Planning Observations
Earth & Sky

Name: ____

Introduction

For a professional astronomer, proper planning for an observing run is absolutely critical. Simply whipping together a list of targets is not sufficient to ensure the collection of the intended data. This holds true especially for ground based telescopes, because they are restricted in what they can see by Earth's curvature and rotation. The brightness of the object will be an issue when observing with a CCD camera because it will need to collect enough photons of the target object to obtain the desired signal-to-noise ratio. This forces a calculation of the necessary exposure time for each object, which is based on the object's magnitude, the moon's brightness, the overall brightness of the sky, certain characteristics of the CCD, and the desired signal-to-noise ratio.

Pre-test

1. From your experiences thus far, what do you think is necessary to plan an observation?

2. Do you think you can take an image of any object at any time of the night? At any night during the year? Why or why not?

3. Do you think you can see Polaris (the north star) from anywhere on Earth? Why or why not?

4. In an earlier lab you should have learned about light pollution, or the dull glow in the sky that may prevent you from getting a clear sighting of stars. How do you think this affects astronomers?

Target List

The first part of planning an observing run is to know what celestial objects would provide the desired data, and what their properties (coordinates, magnitude, apparent size[1]) are. For the purposes of this lab, the list of targets is already chosen and is given in Table 1.

Coordinates

Finding the objects in the night sky depends on knowing their coordinates, and astronomers often use the equatorial coordinate system to do so. This system of coordinates uses an imaginary sphere in space, around Earth, called the *Celestial Sphere*. The coordinates used on this sphere are right ascension (like longitude), and declination (like latitude).

Declination (dec) measures the angle of a star above or below the *Celestial Equator*, which is Earth's equator projected onto the celestial sphere, and is measured in degrees. The dec angle will be 0^o at the equator, $+90^o$ at the north pole near Polaris, and -90^o at the south pole. The declination of the point directly above you, or the zenith, is always equal to your latitude For example, at the north pole, objects at the zenith are at $+90^o$ declination, and at the equator, objects at the zenith are at 0^o declination.

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[1] Apparent size is used for all these objects because they are all galaxies, nebulae, etc. Thus, they are all larger in the sky than stars (point sources.

Right ascension measures the angle of a star east of some reference point, that being the vernal equinox point, which is the point on the celestial sphere representing the sun's position during the spring equinox. Right ascension is measured in hours of arc, so it will be somewhere between 0 and 24 hours of arc for an object's position. A positive value of RA means the angle is measured East from the vernal equinox point. Also note that is it a simple matter to convert between hours of arc and degrees. There are 360^o in a complete circle, and also 24 hours in a circle, so the units are easy to convert back and forth.

Every day, as the Earth turns on its axis from east to west, the hour angle of the meridian (the line connecting the north pole to the zenith, directly overhead; essentially a line across the sky from north to south) steadily increases, turning one whole circle in one sidereal day (more about this later).

1. Why do you think that Right Ascension is measured in hours, and not in degrees? How do you think it applies to preparing an observation?

Target Characteristics

The basic characteristics for the target objects need to be cataloged to correctly calculate signal-to-noise ratios and exposure times. Astronomers no longer need to worry about keeping volumes of data tables around for this information as there are many resources online from which to obtain it. A convenient, searchable archive with lots of useful information is kept at http://www.seds.org/~spider/ngc/ngc.cgi?1. The Enter your Catalog Number field at the bottom of the page, will accept values for various catalogs, but the NGC numbers are all provided for you in Table 1 so use those. Just type the NGC number (either just the number, or 'NGC' then the number). It will bring up a page with an image of the object, and a table of information about it. From the table you will need to obtain the following information: Right Ascension, Declination, Apparent Brightness (which is another way of saying 'apparent magnitude'), and Apparent Size (in arcseconds).

1. Find these values for all the objects in Table 1.

Table 1: List of target objects to be observed.

Item	Name	Right Ascension	Declination	App. Brightness	App. Size
1	Andromeda Galaxy (M31)				
2	Ring Nebula (M57)				
3	Blue Snowball (NGC 7662)				
4	NGC 869				
5	NGC 884				
6	Ptolemy's Cluster (M7)				
7	Open Cluster M47				
8	Orion Nebula (M42)				
9	Globular Cluster M15				

2. Why do you think the apparent brightness and apparent size are needed?

Sidereal vs. Solar Time

When trying to determine when an object will be visible during the year, it is important to understand the concept of sidereal time, as opposed to solar time. Solar time is the system that uses the sun as a reference point. One solar day is the time taken for the sun to come back around to the same position in the sky after one rotation of Earth about it's axis. Sidereal time uses the stars as references. The time necessary for a star to return to the same position in the sky as it was the day before is defined as one sidereal day, which is 4 minutes shorter than a solar day, or the time necessary for the sun to return to the same position in the sky as it was on the previous day. Because of how the coordinate system is set up for sidereal time, an observer will know the local sidereal time at the current location by noting the right ascension of an object that is directly overhead. Sidereal time, however, is not exactly the same as the hours we know, and steadily drifts throughout the year as the earth revolves around the sun.

1. Why do you think the sidereal day 4 minutes shorter than a solar day?

Target Visibility

To determine the visibility of a given object, you will need to know the local sidereal time during the intended observation. The first thing to do, though, is to see if what you want to view is at a declination that will be visible at all. Since declination doesn't change nightly like RA, you can just compare the latitude of the observer with the declination of the object.

Several facts about an object can be obtained from its declination. If the declination is more than 90^o north or south from the latitude, then it will never get above the horizon for you to see it. For example, if you are at 25^o north latitude, you will not be able to see anything below 65^o declination, as $25 - -65 = 90$, or a right angle from directly overhead, which will point directly at the horizon.

In addition, if the absolute value of the declination is greater than the absolute value of the difference between the latitude and the visible celestial pole (+90 or -90), it will ALWAYS be above the horizon. For example, if you are at 25^o north latitude, objects above 65^o declination will always be visible, as $90 - 25 = 65$. (likewise, if you are at 25^o south latitude, objects below -65^o declination will always be visible, as $-90 - -25 = -65$.)[2]

In Figures 1 & 2, you can see why some stars can always be seen at night, and others may never be seen. In the white regions, you can always see an object (except, of course, during the day), in the black regions, you can never see an object from your location, and in the grey regions, we need to use right ascension to determine if and when the object is above the horizon, and if it is so during the time we wish to do our observing.

Determining the RA is more difficult mathematically, but can be done in several different ways. The most basic way to see if the target object will be up in the sky is to figure out the local sidereal time during the intended observation, then compare it with the RA of the target. The sidereal time would be tedious to calculate by hand, which is why there are many handy web-based calculators to do it for you. One such calculator is at http://www.csgnetwork.com/siderealjuliantimecalc.html. You will need to enter the date, time[3], latitude[4], and longitude[5] of the observations into the respective fields, then click calculate. This will convert the values to local sidereal time, which is what you will need.

Since the local sidereal time is equivalent to the RA of the observer's meridian, the difference in the RA values between sidereal time and the target will indicate how close the target is to crossing the

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[2] Note that in the northern hemisphere, an object needs to be GREATER than the difference. In the southern hemisphere, an object needs to be LESS. In either case, the object must be 'above' the difference in the sky.

[3] The time you will need to input is in UT (Universal Time), which is local time as measured from Greenwich, England. For the eastern time zone in the U.S., the local time is offset by -5 hours from Greenwich. For daylight savings, the offset is -4 hours.

[4] Values for latitude are positive for north and negative for south.

[5] Values for longitude are positive for east and negative for west.

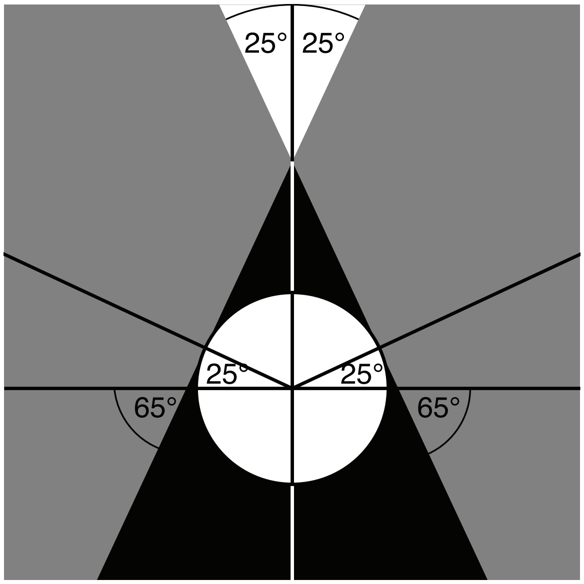

Figure 1: Areas visible at some point during the night from 22^o north latitude, close to the earth.

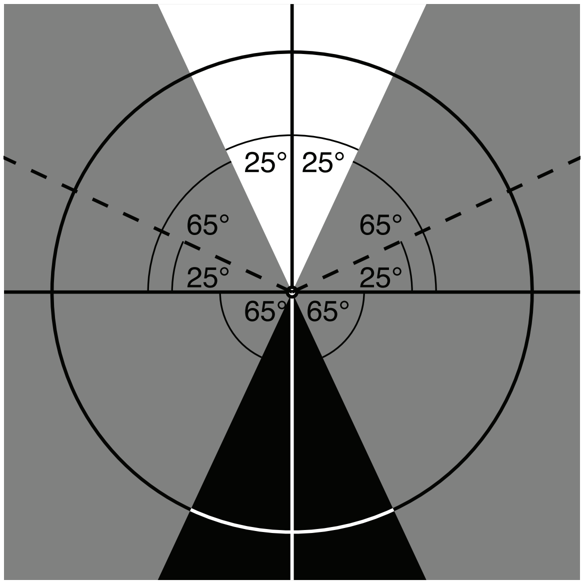

Figure 2: Areas visible at some point during the night from 22^o north latitude, far from the earth.

observer's meridian. If the object is within 6 hours east or west of the observer's meridian, then it will theoretically be visible. Objects may not actually be visible due to trees and buildings on the horizon, and astronomers usually restrict themselves to 3 or less hours from the meridian due to atmospheric extinction effects like you learned in an earlier lab.

Once you have determined which targets are within the declination range for viewing at Troy's latitude, you will use this procedure to see which ones will be visible on the chosen observation date.

1. Are any of the above objects not visible from Troy because their declination is too low? (Troy's latitude is 42.73^o N) Which ones?

2. Assume that you are trying to find out whether any of these objects are visible tonight for an observation at 8:00PM. Write down the date and time used, and what the sidereal time will be at your chosen observation time. Calculate how far from the meridian each object will be at that time.

Date of Observation:

Time of Observation:

Local Sidereal Time for this Observation:

How many hours from the meridian will each object be at that time?

Item	Name	Hours from Meridian
1	Andromeda Galaxy (M31)	
2	Ring Nebula (M57)	
3	Blue Snowball (NGC 7662)	
4	NGC 869	
5	NGC 884	
6	Ptolemy's Cluster (M7)	
7	Open Cluster M47	
8	Orion Nebula (M42)	
9	Globular Cluster M15	

3. Given the number of hours from the meridian and declination that you've calculated, which objects are visible? Which aren't?

4. Use the website above to find the local sidereal time at the Vernal Equinox (March 21, 2007, 12:07am UTC) on the Prime Meridian (0^o)? What is the local sidereal time at the Autumnal Equinox (September 23, 2007 9:51am UTC) on the Prime Meridian?

5. Polaris's declination is $+89^o15'51''$. Is it always above the horizon at the Equator? At 30^o north latitude? At 60^o north latitude? At the north pole (90^o north latitude)?

Calculating Exposure Times

One of the more important pieces of information an astronomer will need for an observing run is the exposure time for each object being observed. The key is to get images of as many objects as possible while maximizing the data (thus, maximizing the signal-to-noise ratio) collected from each one. This can be extremely limiting when the targets are all dim. You will now go through the process of calculating exposure times for the objects on your target list.

The exposure time can be calculated for an object based off its signal-to-noise ratio, a ratio used to determine, roughly, the amount of data needed to strongly differentiate a source of light from the background contributed by visual errors and the brightness of the night sky.

The signal-to-noise ratio of a star is found by:

$$\frac{S}{N} = \frac{N_{star}}{\sqrt{N_{star} + n_{pix}(N_{sky} + N_{dark} + N_{read}^2)}} \tag{1}$$

N_{star} = rate of electrons produced in CCD from source object
n_{pix} = number of CCD pixels gathering light from the object
N_{sky} = rate of electrons produced in CCD from sky background
N_{dark} = rate of electrons produced in CCD by dark current
N_{read} = number of electrons produced from read noise in CCD

These numbers will depend on the properties of the CCD, the telescope, the object being observed (both its apparent size and magnitude), and on the brightness of the background of the sky. You will not need to calculate through all of the equations needed to produce values of exposure times, but instead will use Figures 3 & 4 that take into account these values for you, and are suited to the observatory telescope.

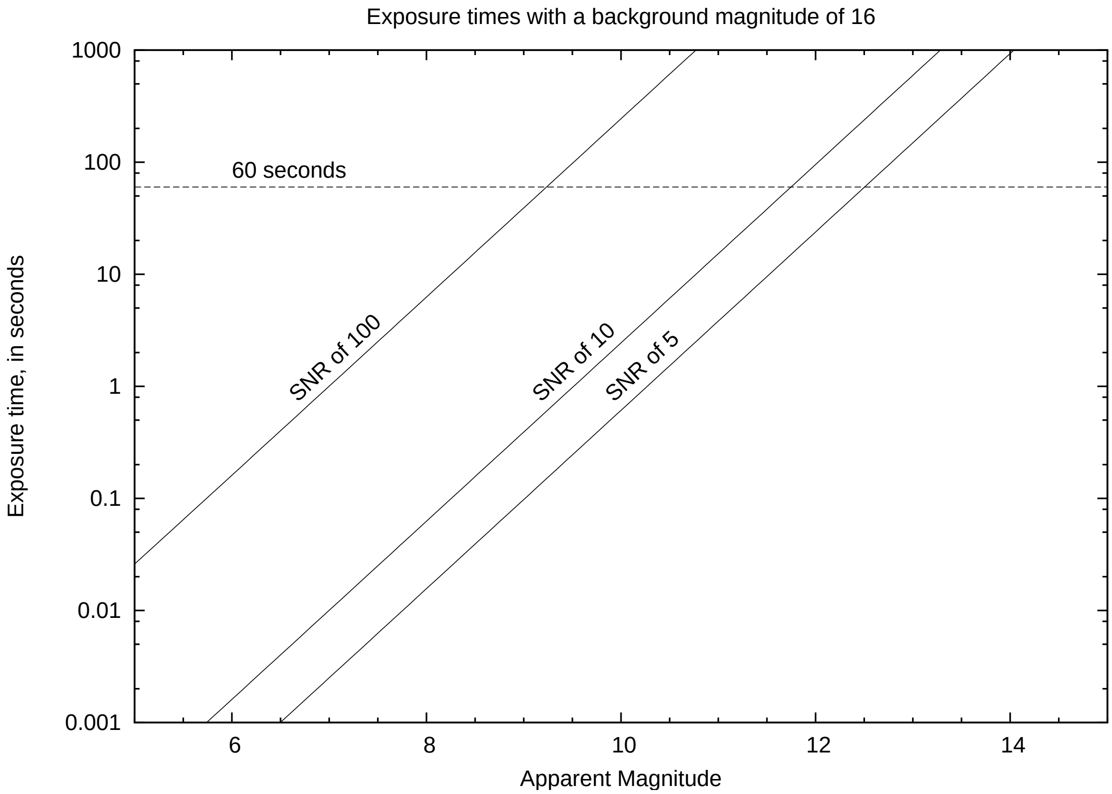

Figure 3: Exposure times for specified signal-to-noise ratios with apparent background magnitude of 16. *Be careful of the logarithmic Y axis!*

1. Using the apparent magnitudes you found earlier, list the approximate exposure times for each of the objects mentioned above if the sky has a background brightness of magnitude 16 (usually the case in Troy) and you desire a signal-to-noise ratio of 100?

Item	Name	Exposure Time (seconds)
1	Andromeda Galaxy (M31)	
2	Ring Nebula (M57)	
3	Blue Snowball (NGC 7662)	
4	NGC 869	
5	NGC 884	
6	Ptolemy's Cluster (M7)	
7	Open Cluster M47	
8	Orion Nebula (M42)	
9	Globular Cluster M15	

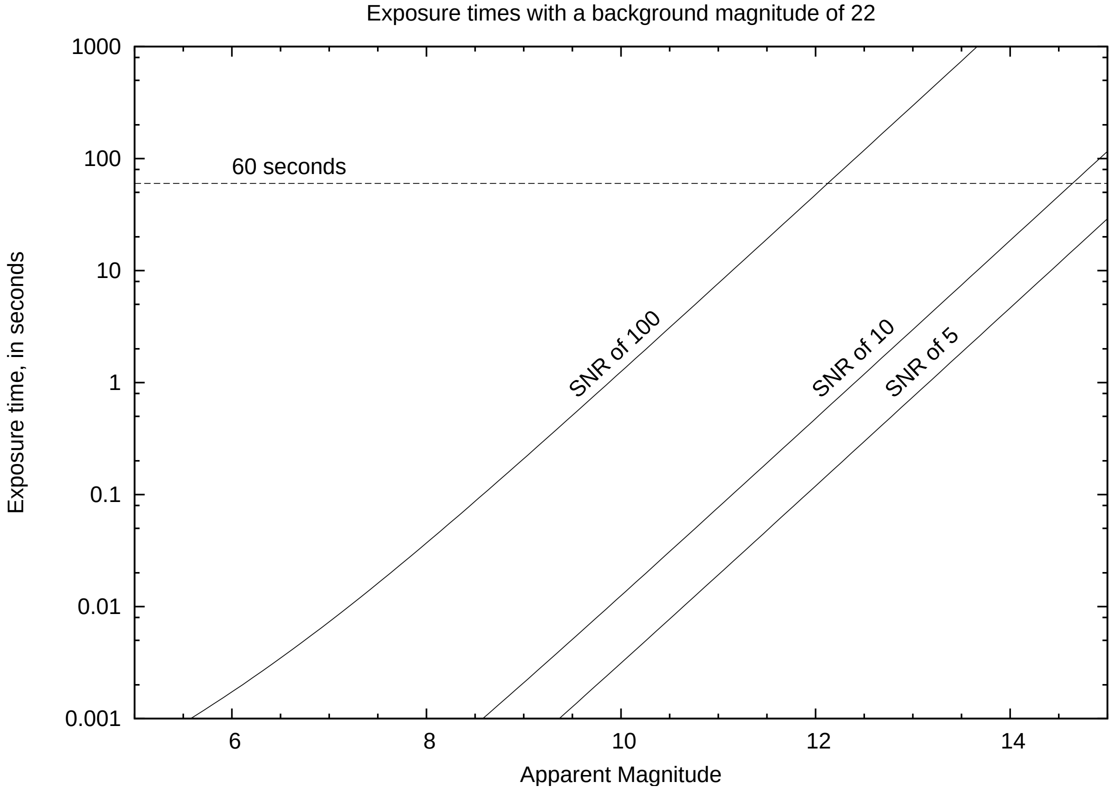

Figure 4: Exposure times for specified signal-to-noise ratios with apparent background magnitude of 22. *Be careful of the logarithmic Y axis!*

2. How many exposures can you take of the Ring Nebula (you should have found the magnitude above) with a signal-to-noise ratio of 100, and a sky with brightness of magnitude 16 in an hour? How many can you take with a signal-to-noise ratio of 100, and a sky with brightness of magnitude 22?

Post-test

1. What do you think the difference of the sidereal times during the two equinoxes that you calculated above means for the stars visible in the night sky?

2. Given what you discovered about Polaris's declination above, why do you think that Polaris is used for navigation in the Northern Hemisphere?

3. Why do you think that astronomers prefer to set up optical telescopes in darker locations?