Light Curves

XUVI: Lecture - 4

What are Light curves?

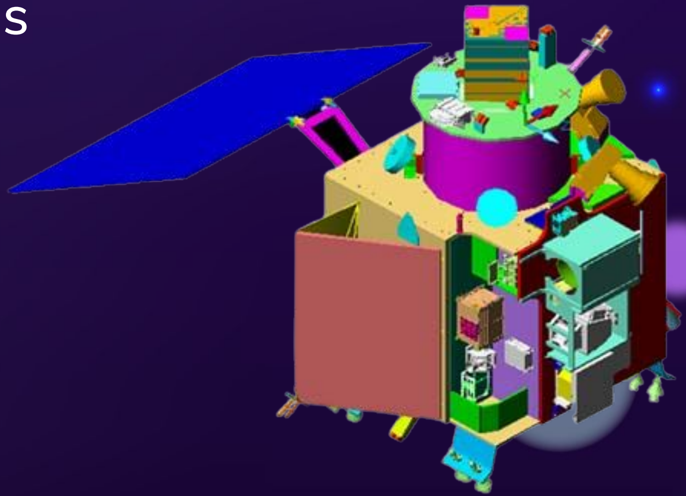
Light curves are graphs that show the brightness of an object over a period of time. In the study of objects which change their brightness over time, such as novae, supernovae, and variable stars, the light curve is a simple but valuable tool to a scientist.

How is it captured

Lightcurve is usually captured as a measure of number of photons striking the observational area per unit time.

The wavelength or energy of the photons may be clubbed together or taken into account separately to obtain the graph of the observed body in various frequencies, like X-Ray, Ultraviolet, Visible, Infrared, etc.

Instruments such as Kepler Space Probe and Chandrayaan have onboard Instruments to capture this data.



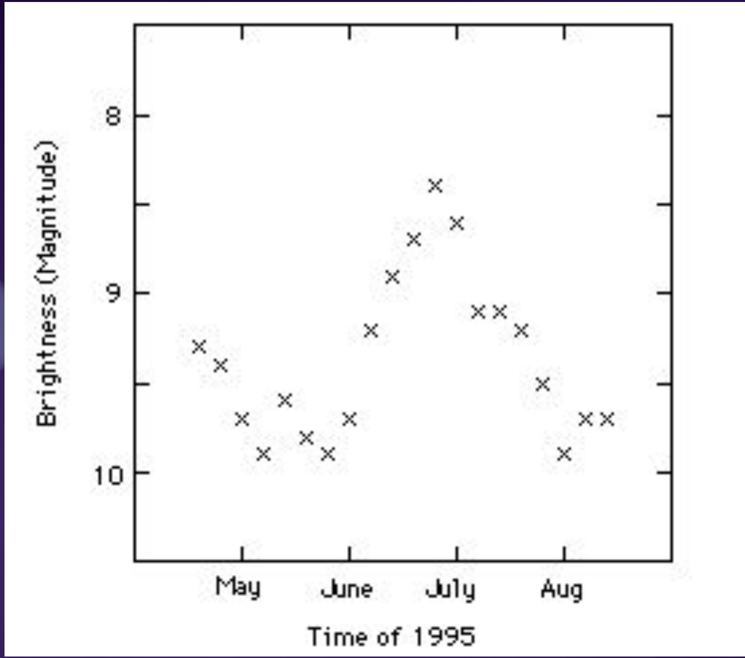
Read Lightcurve data

Lightcurve is generally stored as a binary file, instead of a traditional csv file, but contains tabular data. The common extension you may see in astronomical data are .lc (Light Curve) or .fits (Flexible Image Transport System)

Python offers a ton of tools to operate on binary files. We'll be using *astropy* to read a lightcurve file:

```
from astropy.table import Table
raw_data = Table.read('<file_name>.<extension>')
```

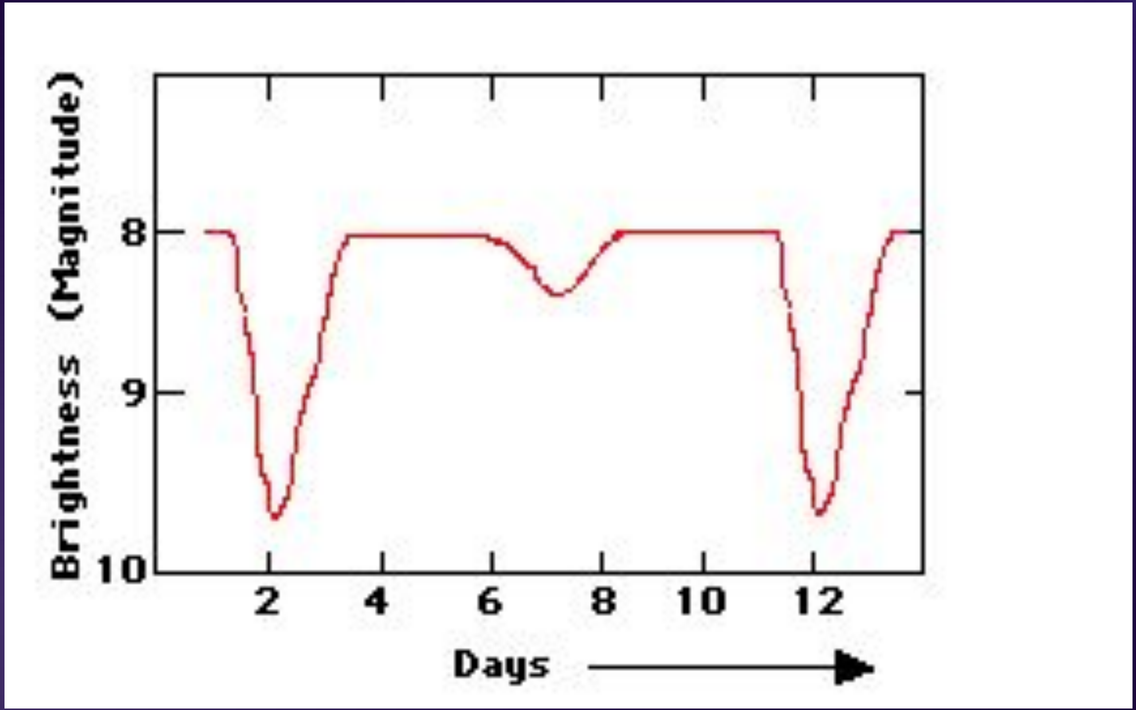
Representation



Usually, they are represented as the measure of brightness over a period of time.

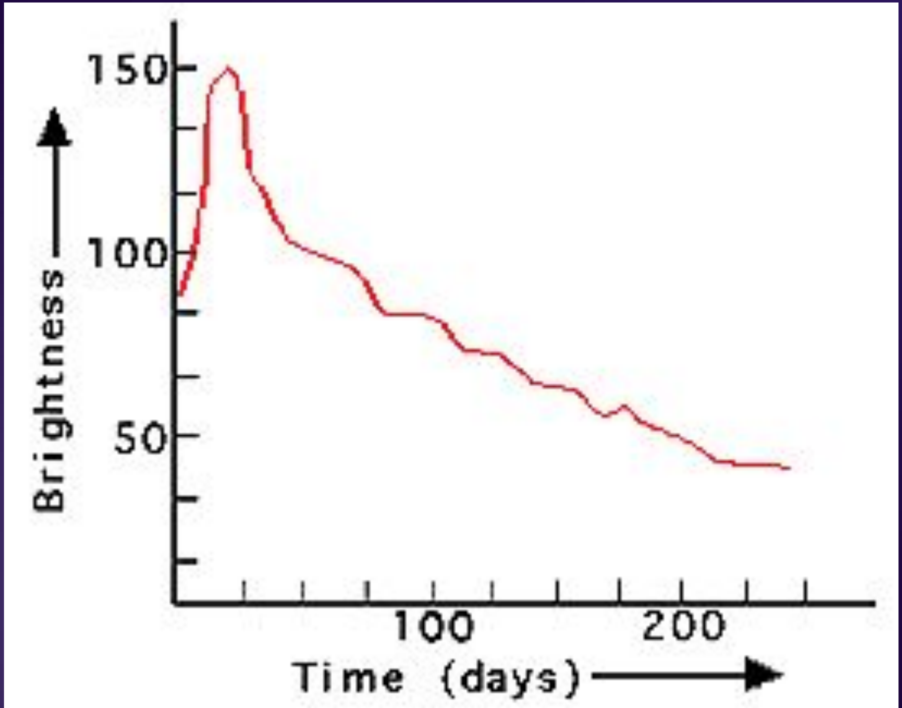
However, they can also be used to represent the amount of light rays (X-Rays generally) emitted by a celestial body, say every second for an hour or so

Example #1



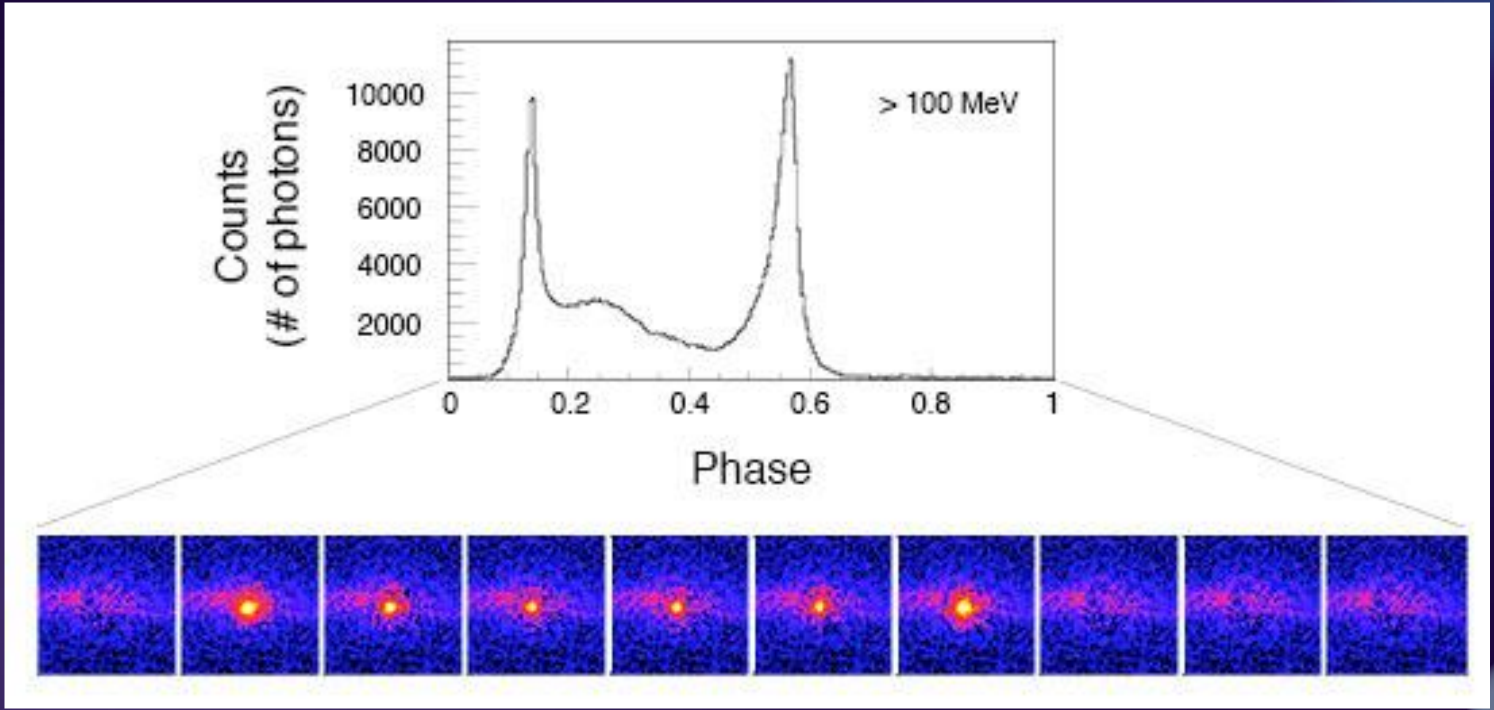
Eclipsing Binary Star

Example #2



Supernova Explosion

Example #3



Vela Pulsar

Timing Analysis

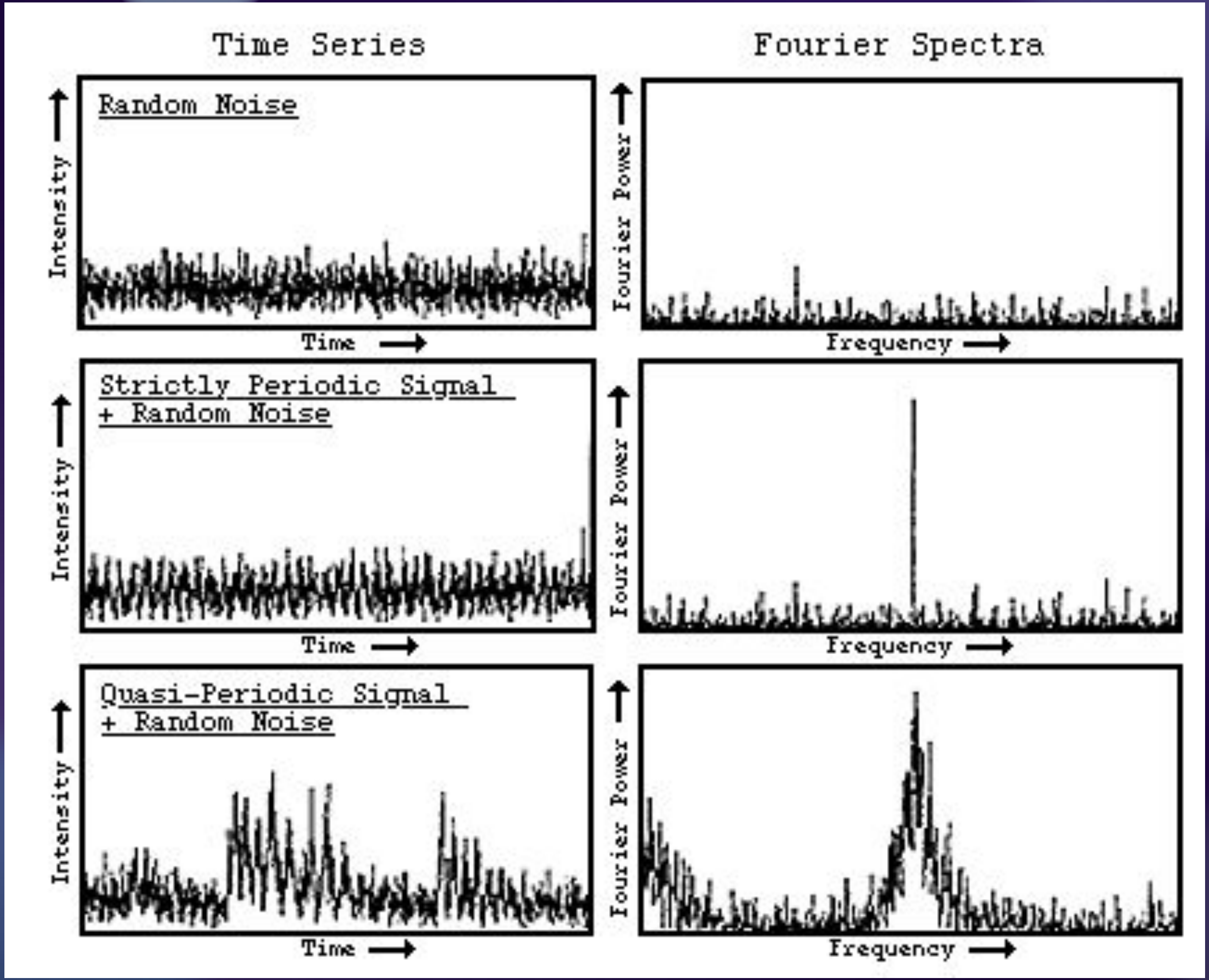
Timing analysis allows astronomers to study the dynamic properties of an object. The targets of timing studies include accretion flows, oscillations, and accretion disk instabilities, as well as magnetic field configurations and instabilities in compact and non-compact stellar systems and active galaxies. 3 Methods are used for timing analysis:

- FOURIER TRANSFORM
- EPOCH FOLDING
- WAVELET ANALYSIS

1. Fourier Transform

A Fourier transform is a mathematical operation that changes data from time domain to frequency domain. This allows the data to be represented as the sum of a series of sines and cosines at various amplitudes, rather than as a continuous function.

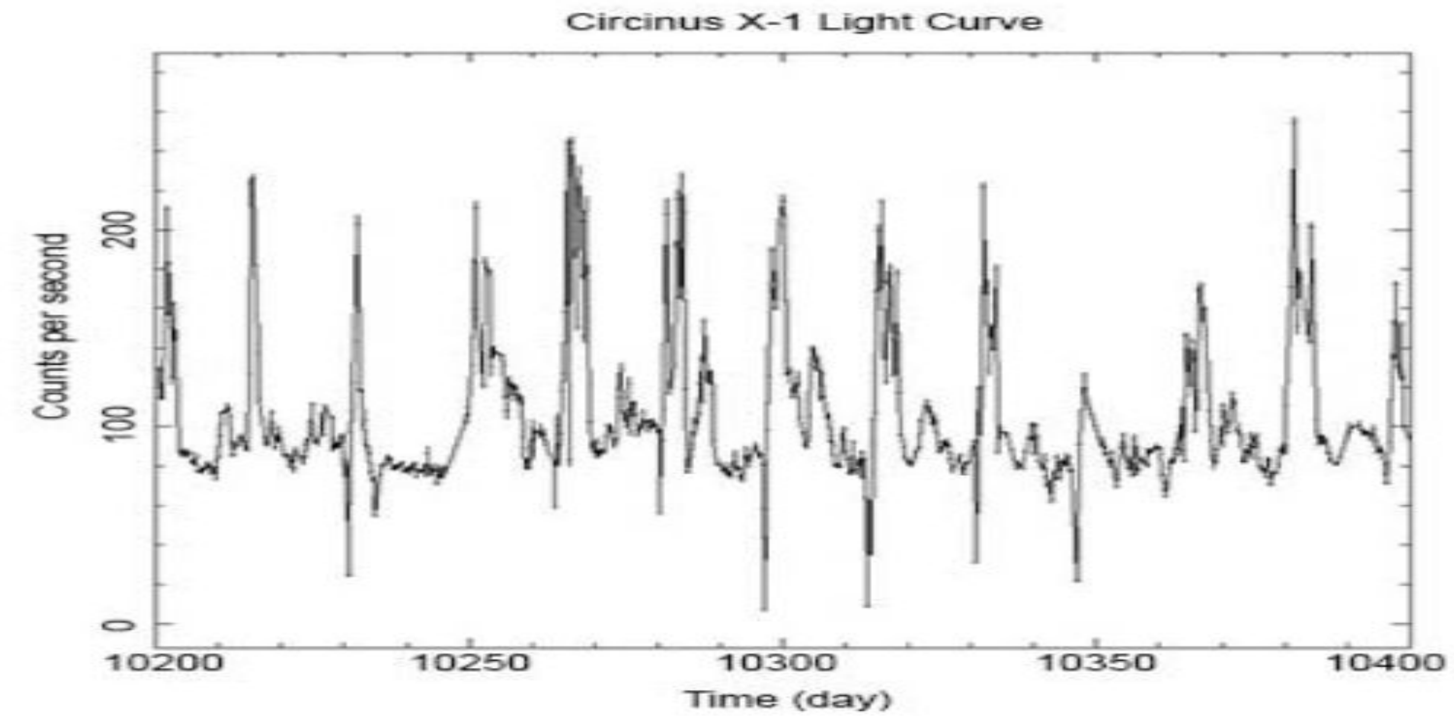
When astronomers are looking for new phenomena, such as pulsars, they are very conservative in what they take to be a real signal. A frequency has to be many times stronger than it would be in a random data set to be taken seriously.


Time Series
Fourier Spectra
Random Noise
Intensity
Time
Fourier Power
Frequency
Strictly Periodic Signal
+ Random Noise
Intensity
Time
Fourier Power
Frequency
Quasi-Periodic Signal
+ Random Noise
Intensity
Time
Fourier Power
Frequency

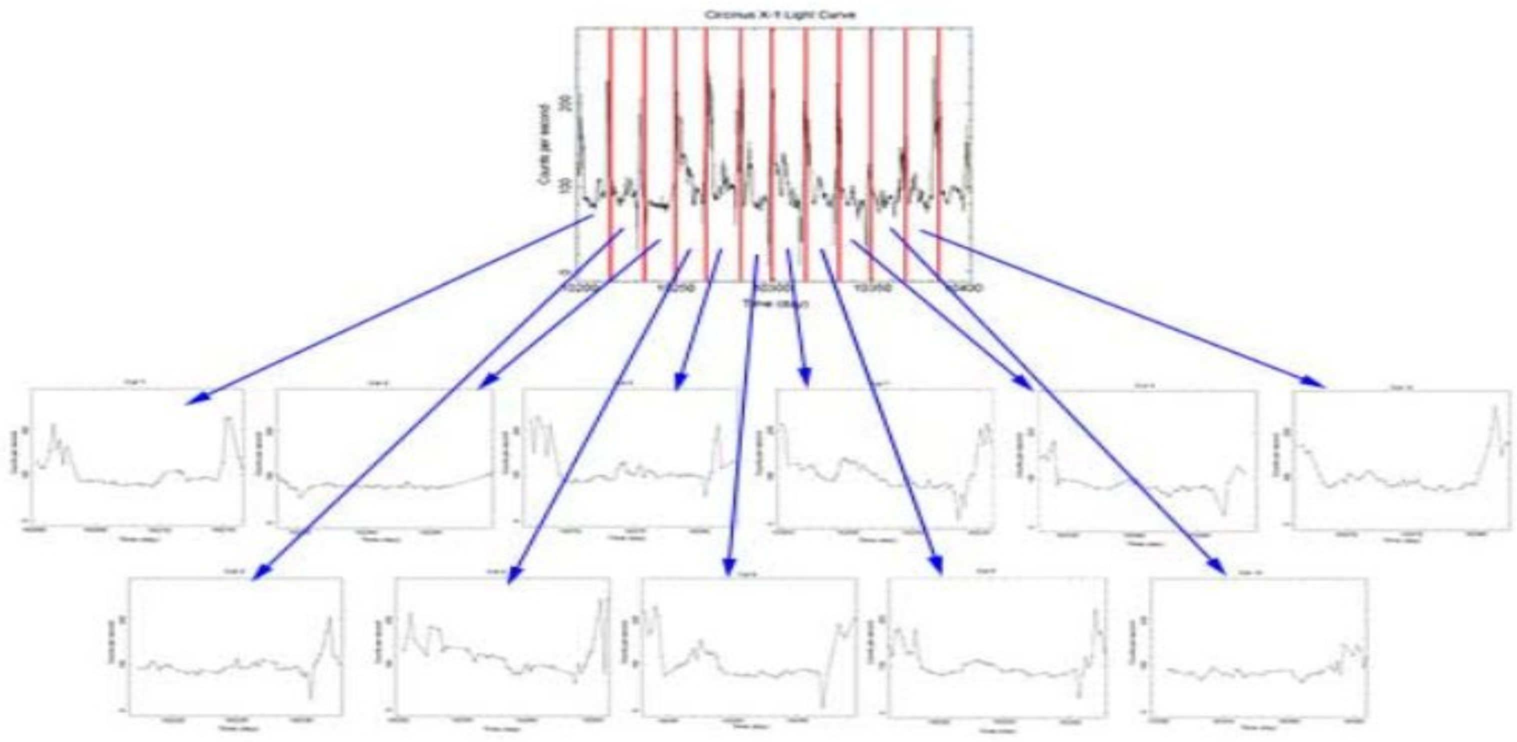
2. Epoch Folding

Another method that is useful for a signal with arbitrary shape is epoch folding. This is done by choosing a range of periods, and "folding" the data at those periods.

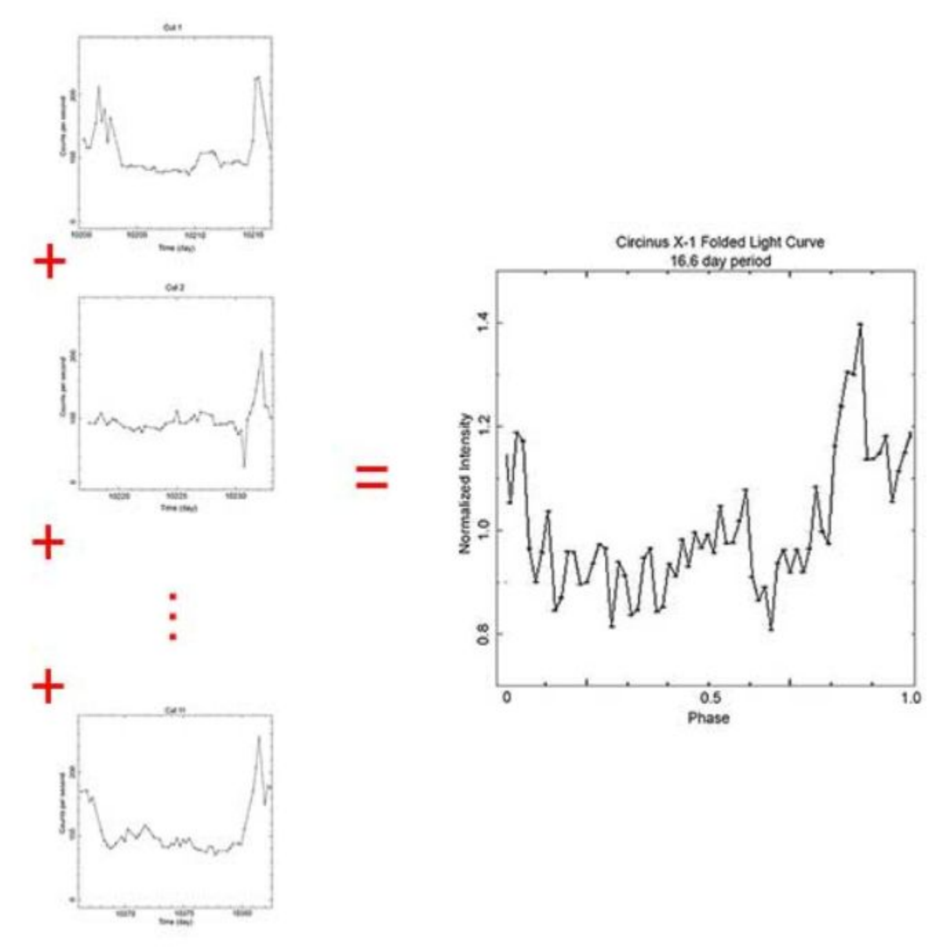
The governing idea is that similar period of time ensures similar light curves i.e. peaks and drops coincides hence produces a sharp and clear curve.



Light curve of X-ray binary system Circinus X-1. (Credit: NASA's Imagine the Universe.)

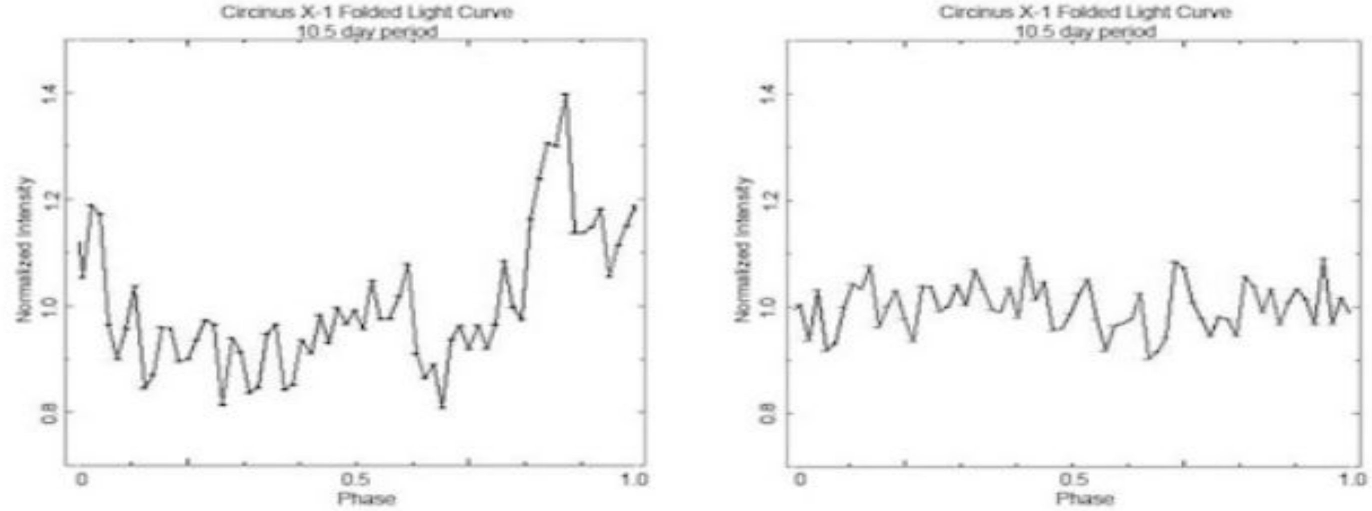


Light curve of X-ray binary system Circinus X-1 cut into 16.6 day segments. (Credit: NASA's Imagine the Universe.)



If we had picked a period that was not close to the period of the system, we would not have seen the peak in the summed light curve. Below are two "folded" light curves – the first is the one we just obtained using a 16.6 day period, the second is one made using a 10.5 day period.

Notice that the 10.5 day period one does not show a strong peak, but is instead rather noisy. This tells us that the 10.5 day period is not close to the real period of the system.



Two folded light curves for Circinus X-1. On the left, the folding period used was 16.6 days, which is close to the real period of the system. On the right, the folding period used was 10.5 days, quite different from the real period of the system. (Credit: NASA's Imagine the Universe.)

3. Wavelet Analysis

For sources that produce periodic signals varying with time, wavelet analysis is used. Wavelet analysis also decomposes a signal into time and frequency space simultaneously. It is used primarily on signals where there are many frequencies, that may change with time, present in a data set.

Since more information is available than was gained from Fourier or epoch folding techniques, we need to represent the results of wavelet analysis differently. The extra information that can be gained comes at the cost of increased difficulty in evaluating whether the result is significant.