

# evolMC demo

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evolMC is a framework for doing Monte-Carlo simulations.

## 0.1 Univariate and multivariate sampling

We wish to use a metropolis sampler to draw from a distribution with density

$$f(x) \propto \frac{\sin(x)}{x} \cdot 1_{(0,\pi)}(x).$$

We can use a uniform distribution on  $(-1, 1)$  to propose distances to jump from the current location.

Since the proposal distribution is symmetric, this is enough information to implement a Metropolis updater.

```
fn <- function(x) sin(x)/x * (0 < x) * (x < pi)
propose <- function(x) x + runif(length(x), -1, 1)
updater <- metropolis(fn, propose)
```

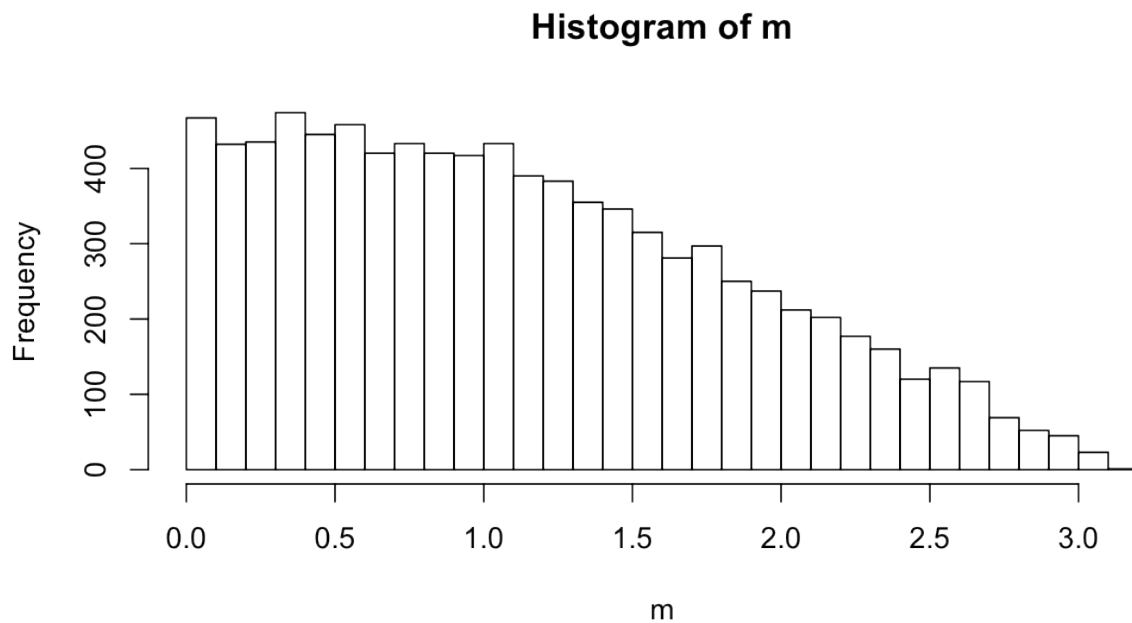
A Markov chain is formed by iteratively calling the updating function starting with some initial value.

```
chain <- iterate(n = 10000, fn = updater, init = 1)
summary(chain)

## Discarding first 1000 states.
##   mean      se   2.5%   97.5%
## 1.11712 0.73918 0.04531 2.66390

hist(chain, breaks = "fd")

## Discarding first 1000 states.
```



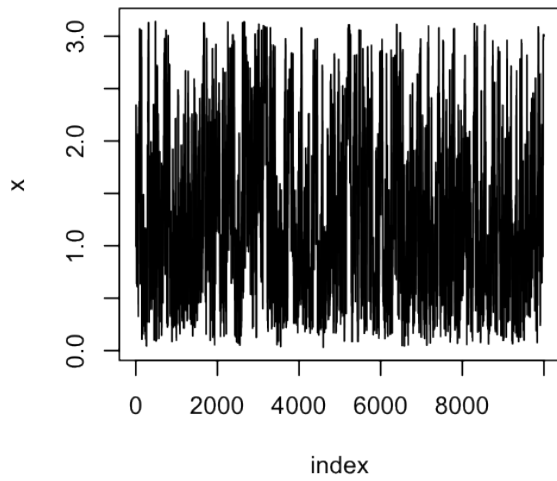
Of course, multivariate distributions may also be sampled.

```
mvtarget <- function(x) prod(sin(prod(x))/x) * all(x > 0, x < pi, prod(x) <
  pi)
mvupdate <- metropolis(mvtarget, propose)
chain2 <- iterate(10000, mvupdate, cbind(x = 1, y = 1))
summary(chain2)

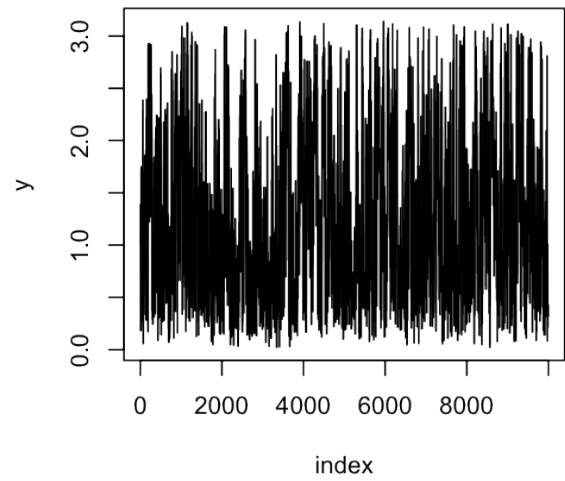
## Discarding first 1000 states.
##           x           y
## mean  1.2974 1.2333
## se    0.8146 0.8110
## 2.5%   0.1614 0.1618
## 97.5%  3.0129 2.9627

plot(chain2)
```

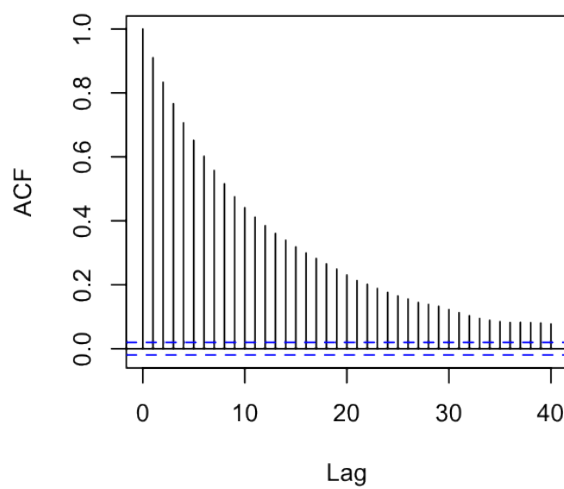
**Traceplot of 1 populations**



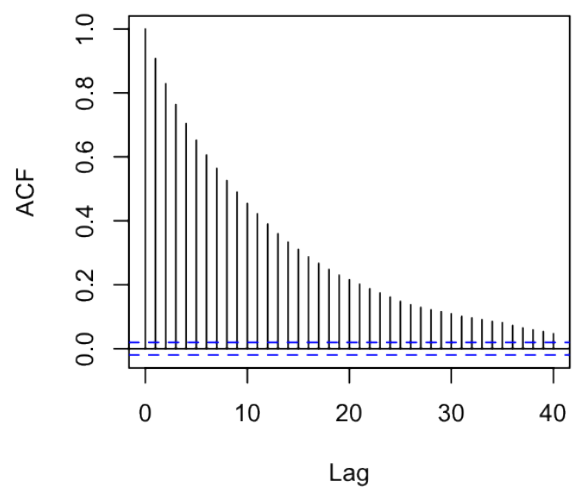
**Traceplot of 1 populations**



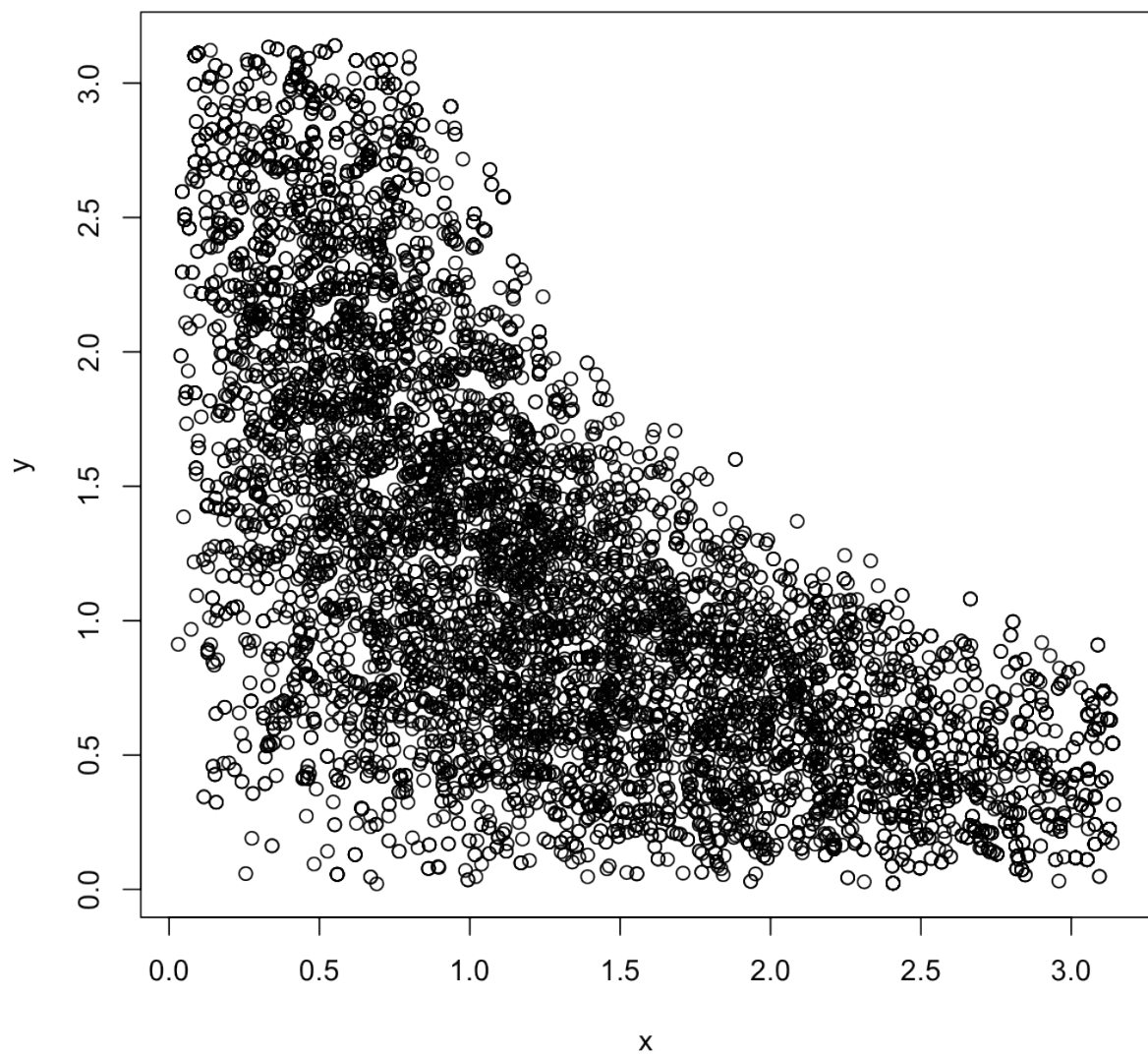
**Series x**



**Series y**



```
plot(t(simplify2array(chain2)[1, , ]))
```

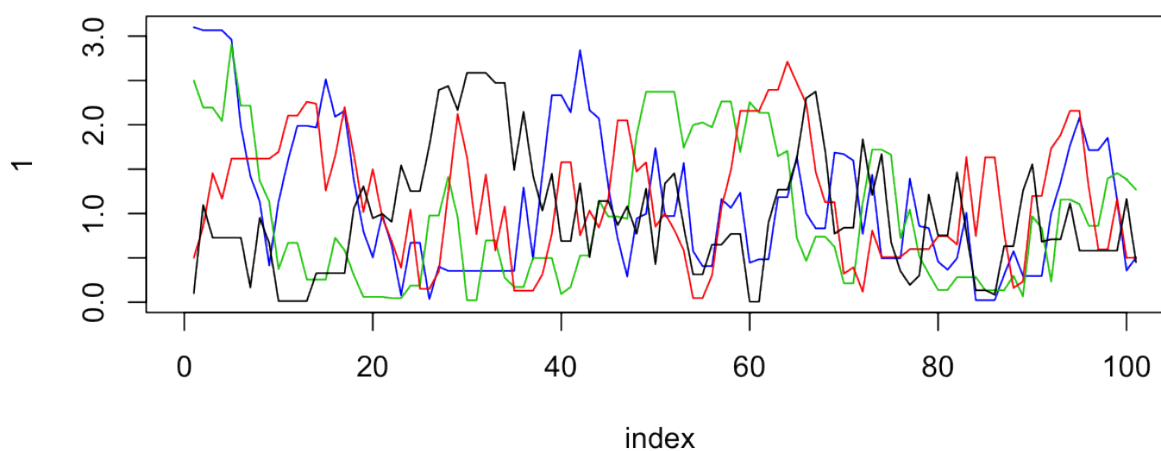


## 0.2 Multiple chains in parallel

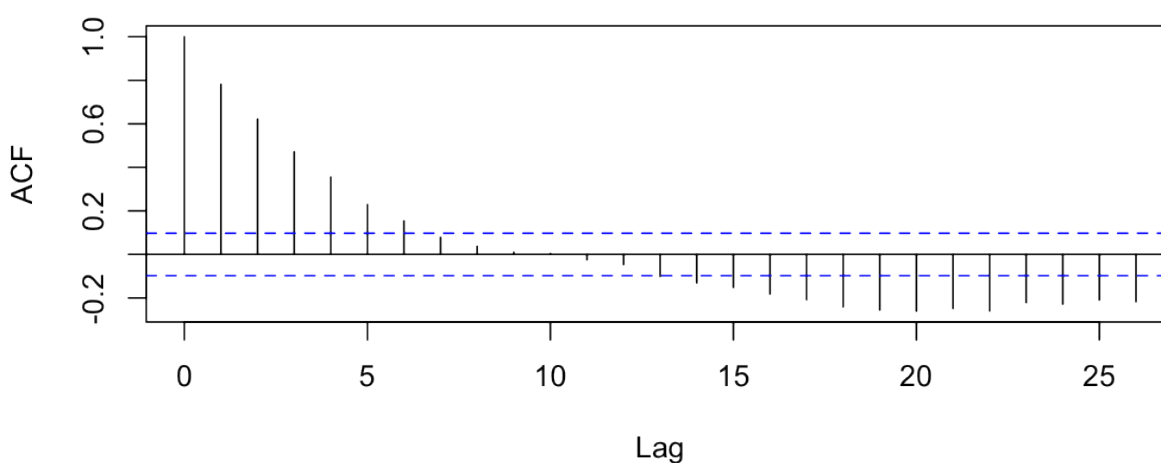
If the target density returns a vector instead of a scalar, we can run multiple chains in parallel. (In this case the state object is a matrix with individuals in rows.) In this situation, the proposal updater should update the entire population.

```
chain3 <- iterate(100, updater, init = rbind(0.1, 0.5, 2.5, 3.1))
plot(chain3)
```

## Traceplot of 4 populations



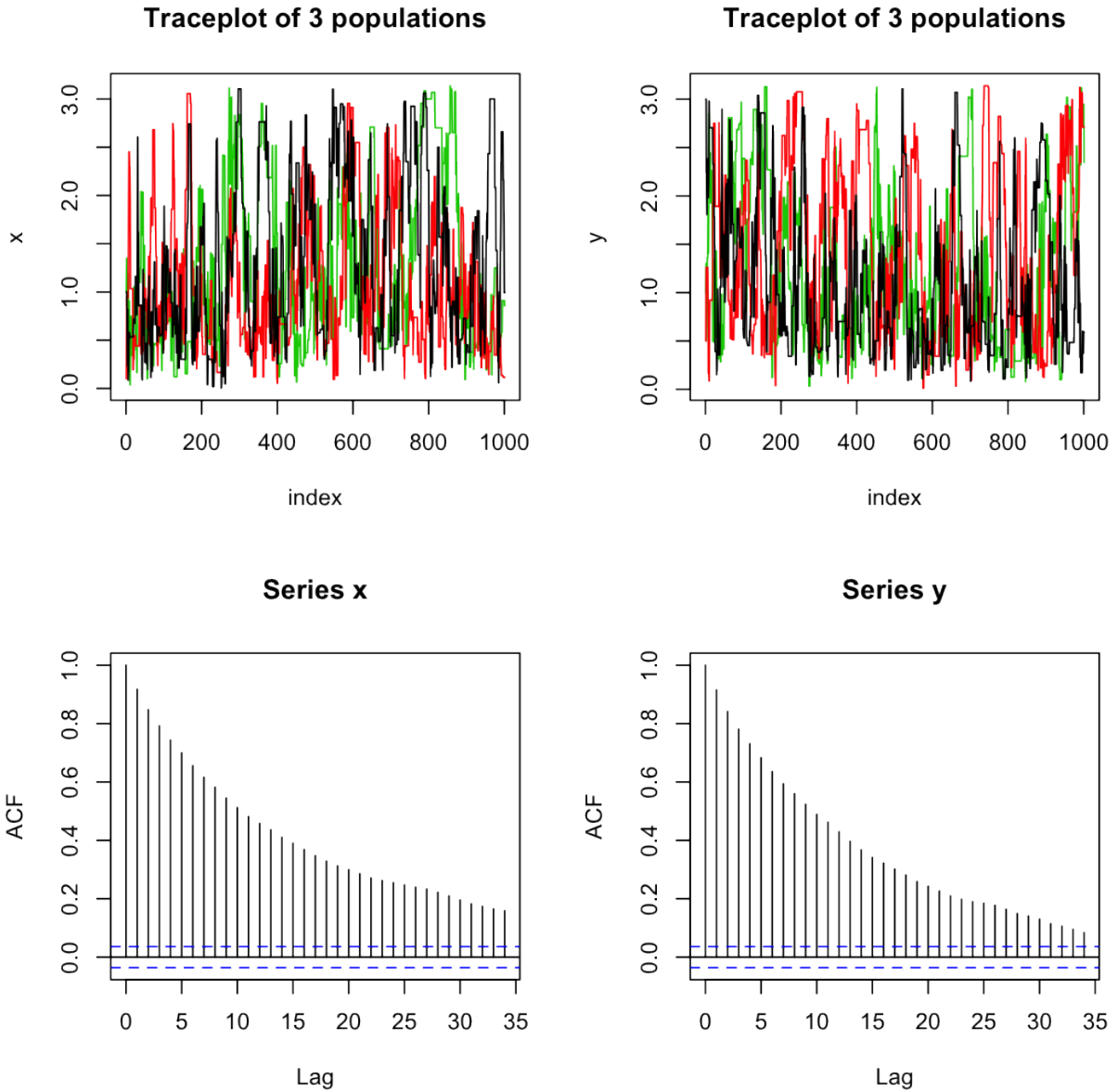
## Series



Multiple chains of multivariate samples are also possible, as long as a logical vector of the same length as that returned by the density function will “correctly” subset individuals from the population state object.<sup>1</sup>

```
mvt2 <- function(x) apply(x, 1, mvtarget)
mvup2 <- metropolis(mvt2, propose)
init <- rbind(c(x = 1, y = 3), c(0.1, 0.5), c(1, 1))
chain4 <- iterate(1000, mvup2, init)
plot(chain4)
```

<sup>1</sup>Thus, a population can be a vector, a matrix with individuals in rows, or a list. Some convenience methods such as print, summary, plot, hist, etc., assume a population is a matrix, but this is not strictly required.



### 0.3 Gibbs sampling

A gibbs updater calls several updating functions sequentially. Here we find Bayesian location-scale parameter estimates for a t-distribution likelihood with known degrees of freedom  $5/2$ . The model specification in this case is  $y|\mu, w \sim N(\mu, w^{-1})$  and  $w|\sigma^2, \nu \sim G(\nu/2, \sigma^2\nu/2)$ , with priors  $\mu \sim N$  and  $\sigma^2 \sim G$ .

```
newcomb <- c(28, -44, 29, 30, 26, 27, 22, 23, 33, 16, 24, 29, 24, 40, 21, 31,
  34, -2, 25, 19, 24, 28, 37, 32, 20, 25, 25, 36, 36, 21, 28, 26, 32, 28,
  26, 30, 36, 29, 30, 22, 36, 27, 26, 28, 29, 23, 31, 32, 24, 27, 27, 27,
  32, 25, 28, 27, 26, 24, 32, 29, 28, 33, 39, 25, 16, 23)
##' Full conditional updater for mu
```

```

f.m <- function(state, ...) {
  k <- seq_len(ncol(state) - length(newcomb))
  w <- rowSums(state[, -k])
  mu <- (state[, -k] %*% newcomb)/(1e-04 + w)
  sd <- 1/sqrt(1e-04 + w)
  n <- nrow(state)
  state[, 1] <- rnorm(n, mu, sd)
  state
}
##' Full conditional updater for sigma^2
f.v <- function(state, df = FALSE) {
  nu <- if (df)
    1/state[, 3] else 5
  k <- seq_len(ncol(state) - length(newcomb))
  n <- ncol(state[, -k])
  rates <- 0.1 + rowSums(state[, -k]) * nu/2
  state[, 2] <- rgamma(nrow(state), 0.1 + n * nu/2, rates)
  state
}
##' Full conditional updater for w
f.w <- function(state, df = FALSE) {
  nu <- if (df)
    1/state[, 3] else 5
  k <- seq_len(ncol(state) - length(newcomb))
  rate <- (nu * state[, 2] + t(apply(state, 1, function(row) (newcomb - row[1])^2)))/2
  state[, -k] <- rgamma(length(state[, -k]), (nu + 1)/2, rate)
  state
}

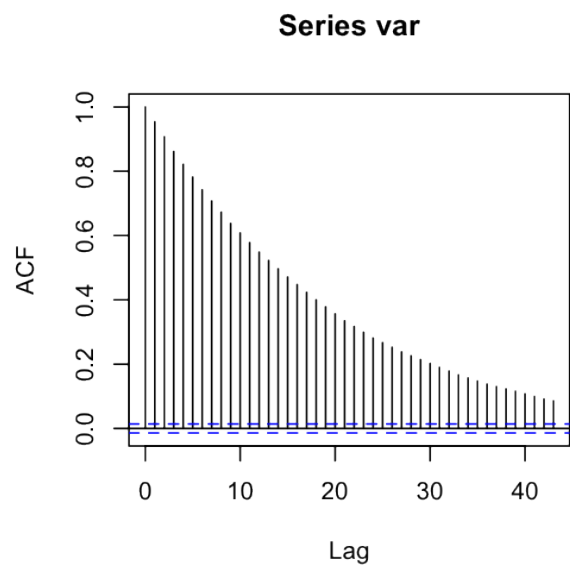
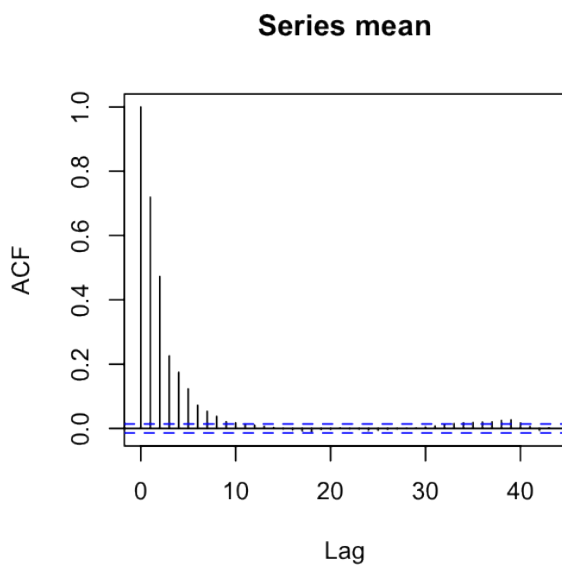
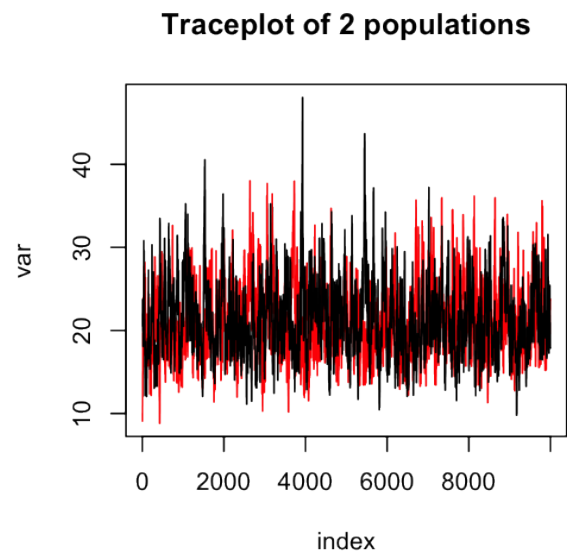
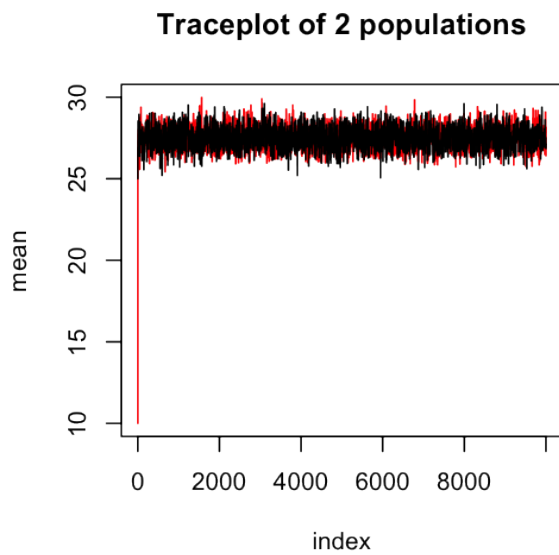
```

The gibbs function is used to create a function which acts as the Gibbs updater.

```

init <- rbind(c(mean = 25, var = 22, rgamma(length(newcomb), 5/2, 22 * 5/2)),
  c(10, 10, rgamma(length(newcomb), 5/2, 10 * 5/2)))
newcomb.gibbs <- gibbs(f.m, f.v, f.w)
chain5 <- iterate(10000, newcomb.gibbs, init)
chain5 <- prune(chain5, TRUE, 1:2)
plot(chain5)

```



```
summary(chain5)
```

```
## Discarding first 1000 states.
##      mean    var
## mean 27.5091 21.219
## se   0.6419  4.511
## 2.5% 26.2784 13.794
## 97.5% 28.7828 31.273
```

Of course, you can use a metropolis updater in place of a full conditional. Here we put a prior on  $\nu^{-1} \sim E(1)T(0, 1)$



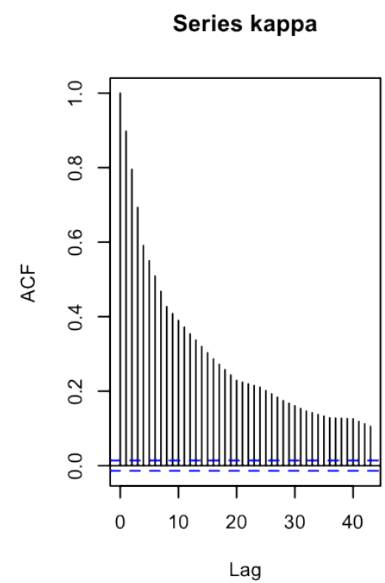
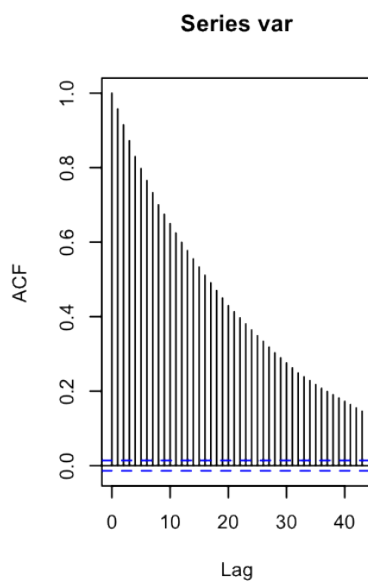
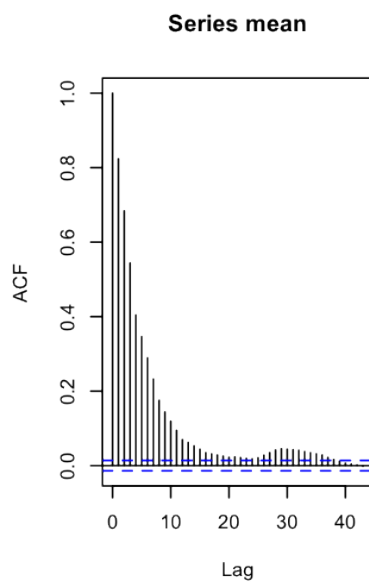
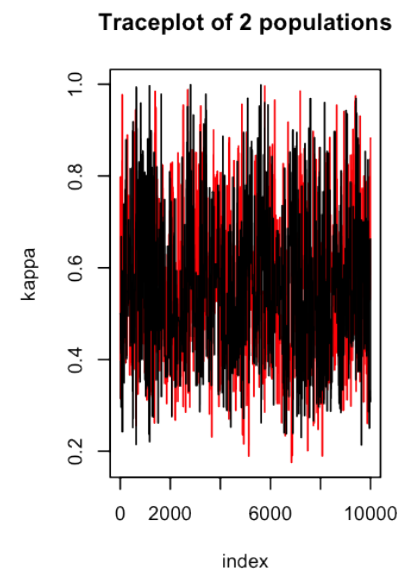
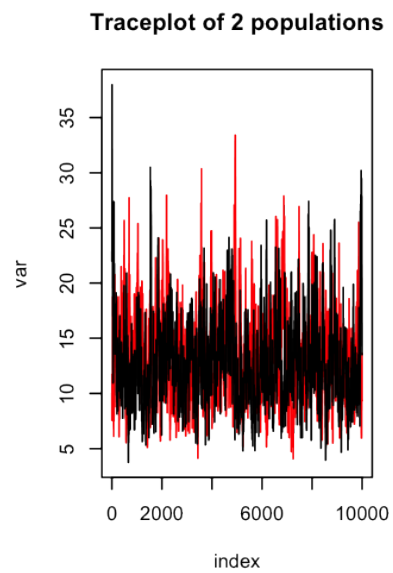
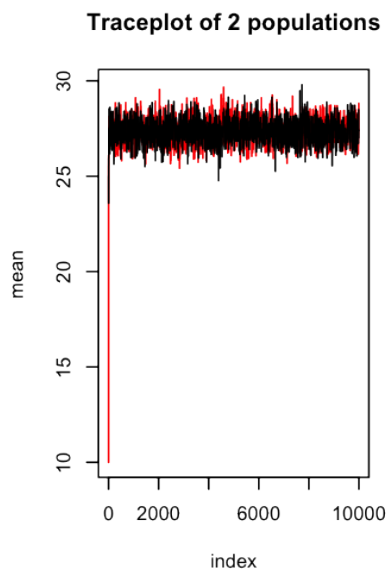
```

dtxp <- function(x, rate = 1, min = 0, max = Inf, log = FALSE) {
  d <- dexp(x, rate) * (x >= min) * (x <= max)
  c <- pexp(max, rate) - pexp(min, rate)
  if (log)
    log(d/c) else d/c
}
posterior <- function(state) {
  if (!is.matrix(state))
    state <- matrix(state, 1)
  f <- function(x) sum(dt((newcomb - x[1])/sqrt(x[2]), 1/x[3], log = TRUE) -
    log(x[2])/2)
  exp(apply(state, 1, f) + dnorm(state[, 1], sd = 100, log = TRUE) + dgamma(state[,
    2], 0.1, 0.1, log = TRUE) + dtxp(state[, 3], max = 1, log = TRUE))
}
kappa.prop <- function(state) {
  state[, 3] <- runif(nrow(state))
  state
}
init <- rbind(c(mean = 25, var = 22, kappa = 0.5, rgamma(length(newcomb), 5/2,
  22 * 5/2)), c(10, 10, 0.4, rgamma(length(newcomb), 5/2, 10 * 5/2)))
newcomb.chain3 <- gibbs(f.m, f.v, f.w, metropolis(posterior, kappa.prop))
chain4 <- iterate(10000, newcomb.chain3, init, df = TRUE)
chain4 <- prune(chain4, TRUE, 1:3)
summary(chain4)

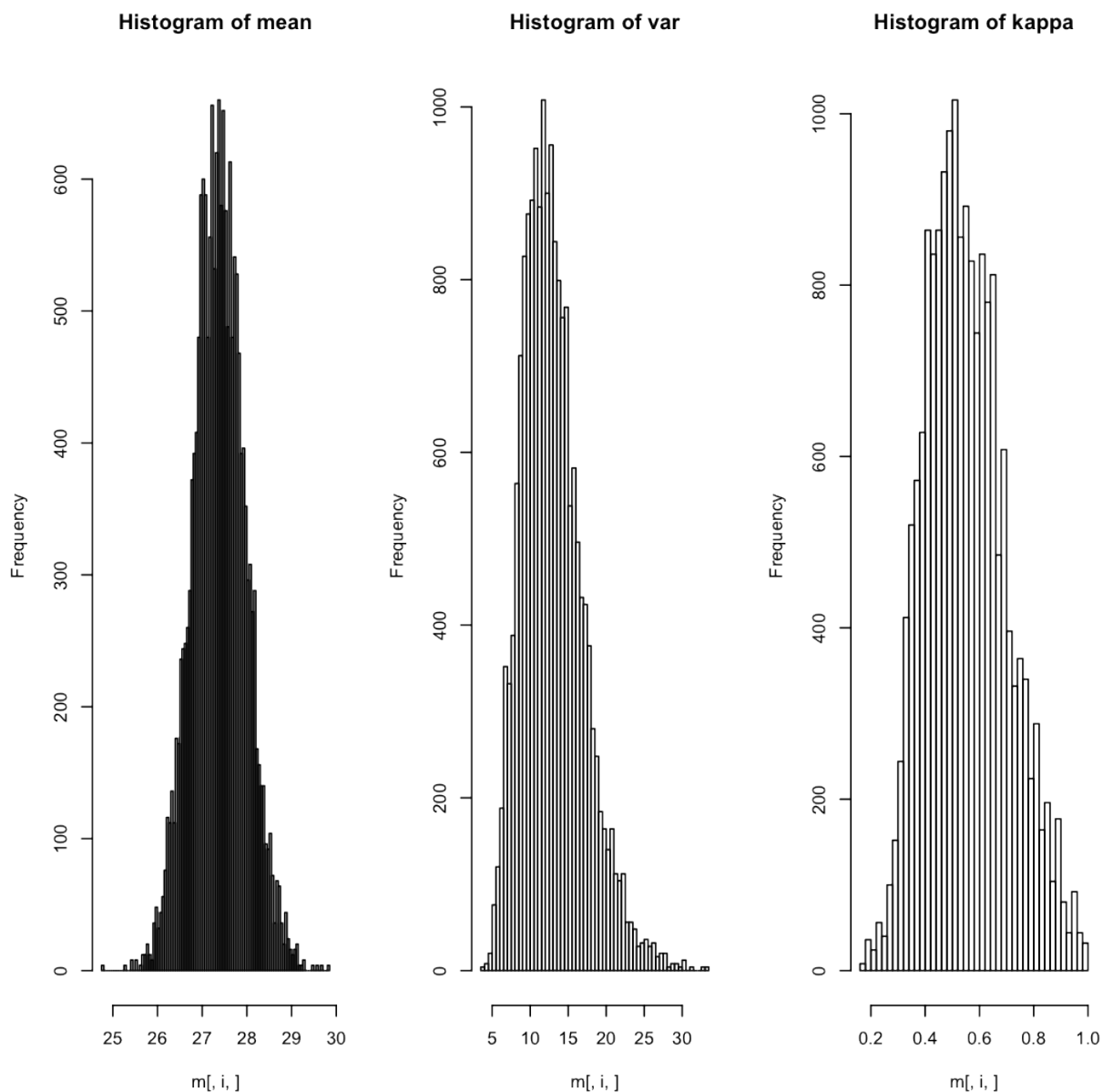
## Discarding first 1000 states.
##           mean    var  kappa
## mean  27.3737 12.950 0.5509
## se     0.5899  4.063 0.1495
## 2.5%   26.2344  6.557 0.3040
## 97.5%  28.5677 22.392 0.8824

plot(chain4)

```



```
hist(chain4, breaks = "fd")
## Discarding first 1000 states.
```



## 0.4 Parallel tempering

We want to sample from a distribution with separated modes. First we set up the target distribution function. This function should take a single individual and return the density of that individual.

```
f <- function(state) exp(sum(log(dnorm(state) + dnorm(state, 10))))
```

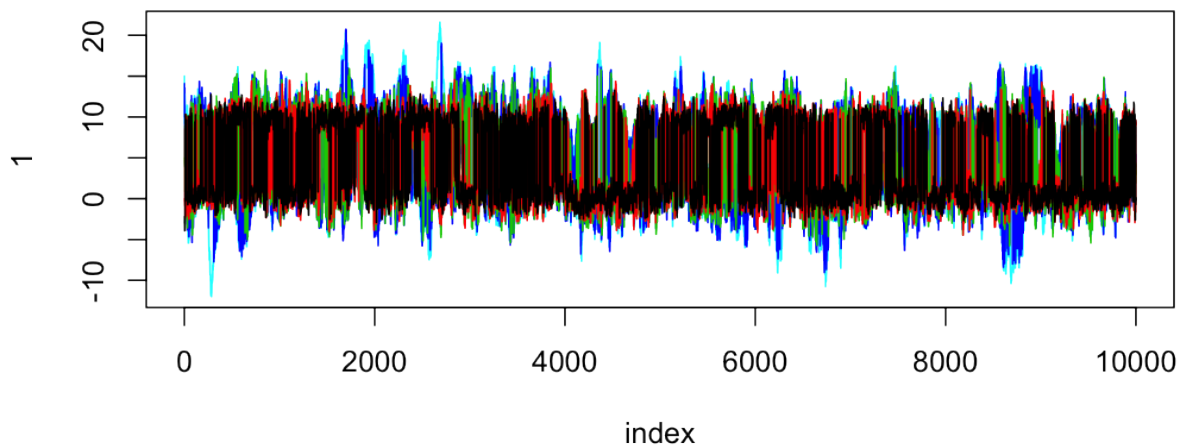
Now we can set up the parallel tempering updater. Function `temper` is similar to `metropolis`, but you must also provide a list of temperatures. (It is assumed that the number of individuals in the population will be the same as the number of temperature levels.)

```

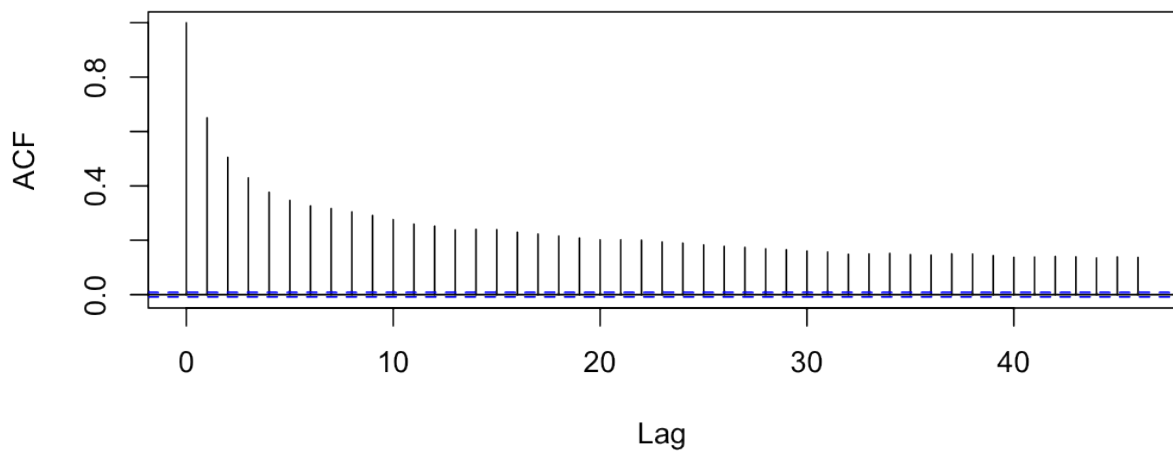
temps <- c(1, 2, 4, 8, 15)
updater <- temper(f, temps, propose)
init <- rbind(-3, 0, 5, 10, 15)
gch <- iterate(10000, updater, init)
plot(gch)

```

**Traceplot of 5 populations**



**Series**

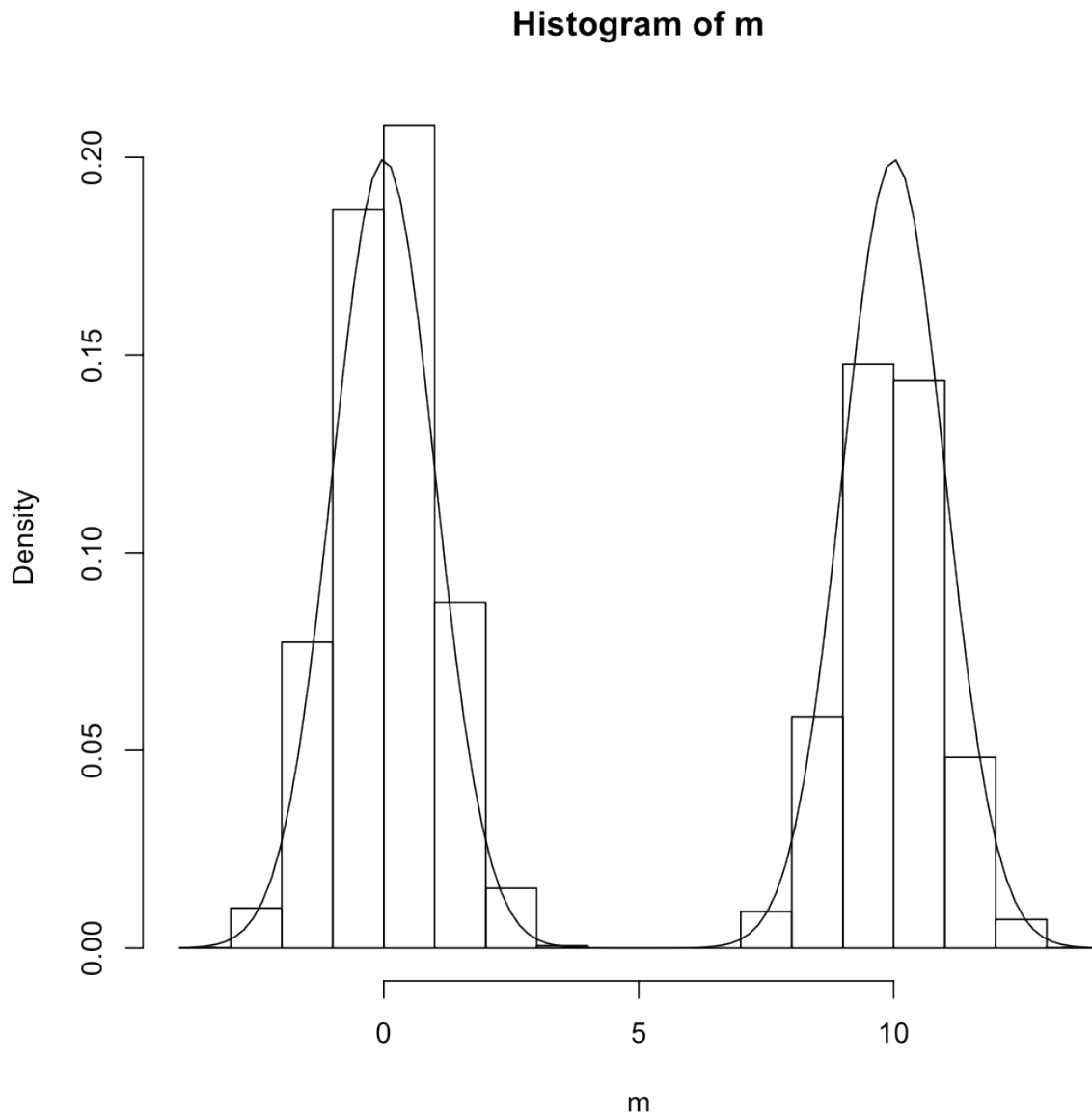


```

xx <- prune(gch, 1, 1) #extract chain with correct distribution
hist(xx, freq = FALSE, breaks = "fd")

## Discarding first 1000 states.
curve((dnorm(x) + dnorm(x, 10))/2, add = TRUE)

```



## 0.5 Evolutionary MC

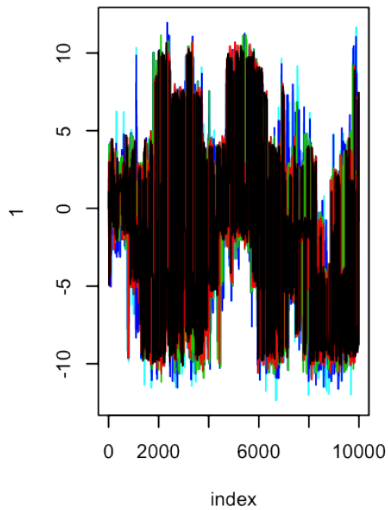
Here we go with the real-deal. Twenty part trivariate-gaussian mixture. The target function is a part of the evolMC package.

```
init <- matrix(0, 5, 3)
means <- t(replicate(20, runif(3, -10, 10)))
ff <- function(x) target(x, means)
e <- seq(0.2, 3, length = 5)
pf <- function(x) x + runif(length(x), -e, e)
chainz <- iterate(10000, gibbs(temper(ff, temps, pf), crossover(ff, temps)),
```

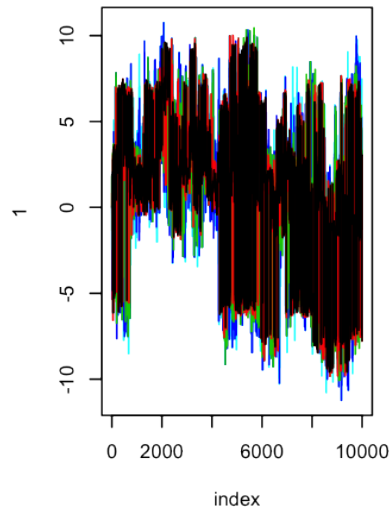
```
init)
```

```
plot(chainz)
```

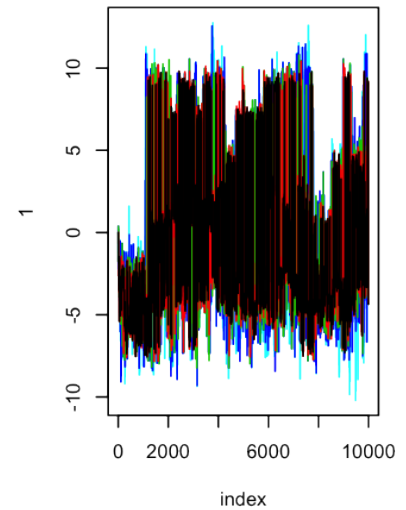
Traceplot of 5 populations



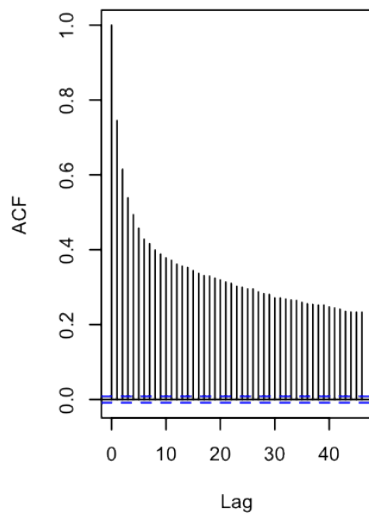
Traceplot of 5 populations



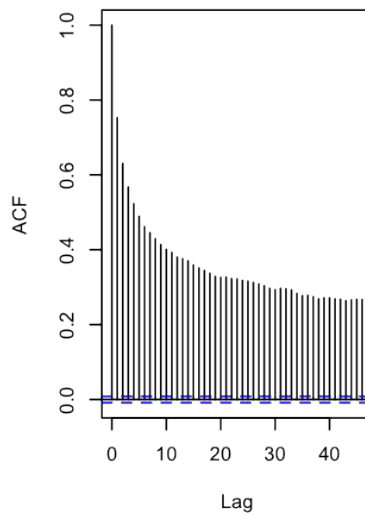
Traceplot of 5 populations



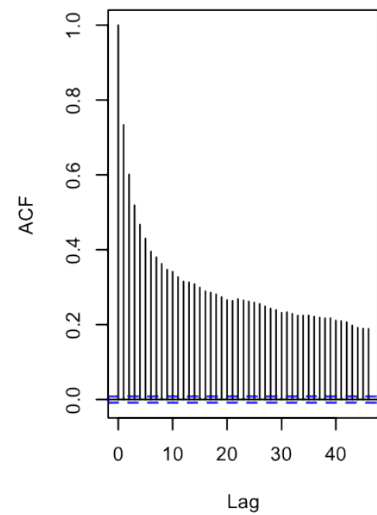
Series



Series



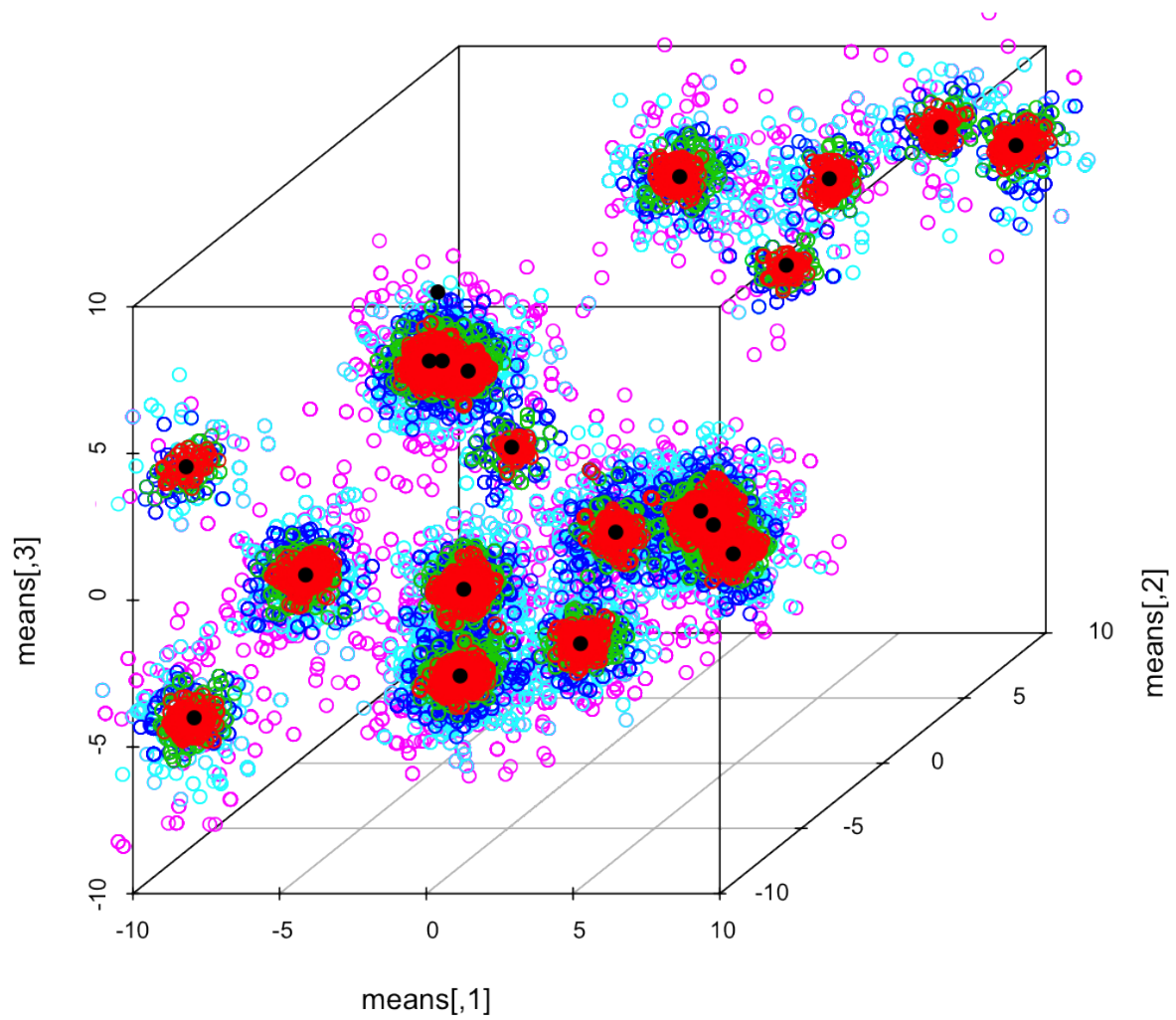
Series



```
## means hist(chainz)
m <- aperm(simplify2array(chainz))
library(scatterplot3d)
pp <- scatterplot3d(means)
sapply(5:1, function(i) pp$points3d(m[, , i], col = i + 1))
## [[1]]
```

```
## NULL
##
## [[2]]
## NULL
##
## [[3]]
## NULL
##
## [[4]]
## NULL
##
## [[5]]
## NULL

pp$points3d(means, col = 1, pch = 19)
```



```
## library(rgl) plot3d(m[, ,1]) plot3d(means,pch=19,size=15)
## sapply(1:5,function(i) points3d(m[, ,i],col=i+1))
```