UNIT 2:

DISTANCES (1st part). GALAXIES

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ACTIVITY

CLASSIFICATION OF GALAXIES

OBJECTIVES

The objective of the following activity is for students to be familiar with astronomical images, getting to know the handling tools given by the image analysis software, recognizing and identifying the different galaxy shapes and classify them according to its morphology. To do all this, the students will use a selection of images obtained with the Liverpool Telescope. They should also calculate, approximately, the galaxy size and be familiar with the different distance units.

INSTRUMENTS AND MATERIALS

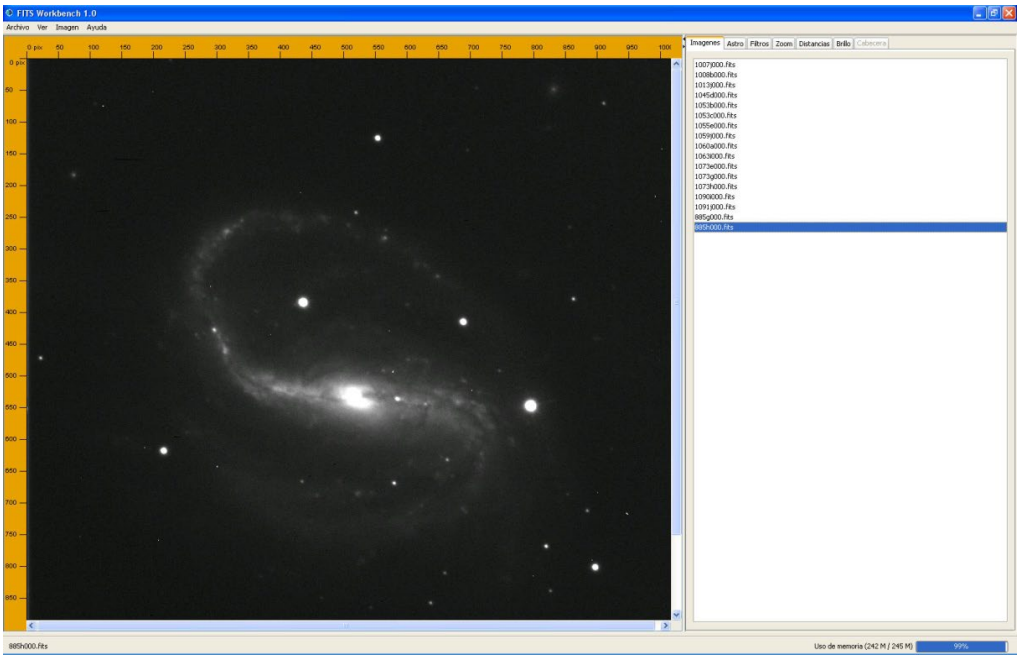
To carry out this activity we are going to use a selection of images of galaxies obtained at different dates with the Liverpool Telescope at Roque de Los Muchachos Observatory, which are contained in the folder /Galaxies/ in our web site **www.iac.es/peter**. To process the pictures, we will use the software *peter_soft* that can be downloaded and installed from the same website. The software tools that we are mainly going to use, will be the ones that measure distances and different types of filters to improve the visualization of the different parts of the galaxies.

METHODOLOGY

We will proceed to download the group of images and analyze them one by one, identifying the galaxies different parts, classifying them by its morphology and measuring its approximate diameter. We will make a table where we will arrange the galaxies by its appearance.

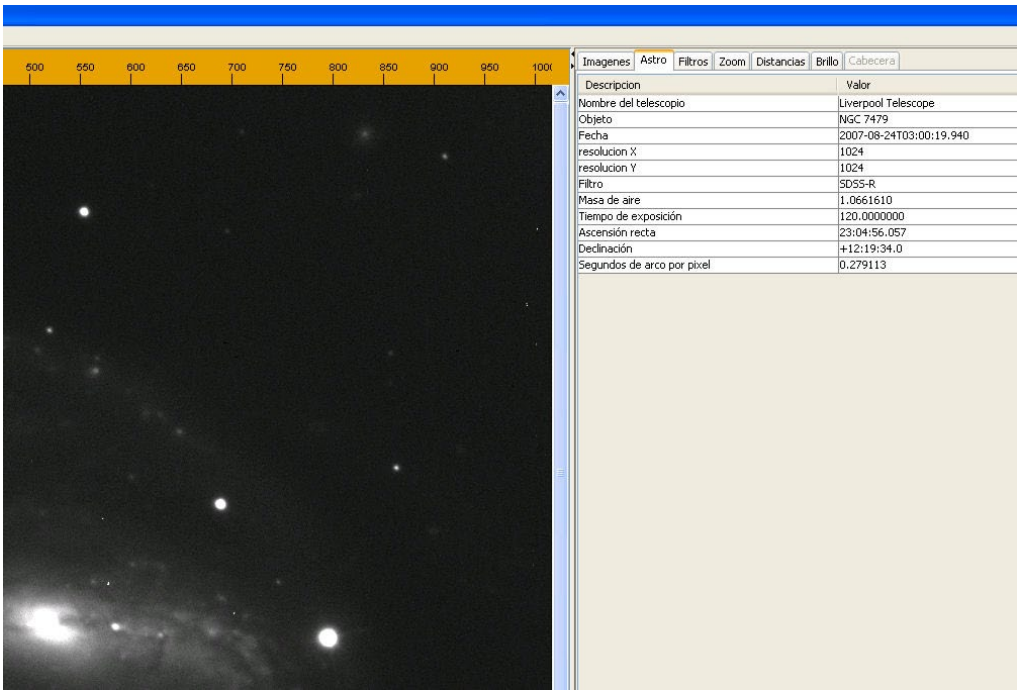
PROCEDURE

First, download and unzip the file "*U2_imagenes_galaxias.zip"* in the hard drive, where all the images of the galaxies we will classify are. Then run the image analysis program *"peter_soft"* and open up the images to analyse.

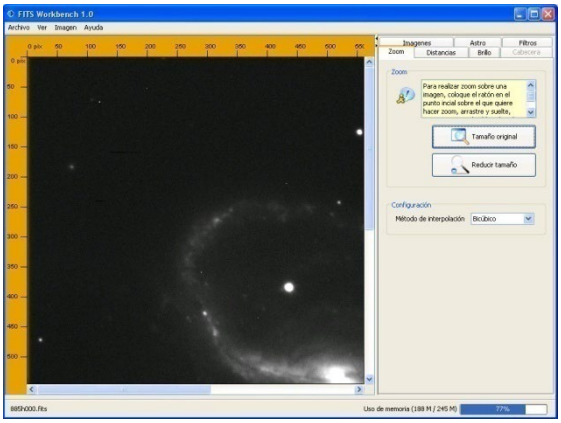


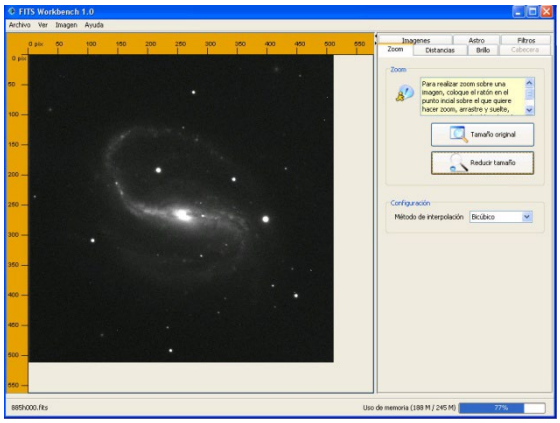
Once the images are loaded, you can obtain their information in the tab ***ASTRO***: date and time when the image was taken, filter used, exposure time in seconds, the scale used in arcseconds per pixel, etc. This information is very important because the measurements and the necessary data for the activity objective depends on it.

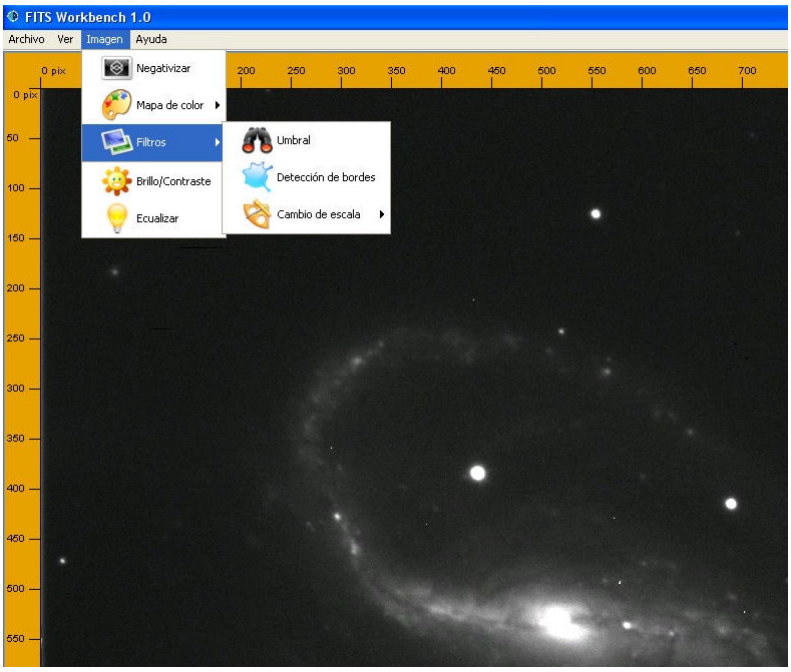
If you need to increase or decrease the size of the images for a more comfortable viewing, press the tab ***Zoom***. You can use that tool to reduce their size and observe the entire galaxy. In most cases, galaxies occupy almost the entire image.



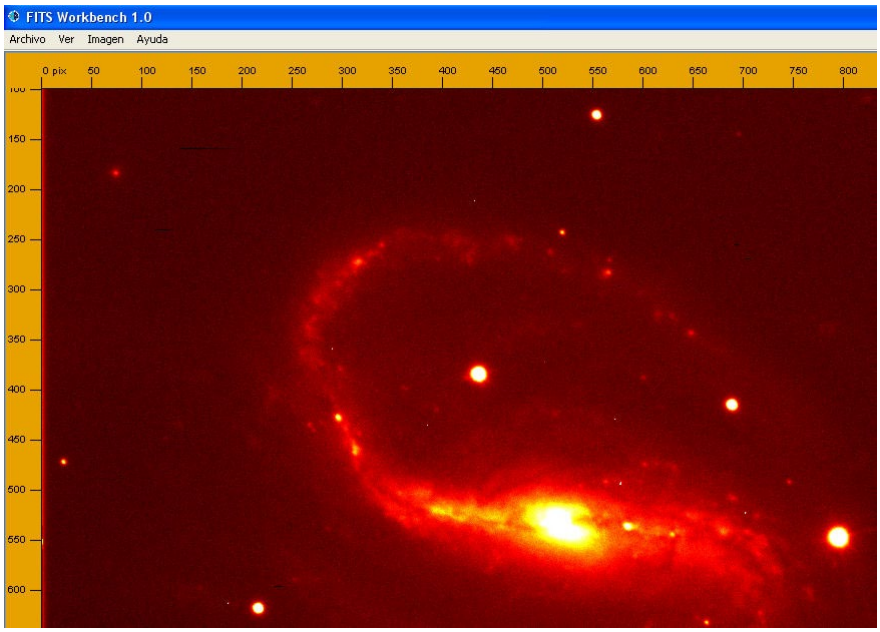
Astronomers use different filters that allow them to properly visualize the bulge, the spiral arms or gas areas of some parts of the galaxies. To do this, you have to use the different filters available in the tab ***Imagen*** in the top toolbar.



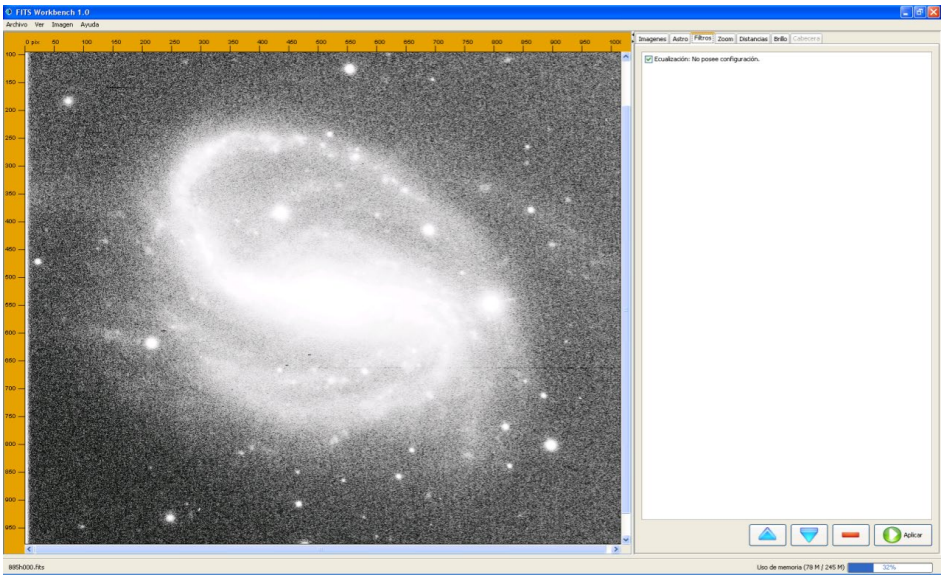




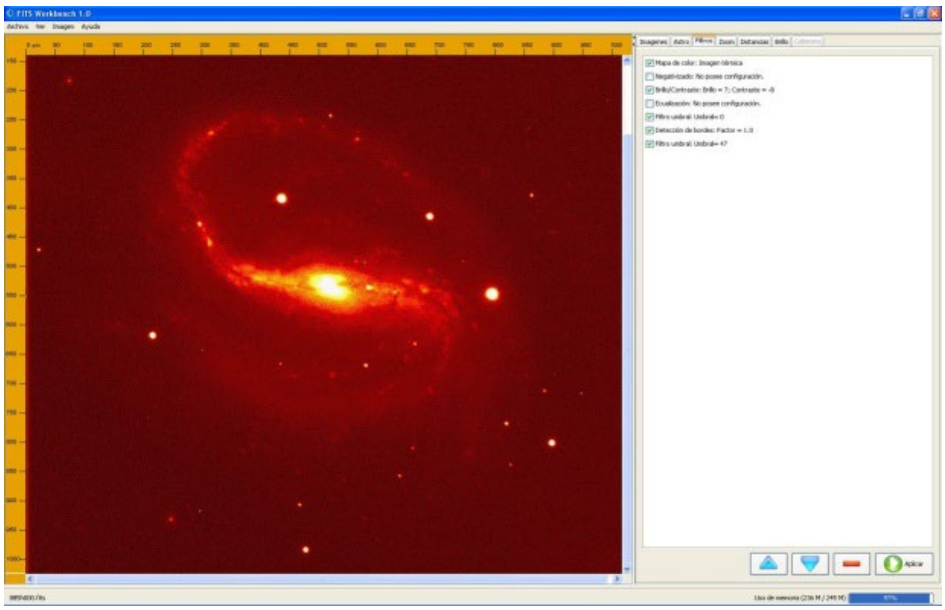
These filters modify the image by changing its brightness, contrast, detecting edges or changing colors. This way, their use can display different aspects of the image that, otherwise, could not be observed at first sight. An example can be found using the filter ***Imagen térmica***. When it´s applied to an image, the option "color map" in the tab ***Imagen*** shows the different parts with a color scale in yellow and red for easy viewing. The brightest areas are shown in white or yellow and the weakest, in dark red tone.



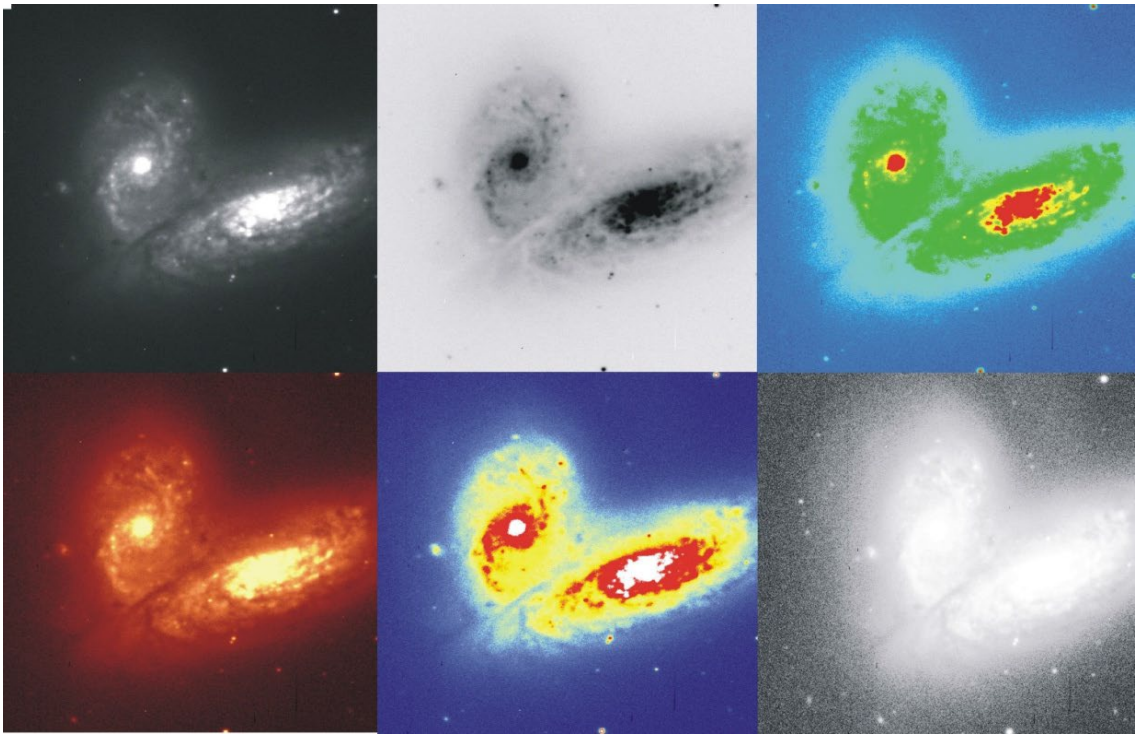
We can also intensify the image by equalizing it, i.e., adjusting the histogram that makes us see the galaxy's weakest parts. To do this, we will use the tool ***Ecualizar***. This process is done at the expense of saturating the brighter parts of it, such as the bulge.



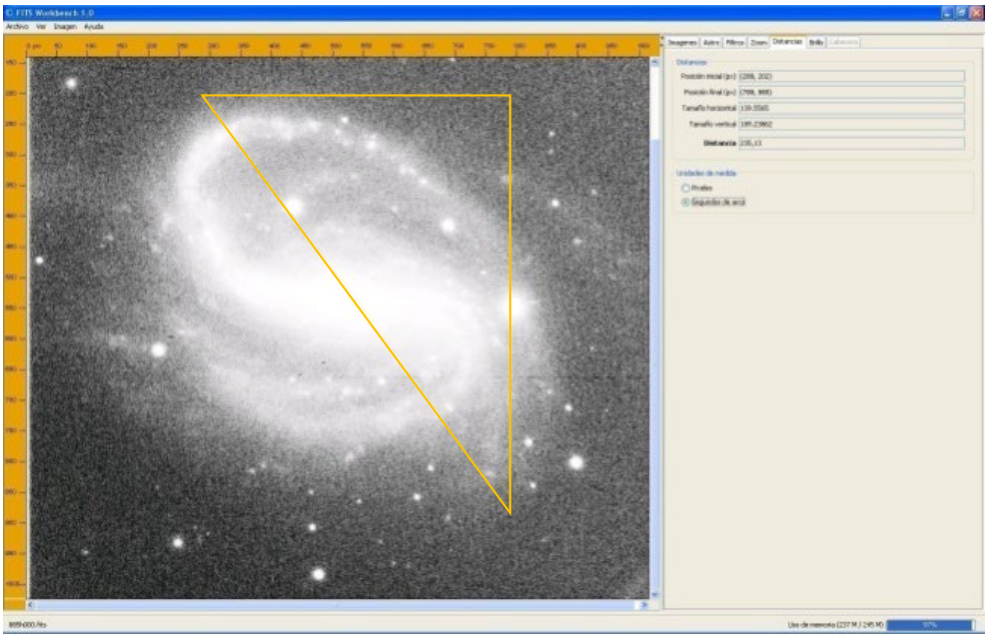
As we use a filter after another, the image changes its appearance for better or worse. In the last case, we can go back cancelling the filter that is not helpful. For that, we need to go to the tab ***Filtros***, at the toolbar (on the image right side), where we can see the image filters applied to each image, selecting those that you want to apply and cancelling the ones you do not. We will do this by checking the filter boxes of the ones we want to apply (by default all the boxes are checked) and unchecking those boxes we do not want to apply. After doing all this, we need to click on the ***Aplicar*** button on the bottom right of the screen.



An image can look very different depending on the filter we use.



To measure the sizes of the galaxies, use the tool ***DISTANCIAS*** (like in previous units) and calculate the galaxy diameter in *pixel*s, by using the appropriate filter that allows you to see how far the galaxy extends to.



In the tab ***ASTRO*** you´ll find the name of the galaxy (***Objeto***); the scale of the image is in *arcsec per pixel*, which is 0.27837"/*pixel* for all Liverpool Telescope images; and also, the pixel scale to the object, which indicates us the corresponding *light-years* to a *pixel* in that particular galaxy image (depending on how far the galaxy is). To calculate this value, we have used Equation (1) on page 4 and the distance to the galaxy that we know by other methods beforehand.

Supplementary Activity 1:

Let's see how we have calculated that scale, for example, in the image *885g000*. The distance to the galaxy NGC 7626 is 162.787 million *light-years*. Therefore, 1 *arcsec* of that galaxy is equivalent to a linear size of:

$$D\ (1'') = 162{,}787\ 10^6 \frac{1}{206.265} = 789{,}213\ light\_years$$

If we measure the angular galaxy diameter in *arcseconds*, we only have to multiply the previous result by the angular diameter measured and would have the linear galaxy diameter in *light-years*. However, if we measure the galaxy diameter in pixels, we need to know the pixel scale to the object and, for that, we shall multiply the previous result by 0.27837"/*pixel*:

$$789{,}213\ \frac{light\_year}{''} \times\ 0{,}27837 \frac{''}{pixel} =\ 219{,}693\ \frac{light\_year}{pixel}\ ,$$

value that matches the scale for this galaxy in the tab ***ASTRO***.

Let´s make a final calculation: how many kilometers correspond to a pixel in this galaxy image? It´s easy, we just have to multiply the scale in light-years per pixel by the corresponding kilometers to a light-year:

$$219{,}693\ \frac{light-year}{pixel} \times 63.240\ \frac{A.U.}{light-year} \times 150\ 10^6 \frac{km}{A.U.} = 2{,}084\ 10^{15}\ km.$$

A single image pixel is equivalent to 2x10^{15} kilometers! Do you now understand why the distances in astronomy are measured with different units than *km*?

We have now all the necessary tools to classify the galaxies according to their morphology

From each image we get: the name of the galaxy (in the tab ***ASTRO***); its classification, i.e., if it´s an elliptical, regular spiral or barred spiral galaxy; its size in pixels, which all together with the pixel scale to the object (also in the tab ***ASTRO***) will serve us to determine the galaxy diameter in light-years. With these data we can fill the following table:

Image	Object Name	Classification	Scale (*light-years-/pixel*)	Diameter (thousands *light-years*)
885g000				
885h000				
885i000				
885j000				
886a000				
920j000				
962a000				
975i000				
1013j000				
1053b000				
1053c000				
1055e000				
1059j000				
1073e000				
1073g000				
1073h000				
1090i000				

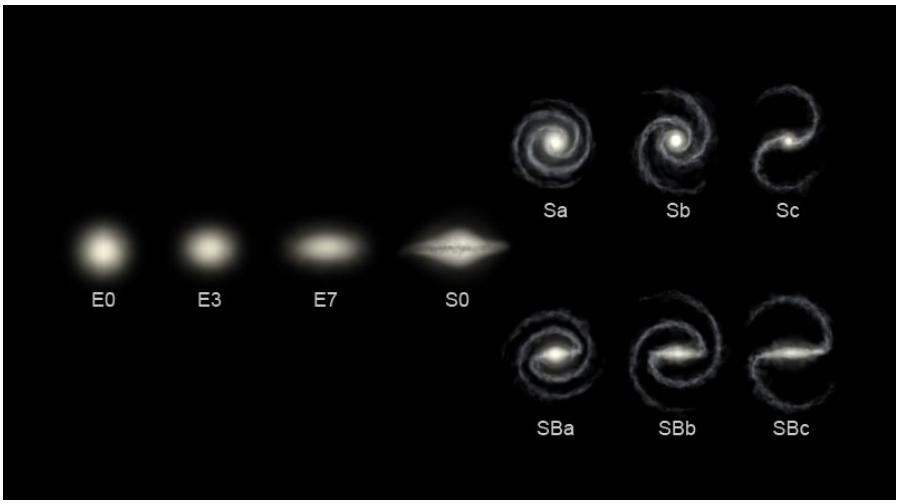
Supplementary Activity 2:

You already have the morphological classification of each galaxy, now you can go a little further and build your own Hubble Sequence. First thing to do is to observe the galaxies a little more closely. Remember what we have learned in the previous part (pages 7-10) and add more information to the classification:

- Elliptical galaxies: look at its shape. If they are almost circular, they are represented by ***E0*** and, the more elliptical they are, the greater the number will increase until ***E7***.
- Lenticular or ***S0*** galaxies: Remember they can be very similar to the elliptical ones, as they are spiral galaxies that have no arms. For example, how do you differentiate it from an ***E7*** *galaxy*? Because we need to see a brighter central component (bulge) and a fainter disk.
- Regular spiral galaxies: look at how open or closed their spiral arms are. Very closed arms galaxies are represented as ***Sa***, slightly opened arms galaxies, as ***Sb*** and deployed arms galaxies, as ***Sc***.
- Barred Spiral Galaxies: you should also notice if they have open or closed spiral arms, although, this time, starting from the bar. We will classify very closed arms galaxies as ***Sba,*** slightly opened arms galaxies as ***SBb*** and fully deployed arm galaxies as ***SBc***.

Some galaxies are harder to classify than others, for example, galaxies observed sideways are very difficult to classify beyond whether they are spirals or elliptical.

Once you have the detailed classification, select the most representative of each galaxies type and place them in the Hubble diagram below:



For more information, visit our website: **www.iac.es/peter**

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