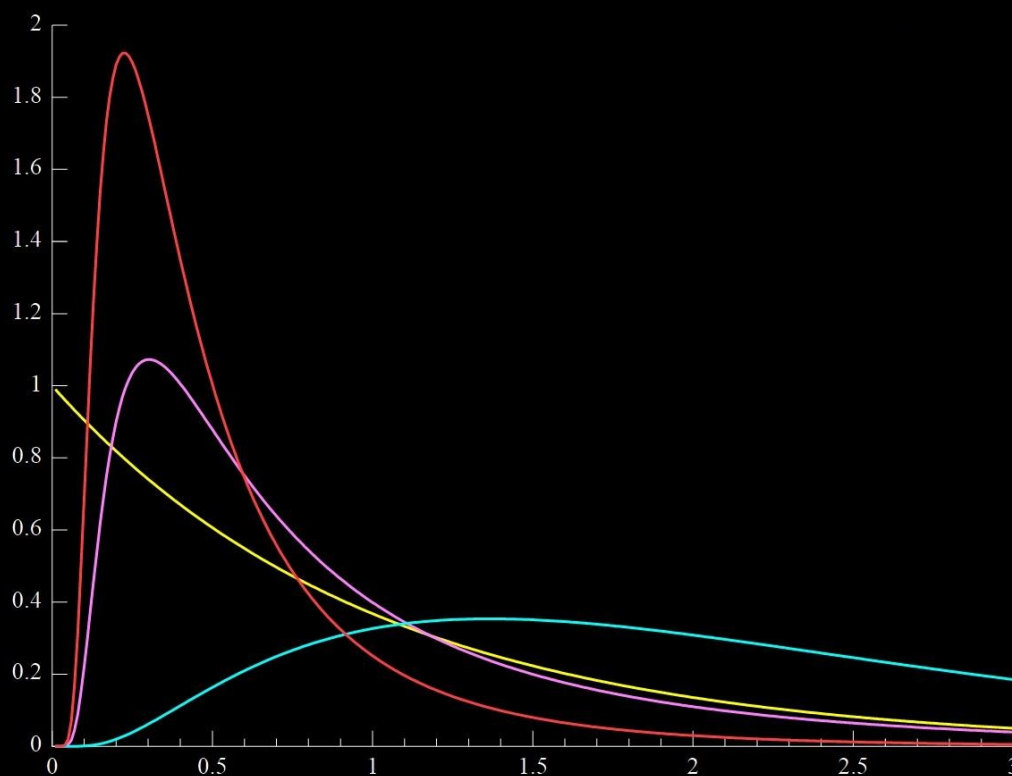




University of Glasgow | School of Physics & Astronomy



ASTRO5003

Statistical Astronomy

Course Information Guide

Course Details

| | | | |
|--------------------|--------------------|------------------------|--|
| | | Schedule: | STAI - 11 lectures, semester 1 STAI - 11 lectures, semester 2 |
| Credits: | 15 | ECTS Credits: | 7.5 |
| Assessment: | 2 hour exam (100%) | Exam Diet: | April/May |
| Level: | Masters | SCQF Level: | 11 |
| Year Cycle: | A (odd years) | Course website: | Moodle Link |

Course Aims

To provide students with an opportunity to develop knowledge and understanding of the key principles and applications of Statistical Astronomy, and their relevance to current developments in astronomy, at a level appropriate for a professional astronomer.

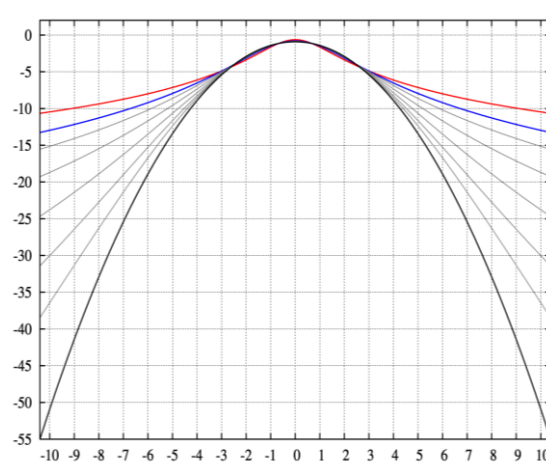
Intended Learning Outcomes

By the end of the course, students will be able to:

- Demonstrate a knowledge and broad understanding of Statistical Astronomy, and show a critical awareness of the significance and importance of the topics, methods and techniques discussed in the lectures and their relationship to concepts presented in other courses.
- Describe and analyse quantitatively processes, relationships and techniques relevant to the topics included in the course outline, applying these ideas and techniques to analyse critically and solve advanced or complex problems which may include unseen elements
- Write down and, where appropriate, either prove or explain the underlying basis of astrophysical laws relevant to the course topics, and discuss their applications.

Semester 1 Course Outline

- *The Meaning of Probability:* Bayesian and frequentist approaches. Deductive reasoning and Boolean algebra. Conditional probability and the extension to plausible reasoning. The idea of probability as a measure of plausibility of a statement. The sum and product rules in probability. Bayes' theorem and Bayesian Probability Theory. Frequentist definition of probability. Probability as a limit of relative frequency, combinatorial probability. Probability distributions and random variables.
- *Probability Distribution:* Poisson distribution and photon statistics as an example of a discrete distribution. Continuous distributions and pdfs. Cumulative distribution functions. The uniform distribution. Central (Normal) distribution, histograms. The Central distribution as a limiting distribution. Measures and moments of a distribution - the mean, variance, standard deviation, median, mode, skewness and kurtosis. Variable transforms. Multivariate distributions. Joint pdfs. Marginal



Example of a Probability Density Function showing different levels of Kurtosis in different colours.

distributions. Statistical independence. The bivariate normal distribution. Samples and parents.

- *Bayesian Parameter Estimation*: Bayes' theorem as applied to parameter estimation and examples of its application. Priors, likelihoods and posterior distributions. The biased coin problem. Dependence (or otherwise) of posterior on choice of prior. General Bayesian parameter estimation. The idea of a model. The universality of the posterior distribution. Best estimates and error bars. The Gaussian approximation to the posterior pdf. Shortest confidence intervals. Symmetric and asymmetric pdfs. The treatment of Gaussian noise, with uniform and non-uniform variance. Model fitting; marginal distributions. Example of fitting to a weak spectral line (Poisson noise).

Semester 2 Course Outline

- *Bayesian Hypothesis Testing*: Bayes' theorem The maximum likelihood and least-squares approximations. Fitting a straight line to data - the period luminosity relation as an example. WMAP results as an example of Bayesian parameter estimation. Bayesian model comparison. Prior odds and the Bayes Factor. Occam's Razor.
- *Frequentist Parameter Estimation and Hypothesis Testing*: The idea of a statistic and of an estimator. Sample mean and variance revisited. Consistency and bias. Maximum likelihood method. Least squares method from the frequentist standpoint. Weights; the chi-squared distribution. Point and interval estimates; confidence; goodness of fit and the chisquared statistic. Fitting general models; Type I and Type II errors and significance. Goodness of fit for discrete distributions. Non-parametric methods. Kolmogorov-Smirnov test.
- *Assigning Bayesian Probabilities*: What is ignorance? Least informative probabilities. The principle of insufficient reason. Transformational invariance. Assigning probabilities to continuous parameters. Location and scale parameters. Improper pdfs. The principle of maximum entropy and its application.

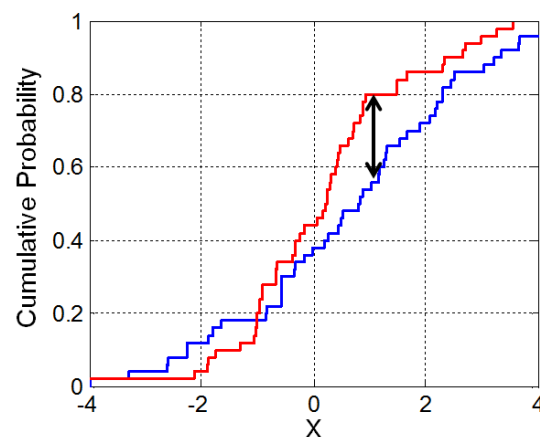


Illustration of the Kolmogorov-Smirnov test, with each line representing a different distribution function. Created in Matlab.

Further Information

Recommended texts

| | | | |
|-----------------------|---|-----------------|------|
| D.S. Sivia | <i>Data Analysis, a Bayesian Tutorial</i> | Oxford | 2006 |
| P.C. Gregory | <i>Bayesian Logical Data Analysis for the Physical Sciences</i> | CUP | 2005 |
| Roger Barlow | <i>Statistics</i> | Wiley | 1989 |
| G.L. Betthorst | <i>Bayesian Spectrum and Parameter Estimation</i> | Springer-Verlan | 1988 |

[Physics & Astronomy reading lists.](#)

[Course specifications](#) - More details about the course in relation to other courses and degree paths on the [course catalogue website](#).

[Time and location of lectures](#) - will be available during term time on the course website via Moodle.

[Enrolment](#) - Through MyCampus, details on the Astronomy 345 Moodle page.