

IntroAstro: An Intense Experience

Developing and delivering Duke's Introduction to Astronomy, 2012-13

Introduction to Astronomy ("IntroAstro") was conceived as an eight week compressed massive open online course (MOOC) version of a full semester campus-based course offered by Dr. Ronen Plesser has offered at Duke in the past. This course was delivered on the Coursera platform as part of Duke's partnership (see <http://onlinecourses.duke.edu/>) from mid-November 2012 through mid-February 2013. This report summarizes the development and delivery of the course, student outcomes, and reflections and feedback of the participants and instructor.

Introduction to Astronomy: Key Findings

- The course delivered over 24 hours of video lectures in 95 segments grouped into eight thematic weeks. Student learning was assessed with 16 graded assignments (2 per week), 6 optional extension quizzes and self-assessments, and ungraded in-video exercises.
- Video production began in August, but intentionally, a significant portion of the video production was done in tandem with course delivery, in some cases as little as a week or less ahead of the release date.
- Developing and delivering this course required a significant time commitment, with over 1000 hours of time invested – more than two-thirds (>680 hours) by the instructor.
- Nearly 60,000 students signed up for the course. Out of 40,000 students who viewed the first video, nearly 11,500 attempted the first graded problem set. Approximately 5,500 remained active viewers and/or participants in the forums throughout the course. Ultimately, 2141 earned a Statement of Accomplishment by averaging 70% or greater on the exercises.
- Students active at the end of the course represented every region of the world (at least 87 countries, with less than 30% from the U.S.). The ages of participants ranged from 9 to 90. More than 80% reported having attained a Bachelor's degree or higher prior to the start of the course, and half reported being employed full time during the course. Many retirees and amateur astronomers participated.
- Forums were very active, with nearly 23,000 posts and comments added during the course, including over 1900 by the instructor or the TA.
- Six Google+ Hangouts were held during the course; these live online sessions engaged 10-15 participants and over 3,000 viewers.
- Student feedback on the course was overwhelmingly positive (mean rating of 6.2 on 7 point scale). Ratings of the instructor were very high also. The most common criticism was that the course was more difficult and/or more time consuming than expected.
- The course attracted atypical audiences such as parents, science educators and pre-college students. These audiences were considered an unanticipated benefit, given the instructor's particular interest and longstanding commitment to science outreach.
- The instructor found the experience rewarding (albeit exhausting) and does plan to re-offer the course in the future. He also plans to re-use demonstration videos produced for the MOOC for campus teaching.

Lessons Learned

- Ultimately, IntroAstro was more intensive than the campus course it evolved from, requiring a time commitment 10-15 hours per week for most students and 20-30 combined hours per week devoted to student interaction from the instructor and TA. Future iterations will likely cover most of the same material, but spread out over a longer time span.
- Preparing the videos was more time consuming than the instructor expected. Producing some video concurrently with the live course did allow the instructor be more responsive to students; however, this also created a great deal of stress for the instructor and support staff. This stress was intensified by the high level of engagement of the instructor with students and greater than anticipated time required to plan and produce the content.
- A one-week break due to December holidays was serendipitous, providing a respite for the instructor and time for students to catch up. Future iterations may deliberately incorporate 2-3 similar breaks into the course design.
- Given the for-profit status of Coursera, copyright and fair use considerations were a concern to the instructor. The instructor did find that responses from scientists contacted directly for permissions were rapid and positive, but only because the course was provided at no cost.
- To minimize overlap between the regular Duke semester and the planned 8 week MOOC session, the instructor selected a late November launch date. In hindsight, overlap between campus teaching responsibilities and effort required to develop the MOOC was also problematic for the instructor.
- During the course, the instructor modified quiz settings to make feedback visible immediately and extended the deadlines for homework to encourage and enable more students to successfully complete these assignments.
- The instructor and students reported that in-video quizzes were a useful feature of the course for promoting understanding and engagement; more of these would likely be included in future iterations of the course.
- Prerequisites were a stumbling block cited by many students. Although the mathematical requirements to solve the homework problems did not exceed the level advertised (high school algebra), many students reported that they did not feel they had sufficient math and/or physics background.
- Algebraic expressions and numeric evaluation enabled more complex assessments, but the lack of unit conversions and recognizing equivalent mathematical expressions was problematic.
- In the hopes of encouraging future students to tackle challenging, meaningful problem sets while reducing anxiety associated with these as high stakes assessments, the instructor plans to incorporate 1-2 midterms and a final exam in future iterations.

"... the opportunity to introduce the ideas, techniques, methods, and most importantly the joy of observing the universe scientifically to thousands of students worldwide certainly justified the time and effort invested. For the University, in my opinion these thousands of new enthusiastic promoters make the effort worthwhile, even if one were to discount the undeniable contribution such a course makes to the mission of 'knowledge in the service of society.'"

- Ronen Plessner

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Yvonne Belanger

Center for Instructional Technology

Duke University

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Report Contributors

Jessica Thornton, *Academic Affairs*

Ronen Plesser, *Department of Physics*

Justin Johnsen, *Center for Instructional Technology*

Quentin Ruiz-Esparza, *Center for Instructional Technology*

Candice Guevarra, *Duke University Libraries*

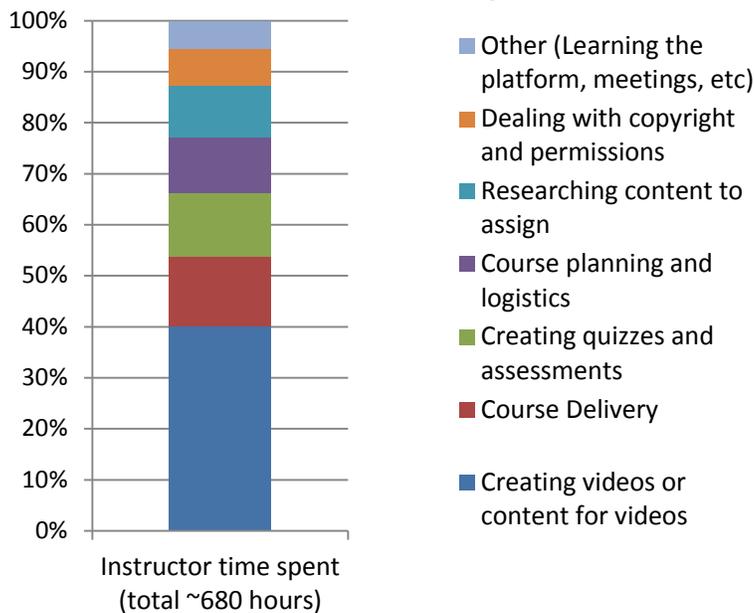
Tatum Sornborger, *Trinity College*

Producing and delivering the course content

Using a tablet, the instructor combined webcam video with screen capture. Screen captured content from the tablet included PowerPoint slides as well as simulations, demonstrations, whiteboard-style worked solutions, and pre-prepared LaTeX calculations. Digital Media Services in Duke's Office of Information Technology's coordinated studio-based video shoots of physics demonstrations. In post-production editing, the screen capture videos were coupled with the studio-produced demonstration videos. A full list of video topics and some sample screen shots are included in Appendix B.

More than 300 hours of time was reported, primarily by the instructor, to produce the course videos. Figure 1 illustrates this time in the context of the overall reported time spent by the instructor developing and delivering the course. In addition to time reported by the instructor, approximately 400 additional hours were reported by other staff in supporting the development and delivery of the course, including 310 hours reported by TA Justin Johnsen for consulting, course building, assessment creation and video production support.

Fig 1. Instructor time spent developing and delivering IntroAstro



The faculty experience: reflections from Ronen Plesser on creating MOOC content

“Designing and preparing video lectures proved far more strenuous and time-consuming (for me) than preparing in-class lectures. Since one receives no immediate feedback, no interrupting questions or puzzled faces in response to poor pedagogy, one feels compelled to hone the presentation far more than in preparing a live class. In many ways a video lecture series feels more like writing a book than like teaching a class.”

“[Short 8-12 min videos concentrating on one concept or technique] work best, in my experience not only to account for student attention span or free time constraints, but [also to help] the instructor maintain the sharp focus that optimizes pedagogical clarity and succinctness.”

“...three hours of video lecture, edited carefully, can convey far more content than three hours in class: no questions, no interruptions, no rambling tangents. Thus, in about 25 hours of video I was able to provide a significantly more comprehensive course, both conceptually and technically deeper, than I am able to offer in a one-semester course on-campus.”

Interaction with the course content

Following a pattern reported in other massive online courses, the number of students declined sharply during the first two weeks. In IntroAstro, the decay over time in the number of students viewing videos closely approximated a power law function, where 'x' represents the segment number and 'y' represents the number of viewers of that video segment. (Figure 2, right). Eventually the number of active viewers plateaued at around 5,500 students.

Of 60,000 students who registered for the course, nearly 40,000 logged into the course site, and 2141 completed all requirements. More than 3700 additional students remained actively engaged throughout the duration of the course (Figure 3, right). Based on pre-course surveys, at least some of the attrition is directly attributable to student intent and not a problem with the course. For example, before the course began, 25% of 12,283 respondents to the pre-course survey indicated that they did not plan to complete all of the homework.

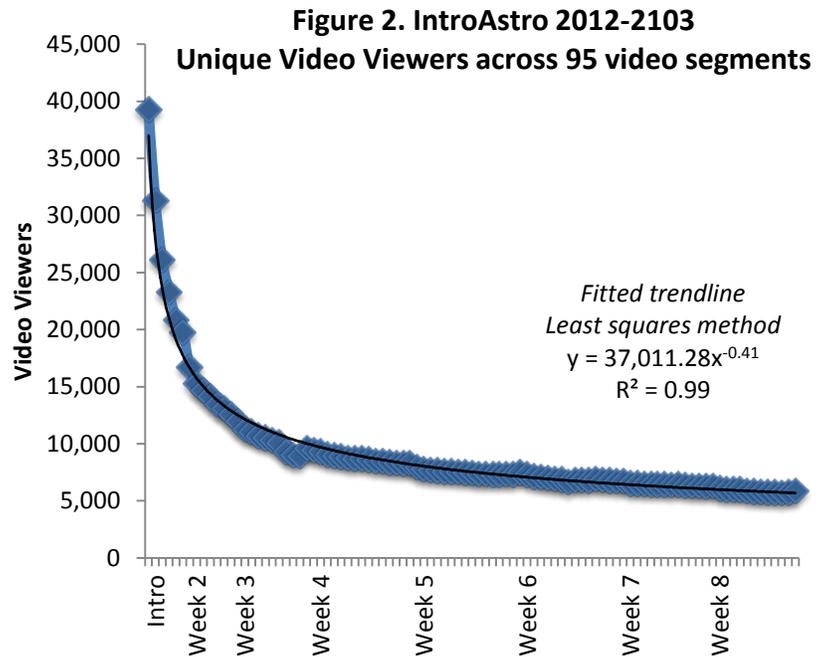
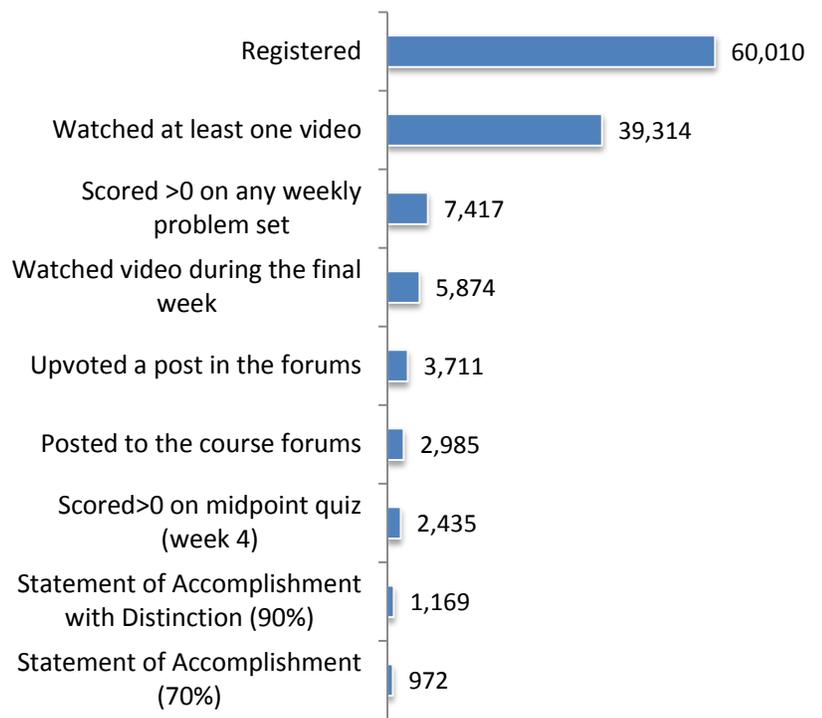


Fig 3. Student persistence in IntroAstro



Interaction among course participants and staff

Within the practical limits of a massive open online course, the instructor and his TA offered an interactive course experience. Each week, the instructor addressed the students with announcements also sent via email. These announcements served to summarize the previous week's content and questions as well as to introduce the upcoming topics.

Interaction between the students and between the students and course staff took place asynchronously on the discussion forums as well as synchronously in weekly Google+ Hangouts. This level of interaction required a significant commitment of time from the course staff; Dr. Plesser and his TA Justin Johnsen reporting spending an average of 20-30 hours per week reading and responding in the forums. Collectively the instructor and TA contributed over 1900 posts and comments to the forums, and the students enrolled in the course collectively posted or commented over 20,000 times. In the end of course survey, a large majority of the students (~70%) agreed that the forums enhanced their learning, were safe and supporting, and fostered peer communication.

“The Coursera model relies heavily on a group of students learning the same material at the same time, forming a virtual class and interacting via discussion forums.... I was quite surprised by the degree to which this model works. Students were almost flawlessly respectful of the course and of each other, and both my impression and their responses suggest that they did indeed bond as a class, to an extent at least rivaling that to which on-campus students bond.”

– Ronen Plesser

In addition to the discussion forums, weekly Google+ Hangouts provided an opportunity for live interaction as well for watchers on YouTube, who could post questions and comments. These Hangouts lasted up to two hours and involved 10-15 students on average. Hosting live events was not without some bumps, such as technical glitches or dominating students, but students and the instructor found them to be valuable overall. As Dr. Plesser observed, “Managing these events is an art we learned through practice; when done well they also served the course mission through creating a sense of community and intellectual excitement.”

Student evaluations and feedback

Students submitted comments and feedback throughout the course on the discussion forums. These comments were monitored by the course staff, and when possible, student suggestions were addressed during the course. A “Course Corrections” page in the course site provided a central location for the instructor and TA to acknowledge errors from the video content, typically reported by students. In these Course Corrections, the student reporting the error was credited for their contribution by the course staff.

After final course grades were computed and Statements of Accomplishment had been awarded, a survey was distributed via email and a link on the course web site to all registered students (1422 respondents). Approximately 2/3 of respondents (64%, n=914) had earned the Statement of Accomplishment, and about 1/3 (36%, n=508) had not. The summaries below include both groups of students unless otherwise noted.

Student demographics

The respondents to the end of course survey were primarily male (81%), over 25 (84%), held at least a Bachelor's degree (83%), had no prior formal education in Astronomy (83%), and resided outside the United States (72%). It is not known whether these respondents are a representative sample of all course participants, but they are more likely to be representative of those students who earned the Statement of Accomplishment (response rate 43%). Among students who selected 'Other' for their current status, common responses included retired, unemployed, amateur astronomer and stay-at-home parent.

Reasons for enrolling

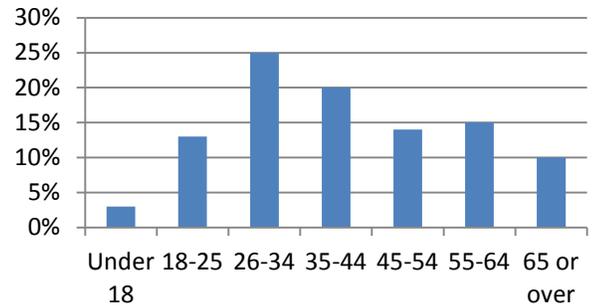
General interest in the topic (95%), an interest in extending their knowledge in the topic, or interest in how online courses are taught (32%) were most commonly cited by students as reasons for enrolling. Professional development (13%), lack of access to education due to cost (10%), geographic isolation (10%), deciding whether to pursue formal education (8%) and supplementing formal education (5%) were less commonly cited as factors. Reasons cited by multiple students in a free response option included:

- To learn or practice English
- Educational enrichment during retirement
- Lifelong learning

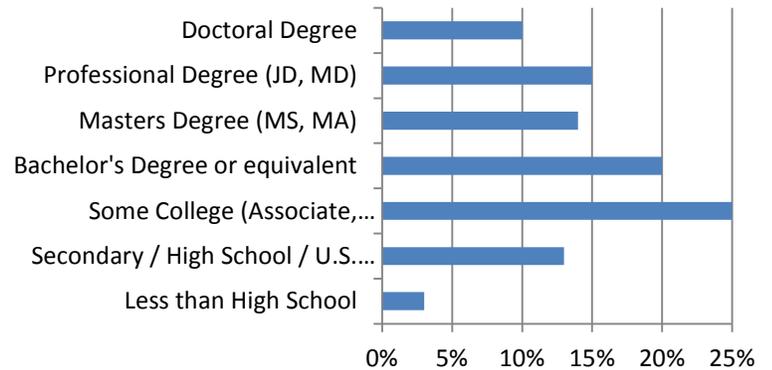
Overall course experience

When asked to rate their overall course experience, the student mean was 6.2 on a 7 point scale (1=poor to 7=excellent). Among those who earned the

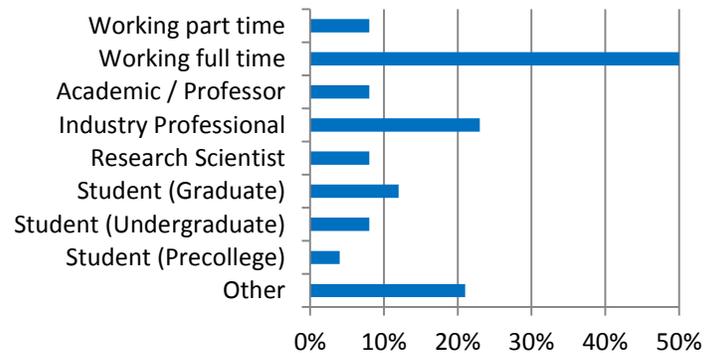
**Age distribution of students
end of course survey, n=1336**



**Prior educational attainment
end of course survey, n=1350**



**Current status - check all that apply
end of course survey, n=1341**



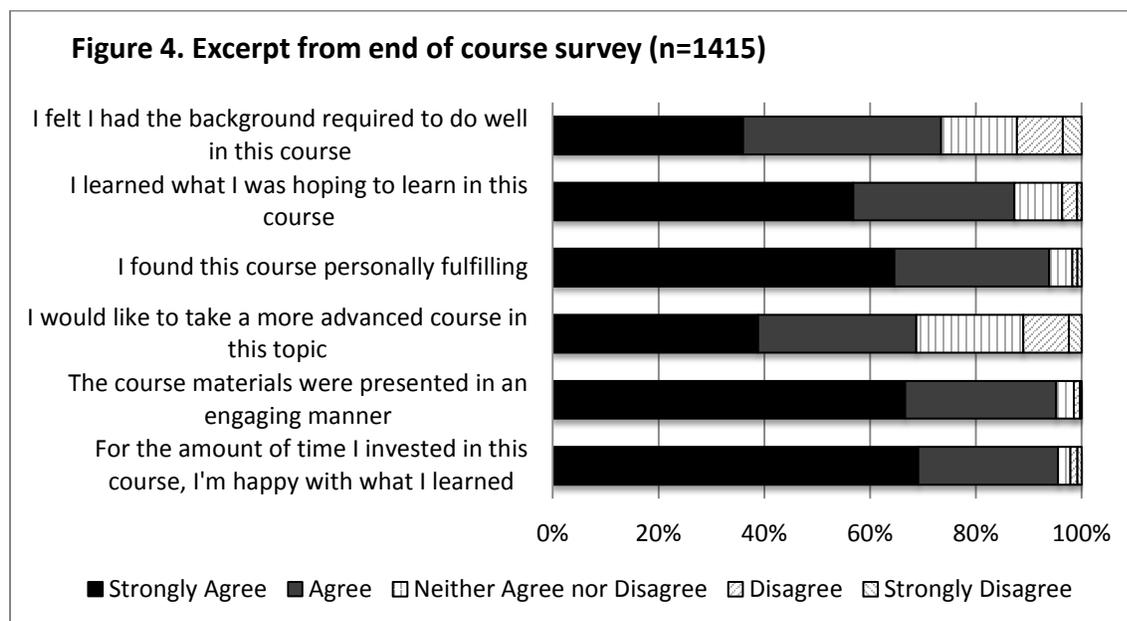
Statement of Accomplishment (SoA), 98% rated the course 5 or better. Among those who did not, 85% rated the course 5 or above. 97% of all students (including 93% of those who did not earn the SoA) indicated that they would probably or definitely take another online course based on their experience in IntroAstro. Students who indicated having taking a previous online course were asked to compare IntroAstro to previous experiences in online learning. Coding of approximately 600 open-ended comments found that students most commonly characterized it as overall superior to previous online courses (40%), more challenging (20%), similar to others (15%), or having a better instructor (12%).

Evaluation of the instructor

Ratings of Dr. Plesser were overwhelmingly positive. 97% agreed that he enhanced their learning of the material (with 75% strongly agreeing), and 95% would take another course from this instructor. In addition, 28% of open-ended ‘additional comments’ at the end of the survey were praise for Dr. Plesser’s teaching who typically described him as committed, passionate and enthusiastic.

Course experience relative to student expectations

Students were asked about their agreement with the extent to which the course had met their needs and expectations. A majority of students strongly agreed that they found the course fulfilling and engaging, learned what they hoped to learn, and were happy with what they learned relative to the time invested. A smaller majority agreed that they had the required background and would be interested in a more advanced course (Figure 4, below).



A majority of the students rated the course too difficult (46% slightly too difficult, 10% much too difficult), and half said the pacing was too fast (slightly too fast 43%, much too fast 7%). A minority of students rated the difficulty level (41%) and the pacing (48%) as “just right.” A majority said the course length was just right (62%), although it is worth noting that the length was extended beyond the initial intended eight weeks to allow students more time to complete assignments. In open-ended feedback on

the survey, over half the students said their only expectation was to learn. 28% of comments (n=936) specifically characterized the course as exceeding their expectations and 18% said the course met their expectations. The most common negative comment (21%) was that the course was more difficult than expected and/or required too much of a time commitment.

Prerequisites

A large amount of student feedback on the course forums related to the difficulty level of the course. To learn more about student's concerns, the following open-ended question was included on the end of course survey: "Did you feel prepared to take this course? Were there prerequisites that would have helped in preparing you?" Among 915 students who commented (a majority of whom did earn the SoA), most felt prepared (58%). Others reported feeling that they had insufficient background in physics (15%) or math (20%). 18% felt that the pre-requisite requirements should be more clearly explained to enrolling students.

Sample comments from students

An enormous amount of feedback about the course was publicly visible in the discussion forums. In the end of course evaluation, many students spoke (mostly positively and often very passionately) about their course experiences in the surveys. Below are a handful of comments selected out of thousands submitted in the forums and surveys to illustrate the range of experiences of the IntroAstro students.

"At the end of week 2, I was tired and ready to give up. At one point, I even shut down my browser out of pure frustration and walked away from my computer. However, within 15-20 seconds of walking away from my workstation, I was back at my desk, logged into Coursera, and peering at that wonderful Introduction to Astronomy Home Page, more determined than ever. At that moment I realized just how much I was enjoying this course, how important it had become to me, and how fortunate I was to be experiencing it. I haven't swayed since."

"I have signed up for a few other Coursera courses but have dropped them because I didn't find the instructor engaging. This course required much more of my time than I was expecting but I stuck with it because of Dr. Plessner. He made the topic of astronomy extremely interesting and I wanted to keep learning about what came next."

"It is by far the best and most challenging of the five Coursera courses I have taken, so far."

"The best part of the course for me is that I have also been able to enjoy watching the videos with my children. While they don't yet grasp the math involved, they have been asking questions when we look up at the stars at night and I can tell that they have been listening and learning alongside me."

"It is very important that these classes actually be at the level advertised. The Astronomy class was challenging and at the correct level for an introductory astronomy course from a nationally ranked university. Don't dumb down the class."

"At first, I wanted to reconnect to whatever I did in this field as a junior high student twenty years ago, maybe pick up some nice facts here or there. It ended up turning my whole life upside down. Now I'm going back to school, to get a second Bachelor's degree (this time in Physics) and I intend to go the whole way up to PhD and beyond, despite being 32 now. I'll have to see where that takes me,

since I already have a nice career that pays me well, but the science bug bit me and I think there's no way back now. Thank you!"

"I had expected to complete the course but the first homework was way too difficult, and I did not have the hours I would have needed to figure it out. For a few more weeks I still had time to watch the videos, but then I ran out of time for that. I am so grateful that you will leave everything available as I hope to return to this over the summer when I have much more time."

"Dr. Plesser's enthusiasm helped to make me excited about the material and inspired me to push forward even when the material seemed difficult. I think this course shows the potential of online education as a valid form of education. I really felt a sense of community as we went through this course together. Dr. Plesser's active participation on the discussion forums really helped to make us feel connected and gave the course a humanistic element. One criticism of online education in general is that it might seem sterile and lacking in human connection - however, the way this astronomy course was run demonstrates that students can study online and yet still feel a sense of connection and community spirit."

"Other courses are pretty much self-contained, and the problems are not that difficult... But for this course I ended up researching, reading, and learning and relearning the things I've long forgotten. I would definitely display the Certificate for all to see. ^_^ It definitely made me pull off all-nighters just to keep up with the pace."

"Unfortunately however, I too am going to have to pass on going the certificate route - the time required to watch all the videos, review all the materials to be sure I have a proper understanding, and complete all the assignments by their due date is far more than I have available to me in one week's worth of free time."

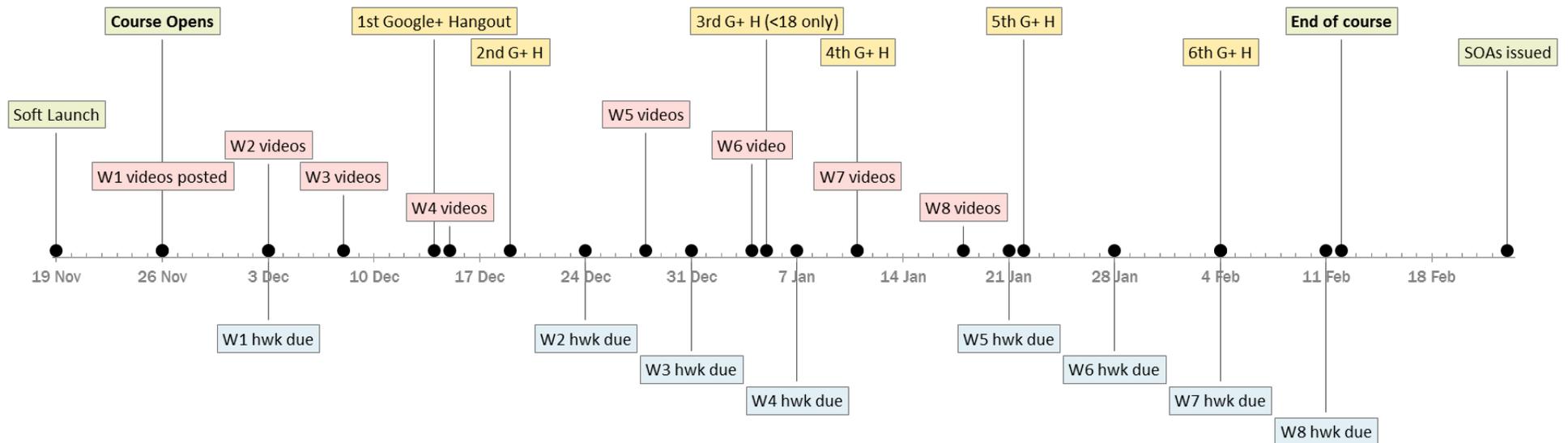
"Dr Plesser's videos are a joy to watch, even with the subject matter being as complicated as it is at times - his knowledge and passion for his profession is clear. And how Justin manages to monitor the discussion forums and respond when appropriate is amazing. I am thoroughly enjoying participating in this learning journey."

"It was much more difficult and took much more time than advertised. Discussion forums were a life saver as it seemed like everyone was going through the same thing. That said - I learned much more than expected for an intro class."

"Professor Plesser's style and implementation provide a model worth studying and emulating going forward. This is not to say it was perfect. He and his assistant are well aware of the shortfalls. But their enthusiasm, openness and honesty enabled them to develop and lead a thrilling expedition of discovery that has inspired and stimulated thousands of students around the world. The future of university education may well look like this going forward."

"Ronen did an excellent job. He took a very complex subject and presented it in a way that a novice like myself could understand. Now when I look up at the sky I have a deeper appreciation for the complexity that exists around me. I am retired and my reason for taking the course is my love of learning. This class fulfilled that aspiration." – *Student who watched all of the lectures, did some of the problem sets, but did not earn a Statement of Accomplishment*

Appendix A. Timeline of Duke's *Introduction to Astronomy* 2012-13



The timeline above illustrates key milestones in the delivery of *Introduction to Astronomy*. In a 'Soft Launch' on November 19, the course web site was made available, and students began to log into the web site, but the official opening of the course took place on November 26 when an email announcing the opening of the course was sent to students. The amount of time permitted for students to submit the homework was extended from one week to three beginning with the Week 2 homework assignment. The course ended on February 11, and the Statements of Accomplishment were issued approximately two weeks later, along with the end of course survey.

Appendix B. Course Syllabus

Week 1: Positional Astronomy (naked-eye Astronomy)

We will spend our first week familiarizing ourselves with descriptions of the positions and motions of celestial objects.

- Lecture 1: Positional Astronomy Introduction
- Lecture 2: The Celestial Sphere
- Lecture 3: The Local View
- Lecture 4: Where is the Sun?
- Lecture 5: Tilt and the Seasons
- Lecture 6: The Moon Moves Too

Week 2: Newton's Universe

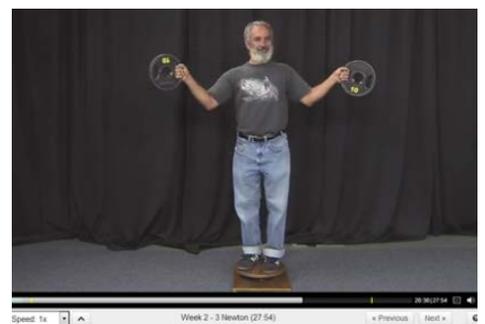
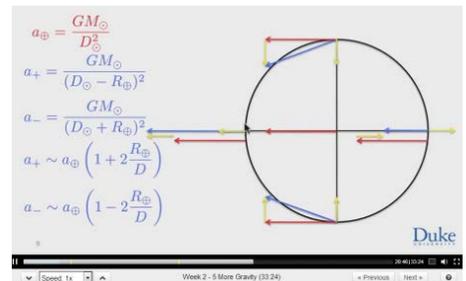
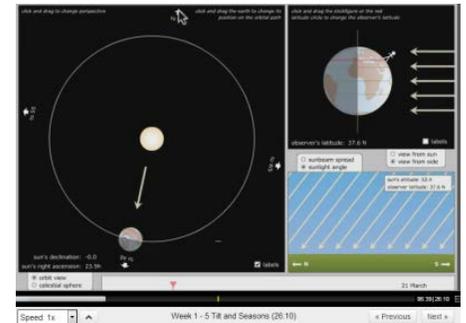
Newtonian physics revolutionized the way we understand our Universe. We will discuss Newton's laws of mechanics, the conservation laws that follow from them, his theory of gravity and some applications to Astronomy, as well as some properties of radiation. The last clip will be a quick look at the features of quantum mechanics relevant to our course. This will be a particularly busy and challenging week, but hard work here will pay off later.

- Lecture 1: What Else Moves?
- Lecture 2: Brahe and Kepler
- Lecture 3: Newton
- Lecture 4: Gravity
- Lecture 5: More Gravity
- Lecture 6: Matter and Radiation
- Lecture 7: Matter, Radiation, and Quantum Physics

Week 3: Planets

We will not have time in this course to do any justice to the broad and exciting field of planetary science. We will spend the week on a general review of the properties and structure of our Solar System and our understanding of its origins and history. We will end with some discussion of the exciting discoveries over the past decade of many hundreds of extrasolar planets.

- Lecture 1: Intro to the Solar System
- Lecture 2: It's Old
- Lecture 3: The Solar Nebula
- Lecture 4: Terrestrial Planet Formation
- Lecture 5: Beyond the Snow Line: Giants
- Lecture 6: Earth is a Planet

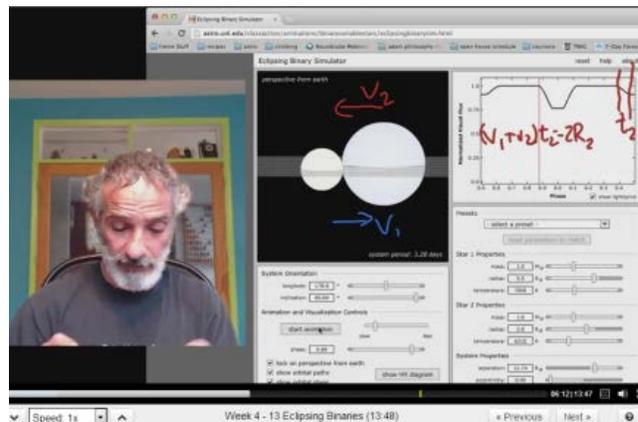


- Lecture 7: Our Moon
- Lecture 8: OPTIONAL! Terrestrial Planets
- Lecture 9: OPTIONAL! Giant Planets
- Lecture 10: OPTIONAL! Asteroids and Comets
- Lecture 11: We May Not Be Alone (Extrasolar Planets)

Week 4: Stars

What we know about stars and a bit about how we found out. We will begin with a quick review of the best-studied star of all, our Sun. We will then talk about classifications; H-R diagrams and main sequence stars; distance, mass, and size measurements; binaries; clusters; and stellar evolution through the main sequence.

- Lecture 1: Introduction
- Lecture 2: Nuclear Physics
- Lecture 3: Solar Energy
- Lecture 4: Neutrinos and a Surprise
- Lecture 5: Solar Structure
- Lecture 6: Solar Weather
- Lecture 7: How I Wonder Where You Are
- Lecture 8: Astrometry
- Lecture 9: Stellar Types
- Lecture 10: Stellar Stats
- Lecture 11: Binary Stars
- Lecture 12: Spectroscopic Binaries
- Lecture 13: Eclipsing Binaries
- Lecture 14: Mass-Luminosity Relation
- Lecture 15: Main-Sequence Stars



Week 5: Stellar Evolution

Early and final stages of stellar evolution and stellar remnants. Giants, white dwarves, novae, variable stars, supernovae, neutron stars and pulsars.

- Lecture 1: Herschel's Garden
- Lecture 2: Pre-Main Sequence
- Lecture 3: Wild Youth
- Lecture 4: Post-Main Sequence Sun I
- Lecture 5: Post-Main Sequence Sun II
- Lecture 6: The End: Planetary Nebula
- Lecture 7: Clusters and Populations
- Lecture 8: Instability
- Lecture 9: White Dwarfs
- Lecture 10: Mass Transfer
- Lecture 11: Life in the Fast Lane
- Lecture 12: Massive Issues
- Lecture 13: Core Collapse
- Lecture 14: Supernova 1987A
- Lecture 15: Neutron Stars

Week 6: Relativity and Black Holes

We will spend most of this week acquiring an understanding of the special theory of relativity. We will then discuss the general theory in a qualitative way, and discuss its application to black holes, gravitational lensing, and other phenomena of interest.

- Lecture 1: Introduction
- Lecture 2: Spacetime
- Lecture 3: Maxwell and c
- Lecture 4: Lorentz Transformation
- Lecture 5: Relativistic Spacetime
- Lecture 6: Invariant Interval
- Lecture 7: Conservation Laws
- Lecture 8: OPTIONAL! Paradoxes
- Lecture 9: Happy Thoughts
- Lecture 10: Gravity is Geometry
- Lecture 11: General Relativity in Astronomy
- Lecture 12: Black Holes
- Lecture 13: Journey to a Black Hole
- Lecture 14: Black Holes in Astronomy
- Lecture 15: Black Holes in Theory

Week 7: Galaxies

Galactic structure and classification. Active galactic nuclei, quasars and blazars. Galactic rotation curves and dark matter. Galaxy clusters and large-scale structure.

- Lecture 1: Discovering the Milky Way
- Lecture 2: Many Bands!
- Lecture 3: Milky Way Components
- Lecture 4: Disk Structure
- Lecture 5: Bulge and Core
- Lecture 6: Halo and Neighbors
- Lecture 7: Weighing the Milky Way
- Lecture 8: VAR!
- Lecture 9: Dark Matter
- Lecture 10: Spirals
- Lecture 11: Galactic Evolution
- Lecture 12: Hubble Redshift
- Lecture 13: Galaxy Clusters

Week 8: Cosmology

What we can say about the universe as a whole. Hubble Expansion. Big bang cosmology. The cosmic microwave background. Recent determination of cosmological parameters. Early universe physics.

- Lecture 1: The Cosmological Principle
- Lecture 2: Homogeneous Isotropic Relativity
- Lecture 3: Friedmann Equations
- Lecture 4: Our Universe: First Look
- Lecture 5: A Brief History of Everything

Lecture 6: Cosmic Microwave Background
Lecture 7: Big Bang Nucleosynthesis
Lecture 8: Precision Cosmology I - CMB
Lecture 9: Precision Cosmology II - SNIa
Lecture 10: Parameters of LCDM Cosmology
Lecture 11: Problems of LCDM Cosmology
Lecture 12: Inflation
Lecture 13: Summary