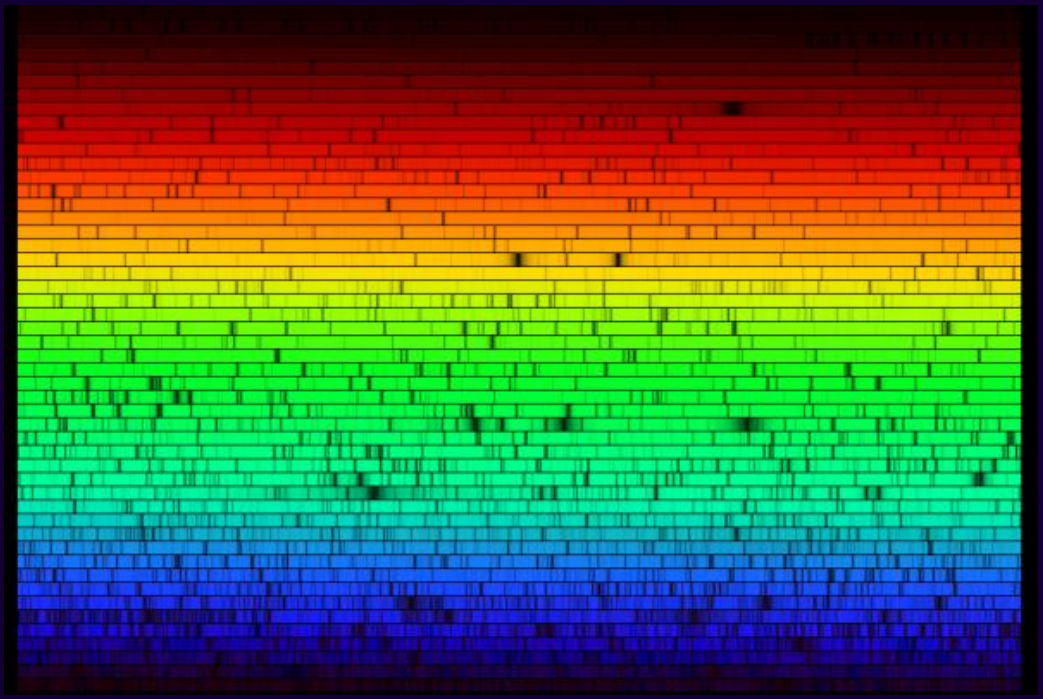
Spectroscopy

Astronomy 101
Syracuse University, Fall 2021
Walter Freeman

November 4, 2021



We are stardust; we are golden; we are billion-year-old carbon
And we got to get ourselves back to the garden.

–"Woodstock", as performed by Crosby, Stills, Nash, and Young (1970)

Announcements

- The due date for Paper 2 is extended until the end of the day **Monday, November 8.**
- If you have questions about your paper, come to office hours or ask in `#paper-questions` on Discord.

Announcements

- The due date for Paper 2 is extended until the end of the day **Monday, November 8.**
- If you have questions about your paper, come to office hours or ask in `#paper-questions` on Discord.

- If you are looking for extra help with your paper, bring it to office hours or send it to Kiersten Edwards, our writing coach, at `kedwar03@syr.edu` or on Discord.

Announcements

- The due date for Paper 2 is extended until the end of the day **Monday, November 8.**
- If you have questions about your paper, come to office hours or ask in `#paper-questions` on Discord.

- If you are looking for extra help with your paper, bring it to office hours or send it to Kiersten Edwards, our writing coach, at `kedwar03@syr.edu` or on Discord.

Are there any questions about the paper?

Announcements

Your next homework assignment is included with today's exercises in class. It is due **next Thursday** before class.

Announcements

Your next homework assignment is included with today's exercises in class. It is due **next Thursday** before class.

The prelab for next week's lab is very important, so you should make sure you do it. It is posted on the course website under "Labs", as usual.

Emission spectra

Every chemical element has a unique *spectrum*: the colors of light that it can emit and absorb.

Other colors simply pass through.

(Molecules have these spectra too: their electron energy levels are more complicated.)

Suppose I put a 5000 K object behind a cloud of gas with energy levels at 0, 3, and 5 eV. What does the 5000 K object do?

A: Emit light of a broad range of wavelengths

B: Absorb light of a broad range of wavelengths

C: Emit light made of 3 and 5 eV photons

D: Absorb light made of 3 and 5 eV photons

Suppose I put a 5000 K object behind a cloud of gas with energy levels at 0, 3, and 5 eV. What could this cloud of gas do?

A: Emit light of a broad range of wavelengths

B: Absorb light of a broad range of wavelengths

C: Absorb photons with at least 2 eV of energy

D: Absorb photons of 2, 3 and 5 eV, and allow the rest to pass

Suppose I put a 5000 K object behind a cloud of gas with energy levels at 0, 3, and 5 eV, and then look at the energies of the photons that come out the other side.

A: Photons with energy 3 and 5 eV

B: Photons with energy 2, 3, and 5 eV

C: Photons of a wide range of energies, *except* 3 and 5 eV

D: Photons of a wide range of energies, *except* 2, 3, and 5 eV

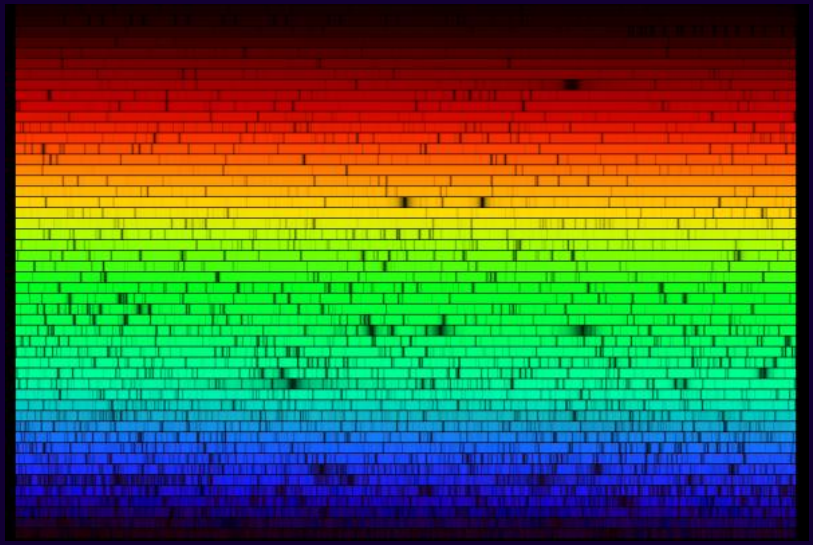
Suppose I put a 5000 K object behind a cloud of gas with energy levels at 0, 3, and 5 eV, and then separate its light by color. (Assume that I am a bird and can see ultraviolet light.) What would I see?

A: Only two bright lines

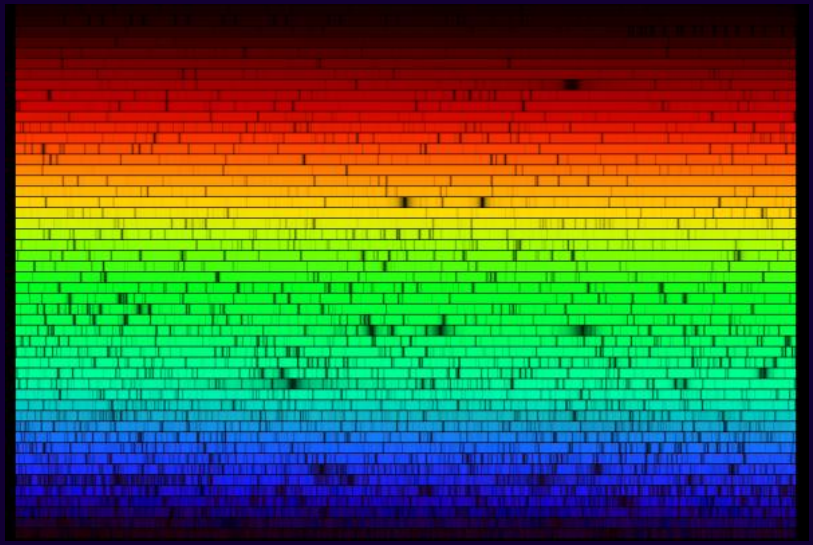
B: Only three bright lines

C: A solid band of color, but with two dark lines

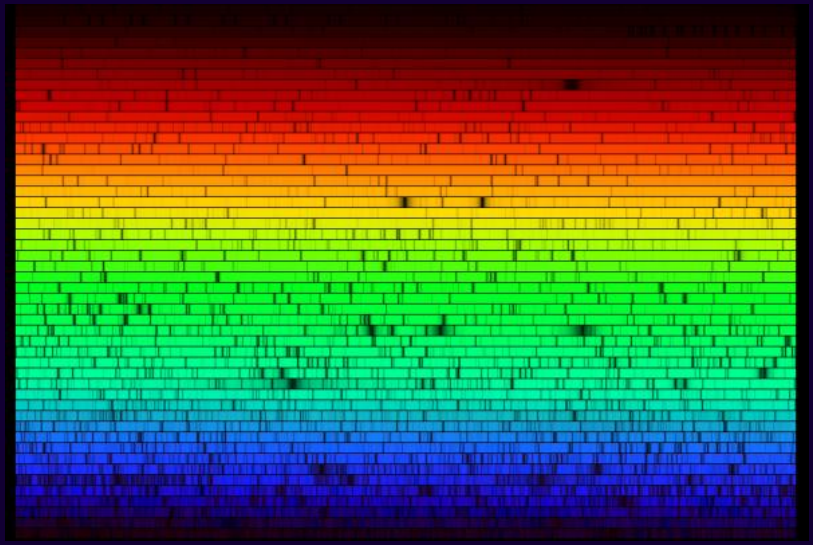
D: A solid band of color, but with three dark lines



- The hot core of the Sun emits light of all wavelengths (thermal radiation)



- The hot core of the Sun emits light of all wavelengths (thermal radiation)
- The gases in the cooler atmosphere absorb light of their particular wavelengths



- The hot core of the Sun emits light of all wavelengths (thermal radiation)
- The gases in the cooler atmosphere absorb light of their particular wavelengths

This picture tells us what's in the Sun!

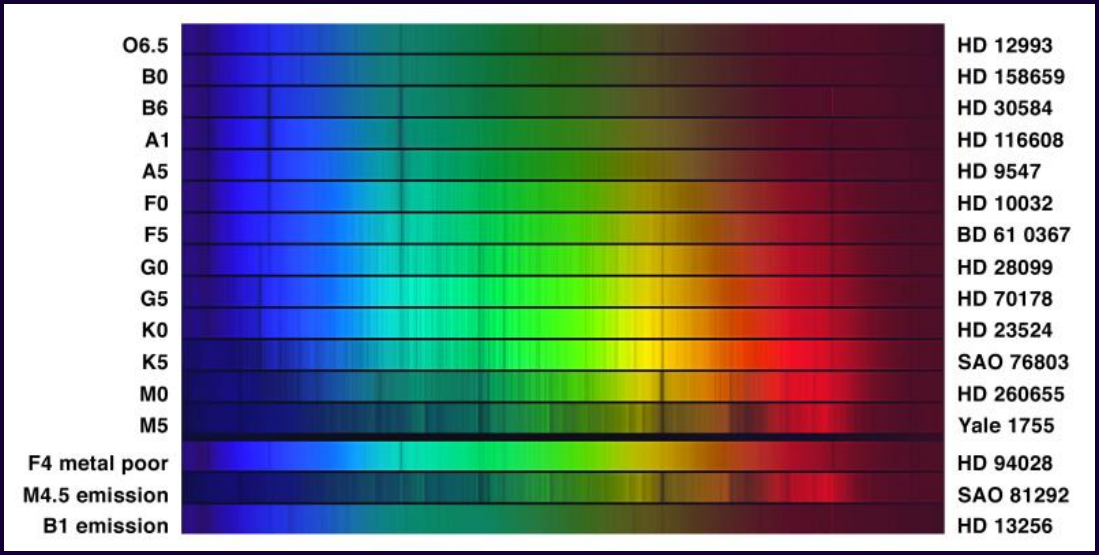
You discover lines in the solar spectrum that don't correspond to any known element. What do you conclude?

A: Something about quantum mechanics is different in the Sun

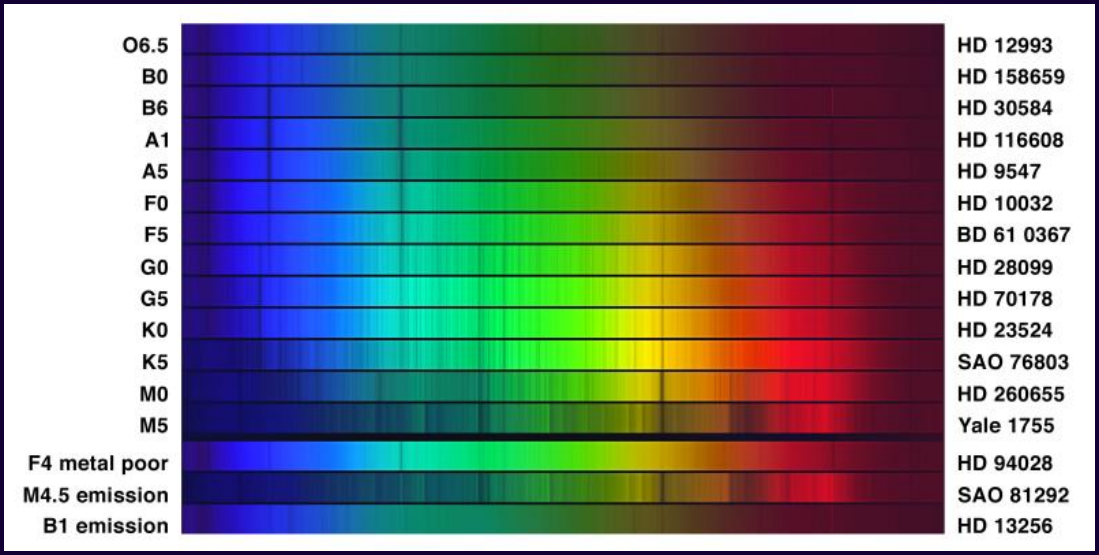
B: Something about light is different in the Sun

C: There's an element in the Sun that's not on Earth – call it **sunium**

D: The extreme temperature of the Sun causes new lines to appear in its gas



All the stars are made of the same stuff – the same stuff as we are.



All the stars are made of the same stuff – the same stuff as we are.

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

–Carl Sagan, *Cosmos*

What a lucky accident!

We're very lucky that atomic transitions happen to lie in our visual range!

There are others that are very interesting to astronomers:

- Molecular vibrations: infrared

What a lucky accident!

We're very lucky that atomic transitions happen to lie in our visual range!

There are others that are very interesting to astronomers:

- Molecular vibrations: infrared
- Molecular *rotations*: microwave

What a lucky accident!

We're very lucky that atomic transitions happen to lie in our visual range!

There are others that are very interesting to astronomers:

- Molecular vibrations: infrared
- Molecular *rotations*: microwave
- "Hyperfine structure" energy levels in hydrogen: 21 cm radio waves

What a lucky accident!

We're very lucky that atomic transitions happen to lie in our visual range!

There are others that are very interesting to astronomers:

- Molecular vibrations: infrared
- Molecular *rotations*: microwave
- "Hyperfine structure" energy levels in hydrogen: 21 cm radio waves

This last is particularly interesting: it is a very particular frequency, echoing out from all corners of the Universe, that says: hydrogen is here. (Hydrogen is 75% of the universe.)