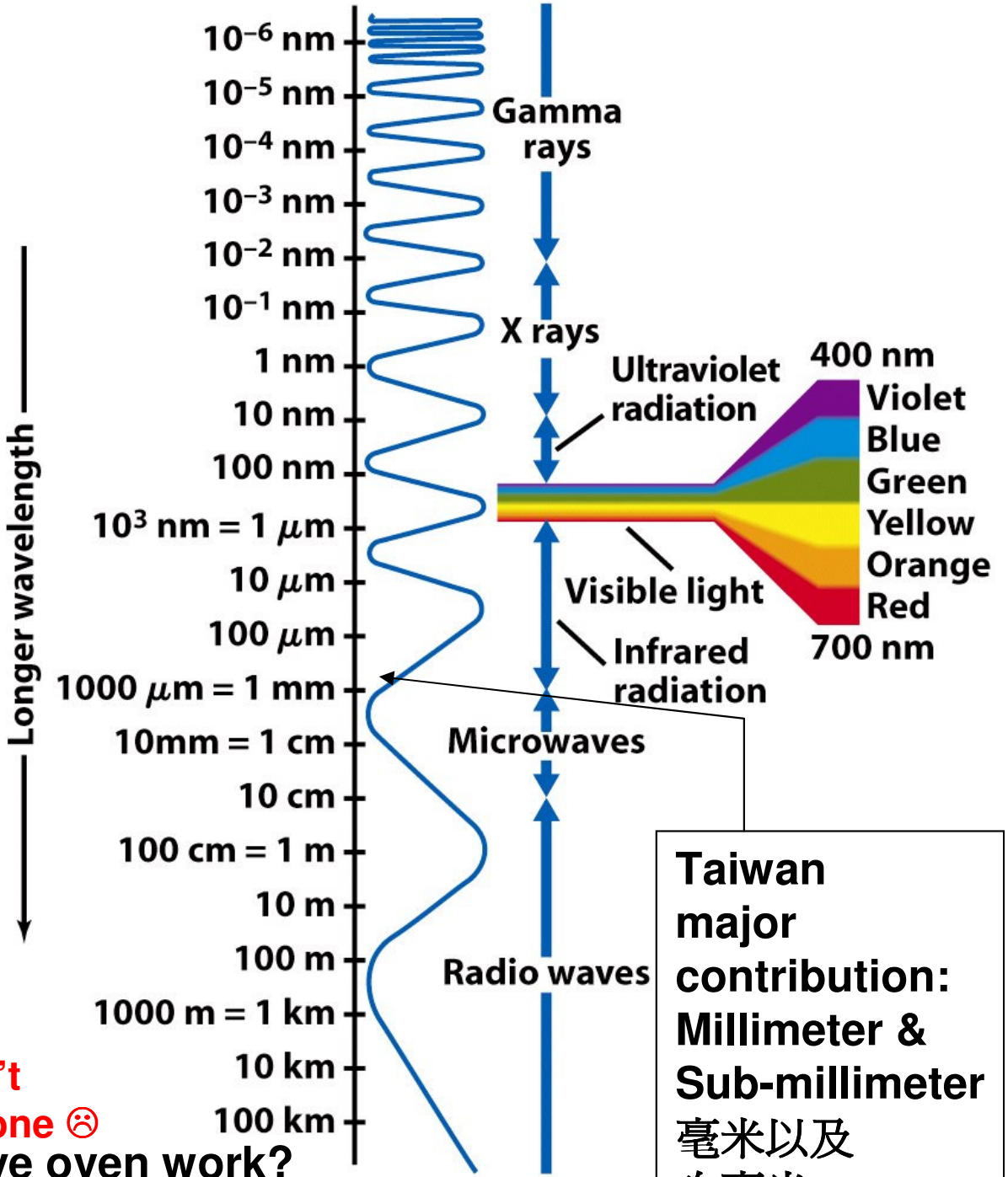


Figure 3-7
Discovering the Universe, Seventh
© 2006 W. H. Freeman and Company

Green House gas

Astronomers don't like water and ozone ☹



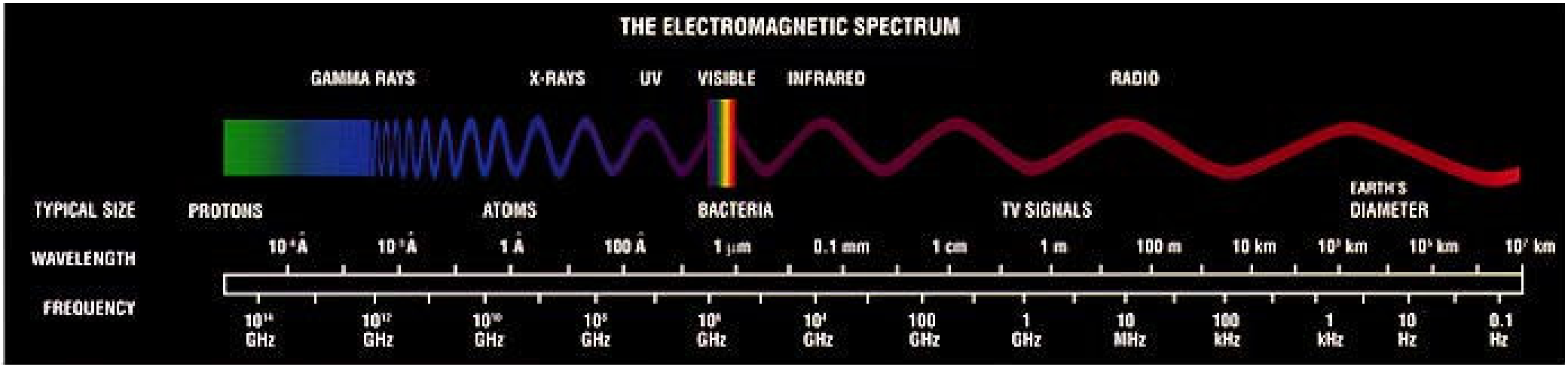
Taiwan major contribution: Millimeter & Sub-millimeter
毫米以及次毫米

Remark: how does a microwave oven work?

Figure 3-4
Discovering the Universe, Seventh Edition
© 2006 W. H. Freeman and Company

wavelength & frequency

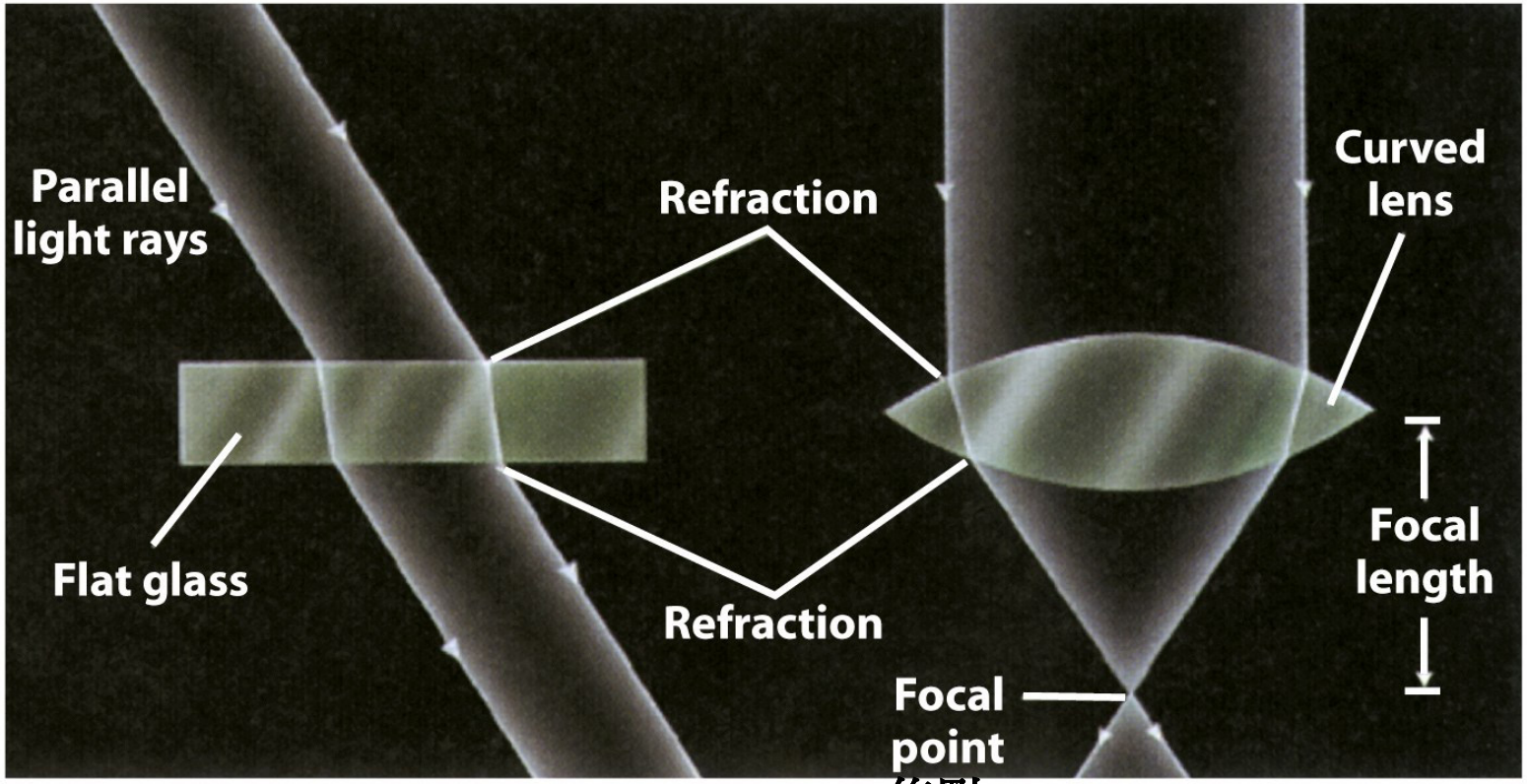
Hertz (Hz，赫) = how many vibration per second



手機頻率 ~ 1 GHz=10^9 Hz
=1000 MHz
=1000 兆赫？

refraction

折射



焦距

焦點

a

b

Figure 3-16ab
Discovering the Universe, Seventh Edition

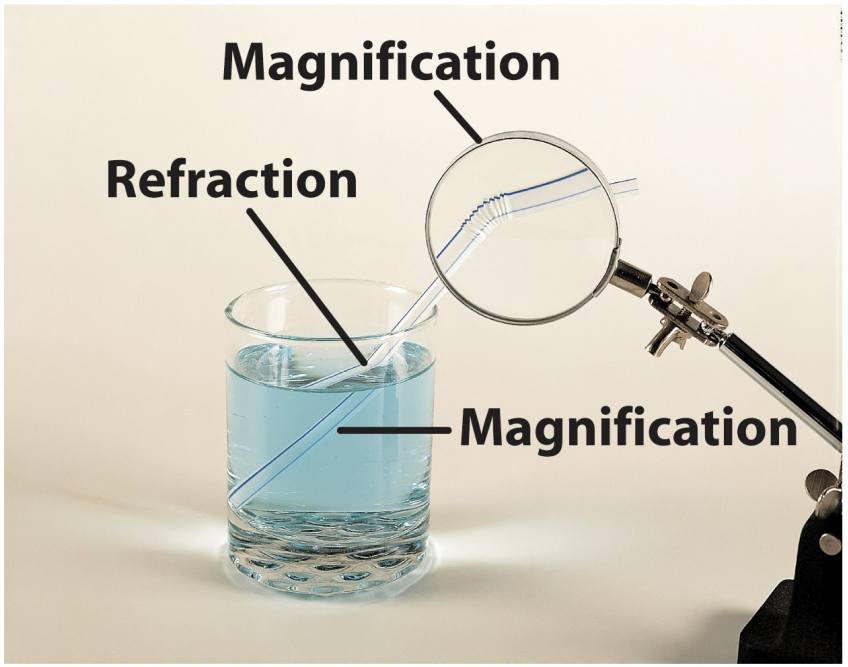


Figure 3-16c
Discovering the Universe, Seventh Edition

Parallel light rays from distant objects

月亮星星跟著我走
But do you remember
“parallax”(視差)?

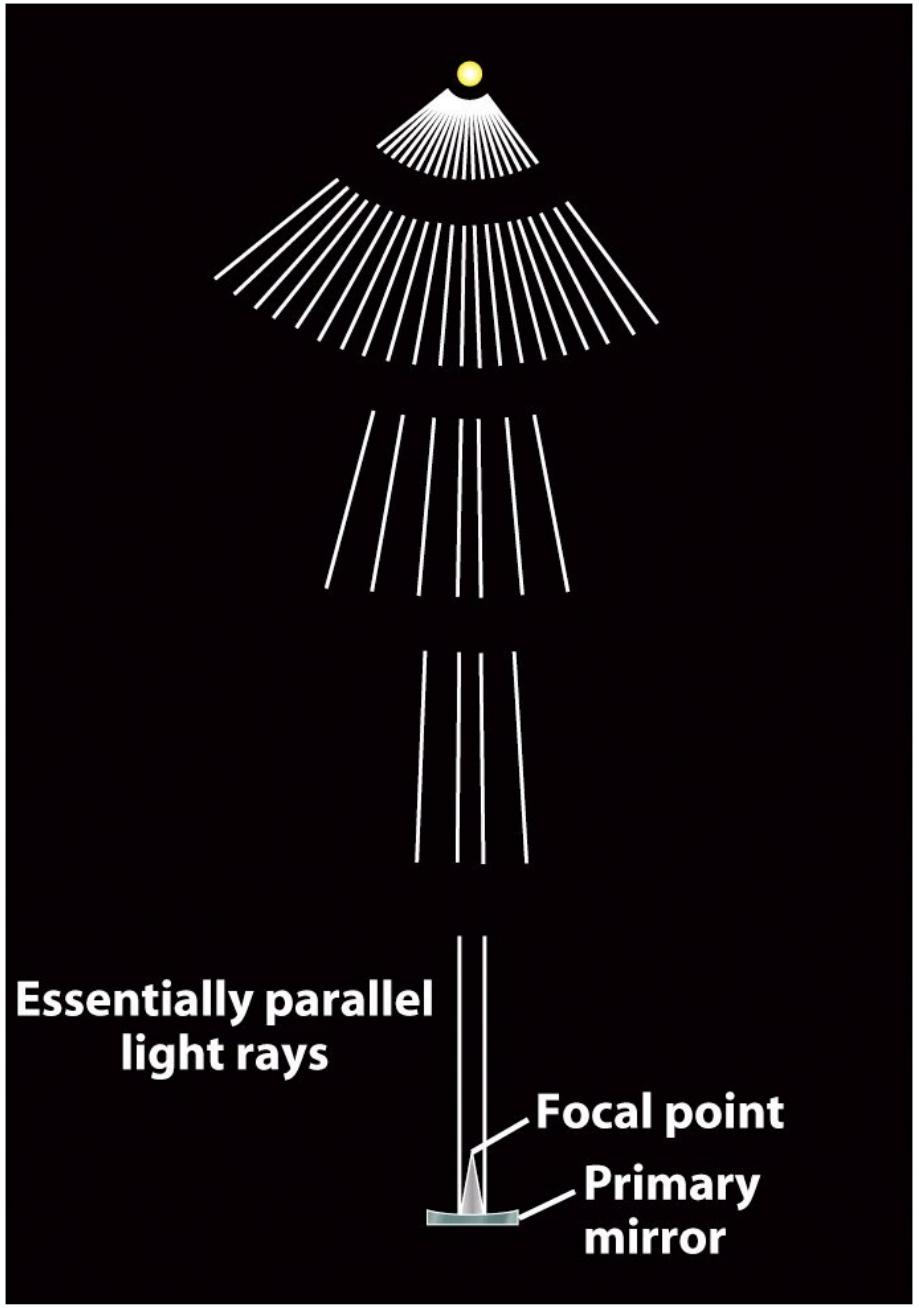


Figure 3-10
Discovering the Universe, Seventh Edition

Extended objects
→ extended image

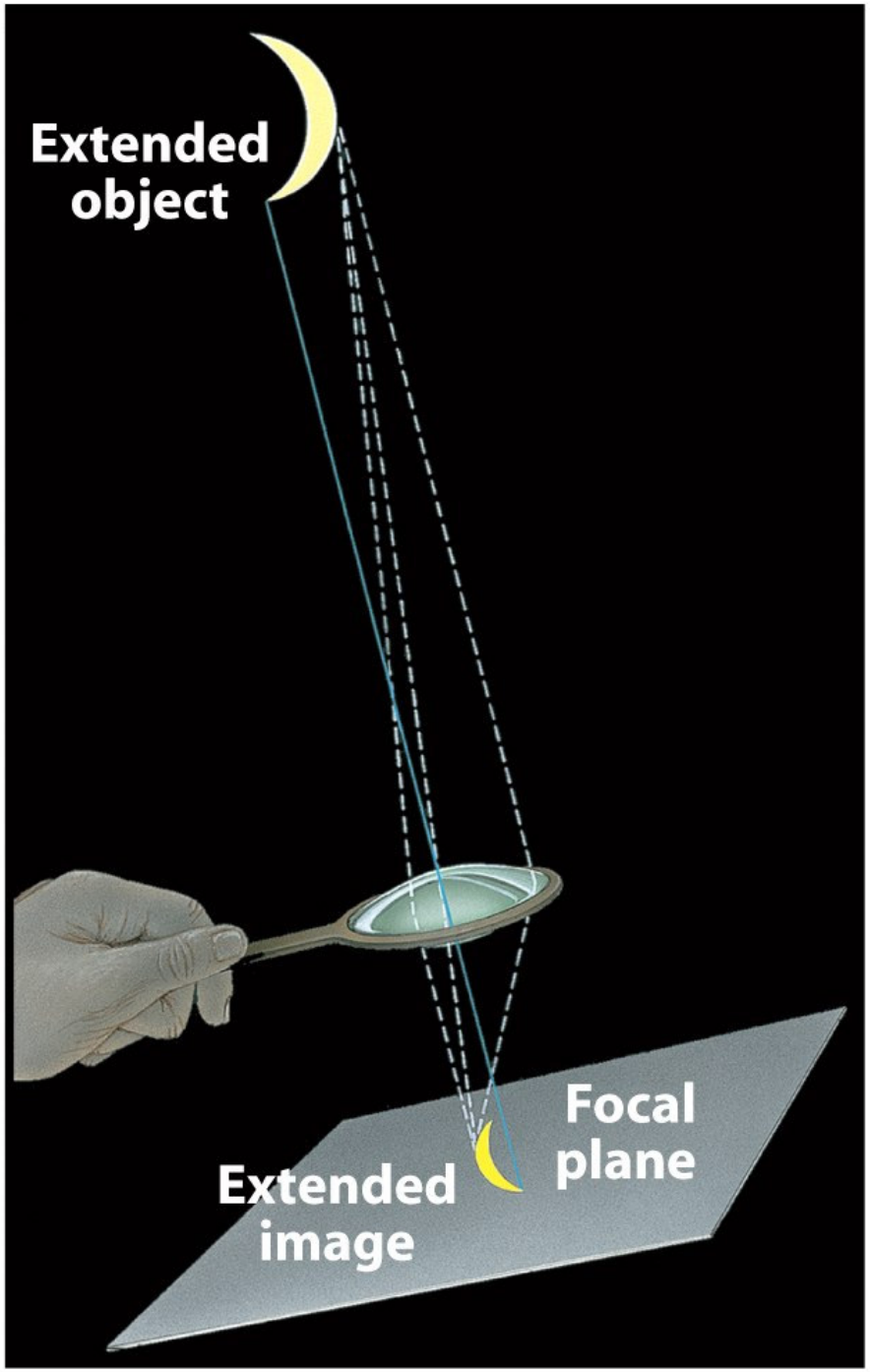


Figure 3-17
Discovering the Universe, Seventh Edition

Essentials of a refracting telescope (折射式望遠鏡)

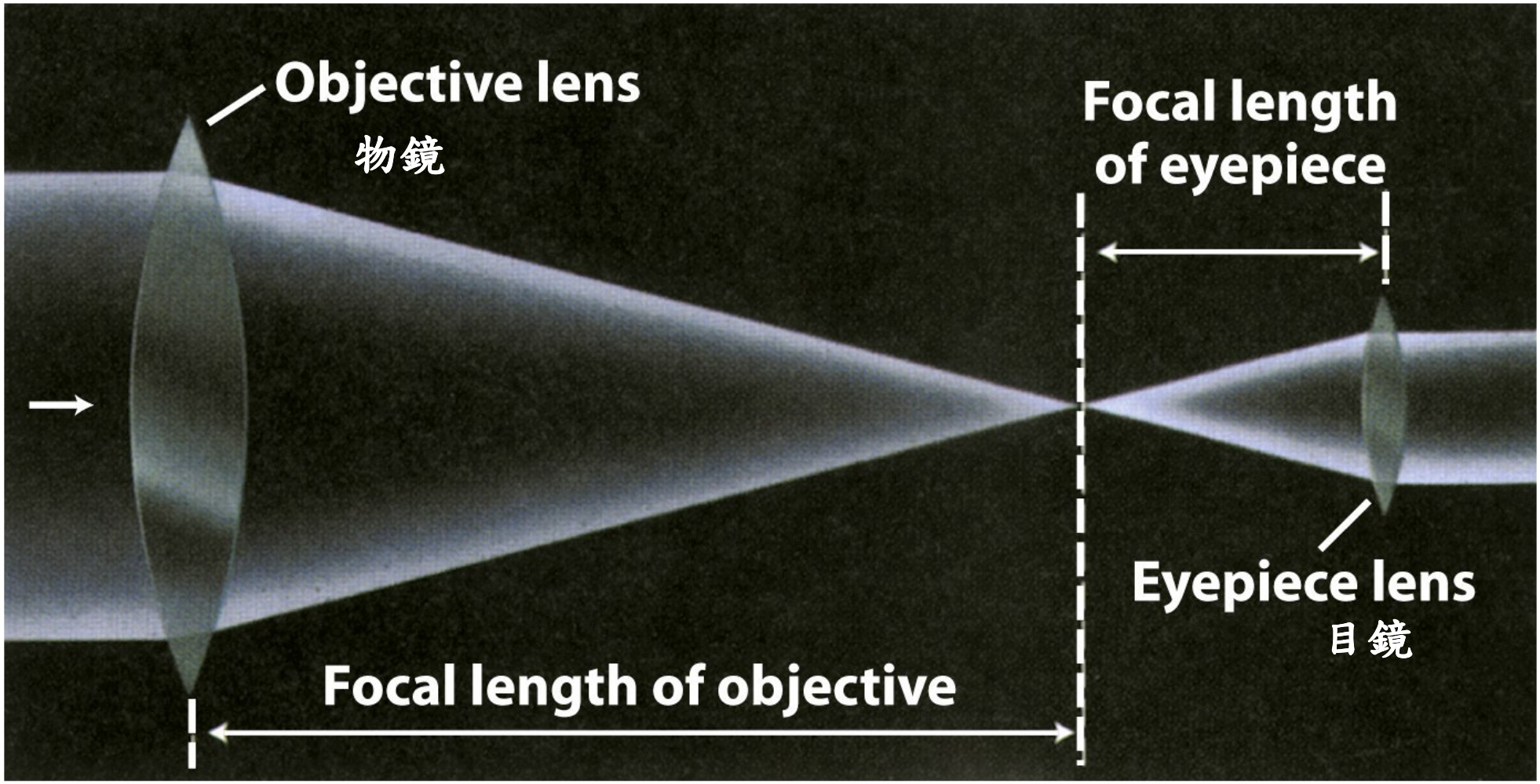


Figure 3-18
Discovering the Universe, Seventh Edition

3 basics for a telescope

- Light-gathering power (集光率) $\propto$ 口徑^2
- Angular resolution (鑑別角度) $\propto \frac{\text{波長}}{\text{口徑}}$
- Magnification (放大率) $= \frac{\text{focal length of the objective}}{\text{focal length of the eyepiece}}$

Angular Resolution:
1 circle=360°
1° (度)= 60'(角分)
1'= 60" (角秒)

brighten, resolve, & magnify
→ bigger is better!

Light-gathering power

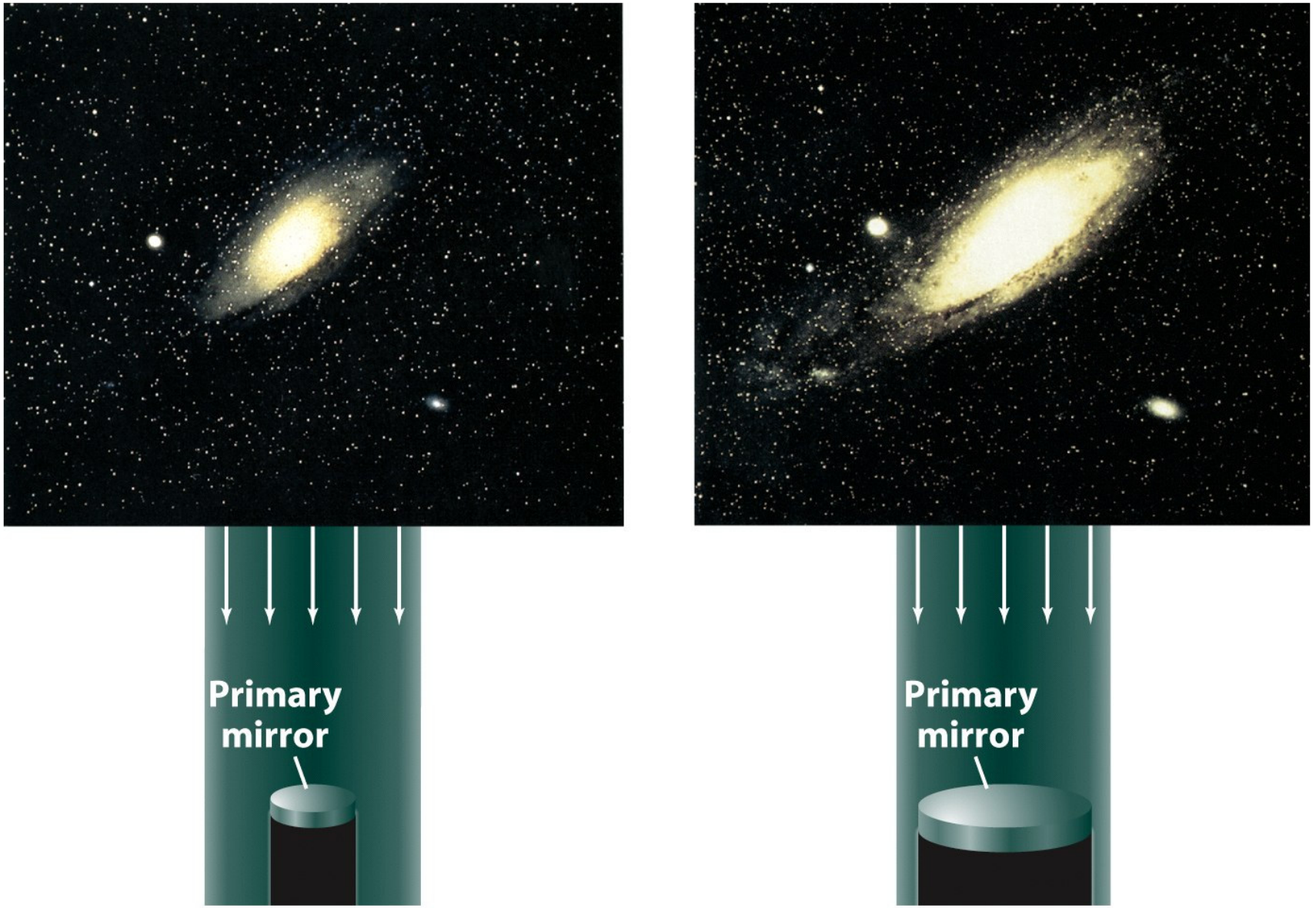


Figure 3-12
Discovering the Universe, Seventh Edition

Angular resolution (worse)

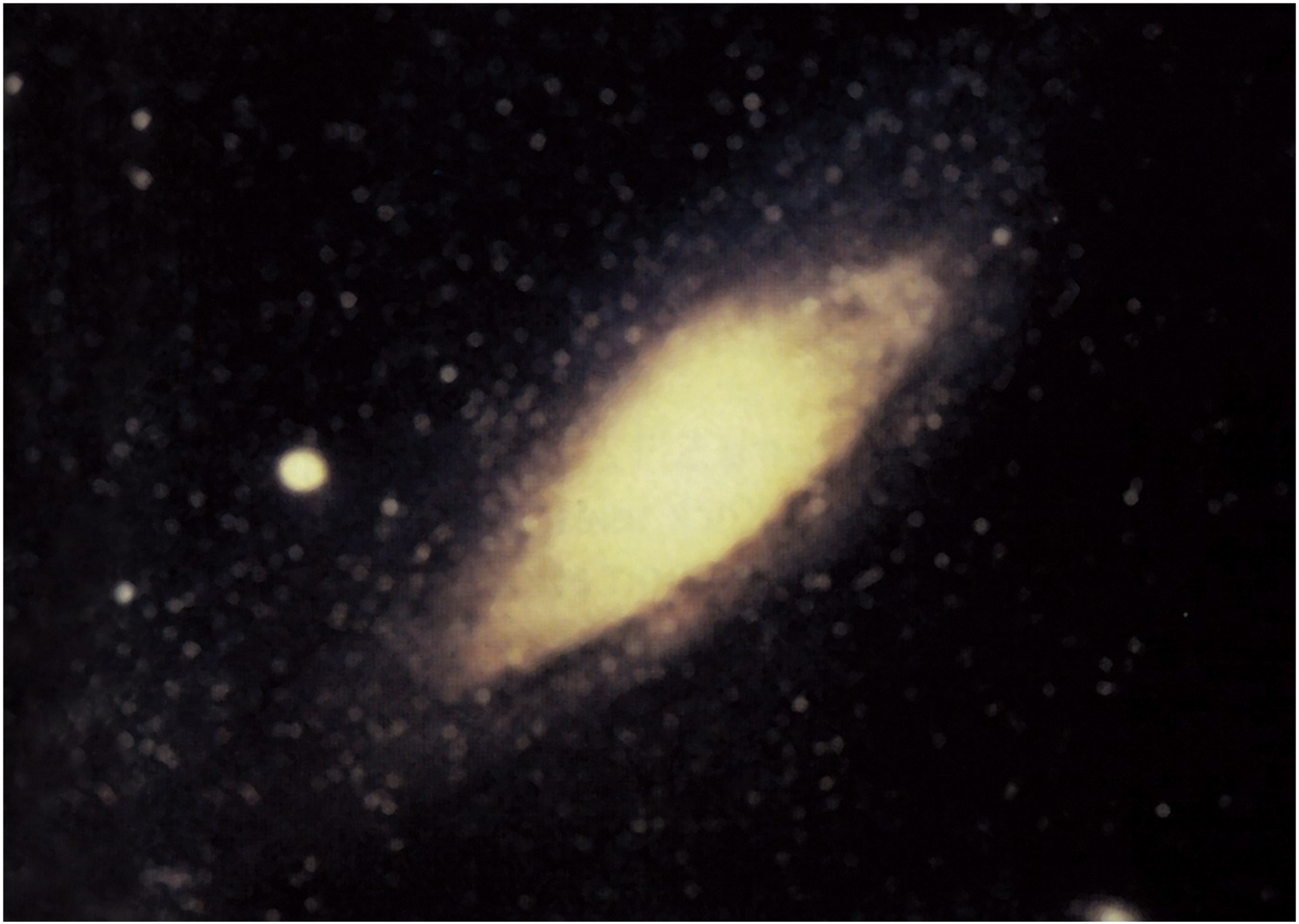
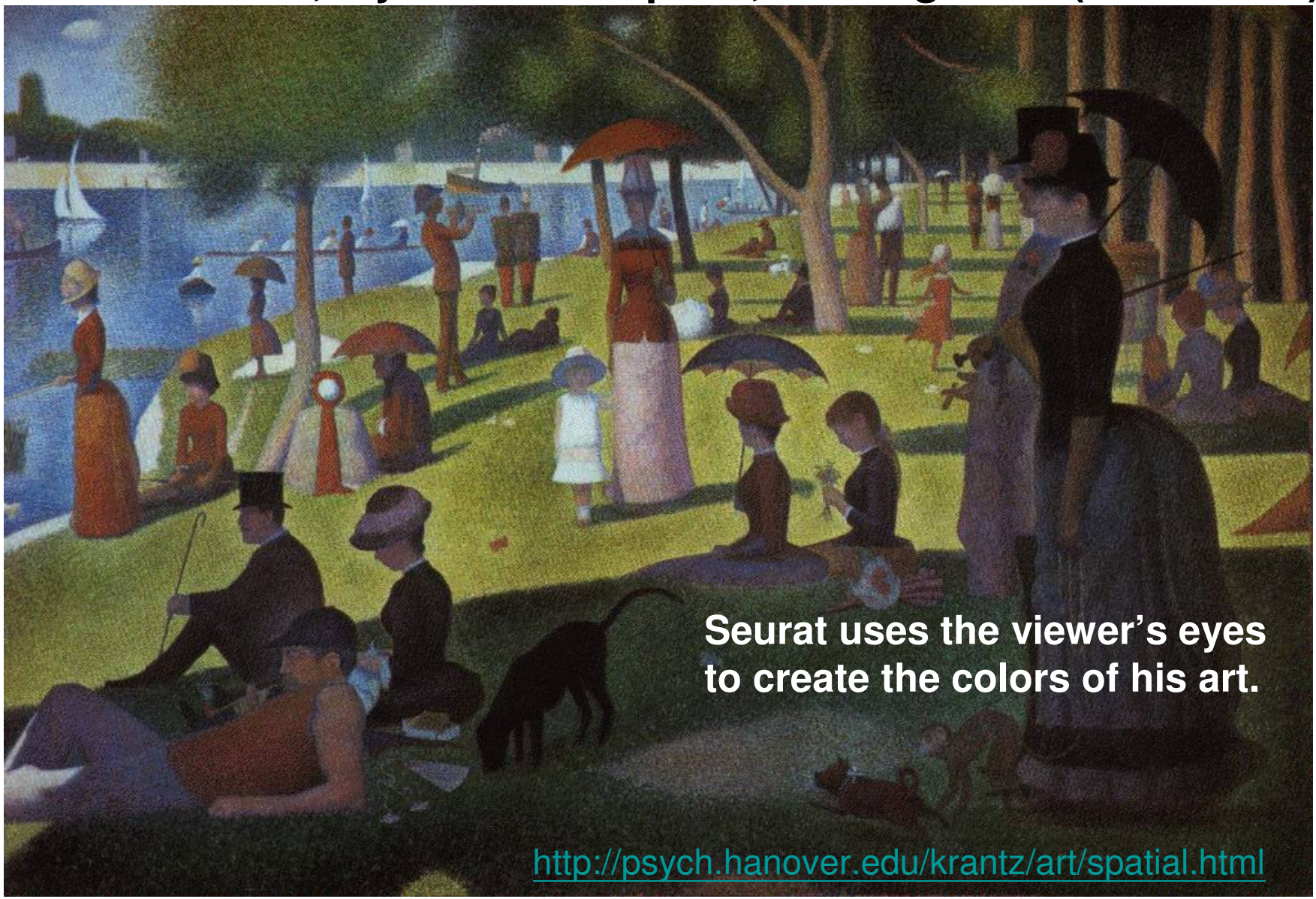


Figure 3-13a
Discovering the Universe, Seventh Edition

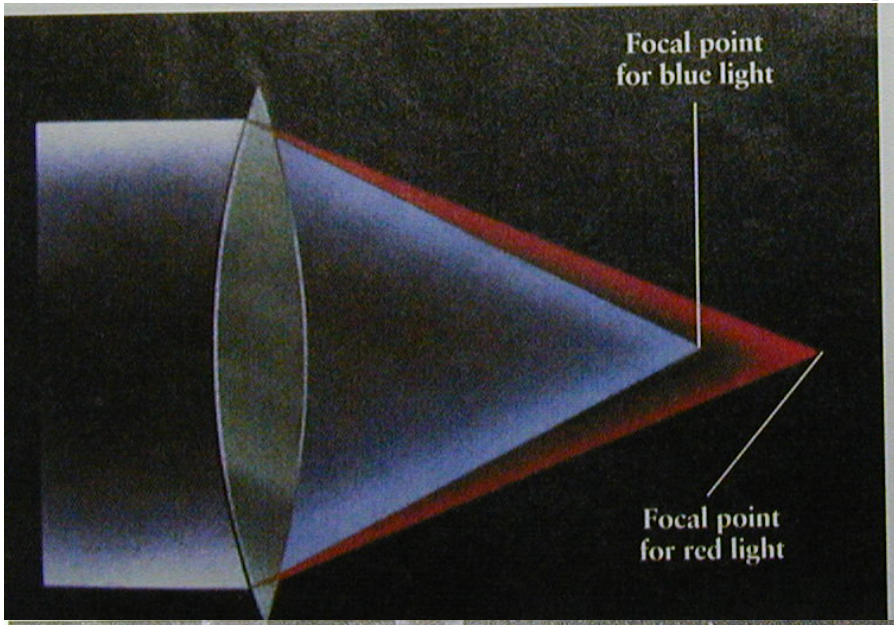
Angular resolution (better)

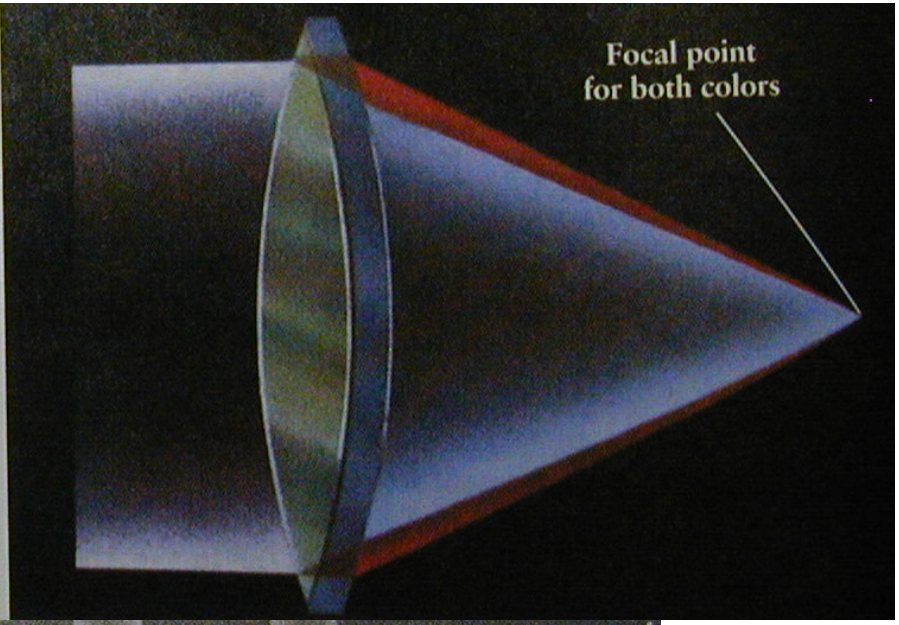
Figure 3-13b
Discovering the Universe, Seventh Edition

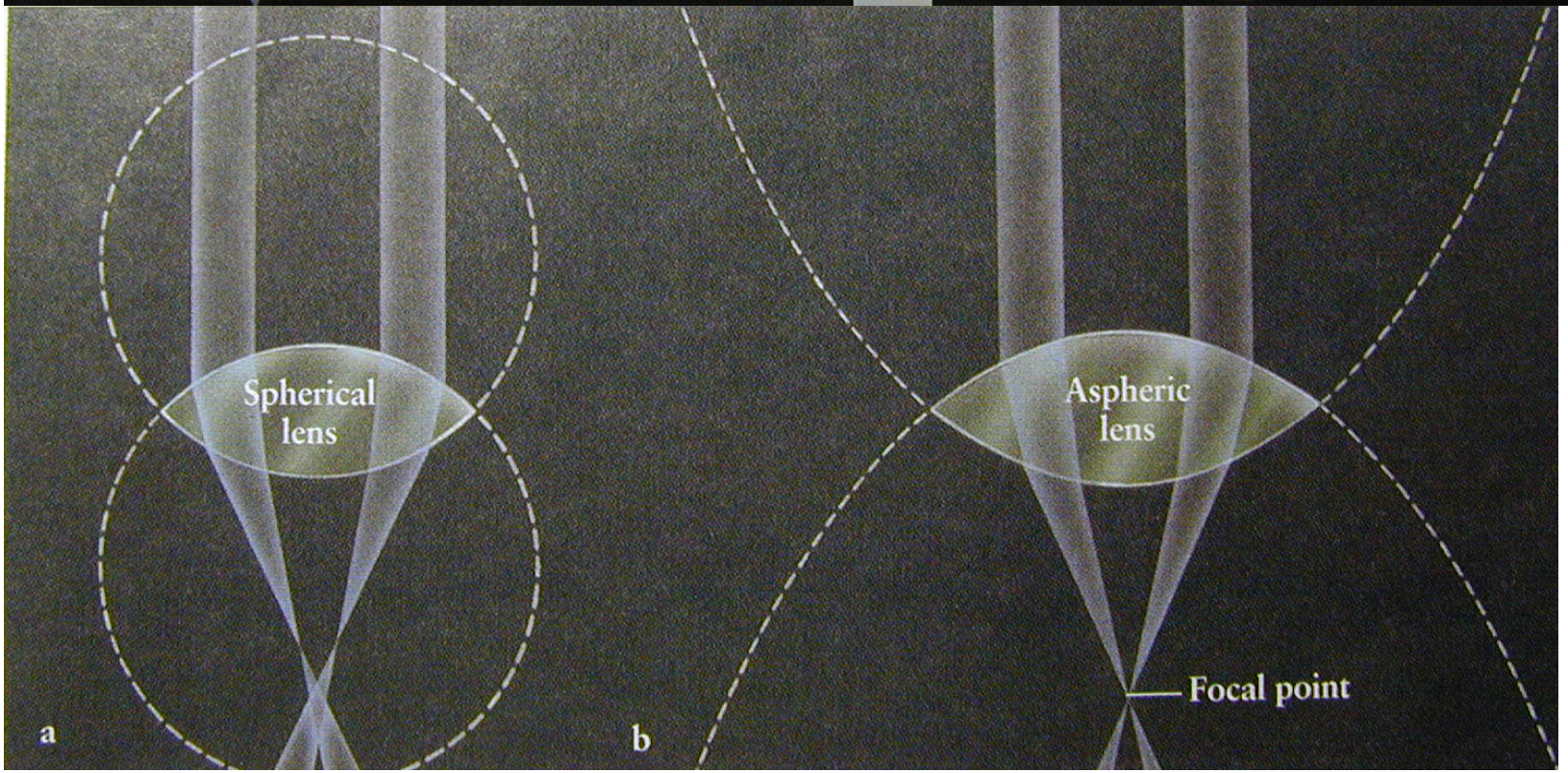
Sunday Afternoon on the Island of Grand Jatte by Georges Seurat
81x120 inches; 2 years to complete; ~ 4 megadots (Pointillism)



Chromatic (色差) & Spherical (球面差)aberration







Largest refracting telescope

Yerkes observatory
102 cm in diameter
19.33 m long

Nowadays, people don't bulid refracting telescopes for professional uses: difficult to deal with a big lens (hard to make, aberration, distortion due to weight), too long….

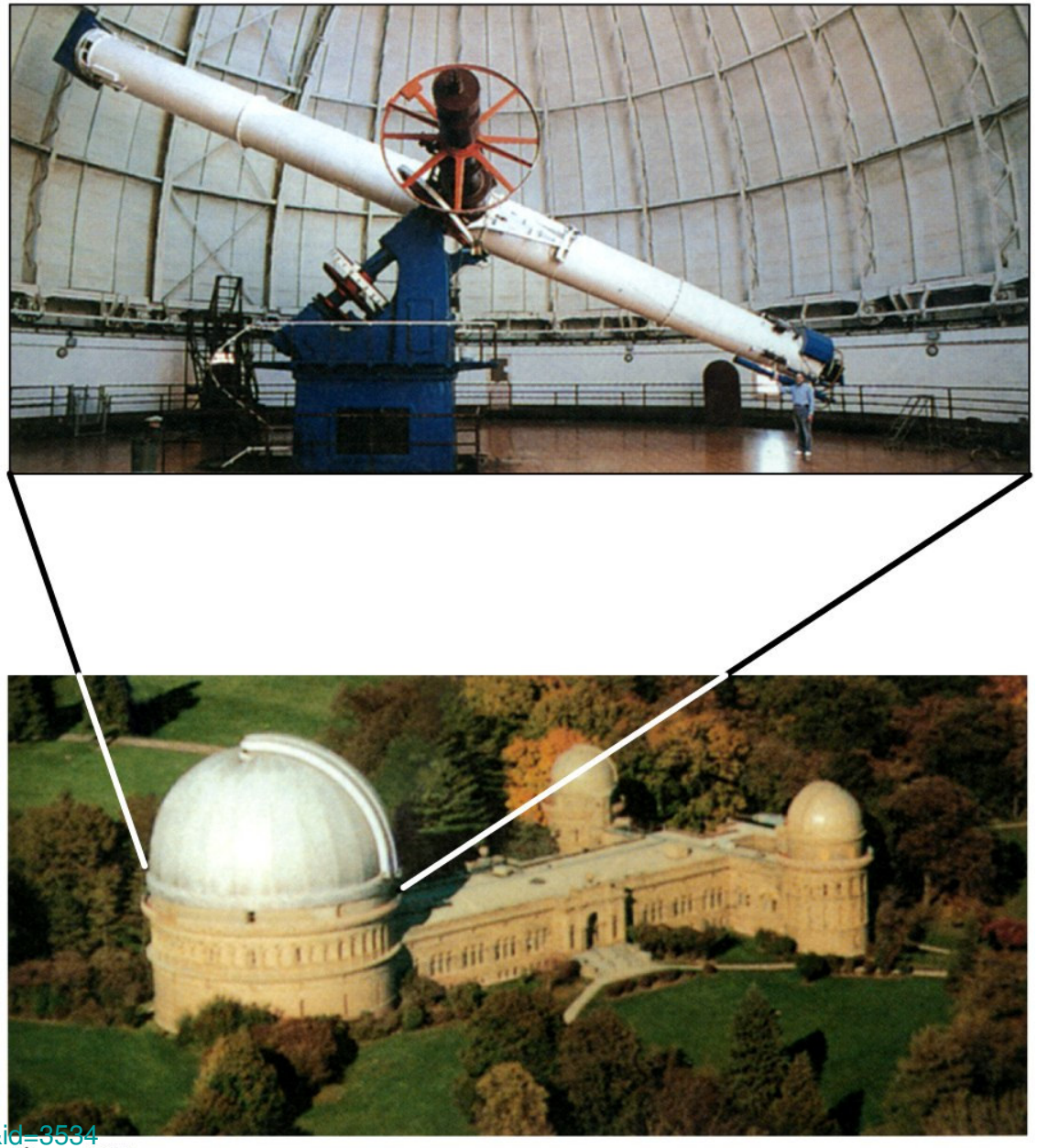


Figure 3-19
Discovering the Universe, Seventh Edition

Bid made for Yerkes Observatory: Aurora University's bid to buy the historic Wisconsin observatory would yield an astronomy outreach center and expand AU's campus.

http://www.astronomy.com/asy/default.aspx?c=a&id=3534

Reflection

反射

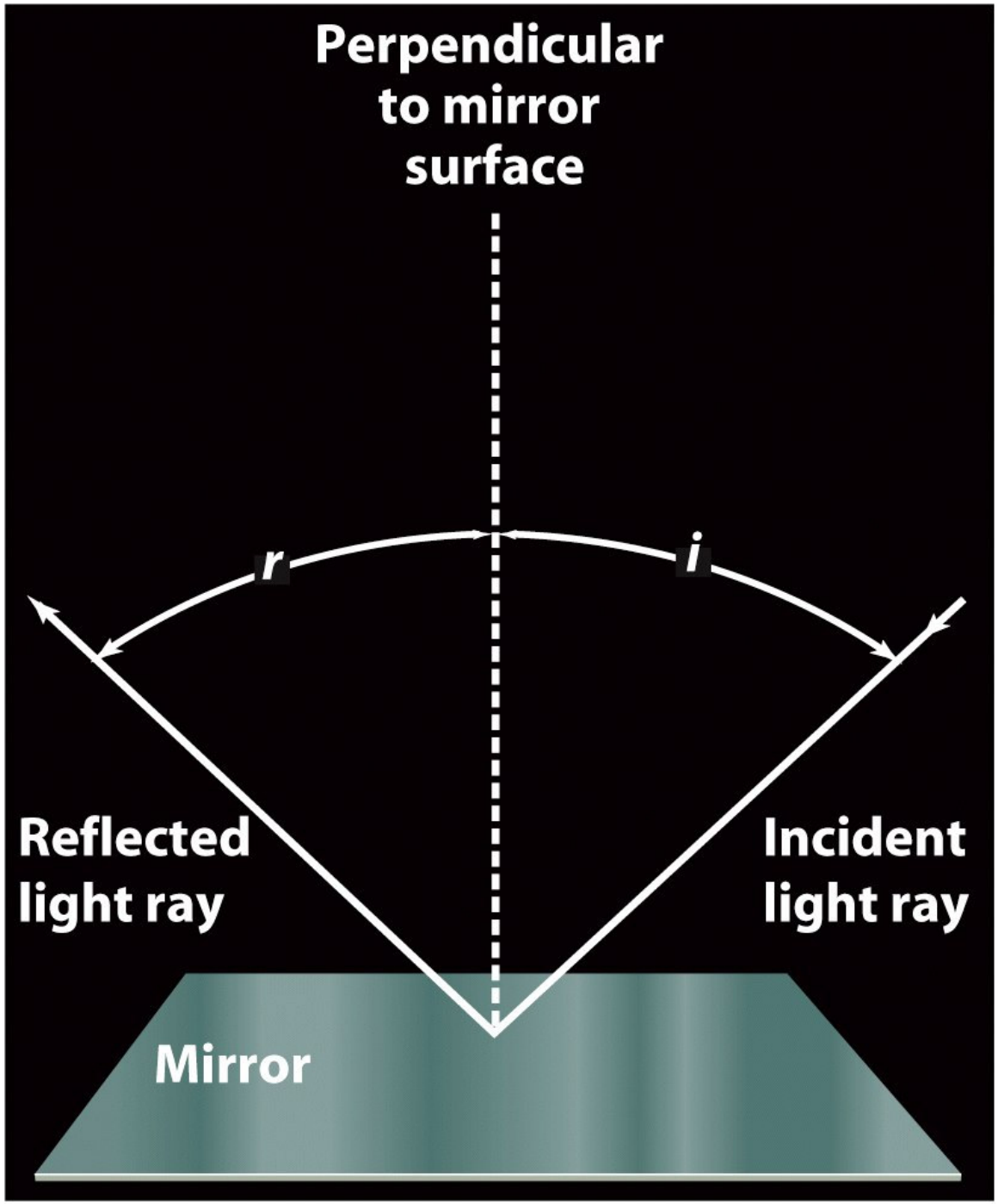


Figure 3-9a
Discovering the Universe, Seventh Edition

Stealth fighter

Reflect incident radar signals up and down, rather than back to the radar station

Spherical aberration

鏡子有球面差但無色差

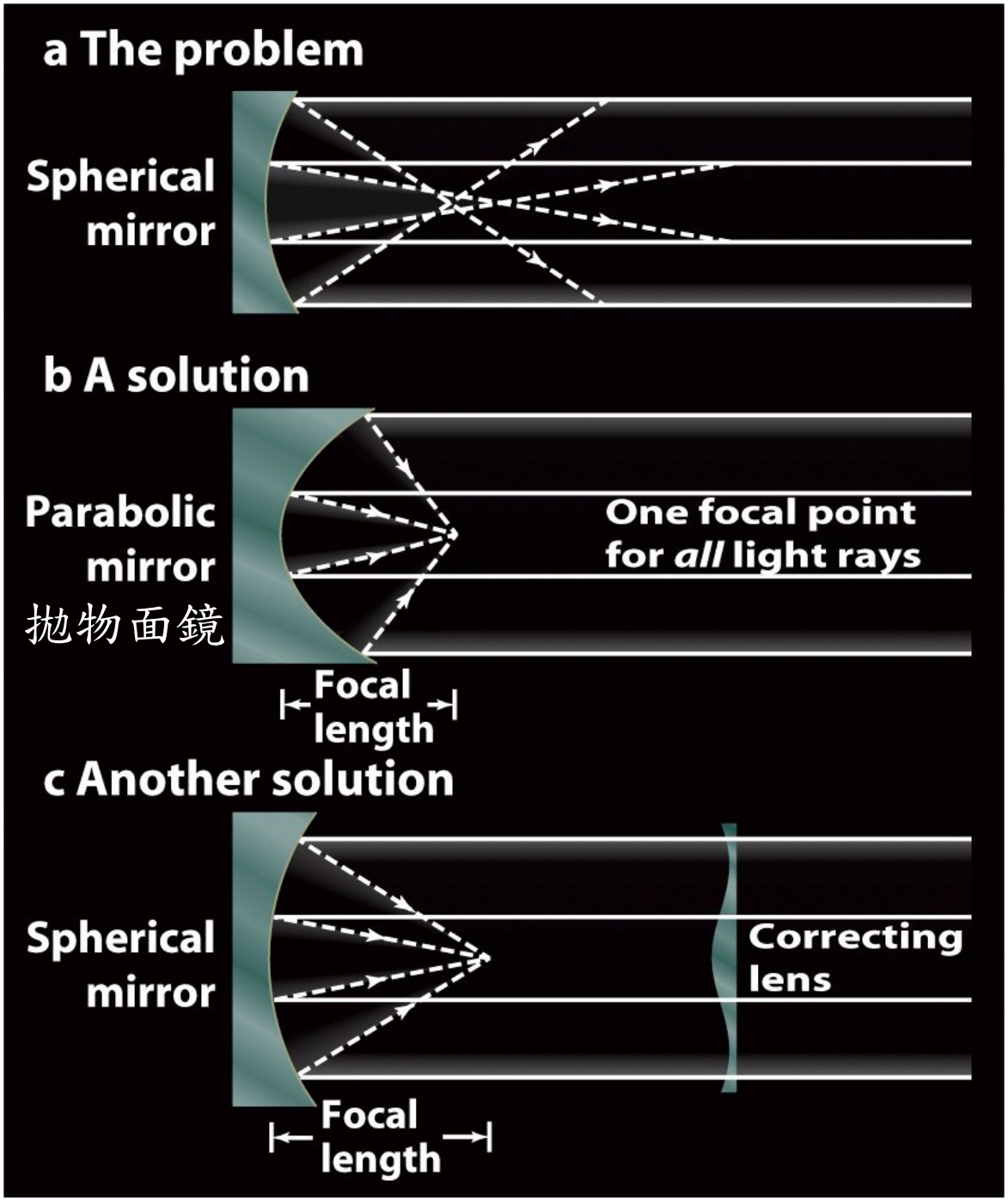


Figure 3-21
Discovering the Universe, Seventh Edition

Reflecting telescopes (反射式望遠鏡)

反射式的鏡筒比折射式短

聚光力因 2nd mirror 的遮擋稍微減弱

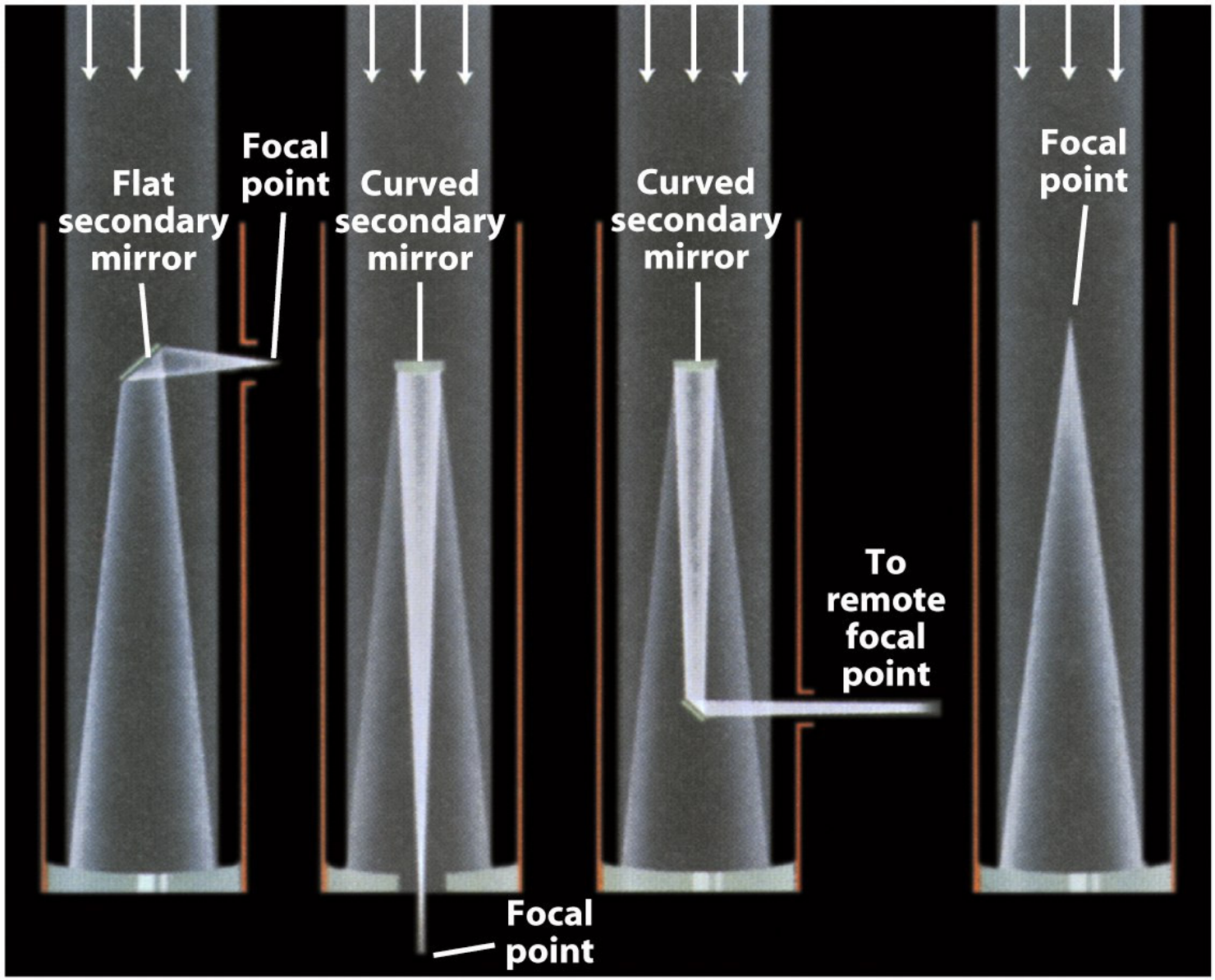


Figure 3-11
Discovering the Universe, Seventh Edition

2nd mirror does not create a hole in the image

Just reduce the amount of light coming into the telescope tube.

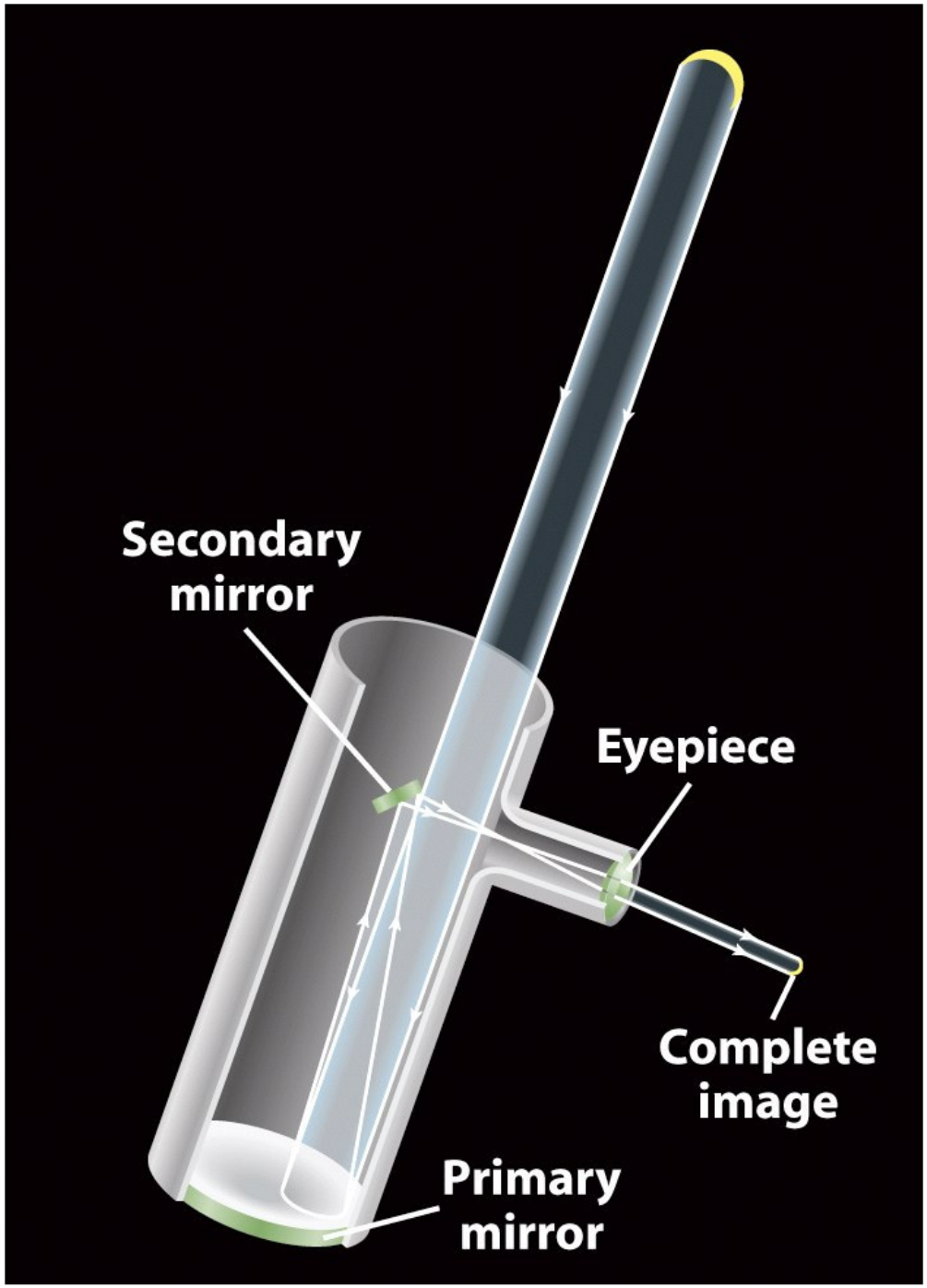
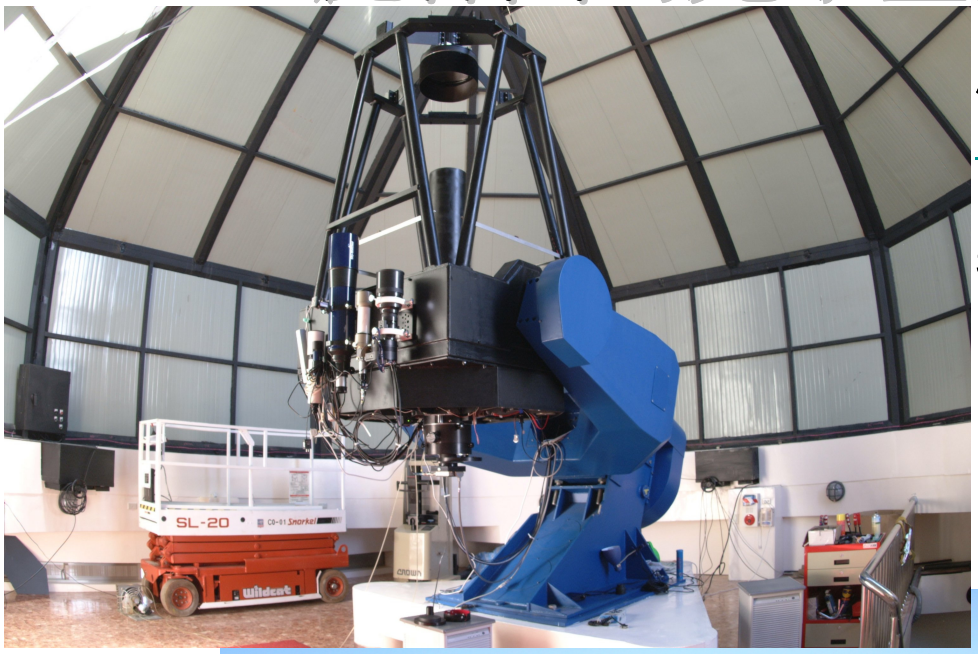


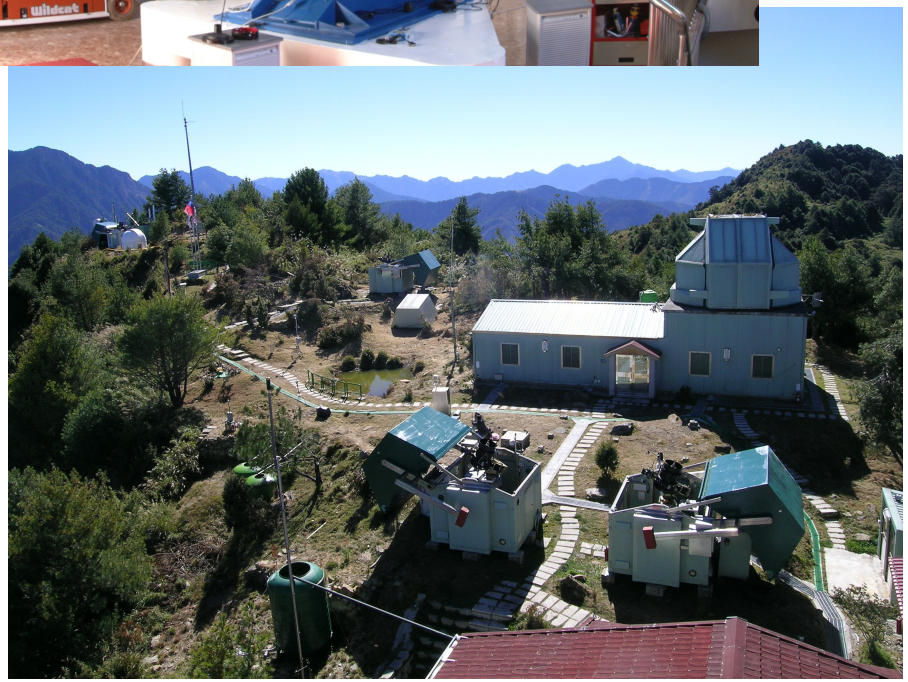
Figure 3-20
Discovering the Universe, Seventh Edition


30
新中橫・玉山國家公園
高程表
0 200 500 1000 2000 3000 4000 公尺
往水里
阿里山森林遊樂區
阿里山舊站
沼平
觀日樓
祝山 2489
往阿里山
阿里山氣象所
阿里山鄉
信義鄉
萬年神木
林馬燮班溪
神木林道
出水溪
東埔山觀景點
夫妻樹
玉山景觀公路
東埔山 2782
東埔隧道
第一迴頭彎觀景點
沙里仙工作站
塔塔加遊客中心
和社溪
新中橫公路
國家公園界碑
石山服務站
東埔山莊
大鐵杉
塔塔加鞍部
南投縣
嘉義縣
玉山前峯 3239
West Peak
玉山西峯 3467
玉山 3952
玉山東峯 3869
玉山北北峯 3833
玉山北峯 3858
玉山氣象測站
金門峒大斷崖
沙里仙溪
陳有蘭溪
自忠
雪峰護管所
雪峰派出所
雪峰小隊
自忠山 2606
東水山 2611
玉山口
石山 2682
玉山林道
麟芷山 2854
麟芷山口
鹿林山莊
鹿林山自然公園
鹿林山 2845
鹿林前山
Lulin
Pai Yun Retreat
排雲山莊
西峯下山屋
阿里山鄉
桃源鄉
林務局楠溪工作站
阿里山鄉
石水山 2800
北霞山 2472
博博猶溪
巴伊車留山 2241
嘉義縣
高雄縣
玉山南峯 3844
玉山小南山 3582
玉山東小南山 3711
南玉山 3383
楠梓仙溪
霞山
楠溪
A
B
C
D
E
F
23°30′

鹿林山的光學望遠鏡(可見光)



鹿林一米望遠鏡(台灣最大)
http://www.lulin.ncu.edu.tw
中央大學計畫興建二米(五年五百億)
scientific goal?



臺美掩星計畫 (Taiwan-America Occultation Survey, a.k.a. TAOS):
http://taos.asiaa.sinica.edu.tw/
中央研究院
中央大學
美國勞倫斯利物摩國家實驗室
美國賓州大學
韓國延世大學
4 telescopes
0.5m in diameter
Search for Kuiper belt objects(the source of comets)

Light pollution (光害)

Effects of twinkling (turbulence)

Ground-based

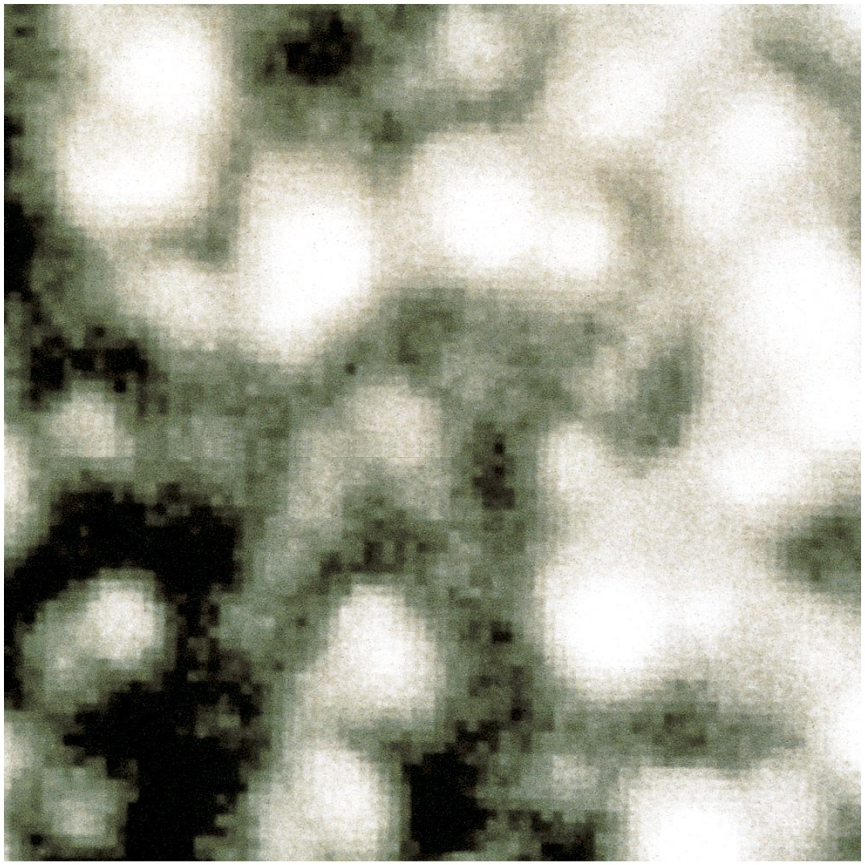


Figure 3-23a
Discovering the Universe, Seventh Edition

Hubble (哈伯) Space telescope

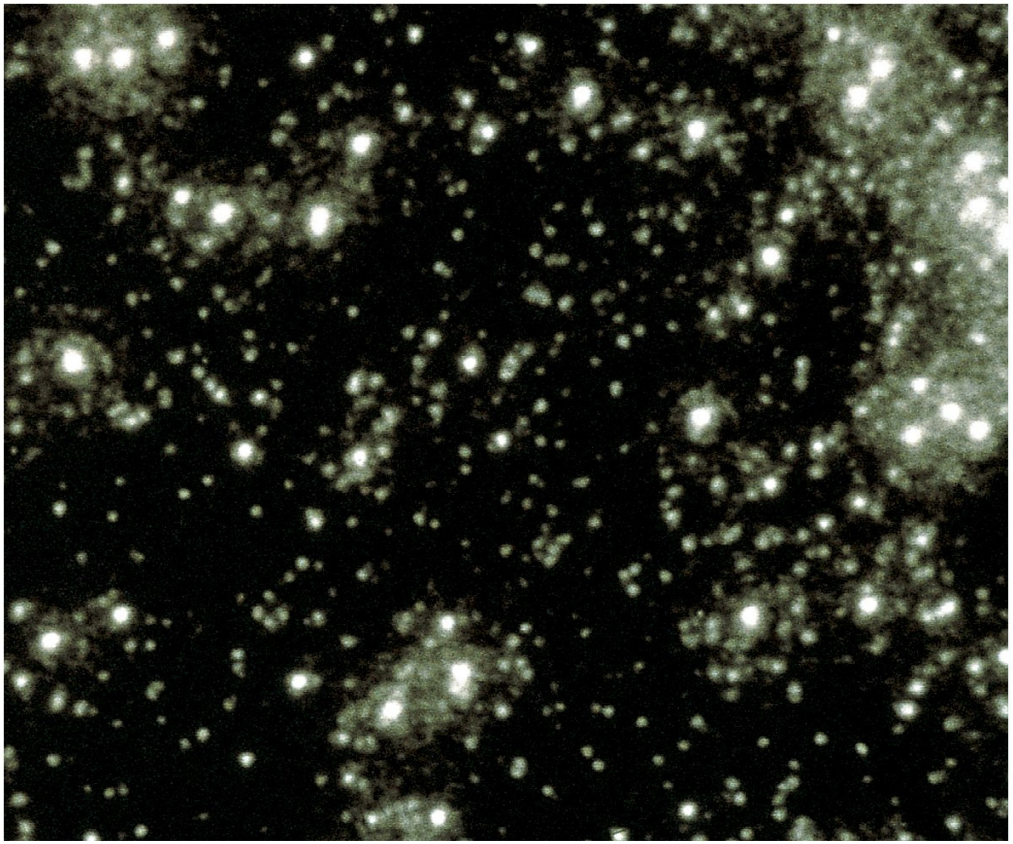
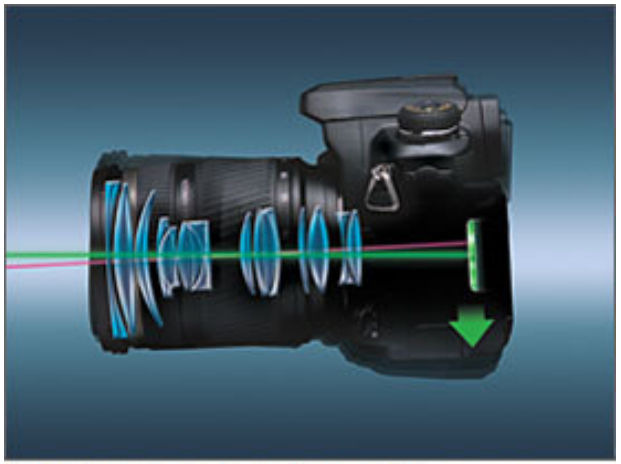


Figure 3-23b
Discovering the Universe, Seventh Edition

Stars twinkle, but planets don't. 坐過飛機嗎？

防手震(anti-shape, image stabilizer)



■ CCDシフト方式手ぶれ補正機能

無防手震功能

有防手震功能

Adaptive Optics (調適光學)

Gemini telescope animation (http://www.tmt.org/tmt/adaptive-optics)

Use a known object as a reference to correct the distortion due to atmospheric turbulence

Ground, no adaptive optics

Hubble space telescope

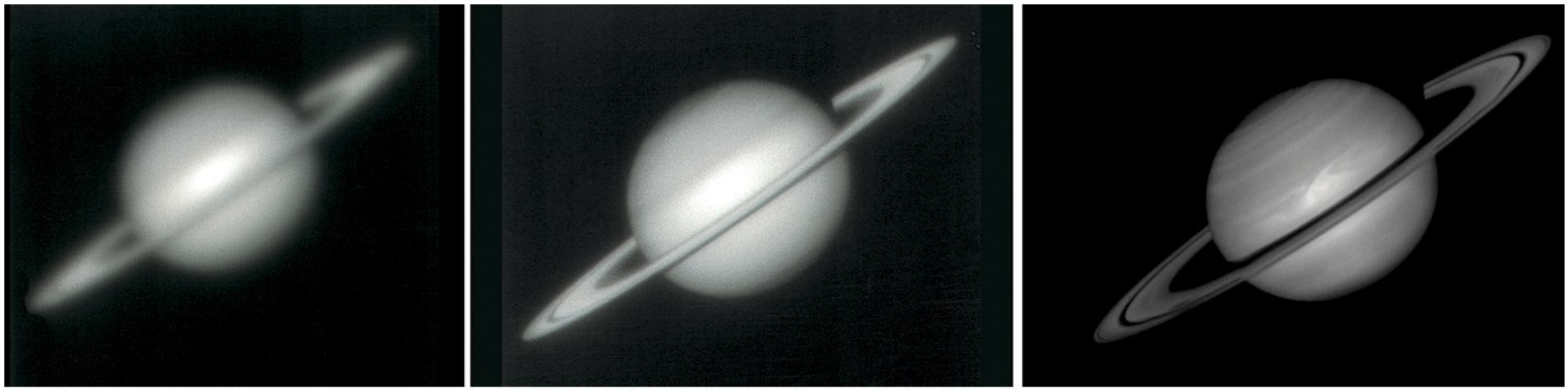


Figure 3-26
Discovering the Universe, Seventh Edition

Ground, with adaptive optics

two 10-m Keck telescopes

Mauna Kea, Hawaii

Dome: protect telesocpes from rain/snow, dusts. & reduce day-night temperature variation

telescopes on the top of mountains:
less light & air pollution
less twinkling
good weather
less CO_2 & H_2O
→ can see infrared

Air pressure is low →
Inside is pressurized

2006/10/18

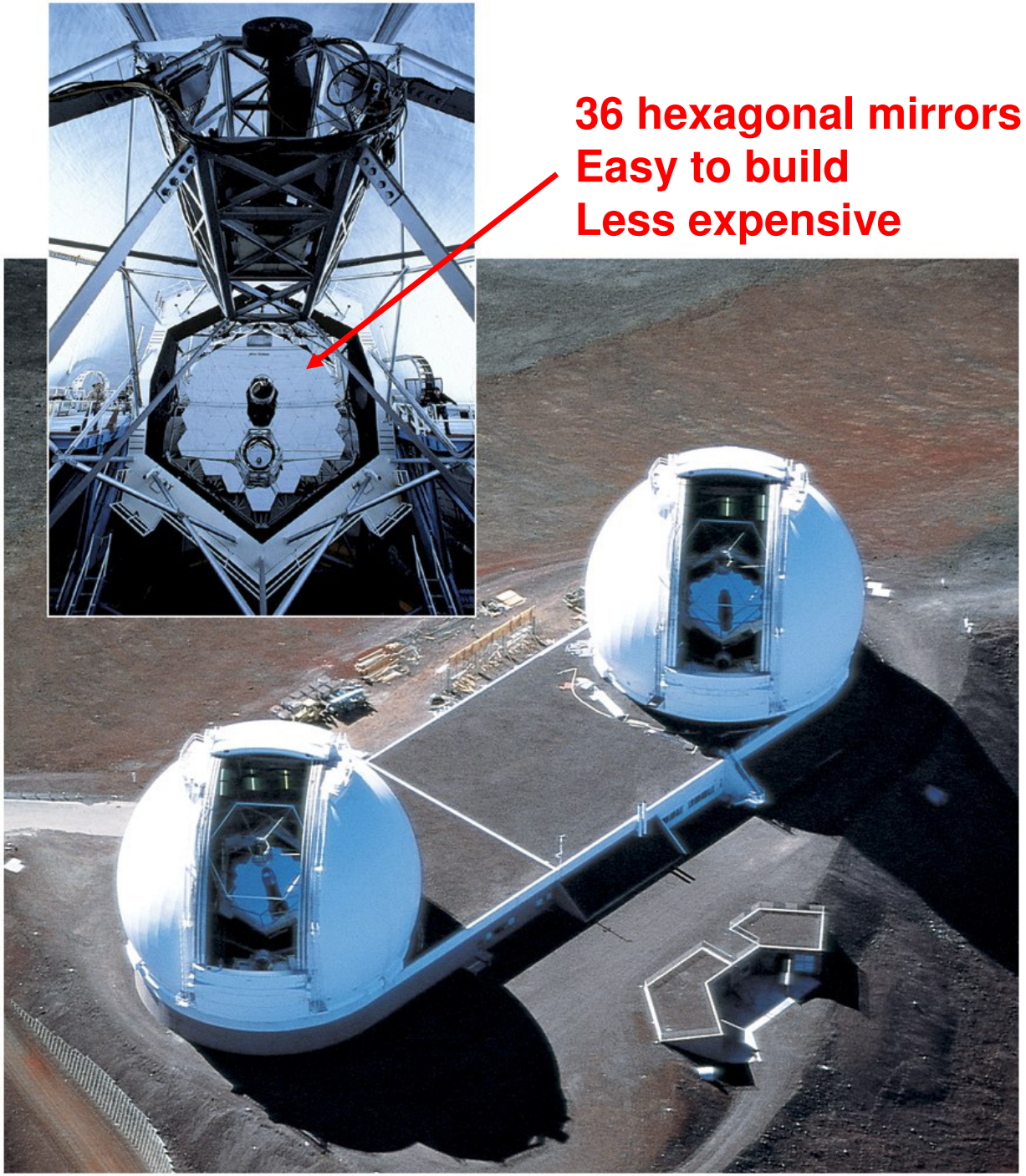


Figure 3-27
Discovering the Universe, Seventh Edition

Charge-coupled devices (CCD)

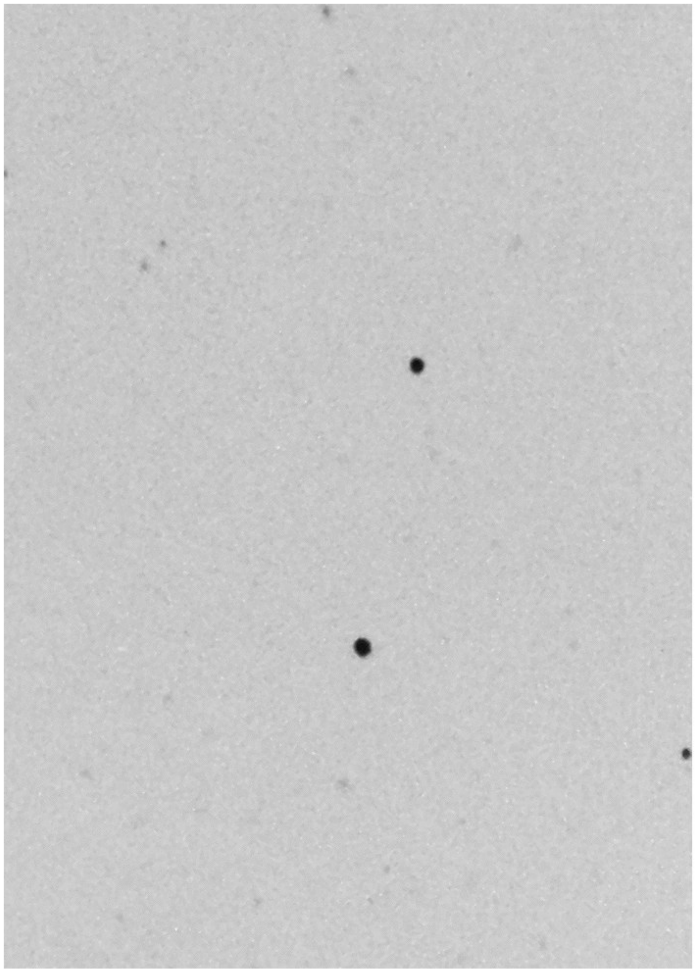


Figure 3-15a
Discovering the Universe, Seventh Edition

Negative photographic image

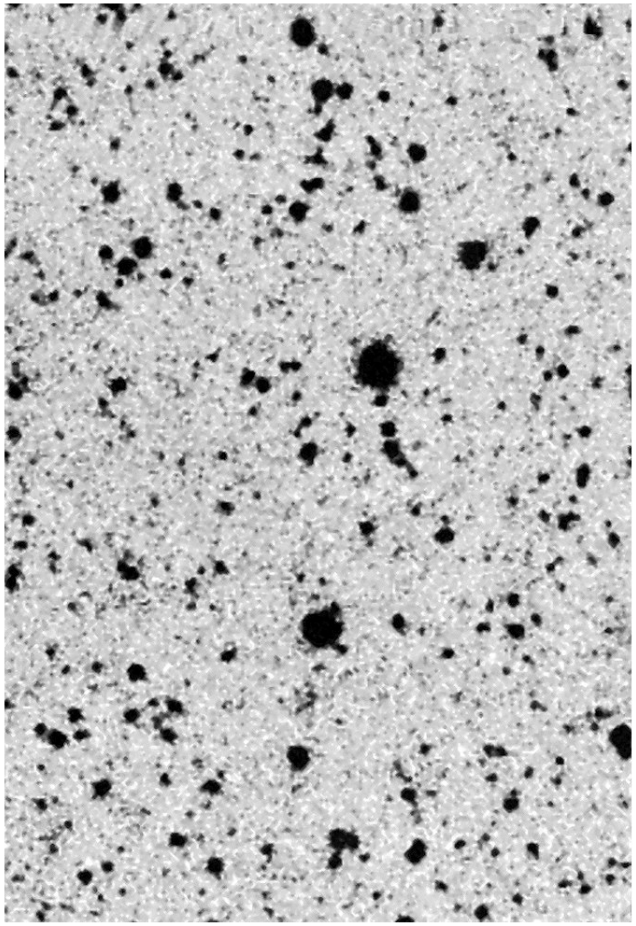


Figure 3-15b
Discovering the Universe, Seventh Edition

Negative CCD image

Figure 3-15c
Discovering the Universe, Seventh Edition

A series of CCD images with different colored filters

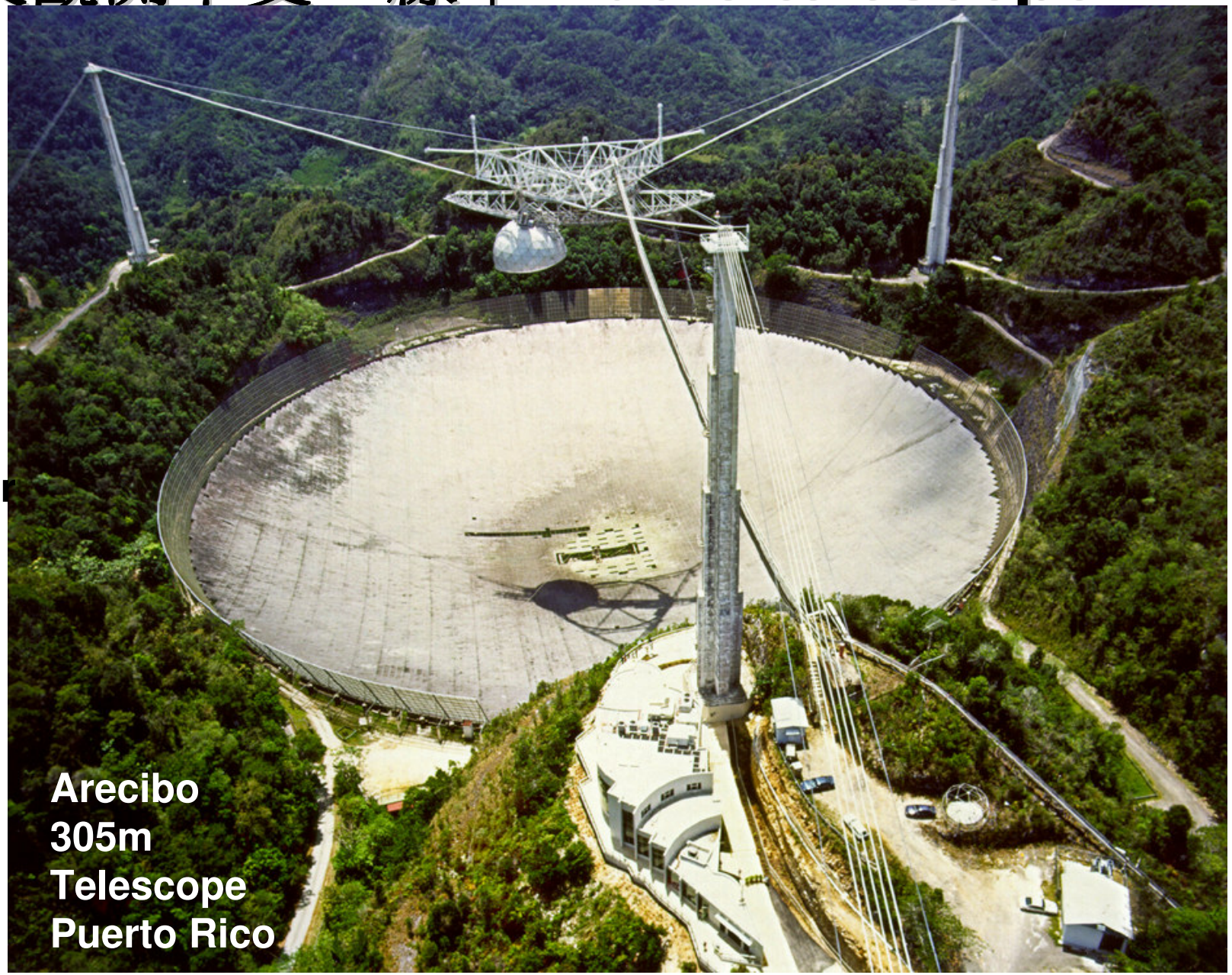
天文觀測不受「線」: radio telescope

Can do day-time observation

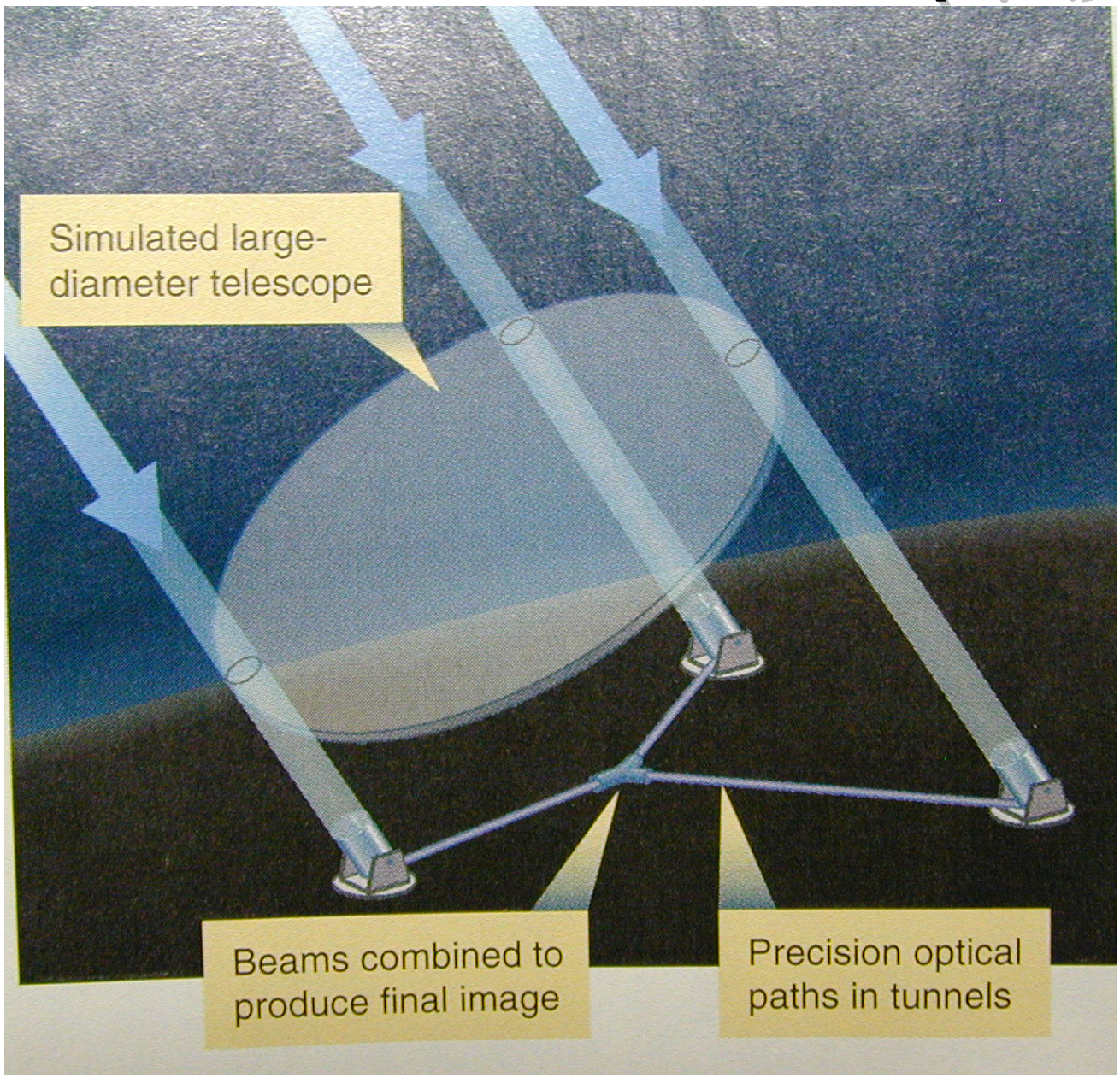
Because of longer wavelength, needs bigger mirror to achieve better resolution.

Golden Eyes (007 Movie)

中國貴州將會有更大的



Interferometer (干涉儀)



Can reach the same resolution, even though the light-gathering power is not significantly improved.

Very Large Array (VLA)

27 dishes
26m in diameter
36km

不同的間距，
不同的解析能力，
所以 zoom in
或 zoom out
隨心所欲

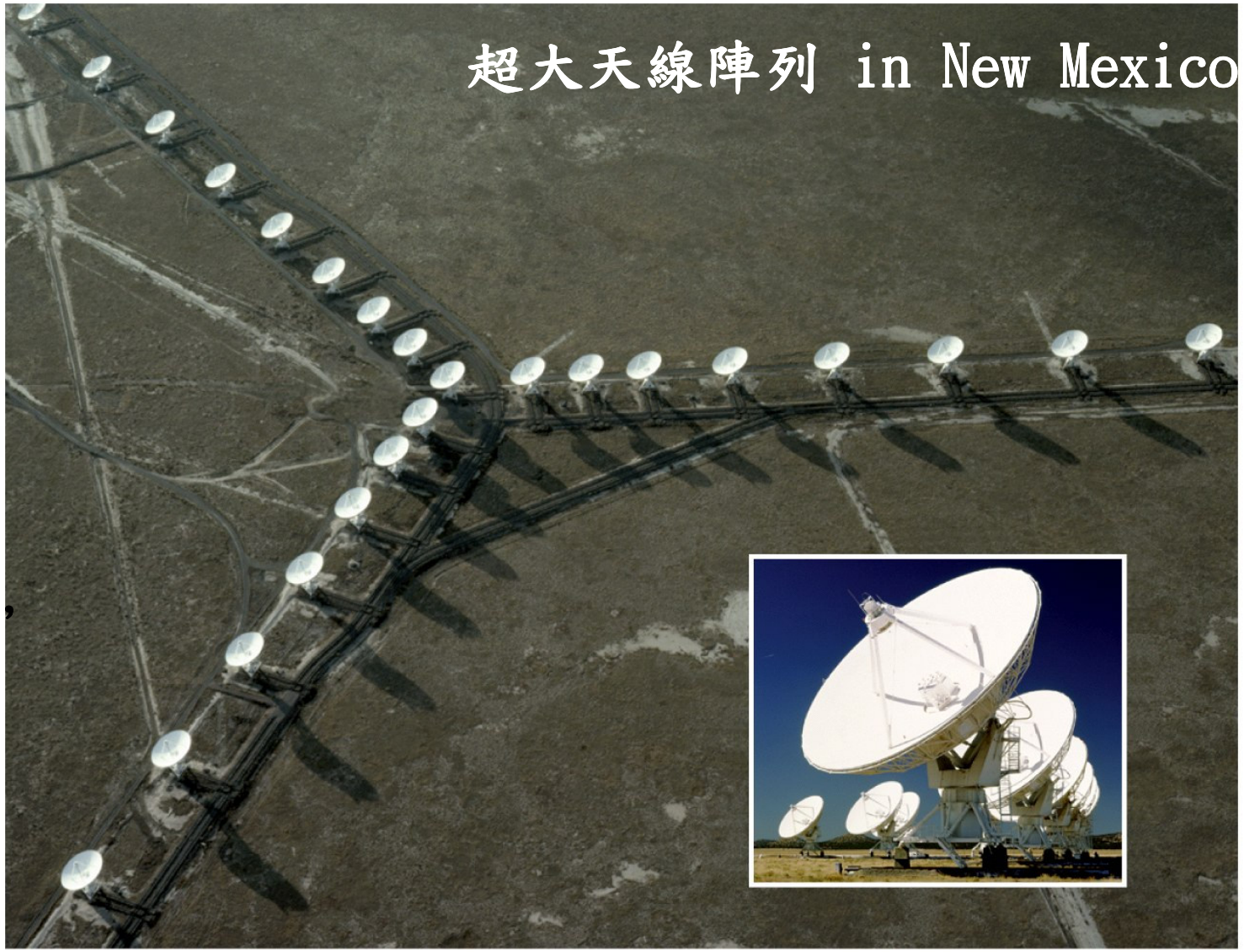


Figure 3-30
Discovering the Universe, Seventh Edition


CONTACT
A message from deep space.
Who will be the first to go?
A journey to the heart of the universe.
織女星 (Vega)
25.3 lyrs away
1.5 solar masses
385 million year old
T=9600 K

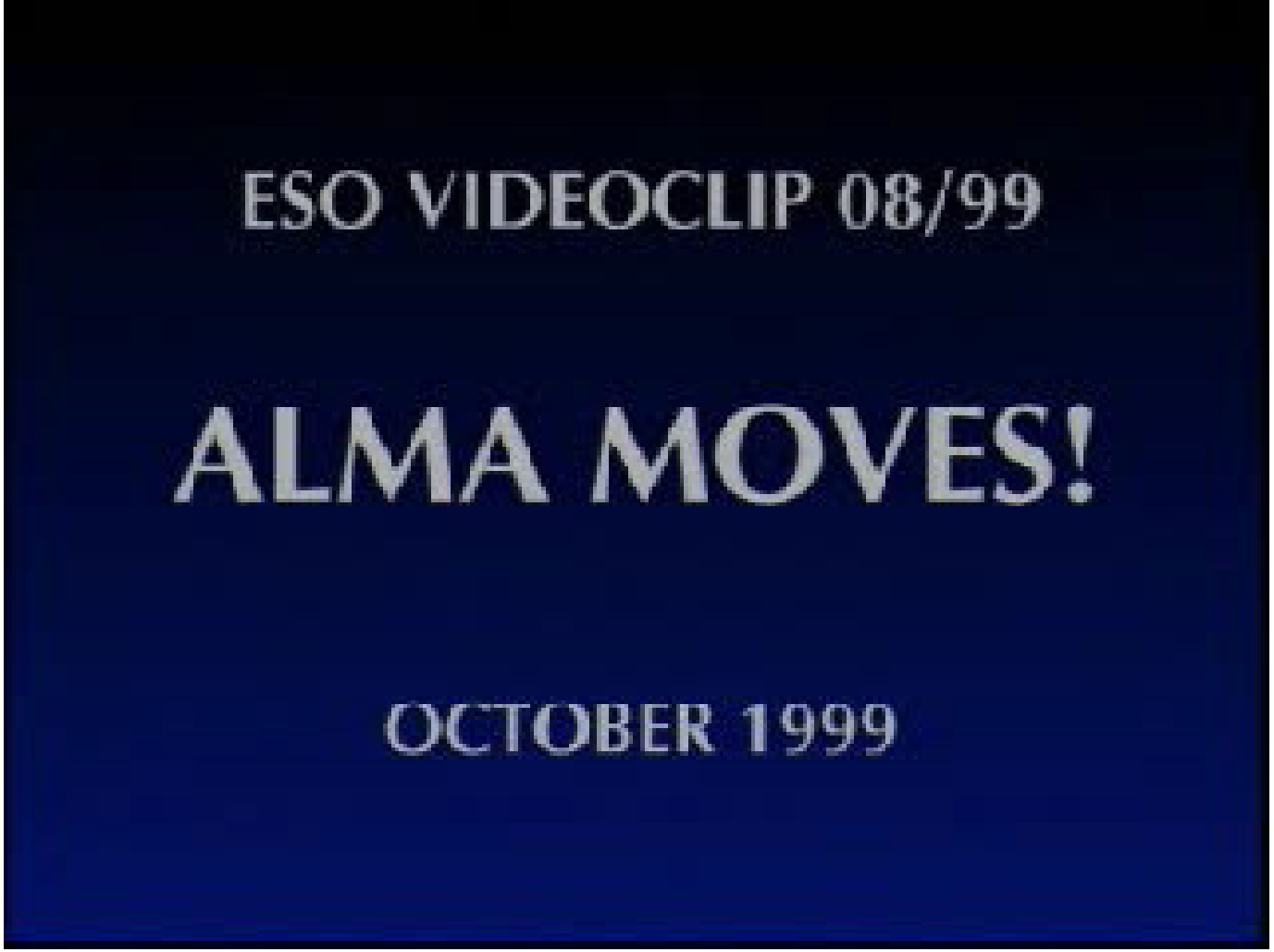
Sub-millimeter Array (SMA)

次毫米波陣列 http://www.asiaa.sinica.edu.tw/~SMART/

Smithsonian institution (6) + 中央研究院天文所 (2)
Mauna Kea, Hawaii
Observe dust & molecular emissions in star forming regions or dying (evolving) star regions.

ALMA

Cover wavelength:
0.3 -9 mm
angular resolution:
0.004”



Atacama Large Millimeter Array (ALMA) is one of the largest ground-based astronomy projects of the next decade. It will be comprised of some sixty-four 12-meter (North America & Europe) and 12 7-meter+4 12 meter (Japan & Taiwan), submillimeter-quality antennas at the high-altitude (5000 m) Llano de Chajnantor, possibly the world's best site for millimeter astronomy, close to San Pedro de Atacama in northern Chile.

http://www.eso.org/outreach/press-rel/pr-1999/vid-08-99.html

ALMA-T (T here means Taiwan)

http://alma.asiaa.sinica.edu.tw/

Sep, 2005

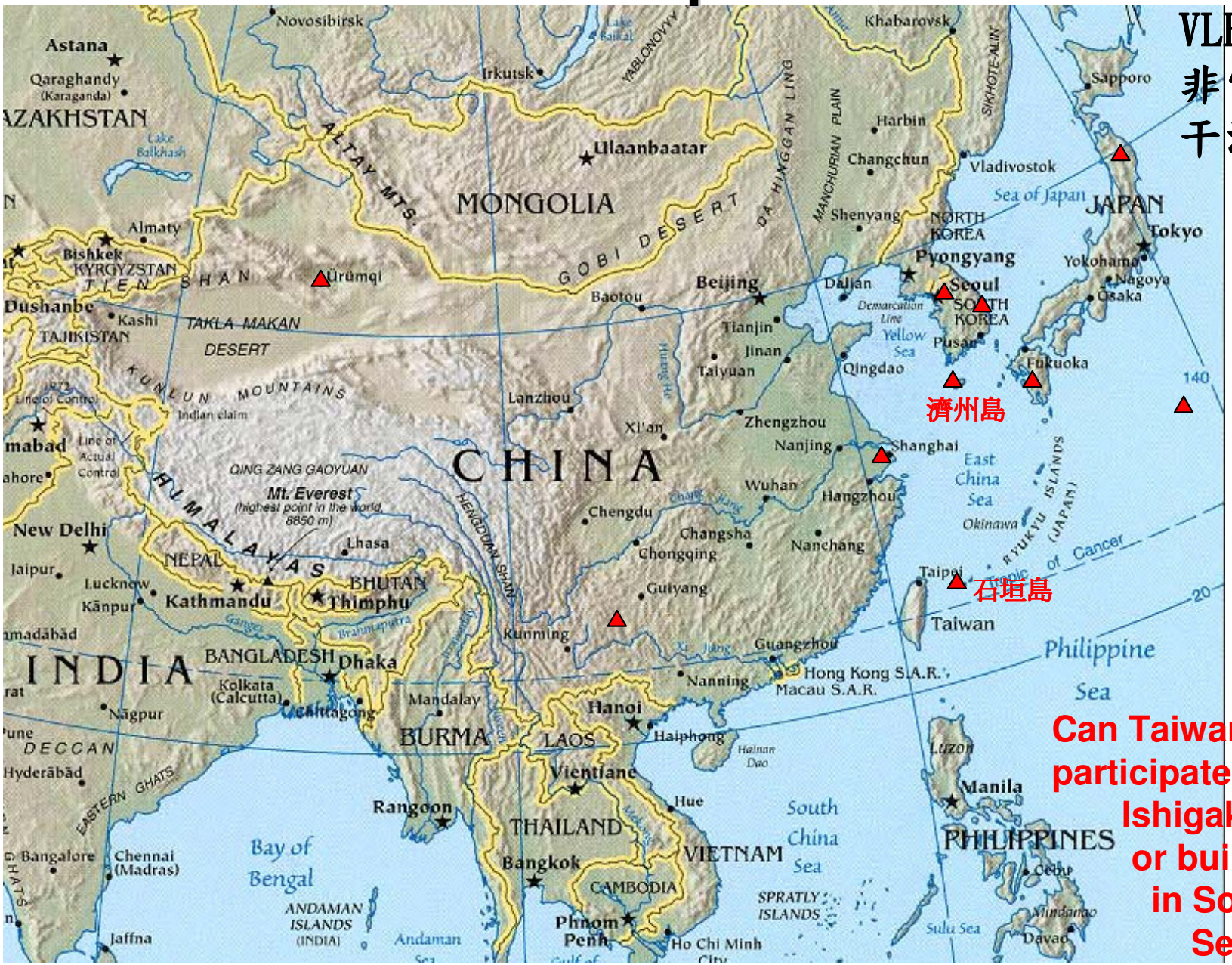
President Lee just stepped down

invest 16M USD (5% of Japanese contribution)

What are we doing now?

1) **Integration center**
2) **circuit**
3) **data archive**

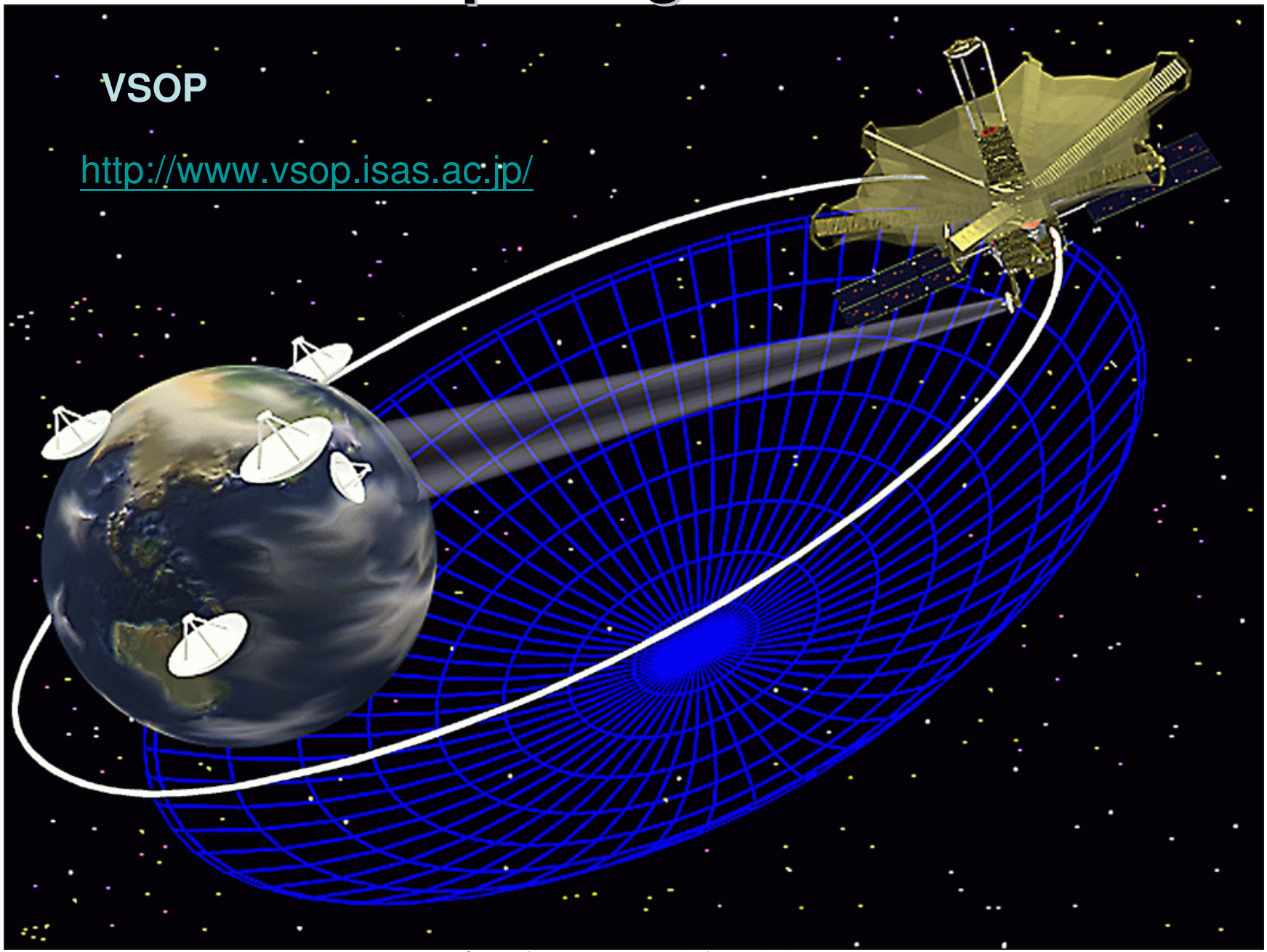
East Asia VLBI? Japan+Korea+China



VLBI：
非常長基線
干涉儀

Can Taiwan participate in? Ishigakijima or build one in South China Sea?

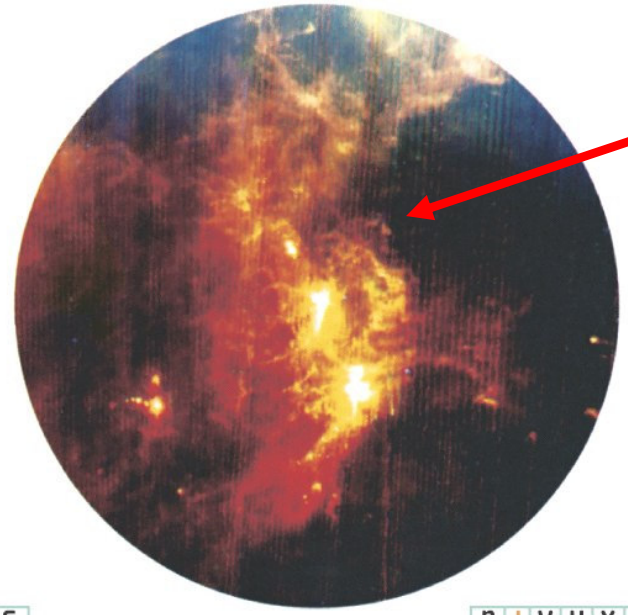
Radio telescope larger than the Earth!



Orion in UV, IR, & visible

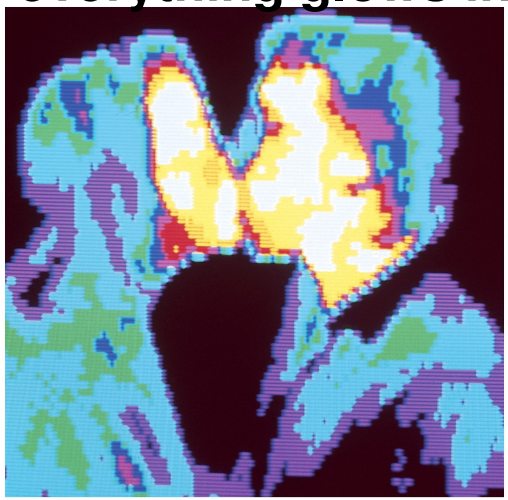
波長短
溫度高
能量高

hot (ionized) gas
& stars



dust

Infrared (actually everything glows in dark)



Unnumbered Figure pg 94
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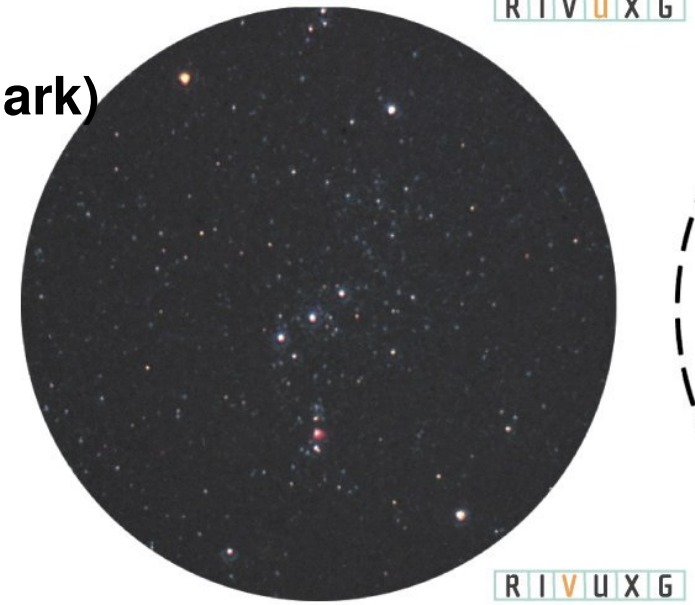

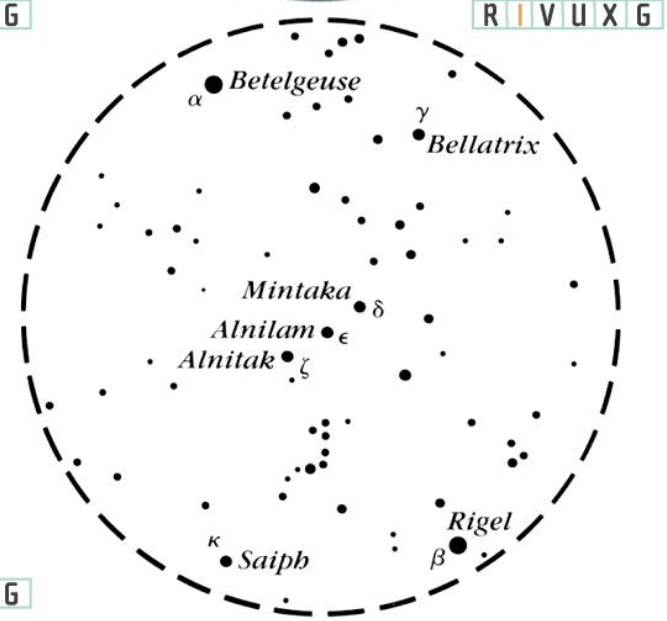

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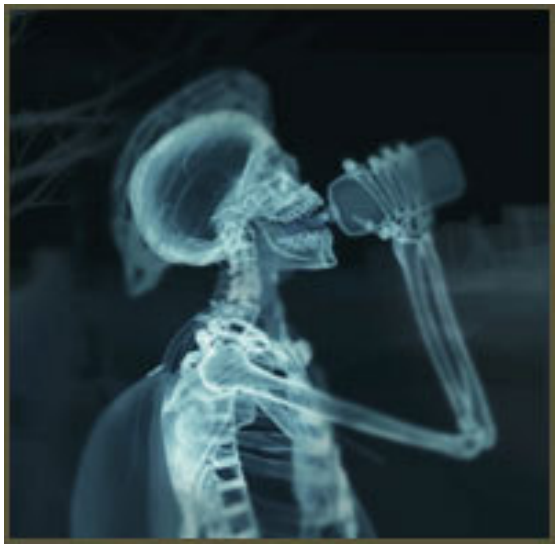
Focusing X-ray

X-ray is so energetic that it can penetrate a normal surface.



X-ray from high energy sources: Supernova remnant, black hole, cluster of galaxies

類似
打水漂

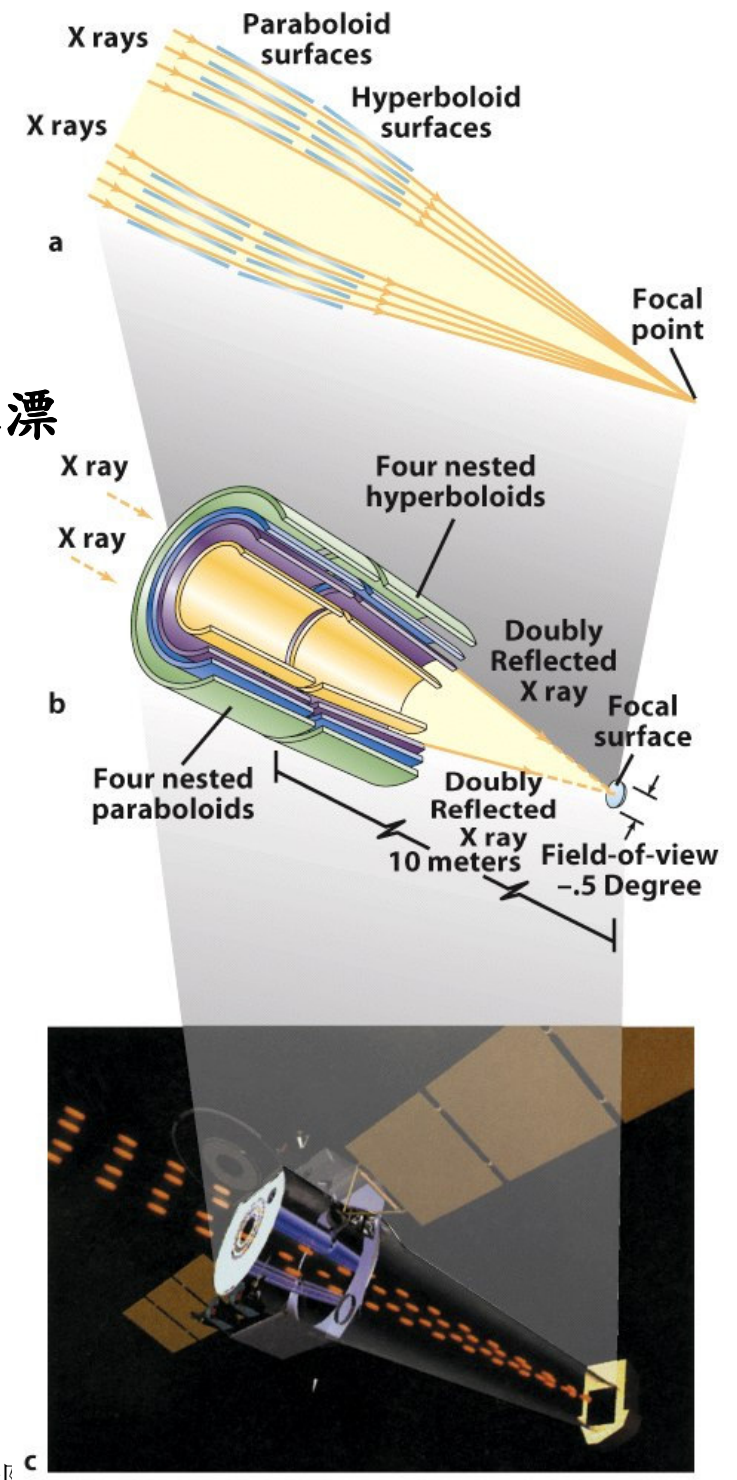


Figure 3-34
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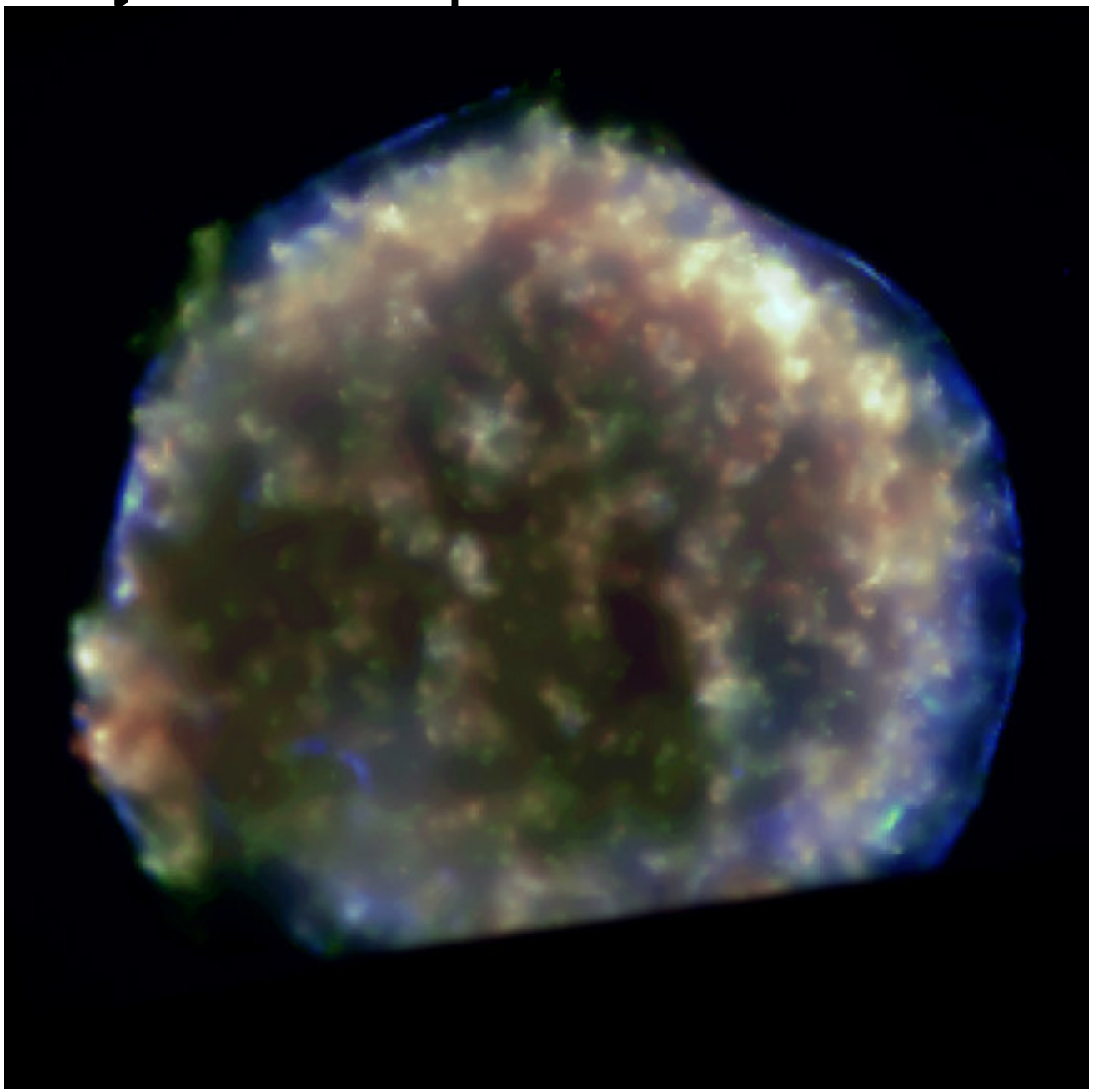
X-Rays From Tycho's Supernova Remnant

7,500 light-years in the constellation Cassiopeia (仙后座)

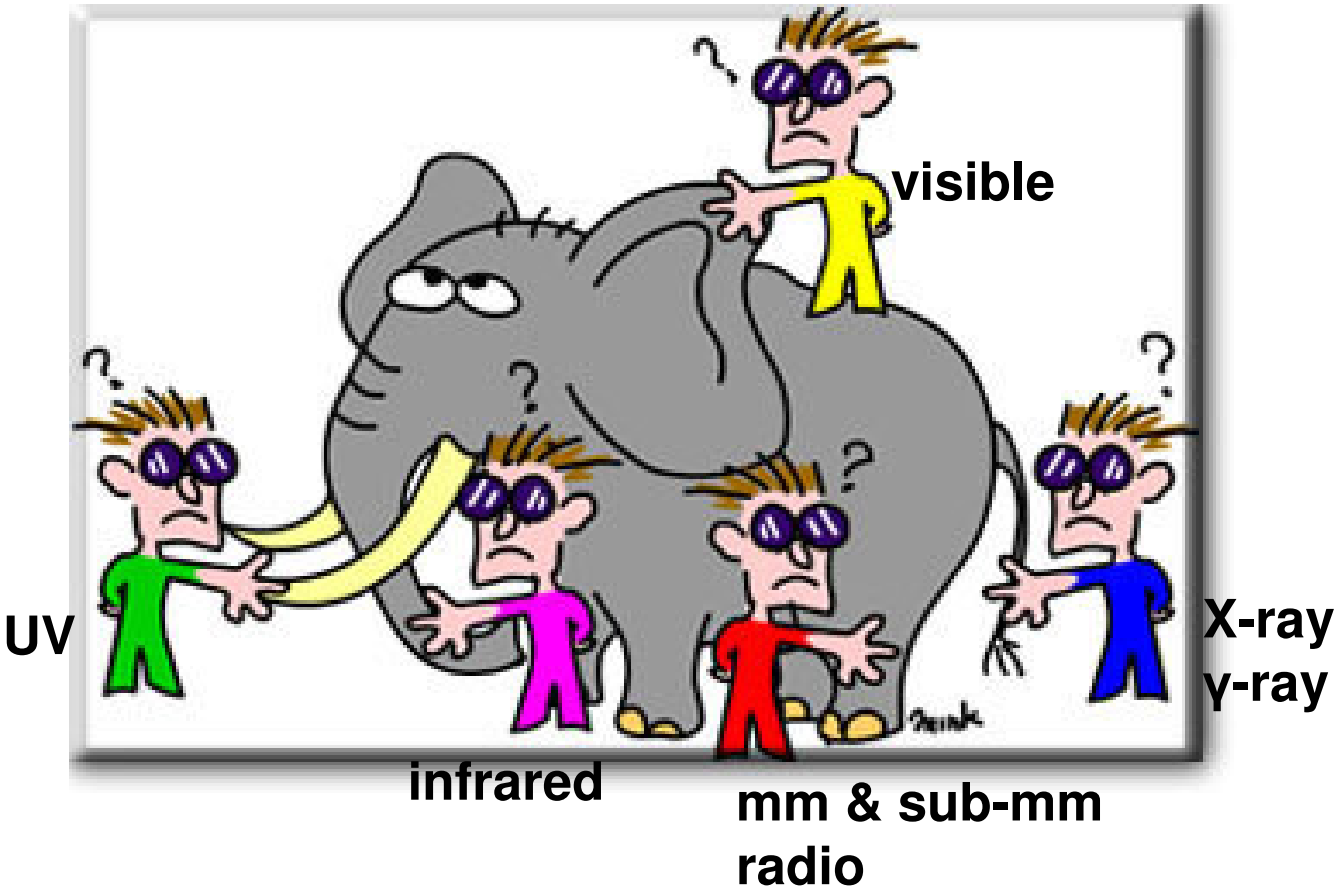
T=10^7 degrees

Image taken by Chandra X-ray observatory



Multi-wavelength investigation

Remember that some wavelengths cannot be seen on the ground.



Light & energy level of atoms

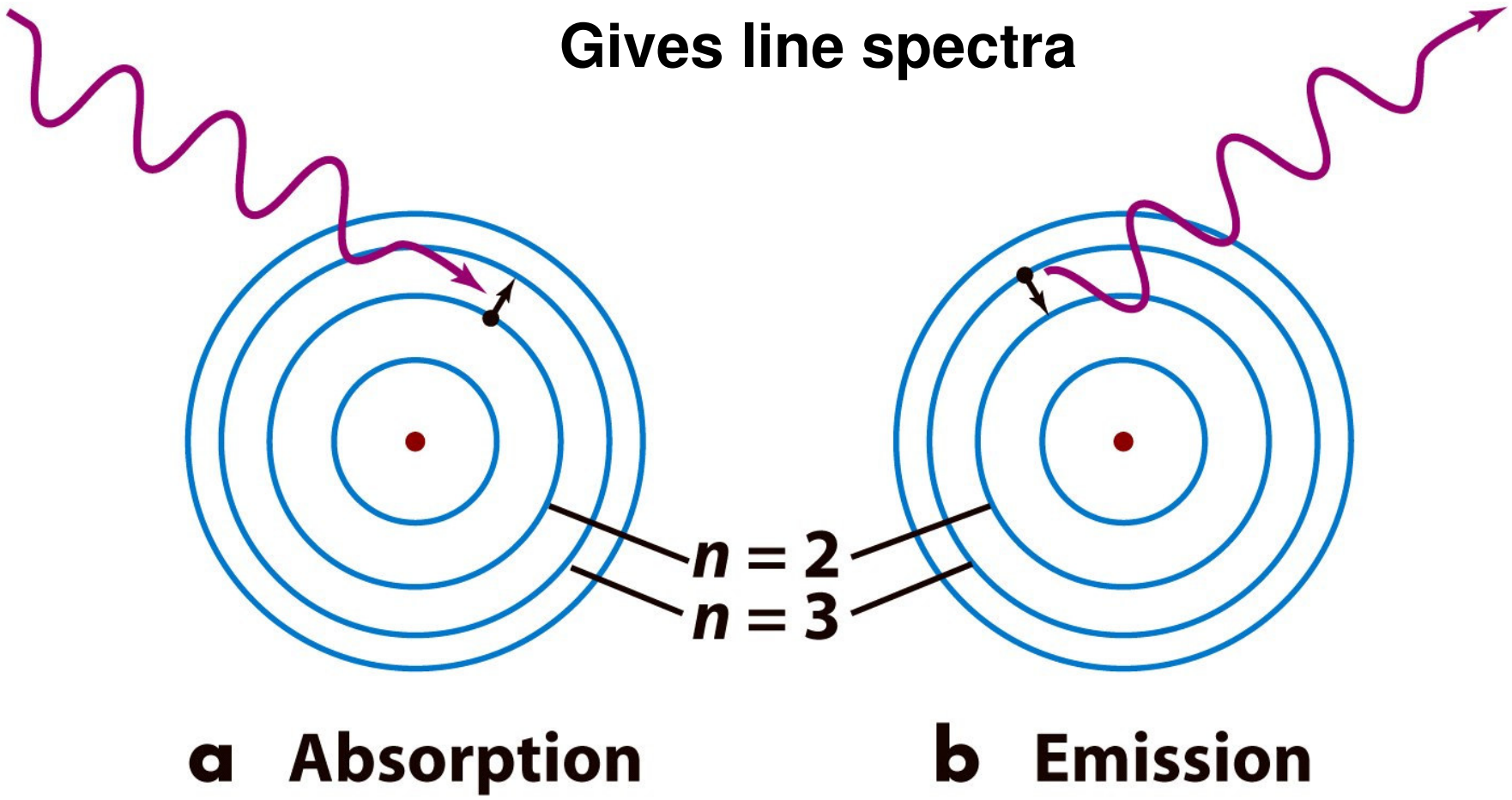


Figure 4-12
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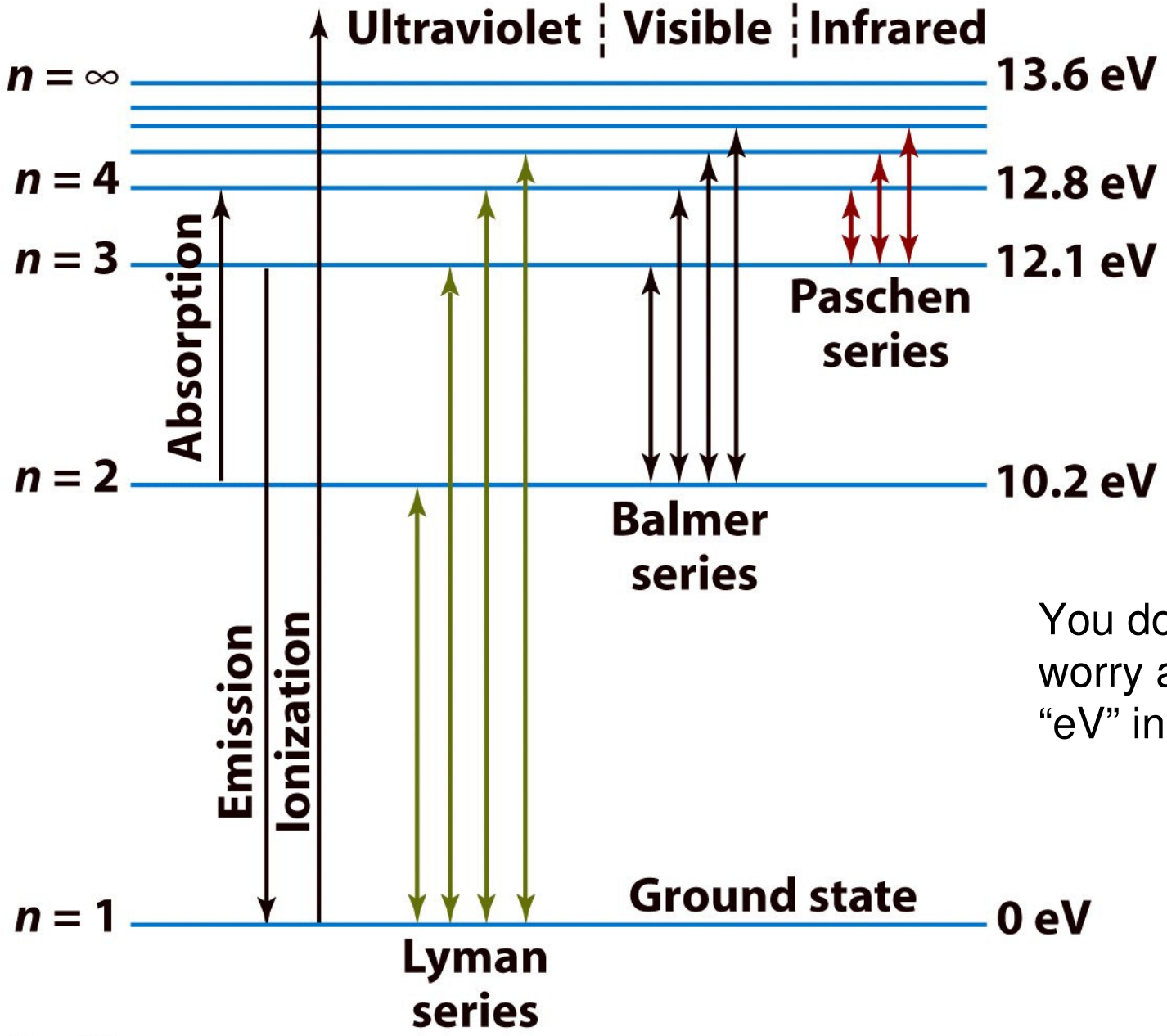
Energy level of H atom



You don't have worry about "eV" in this class.

Figure 4-11
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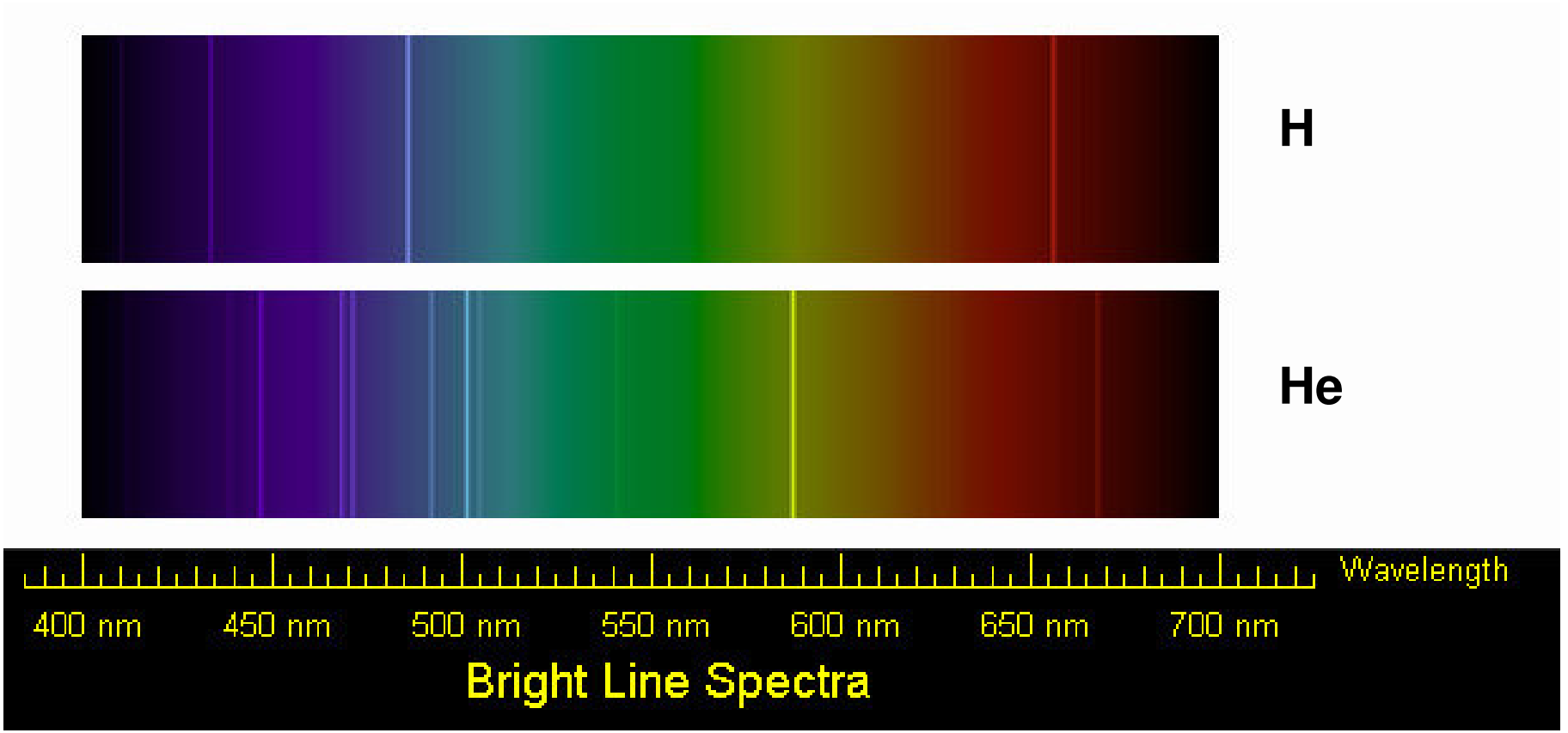
Different atoms have different line spectra



http://heasarc.gsfc.nasa.gov/docs/xmm_lc/edu/lessons/student-worksheet-spectragraph2.html

temperature & color

連續光譜

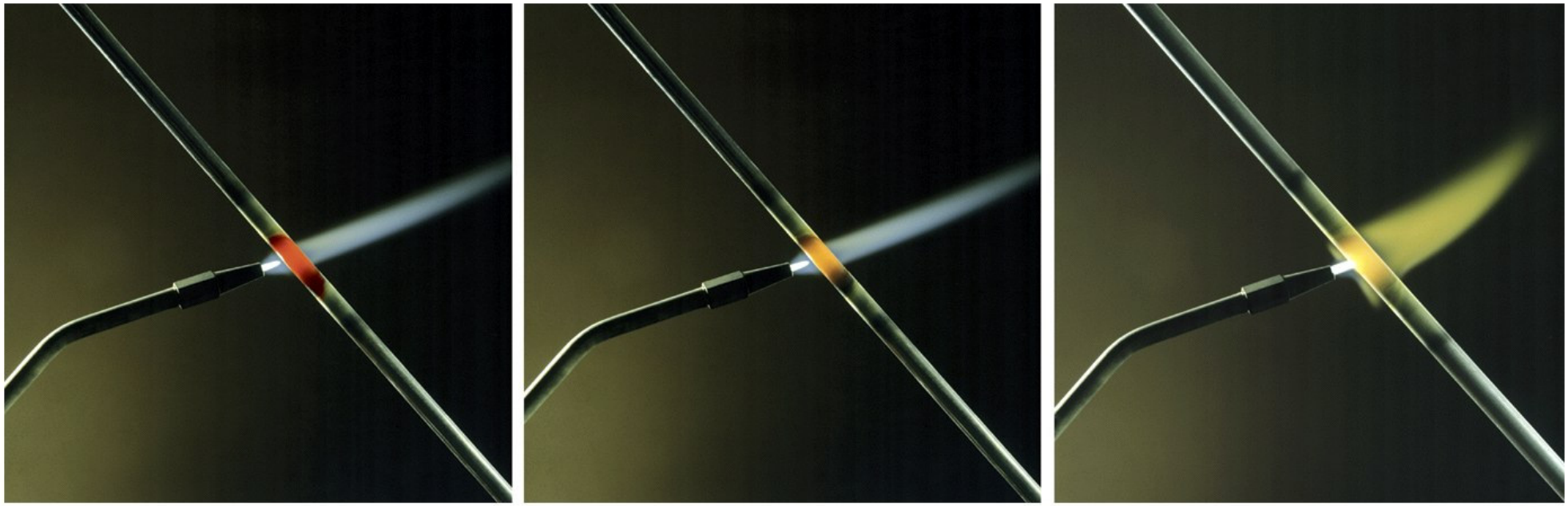


Figure 4-1
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temperature →

請區別我們平常所看的顏色哦:
不是溫度造成的 (黑暗中就看不到了)。

Stars have colors!

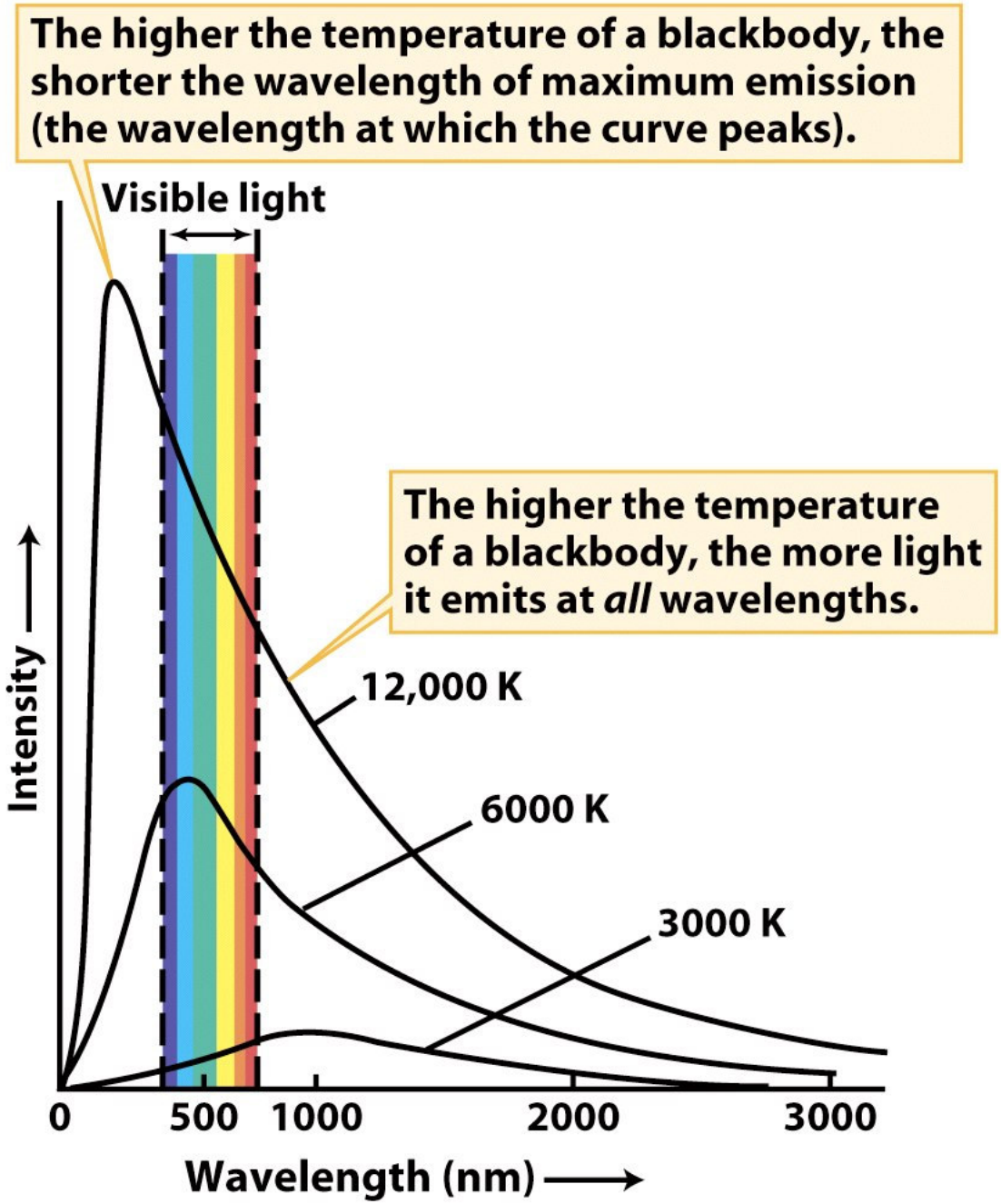

Figure 4-2
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Continuous & Line Spectra

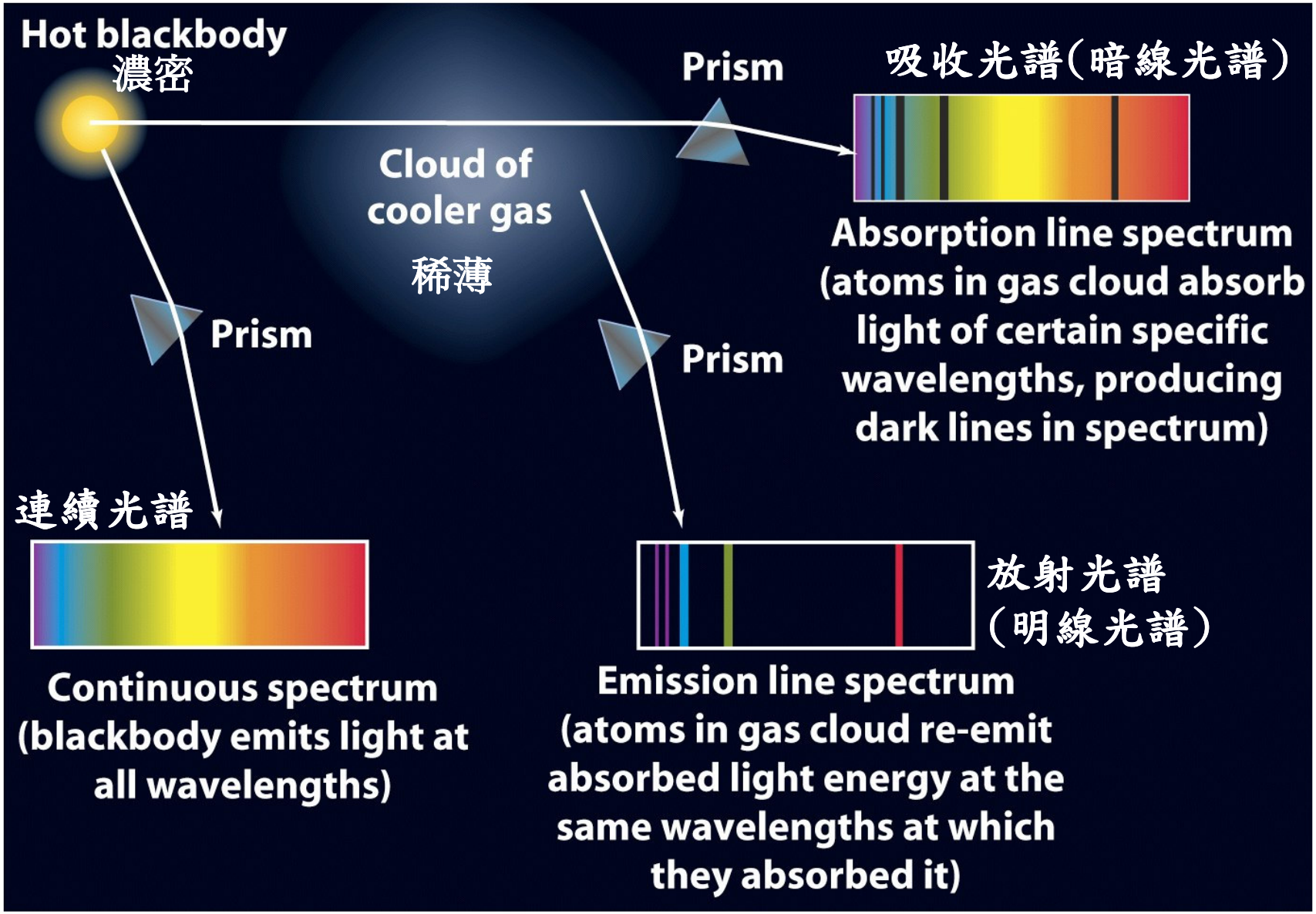

Figure 4-10
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Diffraction Grating (光柵)

In reality, people don't use a prism but a grating to get spectra. Prism is more difficult to make.

radial & proper motions of a star

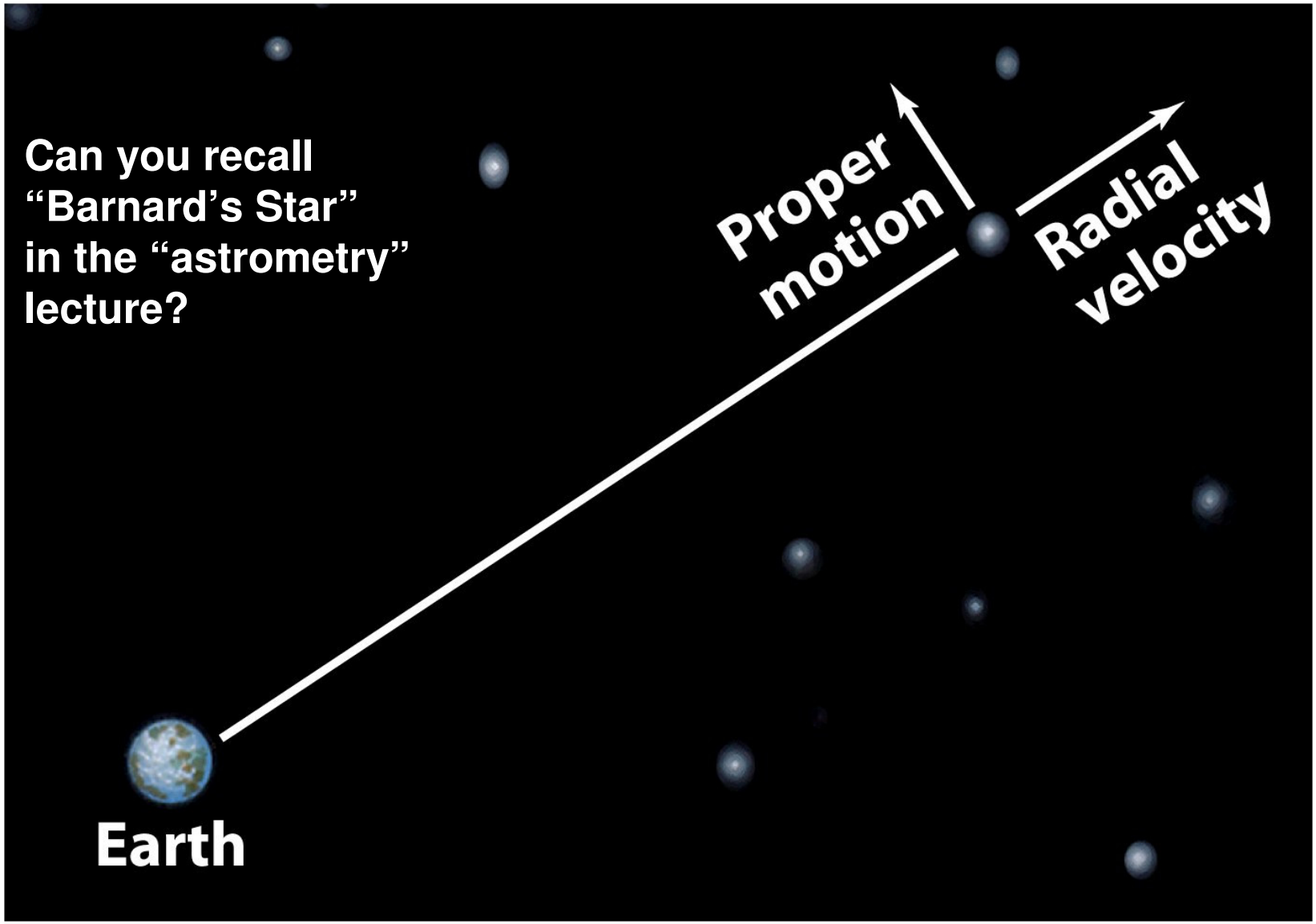

Figure 4-15
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Doppler effect (都卜勒效應)

車子經過時的
喇叭聲

Examples:
rotating astronomical disks
binaries (雙星)
distant galaxies(宇宙膨脹)

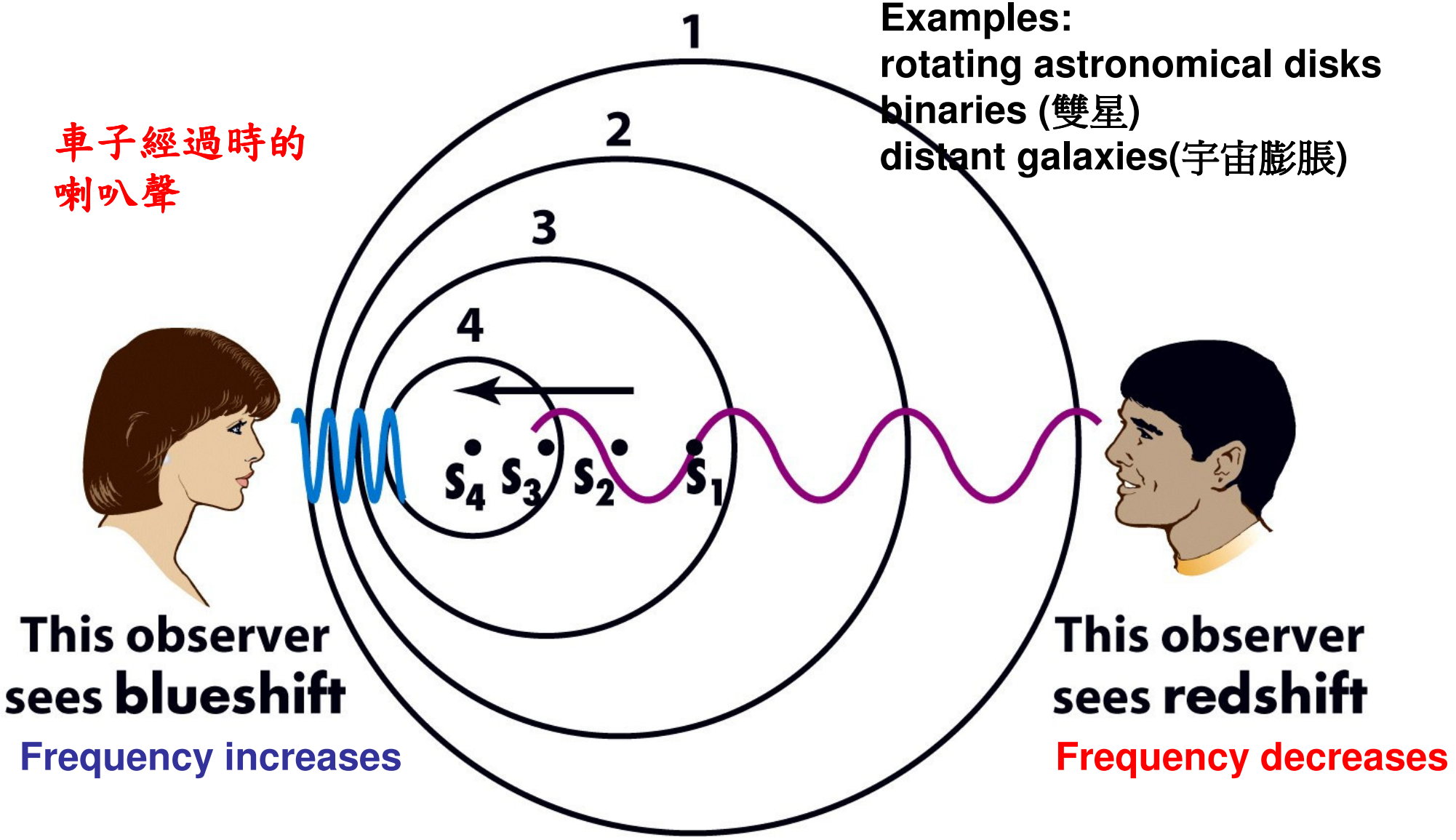

Figure 3-6
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Summary

- 什麼是波?什麼是光譜?
- 地球大氣對所有的光都是透明的嗎?
- 為什麼有彩虹?
- 為什麼星星月亮老是跟著我走?
- 為什麼望遠鏡口徑越大越好?
- 為什麼當代大型天文望遠鏡都採反射式而非折射式？
- 為什麼天文望遠鏡總是要建在高山上?
- 為什麼要有adaptive optics?
- 為什麼無線電望遠鏡都很巨大?
- 許多天文望遠鏡形成陣列有什麼好處?
- 一座可見光望遠鏡可以用來觀測無線電波或x-ray嗎?
- 為什麼線光譜告訴我們是何原子或分子?
- 線光譜和連續光譜有何不同?
- 溫度和顏色有關嗎?
- 什麼是都卜勒效應?
- 觀測由一天體發射出不同波段的光有必要嗎?