

# Package ‘ghyp’

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**Description** Detailed functionality for working with the univariate and multivariate Generalized Hyperbolic distribution and its special cases (Hyperbolic (hyp), Normal Inverse Gaussian (NIG), Variance Gamma (VG), skewed Student-t and Gaussian distribution). Especially, it contains fitting procedures, an AIC-based model selection routine, and functions for the computation of density, quantile, probability, random variates, expected shortfall and some portfolio optimization and plotting routines as well as the likelihood ratio test. In addition, it contains the Generalized Inverse Gaussian distribution. See Chapter 3 of A. J. McNeil, R. Frey, and P. Embrechts. Quantitative risk management: Concepts, techniques and tools. Princeton University Press, Princeton (2005).

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|              |   |
|--------------|---|
| ghyp-package | <i>A package on the generalized hyperbolic distribution and its special cases</i> |
|--------------|---|

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## Description

This package provides detailed functionality for working with the univariate and multivariate Generalized Hyperbolic distribution and its special cases (Hyperbolic (hyp), Normal Inverse Gaussian (NIG), Variance Gamma (VG), skewed Student-t and Gaussian distribution). Especially, it contains fitting procedures, an AIC-based model selection routine, and functions for the computation of density, quantile, probability, random variates, expected shortfall and some portfolio optimization and plotting routines as well as the likelihood ratio test. In addition, it contains the Generalized Inverse Gaussian distribution.

**Details****Initialize:**

|                        |  |
|------------------------|--|
| <code>ghyp</code>      | Initialize a generalized hyperbolic distribution.  |
| <code>hyp</code>       | Initialize a hyperbolic distribution.              |
| <code>NIG</code>       | Initialize a normal inverse gaussian distribution. |
| <code>VG</code>        | Initialize a variance gamma distribution.          |
| <code>student.t</code> | Initialize a Student-t distribution.               |
| <code>gauss</code>     | Initialize a Gaussian distribution.                |

**Density, distribution function, quantile function and random generation:**

|                    |   |
|--------------------|---|
| <code>dghyp</code> | Density of a generalized hyperbolic distribution.               |
| <code>pghyp</code> | Distribution function of a generalized hyperbolic distribution. |
| <code>qghyp</code> | Quantile of a univariate generalized hyperbolic distribution.   |
| <code>rghyp</code> | Random generation of a generalized hyperbolic distribution.     |

**Fit to data:**

|                           |  |
|---------------------------|--|
| <code>fit.ghypuv</code>   | Fit a generalized hyperbolic distribution to univariate data.    |
| <code>fit.hypuv</code>    | Fit a hyperbolic distribution to univariate data.                |
| <code>fit.NIGuv</code>    | Fit a normal inverse gaussian distribution to univariate data.   |
| <code>fit.VGuv</code>     | Fit a variance gamma distribution to univariate data.            |
| <code>fit.tuv</code>      | Fit a skewed Student-t distribution to univariate data.          |
| <code>fit.gaussov</code>  | Fit a Gaussian distribution to univariate data.                  |
| <code>fit.ghypmv</code>   | Fit a generalized hyperbolic distribution to multivariate data.  |
| <code>fit.hypmv</code>    | Fit a hyperbolic distribution to multivariate data.              |
| <code>fit.NIGmv</code>    | Fit a normal inverse gaussian distribution to multivariate data. |
| <code>fit.VGmv</code>     | Fit a variance gamma distribution to multivariate data.          |
| <code>fit.tmv</code>      | Fit a skewed Student-t distribution to multivariate data.        |
| <code>fit.gaussmv</code>  | Fit a Gaussian distribution to multivariate data.                |
| <code>stepAIC.ghyp</code> | Perform a model selection based on the AIC.                      |

**Risk, performance and portfolio optimization:**

|                                 |   |
|---------------------------------|---|
| <code>ESghyp</code>             | Expected shortfall of a univariate generalized hyperbolic distribution.   |
| <code>ghyp.omega</code>         | Performance measure <i>Omega</i> based on a univariate ghyp distribution. |
| <code>portfolio.optimize</code> | Calculate optimal portfolios with respect to alternative risk measures.   |

**Utilities:**

|                   |                                    |
|-------------------|------------------------------------|
| <code>mean</code> | Returns the expected value.        |
| <code>vcov</code> | Returns the variance(-covariance). |

|                             |   |
|-----------------------------|---|
| <code>ghyp.skewness</code>  | Skewness of a univariate ghyp distribution.                               |
| <code>ghyp.kurtosis</code>  | Kurtosis of a univariate ghyp distribution.                               |
| <code>logLik</code>         | Returns Log-Likelihood of fitted ghyp objects.                            |
| <code>AIC</code>            | Returns the Akaike's Information Criterion of fitted ghyp objects.        |
| <code>lik.ratio.test</code> | Performs a likelihood-ratio test on fitted ghyp distributions.            |
| <code>[</code>              | Extract certain dimensions of a multivariate ghyp distribution.           |
| <code>scale</code>          | Scale ghyp distribution objects to zero expectation and/or unit variance. |
| <code>transform</code>      | Transform a multivariate generalized hyperbolic distribution.             |
| <code>ghyp.moment</code>    | Moments of the univariate ghyp distribution.                              |
| <code>coef</code>           | Parameters of a generalized hyperbolic distribution.                      |
| <code>ghyp.data</code>      | Data of a (fitted) generalized hyperbolic distribution.                   |
| <code>ghyp.fit.info</code>  | Information about the fitting procedure, log-likelihood and AIC value.    |
| <code>ghyp.name</code>      | Returns the name of the ghyp distribution or a subclass of it.            |
| <code>ghyp.dim</code>       | Returns the dimension of a ghyp object.                                   |
| <code>summary</code>        | Summary of a fitted generalized hyperbolic distribution.                  |

#### Plot functions:

|                     |  |
|---------------------|--|
| <code>qqghyp</code> | Perform a quantile-quantile plot of a (fitted) univariate ghyp distribution.   |
| <code>hist</code>   | Plot a histogram of a (fitted) univariate generalized hyperbolic distribution. |
| <code>pairs</code>  | Produce a matrix of scatterplots with quantile-quantile plots on the diagonal. |
| <code>plot</code>   | Plot the density of a univariate ghyp distribution.                            |
| <code>lines</code>  | Add the density of a univariate ghyp distribution to a graphics device.        |

#### Generalized inverse gaussian distribution:

|                    |  |
|--------------------|--|
| <code>dgig</code>  | Density of a generalized inverse gaussian distribution               |
| <code>pgig</code>  | Distribution function of a generalized inverse gaussian distribution |
| <code>qgig</code>  | Quantile of a generalized inverse gaussian distribution              |
| <code>ESgig</code> | Expected shortfall of a generalized inverse gaussian distribution    |
| <code>rgig</code>  | Random generation of a generalized inverse gaussian distribution     |

#### Package vignette:

A document about generalized hyperbolic distributions can be found in the doc folder of this package or on <https://cran.r-project.org/package=ghyp>.

#### Existing solutions

There are packages like `GeneralizedHyperbolic`, `HyperbolicDist`, `SkewHyperbolic`, `VarianceGamma` and `fBasics` which cover the univariate generalized hyperbolic distribution and/or some of its special cases. However, the univariate case is contained in this package as well because we aim to provide a uniform interface to deal with generalized hyperbolic distribution. Recently an R port of the S-Plus library `QRMLib` was released. The package `QRMLib` contains fitting procedures for the multivariate NIG, hyp and skewed Student-t distribution but not for the generalized hyperbolic case. The package `fMultivar` implements a fitting routine for multivariate skewed Student-t distributions as well.

## Object orientation

We follow an object-oriented programming approach in this package and introduce distribution objects. There are mainly four reasons for that:

- Unlike most distributions the GH distribution has quite a few parameters which have to fulfill some consistency requirements. Consistency checks can be performed uniquely when an object is initialized.
- Once initialized the common functions belonging to a distribution can be called conveniently by passing the distribution object. A repeated input of the parameters is avoided.
- Distributions returned from fitting procedures can be directly passed to, e.g., the density function since fitted distribution objects add information to the distribution object and consequently inherit from the class of the distribution object.
- Generic method dispatching can be used to provide a uniform interface to, e.g., plot the probability density of a specific distribution like `plot(distribution.object)`. Additionally, one can take advantage of generic programming since R provides virtual classes and some forms of polymorphism.

## Acknowledgement

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## Author(s)

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## References

*Quantitative Risk Management: Concepts, Techniques and Tools* by Alexander J. McNeil, Ruediger Frey and Paul Embrechts  
Princeton Press, 2005

*Intermediate probability: A computational approach* by Marc Paoletta  
Wiley, 2007

*S-Plus and R Library for Quantitative Risk Management QRMLib* by Alexander J. McNeil (2005) and Scott Ulman (R-port) (2007)

coef-method

*Extract parameters of generalized hyperbolic distribution objects***Description**

The function `coef` returns the parameters of a generalized hyperbolic distribution object as a list. The user can choose between the “chi/psi”, the “alpha.bar” and the “alpha/delta” parametrization. The function `coefficients` is a synonym for `coef`.

**Usage**

```
## S4 method for signature 'ghyp'
coef(object, type = c("chi.psi", "alpha.bar", "alpha.delta"))

## S4 method for signature 'ghyp'
coefficients(object, type = c("chi.psi", "alpha.bar", "alpha.delta"))
```

**Arguments**

|                     |  |
|---------------------|--|
| <code>object</code> | An object inheriting from class <code>ghyp</code> .  |
| <code>type</code>   | According to <code>type</code> the parameters of either the “chi/psi”, the “alpha.bar” or the “alpha/delta” parametrization will be returned. If <code>type</code> is missing, the parameters belonging to the parametrization of the construction are returned. |

**Details**

Internally, the “chi/psi” parametrization is used. However, fitting is only possible in the “alpha.bar” parametrization as it provides the most convenient parameter constraints.

**Value**

If `type` is “chi.psi” a list with components:

|                     |                       |
|---------------------|-----------------------|
| <code>lambda</code> | Shape parameter.      |
| <code>chi</code>    | Shape parameter.      |
| <code>psi</code>    | Shape parameters.     |
| <code>mu</code>     | Location parameter.   |
| <code>sigma</code>  | Dispersion parameter. |
| <code>gamma</code>  | Skewness parameter.   |

If `type` is “alpha.bar” a list with components:

|                        |                       |
|------------------------|-----------------------|
| <code>lambda</code>    | Shape parameter.      |
| <code>alpha.bar</code> | Shape parameter.      |
| <code>mu</code>        | Location parameter.   |
| <code>sigma</code>     | Dispersion parameter. |

gamma Skewness parameter.

If type is “alpha.delta” a list with components:

lambda Shape parameter.  
 alpha Shape parameter.  
 delta Shape parameter.  
 mu Location parameter.  
 Delta Dispersion matrix with a determinant of 1 (only returned in the multivariate case).  
 beta Shape and skewness parameter.

### Note

A switch from either the “chi/psi” to the “alpha.bar” or from the “alpha/delta” to the “alpha.bar” parametrization is not yet possible.

### Author(s)

David Luethi

### See Also

[ghyp](#), [fit.ghypuv](#), [fit.ghypmv](#), [ghyp.fit.info](#), [transform](#), [\[.ghyp](#)

### Examples

```
ghyp.mv <- ghyp(lambda = 1, alpha.bar = 0.1, mu = rep(0,2), sigma = diag(rep(1,2)),
               gamma = rep(0,2), data = matrix(rt(1000, df = 4), ncol = 2))
## Get parameters
coef(ghyp.mv, type = "alpha.bar")
coefficients(ghyp.mv, type = "chi.psi")

## Simple modification (do not modify slots directly e.g. object@mu <- 0:1)
param <- coef(ghyp.mv, type = "alpha.bar")
param$mu <- 0:1
do.call("ghyp", param) # returns a new 'ghyp' object
```

---

ESghyp.attribution      *Risk attribution.*

---

### Description

Functions to get the *contribution* of each asset to the portfolio’s *Expected Shortfall* based on multivariate generalized hyperbolic distributions as well as the expected shortfall *sensitivity* to marginal changes in portfolio allocation.

**Usage**

```
ESghyp.attribution(
  alpha,
  object = ghyp(),
  distr = c("return", "loss"),
  weights = NULL,
  ...
)
```

**Arguments**

|         |  |
|---------|--|
| alpha   | a vector of confidence levels for ES.  |
| object  | a multivariate fitted ghyp object inheriting from class <a href="#">ghyp</a> .   |
| distr   | whether the ghyp-object specifies a return or a loss-distribution (see <b>Details</b> ).                                 |
| weights | vector of portfolio weights. Default is an equally-weighted portfolio.   |
| ...     | optional arguments passed from <a href="#">ghyp.attribution</a> to <a href="#">qghyp</a> and <a href="#">integrate</a> . |

**Details**

The parameter `distr` specifies whether the ghyp-object describes a return or a loss-distribution. In case of a return distribution the expected-shortfall on a confidence level  $\alpha$  is defined as  $ES_\alpha := E(X|X \leq F_X^{-1}(\alpha))$  while in case of a loss distribution it is defined on a confidence level  $\alpha$  as  $ES_\alpha := E(X|X > F_X^{-1}(\alpha))$ .

**Value**

ESghyp.attribution is an object of class [ghyp.attribution](#).

**Author(s)**

Marc Weibel

**See Also**

[contribution](#), [ghyp.attribution-method](#), [sensitivity](#), [ghyp.attribution-method](#) and [weights](#) for Expected Shortfall.

**Examples**

```
## Not run:
data(smi.stocks)
## Fit a NIG model to Novartis, CS and Nestle log-returns
assets.fit <- fit.NIGmv(smi.stocks[, c("Novartis", "CS", "Nestle")], silent = TRUE)
## Define Weights of the Portfolio
weights <- c(0.2, 0.5, 0.3)
## Confidence level for Expected Shortfall
es.levels <- c(0.01)
```

```
portfolio.attrib <- ESghyp.attribution(alpha=es.levels, object=assets.fit, weights=weights)

## End(Not run)
```

---

fit.ghypmv

*Fitting generalized hyperbolic distributions to multivariate data*


---

## Description

Perform a maximum likelihood estimation of the parameters of a multivariate generalized hyperbolic distribution by using an Expectation Maximization (EM) based algorithm.

## Usage

```
fit.ghypmv(data, lambda = 1, alpha.bar = 1, mu = NULL, sigma = NULL,
           gamma = NULL, opt.pars = c(lambda = TRUE, alpha.bar = TRUE, mu = TRUE,
                                       sigma = TRUE, gamma = !symmetric),
           symmetric = FALSE, standardize = FALSE, nit = 2000, reltol = 1e-8,
           abstol = reltol * 10, na.rm = FALSE, silent = FALSE, save.data = TRUE,
           trace = TRUE, ...)
```

```
fit.hypmv(data,
          opt.pars = c(alpha.bar = TRUE, mu = TRUE, sigma = TRUE, gamma = !symmetric),
          symmetric = FALSE, ...)
```

```
fit.NIGmv(data,
          opt.pars = c(alpha.bar = TRUE, mu = TRUE, sigma = TRUE, gamma = !symmetric),
          symmetric = FALSE, ...)
```

```
fit.VGmv(data, lambda = 1,
          opt.pars = c(lambda = TRUE, mu = TRUE, sigma = TRUE, gamma = !symmetric),
          symmetric = FALSE, ...)
```

```
fit.tmv(data, nu = 3.5,
         opt.pars = c(lambda = TRUE, mu = TRUE, sigma = TRUE, gamma = !symmetric),
         symmetric = FALSE, ...)
```

```
fit.gaussmv(data, na.rm = TRUE, save.data = TRUE)
```

## Arguments

|           |   |
|-----------|---|
| data      | An object coercible to a matrix.  |
| lambda    | Starting value for the shape parameter lambda.  |
| alpha.bar | Starting value for the shape parameter alpha.bar.   |
| nu        | Starting value for the shape parameter nu (only used in case of a student-t distribution. It determines the degree of freedom and is defined as $-2*\lambda$ .) |

|                          |  |
|--------------------------|--|
| <code>mu</code>          | Starting value for the location parameter <code>mu</code> .  |
| <code>sigma</code>       | Starting value for the dispersion matrix <code>sigma</code> .  |
| <code>gamma</code>       | Starting value for the skewness vector <code>gamma</code> .  |
| <code>opt.pars</code>    | A named logical vector which states which parameters should be fitted.   |
| <code>symmetric</code>   | If TRUE the skewness parameter <code>gamma</code> keeps zero.  |
| <code>standardize</code> | If TRUE the sample will be standardized before fitting. Afterwards, the parameters and log-likelihood et cetera will be back-transformed.    |
| <code>save.data</code>   | If TRUE data will be stored within the <code>mle.ghyp</code> object (cf. <code>ghyp.data</code> ).   |
| <code>trace</code>       | If TRUE the evolution of the parameter values during the fitting procedure will be traced and stored (cf. <code>ghyp.fit.info</code> ).      |
| <code>na.rm</code>       | If TRUE missing values will be removed from data.  |
| <code>silent</code>      | If TRUE no prompts will appear in the console.   |
| <code>nit</code>         | Maximal number of iterations of the expectation maximization algorithm.  |
| <code>reltol</code>      | Relative convergence tolerance.  |
| <code>abstol</code>      | Absolute convergence tolerance.  |
| <code>...</code>         | Arguments passed to <code>optim</code> and to <code>fit.ghypmv</code> when fitting special cases of the generalized hyperbolic distribution. |

### Details

This function uses a modified EM algorithm which is called Multi-Cycle Expectation Conditional Maximization (MCECM) algorithm. This algorithm is sketched in the vignette of this package which can be found in the `doc` folder. A more detailed description is provided by the book *Quantitative Risk Management, Concepts, Techniques and Tools* (see “References”).

The general-purpose optimization routine `optim` is used to maximize the loglikelihood function of the univariate mixing distribution. The default method is that of Nelder and Mead which uses only function values. Parameters of `optim` can be passed via the `...` argument of the fitting routines.

### Value

An object of class `mle.ghyp`.

### Note

The variance gamma distribution becomes singular when  $\mathbf{x} - \boldsymbol{\mu} = 0$ . This singularity is caught and the reduced density function is computed. Because the transition is not smooth in the numerical implementation this can rarely result in nonsensical fits.

Providing both arguments, `opt.pars` and `symmetric` respectively, can result in a conflict when `opt.pars['gamma']` and `symmetric` are TRUE. In this case `symmetric` will dominate and `opt.pars['gamma']` is set to FALSE.

### Author(s)

Wolfgang Breymann, David Luethi

## References

Alexander J. McNeil, Ruediger Frey, Paul Embrechts (2005) *Quantitative Risk Management, Concepts, Techniques and Tools*

ghyp-package vignette in the doc folder or on <https://cran.r-project.org/package=ghyp>.

S-Plus and R library *QRMLib*)

## See Also

[fit.ghypuv](#), [fit.hypuv](#), [fit.NIGuv](#), [fit.VGuv](#), [fit.tuv](#) for univariate fitting routines. [ghyp.fit.info](#) for information regarding the fitting procedure.

## Examples

```
data(smi.stocks)

fit.ghypmv(data = smi.stocks, opt.pars = c(lambda = FALSE), lambda = 2,
           control = list(rel.tol = 1e-5, abs.tol = 1e-5), reltol = 0.01)
```

---

fit.ghypuv

*Fitting generalized hyperbolic distributions to univariate data*

---

## Description

This function performs a maximum likelihood parameter estimation for univariate generalized hyperbolic distributions.

## Usage

```
fit.ghypuv(data, lambda = 1, alpha.bar = 0.5, mu = median(data),
           sigma = mad(data), gamma = 0,
           opt.pars = c(lambda = TRUE, alpha.bar = TRUE, mu = TRUE,
                        sigma = TRUE, gamma = !symmetric),
           symmetric = FALSE, standardize = FALSE, save.data = TRUE,
           na.rm = TRUE, silent = FALSE, ...)

fit.hypuv(data,
           opt.pars = c(alpha.bar = TRUE, mu = TRUE, sigma = TRUE, gamma = !symmetric),
           symmetric = FALSE, ...)

fit.NIGuv(data,
           opt.pars = c(alpha.bar = TRUE, mu = TRUE, sigma = TRUE, gamma = !symmetric),
           symmetric = FALSE, ...)

fit.VGuv(data, lambda = 1,
```

```

opt.pars = c(lambda = TRUE, mu = TRUE, sigma = TRUE, gamma = !symmetric),
            symmetric = FALSE, ...)

fit.tuv(data, nu = 3.5,
        opt.pars = c(nu = TRUE, mu = TRUE, sigma = TRUE, gamma = !symmetric),
            symmetric = FALSE, ...)

fit.gaussuv(data, na.rm = TRUE, save.data = TRUE)

```

## Arguments

|             |   |
|-------------|---|
| data        | An object coercible to a vector.  |
| lambda      | Starting value for the shape parameter lambda.  |
| alpha.bar   | Starting value for the shape parameter alpha.bar.   |
| nu          | Starting value for the shape parameter nu (only used in case of a student-t distribution. It determines the degree of freedom and is defined as $-2*\lambda$ .) |
| mu          | Starting value for the location parameter mu.   |
| sigma       | Starting value for the dispersion parameter sigma.  |
| gamma       | Starting value for the skewness parameter gamma.  |
| opt.pars    | A named logical vector which states which parameters should be fitted.  |
| symmetric   | If TRUE the skewness parameter gamma keeps zero.  |
| standardize | If TRUE the sample will be standardized before fitting. Afterwards, the parameters and log-likelihood et cetera will be back-transformed.                       |
| save.data   | If TRUE data will be stored within the <code>mle.ghyp</code> object.  |
| na.rm       | If TRUE missing values will be removed from data.   |
| silent      | If TRUE no prompts will appear in the console.  |
| ...         | Arguments passed to <code>optim</code> and to <code>fit.ghypuv</code> when fitting special cases of the generalized hyperbolic distribution.                    |

## Details

The general-purpose optimization routine `optim` is used to maximize the loglikelihood function. The default method is that of Nelder and Mead which uses only function values. Parameters of `optim` can be passed via the `...` argument of the fitting routines.

## Value

An object of class `mle.ghyp`.

## Note

The variance gamma distribution becomes singular when  $x - \mu = 0$ . This singularity is caught and the reduced density function is computed. Because the transition is not smooth in the numerical implementation this can rarely result in nonsensical fits.

Providing both arguments, `opt.pars` and `symmetric` respectively, can result in a conflict when `opt.pars['gamma']` and `symmetric` are TRUE. In this case `symmetric` will dominate and `opt.pars['gamma']` is set to FALSE.

**Author(s)**

Wolfgang Breymann, David Luethi

**References**

ghyp-package vignette in the doc folder or on <https://cran.r-project.org/package=ghyp>.

**See Also**

[fit.ghypmv](#), [fit.hypmv](#), [fit.NIGmv](#), [fit.VGmv](#), [fit.tmv](#) for multivariate fitting routines. [ghyp.fit.info](#) for information regarding the fitting procedure.

**Examples**

```
data(smi.stocks)

nig.fit <- fit.NIGuv(smi.stocks[,"SMI"], opt.pars = c(alpha.bar = FALSE),
                   alpha.bar = 1, control = list(abstol = 1e-8))

nig.fit

summary(nig.fit)

hist(nig.fit)
```

---

ghyp-constructors      *Create generalized hyperbolic distribution objects*

---

**Description**

Constructor functions for univariate and multivariate generalized hyperbolic distribution objects and their special cases in one of the parametrizations “chi/psi”, “alpha.bar” and “alpha/delta”.

**Usage**

```
ghyp(lambda = 0.5, chi = 0.5, psi = 2, mu = 0, sigma = diag(rep(1, length(mu))),
      gamma = rep(0, length(mu)), alpha.bar = NULL, data = NULL)

ghyp.ad(lambda = 0.5, alpha = 1.5, delta = 1, beta = rep(0, length(mu)),
        mu = 0, Delta = diag(rep(1, length(mu))), data = NULL)

hyp(chi = 0.5, psi = 2, mu = 0, sigma = diag(rep(1, length(mu))),
    gamma = rep(0, length(mu)), alpha.bar = NULL, data = NULL)

hyp.ad(alpha = 1.5, delta = 1, beta = rep(0, length(mu)), mu = 0,
      Delta = diag(rep(1, length(mu))), data = NULL)
```

```

NIG(chi = 2, psi = 2, mu = 0, sigma = diag(rep(1, length(mu))),
    gamma = rep(0, length(mu)), alpha.bar = NULL, data = NULL)

NIG.ad(alpha = 1.5, delta = 1, beta = rep(0, length(mu)), mu = 0,
    Delta = diag(rep(1, length(mu))), data = NULL)

student.t(nu = 3.5, chi = nu - 2, mu = 0, sigma = diag(rep(1, length(mu))),
    gamma = rep(0, length(mu)), data = NULL)

student.t.ad(lambda = -2, delta = 1, beta = rep(0, length(mu)), mu = 0,
    Delta = diag(rep(1, length(mu))), data = NULL)

VG(lambda = 1, psi = 2*lambda, mu = 0, sigma = diag(rep(1, length(mu))),
    gamma = rep(0, length(mu)), data = NULL)

VG.ad(lambda = 2, alpha = 1.5, beta = rep(0, length(mu)), mu = 0,
    Delta = diag(rep(1, length(mu))), data = NULL)

gauss(mu = 0, sigma = diag(rep(1, length(mu))), data = NULL)

```

### Arguments

|           |   |
|-----------|---|
| lambda    | Shape parameter. Common for all parametrizations.   |
| nu        | Shape parameter only used in case of a Student-t distribution in the “chi/psi” and “alpha.bar” parametrization . It determines the degree of freedom.     |
| chi       | Shape parameter of the “chi/psi” parametrization.   |
| psi       | Shape parameter of the “chi/psi” parametrization.   |
| alpha     | Shape parameter of the “alpha/delta” parametrization.   |
| delta     | Shape parameter of the “alpha/delta” parametrization.   |
| alpha.bar | Shape parameter of the “alpha.bar” parametrization. Supplying “alpha.bar” makes the parameters “chi” and “psi” redundant.                                 |
| mu        | Location parameter. Either a scalar or a vector. Common for all parametrizations.   |
| sigma     | Dispersion parameter of the “chi/psi” parametrization. Either a scalar or a matrix.   |
| Delta     | Dispersion parameter. Must be a matrix with a determinant of 1. This parameter is only used in the multivariate case of the “alpha.beta” parametrization. |
| gamma     | Skewness parameter of the “chi/psi” parametrization. Either a scalar or a vector.   |
| beta      | Skewness parameter of the “alpha/delta” parametrization. Either a scalar or a vector.   |
| data      | An object coercible to a vector (univariate case) or matrix (multivariate case).  |

## Details

These functions serve as constructors for univariate and multivariate objects.

ghyp, hyp and NIG are constructor functions for both the “chi/psi” and the “alpha.bar” parametrization. Whenever `alpha.bar` is not NULL it is assumed that the “alpha.bar” parametrization is used and the parameters “chi” and “psi” become redundant.

Similarly, the variance gamma (VG) and the Student-t distribution share the same constructor function for both the chi/psi and alpha.bar parametrization. To initialize them in the alpha.bar parametrization simply omit the argument `psi` and `chi`, respectively. If `psi` or `chi` are submitted, the “chi/psi” parametrization will be used.

`ghyp.ad`, `hyp.ad`, `NIG.ad`, `student.t.ad` and `VG.ad` use the “alpha/delta” parametrization.

The following table gives the constructors for each combination of distribution and parametrization.

| Distribution | Parametrization                    |                                     |                                |
|--------------|------------------------------------|-------------------------------------|--------------------------------|
|              | “chi/psi”                          | “alpha.bar”                         | “alpha/delta”                  |
| GH           | <code>ghyp(...)</code>             | <code>ghyp(..., alpha.bar=x)</code> | <code>ghyp.ad(...)</code>      |
| hyp          | <code>hyp(...)</code>              | <code>hyp(..., alpha.bar=x)</code>  | <code>hyp.ad(...)</code>       |
| NIG          | <code>NIG(...)</code>              | <code>NIG(..., alpha.bar=x)</code>  | <code>NIG.ad(...)</code>       |
| Student-t    | <code>student.t(..., chi=x)</code> | <code>student.t(...)</code>         | <code>student.t.ad(...)</code> |
| VG           | <code>VG(..., psi=x)</code>        | <code>VG(...)</code>                | <code>VG.ad(...)</code>        |

Have a look on the vignette of this package in the doc folder for further information regarding the parametrization and for the domains of variation of the parameters.

## Value

An object of class `ghyp`.

## Note

The Student-t parametrization obtained via the “alpha.bar” parametrization slightly differs from the common Student-t parametrization: The parameter `sigma` denotes the standard deviation in the univariate case and the variance in the multivariate case. Thus, set  $\sigma = \sqrt{\nu/(\nu - 2)}$  in the univariate case to get the same results as with the standard R implementation of the Student-t distribution.

In case of non-finite variance, the “alpha.bar” parametrization does not work because `sigma` is defined to be the standard deviation. In this case the “chi/psi” parametrization can be used by submitting the parameter `chi`. To obtain equal results as the standard R implementation use `student.t(nu = nu, chi = nu)` (see **Examples**).

Have a look on the vignette of this package in the doc folder for further information.

Once an object of class `ghyp` is created the methods `Xghyp` have to be used even when the distribution is a special case of the GH distribution. E.g. do not use `dVG`. Use `dghyp` and submit a variance gamma distribution created with `VG()`.

### Author(s)

David Luethi

### References

ghyp-package vignette in the doc folder or on <https://cran.r-project.org/package=ghyp>

### See Also

`ghyp-class` for a summary of generic methods assigned to `ghyp` objects, `coef` for switching between different parametrizations, `d/p/q/r/ES/gyhp` for density, distribution function et cetera, `fit.ghypuv` and `fit.ghypmv` for fitting routines.

### Examples

```
## alpha.bar parametrization of a univariate GH distribution
ghyp(lambda=2, alpha.bar=0.1, mu=0, sigma=1, gamma=0)
## lambda/chi parametrization of a univariate GH distribution
ghyp(lambda=2, chi=1, psi=0.5, mu=0, sigma=1, gamma=0)
## alpha/delta parametrization of a univariate GH distribution
ghyp.ad(lambda=2, alpha=0.5, delta=1, mu=0, beta=0)

## alpha.bar parametrization of a multivariate GH distribution
ghyp(lambda=1, alpha.bar=0.1, mu=2:3, sigma=diag(1:2), gamma=0:1)
## lambda/chi parametrization of a multivariate GH distribution
ghyp(lambda=1, chi=1, psi=0.5, mu=2:3, sigma=diag(1:2), gamma=0:1)
## alpha/delta parametrization of a multivariate GH distribution
ghyp.ad(lambda=1, alpha=2.5, delta=1, mu=2:3, Delta=diag(c(1,1)), beta=0:1)

## alpha.bar parametrization of a univariate hyperbolic distribution
hyp(alpha.bar=0.3, mu=1, sigma=0.1, gamma=0)
## lambda/chi parametrization of a univariate hyperbolic distribution
hyp(chi=1, psi=2, mu=1, sigma=0.1, gamma=0)
## alpha/delta parametrization of a univariate hyperbolic distribution
hyp.ad(alpha=0.5, delta=1, mu=0, beta=0)

## alpha.bar parametrization of a univariate NIG distribution
NIG(alpha.bar=0.3, mu=1, sigma=0.1, gamma=0)
## lambda/chi parametrization of a univariate NIG distribution
NIG(chi=1, psi=2, mu=1, sigma=0.1, gamma=0)
## alpha/delta parametrization of a univariate NIG distribution
NIG.ad(alpha=0.5, delta=1, mu=0, beta=0)

## alpha.bar parametrization of a univariate VG distribution
VG(lambda=2, mu=1, sigma=0.1, gamma=0)
## alpha/delta parametrization of a univariate VG distribution
VG.ad(lambda=2, alpha=0.5, mu=0, beta=0)
```

```

## alpha.bar parametrization of a univariate t distribution
student.t(nu = 3, mu=1, sigma=0.1, gamma=0)
## alpha/delta parametrization of a univariate t distribution
student.t.ad(lambda=-2, delta=1, mu=0, beta=1)

## Obtain equal results as with the R-core parametrization
## of the t distribution:
nu <- 4
standard.R.chi.psi <- student.t(nu = nu, chi = nu)
standard.R.alpha.bar <- student.t(nu = nu, sigma = sqrt(nu / (nu - 2)))

random.sample <- rnorm(3)
dt(random.sample, nu)
dghyp(random.sample, standard.R.chi.psi) # all implementations yield...
dghyp(random.sample, standard.R.alpha.bar) # ...the same values

random.quantiles <- runif(4)
qt(random.quantiles, nu)
qghyp(random.quantiles, standard.R.chi.psi) # all implementations yield...
qghyp(random.quantiles, standard.R.alpha.bar) # ...the same values

## If nu <= 2 the "alpha.bar" parametrization does not exist, but the
## "chi/psi" parametrization. The case of a Cauchy distribution:
nu <- 1
standard.R.chi.psi <- student.t(nu = nu, chi = nu)

dt(random.sample, nu)
dghyp(random.sample, standard.R.chi.psi) # both give the same result

pt(random.sample, nu)
pghyp(random.sample, standard.R.chi.psi) # both give the same result

```

---

ghyp-distribution      *The Generalized Hyperbolic Distribution*

---

## Description

Density, distribution function, quantile function, expected-shortfall and random generation for the univariate and multivariate generalized hyperbolic distribution and its special cases.

## Usage

```

dghyp(x, object = ghyp(), logvalue = FALSE)

pghyp(q, object = ghyp(), n.sim = 10000, subdivisions = 200,
      rel.tol = .Machine$double.eps^0.5, abs.tol = rel.tol,
      lower.tail = TRUE)

```

```
qghyp(p, object = ghyp(), method = c("integration", "splines"),
      spline.points = 200, subdivisions = 200,
      root.tol = .Machine$double.eps^0.5,
      rel.tol = root.tol^1.5, abs.tol = rel.tol)
```

```
rghyp(n, object = ghyp())
```

### Arguments

|                            |  |
|----------------------------|--|
| <code>p</code>             | A vector of probabilities.   |
| <code>x</code>             | A vector, matrix or data.frame of quantiles.   |
| <code>q</code>             | A vector, matrix or data.frame of quantiles.   |
| <code>n</code>             | Number of observations.  |
| <code>object</code>        | An object inheriting from class <code>ghyp</code> .  |
| <code>logvalue</code>      | If TRUE the logarithm of the density will be returned.   |
| <code>n.sim</code>         | The number of simulations when computing <code>pghyp</code> of a multivariate generalized hyperbolic distribution.   |
| <code>subdivisions</code>  | The number of subdivisions passed to <code>integrate</code> when computing the distribution function <code>pghyp</code> of a univariate generalized hyperbolic distribution. |
| <code>rel.tol</code>       | The relative accuracy requested from <code>integrate</code> .  |
| <code>abs.tol</code>       | The absolute accuracy requested from <code>integrate</code> .  |
| <code>lower.tail</code>    | If TRUE (default), probabilities are $P[X \leq x]$ , otherwise, $P[X > x]$ .   |
| <code>method</code>        | The method how quantiles are computed (see <b>Details</b> ).   |
| <code>spline.points</code> | The number of support points when computing the quantiles with the method “splines” instead of “integration”.  |
| <code>root.tol</code>      | The tolerance of <code>uniroot</code> .  |

### Details

`qghyp` only works for univariate generalized hyperbolic distributions.

`pghyp` performs a numeric integration of the density in the univariate case. The multivariate cumulative distribution is computed by means of monte carlo simulation.

`qghyp` computes the quantiles either by using the “integration” method where the root of the distribution function is solved or via “splines” which interpolates the distribution function and solves it with `uniroot` afterwards. The “integration” method is recommended when only few quantiles are required. If more than approximately 20 quantiles are needed to be calculated the “splines” method becomes faster. The accuracy can be controlled with an adequate setting of the parameters `rel.tol`, `abs.tol`, `root.tol` and `spline.points`.

`rghyp` uses the random generator for generalized inverse Gaussian distributed random variates from the Rmetrics package *fBasics* (cf. `rgig`).

**Value**

dghyp gives the density,  
 pghyp gives the distribution function,  
 qghyp gives the quantile function,  
 rgyp generates random deviates.

**Note**

Objects generated with `hyp`, `NIG`, `VG` and `student.t` have to use `Xghyp` as well. E.g. `dNIG(0, NIG())` does not work but `dghyp(0, NIG())`.

When the skewness becomes very large the functions using `qghyp` may fail. The functions `qqghyp`, `pairs` and `portfolio.optimize` are based on `qghyp`.

**Author(s)**

David Luethi

**References**

ghyp-package vignette in the doc folder or on <https://cran.r-project.org/package=ghyp> and references therein.

**See Also**

[ghyp-class](#) definition, [ghyp](#) constructors, fitting routines [fit.ghypuv](#) and [fit.ghypmv](#), risk and performance measurement [ESghyp](#) and [ghyp.omega](#), [transformation](#) and [subsetting](#) of `ghyp` objects, [integrate](#), [spline](#).

**Examples**

```
## Univariate generalized hyperbolic distribution
univariate.ghyp <- ghyp()

par(mfrow=c(5, 1))

quantiles <- seq(-4, 4, length = 500)
plot(quantiles, dghyp(quantiles, univariate.ghyp))
plot(quantiles, pghyp(quantiles, univariate.ghyp))

probabilities <- seq(1e-4, 1-1e-4, length = 500)
plot(probabilities, qghyp(probabilities, univariate.ghyp, method = "splines"))

hist(rgyp(n=10000, univariate.ghyp), nclass=100)

## Multivariate generalized hyperbolic distribution
multivariate.ghyp <- ghyp(sigma=var(matrix(rnorm(10), ncol=2)), mu=1:2, gamma=-(2:1))

par(mfrow=c(2, 1))
```

```

quantiles <- outer(seq(-4, 4, length = 50), c(1, 1))
plot(quantiles[, 1], dghyp(quantiles, multivariate.ghyp))
plot(quantiles[, 1], pghyp(quantiles, multivariate.ghyp, n.sim = 1000))

rghyp(n = 10, multivariate.ghyp)

```

---

ghyp-get

*Get methods for objects inheriting from class ghyp*


---

## Description

These functions simply return data stored within generalized hyperbolic distribution objects, i.e. slots of the classes `ghyp` and `mle.ghyp`. `ghyp.fit.info` extracts information about the fitting procedure from objects of class `mle.ghyp`. `ghyp.data` returns the data slot of a `ghyp` object. `ghyp.dim` returns the dimension of a `ghyp` object. `ghyp.name` returns the name of the distribution of a `ghyp` object.

## Usage

```
ghyp.fit.info(object)
```

```
ghyp.data(object)
```

```
ghyp.name(object, abbr = FALSE, skew.attr = TRUE)
```

```
ghyp.dim(object)
```

## Arguments

|                        |  |
|------------------------|--|
| <code>object</code>    | An object inheriting from class <code>ghyp</code> .  |
| <code>abbr</code>      | If TRUE the abbreviation of the <code>ghyp</code> distribution will be returned.   |
| <code>skew.attr</code> | If TRUE an attribute will be added to the name of the <code>ghyp</code> distribution stating whether the distribution is symmetric or not. |

## Value

`ghyp.fit.info` returns list with components:

|                                 |  |
|---------------------------------|--|
| <code>logLikelihood</code>      | The maximized log-likelihood value.                          |
| <code>aic</code>                | The Akaike information criterion.                            |
| <code>fitted.params</code>      | A boolean vector stating which parameters were fitted.       |
| <code>converged</code>          | A boolean whether <code>optim</code> converged or not.       |
| <code>n.iter</code>             | The number of iterations.                                    |
| <code>error.code</code>         | Error code from <code>optim</code> .                         |
| <code>error.message</code>      | Error message from <code>optim</code> .                      |
| <code>parameter.variance</code> | Parameter variance (only for univariate fits).               |
| <code>trace.pars</code>         | Trace values of the parameters during the fitting procedure. |

`ghyp.data` returns NULL if no data is stored within the object, a vector if it is an univariate generalized hyperbolic distribution and `matrix` if it is an multivariate generalized hyperbolic distribution.

`ghyp.name` returns the name of the `ghyp` distribution which can be the name of a special case. Depending on the arguments `abbr` and `skew.attr` one of the following is returned.

|   |  |
|---|--|
| <code>abbr == FALSE &amp; skew.attr == TRUE</code>  | <code>abbr == TRUE &amp; skew.attr == TRUE</code>  |
| (A)symmetric Generalized Hyperbolic                 | (A)symm ghyp                                       |
| (A)symmetric Hyperbolic                             | (A)symm hyp  |
| (A)symmetric Normal Inverse Gaussian                | (A)symm NIG  |
| (A)symmetric Variance Gamma                         | (A)symm VG   |
| (A)symmetric Student-t                              | (A)symm t  |
| Gaussian  | Gauss  |
| <code>abbr == FALSE &amp; skew.attr == FALSE</code> | <code>abbr == TRUE &amp; skew.attr == FALSE</code> |
| Generalized Hyperbolic                              | ghyp   |
| Hyperbolic  | hyp  |
| Normal Inverse Gaussian                             | NIG  |
| Variance Gamma                                      | VG   |
| Student-t   | t  |
| Gaussian  | Gauss  |

`ghyp.dim` returns the dimension of a `ghyp` object.

### Note

`ghyp.fit.info` requires an object of class `mle.ghyp`. In the univariate case the parameter variance is returned as well. The parameter variance is defined as the inverse of the negative hesse-matrix computed by `optim`. Note that this makes sense only in the case that the estimates are asymptotically normal distributed.

The class `ghyp` contains a data slot. Data can be stored either when an object is initialized or via the fitting routines and the argument `save.data`.

### Author(s)

David Luethi

### See Also

`coef`, `mean`, `vcov`, `logLik`, `AIC` for other accessor functions, `fit.ghypmv`, `fit.ghypuv`, `ghyp` for constructor functions, `optim` for possible error messages.

**Examples**

```
## multivariate generalized hyperbolic distribution
ghyp.mv <- ghyp(lambda = 1, alpha.bar = 0.1, mu = rep(0, 2), sigma = diag(rep(1, 2)),
              gamma = rep(0, 2), data = matrix(rt(1000, df = 4), ncol = 2))

## Get data
ghyp.data(ghyp.mv)

## Get the dimension
ghyp.dim(ghyp.mv)

## Get the name of the ghyp object
ghyp.name(ghyp(alpha.bar = 0))
ghyp.name(ghyp(alpha.bar = 0, lambda = -4), abbr = TRUE)

## 'ghyp.fit.info' does only work when the object is of class 'mle.ghyp',
## i.e. is created by 'fit.ghypuv' etc.
mv.fit <- fit.tmv(data = ghyp.data(ghyp.mv), control = list(abs.tol = 1e-3))
ghyp.fit.info(mv.fit)
```

---

ghyp-mle.ghyp-classes *Classes ghyp and mle.ghyp*

---

**Description**

The class “ghyp” basically contains the parameters of a generalized hyperbolic distribution. The class “mle.ghyp” inherits from the class “ghyp”. The class “mle.ghyp” adds some additional slots which contain information about the fitting procedure. Namely, these are the number of iterations (`n.iter`), the log likelihood value (`llh`), the Akaike Information Criterion (`aic`), a boolean vector (`fitted.params`) stating which parameters were fitted, a boolean `converged` whether the fitting procedure converged or not, an `error.code` which stores the status of a possible error and the corresponding `error.message`. In the univariate case the parameter variance is also stored in `parameter.variance`.

**Objects from the Class**

Objects should only be created by calls to the constructors `ghyp`, `hyp`, `NIG`, `VG`, `student.t` and `gauss` or by calls to the fitting routines like `fit.ghypuv`, `fit.ghypmv`, `fit.hypuv`, `fit.hypmv` et cetera.

**Slots****Slots of class ghyp:**

`call`: The function-call of class `call`.

`lambda`: Shape parameter of class `numeric`.

`alpha.bar`: Shape parameter of class `numeric`.

`chi`: Shape parameter of an alternative parametrization. Object of class `numeric`.

**psi:** Shape parameter of an alternative parametrization. Object of class `numeric`.  
**mu:** Location parameter of lass `numeric`.  
**sigma:** Dispersion parameter of class `matrix`.  
**gamma:** Skewness parameter of class `numeric`.  
**model:** Model, i.e., (a)symmetric generalized hyperbolic distribution or (a)symmetric special case. Object of class `character`.  
**dimension:** Dimension of the generalized hyperbolic distribution. Object of class `numeric`.  
**expected.value:** The expected value of a generalized hyperbolic distribution. Object of class `numeric`.  
**variance:** The variance of a generalized hyperbolic distribution of class `matrix`.  
**data:** The data-slot is of class `matrix`. When an object of class `ghypmv` is instantiated the user can decide whether data should be stored within the object or not. This is the default and may be useful when fitting eneralized hyperbolic distributions to data and perform further analysis afterwards.  
**parametrization:** Parametrization of the generalized hyperbolic distribution of class `character`. These are currently either “chi.psi”, “alpha.bar” or “alpha.delta”.

#### Slots added by class `mle.ghyp`:

**n.iter:** The number of iterations of class `numeric`.  
**llh:** The log likelihood value of class `numeric`.  
**converged:** A boolean whether converged or not. Object of class `logical`.  
**error.code:** An error code of class `numeric`.  
**error.message:** An error message of class `character`.  
**fitted.params:** A boolean vector stating which parameters were fitted of class `logical`.  
**aic:** The value of the Akaike Information Criterion of class `numeric`.  
**parameter.variance:** The parameter variance is the inverse of the fisher information matrix. This slot is filled only in the case of an univariate fit. This slot is of class `matrix`.  
**trace.pars:** Contains the parameter value evolution during the fitting procedure. `trace.pars` of class `list`.

#### Extends

Class “`mle.ghyp`” extends class “`ghyp`”, directly.

#### Methods

A “pairs” method (see [pairs](#)).  
 A “hist” method (see [hist](#)).  
 A “plot” method (see [plot](#)).  
 A “lines” method (see [lines](#)).  
 A “coef” method (see [coef](#)).  
 A “mean” method (see [mean](#)).  
 A “vcov” method (see [vcov](#)).

A “scale” method (see [scale](#)).

A “transform” method (see [transform](#)).

A “[.ghyp” method (see [\[\]](#)).

A “logLik” method for objects of class “mle.ghyp” (see [logLik](#)).

An “AIC” method for objects of class “mle.ghyp” (see [AIC](#)).

A “summary” method for objects of class “mle.ghyp” (see [summary](#)).

### Note

When showing special cases of the generalized hyperbolic distribution the corresponding fixed parameters are not printed.

### Author(s)

David Luethi

### See Also

[optim](#) for an interpretation of `error.code`, `error.message` and `parameter.variance`.

[ghyp](#), [hyp](#), [NIG](#), [VG](#), [student.t](#) and [gauss](#) for constructors of the class `ghyp` in the “alpha.bar” and “chi/psi” parametrization. [xxx.ad](#) for all the constructors in the “alpha/delta” parametrization. [fit.ghypuv](#), [fit.ghypmv](#) et cetera for the fitting routines and constructors of the class `mle.ghyp`.

### Examples

```
data(smi.stocks)
multivariate.fit <- fit.ghypmv(data = smi.stocks,
                             opt.pars = c(lambda = FALSE, alpha.bar = FALSE),
                             lambda = 2)

summary(multivariate.fit)

vcov(multivariate.fit)
mean(multivariate.fit)
logLik(multivariate.fit)
AIC(multivariate.fit)
coef(multivariate.fit)

univariate.fit <- multivariate.fit[1]
hist(univariate.fit)

plot(univariate.fit)
lines(multivariate.fit[2])
```

---

ghyp-risk-performance *Risk and Performance Measures*

---

### Description

Functions to compute the risk measure *Expected Shortfall* and the performance measure *Omega* based on univariate generalized hyperbolic distributions.

**Usage**

```
ESghyp(alpha, object = ghyp(), distr = c("return", "loss"), ...)
ghyp.omega(L, object = ghyp(), ...)
```

**Arguments**

|        |   |
|--------|---|
| alpha  | A vector of confidence levels.  |
| L      | A vector of threshold levels.   |
| object | A univariate generalized hyperbolic distribution object inheriting from class <a href="#">ghyp</a> .  |
| distr  | Whether the ghyp-object specifies a return or a loss-distribution (see <b>Details</b> ).              |
| ...    | Arguments passed from ESghyp to <a href="#">qghyp</a> and from ghyp.omega <a href="#">integrate</a> . |

**Details**

The parameter `distr` specifies whether the ghyp-object describes a return or a loss-distribution. In case of a return distribution the expected-shortfall on a confidence level  $\alpha$  is defined as  $ES_\alpha := E(X|X \leq F_X^{-1}(\alpha))$  while in case of a loss distribution it is defined on a confidence level  $\alpha$  as  $ES_\alpha := E(X|X > F_X^{-1}(\alpha))$ .

*Omega* is defined as the ratio of a European call-option price divided by a put-option price with strike price  $L$  (see **References**):  $\Omega(L) := \frac{C(L)}{P(L)}$ .

**Value**

ESghyp gives the expected shortfall and  
ghyp.omega gives the performance measure Omega.

**Author(s)**

David Luethi

**References**

*Omega as a Performance Measure* by Hossein Kazemi, Thomas Schneeweis and Raj Gupta  
University of Massachusetts, 2003

**See Also**

[ghyp-class](#) definition, [ghyp](#) constructors, univariate fitting routines, [fit.ghypuv](#), [portfolio.optimize](#) for portfolio optimization with respect to alternative risk measures, [integrate](#).

**Examples**

```

data(smi.stocks)

## Fit a NIG model to Credit Suisse and Swiss Re log-returns
cs.fit <- fit.NIGuv(smi.stocks[, "CS"], silent = TRUE)
swiss.re.fit <- fit.NIGuv(smi.stocks[, "Swiss.Re"], silent = TRUE)

## Confidence levels for expected shortfalls
es.levels <- c(0.001, 0.01, 0.05, 0.1)

cs.es <- ESghyp(es.levels, cs.fit)
swiss.re.es <- ESghyp(es.levels, swiss.re.fit)

## Threshold levels for Omega
threshold.levels <- c(0, 0.01, 0.02, 0.05)

cs.omega <- ghyp.omega(threshold.levels, cs.fit)
swiss.re.omega <- ghyp.omega(threshold.levels, swiss.re.fit)

par(mfrow = c(2, 1))

barplot(rbind(CS = cs.es, Swiss.Re = swiss.re.es), beside = TRUE,
        names.arg = paste(100 * es.levels, "percent"), col = c("gray40", "gray80"),
        ylab = "Expected Shortfalls (return distribution)", xlab = "Level")

legend("bottomright", legend = c("CS", "Swiss.Re"), fill = c("gray40", "gray80"))

barplot(rbind(CS = cs.omega, Swiss.Re = swiss.re.omega), beside = TRUE,
        names.arg = threshold.levels, col = c("gray40", "gray80"),
        ylab = "Omega", xlab = "Threshold level")
legend("topright", legend = c("CS", "Swiss.Re"), fill = c("gray40", "gray80"))

## => the higher the performance, the higher the risk (as it should be)

```

---

ghyp.attribution-class

*Class ghyp.attribution*

---

**Description**

The class “ghyp.attribution” contains the Expected Shortfall of the portfolio as well as the contribution of each asset to the total risk and the sensitivity of each Asset. The sensitivity gives an information about the overall risk modification of the portfolio if the weight in a given asset is marginally increased or decreased (1 percent).

The function `contribution` returns the contribution of the assets to the portfolio expected shortfall.

**Usage**

```

contribution(object, ...)

## S4 method for signature 'ghyp.attribution'
contribution(object, percentage = FALSE)

sensitivity(object)

## S4 method for signature 'ghyp.attribution'
sensitivity(object)

## S4 method for signature 'ghyp.attribution'
weights(object)

```

**Arguments**

|            |  |
|------------|--|
| object     | an object inheriting from class <a href="#">ghyp.attribution</a> . |
| ...        | additional parameters.   |
| percentage | boolean. Display figures in percent. (Default=FALSE).              |

**Details**

Expected shortfall enjoys homogeneity, sub-additivity, and co-monotonic additivity. Its associated function is continuously differentiable under moderate assumptions on the joint distribution of the assets.

**Value**

contribution of each asset to portfolio's overall expected shortfall.  
sensitivity of each asset to portfolio's overall expected shortfall.  
weights of each asset within portfolio.

**Slots**

ES Portfolio's expected shortfall (ES) for a given confidence level. Class matrix.  
contribution Contribution of each asset to the overall ES. Class matrix.  
sensitivity Sensitivity of each asset. Class matrix.  
weights Weight of each asset.

**Objects from the Class**

Objects should only be created by calls to the constructors [ESghyp.attribution](#).

**Note**

When showing special cases of the generalized hyperbolic distribution the corresponding fixed parameters are not printed.

**Author(s)**

Marc Weibel

Marc Weibel

**See Also**

[ESghyp.attribution](#), [ghyp.attribution-class](#) to compute the expected shortfall attribution.

**Examples**

```
## Not run:
data(smi.stocks)
multivariate.fit <- fit.ghypmv(data = smi.stocks,
opt.pars = c(lambda = FALSE, alpha.bar = FALSE),
lambda = 2)

portfolio <- ESghyp.attribution(0.01, multivariate.fit)
summary(portfolio)

## End(Not run)
```

---

ghyp.moment

---

*Compute moments of generalized hyperbolic distributions*


---

**Description**

This function computes moments of arbitrary orders of the univariate generalized hyperbolic distribution. The expectation of  $f(X - c)^k$  is calculated.  $f$  can be either the absolute value or the identity.  $c$  can be either zero or  $E(X)$ .

**Usage**

```
ghyp.moment(object, order = 3:4, absolute = FALSE, central = TRUE, ...)
```

**Arguments**

|          |   |
|----------|---|
| object   | A univariate generalized hyperbolic object inheriting from class <a href="#">ghyp</a> .   |
| order    | A vector containing the order of the moments.   |
| absolute | Indicate whether the absolute value is taken or not. If <code>absolute = TRUE</code> then $E( X - c ^k)$ is computed. Otherwise $E((X - c)^k)$ . $c$ depends on the argument <code>central</code> . <code>absolute</code> must be <code>TRUE</code> if <code>order</code> is not integer. |
| central  | If <code>TRUE</code> the moment around the expected value $E((X - E(X))^k)$ is computed. Otherwise $E(X^k)$ .   |
| ...      | Arguments passed to <a href="#">integrate</a> .   |

**Details**

In general `ghyp.moment` is based on numerical integration. For the special cases of either a “ghyp”, “hyp” or “NIG” distribution analytic expressions (see **References**) will be taken if non-absolute and non-centered moments of integer order are requested.

**Value**

A vector containing the moments.

**Author(s)**

David Luethi

**References**

*Moments of the Generalized Hyperbolic Distribution* by David J. Scott, Diethelm Wuertz and Thanh Tam Tran  
Working paper, 2008

**See Also**

[mean](#), [vcov](#), [Egig](#)

**Examples**

```
nig.uv <- NIG(alpha.bar = 0.1, mu = 1.1, sigma = 3, gamma = -2)

# Moments of integer order
ghyp.moment(nig.uv, order = 1:6)

# Moments of fractional order
ghyp.moment(nig.uv, order = 0.2 * 1:20, absolute = TRUE)
```

---

gig-distribution

*The Generalized Inverse Gaussian Distribution*


---

**Description**

Density, distribution function, quantile function, random generation, expected shortfall and expected value and variance for the generalized inverse gaussian distribution.

**Usage**

```
dgig(x, lambda = 1, chi = 1, psi = 1, logvalue = FALSE)

pgig(q, lambda = 1, chi = 1, psi = 1, ...)

qgig(p, lambda = 1, chi = 1, psi = 1, method = c("integration", "splines"),
```

```

spline.points = 200, subdivisions = 200,
root.tol = .Machine$double.eps^0.5,
rel.tol = root.tol^1.5, abs.tol = rel.tol, ...)

rgig(n = 10, lambda = 1, chi = 1, psi = 1)

ESgig(alpha, lambda = 1, chi = 1, psi = 1, distr = c("return", "loss"), ...)

Egig(lambda, chi, psi, func = c("x", "logx", "1/x", "var"), check.pars = TRUE)

```

### Arguments

|                            |   |
|----------------------------|---|
| <code>x</code>             | A vector of quantiles.  |
| <code>q</code>             | A vector of quantiles.  |
| <code>p</code>             | A vector of probabilities.  |
| <code>alpha</code>         | A vector of confidence levels.  |
| <code>n</code>             | Number of observations.   |
| <code>lambda</code>        | A shape and scale and parameter.  |
| <code>chi, psi</code>      | Shape and scale parameters. Must be positive.   |
| <code>logvalue</code>      | If TRUE the logarithm of the density will be returned.  |
| <code>distr</code>         | Whether the ghy-p-object specifies a return or a loss-distribution (see <b>Details</b> ).   |
| <code>subdivisions</code>  | The number of subdivisions passed to <a href="#">integrate</a> when computing the the distribution function <code>pgig</code> .   |
| <code>rel.tol</code>       | The relative accuracy requested from <a href="#">integrate</a> .  |
| <code>abs.tol</code>       | The absolute accuracy requested from <a href="#">integrate</a> .  |
| <code>method</code>        | Determines which method is used when calculating quantiles.   |
| <code>spline.points</code> | The number of support points when computing the quantiles with the method “splines” instead of “integration”.   |
| <code>root.tol</code>      | The tolerance of <a href="#">uniroot</a> .  |
| <code>func</code>          | The transformation function when computing the expected value. <code>x</code> is the expected value (default), <code>log x</code> returns the expected value of the logarithm of <code>x</code> , <code>1/x</code> returns the expected value of the inverse of <code>x</code> and <code>var</code> returns the variance. |
| <code>check.pars</code>    | If TRUE the parameters are checked first.   |
| <code>...</code>           | Arguments passed form <code>ESgig</code> to <code>qgig</code> .   |

### Details

`qgig` computes the quantiles either by using the “integration” method where the root of the distribution function is solved or via “splines” which interpolates the distribution function and solves it with [uniroot](#) afterwards. The “integration” method is recommended when few quantiles are required. If more than approximately 20 quantiles are needed to be calculated the “splines” method becomes faster. The accuracy can be controlled with an adequate setting of the parameters `rel.tol`,

abs.tol, root.tol and spline.points.

rgig relies on the C function with the same name kindly provided by Ester Pantaleo and Robert B. Gramacy.

Egig with func = "log x" uses [grad](#) from the R package *numDeriv*. See the package vignette for details regarding the expectation of GIG random variables.

## Value

dgig gives the density,  
 pgig gives the distribution function,  
 qgig gives the quantile function,  
 ESgig gives the expected shortfall,  
 rgig generates random deviates and  
 Egig gives the expected value of either  $x$ ,  $1/x$ ,  $\log(x)$  or the variance if func equals var.

## Author(s)

David Luethi and Ester Pantaleo

## References

- Dagpunar, J.S. (1989). *An easily implemented generalised inverse Gaussian generator*. Commun. Statist. -Simula., **18**, 703–710.
- Michael, J. R., Schucany, W. R., Haas, R. W. (1976). *Generating random variates using transformations with multiple roots*, The American Statistician, **30**, 88–90.

## See Also

[fit.ghypuv](#), [fit.ghypmv](#), [integrate](#), [uniroot](#), [spline](#)

## Examples

```
dgig(1:40, lambda = 10, chi = 1, psi = 1)
qgig(1e-5, lambda = 10, chi = 1, psi = 1)

ESgig(c(0.19,0.3), lambda = 10, chi = 1, psi = 1, distr = "loss")
ESgig(alpha=c(0.19,0.3), lambda = 10, chi = 1, psi = 1, distr = "ret")

Egig(lambda = 10, chi = 1, psi = 1, func = "x")
Egig(lambda = 10, chi = 1, psi = 1, func = "var")
Egig(lambda = 10, chi = 1, psi = 1, func = "1/x")
```

**Description**

The function `hist` computes a histogram of the given data values and the univariate generalized hyperbolic distribution.

**Usage**

```
## S4 method for signature 'ghyp'
hist(x, data = ghyp.data(x), gaussian = TRUE,
     log.hist = F, ylim = NULL, ghyp.col = 1, ghyp.lwd = 1,
     ghyp.lty = "solid", col = 1, nclass = 30, plot.legend = TRUE,
     location = if (log.hist) "bottom" else "topright", legend.cex = 1, ...)
```

**Arguments**

|                          |  |
|--------------------------|--|
| <code>x</code>           | Usually a fitted univariate generalized hyperbolic distribution of class <code>mle.ghyp</code> . Alternatively an object of class <code>ghyp</code> and a data vector. |
| <code>data</code>        | An object coercible to a vector.   |
| <code>gaussian</code>    | If TRUE the probability density of the normal distribution is plotted as a reference.  |
| <code>log.hist</code>    | If TRUE the logarithm of the histogram is plotted.   |
| <code>ylim</code>        | The “y” limits of the plot.  |
| <code>ghyp.col</code>    | The color of the density of the generalized hyperbolic distribution.   |
| <code>ghyp.lwd</code>    | The line width of the density of the generalized hyperbolic distribution.  |
| <code>ghyp.lty</code>    | The line type of the density of the generalized hyperbolic distribution.   |
| <code>col</code>         | The color of the histogram.  |
| <code>nclass</code>      | A single number giving the number of cells for the histogram.  |
| <code>plot.legend</code> | If TRUE a legend is drawn.   |
| <code>location</code>    | The location of the legend. See <code>legend</code> for possible values.   |
| <code>legend.cex</code>  | The character expansion of the legend.   |
| <code>...</code>         | Arguments passed to <code>plot</code> and <code>qqghyp</code> .  |

**Value**

No value is returned.

**Author(s)**

David Luethi

**See Also**

[qqghyp](#), [fit.ghypuv](#), [hist](#), [legend](#), [plot](#), [lines](#).

**Examples**

```
data(smi.stocks)
univariate.fit <- fit.ghypuv(data = smi.stocks[,"SMI"],
                             opt.pars = c(mu = FALSE, sigma = FALSE),
                             symmetric = TRUE)
hist(univariate.fit)
```

---

indices

*Monthly returns of five indices*

---

**Description**

Monthly returns of indices representing five asset/investment classes *Bonds*, *Stocks*, *Commodities*, *Emerging Markets* and *High Yield Bonds*.

**Usage**

```
data(indices)
```

**Format**

hy.bond JPMorgan High Yield Bond A (Yahoo symbol "OHYAX").  
emerging.mkt Morgan Stanley Emerging Markets Fund Inc. (Yahoo symbol "MSF").  
commodity Dow Jones-AIG Commodity Index (Yahoo symbol "DJI").  
bond Barclays Global Investors Bond Index (Yahoo symbol "WFBIX").  
stock Vanguard Total Stock Mkt Idx (Yahoo symbol "VTSMX").

**See Also**

[smi.stocks](#)

**Examples**

```
data(indices)
pairs(indices)
```

---

|                |                              |
|----------------|------------------------------|
| lik.ratio.test | <i>Likelihood-ratio test</i> |
|----------------|------------------------------|

---

### Description

This function performs a likelihood-ratio test on fitted generalized hyperbolic distribution objects of class `mle.ghyp`.

### Usage

```
lik.ratio.test(x, x.subclass, conf.level = 0.95)
```

### Arguments

|                         |  |
|-------------------------|--|
| <code>x</code>          | An object of class <code>mle.ghyp</code> .   |
| <code>x.subclass</code> | An object of class <code>mle.ghyp</code> whose parameters form a subset of those of <code>x</code> . |
| <code>conf.level</code> | Confidence level of the test.  |

### Details

The likelihood-ratio test can be used to check whether a special case of the generalized hyperbolic distribution is the “true” underlying distribution.

The likelihood-ratio is defined as

$$\Lambda = \frac{\sup\{L(\theta|\mathbf{X}) : \theta \in \Theta_0\}}{\sup\{L(\theta|\mathbf{X}) : \theta \in \Theta\}}.$$

Where  $L$  denotes the likelihood function with respect to the parameter  $\theta$  and data  $\mathbf{X}$ , and  $\Theta_0$  is a subset of the parameter space  $\Theta$ . The null hypothesis  $H_0$  states that  $\theta \in \Theta_0$ . Under the null hypothesis and under certain regularity conditions it can be shown that  $-2 \log(\Lambda)$  is asymptotically chi-squared distributed with  $\nu$  degrees of freedom.  $\nu$  is the number of free parameters specified by  $\Theta$  minus the number of free parameters specified by  $\Theta_0$ .

The null hypothesis is rejected if  $-2 \log(\Lambda)$  exceeds the `conf.level`-quantile of the chi-squared distribution with  $\nu$  degrees of freedom.

### Value

A list with components:

|                        |   |
|------------------------|---|
| <code>statistic</code> | The value of the L-statistic.                                   |
| <code>p.value</code>   | The p-value for the test.                                       |
| <code>df</code>        | The degrees of freedom for the L-statistic.                     |
| <code>H0</code>        | A boolean stating whether the null hypothesis is TRUE or FALSE. |

### Author(s)

David Luethi

**References**

*Linear Statistical Inference and Its Applications* by C. R. Rao  
Wiley, New York, 1973

**See Also**

[fit.ghypuv](#), [logLik](#), [AIC](#) and [stepAIC.ghyp](#).

**Examples**

```
data(smi.stocks)

sample <- smi.stocks[, "SMI"]

t.symmetric <- fit.tuv(sample, silent = TRUE, symmetric = TRUE)
t.asymmetric <- fit.tuv(sample, silent = TRUE)

# Test symmetric Student-t against asymmetric Student-t in case
# of SMI log-returns
lik.ratio.test(t.asymmetric, t.symmetric, conf.level = 0.95)
# -> keep the null hypothesis

set.seed(1000)
sample <- rghyp(1000, student.t(gamma = 0.1))

t.symmetric <- fit.tuv(sample, silent = TRUE, symmetric = TRUE)
t.asymmetric <- fit.tuv(sample, silent = TRUE)

# Test symmetric Student-t against asymmetric Student-t in case of
# data simulated according to a slightly skewed Student-t distribution
lik.ratio.test(t.asymmetric, t.symmetric, conf.level = 0.95)
# -> reject the null hypothesis

t.symmetric <- fit.tuv(sample, silent = TRUE, symmetric = TRUE)
ghyp.asymmetric <- fit.ghypuv(sample, silent = TRUE)

# Test symmetric Student-t against asymmetric generalized
# hyperbolic using the same data as in the example above
lik.ratio.test(ghyp.asymmetric, t.symmetric, conf.level = 0.95)
# -> keep the null hypothesis
```

**Description**

The functions `logLik` and `AIC` extract the Log-Likelihood and the Akaike's Information Criterion from fitted generalized hyperbolic distribution objects. The Akaike information criterion is calculated according to the formula  $-2 \cdot \log\text{-likelihood} + k \cdot n_{par}$ , where  $n_{par}$  represents the number of parameters in the fitted model, and  $k = 2$  for the usual AIC.

**Usage**

```
## S4 method for signature 'mle.ghyp'  
logLik(object, ...)  
  
## S4 method for signature 'mle.ghyp'  
AIC(object, ..., k = 2)
```

**Arguments**

|        |   |
|--------|---|
| object | An object of class <a href="#">mle.ghyp</a> .                                     |
| k      | The “penalty” per parameter to be used; the default $k = 2$ is the classical AIC. |
| ...    | An arbitrary number of objects of class <a href="#">mle.ghyp</a> .                |

**Value**

Either the Log-Likelihood or the Akaike’s Information Criterion.

**Note**

The Log-Likelihood as well as the Akaike’s Information Criterion can be obtained from the function [ghyp.fit.info](#). However, the benefit of `logLik` and `AIC` is that these functions allow a call with an arbitrary number of objects and are better known because they are generic.

**Author(s)**

David Luethi

**See Also**

[fit.ghypuv](#), [fit.ghypmv](#), [lik.ratio.test](#), [ghyp.fit.info](#), [mle.ghyp-class](#)

**Examples**

```
data(smi.stocks)  
  
## Multivariate fit  
fit.mv <- fit.hypmv(smi.stocks, nit = 10)  
AIC(fit.mv)  
logLik(fit.mv)  
  
## Univariate fit  
fit.uv <- fit.tuv(smi.stocks[, "CS"], control = list(maxit = 10))  
AIC(fit.uv)  
logLik(fit.uv)  
  
# Both together  
AIC(fit.uv, fit.mv)  
logLik(fit.uv, fit.mv)
```

---

`mean-vcov-skew-kurt-methods`*Expected value, variance-covariance, skewness and kurtosis of generalized hyperbolic distributions*

---

### Description

The function `mean` returns the expected value. The function `vcov` returns the variance in the univariate case and the variance-covariance matrix in the multivariate case. The functions `ghyp.skewness` and `ghyp.kurtosis` only work for univariate generalized hyperbolic distributions.

### Usage

```
## S4 method for signature 'ghyp'  
mean(x)  
  
## S4 method for signature 'ghyp'  
vcov(object)  
  
ghyp.skewness(object)  
  
ghyp.kurtosis(object)
```

### Arguments

`x, object`      An object inheriting from class `ghyp`.

### Details

The functions `ghyp.skewness` and `ghyp.kurtosis` are based on the function `ghyp.moment`. Numerical integration will be used in case a Student.t or variance gamma distribution is submitted.

### Value

Either the expected value, variance, skewness or kurtosis.

### Author(s)

David Luethi

### See Also

`ghyp`, `ghyp-class`, `Egig` to compute the expected value and the variance of the generalized inverse gaussian mixing distribution distributed and its special cases.

**Examples**

```

## Univariate: Parametric
vg.dist <- VG(lambda = 1.1, mu = 10, sigma = 10, gamma = 2)
mean(vg.dist)
vcov(vg.dist)
ghyp.skewness(vg.dist)
ghyp.kurtosis(vg.dist)

## Univariate: Empirical
vg.sim <- rghyp(10000, vg.dist)
mean(vg.sim)
var(vg.sim)

## Multivariate: Parametric
vg.dist <- VG(lambda = 0.1, mu = c(55, 33), sigma = diag(c(22, 888)), gamma = 1:2)
mean(vg.dist)
vcov(vg.dist)

## Multivariate: Empirical
vg.sim <- rghyp(50000, vg.dist)
colMeans(vg.sim)
var(vg.sim)

```

---

pairs-methods

*Pairs plot for multivariate generalized hyperbolic distributions*


---

**Description**

This function is intended to be used as a graphical diagnostic tool for fitted multivariate generalized hyperbolic distributions. An array of graphics is created and qq-plots are drawn into the diagonal part of the graphics array. The upper part of the graphics matrix shows scatter plots whereas the lower part shows 2-dimensional histogramms.

**Usage**

```

## S4 method for signature 'ghyp'
pairs(x, data = ghyp.data(x), main = "'ghyp' pairwise plot",
      nbins = 30, qq = TRUE, gaussian = TRUE,
      hist.col = c("white", topo.colors(100)),
      spline.points = 150, root.tol = .Machine$double.eps^0.5,
      rel.tol = root.tol, abs.tol = root.tol^1.5, ...)

```

**Arguments**

|      |  |
|------|--|
| x    | Usually a fitted multivariate generalized hyperbolic distribution of class <code>mle.ghyp</code> . Alternatively an object of class <code>ghyp</code> and a data matrix. |
| data | An object coercible to a matrix.   |
| main | The title of the plot.   |

|                            |   |
|----------------------------|---|
| <code>nbins</code>         | The number of bins of the 2-d histogram.  |
| <code>qq</code>            | If TRUE qq-plots are drawn.   |
| <code>gaussian</code>      | If TRUE qq-plots with the normal distribution are plotted.  |
| <code>hist.col</code>      | A vector of colors of the 2-d histogram.  |
| <code>spline.points</code> | The number of support points when computing the quantiles used by the qq-plot. Passed to <a href="#">qqghyp</a> . |
| <code>root.tol</code>      | The tolerance of the quantiles. Passed to <a href="#">uniroot</a> via <a href="#">qqghyp</a> .                    |
| <code>rel.tol</code>       | The tolerance of the quantiles. Passed to <a href="#">integrate</a> via <a href="#">qqghyp</a> .                  |
| <code>abs.tol</code>       | The tolerance of the quantiles. Passed to <a href="#">integrate</a> via <a href="#">qqghyp</a> .                  |
| <code>...</code>           | Arguments passed to <a href="#">plot</a> and <a href="#">axis</a> .   |

**Author(s)**

David Luethi

**See Also**[pairs](#), [fit.ghypmv](#), [qqghyp](#)**Examples**

```
data(smi.stocks)
fitted.smi.stocks <- fit.NIGmv(data = smi.stocks[1:200, ])
pairs(fitted.smi.stocks)
```

---

`plot-lines-methods`      *Plot univariate generalized hyperbolic densities*

---

**Description**

These functions plot probability densities of generalized hyperbolic distribution objects.

**Usage**

```
## S4 method for signature 'ghyp,missing'
plot(x, range = qghyp(c(0.001, 0.999), x), length = 1000, ...)
## S4 method for signature 'ghyp'
lines(x, range = qghyp(c(0.001, 0.999), x), length = 1000, ...)
```

**Arguments**

|                     |  |
|---------------------|--|
| <code>x</code>      | An univariate <a href="#">ghyp</a> object.   |
| <code>range</code>  | The range over which the density will be plotted. The default is the range from the 0.1 % quantile to the 99.9 % quantile. When <code>range</code> has a length greater than 2 it is assumed to be the vector of quantiles and the density is computed on <code>range</code> . |
| <code>length</code> | The desired length of the density vector.  |
| <code>...</code>    | Arguments passed to <a href="#">plot</a> and <a href="#">lines</a> respectively.   |

**Details**

When the density is very skewed, the computation of the quantile may fail. See [qghyp](#) for details.

**Author(s)**

David Luethi

**See Also**

[hist](#), [qqghyp](#), [pairs](#), [plot](#), [lines](#).

**Examples**

```
data(smi.stocks)

smi.fit <- fit.tuv(data = smi.stocks[,"SMI"], symmetric = TRUE)
nestle.fit <- fit.tuv(data = smi.stocks[,"Nestle"], symmetric = TRUE)

## Student-t distribution
plot(smi.fit, type = "l", log = "y")
lines(nestle.fit, col = "blue")

## Empirical
lines(density(smi.stocks[,"SMI"]), lty = "dashed")
lines(density(smi.stocks[,"Nestle"]), lty = "dashed", col = "blue")
```

---

plot.ghyp.attrib

*Plot ES contribution*

---

**Description**

These functions plot the contribution of each asset to the overall portfolio expected shortfall.

**Usage**

```
## S3 method for class 'ghyp.attrib'
plot(
  x,
  metrics = c("contribution", "sensitivity"),
  column.index = NULL,
  percentage = FALSE,
  colorset = NULL,
  horiz = FALSE,
  unstacked = TRUE,
  pie.chart = FALSE,
  sub = NULL,
  ...
)
```

**Arguments**

|                           |   |
|---------------------------|---|
| <code>x</code>            | A <code>ghyp.attribution</code> object.                 |
| <code>metrics</code>      | either the contribution or sensitivity will be plotted. |
| <code>column.index</code> | which column of the object.                             |
| <code>percentage</code>   | plot contribution or sensitivity in percent.            |
| <code>colorset</code>     | vector of colors for the chart.                         |
| <code>horiz</code>        | plot horizontally.                                      |
| <code>unstacked</code>    | unstacked plot.   |
| <code>pie.chart</code>    | should a pie chart be plotted.                          |
| <code>sub</code>          | subtitle.   |
| <code>...</code>          | arguments passed to plot function.                      |

**Author(s)**

Marc Weibel

**See Also**

[ESghyp.attribution](#).

**Examples**

```
## Not run:
data(smi.stocks)

## Fit a NIG model to Novartis, CS and Nestle log-returns
assets.fit <- fit.NIGmv(smi.stocks[, c("Novartis", "CS", "Nestle")], silent = TRUE)

## Define Weights of the Portfolio
weights <- c(0.2, 0.5, 0.3)

## Confidence level for Expected Shortfall
es.levels <- c(0.01)
portfolio.attrib <- ESghyp.attribution(alpha=es.levels, object=assets.fit, weights=weights)

## Plot Risk Contribution for each Asset
plot(portfolio.attrib, metrics='contribution')

## End(Not run)
```

---

portfolio.optimize      *Portfolio optimization with respect to alternative risk measures*

---

### Description

This function performs a optimization of a portfolio with respect to one of the risk measures “sd”, “value.at.risk” or “expected.shortfall”. The optimization task is either to find the *global minimum risk* portfolio, the *tangency* portfolio or the *minimum risk* portfolio given a target-return.

### Usage

```
portfolio.optimize(object,
                  risk.measure = c("sd", "value.at.risk", "expected.shortfall"),
                  type = c("minimum.risk", "tangency", "target.return"),
                  level = 0.95, distr = c("loss", "return"),
                  target.return = NULL, risk.free = NULL,
                  silent = FALSE, ...)
```

### Arguments

|               |   |
|---------------|---|
| object        | A multivariate <a href="#">ghyp</a> object representing the loss distribution. In case object gives the return distribution set the argument distr to “return”. |
| risk.measure  | How risk shall be measured. Must be one of “sd” (standard deviation), “value.at.risk” or “expected.shortfall”.  |
| type          | The tpye of the optimization problem. Must be one of “minimum.risk”, “tangency” or “target.return” (see <b>Details</b> ).                                       |
| level         | The confidence level which shall be used if risk.measure is either “value.at.risk” or “expected.shortfall”.   |
| distr         | The default distribution is “loss”. If object gives the return distribution set distr to “return”.  |
| target.return | A numeric scalar specifying the target return if the optimization problem is of type “target.return”.   |
| risk.free     | A numeric scalar giving the risk free rate in case the optimization problem is of type “tangency”.  |
| silent        | If TRUE no prompts will appear in the console.  |
| ...           | Arguments passed to <a href="#">optim</a> .   |

### Details

If type is “minimum.risk” the global minimum risk portfolio is returned.

If type is “tangency” the portfolio maximizing the slope of “(expected return - risk free rate) / risk” will be returned.

If type is “target.return” the portfolio with expected return target.return which minimizes the risk will be returned.

Note that in case of an elliptical distribution (symmetric generalized hyperbolic distributions) it does not matter which risk measure is used. That is, minimizing the standard deviation results in a portfolio which also minimizes the value-at-risk et cetera.

### Value

A list with components:

|                |   |
|----------------|---|
| portfolio.dist | An univariate generalized hyperbolic object of class <a href="#">ghyp</a> which represents the distribution of the optimal portfolio. |
| risk.measure   | The risk measure which was used.  |
| risk           | The risk.   |
| opt.weights    | The optimal weights.  |
| converged      | Convergence returned from <a href="#">optim</a> .   |
| message        | A possible error message returned from <a href="#">optim</a> .  |
| n.iter         | The number of iterations returned from <a href="#">optim</a> .  |

### Note

In case object denotes a non-elliptical distribution and the risk measure is either “value.at.risk” or “expected.shortfall”, then the type “tangency” optimization problem is not supported.

Constraints like avoiding short-selling are not supported yet.

### Author(s)

David Luethi

### See Also

[transform](#), [fit.ghypmv](#)

### Examples

```
data(indices)

t.object <- fit.tmv(-indices, silent = TRUE)
gauss.object <- fit.gausmv(-indices)

t.ptf <- portfolio.optimize(t.object,
                           risk.measure = "expected.shortfall",
                           type = "minimum.risk",
                           level = 0.99,
```

```

      distr = "loss",
      silent = TRUE)

gauss.ptf <- portfolio.optimize(gauss.object,
                              risk.measure = "expected.shortfall",
                              type = "minimum.risk",
                              level = 0.99,
                              distr = "loss")

par(mfrow = c(1, 3))

plot(c(t.ptf$risk, gauss.ptf$risk),
     c(-mean(t.ptf$portfolio.dist), -mean(gauss.ptf$portfolio.dist)),
     xlim = c(0, 0.035), ylim = c(0, 0.004),
     col = c("black", "red"), lwd = 4,
     xlab = "99 percent expected shortfall",
     ylab = "Expected portfolio return",
     main = "Global minimum risk portfolios")

legend("bottomleft", legend = c("Asymmetric t", "Gaussian"),
       col = c("black", "red"), lty = 1)

plot(t.ptf$portfolio.dist, type = "l",
     xlab = "log-loss ((-1) * log-return)", ylab = "Density")
lines(gauss.ptf$portfolio.dist, col = "red")

weights <- cbind(Asymmetric.t = t.ptf$opt.weights,
                 Gaussian = gauss.ptf$opt.weights)

barplot(weights, beside = TRUE, ylab = "Weights")

```

---

 qq-ghyp

*Quantile-Quantile Plot*


---

### Description

This function is intended to be used as a graphical diagnostic tool for fitted univariate generalized hyperbolic distributions. Optionally a qq-plot of the normal distribution can be added.

### Usage

```

qqghyp(object, data = ghyp.data(object), gaussian = TRUE, line = TRUE,
       main = "Generalized Hyperbolic Q-Q Plot",
       xlab = "Theoretical Quantiles", ylab = "Sample Quantiles",
       ghyp.pch = 1, gauss.pch = 6, ghyp.lty = "solid",
       gauss.lty = "dashed", ghyp.col = "black", gauss.col = "black",
       plot.legend = TRUE, location = "topleft", legend.cex = 0.8,
       spline.points = 150, root.tol = .Machine$double.eps^0.5,
       rel.tol = root.tol, abs.tol = root.tol^1.5, add = FALSE, ...)

```

**Arguments**

|               |  |
|---------------|--|
| object        | Usually a fitted univariate generalized hyperbolic distribution of class <a href="#">mle.ghyp</a> . Alternatively an object of class <a href="#">ghyp</a> and a data vector. |
| data          | An object coercible to a vector.   |
| gaussian      | If TRUE a qq-plot of the normal distribution is plotted as a reference.  |
| line          | If TRUE a line is fitted and drawn.  |
| main          | An overall title for the plot.   |
| xlab          | A title for the x axis.  |
| ylab          | A title for the y axis.  |
| ghyp.pch      | A plotting character, i.e., symbol to use for quantiles of the generalized hyperbolic distribution.  |
| gauss.pch     | A plotting character, i.e., symbol to use for quantiles of the normal distribution.  |
| ghyp.lty      | The line type of the fitted line to the quantiles of the generalized hyperbolic distribution.  |
| gauss.lty     | The line type of the fitted line to the quantiles of the normal distribution.  |
| ghyp.col      | A color of the quantiles of the generalized hyperbolic distribution.   |
| gauss.col     | A color of the quantiles of the normal distribution.   |
| plot.legend   | If TRUE a legend is drawn.   |
| location      | The location of the legend. See <a href="#">legend</a> for possible values.  |
| legend.cex    | The character expansion of the legend.   |
| spline.points | The number of support points when computing the quantiles. Passed to <a href="#">qghyp</a> .   |
| root.tol      | The tolerance of the quantiles. Passed to <a href="#">uniroot</a> .  |
| rel.tol       | The tolerance of the quantiles. Passed to <a href="#">integrate</a> .  |
| abs.tol       | The tolerance of the quantiles. Passed to <a href="#">integrate</a> .  |
| add           | If TRUE the points are added to an existing plot window. The legend argument then becomes deactivated.   |
| ...           | Arguments passed to <a href="#">plot</a> .   |

**Author(s)**

David Luethi

**See Also**[hist](#), [fit.ghypuv](#), [qghyp](#), [plot](#), [lines](#)

### Examples

```
data(smi.stocks)

smi <- fit.ghypuv(data = smi.stocks[, "Swiss.Re"])

qqghyp(smi, spline.points = 100)

qqghyp(fit.tuv(smi.stocks[, "Swiss.Re"], symmetric = TRUE),
       add = TRUE, ghyp.col = "red", line = FALSE)
```

---

scale-methods

*Scaling and Centering of ghyp Objects*

---

### Description

scale centers and/or scales a generalized hyperbolic distribution to zero expectation and/or unit variance.

### Usage

```
## S4 method for signature 'ghyp'
scale(x, center = TRUE, scale = TRUE)
```

### Arguments

x                    An object inheriting from class [ghyp](#).

center                A logical value stating whether the object shall be centered to zero expectation.

scale                 A logical value stating whether the object shall be scaled to unit variance.

### Value

An object of class [ghyp](#).

### Author(s)

David Luethi

### See Also

[transform](#), [mean](#), [vcov](#).

**Examples**

```
data(indices)

t.fit <- fit.tmv(indices)
gauss.fit <- fit.gaussmv(indices)

## Compare the fitted Student-t and Gaussian density.
par(mfrow = c(1, 2))

## Once on the real scale...
plot(t.fit[1], type = "l")
lines(gauss.fit[1], col = "red")

## ...and once scaled to expectation = 0, variance = 1
plot(scale(t.fit)[1], type = "l")
lines(scale(gauss.fit)[1], col = "red")
```

---

smi.stocks

*Daily returns of five swiss blue chips and the SMI*

---

**Description**

Daily returns from January 2000 to January 2007 of five swiss blue chips and the Swiss Market Index (SMI).

**Usage**

```
data(smi.stocks)
```

**Format**

SMI Swiss Market Index.  
Novartis Novartis pharma.  
CS Credit Suisse.  
Nestle Nestle.  
Swisscom Swiss telecom company.  
Swiss.Re Swiss reinsurer.

**See Also**

[indices](#)

**Examples**

```
data(smi.stocks)

pairs(smi.stocks)
```

---

`stepAIC.ghyp`*Perform a model selection based on the AIC*

---

### Description

This function performs a model selection in the scope of the generalized hyperbolic distribution class based on the Akaike information criterion. `stepAIC.ghyp` can be used for the univariate as well as for the multivariate case.

### Usage

```
stepAIC.ghyp(data, dist = c("ghyp", "hyp", "NIG", "VG", "t", "gauss"),
             symmetric = NULL, ...)
```

### Arguments

|                        |  |
|------------------------|--|
| <code>data</code>      | A vector, matrix or <code>data.frame</code> .  |
| <code>dist</code>      | A character vector of distributions from where the best fit will be identified.  |
| <code>symmetric</code> | Either <code>NULL</code> , <code>TRUE</code> or <code>FALSE</code> . <code>NULL</code> means that both symmetric and asymmetric models will be fitted. For symmetric models select <code>TRUE</code> and for asymmetric models select <code>FALSE</code> . |
| <code>...</code>       | Arguments passed to <a href="#">fit.ghypuv</a> or <a href="#">fit.ghypmv</a> .   |

### Value

A list with components:

|                         |   |
|-------------------------|---|
| <code>best.model</code> | The model minimizing the AIC.   |
| <code>all.models</code> | All fitted models.  |
| <code>fit.table</code>  | A <code>data.frame</code> with columns <code>model</code> , <code>symmetric</code> , <code>lambda</code> , <code>alpha.bar</code> , <code>aic</code> , <code>llh</code> (log-Likelihood), <code>converged</code> , <code>n.iter</code> (number of iterations) sorted according to the <code>aic</code> . In the univariate case three additional columns containing the parameters <code>mu</code> , <code>sigma</code> and <code>gamma</code> are added. |

### Author(s)

David Luethi

### See Also

[lik.ratio.test](#), [fit.ghypuv](#) and [fit.ghypmv](#).

**Examples**

```
data(indices)

# Multivariate case:
aic.mv <- stepAIC.ghyp(indices, dist = c("ghyp", "hyp", "t", "gauss"),
  symmetric = NULL, control = list(maxit = 500),
  silent = TRUE, nit = 500)

summary(aic.mv$best.model)

# Univariate case:
aic.uv <- stepAIC.ghyp(indices[, "stock"], dist = c("ghyp", "NIG", "VG", "gauss"),
  symmetric = TRUE, control = list(maxit = 500), silent = TRUE)

# Test whether the ghyp-model provides a significant improvement with
# respect to the VG-model:
lik.ratio.test(aic.uv$all.models[[1]], aic.uv$all.models[[3]])
```

---

summary-method

*mle.ghyp summary*

---

**Description**

Produces a formatted output of a fitted generalized hyperbolic distribution.

**Usage**

```
## S4 method for signature 'mle.ghyp'
summary(object)
```

**Arguments**

object            An object of class [mle.ghyp](#).

**Value**

Nothing is returned.

**Author(s)**

David Luethi

**See Also**

Fitting functions [fit.ghypuv](#) and [fit.ghypmv](#), [coef](#), [mean](#), [vcov](#) and [ghyp.fit.info](#) for accessor functions for [mle.ghyp](#) objects.

**Examples**

```
data(smi.stocks)
mle.ghyp.object <- fit.NIGmv(smi.stocks[, c("Nestle", "Swiss.Re", "Novartis")])
summary(mle.ghyp.object)
```

---

transform-extract-methods

*Linear transformation and extraction of generalized hyperbolic distributions*

---

**Description**

The transform function can be used to linearly transform generalized hyperbolic distribution objects (see **Details**). The extraction operator `[]` extracts some margins of a multivariate generalized hyperbolic distribution object.

**Usage**

```
## S4 method for signature 'ghyp'
transform(`_data`, summand, multiplier)

## S3 method for class 'ghyp'
x[i = c(1, 2)]
```

**Arguments**

|                         |   |
|-------------------------|---|
| <code>_data</code>      | An object inheriting from class <a href="#">ghyp</a> .  |
| <code>summand</code>    | A vector.   |
| <code>multiplier</code> | A vector or a matrix.   |
| <code>x</code>          | A multivariate generalized hyperbolic distribution inheriting from class <a href="#">ghyp</a> . |
| <code>i</code>          | Index specifying which dimensions to extract.   |

**Details**

If  $X \sim GH$ , transform gives the distribution object of “multiplier \* X + summand”, where X is the argument named `_data`.

If the object is of class `mle.ghyp`, information concerning the fitting procedure (cf. [ghyp.fit.info](#)) will be lost as the return value is an object of class [ghyp](#).

**Value**

An object of class [ghyp](#).

**Author(s)**

David Luethi

**See Also**

[scale](#), [ghyp](#), [fit.ghypuv](#) and [fit.ghypmv](#) for constructors of [ghyp](#) objects.

**Examples**

```
## Multivariate generalized hyperbolic distribution
multivariate.ghyp <- ghyp(sigma=var(matrix(rnorm(9),ncol=3)), mu=1:3, gamma=-2:0)

## Dimension reduces to 2
transform(multivariate.ghyp, multiplier=matrix(1:6,nrow=2), summand=10:11)

## Dimension reduces to 1
transform(multivariate.ghyp, multiplier=1:3)

## Simple transformation
transform(multivariate.ghyp, summand=100:102)

## Extract some dimension
multivariate.ghyp[1]
multivariate.ghyp[c(1, 3)]
```

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