Hot Science Cool Talks

UT Environmental Science Institute

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Origins of the Universe

Dr. Frank N. Bash

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Origins of the Universe

Dr. Frank N. Bash and Pamela L. Gay, M.A.

In the Beginning…

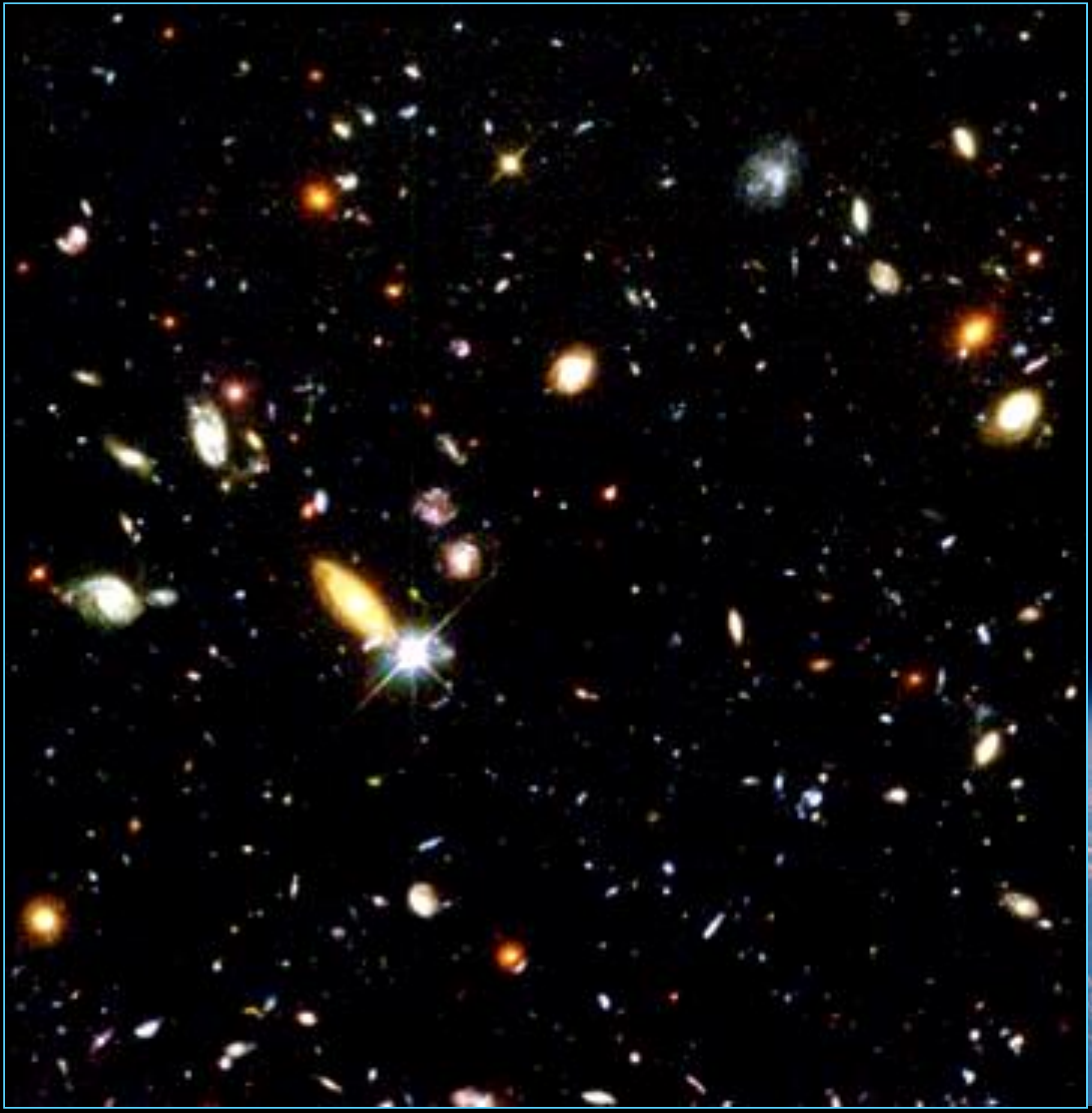
The universe started when the "Big Bang" exploded, and out of this explosion came all the matter, all the energy, and all the space that exists today.

…there was light.

The darkness of night tells a finite story.

When we look at the sky, we see bright stars against the darkness of space.

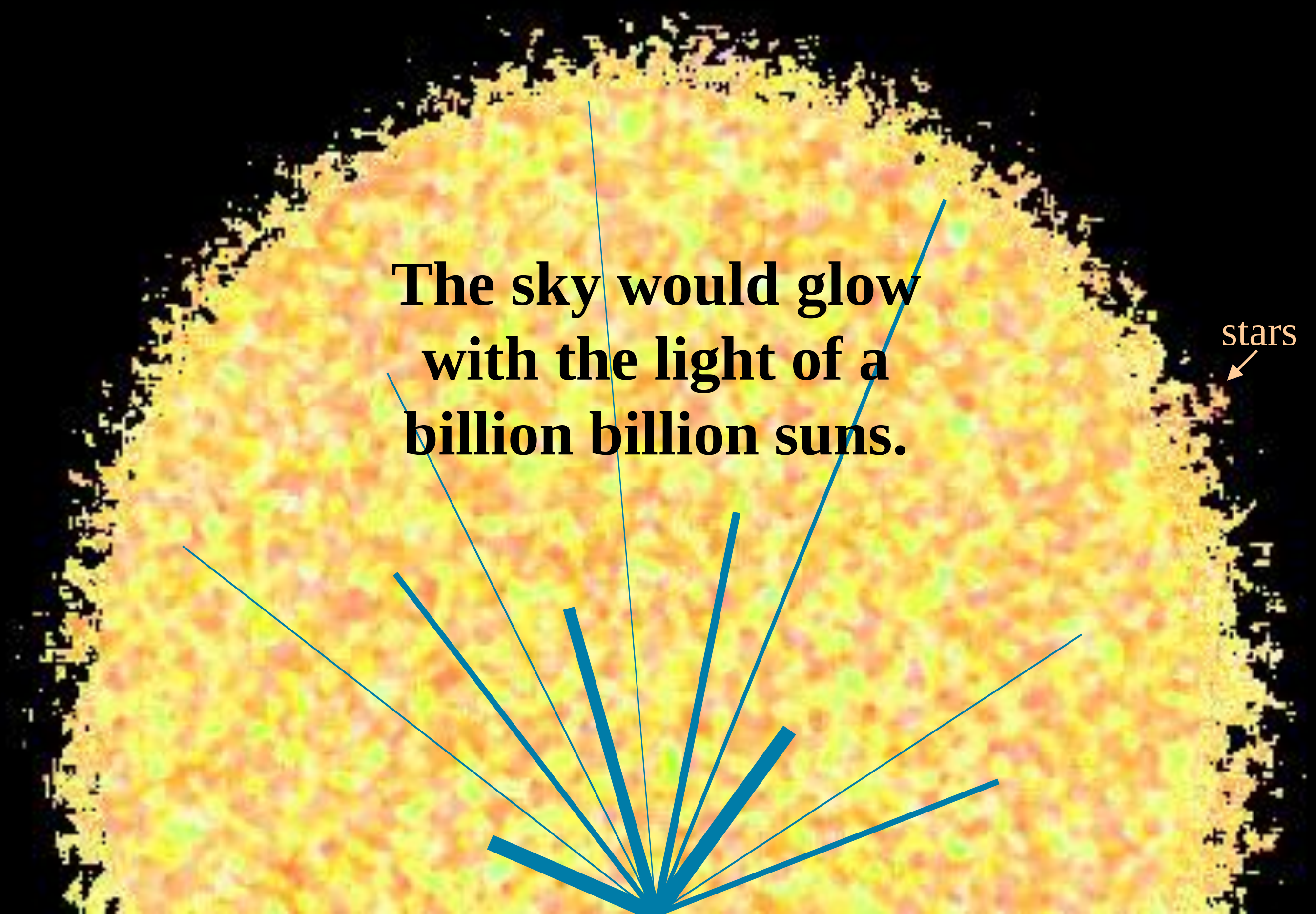
The darkness of night tells a finite story.



Even if we look at the sky with the Hubble Space Telescope we will still find patches of light against darkness.

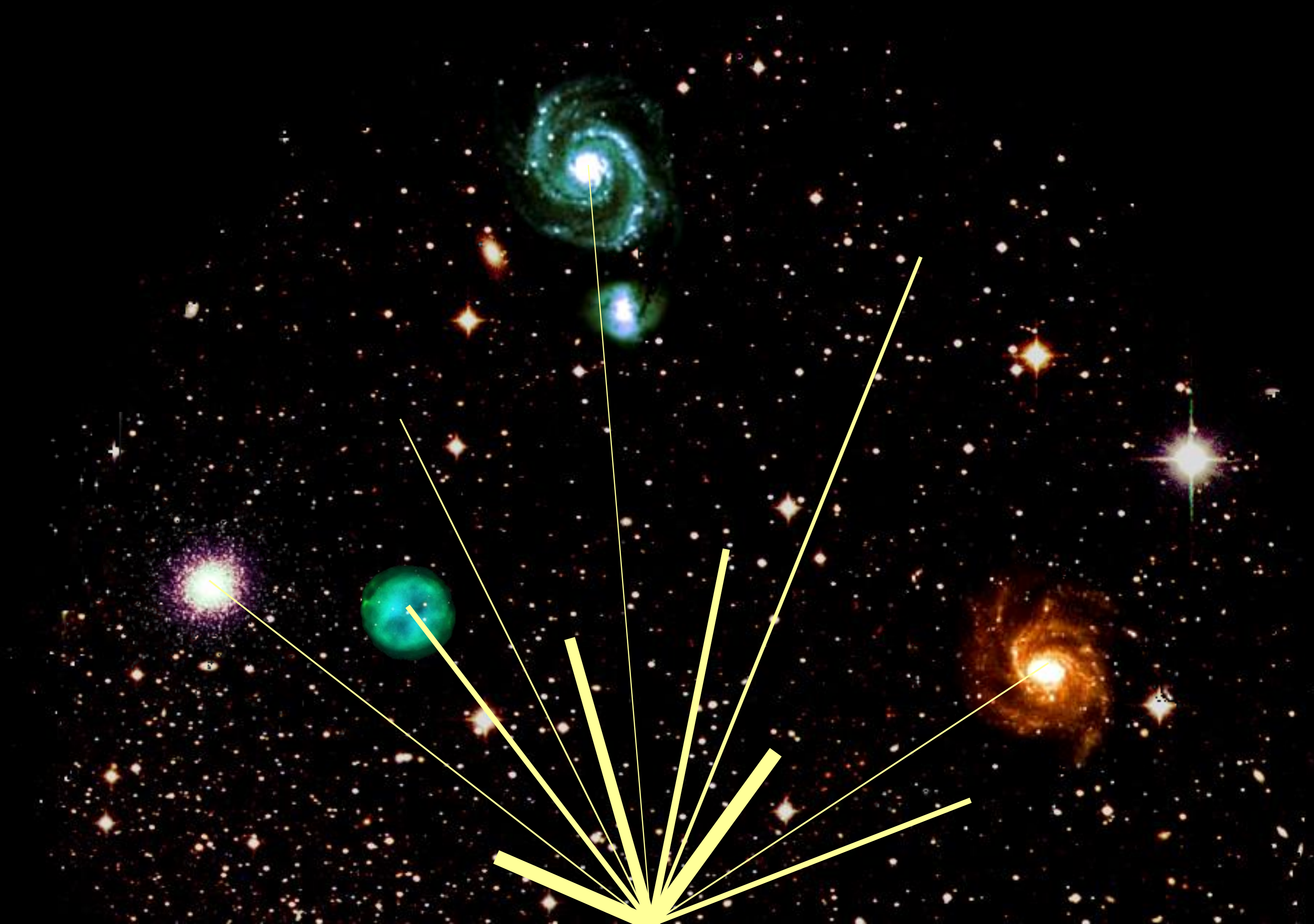
The darkness of night tells a finite story.

If the Universe were infinite in age and dimension, we would see a star in every direction.



The darkness of night tells a finite story.

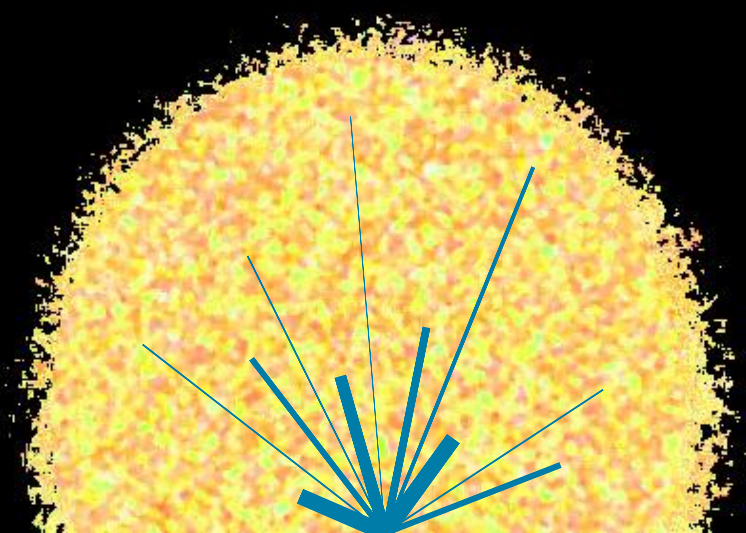
Our eyes can find darkness. This teaches us that the universe is either finite in size or age or *both*.



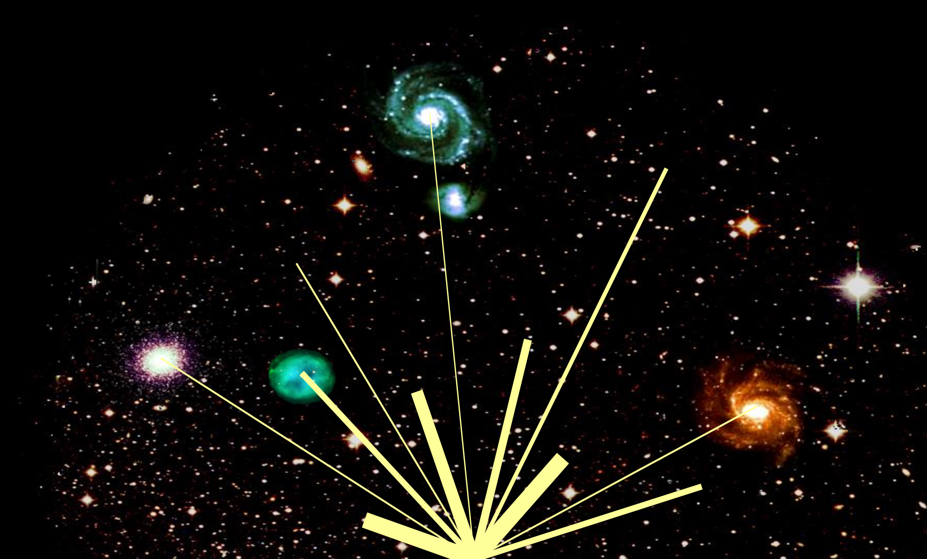
Olber's Paradox

In 1826, astronomer Heinrich Wilhelm Olber became the first to make the consequences of a dark sky popularly understood. In his time it was not clear what was happening, so the word "paradox" was applied.

Infinite Universe



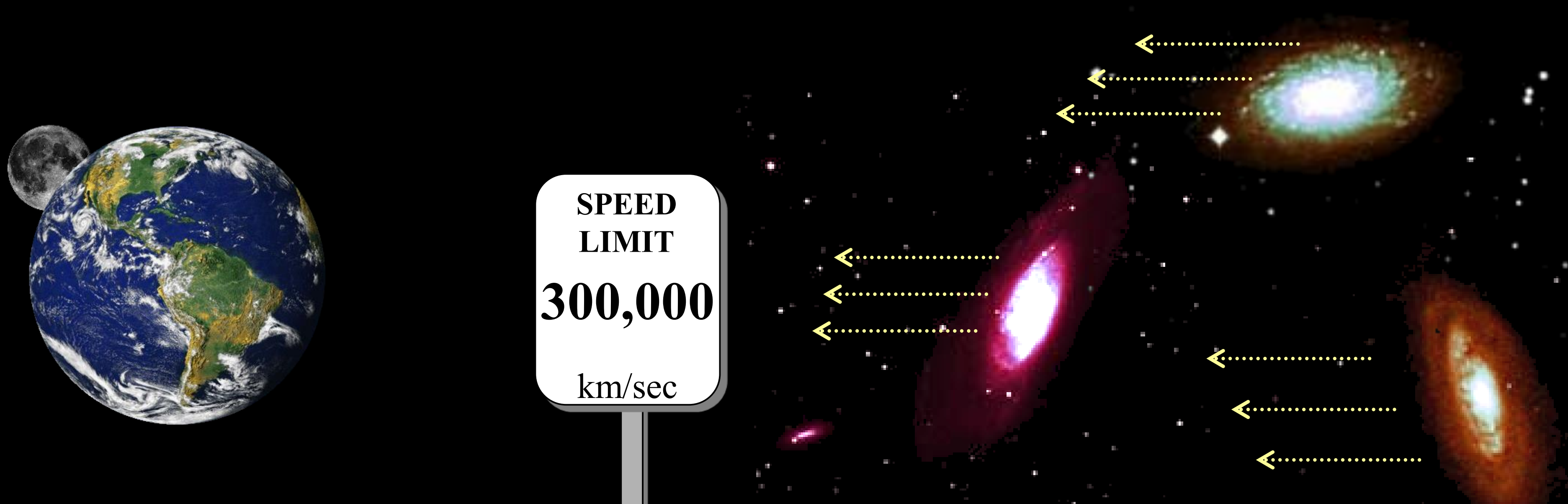
Finite Universe



Olber's Paradox

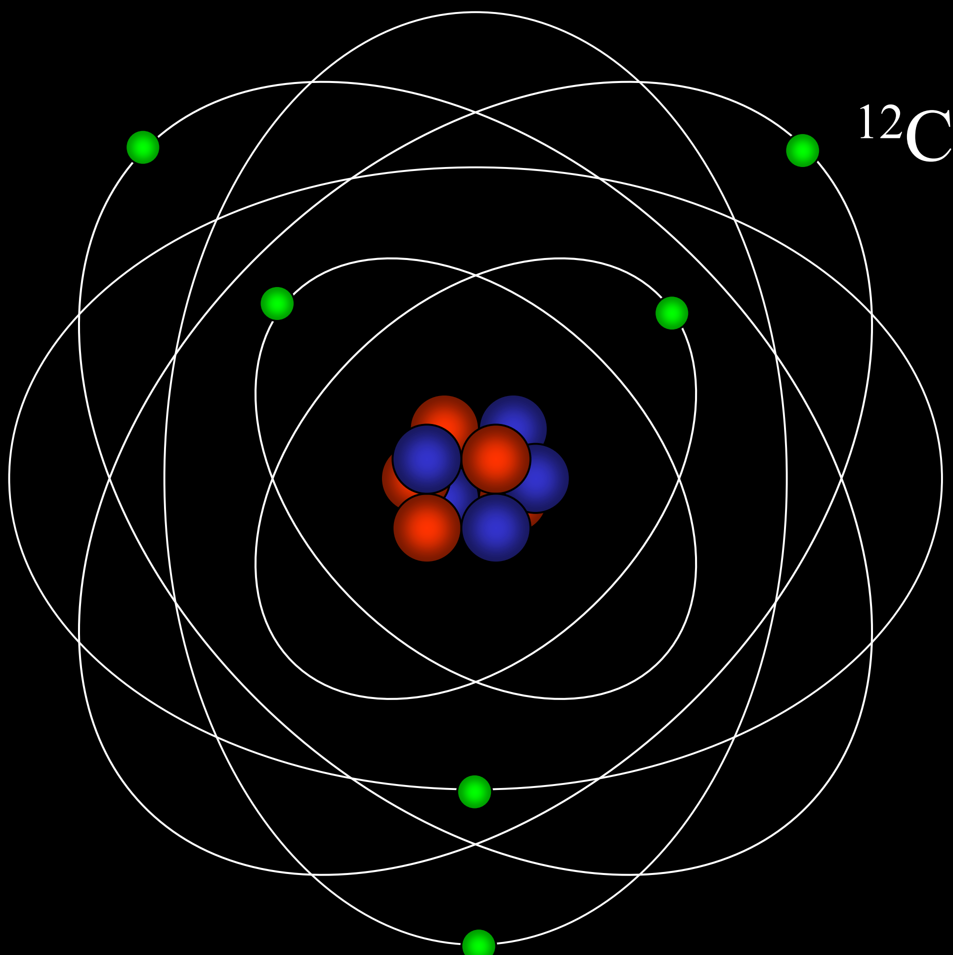
Modern day astronomers understand that the sky is dark primarily because light travels at a specific speed, and light from extremely distant objects hasn't had the time to reach us.

Because the universe is only ~13 billion years old, we can not see objects that are more then ~13 billion light years away. There simply hasn't been enough time for the light first emitted by more distant objects to reach us. Technically, everyday we are able to see a very small bit further out into the heavens.



Spectra

At the beginning of the 20th century astronomers began to use spectroscopes to measure the composition and velocities of stars and galaxies. They did this by looking at atomic transition lines.



Atoms are made of three different particles: electrons, protons and neutrons. The electrons orbit the proton+neutron nucleus. Due to a lot of complicated physics the electrons are only allowed to be in specific orbits.

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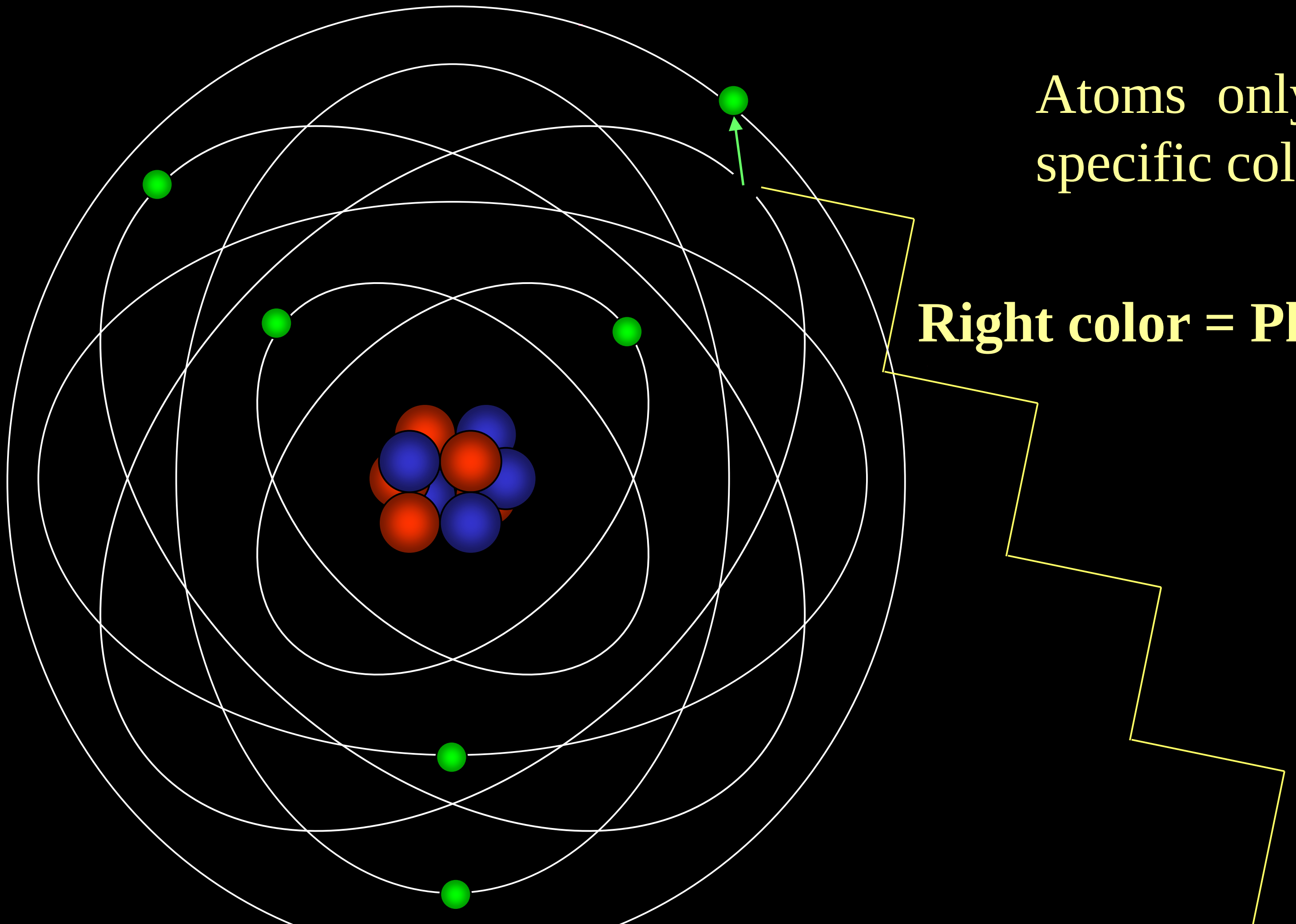

Atoms only interact with specific colors of light.

Right color = Photon Absorbed

Spectra

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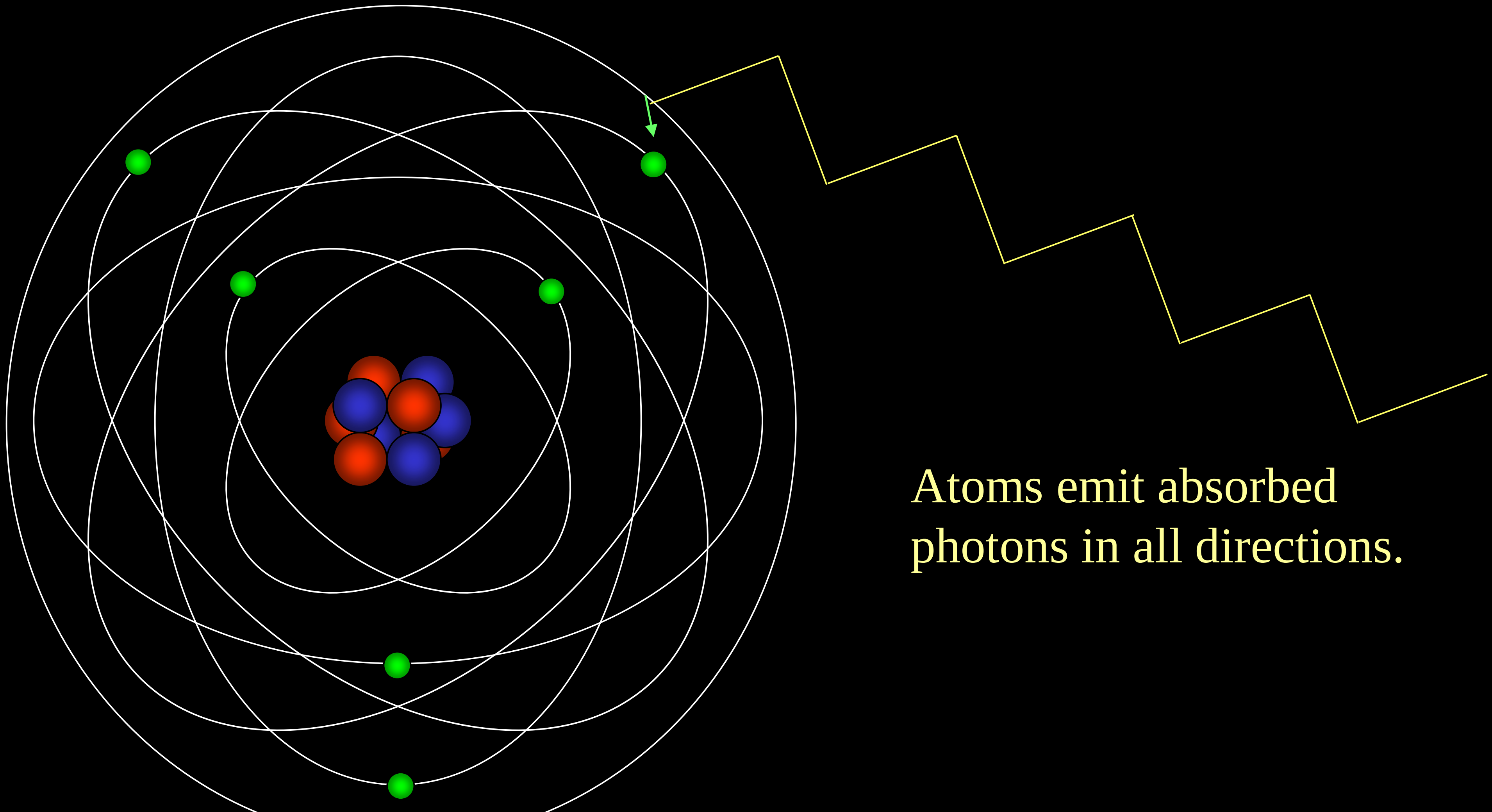

Atoms emit absorbed photons in all directions.

Spectra

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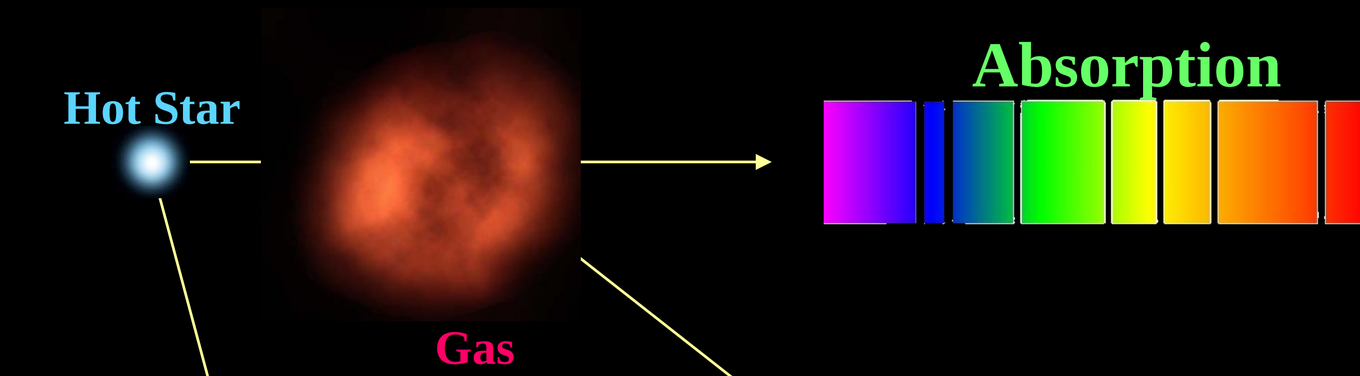
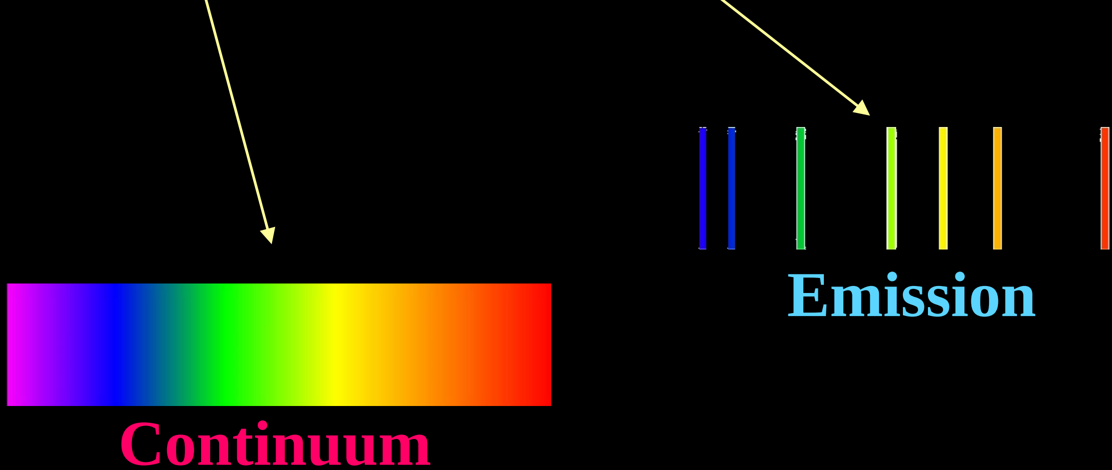
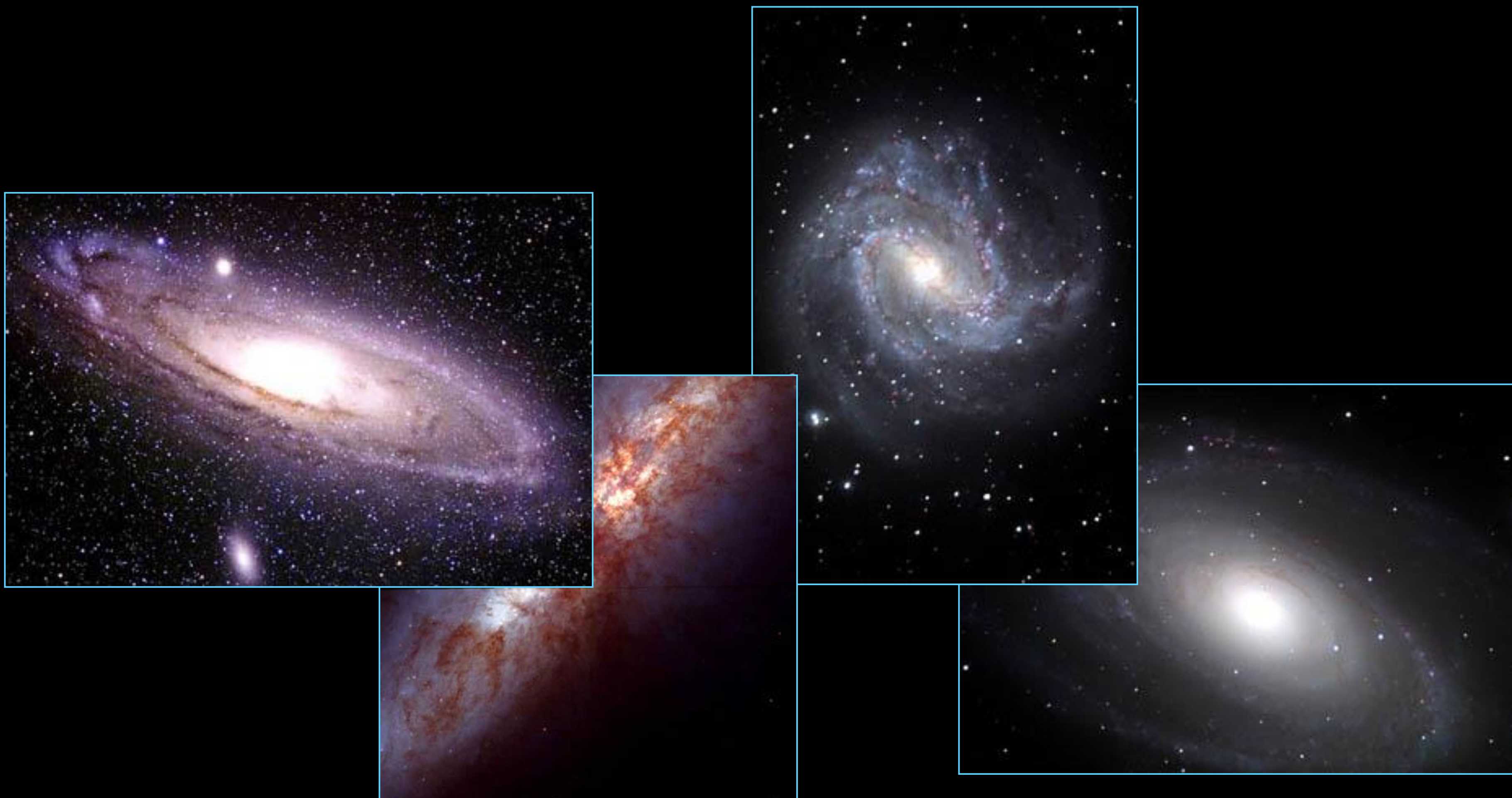




Hot stars emit light in a **continuum** of different colors. When this light passes through cooler gas, the atoms in the gas **absorb** specific colors and **emit** the photons in all directions.

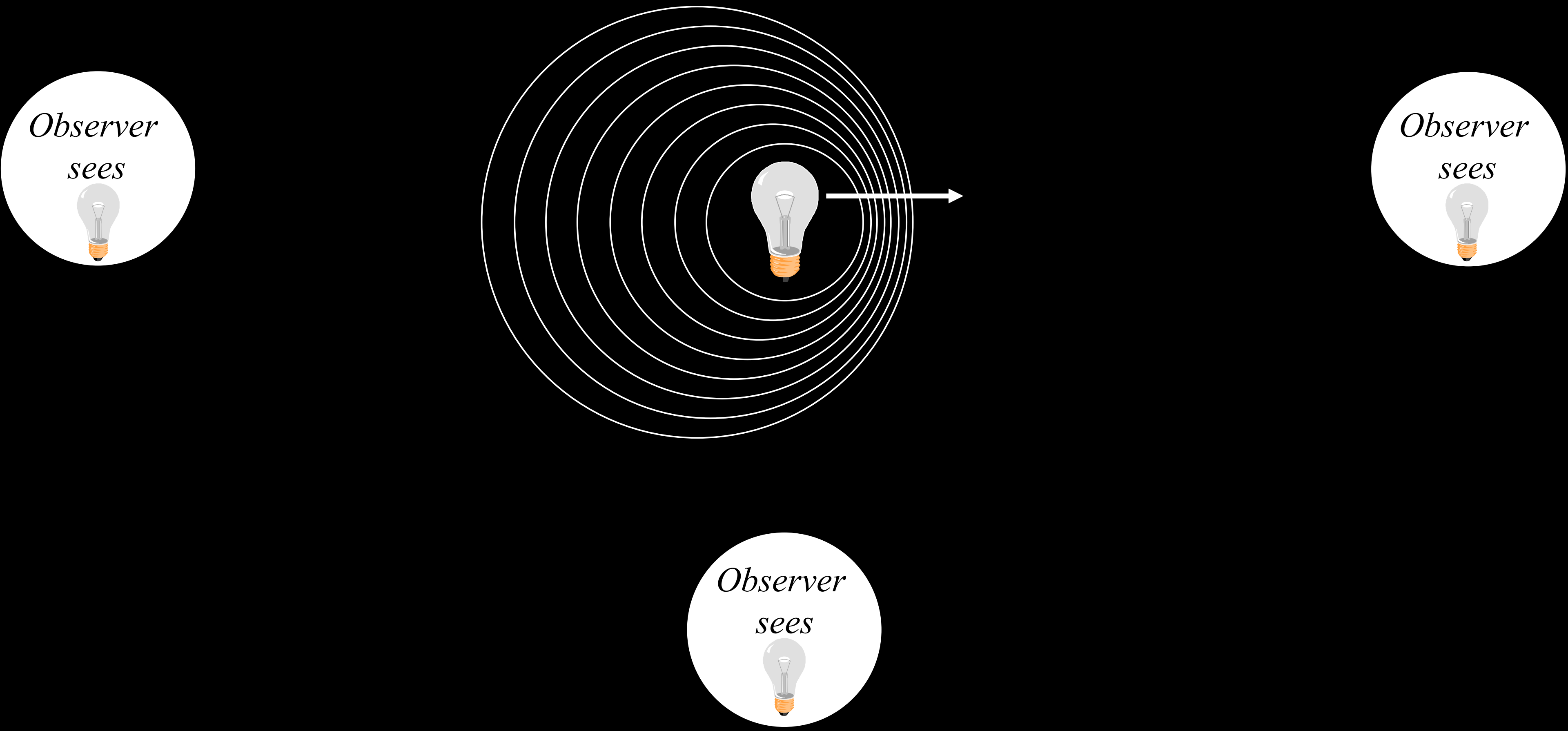
The Receding Universe

In 1917 astronomer Vesto Slipher pointed a Lowell Observatory telescope at 25 of the nearest and brightest galaxies, and measured the galaxies radial velocities using the *Doppler Effect*.



Doppler Shift

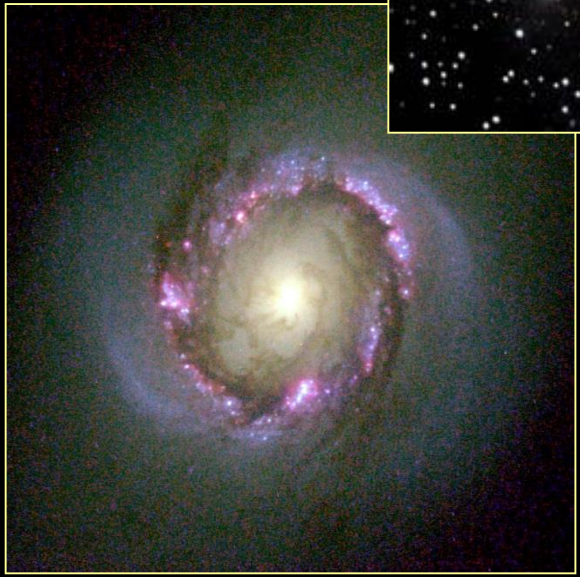
Objects moving towards us have their wavelengths shortened, or blueshifted, while those moving away have their wavelengths lengthened, or redshifted.



The faster the object is moving the more its color gets changed!

The Receding Universe

Much to his surprise, Slipher discovered that 21 of the galaxies had their light shifted to the red, implying that they are moving away from us.



The Receding Universe

While Slipher was able to measure the velocities of galaxies, he had no way of measuring the distance to them. In 1929, Edwin Hubble used Cepheid Variable stars, which are very luminous, and vary their luminosity in a distinctive, recognizable way, as standard stars to measure the distance to these galaxies.

To view this movie, open the "Movies" folder on the CD-ROM and double click on "slide_16.mov"

Hubble's Law

Hubble discovered that the recession velocity of galaxies are directly related to the galaxies' distances.

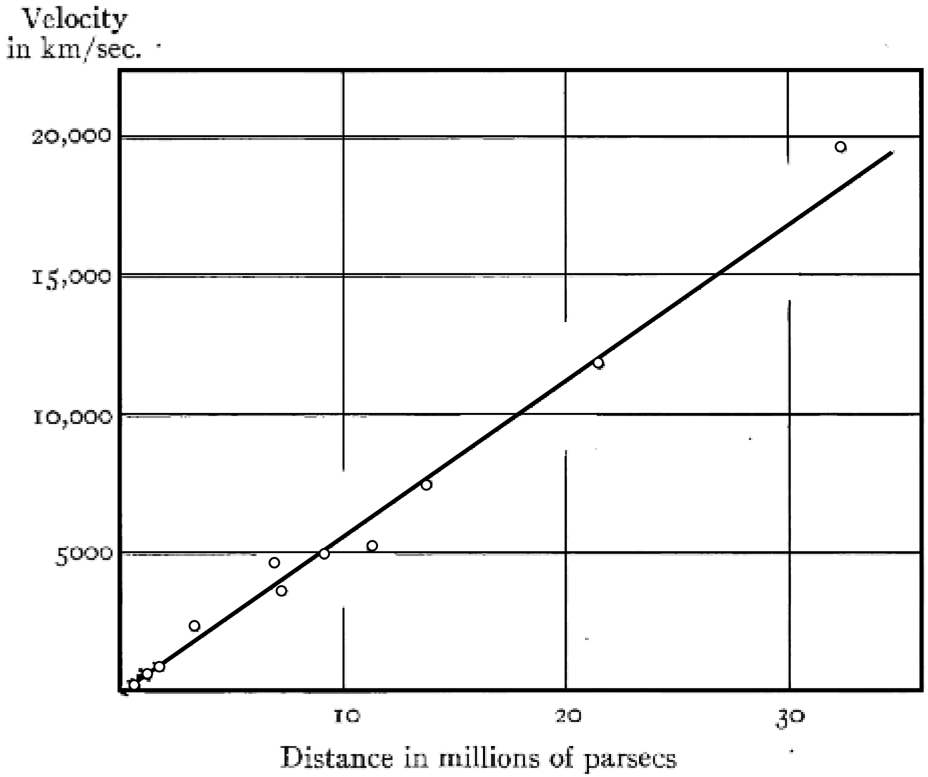


FIG. 5.—The velocity-distance relation. The circles represent mean values for clusters or groups of nebulae. The dots near the origin represent individual nebulae, which, together with the groups indicated by the lowest two circles, were used in the first formulation of the velocity-distance relation.

This is the original plot made by Hubble and published in the Astrophysical Journal in 1931 (vol. 74, p. 43).

Expansion explained

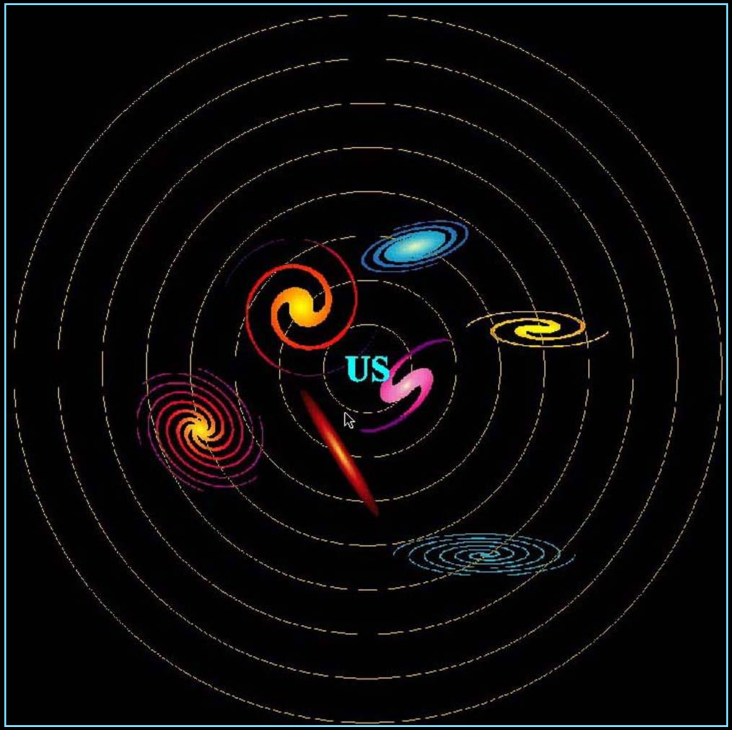
At first glance it may seem that since everything appears to be moving away from us, we must be at a special location, but this is not the case. No matter where we go in the universe, it will always appear that everything is moving away.

From the perspective of each of these cars, all the other cars are moving away.

To view this movie, open the "Movies" folder on the CD-ROM and double click on "slide_18.mov"

Hubble's Law

Today we understand this relation, now called "Hubble's Law", as evidence of the expansion of the universe.



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Hubble's Law

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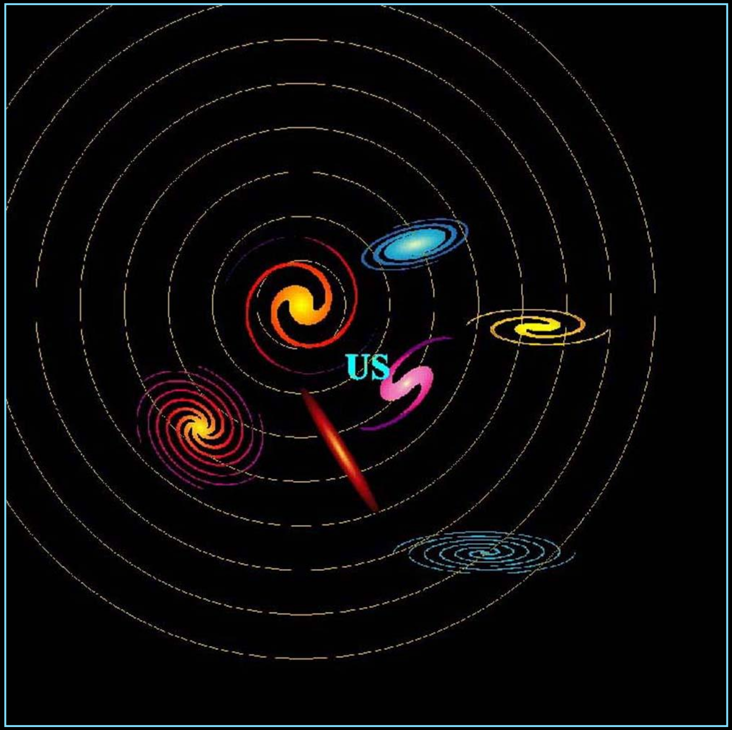


To view this movie, open the "Movies" folder on the CD-ROM and double click on "slide_20.mov"

Expansion implies a beginning…

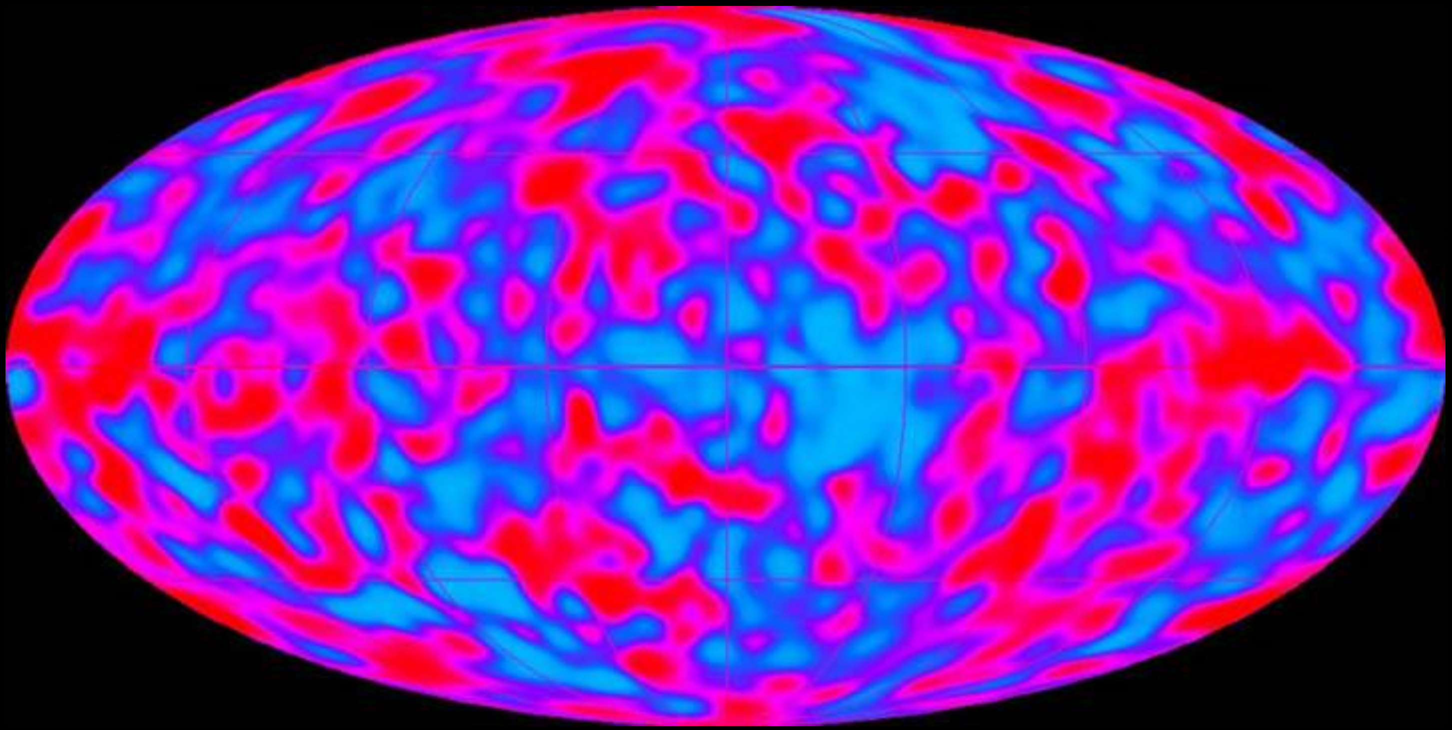
The universe's current expansion implies that there once was a time when the universe was compressed down into a single point – a singularity – and that the universe had a beginning.

To view this movie, open the "Movies" folder on the CD-ROM and double click on "slide_21.mov"

And the light separated from the darkness…

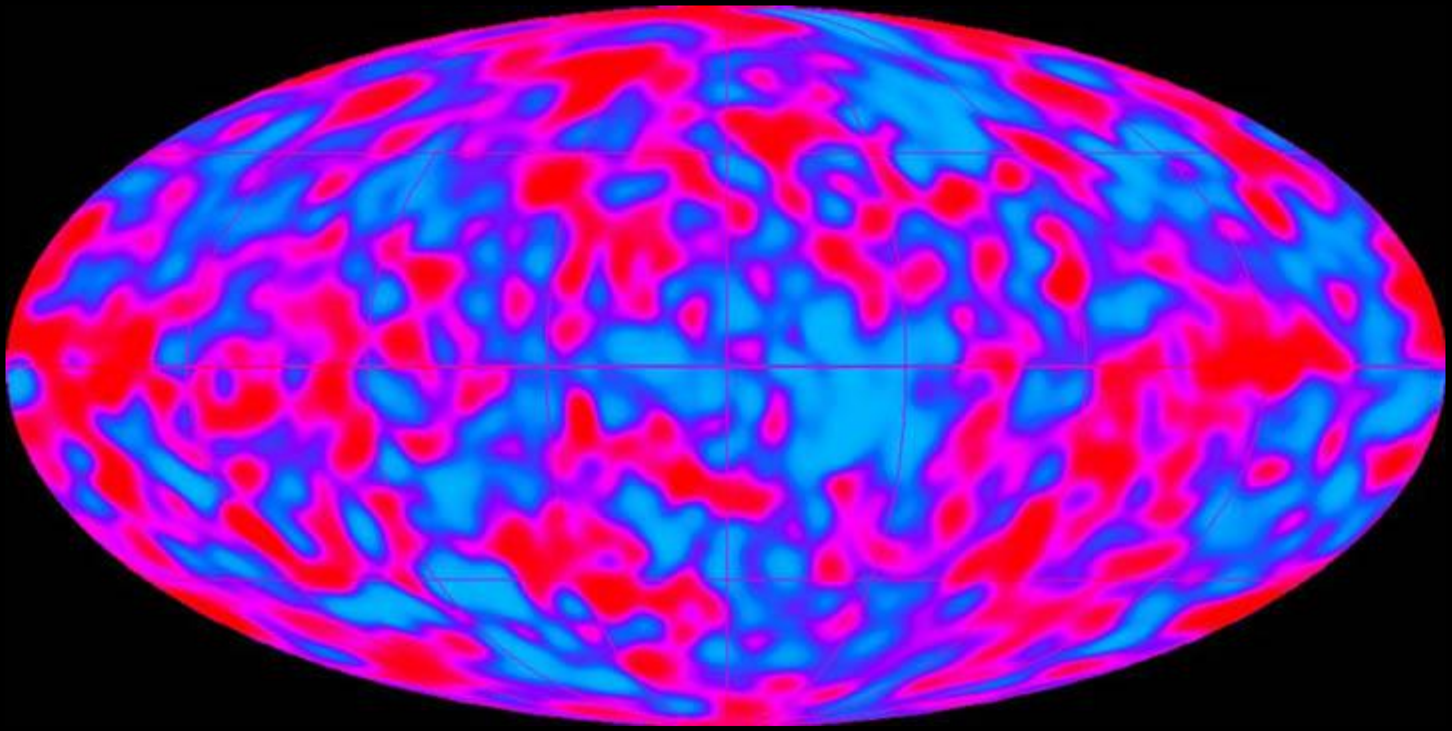
At the first moment of time the universe was nothing more, or less, then extremely hot, dense atomic particles.

If we look far enough away, we should be able to observe the birth of the universe. When we do so, we see this wall of fog 1 million years after the universe formed.



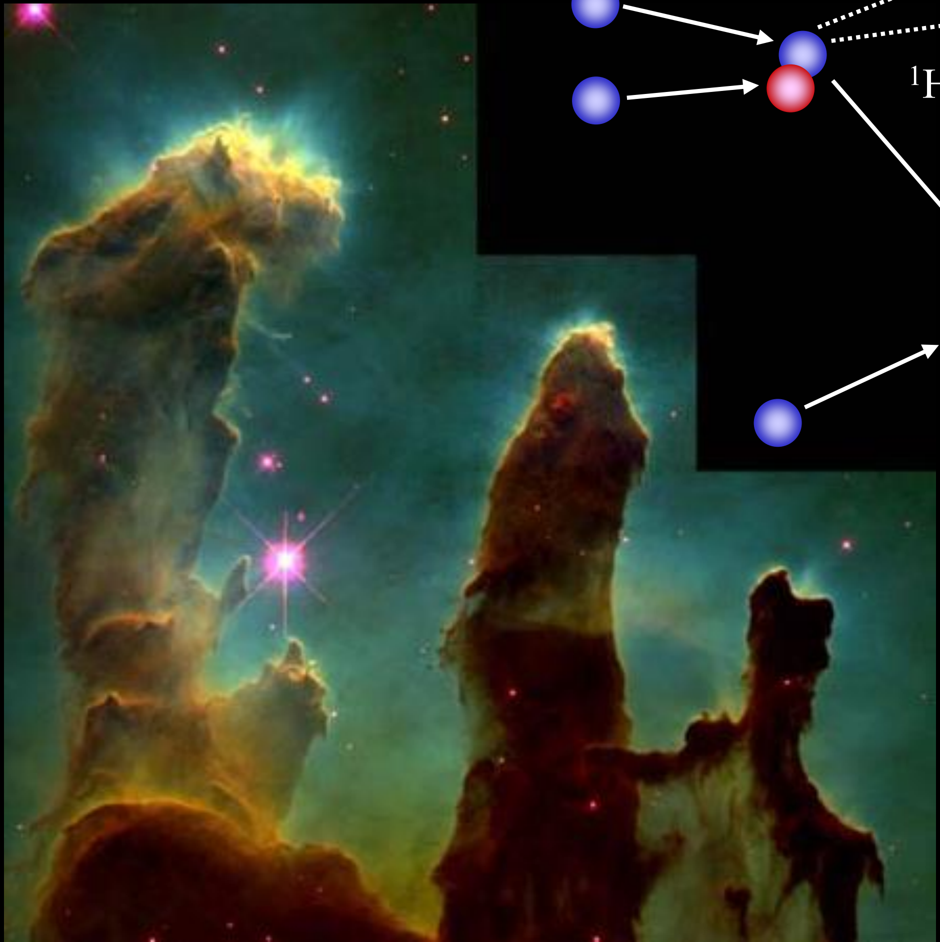
And the light separated from the darkness…

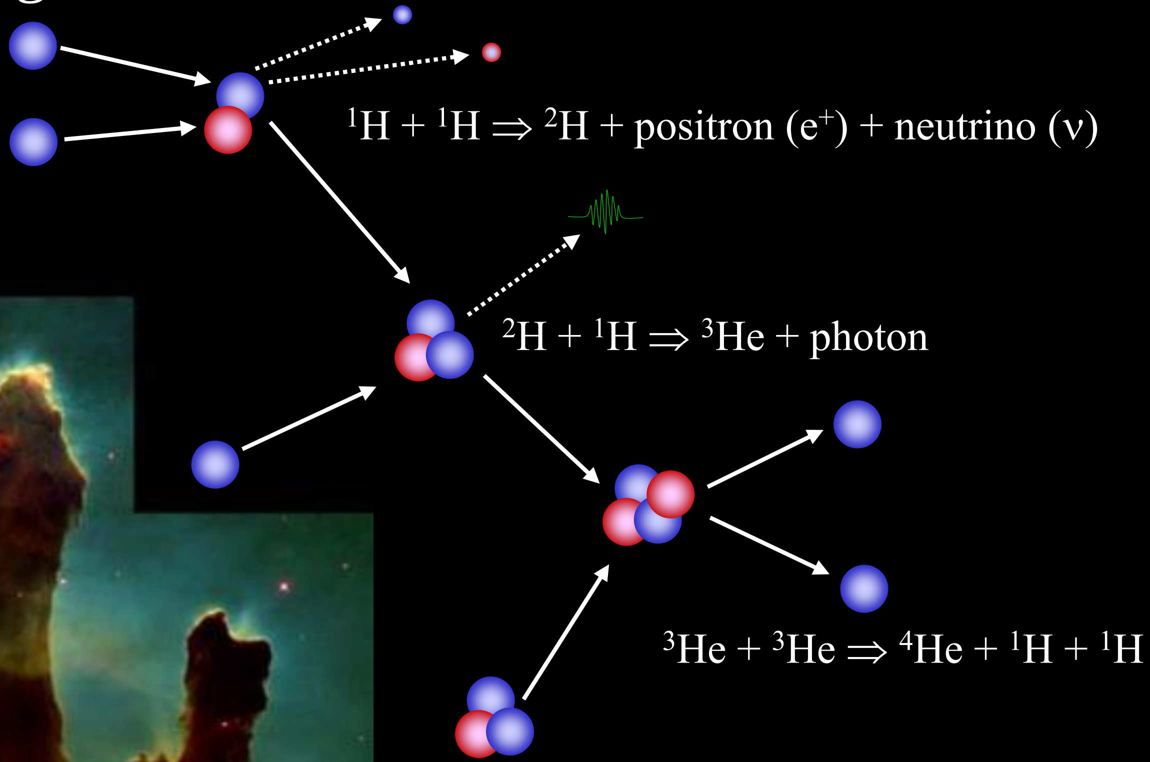
Attempts to look farther (earlier) are frustrated by the very high opacity of the universe at times earlier than 1 million years after its birth. As the early universe expanded, it cooled, until finally hydrogen atoms were able to form. The light that was emitted at that moment in time now appears as a glow of microwave radiation.



Looking for Helium

As the universe continued to cool, Hydrogen lead to the production of Helium and a small amount of Lithium and Beryllium during a process called "Big Bang Nucleosynthesis." This material was later used to form the first generation of stars.





Looking for Helium

Larger atoms – Carbon, Nitrogen, Iron – are formed deep in the cores of stars. This material is released when a star dies, but until that happens it stays trapped out of view. The visible outer atmosphere of stars shows only the original material the stars were made from.

By studying the composition of the outer layers of the oldest stars we can compare our predictions for Big Bang nucleosynthesis with what actually happened.

Helium balances

Astronomers have now surveyed a vast number of the oldest stars in our galaxy and they have never found less then 26% helium - This is exactly in accord with the predictions for the Big Bang.

The West Texas Time Machine

In order to see further out into the heavens, astronomers need to see fainter. The only way to see farther objects is to build bigger telescopes. To this end, the Hobby-Eberly Telescope has been built.

The West Texas Time Machine

Made out of light weight materials and utilizing new design concepts, the HET is the third largest telescope in the world, and produces the greatest amount of science per dollar spent.

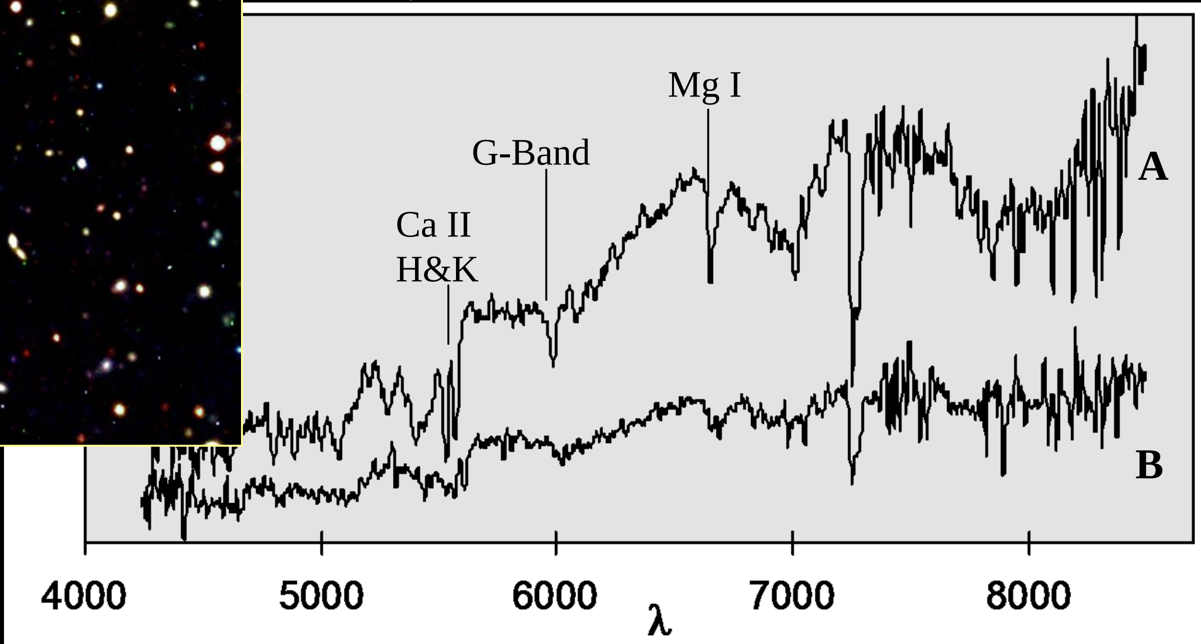
The West Texas Time Machine

This telescope is an international collaboration, with partners and contributing scientists spread across America, Europe and Mexico.

The West Texas Time Machine

Scientists use this telescope to measure the distances to galaxies, the composition of stars, and to try and determine the nature of exotic objects such as gamma ray bursts and binary quasars.

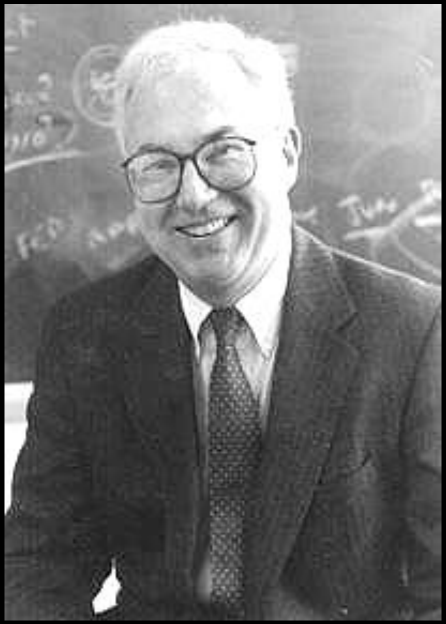
The image at left is a cluster of galaxies discovered at McDonald Observatory. The spectra below, taken with the HET, shows that galaxies A and B have the same velocity, and are thus at the same distance.



The West Texas Time Machine

One can think of the work done at the HET as a kind of cosmic archaeology. By looking further and further out in space, we observe progressively more and more distant objects. Since light takes time to reach us, the light our telescope detects is coming to us from the more and more distant past allowing us to take childhood snapshots of the early universe.

Authors



Frank J. Bash

Dr. Frank Bash serves as director of the McDonald Observatory and is the Frank N. Edmonds Regents Professor of Astronomy at the University of Texas at Austin. A well-known and widely published specialist in radio astronomy, Dr. Bash is interested in large-scale star formation processes in spiral galaxies. As director of the McDonald Observatory, he led the effort for design, funding, and construction of the new 11-meter Hobby-Eberly Telescope.

Pamela L. Gay

Ms. Gay is a doctoral student in astronomy at the University of Texas. Her dissertation concerns galaxy clusters rich in radio galaxies. After receiving her degree she hopes to concentrate her time on teaching and public advocacy of astronomy, and to return to variable star research. In her spare time she rides her horses “Quantum Leap” and “Hayley”.