# Can we communicate with an alien star system?

## The challenge

Recently, astronomers have discovered more than 100 stars, in addition to our own Sun, that are orbited by planets! No one knows whether these alien star systems contain life.

The *solar system* is our Sun plus all the planets, moons and other objects that orbit it.

A *star system* is a star plus all the planets, moons and other objects that orbit it.

You have been asked by the United Nations to explore the possibility of traveling to one of these alien star systems. The U.N. also wants you to explore the possibility of communicating, from Earth, with any life forms that might exist there.

Your challenge is to use the telescope to determine the distance to one of these newly-discovered star systems. Using your findings, report on: How long would it take to reach the star and its planets by spaceship? Could we communicate with beings that might exist there?

Artist's conception of planets orbiting a star similar to our Sun.

 

# Part 1. Your ideas about stars

Suppose that the Earth were always cloudy at night, so that no one had ever seen the night sky. Would it make a difference to you? If so, how?

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______________________________________________________

______________________________________________________

Do you think it's possible to travel to the stars? Would you want to go? If so, why? What would you expect / hope to find?

______________________________________________________

______________________________________________________

______________________________________________________

Describe some of the stories or movies you've seen in which humans travel between star systems. How do they do it?

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______________________________________________________

______________________________________________________

Do you think there are intelligent creatures on planets orbiting other stars? Do you think any of them have ever visited Earth?

______________________________________________________

______________________________________________________

______________________________________________________

 

# Part 2. Planning your exploration

Before you pack your bags for a trip, you need to know how far you'll be going and how long you'll be gone. But how can you tell how far the stars are? In this challenge, you'll choose a star similar to our own Sun, and then try to determine the distance to it.

Discuss with your team, How might you determine how far away something is, without actually going there? It may help to think about these questions: As an object—such as a car—gets farther away, in what ways does it look different? How about a lighthouse at night seen from a passing ship?

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What kinds of clues could you use to tell how far away a star is?

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## Resources you can access

For this investigation, you'll have access to:

- A list of stars believed to be similar in brightness to the Sun, and the stars' sky coordinates.
- A telescope, for taking images of the star you choose to investigate.

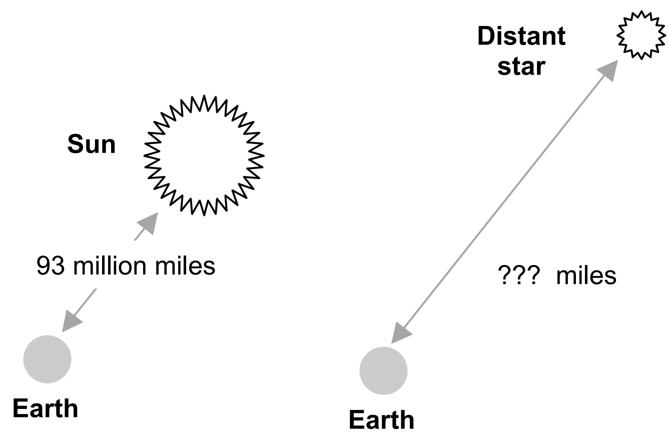
- An image of the Sun for comparison, taken with the same telescope.

- Computer software that lets you measure and compare the brightness of objects in your images.

## Background knowledge or assumptions

- You'll need a rule that relates the brightness of a source of light to its distance. Your teacher will discuss this with you.

- You'll need to know the distance from Earth to your reference star, the Sun: It's 93 million miles.




## Refining your plan

As you put together a plan, discuss these issues:

**Choosing a star to investigate.** Why is it important to choose a star whose brightness is known to be about the same brightness as the Sun?

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________________________________________

 

# Your prediction

**The Grape Solar System.** Before you determine the distance to your target star, make a prediction about what you'll find, using the following scale model:

In this model, use a large grape to represent the size of our Sun. (The Sun is roughly 1 million miles in diameter, so on this scale, 1 grape = 1 million miles.)

The handy chart below shows the relative sizes of the Sun and planets. To really get a sense of how large the solar system is, have one person stand at each planet's distance from the Sun, until you run out of room.

### *Pocket Model of the Solar System*

| | | |
|---|---|---|
| . | Mercury | is 3 feet from the Sun |
| . | Venus | is 3 feet farther |
| . | Earth | is 2 feet farther |
| . | Mars | is 5 feet farther |
| • | Jupiter | is 33 feet farther |
| • | Saturn | is 39 feet farther |
| . | Uranus | is 86 feet farther |
| . | Neptune | is 98 feet farther |
| . | Pluto | is 85 feet farther |

Courtesy Phil Sadler, Harvard-Smithsonian Center for Astrophysics

In this scale model, how far from the Sun would you guess the nearest star is?

________________________ Feet? Yards? Miles?

After you have determined the distance to your chosen star, come back to this section and compare it with your guess above.

 

# Part 3. Carrying out the exploration

## Using the telescope to image a star.

**Choose a star system to investigate.** The stars on the following list are orbited by at least one planet. Astronomers have also found these stars to be near-twins of the Sun in color, temperature, and composition; therefore the stars probably have the same brightness as the Sun as well. No one knows whether these star systems are inhabited. You can research and use another star if you like, but be sure it is as similar to the Sun as possible.

| *Middle of this Month* | *RA highest at midnight* |
|---|---|
| *Jan* | *07h* |
| *Feb* | *09* |
| *Mar* | *11* |
| *Apr* | *13* |
| *May* | *15* |
| *Jun* | *17* |
| *Jul* | *19* |
| *Aug* | *21* |
| *Sep* | *23* |
| *Oct* | *01* |
| *Nov* | *03* |
| *Dec* | *05* |

*Find the current month in the table. The number at right shows the Right Ascension that will be highest at midnight.*

*A Right Ascension that is several hours less (or more) than this will be highest that many hours earlier (or later) in the evening.*

*Example: In March, a star with RA of 11 will be highest around midnight. A star with RA of 7 will be highest 4 hours before midnight, at 8 PM.*

| ✔ | STAR NAME | SKY COORDINATES | | | |
|---|---|---|---|---|---|
| | | Right Ascension (R.A.) | | Declination (Dec.) | |
| | | Hours | Minutes | Degrees | Minutes |
| | **Eta Cassiopeia** | 00 h | 49.1 m | 57 o | 49' |
| | **Upsilon Andromeda** | 01 | 36.8 | 41 | 24 |
| | **HR483** | 01 | 40.6 | 42 | 31 |
| | **55 Cancri** | 08 | 52.6 | 28 | 20 |
| | **47 Ursae Majoris** | 10 | 59.5 | 40 | 26 |
| | **61 Ursae Majoris** | 11 | 41.1 | 34 | 12 |
| | **Beta Canum Venaticorum** | 12 | 33.2 | 41 | 25 |
| | **Lambda Serpentis** | 15 | 45.9 | 7 | 23 |
| | **HD209458** | 22 | 3.16 | 18 | 53 |
| | **51 Pegasi** | 22 | 57.5 | 20 | 46 |
| | | | | | |

**"What's up?"** Make sure you choose a star that will be well above the horizon this time of year. Use the observing guide in the margin.

 

**Time of night to take image.** You can image your star any time of night that it is above the horizon. However, will your measurement of the sun-like star's brightness be affected by how high or low it is in the sky? (Think of what happens to the apparent brightness of the sun when it is high in the sky, compared to sunset or sunrise.)

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_______________________________________________

_______________________________________________

**Camera:** Use the Main camera.

**Filter:** Use the "clear" filter (which is no filter at all).

**Exposure time:** Take images with different exposure times: 0.1 second, 0.5 seconds, 1 second, 5 seconds, and 10 seconds. Be sure to record the exposure times for each image on your data page.

You need an exposure time long enough to see the target star in your image, but not so long that the star's image "saturates." The image "saturates" when the light sensor on the telescope can no longer record any more light from the star. This happens when any of the pixels in the image of the star reaches the maximum value, which is 4095, corresponding to pure white. (See section below for more details.).

If you double the exposure time, how do you think that will affect the brightness you measure for the star in your image?

_______________________________________________

_______________________________________________

_______________________________________________

Why will you need to know this exposure time to make a fair comparison with the brightness of the sun's image?

_______________________________________________________________

_______________________________________________________________

_______________________________________________________________

**Download and save your image.** Be certain to save the images of your chosen star in FITS image format. Follow the directions for downloading and saving on the web page containing your images.

Be sure to label and record the filenames for your images on the DATA PAGE.

**Printing and identifying your star.** It's a good idea to print your images to make it easier to identify your target star. TIP: (First INVERT your image so the stars come out black on a white background. This saves your printer's toner!)

To identify your star in the field of stars on your image, use the handy star charts in the appendix to this investigation, or visit:

http://arch-http.hq.eso.org/dss/dss

## How to measure your star's brightness.

Now you're ready to measure your star's brightness. You'll need to use the MOImage software installed on your computer. Follow these steps:

1. **Launch the image-processing program.** The MOImage program should already be on your computer. If not, download it from:

http://mo-www.cfa.harvard.edu/MicroObservatoryImage

2. **Open the image of your star.** From the MOImage program, open the image of your star. (From the **File** menu, select

**Open Image on Local Disk**, and select your file. Remember: The image must be in FITS format. If not, go back and download the image in FITS format.) Note: On some computers, you can "drag and drop" the FITS image directly from the Website into your MOImage window.

3. **Adjust the image display.** To see the image more clearly, go to the **Process** menu and select **Adjust Image**. When the dialog box appears, click the **Auto** button; the program will automatically adjust the contrast of the image.

4. **Find your target star.** Using the star charts provided, or other star chart, identify your target star among the other stars. Your star will probably be the brightest star in the field of view.

5. **Explore your image:** To help understand the numbers you're about to measure, try moving the cursor over the image of the star. You'll see some numbers changing in the Image Info dialog box. The x- and y-values tell you *which pixel* you are measuring — this is the pixel under the cursor. The p-value shows you the **brightness of that pixel** under the cursor, on a scale from 0 to 4095 (where 0 is pure black and 4095 is pure white.)

   If you move the cursor over the bright area of the star, you'll see that the number is higher. If you move the cursor over the dark night sky, the number will be lower. The number for each pixel was determined by the telescope's light sensor, when the image was taken. The set of numbers is recorded in the FITS file for the image.

   Record a typical value that you get for the star, and also for the background night sky:

   A value for a pixel of the star: ______________________

   A value for a pixel of the background sky: ____________

   Does this result seem reasonable to you?

**Note: If any pixel in the star has a brightness of 4095—the maximum—use another image of the star with a shorter exposure.**

**"If I adjust the image display to make it brighter, will that change the pixel brightness that I measure?"**

No. The brightness tool measures the brightness of your original FITS image—*not* the brightness of the display on your screen. You can process the image all you want, and change how it appears on screen, but the numbers you read for each pixel value will remain the same.

6. **Select only the star in the image**. Select the circle tool on the upper left corner of your image window. Using the mouse, click and drag the mouse to create a circle just large enough to encircle the image of the star. Try to encircle ONLY the star, getting as little background sky in the circle as possible. (You can move the circle with the cursor to position it over the star.)

7. **Measure the brightness of the star**. Under the **Process** menu, select **Measure**. Drag the corner of the dialog box that appears so that you can read all the numbers in the table. The **Area** shows you the number of pixels enclosed in your image. The **Mean** shows you the average value for each of those pixels. The **Total** shows you the total added brightness of all pixels within your circle. This is the brightness of the star in your image, which you'll compare to a similar measurement on the Sun, below.

8. **Record your measurement.** Record your measurement of the star's brightness, below and on your DATA PAGE.

   Total brightness of the star in the image:

   ________________________

   **IMPORTANT NOTE**: Note that your measurement of brightness has **no units**. This number lets you compare the *relative brightness* of two objects, as measured by the telescope. It does not tell you anything about the actual brightness of the star, for example in units such as lumens.

## Measuring the Sun's brightness.

Now you're ready to measure the brightness of the Sun, which is your reference star.

1. **Open the image of the Sun.** Using the MOImage program, open the image of the Sun, which should already be on your computer. (If not, download and save the Sun image to your computer by going to this Web address:

   http://cfa-www.harvard.edu/webscope/archive/sun.FITS

   Be certain to save the image in the FITS format. Follow instructions on the Web page when downloading.

2. **Adjust the image display.** To see the image more clearly, go to the **Process** menu and select **Adjust Image**. When the dialog box appears, click the **Auto** button; the program will automatically adjust the contrast of the image.

3. **Measure the Sun's brightness.** Using the circle tool, measure the Sun's brightness just as you did for your star.

4. **Record the Sun's brightness** here and on your DATA PAGE.

   Total brightness of the Sun in my image:

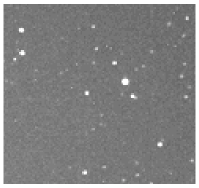
   ________________________ (no units)

Now you are ready to compare the brightness of your star with the brightness of the Sun.

## DISTANCE TO A STAR

# DATA PAGE



Enter the name of your target star and the brightness you measure. To determine your star's distance, use the *Go Figure!* sheet.

| **TARGET STAR** (name) | **BRIGHTNESS** (total pixel count) | **EXPOSURE** (seconds) | **FILTER** (fraction of light passed) | **DISTANCE** (miles) |
|---|---|---|---|---|
| | | | 1 | ? |
| | | | | ? |
| | | | | ? |

Enter your measurement for the brightness of the Sun, which is your reference star:

| **REFERENCE STAR** (name) | **BRIGHTNESS** (total pixel count) | **EXPOSURE** (seconds) | **FILTER** (fraction of light passed) | **DISTANCE** (miles) |
|---|---|---|---|---|
| Sun | | 0.1 | $10^{-8}$ | 93,000,000 |

The Sun was at an altitude of ____15____ degrees above the horizon.

My star was at an altitude of __________ degrees above the horizon.

# GO FIGURE!

## Comparing the brightness of your star with the Sun's brightness.

Simply comparing the brightnesses you measured for the star and the Sun would not be a *fair* comparison. The comparison would only be fair if the two images were taken in *exactly* the same way.

Discuss with your team to see how many things you can come up with that might have been different between the two images. Which of these factors might affect the brightness you measure in each image?

__________________________________________________________

__________________________________________________________

__________________________________________________________

You will be able to correct for some of these differences.

## Correcting the Sun's measured brightness.

Here are two differences that would throw off your results if you didn't correct for them: The Sun image was taken with a *filter*, but your star image was not. Also, the Sun image was taken with *a shorter exposure time* than you used for your star.

**Sun Filter.** The Sun *filter* only lets through $10^{-8}$ (one hundred-millionth) of the sunlight falling on it. Therefore, the Sun is really 100 million times brighter than what you measured!

What brightness would you expect to measure if no Sun filter had been used?:

___________________________________(pixel counts if no filter were used)

**Exposure Time.** The Sun's *exposure time* was only 0.1 second. How many times longer was your star's exposure time?

My star's exposure time was ________________________ times longer than the Sun's exposure time.

Write down the brightness you would expect to measure if no Sun filter had been used AND you used the same exposure time as for your star:

___________________________________(pixel counts if no filter were used AND same exposure time as for star)

This is your corrected measurement for the brightness of the Sun. It allows you to make a fair comparison between the brightnesses you measured for the Sun and the star.

## Fair comparison of the Sun's and the star's brightness.

How many times dimmer does your star appear, compared to the Sun?

My star measures ___________________________________ times dimmer than the (corrected) brightness of the Sun.

Does this number seem reasonable to you?

## Calculating the star's distance.

Use your comparison between the Sun's and the star's brightness to calculate their relative distance. Remember that:

A star that appears **100 times dimmer** than its twin will be only **10 times farther**.
A star that appears **x times dimmer** than its twin will be **$\sqrt{x}$ times farther**.

The star I have explored is ____________________times farther than the Sun.

The Sun is about 93 million miles away. How far is your star? (Don't be afraid of large numbers!)

My star is __________________________________________ miles away from Earth.

Your teacher will show you a way to handle large numbers more easily. It's called "scientific notation." Using scientific notation (that is, exponents), how would you write the distance to your star using exponents?

My star is _________________________________________ miles from Earth.

***Writing large numbers***

**1 thousand =**
$10^3$ = 1,000

**1 million =**
$10^6$ = 1,000,000

**1 billion =**
$10^9$ = 1,000,000,000

**1 trillion =**
$10^{12}$ = 1,000,000,000,000

**INTRODUCING THE "LIGHT-YEAR".** Distances beyond our own solar system are so huge that it makes no sense to measure them in units of miles—the numbers would be too large to work with easily.

Astronomers use a measure of distance called the "light-year." It's the distance that light travels in a year. How far is a light-year? Light travels at 186,000 miles per second, and there are about 32,000,000 seconds in a year. So a light-year is (186,000 mi./sec.) x (32,000,000 sec.) = about 6 trillion miles = 6 x $10^{12}$ miles!

How far is your star in light-years?

_____________________________________________ light-years

Congratulations! You have determined the distance to a star—without ever leaving Earth!

*The Art of Science:*
**WHAT'S THE "RIGHT ANSWER"?**

Sorry! In the real world, there is no "right answer" – there are only results. After all, the universe doesn't come with a manual. But not all results are created equal: Some experimental methods are better than others, and some experiments are carried out more carefully than others. Determining how good your results are – when nature doesn't provide a "textbook" answer to check against – is one of the real challenges of being an investigator.

Compare your result with the results of other students or professional researchers. How do they stack up? Determining the distance to astronomical objects is a challenge even for the professionals, and there's an uncertainty even in their results!

## Is *that* right? Sources of error

It's a good idea to look critically at your results. What are the possible sources of error in your result? For example, what factors could have affected the brightness of your images? Are there unavoidable errors in your measurements? How do you think these factors affected the overall accuracy of your result?

______________________________________________________________

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# Part 4. Making sense of your results

Now that you've got a number for the distance to your star, what does it *mean?* Here are some questions to help you make sense of your results.

**Modeling the Universe**. In your scale model of the solar system you used a grape to represent the Sun. Use a second grape to represent the star you investigated. How far away from the first grape should you put it?

______________________________________________

______________________________________________

______________________________________________

Compare your answer with your initial guess from Part 2 above. Is your target star much farther than you thought it would be? Stars are incredibly far apart!

**Telescope as time machine**. Particles of light travel at 186,000 miles per second. How long does it take a particle of light to reach the Earth from your target star?

How has the world changed in the time it took for light to get from your star to the telescope?

______________________________________________

______________________________________________

______________________________________________

What year did the light that you captured with the telescope actually leave the star? What was happening on Earth then?

______________________________________________

______________________________________________

In what way can you use the telescope as a “time machine”? Does the telescope allow you to look back in time?

**Travel between the stars?** Today's fastest spacecraft travel no faster than 100,000 miles per hour. How long would it take to reach your target star? If you could travel at the speed of light (and you can't: see "Faster than light?"), how long would it take you? Would you have to pack your suitcase for a month? A year? The rest of your life?

**E.T. Phone Home?** Suppose there are intelligent beings on a planet orbiting your target star. How long would it take for a message from them to reach the Earth? How long would a return message from Earth take to reach the star system? If you have a conversation that spans *generations* — what kinds of questions would you ask? What would you want your *children and grandchildren* to learn from beings on other worlds?

**Amazing space.** Some people say that the vastness of space makes them feel lonely, isolated, or insignificant. But others find it exciting that we can see such incredible distances in space, even with the unaided eye—and that we can explore the heavens from our home planet. What do *you* make of your place in space? What does it mean to you, and how does it make you feel?

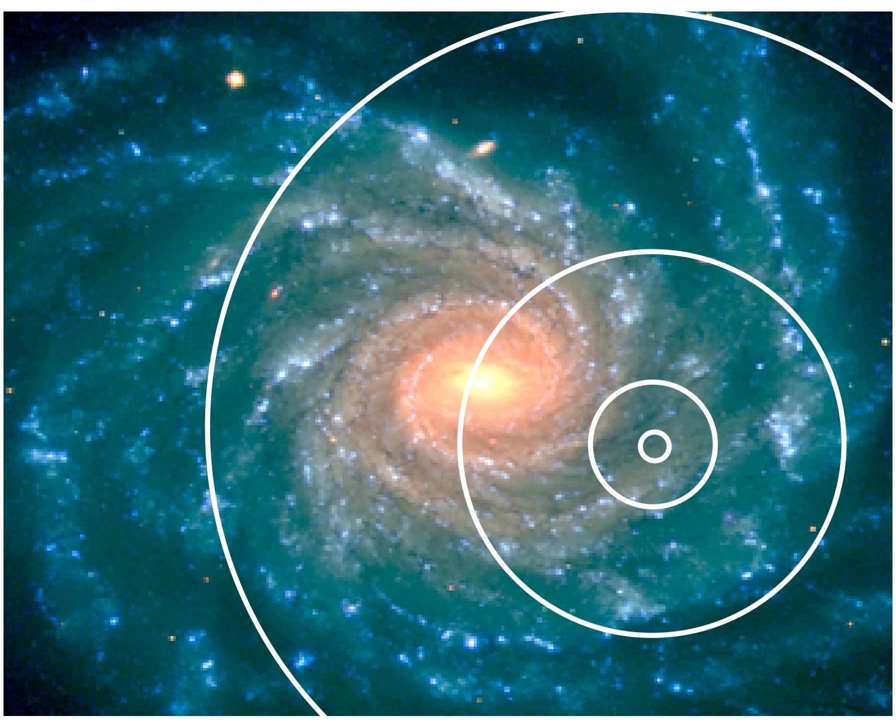
______________________________________________________

______________________________________________________

______________________________________________________

## Puzzler: How far can you see?

In this drawing of the Milky Way galaxy, our solar system is smaller than an atom, and lies at the center of the circles. One of the circles below contains *all* of the stars that you can see individually with your naked eye on a dark night from the best observing spot on Earth. Which circle is it? (The star you just investigated is in this circle too!)



A *galaxy* is a giant "city" of stars and planets and the dust and gas from which they are formed.

Our Milky Way galaxy is home to our solar system—and more than 100 billion others!

# Part 5. Additional projects about stars

Stars in your eyes? Here are some suggestions for additional projects using the MicroObservatory telescopes. Good luck—and always follow your star!

## Star Reporter

Write a popular magazine-type column about the lives of stars —real stars. Illustrate your article with your own telescope images of stars being born, stars dying, star clusters, star colors, or other parts of the secret life of stars that interest you.

In your column, try to address some questions your readers may have:

How long do stars live—and how do we know? What happens to a star when it dies? Are stars good for anything—e.g., how do they affect my life?

Suggested targets: The Orion nebula, Pleiades, Crab Nebula, Ring Nebula. (To point the telescope to these, simply use the pull-down menu on the Control Telescope page.)

## Stars That Dim

Our Sun stays the roughly the same brightness for millions, even billions of years—and a good thing it is, or life might have frozen or burned up. But are there stars that change their brightness?

Use the telescope to follow a "variable star" for several days or weeks. Can you prove that the star actually changes in brightness?

This is not so easy as it might seem. You'll need to compare the brightness of your star to a reference star in the same field of view.

(Otherwise, other effects might interfere, such as haziness of the sky, changes in the altitude of the star, etc.)

Report on what's known about why some stars change their brightness. Write about what it might be like to live near one.

Suggested target stars: Algol, Cepheus.

## How Many Stars in a Galaxy?

Think big for this one. Our Sun is just one little star in our huge Milky Way galaxy. Just how huge *is* a galaxy? To find out, investigate the closest galaxy that looks like our own: the Andromeda galaxy.

Try imaging Andromeda, which is 2 million light-years away. (It's the furthest object you can see with your naked eye.) Using the same technique as in "To the Stars!", measure the brightness of the Andromeda galaxy. (Or you can measure just a portion of the galaxy, and then estimate the brightness of the whole galaxy.)

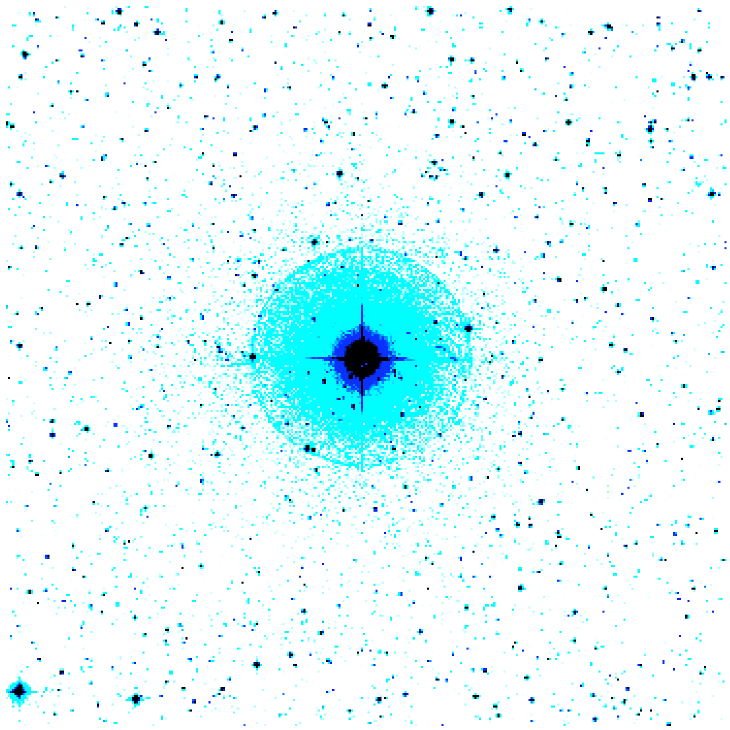
If all the stars in the Andromeda galaxy were about the same brightness as our Sun—(in reality, some are brighter, some are dimmer)—then how many stars do you estimate the Andromeda galaxy contains? (First figure out, what brightness would the Sun be if it were 2 million light-years away? Your measured brightness for the whole Andromeda galaxy will be much larger, of course. How much larger? That's the number of suns the galaxy contains.

In your report, let readers know how to deal with the numbers you get. How large is it? How does it compare to, say, the number of people on Earth? Do you think that there is at least one other intelligent civilization among all those stars?

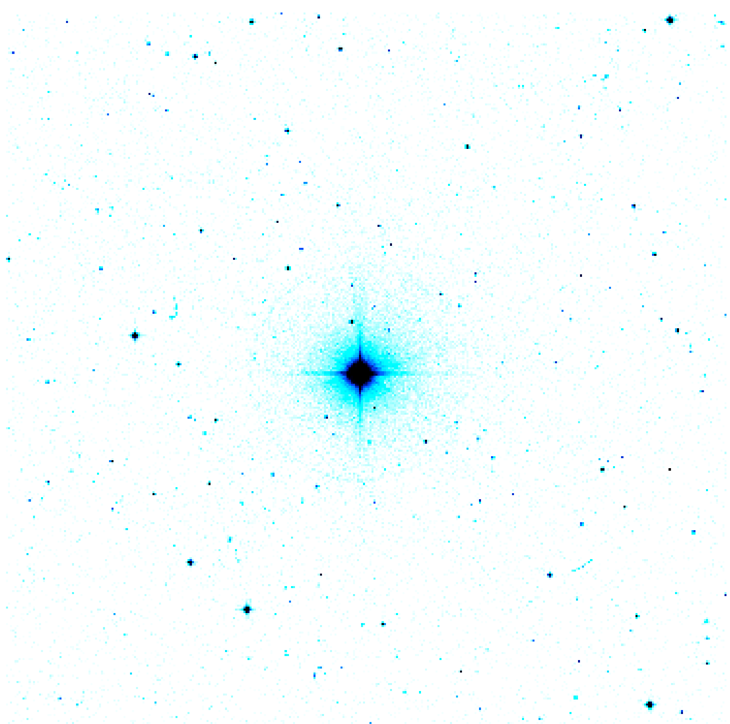
You can also try this activity with the galaxy M-33, in the summer constellation Triangulum. (For both Andromeda, and M-33 you can use archived images that others have taken, if you like, but the images must be in FITS format, which contains the original information about brightness.)

# Star charts

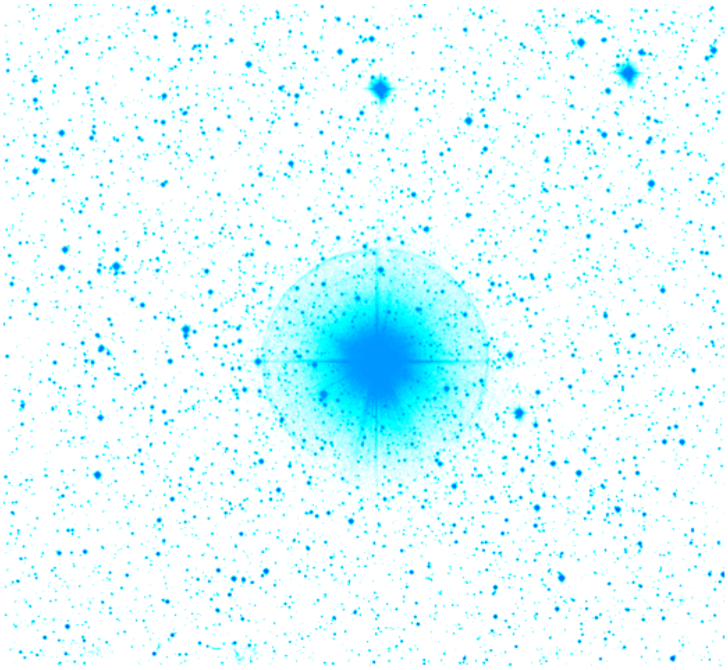


**Upsilon Andromeda**

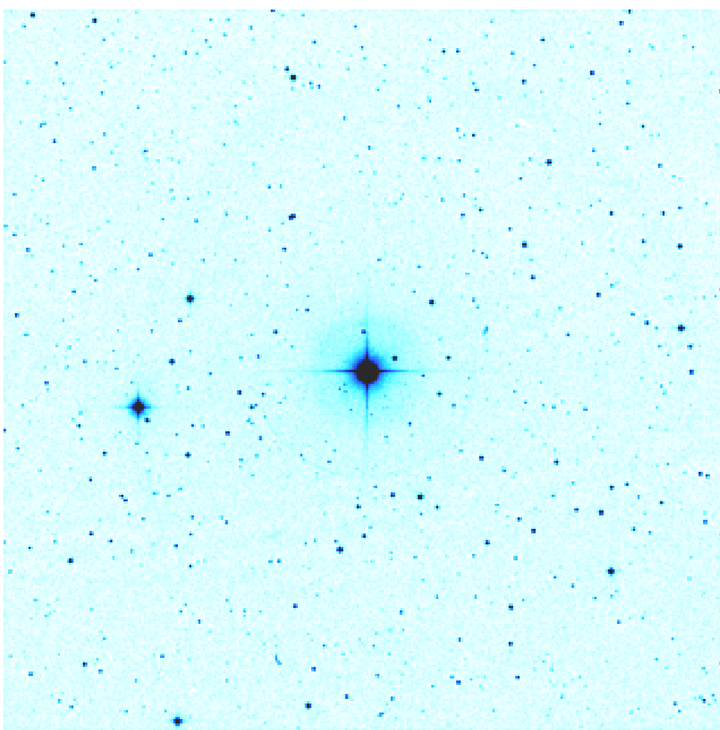


**47 Ursae Majoris**

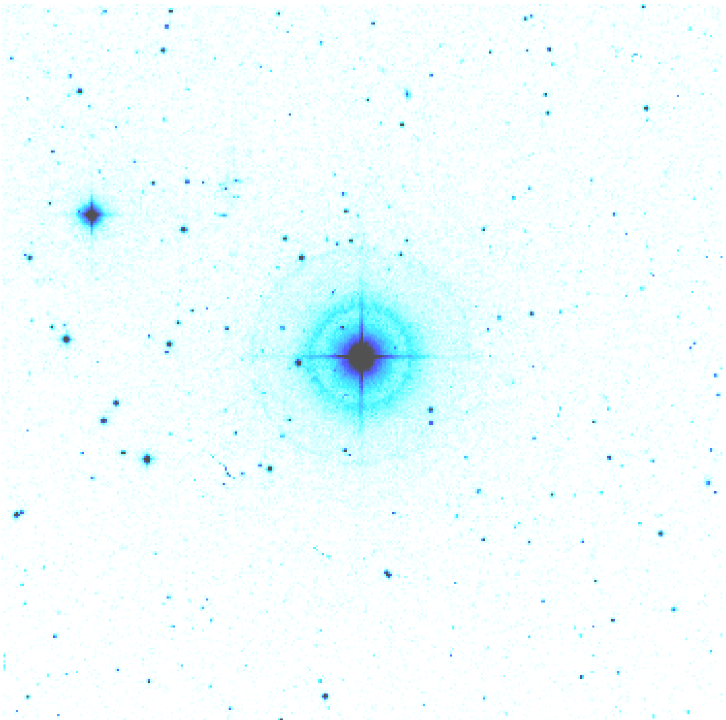


**Eta Cassiopeia**

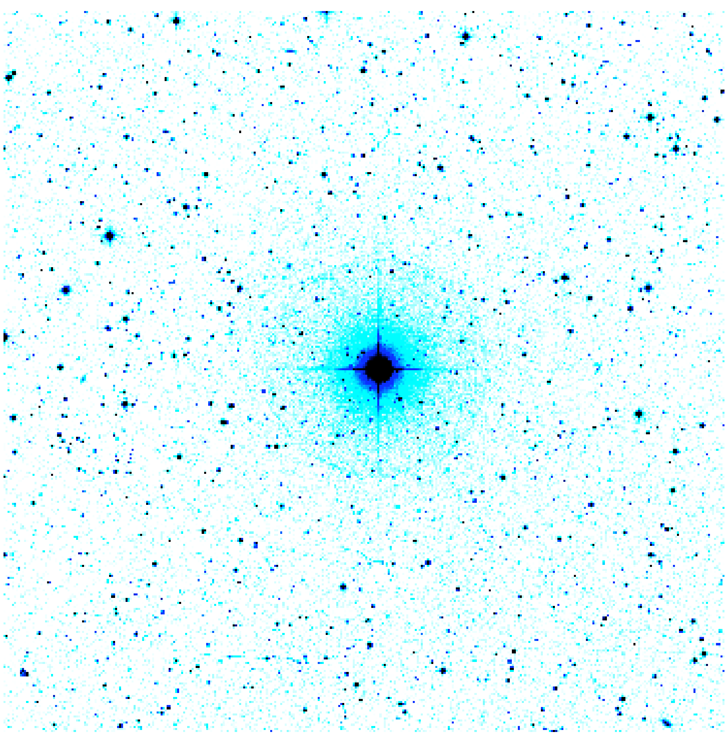


**51 Pegasi**

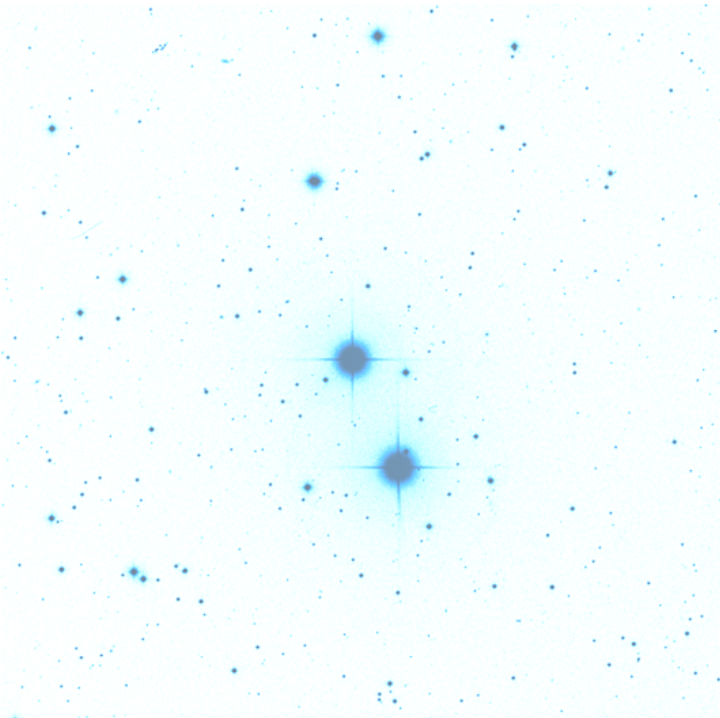
 



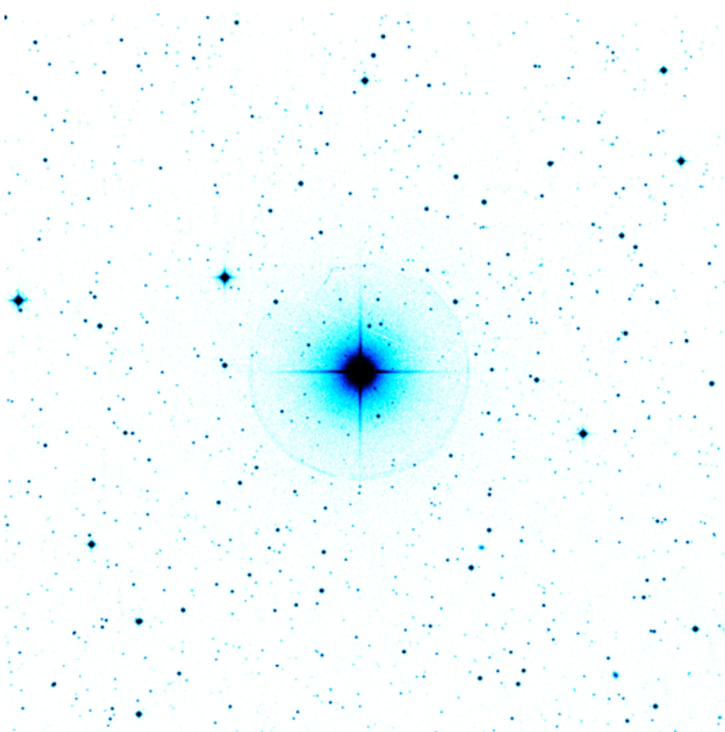
**61 Ursae Majoris**



**HR483**

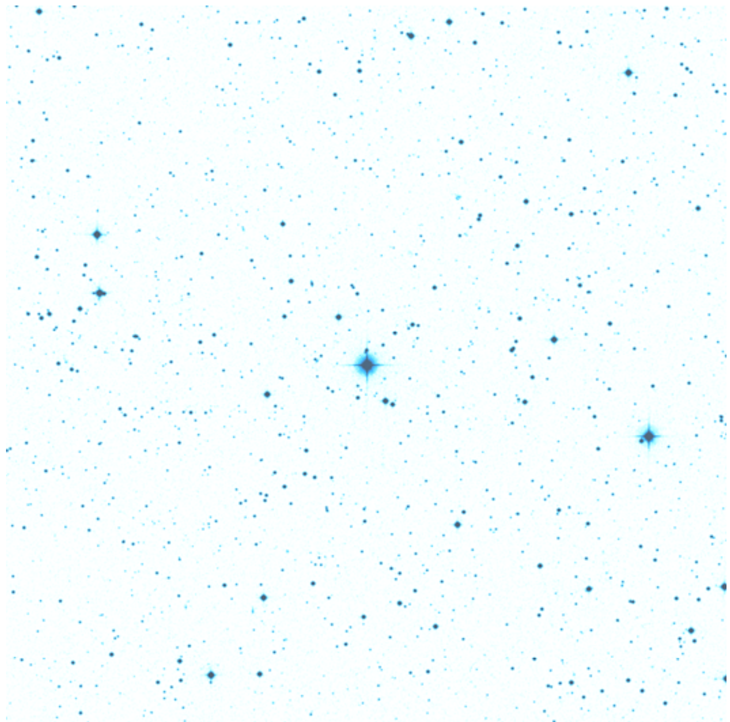


**55 Cancri**

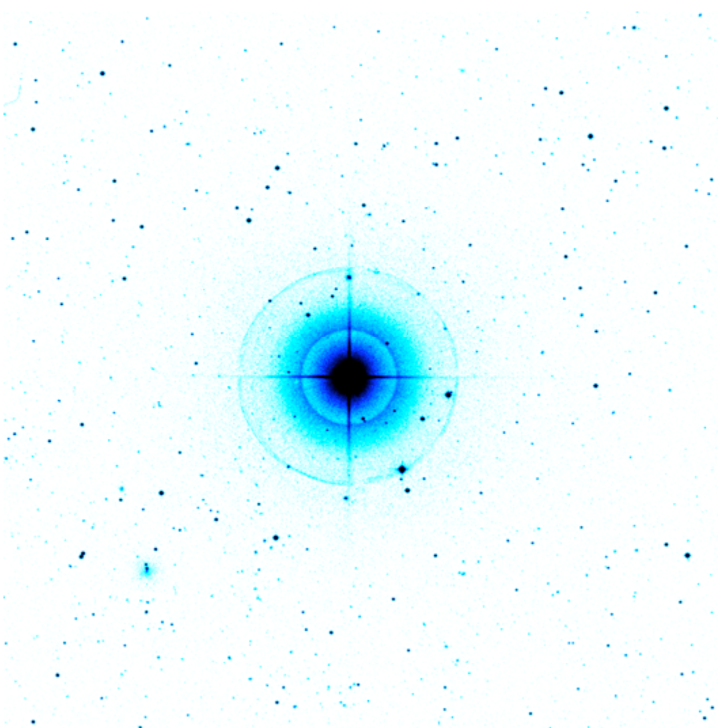


**Lambda Serpentis**



**HD 209458**



**Beta Canum Venaticorum**