

## **Institute for Gravitation and the Cosmos**

### ***ECoS Review Document, March 2010***

The Institute for Gravitation and the Cosmos is a multidisciplinary facility for Penn State researchers, dedicated to the study of the most fundamental structure and constituents of the Universe. The primary mission of the Institute is to promote excellence in collaborative research leading to a deeper understanding of the physical cosmos we inhabit, and to create new disciplines at this frontier of Science.

This document contains information that was requested for the ECOS review of the Institute as well as its three Centers: The Center for Fundamental Theory, The Center for Gravitational Wave Physics, and The Center for Particle Astrophysics.

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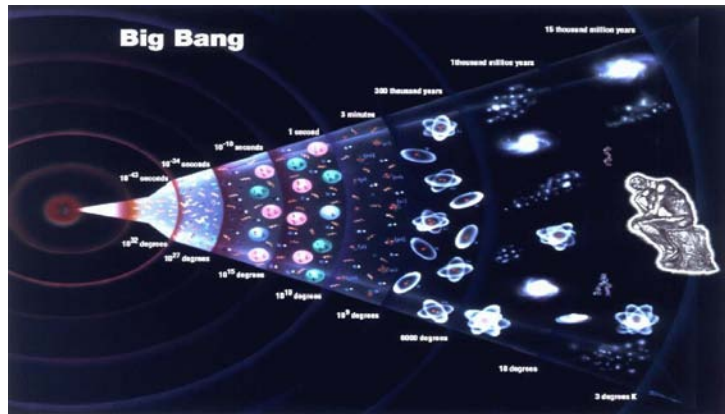
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# 1. Institute for Gravitation and the Cosmos

*From 1993 to 2007, (first the Center and then) the Institute for Gravitational Physics and Geometry at Penn State played a leading role, worldwide, at the interface of physics, mathematics and astronomy. The Institute for Gravitation and the Cosmos, inaugurated in August 2007, builds on these strong foundations by making use of the unique strengths in particle astrophysics that Penn State now enjoys. From quantum cosmology to new observational windows, we seek greater understanding of the physical universe and its extreme events.*

## Goals and Structure

The Institute for Gravitation and the Cosmos (IGC) is dedicated to fostering excellence in education and research in cosmology, general relativity, gravitational wave astronomy, particle astrophysics, quantum gravity and string theory, focusing on the highest energy phenomena and fundamental issues in the Science of the Cosmos. At Penn State it has synergistic interactions with the Schreyer Honors College, the College of Information Science and Technology, four departments in the Eberly College of Science and one in the College of Liberal Arts.

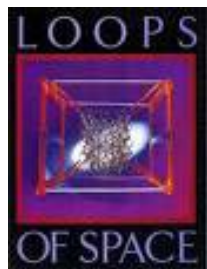


Abhay Ashtekar, holder of the Eberly Chair in Physics serves as the IGC Director and Paul Sommers, Professor of Physics, as the Associate Director. The Institute integrates the theoretical and observational research carried out in its three centers: the *Center for Fundamental Theory*, headed by Murat Gunaydin, Professor of Physics; the *Center for Gravitational Wave Physics*, by Benjamin Owen, Associate Professor of Physics; and the *Center for Particle Astrophysics* by Peter Mészáros, holder of the Eberly Chair of Astronomy and Astrophysics and the Chief Theorist for the Swift GRBE mission.

Activities of the Institute are overseen by an Advisory Board, Chaired by Daniel Larson, Verne M. Willaman Dean, Penn State Eberly College of Science. It has two components. The Internal Advisory Board provides direction to the Institute leadership on all matters related to governance and operation while the External Advisory Board provides advice on scientific directions and development strategies. The Internal Board Members are Jayanth Banavar, Distinguished Professor and George A. and Margaret M. Downsbrough Department Head of Physics; Alberto Bressan, holder of the Eberly Chair in Mathematics; and Larry Ramsey, Professor and Department Head, Astronomy and Astrophysics. The External Board members are Edward Frymoyer, Physicist, Entrepreneur and Alumni Fellow; Henryk Frystacki, Vice President, Siemens; James Hartle, Emeritus Professor of Physics, University of California at Santa Barbara; Christopher Liedel, Senior Vice President and Chief Financial Officer, National Geographic; Roger Penrose, Rouse Ball Professor of Mathematics, Emeritus, Oxford University and Pentz Visiting Professor of Physics and Mathematics, Penn State; Duane Valz, Vice President and Associate General Counsel at Yahoo!; and Clifford Will, James S. McDonnell Professor of Physics, Washington University.

## Centers

*Center for Fundamental Theory:* Thanks in large part to Einstein's revolutionary ideas, our view of the cosmos changed dramatically in the 20th century. The primary goal of this Center is to develop even better theories to take us beyond Einstein. The focus is on cosmology, quantum gravity and string theory, particularly on fundamental questions and on confronting theory with the spectacular observations that are being made



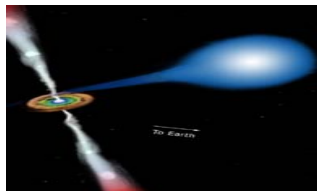
in the realm of cosmology. Loop quantum gravity, a leading approach to the unification of general relativity and quantum physics was developed in large part at Penn State. Now the Center also enjoys strength in string theory and cosmology. Penn State is the *only* US institution in which these three fundamental areas are being developed. Thanks to the new synergy, Penn State researchers have already begun to change the 20th century paradigm on such basic issues as the nature of the big bang and of black holes. Because of its exceptional combination of strengths and the resulting cross fertilization of ideas, the Center is well placed to make deep and lasting contributions.

*Center for Gravitational Wave Physics:* Science runs of LIGO, the ground based gravitational wave observatory, have made gravitational wave astronomy a reality. An

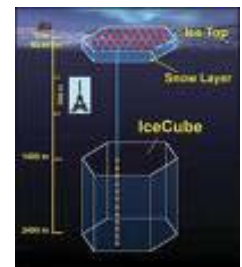


observatory in space, LISA, is among the leading contenders to become a major space science project of NASA and the European Space Agency, ESA. These observations have the potential to transform astronomy and astrophysics in a way not seen since Galileo first turned a telescope to the Heavens. The Center for Gravitational Wave Physics is dedicated to realizing that potential by linking general relativity, astrophysics and gravitational wave observations in the pursuit of deeper understanding of strong field gravity in the most violent astrophysical events. Researchers at the Center combine ideas and tools from diverse disciplines ranging from general relativity to computational science and nuclear physics to develop gravitational wave observations as the newest branch of astronomy.

*Center for Particle Astrophysics:* Almost everything we know about the cosmos has come to us in the form of electromagnetic waves. Particle Astrophysics provides brand new



windows to the cosmos. Penn State faculty are prominent participants in three novel initiatives: the Pierre Auger Cosmic Ray Observatory located in Argentina, the IceCube Neutrino Observatory at the south pole and the Swift Gamma-Ray Burst Explorer satellite. Auger has already started making major discoveries and IceCube is in an advanced stage of construction. Penn State is the *only* U.S. institution participating in both of these major ground-based projects. Gamma ray bursts are especially violent supernova explosions which spew out, in a few blinding seconds, as much energy as a thousand suns do in their entire life times. Swift, with its mission control center at Penn State, has been providing the best observations of these explosions, making Penn State a dominant player in this exciting area. These bursts and other energetic cosmic events can also be studied using cosmic rays, neutrinos and gravitational waves. Thus, there is now exceptional synergy that places Penn State in a unique position to conduct a bold, multi-pronged approach to high energy astrophysics. The potential for major discoveries is enormous.

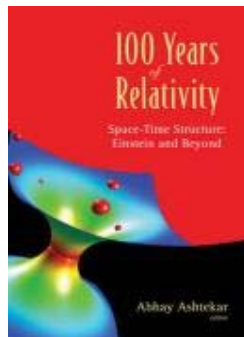
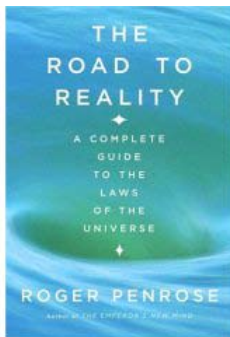


## Education and Outreach

Faculty in the Institute for Gravitational Physics and Geometry and the IGC have trained and mentored a large number of undergraduate and graduate students and well over a hundred and thirty post-docs in emerging disciplines, with special attention to women and under-represented minorities. More than half of them hold faculty positions worldwide and others are research scientists in national facilities or industry. Our post-docs and students have received national and international honors for their research almost every year (see, e.g., News page <http://www.gravity.psu.edu/news/index.shtml> on our web-site). A number of students from other institutions, worldwide, have visited us each year using funds from their home institutions/countries to get advanced training in areas of research in which we specialize.

The Institute faculty has written several advanced monographs which have been used in general relativity, quantum gravity and relativistic astrophysics courses worldwide. They have developed and taught advanced courses at Penn State in emerging, interdisciplinary fields. The Institute hosts webinars in which a number of research groups from the Americas, Europe and Asia participate on a regular basis. The audio and visual files of our conferences, workshops and weekly seminars are also available on the Web and are regularly used by research students and post-docs internationally.

The Institute faculty have also been involved in significant outreach efforts, communicating the excitement of their frontier research to other scientists and to the general public. They have



given plenary talks at the National Science Teachers conferences, initiated the *Frontiers of Science Lecture Series* at Penn State, conducted workshops for high school science teachers on *Extreme Particle Astrophysics*, and given a large number of public lectures worldwide. Their research has been reported in the popular press, including *the New York Times*, *Nature*, *Science*,

*and The Economist*, *Scientific American*, as well as leading European, Asian and South American publications. This work has featured prominently in radio shows and television documentaries on frontiers of science. It has also entered the mainstream media where it provided the basis for one episode in the *Big Bang Theory*, a weekly entertainment show broadcast by CBS, and for several science fiction novels. Two of the recent semi-popular books of the Institute faculty were selections of major book clubs. Further details, particularly on more recent contributions, can be found under activities of the three Centers as well as the Institute outreach web-page, <http://www.gravity.psu.edu/outreach/index.shtml>.

## 2. Governance Document

The Pennsylvania State University has established the Institute for Gravitation and the Cosmos. It builds upon the success of the prior Institute for Gravitational Physics and Geometry. The primary mission of the Institute is to promote excellence in research by facilitating synergy between various areas it encompasses. It will foster collaborative research and activities leading to a deeper understanding of the physical cosmos we inhabit, and hopefully to the creation of new recognized disciplines. The Institute for Gravitation and the Cosmos encompasses three interrelated centers:

Center for Fundamental Theory

Center for Gravitational Wave Physics

Center for Particle Astrophysics

With its emphasis on interdisciplinary studies, the IGC is more than the sum of these centers. It stimulates collaborative research between centers as well as within each center.

**Internal Advisory Board:** This board advises and provides direction to the Institute leadership on all matters relating to its governance and operation. The dean of the Eberly College of Science is the Chair of the Internal Advisory Board. He is responsible for changes in its membership, in consultation with the Institute director. This board appoints the associate director and the center directors upon recommendation by the Institute director. The Institute director will consult with faculty members before making the recommendation. The Internal Advisory Board also approves nominations for new faculty members and renewals of current faculty. These nominations are made by the Institute members through the Institute director and associate director.

**External Advisory Board:** The dean of the Eberly College of Science also chairs the External Advisory Board. He is responsible for changes in its membership, in consultation with the Institute director. The External Advisory Board consults on scientific matters and also on development strategies. Its membership would include distinguished scientists in fields representing all of the centers as well as community leaders who are able to provide advice on development strategies.

**Director:** Working with members, the director will create and articulate a shared scientific vision for the Institute. He also has the primary responsibility for the Institute administration.

The director holds a standing position and will undergo reviews as per PSU policies. Institute resources are apportioned by the director in consultation with the associate director, the center directors, and the Internal Advisory Board, as needed. The director is responsible for an annual report to the Internal Advisory Board summarizing the activities of the Institute. The annual report will be open to all faculty members.

**Associate Director:** The associate director participates in all major administrative decisions. The director and associate director are free to divide among themselves the charge of day-to-day governance issues. The term of appointment can be up to 3 years and may be renewed by the Internal Advisory Board in consultation with the director.

**Center Directors:** The center directors are responsible for administering their separate centers. They represent their centers, acting in consultation with their faculty members as well as the Institute director and associate director. Each center director provides information on the activities of the center for the annual report by the Institute director. Appointment durations can be up to 3 years and may be renewed by the Internal Advisory Board in consultation with the Institute director.

**Faculty members:** Penn State faculty members may be appointed to membership in the Institute by the Internal Advisory Board upon nomination by the Institute director. Appointments are made for up to 3 years at a time but may be renewed by the same procedure. Each faculty member of the Institute will also be a member of at least one of its centers. An Institute member who is a member of more than one center is expected to identify a primary affiliation with one of them.

Membership in the Institute and its centers normally extends also to research associates, postdoctoral scholars, and research students who are working with a faculty member on topics within the scope of the Institute. These members participate in Institute activities, benefit from Institute-sponsored programs and meetings, and are listed in the Institute directory. The Institute director and associate director are responsible for maintaining the full list of current members through consultation with the faculty members.

*This document provides governance guidelines for the initial phase of the IGC. Since establishment of the IGC is rather special in many respects, this document may be revised and updated on an ongoing basis at the discretion of the Internal Advisory Board.*

**Approved by the Internal Advisory Board, January 30th 2008.**

### 3. Facts, Stats and Activities

- **Brief History:** A *Center for Gravitational Physics and Geometry* was created in the Eberly College in 1993 when Abhay Ashtekar assumed the Eberly Chair in Physics at Penn State. In 2001, some of the members of the Center wrote an NSF proposal to create a *Physics Frontier Center in Gravitational Wave Physics*. The proposal was successful. To take advantage of synergy, a new *Institute for Gravitational Physics and Geometry* was created with two centers, one focusing on fundamental theory and the other on the gravitational wave science. A few years later, a third core group in the closely related area of Particle Astrophysics came into existence, thanks to some astute faculty appointments in Physics and Astronomy and Astrophysics departments. Therefore the Institute was enlarged in August 2007 to include Particle Astrophysics and, to appropriately reflect its new, expanded mission, its name was changed to the *Institute for Gravitation and the Cosmos*. As explained in **part 1** of this document, the Institute now has three Centers and covers both theoretical and observational research on fundamental structure and constituents of our universe.
- **Composition:** Currently the Institute has 30 faculty members. 25 come from departments of Astronomy and Astrophysics, Mathematics and Physics in the Eberly College and the department of Philosophy in the College of Liberal Arts. The remaining five are colleagues from other institutions who have had on-going, close research collaborations with the PSU faculty. Our non-faculty ranks include 20 post-docs, 45 Ph.D. students and 6 undergraduates, mostly from the Schreyer Honors College, who are contributing to our research projects. Since the Institute was founded two and a half years ago, we have trained 24 additional post-docs who have left Penn State and moved on to the next stage in their careers. During this period 12 students completed their Ph.D. and went on to post-doctoral positions. Five staff members provide the administrative and technical support at the Institute, four of whom are supported by research grants. Further details, including names of faculty can be found in the reports of individual centers (**parts 5-7**) and a complete list of all members is available on our web-page <http://www.gravity.psu.edu/people/index.php>
- **Diversity and Climate:** Our current faculty includes three members from under-represented minorities and four females. Among our current post-docs and students, 12 are females



and/or from under-represented minority groups. Recent departures include additional 7 members from this group. Several of them have received high honors. Professor Stephon Alexander received an NSF career award; Professor Pablo Laguna was elected to the Mexican Academy of Science; Research carried out by Professor Deirdre Shoemaker and Dr. Kelley Holley-Bockelmann on 'rogue black holes' was the subject of special coverage in National Geographic, Science, MSNBC and news services in Asia and Europe; graduate students Andrew Knapp, Joseph Ochoa and Victor Taveras received minority graduate fellowships from the Alfred P. Sloan Foundation; Victor Taveras received the James B. Hartle prize for his presentation at the 18<sup>th</sup> International conference on general relativity and gravitation held at Sydney and was recently declared the winner of the first Bergmann-Wheeler prize of the International Society on General Relativity and Gravitation for the best thesis in quantum gravity in the last three years; Gabriel Caceres received an NSF graduate research Fellowship; and Meagan Lang was awarded the Gerard A. Hauser Award in the 2009 Penn State Undergraduate Research Symposium. A more complete list of honors can be found on our News page, <http://www.gravity.psu.edu/news/index.shtml>.

Institute faculty (Professors Laguna and Shoemaker) have served on the Eberly College Climate Committee. Institute staff (Ms Neshteruk and Smith) have served on the Eberly College Staff Advisory Committee. We have a large number of international visitors (from more than 15 countries in 2009 alone) who contribute significantly to crosscultural understanding. To enhance interaction between students and post-docs from different Centers within the Institute, we initiated a lunch program in which four junior researchers, from two different Centers, meet for lunch once a week. This has fostered not only scientific interaction across disciplines but also contributed to warmth and friendship. Our degree of success in creating a good climate for everyone – staff, students, post-docs and faculty – can be measured by the fact that our staff members have often said that the IGC is the best place they have worked in.

- **External Funding:** The only major external funding that any of the Centers in the Institute has had is the NSF Physics Frontier Center grant from 2001 to 2008. During this period, the Center received a total of \$5,884,145 from NSF. The Institute as a whole as well as its sub-groups have received several smaller grants for conferences and workshops. These were typically in the range of \$5,000 to \$35,000.

Current research in the Institute is supported by grants from the National Science Foundation, Department of Energy, National Aeronautics and Space Agency and other organizations such as the Alfred P. Sloan Foundation, Jet Propulsion Lab, Smithsonian Astronomical Observatory, and FQxi (Fundamental Questions). Large federal agencies tend to be conservative, almost

always supporting research in established areas rather than programs that seek to create new disciplines at the interface of existing ones. Therefore, we are pursuing our goals primarily through grants that have been awarded either to individual researchers or to a small group of researchers who focus on an area that currently enjoys federal funding. This is far from an ideal setting. Nonetheless, using flexibility in federal grants, we have succeeded in meeting some of the goals of the Institute as a whole. For the period 2007-10, the external funding (rounded off to the nearest thousand) to the Institute members amounted to a total of \$14,002,000. This was divided as follows:

Center for Fundamental Theory:                    \$3, 317, 000

Center for Gravitational Wave Physics:        \$4, 001, 000

Center for Particle Astrophysics:                \$6, 684, 000

This information was provided by the Departments of Physics and Astronomy and Astrophysics and the NSF web-site (for mathematicians).

- **Internal Support/Resources:** Just before its inauguration in 2007, to help launch the Institute, we received a one-time funding of \$36,000/year for three years, a third of which came from the Physics Department (Downsbrough funds), a third from the ECOS Dean's Office, and a third from the Office of the Senior Vice President for Research. We are most grateful for this support. It helped us organize three workshops to brainstorm, with international leaders, on the scope the Institute can aspire to have and to host an international inaugural conference in August 2007. Since then, we have held nine conferences, workshops and focus sessions. This activity has had a significant scientific impact and visibly raised the Penn State profile in this frontier area of science. This funding will run out in the summer of 2010.

Upon the creation of the Institute, Abhay Ashtekar agreed to use his 'retention funds' entirely for the Institute (rather than for his personal research). This has provided a steady operating budget for the Institute. It also pays for our seminars and visitors and enables us to supplement post-doc salaries when they teach advanced courses. The total amount of this support is approximately \$85,000 for 2009-10. From 2010-11, this will be the primary source of support for our workshops and focus sessions as well. Therefore our activity on this front will diminish until we find additional resources, as discussed in **part 4** of this document.

As a part of Ashtekar's initial appointment package, the Eberly College also provides the salary of an administrative assistant (currently Ms Randi Neshteruk) who oversees all the day-to-day operations of the Institute, manages the visitor program, handles visas of post-

docs and visitors, administers gravity post-doc appointments and supervises other Institute staff supported by external funds.

The Institute does not have its own space. Faculty members are housed by their primary departments and therefore spread over 5 buildings. However, in 2006, the Eberly College and the Physics Department contributed generously to renovate a suite of offices in Whitmore where the gravitational physics part of the Institute is now housed. This suite provides the Institute with its primary Seminar and Conference rooms.

The Institute director has full teaching relief, although he has voluntarily taught regular and/or individual study courses every semester. The Associate director (who is also the current co-Spokesperson of the large, international Pierre Auger collaboration) receives one semester teaching relief each year.

- **Activities:** The Institute hosts three weekly seminars: One for each Center. It also hosts a bi-weekly International Loop Quantum Gravity Webinar in which 10-15 groups from the Americas, Europe and Asia participate. Details on seminars can be found at our Events web-page, <http://igc.psu.edu/events/index.shtml>. Since its creation two and a half years ago, the Institute has organized two international conferences and eight workshops and focus sessions through its Centers. These are listed in the Center reports (**parts 5-7** of this document). The proceedings of the two conferences and most of the workshops are available on our Workshops web-page: <http://www.gravity.psu.edu/events/workshops.shtml>. They are routinely used by researchers all over the world.

The Institute also hosts visitors from other institutions worldwide. They range from research students who typically spend several months with us with support from their own institutions or countries to distinguished, senior scientists who come as seminar or colloquium speakers or as participants in our workshops and spend several additional days at the Institute. During the two and half years since the inaugural conference we have had over 100 visitors. The list with dates of visits is available on our Visitors web-page:

<http://www.gravity.psu.edu/visitors/2009-schedule.shtml>

Several Institute faculty lead their disciplines internationally. Paul Sommers is the co-Spokesperson for the Pierre Auger Cosmic Ray Observatory. Peter Meszaros is the Chief Theorist of the SWIFT gamma ray observatory. Derek Fox is the designated Science lead in the proposed JANUS mission. Neil Brandt Chairs the Science Panel on Black Hole Surveys of the International X-ray Observatory. Abhay Ashtekar is the President of the International Society on General Relativity and Gravitation.

## 4. Vision and the Necessary Resources

- **Goals for the near future:** The Institute has already created a few disciplines and contributed significantly to the establishment and growth of several new research areas that lie at the interface of different disciplines. These include Loop Quantum Gravity; Gravitational Wave Physics and Astronomy; The Science of Gamma Ray Bursts, and Exploration of Extreme Astrophysics through Ultra-Relativistic Cosmic Rays.

But the Institute and Center directors believe that it has the potential to accomplish much more. The physical universe is governed by four fundamental forces: gravitational, electromagnetic, weak and strong. Each provides a window on the universe: gravitational waves, gamma rays, neutrinos and cosmic rays. The IGC is unique in its potential to answer the big open questions on the nature of our cosmos by observing it through *all four windows*, shaping the future of each of these missions using inputs from the other three, synthesizing the knowledge from all angles and providing novel interpretations that can easily elude those who look at the universe piecemeal.

Specifically, Penn State is a nexus for novel observatories that are starting to view the high energy universe using messengers that are not part of the electromagnetic spectrum. In particular, the IGC members play prominent roles in LIGO gravitational wave detectors, the IceCube Neutrino Observatory at the South Pole, and the Pierre Auger Cosmic Ray Observatory. These new eyes on the universe are expected to enhance our understanding of powerful bursts that produce short episodes of energetic radiation. Each of these observatories has the capability for detecting very energetic transients on their own. But by pooling information from multiple messengers, it is possible to detect events of much lower energy flux at Earth. It is likely that the first non-electromagnetic detections of astrophysical bursts will result from *sharing information* this way so as to recognize small signals occurring simultaneously at two or more observatories. The IGC plans to exploit our unique advantage of being participants in all these novel observatories to produce a combined search for astrophysical bursts. Included with this combined search will be the data stream from the Swift gamma-ray satellite which has the greatest sensitivity to bursts of gamma rays and whose mission operation center is located at Penn State. We also hope to acquire resources to modify an optical telescope for wide-field follow-up searches to enable rapid studies of these astrophysical bursts with conventional astronomy. The multi-messenger burst alert system will provide real-time notification to the astronomy community when they occur, but it is important to have a telescope whose primary mission is to act on such alerts.

We are starting to develop this system within the IGC. However, to implement it, we will require at least one dedicated post-doc working full time on this project. For now, it will be an interdisciplinary effort that does not clearly fall in the domain of any one program at NSF or DOE. However, as we gain experience with the various sub-threshold triggers and their combinations, it should become clear that this combined sensitivity adds significant value to these major observatories. We believe that it will then be possible to attract significant external funding. By acting now, the IGC will have an opportunity to lead the multi-messenger search for high energy transient astrophysical phenomena. This goal will require an investment of about \$100,000 to cover the post-doc salary and to purchase the necessary computer hardware and software. These one-time, additional resources will have a deep impact on the international community and experts in several different areas will develop a deep appreciation for the new science that can emerge from the unique strengths at the IGC. We very much hope that these rather modest resources can be made available through the Eberly College and the Office of the Senior Vice President for Research.

- **Long Term Goals:** As is clear from our discussion of external funding in **part 3**, individual researchers and small groups within the IGC have adequate funding to pursue their immediate goals. But the IGC has far greater potential. If adequate resources become available to pursue much more ambitious interdisciplinary goals it could enhance its intellectual impact and visibility by an order of magnitude. Federal agencies have been approached both by us and by Institutes elsewhere for block grants that are needed to produce this non-linear impact. Unfortunately such grants do not fall in the realm of their current priorities. Therefore, to fulfill IGC's promise, we need to pursue other avenues. We discussed our needs and goals with our External Advisory Board a year and half ago and have continued to actively pursue the leads we were given. For example, with the help of Chris Liedel, a member of our External Advisory Board, Ashtekar participated in a meeting of physicists and philanthropists last spring and we have invited some of these philanthropists to the IGC to continue the dialogue. Our long-term goals could be met with endowments at two levels, each of which provides diverse naming opportunities for philanthropists.

## I. Endowments for Eminence

- **Naming Opportunity: Institute as a whole (\$8M)**  
Xxxx Institute for Gravitation and the Cosmos
- **Naming Opportunity: Directorship (\$2M)**  
Xxxx Director of the Institute for Gravitation and the Cosmos

These discretionary funds will enable us to:

\*Facilitate inter-disciplinary faculty hires by providing partial salary support for the initial 2-3 year period.

\*Buy in to major observational missions, which in turn can greatly help with recruitment and retention of outstanding faculty

\*Create competitive start-up packages for observational faculty with a seed contribution to a total package of \$500K - \$1M each

\*Provide funds for the initial exploratory research and feasibility studies that are often necessary to attract major grants

\*Help with retention packages for outstanding IGC faculty, e.g., with one time support for equipment, post-docs, etc.

## II. Endowments for Enhancement

- **A Named Visitor Program (\$4M generating \$200K/year)**
  - 4-5 one semester visitors, or 8-10 shorter term visitors to enhance inter-disciplinary research as well as new disciplines. Smaller endowment could provide named visiting appointments for visitors.
- **Six Named Post-doctoral Fellowships (\$400K each, \$20K/year)**
  - will supplement base salaries paid from grants and provide fund for travel and miscellaneous research expenses to attract the very best post-docs to Penn State.
- **Three Named Workshop Series (\$400K each, \$20K/year)**
  - will enable us to: move focused areas forward in a decisive way; bring together areas that have remained separate; and create new disciplines.
- **Named Student Fellowships (\$100K each, \$5k/year)**
  - will provide funds for conference travel and miscellaneous research expenses as an incentive to attract the best students to Penn State. Currently we have two; we need four more.
- **A Named Colloquium Series (\$200K, 10K/year)**
  - will enable us to invite 6 distinguished speakers a year to give interdisciplinary colloquia. (These will be in addition to the more specialized seminars for which we have funding.)

- **A Named Distinguished Lecture a year (\$150K, 7.5K/year)**  
-- will enable us to invite a world leader to give a public lecture and a seminar every year. This offers an excellent outreach opportunity.

To reach these goals, it would help us tremendously if the IGC could be placed in the **Big Ideas** list in the current Penn State Development Campaign. With the help of the Eberly College development office we have prepared several brochures to facilitate this task and would be happy to make a presentation to the appropriate body in the Campaign to make our case.

## 5. Center for Fundamental Theory

**Year established:** August 2007

**URL:** <http://cft.igc.psu.edu>

**Center Director:** Murat Gunaydin

### **Short statement of Center vision or goals: (suitable for posting on ECoS website)**

The primary goal of the Center for Fundamental Theory is to foster research and education of the highest quality in the fields of cosmology, quantum gravity and string theory and related areas of astrophysics and astronomy, mathematical physics and geometry.

### **Currently Active Faculty participants: (name & department)**

Currently, CFT has 8 resident and 4 extramural, visiting faculty.

- Abhay Ashtekar, Martin Bojowald, Murat Gunaydin, Radu Roiban (Physics)
- Roger Penrose (Physics, Mathematics, & Oxford University)
- Emily Grosholz (Philosophy)
- Nigel Higson, Victor Nistor, Adrian Ocneanu, Ping Xu (Mathematics)
- Stephon Alexander (Haverford), Alejandro Corichi (UNAM, Mexico), Jerzy Lewandowski (Warsaw, Poland)

### **How many students and post docs are directly affiliated with the center?**

There are 8 post-doctoral scholars and 19 graduate students affiliated with CFT.

### **What is the administrative structure of the center?**

The Center for Fundamental Theory is one of three centers in the Institute for Gravitation and the Cosmos (IGC). The administrative structure of the IGC is explained in **part 2** of this document.

**Is the center directly supported by an external grant?** If so, please identify the grant (or pending grant), funding period, and amount of support for the operation and activities of the center.



As explained in **part 3** of this document, research activities of CFT are supported by the individual (and small-team) grants.

**Does the center currently receive any direct internal support (from the department, college or university)?** If so, please list sources and amounts by year for the past three years, how the funds were used, and any funds committed for future years.

CFT does not receive any direct internal support from the department, college or university. However, as explained in **part 3** of this document, it receives support through the IGC for its seminars, focus sessions, workshops, conferences and visitors.

**Does the center anticipate needing additional internal funds?**

Yes. As explained in **part 3**, at its inception, the IGC received a one-time funding of \$36,000/year for three years. These resources have been vital for our workshops and focus sessions. From 2010-2011 onward, we will only have access to funds from the IGC operating budget which will not enable us maintain the current level of activity. The workshops and focus sessions we organized have been extremely successful. As a result, other institutions have asked to join forces with us to organize larger workshops. It is important both for continued intellectual growth and our visibility that we maintain our leadership. However, this will require additional resources of about \$15,000/year.

**Has the center been instrumental in obtaining external funding for research or education?** If so, please list the grants and PIs, and a short statement addressing the role of the Center in obtaining the funding.

As explained above, research carried out in the Center for Fundamental theory is supported by the individual (and small-team) grants of its faculty members. Every faculty member in the Center has received external funding. For 2007-2010, the total grant support, rounded to the nearest thousand, was \$3,317,000. This figure was obtained from the Physics Department and (for mathematicians) from the NSF website.

The synergistic interaction between PIs is getting national recognition. In several instances this has led to larger than average grants (in respective fields), support for additional post-docs, and, in one case, contribution from the NSF Mathematics Division to a grant submitted to the Physics Division.

**What resources are used by the center (space, equipment, staff, teaching relief).**

The Center does not have any of these resources of its own. Office space for members is offered by individual departments and we share the administrative assistant and seminar and conference rooms of the IGC. There is no teaching relief.

**What activities (seminars, workshops, etc) has the center recently supported? (Over the last one to three years)**

The CFT organizes weekly seminars and also co-hosts the bi-weekly International Loop Quantum Gravity webinars in which over a dozen groups from the Americas, Europe and Asia participate. A list of the Fundamental Theory/Gravity Theory seminars is available by semester at <http://www.phys.psu.edu/seminars/index.html>.

In addition, the Center has organized six Focus Sessions and Workshops. Each brought to Penn State leading international experts in the field.

- Focus Session on the Nature of Time in Fundamental Science, November 9-10, 2009
- Supergravity vs. Superstring Theory in the Ultraviolet, August 27-30, 2009
- Loop Quantum Cosmology Workshop, October 23-25, 2008
- Topical Workshop on Cosmology: Interplay between Theory and Observation, May 1-3, 2008
- Topical Workshop on Black Holes in Fundamental Physics, May 8-10, 2008
- Gravitation, Cosmos and the Quantum, May 5-6, 2007

The programs and proceedings of these Focus Sessions and Workshops are available at <http://www.gravity.psu.edu/events/workshops.shtml>.

**How has the center contributed to the climate and diversity of the College?**

See **part 3** of this document.

**How else has the center benefited research, education, or outreach in the past three years?**

The research of members of CFT has been highlighted in many media accounts and they have performed numerous outreach activities. These media accounts and outreach activities are listed below.

**Print:**

\*Singularity Resolution in Loop Quantum Cosmology: A Brief Overview  
([http://www.gravity.psu.edu/outreach/articles/lqc\\_overview.pdf](http://www.gravity.psu.edu/outreach/articles/lqc_overview.pdf))

\*Research Highlight, "Gone without a trace,"  
Nature 448 (5 July 2007) 4-5,  
doi:10.1038/448004a

\*News & Views, "Beyond the screen of time"  
by Carlo Rovelli, Nature Physics 3 (2007) 520-521, doi:10.1038/nphys690,  
\*BBC Focus Magazine 173 (February 2007) 27  
\*BBC Sky & Night, November 2007  
\*New Scientist, July 7, 2007  
\*Spektrum der Wissenschaft (June 2007) 32-41 (German)

\*Telepolis special 2 (2007) 96-99 (German)  
 \*astronomie heute 9 (2007) 14 (German)  
 \*Tahdet ja avaruus (Stars and space) 6 (2007) 32-35 (Finnish)  
 \*Glos Wielkopolski, July 3, 2007 (Polish)  
 \*Profil (Austrian weekly), July 21, 2008  
 \*Frankfurter Rundschau (German newspaper), October 21, 2008  
 \*New Scientist, Cover Story (Dec 13) 2008  
 \*Die Zeit (German weekly), Dec 23, 2008  
 \*Der Bund (Switzerland), March 20, 2009  
 \*Der Spiegel (Germany), 14 (2009) 128-130 (March 30, 2009)  
 \*Tages-Anzeiger (Switzerland), April 4, 2009  
 \*Suddeutsche Zeitung (Germany), April 11, 2009  
 \*Frankfurter Allgemeine Sonntagszeitung (FAS, Germany), April 26, 2009  
 \*Frankfurter Allgemeine Zeitung (FAZ, Germany), April 30, 2009  
 \*Die Presse (Austria), May 1, 2009  
 \*Die Welt (Germany), May 29, 2009  
 \*Profil (Austria), May 29, 2009  
 \*Rheinischer Merkur (Germany), 24 (2009)  
 \*Handelsblatt (Germany), June 18, 2009  
 \*Muy Interesante (Spain), May 2009, p.~98  
 \*"Representation and Productive Ambiguity in Mathematics and the Sciences," Oxford University Press, published at the end of 2007, has received eight substantial reviews.  
 \*Essay "Space and Time," is forthcoming in The Oxford Handbook of Philosophy in Early Modern Europe, Desmond Clarke and Catherine Wilson, eds.

**Online:**

\*Loop Quantum Cosmology on YouTube (<http://www.gravity.psu.edu/outreach/articles/video.mp4>)  
 \*Kosmos (<http://www.gravity.psu.edu/outreach/articles/kosmos.mp4>)

\*U.S. News and World Report, "How to Get Out of a Black Hole," May 21, 2008  
 \*Quantum Space-Time - Beyond the Continuum of Minkowski and Einstein - Article in volume commemorating the 100<sup>th</sup> anniversary of Minkowski's paper  
 \*<http://www.nature.com/nature/journal/v449/n7164/full/449797a.html>  
 \*[http://www.eurekalert.org/pub\\_releases/2009-08/aps-vi081709.php](http://www.eurekalert.org/pub_releases/2009-08/aps-vi081709.php)  
 \*<http://physics.aps.org/articles/v2/70>  
 \*<http://www.sciencedaily.com/releases/2009/08/090817143556.htm>  
 \*<http://www.nature.com/nphys/journal/v3/n7/full/nphys665.html>  
 \*Nature Press Release, [http://www.nature.com/nphys/press\\_releases/nphys0607.html](http://www.nature.com/nphys/press_releases/nphys0607.html)  
 \*Penn State Live, <http://live.psu.edu/story/24915>  
 \*ScienceNOW, July 5, <http://sciencenow.sciencemag.org/cgi/content/full/2007/705/3>  
 \*ScientificAmerican.com, July 1, 2007, <http://www.scientificamerican.com/article.cfm?id=echoes-from-before-the-big-bang>  
 \*National Geographic News, July 3, 2007, <http://news.nationalgeographic.com/news/2007/07/070703-big-bounce.html>  
 \*"Today at Berkeley Lab" (World of Science), July 19, 2007, <http://www.lbl.gov/today/2007/Jul/19-Thu/7-19-07.html>  
 \*BBC Sky & Night, October 15, 2007, <http://www.bbcmagazinesbristol.com/newsread.asp?id=35053>  
 \*worldscience.net, July 1, 2007  
 \*Digital journal, July 2, 2007  
 \*The Times of India, July 3, 2007  
 \*Le Monde, July 9, 2007 (French)  
 \*Spiegel Online, July 2, 2007 (German)  
 \*Tagesspiegel, July 2, 2007 (German)

\*Die Presse, July 17, 2007 (German)  
\*scinexx, July 2, 2007 (German)  
\*Gezegen.de, July 4, 2007 (German)  
\*Cids, July 9, 2007 (German, online magazine for schools)  
\*Cielo Sur, August 1, 2007 (Spanish)  
\*El Tamiz, July 2, 2007 (Spanish)  
\*NeoFronteras, July 3, 2007 (Spanish)  
\*Ulisse, July 3, 2007 (Italian)  
\*Gazeta.RU,  
[http://www.gazeta.ru/science/2007/07/05\\_a\\_1880980.shtml](http://www.gazeta.ru/science/2007/07/05_a_1880980.shtml) (Russian)  
\*Daily Telegraph (London), April 16, 2008,  
<http://www.telegraph.co.uk/science/science-news/3339730/Before-the-Big-Bang-the-Big-Bounce.html>

\*PhysOrg, June 13, 2008,  
<http://www.physorg.com/news132570663.html>

#### **Radio/TV:**

\*TV program 3SAT (Germany), April 11, 2008  
\*Kosmos, a documentary created to celebrate 150<sup>th</sup> birthday of Max Planck and shown many times in Germany and France in 2008  
\*Radio: WDR5, January 2, 2009  
\*Radio: Bayerischer Rundfunk, July 14, 2009  
\*Further radio interviews on Hessischer Rundfunk, Deutschlandradio, Inforadio Berlin  
\*TV: 3sat (Scobel), May 14, 2009  
\*TV: 3sat (bookmark), June 20, 2009  
\* The Big Bang, My Ancestors and Me, A documentary, shown many times on German and French TV in 2010.

#### **Visitors:**

In addition, CFT has hosted 40 international visitors for research collaboration. These included 30 senior scientists, five of whom were hosted jointly with the Mathematics department. The remaining 10 visitors were research students who visited us for several months using resources from their home institutions/countries. For details, see: <http://igc.psu.edu/visitors/2008-schedule.shtml>

#### **Outstanding Student Achievements:**

Victor Taveras won the James B. Hartle Prize for the best student presentation at the international gravity conference in Sydney, Australia and was recently declared the winner of the Bergmann-Wheeler Thesis Prize from the International Society on General Relativity and Gravitation.

Edward Wilson-Ewing was awarded the Topical Group in Gravitation of the American Physical Society for the best student presentation at the 12<sup>th</sup> Eastern Gravity Meeting, Rochester, NY.

#### **What are the Center's goals for the next three years?**

CFT is the only research center in this country where theorists are addressing the fundamental questions at the interface of quantum physics, general relativity and cosmology using both leading approaches, string theory and loop quantum gravity. In addition there is synergistic interaction with mathematicians in the closely related fields of non-commutative geometry, non-linear analysis and representation theory. We also believe that the interaction between physicists and philosophers has the potential to have deep impact on philosophy of science, particularly on issues related to the nature of space and time and cosmology. We will foster this

synergy because we believe that very significant developments are likely to occur in the near future at the interface of these diverse disciplines. We would also like to continue to raise the visibility of the Center. As part of this effort, we are in the process of initiating a series of workshops that will rotate between five of the major centers in the world whose research efforts are similar to ours. In addition to Penn State, the other institutions are the Albert Einstein Institute in Golm, Germany, University of Cambridge, Imperial College, London and the George Mitchell Institute of Theoretical Physics at Texas A&M.

**Could the center have a greater impact than it has recently?** If so, how and what resources would be needed to accomplish this?

Yes. As articulated in **part 4** of this document, for all their lip service, federal funding agencies do not support efforts to develop new fields at the interface of existing ones. If we had adequate resources to have a thriving visitor program and for attracting post-docs at the interface of physics and mathematics, we would become one of the handful of institutions that will drive the frontier at the interface of cosmology, loop quantum gravity, string theory and non-commutative geometry.

A faculty appointment in non-linear geometric analysis can have a tremendous impact on research in mathematical general relativity. It will also provide a bridge between the Center and the strong groups in partial differential equations and numerical analysis in the Mathematics Department. Thus, with one judicious appointment, Penn State can quickly become a leading institution in this increasingly influential area.

## 6. Center for Gravitational Wave Physics

**Year established:** 2001

**URL:** <http://cgwp.gravity.psu.edu>

**Center Director:** Ben Owen

**Short statement of Center vision or goals:** (suitable for posting on ECoS website)

The mission of the Center for Gravitational Wave Physics is to foster research of a truly interdisciplinary character linking the highest caliber astrophysics, gravitational wave physics and experimental gravitational wave detection in the pursuit of the scientific understanding of relativistic gravity and the development of gravitational wave observations as a tool of observational astronomy.

**Currently Active Faculty participants:** (name & department)

Currently, CGWP has 7 resident and 2 extramural, visiting faculty.

- Mike Eracleous, Derek Fox, Steinn Sigurdsson (Astronomy & Astrophysics)
- Jinchao Xu (Mathematics)
- Ben Owen (Physics)
- Sam Finn (Physics and Astronomy & Astrophysics)
- Peter Meszaros (Astronomy & Astrophysics and Physics)
- Pablo Laguna, Deirdre Shoemaker (Georgia Tech)

**How many students and post docs are directly affiliated with the center?**

There are 9 post docs, 10 graduate students and 6 undergraduates affiliated with the center.

**What is the administrative structure of the center?**

CGWP is one of three centers in the Institute for Gravitation and the Cosmos (IGC). The administrative structure of the IGC is explained in **part 2** of this document.

**Is the center directly supported by an external grant?** If so, please identify the grant (or pending grant), funding period, and amount of support for the operation and activities of the center.

As explained in **part 3** of this document, research activities of CGWP are supported by the individual (and small-team) grants.

**Does the center currently receive any direct internal support (from the department, college or university)?** If so, please list sources and amounts by year for the past three years, how the funds were used, and any funds committed for future years.

CGWP does not receive any direct internal support from the department, college or university. However, as explained in **part 3** of this document, it receives support through the IGC for its seminars, focus sessions, workshops, conferences and visitors.

**Does the center anticipate needing additional internal funds?**

Yes. The workshops and focus sessions organized by the CGWP brought together general relativists, astrophysicists and computational scientists. As a consequence, CGWP was able to play a dominant role in the recent creation of the new field of gravitational wave science. Until 2008, these activities were supported by a block grant from NSF. As explained in **part 3**, at its inception, the IGC received a one-time funding of \$36,000/year for three years. These resources have been vital for our workshops and focus sessions since 2008. From 2010-2011 onward, we will only have access to funds from the IGC operating budget which will not enable us maintain the current level of activity. To retain our high visibility in the national and international gravitational wave community, it is important that we continue to organize high profile scientific meetings. This will require additional resources of about \$15,000/year.

**Has the center been instrumental in obtaining external funding for research or education?** If so, please list the grants and PIs, and a short statement addressing the role of the Center in obtaining the funding.

CGWP came into existence as a Physics Frontier Center of the National Science Foundation. It enjoyed this status from 2001 to 2008 and received a total funding of \$5,884,145 during this period. Currently it does not have a block grant. As explained above, our research is supported by grants to individual researchers or small teams. For the period 2007-2010 the total grant support, rounded to the nearest thousand, was \$4,001,000. This figure was obtained from Departments of Physics and Astronomy & Astrophysics.

Grant reviews routinely mention the existence of CGWP as an important positive factor in their decisions. Indeed, it has elevated the level of individual grants.

**What resources are used by the center (space, equipment, staff, teaching relief).**

The Center does not have any of these resources of its own. Office space for members is offered by individual departments and we share the administrative assistant and seminar and conference rooms of the IGC. There is no teaching relief.

**What activities (seminars, workshops, etc) has the center recently supported? (Over the last one to three years)**

The Center organizes weekly seminars. A list is available by semester at <http://www.phys.psu.edu/seminars/index.html>.

In addition, the Center has organized three Focus Sessions and Workshops.

Probing Neutron Stars with Gravitational Waves, June 18-20, 2009  
[http://www.gravity.psu.edu/events/neutron\\_stars](http://www.gravity.psu.edu/events/neutron_stars)

Eastern Gravity Meeting, May 12-13, 2008  
<http://www.gravity.psu.edu/events/egm11>

CGWP Poster Reception, April 25, 2008

CGWP has also hosted a number of research visits: Duncan Brown, Alessandra Corsi, Massimo Dotti, Lee Lindblom, Andrew Lundgren, Andrea Lommen, Maura McLaughlin, Chris Messenger, and Christian Ott.

**How has the center contributed to the climate and diversity of the College?**

The Center faculty has one female and one member from under- represented minorities. It has trained a significant number of post-docs and students from these groups (2 post-docs, 4 graduate students, and 1 undergraduate student in the last three years).

**How else has the center benefited research, education, or outreach in the past three years?**

- LIGO papers have been featured in Nature News & Views as well as various on-line news sites.
- Our graduate student Nicolas Yunes won the Blue Apple award, PSU dissertation award, and the first Juergen Ehlers thesis prize of the International Society on General Relativity and Gravitation for the best thesis on classical general relativity written during last three years.
- Ben Owen is Chair of the LIGO web committee, thanks in large part to the Center's role in gravitational wave research, education and outreach.
- Sam Finn and Ben Owen Chair several LIGO committees and CGWP is a key computing center for LIGO data analysis.
- Derek Fox serves on the External LIGO Advisory Committee.



- Undergraduate student Meagan Lang was awarded the Gerard A. Hauser Award for her presentation at the Undergraduate research Symposium. Karan Jani won the first prize in the Physical Sciences Division at the same Symposium. In addition he was selected as one of two finalists for the 2009 nation-wide Vanderbilt Prize for Undergraduate Research in Physics and Astronomy.
- CGWP has organized a Science Jamboree every fall.
- CGWP actively participates in open houses for graduate student recruitment in Physics Astronomy & Astrophysics Departments.
- CGWP organizes graduate student/post doc seminars.
- CGWP faculty provide financial support for students/post docs to attend professional meetings.

### **What are the Center's goals for the next three years?**

- Increase its role in gravitational wave theory and observations as advanced LIGO is built and pulsar timing arrays mature.
- Increase interactions with astrophysics, particle physics, and nuclear physics, including outsiders as well as the rest of the IGC.

**Could the center have a greater impact than it has recently?** If so, how and what resources would be needed to accomplish this?

- The CGWP has been a prominent player in gravitational wave physics, but the field has been expanding and we have lost faculty. We need new hires to retain a leading role.
- Workshops: Our carefully targeted interdisciplinary meetings have benefited other scientific communities (such as nuclear physics) while helping our own research and education and raising our profile. It is important to have more: They have already become less frequent as we have lost faculty and, as explained above, from 2010-2011 we will have less internal resources as well.
- Visitors Program: Several scientists working with multiple faculty have stayed several weeks. This has been highly helpful, especially given the collaborative nature of gravitational wave work. They should be expanded but without additional resources it will be difficult to maintain even the current level beyond summer 2010.

# Center for Particle Astrophysics

**Year established:** August 2007

**URL:** <http://www.cpa.igc.psu.edu>

**Center Director:** Peter Mészáros

## **Short statement of Center vision or goals:** (suitable for posting on ECoS website)

The Center for Particle Astrophysics is engaged in a bold synergistic approach to understanding high energy processes in the universe. Our faculty are prominent participants in three major international projects which make observations using extremely high energy protons, neutrinos and gamma rays. These projects are, respectively, the Pierre Auger Cosmic Ray Observatory, the IceCube Neutrino Observatory and the Swift Gamma-Ray Burst Explorer satellite. Both Auger and IceCube are in advanced stages of construction and are poised to make major discoveries in the next few years. Penn State is the only U.S. institution participating in both of these premier ground-based projects of high energy particle astrophysics. Potentially observable sources for both Auger and IceCube include super-massive black holes at the center of active galaxies, and the explosive phenomena that give rise to gamma ray bursts (GRBs). These are believed to be especially violent supernova explosions and also mergers of collapsed stars in binary systems. Swift is presently providing the best gamma ray and X-ray observations of GRB explosions. Swift has been successfully operating for over three years, its mission control center being at Penn State. Penn State also plays a leading role in theoretical modeling of these explosions.

## **Currently Active Faculty participants: (name & department)**

- Stephane Coutu, Douglas Cowen, Paul Sommers (Physics and Astronomy & Astrophysics)
- Tyce DeYoung, Irina Mocioiu, Mark Strikman (Physics)
- Niel Brandt, Derek Fox, Yuexing Li (Astronomy & Astrophysics)
- Peter Mészáros (Astronomy & Astrophysics, Physics)

## **How many students and post docs are directly affiliated with the center?**

9 post docs and 13 graduate students

**What is the administrative structure of the center?**

The center has a Director (Mészáros), a Seminar/Journal Club Organizer (Mocioiu), and Administrative Assistant (Randi Neshteruk of the IGC), and IT Administrator (Cindy Tisler, shared with IGC). CPA is one of three centers in the Institute for Gravitation and the Cosmos. The global administrative structure of the IGC is explained in **part 2** of this document.

**Is the center directly supported by an external grant?** If so, please identify the grant (or pending grant), funding period, and amount of support for the operation and activities of the center.

Not through a Center grant. Our research and outreach activities are supported by NSF, NASA and DOE grants to individual faculty or small teams.

**Does the center currently receive any direct internal support (from the department, college or university)?** If so, please list sources and amounts by year for the past three years, how the funds were used, and any funds committed for future years.

The CPA does not receive any direct support from the department, college or university. However, as explained in **part 3** of this document, it receives support through the IGC for its seminars, focus sessions, workshops, conferences and visitors.

**Does the center anticipate needing additional internal funds?**

Yes. As explained in **part 3**, at its inception, the IGC received a one-time funding of \$36,000/year for three years. These resources have been vital for our workshops and focus sessions. From 2010-2011 onward, we will only have access to funds from the IGC operating budget which will not enable us maintain the current level of activity. To retain our high visibility in the national and international gravitational wave community, it is important that we continue to organize high profile scientific meetings. This will require additional resources of about \$15,000/year.

**Has the center been instrumental in obtaining external funding for research or education?** If so, please list the grants and PIs, and a short statement addressing the role of the Center in obtaining the funding.

As explained above, research carried out in the Center is supported by the individual (and small-team) grants of its faculty members. Every faculty member in the Center receives external funding. For 2007-2010, the total grant support, rounded to the nearest thousand, was \$6,684,000. This figure was obtained from Departments of Physics and Astronomy & Astrophysics.

D. Cowen, S. Coutu, T. DeYoung et al. organize summer teacher's workshops with the theme "The Extreme Universe," funding by an NSF grant.

CPA has played the lead role in the "multi-messenger astronomy" pre-proposal to the Keck Foundation, involving activities from our Center as well as from the Center for Gravitational Wave Physics and the Department of Astronomy and Astrophysics. This proposal will be submitted to PSU later this year for consideration.

**What resources are used by the center (space, equipment, staff, teaching relief)?**

The Center does not have any of these resources of its own. Office space for members is offered by individual departments and we share the administrative assistant and seminar and conference rooms of the IGC. There is no teaching relief.

**What activities (seminars, workshops, etc) has the center recently supported? (Over the last one to three years)**

The CPA organized the following Workshops:

- Ultra-High Energy Cosmic Rays, Neutrinos, and Photons Workshop, May 16-17, 2007
- Forward Physics at LHC with TOTEM Workshop, April 28-30, 2008
- TeV Unidentified Sources Workshop, June 4-5, 2008
- Low Energy Neutrinos Physics and Astrophysics with IceCube, March 19-20, 2009
- 2<sup>nd</sup> Low Energy Neutrino Physics and Deep Core Workshop, June 28-30, 2010.
- The First Galaxies, Quasars, and Gamma-Ray Bursts Conference, June 7-10, 2010
- We also organize a weekly regular seminar, the HEP/Astrophysics seminar.

The CPA has sponsored research visits by Dr. Shin-Ichiro Ando (Caltech); Dr. Katsuaki Asano (Tokyo Tech Univ); Mr Tamas Herpay (Eotvos Univ., Budapest); Mr. Kohta Murase (Yukawa Institute, Kyoto); Dr. Asaf Pe'er (Space Tel. Sci. Inst); Professor Marek Kowalski and Ms. Anna Franckowiak (Humboldt Univ., Berlin); Dr. Alessandra Corsi (Univ. Rome).

**How has the center contributed to the climate and diversity of the College?**

The CPA participates actively in all Physics and Astronomy outreach activities with demonstrations, lectures, etc. and also helps out in a number of ECoS open houses and alumni events. See also **part 3** of this document.

## How else has the center benefited research, education, or outreach in the past three years?

### Stephane Coutu and Paul Sommers

Relating to the Auger Science article in November 2007 (J. Abraham et al. (Auger Collaboration), "Correlation of the highest-energy cosmic rays with nearby extragalactic objects", Science 318,938-943 (2007):

- AIP listed it as one of the 10 top news stories of 2007, at <http://www.aip.org/pnu/2007/split/850-1.html>
- Ranked #3 by Science Magazine's Breakthroughs of the Year, at <http://www.sciencemag.org/cgi/content/full/318/5858/1844a>
- Ranked by Nature as one of the top 10 non-Nature stories of the year, at: <http://intl.emboj.org/nature/journal/v450/n7173/full/4501130a.html>
- Deemed by Physics World to have been one of the best news stories of 2007: <http://physicsworld.com/cws/article/news/32311>
- In addition, there was a Penn State news release on the Auger Science paper at <http://www.science.psu.edu/alert/Sommers11-2007.htm>
- In addition, Sommers, the co-spokesperson of the Pierre Auger Collaboration was asked multiple times to comment on this and other Auger results by journalists.
- Coutu developed a Google Earth-based model of the Pierre Auger Observatory, which was featured for over a month in 2006/07 as one of the top 20 best on the Google Earth Community Forum. It has been downloaded by over 2900 users (see <http://bbs.keyhole.com/ubb/showthreaded.php/Cat/0/Number/557319/page/vc>).
- Coutu commented on the PAMELA antimatter results for a Physics World online article at: <http://physicsworld.com/cws/article/news/36534> and on the ATIC electron excess
- Coutu provided an ECOS "Probing Question" feature on the prospects of the LHC creating a black hole: <http://www.science.psu.edu/news-and-events/2009-news/CoutuProbingQuestion1-2009.htm>
- Video prepared by the American Museum of Natural History on Auger called "Aiming High: The Search for Ultra-High Energy Cosmic Rays." See [http://sciencebulletins.amnh.org/?sid=a.f.cosmic\\_rays.20090622](http://sciencebulletins.amnh.org/?sid=a.f.cosmic_rays.20090622).
- The most recent Nature coverage: [http://www.nature.com/news/2010/100222/full/4631011a.html?s=news\\_rss](http://www.nature.com/news/2010/100222/full/4631011a.html?s=news_rss).
- World Line Commentary by Lawrence Krauss in New Scientist (8 Dec 2007): <http://www.newscientist.com/article/mg19626331.100-commentary-it-pays-to-push-the-boundaries.html>.

### Doug Cowen

- March 2010 Discover Magazine - <http://discovermagazine.com/photos/25-the-6-coolest-science-experiments-in-antarctica>.
- What can neutrinos tell us about the universe? In Dec 2009 Astronomy Magazine by James Trefil and Wanda O'Brien-Trefill. Astronomers are studying subatomic particles from supernovae and other energetic phenomena, but such particles are difficult to detect.
- Exploratorium live webcast from the South Pole: For the International Polar Year, we gave polar scientists cameras and blogging tools and asked them to document their fieldwork. Follow along on their adventures and see what it's like to be a research scientist in the Arctic or Antarctica. (Dec 2008)

- April 2008 NewScientist - New Scientist features IceCube in montage and in article: New Scientist has featured IceCube in their April 19th issue in an article by Anil Anathaswamy who visited the South Pole last season. An exclusive video is available on YouTube about the construction of the IceCube Neutrino Observatory.
- IceCube on CBS Evening News: A piece on Antarctic science with an overview of IceCube featured on the CBS Evening News with Katie Couric at 8:30 pm on Tuesday, February 12, 2008.
- Jan 2008 NewScientist - New Scientist Space article: Upgraded neutrino detector could root out dark matter - The world's biggest neutrino detector, IceCube, may be augmented to search for signs of dark matter at the Sun's core or at the centre of our galaxy.

#### **Derek Fox (Joined 2008)**

- Sky & Telescope magazine Jan 2009: "The Brightest Burst: A stellar cataclysm last March reached naked-eye visibility - from an incredible 7.5 billion light-years away", Derek Fox & Judith Racusin, pp. 34-40.
- Our discovery of the "most distant object in the Universe", GRB 090423 at redshift  $z=8.26$ , was reported widely including a story and editorial in the October 29, 2009 New York Times.
- Discussion on NPR "All Things Considered" for October 29, 2009, same topic
- Item in the "News and Views" section of Nature magazine (associated with publication of our discovery paper, same topic).
- News item in the September 18, 2009 issue of Science magazine that mentioned the contribution of graduate student Antonino Cucchiara and Derek Fox by name (p. 494).
- A personal research profile - my answer to the question "Where is the study of gamma-ray bursts going?" - appeared in the "AstroConfidential" section of the July 2009 issue of Astronomy magazine (p. 11).
- Interview for the syndicated radio program "Dr. Sky" by Steve Kates, aka Dr. Sky. in October 2009. My episode aired that same month (on different dates for different affiliates) and is archived at the Dr. Sky website, <http://teentalknetwork.com/sky.htm>.

#### **Yuexing Li (Joined 2009)**

- Space show "Journey to the Stars" produced by AMNH was commenced in July 2009. It used my simulation of Milky Way - Andromeda merger as background. This show received rave reviews from major media such as New York Times. It's being shown daily at the Hayden Planetarium at AMNH and receives hundreds of visitors every day.
- Work on high-redshift supermassive black holes was featured in Discover Magazine December 2009 issue in article "Are Black Holes the Architects of the Universe?" as well as in CBS News January 2010 story "Why Black Holes Are Winning Respect."

#### **Peter Meszaros:**

- Daily Collegian, article "The Universe Just Got Hotter," Jan. 30, 2007 by Amy Flashenberg, ([www.collegian.psu.edu](http://www.collegian.psu.edu)).
- News Penn State, "Top high-energy astronomy prize awarded," Jan. 31, 2007. Concerning AAS Rossi prize award to N. Gehrels and the Swift team, inc. Meszaros). (Note: Meszaros won the Rossi prize previously in 2000, with M.J. Rees and B. Paczynski, for his work on the theory of gamma-ray bursts).
- ScienceNOW Daily News (AAAS) "An Engine for Mind-Boggling Blasts," Feb. 14, 2007, by Phil Berardelli,
- News Penn State, "Gamma-ray Bursts Active Longer than Previously Thought", 5/25/07.

- History Channel Documentary, "Mega-Disasters: Gamma-Ray Burst," by Darryl Rehr, aired on History Channel Sept. 18, 2007.
- News Penn State, "Superbright Explosion is Most Distant Object Ever Visible to the Naked Eye," March 31, 2008.
- Le Monde (Paris), "Une Supernova Filmee pour la Premiere Fis des son Debut," 5/24/08.
- Top Ten Physics News Stories, American Physical Society (with the Swift team), 2008
- New York Times, "7.3 Billions Years Later, Einstein's Theory Prevails", by Dennis Overbye, Oct. 28, 2009
- News Penn State, "Penn State Astronomers Ranked High in Scientific Impact," July 10, 2009.
- News Penn State, "Rare Space Experiment Gives Clues About the Fundamental Structure of the Universe," Nov. 3, 2009.
- Thomson Reuters ScienceWatch, Special Topics, "Gamma-ray Bursts," June 2009, <http://sciencewatch.com/ana/st/gamma/09junGamMesz/>.
- Semi-popular book entitled "The High Energy Universe" to be published September 2010 by Cambridge University Press.

### Irina Mocioiu

- Probing Question: What is a neutrino?, Penn State Newswire by Steve Miller
- Research Penn State, October 5 2007; Penn State Live web site: <http://live.psu.edu/story/26255?nw=1>
- Reports on Progress in Physics, 2007: The paper Theory of Neutrinos: A White Paper by R N Mohapatra et al. was chosen as one of the Highlights of 2007. <http://www.iop.org/EJ/journal/-page=extra.2007highlights/0034-4885>
- Nature Physics 4, 269 (2008); <http://www.nature.com/nphys/journal/v4/n4/full/nphys937.html>

### Mark Strikman

These are reviews related to the discovery of short-range correlations in nuclei and dominance of pn vs pp correlations, by Strikman and collaborators:

- "Protons and neutrons cozy up in nuclei and neutron stars," CERN Courier, 49N1, 22 (2009), by D. Higinbotham, E. Piasetzky and M. Strikman.
- Media accounts of this research or outreach.
 

<ul style="list-style-type: none"> <li>○ Physics Today, feature article on the observation of short-range correlations</li> <li>○ BNL News, Protons Pair Up with Neutrons</li> <li>○ Nature Physics (Research Highlights: Unequal pairs)</li> <li>○ Protons Pair Up With Neutrons, EurekAlert, May 29, 2008</li> <li>○ Jefferson Lab in the News: Nuclear Pairs</li> <li>○ Brookhaven National News: Protons Pair Up with Neutrons</li> <li>○ Press release from Kent State University</li> <li>○ ScienceDaily (Penn State University)</li> <li>○ ScientistLive (Penn State University)</li> </ul>	<ul style="list-style-type: none"> <li>○ On Target</li> <li>○ PHYSORG.com</li> <li>○ NFC (in Hebrew)</li> <li>○ Tel Aviv University Press (in hebrew)</li> <li>○ CERN Courier article: "Protons &amp; neutrons certainly prefer each other's company"</li> <li>○ R&amp;D magazine</li> <li>○ The A to Z of Nanotechnology magazine</li> <li>○ Analitica-world</li> <li>○ Matter News</li> <li>○ Softpedia</li> <li>○ News @ Old Dominion</li> </ul>
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**What are the Center's goals for the next three years?**

We would like to find resources and carry out a multi-channel cosmic source observational program to detect and analyze sources that are luminous in two or more of channels such as neutrinos, cosmic rays, gravitational waves and electromagnetic channels. This would be a unique capability, involving CPA and CGWP, the combination of expertise available here being unique in the nation, if not in the world. For further details, see *Goals for the near future* in **part 4** of this document.

**Could the center have a greater impact than it has recently?** If so, how and what resources would be needed to accomplish this?

As described in the *Long-Term Goals* in **part 4** of this document, to attain the next level in our forefront inter-disciplinary research, we need a strong visitor program and post-doctoral fellowships to attract the very best young scientists to Penn State.

One or two faculty positions in Particle Astrophysics, in particular one for a cosmic microwave background experimentalist and another for an interface theoretical cosmologist would have tremendous impact in bringing closer research carried out at the CPA and CFT, the Center for Fundamental Theory.