Package ‘RobPer’

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Description Calculates periodograms based on (robustly) fitting periodic functions to light curves (irregularly observed time series, possibly with measurement accuracies, occurring in astroparticle physics). Three main functions are included: RobPer() calculates the periodogram. Outlying periodogram bars (indicating a period) can be detected with betaCvMfit(). Artificial light curves can be generated using the function tsgen(). For more details see the corresponding article: Thieler, Fried and Rathjens (2016), Journal of Statistical Software 69(9), 1-36, <doi:10.18637/jss.v069.i09>.

License GPL-3

LazyData true

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`RobPer-package` *The RobPer-package*

Description

Calculates periodograms based on (robustly) fitting periodic functions to light curves and other irregulary observed time series and detects high periodogram bars.

Details

Package:	RobPer
Type:	Package
Version:	1.2.2
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License:	GPL-3

Light curves occur in astroparticle physics and are irregularly sampled times series $(t_i, y_i)_{i=1,\dots,n}$ or $(t_i, y_i, s_i)_{i=1,\dots,n}$ consisting of unequally spaced observation times $t_1, \dots, t_n$, observed values $y_1, \dots, y_n$ and possibly measurement accuracies $s_1, \dots, s_n$. The pattern of the observation times t_i may be periodic with sampling period p_s. The observed values y_i may possibly contain a periodic fluctuation $y_{f;i}$ with fluctuation period p_f. One is interested in finding p_f. The measurement accuracies s_i give information about how precise the y_i were measured. They can be interpreted as estimates for the standard deviations of the observed values. For more details see Thieler et al. (2013) or Thieler, Fried and Rathjens (2016).

This package includes three main functions: `RobPer` calculates the periodogram, possibly taking into account measurement accuracies. With betaCvMfit, outlying periodogram bars (indicating a period) can be detected. This function bases on robustly fitting a distribution using Cramér-von-Mises (CvM) distance minimization (see also Clarke, McKinnon and Riley 2012). The function tsgen can be used to generate artificial light curves. For more details about the implementation see Thieler, Fried and Rathjens (2016).

A preliminary version of this package is used in Thieler et al. (2013). The FastS-function and the FastTau-function presented here are slightly changed versions of R-Code published in Salibian-Barrera and Yohai (2006) and Salibian-Barrera, Willems and Zamar (2008).

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Author(s)

Anita M. Thieler, Jonathan Rathjens and Roland Fried, with contributions from Brenton R. Clarke (see betaCvMfit), Matias Salibian-Barrera, Gert Willems and Victor Yohai (see FastS and FastTau) and Uwe Ligges (see TK95).

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References

Clarke, B. R., McKinnon, P. L. and Riley, G. (2012): A Fast Robust Method for Fitting Gamma Distributions. Statistical Papers, 53 (4), 1001-1014

Salibian-Barrera, M. and Yohai, V. (2006): A Fast Algorithm for S-Regression Estimates. Journal of Computational and Graphical Statistics, 15 (2), 414-427

Salibian-Barrera, M., Willems, G. and Zamar, R. (2008): The Fast-tau Estimator for Regression. Journal of Computational and Graphical Statistics, 17 (3), 659-682

Thieler, A. M., Backes, M., Fried, R. and Rhode, W. (2013): Periodicity Detection in Irregularly Sampled Light Curves by Robust Regression and Outlier Detection. Statistical Analysis and Data Mining, 6 (1), 73-89

Thieler, A. M., Fried, R. and Rathjens, J. (2016): RobPer: An R Package to Calculate Periodograms for Light Curves Based on Robust Regression. Journal of Statistical Software, 69 (9), 1-36, <doi:10.18637/jss.v069.i09>

Examples

```
# Generate a disturbed light curve:
set.seed(22)
lightcurve <- tsgen(ttype="sine",ytype="peak" , pf=7, redpart=0.1, s.outlier.fraction=0.1,
    interval=TRUE, npoints=200, ncycles=25, ps=20, SNR=3, alpha=0)

# Plotting the light curve (vertical bars show measurement accuracies)
plot(lightcurve[,1], lightcurve[,2], pch=16, cex=0.5, xlab="t", ylab="y",
    main="a Light Curve")
rect(lightcurve[,1], lightcurve[,2]+lightcurve[,3], lightcurve[,1],
    lightcurve[,2]-lightcurve[,3])

# The lightcurve has a period of 7:
```

```
plot(lightcurve[,1]%%7, lightcurve[,2], pch=16, cex=0.5, xlab="t", ylab="y",
    main="Phase Diagram of a Light Curve")
rect(lightcurve[,1]%%7, lightcurve[,2]+lightcurve[,3], lightcurve[,1]%%7,
    lightcurve[,2]-lightcurve[,3])

# Calculate a periodogram of a light curve:
PP <- RobPer(lightcurve, model="splines", regression="huber", weighting=FALSE,
    var1=FALSE, periods=1:50)

# Searching for extremely high periodogram bars:
betavalues <- betaCvMfit(PP)
crit.val <- qbeta((0.95)^(1/50),shape1=betavalues[1], shape2=betavalues[2])

hist(PP, breaks=20, freq=FALSE, ylim=c(0,100), xlim=c(0,0.08), col=8, main ="")
betafun <- function(x) dbeta(x, shape1=betavalues[1], shape2=betavalues[2])
curve(betafun, add=TRUE, lwd=2)
abline(v=crit.val, lwd=2)

# alternatives for fitting beta distributions:
# method of moments:
par.mom <- betaCvMfit(PP, rob=FALSE, CvM=FALSE)
myf.mom <- function(x) dbeta(x, shape1=par.mom[1], shape2=par.mom[2])
curve(myf.mom, add=TRUE, lwd=2, col="red")
crit.mom <- qbeta((0.95)^(1/50),shape1=par.mom[1], shape2=par.mom[2])
abline(v=crit.mom, lwd=2, col="red")

# robust method of moments
par.rob <- betaCvMfit(PP, rob=TRUE, CvM=FALSE)
myf.rob <- function(x) dbeta(x, shape1=par.rob[1], shape2=par.rob[2])
curve(myf.rob, add=TRUE, lwd=2, col="blue")
crit.rob <- qbeta((0.95)^(1/50),shape1=par.rob[1], shape2=par.rob[2])
abline(v=crit.rob, lwd=2, col="blue")

legend("topright", fill=c("black","red","blue"),
    legend=c("CvM", "moments", "robust moments"), bg="white")
box()

# Detect fluctuation period:
plot(1:50, PP, xlab="Trial Period", ylab="Periodogram", type="l",
    main="Periodogram fitting periodic splines using M-regression (Huber function)")
abline(h=crit.val, lwd=2)
text(c(7,14), PP[c(7,14)], c(7,14), adj=1, pos=4)
axis(1, at=7, labels=expression(p[f]==7))

# Comparison with non-robust periodogram
# (see package vignette, section 5.1 for further graphical analysis)
PP2 <- RobPer(lightcurve, model="splines", regression="L2",
    weighting=FALSE, var1=FALSE, periods=1:50)
betavalues2 <- betaCvMfit(PP2)
crit.val2   <- qbeta((0.95)^(1/50),shape1=betavalues2[1], shape2=betavalues2[2])

plot(1:50, PP2, xlab="Trial Period", ylab="Periodogram", type="l",
    main="Periodogram fitting periodic splines using L2-regression")
```

```
abline(h=crit.val2, lwd=2)
```

---

betaCvMfit *Robust fit of a Beta distribution using CvM distance minimization*

Description

Robustly fits a Beta distribution to `data` using Cramér-von-Mises (CvM) distance minimization.

Usage

```
betaCvMfit(data, CvM = TRUE, rob = TRUE)
```

Arguments

`data`	numeric vector: The sample, a Beta distribution is fitted to.
`CvM`	logical: If `FALSE` the Cramér-von-Mises-distance is not minimized, but only moment estimates for the parameters of the Beta distribution are returned (see Details).
`rob`	logical: If `TRUE`, mean and standard deviation are replaced by median and MAD when calculating moment estimates for the parameters of the Beta distribution (see Details).

Details

`betaCvMfit` fits a Beta distribution to `data` by minimizing the Cramér-von-Mises distance. Moment estimates of the parameters of the Beta distribution, clipped to positive values, are used as starting values for the optimization process. They are calculated using

$$\hat{a} = -\frac{\bar{x} \cdot (-\bar{x} + \bar{x}^2 + \hat{s}^2)}{\hat{s}^2},$$

$$\hat{b} = \frac{\hat{a} - \hat{a}\bar{x}}{\bar{x}}.$$

These clipped moment estimates can be returned instead of CvM-fitted parameters setting `CvM = FALSE`.

The Cramér-von-Mises distance is defined as (see Clarke, McKinnon and Riley 2012)

$$\frac{1}{n} \sum_{i=1}^{n} \left(F(u_{(i)}) - \frac{i - 0.5}{n} \right)^2 + \frac{1}{12n^2},$$

where $u_{(1)}, \ldots, u_{(n)}$ is the ordered sample and F the distribution function of Beta(a, b).

Value

numeric vector: Estimates for the Parameters a, b of a Beta(a, b) distribution with mean $a/(a + b)$.

Note

Adapted from R-Code from Brenton R. Clarke to fit a Gamma distribution (see Clarke, McKinnon and Riley 2012) using Cramér-von-Mises distance minimization. Used in Thieler et al. (2013). See also Thieler, Fried and Rathjens (2016).

Author(s)

Anita M. Thieler, with contributions from Brenton R. Clarke.

References

Clarke, B. R., McKinnon, P. L. and Riley, G. (2012): A Fast Robust Method for Fitting Gamma Distributions. Statistical Papers, 53 (4), 1001-1014

Thieler, A. M., Backes, M., Fried, R. and Rhode, W. (2013): Periodicity Detection in Irregularly Sampled Light Curves by Robust Regression and Outlier Detection. Statistical Analysis and Data Mining, 6 (1), 73-89

Thieler, A. M., Fried, R. and Rathjens, J. (2016): RobPer: An R Package to Calculate Periodograms for Light Curves Based on Robust Regression. Journal of Statistical Software, 69 (9), 1-36, <doi:10.18637/jss.v069.i09>

See Also

See RobPer-package for an example applying `betaCvMfit` to detect valid periods in a periodogram.

Examples

```
# data:
set.seed(12)
PP <- c(rbeta(45, shape1=4, shape2=15), runif(5, min=0.8, max=1))
hist(PP, freq=FALSE, breaks=30, ylim=c(0,7), xlab="Periodogram bar")

# true parameters:
myf.true <- function(x) dbeta(x, shape1=4, shape2=15)
curve(myf.true, add=TRUE, lwd=2)

# method of moments:
par.mom <- betaCvMfit(PP, rob=FALSE, CvM=FALSE)
myf.mom <- function(x) dbeta(x, shape1=par.mom[1], shape2=par.mom[2])
curve(myf.mom, add=TRUE, lwd=2, col="red")

# robust method of moments
par.rob <- betaCvMfit(PP, rob=TRUE, CvM=FALSE)
myf.rob <- function(x) dbeta(x, shape1=par.rob[1], shape2=par.rob[2])
curve(myf.rob, add=TRUE, lwd=2, col="blue")

# CvM distance minimization
par.CvM <- betaCvMfit(PP, rob=TRUE, CvM=TRUE)
myf.CvM <- function(x) dbeta(x, shape1=par.CvM[1], shape2=par.CvM[2])
curve(myf.CvM, add=TRUE, lwd=2, col="green")
```

```
# Searching for outliers...
abline(v=qbeta((0.95)^(1/50), shape1=par.CvM[1], shape2=par.CvM[2]), col="green")

legend("topright", fill=c("black", "green","blue", "red"),
    legend=c("true", "CvM", "robust moments", "moments"))
box()
```

---

disturber *Disturbing light curve data*

Description

Disturbes a light curve replacing measurement accuracies by outliers and/or observed values by atypical values. See RobPer-package for more information about light curves.

Usage

```
disturber(tt, y, s, ps, s.outlier.fraction = 0, interval)
```

Arguments

`tt` numeric vector: Observation times $t_1, \ldots, t_n$ (see Details).

`y` numeric vector: Observed values $y_1, \ldots, y_n$ (see Details).

`s` numeric vector: Measurement accuracies $s_1, \ldots, s_n$ (see Details).

`ps` positive value: Sampling period p_s indirectly defines the length of the time interval, in which observed values y_i are replaced by atypical values (see Details).

`s.outlier.fraction` numeric value in [0,1]: Defines the proportion of measurement accuracies that is replaced by outliers (see Details). A value of 0 means that no measurement accuracy is replaced by an outlier.

`interval` logical: If `TRUE`, the observed values belonging to a random time interval of length $3p_s$ are replaced by atypical values (see Details). If `TRUE` and the light curve is shorter than $3p_s$, the function will stop with an error message.

Details

This function disturbes the light curve $(t_i, y_i, s_i)_{i=1,\ldots,n}$ given. It randomly chooses a proportion of `s.outlier.fraction` measurement accuracies s_i and replaces them by $0.5 \min(s_1, \ldots, s_n)$. In case of `interval=TRUE` a time interval $[t_{start}, t_{start} + 3p_s]$ within the intervall $[t_1, t_n]$ is randomly chosen and all observed values belonging to this time interval are replaced by a peak function:

$$y_i^{changed} = 6\, \tilde{y}_{0.9} \frac{d_{\mathcal{N}(t_{start}+1.5p_s, p_s^2)}(t_i)}{d_{\mathcal{N}(0,p_s^2)}(0)} \quad \forall\, i \;:\; t_i \in [t_{start}, t_{start} + 3p_s],$$

where $d_{\mathcal{N}(a,b^2)}(x)$ denotes the density of a normal distribution with mean a and variance b^2 at x.

In case of `s.outlier.fraction=0` and `interval=FALSE`, `y` and `s` are returned unchanged.

Value

y	numeric vector: New y_i-values, partly different from the old ones if `interval=TRUE` (see Details).
s	numeric vector: New s_i-values, partly different from the old ones if `s.outlier.fraction>0` (see Details).

Note

A former version of this function is used in Thieler et al. (2013). See also Thieler, Fried and Rathjens (2016).

Author(s)

Anita M. Thieler

References

Thieler, A. M., Backes, M., Fried, R. and Rhode, W. (2013): Periodicity Detection in Irregularly Sampled Light Curves by Robust Regression and Outlier Detection. Statistical Analysis and Data Mining, 6 (1), 73-89

Thieler, A. M., Fried, R. and Rathjens, J. (2016): RobPer: An R Package to Calculate Periodograms for Light Curves Based on Robust Regression. Journal of Statistical Software, 69 (9), 1-36, <doi:10.18637/jss.v069.i09>

See Also

Applied in `tsgen` (see there for example).

FastS *S-Regression using the Fast-S-Algorithm*

Description

Performs S-Regression using the Fast-S-Algorithm.

Usage

```
FastS(x, y, Scontrol=list(int = FALSE, N = 100, kk = 2, tt = 5, b= .5,
 cc = 1.547, seed=NULL), beta_gamma)
```

Arguments

x	numeric $(n \times p)$-matrix: Designmatrix.
y	numeric vector: n observations.
Scontrol	list of length seven: control parameters (see Details).
beta_gamma	numeric vector: Specifies one parameter candidate of length p (see Details).

Details

The Fast-S-Algorithm to efficiently perform S-Regression was published by Salibian-Barrera and Yohai (2006). It bases on starting with a set of N parameter candidates, locally optimizing them, but only with kk iterations, optimizing the tt best candidates to convergence and then choosing the best parameter candidate. The rho-function used is the biweight function with tuning parameter cc, the value b is set to the expected value of the rho-function applied to the residuals. The default cc=1.547 and b=.5 is chosen following Rousseeuw and Yohai (1984) to obtain an approximative breakdown point of 0.5. When setting int to TRUE, this adds an intercept column to the design matrix. For more details see Salibian-Barrera and Yohai (2006) or Thieler, Fried and Rathjens (2016).

The R-function FastS used in RobPer is a slightly changed version of the R-code published in Salibian-Barrera and Yohai (2006). It was changed in order to work more efficiently, especially when fitting step functions, and to specify one parameter candidate in advance. For details see Thieler, Fried and Rathjens (2016).

Value

beta	numeric vector: Fitted parameter vector.
scale	numeric: Value of the objective function

Author(s)

Matias Salibian-Barrera and Victor Yohai, modified by Anita M. Thieler

References

Rousseeuw, P. J. and Yohai, V. J. (1984): Robust Regression by Means of S-estimators. In Franke, J., Härdle, W. und Martin, D. (eds.): Robust and Nonlinear Time Series Analysis. Berlin New York: Springer, Lecture Notes in Statistics No. 26, 256-272

Salibian-Barrera, M. and Yohai, V. (2006): A Fast Algorithm for S-Regression Estimates. Journal of Computational and Graphical Statistics, 15 (2), 414-427

Thieler, A. M., Fried, R. and Rathjens, J. (2016): RobPer: An R Package to Calculate Periodograms for Light Curves Based on Robust Regression. Journal of Statistical Software, 69 (9), 1-36, <doi:10.18637/jss.v069.i09>

See Also

Applied in RobPer. See FastTau for example.

FastTau *Tau-Regression using the Fast-tau-Algorithm*

Description

Performs tau-Regression using the Fast-tau-Algorithm.

Usage

```
FastTau(x, y, taucontrol = list(N = 500, kk = 2, tt = 5, rr = 2, approximate = 0),
 beta_gamma)
```

Arguments

x	numeric $(n \times p)$-matrix: Designmatrix.
y	numeric vector: n observations.
taucontrol	list of four integer and one logical value: Control parameters (see Details).
beta_gamma	numeric vector: Specifies one parameter candidate of length p (see Details).

Details

The Fast-tau-Algorithm to efficiently perform tau-Regression was published by Salibian-Barrera, Willems and Zamar (2008). It bases on starting with a set of `N` parameter candidates, locally optimizing them using `kk` iterations, then optimizing the `tt` best candidates to convergence and finally choosing the best parameter candidate. Since calculation of the objective value is computationally expensive, it is possible to approximate it with `rr` iteration steps when choosing `approximate=TRUE`. For more details see Salibian-Barrera, Willems and Zamar (2008).

The R-function `FastTau` used in `RobPer` is a slightly changed version of the R-code published in Salibian-Barrera, Willems and Zamar (2008). It was changed in order to work more efficiently, especially when fitting step functions, and to specify one parameter candidate in advance. For details see Thieler, Fried and Rathjens (2016).

Value

beta	numeric vector: Fitted parameter vector.
scale	numeric: Value of the objective function

Author(s)

Matias Salibian-Barrera and Gert Willems, modified by Anita M. Thieler

References

Salibian-Barrera, M., Willems, G. and Zamar, R. (2008): The Fast-tau Estimator for Regression. Journal of Computational and Graphical Statistics, 17 (3), 659-682

Thieler, A. M., Fried, R. and Rathjens, J. (2016): RobPer: An R Package to Calculate Periodograms for Light Curves Based on Robust Regression. Journal of Statistical Software, 69 (9), 1-36, <doi:10.18637/jss.v069.i09>

See Also

Applied in `RobPer`.

Examples

```
set.seed(22)
# Generate a disturbed light curve
lightcurve <- tsgen(ttype="unif",ytype="sine" , pf=7, redpart=0.1, interval=TRUE,
    npoints=100, ncycles=10, ps=7, SNR=4, alpha=0)
tt <- lightcurve[,1]
y  <- lightcurve[,2]
s  <- rep(1,100)  # unweighted regression

plot(tt, y, type="l", main="Fitting a sine to a disturbed lightcurve")

# Fit the true model (a sine of period 7)... designmatrix:
X <- Xgen(tt, n=100, s, pp=7, design="sine")
# Robust tau-fit:
beta_FastTau <- FastTau(X, y)$beta
# Robust S-fit:
beta_FastS <- FastS(X, y)$beta
# Least squares fit:
beta_lm <- lm(y~0+X)$coeff

# Plot:
sin7_fun <- function(t, beta) beta[1]+ beta[2]*sin(t*2*pi/7)+ beta[3]*cos(t*2*pi/7)
sin_FastTau <- function(t) sin7_fun(t, beta_FastTau)
sin_FastS <- function(t) sin7_fun(t, beta_FastS)
sin_lm <- function(t) sin7_fun(t, beta_lm)
curve(sin_FastTau, col="green", add=TRUE)
curve(sin_FastS, col="blue", add=TRUE, lty=2)
curve(sin_lm, col="red", add=TRUE)

legend("topleft", fill=c("black", "red", "green", "blue"),
   legend=c("Light Curve (disturbed)", "Least Squares Fit", "FastTau Fit", "FastS Fit"))
```

`lc_noise` *Noise and measurement accuracy generator for light curves*

Description

Generates measurement accuracies, a white noise component depending on them and a second (possibly power law, i.e. red) noise component which does not depend on the measurement accuracies. For more details see `tsgen` or Thieler, Fried and Rathjens (2016). See `RobPer-package` for more information about light curves.

Usage

```
lc_noise(tt, sig, SNR, redpart, alpha = 1.5)
```

Arguments

`tt`	numeric vector: Observation times given.
`sig`	numeric vector of same length as `tt`: A given signal to which the noise will be added.
`SNR`	positive number: Defines the relation between signal and noise (see `tsgen` for Details).
`redpart`	numeric value in [0,1]: Proportion of the power law noise in noise components (see `tsgen` for Details).
`alpha`	numeric value: Power law index for the power law noise component (see `tsgen` for Details).

Value

`y`	numeric vector: Observed values: signal + noise.
`s`	numeric vector: Measurement accuracies related to the white noise component.

Note

A former version of this function is used in Thieler et al. (2013).

Author(s)

Anita M. Thieler and Jonathan Rathjens

References

Thieler, A. M., Backes, M., Fried, R. and Rhode, W. (2013): Periodicity Detection in Irregularly Sampled Light Curves by Robust Regression and Outlier Detection. Statistical Analysis and Data Mining, 6 (1), 73-89

Thieler, A. M., Fried, R. and Rathjens, J. (2016): RobPer: An R Package to Calculate Periodograms for Light Curves Based on Robust Regression. Journal of Statistical Software, 69 (9), 1-36, <doi:10.18637/jss.v069.i09>

See Also

Applied in `tsgen` (see there for an example), applies `TK95_uneq`.

Mrk421 *Data: Light curve from Mrk 421*

Description

Gamma ray light curve from Markarian 421.

Usage

```
Mrk421
```

Format

A data frame of three variables, with a time series of length 655 appropriate to `RobPer`.

Details

The data in Mrk421 and Mrk501 have been collected from various original sources, combined, and published by Tluczykont et al. (2010) of the Deutsches Elektronen-Synchrotron.

Their sources are data from the experiments:

Whipple (Kerrick et al. 1995; Schubnell et al. 1996; Buckley et al. 1996; Maraschi et al. 1999)

HEGRA (Aharonian et al. 1999a, 1999b; Krawczynski et al. 2001; Aharonian et al. 2001, 2002, 2003, 2004; Kestel 2003)

CAT (Piron 2000; Piron et al. 2001)

HESS (Aharonian et al. 2005, 2006)

MAGIC (Albert et al. 2008; Donnarumma et al. 2009)

VERITAS (Rebillot et al. 2006; Donnarumma et al. 2009)

Note

See Vignette Section 5.3 for example.

Source

Data kindly provided by the Deutsches Elektronen-Synchrotron, Gamma Astronomy group (see Details).

References

Tluczykont, M., Bernardini, E., Satalecka, K., Clavero, R., Shayduk, M. and Kalekin, O. (2010): Long-term lightcurves from combined united very high energy gamma-ray data. Astronomy & Astrophysics, 524, A48

Their data sources:

Aharonian, F., Akhperjanian, A., Barrio, J., et al. (1999a): The temporal characteristics of the TeV gamma-radiation from Mkn 501 in 1997: I. Data from the stereoscopic imaging atmospheric Cherenkov telescope system of HEGRA. Astronomy & Astrophysics, 342(1), 69

Aharonian, F., Akhperjanian, A., Barrio, J., et al. (1999b): The temporal characteristics of the TeV gamma-emission from Mkn 501 in 1997: II. Results from HEGRA CT1 and CT2. Astronomy & Astrophysics, 349(1), 29

Aharonian, F., Akhperjanian, A., Barrio, J., et al. (2001): The TeV Energy Spectrum of Markarian 501 Measured with the Stereoscopic Telescope System of HEGRA during 1998 and 1999. The Astrophysical Journal, 546(2), 898

Aharonian, F., Akhperjanian, A., Beilicke, M., et al. (2002): Variations of the TeV energy spectrum at different flux levels of Mkn 421 observed with the HEGRA system of Cherenkov telescopes. Astronomy & Astrophysics, 393(1), 89

Aharonian, F., Akhperjanian, A., Beilicke, M., et al. (2003): TeV gamma-ray light curve and energy spectrum of Mkn 421 during its 2001 flare as measured with HEGRA CT1. Astronomy & Astrophysics, 410(3), 813

Aharonian, F., Akhperjanian, A., Beilicke, M., et al. (2004): The Crab Nebula and Pulsar between 500 GeV and 80 TeV: Observations with the HEGRA Stereoscopic Air Cerenkov Telescopes. The Astrophysical Journal, 614(2), 897

Aharonian, F., Akhperjanian, A., Aye, K., et al. (2005): Observations of Mkn 421 in 2004 with HESS at large zenith angles. Astronomy & Astrophysics, 437(1), 95

Aharonian, F., Akhperjanian, A., Bazer-Bachi, A. R., et al. (2006): Observations of the Crab nebula with HESS. Astronomy & Astrophysics, 457(3), 899

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Buckley, J. H., Akerlof, C. W., Biller, S., et al. (1996): Gamma-Ray Variability of the BL Lacertae Object Markarian 421. The Astrophysical Journal, 472, L9

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Maraschi, L., Fossati, G., Tavecchio, F., et al. (1999): Simultaneous X-Ray and TeV Observations of a Rapid Flare from Markarian 421. The Astrophysical Journal, 526, L81

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Piron, F., Djannati-Atai, A., Punch, M., et al. (2001): Temporal and spectral gamma-ray properties of Mkn 421 above 250 GeV from CAT observations between 1996 and 2000. Astronomy & Astrophysics, 374(3), 895

Rebillot, P. F., Badran, H. M., Blaylock, G., et al. (2006): Multiwavelength Observations of the Blazar Markarian 421 in 2002 December and 2003 January. The Astrophysical Journal, 641(2), 740

Schubnell, M. S., Akerlof, C. W., Biller, S., et al. (1996): Very High Energy Gamma-Ray Emission from the Blazar Markarian 421. The Astrophysical Journal, 460, 644

Mrk501 *Data: Light curve from Mrk 501*

Description

Gamma ray light curve from Markarian 501.

Usage

```
Mrk501
```

Format

A data frame of three variables, with a time series of length 210 appropriate to `RobPer`.

Details

The data in Mrk421 and Mrk501 have been collected from various original sources, combined, and published by Tluczykont et al. (2010) of the Deutsches Elektronen-Synchrotron.

Their sources are data from the experiments:

Whipple (Kerrick et al. 1995; Schubnell et al. 1996; Buckley et al. 1996; Maraschi et al. 1999)

HEGRA (Aharonian et al. 1999a, 1999b; Krawczynski et al. 2001; Aharonian et al. 2001, 2002, 2003, 2004; Kestel 2003)

CAT (Piron 2000; Piron et al. 2001)

HESS (Aharonian et al. 2005, 2006)

MAGIC (Albert et al. 2008; Donnarumma et al. 2009)

VERITAS (Rebillot et al. 2006; Donnarumma et al. 2009)

Note

See Vignette Section 5.3 for example.

Source

Data kindly provided by the Deutsches Elektronen-Synchrotron, Gamma Astronomy group (see Details).

References

Tluczykont, M., Bernardini, E., Satalecka, K., Clavero, R., Shayduk, M. and Kalekin, O. (2010): Long-term lightcurves from combined united very high energy gamma-ray data. Astronomy & Astrophysics, 524, A48

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Aharonian, F., Akhperjanian, A., Barrio, J., et al. (1999a): The temporal characteristics of the TeV gamma-radiation from Mkn 501 in 1997: I. Data from the stereoscopic imaging atmospheric Cherenkov telescope system of HEGRA. Astronomy & Astrophysics, 342(1), 69

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Kestel, M. (2003): TeV gamma-Flux and Spectrum of Markarian 421 in 1999/2000 with Hegra CT1 using refined Analysis Methods. Ph.D. Thesis, Technische Universit\"at M\"unchen

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Schubnell, M. S., Akerlof, C. W., Biller, S., et al. (1996): Very High Energy Gamma-Ray Emission from the Blazar Markarian 421. The Astrophysical Journal, 460, 644

`RobPer` *Periodogram based on (robustly) fitting a periodic function to a light curve*

Description

Calculates a periodogram by fitting a periodic function to a light curve, using a possibly robust regression technique and possibly taking into account measurement accuracies. See `RobPer-package` for more information about light curves. For a lot of more details see Thieler, Fried and Rathjens (2016) and Thieler et al. (2013).

Usage

```
RobPer(ts, weighting, periods, regression, model, steps = 10, tol = 1e-03,
 var1 = weighting, genoudcontrol = list(pop.size = 50, max.generations = 50,
 wait.generations = 5), LTSopt =TRUE,
 taucontrol = list(N = 100, kk = 2, tt = 5, rr = 2, approximate = FALSE),
 Scontrol=list(N = ifelse(weighting,200,50), kk = 2, tt = 5, b=.5, cc = 1.547,
 seed = NULL) )
```

Arguments

`ts` dataframe or matrix with three (or two) numeric columns containing the light curve to be analyzed: observation times (first column), observed values (second column), measurement accuracies (thirs column). If it is intended to calculate the periodogram of a time series without measurement accuracies (`weighting=FALSE`), the third column may be omitted.

`weighting` logical: Should measurement accuracies be taken into account performing weighted regression?

`periods` vector of positive numeric values: Trial periods.

`regression` character string specifying the regression method used: Possible choices are `"L2"` (least squares regression using the R-function `lm`, package `stats`), `"L1"` (least absolute deviation regression, using the R-function `rq`, package `quantreg`), "LTS" (least trimmed squares regression, using the R-function ltsReg, package robustbase), "huber" (M-regression using the Huber function), "bisquare" (M-regression using the bisquare function), "S" (S-regression using adapted code from Salibian-Barrera and Yohai 2006, see FastS), "tau" (tau-regression using adapted code from Salibian-Barrera, Willems and Zamar 2008, see FastTau).

model
: character string specifying the periodic function fitted to the light curve: Possible choices are "step" (periodic step function), "2step" (two overlapping periodic step functions, see Details), "sine" (sine function), "fourier(2)" and "fourier(3)" (Fourier series of second or third degree), "splines" (periodic spline function with four B-splines per cycle, generated using spline.des, package splines).

steps
: integer value: Number of steps per cycle for the periodic step function(s).

tol
: (small) positive number: Precision for convergence criteria. Used in case of regression="huber" or "bisquare" or if regression="LTS" and LTSopt=TRUE.

var1
: logical: Should variance estimate be set to 1 in case of weighted M-regression?

genoudcontrol
: list of three integers pop.size, max.generations, wait.generations: Control parameters for the R-function genoud, package rgenoud, see Details and Mebane Jr. and Sekhon (2011). Used in case of regression="bisquare" or if regression="LTS" and LTSopt=TRUE.

LTSopt
: logical: In case of LTS-regression, should regression result of ltsReg be optimized using the R-function genoud, package rgenoud?

taucontrol
: list of four integer values N, kk, tt, rr and one logical approximate: Control parameters for the R-function FastTau. For more details see FastTau and Salibian-Barrera, Willems and Zamar (2008).

Scontrol
: list of three integers N, kk and tt, two positive numbers b and cc and another integer seed: Control parameters for the R-function FastS. For more details see FastS and Salibian-Barrera and Yohai (2006). Please notice that the further Scontrol entry int expected by FastS is automatically set to FALSE in order to let RobPer work properly.

Details

For each trial period, a periodic function (defined by model) is fitted to the light curve using regression technique regression. The periodogram bar is the coefficient of determination. In case of model="2step", two different step functions with opposed jumping times are fitted separately and the periodogram bar is the mean of both coefficients of determination. For a lot of more details see Thieler, Fried and Rathjens (2016) and Thieler et al. (2013).

Value

numeric vector: Periodogram bars related to the trial periods.

Note

Performing weighting = FALSE, regression="L2", model="sine" on a equidistantly sampled time series is equivalent to calculating the standard periodogram of Fourier analysis, see Example.

Performing `regression="L2", model="sine"` is equivalent to calculating a Generalized Lomb-Scargle periodogram (see Zechmeister and Kürster 2009).

Performing `regression="L2", model="step"` is equivalent to calculating an Epoch Folding (Leahy et al. 1983) or Anaysis of Variance (Schwarzenberg-Czerny 1989) periodogram.

Performing `regression="L2", model="2step"` is equivalent to calculating a Phase Dispersion Minimization periodogram (Stellingwerf 1978).

A former version of this function is used in Thieler et al. (2013). For more equivalences see there.

Author(s)

Anita M. Thieler, Jonathan Rathjens and Roland Fried

References

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Zechmeister, M. and Kürster, M. (2009): The Generalised Lomb-Scargle Periodogram. A New Formalism for the Floating-Mean and Keplerian Periodograms. Astronomy and Astrophysics, 496 (2), 577-584

See Also

Applies `FastS` and `FastTau`, `Xgen`, examples in `RobPer-package` and `TK95_uneq`.

Examples

```
# For more examples see RobPer-package and TK95_uneq!

# Example to show the equivalence between the periodogram from Fourier analysis
# and the Lomb-Scargle periodogram in case of equidistant sampling and equal weighting:
set.seed(7)
n <- 120
```

```
# equidistant time series:
zr <- tsgen(ttype="equi", ytype="const", pf=1, redpart= 0, s.outlier.fraction=0.2,
    interval=FALSE, npoints=n, ncycles=n, ps=1, SNR=1, alpha=1.5)
# periodogram of Fourier analysis
PP_konv <- spec.pgram(zr[,2], taper = 0,pad = 0, fast = FALSE, demean = TRUE,
    detrend = TRUE, plot = TRUE)
# Lomb-Scargle periodogram - Note: Due to the regression ansatz,
# RobPer is not able to compute period 2 in this case.
PP_new <- RobPer(ts=zr, weighting=FALSE, periods=1/PP_konv$freq,
    regression="L2", model="sine")
plot(PP_konv$freq, PP_konv$spec, ylab="periodogram", xlab="frequency",
    main="Comparison of RobPer(...regression='LS', model='sine') and spec.pgram")
points(PP_konv$freq, PP_new*var(zr[,2])*n/2, type="l")
legend("top",lty=c(1,0), pch=c(-5,1), legend=c("RobPer*var(y)*n/2", "spec.pgram"))
# Due to different ways of computation, the scaled periodograms are not exactly
# identical, but show very similar behavior.
```

---

sampler *Generator for irregularly sampled observation times*

Description

Generates irregularly sampled observation times with a periodic sampling pattern

Usage

```
sampler(ttype, npoints, ncycles, ps = 1)
```

Arguments

`ttype`	character string: Specifying the sampling pattern. Possible options: `"equi"` and `"unif"` for unperiodic sampling, `"sine"` and `"trian"` for sampling with a periodic density (see Details).
`npoints`	integer: Sample size n (see Details).
`ncycles`	integer: Number of sampling cycles n_s (see Details).
`ps`	positive numeric value: Sampling period p_s (see Details).

Details

`sampler` generates observation times $t_1, \ldots, t_n$ with a periodic sampling of period p_s. Four distributions are possible: In case of `ttype="equi"`, the t_i are equidistantly sampled with $t_i = i\frac{p_s n_s}{n}$. For `ttype="unif"`, the observation times are independently drawn form a uniform distribution on $[0, n_s p_s]$. Both these sampling schemes are aperiodic, the sampling period p_s only influences the length $t_n - t_1$ of the series of observation times.

For `ttype="sine"` and `ttype="trian"`, observation cycles $z_i^\star$ are drawn from a uniform distribution on $\{1, \ldots, n_s\}$ and observation phases $\varphi_i^\star$ are drawn from a density

$$d_{sine}(x) = \sin(2\pi x) + 1$$

(for `ttype="sine"`) or

$$d_{trian}(x) = 3x, \quad 0 \leq x \leq \frac{2}{3},$$

$$d_{trian}(x) = 6 - 6x, \quad \frac{2}{3} < x \leq 1$$

(for `ttype="trian"`). The unsorted observation times $t_i^\star$ are then generated using

$$t_i^\star = \varphi_i^\star + (z_i^\star - 1)p_s.$$

Separately sampling observation cycle and phase was proposed by Hall and Yin (2003). For more details see Thieler, Fried and Rathjens (2016) or Thieler et al. (2013).

Value

numeric vector: Ordered observation times.

Note

To sample from d_{sine}, the function `BBsolve`, package `BB`, is used.

A former version of this function is used in Thieler et al. (2013).

Author(s)

Anita M. Thieler and Jonathan Rathjens

References

Hall, P. and Yin, J. (2003): Nonparametric Methods for Deconvolving Multiperiodic Functions. Journal of the Royal Statistical Society: Series B (Statistical Methodology), 65 (4), 869-886

Thieler, A. M., Backes, M., Fried, R. and Rhode, W. (2013): Periodicity Detection in Irregularly Sampled Light Curves by Robust Regression and Outlier Detection. Statistical Analysis and Data Mining, 6 (1), 73-89

Thieler, A. M., Fried, R. and Rathjens, J. (2016): RobPer: An R Package to Calculate Periodograms for Light Curves Based on Robust Regression. Journal of Statistical Software, 69 (9), 1-36, <doi:10.18637/jss.v069.i09>

See Also

Applied in `tsgen` (see there for an example).

`signalgen` *Generator for periodic signal in a light curve*

Description

Calculates periodically varying values for given observation times.

Usage

```
signalgen(tt, ytype, pf = 1)
```

Arguments

`tt`	numeric vector: Observation times $t_1, \ldots, t_n$ (see Details).
`ytype`	character string: Specifying the shape of the periodic fluctuation (see Details). Possible choices are `"const"`, `"sine"`, `"trian"`,`"peak"`.
`pf`	positive numeric value: Fluctuation period p_f.

Details

The values $y_{f;1}, \ldots, y_{f;n}$ with fluctuation period p_f and related to observation times $t_1, \ldots, t_n$ are generated using

$$y_{f;i} = f\left(\frac{t_i}{p_f}\right), i = 1, \ldots, n.$$

Depending on `ytype` (see above), f is defined as:

$$f_{const}(t) = 0,$$

$$f_{sine}(t) = \sin\left(\frac{2\pi t}{p_f}\right),$$

$$f_{trian}(t) = 3\varphi_1(t), \quad 0 \leq \varphi_1(t) \leq \frac{2}{3},$$

$$f_{trian}(t) = 6 - 6\varphi_1(t), \quad \frac{2}{3} < \varphi_1(t) \leq 1,$$

$$f_{peak}(t) = 9\exp\left(-3p_f^2\left(\varphi_1(t) - \frac{2}{3}\right)^2\right), \quad 0 \leq \varphi_1(t) \leq \frac{2}{3},$$

$$f_{peak}(t) = 9\exp\left(-12p_f^2\left(\varphi_1(t) - \frac{2}{3}\right)^2\right), \quad \frac{2}{3} < \varphi_1(t) \leq 1,$$

with $\varphi_1(t) = t mod 1 = (t - \lfloor t/p_f \rfloor p_f)/p_f$ = `(t%%1)/pf`. f_{const} means that there is no (periodic) fluctuation, f_{sine} defines a sine function, f_{trian} defines a triangular shaped periodic function and f_{peak} a periodically repeating peak.

Value

numeric vector: Values $y_{f;1}, \ldots, y_{f;n}$.

Note

This function is used in Thieler et al. (2013). See also Thieler, Fried and Rathjens (2016).

Author(s)

Anita M. Thieler and Jonathan Rathjens

References

Thieler, A. M., Backes, M., Fried, R. and Rhode, W. (2013): Periodicity Detection in Irregularly Sampled Light Curves by Robust Regression and Outlier Detection. Statistical Analysis and Data Mining, 6 (1), 73-89

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See Also

Applied in `tsgen` (see there for an example).

`star_groj0422.32` *Data: Light curve from GROJ0422+32*

Description

Light curve for gamma ray emission of the source GROJ0422+32.

Usage

```
star_groj0422.32
```

Format

A matrix of three columns, with a time series of length 729 appropriate to `RobPer`.

Details

Data obtained by the BATSE Earth Occultation Monitoring project of the NSSTC, available from `https://gammaray.nsstc.nasa.gov/batse/occultation/`. The experiments are described in Harmon et al. (2002) and Harmon et al. (2004).

Note

See Vignette Section 5.2 for example.

Source

Data kindly provided by the National Aeronautics and Space Administration (NASA); National Space, Science, and Technology Center (NSSTC); Gamma-Ray Astrophysics Team (see Details).

References

Harmon, B. A., Fishman, G. J., Wilson, C. A., Paciesas, W. S., Zhang, S. N., Finger, M. H., Koshut, T. M., McCollough, M. L., Robinson, C. R. and Rubin, B. C. (2002): The Burst and Transient Source Experiment Earth Occultation Technique. The Astrophysical Journal Supplement Series, 138 (1), 149-183

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TK95 *Power law noise generator*

Description

Generates an equidistant time series of power law noise according to Timmer and KÃ¶nig (1995).

Usage

```
TK95(N = 1000, alpha = 1.5)
```

Arguments

N	integer value: Length of the generated time series.
alpha	numeric value: Exponent of the power law. White noise has exponent 0, flicker noise (pink noise) has exponent 1, brown noise has exponent 2.

Value

numeric vector: The generated time series.

Note

This function is used in Thieler et al. (2013). See also Thieler, Fried and Rathjens (2016).

Author(s)

Anita M. Thieler with contributions of Uwe Ligges

References

Thieler, A. M., Backes, M., Fried, R. and Rhode, W. (2013): Periodicity Detection in Irregularly Sampled Light Curves by Robust Regression and Outlier Detection. Statistical Analysis and Data Mining, 6 (1), 73-89

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Timmer, J. and KÃ¶nig, M. (1995) On Generating Power Law Noise. Astronomy and Astrophysics, 300, 707-710

See Also

Applied in `tsgen` by `TK95_uneq`.

Examples

```
set.seed(31)
# Generate power law noise with exponent alpha=1.5:
y <- TK95(N=2000, alpha=1.5)
tt <- seq(along=y)

# Show time series:
plot(tt,y, type="l", main="Power Law Noise", xlab="t", ylab="y")

# Plot Fourier periodogram with log-axes:
temp <- spectrum(y, plot=FALSE)
plot(log(temp$freq), log(temp$spec), main="log-log-Fourier periodogram",
    xlab="log(frequency)", ylab="log(periodogram)")

# A line with slope -alpha for comparison
abline(a=8, b=-1.5, col="red")
text(-2, 12, expression(alpha==1.5), col="red")
```

TK95_uneq — *Power law noise generator for unequally sampled observation times*

Description

Generates power law noise using `TK95` according to Timmer and KÃ¶nig (1995), with modifications proposed in Uttley, McHardy and Papadakis (2002) for given irregular observation times.

Usage

```
TK95_uneq(tt, alpha = 1.5)
```

Arguments

`tt`	numeric vector: Observation times given.
`alpha`	numeric value: exponent of the power law. White noise has exponent 0, flicker noise (pink noise) has exponent 1, brown noise has exponent 2.

Value

numeric vector: Noise values related to the observation times.

Note

This function is applied in Thieler et al. (2013). See also Thieler, Fried and Rathjens (2016).

Author(s)

Anita M. Thieler

References

Thieler, A. M., Backes, M., Fried, R. and Rhode, W. (2013): Periodicity Detection in Irregularly Sampled Light Curves by Robust Regression and Outlier Detection. Statistical Analysis and Data Mining, 6 (1), 73-89

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Timmer, J. and KÃ¶nig, M. (1995) On Generating Power Law Noise. Astronomy and Astrophysics, 300, 707-710

Uttley, P., McHardy, I. M. and Papadakis, I. E. (2002) Measuring the Broad-Band Power Spectra of Active Galactic Nuclei with RXTE. Monthly Notices of the Royal Astronomical Society, 332 (1), 231-250

See Also

Applies `TK95`, applied in `tsgen`.

Examples

```
# Compare with example in TK95 to see that the power law is much more clear in
# equally sampled data!
set.seed(31)
# Generate power law noise with exponent alpha=1.5:
tt <- sampler(ttype="unif", ps=1, ncycles=2000, npoints=2000)
y <- TK95_uneq(tt, alpha=1.5)

# Show time series:
plot(tt,y, type="l", main="Irregular Power Law Noise", xlab="t", ylab="y")

# Plot Lomb-Scargle periodogram with log-axes:
temp <- RobPer(cbind(tt,y,1), weighting=FALSE, model="sine", regression="L2",
```

```
    periods=2000/seq(2, 1000, 2))
plot(log(seq(2, 1000, 2)/2000), log(temp), main="log-log-Fourier periodogram",
    xlab="log(frequency)", ylab="log(periodogram)")
title(main= "Power Law not so obvious", cex.main=0.8, line=0.5)

# A line with slope -alpha for comparison
abline(a=-10, b=-1.5, col="red")
text(-5, -1.5, expression(alpha==1.5), col="red")
```

---

tsgen *Artificial light curve generator*

Description

This function generates light curves (special time series) with unequally sampled observation times, different periodicities both in sampling and observed values, with white and power law (red) noise in the observed values and possibly disturbed observations. See RobPer-package for more information about light curves and also Thieler, Fried and Rathjens (2016) for more details in general.

Usage

```
tsgen(ttype, ytype, pf, redpart, s.outlier.fraction = 0, interval, npoints,
 ncycles, ps, SNR, alpha = 1.5)
```

Arguments

- `ttype` character string: Specifying the sampling pattern. Possible choices are "equi" for equidistant sampling without gaps (unperiodic), "unif" for uniform non-equidistant unperiodic sampling, "sine" for sampling with periodic sine density, "trian" for sampling with periodic triangular density, both with period p_s (see Details and sampler).
- `ytype` character string: Specifying the shape of the periodic fluctuation with period p_f. Possible choices are "const" for constantly being zero (so no periodicity), "sine" for a sine, "trian" for a periodic triangular function, "peak" for a peak function (see Details and signalgen for more details).
- `pf` positive number: Period p_f of the periodic fluctuation, argument of signalgen (see Details and signalgen).
- `redpart` numeric value in [0,1]: Proportion of the power law noise in noise components (see Details). The generated measurement accuracies s_i do not contain information about this noise component.
- `s.outlier.fraction` numeric value in [0,1]: Fraction of measurement accuracies to be replaced by outliers. A value of 0 means that no measurement accuracy is replaced by an outlier (for more details see disturber).
- `interval` logical: If TRUE, the observed values belonging to a random time interval of length $3p_s$ are replaced by atypical values (for more details see disturber).

npoints	integer value: Defines the sample size n for the generated light curve.
ncycles	integer value: number n_s of sampling cycles that is observed (see Details).
ps	positive number: Sampling period p_s, influencing the sampling and how the light curve is disturbed (see Details and disturber).
SNR	positive number: Defines the relation between signal y_f and noise $y_w + y_r$ (see Details).
alpha	numeric value: Power law index α for the power law noise component y_r (see Details).

Details

tsgen generates an artificial light curve consisting of observation times $t_1, \ldots, t_n$, observation values $y_1, \ldots, y_n$ and measurement accuracies $s_1, \ldots, s_n$. It calls several subfunctions (see there for details):

sampler is used to sample observation times $t_1, \ldots, t_n$ in the interval $[0, n_s * p_s]$ with a possibly periodic sampling of period p_s.

signalgen generates periodically varying values $y_{f;1}, \ldots, y_{f;n}$ at time points $t_1, \ldots, t_n$ with fluctuation period p_f.

lc_noise samples measurement accuracies $s_1, \ldots, s_n$ from a Gamma(3,10)-distribution and a white noise component $y_{w;1}, \ldots, y_{w;n}$ with from $\mathcal{N}(0, s_i^2)$ distributions. A second noise component $y_{r;1}, \ldots, y_{r;n}$ does not depend on the s_i. It is generated as red noise, i.e. following a power law with power law index α. For white noise choose $\alpha = 0$, for flicker noise (pink noise) $\alpha = 1$, for brown noise $\alpha = 2$. The power law noise is generated using TK95_uneq and TK95. The noise components are scaled so that the variance of the $y_{r;i}$ has approximately the proportion redpart in the overall noise variance and that SNR is the ratio $var(y_f)/var(y_w + y_r)$. The observed values are set to $y_i = y_{f;i} + y_{w;i} + y_{r;i} \forall i$.

disturber disturbes the light curve replacing measurement accuracies s_i by outliers (if s.outlier.fraction>0) and observed values y_i by atypical values (if interval=TRUE). In case of s.outlier.fraction=0 and interval=FALSE, the function returns all values unchanged.

Value

tt	numeric vector: Generated observation times $t_1, \ldots, t_n$.
y	numeric vector: Generated observation values $y_1, \ldots, y_n$.
s	numeric vector: Generated measurement accuracies $s_1, \ldots, s_n$.

Note

Note that the white noise components' variances are exactly s_i^2, so the s_i are no estimates, but true values. In this sense, the measurement accuracies of a generated light curve are more informative than for real light curves, where the measurement accuracies are estimates, see Thieler et al. (2013), where also a former version of this function is applied.

To lower the informativity of the measurement accuracies, set redpart to a strictly positive value, possibly with alpha=0 if no other noise components than white ones are required.

Author(s)

Anita M. Thieler and Jonathan Rathjens

References

Thieler, A. M., Backes, M., Fried, R. and Rhode, W. (2013): Periodicity Detection in Irregularly Sampled Light Curves by Robust Regression and Outlier Detection. Statistical Analysis and Data Mining, 6 (1), 73-89

Thieler, A. M., Fried, R. and Rathjens, J. (2016): RobPer: An R Package to Calculate Periodograms for Light Curves Based on Robust Regression. Journal of Statistical Software, 69 (9), 1-36, <doi:10.18637/jss.v069.i09>

See Also

Applies `sampler`, `signalgen`, `lc_noise`, `disturber`, `TK95`, `TK95_uneq`.

Examples

```
# Generate a light curve:
set.seed(22)
lightcurve<- tsgen(ttype="sine", ytype="peak" , pf=7, redpart=0.1, s.outlier.fraction=0,
    interval=FALSE, npoints=200, ncycles=100, ps=5, SNR=3, alpha=0)

# Or do it step by step:
# First sampling observation times:
set.seed(22)
tt <- sampler(ttype="sine", npoints=200, ncycles=100, ps=5)

# show obviously irregular observation times as grey vertical bars on a red time line:
plot(tt, tt*0, type="n", axes=FALSE, xlab="Observation Times", ylab="")
    abline(v=tt, col="grey")
axis(1, pos=0, col="red", col.axis="red")

# Sampling period is 5, look at observation times modulo 10:
hist(tt%%5, xlab="Observation time modulo 5",
    main="Sine Distribution for the phase (tt modulo 5)", freq=FALSE)
dsin <- function(tt) 0.2*(sin(2*pi*tt/5)+1)
curve(dsin, add=TRUE)

# Then generate periodic fluctuation
yf <- signalgen(tt, ytype="peak", pf=7)

plot(tt, yf, xlab="Observation Times", ylab="Periodic Fluctuation")
plot(tt%%7, yf, main="Phase Diagram (time modulo 7)",
    xlab="Observation time modulo 7",  ylab="Periodic Fluctuation")

# Add noise and scale signal to the right SNR
temp <- lc_noise(tt,sig=yf, SNR=3, redpart=0.1, alpha=0)
y <- temp$y
s <- temp$s
```

```
# Plotting the light curve (vertical bars show measurement accuracies)
plot(tt, y, pch=16, cex=0.5, xlab="t", ylab="y", main="a Light Curve")
rect(tt, y+s, tt, y-s)

# The lightcurve has period 7:
plot(tt%%7, y, pch=16, cex=0.5, xlab="t", ylab="y",
    main="Phase Diagram of a Light Curve")
rect(tt%%7, y+s, tt%%7, y-s)

# replace measurement accuracies by tiny outliers or include a peak
temp <- disturber(tt,y,s,ps=5, s.outlier.fraction=0, interval=FALSE)

# Phase diagram (observation times modulo 10)
plot(tt%%7, temp$y, pch=16, cex=0.5, xlab="t", ylab="y",
    main="Phase Diagram of a Light Curve")
rect(tt%%7, temp$y+temp$s, tt%%7, temp$y-temp$s)

# The result is the same:
all(cbind(tt,temp$y,temp$s)==lightcurve)
```

Xgen *Designmatrix generator*

Description

This function is used to create the designmatrices needed in RobPer to fit periodic functions. See RobPer or Thieler, Fried and Rathjens (2016) for Details.

Usage

```
Xgen(tt, n, s, pp, design, steps = 10)
```

Arguments

tt	real-valued vector of length n: Observation times.
n	integer: Sample size.
s	numeric vector of length n: Measurement errors to perform weighted regression, else set s=rep(1,n).
pp	positive number: Trial period.
design	character string: Shape of the periodic function to be fitted, possible choices are "step", "sine", "fourier(2)", "fourier(3)", "splines" (see RobPer for details) and "stepB". The latter generates a step function like "step", but with opposite jumping time points. This is needed for RobPer with model="2step" (see RobPer).
steps	Number of steps for the step functions

Value

numeric matrix: Designmatrix.

Note

A former version of this function is used in Thieler et al. (2013).

Author(s)

Anita M. Thieler and Jonathan Rathjens

References

Thieler, A. M., Backes, M., Fried, R. and Rhode, W. (2013): Periodicity Detection in Irregularly Sampled Light Curves by Robust Regression and Outlier Detection. Statistical Analysis and Data Mining, 6 (1), 73-89

Thieler, A. M., Fried, R. and Rathjens, J. (2016): RobPer: An R Package to Calculate Periodograms for Light Curves Based on Robust Regression. Journal of Statistical Software, 69 (9), 1-36, <doi:10.18637/jss.v069.i09>

See Also

Applied in `RobPer`, see `FastTau` for an example.

Index