**Blue Waters Petascale Semester Curriculum v1.0**

**Unit 11: Domain Science: Astrophysical Fluid Dynamics**

**Lesson 3: Fluid Hydrodynamics**

**Instructor Guide**

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*We want to hear from you! Please let us know your experiences using this material by sending email to* [*petascale@shodor.org*](mailto:petascale@shodor.org)

### 11.3 Activity 1

Instructors are encouraged to obtain an allocation for their students, either on a HPC cluster at their institution, or with NCSA (Blue Waters) or XSEDE, which are open to the U.S. academic and research communities. There may be an XSEDE Campus Champion at your institution, or you can become a Campus Champion.

#### Public Resources:

* National Center for Supercomputing Applications (NCSA): Blue Waters
  + About: <https://bluewaters.ncsa.illinois.edu/about-blue-waters>
  + Hardware: <https://bluewaters.ncsa.illinois.edu/hardware-summary>
  + Getting Started: <https://bluewaters.ncsa.illinois.edu/documentation>
  + Education Allocations: <https://bluewaters.ncsa.illinois.edu/education-allocations>
* The eXtreme Science and Engineering Discovery Environment (XSEDE)
  + Resources: <https://portal.xsede.org/allocations/resource-info>
  + Create an XSEDE account: <https://portal.xsede.org/#/guest>
  + Startup allocations: <https://portal.xsede.org/allocations/startup>
  + Education allocations: <https://portal.xsede.org/allocations/education>
  + Current Campus Champions: [Current Champions](https://www.xsede.org/web/site/community-engagement/campus-champions/current)
  + Campus Champions Program: [Campus Champions](https://www.xsede.org/community-engagement/campus-champions)

Once you have an allocation, we encourage you to send detailed instructions to your students before the start of the course/semester/internship so that they may get started. Some students may decide to use PuTTY or ssh from a terminal on a PC or Mac, others may decide to install Linux on their PC to run applications directly. We recommend the latest stable version of SuSE or CentOS, since those are the platforms used by Blue Waters and XSEDE, respectively.

### 11.3 Activity 2

The last two lessons of this unit will be using the publicly available PLUTO code to perform astrophysical hydrodynamic calculations, and the VisIt code

[11.3 Submitting Jobs and Running Programs on Blue Waters](https://docs.google.com/document/d/1KFRjHEi7JooQvVH1Vl_uzRypOShjz5CHKmqedaohBYg/edit#heading=h.daenv6po4lwl)

## Code and Documentation

The Astrophysical Fluid Dynamics unit utilizes PLUTO version 4.3. PLUTO is a freely-distributed software for the numerical solution of mixed hyperbolic/parabolic systems of partial differential equations (conservation laws) targeting high Mach number flows in astrophysical fluid dynamics. The code is designed with a modular and flexible structure whereby different numerical algorithms can be separately combined to solve systems of conservation laws using the finite volume or finite difference approach based on Godunov-type schemes.

Equations are discretized and solved on a structured mesh that can be either static or adaptive. The AMR interface relies on the Chombo library for parallel calculations over block-structured, adaptively refined grids.

The code is written in the C programming language while the AMR interface also requires C++ and Fortran.

PLUTO is a highly portable software and can run from a single workstation up to several thousands processors using the Message Passing Interface (MPI) to achieve highly scalable parallel performance.

The software is developed at the Dipartimento di Fisica, Torino University in a joint collaboration with INAF, Osservatorio Astronomico di Torino and the SCAI Department of CINECA.

### Documentation links:

* PLUTO 4.3 User’s Guide: <http://plutocode.ph.unito.it/userguide.pdf>
* Method Paper, static grid version: Mignone et al. 2007: <https://arxiv.org/pdf/astro-ph/0701854.pdf>
* Method Paper, adaptive grid version: Mignone et al. 2012: <https://arxiv.org/pdf/1110.0740.pdf>
* VisIt: <https://wci.llnl.gov/simulation/computer-codes/visit/manuals>
* Chombo - Software for Adaptive Solutions of Partial Differential Equations: <https://commons.lbl.gov/display/chombo/Chombo+-+Software+for+Adaptive+Solutions+of+Partial+Differential+Equations>

### Code links:

1. Module 11.1:
   1. PLUTO 4.3: <http://plutocode.ph.unito.it/download.html>
   2. Rayleigh-Taylor Instability test code: <http://plutocode.ph.unito.it/Doxygen/Test_Problems/_m_h_d_2_rayleigh___taylor_2init_8c.html>
2. Module 11.2:
   1. VisIt 3.1: <https://wci.llnl.gov/simulation/computer-codes/visit/executables>
   2. HD Jet test code: <http://plutocode.ph.unito.it/Doxygen/Test_Problems/_h_d_2_jet_2init_8c.html>
3. Module 11.3:
   1. Sedov-Taylor blast wave test code: <http://plutocode.ph.unito.it/Doxygen/Test_Problems/_h_d_2_sedov_2init_8c.html>
4. Module 11.4:
   1. MHD Blast Wave test code: <http://plutocode.ph.unito.it/Doxygen/Test_Problems/_m_h_d_2_blast_2init_8c.html>
5. Module 11.5:
   1. Chombo library: download, install, remake PLUTO: <https://commons.lbl.gov/display/chombo/Chombo+Download+Page>
   2. 3D shock cloud test code: <http://plutocode.ph.unito.it/Doxygen/Test_Problems/_m_h_d_2_shock___cloud_2init_8c.html>