Light curve error bars in AstroImageJ & Excel

How to add error bars to your graphs using the free image processing software, AstroImageJ

Classroom Activity

Outline

This worksheet describes how to add error bars to your light curves to investigate how much you can trust the trends you might see. When you have plotted simple graphs, you will present your results on graphs to display the **error bars**.

Prior to carrying out this activity, if you have not used the AstroImageJ software previously or carried out photometry, it is recommended that you read through and complete the **'Light Curve Photometry with AstroImageJ'** worksheet. You must have also completed the photometric analysis of an object, by reading through and completing the relevant worksheet, e.g. **"X-ray binary light curves with AstroImageJ"**.

Background on Uncertainties:

Every measurement that is taken of a star or set of stars comes with an associated uncertainty, which is sometimes called an 'error'. The term uncertainty is perhaps more accurate in the sense that it describes the level of confidence we have in our values, whereas the term error suggests that mistakes have been made in either the data collection or analysis.

Quantifying the uncertainty allows us to place error bars on our data points. The uncertainty is related to a quantity known as signal-to-noise ratio (SNR). The SNR is a measure of the quality of the data i.e. how 'loud' the signal is in relation to the background 'noise' and is given by the equation

SNR = square root (counts * gain)

where counts is the number of photons that fall on a given pixel and gain is a measure of the efficiency of the camera in terms of turning photons into electrons. The gain can be found in the FITS header. Generally, a value for SNR greater than 100 is considered good for accurate photometry.

From the SNR, the uncertainty can be calculated as 1/SNR. From this, we can see that a SNR of > 100 leads to an uncertainty of < 0.01 magnitudes.

The online observatory collaboration consists of the following partners:
Baldone Observatory, Brorfelde Observatory, Cardiff University, Harestua Solar Observatory, Helsinki Observatory

From these equations, it can be seen that shrinking the error bars can be achieved by increasing the signal-to-noise, which in turn is done by either increasing the gain (i.e. having a better, more efficient and almost certainly more expensive camera!) or by increasing the number of counts. Increasing the counts is most easily achieved by increasing the exposure time, although we can examine other solutions such as using larger telescopes or simply observing brighter objects.

Uncertainty in magnitude can be calculated from uncertainty in flux using Equation 1:

Equation 1 - Calculating uncertainty in magnitude from uncertainty in flux.

magnitude uncertainty = (2.5 x flux uncertainty) / flux

Procedure:

Calculating Magnitude Uncertainties

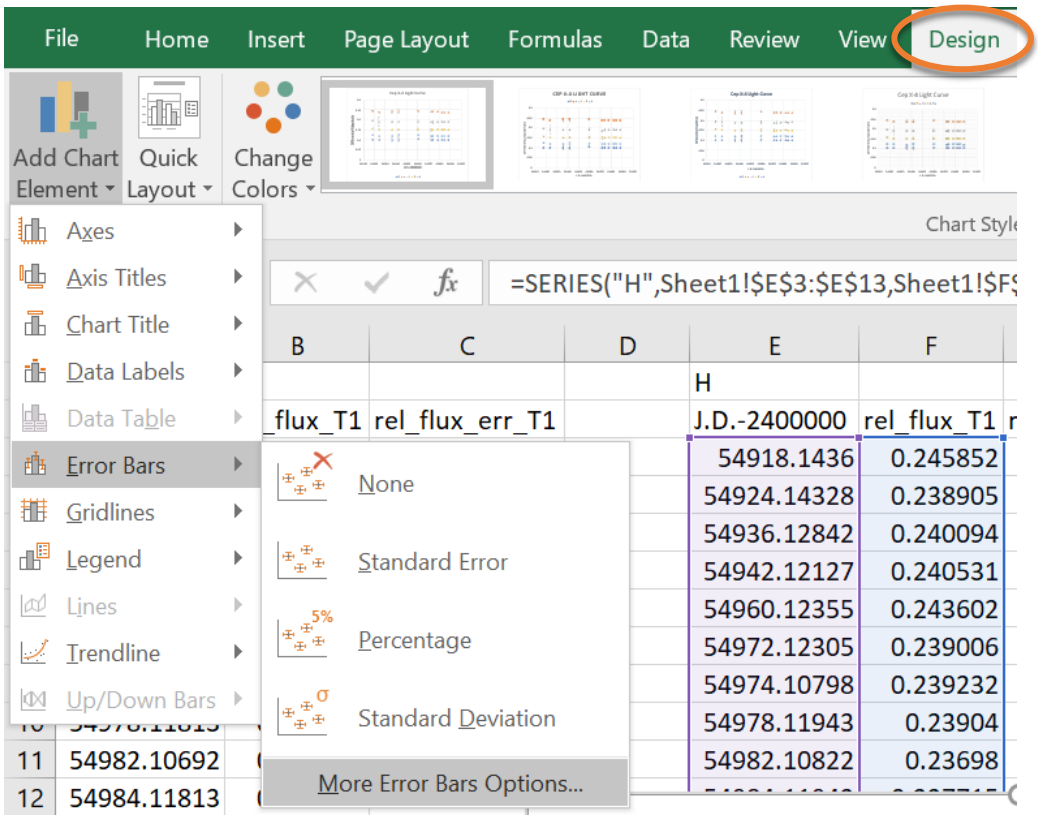
AstroImageJ outputs a column 'rel_flux_err_T1', which is the uncertainty on 'rel_flux_T1'.

1. Add a column to the right of 'rel_flux_err_T1' and name this 'mag err'.
2. In the first box of this column, type "=(2.5*", click on the first box of the 'rel_flux_err_T1' column, then type ")/", followed by clicking on the first box of the 'rel_flux_T1' column. After this, press Enter.
3. Drag this box to the bottom of the spreadsheet.

Adding Error bars

4. Click on a data point (any of the blue circles) on your graph.
5. Under 'Design', select Add Chart Element -> Error Bars -> More Error Bar Options, as in Figure 1.

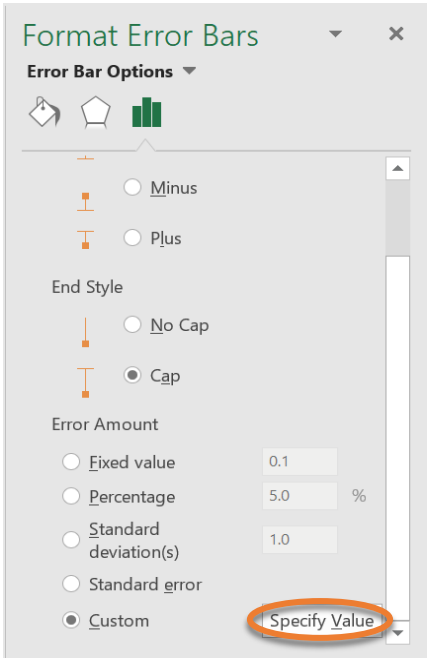
Figure 1 - Choosing More Error Bar Options in Excel.



6

In the 'Format Error Bars' pop-up window that appears on the right, under 'Error Amount' select Custom and Specify Value, shown in Figure 2.

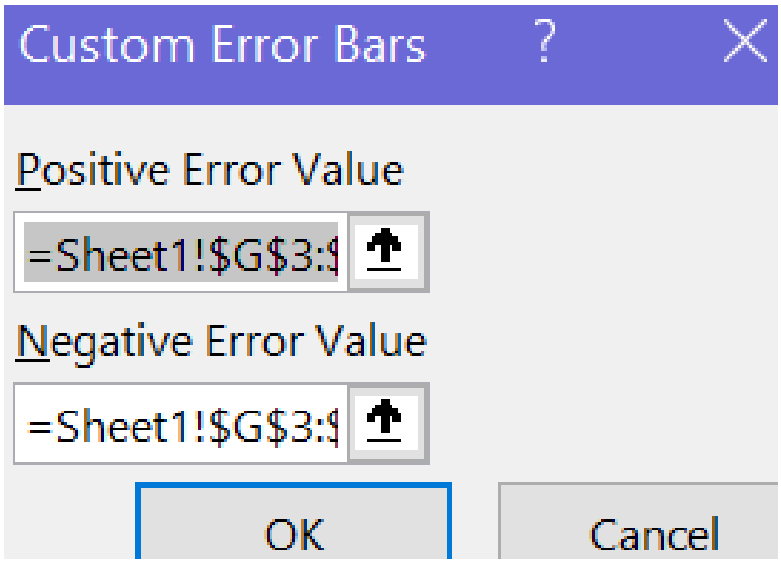
Figure 2 - Choosing to Specify Value for error bars in Excel.



7

In the ‘Custom Error Bars’ pop-up window that appears, highlight the data in the ‘mag err’ column for both the ‘Positive Error Value’ and ‘Negative Error Value’. This is shown in Figure 3.

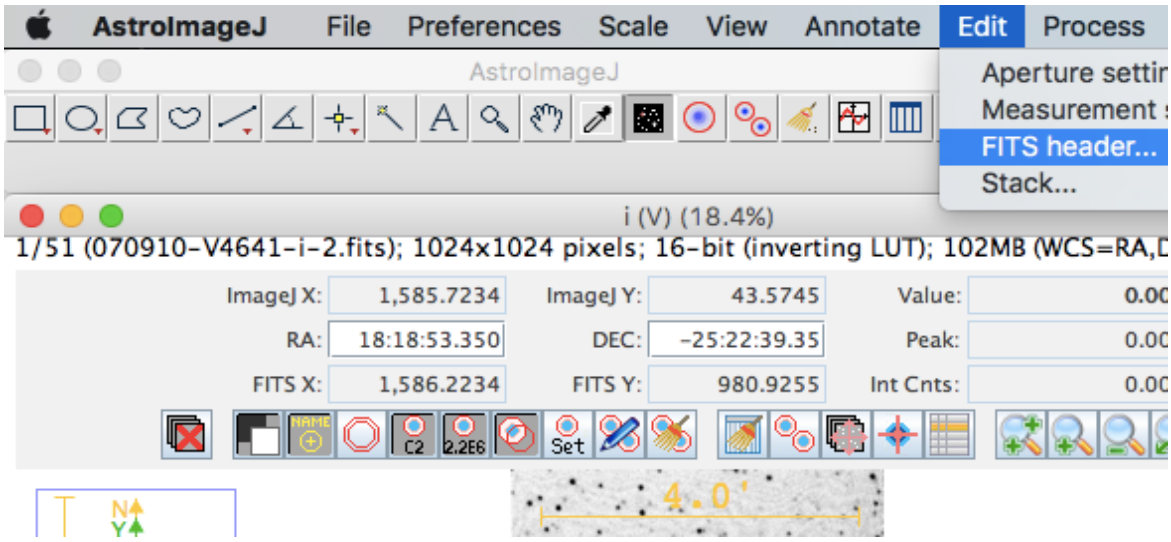
Figure 3 - Choosing values for Custom Error Bars in Excel.



8

In the AstroImageJ photometry window, select Edit -> FITS header…, like in Figure 4.

Figure 4 - Viewing FITS header in AstroImageJ.



9

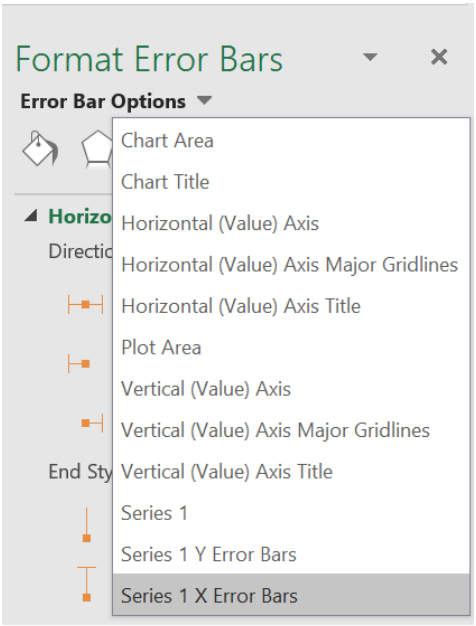
In the ‘FITS Header Editor’ window that pops up, look for ‘EXPTIME’, which is the exposure time. Remember or write down this value.

10 Convert the exposure time in seconds to days by using the equation**: days = seconds/(seconds in a minute * minutes in an hour * hours in a day).**

11 Remember or write down this value.

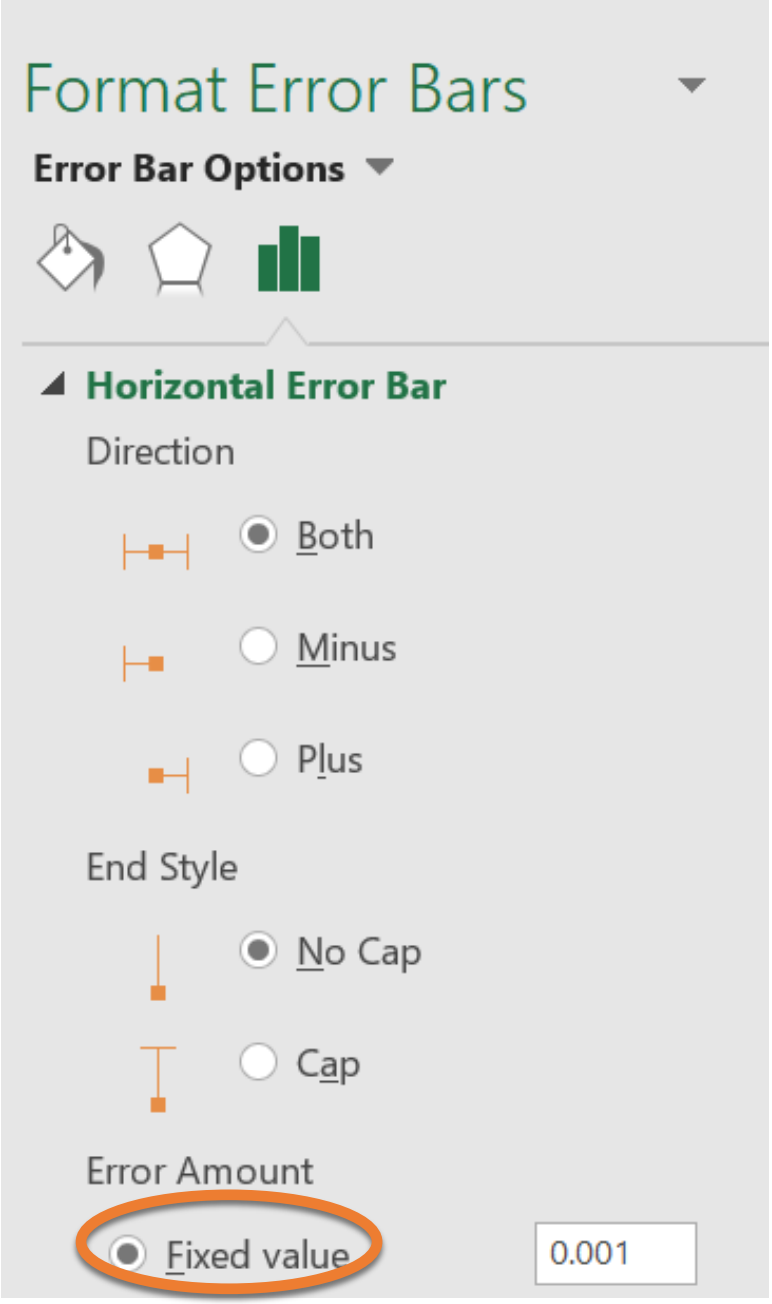
12 Toward the top of the 'Format Error Bars' side menu, select **Error Bar Options -> Series 1 X Error Bars**, as displayed in Figure 5.

Figure 5 - Changing to X Error Bars in Excel.



13 Under 'Error Amount' select **Fixed Value** and type the exposure time in days you've remembered or written down, shown in Figure 6.

Figure 6 - Setting X Error Bars to a Fixed Value in Excel.



For many datasets, the error bars will be very small, perhaps even less than the size of the symbol used to denote the data.

If you have graphs that include a calculated colour such as B-V, errors are a bit more complicated, so you need to learn about errors in quadrature.

To do this, refer to the '**Colour error bars in AstroImageJ**' activity. This can be found on the Faulkes Telescope website.