FM13
Global Coordination of International Astrophysics and Heliophysics Activities from Space and Ground

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FM13. Global Coordination of International Astrophysics and Heliophysics Activities from Space and Ground

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International collaboration has always been an important part of research in astronomy, astrophysics, and heliophysics. Over the past two decades, the increasing complexity and cost of new facilities, the constrained amount of funding available from individual sources, and the rapidly increasing volume of data produced by newer facilities have made international collaboration on large ground- and space-based facilities essential to moving the fields forward. As international cooperation becomes commonplace, data-sharing policies have become ever more important. All IAU members have a stake in the policy decisions made by nations and various scientific consortiums concerning data access and international collaborations. IAU FM13 aimed to provide a forum to discuss how to improve coordination of global strategic planning in astronomy, astrophysics, and heliophysics in order to maximize the scientific return from research facilities.

As astronomical projects grow larger, international collaboration has become essential for both ground and space-based astronomy and heliophysics. Europe -via multiple avenues like the European Commission and Horizon 2020 program- by its very nature has been a model of international cooperation for decades now, but a model that is not easily applied outside of the continent on a broader scale. The European Southern Observatory, CERN, and other projects demonstrate that there is much to learn from this regional space power and lessons to apply to other parts of the world separate from even the success of a fully functional space program (the European Space Agency). Major observatories such as ALMA, HST, SOHO, Planck, and Herschel are international projects with many partners making important technical, scientific and financial contributions.

Meanwhile, countries with starting, or increasing, investments in the space sciences are looking for ways to leverage precious resources by getting involved in international collaborative efforts. However, with a patchwork of national policies concerning data and facility access, as well as little in the way of international lessons learned or expectations for involvement in large-scale observatory projects, it is difficult to gauge the true value of involvement at the outset. At present, the U.S., Europe, Japan and China all conduct their own independent long-term planning process. In the United States, the planning is done primarily through its decadal survey process. ESA plans its major long-term projects as part of its its Cosmic Vision strategic plan, in particular the large L2/L3/L4/L5 missions. Japan has its own national planning process that spans much of its research program.

The 2010 U.S. National Academy of Sciences (NAS) astronomy and astrophysics decadal survey, New Worlds, New Horizons in Astronomy and Astrophysics, states that, "An important characteristic of contemporary astronomy, and therefore of this survey, is that most research is highly collaborative, involving international, interagency, private, and state partnerships. This feature has expanded the scope of what is possible but also makes assessment and prioritization more complicated." (p. xvi). Similarly, the 2012 U.S. NAS heliophysics decadal survey, Solar and Space Physics: A Science for a Technological Society states that "A comprehensive investigation in solar and space physics cannot take place in isolation but should be part of an international effort, with different countries able to bring to bear unique geographic advantages, observing platforms, and expertise", and "while participation in international solar and space research projects could be accomplished through numerous individual, bilateral initiatives and agreements, the overall impact would be increased by coordinated agency involvement".

How do we coordinate these international planning efforts? How can and should we share the data produced both by these international collaborations and by other projects? How should we provide access to these facilities? Furthermore, the huge volume of data produced by current and future observation systems necessitate modes of research that have not heretofore figured prominently in astronomical and heliophysical research enterprises. The Daniel K. Inouye Solar Telescope (DKIST) will collect 3.65 petabytes in its first year of science operations while the Large Synoptic Survey Telescope (LSST) alone will produce 30 TB of data per night.

The potential benefit of enhanced international coordination is high. Much can be learned in astrophysics by adopting a broad-scoped approach, in which ground and space-based facilities look at the same target with different wavelengths, timescales and technologies. Such an approach requires more resources than a single nation could maintain. Heliophysics has the added issue of coordinating truly global ground-based systems and space missions in various regions of the Sun-Earth system. In this context, Earth is an additional spacecraft embedded in its own space plasma environment. For the first time in history, we are capable of looking at a complicated coupled space system in its entirety, from the sun through the heliosphere, magnetosphere, ionosphere, and atmosphere down to the biosphere, in which we try to survive the present climate change. To study and understanding the system around us is the ultimate benchmark to be able to understand other star-planet systems.

Large progress towards combining international ground- and space-based assets has been made by, for example, the multi-spacecraft Cluster and THEMIS coordination with ground-based assets. Additional, truly global instrument networks have been developed by the community in international collaboration, through more-or-less grassroot activities, or in recent years through the International Living with a Star program on agency level. Nevertheless, we still have major gaps in our coverage and understanding of the Sun-Earth system as an entity.

At the XXXth GA, Focus Meeting 13 comprised six focused panels. Each of the panelists made initial remarks and then we had an engaged discussion led by the moderator and involving the panelists and the attendees.

The meeting opened with a panel moderated by Roger Davies on "Large international Space Projects: From Black Holes to Cosmology" at 10:30 on Monday August 30. Thomas Zurbuchen opened the session with a discussion of the role of decadal surveys in prioritization, the importance of independent costings in evaluating missions and the importance to NASA of international contributions. Günter Hasinger talked both about international collaboration and ESA and the excitement of the multi-messenger quest for high redshift black holes. Stefano Vitale provided an overview of the LISA project. He emphasized that unlike most astronomical projects, LISA's data is a time series. He discussed the potential role of multiple teams in the analysis. Zhan Hu provided an overview of the Chinese Space Station Optical Satellite (CSS-OS). He discussed the possibility of international contribution of new instrumentation. CSS-OS will be a serviceable mission with a long planned lifetime. He discussed pixel level co-processing with other upcoming great surveys such as LSST, Euclid and WFIRST. He ended with a discussion

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of the challenges of serving data to the community. Didier Barret provided an overview of the Athena mission and described its current status. Jeff Kruk followed with a discussion of the WFIRST mission. Ryan Hickox described the Lynx X-ray mission concept, a proposed mission that will be revised in the upcoming US decadal survey. He emphasized the search for the origin and growth of supermassive black holes and the connections with other project, particularly the upcoming major ground-based programs.

After the initial panel presentations, the attendees and the panelists discussed open data and the coordination of future missions. We then had an energetic discussion of the role of proprietary periods. Zurbuchen asked, "do we need a year proprietary period?" He noted that it doesn't create the sense of urgency and that scientists have "the right to make a fool of themselves". Alan Title commented on the solar physics community experience with rapid data release. Dave Silva noted that for Target of Opportunity observations, it is essential to get the data out very quickly. Ken Sembach, the Director of Space Telescope Science Institute, commented that there is no HST proprietary period for big programs and only six months for small program. He stated that there is no evidence for damage from short proprietary period from HST. The discussion then turned to whether models and software should be made public. Stefano Vitale noted the importance of the models for projects like LISA.

Athena Coustensis asked about the challenges for collaboration at the agency level. Tom Zurbuchen, the NASA Associate Administrator for Science, and Günther Hasinger, the ESA Director of Science, began by noting the importance of frequent informal communication on promoting and maintaining international collaboration Günter Hasinger described ESA plans for two medium class mission per decade, one ESA only and the other a likely collaboration with NASA on a big project, potentially one of NASA's big projects identified in next decadal survey. The discussion ended with comments on the importance of non-synchronicity in the prioritization process.

The meeting continued after lunch with a session on "Large international Space Projects: Opportunities for Studying Exoplanets, Planet and Star Formation". The incoming IAU President Ewine van Dishoeck chaired this session which brought together leaders of proposed long wavelength missions to discuss the science drivers for potential international projects. The presentations started with the exoplanet science case, summarizing and building on the dedicated Kavli-IAU workshop held in summer 2017 in Leiden, see arxiv.org/abs/1709.06992. Karl Staplefeldt introduced the big questions as well as an overview of the suite of new exoplanet missions on US side, from TESS to JWST and WFIRST, and on the European side from Gaia, to CHEOPS, JWST, Plato and Ariel.. These missions are steps towards answering "are we alone?". Jeff Kruk described the WFIRST exoplanet program, both coronagraphy (also as a technology demonstrator for future missions) and microlensing, with the latter program probing a unique part of the planet mass-orbital distance space . Karl Staplefeldt then presented the 4m HabEx mission, one of the study concepts for a future large US mission. Its main goal is to characterize our nearest planetary systems and detecting and characterizing a handful of ExoEarths. Starlight suppression at the 1e-10 level within 0.1 arc second needs to be achieved, either through advanced coronography or a free flying starshade. Thomas Henning then turned to the LUVOIR concept, after noting that ground-based ELTs and ALMA also will make important contributions to the scientific story. With 8-16m diameter and 4 scientific instruments, LUVOIR is more ambitious than HabEx and has a broader science case, including, for example, extragalactic UV spectroscopy and imaging. The larger aperture decreases the inner working angle so that significantly more exo-earth candidates are available for study. Thomas Henning stressed the importance of direct imaging spectroscopy, providing much more detailed exoplanetary atmosphere spectra than transit spectroscopy with its ppm depths can. The exoplanet discussion

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ended with a summary of the capabilities of the Origins Space Telescope by Ted Bergin. Origins operates in the mid-infrared wavelength range which includes strong, unique biomarkers for earth-like planets such as CH4 and O3. Ewine van Dishoeck stressed the need for broad wavelength coverage. The audience asked several questions of clarification and potential phasing of new missions. Also, critical technologies were discussed. Both HabEx, LUVOIR and Origins are study concepts that will be put forward to the US decadal committee.

The second part of this session centered on Star- and Planet formation. Doug Johnstone introduced the big questions, from the large scales of molecular clouds in our and other galaxies to the smallest scales of protoplanetary disks. Frank Helmich and Toru Yamada then jointly presented SPICA, a cooled 2.5m far-infrared mission and candidate for the ESA M5 slot with strong participation from JAXA. It would cover the wavelength range of 12-230 μm, in between JWST and Herschel/ALMA, with three instruments including a polarimeter to study magnetic fields in ISM filaments. Finally, Ted Bergin showed how Origins with its larger 6m aperture and 4 instruments covering 5-600 μm would be particularly powerful to address questions in star- and planet formation. He focused on the trail of water from clouds to disks and planets and the unique ability to measure gas disk masses through the HD line. With its higher spectral resolution and sensitivity compared with SPICA (which also highlights these science cases) it gains 1-2 orders of magnitude in limiting abundances. The importance of global collaboration and coordination for these missions, which is already happening, was stressed in the subsequent discussion with the audience.

On Tuesday, the focus meeting continued with a 10:30 AM panel on "Global Coordination of Ground-Based Astronomy" This session was a panel with leaders of the major next generation ground-based observatories, both the thirty-meter class telescopes and the large survey telescopes. Debra Elmegreen, the session chair, opened the session with a discussion of the importance of the global system and the history of the OIR system in the US. Xavier Barcons described the role of ESO, an intergovernmental organization that has now grown to 16 member states with the addition of Ireland, is building the ELT, a 39-meter telescope with built-in adaptive optics. The ELT is part of the broader ESO Paranal system. Ram Ramaprakash descried the efforts of the TMT partners (Canada, Caltech, China, India, Japan and University of California) to build the 30-meter telescope in Hawaii. He described the first light instruments, the infrared imager and the wide-field optical spectrometer, and the progress with the Hawaii lease. Pat McCarthy described the GMT partnership (Australia/Brazil/Korea/ASU/Texas/Arizona/Harvard-Smithsonian) to build its telescope on Las Campanas. The collaboration plans to complete the partial primary mirror array by 2024 and the full telescope by 2026. He noted that its GMT near infrared spectroscopy compares favorably with JWST (as does that of the other ELTs). Beth Willman introduced the Large Synoptic Survey Telescope and emphasized that it was a comprehensive system with 20% of the construction budget devoted to the data management system. She also introduced the National Center for Optical and Infrared Astronomy (NCOA), now in the planning stages, which will unify the U.S. share of Gemini, the National Optical Astronomy Observatories, and LSST for ease in management and coordination of operations and observations. Phil Diamond introduced the Square Kilometer Array, an international project involving 600 scientists from Australia, Canada, China, France, Spain, South Africa, the Netherlands and New Zealand through a proposed treaty organization similar to ESO and CERN. The first phase of SKA will run from 2020 to 2027. Phase 2 will be a multi-billion dollar project that will build 2000 dishes across Southern Africa. The SKA will primarily divide its time among scientists from member countries with a modest amount of time available to international scientists outside the collaboration. Alan McConnachie introduced the Maunakea Spectroscopic

Explorer, a project in an early stage and working towards first light in 2026. The MSE will use a 11.25 meter primary and will have 4300 fibers to enable low moderate and high resolution spectroscopy. The MSE repurposes the CFHT infrastructure/site and will be lighter than CFHT. McConnachie emphasized the importance of getting spectroscopy to complement the upcoming large imaging surveys. During the discussion, the panelists and the audience discussed the role of small institutions in these big projects, the lack of open data access and/or long proprietary period for some facilities and the pro/cons of international treaty versus limited liability company for building these large projects.

After lunch, Patricia Whitelock moderated the panel on "Engagement of countries with emerging astronomical communities in international efforts & Governance of International Projects". These panelists asked "Are there ways to better coordinate the major national and international funding agencies and also ground and space-based programs? What guidance for future international projects can be derived from studying the governance, fund-raising and project management strategies of past and current projects? What questions are so important and challenging that they can only be addressed by coordinating truly global resources?" This session also discussed possible ways to coordinate the engagement of astronomers in countries that do not have the resources to be major partners in large ground facilities and space missions. Ron Ekers began the discussion by noting the shared radio astronomy culture. He reviewed the OECD 1998 report and the role of the SKA pathfinders. Vanessa McBride described SALT, MeerKat and big projects in Africa. She contrasted South Africa's long tradition in optical astronomy which helped it build SALT with the lack of a long tradition in radio astronomy. She described the combination of the SALT experience, government support, and the MeerKat's role as a precursor is enabling South Africa's role in SKA. She described the government support of young astronomers and training programs and the development of the African VLBI network. Silvia Torres-Peimbert described the possible routes for small countries, such as Mexico, to participate in large projects. The options include participate in large projects directly: this approach requires money and expertise. An alternative is to construct small dedicated telescopes. While this approach is less expensive, it still requires expertise. She also noted the need for training options for students and scientists to work with the large data bases. She described two major Mexican projects, the Large Millimeter Telescope and the High Altitude Water Cherenkov (HAWC) Observatory. Peter Michelson described lessons learned from the FERMI space telescope involving emerging countries. Bob Williams discussed the role of the IAU working group and the need to involve more representatives from emerging countries. During the discussion, Beth Willman stressed the need to fund under-resourced communities and to make astronomy more inclusive. We also heard about opportunities for astronomy in Ethiopia and the possibilities of using Kilimanjaro as a site.

On Wednesday, FM13 turned towards the Sun with a session on "International Efforts in Heliophysics". Christina Mandrini moderated this panel at 15:30-17:00 on the science drivers on the ground and in space in the era of the Solar Orbiter and the Daniel K. Inouye Solar Telescope (DKIST). Valentin Pillet opened the session with an update on the construction of DKIST. DKIST has implemented a critical science plan and is coordinating its science program with ALMA. John Morgan described the Murchinson radio observatory, a multi-purpose science observatory that includes epoch of reionization and ionospheric physics. Masaki Fujimoto discussed post-Hinode space solar physics. He emphasized the key questions for future missions: the mechanism driving the solar cycle and irradiance variation. Future missions would need to probe the Sun at higher resolution so to understand the physical mechanism on the elemental scales. This will be enabled by high throughput spectroscopic telescopes with improved temporal resolution. Daniel Muller described the Solar Orbiter with its planned launch in Feb 2020. The mission will address "how does the Sun create and control the Heliosphere and why does solar activity change with time?" The mission will act in synergy with Parker Solar Probe and near-Earth assets such as SDO, DKIST and PROBA-3. Lika Guhathakurta concluded by discussing Heliophysics as a scientific discipline.

FM13's final session discussed "Gravitational Waves and Transient Science". Pietro Ubertini moderated this discussion of new opportunities for gravitational wave astronomy, Fast Radio Bursts, and opportunities for coordinated follow-ups in the LIGO/VIRGO/LSST era. He began the session by discussing the recent observations of GW 170817/GRB 170817A, a wonderful example of international collaboration. Fermi and Integral operating 100,000 km apart saw the same signal. Over 3500 scientists worked together to use a vast array of facilities to monitor the evolution of this event and produce transformative science. Matt Evans discussed the LIGO project. He noted the cultural changes from 2015 (before the detection of the binary black holes) to today. He described the next generation of detectors that will enable the detection of events out to cosmological scales.

Marisa Branchesi described the next run of LIGO/VIRGO. During this run, the detections will be announced to all. While the rates are uncertain, she anticipates that there will be 1-15 neutron star-neutron star mergers and tens of black hole/black hole mergers. How will the astronomy community follow-up on these events? In the discussion, David Silva noted that this upcoming set of events will be dimmer and will require 4m and 8m class telescopes. He stressed the need to prioritize the GW event follow ups. In the discussion of follow-up observations, Tim de Zeeuw, the former ESO Director General, noted that various pieces of the optical system have been in place for 20 years. For example, there are rapid response tools at VLT. Marisa Branchesi noted that the expertise of the GRB and SN community was essential for the follow-up and added that the challenge for future will be localization. Chryssa Kouveliotou emphasized the importance of instruments that will enable localization. Alvaro Gimenez, the former ESA Director of Science, discussed the role of space observatories in the localization. He emphasized the importance of the gamma ray burst detection of the counterpart, the dimmest and nearest GRB.

David Buckley's presentation asked, "How do we deal with transient follow-up in the GW/Multi-Messenger/LSST era?". There will be an enormous jump in the number of transients. This generates a need for tools to automatically follow-up on the fast transients with small telescopes. He described the aspirations at South Africa Astronomical Observatory (SAAO) to make the whole Sutherland site an integrated intelligent machine for transient follow-up.

Suijian Xue described the significant impact that the gravitational wave detection has had on Chinese astronomy. He described the plans for emerging observatories for multi-messenger astronomy on the "roof of the world", the Ali Observatories in Tibet. This site is located in the West of Tibet at the altitude of 5100 meters. Plans for this site include HinOTORI, a 40 cm robotic imager (with Hiroshima University) and a 2 meter telescope operating as part of the Las Cumbres Observatory Global Telescope (LCOGT) system. This site is also a potential location for CMB polarization experiments. The site is one of the four driest sites in the world and has the potential to be the "Atacama" of the North. He expressed an eagerness for international collaboration at the site.

The next several talks discussed plans for the next generation of gravitational wave detectors . Matt Evans described the U.S. roadmap of first upgrading LIGO and improving its sensitivity by factor of 2. Next, the program of building "Voyager" in the last 2020s. In the 2030s, the community aims to start construction of a detector capable of detecting events out to redshifts of 10-20. Marisa Branchesi described the formation of the Einstein Telescope consortium in Europe with possible sites in Hungary, the Netherlands

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and Italy. Alvaro Gimenez described the LISA pathfinder, its challenges in 2011, and its role as a precursor to LISA. Suijan Xue described China's plans to develop mission concepts that are broadly similar to LISA and to the Einstein Telescope.

Following the meeting, the FM13 working group met and made a number of recommendations for the upcoming year:

• We have opened the working group to all IAU members and encourage interested IAU members to contact David Spergel (dns@astro.princeton.edu) or Roger Davies (roger.davies@physics.ox.ac.uk).

• We have begun planning for a Kavli Meeting on transient science. The meeting will be held in Capetown in January 2020. The coming decade will be a very exciting time for transient science. We anticipate a rapid pace of transient discovery from LSST, LIGO, high energy missions, and radio observatories. The international astronomy community will need to be ready to follow-up on the most interesting of these events.

• We are planning on upgrading our website so that it can serve as a marketplace for international projects, particularly those seeking new partners.