Leveraging the Pandemic Moment: Revamping a Computational Astrophysics Class

David Chappell
Department of Physics and Mathematics
• Located in Southern California, est. 1891
• Hispanic Serving Institution
• Majority First Generation
• 2800 Undergrads

Physics B.A. and B.S.
• 2 graduates per year (range 0-7)
• 2 full-time faculty
• Limited engineering
## Physics Courses at the University of La Verne

### Lower-Division

<table>
<thead>
<tr>
<th>Course</th>
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<tbody>
<tr>
<td>Physics I</td>
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<td>Physics II</td>
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### Upper-Division

<table>
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<tr>
<td>Classical Mechanics</td>
<td>E&amp;M</td>
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<tr>
<td>Modern</td>
<td>Quantum</td>
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<tr>
<td>Physics Seminar</td>
<td>Advanced Lab/Senior Project</td>
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<tr>
<td>Solid State</td>
<td>Astrophysics</td>
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<tr>
<td>Stat. Mech &amp; Thermo</td>
<td>Computational Methods</td>
</tr>
<tr>
<td>Optics</td>
<td>Nonlinear Dynamics</td>
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</tbody>
</table>

- **Core Classes**: offered every year
- **Core Classes**: (2-year rotation)
- **Core Classes**: (every year)
- **Electives**: (2-3 year rotation)
## Embedded Computation

### Lower-Division
- Physics I
- Physics II

### Upper-Division
- Classical Mechanics
- Modern
- Physics Seminar
- Solid State
- Stat. Mech & Thermo
- Optics
- E&M
- Quantum
- Advanced Lab/Senior Project
- Astrophysics
- Computational Methods
- Nonlinear Dynamics

### Electives
- Core Classes
  - (2-year rotation)
- Core Classes
  - (every year)
- Electives
  - (2-3 year rotation)

### Tools
- Applets
- Maple
- Matlab programming

### Schedule
- Core Classes
  - (2-year rotation)
- Electives
  - (2-3 year rotation)
Proposed Computation Courses

Entering first-year students

Math

Calc I ➔ Calc II ➔ Calc III ➔ Diff Eq.

Physics

Physics I ➔ Physics II ➔ Upper Division

Computation

First Year Seminar ➔ Computational Methods

Graduation “finish line”
Pandemic changes:

- **Flipped class**
  - Outside of class: prerecorded video lectures
  - In class: discussion, working on sample problems and computational projects (Matlab)

- **Midterm project: generalized N-Body simulator (3 weeks)**
  - Part 1 - 1D motion using different integration methods
  - Part 2 - Two-Body problem in 2D using 4th-Order Runge Kutta
  - Part 3 - Arbitrary N-Body problem in 3D
1D motion

Falling Into the Sun

2-Body, 2D

Geometry of Orbital Resonance

N-Body, 3D

Stability of planets in a binary star system

Compare:
- 1st order Euler
- Midpoint method
- 4th Order Runge-Kutta
Exoplanet detection using transit timing variations

4:1 resonance

Agol and Fabrycky 2017
Advanced Lab Projects

Imaging a circular ring around a Schwarzschild Black Hole

Event Horizon Telescope Collaboration

Science Photo Library

Frolov et al., 2014 Phys Rev D.
Geodesic equation of motion

\[ \frac{d\phi}{dr} = \pm \frac{b}{r^2} \frac{1}{\sqrt{1 - \frac{b^2}{r^2} \left(1 - \frac{2M}{r}\right)}} \]
Advanced Lab Projects

Imaging a circular ring around a Schwarzschild Black Hole

emitter

observer

Distorted image of the circular ring
Acknowledgements

Exoplanet project:
  Students: Brienne, Alyssa, Quinn

Black hole geodesic project:
  Students: Hayden, Dylan, Michael, Manuel
  Faculty co-advisor: Christos Tzounis

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