

# Bayesian data analysis – reading instructions 12

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## Chapter 12

Outline of the chapter 12

- 12.1 Efficient Gibbs samplers (not part of the course)
- 12.2 Efficient Metropolis jump rules (not part of the course)
- 12.3 Further extensions to Gibbs and Metropolis (not part of the course)
- 12.4 Hamiltonian Monte Carlo (used in Stan)
- 12.5 Hamiltonian dynamics for a simple hierarchical model (read through)
- 12.6 Stan: developing a computing environment (read through)

Python/R Stan demos

- See `rstan_demo.Rmd`, `pystan_demo.py`, `pystan_demo.ipynb` for demos how to use Stan from R/Python and several model examples

There is only 8 pages to read (sections 12.4-12.6) what is inside Stan.

## MCMC animations

These don't include the specific version of dynamic HMC in Stan, but are useful illustrations anyway.

- Markov Chains: Why Walk When You Can Flow? <http://eleventh.org/blog/2017/11/28/build-a-better-markov-chain/>
- MCMC animation site by Chi Feng <https://chi-feng.github.io/mcmc-demo/>

## Hamiltonian Monte Carlo

An excellent review of static HMC (the number of steps in dynamic simulation are not adaptively selected) is

- Radford Neal (2011). MCMC using Hamiltonian dynamics. In Brooks et al (ed), *Handbook of Markov Chain Monte Carlo*, Chapman & Hall / CRC Press. Preprint <https://arxiv.org/pdf/1206.1901.pdf>.

Stan uses a variant of dynamic Hamiltonian Monte Carlo (using adaptive number of steps in the dynamic simulation), which has been further developed since BDA3 was published. The first dynamic HMC variant was

- Matthew D. Hoffman, Andrew Gelman (2014). The No-U-Turn Sampler: Adaptively Setting Path Lengths in Hamiltonian Monte Carlo. *JMLR*, 15:1593–1623 <http://jmlr.org/papers/v15/hoffman14a.html>.

The No-U-Turn Sampler gave the name NUTS which you can see often associated with Stan, but the current dynamic HMC variant implemented in Stan has some further developments described (mostly) in

- Michael Betancourt (2018). A Conceptual Introduction to Hamiltonian Monte Carlo. arXiv preprint arXiv:1701.02434 <https://arxiv.org/abs/1701.02434>.

Instead of reading all above, you can also watch a nice introduction video

- Scalable Bayesian Inference with Hamiltonian Monte Carlo by Michael Betancourt <https://www.youtube.com/watch?v=jUSZboSq1zg>

## Divergences and BFMI

Divergences and Bayesian Fraction of Missing Information (BFMI) are HMC specific convergence diagnostics developed by Michael Betancourt after BDA3 was published.

- Divergence diagnostic checks whether the discretized dynamic simulation has problems due to fast varying density. See more in a case study [http://mc-stan.org/users/documentation/case-studies/divergences\\_and\\_bias.html](http://mc-stan.org/users/documentation/case-studies/divergences_and_bias.html).
- BFMI checks whether momentum resampling in HMC is sufficiently efficient. See more in <https://arxiv.org/abs/1604.00695>
- Brief Guide to Stan's Warnings <https://mc-stan.org/misc/warnings.html> provides summary of available convergence diagnostics in Stan and how to interpret them.

## Further information about Stan

- <http://mc-stan.org/> & <http://mc-stan.org/documentation/>
  - I recommend to start with these
    - \* Bob Carpenter, Andrew Gelman, Matt Hoffman, Daniel Lee, Ben Goodrich, Michael Betancourt, Marcus A. Brubaker, Jiqiang Guo, Peter Li, and Allen Riddell (2015) In press for Journal of Statistical Software. Stan: A Probabilistic Programming Language. <http://www.stat.columbia.edu/~gelman/research/published/stan-paper-revision-feb2015.pdf>
    - \* Andrew Gelman, Daniel Lee, and Jiqiang Guo (2015) Stan: A probabilistic programming language for Bayesian inference and optimization. In press, Journal of Educational and Behavior Science. [http://www.stat.columbia.edu/~gelman/research/published/stan\\_jebbs\\_2.pdf](http://www.stat.columbia.edu/~gelman/research/published/stan_jebbs_2.pdf)
  - Basics of Bayesian inference and Stan, parts 1+2 Jonah Gabry & Lauren Kennedy <https://www.youtube.com/playlist?list=PLuwyh42iHquU4hUBQs20hkBsKSMrp6H0J>
  - Modeling Language User's Guide and Reference Manual (more complete reference with lot's of examples) <https://github.com/stan-dev/stan/releases/download/v2.17.0/stan-reference-2.17.0.pdf>