

# Package ‘SCEPtERbinary’

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**Title** Stellar Characteristics Pisa Estimation gRid for Binary Systems

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**Description** SCEPtER pipeline for estimating the stellar age for double-lined detached binary systems. The observational constraints adopted in the recovery are the effective temperature, the metallicity [Fe/H], the mass, and the radius of the two stars. The results are obtained adopting a maximum likelihood technique over a grid of pre-computed stellar models.

**Suggests** lattice

**Depends** R (>= 2.10), MASS, parallel, SCEPtER

**LazyData** no

**License** GPL (>= 2)

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**NeedsCompilation** yes

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SCEPtERbinary-package *A grid-based estimation tool for the age of stars in binary systems*

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### Description

The package estimates the age of stars in double-lined detached binary systems, given observational effective temperature, metallicity [Fe/H], mass, and radius of both stars. The results are obtained adopting a maximum likelihood technique on a grid of computed stellar models.

### References

G. Valle, M. Dell’Omodarme, P.G. Prada Moroni, and S. Degl’Innocenti (2014). *Uncertainties in grid-based estimates of stellar mass and radius. SCEPtER: Stellar Characteristics Pisa Estimation gRid*. A&A, 561, A125.

G. Valle, M. Dell’Omodarme, P.G. Prada Moroni, and S. Degl’Innocenti (2014). *Uncertainties in asteroseismic grid-based estimates of stellar ages. SCEPtER: Stellar Characteristics Pisa Estimation gRid*. A&A, accepted.

G. Valle, M. Dell’Omodarme, P.G. Prada Moroni, and S. Degl’Innocenti (2014). *Grid-based estimates of stellar ages in binary systems. SCEPtER: Stellar Characteristics Pisa Estimation gRid*. A&A, submitted.

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block	<i>Block of same initial [Fe/H] for the grid</i>
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### Description

The function computes the group identifier for grid rows, according to their initial metallicities.

### Usage

```
block(grid)
```

### Arguments

grid            the grid of stellar models.

### Value

block returns a vector with the group identifier for each row of the supplied grid.

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errorObsBin	<i>Perturbe a set of observational data</i>
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### Description

The function returns a perturbed object, starting from observational data and a vector of uncertainties.

### Usage

```
errorObsBin(sigma, STAR, parallel=FALSE, corr=c(0,0,0,0,0,0,0))
```

### Arguments

sigma	a vector of 14 elements containing the uncertainties on observational data. The error on mass and radius must be expressed as relative error. If the errors on the observations of the two stars are identical, it is possible to provide a vector of length 7.
STAR	a vector of 18 elements containing the observational data.
parallel	logical flag specifying if the computation should be performed in parallel on a multi-core architecture.
corr	a vector with the assumed the correlation between corresponding observables of the two stars. Default to zero (no correlations).

### Details

The vector of observations STAR must contain, in the order:

1. The effective temperature (in K) of the star.
2. The logarithm of the surface gravity of the star (in  $\text{cm s}^{-2}$ ).
3. The metallicity [Fe/H] of the star.
4. The value of large frequency separation of the star, divided by the solar value of this quantity.
5. The value of the frequency of maximum oscillation power of the star, divided by the solar value of this quantity.
6. The mass (in solar units) of the star.
7. The radius (in solar unit) of the star.

The vector of the uncertainties on the observation sigma must contain the uncertainty on the above quantity. The uncertainty on the asteroseismic parameters, mass, and radius must be expressed as relative error.

### Value

errorObsBin returns an object obtained sampling from a multivariate normal distribution with vector of mean STAR and covariance matrix computed according to the value of corr.

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estimateBin                      *Age estimates for the supplied binary systems*

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### Description

The function computes the grid-based estimates of the age for the supplied binary systems.

### Usage

```
estimateBin(data, STAR, sigma, thr, sel, parallel=FALSE)
```

### Arguments

data	the matrix estimation grid. The matrix should be sorted according to the values in the first column (the stellar effective temperature).
STAR	a matrix of 18 columns, containing in each row the observational data of the stellar objects.
sigma	a vector of 14 elements, containing the error on observational data. The error on mass and radius are expressed as relative error. If the errors on the observables of the two stars are identical, it is possible to provide a vector of length 7.
thr	the threshold for the selection of cases over which the computation of likelihood is performed.
sel	a vector of 7 elements, containing 1 or 0 for inclusion or exclusion of a observational data from the likelihood computation.
parallel	logical flag indicating if the estimations should be performed in parallel on a multi-core architecture.

### Value

STAR should contains the observables for primary and secondary stars. In order, it should contains the stellar effective temperature, the logarithm of the surface gravity, the metallicity [Fe/H], the average large frequency separation (in micro Hz), the maximum oscillation power (in micro Hz), the mass (in solar units), the radius (in solar units), the age (if known), and the relative age (if known). Identical quantities for the secondary stars should follows. sigma should contain, in the same order, the uncertainties on the observational quantities.

estimateBin returns a data frame obtained with the estimates of stellar parameters for each row of the input matrix STAR. In the columns of the data frame there are: the identifier id of the row of the object matrix adopted for the estimate; the independent star estimate of the primary mass M1 (in solar units), radius R1 (in solar units), age age1 (in Gyr); the corresponding independent estimates for the secondary (M2, R2, age2); the joint-likelihood estimates of these quantities obtained explicitly assuming coevality (M1b, R1b, age1b, M2b, R2b, age2b); the relative age r of the primary star (0 = ZAMS; 1 = TAMS); the best estimate of the age of the system ageBin under coevality assumption; the mean of the age of the two independent estimates of the stellar ages.

Age estimates are obtained by a maximum likelihood technique. Details on the technique can be found in the references reported below.

## References

G. Valle, M. Dell’Omodarme, P.G. Prada Moroni, and S. Degl’Innocenti (2014). *Uncertainties in grid-based estimates of stellar mass and radius. SCEPtER: Stellar Characteristcs Pisa Estimation gRid*. A&A, 561, A125.

G. Valle, M. Dell’Omodarme, P.G. Prada Moroni, and S. Degl’Innocenti (2014). *Uncertainties in asteroseismic grid-based estimates of stellar ages. SCEPtER: Stellar Characteristcs Pisa Estimation gRid*. A&A, accepted.

G. Valle, M. Dell’Omodarme, P.G. Prada Moroni, and S. Degl’Innocenti (2014). *Grid-based estimates of stellar ages in binary systems. SCEPtER: Stellar Characteristcs Pisa Estimation gRid*. A&A, submitted.

## Examples

```
require(SCEPtER)
data(stdGrid)
ogrid <- stdGrid[ do.call(order, as.data.frame(stdGrid[,1])), ]

## observational constraint: Teff, [Fe/H], M, R
vsel <- c(1,0,1,0,0,1,1)
sigma <- c(100, 0.25, 0.1, 0.025, 0.05, 0.01, 0.005)

## syntetic sample of 10 bynary systems
bl <- block(stdGrid)
sam <- sampleBinStar(10, stdGrid, bl, restrict=TRUE)

## add Gaussian noise to the observations
starbp <- errorObsBin(sigma, sam)

resB <- estimateBin(ogrid, starbp, sigma, 3, vsel, parallel=FALSE)

## An observed system: PK Peg
## observation from Clausen et al. (2010). A&A, 516, A42.

obs <- c(6265,NA,-0.12,NA,NA,1.414,1.988,NA,NA, 6320,NA,-0.12,NA,NA,1.257,1.474,NA,NA)
sigma <- c(85,0,0.07,0,0,0.007/1.414,0.008/1.988, 90,0,0.07,0,0,0.005/1.257,0.017/1.474)

## for sensible estimate adopt at least nrow=10000
star <- matrix(obs, nrow=100, ncol=18, byrow=TRUE)

## add Gaussian noise
starp <- errorObsBin(sigma, star)

resB <- estimateBin(ogrid, starp, sigma, 3, vsel, parallel=FALSE)

quantile(resB$ageBin, c(0.16, 0.5, 0.84))
```

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sampleBinStar	<i>Sample a set of binary systems out of a grid</i>
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**Description**

The function extracts, without replacement, a sample of binary systems out of a grid.

**Usage**

```
sampleBinStar(n, grid, block, restrict=TRUE, parallel=FALSE)
```

**Arguments**

n	the number of objects to be sampled.
grid	the grid from which the objects are sampled.
block	the length of blocks of the same initial metallicity [Fe/H]
restrict	logical flag indicating if only models younger than 14 Gyr should be considered.
parallel	logical flag indicating if the estimations should be performed in parallel on a multi-core architecture.

**Value**

sampleBinStar returns a matrix of n rows, sampled without replacement from grid. A maximum age difference of 10 Myr is allowed in the binary system selection.

**Examples**

```
require(SCEPtER)
data(stdGrid)

bl <- block(stdGrid)
sam <- sampleBinStar(10, stdGrid, bl, restrict=TRUE)
```

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