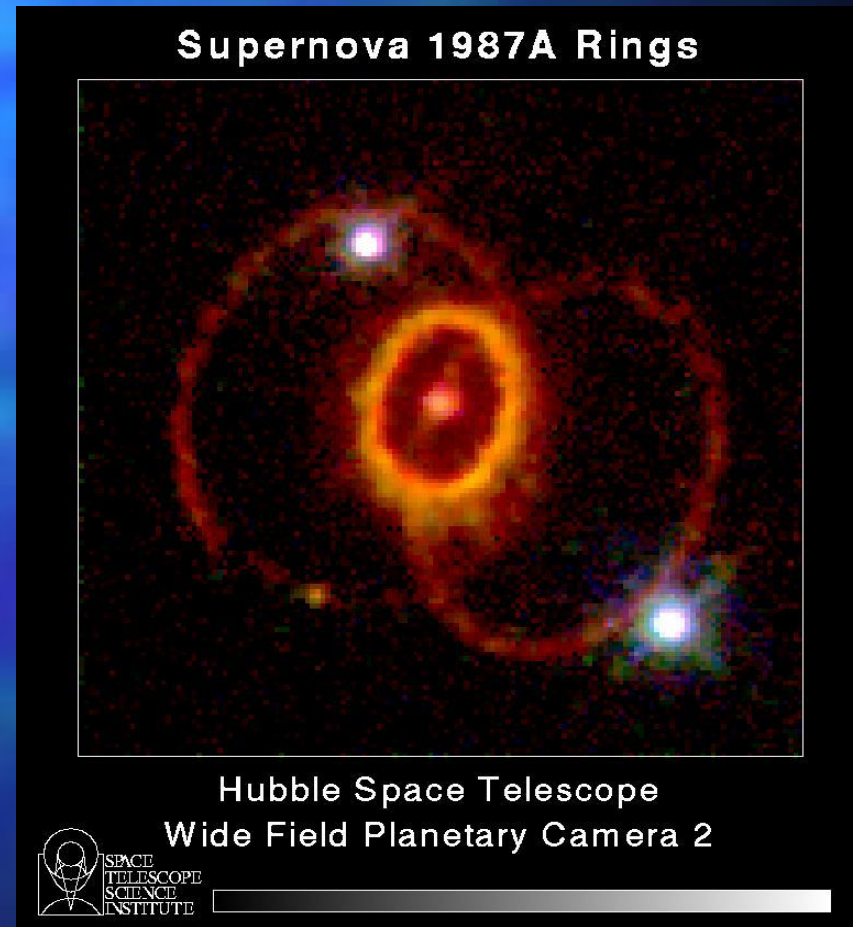


What you'll learn

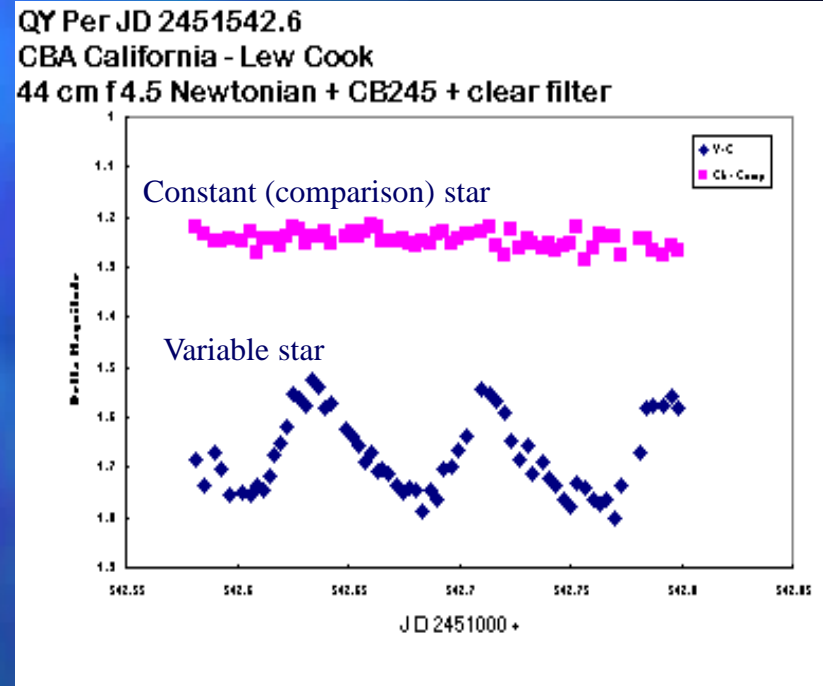
- This learning experience will take about 15 minutes.
- In addition to estimating brightness, you'll learn how to find variable stars with AAVSO charts.



Supernovae are Variable Stars too!

What you'll learn

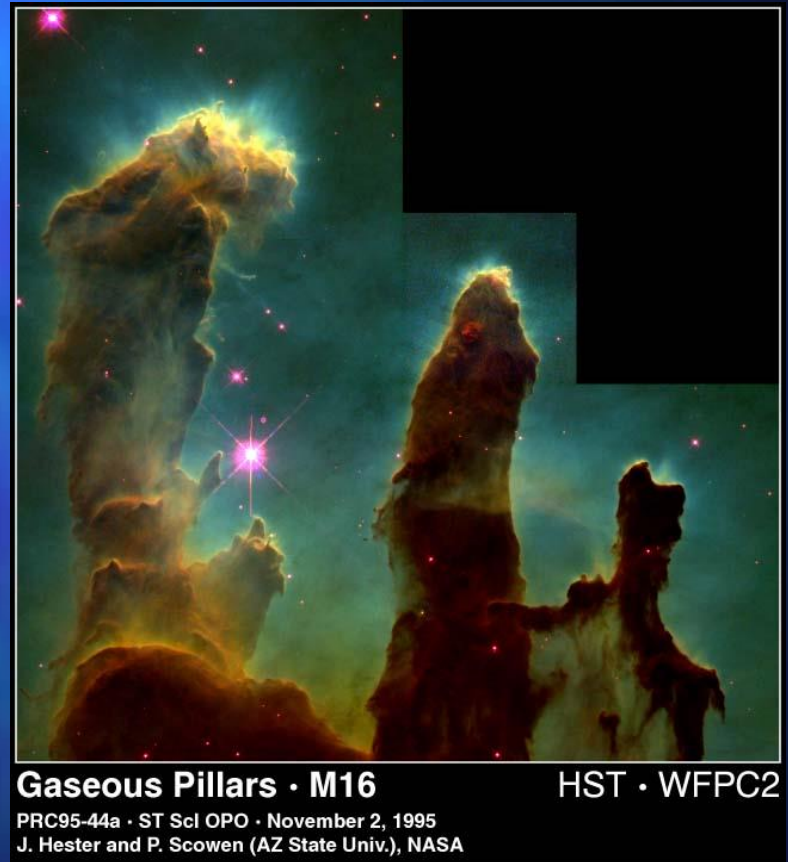
- We'll also cover how scientific data can be useful even when it contains "noise".
- You'll learn that your observations can be very valuable, even while you're learning to make better and better estimates.



CCD brightness data from long time AAVSO
Member Lew Cook

Astronomy needs data!

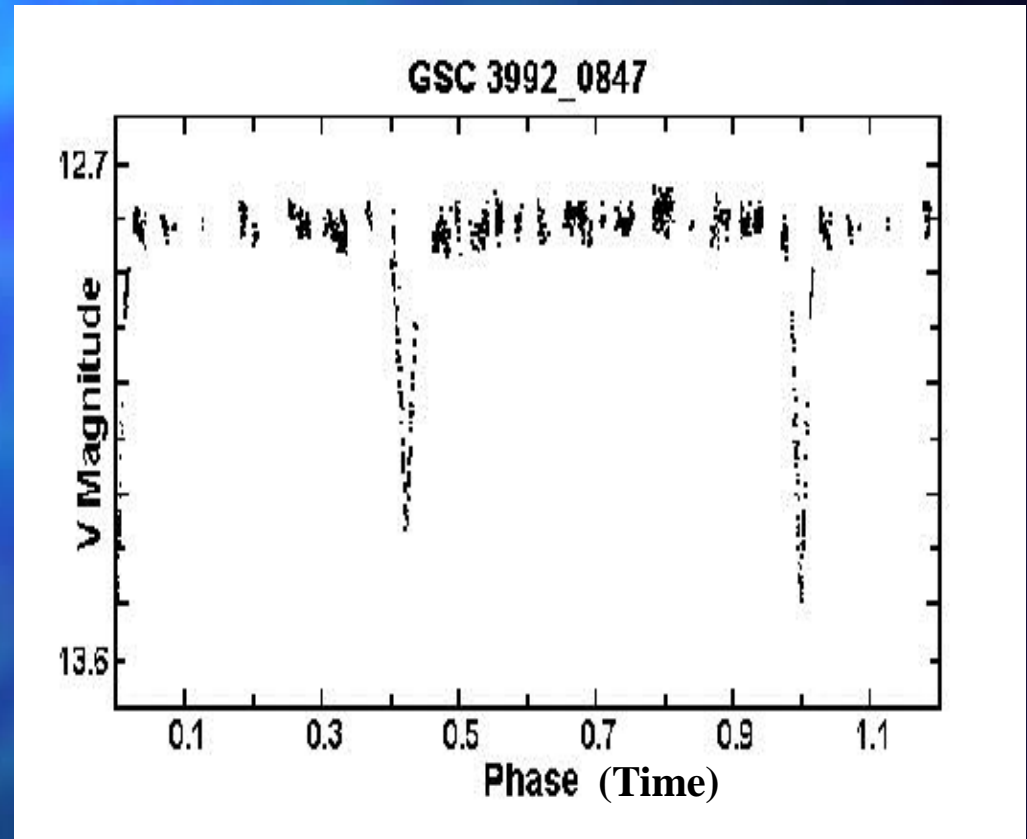
- The sky is full of wonderful things to see.
- But, just looking at its beauty often doesn't provide answers to the riddles of the universe.



Hubble Space Telescope

Astronomy theories need data!

- Most of the discoveries astronomers have made about the universe needed light measurements to confirm or suggest theories.



Data is information from instruments

- There are all kinds of instruments astronomers use to make measurements of star brightness.
- We call these measurements photometric data.
- Photometric means light-measuring.



Your eyes are your instruments

- You are going to use your own eyes and a special technique for making photometric measurements.
- The technique is called: Interpolation of Magnitude.



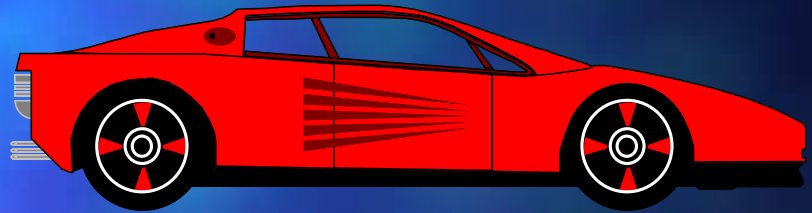
What is interpolation?

- *Interpolation* is a word scientists use when a measurement is estimated between two known values.
- People interpolate all the time!



Interpolation

- Your car's gas gauge needle is half way between empty and 1/4 tank.

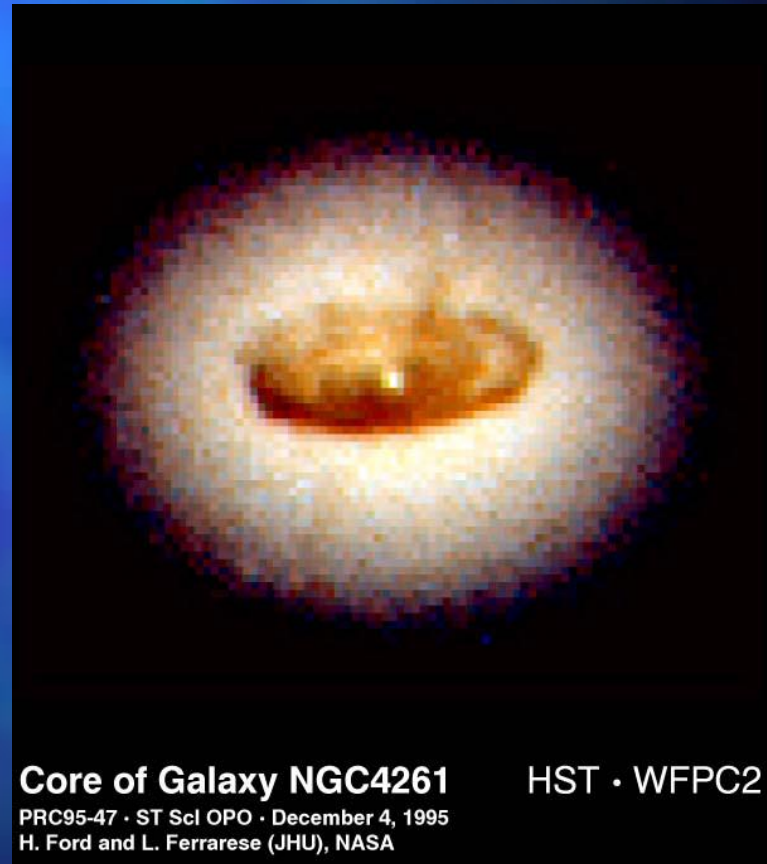


- You *interpolate* you have 1/8 of a tank left--time to get gas!



Interpolating star magnitude

- Making a brightness estimate is easy in theory but requires some practice.
- We call the measurement of brightness the star's *magnitude*.



Core of Galaxy NGC4261

PRC95-47 · ST ScI OPO · December 4, 1995
H. Ford and L. Ferrarese (JHU), NASA

HST · WFPC2

Interpolation of magnitude

- We estimate the brightness of the variable star by using at least two stars of known brightness; one brighter than the variable, one fainter.



Andromeda Galaxy (C. Pullen)

Interpolation of magnitude

- Just like the gas tank example, if a star's brightness seemed about half way between two stars that were known to be magnitudes 5.0 and 6.0, what is the magnitude of the variable star?



Crab Nebula (C. Pullen)

Interpolation of magnitude

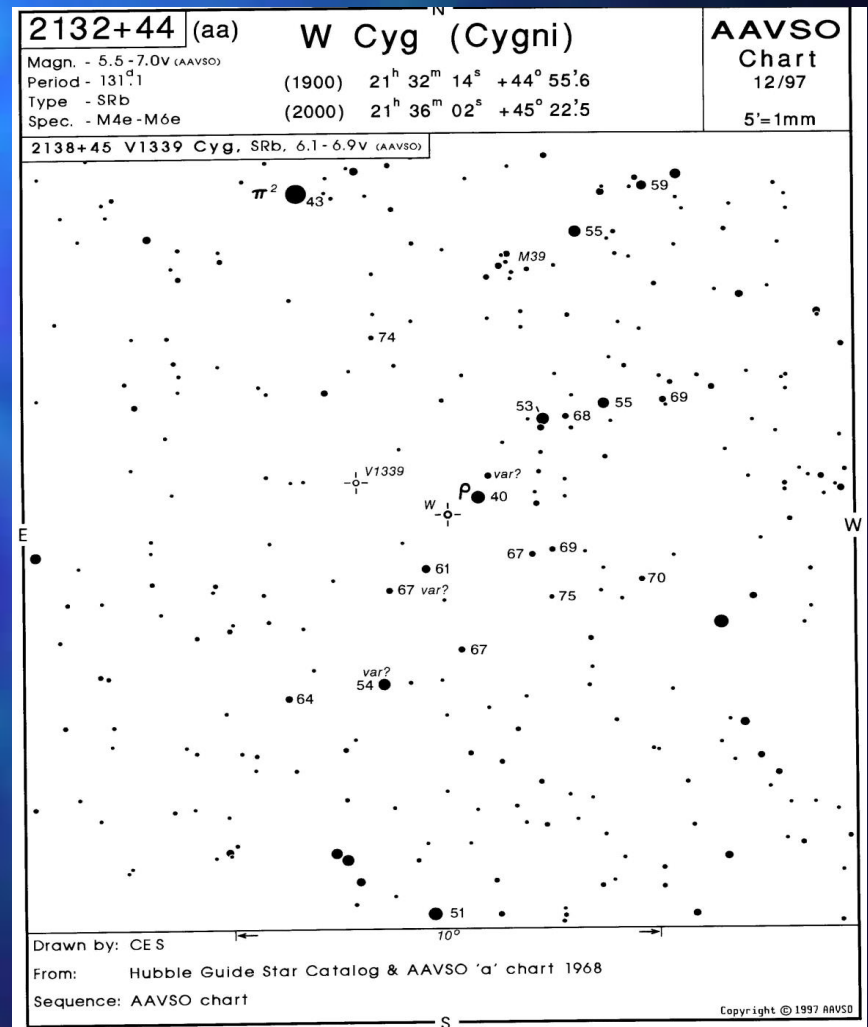
- That's right -- half way between 6.0 and 5.0 is

5.5!



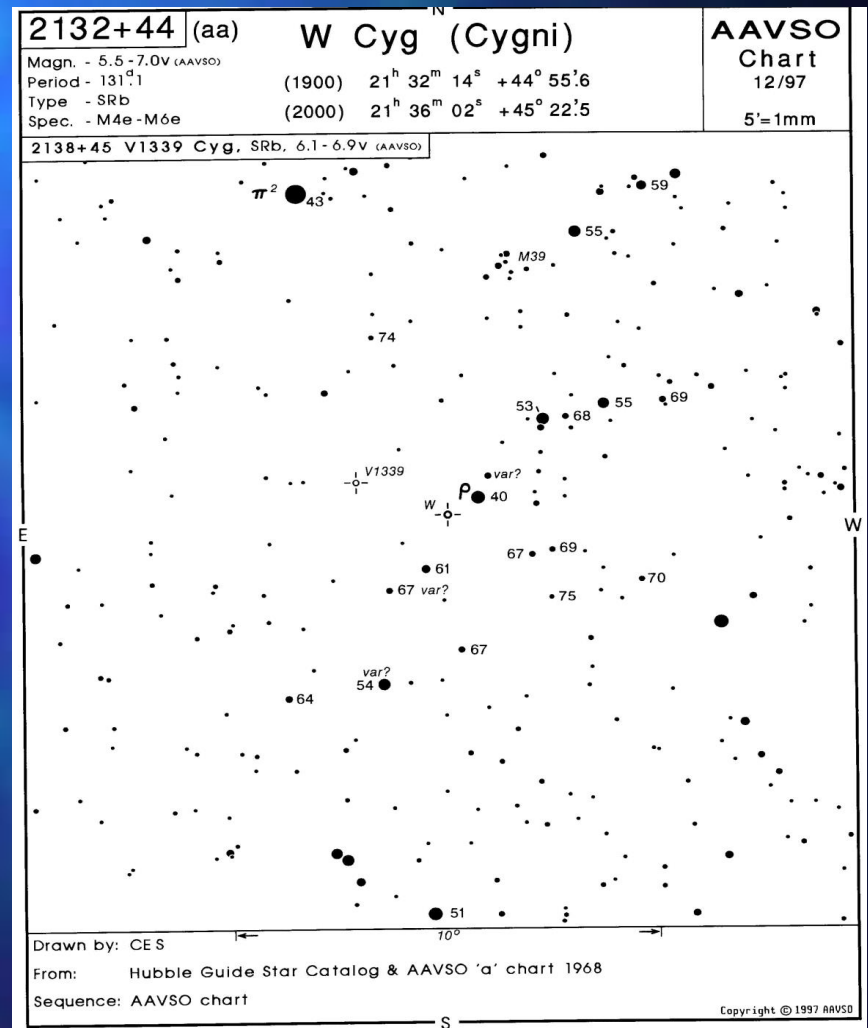
How to find a variable star

- The AAVSO makes thousands of star charts (sky maps, like road maps) used to find and estimate the magnitude of variable stars.
- Because all AAVSO observers use the same charts, our results can be very good, and can be compared with each other's.



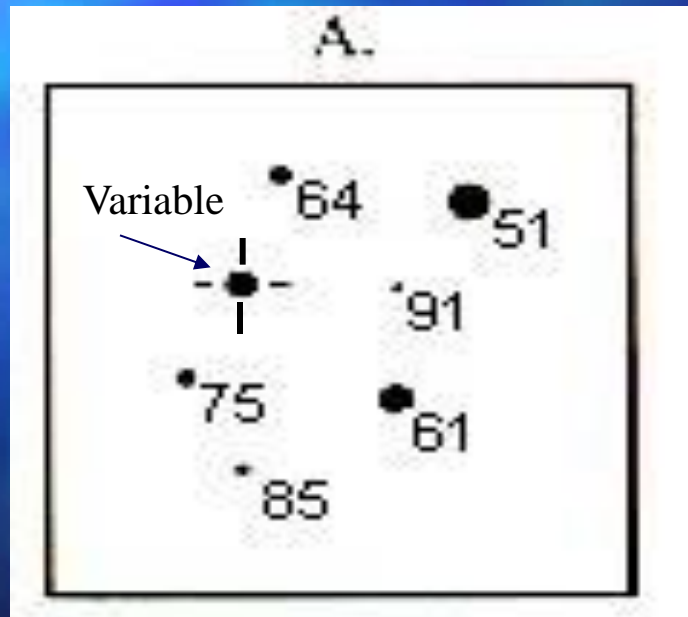
How to find a variable star

- You have a copy of this AAVSO chart. It is for W Cygni, a star you can find with binoculars from your own yard.
- But, first let's try a simple lesson in interpolation and using star charts.



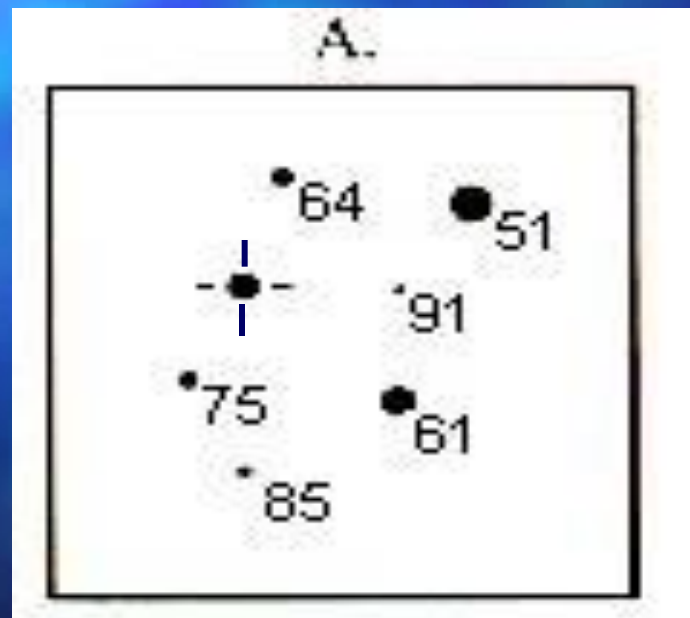
Variable and comparison stars

Look at the example below. The variable is shown between the four focus lines. The magnitudes of the comparison (“comp”) stars are shown on the chart next to the stars (64,51,91, etc.).



Decimal points can be confusing

Note that the star magnitudes are actually decimals but we don't show the decimal point because it could be confused as a star. So, the magnitudes below are really 6.4, 5.1, 9.1, etc.

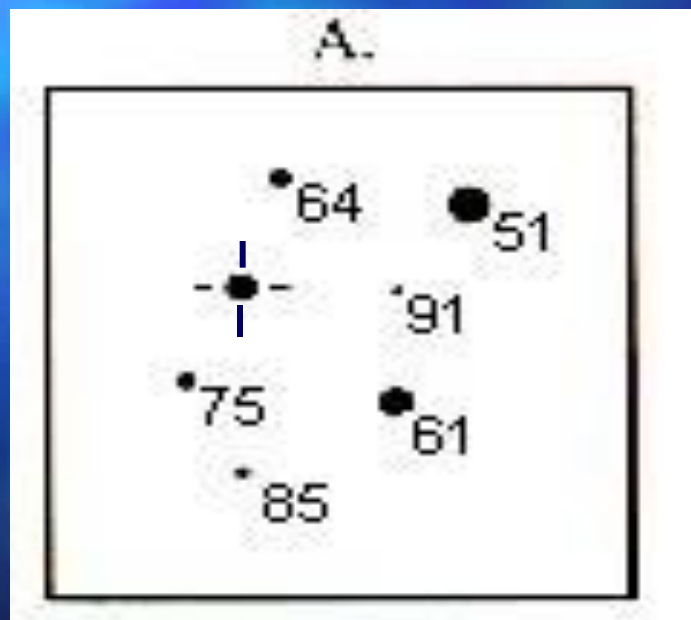


A big magnitude number is faint, a big dot is bright!

The brighter the star is, the smaller its magnitude number.

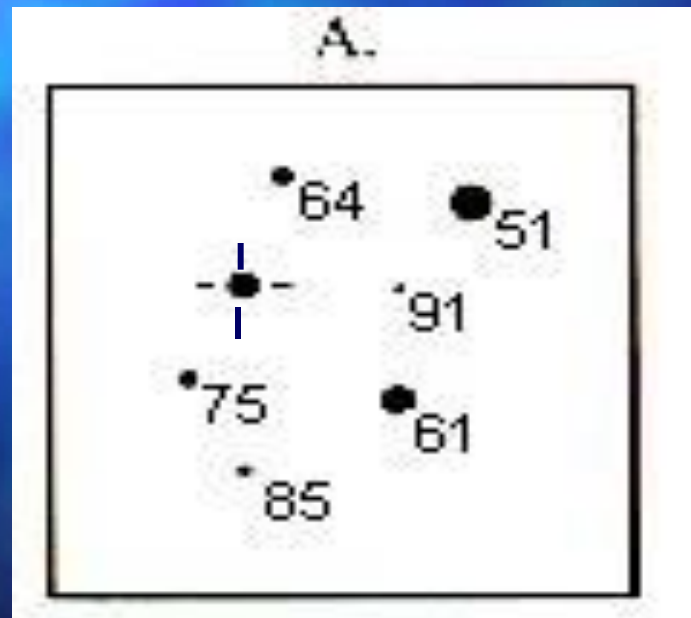
5.1 is brighter than 6.4.

On the chart, notice that the dot is bigger (brighter) for the 5.1 star than the 6.4 star to its left.



Making your first estimate

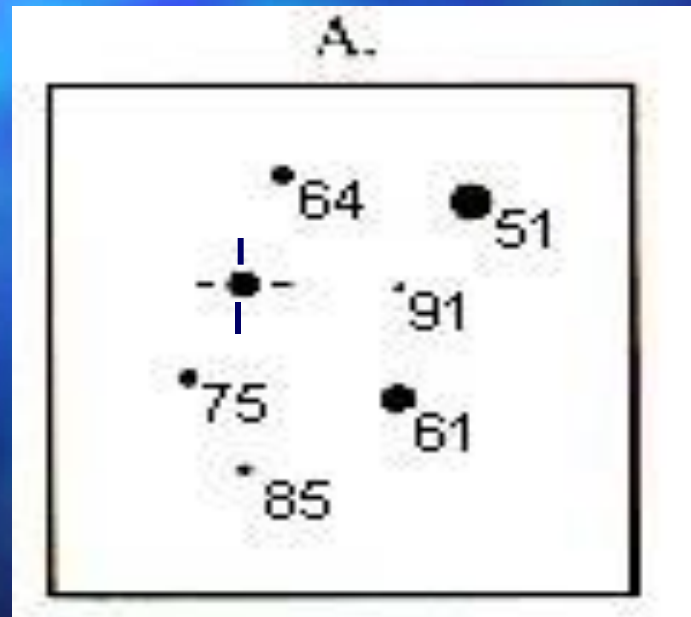
Is the variable brighter or fainter than the brightest (5.1) star?



Making your first estimate

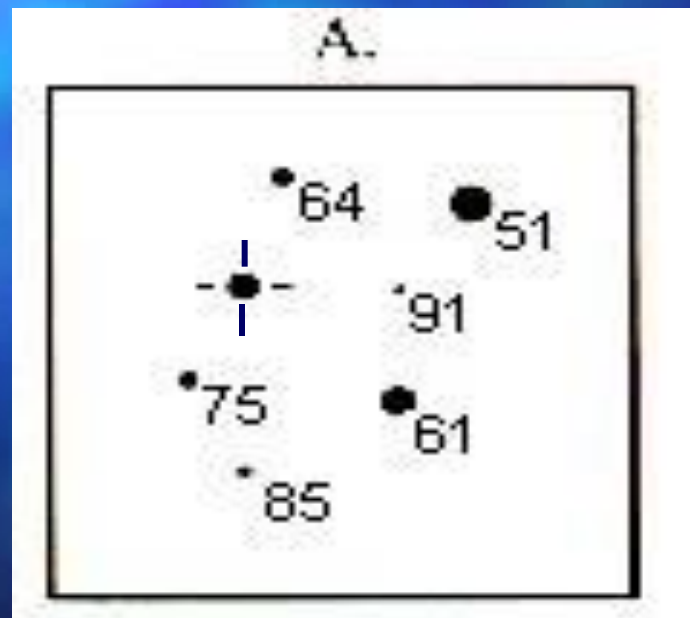
Is the variable brighter or fainter than the brightest (5.1) star?

Fainter!



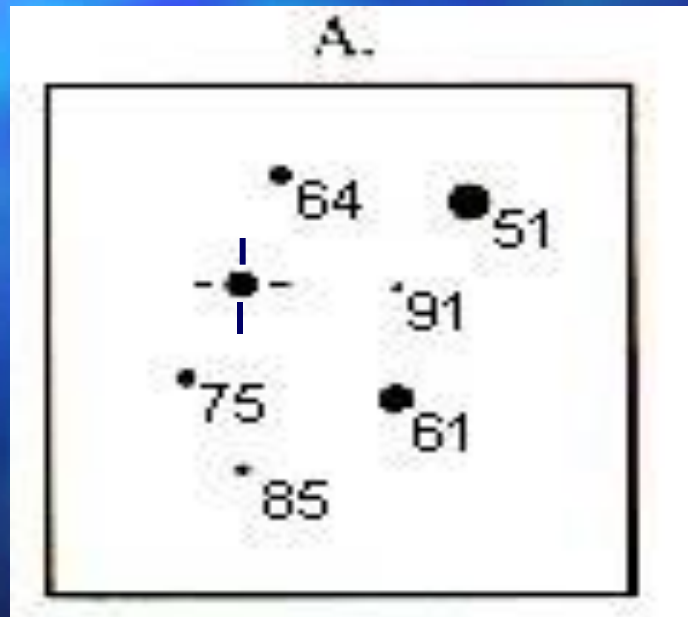
Making your first estimate

Is the variable brighter or fainter than the next brightest star (6.1)?



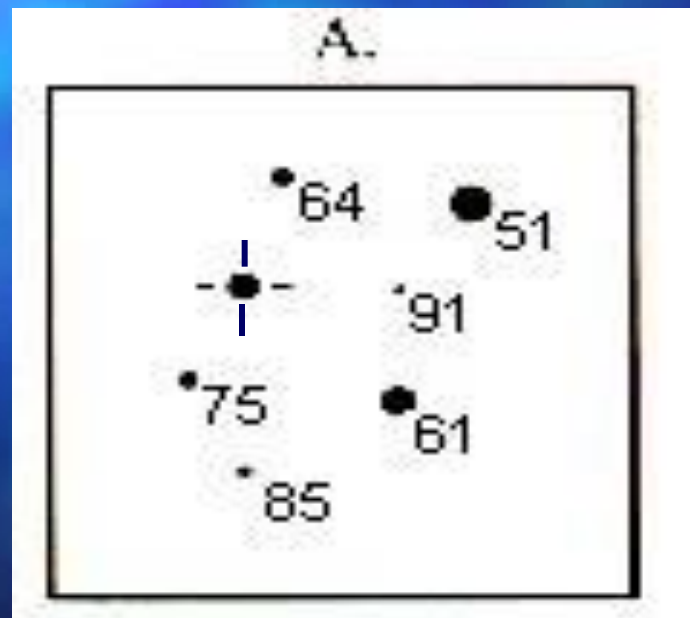
Making your first estimate

Is the variable brighter or fainter than the next brightest star (6.1)? Fainter!



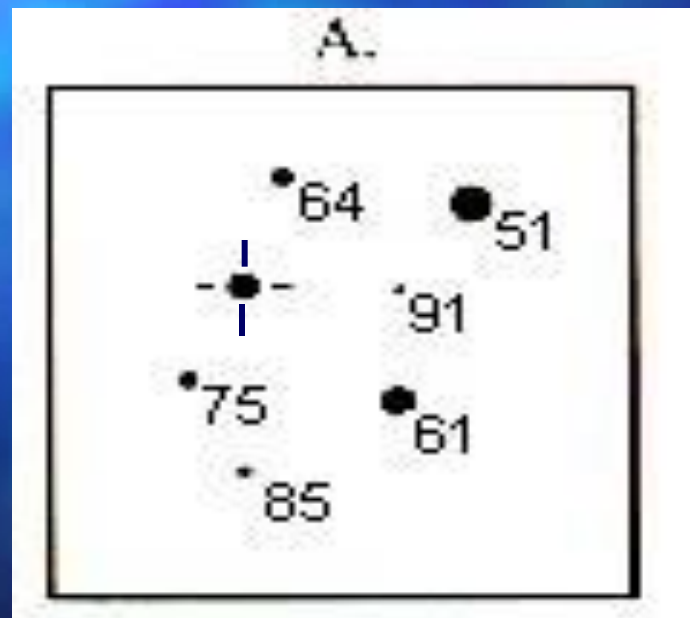
Making your first estimate

Is the variable brighter or fainter than the next brightest star (6.4)?



Making your first estimate

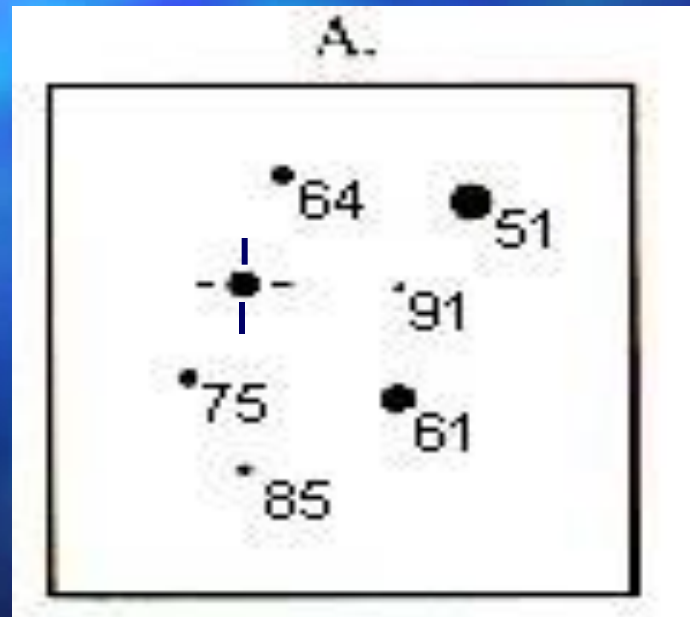
Is the variable brighter or fainter than the next brightest star (6.4)? Brighter!



Here comes the gas gauge!

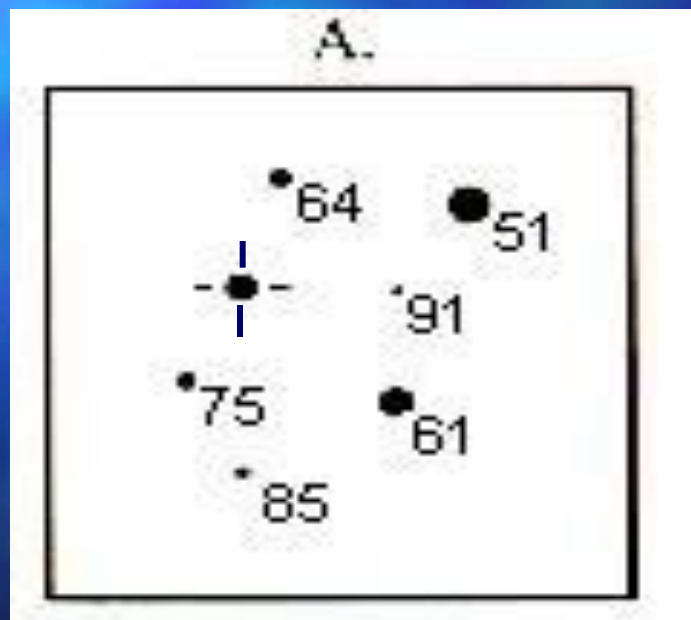
So, the variable is brighter than 6.4 but not as bright as 6.1. What are you going to do with those numbers?

Interpolate!



Interpolation is an educated guess

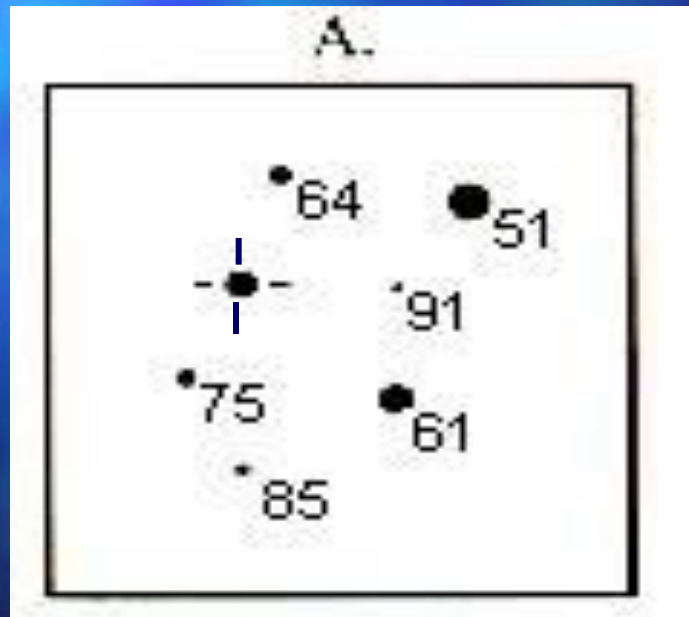
Is it about half way between 6.4 and 6.1?
Then, your estimate would be 6.2 or 6.3.
But, which one?



Use your feelings

Maybe you think it is just a little brighter than midway.
Your estimate would be 6.2! A little fainter, your estimate would be 6.3.

Don't try to think what it should be, just go with the flow.



Your ability to feel the best answer will get better with practice.

Making your first estimate

- But, whatever your estimate, congratulations on your first variable star observation!
- Write your result on the back of the star chart you were given.



Why do we call it an Estimate?

- Different people will make different estimates of brightness using this method. We all see the world differently.
- Yet, all the estimates are “right”! There is no one correct answer.
- All scientific measurements have variation. We call it *error* or *noise*.

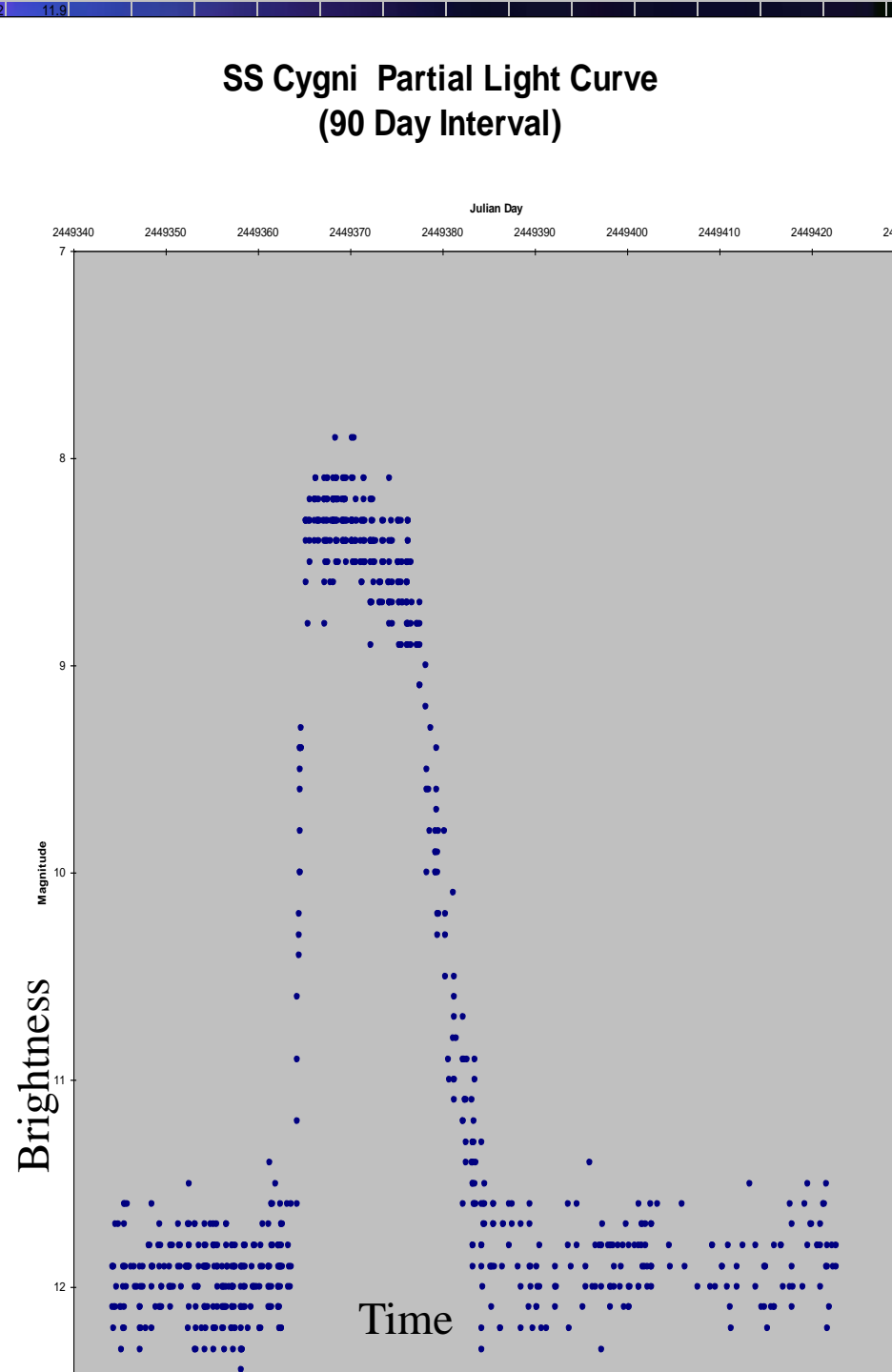
I thought scientists only used exact numbers!

- Well, a number can never be *too* exact in science, especially astronomy. But, all measurements are really estimates to a certain precision. The trick is understanding what that precision is.



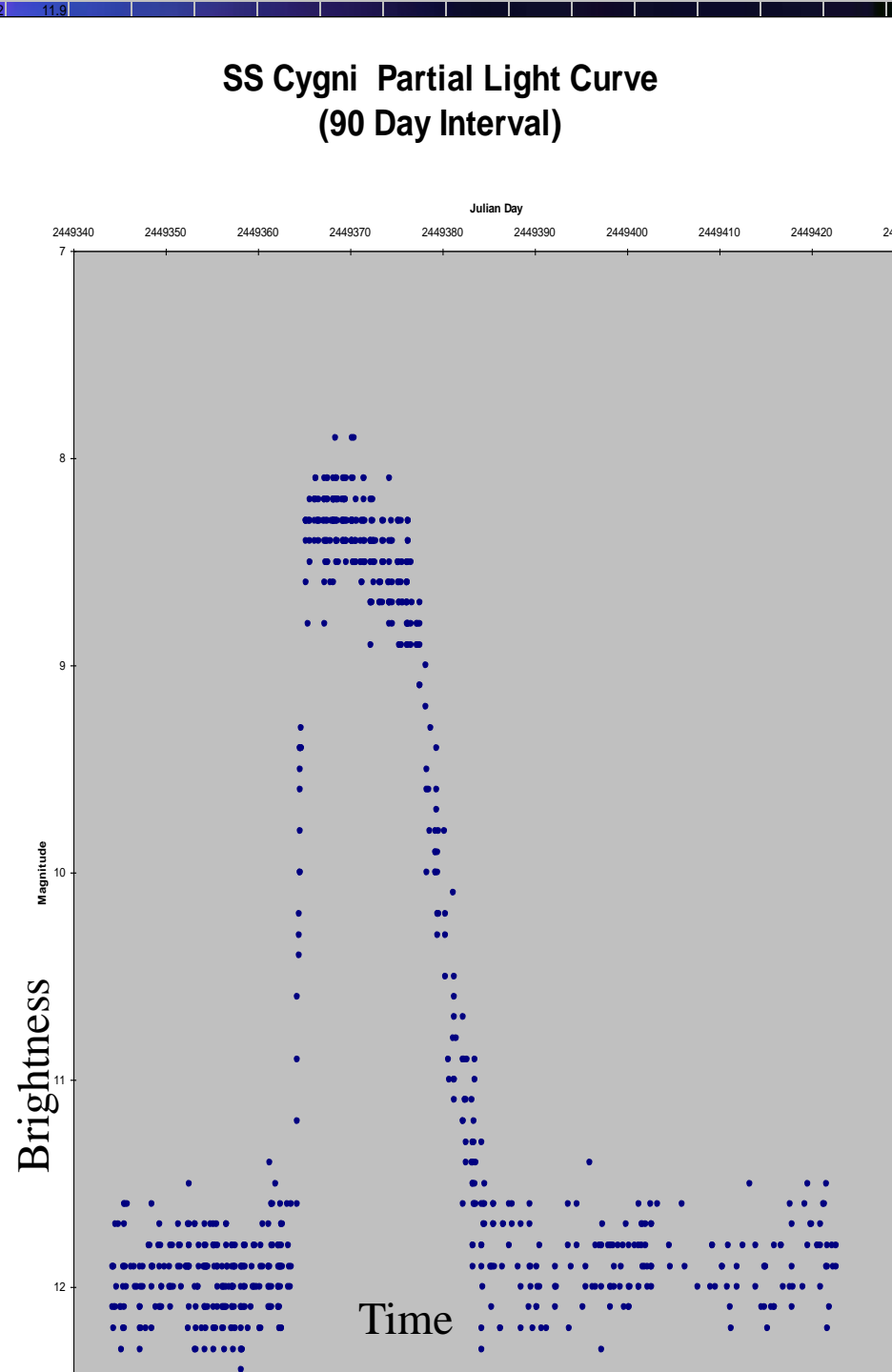
Precision in data

- The graph on the right is a portion of the AAVSO data that show the change in brightness over time of a star called SS Cygni.
- We call this a light curve.
- SS Cygni is located in the constellation of Cygnus the Swan.



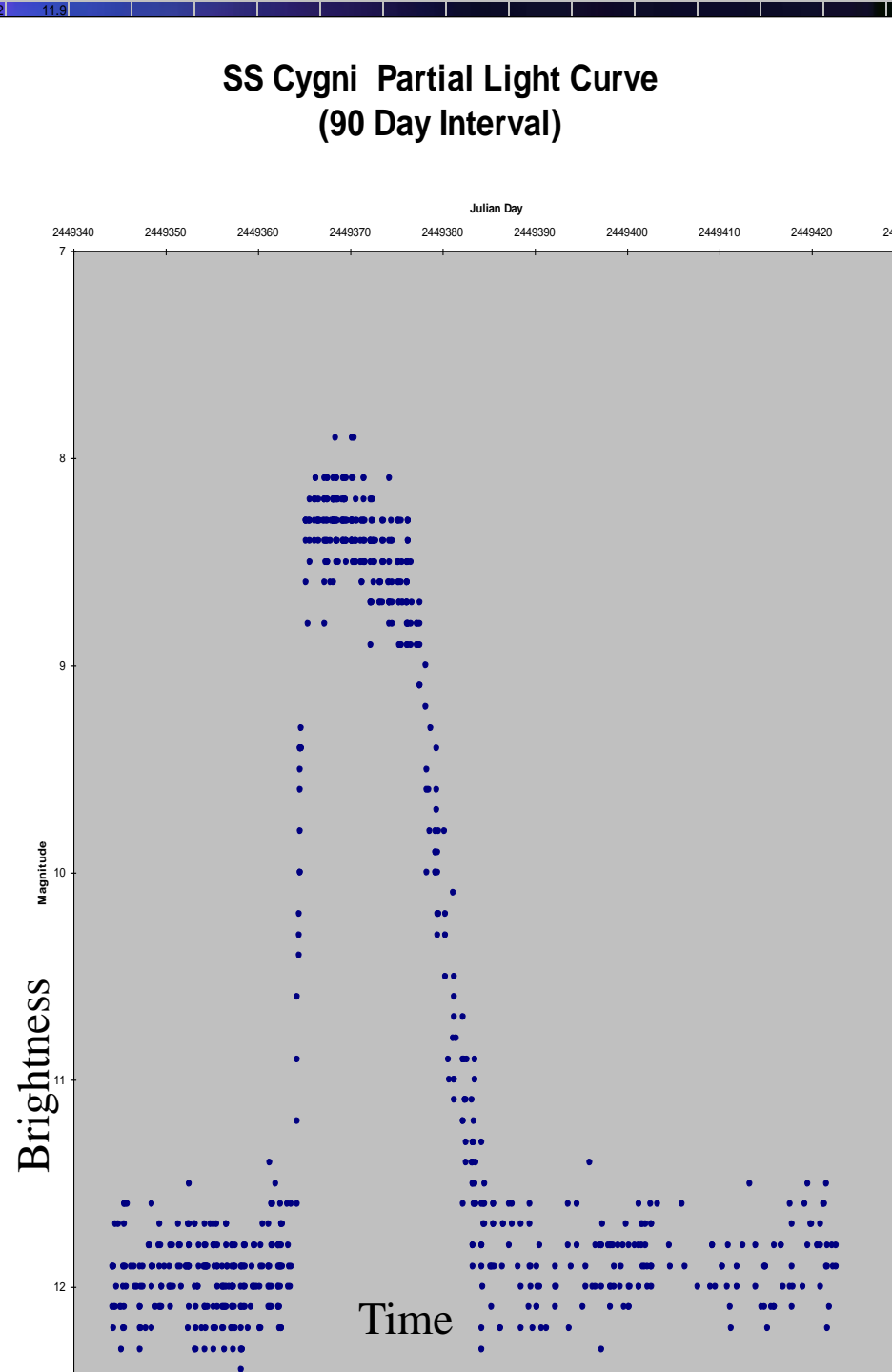
Precision in data

- SS Cygni brightens dramatically every few months.
- Each dot represents a measurement made by an AAVSO observer somewhere in the world. We have records on some stars back to 1911!
- You can make measurements like these too!



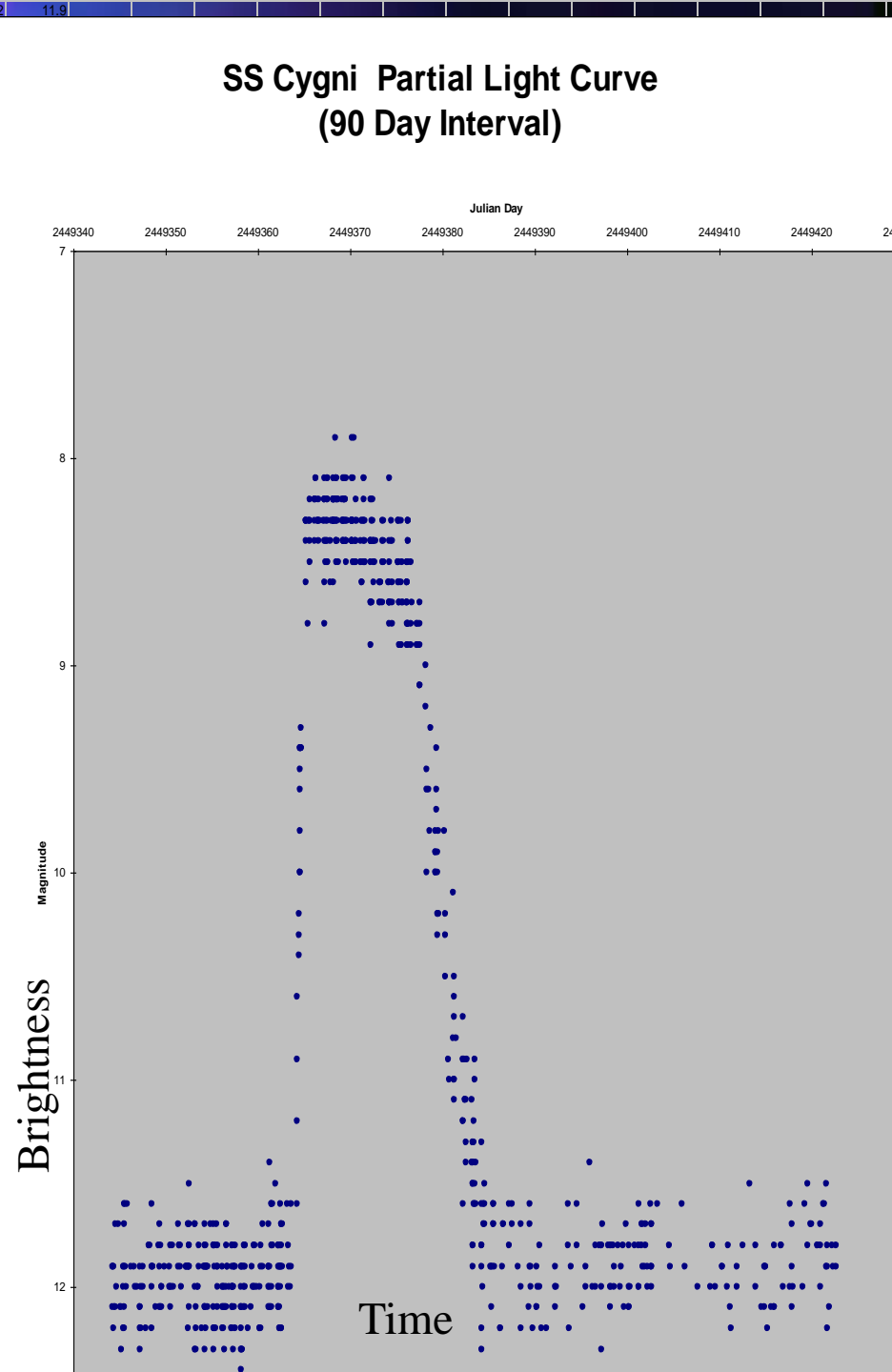
Precision in data

- The magnitude is plotted on the Y axis (up and down)
- The day and time of the observation is plotted on the X axis (left and right)



Precision in data

- You can see the noise in the data.
- Note that the curve is not a nice straight line.
- Rather, it is a wide band of individual observations.



Every estimate is needed

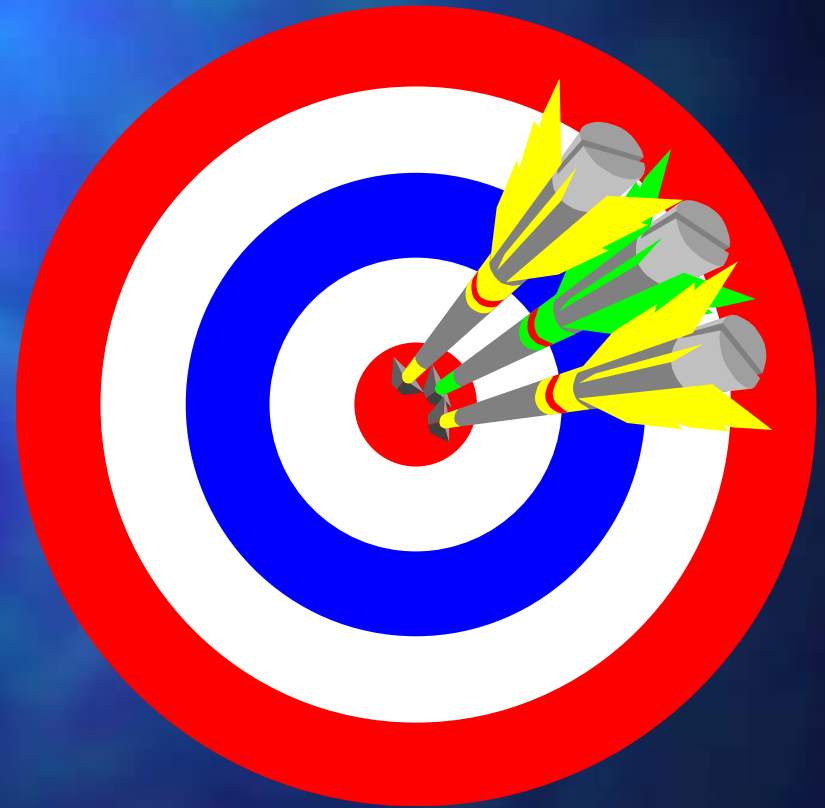
- Astronomers and physicists can use even noisy data to learn many things about how stars work.
- With practice, AAVSO visual observers can estimate brightness to a precision near 0.1 magnitude.



Artist's Conception - SS
Cygni (AAVSO)

There is no perfect estimate

- Your observations are estimates because everyone gets a little different result.
- You don't have to be perfect--just do the best job you can.
- Practice will help a lot!



Want to try again?

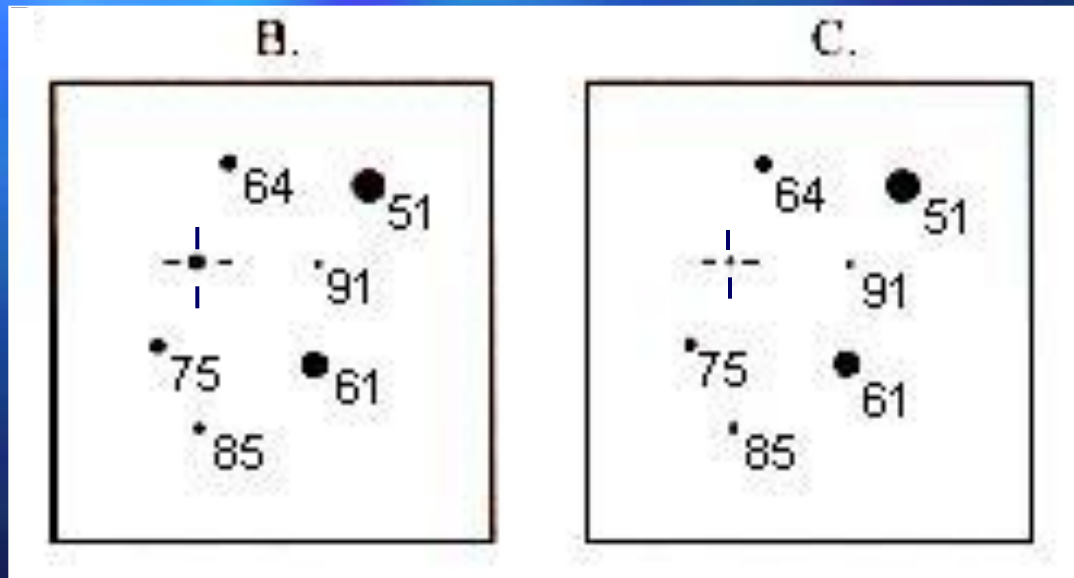


Let's Do It!

Cat's Eye Nebula (Hubble Space Telescope)

More practice

This time, estimate the same variable but in frames B and C. These frames could be the variable star at different times in its light curve. Write your answers on the form.

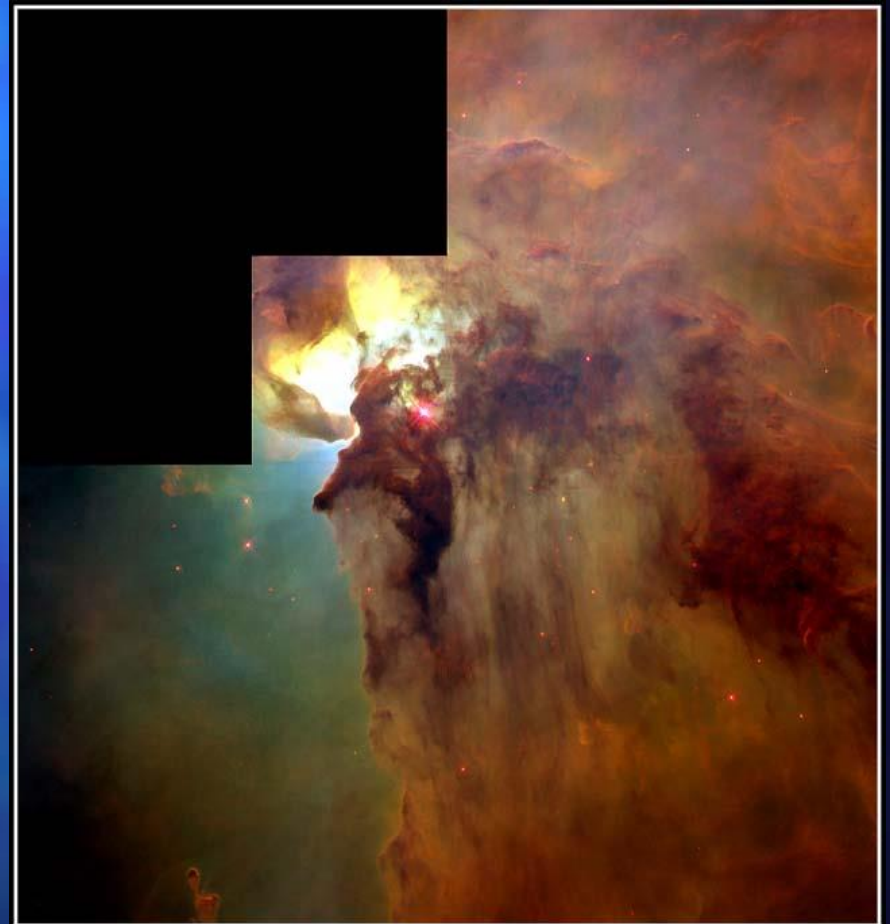


How did it go?

Was it easier the second
and third time?

I bet you are
ready for a real
star.

Let's try one!



Lagoon Nebula • M8

HST • WFPC2

PRC96-38a • ST ScI OPO • January 22, 1997

A. Caulet (European Southern Observatory) and NASA

W Cygni

- We are now going to make two estimates of a semi-regular star called W Cygni (W Cyg). You should have its chart in front of you.
- Click and it will be the next picture.



North is up

W Cyg Field Slide #1 28 April 1995 Julian Date 2449835



Are you able to find it?
(Click for a little help!)

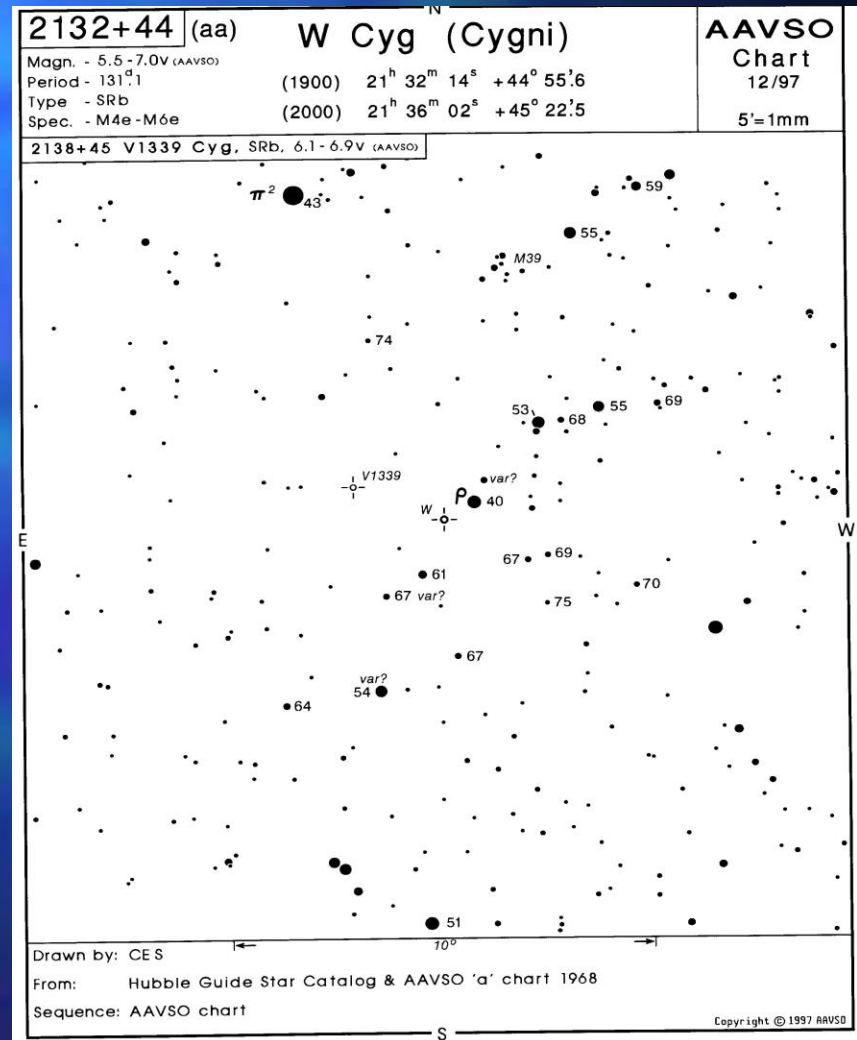
You're kidding!

- OK, there *are* lots of stars in the picture...
- You will need to learn to "star hop" to the star you want. But it's easy.
- Here's how!



W Cyg first estimation

- Take a look at the AAVSO W Cyg (size aa) chart.
- Hold it so that it is tilted about 45 degrees clockwise (to the right). It will better match the picture if tilted a little.



Why tilt the chart?

- The way a group of stars looks in a telescope can vary because of the type of telescope, how you look into it, and the season or time of night.



Why tilt the chart?

- Learning how to match the telescope view to the chart is something you'll learn when actually observing.
- But, back to our estimate!



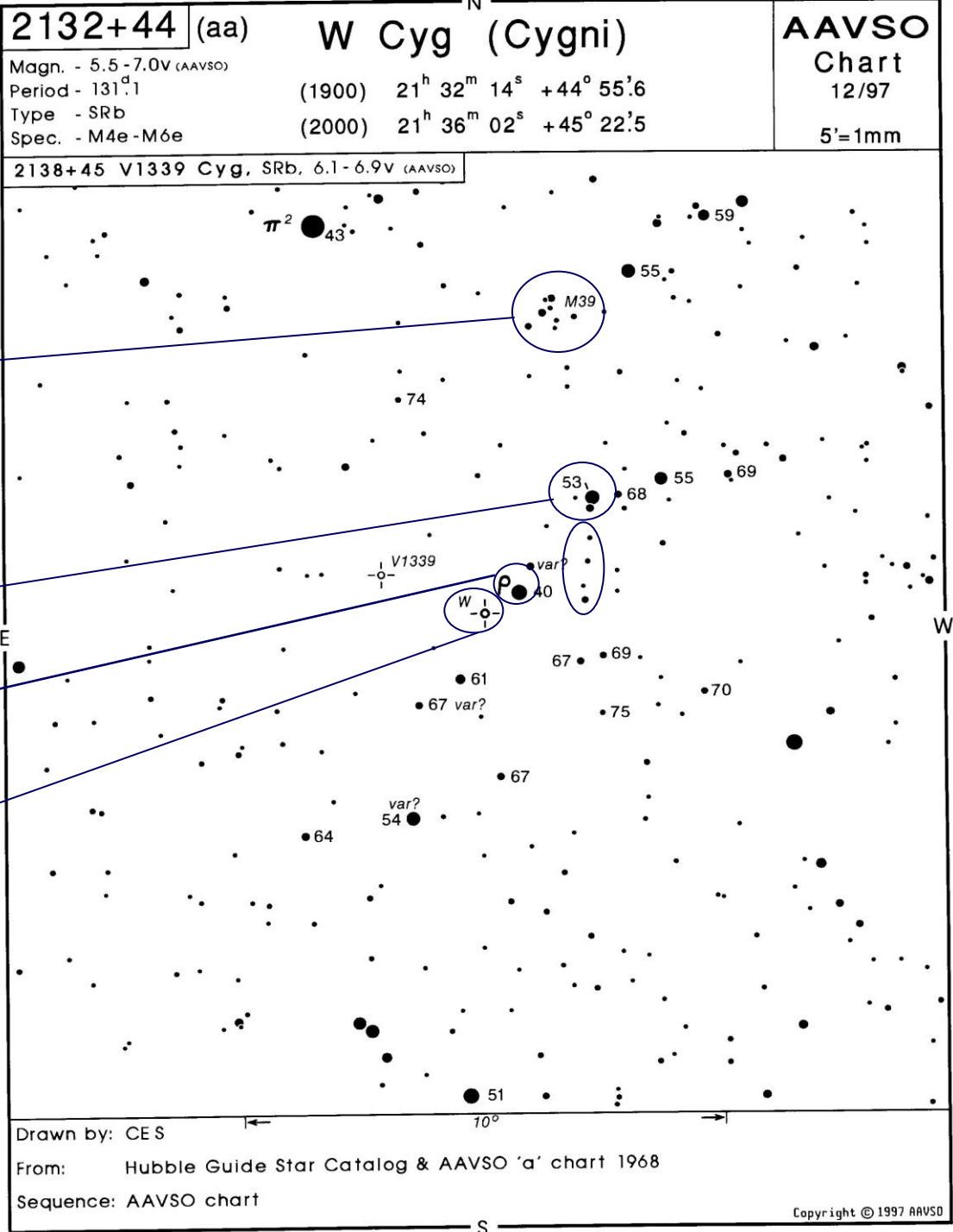
I'll give you some help.

M39

5.3 Comp star with
line to the south

Rho Cyg

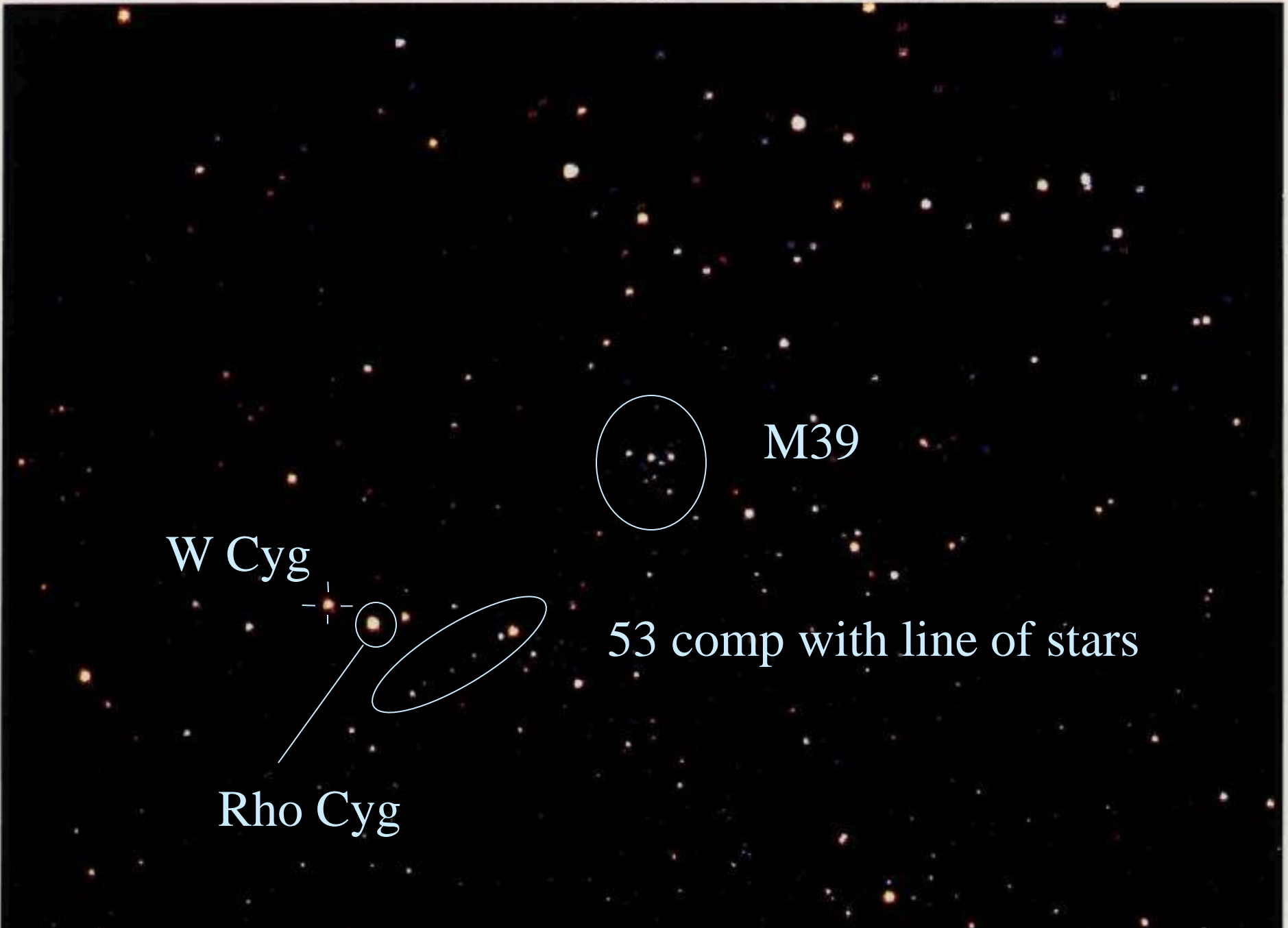
W Cyg



Finding landmarks

- This is how you star hop--from the easiest thing to see to the variable star.
- Now, let's try it on the photo!
- We'll go full screen and I'll show you the landmarks we just found on our chart.

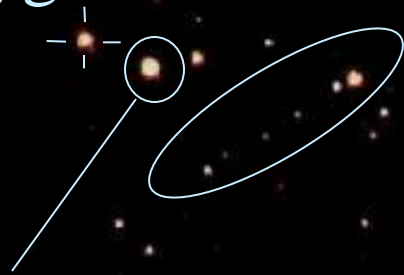




W Cyg



M39



53 comp with line of stars

Rho Cyg



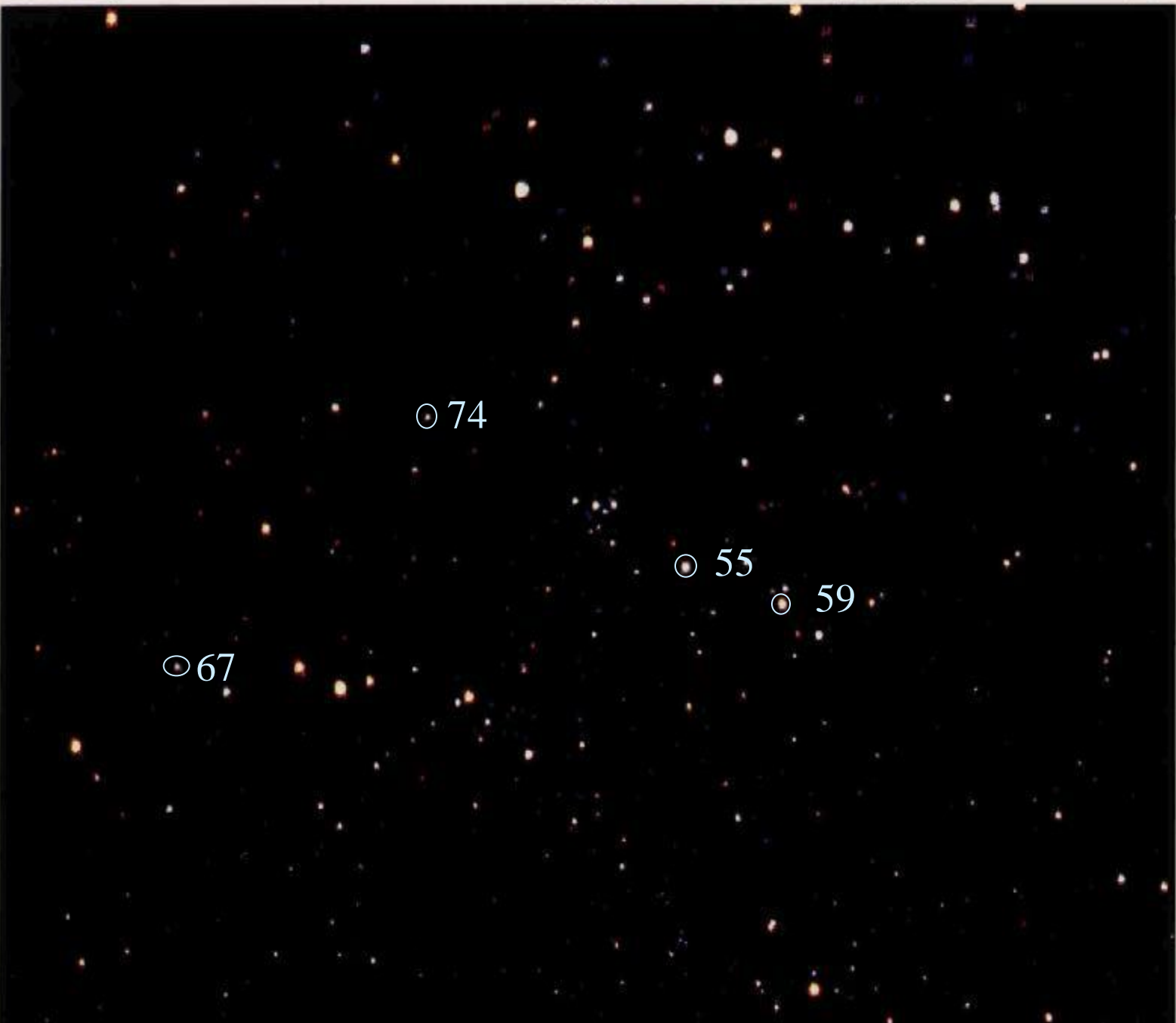
Can you find
the landmarks
on your own?

See if you can
find the comp
stars as well.

Did you find
them?

North is up

W Cyg Field Slide #1 28 April 1995 Julian Date 2449835



Here are some of the comp stars.

Can you find any more?



Now that you have found the comp stars, try to estimate W Cyg.

Write your estimate on the form.

We'll keep a pointer on W in case you get lost.

How did you do?

- Were you able to do it?
- If not, or if you had a lot of trouble finding things, ask now before the next (and last) estimate.



North is up

W Cyg Field Slide #3 19 July 1995 Julian Date 2449917

Here is a photo of W Cyg taken 82 days later. Try another estimate.

Write the result on your form.

If you need help finding it, click to the next slide.



North is up

W Cyg Field Slide #3 19 July 1995 Julian Date 2449917



Does that
help?

North is up

W Cyg Field Slide #3 19 July 1995 Julian Date 2449917



Note that the photo doesn't look like the one in April. This is because the sky changes appearance from season to season and even night to night. This change is one of the challenges of variable star observing!

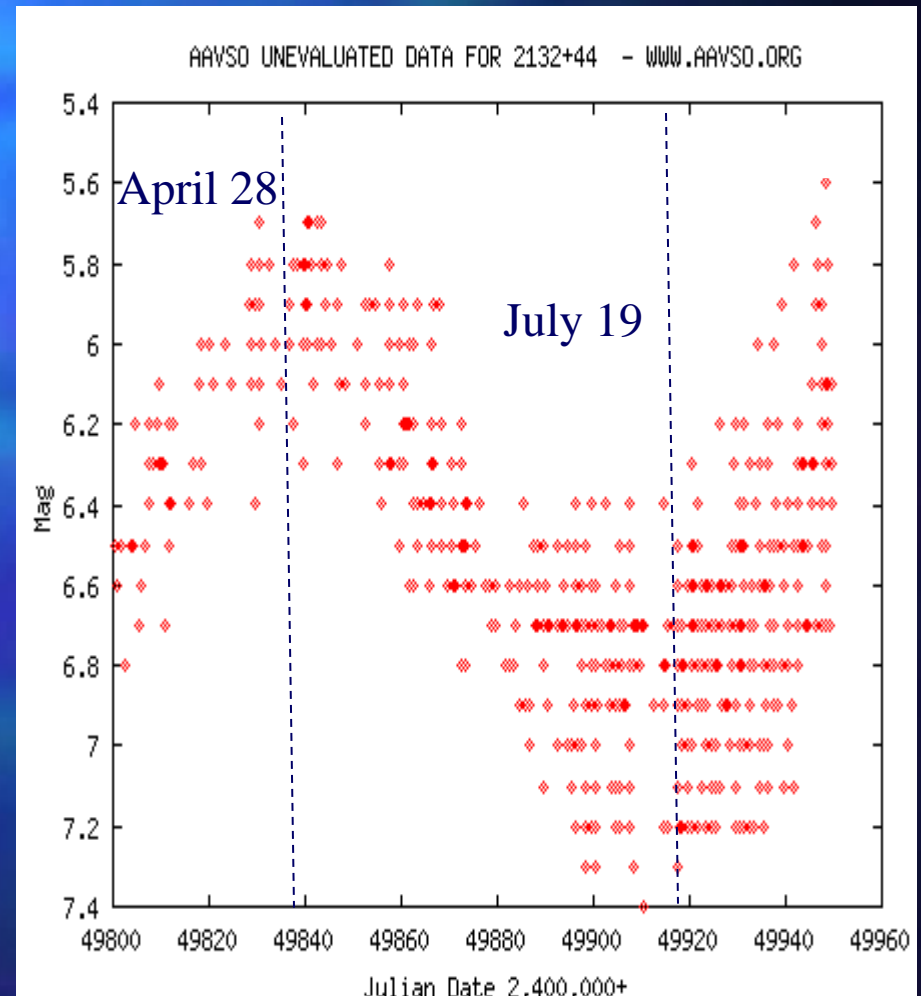
How did you do?

- Is it getting easier to make the estimates?
- Did you have less trouble finding W Cyg and the comparison stars?
- Practice really helps, doesn't it!



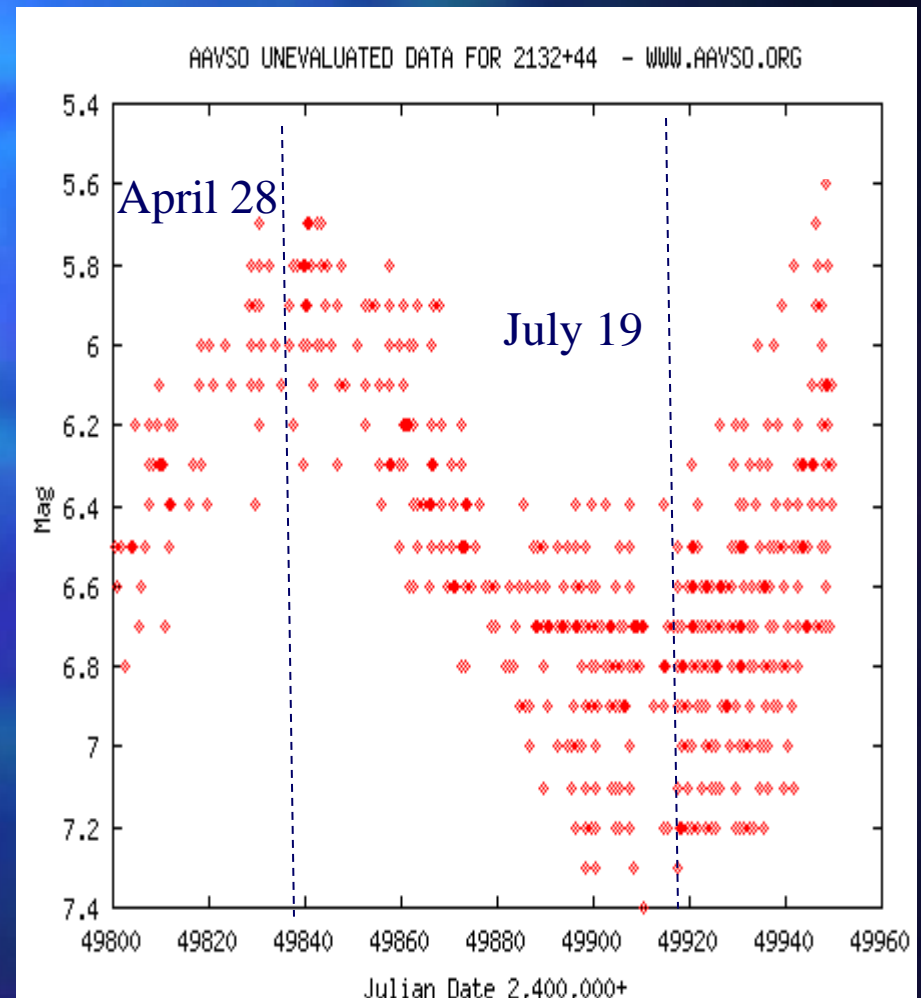
Is that your final answer...?

- On the right is a section of the light curve of W Cyg from the AAVSO data base.
- The two dates on which you made estimates are shown with dashed lines.



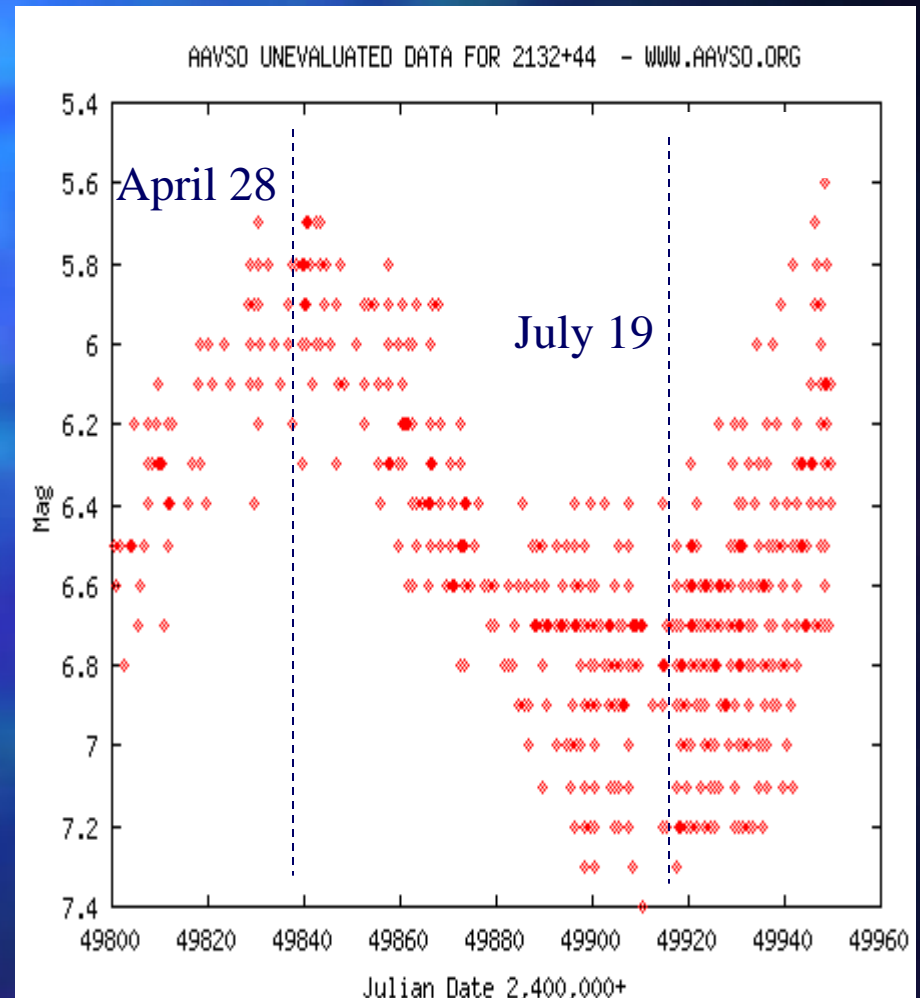
Is that your final answer...?

- On April 28 the observations were between about 6.3 and 5.7 magnitude.
- On July 19, the observations were between about 7.3 and 6.4 magnitude.



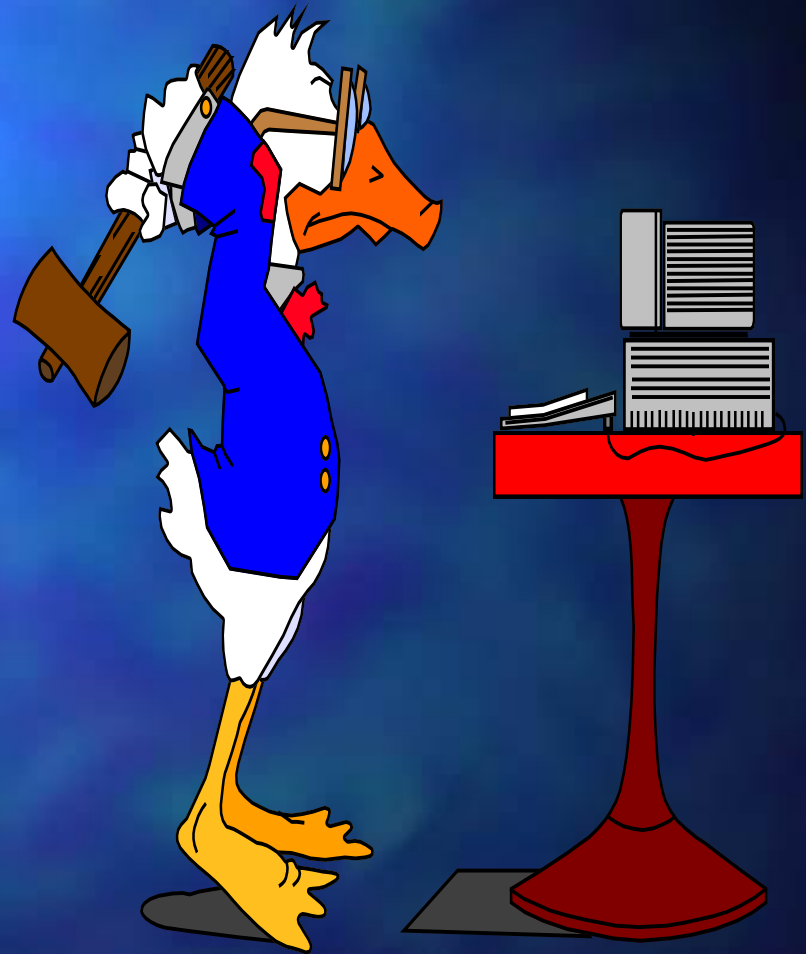
Is that your final answer...?

- How did you do compared to other AAVSO observers?
- If one or more of your estimates are outside of the band of results, why?



If your results were different from AAVSO observers'...

- Practice helps. Some AAVSO observers have made thousands of measurements.
- You were looking at a computer, not the sky.
- You are still learning!



Variable star observing can be very challenging sometimes!

You are teaching your eyes to see the world differently!

- Many new observers need time before they can see fine differences in brightness. This takes practice but is a skill that can help you enjoy all the beauty in the night sky.

M100 Galactic Nucleus

Hubble Space Telescope
Wide Field Planetary Camera 2



Wide Field Planetary Camera 1



Wide Field Planetary Camera 2

You are a winner!

- Now we will plot your results today along with everybody else's.
- I bet you did pretty well!
- While it's not a contest, look at the class data and see how you did.

Be it Known that
on This Day...

I learned how to
measure the
brightness of a
variable star!

