SABBATICAL LEAVE REQUEST

Prepared October 17, 2008

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> Through this document, I am requesting permission from the LSU
> Board of Supervisors to take one full semester of sabbatical leave
> at full pay during the Spring semester of the year 2010.

1. Purpose and Objectives of the Leave

This sabbatical leave will provide an opportunity for me to become immersed in several specific activities within a research institute at an educational institution that offers a strong tradition of academic excellence and a stimulating research environment, but where I will be uninterrupted by regular classroom teaching duties and the numerous regular committee assignments that have become associated with my daily routine at LSU. My primary objectives are:

1. To learn how to take full advantage of the rapidly expanding capabilities of modern scientific visualization tools to quantitatively analyze the results of my research group's large-scale, high-performance-computer simulations of astrophysical fluid flows.

2. To expand considerably the content, capabilities and utility of the online, graduate-level textbook that I have been developing over the past decade at LSU, incorporating interactive scientific visualization tools and the ability to trace the provenance of numerical simulations that further our understanding of astrophysical systems.

3. To learn how to modify my group's primary numerical simulation algorithms so that they will execute efficiently on future petascale computer architectures whose processing power will be drawn from hardware accelerators that resemble today's graphics processing units (GPUs).

Over the past 30 years (26 of which I have spent at LSU), the research activities of my group have largely been focused on gaining a better understanding of dynamically evolving astrophysical systems, such as: interacting and merging binary stars; neutron stars that form in conjunction with supernova explosions; star formation processes in our Galaxy's interstellar medium; and the gaseous disks of remote galaxies. In most of these studies, large-scale computational fluid dynamic (CFD) techniques have been used to model these astrophysical systems and scientific visualization techniques have been used to analyze the results of each CFD simulation. The lessons that I expect to learn while pursuing each of the objectives itemized above will enable my research group to (a) carry out more ambitious numerical simulations over the coming decade, (b) more thoroughly analyze the numerical results of each simulation, and (c) publish reproducible simulation results in a venue that embraces digital technologies much more fully than do existing archival journals.

2. Outline of Proposed Activities and Work Plan

a.) Background

Throughout my career at LSU, a significant portion of my research activities have been focused on the development of tools

(primarily in the form of efficient numerical algorithms) that will permit astronomers to accurately model the structure, stability, and dynamical evolution of rapidly rotating, (Newtonian) self-gravitating astrophysical fluid systems. Through continuous funding from the astronomy division of the National Science Foundation (NSF) over the first 15 years of my LSU career, much of this work was conducted with the expressed purpose of gaining a better understanding of the processes by which binary star systems form in our Galaxy; see my invited, 2001 review article on this topic [1]. Ten years ago, I requested [2] and was granted permission to spend one semester of sabbatical leave at the California Institute of Technology (Caltech). One stated objective accompanying that 1998 sabbatical leave request was,

> "to better understand the connection between the models of (Newtonian) self-gravitating fluid system that have been constructed ... by students in my group ... and the models of relativistic systems that may be used effectively to decipher the properties of gravitational wave signals that are expected to be detected by LIGO instrumentation."

The Spring 2000 semester that I spent at Caltech while on sabbatical leave was extraordinarily successful. The two research papers [3, 4] that resulted directly from a collaborative research project that was spawned in Kip Thorne's research group that spring proved to be just the tip of the iceburg. Among the collection of referreed publications that I have published since 2000, twelve have been devoted to studies of astrophysical systems that are potential sources of gravitational-wave radiation. The reputation that my group quickly established regarding its ability to produce quantitatively accurate models of such, often quite complex, astrophysical sources has permitted me to maintain a continuous stream of funding from NSF's astronomy program *while switching fields* (from having recognized expertise in "star formation" to having recognized expertise in the area of "gravitational-wave sources"). This also put me in an opportunistic position to collaborate effectively with Luis Lehner in landing a 4-year, multi-million dollar grant from the NSF's Information Technology Research (ITR) program in 2003. Other NSF and NASA grants have followed; over the past 5.5 years, I have either led or been a significant co-investigator on federal awards totaling just over $5.5 million.

My success in crossing from one field into another, and in nurturing successful multi-disciplinary research collaborations has been recognized in several additional ways in the national scientific arena:

- [2002 - 2005] I served a 3-year term on a 12-member, international "program advisory committee," reporting to the Director of the NSF-funded LIGO project;
- [2007 - present] I am serving as a member of the Advisory Committee (MPSAC) to the Assistant Director of NSF's Directorate of Mathematical & Physical Sciences;
- [2007] I became a Fellow of AAAS (American Association for the Advancement of Science).

Presently, I see an opportunity to expand the activities of my research group in yet another productive direction by taking advantage of expertise that has grown rapidly in the Computer Science community over the past decade. In particular, I am confident that my group can take advantage of and build upon significant advances that have been made recently in the arena of scientific visualization. In an effort to move aggressively in this direction, while on sabbatical leave during the Spring 2010 semester I propose to immerse myself in the research activities of the Scientific Computing and Imaging (SCI) Institute at the University of Utah. This is a research institute with an impressive history of leadership in the area of scientific visualization and is where a great deal of the forefront research in this exciting arena is currently taking place.

Figure 1
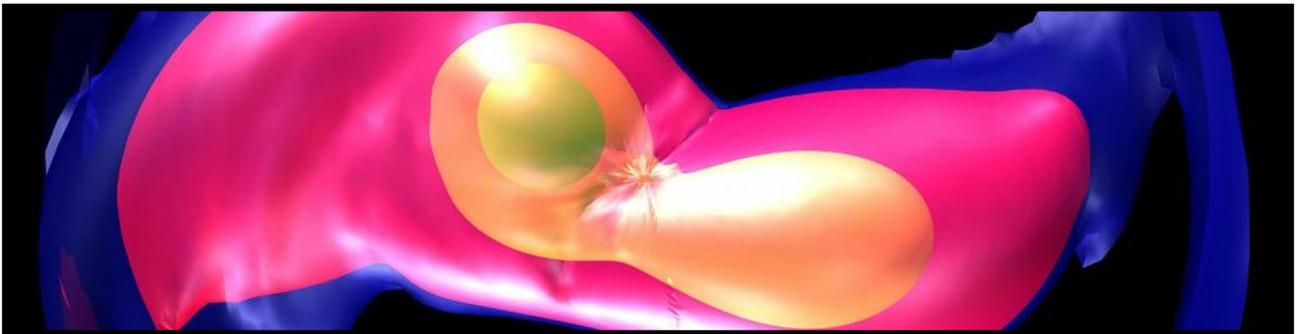
I should perhaps point out that I am not a novice in this arena. As detailed in [5], over the past 25 years my group has invested a considerable amount of effort developing its own visualization tools, borrowing from scattered sources various techniques that have adequately addressed a limited set of our data analysis needs. Although this has not in the past been a focus of our research, two refereed articles have resulted from some of our exploratory work with LSU graduate students in other fields [6,7].

More significantly, as is pointed out in a side-bar entitled "Scientific Visualization as a Vehicle for Outreach" that accompanies [5], some color images (e.g., Figure 1 shown here) and animation sequences illustrating the results of my group's astrophysical fluid simulations have been featured in a variety of national venues. Based on this experience, two years ago I was invited to serve as co-editor of the "Visualization Corner" for the technical magazine entitled, "Computing in Science & Engineering" that is jointly published by the American Institute of Physics and the IEEE Computer Society. It is upon this background that I expect to build significant collaborations and additional expertise while on leave at Utah's SCI Institute.

b.) Objective #1

Over the past decade, the computer science community has significantly accelerated its research efforts in the area of scientific visualization. As a result of this activity, a broad array of visualization tools has been developed and is being supported via an active "open source" community of developers and programmers. In my judgment, the time is ripe for my group to begin to take full advantage of the computer science community's new, extensive "visualization toolkit [vtk]." Objective #1 has grown out of this strategic realization.

The researcher with whom I am sharing co-editor responsibilities for the CiSE Visualization Corner is Cláudio Silva, Associate Professor of Computer Science at the University of Utah and Associate Director of the SCI Institute. Cláudio's group has developed a flexible graphical-user-iterface, called "VisTrails," that allows researchers throughout the computational sciences to effectively utilize the computer science community's open-source "vtk" modules. This past summer (2008) I invested approximately six weeks of research time — including spending one week in Utah — learning how to use VisTrails. My progress over this short period of time is chronicled on the webpage referenced in [8]. It is this recent experience that has convinced me that an extended period of time spent in collaboration with researchers at the SCI Institute will significantly benefit the computational simulation efforts of my research group in the future.

c.) Objective #2

Objective #2 is closely related to the first. Since the dawn of the era of web browsers, I have been extremely frustrated by the slow pace at which the scientific community has been willing to embrace digital technologies in support of archival journal and textbook publications. Since 1994 I have been steadily developing and adding content to an on-line, graduate-level textbook entitled, "The Structure, Stability, and Dynamics of Self-Gravitating Systems" [9]. As it presently stands, this on-line text is structured within some fairly static constraints that were imposed by the earliest web browsers. The growing popularity and versatility of "wikis" provides an opportunity to restructure this on-line textbook into a new, more versatile framework. Most excitingly, Cláudio Silva's research group has recently tied VisTrails into a wiki development environment so that interactive, three-dimensional visualization aids can be seamlessly integrated with textbook or journal article content and even the *provenance* of simulations and data analysis studies can be automatically tracked. This new web-based framework offers an excellent opportunity to significantly expand the content and value of scientific publications, especially publications that are intended to report on the results of large-scale numerical simulations. The requested leave will provide me with an opportunity to lead the computational science community into this new arena.

d.) Objective #3

As alluded to above in my outline of objective #3, developments in the visualization community are simultaneously touching the research efforts of my group in a third important way. The GPUs that reside in virtually all laptop and desktop PCs — primarily intended to support the execution of computationally demanding video games — are extraordinarily fast compute engines which, for certain classes of problems, can significantly outperform the PC's general-purpose, central processing unit. Over the past few years, the manufacturers of GPUs have begun to make it possible for researchers outside of the video-game industry to write programs that are tuned to a GPU's capabilities. In particular, NVIDIA has developed a compiler language called "CUDA" for use in writing algorithms that directly execute on NVIDIA's GPU hardware. Recognizing the important role that researchers at the SCI Institute have historically played in furthering research in the graphics and scientific visualization arenas, NVIDIA has recently named SCI as a "CUDA Center of Excellence." Through this new Center, researchers and visitors at SCI have a golden opportunity to explore this area of frontier research. While on sabbatical leave in Utah, I plan to explore to what extend the most computationally demanding segments of my group's CFD simulation algorithms can be migrated to run efficiently on GPUs.

3. Location of Leave

My plans are to base my sabbatical leave activities in the Scientific Computing and Imaging (SCI) Institute on the campus of the University of Utah in Salt Lake City, Utah. In concert with my planned research activities, described above, I will have two primary academic contacts within SCI:

- Cláudio Silva, Associate Director of the SCI Institute, and Associate Professor of Computer Science, University of Utah;
- Christopher Johnson, Director of the SCI Institute, Distinguished Professor of Computer Science, and Adjunct Professor of Physics, University of Utah.

As documented by the accompanying letter from Professors Silva and Johnson, I have been invited to participate in the broad activities of SCI in support of my efforts to adapt and extend scientific visualization tools to the analysis, presentation, and archival needs of my research group and to explore the capabilities of future petascale computing hardware. As the letter of invitation indicates, I have been assured that office space will be provided at the SCI Institute on the campus of the University of Utah from which my research activities may comfortably be based.

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4. Alternate Plans

The research and learning objectives outlined in §§1 and 2, above, reflect natural components of a very broad, computational science research agenda that I have been and will continue to be pursuing over a period of many years. Groundwork has already been laid in all of the identified areas, and I fully expect work in these areas to continue, after my return to LSU following the sabbatical leave. While I anticipate being able to make significant progress toward achieving all three of the itemized objectives while on sabbatical, my work plan is flexible. For example, should the collaborative efforts at SCI prove to be particularly conducive toward making accelerated progress in one of the identified areas, I plan to take advantage of that opportunity and focus most of my time and effort in that area while in residence at SCI. Given the invigorating research environment at SCI, however, it is much more likely that I will find an overabundance of opportunities and will have to be selective in the choice of activities with which I become involved. With this in mind, I expect to give preference to the first and second objectives outlined above and, if necessary, pursue the third objective upon my return to LSU where some exploratory investigations into the use of GPUs are also being made within the CCT.

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5. Travel

During the Spring 2010 semester, I expect to spend most of my time in Salt Lake City, Utah, working in residence at the SCI Institute on the campus of the University of Utah. Because I do not expect my family to be traveling with me to Utah, I almost certainly will make several return visits to Baton Rouge during the January-May time period. However, my focus will be on taking advantage of the collaborative opportunities that will be available to me in Utah, so my return visits to Baton Rouge will not be lengthy.

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6. Compensation

I do not expect to receive any compensation from sources other than the LSU System while on leave.

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7. Courses for Credit or Audit

I do not expect to take any courses for credit or audit while on sabbatical leave at the SCI Institute in Utah.

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8. Enhancement as a Scholar and Benefit to the University

It has been clear to me for many years that the best way in which I can help raise the quality and reputation of LSU is to continue to pursue challenging research projects, to immerse LSU students in those projects, and to demand of myself and my students the highest levels of achievement. In addition, I must make a concerted effort to broadcast our discoveries and achievements to the broader research community. My planned activities while on sabbatical leave are all designed to further these practical objectives. I see an opportunity to expand the activities of my research group in new, productive directions by taking advantage of expertise in scientific visualization that has grown rapidly in the Computer Science community over the past decade. Through collaborative interactions with researchers who are visiting the SCI Institute, as well as with those who are resident at the Insitute, I will have the opportunity to advertise the success stories that have been and are continuing to emerge at LSU. Finally, I am confident that the knowledge that I gain while on sabbatical leave at the University of Utah will enhance the content and quality of material that I am able to present in the classroom to both undergraduate and graduate students upon my return to LSU.

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9. Signature

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Joel E. Tohline

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10. References

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UNIVERSITY
OF UTAH

17 October 2008

Professor Joel E. Tohline
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Dear Joel,

We invite you to spend your spring 2010 sabbatical leave at the Scientific Computing and Imaging (SCI) Institute at the University of Utah. SCI provides a stimulating environment for researchers, like you, who are interested in exploring the frontiers of scientific visualization & imaging and in applying innovative visualization & imaging techniques to challenging problems that face the broad computational sciences community. Your particular interest in adapting and extending scientific visualization tools such as VisTrails to the analysis, presentation, and archival needs of your astrophysics research group overlaps extremely well with ongoing research activities here at SCI. You also will find that, as an NVIDIA-sponsored "CUDA Center of Excellence," SCI will be an excellent base from which you can explore the capabilities of future, petascale computing hardware.

To accommodate your sabbatical visit, we will provide you with an office within the new Warnock Engineering Building on the campus of the University of Utah during the months of January-May, 2010. Your office will be in a location that will promote smooth and regular interactions with Claudio Silva's group and with researchers in our CUDA Center of Excellence; the office will also include a network-connected, linux desktop computer for your use. Our administrative staff will assist you in your efforts to locate suitable housing for your extended visit, and will be available throughout your stay to help you with routine tasks that naturally accompany collaborative research activities.

We are excited about the fruitful interdisciplinary interactions that will surely unfold during your extended visit to SCI. We very much look forward to your arrival in early 2010.

Sincerely,

Chris Johnson
Director,
Scientific Computing and Imaging Institute
Distinguished Professor,
School of Computing

Claudio Silva
Associate Director,
Scientific Computing and Imaging Institute
Associate Professor,
School of Computing