Starformation

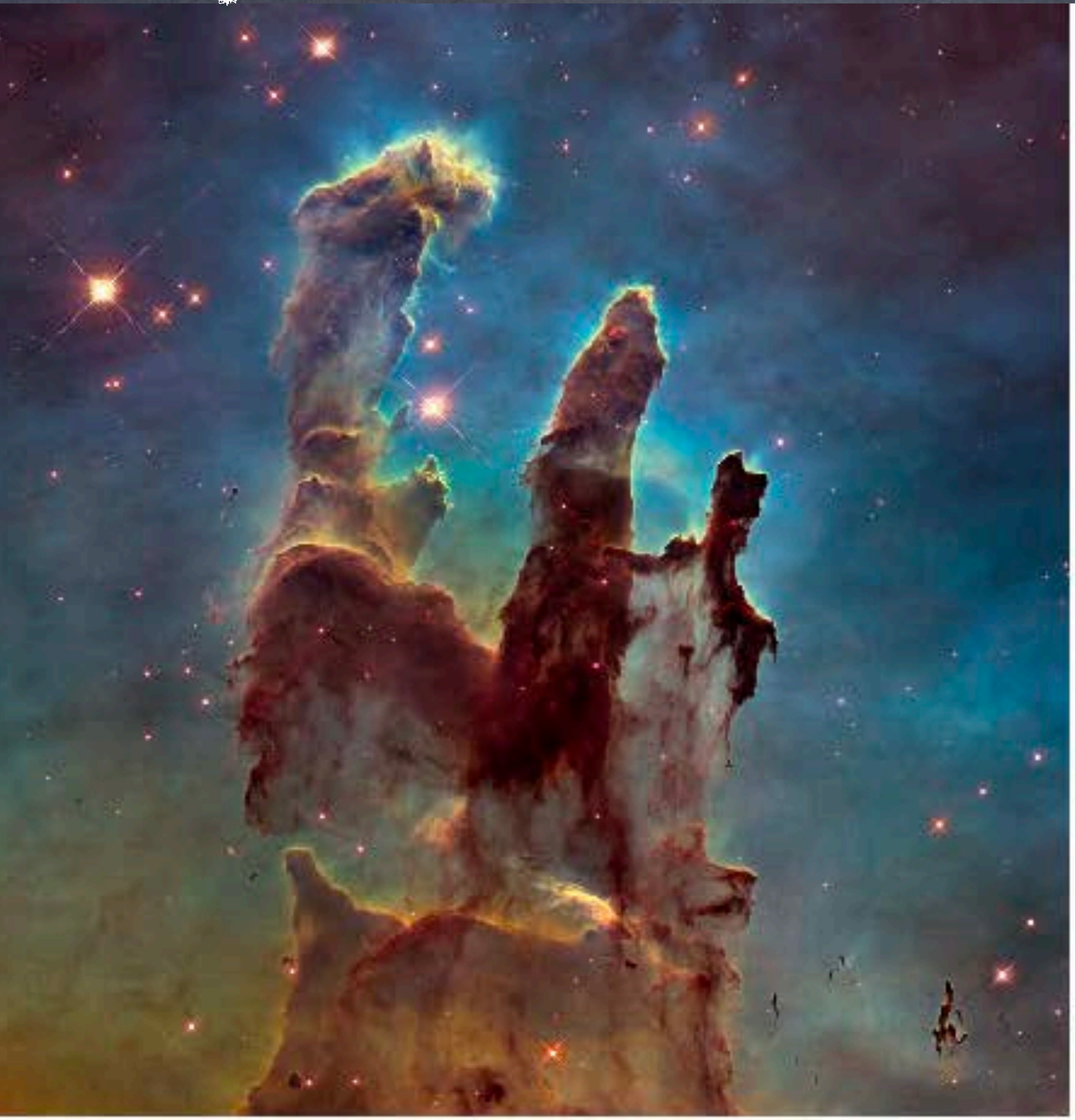
Chapter 21

Stars form out of the interstellar medium

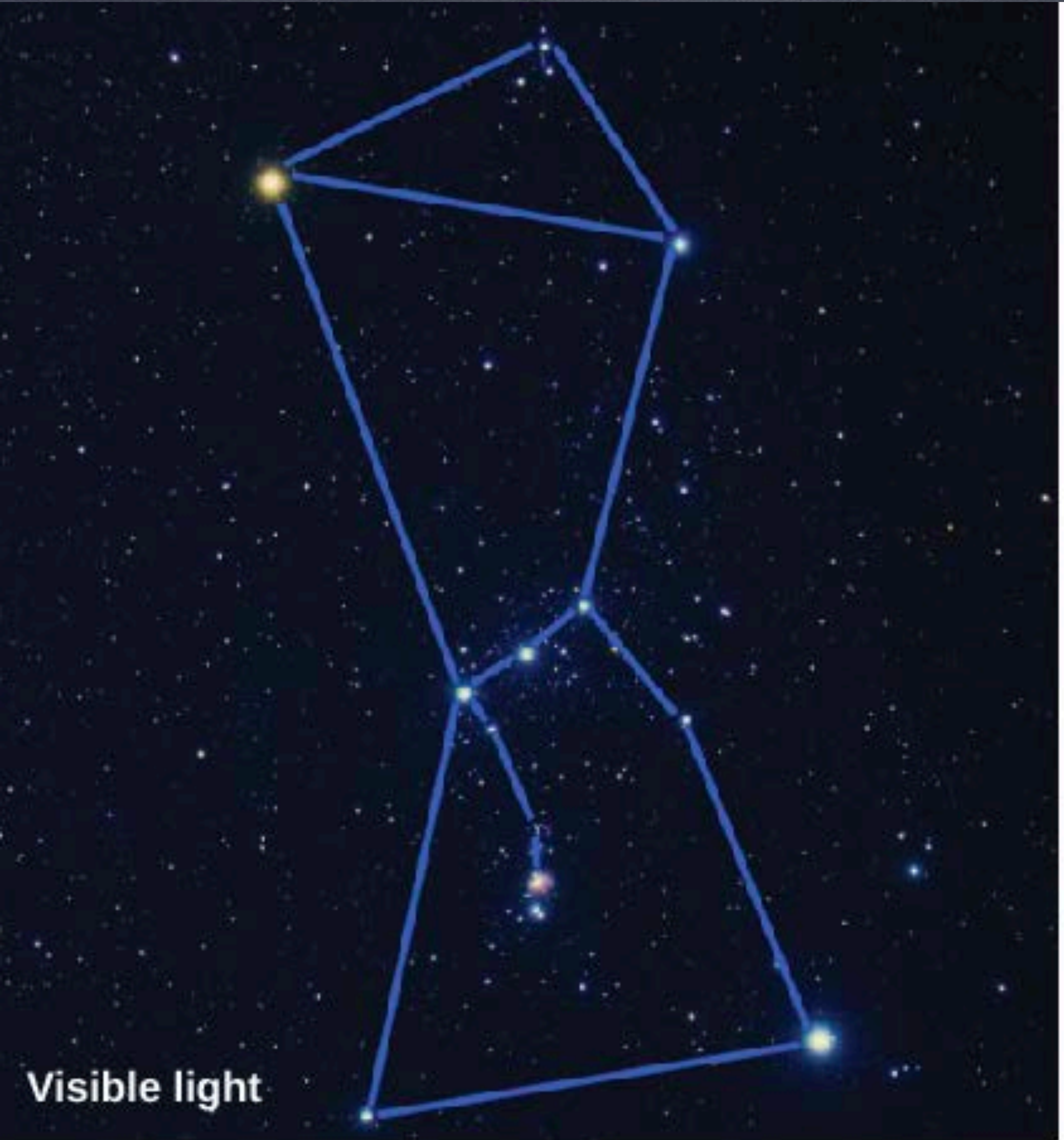
Starformation

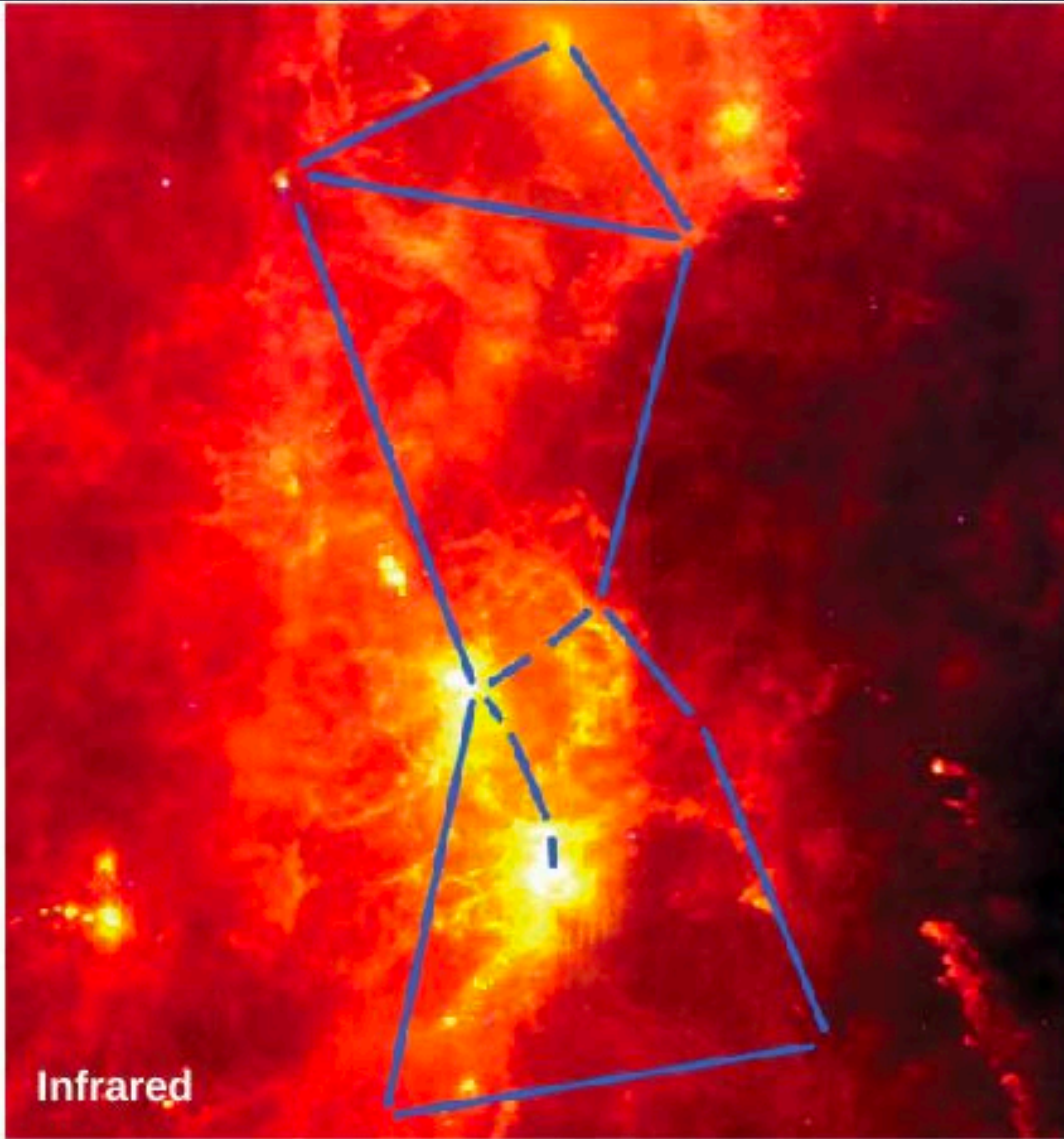
- Stars form out of dense gas. We have seen that the densest gas clouds are molecular clouds.
- Giant molecular clouds are the birth place of most of the stars in our galaxy. In the centers of these clouds the temperature is only 10-20K and most of the gas is in molecules.
- A molecular could can have masses from 1000 to 3 million times the mass of the sun. But in the cloud the densest regions called clumps are 50 to 500 solar masses.
- The cores of these clumps are where most stars form. Even starting with the densest part of the ISM these cores still need to contract so that their density increases by 10^{20}.

These nebula have star formation going on which eats away at the cloud and gives them their unique shapes.

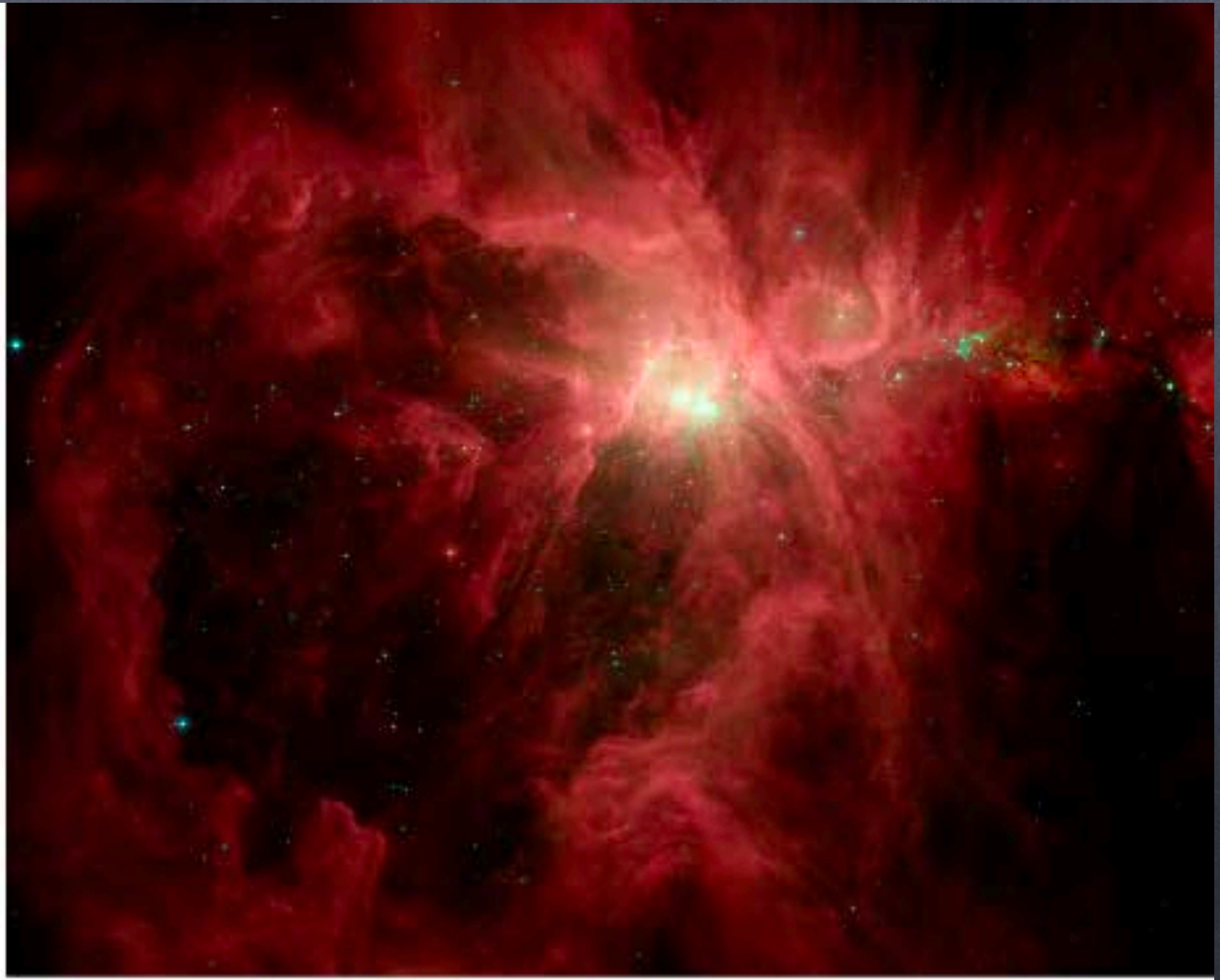


The constellation Orion is full of gas clouds in the infrared



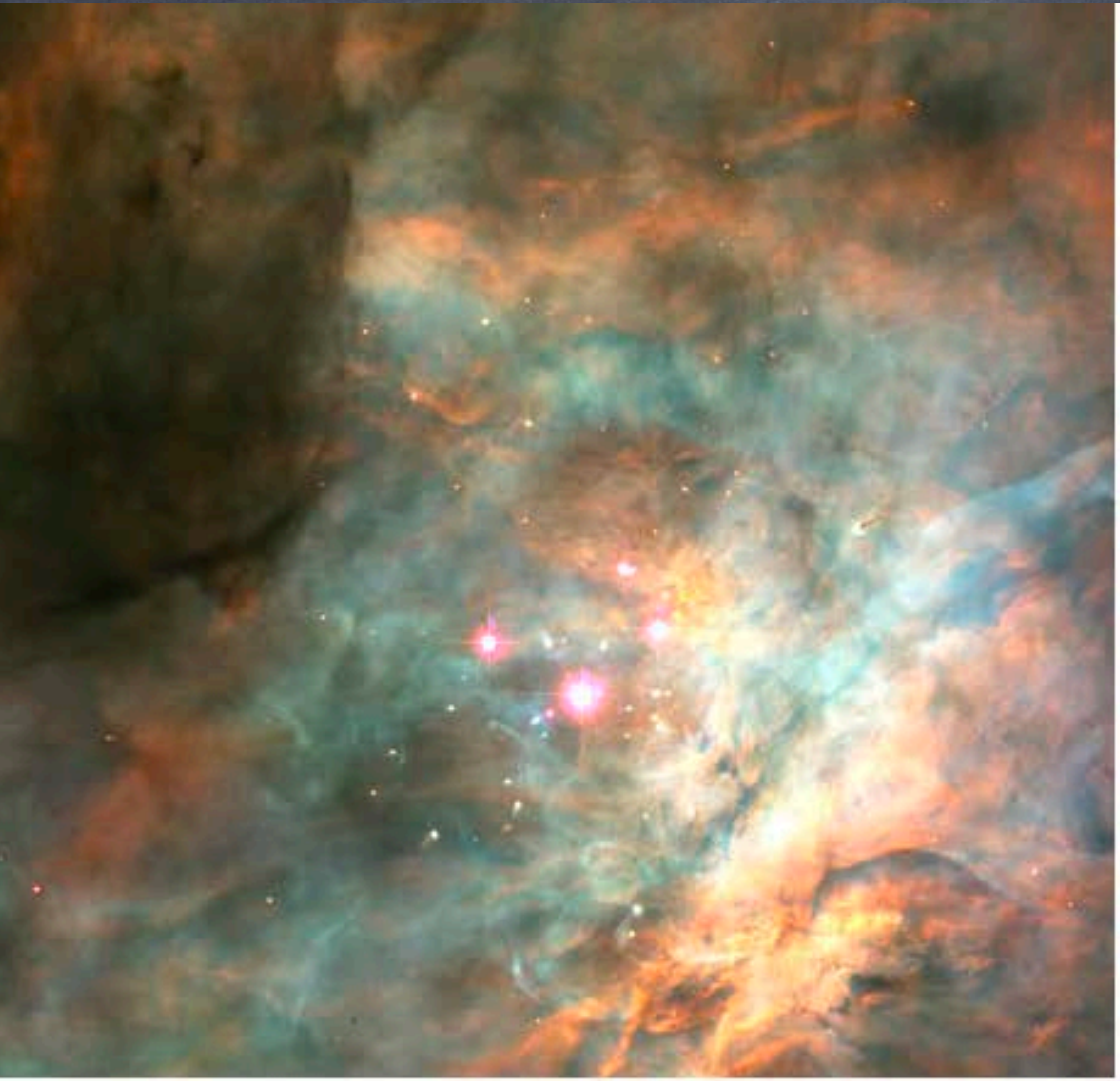


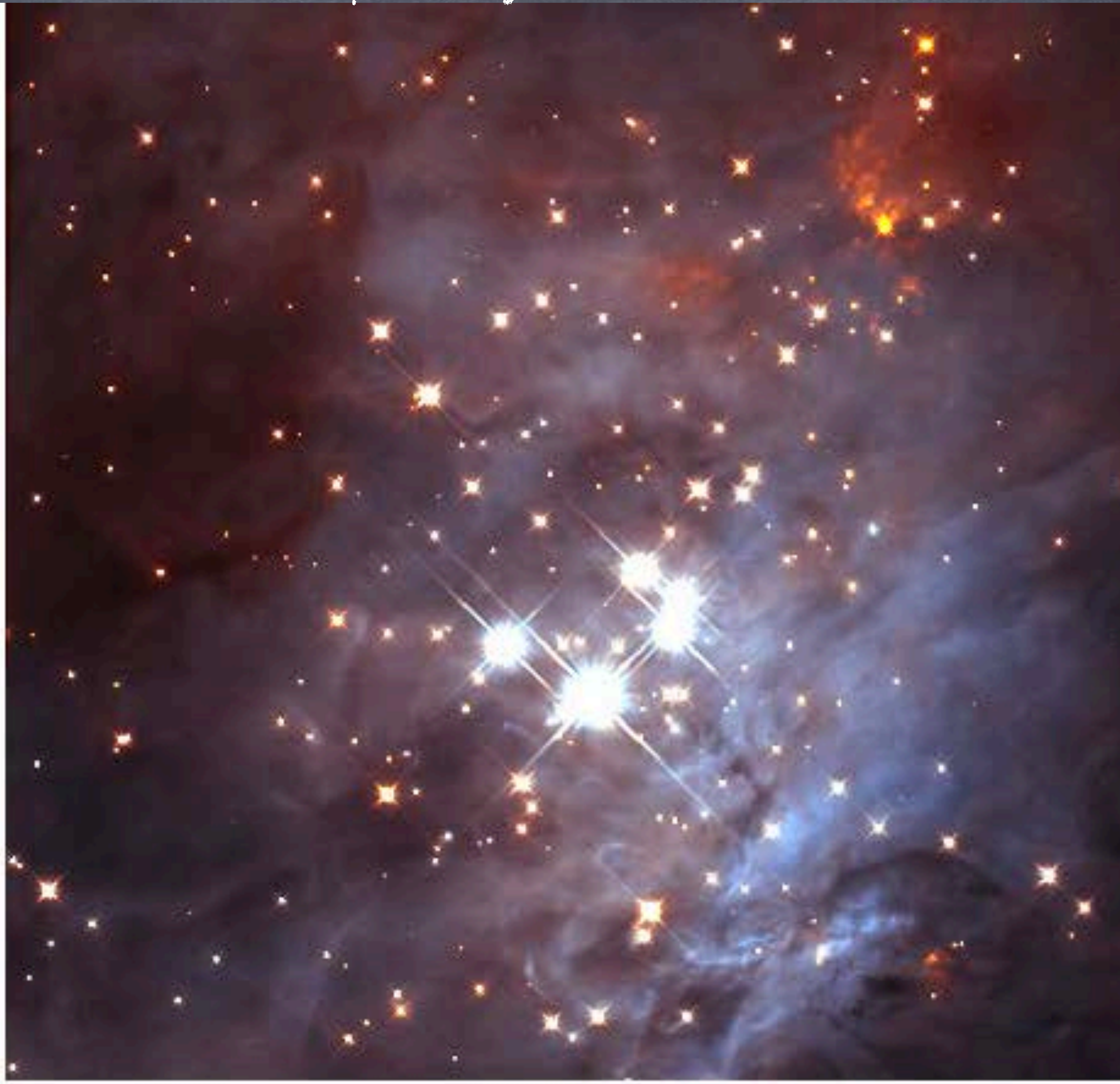
The Orion nebula has ongoing star formation. There are 2200 young stars in this region which is only 12 light years in diameter. That is very densely packed with young stars, our nearest neighbor is 4 light years away.



The central region of the Orion nebula. The stars are much easier to see in the infrared where they aren't reddened as much by dust.

https://www.youtube.com/watch?v=JoeKQeJuHvw

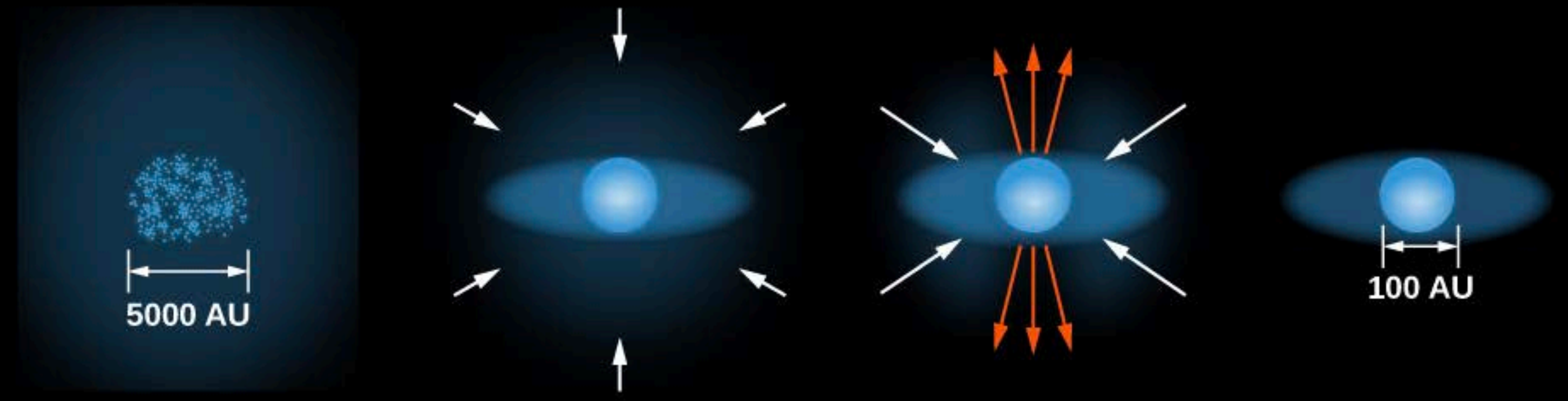




Star formation blows away the remaining part of the nebula. In fact observations suggest star formation is very inefficient. Only 1% of the gas becomes stars, the rest is blown away and returns to the interstellar medium

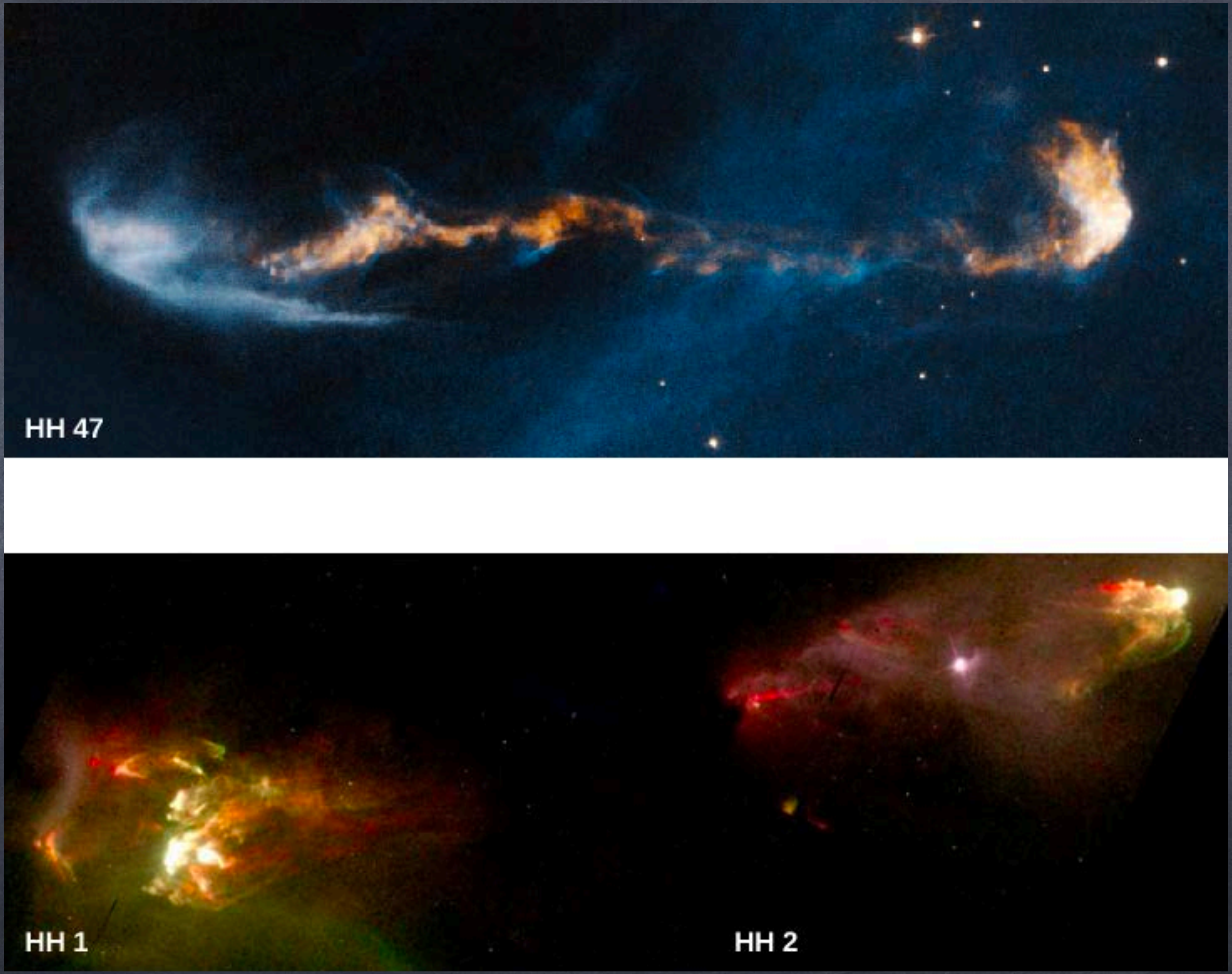
Triggered star formation - There is examples of places. where we see star formation close to a another slightly older episode of star formation. It is believed that gas expelled from the first event runs into another molecular cloud and compresses the gas there and triggering star formation at the new location. It is unclear if all star formation is triggered or not.

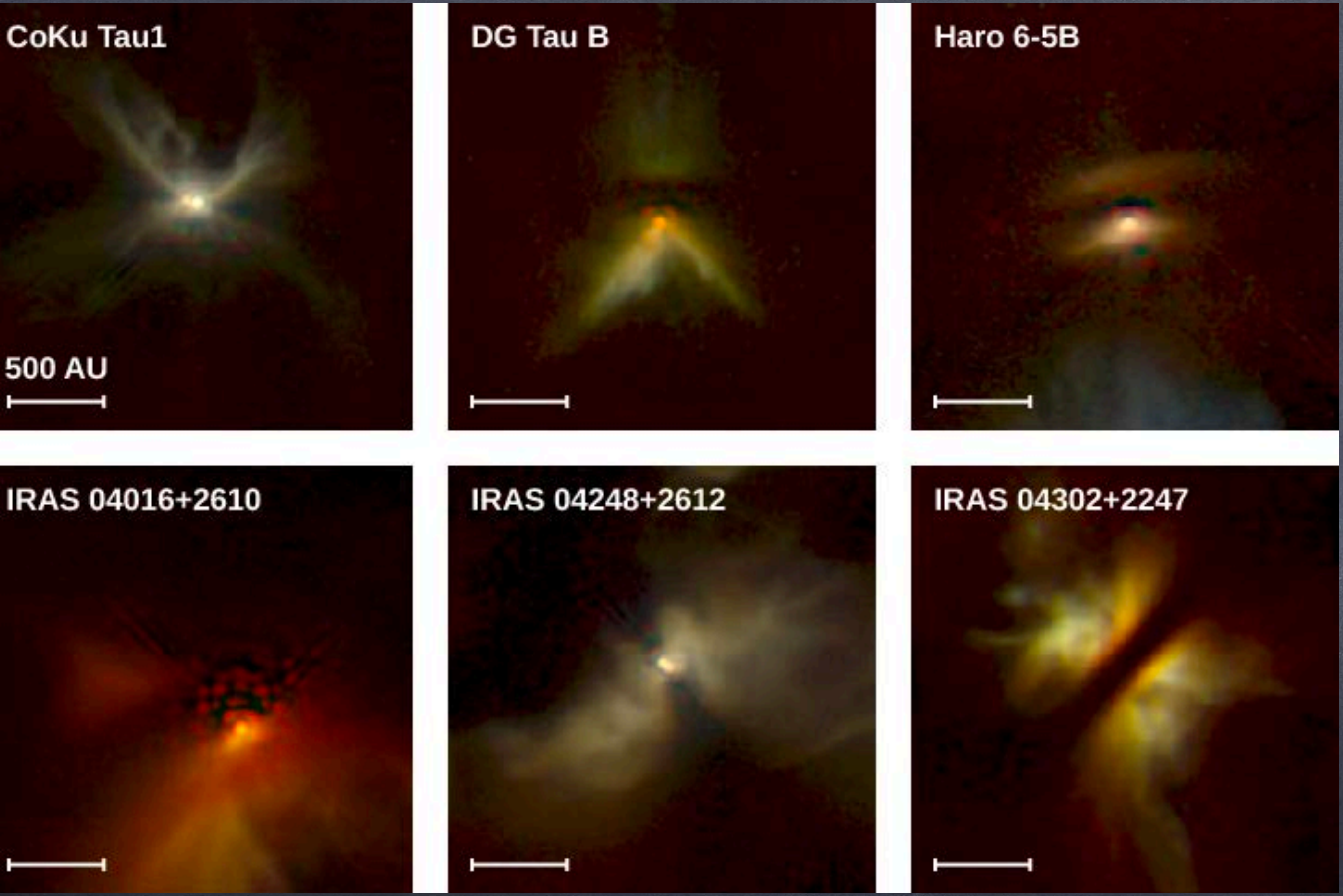
It is very hard to observe the actual birth of a star, one because it is shrouded in dust and two because it happens quickly, astronomically speaking. What we can reason must happen is the core shrinks and forms a disk by angular momentum conservation. Then the heated gas forms bipolar outflows and eventually stops new material from accreting. At this stage we say we have a protostar since fusion hasn't yet turned on.



We can observe these outflows in some cases.

Sometimes these outflows collide with other gas and light them up which we can then observe.

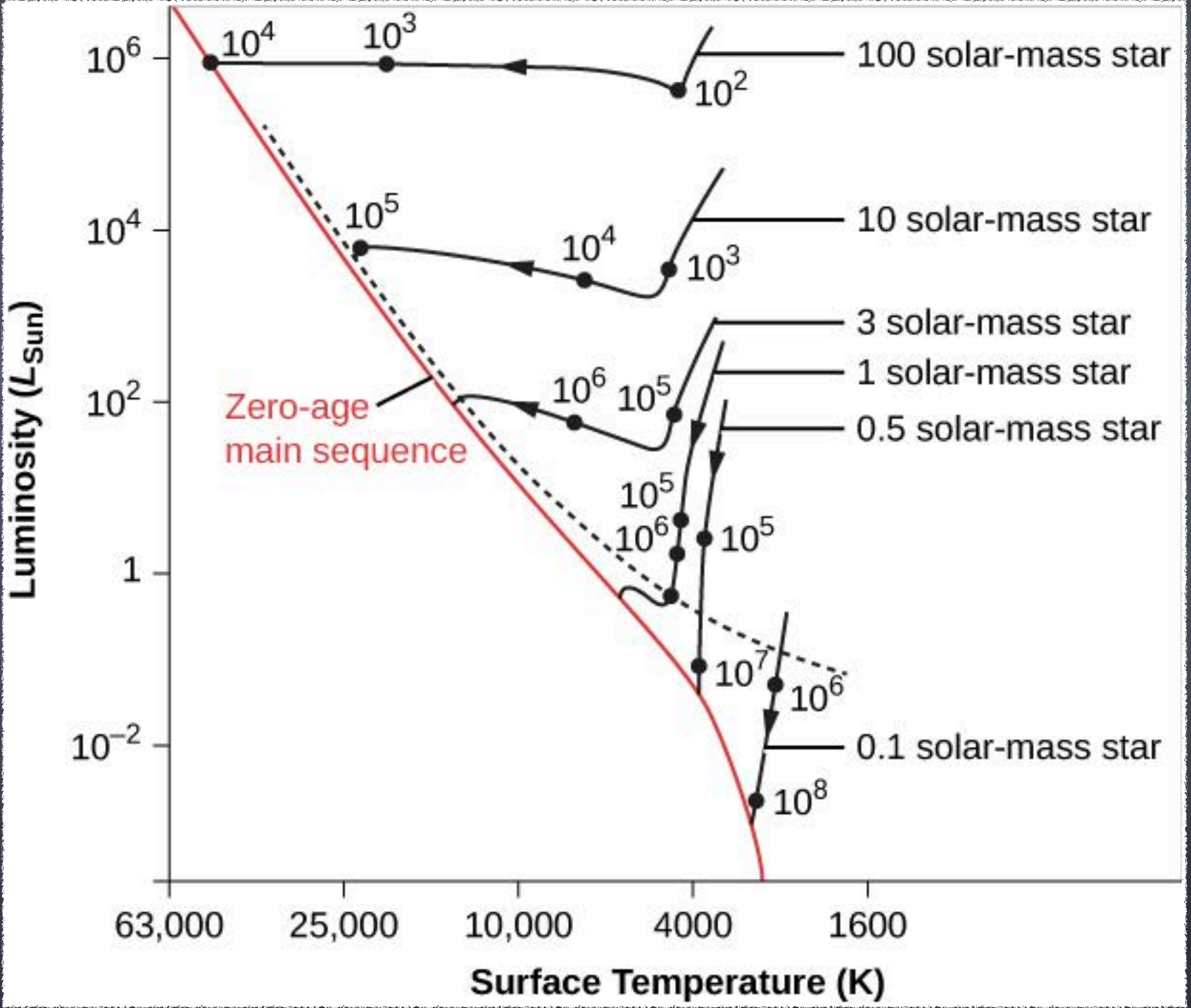




The winds eventually sweep away the gas and dust and we can see the protostar in the infrared surrounded by a protoplanetary disk.

The protostar will still contract for awhile before becoming dense enough for fusion to start.

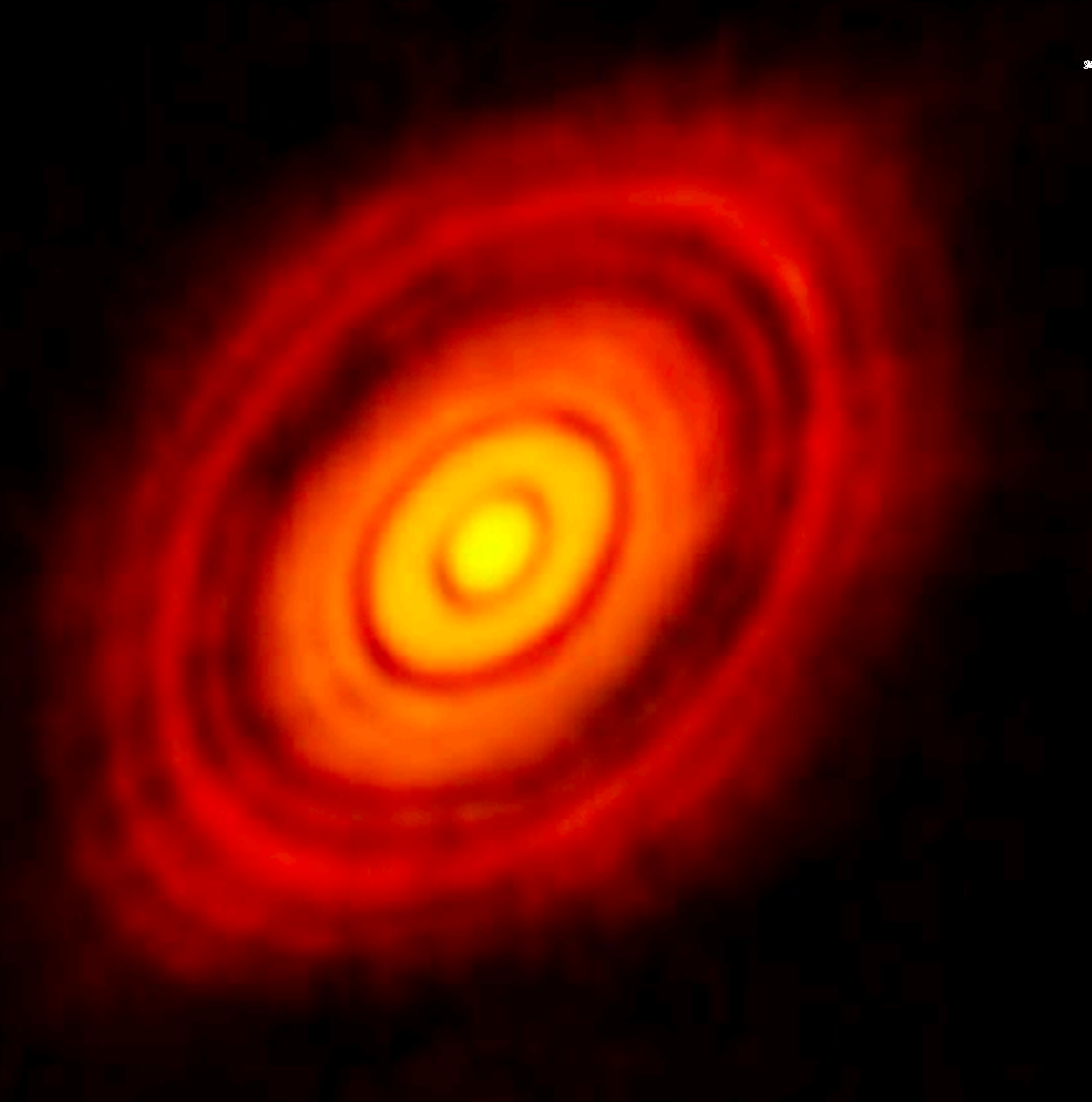
When protostars form it takes them some time to contract and make it to the main sequence as shown by the numbers on the HR diagram. The time strongly depends on the protostar's mass, 100 solar mass stars take only 10,000 years while 1/10 of a solar mass stars take 100 million years.



As a protostar forms a protoplanetary disk forms too. In the protoplanetary disk planets will form.

Observations of protoplantary disks with Hubble (left) and a model of the disk (right).

The rings and gaps are evidence that planets are forming in this protoplanetary disk. Planets, like sheepherd moons in Saturn's rings, create the ring and gap patterns.

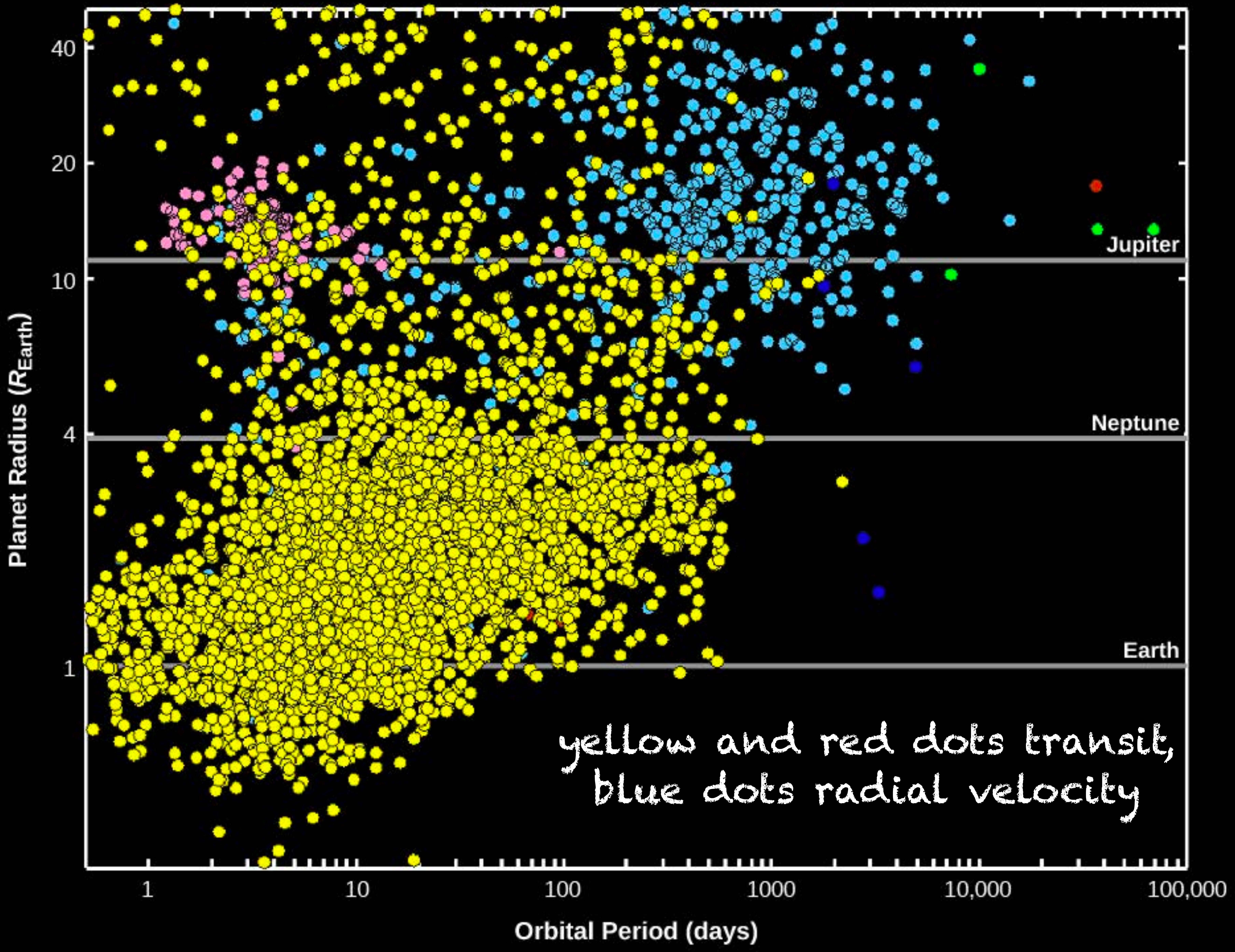


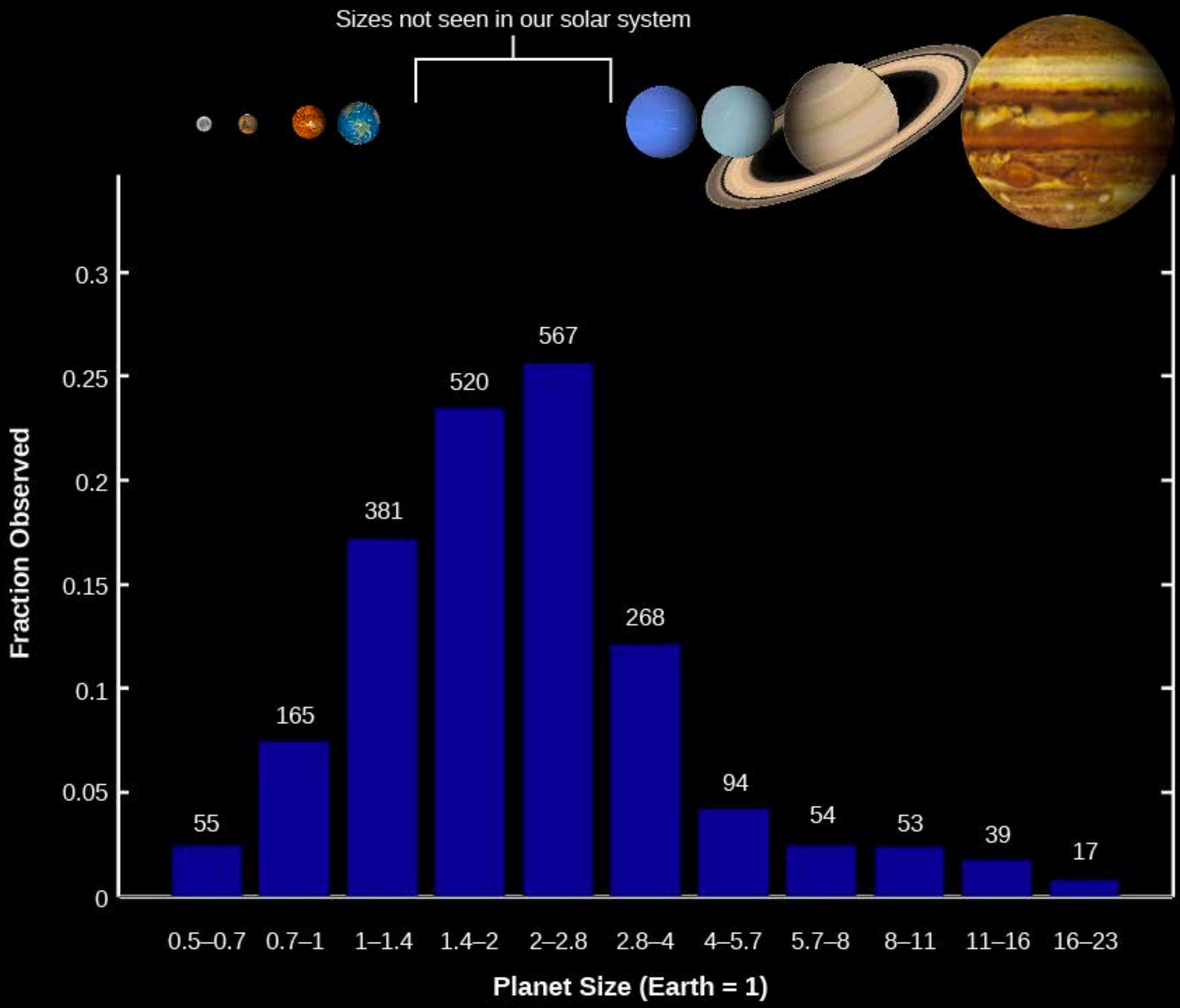
https://public.nrao.edu/gallery/nrao-video-webcast-hl-tau/

Exoplanets

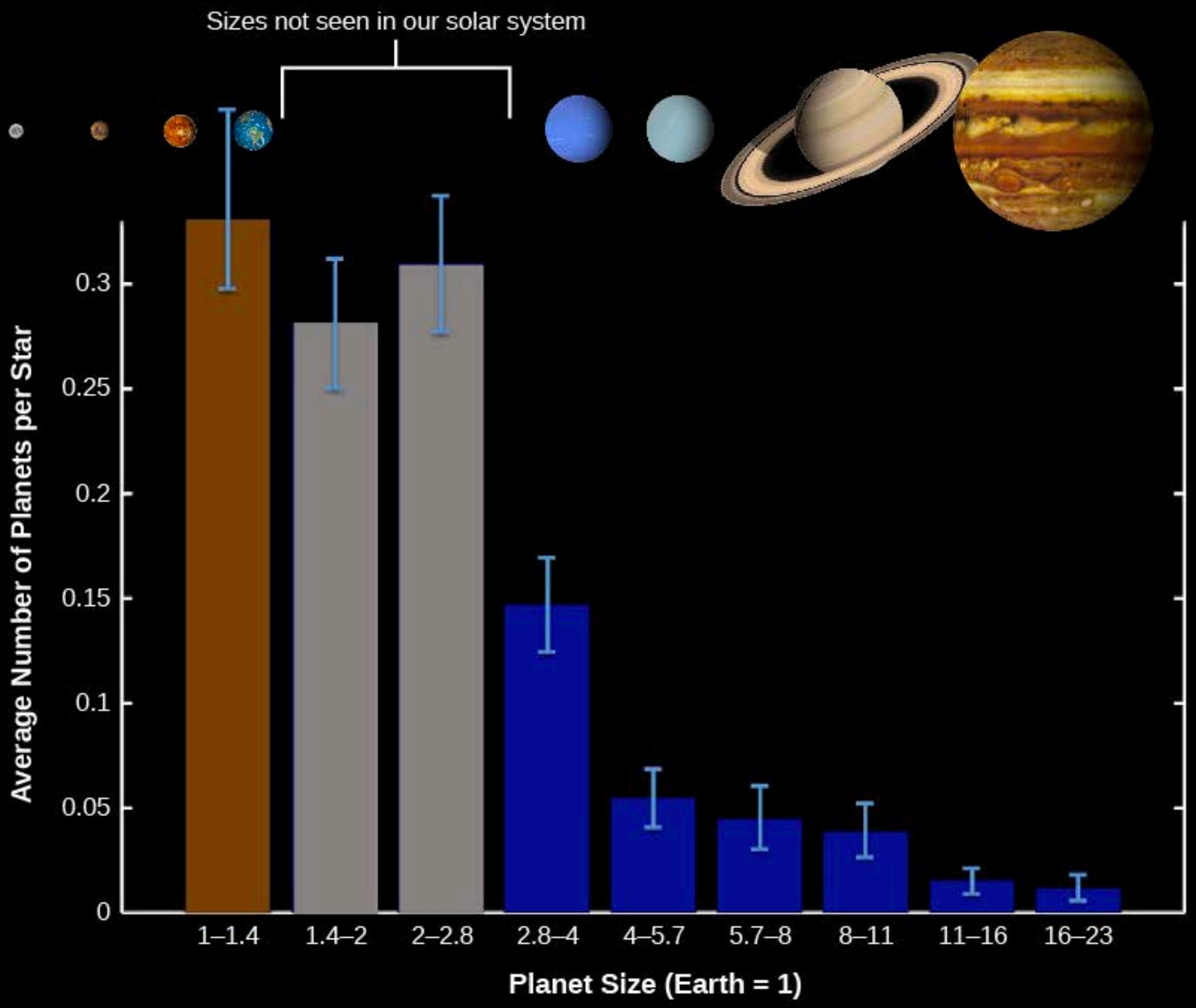
- With thousands of exoplanets detected we also know something about what types of planets form out of a planetary disk.
- However, selection effects make it hard to know the true distribution of planet properties.
- Also the importance of other factors, like the type of star, when it formed and the properties of other planets in the system makes it hard to understand planet formation like we understand star formation.
- However, more data will only improve the situation.

Exoplanets discovered have biases that make the true distribution of planet properties hard to determine. More massive planets and shorter periods are easier to detect.





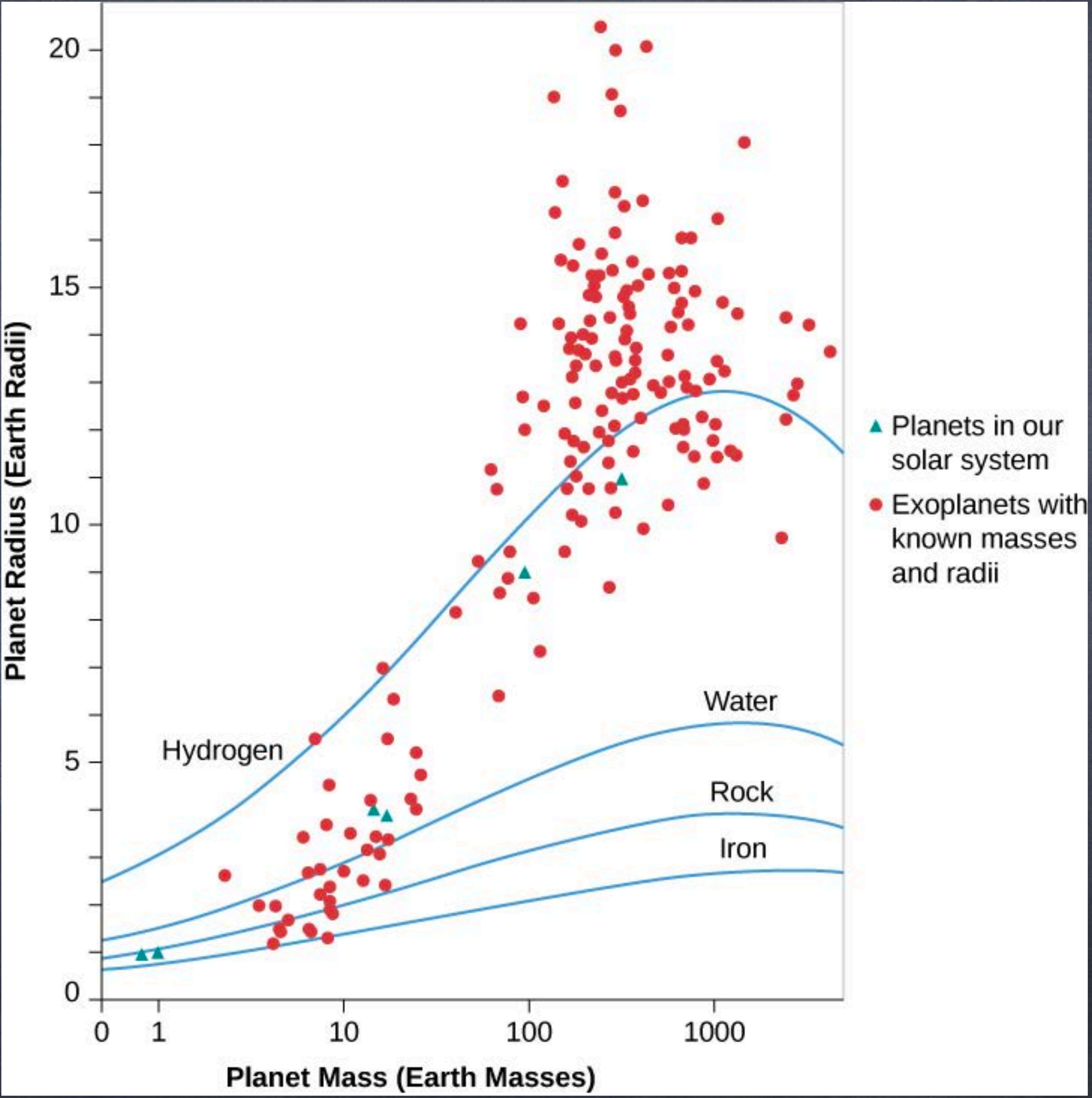
Distribution of planet sizes as found by Kepler. Most notable is the number of planets that fall in the size gap between Earth and Neptune.



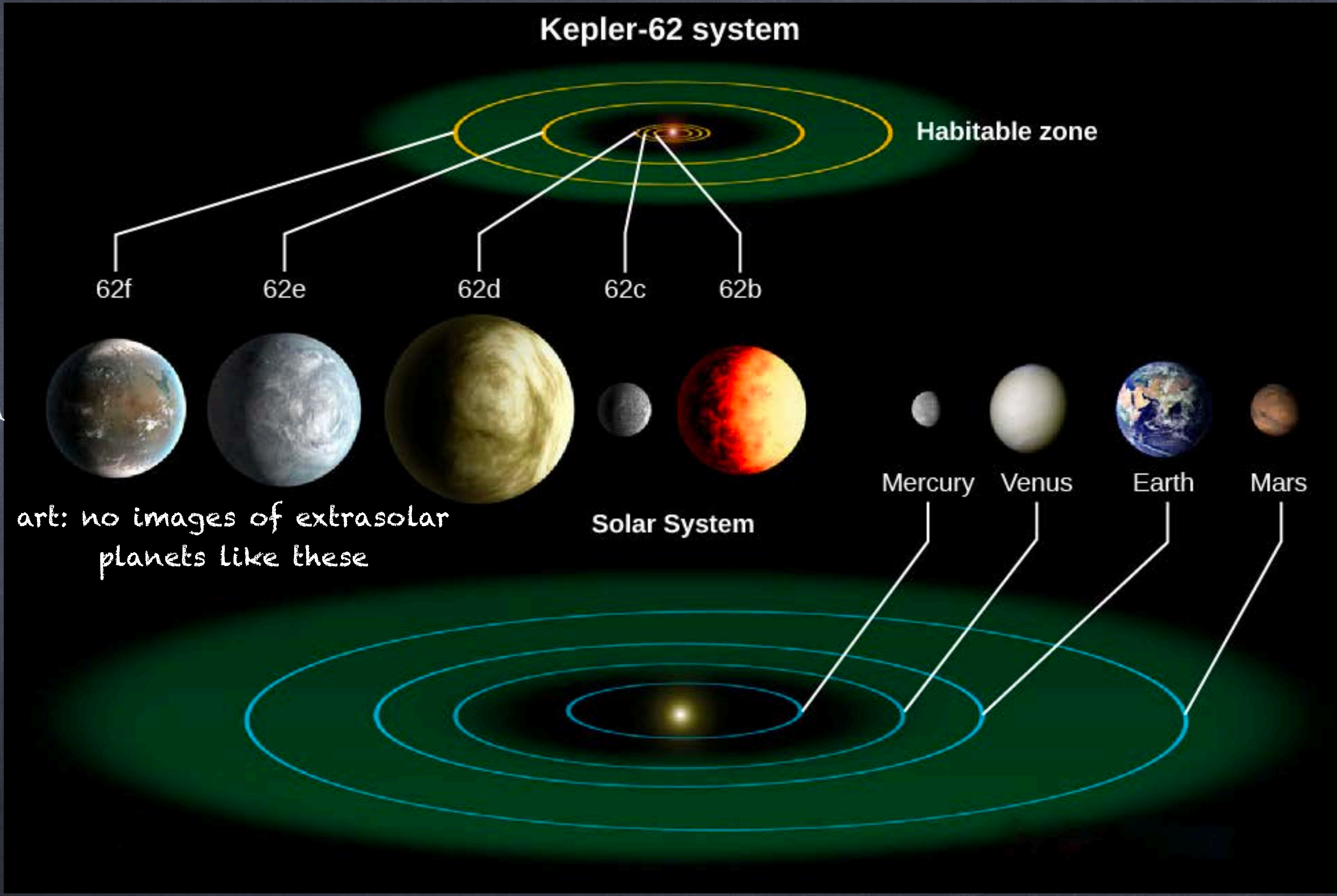
If we only look at planets around stars like the sun we get this distribution instead, with more Earth size planets. What role the type of star plays in the planets that form is unclear, but could be important.

The densities of exoplanets suggest differences from what we have in our solar system. There are many planets with densities less than hydrogen. These are probably gas planets that are heated up so they expand and have lower densities.

There are also planets with the density of water. These seem to be water worlds, like the icy moons we have in our solar system, but a planet which we dont have.



Kepler has found many multi planet systems that we can use to begin to understand what effects planets have on the other planets in a solar system.



art: no images of extrasolar planets like these