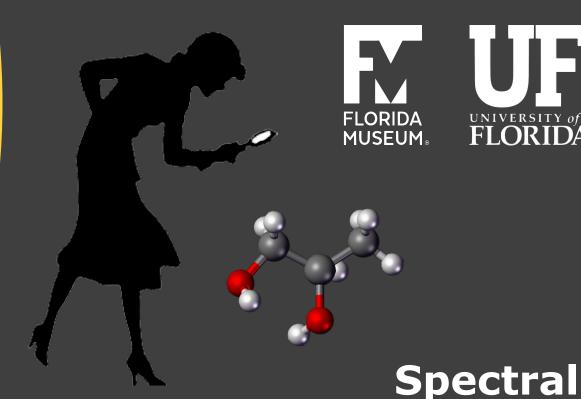


Scientist in Every Florida School

Thompson Earth Systems Institute

Fun fact: the Sun is made of mostly hydrogen and helium. If you could put it in a very big pool, it would float!



Alyssa Bulatek (she/her) Astronomy

Detective Work:

in Space

Finding Molecules

Outline

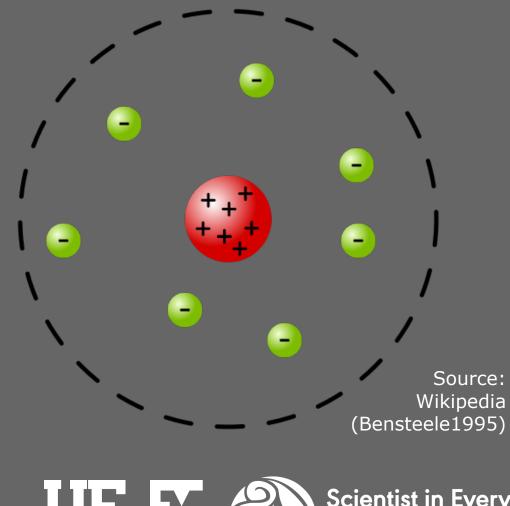
- Where do elements come from?
- How do molecules form from atoms?
- Can molecules that form on Earth also exist in space?
- How do we detect molecules in space?
- What does an astronomer's job look like?

Takeaway: elements on the periodic table are relevant to everyday life, and some of the same elements we encounter daily can also be found in space!



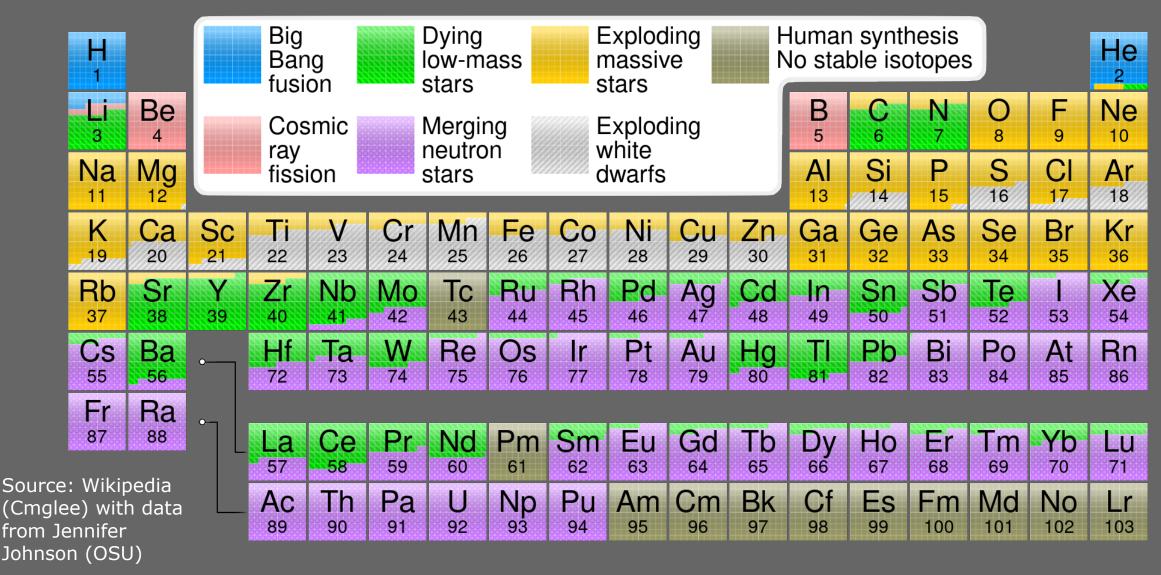
What is the anatomy of an atom?

- Different models of the atom have been suggested
 - Rutherford-Bohr: tight nucleus, broad "electron cloud"
- The number of protons that an atom has determines which element it is
- Cool interactive periodic table: https://ptable.com/









Where do the elements come from?

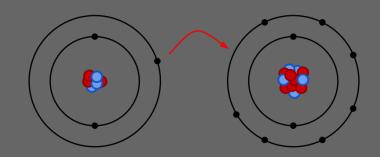




Scientist in Every Florida School
Thompson Earth Systems Institute

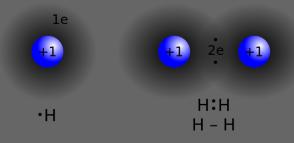
How do elements combine to make molecules?

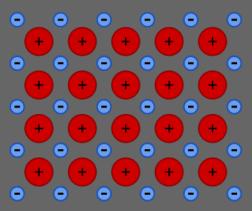
 When atoms get close to each other, the **electrons** orbiting their nuclei interact



- Three main types of bonds:
 - Ionic
 - Covalent
 - Metallic
- Bonds between molecules exist, though they are weaker than atomic bonds







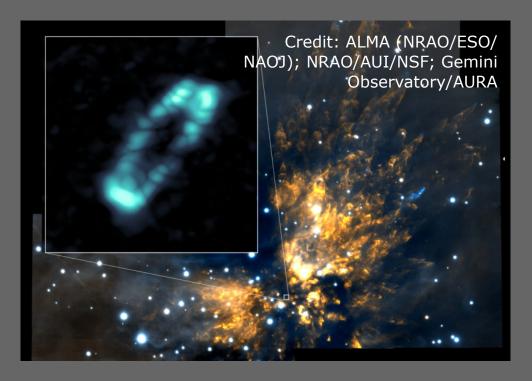






 A quick quiz! What "common" substances do these formulas represent?

 H_2O CO NaCl N_2O NH_3 CH_3CH_2OH $(CH_3)_2CO$

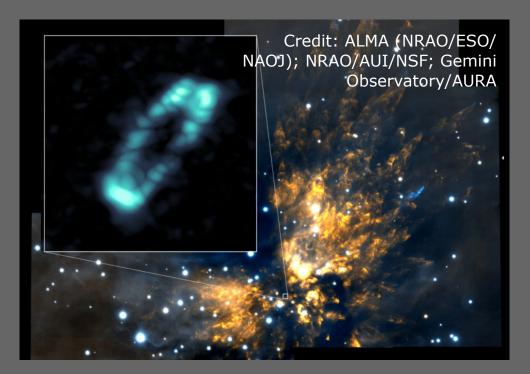




 A quick quiz! What "common" substances do these formulas represent?

 H_2O CO NaCl N_2O NH_3 CH_3CH_2OH $(CH_3)_2CO$

water







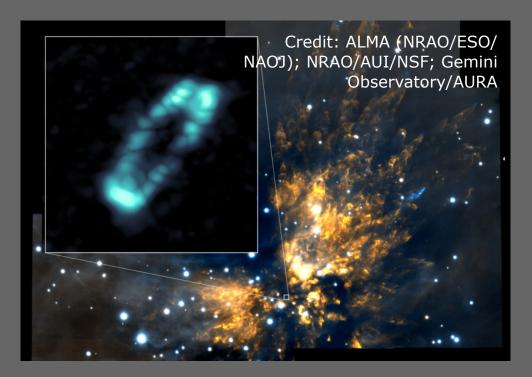


 A quick quiz! What "common" substances do these formulas represent?

H₂O water
CO carbon monoxide
NaCl
N₂O
NH₃

CH₃CH₂OH

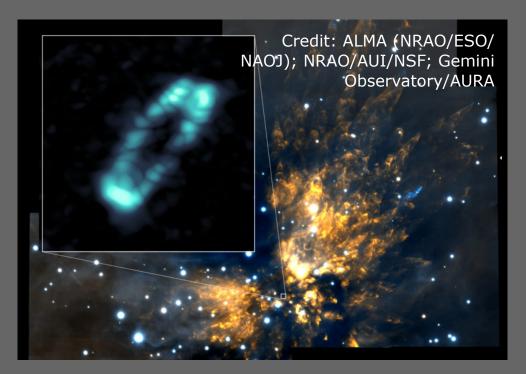
(CH₃)₂CO





 A quick quiz! What "common" substances do these formulas represent?

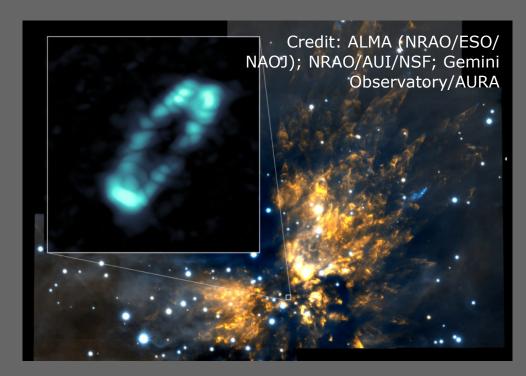
 $\begin{array}{ccc} H_2O & water \\ CO & carbon monoxide \\ NaCl & salt \\ N_2O & \\ NH_3 & \\ CH_3CH_2OH & \\ (CH_3)_2CO & \end{array}$





 A quick quiz! What "common" substances do these formulas represent?

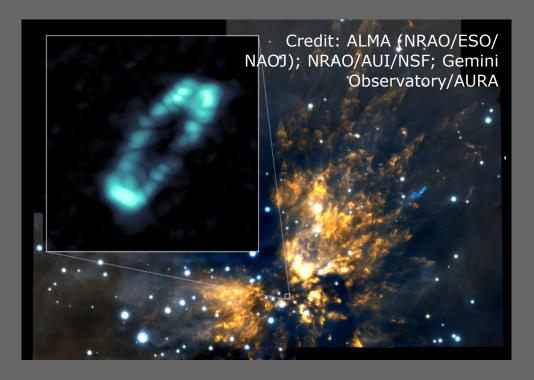
 H_2O water CO carbon monoxide NaCl salt N2O laughing gas NH3 CH3CH2OH (CH3)2CO





 A quick quiz! What "common" substances do these formulas represent?

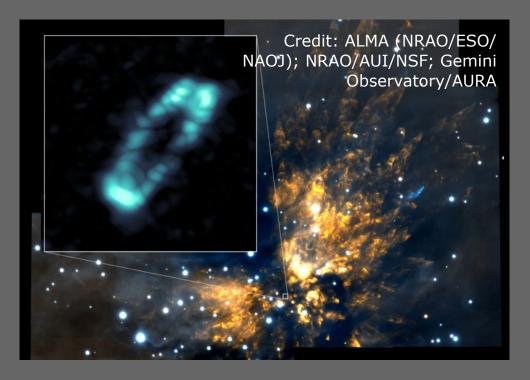
 H_2O water CO carbon monoxide NaCl salt N2O laughing gas NH3 ammonia CH3CH2OH (CH3)2CO





 A quick quiz! What "common" substances do these formulas represent?

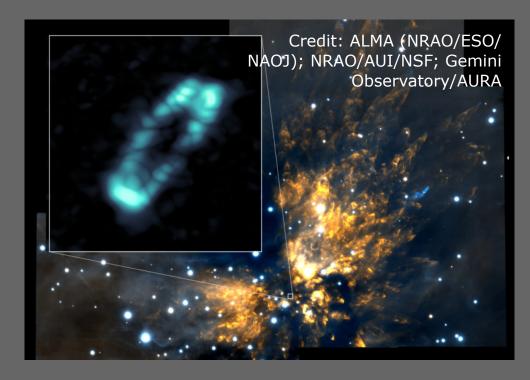
H₂O water
CO carbon monoxide
NaCl salt
N₂O laughing gas
NH₃ ammonia
CH₃CH₂OH grain alcohol
(CH₃)₂CO





 A quick quiz! What "common" substances do these formulas represent?

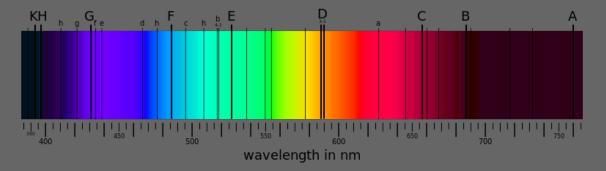
H₂O water
CO carbon monoxide
NaCl salt
N₂O laughing gas
NH₃ ammonia
CH₃CH₂OH grain alcohol
(CH₃)₂CO acetone

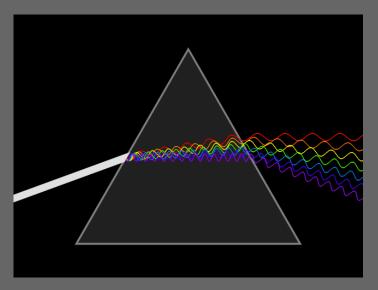




How do we detect atoms/molecules in space?

- Light is an astronomer's go-to tool
- Like molten metal, atoms and molecules in space emit light when they are hot (called a spectrum)
- The light emitted by a certain compound is unique to that compound

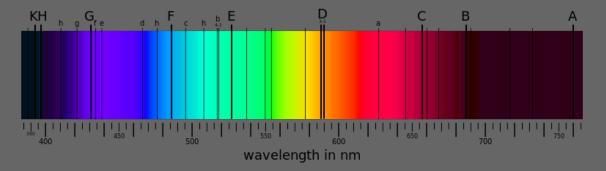


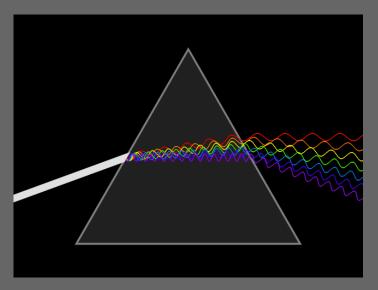




How do we detect atoms/molecules in space?

- Light is an astronomer's go-to tool
- Like molten metal, atoms and molecules in space emit light when they are hot (called a spectrum)
- The light emitted by a certain compound is unique to that compound







Yerkes Observatory refractor (40" lens at the same scale) Williams Bay, Wisconsin, USA (1893)

Great Paris Exhibition Telescope

(lens at the same scale) Paris, France (1900)

Hooker Telescope (100") Mt Wilson. California, USA (1917)



Multi-Object Fiber Spectroscopic Telescope Hebei, China (2009)

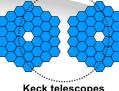


Southern African

Large Telescope

Sutherland,

Canarias La Palma. Canary Islands, Spain (2007)



Keck telescopes Mauna Kea, Hawaii, USA (1993, 1996)







Gemini North Mauna Kea, Hawaii, USA (1999)

Subaru Telescope

Mauna Kea

Hawaii, USA

(1999)

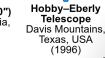


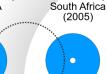
Thirty Meter Telescope Mauna Kea, Hawaii, USA (planned 2027)



Multiple Mirror Telescope

Mount Hopkins, Arizona, USA





Large Binocular Telescope Mount Graham.

Arizona, USA (2005)

Gemini South Cerro Pachón.





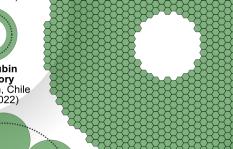








Vera C. Rubin Observatory Cerro Pachón, Chile (planned 2022)



Human at the

same scale

(1979 - 1998)

BTA-6 (Large Altazimuth Telescope) Zelenchuksky Russia (1975)

British Columbia. Canada (2003)

Gaia Earth-Sun L 2 point (2014)



Hubble Space Telescope **James Webb** Low Earth Space Telescope Earth-Sun L 2 point



(1990)

Large

Zenith

Telescope



(2000, 2002)

Very Large Telescope

Cerro Paranal, Chile





Giant Magellan Telescope Las Campanas, Chile (planned 2029)



0 5 10m 0 10 20 30 ft

Extremely Large Telescope

Cerro Armazones, Chile

(planned 2025)

Basketball court at the same scale

Source: Wikipedia (Pachango)



Source: Wikipedia (Iztok Bončina/ESO)



Source: Wikipedia (Cmglee)





Telescopes (the

best part of my job)

Scientist in Every Florida School

Thompson Earth Systems Institute



Tennis court at the same scale

Overwhelmingly Large Telescope (cancelled) Arecibo Observatory 305 m radio telescope at the same scale

FAST (Five-hundred-meter Aperture Spherical [radio] Telescope) at the same scale

Me and astronomy

- My interest in astronomy was piqued while watching the TV show Cosmos (2014)
- I liked doing physics problems more than writing papers (but I didn't like math), and looking at pretty pictures of space is a nice part of the job!
- Useful classes: physics, geometry, computer science







A day in my life as a graduate student

- I use the Atacama Large Millimeter/submillimeter Array (ALMA) to figure out which atoms and molecules are present at different stages of a newborn star's early life
- In reality....
 - Homework and projects
 - Writing code
 - Making and editing images from raw telescope data
 - Teaching/TAing
 - Meetings (on Zoom)
 - Observing
 - Outreach (like this presentation!)







Takeaways

- Elements are formed in a variety of places throughout the universe (and throughout time).
- Atoms can bond together to form molecules, which make up the materials (living and nonliving) that we encounter every day.
- Astronomers use light released by hot atoms and molecules to identify them.





Scientist in Every Florida School

Thompson Earth Systems Institute

Learn more: bit.ly/SEFSsite





Thank you!

I am happy to answer any questions you have about physics, astronomy, college, or more!

Image Credits

- Rutherford model of the atom: https://commons.wikimedia.org/wiki/ File:Rutherford_atomic_planetary_model.svg
- Periodic table: https://en.wikipedia.org/wiki/Atom#/media/ File:Nucleosynthesis_periodic_table.svg
- Covalent bonding: https://en.wikipedia.org/wiki/Covalent_bond#/media/ File:Covalent_bond_hydrogen.svg
- Salt in the Orion Source I disk: https://public.nrao.edu/gallery/alma-image-of-salt-in-orion-source-i/
- Comparison of optical telescope mirrors: https://commons.wikimedia.org/wiki/ File:Comparison_optical_telescope_primary_mirrors.svg
- ALMA: https://commons.wikimedia.org/wiki/File:ALMA_Antennas_on_Chajnantor.jpg
- GTC: https://commons.wikimedia.org/wiki/File:Grantelescopio.jpg
- All images without citations are in the public domain.

