

# Package ‘BayHaz’

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**Title** R Functions for Bayesian Hazard Rate Estimation

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**Depends** R (>= 1.8.0), splines

**Suggests** coda

**Description** A suite of R functions for Bayesian estimation of smooth hazard rates via Compound Poisson Process (CPP) and Bayesian Penalized Spline (BPS) priors.

**License** GPL (>= 2)

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BayHaz-package	<i>R Functions for Bayesian Hazard Rate Estimation</i>
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## Description

A suite of R functions for Bayesian estimation of smooth hazard rates via Compound Poisson Process (CPP) and Bayesian Penalized Spline (BPS) priors.

## Details

Package: BayHaz  
 Type: Package  
 Version: 0.1-3  
 Date: 2007-10-07  
 License: GPL Version 2 or later

This package provides Users with functions to use CPP prior distributions for Bayesian analysis of times to event; see La Rocca (2005). It also handles first order autoregressive BPS hazard rates, based on Hennerfeind *et al.* (2006). Prior elicitation, posterior computation, and visualization are dealt with. For illustrative purposes, a data set in the field of earthquake statistics is supplied. Package 'coda' is suggested for output diagnostics.

## Author(s)

Luca La Rocca <http://www-dimat.unipv.it/luca>  
 Maintainer: Luca La Rocca <luca.larocca@unimore.it>

## References

La Rocca, L. (2005). On Bayesian Nonparametric Estimation of Smooth Hazard Rates with a View to Seismic Hazard Assessment. *Research Report* n. 38-05, Department of Social, Cognitive and Quantitative Sciences, Reggio Emilia, Italy.

Hennerfeind, A., Brezger, A. & Fahrmeir, L. (2006). Geoadditive survival models. *Journal of the American Statistical Association* 101, 1065–1075.

## See Also

[CPPpriorElicit](#), [CPPpostSample](#), [CPPplotHR](#), [BSPriorElicit](#), [BSPostSample](#), [BSPlotHR](#), [earthquakes](#), [CPPpost2mcmc](#), [BSPost2mcmc](#)

**Examples**

```

# the following analysis uses CPP hazard rates but can be easily adapted to BPS hazard rates

# set RNG seed (for example reproducibility only)
set.seed(1234)

# select a CPP prior distribution (with default number of CPP jumps)
hypars<-CPPpriorElicit(r0 = 0.1, H = 1, T00 = 50, M00 = 2, extra = 0)

# plot some sample prior hazard rates
CPPplotHR(CPPpriorSample(ss = 10, hyp = hypars), tu = "Year")

# load a data set
data(earthquakes)

# generate a posterior sample
post<-CPPpostSample(hypars, times = earthquakes$ti, obs = earthquakes$ob)

# check that no additional CPP jumps are needed:
# if this probability is not negligible,
# go back to prior selection stage and increase 'extra'
ecdf(post$sgm[,post$hyp$F])(post$hyp$T00+3*post$hyp$sd)

# plot some posterior hazard rate summaries
CPPplotHR(post , tu = "Year")

# save the posterior sample to file for later use
save(post, file = "post.rda")

# convert the posterior sample into an MCMC object
post<-CPPpost2mcmc(post)

# take advantage of package 'coda' for output diagnostics
pdf("diagnostics.pdf")
traceplot(post)
autocorr.plot(post, lag.max = 5)
par(las = 2) # for better readability of the cross-correlation plot
crosscorr.plot(post)
dev.off()

```

BPSevalHR

*Function to Evaluate BPS Hazard Rates***Description**

A function to evaluate a (prior or posterior) sample of first order autoregressive BPS hazard rates on a grid of time points.

**Usage**

```
BPSevalHR(time, sample)
```

**Arguments**

`time` vector of time points where the hazard rates in the sample should be evaluated  
`sample` sample of BPS hazard rates (as generated by [BPSpriorSample](#) or [BPSpostSample](#))

**Value**

A matrix with as many rows as hazard rates in the sample and as many columns as time points in the grid.

**See Also**

[BPSplotHR](#)

**Examples**

```
# set RNG seed (for example reproducibility only)
set.seed(1234)

# select a BPS prior distribution
hypars<-BPSpriorElicit(r0 = 0.1, H = 1, T00 = 50, ord = 4, G = 3, c = 0.9)
# generate a sample of ten hazard rates
prior<-BPSpriorSample(ss = 10, hyp = hypars)

# evaluate the ten hazard rates at year multiples
BPSevalHR(time = seq(0,50), sample = prior)
```

---

BPSplotHR

*Function to Plot BPS Hazard Rates*

---

**Description**

A function to plot a (prior or posterior) sample of first order autoregressive BPS hazard rates.

**Usage**

```
BPSplotHR(sample = BPSpriorSample(0), npts = 101, tu = "Time Unit", title = NULL)
```

**Arguments**

`sample` sample of BPS hazard rates (as generated by [BPSpriorSample](#) or [BPSpostSample](#))  
`npts` number of time points where the hazard rates in the sample should be evaluated  
`tu` name of the time unit to be used for labelling the time axis  
`title` main title for the plot

**Details**

For a prior sample, the individual trajectories are plotted (as solid lines) and dashed lines are added to represent the pointwise prior mean and +/- one standard deviation band.

For a posterior sample, the pointwise posterior mean and equal tail 95% credible band are drawn (as solid lines) and dashed lines are added to represent the analogous posterior summaries for the constant hazard rate model (using a conjugate gamma prior and letting its shape and rate parameters tend to zero). Furthermore, the observations are marked on the time axis ("x" for exact observations, "o" for censored observations).

The range spanned by the time axis always goes from the origin to `sample$hyp$T00`.

**Value**

Always NULL.

**See Also**

[BayHaz-package](#), [BPSevalHR](#)

**Examples**

```
# set RNG seed (for example reproducibility only)
set.seed(1234)

# select a BPS prior distribution
hypars<-BPSpriorElicit(r0 = 0.1, H = 1, T00 = 50, ord = 4, G = 3, c = 0.9)
# generate a sample of ten hazard rates
prior<-BPSpriorSample(ss = 10, hyp = hypars)

# plot the ten hazard rates
BPSplotHR(prior, tu = "Year")
```

---

BPSpost2mcmc

*Function to Convert BPS Posterior Samples into MCMC Objects*

---

**Description**

A function to convert a first order autoregressive BPS posterior sample into an MCMC object, so that package 'coda' can be used for output diagnostics.

**Usage**

```
BPSpost2mcmc(sampost)
```

**Arguments**

`sampost` posterior sample of BPS hazard rates (as generated by [BPSpostSample](#))

**Value**

An MCMC object, complete with burn-in and thinning information.

**Note**

If package 'coda' is not available, a matrix with meaningful column names is returned.

**See Also**

[BayHaz-package](#), [BPSpostSample](#)

**Examples**

```
# set RNG seed (for example reproducibility only)
set.seed(1234)

# select a BPS prior distribution
hypars<-BPSpriorElicit(r0 = 0.1, H = 1, T00 = 50, ord = 4, G = 3, c = 0.9)
# load a data set
data(earthquakes)
# generate a posterior sample
post<-BPSpostSample(hypars, times = earthquakes$ti, obs = earthquakes$ob)

# convert the posterior sample into an MCMC object
MCMCpost<-BPSpost2mcmc(post)
```

---

BPSpostSample

*Function to Sample Hazard Rates from BPS Posteriors*

---

**Description**

A function to generate a random sample of hazard rates from the posterior distribution originated by a first order autoregressive BPS prior through the observation of a sequence of possibly right censored times to event.

**Usage**

```
BPSpostSample(hyp, times, obs = NULL, mclen = 10, burnin = 0, thin = 1, df = 10, etastar = NULL)
```

**Arguments**

hyp	list of hyperparameters (as generated by <a href="#">BPSpriorElicit</a> )
times	vector of (possibly right censored) times to event
obs	vector of censoring indicators (0 = censored, 1 = exact)
mclen	requested sample size
burnin	burn-in parameter
thin	thinning parameter

df	degrees of freedom for the multivariate Student-t proposal distribution
etastar	posterior mode and corresponding hessian in list format (as generated by <code>optim</code> with <code>hessian = TRUE</code> )

### Details

A Markov chain sample of length `mclen` from the posterior distribution originated by `hyp` through the observation of `times` and `obs` is generated using a tailored proposal density Metropolis-Hastings sampler (starting at the posterior mode); see Chib & Greenberg (1995).

The first `burnin` states of the Markov chain are discarded, then one every `thin` is kept.

If `obs` is `NULL`, it is assumed that all observations are exact (no censoring).

### Value

A list with seven components:

<code>hyp</code>	list of hyperparameters identifying the BPS prior that originated the posterior distribution from which the sample was extracted (copy of the input argument)
<code>dat</code>	dataframe with two variables ( <code>times</code> and <code>obs</code> ) containing the observations on which the posterior distribution is based
<code>burnin</code>	burn-in parameter used (copy of the input argument)
<code>thin</code>	thinning parameter used (copy of the input argument)
<code>df</code>	degrees of freedom used for the multivariate Student-t proposal distribution (copy of the input argument)
<code>etastar</code>	posterior mode and corresponding hessian in list format (copy of the input argument or computed via <code>optim</code> if the input argument was <code>NULL</code> )
<code>eta</code>	matrix with <code>mclen</code> rows (and <code>length(hyp\$knots) - hyp\$ord</code> columns) containing the spline weights

### Note

If `mclen` is equal to zero `eta` will be a chain of length one containing the posterior mode.

### References

Chib, S. & E. Greenberg (1995). Understanding the Metropolis-Hastings algorithm. *American Statistician* 49, 327–335.

### See Also

[BayHaz](#)-package, [BPSevalHR](#), [BPSplotHR](#), [BPSpost2mcmc](#)

**Examples**

```

# set RNG seed (for example reproducibility only)
set.seed(1234)

# select a BPS prior distribution
hypars<-BSPriorElicit(r0 = 0.1, H = 1, T00 = 50, ord = 4, G = 3, c = 0.9)
# load a data set
data(earthquakes)

# find the posterior mode
postmode<-BSPostSample(hypars, times = earthquakes$ti, obs = earthquakes$ob, mclen = 0)
# evaluate the posterior mode hazard rate at year multiples
BPSevalHR(time = seq(0,50), sample = postmode)

# generate a posterior sample
post<-BSPostSample(hypars, times = earthquakes$ti, obs = earthquakes$ob, etastar = postmode$etastar)
# plot some posterior hazard rate summaries
BPSplotHR(post, tu = "Year")

```

---

BSPriorElicit

*Function to Set Hyperparameters of BPS Priors*


---

**Description**

A function to set the hyperparameters of a first order autoregressive BPS prior distribution, approximately assigning constant prior mean hazard rate and corresponding coefficient of variation.

**Usage**

```
BSPriorElicit(r0 = 1, H = 1, T00 = 1, ord = 4, G = 30, c = 0.9)
```

**Arguments**

r0	prior mean hazard rate ( $r_0$ )
H	corresponding coefficient of variation
T00	time-horizon of interest ( $T_\infty$ )
ord	spline order ( $k$ )
G	number of internal spline knots
c	correlation coefficient between two consecutive spline weights

**Details**

A first order autoregressive BPS prior hazard rate is defined, for  $0 < t < T_\infty$ , by

$$\rho(t) = \exp\left\{ \sum_{j=1}^{G+k-2} \eta_j B_j(t) \right\}$$

where:

- $\eta_j$  is the  $j$ -th element of a normally distributed vector of spline weights (see below for details)
- $B_j(t)$  is the  $j$ -th B-spline basis function of order  $k$ , evaluated at  $t$ , defined on a grid of  $G+2k-2$  equispaced knots with first internal knot at 0 and last internal knot at  $T_\infty$  (see [splineDesign](#) for details)

The spline weights form a stationary AR(1) process with mean  $m$ , variance  $w$  and lag-one autocorrelation  $c$ . The elicitation procedure takes  $w = H^2$  and  $m = \log r_0 - 0.5 * w$ , based on the mean and variance formulas for the log-normal distribution. As B-spline basis functions form a partition of unity within internal nodes, the mean of  $\rho(t)$  is approximately equal to  $r_0$ , for  $0 < t < T_\infty$ , and its standard deviation to  $Hr_0$ .

### Value

A list with nine components:

r0	prior mean hazard rate (copy of the input argument)
H	corresponding coefficient of variation (copy of the input argument)
T00	time-horizon of interest (copy of the input argument)
ord	spline order (copy of the input argument)
G	number of internal spline knots (copy of the input argument)
c	correlation coefficient between two consecutive spline weights (copy of the input argument)
knots	full grid of spline knots
m	mean of spline coefficients
w	variance of spline coefficients

### See Also

[BayHaz-package](#), [BPSpriorSample](#), [BPSpostSample](#)

### Examples

```
# ten events per century with unit coefficient of variation and fifty year time horizon
# cubic splines with minimal number of knots and strongly correlated spline weights
hypars<-BPSpriorElicit(r0 = 0.1, H = 1, T00 = 50, ord = 4, G = 3, c = 0.9)
```

---

BPSpriorSample

*Function to Sample Hazard Rates from BPS Priors*

---

### Description

A function to generate a random sample of hazard rates from a first order autoregressive BPS prior distribution.

**Usage**

```
BPSpriorSample(ss = 1, hyp = BPSpriorElicit())
```

**Arguments**

ss	requested sample size
hyp	list of hyperparameters (as generated by <a href="#">BPSpriorElicit</a> )

**Details**

A random sample of `ss` hazard rates is extracted from the first order autoregressive BPS prior distribution identified by `hyp`.

**Value**

A list with two components:

hyp	list of hyperparameters identifying the BPS prior distribution from which the sample was extracted (copy of the input argument)
eta	matrix with <code>ss</code> rows (and <code>length(hyp\$knots)-hyp\$ord</code> columns) containing the spline weights

**See Also**

[BPSevalHR](#), [BPSplotHR](#)

**Examples**

```
# set RNG seed (for example reproducibility only)
set.seed(1234)

# select a BPS prior distribution
hypars<-BPSpriorElicit(r0 = 0.1, H = 1, T00 = 50, ord = 4, G = 3, c = 0.9)

# generate a sample of ten hazard rates
prior<-BPSpriorSample(ss = 10, hyp = hypars)
```

---

 CPPevalHR

---

*Function to Evaluate CPP Hazard Rates*


---

**Description**

A function to evaluate a (prior or posterior) sample of CPP hazard rates on a grid of time points.

**Usage**

```
CPPevalHR(time, sample)
```

**Arguments**

`time` vector of time points where the hazard rates in the sample should be evaluated  
`sample` sample of CPP hazard rates (as generated by [CPPpriorSample](#) or [CPPpostSample](#))

**Value**

A matrix with as many rows as hazard rates in the sample and as many columns as time points in the grid.

**See Also**

[CPPplotHR](#)

**Examples**

```
# set RNG seed (for example reproducibility only)
set.seed(1234)

# select a CPP prior distribution
hypars<-CPPpriorElicit(r0 = 0.1, H = 1, T00 = 50, M00 = 2)
# generate a sample of ten hazard rates
prior<-CPPpriorSample(ss = 10, hyp = hypars)

# evaluate the ten hazard rates at year multiples
CPPevalHR(time = seq(0,50), sample = prior)

# load a data set
data(earthquakes)
# generate a posterior sample
post<-CPPpostSample(hypars, times = earthquakes$ti, obs = earthquakes$ob)

# evaluate the posterior hazard rates at year multiples
CPPevalHR(time = seq(0,50), sample = post)
```

---

CPPplotHR

*Function to Plot CPP Hazard Rates*

---

**Description**

A function to plot a (prior or posterior) sample of CPP hazard rates.

**Usage**

```
CPPplotHR(sample = CPPpriorSample(0), npts = 101, tu = "Time Unit", title = NULL)
```

**Arguments**

sample	sample of CPP hazard rates (as generated by <a href="#">CPPpriorSample</a> or <a href="#">CPPpostSample</a> )
npts	number of time points where the hazard rates in the sample should be evaluated
tu	name of the time unit to be used for labelling the time axis
title	main title for the plot

**Details**

For a prior sample, the individual trajectories are plotted (as solid lines) and dashed lines are added to represent the pointwise prior mean and +/- one standard deviation band.

For a posterior sample, the pointwise posterior mean and equal tail 95% credible band are drawn (as solid lines) and dashed lines are added to represent the analogous posterior summaries for the constant hazard rate model (using a conjugate gamma prior and letting its shape and rate parameters tend to zero). Furthermore, the observations are marked on the time axis ("x" for exact observations, "o" for censored observations).

The range spanned by the time axis always goes from the origin to `sample$hyp$T00`.

**Value**

Always NULL.

**See Also**

[BayHaz-package](#), [CPPEvalHR](#)

**Examples**

```
# set RNG seed (for example reproducibility only)
set.seed(1234)

# select a CPP prior distribution
hypars<-CPPpriorElicit(r0 = 0.1, H = 1, T00 = 50, M00 = 2)
# generate a sample of ten hazard rates
prior<-CPPpriorSample(ss = 10, hyp = hypars)

# plot the ten hazard rates
CPPplotHR(prior, tu = "Year")

# load a data set
data(earthquakes)
# generate a posterior sample
post<-CPPpostSample(hypars, times = earthquakes$ti, obs = earthquakes$ob)

# plot some posterior hazard rate summaries
CPPplotHR(post, tu = "Year")
```

---

`CPPpost2mcmc`*Function to Convert CPP Posterior Samples into MCMC Objects*

---

**Description**

A function to convert a CPP posterior sample into an MCMC object, so that package 'coda' can be used for output diagnostics.

**Usage**

```
CPPpost2mcmc(sampost)
```

**Arguments**

`sampost` posterior sample of CPP hazard rates (as generated by [CPPpostSample](#))

**Value**

An MCMC object, complete with burn-in and thinning information.

**Note**

If package 'coda' is not available, a matrix with meaningful column names is returned.

**See Also**

[BayHaz-package](#), [CPPpostSample](#)

**Examples**

```
# set RNG seed (for example reproducibility only)
set.seed(1234)

# select a CPP prior distribution
hypars<-CPPpriorElicit(r0 = 0.1, H = 1, T00 = 50, M00 = 2)
# load a data set
data(earthquakes)
# generate a posterior sample
post<-CPPpostSample(hypars, times = earthquakes$ti, obs = earthquakes$ob)

# convert the posterior sample into an MCMC object
MCMCpost<-CPPpost2mcmc(post)
```

---

 CPPpostSample

*Function to Sample Hazard Rates from CPP Posteriors*


---

### Description

A function to generate a random sample of hazard rates from the posterior distribution originated by a CPP prior through the observation of a sequence of possibly right censored times to event.

### Usage

```
CPPpostSample(hyp, times, obs = NULL, mclen = 10, burnin = 0, thin = 1, lab = FALSE)
```

### Arguments

hyp	list of hyperparameters (as generated by <a href="#">CPPpriorElicit</a> )
times	vector of (possibly right censored) times to event
obs	vector of censoring indicators (0 = censored, 1 = exact)
mclen	requested sample size
burnin	burn-in parameter
thin	thinning parameter
lab	logical: should latent labels be returned?

### Details

A random scan (random start) Gibbs sampler (with slice sampling updating of jump-times) is used to generate a Markov chain sample of length `mclen` from the posterior distribution originated by `hyp` through the observation of `times` and `obs`; see La Rocca (2005).

The first `burnin` states of the Markov chain are discarded, then one every `thin` is kept.

If `obs` is `NULL`, it is assumed that all observations are exact (no censoring).

### Value

A list with eight components:

hyp	list of hyperparameters identifying the CPP prior that originated the posterior distribution from which the sample was extracted (copy of the input argument)
dat	dataframe with two variables ( <code>times</code> and <code>obs</code> ) containing the observations on which the posterior distribution is based
burnin	burn-in parameter used (copy of the input argument)
thin	thinning parameter used (copy of the input argument)
sgm	matrix with <code>mclen</code> rows (and <code>hyp\$F</code> columns) containing the CPP jump-times
xi0	matrix with <code>mclen</code> rows (and just one column) containing the jump-sizes in the origin
csi	matrix with <code>mclen</code> rows (and <code>hyp\$F</code> columns) containing the CPP jump-sizes
gam	matrix with <code>mclen</code> rows (and <code>length(times)</code> columns) containing the latent labels ( <code>NULL</code> if <code>lab</code> is <code>FALSE</code> )

**Note**

The latent label  $\gamma_i$  is equal to  $j$  when the  $i$ -th time to event is associated with the  $j$ -th CPP jump; it is only defined for exact observations, but for censored observations it is conventionally set equal to  $-1$ .

**References**

Luca La Rocca (2005). On Bayesian Nonparametric Estimation of Smooth Hazard Rates with a View to Seismic Hazard Assessment. *Research Report n. 38-05*, Department of Social, Cognitive and Quantitative Sciences, Reggio Emilia, Italy.

**See Also**

[BayHaz-package](#), [CPPEvalHR](#), [CPPplotHR](#), [CPPpost2mcmc](#)

**Examples**

```
# set RNG seed (for example reproducibility only)
set.seed(1234)

# select a CPP prior distribution
hypars<-CPPpriorElicit(r0 = 0.1, H = 1, T00 = 50, M00 = 2)
# load a data set
data(earthquakes)

# generate a posterior sample
post<-CPPpostSample(hypars, times = earthquakes$ti, obs = earthquakes$ob)
```

---

CPPpriorElicit

*Function to Set Hyperparameters of CPP Priors*

---

**Description**

A function to set the hyperparameters of a CPP prior distribution, following the procedure described in La Rocca (2005).

**Usage**

```
CPPpriorElicit(r0 = 1, H = 1, T00 = 1, M00 = 1, extra = 0)
```

**Arguments**

r0	prior mean hazard rate ( $r_0$ )
H	corresponding coefficient of variation
T00	time-horizon of interest ( $T_\infty$ )
M00	number of extremes within the time-horizon in a "typical" hazard rate trajectory ( $M_\infty$ )
extra	number of additional CPP jumps (compared with default)

**Details**

A CPP prior hazard rate is defined, for  $0 < t < T_\infty$ , by

$$\rho(t) = \xi_0 k_0(t) + \sum_{j=1}^F \xi_j k(t - \sigma_j)$$

where:

- $\sigma_j$  is the time of the  $j$ -th jump of a CPP process with gamma distributed jump-sizes
- $\xi_j$  is the  $j$ -th jump-size of the above process
- $k$  is a zero-mean Gaussian density (kernel)
- $F$  is a positive integer such that (with high probability)  $\sigma_{F+1}$  is much larger than  $T_\infty$
- $\xi_0$  is an independent random variable with the same distribution as  $\xi_j$
- $k_0$  is a suitable function such that the mean of  $\rho(t)$  does not depend on  $t$

The elicitation procedure makes the mean of  $\rho(t)$  identically equal to  $r_0$  and its standard deviation approximately equal to  $Hr_0$ . An exponential distribution is selected for the jump-sizes. The kernel bandwidth choice is based on  $M_\infty$  (and  $T_\infty$ ).

**Value**

A list with nine components:

r0	prior mean hazard rate (copy of the input argument)
H	corresponding coefficient of variation (copy of the input argument)
T00	time-horizon of interest (copy of the input argument)
M00	number of extremes within the time-horizon in a "typical" hazard rate trajectory (copy of the input argument)
a	shape parameter of the jump-size distribution (always equal to 1)
sd	standard deviation of the Gaussian kernel (bandwidth)
q	expected number of CPP jumps per time unit
b	rate parameter of the jump-size distribution
F	maximum number of jumps within the time-horizon (with high probability)

**Note**

As the default value of F is computed *a priori*, additional jumps may be needed *a posteriori*.

**References**

Luca La Rocca (2005). On Bayesian Nonparametric Estimation of Smooth Hazard Rates with a View to Seismic Hazard Assessment. *Research Report n. 38-05*, Department of Social, Cognitive and Quantitative Sciences, Reggio Emilia, Italy.

**See Also**

[BayHaz-package](#), [CPPpriorSample](#), [CPPpostSample](#)

**Examples**

```
# ten events per century with unit coefficient of variation
# fifty year time horizon with a couple of extremes in a "typical" trajectory
hypars<-CPPpriorElicit(r0 = 0.1, H = 1, T00 = 50, M00 = 2)
```

---

CPPpriorSample      *Function to Sample Hazard Rates from CPP Priors*

---

**Description**

A function to generate a random sample of hazard rates from a CPP prior distribution.

**Usage**

```
CPPpriorSample(ss = 1, hyp = CPPpriorElicit())
```

**Arguments**

ss	requested sample size
hyp	list of hyperparameters (as generated by <a href="#">CPPpriorElicit</a> )

**Details**

A random sample of ss hazard rates is extracted from the CPP prior distribution identified by hyp.

**Value**

A list with four components:

hyp	list of hyperparameters identifying the CPP prior distribution from which the sample was extracted (copy of the input argument)
sgm	matrix with ss rows (and hyp\$F columns) containing the CPP jump-times
xi0	matrix with ss rows (and just one column) containing the jump-sizes in the origin
csi	matrix with ss rows (and hyp\$F columns) containing the CPP jump-sizes

**See Also**

[CPPevalHR](#), [CPPplotHR](#)

### Examples

```
# set RNG seed (for example reproducibility only)
set.seed(1234)

# select a CPP prior distribution
hypars<-CPPpriorElicit(r0 = 0.1, H = 1, T00 = 50, M00 = 2)

# generate a sample of ten hazard rates
prior<-CPPpriorSample(ss = 10, hyp = hypars)
```

---

earthquakes	<i>Waiting Times between Strong Earthquakes in the Appennino Abruzzese</i>
-------------	--

---

### Description

This data set gives the waiting times (in years) between earthquakes with moment magnitude greater than 5.1, in the Italian seismogenic zone 923, from year 1650 to year 2002, as obtained by La Rocca (2005) based on the catalogue by Gruppo di Lavoro CPTI (2004).

### Usage

```
data(earthquakes)
```

### Format

A data frame with 47 observations on the following 2 variables:

ti earthquake inter-event times (years)  
ob censoring indicators (0 = right censored, 1 = exact)

### Note

All observations are exact, except for the last one (a characteristic of this kind of data).

### Source

Gruppo di Lavoro CPTI (2004). Catalogo Parametrico dei Terremoti Italiani, versione 2004 (CPTI04). INGV, Bologna, <http://emidius.mi.ingv.it/CPTI>. In Italian.

### References

Luca La Rocca (2005). On Bayesian Nonparametric Estimation of Smooth Hazard Rates with a View to Seismic Hazard Assessment. *Research Report n. 38-05*, Department of Social, Cognitive and Quantitative Sciences, Reggio Emilia, Italy.

### See Also

[BayHaz-package](#)

**Examples**

```
# load data set
data(earthquakes)

# show data set structure
str(earthquakes)
```

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