ASTRONOMY 6523
Spring 2013
Signal Modeling, Statistical Inference and Data Mining in Astrophysics
Professor: Jim Cordes

Place and Time: 622 Space Sciences Building, TTh 2:55-4:10 p.m.

Text: Bayesian Logical Data Analysis for the Physical Sciences, P. C. Gregory

Additional References: Unpublished notes & selected articles
Probability, Random Variables & Stochastic Processes, A. Papoulis
Bayesian Inference in Statistical Analysis, G.E.P. Box & G. C. Tiao
Probability Theory, E. Jaynes

Aims of the Course: The emphasis is on statistical descriptions, analysis, detection, inference;
model building and model fitting to empirical data.

Techniques will be demonstrated through case studies encountered in
astronomy and elsewhere and also with data challenges.

Responsibilities: Attending lectures and asking questions
Problem sets (analytical & computational)
Short projects
Term project
Final oral exam

Office, etc: 520 SSB, jmc33@cornell.edu, 607 255-0608

Web Page: http://www.astro.cornell.edu/~cordes/A6523
Written Materials: Instructor’s notes
Articles from astrophysical, geophysical and engineering literature

Assignments: Grading criteria include legibility, grammar, correctness, and completeness
Project:
Topic and Abstract: Due 12 March in written form and presented to class (5 min)
In class presentation: Week 12 or 13 into the semester (~15 minutes)
Written report: Due during finals week;
Text edited, In journal article style, Bibliography, Plots: labeled axes,
Grading: legibility, grammar, correctness, completeness

Computations: You can use any language or package you like
(MATLAB, IDL, Python, Mathematica; C, C++, Fortran, etc.)
Main Topic Blocks:

1. Linear Systems and Basis Vectors
2. Probability and Stochastic Processes
3. Spectral Analysis
4. Statistical Inference (Frequentist and Bayesian)
5. Model Fitting
6. Localization Methods
7. Detection Applications
8. Classification Applications
9. Tests and Tools:
   (a) Detection methods (false alarms, ROC curves)
   (b) Tests: whiteness, Gaussianity, stationarity, Markovianity, chaos vs stochastic processes . . .
   (c) Bayesian priors, marginalization, and odds ratio
   (d) Extreme value and order statistics
   (e) Correlation functions, structure functions, and bispectra
   (f) Principal component analysis (PCA)
   (g) Phase retrieval methods (deconvolution)
   (h) Simulation methods
   (i) Optimization and sampling (simulated annealing, genetic algorithms, Markov Chain Monte Carlo)
10. Case studies:
    (a) Modeling state changes in astrophysical objects with Markov processes
    (b) Detecting gravitational waves (stochastic, CW/Chirped, bursts)
    (c) Characterizing processes on the sphere (e.g. Cosmic Microwave Background)
    (d) Wave propagation through random media
    (e) Optimal model fitting against arbitrary kinds of additive noise (especially “red” noise)
    (f) Image formation and processing
    (g) Classifiers