The Universe in the Infrared: Spitzer's Final Voyage

Dr. Luisa M. Rebull
NASA's Infrared Science Archive (IRSA)
Caltech-IPAC
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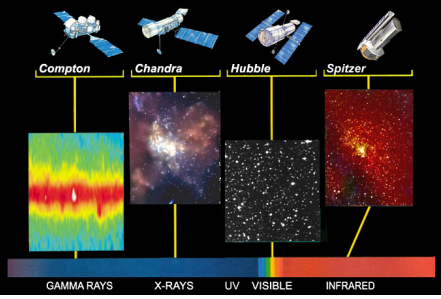
Outline

- What is infrared?
- Spitzer – spacecraft logistics, engineering
- Highlights of science results (highly incomplete)
  - Big Saturn ring
  - Galactic structure
  - Stars have disks! And the story of star formation
  - Exoplanets
- LOTS of data … and it's yours too!

NASA's Great Observatories

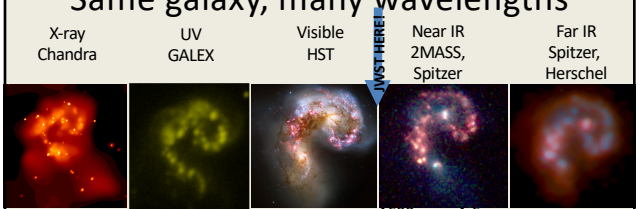


(What about the new telescope?)

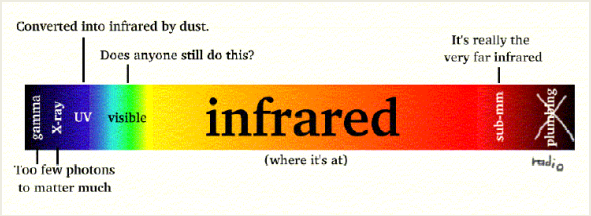
- The new telescope is the James Webb Space Telescope, JWST.
- It is not a "Great Observatory," but it is still a "flagship mission." (Funding lines…)
- It observes in optical and near/mid-IR.

Same galaxy, many wavelengths

X-ray Chandra	UV GALEX	Visible HST	Near IR 2MASS, Spitzer	Far IR Spitzer, Herschel
2 nm 1.5×10^6 K Black Hole accretion disks	200 nm 14,500 K Hot stars = young stars	500 nm=0.5 µm 5800 K Run of the mill stars (all ages)	1600 nm = 1.6 µm 1800 K Very cool stars (usually old)	100,000 nm= 100 µm 29 K Cool dust - heated by hot stars



IPAC's Electromagnetic Spectrum



Slide from G. Rieke

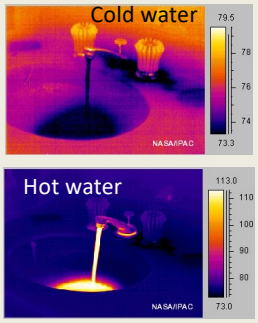
"Remapped color" image

Visible light

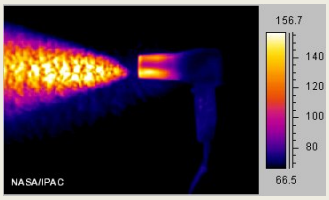
Infrared light

Temperature scale!

Hot things glow in the infrared

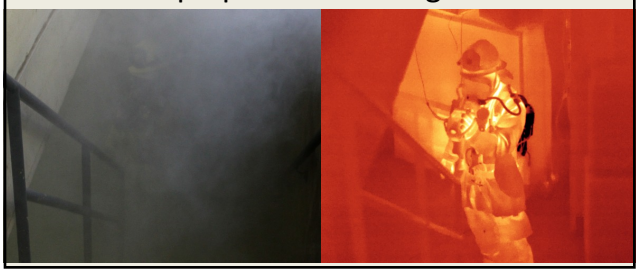


Infrared can reveal things hidden in visible light



Infrared can see through some things opaque to visible light.

Infrared can see through some things opaque to visible light.

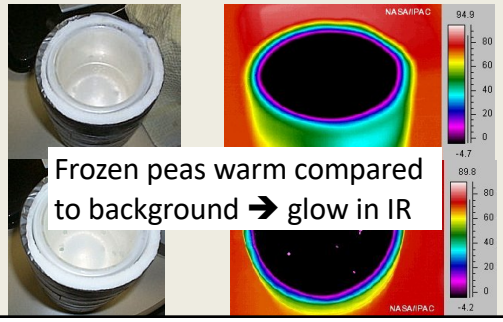


Some things transparent in visible light are opaque in infrared.

Frozen peas in liquid nitrogen

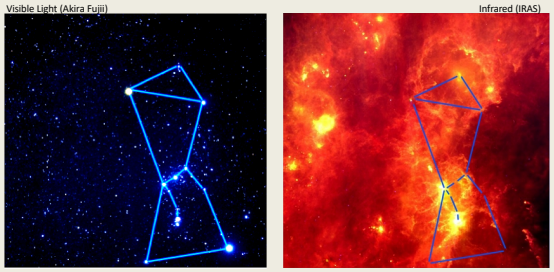
No peas yet

With peas



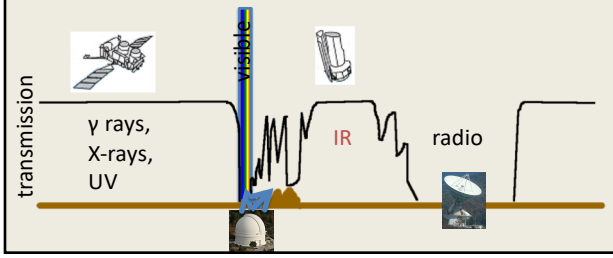
Frozen peas warm compared to background ➔ glow in IR

Lifting the Cosmic Veil



Why do we need to go to space?

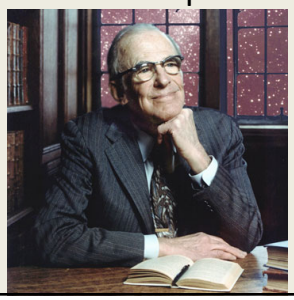
1: Space is COLD. 2: Atmosphere absorbs IR light.



Spitzer's launch

- NASA funded
- Launched, Canaveral, 25 Aug 2003
- (~18 years ago!)

Spitzer the Man



- Name was chosen from >7000 entries.
- Professor Lyman Spitzer (1914-1997)
- In *1946*, Dr. Spitzer was the first to propose putting a telescope in space, and was a primary force behind Hubble.
- Dr. Spitzer studied the interstellar medium.

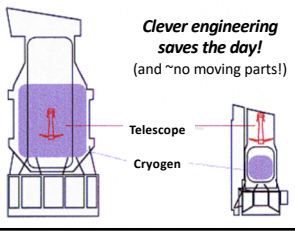
Spitzer the Spacecraft

Old Design 1990

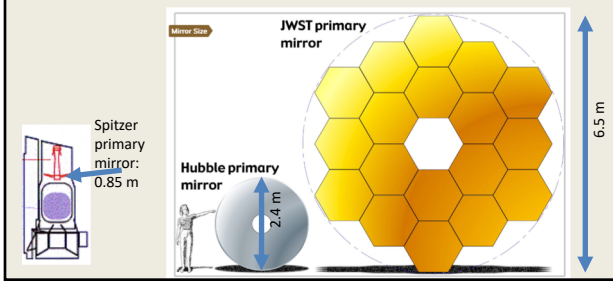
New Design 2003

Clever engineering saves the day!

(and ~no moving parts!)

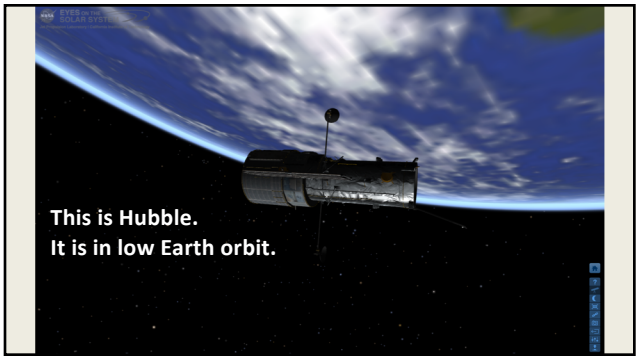


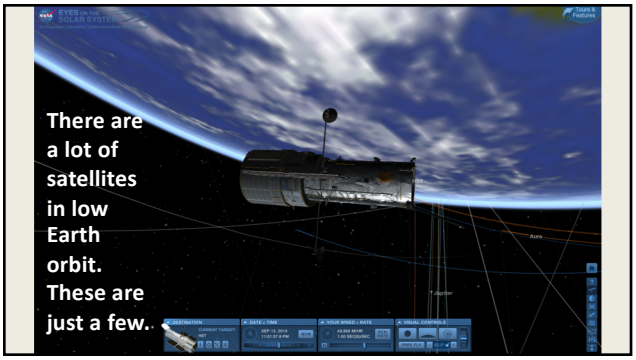
(obligatory JWST comparison)

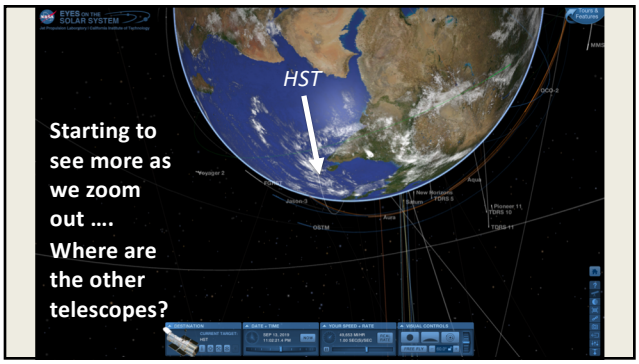


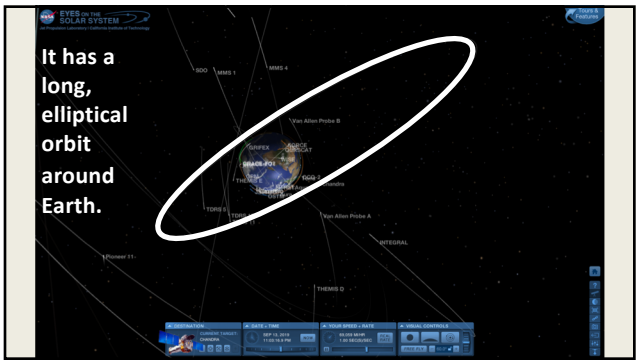
Orbits, orbits, orbits

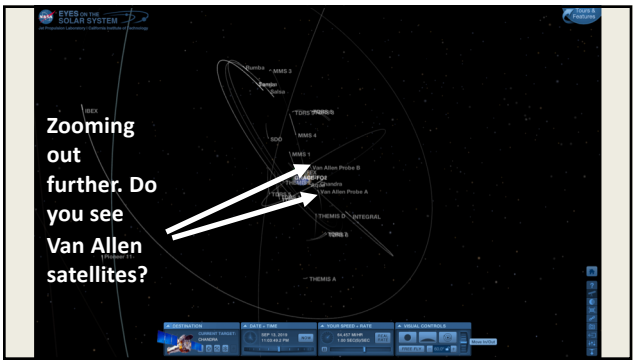
- What follows is a series of screen snapshots from something called "Eyes on the Solar System" from JPL… If you haven't played with this yet, you should!

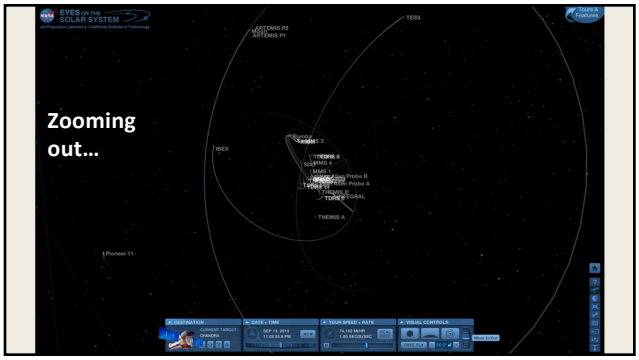


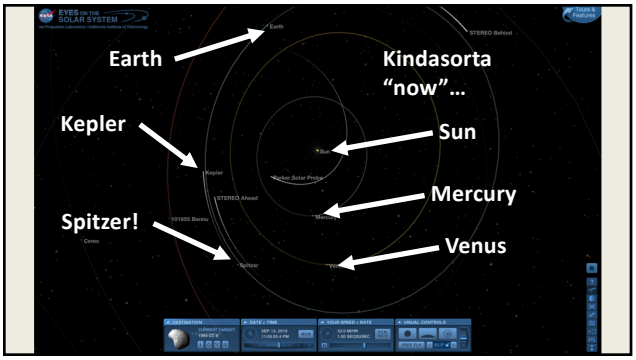


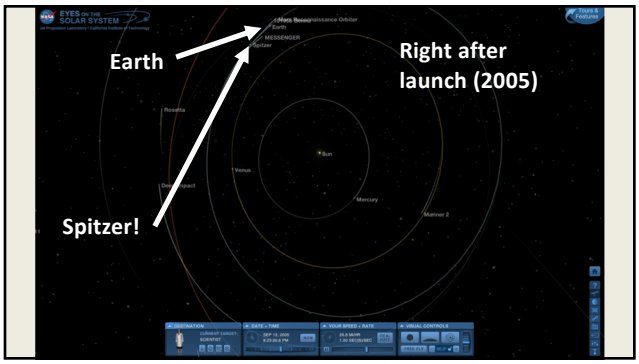


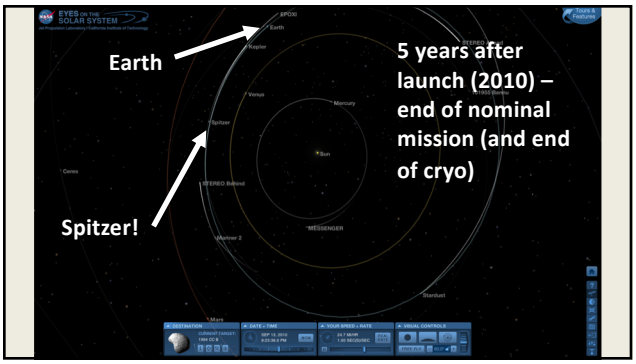

It has a long, elliptical orbit around Earth.

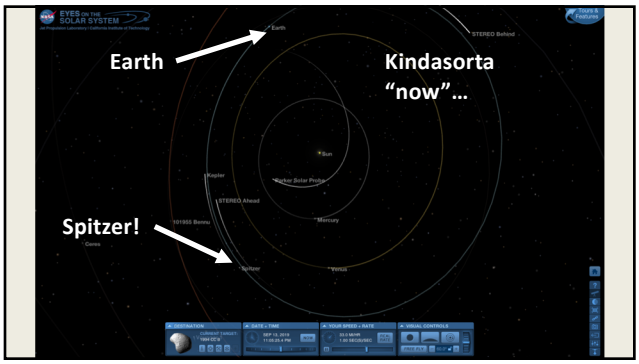

Zooming out further. Do you see Van Allen satellites?


Zooming out…


Earth
Kindasorta "now"…
Kepler
Sun
Mercury
Spitzer!
Venus


Earth
Right after launch (2005)
Spitzer!


Earth
5 years after launch (2010) – end of nominal mission (and end of cryo)
Spitzer!



Takeaway points

- HST orbits Earth, close to Earth. CXO orbits Earth, in a long elliptical orbit. Spitzer orbits the Sun (not the Earth!)
- Spitzer is trailing slowly away from us.

This orbit is good!

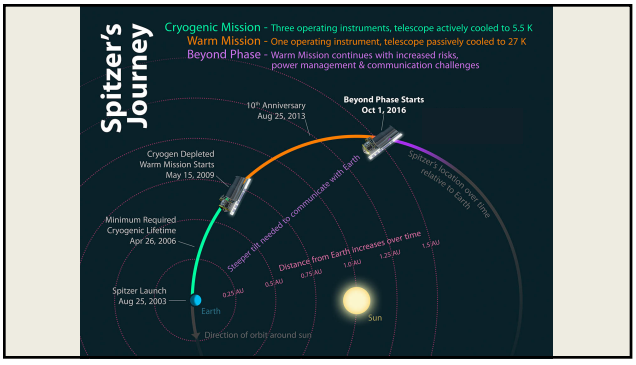
- 1-**No Need for Earth-Moon Avoidance**: Maximizes observing time
- 2-**No Earth Radiation Belts**: No damage to detectors or electronics
- 3-**Better Thermal Environment**: Allows passive cooling

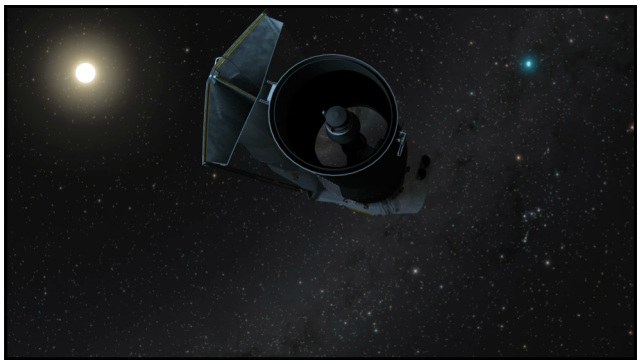
Lifetime: cool is critical

- 25 August 2003 – 15 May 2009 (5.5+ yr nominal life) – operating at <12K
- Warm Spitzer (~28K) started 24 July 2009. Only 2 cameras on one instrument still worked, but they worked ~like they did before.
- Turned off Jan 30, 2020.
- 16 years of data to mine!

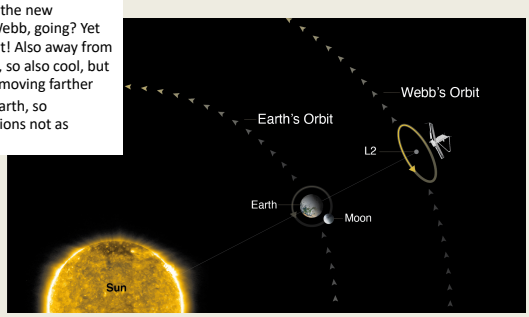
Connecting the dots

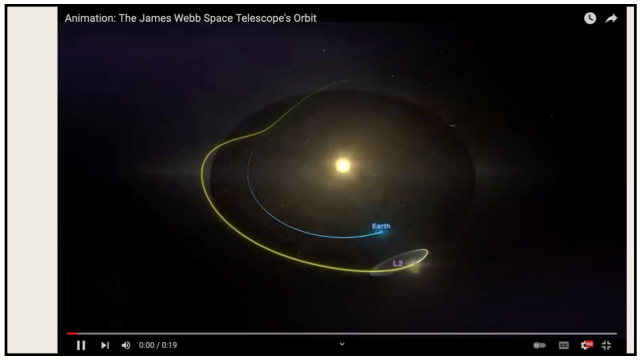
- This Earth-trailing orbit …
- … plus needing to be cool (passively) …
- … plus no moving parts …
- … means that it has to turn to talk to Earth …
- … plus antenna that was designed for <1 AU …
- This creates a natural end to the mission!





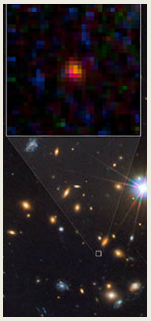
So, where is the new telescope, Webb, going? Yet another orbit! Also away from Earth/Moon, so also cool, but not steadily moving farther away from Earth, so communications not as challenging.





What did we study?

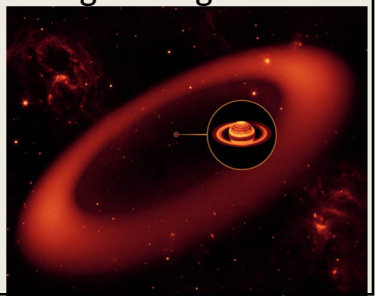
Old, Cold, Dirty!



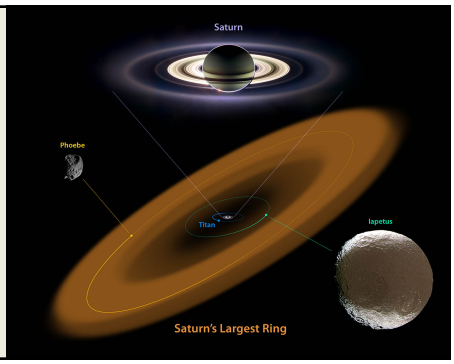
SOLAR SYSTEM…

Saturn's largest ring

- Spitzer discovered a big, dusty, "fluffy," tenuous outer ring of Saturn!
- Visible only in IR. If we could see it, it's about 2 full Moons across! → **Artist's conception!**
- Tilted 27° from rest of rings and Phoebe (distant Saturnian moon) orbits within it (likely populates it too).
- Iapetus dark on one side – like bugs on your windshield!



Verbiscer et al. (2009); NASA/JPL-Caltech/R. Hurt (SSC)



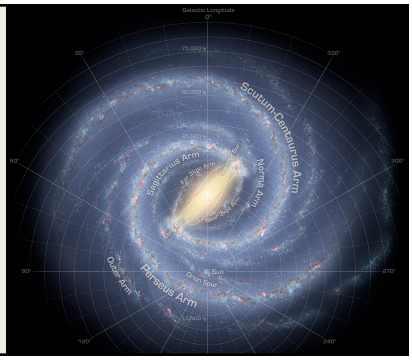
Verbiscer et al. (2009);
NASA/JPL-Caltech/R. Hurt (SSC)

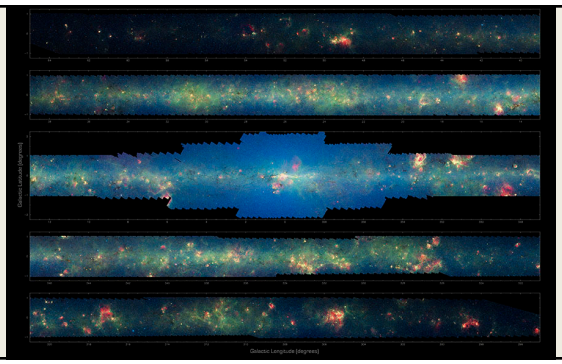
OUR GALAXY

Galactic Structure

- Hard to study our own galaxy!
- Dust blocks our view in the optical; Spitzer enabled us to see through the dust to map out the structure of our Galaxy.
- See the bar and arms better than ever before.

NASA/JPL-Caltech/R. Hurt (SSC)

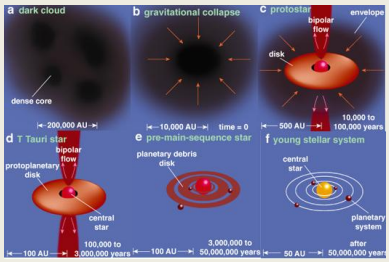




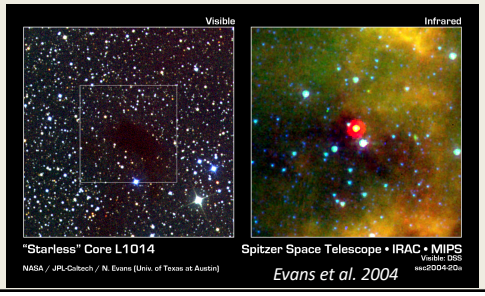
Young stars have dusty disks!

Artist's conception - NASA/JPL-Caltech

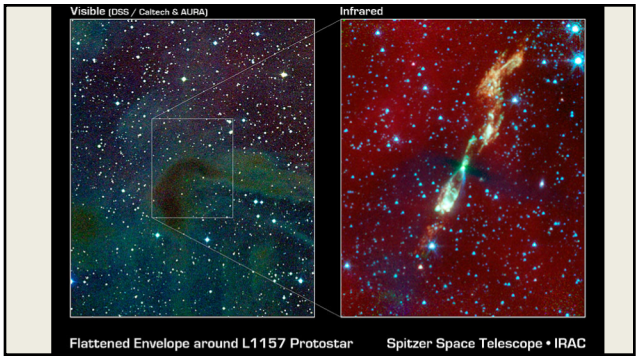
Star Formation

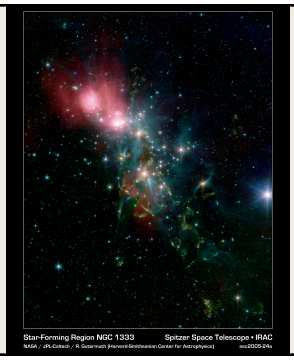


LDN 1014



Evans et al. 2004





NGC 1333: Everything green is a jet.

Gutermuth et al. 2005

M16: "Pillars of Creation"

Image is ~1.2 arcmin square

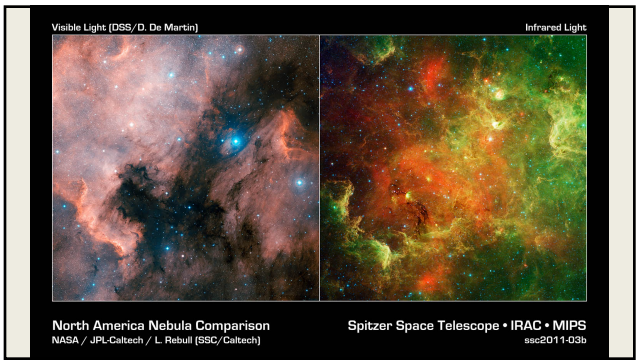
HST-WFPC2 (optical)

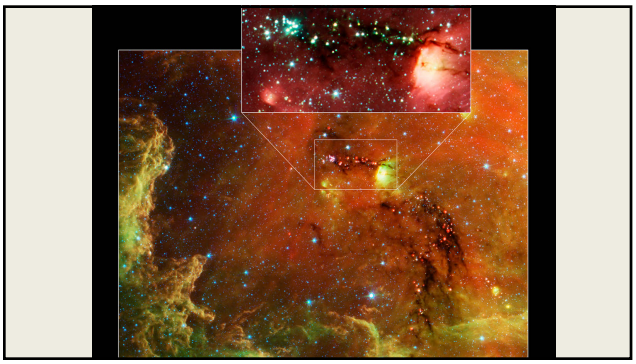
Hester & Scowen (Arizona State/ NASA), Nov 1995

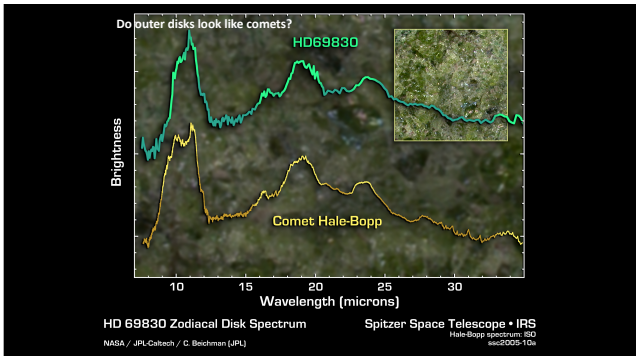
Blue=[O III] (5007 A); Green= Hα (6560 A); Red=[S II] (6731 A)

Spitzer : 4.5, 8, 24, and 70 microns

(Flagey et al. 2007)







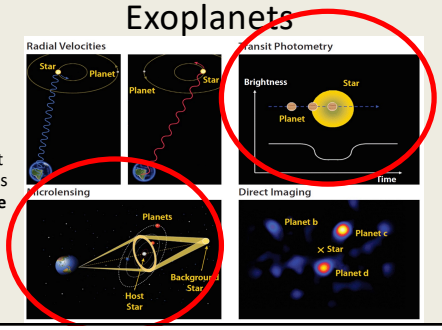
Spitzer & Star Formation

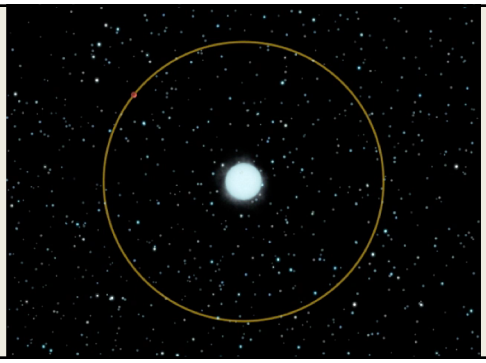
- Spitzer increased number of young stars known by several factors of 10.
  - Therefore: interaction between clouds and stars, clustering of stars, timescales of star formation stages…
- Planet-forming disks are numerous. (No wonder so many stars have planets!)

EXOPLANETS

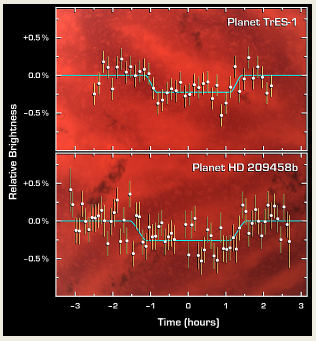
Exoplanets

Spitzer generally doesn't **discover** planets, but does help us **characterize** the planets (or find more planets!).



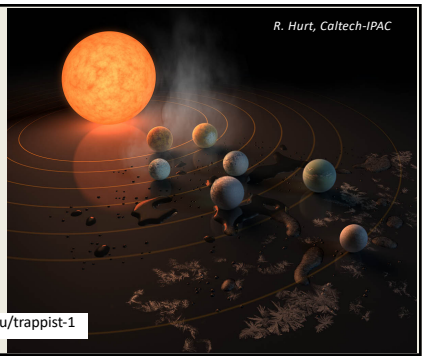


Spitzer: Light from the planet itself!



Charbonneau et al. 2005; Deming et al. 2005

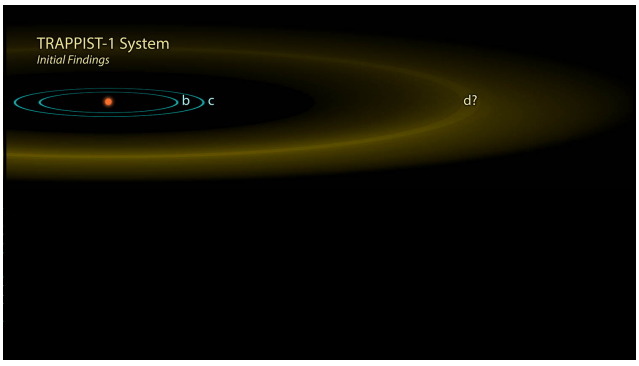
Trappist-1!!!



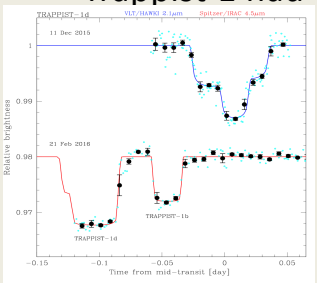
http://www.spitzer.caltech.edu/trappist-1

TRAPPIST-1

- Small red dwarf star (M8), ~40 LY (12 pc) from us.
  - ~0.09 Msun, ~0.1 Rsun (~1.1 Rjupiter).
- Gillon et al. (2016) – using their telescopes (TRAPPIST) reported finding 3 planets.
- Got time (~6 hrs) in 2016 using Spitzer (because the star is faint and red – 4000x brighter in IR than optical!) to learn more about the planets.



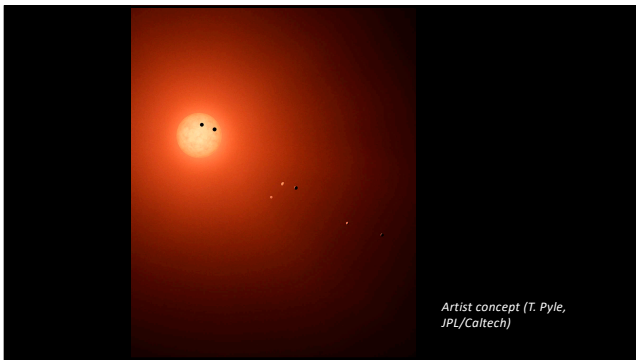
Trappist-1 had weird transits



Optical ground-based follow-up photometry

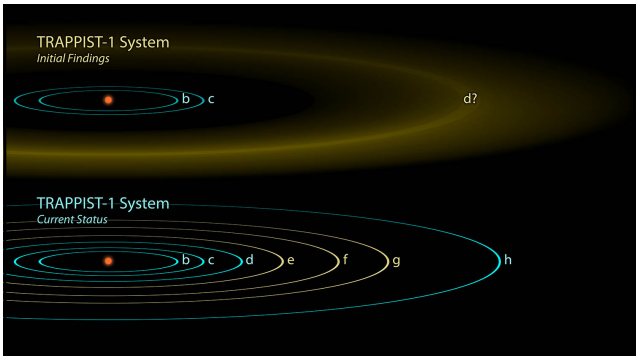
Spitzer follow-up

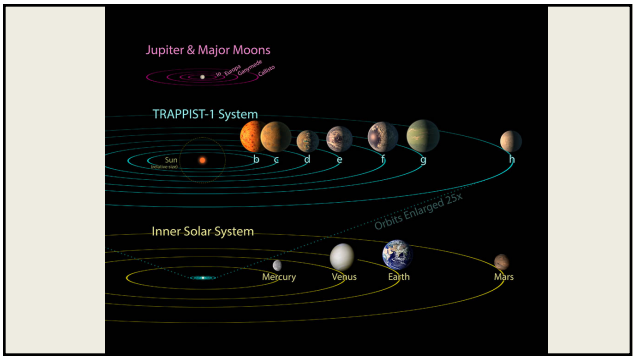
At first, did not understand the light curves!



TRAPPIST-1

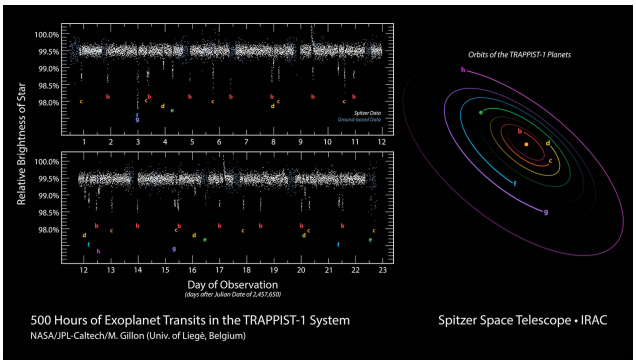
- Got Spitzer time in 2016 to ~stare for 20 days! Spitzer's orbit, stability, and infrared sensitivity make it ideal for this. Minimized interruptions for spacecraft "housekeeping."
- (Lots of other space-based and ground-based observatories working hard!)
- Published in 2017…





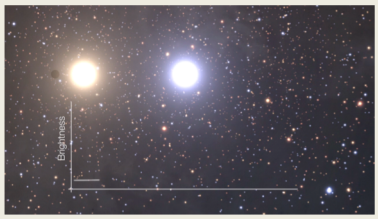
Science never stops

- Then got ~1000 hours of ~continuous Spitzer time!
- Gathering more data, knowing more about the orbits, masses, densities of these planets.
- 2018: refined properties of planets. Much better sense of which might have rock and liquid water.
- Know more about TRAPPIST-1 than any other SS except for ours.



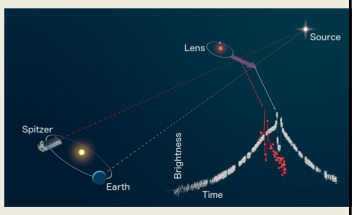
This is likely what you would really see from TRAPPIST-1e…those planets are REALLY close together!
(Whole series of these "Exoplanet Travel Bureau" posters – you can get them online.)

Gravitational Microlensing



Microlensing parallax

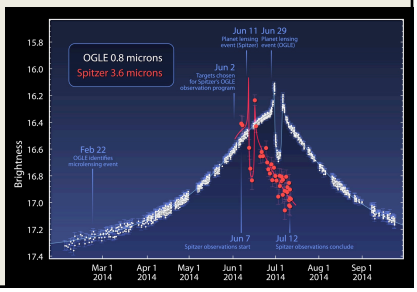
Math leads to multiple solutions with different mass/distance combinations. Having Spitzer at a different location allows us to disentangle M, d.



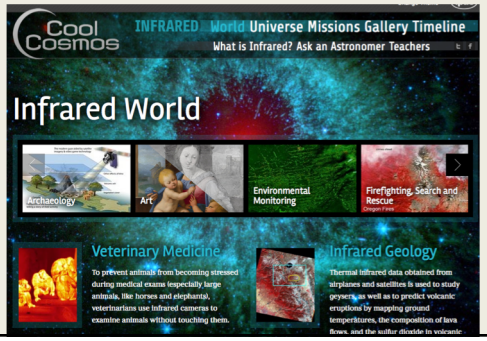
First microlensing planet with Spitzer

- Star mass = 0.7 Solar
- Planet mass = 0.5 Jupiter
- Planet distance from
- star = 3.1 AU

NASA/JPL-Caltech/A. Udalski (Warsaw University Observatory)



Your data too!



Go play!

- http://www.spitzer.caltech.edu/ ("IR-relevant astronomy" videos)
- https://universeunplugged.ipac.caltech.edu/ "Universe Unplugged" videos
- http://www.spitzer.caltech.edu/final-voyage
- http://coolcosmos.ipac.caltech.edu/
- Virtual Reality (Occulus store, YouTube: "Exoplanet Excursions")
- Exoplanet Travel Bureau – posters but also interactive site
- Eyes on the Solar System https://eyes.nasa.gov/
- App: NASA Selfies
- Book: More things in the Heavens, Werner & Eisenhardt (2019)
- (Are you a high school teacher? Google NITARP and apply!)
- (When will we get results from Webb? They are still cooling off and commissioning the instruments, so maybe in 4-5-6 months? https://webb.nasa.gov/content/webbLaunch/whereIsWebb.html)