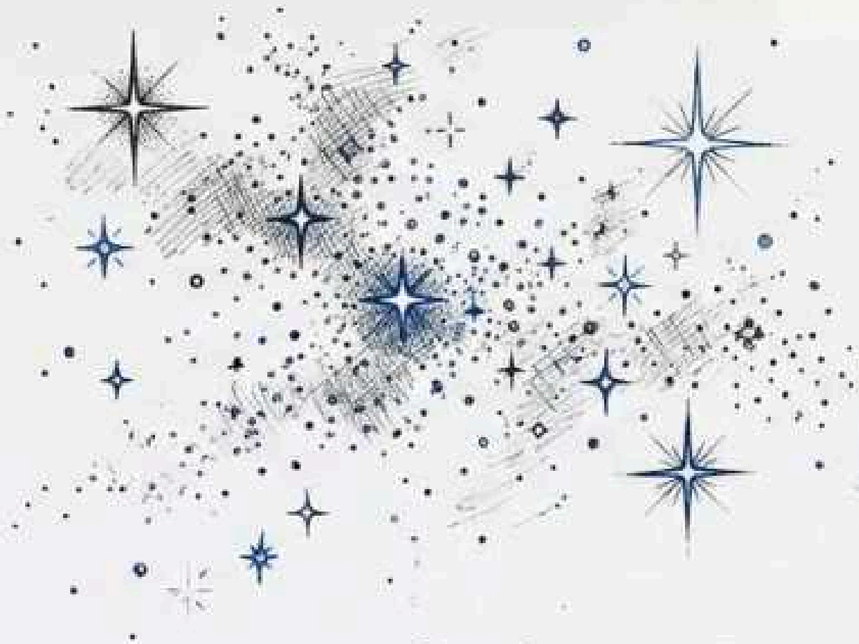
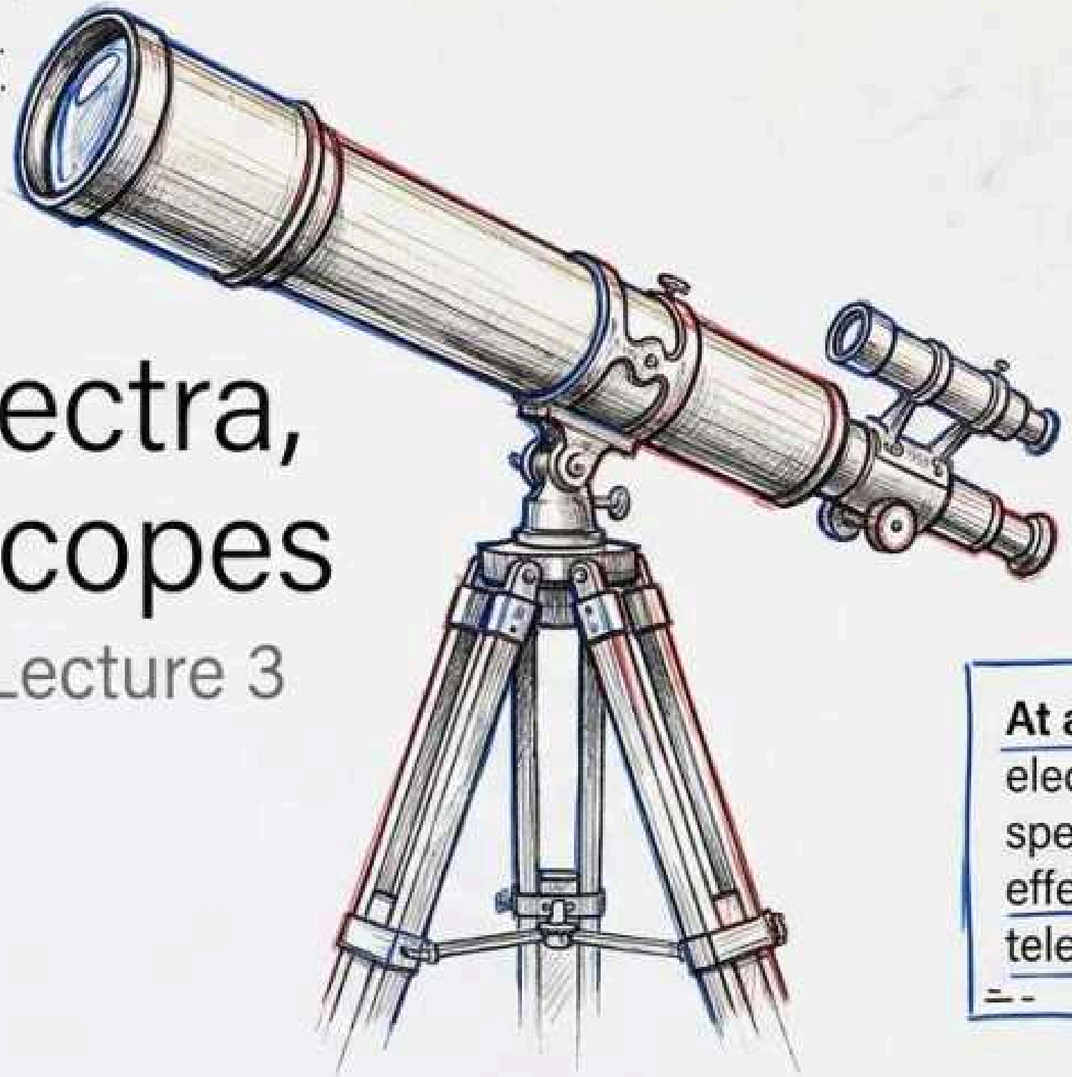
¶ 3.1





Light, Spectra, and Telescopes

ASTR 101 B — Lecture 3

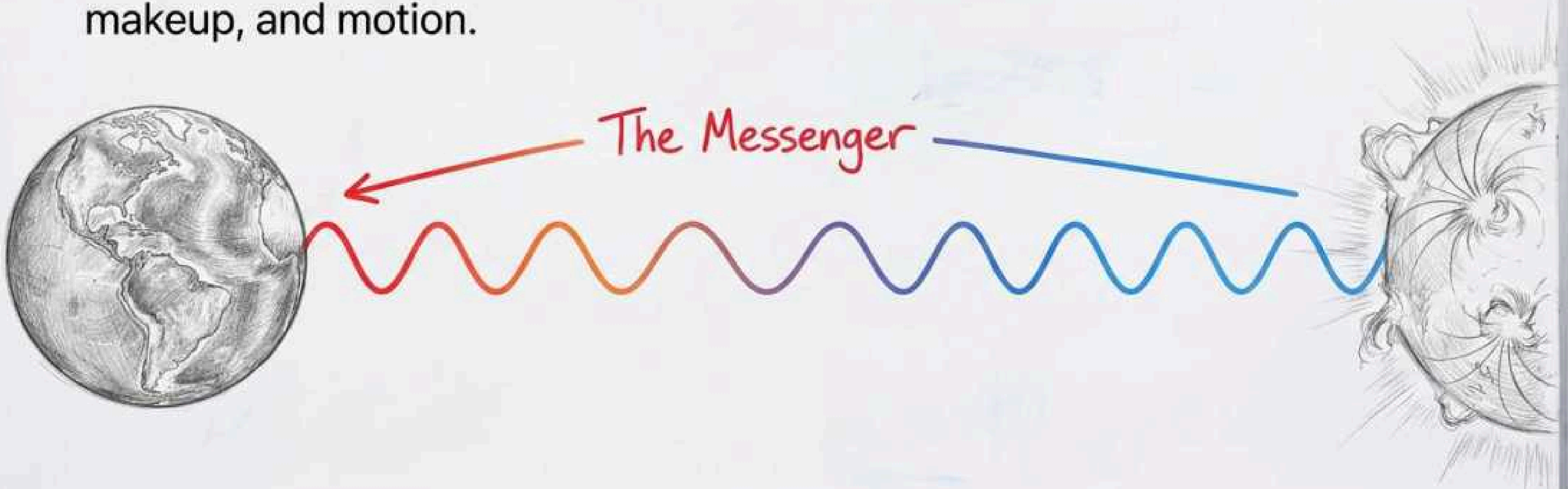
At a glance: Light, the electromagnetic spectrum, spectra and the Doppler effect, and how telescopes work.

Gemini Notebook

The Ultimate Toolkit

¶ 3.2

- ✓ Astronomers cannot visit the stars; everything we know comes from traveling radiation.
- ✓ This radiation decodes a star's temperature, makeup, and motion.

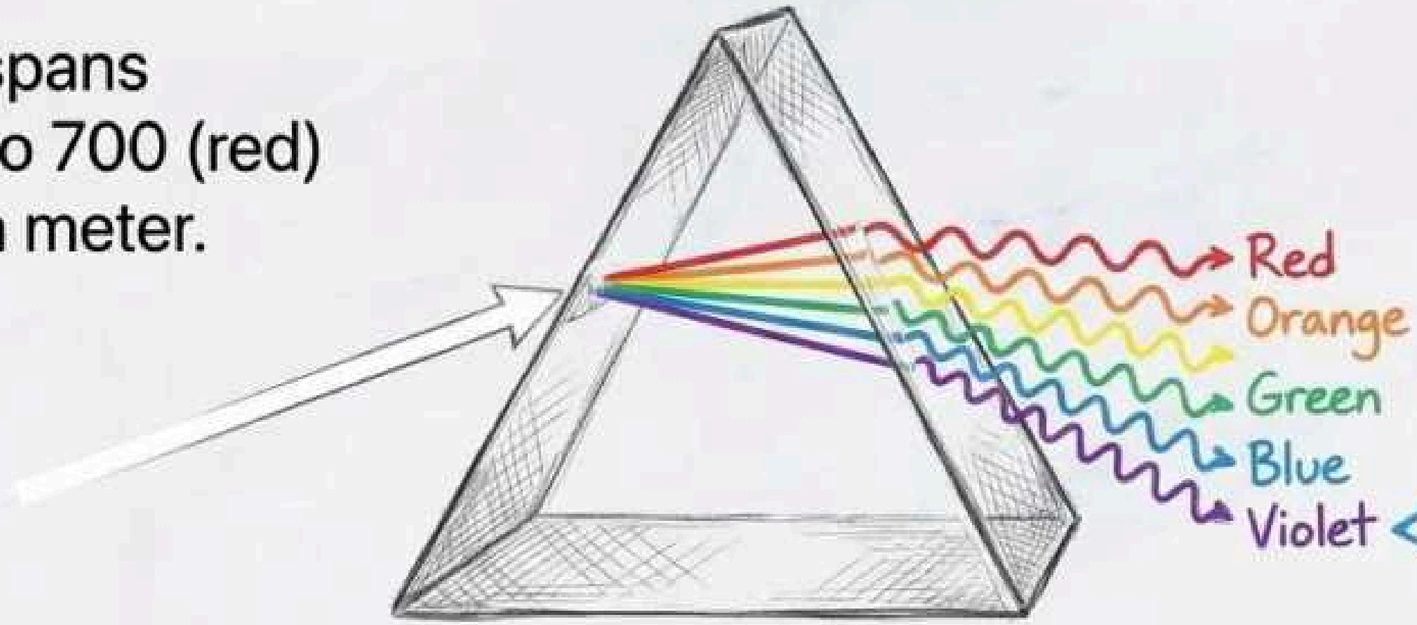


Gemini Notebook

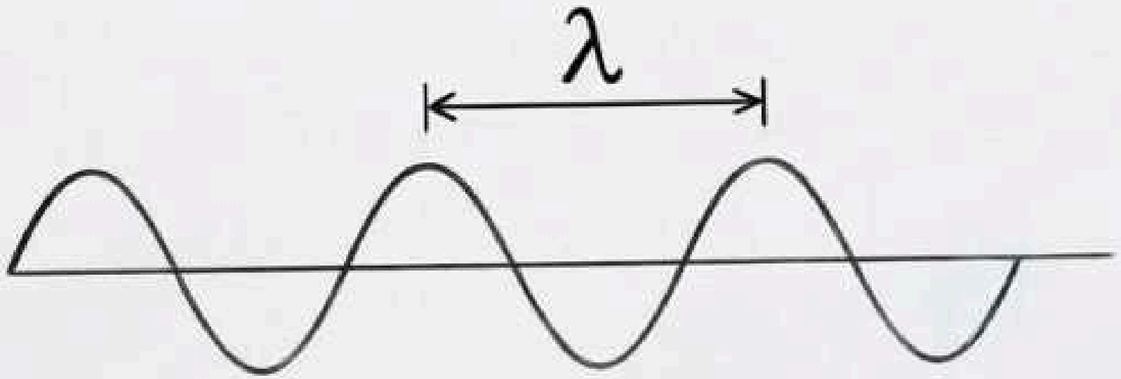
Light is a Wave

¶ 3.3

Visible light spans 400 (violet) to 700 (red) billionths of a meter.



Violet light has the shortest wavelength, red has the longest. All colors combined look white.



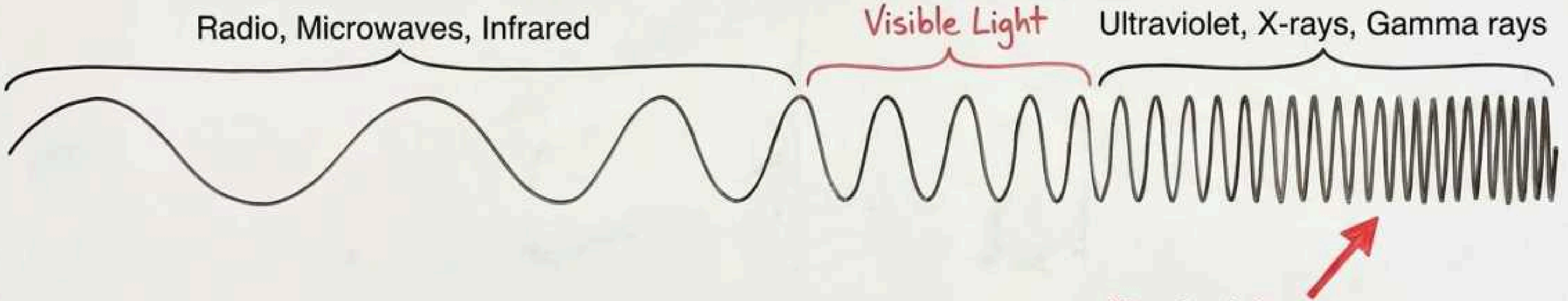
Gemini Notebook

The Electromagnetic Spectrum

¶ 3.4

$$c = \lambda f$$

(Speed of light is constant for all)



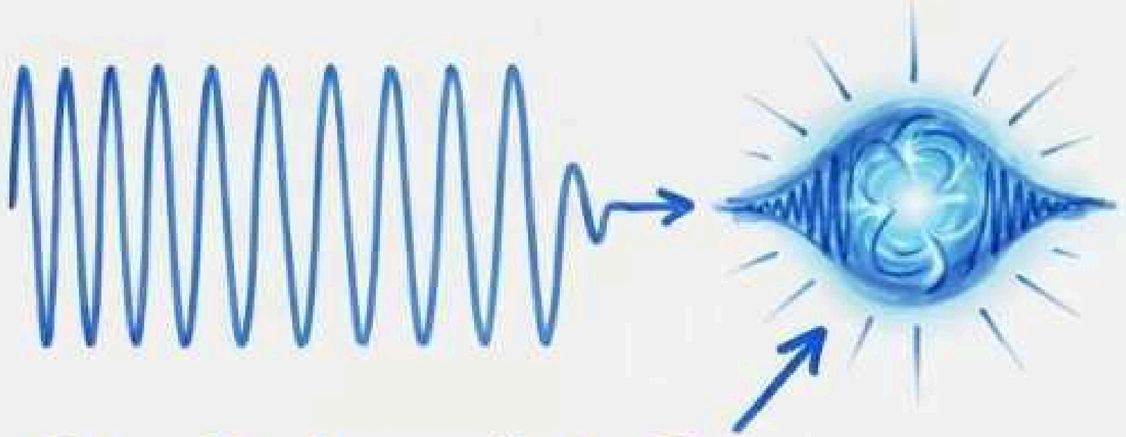
Key Insight:
Shorter wavelengths carry more energy per particle of light.

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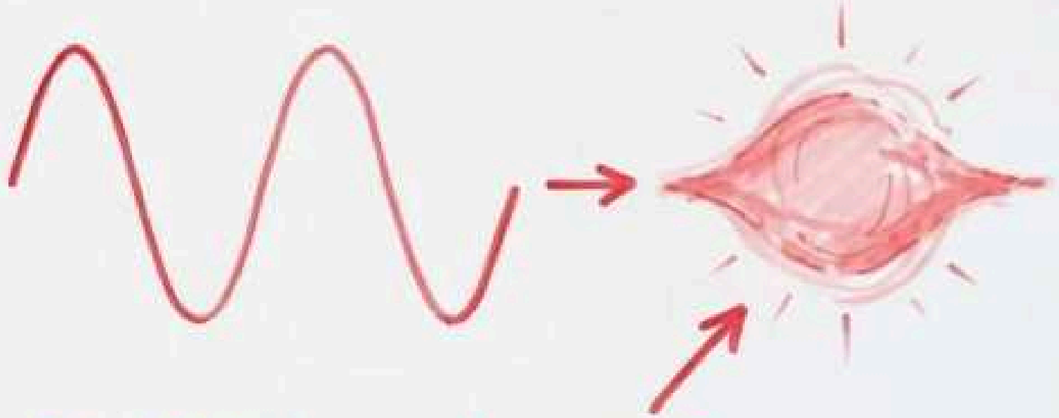
Packets of Energy $E = hf$

¶ 3.5

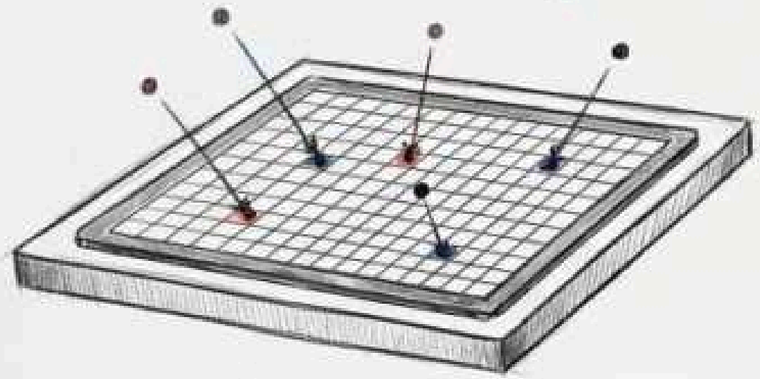
Light also comes in tiny packets called photons.



Blue Photon = High Energy



Red Photon = Lower Energy



"A faint star sends us only a trickle of photons... modern cameras can record the arrival of a single photon."

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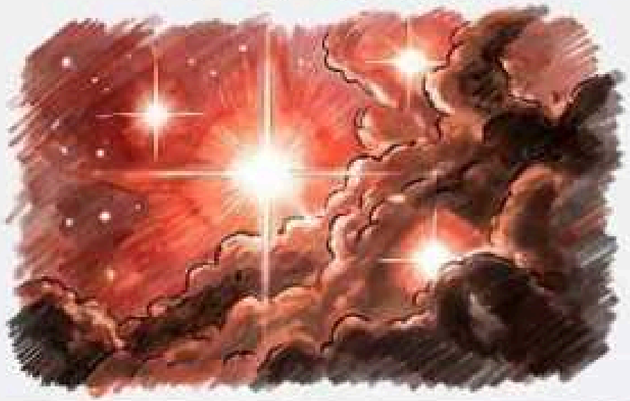
Different Wavelengths, Different Targets

¶ 3.6

Radio



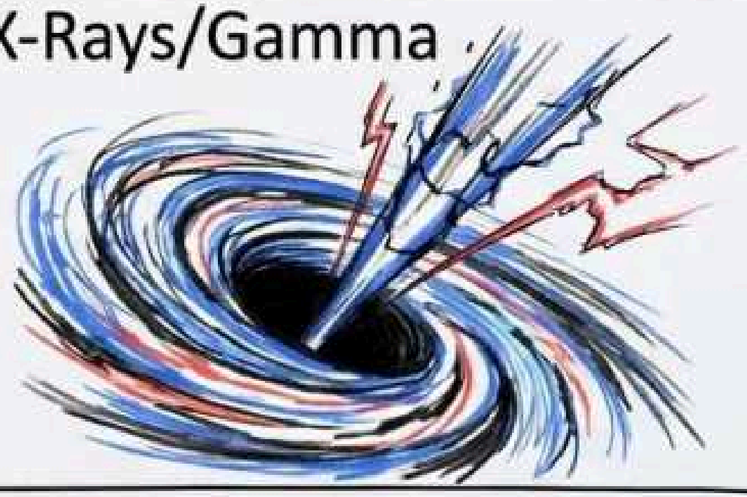
Infrared



Visible



X-Rays/Gamma



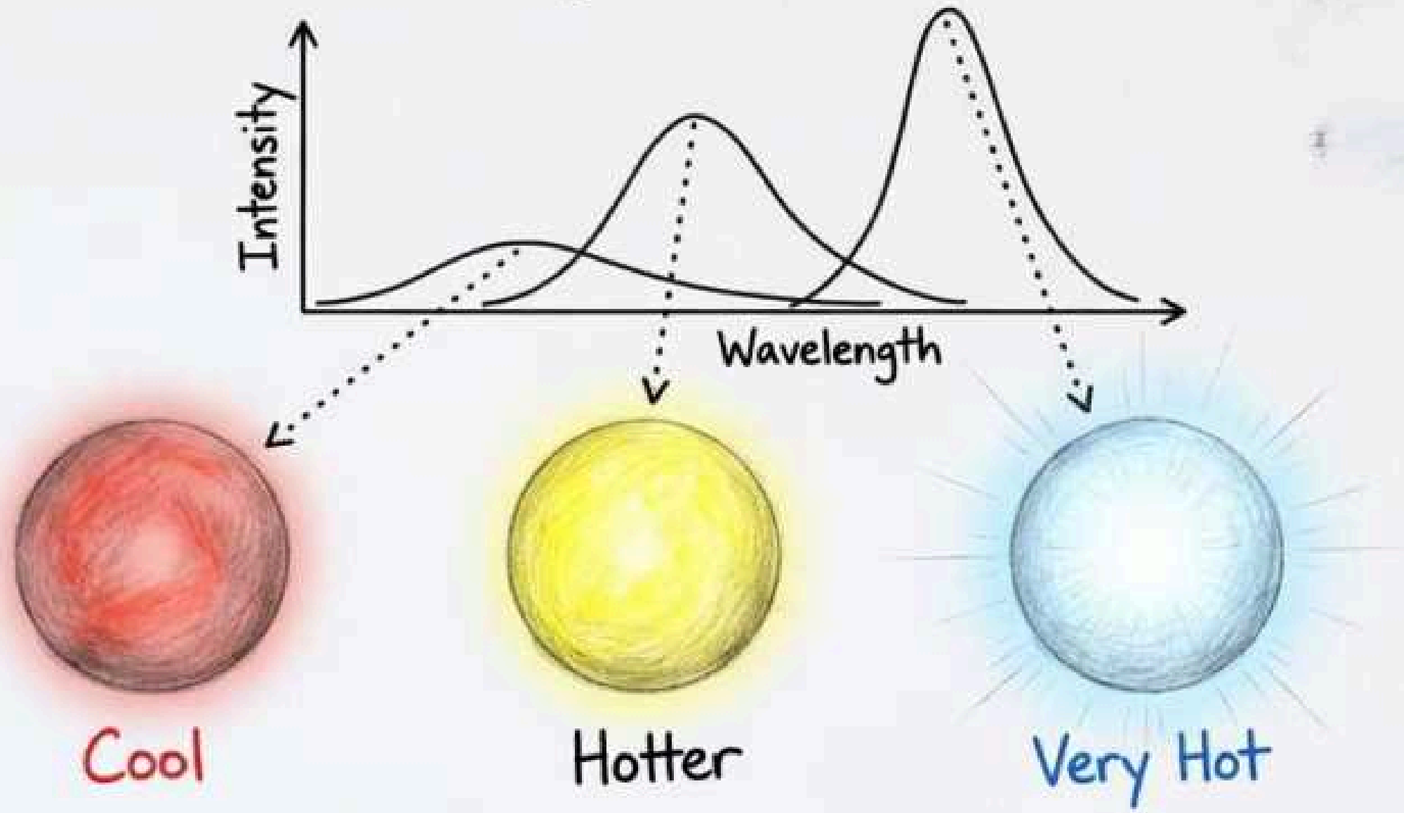
Looking at the sky in only one color would be like reading a book with half the words missing.

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¶ 3.7

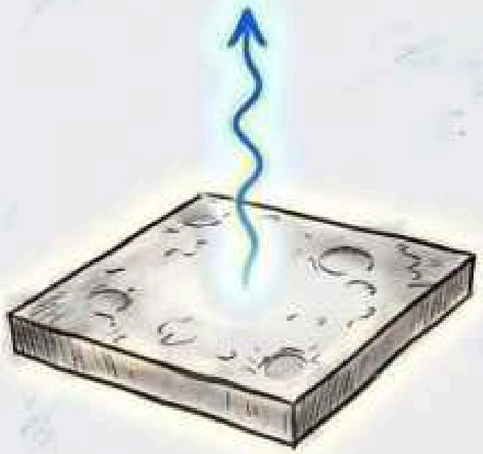
Clue 1: Temperature

Every hot object glows; the hotter the object, the shorter the wavelength at which it shines brightest.



Temperature & Energy Output

¶ 3.8

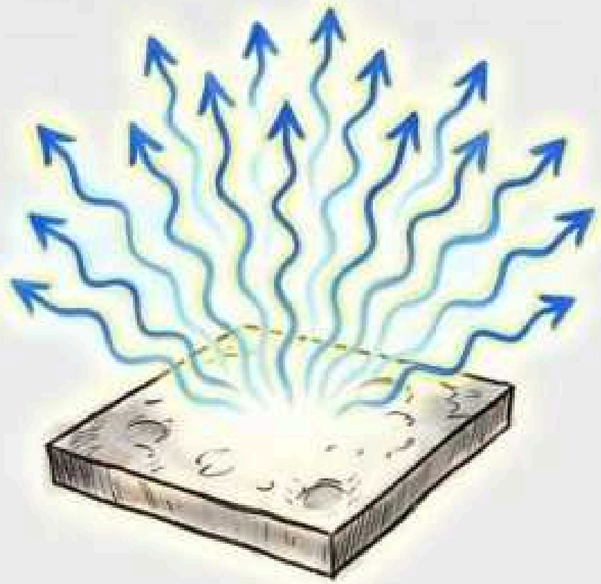


Temperature T

$$L = 4\pi R^2 \sigma T^4$$

Size

Temperature



Temperature 2T

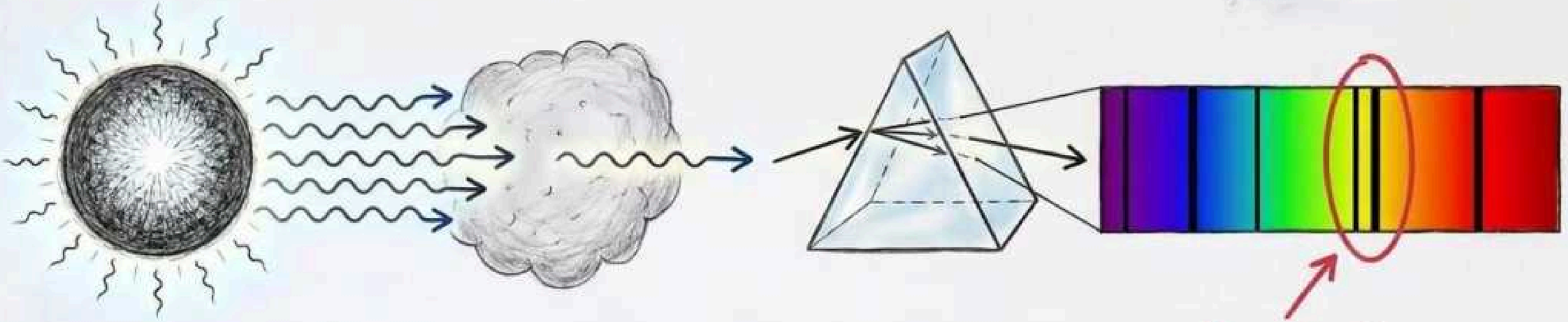
Key Insight: Energy grows with the fourth power of temperature.
Double the temperature = 16x the energy output.
Total brightness depends on size and temperature.

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¶ 3.9

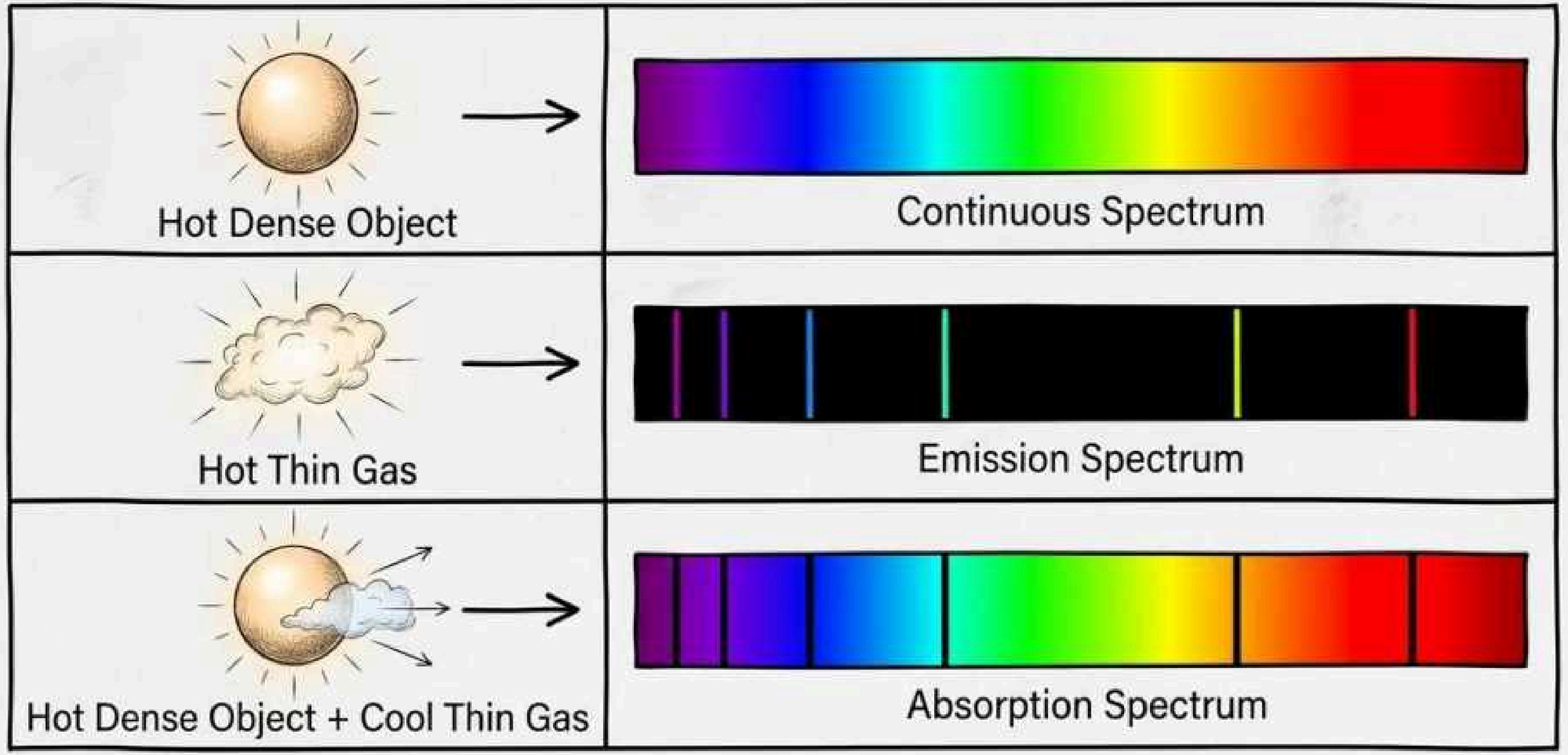
The Most Powerful Clue: The Spectrum

A star's light is not a smooth rainbow. Thin dark lines appear where specific colors were absorbed by particular atoms in the star's outer layers.



Kirchhoff's Three Spectra (1850s)

¶ 3.10

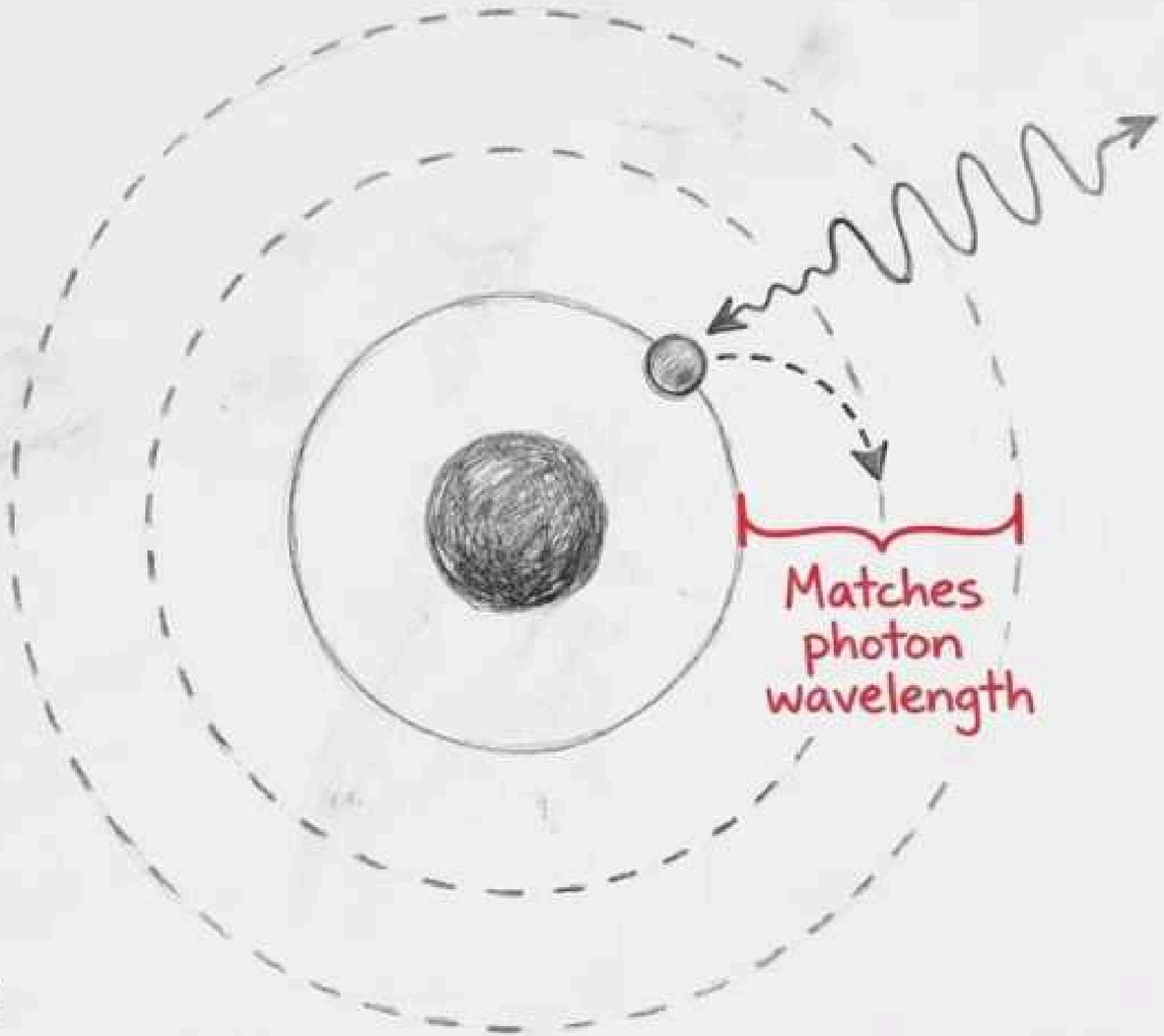


Conclusion: The pattern of lines is an atomic fingerprint.

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The Quantum Reason

Atoms can only hold certain amounts of energy. They absorb or emit light only when the light exactly matches the gap between two energy levels.



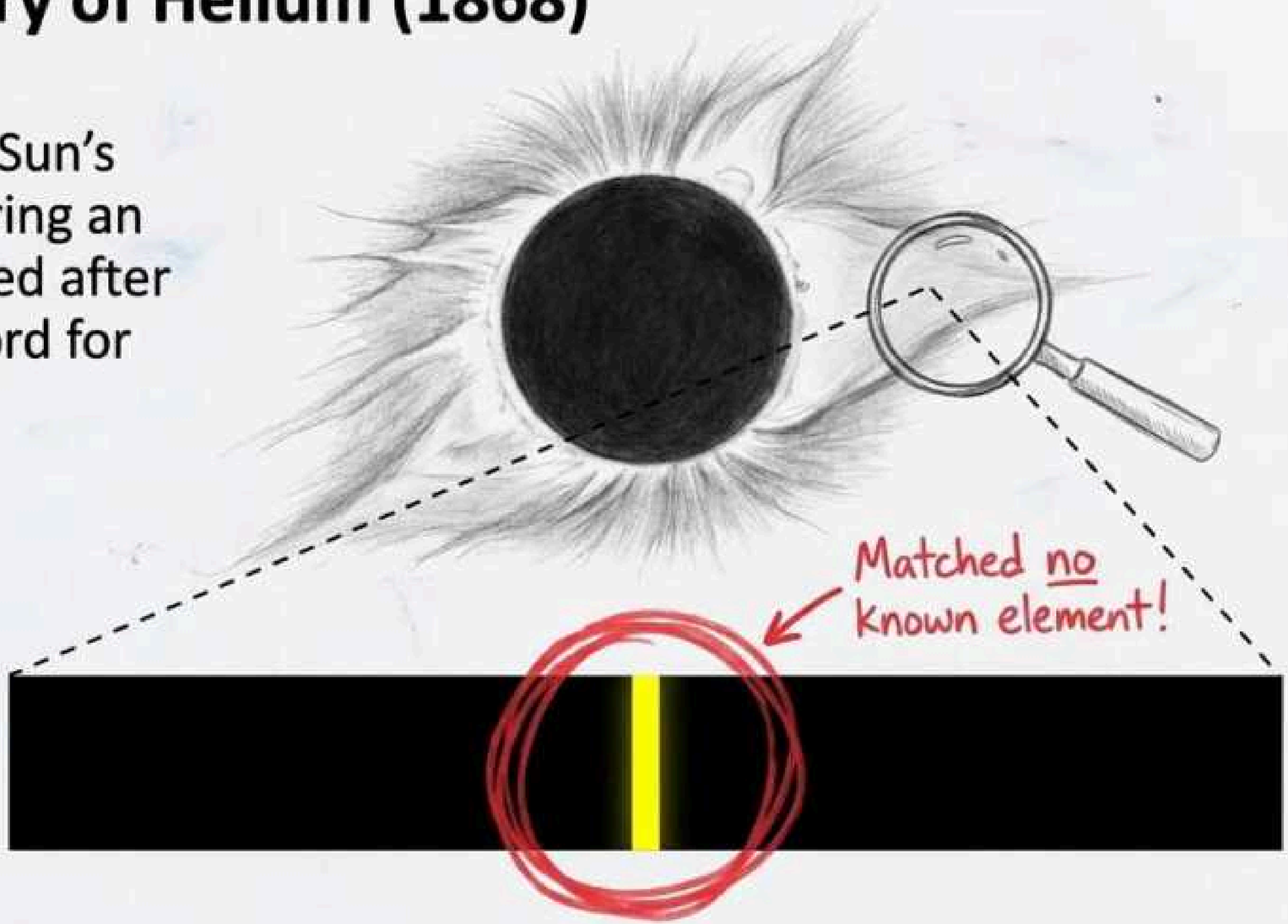
Result: Hydrogen, helium, iron—every element has its own set of gaps, and therefore its own distinct set of lines.

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The Discovery of Helium (1868)

¶ 3.12

Found in the Sun's spectrum during an eclipse. Named after the Greek word for the Sun.



Impact: We knew of it in the Sun before we found it at home, almost 30 years later.

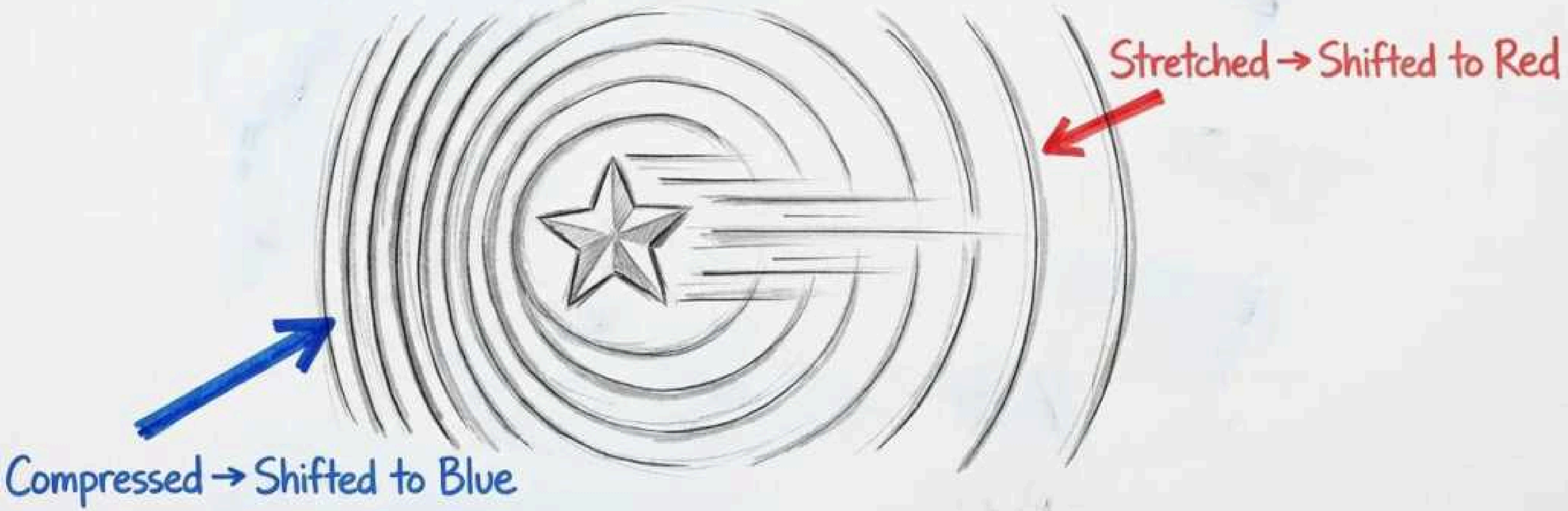
Gemini Notebook

¶ 3.13

The Doppler Effect

Analogy: The same effect that changes the pitch of a passing ambulance siren.

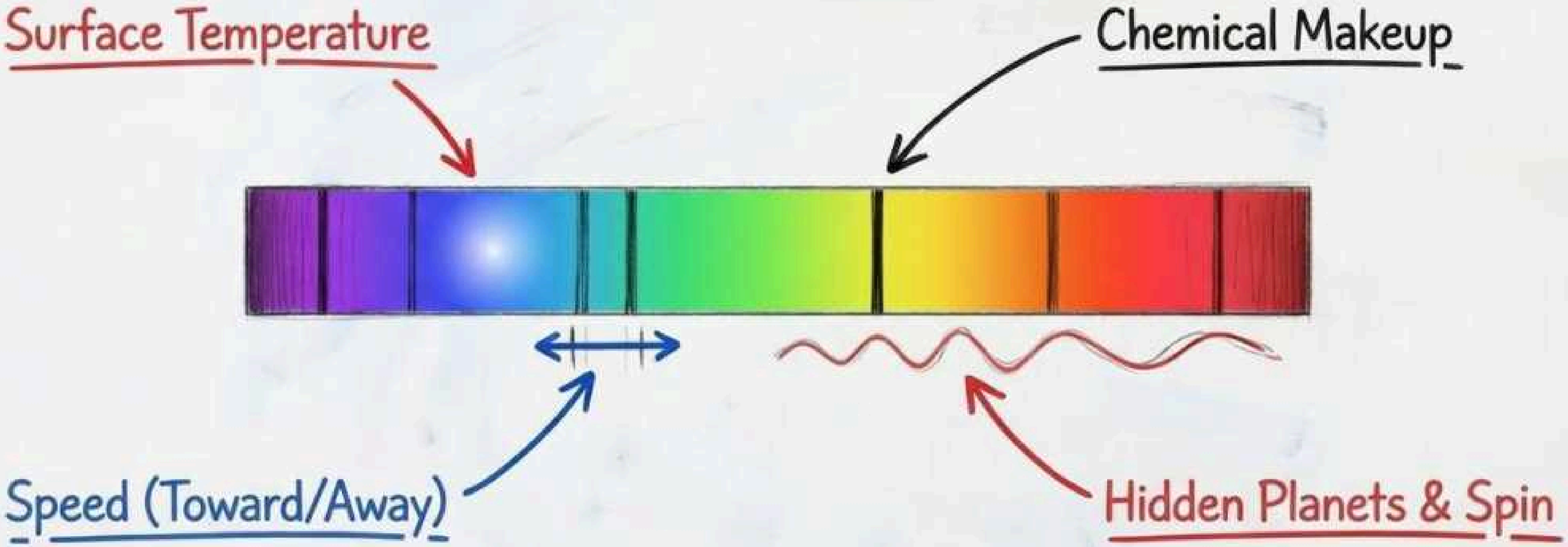
Measurement: The size of the shift tells us the speed along our line of sight.



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¶ 3.14

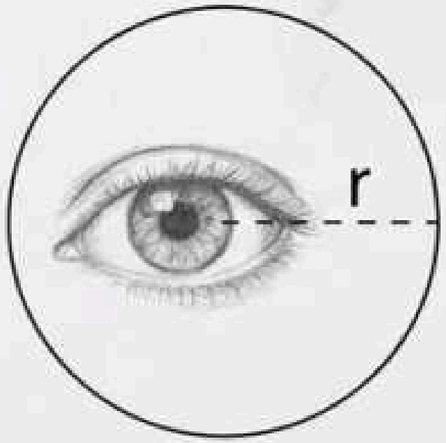
The Ultimate Cipher



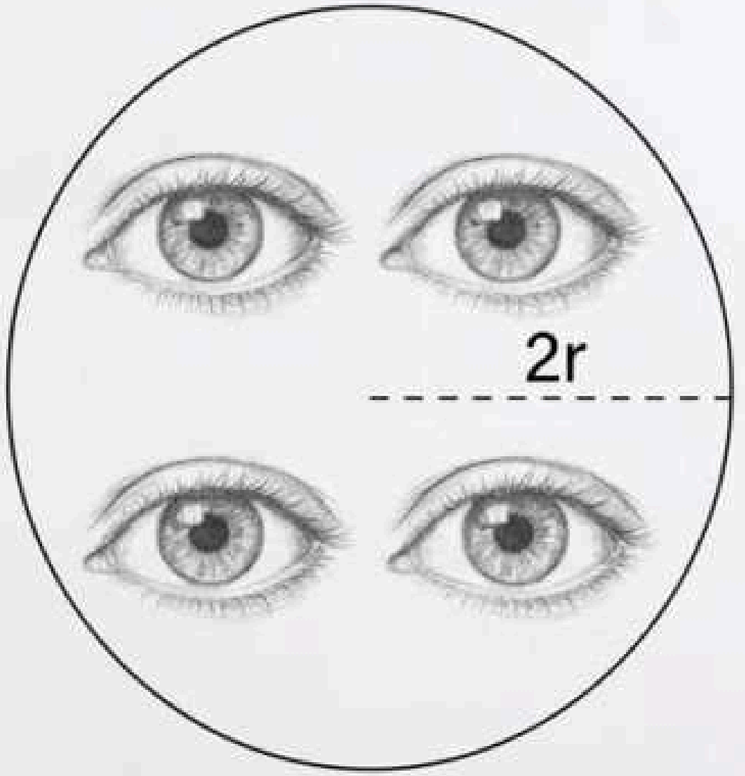
Takeaway: A single spectrum unpacks an entire planetary system. Planet gravity gravity causes a tiny wobble in the star's motion, captured by Doppler shifts.

Gemini Notebook

Telescope Basics



$$\text{Area} = \pi r^2$$



Job 1: Collect light. Doubling diameter collects four times as much light to make faint things visible.

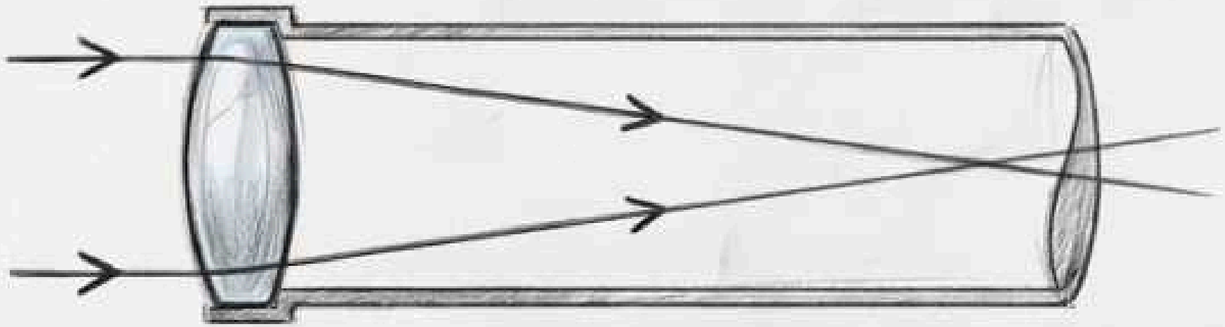
Job 2: Show fine detail (also improves as diameter grows).

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¶ 3.16

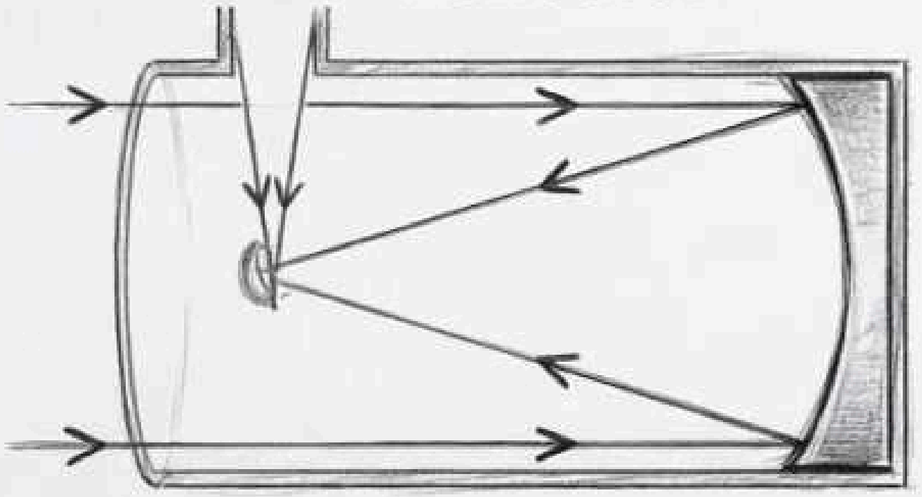
Lenses vs. Mirrors

Refractor



Galileo, 1609: Moon mountains, Jupiter's moons, Venus phases.

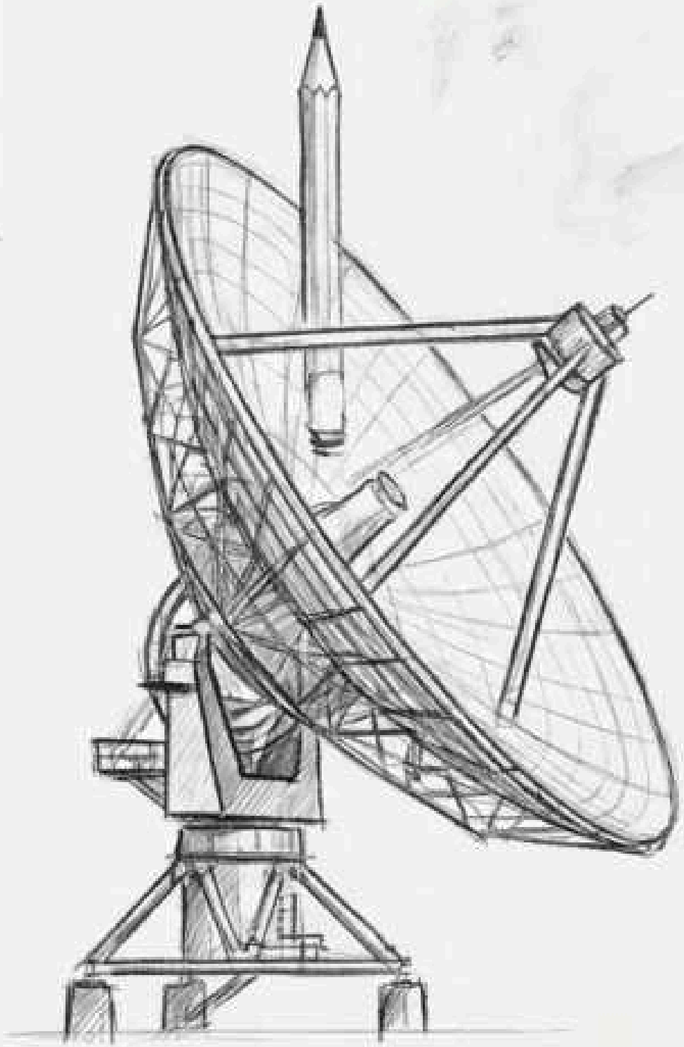
Reflector



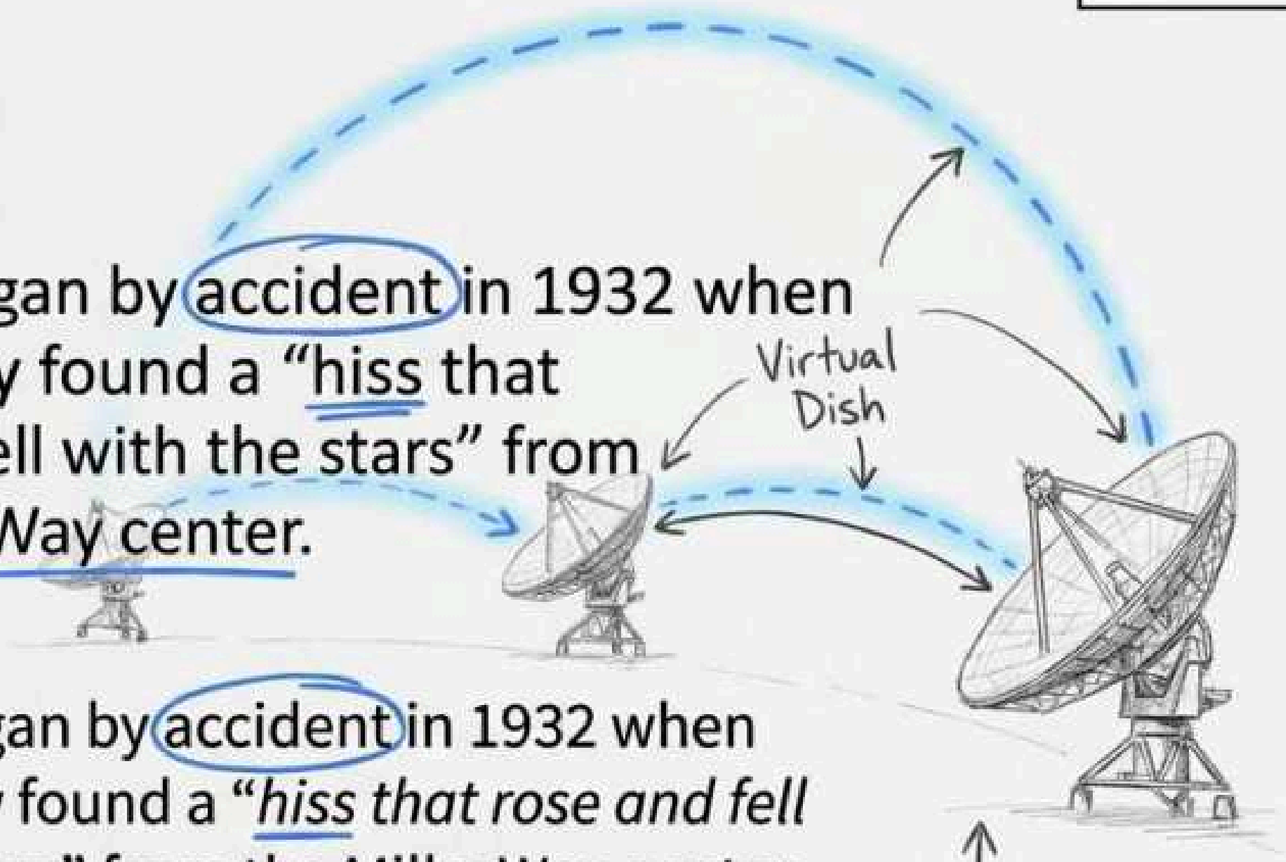
Key Fact: Almost every large modern telescope is a reflector because mirrors can be built much larger than lenses.

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Radio Arrays

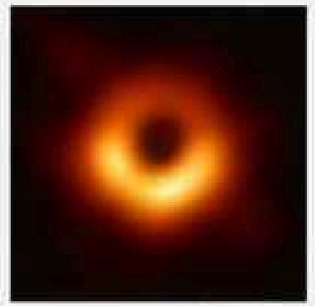


- **Origin**: Began by accident in 1932 when Karl Jansky found a "hiss that rose and fell with the stars" from the Milky Way center.



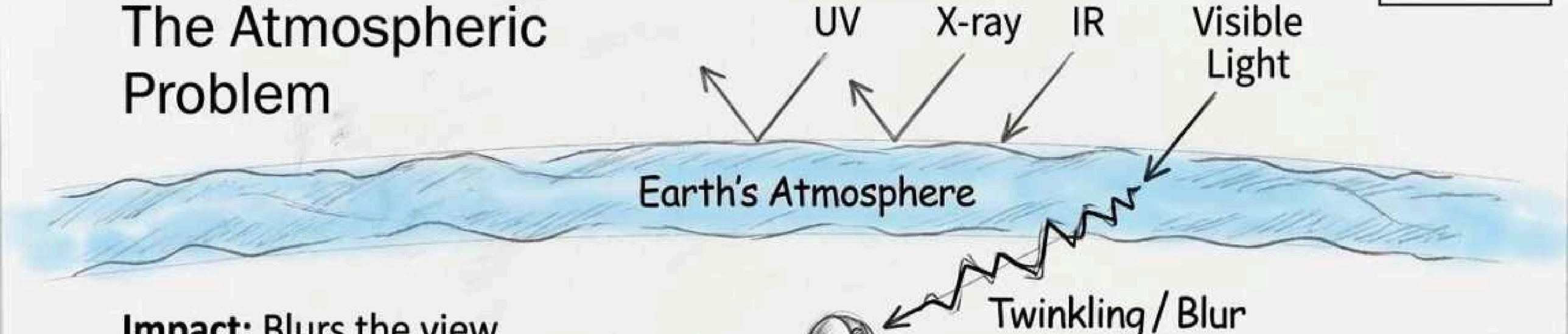
- **Origin**: Began by accident in 1932 when Karl Jansky found a "*hiss that rose and fell* with the stars" from the Milky Way center.
- **Technique**: Linking far-apart dishes makes them act like *one* telescope as wide as the distance between them.

EHT Example →



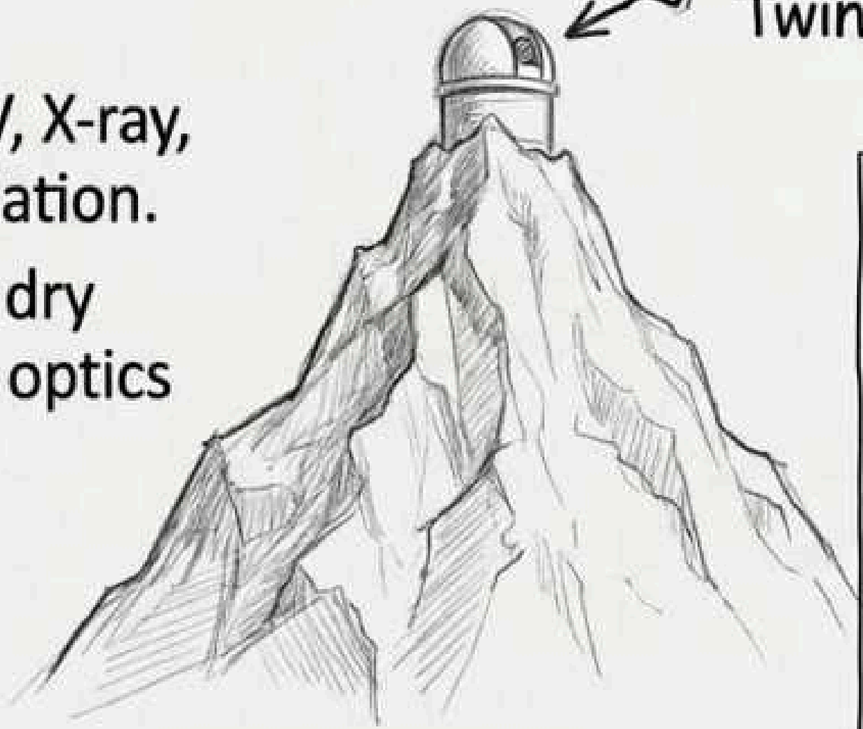
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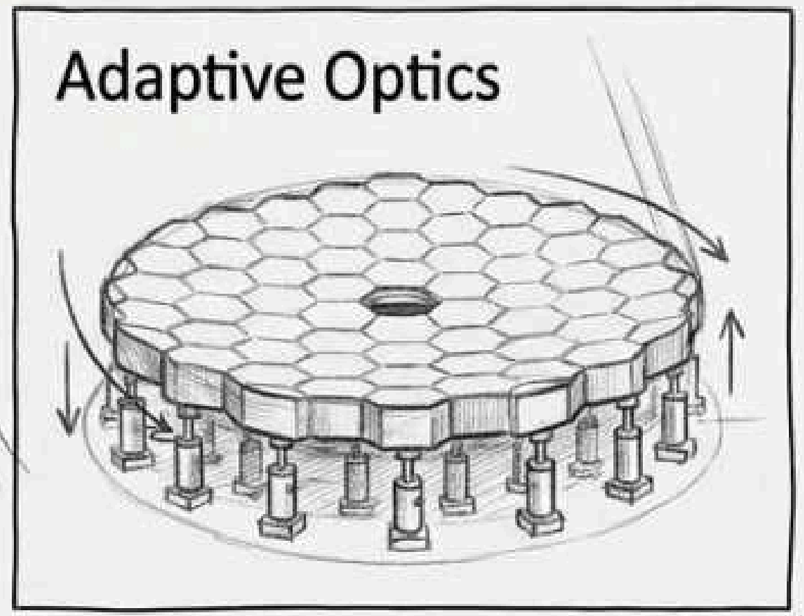
The Atmospheric Problem



Impact: Blurs the view (twinkling) and blocks UV, X-ray, gamma, and most IR radiation.

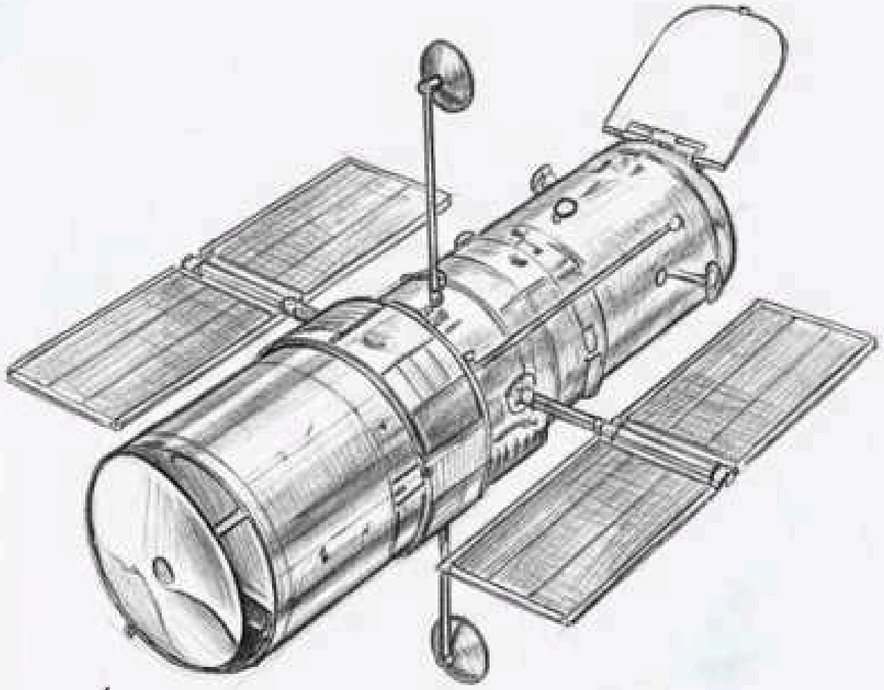
Solutions: Build on high, dry mountains; use adaptive optics (flexing mirrors to cancel blur); or go to space.



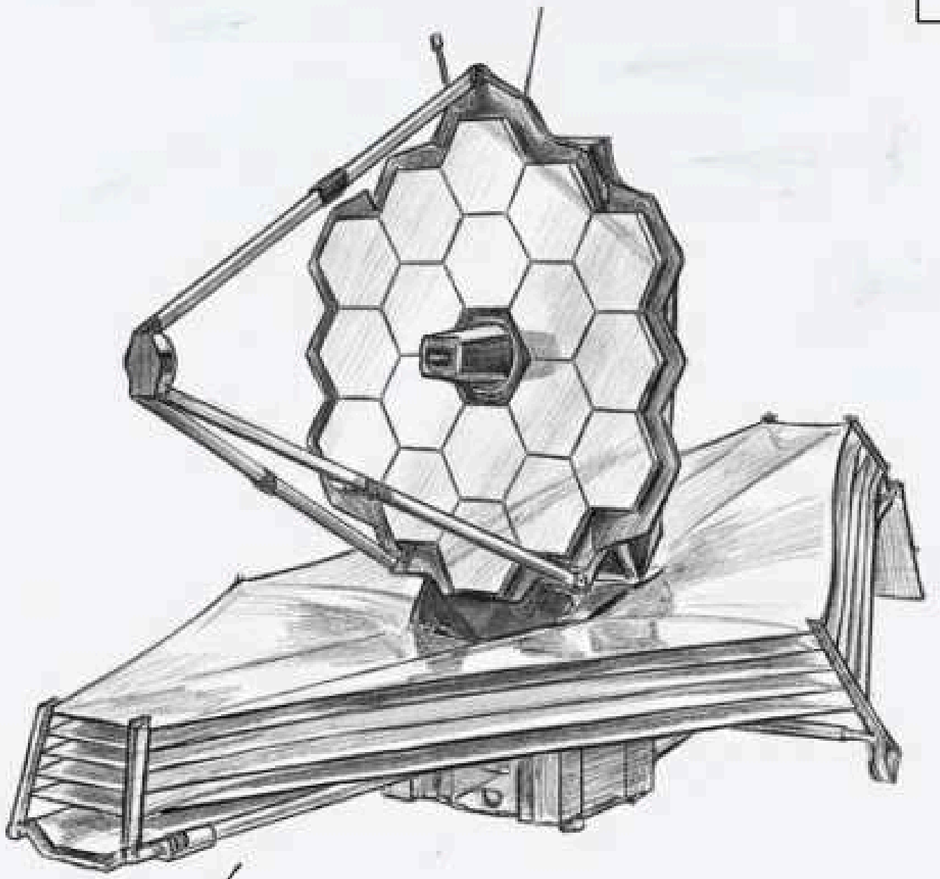


Gemini Notebook

Escaping the Atmosphere



Hubble Space Telescope
1990 / Visible Light
Sharp images above the atmosphere.



James Webb Space Telescope
2021 / 6.5m wide / Infrared
Seeing the earliest galaxies stretched by cosmic expansion.

Gemini Notebook

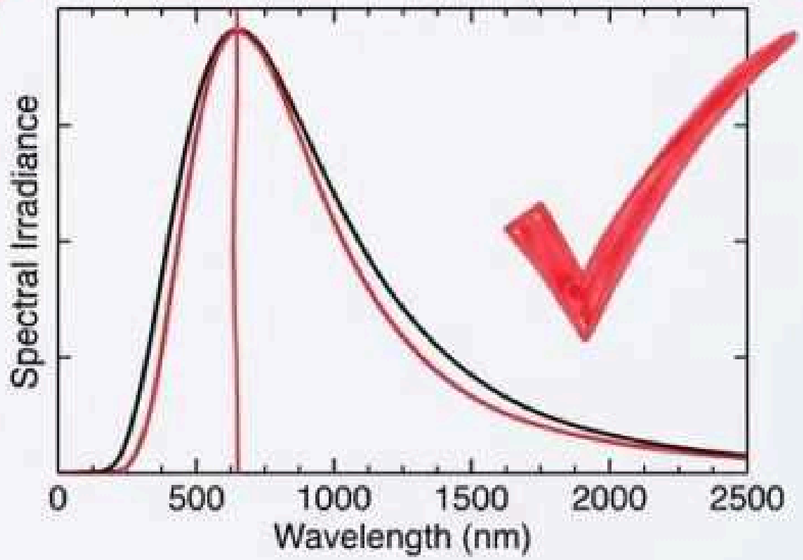
Synthesis: Color is Hard Science

¶ 3.20

(Opinion)



(Fact)



Exact Surface Temp: 3,000 K

Takeaway Question: A friend says that a star's color is just a matter of opinion. Using what you know about temperature and wavelength, explain why it is not.

Preview:
Next up—Lecture 4: Using light to study our nearest star, the Sun

Gemini Notebook