

Our Climate: A Global Challenge



Academy of Lifelong Learning
Denver, CO
Feb. 26, 2015

Matters of Perspective: Time

- Can you remember what the weather was like last Thursday?
- Can you think back to the time of Christ?
- Can you imagine astronomical time scales and distances (where we measure distance using time because the speed of light is a universal constant?)

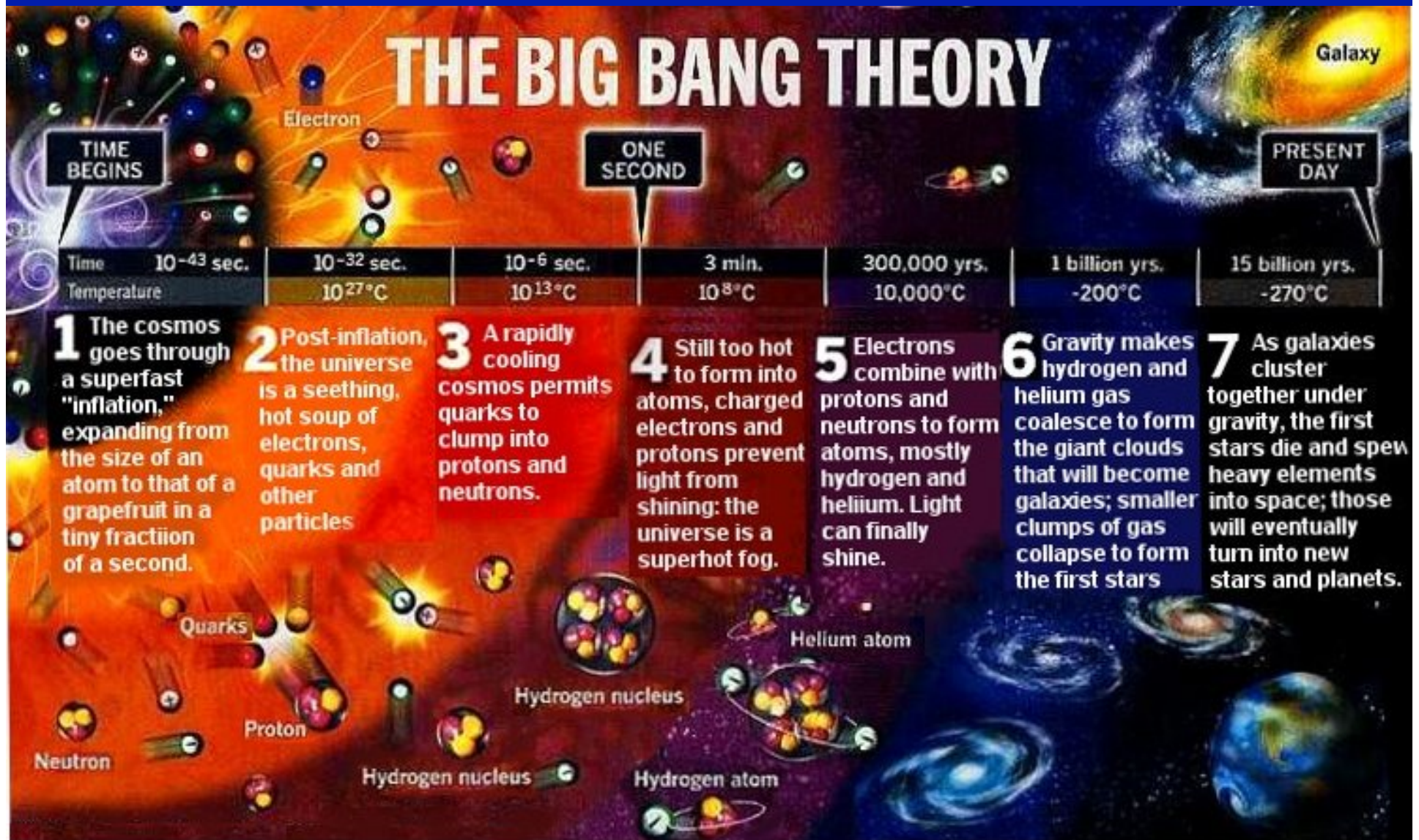
$$x(\text{meters}) = c(\text{meters/sec}) * \text{time}(\text{sec})$$

We will begin at the beginning, a long, long time ago.

Origin of the Solar System

The Universe
Stars, planets, Earth

See Jim Eraker's class for details



Observable Universe

Accelerated Expansion of the Universe

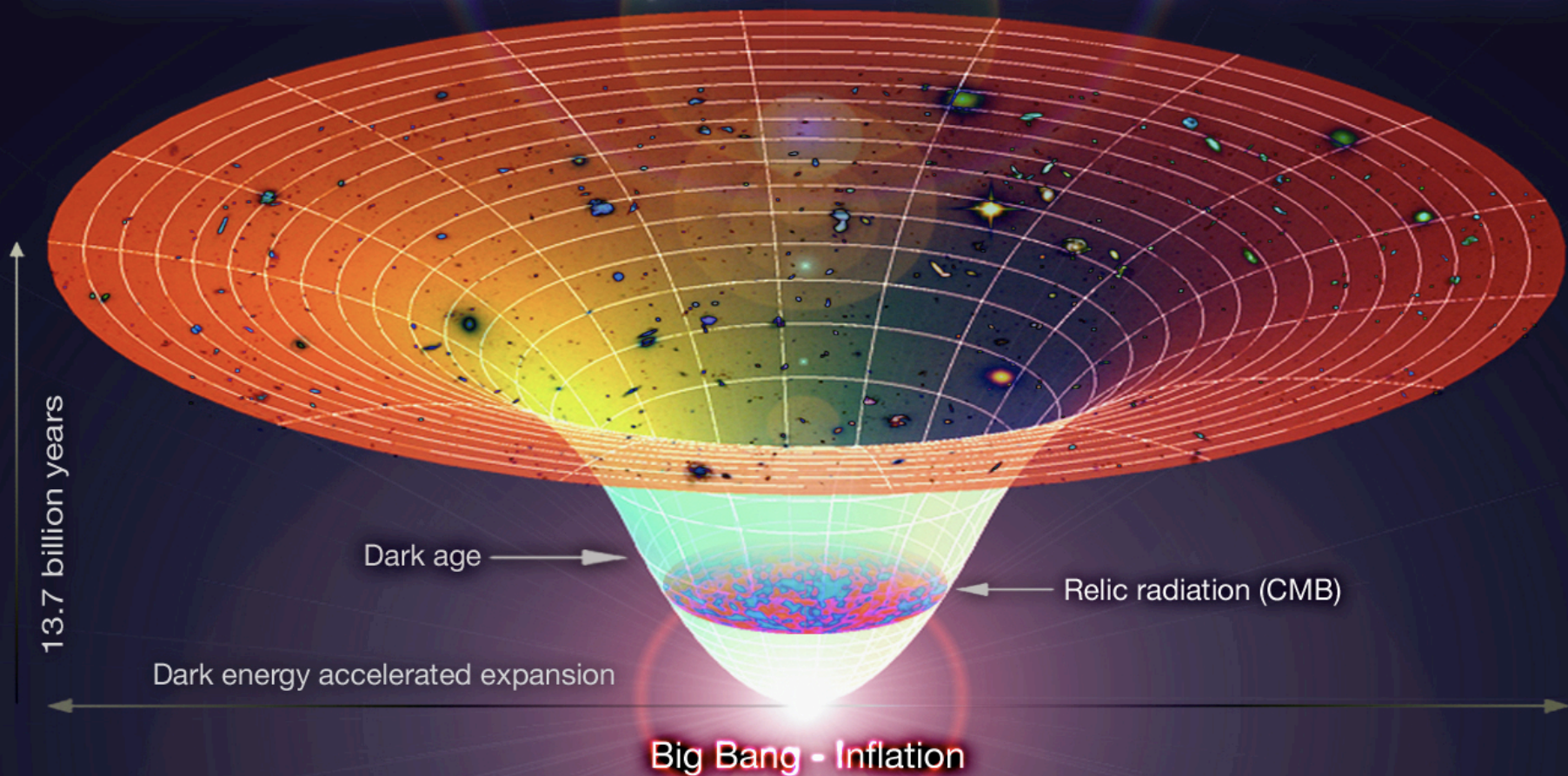
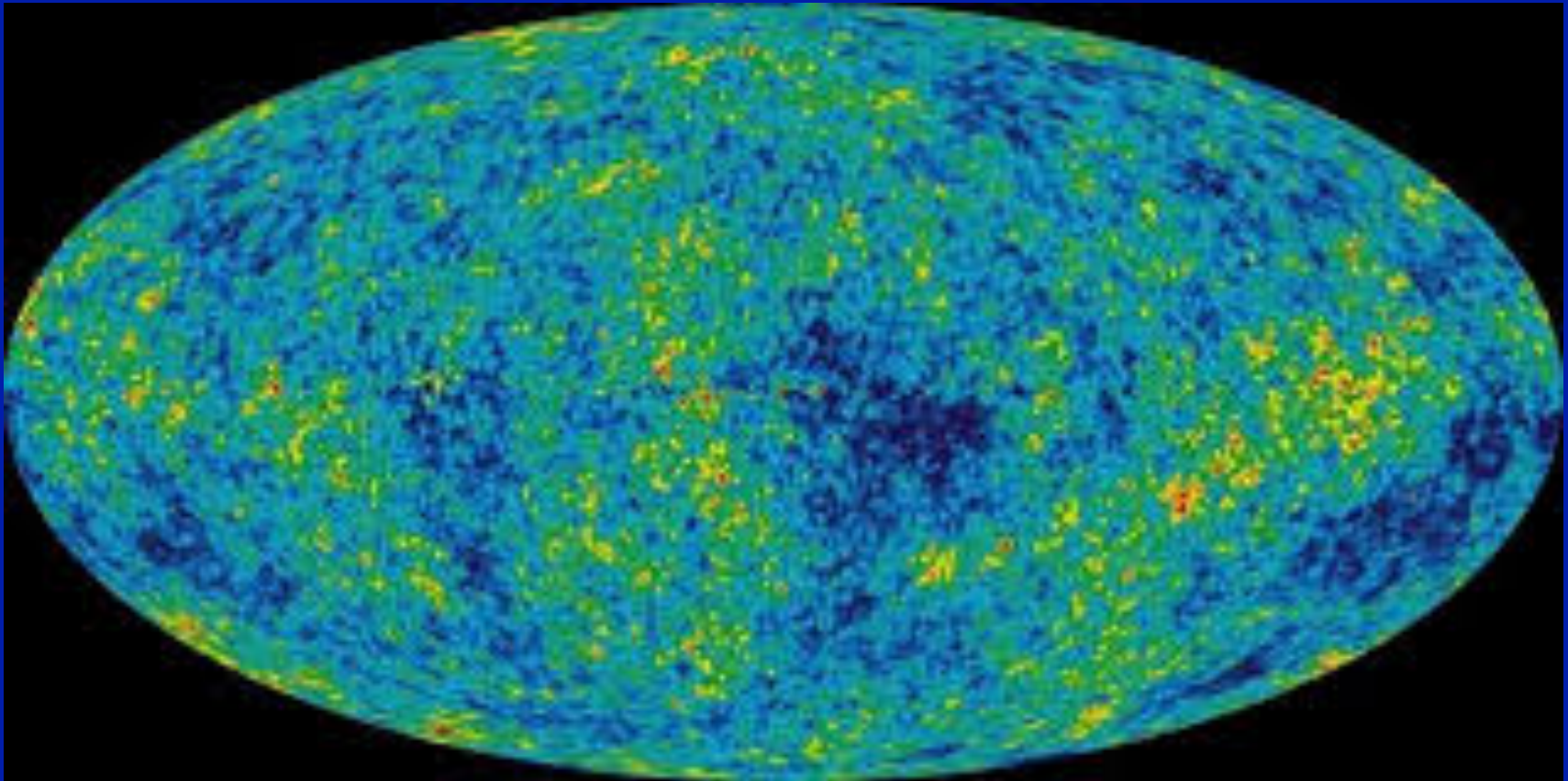
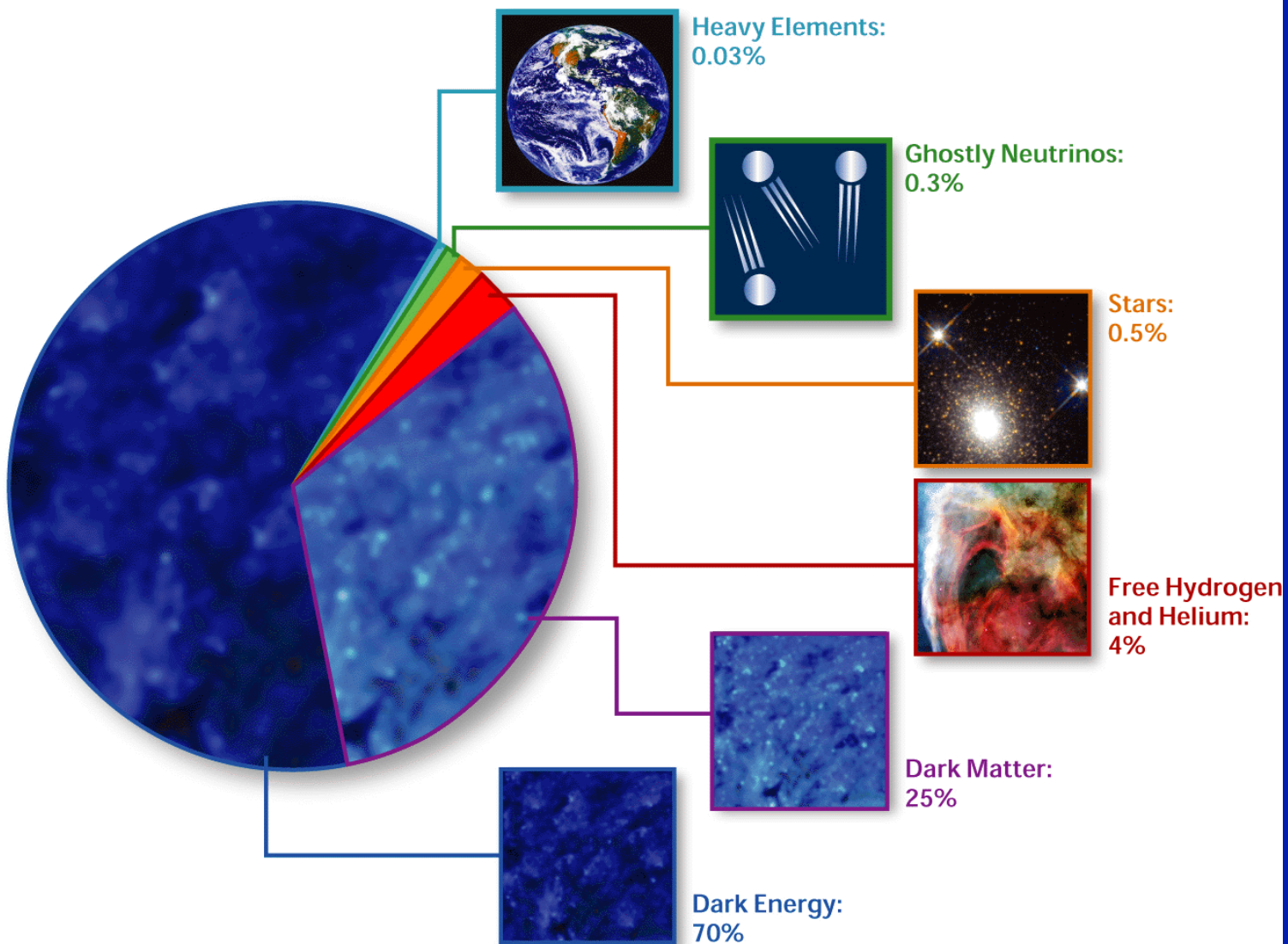


image: Coldcreation

Analyze the bumps and wiggles
on these maps of the relic
microwave background

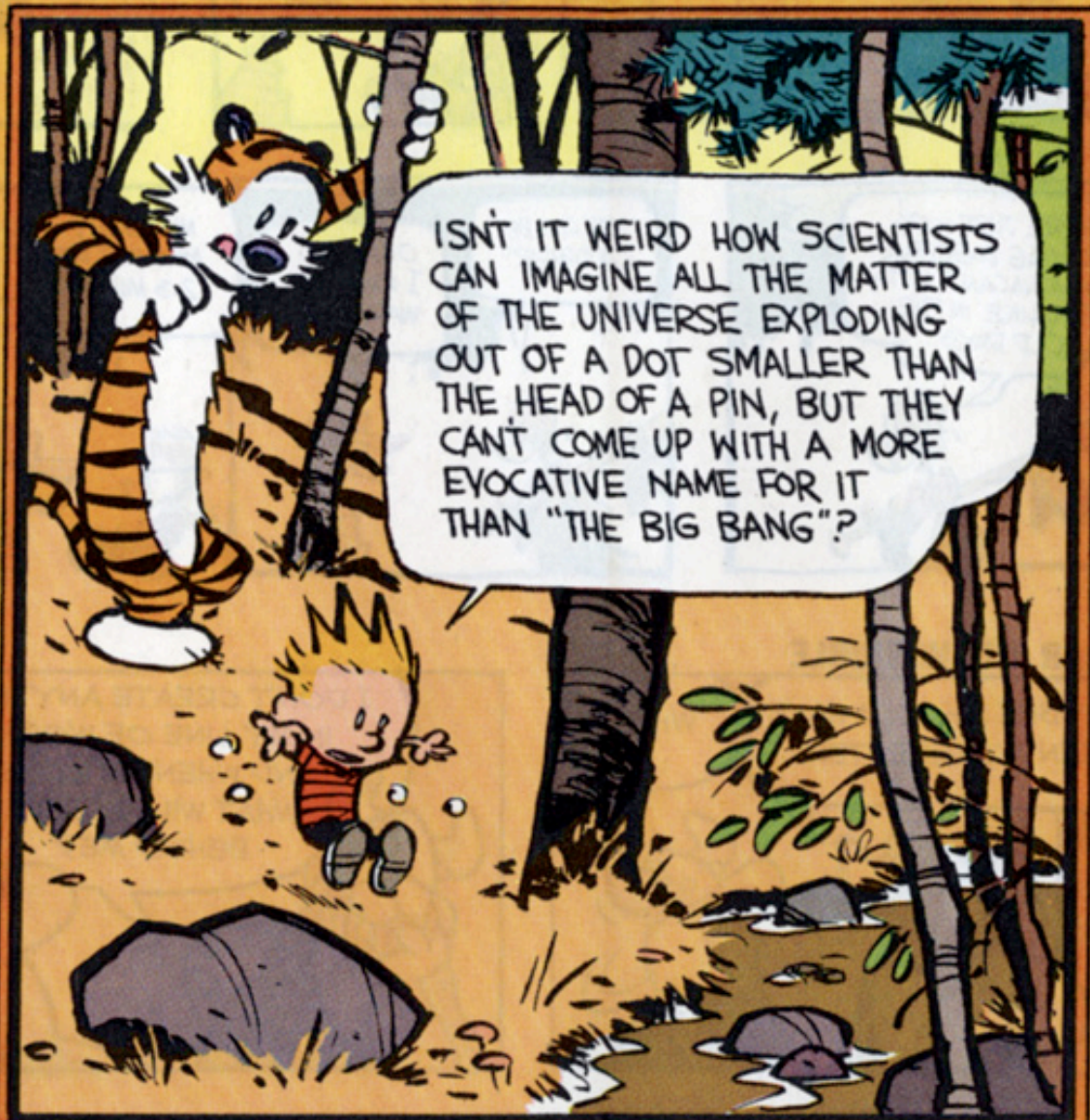


What are we made of?

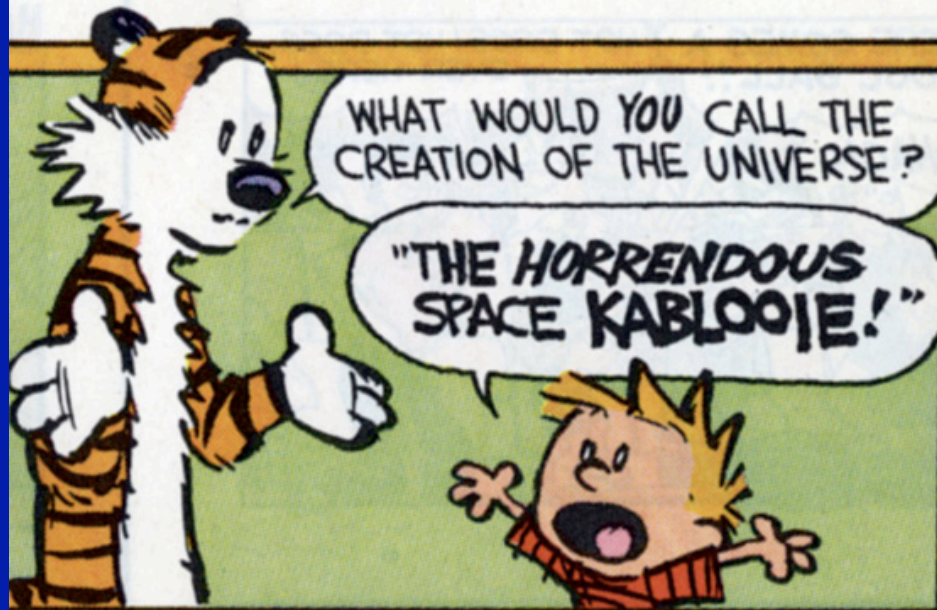


calvin and Hobbes

by WATSON ©1992



THAT'S THE WHOLE PROBLEM WITH
SCIENCE. YOU'VE GOT A BUNCH OF
EMPIRICISTS TRYING TO DESCRIBE
THINGS OF UNIMAGINABLE WONDER.

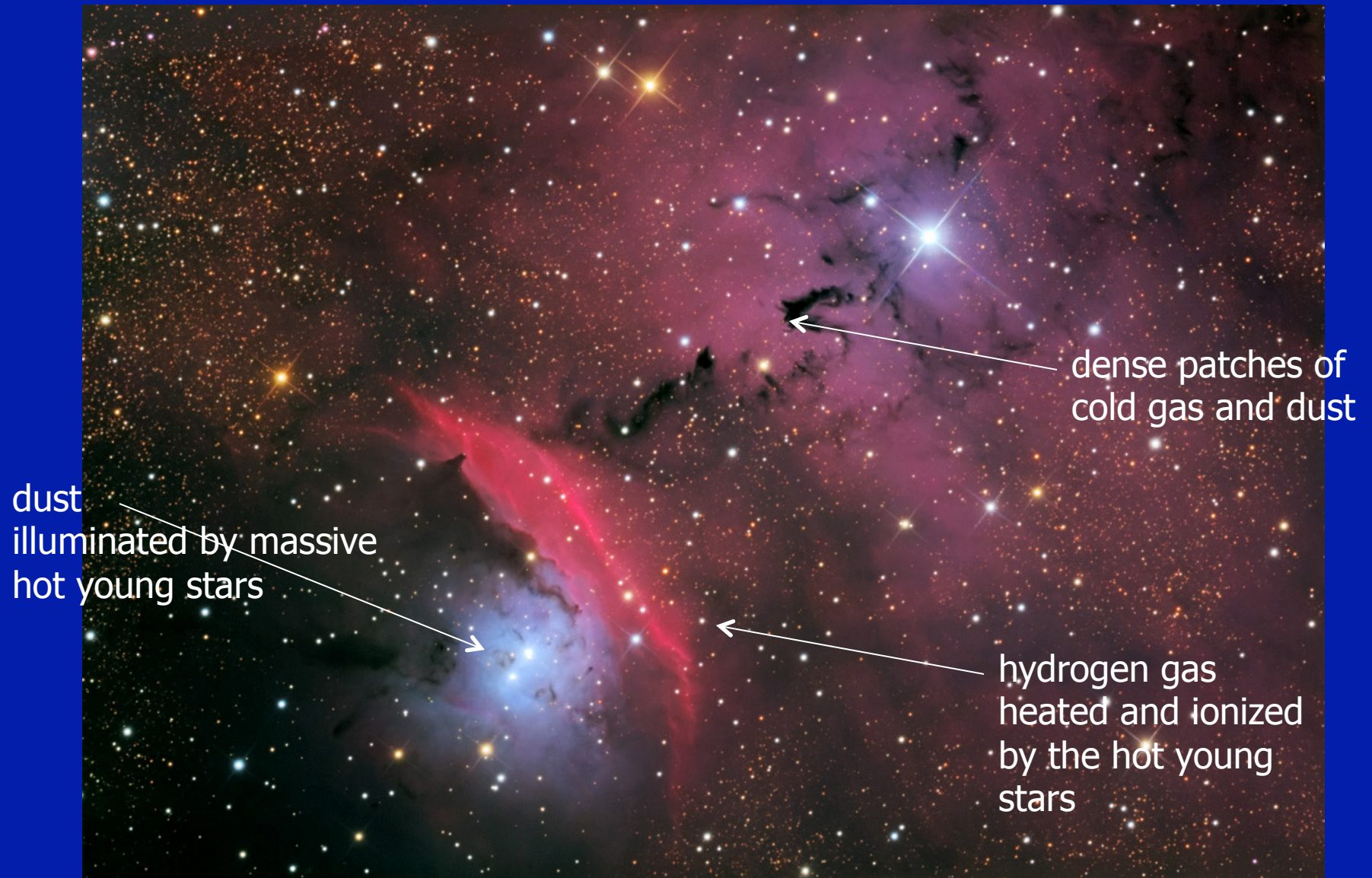


The early history

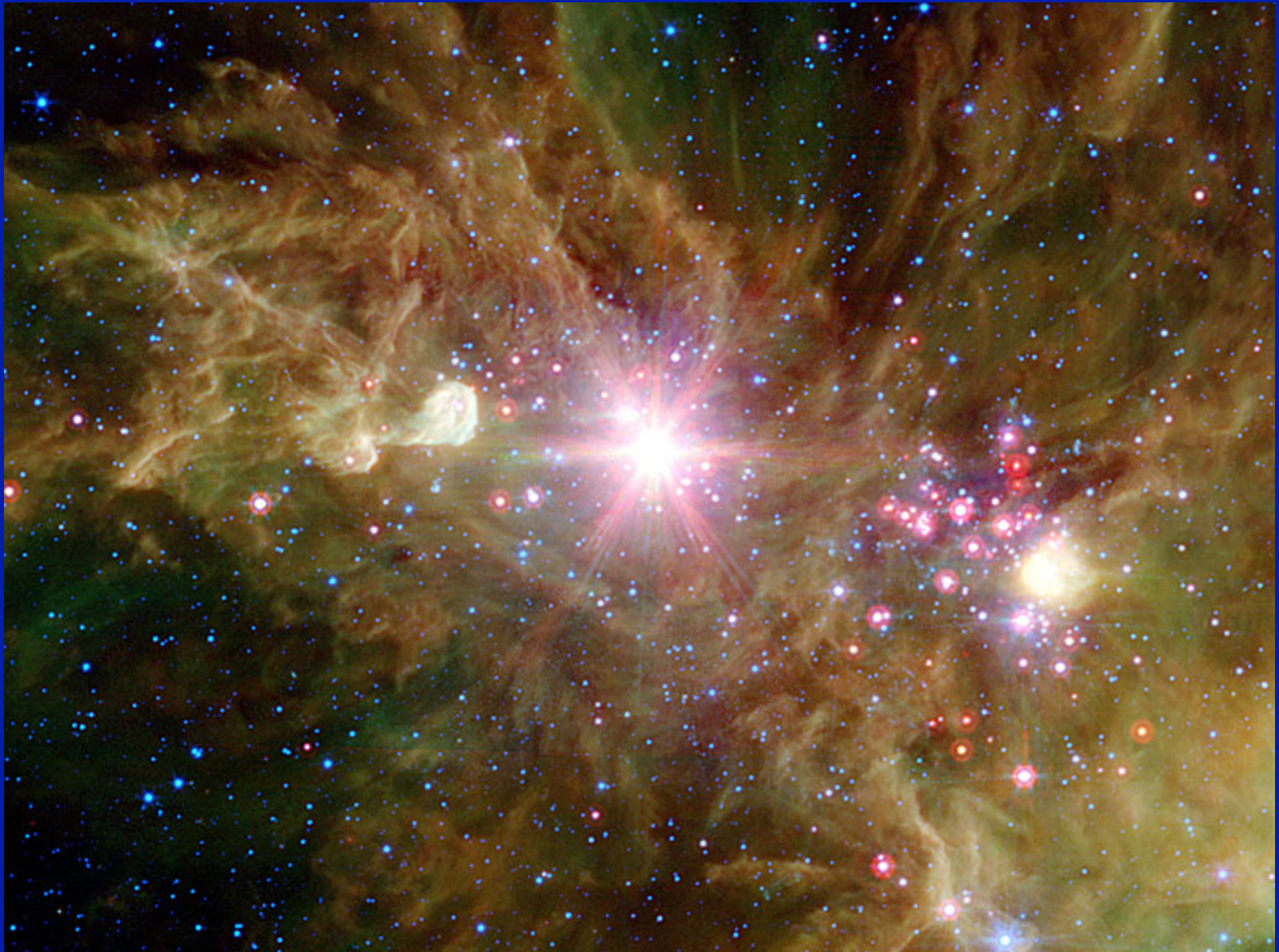
- Universe born 13.7 +/- 0.1 billion years ago
- Birth, life and death of stars – made the elements
- Birth of our sun and planet
 - Sun and Earth formed 4.54 billion years ago
- Took care of the first 9.1 billion years already
 - No Earth, no climate, no scientists

Stellar nursery NGC 6559

In the Constellation Sagittarius near the Center of the Milky Way



Another stellar nursery: the Snowflake Cluster



NGC 604 – ionized hydrogen



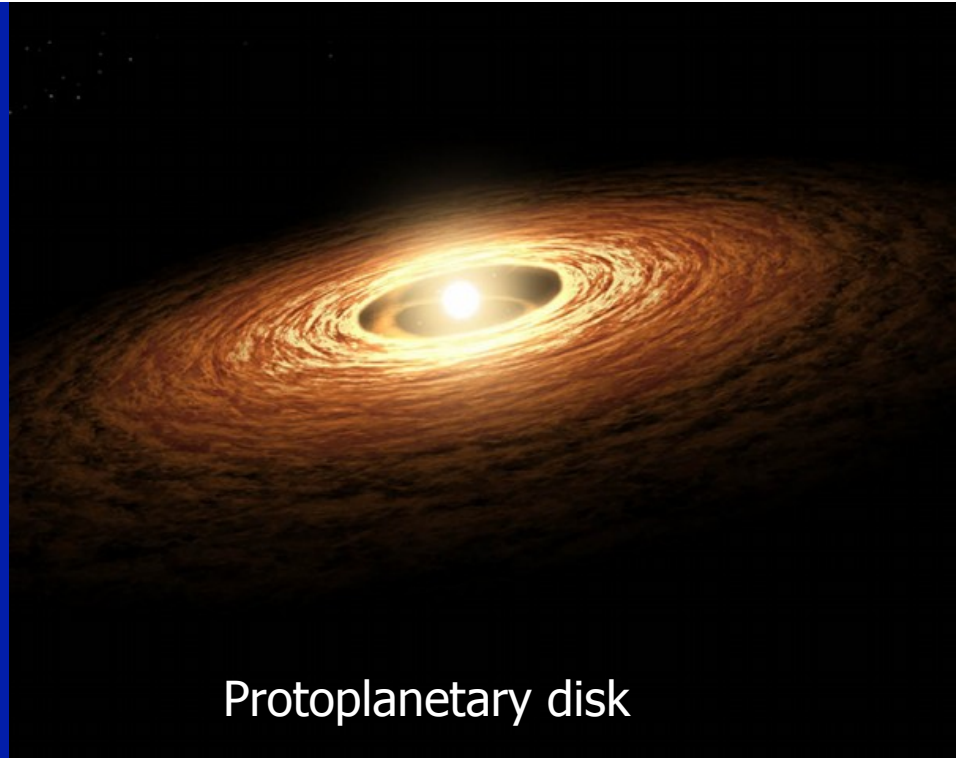
2.7 M light years away in a nearby galaxy.

At the distance of the Orion nebula, it would outshine Venus.

The gas is hydrogen, ionized by a dense cluster of new hot very massive stars at the center.

Pretty, but not Judy Garland.



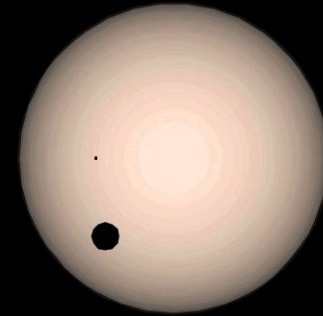


Protoplanetary disk

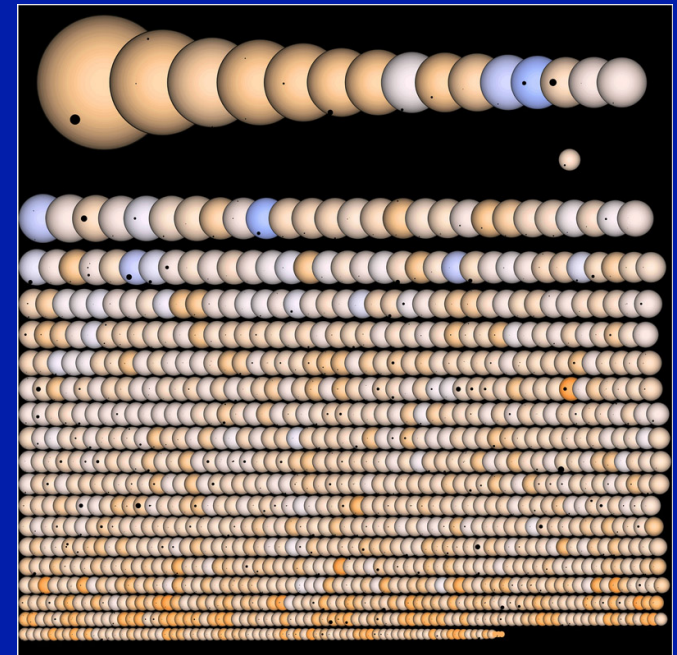
Planets are “common” nearby in our galaxy and, by inference, in the rest of the Universe, but they are very difficult to see against the background of the bright stars they orbit.

A satellite called *Kepler* found all these planets by noticing a dip in the intensity of light as a planet passes in front of a star.

Jupiter and Earth



“in transit” across the sun.

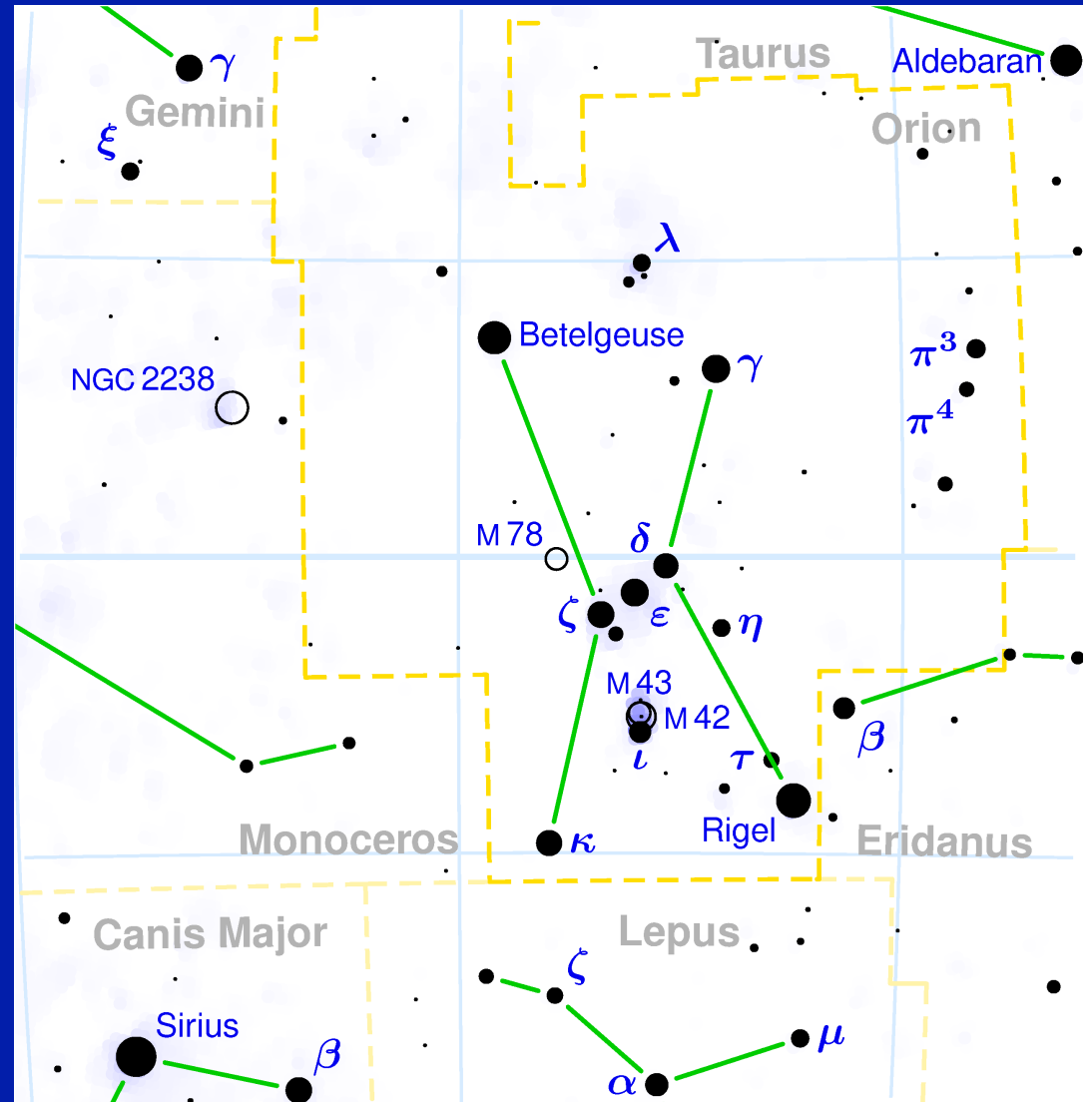


Lots of planets are being born here



Studies of these systems tells us that the solar system, the sun and the surrounding planets, formed from the condensation of a cloud of gas that was distributed through the interstellar medium by the explosion of stars.

The Constellation Orion



Orion Nebula: M42



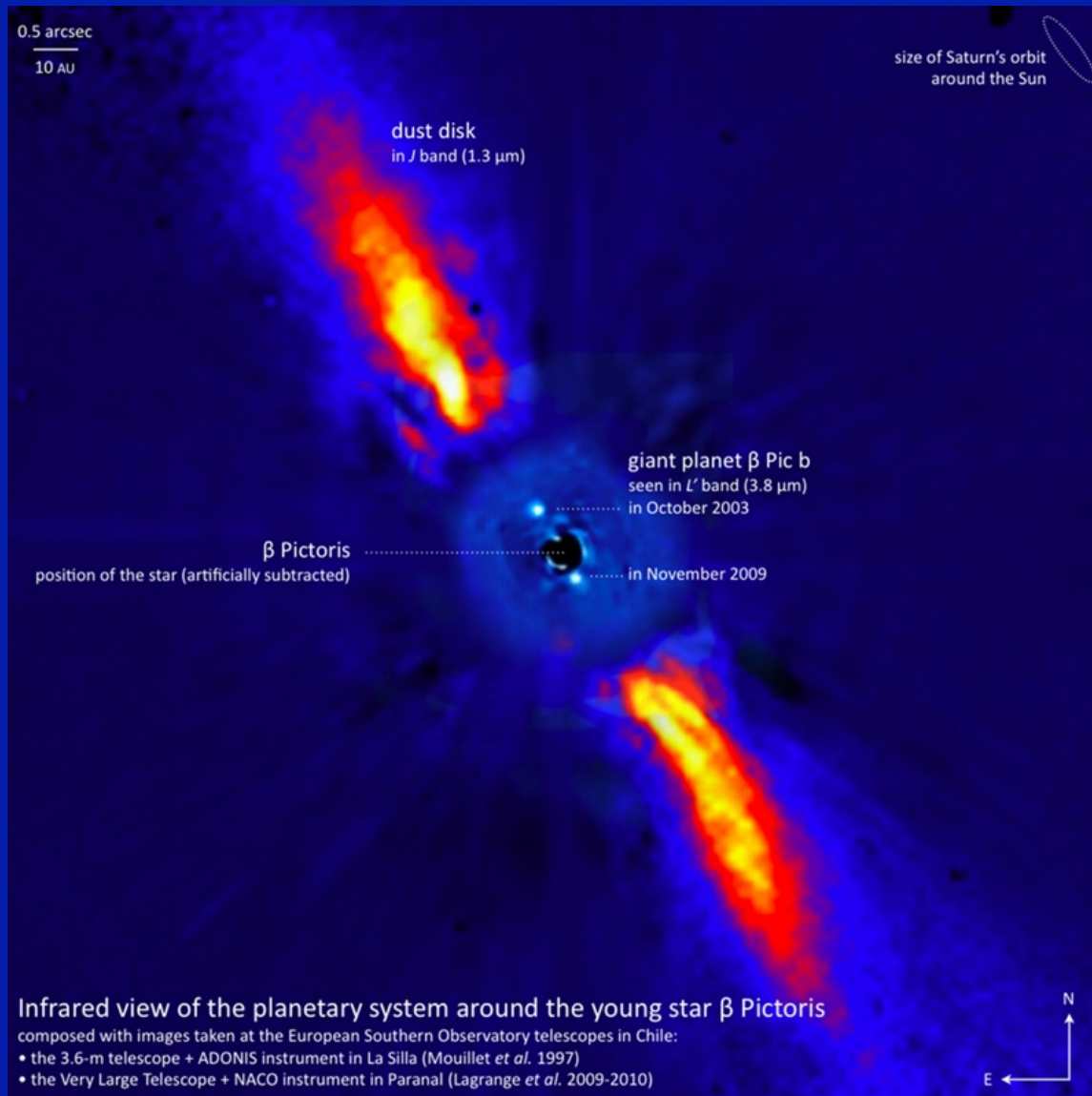
Molecular cloud in Orion: H₂



How much H and other volatiles are trapped as a planet forms is unknown, but H certainly is "around" in abundance.

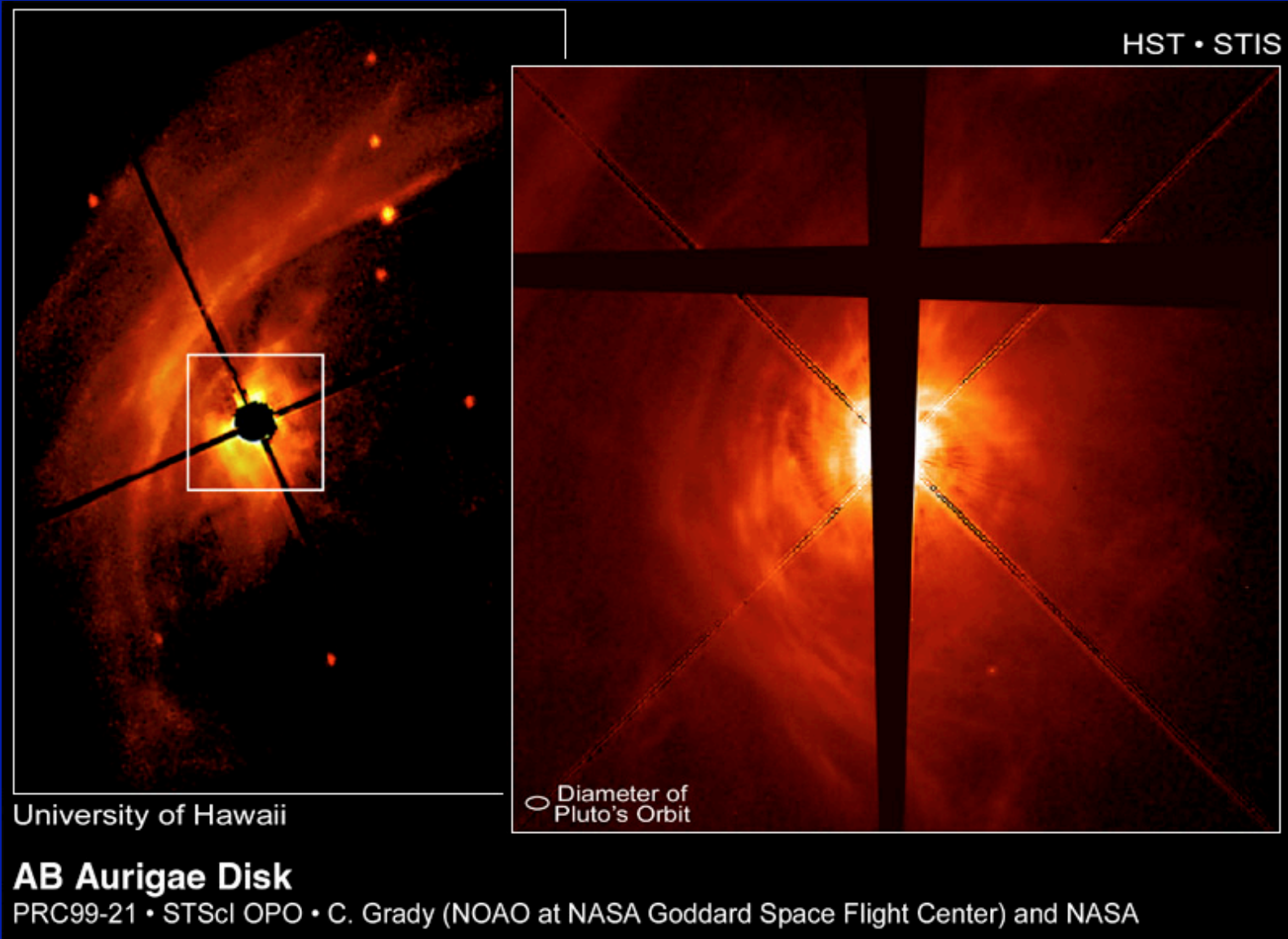
Perhaps the conditions for gases to be trapped in clathrates (crystalline traps of water) played a role, and maybe trapping in eddies or vortexes also played a role.

Beta Pictoris (63 light years)



10-20 million years old

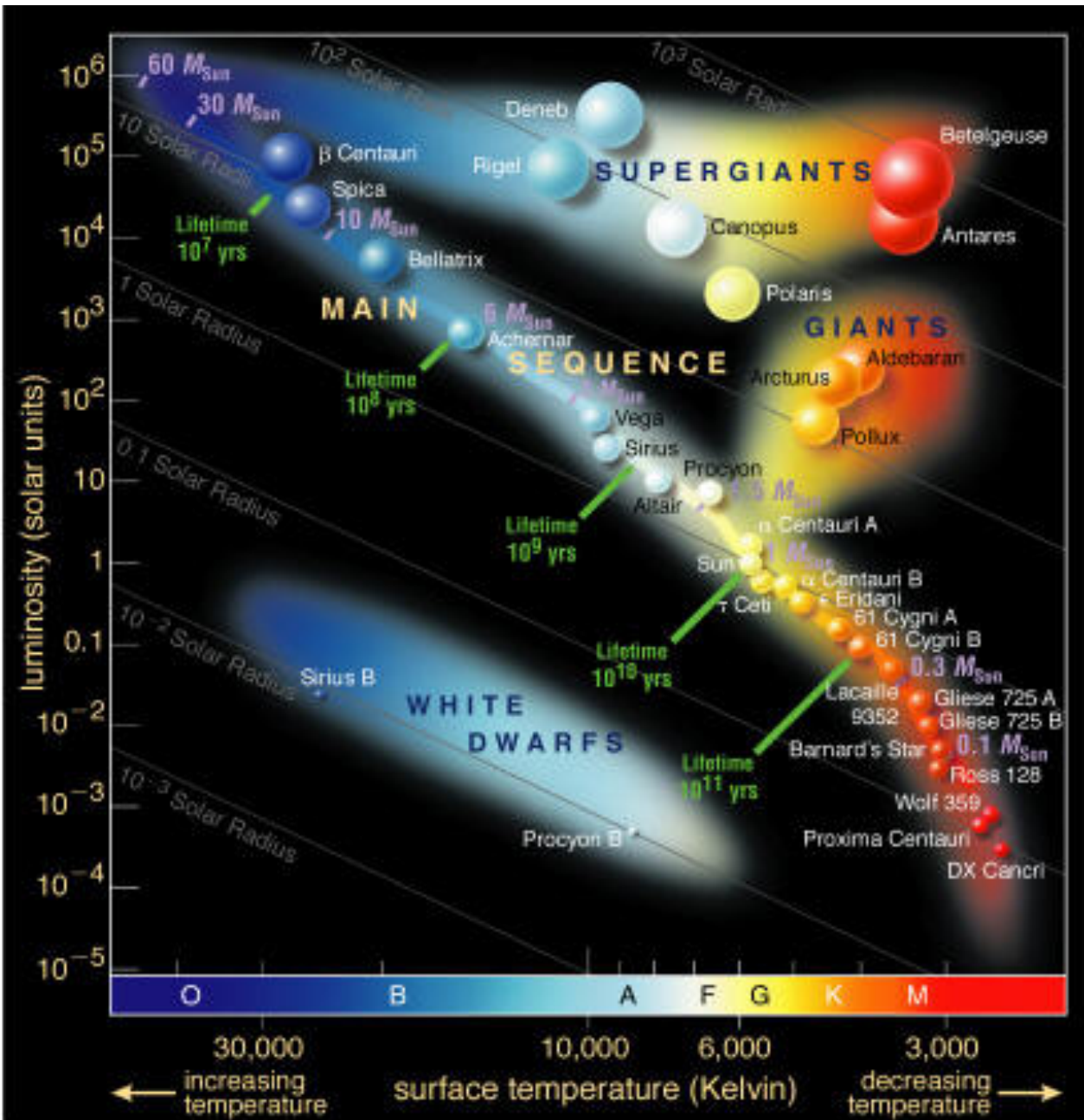
Protoplanetary Disks



Planetary system being formed:



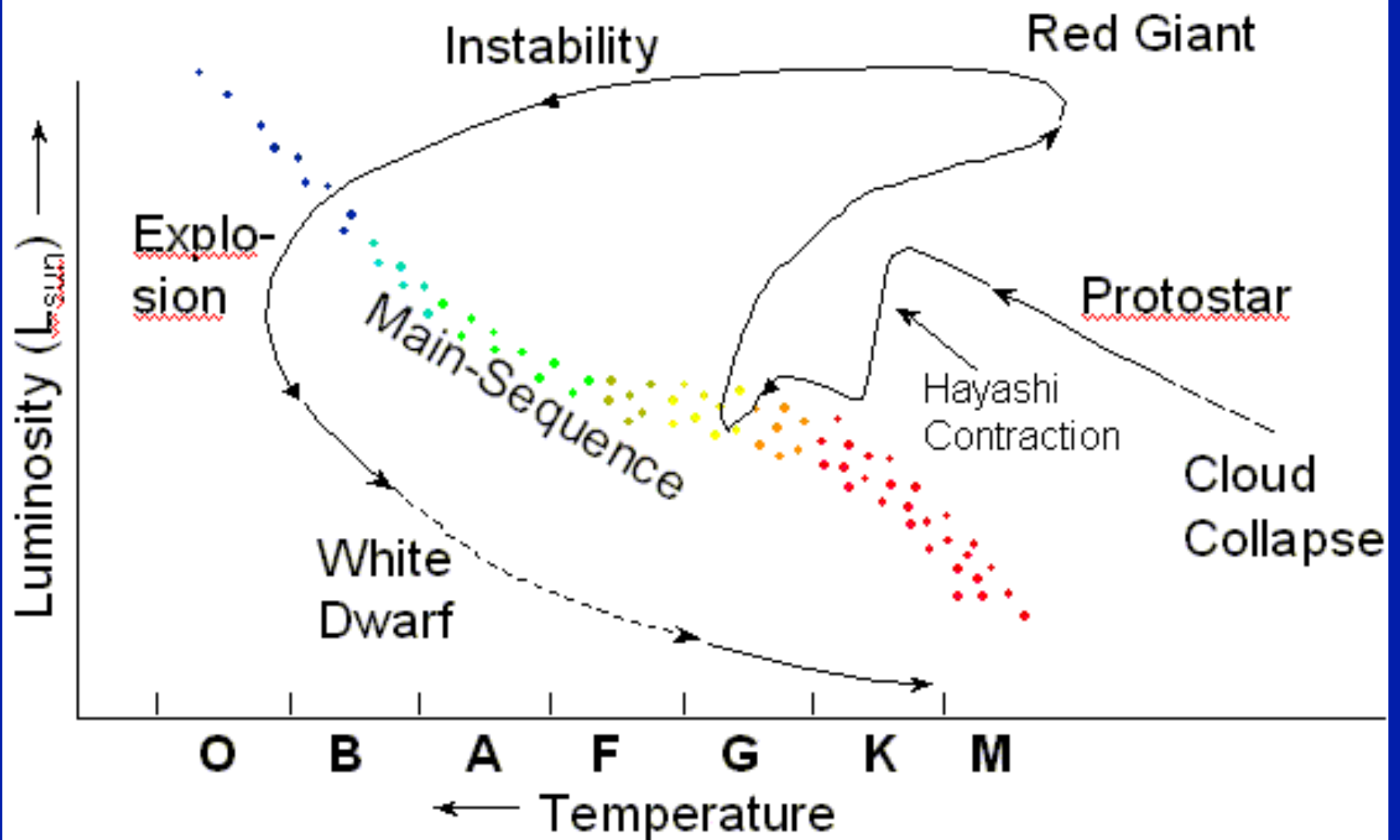
AB Aurigae
469 light years away
2-4 M years old



The HR diagram is named after astronomers Hertzsprung and Russel who developed it in 1910. It tracks how stars evolve.

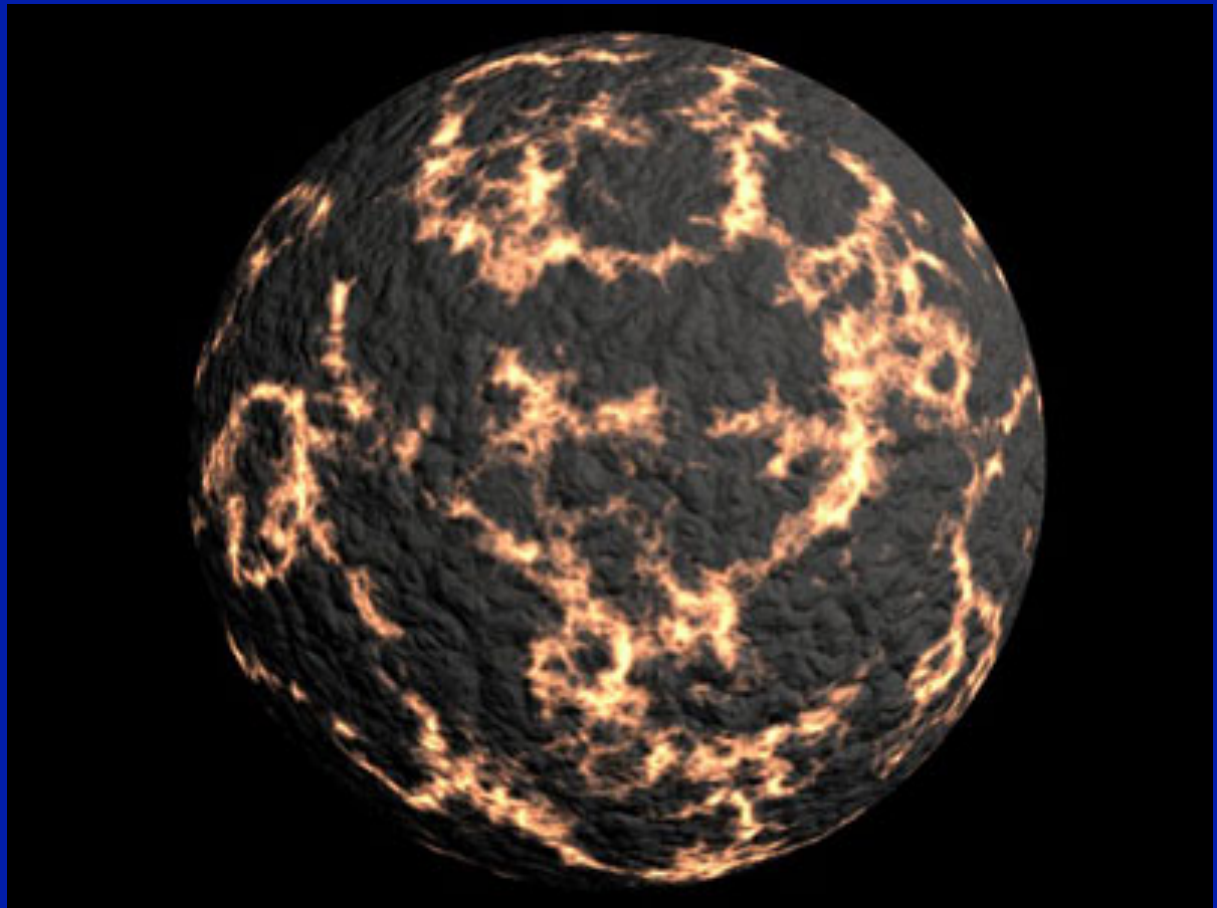
Sun will last 11 B yrs
 $50 \times M_{\odot}$ 10 M yrs
 $100 \times M_{\odot}$ 1 M yrs

Evolution of the Sun



Primordial Earth 4.5 Bya

Sun 30% cooler than today
Earth hot and constantly bombarded
Accretion was still going on.



Stellar death

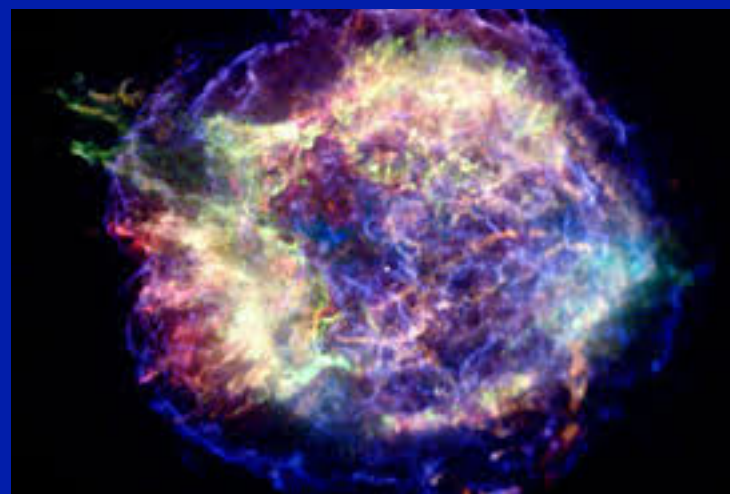
- Stars build the heavier elements, especially in their death throes
- Stellar death recycles heavy elements to the interstellar medium
- New stars are made with heavy nuclei
 - First generation stars had no heavy nuclei
 - They were larger and lived only a short time

Supernova in Pinwheel Galaxy



21 Million light years away

Supernova remnants



Everything evolves

- The universe
- Galaxies
- The sun
- Planets
- Earth
- Continents
- Viruses
- Microbes
- Species
- Home sapiens

**It is natural to evolve: birth, life, death.
Evolution has all kinds of time scales.**

Our scope isn't much

- Tenure of human (sentient?) beings
 - Fraction matter+energy, stuff we are made of=0.03%
 - Fraction of the time
 - Life $3.8 \times 10^9 / 13.8 \times 10^9 = 27\%$
 - Some humans $1 \times 10^6 / 13.8 \times 10^9 = 0.007\%$
 - Threat to planet $100 / 13.8 \times 10^9 = 7$ billionth %
 - Lest we start feeling bad, bacteria have changed atmosphere
 - Fraction of space
 - Circumference of Earth/Size of observable universe 3×10^{-19}
 - Use whole Solar system (it changes by factor of 3400) = 1×10^{-15}

Extras not used

Origin of the Solar System



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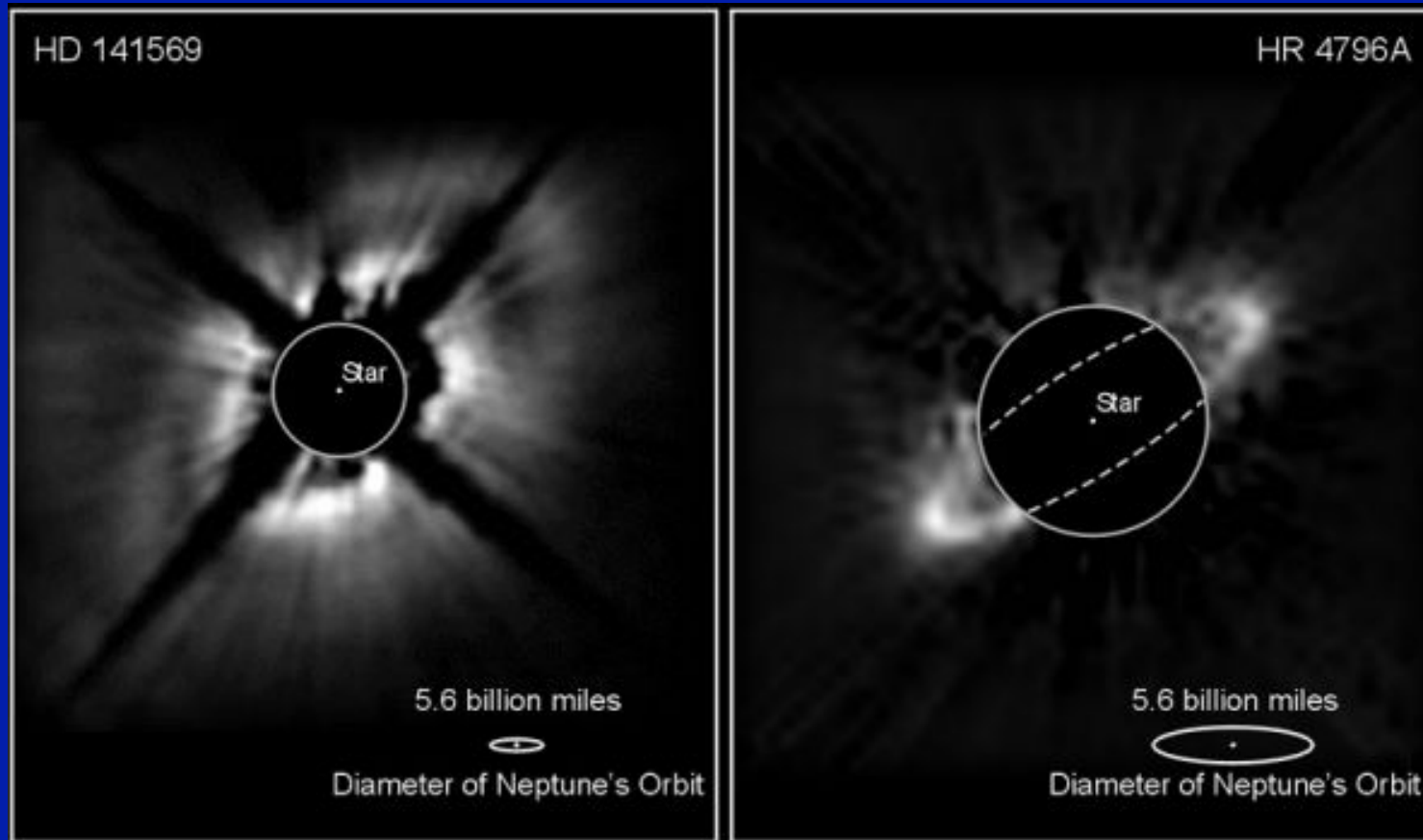
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HD 141569 (320 light years)

5 million years old

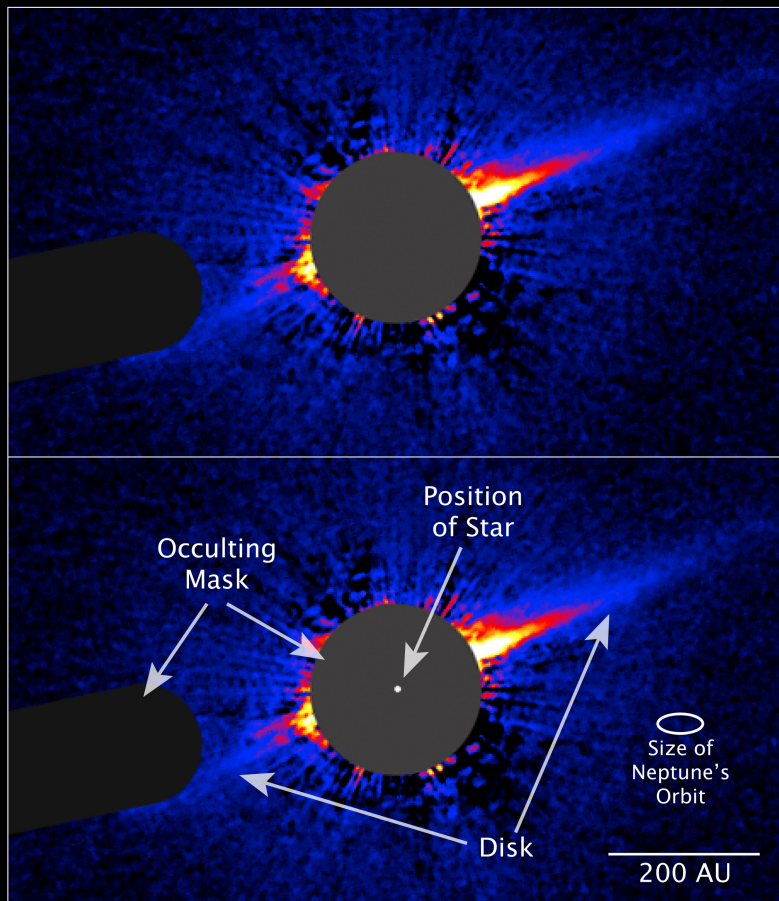


HD 15115 (150 light years)

Asymmetric dust cloud orbits star. Dust cloud surrounds a planet being formed.

HD 15115 Disk

HST ACS/HRC



NASA, ESA, and P. Kalas (University of California, Berkeley)

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