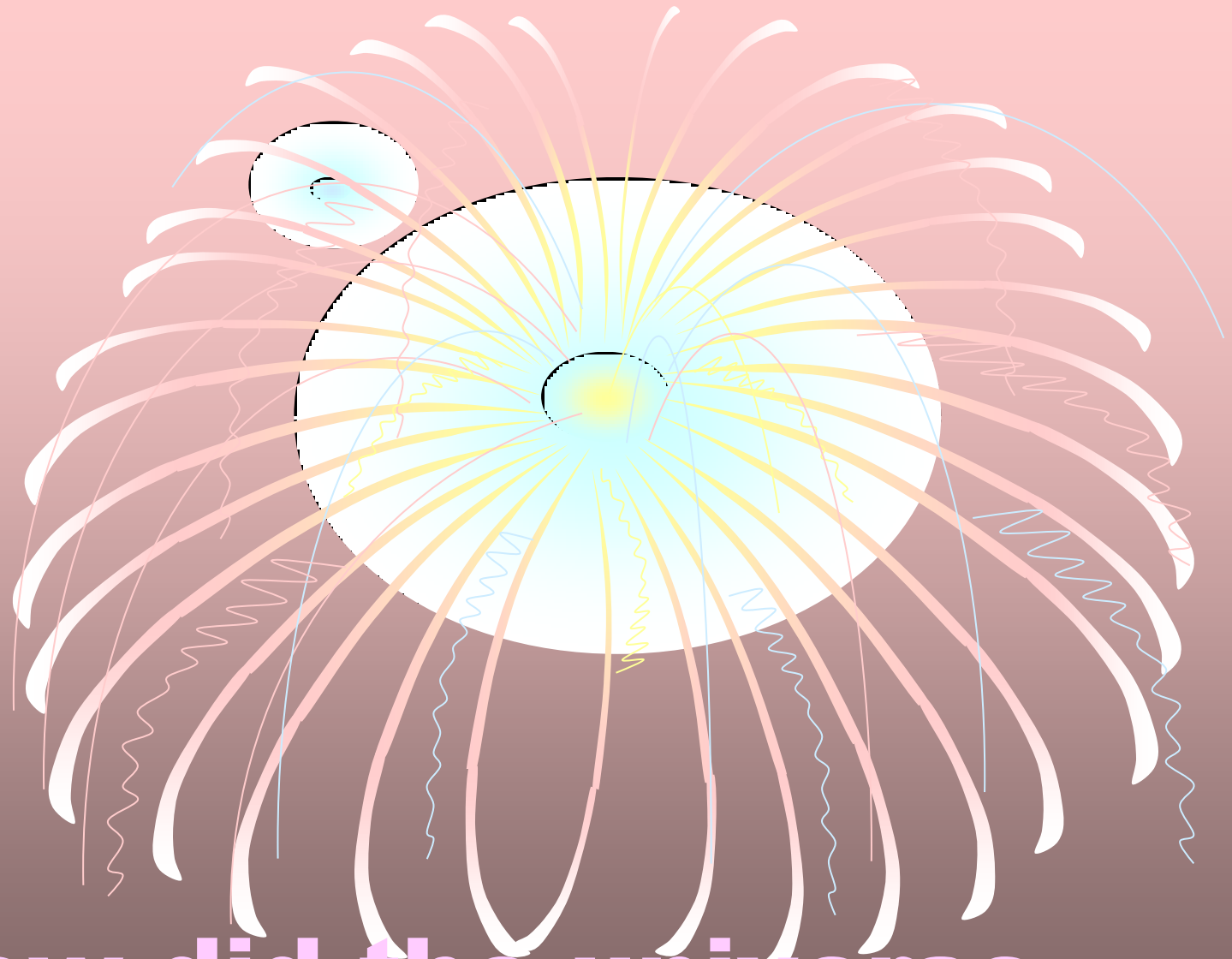


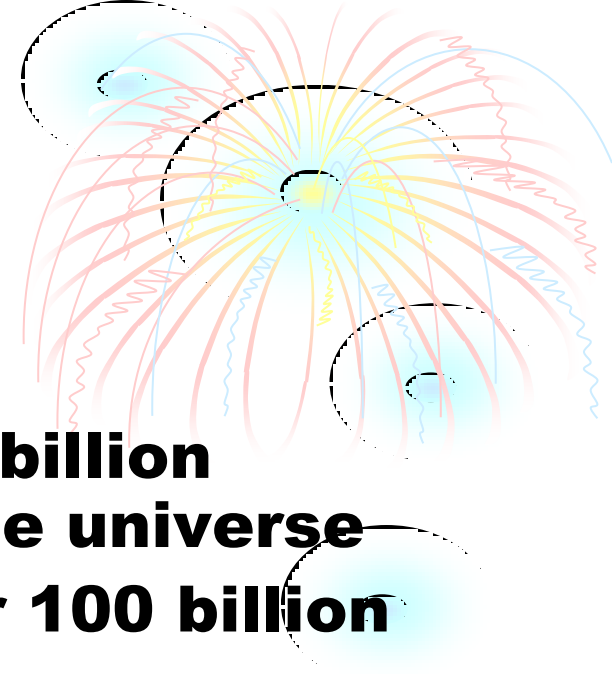
Galaxies





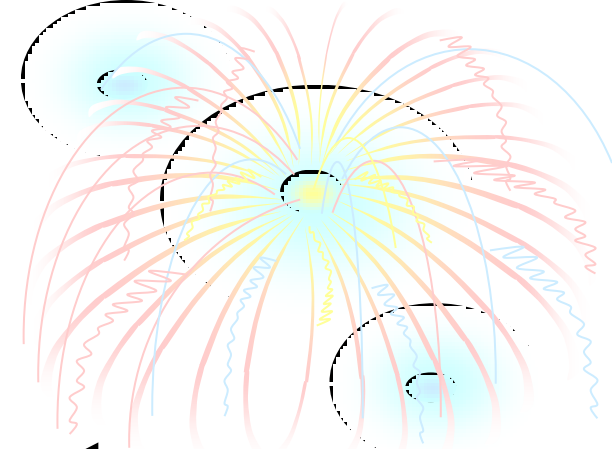
**How did the universe
form? 1 and 2**

Galaxies

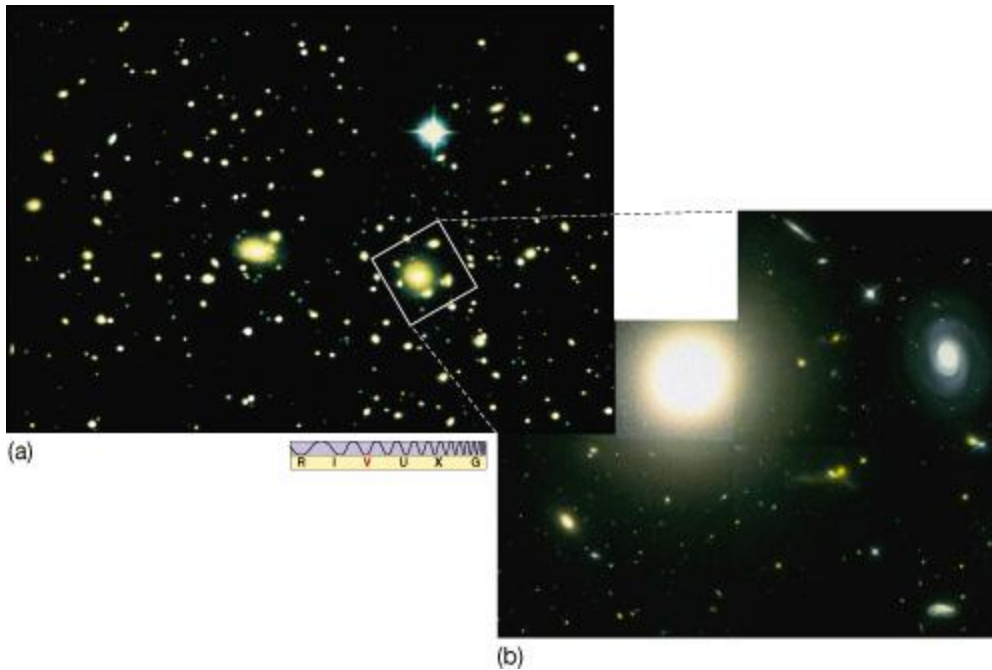


- **Astronomers estimate that 40 billion galaxies exist in the observable universe**
- **The universe may contain over 100 billion galaxies**
- **Even a modest-sized galaxy harbors more stars than the number of people who have ever lived on Earth**
- **The light we will receive tonight from the most distant galaxies was emitted long before Earth even existed**

Coma Cluster

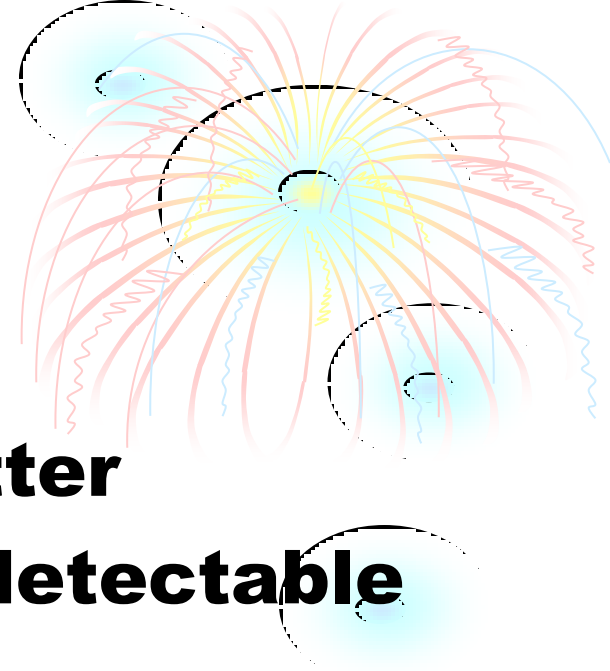


- **Almost every patch or point of light in this picture is a galaxy**



Dark Matter

- **Galaxies contain dark matter**
- **Dark matter produces no detectable light**
- **We know it exists because of its gravitational pull on stars and gas**
- **In the Milky Way, dark matter accounts for more than 90% of the galaxy's total mass**

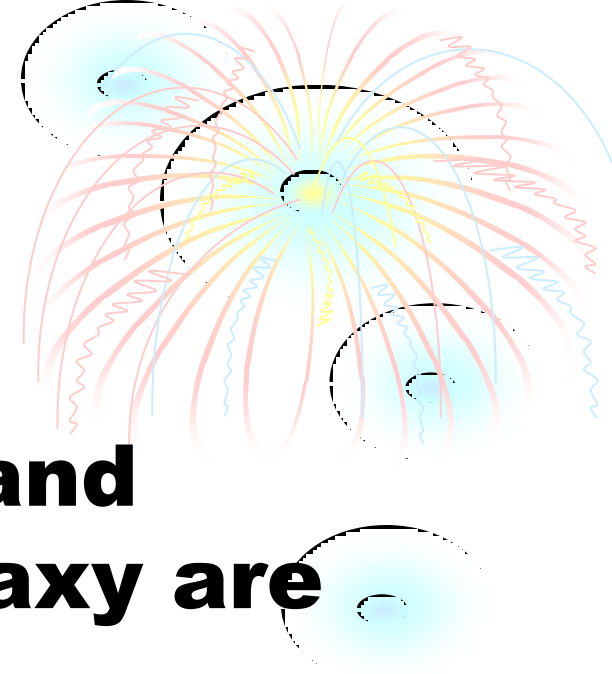


Categorizing Galaxies

- **Edwin Hubble was the first to categorize galaxies in a comprehensive way**
- **He classified galaxies into four basic types**
 - **Spirals**
 - **Barred spirals**
 - **Ellipticals**
 - **Irregulars**



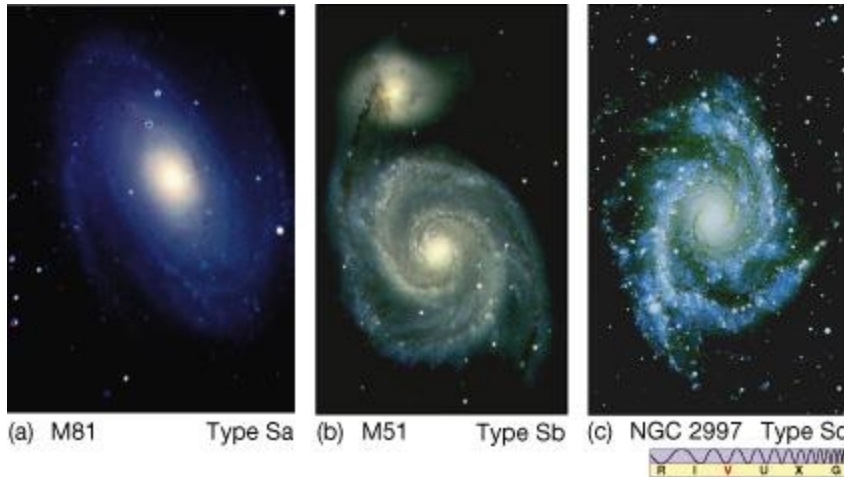
Spiral Galaxies



- **The Milky Way galaxy and nearby Andromeda galaxy are spiral galaxies**
- **All spiral galaxies contain:**
 - **A flattened disk in which spiral arms are found**
 - **A central bulge**
 - **An extended halo of faint, old stars**

Types of Spiral Galaxies

- **A spiral galaxy is denoted by the letter S and classified as type a, b, or c, according to the size of its central bulge**



As we progress from type Sa to Sb to Sc, the bulges become smaller while the spiral arms tend to become less tightly wound

Barred Spiral Galaxy

- **A spiral galaxy in which a bar of material passes through the center with spiral arms beginning near the ends of the bar**



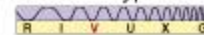
(a) NGC 3992 Type SBa



(b) NGC 1365 Type SBb



(c) NGC 6872 Type SBc



Elliptical Galaxies

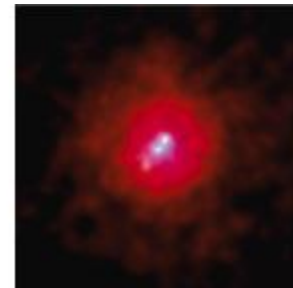
- **Range in shape from highly elongated to nearly circular in appearance**
- **Subdivided according to how elliptical they are**
 - **The most circular are designated E0**
 - **Slightly flattened systems are labeled E1**
 - **The most elongated ellipticals are type E7**



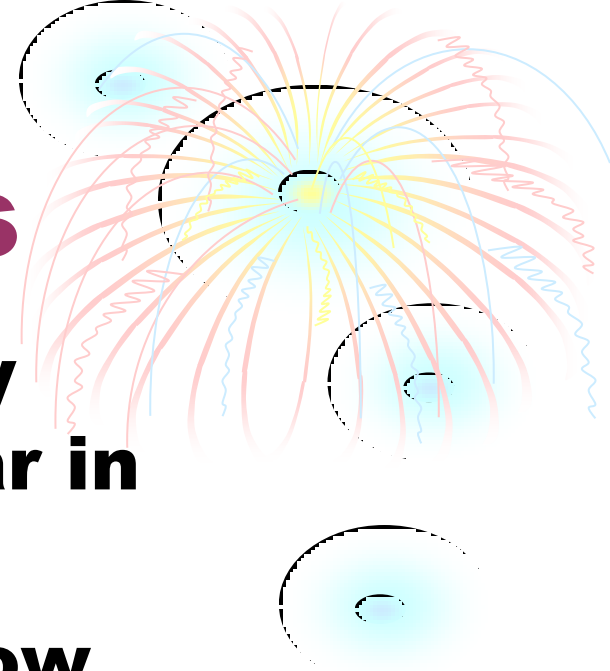
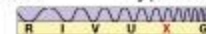
(a) M49 Type E2



(b) M84 Type E3



(c) 3C295 Type E1



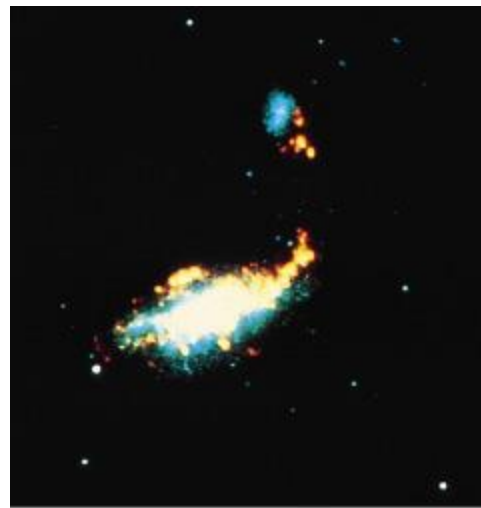
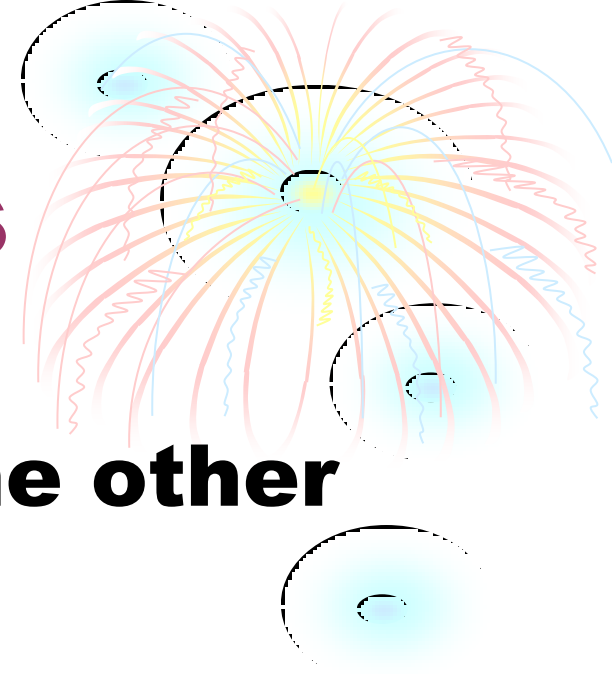
Different Size Ellipticals



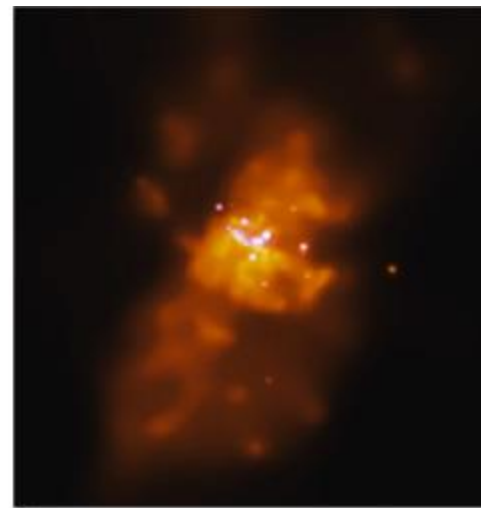
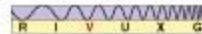
- **Giant elliptical galaxies contain trillions of stars**
- **Dwarf elliptical galaxies contain only a few million stars**
 - **Dwarfs are the most common type of ellipticals**

Irregular Galaxies

- **Do not fit into any of the other categories**



(a) NGC 4485/4490

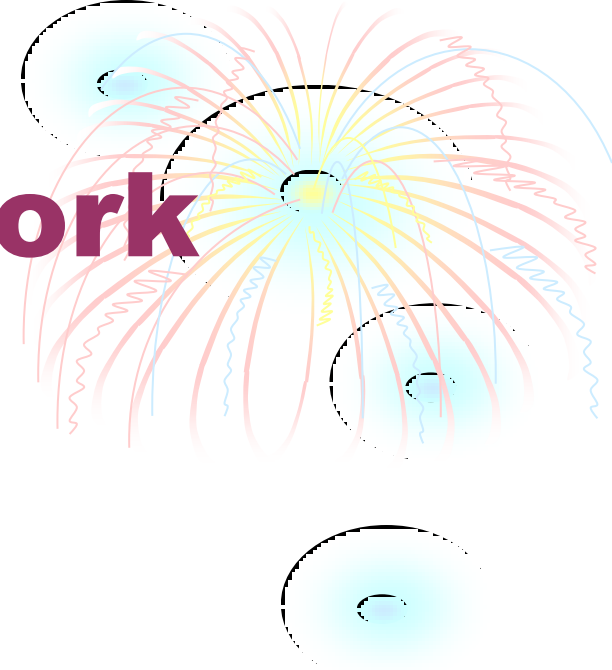
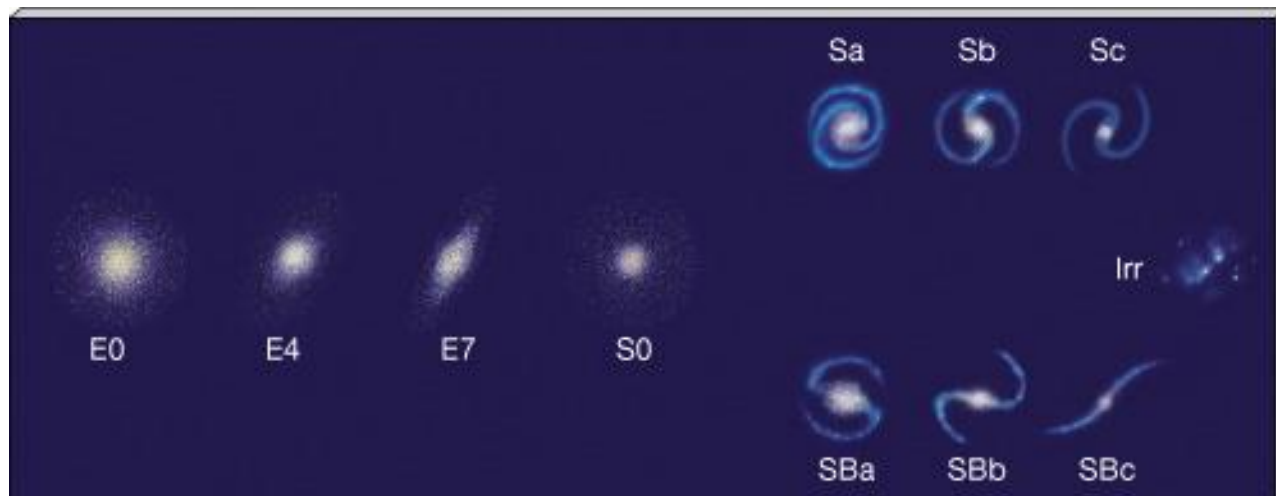


(b) M82



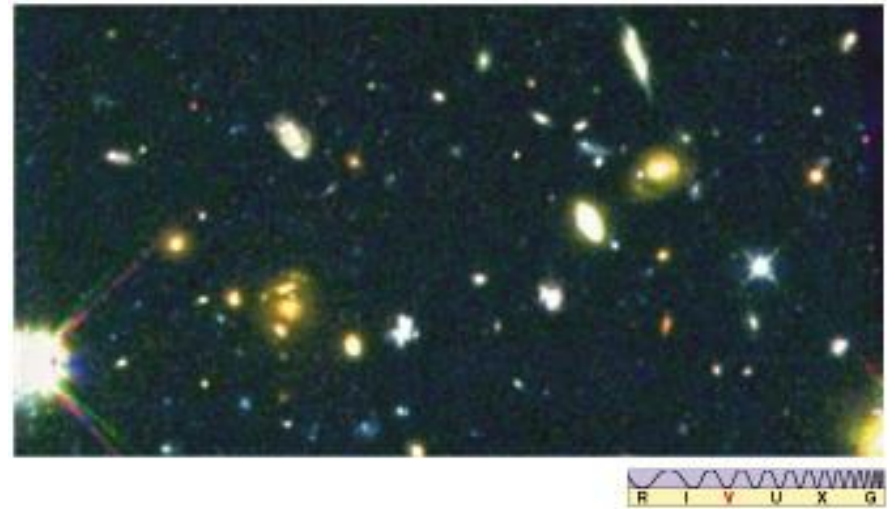
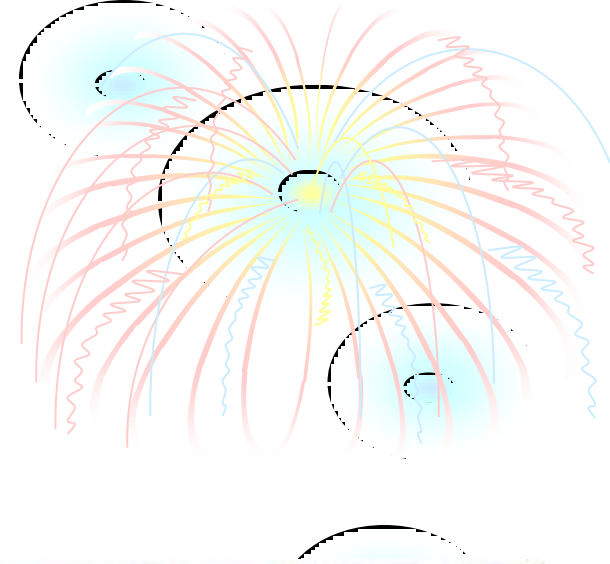
Galactic Tuning Fork

- **Hubble's basic galaxy classification scheme**
- **Indicates similarity in appearance among galaxies**



Galaxy Clusters

- **A collection of galaxies held together by their mutual gravitational attraction**



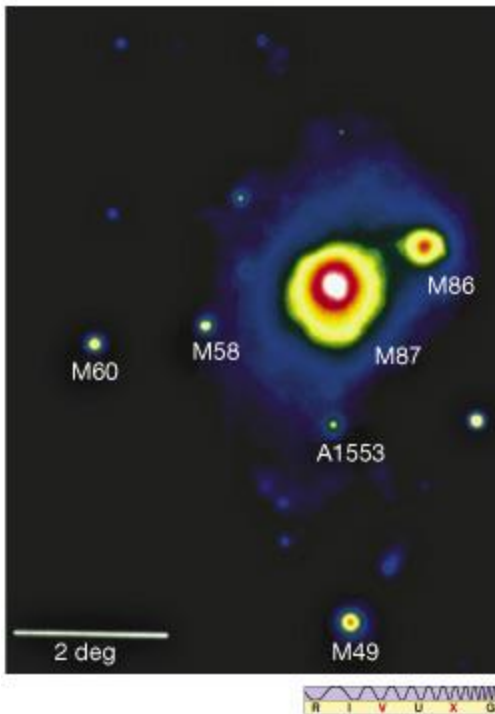
Superclusters



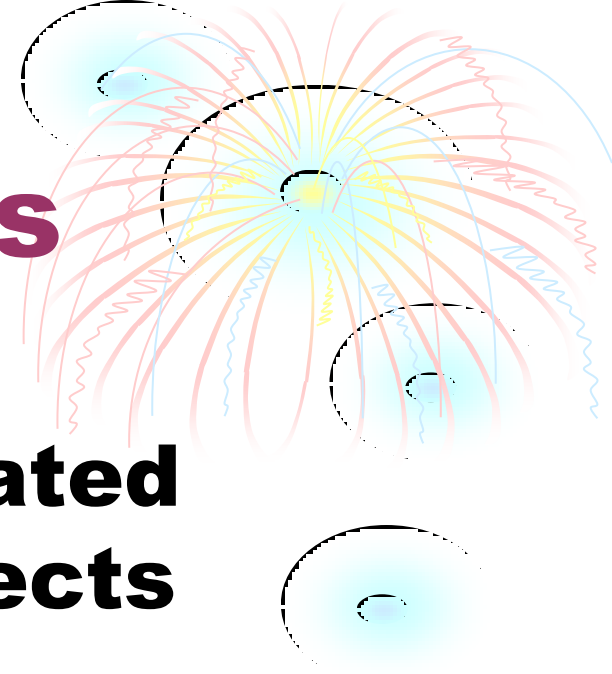
- **Most astronomers believe that the galaxy clusters themselves are clustered, forming titanic agglomerations of matter known as superclusters**

Galaxy Formations

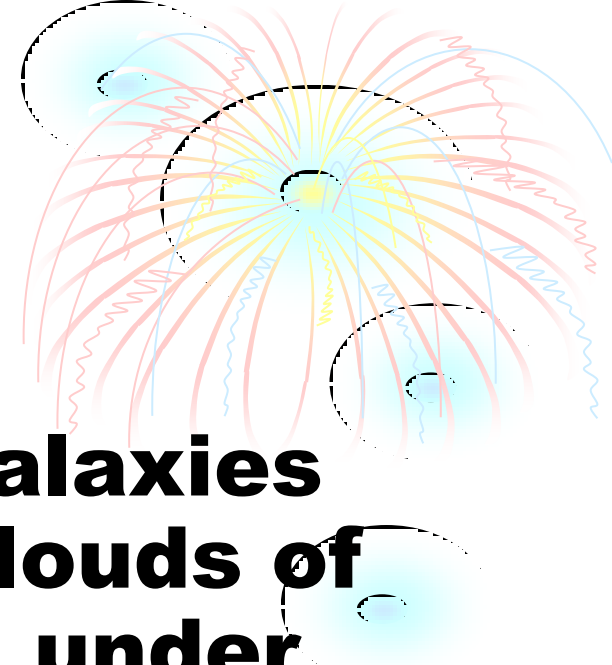
- **Galaxies grow by repeated merging of smaller objects**



Their proximity to one another suggests that we may be seeing a group of pregalactic fragments about to merge to form a galaxy. The events pictured took place about 10 billion years ago



Galaxy Formation



- **One theory says that galaxies were born when vast clouds of gas and dust collapsed under their own gravitational pull, allowing stars to form**
- **Another theory says the young universe contained many small "lumps" of matter, which clumped together to form galaxies**

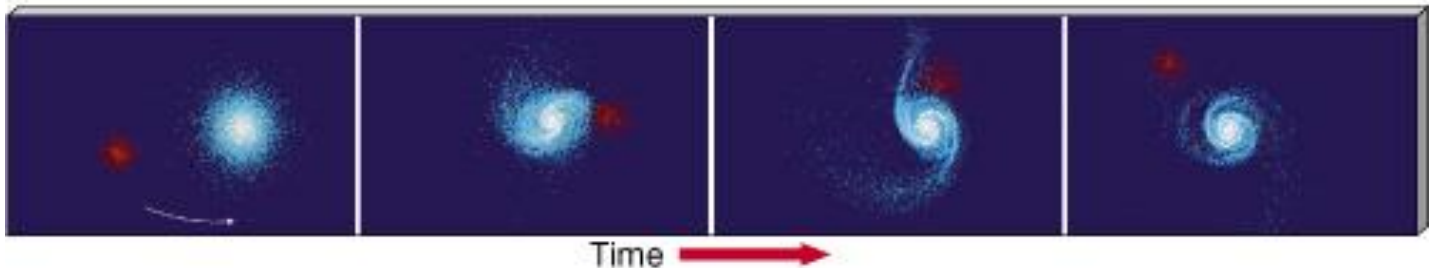
Galaxy Interactions

- **Our universe continues to evolve**
- **Small galaxies are frequently gobbled up by larger ones**
- **The Milky Way may contain the remains of several smaller galaxies that it has swallowed during its long lifetime**
- **The Milky Way is digesting at least two small galaxies even now, and may pull in others over the next few billion years**



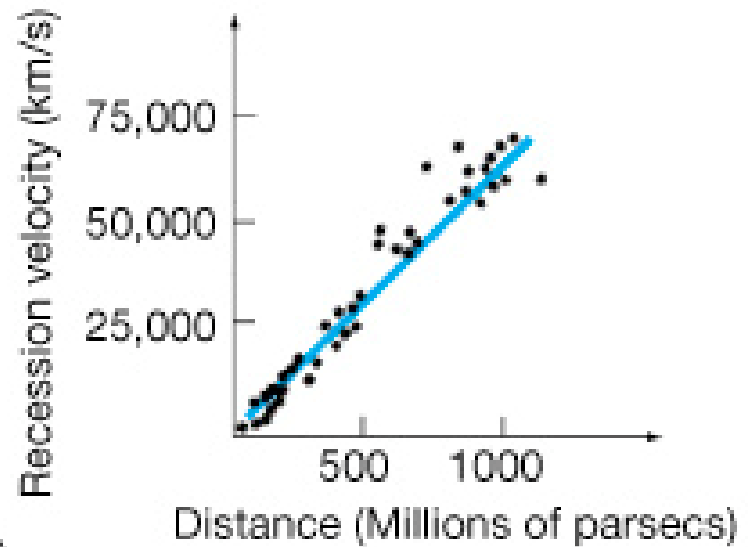
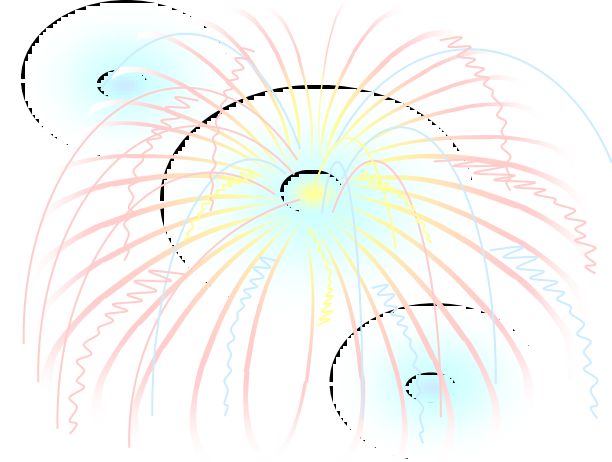
Galaxy Interactions

- **Collisions and interactions between galaxies are relatively commonplace events**
- **Galactic cannibalism occurs if two galaxies interact and one happens to have a much lower mass than the other**
- **It now seems that many of the most spectacular changes that occur in galaxies result from interactions with other galaxies**



Hubble's Law

- **Virtually every spiral galaxy has a redshifted spectrum-it is receding from our galaxy**
- **With the exception of a few nearby systems, every known galaxy is part of a general motion away from us in all directions**
- **The rate at which a galaxy recedes is directionally proportional to its distance from us**



Galaxies Fade

- **Current observations suggest that "dark energy" is causing the universe to expand faster, driving galaxies farther apart**
- **If that's correct, then galaxies will gradually fade from sight as their stars burn out**
- **The nuclear fires of stars like the Sun will be extinguished in a few billion years**
- **After the stars wink out, all that will remain of them will be crushed corpses**
- **Gravity itself may weaken, so these stellar remnants may lose their planets**
- **The Milky Way and all the other galaxies will lose their grip on their dead stars**
- **Some of the stars will sail off into space, while others will fall into the giant black holes that will dominate the hearts of all the galaxies**

