

The Importance of Computation in Astronomy Education

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Executive Summary: Computational skills are required across all astronomy disciplines. Many students enter degree programs without sufficient skills to solve computational problems in their core classes or contribute immediately to research. We recommend advocacy for computational literacy, familiarity with fundamental software carpentry skills, and mastery of basic numerical methods by the completion of an undergraduate degree in Astronomy.

We recommend the AAS Education Task Force advocate for a significant increase in computational literacy.

We encourage the AAS to modestly fund efforts aimed at providing Open Education Resources (OER) that will significantly impact computational literacy in astronomy education.

1 Computational Needs in Astronomy & Astrophysics

Computational skills are required at all levels of education and research in astronomy. Theoretical astrophysics is dominated by simulation instruments, often written in compiled and interpreted languages. Observational astronomy is entirely digital, with software pipelines for reducing and analyzing data. Community tools, such as the Python-based AstroPy⁵, are actively developed for these pipelines. The workflow in astronomy is often expressed in UNIX-like environments such as OS X or Linux. Students in secondary or undergraduate programs may be unfamiliar with (and put off from) the command line and the job skills that it enables.

2 Undergraduate Education

Many astronomy and astrophysics programs encourage their majors to take some computer programming classes. For example, the State University of New York transfer path for physics requires an Introduction to Computer Science in the first 2 years⁶. However, this is where the encouragement of developing essential, transferrable job skills in computation frequently ends.

Astronomy students should be versed in elements of scientific computing and basic numerical analysis in astronomy courses that leverage community developed infrastructure. For example, Open Source web-based tools can be used to explore all stages of stellar evolution. Open data archives enable access to galactic and extragalactic data. These, and other, community developments offer educators outstanding opportunities to bring students directly into contact with real-world data, and to integrate data analysis and computation into the curriculum. Some examples of data-driven educational exercises include:

- Inferring the mass, radius, and density of the historic transiting exoplanet HD209458b
- Creation of a HR diagram from Tycho data
- Examination of stellar interiors using MESA-web
- Determination of the Hubble constant H_0 from Supernova Type Ia light curve data
- Analysis of gravitational waves from the historic binary black hole merger GW150914

We applaud the AAS's advocacy for increased literacy in scientific computation, as exemplified by the Hack Day events at recent AAS meetings. We suggest the AAS enhance its encouragement of sharing computational tools, educational lessons, and projects amongst their members.

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⁵ <http://www.astropy.org/>

⁶ http://www.suny.edu/attend/get-started/transfer-students/suny-transfer-paths/pdf/transferSUNY_Physics.pdf

3 Graduate Education

A popular way to train graduate students in specialized codes and techniques used in each astronomy discipline are summer schools and workshops. We encourage the AAS to:

- Extend and promote these training sessions in association with the AAS meetings. For example, the Software Carpentry⁷ sessions at recent AAS meetings are an excellent example of this training, and there is significant potential to further expand upon these sessions.
- Offer software instrument-specific training sessions at the AAS meetings. For example, “Best practices for CLOUDY⁸”, “Introduction to MAESTRO⁹”, or “Advanced yt¹⁰” can provide critical training and community networking opportunities for graduate students.
- Organize instructor training sessions for Software Carpentry, to facilitate participants offering these workshops at their own institutions.

4 Open Source and Open Education Resources

Open Education Resources (OER) are freely accessible, openly licensed documents and media for teaching, learning, assessing, and research. OER are among the leading trends in education, yet there is a paucity of quality material for astronomy. A few notable exceptions include: (1) astroEDU¹¹, which launched in February 2015, targets K-12 and is supported by the IAU Office for Astronomy Development; (2) the Astrobetter Wiki¹², which include links to user-contributed class slides, animations, texts, and other resources; (3) open-licensed texts such as the Open Astrophysics Bookshelf¹³ and others¹⁴; (4) MESA-Web¹⁵, a web-based portal for stellar evolution aimed at secondary and undergraduate education; and (5) IPython/Jupyter notebooks for deployment of interactive computation-based exercises.

- We encourage the AAS to modestly fund efforts aimed at providing OER material that will significantly enhance the use of computation in astronomy education.

5 Careers

Computational skills and critical thinking are among the most transferable job skills that an astronomy education can provide. We encourage the continued advocacy by the AAS for increased computational literacy, exemplified by the Hack Day events at recent AAS meetings, to provide skills that employers consistently seek.

⁷ <http://software-carpentry.org/> ⁸ <http://trac.nublado.org> ⁹ <http://boxlib-codes.github.io/MAESTRO/>

¹⁰ <http://yt-project.org/> ¹¹ <http://astroedu.iau.org> ¹² <http://www.astrobetter.com/wiki/Wiki+Home>

¹³ <https://open-astrophysics-bookshelf.github.io> ¹⁴ <http://www.pa.msu.edu/~ebrown/lecture-notes.html>

¹⁵ <http://mesa-web.asu.edu>