

IGC Report to Dean Larson and Associate Dean Stephenson
November 5th 2014

PLAN

1. Brief Overview (5 minutes)
2. News and Initiatives since the IAB Meeting of November 20th, 2013 (20 minutes)
3. Activities (15 minutes)
4. Summary and Request for Advice (20 minutes)

1. Overview:

- **Mission Statement:** The Institute for Gravitation and the Cosmos (IGC) is a multidisciplinary institute of Penn State researchers dedicated to the study of the most fundamental structure and constituents of the Universe.
- **Evolution:** IGC was created in 2007 with three Centers. It grew out of the Institute for Gravitational Physics and Geometry to take advantage of the then recent strengths in Particle Astrophysics at Penn State. From its inception, it has been regarded as a 'living organism' that can grow and transform to take full advantage of new intellectual opportunities across various disciplines and to adjust to the local strengths at Penn State. In 2011, it was re-structured. The Center for Gravitational Wave physics was absorbed into the Center for Particle Astrophysics to form a larger Center for Particle and Gravitational Astrophysics (CPGA) and a new Center for Theoretical and Observational Cosmology (CTOC) was created.

Abhay Ashtekar is the founding Director of IGC; *Peter Meszaros*, of CPGA; *Donald Schneider*; of CTOC and *Murat Gunaydin*, of the Center for fundamental theory (CFT). In November 2013, Doug Cowen was appointed the Associate Director of IGC (to replace Paul Sommers, the founding Associate Director, who had just retired). During 2013-14 *Murat Gunaydin*, was on sabbatical in Europe and by mutual agreement, *Abhay Ashtekar* took on his responsibilities at CFT.

- **Current Composition:** Currently, IGC has 30 faculty members in residence at Penn State, 1 research Associate, 22 post-docs, 38 graduate students and a (variable) smaller number of undergraduates from departments of *Astronomy and Astrophysics, Mathematics, Philosophy and Physics*. Six of our current faculty are from under-represented groups. In addition, faculty from the Statistics department and IST have collaborated closely on different aspects of the AMON project. The IGC has one administrative assistant. (*Distribution: faculty: 15 in Physics; 11 in A&A, 3 in Mathematics; 1 in Philosophy. RA: 1 in A&A. Post-docs: 8 in A&A, 14 in Physics*).

2. News and Initiatives since the Internal Advisory Board (IAB) Meeting of November 20, 2013

- In 2013, with the approval of the Internal Advisory Board (IAB), five **new faculty** were added to IGC: *Eugenio Bianchi* (Physics), *Chad Hanna* (Physics), *Donghui Jeong* (A&A), *Miguel Mostafa* (Physics) and *George Pavlov* (A&A). They have all contributed significantly to the IGC activities over the past year. In particular, Miguel Mostafa has assumed the leadership of the AMON project.
- *Niel Brandt*, a member of CPGA and CTOC, was named the Verne M. Willaman Professor of Astronomy and Astrophysics. *Abhay Ashtekar* was named to a Distinguished Visiting Chair at the Perimeter Institute. *Sarah Shandera* was named an Emmy Noether Fellow by the Perimeter Institute.
- Two of last year's IGC faculties are now at other institutions. Ty Deyoung (Particle Astrophysics) resigned from Penn State and Victor Nistor (Mathematics) has been on an extended leave.
- A new joint appointment between Physics and A&A was made. *Kohta Murase* will join us during the current academic year as the 31st faculty in residence at IGC.
- With the approval of the IAB, IGC launched a new, IGC **Post-doctoral Research Scholar Program** to attract exceptional post-docs to Penn State. Every year, three appointments are made, one per center. The salary comes from the federal grants but IGC provides a supplement of \$5K/year to each of these post-docs for academic expenses of their choice. The program has been highly successful. We were able to attract top candidates who declined offers from prestigious institutions and who would probably not have come to Penn State without this added incentive. The current IGC post-doctoral scholars are: *Nishant Agarwal* (CTOC) who has been active in bridging physics and astronomy researchers in cosmology; *Marc Geiller* (CFT) who interacts actively with physicists and mathematicians; and *Foteini Oikonomou* (CPGA) who works on cosmic rays, gamma rays and neutrinos and can therefore bridges diverse groups.

- The project **Astrophysical Multi-messenger Observatory Network** (AMON) was launched at IGC with seed funding from the Office of the Vice President of Research. It has now received NSF support (with *Miguel Mostafa* as the PI and *Doug Cowen* and *Derek Fox* as co-PIs). The group now consists of two post-docs, two students and six faculty with active interest (*Stephane Coutu*, *Peter Meszaros* and *Chad Hanna* in addition to those on the proposal) with expertise in gravitational waves, cosmic rays, TEV gamma rays, and neutrinos, enabling one to study the most extreme events in the universe using all four forces of Nature. AMON has signed collaboration letters with 9 large, international observatories across US and Europe (LIGO/VIRGO), from the south Pole (IceCube), the deep Mediterranean (ANTARES), the Argentinian Pampas (Auger), the Mexican mountains (HAWC), and space missions (Fermi, Swift). AMON has enormous potential and it is beginning to gain prominence in particle astrophysics. ICECUBE, for example, is now eager for AMON to incorporate neutrinos in real time.
- IGC support for professional development travel was a major incentive for *Tyler Anderson* to accept the position as the head of the **new electronics shop**. This shop has already had significant impact in raising the profile of the Penn State team within the large ICECUBE collaboration. He will assist and train graduate students and post-docs in A&A and physics departments working on diverse projects. The expertise they acquire is expected to enhance external funding to these groups.
- Electronics developed at PSU by *Stephane Coutu* and *Tyler Anderson* constitutes a crucial part of the payload that will be sent in the spring of 2015 to the **International Space Station** (ISS) as part of the ISS-**Cosmic Ray Energetics and Mass** (CREAM) instrument, for a 3-year stint. This instrument will have unprecedented sensitivity to measure the nuclear cosmic ray spectra and composition.
- Thanks to the support of the Eberly College of Science, Penn State is an institutional member of the **Sloan Digital Sky Survey** (SDSS) IV. CTOC and CPGA members *Niel Brandt* and *Mike Eracleous* are leading the PSU efforts.

- CTOC members *Robin Ciardullo*, *Caryl Gronwall*, *Derek Fox* and *Donghui Jeong* are leaders in the **Hobby-Eberly Telescope Dark Energy Experiment** (HETDEX). The program will study the expansion of the universe from redshifts $z=2$ to $z=4$, constraining the properties of 'dark energy' (in particular, whether it can be taken to be just the cosmological constant or not).
- The CTOC members in *Niel Brandt's* group are now receiving observations from the **Chandra satellite** that will provide the most sensitive view of the X ray universe, revealing the evolution of supermassive black holes over almost the entire cosmic history.
- CTOC and CPGA members play an important role in the **Large Synoptic Sky Survey Telescope** (LSST). In particular, *Niel Brandt* is a member of the LSST scientific advisory committee and Chairs the Science collaboration on Active Galactic Nuclei and the Interest Group on Deep Drilling Fields of LSST.
- The CPGA team led by *Miguel Mostafa* has supplied crucial hardware to the **High Altitude Water Cherenkov (HAWC) gamma ray observatory** in Puebla, Mexico. The observatory has started taking data and has already measured a significant small-scale anisotropy in the arrival direction distributions of cosmic rays above 1 TeV. It is now being used to search for gamma rays created in the self-annihilation of multi-TeV dark matter.
- *Doug Cowen* is the US lead for **Precision IceCube Next Generation Upgrade** (PINGU), which is a significant component of a future \$300M NSF/MREFC proposal called IceCube-Gen2.
- *Derek Fox* is the Project Scientist for a future \$100M proposed satellite mission called **XTIDE** that will characterize the transient X-ray universe. The proposal will be submitted to NASA in December 2014.
- The CPGA team led by *Stephane Coutu* and *Miguel Mostafa* will participate in the proposal to NSF **Auger Beyond 2015** for a major upgrade of the Auger cosmic ray observatory.

- On the theory side, the CFT and CTOC research led by *Abhay Ashtekar* on the very early universe has provided novel possibilities to look for signatures of quantum gravity in the very early universe and, conversely, opened new avenues to use observations to constrain the initial conditions of the universe at the Big Bounce. This occurs in the deep Planck regime of quantum gravity where quantum theory meets general relativity head-on. This work will be presented in a plenary talk at the **Universe After Planck Conference** in Paris in December 2014.
- *Peter Meszaros* is an Associate Editor of the Journal of Cosmology and Particle Astrophysics (*JCAP*). *Steinn Sigurdsson* is a Scientific Editor of Astrophysical Journal. *Emily Grosholz* is the guest editor of a special issue, Cosmology and Time, of the journal Studies in History and Philosophy of Modern Physics. The issue was based on a philosophy/physics workshop she organized at IGC. *Abhay Ashtekar* is the Editor in Chief of General Relativity and Gravitation, and, Advances in Mathematical and Theoretical Physics. He is also the Editor in Chief of the Cambridge University Press volume, **General Relativity and Gravitation: A Centennial Perspective**, commissioned by the International Society for General Relativity and Gravitation.
- **Younger members** of IGC won several honors and awards. It is particularly gratifying that many of them are women. *Kathryne Sparks Woodle* was named the APS Woman of the Month for July 2014. She served as the Chair of the local organizing committee of the APS Conference for Undergraduate Women in Physics (CUWiP), which was held at Penn State in January 2014 and received support from IGC. *Aruna Kesavan* was the co-Chair of the first meeting of the APS Mid-Atlantic Section, which drew to Penn State over 400 participants, a record for any regional APS meeting. During this meeting, Justin Lanfranchi and Lea Hagen won awards for their graduate posters, and Beatrice Bonga for her graduate student talk. Anne-Sylvie Deutsch received the Physics and Astronomy for Women Society (PAWS) Travel Fund award. She will give a poster presentation at the "Primordial Universe after Planck" conference in Paris, December 15-19, 2014. Finally, *Kazumi Kashiwama* was awarded a prestigious NASA Einstein Fellowship.

- Outreach: A 43 minute YouTube video, *Before the Big Bang: Loop Quantum Cosmology explained*, based primarily on recent IGC research, was produced by a London Banker Philip Halper in 2013. It has accumulated over 66,400 hits. *Abhay Ashtekar* co-edited a Springer Handbook of space-time, a 950 pages volume with 39 chapters covering philosophy, mathematics and physics underlying modern theories of space-time structure, with emphasis on general relativity. This volume is addressed to beginning researchers. It will be available at all major libraries (that have contracts with Springer) and individual chapters can also be purchased in the electronic form.

For brevity, we have included only illustrative examples of honors and outreach activities here.

3. Activities:

- CFT organized a joint Mathematics Physics workshop, held in McAllister Building, on **Non-Associativity in Physics and Related Mathematical Structures**. This focused meeting brought to Penn State, leading mathematicians and physicists, including the Field Medalist *Efim Zelmanov*, for lectures and discussions. It was deemed by both groups to be highly successful.
- CTOC organized the second **Neighborhood Workshop on Astrophysics and Cosmology**. It attracted over 90 participants from 10 universities and was considered to be highly successful by all participants, especially by young researchers. This series of workshops has already raised our profile in cosmology.
- CTOC organized a **HETDEX Science Meeting** to discuss the current status and sharpen the science requirements.
- CPGA organized a focused workshop on **AMON** in which leaders from the participating observatories participated to streamline procedures for handling the large and diverse data.
- IGC was a co-sponsor of the **Northeast Conference for Undergraduate Women in Physics**. The main organizer was the IGC graduate student

Kathryne Sparks Woodle. APS pronounced this meeting as a highly successful event.

Events planned for 2015

- IGC has assumed leadership in organizing the 2015 **ECOS Frontiers of Science Lectures**. Because 2015 makes the centennial of the discovery of general relativity, the series will be entitled **Einstein's Cosmos: 100 Years after the discovery of General Relativity**. The scientific committee consists of Abhay Ashtekar (Chair), Donghui Jeong, Peter Meszaros and Steinn Sigurdsson and we received valuable advice from Donald Schneider. Frank Pugh and Barbara Kennedy served as advisors. As usual we will have six lectures. Three will be from Penn State: *Eugenio Bianchi* on Gravity and the Quantum; *John Nousek* on Birth Cries of Black Holes; and *Jason Wright* on Gravitational Lensing and Exoplanets. The other three will be given by experts from outside Penn State: *Nergis Mavalvala* (Marble Professor of Astrophysics and a winner of a MacArthur award) will speak on gravitational waves; *John Norton* (Director of the Pittsburgh Center for History and Philosophy of Science) will speak on the conceptual fabric and discovery of general relativity; and *David Weinberg* (Henry L. Cox Professor, Distinguished Professor of Mathematical and Physical Sciences, Ohio State University) will speak on cosmology.
- Under the auspices of the International Society for General Relativity and Gravitation and the American Physical Society, in June 2015 IGC will host an international conference entitled **General relativity and gravitation: A centennial perspective**. The plenary program is now fixed. It will feature international leaders in all areas of this field and will be landmark event. Ten plenary lectures will provide broad overviews of major developments in the entire field, with emphasis on advances that occurred in the last 30 years. Five Perspective sessions, each of 90-100 minutes, will feature Panel discussions on future prospects. The panelists will be by and large younger researchers, and we expect lively debates on competing ideas as well as unfolding of synergy among diverse approaches that are currently being pursued.
- Each of the three centers will organize at least one workshop and/or focus session. CPGA has already made plans for a workshop on Auger

that will take place in DESY, Hamburg, to further consolidate ideas between various laboratories.

4. Summary and Request for Advice:

As the list of research directions and activities illustrates, the intellectual scope of IGC is extremely wide. By now, enough time has passed for cross-disciplinary collaborations to cement. As several researchers pointed out during the annual 'get together' we hosted in October, a large number of these synergistic activities were made possible because of direct support that IGC provided and/or through IGC activities that bring together experts from diverse areas to brainstorm, learn from one another, and collaborate. An outstanding example is provided by our cosmology effort. Under the leadership of our most recent hires in this area, *Donghui Jeong and Sarah Shandera*, a group of a dozen researchers (including Ashtekar and Bianchi) meet weekly to exchange diverse ideas on astronomy and physics of the universe spanning some 10 billion years.

Thanks to the IGC research and activities, Penn State has been consistently ranked among the top 10 groups in the country in Gravitation and Cosmology. Due to the enhanced synergy, our visibility will likely rise further in the coming years. Synergy between Astronomy and Astrophysics, Physics and Philosophy has blossomed in many directions through both CPGA and CTOC. However, we are still quite far from fulfilling our potential in terms of synergy with mathematics. This semester, the Mathematics department has provided some teaching support to a Physics post-doc. This is a good beginning as it has already led to an increase in interaction. But we need more ideas.

Since Dean Larson has watched with interest the evolution first of IGPG and then of IGC, we would greatly value any advice he has for us to take this institute to the next level of excellence.