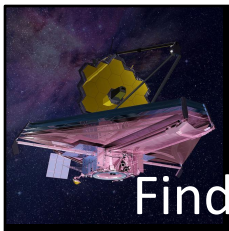
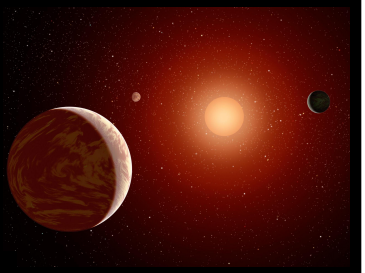


Finding the Ingredients of Other Worlds

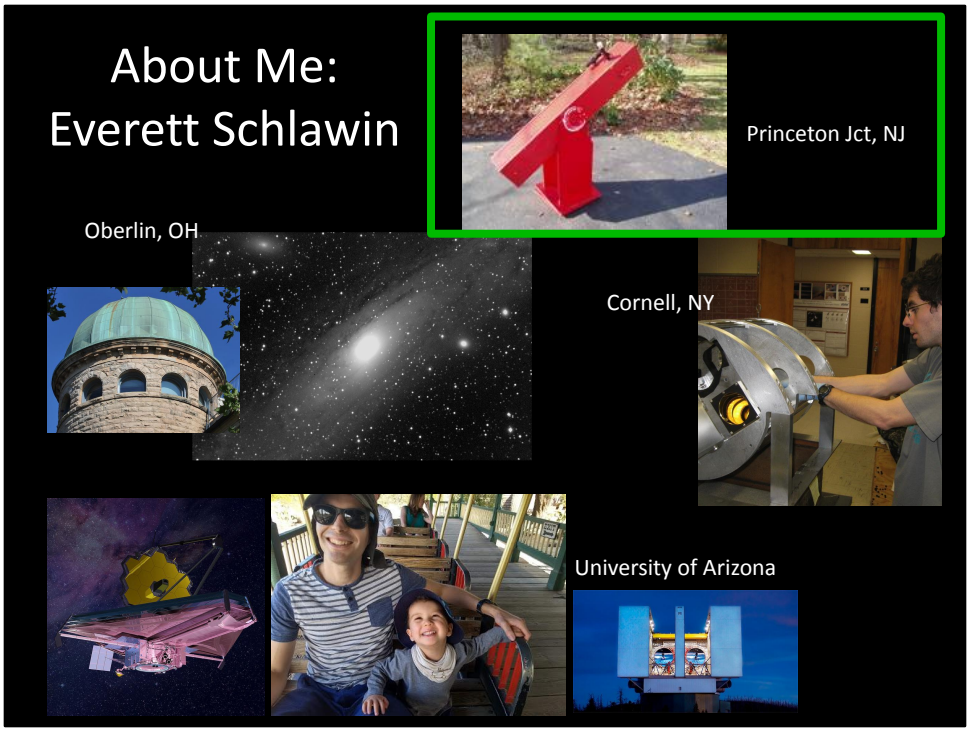
How Spectra Tell Us what Extrasolar Planets are Made Of

Everett Schlawin
NOIRLab 10/3/20



With Help from the NIRCam team: (PI) Marcia Rieke et al.,
Some slides borrowed from John Mather, Christina Williams, George Rieke, Kevin Hainline

Image Credits: https://www.nasa.gov/



My story –
Princeton:
Backyard telescopes
Ground mirror and built mount
Focused on math and physics classes

Oberlin:
- Rooftop observatory in college
- Image of Andromeda
- Majored in physics, did research projects

Cornell graduate school in astronomy
Mix of projects
- Exoplanet lightcurves
- Worked on ArcoIRIS instrument now in Chile

Arizona – where my son was born
JWST
Take advantage of Az telescopes like LBT

How I got interested in Astronomy

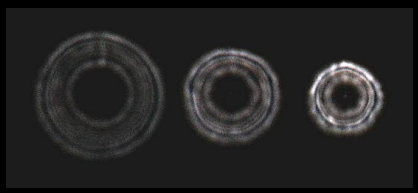


Image credit: arnholm.org

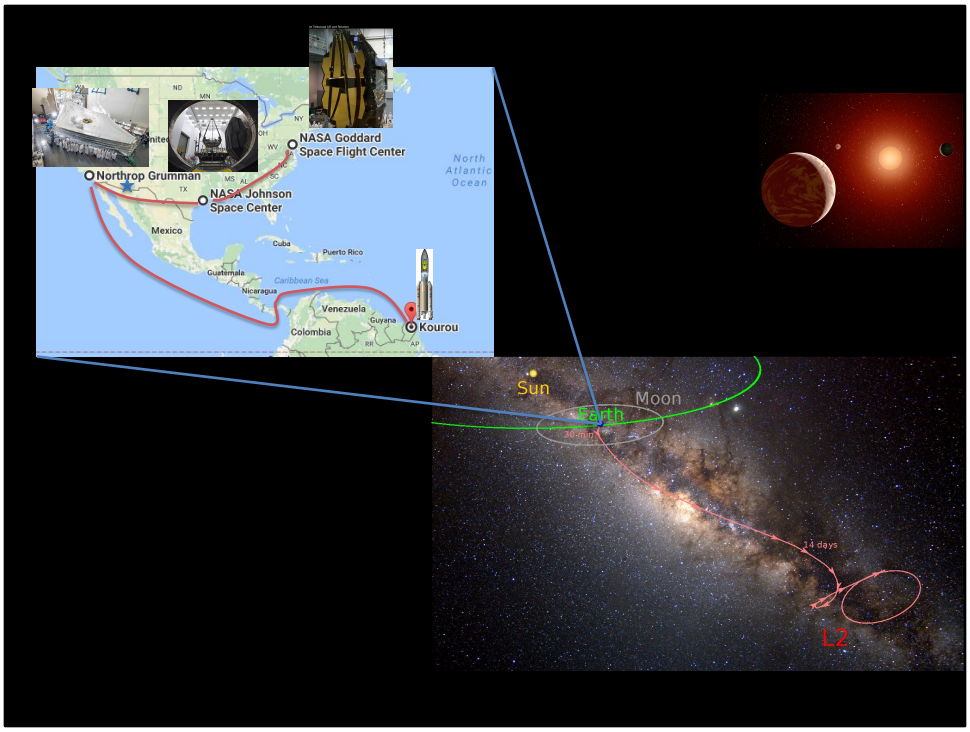
Image from Oberlin College Observatory

Borrowed telesopce
Donut shrinks w/ focus knob

And then Jupiter!
Reddish belts

Journey of the James Webb Space Telescope

That was my journey, now Webb's journey
MAKE IT BRIEF
Maryland, Texas, California
Launch 2021 (currently ~October) – many of you will be in college when data is available
Travel to a special point – Lagrangian
1 year orbit w/ combined pull of Earth & Sun



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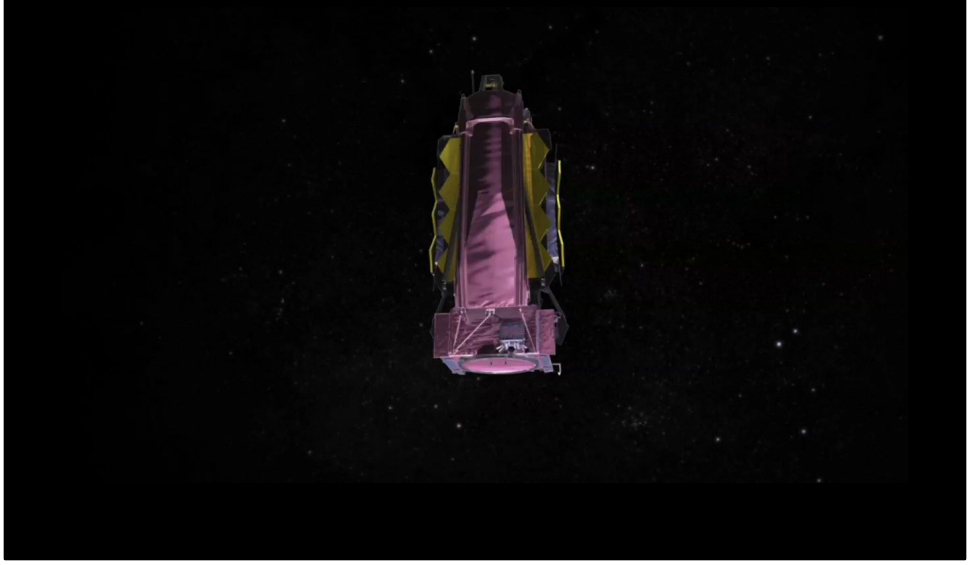
The James Webb Space Telescope Deployment



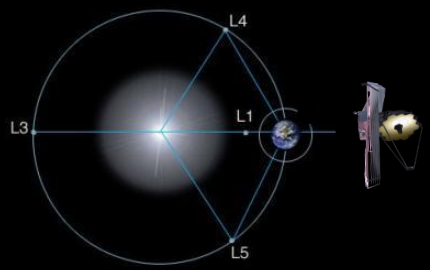
How Webb will deploy

- Antenna & Solar Panels
- Covers to Sunshield
- Sunshield: telescope to -390 F, sun-facing side is 190 F, “ice and fire”
- Tensioning
- Mirror deploy

Full info
Here’s how Webb will open up
Antenna - communication
Solar panels – power
Sunshield palettes
Tower for telescope + instruments
(not shown) Aft flap
Membrane launch restraints & covers
Booms extend
Tension membranes
Sunshield allows telescope to cool to about -390 F while sun-facing side is 190 F, “ice and fire”
Cool – so infrared radiation doesn’t ”overwhelm” cosmos
Secondary mirror deploy
(not shown) aft radiator

Primary mirror deploy

L2 Orbit – Stable and Uninterrupted



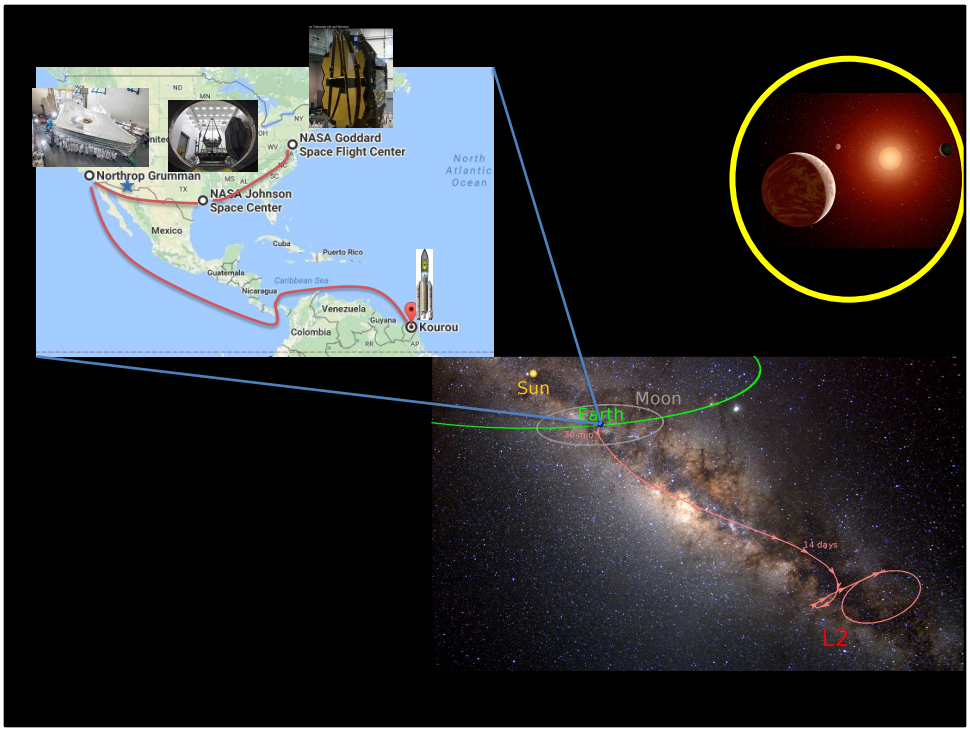
(Image not to scale)

From: John Mather, JWST Science & Progress 2012

-No interruptions due to Earth
-About a million miles away!
-Greater T stability not Sun/shadow

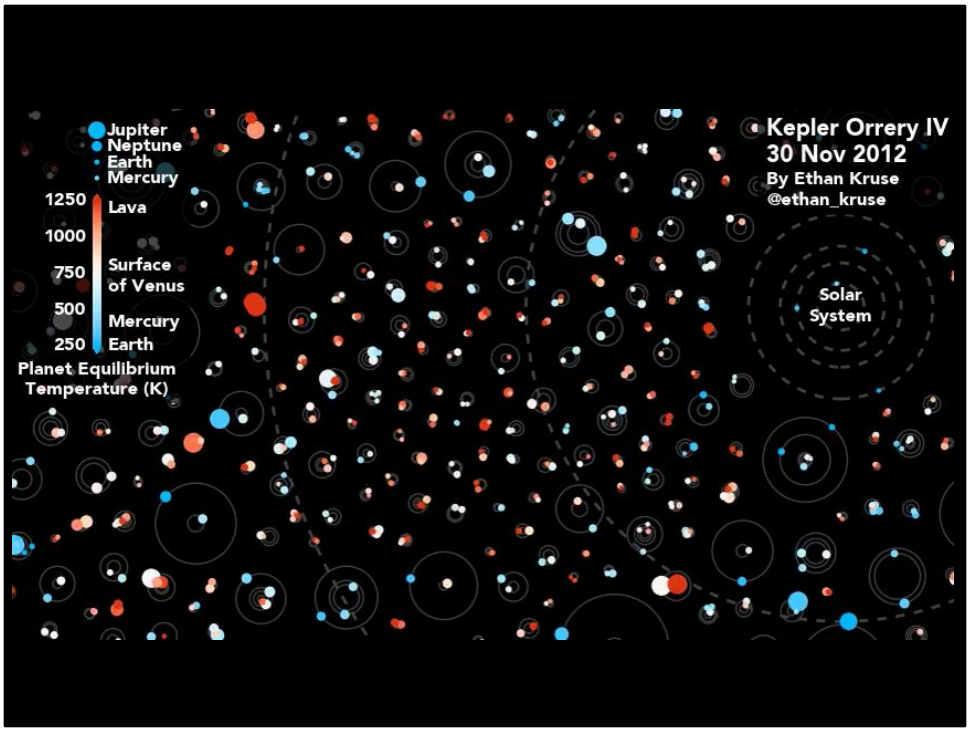
Infrared Light Senses Heat

From: spitzer.caltech.edu

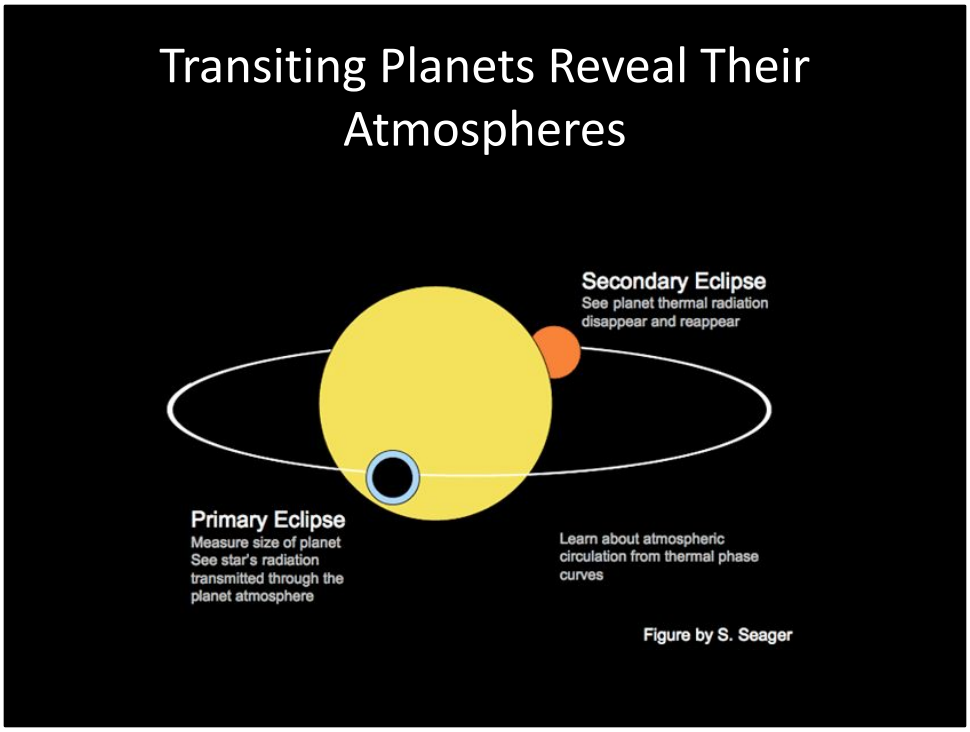


From Lagrangian point
Study *known* planets in detail
Finding planets - done by other telescopes

Most planets discovered by this telescope
Stared at a patch of sky
Near Cygnus



Boy, did it find planets – thousands!
If you were to bring them to SS, and overlay, this is how they would compare
Not what you see in the sky – visual of planets
None is the same as the solar system!



Today, special alignment of planets – transiting
Orbit aligned – planet goes in front of and behind star
There's just one planet here in 2 different positions
Primary Eclipse – learn about atmosphere from spectrum

Spectra Are Made by Splitting Light into its Component Colors

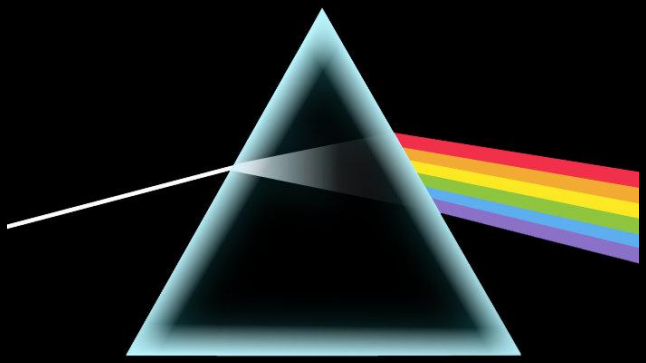
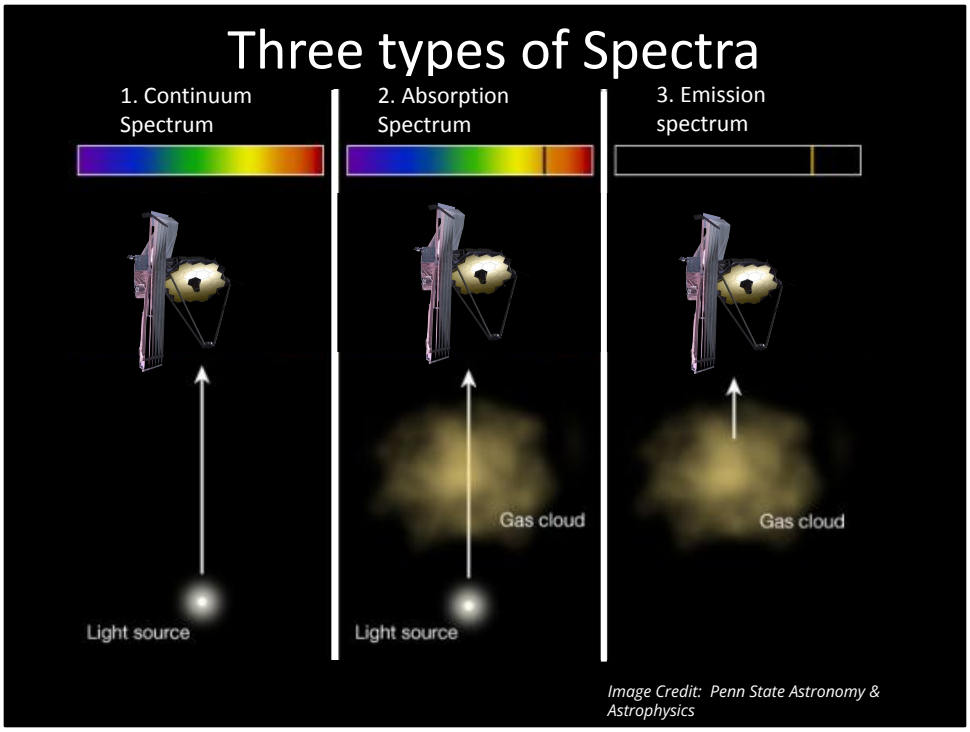
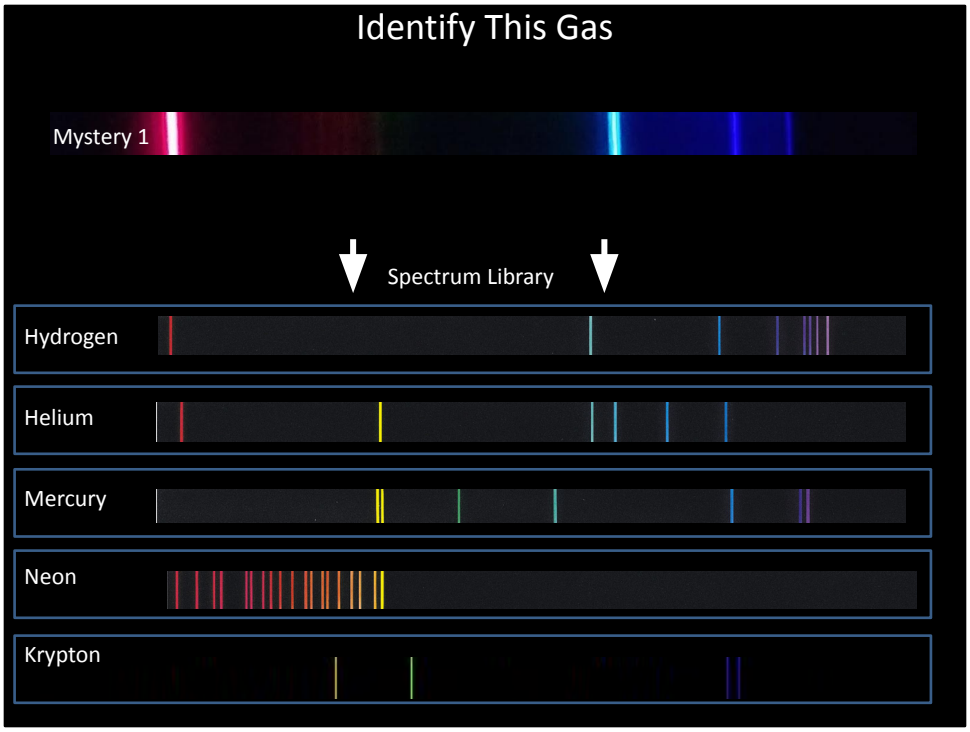


Image Credit: Pink Floyd's The Dark Side of the Moon Album Cover, npr.org

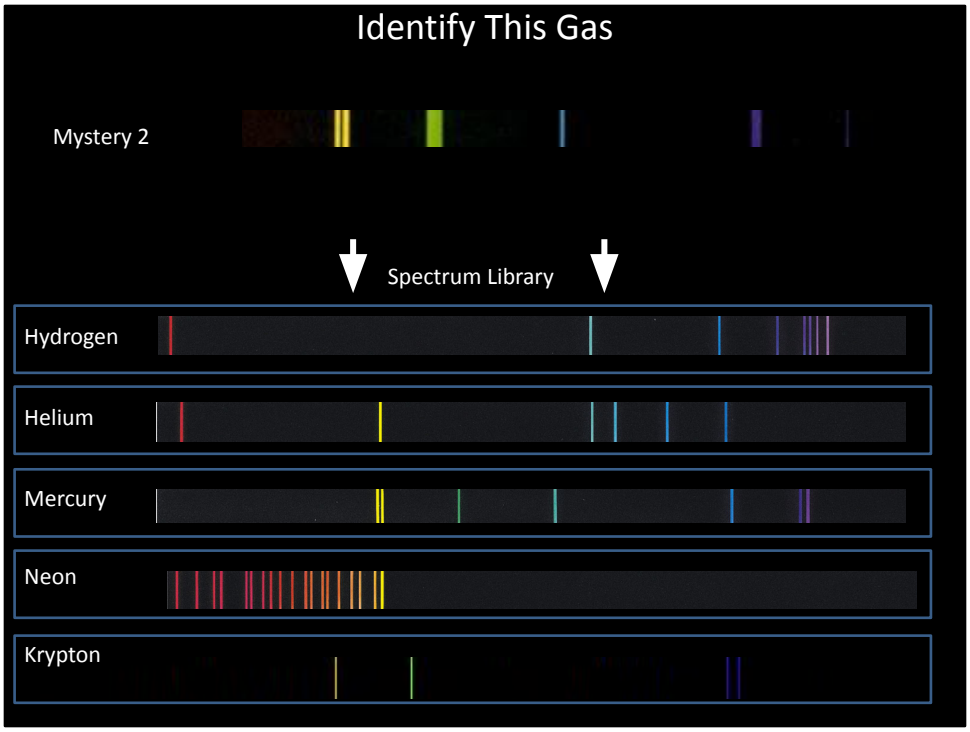
Spectra split light into rainbow of colors
Study each color
Wavelength – Color of Light



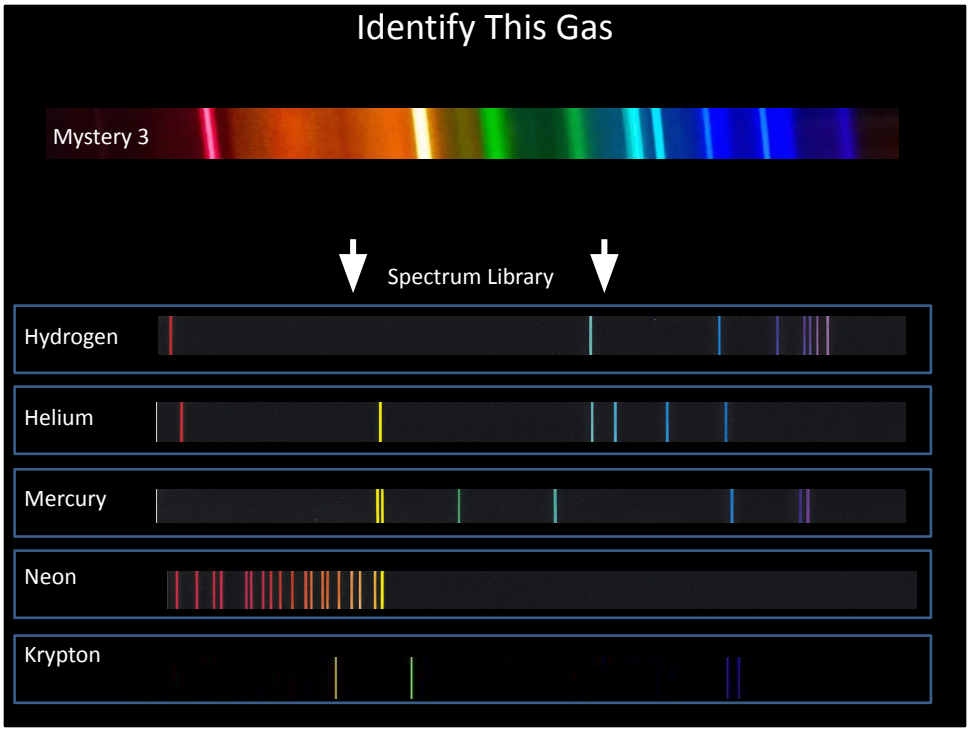
Today we'll talk about 3 types of spectra
1: Continuum light source
2: Gas is in the way and absorbs light – absorption spectrum
3: Gas is brighter than background – emission spectrum



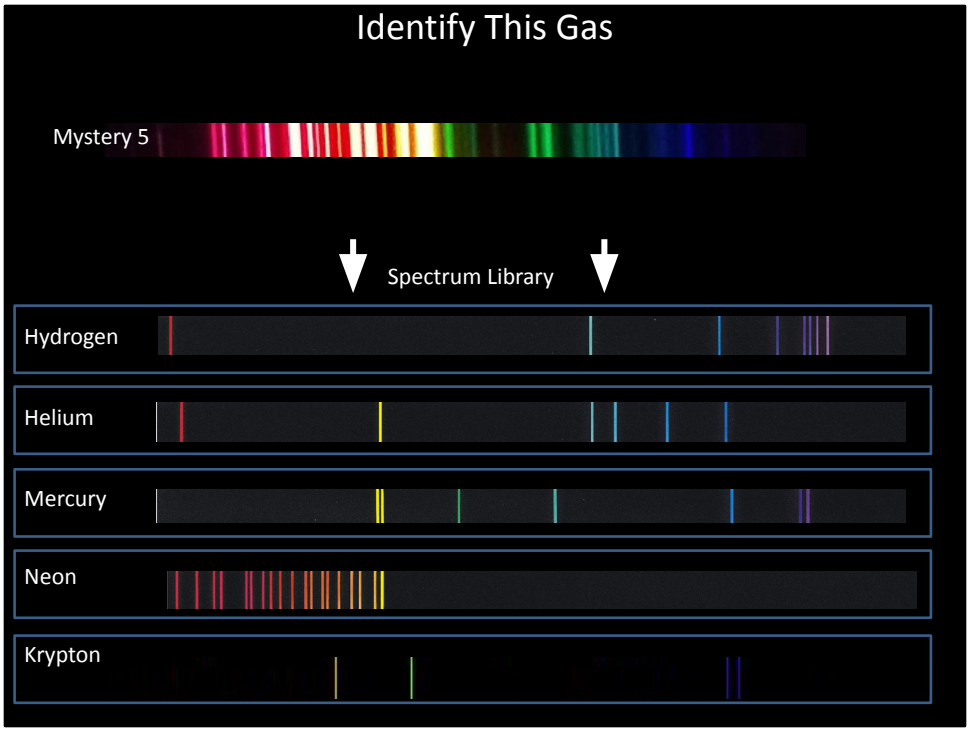
Only using light
Each gas has its own fingerprint
H



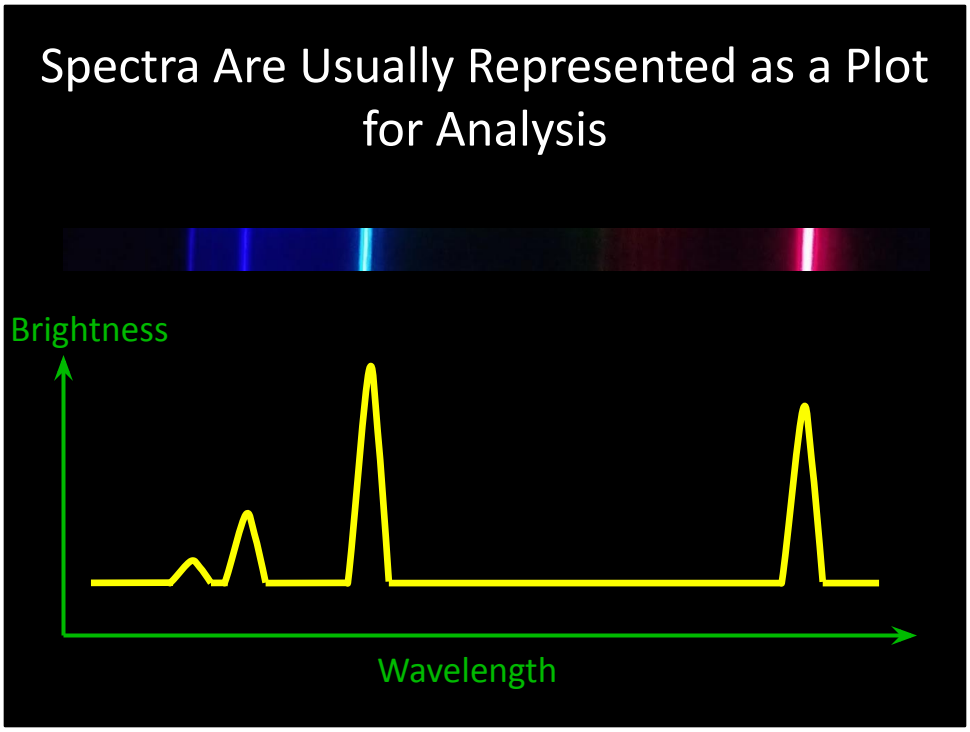
Only using light
Each gas has its own fingerprint
Hg



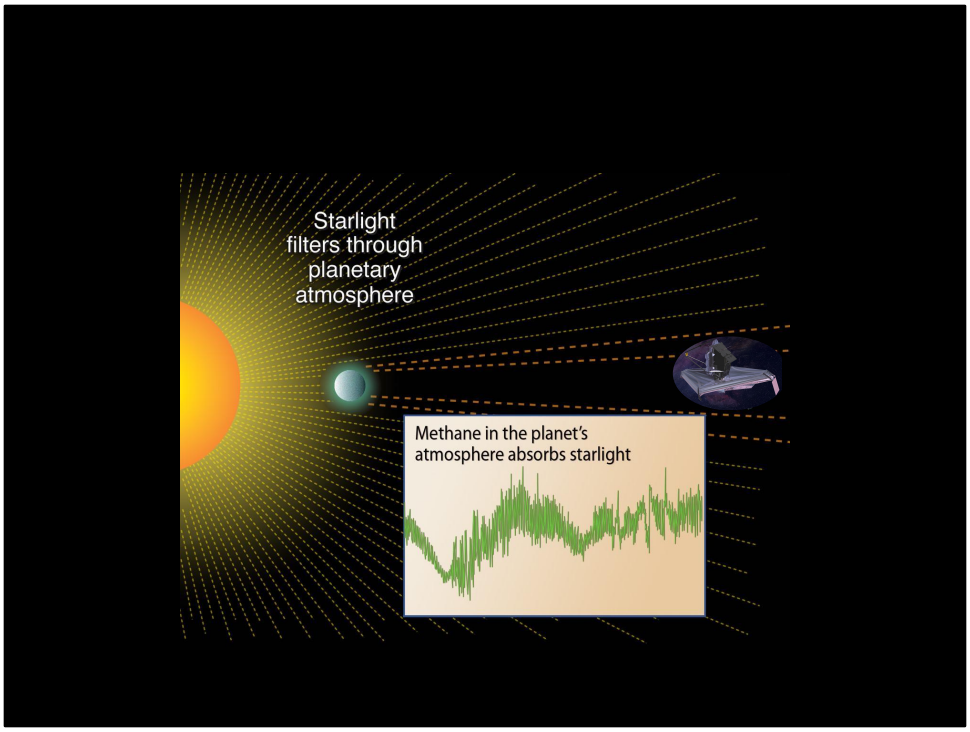
Only using light
Each gas has its own fingerprint
He



Only using light
Each gas has its own fingerprint
Ne

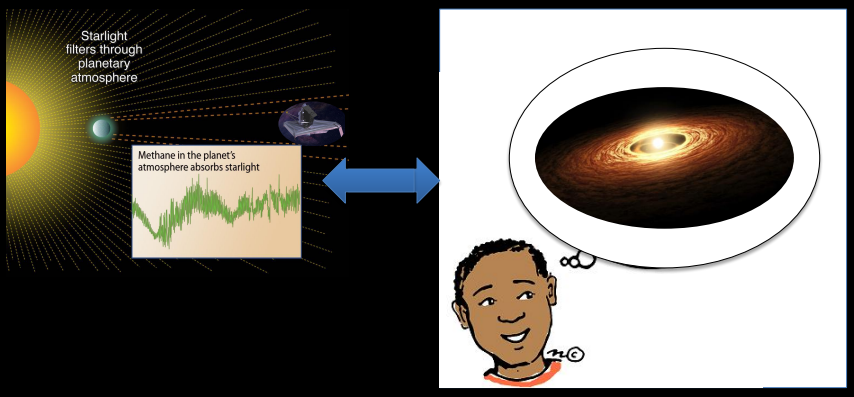


Astronomers basically use advanced glasses
Plot the brightness versus wavelength for analysis
Each element and molecule – unique spectral fingerprint



Primary Eclipse/Transit
Measure the abs by planet atm
Identify Gases w/ telescope

We can learn about how planets form by studying their spectra

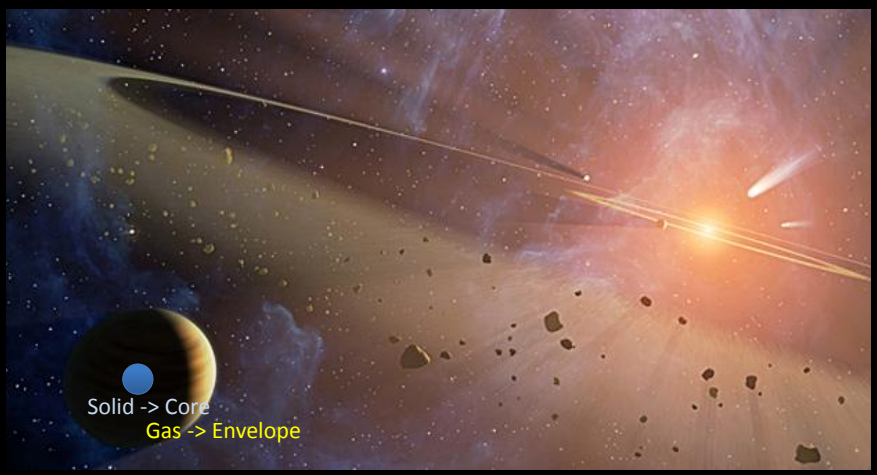


https://astrobites.org/2014/10/13/planet-formation-on-a-budget/
http://www.spacetelescope.org/images/heic1410a/
http://clipartix.com/thought-bubble-clipart-image-31740/

21

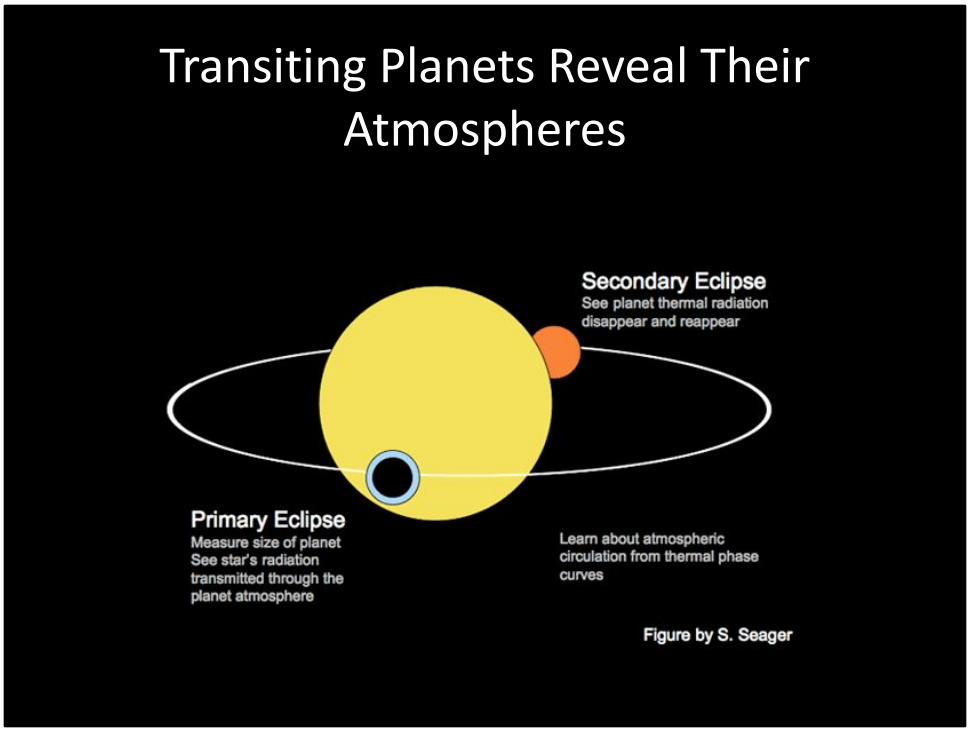
Spectra - what atmosphere is made of
Also clues to how planets are made
Hard to go directly from atmosphere to formation
Instead, compare formation model in disk to atmosphere

Planet Spectra Can Tell Us How/Where They Form



22

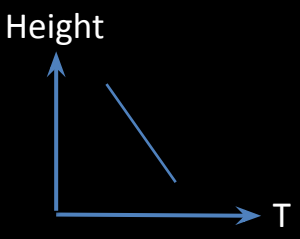
Our basic picture – planets start from solids
Stick together
If gravity, pull gas from surroundings
Build an envelope
Predictions - solids smash into envelope
Polluted with planet building blocks

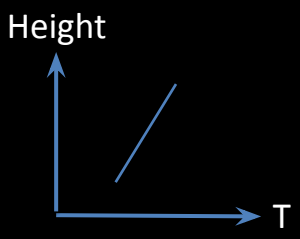


Now Secondary eclipse
As planet moves behind star

Secondary eclipses tell you about temperature

- T decreases with height
- Temperature Inversion





24

Temperature - does it get hotter or colder as you go up?

Where would aliens spend the summers?

- T decreases with height
- Temperature Inversion

Energy input on bottom
Less stable

25

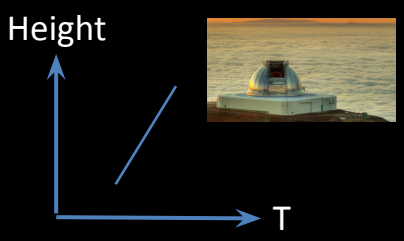
Here, it gets colder as you go up
Escape from summer heat on Mt Lemmon

NSF | NOIRLab
Speaker Notes for Exoplanets

Where would aliens spend the summers?

- T decreases with height
- Temperature Inversion

Energy input on bottom
Less stable

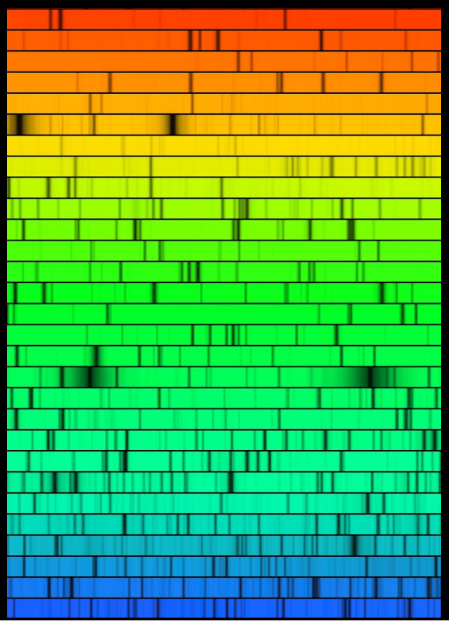


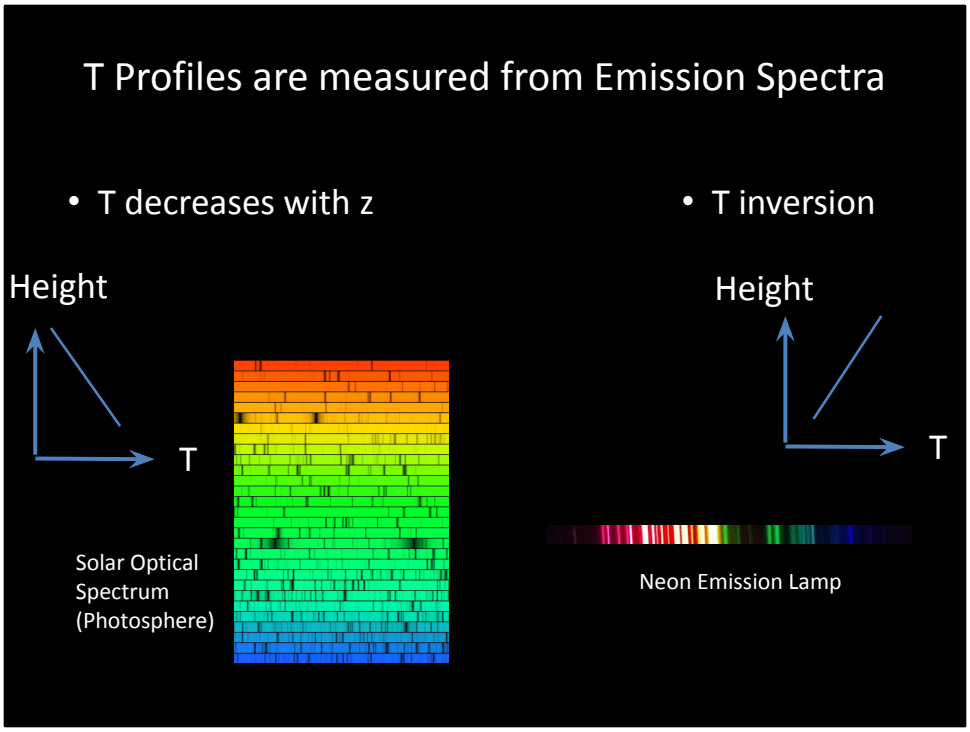
Energy input on top
More stable

26

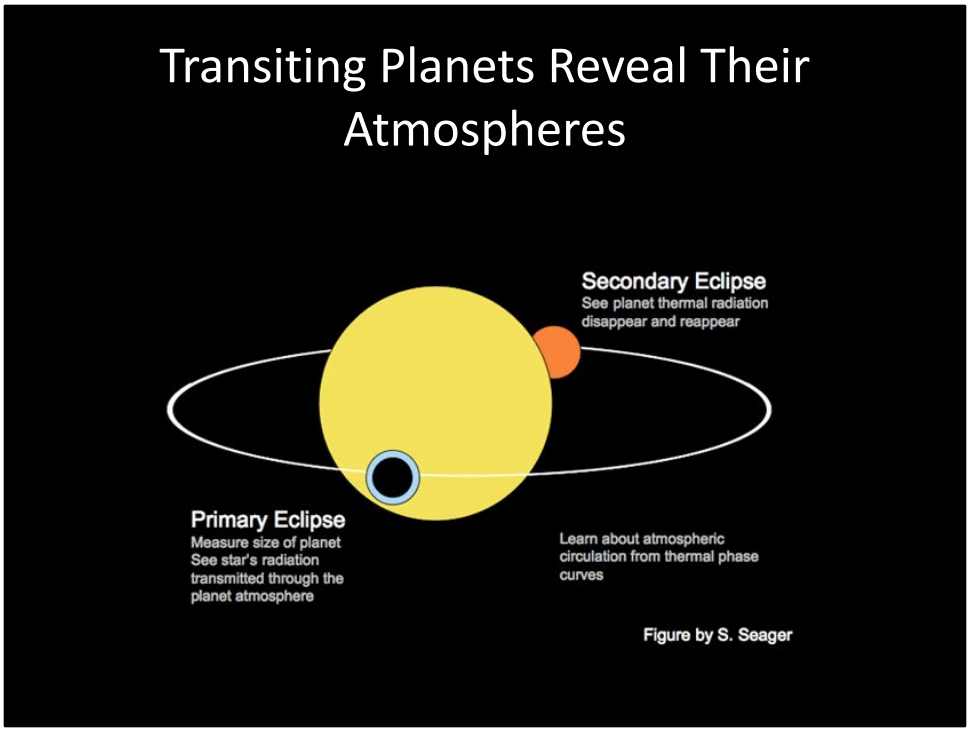
Temperature inversion – hotter as you go up

The Solar Spectrum



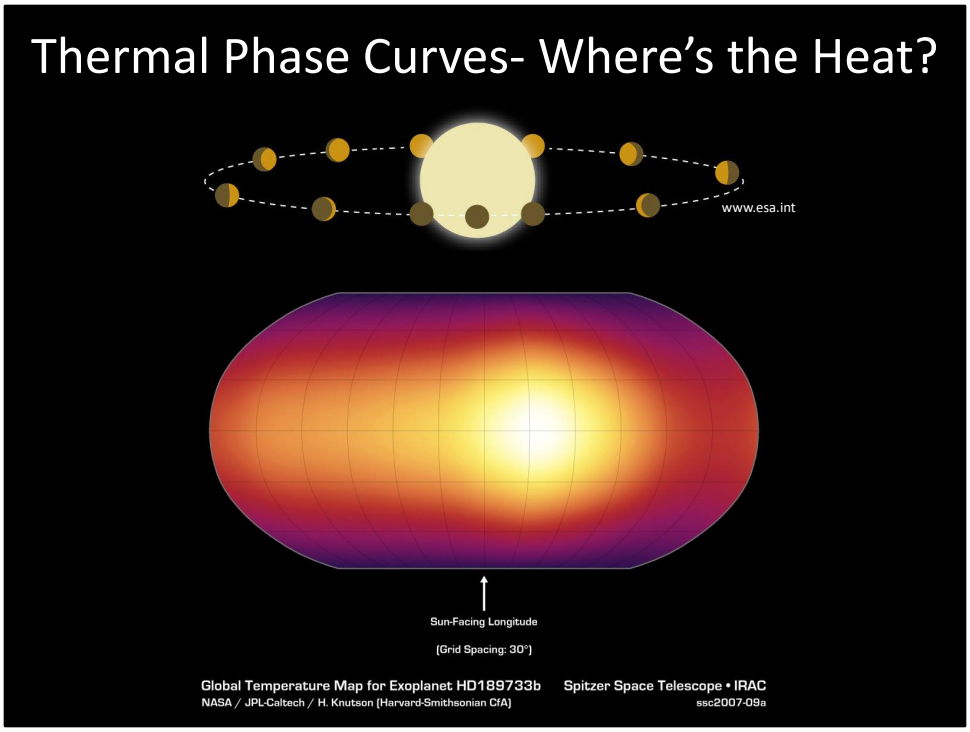


You can use spectra to figure out this question
Absorption spectrum – like Solar Spectrum
Or, inversion like lamp – hot gas brighter than background
Why useful – tell us about circulation vertically
- Teach us about where the energy is going

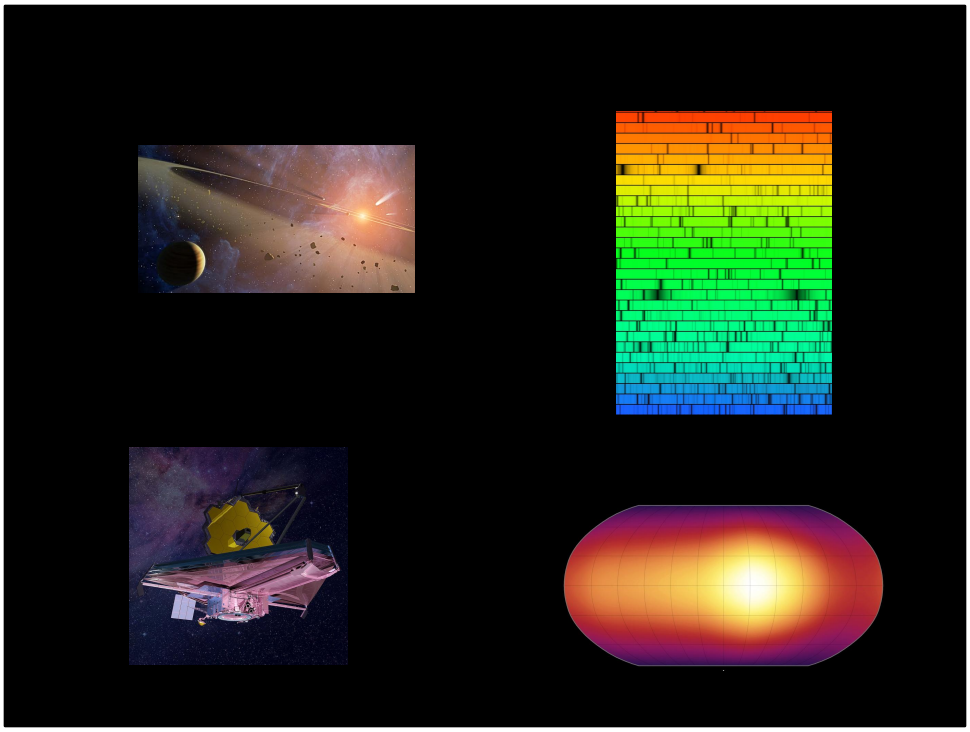


Another way to learn about planets – follow entire orbit

Thermal Phase Curves- Where's the Heat?



Measure light as the planet rotates around star
Predicted here that winds would carry heat to the East
And that's what's measured



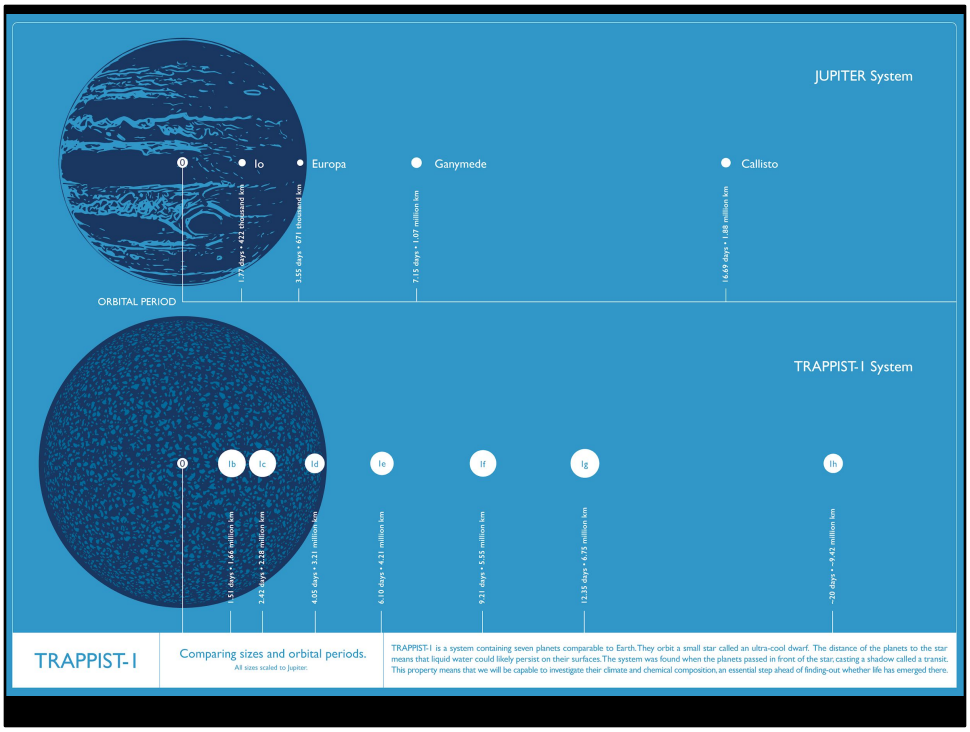
Spectra of and light from transiting planets
 * heat distribution
 * maps
 * what the atmospheres are made of
What about big human question?

Are we alone?
Captured our imaginations including in Hollywood

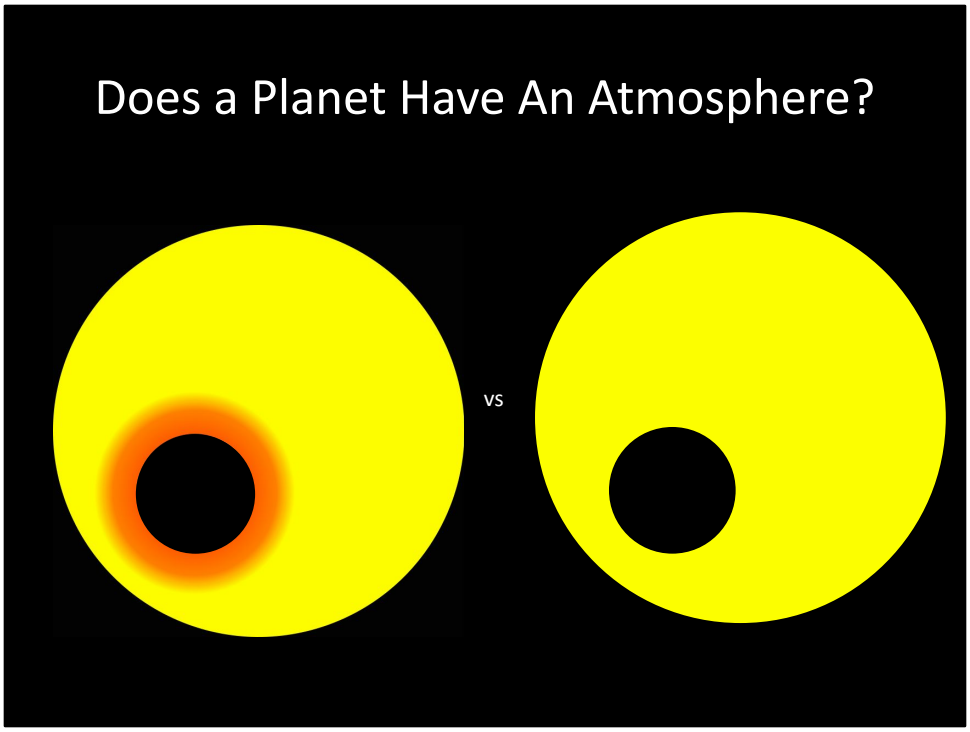
Best system to search so far is TRAPPIST-1
Artists view of what it might be like
These posters are available online

You can download these posters!
https://exoplanets.nasa.gov/alien-worlds/exoplanet-travel-bureau/

You can write down the website or hold phone up to QR code & zoom in on it



TRAPPIST-1 – small star, barely bigger than Jupiter
This shows the relative sizes
Distances are NOT to scale
Analogy of camp fire on a cold night – too hot, too cold, just right

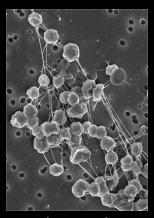


First question – does the planet have an atmosphere
Measure the light thorough the atmosphere
Absorption of some colors – atmosphere
Same at all colors – no atmosphere – just black silhouette

We can look for life like the Earth's

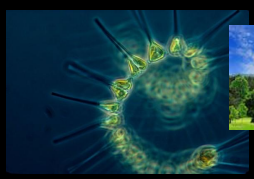
(in the future)

Methanogens -> Methane



https://microbewiki.kenyon.edu/index.php/

Photosynthesis -> Oxygen



https://www.arborday.org

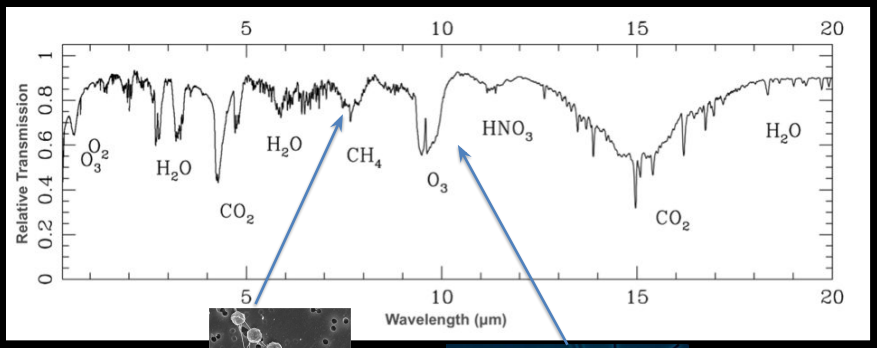
http://earthsky.org/

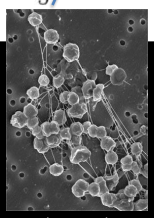
Someday – look for evidence of life
On Earth - wouldn't have CH4 & O2 without life
Methanogens and photosynthesis produce these
They would react and go away

Phytoplanton – oxygen
Methanogens – CH4

We can look for life like the Earth's

(in the future)





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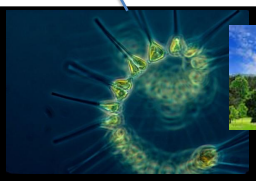
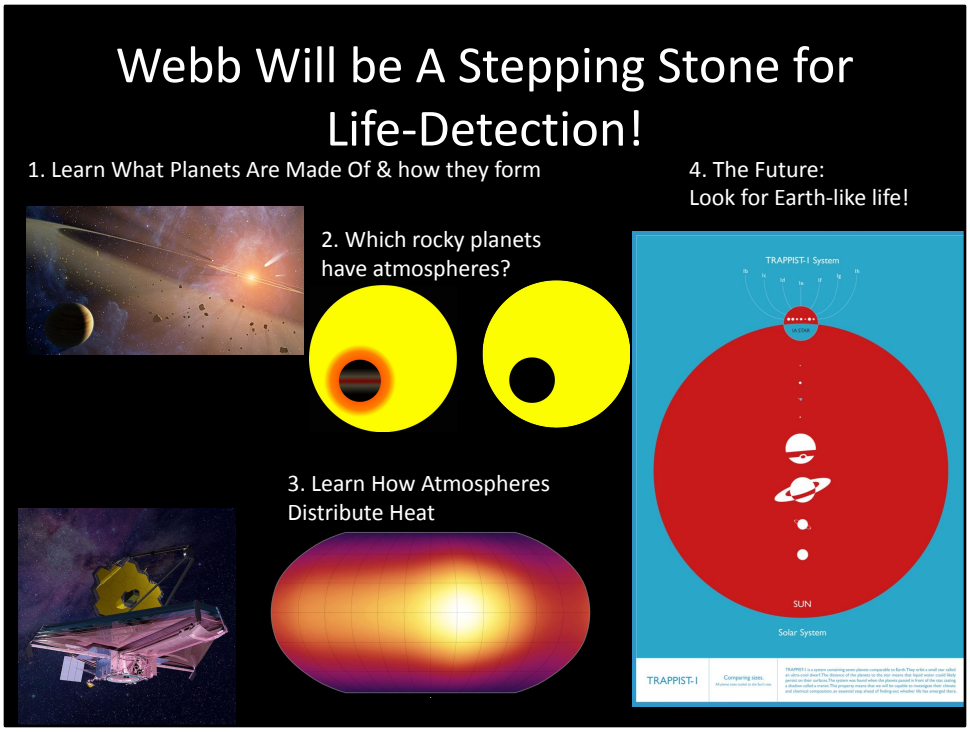


http://earthsky.org/

https://www.arborday.org

Look for life with a spectrum
Absorption from methane
Absorption from Oxygen that gets turned to Ozone or O3
Future telescope - may begin to tell us if we are alone
Also mention VENUS!!

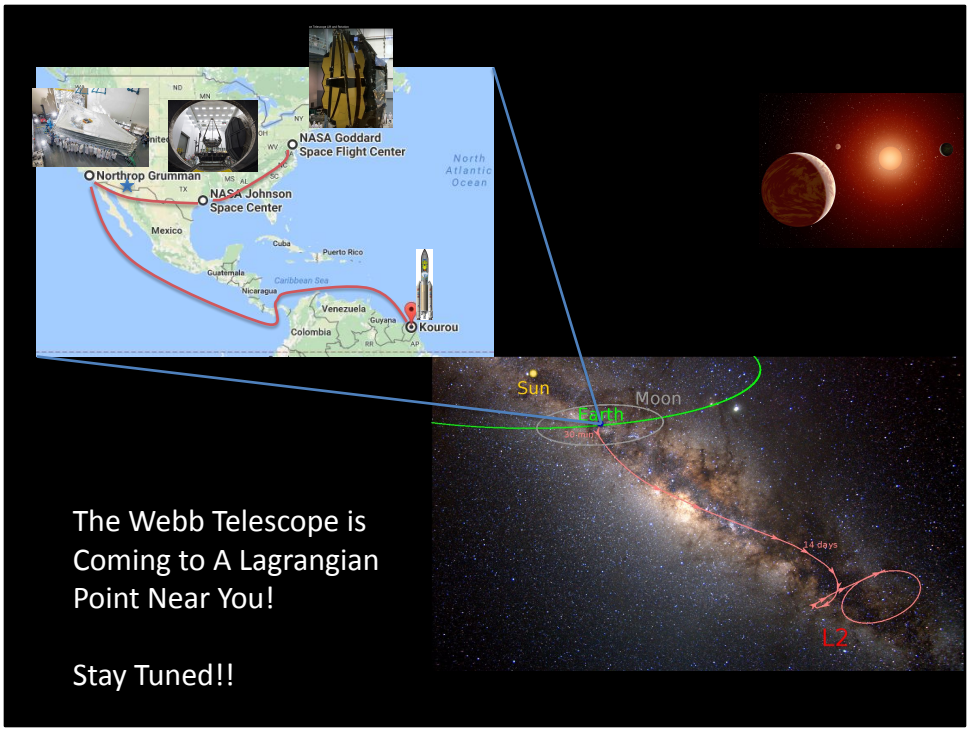
Phytoplanton – oxygen
Methanogens – CH4



Today, learned that spectra of planets gets us

- Composition – what atmosphere is made of & how they form
- Make maps and learn where heat goes
- Learn more about how life forms

- Webb telescope will make these measurements
- Someday, look for Earth-like life



Thank you for joining me on this journey
Webb Telescope
How it will teach us about the other planets in our Universe
Webb is coming to a Lagrangian point near you – stay tuned!