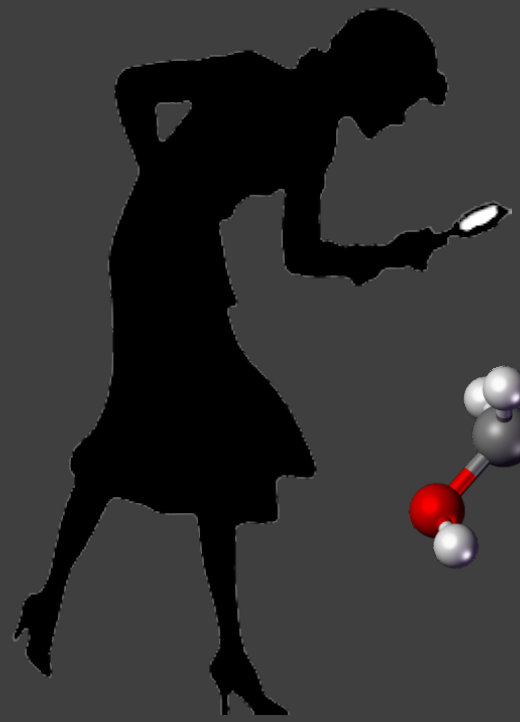
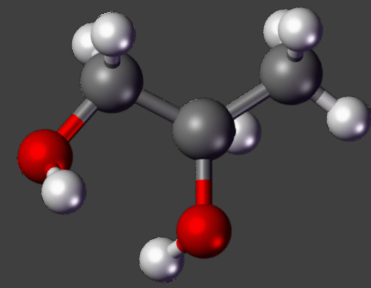
Scientist in Every Florida School

Thompson Earth Systems Institute





FLORIDA MUSEUM

UF UNIVERSITY of FLORIDA

Spectral Detective Work: Finding Molecules in Space

Alyssa Bulatek (she/her)
Astronomy

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

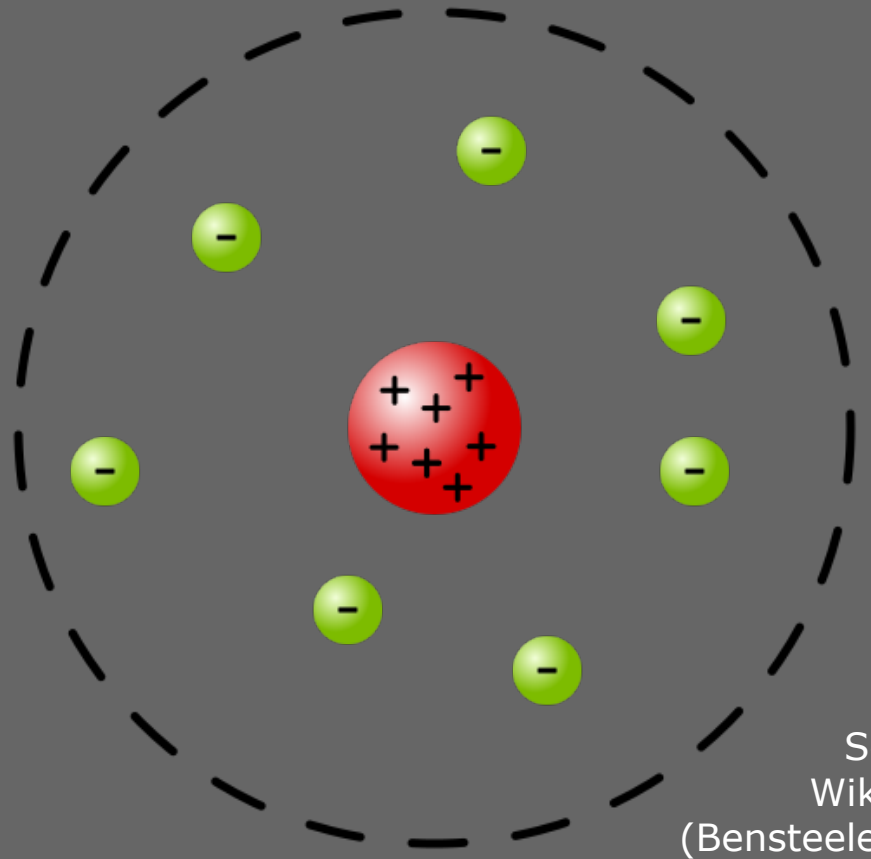
Outline

- 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?

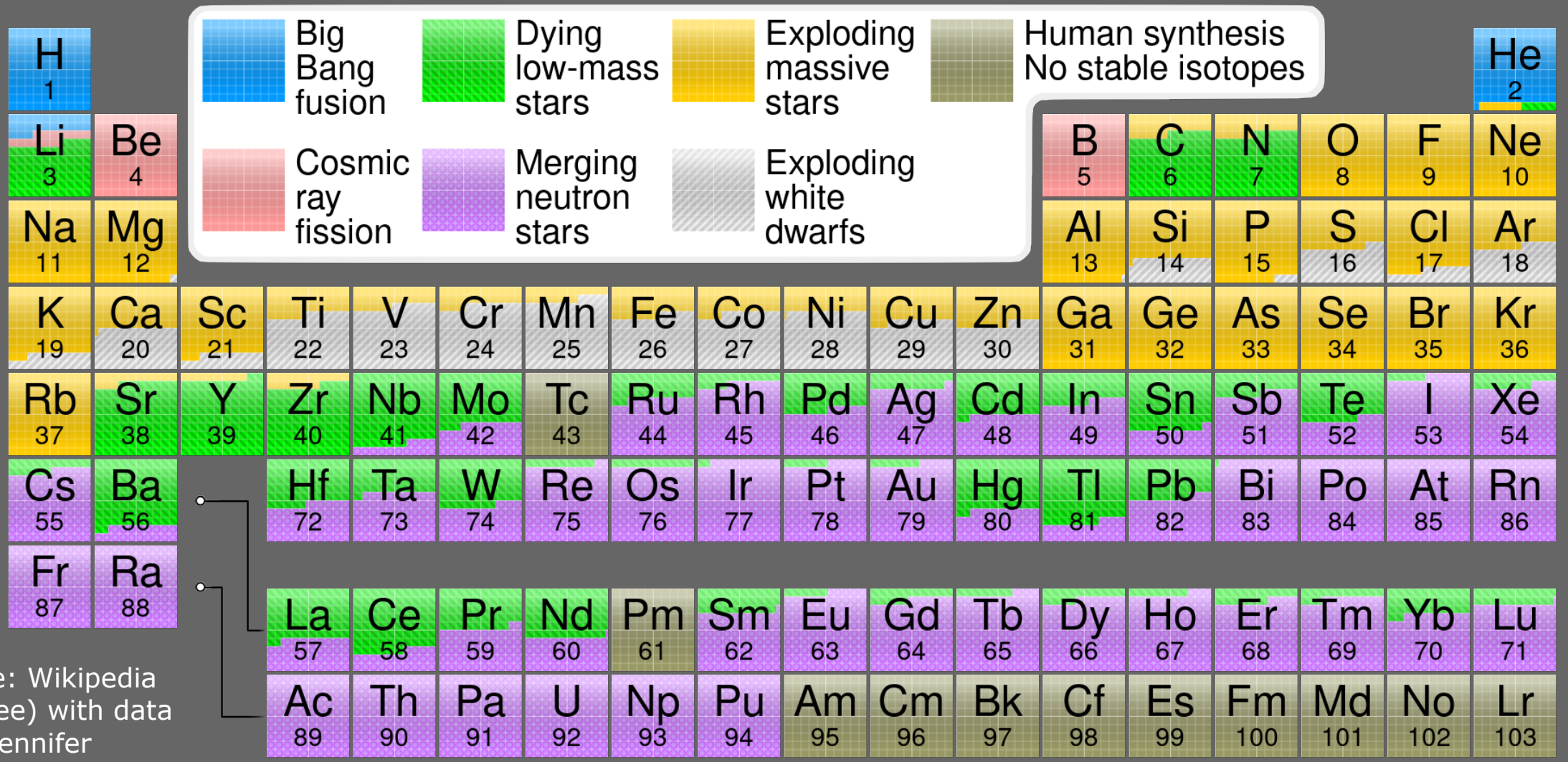
Takeaway: elements on the periodic table are relevant to everyday life, and some of the same elements we encounter daily can also be found in space!

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/



Source: Wikipedia (Bensteele1995)



Source: Wikipedia (Cmglee) with data from Jennifer Johnson (OSU)

Where do the elements come from?

UF UNIVERSITY of FLORIDA

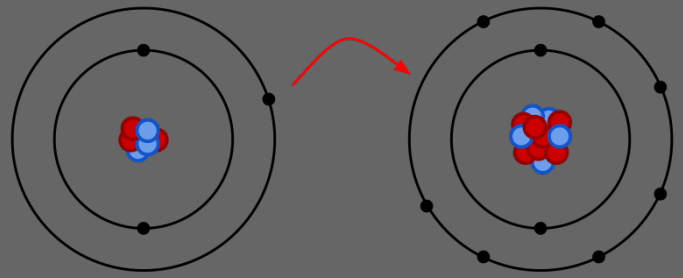
FLORIDA MUSEUM

Scientist in Every Florida School

Thompson Earth Systems Institute

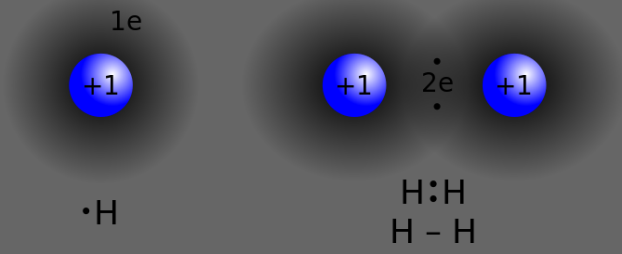
How do elements combine to make molecules?

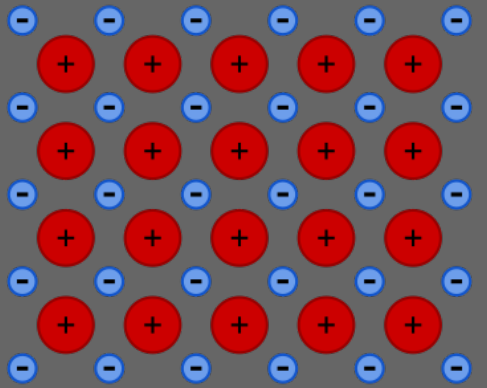
- When atoms get close to each other, the **electrons** orbiting their nuclei interact



Source: Wikipedia (Jacek FH)

- Three main types of bonds:
  - *Ionic*
  - *Covalent*
  - *Metallic*





- Bonds between molecules exist, though they are weaker than atomic bonds

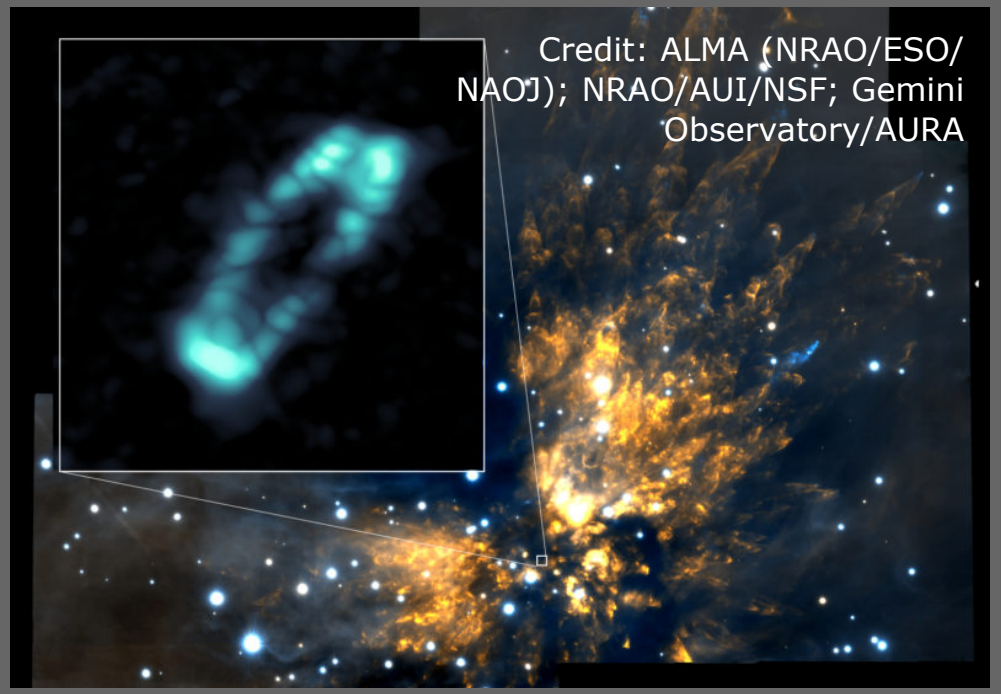
UF UNIVERSITY of FLORIDA
FLORIDA MUSEUM
Scientist in Every Florida School
Thompson Earth Systems Institute

Where are molecules found?

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

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

- All of those molecules have also been detected in space!



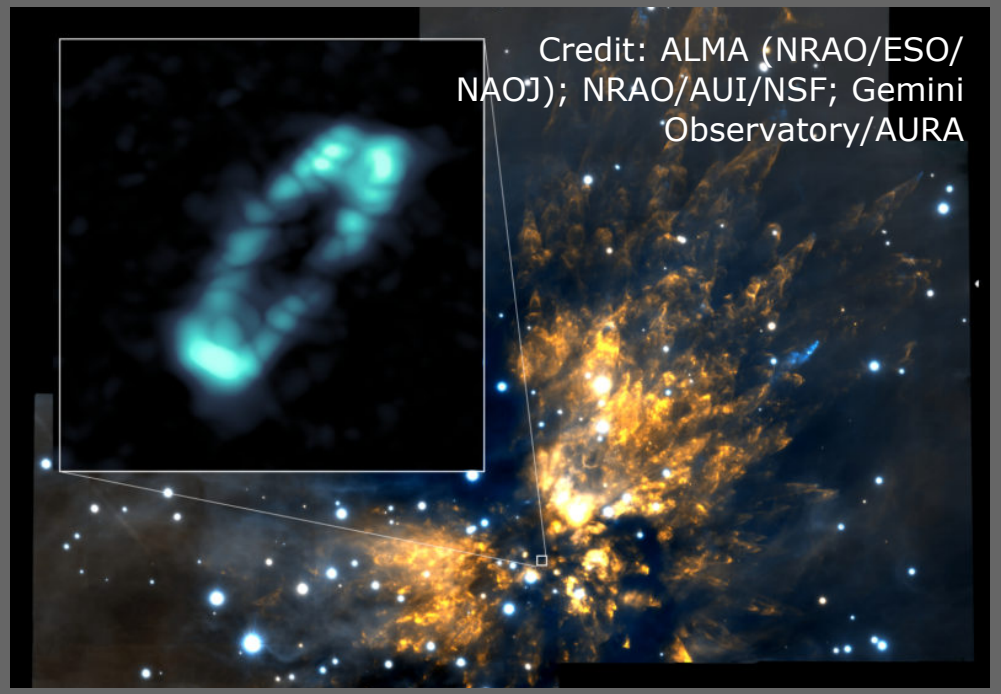
UF UNIVERSITY of FLORIDA
FLORIDA MUSEUM
Scientist in Every Florida School
Thompson Earth Systems Institute

Where are molecules found?

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

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

- All of those molecules have also been detected in space!



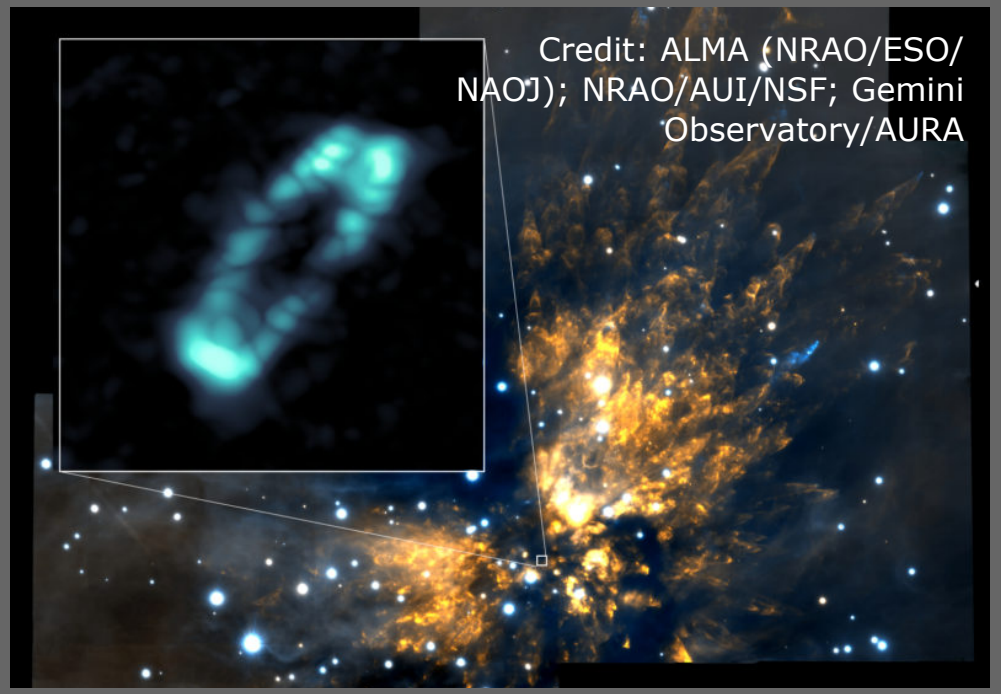
UF UNIVERSITY of FLORIDA
FLORIDA MUSEUM
Scientist in Every Florida School
Thompson Earth Systems Institute

Where are molecules found?

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

H_2O	water
CO	carbon monoxide
NaCl	
N_2O	
NH_3	
CH_3CH_2OH	
$(CH_3)_2CO$	

- All of those molecules have also been detected in space!



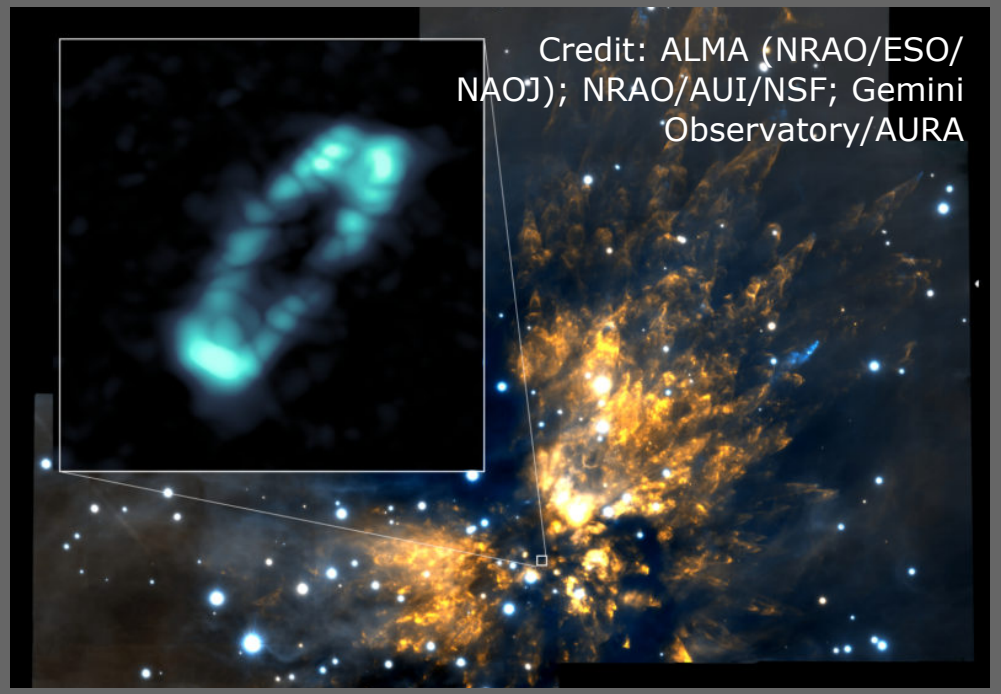
UF UNIVERSITY of FLORIDA
FLORIDA MUSEUM
Scientist in Every Florida School
Thompson Earth Systems Institute

Where are molecules found?

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

H_2O	water
CO	carbon monoxide
NaCl	salt
N_2O	
NH_3	
CH_3CH_2OH	
$(CH_3)_2CO$	

- All of those molecules have also been detected in space!



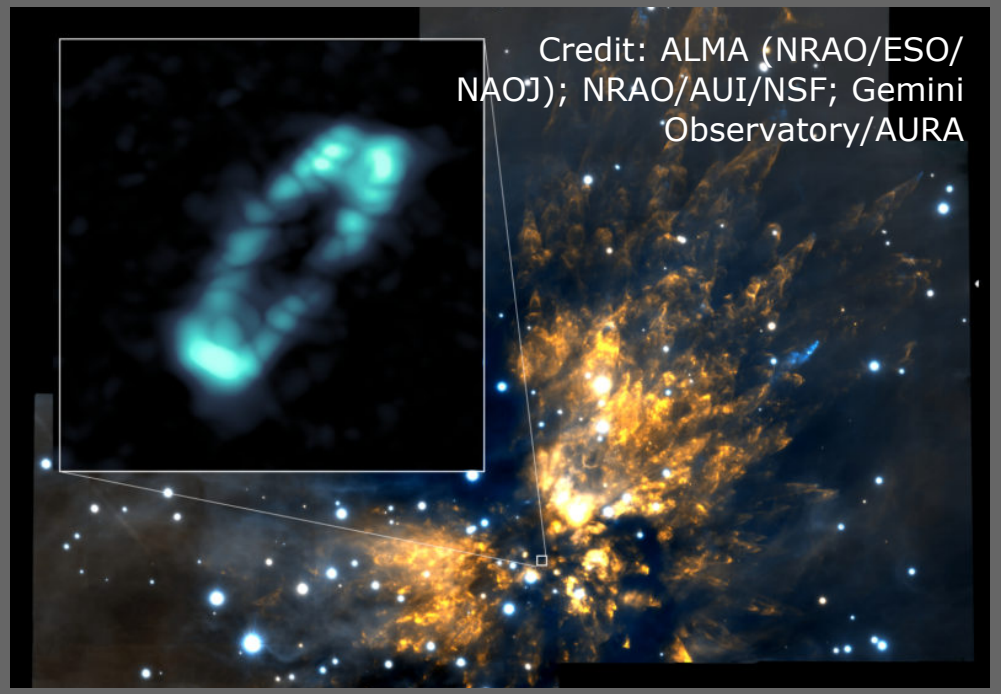
UF UNIVERSITY of FLORIDA
FLORIDA MUSEUM
Scientist in Every Florida School
Thompson Earth Systems Institute

Where are molecules found?

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

H_2O	water
CO	carbon monoxide
NaCl	salt
N_2O	laughing gas
NH_3	
CH_3CH_2OH	
$(CH_3)_2CO$	

- All of those molecules have also been detected in space!

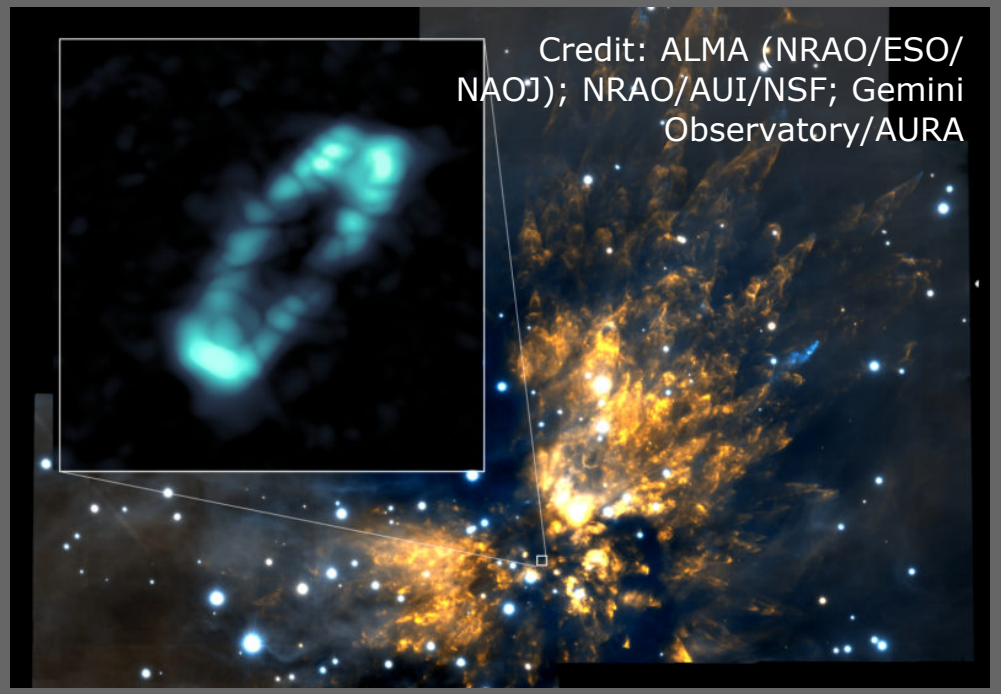


Where are molecules found?

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

H_2O	water
CO	carbon monoxide
NaCl	salt
N_2O	laughing gas
NH_3	ammonia
CH_3CH_2OH	
$(CH_3)_2CO$	

- All of those molecules have also been detected in space!



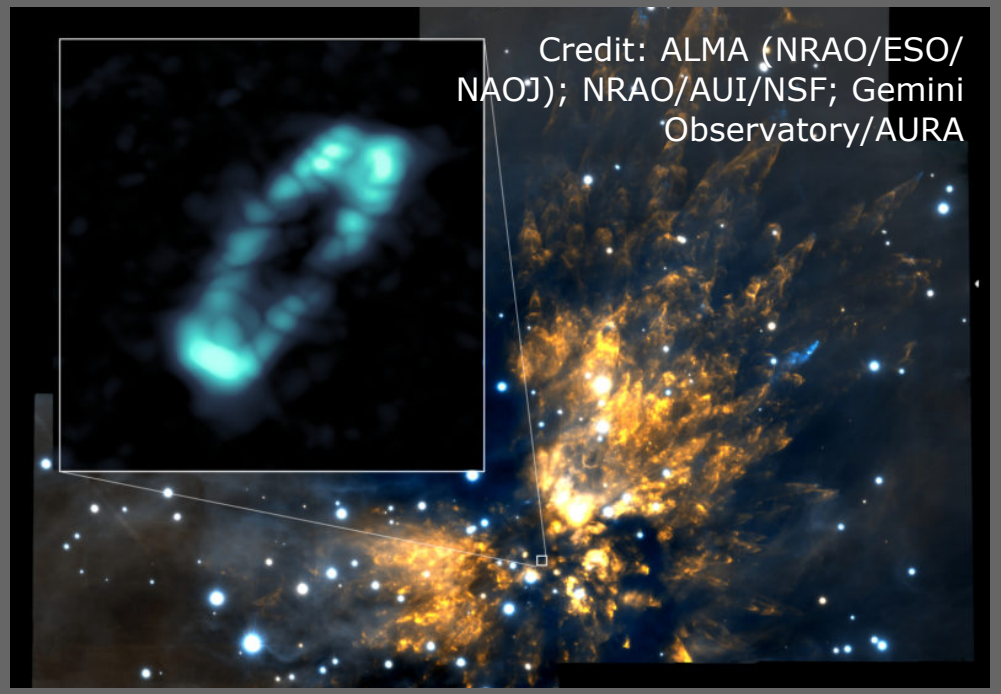
UF UNIVERSITY of FLORIDA
FLORIDA MUSEUM
Scientist in Every Florida School
Thompson Earth Systems Institute

Where are molecules found?

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

H_2O	water
CO	carbon monoxide
NaCl	salt
N_2O	laughing gas
NH_3	ammonia
CH_3CH_2OH	grain alcohol
$(CH_3)_2CO$	

- All of those molecules have also been detected in space!



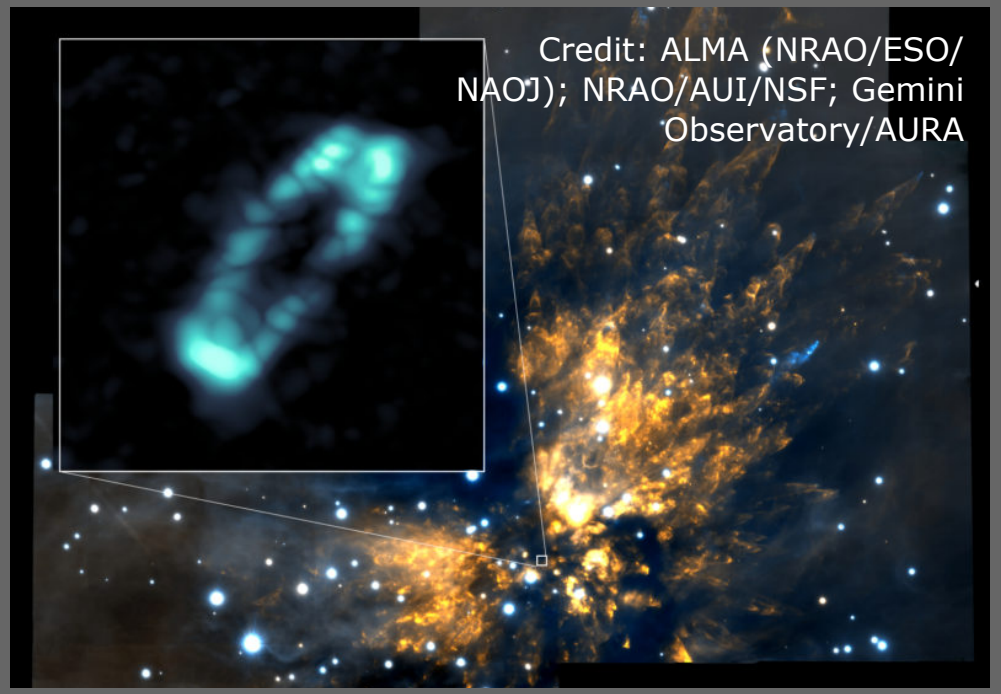
UF UNIVERSITY of FLORIDA
FLORIDA MUSEUM
Scientist in Every Florida School
Thompson Earth Systems Institute

Where are molecules found?

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

H_2O	water
CO	carbon monoxide
NaCl	salt
N_2O	laughing gas
NH_3	ammonia
CH_3CH_2OH	grain alcohol
$(CH_3)_2CO$	acetone

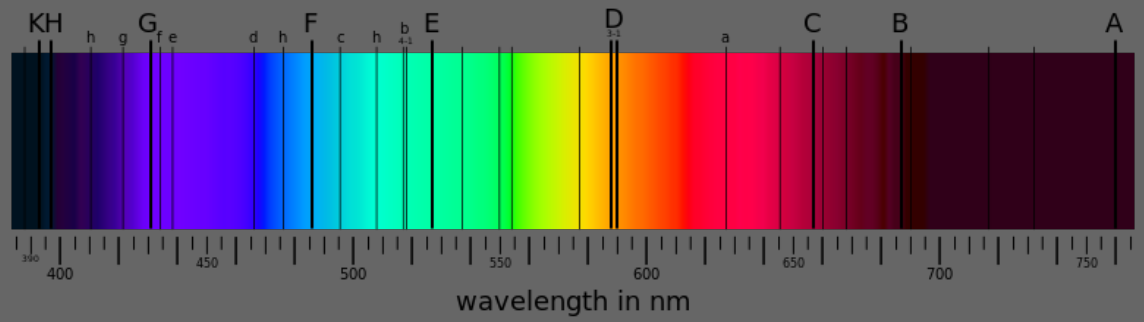
- All of those molecules have also been detected in space!

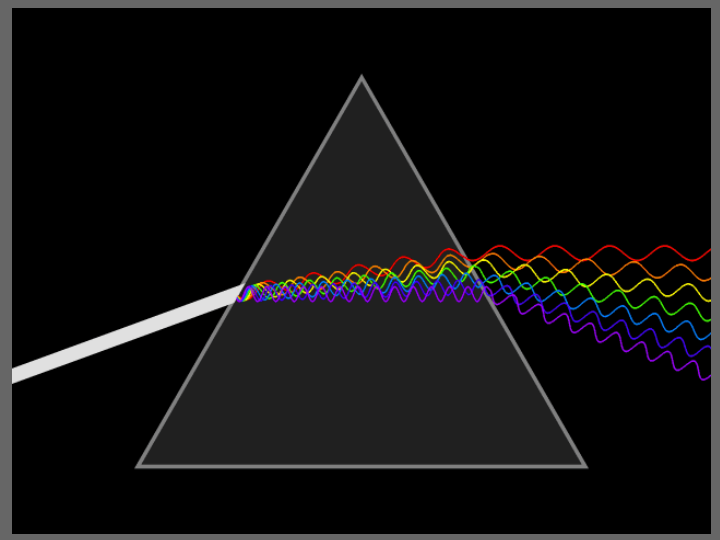


UF UNIVERSITY of FLORIDA
FLORIDA MUSEUM
Scientist in Every Florida School
Thompson Earth Systems Institute

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

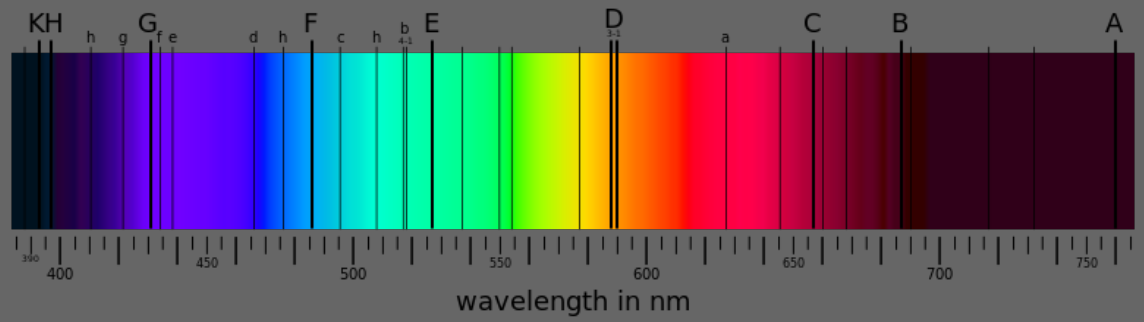


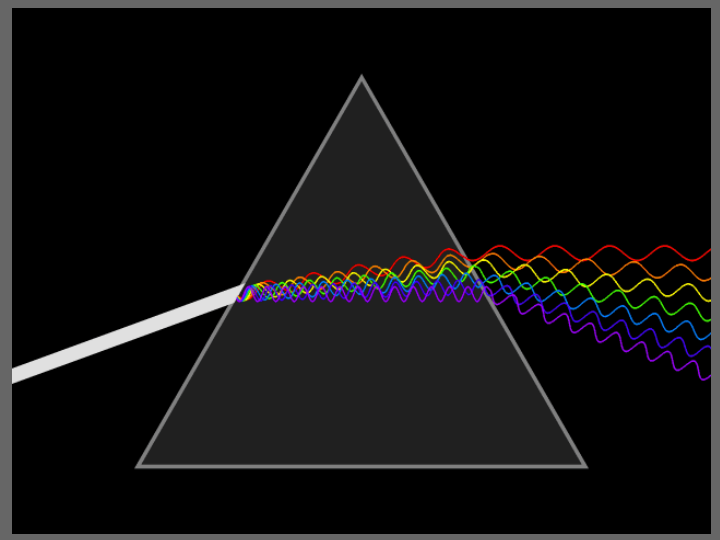


UF UNIVERSITY of FLORIDA
FLORIDA MUSEUM
Scientist in Every Florida School
Thompson Earth Systems Institute

How do we detect atoms/molecules in space?

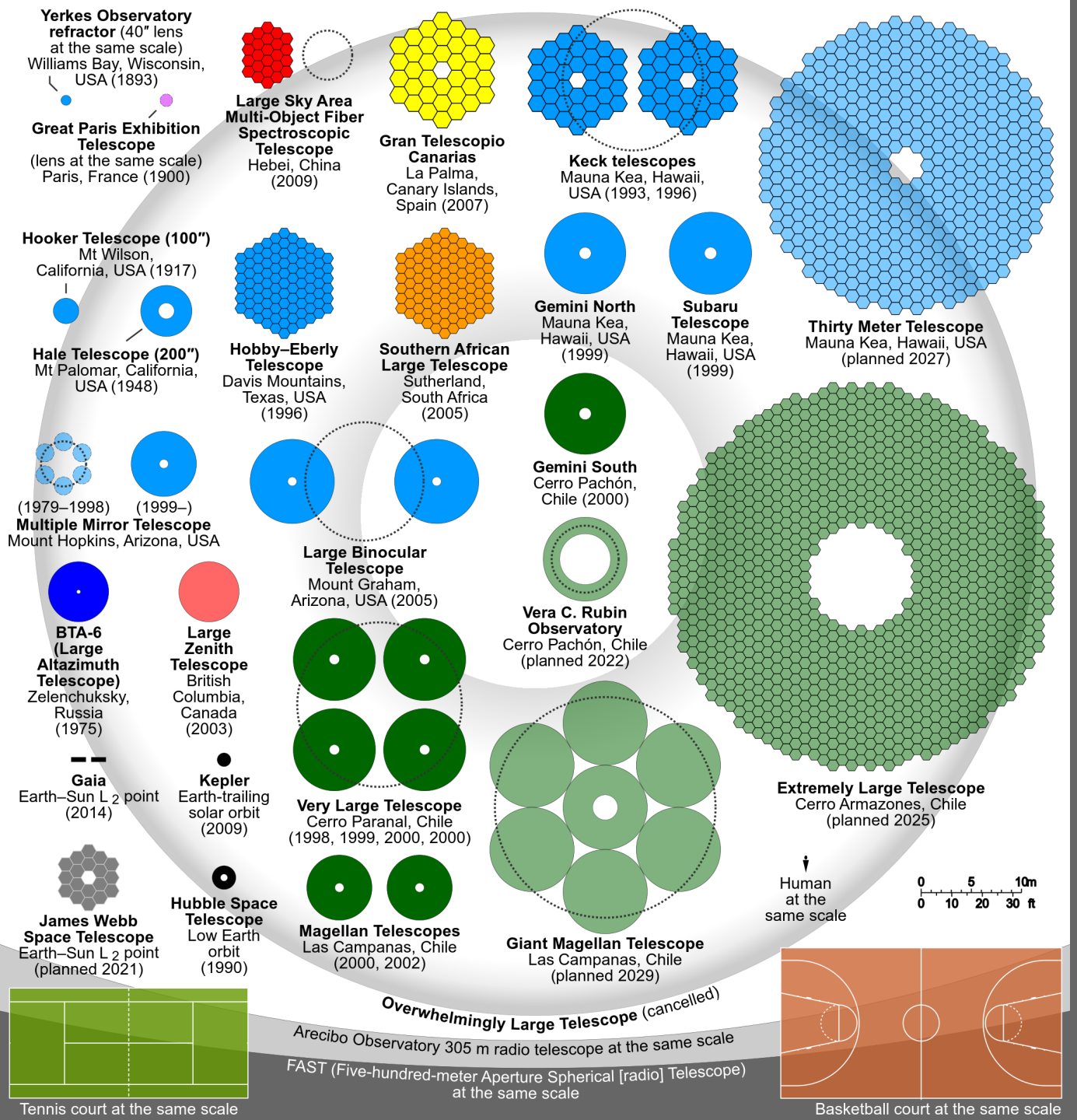
- Light is an astronomer's go-to tool
- Like molten metal, atoms and molecules in space emit light when they are hot (called a **spectrum**)
- The light emitted by a certain compound is unique to that compound





UF UNIVERSITY of FLORIDA
FLORIDA MUSEUM
Scientist in Every Florida School
Thompson Earth Systems Institute

Telescopes (the best part of my job)



Source: Wikipedia (Pachango)

Source: Wikipedia (Iztok Bončina/ESO)

Source: Wikipedia (Cmglee)

UF UNIVERSITY of FLORIDA

FLORIDA MUSEUM

Scientist in Every Florida School

Thompson Earth Systems Institute

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

UF UNIVERSITY of FLORIDA
FLORIDA MUSEUM
Scientist in Every Florida School
Thompson Earth Systems Institute

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!)*

UF UNIVERSITY of FLORIDA
FLORIDA MUSEUM
Scientist in Every Florida School
Thompson Earth Systems Institute

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

FLORIDA MUSEUM

UF UNIVERSITY of FLORIDA

Thank you!

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

Learn more:
bit.ly/SEFSsite

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.

UF UNIVERSITY of FLORIDA
FLORIDA MUSEUM
Scientist in Every Florida School
Thompson Earth Systems Institute