Unit PHYS5513 “Computational Statistics for Physics” (Sem 2, 2025)

All course material, assignments, videos and guidelines are available at: https://tinyurl.com/phys5513

Contact

This unit is taught in equal parts by the two course coordinators:
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Content

This unit provides key tools for the statistical and numerical analysis of complex problems in physics and astrophysics. It includes a solid introduction to the R statistical programming language and contains many practical examples from cosmology and astrophysics, as well as some examples from general physics and medicine.

Learning outcomes

#	Outcome	Assessment
1	Good coding skills of the R language; ability to use native routines, manipulate built-in data structures, interface with other scientific programming languages (C++, C, Fortran), and read/write various scientific data types (e.g. ascii, HDF5, FITS).	Assignment
2	Understand key concepts of numerical analysis, and ability to numerically evaluate difficult functions, equations, integrals and differential equations in R.	Assignment
3	Understand and apply basic statistical concepts, such as probability trees, probability density functions, statistical ensembles, resampling techniques and key statistical tests.	Assignment
4	Understand and apply the concepts behind Bayesian inference, including ability to derive and manipulate likelihood functions and related concepts, including Laplace approximation.	Assignment
5	Ability to solve advanced inference problems using MCMC techniques; understanding of correlations and ability to perform multi-dimensional linear fits.	Assignment
6	Understand and apply the concepts of spatial correlations and spectral analysis; ability to evaluate and manipulate Fourier series, Fourier transforms and discrete fourier transforms.	Assignment

Lecture format

The unit is presented in 18 sections, grouped into six parts of three sections each. Each section corresponds to one 2h-workshop. Each part is taught by one lecturer, in an alternating manner as per schedule on the next page. The lecture content is supported by detailed lecture notes supplied in PDF and Rmarkdown format (one set of files per section). These notes are comprehensive and often contain more material than discussed during the lecture. We recommend that students read the lecture notes before the respective lectures.

The assessment is based on six equally-weighted assignments, corresponding to the six parts of the course. There is *no* final exam. The assignments are distributed at the beginning of the respective parts of the course. Questions on how to solve the assignment can be asked during the lectures.

Following UWA’s 150h/unit rule, students are expected to allocate their time roughly as follows: 36h in-class for lectures, 9h in-class for assignment discussions, 45h on readling/processing lecture notes (=2-3h/section), and 60h on completing the assignments (=10h/assignment).

The 18 workshops are not recorded and we encourage in-person attendance.

Assignments & Marks

Six assignments will be distributed as PDF files. Solutions must be submitted as a single Rmarkdown document with the compiled PDF file. Upload both files to the LMS link before the due date. Hard copies or scans are not accepted.

By UWA's new Exceptional Variation to Assessment, submissions within 48 hours from the due date are marked late but receive no penalty. After 48 hours, penalties incur: first a 15% deduction, then 5% per additional day, up to the 7th day, where the total deduction is 35%. Work submitted more than 7 days after the due date is not accepted.

Academic integrity is crucial, the guideline being that students must own and understand their submitted solutions. Students are welcome and encouraged to discuss assignments with peers and use online resources, including AI, but copying or paraphrasing others' work and code or employing services to complete assignments is not allowed.

Minimal solutions will be available within three weeks of each deadline. The first four assignments will be discussed in class; the final two will not, but feedback will be provided via LMS and individual appointments with lecturers are available. Final grades will be released after the exam period.

Schedule

Week	Mo date	Mo	Tu	We	Th	Fr
Orientation	14/07/25					
1	21/07/25	P1	10am-12pm L1.1		10am-12pm L1.2	
2	28/08/25		10am-12pm L1.3			A1 11:59pm
3	04/08/25	P2			10am-12pm L2.1	
4	11/08/25		10am-12pm L2.2		10am-12pm L2.3	
5	18/08/25	A2 11:59pm, P3	10am-12pm L3.1/S1		10am-12pm L3.2	
6	25/08/25		10am-12pm L3.3			A3 11:59pm
Study break	01/09/25					
7	08/09/25	P4	10am-12pm L4.1/S2			
8	15/09/25		10am-12pm L4.2		10am-12pm L4.3	A4 11:59pm
9	22/09/25	P5	10am-12pm L5.1/S3		10am-12pm L5.2	
10	29/09/25	King's BD	10am-12pm L5.3			A5 11:59pm
11	06/10/25	P6	10am-12pm L6.1/S4		10am-12pm L6.2	
12	13/10/25		10am-12pm L6.3			A6 11:59pm
Study break	20/10/25					

Legend

P# Distribution of the lecture notes and the assignment for part # via Dropbox
L#.# Lecture on part #, section # (different parts distinguished by green/blue colour)
A# Due date of assignment number #
S# Discussion of solutions of assignment #

Detailed content

PART 1: R language

- R basics
- Interfacing with compiled languages, including Rcpp examples, e.g. logistic map, mandelbrot, game of life
- I/O handling & big data (read/write binary, ascii, FITS, HDF5, FST, arrow, feather, png/jpeg/bmp)

PART 2: Numerical analysis

- Random numbers, non-elementary functions, interpolation/extrapolation, smoothing, density estimation
- Numerical calculus: integration, differentiation, differential equations
- Numerical optimisation (without MCMC)

PART 3: Statistical concepts

- Probability trees and first glimpse at Bayesian statistics
- Statistical ensembles, populations/samples, probability density functions
- Statistical tests and sampling/resampling techniques

PART 4: Bayesian inference

- Bayes' theorem, maximum likelihood and maximum a posteriori estimation, model evidence
- Laplace approximation: parameter uncertainties, error propagation, Fisher information, Jeffreys priors
- Number density functions, mass functions

PART 5: Advanced applied inference

- MCMC (write basic metropolis hastings sampler, then LaplaceDemon)
- Correlations, linear modelling (+hyperfit)
- Galaxy modelling (+profit)

PART 6: Temporal and spatial statistics

- Fourier representation: Fourier series, FT, DFT; extended examples (e.g. image compression)
- 2-point and higher order statistics and common estimators
- Spherical harmonics and selected applications, including CMB