Chapter 27
LIGO and Science Diplomacy

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The discovery of gravitational waves in LIGO captured the imagination of the public, worldwide. Why? The answer is one that is fundamental to the human race. A universal feature that sets humans apart from other living species is our curiosity about nature and the world we live in. Some of this knowledge is self-serving, like how to cope with diseases or how to improve our way of life. However, our curiosity goes well beyond just satisfying needs, as it includes our fascination with the stars, the origin of the universe, or just simply our understanding how things work.

Physics is one of the more obtuse areas of curiosity-driven science. It includes the study of the basic constituents that make up our physical world and how they interact. Yet, discoveries in this general area of science are considered front-page news! It is quite understandable that my colleagues from other areas of science often ask me about LIGO and gravitational waves, or the Higgs particle, or whether neutrinos move faster than the speed of light, etc. More interestingly, someone I meet often asks me the same questions on airplanes, at parties, or almost any gathering of people, when my identity as a physicist is revealed.

A key common interest of people all over the world are the science questions that physicists study. This universal interest, coupled with the international and non-political nature of the field, make physics research an ideal and unique tool for science diplomacy. Ironically, one of the most fundamental areas, particle physics, was born following World War II, out of the Atomic Bomb effort. The original research that led to the Atomic Bomb originated from the development of quantum mechanics and nuclear physics in the 1930s and the tools built in the bomb effort led to the peaceful worldwide physics research using particle accelerators after the war. Many of the same physicists, who were integral to the Atomic Bomb efforts, moved on to exploring fundamental questions in particle physics after the war, using ever-larger

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particle accelerators, culminating in very large international facilities like those at CERN in Geneva, Switzerland.

A second area of fundamental physics is LIGO, an experimental facility to study Einstein's theory of general relativity, his prediction of the existence of gravitational waves and a new astronomical science with gravitational waves. These research topics are conducted by large international collaborations that grew up first with university facilities, but soon required larger collaborative facilities. Even though particle physics evolved from weapons laboratories after WWII, the field now has totally free access and requires no security clearances. Scientific results are published in scientific journals without censorship and with worldwide 'open-access.'

The public excitement with the science of gravitational waves and particle physics has created strong connections between the public and the science. This, along with the international nature of the fields, provides special opportunities for them to play special roles in relations between people from different countries.

Science for Diplomacy—The Royal Society in the UK and the American Association for the Advancement of Science in the U.S. have defined three types of science diplomacy: (1) "Science in diplomacy": Science can provide advice to inform and support foreign policy objectives; (2) "Diplomacy for science": Diplomacy can facilitate international scientific cooperation; and (3) "Science for diplomacy": Scientific cooperation can improve international relations. All three of these aspects of science diplomacy are important, but it is the third where fundamental physics has had and will continue to have the largest direct impact. Much of the research in fundamental physics is carried-out through international collaborations using large experimental facilities.

One of the best examples is the development of international collaborations to build and do science on large particle accelerators. As accelerators became larger and more international, the International Union of Pure and Applied Physics (IUPAP) took special interest in the international aspects of this field. As an organization, IUPAP, was formed in 1922 with the specific aim to "to stimulate and promote international cooperation in physics; to sponsor suitable international meetings and to assist organizing committees; to foster the preparation and the publication of abstracts of papers and tables of physical constants; to promote international agreements on other use of symbols, units, nomenclature and standards; to foster free circulation of scientists; to encourage research and education." IUPAP is presently composed of 59 member countries, representing their identified physics communities.

IUPAP has played a special role in internationalizing particle physics by establishing a standing committee, the International Committee on Future Accelerators (ICFA) to coordinate particle accelerator facilities on an international scale. In 1980, ICFA made a statement that has to a large extent been responsible for the almost total internationalization of the field. The statement, "ICFA Guidelines for the Interregional Utilization of Major Regional Experimental Facilities for High-Energy Particle Physics Research" contained two key guidelines that have operationally opened up the use of large particle accelerators to physicists from around the world, independent of politics or the wealth of the country. It passed a resolution that for the use of these expensive large accelerators:

- "The national or institutional affiliations of the teams should not influence the selection of an experiment nor the priority accorded to it,"
- "Operating laboratories should not require experimental groups to contribute to the running costs of the accelerators or colliding beam machines nor to the operating costs of their associated experimental areas."

These principles are being followed by every major accelerator laboratory, and this has resulted in creating an international model for participation in particle physics research that is truly open to scientists from around the world. Major accelerator laboratories in Europe, Asia, the US and Russia follow this model for participation. More and more, these large facilities have become the primary tools for addressing the forefront problems in the field, and the research is performed by international teams of scientists through partnerships between countries that provide the major resources and jointly share the governance of the research organizations.

LIGO: A Model of Independent Worldwide Scientific Collaboration—Albert Einstein gave us a new theory of gravity in 1915, more than 200 years after Newton introduced his Unified Gravity theory. Einstein's theory was the next big step in understanding gravity, especially as it applies to understanding our universe. As an outcome of this theory, Einstein predicted the existence of gravitational waves in 1916 and they were detected 100 years later in LIGO (Laser Interferometer Gravitational-wave Observatory). LIGO is a self-organized collaboration of scientists and scientific institutions from 18 countries and about a hundred institutions from around the world. LIGO is the natural extension of scientists collaborating across borders to accomplish joint scientific goals. LIGO has extended that model to a large collaboration having its own governance that is open to scientists from around the world.

The fact that such complex science done over decades is being accomplished without formal agreements between countries, funding agencies or the scientist's institutions bodes well for achieving complex goals jointly by nations, without the burdens of complex government agreements. The success opens the door for other cooperation between countries on complex problems with formal agreements being employed, only as required.

CERN: A European Particle Physics Laboratory—International scientific collaborations are also carried out through much more formal international treaties or other cooperative vehicles, like for the CERN Laboratory in Geneva Switzerland. The Large Hadron Collider (LHC) has become the centerpiece of the field of particle physics. Following World War II, Europe was no longer a world leader in physics research. Rebuilding European science represented a major challenge, but a group of physicists, including Edoardo Amaldi in Italy, Pierre Auger in France and Niels Bohr in Denmark had the idea of jointly creating a European laboratory for particle physics. They prophesized that such a laboratory would unite European scientists to share the costs of developing world-class future facilities.

CERN was established at an intergovernmental meeting of UNESCO in Paris in December 1951, where the first resolution concerning the establishment of a European Council for Nuclear Research was adopted. In 1953, the 12 founding Member States: Belgium, Denmark, France, the Federal Republic of Germany, Greece, Italy, the Netherlands, Norway, Sweden, Switzerland, the United Kingdom, and Yugoslavia ratified the agreement, soon after the European Organization for Nuclear Research (CERN) was established and Geneva was chosen as the location. The laboratory was established as a treaty organization and this has given it stability over the vicissitudes of economies, politics, etc. over its 60 years.

At present, CERN having built the Large Hadron Collider (LHC), a ~10 billion dollar facility, is the most important particle physics laboratory in the world. It has made more than its share of major discoveries in particle physics, including the discovery of the Higgs boson, and more are likely to come. Following the guidance from ICFA, the experimental program at LHC is carried-out by international collaborations that extend far beyond the European countries who support and are member-states for CERN.

In addition to the direct science coming from CERN, it has had a major impact on technological developments that are being exploited around the world. Perhaps the invention that has had the broadest impact on our everyday life is the worldwide web invented by Tim Berners-Lee in 1990. He developed this distributed information system, in order to meet the demand for information sharing between scientists all over the world. In 1991, he had developed an early Web system with browsers, URLs, etc., and it was released to the particle physics community. Rather quickly, the Web was adopted throughout the academic world in universities and research laboratories. As systems developed to use the web on PCs, the usefulness spread from high tech laboratories having powerful computers to all of us, and it has quickly become an indispensable tool for everyday life.

Interestingly, the World Wide Web was developed in an international particle physics laboratory, where information is shared across national boundaries without restriction. Just as this policy has enable particle physics to advance as a worldwide joint enterprise, the associated resulting technologies are now available to be exploited openly without borders.

The Next Particle Accelerator: A Global Initiative—We have learned much about the benefits of international collaboration in science, such as those on large accelerators for particle physics. International collaboration has enabled us, both by combining resources and talents, to make scientific breakthroughs that may not have been possible, otherwise. Further, the same international partnerships produces technical innovations and breakthroughs that can benefit society more broadly, and ones that can be disseminated throughout the world with few political obstacles.

This effort to develop a next generation particle accelerator are broadening yet further the science for diplomacy benefits being realized at CERN and, more generally, in particle physics. There are many issues involved in bringing scientists together in such an undertaking, such as obtaining visas for all participating scientists, intellectual property rights agreements between participating laboratories, industry and countries, importing sensitive scientific equipment, etc. These are all ways in which particle physicists are solving problems that are integral to enabling countries to work together.

Particle Accelerators are expensive, so one might well conclude that it is an area of science only available to scientists from richer countries. As I mentioned above, the guidelines from ICFA have made even the largest and most expensive accelerators, like the LHC, available to scientists from all around the world. The two large experimental collaborations at the LHC have more than 10,000 collaborating scientists and engineers from over 100 countries, as well as from hundreds of universities and laboratories. The global design effort for the next particle accelerator has several thousand scientists from around the world collaborating on the formative ideas and design stage. In these collaborations, all these scientists have equal access to the data and participate in small international groups on the specialized technical or physics efforts on the experiments. For scientists from developing countries, particle physics collaborations provide an almost unique opportunity to work with the most advanced.

SESAME: Science for Diplomacy in the Middle East—In addition to physicists from the developing countries participating in particle physics research at the major accelerator facilities, as discussed above, there are also important initiatives in the developing countries. Perhaps the most ambitious is an International Centre being developed in Jordan is called SESAME (Synchrotron-Light for Experimental Science and Applications in the Middle East). SESAME is an accelerator facility built in the Middle East as first established by UNESCO. The facility is located near Amman, Jordan, on a site donated by the Jordanian government, who also has built a very large modern building to house the accelerator and laboratories. The primary goal of the laboratory is to create a state-of-the-art synchrotron light research facility.

A synchrotron light source is a special particle accelerator that accelerates electrons to high energy and then converted them into a photon or light beam. Synchrotron light facilities are broadly used around the world for a wide range of research topics, including condensed matter physics, material science, biology and medicine. They also have many practical applications, such as doing precision lithography.

However, the importance of this initiative goes well beyond the scientific goals and is truly an example of how science can be used for diplomacy that cannot be accomplished otherwise. SESAME is a major intergovernmental scientific facility, whose members are Bahrain, Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, the Palestinian Authority, and Turkey. Like for the creation of CERN, the SESAME accelerator facility requires more resources than are possible for the individual member science budgets, as well as requiring the combined skills and talents to develop such a facility.

The stated aims of SESAME are admirable. They are: (1) "Foster scientific and technological capacities and excellence in the Middle East and the Mediterranean region (and prevent or reverse the brain drain) by constructing an outstanding scientific device and enabling world-class research by scientists in a diverse range of fields including biology and medical sciences, materials science, physics and chemistry, and archaeology; and (2) "Build scientific links and foster better understanding and a culture of peace through scientific collaboration. As the language of science is universal, scientists can try to build a bridge of understanding and perhaps trust for the benefit of all."

SESAME is the first major collaborative research facility in the Middle East and it is being formed following the success and organization of CERN as a model.

SESAME is being built using the CERN model for regional collaboration and scientific success. In addition, being undertaken in a region with so many long-standing political issues, it is an inspiring model how to bridge these differences. The project continues to face challenges and uncertainties, but a lot of progress has been made both technically and politically, due to the efforts of the members, especially Jordan. The enthusiasm of the scientists involved and the widespread international support have been keys to convincing the member governments having enormous political differences to collaborate and jointly provide resources for SESAME. This is a model and an existence proof that governments in the Middle East can work together on joint problems.

Science for Diplomacy: Long Term Benefits—Physics has proven to be a field where major nations are effectively pooling resources to develop the most advanced and ambitious forefront scientific instruments in the form of large particle accelerators, LIGO and large astrophysics facilities. The broad and open participation in physics research has provided a very successful model of Science for Diplomacy. The next generation of facilities is being developed through a truly global model, where the ideas, concepts, design and implementation are being done through global collaboration. The concept is being extended to building similar collaborative structures for particle accelerator facilities in less developed countries.

The most important benefit of the collaborations and partnerships formed for carrying out particle physics is less tangible, but very real. The close collaboration of particle physicists from all over the world to carry out today's research is creating a generation of scientists, for whom, working together across borders to solve common problems is both natural and effective. Hopefully, these attitudes can spread to influence positively countries working together on common problems, whether they be climate change or nuclear disarmament.