MEMORANDUM

Date: 20 August 2015
To: Dr. Mark Archambault, Chair, Undergraduate Curriculum Committee
CC'd: Dr. Hamid Rassoul, Dean, College of Science
From: Dr. Véronique Petit, Physics and Space Sciences
Re: New SPS course: Advanced Research Techniques and Data Analysis

All of us know how research as a physicist is rather different than what students often perceive as “work” while in the classroom. The transition for solving homework sets to pursuing original research of course requires an excellent foundation in physics knowledge, but also a different skill set: paper writing, communication, data analysis, statistical inference, project management, numerical computing, problem solving, etc.

This new course will therefore develop the skills and tools necessary to perform active research in physics. Although arranged around a data-oriented astrophysics thematic, this new course will be of extreme value to all physics and space science majors in all their desired career paths.

The specific learning goals for this course are for students to:
- gain experience in critical thinking and problem solving,
- understand the manipulation of data to extract physically meaningful quantities and their associated uncertainties,
- practice and reinforce the use of statistical inference to assess the plausibility of hypotheses or models,
- become aware the traps and pitfalls of numerical calculations,
- develop the skills for creating useful visualization of quantitative information.

This course will be organized in a “flipped classroom” model, where the homework projects involving a large component of scientific computing in Python and applied statistics, will be directed at the practical applications of these skills.

Although C++/Fortran knowledge is still an absolutely necessity for any physicist, Python is a rising language who is now leading the way as a post-processing tool to more complex codes. Adding some experience in Python programming to our major’s curriculum will greatly augment their employability.
We would like to note that the PSS department has a class listed as:

PHY 3030 Introduction to Computational Physics (3 credits):
Numerical experimentation is an increasingly powerful tool for exploring nature, complementing theory and laboratory experiments. Includes finite difference equations, sports physics, oscillatory motion and chaos, orbital mechanics, Monte Carlo methods, quantum mechanics, self-organized criticality. Prerequisites: MTH 1002, PHY 2002.

The new course we propose here is different from PHY 3030. Although the new course includes some numerical methods, the focus is also on data analysis, statistical inference, data representation/visualization, etc, which are not part of Computational Physics.

Regards,
Véronique Petit

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Dr. Véronique Petit
Assistant Professor
Dept. of Physics & Space Sciences
Florida Institute of Technology
Olin Physical Science, 346
VPetit@fit.edu, 321-674-8267
New courses are available beginning with the fall term in which they appear in the University Catalog.

<table>
<thead>
<tr>
<th>SUBJECT</th>
<th>PHYSICAL SCIENCE</th>
<th>COURSE NO.*</th>
<th>4050</th>
<th>CREDIT HOURS</th>
<th>3</th>
<th>ACADEMIC YEAR TO BE ADDED TO THE FILE</th>
<th>Fall 2016</th>
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</thead>
</table>

*Justify level if 1000-level and no co-or prerequisites.

| CLASS HOURS | 45/semester | LECTURE HOURS | 45/semester | LAB HOURS | 0/semester | CONTACT HOURS (CEU ONLY) | N/A |

<table>
<thead>
<tr>
<th>DEPARTMENT</th>
<th>Physics and Space Sciences</th>
<th>SCHEDULE TYPE</th>
<th>Lecture (A)</th>
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| [ ] COLLEGE OF AERONAUTICS – 23 | [ ] COLLEGE OF PSYCHOLOGY AND LIBERAL ARTS – 25 |
| [ ] NATHAN M. BISK COLLEGE OF BUSINESS – 24 | [ ] COLLEGE OF SCIENCE – 26 |
| [ ] COLLEGE OF ENGINEERING – 1 | [ ] EXTENDED STUDIES / NATHAN M. BISK COLLEGE OF BUSINESS – 90 |

| COMPUTER TITLE | Restricted to 25 characters, including spaces | Research Techniques | Dual-Prefix | Bi-Level | Full-Load |

| CATALOG TITLE | Advanced Research Techniques and Data Analysis |

| CATALOG DESCRIPTION OF COURSE | Restricted to 350 characters, including spaces |

'Covers the skills and tools necessary to perform active research in physics, particularly in data-oriented astrophysics. Describes the manipulation of data to extract physically meaningful quantities and their associated uncertainties. Includes the use of statistical inference, numerical calculations and visualization of quantitative information.'

This description has been approved by the catalog office.

Date: 8/24/2015

Catalog & Curriculum Manager

In addition, please attach a course syllabus and/or more detailed description.

<table>
<thead>
<tr>
<th>RESTRICTIONS</th>
<th>Prerequisite CSE 1502</th>
<th>Corequisite Course Number</th>
<th>and or</th>
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<tbody>
<tr>
<td>[ ] Prerequisite CSE 1503</td>
<td>[ ] Corequisite Course Number</td>
<td>and or</td>
<td></td>
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<tr>
<td>[ ] Prerequisite MTH 3210</td>
<td>[ ] Corequisite Course Number</td>
<td>and or</td>
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| ADDITIONAL RESTRICTION | PHY 2003 |

| (e.g., Major, Class Level, Department Head Approval) |

If this course replaces a course currently offered in BANNER, please indicate old course information and the date/term the course may be removed from the system.

| SUBJECT | Alpha Prefix (e.g., CSE) | COURSE NO. | (e.g., 1301) | TERM TO INACTIVATE |

| [ ] Yes | No | Will this course be used to measure program-level student learning outcomes? If yes, review and signature required.* |
| [ ] Yes | No | Will this course be used to satisfy the scholarly inquiry requirement? If yes, attach "Q" materials for review. |
| [ ] Yes | No | Will this course impact any existing programs? If yes, attach "Changing Graduation Requirements" form for each program that is impacted. |

APPROVALS: On completion of description and course number verification, affix appropriate signatures as indicated, and submit completed form to Chair, Graduate Council, or Chair, Undergraduate Curriculum Committee for approval.

Date: 8/24/15

Chair, Graduate Council

Date: 8/24/15

Chair, Undergraduate Curriculum Committee

Date: 8/24/15

**Vice President for Institutional Effectiveness

Date:

Florida Institute of Technology • Office of the Registrar

150 West University Boulevard, Melbourne, FL 32901-6975 • (321) 674-8114 • Fax (321) 674-7827
Adding a New Course to the Curriculum

This is a request for reactivation of a course in the system. □ Yes    □ No

New courses are available beginning with the fall term in which they appear in the University Catalog.

Subject: SP 4050
Course No.: (e.g., CSE 1901)
Credit Hours: 3
Academic Year to Be Added to the File: Fall 2016
Yes

Class Hours: 45/semester
Lecture Hours: 45/semester
Lab Hours: 0/semester
Contact Hours (CEU Only): N/A

Department: Physics and Space Sciences
Schedule Type: Lecture (A)

College of Aeronautics - 23
College of Psychology and Liberal Arts - 25
College of Science - 26
College of Engineering - 1
Extended Studies / Nathan M. Bisk College of Business - 90

Computer Title: Restricted to 25 characters, including spaces
Research Techniques

Full-Load

Catalog Title: Advanced Research Techniques and Data Analysis
Catalog Description of Course: Restricted to 350 characters, including spaces
Covers the skills and tools necessary to perform active research in physics, particularly in data-oriented astrophysics. Describes manipulation of data to extract physically meaningful quantities and their associated uncertainties. Includes the use of statistical inference, numerical calculations and visualization of quantitative information.

This description has been approved by the catalog office.

In addition, please attach a course syllabus and/or more detailed description.

Restrictions: Prerequisite CSE 1502
Course Number
Corequisite CSE 1503
Course Number

Grades to Be Issued: A, B, C, D, F
CEU
S, U
P, F
Other

Additional Restrictions: PHY 2003

If this course replaces a course currently offered in Banner, please indicate old course information and date/term the course may be removed from the system.

Subject: Alpha Prefix (e.g., CSE)
Course No. (e.g., 1901)
Term to Inactivate

Yes    □ No    Will this course be used to measure program-level student learning outcomes? If Yes, review and signature required.

Yes    □ No    Will this course be used to satisfy the scholarly inquiry requirement? If Yes, attach "Q" materials for review.

Yes    □ No    Will this course impact any existing programs? If Yes, attach "Changing Graduation Requirements" form for each program that is impacted.

Approvals: On completion of description and course number verification, affix appropriate signatures as indicated, and submit completed form to Chair, Graduate Council, or Chair, Undergraduate Curriculum Committee for approval.

Department Head/Program Chair
Date

Dean or Associate Dean
Date

Catalog & Curriculum Manager
Date

Registrar's Use Only
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Operator Init.
Date

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Catalog & Curriculum Manager
Date

- Vice President for Institutional Effectiveness

Date
Advanced Research Techniques and Data Analysis

Basic information

Instructor: Dr. Veronique Petit
Contact:
  • Phone: 321-674-8267
  • Office: 346 OPS
  • Email: VPetit@fit.edu
Times/Location: TBD.
Office hours: Mon 3-4pm, Wed 3-4pm, Thurs 11am-12pm. You can set an appointment at other time.
Course website: On Canvas

Course Overview

This course will develop the skills and tools necessary to perform active research in physics, particularly in data-oriented astrophysics. Each block of two weeks will cover a specific subject. Homework projects, involving a large component of scientific computing in Python and applied statistics, will be directed at the practical applications of the skills learned in class.

The learning goals for this course includes:
• Gain experience in critical thinking and research skills.
• Understand the manipulation of data to extract physically meaningful quantities and their associated uncertainties.
• Understand the use of statistical inference to assess the plausibility of hypotheses or models.
• Be aware the traps and pitfalls of numerical calculations.
• Develop the skills for creating useful visualization of quantitative information.

All software used during this course is open source/freeware. Students that do not possess a personal laptop must contact me as soon as possible.

Textbook

The dedicated textbook for this course is Computation Physics by Mark Newman.

Additional resources will be provided on the course website, and the following textbooks, available at the library and for consultation in the Astro 3rd floor lab, can be used as reference:

• Numerical Recipes in C: The Art of Scientific Computing, by Saul Teukolsky, Brian P. Flannery, William T. Vetterling, and William H. Press. This is the bible of numerical technics, laid out by series of practical examples.
• Bayesian Logical Data Analysis for the Physical Sciences by Phil Gregory. A textbook on Bayesian statistics with specific Physics applications.
• Modern Statistical Methods for Astronomy by Eric D. Feigelson, G. Jogesh Babu. A reference book similar to numerical recipe, but applied to astronomy.
Advanced Research Techniques and Data Analysis

Grades

The final grade for the course will depend primarily on:
- In class weekly quizzes (10%),
- Bi-weekly homework projects (50%),
- Independent research project, which include a proposal, a mid-term report, and a final report (20%),
- Final examination (20%).

Pre-requisites

CSE 1502 or CSE 1503 -- Introduction to software development with C++ / Fortran,
PHY 2003 -- Modern Physics,
MTH 3210 -- Introduction to Partial Differential Equations and Applications.

Policies

Academic dishonesty, including cheating, plagiarism, and fabrication is a serious offense that will result in contacting the Dean of Students and others according to campus policy. The policy, procedures, and charges can be found at: http://www.fit.edu/studenthandbook/print.php#policy_2490.

Collaboration on homework projects is allowed and encouraged. For example, meeting together in a group to figure out a problem is an excellent idea. However, all submitted work must be your own using your own words and explanations -- you should be able to readily explain to me in person all parts of your projects.

If for any reason, at any time during the semester, you find yourself confused or falling behind, please let me know immediately. We can work together to find a way for you to succeed.
Course schedule

Week 1
Introduction to research and programming in Python.

Week 2-3
Data processing and error analysis:
- Measuring equivalent width of spectral lines.
- Measuring flux from source in image.
Skills learned: I/O in Python, astronomical “FITS” format, numerical integration, error propagation.

Week 4-5
Forward modeling and $\chi^2$ statistics:
- Modeling an X-ray spectral line with Gaussian.
- Discuss how to make good figures.
Skills learned: confidence intervals, brute force vs minimum search approaches, use of contour plots.

Week 6-7
Bayesian inference and model selection:
- Modeling an X-ray spectral line with 2 competitive models.
- Discuss model selection and the Occam factor.
Skills learned: Bayesian parameter estimation, credible regions, visualization of multi-variate data.

Week 8-9
Simulating data:
- Creating simulated data set with noise and sampling.
- Evaluating biases in survey of stars’ rotational velocities.
Skills learned: use of histograms and cumulative distributions, statistical vs systematic errors.

Week 10-11
Monte-Carlo, Markov-chains, and resampling methods
- Using Markov-chain to solve the spectral line problem.
- Monte-Carlo radiative transfer.
Skills learned: Metropolis-Hasting algorithm, point density plots.

Week 12-13
Time series analysis:
- Determine periodicity of Kepler light curve with Fourier methods.
- Discuss aliasing, window function, and sampling.
Skills learned: Fourier analysis, sampling biases.

Week 14-15
Numerical simulation:
- Write a 2-body code for gravitational interactions between 2 bodies (with relativistic terms).
- Discuss efficient ODE integration techniques.
Skills learned: finite difference approach, creating display animations.

Or
Iterative computation with boundary condition:
- Calculate a stellar atmosphere structure.
- Discuss best practices for scientific computing.
Skills learned: finite difference approach, alpha iterative scheme, multivariable plots.