The formation of Stars and Evolution of Galaxies

Aadil Aziz Bhat[1], Asif Iqbal[2], Aaqib ManzoorRather[3], Mohd Aarif Dar[4], Dr. Rajeev Kumar Singh[5]
[1,2,3,4] *M.Phil Scholar, Physics, Bhagwant University,Rajasthan, India*
[5] *Associate Professor, Physics, Bhagwant University,Rajasthan, India*

Abstract- **In this paper we are a presenting the formation of stars and evolution of galaxies. Red sequence galaxies are generally non-star-forming elliptical galaxies with little gas and dust, while blue cloud galaxies tend to be dusty star-forming spiral galaxies. Theories of galaxy evolution must therefore be able to explain how star formation turns off in galaxies. The study of galaxy formation and evolution is concerned with the processes that formed a heterogeneous universe from a homogeneous beginning, the formation of the first galaxies, the way galaxies change over time, and the processes that have generated the variety of structures observed in nearby galaxies. Galaxy formation is hypothesized to occur from structure formation theories, as a result of tiny quantum fluctuations in the aftermath of the Big Bang. The simplest model in general agreement with observed phenomena is the Lambda-CDM model—that is, that clustering and merging allows galaxies to accumulate mass, determining both their shape and structure.**

Index Terms- **Stars, Galaxies, Evolution, Process, Homogenous.**

1. INTRODUCTION

Here we will talk about the formation and evolution of two of the three main types of galaxies, spirals and ellipticals. There is still much astronomers don't know about the process, but we'll give you their best guesses. Galaxies are thought to have begun from large irregular clouds of hydrogen and helium. This gas was created in the first few mintues of the universe. Certain sections of the clouds were probably slightly more dense than others. Because of this higher density, gravity caused them to collapse. As the large cloud collapsed, it cooled. On an even smaller scale, pieces of the collapsing cloud, also collapsed into even smaller pieces. These smaller denser regions created the first stars. When the first stars reached the end of their life cycle, they exploded, heating the surrounding gas and slowing the collapse of the galaxy cloud. These explosions also introduced heavier metals, such as carboon and nitrogen, into the galactic cloud. Eventually, this process of collapse, star formation, and slowing, balanced, giving us stable galaxies. How this process created elliptical and spiral galaxies, is yet another question. There are two main theories. The first theory is: as the cloud collapsed to form a galaxy, it's spin is determined what type of galaxy it became. Some theorists believe that spiral galaxies were formed from clouds that had a significant spin. As the cloud collapsed the spin got even faster still, this is a feature of the principle of angular momentum. As this the spin increased, it flattened the material in the cloud along the spin axis, forming the characteristic disk of spiral galaxies. Elliptical galaxies were simply formed from clouds that didn't have this spin. They therefore formed a more round structure, which has no particular axis of rotation.

The second theory is that elliptical galaxies were formed from collisions of spiral galaxies. This theory is supported by a couple of interesting facts. First, in the early universe galaxies were much closer together then they are now. Since they were closer together, especially in galaxy clusters, collisions were probably very common. So if collisions of spirals made ellipticals, the process of elliptical galaxy creation was definitely present. Second, large elliptical galaxies typically occur in rich galaxy clusters, where collisions most likely happen. Third, ellipticals don't have much interstellar gas, when compared to spirals. Why? In the context of this theory, the collision of spirals would have ignited much of the gas, turning them into stars. This process can be seen today in galaxy collisions. Elliptical galaxies do show evidence of this "new" population of star formation, even though they currently have very low formation rates. Newer stars have a different metal composition than older stars, since they were created later in the galaxy's evolution (i.e. after several star life cycles). Astronomers can measure the amount of "heavy" metals in a star through a process called spectrophotometry. In some elliptical galaxies, there are two distinct populations of globular clusters an "old" and a "new."

Fig-1: Stephan's Quartet showing galaxy collsion

II. PROPERTIES OF GALAXIES

Because of the inability to conduct experiments in outer space, the only way to "test" theories and models of galaxy evolution is to compare them with observations. Explanations for how galaxies formed and evolved must be able to predict the observed properties and types of galaxies. Edwin Hubble created the first galaxy classification scheme known as the Hubble tuning-fork diagram. It partitioned galaxies into ellipticals, normal spirals, barred spirals (such as the Milky Way), and irregulars. These galaxy types exhibit the following properties which can be explained by current galaxy evolution theories:

- Many of the properties of galaxies (including the galaxy color–magnitude diagram) indicate that there are fundamentally two types of galaxies. These groups divide into blue star-forming galaxies that are more like spiral types, and red non-star forming galaxies that are more like elliptical galaxies.
- Spiral galaxies are quite thin, dense, and rotate relatively fast, while the stars in elliptical galaxies have randomly-oriented orbits.
- The majority of giant galaxies contain a supermassive black hole in their centers, ranging in mass from millions to billions of times the mass of our Sun. The black hole mass is tied to the host galaxy bulge or spheroid mass.
- Metallicity has a positive correlation with the absolute magnitude (luminosity) of a galaxy.

There is a common misconception that Hubble believed incorrectly that the tuning fork diagram described an evolutionary sequence for galaxies, from elliptical galaxies through lenticulars to spiral galaxies. This is not the case; instead, the tuning fork diagram shows an evolution from simple to complex with no temporal connotations intended.[1] Astronomers now believe that disk galaxies likely formed first, then evolved into elliptical galaxies through galaxy mergers. Current models also predict that the majority of mass in galaxies is made up of dark matter, a substance which is not directly observable, and might not interact through any means except gravity. This observation arises because galaxies could not have formed as they have, or rotate as they are seen to, unless they contain far more mass than can be directly observed.

III. FORMATION OF GALAXIES

More recent theories include the clustering of dark matter halos in the bottom-up process. Instead of large gas clouds collapsing to form a galaxy in which the gas breaks up into smaller clouds, it is proposed that matter started out in these "smaller" clumps (mass on the order of globular clusters), and then many of these clumps merged to form galaxies,[4] which then were drawn by gravitation to form galaxy clusters. This still results in disk-like distributions of baryonic matter with dark matter forming the halo for all the same reasons as in the top-down theory. Models using this sort of process predict more small galaxies than large ones, which matches observations. Astronomers do not currently know what process stops the contraction. In fact, theories of disk galaxy formation are not successful at producing the rotation speed and size of disk galaxies. It has been suggested that the radiation from bright newly formed stars, or from an active galactic nucleus can slow the contraction of a forming disk. It has also been suggested that the dark matter halo can pull the galaxy, thus stopping disk contraction.[5] The Lambda-CDM model is a cosmological model that explains the formation of the universe after the Big Bang. It is a relatively simple model that predicts many properties observed in the universe, including the relative frequency of different galaxy types; however, it underestimates the number of thin disk galaxies in the universe.[6] The reason is that these galaxy formation models predict a large number of mergers. If disk galaxies merge with another galaxy of comparable mass (at least 15 percent of its mass) the merger will likely destroy, or at a minimum greatly disrupt the disk, and the resulting galaxy is not expected to be a disk galaxy (see next section). While this remains an unsolved problem for astronomers, it does not necessarily mean that the Lambda-CDM model is completely wrong, but rather that it requires further refinement to accurately reproduce the population of galaxies in the universe. Olin Eggen, Donald Lynden-Bell, and Allan Sandage[2] in 1962, proposed a theory that disk galaxies form through a monolithic collapse of a large gas cloud. The distribution of matter in the early universe was in clumps that consisted mostly of dark matter. These clumps interacted gravitationally, putting tidal torques on each other that acted to give them some angular momentum. As the baryonic matter cooled, it dissipated some energy and contracted toward the center. With angular momentum conserved, the matter near the center speeds up its rotation. Then, like a spinning ball of pizza dough, the matter forms into a tight disk. Once the disk cools, the gas is not gravitationally stable, so it cannot remain a singular homogeneous cloud. It breaks, and these smaller clouds of gas form stars. Since the dark matter does not dissipate as it only interacts gravitationally, it remains distributed outside the disk in what is known as the dark halo. Observations show that there are stars located outside the disk, which does not quite fit the "pizza dough" model. It was first proposed by Leonard Searle and Robert Zinn [3] that galaxies form by the coalescence of smaller progenitors. Known as a top-down formation scenario, this theory is quite simple yet no longer widely accepted.

IV. STAR FORMATION RATES AND INTERSTELLAR RECYCLING

The star formation rate in a galaxy depends on two types of processes: (1) effects that drive star formation by creating massive, dense star-forming clouds, and (2) negative feedback effects that limit the efficiency of star formation by destroying these clouds before most of their matter has been turned into stars. Although star formation may in some circumstances also produce positive feedback effects that stimulate further star formation the net feedback effect of star formation must be negative rather than positive, otherwise all of the gas in galaxies would have been consumed long ago in a runaway process lasting only a small fraction of the age of the universe.

1. Interstellar Gas Cycling and Cloud Motions
2. Feedback Effects and the Efficiency of Star Formation
3. Effects Driving Star Formation

V. GALAXY MERGERS AND THE FORMATION OF ELLIPTICAL GALAXIES

Elliptical galaxies (such as IC 1101) are among some of the largest known thus far. Their stars are on orbits that are randomly oriented within the galaxy (i.e. they are not rotating like disk galaxies). A distinguishing feature of elliptical galaxies is that the velocity of the stars does not necessarily contribute to flattening of the galaxy, such as in spiral galaxies.[7] Elliptical galaxies have central supermassive black holes, and the masses of these black holes correlate with the galaxy's mass.

Elliptical galaxies have two main stages of evolution. The first is due to the supermassive black hole growing by accreting cooling gas. The second stage is marked by the black hole stabilizing by suppressing gas cooling, thus leaving the elliptical galaxy in a stable state.[8] The mass of the black hole is also correlated to a property called sigma which is the dispersion of the velocities of stars in their orbits. This relationship, known as the M-sigma relation, was discovered in 2000.[9] Elliptical galaxies mostly lack disks, although some bulges of disk galaxies resemble elliptical galaxies. Elliptical galaxies are more likely found in crowded regions of the universe (such as galaxy clusters).

Astronomers now see elliptical galaxies as some of the most evolved systems in the universe. It is widely accepted that the main driving force for the evolution of elliptical galaxies is mergers of smaller galaxies. Many galaxies in the universe are gravitationally bound to other galaxies, which means that they will never escape their mutual pull. If the galaxies are of similar size, the resultant galaxy will appear similar to neither of the progenitors,[10] but will instead be elliptical. There are many types of galaxy mergers, which do not necessarily result in elliptical galaxies, but result in a structural change. For example, a minor merger event is thought to be occurring between the Milky Way and the Magellanic Clouds.

Mergers between such large galaxies are regarded as violent, and the frictional interaction of the gas between the two galaxies can cause gravitational shock waves, which are capable of forming new stars in the new elliptical galaxy.[11] By sequencing several images of different galactic collisions, one can observe the timeline of two spiral galaxies merging into a single elliptical galaxy.[12]

In the Local Group, the Milky Way and the Andromeda Galaxy are gravitationally bound, and currently approaching each other at high speed. Simulations show that the Milky Way and Andromeda are on a collision course, and are expected to collide in less than five billion years. During this collision, it is expected that the Sun and the rest of the Solar System will be ejected from its current path around the Milky Way. The remnant could be a giant elliptical galaxy.[13]

VI. CONCLUSION

Many galaxies in the universe are gravitationally bound to other galaxies, which means that they will never escape their mutual pull. If the galaxies are of similar size, the resultant galaxy will appear similar to neither of the progenitors,[10] but will instead be elliptical. There are many types of galaxy mergers, which do not necessarily result in elliptical galaxies, but result in a structural change. There is a common misconception that Hubble believed incorrectly that the tuning fork diagram described an evolutionary sequence for galaxies, from elliptical galaxies through lenticulars to spiral galaxies. This is not the case; instead, the tuning fork diagram shows an evolution from simple to complex with no temporal connotations intended.[1] Astronomers now believe that disk galaxies likely formed first, then evolved into elliptical galaxies through galaxy mergers. Current models also predict that the majority of mass in galaxies is made up of dark matter, a substance which is not directly observable, and might not interact through any means except gravity. Many of the properties of galaxies (including the galaxy color–magnitude diagram) indicate that there are fundamentally two types of galaxies. These groups divide into blue star-forming galaxies that are more like spiral types, and red non-star forming galaxies that are more like elliptical galaxies.

REFERENCES

[1] Hubble, Edwin P. "Extragalactic nebulae." The Astrophysical Journal 64 (1926).

[2] Eggen, O. J.; Lynden-Bell, D.; Sandage, A. R. (1962). "Evidence from the motions of old stars that the Galaxy collapsed". The Astrophysical Journal. 136: 748. Bibcode:1962ApJ...136..748E.doi:10.1086/147433.

[3] Searle, L.; Zinn, R. (1978). "Compositions of halo clusters and the formation of the galactic halo". The Astrophysical Journal. 225: 357–379Bibcode:1978ApJ...225..357S.doi:10.1086/156499.

[4] White, Simon; Rees, Martin (1978). "Core condensation in heavy halos: a two-stage theory for galaxy formation and clustering". MNRAS. 183: 341 Bibcode:1978MNRAS.183..341W.doi:10.1093/mnras/183.3.341.

[5] Christensen, L.L.; de Martin, D.; Shida, R.Y. (2009). Cosmic Collisions: The Hubble Atlas of Merging Galaxies. Springer. ISBN 9780387938530.

[6] Steinmetz, Matthias; Navarro, Julio F. (2002-06-01). "The hierarchical origin of galaxy morphologies". New Astronomy. 7 (4): 155–160. arXiv: astro-ph/0202466 Bibcode:2002NewA....7..155S.doi:10.1016/S1384-1076(02)00102-1.

[7] Kim, Dong-Woo (2012). Hot Interstellar Matter in Elliptical Galaxies. New York: Springer. ISBN 978-1-4614-0579-5.

[8] Churazov, E.; Sazonov, S.; Sunyaev, R.; Forman, W.; Jones, C.; Böhringer, H. (2005-10-01). "Supermassive black holes in elliptical galaxies: switching from very bright to very dim". Monthly Notices of the Royal Astronomical Society: Letters. 363 (1): L91–L95. arXiv:astro-ph/0507073 . Bibcode:2005MNRAS.363L..91C.doi:10.1111/j.1745-3933.2005.00093.x. ISSN 1745-3925.

[9] Gebhardt, Karl; Bender, Ralf; Bower, Gary; Dressler, Alan; Faber, S. M.; Filippenko, Alexei V.; Richard Green; Grillmair, Carl; Ho, Luis C.

(2000-01-01). "A Relationship between Nuclear Black Hole Mass and Galaxy Velocity Dispersion". The Astrophysical Journal Letters. 539 (1): L13. arXiv:astro-ph/0006289 . Bibcode:2000ApJ...539L..13G. doi:10.1086/312840. ISSN 1538-4357.

[10] Barnes, Joshua E. (1989-03-09). "Evolution of compact groups and the formation of elliptical galaxies". Nature. 338 (6211): 123–126. Bibcode:1989Natur.338..123B. doi:10.1038/338123a0.

[11] "Current Science Highlights: When Galaxies Collide". www.noao.edu. Retrieved 2016-04-25.

[12] Saintonge, Amelie. "What happens when galaxies collide? (Beginner) - Curious About Astronomy? Ask an Astronomer". curious.astro.cornell.edu. Retrieved 2016-04-25.

[13] Cox, T. J.; Loeb, Abraham (2008-05-01). "The collision between the Milky Way and Andromeda". Monthly Notices of the Royal Astronomical Society. 386 (1): 461–474. arXiv:0705.1170 . Bibcode:2008MNRAS.386..461C. doi:10.1111/j.1365-2966.2008.13048.x. ISSN 0035-8711.

[14] "Giant Galaxies Die from the Inside Out". www.eso.org. European Southern Observatory. Retrieved 21 April 2015.

[15] Carroll, Bradley W.; Ostlie, Dale A. (2007). An Introduction to Modern Astrophysics. New York: Pearson. ISBN 978-0805304022.

[16] Blanton, Michael R.; Hogg, David W.; Bahcall, Neta A.; Baldry, Ivan K.; Brinkmann, J.; Csabai, István; Daniel Eisenstein; Fukugita, Masataka; Gunn, James E. (2003-01-01). "The Broadband Optical Properties of Galaxies with Redshifts 0.02 < z < 0.22". The Astrophysical Journal. 594 (1): 186. arXiv:astro-ph/0209479 . Bibcode:2003ApJ...594..186B.doi:10.1086/375528. ISSN 0004-637X.

[17] Faber, S. M.; Willmer, C. N. A.; Wolf, C.; Koo, D. C.; Weiner, B. J.; Newman, J. A.; Im, M.; Coil, A. L.; C. Conroy (2007-01-01). "Galaxy Luminosity Functions to z 1 from DEEP2 and COMBO-17: Implications for Red Galaxy Formation". The Astrophysical Journal. 665 (1): 265. arXiv:astro-ph/0506044 . Bibcode:2007ApJ...665..265F.doi:10.1086/519294. ISSN 0004-637X.

[18] Blanton, Michael R. (2006-01-01). "Galaxies in SDSS and DEEP2: A Quiet Life on the Blue Sequence?". The Astrophysical Journal. 648 (1): 268. arXiv:astro-ph/0512127 . Bibcode:2006ApJ...648..268B.doi:10.1086/505628. ISSN 0004-637X.

[19] Gabor, J. M.; Davé, R.; Finlator, K.; Oppenheimer, B. D. (2010-09-11). "How is star formation quenched in massive galaxies?". Monthly Notices of the Royal Astronomical Society. 407 (2): 749–771. arXiv:1001.1734 . Bibcode:2010MNRAS.407..749G.doi:10.1111/j.1365-2966.2010.16961.x. ISSN 0035-8711.

[20] Kereš, Dušan; Katz, Neal; Davé, Romeel; Fardal, Mark; Weinberg, David H. (2009-07-11). "Galaxies in a simulated ΛCDM universe – II. Observable properties and constraints on feedback". Monthly Notices of the Royal Astronomical Society. 396 (4): 2332–2344. arXiv:0901.1880 Bibcode:2009MNRAS.396.2332K.doi:10.1111/j.1365-2966.2009.14924.x. ISSN 0035-8711.

[21] Peng, Y.; Maiolino, R.; Cochrane, R. "Strangulation as the primary mechanism for shutting down star formation in galaxies". Nature. 521 (7551): 192–195. arXiv:1505.03143 Bibcode:2015Natur.521..192P.doi:10.1038/nature14439. PMID 25971510.