

## The New Cosmology: Our Expanding Universe

### FROM A FLAT TO A SPHERICAL EARTH

The early idea was that Earth was a flat stationary plate, and the sky above was like a moving domed roof. That the earth was flat was obvious from sense experience: earth is experienced as flat and we don't fall off. That the sky was moving was also obvious from experience, since all the objects in the sky seem to be moving around us in a half-circle from morning to dusk: the sun, the moon, the stars. Later, the ancient Greeks figured out that Earth could not be flat. As travelers, the Greeks were navigating using the stars for orientation. One orientation point was the North Star. They noticed that starting out from Athens, the North Star would hover just above the horizon, but the farther they traveled north, the further it would rise above the horizon. This could only be explained if the Earth was round and not flat.

### THE PTOLEMAIC CONCEPTION OF THE UNIVERSE

In the middle, we have Earth, and revolving around earth, we have eight different spheres, that each of them control the movement of different bodies in the sky. The sphere closest to earth would thus account for the movement of the moon; the fourth sphere would be the sphere of the sun; the eighth sphere, farthest away, would be the sphere of the fixed stars. We are in the center, and everything else is moving around us in perfect circles. This is called the **Geo-centric** universe.

### PROBLEMS WITH THE PERFECT CIRCLES

Some bodies seemed to wander around in strange patterns, one therefore gave these bodies the name, *planetos*, the Greek for *wanderer*. One did not want to give up the dogma of the circle as the perfect and fundamental universal principle, so one tried to account for these strange movements by adding epi-circles to the original circles. One added a circle to the original circle, such that the second circle had a center moving with the original circle.

### THE COPERNICAN REVOLUTION

The problem with the Ptolemaic model was the epi-circular movements. Since they were added merely for dogmatic and ideological reasons, the problem was that every movement could be explained by means of epi-circles, depending on how big one made the circle and how many of them one invented to do the job. Copernicus realized that placing the sun in the center of the universe, and the planets orbiting this center, would both be simpler and would explain observable fact that before could not be explained. This is called the **Helio-centric** universe.

### NEWTON AND GRAVITY

It was not before Newton, one understood the law of gravity. According to Newton's law, two bodies will attract each other with a force that is proportional to their mass, and inverse proportional to their distance. If we have the bodies, Earth and an apple, the two bodies attract each other, but because the Earth is enormous compared to an apple, we only experience a pull in one direction, the apple falls downwards. Newton extrapolated, the moon also 'falls downwards,' but because of the centrifugal force pulling it in the other direction, it would be held in a stable orbit around earth. Newton's law for Gravitational attraction: "each body in the universe is attracted toward every other body by a force that is stronger the more massive the bodies and the closer they are to each other."

### DISTANCES IN THE UNIVERSE: PLANETS, STARS, AND GALAXIES

When we measure distances in the universe, we no longer measure in kilometers, but in *light-years*. The distance traveled by light in one year is a *light-year*. It takes the light of the sun eight minutes to travel to earth, so the sun is eight *light-minutes* away from us. The light from the star closest to our own sun (Alpha Centauri) is about four years to reach us; so, it is four light-years away from us.

### OUR ADDRESS IN THE UNIVERSE

In our galaxy, the *Milky Way*, there are billions of stars like our sun (approximately 100 billions). We live in the outskirts of the Milky Way.

### SPEED OF LIGHT

Light has an invariable speed, and since we know its value, we can measure distances by measuring the time it takes for light to travel to an event (we no longer measure distances in a metrical system).

### THE FUTURE AND PAST LIGHT CONE

When we observe galaxies and galaxy clusters, we only see what is past. The father away the object is, the longer it takes for its light to reach us, and the further we look back into the Past Light Cone. What happens in our present, we cannot know; we cannot know what space is on the so-called Hyper-Surface of the Present. Relative to the Future Light Cone of an object, we are in the Elsewhere; only as time passes, we move into the light emitted from the object. We always only see the absolute past. We are consequently limited to observe the absolute past, our so-called **observable universe**; we see only galaxies from which light has been traveling for millions or billions of years. Therefore, the deeper we look in the universe, the younger a universe we see.

### DOPPLER EFFECT AND RED-SHIFT

As in sound, there is a difference in the light spectrum according to whether the object moves away from us, or toward us. If it is moving toward us, the pattern of absorption lines is **'shifted' toward blue**. If it is moving away from us, the pattern is **'shifted' toward red**.

### HUBBLE'S DISCOVERY: GALAXIES MOVE AWAY FROM US

Distant galaxies are moving rapidly away from us; they are all red-shifted. Furthermore, not only are galaxies moving away, but there is a correlation between their distance from us and their velocity. In other words, the father away they are from us, the faster they move away. This is the Hubble Law; the ration between distance and velocity is 0.72, and is the so-called Hubble Constant.

### THE UNIVERSE IS EXPANDING

The universe expands, like if you blow up a balloon, or set a raisin bread to rise. In the form of the raisins, you have certain points representing galaxies. If we choose one of the raisins to be our observation point, as the dough rises, the other raisins recede away from that point according to the Hubble Law: the further away they are, the more they recede. Understanding this logic, it did not take much thinking to figure out that if the universe is expanding, it must at some point have been denser; galaxies must have been closer together than they are now.

### THE UNIVERSE IS EXPANDING FROM A SINGULARITY IN AN "INFLATIONARY HOT BIG BANG EVENT"

The expanding universe starts in a super-hot Big Bang 'explosion' in the first fraction of a second ( $T = 10^{-43}$ ); it is at this point the size of a tennis-ball. At this point, there are no particle formation and no physical forces; consequently no physical laws. At  $T = 10^{-32}$  second, the big bang singularity starts to inflate exponentially (with a doubling time of 1 pico-second). As fractions of seconds go by, the different natural forces start to form (weak and strong nuclear, electromagnetic, and gravitational); after other fractions of seconds, the first sub-atomic particles start to form. After about a second, we have the first simple atoms, Hydrogen and Helium.

### THE COSMIC MICROWAVE BACKGROUND

The existence of the Microwave Background is proof of the Big Bang theory and the expansion of the universe.