1 Galaxies, Stars and Nebulae

INTRODUCTION

The photographs that we will be using are reproductions of plates taken by the 1.2 m (48 in) Schmidt telescope on Mount Palomar. Schmidt telescopes are designed specifically for photographing relatively large (by astronomical standards) areas of the sky with very good definition. This particular Schmidt telescope is the largest one in the world and was designed, at least in part, with the idea of compiling an atlas of the entire sky visible from southern California. The atlas took about 10 years to complete, under the auspices of the National Geographic Society, and the Hale Observatories which are run by the Carnegie Institution and California Institute of Technology. It has since been invaluable to astronomers. The telescope was large enough that the pictures include the most distant objects known, and yet the field of view was wide enough (In a large telescope the field of view is usually quite small) that the entire sky is covered by a reasonable number of photographs. Astronomers use the photographs both for survey work in determining the numbers and kinds of different classes of astronomical objects and for discovering and identifying objects that need to be studied further with other types of telescopes.

The original photographs were made on glass, as are most astronomical photographs, because glass is less subject to the stretching, shrinking and warping that can occur with the acetate and other bases used for ordinary photographic film. The original photographs are stored in a vault, but many copies have been made and sold to various observatories and astronomical institutions around the world. All the copies (ours are prints but transparencies are also available) are negative contact copies because, as a matter of practical experience, these preserve more of the details of the original than do any other types of copies. Each print is about 35 cm square and covers an area of the sky of 6° x 6° giving a scale of roughly one degree per 6 cm. (The full moon would thus be about 3 cm in diameter.) For each position on the sky, there are two different photographs, one taken originally in blue light and one taken in red light. This lets us estimate the colors of different objects and even, in extreme cases, see objects in one color that are nearly or totally invisible in the other.

These prints are of extremely high quality and are the same ones that
astronomers use. They are very difficult to replace so please be extremely
careful. Please NO PENS OR PENCILS ANYWHERE NEAR THE PHOTO-
GRAPHS! DO NOT WRITE ON PAPER THAT IS ON TOP OF THE
PHOTOGRAPHS!

BASIC DATA

In the upper left hand corner of each photograph (which corresponds to
the northeast corner on the sky) is a block containing the basic informa-
tion about the photograph. This information includes the plate sensitivity
(whether it was sensitive to blue light=O or to red light=E), plate number
(the red and blue photographs of the same piece of sky will have the same
number), the date on which the original photograph was taken, and the astron-
omical coordinates (right ascension and declination, which are analogous
to latitude and longitude on the earth) which indicate the exact position in
the sky of the center of the photograph.

OBJECT

1. To recognize the importance of practise in looking at photographs of
astronomical objects.

2. To be able to recognize visually spiral and elliptical galaxies in both
face-on and edge-on orientations.

3. To estimate the distance to one cluster of galaxies given the distance
to another.

4. To appreciate the usefulness of photographs of more than one color.

5. To recognize the variety of objects visible in the sky.
GALAXIES

INTRODUCTION

The upper left corner of each print has a number which identifies the area of sky it covers. In this exercise you will be using prints 0-83 and 0-1563. Remember that these are negatives, so that light from a star or galaxy appears black on the prints. The spikes and circles around the images of bright stars are an artifact of the telescope structure. All stars, except of course the sun, appear as points of light to even the largest telescopes. The faint circular images which appear here and there are “ghost” images of stars which arise when light from a bright star bounces off the photograph, then gets reflected somewhere inside the telescope and finally returns somewhere else on the photograph.

PROCEDURE

1. Hercules Field

Inspect the print labeled 0-83 for a while. Most of the dots in the print are foreground stars in our Milky Way. This print also shows hundreds of galaxies which are not immediately apparent until you have achieved some experience with the other print.

2. Virgo Cluster

Now study the print 0-1563. You will notice many objects here that are clearly not stars. They are galaxies, mostly belonging to a cluster of galaxies in the constellation Virgo, called the Virgo Cluster of Galaxies. It is the nearest cluster of galaxies to us. We can say that these galaxies are all at approximately the same distance from us (about 51 million light years) and, therefore, any differences we find in the size or brightness between different galaxies are an indication of the intrinsic properties of these galaxies and not due to differences in their distance from us.

Study the print with a magnifier long enough to be able to distinguish:

a) elliptical galaxies (they show no structure, but get fainter from the center out) from spiral galaxies.

b) spiral arms of spiral galaxies that are smooth bands of light from those that are clumpy.

c) spiral galaxies seen edge-on from those seen face-on.

d) spiral galaxies which show a distinct bar across the nucleus (barred spirals).

e) irregular galaxies or peculiar systems like pairs of galaxies which might
be colliding or orbiting each other. One of the best ways to look at galaxies carefully is to try to sketch some of them. Sketch at least 6 different galaxies (one from each of the above groups) in boxes about 3 cm square. Classify each galaxy as to which of the above groups it belongs.

3. Dust Lane

Near the upper right corner of 0-1563, just above the giant elliptical galaxy M86, is an elongated galaxy with a white lane across it NGC 4402. Sketch this system. What do you think the white lane is? Why are no stars visible where the white lane is?

Can you see white lanes or patches in any other galaxies? In what type of galaxy is there a tendency for white lanes and patches to occur?

4. Hercules Cluster

Now return to print 0-83. With your new experience, you will be able to find a group of several hundred galaxies clumped in a part of this print. Make a rough sketch of the features in the print showing location and outline of the cluster of galaxies (not the individual galaxies). This is the Hercules Cluster of Galaxies, in the constellation Hercules. Use a magnifier to check whether the Hercules Cluster contains spiral and elliptical galaxies like the Virgo Cluster. What do you find?

5. Distance to Hercules Cluster

Astronomers assume that the larger galaxies in each cluster are in fact very similar in size.

a) Why do the galaxies in the Hercules Cluster look so much smaller than those in the Virgo Cluster?

b) Estimate the distance of the Hercules Cluster, given that the Virgo Cluster is 51 million light years away. (Freedman et al., 1994). To do this, use your magnifier to measure the sizes of the approximately largest galaxies in each cluster, noting the type of galaxy beside each measurement (elliptical, E, or spiral, S). Then use the average size of the brightest galaxies as an indicator of relative distance.

Notes:

i) You will need to think carefully about the criterion you use for measuring size and then try to apply the same criterion to all your measurements.

ii) Estimate roughly the accuracy of your result.

iii) Compare the sizes you measured for the elliptical and spiral galaxies separately and discuss any differences you notice.
STARS AND NEBULAE

INTRODUCTION

The upper left corner of each print has a number which identifies the area of sky it covers. There is a red (E) print and a blue (O) print for each area.

Prints 1099 and 754 cover adjacent areas of sky and you can arrange them as shown in the diagram. The area covered is $6^\circ \times 12^\circ$, in the constellation Cygnus, where we are looking along a spiral arm of our galaxy. The very bright star Deneb is at the line of overlap as shown in the diagram and the direction of the Milky Way is marked.

The spikes and circles around the images of bright stars are an artifact of the telescope structure. All stars, except of course the sun, appear as points of light to even the largest telescopes. The faint circular images which appear here and there are "ghost" images of stars which arise when light from a bright star bounces off the photograph, then gets reflected somewhere inside the telescope and finally hits somewhere else on the photograph.

Figure 1. The Stars and Nebulae Prints

PROEDURE

Make a sketch similar to figure 1. in your lab book. Show the outline of the POSS print and mark on a few of the bright stars. Mark the position of the following objects on it.

1. Stars
a) The brighter a star is in the sky, the larger its image on the photograph will be. Would you expect, therefore, the image of a blue star to be larger or smaller on the blue prints than on the red prints?

b) Near the lower right part of the print 1099 there are two fairly bright stars that appear near each other in the sky. 30 Cygni is the star to the north and 31 Cygni is to the south. Which is the bluer of these stars?

c) Find and mark the location of another very blue and another very red star.

2. Planetary Nebula

A planetary nebula appears on print 1099. It contains ionized hydrogen ejected by a dying star, so you would expect its color to be red.

Search on the print of the appropriate color and give its position. Clue: it is small and round, with a sharp boundary.

Search for it on the print of the other color. What do you find? Explain how it is formed.

3. Globule

A globule is a very thick dust cloud, so small that it may soon collapse to form a new star. Since dust absorbs all light emitted by more distant stars and nebulae behind it what color will the globule appear on the prints?

Search on print E-754 for the tiniest dust cloud you can find and mark its position. The globule may look like a speck of dust on the print or a flaw in the film. How can you check that it is a real globule and not merely a flaw?

4. Reflection Nebula

A reflection nebula occurs when dust scatters light from a nearby star. This makes the star redder and the scattered light seems to come from an extended region surrounding the star. The same thing happens in our atmosphere, making our sky blue.

A reflection nebula appears in the right half of 0-754. Search for this reflection nebula, mark its position, and explain how it is formed.

5. Milky Way

The diagram given earlier shows roughly where the Milky Way is located. Now look on the red prints and compare the number of stars in the Milky Way (per square cm) with the number in the upper right part of print 1099. What do you find?

We believe that our Galaxy is a disk of billions of stars, and that most of these are situated in the direction of the Milky Way. Why, then do we not see the greatest number of stars along its central line?
We can make a very rough estimate of the number of stars in our galaxy by counting how many stars there are in a small area and then multiplying by how many small areas there are in the sky. Count the stars in a millimeter by a millimeter square and then multiply by 100 Million to find roughly how many stars there are in the Milky Way galaxy.

6. Dust Clouds

Two dust clouds appear on E-754 at the lower left and lower right. Each is a thick, opaque cloud. Given this information, which cloud is farther away? Explain your reasoning.

7. Miscellaneous

a) Look at E-1099 and E-754 together and notice how the long filamentary structures tend to curve and suggest they may be part of a circular structure with its center on the lower part of E-754. Although it is hard to see on the print, near the center is a group of stars known as the OB association Cygnus OB2. They are very strongly reddened by the interstellar dust between us and them and this dust has also dimmed their light. If this dust were absent, some of the stars would be among the brightest stars visible in the sky. Can you see this association? It is also interesting because there is a source of X-rays as well as a large, strong source of radio waves in the same directions which may have been left by a supernova.

b) Examine anything else that looks interesting and see what you can deduce about it from a comparison of the two prints or from a comparison with other nearby regions.

c) Imagine trying to give a name to each star in the upper right part of print 1099.

Web Site

http://www.stsci.edu/resources/