

Due: Fri Nov 7 2014 12:00 PM EST

Question

1

Instructions

Lab 5: The Cosmic Distance Ladder II: Standard Candles

Read the lab before attending lab. You might find it easier to navigate if you expand only one or two sections at a time.

The following summary video is available to you in case you miss lab or want to review it when completing the lab:

[Cosmic Distance Ladder II: Standard Candles](#) (19:37)

You are permitted 100 submissions per question. Use some of these to save your work.

If you do not save your work periodically, you risk losing it when WebAssign times you out. WebAssign does this after a few hours for security reasons.

Do not open multiple copies of this assignment, or multiple WebAssign assignments, or you risk losing your answers upon saving or submitting.


Enter all calculated values to at least two significant digits.

Do not add units when entering numerical responses. WebAssign will not accept your response.

Do not use special characters when naming files. WebAssign will not accept your file.

IMPORTANT: Submit your observations for Lab 6 immediately. These observations take up to a week to complete, and you must have them to do Lab 6. Instructions for submitting these observations can be found in Lab 6, Procedure, Section B, Part 1.

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1.  Question Details

UNCAstro101L1 5.IL.001. [2208228]

LAB 5 — COSMIC DISTANCE LADDER II: STANDARD CANDLES

GOALS

In this lab, you will:

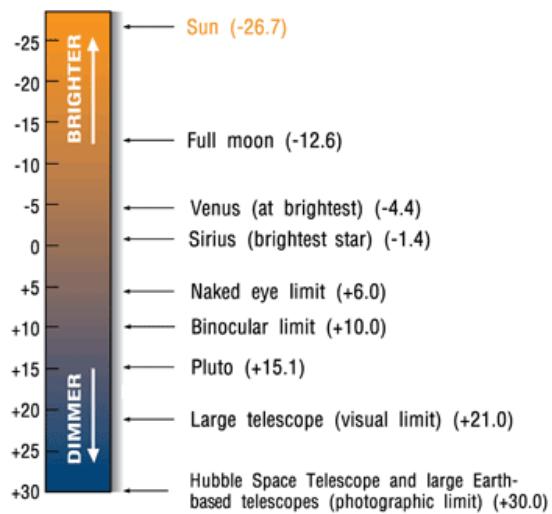
- Use RR Lyrae variable stars to measure distances to objects within the Milky Way galaxy.
- Use Cepheid variable stars to measure distances to nearby galaxies.
- Use Type Ia supernovae to measure distances to faraway galaxies.

EQUIPMENT

Computer with Internet connection

BACKGROUND: A. MAGNITUDES

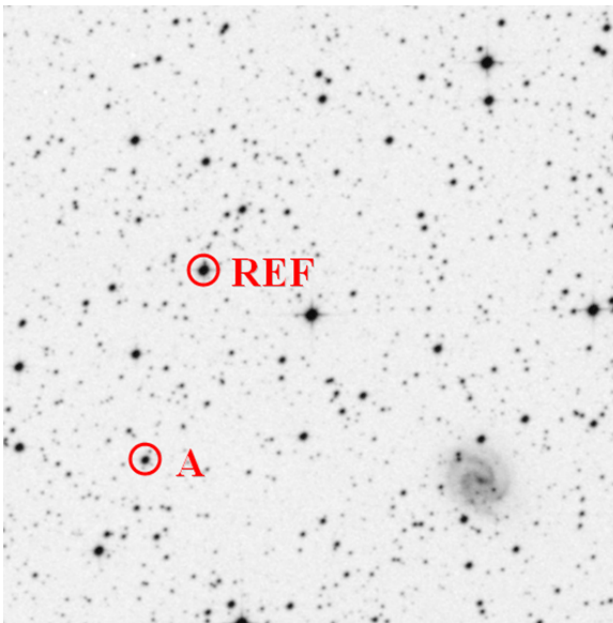
Astronomers use **apparent magnitudes**, which are often referred to simply as magnitudes, to measure brightness.



The more negative the magnitude, the brighter the object. The more positive the magnitude, the fainter the object.

In this [tutorial](#), you will learn how to measure, or **photometer**, uncalibrated magnitudes.

In [Afterglow](#), go to "File", "Open Image(s)", "Sample Images", "Astro 101 Lab", "Lab 5 — Standard Candles", "CD-47" and open the image "CD-47 8676".



Question: Using the above finder chart, measure the uncalibrated magnitude of star A to two decimal places. (2 points)

mag

Uncalibrated magnitudes are always off by a constant and this constant varies from image to image, depending on observing conditions among other things. To calibrate an uncalibrated magnitude, one must first determine the value of this constant, which we do by photometering a **reference star** — a star of **known** magnitude — in the image.

Question: Using the finder chart, measure the uncalibrated magnitude of the marked reference star to two decimal places. (2 points)

mag

Question: The known, true magnitude of this reference star is 12.01. Calculate the correction constant to two decimal places. (2 points)

correction constant = true magnitude of reference star – uncalibrated magnitude of reference star

mag

Question: Finally, calibrate the uncalibrated magnitude of star A to two decimal places by adding the correction constant to it. (2 points)

calibrated magnitude = uncalibrated magnitude + correction constant

mag

The true magnitude of star A is 13.74. Your calibrated magnitude should be within a few hundredths of a magnitude of this value. If it is not, check that you selected the correct stars and check your math, until you arrive at the correct answer.

⊞ BACKGROUND: B. STANDARD CANDLES

In Lab 4, we learned that distance is one of the most difficult things to measure in astronomy. In Lab 4, we learned a technique for measuring the distances to nearby stars, called parallax. However, if a star is more distant than about 0.5 kiloparsecs (about 1,600 light years), its parallax angle is too small to be measured with current technology. Consequently, its distance cannot be determined in this way.

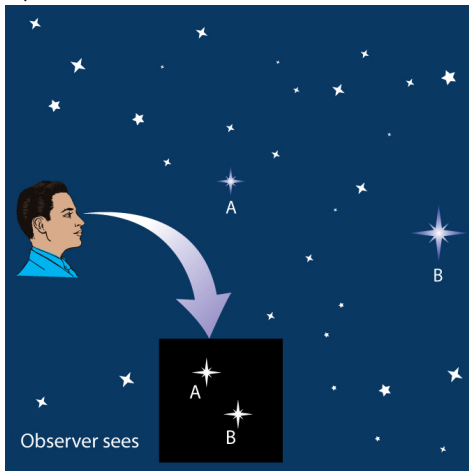
However, if the luminosity, L , of the star is known, its distance, D , can be calculated by measuring its brightness, B :

$$B = \frac{L}{4\pi D^2}.$$

Solving for distance yields:

$$D = \sqrt{\frac{L}{4\pi B}}.$$

Imagine that you see a light off in the distance. You cannot tell how far away it is but you can measure how bright it is. Perhaps it is a low wattage light bulb not very far away. Or perhaps it is a high wattage light bulb very far away. Or perhaps it is something in between. You can measure its brightness **but unless you know its wattage — which is the same thing as its luminosity** — you cannot use the above equation to calculate its distance.



An object of known luminosity is called a **standard candle**. Most stars are not standard candles — their luminosities are not known and consequently their distances cannot be easily calculated. However, some special types of variable and exploding stars do have known, standard luminosities. Consequently, **if you can identify a star as being one of these special types, you know its luminosity**. Then you only have to measure its brightness to be able to compute its distance.

Instead of brightness and luminosity, astronomers use **apparent magnitude, m** , for brightness and **absolute magnitude, M** , for luminosity. The above equation giving D as a function of B and L can be rewritten as an equation giving D as a function of m and M :

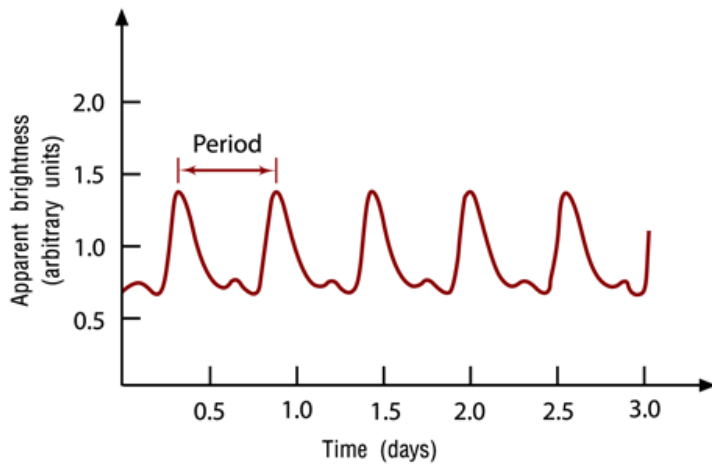
$$D = 0.01 \text{ kpc} \times 1.585^{(m - M)}.$$

In this lab, you will measure the distances to three standard candles: two types of variable stars and one type of exploding star, or supernova. For each one, you will (1) confirm that it is a standard candle, (2) use this knowledge to determine its absolute magnitude (think luminosity), (3) measure its apparent magnitude (think brightness), and (4) use the above equation to calculate its distance.

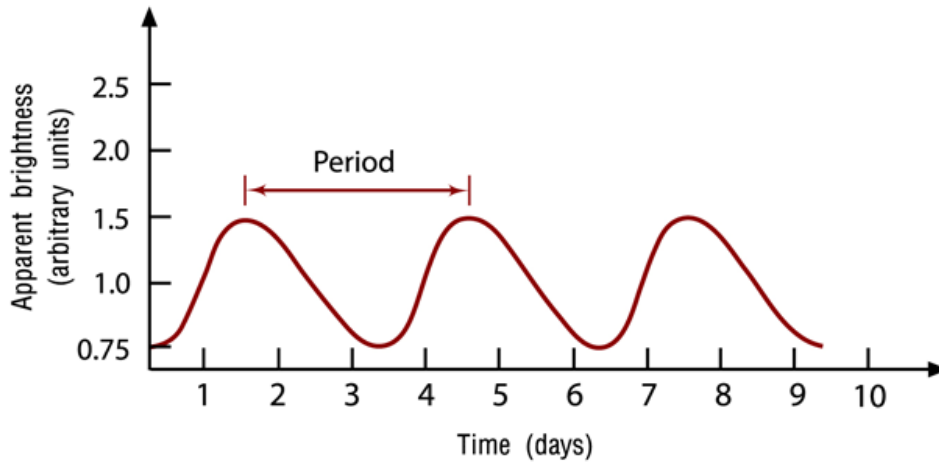
⊞ BACKGROUND: C. RR LYRAE AND CEPHEID VARIABLE STARS

RR Lyrae and Cepheid stars are two types of variable stars. Their outer layers expand and contract over and over. They grow brighter as they expand and fainter as they contract.

Some RR Lyrae stars vary with periods as short as seven hours and some vary with periods as long as one day.



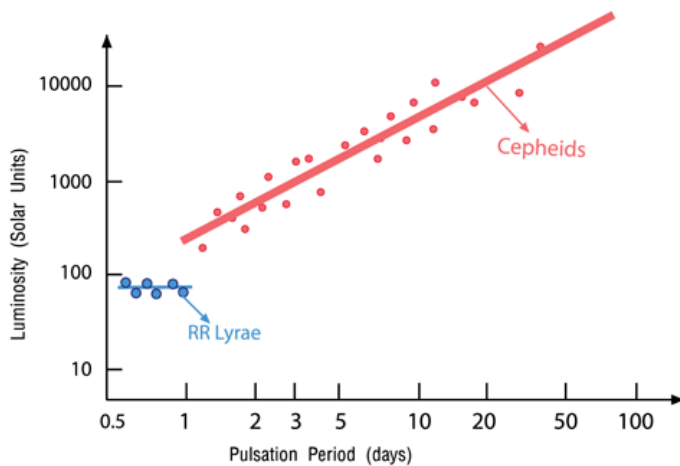
Cepheid stars vary with longer periods, ranging between a few days and a few months.



Distances have been measured to **nearby** RR Lyrae stars in our galaxy using parallax techniques (see Lab 4). These distances, in combination with measurements of the stars' average apparent magnitudes (think average brightnesses), made possible the calculation of their average absolute magnitudes (think average luminosities). **It turned out that all RR Lyrae stars have about the same average absolute magnitude: $M \approx 0.75$.**

Consequently, **if** a variable star's period reveals it to be an RR Lyrae star, its $M \approx 0.75$. This information can be used to calculate distances to **faraway** RR Lyrae stars, such as those in the globular star clusters that orbit our galaxy.

Distances have also been measured to **nearby** Cepheid stars in our galaxy using parallax techniques (see Lab 4). These distances, in combination with measurements of the stars' average apparent magnitudes (think average brightnesses), made possible the calculation of their average absolute magnitudes (think average luminosities). **It turned out that all Cepheid stars have average absolute magnitudes that are related to their periods in the following way.**



Written as an equation:

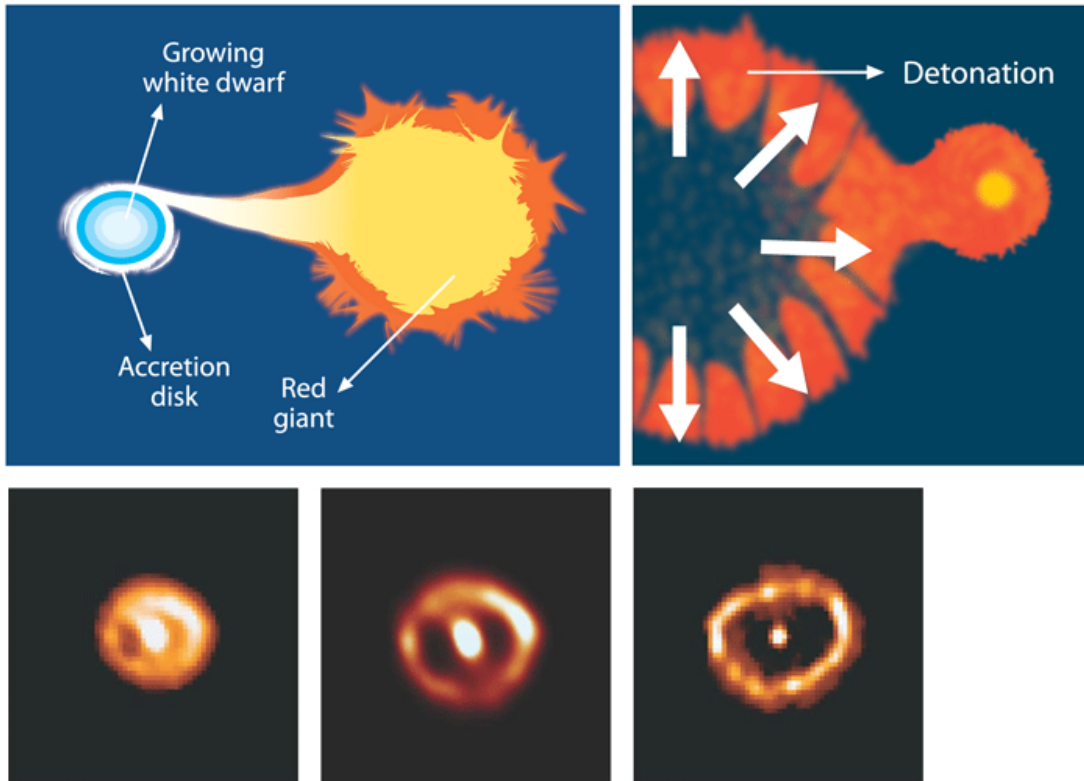
$$M \approx -1.43 - \left[2.81 \times \log\left(\frac{P}{1 \text{ day}}\right) \right].$$

Note: In this equation, "log" is a base 10 logarithm. If using a spreadsheet, it will incorrectly be treated as a natural logarithm.

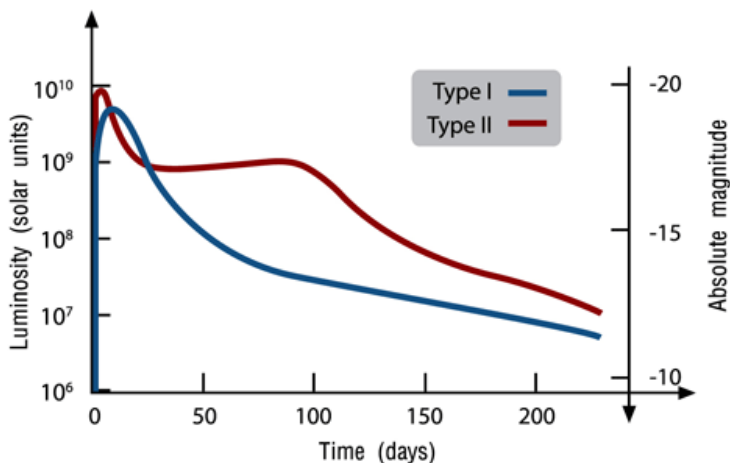
Consequently, if a variable star's period reveals it to be a Cepheid star, its $M \approx -1.43 - [2.81 \times \log(P / 1 \text{ day})]$. This information can be used to calculate distances to **faraway** Cepheid stars, such as those in nearby galaxies.

BACKGROUND: D. TYPE Ia SUPERNOVAE

Type Ia supernovae are a type of exploding star. They occur when a compact star, called a white dwarf, orbits too close to a giant star. Gas flows from the giant star to the white dwarf, increasing its mass until it begins to collapse under its own weight. As the white dwarf collapses, it heats up, until it reaches 6×10^8 K, the temperature at which carbon fusion occurs. Since white dwarfs are primarily made of carbon, the entire star ignites and explodes, resulting in what we call a Type Ia supernova.



Type Ia supernovae can be distinguished from other types of supernovae by their brightness history, or **light curve**. Type Ia supernovae fade away after the peak, but other types of supernovae plateau for months after they peak, before they fade away.



Distances have been measured to **nearby** galaxies in which Type Ia supernovae have occurred by finding Cepheid stars in those galaxies and measuring the distances to them. These distances, in combination with measurements of the supernovae's peak apparent magnitudes (think peak brightnesses), made possible the calculation of their peak absolute magnitudes (think peak luminosities). **It turned out that all**

Type Ia supernovae have about the same peak absolute magnitude: $M \approx -19.3$.

Consequently, if a supernova's light curve reveals it to be a Type Ia supernova, its $M \approx -19.3$. This information can be used to measure distances to **faraway** Type Ia supernovae, such as those in faraway galaxies.

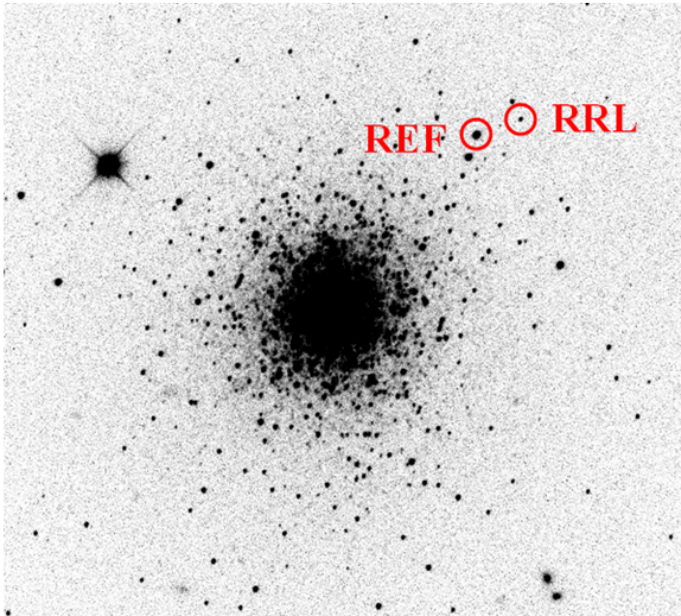
PROCEDURE: A. DISTANCE TO A GLOBULAR CLUSTER - 1. Observe a Globular Cluster

First, we are going to monitor an RR Lyrae star in a globular cluster once an hour for a week. The following globular clusters are observable from PROMPT for most of the night in different semesters.

Semester: Northern-Hemisphere Fall (Southern-Hemisphere Spring)

Globular Cluster: NGC 1261

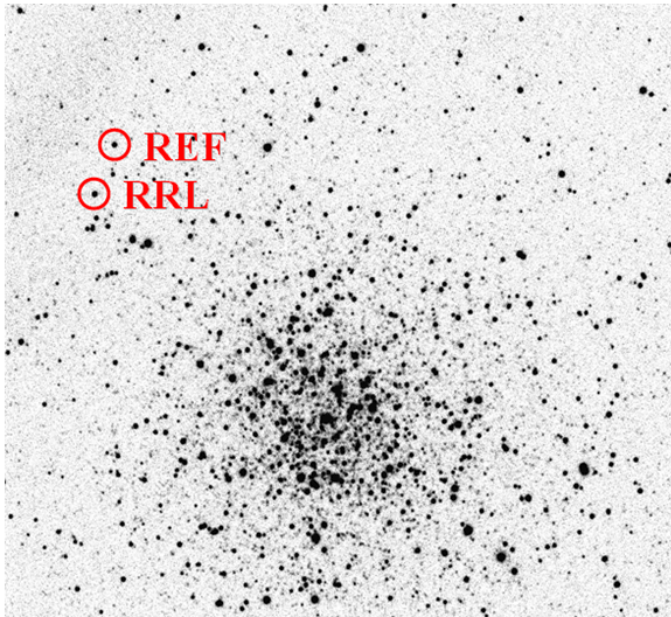
Reference Star's Magnitude: 13.87



Semester: Northern-Hemisphere Spring (Southern-Hemisphere Fall)

Globular Cluster: NGC 3201

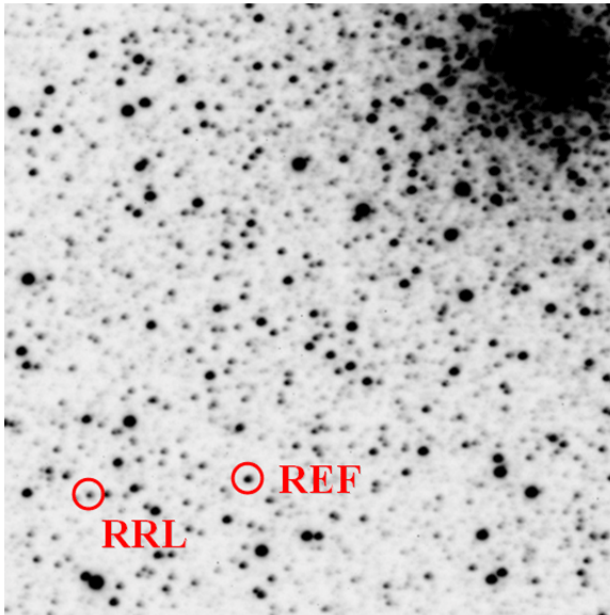
Reference Star's Magnitude: 13.60



Semester: Northern-Hemisphere Summer (Southern-Hemisphere Winter)

Globular Cluster: M28

Reference Star's Magnitude: 12.98



The RR Lyrae star and a reference star of known magnitude have been marked in each image. The reference star's known magnitude, which appears above each finder chart, has been corrected for the dimming effects of intervening dust.

This observation will require many exposures — too many for Skynet to complete if everyone in every section requests them. Consequently, we will request only one set of exposures per section: Your instructor will request one exposure every hour for 7 days \times 24 hours/day = 168 hours on all available PROMPT telescopes except for PROMPT-2, 7, and 8. Each exposure will be 80 seconds in duration and taken through the V filter.

Question: Which globular cluster is your section observing? (1 point)

- ☐ NGC 1261
- ☐ NGC 3201
- ☐ M28

You will be able to access these images once they are completed from your instructor's folder under "Sample Images", "Astro 101 Lab", "Lab 5 — Standard Candles".

PROCEDURE: A. DISTANCE TO A GLOBULAR CLUSTER - 2. Determine the Distance to the Globular Cluster

Next, you must photometer and calibrate the RR Lyrae star in each image. You could do this for each image separately, but this would be a lot of work. In this [tutorial](#), you will learn how to photometer objects in many images simultaneously.

Use [Afterglow](#) to photometer the RR Lyrae star and the reference star in each of your images.

Select "Centroid Sources" and "Stellar Method (PSF)". Select "Use WCS".

In one of your images, select the RR Lyrae star and label it. Select the reference star and label it. To find these stars, use your globular cluster's finder chart in Section A.1.

Note: It is very important that you select the correct stars!

Select "Find Sources In All Images". Check a few of your other images to confirm that Afterglow did this correctly. Note that some of the images might be rotated 180°, depending on which side of the meridian the mount was on.

In this [tutorial](#), you will learn about period folding.

In this [tutorial](#), you will learn how to graph your data and measure a variable star's period.

Make a graph of calibrated magnitude vs. period-folded time.

Calibrate the variable star's uncalibrated magnitudes by subtracting the reference star's uncalibrated magnitudes and adding the reference star's known magnitude, which appears above your globular cluster's finder chart in Section A.1. Do this by selecting the variable star, selecting the reference star, and entering the reference star's known magnitude.

Use "Fourier View" to get a first guess for the period. Set "Start Period" to 0.3 days, "Stop Period" to 1 day, "Step Size" to 0.001 days,

and make sure that "Period Folding" is turned off.

Go back to "Light Curve View". Turn "Period Folding" on and fine-tune the period until the data form a single, full cycle of the light curve. Save your final graph as a png file.

Question: Upload your final png graph. (5 points)

No file chosen

Question: The time between peaks (or troughs) is the period. Record the period (P). (1 point)

days

Question: Is this period consistent with the star being an RR Lyrae star? (1 point)

- ☐ Yes
- ☐ No

Question: If so, what is the star's average absolute magnitude (M) (think average luminosity) to 0.01 magnitudes? (1 point)

Halfway between the peak and the trough is the average apparent magnitude (think average brightness) of the star.



Question: Estimate the average apparent magnitude (m) to 0.05 magnitudes. (1 point)

Question: Calculate the distance (D) to the RR Lyrae star, and hence to the globular cluster, using its absolute and apparent magnitudes. (1 point)

kpc

Show your work. (1 point)

Question: Wiki and record the true distance (D) to the globular cluster. (1 point)

kpc

Question: Calculate your percent error. (1 point)

%

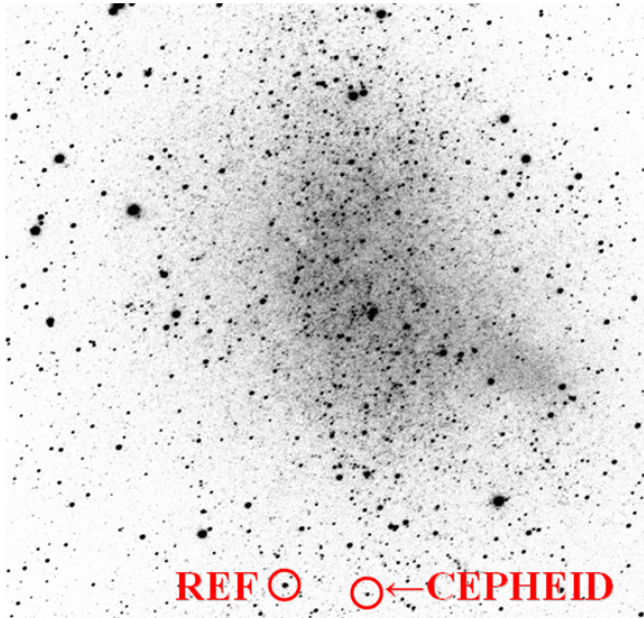
Question: Discuss significant sources of error. (2 points)

PROCEDURE: B. DISTANCE TO A NEARBY GALAXY

Next, we are going to use a Cepheid star to measure the distance to a nearby galaxy:

Galaxy: NGC 6822

Reference Star's Magnitude: 15.25



The Cepheid star and a reference star of known magnitude have been marked. The reference star's magnitude, which appears above the finder chart, has been corrected for the dimming effects of intervening dust.

Since this observation takes months to complete, we have carried it out for you in advance. You can access these images under "Sample Images", "Astro 101 Lab", "Lab 5 — Standard Candles", "Nearby Galaxy NGC 6822".

Use [Afterglow](#) to photometer the Cepheid star and the reference star in each of your images.

Select "Centroid Sources" and "Stellar Method (PSF)". Select "Use WCS".

In one of your images, select the Cepheid star and label it. Select the reference star and label it. To find these stars, use the finder chart.

Note: It is very important that you select the correct stars!

Select "Find Sources In All Images". Check a few of your other images to confirm that Afterglow did this correctly. Note that some of the images might be rotated 180°, depending on which side of the meridian the mount was on.

Make a graph of calibrated magnitude vs. period-folded time.

Calibrate the variable star's uncalibrated magnitudes by subtracting the reference star's uncalibrated magnitudes and adding the reference star's known magnitude, which appears above the finder chart. Do this by selecting the variable star, selecting the reference star, and entering the reference star's known magnitude.

Use "Fourier View" to get a first guess for the period. Set "Start Period" to 1 day, "Stop Period" to 200 days, "Step Size" to 0.5 days, and make sure that "Period Folding" is turned off.

Go back to "Light Curve View". Turn "Period Folding" on and fine-tune the period until the data form a single, full cycle of the light curve. Save your final graph as a png file.

Question: Upload your final png graph. (5 points)

No file chosen

Question: The time between peaks (or troughs) is the period. Record the period (P). (1 point)

days

Question: Is this period consistent with the star being a Cepheid star? (1 point)

- ☐ Yes
- ☐ No

Question: If so, calculate the star's average absolute magnitude (M) (think average luminosity) to 0.01 magnitudes? (1 point)

Show your work. (1 point)

Question: Half the distance between the peak and the trough is the average apparent magnitude (m) (think average brightness) of the star. Estimate this to 0.05 magnitudes. (1 point)

Question: Calculate the distance (D) to the Cepheid star, and hence to the nearby galaxy, using its absolute and apparent magnitudes. (1 point)

kpc

Show your work. (1 point)

Question: Wiki and record the true distance (D) to NGC 6822. (1 point)

kpc

Question: Calculate your percent error. (1 point)

%

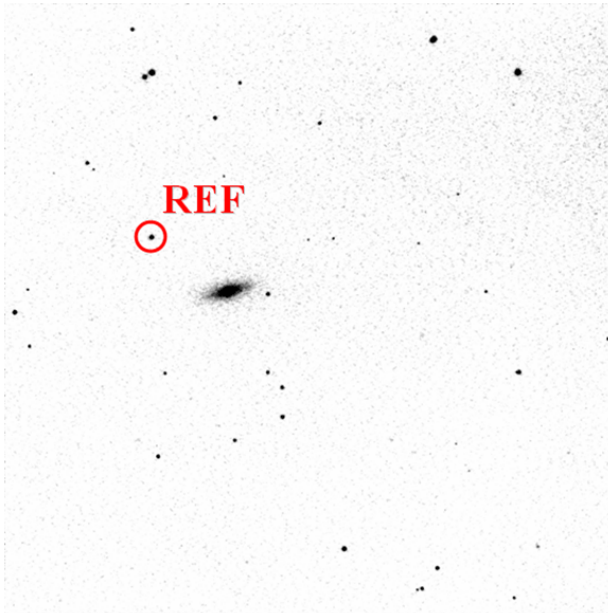
Question: Discuss significant sources of error. (2 points)

+ PROCEDURE: C. DISTANCE TO A FARAWAY GALAXY

Finally, we are going to use a Type Ia supernova to measure the distance to a faraway galaxy. Since supernovae occur unpredictably, we will use one that has already been discovered and monitored with PROMPT (PROMPT is the leading discoverer of supernovae in the southern hemisphere).

Galaxy: NGC 2765

Reference Star's Magnitude: 14.39



A reference star of known magnitude has been marked. The reference star's magnitude, which appears above the finder chart, has been corrected for the dimming effects of intervening dust.

You can access these images under "Sample Images", "Astro 101 Lab", "Lab 5 — Standard Candles", "Faraway Galaxy NGC 2765".

First, use [Afterglow](#) to identify which object is the supernova.

Select and align all of the images from this telescope. For "Alignment Method", select "One Star Manual". For "Cropping Method", select "Intersection". Select "Centroid Sources" and "Stellar Method (PSF)". In your first image, identify a bright, but not saturated, star that is not on the edge of the image. Align to this star in each of the images.

Turn your selected and aligned images into a movie. The supernova will be the fading object. To better see which object is fading, stop the movie, select "Histogram", set "Max" to "99.99", "Equalize Histogram", and restart the movie. Hint: it is close to the galaxy.

Download your movie and check it by playing it with other software on your computer.

Note: Do not be distracted by the rapidly flickering pixels. They are caused by cosmic rays striking the camera.

Question: Upload your final avi or mov movie. (5 points)

No file chosen

Use Afterglow to photometer the supernova and the reference star in each of your images.

Select "Centroid Sources" and "Stellar Method (PSF)". Select "Use WCS".

In one of your images, select the supernova and label it. Select the reference star and label it. To find the reference star, use the finder chart.

Note: It is very important that you select the correct stars!

Select "Find Sources In All Images". Check a few of your other images to confirm that Afterglow did this correctly. Note that some of the images might be rotated 180°, depending on which side of the meridian the mount was on.

Make a graph of calibrated magnitude vs. time.

Calibrate the supernova's uncalibrated magnitudes by subtracting the reference star's uncalibrated magnitudes and adding the reference star's known magnitude, which appears above the finder chart. Do this by selecting the supernova, selecting the reference star, and entering the reference star's known magnitude.

Note: Your graph should be dominated by fading, not noise. If it is dominated by noise, you selected the wrong star for the supernova. Try again!

Do not use "Fourier View" and do not period fold. Save your final graph as a png file.

Question: Upload your final png graph. (5 points)

No file chosen

Question: Is the light curve consistent with the supernova being a Type Ia supernova? (1 point)

☐ Yes

☐ No

Question: If so, what is the supernova's peak absolute magnitude (M) (think peak luminosity) to 0.1 magnitudes? (1 point)

Question: Estimate the peak apparent magnitude (m) (think peak brightness) of the supernova to 0.1 magnitudes. (1 point)

Question: Calculate the distance (D) to the supernova, and hence to the faraway galaxy, using its absolute and apparent magnitudes. (1 point)

 kpc

Show your work. (1 point)

Question: The true distance (D) to NGC 2765 is 56,000 kpc. Calculate your percent error. (1 point)

 %

Question: Discuss significant sources of error. (2 points)

Assignment Details

Name (AID): **Lab 5: Distance Ladder II: Standard Candles (T) (2628698)**

Submissions Allowed: **100**

Category: **Homework**

Code:

Locked: **Yes**

Author: **Reichart, Daniel** (reichart@physics.unc.edu)

Last Saved: **Jun 19, 2013 05:39 PM EDT**

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