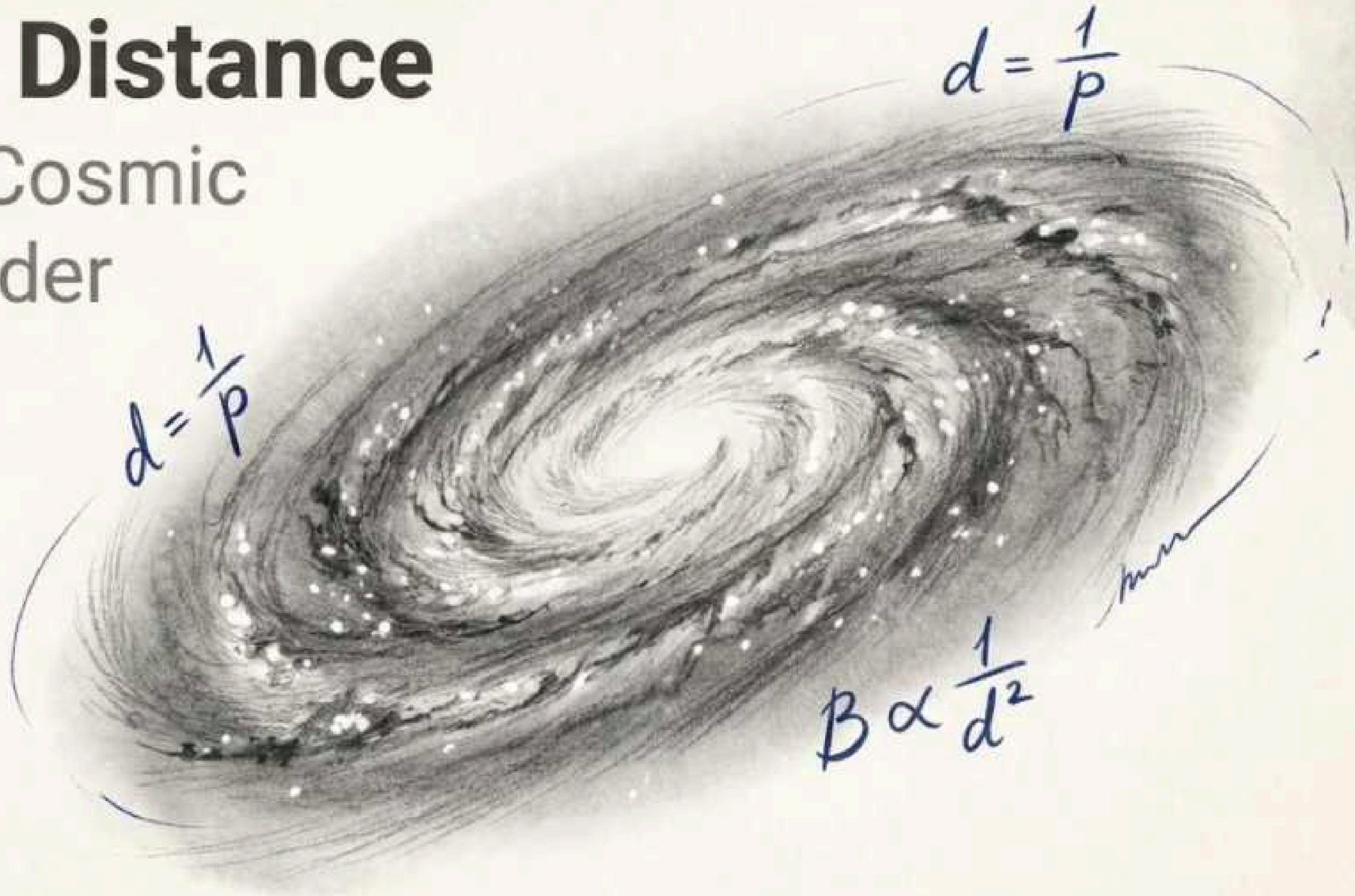
ASTR 210 B Lecture 1: Scale and Distance

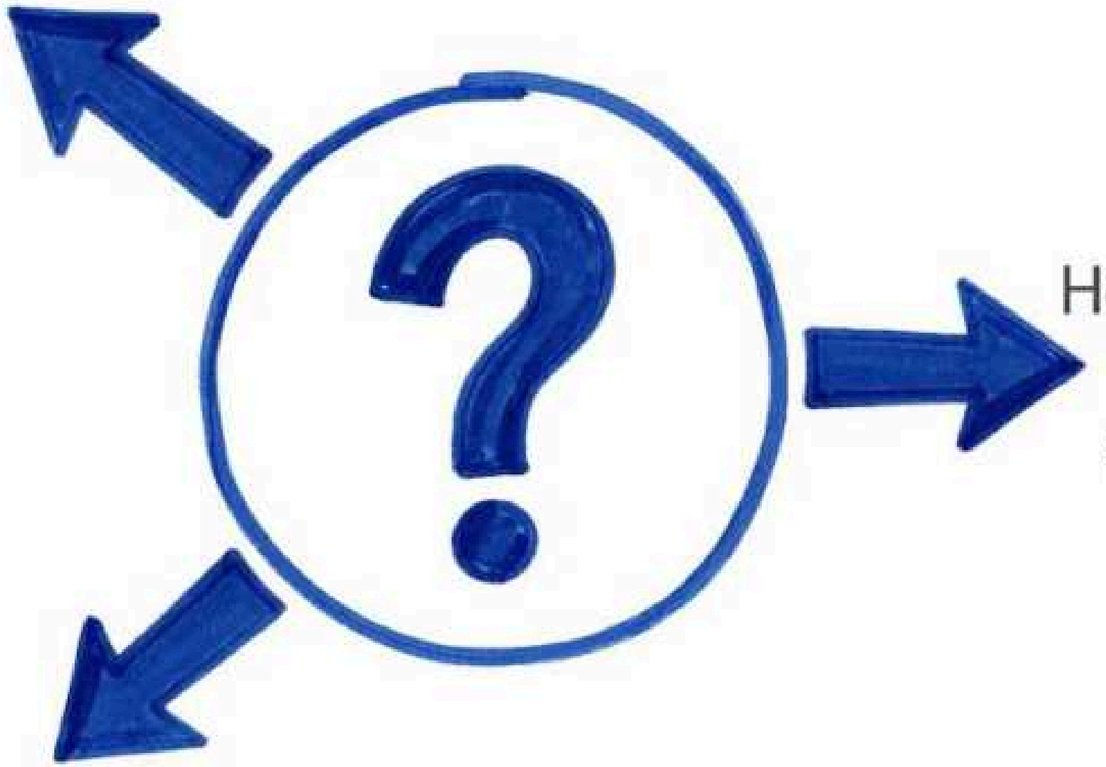
Building the Cosmic Distance Ladder



¶ 1.1

Scale

How big is the universe?



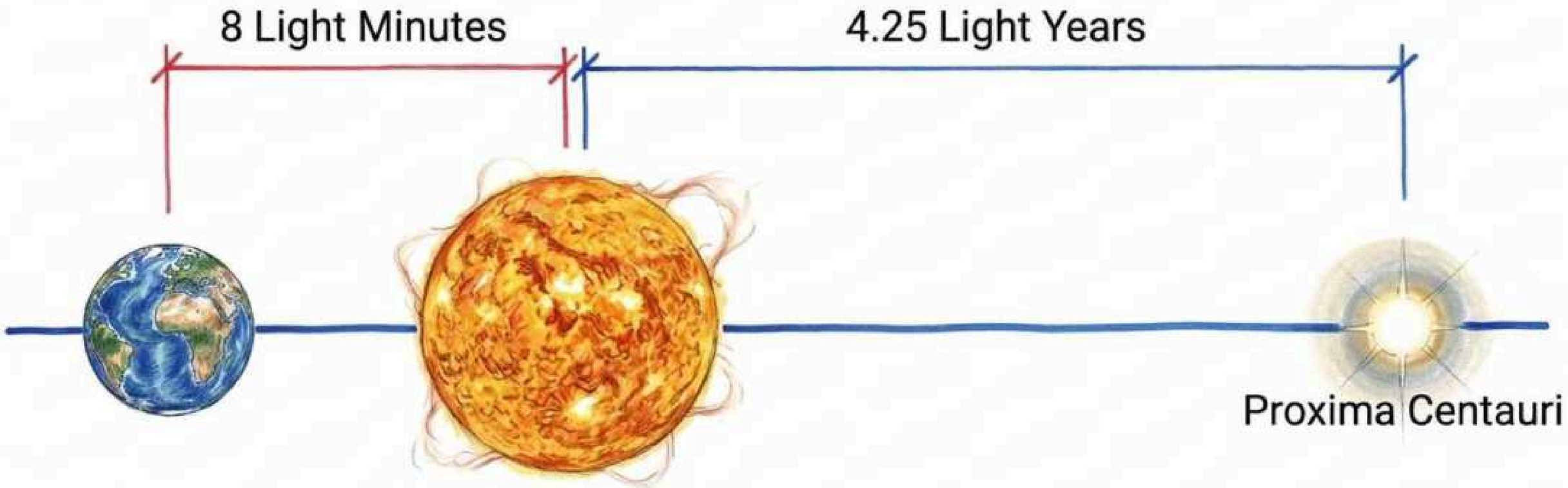
Method

How can we measure the distance to something we can never visit?

Scope

What is the difference between the universe and the observable universe?

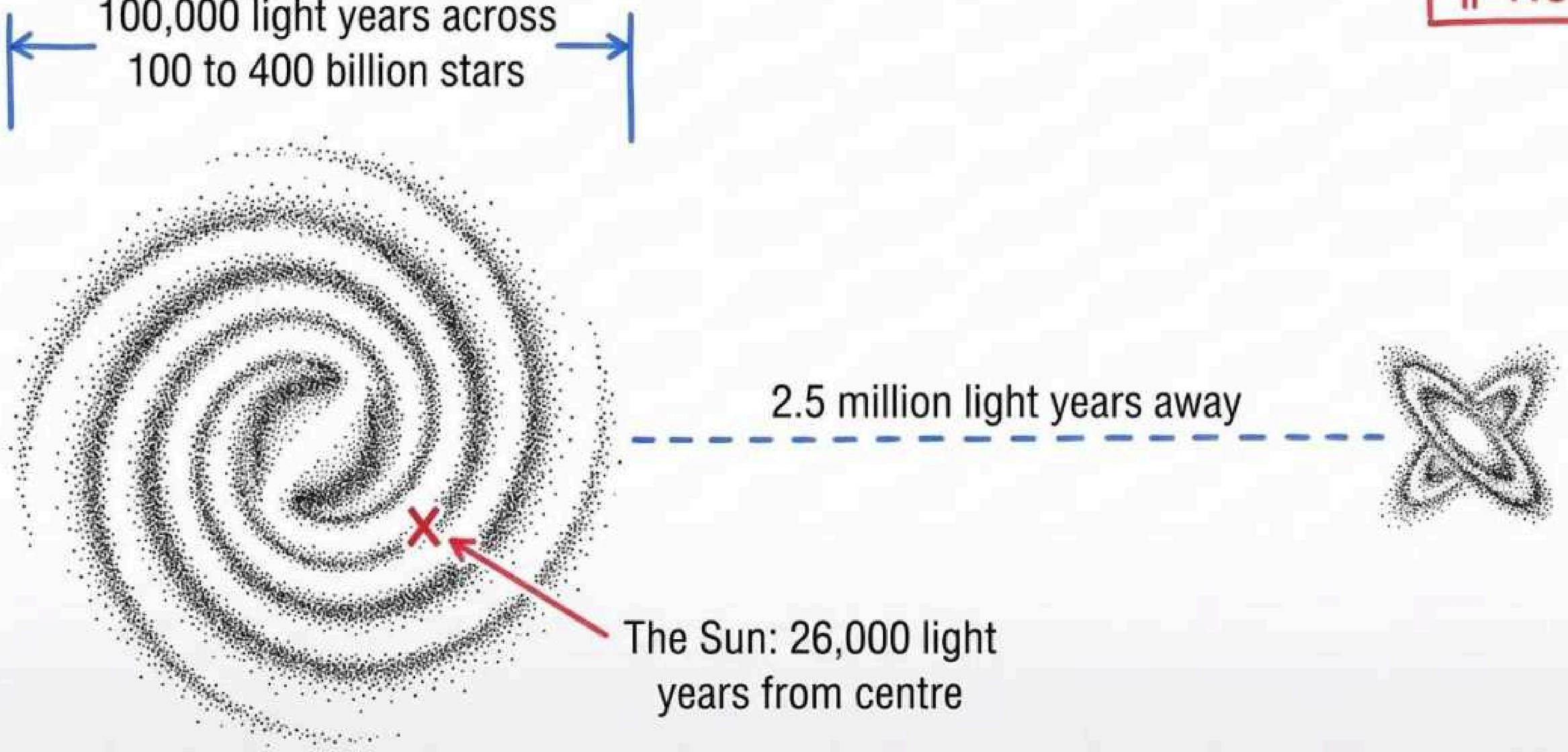
¶ 1.2



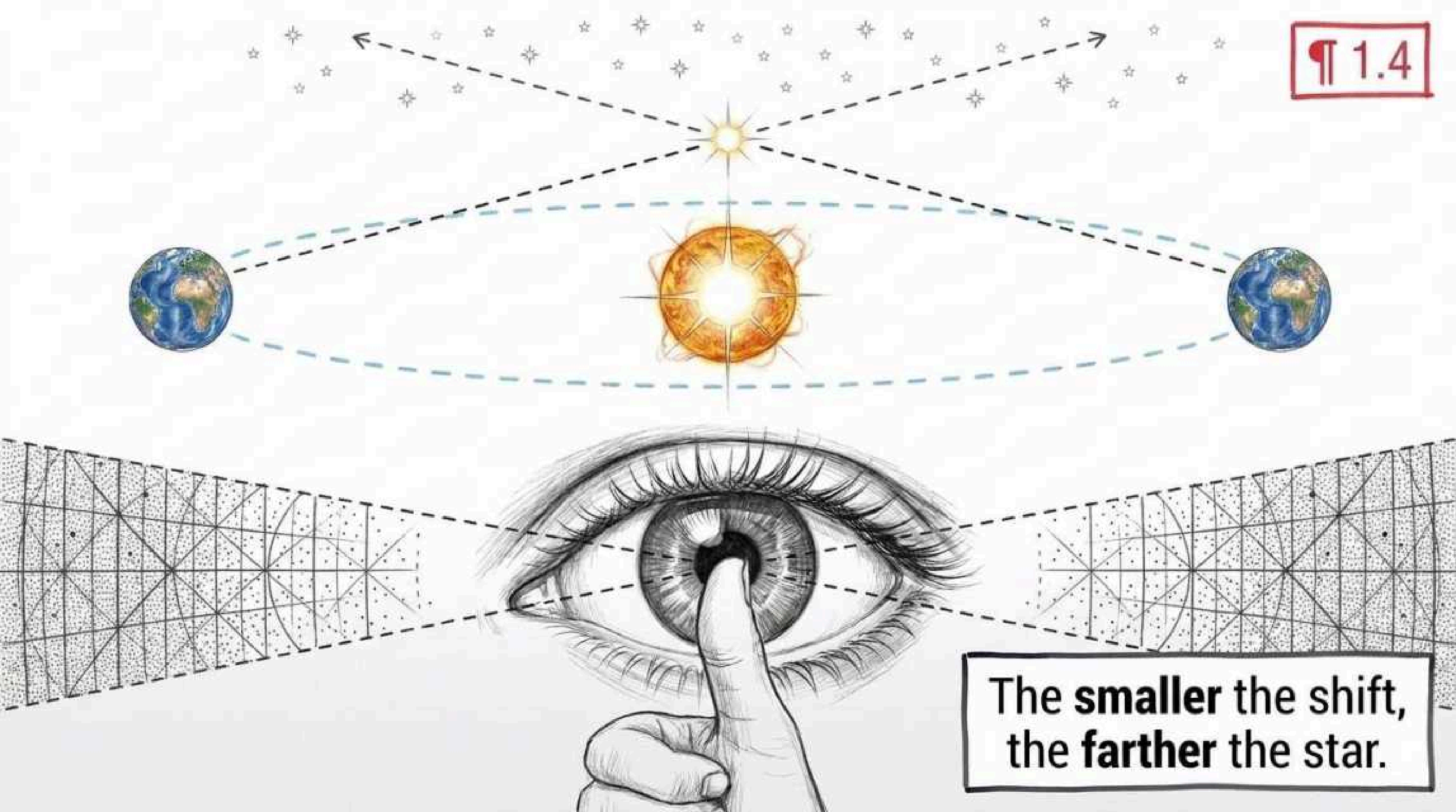
The Light Year

The distance light travels in one year (approx. 9.5 trillion kilometres).

¶ 1.3


100,000 light years across
100 to 400 billion stars
2.5 million light years away
The Sun: 26,000 light years from centre

¶ 1.4



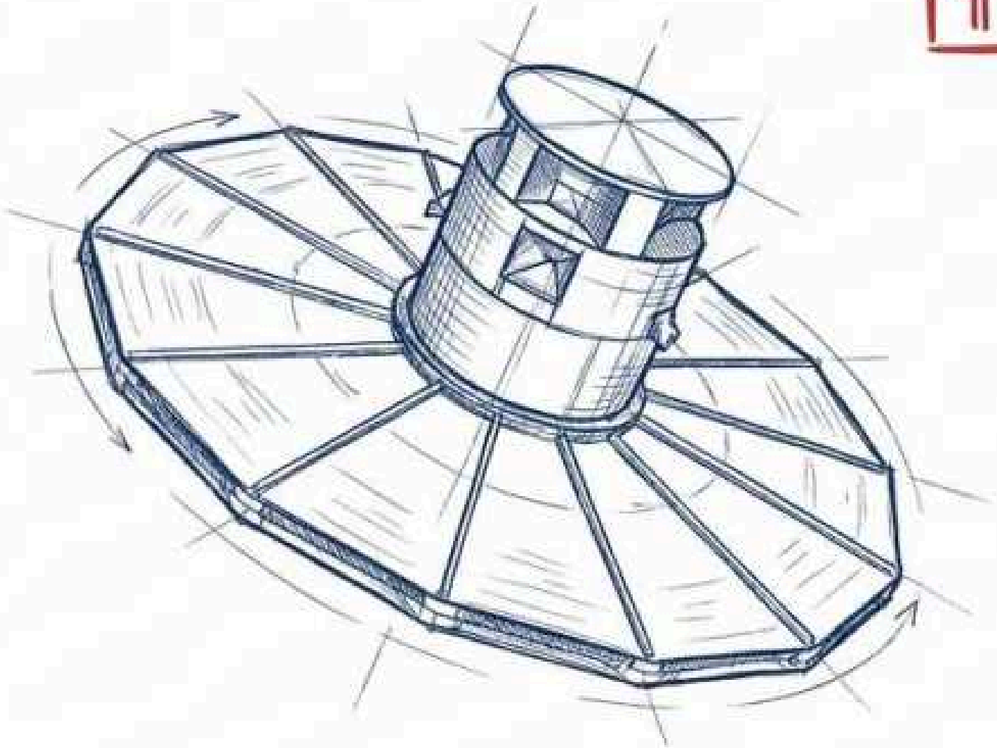
The **smaller** the shift,
the **farther** the star.

¶ 1.5

$$d = \frac{1}{p}$$

1 Parsec (pc)

Distance where a star shifts by 1 arcsecond (~3.25 light years).

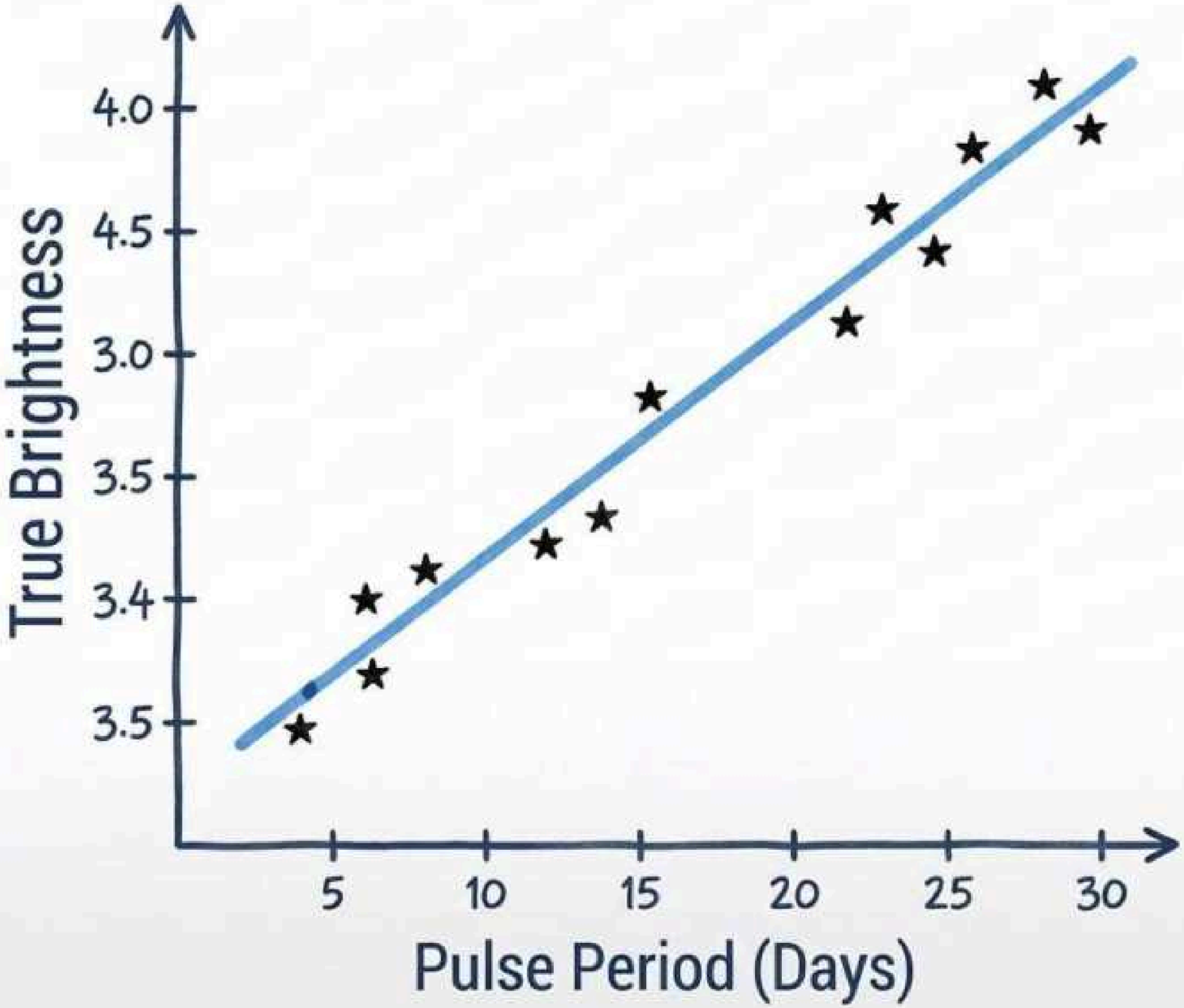


1838: Friedrich Bessel measures the first stellar parallax.

2013: Gaia space telescope launches.

↖ Measured parallaxes for >1 billion stars.

¶ 1.6

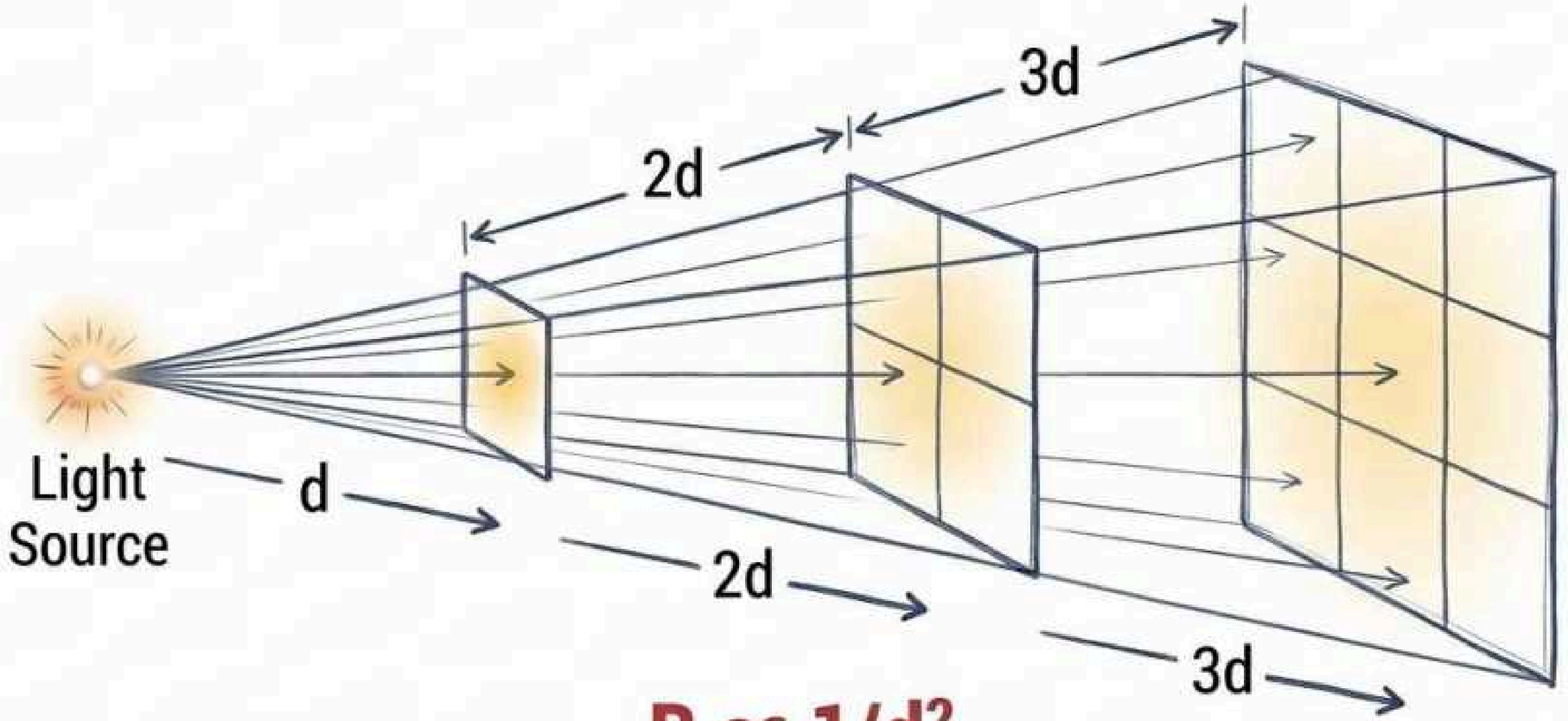




The 1912 Breakthrough

Cepheid Variables: Pulsing stars that pulse more slowly the brighter they truly are.

¶1.7



$$B \propto 1/d^2$$

(Apparent brightness fades with the square of distance)

Standard Candles

If a Cepheid pulses every 10 days, its true brightness is known. By comparing this true brightness to how dim it appears, we can calculate its exact distance.

¶ 1.8

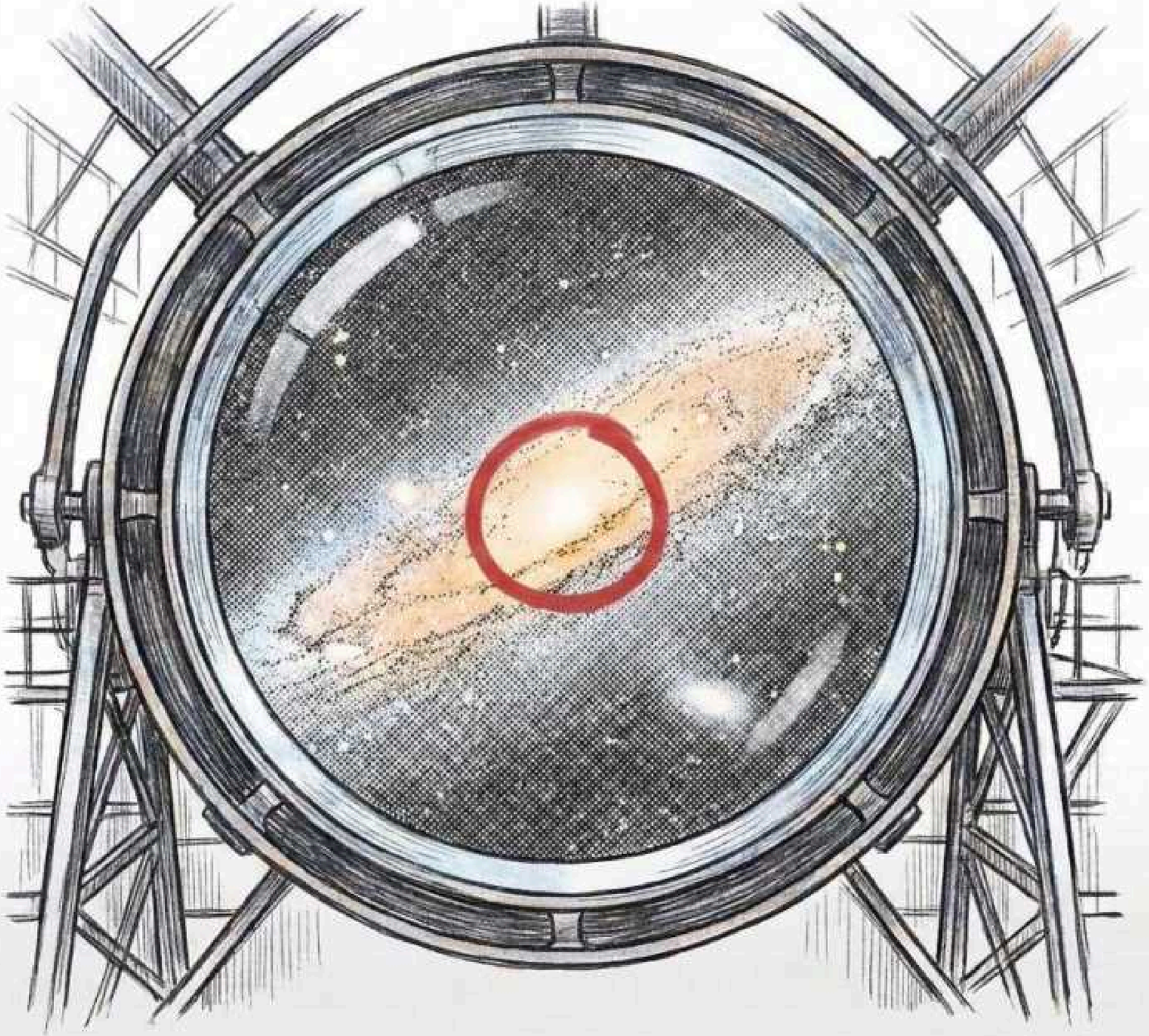
The Great Debate (1920)

Harlow Shapley

- The Milky Way is the whole universe.
- Spiral nebulae are nearby clouds of gas within our galaxy.

Heber Curtis

- The Milky Way is just one galaxy among many.
- Spiral nebulae are separate, distant galaxies far beyond our own.



¶1.9

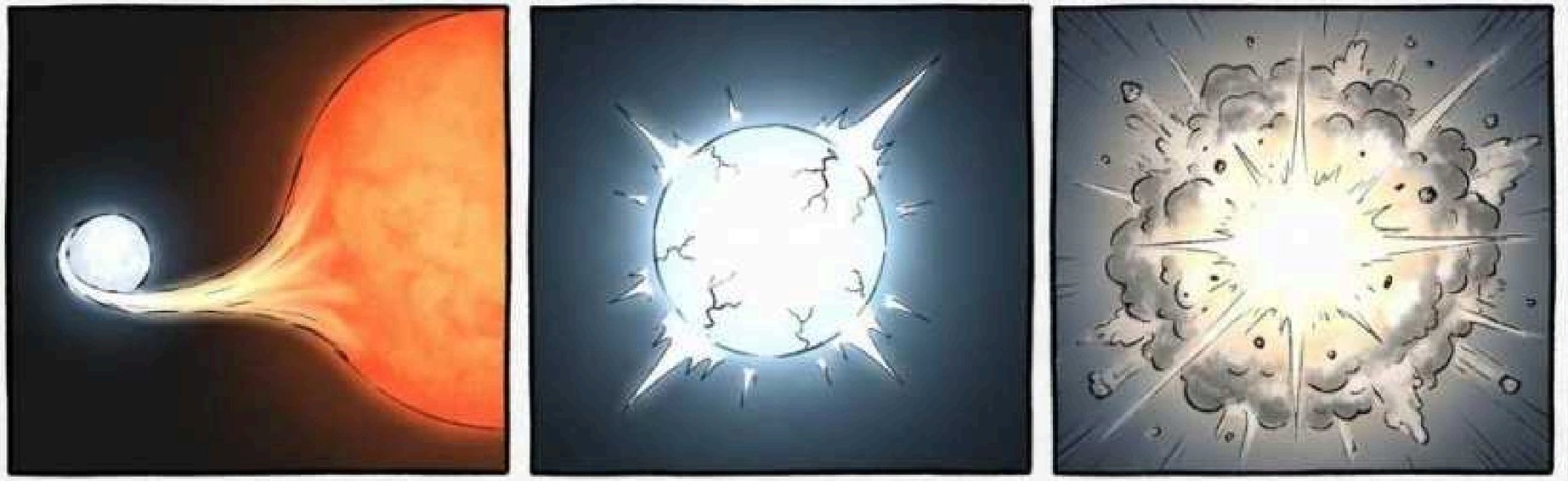
Edwin Hubble, 1923

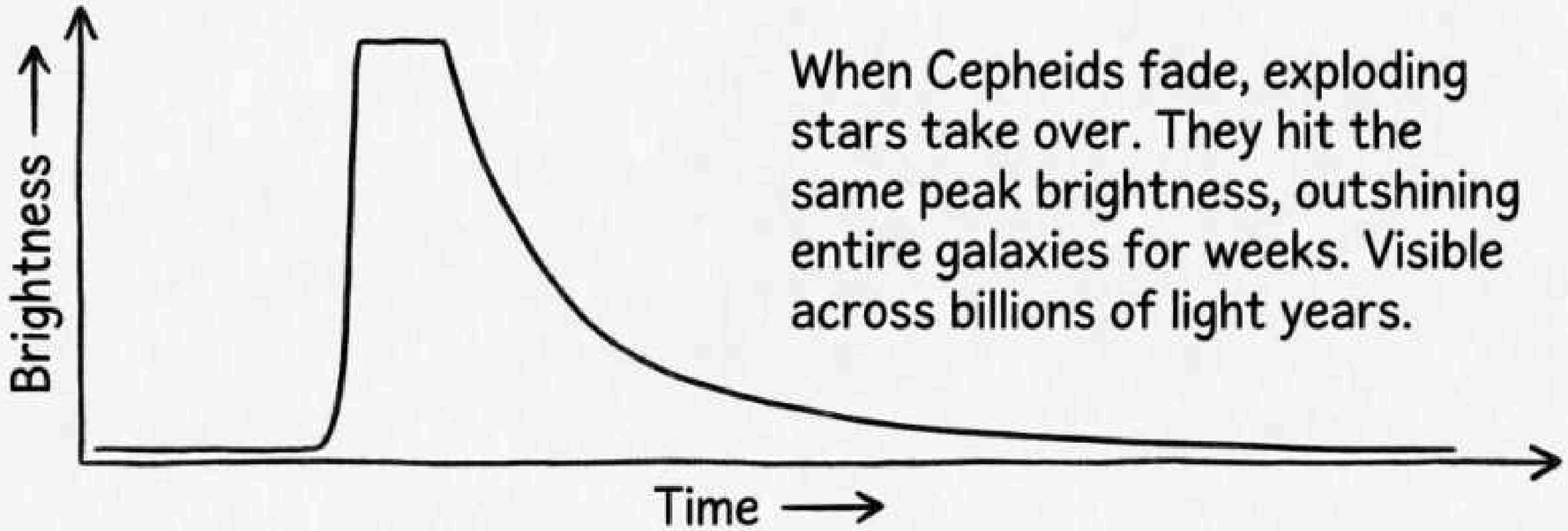
Hubble found a Cepheid variable in the Andromeda n.

The standard candle calculation proved it was far outside the Milky Way.

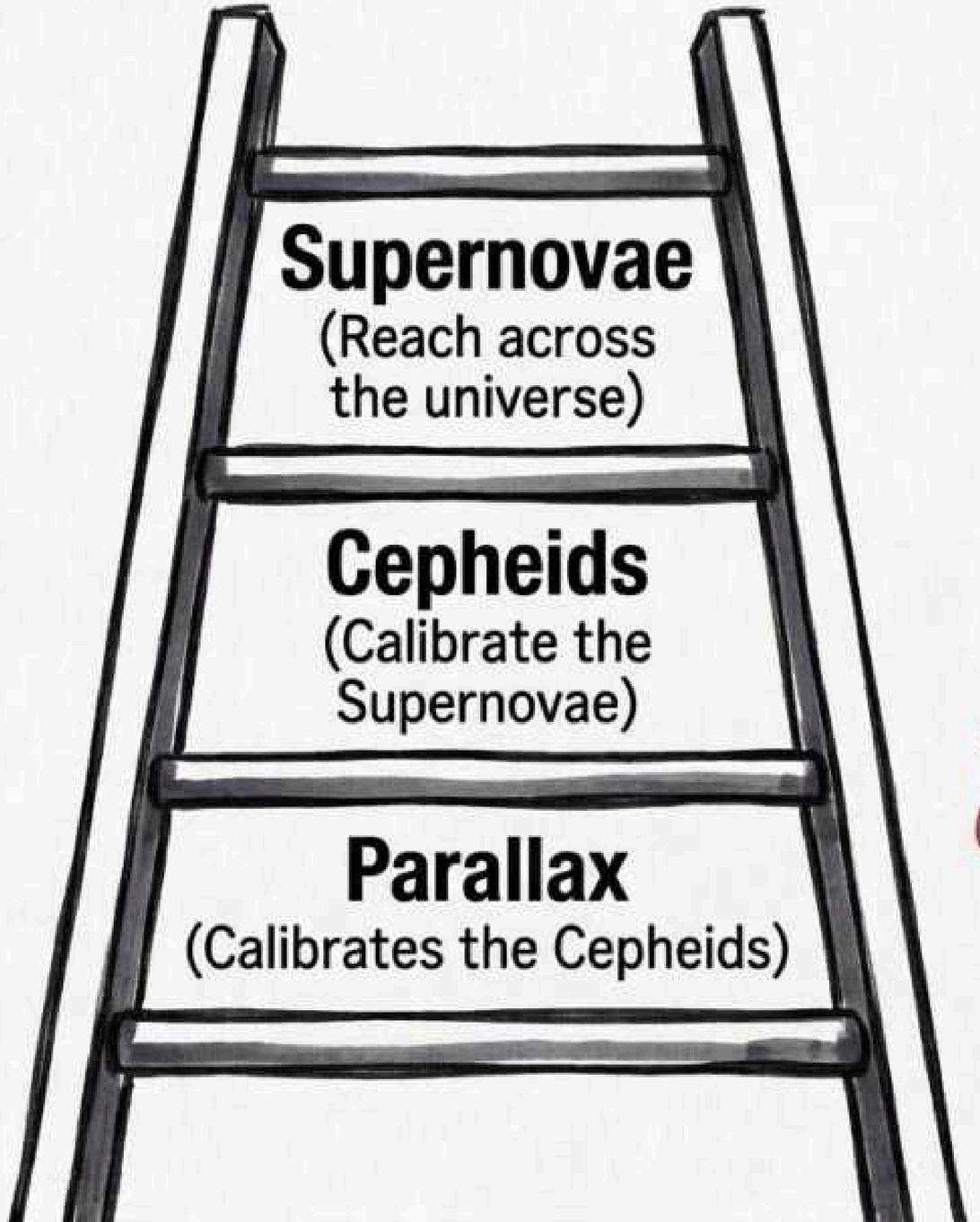
Andromeda was a separate galaxy. The universe had just become vastly larger.

Type Ia Supernova





When Cepheids fade, exploding stars take over. They hit the same peak brightness, outshining entire galaxies for weeks. Visible across billions of light years.

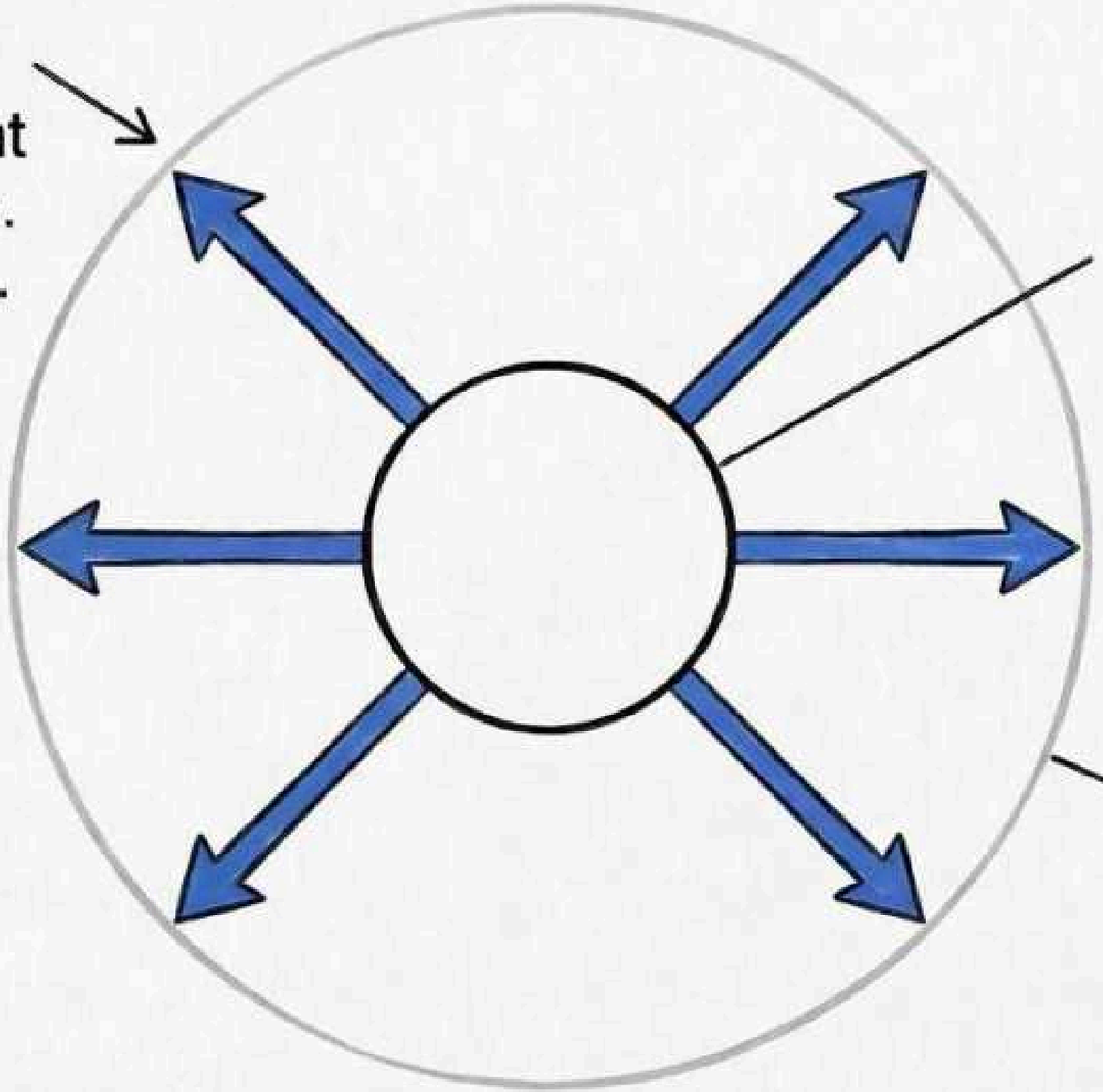




An error on a lower rung spreads upward. Check each step!

¶ 1.12

Finite speed of light +
Finite age of universe
= We only see light that had time to reach us.
had time to reach us.

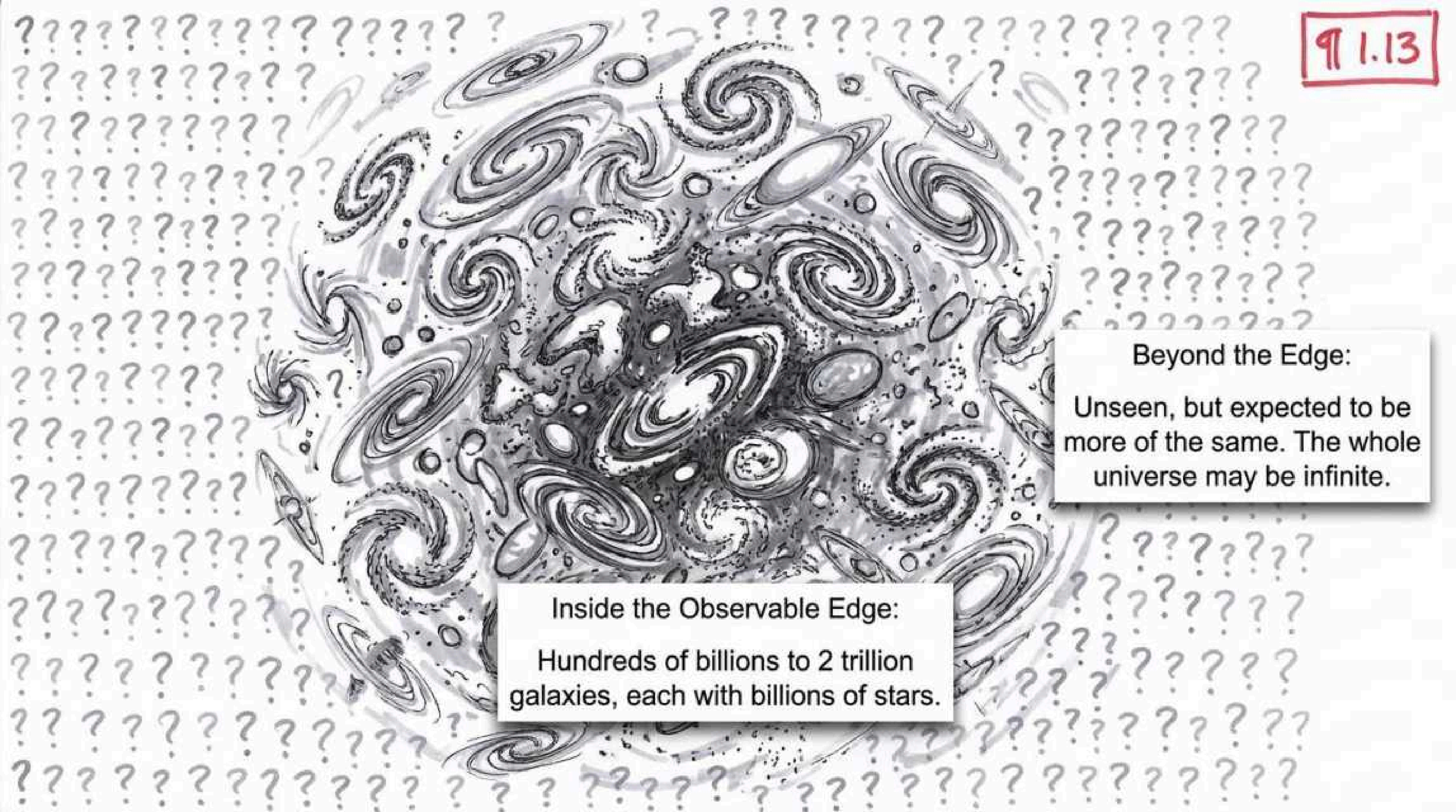


Light Travel Limit

Edge pushed out by expanding space:
46 billion light years away

Total Observable Diameter = 93 billion light years

¶ 1.13



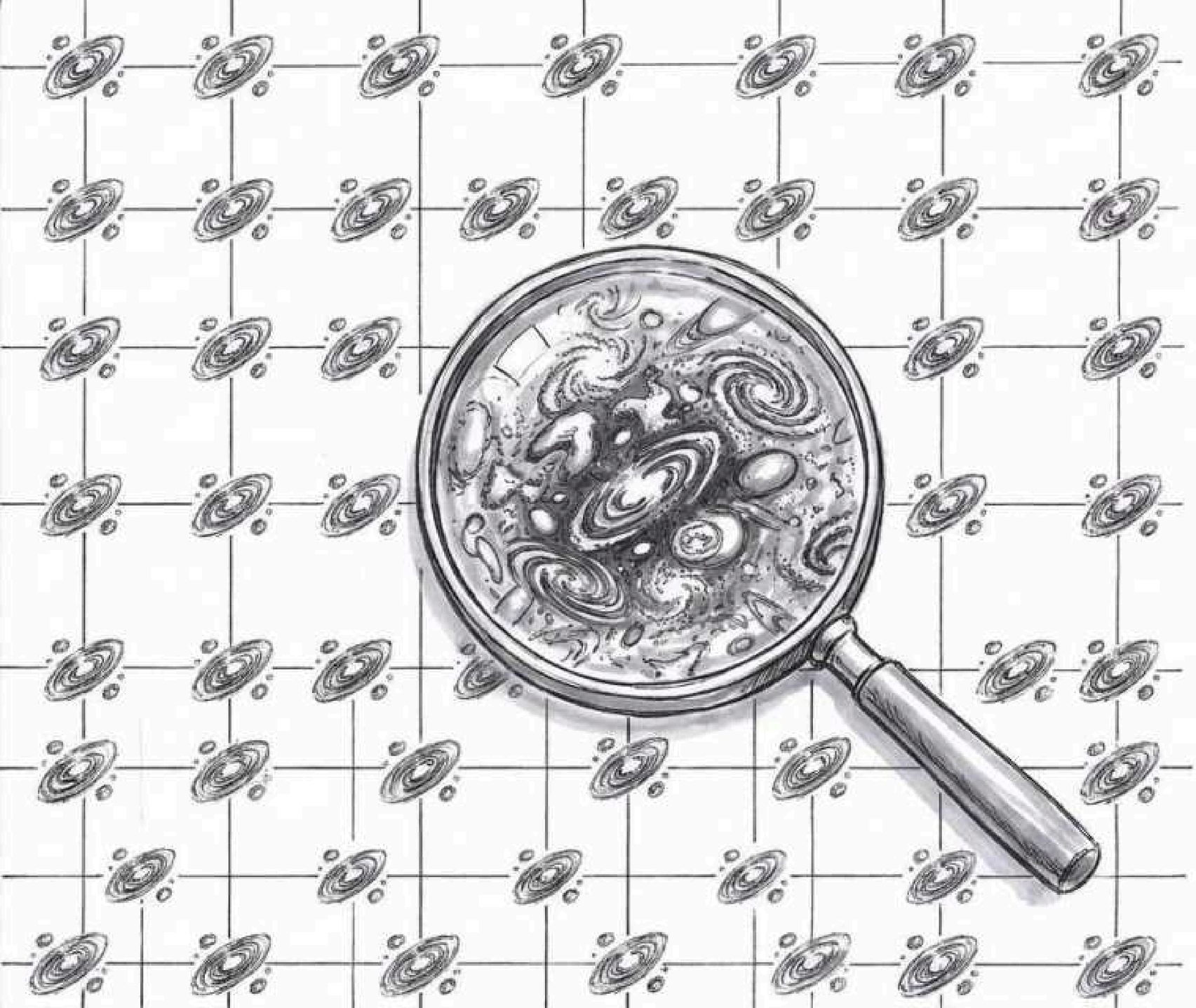
Beyond the Edge:

Unseen, but expected to be more of the same. The whole universe may be infinite.

Inside the Observable Edge:

Hundreds of billions to 2 trillion galaxies, each with billions of stars.

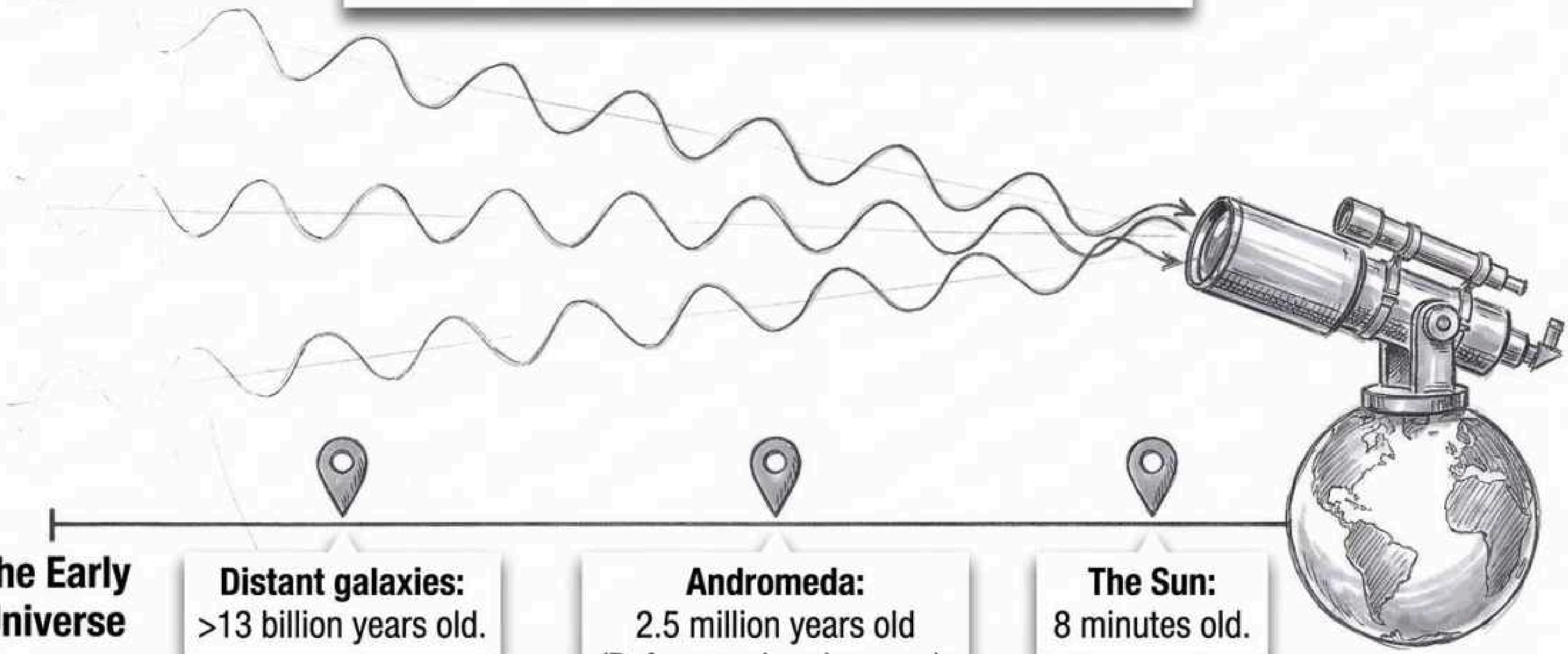
¶1.14



The Cosmological Principle

- On the largest scales, the universe looks the same everywhere and in every direction.
- We do not occupy a special place.
- This uniformity allows simple equations to describe the whole universe.

Telescopes = Time Machines



Infinite, Unchanging Universe



The Actual Night Sky



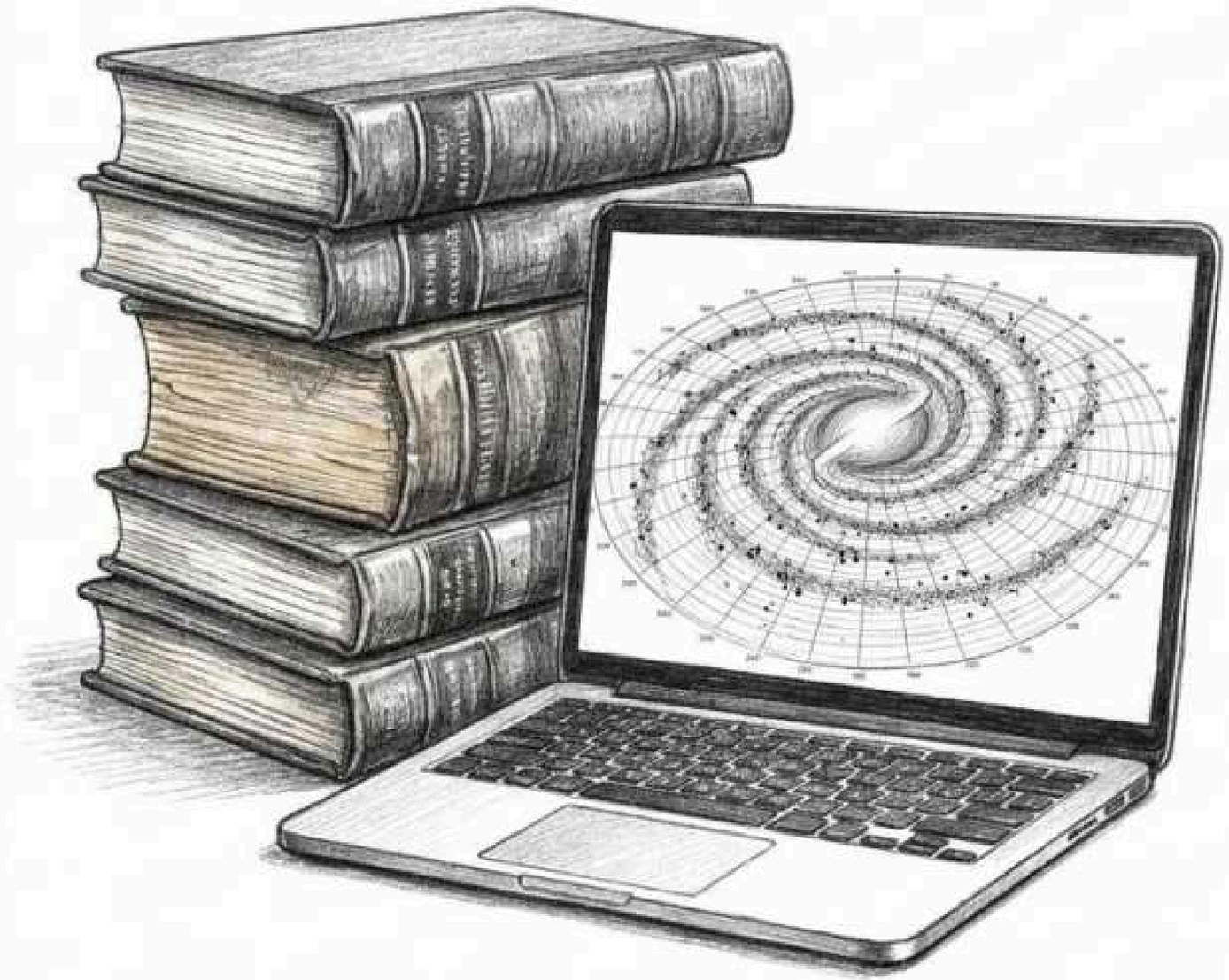
Olbers' Paradox (1823)

If space were infinite, unchanging, and full of stars, the sky would blaze like the Sun. A dark night sky proves the universe has a finite age.

Distances in Cosmology

Light Travel Distance	Proper Distance
How long the light has been travelling to reach us.	How far away the object is NOW, accounting for the expansion of the universe during the light's journey.

Caution: For distant galaxies, these two numbers can differ by billions of light years.



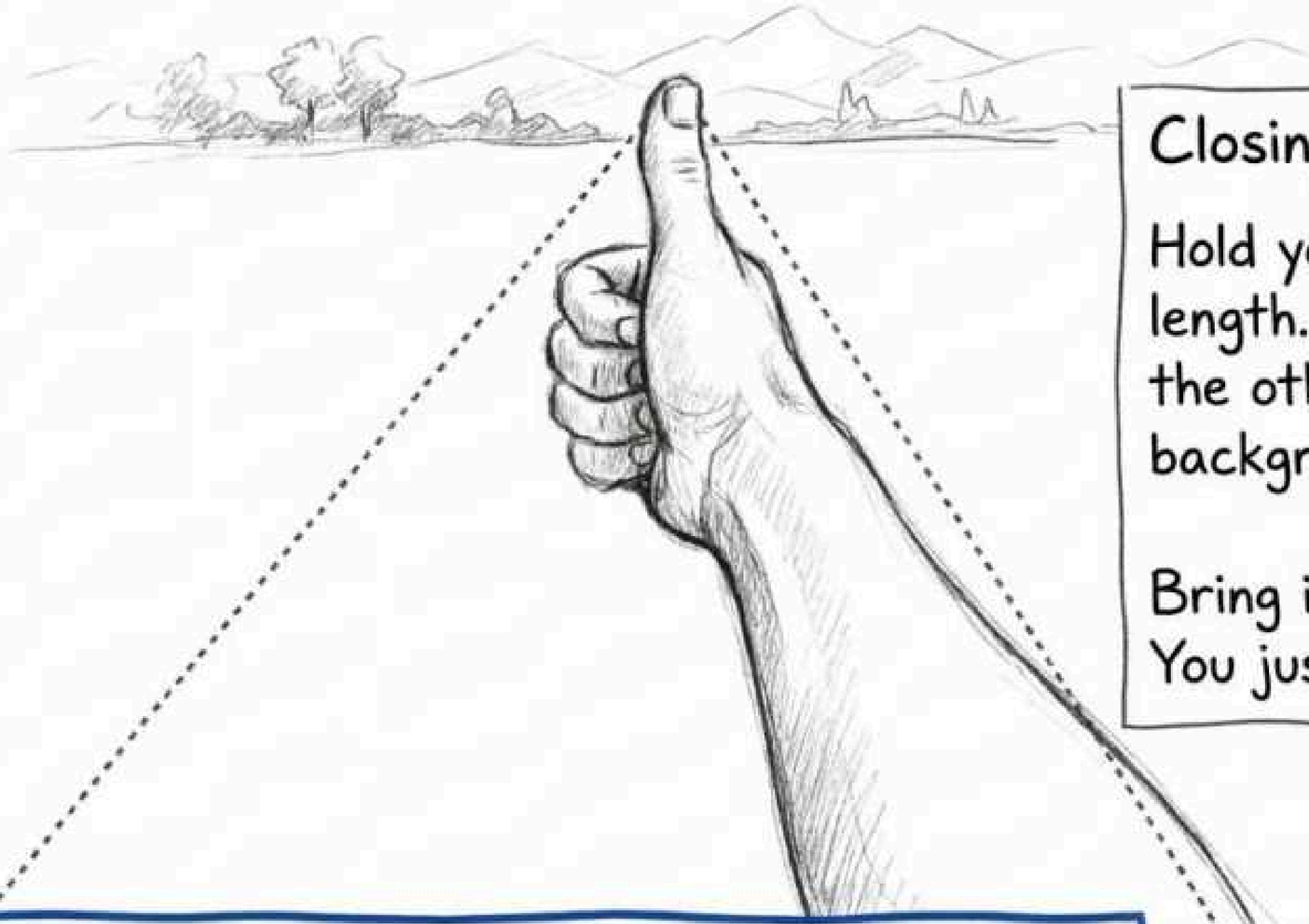
Where to go next?

1. Coming of Age in the Milky Way (Timothy Ferris)
   The history of how humans measured the cosmos.

2. Gaia Mission Public Website
   View modern, interactive maps of our galaxy.

3. Introductory Astronomy Textbooks
   Deep dives into the math of the distance ladder.

¶ 1.19



Closing Exercise:

Hold your thumb at arm's length. Look with one eye, then the other, against a distant background. Notice the jump.

Bring it closer and try again. You just measured parallax.

Preview: Lecture 2 — The Expanding Universe