



From Photometry to Periods

There are many steps from an astronomical image to a science-quality light curve:

- Reducing the image
 - Artifact corrections, biases, flats, etc.
 - Aperture or differential photometry
 - Generating image catalogs of photometry
 - Cross-correlating / rectifying images/ catalogs
 - Extracting the light curve for each source
 - Ensemble Analysis
 - Zero point corrections
 - Detrending
 - Red noise filtering
-

Variability

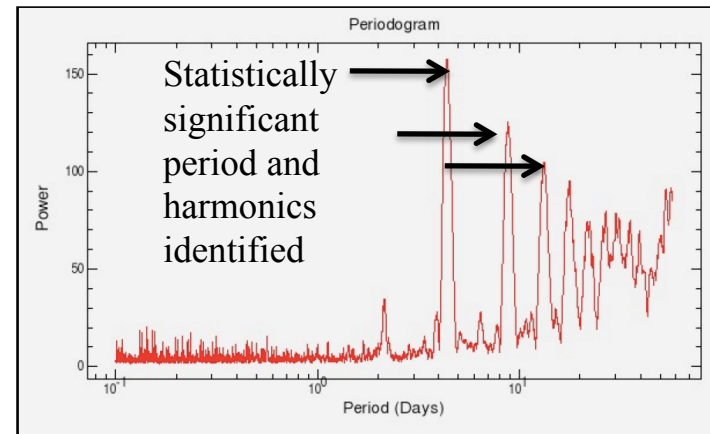
How do you find variables?

→ Statistics

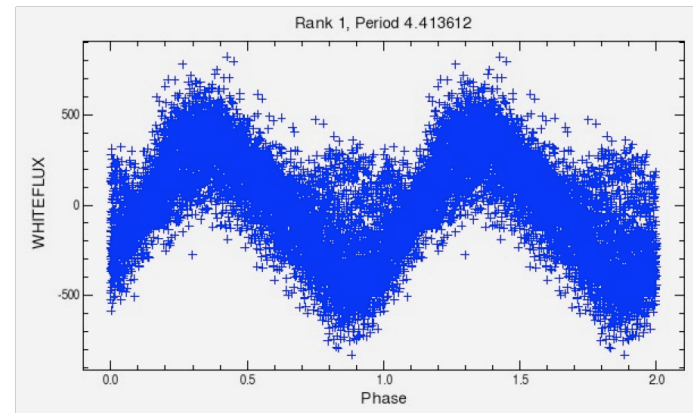
NStED provides a series of standardized variability statistics for all light curves it serves, including:

- Mean, median
- Standard Deviation (aka RMS) w/r/t the median
- Chi-Squared
- Fraction & # of data > 5-sigma deviant from median
- Median Uncertainty
- Median Absolute Deviation Statistic (or MADS)

Time-scale → Physical Mechanism



Plavchan periodogram for a CoRoT source.



Phased Light Curve for CoRoT source showing possible ellipsoidal variations.

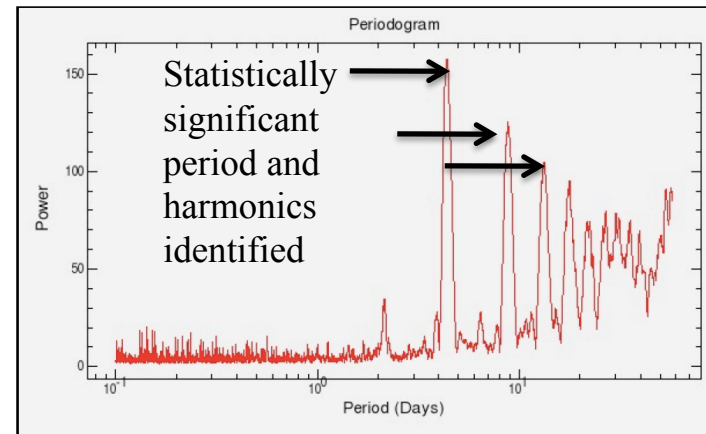
Periodic Variability

Why Look for Periods?

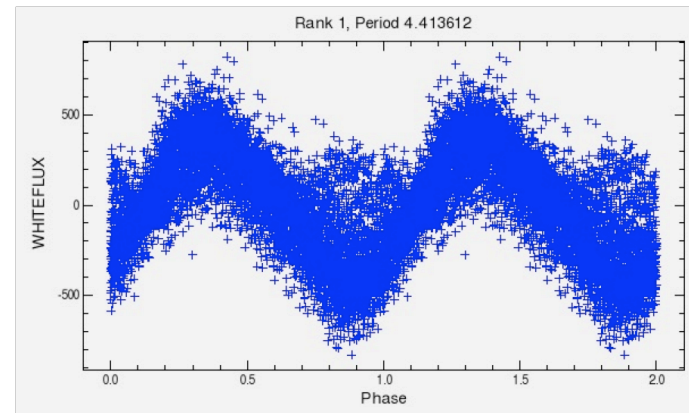
A variety of astrophysical phenomena can produce periodic time-series data, including:

- Stellar variability
- Eclipsing binaries
- Transiting planets
- Radial velocity planets

Time-series data of astrophysical objects are inherently noisy measurements: photon noise, atmospheric conditions and other factors can introduce random variation into the magnitude of the observations.



Plavchan periodogram for a CoRoT source.



Phased Light Curve for CoRoT source showing possible ellipsoidal variations.

Periodogram

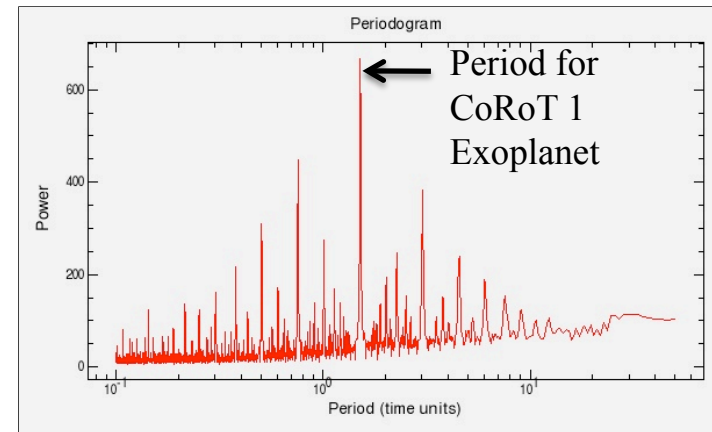
What is a periodogram?

A periodogram calculates the significance of different frequencies in time-series data to identify any intrinsic periodic signals.

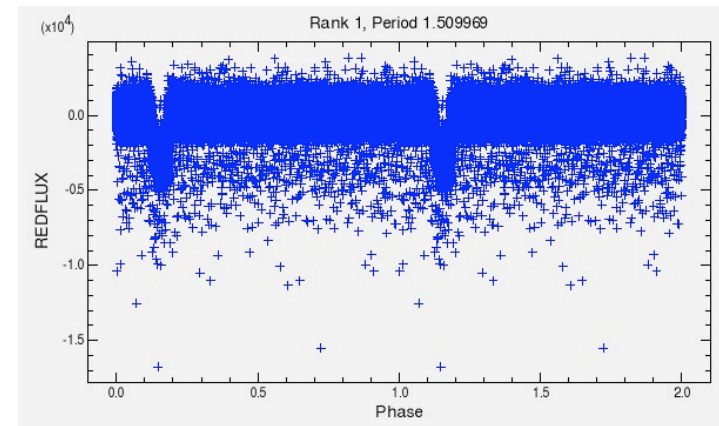
A periodogram is similar to the Fourier Transform, but is optimized for unevenly time-sampled data, and for different shapes in periodic signals.

A periodogram is brute-force. Many different frequencies are evaluated and candidate periodic signals.

The statistical significance of each frequency is computed based upon a series of algebraic operations that depend on the particular algorithm used and periodic signal shape assumed.

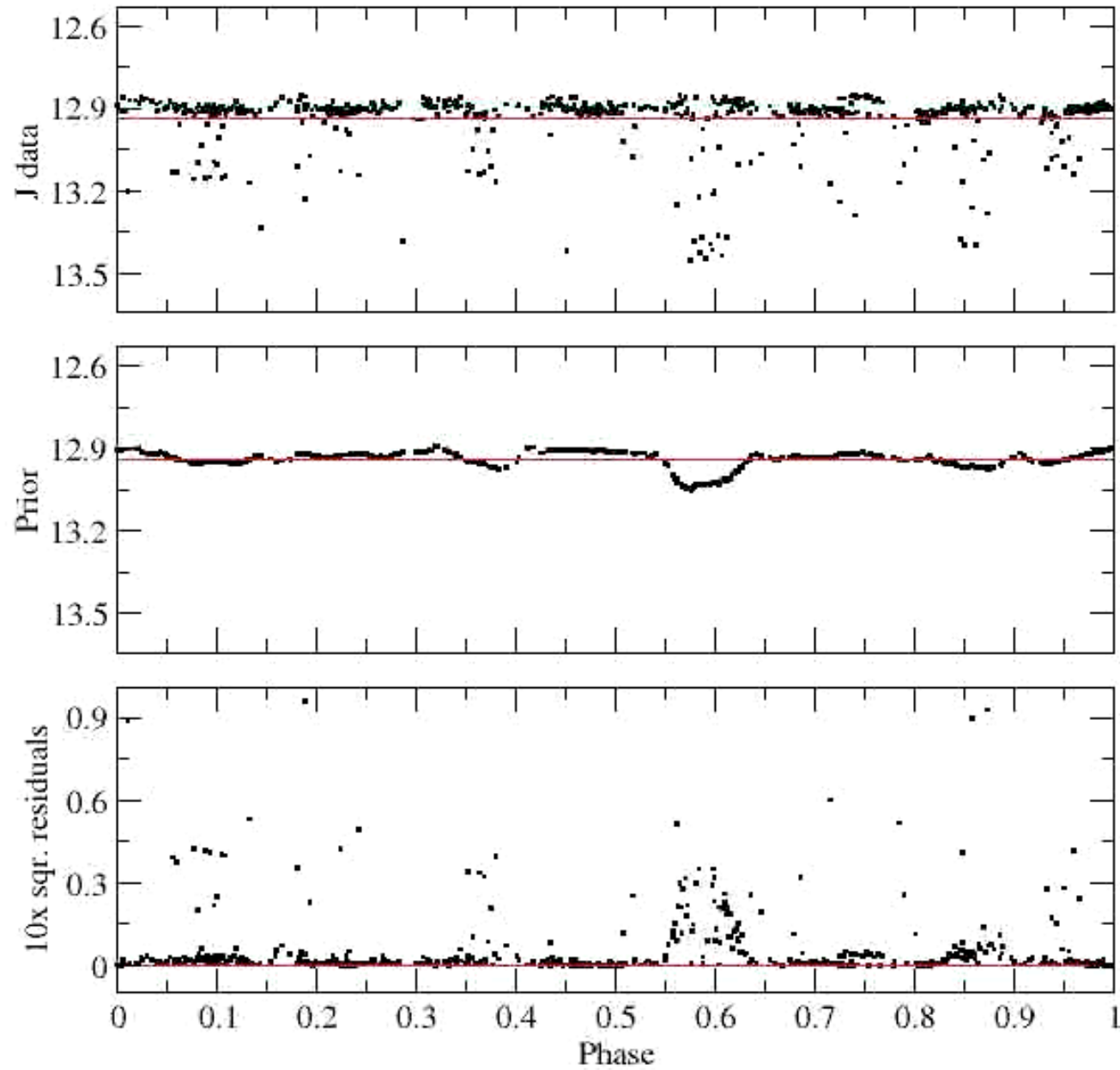


BLS periodogram for CoRoT-1.



Phased Light Curve for CoRoT-1 showing the transiting exoplanet signal

RA: 126.475225 Dec: -39.145588 Period: 7.9600 days





NStED Periodogram Service

Easy to Use Web Interface

NStED has designed an easy to use web interface for the community to use.

The user can upload their own data in IPAC ASCII format or as binary FITS tables.

NStED's current holdings of space and ground-based light curves and radial velocities can be directly fed into the periodogram service from the time-series viewer.

The service intelligently selects the time and data value columns from the files for computing a periodogram with optimized default parameters.

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Overview

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This service returns periodograms computed from input time series data. It accepts as input a file containing time series data in either column delimited ASCII format ("IPAC Table Format") or FITS table format, with multiple header units. If a FITS file is input, the service will process the header unit selected by the user.

NStED Periodogram Service

Input	
<input type="button" value="Submit"/>	
Periodogram type	<input checked="" type="radio"/> Lomb-Scargle <input type="radio"/> BLS <input type="radio"/> Plavchan
Input file	<input type="text"/> <input type="button" value="Browse..."/> <input type="button" value="Upload"/>
Time column	<input type="text"/>
Data column	<input type="text"/>
Adjustable Periodogram Parameters	



NStED Periodogram Service

URL: <http://nsted.ipac.caltech.edu/periodogram/cgi-bin/Periodogram/nph-start>

Workshop/CarlSagan

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Please note that the user light curve upload is a service that is not yet available to the public, and is still undergoing testing and validation.

NStED Periodogram Service

Input	
<input type="button" value="Submit"/>	
Periodogram type	<input checked="" type="radio"/> Lomb-Scargle <input type="radio"/> BLS <input type="radio"/> Plavchan
Input file	/Data/Research/Conference <input data-bbox="1753 941 1848 966" type="button" value="Browse..."/>
	Format <input checked="" type="radio"/> FITS <input type="radio"/> ASCII
	Header Data Unit <i>Note: FITS file upload may take up to 2 minutes</i> <input type="text" value="1"/>
<input data-bbox="1459 1136 1659 1234" type="button" value="Upload"/>	
Time column	<input type="text"/>
Data column	<input type="text"/>



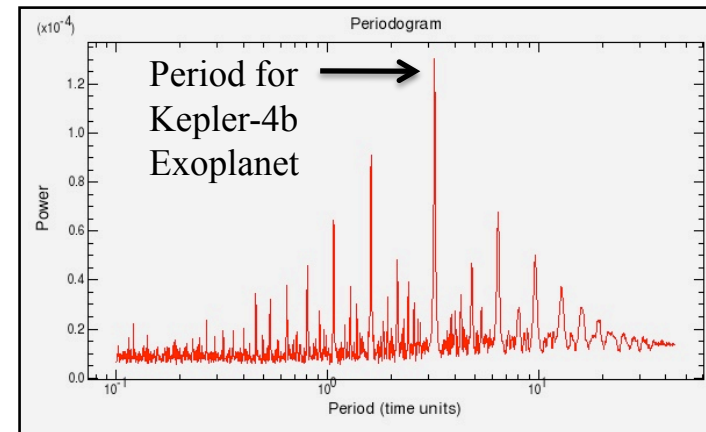
NStED Periodogram Service

Different Algorithms

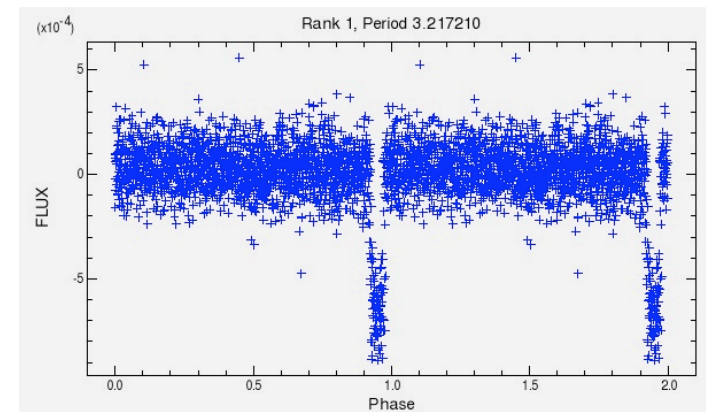
NStED's service current supports the following periodogram algorithms:

- **Lomb-Scargle** is an approximation of the Fourier Transform for unevenly spaced time sampling. It identifies periodic signals that are simple combinations of sines and cosines.
- **Box-Least Squares (BLS)** is optimized to detect periodic transits, by fitting the time series to a repeating "box"-shaped light curve.
- **Plavchan** is a binless phase-dispersion minimization algorithm that identifies periods with coherent phased light curves (i.e., least "dispersed"). There is no assumption about the underlying shape of the periodic signal.

Different periodogram algorithms are sensitive to different periodic signal shapes, and can be used in tandem as a powerful complementary analysis technique.



BLS periodogram for Kepler -4b, the smallest transiting exoplanet discovered by Kepler to date.



Phased Light Curve for Kepler-4b.



NSTED Periodogram Service

Adjustable Algorithm and Search Parameters

The user can adjust:

- File options
- Data columns to use in computation
- Simple data constraint filtering
- Period Sampling Options, including a variety of period-step methods
- Algorithm options custom to each algorithm, with optimized values chosen by default
- The number of phased curves to return
- Limits on the statistical significance of returned periods
- The statistics to use in computing the significance of periodogram power values

Periodogram parameters (click to expand/collapse)	
- File options	
Time column	MJD
Data column	FLUX
Constraint column	None
Constraint range	Min 0.00 Max 0.00
<i>This input file contains 2102 measurements ranging from 0.99 to 1.00. The time period spanned is 2454953.54 to 2454997.98.</i>	
Period sampling options	
Period range	Min 0.10 Max 44.00
Period step method	Exponential
Oversample factor	1
- Algorithm options	
Number of bins	
Fraction of Period in Transit	Min 0.050 Max 0.100
- Output options	
Number of peaks to return	50



NStED Periodogram Service

The service is FAST

The brute-force nature of periodograms makes their computation become quickly time intensive on single-CPU systems as the number of observations and periods sampled grow.

For example, the periodogram for a CoRoT light curve can take up to 30 minutes on a single CPU.

The brute-force nature of periodograms also make the algorithms readily available to parallelization.

NStED has optimized our algorithms to be fully parallelized across a 128-core cluster.

Computation times can be reduced to less than a minute for time-series data with hundreds of thousands of data values.

Submit

Reset

$\leq 1s$ is the estimated processing time with these parameters.

Periodogram parameters
(click to expand/collapse)



NStED Periodogram Service

Easy to Understand Results Page

NStED returns a plot of the periodogram that can be zoomed and investigated dynamically.

The Periodogram values can be downloaded as an ASCII file.

The service displays a table of the most statistically significant candidate periods, with links to plots of their phased light curves.

Download Periodogram

Rank	Period	Power	P-value	Link
1	3.238425	0.001625	0	Phased curve
2	1.618796	0.001187	0	Phased curve
3	1.077005	0.000902	1.85369e-06	Phased curve
4	6.478517	0.000836	4.35052e-05	Phased curve
5	0.809190	0.000725	0.00430731	Phased curve
6	0.154565	0.000676	0.005802	Phased curve

The P-values above are computed for 1855 periods sampled, and a Gaussian power distribution is assumed. The mean power for this set of periods is 0.0002 and the standard deviation is 0.0001. Note that the estimates of significance (p-value) are not reliable for a small number of periods sampled, or a small period range.