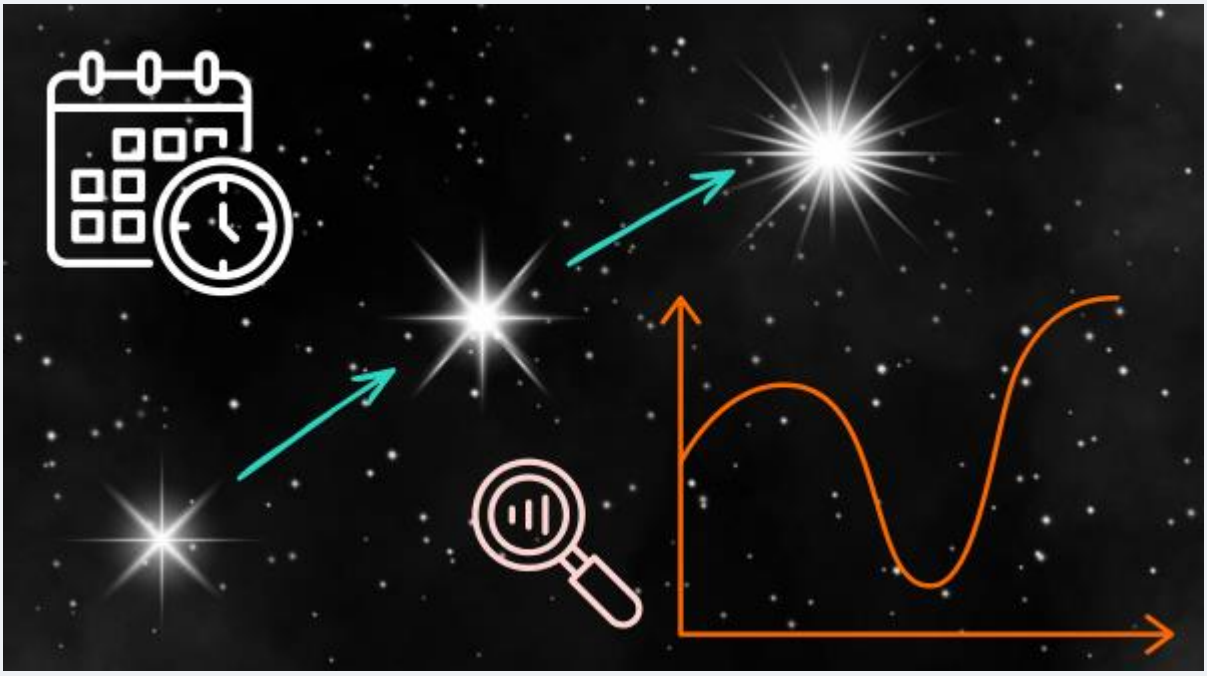
MEASURE THE BRIGHTNESS OF A VARIABLE STAR



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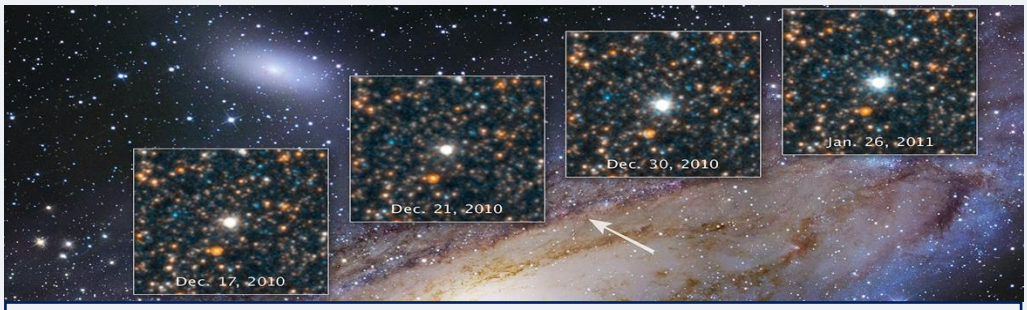
MEASURE THE BRIGHTNESS OF A VARIABLE STAR

Introduction

Many stars appear to change in brightness over time. These are called **variable stars**. Different types of variable stars fluctuate in brightness for different reasons.



A variable star in the Andromeda Galaxy

Image Credit: NASA, ESA, Hubble Heritage Project (STScI, AURA)

We study most variable stars by measuring brightness changes over a few hours, days or even months. This is plotted on a graph known as a **light-curve**.

Some types of variable star show a repeating pattern in their brightness changes, giving them distinct light-curves. This allows us to classify the stars we investigate.

The time it takes for one full cycle of brightness changes is called the **period** of a variable star. Periods can span from less than a second to several years.

List some ideas about why stars might change brightness over short periods of time (i.e. less than a year):

- **Increase or decrease in size**
- **Surface eruptions from flares or mass ejections**
- **Novae and supernovae**
- **An orbiting object periodically blocking light (e.g., a planet or another star)**
- **Dark sunspots becoming visible then disappearing as the star rotates**
- **Non-spherical shape of a star**

MEASURE THE BRIGHTNESS OF A VARIABLE STAR

You will analyse observations of a known variable star discovered in 1903: W Ursae Majoris (**W UMa)**, in the constellation of Ursa Major. It has a period of 8 hours and 26 seconds, or 0.3336 days.

You'll find the date and time that each image was taken at. You will also measure the brightness of W UMa and 2 non-varying stars nearby. This method is known as **relative photometry** and is used to remove brightness variations caused by the atmosphere or instrumentation.

These measurements will be inputted into a pre-prepared Excel spreadsheet. A light-curve is automatically generated . This plots magnitude against phase.

Magnitude is how astronomers' express brightness. The lower the magnitude, the brighter the object. The **phase** shows where in that period (or repeating pattern) our observation was taken. Phase 0.0 is the start and phase 1.0 is the end.

Finally, you will then compare the light-curve to those of known types of variable stars to classify W UMa.

Note: There are 2 versions of this activity.

- **Short Activity** (30 – 60 minutes)
- **Full Activity** (60 – 90 minutes)

The instructions and outcomes for each activity is the same. The Excel spreadsheet has a sheet for each version. These are named 'Short Activity' and 'Full Activity'. Please ensure you are entering data into the correct sheet for your activity version.

However, the data sets that need to be downloaded are different.
- Short Activity: 'W UMa – Data Set 3' **only**
- Ful Activity: 'W UMa – Data Set 1', 'W UMa – Data Set 2' **and** 'W UMa – Data Set 3'

Each data set is a **ZIP file** containing 20 images. ZIP files are a way of collating and compressing large amounts of data into a single downloadable file. To access the data, it will need to be **unzipped**.

On Windows systems, right-click on the downloaded file, select the 'Extract All' option and follow the instructions. On Mac systems, double-click on the downloaded file and the data will automatically be extracted.

MEASURE THE BRIGHTNESS OF A VARIABLE STAR

Instructions

Step 1 – Open the Excel Spreadsheet

- Download and open the '**Measure the Brightness of a Variable Star – Results**' Excel spreadsheet.
- Click on the correct tab for the version of the activity you are doing ('**Short Activity**' or '**Full Activity**').

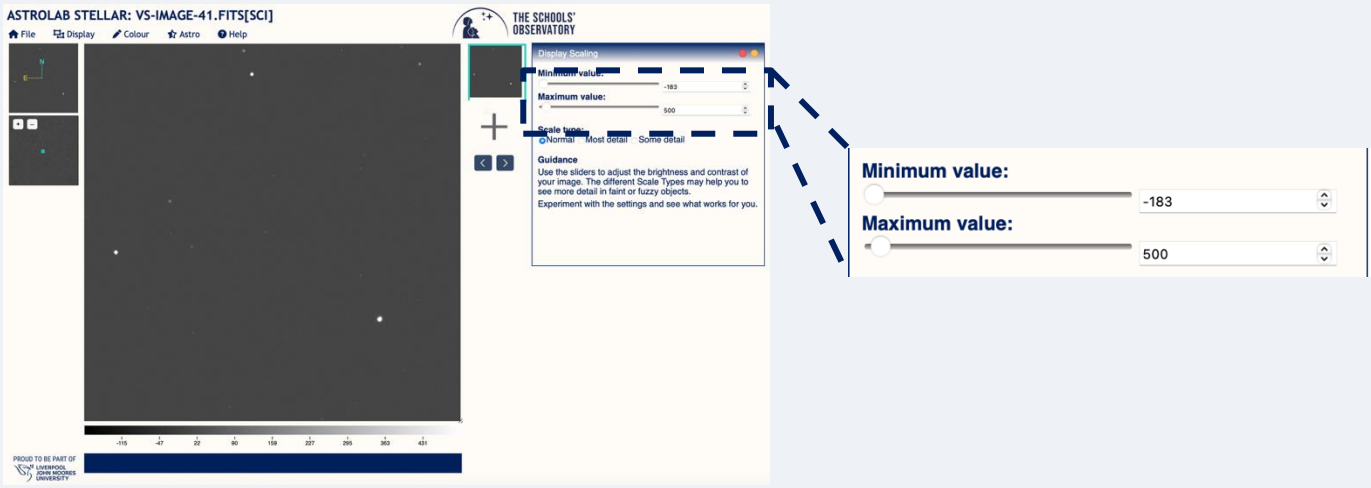
As you complete the activity, two graphs will be automatically generated. '**W UMa Magnitude v Phase**' is the light-curve. You will analyse this at the end. 'Comparison 1 / Comparison 2 v Phase' displays the magnitude changes of the comparison stars. A flat line shows that their brightness is not changing.

Step 2 – Load Your First Image

- Open AstroLab Stellar.
- Go to File > **Open an image**.
- Use the file explorer that appears to find the first image you will analyse ('**VS-Image-41**' for the short activity, or '**VS-Image-01**' for the full activity).
- Double-click the image or select '**Upload**'.

Step 3 – Scale the Image

- Go to Display > **Scaling**.
- In the toolbox that appears, type **500** into the '**Maximum value**' box and press enter.
- You should now see some stars like in the picture below.



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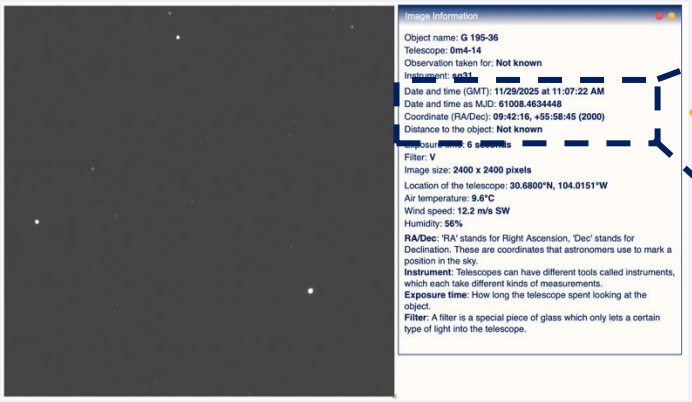
Step 4 – Find the Date and Time of the Observation

- Go to Astro > **Observation Details**.
- Look for '**Date and time as MJD**' in the toolbox that appears.



Date and time (GMT): **11/29/2025 at 11:07:22 AM**
Date and time as MJD: **61008.4634448**
Coordinate (RA/Dec): **09:42:16, +55:58:45 (2000)**
Distance to the object: **Not known**

MJD is a way to express the date and time as a single value.

It is used by astronomers to simplify calculations involving intervals of time.

Step 5 – Record the Date and Time of the Observation

- Go to the Excel spreadsheet and input the **MJD** in column B for the image you are analysing (check the image name displayed in AstroLab if needed).
- You should notice that a **phase** is automatically calculated in column C.

Step 6 – Identify the Stars

- Use the picture below to identify each star you'll be analysing. You will need to know this in following steps.

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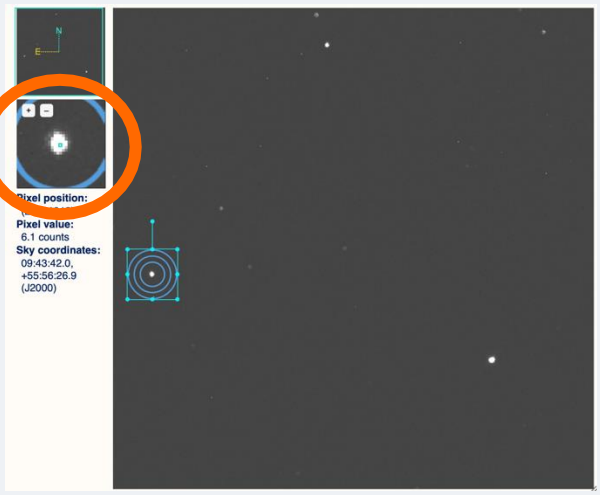
Step 7 – Measure the Brightness of W UMa

- Go to Astro > **Measure Brightness**.
- Select the '**Add Target**' button in the toolbox. A box containing 3 circles should appear.
- Type **60** into the '**Target radius**' box and then click elsewhere in the toolbox. Or use the slider or arrow buttons instead to increase the radius to 60.
- Move the target and place W UMa in the **centre**. The results are displayed in the toolbox

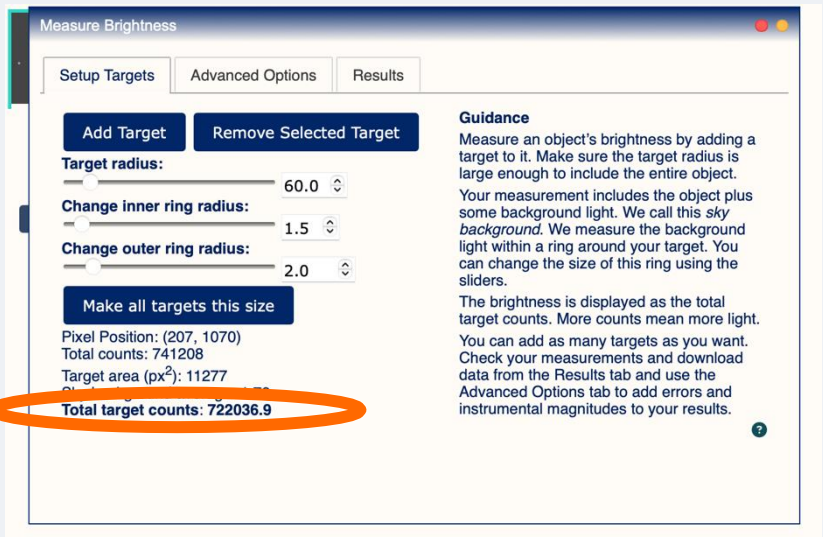
Tip: A close-up view of the image beneath your cursor is displayed in the left lower panel (circled in orange opposite). Use this to help you place the small blue dot in the centre of W UMa.

You can also watch our video guide for further help.



Step 8 – Record the Brightness of W UMa

- Look at the results in the toolbox. The value you need is '**Total target counts**'.
- Go to the **Excel spreadsheet** and input this value into **column D** (W UMa Counts) for the image you are analysing (check the image name displayed in AstroLab if needed).



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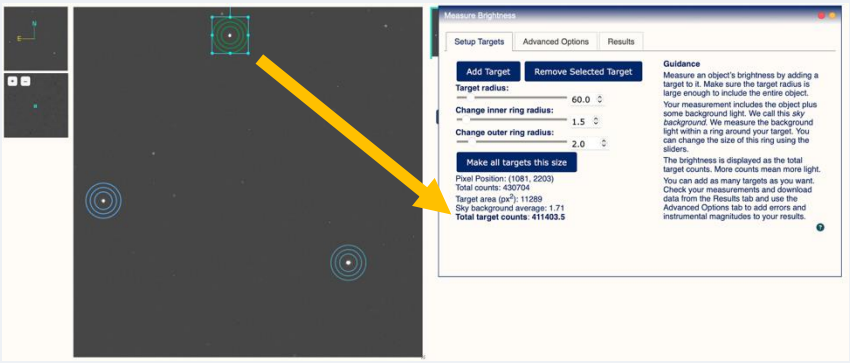
Step 9 – Measure the Brightness of the Comparison Stars

- Go back to **AstroLab**.
- Use the '**Add Target**' button in the toolbox to add **2** new targets. Both should be the **same size** as the first and they may stack on top of each other.
- Move the targets so a comparison star is **centred** in each one. Use the small dot and close-up view to help with this.
- Select a specific target to display the results for that star in the toolbox.



Selecting the green target displays the results for that star (comparison star 2, in this case).

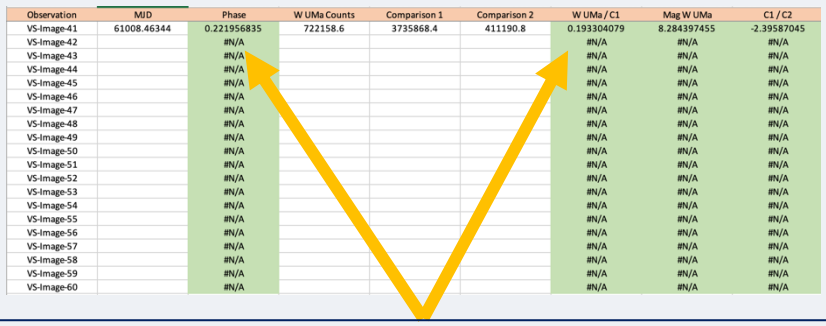
Click on a different target to see the results of the other stars.

Step 10 – Record the Brightness of the Comparison Stars

- Select the target around **comparison star 1** (lower right).
- Look at the results in the toolbox. The value you need is '**Total target counts**'.
- Go to the **Excel spreadsheet** and input this value into **column E** (Comparison 1) for the image you are analysing.
- Go back to AstroLab and select the target around **comparison star 2** (upper middle).
- Look at the results in the toolbox. The value you need is '**Total target counts**'.
- Go to the **Excel spreadsheet** and input this value into **column F** (Comparison 2) for the image you are analysing.

Always check that you've typed correctly. Compare the result in AstroLab to your spreadsheet.

Comparison Star 1 will be the largest value, then W UMa, and Comparison Star 2 the lowest.



Observation	MJD	Phase	W UMa Counts	Comparison 1	Comparison 2	W UMa / C1	Mag W UMa	C1 / C2
VS-Image-41	61008.46344	0.221956835	722158.6	3735868.4	411190.8	0.193304079	8.284397455	-2.39587045
VS-Image-42		#N/A				#N/A	#N/A	#N/A
VS-Image-43		#N/A				#N/A	#N/A	#N/A
VS-Image-44		#N/A				#N/A	#N/A	#N/A
VS-Image-45		#N/A				#N/A	#N/A	#N/A
VS-Image-46		#N/A				#N/A	#N/A	#N/A
VS-Image-47		#N/A				#N/A	#N/A	#N/A
VS-Image-48		#N/A				#N/A	#N/A	#N/A
VS-Image-49		#N/A				#N/A	#N/A	#N/A
VS-Image-50		#N/A				#N/A	#N/A	#N/A
VS-Image-51		#N/A				#N/A	#N/A	#N/A
VS-Image-52		#N/A				#N/A	#N/A	#N/A
VS-Image-53		#N/A				#N/A	#N/A	#N/A
VS-Image-54		#N/A				#N/A	#N/A	#N/A
VS-Image-55		#N/A				#N/A	#N/A	#N/A
VS-Image-56		#N/A				#N/A	#N/A	#N/A
VS-Image-57		#N/A				#N/A	#N/A	#N/A
VS-Image-58		#N/A				#N/A	#N/A	#N/A
VS-Image-59		#N/A				#N/A	#N/A	#N/A
VS-Image-60		#N/A				#N/A	#N/A	#N/A

As you enter measurements, calculated values will appear in the green shaded columns, as will points on the graph.

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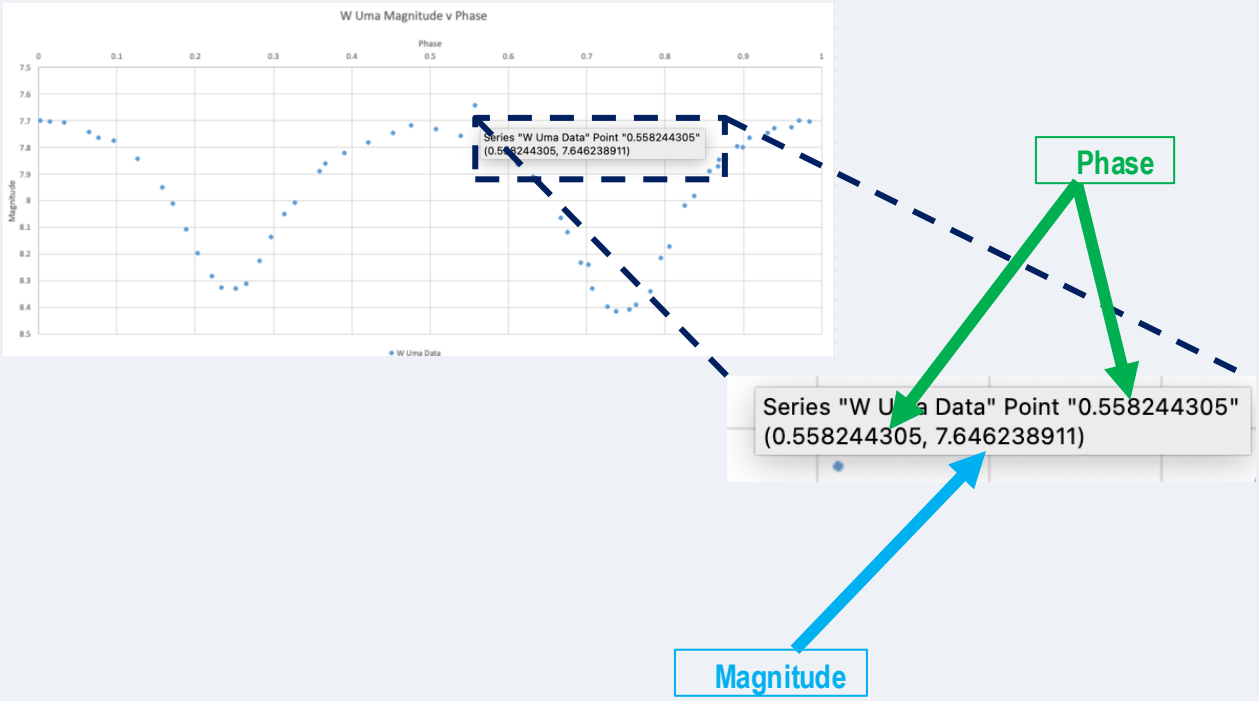
Step 11 – Repeat for All Images

- Go back to **AstroLab**.
- Refresh the webpage to remove the last image you analysed.
- Go to File > **Open an image** and use the file explorer that appears to find the next image you will analyse.
- Double-click the image or select '**Upload**'.
- **Repeat steps 3 to 11** until you've analysed all the images for the version of the activity you're doing (Short Activity: Images 41 to 60, Full Activity: Images 1 to 60).

Step 12 – Check Your Results

- Look carefully at the **graphs** in the Excel spreadsheet. 'W UMa Magnitude v Phase' is a light-curve that should show **2** dips in magnitude. 'Comparison 1 / Comparison 2 v Phase' shows the magnitude changes for the comparison stars. This should be a **flat line**.
- Check if any points appear **out of place**. These are outliers/anomalous results. They could be genuine but are often due to a value being **incorrectly entered**.
- **Hover over a point** that appears out of place. This shows the phase and magnitude of that point. Use these values to **identify the image** that was analysed.
- Re-check the **MJD** for that image and re-do the **brightness measurements** if needed.



Conclusion

Describe the magnitude changes of W UMa over an entire phase.

At phase 0, the magnitude of W UMa is around 7.7. This starts to increase (get less bright) and reaches 8.3 at phase 0.25. The magnitude begins to decrease (gets brighter), reaching 7.7 again at phase 0.5.

It then increases and reaches 8.4 at around phase 0.75. The magnitude then decreases again and reaches 7.7 at phase 1.

Research the different types of variables stars in our Learn section.

Using this knowledge and the fact that W UMa has a period of 0.336 days, explain which type of variable star it must be. Refer to the period and light-curve in your answer.

W UMa is an eclipsing binary. It has a short period of 0.336 days, which is within the typical range of this type (usually a few hours to a few days). The light-curve of W UMa also has 2 dips (decrease in brightness) that reach different magnitudes; 8.3 and 8.4. This matches the light-curve of an eclipsing binary which show a primary and secondary eclipse.

W UMa cannot be a Cepheid or Mira variable star. Cepheids have periods of days to weeks, and Mira variables have periods that last months. W UMa has a period 0.336 days, which is too short for these types.

W UMa also cannot be an RR Lyrae star. Its light-curve doesn't match the distinct shape and instead shows 2 smooth curves.

Explain what causes the variability in magnitude of W UMa over an entire phase.

W UMa is an eclipsing binary. This is a system containing 2 stars that orbit each other. Since they orbit in a plane in line with our view of them, they periodically eclipse each other.

When both stars are side-by-side, light isn't blocked. We see maximum brightness (lowest magnitude). As the fainter star moves in front of the brighter one, some light from the brighter star is blocked. This causes a dip in brightness (increase in magnitude). This is known as the primary eclipse. As the brighter star moves in front of the fainter one, some light from the fainter star is blocked, and there's a dip in brightness (increase in magnitude). Since this dip is smaller, it is known as the secondary eclipse.

Extra Information: W UMa

W UMa is located **168 light-years** from Earth, in the constellation Ursa Major. Its apparent magnitude (brightness) varies by **0.7** over a period of 0.336 days. This equates to a drop in brightness of **25%**.

W UMa is the prototype for a class of variable stars known as **close-orbiting eclipsing binaries**. In fact, these companion stars orbit so closely that they are effectively touching, with material being transferred from the small star to the larger. This causes the stars to have **same surface temperature**.

The light-curves of close-orbiting eclipsing binaries show **almost equal** primary and secondary eclipses.

Binary System: W UMa	
Primary: W UMa A Radius: 1.1 x the Sun Brightness: 1.5 x the Sun	Secondary: W UMa B Radius: 0.8 x the Sun Brightness: 0.9 x the Sun