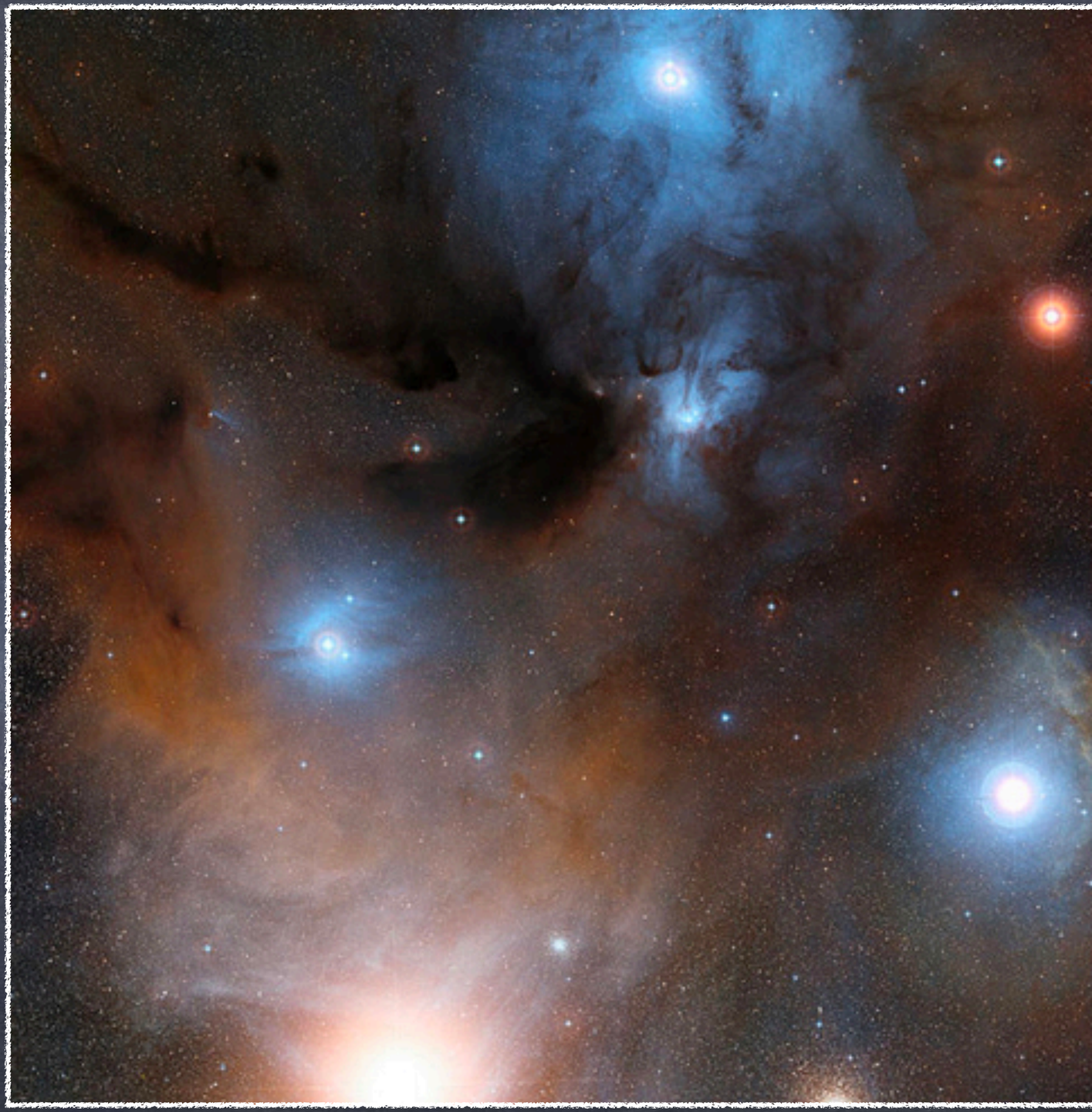
Gas and Dust in Space

Chapter 20

The Interstellar Medium

- Astronomers call all the stuff between stars in a galaxy the interstellar medium or ISM. This medium is mostly composed of gas (mainly hydrogen and helium) and it also contains dust grains.
- Dust grains are like specs of rock often with ices on them too. These are the same dust grains that came together to form the planetesimals in the solar system.
- The interstellar medium is not uniform. Some areas are low density, some clump into large clouds.

The reddish nebulae in this photograph glow with light emitted by hydrogen atoms. The darkest areas are clouds of dust that block the light from stars behind them. The upper part of the picture is filled with the bluish glow of light reflected from hot stars embedded in the outskirts of a huge, cool cloud of dust and gas. The cool supergiant star Antares can be seen as a big, reddish patch in the lower-left part of the picture. The star is shedding some of its outer atmosphere and is surrounded by a cloud of its own making that reflects the red light of the star.

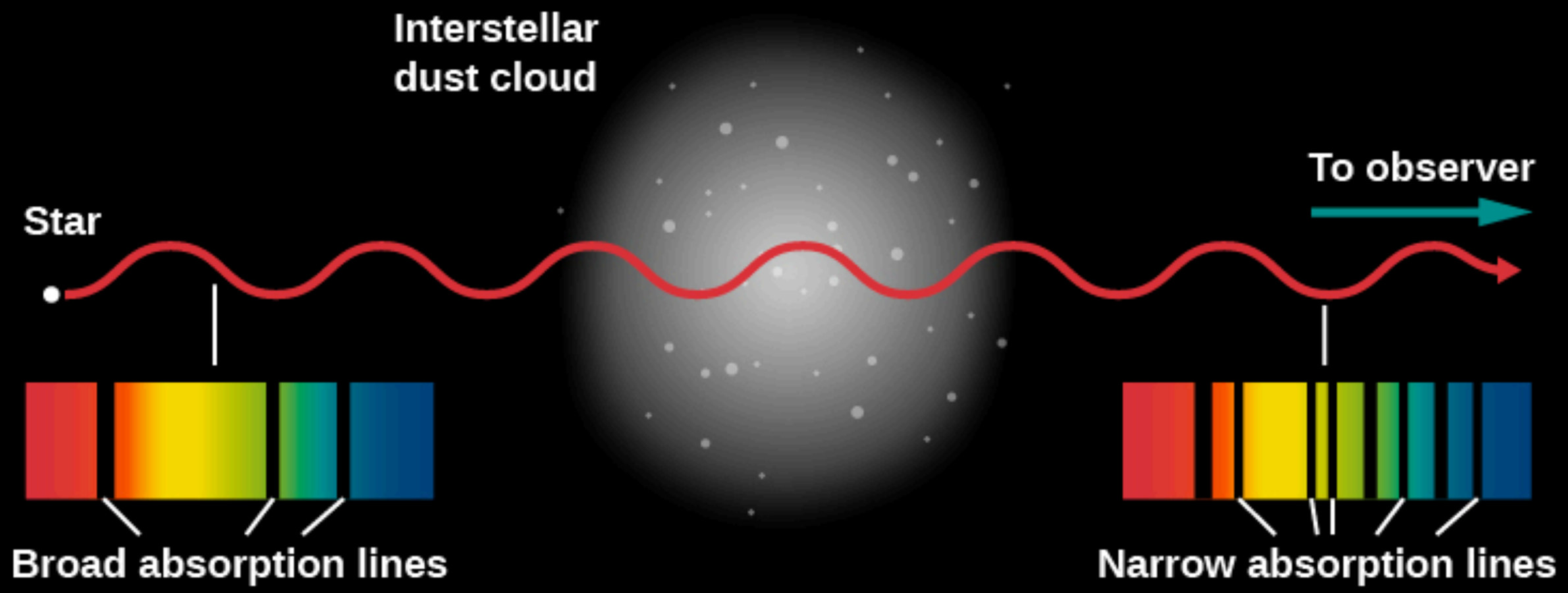


- The interstellar medium is extremely low density. What we call a vacuum on Earth is higher density than the interstellar medium.
- The average density of the ISM is one atom per cubic cm. Air on Earth has 10^{19} atoms per cubic cm for comparison. Some regions of the ISM are thousands of times denser, but that is still really low density.
- The density of dust is even less, a cubic km of space would have only a few hundred dust grains which are less than 1/10000 of a mm in length.
- But the galaxy is also very big, so this low density stuff adds up. The total mass in the ISM is 10 billion times the mass of the Sun.

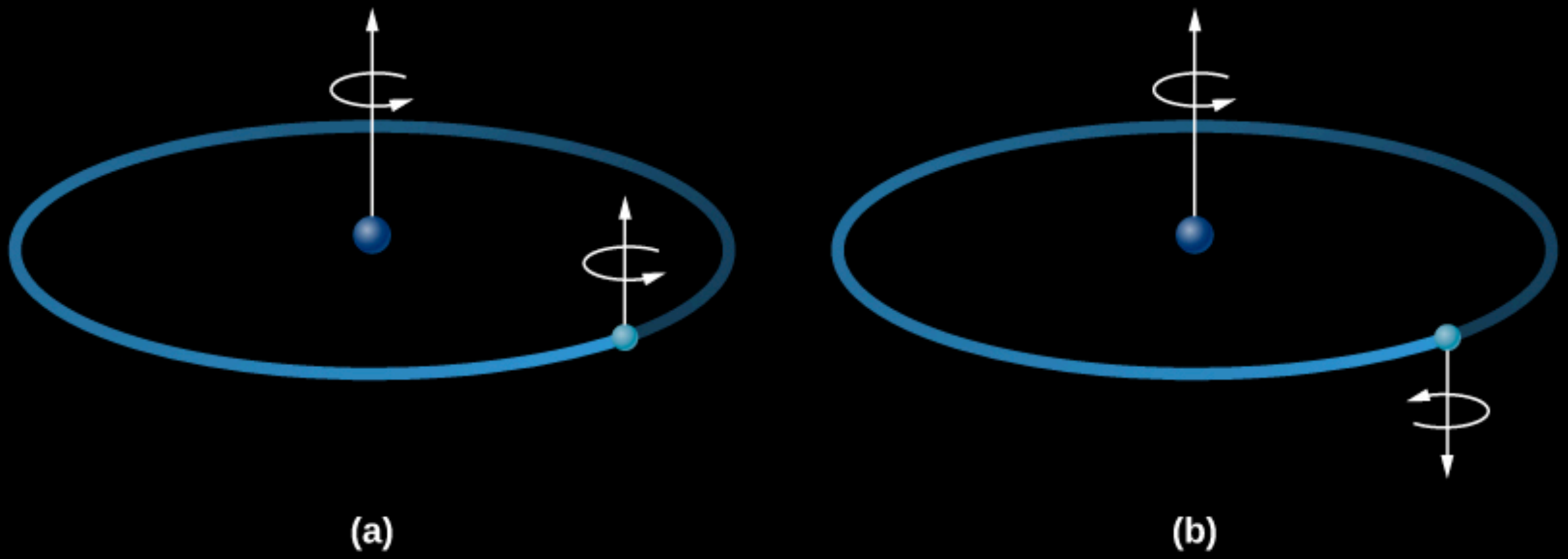
Ionized Hydrogen (HII) Regions

- The temperature of gas in the ISM varies from millions to hundreds of degrees.
- Gas around young stars can be heated to 10,000K and ionized (looses its electron).
- It will then gain an electron and emit light which glows red.
- A fluorescent light on Earth works in a similar way.

Most of the ISM is neutral gas, some as cold as 100K or even 10K. This gas doesn't emit in the visible wavelengths, but we can see it as absorption of background light. The absorption lines are narrow because the gas is cold.



Neutral hydrogen can be 'seen' in the radio at a wavelength of 21cm. This corresponds to the energy difference between when the spin of a proton is the same as an electron and when they spin the opposite direction. On average an atom takes 10 million years to emit this radiation and flip its spin, but of course there are many atoms.



Supernova Remnants

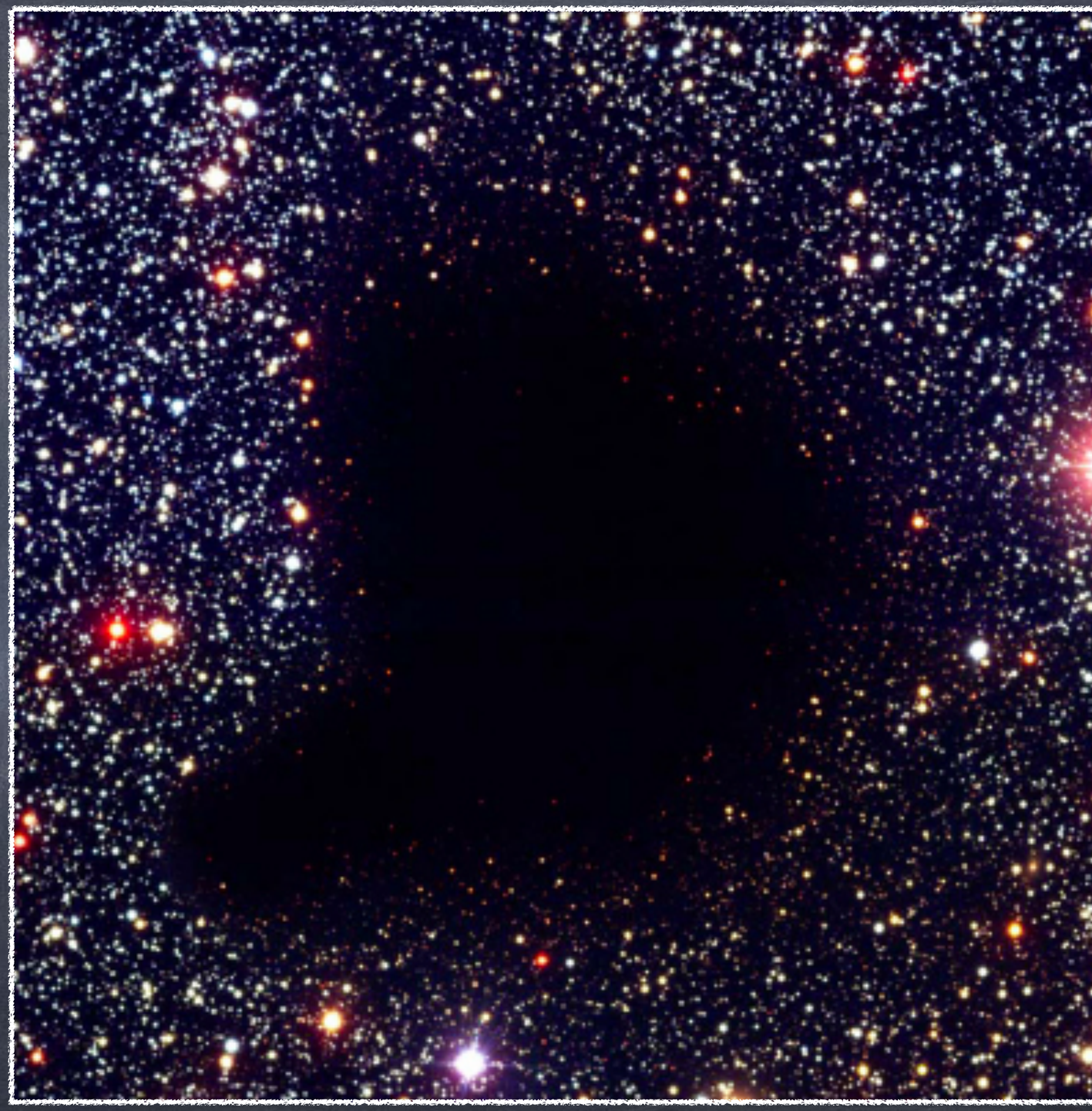
- Some gas in the ISM is at millions of degrees. It is visible in x-rays.
- This was a surprise since this is much hotter than any star. It turns out this gas is heated by exploding massive stars called supernova.
- When the star explodes it ejects gas that collides with the ISM heating it to millions of degrees.

Giant Molecular Clouds

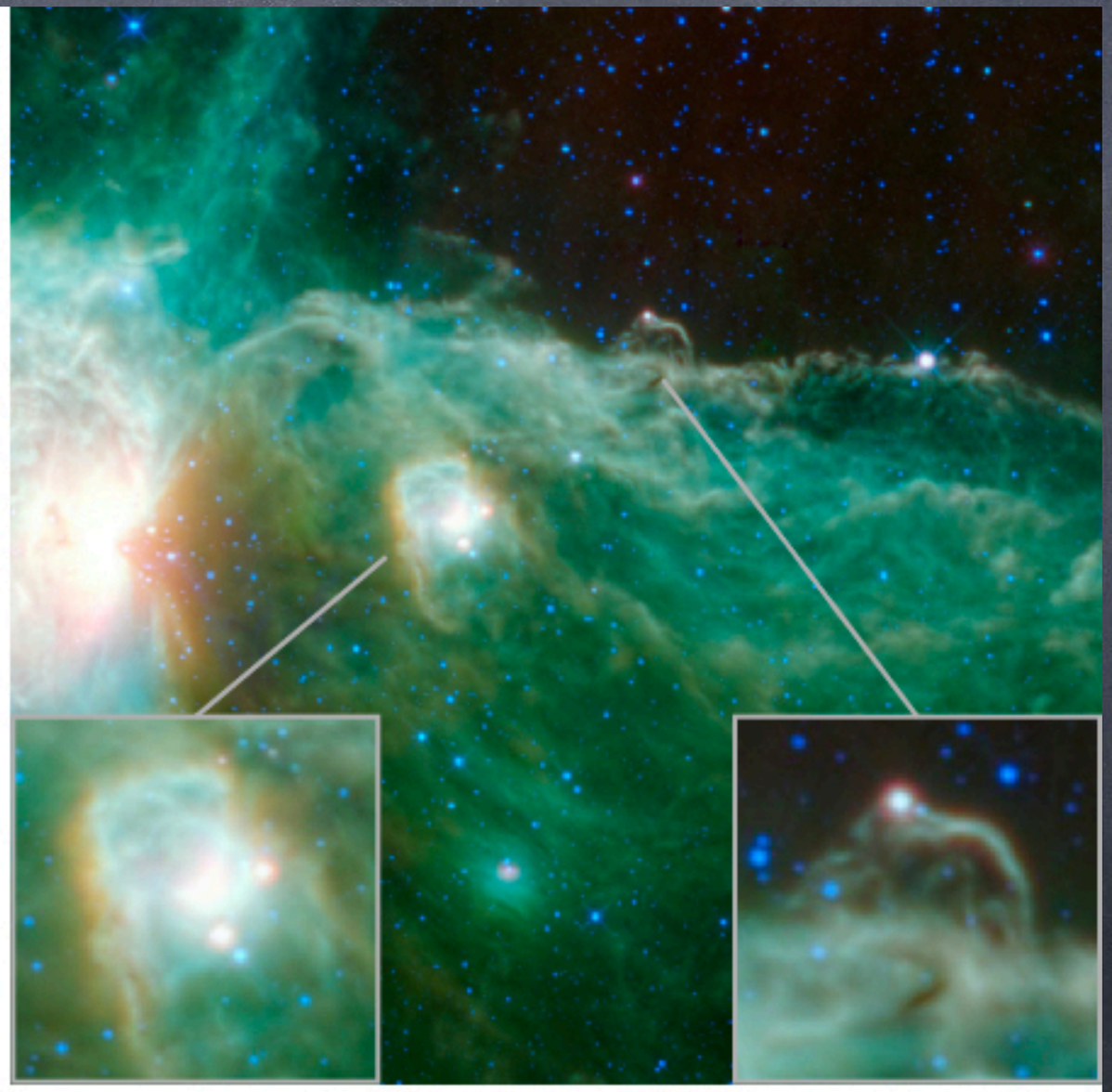
- On the other extreme there are clouds so cold that hydrogen and other elements can form molecules.
- Many molecules we recognize can be found in these molecular clouds: ammonia, formaldehyde, ethyl alcohol, benzene.
- These clouds are very dense and take up a small fraction of the space in the ISM, but still about 20-30% of the mass.

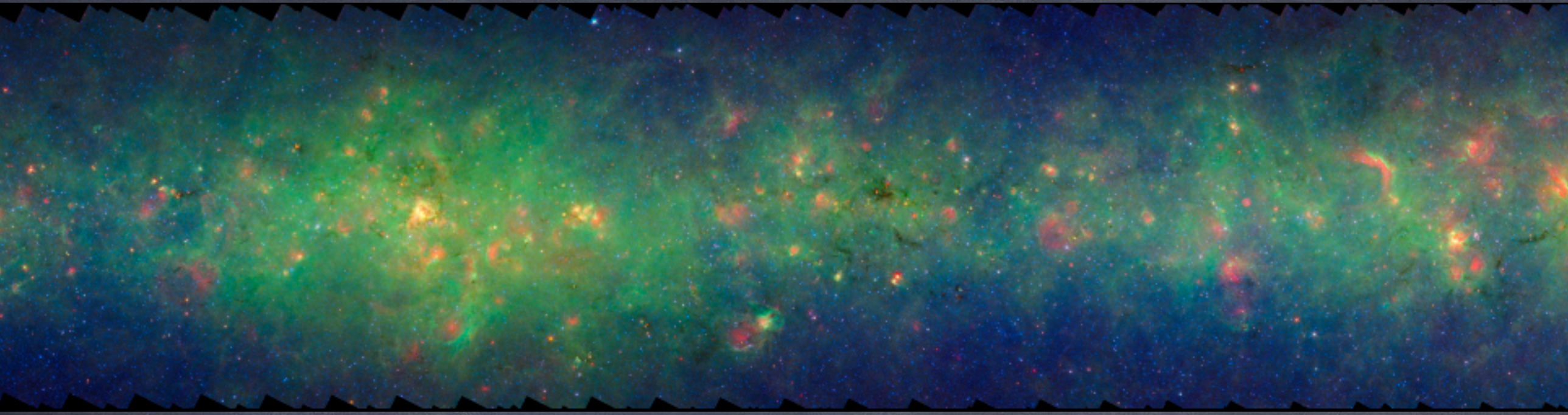
Dust Clouds

- Dust clouds can be 'seen' by how they block the light of background stars. There are just as many stars behind the dark region, but the dust has scattered all of that light.
- They can also be seen by emitted light in the infrared and by reddening background stars.



The Horsehead nebula in visible light (left) and infrared (right). Notice that the dark nebula emits in the infrared.

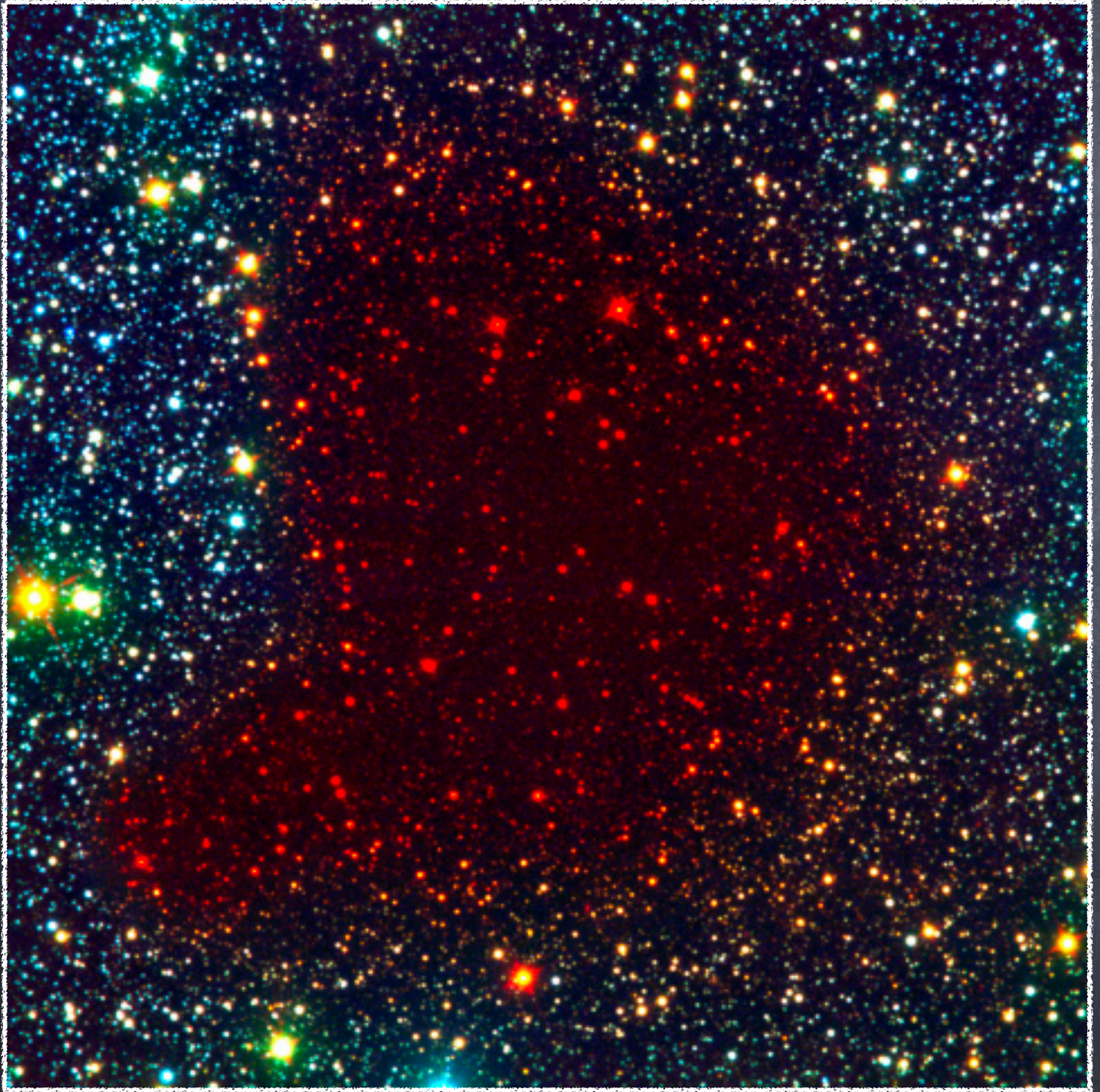




An infrared image of the Milky Way shows lots of emission from dust clouds. Warm dust is the main source of infrared light.

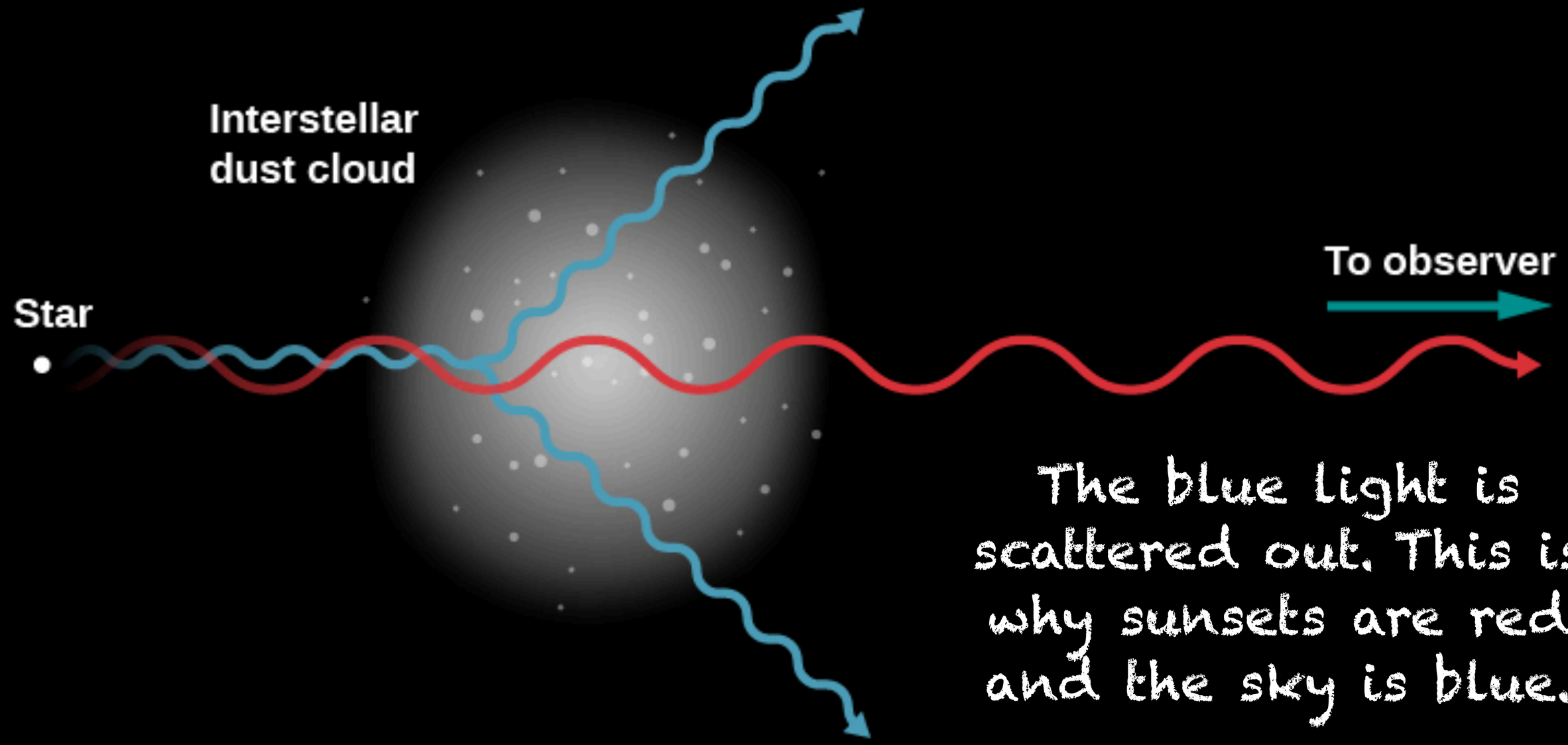
Reflection Nebula

- Here the blue light from hot stars has been scattered off of dust which creates these blue halos.
- It is like the halo you see around a street light when there is fog.

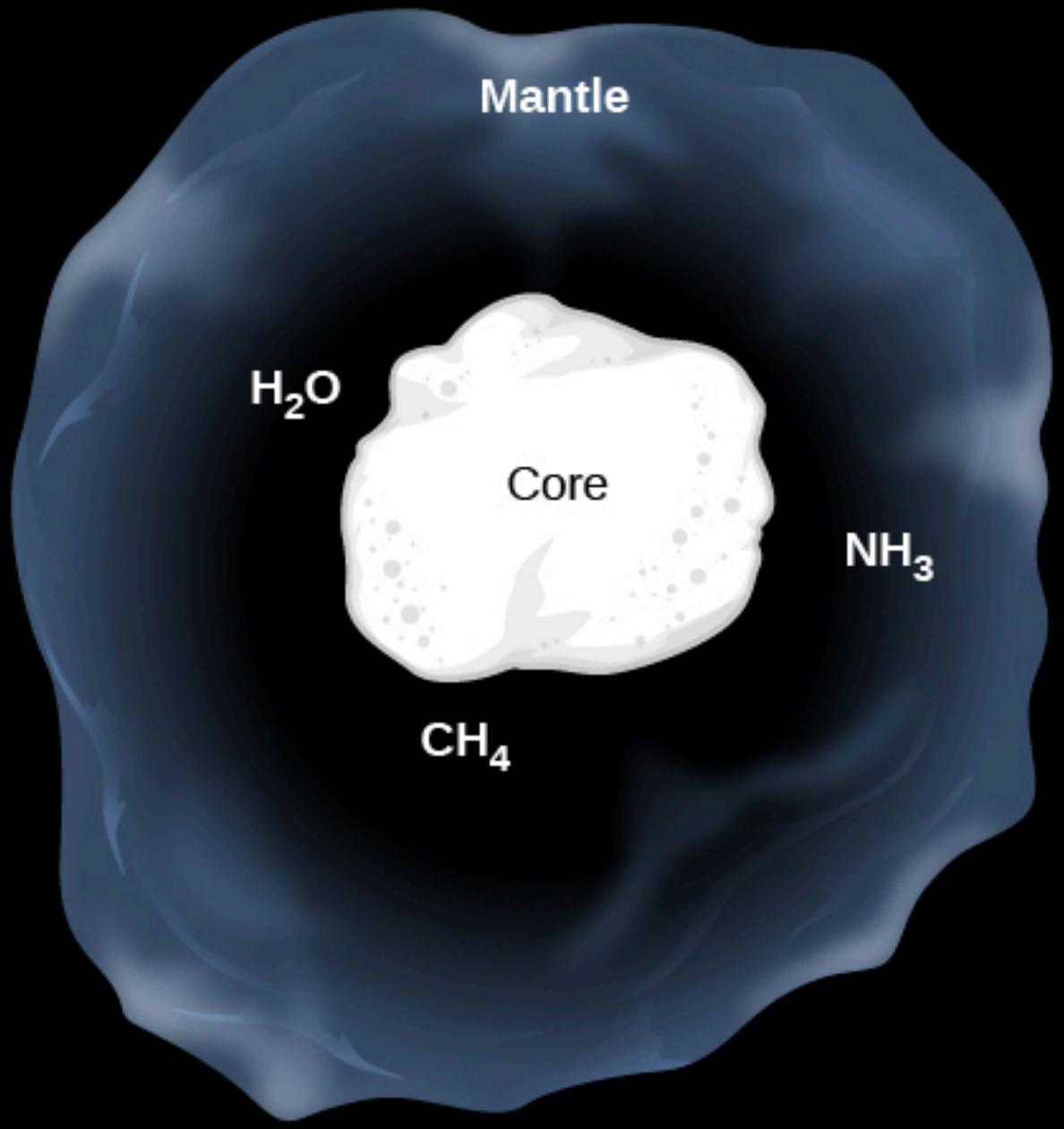


Reddening

- One of the most pronounced effects of dust is reddening, like you see in sunsets.
- Dust scatters shorter wavelengths more than longer ones, so the bluer the light the more is removed.
- This image show infrared and visible. You can see the infrared makes it trough were the visible does not.



The blue light is scattered out. This is why sunsets are red and the sky is blue.



Dust is probably a rock like core surrounded, by ices like water, ammonia and methane. These grains are only 1/100 the width of human hair. We know this because of how they effect light, scattering blue but not infrared light means they must be about the size of that light.

Cosmic Rays

- Also in the interstellar medium are cosmic rays.
- These are charged particles, mostly protons and atomic nuclei, moving at incredible speeds, around 90% the speed of light.
- This is much like the solar wind only higher energies. We detect these particles as they hit the upper layers of Earth's atmosphere. With out an atmosphere, they would be hitting Earth's surface.

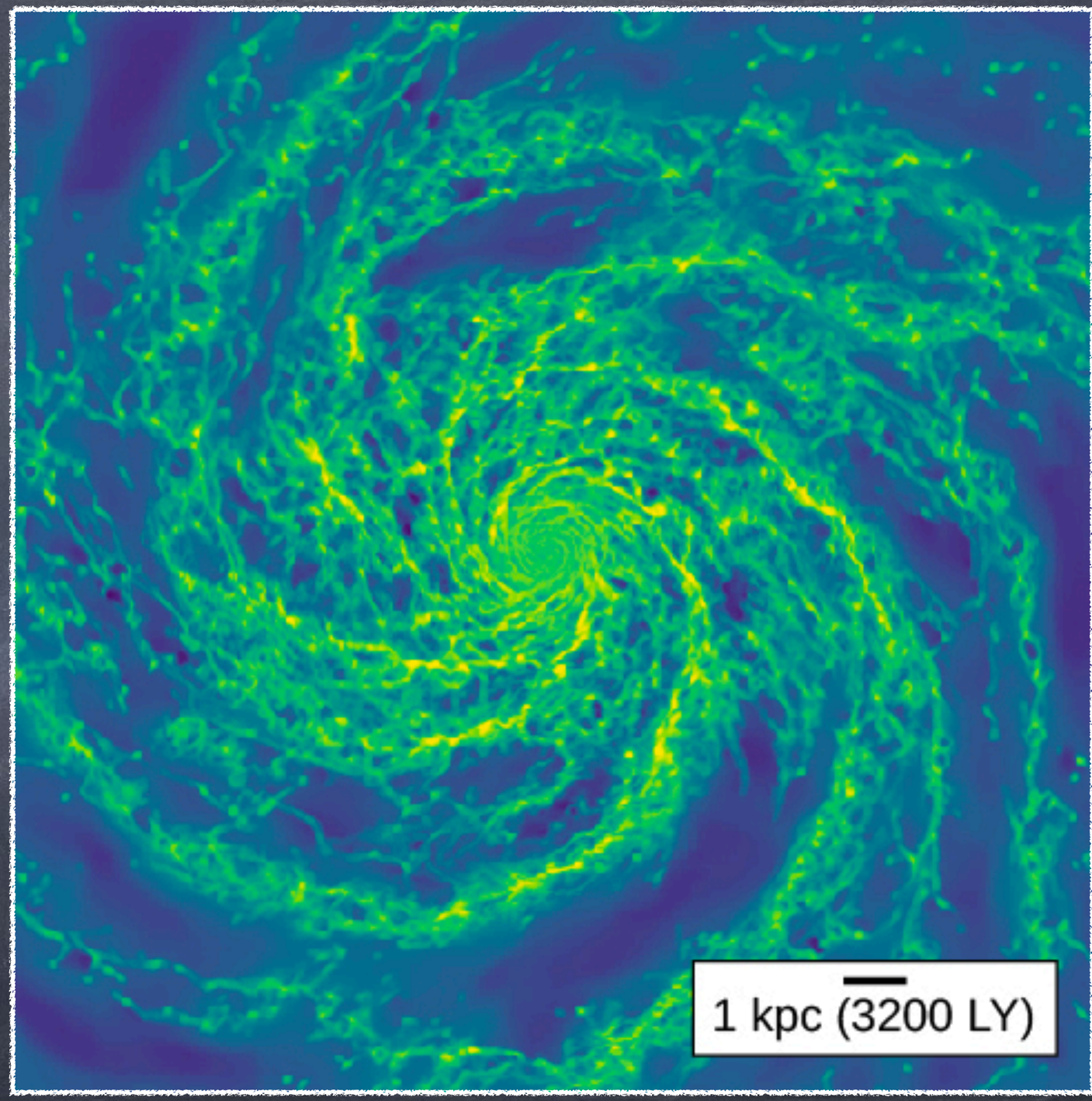
Cosmic Rays

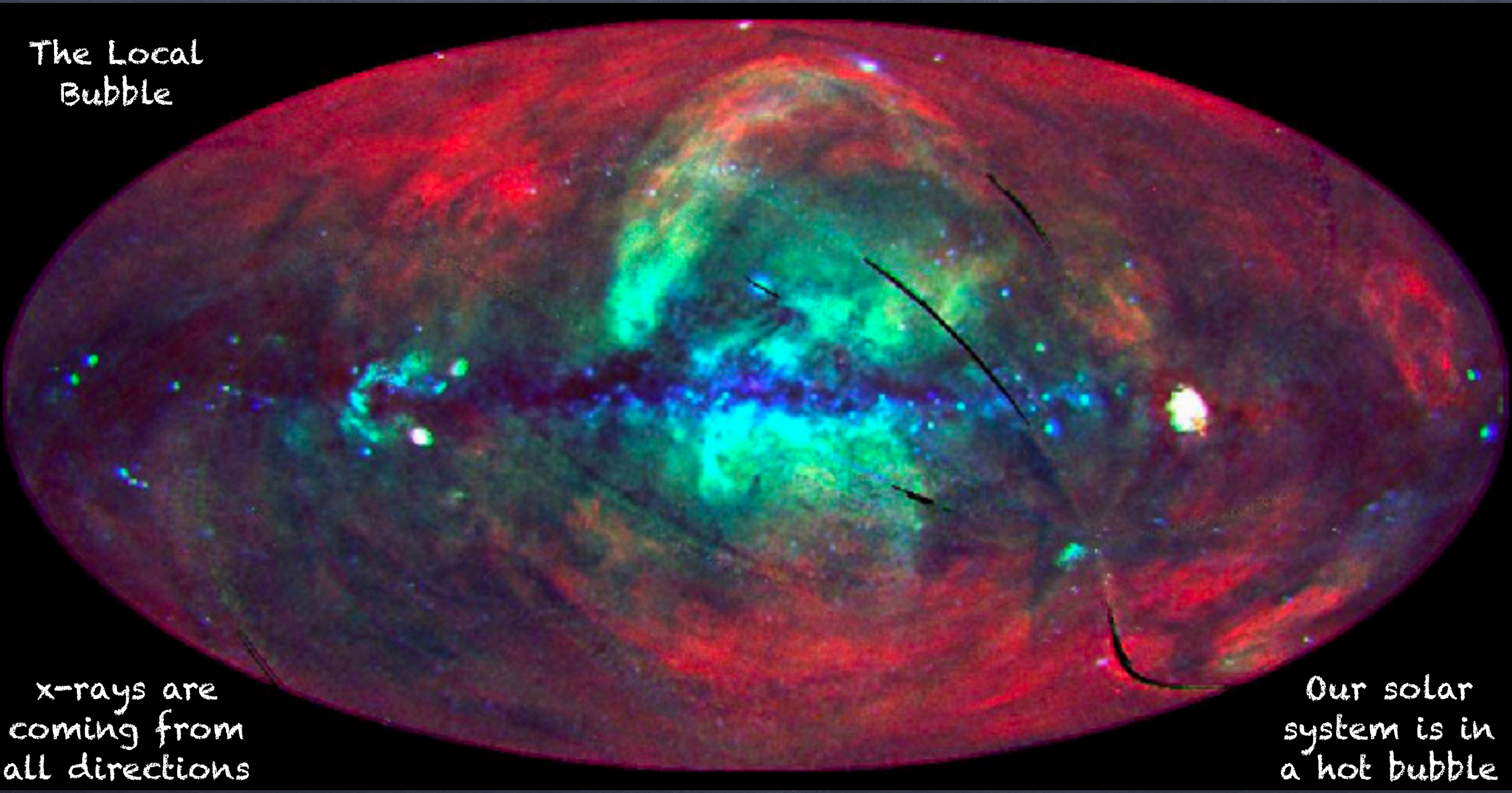
- Because these are charged particles they are effected by magnetic fields. Based on the magnetic fields in the galaxy, the lower energy cosmic rays must be produced in the galaxy while the higher energy ones come from outside our galaxy.

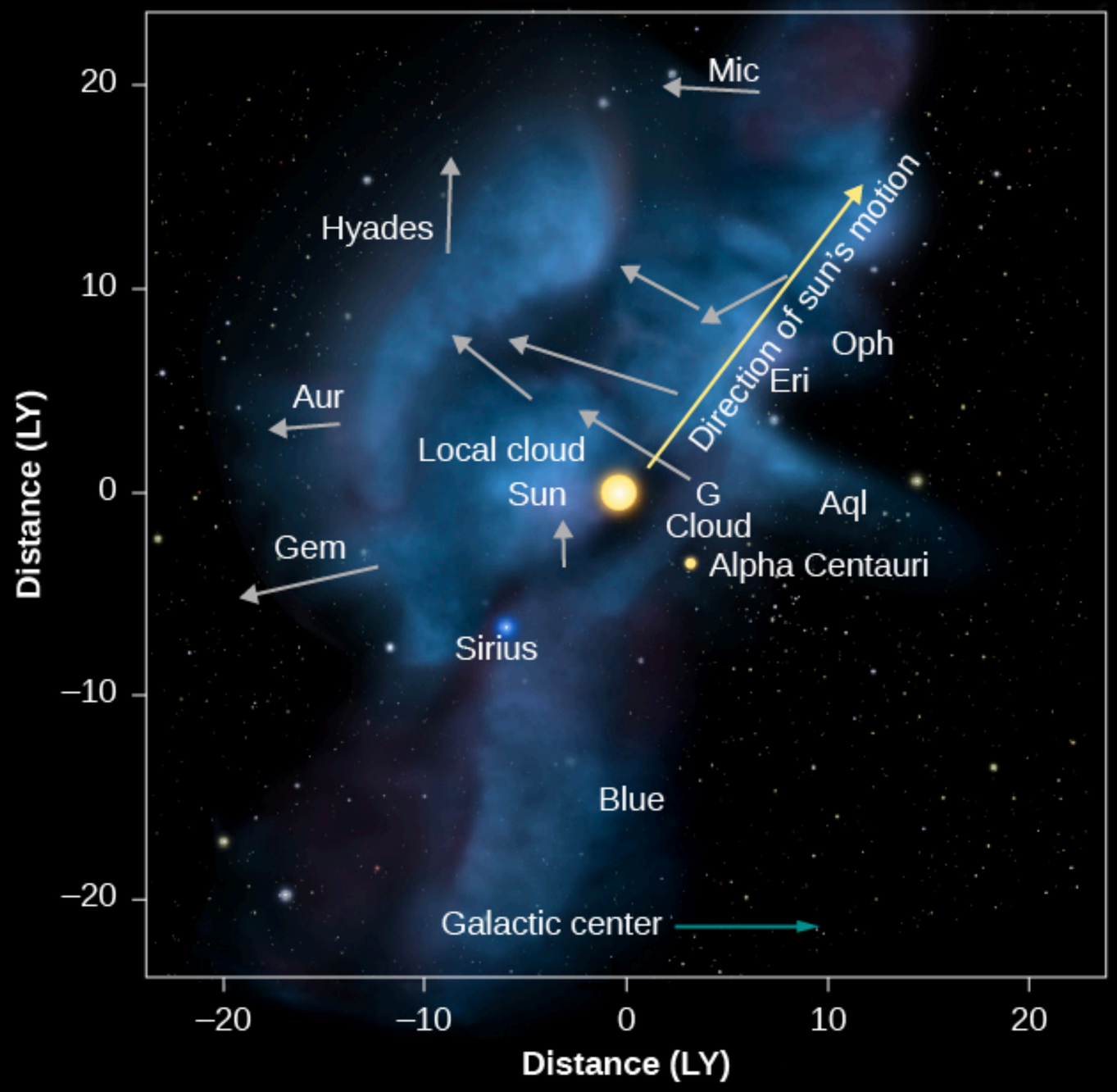
- The lower energy cosmic rays are made in super nova explosions. Particles are accelerated to very high energies as they ride the shock wave from the super nova.

- Higher energy cosmic rays are probably created in super massive black holes in active galaxies.

- The material in the ISM does not simply stay in place, but flows through out the galaxy.
- It moves from low density to high density regions and then back again.
- The heavier elements that form dust are created in stars and released in winds and supernova.
- The dust grains are part of the cloud of gas that forms a new solar system and will make up the planetesimals.
- Material is shared back and forth over the lifetime of the Universe, little remains unchanged.




The Local Bubble
x-rays are coming from all directions
Our solar system is in a hot bubble



The sun moves through the interstellar medium. Currently we are in a warm cloud inside the hot local bubble.