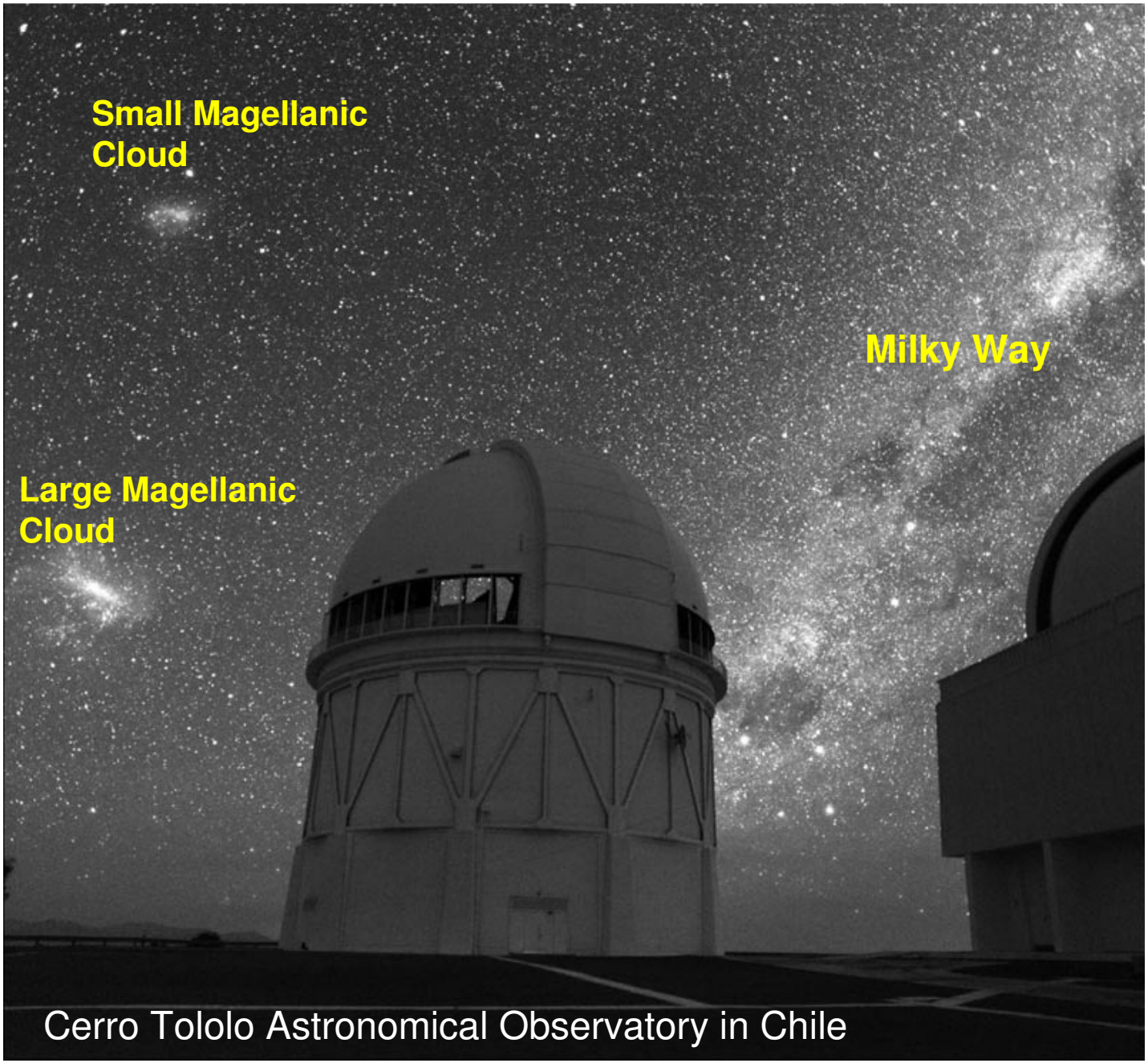
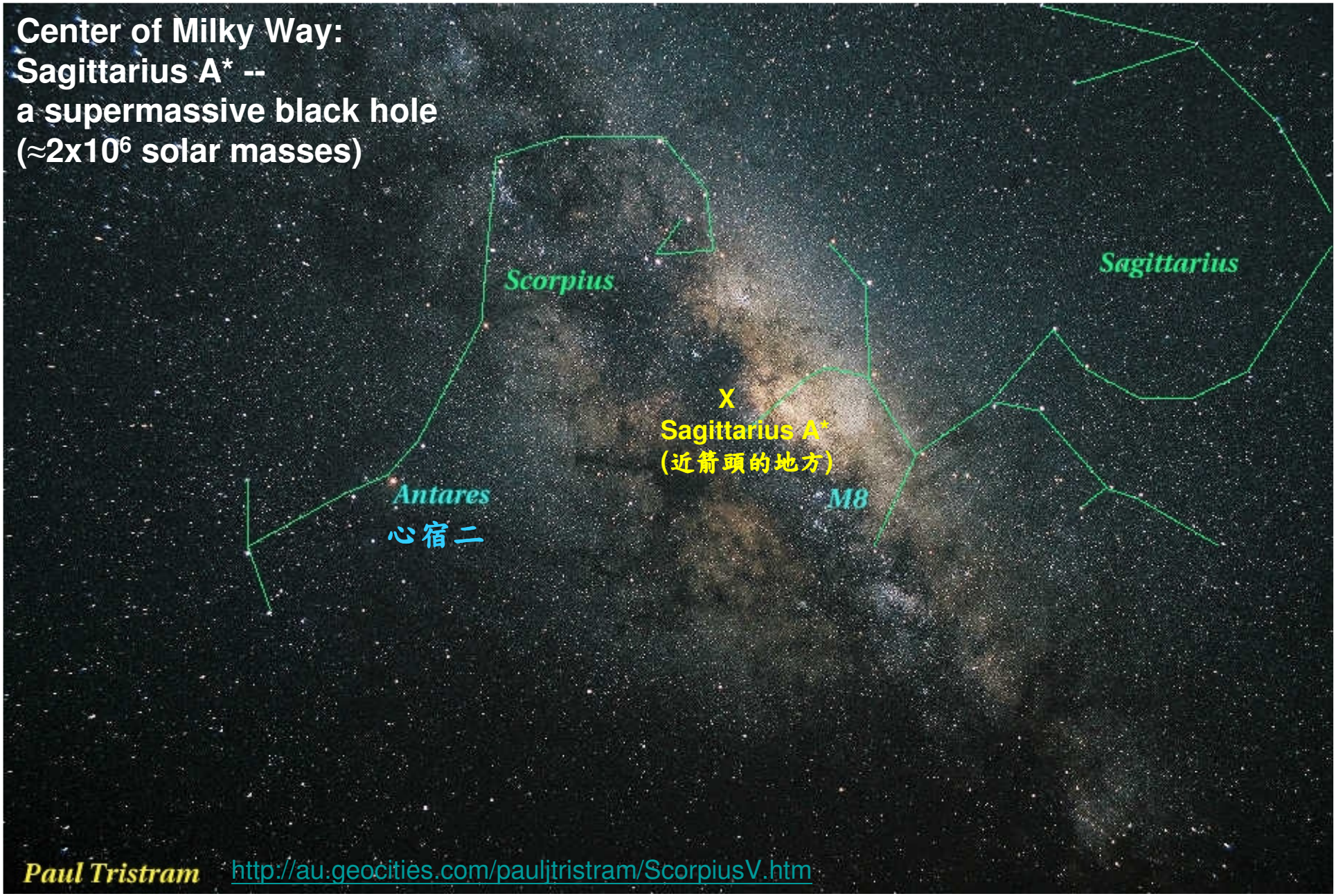
眾星與暗物質的國度：星系與星系團 (I & II)

辜品高

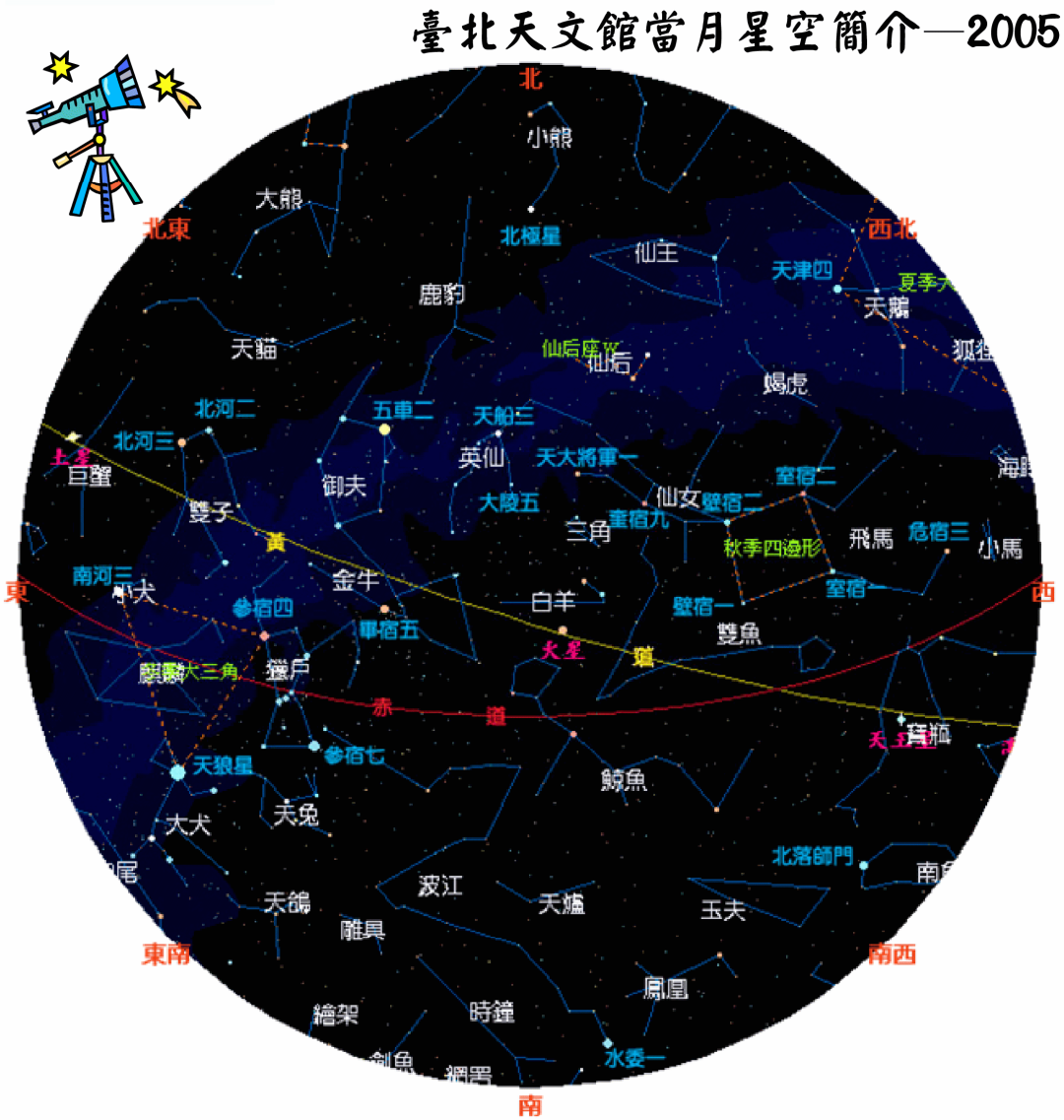
師大地科系

中研院天文所


Small Magellanic Cloud
Milky Way
Large Magellanic Cloud
Cerro Tololo Astronomical Observatory in Chile


Center of Milky Way:
Sagittarius A* --
a supermassive black hole
(≈2x10^6 solar masses)
Scorpius
Sagittarius
X
Sagittarius A*
(近箭頭的地方)
M8
Antares
心宿二
Paul Tristram
http://au.geocities.com/pauljtristram/ScorpiusV.htm

The Milky Way on the sky in December



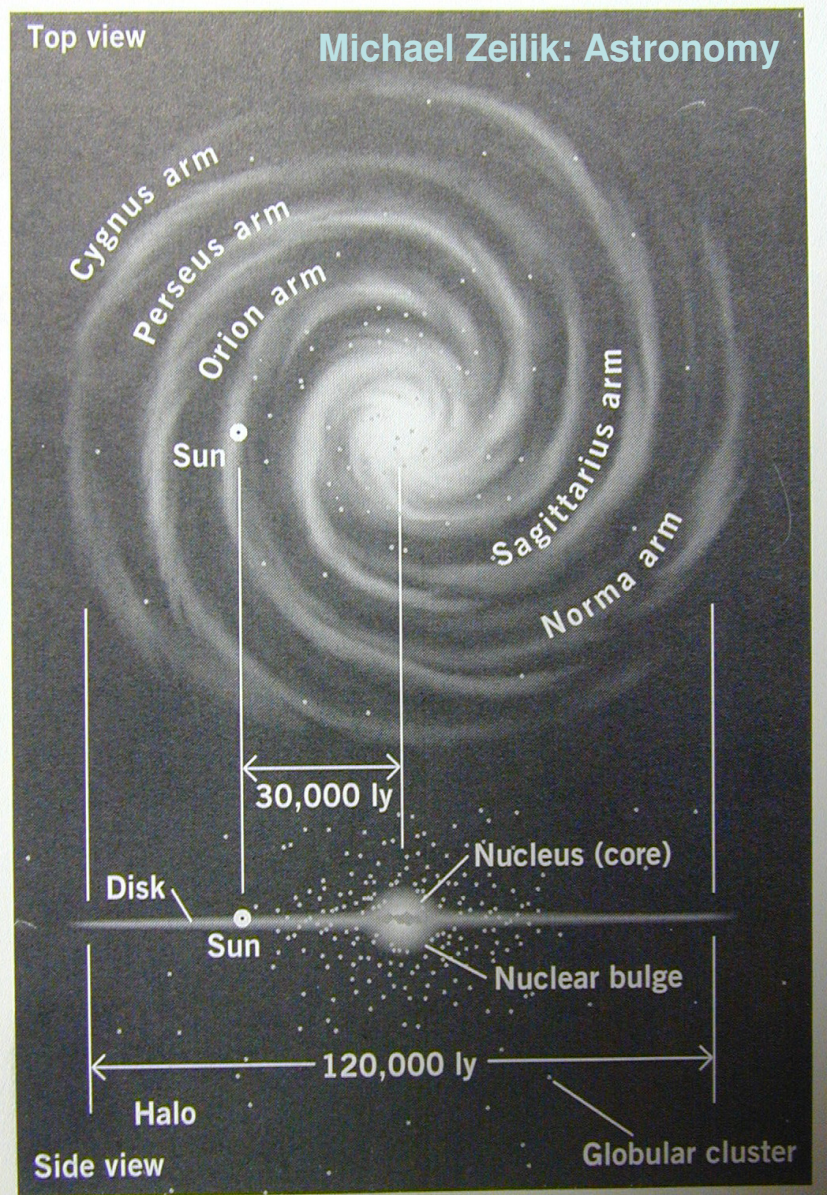
The Milky Way is not aligned with the ecliptic.

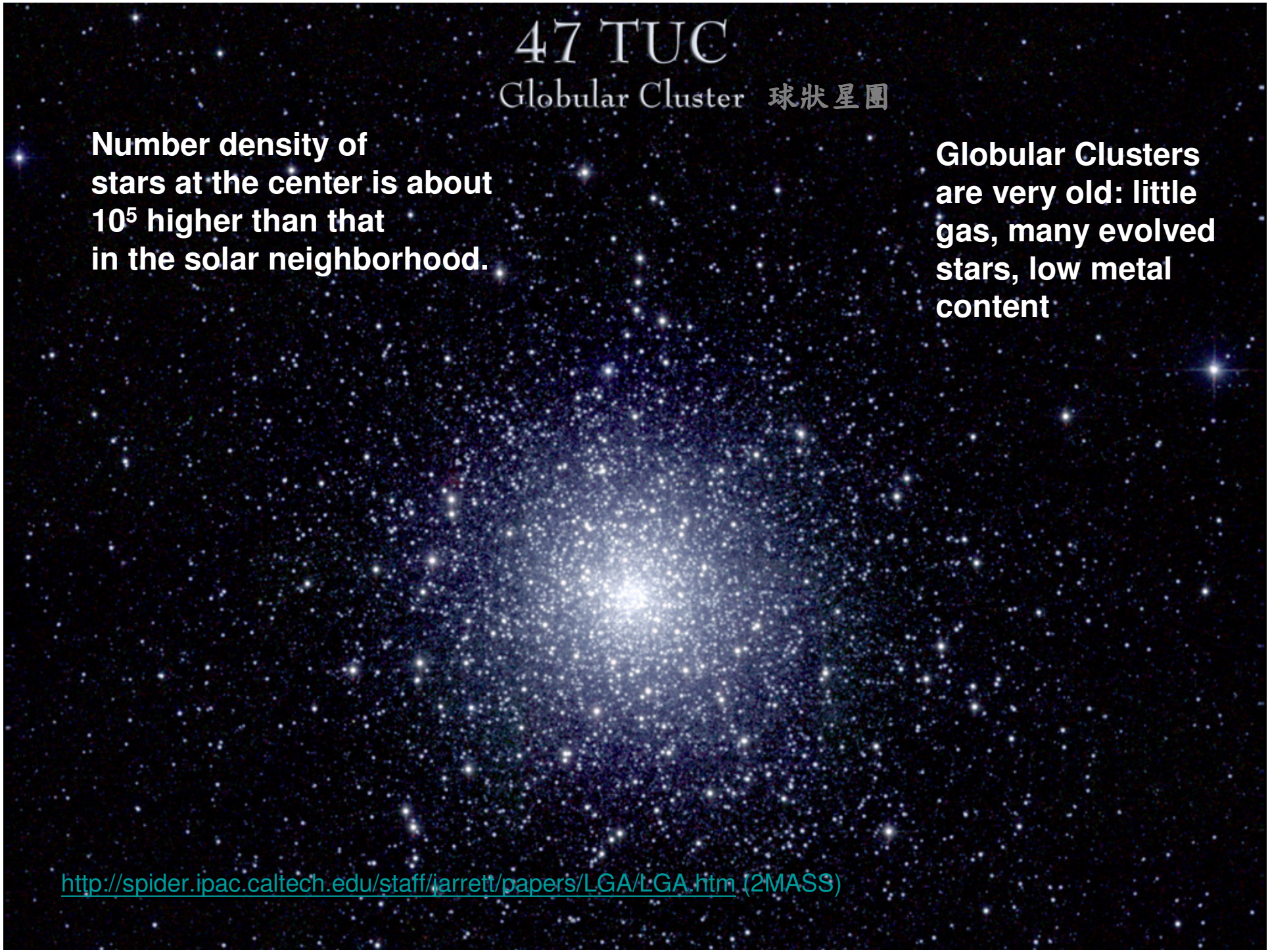
The sky map of the whole year shows the milky way divides the whole sky into two equal parts.

Structure of the Milky Way

Spiral galaxy:
most of forming stars (+gas & dust) lie in the spiral arms and around the center (optical wavelength is dominated by OB stars).
Most of the old stars are located in the galactic halo.

Gas & dust obscure our view to the galactic plane
→ How do we know?
Ans: through the light at longer wavelengths than optical.




47 TUC
Globular Cluster 球狀星團
Number density of stars at the center is about 10^5 higher than that in the solar neighborhood.
Globular Clusters are very old: little gas, many evolved stars, low metal content
http://spider.ipac.caltech.edu/staff/jarrett/papers/LGA/LGA.htm (2MASS)

The solar system does not lie at the center of the Milky Way

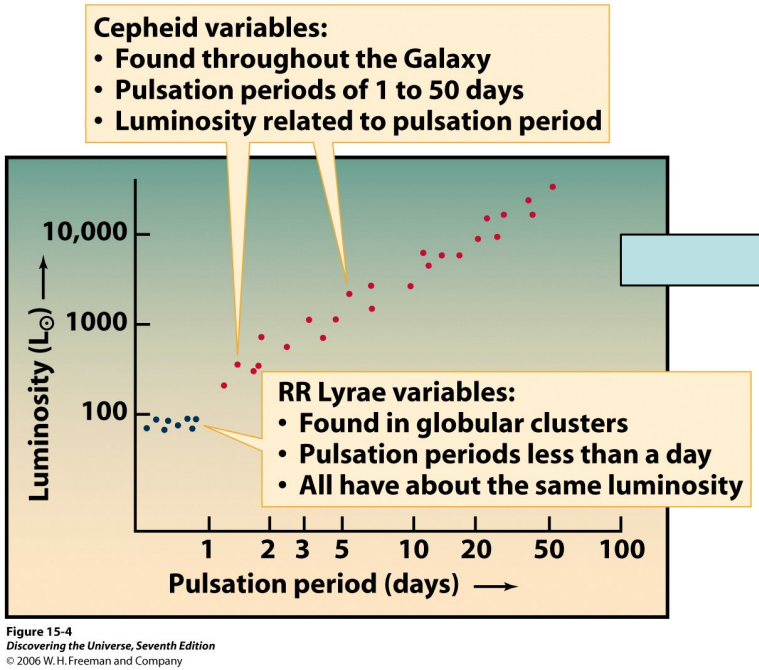


Figure 15-4
Discovering the Universe, Seventh Edition
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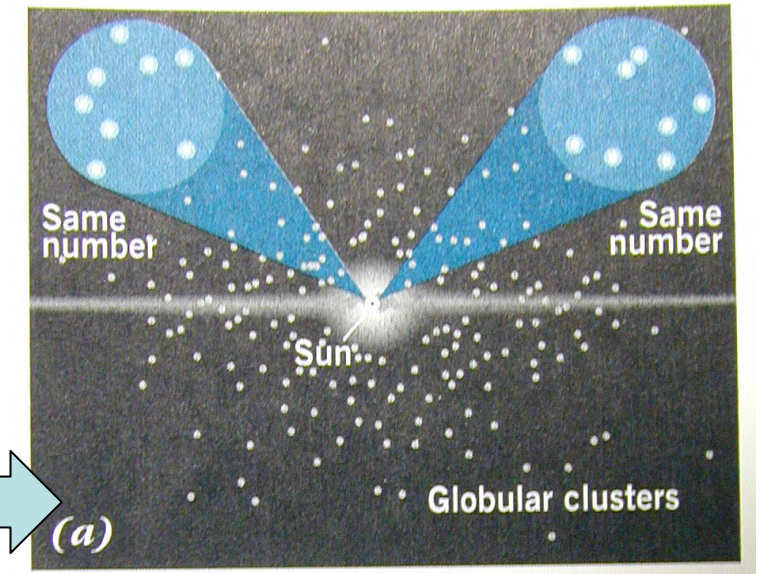
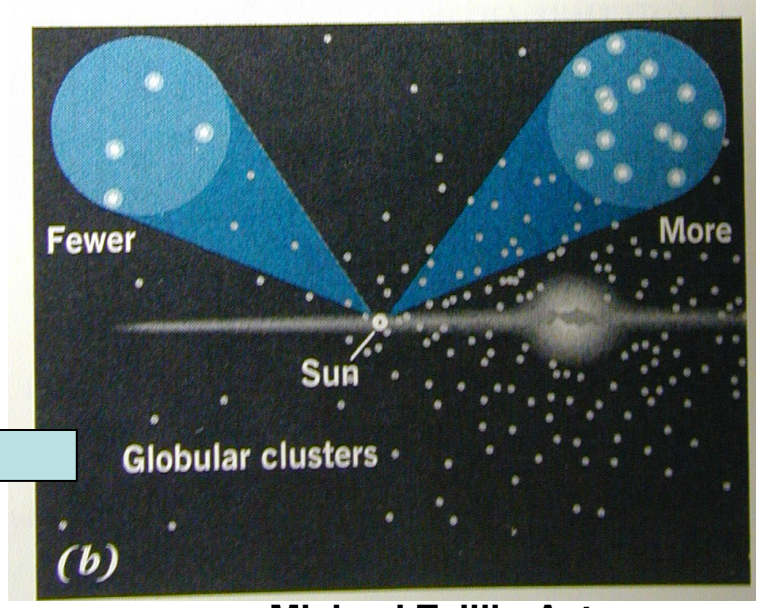
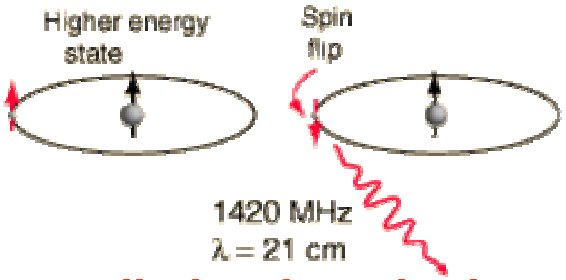




We know (1) the distance to the galactic center (2) the orbital speed of the solar system (230km/s, or 230 million years per orbit)

Michael Zeilik: Astronomy

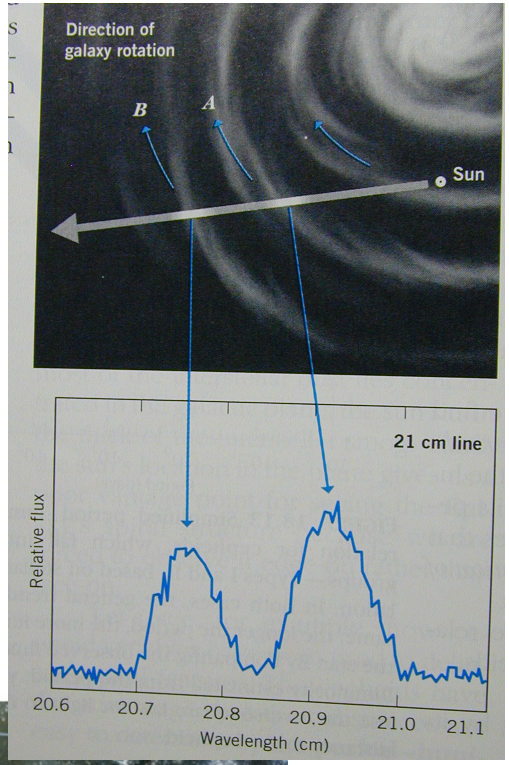
A hydrogen map of the Milky Way



21-cm radiation from hydrogen atoms

Doppler shift → location and speed of the hydrogen atom gas

Radio map is a bit complicated: many branches & spurs



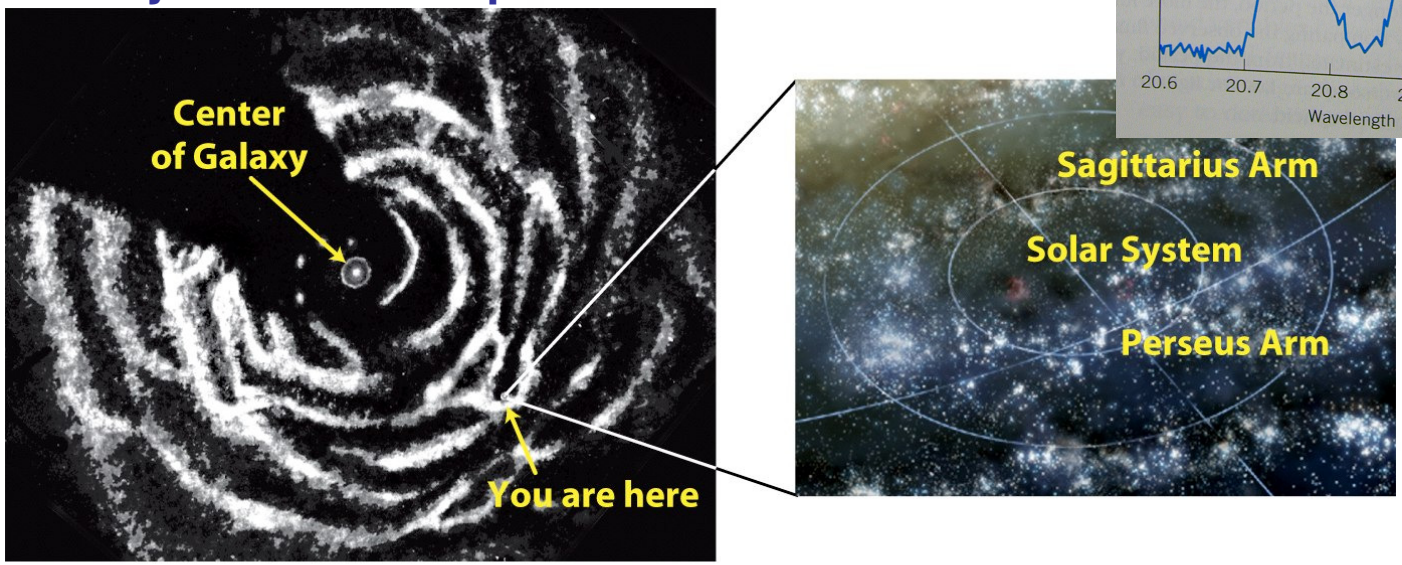


Figure 15-9
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A dust map of the Milky Way

Far-infrared → dust distribution

The Galaxy is rotating

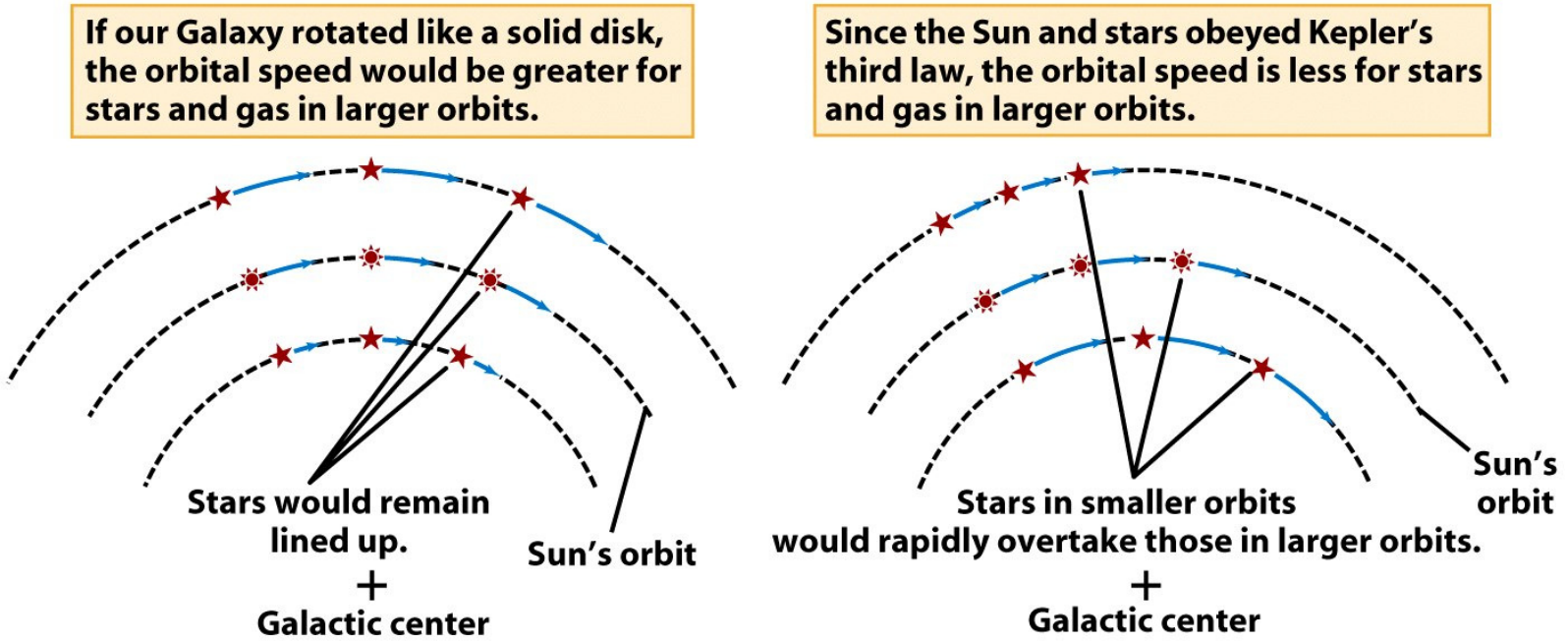

Figure 15-17
Discovering the Universe, Seventh Edition

Rotation curve → dark matter

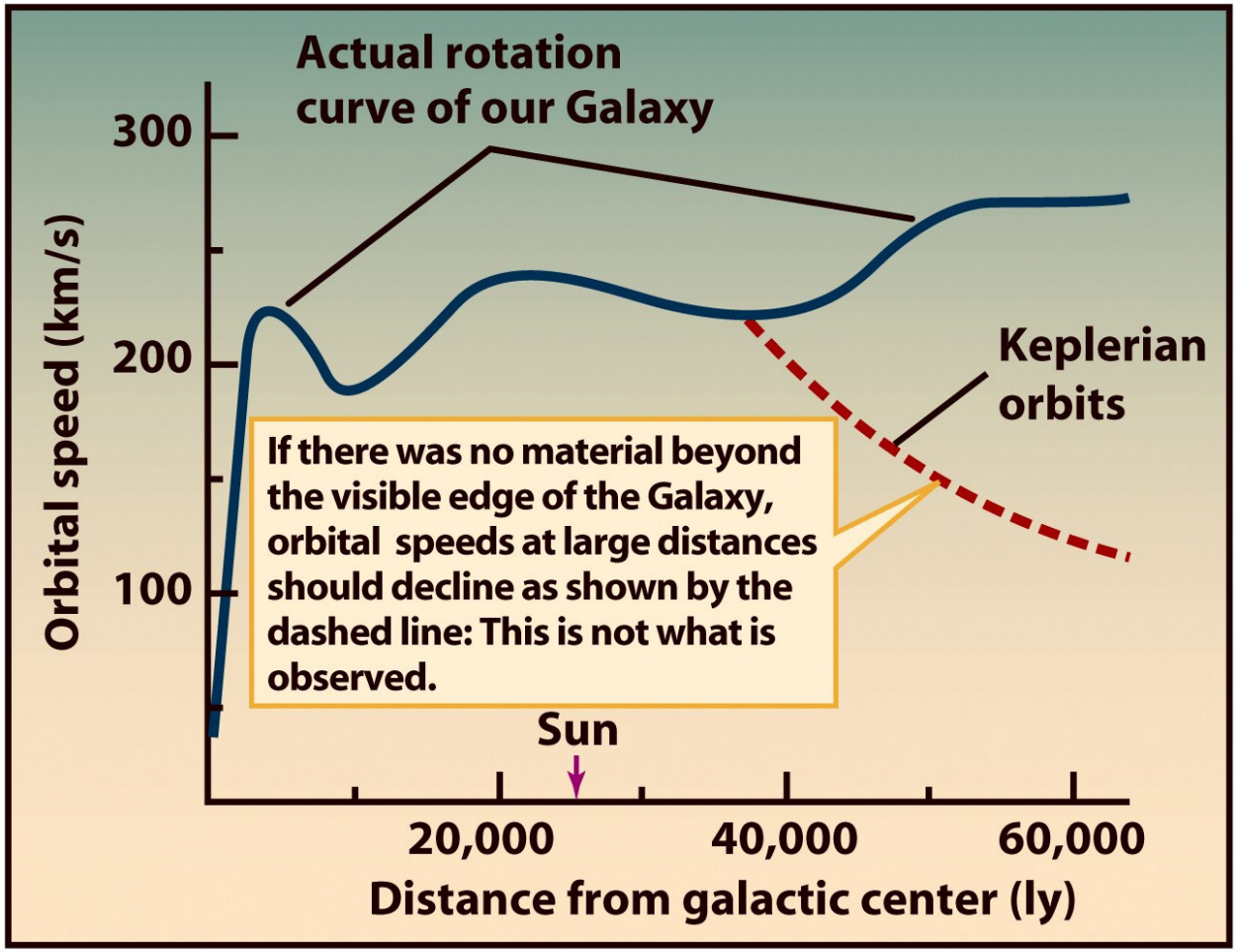

Figure 15-18
Discovering the Universe, Seventh Edition

Rotational curve → dark matter

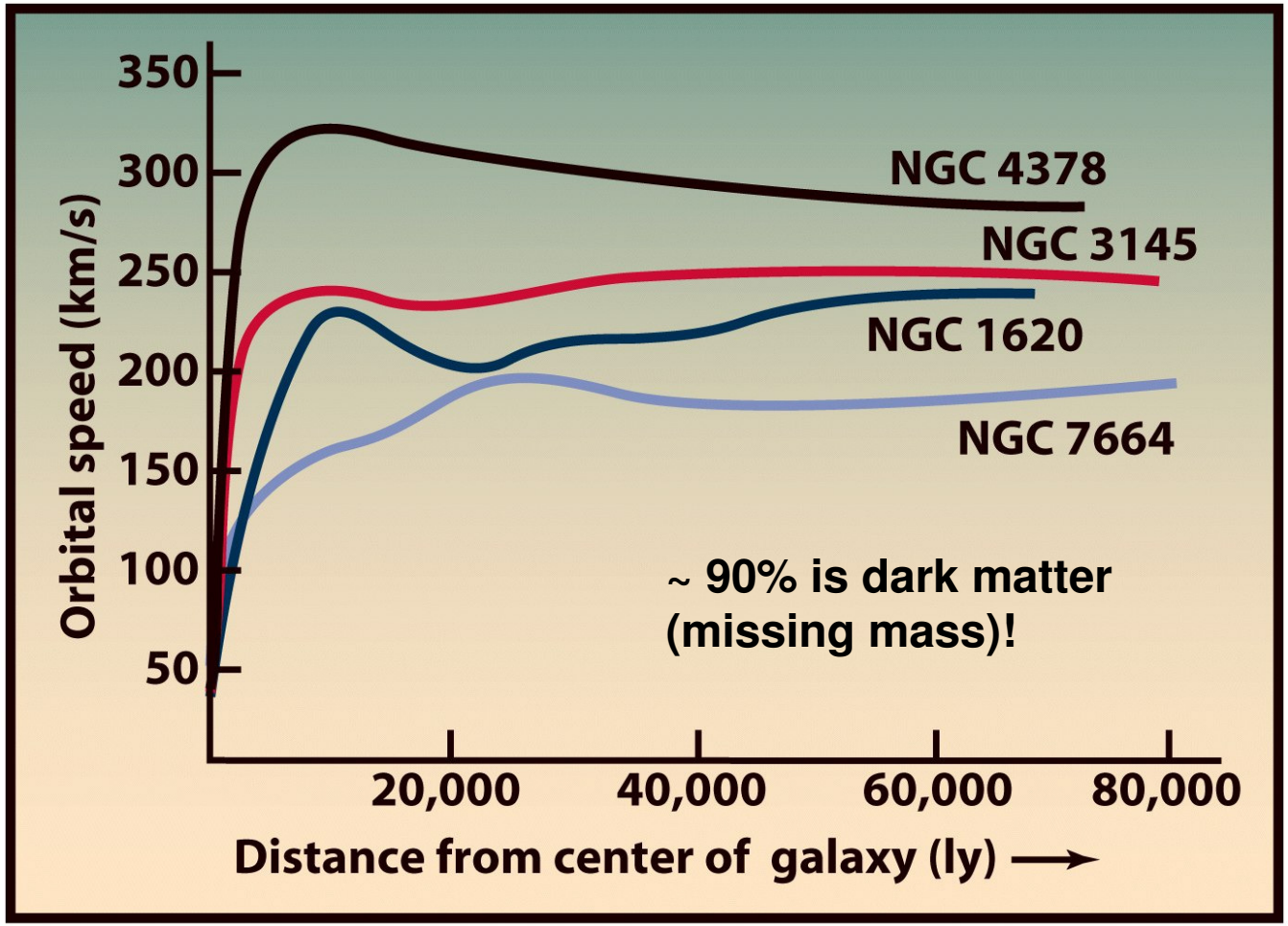

Figure 16-28
Discovering the Universe, Seventh Edition

Gravitational Microlensing (重力微透鏡)

1919 solar eclipse tested general relativity

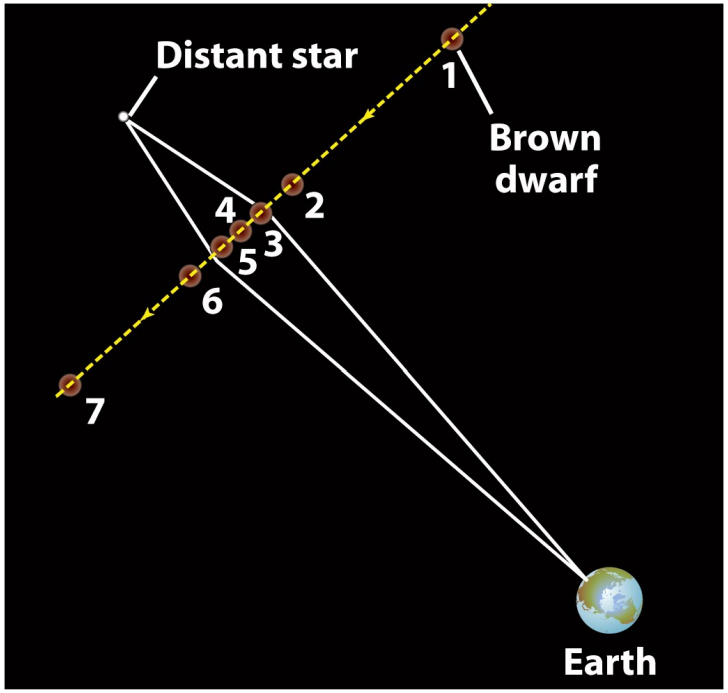

Figure 15-19a
Discovering the Universe, Seventh Edition

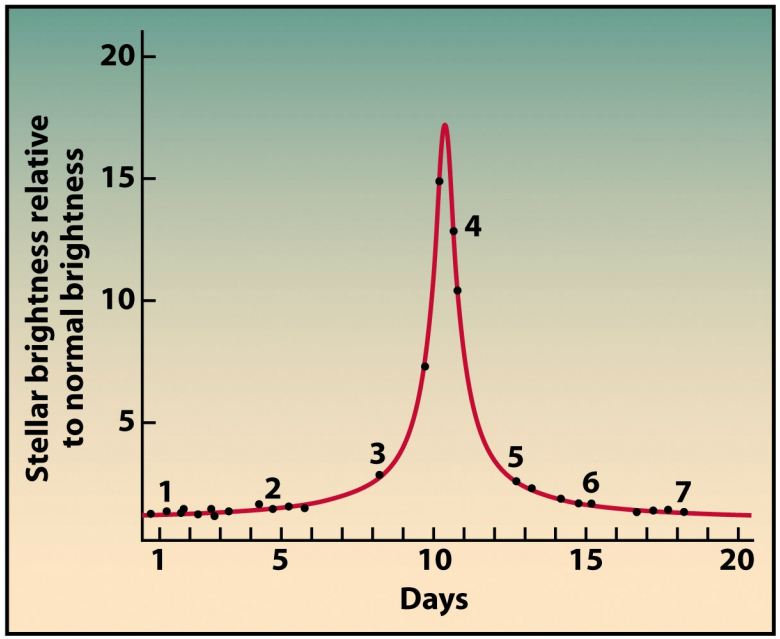

Figure 15-19b
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In the past, gravitational microlensing studies did not find substantial events to support that unseen small celestial bodies (such as low mass stars, brown dwarfs) are dark matters in the Milky Way.

The Local Group (本星系群)

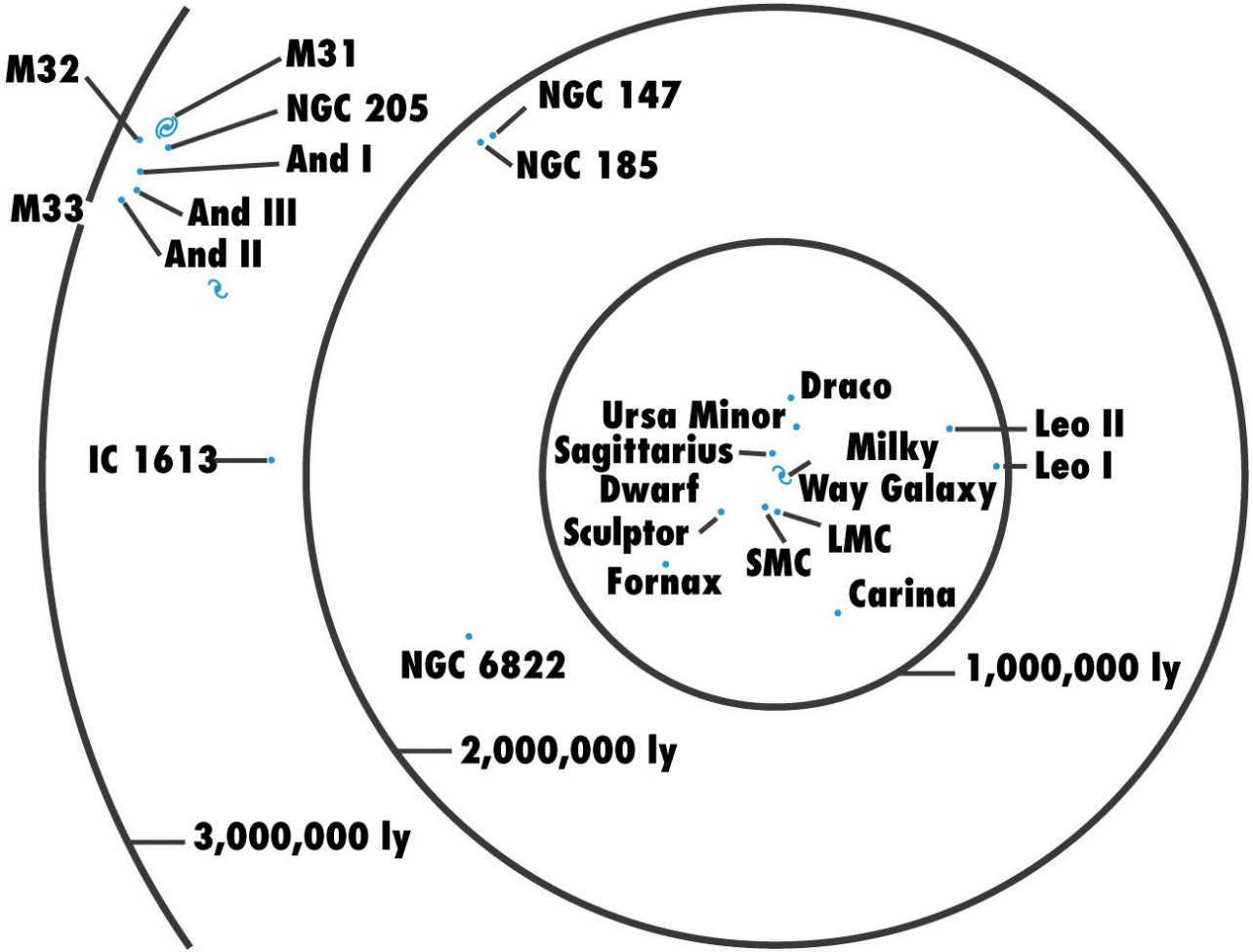

Figure 16-18
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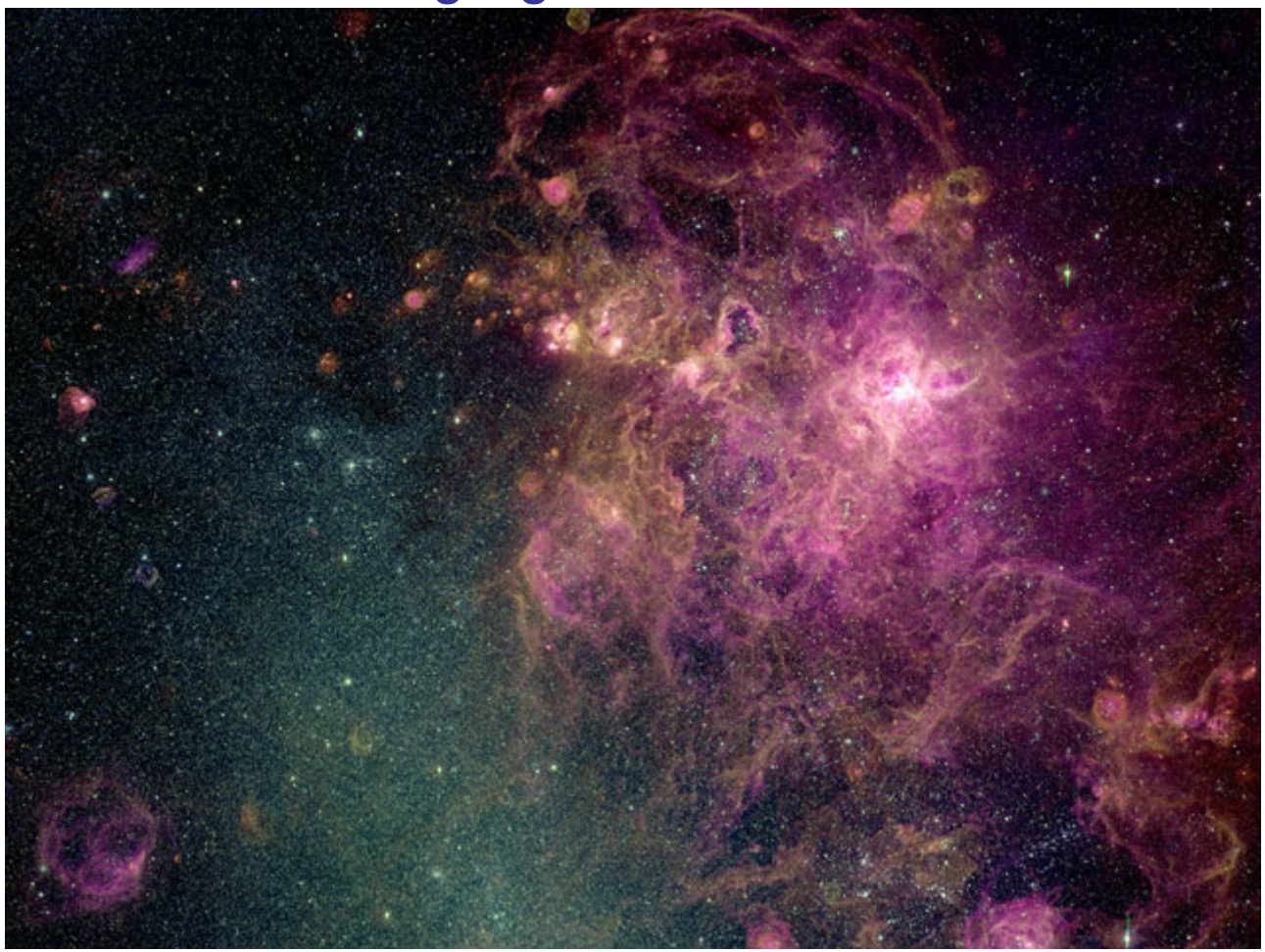
Large & Small Magellanic Clouds

Irregular galaxies

The Tarantula Nebula in LMC

Star forming region

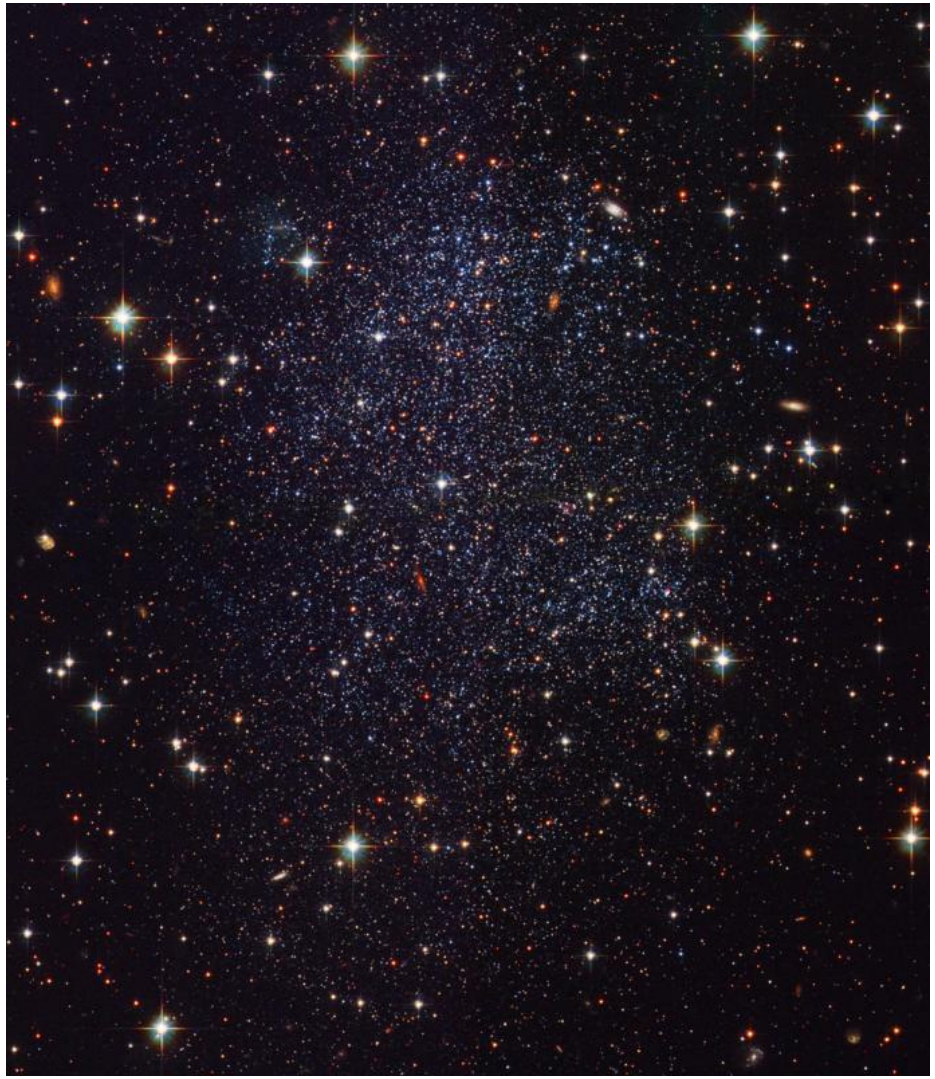


Sagittarius Dwarf Galaxy

Dwarf elliptical galaxy discovered in 1994

Closest known galaxy to the Milky way (80,000 ly away)

will be absorbed by The Milky Way



M 31 (Andromeda)仙女座大星系

Hubble's Tuning Fork Diagram

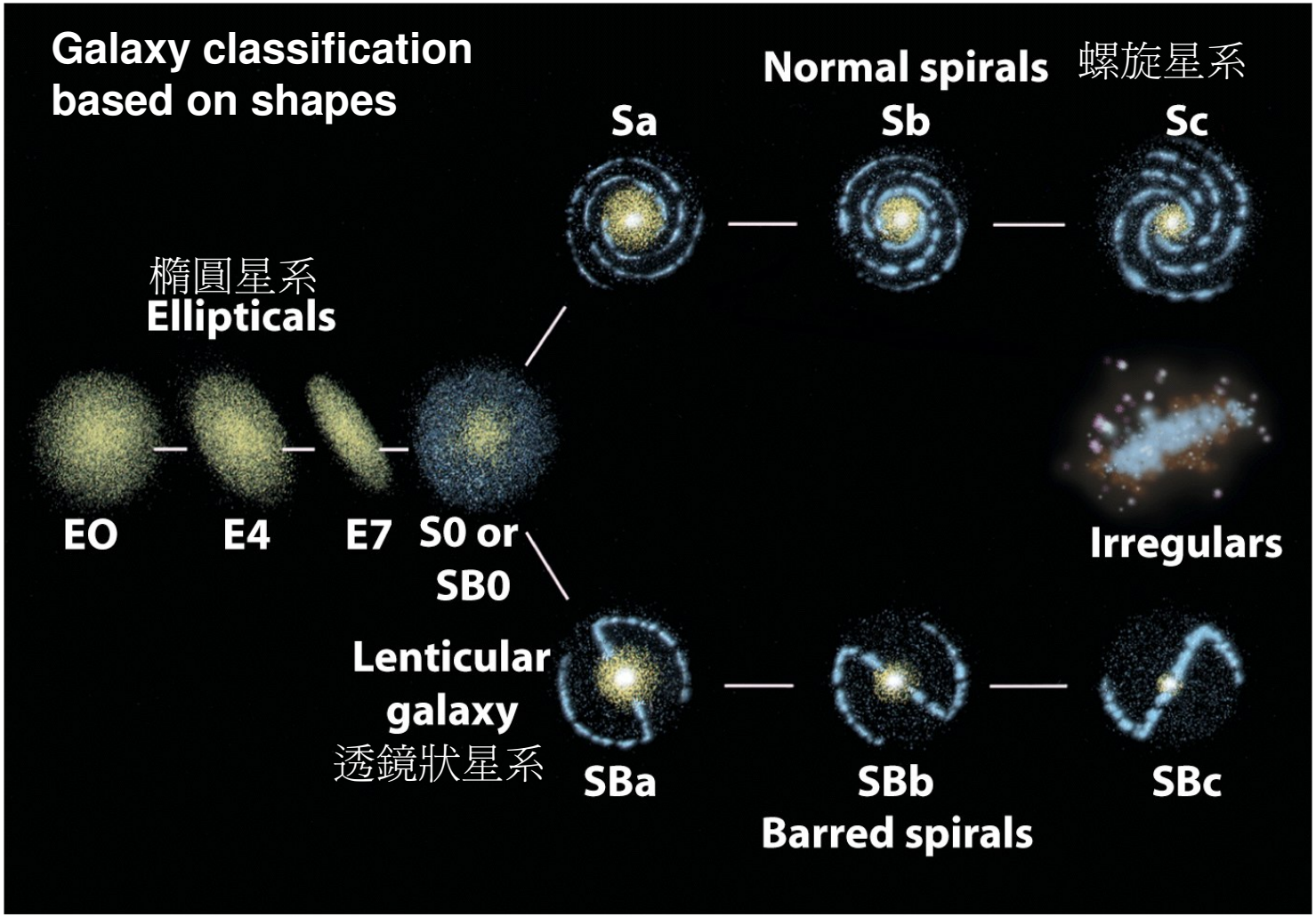


Figure 16-12
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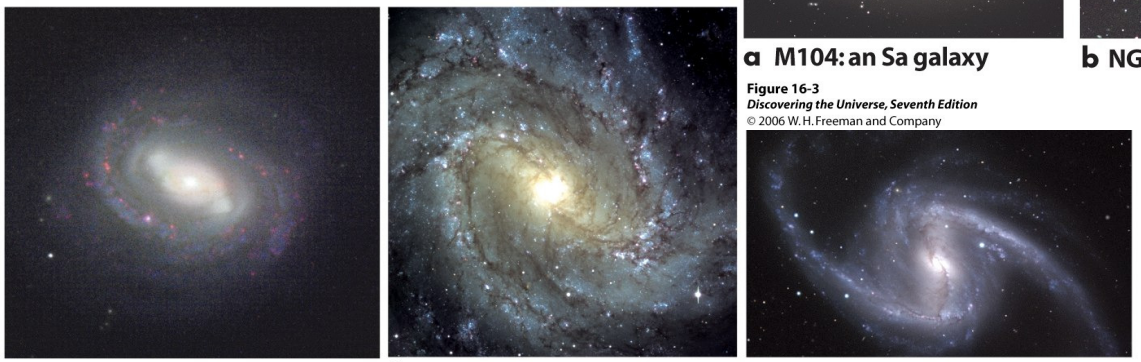
Morphology comparison

a M104: an Sa galaxy b NGC 891: an Sb galaxy c NGC 4631: an Sc galaxy

Figure 16-3
Discovering the Universe, Seventh Edition



a M58: an SBa galaxy b M83: an SBb galaxy c NGC 1365: an SBc galaxy

Figure 16-8
Discovering the Universe, Seventh Edition

a M105: an E0 galaxy b M49: an E4 galaxy c NGC 4526: an E7 galaxy

Figure 16-11
Discovering the Universe, Seventh Edition

Properties of “nearby” Galaxies

TABLE 16-1 Some Properties of Galaxies

	Spiral (S) and barred spiral (SB) galaxies	Elliptical galaxies (E)	Irregular galaxies (Irr)
Mass ($M_\odot$)	10^9 to 4×10^{11}	10^5 to 10^{13}	10^8 to 3×10^{10}
Luminosity ($L_\odot$)	10^8 to 2×10^{10}	3×10^5 to 10^{11}	10^7 to 10^9
Diameter (ly)	1.6×10^5 to 8×10^5	3×10^3 to 6.5×10^5	3×10^3 to 3×10^4
Stellar populations	disk: young Population I central bulge and halo: Population II and old Population I	Population II and old Population I	mostly Population I
Percentage of observed galaxies	77%	*20%	3%

*This percentage does not include dwarf elliptical galaxies that are as yet too dim and distant to detect. Hence, the actual percentage of galaxies that are ellipticals is likely to be higher than shown here.

Table 16-1
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Spiral galaxies: Winding Problem

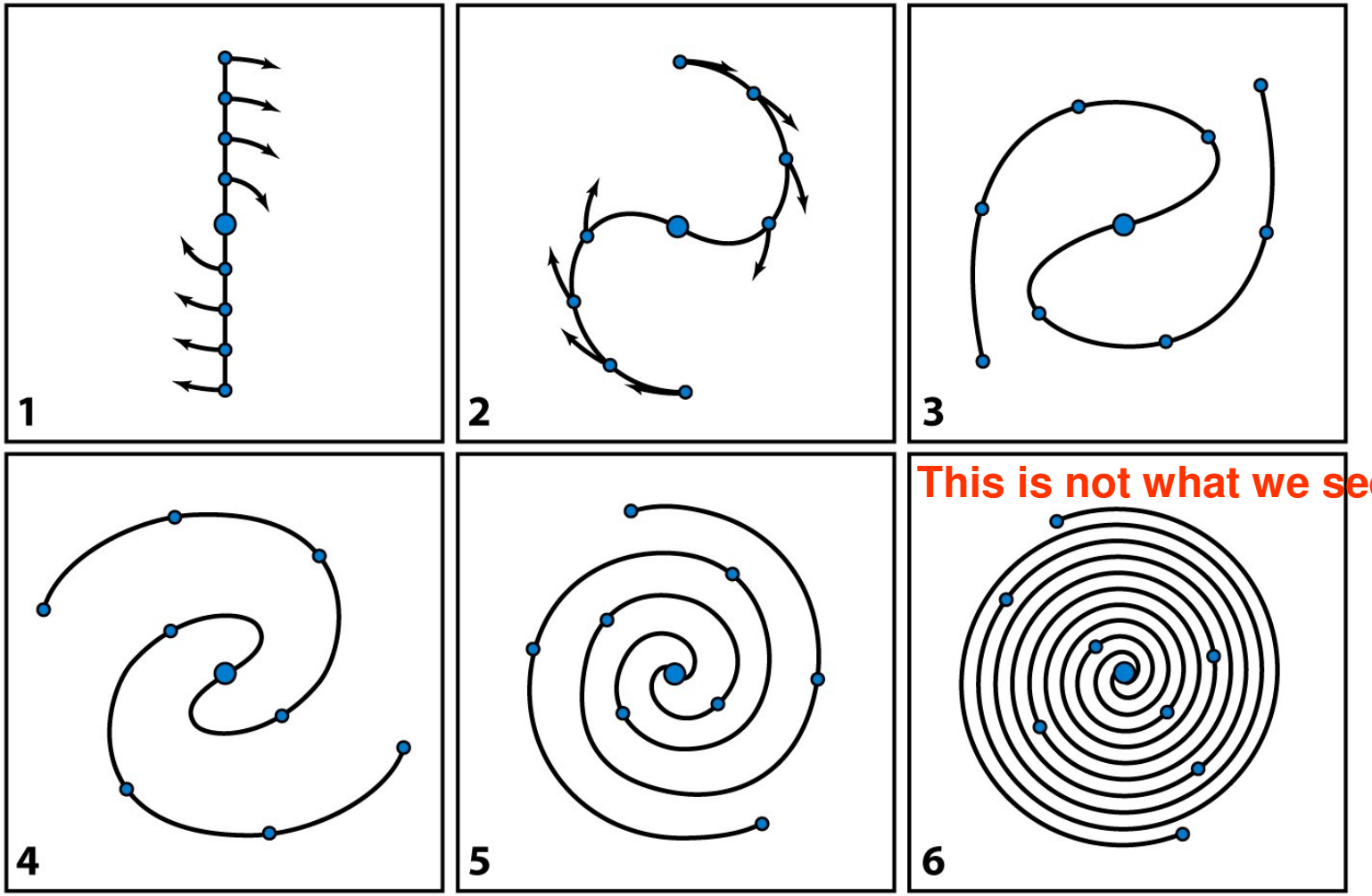

Figure 16-5
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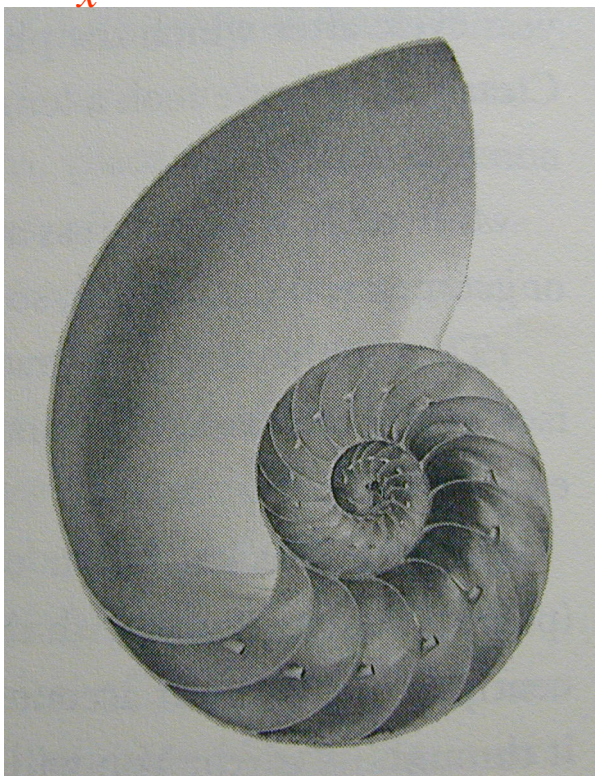
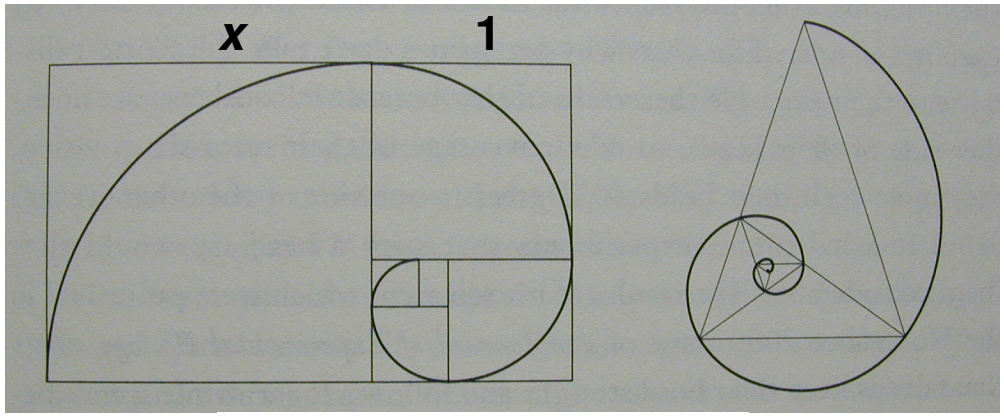
Logarithmic Spiral: Golden ratio

$$\frac{x}{1}=\frac{x+1}{x}\Rightarrow x=\sqrt{1+\sqrt{1+\sqrt{1+\sqrt{1+.....}}}}=1.6180339887...$$

Mario Livio: The Golden Ratio



nautilus (鸚鵡螺)



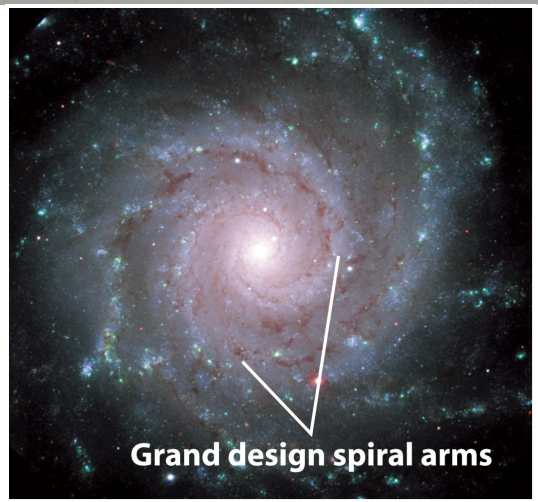


Figure 16-4b
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Active Galactic Nuclei (AGN)
活耀星系核

TABLE 17-1 Galaxy and Quasar Luminosities

Object	Luminosity (watts)	
Sun	4×10^{26}	
Milky Way Galaxy	10^{37}	
Seyfert galaxies	$10^{36} - 10^{38}$	AGN
Radio galaxies	$10^{36} - 10^{38}$	AGN
Quasars (quasi-stellar object/QSO) 類星體	$10^{38} - 10^{42}$	AGN

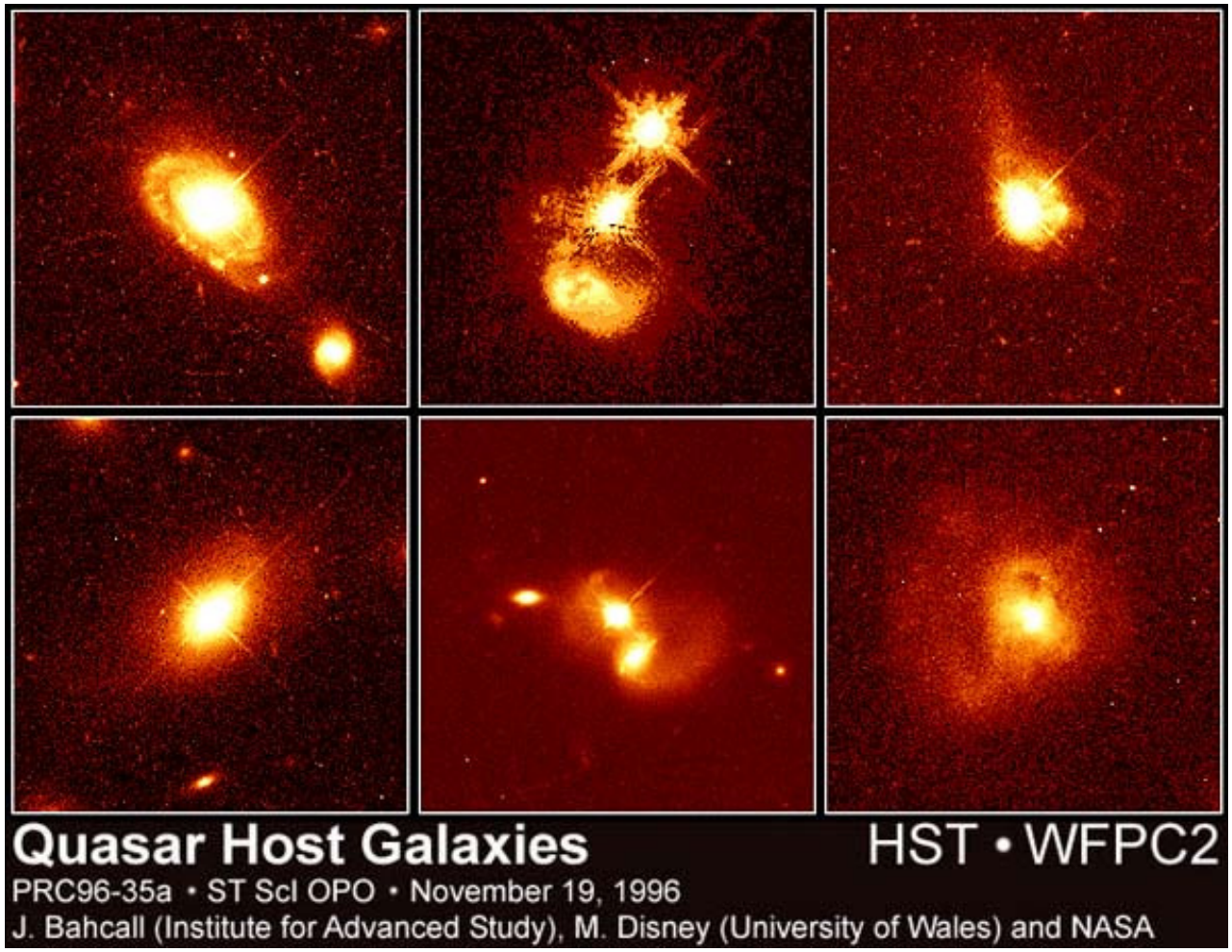
Table 17-1
Discovering the Universe, Seventh Edition

Probably almost all of galaxies host a supermassive black hole at their center.

Active Galactic Nuclei (AGN)

Quasar(QSO): AGN far from us

Galaxies Merge when the Universe is young



Active Galactic Nuclei (AGN)

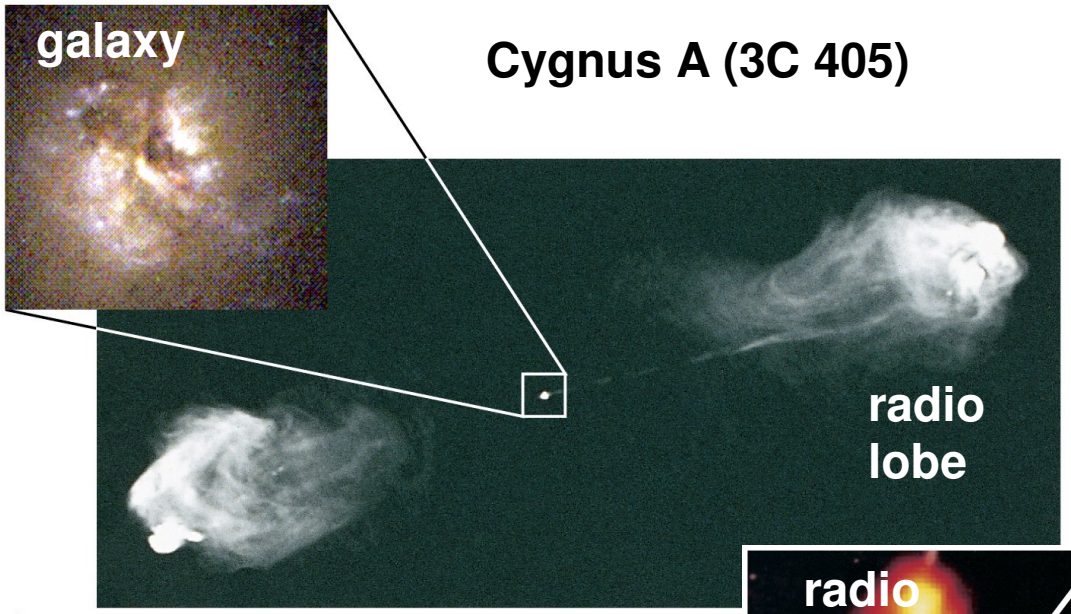


Figure 17-1
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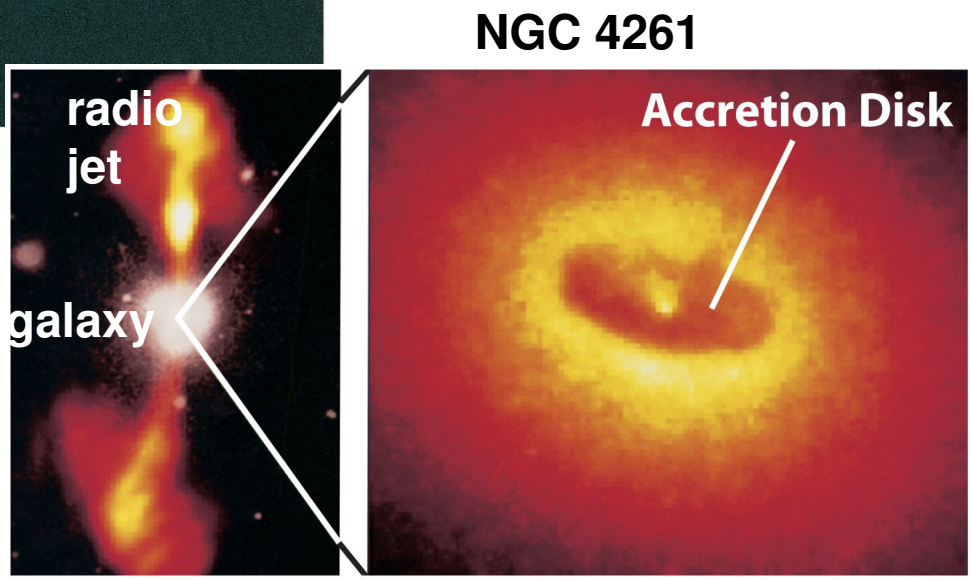

Figure 17-15b
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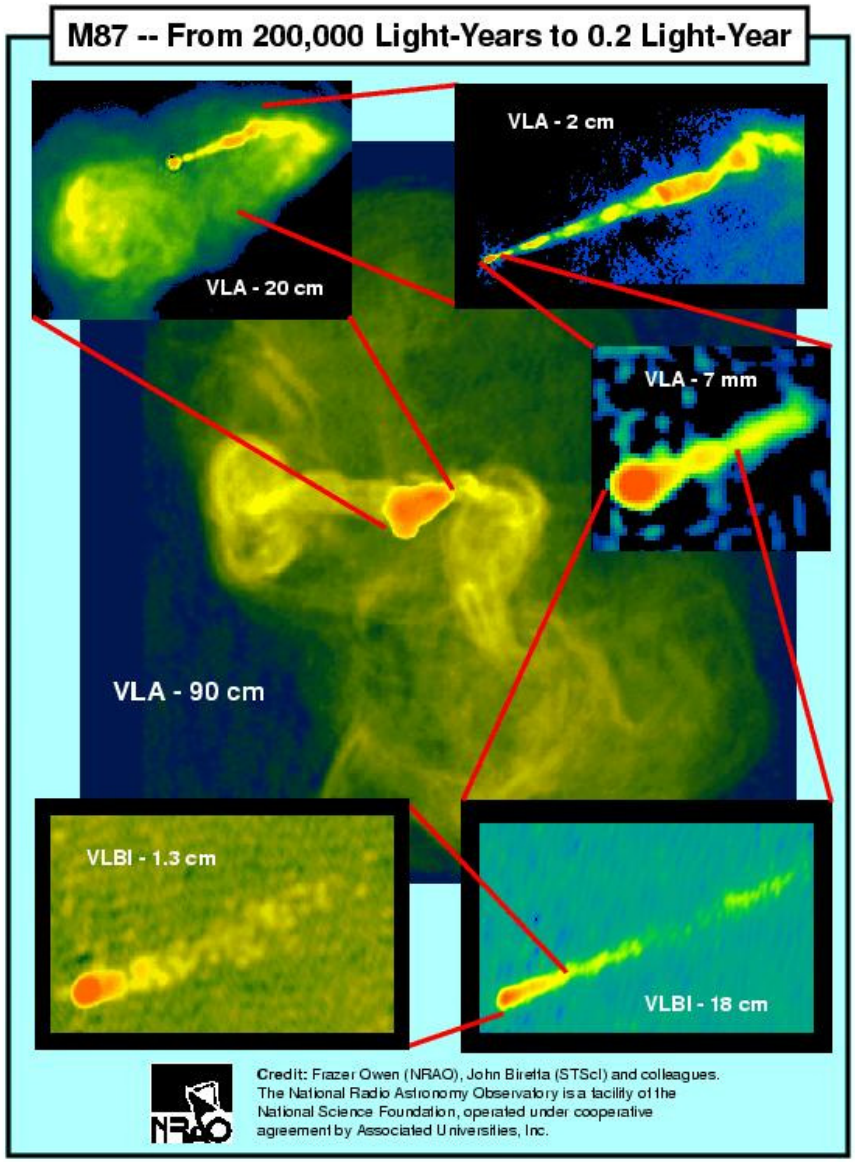
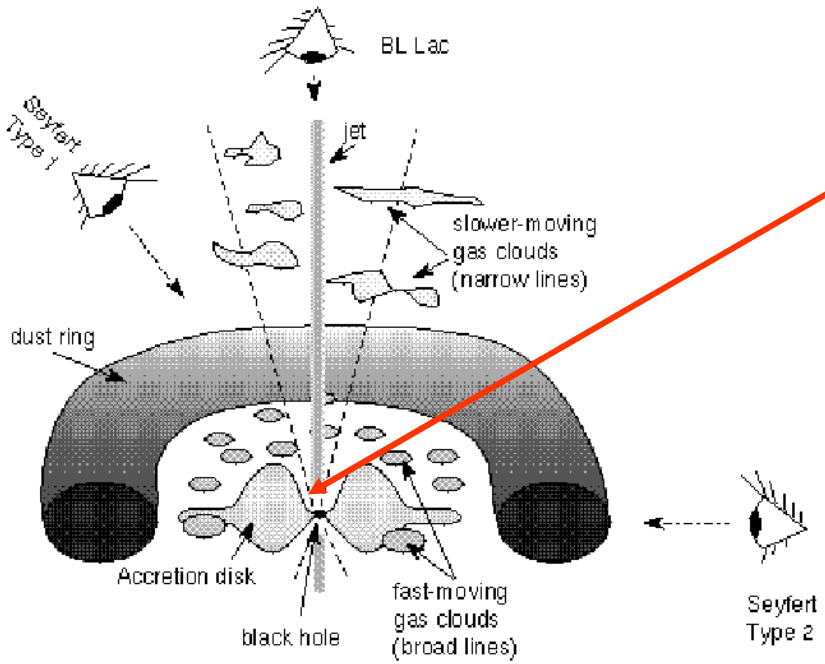
M87
(elliptical galaxy in Virgo Cluster)



Unified Model for all AGNs



Viewing angle of the accretion disk and dust ring determines the type of active galaxy we will see. For example: 30–60° above the disk, we can see the broad-line region: a Type 1 Seyfert, but edge-on, we see just the narrow-line region from clouds further away from black hole and the warm glow of the dust ring in the infrared: a Type 2 Seyfert.

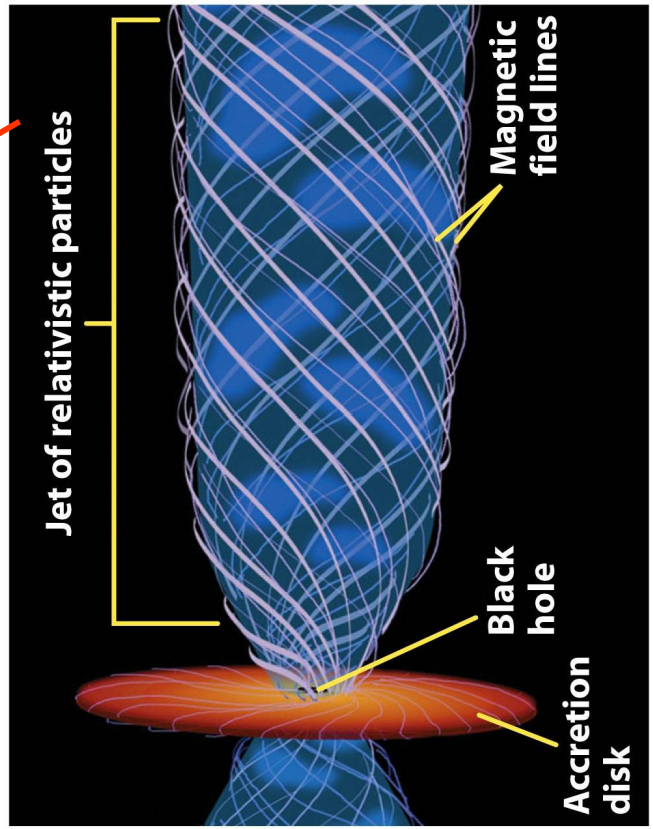


Figure 17-17
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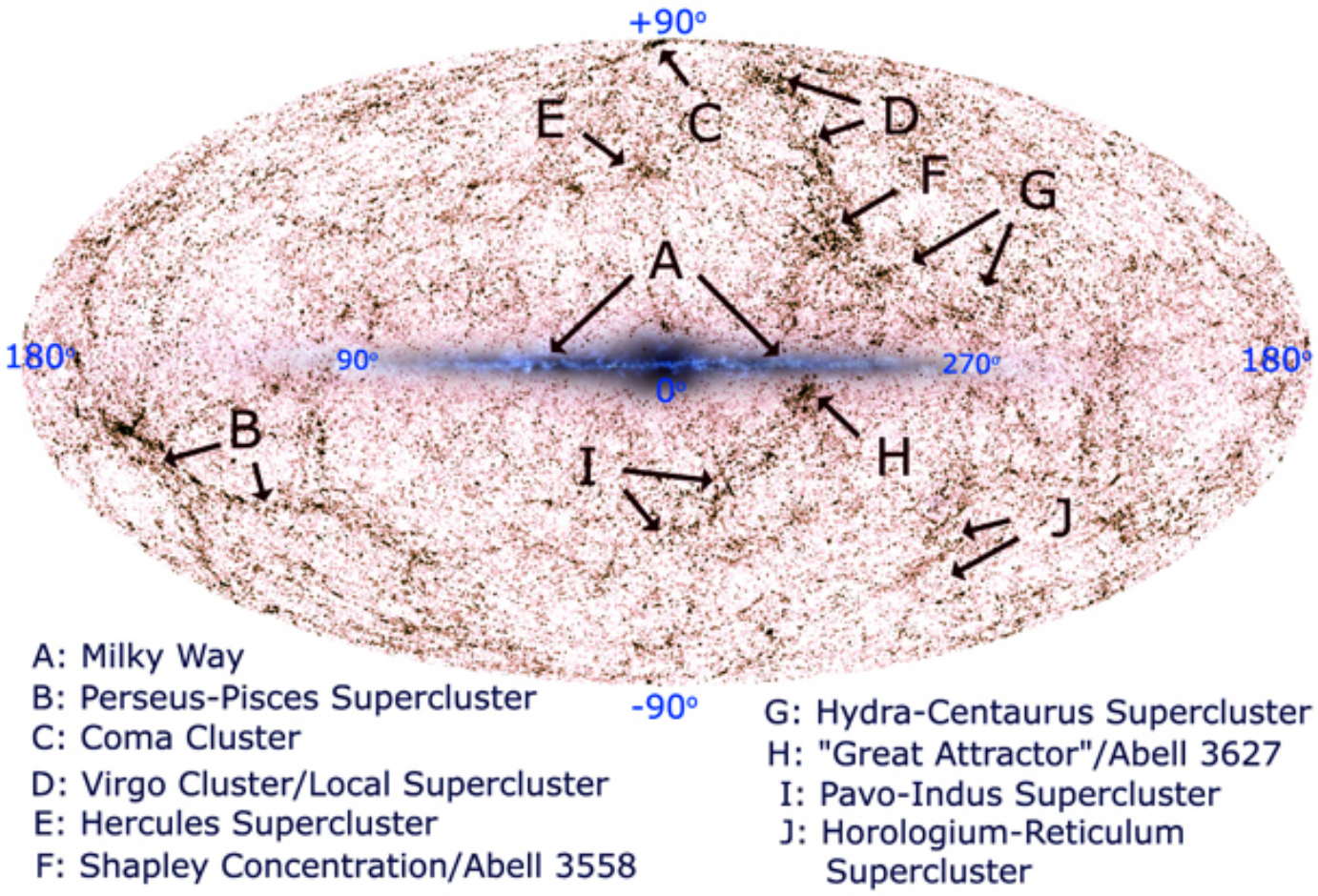
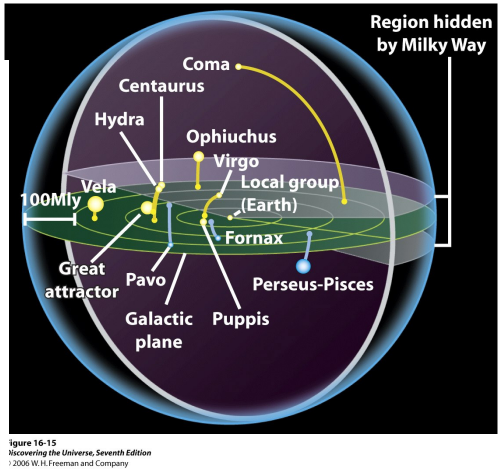
Clusters of galaxies (galaxy clusters) 星系團





Superclusters
Void

Motions of Sun, Milky Way, Local Group…

http://spider.ipac.caltech.edu/staff/jarrett/papers/LSS/

Clusters of galaxies

Hercules Cluster: 700 million ly away

Figure 16-21
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Interacting Galaxies

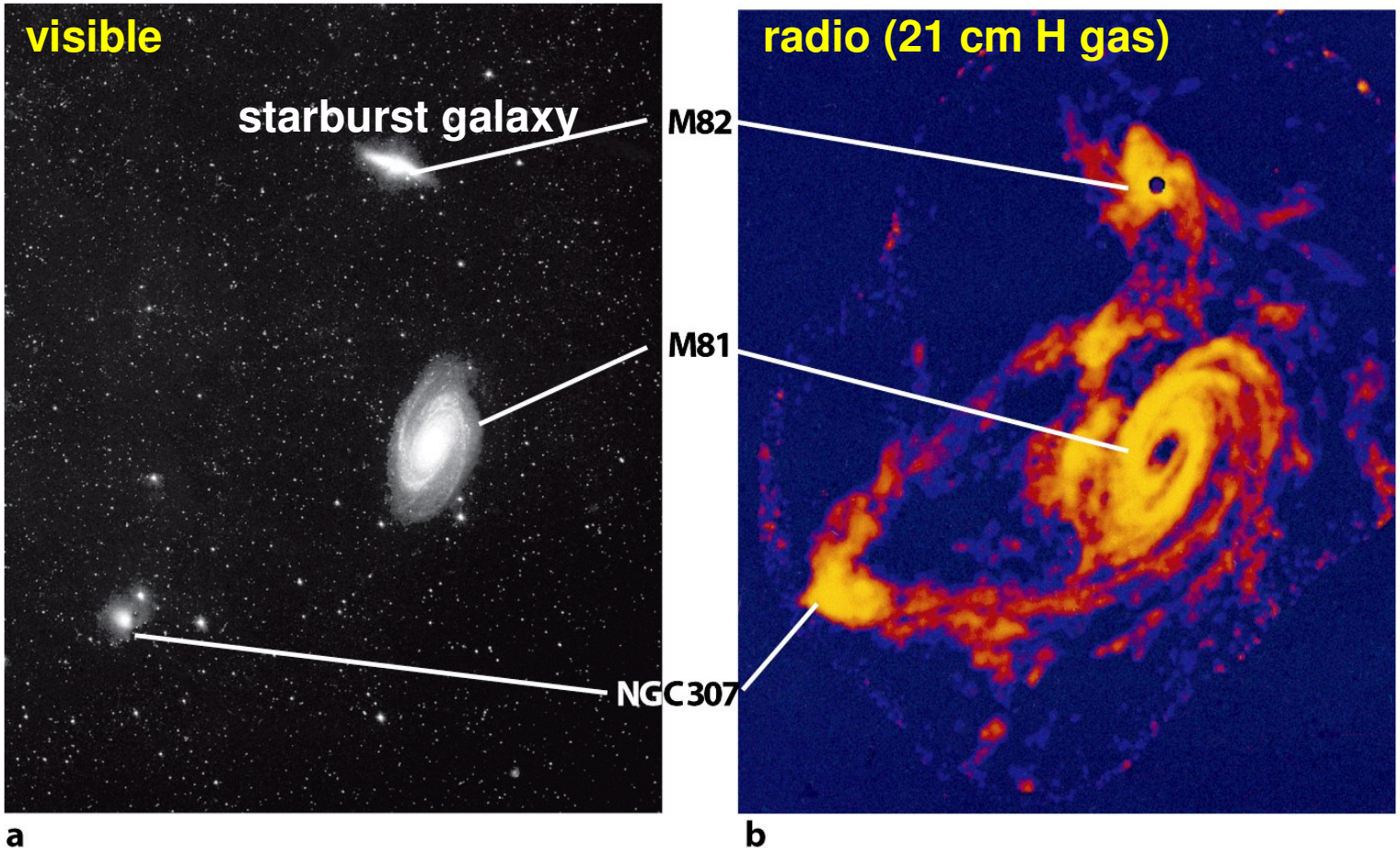

Figure 16-24
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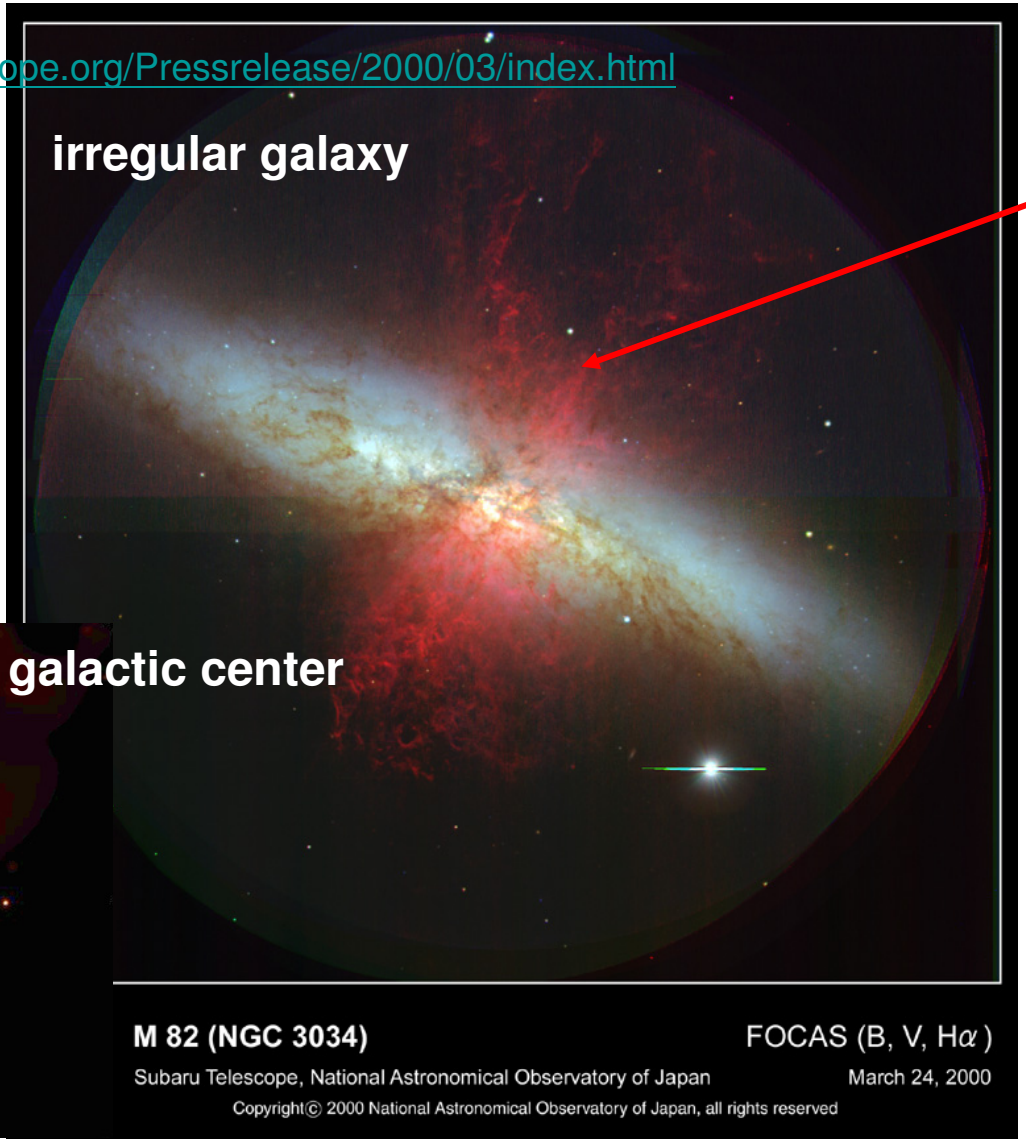
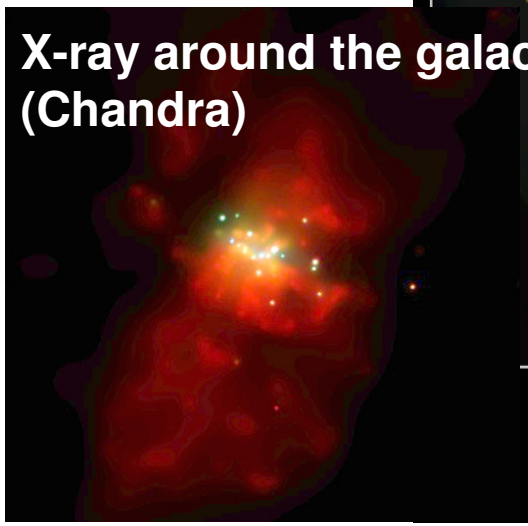
Starburst Galaxies

http://subarutelescope.org/Pressrelease/2000/03/index.html

very high light (IR processed by dusts) To mass ratio → burst of star formation



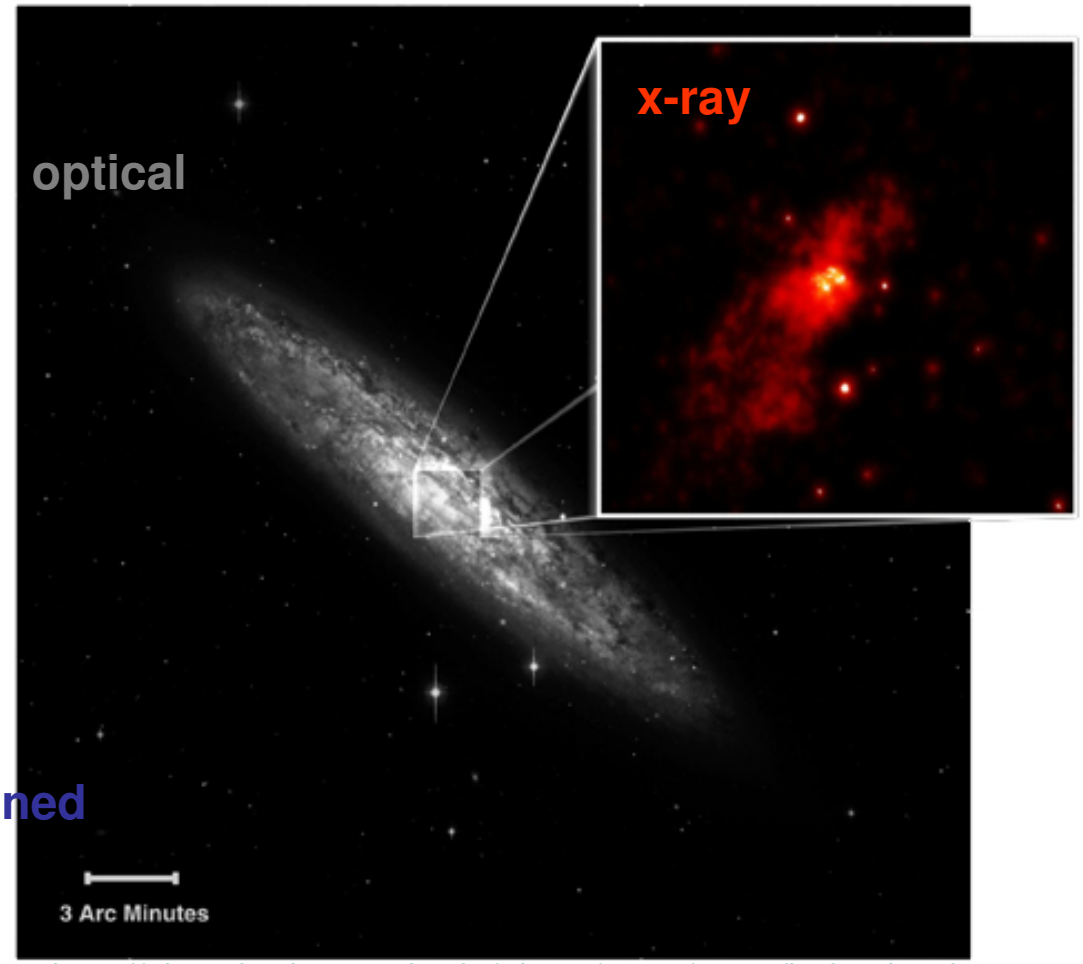
Outflow!
H α emission



Radio telescope found H2 also flowing out of the nucleus of M82.
The outflow is driven by massive stars (starburst) & supernova remnants.

Another starburst galaxy

NGC 253: 8 million light years away in constellation Sculptor

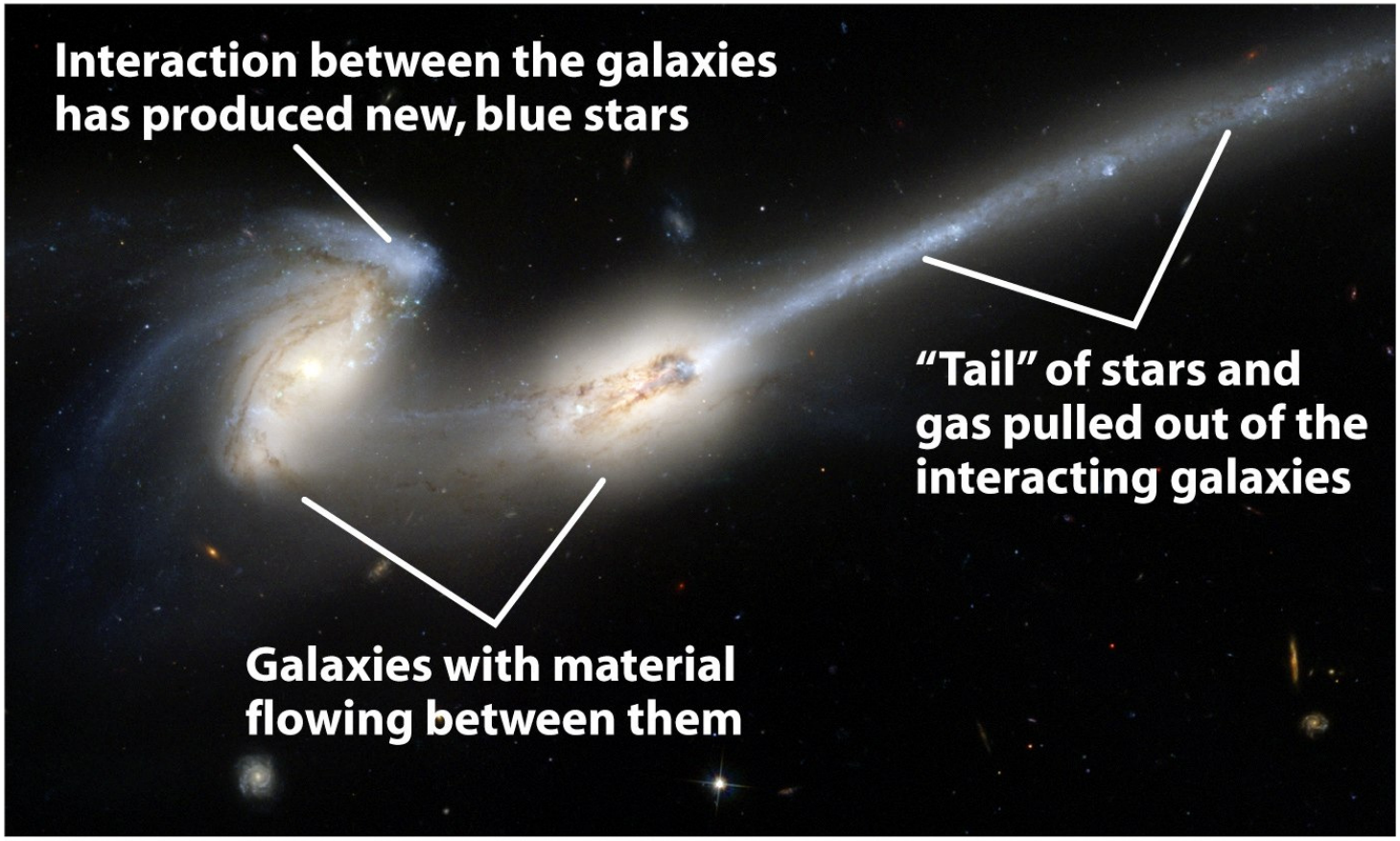


No neighboring galaxies to drive starbust, but an interaction may have happened a long time ago

x-ray might be driven by the interaction between the outflow and the ambient gas.

http://chandra.harvard.edu/photo/2001/0012/index.html

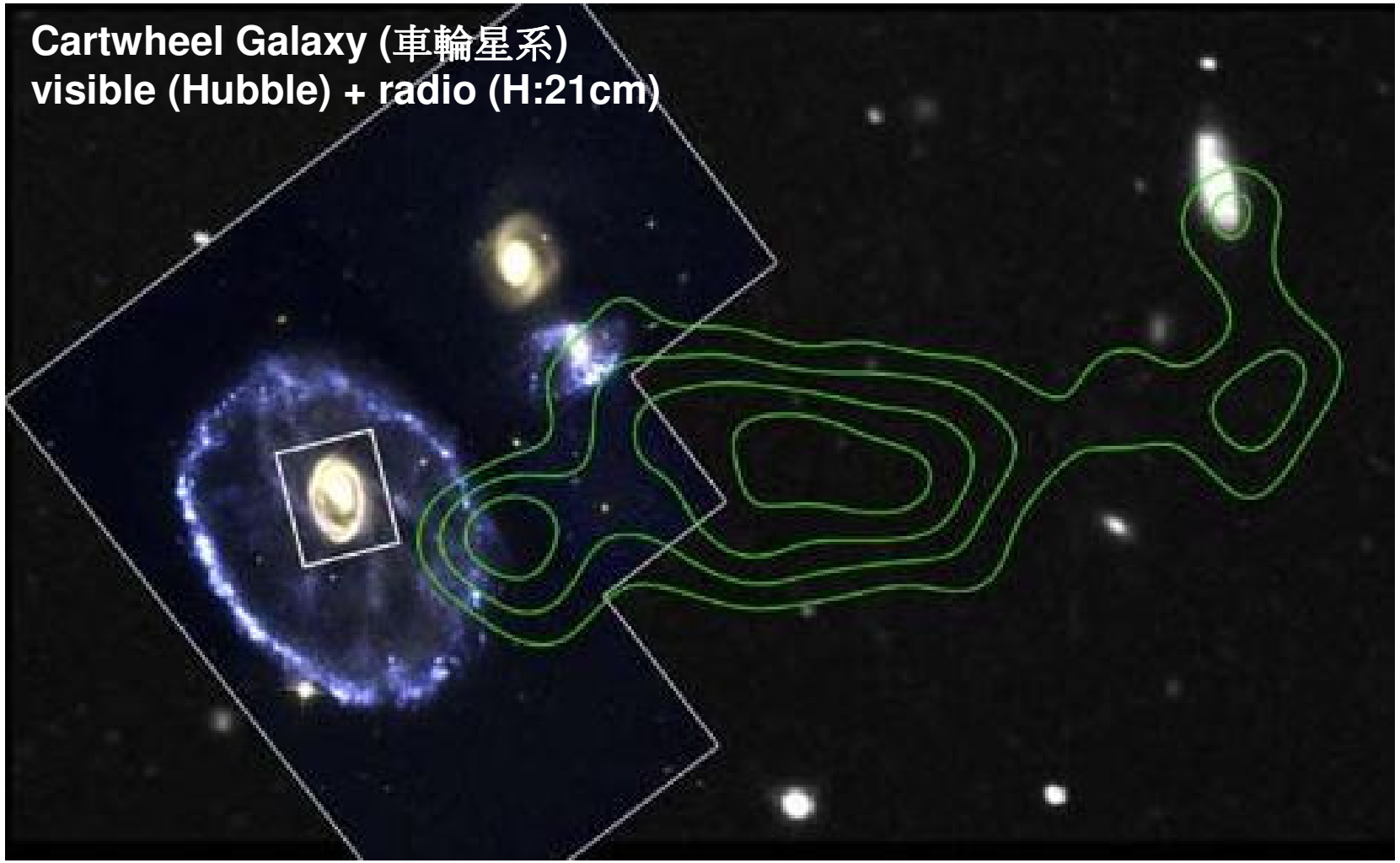
Interacting Galaxies



NGC 4676

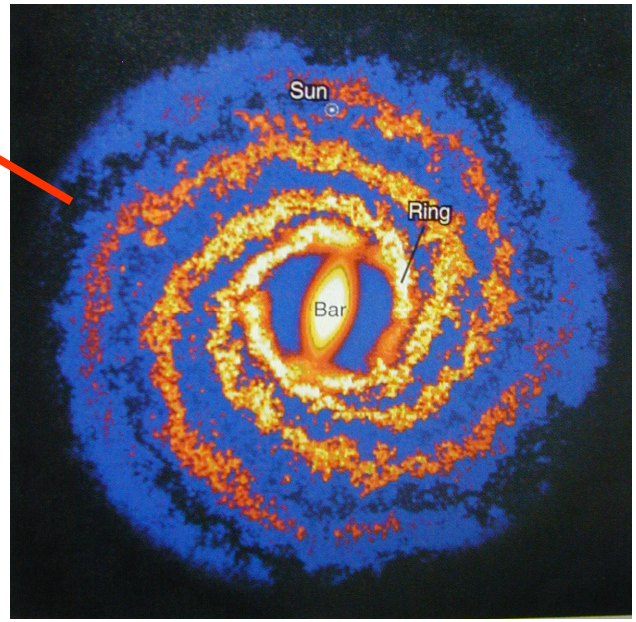
Figure 16-25a
Discovering the Universe, Seventh Edition

Interacting Galaxies



http://www.phys.ncku.edu.tw/~astrolab/mirrors/apod/ap970224.html

M 31 & the Milky Way will collide



Note that the chance of direct collisions between stars should be low during galaxy collision. Here we are talking about gravitational interaction.

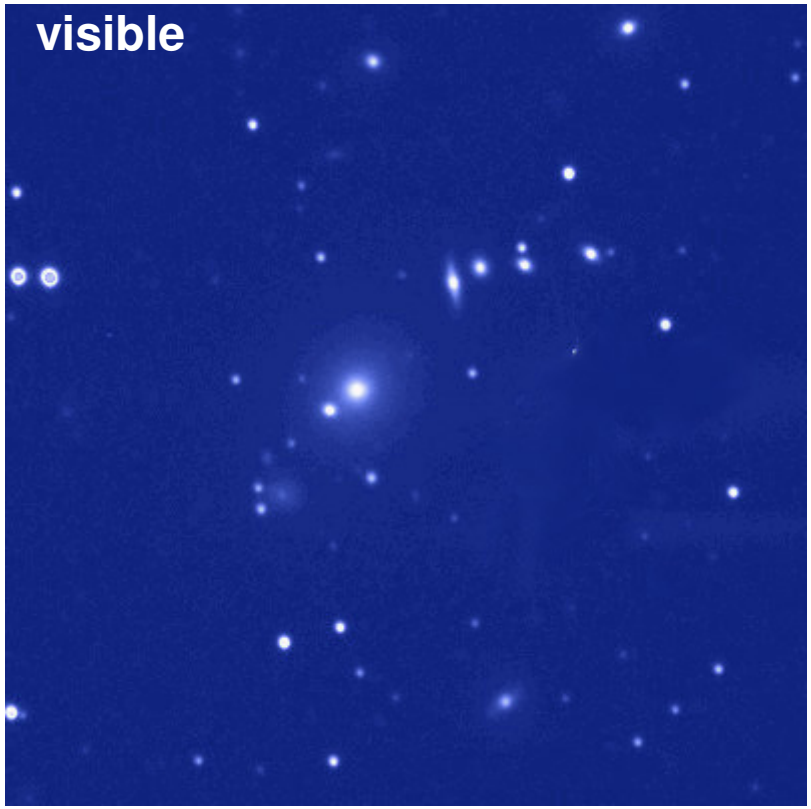
Content of a cluster of galaxies

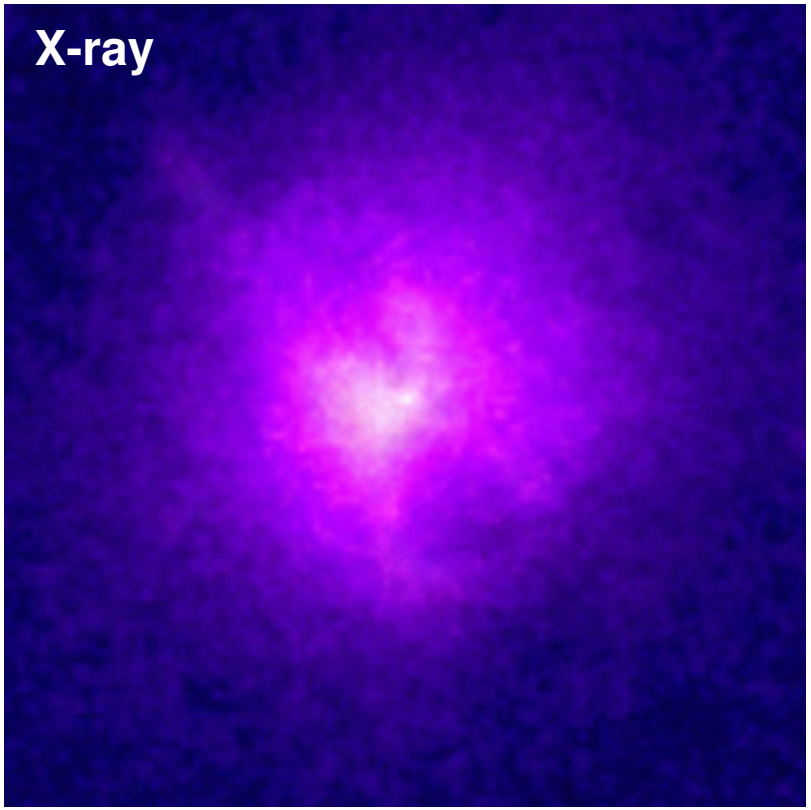
- Large and dwarf galaxies, and sometimes a massive elliptical galaxy (cD galaxy) at the center
- very hot intergalactic gas ($T \sim 10^7 K$ → X-ray emission): how to maintain the high temperature?
- Dark matter (velocity dispersion of galaxies; gravitational lensing)

Hydra A: a galaxy cluster (長蛇座星系團)

840 million light years away (z=0.054)

X-ray → most of matter is dark matter (recall 水星與泰坦的考題)

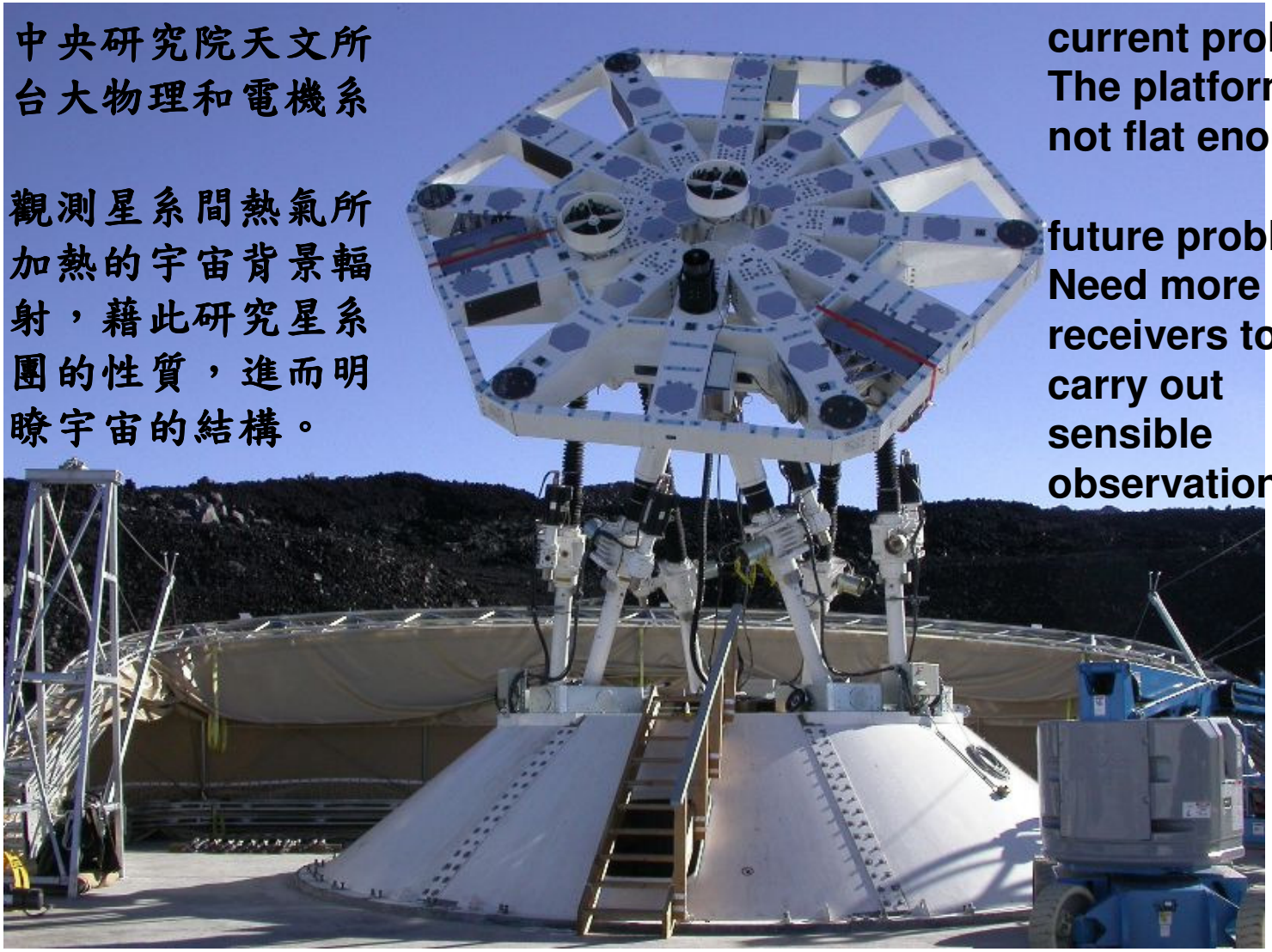




http://chandra.harvard.edu/photo/0087/index.html

李遠哲陣列(AMiBA):位於Mauna Loa

http://www.asiaa.sinica.edu.tw/news/newspaper/AMiBAdedication/amiba_news_release_ch-AS.pdf



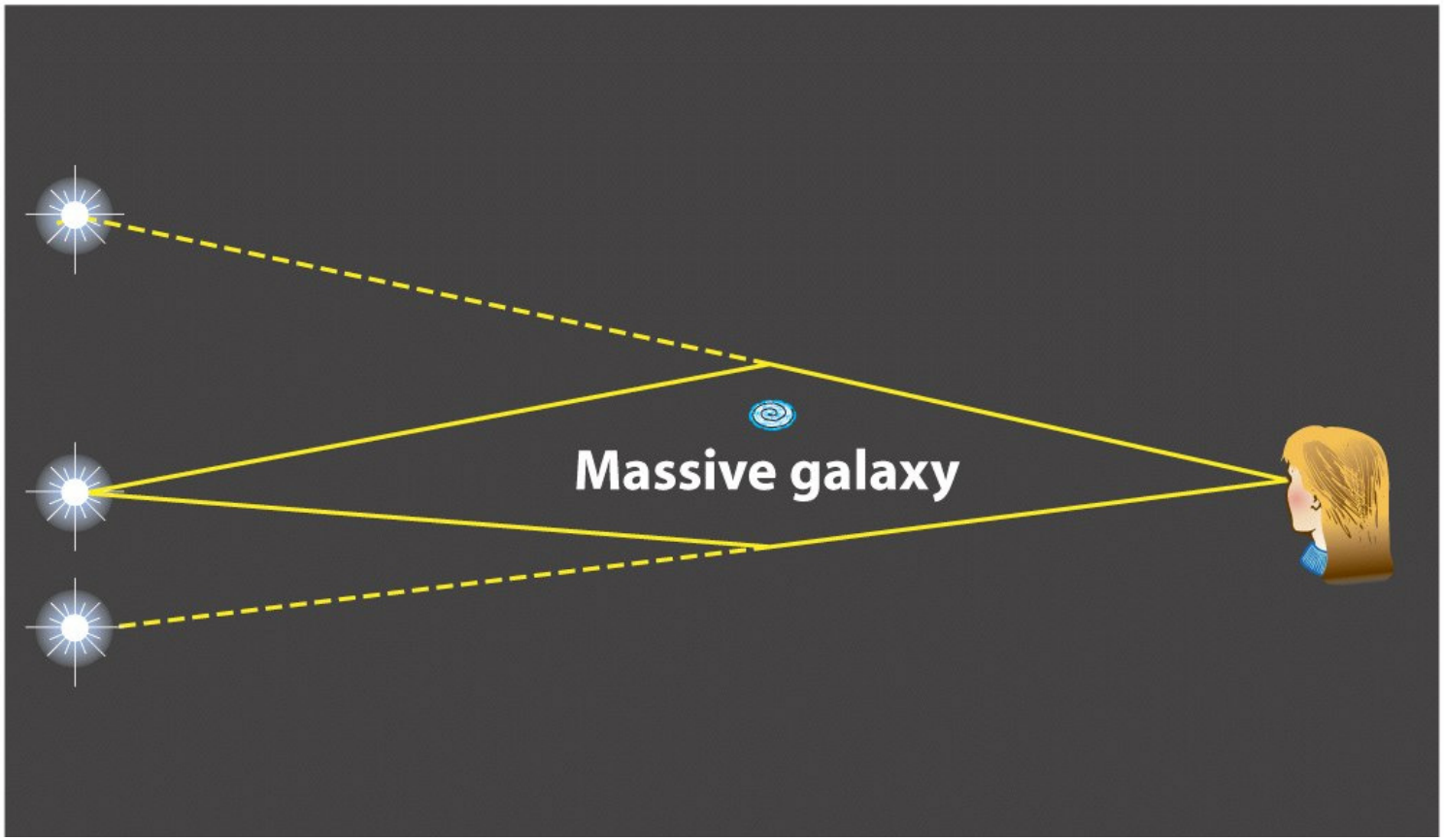
中央研究院天文所
台大物理和電機系

觀測星系間熱氣所加熱的宇宙背景輻射，藉此研究星系團的性質，進而明瞭宇宙的結構。

current problem: The platform is not flat enough.

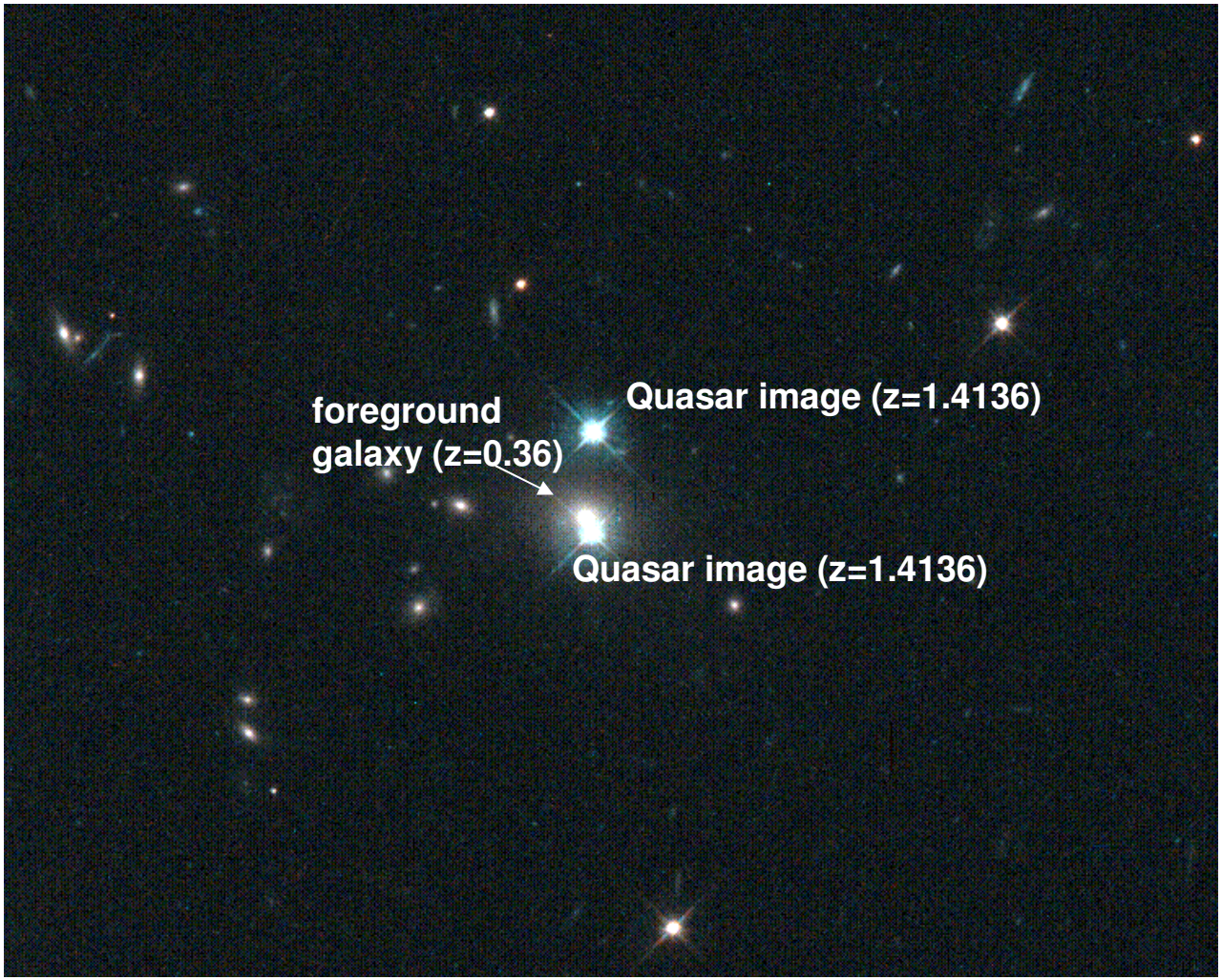
future problem: Need more receivers to carry out sensible observations

Gravitational lensing (重力透鏡)



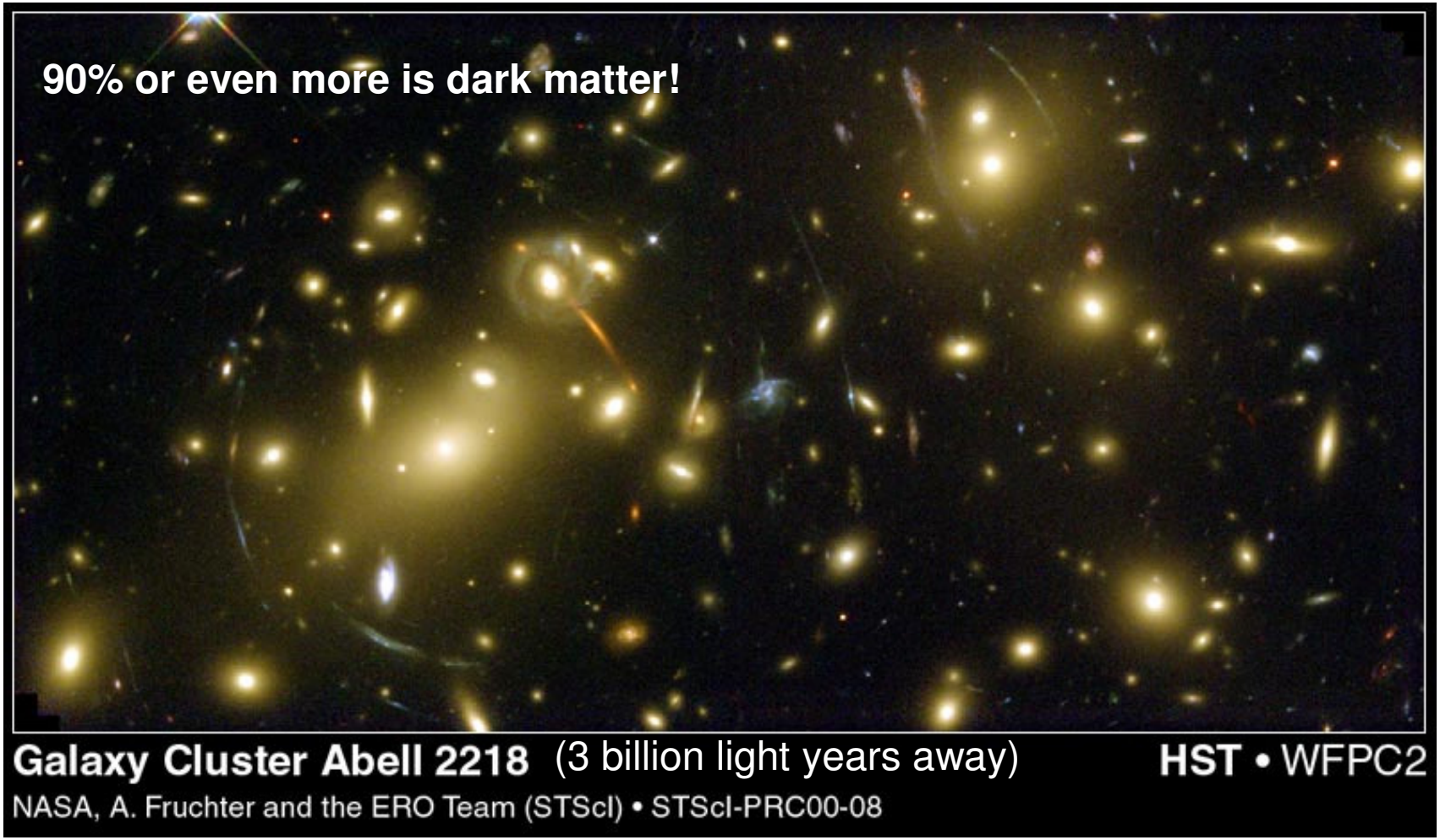
c.f. gravitational microlensing (重力微透鏡)

Quasar Q0957+561



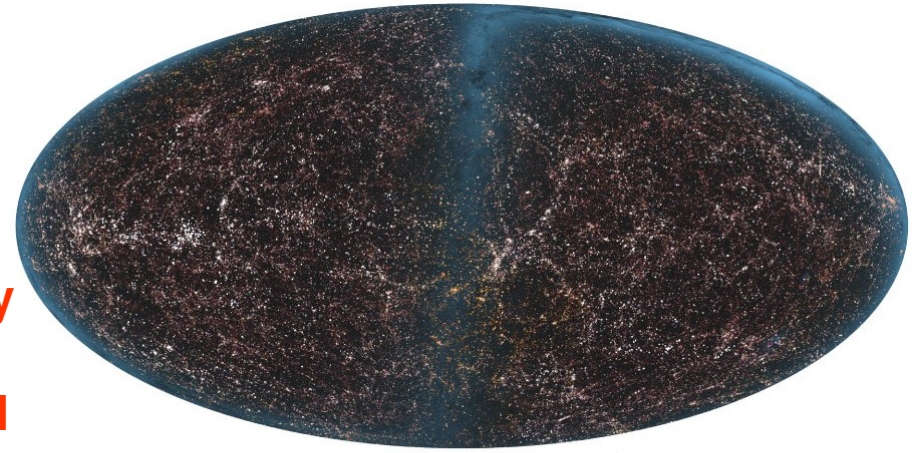
http://www.astr.ua.edu/keel/agn/q0957.html

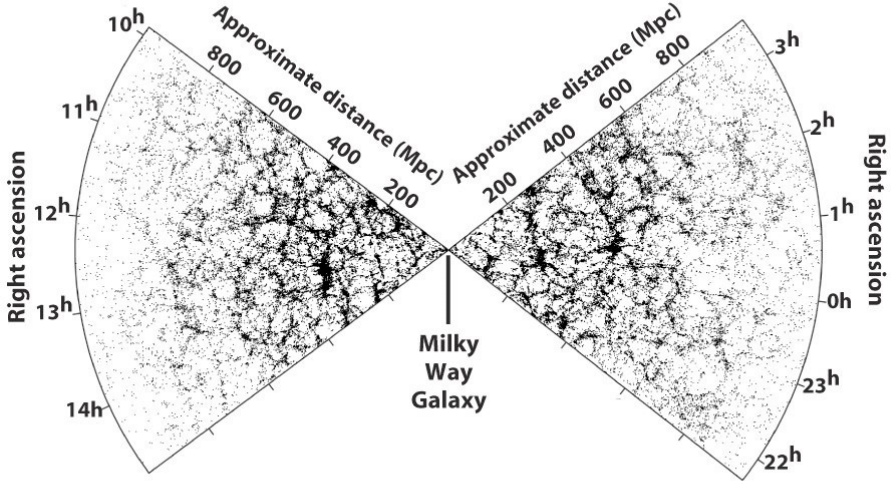
A galaxy cluster is a lens!



Large-scale structure

filamentary structure: wall & void





The 2dF galaxy survey

Figure 16-16
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