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Creating Hertzsprung-Russell Diagrams Of Open Clusters

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I. INTRODUCTION

This research project is meant to set up Utah State University's 20 inch diameter telescope and use imaging techniques to do research science with stellar clusters. Using known information taken from stellar catalogues, open clusters will be selected to image. From the image, absolute magnitudes or luminosities will be collected from each star in the cluster using imaging software. We will then compare these to their spectral types, or temperatures, to create Hertzsprung-Russell diagrams of the open clusters. A Hertzsprung-Russell (H-R) diagram is a scatter plot of luminosity vs spectral type for stars. The following report will explain target selection of open clusters, imaging methods, and calculations used to create H-R diagrams of open clusters.

II. BACKGROUND

It is widely accepted that stars are formed in clusters from the collapse of a dense molecular cloud. There are generally two classifications of stellar clusters, Open and Globular. Globular clusters are located in the halo of our galaxy, are older than 11 billion years, and contain tens to hundreds of thousands of stars. These clusters are difficult to use for this particular project due to the large number of stars, and large distances to them. We will then only be looking at open clusters. Open clusters range in size from containing just a few to several thousand stars, all of which are roughly the same age, and distance from us. There are more than 1,100 open clusters located in the Milky Way galaxy alone.

Hertzsprung-Russell diagrams plot a star's absolute magnitude (brightness) vs temperature (color). When you plot these two variables, you see an immediate trend. FIG. 3 depicts a typical H-R diagram with the regions labeled for reference. The hottest, and most luminous stars lie at the top left, with the coldest, dimmest stars residing on the bottom right on the graph. Most stars occupy the region known as the main sequence, a negatively sloped line in the center. When a cluster of stars forms, every star begins on the main sequence. Stars that are plotted in this region are currently fusing Hydrogen in their cores; stars spend ninety percent of their lifetimes, on the main sequence. When a star runs out of hydrogen to burn, it begins burning heavier elements and moves off of the main sequence towards the red giant branch. The point on the main sequence where stars start to diverge is called the turnoff point. The mass of these stars is the turn off mass of the cluster. This mass then tells us the

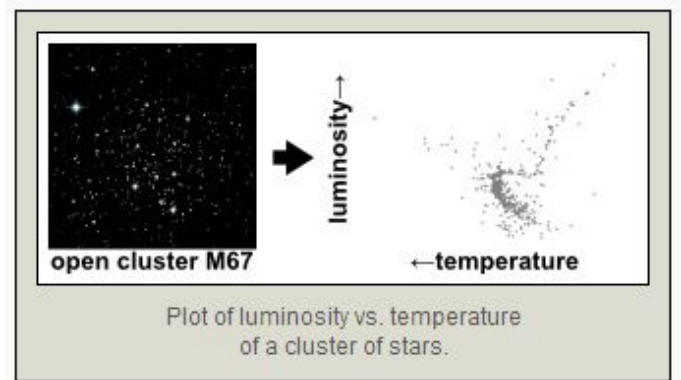


FIG. 1. This diagram depicts an H-R diagram of open cluster M67.

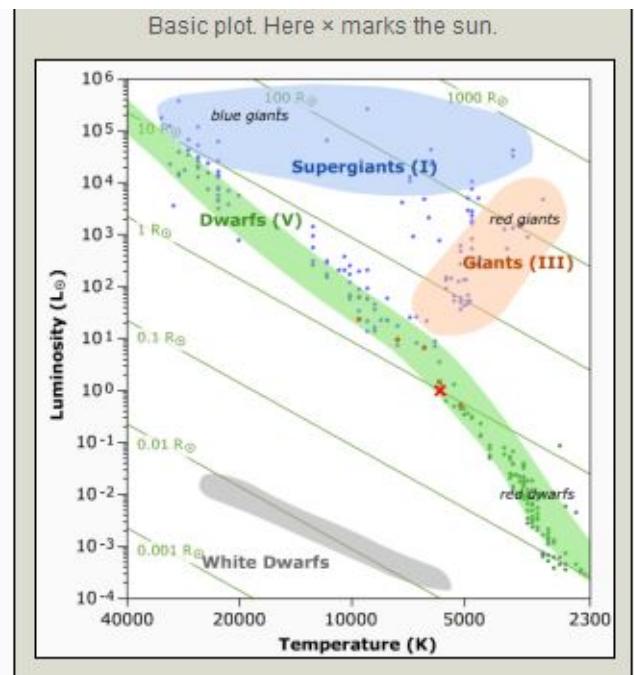


FIG. 2. This is a reference H-R diagram with the sections labeled. The main sequence is colored green. Image credit: University of Nebraska-Lincoln.

age of the cluster.

III. TARGET SELECTION

The NGC/IC Project has the goal of correcting the original NGC catalogue of the 7,840 NGC objects. This

has produced the HCNGC, or the The Historically Corrected New General Catalogue. The HCNGC contains the brightest galaxies, nebulae, and clusters of stars; making it a great source of close, bright open clusters. The HCNGC excel file contains both historical information, as well as contemporary data about each of the 7,840 objects. Filtering out all of the objects, except open clusters, leaves us with 765 possible open cluster candidates. For the purpose of this project, we want to ensure that the open cluster we choose can be imaged easily, with the stars scattered, so that we can get their individual luminosities and colors. So we have to set limiting factors on the size and density of the cluster. The clusters are also sorted by declination, for ease of selection for remote observatories.

A. Cluster Density

To determine whether or not a cluster would be good for imaging, we need to look at the cluster density. In this case, this would be the number of stars belonging to the cluster divided by the number of pixels in the image. The result should be less than one, and the smaller the value, the more pixels per star there will be to cultivate data from. Now, to figure out the pixel scale of an image of a cluster, we will use equation 1.

$$PixelScale = \frac{206,265[arcseconds] * PixelSize}{FocalLength} \quad (1)$$

The Pixel size is intrinsic to the specific camera used. While the focal length is specific to the telescope used. The USU Observatorys main telescope is the CDK20, or 20 Corrected Dall-Kirkham Astrograph telescope. The CDK20 has an aperture to 20 inches and a focal length of 3454mm. The CCD camera used to image with the telescope is the SBIG(SBIG STL-1001E). The Pixel size of the SBIG is 24x24 microns. From equation 1 we can get the relationship between arcseconds and pixels. Dividing pixel size by focal length gives a result in radians. There are 57.3 degrees in one radian, and 57.3*60 arcminutes, or 57.3*3600 arcseconds per radian. To convert this answer from radians to archminutes you just multiply by 3438. The field of view for the chip, or any pixel, is much smaller than one radian. This allows us to use the small angle approximation. This lets us relate the angle theta to pixel width over focal length, and gives us arcseconds per pixel.

$$(arcsec/pixel) = \frac{(PixelSize[\mu m])}{(FocalLength[mm])} \quad (2)$$

For our scope, and camera this gives us $(24[\mu m])/(3454[mm]) = 0.006948466arcsec/pixel$. Now that we know this, the diameter(D) of the selected test cluster(in arcseconds) will be entered in the maple worksheet, getting the angular area of the cluster. The area of the cluster will be multiplied by

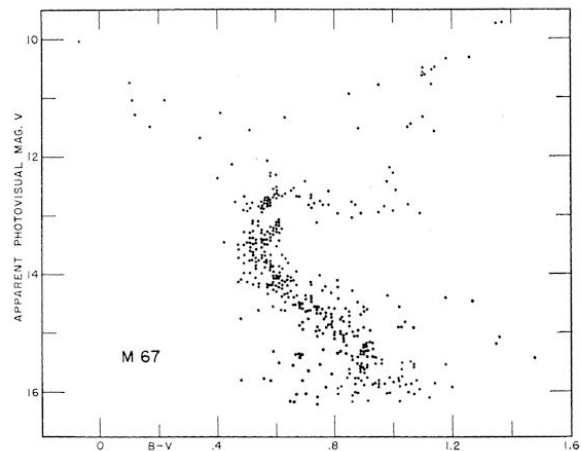


FIG. 3.—The color-magnitude diagram for M67

FIG. 3. This is an H-R diagram of open cluster M67, the graph we hope to create should look very similar to this. image courtesy of AstroImaging.org.¹

the arcseconds/pixel ratio to give the number of pixels the image will contain. Finally, to see whether or not the cluster density is desirable, we divide the number of stars (N_{stars}) contained in the cluster by the pixels.

$$\frac{arcsec}{pixel} * (\pi * (\frac{D}{2})^2) = PixelsInImage \quad (3)$$

$$\frac{N_{Stars}}{PixelsInImage} = ClusterDensity \quad (4)$$

Equation 4 gives the density of stars to pixels, with the desired result being greater than 1. Following the steps through with each test cluster, we can determine a large selection of clusters that would be good for imaging.

IV. FUTURE WORK

In order to take accurate data, we need to have accurate images with the SBIG CCD camera. A basic first step for calibrating a telescope-camera system to do science is flat-fielding. A flat-field correction is a technique of comparing pixels from images of the Dark Frame and Light frame to find and compensate for dust, gains, dark currents and light sensitivity of the camera. Now that a flat field corrector has been made for the SDK20 telescope, we can begin taking images, and taking data. This summer we will take the first photometry measurements of luminosities of open clusters and develop H-R diagrams.

A. Imaging And Taking Data

In order to get the magnitudes of the stars in the cluster, a software needs to be selected. There are many good candidates for software, however we have chosen to use the freeware Iris, an astronomical images processing software. It has been developed to be used with the SBIG CCD cameras, and includes many tutorials for astro imaging.² A more detailed manual for this software will be made during the summer of 2014. To get a stars magnitude, you will need to set a reasonable magnitude constant in each filter (B band,R band,V band) as well as select 3 radii. The first radii is labeled radius1, which surrounds where the starlight will be added (it should encompass all the detected light of the star). Radius 2 and radius 3 are the annulus where sky light is subtracted. Doing this for each star, you will compile a spreadsheet of the magnitude values in each filter. A stars luminosity and temperature (or B-V color index) determine its position on the H-R diagram. Next we will create an H-R diagram with the magnitudes we have in the spreadsheet. To get the B-V index, we will take the magnitude difference of each star in the B and V filters. Plotting the B-V magnitudes on the horizontal axis, and the absolute magnitudes on the vertical axis. The color (magnitude) of the star at the top left of the main sequence will correspond to the lifetime of the open cluster.

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