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Open Skies Policies in Astronomy: The Growing Need for Diplomacy on the Final Frontier

Jean-Christophe Mauduit

Astronomy and diplomacy have always been interwoven, from early international scientific collaboration and the first international NGOs in the twentieth century to twenty-first-century multinational projects and the rise of global astronomy organizations. The growing scale and cost as well as the need for cutting-edge technology have necessitated larger numbers of partners in astronomy collaborations. As a consequence, observing time on telescopes is being divided among various national users. Today, the astronomy community is thus nearing a shift regarding its global, inclusive character, and its own internationalization could have important ramifications for open access to astronomical facilities. This paper explores issues related to international funding of large astronomical facilities and the associated role for diplomacy.

Astronomy and Diplomacy: A Historically Tight Relationship

Astronomers have always communicated and collaborated across nations, exchanging ideas through letters but also traveling to visit one another or teaming up on scientific projects and expeditions. Historically, astronomers crossed

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borders relatively easily and even became associated with kingdoms far from their homelands: Tycho Brahe, the famed late sixteenth-century Danish astronomer, eventually became the official astronomer of the Holy Roman emperor Rudolph II, in Prague, working with the German astronomer Johannes Kepler. Similarly, in 1676, the Danish astronomer Ole Rømer was the first to calculate the speed of light, while working at the Paris Observatory—itsself established and led by Giovanni Cassini, an Italian astronomer who served as the royal astronomer to France’s King Louis XIV.

As early as 1761, the transit of Venus across the Sun, critical for enabling astronomers to calculate the size of the solar system, led to international coordination. Toward the end of the nineteenth century, the *Carte du Ciel*, a project through which participants sought to map millions of stars, thus involved twenty observatories on virtually every continent. Upon invitation by the French Ministry of Foreign Affairs, whose minister opened the meeting, thereby signifying its diplomatic importance, the 1887 conference at the Paris Observatory included thirty-seven foreign astronomers, some of whom were officially sent endorsed by their governments to participate in the project and help construct the needed instruments.

Given its inherent transnational nature and the need for telescope observations around the globe, astronomy quickly emerged as a pioneer of large international scientific collaborations. It is thus unsurprising that the International Astronomical Union (IAU), founded in 1919, was one of the first such scientific entities created and one of the earliest members of the International Council for Science. Even though the IAU is technically an international NGO, the basic unit for membership, interestingly, is a member state. For astronomers to participate, governments have always had to establish a delegation and to directly contribute to the institution’s finances. In this context, it has been argued that the IAU is “an institutional and ideological expression of scientific diplomacy” and that astronomers “behaved like ambassadors of their own country” and wanted to be at the “center of attention in scientific and diplomatic negotiations.” Throughout its history, the IAU has acted to protect international collaboration in astronomy during times of tension (e.g., organizing meetings involving astronomers from the opposing sides in the Cold War or, more recently, pursuing links with astronomers from the Democratic Republic of North Korea). This purpose was enshrined in the first statutes adopted by the IAU, on July 26, 1919, as it sought “to facilitate the relations between astronomers of different countries where international co-operation is necessary or useful.” Similarly, American astronomer George Ellery Hale is known for his post-World War I advocacy of reconciliation between scientists of the Allied and Central Powers.

Privately Funded, Elite Astronomy: The Pre-WWII U.S. Case

In the interwar period, George Hale was also a prolific founder of prestigious U.S. observatories such as Yerkes, Mount Wilson, and Palomar. Many of these were set up through private funds—e.g., by the financier Charles Yerkes, the industrialist Andrew Carnegie, and the Rockefeller Foundation. Indeed, before World War II, the field of astronomy in the United States was largely privately funded, with major optical instruments constructed and operated by universities or a consortium of universities, using endowments from private foundations. Use of these telescopes was generally restricted to the community they served, even excluding other astronomers within the same nation. Although publicly funded telescopes eventually became integral to post-WWII astronomy, the private component persisted throughout the twentieth century and still exists today. For example, the two Keck telescopes—built atop Hawaii’s Mauna Kea in 1993 and 1996, respectively—were made possible by private grants totaling more than \$140 million through the W. M. Keck Foundation and are currently operated by the California Association for Research in Astronomy (consisting of the California Institute of Technology and University of California). Because of the private nature of the funding, these telescopes have traditionally been, and still remain, closed to scientists outside the participating institutions, despite a vision statement promoting “a world in which all humankind is inspired and united by the pursuit of knowledge of the infinite variety and richness of the Universe.”

Access to these observatories by astronomers outside a given private collaboration is sometimes possible via financial contributions or time-exchange programs negotiated by universities (e.g., Swinburne University, Yale, and the Australian National University) or agencies, either domestic (National Aeronautics and Space Administration [NASA], National Optical Astronomy Observatory [NOAO]) or foreign (National Astronomical Observatory of Japan/Subaru Telescope). Time-exchange programs set aside a certain number of hours or nights on their respective instruments for the exclusive use of parties to the reciprocity agreement. Therefore, these programs are typically only available to astronomers whose country or institution has desirable collateral instruments—or, alternatively, to those whose observatories can restrict astronomers from using these elite instruments in the first place. This has unfortunately created situations in which U.S.-based astronomers without access to Keck have been asked to apply through time-exchange programs only, thereby discouraging good relations and having an overall negative impact on science.

The Realm of Domestic Funding and Open Skies Policies

In response to the restrictive nature of privately operated telescopes in the United States, astronomers outside these elite institutions pushed for the creation of national observatories. Thus were established, after World War II, the NOAO and the National Radio Astronomy Observatory (NRAO)—also among the first National Science Foundation (NSF) entities to be federally funded—with the aim of giving all U.S. astronomers access to top facilities. These observatories quickly adopted a so-called open skies policy (OSP), which guaranteed any researcher, U.S. or international, equal and free access to the federally funded NOAO/NRAO telescopes.

Although it is difficult to track the original impulse for an OSP, the idea may well have emerged from the early frustrations experienced by U.S. astronomers, who in turn felt international astronomers should not be excluded from accessing these facilities. Some in the astronomy community specifically credit radio astronomers for facilitating such international open access. Yet regardless of its origin, an OSP allows for the best science to be carried out. Through such a policy, any astronomer in the world with a groundbreaking idea can gain access to the specific instrument needed to carry out his or her research. Since the postwar period, these OSPs in astronomy have been common U.S. practice, and while they have mostly been *ius non scriptum*, they have been alluded to in reports of the NSF's Division of Astronomical Sciences, and largely followed by federally funded agencies (NASA's Hubble Space Telescope, for example, among the most expensive U.S. astronomical facilities, is open to any astronomer in the world). Given the increasing number of international projects and organizations—and the diversity of funders, who are not necessarily attuned to the idea of open skies—these guidelines have since been made explicit in a 2014 report by the U.S. Astronomy and Astrophysics Advisory Committee (AAAC). The report lays out “Principles for Access to Large Astrophysics Projects and Facilities,” summarized as follows:

The best science relies upon selecting the most compelling astrophysics investigations. Access to a large astrophysics project or facility (typically observing time) should be allocated through an open, merit-based process, recognizing that some level of preferred access may be reasonable for the implementing consortium and the funding partners to reap the benefits of their telescope investments. Calls for proposals extending beyond the implementing consortium should be open to the global astrophysics community.

It should be emphasized that such principles not only keep science open-access and merit-based, they also ensure that researchers in less-advanced countries—which cannot fund major telescopes or be part of international collaborations—

have access to the instruments they need to carry out their research. Open access also enhances scientific collaborations between local and international researchers, and serves the goals of public diplomacy. For example, as a result of its open access policy, India's Giant Metrewave Radio Telescope significantly increased the country's exposure to top international scientists who sought to use the telescope—thereby raising the number of international collaborations, boosting cross-pollination of ideas, and so forth. It also enhanced India's astronomy research prestige on the international scene, with the rate of more than 50 percent foreign, versus domestic, proposals attesting to the instrument's quality. Similarly, the Japanese Subaru telescope, from the National Astronomical Observatory of Japan, features an open access policy that promotes Japanese researchers' international collaborations:

About 65% of total nights will be assigned to Open Use Proposals. Although Subaru Telescope is entirely funded by the Japanese government, we also invite proposals from the international community. Limited number of nights are available for such international. Non-Japanese researchers are encouraged to submit their proposals in collaboration with Japanese researchers.

Despite their clear advantages, the AAAC's OSP guidelines are nonbinding, even as they offer a road map for U.S. agencies. The AAAC further states that "there may be grounds for justifiable deviations from these principles." Such language stems from a changing environment, mainly connected to the growing cost of related projects, with a corresponding need for large numbers of international funding partners. For example, the billion-dollar Giant Magellan Telescope project, for which commissioning is scheduled to begin in 2022, would be a partnership involving the United States, Australia, Brazil, Korea, and Chile as the host country. Similarly, the Thirty Meter Telescope, planned for construction in Hawaii, would cost upwards of \$1 billion and feature not only nations—e.g., Japan, India, China, and Canada—but also the Gordon and Betty Moore Foundation, Caltech, the University of California, and others. These partners, in turn, would most likely want a certain return on their initial, significant investment. One of the first major international organizations in astronomy, the European Southern Observatory (ESO), can help shed light upon the inner workings of such complex future international projects.

Early Regional Collaboration: The European Southern Observatory

The first international astronomical organization, the ESO, was created by international treaty on October 5, 1962, ratified by the Netherlands, Sweden, the Federal Republic of Germany, France, and Belgium. The treaty eventually entered into force on January 17, 1964. Its inception is itself the result of diplomacy for

science, in the post–World War II context of enhanced collaboration following the U.S. agenda for European integration. Interestingly, without an initial grant by the U.S.-based Ford Foundation, the ESO might never have come into being. The goal of this European organization was to give EU astronomers access to the skies of the southern hemisphere. In its modern form, the ESO is supported by fifteen member states (comprising about 30 percent of the world’s astronomers), but other member states outside Europe, such as Brazil, , may soon join.

The ESO has some of the most powerful and highly sought-after telescopes and other instruments in astronomy. For example, the Very Large Telescope (VLT) consists of four unit telescopes 8.2 meters in diameter and has been called the “world’s most advanced visible-light astronomical observatory.” ESO facilities are technically open to astronomers from any institutions, as “proposals for observing time may be submitted by scientists from any institution.” However, proposals submitted by teams where “at least two-thirds of the applicants are not affiliated to ESO member state institutes” can only be accepted if:

(1) the proposal has to be scientifically outstanding; (2) the required telescope/instrumentation is not available at any other observatory accessible to the applicants; (3) if similar proposals of ESO member states and non-members state [sic] proposals are rated equally, preference will be given to the ESO member state proposals.

These ground rules suggest that breakthrough science led by non-member-state researchers can likely be achieved at the ESO. However, given that the “outstanding” level of any proposal is left to the discretion of the observatory’s Time Allocation Committee, and without any public access to statistics online, assessing the level at which these international astronomers can actually compete with ESO member-state astronomers is difficult.

Also notable is that Chile, as the host country of ESO telescopes, enjoys a special status in the international organization, with 10 percent of observing time reserved for researchers at Chilean institutions. Such terms have historically been negotiated by the University of Chile. Chile’s position has prompted foreign researchers to flock to the country, and Chile’s astronomy field to develop rapidly, while also creating long-lasting ties between Chilean and European researchers. This scenario has not, however, sparked Chilean engagement with its neighbors such as through invitations to share part of this reserved time.

The Rise of Bilateral and Multilateral Agreements: Gemini and ALMA/LLAMA

At the turn of the twenty-first century, astronomical instruments, ground- or space-based, grew increasingly expensive and out of range of traditional domestic funding for most countries. In addition, the complexity of these instruments required a diversity of technologies (e.g., adaptive optics, multifiber spectrographs, submillimeter bolometers) not necessarily available in a single country. Individual governments have, as a result, found it more and more difficult to single-handedly fund an observing facility. This trend has led to a multitude of international projects and ever closer international collaboration when building astronomical instruments. The AAAC likewise advocates such a course as “community-wide coordination and collaboration,” recommending “jointly developing an astrophysics project as a partnership or choosing unique astrophysics projects that are complementary,” and in turn preventing unnecessary duplication of instruments. Such shared efforts are only possible, however, when OSPs—or at least bilateral or multilateral agreements—are in place.

International coordination and collaboration, such as that between the United States and Australia, are largely adopted as a strategy to save money and advocate greater collaboration. The United States invoked both such explanations in capping its participation in the Gemini Observatory project at \$88 million, instead of the \$144 million requested by the NSF. This reduced financial commitment compelled American astronomers to seek out other international partners. The Gemini Observatory, with its two 8.1-meter-class telescopes, one in the northern hemisphere in Hawaii and one in the southern hemisphere in Chile, is thus now an international collaboration among the United States, Canada, Brazil, Argentina, and Chile (the United Kingdom dropped out in 2012 for lack of funding). While the project is international in nature and certainly creates deeper ties between the participating countries, observing time has been allocated in proportion to each participant’s financial stake.

Another more recent example of international partnership, involving Europe, the United States, Canada, Japan, South Korea, Taiwan, and Chile, is the Atacama Large Millimeter/submillimeter Array (ALMA), a radio interferometer telescope consisting of sixty-six antennas sitting at an altitude of 5,000 meters in the north of Chile’s Atacama Desert. Article 21.2 of the 2003 “Agreement between the United States of America and the European Southern Observatory” for ALMA states, “Observing Time available to the Parties during Operations shall be divided between them in equal shares, and distributed equitably according to the seasons of the year.” According to some sources, the addition of partners has resulted in guaranteed time observations at 37.5 percent for the United States and Canada,

37.5 percent for ESO member states, and 25 percent for East Asia (Japan, Korea, and Taiwan), and debates have surrounded the possibility of capping open-access time to astronomers outside the collaboration at around 3 percent. Yet while partner nations have guaranteed time, astronomers outside the collaboration can observe during the U.S. slot, given that the United States maintains an OSP. Hence, this ongoing debate, along with the possibility for outsiders to observe on U.S. time, might explain why Article 1.3 of the ALMA guide still stipulates that “users of any professional background, nationality or affiliation may submit an ALMA proposal. All proposals are evaluated on the basis of scientific merit and technical feasibility.”

From International Projects to International Organizations: SKA as a Case Study

In recent decades, quite a few astronomy projects have become international collaborations through bilateral or multilateral agreements. However, multinational projects could now be moving toward actually being treaty-based international organizations. While the ESO was originally limited to countries on the European continent, it is now evolving into a more international entity by including member states such as Brazil. Similarly, the Square Kilometre Array (SKA), a project to build the largest radio telescope on Earth, is currently becoming a formal treaty-based international organization. These trends reflect the globalization of collaborations and the growing need for diplomacy in astronomy.

The SKA now encompasses countries that span many continents, with its current members being Australia, Canada, China, India, Italy, New Zealand, South Africa, Sweden, the Netherlands, and the United Kingdom. On April 19–21, 2016, the SKA member states concluded their third round of negotiations, and the final treaty is expected to be signed in 2017. The SKA will also be the first astronomy project gathering three of the five major emerging national economies: India, China, and South Africa—the last of which will host the core of the radio telescope in its Karoo Desert. Beyond its member states, eight African partner countries will host parts of the telescope, given that hundreds of its antennas will be installed across the African continent. As such, the SKA is considered a flagship of “South African science diplomacy,” on the African continent as well as globally. These benefits of science for diplomacy are reflected in its draft prospectus: “At a time of tension in many spheres of international relations, SKA also offers a unique forum for positive interactions between a wide range of countries in pursuit of common scientific ideals.”

The involvement of so many partners, however, might actually be an impediment to international access. This is because the high expense associated with the project could prompt participating governments to demand guaranteed

time as a scientific return on investment, thereby restricting access and leaving little time to nonmembers. In this specific case, the U.S. astronomy community, the world's largest in numbers, might not have access to the largest radio telescope on Earth. Indeed, the United States has so far neither joined the project nor contributed financially to it, which, from the viewpoint of SKA-financing countries, could feed the notion that U.S. access would be unfair. Nonetheless, the SKA draft guidelines indicate that "provision will be made, consistent with the boundary conditions for access by Members, to enable access for non-member states."

Given that a few ESO member countries are also part of the SKA, providing partial overlap, a merger has been considered, although it is unlikely to go through. Instead, the two organizations will probably have to establish bilateral relations in the form of agreements or treaties.

Diplomacy Issues Stemming from International Projects: A Future Diplomatic Conundrum?

International astronomy projects will likely call for diplomatic adeptness in a number of areas. Following is a sampling of what stakeholders can expect.

The Growing Number of International Projects: A Summary of the Situation

With more and more international projects, along with massive investment from major developing countries and surging activity in less-advanced countries, astronomy is slowly entering a new age of globalized collaboration. Coordination, and therefore a greater diplomacy and dialogue, will be needed among partner countries, international projects, and international organizations to protect open access to astronomical facilities, allowing the pursuit of the best science possible.

For their part, instruments in astronomy are rarely redundant, and each, to some extent, has unique capabilities. Many cover only specific parts of the electromagnetic spectrum, and astronomical objects and phenomena usually need to be observed at various wavelengths, requiring a wide variety of instruments. For example, Japanese astronomers observing an object in the optical part of the spectrum on Japan's Subaru telescope might also need to observe it in radio wavelengths with the SKA to fully understand a certain phenomenon. As a follow-up, they may need access to other highly specialized instruments placed on very specific telescopes, such as the Multi Unit Spectroscopic Explorer (MUSE) at the VLT. To facilitate access for their respective communities to various instruments, international projects and organizations will therefore inevitably have to sign reciprocity agreements, memoranda of understanding, or even treaties. Such arrangements already exist today linking specific telescopes or international

projects (e.g., Keck-Subaru, ESO-ALMA). But the growing number of international actors will require greater negotiation and diplomacy to accomplish this science—between two international organizations (e.g., ESO and SKA) but also between international organizations and states (e.g., ESO and Japan, with its Subaru telescope). Senior astronomers, heads of astronomical institutions, and funding agencies all acknowledge the growing complexity of this situation.

Whereas this future enhanced diplomacy might address the question of access to different instruments between major nations and organizations, it does not yet properly address the inevitable elitism it will engender. Indeed, only countries able to afford instruments—and hence trade time and reciprocal agreements—will have access to astronomy research. Meanwhile, many other countries are attempting to intensify their astronomy and space-sciences capabilities for reasons as diverse as knowledge and technology development, the attracting of students into STEM fields, mastery of crucial satellite data, prestige through participation in major scientific discoveries, and broader international engagement in the sciences. On the whole, these countries will, unfortunately, be unable to cofinance or even join these large collaborations, leaving them without any bargaining power. Such countries, nonetheless, share the fundamental right to engage and participate in science.

Policies in Astronomy: A Glimpse into the Future

As mentioned earlier, large international astronomy projects usually remain somewhat open beyond their original funders. But without any transparency in actual time allocations, without clear international guidelines, and given a potential rise in undisclosed internal reciprocity agreements, it is unclear to what extent astronomy will self-regulate to enable access to astronomers worldwide. Toward such an end, several policy avenues exist.

The most prominent one is the U.S. OSP, which recently reiterated, and strongly recommended, international open access to all federally funded facilities (e.g., NOAO/NRAO/NASA) as well as maintenance, within reason, of this specific policy in international partnerships (e.g., ALMA). Hence, although U.S. instruments cost a great amount of taxpayers' dollars—to begin with, approximately \$2.5 billion for the Hubble Space Telescope—they remain open internationally. This model, if applied globally, would allow any astronomer to submit research proposals and observe on any telescope without the involvement of governments or private funders in the process. Such a merit-based, science-first approach would certainly simplify an otherwise increasingly complex situation if adopted worldwide. However, any country or international organization that would finance an instrument would most likely see a greater proportion of astronomers from advanced countries flooding

its observing time, which could pose a challenge for international organizations such as the SKA. In addition, the incentive for governments or institutions to fund large instruments would appear to diminish if access were universal. Given the rising number of actors in the field, the United States may itself have an interest in advocating such a policy, which would allow its astronomers access to the best facilities worldwide without necessarily assuming the funding burden. Nonetheless, countries like India, with its Giant Metrewave Radio Telescope, have successfully taken that gamble in the past. The question remains whether the Indian government, as a financing member of the SKA, would advocate for open access to this international telescope.

Another potential avenue involves pooling of resources. In order to gain access to major telescopes and to make up for their limited number of astronomers, certain less-astronomically-advanced countries could pool resources to construct or use telescopes or even buy time allocations to compensate a consortium financially. Regional examples of this type of pooling include the Argentina-Brazil Large Latin American Millimeter Array (LLAMA) collaboration as well as the East Asian Observatory (EAO). In the former case, Argentina and Brazil pooled their resources to finance an ALMA antenna, potentially leveraging their way into the ALMA collaboration. Along with the general interest of this case, its “tech transfer” component bears noting, given that LLAMA purchased the antenna from the German manufacturer of the ALMA antennas. (Here, worth noting, the LLAMA purchaser will not necessarily reap a fair return on investment because the technology is not being developed locally and will only benefit scientists.) Similarly, the EAO is a regional collaboration within the East Asian region including China, Taiwan, Japan, and South Korea. The involvement of both China and Taiwan in this arrangement represents an interesting example of science for diplomacy, considering their historically difficult diplomatic relationship. This consortium now operates jointly the Hawaii-based James Clerk Maxwell Telescope (JCMT), which was funded originally in 1987 by a partnership of the United Kingdom (55%), Canada (25%), and the Netherlands (20%). Scientific proposals to the JCMT are restricted to members of the collaboration or allowed through reciprocity agreements. While this option has the advantage of bringing together countries in regional proximity, usually with other scientific collaboration networks in place, it is not based on science merit: only countries that can pay for their time can perform astronomy.

Astronomy Leading by Example?

Astronomy continues to be a pioneer of large globe-spanning collaborations, and an ever-growing multiplicity of actors is needed to build these ever-more-complex instruments. Indeed, new international projects, too, are becoming more

complex in their membership and funding, involving not only nation-states but also private foundations and international organizations, as with the future Thirty Meter Telescope and Large Synoptic Survey Telescope projects. The challenges tied to addressing the intricate related issues will therefore inevitably rise.

To prepare for these upcoming challenges, the astronomy community must engage in international dialogue now. Whereas existing forums for such dialogue include the OECD Global Science Forum and UNESCO, the most prominent and internationally inclusive astronomy venue is the IAU, which can issue international guidelines through its General Assembly. These guidelines, though nonbinding, can gain de facto international recognition. As it stands, policies are left to countries or organizations that might have differing agendas.

In addition, the issue of open access might be easier to address in the astronomy field than in other fields, given its potentially less-direct repercussions on technology and economic dominance. This is particularly true when compared to international collaborations such as the International Thermonuclear Experimental Reactor project. The solutions identified at the international level for astronomy could set a precedent for other scientific fields. Faced with this science diplomacy challenge, will astronomy lead by example? **SD**

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