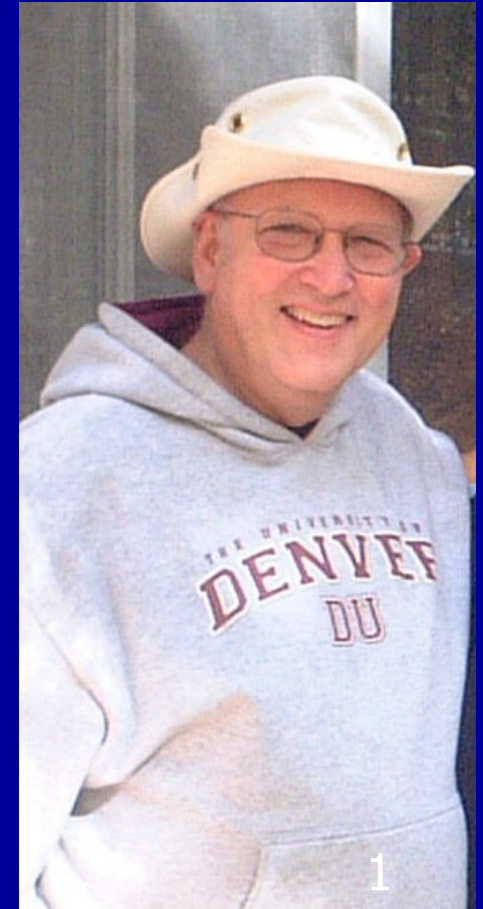
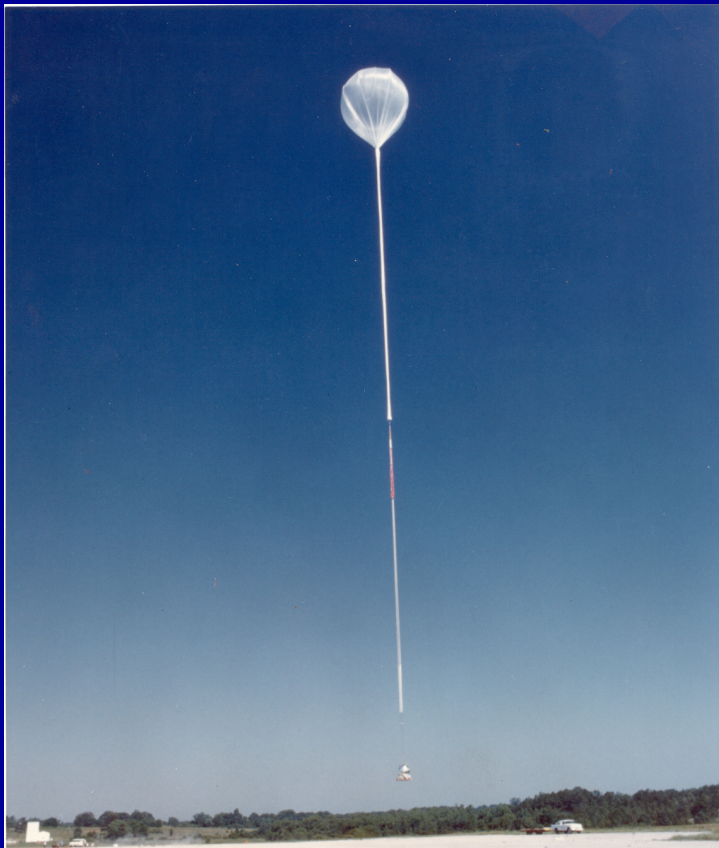
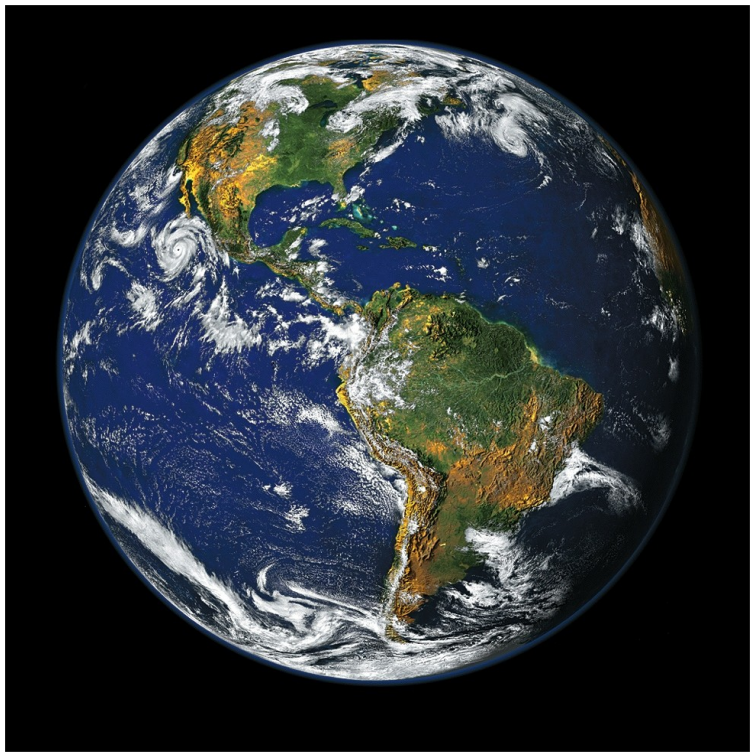


# Director of Space Sciences 2000-2004





# Lecture 1: History of the Earth

Music to gather by

<https://www.youtube.com/watch?v=4-GC20KIRUY>

**Learners:** *Ice Ages and Climate*

October 2 - November 14, 2019

Jonathan F. Ormes

[JFOrmes@comcast.net](mailto:JFOrmes@comcast.net)



# Stanford University



# UNIVERSITY OF MINNESOTA



# Public Announcement

Presentation slides and handouts can be downloaded from  
my public Web site at DU:

<http://portfolio.du.edu/OurClimate>

The site is public.

You do not need to create an account.

On Google, you can search for "[OurClimate](#)".

Lectures will be posted in the right hand column under the label

*[Ice Ages and Climate](#)*



# Course outline

1. A brief history of the planet
  - Evolution of atmosphere
  - Snowball Earth events
  - Mass extinctions
2. Paleoclimate and Ice Ages
  - *The Two Mile Time Machine* by Richard Alley
3. Current climate
4. How do we know it is human caused
5. What can be done?
  - Energy revolution and climate prospects
  - Predicting the future
  - Ethics and scarcity

# Visit NICL (November 20<sup>th</sup>)





# This from Richard Nunn regarding access to the NICL.

Denver Federal Center  
One Denver Federal Center  
Building 810, Entrance E-11, MS 975  
Denver, CO 80225-0046

**Bring warm coat,  
gloves and hat.**

Take 6th Avenue to the Kipling Avenue south exit. Take Kipling Avenue south to the second light at **Gate 1** of the Denver Federal Center. Turn right into Gate 1. Be prepared to show picture identification at the gate. After clearing security, drive through the gate straight ahead (the road curves somewhat to the left) to the second stop sign. Turn left. As you turn you will see the first in a series of blue and white signs that will guide you around Building 810 to NICL. Follow these signs to Door S-29. Parking is unrestricted.

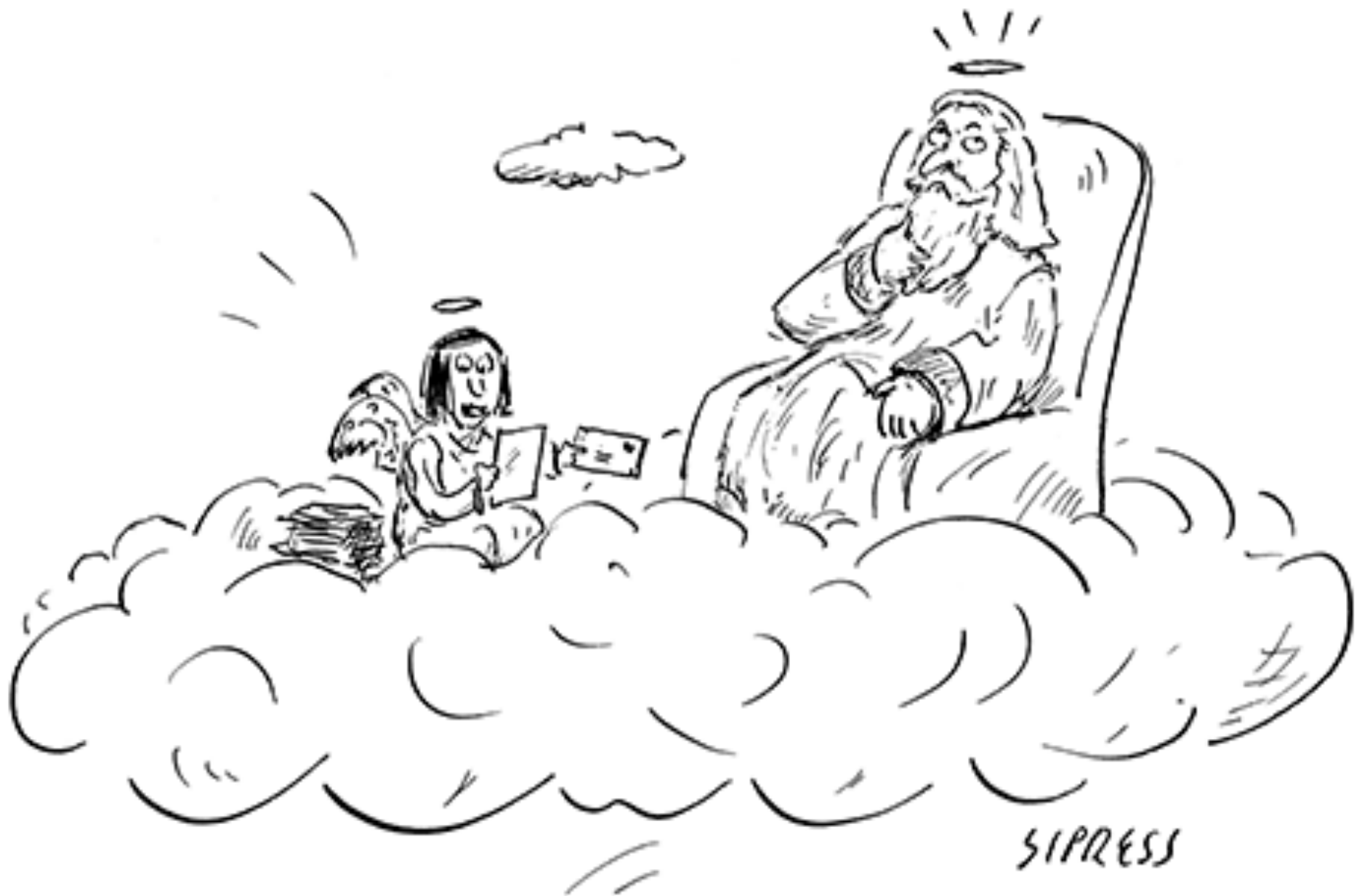
Everyone will need to have some form of ID such as a **driver's license.**

**Non-US citizens,** must have their **green cards or passports** for identification.

# Why this lecture?

- Put homo sapiens in perspective
- Put Earth in perspective
- Give background as to where we came from to give some context for discussion of what might be in store in the future





©New  
Yorker  
*"Mrs. Marsha Mullhouse, of Kenosha, Wisconsin, asks, 'Are You subject to the laws of physics, or are the laws of physics subject to You?' "*



# calvin and Hobbes

by WATSON ©1992

I'VE BEEN READING  
ABOUT THE BEGINNING  
OF THE UNIVERSE.  
THEY CALL IT  
"THE BIG BANG."

ISN'T IT WEIRD HOW SCIENTISTS  
CAN IMAGINE ALL THE MATTER  
OF THE UNIVERSE EXPLODING  
OUT OF A DOT SMALLER THAN  
THE HEAD OF A PIN, BUT THEY  
CAN'T COME UP WITH A MORE  
EVOCATIVE NAME FOR IT  
THAN "THE BIG BANG"?

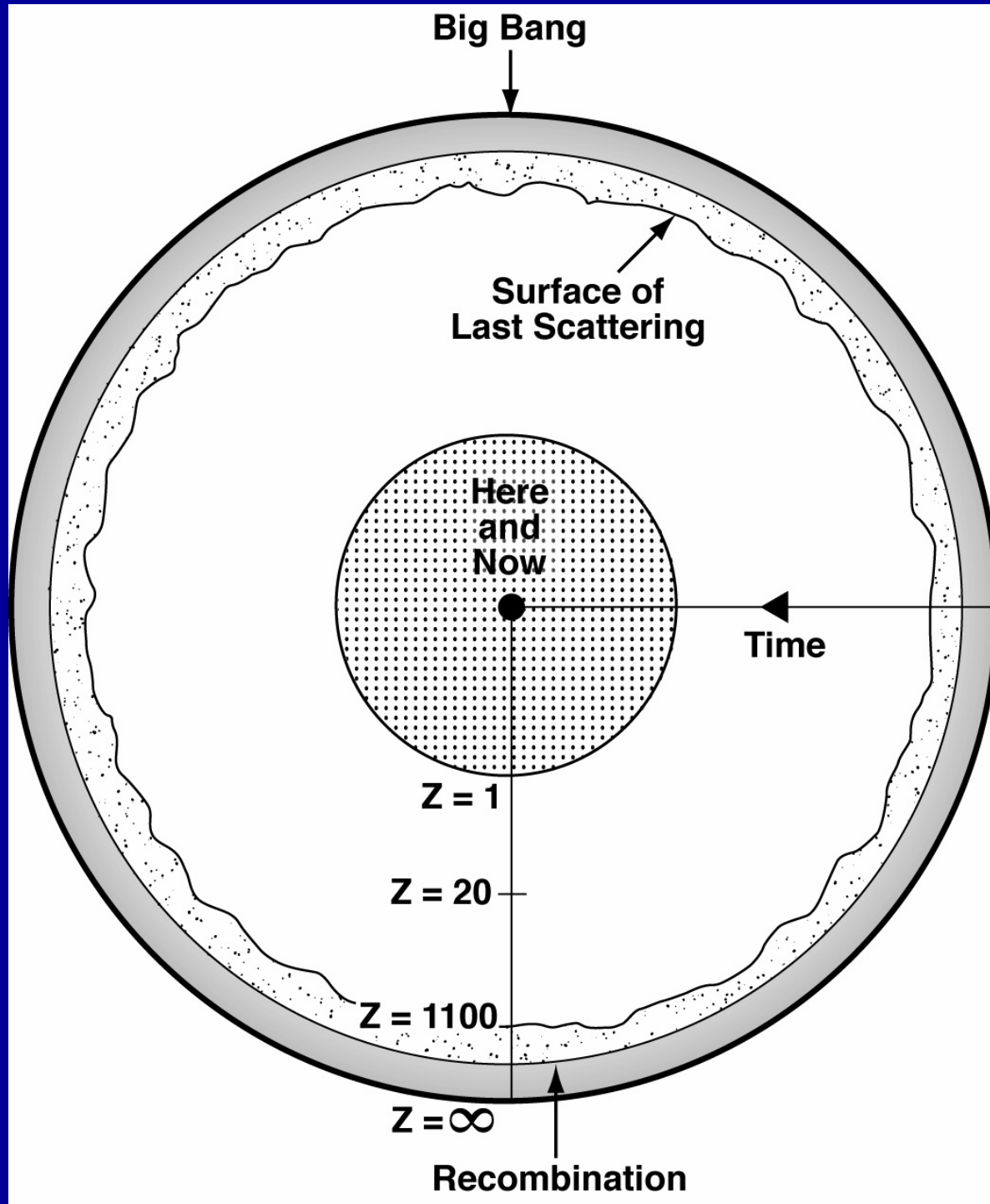
**Big Bang - Cosmic Explosion**  
**13.7 billion years ago**

**IMPOSSIBLE TO  
DRAW A PICTURE!**



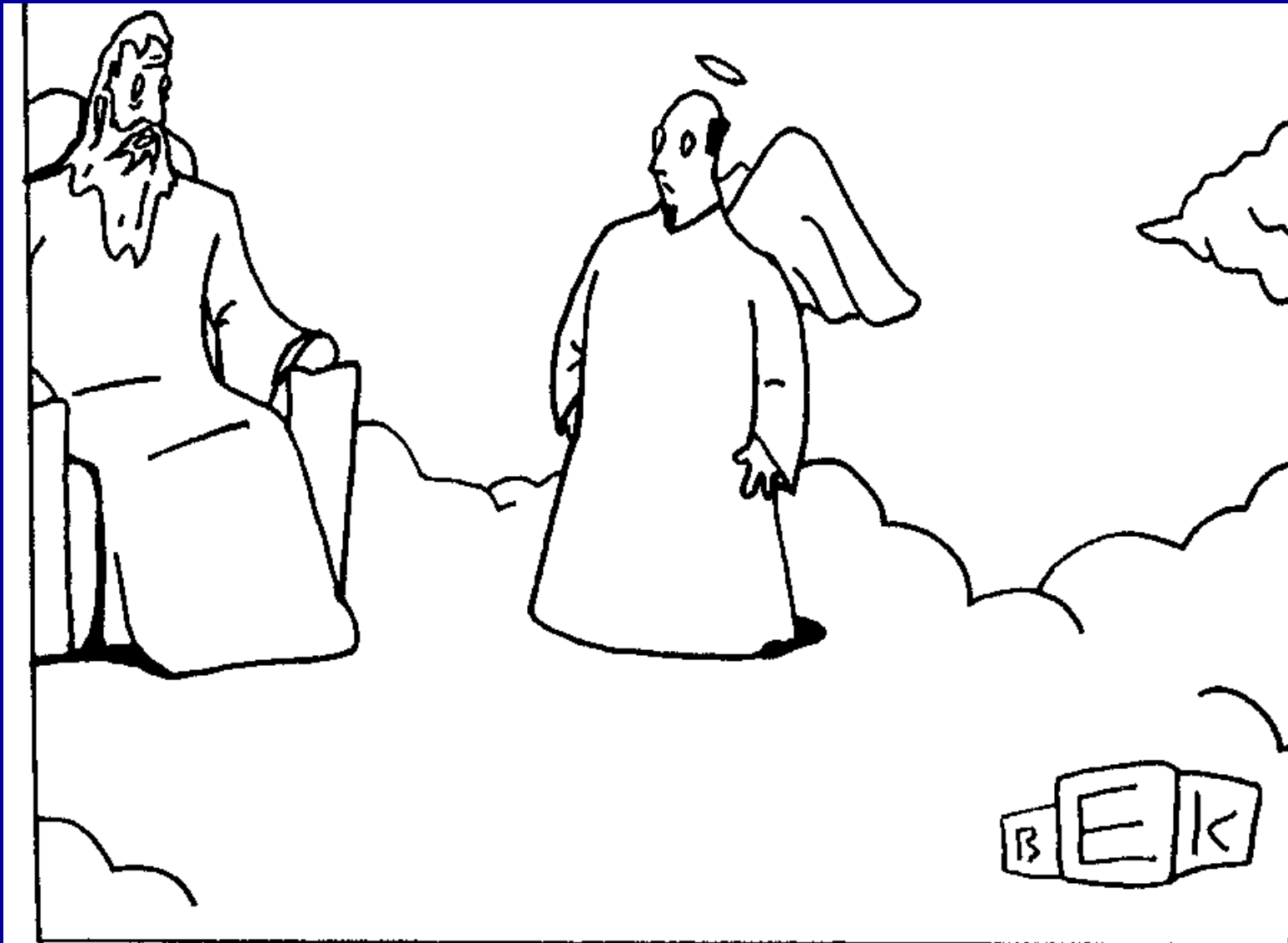
# The Big Bang

- It leads back to a singularity with infinite density – mathematical and physical nonsense – need quantum gravity
- We are at the exact center of our observable Universe, as is every place in the Universe.
- We are inside the Universe, so the Big Bang is not like an explosion we observe from outside.



# The Big Bang

## Philosophical Significance?



*"This is a little embarrassing to admit, but everything that happens, happens for no real reason."*

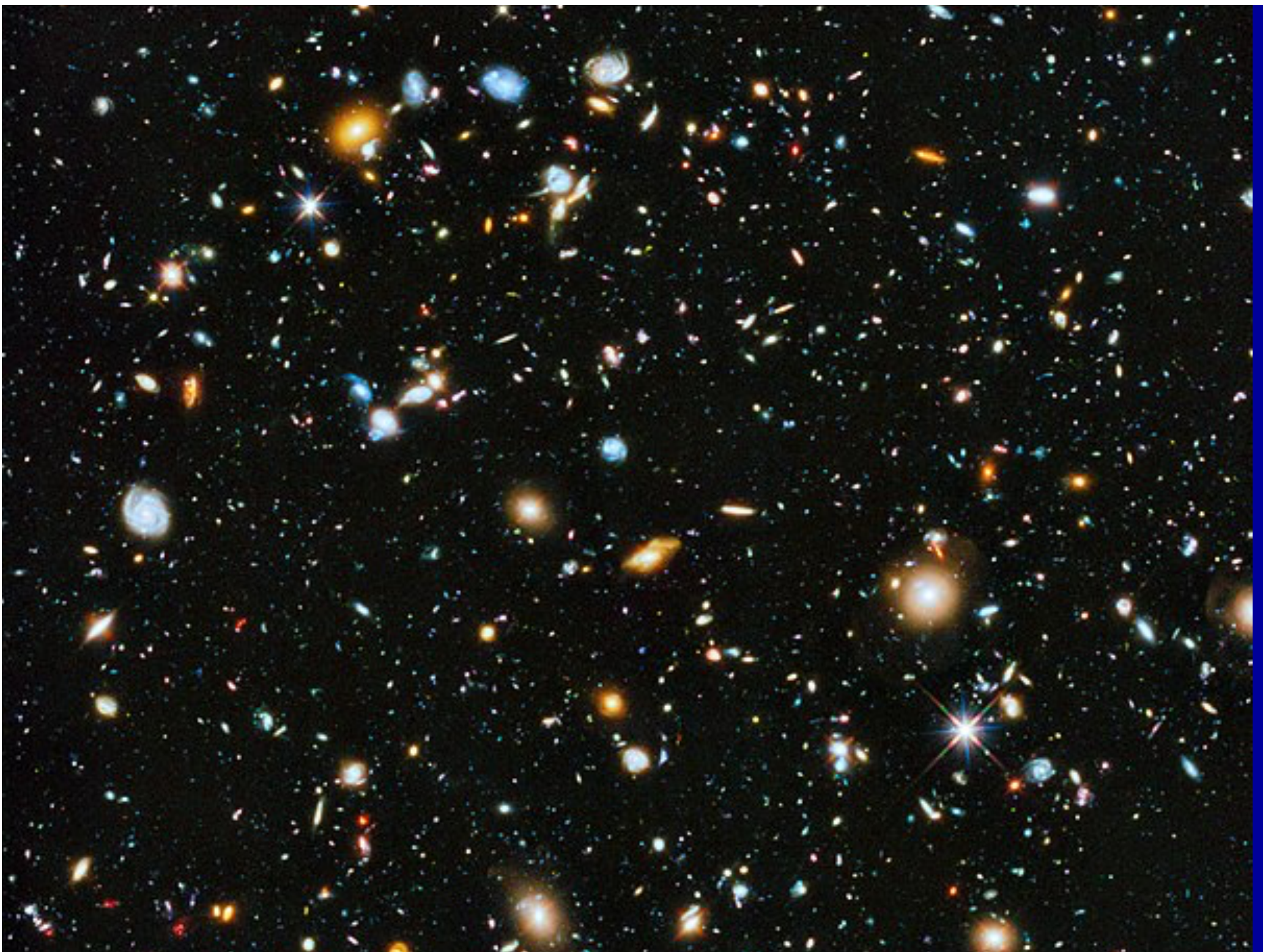


# If the Universe were one day long

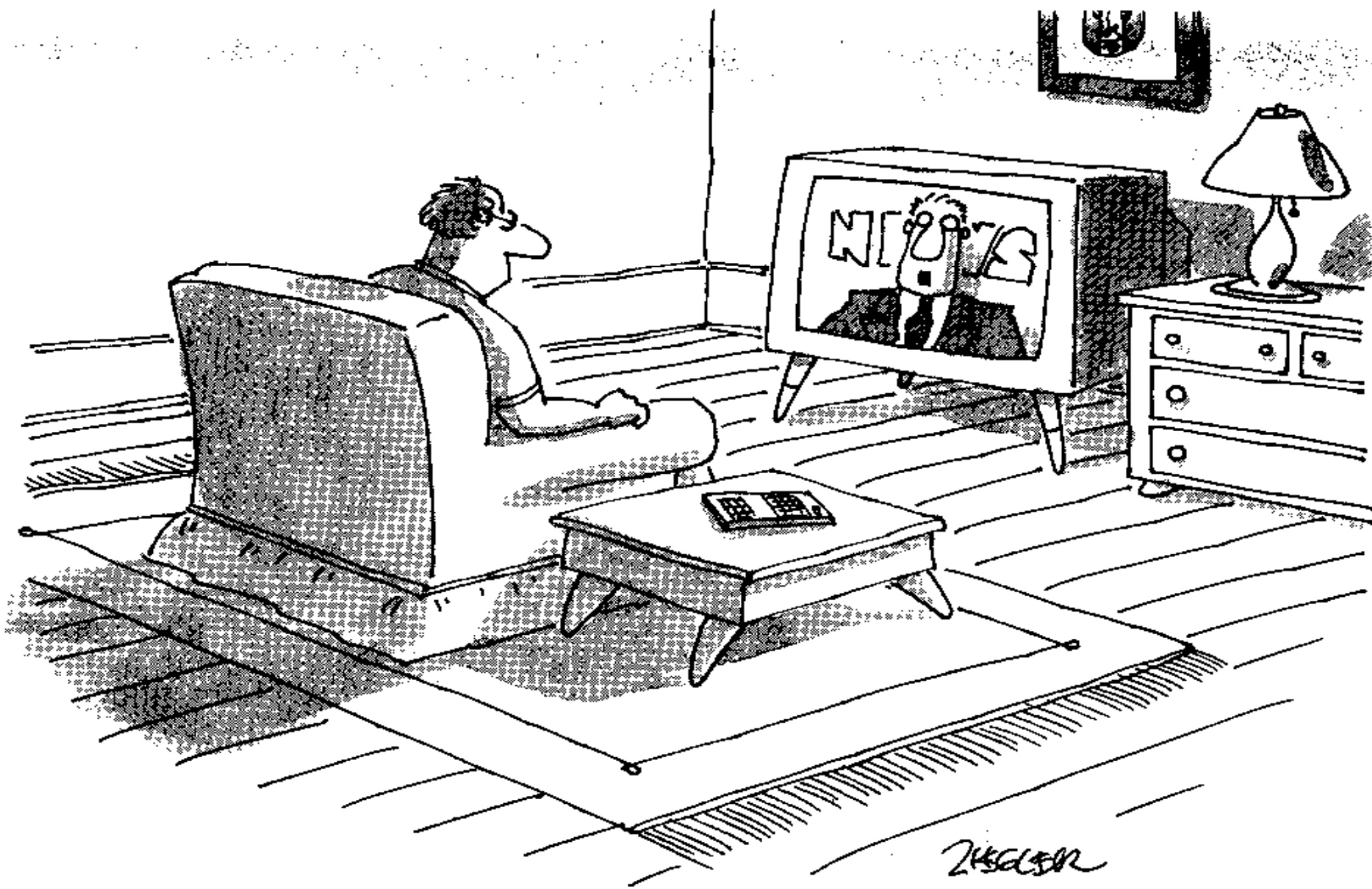
- On the clock of the Universe, starting at 13.7 Gya, solar system formed (4.55 Gya) at about 4 PM in the afternoon

# If the Earth was now one day old

- Hominins (not chimpanzees) appear (2Mya) at 37 seconds before midnight
- Homo sapiens (2-300,000 ya) 3-5 seconds before midnight



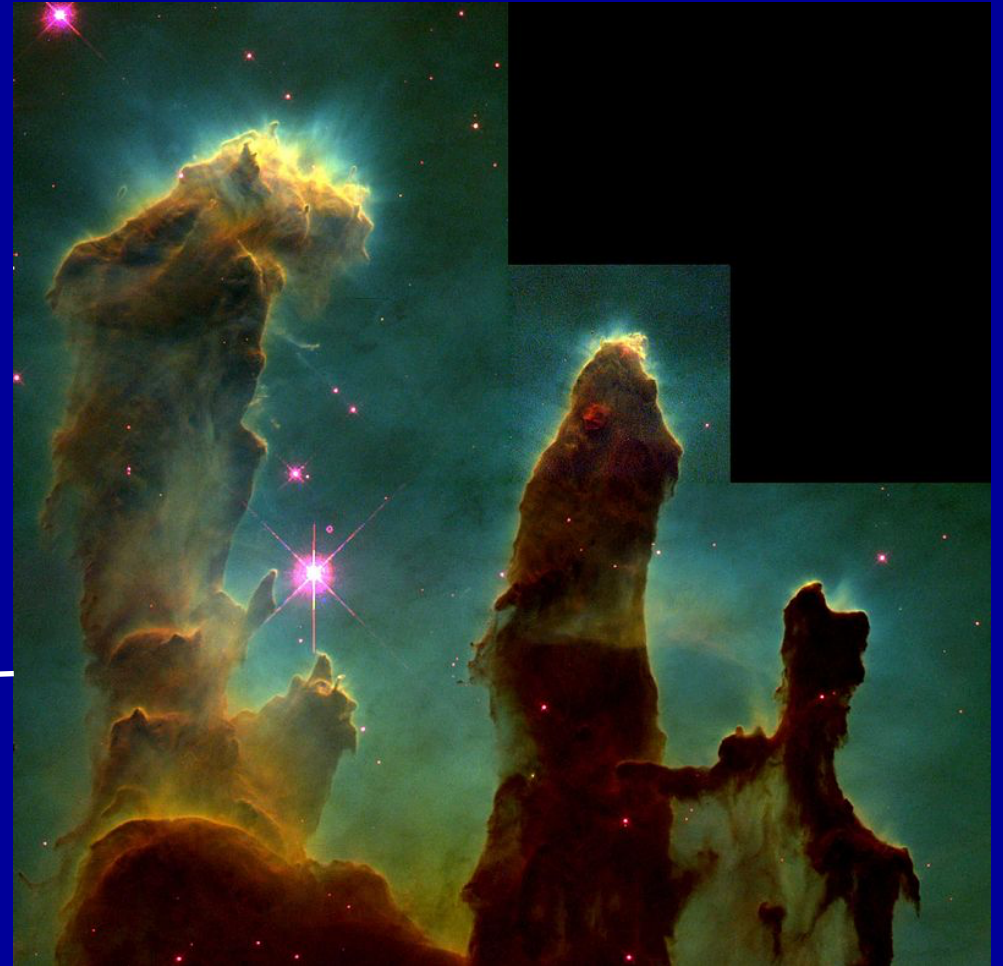
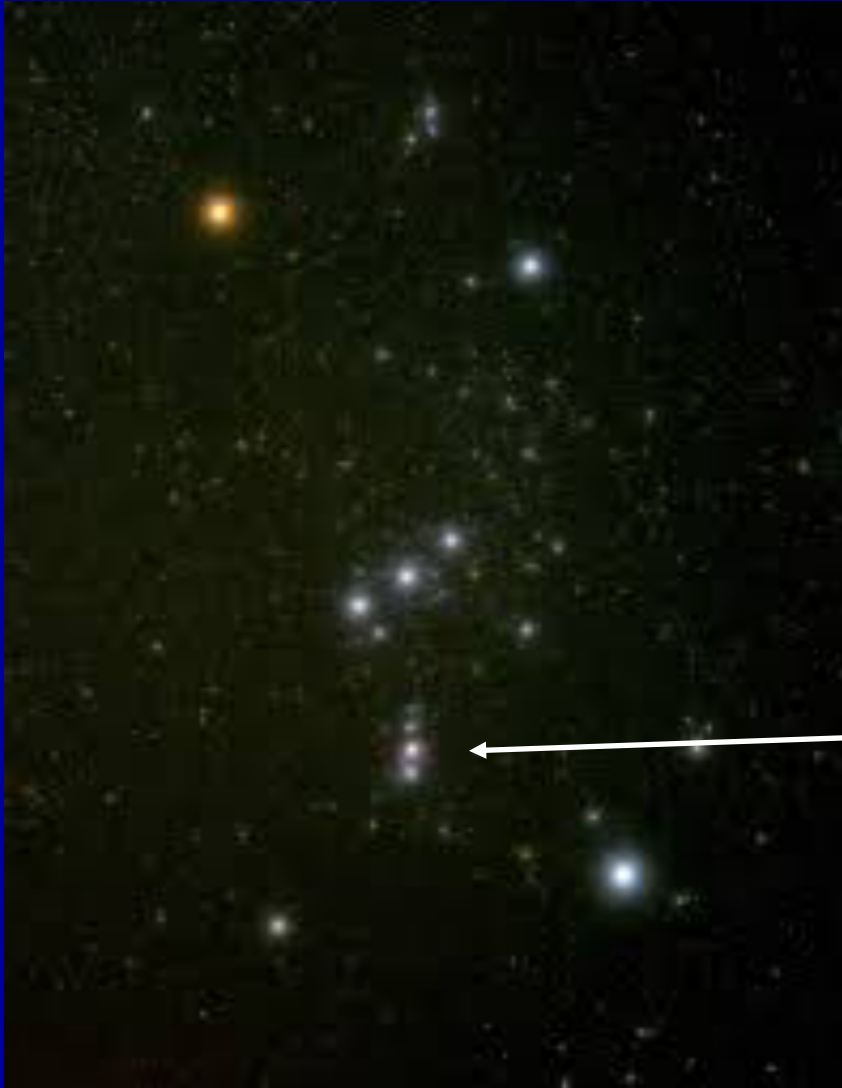




*"Scientists confirmed today that everything we know about the structure of the universe is wrongedy-wrong-wrong."*

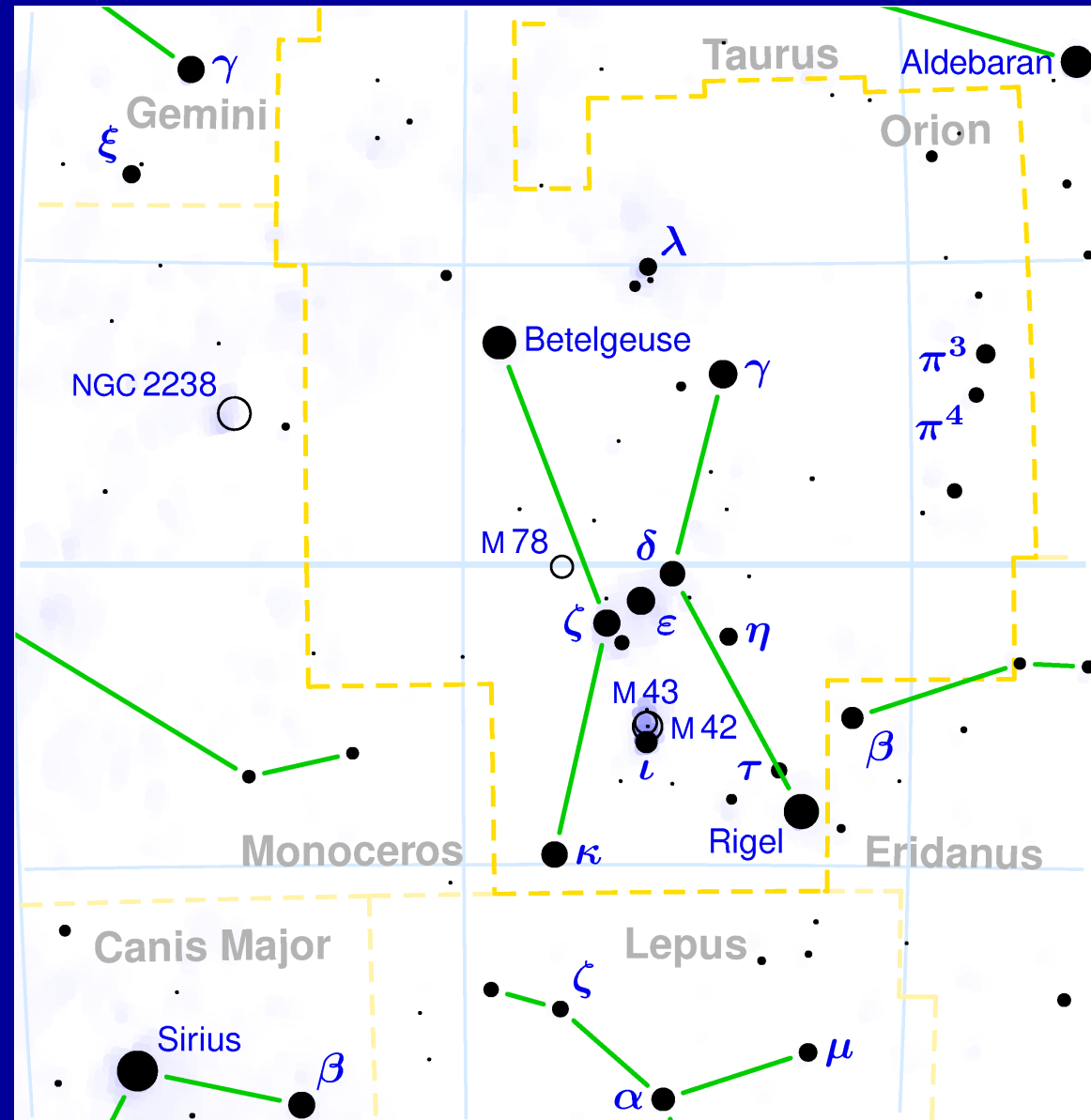


# Orion Nebula



**Credit: Hubble Space Telescope**

# The Constellation Orion



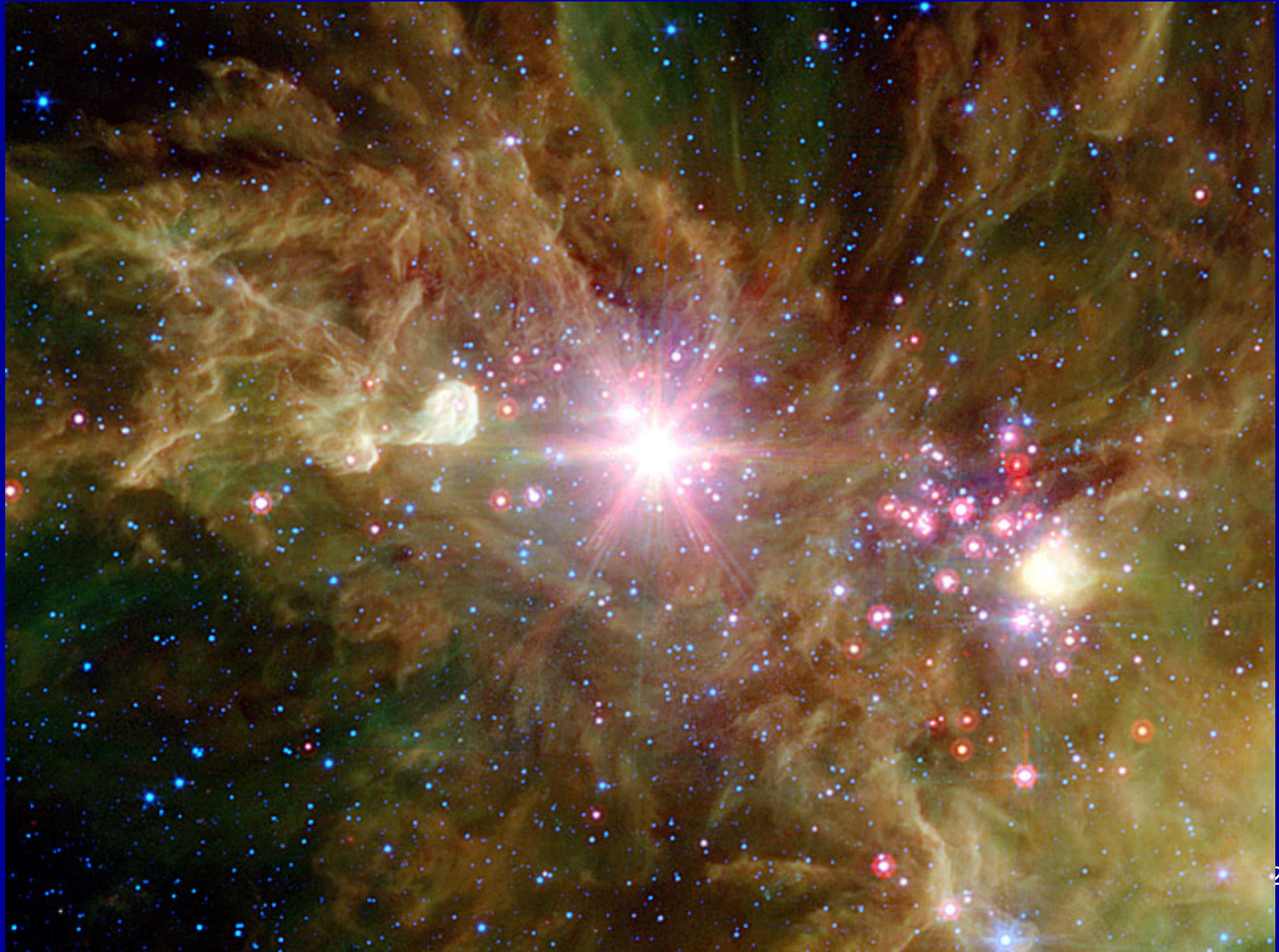


# Orion Nebula





# Another stellar nursery: the Snowflake Cluster



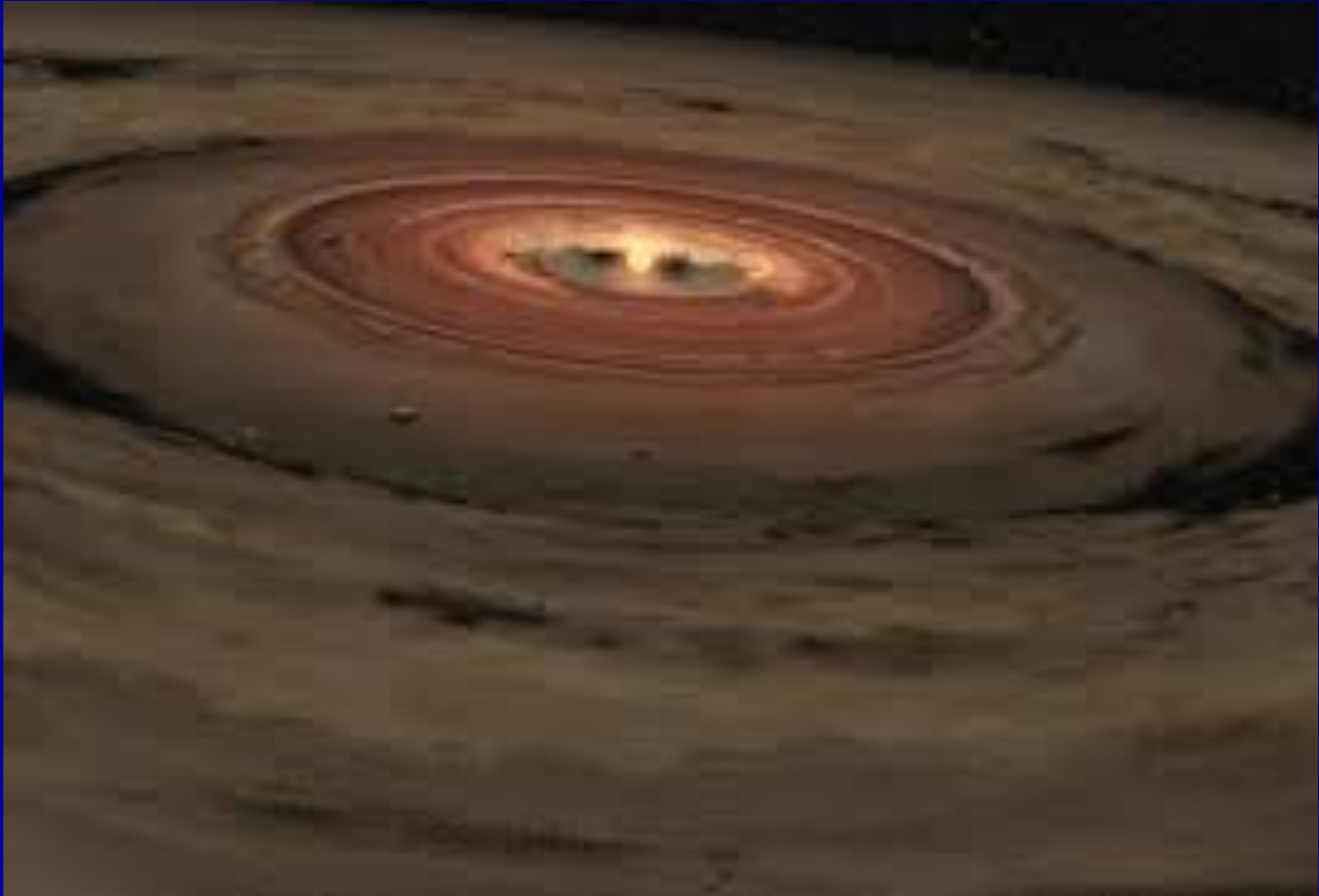


# A Star is Born

**Pretty, but not Judy Garland.**



# protostar

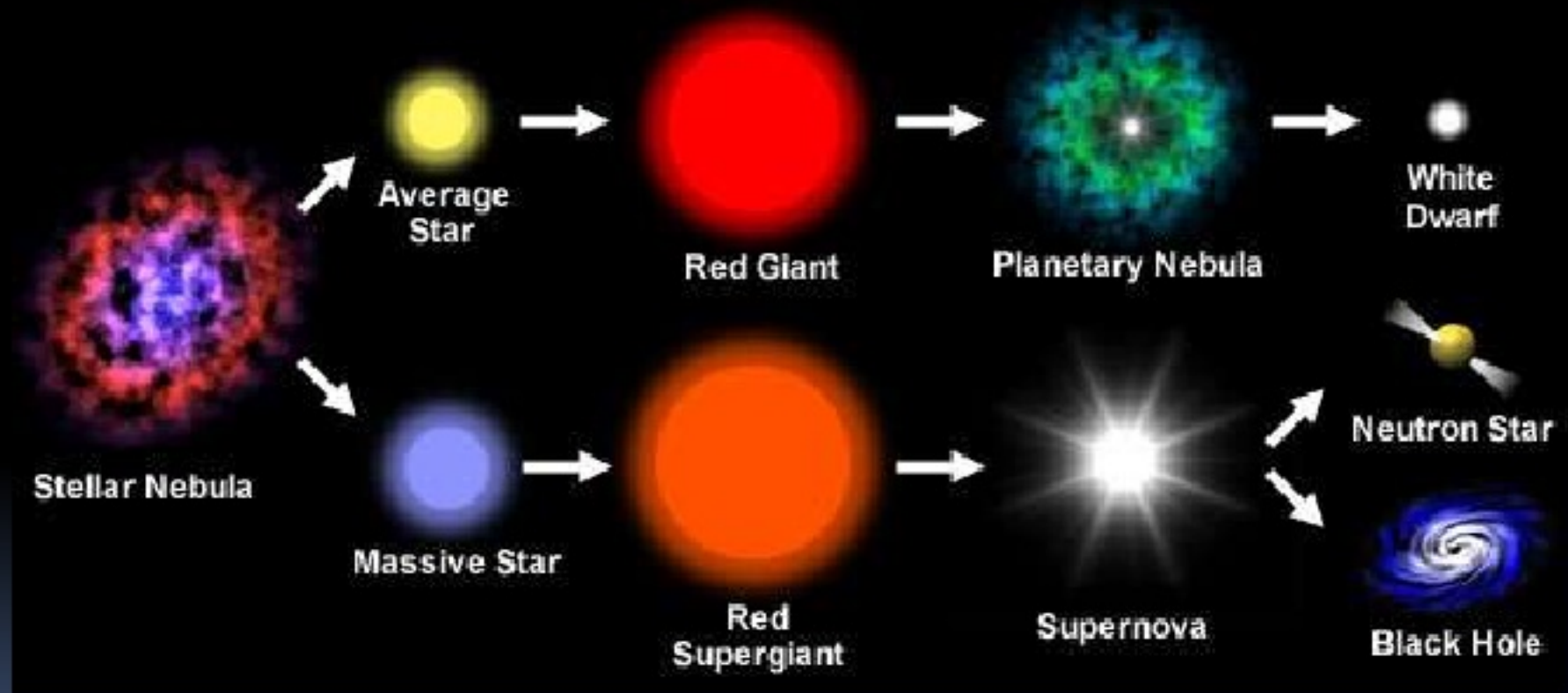




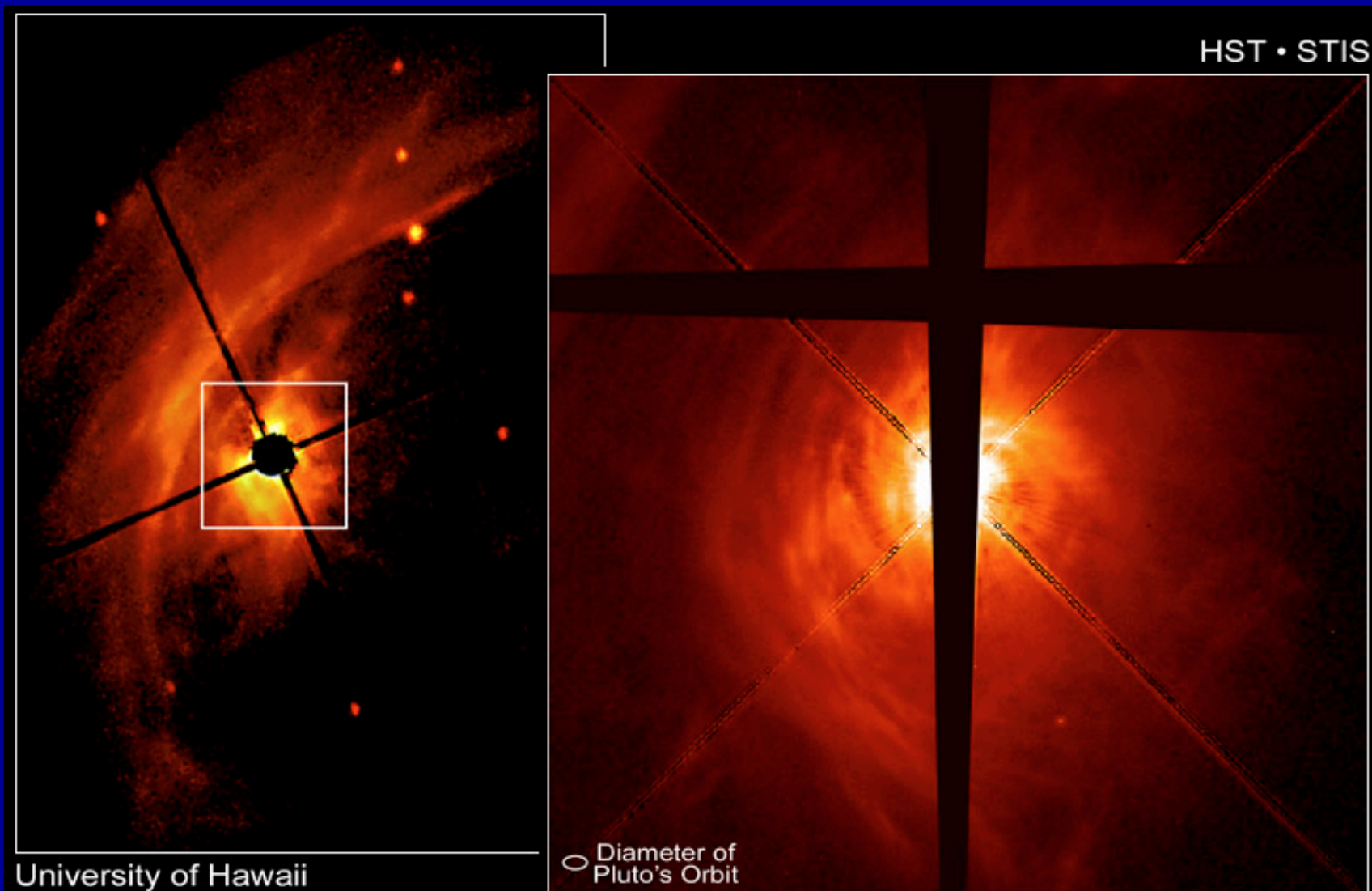
# Stellar death

- Stars build the elements, especially in their death throws
- Stellar death recycles stellar ashes to the interstellar medium
- New stars are made with heavy nuclei
  - First generation stars had no heavy nuclei
  - They were larger (more massive) and lived only a short time

## Life Cycle of a Star



# Protoplanetary Disks

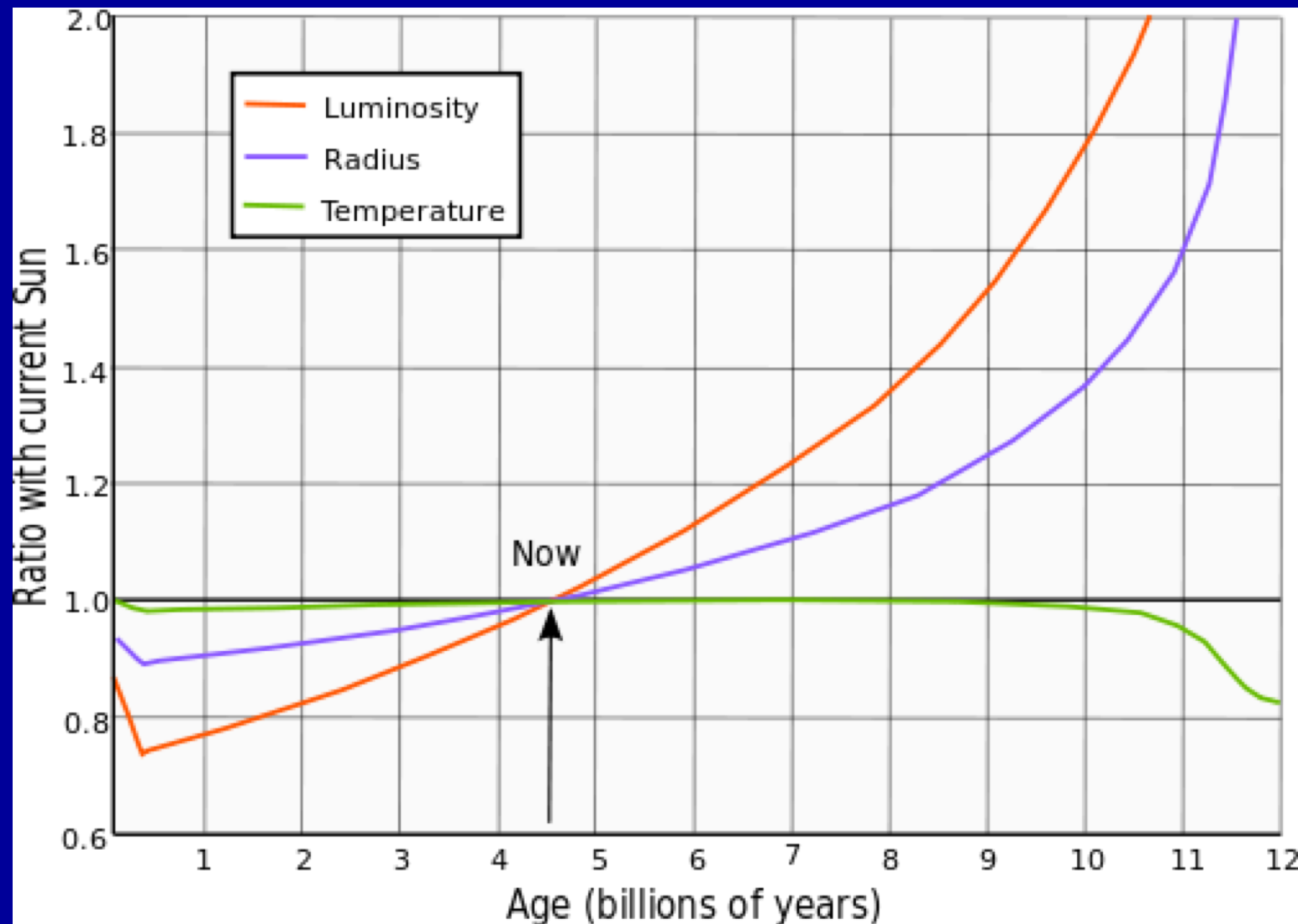


## AB Aurigae Disk

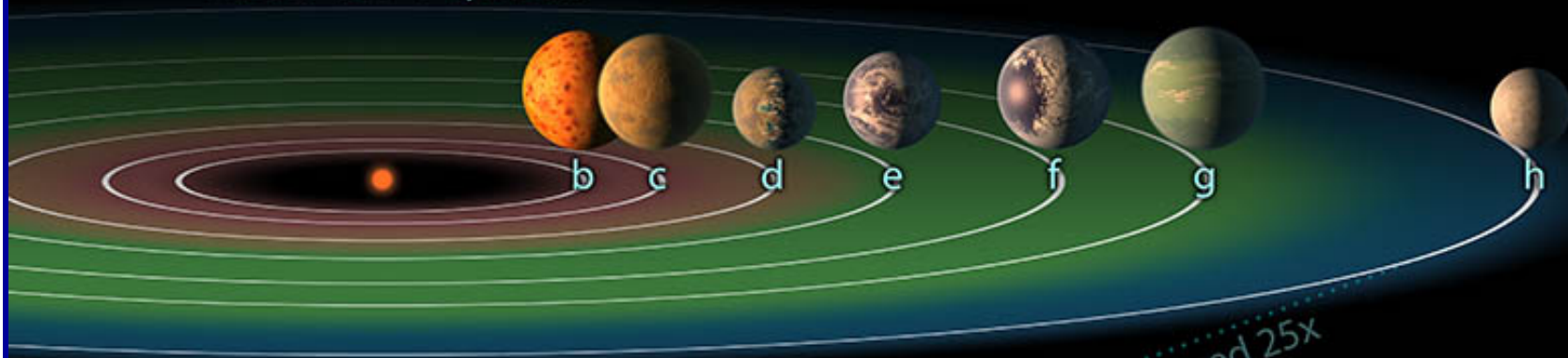
PRC99-21 • STScI OPO • C. Grady (NOAO at NASA Goddard Space Flight Center) and NASA



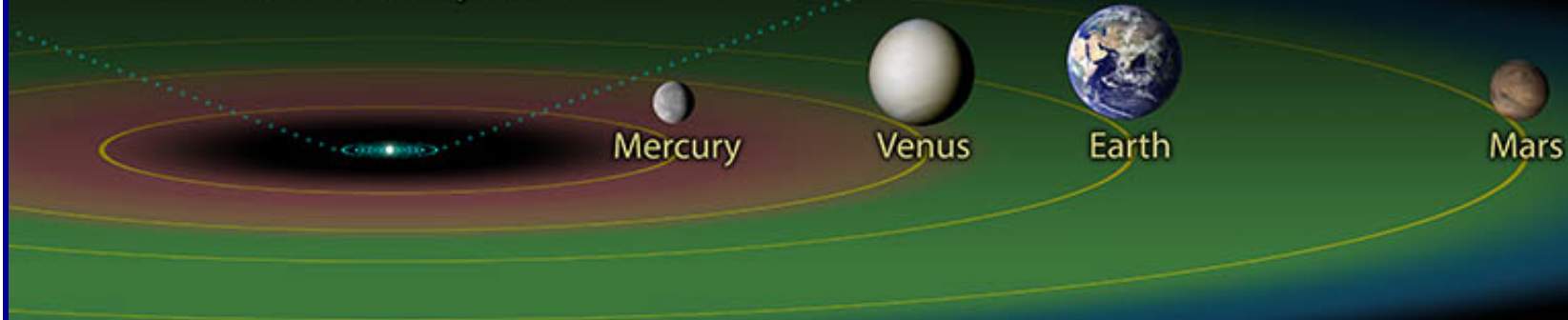
# The sun evolves



## TRAPPIST-1 System



## Inner Solar System



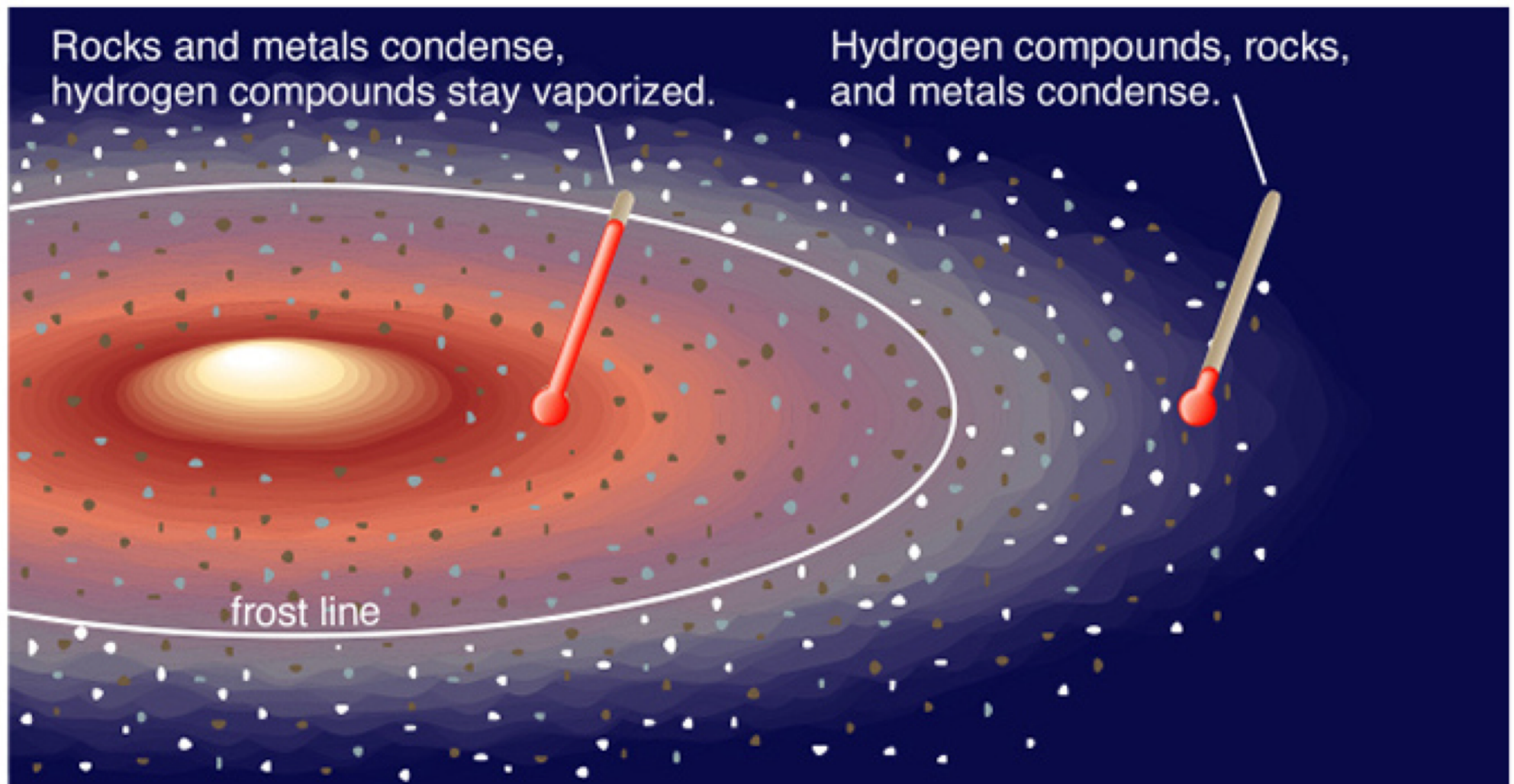
Illustration

**Kepler: 1200 planets =>  
500 million planets orbiting stars like sun in our Milky Way galaxy**





# Frost line



# origin of the moon

**Early Earth suffered, for almost 0.5 billion years, from an extensive meteoroid bombardment (until 4. Bya??).**

**The moon was probably created by the impact of a Mars sized object making a glancing blow of proto-Earth leaving behind debris out of which the Earth and moon coalesced.**

**The object is called Theia after the mother of Selene, the Greek goddess of the moon.**

**This explains lack of volatiles and iron, while preserving other Earth-moon similarities.**

**Lunar mare (dark areas) created 3–3.5 Bya.  
Later large impacts fractured the lunar crust.  
Produced massive lava flows from interior.**





# Formation of the oceans

**Comets brought water**

**4. Bya when Earth  
was 0.5 billion years old**

**Meteorites brought iron  
other metals (and probably  
some of the water)**

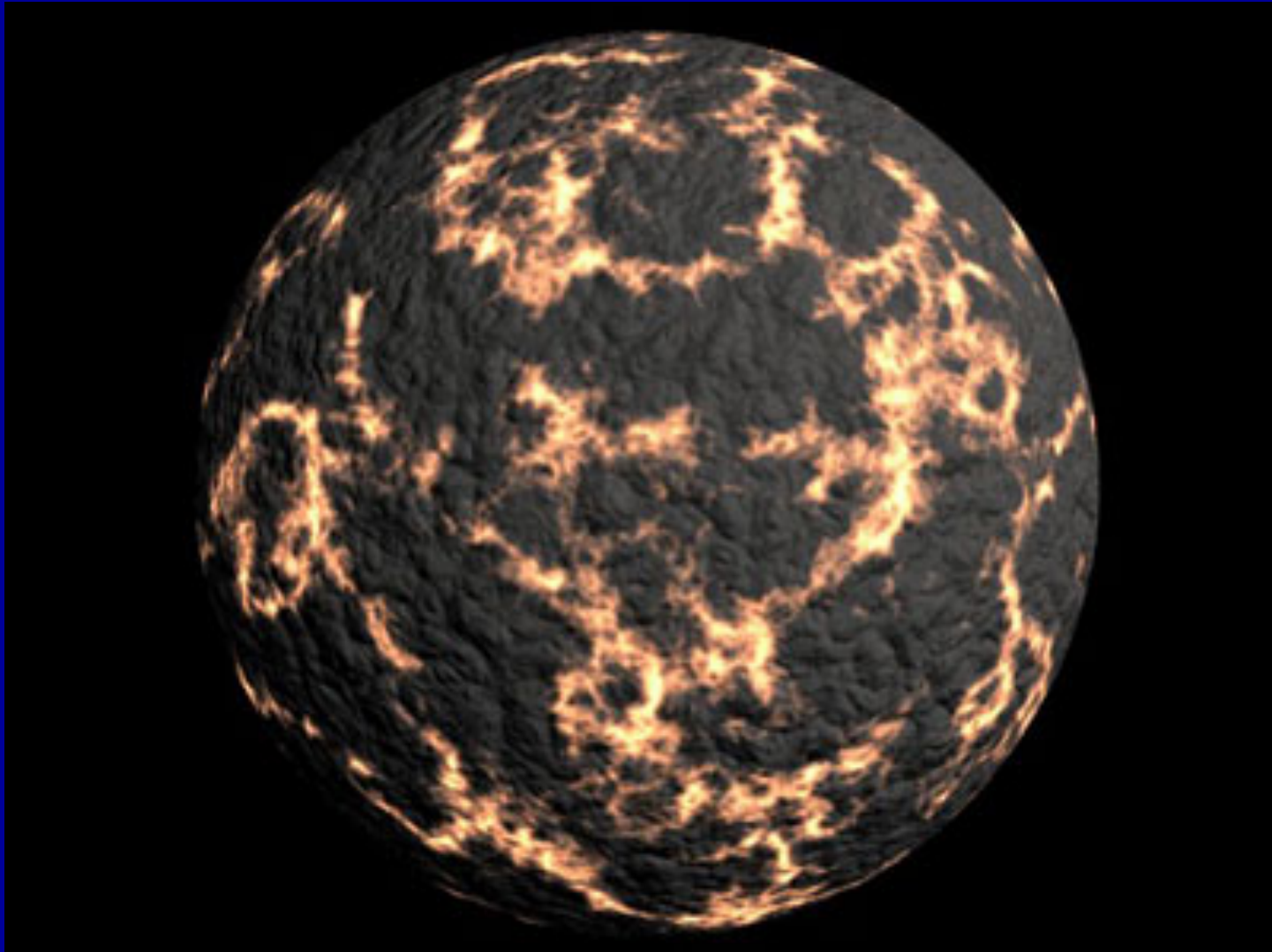
**Internal heating of the Earth**

- **bombardment**
- **gravitational collapse**
- **radioactive decay**

**Now internal heat is a minor contribution  
Primordial Earth it would have been dominant**



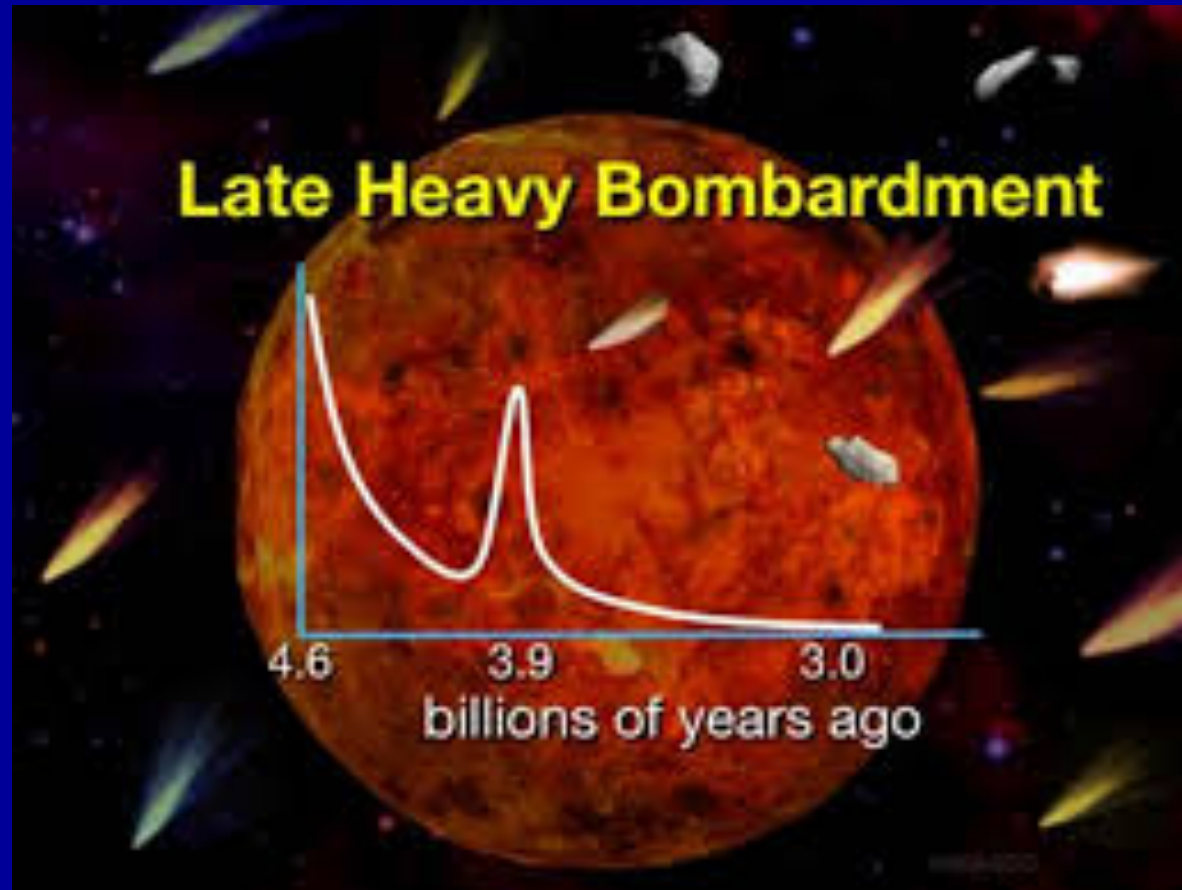
Primordial Earth:  
a molten ball of hot lava.



**Collision with another fairly large “planet” formed the moon.**

**Data from the study of impact craters on the moon.**

**This or a similar impact probably brought the carbon and silicon for the development of life.**







Source: NASA

# Earth colored: early

- Black
  - Volcanic - hot
- Grey
  - igneous rocks - granite: quartz and feldspar (e.g. the cliffs at Yosemite)
- Blue
  - water, brought by comets and asteroids
  - Probably enough water came with the original formation of the planet to provide for early forms of life