Making an H-R diagram
Earth & Sky

Name: ______________________________

Introduction

Astronomers have discovered relationships between the surface temperatures and luminosities (brightnesses) of stars. These relationships are often presented in a plot of luminosity versus temperature. From an observer's perspective, color is a measure of temperature, and luminosity is measured in magnitudes, so often one sees plots of magnitude versus color. Keep in mind that these are just different ways of measuring the same two things. In general, plots of this type are called Hertzsprung-Russell diagrams (or H-R diagrams for short). In this activity you will make an H-R diagram for the open cluster M103 using color images from an earlier activity.

Pre-test

1. H-R diagrams traditionally have color/temperature on the horizontal axis (blue/hot on the left, red/cool on the right), and magnitude/luminosity on the vertical axis (large magnitude/faint going down, small magnitude/bright going up). Draw a sketch of what you think an H-R diagram should look like:

Setup

In order to make your H-R diagram, you need to measure the color and magnitude of a number of stars in M103. Since you already have (from an earlier activity) images of M103 through 3 different filters, this is relatively easy. MaxIm DL provides a tool to measure the intensity/magnitude of stars in an image, and color is defined as the difference in magnitude for different filters. The measurement of intensity/magnitude information from an image is called *photometry*, and used to be performed on photographic plates (a much more difficult task).

Open the three images you have of M103 through the R, G, and B filters. Use **Process** > **Calibrate All** to make sure they are properly calibrated. (It's probably also a good idea to set the **Screen Stretch** to **High**.) Then go to **Analyze** > **Photometry** to start MaxIm's photometry tool. In the Photometry window that opens, make sure the **Image List** contains all three images. If there are other open images that appear, use **Exclude** to remove them.

1. Write down the order in which your images appear. This information will be important later on.

Before you continue, makes sure the checkboxes for **Act on all images**, **Use star matching**, and **Snap to centroid** are all checked.

Then place your cursor over the photometry image window. You will see concentric rings instead of a normal cursor. The inner circle is called the *aperture*, the middle ring is called the *gap*, and the outer ring is called the *annulus*. The aperture measures the light from the star, and the annulus measure the sky background, while the gap makes sure the annulus is truly away from the star. The size of all three regions is controlled by right-clicking on an image and selecting an appropriate action from the menu that appears.

Adjust the rings so the aperture fits around a typical star in the image, the gap separates the annulus from the star, and the annulus doesn't start to run into another star.

Photometry

(Important note: DO NOT CLOSE THE PHOTOMETRY WINDOW UNTIL YOU HAVE SAVED YOUR DATA.)

Now, go to the menu **Mouse click tags as:** in the Photometry window. Choose the reference option, and click on star #127, as determined from Figure 2. (Your image should resemble Figure 1; use this to orient yourself in Figure 2.) A copy of the photometry rings will snap into place. Enter 9.23 as the **Ref Mag** in the Photometry window. Once this is done, change **Mouse click tags as:** to **New Object**.

You are now ready to select the stars whose magnitude you want to determine. You want to avoid the very brightest and dimmest while selecting a range of brightnesses. Also, in order to only select stars actually in the cluster, only choose stars listed below Figure 2. Click on the stars you decide on, and as before, photometry rings will appear around them. Note that the rings will automatically snap to the center of the star, so you don't have to be too meticulous about where you click. If you make a mistake, use the **Untag** command in the Photometry window. Also, if the label for a tagged star is in the way, you can click and drag it around.

Select cluster members until you have tagged at least twenty stars. MaxIm DL has automatically tagged the stars in all three images. Click on **View Plot**, then on **Save Data**. This will let you save the measured magnitudes for all your tagges stars in all images as a comma-separated data file. Save your data where you can find it. Once your data is saved, you can close the **Photometry** windows.

Plotting

You now have all the data you need to make an H-R diagram. Open your data file in the program of your choice (Excel and Matlab both work). Each row represents an image, and each column represents a star, while the values are the magnitude of that star in that image. The rows correspond to the ordering you wrote down in **1.**

You can choose any filter magnitude to be your luminosity measurement, and any difference of filter magnitudes to be your color index . Blue versus (Blue - Red) seems to work well. Make a plot of magnitude versus color index (magnitude difference between filters). This is your H-R diagram.

2. Sketch your H-R diagram below. Be sure to label the axes.

Analysis

H-R diagrams that are plotted with thousands of different stars tend to have several distinct groups that stars fall into. You probably noticed that many of the stars fell into a rather distinct curve leading from hotter, bluer, and brighter stars to cooler, redder, and dimmer stars. This curve is known as the Main Sequence, and almost all stars exist on the Main Sequence for the majority of their lives. The curve may, however, seem to curve in on itself with some redder stars also at a higher magnitude. These stars are the giants, stars that used to be hotter and bluer now nearing the end of their lifespan.

Post-test

1. Draw a sketch of what you think an H-R diagram should look like:

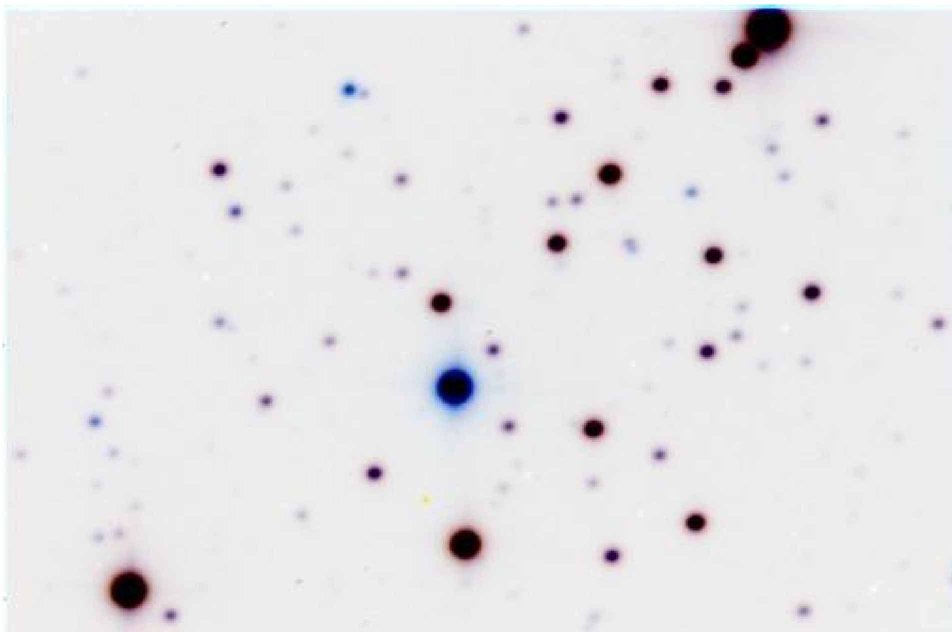

Figure 1: The center of the open cluster Messier 103.

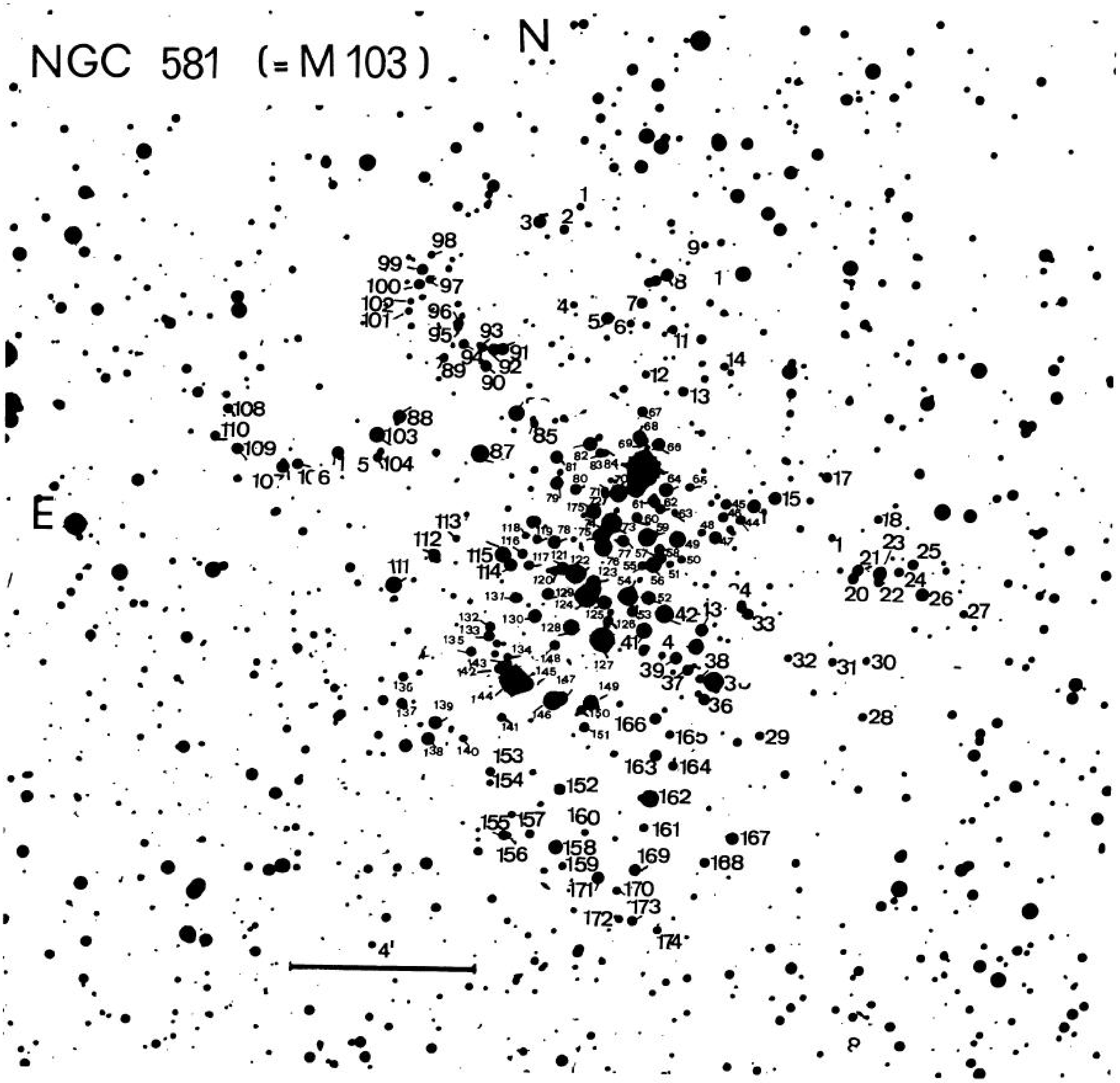

Figure 2: Physical members: 15, 16, 34, 36, 37, 38, 39, 40, 42, 43, 44, 45, 46, 47, 48, 49, 51, 52, 53, 54, 55, 56, 57, 58, 59, 63, 64, 65, 66, 67, 68, 70, 71, 72, 73, 74, 75, 76, 78, 79, 80, 82, 83, 116, 117, 118, 119, 120, 121, 122, 123, 125, 126, 128, 129, 130, 132, 134, 141, 143, 145, 147, 148, 149, 150, 162, 163, 175.