

## Classification of Galaxies

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After having shown that The Great Spiral Nebula in Andromeda was in fact a galaxy in its own right, Edwin Hubble went on to study galaxies in some detail. One of his achievements was to set up a classification system for galaxies which is still used. He classified them by shape. Today you will be exploring that classification scheme. The three major classifications are elliptical galaxies, spiral galaxies, and irregular galaxies. Each of these types is subdivided by shape. Further divisions which aid in identification are “dwarf” and “giant” ellipticals and “merging galaxies.”

The simplest looking galaxies are the ellipticals. They are smooth looking and have the shape of spheres or ellipsoids - flattened spheres. They are classified as E0, E1, E2, and so on up to E7 on the basis of the amount of flattening. If we measure the long axis of the ellipse and call it “a” and measure the short axis and call it “b”, the E number can be calculated using the formula

$$E \text{ number} = \frac{a - b}{a} \times 10$$

rounded to the nearest whole number

Figure 18.1 in your text on page 524 shows several galaxies of various types. Figure 18.5 on page 527 shows how the number scheme is applied to them. A web search will show the galaxy M84 is an E0 elliptical. Note that the shape that we see may depend on the direction that we are looking at a galaxy. A spherical galaxy would always appear circular, that is, as an E0. However an E5 could appear circular from a different direction or as an E1 or E2 etc. Statistical studies do however indicate that some of the ellipticals must actually be fairly good spheres.

The spiral galaxies are those that show some type of structure and they fall into two subclasses, the normal spirals and the barred spirals. The barred spirals, which account for about 1/3 of the spirals, have conspicuous bars of stars running through their nuclei. They will typically have spiral arms coming off the ends of the bar. Normal spirals are divided into S0, Sa, Sb, and Sc. The S0 show a nucleus and a disk structure but not clear arms. Sa galaxies have a large nucleus and tightly wound arms. Sc galaxies have a small nucleus with loosely wound arms. Sb galaxies are intermediate with a medium sized nucleus and arms more tightly wound than an Sc but more loosely wound than an Sa. Examples are shown in Figure 18.5 on page 527. Spirals, especially Sc spirals, are very photogenic. Most of the galaxy pictures you will see will probably be of spirals however, most galaxies are thought to be small ellipticals. The barred spirals are divided into SB0, SBa, SBb, and SBc. A good barred spiral is shown on page 522. These sub classifications are similar to those for the normal spirals. SB0 has a large nucleus and a bar but lacks arms. As one goes from SBa to SBb to SBc the nucleus gets smaller and the arms become less tightly wound.

The final category is irregular galaxies that do not have a regular shape. Hubble had originally distinguished two categories of these but it later became clear that the distinction was that more structure could be seen in the closer ones. Since the difference was only an apparent difference the distinction was dropped. Figure 19.19

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on page 570 shows the Large and Small Magellanic Clouds, examples of nearby irregular galaxies.

While most galaxies do fit into Hubble's classification scheme there are galaxies that don't. For example some galaxies have the form of rings or show tidal tails. These are the result of recent (or soon to be) merger events. There are also galaxies that have odd unexpected features. These galaxies are classed as peculiar. Hence a galaxy could be E1 (pec). An example of an interacting pair is shown in Figure 18.26, page 547.

Study the examples in the text. Pay special attention to the fork diagram in Figure 18.5 on page 527. Further examples may be found at the Princeton galaxy classification site [http://www.astro.princeton.edu/~frei/Gcat.htm/cat\\_ims.htm](http://www.astro.princeton.edu/~frei/Gcat.htm/cat_ims.htm)

In this exercise, you will classify a number of galaxies and contribute to the overall science output of the Sloan Digital Sky Survey (SDSS). This should also give you a feel for some of the problems encountered by professional astronomers trying to do this work. Don't get paranoid about "messing up" science results. The system is set up to weigh your results based on an initial trial and each galaxy will have 10 or more people looking at it.

**A written report (format below) is required from each person** (this is **NOT** a group effort). Feel free to classify as many galaxies as you like (there are about 90 million of them in the system awaiting a pair of eyes). You must get a minimum of 10 ellipticals, 10 spirals, and 5 mergers or others. For five of the ellipticals, you should measure the major and minor axes and determine the ellipticity sub-category. Be sure to write these measurements down because the software does not record this for you.

To start: Go to the web page <http://www.galaxyzoo.org>. You will need to register to use the site (make sure to remember this). After you register, a confirmation email will be sent to you. You must click the confirmation link found in the confirmation email before your registration is complete. After registering and logging in, read the "**The Science**" section for background and what you are contributing to. The directions to get into the classification system and the tutorial (required of all new users) are found under the "**How to Take Part**" tab. After reading through the examples (and looking at the pictures) you can proceed with the classification part of the project (this is where you need to start keeping notes of your work).

When you have classified at least 10 smooth galaxies (ellipticals), 10 galaxies with structure (spiral galaxies) and 5 "Odd" galaxies (irregulars) you can click the "**My Galaxies**" tab at the top of the page to see a summary of the galaxies you have classified. You can review the ones you have classified and add the ones you liked best to your favorites.

If you get tired doing this project you can log out and come back later to finish or continue for fun (remember your login information) and you'll get a feel for what it's like

going through thousands of these by eye. Remember in the old days you would be looking through magnifying lenses at photographic plates! **If you enjoy this project you can continue classifying for years!** You will run out of energy before we run out of galaxies.

### **Format for Written Report**

a) The paper should be neatly typed and should include the following

1. Cover page.

Title of the lab, your name, Meeting time and Date

2. Introduction

This is a brief summary of the objectives of the lab. Include information on where you went on the Internet and who runs the site.

3. Body of the report

a) Outline of classification scheme.

Begin with an explanation of the galaxy classification scheme developed Edwin Hubble. Be sure to refer to the sub-category (0,1,2,3... or 0, a, b, c) for each main galaxy type and how these sub-categories are defined. Refer to Chapter 18 of your textbook or the GalaxyZoo site or links.

b) Write a few sentences about the galaxies you classified. How many total did you need in order to reach the goals of 10 elliptical, 10 spiral, 5 other?

c) For the spiral galaxies, do you have the same number of barred versus non-barred galaxies? Why do you think this is the case?

4. Include the printouts from the **“My Galaxies”** pages – the classifications, not the images. You CAN include the images of your favorites if you desire.