GALAXIES

Project Report

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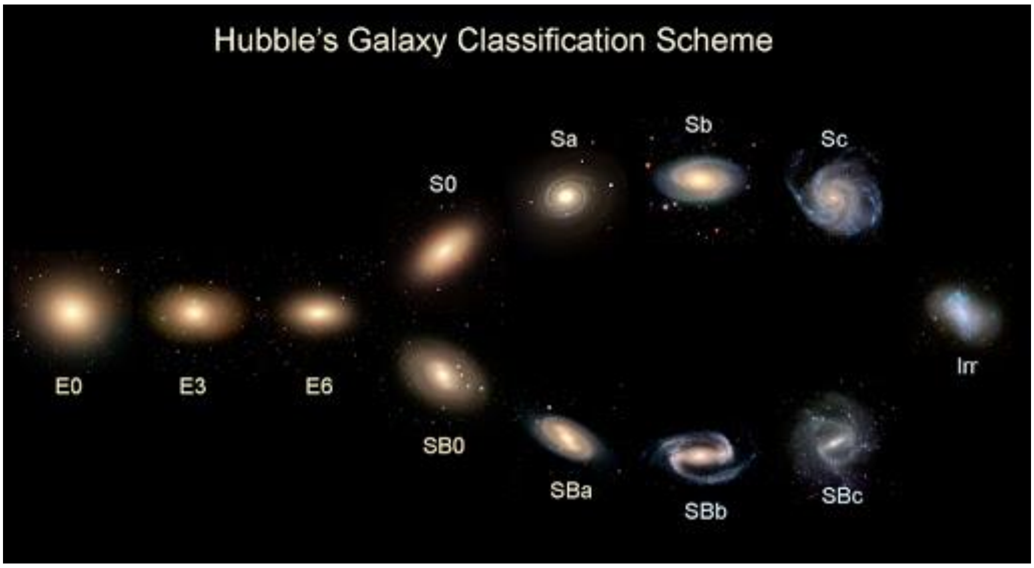
1. Types of Galaxies

Galaxies are vast cosmic islands of stars, gas, dust, and dark matter held together by gravity. There is an immensely varied array of galaxies, ranging from faint, diffuse dwarf objects to brilliant spiral-shaped giants. Almost all large galaxies are thought to have a supermassive black hole at its centre that provide such a large gravity and keeps all mass of the galaxy in place.

Galaxies differ from one another in shape, with variations resulting from the way in which the systems were formed and subsequently evolved. Galaxies are extremely varied not only in structure but also in the amount of activity observed. Some are the sites of vigorous star formation, with its attendant glowing gas and clouds of dust and molecular complexes. Others, by contrast, are quiescent, having long ago ceased to form new stars. They are divided into: elliptical, spiral, irregular.

- *Elliptical Galaxy:* Elliptical galaxies have a rotational symmetry. They have two principle axes which define their shape. Elliptical galaxies lack interstellar dust which proves its incapability to form new stars and planets. They emit light in the red region which signifies the presence of old and dying stars. Hence, elliptical galaxies are older galaxies. Elliptical galaxies are thought to have formed of galaxy mergers or interstellar cloud collapse. Due to shape of the galaxy, the stars cannot rotate systematically as in case of spiral galaxies which makes its study difficult.
- *Spiral Galaxy:* Spiral galaxies have arm like outgrowths that spread out of a common centre. These galaxies are rich in interstellar dust (about 15% of total galactic mass) that makes up new stars. This is why new stars are frequently formed in these galaxies, making them active. These galaxies are formed by the collision of two galaxies. Spiral galaxies are divided into two types depending on their central. Type 1 contains a bulge in the centre and spiral arms extend from the centre. Type 2 contains a bar like structure with spiral arms originating from the ends of bar at centre. These are again classified based on how tightly they are wound around the centre.
- *Irregular Galaxy:* Irregular galaxies are galaxies that does not fit into either of the two above. They have no defined shape nor structure and may have formed from collisions, close encounters with other galaxies or violent internal activity. They contain both old and young stars, significant amounts of gas and usually exhibit bright knots of star formation. Large magellanic clouds also come under this category.



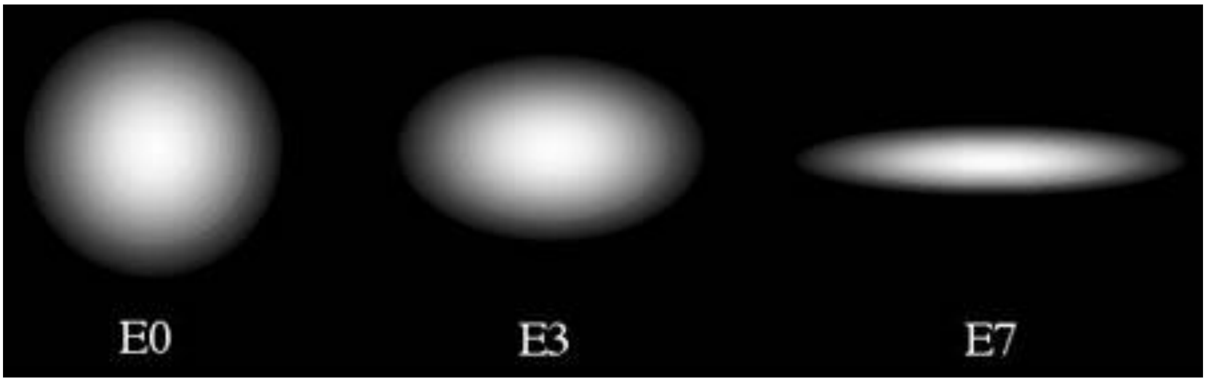
2. Classification of Elliptical Galaxies

Elliptical galaxies vary greatly in both size and mass with diameters ranging from 3000 lightyears to more than 700,000 lightyears, and masses from 10^5 to nearly 10^{13} solar masses. Elliptical galaxies have a broader range in size than other types of galaxies. The smallest are dwarf elliptical galaxies, which can be less than 10 percent of the size of the Milky Way. But ellipticals can also stretch to more than a million light-years across, and contain more than ten trillion stars. So, we need to further classify them. We can only classify these galaxies on the basis of shape and ellipticity of the ellipse. It is not possible to classify them on the basis of their luminosity as the images from the telescope are taken in the B band filter. So, colour is not a suitable method for classification.

Elliptical galaxies' shape ranges from almost circular to cigar-shaped elongated. An elliptical galaxy has a major and a minor axis. These axes define ellipticity of a galaxy. Galaxies are categorised as E_n (n starting from 0). E_7 is the most elongated form of elliptical galaxy found till date. A galaxy's appearance is related to how it lies on the sky when viewed from Earth. A galaxy having the E7 shape but seen head on would appear as an E0, for instance, because observers would not see its stretched shape, which lies "behind" it. n for a galaxy is determined by

n=10*(1-a/b)

where a is length of minor axis and b in length of major axis. These axes are determined by the isophote of the galaxies. Isophotes are lines of same surface brightness values. For an elliptical galaxy, they appear elliptical in shape.



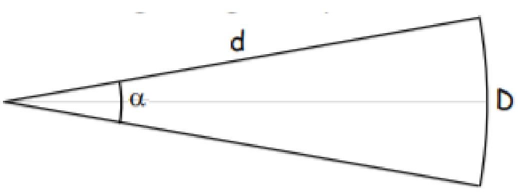
3. Radial Surface Brightness Profiles of Elliptical Galaxies

Surface brightness quantifies the apparent brightness or flux density per unit angular area of a spatially extended object such as a galaxy or nebula, or of the night sky background. An object's surface brightness depends on its surface luminosity density, i.e., its luminosity emitted per unit surface area.

Luminous flux density is defined by

$$B=\frac{L}{4\pi d^2}\ .$$

Consider a square area with a side of length D of a galaxy at distance d. This length will subtend an angle, $\alpha=\frac{D}{d}$



Surface brightness can then be given by

$$I(R)=\frac{B}{\alpha^2}\,,$$

where α is the angle subtended by the galaxy on the observer’s eye.

On substituting α, we get

$$I(R)=\frac{L}{4\pi D^2}$$

Surface brightness is independent of distance (d) since flux decreases as 1/d2, but the area subtended by 1 square arcsec increases as d^2.

For an elliptical galaxy, we have

$$I(R)=I(R_e)\exp(-7.67((R/R_e)^{1/4}-1)),$$

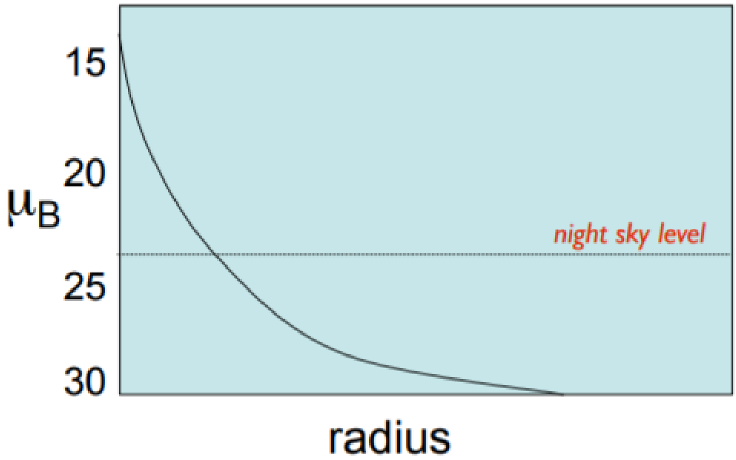
where R_e is the effective radius of the galaxy sphere. This equation defines the de Vaucouleurs' law or the $R^{1/4}$ law.

De Vaucouleurs' Law describes how the surface brightness of an elliptical galaxy varies as a function of apparent distance from the centre of the galaxy.

In the above equation, we have used a term R_e.This is called effective radius. Effective radius or half-light radius of a galaxy is the radius at which half of the total light of the system is emitted. When a circle with the galaxy centre as its centre and R_e radius is drawn, the circle encloses half of the light emitted by the whole galaxy.

Surface Brightness Profile:

Our classification of galaxies into different morphological types is dependent on our visual impression of their images, so understanding the distribution of their light is crucial for understanding their physics The determination of brightness in an image is called "photometry" (measuring light), but this process also covers determination of shapes and brightness profiles. A Surface brightness profile is produced by azimuthally averaging along isophotes (elliptical annuli). For plotting these kinds of isophotes, we need to remove the external factors that disturb the image. These factors can be the cosmic rays, the surrounding noise. To remove these disturbances, we work with images by creating mean bias and flat-field images.



For measuring the surface brightness of a galaxy, we need to take the average of brightness values for both the sides of the centre to get precise results. Plot the surface brightness values on the graph. This will prove the de Vaucouleurs' law.

4. Result

We have identified the type of elliptical galaxy by finding the ellipticity of the galaxy. The type of galaxy is E_1. This shows that the galaxy is not too much elongated.

After categorisation, we have successfully plotted the graph of $\log(I_{final})$ as a function of $R^{1/4}$.

We conclude that the isophote near the galaxy is elliptical and so is the outermost isophote. But the difference lies in the alignment of principle axes with respect to one another. This misalignment is due to the presence of a bulge at the centre of the galaxy. The bulge emits the light at a different angle due to its outward extension in shape. This causes us to look at the bulge from a different angle.