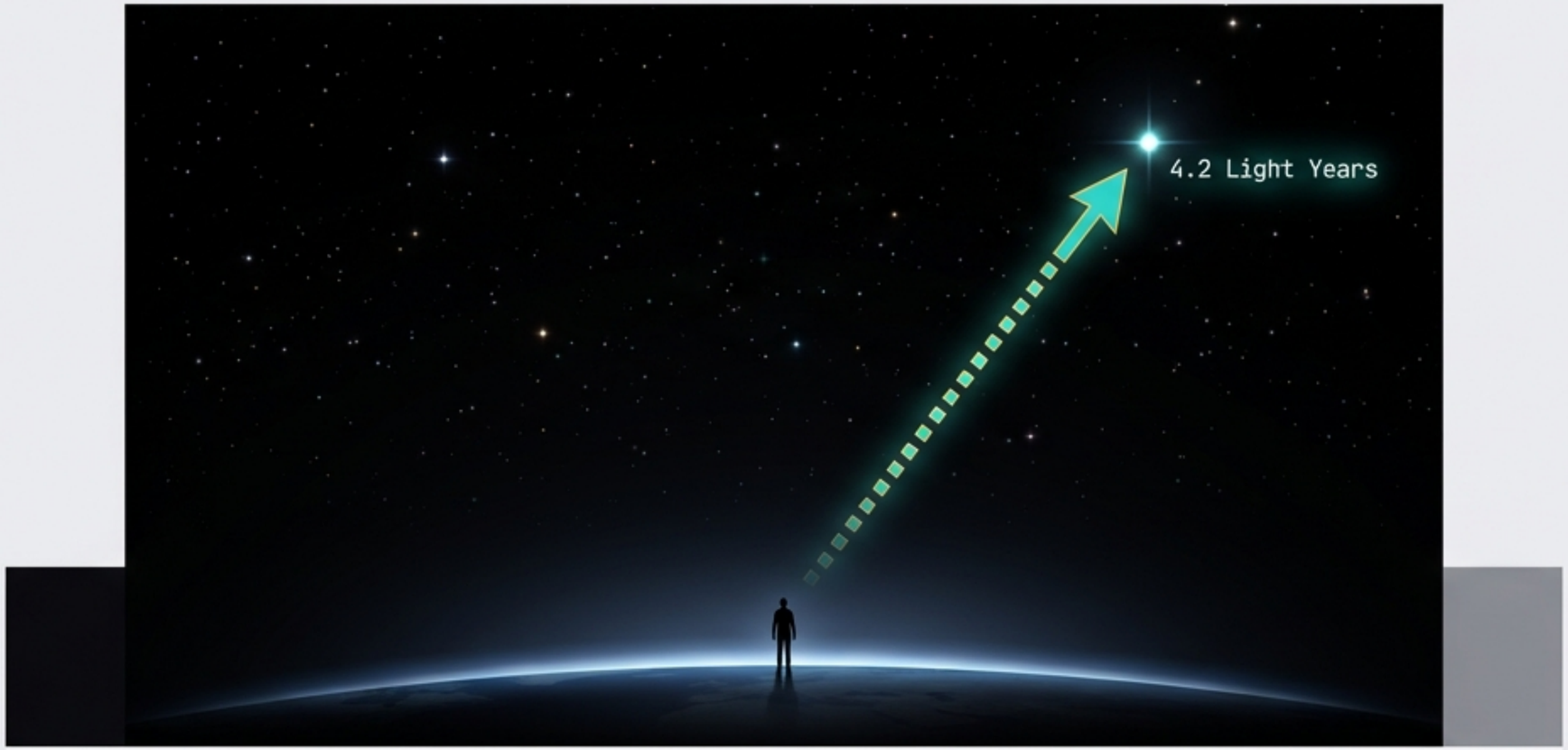

Spoiler Alerts: The Universe Is Weird
ASTR 201: How Astronomers Turn Photons into Physical Truth
Spring 2026 | Dr. Anna Rosen
Thesis: Pretty pictures → measurements → models → inferences
NotebookLM



We Are Stuck Here. They Are Way Over There.

We cannot sample the Sun. We cannot touch the stars. We cannot travel to the edge of the universe with a tape measure.

Unlike geologists who hold their rocks, or biologists who dissect their specimens, astronomers are separated from their subject by an impassable void.

Yet, we claim to know the Sun is 5,800 K, the universe is 13.8 billion years old, and you are made of stardust.

How? By treating light as a carrier of information. Astronomy is the science of inferring physical reality from constrained measurements.

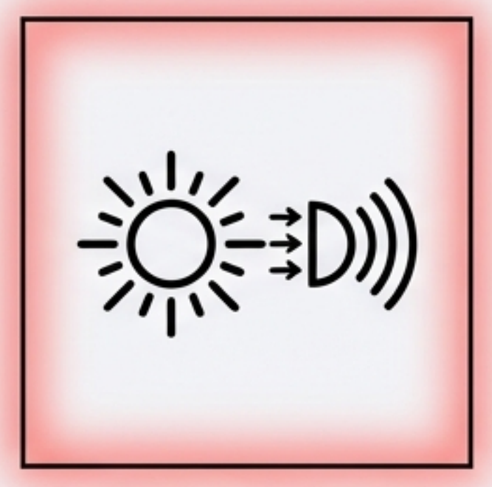
The Astronomer's Toolkit

Only Four Observables

From our vantage point on Earth, we are severely limited. We count photons, we track where they come from, we measure their energy, and we watch how they change.

That is it. Everything else—Mass, Temperature, Radius, Age—is a calculation derived from these four inputs.

WHAT WE CANNOT MEASURE DIRECTLY:
Temperature, Composition, Distance, Mass, Age.



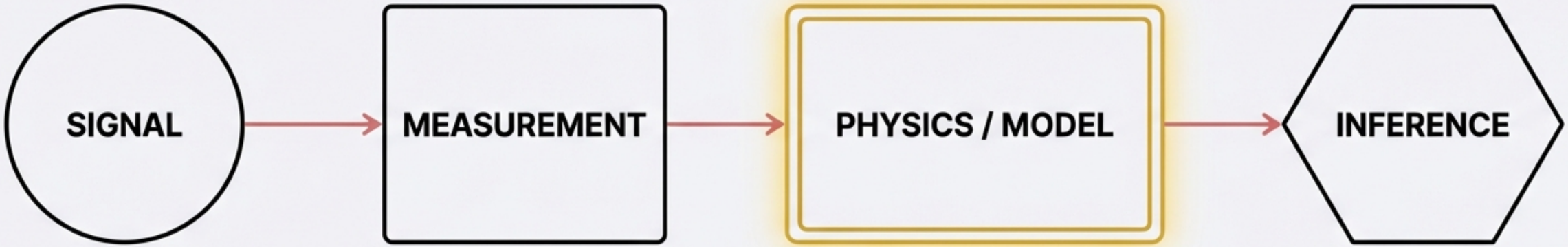
1. Brightness
(Energy/Flux)

2. Position
(Geometry/Angles)

3. Wavelength
(Spectroscopy/Color)

4. Timing
(Changes over time)

Physics is the Rosetta Stone.



Helvetica Now Display

Measurement: Star is Red
+
Model: Wien's Law
=
Inference: Low Temperature

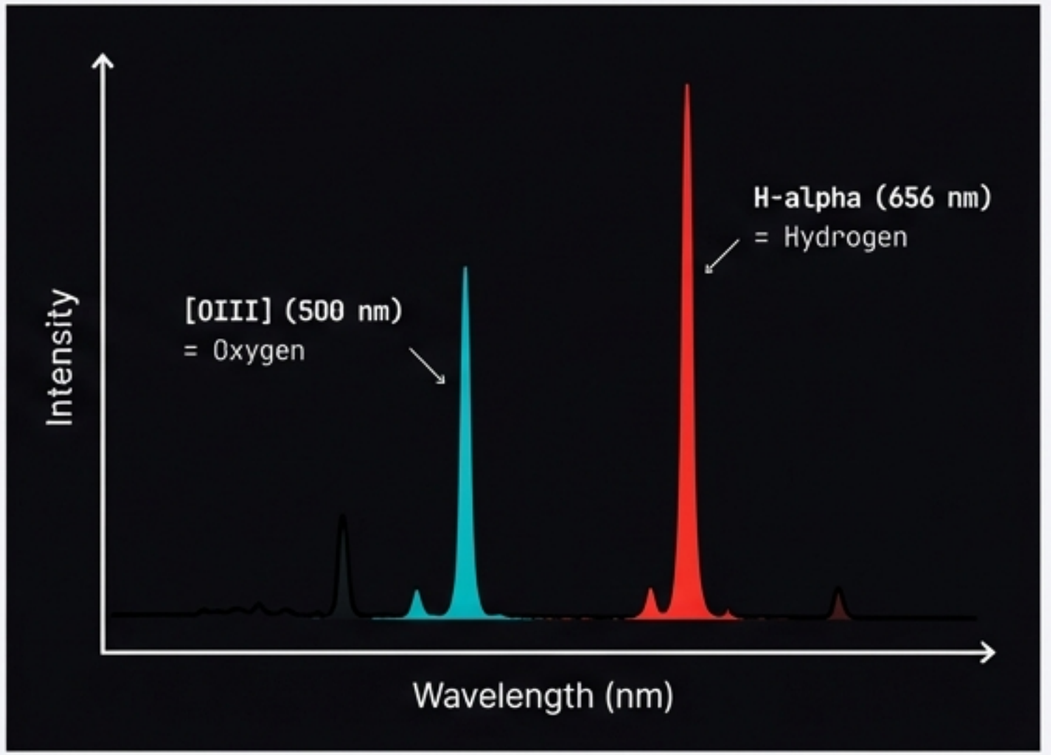
Helvetica Now Display

Measurement: Star is Faint
+
Model: Inverse-Square Law
=
Inference: Large Distance

Helvetica Now Display

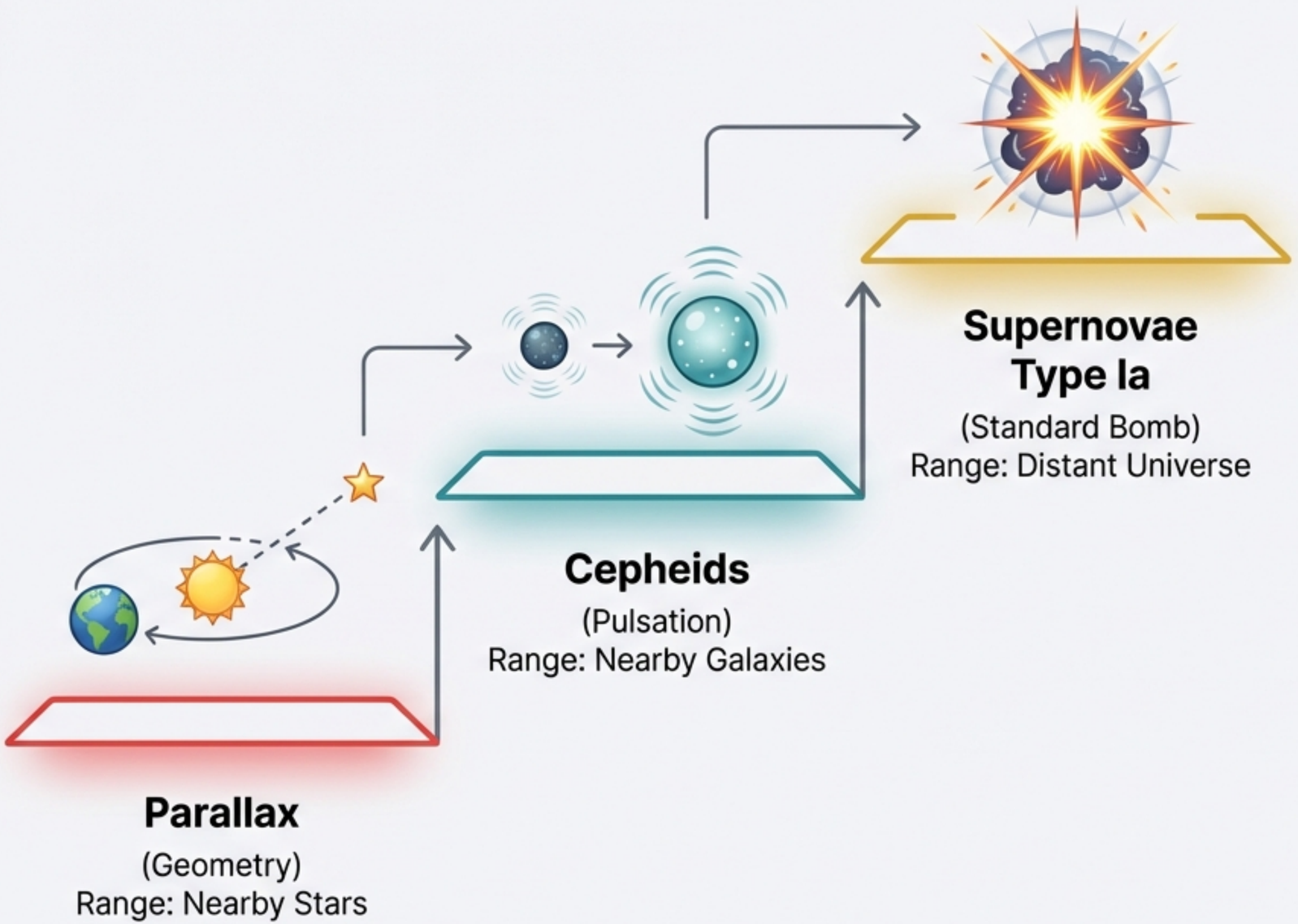
Measurement: Lines Shift
+
Model: Doppler Effect
=
Inference: Star is Moving

Color is Encoded Physics.



We do not just see colors; we see atomic fingerprints. Quantum mechanics dictates that atoms emit light at specific, quantized wavelengths. The red you see is Hydrogen. The teal is Oxygen. A spectrum is a chemical inventory of an object you cannot touch.

How Far Is Far? (The Cosmic Distance Ladder)



Supernovae Type Ia
(Standard Bomb)
Range: Distant Universe

Cepheids
(Pulsation)
Range: Nearby Galaxies

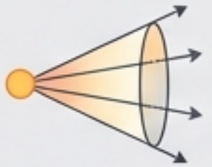
Parallax
(Geometry)
Range: Nearby Stars

The Decoder: Inverse-Square Law

$$F = \frac{L}{4\pi d^2}$$

F = Flux (brightness we measure)
L = Luminosity (intrinsic brightness)
d = distance

Flux (F) drops as distance (d) squared.



If we know the intrinsic Luminosity (L) of a "Standard Candle," measuring its faintness tells us exactly how far away it is. Double the distance = 1/4 the brightness.

Many Windows, One Truth.

VISIBLE LIGHT (Opaque Dust)

INFRARED (Transparent Dust + New Stars)

What is invisible at one wavelength is brilliant at another. Radio: Cold Gas. Visible: Stars. X-Ray: Million-degree plasma. Infrared: Star formation.

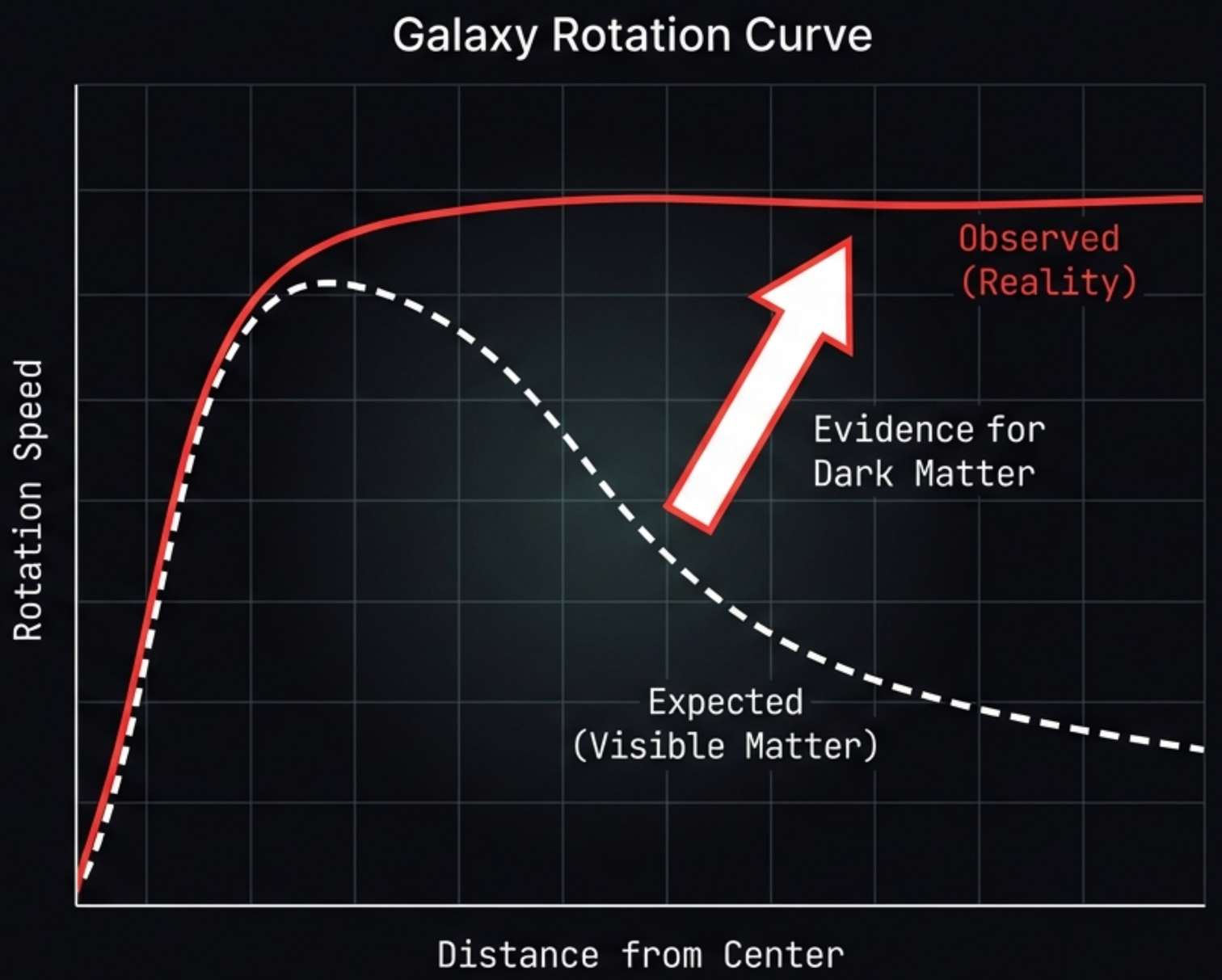
Most of the Universe is Invisible.

The Inference of Dark Matter

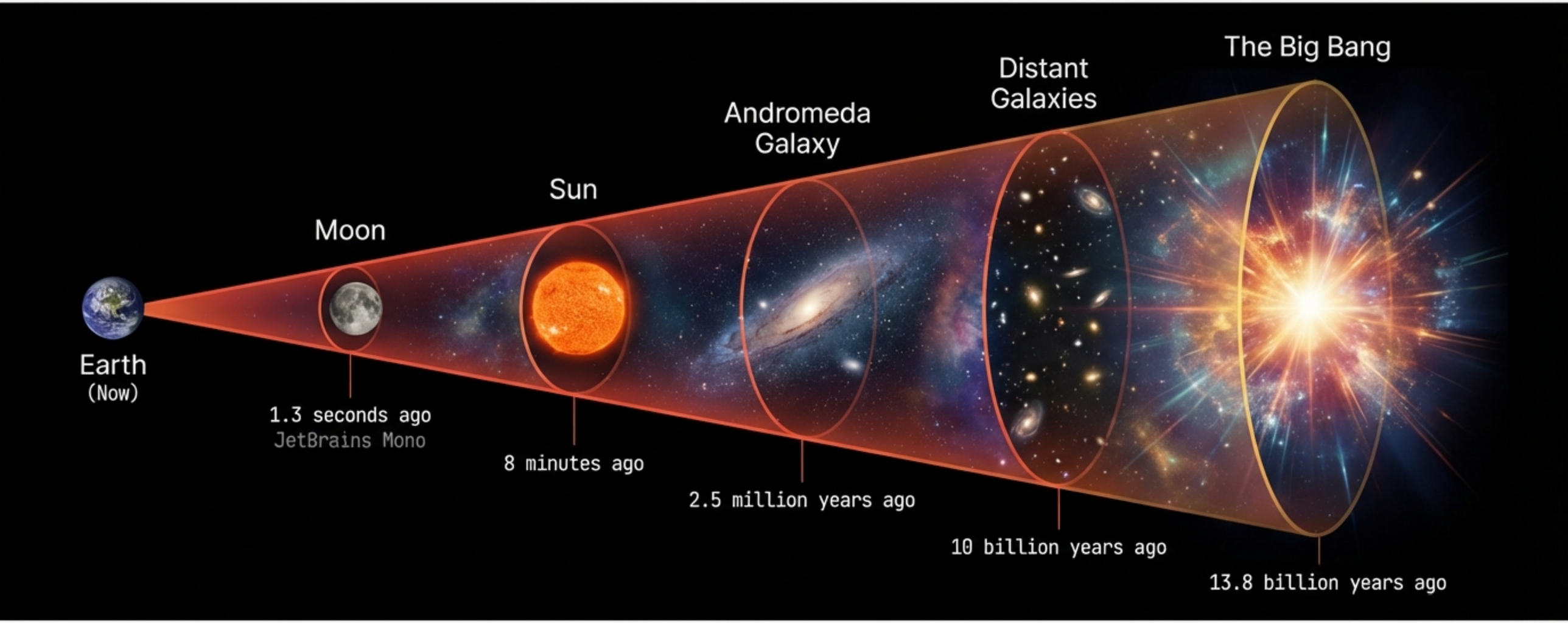
Galaxies spin too fast. Based on the visible matter (stars and gas), the outer edges should rotate slowly. Instead, they speed along, held in place by the gravity of something we cannot see.

The Conflict:
Visible Mass < Required Mass

The Inference:
Dark Matter outweighs visible matter 5 to 1. Motion reveals mass.



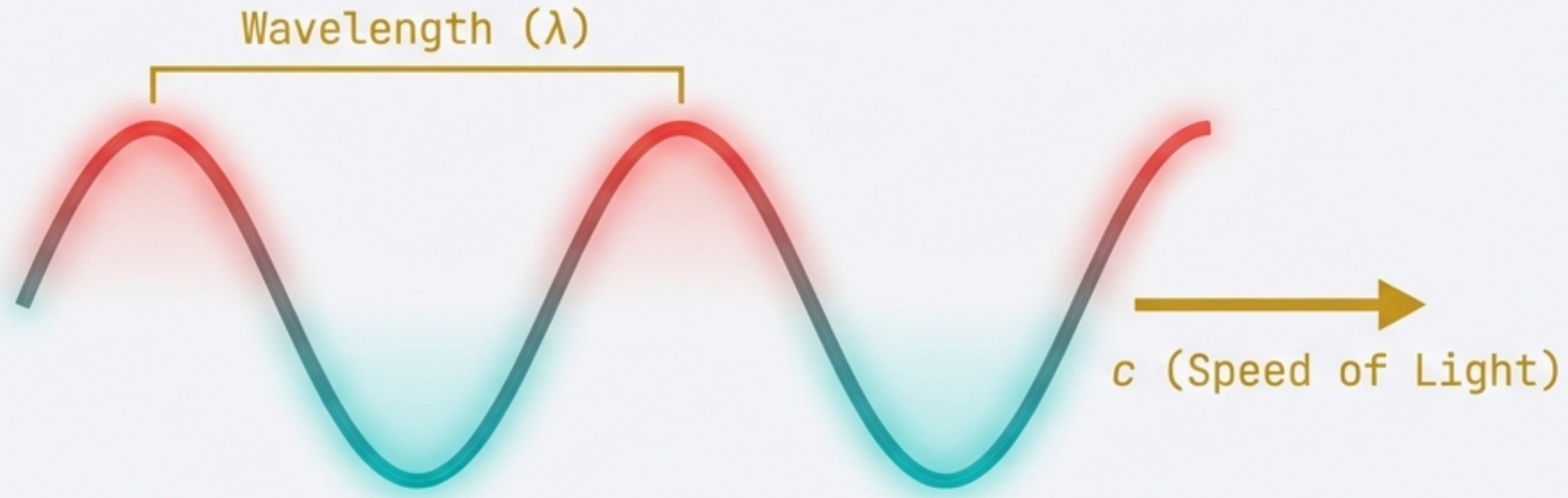
The Universe is a Time Machine.



The **speed of light (*c*) is finite**. We do not just see *where* things are; we see *when* they were. To look out is to look back.

The Messenger: Light Physics

Act III: The Engine



$$c = \lambda\nu$$

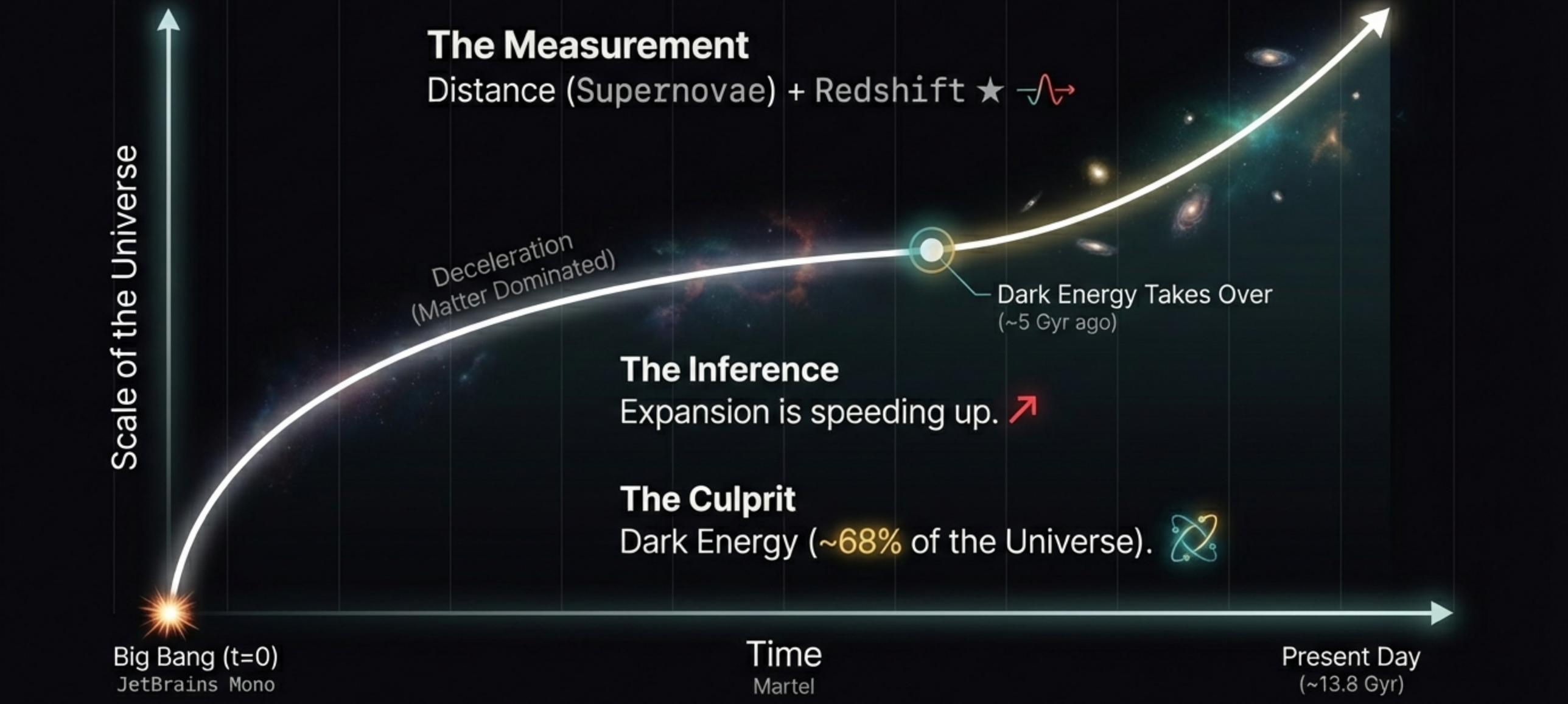
Light speed is constant.
Wavelength and frequency vary inversely.

$$E = h\nu$$

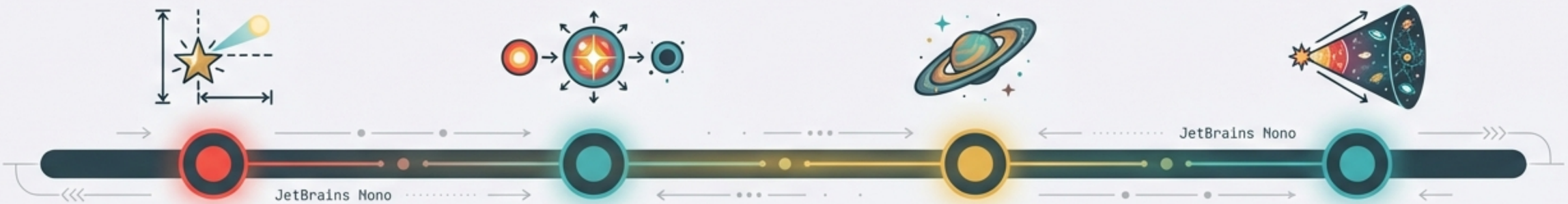
Energy is proportional to frequency.
Blue/X-ray = High Energy (Violent).
Red/Radio = Low Energy (Calm).

The constant *h* signals Quantum Mechanics.

13.8 Billion Years and Accelerating.



The Semester at a Glance



Foundations

Measuring Stars, Distance, Luminosity.

Stellar Life & Death

Nuclear Physics, Structure, Remnants.

Origins

Star Formation, Planets, Interstellar Medium.

Cosmology

Galaxies, Dark Matter, The Big Bang.

What You Should Recognize (For Now)

- **The Pipeline:**
  Signal → Measurement → Model → Inference.
- **Light:** Finite speed, carries energy, encodes composition.
- **The ‘Big Three’ Spoilers:** Dark Matter exists, Dark Energy drives acceleration, the Universe is evolving.

TAKEAWAY: You do not need to master the math yet. Just recognize the pattern.

The cosmos is within us.
We are made of star-stuff.
We are a way for the universe
to know itself.

The iron in your blood and the calcium in your bones were forged in stars that died billions of years ago. This semester is about earning the right to make that claim.

NEXT CLASS: MATH BOOT CAMP

Appendix: Key Constants & Definitions

Constants (JetBrains Mono)

c (Speed of Light):
$\approx 3 \times 10^{10}$ cm/s

h (Planck's Constant):
$\approx 6.63 \times 10^{-27}$ erg·s

$L_\odot$ (Solar Luminosity):
$\approx 3.8 \times 10^{33}$ erg/s

Definitions (Martel)

Flux (F): Light energy per unit area/time (measured).

Luminosity (L): Total energy emitted (inferred).

Photon: A “packet” of light energy.

Redshift: Stretching of wavelength due to motion/expansion.

Lookback Time: The delay caused by the finite speed of light.