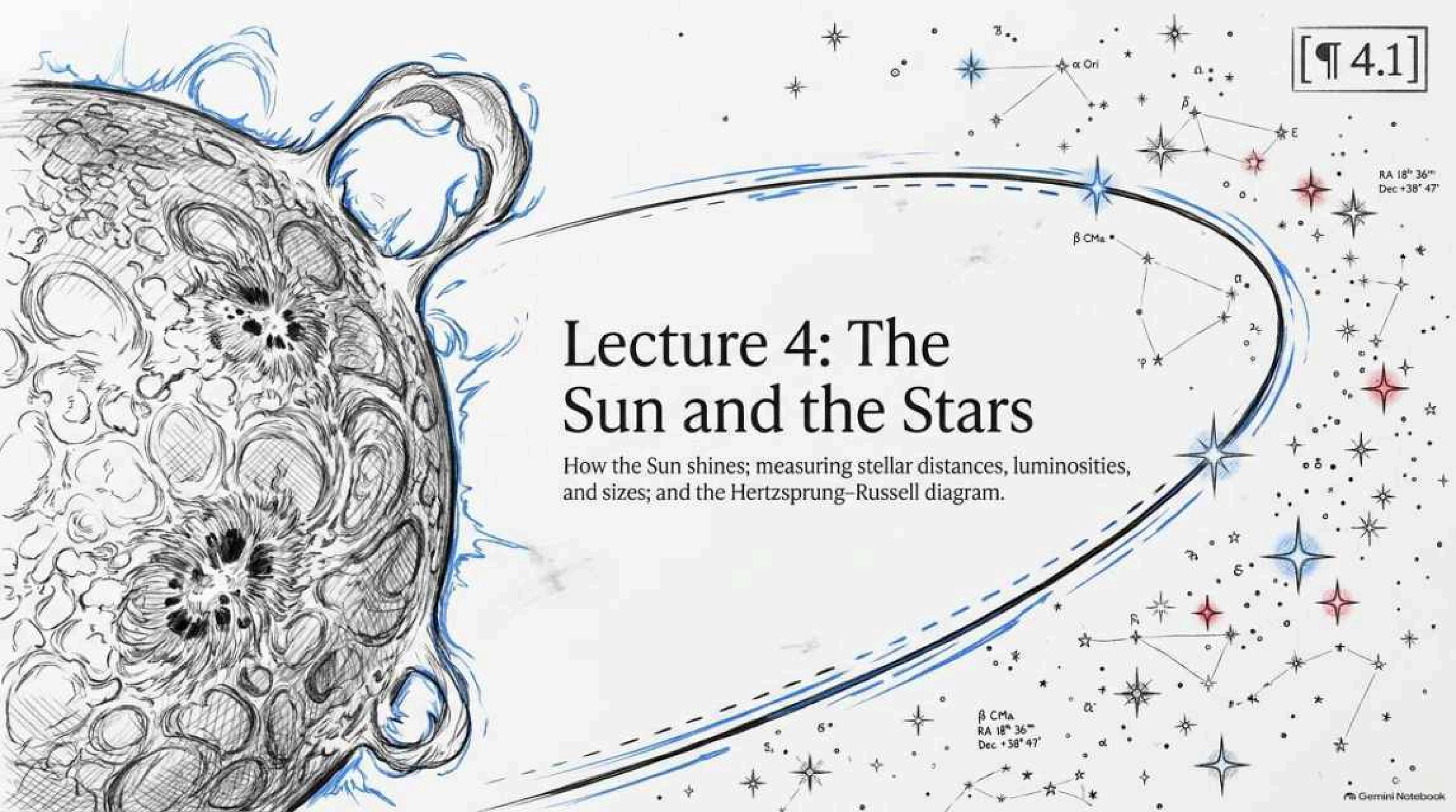
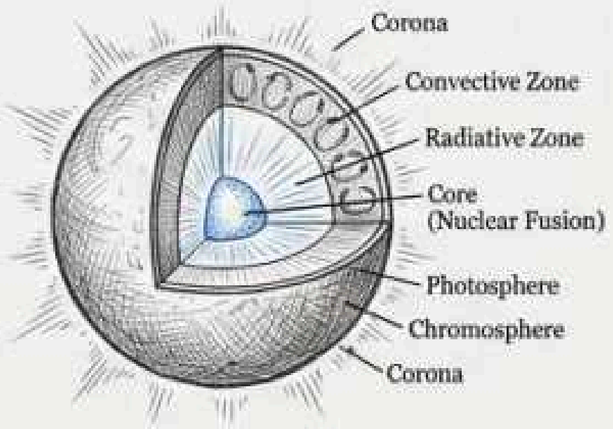


Lecture 4: The Sun and the Stars

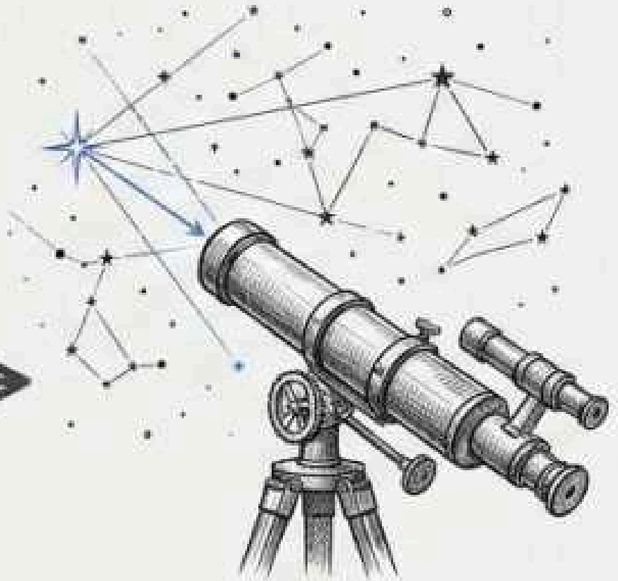
How the Sun shines; measuring stellar distances, luminosities, and sizes; and the Hertzsprung–Russell diagram.

[¶ 4.2]

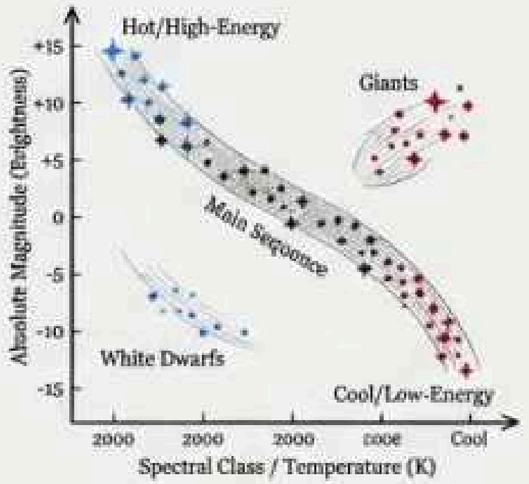
The only star close enough to study in detail serves as our baseline.



How the Sun Shines



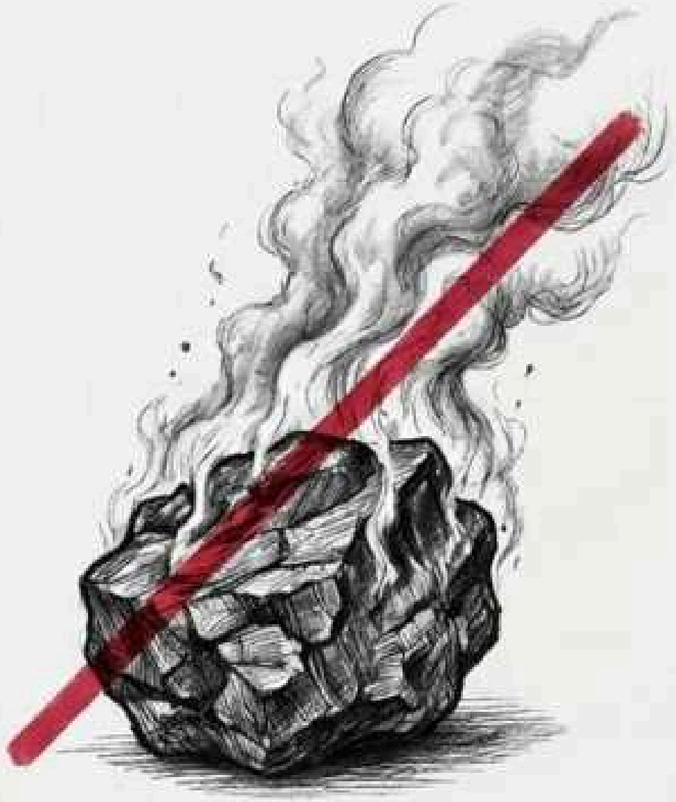
Measuring Distance, Brightness, and Temperature



The Hertzsprung–Russell Diagram (The Ultimate Map)

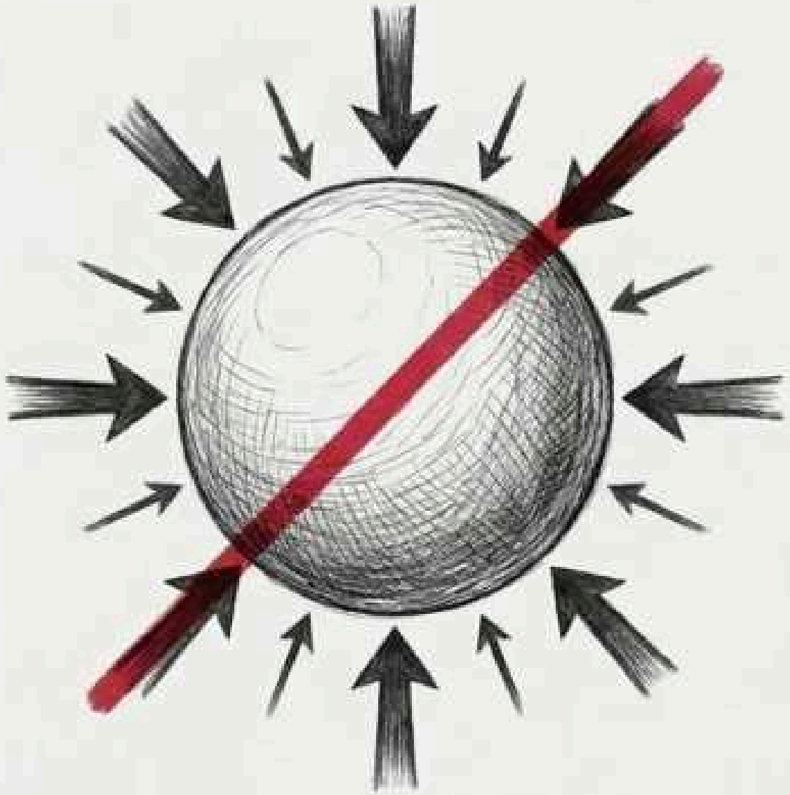
Gemini Notebook

[¶ 4.3]



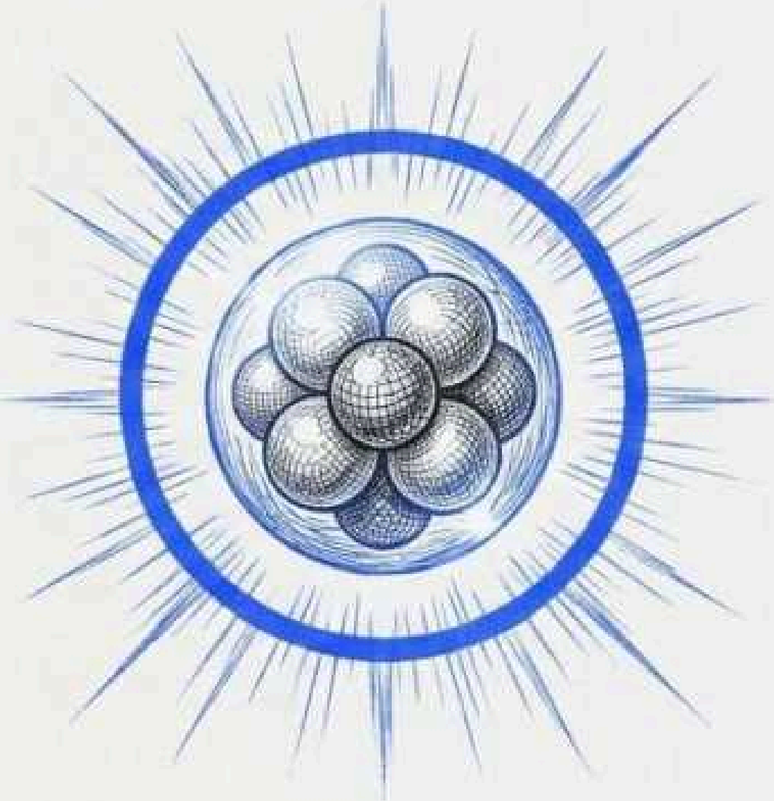
Coal / Chemical

Could only last a few thousand years.



Gravitational Contraction

Would only last tens of millions of years (Earth's geology proved this impossible)



Twentieth-Century Solution

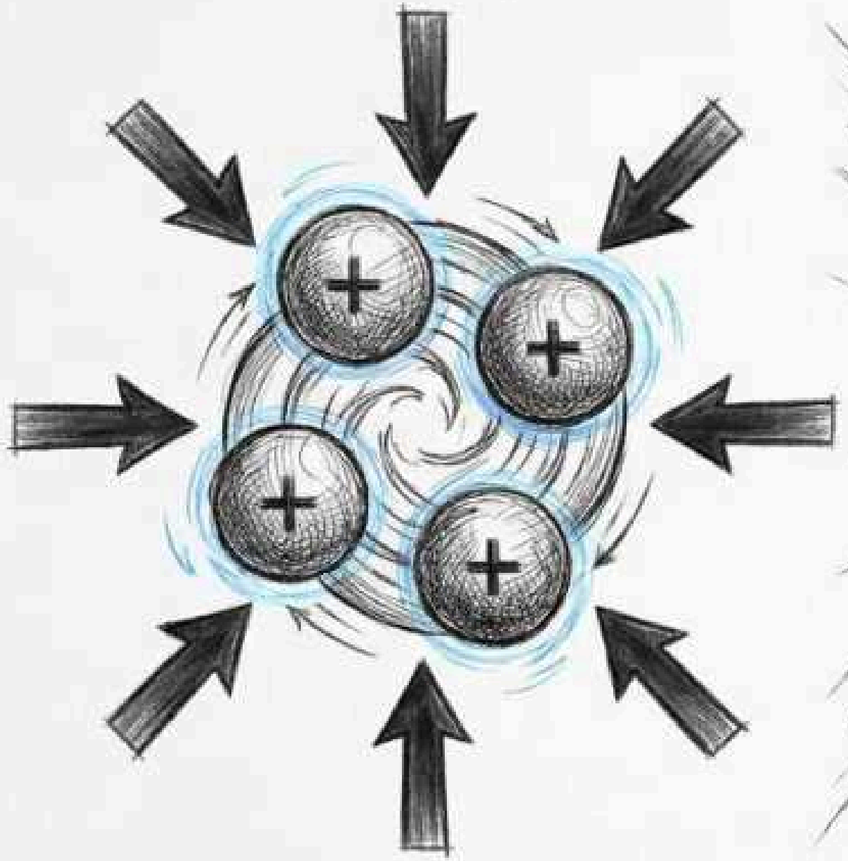
Nuclear Fusion.

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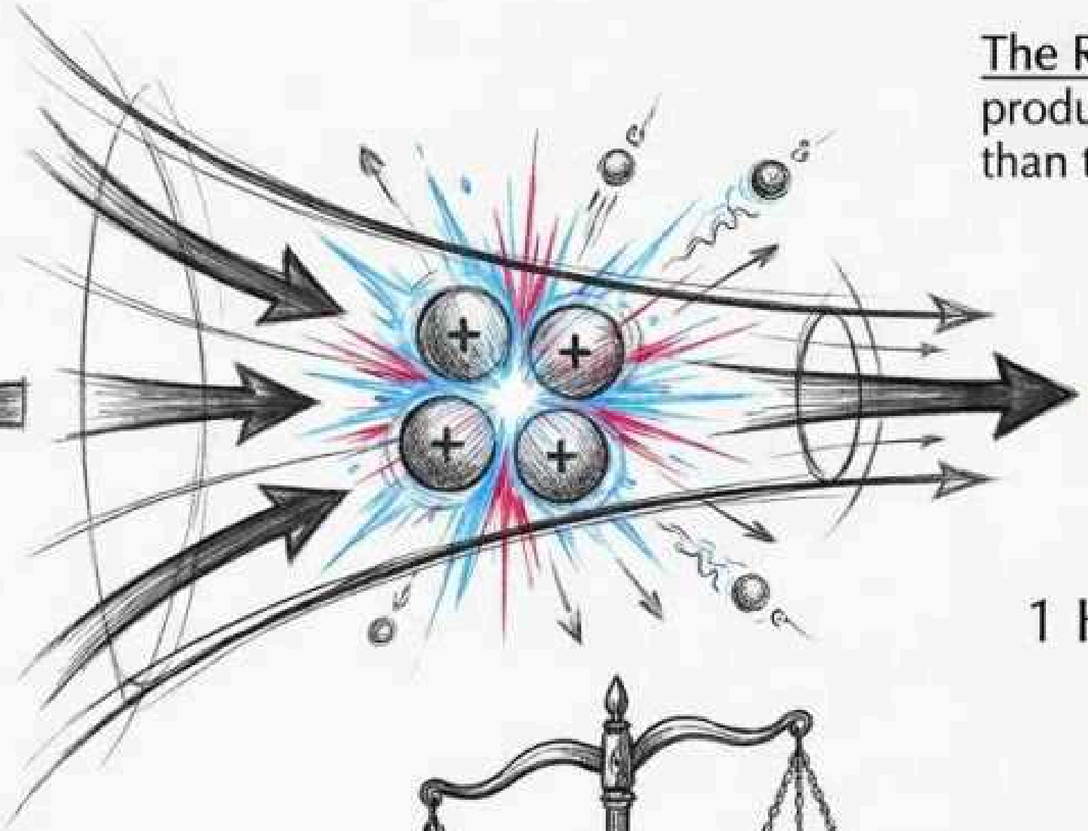
¶ 4.4

Core Conditions: ~15,000,000 Kelvin and enormous pressure.

The Process: Fusion



4 Hydrogen Nuclei



The Result: The final product weighs slightly less than the ingredients.



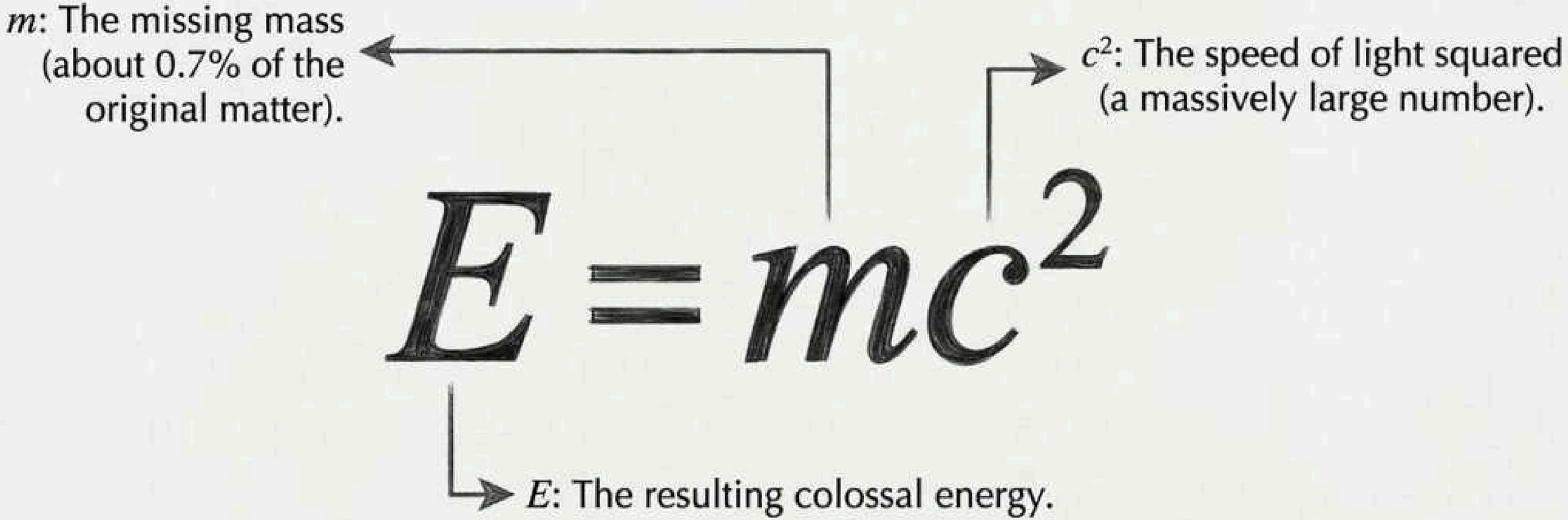
1 Helium Nucleus



The Result: The final product weighs slightly less than the ingredients.

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[¶ 4.5]



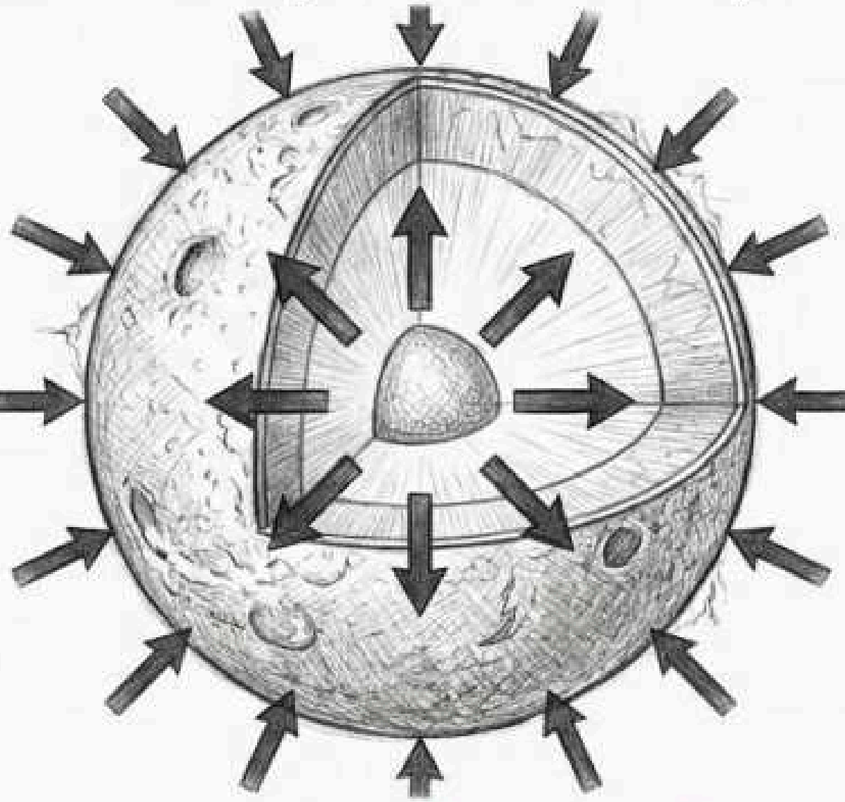
The Sun converts ~4 million tonnes of matter into energy every single second, sustaining this for 4.5 billion years.

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[¶ 4.6]

Hydrostatic Equilibrium

The perfect balance that keeps the Sun steady for billions of years.



If fusion speeds up → core expands and cools → fusion slows down

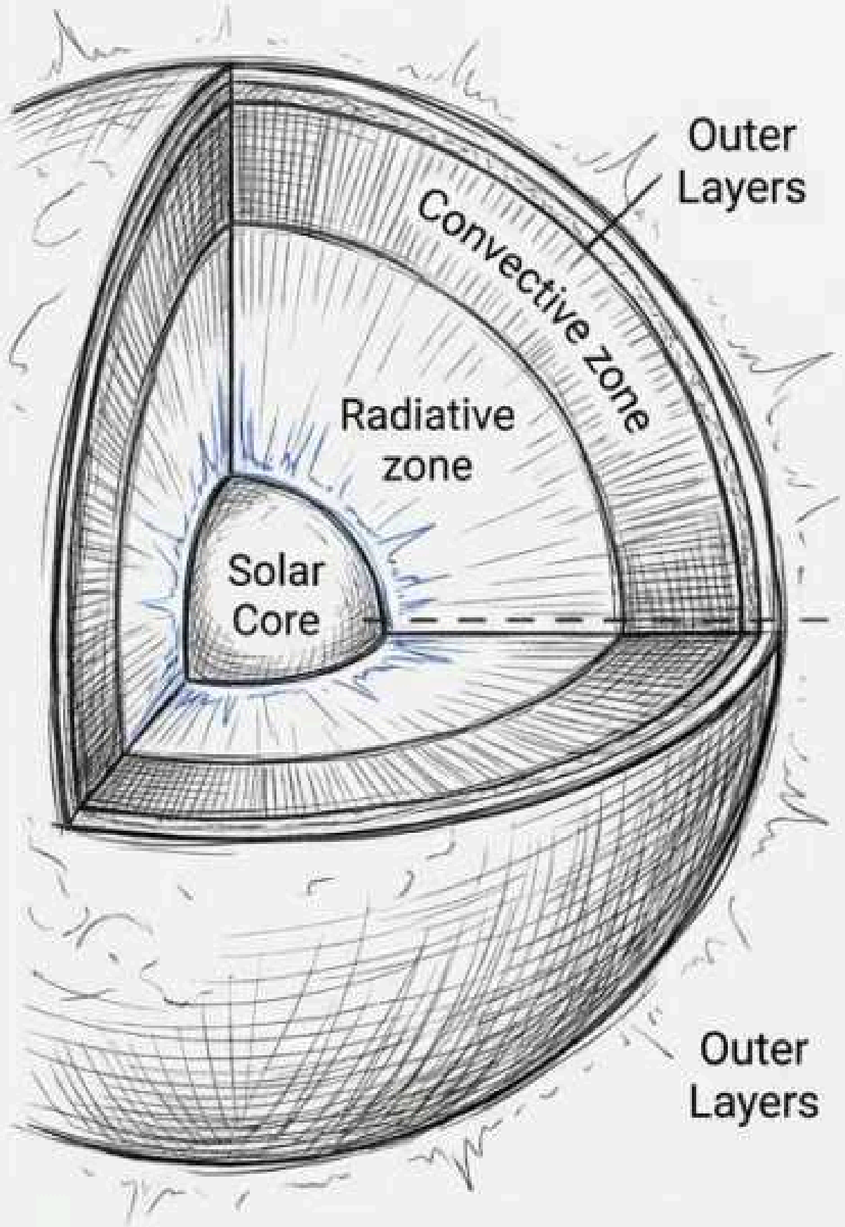
If fusion slows down → core shrinks and heats → fusion speeds up

Gemini Notebook

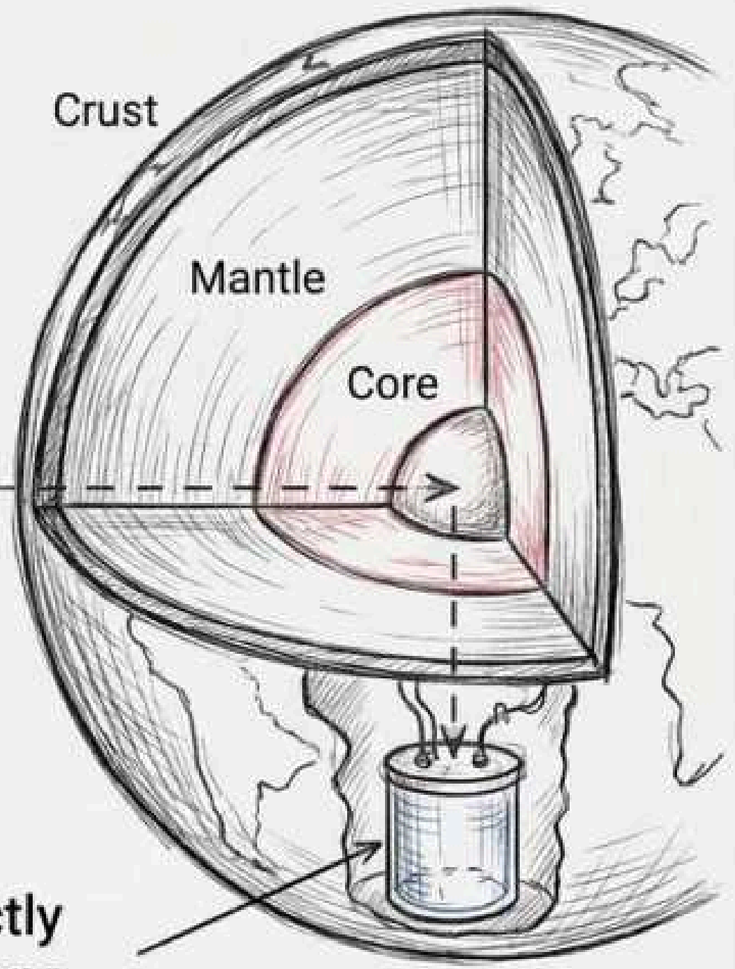
[¶ 4.7]

Ghost Particles: Neutrinos.

Trillions pass through your body every second without a trace.



Neutrino Path

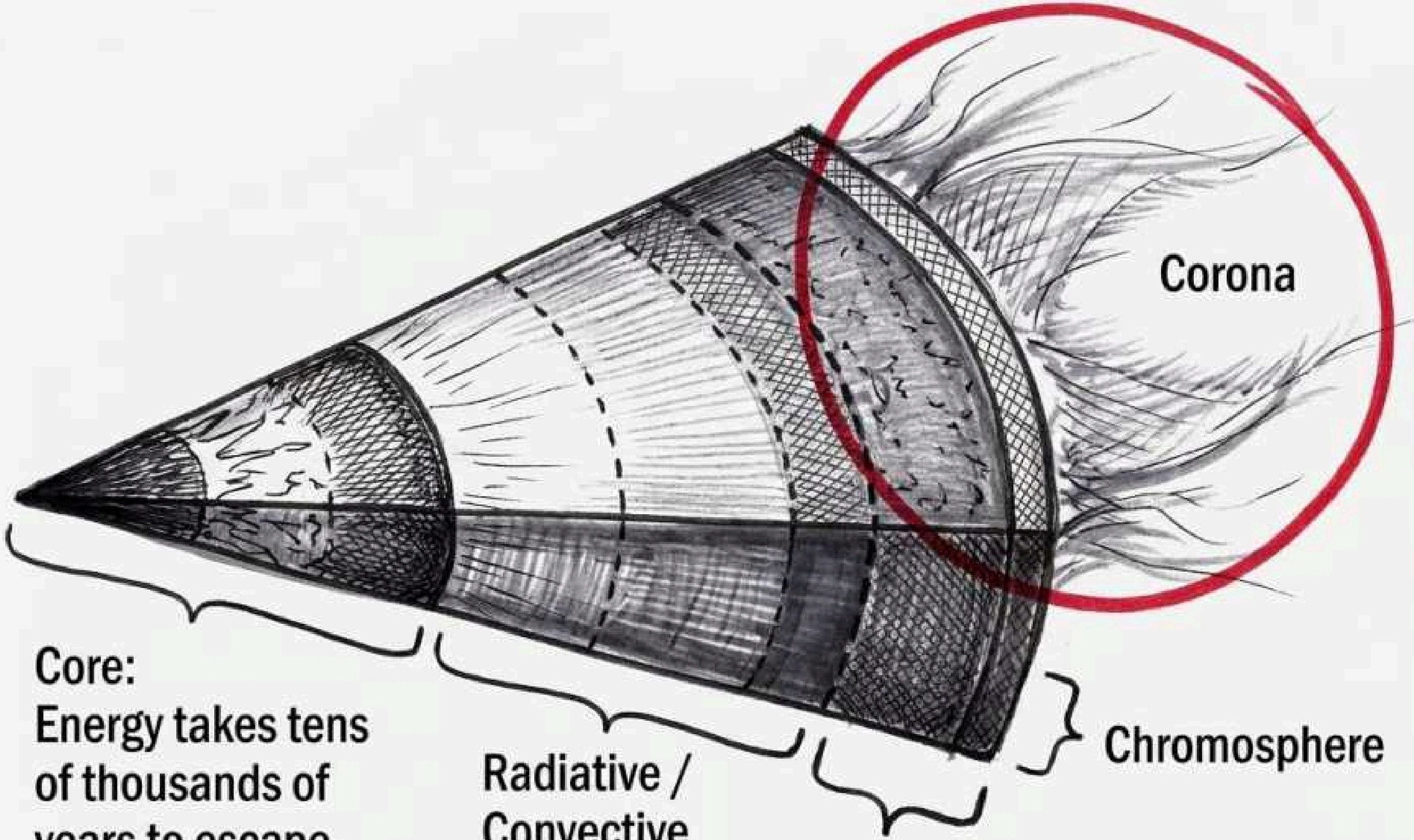


Arrival rates at under-ground detectors perfectly match fusion predictions, proving the Sun's engine.

Underground Neutrino Detector (Vat)

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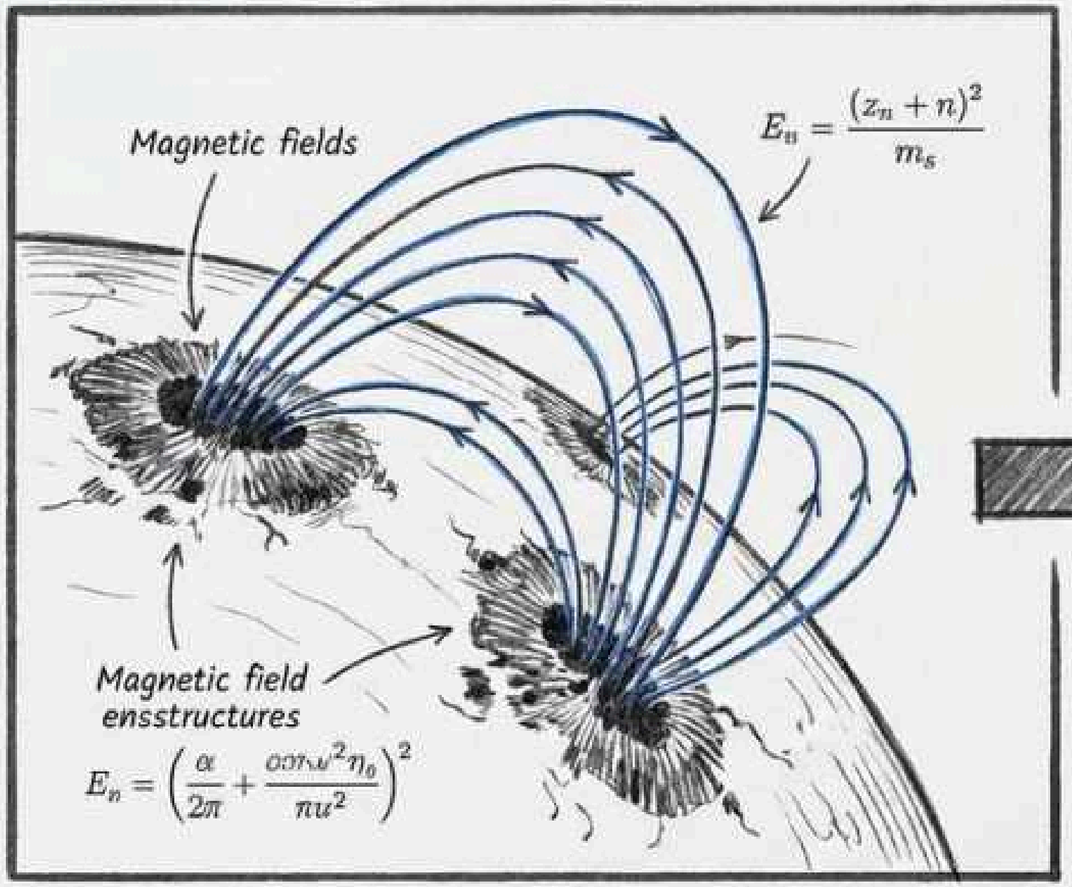
[¶ 4.8]



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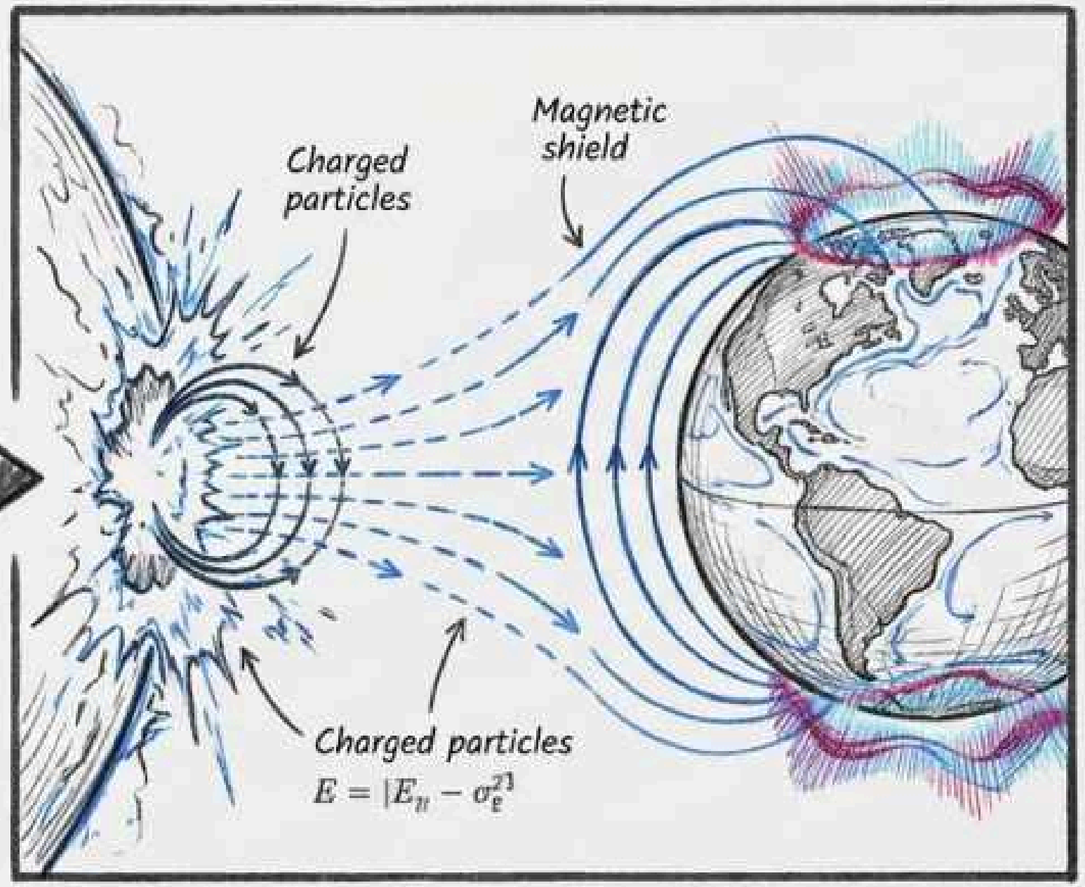
[¶ 4.9]

THE CAUSE



Sunspots: Regions of strong magnetic fields (11-year rise/fall cycle).

THE EFFECT



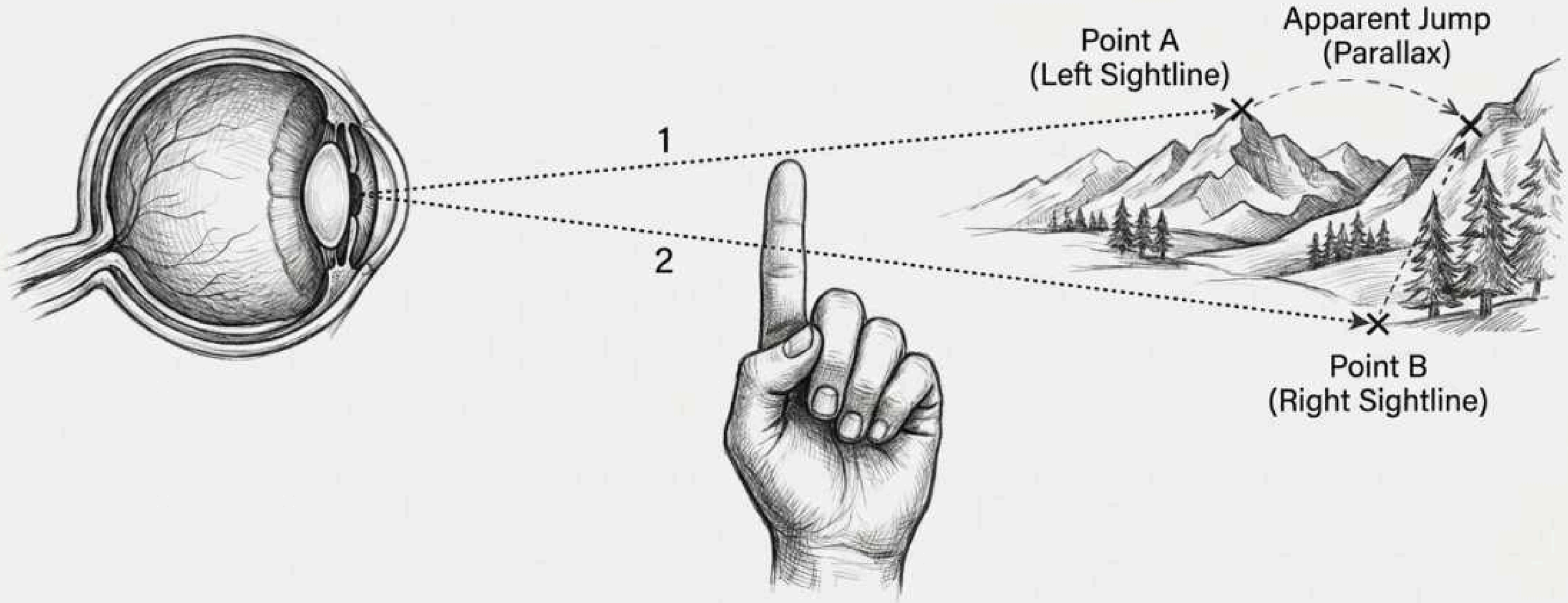
Solar Flares: Eruptions that trigger Earth's auroras and can disrupt satellites and power grids.

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The Parallax Concept.

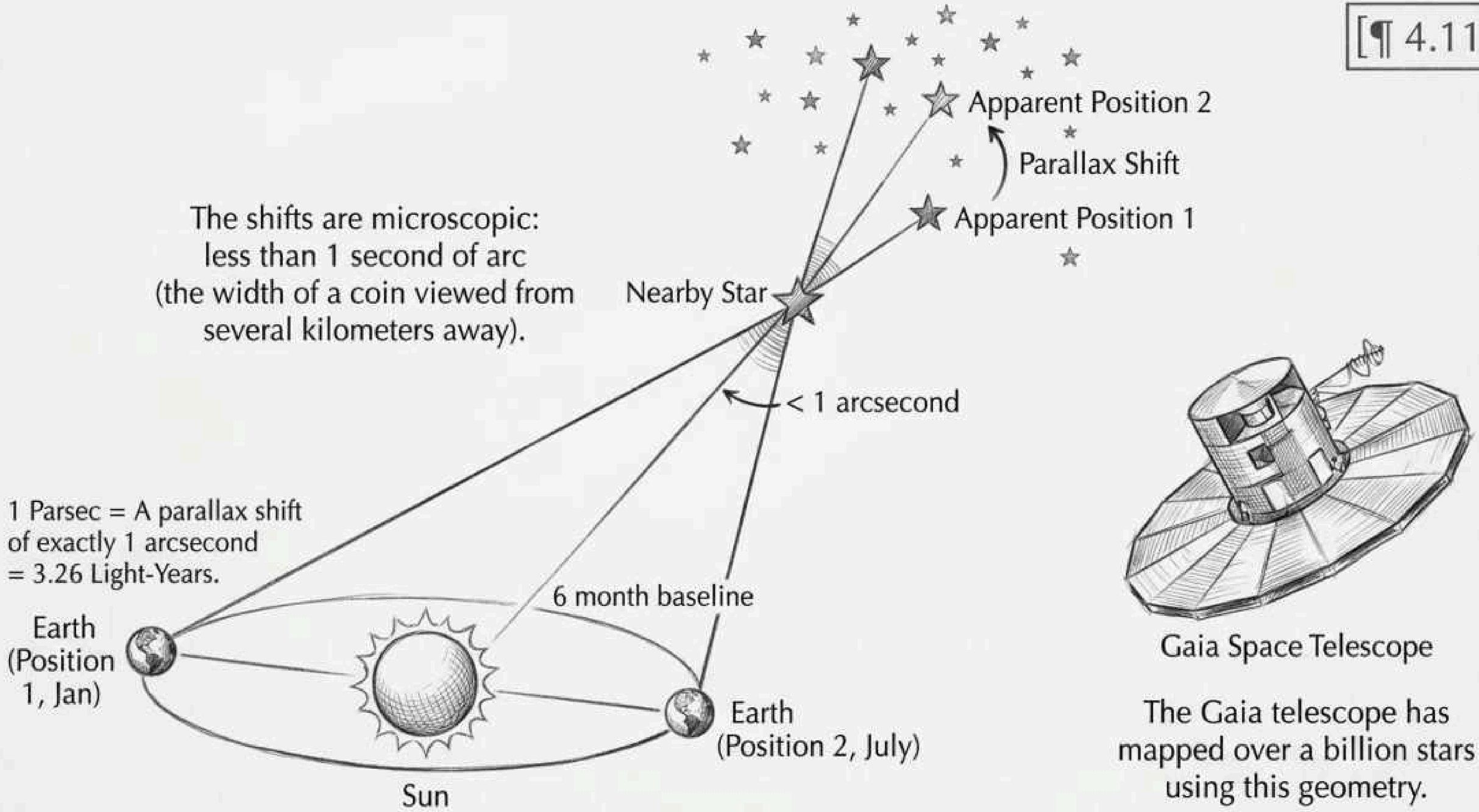
[¶ 4.10]

A hand or signs aractr with persvectily analogy.
Nearby objects shift against far-off backgrounds
when observed from different positions.



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[¶ 4.11]



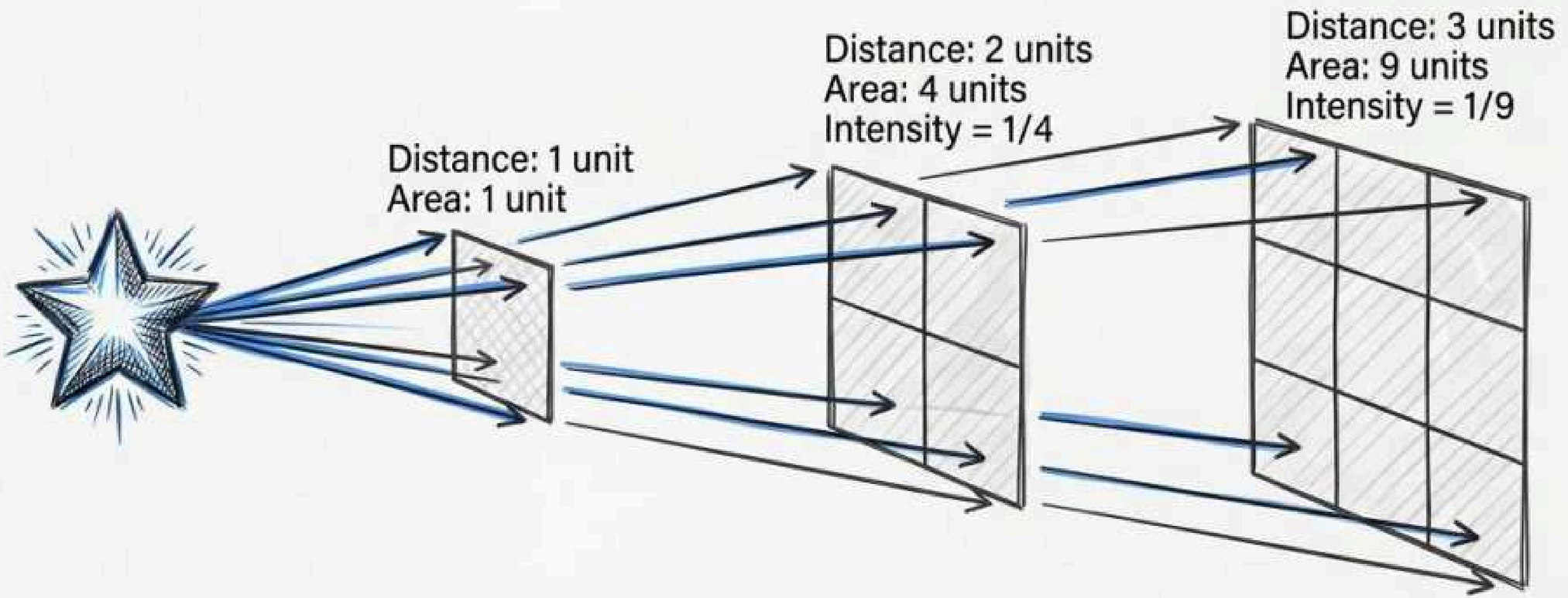
Gaia Space Telescope

The Gaia telescope has mapped over a billion stars using this geometry.

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Astrophysicist Whiteboard

¶ 4.12



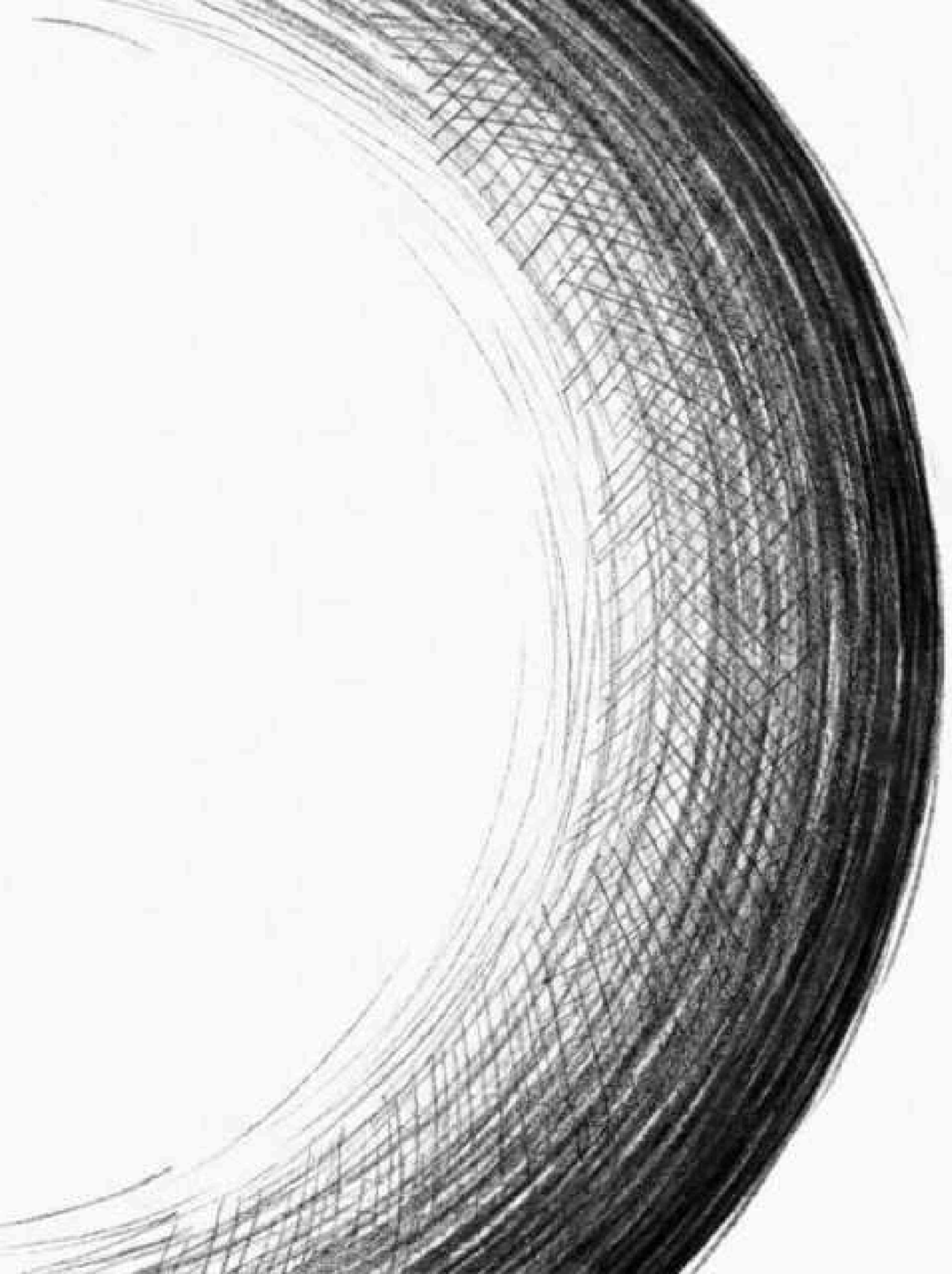
Apparent Brightness: How bright a star looks to us (depends on distance).

Luminosity: The total energy emitted per second (its true power).

Note: Stars range from 1,000,000x more luminous than our Sun to 1,000,000x less.

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¶ 4.13





$$L \propto R^2 T^4$$

Luminosity depends on Size and Temperature.

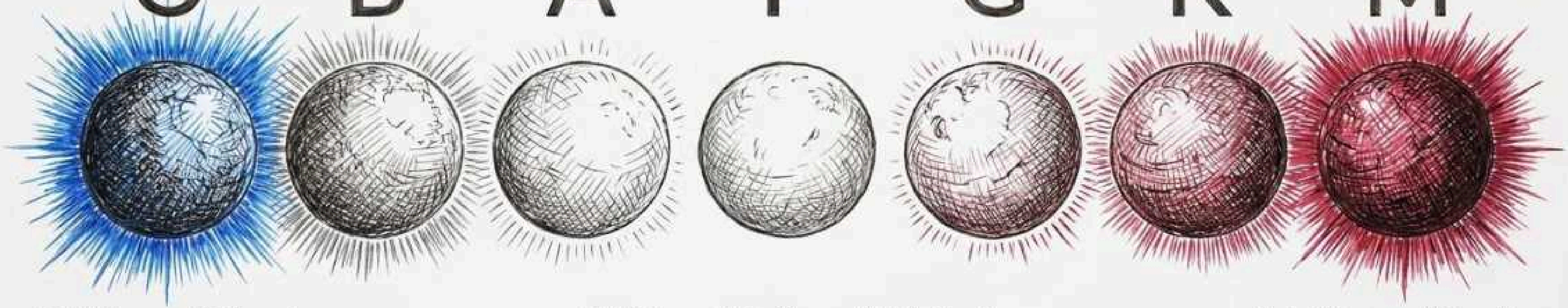
Therefore:
If we know Luminosity + Temperature (from its color), we can calculate exact Size.

Result: Some stars are hundreds of times wider than the Sun; others are smaller than Earth.

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[¶ 4.14]

O B A F G K M



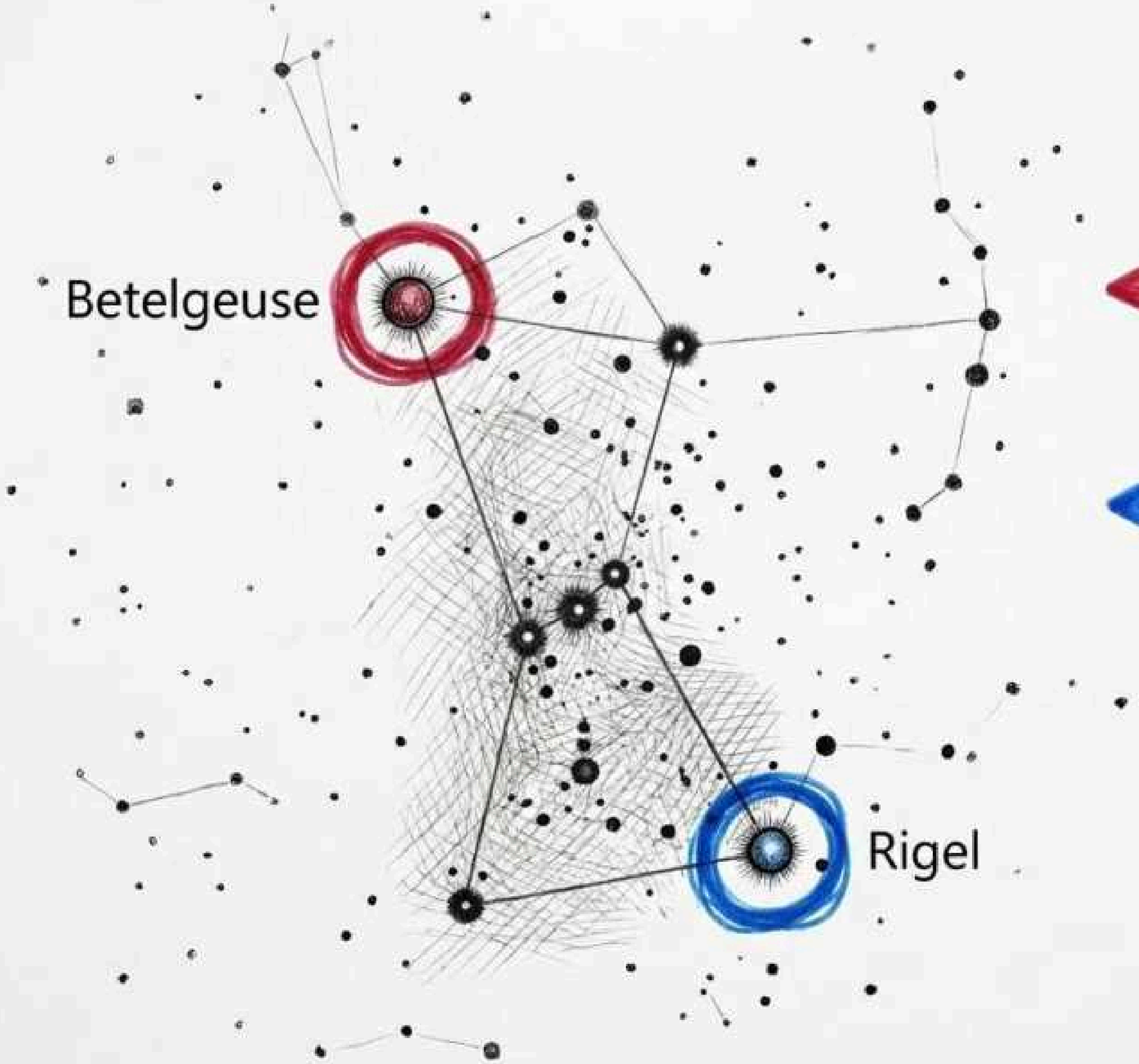
O Stars (Blue):
> 30,000 K

G Star (Yellow/White):
Our Sun

M Stars (Red):
< 3,500 K

Oh, be a fine guy, kiss me.

Gemini Notebook



Betelgeuse:
A cool, orange-red giant.

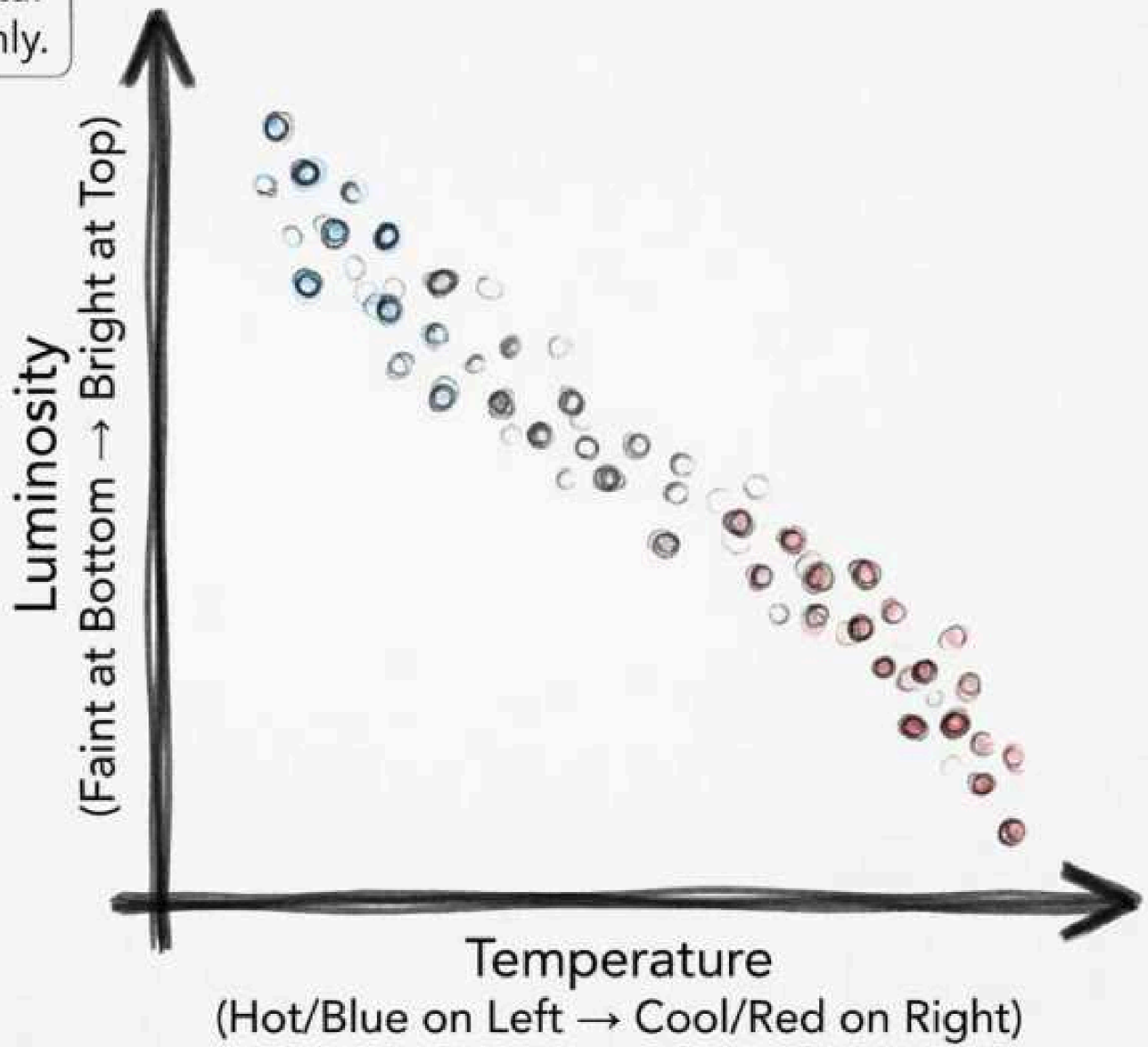
Rigel:
A hot, blue-white supergiant.

Both are enormously luminous. Their colors are a direct, visible readout of their surface temperatures.

Gemini Notebook

¶ 4.16

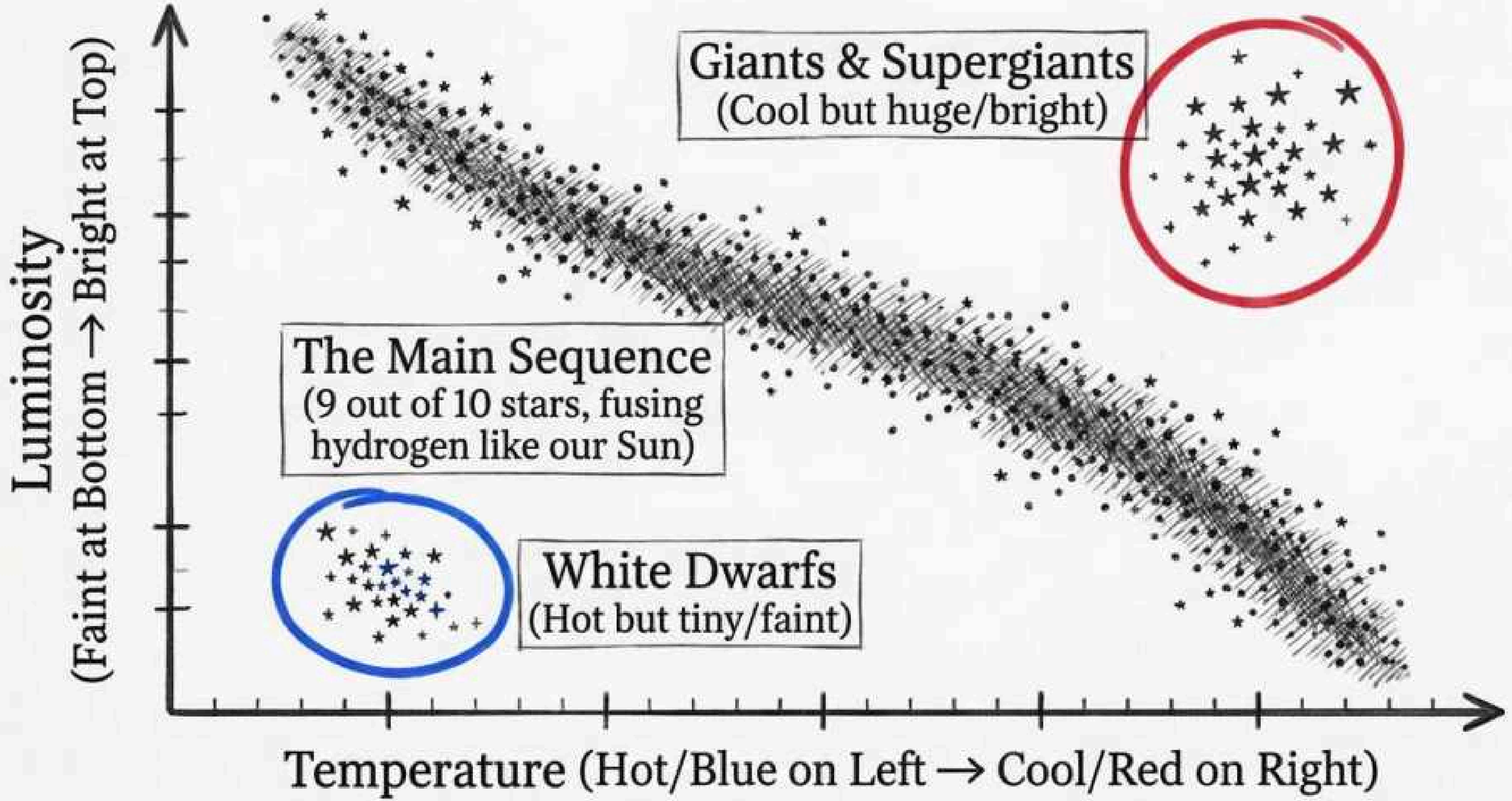
Early 1900s: Ejnar Hertzsprung & Henry Norris Russell plot the data. The stars did not scatter randomly.



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The Hertzsprung-Russell Diagram: The Ultimate Map of Stellar Life.

¶ 4.17



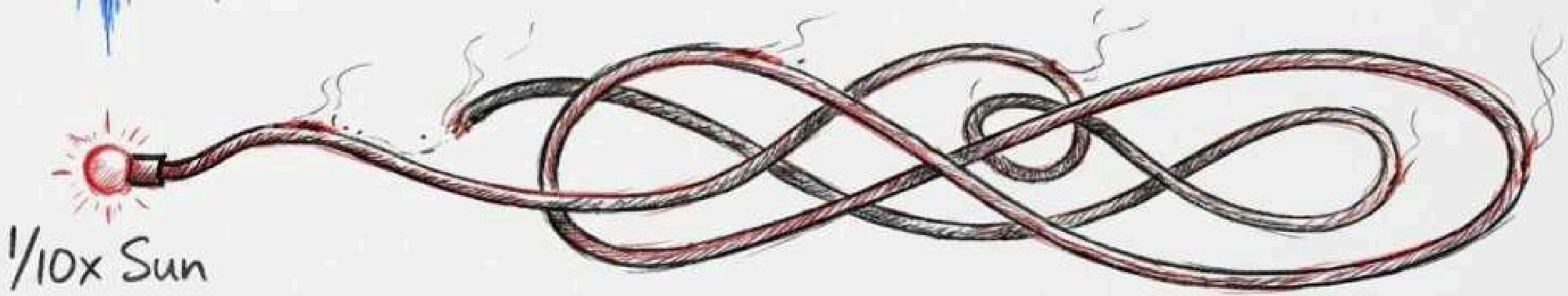
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Mass is Destiny.

¶ 4.18



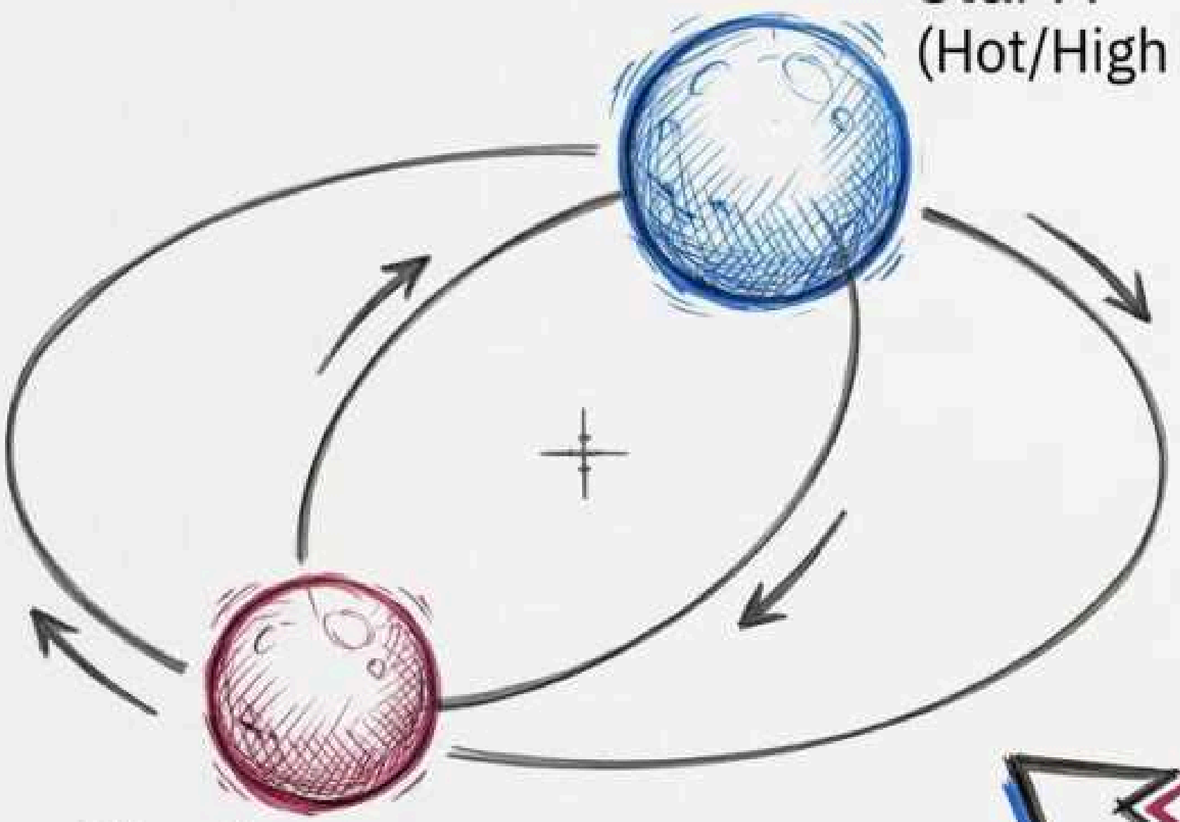
High Mass (Blue): Thousands of times brighter, burns fuel furiously, lives only tens of millions of years.



Low Mass (Red): Shines faintly, sips fuel, can live for trillions of years (longer than the universe has existed).

Gemini Notebook

¶ 4.19



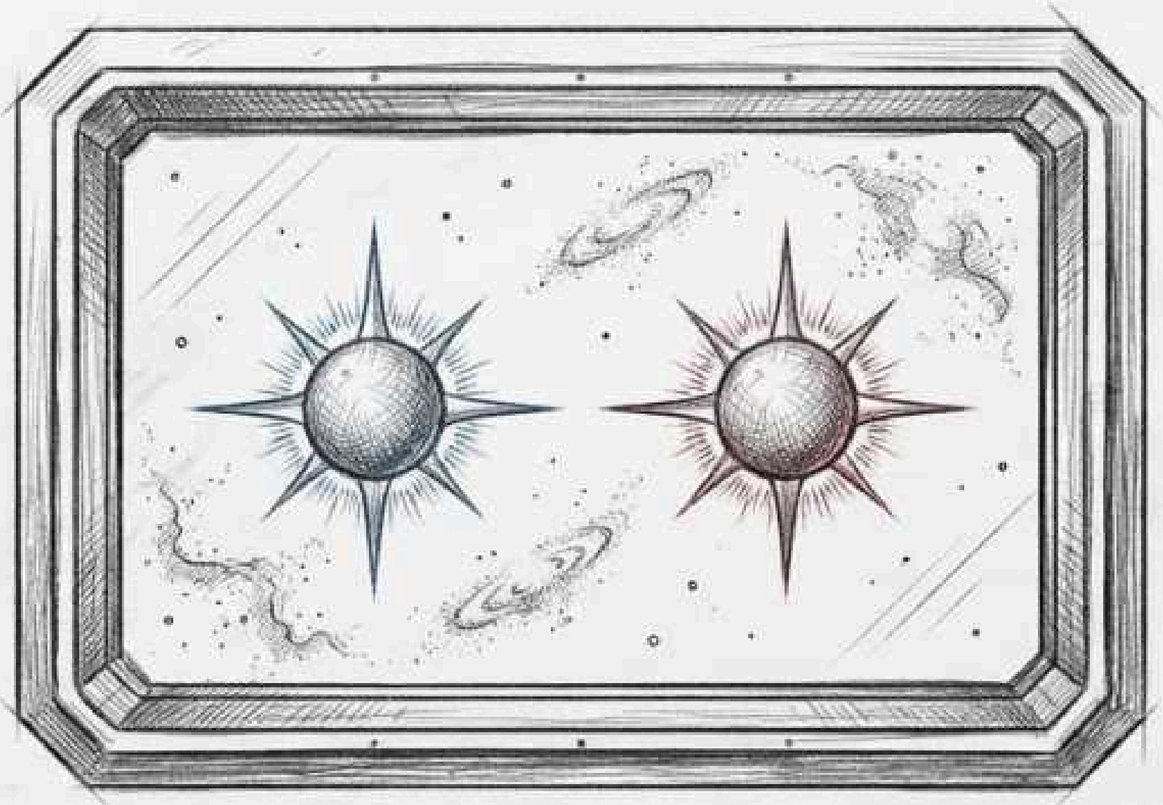
Weighing Stars with Binary Pairs.

$$T^2 = \left[\frac{4\pi^2}{G(M_1+M_2)}\right] \cdot a^3$$

Orbit size and period reveal exact mass.

Context: Roughly half of all Sun-like stars have a binary companion, making our solitary Sun somewhat unusual.

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The Parting Riddle: These two stars look equally bright in the night sky. Based on this lecture, **name two completely different astrophysical** reasons this could be true.

Next: Lecture 5 — We follow stars from birth to death, and track the atoms in our own bodies.

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