EDUCATIONAL PROPOSAL: *Each applicant is expected to propose a plan that has promise to improve undergraduate science education. This is an opportunity to share the philosophy and principles that guide you as a scholar-educator. Competitive applications must include concrete examples of efforts to date, your educational plan, and how that plan supports and complements your department's undergraduate educational priorities. Your educational plan must be substantive and demonstrate a long-term commitment to your role as a scholar-educator. RCSA program officers screen educational plans/proposals initially, and only those that pass this screening are submitted to peer review of both the education and research proposals, giving equal weight to both.*

STATEMENT OF THE PROBLEM, SIGNIFICANCE OF THE PROBLEM, AND YOUR PLAN OF PROCEDURE (Describe your department's recognized areas of educational priorities and explicitly detail how your plan fits. State clearly the problems or issues you wish to address and how they relate to any ongoing work. Cite precedent. Carefully outline the importance of your plan and the impact it may have on your undergraduate students. A viable approach should be given, including examples from your own experience and/or from the literature. Indicate ways in which the completion of this work has a broader impact. Use Arial 11 point font. Limit to four pages.)

> ***"If a nation expects to be ignorant and free, in a state of civilization, it expects what never was and never will be." —Thomas Jefferson***

Problem: Science Learning in a Technical World
Scientific and technological literacy go hand in hand with cultural awareness. The current technological pressures on society — mounting energy limitations, space exploration costs vs. rewards, increasing automation of financial markets, health care as a research industry, privacy vs. social connectedness — will be dwarfed in scale and scope by the range of complex technical issues that will dominate by the middle part of this century. Science and technology will become such a pervasive part of the cultural canvas that they will seem to fade into the background, just as high-speed travel and global communications — so miraculous when my grandparents were young — now do. Yet, even as our society is rapidly transitioning towards a deeply technical future, we have not experienced concomitant gains in our ability to grasp the scientific underpinnings of our modern world. Forty-nine percent of United States adults do not know how long it takes for the Earth to revolve around the Sun [E1]. Out of 30 countries, US students rank 21st in science and 25th in math in recent standardized testing [E2]. For students in particular, part of the problem no doubt is the breathtaking pace with which information is now bombarding them from all directions: laptops, smart phones, "informative" kiosks and ticker-strewn news channels filling the cafeterias and lobbies. But a deeper concern is that methods for teaching science, in particular to those who will not have technical careers, have not evolved to match the increasingly *visual, interactive* world of information around them. *I plan to harness the incredible potential of the UT Ritter Planetarium's new digital full-dome system to build interactive, engaging, and visually immersive astronomy lab modules designed specifically to address this need.*

Background and Accomplishments: Since arriving at University of Toledo, I have worked to expand and re-tailor our astronomy curriculum, increase the research visibility of the group, and spread our research more effectively through outreach at many levels. I am taking an active role in shaping the future of the astronomy curriculum at UT, including initial development of a "Physics of Astrophysics" advanced undergraduate and graduate primer, and a "Computational Methods and Statistics in Astronomy" course in a similar vein. While the number of new majors in our astronomy programs is rising rapidly, and includes a large contingent of future educators obtaining BA's, I believe we can significantly increase student recruitment and retention by improving and refocusing our curriculum to better integrate interactive and visual technology (online and otherwise). I introduced online homework systems to our astronomy faculty, including innovative ways to solicit feedback and ensure effectiveness. Now all 5 sections of introductory astronomy use the system each semester. I incorporate active learning tools in the classroom, and use live feedback (e.g. homemade colored quadrant response systems) and task-oriented student discussion exercises. I bring new visual elements as often as possible into the classroom (sometimes drawing on 3D modeling skills from my woodworking hobby), and make active use of demonstrations. In part for my commitment to undergraduate teaching I was thrilled to receive after only one year the 2009–2010 Arts & Sciences Faculty Excellence Award. I have been just as focused on outreach, working with colleagues from UT and elsewhere on multiple outreach grants and activities, and with the public through K-12 and community lectures and forums throughout the region.

Significance: In my most recent semester, I taught a class entitled "*New Frontiers of Astronomy & Astrophysics.*" With 12 non-major undergraduate students, I structured the class around a single premise:

the rate of new discovery about the Universe has now outstripped our ability to capture it in the traditional formats of textbooks and fixed syllabi. I challenged the students to bring in by their own initiative up to 50% of the material we covered in the class from recent news. I expected this to be an over-ambitious goal, but in fact by the end of the semester the students were contributing well over half of all the material. And by and large, what they brought to share were visual representations — new images of galaxies formed just after the Big Bang, animations of a new 6 exoplanet solar system discovered by Kepler, stereo movies of massive coronal mass ejections on the Sun, images and simulations of the kilometer cubed array of photo-sensors of high energy cosmic ray detectors under the Antarctic ice. These students were incredibly comfortable with sorting, selecting, and manipulating visual information. As I have learned in my large introductory astronomy courses, a well-timed segment of animation can improve knowledge retention far more than a half an hour of lecturing [E3]. Visual thinking does not replace analytical thought, but supplements it. Even simple visuals can have a major impact. In an introductory astronomy lecture last year, I modeled an eclipsing exoplanet system using a disk of white cardboard and a black plate to show that the planet-star distance does not factor into the amount of light dimming during eclipse. On an *identical* question testing this knowledge, students performed approximately twice as well as in the year prior. Visual learning works.

While I have been extremely aggressive about introducing effective visual materials into my introductory and advanced astronomy and astrophysics teaching — both of my own creation and obtained from other sources — I have had less success in the one place where hand-on learning could be powerfully impacted by adopting visual thinking methods: the introductory astronomy lab. Our labs, which I've instructed most semesters since arriving, are given to ~100 non-majors in 8 sections every semester, with graduate student TA section leads. Like many similar courses at other institutions, we cover motions in the solar system and night sky, the celestial sphere, parallax, the inverse square law of light, scale of the Galaxy, etc. I have worked with students to gradually improve the lab exercises, introducing, for example, a new popular rooftop triangulation experiment that students rate highly. Yet, for most modules (such as, e.g. "Orbit of Mars"), the materials used remain almost entirely passive: charts and overlays, rulers and compasses, photographic star fields. Despite dedicated efforts, our evidence is that knowledge of certain fundamental astronomy concepts is not being effectively conveyed. And where we do use visual materials (for example, a subset of the CLEA Labs [E4]), they are often outdated and overly scripted. My goal is to design and introduce new lab modules making full use of the immersive visual capabilities of the soon to be commissioned digital full-dome display system in our Ritter Planetarium.

Plan: The Ritter Planetarium is a 40' dome seating 90 on the UT campus. Ritter is used extensively for outreach and education in an Ohio/Indiana/Michigan region home to more than 1 million people. More than 25,000 guests, most of them K-12 students, come through each year. At present, Ritter is undergoing a $1/2 million upgrade to a new Spitz SciDome XD digital projection system (the first of its kind!). In the past we have utilize Ritter for our introductory astronomy lecture courses in only a minimal way, substituting a single lecture, for example. And our introductory lab course does not presently use the planetarium at all, despite the fact that schedule (1/2 sections in the daytime) and weather conditions allow only limited night-sky observing. The new full-dome system will offer incredible flexibility for displaying visual astronomy material. I intend to develop as an entry point four new labs targeting 1) the night sky and celestial sphere, 2) planetary motions, 3) the distribution of galaxies in the universe, 4) the electromagnetic spectrum and the multi-wavelength Universe. These will go far beyond a traditional lecture format. A unique and important component will be the *student's ability to directly control the visuals*. For example, the dome control software incorporates the Starry Night virtual planetarium. With the guidance of their astronomy grad student TA, students will work in teams to build visualization scripts specific to a given topic on lab computers. The group will themselves deploy and narrate these visuals later in the planetarium itself. These and other interactive labs will also benefit from and contribute to a major departmental educational focus: a new collaboration with UT's College for Visual and Performing Arts, the *ArtScience* initiative. CVPA faculty and students (film, visual, and art) with extensive experience in 2D and 3D modeling will collaborate with researchers and educators to incorporate real and modeled galaxy distributions and data sets into the flexible visualization software the system will include. Among the 8 sections, teams will compete for a "best-of" award for most informative and appealing visualization, bringing together all the students from all sections as peer judges at the end of the semester.

EM Spectrum: A familiar staple of an introductory astronomy lectures is a chart of the electromagnetic spectrum, color-coded for visual appeal, and cheerfully annotated with analogous objects and everyday sources of radiation — "*size of a human hair!, a foot ball field*!, *FM radio!, a heat lamp!, your dental X-Ray*!" The presenter entreats the audience to conceive that all of this oscillating vastness, of which the visible spectrum forms but a staccato rainbow blip, all of it, is *light*. She then transitions quickly to the dazzling array of astronomy made possible by our ability to see and measure this 'invisible light'. Despite repeated mention of the wavelengths of light used to make these discoveries, from experience I know that most in the audience will have a difficult time understanding how you could *see anything* that's invisible. Many will simply assume an X-ray composite is *really* just an image of a blue sphere, a radio continuum map just a pair of white streams, an infrared panel just a collection of red clouds. What's needed is a *direct demonstration* that this light is real, and can be used to learn completely novel things about the universe we live in. Almost all of my own research makes extensive use of multi-wavelength observational facilities that could not have existed even 30 years ago. The fact that cutting edge astronomical research is being conducted using wavelengths of light invisible to the human eye is a fascinating, but wholly inaccessible concept to most students and non-technical members of the public. To address this, working with industry partners and through the support of the Astronomical Society of the Pacific [E4], in 2009 I obtained a high-resolution thermal imaging (10μm) camera for education and outreach. I have developed a number of new demos for the camera, widely deploying them in the classroom, at outreach events, and in public lectures. I plan to expand this use significantly in an interactive lab on the electromagnetic spectrum. In addition to the spectrometer and gas-discharge lamps we use now in the lab, this module will incorporate live infrared imagery. I plan to incorporate these in interactive form in the planetarium, for example asking students to quantitatively contrasting multi-wavelength views of a galaxy with normal and thermal images of everyday objects, to further elucidate the interaction of matter and light.

Real Data: Learning based directly on manipulating real data, coupled with the context of cutting-edge technologies by which the data were obtained, and the global scientific context of why they are important, is significantly more valuable than "pre-rigged" studies [E5], resulting in a deeper feeling of involvement for students. I have introduced real data, including my own and from major surveys, into advanced undergraduate and graduate courses, to good effect. I hope to extend the use of "real data" to include introductory labs, with carefully edited data sets designed to highlight simple but powerful concepts.

Recruitment: Introductory Astronomy is an excellent recruitment tool for our Astronomy major. With new interactive immersive lab modules, I fully expect to find and recruit talented young students, many of whom will not have yet chosen a major, into my own research. I include undergraduates in my own research group through our NSF REU summer program, as well as by recruiting local students to work with me throughout the school year. Almost all of the latter group have been recruited from lower-level undergraduate courses. Those students in our major working directly with faculty and postdocs on research typically have very positive outcomes: almost all stay with the major, many going on to graduate or excellent teaching programs. I would use funding from the Cottrell Scholars award directly to support undergraduates in my research. I have also been in interesting discussions locally on bringing highly motivated and talented high-school students into my group.

Impact: Most students of my introductory courses will never become scientists. It is not realistic to expect them to take away highly detailed information on, for example, black hole physics. Instead, I believe instilling a basic understanding of the methods and motivations of data-based and fact-driven decision-making is a vital goal, both for their future success in a technical global economy, but more importantly to guide them towards rational, evidence-based consideration in their relationship to the world around them. You have so brief a time to make a lasting impression on students. From my experience, direct and interactive student involvement in the classroom, and an exciting and impactful visual presentation of the fundamental beauty and structure of the Universe are both highly effective ways to engage students. Using the newly upgraded Ritter Planetarium as a backdrop, I plan to combine these approaches directly.

EDUCATIONAL PROPOSAL: *(continued)*

ASSESSMENT PLAN: *Define expected outcomes of your educational plan. How will your evaluation design provide information to improve your project as it develops and progresses? How will you determine whether your stated project objectives are being met according to the proposed timeline?*

Evaluation is perhaps the most easily overlooked part of any education development, but also one of the most important. In addition to the normal numeric and essay-form evaluations the department uses, I offer students many formal and informal opportunities to provide feedback on the methods, materials, and directions of the class. In particular for new or innovative styles, I find this not only allows mid-course correction, but also automatically activates student interest and commitment to the success of the course.

The plan I have outlined will lead in the long term to a substantial fraction of our introductory astronomy labs being transitioned into immersive, student-led exercises making full use of the full-dome digital format. For this to be successful, pervasive, ongoing evaluation is indispensable. I anticipate introducing and evaluating approximately one new lab per semester, in collaboration with the graduate student teaching assistants. To assess effectiveness, I will phase introduction across the eight sections, with student lab-write-ups and short targeted "what you learned" exercises comparing learning outcomes between the traditional and new full-dome replacements (e.g.: "Describe the reasons for retrograde motion of Mars."). Principal evaluation will be made by the graduate student TA's themselves. I will also lead or participate in a substantial fraction of these labs during their introduction. There's no more direct assessment on effectiveness than moving among the students and asking their frank opinion about the exercise (after assuring them their TA, and not myself, will assign the final grade!). I will also make use of University of Toledo's student observers, who are exceptionally well trained at identifying sticking points in students' ability to connect to material. As for our current labs, I anticipate evolving the projects in response to assessment and evaluations, and expect to recruit our graduate student TA's directly into this process.

In the longer term, I plan to widely distribute the new full-dome educational components with complete documentation, script libraries, and relevant software, as well as evaluation material. With the help of our outstanding planetarium staff, I anticipate actively advertising our new interactive astronomy educational modules to universities, communities, and high schools with compatible full-dome systems (numbering in the hundreds, and growing rapidly).

Identify departmental or institutional colleagues who might play a role in this educational endeavor (as mentors, collaborators, etc.) as appropriate and describe the role they will play.

•*Karen Bjorkman* is a close colleague and mentor with whom I collaborate on educational and outreach proposals and activities, and course techniques and development. Starting early this year, Karen began serving as Dean of our College of Natural Sciences and Mathematics. Working with Karen in her new role will greatly increase my ability to effectively deploy novel techniques in the classroom and beyond.
•*Lawrence Anderson-Huang*, former director of the planetarium, is now Chair of Physics & Astronomy. He also greatly values innovative teaching, and is highly supportive of my past and planned efforts in this area. •*Alex Mak* is our Associate Planetarium Director, and is overseeing the installation of our new full-dome Spitz SciDome XD system this summer. He is an avid educator, and a deep source of fresh new ideas. I anticipate working in close collaboration with Alex during the development of full-dome astronomy lab modules. •*Michael Cushing* is a close friend, and an incoming member of the astronomy faculty at UT (2011). Mike will also serve as the new Director of the Ritter Planetarium, and has been a close collaborator on course development for introductory astronomy. His detail-focused approach to outreach and teaching will be incredibly valuable in introducing the planetarium into our core astronomy curriculum.
•*Debra Davis* is Dean of the College for Visual and Performing Arts at UT. She is spearheading the ArtScience Initiative — a new collaboration to bring the arts and the sciences together under one roof for collaborative creation and production of educational planetarium presentations and programs.

LETTER OF SUPPORT: *Include a letter of support from your Departmental Chair, Dean or Provost that endorses your educational proposal and indicates why you are the appropriate faculty member to undertake this project. Insert this letter as Page (9a) of your application.*

LIST OF REFERENCES: *(Annotate the proposal with a list of references from the primary literature. Include all authors and titles. If more space is required, attach a maximum of one additional page. Use Arial 10 or 11 point font.)*

[E1] National Science Board, *Science and Engineering Indicators: 2010*

[E2] National Academy of Sciences, 2010, *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5*

[E3] McGrath, M.B., Brown, J.R., *Visual learning for science and engineering*, Computer Graphics and Applications, IEEE, 2005

[E4] Contemporary Laboratory Experiences in Astronomy, Project CLEA

[E5] Simple Effective Education and Dissemination (SEED) Grants For Astronomy Researchers

[E6] Borne, K, Jacoby, S. et al., *The Revolution in Astronomy Education: Data Science for the Masses*, Astro2010 Decadal Survey Submission, State of Profession, 2010