UNIVERSITÀ DEGLI STUDI DI PADOVA

DIPARTIMENTO DI SCIENZE STATISTICHE

PHD COURSE IN STATISTICS

Specialist Course | Cycle XXXIX

May, 2024 | Campus S. Caterina

Bayesian Statistical Methods for Astronomy

David A. van Dyk

Imperial College London

Tuesday	**May 28**	**09:00 – 12:00** **14:30 – 17:30**	**Room SC40-SC20**
Thursday	**May 30**	**09:00 – 12:00** **14:30 – 17:30**	**Room SC40-SC20**

Program
https://www.stat.unipd.it/ricerca/courses-202324-xxxix-cycle

Bayesian Statistical Methods for Astronomy

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Course Description

Bayesian statistical methods are becoming ever more popular in astronomy. The clear mathematical foundations on which Bayesian methods are based allow researchers to design statistical models that directly account for complexities in physical sources, instrumentation, and data collection, while providing a straightforward way to combine multiple information sources and/or data streams. On the other hand, Bayesian method require "prior distributions" to be specified on all unknown parameters and fitting complex Bayesian statistical models (e.g., computing parameter estimates and their uncertainties) requires sophisticated computational techniques such as Markov chain Monte Carlo (MCMC).
This course will review the mathematical foundations of Bayesian methods, discuss techniques for specifying prior distributions, and study computational techniques including MCMC. Particular attention will be paid to Bayesian multi-level models— statistical models with multiple levels of structure. These models have wide applicability in astronomy and astrophysics because information is often available on multiple "levels" that allow complex models to be represented as a sequence of simple sub-models. Hierarchical models are a particular type of multi-level model that describe a population of objects (stars, pixels, etc.) with object-level parameters following a common distribution (specified in a lower level of the multi-level model). In the course we will discuss how Bayesian hierarchical models facilitate a concept called "shrinkage," which can produce better estimates of the parameters describing the objects in populations than can simple object-by-object estimators. We will demonstrate advantages of using multi-level/hierarchical models and shrinkage estimators via examples from cosmology.

This short course will be delivered in three parts.
Part I: Introduction to the foundations of data analysis from a Bayesian perspective.
Part II: Overview of modern statistical computing, focusing on Markov chain Monte Carlo.
Part III: Bayesian modelling techniques, including multi-level models, hierarchical models, and shrinkage estimates.
In all three parts, examples will be taken from astronomy to clarify the mathematical, statistical, and computational concepts.

Suggested Reading

Gelman, Carlin, Stern, Dunson, Vehtari, and Rubin (2013). Bayesian Data Analysis. Chapman & Hall / CRC.
Fraix-Burnet, Girard, Arbel, Marquette (2018). Statistics for Astrophysics: Bayesian Methodology. EDP Sciences, France. Particularly Chapters 1-3.