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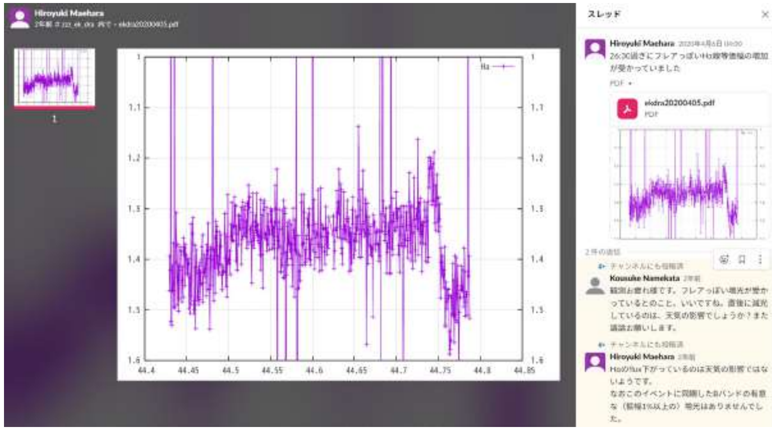
My superflare research in Kyoto and Okayama

Hiroyuki Maehara, Invited Discourse speaker



The H-alpha light curve of the superflare and post-flare dimming on EK Dra, which I posted to the Slack channel for our observing campaign.

Solar flares are the rapid releases of magnetic energy stored near the sunspots through magnetic reconnection and are sometimes accompanied by coronal mass ejections (CMEs). They sometimes impact various social systems such as power grids, satellites, and radio communications. Similar flares also occur on other stars. In addition, some active stars exhibit more energetic flares called "superflares." The occurrence rate of solar flares depends on flare energy; more energetic flares occur less frequently, according to solar observations. Can superflares occur on our Sun? How often would superflares occur on the Sun? These are big questions but difficult to answer only from modern solar observations. One possible way to answer these questions is the long-term, continuous, and precise observations of many "Sun-like" stars.

In 2010 when I was a postdoc at the Kwasan Observatory, Kyoto University, I started to search for flare candidates on solar-type stars from the Kepler light curves with Prof. Kazunari Shibata and his 1st-grade undergraduate students. In December 2010, one of the undergraduate students, Takuya Shibayama, discovered some solar-type stars showing flare candidates. After developing the flare search code, we detected thousands of flare candidates on solar-type stars. At first, I thought that they were not real superflares on solar-type stars, but contaminations of flares on M dwarfs in the photometric aperture. However, the detailed analysis found that the contaminated flare scenario cannot explain some of these flare candidates on solar-type stars. Finally, we concluded that superflares could occur on solar-type stars (e.g., Maehara et al., Nature 485, 478, 2012; Shibayama et al., ApJS 209, 5, 2013; Shibata et al., PASJ 65, 49, 2013).

Can superflares produce “super-CMEs”? To answer this question, we need spectroscopic observations of superflares. The 3.8-m “Seimei” telescope was constructed by Kyoto University in 2018 at Okayama and started its scientific operations in February 2019. Our team has performed the intensive time-resolved spectroscopy of solar-type stars showing superflares by using the Seimei telescope simultaneously with the TESS observations since 2020. Despite the COVID-19 pandemic, we successfully observed superflares on some active solar-type stars. On 5 April 2020, we found mysterious phenomena in the H-alpha light curve of EK Dra. The H-alpha intensity decreased just after the flare and became fainter than the pre-flare level. Dr. Kousuke Namekata solved this mystery. The comparison with the Sun-as-a-star H-alpha spectra during solar flares suggests that the massive filament eruption associated with the superflare occurred on EK Dra and caused the post-flare dimming in the H-alpha light curve (Namekata et al., Nature Astronomy 6, 241, 2022). However, it is still unclear whether superflares and subsequent massive filament eruptions can lead to super-CMEs. Further simultaneous multi-wavelength observations are necessary to unveil the connection between superflares and super-CMEs.

Dr. Hiroyuki Maehara is an assistant professor at National Astronomical Observatory of Japan (NAOJ).

A Career in Space Astrometry

Michael Perryman, Shaw Prize Winner

I started out on my scientific career with a mother passionate about education, and an inspiring school teacher excited by the beauty of mathematics. I studied mathematics and theoretical physics at Cambridge University between 1973-1976, and received my doctorate from the Cavendish Laboratory, Cambridge University, in 1979, on the subject of the cosmological evolution of extragalactic radio sources.

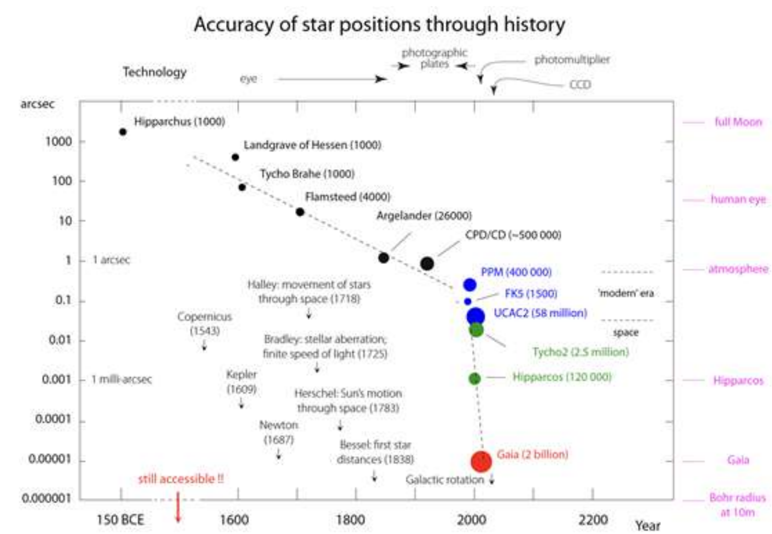
I joined the European Space Agency (ESA), in The Netherlands, as a research fellow in 1980. A year later, at the age of just 26, I was appointed as Project Scientist for the recently-adopted Hipparcos space astrometry mission, which I subsequently headed as lead scientist between 1981-1997.

Astrometry was a new field for ESA. My work involved overall coordination of the scientific aspects of the satellite design, manufacture and testing, assisting with the parallel preparation of the input catalogue and overall data analysis (major tasks led by my long-term colleagues Erik Høg, Jean Kovalevsky, Lennart Lindegren, and Catherine Turon), and chairing the Hipparcos Science Team. Like all space missions, Hipparcos presented a continuous series of difficult challenges, tackled in collaboration with a highly motivated team of scientific colleagues across Europe, project managers in ESA, and talented engineers in European industry. After its launch in 1989, the satellite failed to reach its target geostationary orbit, and I also took over the overall mission management with the numerous associated recovery operations. It was a tense, difficult and protracted period, but the project eventually delivered all and more of its original scientific objectives, and validated the principles underpinning space astrometry.

In 1993, together with Lennart Lindegren, and building on earlier ideas by Erik Høg and Lennart Lindegren, I jointly proposed a more ambitious mission to take advantage of technological advances such as CCDs, large lightweight ceramic mirrors and structures, and micro-Newton gas thrusters. The mission was approved by ESA's Science Programme Committee in 2000. I was the scientific leader of the Gaia project from its inception until shortly before the Critical Design Review in 2008, establishing the payload concept, its technical feasibility, the data analysis principles, its organisation structure, and its scientific case. Its launch in 2013 was just one year after that targeted at its adoption in 2000.

Now eight years into its operational lifetime, Gaia is generating progressively improved catalogues of more than two billion stars, leading to a detailed portrait of our Galaxy and its formation, and impacting on all branches of astronomy. What is of enormous satisfaction to me today is reading the scientific papers based on the Gaia results, and admiring their ingenuity, their breadth, and the huge scientific advances that they represent. I host some regular essays and interviews at my own site www.michaelperryman.co.uk.

I am very grateful to the Shaw Prize Foundation for their recognition of my contributions to space astrometry, which I am delighted to share with my colleague Lennart Lindegren. And let me also stress the self-evident: that the major scientific advances gained by Hipparcos and Gaia could only have come about through the dedicated and outstanding contributions of many others - scientists, managers, and engineers - over very many years.



The accuracy of star positions through history, showing some of the barriers, the adopted technologies, and a selection of achievements as accuracies improved

From galaxies to haloes – “reverse engineering” of the evolving galaxy population

Yingjie Peng, S373 plenary speaker

Yingjie Peng is an astronomer and phenomenologist at the Kavli Institute for Astronomy and Astrophysics (KIAA) and the School of Physics at Peking University. He received his PhD from ETH Zurich in 2012 with the award of the ETH Medal, and then he became a research associate at Cavendish Laboratory and a postdoctoral fellow at Kavli Institute for Cosmology, University of Cambridge. He was also a fellow of the Homerton College, University of Cambridge. In 2015, he returned to China and joined KIAA as a tenure-track Assistant Professor through the Chinese National Youth Thousand Talents Program. He was awarded the MERAC Prize in Observational Astrophysics by the European Astronomical Society (EAS) in 2016, and the National Science Fund for Distinguished Young Scholars in 2021. He is now Full Professor at KIAA and School of Physics.

The main focus of Yingjie Peng’s research is studying galaxy formation and evolution through cosmic time. New technologies and more powerful telescopes have enabled routinely large multi-wavelength sky surveys from nearby to the distant Universe, delivering an unprecedented wealth of high-quality data. This enables the statistical study of detailed galaxy properties and their evolution over a broad range of cosmic time with great precision. However, there are still many unsolved fundamental questions in this field, as galaxy formation and evolution are complicated non-linear processes with many different physics involved at different epochs. The main philosophy and approach of his research are using the large multi-wavelength surveys in the nearby and distant universe to “reverse engineer” the observed galaxy population at different epochs, identify the key features of the galaxy populations, and derive the analytical forms for the dominant evolutionary processes that control galaxy evolution, by using continuity approach and building phenomenological models. The goal is to build a simple, self-consistent and powerful analytical framework to describe the formation and evolution of different galaxy populations, from dark matter haloes to gas and to the stellar population, to explore the key issues in the galaxy ecosystem, such as the physical mechanism of star-formation quenching; the cosmic star-formation history and stellar mass assembly history of galaxies, and their connections to the dark matter haloes; the self-regulation of star formation and gas cycle; the role of the AGN feedback.

Yingjie Peng has been actively involved in several ongoing or forthcoming observation projects and facilities, such as MOONS, MSE, FAST, SKA, and the Chinese Space Station Telescope (CSST). High-quality data obtained by large multiple-wavelength surveys from X-ray to radio, and their synergies are the foundation of this reverse engineering and phenomenological approach.

Farewell by IAU President Elect

Willy Benz, IAU President Elect

A farewell always brings a touch of sadness because it marks the end of something and the time to say goodbye. Yes, the GA 2022 is drawing to a close, but what a pleasure it was to meet and speak with people in person. After over two years of meeting people on computer screens, it was a delight to come to Busan. For all the exciting invited presentations, the different symposia, and all the meetings and activities that together make up a General Assembly. Placed under the motto of "Astronomy for all", the event displayed the broad spectrum of IAU sponsored activities from science and education to outreach and development. Not to forget global coordination between ground and space astrophysics and the protection of our astronomical sky.

But there is a lot more to it than the sessions. There are the people we meet, the one-on-one discussions during coffee breaks, poster sessions, around exhibits, spontaneous exchanges in the hallways, networking during receptions and dinners, etc. All these little things that are as essential to us as morning coffee.

The first thing I realised while coming to the Republic of Korea for the first time, was how wonderfully organised this country is. From the rather complex entry procedures at the arrival airport, the high-speed trains, to the organisation of the largest astronomical gathering, everything works perfectly. The tremendous growth of the Korean astronomical community is not only evidenced by the successful organisation of GA2022 but also, and mainly, through its involvement in major astronomical projects (e.g. Gemini, ALMA, GMT, and even a successful launch of a satellite aimed at studying the Moon). And finally, there is the hospitality with which our hosts have treated us the whole week which will make this GA unforgettable beyond science.

A farewell is also an opportunity to look ahead. The next General Assembly in Cape Town in South Africa is only two years away and it will be the first of its kind on the African continent; a historic event. Reaching professional astronomers all over the world has always been at the heart of the IAU mission. The use of astronomy to also reach the people to foster development and education is a more recent element of the IAU strategy. Cape Town being the home of the IAU Office of Astronomy for Development, there is no better place!

It's time to say thank you, goodbye, and have a safe trip home to everybody. I am sure you will return home with many new ideas, friends, memories, and stories to share. I look forward to seeing you all in Cape Town in a couple of years.

Welcome reception. What a great pleasure to be able to meet people again around good food and a drink.

The KASI booth in the Exhibit Hall. Showcasing the amazing activities carried out by the Korean astronomical community

A Message from the Assistant General Secretary

Diana Worrall, IAU Assistant General Secretary

It is a great pleasure to be here in Busan, in person, for the GA. Under normal circumstances this GA would have been over before I took on my Assistant General Secretary responsibilities. As it is, I've had the pleasure of helping in a small way and seeing at first hand the dedication of colleagues in making this GA a reality. As may be true for others of you, this is my first trip to a scientific conference outside my home country (in my case the UK) since the start of the covid pandemic.

The Assistant General Secretary, Diana Worrall, outside the Paris Observatory in late April 2022. The Executive Committee meeting was held at the Institut d'Astrophysique de Paris, next door.

My first post-pandemic-onset foreign trip was actually to the IAU Executive Committee meeting in Paris this April, at which the Busan GA was an important discussion topic. The second was again to Paris, a couple of weeks later, to assist the General Secretary in the allocation of grants for this meeting. With that we were greatly helped by Piero Benvenuti in using the software tools that as General Secretary he had developed for the previous GA which now seems rather a long time ago --- 2018 in Vienna!

My science has been informed by, and I've drawn inspiration from, the meetings I've attended. Each GA has provided me with a special memory of the people I've met and the places I've visited. Never in the past did I expect to be one of those expected to be on stage at a Closing Ceremony!

As this GA begins to draw to a close we have only two years to wait before the next, in Cape Town in 2024. Meanwhile, a rich array of IAU Scientific meetings on a broad range of topics awaits our participation. Not least, the IAU is sponsoring nine newly-selected symposia in 2023, and four selected earlier are also still to be held (see https://www.iau.org/science/meetings/future/symposia/).

Sparked by this GA, I'm sure you will have 2024 in your sights. The deadline for letters of intent (LoI) for six symposia and twelve focus meetings for the 2024 GA are due soon, on September 15th, together with LoI for three non-GA symposia. If you miss the LoI deadline, you can still submit a full proposal by December 1st, but you are strongly encouraged to consult in advance with the IAU Division you choose as your Coordinating Division to receive their constructive feedback on your plans. Rules and Guidelines for hosting IAU Symposia can be found at https://www.iau.org/science/meetings/rules/. The IAU looks forward to hearing from you.

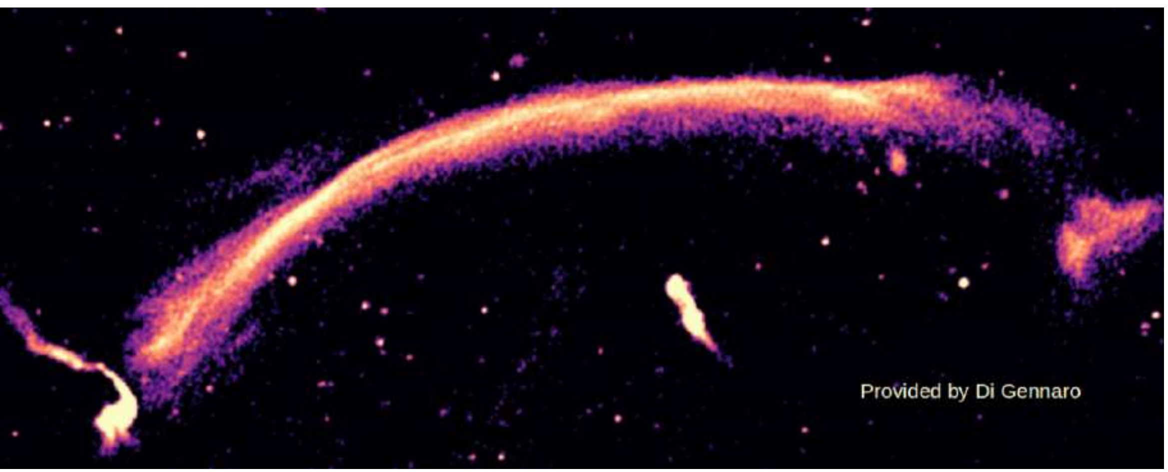
Focus Meeting 6

Dynamics of the ICM: Radio and X-ray Observations and Theory

Focus Meeting 6: Dynamics of the ICM - Radio and X-ray Observations and Theory	
START DATE	Wednesday, 10 August
END DATE	Thursday, 11 August
ORAL SESSIONS	Room 106, 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

Most of the baryonic matter of galaxy clusters is in the form of hot gas in the intracluster medium (ICM). The ICM has been recognized as a vital element in the formation and evolution of the large-scale structure of the universe and individual galaxies, as well as an essential diagnostic tool when studying galaxy clusters. It is highly dynamic and also contains nonthermal components such as magnetic fields and cosmic-ray protons and electrons. In the Focus Meeting 6 (FM6) of IAUGA 2022, among cross-communities of radio, X-ray, and SZ observations and theory, we will initiate discussions that define the roles of turbulence, shocks and cold/sloshing fronts in the ICM, as well as establish reliable, discriminating observational signatures of their properties and inter-relationships. In particular, we will address critical observational and theoretical challenges in the coming decades, specifically how emerging and planned observational efforts, such as LOFAR, uGMRT, MeerKAT, ASKAP, SKA, ngVLA (radio), eROSITA, XRISM, ATHENA (X-ray), and ACT, SPT, Planck, MUSTANG2 on the 100-meter GBT, NIKA2 on the IRAM 30-meter, ALMA + ACA, CCAT-prime, TolTEC on the 50-m LMT/GTM, Simons Observatory, APEX/CONCERTO, CMB-S4, AtLAST, LST, and potential new space-based CMB probes (SZ), can be combined with theoretical understandings to enable a comprehensive picture of the ICM. The need for such a gathering is motivated by revelations of the importance of the dynamics of the ICM through recent observations, especially in radio, X-ray, and SZ, but also in other bands, as well as developments in simulation and theory hinting at possible interpretations. The current understanding is still very incomplete. However, observations with coming facilities, together with signals from multi-messenger astronomy, and rapid progress in simulation and theory have the potential to resolve fundamental blocks to the understanding of the nature of the ICM.

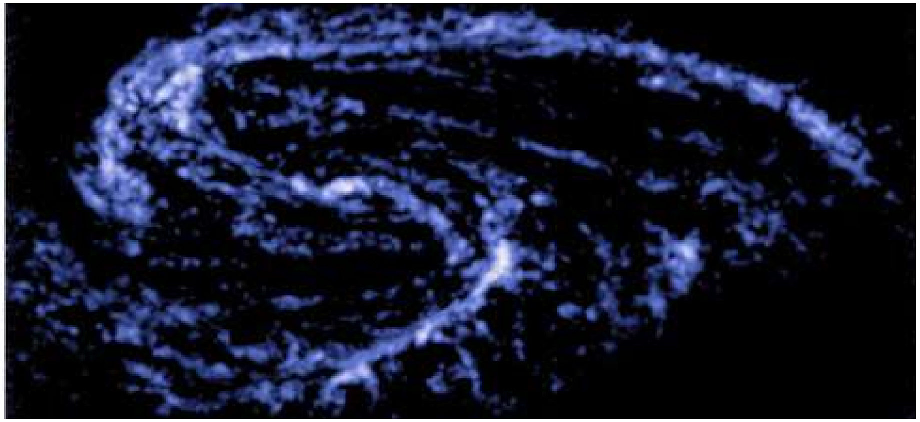


The topics of IAUGA2022 FM6 includes

1) Measuring and interpreting the dynamical states of the ICM,
2) ICM shocks, cold fronts, sloshing fronts, turbulence; their natures and their consequences
3) Nature and origins of radio halos and radio relics in galaxy clusters
4) What the new generation of radio, X-ray, and SZ (Sunyaev-Zeldovich effect) observatories will reveal and what new challenges and opportunities can we expect?

Dongsu Ryu, the SOC chair of IAUGA2022 FM6, is a professor at Ulsan National Institute of Science and Technology (UNIST). Currently, he is the director of the Center for High-Energy Astrophysics in UNIST.

Resolving the Rise and Fall of Star Formation in Galaxies



The past decade has seen rapid growth in our ability to examine star formation in significant samples of galaxies, thanks to ever larger observational surveys (including those based on integral field spectroscopy) and groundbreaking new facilities such as ALMA. At the same time, our understanding of the Milky Way is being revolutionized by the fossil record of past star formation revealed by projects such as Gaia and APOGEE. The general picture of galaxy evolution is one of steady, inside-out growth and maturation of galaxy disks accompanied by rapid aging of the highest mass galaxies due to internal and/or external processes that inhibit star formation. Yet the roles of various factors in the aging process - e.g., galaxy mergers, gas consumption, environmental refueling (or lack thereof), and nuclear activity - remain poorly understood. Integrated over the galaxy population, the effect of galactic aging can be seen as a dramatic decline in the cosmic star formation rate since the epoch of "cosmic noon" at a redshift z~2.

For galaxies that are still forming stars today, the star formation rate is strongly correlated with the stellar mass and the supply of molecular gas. However, the exact form of these star formation (scaling) relations, their universality, and the role of additional physical parameters (including galaxy conditions and environment) remain important topics of discussion. Moreover, these relations have provided limited insight into the cessation of star formation, commonly termed "quenching".

Until fairly recently, the communities that studied star formation in galaxies were divided into those who studied small scale processes at high resolution in very nearby galaxies (including our own), and those who treated star formation as a galaxy-scale process,

IAU Symposium 373: Resolving the Rise and Fall of Star Formation in Galaxies	
START DATE	Tuesday, 9 August
END DATE	Thursday, 11 August
ORAL SESSIONS	Room 205, 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 studied out to high redshifts. In the last decade, the study of star formation has been undergoing a revolution that has connected these communities – thanks to a combination of new interferometric facilities in the radio and sub-mm (e.g., ALMA, NOEMA) and IFUs in the optical (VLT MUSE and surveys such as CALIFA, MaNGA, and SAMI). The key advance has been the ability to spatially resolve the sub-kiloparsec scales on which star formation relations are established, bridging the gap between resolved studies in the local neighborhood and large scale galaxy surveys. As we finally meet for a General Assembly in 2022, JWST observations are underway, and we will soon witness a flood of data from surveys including the Legacy Survey of Space and Time at the Vera Rubin Observatory. Helping to interpret these new data will require a new generation of cosmological simulations and new techniques for confronting them with observations.

IAU Symposium 373, running from 9-11 August at the XXXI General Assembly meeting in Busan, provides an opportunity to share the latest findings in the field of star formation on sub-galactic scales. It is divided into the following topical sessions:

- Scales of Star Formation: From Molecular Cores to Galaxies
- Sustaining Star Formation: Gas Conditions & Environment
- The Decline of Star Formation: Feedback, Fuel Shortage or Inefficiency?
- The Rise and Fall of Star Formation Across Cosmic Time
- Regulation of Star Formation and the Evolution of Galaxies

A key objective for the meeting is to synthesize our knowledge of how star formation is regulated within individual galaxies and leverage it to understand the rise and fall of the star formation rate on cosmological timescales. To this end, the organizers have solicited talks from experts in different methodologies, addressing star formation at both low and high redshift. The resulting program of talks highlights the youth and diversity of the field, and will hopefully inspire many new collaborations, despite the ongoing challenges to conference participation imposed by the pandemic and economic and political factors. This symposium is particularly well-suited for a GA because many astronomers attending the GA will be interested in aspects of star formation (e.g., in relation to galaxy evolution) but may not consider themselves star formation specialists.

Given the limited time available for a GA symposium, we have had to be quite selective in terms of topics covered, and participants may notice less emphasis on interstellar processes and on the formation of individual stars and clusters than would be typical for a star formation conference. Many of these topics will be explored in other GA sessions (e.g., Division H and J meetings) which we strongly encourage interested parties to attend.

TONY WONG is a professor of astronomy at the University of Illinois, with research interests in molecular clouds and star formation.

EVA SCHINNERER leads the research group "Extragalactic Star Formation" at the Max Planck Institute for Astronomy (Heidelberg, Germany) where she is also a staff member.

What May be the Biggest Heliophysics Discovery at the General Assembly that you Missed

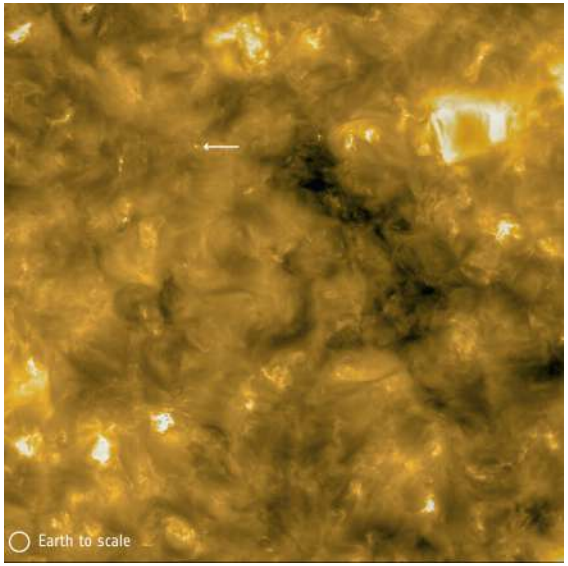


Image of a small area on the solar surface in the extreme ultraviolet range, with a campfire indicated by the white arrow. The image was obtained by the extreme ultraviolet imager (EUI) instrument onboard the Solar Orbiter (credit ESA).

As many have noted, the world has certainly changed since the last IAU General Assembly. But besides the most obvious social changes, a great deal has been happening in solar physics. Indeed, the virus is not the only corona that scientists have been paying attention to.

For decades solar physicists have been puzzling over a major mystery: why the Sun's corona is so hot. The surface of the Sun is around 5,800K, but the corona is a factor of 300 hotter, at 2,000,000K. This high corona is of course an important factor in space weather and has profound implications for Earth and ourselves, but we don't yet fully understand why its temperature is so extreme.

Eugene Parker was among the first to tackle the problem. In the 1970s and 1980s he developed a theory of so-called 'nanoflares' – much smaller versions of solar flares – as a potential heating mechanism. The idea was that individual flares were too small to be seen with the technology of the time, but that they existed on the Sun in great numbers, so could collectively convey a huge amount of heat energy.

This General Assembly in Busan has been the first opportunity in a long time for solar physicists to meet in person and discuss the coronal heating problem within the IAU framework. And it turns out to have been an extremely important one.

It's the first time we have met since the ESA Solar Orbiter spacecraft approached the Sun at just 77 million km in 2020, capturing images from closer to our star than ever before. The images appeared to contain the unmistakable signatures of nanoflares visible as 'campfires' in the extreme ultraviolet range – which had only been theoretical up until that point – as detailed in an ESA press release in July 2020.

From Solar Orbiter's data, we have discovered that these structures exist, and that they are a few hundred km in size, hinting that they could indeed be the cause of the corona's extreme temperature. But those images were only the beginning. That's why this face-to-face meeting in Busan has been so invaluable – it has really showcased all the progress being made on coronal heating by solar physicists who are analysing the data and developing the theory.

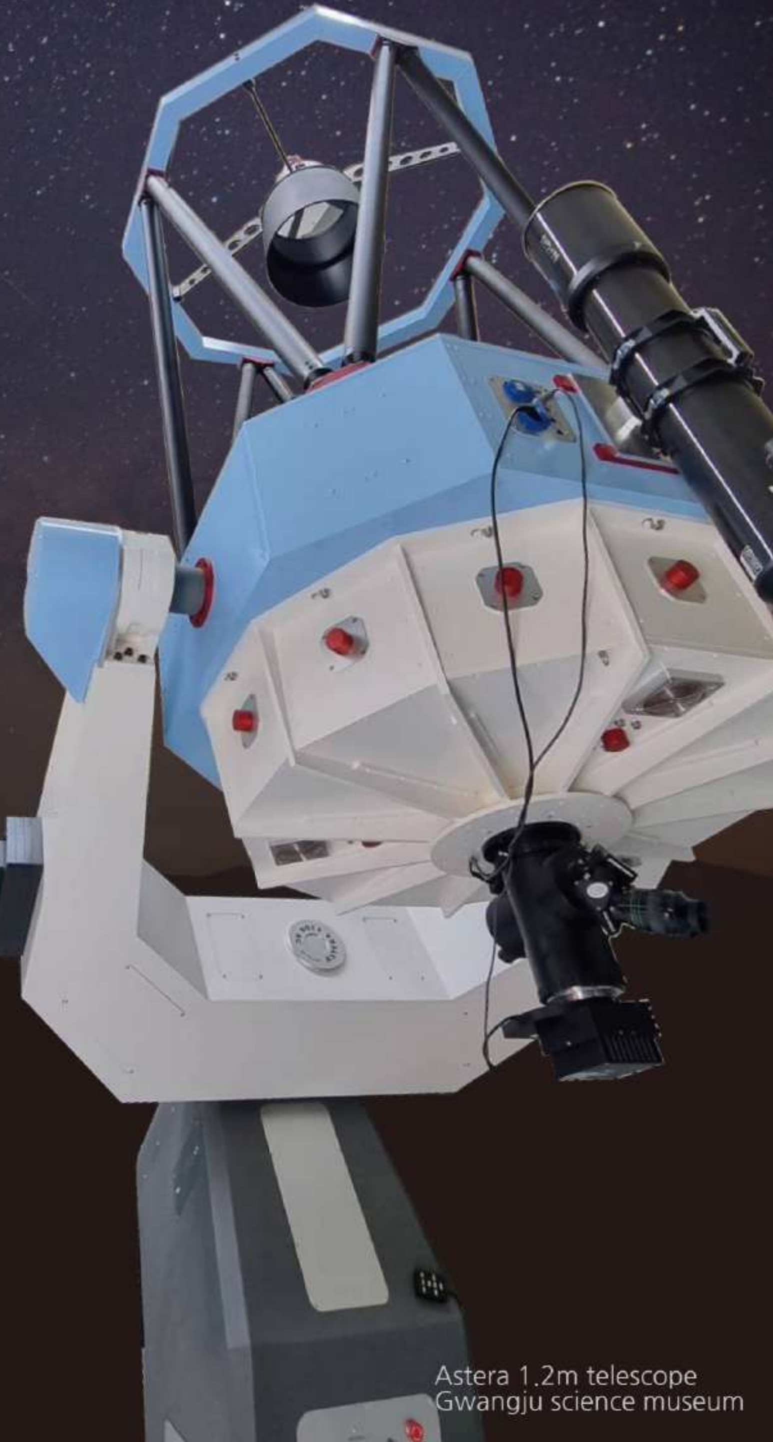
At this IAU GA, seven presentations were made on this topic as part of symposia 370, 372 and division E. Fore example, Jack Reid et al's talk explained simulations of how campfires could distribute heat, while Divya Oberoi et al's talk explored weak radio emissions that could be coming from the campfires.

Although more work has to be done to know for sure, the field of heliophysics is slowly converging on the connection between the campfires and the coronal heating. Only now, when we could all meet and exchange our views and research in person here in Busan, has the importance of this discovery dawned on us.

Many thanks to the local organisers for enabling this in-person exchange of views. Let's see what we can discover within the next triennium.

Professor Ilya Usoskin from the University of Oulu, Finland is an expert in cosmic-ray, solar and heliospheric physics.

Laura Hiscott is IAU Deputy Press Officer.



Astera 1.2m telescope
Gwangju science museum

Conference Dinner