

# Package ‘lomb’

May 27, 2021

**Type** Package

**Title** Lomb-Scargle Periodogram

**Version** 2.0

**Date** 2021-05-19

**Author** Thomas Ruf, partially based on C original by Press et al. (Numerical Recipes) and the Python module Astropy.

**Maintainer** Thomas Ruf <Thomas.Ruf@vetmeduni.ac.at>

**Description** Computes the Lomb-Scargle Periodogram for unevenly sampled time series. Includes a randomization procedure to obtain exact p-values.

**License** GPL (>= 3)

**Encoding** UTF-8

**LazyData** true

**Imports** ggplot2, gridExtra

**NeedsCompilation** no

**Repository** CRAN

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## R topics documented:

lomb-package	2
ggamma	3
ibex	4
levopt	4
lsp	5
pvaluev	8
plot.lsp	9
randlsp	10
summary.lsp	12
summary.randlsp	13
theme_lsp	14

<b>Index</b>	<b>15</b>
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lomb-package

*Lomb-Scargle Periodogram*

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## Description

The Lomb-Scargle periodogram is the most widely used method to detect even weak periodic components in unequally sampled time series. It can also be used for equally sampled time series.

## Details

Package: lomb  
Type: Package  
Version: 2.0  
Date: 2021-02-01  
License: GPL-3

Function `lsp` computes the Lomb-Scargle periodogram for unevenly sampled times series (e.g., series with missing data). P-values for the false-alarm probability of the highest peak in the periodogram are computed. Alternatively, function `randlsp` computes a bootstrap P-value for the largest peak in the periodogram by repeatedly randomizing the time-series sequence. Both functions allow setting the range of frequencies to be inspected, as well as the stepsize (oversampling factor) used for frequency scanning.

## Author(s)

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## References

Ruf, T. (1999) The Lomb-Scargle Periodogram in Biological Rhythm Research: Analysis of Incomplete and Unequally Spaced Time-Series. *Biological Rhythm Research* **30**: 178–201

## Examples

```
data(lynx)
lsp(lynx)
```

---

ggamma	<i>Utility function called by pbluev()</i>
--------	--

---

**Description**

Largely from astropy.timeseries

**Usage**

```
ggamma(N)
```

**Arguments**

N                    A positive number

**Value**

```
sqrt(2 / N) * exp(lgamma(N / 2) - lgamma((N - 1) / 2))
```

**Author(s)**

Thomas Ruf <thomas.ruf@vetmeduni.ac.at>.

**References**

VanderPlas, J. & Ivezić, Z. (2015) Periodograms for Multiband Astronomical Time Series. *The Astrophysical Journal* **812.1**:18

**See Also**

[pbluev](#)

**Examples**

```
ggamma(3)
```

---

ibex	<i>Rumen Temperature In An Alpine Ibex</i>
------	--

---

**Description**

Telemetric measurements of rumen temperature in a free-living alpine ibex (*Capra ibex*) measured at unequal time intervals.

**Usage**

```
data(ibex)
```

**Format**

A data frame with 1201 observations on 3 variables.

**date** a character variable giving date and time of measurements.

**hours** a numerical variable giving hours elapsed since the first measurement.

**temp** a numerical variable giving rumen (stomach) temperature in degrees Celsius.

**Source**

A subset of data from Signer, C., Ruf, T., Arnold, W. (2011) *Functional Ecology* **25**: 537-547.

**Examples**

```
data(ibex)
datetime <- as.POSIXlt(ibex$date)
plot(datetime, ibex$temp, pch=19, cex=0.3)
```

---

levopt	<i>Internal function to find significance level</i>
--------	---

---

**Description**

Called by optim to find significance value (0-1) corresponding to p-value (x).

**Usage**

```
levopt(x, alpha, fmax, tm)
```

**Arguments**

x	Initial value of parameter to be optimized.
alpha	Desired significance level, defaults to 0.01.
fmax	Maximum frequency inspected.
tm	Vector of times inspected.

**Value**

Scalar. The value at which the periodogram reaches significance.

**Author(s)**

Thomas Ruf <thomas.ruf@vetmeduni.ac.at>.

**References**

VanderPlas, J. & Ivezić, Z. (2015) Periodograms for Multiband Astronomical Time Series. *The Astrophysical Journal* **812.1**:18

**See Also**

pvaluev

**Examples**

```
##---- Do not call directly, internal function
```

---

lsp

*Lomb-Scargle Periodogram*

---

**Description**

Computes the Lomb-Scargle periodogram for a time series with irregular (or regular) sampling intervals. Allows selecting a frequency range to be inspected, as well as the spacing of frequencies scanned.

**Usage**

```
lsp(x, times = NULL, from = NULL, to = NULL, type = c("frequency", "period"),
    ofac = 1, alpha = 0.01, normalize=c("standard","press"), plot = TRUE,...)
```

**Arguments**

x	The data to be analyzed. x can be either a two-column numerical dataframe or matrix, with sampling times in column 1 and measurements in column 2, a single numerical vector containing measurements, or a single vector <code>ts</code> object (which will be converted to a numerical vector).
times	If x is a single vector, times can be provided as a numerical vector of equal length containing sampling times. If x is a vector and times is NULL, the data are assumed to be equally sampled and times is set to 1:length(x).
from	The starting frequency (or period, depending on type) to begin scanning for periodic components.
to	The highest frequency (or period, depending on type) to scan.

type	Either “frequency” (the default) or “period”. Determines the type of the periodogram x-axis.
ofac	The oversampling factor. Must be an integer $\geq 1$ . Larger values of ofac lead to finer scanning of frequencies but may be time-consuming for large datasets and/or large frequency ranges (from...to).
alpha	The significance level. The periodogram plot shows a horizontal dashed line. Periodogram peaks exceeding this line can be considered significant at alpha. Defaults to 0.01. Only used if plot=TRUE.
normalize	The type of normalization used, either “standard” or “press”. If normalization is standard (the default) the periodogram is confined to the interval 0-1, and the statistical significance of the largest peak in the periodogram is computed according to Baluev (2008).if normalization is set to “press” the periodogram will be normalized using the factor $1/(2 * \text{var}(y))$ and the p-value for the significance of the largest peak in the periodogram is computed from the exponential distribution, as outlined in Press et al. (1994), see below
plot	Logical. If plot=TRUE the periodogram is plotted.
...	Further parameters.

### Details

For a more robust - but potentially time-consuming estimation of p-values (when n is large) see [randlsp](#).

Significance levels in both lsp and [randlsp](#) increase with the number of frequencies inspected. Therefore, if the frequency-range of interest can be narrowed down *a priori*, use arguments “from” and “to” to do so.

### Value

A named list with the following components:

normalize	The type of normalization used.
scanned	A vector containing the frequencies/periods scanned.
power	A vector containing the normalized power corresponding to scanned frequencies/periods.
data	Names of the data vectors analyzed.
n	The length of the data vector.
type	The periodogram type used, either "frequency" or "period".
ofac	The oversampling factor used.
n.out	The length of the output (powers). This can be $>n$ if ofac $>1$ .
alpha	The false alarm probability used.
sig.level	Powers $> \text{sig.level}$ can be considered significant peaks at $p=\text{alpha}$ .
peak	The maximum power in the frequency/period interval inspected.
peak.at	The frequency/period at which the maximum peak occurred.
p.value	The probability that the maximum peak occurred by chance.

**Note**

For a description of the properties of the Lomb-Scargle Periodogram, its computation and comparison with other methods see Ruf, T. (1999). Function `lsp` uses the algorithm given by Press et al (1994). The Lomb-Scargle Periodogram was originally proposed by Lomb N.R. (1976) and further extended by Scargle J.D. (1982). An improved method for assessing the statistical significance of candidate periodicities by Baluev (2008), based on extreme value theory, is also implemented. This implementation uses code modified from the `Astropy.timeseries` (© Copyright 2011–2021, The Astropy Developers.BSD3) Python package (VanderPlas et al. 2012, 2015).

**Author(s)**

Thomas Ruf <thomas.ruf@vetmeduni.ac.at> based on code by Press et al (1994).

**References**

- Baluev, R. V. (2008). Assessing the statistical significance of periodogram peaks. *Monthly Notices of the Royal Astronomical Society*, **385(3)**, 1279-1285.
- Lomb N.R. (1976) Least-squares frequency analysis of unequally spaced data. *Astrophysics and Space Science* **39**:447–462
- Press W.H., Teukolsky S.A., Vetterling S.T., Flannery, B.P. (1994) *Numerical recipes in C: the art of scientific computing*. 2nd edition. Cambridge University Press, Cambridge, 994pp.
- Ruf, T. (1999) The Lomb-Scargle Periodogram in Biological Rhythm Research: Analysis of Incomplete and Unequally Spaced Time-Series. *Biological Rhythm Research* **30**: 178–201.
- Scargle J.D. (1982) Studies in astronomical time series. II. Statistical aspects of spectral analysis of unevenly spaced data. *The Astrophysical Journal* **302**: 757–763.
- VanderPlas, J., Connolly, A. Ivezic, Z. & Gray, A. (2012) Introduction to astroML: Machine learning for astrophysics. *Proceedings of the Conference on Intelligent Data Understanding*
- VanderPlas, J. & Ivezic, Z. (2015) Periodograms for Multiband Astronomical Time Series. *The Astrophysical Journal* **812.1**:18

**See Also**

[randlsp summary.lsp](#)

**Examples**

```
# ibex contains an unevenly sampled time series
data(ibex)
lsp(ibex[,2:3],ofac=5)
lsp(ibex$temp,times=ibex$hours,type='period',ofac=5)

# lynx contains evenly sampled data
lsp(lynx)
lynx.spec <- lsp(lynx,type='period',from=2,to=20,ofac=5)
summary(lynx.spec)

# generate unevenly sampled data
```

```
time=(runif(200,1,1000))
y=2*cos(time/6)+rnorm(200,0,4)
lsp(y,times=time,ofac=10, to=0.3)

# to obtain periodogram as in Press et al (for backwards compatibility):
result=lsp(y,times=time,to=0.3,normalize="press")
print(result)
```

---

pvaluev

*False alarm probability*

---

### Description

Computes the statistical significance of peaks (range 0-1) in the standardized periodogram. Typically not called by the user.

### Usage

```
pvaluev(Z, fmax, tm)
```

### Arguments

Z	the height of a periodogram peak
fmax	the highest frequency inspected
tm	a vector with measurement timepoints

### Details

Based on results in extreme value theory, improved analytic estimations of false alarm probabilities are given.

### Value

Returns the significance of the largest peak in the periodogram.

### Note

Code based on `astropy.timeseries`

### Author(s)

Thomas Ruf <thomas.ruf@vetmeduni.ac.at>.

### References

Baluev, R. V. (2008). Assessing the statistical significance of periodogram peaks. *Monthly Notices of the Royal Astronomical Society*, **385**(3), 1279-1285.



**See Also**

[summary.lsp](#)

**Examples**

```
pbaluev(0.19,2.0,1:100)
```

---

plot.lsp

*Plot Lomb-Scargle Periodogram*

---

**Description**

Plots the normalized power as a function of frequency (or period, depending on type in function lsp).

**Usage**

```
## S3 method for class 'lsp'
plot(x, main = "Lomb-Scargle Periodogram", xlabel = NULL,
     ylabel = "normalized power", level = TRUE, plot=TRUE,...)
```

**Arguments**

x	Object of class lsp as returned from function lsp.
main	Character. Main title of the periodogram plot. Defaults to “Lomb-Scargle Periodogram”.
xlabel	Character. X-axis label of the periodogram plot.
ylabel	Character. Y-axis label of the periodogram plot.
level	Logical. If TRUE, the significance level is displayed as a dashed line.
plot	If TRUE, the periodogram is plotted.
...	Further parameters.

**Details**

Usually, this function is only called by function lsp. It maybe called by the user for some control of the output. For better control, plot results from lsp (`$scanned`, `$power`) as desired.

**Value**

Invisibly returns the object of class lsp it is called with.

**Author(s)**

Thomas Ruf <thomas.ruf@vetmeduni.ac.at>

**See Also**[lsp](#)**Examples**

```
data(ibex)
ibex.spec <- lsp(ibex[,2:3],type='period', from=12,to=36,ofac=10, plot=FALSE)

plot.lsp(ibex.spec, main="Daily rhythms in Tb",xlabel="Period (h)",ylabel="Power",level=FALSE)
```

---

**randlsp***Randomize Lomb-Scargle Periodogram*

---

**Description**

randlsp is used to obtain robust p-values for the significance of the largest peak in a Lomb-Scargle periodogram by randomization. The data sequence is scrambled repeatedly and the probability of random peaks reaching or exceeding the peak in the original (unscrambled) periodogram is computed.

**Usage**

```
randlsp(repeats=1000, x, times = NULL, from = NULL, to = NULL,
        type = c("frequency", "period"), ofac = 1, alpha = 0.01,
        plot = TRUE, trace = TRUE,...)
```

**Arguments**

repeats	An integer determining the number of repeated randomizations. Large numbers ( $\geq 1000$ ) are better but can make the procedure time-consuming.
x	The data to be analyzed. x can be either a two-column numerical dataframe or matrix, with sampling times in column 1 and measurements in column 2, a single numerical vector containing measurements, or a single vector <b>ts</b> object (which will be converted to a numerical vector).
times	If x is a single vector, times can be provided as a numerical vector of equal length containing sampling times. If x is a vector and times is <b>NULL</b> , the data are assumed to be equally sampled and times is set to <code>1:length(x)</code> .
from	The starting frequency (or period, depending on type) to begin scanning for periodic components.
to	The highest frequency (or period, depending on type) to scan.
type	Either “frequency” (the default) or “period”. Determines the type of the periodogram x-axis.
ofac	The oversampling factor. Must be an integer $\geq 1$ . Larger values of ofac lead to finer scanning of frequencies but may be time-consuming for large datasets and/or large frequency ranges (from...to).

alpha	The significance level. The periodogram plot shows a horizontal dashed line. Periodogram peaks exceeding this line can be considered significant at alpha. Defaults to 0.01. Only used if plot=TRUE.
plot	Logical. If TRUE, two plots are displayed (i) The periodogram of the original (unscrambled) data (ii) A histogram of peaks occurring by chance during sequence randomization. A vertical line is drawn at the height of the peak in a periodogram of the original data.
trace	Logical. If TRUE, information about the progress of the randomization procedure is printed during the running of randlsp.
...	Further parameters.

### Details

Function randlsp preserves the actual measurement intervals, which may affect the periodogram (see Nemec & Nemec 1985, below). Hence, this is a conservative randomization procedure.

P-values from both randlsp and lsp increase with the number of frequencies inspected. Therefore, if the frequency-range of interest can be narrowed down *a priori*, use arguments “from” and “to” to do so.

### Value

A named list with the following items:

scanned	A vector containing the frequencies/periods scanned.
power	A vector containing the normalized power corresponding to scanned frequencies/periods.
data	Names of the data vectors analyzed.
n	The length of the data vector.
type	The periodogram type used, either “frequency” or “period”.
ofac	The oversampling factor used.
n.out	The length of the output (powers). This can be >n if ofac >1.
peak	The maximum power in the frequency/period interval inspected.
peak.at	The frequency/period at which the maximum peak occurred.
random.peaks	A vector of peaks (with length=repeats) of maximum power values computed from randomized data.
repeats	The number of randomizations.
p.value	The probability that the peak in the original data occurred by chance, computed from randomizing the data sequence.

### Author(s)

Thomas Ruf <thomas.ruf@vetmeduni.ac.at>

**References**

Nemec A.F.L, Nemec J.M. (1985) A test of significance for periods derived using phase-dispersion-minimization techniques. *The Astronomical Journal* **90**:2317–2320

**See Also**

[lsp](#)

**Examples**

```
time=(runif(100,1,1000))
signal=2*cos(time/6)+rnorm(100,0,4)
randlsp(200,x=signal,times=time, to=0.2,trace=FALSE) #use more repats to get better results
```

---

summary.lsp

*Summarize Lomb-Scargle Periodogram Results*

---

**Description**

Summary method for class lsp.

**Usage**

```
## S3 method for class 'lsp'
summary(object,...)
```

**Arguments**

object            an object of class lsp.  
 ...                currently, no other arguments are required.

**Value**

summary.lsp returns a one column data.frame with results from function lsp. Row names and contents are as follows:

Time	Name of the sampling time variable.
Data	Name of the measured variable.
Type	either “frequency” or “period”.
Oversampling factor	The degree of oversampling ( $\geq 1$ ).
From	The lowest frequency (or period, depending on type) inspected.
To	The highest frequency (or period, depending on type) inspected.
# frequencies	The number of frequencies (or periods, depending on type) inspected.
PNmax	The peak normalized power in the periodogram.

At frequency	The frequency at which PNmax occurred.
At period	The period at which PNmax occurred.
P-value (PNmax)	The probability that PNmax occurred by chance. May slightly vary with the normalization.

**Author(s)**

Thomas Ruf <thomas.ruf@vetmeduni.ac.at>

**See Also**

[lsp](#)

**Examples**

```
data(lynx)
summary(lsp(lynx))
```

---

summary.randlsp	<i>Summarize Randomised Lomb-Scargle Periodogram Results</i>
-----------------	--

---

**Description**

Summary method for class randlsp.

**Usage**

```
## S3 method for class 'randlsp'
summary(object,...)
```

**Arguments**

object	an object of class randlsp.
...	currently, no other arguments are required.

**Value**

summary.randlsp returns a one column data.frame with results from function randlsp. Row names and contents are as follows:

Time	Name of the sampling time variable.
Data	Name of the measured variable.
Type	either “frequency” or “period”.
Oversampling	The degree of oversampling ( $\geq 1$ ).
From	The lowest frequency (or period, depending on type) inspected.

To	The highest frequency (or period, depending on type) inspected.
# frequencies	The number of frequencies (or periods, depending on type) inspected.
PNmax	The peak normalized power in the periodogram.
At frequency	The frequency at which PNmax occurred.
At period	The period at which PNmax occurred.
Repeats	The number of randomizations.
P-value (PNmax)	The probability that PNmax occurred by chance, computed from randomizing the data sequence.

**Author(s)**

Thomas Ruf <thomas.ruf@vetmeduni.ac.at>

**See Also**

[randlsp](#)

**Examples**

```
data(lynx)
summary(randlsp(500,lynx))
```

---

theme\_lsp                      *ggplot2 theme for periodogram*

---

**Description**

A theme derived from theme\_bw.

**Usage**

```
theme_lsp()
```

# Index

- \* **datasets**
  - ibex, [4](#)
- \* **package**
  - lomb-package, [2](#)
- \* **ts**
  - ggamma, [3](#)
  - lsp, [5](#)
  - pvaluev, [8](#)
  - plot.lsp, [9](#)
  - randlsp, [10](#)
  - summary.lsp, [12](#)
  - summary.randlsp, [13](#)

ggamma, [3](#)

ibex, [4](#)

levopt, [4](#)

lomb (lomb-package), [2](#)

lomb-package, [2](#)

lsp, [2](#), [5](#), [10–13](#)

pvaluev, [3](#), [8](#)

plot.lsp, [9](#)

randlsp, [2](#), [6](#), [7](#), [10](#), [14](#)

summary.lsp, [7](#), [9](#), [12](#)

summary.randlsp, [13](#)

theme\_lsp, [14](#)

ts, [5](#), [10](#)