TEACHING PROPOSAL

The Problem: Teaching Science to Non-Scientists

Critical thinking skills and science literacy at all levels are fundamental, as citizens of the modern world must understand how science affects policy, business, and personal decision making [T1]. Technological literacy, which can go hand-in-hand with overall science literacy, is an ever-present demand of our daily lives. Students at the undergraduate level at institutions like the University of Chicago are future leaders – political leaders, business leaders, cultural leaders – and ensuring they are connected to, engaged by, and cognizant of current research is vitally important. Moreover, for today's students the modern 'participatory media culture' is an everyday reality [T2], and yet the classroom experience of these students is often little different from their parent's. The potential of using technology in complex subjects is well documented [T1, T3]. Astronomy research is now extremely data rich and the related computational work is data-centric [T4, T5] yet exploitation of technology to bring that flood of data and research into the classroom is limited.

A Solution: Using Emerging Technologies and Data to Bring New Research to the Classroom

I propose to bring my research, data, and experiences as a researcher, to the classroom and beyond, and in so doing encourage science literacy – both in my own university's student body, and the broader public – via emergent technologies. I will do this by incorporating the *entire* RCS2 survey into two platforms for data visualization and teaching: Microsoft Research's World Wide Telescope (WWT), and Google's Google Sky [T6, T7]. These spectacular visualization environments (essentially desktop planetaria with rich data links) already include extensive astronomical datasets such as the Sloan Digital Sky Survey (SDSS, of which Chicago is a founding institution). The SDSS is the *largest* database of digital images of the sky ever created [T8] and the imaging from the RCS2 program is not far behind in sheer size, and is complementary in scientific scope. Using these datasets, and these new tools, I will develop a sequence of computer-based labs for my department's Core academic courses, which are offered to the entire student body. Further, I will develop a sequence of interactive 'tours' based on RCS2 data for general consumption, highlighting topics surrounding my own research. These will include still and video footage of the research sites I visit – principally remote ground-based observatories. The tours will be first presented in a live format at the Adler Planetarium & Astronomy Museum's Space Visualization Lab [T9], which will allow their narratives to be developed and refined based on visitor feedback. This will bring current research and a real world massive data set into the classroom and onto the web; making me a more effective teacher, my students more engaged, and better focusing formal and informal science education on cutting-edge questions in astrophysics and the valuable skills of navigating and processing information.

A Plan Based on Experience

Teaching: I joined the faculty at the University of Chicago in October 2006. The UC is known worldwide as a particularly rigorous institution in academics: all of our undergraduates, regardless of major, are required to take courses in the physical sciences. The university's commitment to this broad science education for all students was one factor in my decision to come to Chicago. Since arriving I have been, at my request, teaching one of the undergraduate Core courses offered by the Astronomy and Astrophysics Department. This challenging course, 'PHSC119: The Astronomy and Astrophysics of Stars', is the first of a two-part sequence (the other being 'PHSC120: Cosmology and How We Know') which draws upon the entire undergraduate population, and has the largest enrollment in our department (~70 students per quarter). I have taught this course twice and will teach it twice more in the coming year. PHSC119 is really a physics course aiming to teach a broad spectrum of students some of the fundamentals of gravitation and electromagnetism. Unlike 'introductory' science courses at many institutions, our students are expected to solve and understand mathematical representations of basic physics. The course is challenging, and like all review courses can suffer from a tendency to emphasize established answers over unanswered questions. I have endeavored to move PHSC119 away from this, and am determined to do more yet to instill critical thinking and appreciation of the creativity of science into this course.

As an example: In October 2007, while in the middle of teaching PHSC119, I traveled to the Las Campanas Observatory in Chile to commission a new instrument on the 6.5m Magellan telescopes [T10]. Rather than simply arranging for another professor to cover my lectures, I instead looked upon this absence from campus as an opportunity to bring a cutting-edge observatory (and the up-to-the-minute commissioning of a new astronomical tool) into the classroom. I traveled to the site with an HD video camera, and an extra laptop equipped for video conferencing. The lectures for that week were delivered

TEACHING, continued

from the dome floor of one of the world's largest telescopes(the topics for that week were focused on telescopes and optics), with cameras set up in the classroom as well to allow for two-way interaction. I also spent any available waking hours recording a library of videos showing both the details of the Magellan telescopes and instruments, and the overall observatory environment. These were composed into about 30 minutes of video which I sent back to campus mid-week as a backup in case of connection failures from the mountain (which are common). These videos (with commensurately better sound and images, though lacking in interactivity) formed the basis of the week's final lecture, with another professor acting, by previous arrangement, as my backup in the classroom when the network link did indeed fail. Notably, this video has found its way into outreach efforts at the department, and at the Adler Planetarium in Chicago [T11]. This experience, and the extraordinarily enthusiastic response from my students, emphasized to me how important and compelling it is to make the connection between my own research and the classroom.

Since arriving at Chicago I have also for one semester been the lab supervisor for our entire PHSC course sequence. Both PHSC119 and PHSC120 have a weekly lab component, with a range of experiments performed. These range from relatively simple exercises in optics, a sequence of computer-based labs in cosmology, and even a lab in which students actually measure the temperature of the cosmic microwave background. This final lab, using a recycled detector from the BIMA radio array (a current research facility in Owen's Valley, CA), is a good example of what our labs should be.

Public Education: The Astronomy and Astrophysics Department at Chicago has a strong history in and ongoing commitment to public education and outreach. We are, for example, one of very few university departments to employ a full-time senior staff member explicitly to head our public education and outreach activities. We are also strongly connected to the Adler Planetarium, with members of their staff holding joint positions within our department. I share this commitment, and see efforts to educate the general public about the latest scientific advances as a core mission of all scientists. I consider it fundamental to the scientific process that results and ideas be communicated both to my peers, and to society as a whole. There are simply too many historical instances of insight coming from 'outside the field' to dismiss the impact of curious minds; indeed the US has a large and vibrant community of amateur astronomers who contribute greatly to astronomical research [e.g., T12]. In addition, I only get to be an astronomer because society deems it something of value. My work in communicating the excitement of my own research to the public is an investment in the future of my field. Finally, one of the critical advantages of astrophysics in the broadest sense is the enthusiasm with which it is embraced by the general public; as an example astronomy is the only science offered in dedicated museum-like facilities (i.e. planetaria) in most large cities in the US. This makes astronomy a unique vehicle for generating general science literacy.

My own public outreach activities include several long public lectures on cosmology and telescopes at Mt. Wilson this past summer, and an extended public round-table discussion of current questions in astrophysics at the Chicago Art Institute this past winter, as part of the conference 'Cosmic Cartography' [T13] - for which I was the lead organizer. I have also agreed to be a guest speaker for the Summer Science Program [T14] in 2009, and have other ongoing outreach commitments locally.

This past December the Kavli Institute for Cosmological Physics (KICP) offered another in a series of 'short courses' for museum and planetarium staff. These three-day intensive courses provide educators and science communicators with the knowledge and tools to present cutting-edge astronomy effectively to the general public. This offers a huge multiplex advantage and impact, since our short course students prepare science education programming seen by literally millions of people. One personally notable outcome of my own contribution to this short course – a lecture on dark matter and strong lensing - was the inclusion of a small portion of that lecture in the online World Wide Telescope (WWT).

The Proposal In Detail: Both Google Sky and WWT are frameworks for displaying astronomical data, with navigation and search functions for moving through vast databases with layers of data at any point in a virtual sky. More than this, they offer the opportunity to develop linked content - 'tours' – which expands the use of these tools from a simply visual experience to a truly immersive and instructive event. The mission of these efforts is education and scientific discovery [T15]. It is difficult to overstate the reach of these platforms: in less than a year these applications have been accessed by *millions* of people!

These platforms are new and we are just beginning to explore their possibilities for education (and will

TEACHING, continued

be for some time). It is clear they will be extraordinarily useful, but details are, as of yet, mostly lacking. KICP will shortly be hosting a workshop that brings together the WWT and Google Sky development teams, and a small group of educators (myself included) from a range of institutions [T16]. The goal is to explore, with the guidance of the software experts, ways in which these platforms can be used to create tours, classroom applications, research environments, and laboratory exercises.

My own agenda for WWT and Google Sky is to integrate my own research work - and specifically the RCS2 imaging survey - into these platforms. As was noted in the research section above, RCS2 is a multi-color imaging survey consisting of some 90,000 individual digital images - with each image equivalent to the output of a 9.5 Megapixel camera. The total number of objects (stars, galaxies, quasars etc.) recorded in these images (approximately 100 million!) is comparable to that in the SDSS (one of the core datasets in both WWT and Google Sky). RCS2 is a smaller survey in sky area, but with much sharper and deeper images that allow a more detailed look at the nearby universe, and a view of the more distant universe than SDSS. Integrating this image database into WWT and Google Sky will be challenging - in part because the requirements of purely scientific data analysis versus the preparation of multi-color images for public consumption are somewhat different - but enabled by the technologies already in place within these platforms. I have already had discussions with the principals at both Google Sky (R. Scranton) and WWT (C. Wong) regarding this and will initiate detailed planning at the workshop. It should be noted that in the absence of such tools it would be impossible for individual researchers to bring large datasets into the public domain in an accessible way; such efforts are the only way, now and in the future, to tame the flood of new data which typifies modern astronomy. Bringing this modern data-driven science into the classroom will generate new opportunities for learning [T1].

With the RCS2 data available within WWT and Google Sky I will then prepare a set of new lab exercises for our PHSC Core courses. Three new labs are obvious: 1) on the properties of star clusters, and the relevant connection to the story of stellar evolution, for PHSC119, 2) on the observable properties of galaxies over cosmic time, and the expansion of the universe, for PHSC120, and 3) on the nature of galaxy clusters and their constituent galaxies, mass measurements thereof and the evidence for dark matter, also for PHSC120. These 3 cleave relatively closely to existing labs, but will present students with up-to-date (and visually stunning) data in a comprehensive analysis environment, with linked mini-tours which take the experience well beyond the typical lab handout. Other labs are certainly likely – and I will explore the possibilities as I learn more about WWT and Google Sky.

I will also prepare a sequence of tours highlighting the research being done with RCS2 data. This will integrate not only the survey images, but the extensive follow-up work on this survey now underway (including space-based observations using all of NASA's current Great Observatories, and extensive data from the largest ground-based telescopes.) Since I travel to these latter facilities regularly, I plan to make a point of traveling with HD still and video equipment, and recording the observatory environment and observing experience for inclusion in these tours [T17]. My own use of such video in a classroom setting has convinced me of the positive impact this has for education - it engages the tourist in the tour.

I would also note that I will include undergraduate students wherever possible (the likely greatest use of the award will be to engage students through work-study programs). There are several obvious places for direct student involvement, e.g.: 1) with guidance, computer savvy undergraduates could handle much of the migration of RCS2 data onto the WWT and Google Sky platforms, and in doing so would learn much about RCS2 and the process of acquiring and analyzing said data; 2) a comprehensive effort to document the observing process could include selected students of any background, with travel to the observatory sites; 3) the generation of tours could include students both as creators of content and as an informed test audience for content I will generate. Including students in this way offers the opposite extreme from web-based tours: the latter provides a modest brush of science education for a truly broad audience and the former provides a deep engagement on elements of research. Both are important, and serve to bracket the core mission of bringing our research straight into the classroom.

As a final point it is worth recognizing that web-based instruction and public education offers one other advantage: it naturally tracks and monitors the exposure that these 'products' receive. This provides immediate feedback on the success – at least via access statistics – of these education efforts.

References and Footnotes, Teaching Proposal

T1. *Fostering Learning in the Networked World: The Cyberlearning Opportunity and Challenge* (Report of the NSF Task Force on Cyberlearning)

T2. Jenkins, H., Clinton, K., Purushotma, R., Robinson, A. J. & Weigel, M. (2006). *Confronting the Challenges of Participatory Culture: Media Education for the 21st Century*. Chicago, IL: The MacArthur Foundation.

T3. Edelson, D. C., Gordin, D. N. & Pea, R. (1999). *Addressing the challenges of inquiry-based learning through technology and curriculum design*. Journal of the Learning Sciences, 8(3-4): 391-450.

T4. Bell, G., Gray, J. & Szalay, A. S. (2006). *Petascale computational systems*. Computer, 110(1): 110-112.

T5. Gray, J., Liu, D. T., Nieto-Santisteban, M., Szalay, A. S., DeWitt, D. J. & Heber, G. (2005). *Scientific data management in the coming decade*. ACM SIGMOD Record, 34(4): 34-31.

T6. World Wide Telescope, http://www.worldwidetelescope.org/

T7. Google Sky, http://www.google.com/sky/

T8. The Sloan Digital Sky Survey, http://www.sdss.org/

T9. Adler Planetarium & Astronomy Museum's Space Visualization Lab http://www.adlerplanetarium.org/svl/index.shtml

T10. Chicago Chronicle April 3, 2008 Vol. 27 No. 13, http://chronicle.uchicago.edu/080403/astronomy.shtml

T11. in the Adler SVL [T9] and http://svl.adlerplanetarium.org/coresampling/, and *Cosmic Cartography, Journey Through The Universe,* http://cosmicmaps.uchicago.edu/public.html

T12. Lintott, C. (2008). *Voorwerp Fever: The Story of a Major Astronomical Discovery by a Schoolteacher.* Online only, http://www.galaxyzooblog.org/page/4/

T13. Cosmic Cartography, http://cosmicmaps.uchicago.edu/

T14. The Summer Science Program, http://www.summerscience.org/home/index.php

T15. To quote from the WWT website [T5 above] : "To re-awaken the interest for science in the younger generations through astronomy and new technologies through the virtual observatory of the WWT. This also provides a wonderful base for teaching astronomy, scientific discovery, and computational science."

T16. *Viewing the Universe Via the World Wide Web*, Sept. 3-5 2008,http://kicp-workshops.uchicago.edu/universe2008/

T17. Note that neither WWT nor Google Sky *currently* support embedded video (though they will, eventually – only still photos and panoramas are currently supported); video can and will be used directly in the classroom and at the Adler Planetarium even in the absence of such support.