TEACHING STATEMENT

The goal of teaching astronomy at the undergraduate level is not to produce the next generation of astronomers. Although a few of our majors do go on to graduate school in astrophysics each year, and a fraction of those ultimately become professional astronomers, this alone does not justify our teaching of nearly 1600 lecture and laboratory students each year. Nor does it explain why so many students, freshmen in particular, chose to take introductory astronomy – our courses are not required by any department on campus, including our own.

Personally, I think it is because astronomy offers so much that so easily captures the imagination – the biggest and most massive objects in the universe, the biggest explosions, the greatest energies, the farthest distances and the longest times, the beginning of time and the origin of everything, the evolution of life, other worlds. In this mix, there is not only something for everyone, there are launch pads into physics, chemistry, geology, biology, mathematics, and through our instrumentation, applied sciences, including materials, engineering, and computer science. As I often say: Astronomy is the gateway drug of the sciences.

This is important, because if the United States is to remain competitive and secure in an increasingly technological world, we need to inspire greater numbers of young people to pursue careers in science, technology, engineering, and mathematics (STEM), and we need to elevate literacy of and enthusiasm for STEM among the general public.

Since arriving at Chapel Hill, my goals have been to broaden exposure to astronomy and dramatically improve access to and ease of use of astronomical instrumentation to these ends, not only for undergraduate students at UNC-Chapel Hill (§A), but also for undergraduate through elementary school students across North Carolina, and for the general public (§A.3, §B).

A. New Introductory Astronomy Curriculum and Research Experiences for Undergraduate and Graduate Students

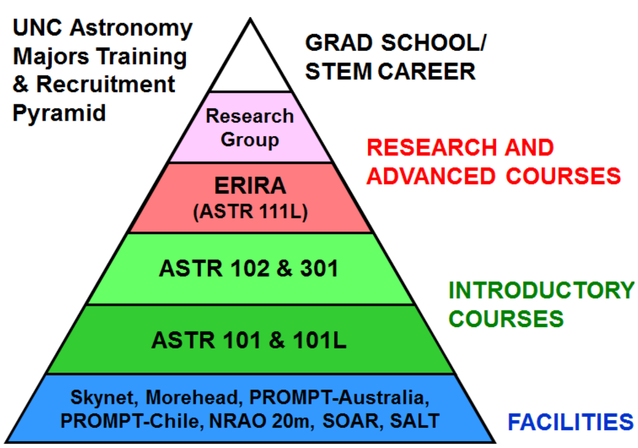


Figure 1: *UNC-Chapel Hill/Skynet's undergraduate research assistant development and recruitment pyramid.*

Over the past three years, I have spearheaded an expansion and modernization of UNC-Chapel Hill's introductory astronomy curriculum, capitalizing on our new facilities, and on Skynet and PROMPT in particular. The new curriculum also serves as a pipeline for the development and recruitment of undergraduate research assistants, both for Skynet's GRB group and for other research groups at UNC-Chapel Hill. I describe this pipeline, or pyramid (see Figure 1), in this section.

A.1. ASTR 101/102: Introduction to Astronomy

At most universities, introductory astronomy is taught as a two-semester sequence, but at UNC-Chapel Hill it had always been taught in a single semester, which for the students was akin to drinking from a fire hose. In 2009, I split the old course into two new courses:

ASTR 101: Introduction to Astronomy: The Solar System
Celestial motions of the earth, sun, moon, and planets; the nature of light; ground and space-based telescopes; comparative planetology; the earth and the moon; terrestrial and gas planets and their moons; dwarf planets, asteroids, and comets; planetary system formation; extrasolar planets; the search for extraterrestrial intelligence (SETI).

ASTR 102: Introduction to Astronomy: Stars, Galaxies, and Cosmology
The sun; stellar observables; star birth, evolution, and death; novae and supernovae; white dwarfs, neutron stars, and black holes; Einstein's theory of relativity; the Milky Way galaxy; normal galaxies, active galaxies, and quasars; dark matter and dark energy; cosmology; the early universe.

This created time to explore the material more thoroughly and more enjoyably, to introduce new material (e.g., a week of relativity in ASTR 102), and to introduce in-class demonstrations. Altogether, I developed over 50 in-class demonstrations, which I found to be particularly effective at conveying otherwise difficult concepts and at generating discussion, even in the largest classes. I have now taught these courses successfully to as few as approximately 10 students and to as many as approximately 400 students, where success is measured by end-of-course evaluations that are among the highest in our department, as well as by growing enrollment.

In our first year, nearly 400 students took ASTR 101 in the fall and of these approximately 75 students continued on to take ASTR 102 in the spring. This year, we have enrolled nearly 700 students in ASTR 101 in the fall and expect significantly more students to take ASTR 102 in the spring now that it is listed in our undergraduate bulletin. (See attached study "Intro Astro Enrollment 2000 – Present" for more information.)

Videos of all of my ASTR 101 lectures from Fall 2010 can be found here: http://www.physics.unc.edu/project/reichart/astr101/.

The students who take ASTR 102 tend to be the strongest and most enthusiastic of the students who took ASTR 101 the previous semester. They are potential majors and researchers and I tailor the course accordingly. As we complete each unit, I invite a faculty member who does research in the area that we just completed into the class to present their research, and to highlight undergraduate research and undergraduate research opportunities in their research group. Approximately one-fifth of our ASTR 102 students apply to ERIRA, which I have developed over many years into a bridging (laboratory course → undergraduate research) experience, primarily for majors (see §A.3).

A.2. ASTR 101L: Introduction to Astronomy Laboratory: Our Place in Space

The centerpiece of our new introductory astronomy curriculum has been the modernization of our introductory astronomy laboratory course, ASTR 101L, which is now serving over 500 students per year.

For decades, ASTR101L made use of Morehead Planetarium and Science Center's (MPSC's) planetarium for five day labs and small telescopes on our campus observing decks for five night labs. However, both sets of labs were problematic. Measurements within the planetarium chamber often suffer from greater than 100% error depending on where you sit. Furthermore, MPSC will soon be closed for 2 – 3 years for renovation and expansion. The visual observing labs suffered from Chapel Hill's weather, bright skies, proximity to athletic field lights ruining dark adaptation, inability to see the north star, which is necessary to properly align the telescopes, outdated and difficult to use telescopes, and a weak set of backup labs. Finally, neither set of labs strongly reinforced the lecture curriculum. Feedback from these labs was generally negative.

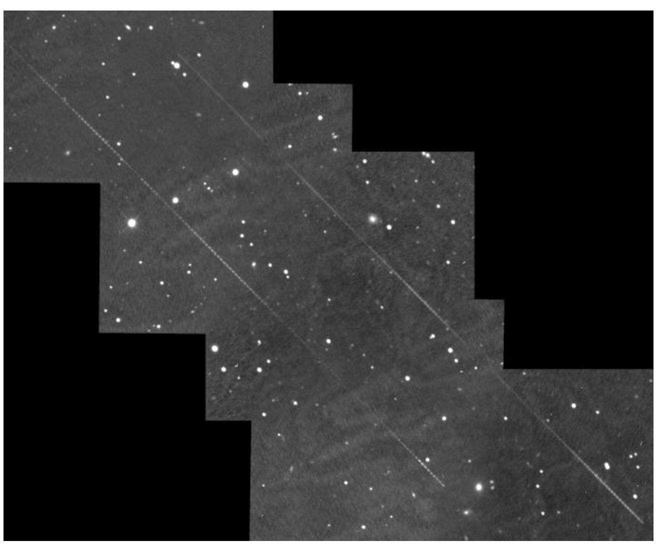


Figure 2: *Mosaic of images of near-Earth asteroid 2001 FE90 observed simultaneously from PROMPT (Chile) and Dark Sky Observatory (North Carolina). A parallactic shift of about 8' and a rotational period of about 30 minutes can be measured from the images.*

Supported by a series of NC Space Grant awards, I have developed a series of seven, and soon eight, new labs, two of which are two-week labs, and six of which are primarily Skynet and PROMPT-based. After an introductory lab in which students learn how to use Skynet (making use of our campus telescope, which is now also integrated into Skynet), the labs strongly reinforce both the new ASTR 101/102 lecture curriculum and each other. Among other things, students use Skynet to collect their own data to distinguish between geocentric and heliocentric models using the phase and angular size of Venus, to measure the mass of a Jovian planet using the orbit of one of its moons and Kepler's third law, to measure the distance to an asteroid using parallax measured simultaneously by Skynet telescopes in different hemispheres (see Figure 2), and to measure the distance to a globular cluster using an RR Lyrae star as a standard candle. More is done with archival data that takes longer than a semester to collect (e.g., Cepheid stars, Type Ia supernovae, etc.)

None of this would be possible if it were not for "Afterglow", which is easy-to-use, but professional quality, web-based image reduction and analysis software that my Skynet team has been developing. Without Afterglow, the labs would consist of little more than taking pretty pictures. The students are currently using a beta version. **Try it yourself:** http://skynet.unc.edu/afterglow, login = "guest", password = "reichart". Continued development of Afterglow has been funded by both NSF MRI-R^2 Award 0959447 and NC Space Grant. Complete with video tutorials and an easy-to-use, web-based graphing accessory that we have also developed, both Afterglow and the new labs are available here: http://skynet.unc.edu/ASTR101L/.

Furthermore, since labs that primarily make use of web-based control of remote facilities and web-based analysis software need not be carried out on campus, I have developed a fully online version of ASTR 101L for Carolina Courses Online, which serves people of all ages and backgrounds across the state and country, as well as members of our military stationed abroad. It is a unique opportunity for distance-learning students to fulfill their undergraduate laboratory requirement without having to be on campus. I now offer online sections of ASTR 101L and ASTR 101 three semesters per year and of ASTR 102 two semesters per year.

A.3. ASTR 111L: Educational Research in Radio Astronomy (ERIRA)

ERIRA is a unique experience that I have developed over 20 years to encourage majors and potential majors to get excited about and get involved in research.

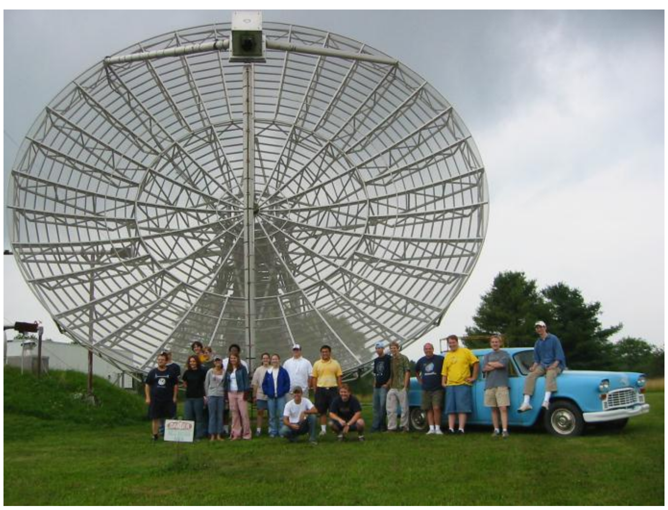


Figure 3: *The 40-foot diameter radio telescope and ERIRA particpants and coordinators at NRAO-Green Bank.*

Every summer since 1992, I and a small group of radio astronomy educators from across the country have taken 15 mostly undergraduate students but also a few high school students and occasionally a member of the general public on an intense, one-week workshop at the National Radio Astronomy Observatory in Green Bank, WV (NRAO-Green Bank) called "Educational Research in Radio Astronomy", or ERIRA. To participate, students must complete a short application (http://www.physics.unc.edu/~reichart/erira), after which I select them on the basis of enthusiasm first, and background in astronomy and science second. This makes for a diverse and highly motivated group. In recent years, most of our participants have come from UNC-Chapel Hill – UNC-Chapel Hill's ASTR 102 classes in particular – other PROMPT Collaboration institutions (see §B), and North Carolina high schools. However, anyone is welcome to apply. ERIRA is now funded by NSF ESP Award 0943305 and UNC-Chapel Hill participants receive experiential education credit, which is required for graduation.

Radio astronomy is a wonderful teaching tool: Unlike optical astronomy, it can be done during the day when students are naturally awake, and it can be done through most weather conditions. Coupled with optical astronomy, it is a powerful package: It fosters a better understanding of the electromagnetic spectrum and the important role that multi-wavelength observations play in 21st-century astronomy. Furthermore, it exposes students to a wide range of astrophysical phenomena – solar system objects, star-forming regions, supernova remnants, galaxies, quasars – and a wide range of emission processes – blackbody, synchrotron, bremsstrahlung, radio and optical emission lines – in ways that are fundamentally different than when they are experienced in only one waveband or the other. However, due to the prohibitive cost of building, operating, and maintaining sufficiently large radio telescopes, most astronomy programs do not teach radio astronomy, at least not in an observational or laboratory setting. Overcoming this has been one of the driving principles behind ERIRA, and is now one of the driving principles behind Radio Skynet (see Research Statement).

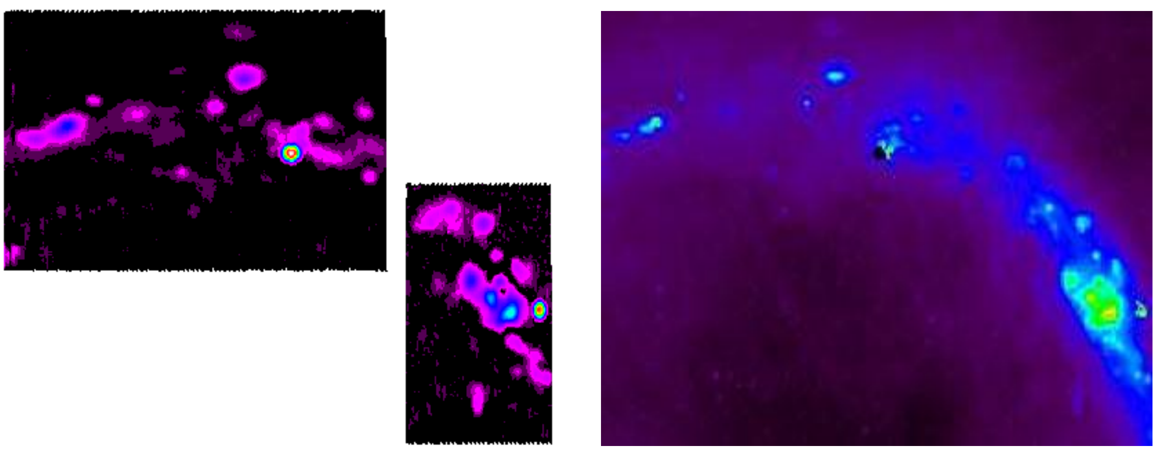


Figure 4: *A comparison of broadband images made by undergraduate and high school students using Green Bank's 40-foot diameter radio telescope and my data reduction and analysis software (left) and the same region of the sky as observed by the 100-meter diameter Effelsberg telescope (right). The primary difference is that in processing the images on the left, our students chose to subtract out more background structure; the substructure matches very nicely. The bright sources are Cassiopeia A and Cygnus A. For the past 20 years, our students have been measuring the brightness of Cas A relative to that of Cyg A, a calibration source, and found that it is fading more slowly than it had been historically. We published a paper on this (Reichart & Stephens 2000, ApJ, 537, 9040) and my undergraduate student Rebecca Egger is finishing work on a follow-up paper, which she will first author and submit to the Astrophysical Journal this year.*

The students begin the week by learning how to use Green Bank's 40-foot diameter telescope (see Figure 3) and its neutral-hydrogen spectrometer (which came from Green Bank's 300-foot diameter telescope after it collapsed). Working in five teams of three, they map most of the Galactic plane and a few extragalactic and solar system regions of interest using data acquisition software that I have developed (see Figure 4). Given that the 40-foot is a transit telescope, this requires days of almost around-the-clock observing. The students then produce images of these regions, again using software that I have developed. From these images, they "discover" supernova remnants, star-forming regions, galaxies, and quasars, as well as solar system objects like the sun, the moon, and Jupiter.

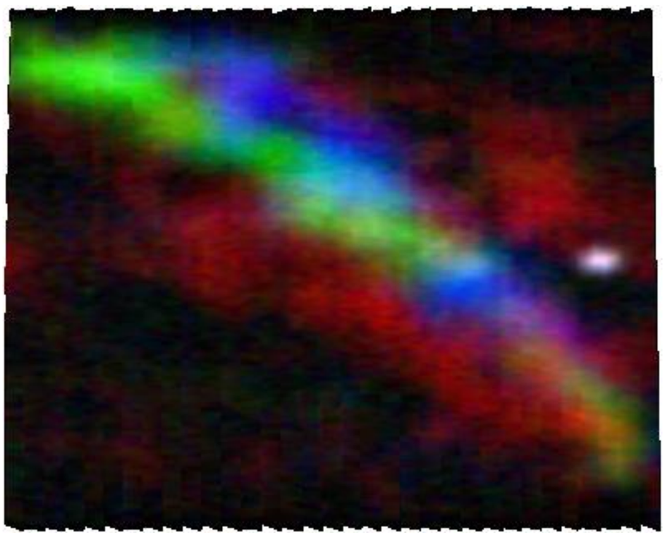


Figure 5: *An RGB combination of three narrowband images made by undergraduate and high school students using NRAO-Green Bank's 40-foot diameter telescope and our data reduction and analysis software. The narrowband frequencies were chosen such that the red image captures neutral-hydrogen emission from our arm of the Galaxy; the green image captures Doppler-shifted neutral-hydrogen emission from the next arm out; and the blue image captures even higher velocity neutral-hydrogen emission from the arm beyond that. The red arm is broad and diffuse because we are in it. The blue arm sits above the green arm because the Galaxy is warped, which our students discovered...only to learn that it had already been discovered 28 years earlier. Cygnus A is a broadband synchrotron source, and consequently appears white.*

Meanwhile, the students begin work on smaller, more research-oriented projects. These projects usually include:

- Producing a tri-color image of the Andromeda galaxy's disk and estimating its mass (see Figure 6)
- Measuring and interpreting the changing fading rate of the supernova remnant Cassiopeia A
- Detecting Jupiter and showing that it cannot be a thermal source
- Constructing an antenna to detect Jupiter's moon Io interacting with Jupiter's magnetic field
- Measuring the rotation curve and mass distribution our galaxy using the 21-cm emission line of neutral hydrogen
- Producing a tri-color image of a portion of our galaxy and showing that it is warped (see Figure 5)

- Measuring the surface temperature of the moon
- "Deep" and polarimetric imaging of the Orion Nebula and the North Polar Spur (see Figure 7)
- Detecting pulsar PSR 0329+54 and measuring its pulse profile
- Using the 40-foot to predict sunspot numbers and other measures of solar activity
- Constructing an antenna to predict sunspot numbers and other measures of solar activity
- Constructing a 2-meter diameter radio telescope that is good enough to detect the sun

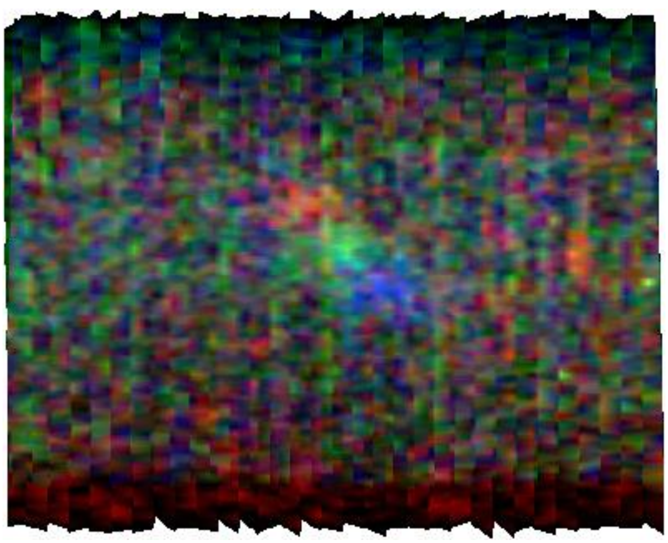


Figure 6: *An RGB combination of three narrowband images of Andromeda made by undergraduate and high school students using Green Bank's 40-foot diameter telescope and my data reduction and analysis software. The narrowband frequencies were chosen such that the red, green, and blue images capture Doppler-shifted neural hydrogen emission from the receding side, center, and approaching side of Andromeda, respectively. Students use these data to estimate the mass of Andromeda. In a related project, students use the neutral hydrogen spectrometer to measure the maximum Doppler shift of gas along the Galactic plane and calculate the radial mass distribution of the Milky Way.*

Since the development of Skynet and PROMPT, I have also been offering a number of optical projects that expand on what many of the students experienced in ASTR 101L. Typically, each student selects two or three of these radio and optical projects. Unlike the mapping project described above, the students are responsible for the design of these projects as well as their observations. However, typically 5 – 7 educators are on hand to help. All teams present their results to their fellow participants on the final day.

Between observing with the 40-foot and working on their projects, the students attend a crash course on basic radio astronomy, special interest talks by the educators, research talks by both the educators and fellow participants who have already begun research at their home institutions, and a walking tour of the observatory, which includes the Green Bank Telescope, the world's largest fully steerable telescope. Altogether, there is very little time for sleep. This is particularly true the night before final presentations. However, the students thrive and bond under these conditions and would not have it any other way. For example, here is a quote from one of last year's students:

"Thank you again for giving me, and others, the opportunity to participate in such an awesome program. I not only learned so much about radio astronomy, but I learned

more about myself and what I can do when pushed to the limits. I formed many friendships and made lasting memories during my stay at Green Bank, and for that I am grateful. Never has a week been so exhausting, yet so much fun! It was and probably will be the highlight of my undergraduate experience. Thanks again." – Ben Andrews, UNC-Chapel Hill

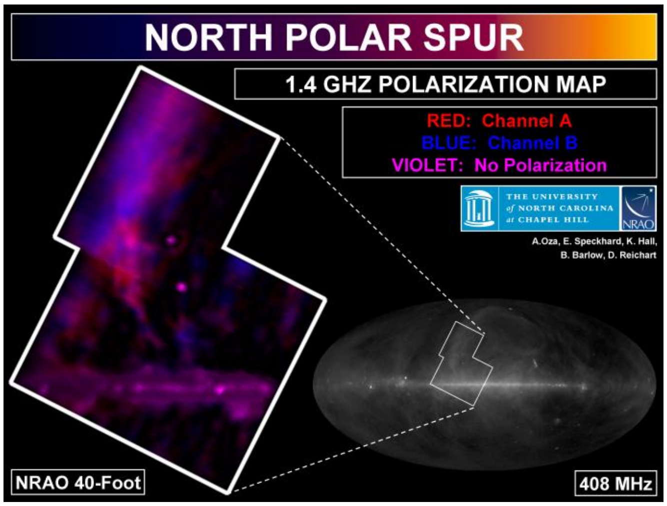


Figure 7: *A red-blue combination of two perpendicularly polarized images of the North Polar Spur made by undergraduate and high school students using Green Bank's 40-foot diameter telescope and my data reduction and analysis software, revealing its extreme polarization.*

For the educators, this week is more than one of service, but one of learning from each other, brainstorming new approaches, and trying them out on the spot with the most receptive group of students that we will ever find. In many ways, we get as much out of the experience as they do.

A.4. Undergraduate and Graduate Student Research

Students who participate in ERIRA usually end up majoring in physics and astronomy and working in research groups within the department. Over a dozen undergraduate students have joined Skynet's GRB group after participating in ERIRA. Altogether, they have authored or co-authored 19 journal articles, two conference proceedings, approximately 220 observing reports, and one honors thesis. The highest profile of these was a first-author publication in Nature by then-undergraduate student Joshua Haislip, who with me discovered and identified the most distant explosion in the universe then known, GRB 050904 at redshift $z = 6.3$ (see Figure 8). For the WMAP cosmology, this redshift corresponds to 12.8 billion years ago, when the universe was only 6% of its current age.

I have also had five graduate students in Skynet's GRB group since 2002 (one of these was recruited from ERIRA as well). Altogether they have authored or co-authored 22 journal articles, four conference proceedings, approximately 240 observing reports, four masters theses, and two doctoral dissertations.

I also mentor our undergraduate and graduate students in grant writing. Since 2002, our undergraduate students have raised $96K in the form of 29 small grants and awards that they applied for themselves. Similarly, our graduate students have raised $76K in the form of 13 small grants and awards that they applied for themselves.

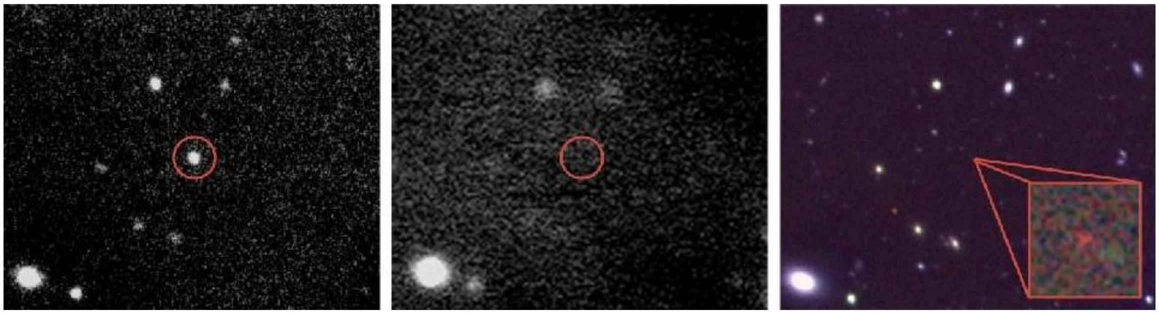


Figure 8: *Left panel: Near-infrared discovery image of the bright afterglow of GRB 050904 from SOAR atop Cerro Pachon in Chile. Middle panel: Near-simultaneous non-detection of the afterglow at optical wavelengths, implying z > 6, from one of the six PROMPT telescopes atop Cerro Tololo, only 10 km away. Right panel: Color composite image of the very red afterglow 3.2 days after the burst from Gemini South, also atop Cerro Pachon. From Haislip et al. 2006, Nature, 440, 181.*

B. Students of All Ages throughout North Carolina

PROMPT's primary mission is to observe gamma-ray bursts (GRBs) – deaths of massive stars and births of black holes – simultaneously at multiple wavelengths when they are only tens of seconds old. With bulk Lorentz factors of $\Gamma \sim 100$ and isotropic-equivalent luminosities of $L \sim 10^{54}$ erg/sec, they are both probes of ultra-relativistic physics and backlights with which we can probe star-forming regions and the early universe

When no sufficiently bright GRBs are observable, which is approximately 85% of the time, PROMPT is used by professional astronomers, students of all ages – graduate through elementary – and members of the general public across North Carolina, the US, and the world for a wide array of research, research training, and educational and public outeach (EPO) efforts.

PROMPT Collaboration institutions include (1) UNC-Chapel Hill, (2) 12 regional undergraduate institutions, including three minority-serving institutions (Appalachian State University, Elon University, Fayetteville State University, Guilford College, Guilford Technical Community College, Hampden-Sydney College, North Carolina Agricultural and Technical State University, UNC-Asheville, UNC-Charlotte, UNC-Greensboro, UNC-Pembroke, and Western Carolina University), (3) UNC-CH's Morehead Planetarium and Science Center (MPSC), and (4) the US and Chilean astronomical communities. PROMPT Collaboration access began on February 1, 2006, only a year and a half after receiving funding, and to date these four groups have used 7,057, 5,720, 1,604, and 13,422 hours of observing time, respectively.

PROMPT's most successful EPO efforts have been carried out in partnership with MPSC. Over the past four years, we have trained approximately 75 high school teachers to use Skynet's professional interface (http://skynet.unc.edu) and these teachers have gone on to train thousands of North Carolina high school students using a 127-page curriculum that we developed (http://skynet.unc.edu/observe.pdf). This curriculum satisfies North Carolina Earth and environmental science graduation requirements. Here are a few quotes from participating teachers and students:

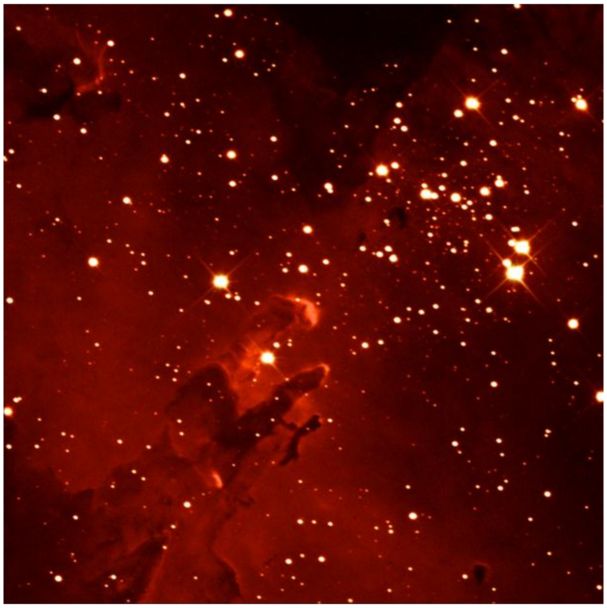


Figure 9: *Skynet/PROMPT image of the Eagle Nebula made by high school students as part of Project OBSERVE.*

"I am so excited to have parents coming up and thanking me for doing all this. Their kids are up late at night checking images, calling them into the room to see and IM-ing their friends to check out their images. Parents are excited to see their children take such an interest in an academic topic." – Ben Davis, Teacher, Albemarle High School, NC

"I can't thank you enough on behalf of Enloe's astronomy classes for the amazing work your team has put into the OBSERVE program. I think Mr. Hicks choked up more than one time at the fact that high school students were scrambling to their computers the moment they woke up every morning to see how their images turned out. (:" – Jessica Bodford, Student, Enloe High School, NC

"One particular student of mine has a Behavior Improvement Plan. He has difficulty relating to any of his teachers or classmates, or doing his class work. But using Project: OBSERVE, finding the right galaxy, learning about what was visible in the Chilean night sky, how to enter jobs, how to manipulate his rough photos, sparked an interest that no one had seen in this young man before!" – Kathy Williams, Teacher, Scotland County Schools, NC

Figure 10: *Part of MPSC's "Zoom In!" exhibit.*

Also in partnership with MPSC, we have developed an introductory version of Skynet's interface and have incorporated it into MPSC's "Zoom In!" exhibit. Over the past two years, approximately 18,000 elementary and middle school students, as well as members of the general public, have used it to request observations on PROMPT. PROMPT takes a unique image for each user, emails them a link to it, and then Skynet allows them to request nine more observations from home or school before having to return to MPSC. **Try it yourself:** http://skynet.unc.edu/morehead/authorize.php, password = “reichart”.

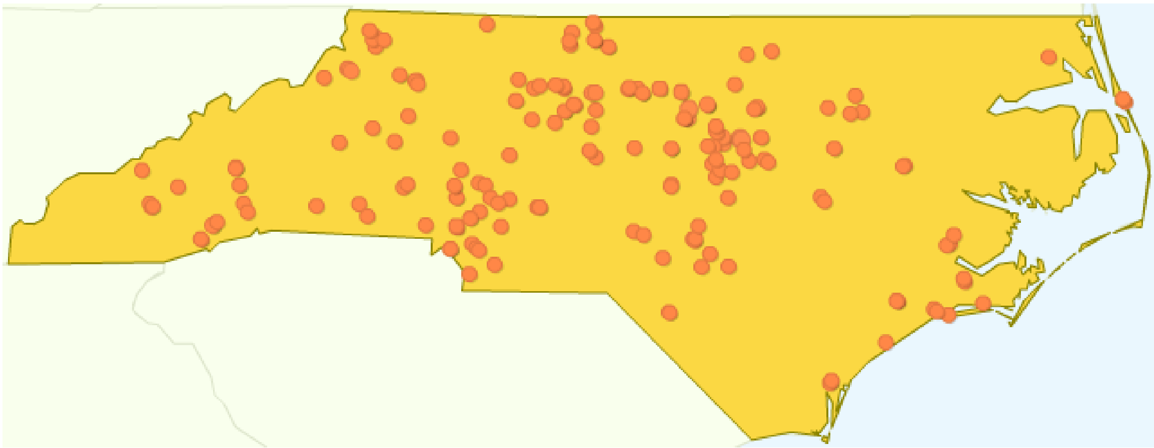


Figure 11: *Skynet’s web interfaces have had 57,000 visits per year, most of which have come from these locations, many of them rural, in North Carolina. The average user spends 7 minutes viewing 10 pages per visit.*

C. ASTR 702: High-Energy Astrophysics

I have also taught this graduate student-level course, based on most of Shapiro and Teukolsky and on some of Rybicki and Lightman. This has been enjoyable, but relatively straightforward.

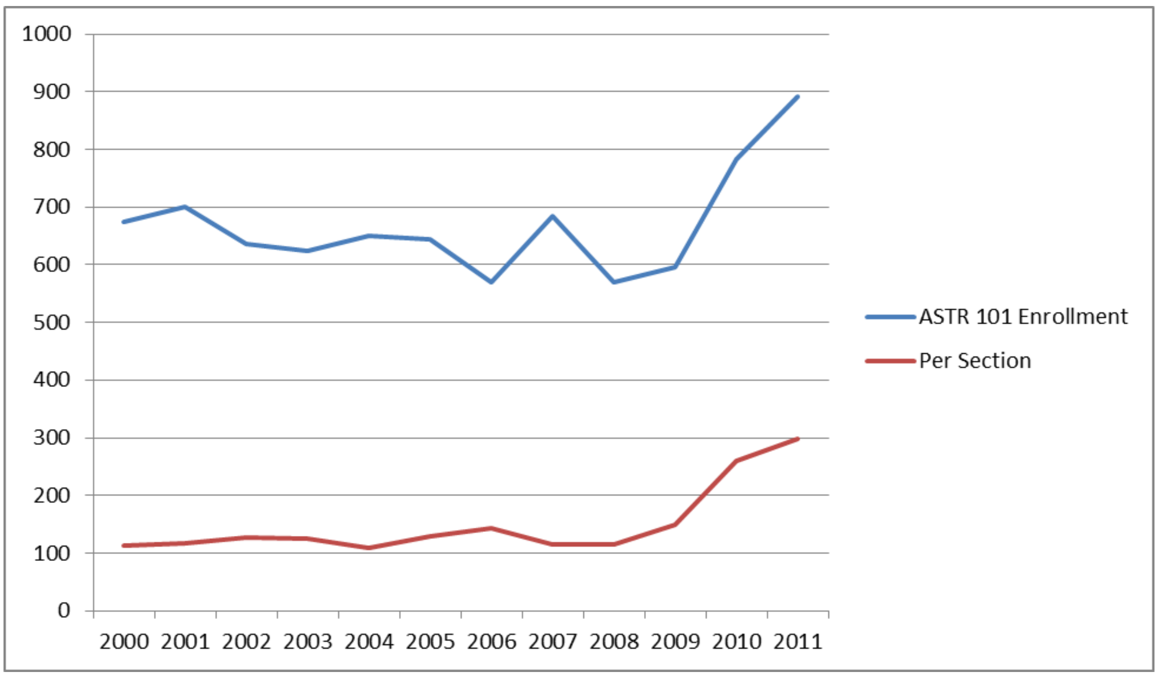
INTRO ASTRO ENROLLMENT 2000 – PRESENT

ASTR 101

ASTR 101 enrollment slowly declined from a peak of 701 students in 2001-02 to 570 in 2006-07. We tried to combat this by offering additional sections in 2007-08, which increased enrollment to 684, but this was not sustainable, with enrollment again dropping to 570 in 2008-09.

I spent 2008-09 developing the new, split 101/102 curriculum and began implementing the new version of 101 Spring 2009. I began moving sections of 101 from 215 Phillips (148 seats) to 111 Carroll (425 seats) Fall 2010, completing this process Fall 2011.

ASTR 101 enrollment has increased by ≈56% over the past three years (≈892 expected in 2011-12). At the same time, the number of sections has decreased from typically 5 or 6 per year to 3 per year (taught by Reichart and LaCluyzé). Teaching evaluations have remained strong (between 4 and 4.5).



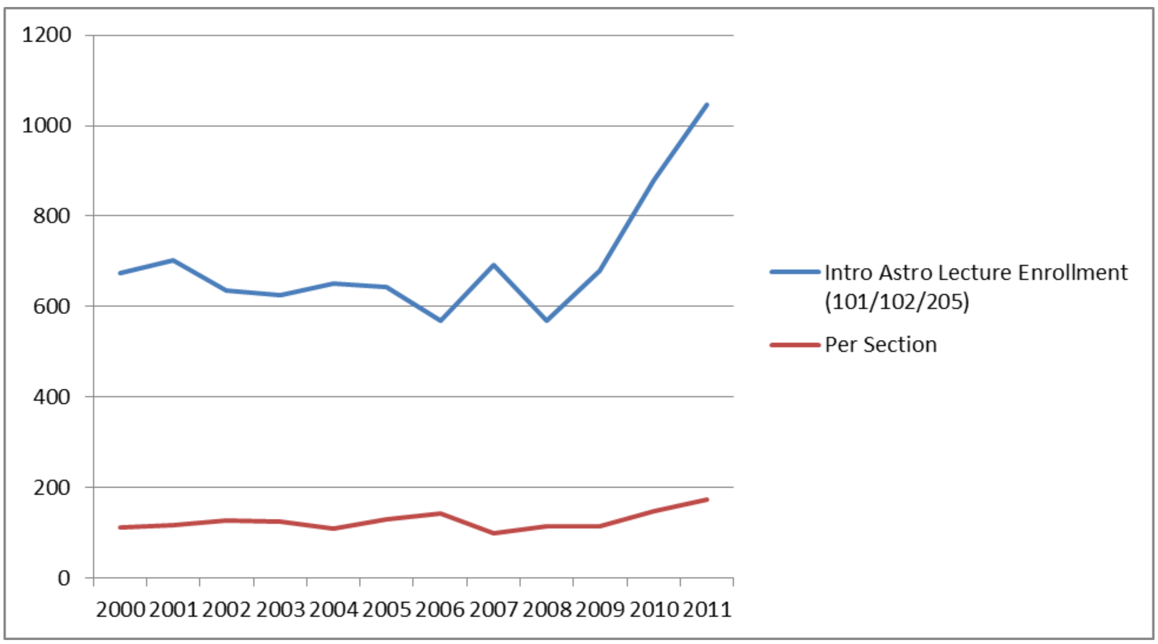
ALL INTRO ASTRO LECTURE COURES (101/102/205)

Reducing the number of sections of 101 freed up instructors to teach our other, new intro astro lecture courses, 102 and 205.

In its first two years, ASTR 102 enrollment was ≈80 per year. Representing the most interested ≈10% of 101 students, 102 students are targeted for, and 102 is designed for, major/minor recruitment (see below). Taught by Kannappan, Cecil, Reichart.

ASTR 205, developed and taught by Clemens, has increased by ≈128% over the past year (≈60 expected in 2011-12).

Altogether, intro astro lecture enrollment (101 + 102 + 205) has increased by ≈84% over the past three years (≈1047 expected in 2011-12). This new ensemble of courses requires 6 instructors per year, in line with our historical requirements. Teaching evaluations have been uniformly strong.

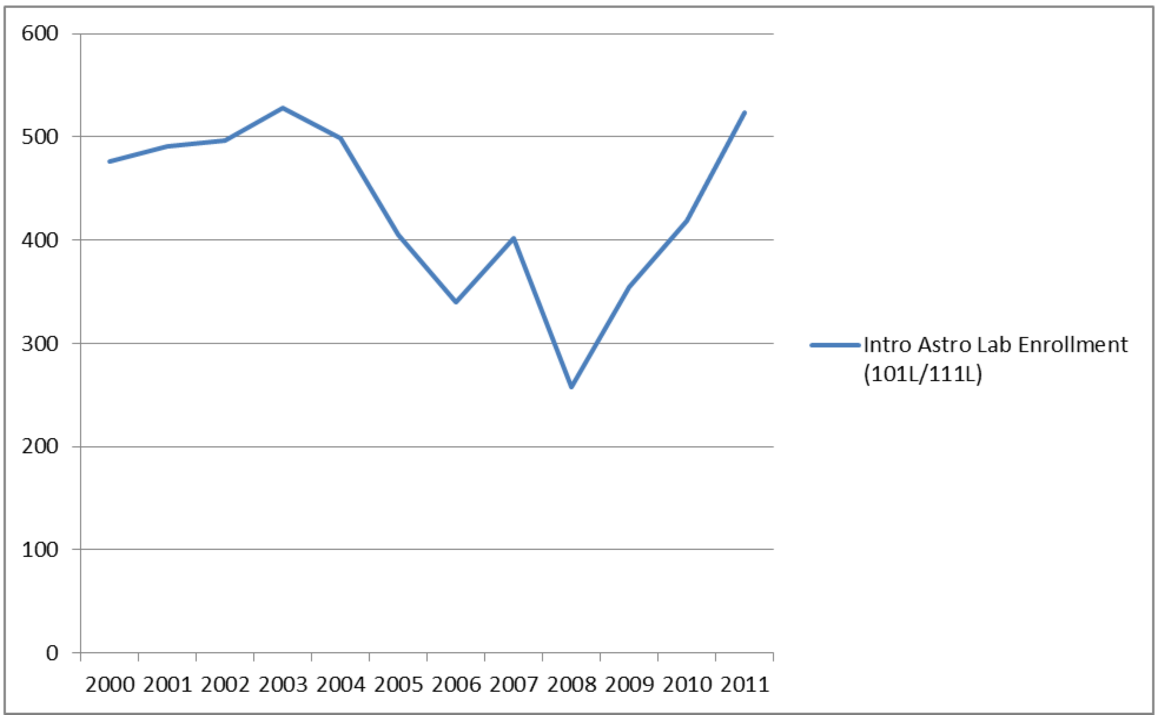


ALL INTRO ASTRO LAB COURES (101L/111L)

ASTR 101L enrollment quickly declined from a peak of 528 students in 2003-04 to 253 in 2008-09. The bump in enrollment in 2007-08 is tied to our attempt to offer additional sections of the lecture course (see above).

I spent 2008-09 developing the new, Skynet-based curriculum and began implementing the new version of 101L Summer 2009. ASTR 101L enrollment has increased by ≈104% over the past three years (≈516 expected in 2011-12).

I added ASTR 111L, an EE course for potential majors/minors, in 2008-09. It now serves ≈8 potential majors/minors per year. Altogether, intro astro lab enrollment (101L + 111L) has increased by ≈103% over the past three years (≈524 expected in 2011-12).

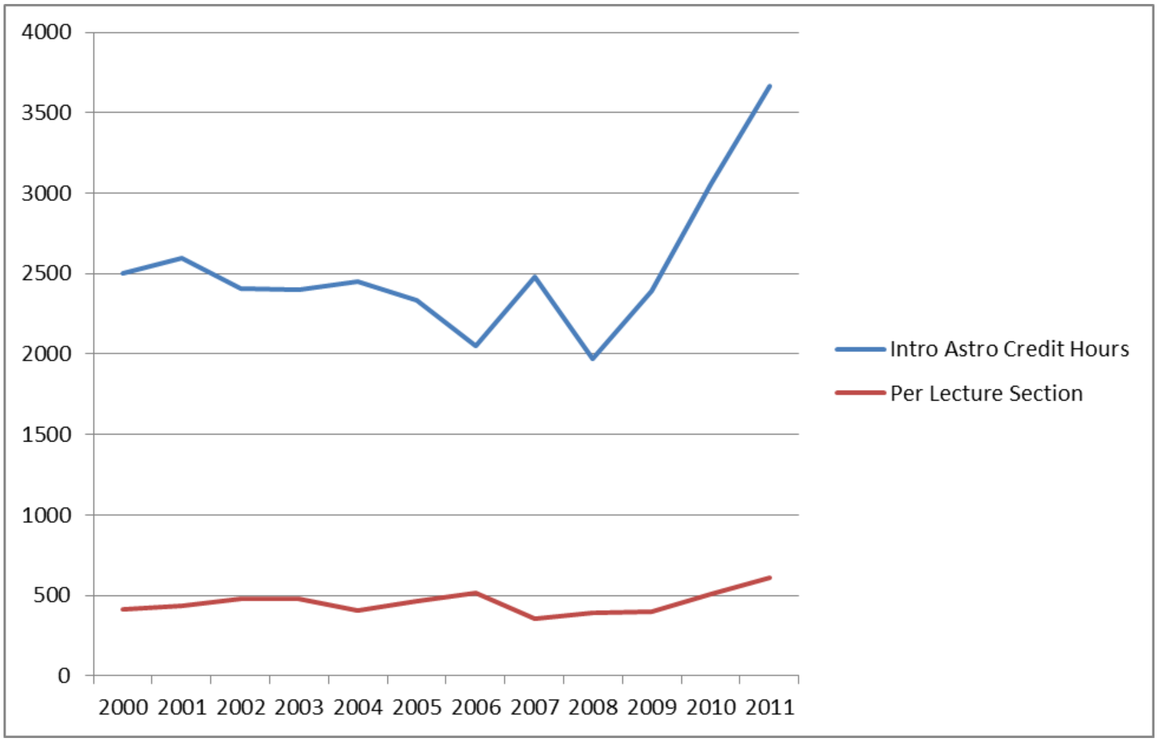


TOTAL CREDIT HOURS

The lecture courses are worth 3 credits each and the lab courses are worth 1 credit each.

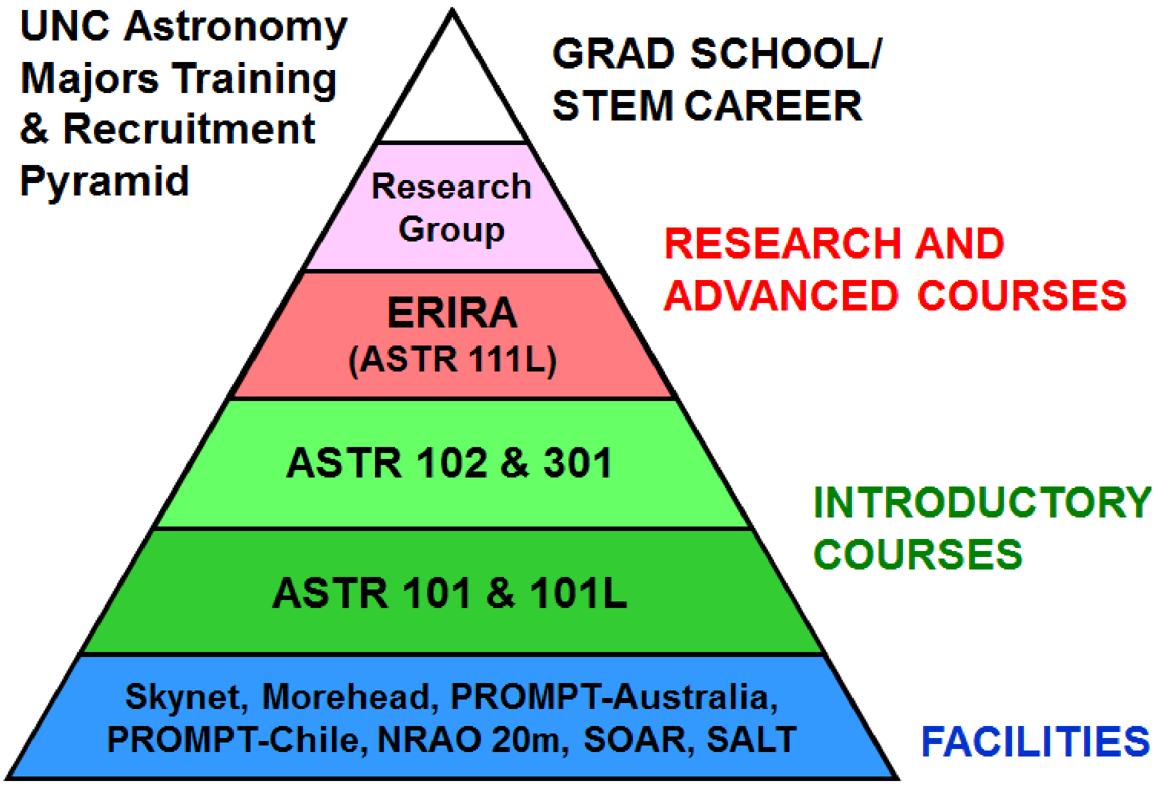
Total credit hours slowly declined from a peak of 2594 hours in 2001-02 to 1968 hours in 2008-09.

Since the introduction of the new intro astro curriculum three years ago, total credit hours have increased by ≈89% (≈3665 hours expected in 2011-12).



MAJORS/MINORS

The new intro astro curriculum is designed not only to increase enrollment, but to increase majors/minors:



Last year, we introduced a new version of ASTR 301, a 1-credit add-on to 102 for majors/minors (taught by Kannappan). It can be used as an early indicator as to whether the new curriculum, and the new major/minor requirements, are resulting in more majors/minors.

Over the past year, ASTR 301 enrollment has increased by ≈200% (≈15 expected in 2011-12).

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*All 2011-12 numbers conservatively assume that 10% of students currently enrolled will drop and that spring + summer to fall enrollment ratios will be the same as last year.