# VISITING STUDENT PROGRAMME - 2023

# The quenching of star formation by massive bulges in disk galaxies

**Student:**
Ritabik Banerjee
NISER, Bhubaneshwar

**Guide:**
Dr.Mousumi Das
IIA, Bangalore

26 July 2023

## Indian Institute of Astrophysics, Bangalore

# Contents

# The quenching of star formation by massive bulges in disk galaxies

**Ritabik Banerjee**
**School of physical Sciences**
**National Institute of Science Education and Research , Bhubaneshwar**

## Abstract

Early type spiral galaxies and some SO galaxies are found to have large, massive bulges. These bulges can make the disks of their host galaxies kinematically hotter just because they make the potential much deeper in the center of the galaxy, resulting in an increase of the disk stellar velocity dispersion. Hotter disks are less likely to support star formation mainly because they do not form global disk instabilities like bars and spiral arms. In this project we will calculate the different componets of the spiral galaxies and trying to understand the distribution of ratio between the bulge and disk and total mass of the galaxies, by using the galaxy sample S4G. In future We will compare the bulge to disk ratio with the galaxy colours, star formation rates and specific star formation rates and try to test or verify the hypothesis.

**Keywords:** Vizier, S4G, Spiral Galaxies, Star Formation rates(SFRs), Specific Star formation rates(sSFRs)

## 0.1 Introduction

In this project we are dealing with stars,galaxies,galaxy bulges,star formation as well as the other components of the galaxies,thus we have to first start from the basic understanding of these celestial objects.In this section we will describe how the stars,galaxies etc forms and behave in this cosmos.

### 0.1.1 Galaxies

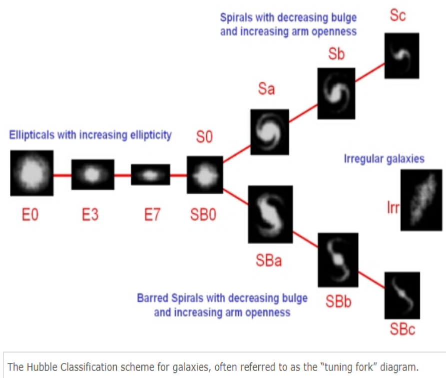
Galaxy, any of the systems of stars and interstellar matter that make up the universe. Many such assemblages are so enormous that they contain hundreds of billions of stars.Galaxies are classified by their morphologies:

**Elliptical galaxies:** These galaxies have an ellipsoidal shape, which gives them an elliptical appearance, regardless of the angle of view. They appear to have very little structure, and they usually have very little interstellar matter.Consequently, these galaxies also have a low portion of open clusters and a reduced rate of new star formation. Instead, they are dominated by generally older, more evolved stars orbiting the common center of gravity in random directions. The stars contain low abundances of heavy elements because star formation ceases after the initial burst. In this sense, they are similar to the much smaller globular clusters.

**Spiral Galaxies:** Spiral galaxies resemble spiraling pinwheels. Though the stars and other visible material in such a galaxy lie mainly on a plane, the majority of mass in spiral galaxies exists in a roughly spherical halo of dark matter which extends beyond the visible component, as demonstrated by the universal rotation curve concept.Some of the spiral galaxies have barred part in the central disk region alongwith the spiral arms. Spiral galaxies consist of a rotating disk of stars, interstellar medium, and a central bulge of generally older stars. Extending outward from the bulge are relatively bright arms.

**Lenticular Galaxies:**A lenticular galaxy is an intermediate form that has properties of both elliptical and spiral galaxies. These are categorized as Hubble type S0, and they possess ill-defined spiral arms with an elliptical halo of stars.

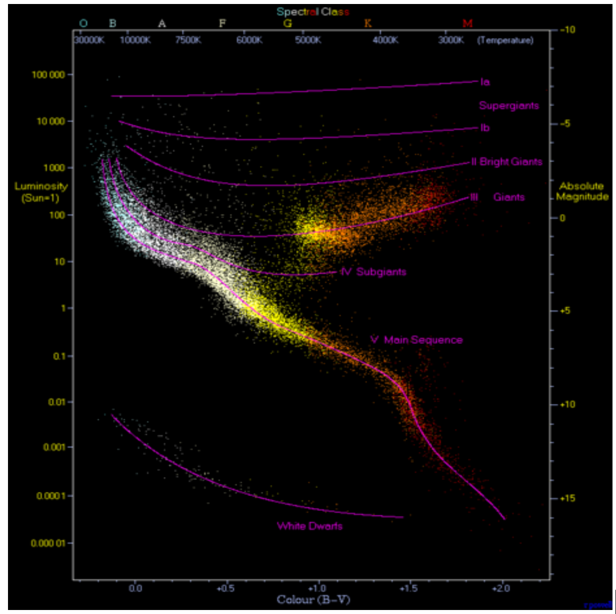
**Irregular Galaxies:** These type of galaxies fall under neither of the classications. They are very irregular in shape and are labelled as Irr in Hubble Classication System.




[1]

### 0.1.2 Stars

Stars are self-gravitating gas masses that are protected from collapsing by pressure (both thermal and degeneracy). By examining a star's luminosities, which provide information on its motions,a surface temperature estimate (on the assumption of a blackbody energy distribution). Although certain stars are supported by degeneracy pressure, which does not require nuclear fusion to balance its gravity, most stars are powered by nuclear fusion processes that occur in the interior layers of the stars.
We must start with the Hertzsprung-Russell Diagram (HR Diagram)[2] in order to investigate a star's attributes because it depicts a star's absolute magnitude as a function of color for a specific stellar population. By displaying how many stars are in the main sequence and how many stars are in other branches, the HR diagram provides us an idea of the age of the stellar population. It also provides us with a sense of the population's metallicity, which may be determined by looking at the horizontal branch's pattern. Additional observables like absolute magnitude, apparent magnitude, distance modulus, hue, etc. can be used to measure the properties of stars in greater detail.

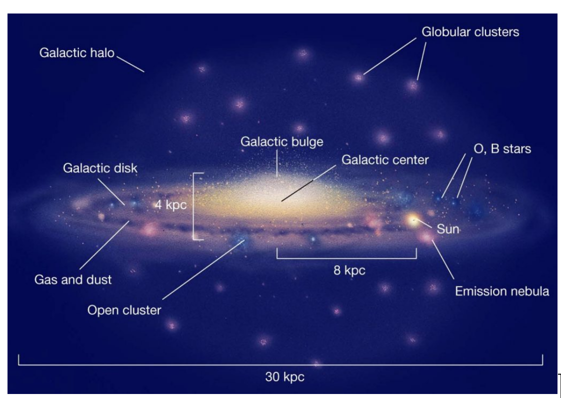



[3]

Stars can also be classified on the basis of their spectral classes, which is determined by the prominence of various absorption lines in their stellar spectra. In decreasing order of temperature the spectral classes are labelled as O,B,A,F,G,K, and M. The spectral classes are further subdivided into sublasses by the numbers 0,1,...,9.

### 0.1.3 Spiral Galaxies

Spiral galaxies are a type of galaxy characterized by their distinct spiral arms, which emanate from a central bulge. They are one of the three main types of galaxies, along with elliptical galaxies and irregular galaxies. Spiral galaxies are often more flattened and disk-shaped compared to elliptical galaxies.




][4]

Some features of Spiral Galaxies:

**Spiral Arms**

The most prominent feature of spiral galaxies is their spiral arms, which appear as long, curving structures extending from the center of the galaxy. These arms contain a higher density of stars, gas, and dust compared to the rest of the disk.

**Density Waves:** Spiral arms are not rigid structures; they are density waves that propagate through the galactic disk. As the wave passes, it compresses the interstellar gas and triggers the formation of new stars. Let $\delta\rho$ be the perturbation in the density from the equilibrium density $\rho_0$ in a rotating galactic disk with axisymmetric spiral density waves. The continuity equation for the perturbation in density is given by:

$$\frac{\partial \delta\rho}{\partial t} + \nabla \cdot (\rho_0 \mathbf{V}) = 0, \tag{1}$$

where $\mathbf{V}$ is the velocity vector.

The equation of motion for the perturbed velocity field is described by Euler's equation:

$$\frac{\partial \mathbf{V}}{\partial t} + (\mathbf{V} \cdot \nabla)\mathbf{V} = -\nabla\phi, \tag{2}$$

where $\phi$ is the gravitational potential.

The perturbed gravitational potential driven by spiral density waves can be expressed as:

$$\Phi_{\text{pert}} = \sum_{m=1}^{\infty} \Phi_m(R)\cos(m\theta - \omega t)$$

where:
- $\Phi_{\text{pert}}$ is the perturbed gravitational potential,
- $\Phi_m(R)$ is the amplitude of the $m$-th Fourier component as a function of the radial distance $R$,
- $\theta$ is the azimuthal angle,
- $\omega$ is the pattern speed of the spiral wave, and
- $m$ is the number of spiral arms (integer value).

The energy equation describes the conservation of energy within the galactic disk. It accounts for the various heating and cooling processes that contribute to the energy balance. The general form of the energy equation can be written as:

$$\frac{\partial u}{\partial t} + (\nabla \cdot \mathbf{F}) = H - C$$

where: - $u$ is the internal energy per unit volume,
- $t$ is time,
- $\nabla \cdot \mathbf{F}$ is the divergence of the energy flux vector $\mathbf{F}$,
- $H$ represents the net heating rate per unit volume, and
- $C$ represents the net cooling rate per unit volume.

**Differential Rotation**: As the galaxy rotates, the spiral arms are not fixed in position. They move at different speeds relative to the rotation of the galaxy, giving rise to a winding pattern over time.

The differential rotation of galaxies refers to the rotation of their individual components (e.g., stars, gas, and dust) at different angular velocities depending on their distance from the galactic center. This phenomenon is a consequence of the conservation of angular momentum during the galaxy's formation and evolution. Mathematically, the differential rotation can be described using the following equation:

$$v(R) = R\frac{d\theta}{dt}$$

where: - $v(R)$ is the rotation velocity at a given radial distance $R$ from the galactic center,
- $R$ is the radial distance from the galactic center,
- $\theta$ is the azimuthal angle, and
- $\frac{d\theta}{dt}$ is the angular velocity (rate of change of angle) of the rotating component.

In the case of a spiral galaxy, the rotation curve describes how the rotation velocity $v(R)$ varies with $R$ throughout the galactic disk. Observationally, the rotation curve of spiral galaxies shows a nearly flat profile, indicating that the rotation velocity remains relatively constant with increasing radial distance from the center. This behavior suggests the presence of a significant amount of dark matter in the galaxy's outer regions, contributing to the observed differential rotation.

The concept of differential rotation is crucial for understanding the dynamics of galaxies, the distribution of mass, and the presence of dark matter. It plays a fundamental role in models of galactic structure and the study of galactic evolution. Differential rotation is one of the key factors that enable the formation and stability of galactic disks and their spiral arms.

**Halo and Dark Matter:** Surrounding the visible disk of the galaxy is a more extended, nearly spherical region known as the halo. The halo contains older stars, globular clusters, and a significant amount of dark matter.

**Bar of a galaxy:** The bar of a galaxy is an elongated structure extending from the galactic center, observed in certain galaxies like barred spirals and barred lenticulars. It features a mix of stars, gas, and dust, influencing the galaxy's dynamics and evolution. The bar's shape follows the major axis of the galaxy, often with spiral arms originating from its ends. Its gravitational forces alter orbits, leading to non-circular motions and reshaping the galaxy's density distribution. The bar drives gas inflows, promoting star formation and feeding the central black hole. Understanding bar formation and evolution provides crucial insights into a galaxy's history and how these structures contribute to its intricate structure and dynamics.[7]

### 0.1.4 Central Bulge

The central bulge of a spiral galaxy is a spheroidal or ellipsoidal structure situated at the galaxy's center. Composed mainly of older stars and dark matter, the bulge significantly contributes to the galaxy's mass and gravitational potential. It plays a vital role in shaping the galaxy's dynamics and evolution. The bulge's density profile, often described using the Sersic profile, helps characterize its structure and concentration. Its gravitational influence affects the orbits and kinematics of stars and gas within the galaxy. The central bulge's formation remains a subject of ongoing research, shedding light on the galaxy's evolutionary history and structural properties.


[5]

The central bulge of spiral galaxies can be mathematically described using various models, depending on the specific characteristics and assumptions made for the bulge. One common mathematical description is based on a spherically symmetric density profile. A commonly used model for the density distribution of the central bulge is the Sersic profile, given by:

$$I(r) = I_0 \exp\left[-\left(\frac{r}{r_e}\right)^{1/n}\right]$$

where: - $I(r)$ is the density at a radial distance $r$ from the galactic center,
- $I_0$ is the central density,
- $r_e$ is the effective radius, which characterizes the size of the bulge, and
- $n$ is the Sersic index, which controls the steepness of the density profile.

The Sersic profile is a versatile model that can represent a range of bulge types, from compact and round to more extended and flattened structures. The value of $n$ determines the concentration and shape of the bulge: larger $n$ values result in more centrally concentrated and rounder bulges, while smaller $n$ values lead to more extended and flattened bulges.

Other mathematical models can also be used to describe the central bulge, depending on the specific properties of the galaxy and the available observational data. For example, some bulges may be better described by a different density profile or a combination of multiple components, such as a bulge-disk decomposition model.

It is important to note that mathematical models for the central bulge are often derived from observations, numerical simulations, and theoretical considerations. These models are used to understand the structural and dynamical properties of bulges in spiral galaxies and to gain insights into the formation and evolution of galactic structures.
The potential form of a central bulge in a galaxy can be mathematically described using a spherically symmetric model, such as the Plummer potential. The Plummer potential is commonly used to represent the gravitational potential of a spherical system, including central bulges. In LaTeX code, the Plummer potential is given by:

$$\Phi_{\text{bulge}}(r) = -\frac{GM_{\text{bulge}}}{\sqrt{r^2 + r_c^2}}$$

where:
- $\Phi_{\text{bulge}}(r)$ is the gravitational potential of the central bulge at a radial distance $r$ from the galactic center,
- $G$ is the gravitational constant,
- $M_{\text{bulge}}$ is the mass of the central bulge, and
- $r_c$ is a characteristic radius known as the Plummer scale length.

The Plummer potential provides a simple yet effective way to model the gravitational influence of the central bulge in a galaxy. It is commonly used in theoretical studies and numerical simulations to analyze the dynamics and properties of galactic structures.[9]

### 0.1.5 Disk Structure

The disk of a spiral galaxy constitutes the predominant, flat structure composed of stars, gas, and dust. Its flattened, circular shape hosts stars of varying ages, with young stars forming in the spiral arms and older ones spread throughout. Rich in interstellar gas and dust, the disk serves as a hub for ongoing star formation, with molecular clouds birthing new stars and dust playing a role in obscuring certain parts of the galaxy. The presence of spiral arms highlights regions of increased star formation, driven by density waves. Understanding the disk's stability, rotation curve, and interplay with dark matter is crucial for studying galactic evolution and star formation processes.


[6]

Disk galaxies can be mathematically described using various models that characterize their structural and dynamical properties. Here are some common mathematical forms used to model disk galaxies:

Exponential Disk: The exponential disk model describes the surface brightness distribution of stars in the disk as an exponential function of the radial distance from the galactic center. Mathematically, the surface brightness $I(R)$ is given by:

$$I(R) = I_0 \exp\left(-\frac{R}{h}\right)$$

where $I_0$ is the central surface brightness, $R$ is the radial distance from the center, and $h$ is the scale length that characterizes the size of the disk.

### 0.1.6 Velocity dispersion

Velocity dispersion in disk galaxies refers to the random motions of stars and gas particles in the galactic disk. It is a measure of the spread in velocities around the mean rotational velocity due to the thermal motion and gravitational interactions within the disk. Velocity dispersion plays a crucial role in determining the stability, kinematics, and dynamics of the galaxy.

In the context of stars, the velocity dispersion is typically measured in the plane of the disk. It provides information about the internal pressure and the balance between gravitational forces and random motions in the disk. The velocity dispersion is related to the temperature and thermal energy of stars in the disk.

For gas in the disk, the velocity dispersion represents the random motions of individual gas particles due to thermal energy and turbulent motions. It is essential for understanding the state of the interstellar medium, gas accretion, and star formation processes in the disk.

Mathematically, the velocity dispersion in the disk can be quantified using the second moment of the velocity distribution function. For a population of stars or gas particles, the radial and azimuthal components of the velocity dispersion can be expressed as:

$$\sigma_R^2 = \frac{1}{N}\sum_{i=1}^{N}\left(v_{i,R} - \bar{v}_R\right)^2$$

$$\sigma_\theta^2 = \frac{1}{N}\sum_{i=1}^{N}\left(v_{i,\theta} - \bar{v}_\theta\right)^2$$

where: - $\sigma_R$ and $\sigma_\theta$ are the radial and azimuthal velocity dispersions, respectively,
- $v_{i,R}$ and $v_{i,\theta}$ are the radial and azimuthal components of the velocity of the $i$-th particle in the disk,
- $\bar{v}_R$ and $\bar{v}_\theta$ are the mean radial and azimuthal velocities, respectively, and
- $N$ is the total number of particles in the disk.[8]

Observationally, velocity dispersion can be measured through spectroscopic observations of stars or gas in the disk using techniques like stellar kinematics or emission line spectroscopy. The velocity dispersion provides valuable insights into the dynamics, structure, and physical conditions of disk galaxies.

### 0.1.7 Quenching of Star Formation in Disk galaxies

Quenching star formation in disk galaxies is a crucial process that transforms active star-forming galaxies into quiescent ones. Several mechanisms contribute to this phenomenon. Feedback from active galactic nuclei (AGN) releases powerful energy, heating and expelling gas from the disk. Interactions with neighboring galaxies or the intergalactic medium can strip the disk of its interstellar gas, depriving it of the fuel needed for new stars. In galaxy clusters, ram pressure stripping by the intracluster medium removes the disk's gas, hindering further star formation.

The presence of a massive dark matter halo can heat and expand the disk, reducing gas density and quenching star formation. Galactic interactions and mergers disturb the disk's structure, leading to bursts of star formation followed by gas exhaustion. Stellar winds and supernovae feedback can also drive gas outflows, disrupting star-forming regions. Understanding star formation quenching is vital for comprehending galaxy evolution and their diverse morphologies and properties. Observational studies and theoretical models elucidate the complex interplay between quenching mechanisms, shaping the destiny of disk galaxies throughout cosmic history.

**Feedback Quenching by Massive Bulge:**

Hypothetically the theory says that the quenching of star formation by a massive bulge in a disk galaxy is explained by using classical potential theory. The gravitational potential of the bulge creates a deep potential well, which increases the velocity dispersion of stars in the disk. The higher velocity dispersion leads to greater random motions, inhibiting gas collapse and star formation. As a result, the presence of a massive bulge suppresses the formation of new stars in the disk, causing a decline in star formation activity and transforming the galaxy into a quiescent state.

## 0.2 Methodology

In this section we will discuss about how we collect the data and reduce it basically.

### 0.2.1 Data Collection from Vizier Catalogue

In this project we have taken the S4G[10] data from the vizier catalogue which contains all the photometric data's as per the components of the spiral galaxies.Generally we have a large number of aproxx 2400 galaxies. In this part we use the S4G paper by (Salo et.al)[11] to calculate the bulge to disk mass ratio of the galaxies.
To calculate SFR,specific SFR we are using the Galex data of FUV and NUV magnitudes.(Salim et.al)[12]

We generally took the the distance modulus of the galaxies from the NED IPAC to calculate the distance of the galaxies so that we must able to calculate the Absolute magnitudes of all the galaxies.Firstly the magnitudes values of all the galaxies are apparent so to calculate the mass and luminosities we have the absolute magnitudes.

### 0.2.2 Data reduction and Analysis

Here we first plots the distribution of the galaxies according to their luminosity fraction of different components.We have a large number of 2400 galaxies which must be first check correctly that the the models used in the data are correct to fit the components. In the paper of (Salo et.al) they have used GALFIT to fit the components of the galaxies and calculate the magnitudes of the galaxies.

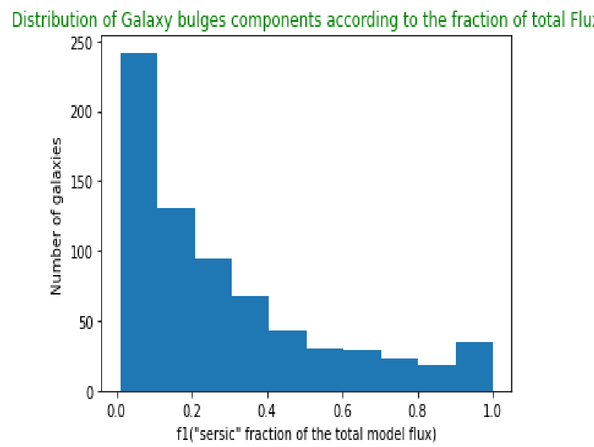



Figure 1: Light ratio of the bulge component using sersic function

In the above figure they have used the sersic function to fit the luminosity of the bulge components.

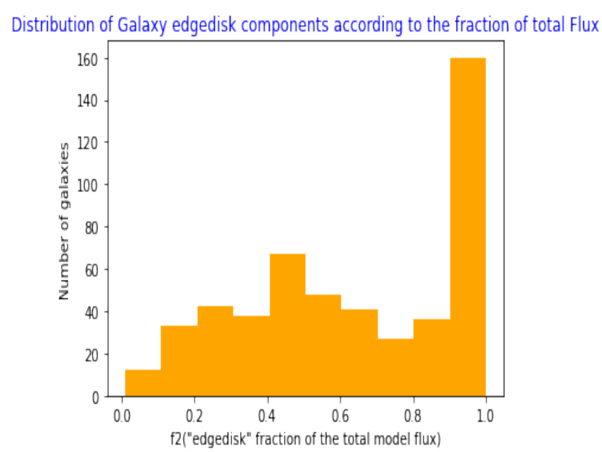


Figure 2: Light ratio of the edgedisk component using edgedisk function

In this profile they have used the edgedisk components profile of the galaxies to fit that edge part.

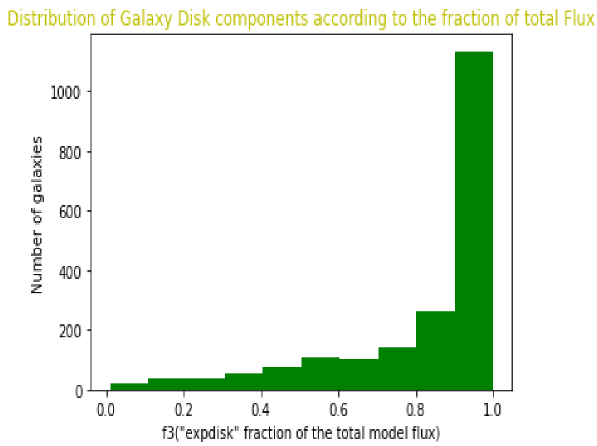



Figure 3: Light ratio of the disk component using exponential or radial profile

In this part they have used the exponential profile of the galaxies to fit that disk part.

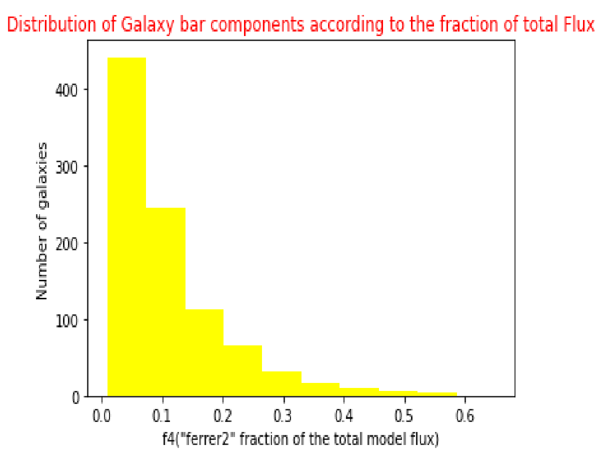



Figure 4: Light ratio of the bar component using ferrer2 profile

In this part they have used the ferrer2 profile of the galaxies to fit that bar part of the galaxy in the sample data.

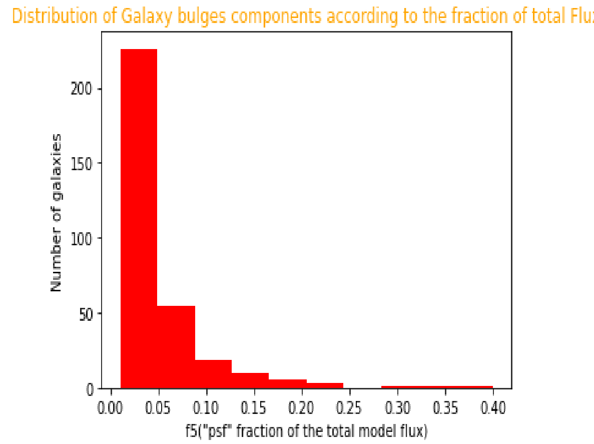



Figure 5: Light ratio of the nucleus component using psf profile

In this part they have used the psf profile of the galaxies to fit that nucleus part of the galaxy in the sample data.PSF generally means the point spread function which is used to fit the components or objects which are unable to observe via images.
We have observed that the all the data points are corectly fitted in Galfit which can be directly told from the form of the distribution. We have thus select the data sets which have both bulge as well as disk fitted in them which means they have both bulge and disk components in them.So from that we sorted the data sets accordingly and after that we got 504 datapoints from the 2400 galaxy data samples. Sometimes the central disk components are plotted from the sersic profile so we have deducted that data from the datasets and consider the classical bulges only.

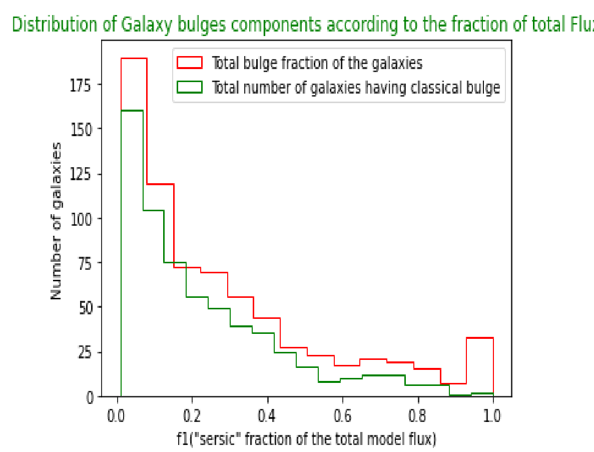



Figure 6: Galaxy distribution of the light ratio fitted with sersic profile of both bulge as well as central disk components.

Here the remaining portion other than green plot are fitted of central disk components by using the sersic

profile.
Thus after that we check the magnitudes distribution of the galaxies whether plotted or fitted with sersic and exponential disk profile and and their intersection points between them.

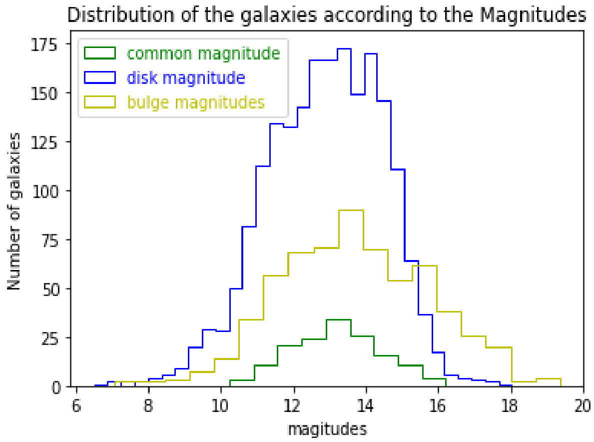



Figure 7: Distribution of the galaxies according to their magnitudes values.

After this we verified all the values and use this data points to calculate the bulge,disk as well as the total masses of the galaxies.

**Data analysis**

After the reduction of the data we started to calculated all the desired values we need.And all this fitted datapoints are calculated and observed datapoints are in 2.6 micron.
We first started to get the Mean Distance modulus of the galaxies to calculate the distance from us by using NED IPAC data catalogue.

The distance modulus $(m - M)$ is a measure used in astronomy to relate the apparent magnitude $(m)$ of an object to its absolute magnitude $(M)$, and thereby, determine its distance $(d)$ from Earth. The relationship between the distance modulus and distance is given by:

$$m - M = 5 \log_{10} \left( \frac{d}{10} \right)$$

where: - $m$ is the apparent magnitude of the object (as observed from Earth),
- $M$ is the absolute magnitude of the object (the apparent magnitude it would have if placed at a standard distance of 10 parsecs, i.e., 10 pc),
- $d$ is the distance to the object in parsecs (pc), and
- $\log_{10}$ denotes the base-10 logarithm.

By rearranging the equation, we can express the distance $(d)$ in parsecs as:

$$d = 10^{(m-M+5)/5}$$

This formula allows astronomers to determine the distance to celestial objects, such as stars, galaxies, and other astrophysical sources, based on their observed apparent magnitudes and known absolute magnitudes. It is an essential tool in distance measurements in astronomy. [13] After calculating the distance we calculate the absolute magnitudes from the above sample data.

$$M = m - 5 \log_{10}(d) - 25$$

This equation allows you to calculate the absolute magnitude ( M) of an object based on its apparent magnitude ( m) and the distance to the object in megaparsecs ( d). It is a crucial formula used in astronomy and cosmology to estimate the intrinsic luminosity or brightness of celestial objects and study their properties and evolution. [14] After these steps we calculate the masses of the bulges and disk.Diks masses are as the total of bar , disk and the nucleus masses in them. Bulge mass and the disk masses are calculated by using the magnitudes relation with the luminosity.

$$M_{\text{bulge}} = 10^{(m_{\text{sun}} - M_{\text{bulge}})/(2.5)} \times (M/L)_{\text{sun}}$$

where $M_{\text{bulge}}$ is the absolute magnitude of the bulge. This formula allows you to estimate the bulge mass of a galaxy based on its observed apparent magnitude $m_{\text{bulge}}$ and the bulge's mass-to-light ratio $(M/L)_{\text{bulge}}$, which provides valuable information about the galaxy's stellar populations and mass distribution.We will get this in terms of solar masses. The mass to light ratio of the sun is taken from the source and given as 0.5.[15] The suns absolute magnitude is taken as 6.02 at 3.6 micron.[16] And the disk masses is calculated similarly by using the disk magnitudes. The bar has its central brightness and the magnitudes are calculated form the relation between the central brightness and magnitudes.
The input file also specifies how to convert the image values to magnitudes. The data images are in flux units (MJy/sr). A conversion from pixel values Fi to (AB) surface brightness and integrated magnitudes is done with the formulas:

$$\text{mag}_{3.6} = -2.5 \log_{10} (X_i \cdot F_i + zp)$$

where pix $= 0.75''$ and the zeropoint at 3.6 µm is zp = 21.097 (Mu˜noz–Mateos et al. 2014)[17]. Values of pix and zp are inserted into GALFIT input file.

So we use the formula above to calculate the magnitudes of the function by using ferrer2 profile. The surface density profile $\Sigma(r)$ is defined as:

$$\Sigma(r) = \begin{cases} \Sigma_0 \left(1 - \left(\frac{r}{r_{\text{out}}}\right)^{2-\beta}\right)^{\alpha} & \text{if } r < r_{\text{out}} \\ 0 & \text{if } r \geq r_{\text{out}} \end{cases}$$

where:

- $\Sigma_0$ is a constant parameter representing the value at $r = 0$.
- $r_{\text{out}}$ is the cutoff radius.
- $\beta$ and $\alpha$ are parameters governing the shape of the function.

From this. relation we calculate the masses of the bar components.And then the nulceus mass is calculated using the magnitudes given in the samples calculated through the psf profile. Thus we all calculate the disk mass as disks mass + bar mass + nulceus mass and as well as the bulge mass from the above relations.
And total masses of the galaxies are calculated using the bulge mass,disk mass,bar mass and nucleus mass. After calculating the masses we verify this calculation with a published data and thus we have correct values calculated which matches with the published data.
This data is verified from the S4G data sets.[18]

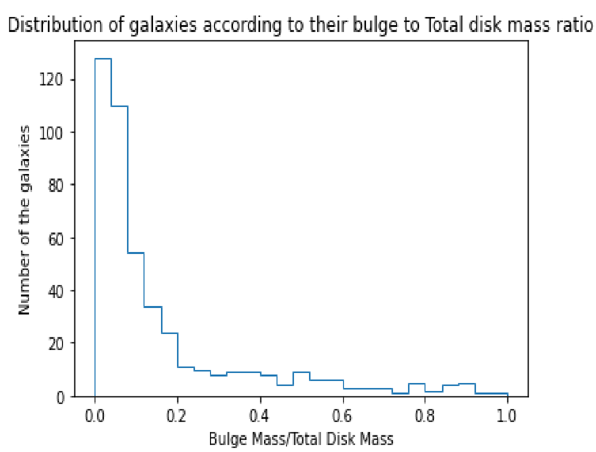



Figure 8: Distribution of the galaxies according to their bulge to disk mass ratio values.

This ratio is similar to the light ratio so we match the plot with the vizier light ratio plots and the form is same.So manage to sty that that our calculation are correct.

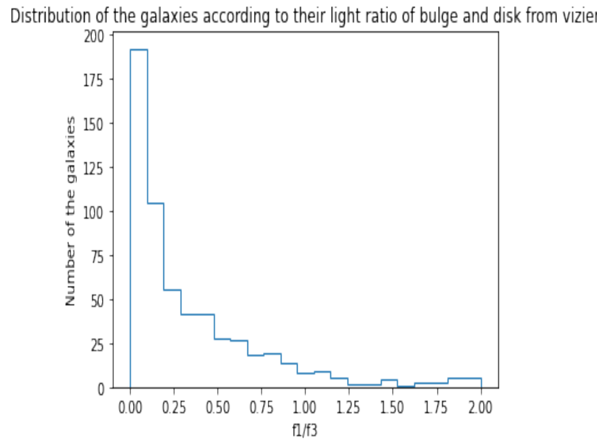



Figure 9: Distribution of the galaxies according to their light ratio of bulge to disk values.

In this part we get some values which have bulge masses greater than the disk masses so we neglect the values as we need the spiral galaxies only in this calculation of SFR and sSFRs(Specific Star formation rates).

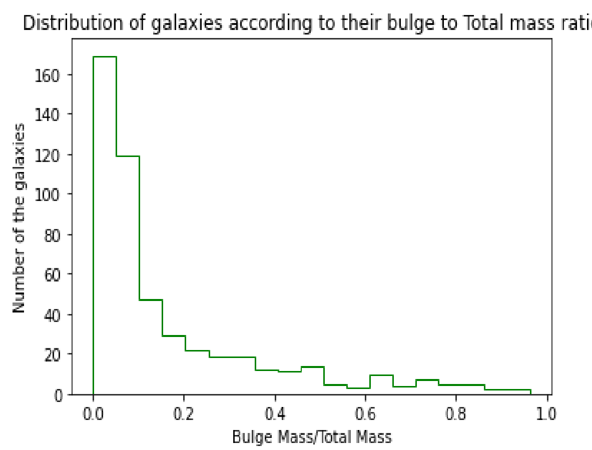



Figure 10: Distribution of the galaxies according to their bulge to total mass ratio values.

The star formation rates are calculated using the formula taken from paper(Salim et . al)[19]
The conversion factor between a dust-corrected rest-frame FUV luminosity (in ergs $\text{s}^{-1}$ $\text{Hz}^{-1}$).
This conversion factor serves as the inverse conversion factor between the FUV luminosity and the SFR, and it comes from the stellar population modeling used in the SED fitting.

The median conversion factor is

$$\log \eta_0 = 28.165$$

. And the SFRs is calculated as

$$\text{SFR} = 1.08 \times 10^{-28} L_{\text{FUV}}$$

where SFR is in $M_\odot$ $yr^{-1}$ and L is in ergs $s^{-1}$ $Hz^{-1}$.

## 0.3 Conclusion and Future Prospects

In this project we have calculated the masses of different components of the spiral galaxy and plotted the ratio's between the bulge masses with disk and total mass of the galaxy using the vizier S4G catalogue.We understood that the most of the galaxies in our sample have lesser bulge mass than the disks. We have calculated this masses using different models for different components of the galaxies. This is also been verified from the other datasets top be sure that we are getting the correct values.

**Future Prospects** : Thus in future we will try to continue this topic and will calculate the SFR, SFRs as well colors of the galaxies in our datasets, thus comparing them to verify the hypothesis that increasing bulge masses quench the star formation in the early type SO galaxies.

**Description of the given tabulated dataset of the galaxies in our sample**

| **Components of the tabulated data** | **Describtion** |
|---|---|
| Name | Names of the galaxies [Note:Omit the inverted commas and b part] |
| mag1 | magnitude of the bulge |
| mag2 | magnitude of the disk |
| Redshift | Redshift of the galaxies |
| Ratio_ L | Light ratio of the bulge and disk |
| Distmodu | Distance Modulus |
| Distmodu_ st. | Standard deviation error of the distance modulus |
| Distance | Distance of the galaxies |
| Absmag1 | Absolute magnitude of the bulge |
| Absmag2 | Absolute magnitude of the disk |
| Bulge mass | Bulge masses of the galaxies |
| Disk mass | Disk masses of the galaxies |
| Ratio | Ratio of bulge to disk mass excluding the bar and nucleus part |
| Ratio_ Mass | Ratio of bulge to total mass excluding the bar and nucleus part |
| Galaxy Morphology | Shape of the galaxy |
| Total Disk_ mass | Total mass of the disk including bar part |
| Total ratio | Ratio of bulge mass with disk mass |
| Total mass | Total mass of the galaxy including bar, bulge, disk, and nucleus part |
| Total_ c | Total number of Components in the galaxies |
| Total ratio_ f | Ratio of bulge with total mass of the galaxy |

| Name | mag1 | mag2 | Redshift | Ratio_L | Distmodu | stmodu_ | Distance | Absmag1 | Absmag2 | Bulge mass | Disk mass | Ratio | Ratio_Mass | Galaxy Morphology | Total Disk_mass | Total ratio | Total mass | Total_c | Total ratio_f |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| b'ESO027-001' | 13.985 | 11.518 | 0.008573 | 0.093452 | 30.44 | 1.43 | 18.308 | -17.3282 | -19.7952 | 1092073356.9251695 solMass | 10593801029.407927 solMass | 0.103086074 | 0.0934524299 | SB(s)c | 43221977980.87303 solMass | 0.0252666214 | 44314051337.7982 solMass | [b'sersic ' b'expdisk ' b'ferrer2 '] | 0.02464395206 |
| b'ESO120-012' | 15.169 | 14.191 | 0.004498 | 0.288892 | 30.56 | 0.44 | 14.4 | -15.6228 | -16.6008 | 227036136.9126205 solMass | 558849656.7582283 solMass | 0.4062561982 | 0.2888920232 | (R')SB(rs)d | 558849656.7582283 solMass | 0.4062561982 | 785885793.6708488 solMass | [b'sersic ' b'expdisk '] | 0.2888920232 |
| b'ESO237-052' | 17.987 | 14.231 | 0.009674 | 0.030489 | 32.68 | 0.23 | 36.46 | -14.8220 | -18.5780 | 108593375.5231574 solMass | 3453053705.2637773 solMass | 0.03144850465 | 0.03048965073 | SB(s)dm pec? | 36222031340.549576 solMass | 0.0029979924 | 36330624716.07273 solMass | [b'sersic ' b'expdisk ' b'ferrer2 '] | 0.00298903133 |
| b'ESO245-005' | 15.124 | 12.596 | 0.001304 | 0.088800 | 28.16 | 0.23 | 4.193 | -12.9886 | -15.5166 | 20064102.099853545 solMass | 205882640.3038665 solMass | 0.09745407418 | 0.08880013886 | IB(s)m | 205882640.3038665 solMass | 0.0974540741 | 225946742.40372005 solMass | [b'sersic ' b'expdisk '] | 0.08880013886 |
| b'ESO342-050' | 15.414 | 11.945 | 0.008866 | 0.039351 | 32.31 | 0.26 | 31.464 | -17.0750 | -20.5440 | 864963678.8148206 solMass | 21115329901.46474 solMass | 0.04096377764 | 0.03935178007 | SA(rs)c pec? | 21115329901.46474 solMass | 0.0409637776 | 21980293580.27956 solMass | [b'sersic ' b'expdisk '] | 0.03935178007 |
| b'ESO357-025' | 16.055 | 15.277 | 0.006081 | 0.328149 | 31.2 | 0.53 | 17.275 | -15.1320 | -15.9100 | 144479462.21421134 solMass | 295805412.6300599 solMass | 0.4884273784 | 0.3281499558 | SAB0^0? | 295805412.6300599 solMass | 0.4884273784 | 440284874.84427124 solMass | [b'sersic ' b'expdisk '] | 0.3281499558 |
| b'ESO358-015' | 17.194 | 15.201 | 0.004631 | 0.137570 | 31.04 | 0.01 | 16.1 | -13.8401 | -15.8331 | 43956363.52492911 solMass | 275563540.7374828 solMass | 0.1595144387 | 0.1375700322 | SBm? pec | 275563540.7374828 solMass | 0.1595144387 | 319519904.2624119 solMass | [b'sersic ' b'expdisk '] | 0.1375700322 |
| b'ESO358-025' | 13.952 | 13.764 | 0.004633 | 0.456819 | 31.17 | 0.37 | 18.614 | -17.3971 | -17.5851 | 1163722479.151365 solMass | 1383723840.2626693 solMass | 0.8410077541 | 0.4568192351 | SA0^-? | 1383723840.2626693 solMass | 0.8410077541 | 2547446319.4140344 solMass | [b'sersic ' b'expdisk '] | 0.4568192351 |
| b'ESO402-026' | 12.53 | 12.614 | 0.009033 | 0.519332 | 33.56 | 0.07 | 48.15 | -20.8829 | -20.7989 | 28851114029.977882 solMass | 26703155652.14372 solMass | 1.080438372 | 0.5193320729 | (R')SB(rs)ab? | 172280946413.95453 solMass | 0.1674654953 | 201132060443.9324 solMass | [b'sersic ' b'expdisk ' b'ferrer2 '] | 0.1434436358 |
| b'ESO444-033' | 17.291 | 14.867 | 0.008106 | 0.096862 | 32.38 | 0.38 | 31.45 | -15.1971 | -17.6211 | 153395035.36935604 solMass | 1430247851.0126095 solMass | 0.1072506666 | 0.09686213773 | SBm? edge-on | 141668886990.2848 solMass | 0.0010827715 | 141822282025.65414 solMass | [b'sersic ' b'expdisk ' b'ferrer2 '] | 0.001081600389 |
| b'ESO469-008' | 19.362 | 15.442 | 0.005881 | 0.026327 | 32.97 | 0.22 | 39.26449 | -13.608 | -17.528 | 35495230.792764395 solMass | 1312713659.49685 solMass | 0.02703958364 | 0.02632769376 | SB(s)m? | 1312713659.49685 solMass | 0.0270395836 | 1348208890.2896144 solMass | [b'sersic ' b'expdisk '] | 0.02632769376 |
| b'ESO486-003' | 16.867 | 15.464 | 0.005881 | 0.215478 | 32.76 | 0.08 | 35.64511 | -15.893 | -17.296 | 291185673.97187454 solMass | 1060156558.3699238 solMass | 0.2746628992 | 0.2154788528 | SAB(s)m | 1060156558.3699238 solMass | 0.2746628992 | 1351342232.3417983 solMass | [b'sersic ' b'expdisk '] | 0.2154788528 |
| b'ESO503-022' | 15.372 | 14.532 | 0.006314 | 0.315686 | 31.62 | 0.37 | 23.22 | -16.4573 | -17.2973 | 489659782.28467536 solMass | 1061437520.0236096 solMass | 0.4613175746 | 0.3156860511 | IB(s)m? pec | 1061437520.0236096 solMass | 0.4613175746 | 1551097302.308285 solMass | [b'sersic ' b'expdisk '] | 0.3156860511 |
| b'ESO508-034' | 16.734 | 14.562 | 0.006368 | 0.119151 | 32.12 | 0.25 | 30.6 | -15.6946 | -17.8666 | 242556466.49500498 solMass | 1793134462.085983 solMass | 0.1352695359 | 0.1191519121 | SAB(s)m? | 1793134462.085983 solMass | 0.1352695359 | 2035690928.580988 solMass | [b'sersic ' b'expdisk '] | 0.1191519121 |
| b'ESO541-004' | 16.408 | 12.207 | 0.006668 | 0.020446 | 32.38 | 0.35 | 32.527 | -16.1532 | -20.3542 | 370047967.9505046 solMass | 17727929816.13892 solMass | 0.02087372704 | 0.02044692354 | SAB(rs)bc | 17727929816.13892 solMass | 0.0208737270 | 18097977784.089424 solMass | [b'sersic ' b'expdisk '] | 0.02044692354 |
| b'ESO544-030' | 14.176 | 13.38 | 0.005365 | 0.324505 | 30.79 | 0.5 | 16.117 | -16.8604 | -17.6564 | 709803957.0759201 solMass | 1477537173.5441813 solMass | 0.4803966829 | 0.3245053765 | SB(s)dm pec? | 1477537173.5441813 solMass | 0.4803966829 | 2187341130.6201015 solMass | [b'sersic ' b'expdisk '] | 0.3245053765 |
| b'ESO549-018' | 17.715 | 12.306 | 0.00529 | 0.006814 | 32.28 | 0.47 | 31.044 | -14.7448 | -20.1538 | 101140559.9856172 solMass | 14740945952.642935 solMass | 0.006861198753 | 0.006814443502 | SAB(rs)c | 14740945952.642935 solMass | 0.0068611987 | 14842086512.628551 solMass | [b'sersic ' b'expdisk '] | 0.006814443502 |
| b'ESO549-035' | 17.697 | 15.588 | 0.006078 | 0.125377 | 32.69 | 0.37 | 34.51437 | -14.993 | -17.102 | 127107156.8102466 solMass | 886686312.2712774 solMass | 0.1433507601 | 0.1253777625 | Sc | 886686312.2712774 solMass | 0.1433507601 | 1013793469.081524 solMass | [b'sersic ' b'expdisk '] | 0.1253777625 |
| b'ESO550-024' | 15.834 | 12.521 | 0.002995 | 0.045157 | 30.47 | 0.5 | 13.612 | -14.8356 | -18.1486 | 109954722.08395605 solMass | 2324951433.234398 solMass | 0.04729334149 | 0.04515768373 | SB(s)d? | 2324951433.234398 solMass | 0.0472933414 | 2434906155.318354 solMass | [b'sersic ' b'expdisk '] | 0.04515768373 |
| b'ESO576-003' | 15.828 | 13.445 | 0.009873 | 0.100216 | 32.46 | 0.4 | 34.5 | -16.8610 | -19.2440 | 710245015.4278263 solMass | 6376879265.295304 solMass | 0.11137815 | 0.1002162495 | SB(s)d pec? | 6376879265.295304 solMass | 0.11137815 | 7087124280.72313 solMass | [b'sersic ' b'expdisk '] | 0.1002162495 |
| b'ESO582-004' | 16.154 | 14.366 | 0.007382 | 0.161540 | 32.44 | 0.33 | 30.817 | -16.2899 | -18.0779 | 419711357.0864059 solMass | 2178465673.5060196 solMass | 0.192663746 | 0.161540708 | Sc? | 2178465673.5060196 solMass | 0.192663746 | 2598177030.5924253 solMass | [b'sersic ' b'expdisk '] | 0.161540708 |
| b'ESO601-025' | 18.086 | 14.317 | 0.005797 | 0.030137 | 31.92 | 0.4 | 25.75 | -13.9678 | -17.7368 | 49445237.934229575 solMass | 1591198904.4071865 solMass | 0.0310742031 | 0.03013769815 | SAB(s)m? | 1591198904.4071865 solMass | 0.0310742031 | 1640644142.3414161 solMass | [b'sersic ' b'expdisk '] | 0.03013769815 |
| b'ESO603-031' | 15.572 | 14.554 | 0.007575 | 0.281382 | 32.66 | 0.13 | 34.04081 | -17.088 | -18.106 | 875326354.1916815 solMass | 2235475962.315206 solMass | 0.3915615148 | 0.2813828283 | Sa | 2235475962.315206 solMass | 0.3915615148 | 3110802316.5068874 solMass | [b'sersic ' b'expdisk '] | 0.2813828283 |
| b'IC0167 ' | 14.55 | 13.698 | 0.009813 | 0.313303 | 31.57 | 0.94 | 27.683 | -17.6610 | -18.5130 | 1483871555.196896 solMass | 3252342765.543303 solMass | 0.4562469771 | 0.3133032956 | SAB(s)c | 10771863129.820059 solMass | 0.1377544012 | 12255734685.016954 solMass | [b'sersic ' b'expdisk ' b'ferrer2 '] | 0.1210756918 |
| b'IC1029 ' | 12.588 | 12.013 | 0.007942 | 0.370611 | 33.26 | 0.6 | 47.722 | -20.8055 | -21.3805 | 26866263945.74907 solMass | 45625462211.230225 solMass | 0.5888436554 | 0.3706114528 | SAb? edge-on | 45625462211.230225 solMass | 0.5888436554 | 72491726156.9793 solMass | [b'sersic ' b'expdisk '] | 0.3706114528 |
| b'IC1055 ' | 15.429 | 11.874 | 0.009713 | 0.036464 | 33.01 | 0.14 | 39.183 | -17.5364 | -21.0914 | 1323016841.6800625 solMass | 34959512885.39811 solMass | 0.03784425847 | 0.03646429429 | (R')SA(r)b? | 34959512885.39811 solMass | 0.0378442584 | 36282529727.07817 solMass | [b'sersic ' b'expdisk '] | 0.03646429429 |
| b'IC1438 ' | 12.955 | 12.282 | 0.008659 | 0.349814 | 32.67 | 0.04 | 33.8 | -19.6895 | -20.3625 | 9611770771.64672 solMass | 17865015810.62466 solMass | 0.5380219572 | 0.3498142238 | (R')SAB(rs)a? | 170292009734.7183 solMass | 0.0564428759 | 179903780506.36502 solMass | [b'sersic ' b'expdisk ' b'ferrer2 '] | 0.05342728621 |
| b'IC1447 ' | 16.776 | 12.615 | 0.00985 | 0.021197 | 33.55 | 0.07 | 48.3 | -16.6437 | -20.8047 | 581385593.3835502 solMass | 26845053007.070625 solMass | 0.02165708495 | 0.0211979981 | SA(r)b? | 26845053007.070625 solMass | 0.0216570849 | 27426438600.454174 solMass | [b'sersic ' b'expdisk '] | 0.0211979981 |
| b'IC1555 ' | 15.588 | 14.387 | 0.0051 | 0.248587 | 31.55 | 0.3 | 23.08 | -16.2281 | -17.4291 | 396498559.0083464 solMass | 1198509865.6001675 solMass | 0.3308262789 | 0.2485871252 | SA(s)d | 1198509865.6001675 solMass | 0.3308262789 | 1595008424.6085138 solMass | [b'sersic ' b'expdisk '] | 0.2485871252 |
| b'IC1826 ' | 13.519 | 12.954 | 0.004703 | 0.372762 | 32.76 | 1.05 | 36.16 | -19.2721 | -19.8371 | 6543752243.854895 solMass | 11011002162.806276 solMass | 0.5942921586 | 0.372762392 | SAB0^+(rs)? | 11011002162.806276 solMass | 0.5942921586 | 17554754406.66117 solMass | [b'sersic ' b'expdisk '] | 0.372762392 |
| b'IC1953 ' | 16.14 | 11.593 | 0.006201 | 0.014950 | 31.91 | 0.34 | 24.64 | -15.8182 | -20.3652 | 271801225.9811091 solMass | 17908178366.067 solMass | 0.01517749156 | 0.01495057927 | SB(rs)d | 35787938119.70666 solMass | 0.0075947718 | 36059739345.68777 solMass | [b'sersic ' b'expdisk ' b'ferrer2 '] | 0.007537526086 |
| b'IC2051 ' | 13.493 | 10.693 | 0.005847 | 0.070509 | 31.97 | 0.28 | 23.89 | -18.3980 | -21.1980 | 2925514829.062357 solMass | 38565796371.581406 solMass | 0.0758577575 | 0.07050909563 | SB(r)bc? | 53671045742.34717 solMass | 0.0545082509 | 56596560571.40952 solMass | [b'sersic ' b'expdisk ' b'ferrer2 '] | 0.05169068225 |
| b'IC2056 ' | 12.322 | 12.244 | 0.003779 | 0.482047 | 31.5 | 0.61 | 20.5 | -19.2367 | -19.3147 | 6333995149.342212 solMass | 6805777182.871894 solMass | 0.9306791832 | 0.4820475568 | (R)SAB(r)bc? | 7030722898.783629 solMass | 0.9009024023 | 13364718048.125841 solMass | [b'sersic ' b'expdisk ' b'psf '] | 0.4739340648 |
| b'IC2627 ' | 14.422 | 11.453 | 0.006971 | 0.060965 | 28.22 | 2.18 | 18.48 | -16.9115 | -19.8805 | 744001717.5080029 solMass | 11459718196.104788 solMass | 0.06492321231 | 0.06096515839 | SA(s)bc? | 11459718196.104788 solMass | 0.0649232123 | 12203719913.612791 solMass | [b'sersic ' b'expdisk '] | 0.06096515839 |
| b'IC3102 ' | 13.561 | 11.795 | 0.00742 | 0.164304 | 32.2 | 0.47 | 28.85 | -18.7397 | -20.5057 | 4007390269.473837 solMass | 20382696569.189682 solMass | 0.1966074634 | 0.1643040591 | SA0^+(s)? | 20382696569.189682 solMass | 0.1966074634 | 24390086838.66352 solMass | [b'sersic ' b'expdisk '] | 0.1643040591 |
| b'IC3229 ' | 15.481 | 15.483 | 0.005162 | 0.500460 | 31.76 | 0.45 | 22.49054 | -16.279 | -16.277 | 415499020.52221686 solMass | 414734347.54763234 solMass | 1.001843766 | 0.5004605169 | Sbc | 414734347.54763234 solMass | 1.001843766 | 830233368.0698493 solMass | [b'sersic ' b'expdisk '] | 0.5004605169 |
| b'IC3259 ' | 16.357 | 13.308 | 0.00475 | 0.056880 | 31.45 | 0.32 | 21.25 | -15.2797 | -18.3287 | 165534252.91317496 solMass | 2744655702.840655 solMass | 0.06031148196 | 0.05688090999 | SAB(s)dm? | 2744655702.840655 solMass | 0.0603114819 | 2910189955.75383 solMass | [b'sersic ' b'expdisk '] | 0.05688090999 |
| b'IC3268 ' | 14.04 | 13.965 | 0.002428 | 0.482737 | 32.25 | 0.79 | 21.8 | -17.6522 | -17.7272 | 1471915882.597449 solMass | 1577186283.8890145 solMass | 0.9332543008 | 0.4827374756 | pec | 1577186283.8890145 solMass | 0.9332543008 | 3049102166.4864635 solMass | [b'sersic ' b'expdisk '] | 0.4827374756 |
| b'IC3392 ' | 14.982 | 11.802 | 0.005566 | 0.050743 | 30.56 | 0.34 | 16.117 | -16.0544 | -19.2344 | 337861274.62579906 solMass | 6320310523.637077 solMass | 0.05345643594 | 0.05074385054 | SAb? | 6320310523.637077 solMass | 0.0534564359 | 6658171798.2628765 solMass | [b'sersic ' b'expdisk '] | 0.05074385054 |
| b'IC4214 ' | 11.917 | 11.462 | 0.007705 | 0.396739 | 32.33 | 0.63 | 27.3 | -20.2638 | -20.7188 | 16311552505.82009 solMass | 24802490868.826656 solMass | 0.6576578374 | 0.3967391958 | (R')SB(r)ab | 195624646513.58456 solMass | 0.0833818887 | 211936199019.40466 solMass | [b'sersic ' b'expdisk ' b'ferrer2 '] | 0.0769644477 |
| b'IC4216 ' | 17.276 | 13.254 | 0.009487 | 0.024023 | 32.75 | 0.01 | 35.48133 | -15.474 | -19.496 | 197956608.364083 solMass | 8042109911.995402 solMass | 0.02461500906 | 0.0240236663 | SAB(rs)cd | 38982445286.53727 solMass | 0.0050780962 | 39180401894.90135 solMass | [b'sersic ' b'expdisk ' b'ferrer2 '] | 0.005052439454 |
| b'IC4237 ' | 16.37 | 11.822 | 0.008876 | 0.014937 | 33.01 | 0.41 | 40.073 | -16.6442 | -21.1922 | 581666051.3230268 solMass | 38359568845.53162 solMass | 0.01516351901 | 0.0149370212 | SB(r)b? | 69210383001.6747 solMass | 0.0084043177 | 69792049052.99773 solMass | [b'sersic ' b'expdisk ' b'ferrer2 '] | 0.008334273878 |
| b'IC4316 ' | 15.897 | 13.788 | 0.001941 | 0.125377 | 28.16 | 0.11 | 4.43 | -12.3350 | -14.4440 | 10989487.940725569 solMass | 76661525.44390883 solMass | 0.1433507601 | 0.1253777625 | IBm? pec | 76661525.44390883 solMass | 0.1433507601 | 87651013.38463439 solMass | [b'sersic ' b'expdisk '] | 0.1253777625 |
| b'IC5039 ' | 17.809 | 12.407 | 0.009053 | 0.006858 | 32.06 | 0.6 | 32.473 | -14.7486 | -20.1506 | 101488031.62892398 solMass | 14696530808.383572 solMass | 0.006905577442 | 0.00685821749 | Sbc? edge-on | 135701734915.38887 solMass | 0.0007478757 | 135803222947.01779 solMass | [b'sersic ' b'expdisk ' b'ferrer2 '] | 0.000747316812 |
| b'IC5078 ' | 15.077 | 12.137 | 0.004917 | 0.062512 | 31.48 | 0.34 | 21.488 | -16.5839 | -19.5239 | 550252462.7443601 solMass | 8252052740.755485 solMass | 0.06668067692 | 0.06251231354 | SA(s)c? | 8252052740.755485 solMass | 0.0666806769 | 8802305203.499846 solMass | [b'sersic ' b'expdisk '] | 0.06251231354 |
| b'IC5240 ' | 12.103 | 11.68 | 0.005886 | 0.403814 | 32 | 0.4 | 25.36 | -19.9177 | -20.3407 | 11859557982.828451 solMass | 17509288666.074276 solMass | 0.677329514 | 0.4038142228 | SB(r)a | 97335039423.38092 solMass | 0.1218426381 | 109194597406.20937 solMass | [b'sersic ' b'expdisk ' b'ferrer2 '] | 0.1086093842 |
| b'IC5264 ' | 14.543 | 11.88 | 0.006471 | 0.079240 | 32.74 | 1.9 | 47.75 | -18.8518 | -21.5148 | 4443413766.080605 solMass | 51631739413.94993 solMass | 0.08605973412 | 0.0792403322 | Sab pec edge-on | 51631739413.94993 solMass | 0.0860597341 | 56075153180.03053 solMass | [b'sersic ' b'expdisk '] | 0.0792403322 |
| b'IC5267 ' | 11.33 | 10.75 | 0.005711 | 0.369537 | 31.53 | 0.74 | 26.08 | -20.7515 | -21.3315 | 25561431899.097145 solMass | 43609908800.75242 solMass | 0.5861381645 | 0.3695378988 | SA0/a(s) | 43609908800.75242 solMass | 0.5861381645 | 69171340699.84956 solMass | [b'sersic ' b'expdisk ' b'expdisk '] | 0.3695378988 |
| b'IC5269 ' | 13.626 | 12.382 | 0.006561 | 0.241263 | 31.55 | 0.81 | 26.15 | -18.4613 | -19.7053 | 3101083003.7562175 solMass | 9752442327.845436 solMass | 0.3179801428 | 0.2412632273 | SAB0(rs)? | 9752442327.845436 solMass | 0.3179801428 | 12853525331.601654 solMass | [b'sersic ' b'expdisk '] | 0.2412632273 |
| b'IC5269B ' | 15.112 | 12.825 | 0.005561 | 0.108475 | 31.76 | 0.47 | 25.106 | -16.8868 | -19.1738 | 727319201.5895122 solMass | 5977575267.635568 solMass | 0.1216746204 | 0.1084758612 | | 5977575267.635568 solMass | 0.1216746204 | 6704894469.22508 solMass | [b'sersic ' b'expdisk '] | 0.1084758612 |
| b'IC5271 ' | 14.292 | 10.838 | 0.005729 | 0.039877 | 31.79 | 0.15 | 22.63 | -17.4814 | -20.9354 | 1257590106.9191117 solMass | 30278831576.014866 solMass | 0.04153364055 | 0.03987738747 | Sb? | 30278831576.014866 solMass | 0.0415336405 | 31536421682.93398 solMass | [b'sersic ' b'expdisk '] | 0.03987738747 |
| b'IC5321 ' | 15.402 | 13.702 | 0.009583 | 0.172821 | 32.99 | 0.19 | 41.867 | -17.7073 | -19.4073 | 1548508840.7994666 solMass | 7411629294.342699 solMass | 0.2089296131 | 0.172821983 | SBa pec? | 7411629294.342699 solMass | 0.2089296131 | 8960138135.142166 solMass | [b'sersic ' b'expdisk '] | 0.172821983 |
| b'IC5332 ' | 14.026 | 10.577 | 0.002338 | 0.040054 | 28.23 | 0.58 | 8.4 | -15.5953 | -19.0443 | 221375001.1528421 solMass | 5305527579.607669 solMass | 0.04172535112 | 0.04005408055 | SA(s)d | 5305527579.607669 solMass | 0.0417253511 | 5526902580.760511 solMass | [b'sersic ' b'expdisk '] | 0.04005408055 |
| b'NGC0055 ' | 9.705 | 8.204 | 0.000437 | 0.200612 | 26.3 | 0.62 | 1.942 | -16.7362 | -18.2372 | 633094375.9008814 solMass | 2522716544.9499683 solMass | 0.2509573964 | 0.2006122647 | SB(s)m? edge-on | 2522716544.9499683 solMass | 0.2509573964 | 3155810920.8508496 solMass | [b'sersic ' b'expdisk '] | 0.2006122647 |

Figure 11: Data of the sample galaxies

Link to the whole sheet

# Bibliography


[1] https://astronomy.swin.edu.au/cosmos/H/Hubble+Classification

[2] https://archive.org/details/ThePhysicalUniverseAnIntroductionToAstronomyFrankShu

[3] https://en.wikipedia.org/wiki/Hertzsprung%E2%80%93Russell_diagram

[4] https://astrobites.org/2018/11/27/cluster-creation-in-a-cosmological-context/

[5] https://en.wikipedia.org/wiki/Galactic_bulge

[6] https://apod.nasa.gov/apod/ap080329.html

[7] https://archive.org/details/ThePhysicalUniverseAnIntroductionToAstronomyFrankShu

[8] https://press.princeton.edu/books/paperback/9780691130279/galactic-dynamics

[9] https://press.princeton.edu/books/paperback/9780691130279/galactic-dynamics

[10] https://vizier.cds.unistra.fr/viz-bin/VizieR-3?-source=J/ApJS/219/4&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa

[11] https://ui.adsabs.harvard.edu/abs/2015ApJS..219....4S/abstract

[12] https://iopscience.iop.org/article/10.1086/519218

[13] https://archive.org/details/introductiontomo0000carr

[14] https://archive.org/details/introductiontomo0000carr

[15] https://books.google.co.in/books/about/Allen_s_Astrophysical_Quantities.html?id=w8PK2XFLLH8C&redir_esc=y

[16] http://mips.as.arizona.edu/~cnaw/sun.html

[17] https://iopscience.iop.org/article/10.1088/0004-637X/781/1/12/pdf

[18] https://ui.adsabs.harvard.edu/abs/2010PASP..122.1397S/abstract

[19] https://arxiv.org/abs/0704.3611