SIR_example_boardingSchool.r

max

2022-04-05

```
library(outbreaks)
library(bayesplot)
```

```
## This is bayesplot version 1.8.1
## - Online documentation and vignettes at mc-stan.org/bayesplot
## - bayesplot theme set to bayesplot::theme_default()
##    * Does _not_ affect other ggplot2 plots
##    * See ?bayesplot_theme_set for details on theme setting
```

```
library(cmdstanr)
```

```
## This is cmdstanr version 0.4.0.9000
## - Online documentation and vignettes at mc-stan.org/cmdstanr
## - CmdStan path set to: /home/max/.cmdstanr/cmdstan-2.28.2
## - Use set_cmdstan_path() to change the path
##
## A newer version of CmdStan is available. See ?install_cmdstan() to install it.
## To disable this check set option or environment variable CMDSTANR_NO_VER_CHECK=TRUE.
```

```
library(rstan)
```

```
## Loading required package: StanHeaders
## Loading required package: ggplot2
## rstan (Version 2.21.3, GitRev: 2e1f913d3ca3)
## For execution on a local, multicore CPU with excess RAM we recommend calling
## options(mc.cores = parallel::detectCores()).
## To avoid recompilation of unchanged Stan programs, we recommend calling
## rstan_options(auto_write = TRUE)
```

```
stanfit <- function(fit) rstan::read_stan_csv(fit$output_files())

########### Data loading and prep

data(influenza_england_1978_school)
Ndata <- 763
sol <- influenza_england_1978_school
sol$time <- as.numeric(sol$date-min(sol$date)) + 2
sol$I <- sol$in_bed
forfit.sol <- sol
```

```r
noisy_I <- forfit.sol$I/Ndata
iniTime <- 0
iniI <- 1/Ndata

epi.data <- list(
  n_obs = length(noisy_I),
  t0 = iniTime,
  ts = forfit.sol$time,
  y_init = iniI,
  y = noisy_I,
  mu_beta = 0,
  sigma_beta = 1,
  mu_gamma = 0,
  sigma_gamma = 1,
  as = 9, #254,
  bs = 1#350-254
)

########## Model fitting

options(mc.cores = parallel::detectCores())
check_cmdstan_toolchain(fix = TRUE, quiet = TRUE)
file <- file.path("../stan", "sir_simple_I.stan")
SIR_code <- cmdstan_model(file)

pars.interest <- c("beta", "gamma", "S0", "R0", "sigma")

SIR.map.s1 <- SIR_code$optimize(data = epi.data, seed = 123)
```

```
## Rejecting initial value:
##   Error evaluating the log probability at the initial value.
## Exception: lognormal_lpdf: Location parameter[5] is -nan, but must be finite! (in '/tmp/RtmpF48rqt/m
## Rejecting initial value:
##   Error evaluating the log probability at the initial value.
## Exception: lognormal_lpdf: Location parameter[9] is -nan, but must be finite! (in '/tmp/RtmpF48rqt/m
## Initial log joint probability = -6867.72
##     Iter      log prob        ||dx||      ||grad||       alpha      alpha0  # evals  Notes
## Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps steps (
## Exception: lognormal_lpdf: Location parameter[1] is -nan, but must be finite! (in '/tmp/RtmpF48rqt/m
## Exception: lognormal_lpdf: Location parameter[5] is -nan, but must be finite! (in '/tmp/RtmpF48rqt/m
## Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps steps (
## Exception: lognormal_lpdf: Location parameter[2] is -nan, but must be finite! (in '/tmp/RtmpF48rqt/m
## Exception: lognormal_lpdf: Location parameter[7] is -nan, but must be finite! (in '/tmp/RtmpF48rqt/m
## Exception: lognormal_lpdf: Location parameter[4] is -nan, but must be finite! (in '/tmp/RtmpF48rqt/m
##       22       23.6556   4.58599e-05    0.00121342           1           1       44
## Optimization terminated normally:
##   Convergence detected: relative gradient magnitude is below tolerance
## Finished in  22.3 seconds.
```

```r
fit_mcmc <- SIR_code$sample(data = epi.data, seed = 123,
                            chains = 4, parallel_chains = 4,
                            refresh = 0)
```

```
## Running MCMC with 4 parallel chains...
```

```
## Chain 1 Rejecting initial value:
## Chain 1   Error evaluating the log probability at the initial value.
## Chain 1 Exception: lognormal_lpdf: Location parameter[5] is -nan, but must be finite! (in '/tmp/Rtmpl
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## Chain 1 Rejecting initial value:
## Chain 1   Error evaluating the log probability at the initial value.
## Chain 1 Exception: lognormal_lpdf: Location parameter[9] is -nan, but must be finite! (in '/tmp/Rtmpl
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## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 1 Exception: lognormal_lpdf: Location parameter[1] is -inf, but must be finite! (in '/tmp/Rtmpl
## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 1
## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 1 Exception: lognormal_lpdf: Location parameter[1] is -inf, but must be finite! (in '/tmp/Rtmpl
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## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 1
## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 1 Exception: ode_rk45: ode parameters and data[1] is inf, but must be finite! (in '/tmp/RtmpF48
## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 1
## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 1 Exception: ode_rk45: ode parameters and data[1] is inf, but must be finite! (in '/tmp/RtmpF48
## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi
```

```
## Chain 1
## Chain 2 Rejecting initial value:
## Chain 2   Error evaluating the log probability at the initial value.
## Chain 2 Exception: lognormal_lpdf: Location parameter[2] is -nan, but must be finite! (in '/tmp/Rtmpl
## Chain 2 Exception: lognormal_lpdf: Location parameter[2] is -nan, but must be finite! (in '/tmp/Rtmpl
## Chain 3 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 3 Exception: ode_rk45: ode parameters and data[1] is inf, but must be finite! (in '/tmp/RtmpF48
## Chain 3 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 3 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 3
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[1] is -nan, but must be finite! (in '/tmp/Rtmpl
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[1] is -nan, but must be finite! (in '/tmp/Rtmpl
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 4
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 3 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 3 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 3 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 3 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 3
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
```

```
## Chain 4 Exception: ode_rk45: ode parameters and data[1] is inf, but must be finite! (in '/tmp/RtmpF4
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like cova
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of th
## Chain 4 Exception: lognormal_lpdf: Location parameter[1] is -inf, but must be finite! (in '/tmp/Rtmp
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like cova
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of th
## Chain 2 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like cova
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of th
## Chain 2 Exception: lognormal_lpdf: Location parameter[1] is -nan, but must be finite! (in '/tmp/Rtmp
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like cova
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of th
## Chain 2 Exception: lognormal_lpdf: Location parameter[7] is -nan, but must be finite! (in '/tmp/Rtmp
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like cova
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of th
## Chain 2 Exception: ode_rk45: ode parameters and data[2] is inf, but must be finite! (in '/tmp/RtmpF4
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like cova
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of th
## Chain 2 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like cova
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 2
## Chain 3 finished in 8.5 seconds.
## Chain 4 finished in 5.9 seconds.
```

```
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 finished in 21.5 seconds.
## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 1 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 1
## Chain 1 finished in 38.5 seconds.
##
## All 4 chains finished successfully.
## Mean chain execution time: 18.6 seconds.
## Total execution time: 38.7 seconds.
```

```
SIR.posterior.s1 <- fit_mcmc
SIR.posterior.s1$cmdstan_diagnose()
```

```
## Processing csv files: /tmp/Rtmp2Px7Ds/sir_simple_I-202204051648-1-0cf3d4.csv, /tmp/Rtmp2Px7Ds/sir_sim
##
## Checking sampler transitions treedepth.
## Treedepth satisfactory for all transitions.
##
## Checking sampler transitions for divergences.
## No divergent transitions found.
##
## Checking E-BFMI - sampler transitions HMC potential energy.
## E-BFMI satisfactory.
##
## Effective sample size satisfactory.
##
## Split R-hat values satisfactory all parameters.
##
## Processing complete, no problems detected.
```

```
SIR.posterior.s1$cmdstan_summary()
```

```
## Inference for Stan model: sir_simple_I_model
## 4 chains: each with iter=(1000,1000,1000,1000); warmup=(0,0,0,0); thin=(1,1,1,1); 4000 iterations sav
##
## Warmup took (37, 20, 6.5, 3.9) seconds, 1.1 minutes total
## Sampling took (1.5, 1.8, 2.0, 2.0) seconds, 7.3 seconds total
##
##                    Mean     MCSE   StdDev       5%      50%      95%    N_Eff  N_Eff/s    R_hat
##
## lp__            1.5e+01  6.5e-02  2.2e+00  1.1e+01  1.6e+01  1.8e+01  1.1e+03  1.5e+02  1.0e+00
## accept_stat__      0.92  1.5e-02     0.12     0.69     0.97      1.0  6.1e+01  8.3e+00  1.0e+00
## stepsize__         0.24  2.1e-02    0.030     0.21     0.24     0.29  2.0e+00  2.7e-01  3.9e+13
```

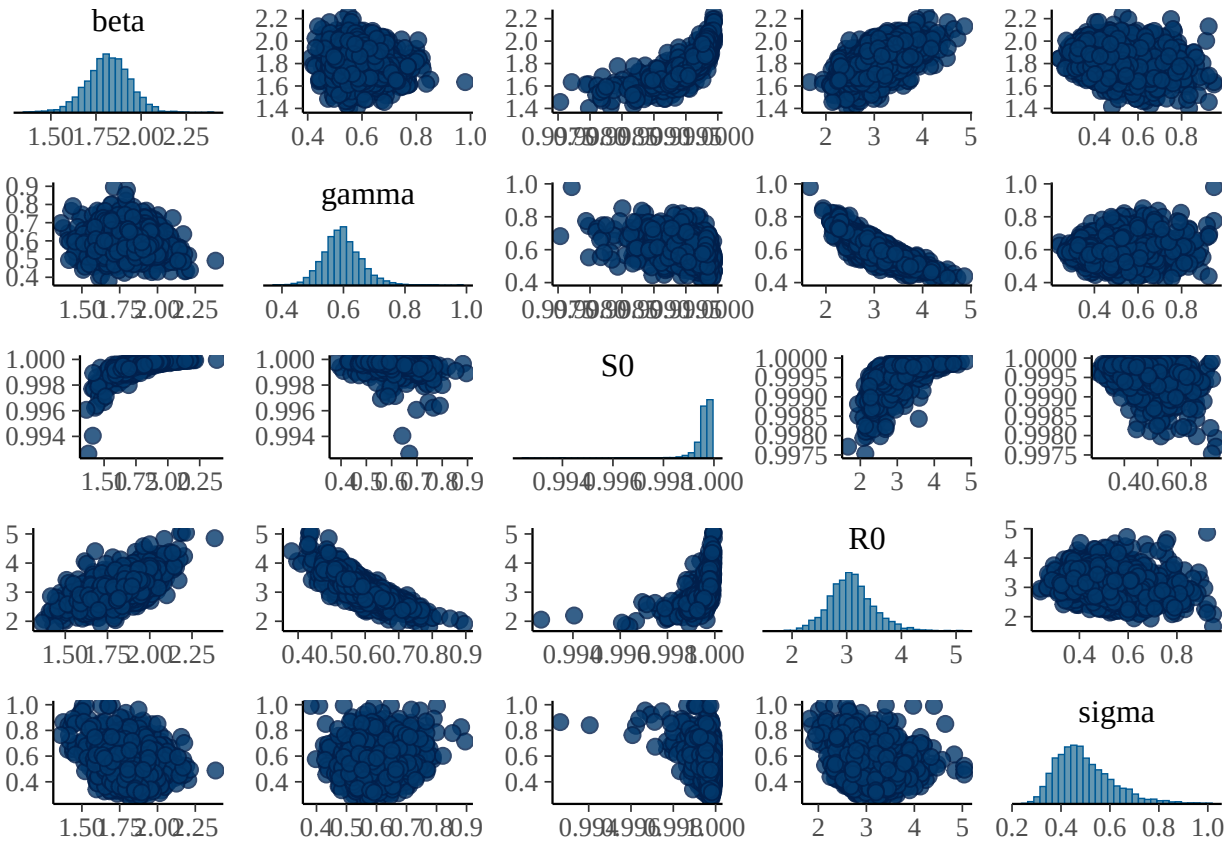
```
## treedepth__         3.7  4.8e-02     0.52      3.0      4.0      4.0  1.1e+02  1.6e+01  1.0e+00
## n_leapfrog__         15  5.4e-01      5.2      7.0       15       31  9.5e+01  1.3e+01  1.0e+00
## divergent__        0.00      nan     0.00     0.00     0.00     0.00      nan      nan      nan
## energy__            -12  8.7e-02      2.8      -16      -13     -7.2  1.0e+03  1.4e+02  1.0e+00
##
## r_init[1]       5.0e-01  5.1e-03  2.9e-01  4.3e-02  5.0e-01  9.6e-01  3.3e+03  4.5e+02  1.0e+00
## r_init[2]       5.0e-01  4.4e-03  2.9e-01  4.7e-02  5.1e-01  9.5e-01  4.5e+03  6.1e+02  1.0e+00
## beta            1.8e+00  3.0e-03  1.2e-01  1.6e+00  1.8e+00  2.0e+00  1.6e+03  2.1e+02  1.0e+00
## gamma           6.0e-01  1.2e-03  6.2e-02  5.0e-01  5.9e-01  7.0e-01  2.8e+03  3.9e+02  1.0e+00
## S0              1.0e+00  9.2e-06  3.3e-04  1.0e+00  1.0e+00  1.0e+00  1.3e+03  1.8e+02  1.0e+00
## sigma           5.0e-01  3.1e-03  1.2e-01  3.4e-01  4.7e-01  7.1e-01  1.4e+03  1.9e+02  1.0e+00
## R0              3.1e+00  9.0e-03  4.1e-01  2.4e+00  3.1e+00  3.8e+00  2.0e+03  2.8e+02  1.0e+00
## y0[1]           1.0e+00  9.2e-06  3.3e-04  1.0e+00  1.0e+00  1.0e+00  1.3e+03  1.8e+02  1.0e+00
## y0[2]           3.9e-04  9.2e-06  3.3e-04  1.2e-04  3.1e-04  9.1e-04  1.3e+03  1.8e+02  1.0e+00
## y0[3]           0.0e+00      nan  0.0e+00  0.0e+00  0.0e+00  0.0e+00      nan      nan      nan
## theta[1]        1.8e+00  3.0e-03  1.2e-01  1.6e+00  1.8e+00  2.0e+00  1.6e+03  2.1e+02  1.0e+00
## theta[2]        6.0e-01  1.2e-03  6.2e-02  5.0e-01  5.9e-01  7.0e-01  2.8e+03  3.9e+02  1.0e+00
## y_hat[1,1]      9.9e-01  7.6e-05  2.8e-03  9.9e-01  9.9e-01  1.0e+00  1.4e+03  1.8e+02  1.0e+00
## y_hat[1,2]      4.0e-03  4.6e-05  1.7e-03  2.1e-03  3.6e-03  6.9e-03  1.4e+03  1.9e+02  1.0e+00
## y_hat[1,3]      1.9e-03  3.0e-05  1.1e-03  7.8e-04  1.6e-03  3.7e-03  1.4e+03  1.9e+02  1.0e+00
## y_hat[2,1]      9.8e-01  1.6e-04  6.5e-03  9.7e-01  9.8e-01  9.9e-01  1.6e+03  2.2e+02  1.0e+00
## y_hat[2,2]      1.3e-02  9.4e-05  4.0e-03  8.0e-03  1.2e-02  2.0e-02  1.8e+03  2.4e+02  1.0e+00
## y_hat[2,3]      6.3e-03  7.4e-05  2.8e-03  3.4e-03  5.8e-03  1.1e-02  1.4e+03  2.0e+02  1.0e+00
## y_hat[3,1]      9.4e-01  3.1e-04  1.5e-02  9.1e-01  9.4e-01  9.6e-01  2.4e+03  3.3e+02  1.0e+00
## y_hat[3,2]      4.0e-02  1.8e-04  1.0e-02  2.7e-02  3.9e-02  5.8e-02  3.3e+03  4.4e+02  1.0e+00
## y_hat[3,3]      2.1e-02  1.5e-04  6.3e-03  1.3e-02  1.9e-02  3.1e-02  1.7e+03  2.4e+02  1.0e+00
## y_hat[4,1]      8.3e-01  6.5e-04  3.9e-02  7.6e-01  8.3e-01  8.8e-01  3.6e+03  4.9e+02  1.0e+00
## y_hat[4,2]      1.1e-01  5.0e-04  2.9e-02  7.2e-02  1.1e-01  1.6e-01  3.3e+03  4.5e+02  1.0e+00
## y_hat[4,3]      6.2e-02  2.5e-04  1.4e-02  4.4e-02  6.1e-02  8.6e-02  2.9e+03  3.9e+02  1.0e+00
## y_hat[5,1]      6.1e-01  1.4e-03  7.6e-02  4.8e-01  6.2e-01  7.3e-01  2.9e+03  4.0e+02  1.0e+00
## y_hat[5,2]      2.3e-01  1.1e-03  5.3e-02  1.5e-01  2.3e-01  3.2e-01  2.4e+03  3.2e+02  1.0e+00
## y_hat[5,3]      1.6e-01  4.6e-04  2.9e-02  1.2e-01  1.6e-01  2.1e-01  3.9e+03  5.3e+02  1.0e+00
## y_hat[6,1]      3.8e-01  1.9e-03  8.8e-02  2.4e-01  3.8e-01  5.3e-01  2.2e+03  3.0e+02  1.0e+00
## y_hat[6,2]      3.0e-01  1.2e-03  5.0e-02  2.1e-01  3.0e-01  3.8e-01  1.9e+03  2.6e+02  1.0e+00
## y_hat[6,3]      3.2e-01  8.2e-04  4.6e-02  2.5e-01  3.2e-01  4.0e-01  3.1e+03  4.3e+02  1.0e+00
## y_hat[7,1]      2.3e-01  1.7e-03  7.3e-02  1.2e-01  2.2e-01  3.6e-01  1.9e+03  2.6e+02  1.0e+00
## y_hat[7,2]      2.8e-01  7.2e-04  3.4e-02  2.2e-01  2.8e-01  3.3e-01  2.3e+03  3.1e+02  1.0e+00
## y_hat[7,3]      5.0e-01  1.1e-03  5.3e-02  4.0e-01  5.0e-01  5.8e-01  2.4e+03  3.3e+02  1.0e+00
## y_hat[8,1]      1.5e-01  1.3e-03  5.6e-02  7.0e-02  1.4e-01  2.5e-01  1.8e+03  2.4e+02  1.0e+00
## y_hat[8,2]      2.1e-01  4.4e-04  2.5e-02  1.7e-01  2.1e-01  2.5e-01  3.2e+03  4.4e+02  1.0e+00
## y_hat[8,3]      6.4e-01  1.1e-03  5.1e-02  5.5e-01  6.5e-01  7.2e-01  2.0e+03  2.7e+02  1.0e+00
## y_hat[9,1]      1.1e-01  1.1e-03  4.5e-02  4.9e-02  1.0e-01  1.9e-01  1.7e+03  2.3e+02  1.0e+00
## y_hat[9,2]      1.5e-01  3.3e-04  2.0e-02  1.2e-01  1.5e-01  1.8e-01  3.6e+03  4.9e+02  1.0e+00
## y_hat[9,3]      7.5e-01  1.1e-03  4.5e-02  6.7e-01  7.5e-01  8.1e-01  1.7e+03  2.3e+02  1.0e+00
## y_hat[10,1]     8.7e-02  9.2e-04  3.8e-02  3.8e-02  8.0e-02  1.6e-01  1.7e+03  2.3e+02  1.0e+00
## y_hat[10,2]     9.6e-02  2.7e-04  1.6e-02  7.3e-02  9.5e-02  1.2e-01  3.4e+03  4.6e+02  1.0e+00
## y_hat[10,3]     8.2e-01  9.8e-04  3.9e-02  7.4e-01  8.2e-01  8.7e-01  1.6e+03  2.2e+02  1.0e+00
## y_hat[11,1]     7.6e-02  8.2e-04  3.4e-02  3.2e-02  7.0e-02  1.4e-01  1.7e+03  2.4e+02  1.0e+00
## y_hat[11,2]     6.1e-02  2.1e-04  1.2e-02  4.4e-02  6.0e-02  8.2e-02  3.1e+03  4.2e+02  1.0e+00
## y_hat[11,3]     8.6e-01  8.8e-04  3.4e-02  8.0e-01  8.7e-01  9.1e-01  1.5e+03  2.1e+02  1.0e+00
## y_hat[12,1]     6.9e-02  7.5e-04  3.2e-02  2.9e-02  6.4e-02  1.3e-01  1.8e+03  2.4e+02  1.0e+00
## y_hat[12,2]     3.9e-02  1.6e-04  8.5e-03  2.7e-02  3.8e-02  5.4e-02  2.9e+03  3.9e+02  1.0e+00
## y_hat[12,3]     8.9e-01  8.1e-04  3.2e-02  8.3e-01  9.0e-01  9.3e-01  1.5e+03  2.1e+02  1.0e+00
## y_hat[13,1]     6.6e-02  7.2e-04  3.0e-02  2.7e-02  6.0e-02  1.3e-01  1.8e+03  2.4e+02  1.0e+00
```

```
## y_hat[13,2]     2.4e-02  1.2e-04  6.0e-03  1.6e-02  2.3e-02  3.5e-02  2.7e+03  3.7e+02  1.0e+00
## y_hat[13,3]     9.1e-01  7.6e-04  3.0e-02  8.5e-01  9.2e-01  9.5e-01  1.6e+03  2.1e+02  1.0e+00
## y_hat[14,1]     6.4e-02  6.9e-04  2.9e-02  2.6e-02  5.8e-02  1.2e-01  1.8e+03  2.5e+02  1.0e+00
## y_hat[14,2]     1.5e-02  8.3e-05  4.2e-03  9.5e-03  1.4e-02  2.3e-02  2.6e+03  3.5e+02  1.0e+00
## y_hat[14,3]     9.2e-01  7.3e-04  2.9e-02  8.6e-01  9.3e-01  9.6e-01  1.6e+03  2.2e+02  1.0e+00
## y_rep[1]        4.6e-03  8.0e-05  3.7e-03  1.3e-03  3.7e-03  1.1e-02  2.1e+03  2.9e+02  1.0e+00
## y_rep[2]        1.5e-02  1.9e-04  1.0e-02  4.9e-03  1.2e-02  3.2e-02  3.0e+03  4.1e+02  1.0e+00
## y_rep[3]        4.6e-02  4.7e-04  3.0e-02  1.6e-02  3.9e-02  1.0e-01  4.1e+03  5.6e+02  1.0e+00
## y_rep[4]        1.3e-01  1.5e-03  9.3e-02  4.3e-02  1.1e-01  2.8e-01  3.7e+03  5.0e+02  1.0e+00
## y_rep[5]        2.6e-01  2.8e-03  1.7e-01  8.7e-02  2.2e-01  5.4e-01  3.7e+03  5.1e+02  1.0e+00
## y_rep[6]        3.4e-01  3.6e-03  2.1e-01  1.2e-01  2.9e-01  7.0e-01  3.4e+03  4.6e+02  1.0e+00
## y_rep[7]        3.1e-01  2.9e-03  1.8e-01  1.2e-01  2.8e-01  6.4e-01  3.9e+03  5.3e+02  1.0e+00
## y_rep[8]        2.4e-01  2.2e-03  1.4e-01  8.8e-02  2.1e-01  4.9e-01  4.1e+03  5.6e+02  1.0e+00
## y_rep[9]        1.7e-01  1.6e-03  9.7e-02  6.3e-02  1.5e-01  3.4e-01  3.6e+03  4.9e+02  1.0e+00
## y_rep[10]       1.1e-01  1.1e-03  6.8e-02  4.0e-02  9.6e-02  2.3e-01  3.9e+03  5.3e+02  1.0e+00
## y_rep[11]       7.1e-02  7.8e-04  4.7e-02  2.6e-02  6.0e-02  1.4e-01  3.7e+03  5.0e+02  1.0e+00
## y_rep[12]       4.4e-02  5.6e-04  3.1e-02  1.5e-02  3.7e-02  9.2e-02  3.0e+03  4.1e+02  1.0e+00
## y_rep[13]       2.8e-02  2.8e-04  1.8e-02  9.6e-03  2.3e-02  6.0e-02  3.9e+03  5.3e+02  1.0e+00
## y_rep[14]       1.7e-02  2.3e-04  1.3e-02  5.7e-03  1.5e-02  3.7e-02  3.5e+03  4.8e+02  1.0e+00
##
## Samples were drawn using hmc with nuts.
## For each parameter, N_Eff is a crude measure of effective sample size,
## and R_hat is the potential scale reduction factor on split chains (at
## convergence, R_hat=1).
```

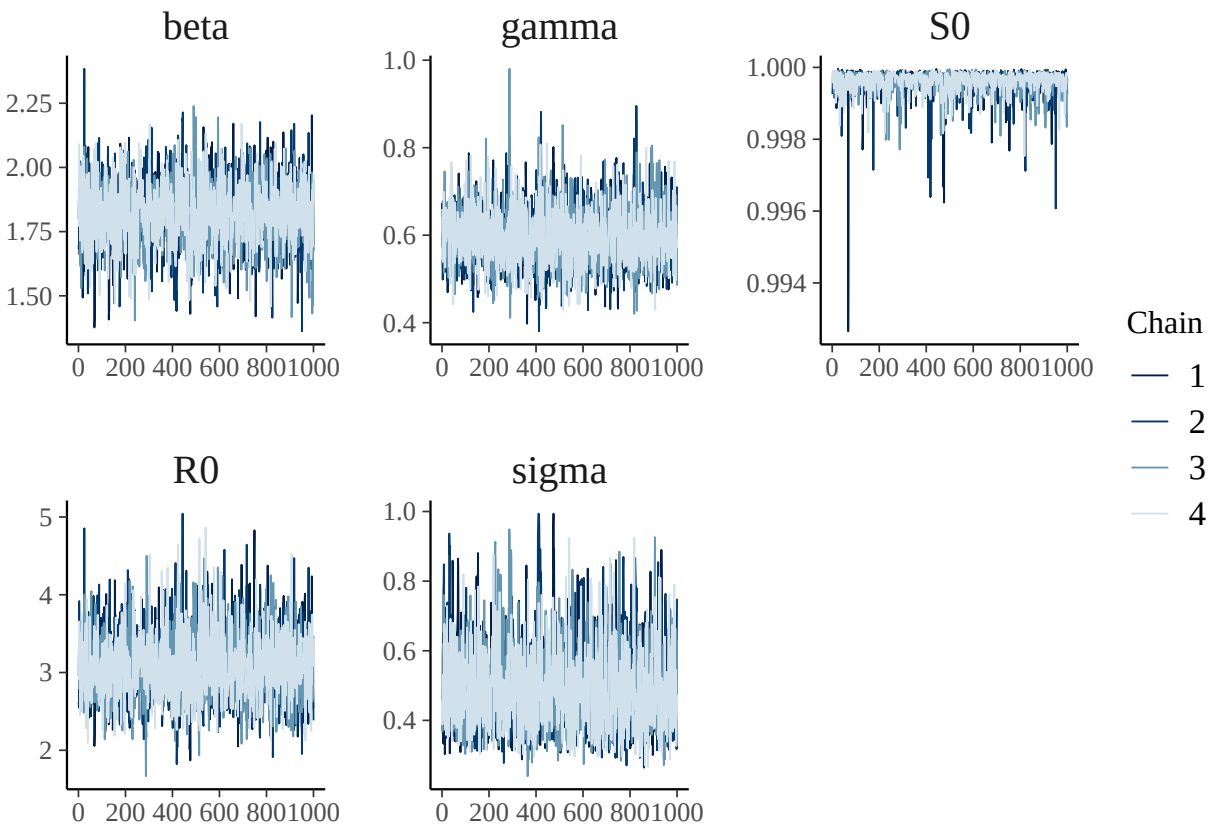
```
print(stanfit(SIR.posterior.s1), pars = pars.interest)
```

```
## Inference for Stan model: sir_simple_I-202204051648-1-0cf3d4.
## 4 chains, each with iter=2000; warmup=1000; thin=1;
## post-warmup draws per chain=1000, total post-warmup draws=4000.
##
##       mean se_mean   sd 2.5%  25%  50%  75% 97.5% n_eff Rhat
## beta  1.82    0.00 0.12 1.57 1.74 1.82 1.90  2.05  1562    1
## gamma 0.60    0.00 0.06 0.48 0.56 0.59 0.63  0.73  2837    1
## S0    1.00    0.00 0.00 1.00 1.00 1.00 1.00  1.00  1311    1
## R0    3.09    0.01 0.41 2.34 2.82 3.06 3.31  3.97  2017    1
## sigma 0.50    0.00 0.12 0.32 0.41 0.47 0.56  0.78  1421    1
##
## Samples were drawn using NUTS(diag_e) at Tue Apr 05 16:49:23 2022.
## For each parameter, n_eff is a crude measure of effective sample size,
## and Rhat is the potential scale reduction factor on split chains (at
## convergence, Rhat=1).
```

```
mcmc_pairs(SIR.posterior.s1$draws(pars.interest))
```




```
p <- mcmc_trace(SIR.posterior.s1$draws(pars.interest))
p + facet_text(size = 15)
```




```
simulated_trajectories.s1 <- SIR.posterior.s1$draws('y_rep', format = "df")[, c(1:14)]
```

```
## Warning: Dropping 'draws_df' class as required metadata was removed.
```

```
predicted.s1 <- data.frame(time = epi.data$ts,
                           lower = apply(simulated_trajectories.s1,
                           2, function(x) as.numeric(quantile(x, probs = .025)))[1:14],
                           post_mean = colMeans(simulated_trajectories.s1),
                           post_median = apply(simulated_trajectories.s1, 2, median),
                           upper = apply(simulated_trajectories.s1,
                           2, function(x) as.numeric(quantile(x, probs = .975)))[1:14],
                           s = "1")

### sigma_beta = sigma_gamma = 10
epi.data$sigma_beta <- 10
epi.data$sigma_gamma <- 10

SIR.map.s10 <- SIR_code$optimize(data = epi.data, seed = 123)
```

```
## Rejecting initial value:
##   Error evaluating the log probability at the initial value.
## Exception: lognormal_lpdf: Location parameter[5] is -nan, but must be finite! (in '/tmp/RtmpF48rqt/m
## Rejecting initial value:
##   Error evaluating the log probability at the initial value.
## Exception: lognormal_lpdf: Location parameter[9] is -nan, but must be finite! (in '/tmp/RtmpF48rqt/m
## Initial log joint probability = -6871.24
##     Iter      log prob        ||dx||      ||grad||       alpha      alpha0  # evals  Notes
##       23       103.257     0.0353925   2.20322e-06           1           1       37
## Optimization terminated normally:
```

```
##   Convergence detected: relative gradient magnitude is below tolerance
## Finished in  0.1 seconds.
```

```r
fit_mcmc <- SIR_code$sample(data = epi.data, seed = 123,
                            chains = 4, parallel_chains = 4,
                            refresh = 0)
```

```
## Running MCMC with 4 parallel chains...

## Chain 1 Rejecting initial value:

## Chain 1   Error evaluating the log probability at the initial value.

## Chain 1 Exception: lognormal_lpdf: Location parameter[5] is -nan, but must be finite! (in '/tmp/Rtmpl
## Chain 1 Exception: lognormal_lpdf: Location parameter[5] is -nan, but must be finite! (in '/tmp/Rtmpl

## Chain 1 Rejecting initial value:

## Chain 1   Error evaluating the log probability at the initial value.

## Chain 1 Exception: lognormal_lpdf: Location parameter[9] is -nan, but must be finite! (in '/tmp/Rtmpl
## Chain 1 Exception: lognormal_lpdf: Location parameter[9] is -nan, but must be finite! (in '/tmp/Rtmpl

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: lognormal_lpdf: Location parameter[1] is -inf, but must be finite! (in '/tmp/Rtmpl

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: lognormal_lpdf: Location parameter[1] is -inf, but must be finite! (in '/tmp/Rtmpl

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

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## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: lognormal_lpdf: Location parameter[1] is -nan, but must be finite! (in '/tmp/Rtmpl

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## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: ode_rk45: ode parameters and data[1] is inf, but must be finite! (in '/tmp/RtmpF48

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi
```

```
## Chain 1
## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 1 Exception: ode_rk45: ode parameters and data[1] is inf, but must be finite! (in '/tmp/RtmpF48
## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 1
## Chain 2 Rejecting initial value:
## Chain 2   Error evaluating the log probability at the initial value.
## Chain 2 Exception: lognormal_lpdf: Location parameter[2] is -nan, but must be finite! (in '/tmp/Rtmpl
## Chain 2 Exception: lognormal_lpdf: Location parameter[2] is -nan, but must be finite! (in '/tmp/Rtmpl
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[1] is -nan, but must be finite! (in '/tmp/Rtmpl
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[1] is -nan, but must be finite! (in '/tmp/Rtmpl
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 4
## Chain 3 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 3 Exception: lognormal_lpdf: Location parameter[3] is -nan, but must be finite! (in '/tmp/Rtmpl
## Chain 3 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 3 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 3
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
```

```
## Chain 4 Exception: ode_rk45: ode parameters and data[1] is inf, but must be finite! (in '/tmp/RtmpF48
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[1] is -inf, but must be finite! (in '/tmp/Rtmpl
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[4] is -nan, but must be finite! (in '/tmp/Rtmpl
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 4
## Chain 1 finished in 5.3 seconds.
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
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## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
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## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: lognormal_lpdf: Location parameter[7] is -nan, but must be finite! (in '/tmp/Rtmpl
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: ode_rk45: ode parameters and data[2] is inf, but must be finite! (in '/tmp/RtmpF48
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
```

```
## Chain 4 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
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## Chain 2
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
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## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[4] is -nan, but must be finite! (in '/tmp/Rtmpl
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
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## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
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## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[1] is -nan, but must be finite! (in '/tmp/Rtmpl
```

```
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of th
## Chain 4 Exception: lognormal_lpdf: Location parameter[7] is -nan, but must be finite! (in '/tmp/Rtmp
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
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## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of th
## Chain 4 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
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## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of th
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## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of th
## Chain 4 Exception: lognormal_lpdf: Location parameter[7] is -nan, but must be finite! (in '/tmp/Rtmp
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of th
## Chain 4 Exception: lognormal_lpdf: Location parameter[3] is -nan, but must be finite! (in '/tmp/Rtmp
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of th
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## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of th
## Chain 4 Exception: lognormal_lpdf: Location parameter[1] is -nan, but must be finite! (in '/tmp/Rtmp
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
```

```
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[4] is -nan, but must be finite! (in '/tmp/Rtmpl
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## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
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## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
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## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
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## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[3] is -nan, but must be finite! (in '/tmp/Rtmpl
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[11] is -nan, but must be finite! (in '/tmp/Rtmp
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[12] is -nan, but must be finite! (in '/tmp/Rtmp
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or mi
```

```
## Chain 4
## Chain 3 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 3 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 3 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 3 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 3
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[1] is -nan, but must be finite! (in '/tmp/Rtmpl
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
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## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[2] is -nan, but must be finite! (in '/tmp/Rtmpl
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 4
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
```

```
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[7] is -nan, but must be finite! (in '/tmp/Rtmp
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[4] is -nan, but must be finite! (in '/tmp/Rtmp
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[1] is -nan, but must be finite! (in '/tmp/Rtmp
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[9] is -nan, but must be finite! (in '/tmp/Rtmp
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
## Chain 2 finished in 48.3 seconds.
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
```

```
## Chain 3 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 3 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 3 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 3 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 3
## Chain 3 finished in 59.2 seconds.
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[1] is -nan, but must be finite! (in '/tmp/Rtmp
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[3] is -nan, but must be finite! (in '/tmp/Rtmp
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[9] is -nan, but must be finite! (in '/tmp/Rtmp
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[1] is -nan, but must be finite! (in '/tmp/Rtmp
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
```

```
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[4] is -nan, but must be finite! (in '/tmp/Rtmpl
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[5] is -nan, but must be finite! (in '/tmp/Rtmpl
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[11] is -nan, but must be finite! (in '/tmp/Rtm
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
```

```
## Chain 4 Exception: lognormal_lpdf: Location parameter[4] is -nan, but must be finite! (in '/tmp/Rtmpl
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[1] is -nan, but must be finite! (in '/tmp/Rtmpl
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 4
## Chain 4 finished in 99.9 seconds.
##
## All 4 chains finished successfully.
## Mean chain execution time: 53.2 seconds.
## Total execution time: 102.7 seconds.
##
## Warning: 47 of 4000 (1.0%) transitions ended with a divergence.
## This may indicate insufficient exploration of the posterior distribution.
## Possible remedies include:
##   * Increasing adapt_delta closer to 1 (default is 0.8)
##   * Reparameterizing the model (e.g. using a non-centered parameterization)
##   * Using informative or weakly informative prior distributions
```

```
SIR.posterior.s10 <- fit_mcmc
SIR.posterior.s10$cmdstan_diagnose()
```

```
## Processing csv files: /tmp/Rtmp2Px7Ds/sir_simple_I-202204051649-1-786441.csv, /tmp/Rtmp2Px7Ds/sir_sim
##
## Checking sampler transitions treedepth.
## Treedepth satisfactory for all transitions.
##
## Checking sampler transitions for divergences.
## 47 of 4000 (1.2%) transitions ended with a divergence.
## These divergent transitions indicate that HMC is not fully able to explore the posterior distributio
## Try increasing adapt delta closer to 1.
## If this doesn't remove all divergences, try to reparameterize the model.
##
## Checking E-BFMI - sampler transitions HMC potential energy.
## The E-BFMI, 0.07, is below the nominal threshold of 0.3 which suggests that HMC may have trouble expl
## If possible, try to reparameterize the model.
##
## The following parameters had fewer than 0.001 effective draws per transition:
##   beta, gamma, S0, sigma, y0[1], y0[2], theta[1], theta[2], y_hat[1,1], y_hat[2,1], y_hat[4,1], y_hat
## Such low values indicate that the effective sample size estimators may be biased high and actual peri
##
## The following parameters had split R-hat greater than 1.1:
##   beta, gamma, S0, sigma, y0[1], y0[2], theta[1], theta[2], y_hat[1,1], y_hat[2,1], y_hat[4,1], y_hat
## Such high values indicate incomplete mixing and biased estimation.
## You should consider regularizating your model with additional prior information or a more effective p
##
## Processing complete.
```

```r
SIR.posterior.s10$cmdstan_summary()
```

```
## Inference for Stan model: sir_simple_I_model
## 4 chains: each with iter=(1000,1000,1000,1000); warmup=(0,0,0,0); thin=(1,1,1,1); 4000 iterations sav
##
## Warmup took (3.3, 47, 58, 49) seconds, 2.6 minutes total
## Sampling took (2.0, 1.7, 1.7, 51) seconds, 56 seconds total
##
##                    Mean     MCSE   StdDev       5%      50%      95%    N_Eff  N_Eff/s    R_hat
##
## lp__            5.8e+00  6.5e+00  9.3e+00 -1.1e+01  1.1e+01  1.4e+01  2.1e+00  3.7e-02  4.8e+00
## accept_stat__      0.89  1.7e-02     0.17     0.54     0.96     1.00  9.6e+01  1.7e+00  1.0e+00
## stepsize__         0.20  1.1e-03    0.051     0.12     0.22     0.24  2.0e+03  3.6e+01  7.3e+13
## treedepth__         3.9  1.9e-01     0.68      3.0      4.0      5.0  1.3e+01  2.3e-01  1.1e+00
## n_leapfrog__         17  3.7e+00      8.1      7.0       15       31  4.7e+00  8.4e-02  1.3e+00
## divergent__       0.012      nan     0.11     0.00     0.00     0.00      nan      nan      nan
## energy__           -2.8  6.5e+00      9.5      -12     -7.2       15  2.1e+00  3.8e-02  3.8e+00
##
## r_init[1]       5.0e-01  5.3e-03  2.9e-01  4.4e-02  5.0e-01  9.5e-01  3.0e+03  5.3e+01  1.0e+00
## r_init[2]       5.1e-01  5.1e-03  2.9e-01  4.7e-02  5.1e-01  9.6e-01  3.2e+03  5.8e+01  1.0e+00
## beta            1.4e+00  5.6e-01  7.9e-01  6.9e-07  1.8e+00  2.0e+00  2.0e+00  3.6e-02  8.3e+00
## gamma           4.5e-01  1.8e-01  2.6e-01  8.7e-07  5.7e-01  6.9e-01  2.1e+00  3.7e-02  5.2e+00
## S0              9.8e-01  2.1e-02  3.2e-02  9.2e-01  1.0e+00  1.0e+00  2.2e+00  3.9e-02  3.2e+00
## sigma           6.1e-01  1.5e-01  2.3e-01  3.5e-01  5.3e-01  9.9e-01  2.4e+00  4.2e-02  2.4e+00
## R0              7.6e+07  7.4e+07  3.1e+09  2.1e-03  3.1e+00  3.3e+02  1.8e+03  3.2e+01  1.0e+00
## y0[1]           9.8e-01  2.1e-02  3.2e-02  9.2e-01  1.0e+00  1.0e+00  2.2e+00  3.9e-02  3.2e+00
## y0[2]           1.8e-02  2.1e-02  3.2e-02  1.3e-04  3.9e-04  8.3e-02  2.2e+00  3.9e-02  3.2e+00
## y0[3]           0.0e+00      nan  0.0e+00  0.0e+00  0.0e+00  0.0e+00      nan      nan      nan
## theta[1]        1.4e+00  5.6e-01  7.9e-01  6.9e-07  1.8e+00  2.0e+00  2.0e+00  3.6e-02  8.3e+00
## theta[2]        4.5e-01  1.8e-01  2.6e-01  8.7e-07  5.7e-01  6.9e-01  2.1e+00  3.7e-02  5.2e+00
## y_hat[1,1]      9.8e-01  2.0e-02  3.0e-02  9.2e-01  9.9e-01  1.0e+00  2.2e+00  4.0e-02  3.0e+00
## y_hat[1,2]      2.0e-02  2.0e-02  3.0e-02  2.2e-03  4.1e-03  8.2e-02  2.2e+00  3.9e-02  3.3e+00
## y_hat[1,3]      1.6e-03  1.2e-04  2.1e-03  1.1e-07  1.4e-03  3.8e-03  3.1e+02  5.6e+00  1.0e+00
## y_hat[2,1]      9.7e-01  1.6e-02  2.5e-02  9.2e-01  9.8e-01  9.9e-01  2.4e+00  4.3e-02  2.3e+00
## y_hat[2,2]      2.7e-02  1.7e-02  2.6e-02  8.2e-03  1.3e-02  8.2e-02  2.3e+00  4.0e-02  2.9e+00
## y_hat[2,3]      5.1e-03  1.4e-03  3.9e-03  1.7e-07  5.0e-03  1.1e-02  8.2e+00  1.5e-01  1.2e+00
## y_hat[3,1]      9.4e-01  3.1e-03  1.8e-02  9.0e-01  9.4e-01  9.6e-01  3.1e+01  5.6e-01  1.0e+00
## y_hat[3,2]      4.7e-02  9.2e-03  1.8e-02  2.7e-02  4.2e-02  8.3e-02  3.7e+00  6.5e-02  1.4e+00
## y_hat[3,3]      1.6e-02  5.7e-03  9.9e-03  2.2e-07  1.7e-02  3.0e-02  3.0e+00  5.4e-02  1.7e+00
## y_hat[4,1]      8.5e-01  3.3e-02  5.8e-02  7.6e-01  8.4e-01  9.5e-01  3.1e+00  5.4e-02  1.6e+00
## y_hat[4,2]      1.0e-01  1.5e-02  3.3e-02  5.3e-02  9.9e-02  1.6e-01  5.3e+00  9.3e-02  1.3e+00
## y_hat[4,3]      4.7e-02  1.9e-02  2.9e-02  2.8e-07  5.6e-02  8.4e-02  2.4e+00  4.2e-02  2.4e+00
## y_hat[5,1]      6.9e-01  1.0e-01  1.6e-01  4.8e-01  6.5e-01  9.4e-01  2.4e+00  4.3e-02  2.4e+00
## y_hat[5,2]      1.9e-01  5.2e-02  8.5e-02  5.4e-02  2.0e-01  3.2e-01  2.7e+00  4.9e-02  1.9e+00
## y_hat[5,3]      1.2e-01  4.9e-02  7.4e-02  3.4e-07  1.5e-01  2.1e-01  2.2e+00  4.0e-02  3.0e+00
## y_hat[6,1]      5.1e-01  1.7e-01  2.5e-01  2.4e-01  4.1e-01  9.4e-01  2.2e+00  3.9e-02  3.4e+00
## y_hat[6,2]      2.5e-01  7.3e-02  1.1e-01  5.4e-02  2.8e-01  3.8e-01  2.3e+00  4.1e-02  2.7e+00
## y_hat[6,3]      2.4e-01  9.9e-02  1.4e-01  3.9e-07  3.0e-01  4.0e-01  2.1e+00  3.8e-02  3.7e+00
## y_hat[7,1]      4.0e-01  2.2e-01  3.1e-01  1.2e-01  2.5e-01  9.4e-01  2.1e+00  3.7e-02  5.2e+00
## y_hat[7,2]      2.3e-01  6.6e-02  9.7e-02  5.4e-02  2.7e-01  3.3e-01  2.2e+00  3.9e-02  3.5e+00
## y_hat[7,3]      3.8e-01  1.5e-01  2.2e-01  4.5e-07  4.8e-01  5.8e-01  2.1e+00  3.7e-02  5.0e+00
## y_hat[8,1]      3.4e-01  2.4e-01  3.4e-01  7.2e-02  1.6e-01  9.4e-01  2.0e+00  3.6e-02  7.6e+00
## y_hat[8,2]      1.8e-01  4.5e-02  6.6e-02  5.4e-02  2.0e-01  2.5e-01  2.2e+00  3.9e-02  3.1e+00
## y_hat[8,3]      4.8e-01  2.0e-01  2.8e-01  5.0e-07  6.3e-01  7.1e-01  2.0e+00  3.6e-02  6.8e+00
```

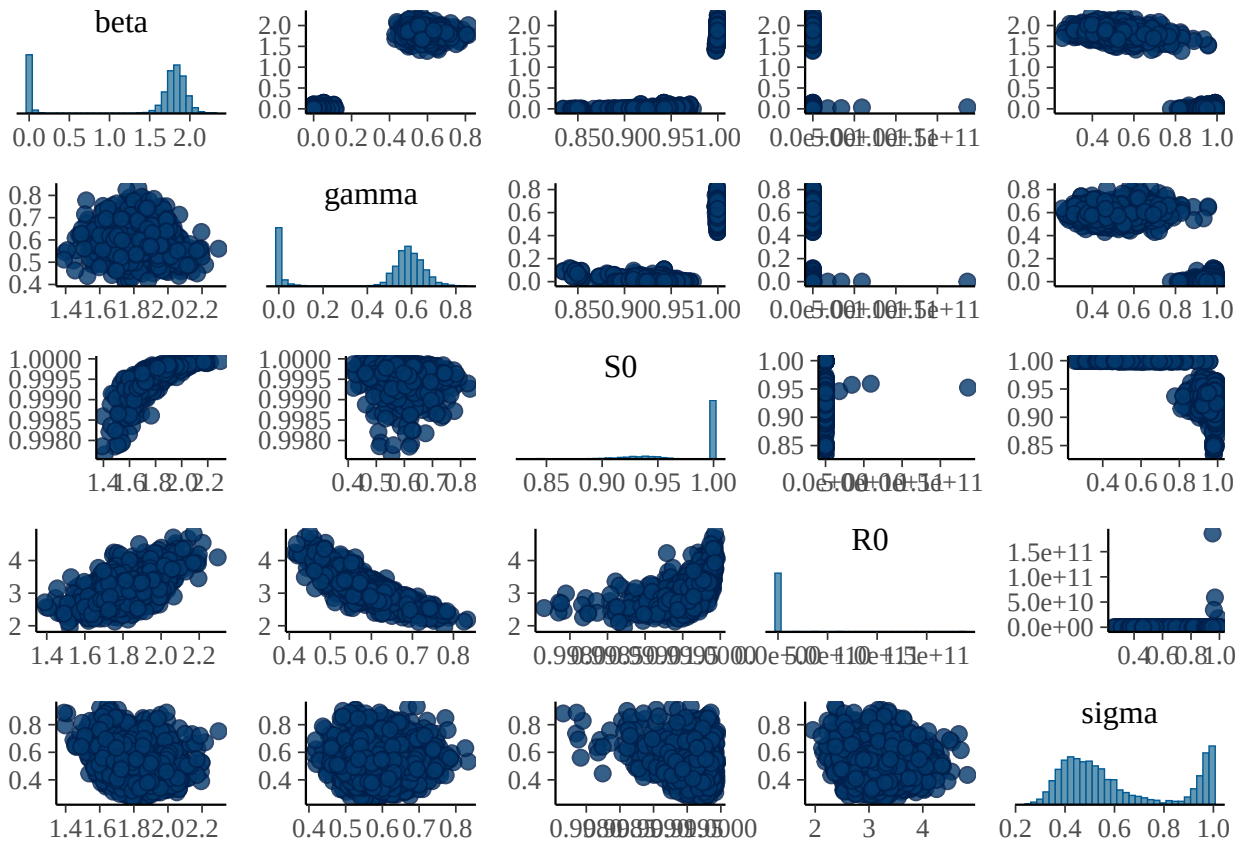
```
## y_hat[9,1]      3.1e-01  2.5e-01  3.6e-01  5.0e-02  1.2e-01  9.4e-01  2.0e+00  3.6e-02  9.9e+00
## y_hat[9,2]      1.3e-01  2.4e-02  3.8e-02  5.4e-02  1.4e-01  1.8e-01  2.5e+00  4.4e-02  2.2e+00
## y_hat[9,3]      5.6e-01  2.3e-01  3.2e-01  5.6e-07  7.4e-01  8.1e-01  2.0e+00  3.6e-02  9.0e+00
## y_hat[10,1]     2.9e-01  2.6e-01  3.7e-01  4.0e-02  9.4e-02  9.4e-01  2.0e+00  3.6e-02  1.2e+01
## y_hat[10,2]     8.9e-02  8.7e-03  2.0e-02  5.4e-02  9.0e-02  1.2e-01  5.1e+00  9.0e-02  1.3e+00
## y_hat[10,3]     6.2e-01  2.5e-01  3.5e-01  6.2e-07  8.1e-01  8.7e-01  2.0e+00  3.6e-02  1.1e+01
## y_hat[11,1]     2.9e-01  2.6e-01  3.7e-01  3.4e-02  8.2e-02  9.4e-01  2.0e+00  3.6e-02  1.3e+01
## y_hat[11,2]     6.3e-02  2.0e-03  1.4e-02  4.5e-02  6.1e-02  8.8e-02  5.0e+01  8.9e-01  1.0e+00
## y_hat[11,3]     6.5e-01  2.6e-01  3.7e-01  6.8e-07  8.6e-01  9.1e-01  2.0e+00  3.6e-02  1.4e+01
## y_hat[12,1]     2.8e-01  2.6e-01  3.7e-01  3.0e-02  7.6e-02  9.4e-01  2.0e+00  3.6e-02  1.4e+01
## y_hat[12,2]     4.6e-02  9.9e-03  1.8e-02  2.8e-02  4.1e-02  8.3e-02  3.3e+00  5.9e-02  1.5e+00
## y_hat[12,3]     6.7e-01  2.7e-01  3.9e-01  7.3e-07  8.9e-01  9.3e-01  2.0e+00  3.6e-02  1.5e+01
## y_hat[13,1]     2.8e-01  2.6e-01  3.7e-01  2.9e-02  7.2e-02  9.4e-01  2.0e+00  3.6e-02  1.4e+01
## y_hat[13,2]     3.5e-02  1.4e-02  2.3e-02  1.7e-02  2.6e-02  8.3e-02  2.6e+00  4.5e-02  2.1e+00
## y_hat[13,3]     6.9e-01  2.8e-01  3.9e-01  7.9e-07  9.0e-01  9.5e-01  2.0e+00  3.6e-02  1.6e+01
## y_hat[14,1]     2.8e-01  2.6e-01  3.7e-01  2.7e-02  7.0e-02  9.4e-01  2.0e+00  3.6e-02  1.5e+01
## y_hat[14,2]     2.9e-02  1.7e-02  2.6e-02  1.0e-02  1.6e-02  8.3e-02  2.4e+00  4.2e-02  2.4e+00
## y_hat[14,3]     6.9e-01  2.8e-01  4.0e-01  8.5e-07  9.2e-01  9.6e-01  2.0e+00  3.6e-02  1.7e+01
## y_rep[1]        2.9e-02  3.2e-02  7.1e-02  1.5e-03  4.5e-03  1.5e-01  5.1e+00  9.0e-02  1.3e+00
## y_rep[2]        3.9e-02  3.1e-02  8.9e-02  5.1e-03  1.5e-02  1.6e-01  8.3e+00  1.5e-01  1.2e+00
## y_rep[3]        5.9e-02  1.7e-02  7.2e-02  1.5e-02  4.1e-02  1.5e-01  1.8e+01  3.2e-01  1.1e+00
## y_rep[4]        1.2e-01  1.9e-03  1.1e-01  2.7e-02  1.0e-01  2.8e-01  3.3e+03  5.9e+01  1.0e+00
## y_rep[5]        2.3e-01  5.1e-02  1.7e-01  2.9e-02  2.0e-01  5.4e-01  1.1e+01  2.0e-01  1.1e+00
## y_rep[6]        2.9e-01  7.9e-02  2.1e-01  2.9e-02  2.6e-01  6.5e-01  7.2e+00  1.3e-01  1.2e+00
## y_rep[7]        2.7e-01  6.6e-02  2.0e-01  3.1e-02  2.4e-01  6.0e-01  9.5e+00  1.7e-01  1.1e+00
## y_rep[8]        2.0e-01  4.5e-02  1.5e-01  2.6e-02  1.8e-01  4.5e-01  1.1e+01  1.9e-01  1.1e+00
## y_rep[9]        1.5e-01  1.7e-02  1.1e-01  2.7e-02  1.3e-01  3.3e-01  4.7e+01  8.4e-01  1.0e+00
## y_rep[10]       1.1e-01  1.3e-03  7.7e-02  2.7e-02  9.1e-02  2.4e-01  3.7e+03  6.7e+01  1.0e+00
## y_rep[11]       8.1e-02  8.5e-03  8.7e-02  2.2e-02  6.1e-02  1.9e-01  1.0e+02  1.9e+00  1.0e+00
## y_rep[12]       6.0e-02  2.1e-02  8.3e-02  1.6e-02  4.0e-02  1.7e-01  1.6e+01  2.9e-01  1.1e+00
## y_rep[13]       4.9e-02  2.7e-02  8.4e-02  9.7e-03  2.7e-02  1.6e-01  9.2e+00  1.6e-01  1.1e+00
## y_rep[14]       4.1e-02  3.0e-02  8.3e-02  6.1e-03  1.7e-02  1.5e-01  7.4e+00  1.3e-01  1.2e+00
##
## Samples were drawn using hmc with nuts.
## For each parameter, N_Eff is a crude measure of effective sample size,
## and R_hat is the potential scale reduction factor on split chains (at
## convergence, R_hat=1).
```

```
print(stanfit(SIR.posterior.s10), pars = pars.interest)
```

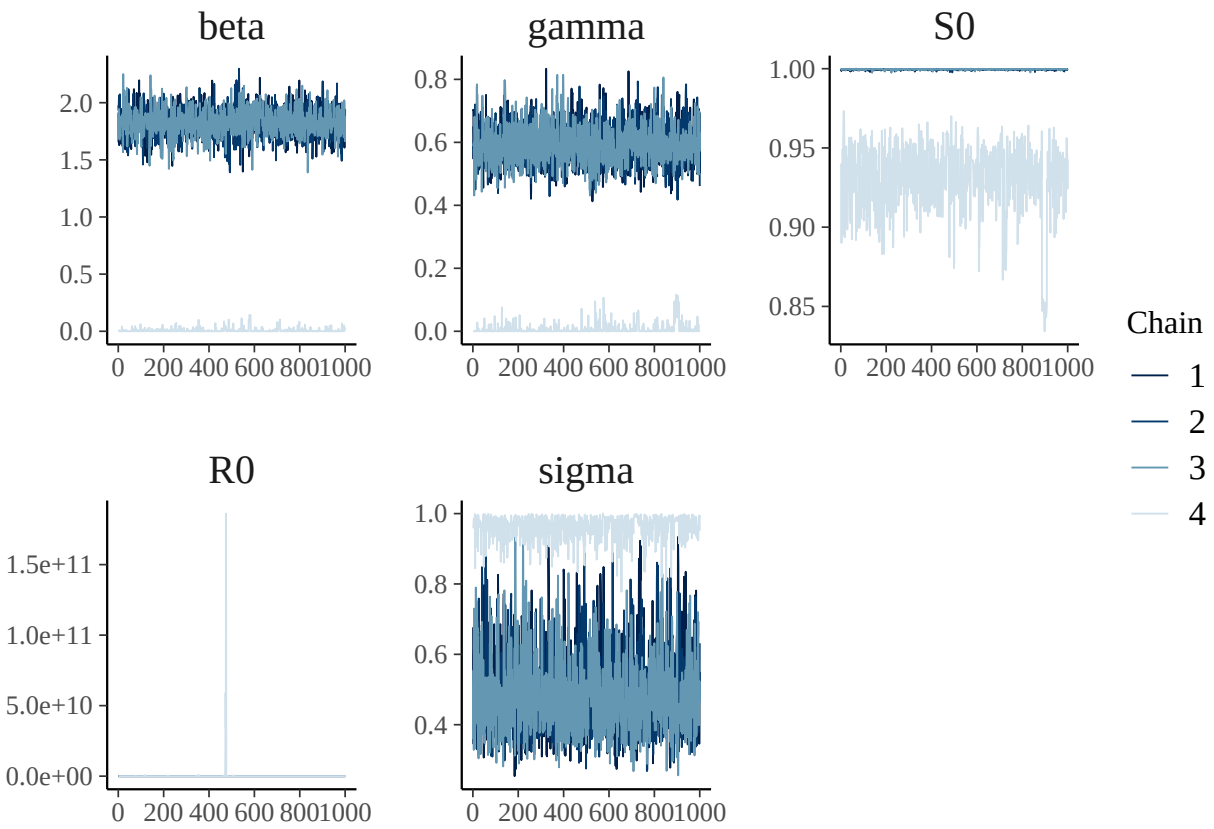
```
## Inference for Stan model: sir_simple_I-202204051649-1-786441.
## 4 chains, each with iter=2000; warmup=1000; thin=1;
## post-warmup draws per chain=1000, total post-warmup draws=4000.
##
##              mean     se_mean           sd 2.5%  25%  50%  75%    97.5% n_eff
## beta         1.37        0.56 7.900000e-01 0.00 1.08 1.78 1.88     2.04     2
## gamma        0.45        0.18 2.600000e-01 0.00 0.34 0.57 0.62     0.71     2
## S0           0.98        0.02 3.000000e-02 0.91 0.99 1.00 1.00     1.00     2
## R0    75621564.35 74321291.10 3.147773e+09 0.00 2.69 3.06 3.45 20151.87  1794
## sigma        0.61        0.15 2.300000e-01 0.33 0.43 0.53 0.86     0.99     2
##       Rhat
## beta  8.30
## gamma 5.21
## S0    3.16
## R0    1.00
```

```
## sigma 2.43
##
## Samples were drawn using NUTS(diag_e) at Tue Apr 05 16:51:09 2022.
## For each parameter, n_eff is a crude measure of effective sample size,
## and Rhat is the potential scale reduction factor on split chains (at
## convergence, Rhat=1).
```

```
mcmc_pairs(SIR.posterior.s10$draws(pars.interest))
```




```
p <- mcmc_trace(SIR.posterior.s10$draws(pars.interest))
p + facet_text(size = 15)
```




```
simulated_trajectories.s10 <- SIR.posterior.s10$draws('y_rep', format = "df")[, c(1:14)]
```

```
## Warning: Dropping 'draws_df' class as required metadata was removed.
```

```
predicted.s10 <- data.frame(time = epi.data$ts,
                            lower = apply(simulated_trajectories.s10,
                                          2, function(x) as.numeric(quantile(x, probs = .025)))[1:14],
                            post_mean = colMeans(simulated_trajectories.s10),
                            post_median = apply(simulated_trajectories.s10, 2, median),
                            upper = apply(simulated_trajectories.s10,
                                          2, function(x) as.numeric(quantile(x, probs = .975)))[1:14],
                            s = "10")

### sigma_beta = sigma_gamma = 100
epi.data$sigma_beta <- 100
epi.data$sigma_gamma <- 100

SIR.map.s100 <- SIR_code$optimize(data = epi.data, seed = 123)
```

```
## Rejecting initial value:
##   Error evaluating the log probability at the initial value.
## Exception: lognormal_lpdf: Location parameter[5] is -nan, but must be finite! (in '/tmp/RtmpF48rqt/m
## Rejecting initial value:
##   Error evaluating the log probability at the initial value.
## Exception: lognormal_lpdf: Location parameter[9] is -nan, but must be finite! (in '/tmp/RtmpF48rqt/m
## Initial log joint probability = -6875.84
##     Iter      log prob        ||dx||      ||grad||       alpha      alpha0  # evals  Notes
##       13       134.297       2.20037        4.5701         0.1       0.001       76  LS failed, Hess
## Exception: sir_simple_I_model_namespace::log_prob: R0 is -nan, but must be greater than or equal to 0
```

```
## Exception: sir_simple_I_model_namespace::log_prob: R0 is -nan, but must be greater than or equal to 0
## Exception: sir_simple_I_model_namespace::log_prob: R0 is -nan, but must be greater than or equal to 0
## Error evaluating model log probability: Non-finite gradient.
## Error evaluating model log probability: Non-finite gradient.
## Error evaluating model log probability: Non-finite gradient.
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## Error evaluating model log probability: Non-finite gradient.
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## Exception: sir_simple_I_model_namespace::log_prob: R0 is -nan, but must be greater than or equal to 0
## Exception: sir_simple_I_model_namespace::log_prob: R0 is -nan, but must be greater than or equal to 0
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## Error evaluating model log probability: Non-finite gradient.
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## Error evaluating model log probability: Non-finite gradient.
##       18       232.035       1.44191       1.86047         0.1       0.001      141  LS failed, Hessi
## Error evaluating model log probability: Non-finite gradient.
## Exception: sir_simple_I_model_namespace::log_prob: R0 is -nan, but must be greater than or equal to 0
## Exception: sir_simple_I_model_namespace::log_prob: R0 is -nan, but must be greater than or equal to 0
## Error evaluating model log probability: Non-finite gradient.
## Error evaluating model log probability: Non-finite gradient.
## Error evaluating model log probability: Non-finite gradient.
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## Exception: sir_simple_I_model_namespace::log_prob: R0 is -nan, but must be greater than or equal to 0
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## Error evaluating model log probability: Non-finite gradient.
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## Error evaluating model log probability: Non-finite gradient.
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## Exception: sir_simple_I_model_namespace::log_prob: R0 is -nan, but must be greater than or equal to 0
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## Exception: sir_simple_I_model_namespace::log_prob: R0 is -nan, but must be greater than or equal to 0
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##       24       268.188       1.64124       1.39693         0.1       0.001      189  LS failed, Hess
## Error evaluating model log probability: Non-finite gradient.
## Exception: sir_simple_I_model_namespace::log_prob: R0 is -nan, but must be greater than or equal to 0
## Exception: sir_simple_I_model_namespace::log_prob: R0 is -nan, but must be greater than or equal to 0
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##       30       594.979      0.680526       58.5085        0.01       0.001      240  LS failed, Hessi
## Exception: sir_simple_I_model_namespace::log_prob: R0 is -nan, but must be greater than or equal to 0
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##       36       737.856        1.3087       2.12437         0.1       0.001      290  LS failed, Hess
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##       43       747.875      0.142863       1.36581         0.1       0.001      376  LS failed, Hess
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##       45       748.643     0.0577207         1.517      0.0325       0.001      428  LS failed, Hess
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```

```
##       46       748.643     0.0577207         1.517       0.001       0.001      517  LS failed, Hessi
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## Error evaluating model log probability: Non-finite gradient.
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## Error evaluating model log probability: Non-finite gradient.

## Optimization terminated with error:

##   Line search failed to achieve a sufficient decrease, no more progress can be made

## Finished in  0.2 seconds.
```

```
fit_mcmc <- SIR_code$sample(data = epi.data, seed = 123,
                            chains = 4, parallel_chains = 4,
                            refresh = 0)
```

```
## Running MCMC with 4 parallel chains...

## Chain 1 Rejecting initial value:

## Chain 1   Error evaluating the log probability at the initial value.

## Chain 1 Exception: lognormal_lpdf: Location parameter[5] is -nan, but must be finite! (in '/tmp/Rtmp
## Chain 1 Exception: lognormal_lpdf: Location parameter[5] is -nan, but must be finite! (in '/tmp/Rtmp

## Chain 1 Rejecting initial value:

## Chain 1   Error evaluating the log probability at the initial value.

## Chain 1 Exception: lognormal_lpdf: Location parameter[9] is -nan, but must be finite! (in '/tmp/Rtmp
## Chain 1 Exception: lognormal_lpdf: Location parameter[9] is -nan, but must be finite! (in '/tmp/Rtmp

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of th

## Chain 1 Exception: lognormal_lpdf: Location parameter[1] is -inf, but must be finite! (in '/tmp/Rtmp

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like cova

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or m

## Chain 1
```

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## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 1 Exception: lognormal_lpdf: Location parameter[1] is -inf, but must be finite! (in '/tmp/Rtmpl
## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar
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## Chain 1
## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 1 Exception: ode_rk45: ode parameters and data[1] is inf, but must be finite! (in '/tmp/RtmpF48
## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 1
## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the
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## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 1
## Chain 2 Rejecting initial value:
## Chain 2   Error evaluating the log probability at the initial value.
## Chain 2 Exception: lognormal_lpdf: Location parameter[2] is -nan, but must be finite! (in '/tmp/Rtmpl
## Chain 2 Exception: lognormal_lpdf: Location parameter[2] is -nan, but must be finite! (in '/tmp/Rtmpl
## Chain 3 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 3 Exception: lognormal_lpdf: Location parameter[2] is -nan, but must be finite! (in '/tmp/Rtmpl
## Chain 3 If this warning occurs sporadically, such as for highly constrained variable types like covar
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## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: lognormal_lpdf: Location parameter[1] is -nan, but must be finite! (in '/tmp/Rtmpl
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## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
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## Chain 3
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of th
## Chain 2 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 2
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of th
## Chain 4 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
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## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of th
## Chain 4 Exception: ode_rk45: ode parameters and data[1] is inf, but must be finite! (in '/tmp/RtmpF4
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like cova
## Chain 4 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 4
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of th
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## Chain 3 Informational Message: The current Metropolis proposal is about to be rejected because of th
## Chain 3 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 3 If this warning occurs sporadically, such as for highly constrained variable types like cova
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## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of th
## Chain 2 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like cova
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of th
## Chain 2 Exception: lognormal_lpdf: Location parameter[3] is -nan, but must be finite! (in '/tmp/Rtmp
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like cova
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of th
## Chain 2 Exception: lognormal_lpdf: Location parameter[7] is -nan, but must be finite! (in '/tmp/Rtmp
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like cova
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or m
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```

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## Chain 2
## Chain 4 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 4 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 4 If this warning occurs sporadically, such as for highly constrained variable types like covar
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## Chain 4
## Chain 3 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 3 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 3 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 3 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 3
## Chain 1 finished in 5.6 seconds.
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: ode_rk45:  Failed to integrate to next output time (2) in less than max_num_steps
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
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## Chain 3 but if this warning occurs often then your model may be either severely ill-conditioned or mi
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## Chain 3
## Chain 3 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 3 Exception: lognormal_lpdf: Location parameter[12] is -nan, but must be finite! (in '/tmp/Rtmp
## Chain 3 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 3 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 3
## Chain 3 Informational Message: The current Metropolis proposal is about to be rejected because of the
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## Chain 4 Exception: lognormal_lpdf: Location parameter[1] is -nan, but must be finite! (in '/tmp/Rtmpl
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## Chain 4 Exception: lognormal_lpdf: Location parameter[3] is -nan, but must be finite! (in '/tmp/Rtmpl
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## Chain 3 Exception: lognormal_lpdf: Location parameter[10] is -nan, but must be finite! (in '/tmp/Rtmp
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## Chain 3 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 3 Exception: lognormal_lpdf: Location parameter[5] is -nan, but must be finite! (in '/tmp/Rtmp
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## Chain 3 Exception: lognormal_lpdf: Location parameter[8] is -nan, but must be finite! (in '/tmp/Rtmpl
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## Chain 3 Exception: lognormal_lpdf: Location parameter[10] is -nan, but must be finite! (in '/tmp/Rtmp
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## Chain 3 Exception: lognormal_lpdf: Location parameter[4] is -nan, but must be finite! (in '/tmp/Rtmpl
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## Chain 3 Exception: lognormal_lpdf: Location parameter[12] is -nan, but must be finite! (in '/tmp/Rtmp
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## Chain 4
## Chain 4 finished in 1082.2 seconds.
##
## All 4 chains finished successfully.
## Mean chain execution time: 533.8 seconds.
## Total execution time: 1084.8 seconds.
##
## Warning: 1197 of 4000 (30.0%) transitions ended with a divergence.
## This may indicate insufficient exploration of the posterior distribution.
## Possible remedies include:
##   * Increasing adapt_delta closer to 1 (default is 0.8)
##   * Reparameterizing the model (e.g. using a non-centered parameterization)
##   * Using informative or weakly informative prior distributions
```

```
SIR.posterior.s100 <- fit_mcmc
SIR.posterior.s100$cmdstan_diagnose()
```

```
## Processing csv files: /tmp/Rtmp2Px7Ds/sir_simple_I-202204051651-1-43b5f2.csv, /tmp/Rtmp2Px7Ds/sir_sim
##
## Checking sampler transitions treedepth.
## Treedepth satisfactory for all transitions.
##
## Checking sampler transitions for divergences.
## 1197 of 4000 (30%) transitions ended with a divergence.
```

```
## These divergent transitions indicate that HMC is not fully able to explore the posterior distributio
## Try increasing adapt delta closer to 1.
## If this doesn't remove all divergences, try to reparameterize the model.
##
## Checking E-BFMI - sampler transitions HMC potential energy.
## The E-BFMI, 0.054, is below the nominal threshold of 0.3 which suggests that HMC may have trouble exp
## If possible, try to reparameterize the model.
##
## The following parameters had fewer than 0.001 effective draws per transition:
##   beta, gamma, S0, sigma, y0[1], y0[2], theta[1], theta[2], y_hat[1,1], y_hat[2,1], y_hat[4,1], y_hat
## Such low values indicate that the effective sample size estimators may be biased high and actual peri
##
## The following parameters had split R-hat greater than 1.1:
##   beta, gamma, S0, sigma, y0[1], y0[2], theta[1], theta[2], y_hat[1,1], y_hat[2,1], y_hat[4,1], y_hat
## Such high values indicate incomplete mixing and biased estimation.
## You should consider regularizating your model with additional prior information or a more effective p
##
## Processing complete.
```

```
SIR.posterior.s100$cmdstan_summary()
```

```
## Inference for Stan model: sir_simple_I_model
## 4 chains: each with iter=(1000,1000,1000,1000); warmup=(0,0,0,0); thin=(1,1,1,1); 4000 iterations sav
##
## Warmup took (3.5, 159, 398, 449) seconds, 17 minutes total
## Sampling took (2.2, 1.7, 488, 633) seconds, 19 minutes total
##
##                    Mean     MCSE   StdDev       5%      50%      95%    N_Eff  N_Eff/s    R_hat
##
## lp__           -4.0e+00  7.4e+00  1.1e+01 -1.7e+01 -7.7e+00  8.9e+00  2.1e+00  1.8e-03  5.3e+00
## accept_stat__      0.86  5.0e-02     0.20     0.42     0.94     1.00       17  1.5e-02  1.1e+00
## stepsize__         0.17  1.5e-03    0.066     0.10     0.19     0.27     2000  1.8e+00  7.7e+13
## treedepth__         3.6  1.4e-01     0.97      2.0      4.0      5.0       50  4.4e-02  1.0e+00
## n_leapfrog__         17  1.4e+00      8.9      3.0       15       31       40  3.5e-02  1.0e+00
## divergent__        0.30  1.0e-02     0.46     0.00     0.00      1.0     2000  1.8e+00  1.4e+00
## energy__            7.0  7.5e+00       11     -6.8       11       21      2.1  1.9e-03  4.2e+00
##
## r_init[1]       5.1e-01  8.4e-03  2.9e-01  5.8e-02  5.1e-01  9.6e-01  1.2e+03  1.1e+00  1.0e+00
## r_init[2]       5.0e-01  7.1e-03  2.9e-01  4.7e-02  5.0e-01  9.5e-01  1.7e+03  1.5e+00  1.0e+00
## beta            9.1e-01  6.5e-01  9.2e-01  7.2e-73  1.3e+00  2.0e+00  2.0e+00  1.8e-03  1.1e+01
## gamma           2.9e-01  2.1e-01  3.0e-01  3.7e-74  4.0e-01  6.7e-01  2.0e+00  1.8e-03  7.5e+00
## S0              9.7e-01  2.4e-02  3.6e-02  9.1e-01  1.0e+00  1.0e+00  2.2e+00  2.0e-03  3.3e+00
## sigma           7.3e-01  1.7e-01  2.5e-01  3.6e-01  8.6e-01  1.0e+00  2.3e+00  2.0e-03  2.8e+00
## R0             4.7e+138 4.7e+138 3.0e+140  5.1e-46  3.2e+00  8.3e+47  4.0e+03  3.6e+00  1.0e+00
## y0[1]           9.7e-01  2.4e-02  3.6e-02  9.1e-01  1.0e+00  1.0e+00  2.2e+00  2.0e-03  3.3e+00
## y0[2]           3.4e-02  2.4e-02  3.6e-02  1.4e-04  2.6e-02  9.0e-02  2.2e+00  2.0e-03  3.3e+00
## y0[3]           0.0e+00      nan  0.0e+00  0.0e+00  0.0e+00  0.0e+00      nan      nan      nan
## theta[1]        9.1e-01  6.5e-01  9.2e-01  7.2e-73  1.3e+00  2.0e+00  2.0e+00  1.8e-03  1.1e+01
## theta[2]        2.9e-01  2.1e-01  3.0e-01  3.7e-74  4.0e-01  6.7e-01  2.0e+00  1.8e-03  7.5e+00
## y_hat[1,1]      9.6e-01  2.2e-02  3.3e-02  9.1e-01  9.7e-01  1.0e+00  2.2e+00  2.0e-03  3.0e+00
## y_hat[1,2]      3.6e-02  2.3e-02  3.4e-02  2.3e-03  2.7e-02  9.0e-02  2.2e+00  2.0e-03  3.1e+00
## y_hat[1,3]      9.2e-04  6.7e-04  1.2e-03  5.0e-75  5.7e-04  2.9e-03  3.5e+00  3.1e-03  1.5e+00
## y_hat[2,1]      9.6e-01  1.8e-02  2.8e-02  9.1e-01  9.6e-01  9.9e-01  2.4e+00  2.2e-03  2.3e+00
## y_hat[2,2]      4.1e-02  2.0e-02  3.0e-02  8.7e-03  3.4e-02  9.0e-02  2.3e+00  2.1e-03  2.7e+00
## y_hat[2,3]      3.2e-03  2.3e-03  3.8e-03  7.6e-75  2.1e-03  9.2e-03  2.7e+00  2.4e-03  1.9e+00
```

```
## y_hat[3,1]      9.3e-01  1.4e-03  1.7e-02  9.1e-01  9.4e-01  9.6e-01  1.5e+02  1.3e-01  1.0e+00
## y_hat[3,2]      5.5e-02  1.0e-02  2.0e-02  3.0e-02  5.2e-02  9.0e-02  3.8e+00  3.3e-03  1.4e+00
## y_hat[3,3]      1.0e-02  7.4e-03  1.1e-02  1.0e-74  8.2e-03  2.8e-02  2.3e+00  2.1e-03  2.5e+00
## y_hat[4,1]      8.8e-01  4.0e-02  6.4e-02  7.7e-01  8.9e-01  9.5e-01  2.5e+00  2.3e-03  2.1e+00
## y_hat[4,2]      9.2e-02  1.8e-02  3.4e-02  4.8e-02  8.6e-02  1.6e-01  3.8e+00  3.4e-03  1.4e+00
## y_hat[4,3]      3.2e-02  2.3e-02  3.3e-02  1.3e-74  2.4e-02  8.1e-02  2.2e+00  1.9e-03  3.4e+00
## y_hat[5,1]      7.7e-01  1.2e-01  1.8e-01  5.0e-01  8.6e-01  9.5e-01  2.2e+00  2.0e-03  3.2e+00
## y_hat[5,2]      1.5e-01  6.0e-02  9.3e-02  4.8e-02  1.2e-01  3.1e-01  2.4e+00  2.1e-03  2.4e+00
## y_hat[5,3]      8.2e-02  5.8e-02  8.5e-02  1.5e-74  7.3e-02  2.0e-01  2.1e+00  1.9e-03  4.2e+00
## y_hat[6,1]      6.5e-01  2.0e-01  2.9e-01  2.5e-01  8.6e-01  9.5e-01  2.1e+00  1.9e-03  4.8e+00
## y_hat[6,2]      1.9e-01  8.5e-02  1.3e-01  4.8e-02  1.3e-01  3.7e-01  2.2e+00  1.9e-03  3.6e+00
## y_hat[6,3]      1.6e-01  1.2e-01  1.7e-01  1.8e-74  1.5e-01  3.9e-01  2.1e+00  1.8e-03  5.3e+00
## y_hat[7,1]      5.7e-01  2.5e-01  3.6e-01  1.3e-01  8.6e-01  9.5e-01  2.0e+00  1.8e-03  7.4e+00
## y_hat[7,2]      1.8e-01  7.6e-02  1.1e-01  4.8e-02  1.4e-01  3.2e-01  2.1e+00  1.9e-03  4.5e+00
## y_hat[7,3]      2.5e-01  1.8e-01  2.5e-01  2.0e-74  2.2e-01  5.7e-01  2.0e+00  1.8e-03  7.1e+00
## y_hat[8,1]      5.4e-01  2.8e-01  4.0e-01  7.7e-02  8.6e-01  9.5e-01  2.0e+00  1.8e-03  1.1e+01
## y_hat[8,2]      1.4e-01  5.2e-02  7.6e-02  4.8e-02  1.3e-01  2.4e-01  2.1e+00  1.9e-03  3.9e+00
## y_hat[8,3]      3.2e-01  2.3e-01  3.3e-01  2.3e-74  3.1e-01  7.1e-01  2.0e+00  1.8e-03  9.8e+00
## y_hat[9,1]      5.2e-01  2.9e-01  4.2e-01  5.4e-02  8.6e-01  9.5e-01  2.0e+00  1.8e-03  1.4e+01
## y_hat[9,2]      1.1e-01  2.8e-02  4.3e-02  4.8e-02  1.1e-01  1.7e-01  2.3e+00  2.1e-03  2.5e+00
## y_hat[9,3]      3.8e-01  2.7e-01  3.8e-01  2.5e-74  4.0e-01  8.0e-01  2.0e+00  1.8e-03  1.3e+01
## y_hat[10,1]     5.1e-01  3.0e-01  4.3e-01  4.3e-02  8.6e-01  9.5e-01  2.0e+00  1.8e-03  1.6e+01
## y_hat[10,2]     8.2e-02  1.0e-02  2.1e-02  4.8e-02  8.3e-02  1.2e-01  4.1e+00  3.7e-03  1.4e+00
## y_hat[10,3]     4.1e-01  2.9e-01  4.1e-01  2.8e-74  4.8e-01  8.6e-01  2.0e+00  1.8e-03  1.6e+01
## y_hat[11,1]     5.0e-01  3.0e-01  4.3e-01  3.7e-02  8.6e-01  9.5e-01  2.0e+00  1.8e-03  1.8e+01
## y_hat[11,2]     6.5e-02  1.9e-03  1.5e-02  4.5e-02  6.3e-02  9.2e-02  6.2e+01  5.5e-02  1.0e+00
## y_hat[11,3]     4.3e-01  3.1e-01  4.3e-01  3.0e-74  5.4e-01  9.0e-01  2.0e+00  1.8e-03  2.0e+01
## y_hat[12,1]     5.0e-01  3.1e-01  4.3e-01  3.4e-02  8.6e-01  9.5e-01  2.0e+00  1.8e-03  1.9e+01
## y_hat[12,2]     5.4e-02  1.1e-02  2.0e-02  2.9e-02  4.9e-02  9.1e-02  3.3e+00  2.9e-03  1.6e+00
## y_hat[12,3]     4.5e-01  3.2e-01  4.5e-01  3.3e-74  6.0e-01  9.3e-01  2.0e+00  1.8e-03  2.2e+01
## y_hat[13,1]     5.0e-01  3.1e-01  4.4e-01  3.2e-02  8.6e-01  9.5e-01  2.0e+00  1.8e-03  2.0e+01
## y_hat[13,2]     4.6e-02  1.6e-02  2.5e-02  1.8e-02  3.9e-02  9.1e-02  2.5e+00  2.2e-03  2.1e+00
## y_hat[13,3]     4.6e-01  3.2e-01  4.6e-01  3.5e-74  6.4e-01  9.4e-01  2.0e+00  1.8e-03  2.4e+01
## y_hat[14,1]     5.0e-01  3.1e-01  4.4e-01  3.0e-02  8.6e-01  9.5e-01  2.0e+00  1.8e-03  2.0e+01
## y_hat[14,2]     4.2e-02  1.9e-02  2.9e-02  1.1e-02  3.3e-02  9.1e-02  2.3e+00  2.1e-03  2.5e+00
## y_hat[14,3]     4.6e-01  3.3e-01  4.6e-01  3.8e-74  6.6e-01  9.5e-01  2.0e+00  1.8e-03  2.5e+01
## y_rep[1]        5.8e-02  4.0e-02  1.2e-01  1.6e-03  1.3e-02  2.5e-01  8.9e+00  7.9e-03  1.1e+00
## y_rep[2]        6.0e-02  3.4e-02  1.1e-01  6.2e-03  2.3e-02  2.3e-01  1.1e+01  9.5e-03  1.1e+00
## y_rep[3]        7.5e-02  2.0e-02  9.5e-02  1.4e-02  4.7e-02  2.3e-01  2.2e+01  2.0e-02  1.1e+00
## y_rep[4]        1.2e-01  2.3e-03  1.3e-01  1.9e-02  9.3e-02  3.2e-01  3.0e+03  2.7e+00  1.0e+00
## y_rep[5]        1.9e-01  6.0e-02  1.9e-01  1.9e-02  1.5e-01  5.0e-01  9.7e+00  8.6e-03  1.1e+00
## y_rep[6]        2.3e-01  9.0e-02  2.2e-01  1.9e-02  1.8e-01  6.1e-01  5.7e+00  5.1e-03  1.2e+00
## y_rep[7]        2.2e-01  8.0e-02  2.0e-01  1.8e-02  1.7e-01  5.8e-01  6.1e+00  5.4e-03  1.2e+00
## y_rep[8]        1.8e-01  5.0e-02  1.6e-01  1.8e-02  1.5e-01  4.4e-01  1.0e+01  8.9e-03  1.1e+00
## y_rep[9]        1.4e-01  2.1e-02  1.2e-01  1.9e-02  1.1e-01  3.3e-01  3.3e+01  2.9e-02  1.0e+00
## y_rep[10]       1.1e-01  1.9e-03  1.1e-01  1.9e-02  8.4e-02  2.7e-01  3.3e+03  3.0e+00  1.0e+00
## y_rep[11]       8.8e-02  9.4e-03  1.0e-01  1.7e-02  6.3e-02  2.3e-01  1.1e+02  1.0e-01  1.0e+00
## y_rep[12]       7.7e-02  2.3e-02  1.1e-01  1.4e-02  4.6e-02  2.4e-01  2.0e+01  1.8e-02  1.1e+00
## y_rep[13]       6.9e-02  3.0e-02  1.1e-01  1.1e-02  3.4e-02  2.4e-01  1.4e+01  1.2e-02  1.1e+00
## y_rep[14]       6.3e-02  3.5e-02  1.1e-01  6.8e-03  2.4e-02  2.4e-01  1.0e+01  8.9e-03  1.1e+00
##
## Samples were drawn using hmc with nuts.
## For each parameter, N_Eff is a crude measure of effective sample size,
## and R_hat is the potential scale reduction factor on split chains (at
```

```
## convergence, R_hat=1).
```

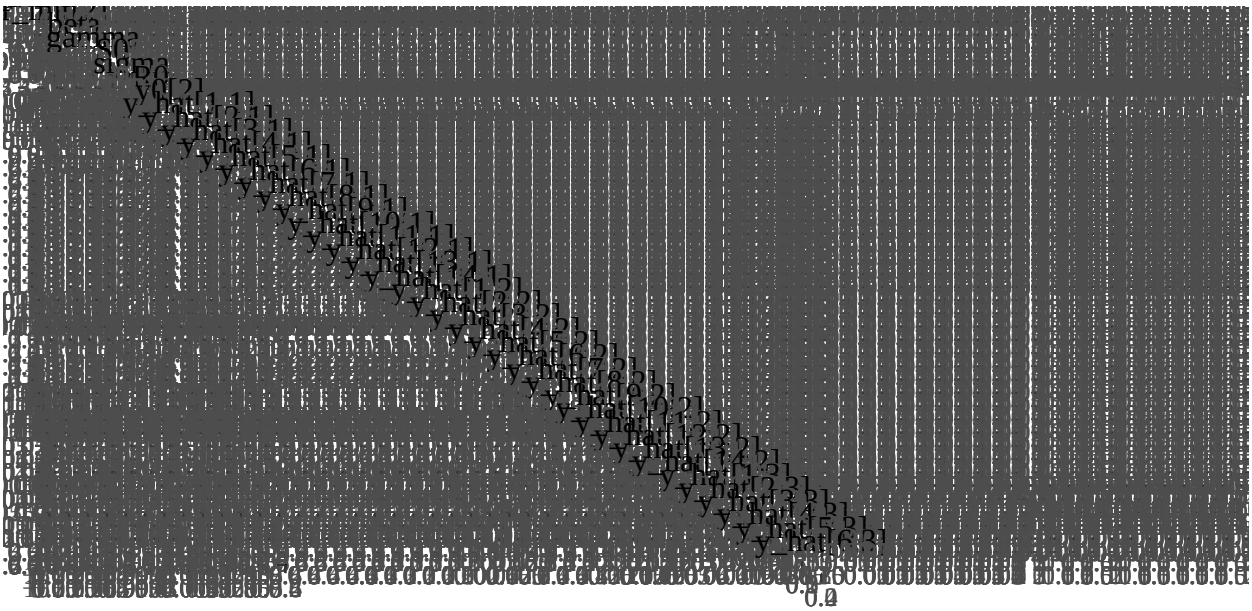
```
print(stanfit(SIR.posterior.s100), pars = pars.interest)
```

```
## Inference for Stan model: sir_simple_I-202204051651-1-43b5f2.
## 4 chains, each with iter=2000; warmup=1000; thin=1;
## post-warmup draws per chain=1000, total post-warmup draws=4000.
##
##             mean       se_mean            sd 2.5%  25%  50%     75%
## beta   9.100e-01  6.500000e-01  9.200000e-01 0.00 0.00 0.66    1.82
## gamma  2.900e-01  2.100000e-01  3.000000e-01 0.00 0.00 0.22    0.58
## S0     9.700e-01  2.000000e-02  4.000000e-02 0.90 0.93 0.98    1.00
## R0    4.742e+138 4.737246e+138 2.999104e+140 0.00 2.50 3.16 2955.14
## sigma  7.300e-01  1.600000e-01  2.500000e-01 0.34 0.47 0.86    0.97
##              97.5% n_eff  Rhat
## beta  2.030000e+00     2 10.95
## gamma 6.900000e-01     2  7.52
## S0    1.000000e+00     2  3.26
## R0    3.443945e+63  4008  1.00
## sigma 1.000000e+00     2  2.82
##
## Samples were drawn using NUTS(diag_e) at Tue Apr 05 17:09:17 2022.
## For each parameter, n_eff is a crude measure of effective sample size,
## and Rhat is the potential scale reduction factor on split chains (at
## convergence, Rhat=1).
```

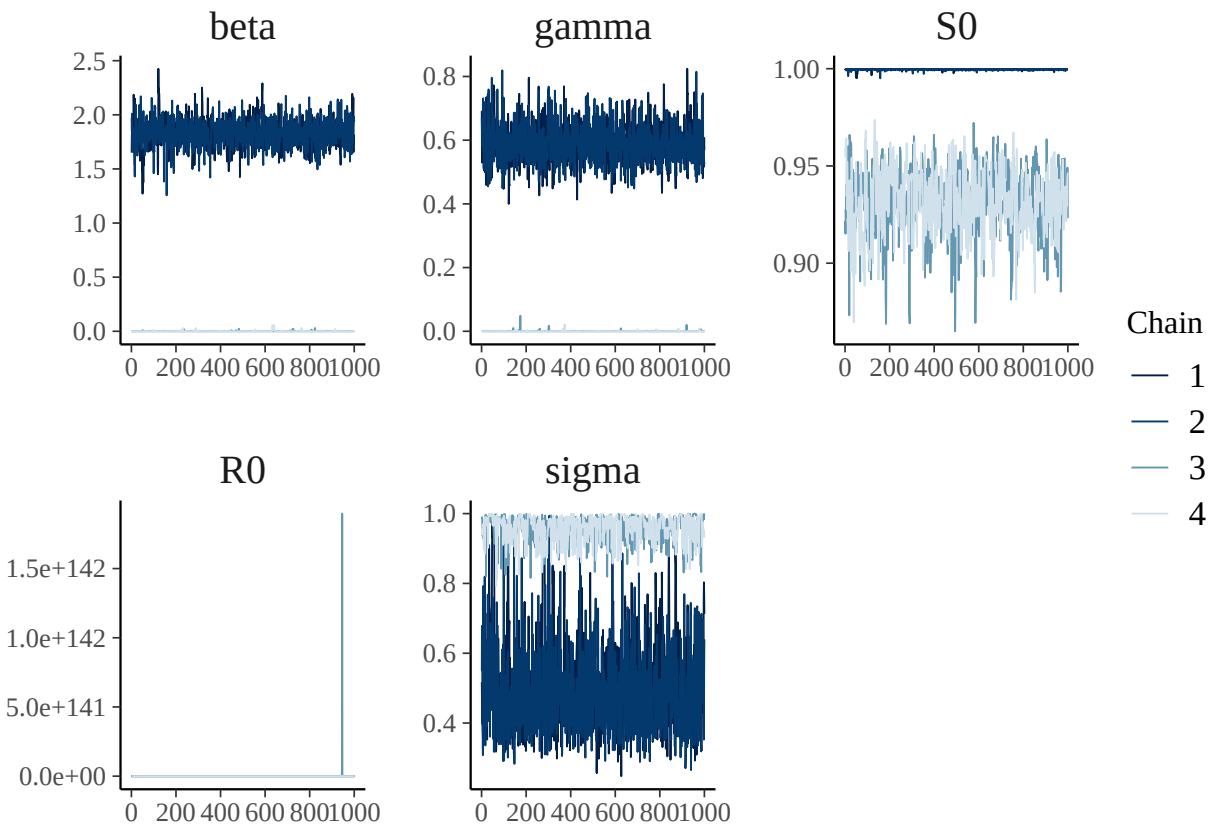
```
mcmc_pairs(SIR.posterior.s100$draws())
```

```
## Warning: The following parameters were dropped because they are constant: y0[3]
```

```
## Warning: The following parameters were dropped because they are duplicative:
## y0[1], theta[1], theta[2]
```



```
p <- mcmc_trace(SIR.posterior.s100$draws(pars.interest))
p + facet_text(size = 15)
```

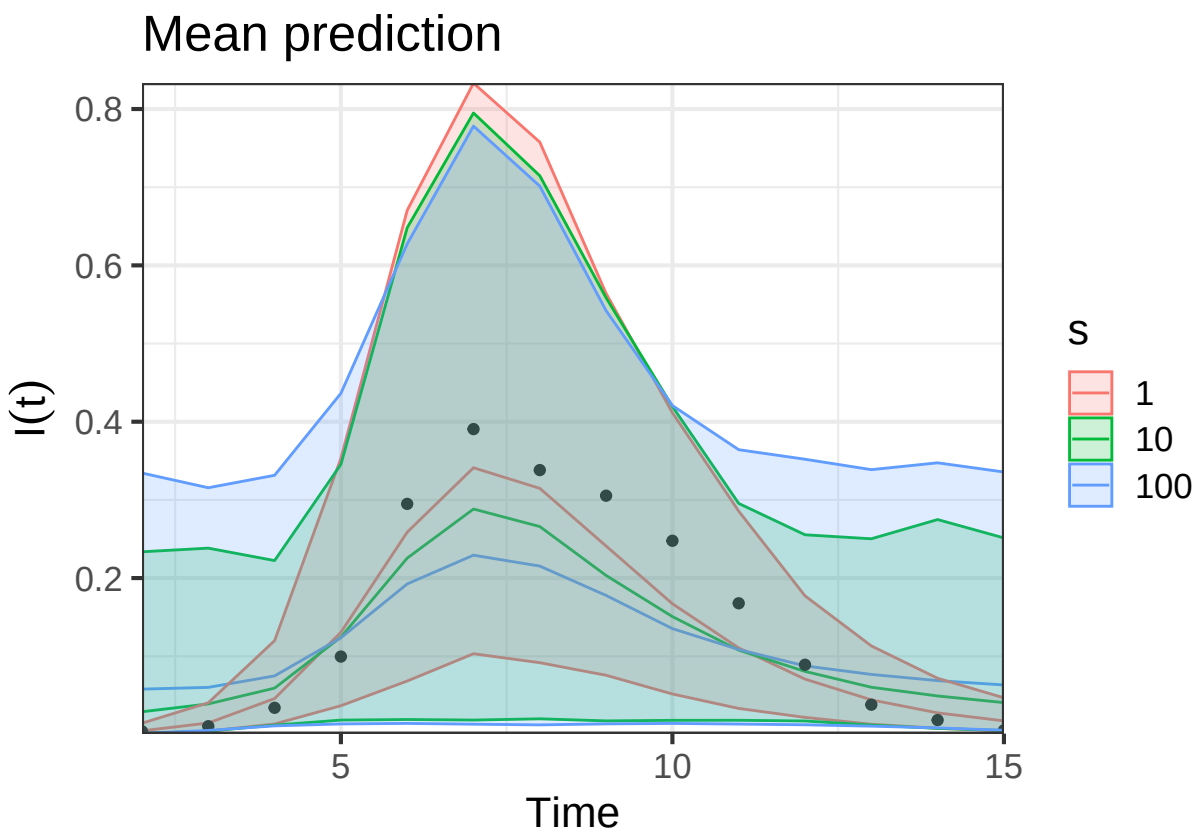



```
simulated_trajectories.s100 <- SIR.posterior.s100$draws('y_rep', format = "df")[, c(1:14)]
```

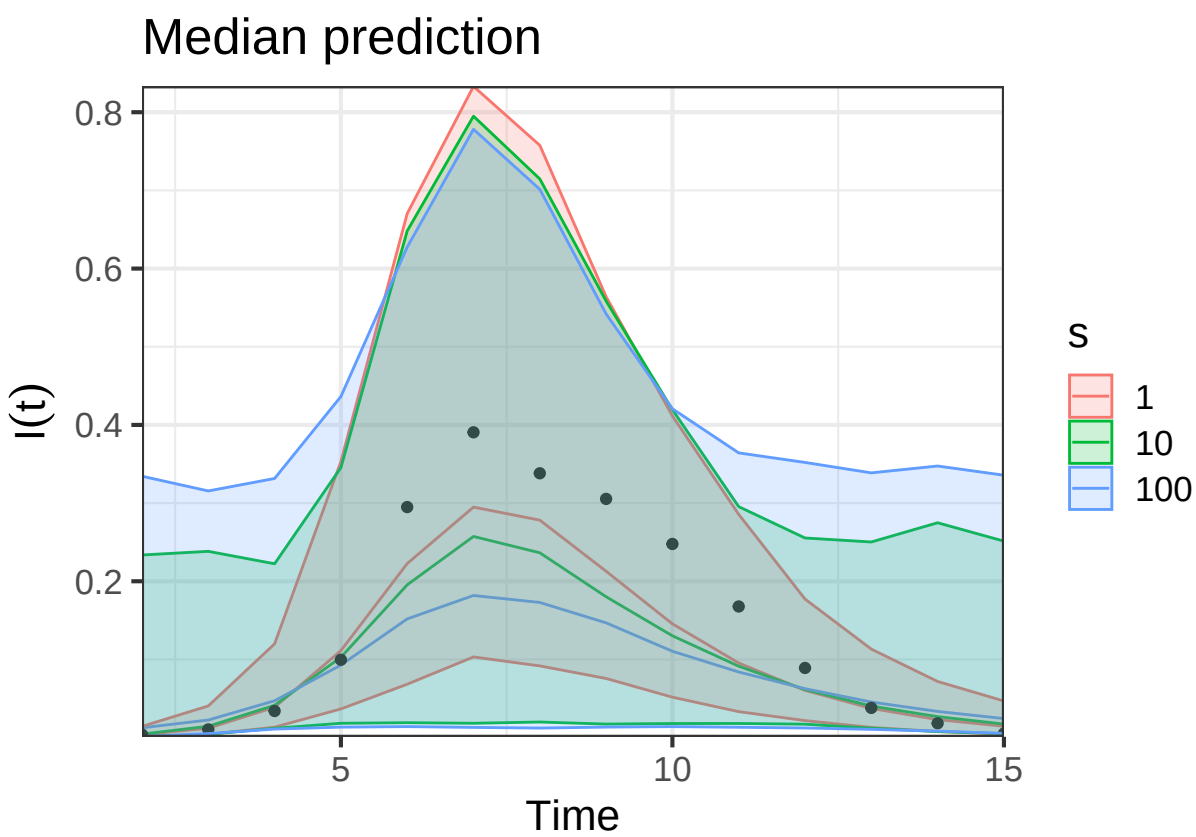
```
## Warning: Dropping 'draws_df' class as required metadata was removed.
```

```
predicted.s100 <- data.frame(time = epi.data$ts,
                             lower = apply(simulated_trajectories.s100,
                                           2, function(x) as.numeric(quantile(x, probs = .025)))[1:14],
                             post_mean = colMeans(simulated_trajectories.s100),
                             post_median = apply(simulated_trajectories.s100, 2, median),
                             upper = apply(simulated_trajectories.s100,
                                           2, function(x) as.numeric(quantile(x, probs = .975)))[1:14],
                             s = "100")

#### Plotting and annotating

prediction.bands.SIR <- do.call(rbind,
                                list(predicted.s1,
                                     predicted.s10,
                                     predicted.s100))

library(ggplot2)

predictions_SIR <- ggplot(data = prediction.bands.SIR,
                          aes(x = time, y = post_mean,
                              colour = s, fill = s)) +
  geom_line() +
  geom_point(data = data.frame(time = epi.data$ts, I = epi.data$y),
             aes(x = time, y = I), inherit.aes = FALSE) +
```

```
  geom_ribbon(aes(ymin = lower, ymax = upper), alpha = .2) +
  scale_x_continuous("Time", expand = c(0, 0)) +
  scale_y_continuous(expression(I(t)), expand = c(0, 0)) +
  ggtitle("Mean prediction") +
  theme_bw(base_size = 16)

predictions_SIR
```




```
predictions_SIR_median <- ggplot(data = prediction.bands.SIR,
                           aes(x = time, y = post_median,
                               colour = s, fill = s)) +
  geom_line() +
  geom_point(data = data.frame(time = epi.data$ts, I = epi.data$y),
             aes(x = time, y = I), inherit.aes = FALSE) +
  geom_ribbon(aes(ymin = lower, ymax = upper), alpha = .2) +
  scale_x_continuous("Time", expand = c(0, 0)) +
  scale_y_continuous(expression(I(t)), expand = c(0, 0)) +
  ggtitle("Median prediction") +
  theme_bw(base_size = 16)

predictions_SIR_median
```




```
R0.s1 <- data.frame(R0 = SIR.posterior.s1$draws('R0', format = "df"), s="1")
R0.s10 <- data.frame(R0 = SIR.posterior.s10$draws('R0', format = "df"), s="10")
R0.s100 <- data.frame(R0 = SIR.posterior.s100$draws('R0', format = "df"), s="100")

R0.posteriors <- do.call(rbind, list(R0.s1, R0.s10, R0.s100))
R0.posteriors <- R0.posteriors[, c(1:5)]

### Posterior quantities for R0 (mean, median, sd)
aggregate(R0.R0~s, mean, data = R0.posteriors)
```

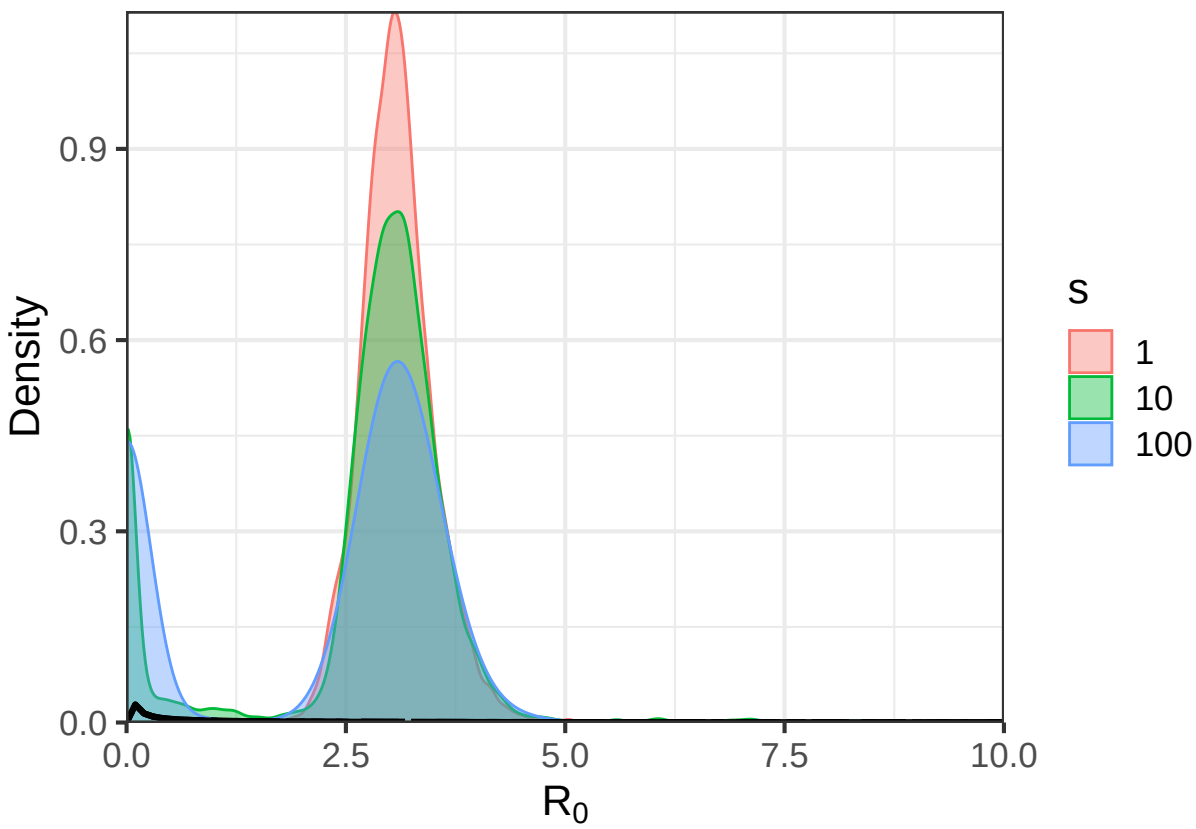
```
##     s         R0.R0
## 1   1  3.086597e+00
## 2  10  7.562156e+07
## 3 100 4.742000e+138
```

```
aggregate(R0.R0~s, median, data = R0.posteriors)
```

```
##     s    R0.R0
## 1   1 3.063315
## 2  10 3.064410
## 3 100 3.160955
```

```
aggregate(R0.R0~s, sd, data = R0.posteriors)
```

```
##     s         R0.R0
## 1   1  4.059173e-01
## 2  10  3.147773e+09
## 3 100 2.999104e+140
```

```r
R0_posterior <- ggplot(data = R0.posteriors,
                       aes(x = R0.R0, colour = s, fill = s)) +
  geom_density(alpha = .4) +
  # geom_vline(xintercept = 1.5, linetype = "dotted", size = 1.01) +
  stat_function(fun = function(x) dlnorm(x, meanlog = 0,
                                         sdlog = sqrt(epi.data$sigma_beta^2 + epi.data$sigma_gamma^2)),
                inherit.aes = FALSE, linetype = "longdash", size = 1.10) +
  stat_function(fun = function(x) dlnorm(x, meanlog = 0,
                                         sdlog = sqrt(epi.data$sigma_beta^2 + epi.data$sigma_gamma^2)),
                inherit.aes = FALSE, linetype = "twodash", size = 1.10) +
  stat_function(fun = function(x) dlnorm(x, meanlog = 0,
                                         sdlog = sqrt(epi.data$sigma_beta^2 + epi.data$sigma_gamma^2)),
                inherit.aes = FALSE, linetype = "F1", size = 1.10) +
  scale_x_continuous(expression(R[0]), expand = c(0, 0),
                     limits = c(0, 10)) +
  scale_y_continuous("Density", expand = c(0, 0)) +
  theme_bw(base_size = 16)

R0_posterior
```

```
## Warning: Removed 1445 rows containing non-finite values (stat_density).
```