Finding the best ugrizy filter to use on the LSST at the Rubin Observatory when using the TRGB method.

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Abstract:

When measuring the distance of galaxies, the stars of the galaxies' chemical properties often disrupt the accurate measurement. The purpose of this research is to find the best filter to accurately measure distance using the Tip of the Red Giant Branch method with the Large Synoptic Survey Telescope at the Rubin Observatory. The y filter of the ugrizy filters is the best filter for the Large Synoptic Survey Telescope at Rubin Observatory when observing distance using the Tip of the Red Giant method.

Introduction:

Throughout the last century, scientists have been formulating ways in order to measure the distance between galaxies in order to deepen humanity's overall knowledge about outer space. The hunger to find new ways of measuring the galaxy led to incredible scientific achievements. This includes the discovery of the Tip of the Red Giant Branch method and the construction of the Large Synoptic Survey Telescope.

LSST:

The LSST is a powerful telescope located at the Rubin Observatory in central Chilé. LSST stands for Large Synoptic Survey Telescope, and the purpose of the telescope to map the galaxy and small objects in our solar system. The LSST is not fully built yet and is currently being constructed and improved every day. In this study, I used the LSST to conduct research.

TRGB Method:

The Tip of the Red Giant Branch method is a technique used by scientists to measure distance between galaxies using the luminosity and temperature of stars **[1][6]**. The TRGB can be used to measure distance because of its bright luminosity **[2]**. This method however can be highly disrupted by external factors. These external factors can include the chemical properties of the stars as those chemical properties can exaggerate the luminosity and temperature of said stars. These disturbances, however, can be reduced using photometric filters. It is important to reduce the amount of disturbances when using the TRGB method or else it can give misleading data regarding distance to nearby galaxies **[4]**. The LSST uses the ugrizy filter set and the purpose of this study is to find out which filter out of the ugrizy filter set is the best to reduce disturbances when using the TRGB method.

Significance:

This research is new and original as the Large Synoptic Survey Telescope (LSST) at Rubin Observatory is a new telescope with little research done on it. With the LSST being a very powerful telescope, using the TRGB method on the telescope can deepen our overall knowledge about outer space as accurate data about the distance to galaxies can give us information about planets, stars, and other entities in space. That is why it is important to find the correct photometric filter for the LSST telescope at Rubin Observatory.

Objectives: The purpose of the research is to find the best filter out of the ugrizy filter set to accurately measure distance using the TRGB method with the LSST at the Rubin Observatory.

Hypothesis: The i filter of the ugrizy filters is the best expected filter for the LSST at Rubin Observatory when observing distance using the TRGB. I expect this filter to be the best as it is also used by multiple other world-renowned telescopes for accurate data gathering.

Materials & Methods: The Tip of the Red Giant Branch is a method used by scientists to measure distance to galaxies. The data (luminosity & temperature) will be gathered using a simulation. The data will be analyzed through a graph.

1. **Materials:**
    - Computers to use a simulation and excel
    - Access to Excel Spreadsheets
    - The simulation website for data collection: http://stev.oapd.inaf.it/cgi-bin/cmd
2. **Methods**
    - The Tip of the Red Giant Branch Method for distance measurement
    - The use of Excel graphs in order to use the TRGB method

Experimental/Simulations Design and Data Analysis: The simulation will first be conducted by entering data into a color magnitude diagram (CMD) input. From there, a simulation will occur in which a CSV file will be outputted. Next, the data from the CSV file is uploaded into an excel sheet. Finally, a graph is produced from the data using excel functions. In this experiment, I did this process with varying metallicities and gigayear ages to produce accurate data. The process was repeated with the metallicities of [M/H] = 0, -1, and -2 and varying gigayear (gyr) ages of 9, 11, and 13.

Metallicity ([M/H]) is the abundance of metals in a star. [M/H] should not affect the correlation of the data when varying it. If [M/H] does affect the correlation of the data, then the photometric filter does not do a good job reducing the amount of disturbances when using the TRGB method. A gigayear (gyr) is 1 billion years. I aged the stars in the experiment as gyrs should not affect the correlation of the data when varying it. If gyrs do affect the correlation of the data, then the

photometric filter does not do a good job reducing the amount of disturbances when using the TRGB method.

Results:

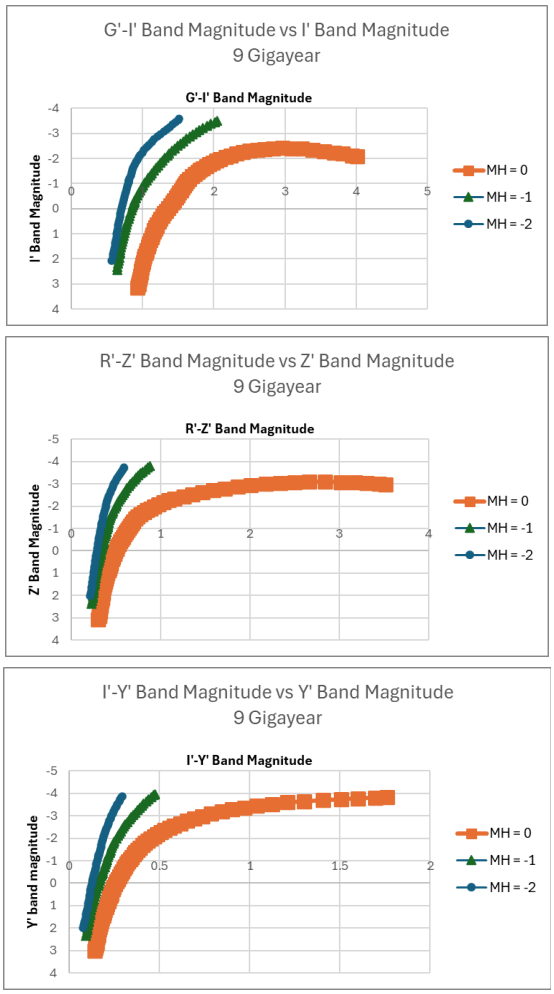


Figure 1. The figure above compares the nine gigayear age graphs between different photometric filters. It also compares the data of varying metallicities of each photometric filter. The results are similar in 11 gyr age and 13 gyr age graphs. Check Figure 2 below.

When comparing photometric filters, the color magnitude diagrams are usually compared between each other in the ‘x-y vs y’ format and so on. Color magnitude diagrams use the ‘x-y vs y’ because it helps emphasize the color differences between filters when comparing them. The

y-axis of the graphs are also in reverse as the y-axis shows luminosity and it is traditionally correct to have the luminosity negative to positive. In order to check which graph is most accurate, you must first see which graph is the most constant between the varying metallicities. We know that varying metallicity (abundance of metals, [M/H]) should not change correlation of the data as metallicity only affects the luminosity and color, therefore, the data should be close to constant when varying metallicities. When referring to figure 1, the photometric filters have varying results. Figure 1 shows that the y filter (picture 3) stays the most constant when varying metallicities. The i filter (picture 1) is heavily distorted when comparing the difference between the metallicities. The z filter's correlation (picture 2) is better than the i filter's correlation (picture 1) but is still worse than the y filter's correlation (picture 3) between varying metallicities. This trend is also seen in different gigayear ages for the same graphs (check figure 2). Therefore, the y filter is the best photometric filter to use when accurately finding the distance between galaxies using the TRGB method.

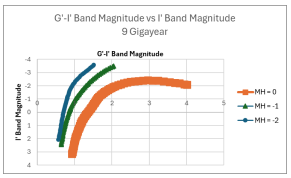
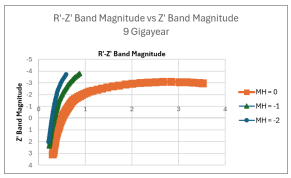
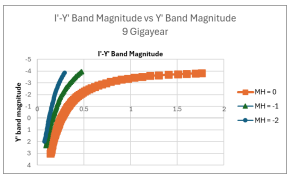
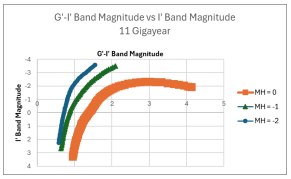
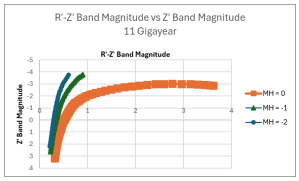
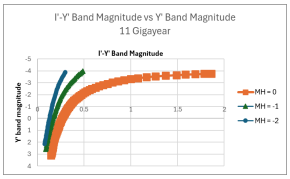
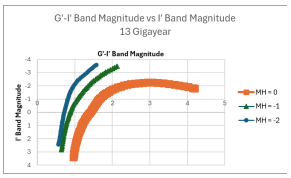
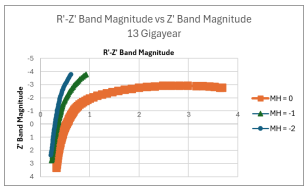
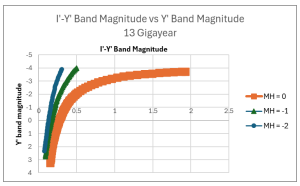
	g-i Band Magnitude vs i Band Magnitude	r-z Band Magnitude vs z Band Magnitude	i-y Band Magnitude vs y Band Magnitude
9 Gigayear			
11 Gigayear			
13 Gigayear			

Figure 2. The figure above shows the comparison of all TRGB graphs between photometric filters, gigayear age, and metallicities.

Discussion:

Reflecting back on the initial hypothesis, I was originally wrong. The i filter is not the best filter to use on the LSST when using the TRGB method. However, the y filter is the best filter to use on the LSST when using the TRGB method. Using CMDs, metallicity, gyr ages, simulations, and graphing tools, I have come to this conclusion. This type of experiment has been used many different times for other reasons. For example, some scientists have used CMDs to study the TRGB method **[3]**. Another team of scientists have used CMDs to study different filters and their effect on the TRGB method **[5]**. Therefore, I used CMDs for my study and came to a reasonable

conclusion as other scientists have before me. With this new research established, we can now advance scientific studies to deepen humanity's knowledge about space using the TRGB on the LSST.

Conclusion:

After my studies, it is evident that the y filter is the best filter out of the ugrizy filter set to use on the LSST at Rubin Observatory when using the TRGB method as it gives the most accurate results with varying [M/H] and age.

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