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미리내 The Milky Way

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#IAUGA2022 is an official hashtag of the IAUGA2022

SOLAR PHYSICS IN THE 2020s: HOW WE GOT HERE

Valentin Martinez Pillet, S372 plenary speaker

In the late 80s, various European countries built a series of solar telescopes in the Canary Islands. The Swedish Tower at La Palma (50cm, now 1m) focused on obtaining the highest quality images of the solar surface. The German telescopes (45-70 cm) on Tenerife in high resolution spectroscopy. The French-Italian THEMIS (90cm), also on Tenerife, specialized in polarimetry. The solar group at the Instituto de Astrofisica de Canarias, where I began my career, contributed instrumentation for these telescopes by providing polarimetric capabilities to those that didn't have it from the start. In this intellectually vibrant environment, I forged my career path that also benefited from a postdoctoral stay in the US, where I participated in the commissioning of a polarimeter for a solar telescope (76cm) operated by the National Solar Observatory (NSO) in New Mexico. Diffraction limited imaging and spectropolarimetry are crucial to understand solar magnetic fields at their fundamental scales. The photon mean-free path and the scale height in the solar photosphere are about 100km. With typical convective velocities of several km/s, the evolutionary times scales are of a few tens of seconds. Solar magnetic concentrations polarize only one out of several thousands of photons in a typical spectral line. Detecting them is crucial to understand how the Sun creates its magnetic environment. Using standard formulas, it is not too difficult to see that this detection needs telescopes of several meters of aperture. However, the use of vacuum systems prevented at that time building capable telescopes above 1m. One solution adopted by solar astronomers was to fly in space or in stratospheric balloons telescopes as large as realistically possible. The SUNRISE telescope (1m, led by Germany) flew for the first time in 2009 and, at that time, it was the largest solar telescope equipped with a spectropolarimeter, that I built, and that obtained data that is still unsurpassed. SUNRISE obtained the most detailed animations of the weakest known manifestation of tangled, mixed polarity, magnetic fields. Our best hope today to make critical progress in our understanding of solar magnetism is the recently built Daniel K Inouye Solar Telescope (DKIST, Maui, Hawai'i) operated by the NSO since late 2021. Having eliminated the need for vacuum systems, the National Science Foundation (NSF) DKIST has a 4m aperture and will provide the required on-disk resolution and sensitivity. Additionally, NSF´s DKIST will observe the solar corona thanks to its unique off-axis design and occulters that block the direct light from the Sun's disk. This ability to observe the off-limb corona comes at a time when NASA and ESA operate two encounter missions, Parker Solar Probe (PSP) and Solar Orbiter, that approach the Sun and measure in-situ the pristine consequences of the magnetic interactions that create various forms of the expanding Sun. By combining in-situ measurements of the near-sun plasma and detailed remote observations of multiple layers of the Sun, DKIST, PSP, and Solar Orbiter form an unprecedented multi-messenger constellation to study the magnetic connectivity inside the Sun's astrosphere.

Imaging Black Holes: Building the Event Horizon Telescope

Sheperd Doeleman, Public Lecturer

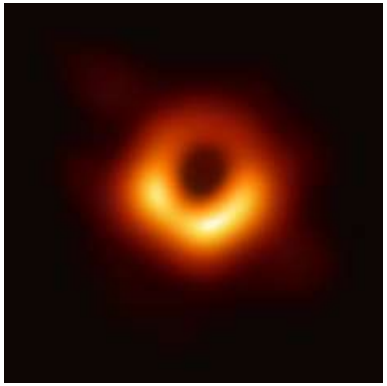


Image of M87

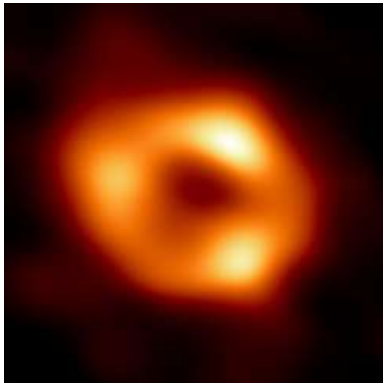


Image of Sgr A*

Earlier this year the Event Horizon Telescope (EHT) Collaboration announced the first image of SgrA*, the supermassive black hole at the center of the Milky Way. An unmistakable ring shape revealed the black hole 'shadow': a feature long-predicted by Einstein's gravity. By confining over 4 million solar masses to lie within the photon orbit, this result presents us with the best and clearest evidence for the existence of supermassive black holes and their cosmic role at the centers of galaxies. Together with the image of M87 (6.5 billion solar masses), announced in 2019, EHT black hole images now confirm strong-field GR predictions over more than three orders of magnitude in mass. The EHT has done this by creating an Earth-sized virtual telescope that links radio dishes around the world, synchronized by GPS and stabilized with a network of atomic clocks.

And this is just the beginning. The EHT has already mapped the magnetic field structure surrounding M87 through polarimetric imaging, and data from following epochs will soon enable us to precisely study black hole accretion and jet launching on horizon scales. More than this, the next-generation EHT project (ngEHT) will extend the observing frequency range, quadruple the bandwidth, and double the number of telescopes in the global array for unprecedented new movie-making capability. These advances set the stage for true black hole 'cinema' – high-fidelity time resolved video of the horizon – by the end of this decade.

I suppose my preparation for this type of work began in Antarctica, where I spent a year after my undergraduate degree running several atmospheric and physics experiments in challenging circumstances. In graduate school, I was extremely fortunate to work with Alan Rogers at MIT who introduced me to the magic of mm-wavelength interferometry. The next decade was spent developing and deploying ultra-wideband instrumentation to increase the sensitivity of planet-sized arrays, which led to the 2008 discovery of horizon-scale structure in SgrA* and the launch of the EHT. It has been a joy and privilege to work with the EHT community, now grown to over 300 members.

Apart from the scientific impact of these discoveries and new directions, a human dimension to these projects resonates with the curious public. This work has produced visual evidence of the most mysterious objects in the Universe – making real and distinct the limits of our understanding of fundamental physics. But it has also relied on coordinating resources and expertise from around the world: a hopeful example of how we can tackle seemingly impossible global challenges when a coherent vision binds everyone on the planet together.

Sheperd Doeleman, Founding Director of the Event Horizon Telescope

Activities of Division B Commissions and Working Groups

Figure 1. Starlink satellites and star trails in the Milky Way direction

Division Meeting B: Facilities, Technologies and Data Science	
START DATE	Friday, 5 August
END DATE	Monday, 8 August
ORAL SESSIONS	Room 101, Convention Hall, 1st Floor
POSTERS	e-Poster Zone, Convention Hall, 3rd Floor

For details on presenters, topics, and times see the online program on the GA website

IAU Division B, Facilities, Technologies and Data Science, has at present 4256 active members and 355 junior members. It has 8 participating Commissions with a total of 12 working groups (Division, Commission, and Inter-Commission). The Division Steering Committee prepared a program to present several relevant activities in its Commissions and working groups at the Division Days at the IAU GA.

Division B days will open with a Plenary Session (Friday August 5th at 10:30), where PhD winners of our Division in the last 4 years will present and discuss their scientific results. All topics are very timely and relevant in the present astrophysical landscape: Spectropolarimetric and imaging properties of Fabry-Pérot etalons; Laboratory studies of interstellar methane ice in the era of JWST; Exact wide-field interferometric imaging via distributed sparse image reconstruction; and The astrochemical factory: Producing the first biomolecule building blocks.

In the afternoon, activities will be split into two parallel sessions: **New Facilities and Growing Archives and History of Radio astronomy in Eastern Asia.**

In the **New Facilities and Growing Archives** sessions will focus on important developments in the field of Computational Astrophysics (Commission B1) and first results and properties of new relevant telescopes: the Iranian National Observatory 3.4m optical telescope, the FAST radio telescope in China, and the Imaging X-ray Polarimeter Explorer (IXPE). Furthermore, problems related to the SKA data reduction and important results from the SKA precursor ASKAP will be presented. Virtual Observatory (VO) science will be introduced and problems/solutions related to the rapidly increasing satellite pollution in radio and optical bands will be discussed (Figure 1).

In the **History of Radio Astronomy in Eastern Asia** sessions, coordinated by the WGHRA, the radio astronomy developments in the Republic of Korea, Japan, Taiwan and China will be presented. We like to draw attention to a talk on the history of space VLBI in Japan.

On Monday August 8th Commission B5 (**Laboratory Astrophysics**) will present and discuss its activity in Korea, South America, Japan, the US and Europe in the morning session with contributions from local people. A presentation on the relevance of Quantum Sensing for Astronomy will be given. At the same time in a parallel session, the working group **The Global VLBI Alliance** will present talks on main VLBI arrays: EVN, VLA/ngVLA, LBA, EAVLBI (Figure 2) and invite astronomers to join the GVA Science Forum.

In the afternoon session, the International **Virtual Observatory Activity** will be discussed and main principles will be presented. At the same time, the **UV working** group will discuss UV photometry, approved standards and their implementation.

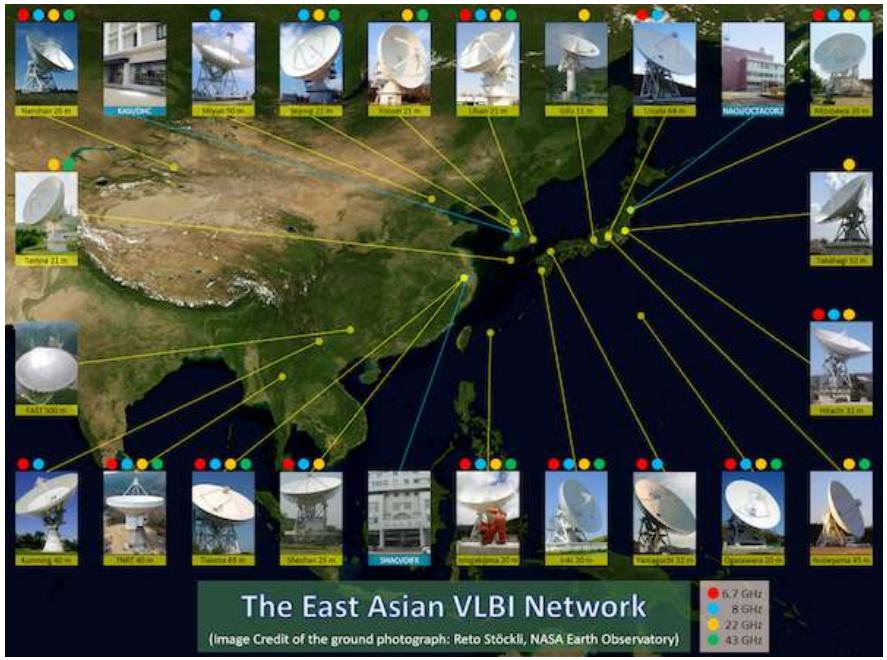


Figure 2. Concept map of the EAVN including the three correlator sites in China, Japan, and Korea. FAST 500 m telescope, which is to be used for EAVN observations at lower frequencies (< 1.6 GHz), and the Thai National Radio Telescope (TNRT), which is under construction, are also included in the map. Photograph of each radio telescope and correlator site are overlaid on 'the Blue Marble' image. Credit of the ground image: NASA's Earth Observatory.

Gabriele Giovannini was appointed in 2001 Full Professor in Astrophysics at the Bologna University. In the years 2010 – 2012 he was the Director of the PhD School in Mathematics, Physics, and Astrophysics of the Bologna University. In 2011 was named INAF representative in the RadioAstron International Science Council (RISC). He retired in 2020, and because of his activity, he was named Professor of the ALMA Mater (PAM), University of Bologna. He was the Past President of Commission B4 Radio Astronomy (2015-2018) and Past Vice-President of Division B Facilities, Technologies and Data Science (2018-2021) and now he is President of Division B.

Towards inclusion in astronomy education, outreach, history and heritage

The pandemic has had a profound effect on the way we, as science communicators or astronomers engaged in science communication, approach educational projects. Almost all in-person educational and outreach activities abruptly halted in March and April 2020.

The projects which suffered the most were those delivered in-person, some having to completely stop all activities. Many projects were either able to shift their activities online or change their activities sufficiently so they could be performed remotely, even if they had to pause their activities. Not all projects were successful and many also had to stop while cases of Covid-19 were high, those in the developing world were particularly badly affected.

Division Meeting C: Education, Outreach and Heritage	
START DATE	Friday, 5 August
END DATE	Monday, 8 August
ORAL SESSIONS	Room 104, Convention Hall, 1st Floor
POSTERS	e-Poster Zone, Convention Hall, 3rd Floor

For details on presenters, topics, and times see the online program on the GA website

In addition to the pandemic, social and cultural movements have also had a large impact on astronomy. It is important that we as astronomers, are fully aware and sympathetic towards indiginous concerns and these social movements. We need to be inclusive in the way we preserve the history of astronomy and tell the stories of different cultures.

The objective of this session is to open astronomical science to broader perspectives including gender, the role of native societies in preserving celestial heritage, and indeed how astronomy can play a decisive role as an open discipline in the development of science in all continents. Education and outreach should indeed play a role in that. We all live under one sky.

For the Division Days for Division C (Education, Outreach and Heritage) we wanted to shine some attention on some of these as well as providing practical lessons from the experiences of education and outreach practitioners had during the pandemic.

Edward Gomez is the education director for Las Cumbres Observatory and director of the Global Sky Partners programme. He is the vice-president of IAU Division C, an astronomer, coder, science communicator, story-teller and dad of twins.

Across the Mass Spectrum of Neutron Stars and Black Holes

Workshop for Division D : High-Energy Phenomena & Fundamental Physics

Black holes and neutron stars have served as showcases for relativity and quantum physics for more than half a century. They are now being observed in more ways than ever before, across all wavelengths from radio to gamma rays, and as gravitational-wave sources in binary inspirals. This multi-messenger toolkit provides insights into the intrinsic properties of these compact, strongly gravitating objects. Knowing their mass is essential to interpreting the various facets of their physical structure and radiative activity. Their mass distribution also reflects the history of their formation in a single collapse or in a merger event, as well as their cumulative accretion history before and after formation. Recent observations have dramatically expanded our views on the mass range of neutron stars and black holes, so Division D has organized a workshop to review these findings, spanning both Galactic and extragalactic settings. The workshop summarizes the observational status quo, explores potential pathways to explain extant data, and briefly highlights future prospects for new observations to propel our understanding forward.

Division Meeting D: High Energy Phenomena and Fundamental Physics	
START DATE	Friday, 5 August
END DATE	Monday, 8 August
ORAL SESSIONS	Room 201, Convention Hall, 2nd Floor
POSTERS	e-Poster Zone, Convention Hall, 3rd Floor

For details on presenters, topics, and times see the online program on the GA website

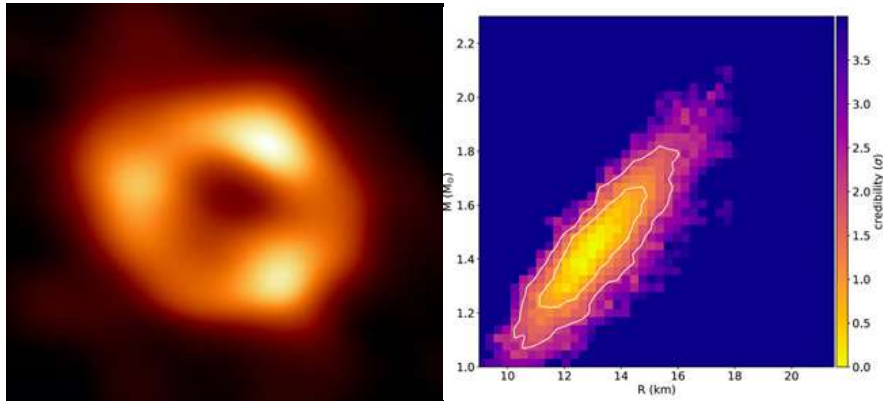


Fig. 1: Left: Event Horizon Telescope mm-band image of the environs of the Sagittarius A* supermassive black hole (around 4 million solar masses) at the center of the Milky Way. [From EHT web page]. Right: mass-radius constraint diagram from NICER X-ray light curve data for the millisecond pulsar J0030+0451 [Miller et al., ApJ Letters 887, L24, 2019)]

For neutron stars, the presentations will compare mass and radius measurements from the modulated thermal emission from hot spots on the stellar surface, dynamical mass measurements in binary systems, which exploit the arrival time of radio pulses or Doppler shifts of emission lines from the companion star, and mass estimates from the gravitational-wave data. The program will also address constraints from eclipses in binary systems. A seminal theme of interest concerns what the mass-radius relation of neutron stars is, which places important constraints on the equation of state of cold neutron or more exotic matter at nuclear densities.
Furthermore, of key importance are why typical masses congregate around the Chandrasekhar mass and why the maximum observed mass of neutron stars appears to be below some theoretical expectations? This sets the scene for the so-called "mass gap" between Galactic neutron stars and black holes.

For black holes, the program will review the surprisingly large masses found by gravitational-wave events in the stellar graveyard, explore how stellar evolution and environmental dynamics can produce them. It will explore what the implications are of the relatively poor census of black holes in the intermediate 102-105 solar-mass domain, contextualized per a range of theoretical predictions. The different means to measure the mass of supermassive objects (e.g. from gas or stellar motions, reverberation mapping, tidal disruption events,

accretion luminosities, etc.) will be reviewed, including the topical data of Sgr A* and M87 from the Event Horizon Telescope data. The workshop will examine how black-hole masses scale with the velocity dispersion or stellar mass in the surrounding bulge as the black holes and their host galaxies co-evolve, thereby connecting to the topical AGN feedback problem. Also discussed are how black holes heavier than a billion solar masses can form rapidly, within a few hundred million years after the Big Bang, and from what seeds they can grow.

Prof. Isabelle A. Grenier, President of IAU Division D. CEA-Saclay and Université de Paris, France. Has worked extensively over many years on the observational study of the ISM, molecular complexes, supernova remnants, cosmic rays and signatures of particle acceleration.

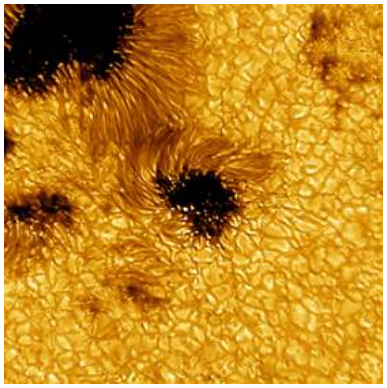
Prof. Matthew G. Baring, Vice-President of IAU Division D. Rice University, USA. Has worked extensively over many years on the theoretical study of neutron stars and black holes, gamma-ray bursts and blazars, radiation processes, cosmic rays and particle acceleration at shocks.

Division E Days: Heliophysics in the 21st Century

The research covered by Division E includes the study of the Sun, its variability, activity, and dynamics, as well as its impact on the Earth and other bodies within the heliosphere. The proximity of the Sun enables detailed investigation of its structure, the dynamo operating in its interior, and the radiation and solar wind that propagate outward, in the heliosphere. Dynamical phenomena include flares, coronal mass ejections, shock fronts and their propagation, as well as the acceleration of particles into the interplanetary medium.

Division Meeting E: Sun and Heliosphere	
START DATE	Friday, 5 August
END DATE	Monday, 8 August
ORAL SESSIONS	Room 108, Convention Hall, 1st Floor
POSTERS	e-Poster Zone, Convention Hall, 3rd Floor

For details on presenters, topics, and times see the online program on the GA website



A new high-resolution image of sunspots captured by the Daniel K. Inouye Solar Telescope on 11 May 2021. The data leading to this image were acquired with the Visible Broadband Imager blue channel at a wavelength of 450 nanometers (spatial resolution around 20 km at the Sun). Credit: NSO/AURA/NSF.

The Workshop "Heliophysics in the 21st Century" is organized in five sessions. Three of these sessions are devoted to the main scientific pillars of Division E: Solar Radiation and Structure, Solar Active Phenomena, and Solar Impact throughout the Heliosphere. Two invited lectures per session will highlight recent progress in these three broad fields, encompassing advances in solar dynamo theory and solar cycle prediction, the dynamics of small-scale atmospheric structures, filament disruptions and their implications, modeling and simulations of solar magnetic phenomena, large-scale structures in the heliosphere and their space weather impact, as well as the dynamics of the global solar wind and the heliospheric magnetic field over small and very long temporal scales. A relevant number of contributions will accompany these invited reviews.

We will have the pleasure to dedicate a session to the talks of seven young solar physicists, winners of IAU PhD and IAU "at-large" PhD Prizes between 2018 and 2021, who will present their thesis results.

Another session will be devoted to the status and science of recent and future instrumentation both ground-based and space-borne. Highlights include the related collaborative features between the recently launched Solar Orbiter and the new National Solar Observatory facility, the 4-meter, Daniel K. Inouye Solar Telescope (DKIST). The next-generation Global Oscillation Network Group (ngGONG) instrumentation, which incorporates space weather requirements, will also be presented. Parker Solar Probe and ground-breaking discoveries, such as solar wind switchbacks, will be reviewed. Among future missions, the status and science objectives of the Polarimeter to Unify the Corona and Heliosphere (PUNCH) and Aditya-L1 will be discussed. PUNCH is a NASA Small Explorer (SMEX) mission that aims to better understand how the mass and energy of the Sun's corona become the solar wind. It consists of four suitcase-sized satellites that will work together to produce images of the entire inner solar system around the clock and determine the cross-scale physical processes that unify the corona with the rest of the heliosphere. Aditya-L1 is a future coronagraphy spacecraft to study solar atmosphere, in particular the corona, currently being designed and developed by the Indian Space Research Organization (ISRO) and various other Indian research institutes, which will be inserted in a halo orbit around the L1 point between the Earth and Sun.

Join us in this trip from inside the Sun to the heliosphere!

Cristina H. Mandrini, chair of the Division E Days and President of IAU Division E, is a Senior Researcher at the Institute of Astronomy and Space Physics (Instituto de Astronomía y Física del Espacio), Buenos Aires, Argentina, and retired Professor at the University of Buenos Aires, Department of Physics.

PhD Prize Winners in 2018-2021

PhD Prize Year	Division	Name and Country	Title of PhD Thesis
2018-2019	B	Niels Ligterink, Netherlands	“The Astrochemical Factory: A solid base for interstellar reactions”
2018-2019	D	Laura Becerra, Colombia	“Accretion in Compact Stars: Hypercritical Accretion in the Induced Gravitational Collapse and the Post-Merger Evolution of White Dwarfs Mergers”
2018-2019	E	Jenna Samra, USA	“An Airborne Infrared Spectrometer for Coronal Observations: Development, Characterization, and First Science Results from the 2017 Solar Eclipse”
2018-2019	F	Tim Lichtenberg, Switzerland	“Thermal Evolution of Forming Planets: Isotope Enrichment, Differentiation & Volatile Retention”
2018-2019	G	Adam Jermyn, UK	“Turbulence and Transport in Stars and Planets”
2018-2019	H	Meriem El Yajouri, Morocco	“Diffuse Interstellar absorption Bands: a new look at an old problem”
2018-2019	J	Jorryt Matthee, Netherlands	“Identifying the origin of galaxy formation”
2018-2019	PhD at-large Prize	Gopal Hazra, India	“Understanding the behaviour of the Sun’s large scale magnetic field and its relation with the meridional flow”
2019-2020	A	Joseph O’Leary, Australia	"General relativistic and post-Newtonian dynamics for near-Earth objects and solar system bodies"
2019-2020	B	Luke Pratley, UK	"Radio Astronomy in the Big Data Era"
2019-2020	C	Maria Giulia Andretta,Italy	"The conquest of the Moon. The history, the legacies and the cultural influence of the Moon landing. Analysis of the Italian media phenomenon as an example of pop science"
2019-2020	D	Guang Yang, USA	"What drives the growth of black holes?"
2019-2020	E	Munehito Shoda, Japan	"Fast solar wind driven by parametric decay instability and Alfvén wave turbulence"
2019-2020	F	Przemyslaw Mroz, Poland	"Astrophysical applications of gravitational microlensing in the Milky Way"
2019-2020	G	Simon Blouin, Canada	"Modeling of high-density effects at the photospheres of cool white dwarfs"
2019-2020	H	Jennifer Bergner, USA	"Tracing organic complexity during star and planet formation"
2019-2020	J	Anna-Christina Eilers, Germany	"Unravelling 13 Billion Years of Cosmic History with Spectroscopic Studies: From the Milky Way to the Epoch of Reionization"
2019-2020	PhD at-large Prize	Prantika Bhowmik, India	"Data Constrained Models for Solar Activity Predictions"

2020-2021	A	Etienne Savalle, France	“Testing general relativity with clocks in space, and dark matter research with cold atom interferometry on Earth”
2020-2021	B	Danna Qasim, the Netherlands	“Dark Ice Chemistry in Interstellar Clouds”
2020-2021	C	Magdalena Kersting, Norway	“General Relativity in Secondary School: Research-Based development of Learning Resources and Analyses of Students”
2020-2021	D	Ziggy Pleunis, Canada	“Fast radio burst detection and morphology with the CHIME telescope”
2020-2021	E	Camilla Scolini, Belgium	“Modeling analyses of the evolution of magnetic fields in coronal mass ejections, from Sun to Earth”
2020-2021	F	Jane Huang, USA	“Rings and Spirals in Protoplanetary Disks: The ALMA View of Planet Formation”
2020-2021	G	Lisa Bugnet	“Characterization of solar-type stars and study of their internal magnetic fields along the evolution”
2020-2021	H	Cecilia Bacchini, Italy	“Star formation laws and gas turbulence in nearby galaxies”
2020-2021	J	Solène Chabanier, France	“Neutrino and dark matter cosmology with the Lyman-α forest, the interplay between large-scale evolution and small-scale baryonic physics”
2020-2021	PhD at-large Prize	Raissa de Lourdes Freitas Estrela, Brazil	“Exoplanet Atmospheres and Habitability”
2021-2022	A	Chris Hamilton, UK	"Secular Dynamics of Binaries in Stellar Clusters"
2021-2022	B	Francisco Javier Bailen Martinez, Spain	"Spectropolarimetric and Imaging Properties of Fabry-Pérot Etalons. Applications to Solar Instrumentation."
2021-2022	C	David Barrado Navascués, Spain	"Cosmography: the science of the two Orbs"
2021-2022	D	Riccardo Arcodia, Germany	"Accretion onto Black Holes Across the Mass Scale”
2021-2022	E	Souvik Bose, Norway	"On the Dynamics of Spicules and Mass-Flows in the Solar Atmosphere"
2021-2022	F	Megane Mansfield, USA	"Revealing the Atmospheres of Highly Irradiated Exoplanets: From Ultra-Hot Jupiters to Venus Analogues"
2021-2022	G	Kareem El-Badry, USA	"Binary Stars Across the Milky Way: Probes of Star Formation and Evolution"
2021-2022	H	Anirudh Chiti, USA	"Mapping the Ancient Milky Way & its Relic Dwarf Galaxies”
2021-2022	J	Zhijie Qu, USA	"The Warm-Hot Circumgalactic Medium and its Co-Evolution with the Galaxy Disk"
2021-2022	PhD at-large Prize	Reetika Joshi, India	"Study of Solar Jets and Related Flares"

PhD Prize Honorable Mentions in 2021

Division	Name and Country	Details
B	Divita Gupta, France	"Rate Coefficients and Branching Ratio Measurements for Reactions of Astrochemical Relevance Involving CN Radicals"
C	Saeed Salimpour, Australia	"Visualising the Cosmos: Teaching Cosmology in High School in the era of Big Data"
D	Benjamin Crinquand, France	"Particle Acceleration in Kerr Black-Hole Magnetospheres"
D	Kishalay De, USA	"The Whisper and the Bang: Cosmic Fireworks in the Lives of Compact Binaries"
E	Wenzhi Ruan, Belgium	"Solar Flares and Kelvin-Helmholtz Instabilities: Particle Acceleration and High Energy Radiation"
F	Chloe Fisher, Switzerland	"Characterising Exoplanet Atmospheres using Traditional Methods and Supervised Machine Learning"
F	Rafael Luque Ramirez, Spain	"Planetary Systems Around Red Dwarfs and Activity of their Host Stars"
H	Rebecca Levy, USA	"Investigating Star Formation Feedback through Gas Kinematics in Nearby Galaxies"
J	Martyna Chruslinska, Germany	"Galaxies, Binaries and Gravitational Waves"

Young Astronomers Lunch (YAL)

Young Astronomers Lunch (YAL) meeting will take place at Hall 5A, Exhibition Center II, BEXCO on the 5th of August at 12:00-13:30. The aim of the Young Astronomers Lunch is to stimulate networking opportunities between senior astronomers and young astronomers at the start of their careers. The main objectives of the YAL are:

- to give young astronomers (i.e. early career astronomers) the opportunity to discuss predefined topics of their choice, related to careers and research organization in astronomy, with more experienced astronomers,
- to raise the awareness of the YAs of their importance to the IAU,
- to enhance networking among YAs of different countries.

You can sign up for this event when you register for the GA.

We kindly acknowledge a generous donation by US National Academy of Sciences (US NAS) and the Norwegian Academy of Science and Letters (NASL) that have made the organization of this event possible.

※ To participate in this event please bring the ticket issued with your name badge.

Korean history and astronomy

Astronomy, along with mathematics and medical science, is one of the oldest fields in the history of humanity's pursuit of knowledge. Aside from China, Korea is the country with the longest history of astronomy in the world. Korea honors a long-standing legacy of astronomy, treasured for thousands of years.

Ancient Astronomy

The origin of Korean ancient astronomy dates back to the prehistoric era. Astronomical signs in the prehistoric age are star-like cup-marks carved on cover stones of dolmens. It is evident that ancient Korean kingdoms established their own bureaus of astronomy, built observatories, and employed administrators designated to observe astronomical phenomena. Initial observations of astronomical phenomena started from the 1st century BCE and over 20,000 extensive historical records and relics have passed down from generation to generation. In particular, Cheomseongdae Observatory, built in 633 CE is one of the oldest observatories in the world.

King Sejong the Great (1418-1450) and Joseon Dynasty

In general, Korean kings and nobilities were in favor of supporting astronomy. The reign of King Sejong the Great, between 1418 and 1450 is known as the unprecedented Golden Age of Korean science and culture, with particular attention to astronomical instruments and technologies. King Sejong the Great commissioned a substantial revision of Western, Islamic and East Asian traditional sciences and placed Korea as one of the frontrunners leading the calendrical science, astronomical observation, and invention of related instruments in the region.

One of the outstanding astronomical heritages during the Joseon Dynasty is a star chart carved on a stone plate in 1395. The stone star chart contains 1,467 stars with various sizes. According to modern calculations, it is known that the location of the star was found to be located in the 1st century and the 14th century.

The astronomical instruments and calendars during the Joseon Dynasty are well examined by Needham et al. 's book entitled "The Hall of Heavenly Record: Korean Astronomical Instruments 1380-1780," published by Cambridge University Press in 1986. Needham et al. label Korean astronomy as "a true national variant of the East-Asian astronomical tradition" and note, "The instruments and written records are a valuable legacy to the history of science everywhere."

Modern Astronomy

Due to the tragic collapse of the Joseon Dynasty in 1910 and followed Japanese colonial rule and Korean War, Korean modern astronomy in the early 20th century struggled for existence. Nonetheless, Koreans in the midst of hardship strived to continue and honor the legacy of astronomy research. Since the first modern lecture on astronomy taught at the Yonsei University in 1915 and the launch of the first independent department of astronomy at the Seoul National University in 1958, Korean astronomy underwent steady expansion.

Now with eight universities offering up to Ph.D programs in astronomy and astrophysics, Korean astronomy enjoys a rapid growth in numbers of well educated human resources, cutting edge research outputs, and astronomical instruments. Together with Korean astronomers' dedicated commitment to astronomy and substantial government support, Korea is engaged in various activities including the launch of space telescopes, Korea VLBI network (KVN), the network of three wide-field telescopes in the Southern Hemisphere (KMTNet) monitoring the sky 24 hours a day. Active international collaborations are also sought, by partaking in the Giant Magellan Telescope (GMT) consortium. After a long pause, Korea once again steers the way into the great endeavor to stand on the frontline of astronomy and space science for mankind and a better tomorrow.

Korea's Ancient Observatory

Cheomseongdae in Kyeonju of Korea, built in AD633 in thee Silla Kingdom

Astronomical Observatory in Gaeseong of North Korea, built in ~13th Century in the Goryeo Dynasty (National Research Institute of Cultural Heritage, 2018)

The Three Kingdoms period of Korea (57BC-AD935)

The Three Kingdoms period is defined as when Silla, Baekje and Goguryeo dominated the Korean peninsula and the neighboring areas. In Gyeongju, the capital of Silla, stands a 9.1-m high bottle-shaped observatory, Cheomseongdae. The observatory, built in 633, is the oldest astronomical observatory in the world that is still preserved. This observatory, taking the shape of circle and square, symbolizes the ancient cosmology of the East, and there is a window in the middle of the south side of the body. According to records, the observer went through a window and climbed to the top, observing the sky.

Cheomseongdae's appearance and shape allude to various astronomical symbolism. Layers of stones symbolize the 24 solar terms (seasonal division) and the 28 oriental constellations (lunar mansions), and the number of stones in Cheomseongdae has been theorized to reference the number of days of a year.

It is known that Goguryeo and Baekje were as active in astronomical observations as in Silla, but there remains no observatory. Meanwhile, records from the 18th century show that Goguryeo royal observatory was located to the south of the royal palace. Baekje had a high level of astronomical studies, so much so that it shaot of relevant knowledge with Japan, but no records are remaining about astronomical observatories in Baekje.

Goryeo Dynasty (AD918-1392)

In Gaeseong (開城), the capital of the Goryeo Dynasty in northern Korea, stands a stone structure known to be the remnant of an observatory. The observatory was built around the 13th century, the current remains of which consist of a stone platform about 3m2 supported by five 3-m high upright stones. Goryeosa, the official history book of the Goryeo Dynasty, includes a record that an astronomical observatory and an astronomical instrument were made to observe astronomy in 1281, implicating that a simple observation instrument was installed on the observatory at that time. Goryeosa contains about five thousand astronomical records.

Joseon Dynasty (AD1392-1910)

The Joseon dynasty built its main palace in Hanyang (now Seoul) and installed an astronomical observatory with several observation instruments in 1432. The astronomical observatory at that time was much larger than that of Silla or Goryeo, enabling far more professional observation. Unfortunately, all the royal observatory and observation instruments at that time disappeared, and only two simple observatories have remained to date. More than 20,000 records of astronomical observations in the Joseon dynasty have been kept.

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Busan Tour Attractions

Busan is a stunning confluence of scenery, culture and cuisine in repose between mountains and sea. It's long been domestically lauded as the country's best beach getaway, but South Korea's second largest city packs an eclectic offering of activities to suit all travelers: hike hills to Buddhist temples, settle into sizzling hot springs and feast on seafood still a-wriggle at Jagalchi, the country's largest fish market.

IAUGA 2022 provides several Busan tour programs including free tour, half-day tour, and one-day tour. Further information about all tours can be found at https://www.iauga2022.org/tour/. Through this tour, you can get an up-close-and personal look at some of the must-visit locations on Busan including Songdo Cloud Walkway, Busan X the SKY, Haeundae Blue Line Park, Haedong Yonggungsa Temp, The Bay 101 Yacht Tour, Gamcheon Culture Village, and Hongbeopsa Temple (Tour Overview).

You can also explore some of the main tourist attractions near IAUGA venue. Tour the Haeundae with a self-guided walk and visit four most popular attractions in Haeundae.

Haeundae Beach

• **Haeundae Beach**

Haeundae Beach is one of Korea's hottest summer destinations, attracting over 10 million visitors every season. Its 1.5 km white sandy beach is lined with many entertaining facilities. Haeundae Beach has become the most popular spot for foreign tourists and vacationers from all over the country who enjoy swimming and sunbathing on a sunny beach.

Dongbaek Coastal Trail

• **Dongbaek Coastal Trail**

Walk along the Haeundae Beach deep in thought while looking out at the open sea to reach the cozy Dongbaekseom Island located at the end. Formerly an island, the coastal trail is now connected to the land through years of sedimentation. The people of Busan, however, still refer to the place as Dongbaekseom Island. Dongbaek Park, built with the natural elements of the area still intact, is a beautiful place with a dense habitation of black pine. The coastal trail connects to a white lighthouse and a wide observatory, where you can look out into the ocean to see the Nurimaru APEC House and Gwangandaegyo Bridge. Turn your gaze a bit to the left to see the Oryukdo Islets. This is a great spot to view the sea of Busan all at once.

• Dalmajigil Road

Dalmajigil Road, which one should definitely not miss when visiting Haeundae. Dalmajigil, a hilly road from Mipo at the end of Haeundae to Songjeong Beach, is a place for healing in nature away from the hustle and bustle of the city by absorbing oneself in meditation and relaxation. The Dalmajigil Road requires climbing up the Dalmaji Hill, but the slope up is not troublesome at all. Thanks to the rising level, Haeundae Beach, Dongbaekseom Island, and Gwangandaegyo Bridge come into view simultaneously. The beautiful cafés and romantic restaurants located along the stone wall path make visitors' hearts flutter with anticipation.

Dalmajigil Road

• Busan X the SKY

Busan X the SKY is located in the second highest building in Korea, Haeundae LCT the Sharp (411.6 m). In this highest, biggest-scale observatory, you can view the wide-spread ocean of Haeundae and the beautiful city of Busan. On top of the world-famous landmarks of Busan such as the Gwangandaegyo (Diamond Bridge) and Marine City, you can view the day and night of Busan while you enjoy the premium services of the interior media facade, lounge cafe, and casual cafe. Experience the whole world below your feet at BUSAN X the SKY.

Busan X the SKY

Korea Tour Attractions

1) Hahoe Village in Andong

Hahoe Village in Andong is Korea's most representative folk village with a long history. The village is full of wooden and thatched-roof houses and sits between a river and mountains. It shows Confucian culture from the 14th-15th century and was registered as a UNESCO World Heritage in 2010. The village has a beautiful river and lake scenery, perfect for walking around, and a splendid night view as well. Find more information at http://www.hahoe.or.kr/.

2) Gyeongju

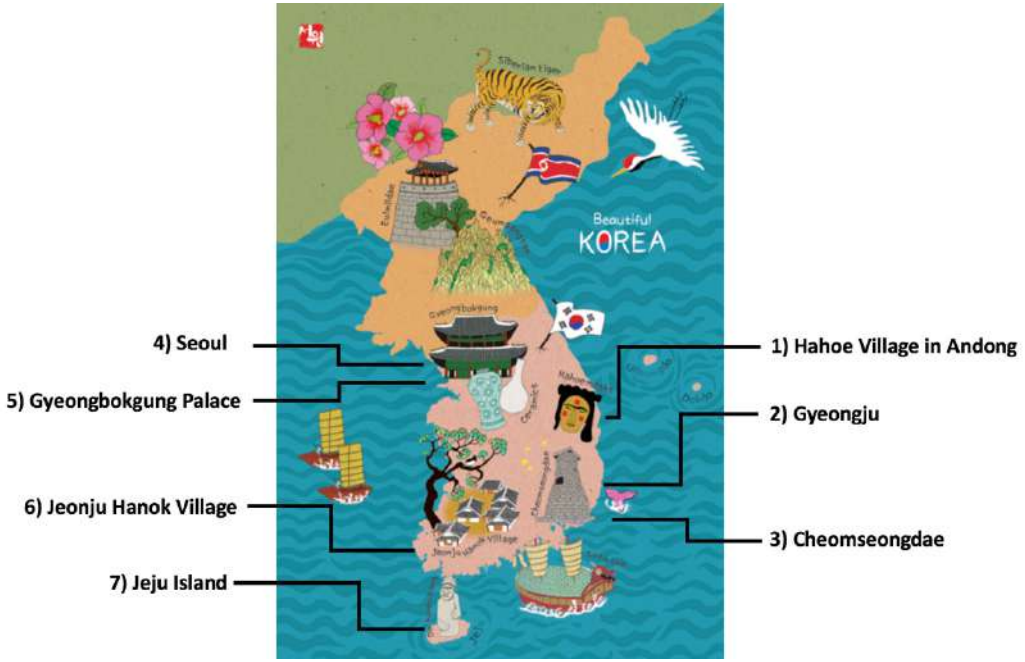
Gyeongju was the capital city of the ancient kingdom of Silla. The city is often referred to as a "museum without walls" because of the many cultural relics scattered throughout the city. Almost everything in this city, from the streets to the mountains, is rich in history. Gyeongju has roughly 300 sites that have been designated as a cultural heritage, with some of them being UNESCO-recognized World Heritage Sites. Find more information at https://www.gyeongju.go.kr/.

3) Cheomseongdae

This scientific stone building is the "oldest astronomical observatory in Asia" and was built by Queen Seondeok. It is filled with ancient scientific secrets. The 365 stones from which Cheomseongdae was built represents the number of days in a year, and the total of 29 levels and 30 levels of stone steps (depending on which level to count from) represents the number of days in a lunar month. The top 12 columns and the bottom 12 columns of the window symbolize the 24 seasonal divisions of the year according to the lunar calendar. Experts believe astronomers would have stepped inside the structure as they observed the starts. Find more information at https://www.gyeongju.go.kr/.

4) Seoul

Seoul is the capital of Korea and is the heart of Korea's culture and education as well as politics and economy. Seoul is home to many historic sites and places of traditional culture. The shopping and entertainment districts also draw a large number of tourists every year. The Hangang River, which runs through the center of the city, is a distinctive landscape of Seoul



that offers a myriad of resting areas for citizens. Find more information at https://english.visitseoul.net/.

5) Gyeongbokgung Palace

Built in 1395, Gyeongbokgung Palace is commonly referred to as the Northern Palace because its location is furthest north when compared to the neighboring palaces of Changdeokgung (Eastern Palace) and Gyeonghuigung (Western Palace). Gyeongbokgung Palace is arguably the most beautiful, and remains the largest of all five palaces. The premises were once destroyed by fire during the Imjin War (1592-1598). However, all of the palace buildings were later restored under the leadership of Heungseondaewongun during the reign of King Gojong (1852-1919). Find more information at http://www.royalpalace.go.kr.

6) Jeonju Hanok Village

Jeonju Hanok Village is the largest traditional hanok village in Korea, with more than 700 hanoks in the Pungnam-dong area of Jeonju.It is the only hanok district that is located in the center of a city. It is an important space in the development process of Korea's modern housing culture, which started in 1910, and is the home of about 20 cultural facilities including Gyeonggijeon, Omokdae, and Hyanggyo. It is a representative travel destination of Korea and is integrated with the style of Korea such as hanok, hanji, hansori, hanbok, Korean food, and oriental medicine. Find more information at http://hanok.jeonju.go.kr.

7) Jeju island

Jeju Island, designated as Jeju Special Autonomous Province, lies southwest of the Korean Peninsula and is the largest tourist destination in Korea. The whole island was designated as a special tourist zone, and wherever tourists go, they can look upon beautiful scenery. Jeju Island earned the UNESCO triple crown, being designated as a World Natural Heritage, Global Geopark, and Biosphere Reserve as well as one of the Seven Wonders of Nature. Traveling the 182-kilometer circuit road along the coastline by car, motor scooter or bike is recommended. There is a trail for walking called “Jeju Olle-gil” for those who choose to make a round trip on foot. Find more information at https://www.visitjeju.net/en/.

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Welcome Message on the Diamond Bridge from the Busan Metropolitan City
(Photo by Jeon, Young-Beom (KASI))