

PALOMAR SKY SURVEY
Astronomy 124/348

Instructions: Please fill in the following forms and data sheets, and hand this in as your lab. Any additional sheets you provide should be securely attached. If you have any questions please ask the teaching assistant on duty.

Name: _____

ID Number: _____

Date and Time Completed: _____

Instructor: _____

Grade and Comments: _____

Please sign the following special pledge:

On my honor as a student, the work I am submitting here is entirely my own. I have not collaborated with or received help in any way from any other person on this laboratory (except those officially designated by the Astronomy Department). I understand that collaboration in any form would be a serious honor violation, would be considered reprehensible by the academic standards in force in this course, and will immediately be brought to the attention of the Honor Committee.

(signature)_____ (date)_____

NAME: _____ ID Number: _____ Grade: _____

PALOMAR SKY SURVEY Astronomy 124/348

Introduction to the Sky Survey. The Palomar Sky Survey is a series of photographs covering the entire sky north of -27° declination taken with the 48-inch Schmidt camera at Mount Palomar. A similar survey is now being made for the southern sky from Chile and Australia. A Schmidt camera is a special purpose instrument designed for photographing much larger areas of the sky than is possible with a normal telescope. The 48-inch has a field of view of 6.6° , about the area covered by 4 fingers held up at arm's length. It used emulsions coated on glass plates 14 inches square. Because of the wide angle of view, the scale is rather small. One minute ($'$) of arc is about 0.90 millimeter. Therefore, if the full moon were photographed when its angular diameter is $32'$, what would be its linear diameter on the Sky Survey prints?
_____.

You will be using photographic contact prints made from the original plates with an intermediate glass positive. The prints are negative images: light areas in the sky (stars, galaxies, etc.) are black on the prints, and vice versa. The blacker the image on the print, the brighter the object is in the sky. Prints exactly like these we are using are often used by professional astronomers. Much of our knowledge about the number and distribution of objects such as galaxies and planetary nebulae has been obtained from the Sky Survey.

The survey was made in two colors, with a picture taken of each region with a red sensitive emulsion (E print) and a blue sensitive emulsion (O print). Extremely faint stars are recorded: 20th magnitude on the red plates and 21st on the blue. The faintest stars shown on the prints are 100 million times fainter than the brightest. Star brightnesses are measured in magnitudes, with brighter stars having smaller magnitude numbers. The brightest stars in the sky are in the magnitude range -1 to $+1$. The faintest stars visible from Charlottesville on a clear night are about magnitude 5. Additional explanation may be found in many standard introductory astronomy texts, such as Abell, Exploration of the Universe, Snow, The Dynamic Universe, and others. You may wish to refer to such a text for review or clarification. They are available in the Science–Engineering Library in Clark Hall. The two colors give information on the color of an object, with red stars, for example, showing up darker on the red print, blue stars darker on the blue print, and neutral objects (yellow stars like the Sun) pretty much the same on both.

Data for each print are given in a small box in the upper left hand corner of the print. The table gives the following information:

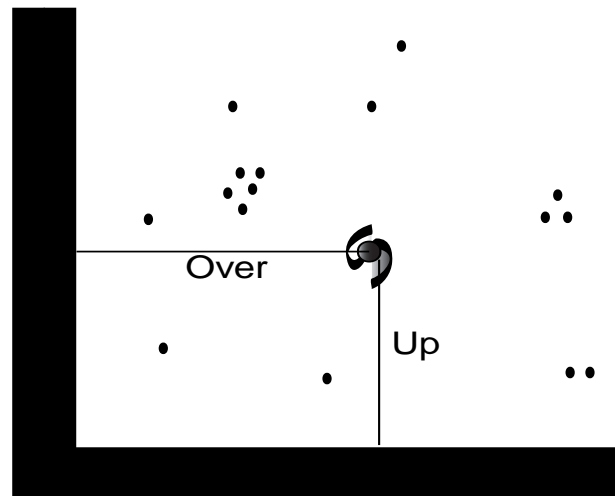
| <u>color code</u> | <u>Plate Number</u> | <u>Date of Photograph</u> | <u>Position of Plate Center in Right Ascension and Declination</u> |
|---------------------|---------------------|---------------------------|--|
| E = red O = blue | O-1576 | Mar 15-16, 1956 | $12^h 28^m 47^s +17^\circ 28' 30''$ |

Positions of objects in the sky are measured in a coordinate system which is analogous to latitude and longitude on Earth. Declination measures the angular distance north or south

from the Celestial Equator. Right Ascension measures the distance east around the equator from a specific zero point. Thus the position of any object or place in the sky can be specified by these two numbers, just as knowing the latitude and longitude specifies the position of a place on the Earth.

For these labs you will be using four prints. The prints are fragile and expensive, so be very careful with them. Please be especially careful not to mark on the prints or write on a paper lying on top of the prints.

Casually examine the prints. Note the wealth of fine detail visible through a magnifier. You can also find many flaws in the plates. It is almost impossible to obtain a perfect plate this size. You should easily be able to distinguish flaws. Some bright stars will have rings around them with a cross through them. This is due to internal obstructions in the telescope.



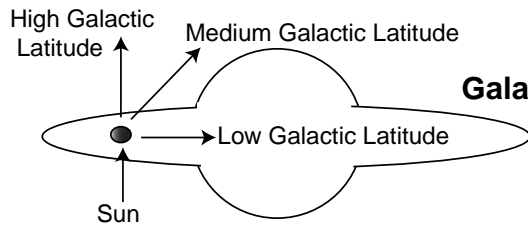
You will be asked to locate several objects on the prints. The picture area is surrounded by a black border. Use a ruler to measure the distance in centimeters from the left inside border of the picture area over to the center of an object, and from the bottom inside border up to the center of an object. Report its position as a pair of numbers: (over,up). Accuracy to the nearest millimeter is usually sufficient.

The Milky Way Galaxy. From a dark location on a clear night, we can see a large number of individual stars sprinkled about the sky in all directions. In addition, we may see a hazy band of light stretching across the sky, the Milky Way. Telescopes show it to be composed of uncountable millions of faint stars whose combined light produces the glow we see with the naked eye.

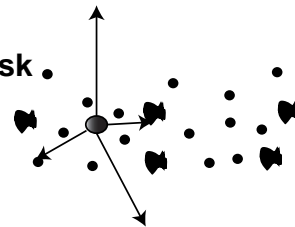
The Sun and all of these other stars, bright and faint, are bound together by gravity into an enormous aggregate called a galaxy, containing an estimated 200 billion stars. The Milky Way Galaxy is not just a huge shapeless mass of stars, but has a definite structure. It is a large, thin disk of stars, like two dinner plates edge to edge, with a spherical concentration of stars at the center and a relatively small number of isolated stars scattered around the disk in a large spherical halo. The disk measures about 100,000 light years edge to edge, and the Sun is located about 2/3 of the way out from the center. When we look out into space

along the plane of the disk, we see many more stars than when we look up or down out of the disk. This is why the Milky Way appears as a band across the sky.

In addition to stars, the Galaxy contains clouds of gas (mostly hydrogen) and extremely fine dust grains (probably graphites, silicates, and ices). They are called nebulae (plural), from the Latin nebula, “cloud”. The dust in particular is troublesome to astronomers, as it blocks out the light from distant stars. Thus we actually cannot see very far into space if we look into the plane of the Milky Way. However, if we look up or down out of the plane, toward the galactic poles, the dust layer is much thinner and very distant objects can be studied.



Structure of the Milky Way Galaxy



Dust limits our vision in the disk of the Milky Way but not out of it

Other Galaxies. Looking out from our own galaxy, astronomers have discovered a vast number of other self-contained systems of stars—other galaxies. Many are similar to the Milky Way Galaxy; others are much different in size, shape, and the types of stars and other material found in them. While some galaxies may be isolated individuals, most are found in either loose groupings or in more compact clusters containing hundreds or thousands of member galaxies. Cluster members are bound to the cluster by gravity, just as the stars are bound in each galaxy. Our own galaxy appears to be located in a loose group of a dozen or more nearby galaxies, most of which are smaller than ours. This Local Group is located on the edge of a much larger cluster of galaxies in the direction of the constellation Virgo.

1 Stars, Gas, and Dust in the Milky Way

1. Obscuration

When we look in the plane of the Milky Way, obscuring matter in the disk prevents us from seeing objects more than a few thousand light years away. Toward the center of the galaxy in Sagittarius, the myriad of stars seem little different from those we see 180° away in Taurus. While it is rare to find a distant galaxy visible through the disk of the Milky Way, other galaxies are easily seen perpendicular to the disk.

Look at the blue-sensitive prints O-200, O-1311, and O-1576. There are many stars in O-200, fewer in O-1311, and fewest in O-1576. There are few if any galaxies in O-200, dozens in O-1311 and hundreds in O-1576. Search over each of the three prints to find a small area with bright stars. Rely on the cross-shaped artifact to distinguish bright stars from faint ones. Then adjust the position of a 10 cm² overlay until it contains the largest number of bright stars. Count the number of bright stars, rank the print as being of a region at low (< 5°), medium (~ 40°), or high (> 70°) galactic latitude, and calculate the average number of bright stars per cm² to complete the following table. Remember that at low galactic latitude there is much more dust blocking our view of stars and galaxies, so we will see fewer stars and almost no galaxies at all on a print from low galactic latitude.

| Galactic Latitude | Print # | Max # of bright stars per 10 cm ² | Max # of bright stars per cm ² |
|-------------------|---------|--|---|
| Low | _____ | _____ | _____ |
| Medium | _____ | _____ | _____ |
| High | _____ | _____ | _____ |

2. Absorption Nebulae

Most interstellar clouds neither emit nor reflect visible light. They can sometimes be detected directly by a radiotelescope, but ordinarily are found, if at all, by their dust's absorption of visible light from more distant luminous objects. Thus an apparent scarcity of stars in a given region or a dark band across an emission nebula is the only evidence for an absorption nebula. An example of the first effect is at (10, 28) on O-200. Notice how the average number of stars seems much less in this area than in surrounding regions. There are several large (larger than 1 cm²) absorption regions on O-200. Viewing from 2-3 feet away makes them more apparent. Find two absorption nebulae and do a star count in each, using the 1 cm² area:

| | Location | Count |
|----------|----------------|-------|
| Region 1 | (_____, _____) | _____ |
| Region 2 | (_____, _____) | _____ |

Assuming that the dust in these clouds completely blocks out the light from stars behind them, which region is further away? _____.

3. Colors of Stars

On print E-200 (red-sensitive) there is a bright star at (7.0, 9.6) with a companion star at (7.1, 9.9). Now, find the same pair of stars on O-200 (blue-sensitive). The bright star seems approximately as bright on both prints, but the companion is much fainter on the blue print, hence it is a red star.

Using prints O-200 and E-200 complete the following table by indicating the star color as either blue (B) or red (R).

| Star Position | Star Color |
|---------------|------------|
| (27.1, 20.7) | _____ |
| (28.5, 26.5) | _____ |
| (7.7, 4.8) | _____ |
| (6.1, 5.3) | _____ |
| (9.7, 20.7) | _____ |

4. Emission Nebulae

Ordinarily, nebulae do not emit significant visible light of their own. But if the gas is heated by some mechanism until the electrons are stripped from the hydrogen atoms, i.e. until the hydrogen is “ionized”, the electrons being recaptured by hydrogen nuclei emit their excess energy as visible light. A cloud in this state will show up as a bright, extended object. Many such emission nebulae are on 200 (remember that a bright object in the sky is represented by a dark object on the print). These regions are called HII regions. The visible radiation is predominantly from the electrons’ transition from the third to second orbit and has a wavelength of 6560 angstroms. Using prints O-200 and E-200, find two more emission nebulae and give their positions: (_____, _____), (_____, _____).

On the blue-sensitive print O-200 there are two stars centered at (27.5, 11.4) which are surrounded by nebulosity. On E-200 the nebulosity is much brighter, hence the nebula is _____ in color. Note that there is a U-shaped region in the nebula from which very little light originates. This a dust lane, or dark filamentary nebula and is easily seen on both prints. There is a much larger dark nebula on the lower left edge of the bright nebula that contains the two stars.

On O-200 there is a star at (14.2, 27.6) which is near the center of a nebula with sharp edges. (The star is known as HD192163, the nebula as NGC 6888). On E-200 the nebula is much brighter, therefore it is red in color. The central star, blue in color, is very bright and according to current astrophysical theory ejects (or ejected) a strong stream of matter into the surrounding space. The ejected material sweeps up interstellar gas and dust, slows down, and cools off. When the material is cool enough to form hydrogen atoms, it radiates the red light that we see in a roughly elliptical shell surrounding the star.

The distance to the central star has been determined by a combination of astronomical theory and observation to be 3400 light years. Let us accept this value and find out how large the nebula is. We will measure its largest size on E-200 (where the image is stronger), convert this value to angular size, and calculate the linear size in light years:

Complete the following:

Maximum size on print in mm _____mm.

Angular size in arc seconds _____arc seconds. (above value $\times 67.1$)

Angular size in degrees _____degrees. (above value divided by 3600)

Angular size in radians _____radians. (above value divided by 57.3)

Linear size in light years using size = distance \times angular size _____light years.

There are about 9×10^{12} km in one light year. Find the linear size of the nebula in kilometers:
kilometers.

Massive stars can produce winds of 1000 km s^{-1} . Using the linear size that you calculated above, calculate the age of the nebula in years using:

$$\frac{\text{linear size in km}}{\text{velocity in km s}^{-1}} \times 3.2 \times 10^{-8} \text{ years s}^{-1} =$$

_____years.

Is the age of the nebula greater than or less than the age of the Sun? _____

2 Other Galaxies and the Hubble Classification

Turn to the Illustrations of Galaxies, following page 32 in the Hubble Atlas (on reserve at the Science–Engineering Library). On these prints black is the absence of light. The Hubble Atlas gives one or two names for each galaxy and a Hubble classification. For example, the upper right hand galaxy in plate 1 is identified on the left hand page as NGC 4406 and M86. (It is galaxy number 4406 in the “New General Catalog” and it is number 86 in Messier’s list of objects). Note that near M86 a much smaller elliptical galaxy is visible.

Use the following table to study the various types of galaxies in the Hubble Atlas. Compare the appearance of the listed galaxies and their descriptions to galaxies of similar type. Note the characteristics which distinguish between classes, although there can be some variation within a class.

Elliptical galaxies are characterized by smooth ellipsoidal forms and lack of interstellar dust and gas. They are classified according to their eccentricity, from round E0 galaxies to highly elongated E7 galaxies. Spiral galaxies are subdivided into classes determined by the size of their nucleus and the openness of their spiral arms. An Sa galaxy will have a very bright, dominant nucleus and tightly wound spiral arms. An Sc galaxy will have a small, indistinct nucleus and very loose, open spiral arms. Sb galaxies are intermediate between these two types. Barred spirals (SBa, SBb, SBc) are classified similarly, with the additional feature of an elongated nuclear bar. S0 galaxies are the transitional type between elliptical and spiral galaxies, with a disk which is more visible than in an E7, but with no spiral arms. There are galaxies which clearly do not fall into the above classification scheme and are designated Irr, for irregular galaxy. Brightness, size and orientation do not enter into the classification. Beware of these influences when classifying the unknown galaxies!

| Plate # | NGC # | Hubble Type | Plate # | NGC # | Hubble Type |
|---------|-------|-------------|---------|-------|-------------|
| 1 | 4278 | E1 | 1 | 3377 | E6 |
| 5 | 524 | S0 | 6 | 5866 | S0 |
| 30 | 3672 | Sc | 25 | 5907 | Sc |
| 15 | 3521 | Sb | 25 | 4565 | Sb |
| 11 | 3623 | Sa | 43 | 175 | SBa |
| 49 | 2525 | SBc | 39 | 2366 | Irr |

Let us now inspect the sky survey print O-1576. Consider the galaxy whose coordinates in centimeters are (11.8, 2.7). Note that the nucleus is quite small and the bar distinct. Therefore, the best classification for this galaxy appears to be SBc. The spiral arms are rather tight for this class but there is one dominant pair of arms that seem to fit well. An alternate classification is SBb, which seems less appropriate. The galaxy whose coordinates are (19.0, 0.4) is classified as an E6. It is distinguished from an edge on spiral by the lack of dust lanes or distinct disk.

Determine the Hubble classification for the following galaxies.

| | |
|------------|-------|
| 1.2, 13.0 | _____ |
| 28.0, 9.9 | _____ |
| 27.0, 14.6 | _____ |
| 24.8, 22.5 | _____ |
| 24.0, 22.6 | _____ |
| 9.9, 1.3 | _____ |
| 17.9, 14.8 | _____ |
| 20.8, 16.6 | _____ |
| 16.3, 2.3 | _____ |
| 29.8, 3.4 | _____ |

Find the largest spiral galaxy on print O-1576 and the largest elliptical galaxy. Complete the following table.

| | Position | Largest Diameter in mm | Largest Diameter in arc seconds |
|--------------------|----------|------------------------|---------------------------------|
| Largest spiral | _____ | _____ | _____ |
| Largest elliptical | _____ | _____ | _____ |

Measure with respect to the faintest outlying part of the galaxy that you can see to determine the largest diameter. Both of these galaxies are members of the Virgo cluster of galaxies and can be assumed to have the same distance from the solar system. If their distances are the same, their sizes are proportional to their angular sizes, which are in turn proportional to the diameters you measured. Calculate the ratio of the size of the spiral to that of the elliptical _____. Examine the small elliptical galaxy at (25.0, 8.7). Measure the diameter of the small galaxy, again choosing the faintest outer edges that you can detect. The diameter is _____ mm. Assume that the small galaxy is also a member of the Virgo cluster of galaxies. Then its distance is the same as that of the large elliptical galaxy that you have measured above. Compute the ratio of the size of the large elliptical galaxy to that of the small one. The result is _____. From these calculations, is it safe to say that, in general, spiral galaxies are larger than elliptical galaxies? _____.

Let us determine the distance to the Virgo cluster from your measurement of the diameter of the large spiral galaxy and the assumption that this galaxy has the same linear size as our galaxy. It has been determined from observations of neutral hydrogen atoms that the gas has a linear diameter of about 100,000 light years. We must suppose that the starlight is similarly distributed. To do the calculation you will need to use the following formula (see §4).

$$\text{distance} = \text{linear diameter} / \text{angular diameter (in radians)}$$

The distance to the largest spiral in the Virgo Cluster is _____ light years, and this is also the distance to the cluster.

Examine Sky Survey print O-1311. A cluster of galaxies may be seen just to the right of the center of the print. (In the upper left there is a much more conspicuous cluster, of bright stars instead of galaxies, called the Praesepe cluster.) Find the largest spiral galaxy in the galaxy cluster and enter its position, and largest diameter in the following table.

| Position | Diameter (mm) | Diameter (arc seconds) |
|----------|---------------|------------------------|
| _____ | _____ | _____ |

Again we make the assumption that the linear diameter of the galaxy is the same as that of our galaxy (100,000 light years) and calculate the distance with the equation given above (and in §4).

The distance to the largest spiral galaxy in this cluster of galaxies is _____ly.

How much further away is this cluster of galaxies in comparison to the Virgo cluster? _____.