

# Hot Science Cool Talks

UT Environmental Science Institute

**# 84**

## ***Space Telescopes as Time Machines: Hubble's Legacy and the Future Through the James Webb Space Telescope***

**Dr. Jason Kalirai**

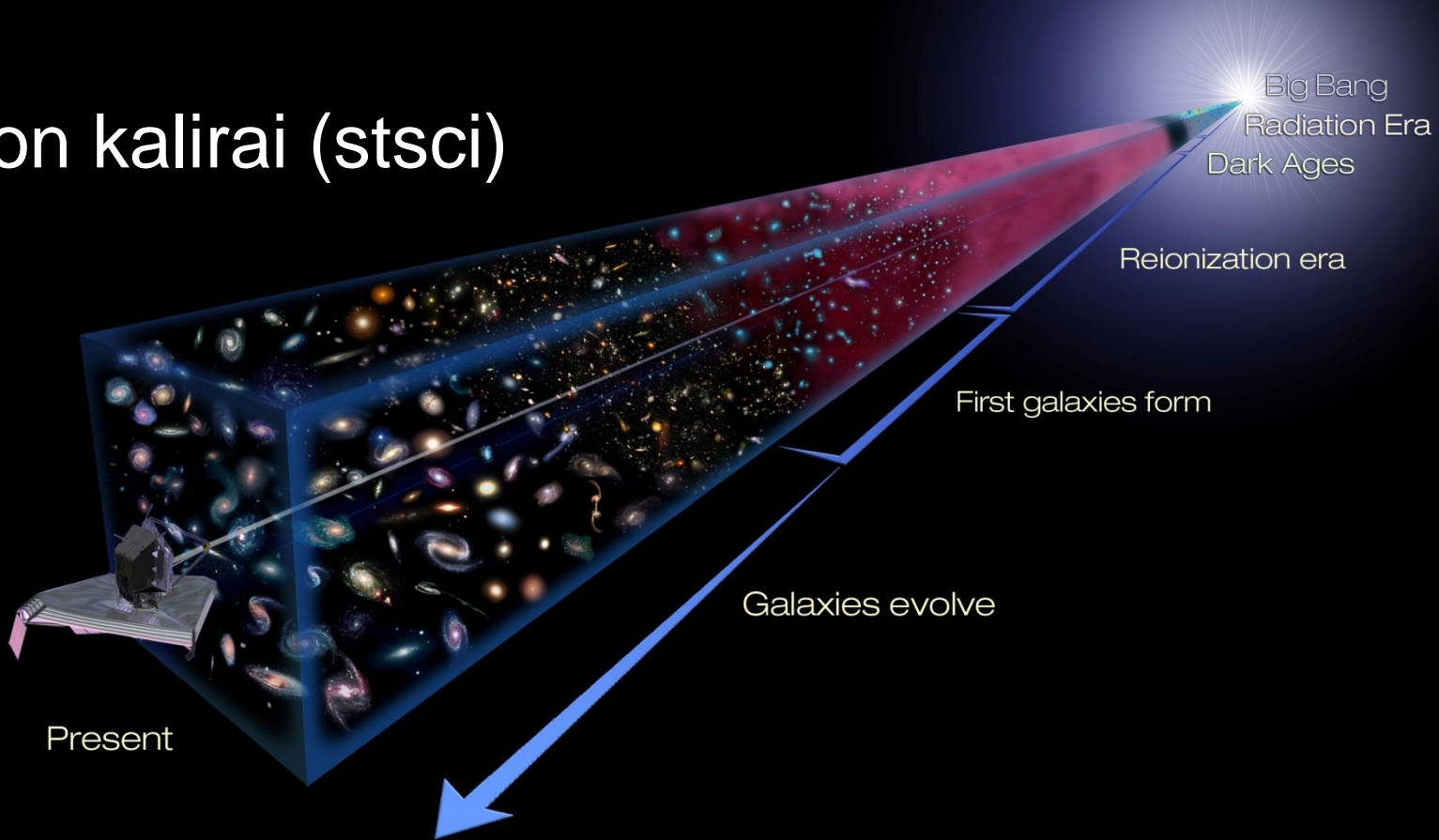
**March 6, 2013**

Produced by and for *Hot Science - Cool Talks* by the Environmental Science Institute. We request that the use of these materials include an acknowledgement of the presenter and *Hot Science - Cool Talks* by the Environmental Science Institute at UT Austin. We hope you find these materials educational and enjoyable.

# Telescopes as Time Machines

## The Legacy of Hubble & The Future with the James Webb Space Telescope

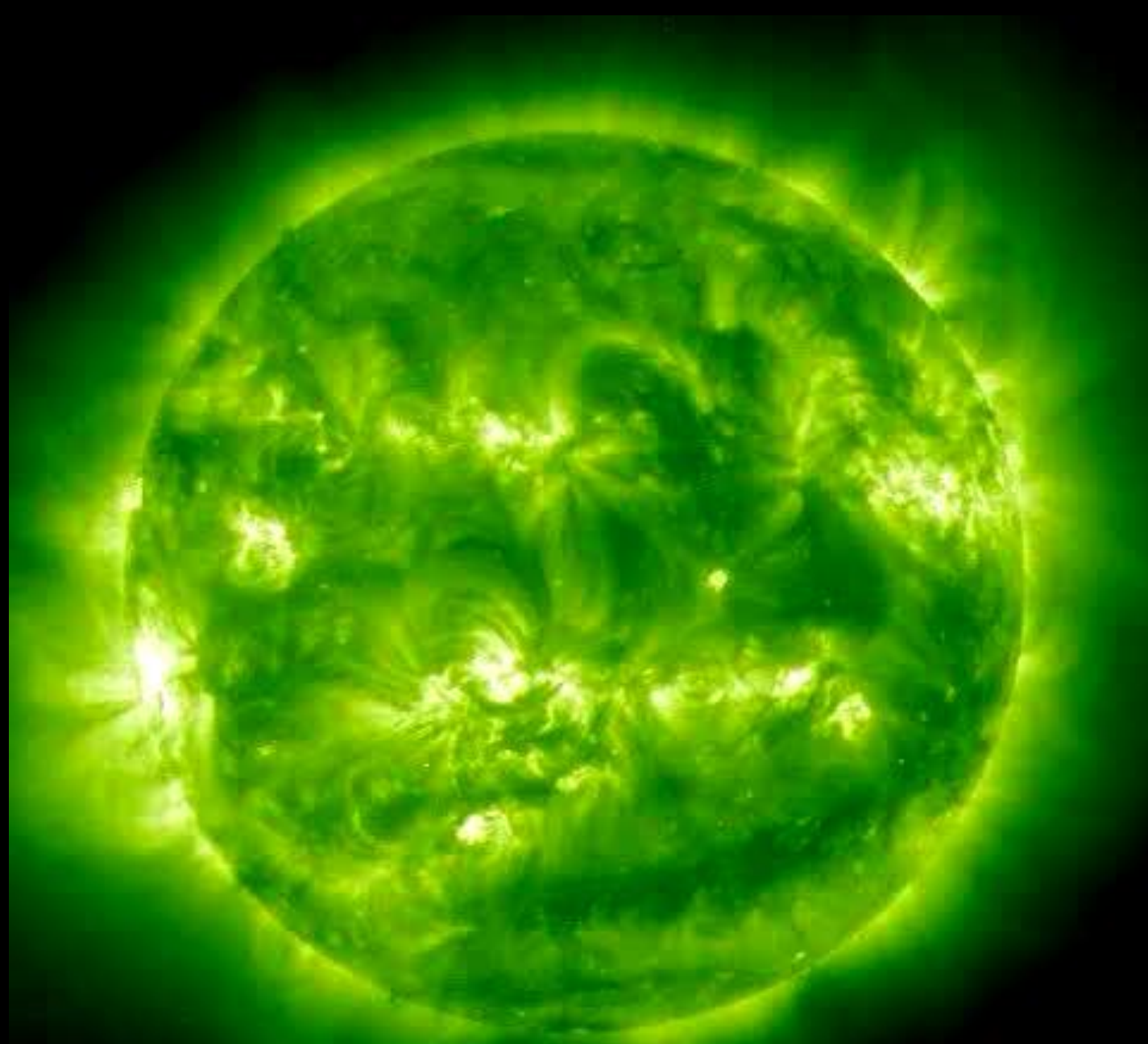
jason kalirai (stsci)









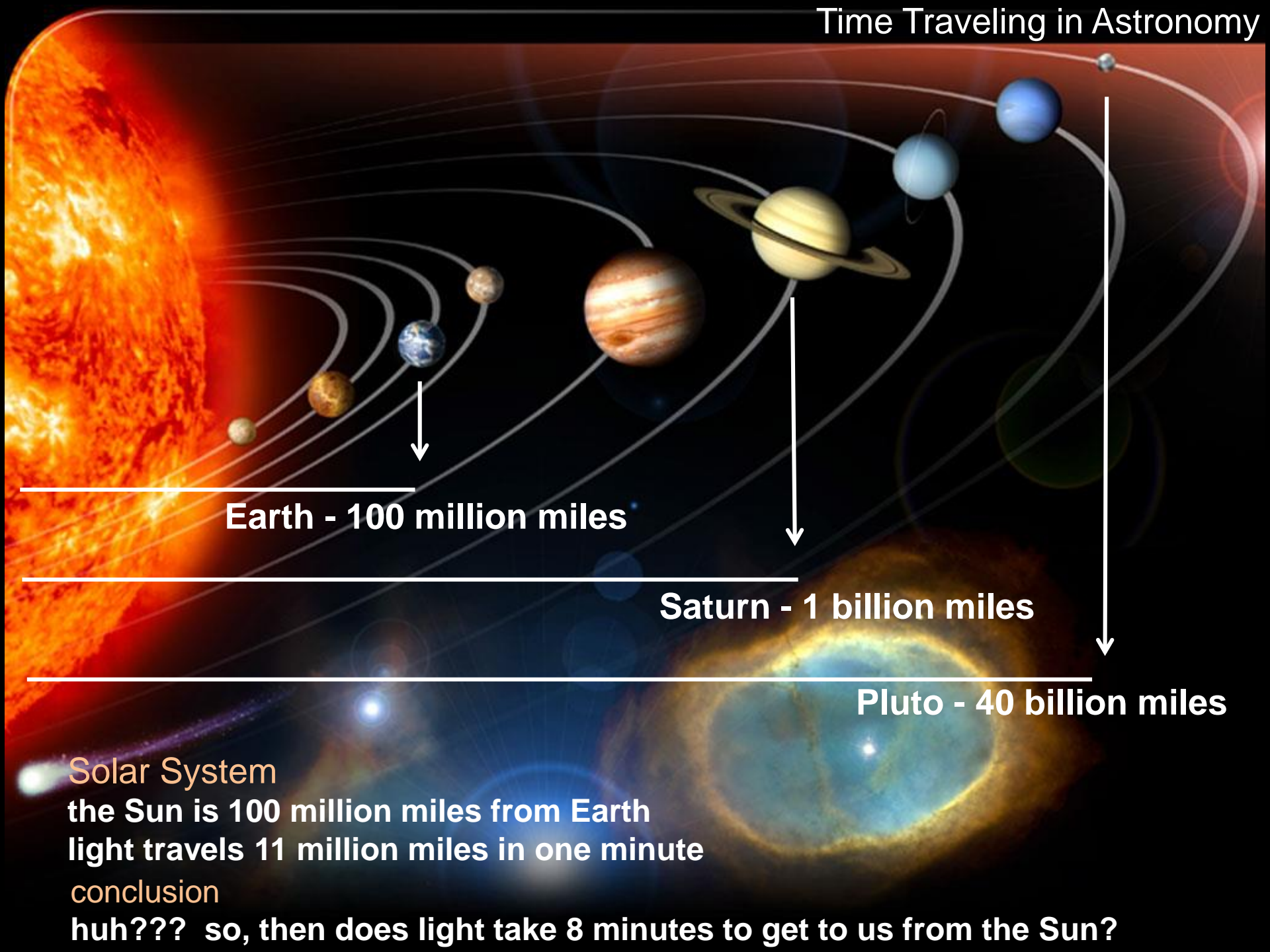


1999/12/13 19:48:10



Dude, can you get to the time machine part? ...am I a space alien?





Earth - 100 million miles

Saturn - 1 billion miles

Pluto - 40 billion miles

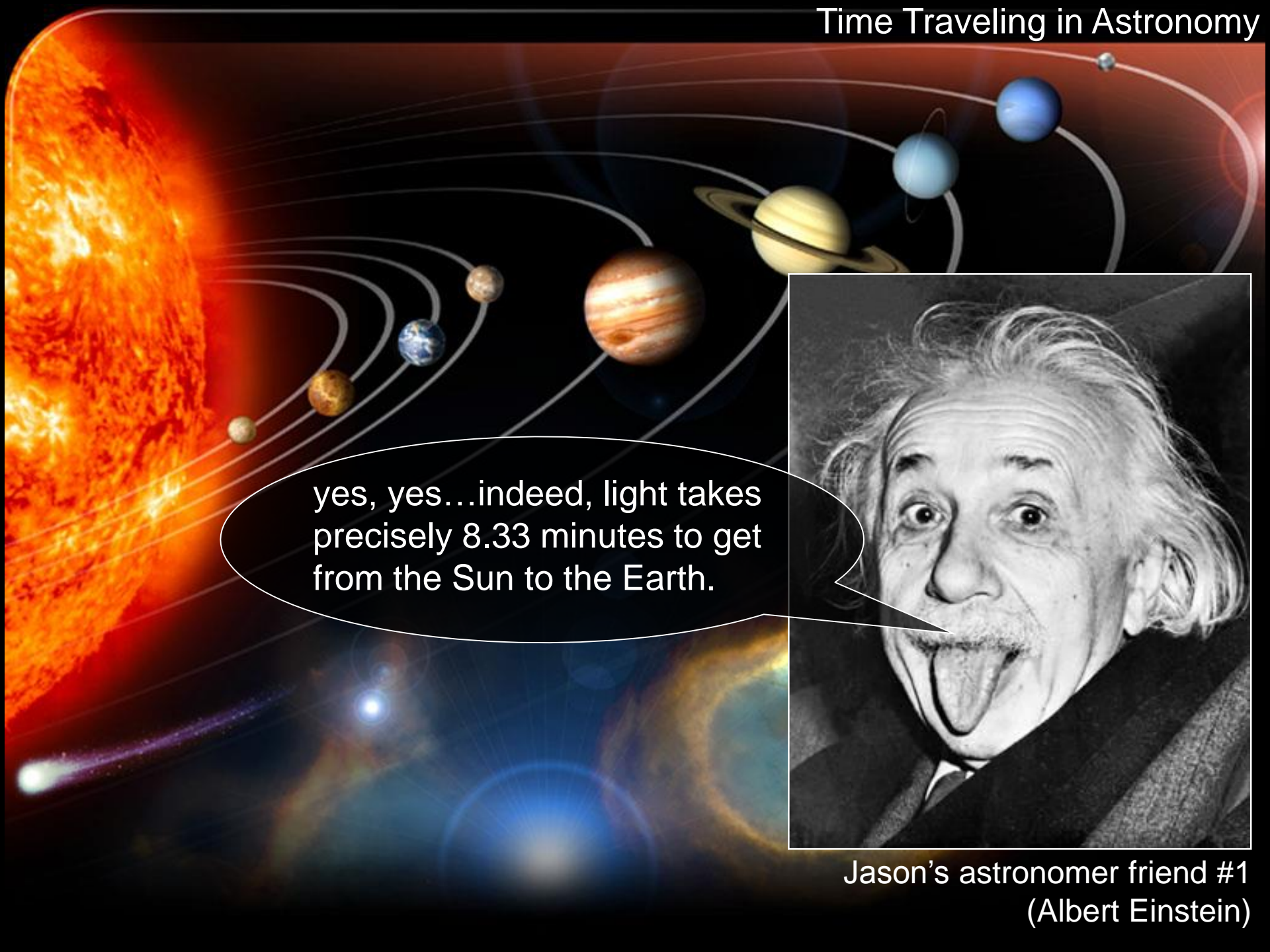
**Solar System**

the Sun is 100 million miles from Earth  
light travels 11 million miles in one minute

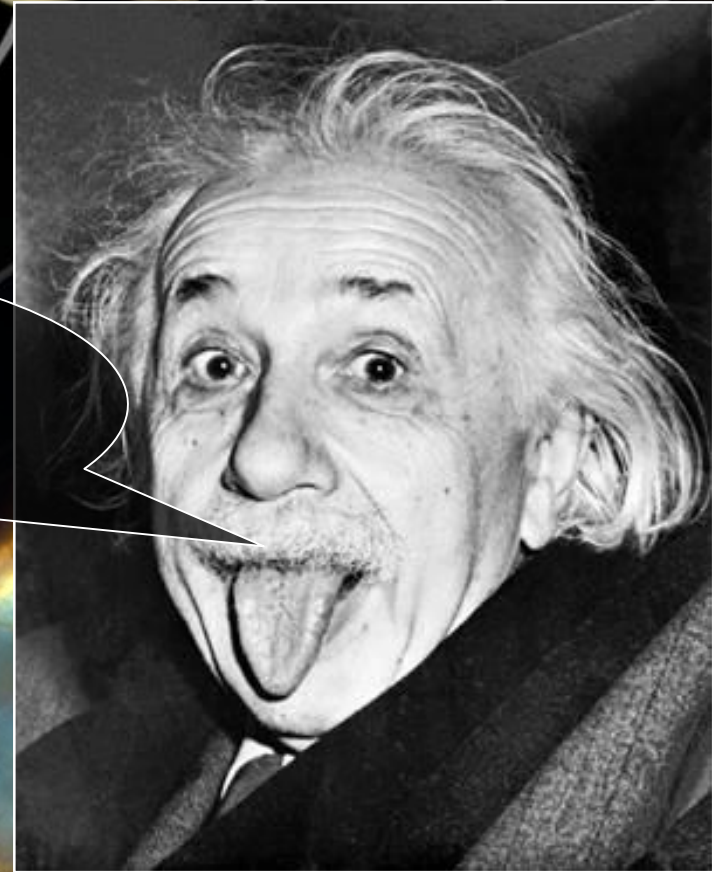
conclusion

huh??? so, then does light take 8 minutes to get to us from the Sun?





yes, yes...indeed, light takes precisely 8.33 minutes to get from the Sun to the Earth.



Jason's astronomer friend #1  
(Albert Einstein)

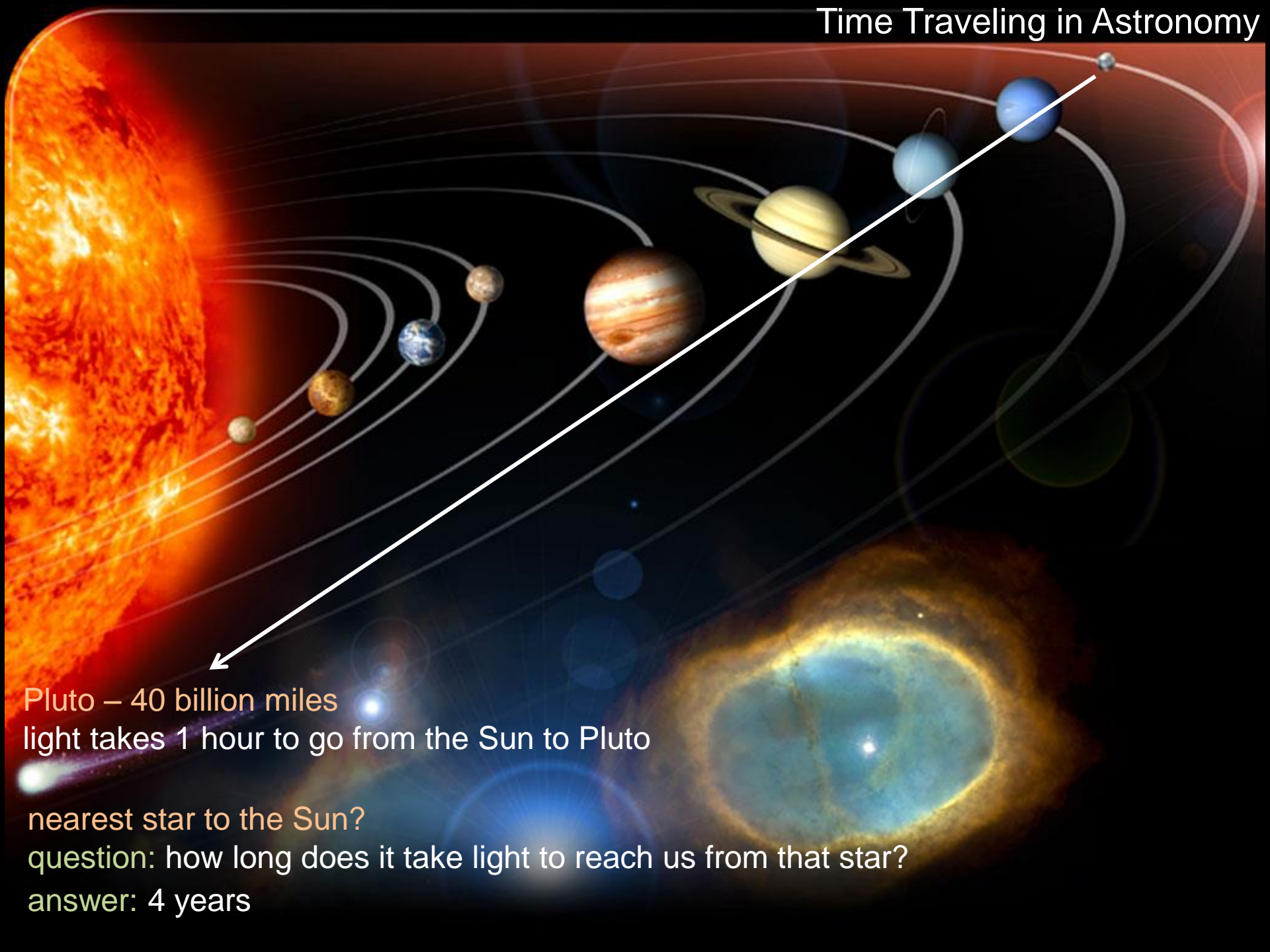


# Time Traveling in Astronomy



ha ha...my death star  
destroyed your Sun...  
7.5 minutes ago!

Jason's astronomer friend #2  
(Darth Vader)



Pluto – 40 billion miles  
light takes 1 hour to go from the Sun to Pluto

nearest star to the Sun?

question: how long does it take light to reach us from that star?

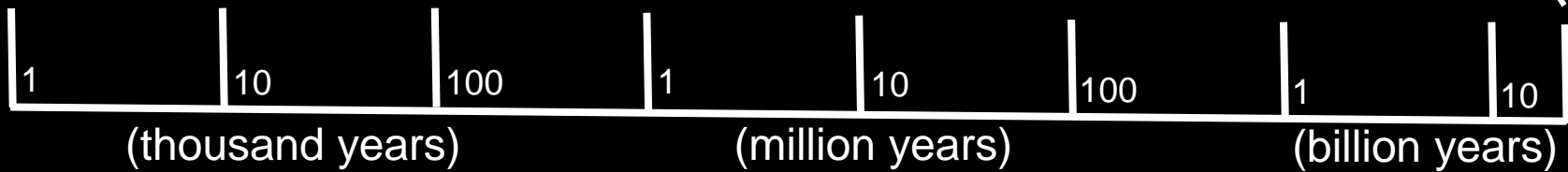
answer: 4 years



the greatest **time machine** ever built



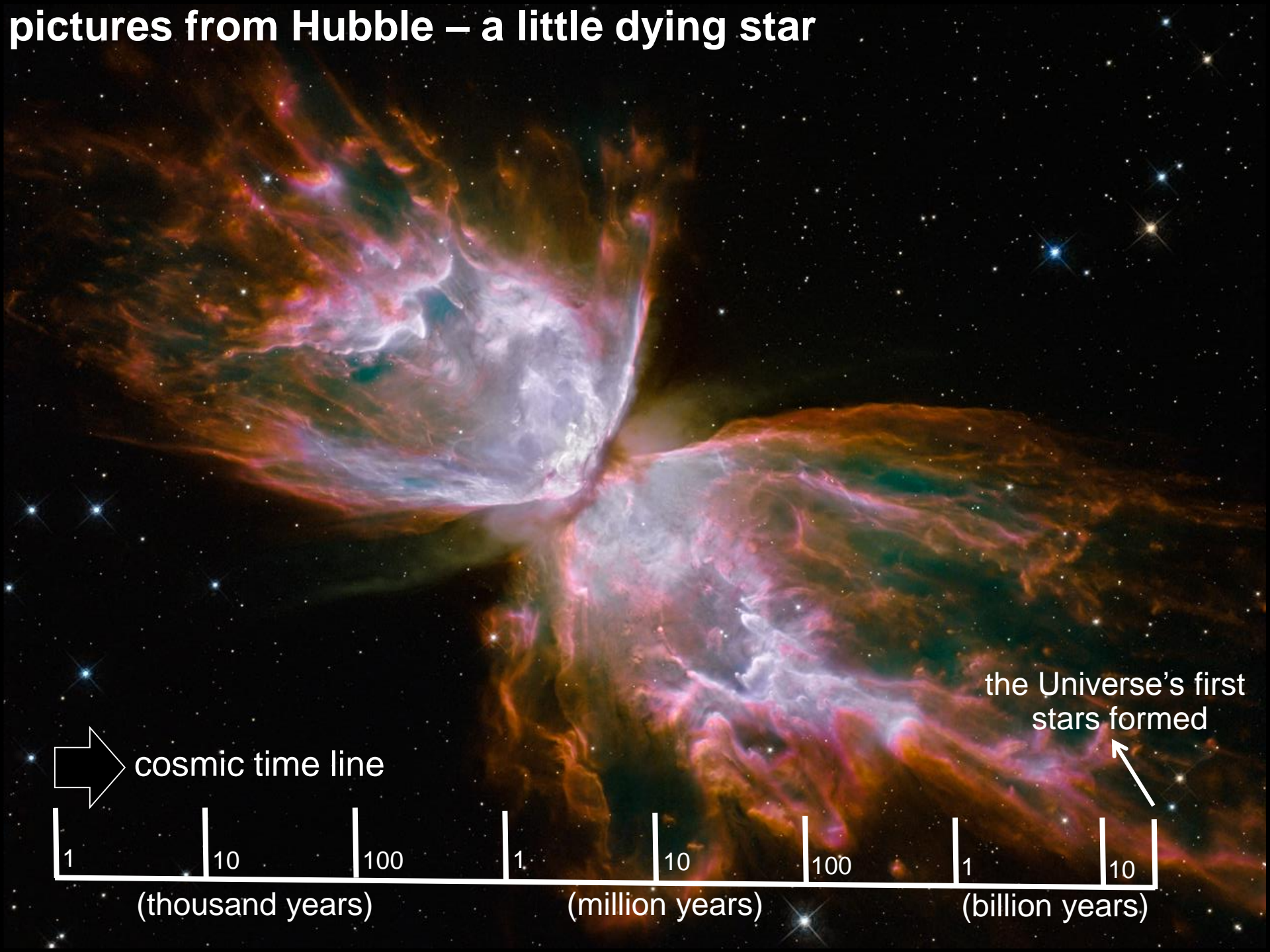




the Universe's first  
stars formed



# pictures from Hubble – a little dying star



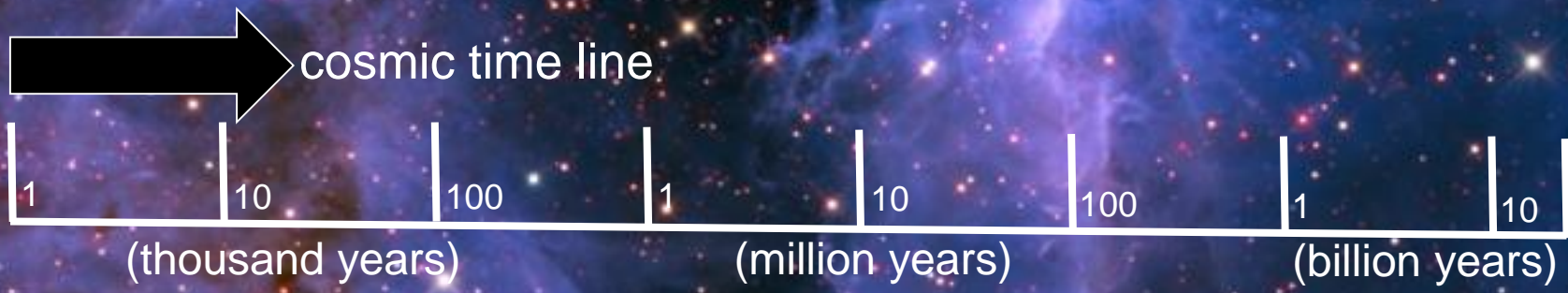
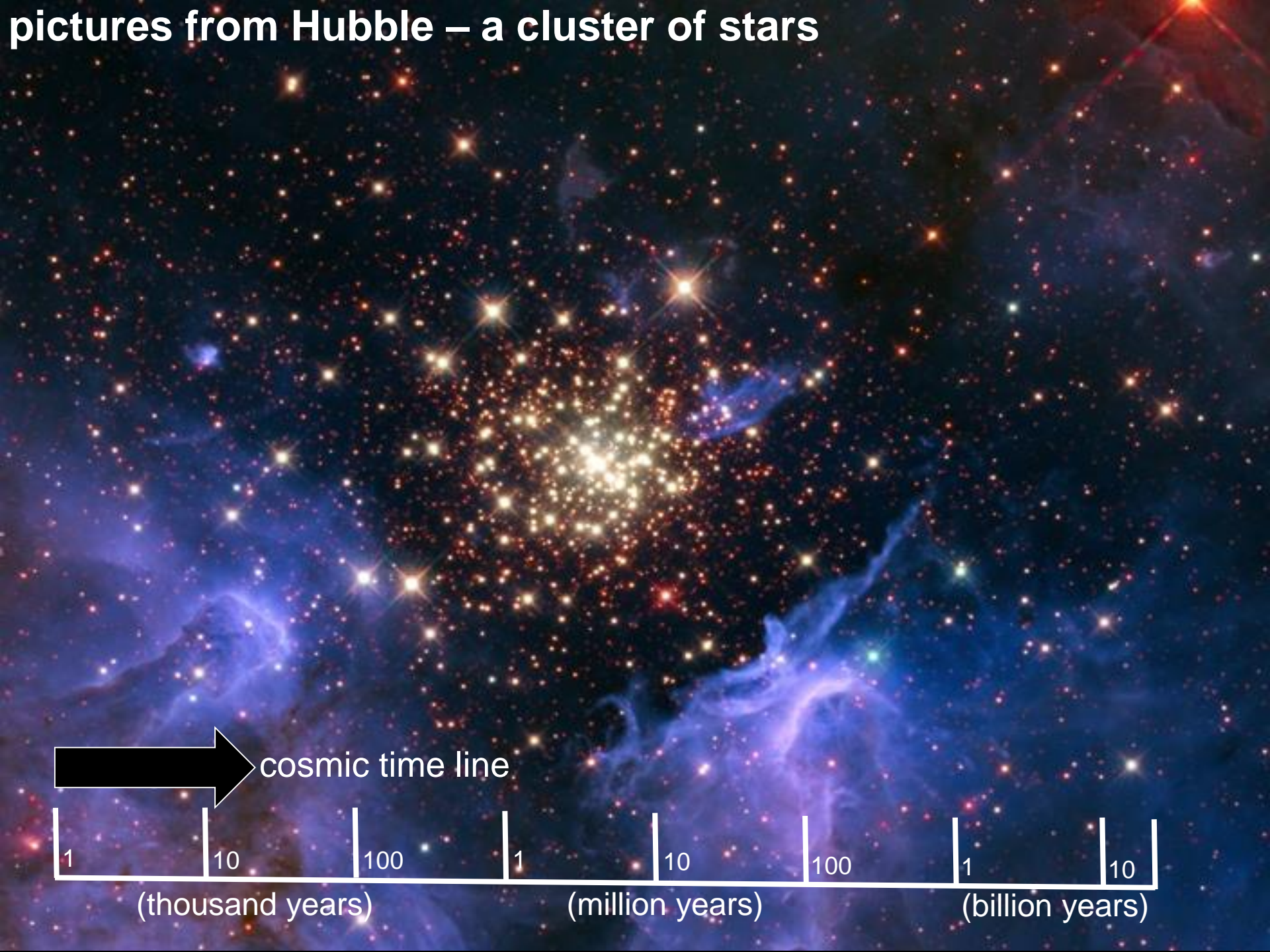
the Universe's first  
stars formed

cosmic time line



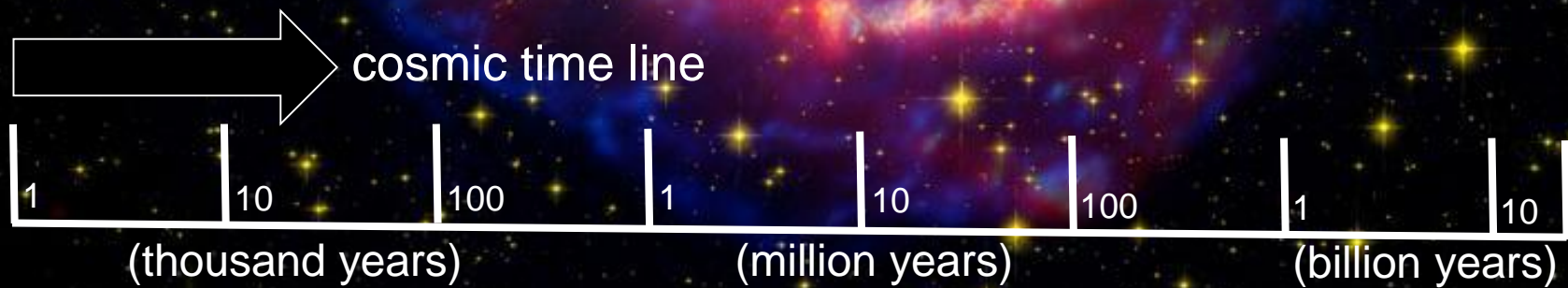


# pictures from Hubble – a cluster of stars

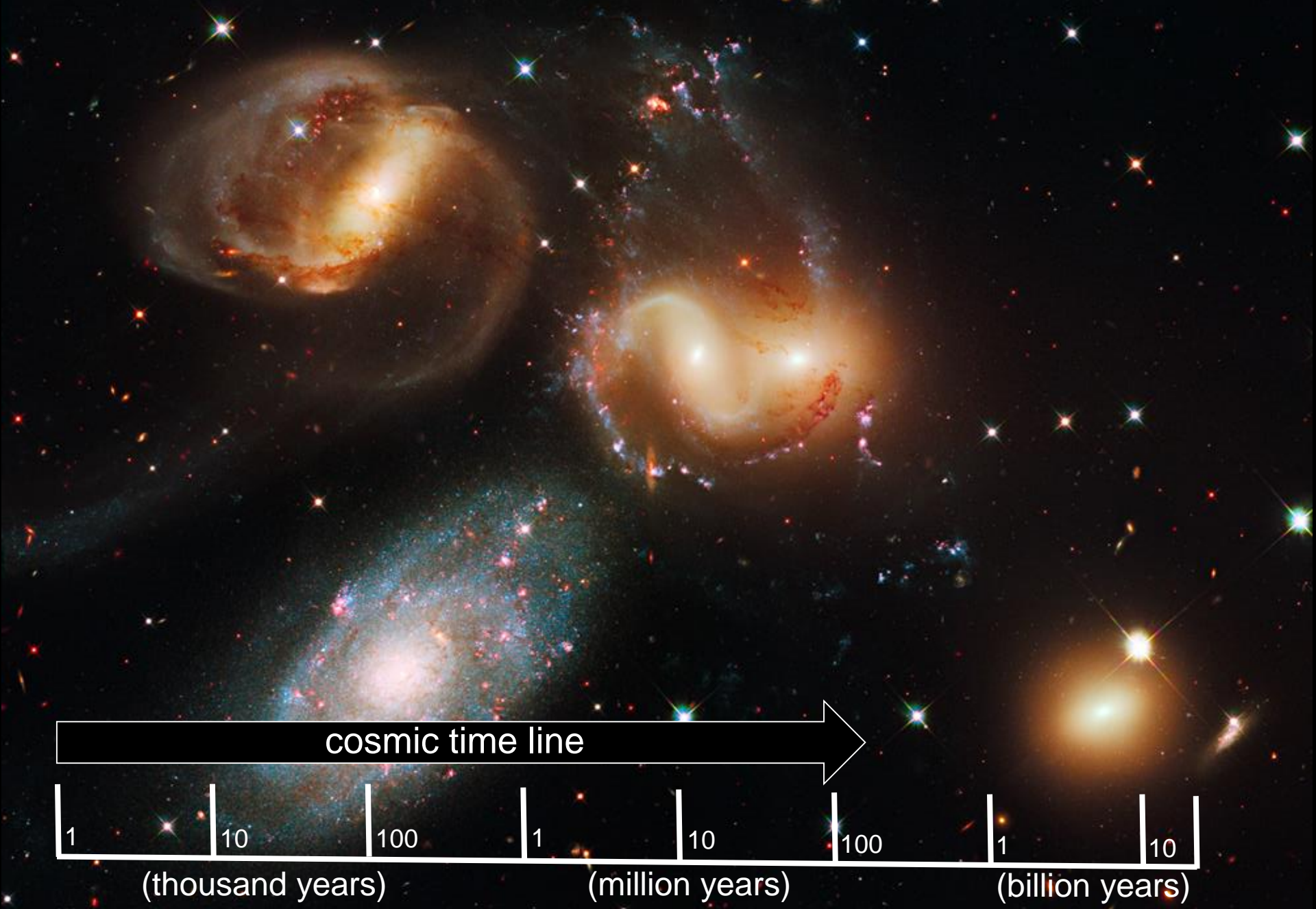




# pictures from Hubble – a BIG dying star



# pictures from Hubble – interacting galaxies





# Hubble discoveries

supermassive **black holes**

the age of the **universe**

gravitational lensing of **galaxies**

**dark energy** and the expansion of the Universe

influence of **dark matter**

imaging and spectroscopy of giant **exoplanets**

intensities of **supernovae**





the new and improved Hubble!





# Hubble's 'frontier fields' (2013 – 2016)



cosmic time line



what's next?



# James Webb Space Telescope

A detailed illustration of the James Webb Space Telescope (JWST) in space. The telescope is shown from a three-quarter perspective, highlighting its large, gold-colored segmented primary mirror and the complex structure of the secondary mirror and instruments. The background is a vast field of stars and a colorful nebula with blue and orange hues.

## **JWST organization**

**Mission Lead:** NASA's Goddard Space Flight Center

**International Collaborators:** European and Canadian Space Agencies

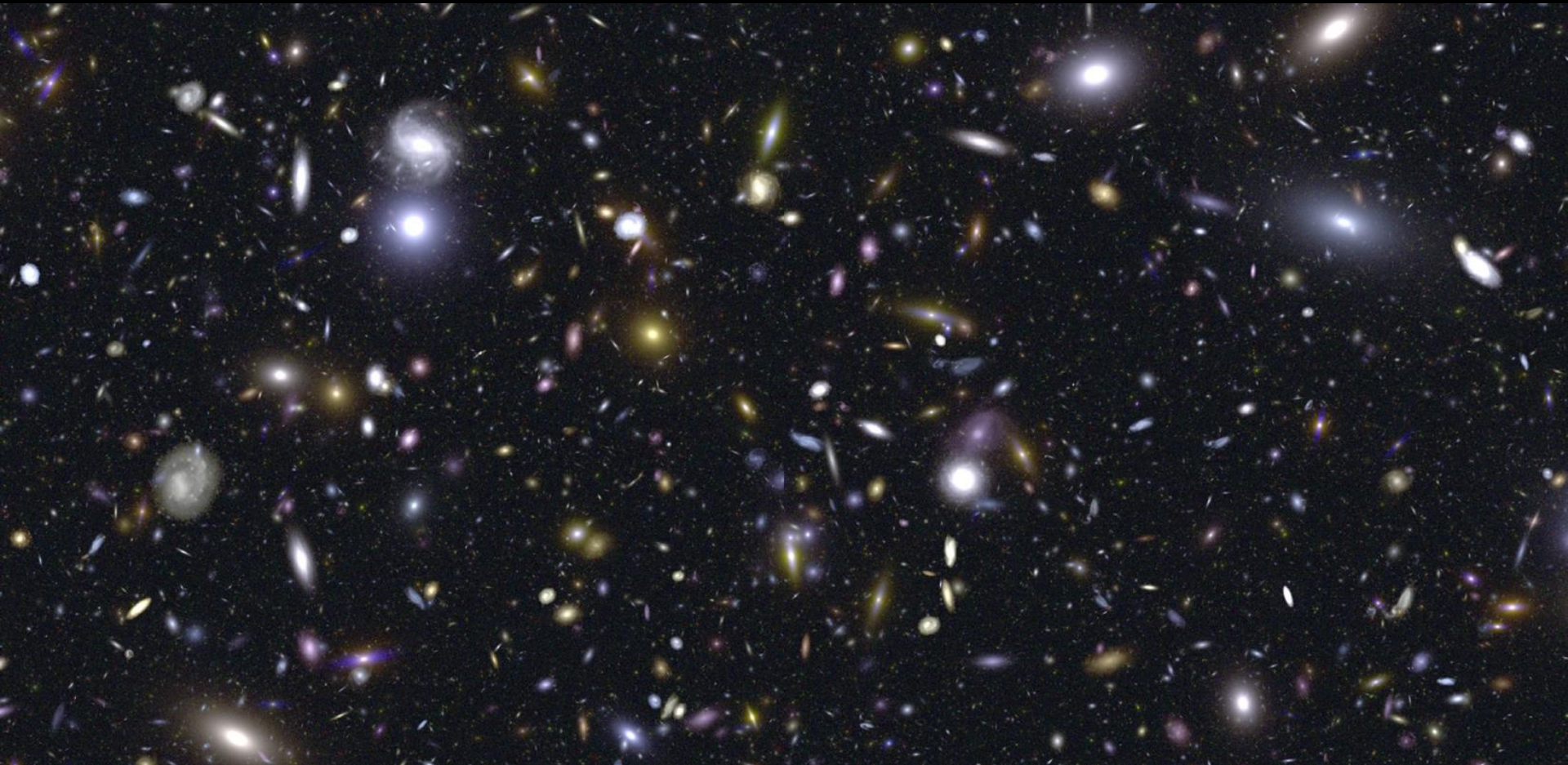
**Prime Contractor:** Northrop Grumman Aerospace Systems

**Operations Center:** Space Telescope Science Institute



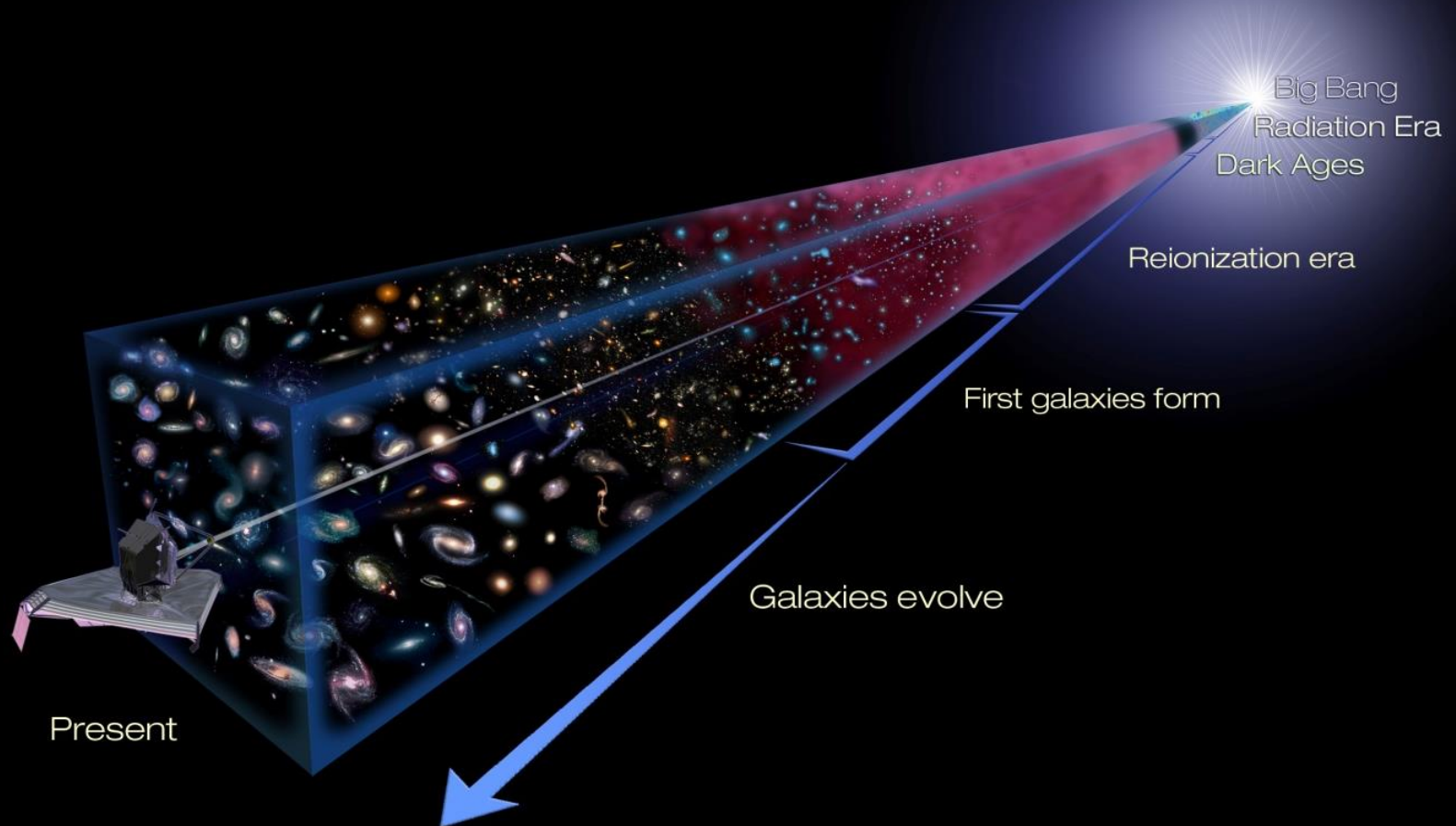
# science challenge #1

to seek the Universe's **first stars** and **galaxies**



# science challenge #2

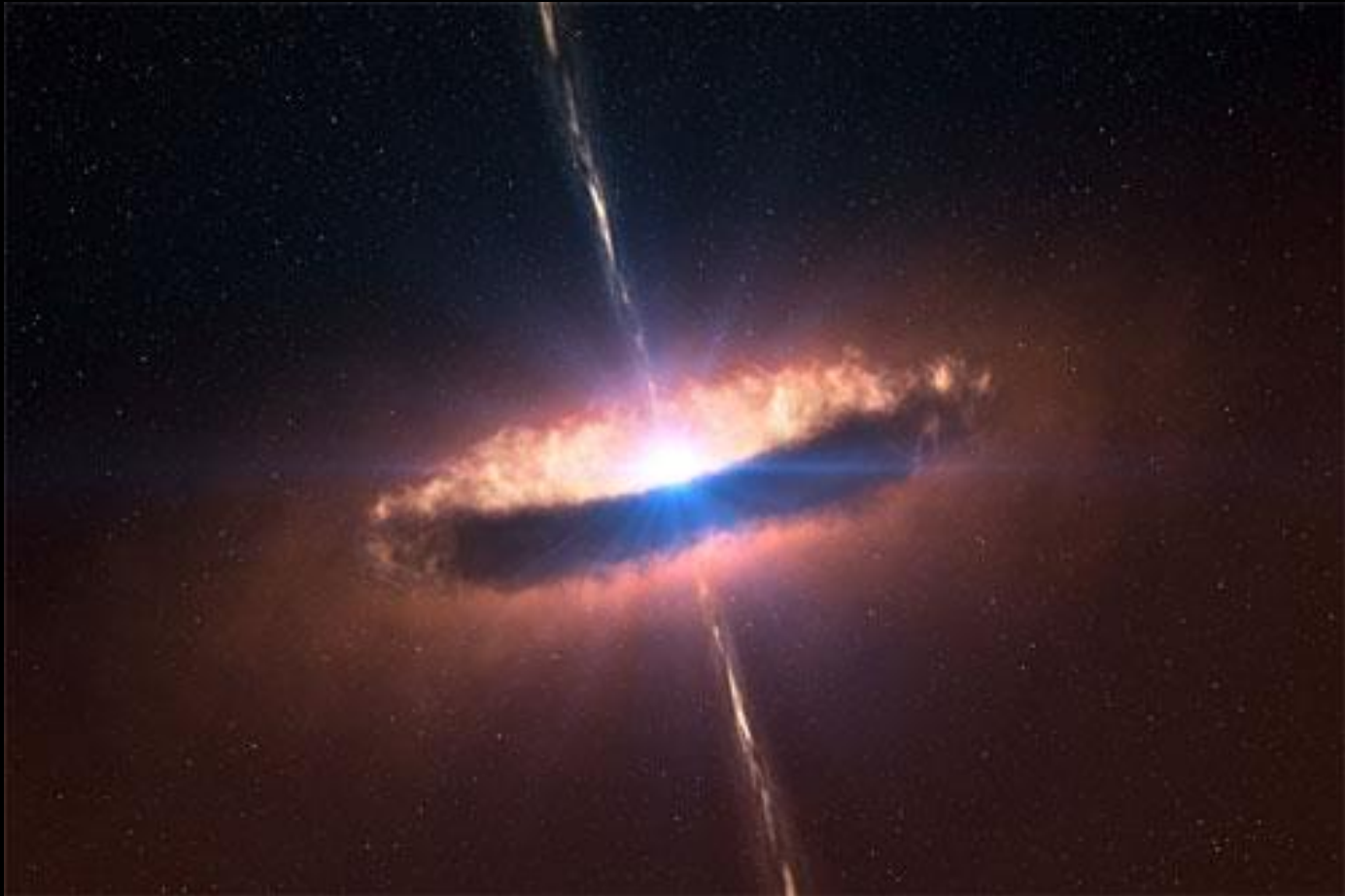
to determine how **galaxies evolve** from the early Universe to the present (stars, gas, metals, dark matter)





# science challenge #3

to solve the mysteries of **star formation** and reveal the **birth of planetary systems**



# science challenge #4

to measure the chemistry of **Solar Systems** (including our own)  
and probe the **building blocks of life**



# astronomy's next great observatory

answering the challenges – James Webb Space Telescope

>100x more power than Hubble and other telescopes

>50x the resolution of Spitzer; near & mid-infrared wavelengths

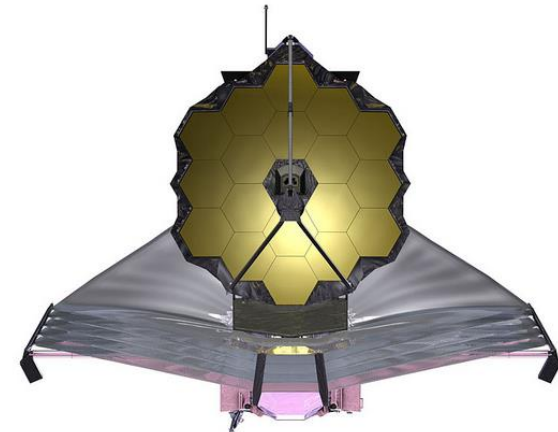
comparable in size to the largest ground-based telescopes, yet light weight

launches out to 1 million miles, deployable in space

operates at cryogenic temperatures

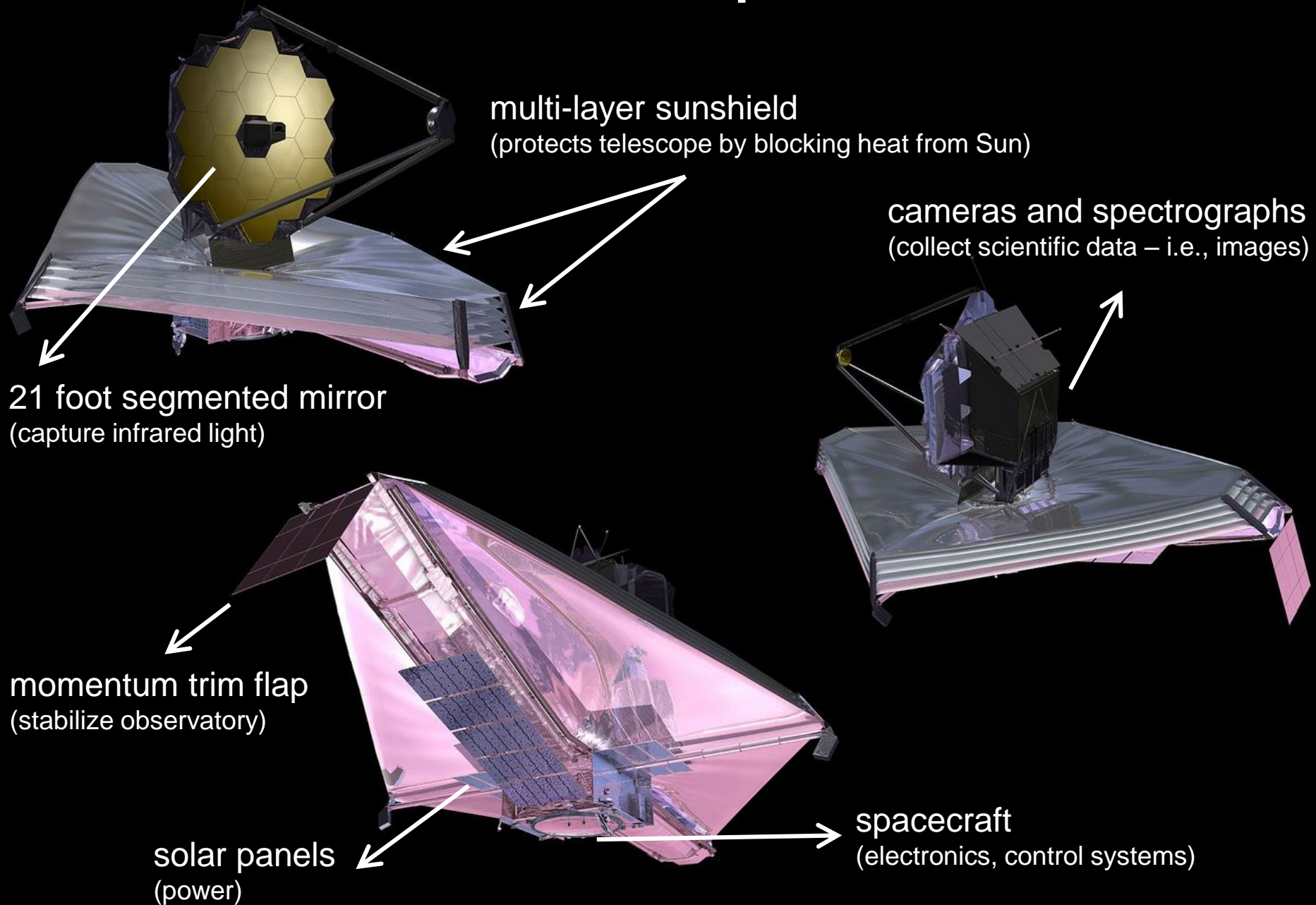
contains a new generation of complex instrumentation to ensure diverse

modes of operation without servicing





# it's a bird, it's a plane, it's...



# the JWST concept

technological firsts to achieve this mission

segmented beryllium primary mirror

composite backplane structure

mirror phasing and control software

application specific integrated circuit

microshutters

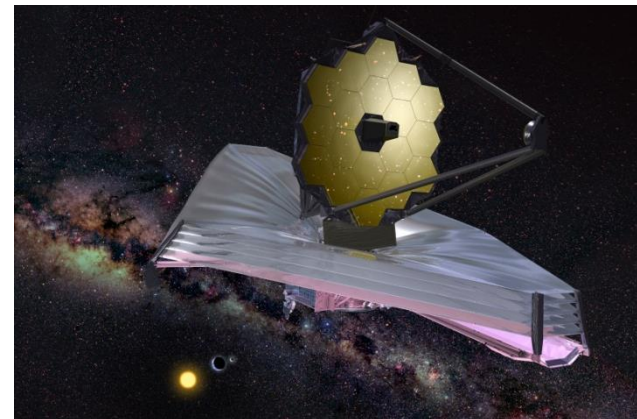
sunshield membranes

mid-infrared detectors

cryo-cooler for mid-infrared instrument

other “inventions” (e.g., tinsley’s shack-hartmann technique for mirror

surface measurement, SSMS)



# the JWST concept

technological firsts to achieve this mission

segmented beryllium primary mirror

composite backplane structure

mirror phasing and control software

application specific integrated circuit

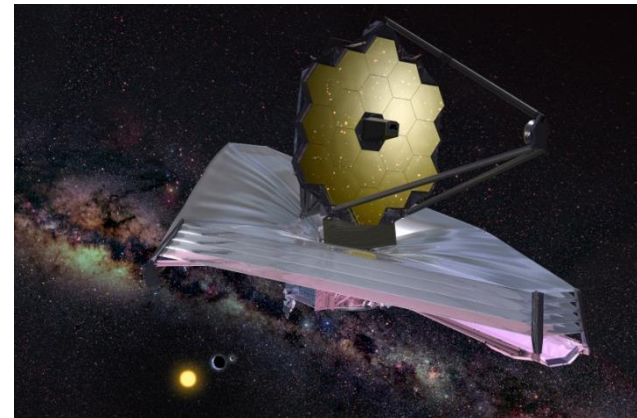
microshutters

sunshield membranes

mid-infrared detectors

cryo-cooler for mid-infrared instrument

other “inventions” (e.g., tinsley’s shack-hartmann technique for mirror surface measurement, SSHS)





# the JWST mirrors journey



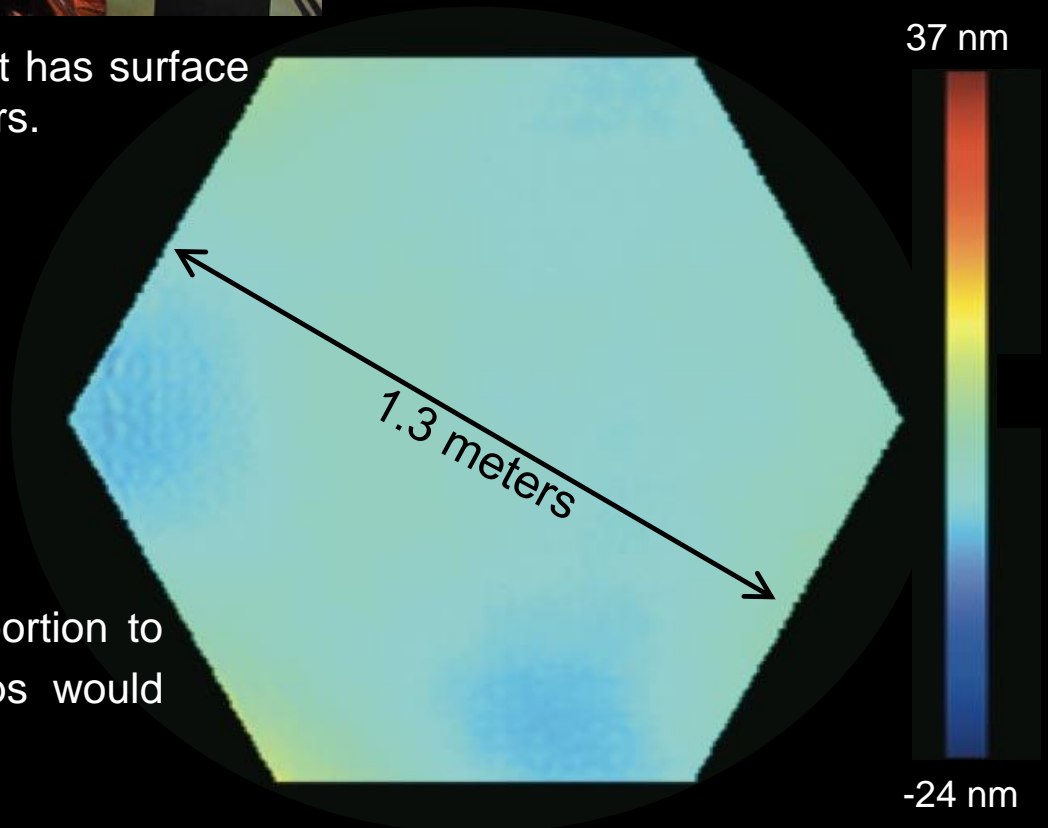
## Beryllium Across the Country

- 1.) Brush Wellman Inc's Mine (Powder – Utah)
- 2.) Brush Wellman Fac. (purification – Ohio)
- 3.) Axsys Tech (Honeycomb/shaping – Alabama)
- 4.) Tinsley Lab (Grind/Polish/testing at room temp – California)
- 5.) Ball (Mounts/Actuators/testing – Colorado)
- 6.) X-ray and Cryogenic Facility (Cold vacuum testing – Alabama)
- 7.) Ball (Remove mounts/actuators – Colorado)
- 8.) Tinsley Lab (Fine tune polish based on cryogenic testing – California)
- 9.) Ball (Cleaning and preparation for coating – Colorado)
- 10.) Quantum Coating Inc. (Gold coating – New Jersey)
- 11.) Ball (Reassemble segments with mounts and actuators / Vibration testing – Colorado)
- 12.) X-Ray and Cryogenic facility (Final cryogenic acceptance testing on segments – Alabama)
- 13.) NASA GSFC (Assembly and ISIM integration / Acoustic and vibration testing – Maryland)
- 14.) NASA JSC (Final cryogenic testing of JWST – Texas)

we're talking smooth...



each 1.3 meter JWST mirror segment has surface aberrations measuring ~20 nanometers.



if this mirror was stretched in proportion to the size of the **Texas**, the bumps would only be **1 centimeter** high.

# 21 foot mirror in space





# the JWST concept

technological firsts to achieve this mission

segmented beryllium primary mirror

composite backplane structure

mirror phasing and control software

application specific integrated circuit

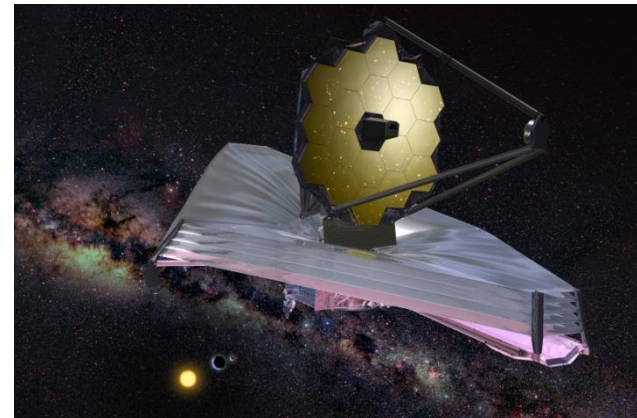
microshutters

sunshield membranes

mid-infrared detectors

cryo-cooler for mid-infrared instrument

other “inventions” (e.g., tinsley’s shack-hartmann technique for mirror surface measurement, SSHS)



tennis-court sized 5-layer sunshield

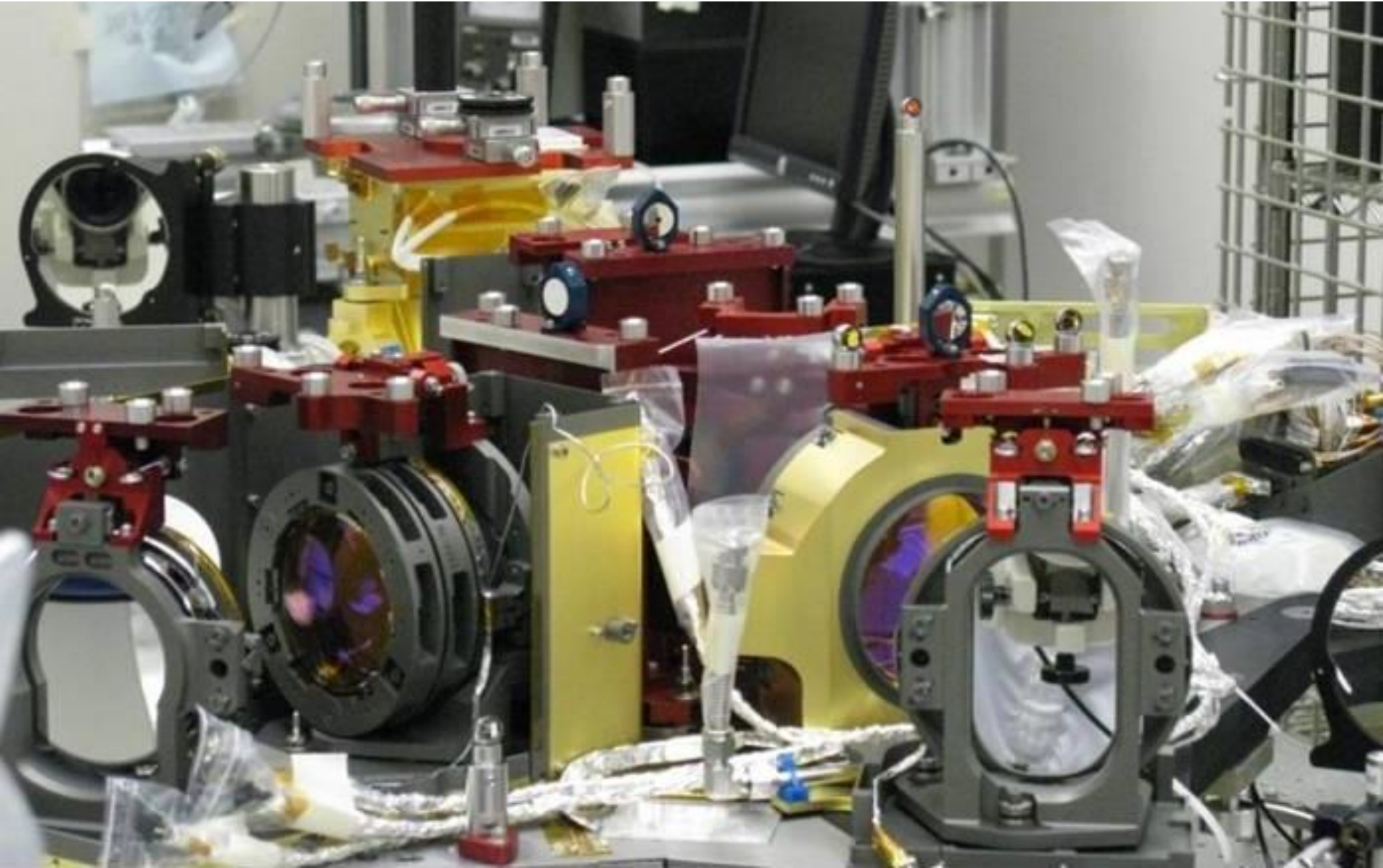
# tennis-court sized 5-layer sunshield



JWST sunshield cold side, -388 F  
JWST sunshield hot side, 185 F

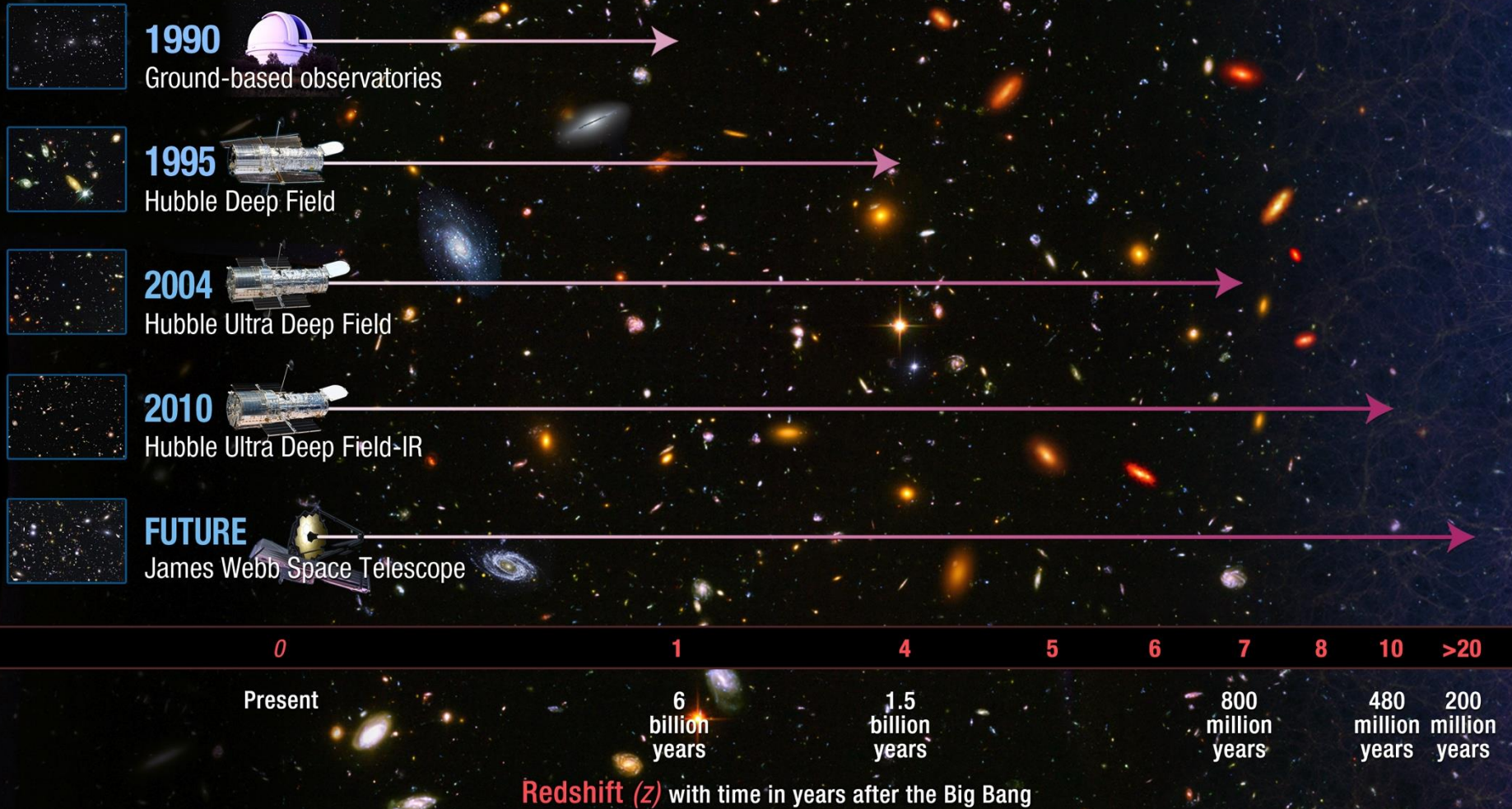


one of JWST's "cameras"



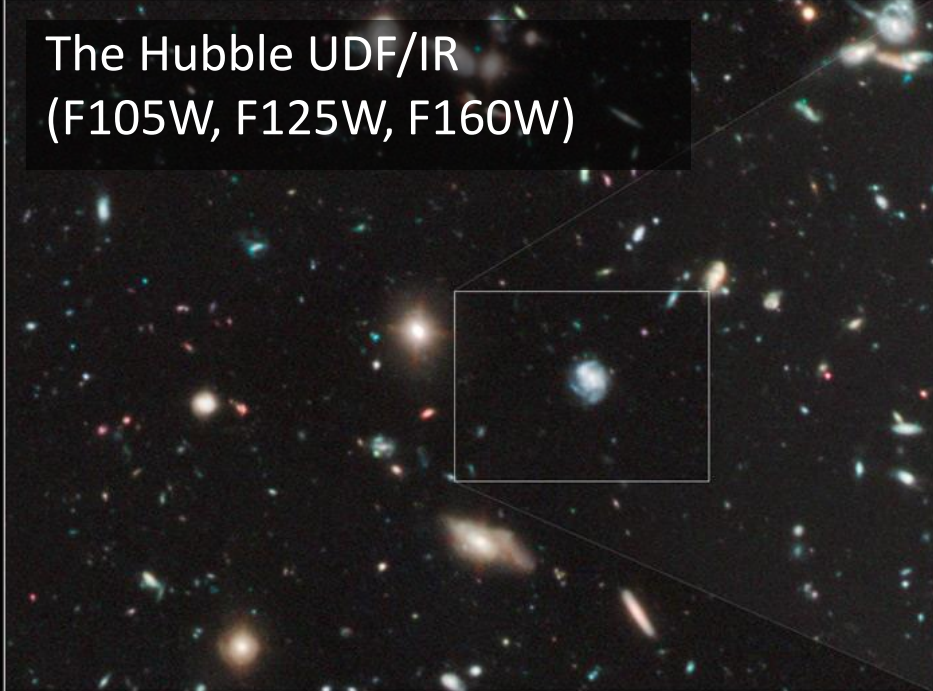


# JWST and the first galaxies

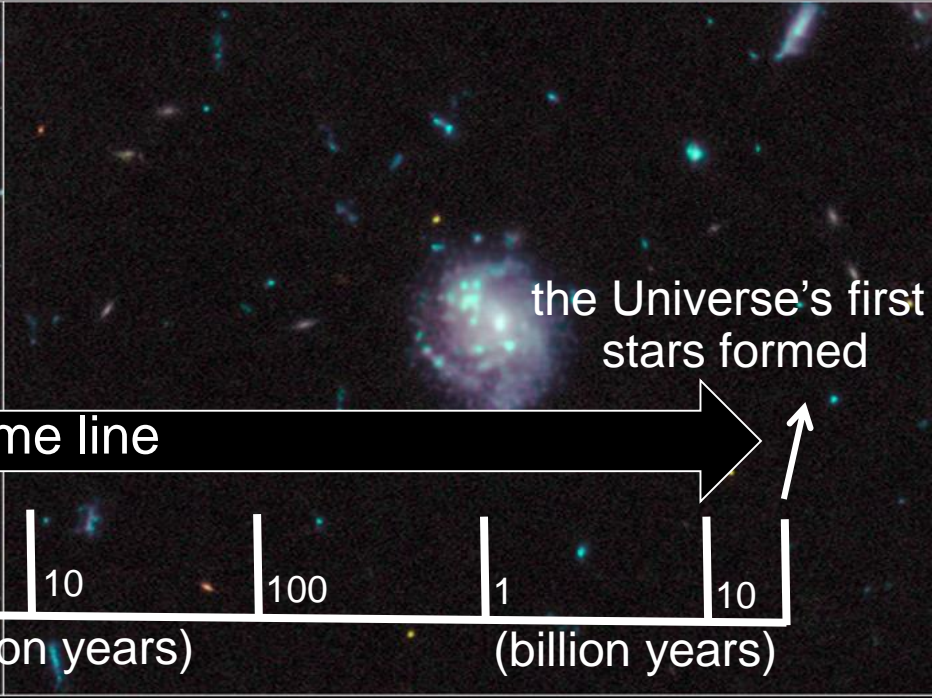
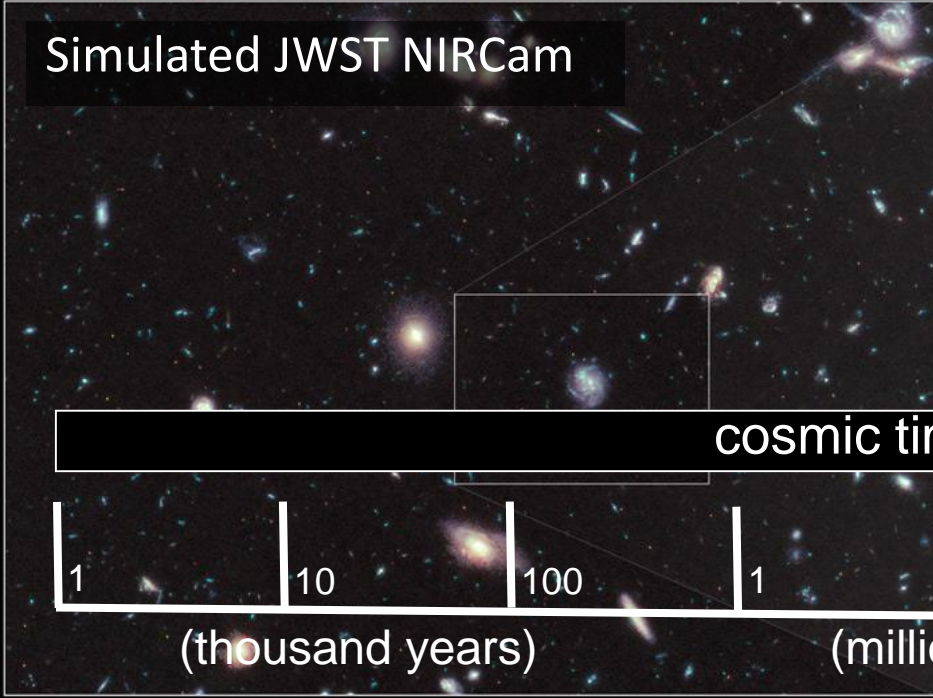




The Hubble UDF/IR  
(F105W, F125W, F160W)



Simulated JWST NIRCam



the Universe's first  
stars formed

cosmic time line





“Mr. Hubble says that trophies are for people with self-esteem issues.”



State Farm Mutual Automobile Insurance Company, State Farm Indemnity Company, Bloomington, IL.  
State Farm Bank, Bloomington, IL, Member FDIC

# JWST and the first stars

first stars thought to be very massive (25 – 500 mass of Sun)

form in isolation

very, very hot = 100,000 K

luminous sources of lots of ionizing photons ( $> 10^{50}$  /s)

very short lifetimes = 2-3 million years



new simulated light curves show late time rise over more than 100 days

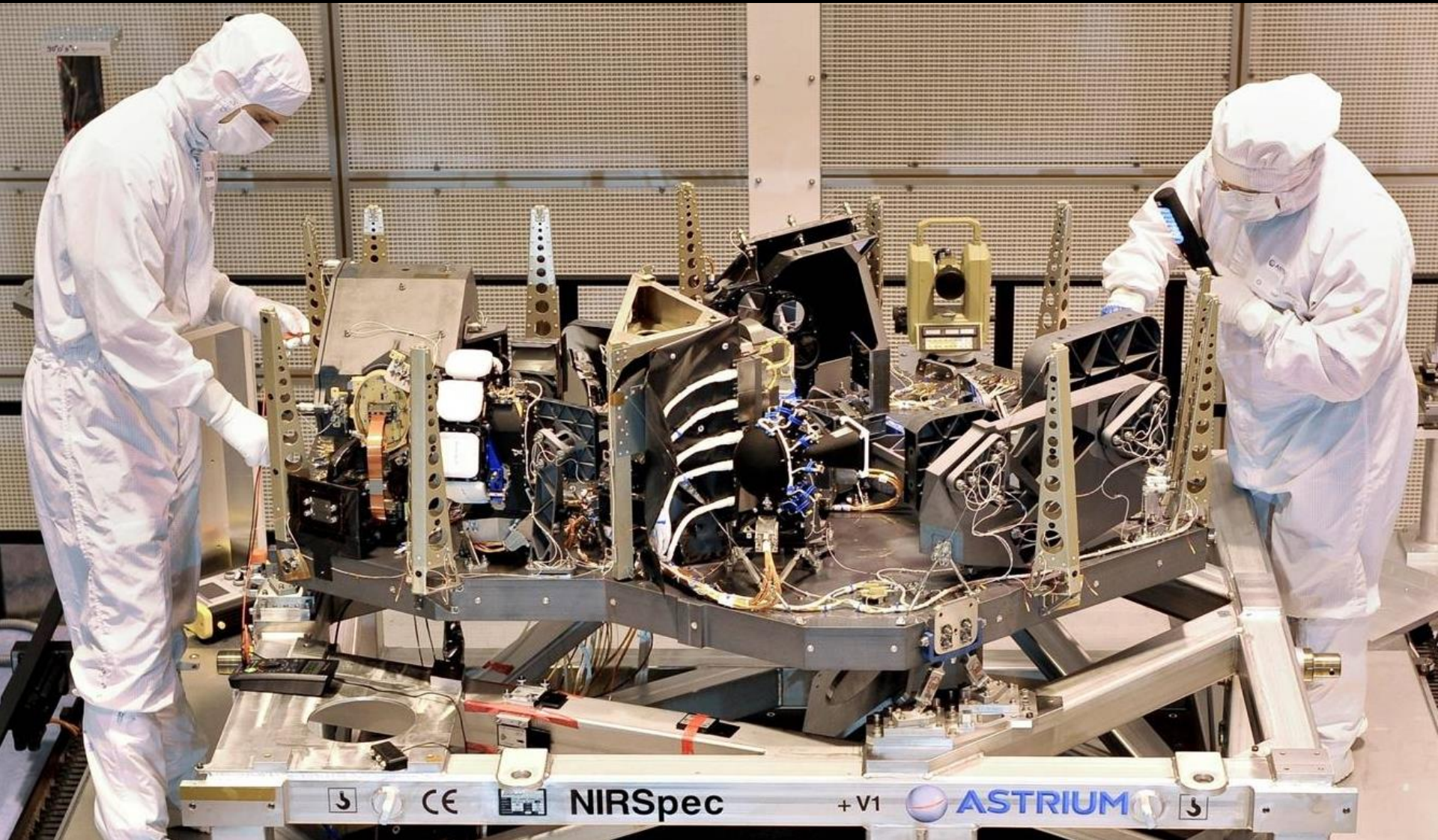
infrared energy diffuses out through dense ejecta of supernova

can be measured with JWST to the Universe's earliest epochs

ground based follow up with 30-m telescopes will help distinguish progenitors



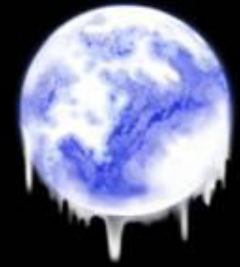
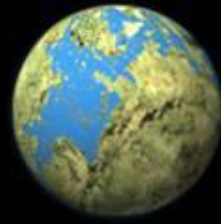
another one of JWST's "cameras"





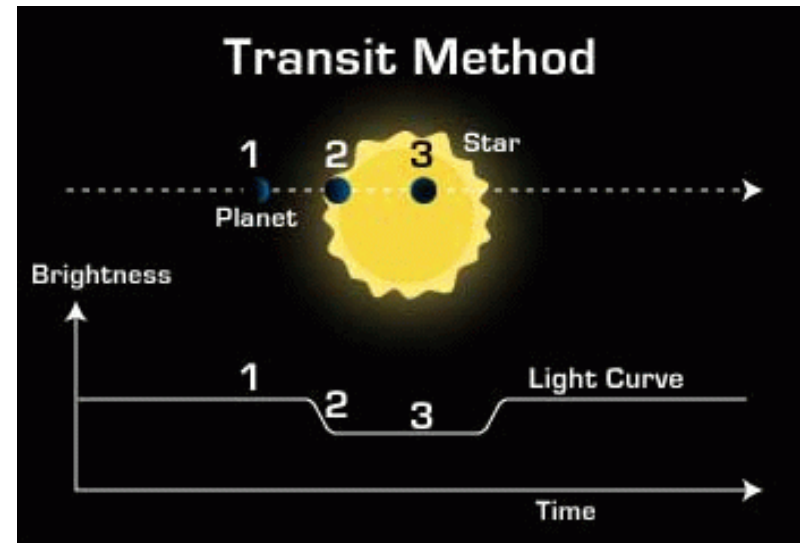
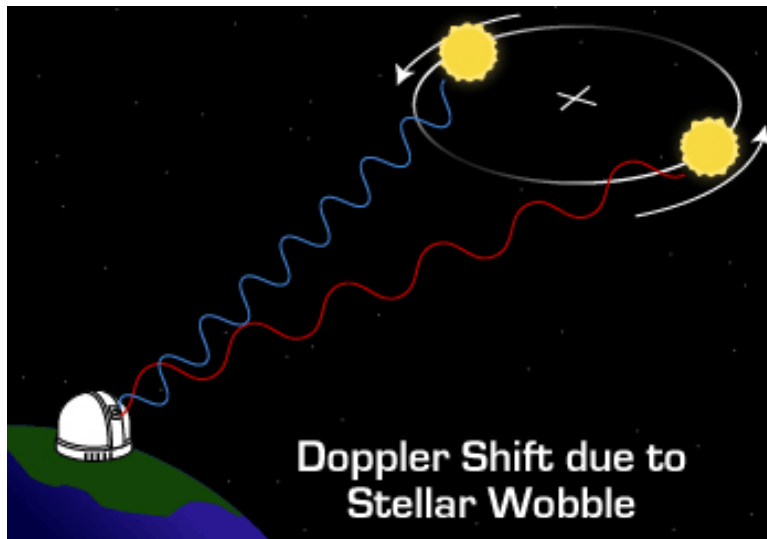
# JWST – finding life-bearing planets

searching for the goldilocks planet



# JWST – finding life-bearing planets

determining robust physical parameters



doppler method

determine planet mass

transit method

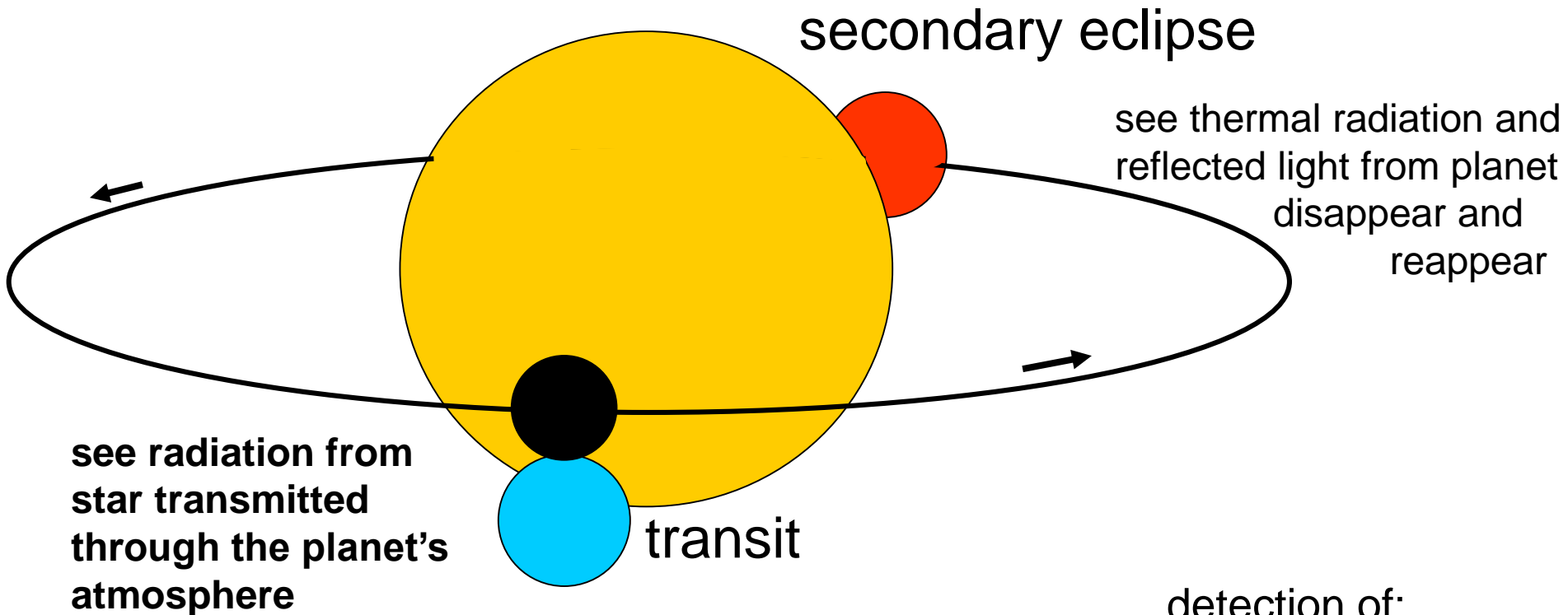
determine planet diameter

calculate planet density and infer composition:

gas giant (Jupiter), ice giant (Neptune), or rocky planet (Earth)

# JWST – finding life-bearing planets

transits allow studies of atmospheres



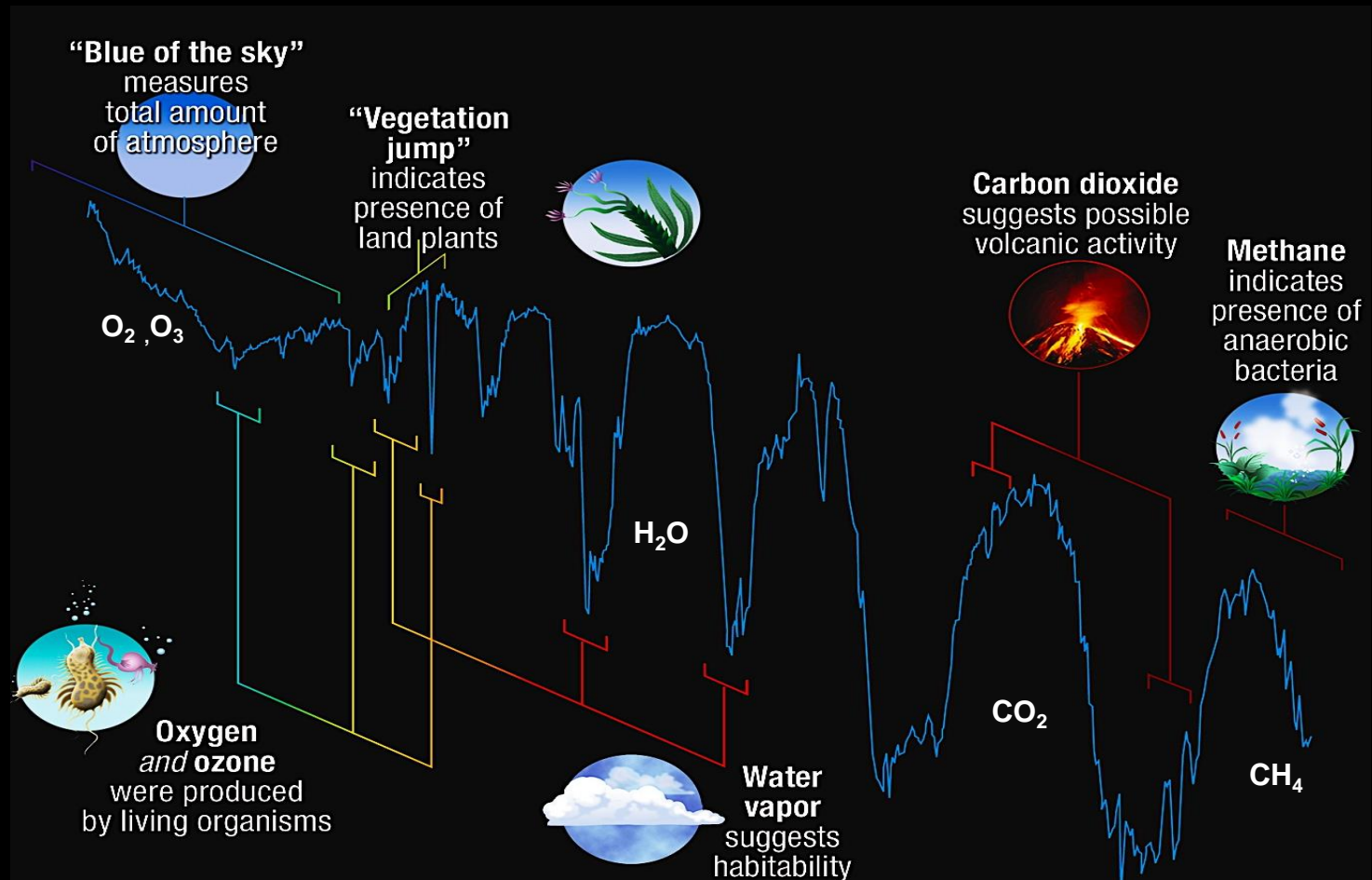
detection of:

- atoms, molecules
- stratospheres
- clouds
- winds



# JWST – finding life-bearing planets

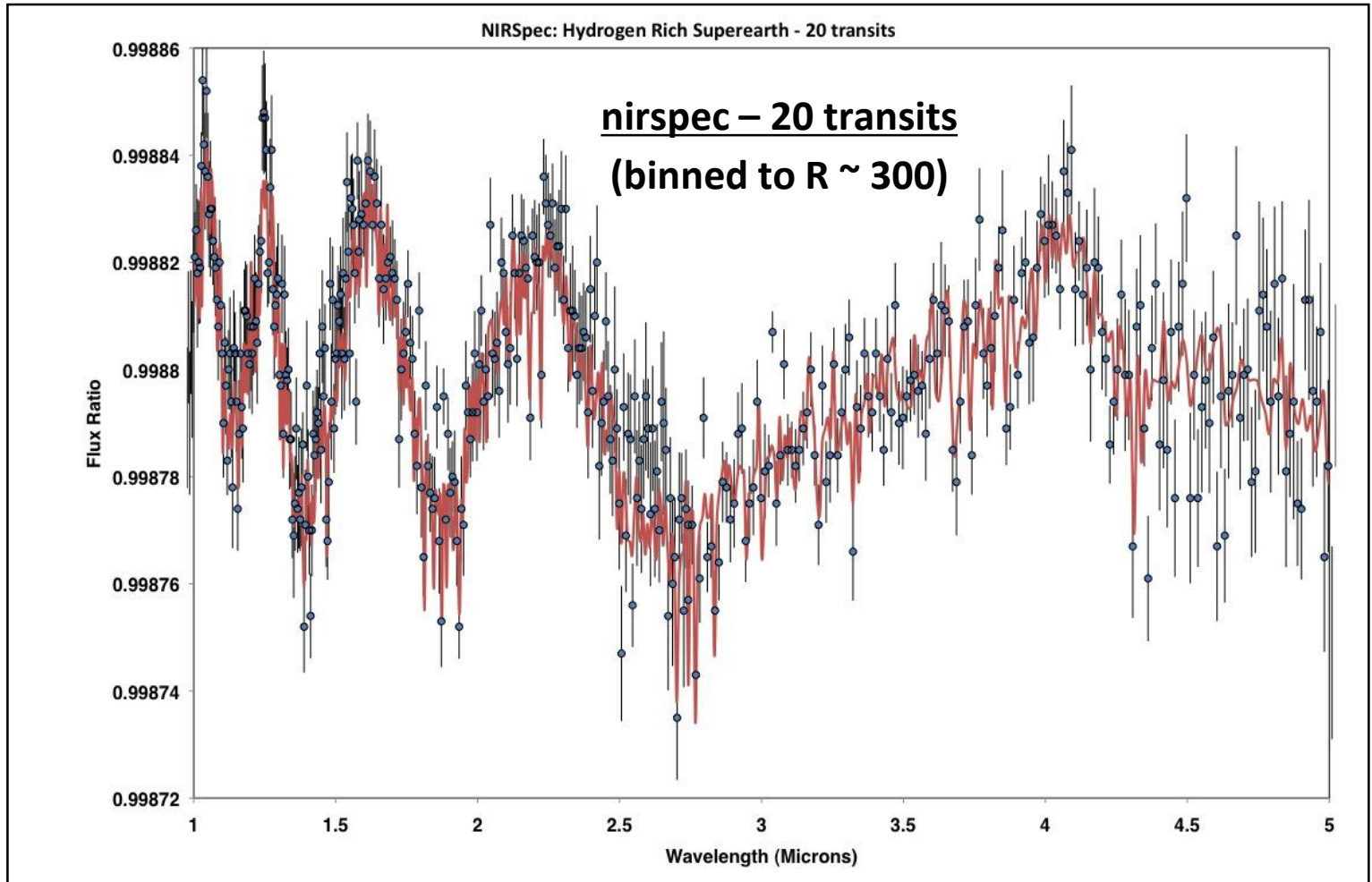
what would the Earth's spectrum look like?



# JWST – finding **life**-bearing planets

simulated JWST/nirspec observation

hydrogen-rich super earth ( $1.4 R_{\text{EARTH}}$ ,  $5 M_{\text{EARTH}}$ )



M. Clampin – Model by E. Kempton

this brings us to  
the **biggest** and  
most profound  
question facing all  
of astronomy today





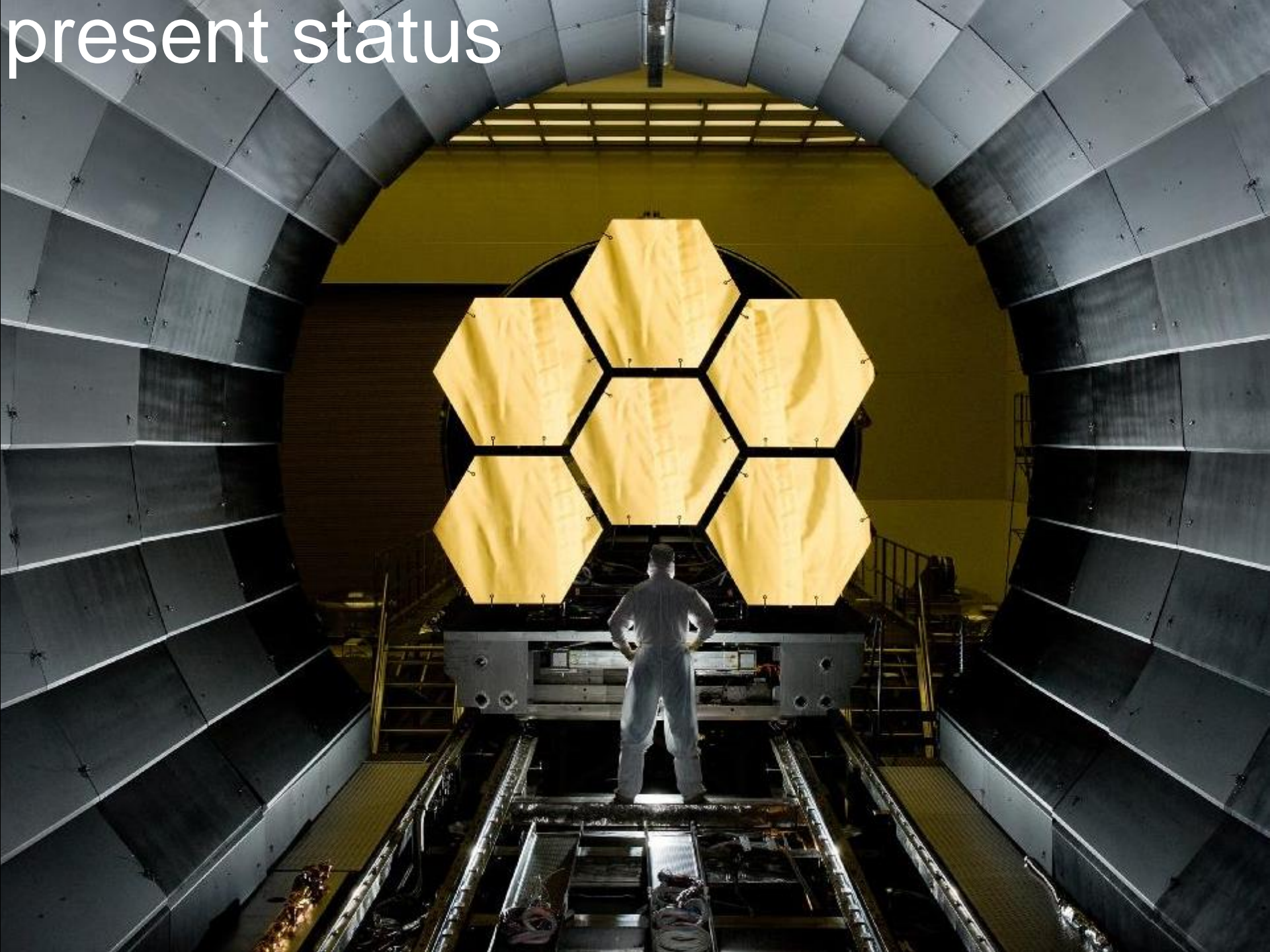
DADA...why did miss jamie say that you  
kicked out pluto because you're a **scientist!**

POOR  
PLUTO





present status





integration and testing



Thermal Vacuum Chamber A – JSC, Houston Texas

# JWST – launch



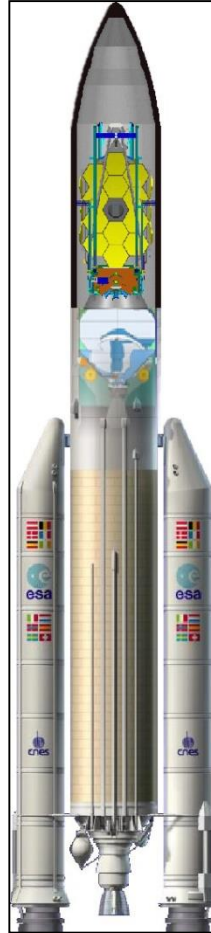


# JWST – launch





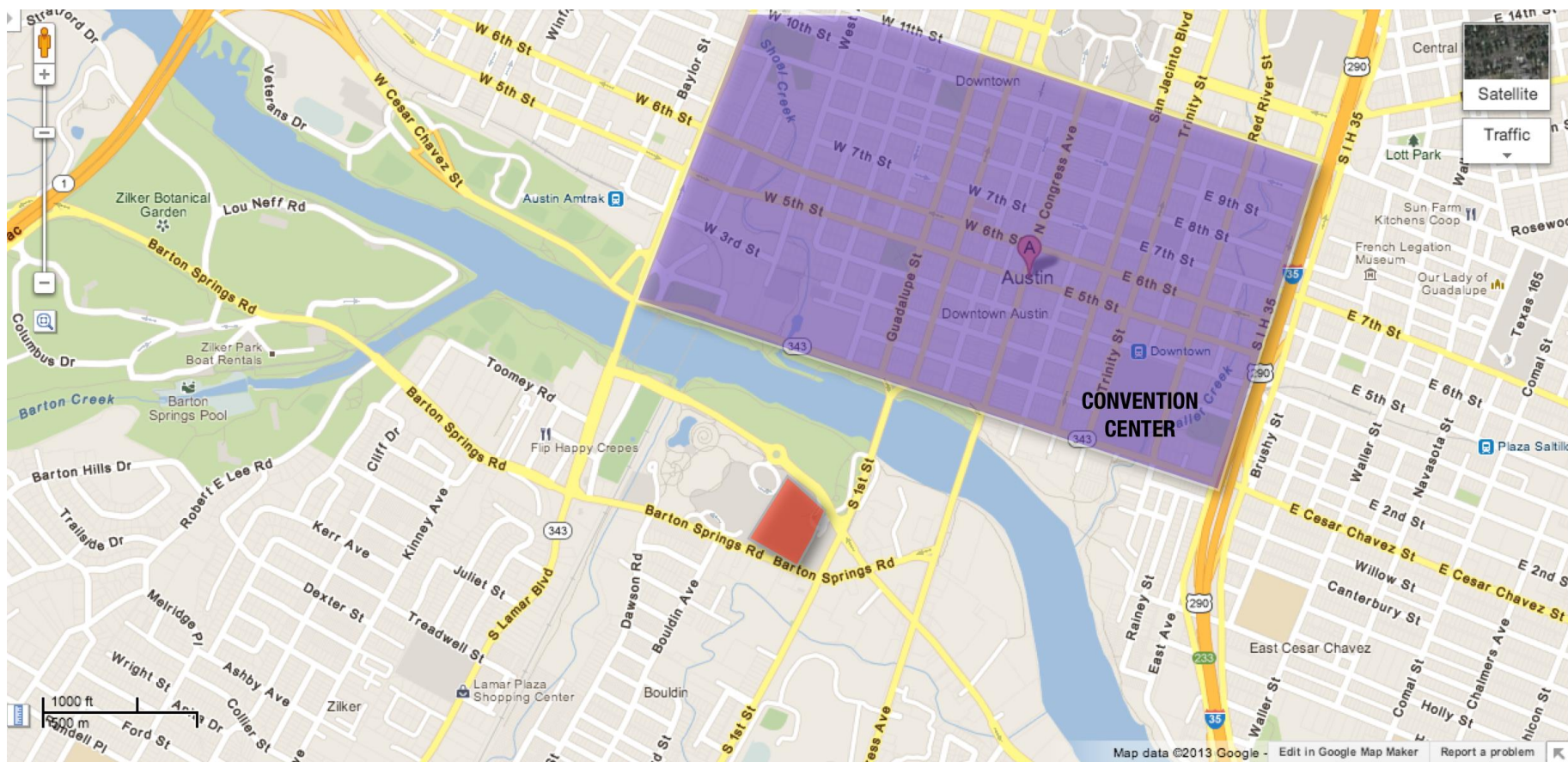
# JWST – launch



Arianespace – ESA - NASA



# come see us at South by Southwest Friday – Sunday, Long Center for Performing Arts



**LOCATION**  
LONG CENTER FOR THE PERFORMING ARTS, AUSTIN, TX

**Schedule:** <http://www.nasa.gov/externalflash/JWSTSXSXSW/>  
**Twitter:** #JWST



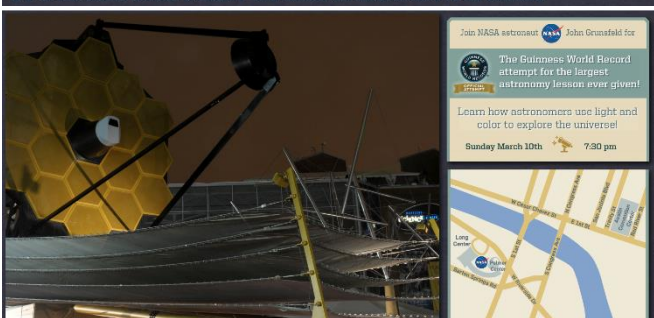
# come see us at South by Southwest Friday – Sunday, Long Center for Performing Arts

**MARCH 8, 2013**

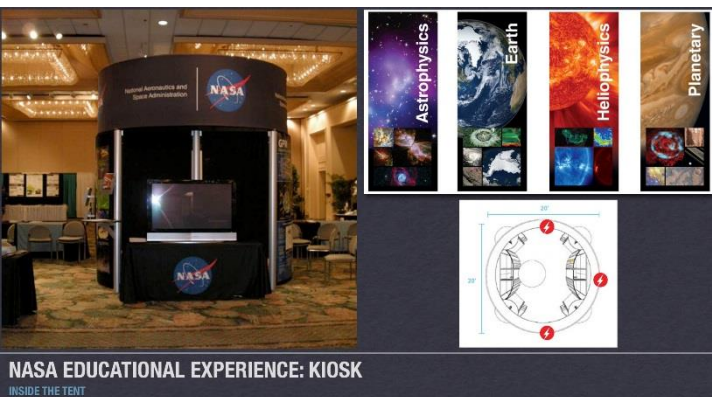
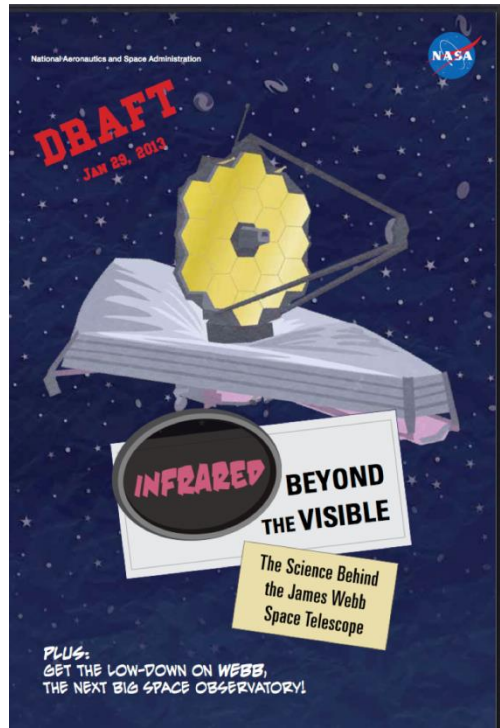
9:00 AM	Volunteer Briefing
9:30 AM	Volunteer Briefing
10:00 AM	STEM Education Event, WWT: Control the Universe
10:30 AM	STEM Education Event, WWT: Control the Universe
11:00 AM	STEM Education Event, WWT: Control the Universe
11:30 AM	STEM Education Event, WWT: Control the Universe
12:00 PM	Microsoft's Worldwide Telescope - Jonathan Fay (Microsoft), STEM Education Event
12:30 PM	NASA Exploration Videos, STEM Education Event
1:00 PM	[T] Beyond Hubble: Cosmic Mysteries and NASA's Webb Telescope - Dr. Jason Kalirai (STScI), STEM Education Event
1:30 PM	WWT: Control the Universe - Kinect Showcase
2:00 PM	[T] - Unraveling Cosmic Mysteries: Hubble and The Webb Space Telescope - Dr. Frank Summers (STScI)
2:30 PM	Skype Q&A from NASA Centers: Goddard Space Flight Center
3:00 PM	The Magic is in the Mirrors - Allison Barto (Ball)
3:30 PM	[T] - Engineering and Technology at the Extremes: The Webb Space Telescope - Scott Willoughby (NGAS)
4:00 PM	NASA's Webb Telescope in Texas - Steve Finkelstein (UT)
4:30 PM	Skype Q&A from NASA Centers: Johnson Space Flight Center
5:00 PM	Crowd-Sourcing Science: YOU Be the Discoverer! - Dr. Pamela Gay (CosmoQuest)
5:30 PM	Microsoft's Worldwide Telescope - Jonathan Fay (Microsoft)
6:00 PM	[T] Dawn of the Universe: Webb is a Cosmic Time Machine - Dr. James Bullock (Irvine)
6:30 PM	WWT: Control the Universe - Kinect Showcase
7:00 PM	Star Party, Keynote - NASA's Webb Telescope in Texas - Dr. Jeff Hanley (NASA), Dr. Mary Cerimeli (NASA)
7:30 PM	Star Party, Keynote - NASA's Webb Telescope in Texas - Dr. Karl Gebhardt (UT), Dr. Sarah Tuttle (UT)
8:00 PM	Star Party, [T] - Engineering and Technology at the Extremes: The Webb Space Telescope - Scott Willoughby (NGAS)
8:30 PM	Star Party, [T] - Beyond Hubble: Cosmic Mysteries and NASA's Webb Telescope - Dr. Amber Straughn (NASA)
9:00 PM	Star Party, Microsoft Star Party, Worldwide Telescope - Jonathan Fay (Microsoft)
9:30 PM	Star Party, Crowd-Sourcing Science: YOU Be the Discoverer! - Dr. Pamela Gay (CosmoQuest)
10:00 PM	Star Party, [T] - Unraveling Cosmic Mysteries: Hubble and The Webb Space Telescope - Dr. Frank Summers (STScI)
10:30 PM	Star Party, Viz Wall Open House
11:00 PM	Star Party, Viz Wall Open House
11:30 PM	Star Party, Viz Wall Open House
12:00 AM	Day Ends



**GOOGLE HANGOUTS AND STAR PARTIES**  
BE AT THE EVENT REMOTELY WITH DAILY G+ HANGOUTS - LOCAL AMATEURS STAR PARTIES IN FRONT OF THE FULL SCALE MODEL

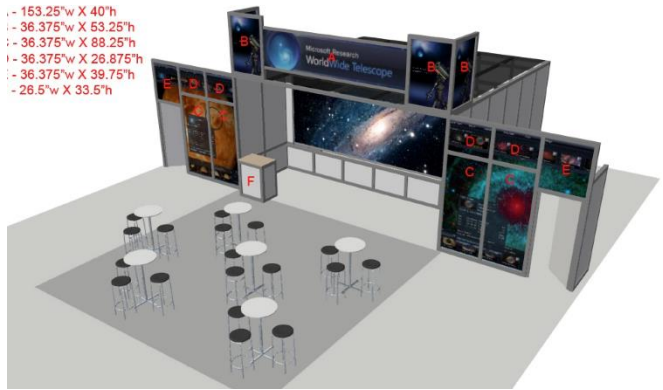


**GUINNESS WORLD RECORD**  
LARGEST ASTRONOMY LESSON - BY JOHN GRUNSFELD AND OUR OWN FRANK SUMMERS - RECORD STANDS AT 488



**NASA EDUCATIONAL EXPERIENCE: KIOSK**  
INSIDE THE TENT

- 153.25'w X 40'h
- 36.375'w X 53.25'h
- 36.375'w X 88.25'h
- 36.375'w X 26.875'h
- 36.375'w X 39.75'h
- 26.5'w X 33.5'h



follow #JWST on twitter

Schedule: <http://www.nasa.gov/externalflash/JWSTSXSXSW/>

# James Webb



**James Webb (1906 – 1992)**

second administrator of NASA (1961 – 1968)  
oversaw 1<sup>st</sup> manned spaceflight program (mercury)  
oversaw 2<sup>nd</sup> manned spaceflight program (gemini)  
oversaw mariner planetary exploration program  
oversaw pioneer planetary exploration program  
oversaw apollo program



# Hubble's 'frontier fields' (2013 – 2016)

Pandora's Cluster  
Abell 2744



Abell 370



MACS0416-24



dark matter  
gas

innovative design (6 fields)  
first deep lensed IR images  
+  
new "blank" deep fields



follow the STScI blog: <https://blogs.stsci.edu/hstdfi/>