

# MCMC examples

```
library(MCMCglmm) ## older, Gibbs-sampling
library(brms)     ## newest, lme4-like syntax, very flexible, compiled
library(rstanarm) ## lme4-like syntax, pre-compiled
library(lme4)     ## to get data
options(brms.backend = "cmdstanr")
library(broom.mixed) ## 'tidy'
library(tidybayes)  ## convenience functions for getting MCMC output in 'tidy' format
library(bayesplot)
library(bayestestR) ## diagnostics
library(ggplot2); theme_set(theme_bw())
library(shinystan)  ## diagnostics for Stan in a Shiny window
library(tidyverse) ## general-purpose manipulations
```

- a little more on priors:

– parameter-expanded priors:  $y_j | \mu, \xi_j \sim N(\mu + \alpha \sigma_j, \sigma_j^2)$ ,  $\sigma_j \sim N(0, \sigma_\xi^2)$ ;  
 $\alpha \sim N(\alpha_0, \sigma_\alpha)$ ,  $\sigma_\alpha \sim \text{inverse-Gamma}(\nu)$

```
df(v/alpha.V, df1 = 1, df2 = nu, ncp = (alpha.mu^2)/alpha.V)
2 * dt(sqrt(v)/sqrt(alpha.V), df = nu, ncp = alpha.mu/sqrt(alpha.V))
```

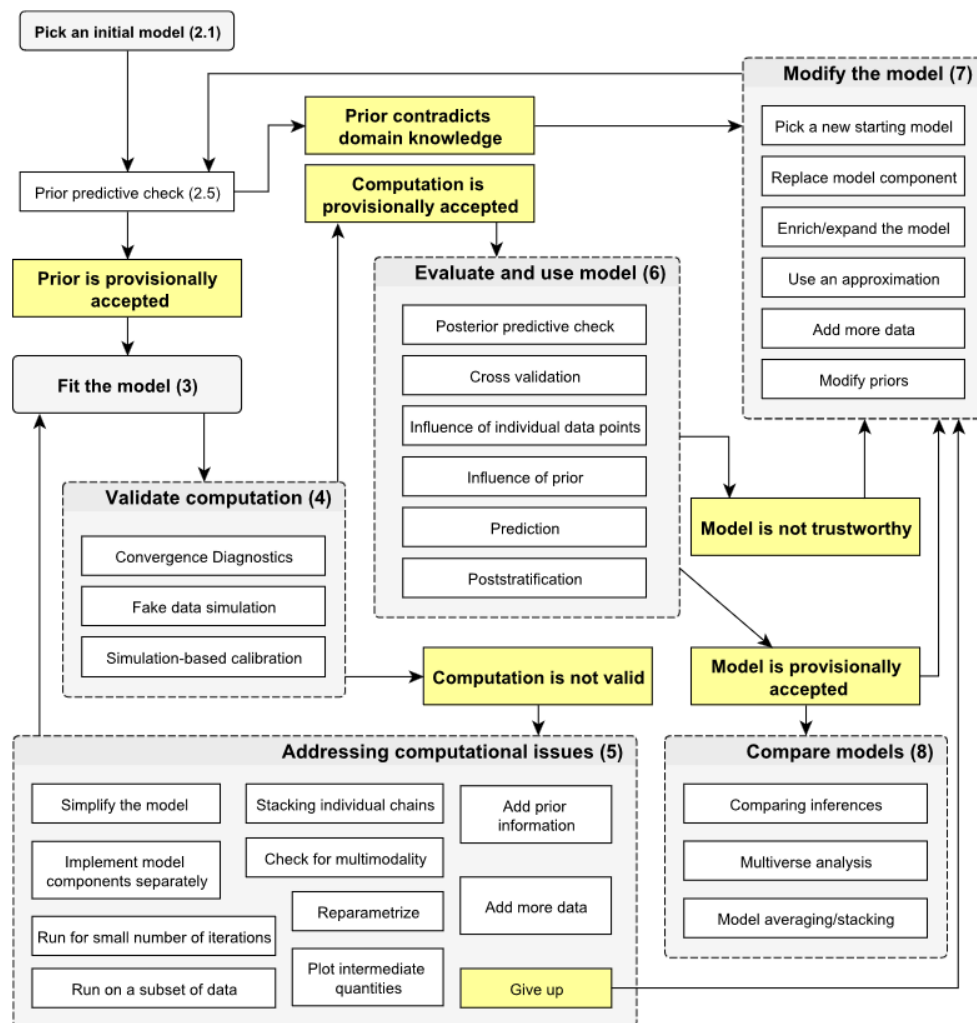
... always set `alpha.mu=0`, can set `V = 1` (or `diag()` in more complex cases) wlog;  
`sqrt(alpha.V)` (scale) and `nu` are the only relevant parameters

## effective sample size

- number of samples, corrected for autocorrelation
- ESS may be > sample size! (e.g. *antithetic sampling*)
- efficiency of a sampler is not (samples/time), but (effective samples/time)
- effective sample size >1000 for both tail and bulk quantities (Vehtari et al. 2021)

## Bayesian workflow

Gelman et al. (2020)



## simulation-based calibration

Talts et al. (2020)

### default priors/prior predictive simulations:

- `rstanarm` default priors: <https://cran.r-project.org/web/packages/rstanarm/vignettes/priors.html>

Using the good old `sleepstudy` example:

```
priorpred <- stan_lmer(Reaction ~ Days + (Days|Subject),  
                      prior_PD = TRUE, data = sleepstudy, chains = 1,  
                      seed = 101,  
                      refresh = 0)
```

```
prior_summary(priorpred)
```

Priors for model 'priorpred'

-----

Intercept (after predictors centered)

Specified prior:

~ normal(location = 299, scale = 2.5)

Adjusted prior:

~ normal(location = 299, scale = 141)

Coefficients

Specified prior:

~ normal(location = 0, scale = 2.5)

Adjusted prior:

~ normal(location = 0, scale = 49)

Auxiliary (sigma)

Specified prior:

~ exponential(rate = 1)

Adjusted prior:

~ exponential(rate = 0.018)

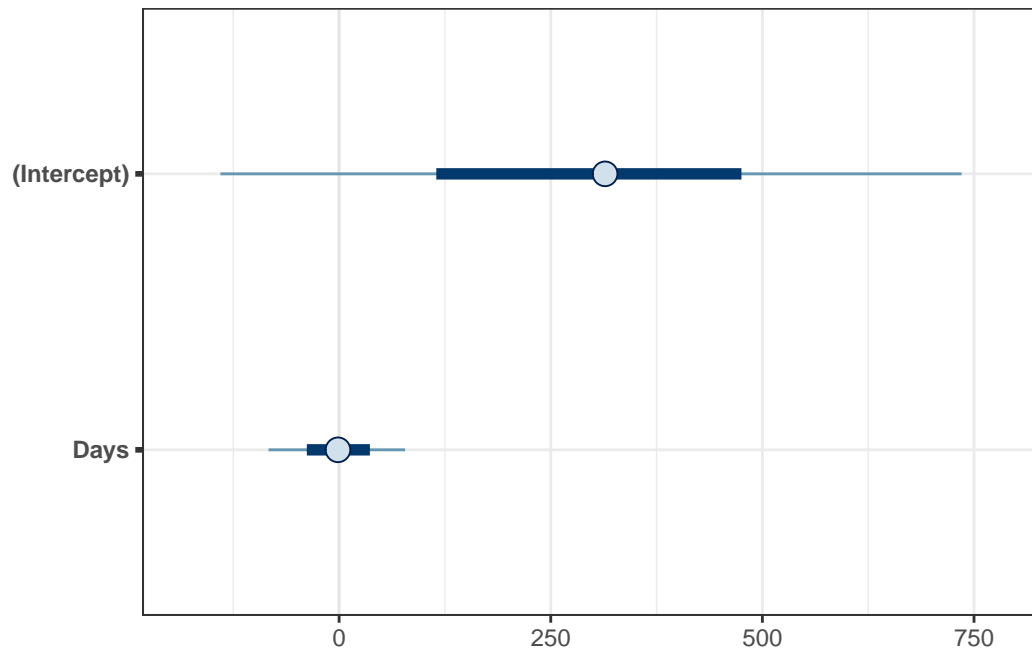
Covariance

~ decov(reg. = 1, conc. = 1, shape = 1, scale = 1)

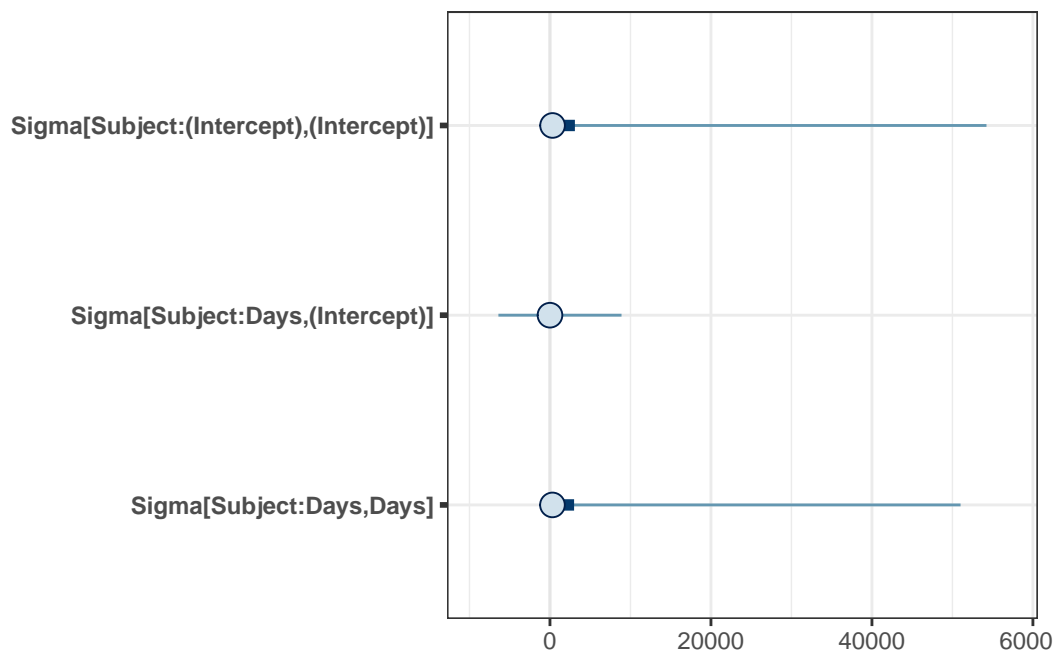
-----

See `help('prior_summary.stanreg')` for more details

```
plot(priorpred, pars = c("(Intercept)", "Days"))
```



```
plot(priorpred, regex_pars = "Sigma")
```



```
stanfit <- stan_lmer(Reaction ~ Days + (Days|Subject),
  data = sleepstudy, chains = 4)
```

```
print(bayestestR::diagnostic_posterior(stanfit), digits = 4)
```

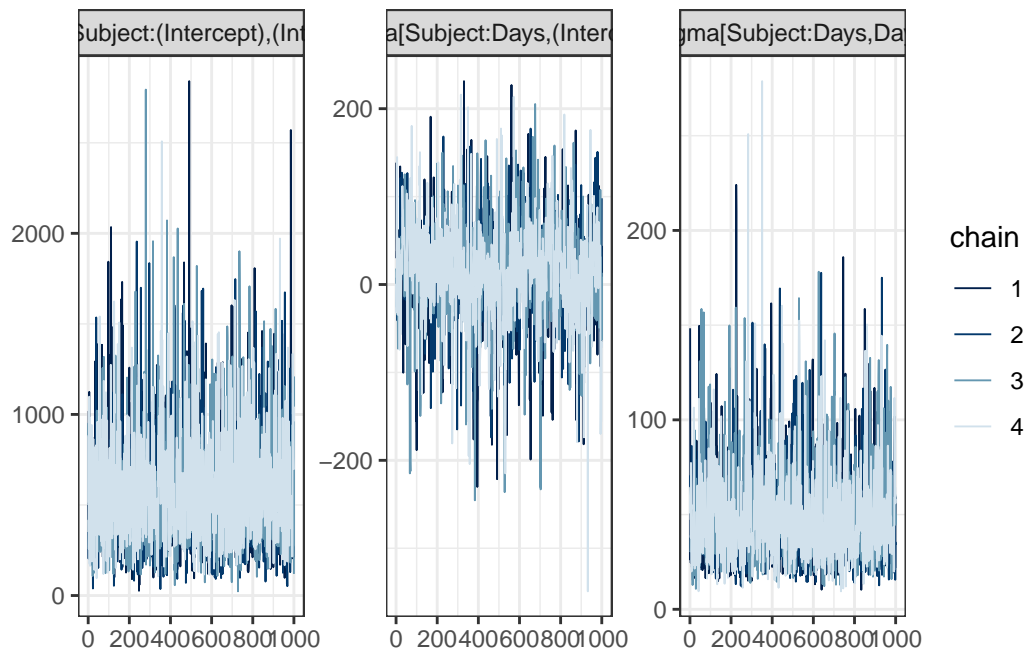
```

      Parameter Rhat  ESS    MCSE
1 (Intercept) 1.001 1765 0.15964
38      Days 1.002 1315 0.04827

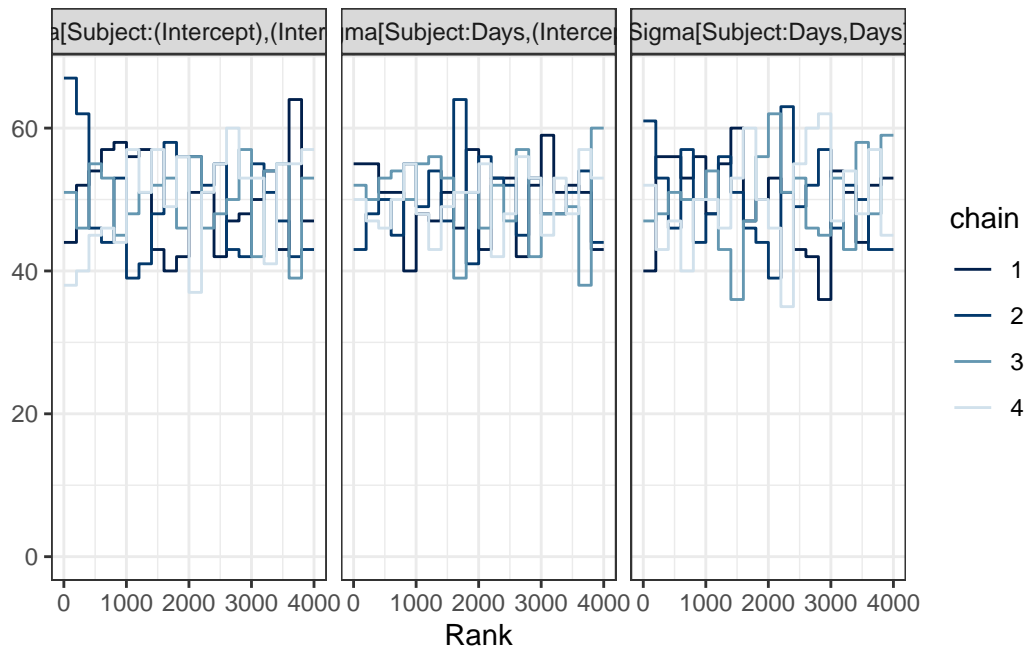
```

```
launch_shinystan(stanfit)
```

```
mcmc_trace(stanfit, regex_pars= "Sigma")
```



```
mcmc_rank_overlay(stanfit, regex_pars= "Sigma")
```



- MCMC diagnostics
  - trace plots, improved trace plots
  - R-hat Vehtari et al. (2021)
  - divergences (HMC only)

See <http://bbolker.github.io/bbmisc/bayes/examples.html>

## doing stuff with the results

```
tidy(stanfit, effects=c("fixed", "ran_pars"), conf.int = TRUE)
```

```
# A tibble: 6 x 6
```

term	estimate	std.error	conf.low	conf.high	group
<chr>	<dbl>	<dbl>	<dbl>	<dbl>	<chr>
1 (Intercept)	251.	6.34	240.	262.	<NA>
2 Days	10.5	1.65	7.52	13.2	<NA>
3 sd_(Intercept).Subject	23.8	NA	NA	NA	Subject
4 sd_Days.Subject	6.94	NA	NA	NA	Subject
5 cor_(Intercept).Days.Subject	0.0806	NA	NA	NA	Subject
6 sd_Observation.Residual	26.0	NA	NA	NA	Residual

❖ why don't we get confidence intervals ?? Do it by hand ...

```
(as_draws(stanfit)
  |> tidyr::pivot_longer(everything())
  |> group_by(name)
  |> summarise(estimate = median(value),
              lwr = quantile(value, 0.025),
              upr = quantile(value, 0.975))
  |> filter(!stringr::str_detect(name, "~b\\\\"))
)
```

```
# A tibble: 9 x 4
  name                estimate    lwr    upr
  <chr>              <dbl>   <dbl> <dbl>
1 (Intercept)        251.    238.  265.
2 .chain              2.5      1     4
3 .draw              2000.   101. 3900.
4 .iteration           500.    26.0  975.
5 Days                10.5     6.86  13.8
6 Sigma[Subject:(Intercept),(Intercept)] 510.    156. 1295.
7 Sigma[Subject:Days,(Intercept)]         16.0 -106.  112.
8 Sigma[Subject:Days,Days]                 42.9   18.1  108.
9 sigma                26.0    23.2  29.4
```

```
form1 <- Reaction ~ Days + (Days|Subject)
get_prior(form1, sleepstudy)
```

	prior	class	coef	group	resp	dpar	nlpar	lb	ub
	(flat)	b							
	(flat)	b	Days						
	lkj(1)	cor							
	lkj(1)	cor		Subject					
student_t(3, 288.7, 59.3)		Intercept							
student_t(3, 0, 59.3)		sd							0
student_t(3, 0, 59.3)		sd		Subject					0
student_t(3, 0, 59.3)		sd	Days	Subject					0
student_t(3, 0, 59.3)		sd	Intercept	Subject					0
student_t(3, 0, 59.3)		sigma							0
source									
default									

```
(vectorized)
  default
(vectorized)
  default
  default
(vectorized)
(vectorized)
(vectorized)
  default
```

```
b_prior <- c(set_prior("normal(200, 50)", "Intercept"),
             set_prior("normal(0, 10)", "b"),
             set_prior("normal(0, 1)", "sigma")
            )
```

```
b <- brm(form1, sleepstudy,
         prior = b_prior,
         seed = 101,          ## reproducibility
         sample_prior = 'only', ## for prior predictive sim
         chains = 1, iter = 500, ## very short sample for convenience
         silent = 2, refresh = 0 ## be vewy vewy quiet ...
        )
p_df <- sleepstudy |> add_predicted_draws(b)
```

‘spaghetti plot’ of prior preds

```
gg0 <- ggplot(p_df, aes(Days, .prediction, group=interaction(Subject, .draw))) +
  geom_line(alpha = 0.1)
```

```
b_prior4 <- c(set_prior("normal(200, 5)", "Intercept"),
              set_prior("normal(0, 2)", "b"),
              set_prior("normal(0, 1)", "sd"),
              set_prior("normal(0, 1)", "sigma")
             )
cc <- capture.output(
  b_reg <- brm(form1, sleepstudy,
               prior = b_prior4,
               seed = 101,
               init = 0,
               control = list(adapt_delta = 0.95)
```



```
)  
)
```

Start sampling

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From the [Stan forums](#):

This is common and not a problem, the algorithm explores a large range of values in the warm-up phase and often triggers numerical problems that go away.

```
print(bayestestR::diagnostic_posterior(b_reg), digits = 4)
```

	Parameter	Rhat	ESS	MCSE
1	b_Days	1.0002	3744	0.01764
2	b_Intercept	0.9997	3297	0.05154

```
## debug(MCMCglmm::priorformat)
m <- MCMCglmm(Reaction ~ Days, random = ~us(1+Days):Subject,
             data = sleepstudy,
             verbose=FALSE,
             prior = list(G=list(G1=list(V=diag(2), nu = 0.1))))
broom.mixed::tidy(m)
```

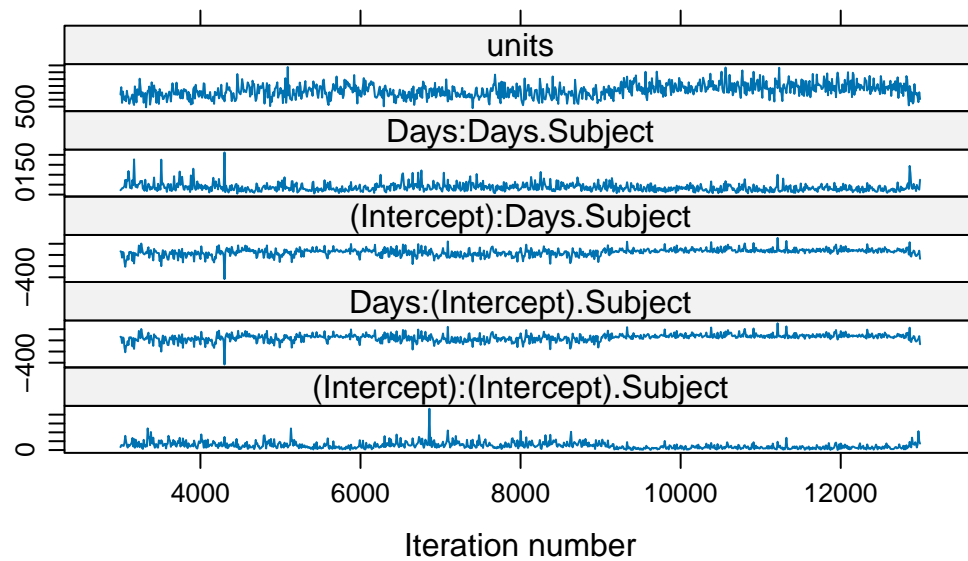
```
# A tibble: 6 x 5
  effect    group    term                estimate std.error
  <chr>    <chr>    <chr>                <dbl>    <dbl>
1 fixed    <NA>      (Intercept)          252.      6.65
2 fixed    <NA>      Days                 10.5      1.61
3 ran_pars Subject var__(Intercept)    508.     357.
4 ran_pars Subject cov__(Intercept).Days  49.1     63.5
5 ran_pars Subject var__Days          33.3     19.9
6 ran_pars Residual var__Observation  700.     98.6
```

```
try(MCMCglmm(Reaction ~ Days, random = ~us(1+Days):Subject,
            data = sleepstudy,
            verbose=FALSE,
            prior = list(G=list(G1=list(V=diag(2), nu = 0.1,
                                         alpha.mu = 0, alpha.V = diag(2))))))
```

```
Error in priorformat(if (NOPriorG) { :
  alpha.mu is the wrong length for some prior$G/prior$R elements
```

```
m2 <- MCMCglmm(Reaction ~ Days, random = ~us(1+Days):Subject,
              data = sleepstudy,
              verbose=FALSE,
              prior = list(G=list(G1=list(V=diag(2), nu = 0.1,
                                         alpha.mu = rep(0,2),
                                         alpha.V = diag(2)))))
```

```
lattice::xyplot(m2$VCV)
```



Run longer (and thin)? Strengthen prior?

## to do

- sort out `cmdstanr` make stuff
- test silencing of `brms` messages
- improve `tidy` for `rstanarm`
- better ways to get draws
- prior pred sims for `MCMCglmm`? (examples of parameter-expansion)
- SBC examples?
- figure out compilation caching for `brms`?

Gelman, Andrew, Aki Vehtari, Daniel Simpson, Charles C. Margossian, Bob Carpenter, Yuling Yao, Lauren Kennedy, Jonah Gabry, Paul-Christian Bürkner, and Martin Modrák. 2020. “Bayesian Workflow.” *arXiv:2011.01808 [Stat]*, November. <http://arxiv.org/abs/2011.01808>.

Talts, Sean, Michael Betancourt, Daniel Simpson, Aki Vehtari, and Andrew Gelman. 2020. “Validating Bayesian Inference Algorithms with Simulation-Based Calibration.” *arXiv:1804.06788 [Stat]*, October. <http://arxiv.org/abs/1804.06788>.

Vehtari, Aki, Andrew Gelman, Daniel Simpson, Bob Carpenter, and Paul-Christian Bürkner. 2021. “Rank-Normalization, Folding, and Localization: An Improved R-hat for Assessing Convergence of MCMC (with Discussion).” *Bayesian Analysis* 16 (2): 667–718. <https://doi.org/10.1214/20-BA1221>.