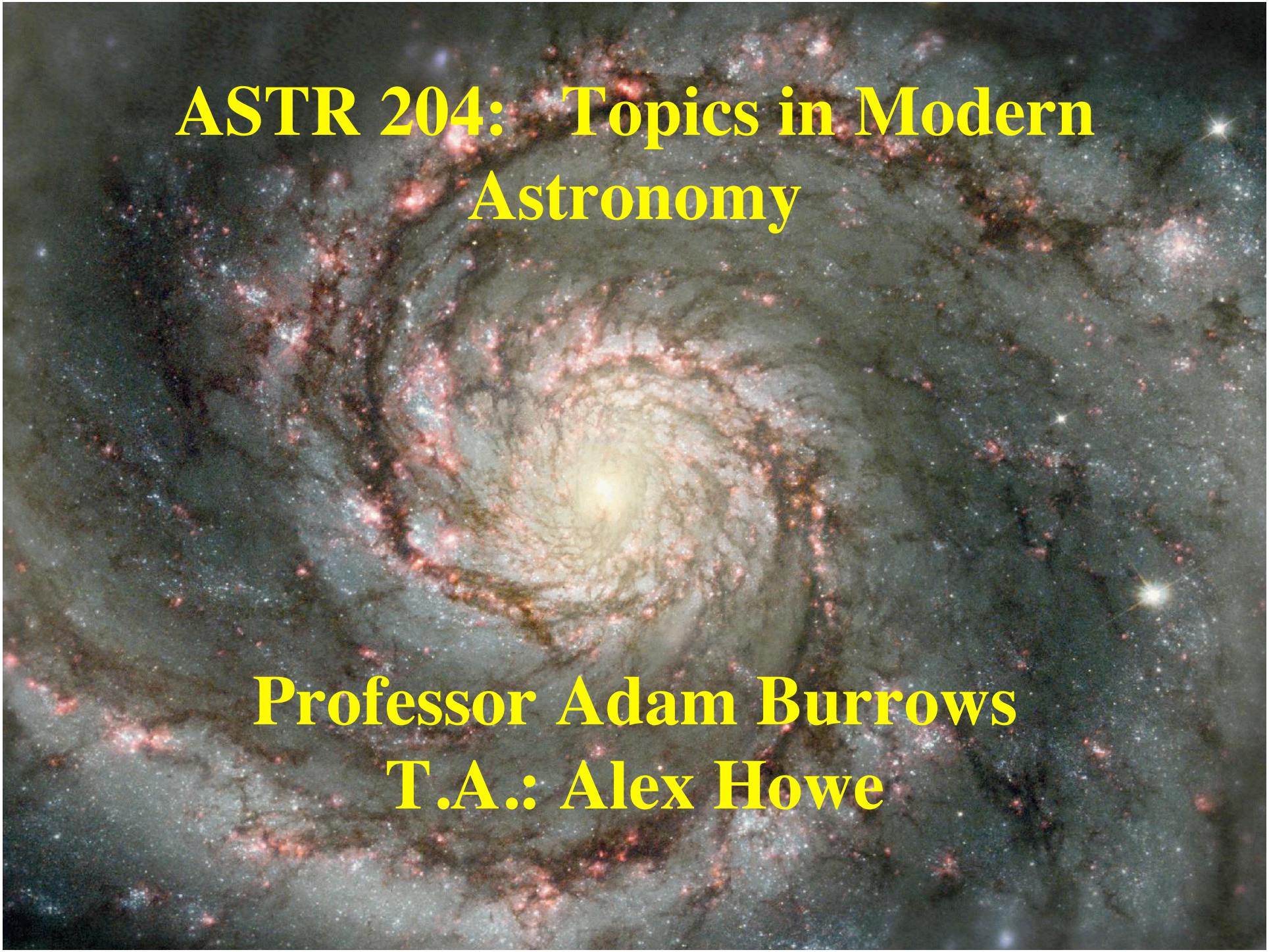

ASTR 204: Topics in Modern Astronomy
Professor Adam Burrows
T.A.: Alex Howe

Astrophysics 204 (Approximate) Schedule: Spring 2012

H = Homework Due

Date	Lecturer	Homeworks	Description and Chapter Reading Assignments (due dates)
Feb 6	AB		Introduction and Requirements; Scales and Brief Tour of the Universe
Feb 8	AB		Orbital Mechanics (Chapter 3)
Feb 13	AB		The Earth-Moon System (Chapter 4)
Feb 15	AB	H1	The Interaction of Radiation and Matter (Chapter 5)
Feb 20	AB		
Feb 22	AB	H2	Astronomical Detection of Light (Telescopes, etc.) (Chapter 6)
Feb 27	AB		The Sun (Chapter 7)
Feb 29	AB	H3	Overview of the Solar System (Chapter 8)
Mar 5	AB		Earth and Moon (Chapter 9)
Mar 7	AB	H4	The Planets (Chapter 10)
			Midterm Week
Mar 12	AB		The Solar System in Perspective (Chapter 12)
Mar 14	AB		MIDTERM
			Spring Recess Mar 17-25
Mar 26	AB		Properties of Stars (Chapter 13)
Mar 28	AB	H5	Stellar Atmospheres (Chapter 14)
Apr 2	AB		Stellar Interiors (Chapter 15)
Apr 4	AB	H6	Stellar Remnants (Chapter 18)
Apr 9	AB		The Interstellar Medium (Chapter 16)
Apr 11	AB	H7	Formation and Evolution of Stars (Chapter 17)
Apr 16	AB		Our Galaxy (Chapter 19)
Apr 18	AB	H8	Galaxies (Chapter 20)
Apr 23	AB		Clusters and Superclusters (Chapter 22)
Apr 25	AB	H9	Cosmology (Chapter 23)
Apr 30	AB		History of the Universe (Chapter 24)
May 1	AB	H10	
			Reading Period May 7-15
May 7			
May 9	AB		Review
May 14	AB		Review
			Exam Period May 16-26
May 16			Extra Review

http://www.astro.princeton.edu/~burrows/classes/204

What is astronomy?

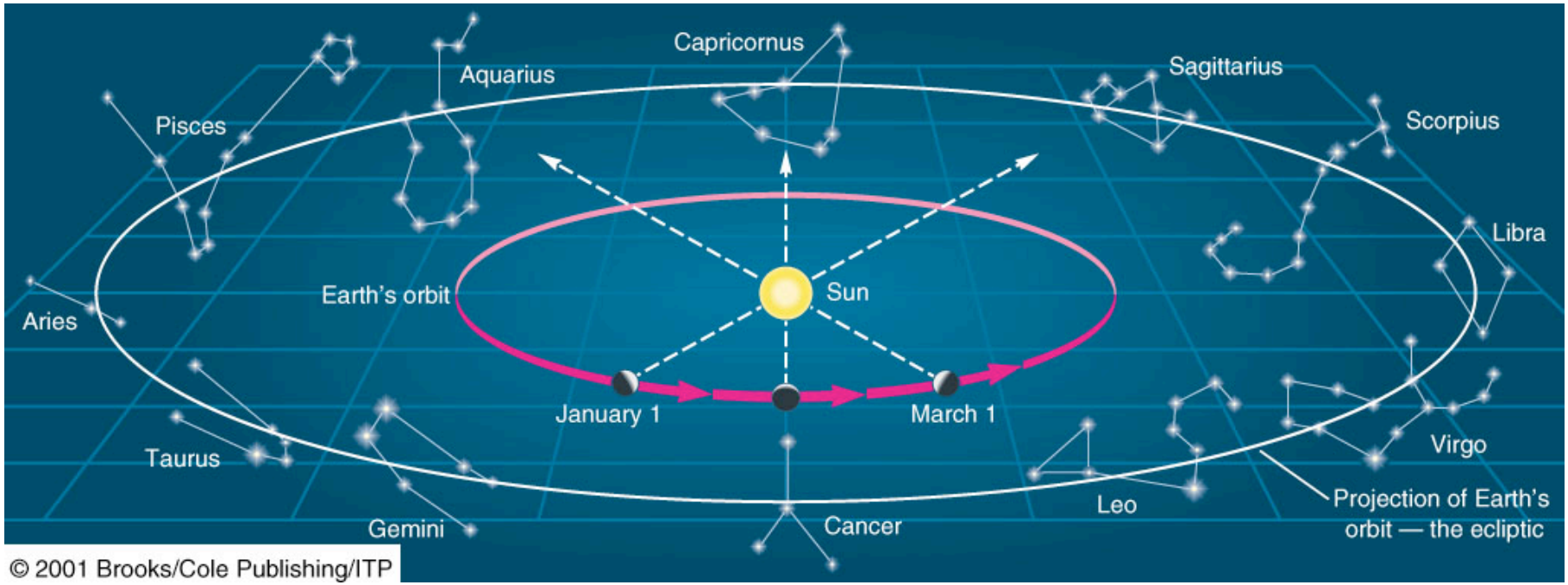
- The observation and study of everything in the Universe (except the Earth?)
- Oldest of all the sciences

What is astrophysics?

- Application of physical laws to understand celestial objects.

What is astrology?

- Belief system that motions and positions of planets/Moon/Sun can affect events on Earth.
- Is demonstrably false.

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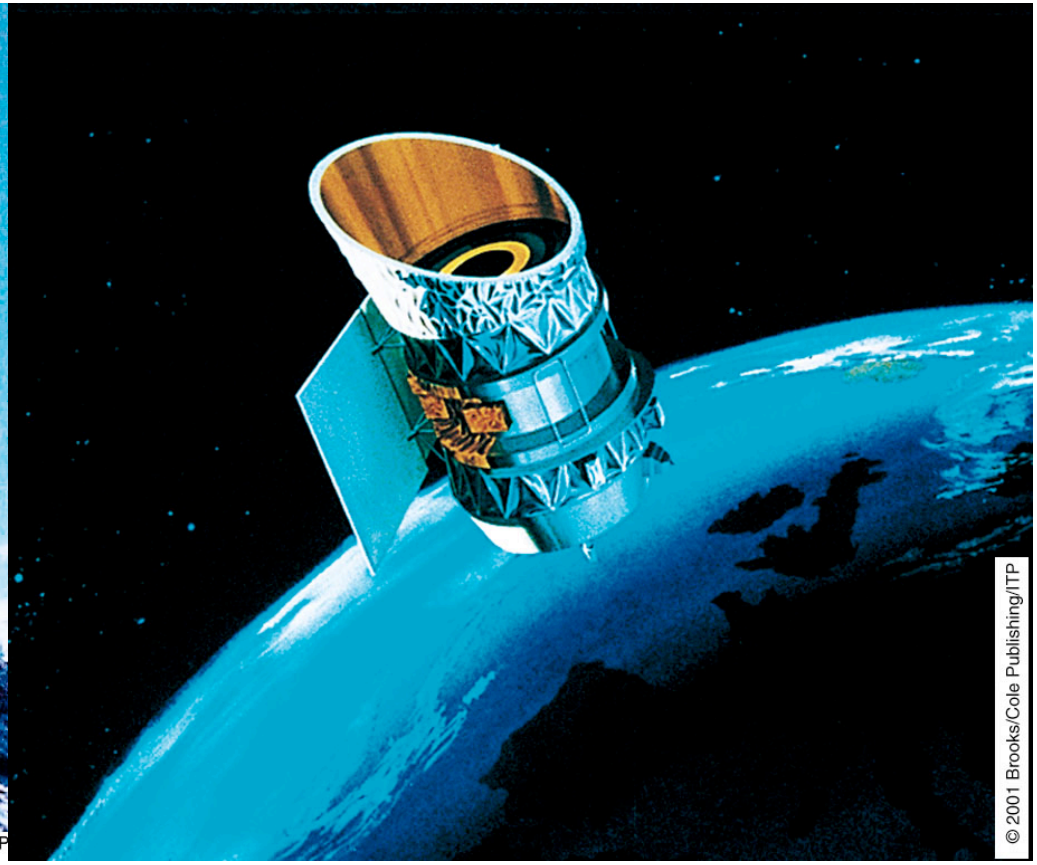

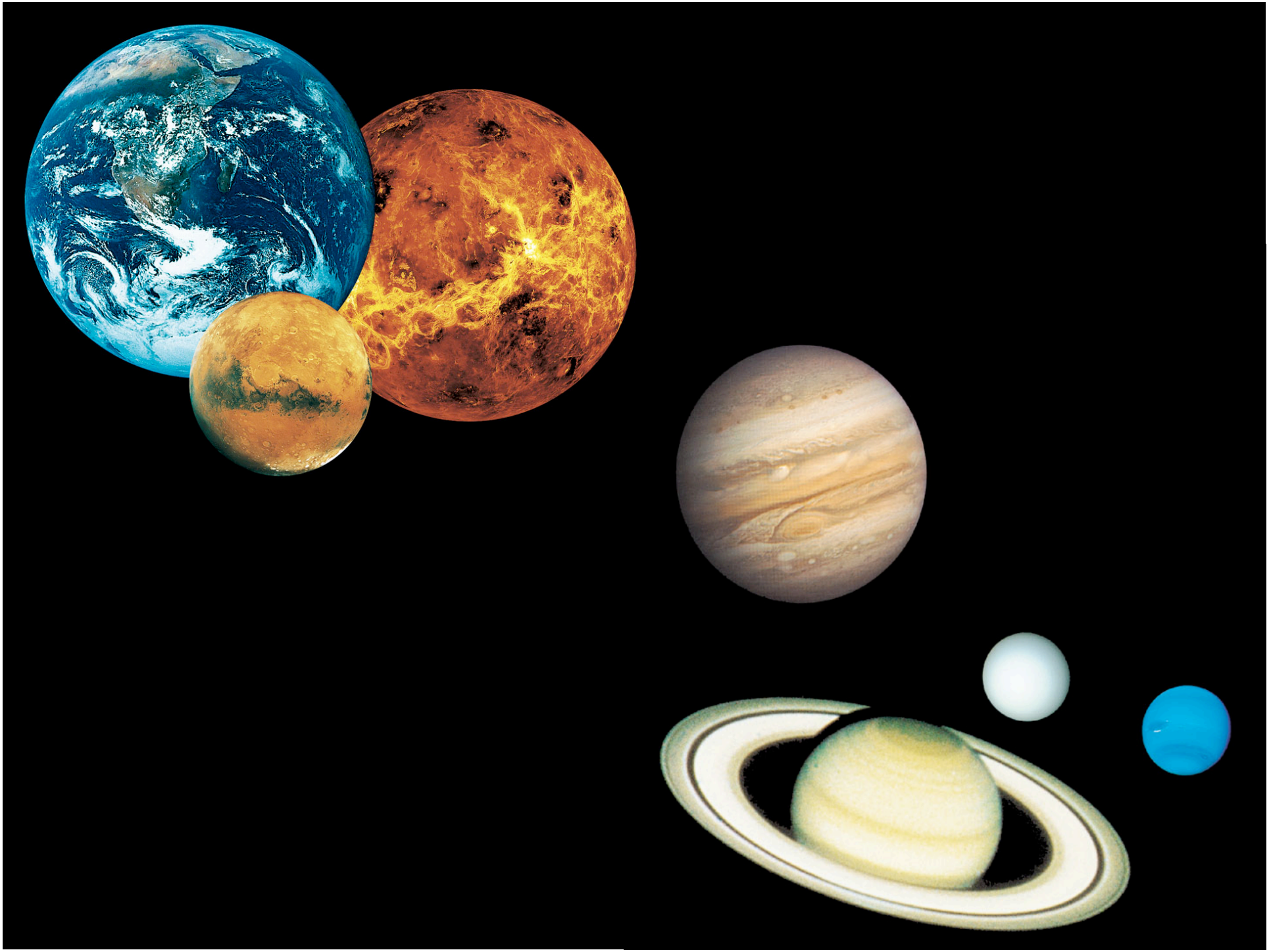

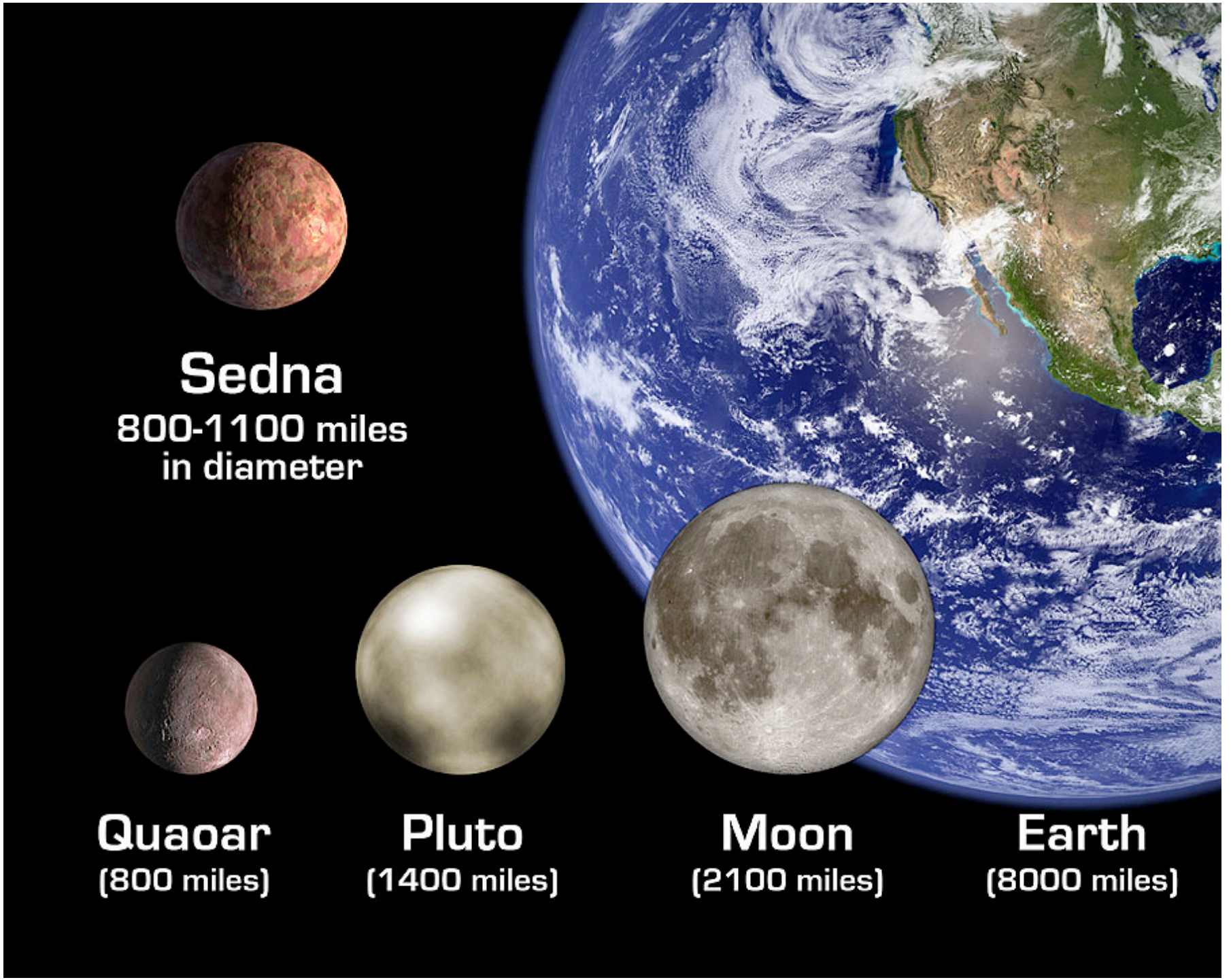
Sedna
800-1100 miles
in diameter
Quaoar
(800 miles)
Pluto
(1400 miles)
Moon
(2100 miles)
Earth
(8000 miles)

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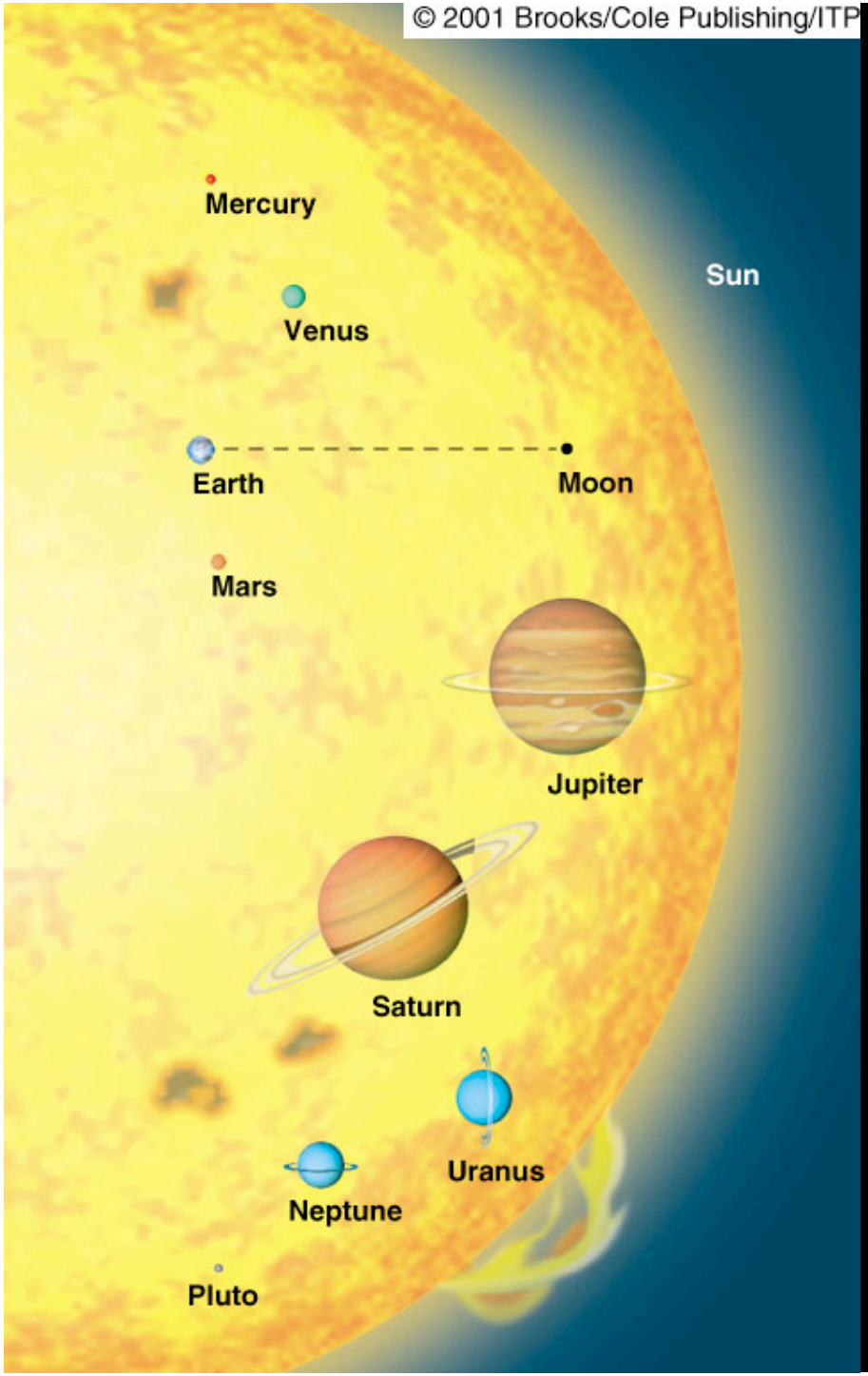
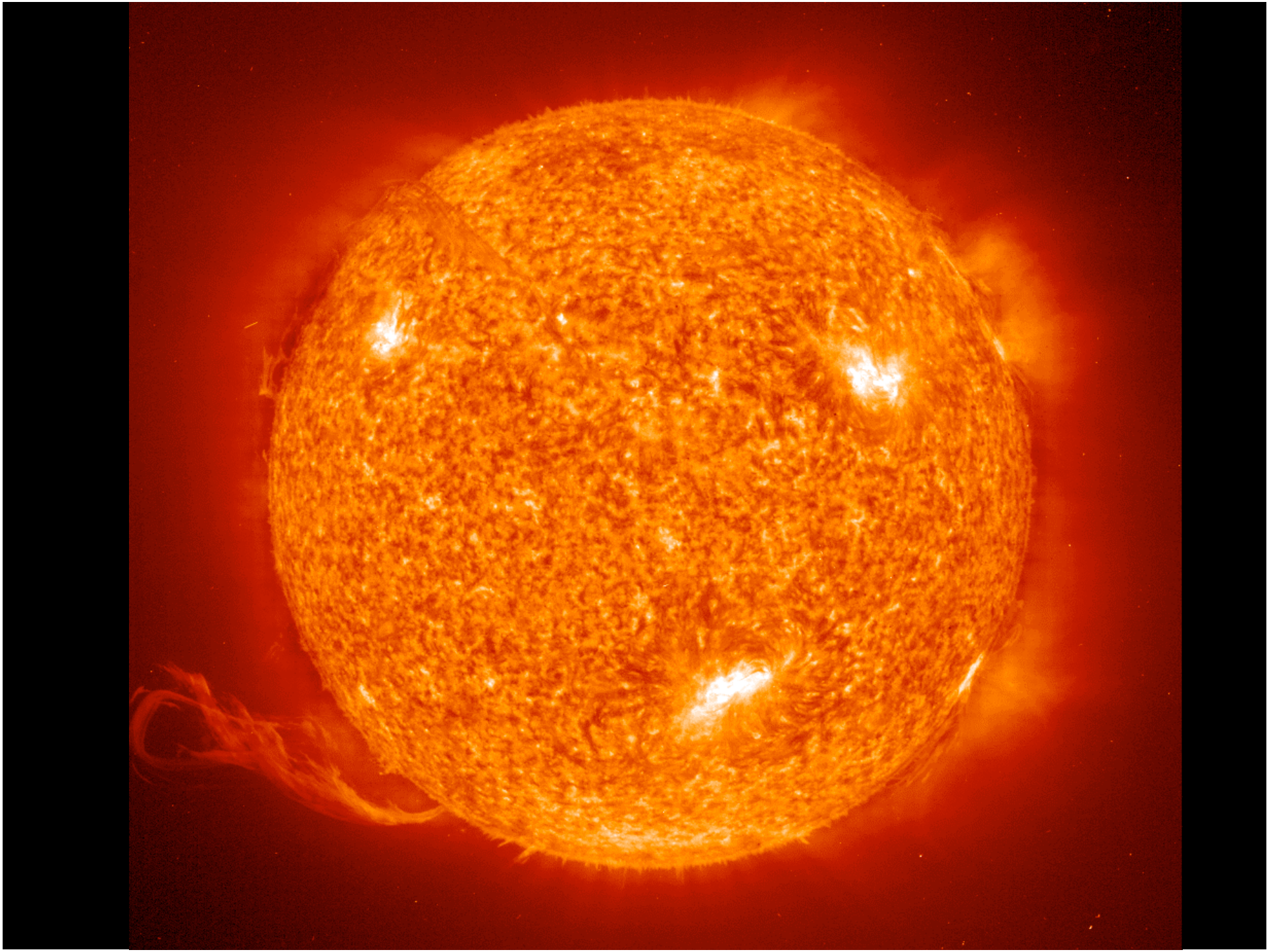
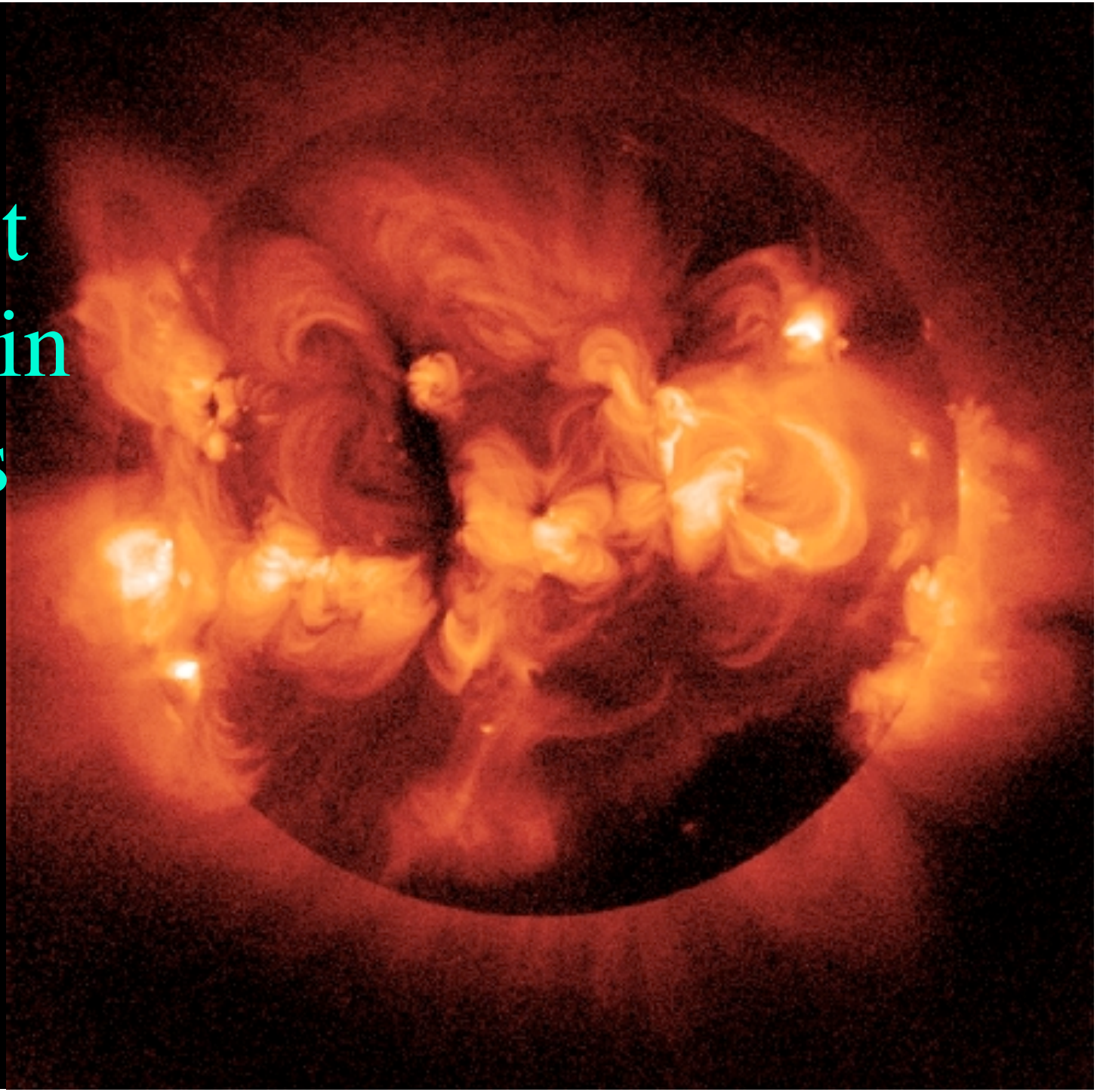


The Sun: Our Star

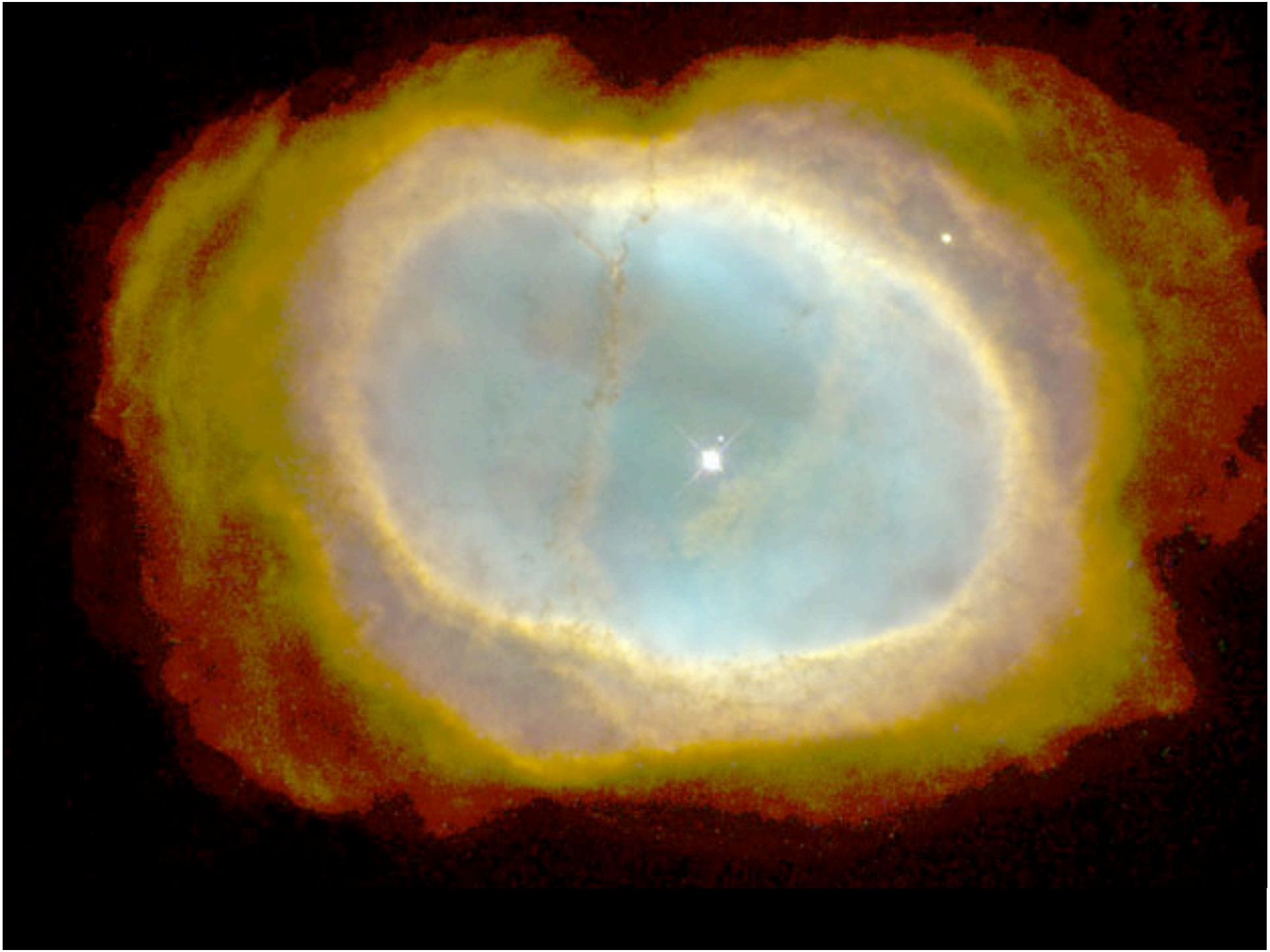
- Contains 99.9% of the mass in the Solar System
- Source of heat and light for Earth
  - Life impossible without it
- Only star we can study in great detail



The hot Corona in X-rays

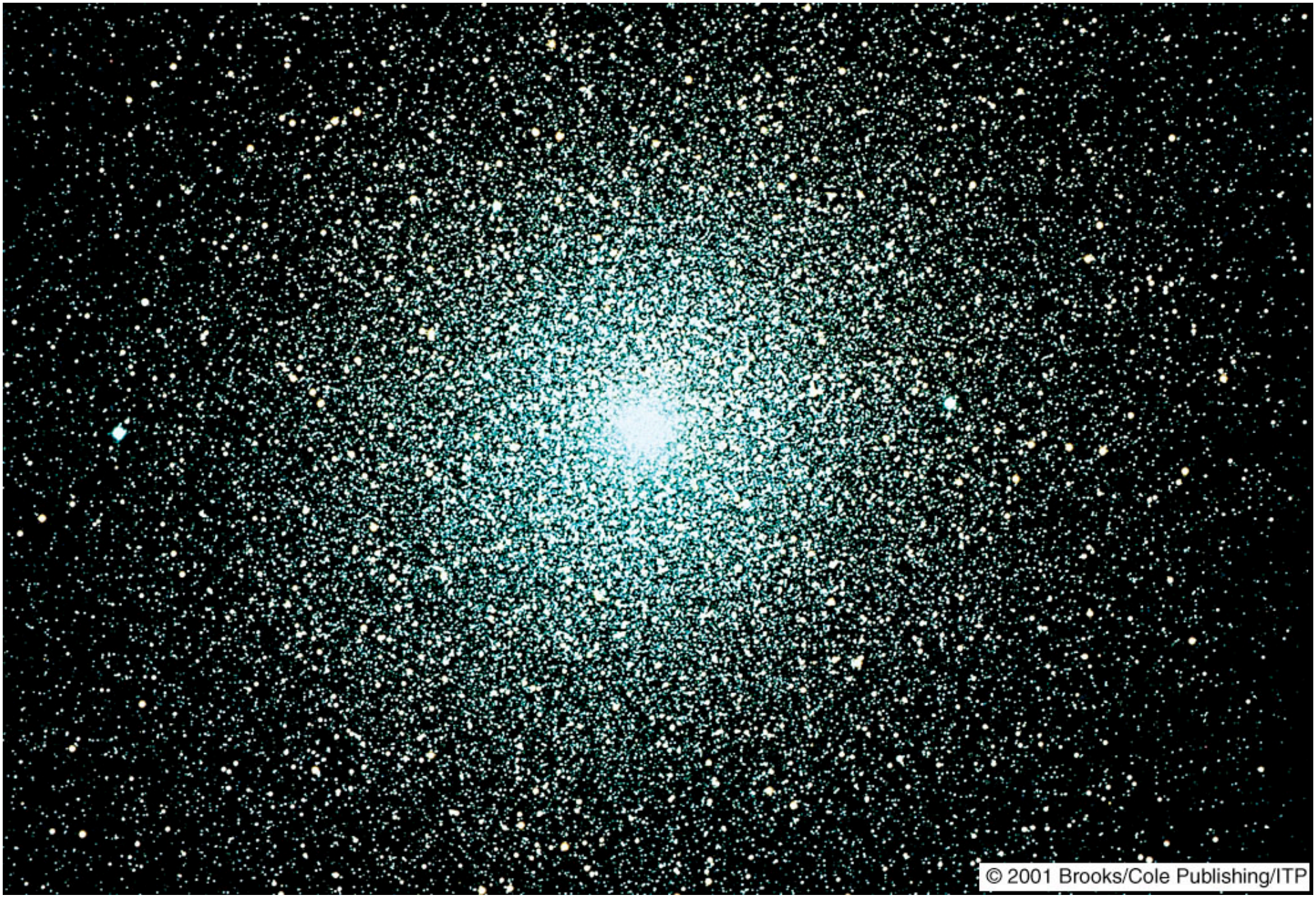


Cat's eye nebula

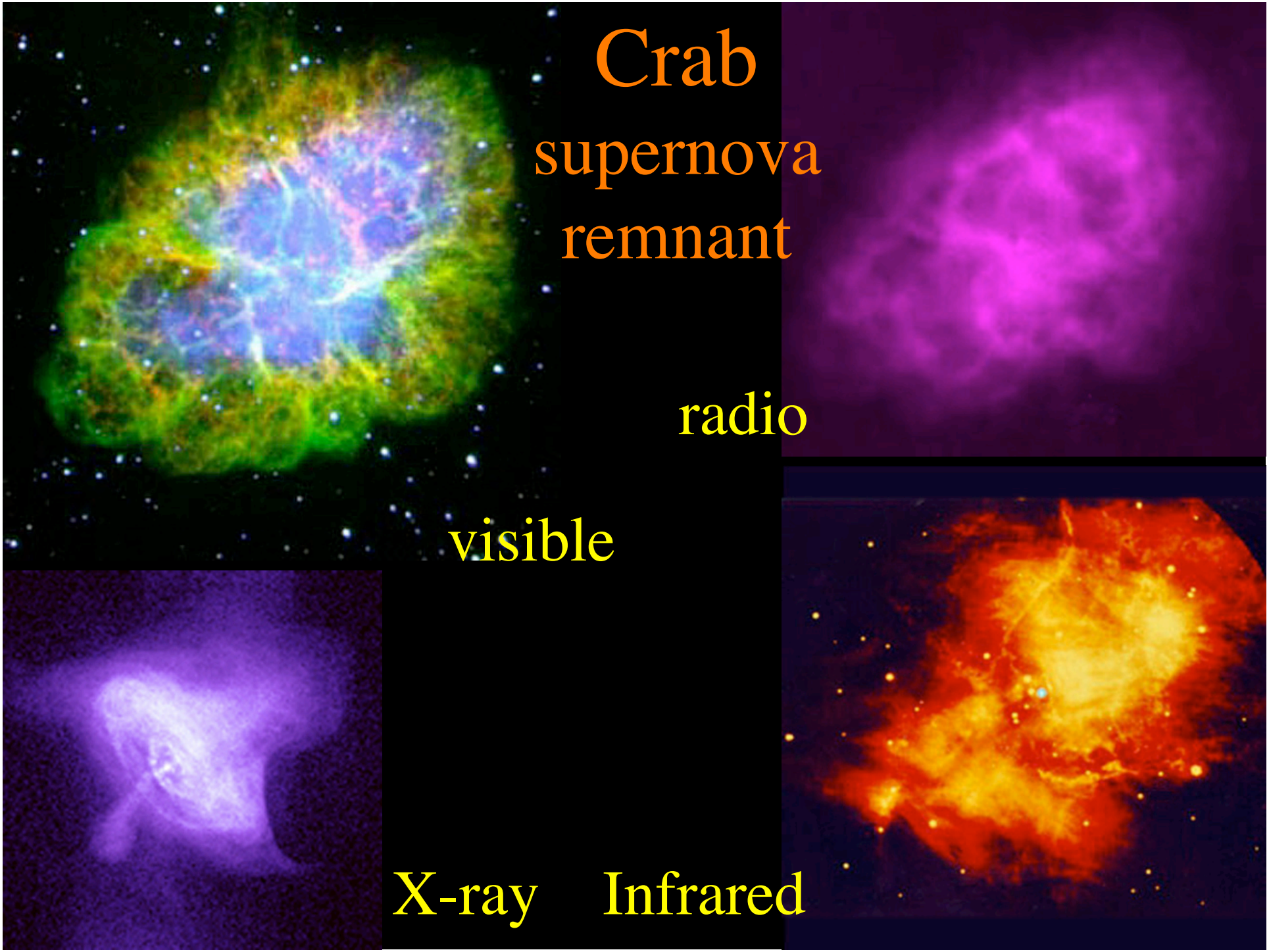


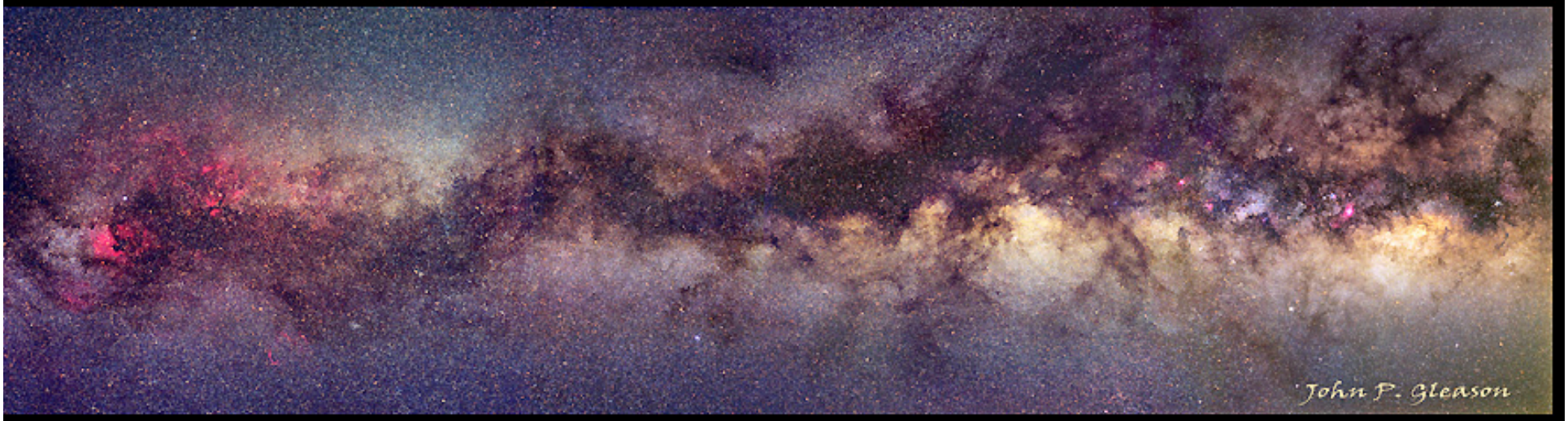
Open Cluster: 100 to 1000 stars

Globular Cluster: 10^5 to 10^6 stars

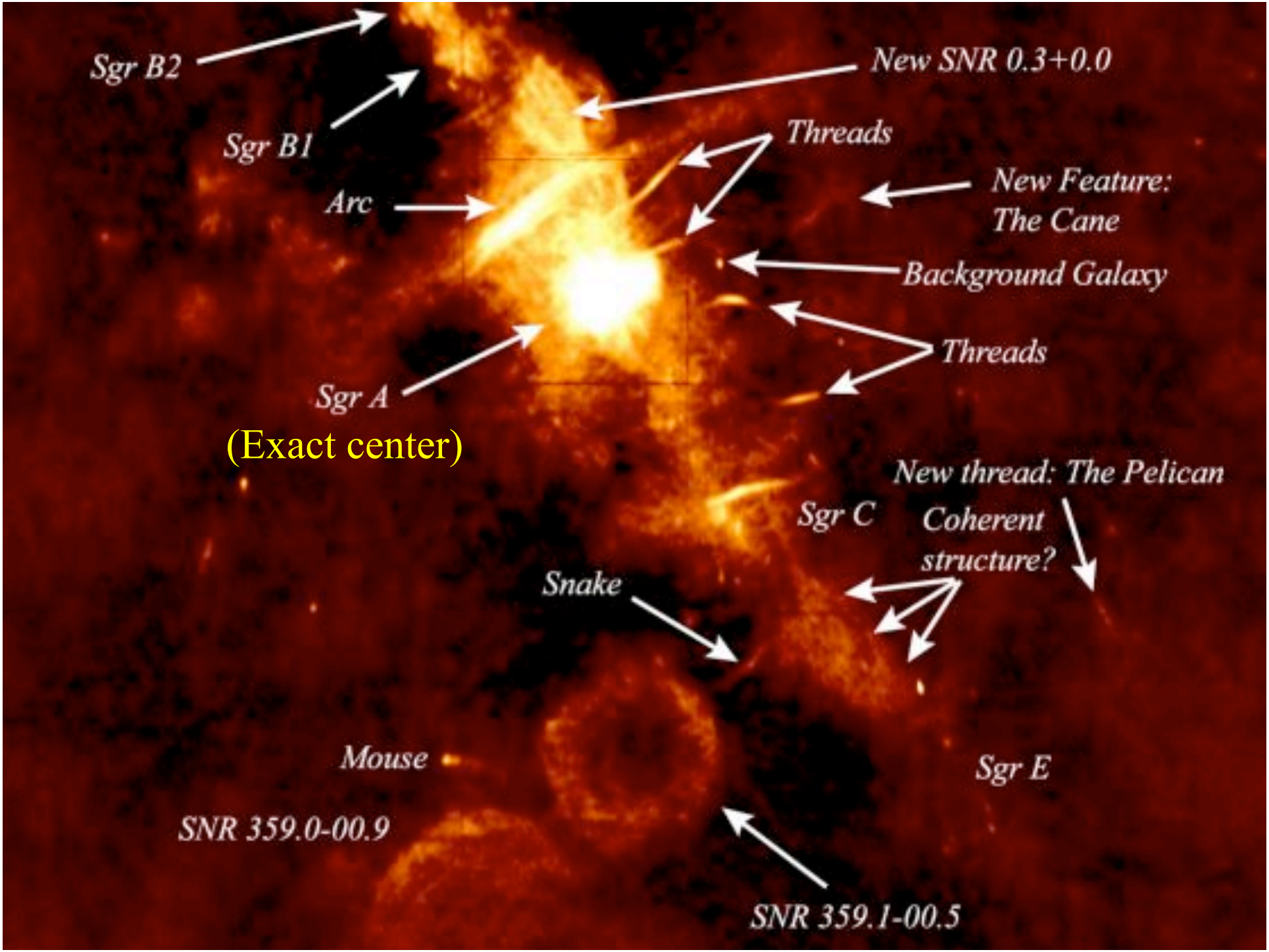


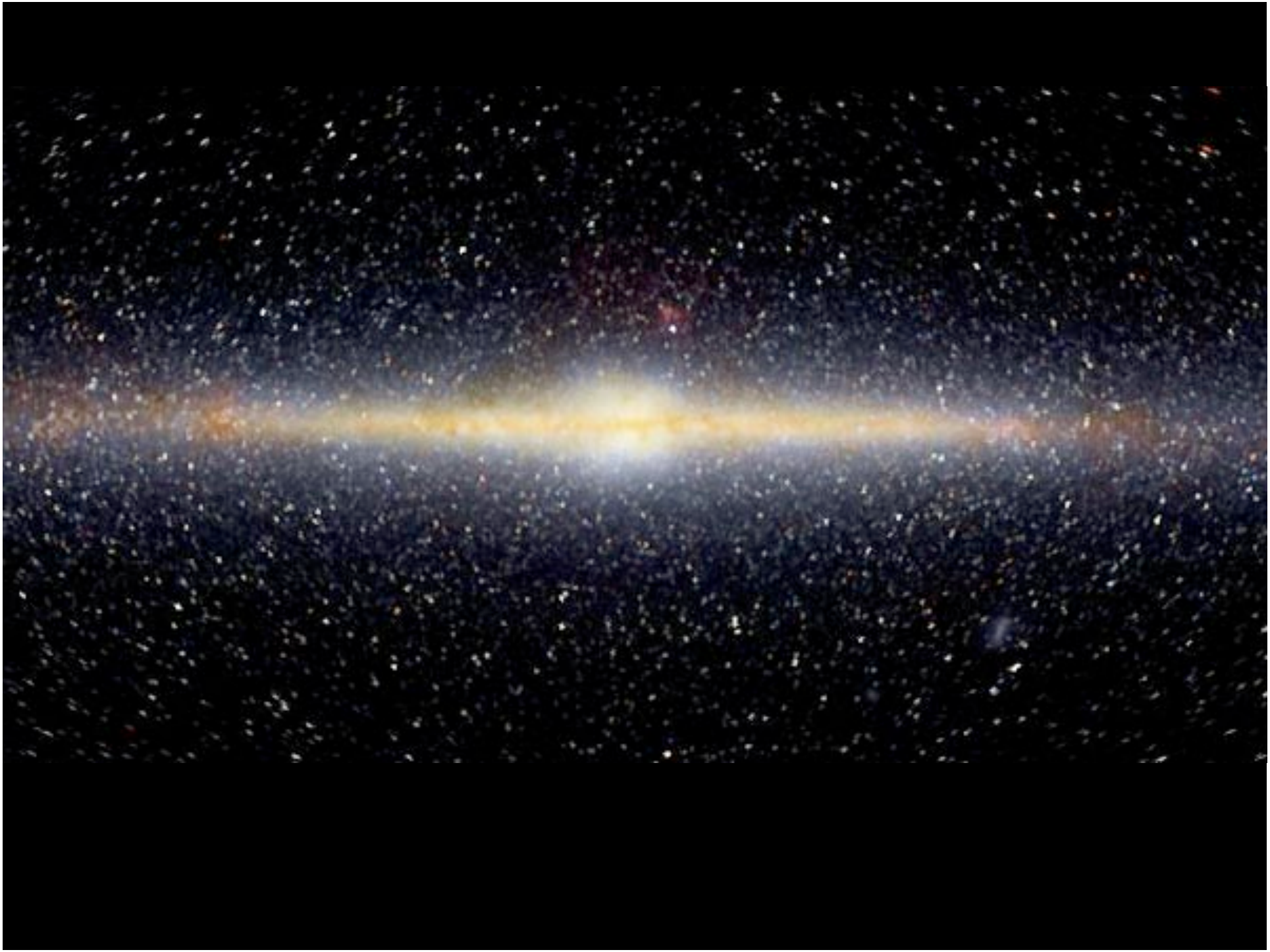
Planetary Nebula Mz 3


Crab
supernova
remnant
radio
visible
X-ray
Infrared

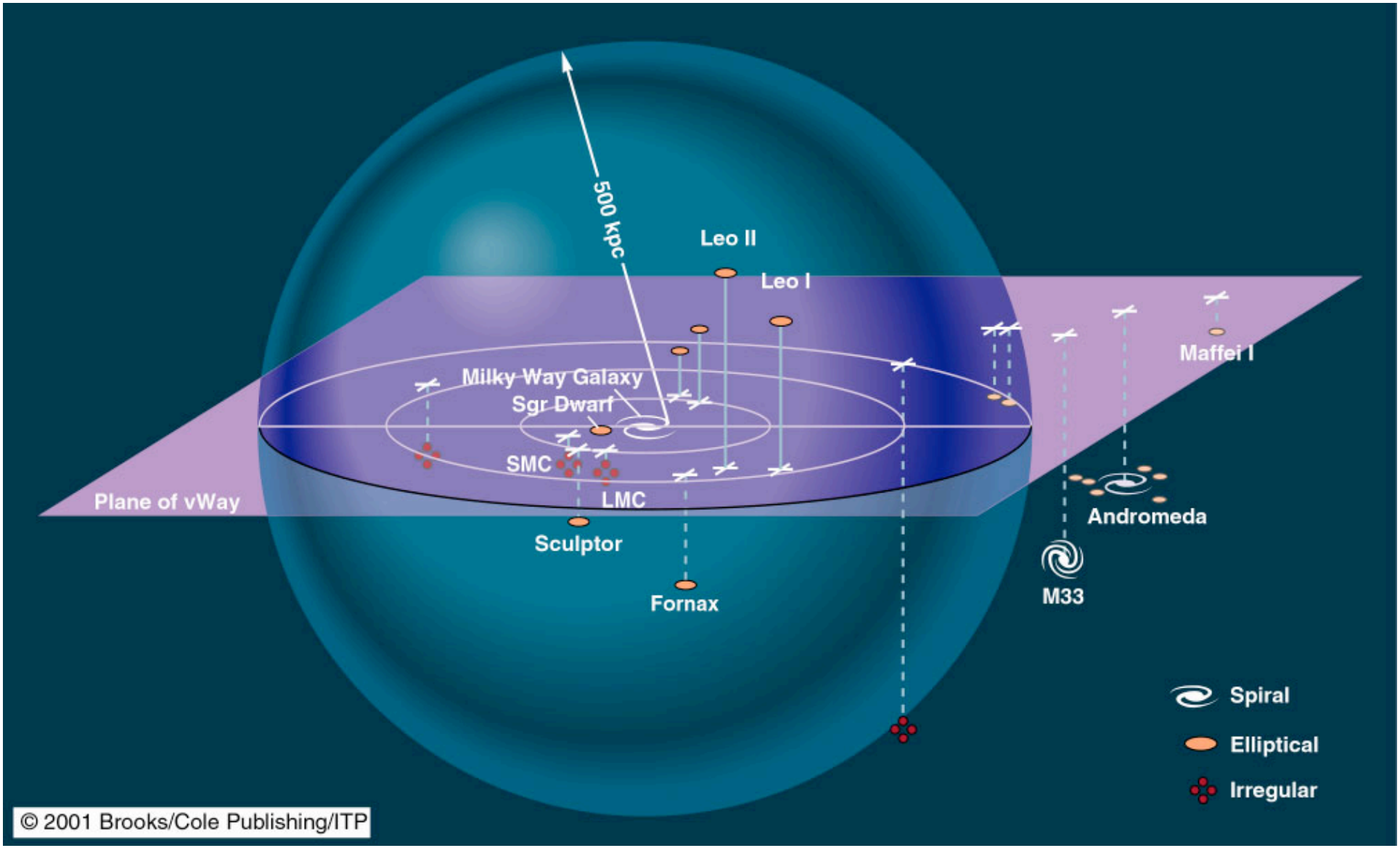


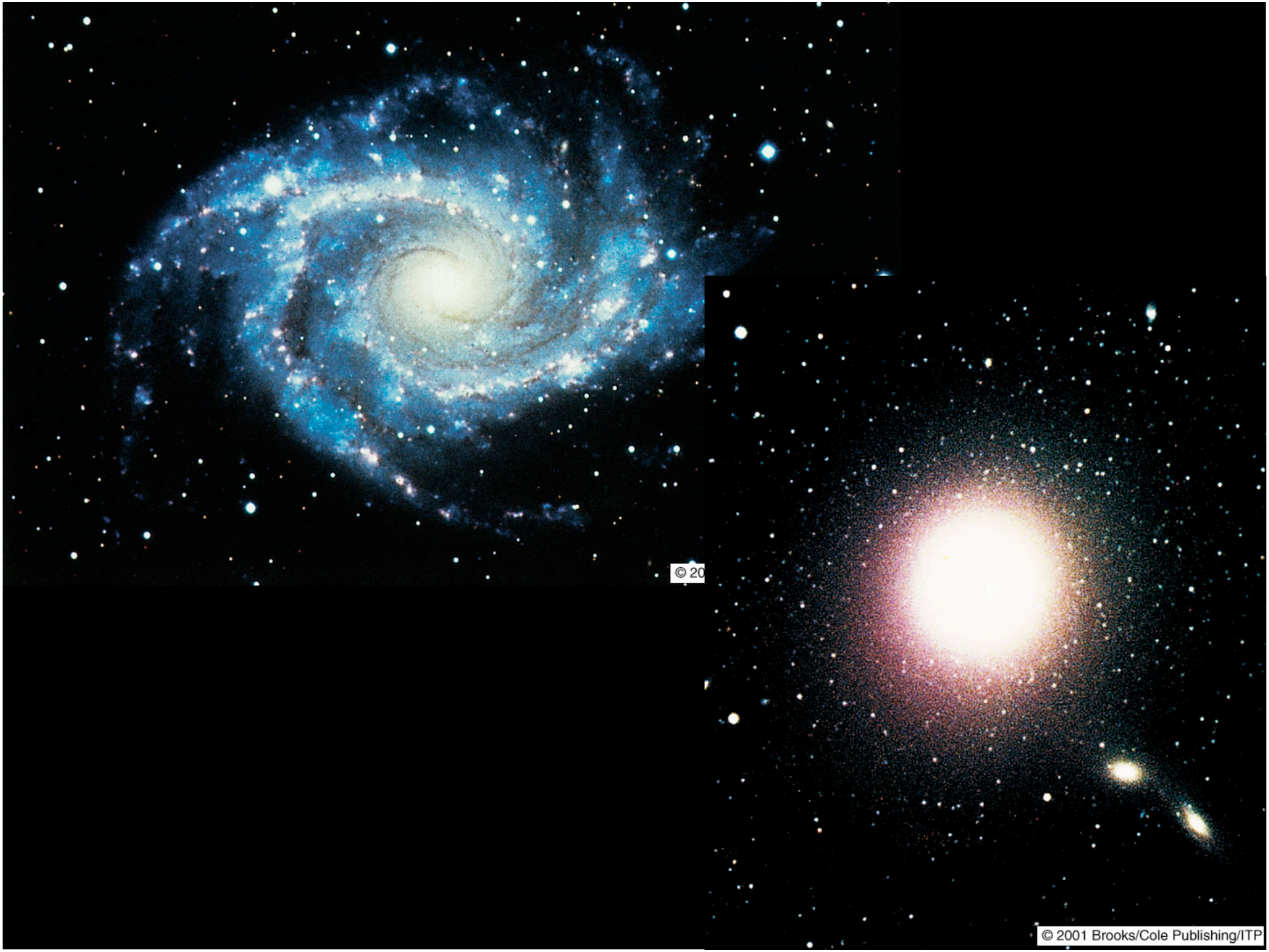
Milky Way Galaxy


Sgr B2
Sgr B1
New SNR 0.3+0.0
Threads
Arc
New Feature:
The Cane
Background Galaxy
Threads
Sgr A
(Exact center)
New thread: The Pelican
Sgr C
Coherent
structure?
Snake
Mouse
Sgr E
SNR 359.0-00.9
SNR 359.1-00.5



The Milky Way is in a poor cluster – the Local Group

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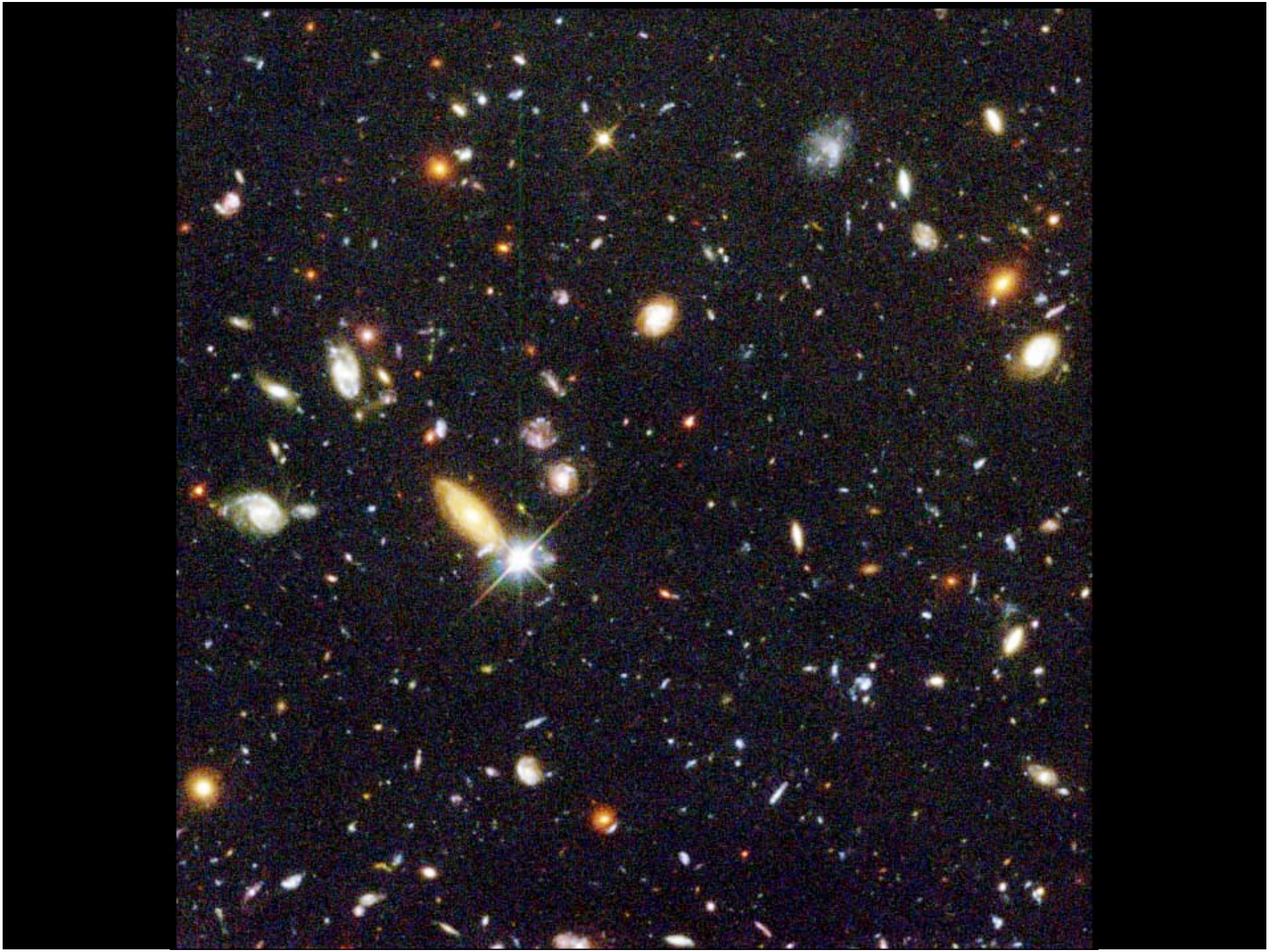
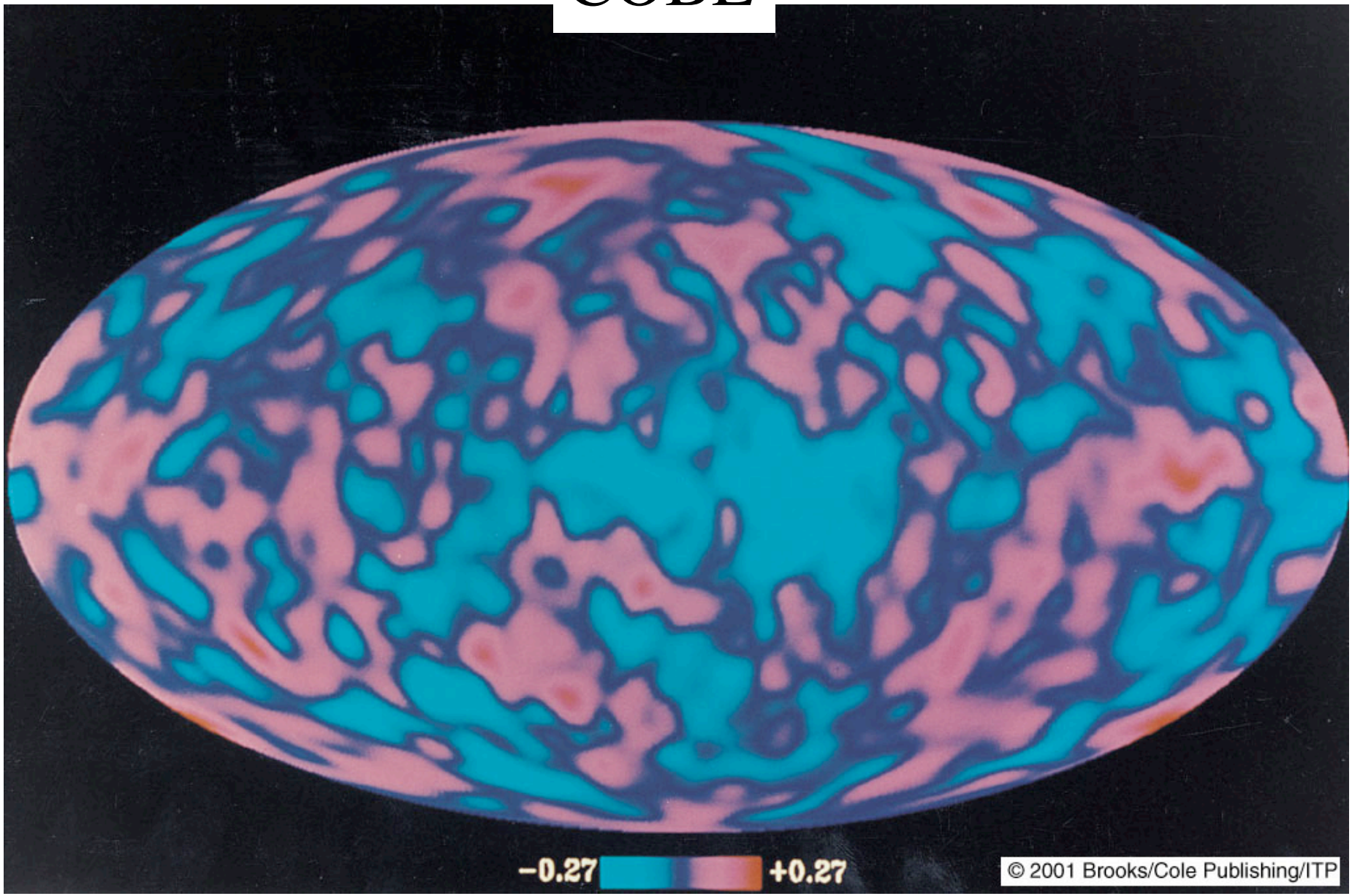
Spiral Galaxy Pair NGC 3314

Hubble Heritage

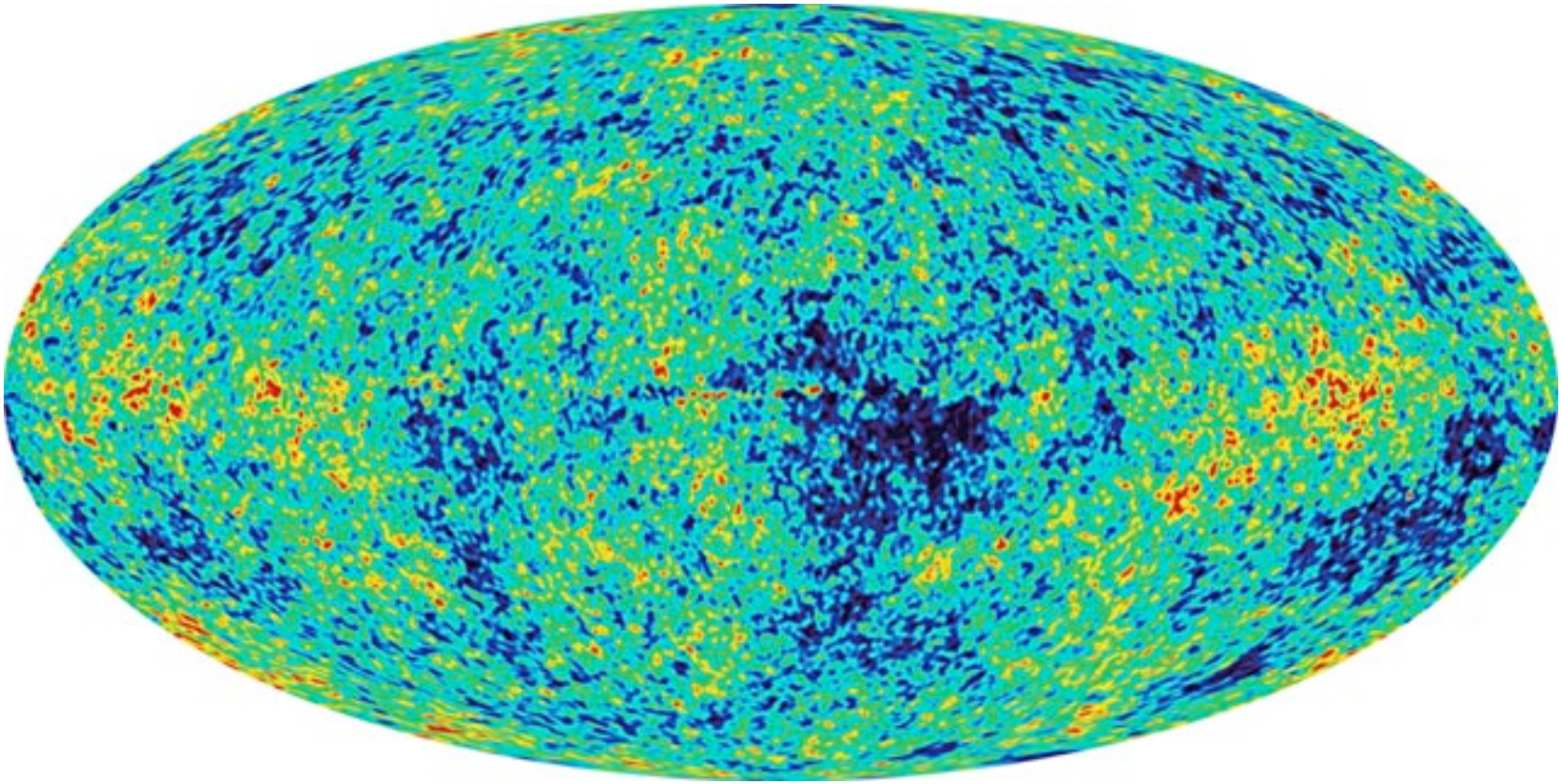
PRC00-14 • Space Telescope Science Institute • NASA and The Hubble Heritage Team (STScI/AURA)



COBE



CMB: temperature fluctuations 300,000 years after the Big Bang



WMAP: ~20 x better resolution

The Universe is really, really big….

Average distance between the Earth and Sun is one *astronomical unit (AU)*.

1 AU = 93 million miles

Sun is 1 AU away.
Pluto is about 40 AU away.
Nearest star is 300,000 AU away.
Our galaxy is 10 billion AU across.

Earth and Moon as seen by Galileo spacecraft

The Universe is really, really big….

Imagine the Earth was a basketball…

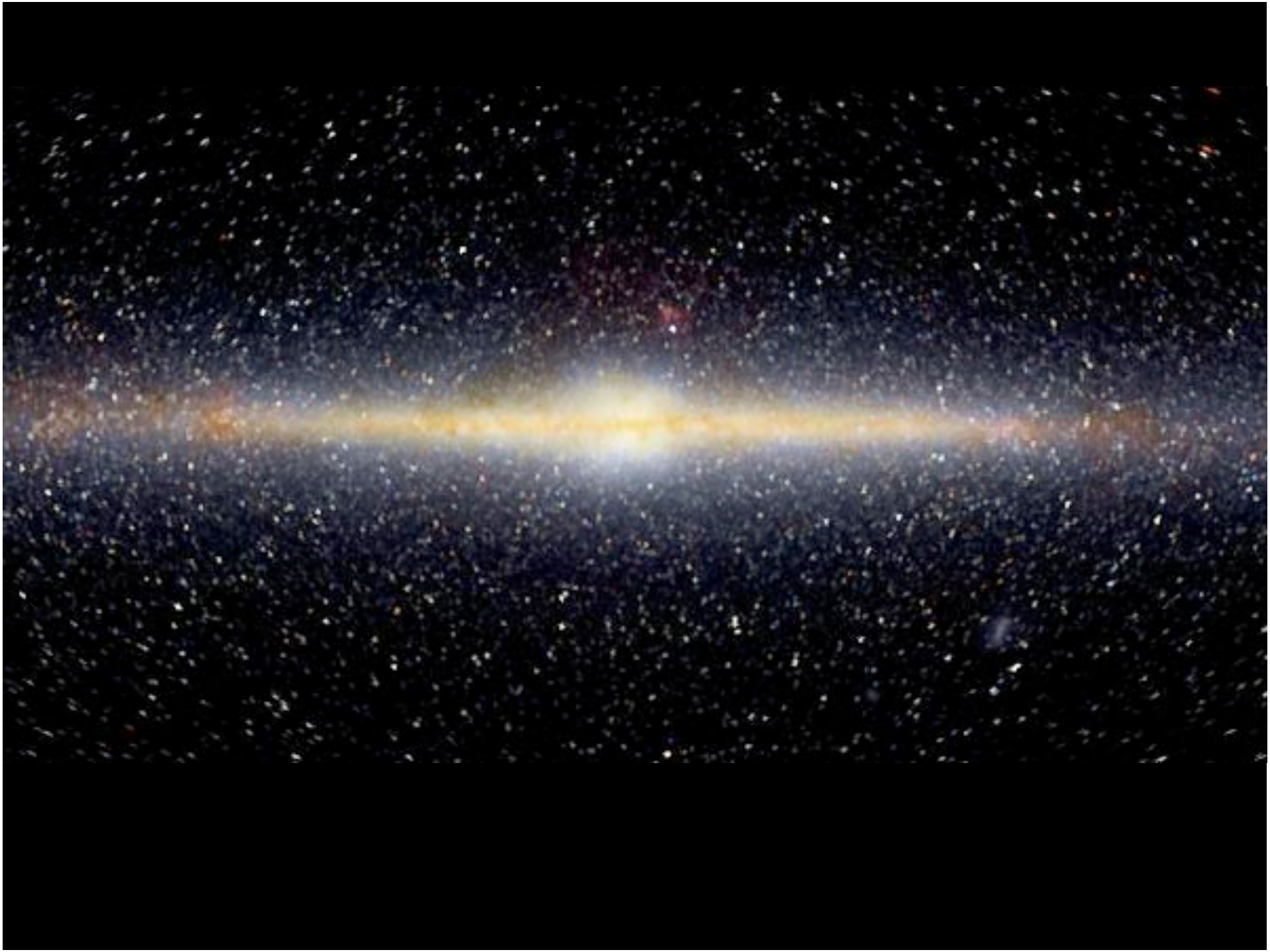
⇒The moon would be a tennis ball 30 ft. away

⇒The Sun would be a ten story building 2.2 miles away

⇒Pluto would be a tennis ball 80 miles away

⇒The *nearest* star would be 500,000 miles away.

It is very difficult to travel to the planets and even the nearest stars.



The Universe is really, really big….

Milky Way galaxy contains 100 billion stars, and is 100,000 light years across.

1 light year = distance light travels in one year = 6 trillion miles

The Universe is really, really big….

Milky Way galaxy contains 100 billion stars, and is 100,000 light years across.

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Nearest galaxies (Magellanic Clouds) are 200,000 ly away
Nearest spiral galaxy (Andromeda) is 2.3 million ly away
Most distant galaxies are about 10 billion ly away
⇒We see these galaxies as they were billions of years ago.
⇒Traveling back in time is possible with Astronomy 204

Factor:
1

52 feet
across

Step 1

Factor:

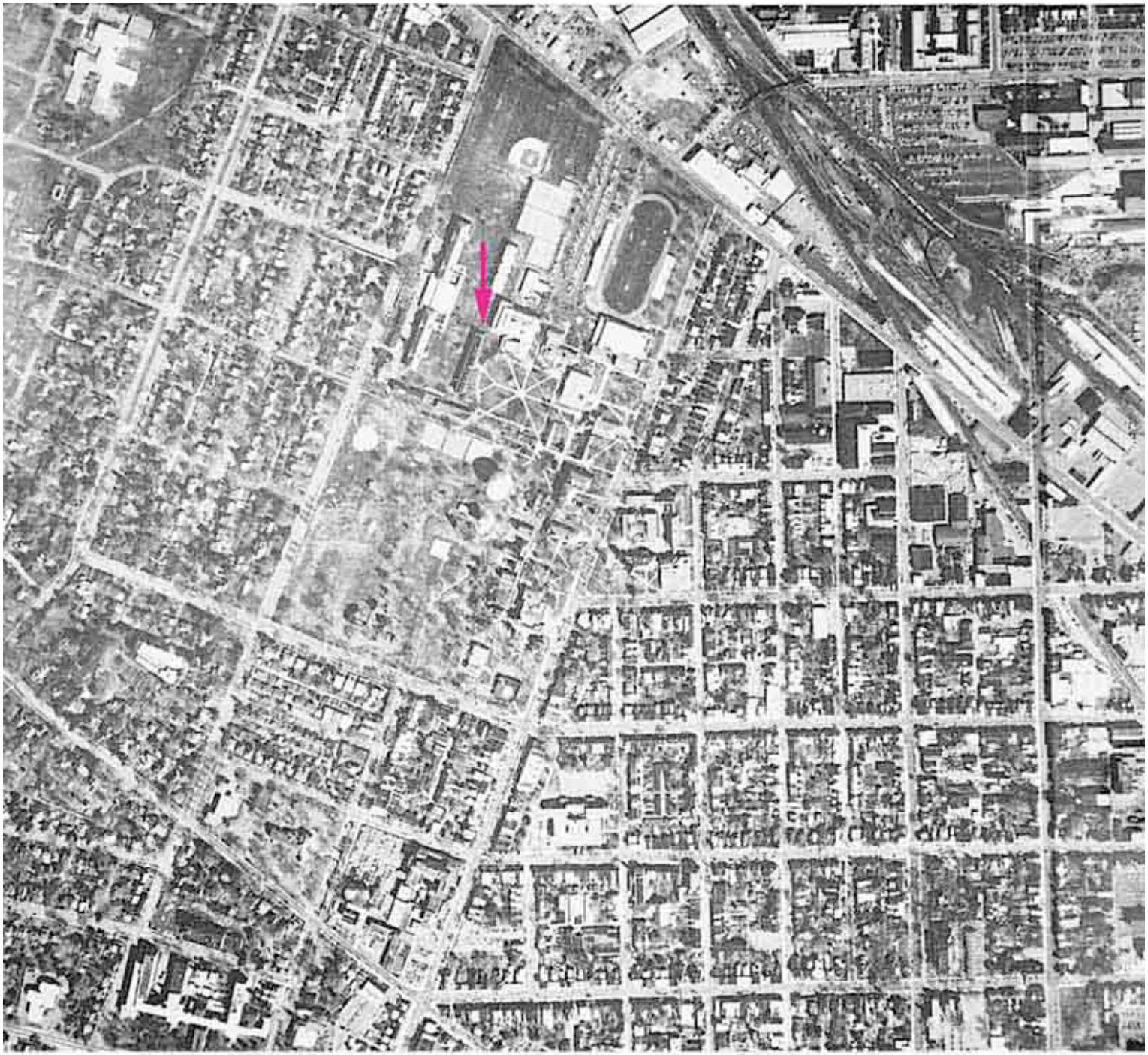
$10^2 = 100$

5200 feet

= 1 mile

=1.6 km

across



Step 2

Factor:

$10^4 = 10{,}000$

16,000 m

=160 km

across

Step 3

Factor:

10^6 =

1,000,000

16,000 km

across

Step 4

Factor:

10^8 =

100 million

100,000,000

1,600,000 km

across

Step 5

Factor:

10^{10}

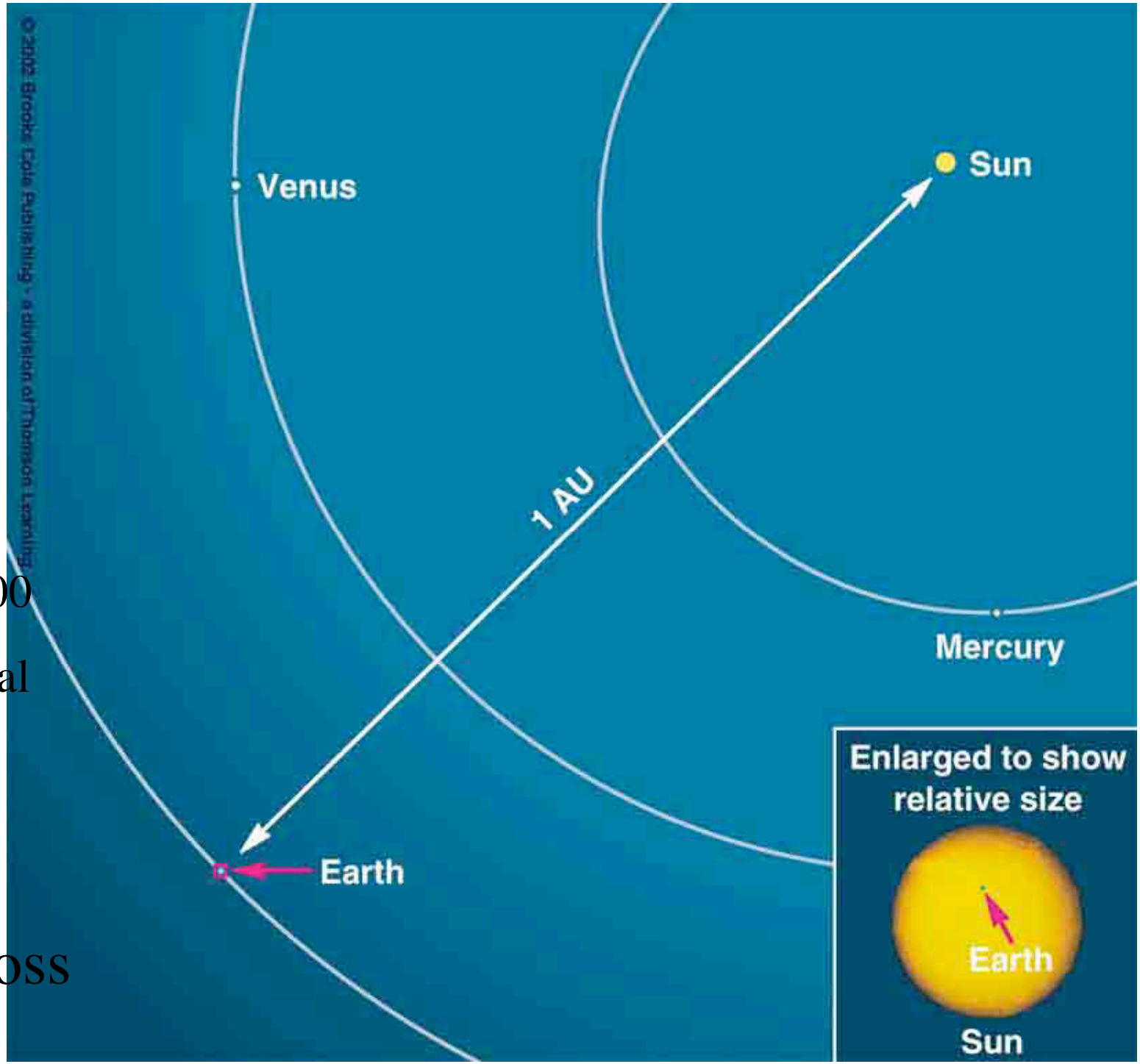
10 billion

10,000,000,000

1 Astronomical Unit (AU) =

1.5×10^{8} km

1.1 AU across



Step 6

Factor:

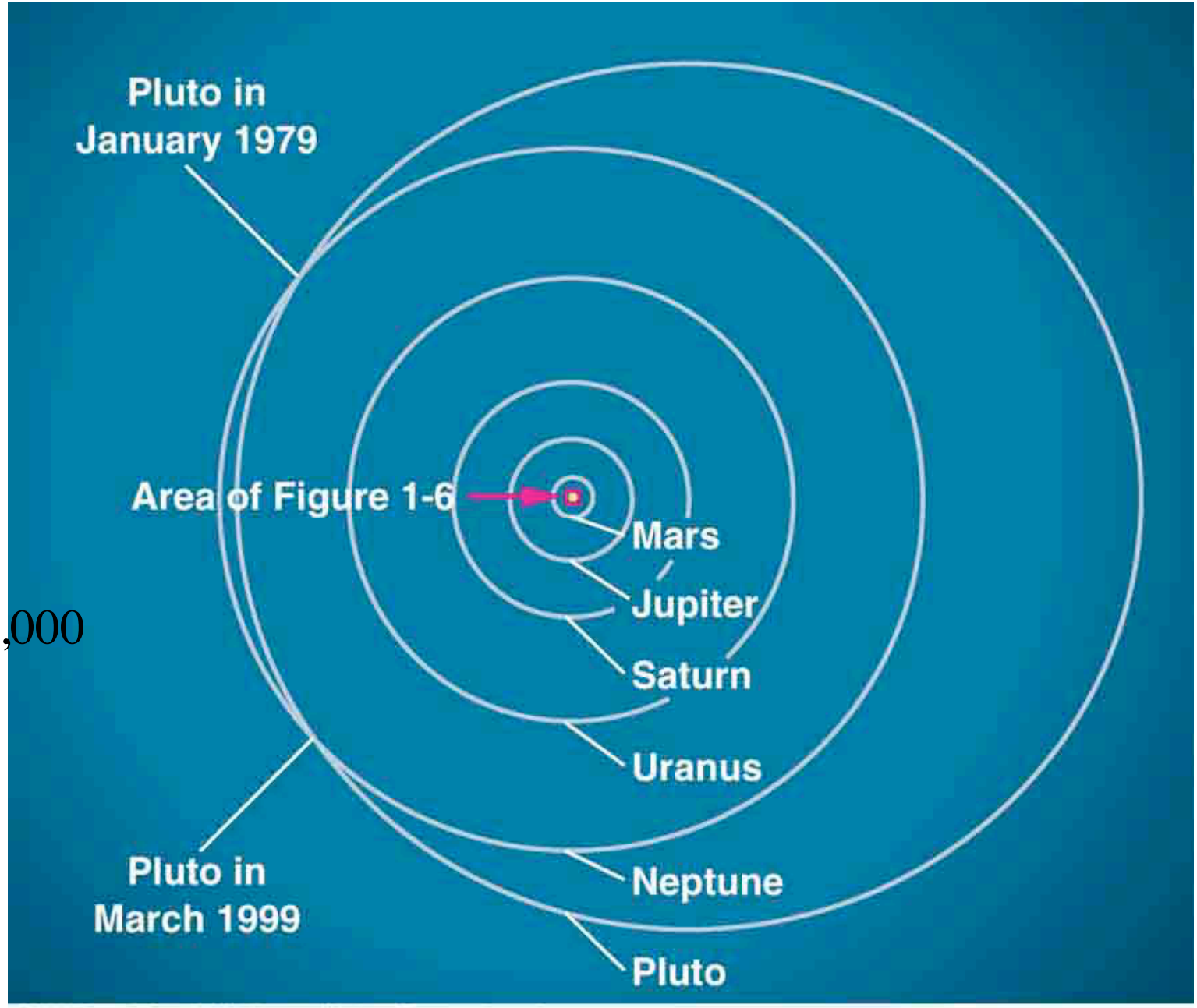
10^{12}

1 trillion

1,000,000,000,000

110 AU

across



Step 7

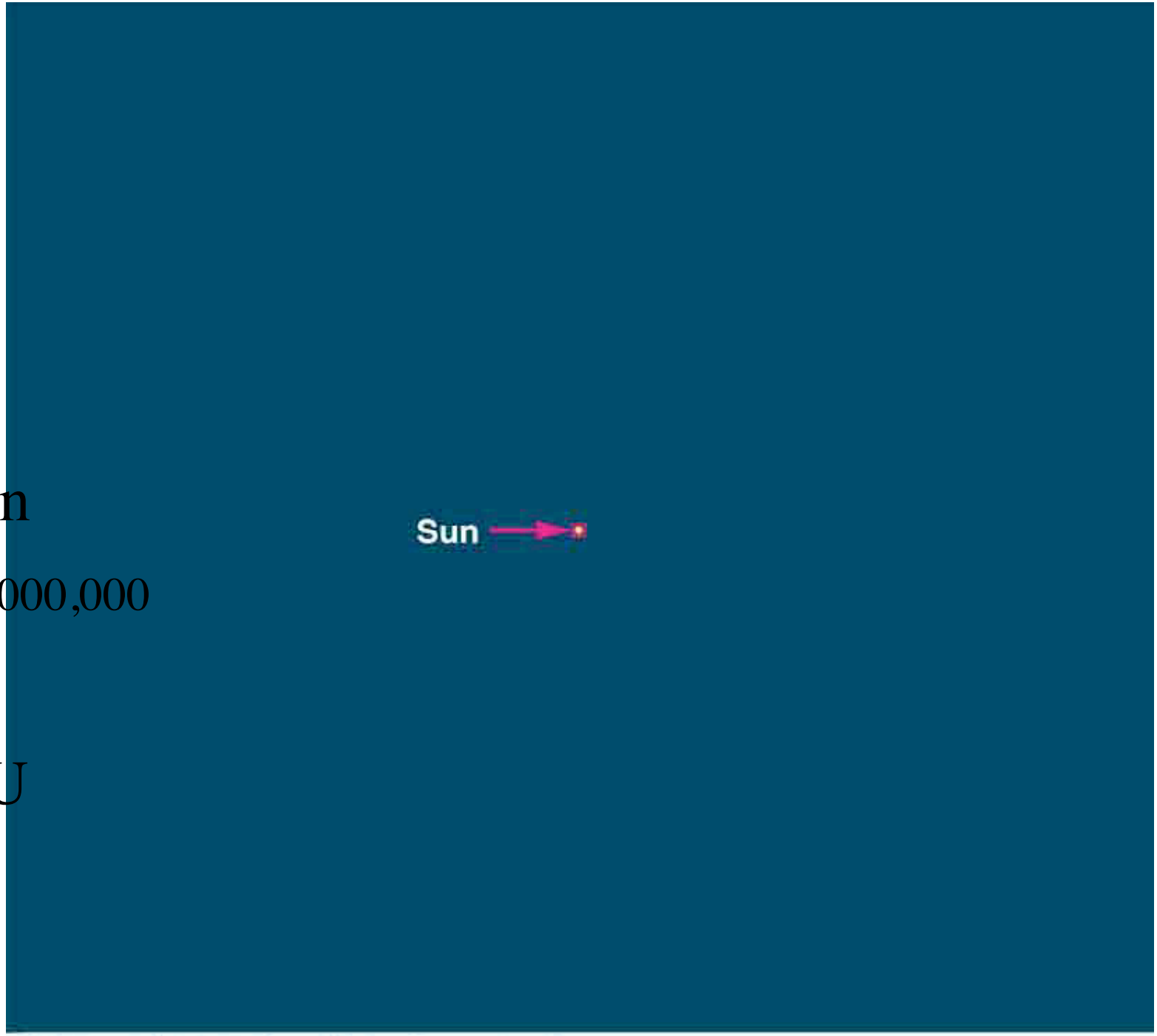
Factor:

10^{14}

100 trillion

100,000,000,000,000

11,000 AU across



Step 8

Factor:

10^{16}

10,000,000,000,000,000

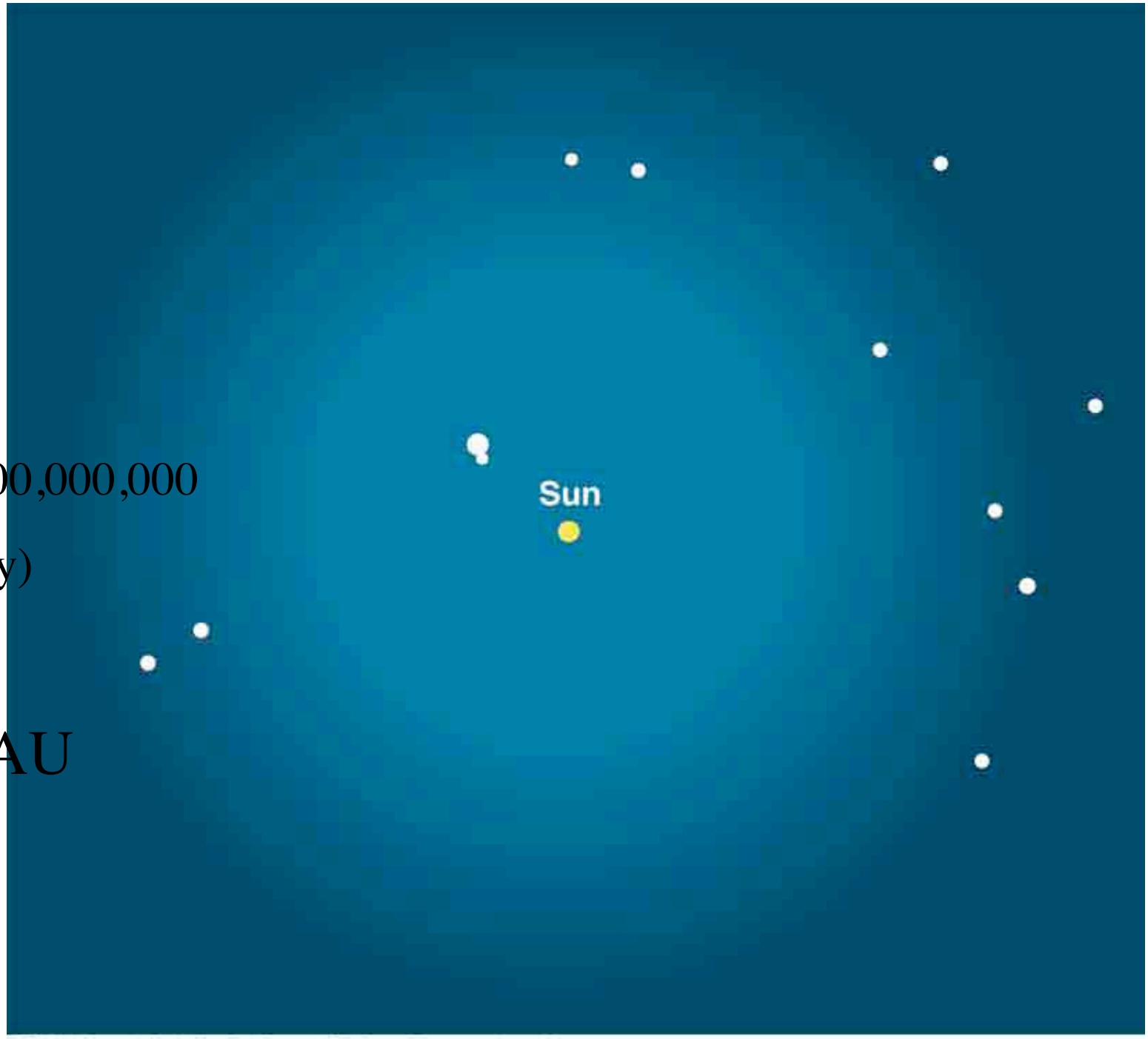
1 light year (ly)

= ~10^{13} km

1 million AU

17 ly

across



Step 9

Factor:

10^{18}

1,000,000,000,000,000,000

1,700 ly

across

Step 10

Factor:

10^{20}

100,000,000,000,000,000,000

170,000 ly across

Step 11

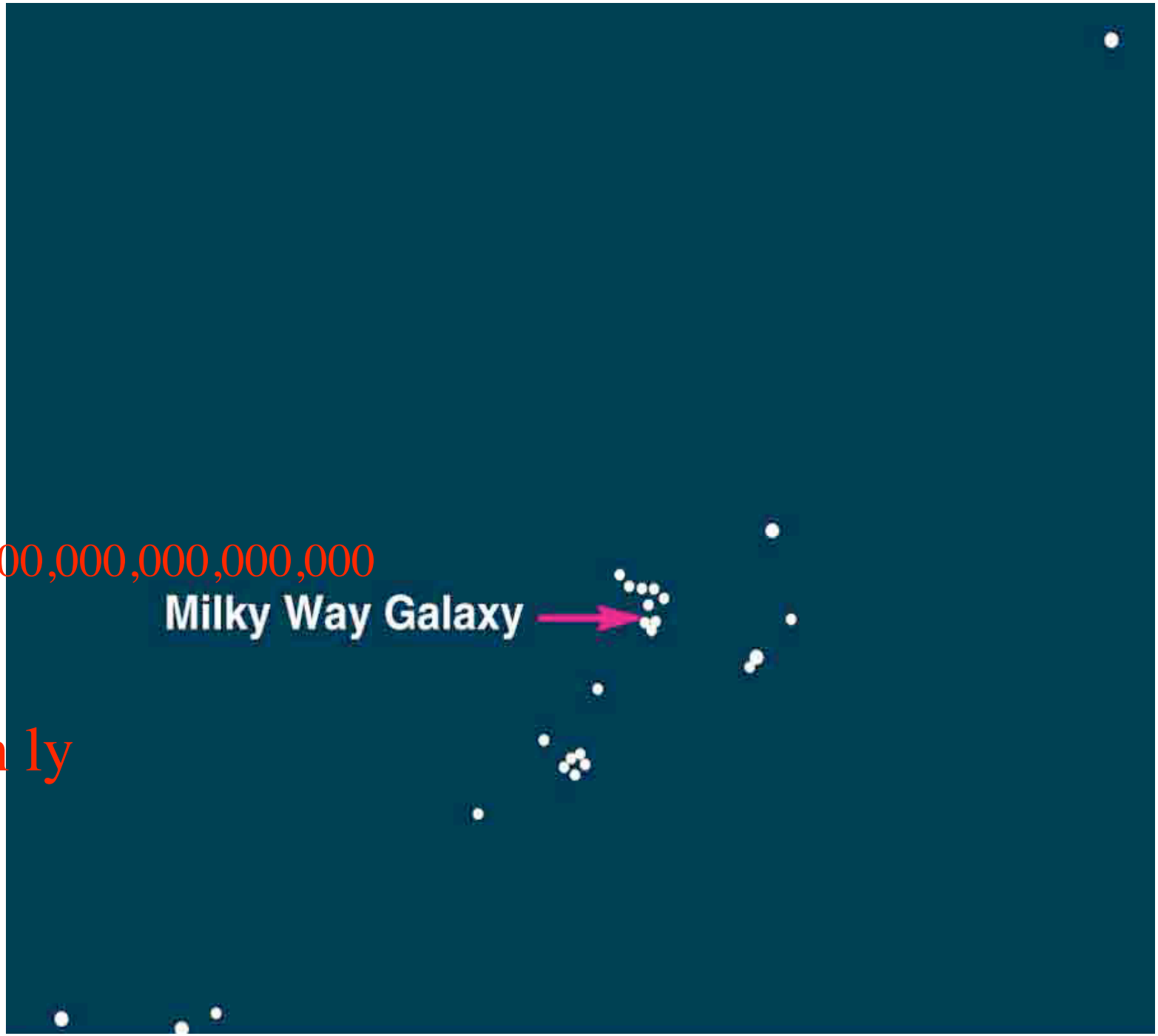
Factor:

10^{22}

10,000,000,000,000,000,000,000

17 million ly

across



Step 12

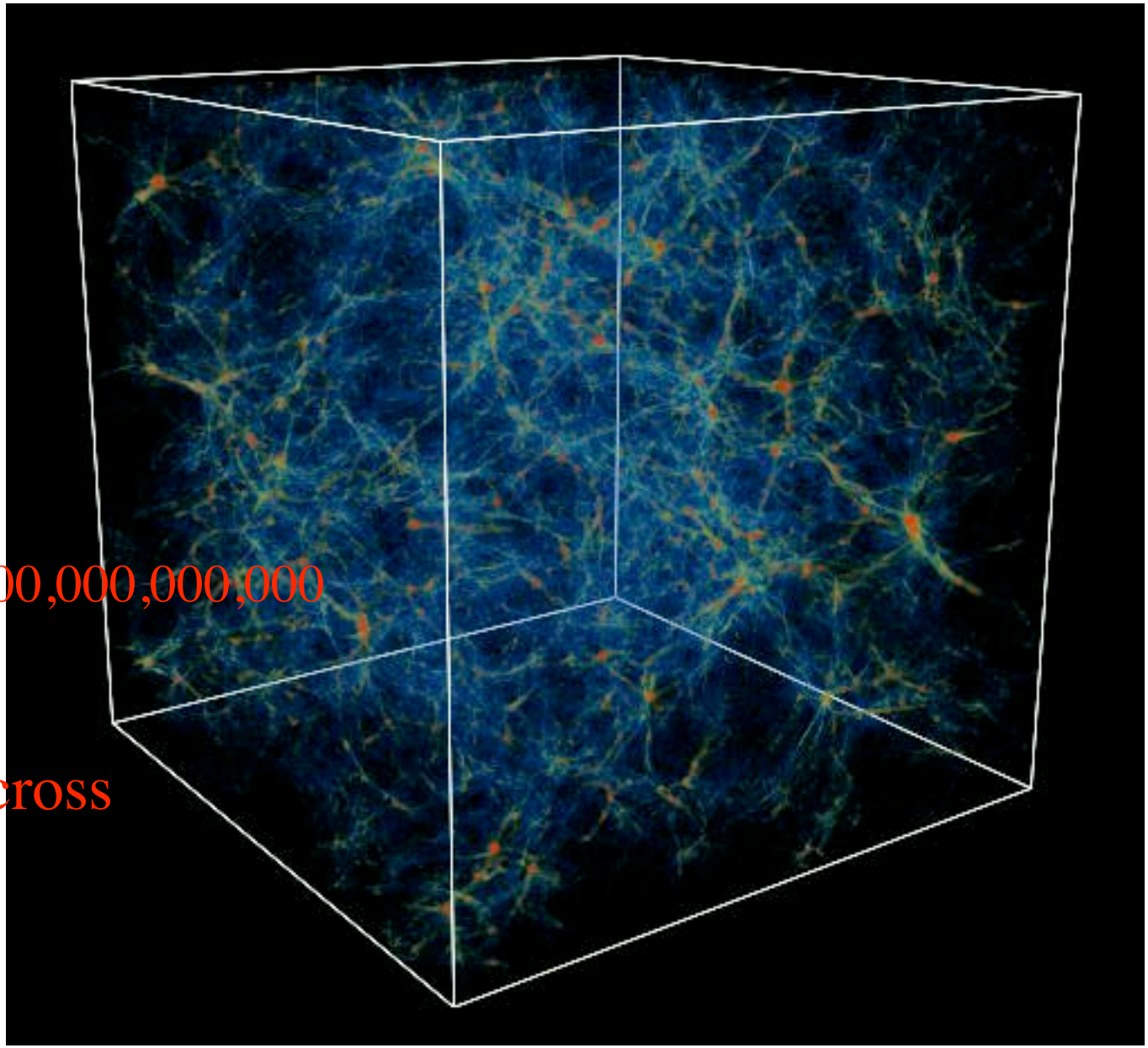
Factor:

10^{24}

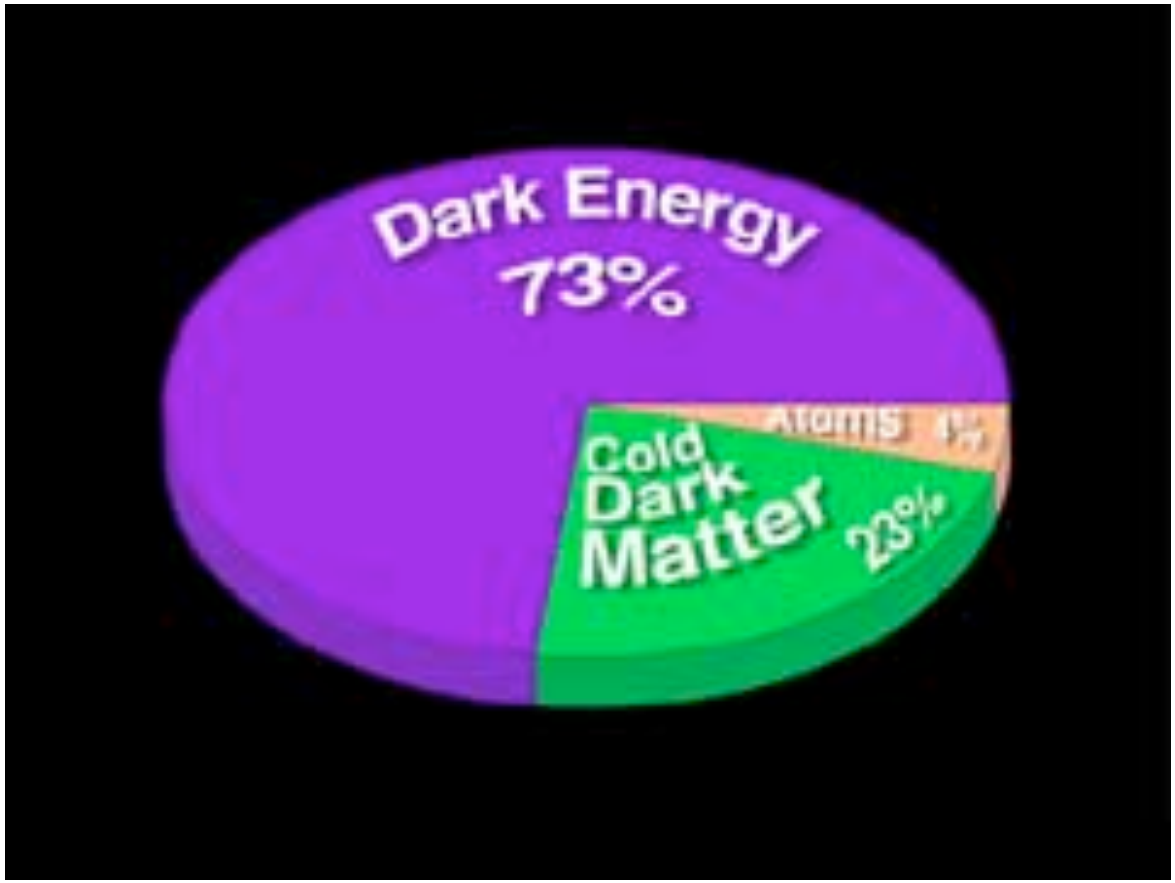
1,000,000,000,000,000,000,000,000

1,700,000,00 ly across

across



Mass/Energy Budget of the Universe



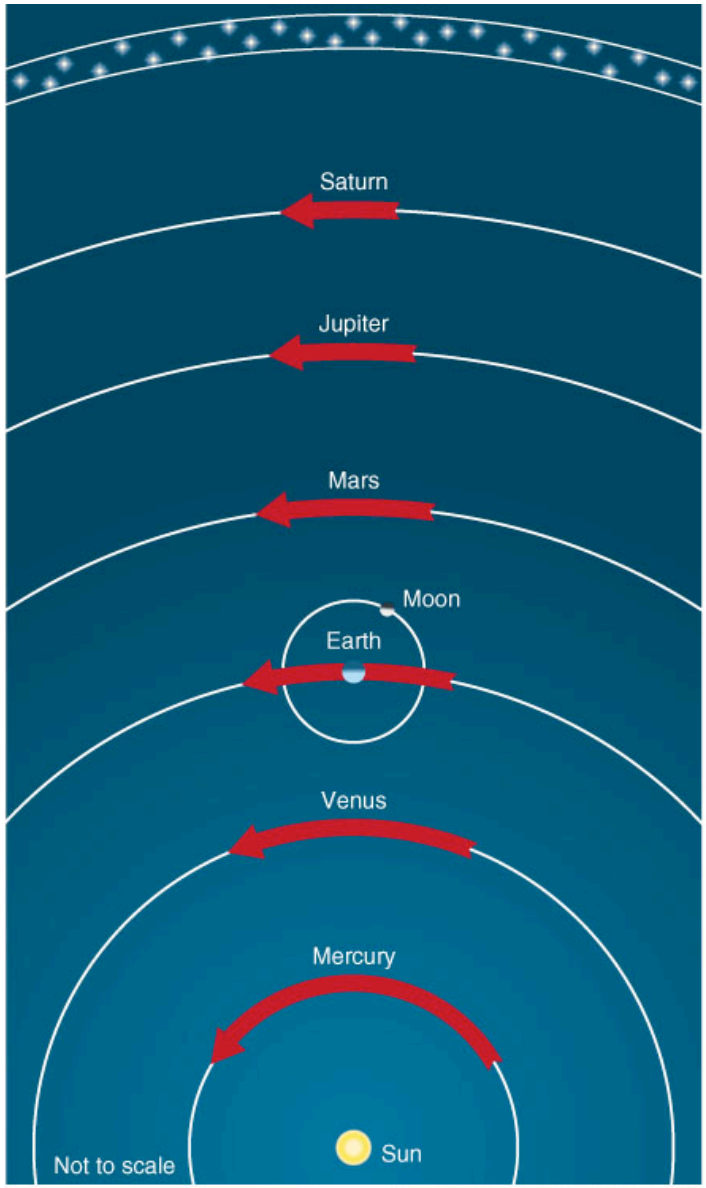
Basics of Kepler and Newton

Orbits of the planets, moons, …

Kepler's Laws, as derived by Newton.

- Kepler's Laws
- Universal Law of Gravity
- Three Laws of Motion
- Deriving Kepler's Laws

Recall: The Copernican Model

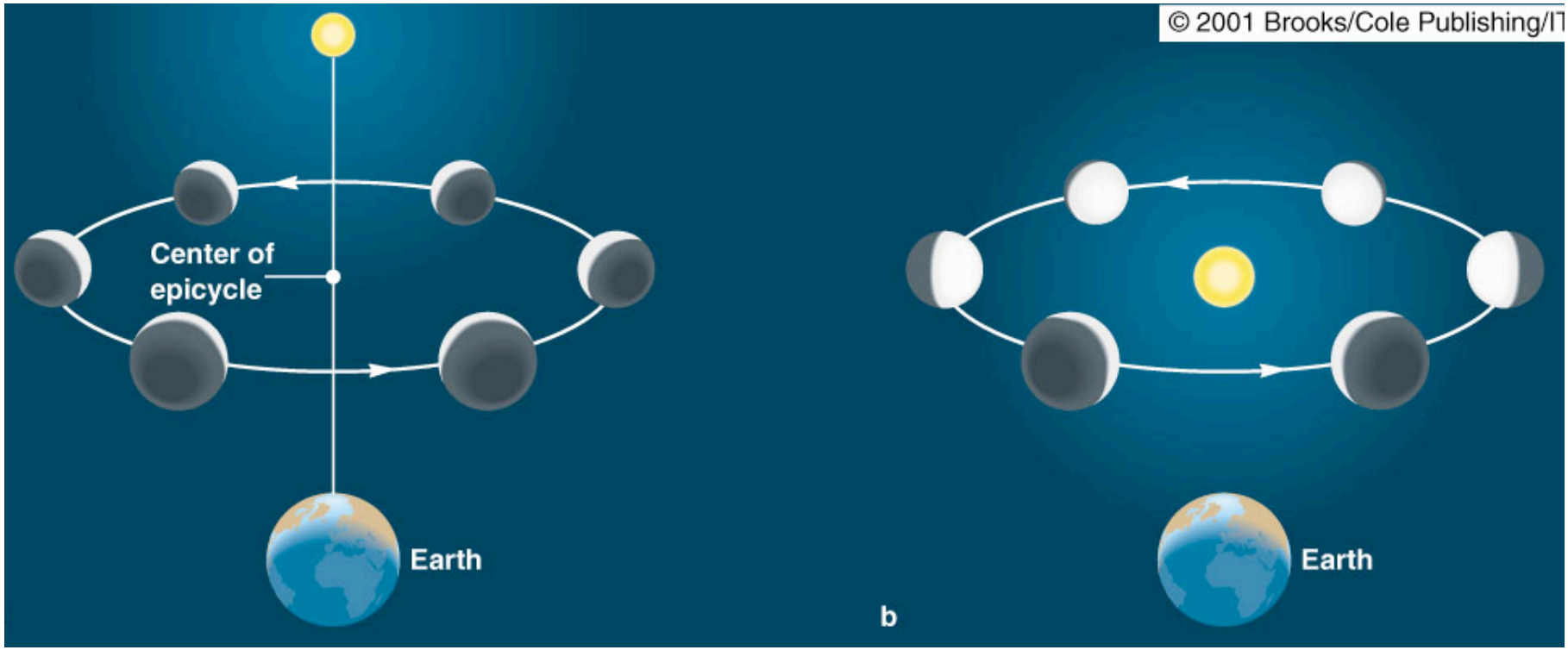


- Postulated planets orbit Sun, not Earth
- Worked out correct order of planets from Sun
- Realized planets near Sun move fastest
- Accurately measured distances of planets from Sun, and orbital periods

Telescopic observations of the phases of Venus confirm the heliocentric model

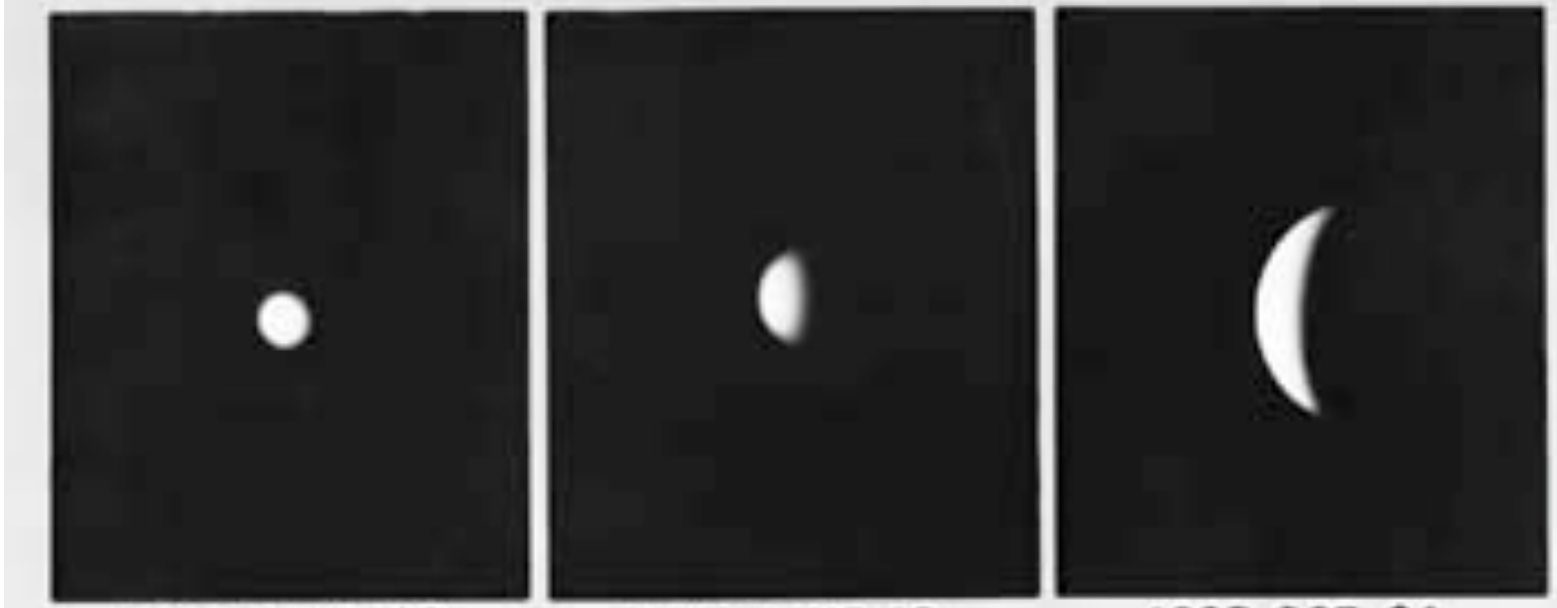
Geocentric

Heliocentric

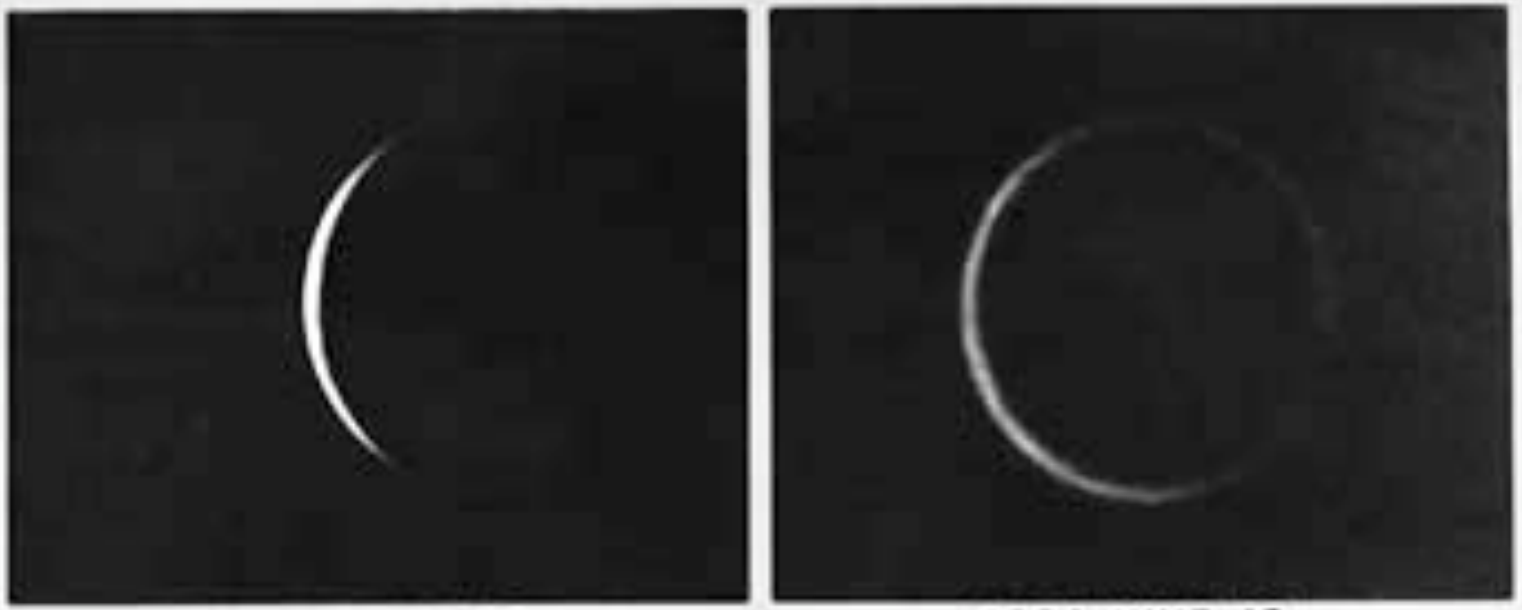


Always crescent

Full range of phases



1910 SEPT 27 1910 JUNE 10 1927 OCT 24



1919 SEPT 25 1964 JUNE 19

Tycho Brahe (b.1546)

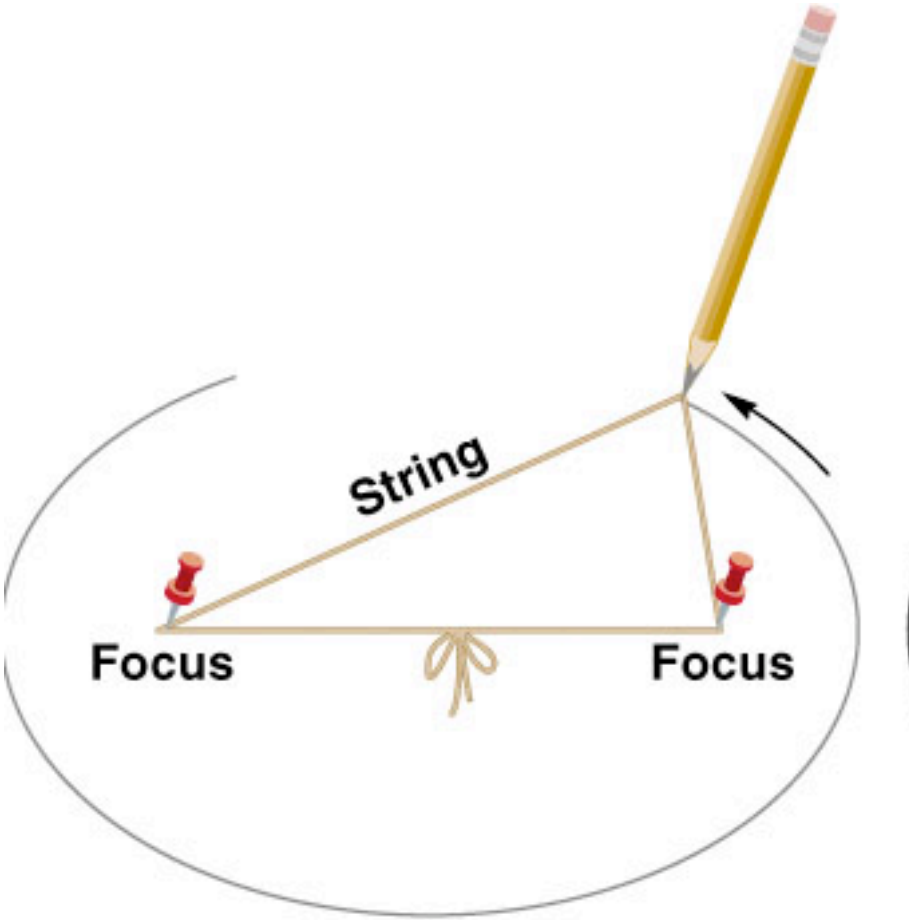
Collected most accurate observations of planetary motions to date. Found Copernican model still did not agree with data.

Kepler (b.1571)

Hired as an assistant by Tycho to interpret observations of planetary motion.

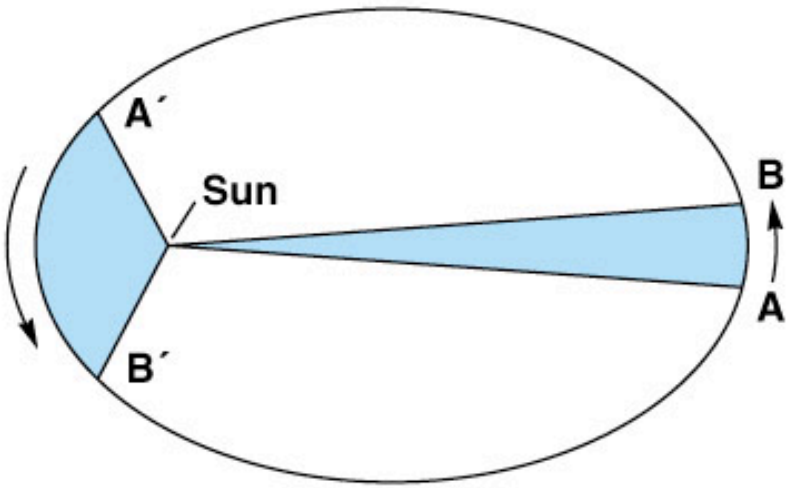
Kepler's Three Laws

I. Orbits of planets are ellipses with sun at one focus



Kepler's Three Laws

II Line from planet to sun sweeps out equal areas in equal intervals of time



b

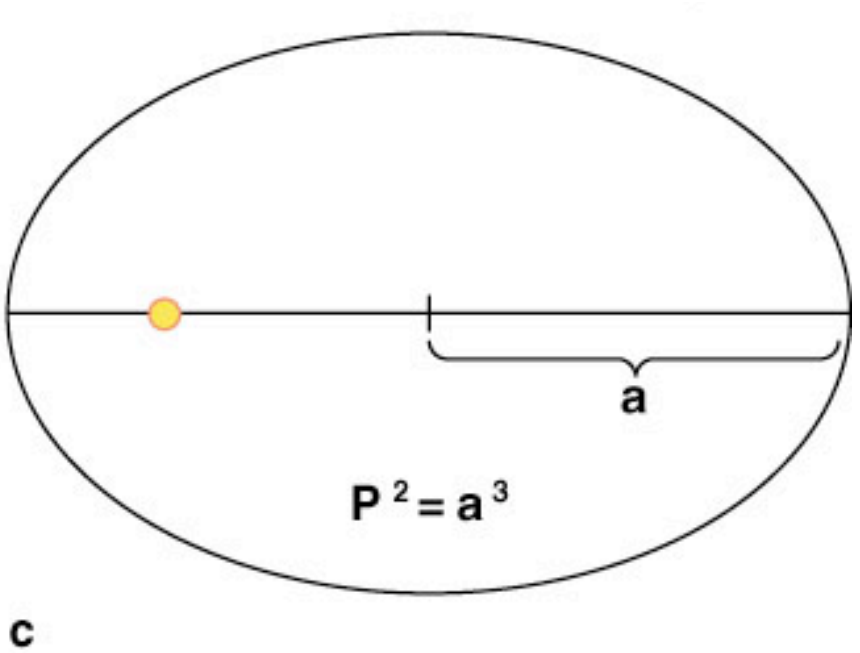
Kepler's Three Laws

III Planet's orbital period squared is proportional to its average distance from sun cubed:

$$P^2 = a^3$$

P is period in years

a is average distance in AU



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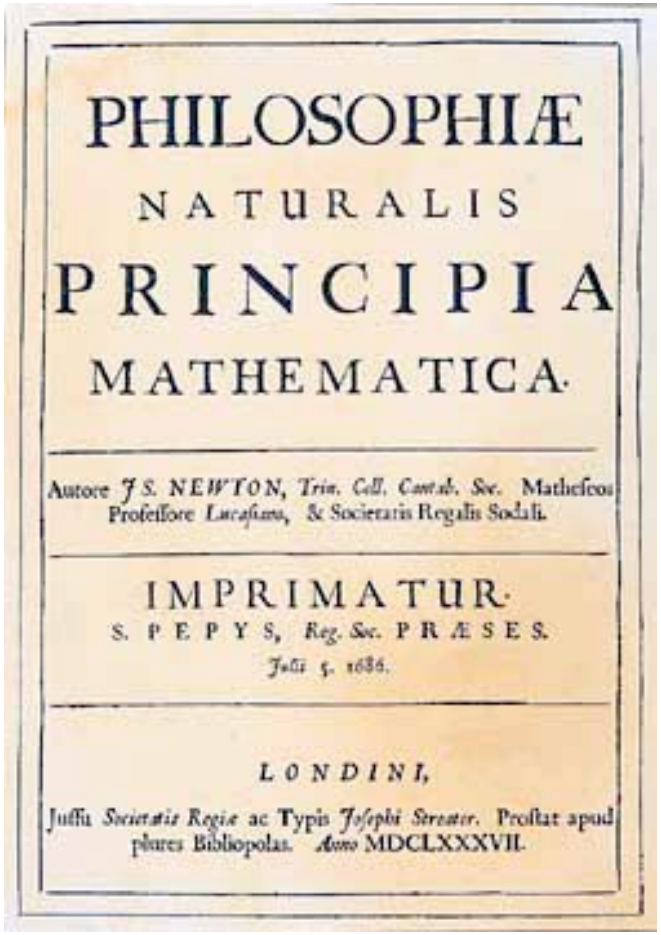
Newton (b.1642)

Mathematician and physicist. Developed Laws of mechanics and gravity, and invented calculus, to explain planetary motion



PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.

Autore *J S. NEWTON, Trin. Coll. Cantab. Soc.* Matheseos Professore *Lucasiano*, & Societatis Regalis Sodali.

IMPRIMATUR.
S. PEPYS, *Reg. Soc.* PRÆSES.
Julii 5. 1686.

LONDINI,
Justu *Societatis Regiæ* ac Typis *Josephi Streater.* Prostat apud plures Bibliopolas. *Anno* MDCLXXXVII.

Newton's Laws of Motion

I An object

at *rest* continues so or

in *uniform motion* continues so

unless acted upon by some (net) *force*

The momentum of an object remains constant unless it experiences an external force

Principle of Inertia

Newton's Laws of Motion

II A body's *change* of motion is proportional to the force acting on it, and in the direction of the force.

$$\mathbf{F} = m\mathbf{a} = m(d\mathbf{v}/dt) = (d\mathbf{p}/dt)$$

Where m is mass of body, and $\boldsymbol{a}$ its acceleration (any change in speed **or** direction), $\boldsymbol{v}$ is velocity, $\boldsymbol{p}$ is momentum, $m\boldsymbol{v}$

Newton's Laws of Motion

III When a body exerts a force on a 2nd body, the 2nd body exerts an equal but oppositely directed force on the 1st body

Action – Reaction

$\mathbf{F}_{12} = -\mathbf{F}_{21}$

Laws applied to planetary motion

- First law says there must be a force acting on the planets
- Newton realized that force must be *gravity*, that inverse-square-law forces lead to elliptical orbits

Gravity

- Same force that causes an apple to fall to Earth causes the Moon to orbit the Earth
- Law of Gravity: gravitational force between two masses M and m separated by distance R is

$$F = G M m / R^2$$

G is a constant number (6.67×10^{-11} Nm^2/kg^2 = 6.67×10^{-8} (cgs))

Kepler's Laws explained

- Using only Laws of Mechanics and Gravity (and *the calculus*), Newton could derive Kepler's three laws.
- Kepler *discovered* them, but Newton *understood* them.