Proceedings for the 4th Shaw-IAU Workshop on Astronomy for Education

Leveraging the potential of astronomy in formal education

15 – 17 November, 2022

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Publications of the IAU Office of Astronomy for Education

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The following is a collection of summaries from the 4th Shaw-IAU workshop on Astronomy for Education held 15 – 17 November, 2022 as a virtual event. The workshop was organised by the IAU Office of Astronomy for Education. More details can be found on: `https://astro4edu.org/shaw-iau/4th-shaw-iau-workshop/`.

The IAU Office of Astronomy for Education (OAE) is hosted at Haus der Astronomie (HdA), managed by the Max Planck Institute for Astronomy. The OAE's mission is to support and coordinate astronomy education by astronomy researchers and educators, aimed at primary or secondary schools worldwide. HdA's hosting the OAE was made possible through the support of the German foundations Klaus Tschira Stiftung and Carl-Zeiss-Stiftung. The Shaw-IAU Workshops on Astronomy for Education are funded by the Shaw Prize Foundation.

The OAE is supported by a growing network of OAE Centers and OAE Nodes, collaborating to lead global projects developed within the network. The OAE Centers and Nodes are: the OAE Center China–Nanjing, hosted by the Beijing Planetarium (BJP); the OAE Center Cyprus, hosted by Cyprus Space Exploration Organization (CSEO); the OAE Center Egypt, hosted by the National Research Institute of Astronomy and Geophysics (NRIAG); the OAE Center India, hosted by the Inter-University Centre for Astronomy and Astrophysics (IUCAA); the OAE Center Italy, hosted by the National Institute for Astrophysics (INAF); the OAE Node Republic of Korea, hosted by the Korean Astronomical Society (KAS); OAE Node France at CY Cergy Paris University hosted by CY Cergy Paris University; and the OAE Node Nepal, hosted by the Nepal Astronomical Society (NASO).

Foreword

4th Shaw-IAU Workshop on Astronomy for Education

What would you need to know to be able to strengthen the role of astronomy in schools? You might want to look at how curricula are created in the first place, and you will want to profit from the experiences of those who have already been successful in including astronomy in their countries' curricula. You would likely be interested in the various roles that astronomy can play in practice, in both primary and secondary schools. You might turn to astronomy education research for answers to questions about what fosters student interest in the STEM subjects science, technology, engineering and mathematics — and since at least part of the answer appears to be that cutting-edge results, such as those involving black hole shadows or exoplanets, are of particular interest to numerous students, you might want to look into including those topics in school teaching. Last but not least, you might look for synergies between astronomy and raising awareness for one of the most pressing challenges of our time: climate change.

That, at least, were our assumptions when we considered which sessions to include in this year's Shaw-IAU Workshop, and from the feedback received so far, we seem to have hit the mark. The workshop itself was truly global, with 600 participants from more than 90 countries. We particularly salute those participants who had to make special efforts to attend, circumventing state-imposed restrictions on international communication. With these proceedings, as well as the videos and posters from the workshop that are available online, we make the various contributions available beyond the confines of the workshop itself.

Although the total count is only up to four, the Shaw-IAU Workshops have already become something of an institution. Their genesis, of course, is directly linked to the International Astronomical Union's establishment of its Office of Astronomy for Education in late 2019, hosted at Haus der Astronomie and the Max Planck Institute for Astronomy in Heidelberg, Germany, and the evolution of the Shaw-IAU Workshops has paralleled the building of the OAE as a whole. The online format started out in 2020 as a pandemic necessity. But we soon realised that the kind of online meeting the Workshops provided was a highly accessible format that would allow us to make these workshops truly global, and to set the threshold for participation as low as possible. We acknowledge that there still *is* a threshold – since internet access with sufficient bandwidth is required – and we will continue to look for ways of increasing accessibility even further. Perhaps the hybrid format pioneered by the OAE Center China-Nanjing this year, which combined the virtual and international Shaw-IAU Workshop with an in-person teacher workshop (as well as a nation-wide online workshop) is a model for the future?

On the part of the Office of Astronomy for Education, we hope that these proceedings will help you to make better and more effective use of astronomy in support of primary and secondary school education. It's a big universe out there — let's encourage students to explore it!

Markus Pössel
Director, IAU Office of Astronomy for Education
Heidelberg, December 2022

Contents

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In addition to the efforts from the OAE office in Heidelberg, Germany, the following OAE Centers and Nodes made key contributions to organising this event:

Gravitational Waves, Black Hole Shadows and Exoplanets: Can We Make a Place for Cutting-Edge Results in Schools?

Session organisers: Anna Sippel (OAE Heidelberg), Niall Deacon (OAE Heidelberg), Stefano Sandrelli (OAE Center Italy), Surhud More (OAE Center India), and Rosa Doran (NUCLIO, Portugal)

Session overview

Cutting-edge science is not only exciting and interesting but also acts as an important introduction to both, scientific content, and the challenges of doing science. Many of you will have first become fascinated by astronomy thanks to hearing about a new, ground-breaking result. But cutting-edge science is difficult to teach about: By definition, it is a rapidly changing topic, and the latest results today may eventually become redundant in the future. This constantly shifting scientific landscape makes the incorporation of cutting-edge results into lessons and curricula tricky.

In this session, we discuss how to introduce cutting-edge results in schools, and highlight the challenges faced by astronomers, science communicators and teachers in building educational content for scientific areas such as gravitational waves, black holes shadows, and exoplanets into the curriculum.

Ten speakers will be sharing their challenges and achievements in this difficult but important task: From introducing a robust educational framework to a module connecting the astrophysics of black holes to the properties of the waves to using observational facilities and real data of exoplanets for project based and interactive learning activities, a very broad range of topics is covered. Exoplanet data are also used for active-learning tasks for students in mathematics and physics classes while another project focuses on using astronomy to implement transferable skills particularly prevalent in IT and maths. Highlights from collaborations such as LIGO Virgo KAGRA as well as EHT are presented, to convey gravitational-wave astronomy to students and teachers around the world, and we also get an introduction to Space Scoops, which brings news from across the universe to kids around the world.

Combining Design-Based Research and the Model of Educational Reconstruction in Astronomy Education

Speaker: Magdalena Kersting, University of Copenhagen, Denmark

How can we make a place for cutting-edge astronomy research in schools? Which methods ensure that our instructional activities work in diverse educational contexts and become relevant to students? While cutting-edge topics such as gravitational waves, black hole shadows, and exoplanets have great potential to motivate students, the novelty of these topics poses challenges for teachers and instructors. This contribution will present a robust educational framework, the Model of Educational Reconstruction. I will argue that we can combine this framework with design-based research methods to develop instructional resources that engage students and successfully convey the subject matter. Case studies in general relativity education will illustrate the efficacy of this approach in astronomy education.

Talk link: https://youtu.be/vq9cobm3AzI

Science classrooms are critical places to foster positive attitudes in science and prepare for future career choices. Since astronomy, applications of physics in space, and unsolved physics problems are popular topics among students (Kersting et al., 2021; Sjøberg & Schreiner, 2010), cutting-edge astronomy can realise the potential of formal science education to motivate and inspire students. Besides, these topics often create a sense of personal relevance among students and have been found to engage girls and boys alike (Kaur et al., 2020; Kersting et al., 2021; Sjøberg & Schreiner, 2010). Nevertheless, the novelty of cutting-edge research can present teachers and educators with challenges. Usually, little is known about students' learning processes, including possible alternative conceptions, in these learning domains. Additionally, teachers can seldom rely on previous experience in teaching such cutting-edge topics.

It is here that physics and science education researchers can contribute to making a place for cutting-edge astronomy results in schools. By integrating the perspectives of scientists, teachers, and students, education researchers are well positioned to develop instructional approaches and learning resources that convey new science concepts successfully while also engaging students in diverse contexts. A promising approach for synthesising these different perspectives and designing successful science instruction is combining the Model of Educational Reconstruction and design-based research (Kamphorst, 2021; Kamphorst & Kersting, 2019; Kersting, 2019).

While the Model of Educational Reconstruction serves as an overarching framework to reconstruct novel scientific topics from an educational perspective (Duit et al., 2012), design-based research provides an iterative methodology for developing and testing learning resources effectively (Anderson & Shattuck, 2012). The Model of Educational Reconstruction takes its starting point from the assumption that "science subject matter issues as well as student learning needs and capabilities have to be given equal attention in attempts to improve the quality of teaching and learning" (Duit et al., 2012, p. 13). In recent years, physics and science education researchers have proposed educational reconstructions of special relativity (Kamphorst et al., 2021), general relativity (Kersting et al., 2018), dark matter (Woithe & Kersting, 2021), nanotechnology (Laherto, 2010), non-linear systems (Stavrou, 2015), and climate change (Niebert & Gropengießer, 2013), among others.

Design-based research (DBR) tries to create instructional materials that function well in the "messy" environment of everyday school education (Kamphorst & Kersting, 2019). design-based research methods depend on several iterations of development and testing conducted in close cooperation with teachers and educational practitioners. Such cycles of iterations include problem analysis, solution creation and design, implementation, and subsequent assessment. Learning designs are continuously updated and improved because of teacher input, student views, and new research on learning processes. This constant re-evaluation and adaption of instructional resources are particularly useful when researchers and educators try adapting the material to different learning contexts and age groups.

While the Model of Educational Reconstruction provides perspectives on the subject area, teaching, and learning (theories), design-based research provides a methodological structure to include practitioners and design hypotheses. Common to both is the iterative approach in which classroom studies inform the design of learning resources. Examples of such iterations on specific learning resources and an educational reconstruction of general relativity can be found in (Kersting, 2019). In summary, combining the Model of Educational Reconstruction with design-based research methods can help us leverage the potential of (cutting-edge) astronomy in formal education.

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Bringing Gravitational Waves Into the Classroom Using Streamlit

Speaker: Sumeet Kulkarni, University of Mississippi, USA

Physics concepts surrounding oscillations and waves at the middle- and high-school level can be introduced in a more enticing way by hooking students with cutting-edge research in gravitational waves. We have developed an online, interactive module that serves this purpose using Streamlit, a python-based library. The module connects the astrophysics of black holes to the properties of waves that they emit, forming a toolkit for teaching the same in an engaging way. It can be self-completed, used in an online lesson, or interactively in a classroom module. Formative assessment questions are provided at a conceptual level.

Talk link: `https://youtu.be/j7WcEimtJtI`

The LIGO Science Education Center (SEC) in Livingston, Louisiana, USA was established to increase science engagement and provide access to quality physics education at one of the two Laser Interferometer Gravitational-wave Observatory (LIGO) sites in the country. Through on-site school field trips and detector tours, the focus of LIGO SEC has always been to connect fundamental physics involved in the detection of gravitational waves to the concepts being taught in schools. A lot of this involves hands-on demonstrations that build upon certain instrumental challenges encountered by LIGO. For instance, the mirrors used inside the interferometer are controlled using electrostatic actuators – this is not too different from how the build up of static charge enables us to displace light objects. Another example involves using pressure and vacuum demos, given that the 4-km long LIGO arms contain one of the largest vacuums in the whole world, to avoid scattering of the laser light that they carry.

With the onset of the COVID-19 pandemic, SEC field trips had to be conducted virtually. This change was accompanied by a creative redesign of the hands-on activities using materials that could be shipped or easily procured at home. At the same time, the value of developing web-based lessons was evident. However, the challenges of developing in-house web applications are many: how to transfer software to the students? How to make sure it is compatible with a wide array of computers and operating systems? How to strike a balance between creating a well-developed lesson plan and writing the actual code?

I spent the Spring semester of 2022 at LIGO Livingston SEC as an outreach fellow. I was well-versed in the Python programming language for my research, and I soon encountered Streamlit, an open-source framework for easy web-deployment of python code. Streamlit had been used previously within the LIGO education and public outreach (EPO) group to create a webpage [1] where users could easily visualise public data displaying the Gravitational-wave events detected by LIGO-Virgo so far.

With the goal of using the fundamentals of gravitational waves to teach high-school physics concepts of oscillations and waves, I experimented with the Streamlit interface and found it to be very easy to work with. I wanted to explain how a gravitational waveform recorded by our detectors is linked with the picture of two black holes spiralling into one another and colliding. The way these black holes move leads to interesting dynamics seen as changes in the frequency and amplitude of waves, which in turn can be used to teach these concepts. Streamlit enables making interactive plots where wave parameters can be modified by the user, and can even be played out as sound. At the end of the lesson, having learned different features of a gravitational wave, students can "make their own gravitational wave" by selecting masses of black holes. There is even a game at the end where students try to figure out which two black holes emit a particular waveform corresponding to one of the actual events detected by LIGO-Virgo.

Our new app [2] is cloud-based and hosted on the Streamlit server, which makes it possible for anyone to access it. There is no setup time and requirement involved for teachers. The lessons themselves can be either self-guided or conducted in classroom groups. All in all, Streamlit makes it possible for creating a free, easy to deploy, interactive online classroom lesson to teach the simple physics of oscillations and waves by connecting it to the frontiers of gravitational wave research.

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Contemporary Topics, Innovative Classrooms: Gravitational Waves and Dark Matter – Leveraging Astrophysics Research Collaboratives to Expand Physics

Speaker: Jackie Bondell and Ian Dewey, OzGrav/CDMPP, Australia

We introduce two initiatives led by Australian Centres of Excellence (CoEs) to create innovative lessons and professional development activities introducing curriculum-aligned contemporary Astrophysics concepts. The CoE for gravitational wave discovery developed extended projects aligned with senior physics curricula for students to do hands-on depth study of black hole mergers using interferometers and Python coding. The CoE for dark matter particle physics designed longitudinal partner programs in which schools have regular incursions and curriculum-aligned lessons related to the nature of science and the science of detecting the unseen, focusing on underserved schools. Both groups collaborate with science education researchers to study the efficacy of these school engagement initiatives.

Talk link: `https://youtu.be/_yk_w-Wskyo`

Can we find space in the curriculum for contemporary physics and astronomy topics? How can we do this while providing teachers with the resources and professional development to use in an ongoing capacity? And what are scientists and research collaboratives doing to support education initiatives? We introduce and begin to explore these topics in this talk and invite attendees to access our resources for their own use in education. Specifically, we will introduce the Dark Matter Partner Schools Programs and the Gravitational Waves Depth Study.

Who are we?: We are a group of educators, science communicators, and researchers with the goal of providing contemporary Physics and Astronomy education opportunities to a diverse cross-section of students.

Our work comes under two Australian research collaboratives: the ARC Centre of Excellence for Dark Matter Particle Physics (CDM) and the ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav). These groups are supported by the Australian Research Council. Jackie Bondell is the Education and Outreach Coordinator for both centres.

Carlos Lopez is the former principal of Stawell Secondary College, a government school in regional Victoria. Stawell is where the Southern Hemisphere's first underground dark matter detection lab is being built. He has been instrumental in liaising with CDM to support the pilot of the Dark Matter Partner Schools program.

A cohort of OzGrav scientists has contributed to the Gravitational Waves Depth Study content. These include Maddy Parks, Kendall Jenner, Zachary Holmes, Dr Dan Brown, and A/Prof Paul

Lasky. Ian Dewey is a Physics Teacher who has been a key driver to develop and drive the use of these Gravitational Wave activities in South Australian schools.

What are we doing?: OzGrav and CDM both have Education and Outreach portfolios. The goals of these are to bridge the research with the general public, with a focus on engaging teachers and students with exciting contemporary Physics programs. This talk focuses on two of these programs: CDM's Regional Partner Schools Program and OzGrav's Gravitational Wave Depth Study.

CDM's Regional Partner Schools Program builds multi-year collaborations with regional and rural schools to collaborate with teachers on delivering lessons that incorporate topics that align with Dark Matter science and the curriculum. The program provides multiple touchpoints over the course of many years with the goal of creating better pipelines into STEM for students from underserved areas.

OzGrav's Gravitational Wave Depth Study provides late secondary students to investigate gravitational wave (GW) physics in the context of the Physics study design. This includes modules using tabletop interferometers to understand GW detectors and a coding module to analyse GW signals from real LIGO data. This program was led by high school teacher Ian Dewey collaborating with OzGrav researchers and will be scaled to make it available to more educators.

Why these collaborations?: These programs aim to bring exciting new contexts to science education by connecting contemporary research and scientists with teachers and students. They particularly aim to improve pathways into tertiary STEM for a large cross-section of students while providing resources to support teachers in incorporating new content into their classrooms. We specifically focus when possible to engage with schools that are geographically distant from the metro centres as accessibility to many STEM opportunities is hampered by geography.

Project-Based Learning on Exoplanetary Explorations

Speaker: Chen Cao, Shandong University, Shandong Astronomical Society, China

Collaborators: Dongyang Gao (Shandong University, Nanjing University), Nan Song (China Science and Technology Museum), Dayong Ren (Shandong University)

In this contribution, we will discuss how to use observational facilities and real data of exoplanets (transits, radial velocities, transmission spectra, etc.) to make project based learning for high school & undergraduate students. Our research projects on exoplanet detection, characterisation, formation & evolution and habitability, allow students to form advisor led teams, for interactively learning exoplanetary sciences, scheduling observations, obtaining & reducing the data, making analysis and having discussions. Project based learning will engage students in solving problems, answering questions and team working. As a result, they can develop deep content knowledge as well as creativity, critical thinking, collaboration, and communication skills.

Talk link: `https://youtu.be/V40c58pyy0U`

In this contribution, we present our initial project-based learning (PBL in short) program on cutting-edge exoplanetary explorations. Since 1990s, advances in science and technology have enabled us to detect planetary systems orbiting around other stars, called exoplanets. Using only three decades, we have found over 5100 exoplanets around 3800+ exoworlds, it is now the forefront field in modern astronomy & astrophysics, we are on the "Pathways to Habitable Worlds" (Astro2020). It is relatively "new/innovative" in astronomy and has many challenging problems/questions, so should be good as a PBL testbed. Project-based learning (PBL) is a student-centered pedagogy that involves a dynamic classroom approach in which it is believed that students acquire a deeper knowledge and develop success skills as well as: critical thinking, collaboration, creativity, and communication skills, through active exploration of real-world challenges and problems.

There are three steps (phases) for our PBL-exoplanets program: Phase I. scientific popularisation program on exoplanets discoveries; Phase II. observational system design and improvements for exoplanets studies; Phase III. (small) research topics on exoplanetary sciences.

During phase one, students should learn basic knowledge of our solar system and exoplanets, by reading astronomical textbooks and papers, also by web-searching. This student-centered learning activity is focused on planet formation, exoplanet detection & characterisation, and their habitability (atmosphere). This is accompanied by group discussions between students, teachers, and experts. Finally, the students should organise outreach and education activities for other students and public, these "artifacts" include: writing introductory articles, making short videos, and giving oral talks on exoplanets. Also these outreach activities can be used in IAU's NameExoWorlds 2022 campaign.

In phase two, students will start to familiar with telescopes and try to schedule their own exoplanet observations. Also, they must learn and practice on data reduction and analysis. Particularly, they should focus on problems like how to make good and efficient photometric and spectroscopic observational strategies, and how to improve the precisions, for example for reference photometry in exoplanets transit studies. Finally in this step, students should write observing proposals and technical testing reports, give presentations and make discussions. Our undergraduate and high school students have already made some observations & studies on exoplanets' transits using the 1m, 30cm, 60cm telescopes in our Weihai Observatory of Shandong university (WHO [1]). We got high-quality transit light curves and analyse the planetary parameters, some results were published in peer-reviewed articles (Zhang+2011, AcASn [2]).

In phase three, students can select and do some small but interesting research projects (topics) on exoplanets, this includes (but not limited to): participating in citizen science projects like Planet Hunters – TESS, performing transit and follow-up observations on exoplanets and candidates, make statistical analysis on exoplanetary and their host stars' properties, and study exoplanets' habitability by analysing their atmospheres using transmission spectroscopy, etc. Students will write their final research reports and articles, some excellent ones can submit to refereed journals. Also, they must present their results and findings to other students, teachers, experts, and the general public, to get feedback and evaluations. Their achievements can also attend China Adolescents Science & Technology Innovation Contest (for high schools) or Chinese undergraduate Astronomical Innovation Contest etc., this will be a great stimulation for our PBL-exoplanets program.

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Meet the IAU Astronomers!

Speaker: Suzana Filipecki Martins, Office of Astronomy Outreach, Japan

The “Meet the IAU Astronomers!” programme connects teachers, informal educators and amateur astronomer groups with IAU-members for meet-up (events) where professional astronomers have the chance to share their research, the importance of astronomy for society, and why following astronomy as a career is a viable and rewarding choice. The “Meet the IAU Astronomers!” programme goals is to “facilitate international communication through exchanges” and “encourage communication of science and critical thinking through IAU member public engagement”. A relaunch in spring 2022 was set to align the programme objectives and event structure with new evaluation instruments and to provide astronomers and organisers with tools that allow them to deliver inclusive events. Presented in comprehensive handbooks, the proposed structure and methodology widen the scope of the events and aim to facilitate events that strive to create lasting personal and social impact on the communities, participants and the astronomers themselves. The handbooks also encourage astronomers to consciously incorporate inclusive outreach practices and strategies that will encourage critical thinking, for example, by including opportunities for participants to identify, analyse, and evaluate the content shared. In this contribution, we introduce the programme and describe best practices gathered from other projects, such as STEM Ambassadors, that reflect inclusive practices and inform the “Meet the IAU Astronomers!” programme.

Talk link: https://youtu.be/zKqp5xIvN7Q

The “Meet the IAU Astronomers!” programme connects teachers, amateur astronomers, and informal educators with professional astronomers who are members of the International Astronomical Union (IAU) for virtual or in-person events. Through these events, the IAU members speak with children, adults, and other members of the public on astronomical research topics, the importance of astronomy for society, and choosing astronomy as a career. “Meet the IAU Astronomers!” programme is a variation of a tried and tested STEM outreach activity commonly known as STEM Ambassadors. From a learner perspective, programmes such as “Meet the IAU Astronomers!” “support learning by helping young people to understand real-world applications of science, they illuminate STEM careers through careers talks and links with the world of work, and they raise aspirations, demonstrating to students the wide range of people who pursue a future in STEM (https://www.stem.org.uk/sites/default/files/pages/downloads/STEM%20Ambassadors%20Report%2021_06%20FINAL.pdf).

At the same time, the programme aligns with IAU’s Goal 4 “The IAU engages the public in astronomy through access to astronomical information and communication of the science of astronomy", and OAO's strategic action: "Encourage communication of science and critical thinking through IAU member public engagement, professional-amateur, and citizen science activities"(IAU Strategic Plan 2020-2030 - https://www.iau.org/static/administration/about/strategic_plan/strategicplan-2020-2030.pdf).

"Meet the IAU Astronomers!" (https://www.iau.org/public/meettheiauastronomers/) objectives are to:

- Communicate the science of and current research in astronomy.
- Stimulate critical thinking.
- Change perceptions, attitudes, behaviours, social norms and stereotypes towards astronomers, showing that astronomy is a collaborative science made by a diverse group of individuals.
- Stimulate the uptake of astronomy as a career choice, especially for girls and children from underserved communities.
- Engage astronomers with wider communities and help build a perception of how their work contributes to making our planet more peaceful, sustainable and fair.
- Encourage the participation of IAU members in public engagement and collaborations.

After its first years of implementation, the programme was relaunched in the Spring of 2022. The OAO put in place new tools for astronomers and event organises with the aim of better aligning the programme objectives and its implementation. Tools included:

- Guidebooks for Astronomers and organisers that include information on how to prepare for the event, how to make the event more inclusive, and how to stimulate critical thinking.
- A set structure for the event.
- Surveys that help the OAO understand if the project is responding to its goals and objectives and if they are being implemented in the best way possible.

As of November 2022, 203 astronomers have registered to take part in the programme. The registered astronomers come from 52 countries, primarily from the United States, India, Spain, the United Kingdom and Germany, who can deliver events in 40 languages. The IAU Office for Astronomy Outreach (OAO) has received 42 event requests from 28 countries, mainly Pakistan, Mexico, Albania, Argentina, and Peru.

Resources:

- Other STEM Ambassadors programmes: STEM Ambassadors (UK): https://www.stem.org.uk/stem-ambassadors; Fureai Astronomy: https://prc.nao.ac.jp/delivery/; Portal to the Public Network: https://popnet.instituteforlearninginnovation.org/about/

The Dutch Black Hole Consortium Education Programme: A Cutting-Edge Interdisciplinary Research Collaboration with Education at its Heart

Speaker: Joanna Holt (On behalf of the Dutch Black Hole Consortium), Smart Education Lab, Amsterdam University of Applied Sciences and Netherlands Research School for Astronomy (NOVA), the Netherlands

The Dutch Black Hole Consortium brings together cutting-edge research from subjects as diverse as astronomy, engineering, and geology to further our understanding of black holes and gravitational waves. At its heart is an ambitious educational project to bring the results into both classrooms and informal learning settings. For primary level, lessons are being created using innovative smart education techniques and research will focus on how to support learners to think scientifically. At secondary level, the focus lies with teacher education; trainee physics teachers will be able to experience real scientific research to inspire and improve their classroom practises. The consortium is also developing a large citizen science project and exhibits for two science museums/centres.

Talk link: https://youtu.be/QUPs-m0t0tI

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The Dutch Black Hole Consortium comprises a group of more than 30 scientists carrying out interdisciplinary research in the Netherlands. The collaboration is extremely broad including astronomers, theoretical physicists, engineers and telescope developers, geologists, seismologists and education and outreach specialists. Whilst at face value the topics sound unrelated, all are necessary to further our understanding of black holes.

Another crucial aspect that makes this collaboration unique is the emphasis on education and outreach. Whilst education and outreach is often an add-on in many projects, a third of the work effort and budget in the Dutch Black Hole Consortium is dedicated to disseminating black hole science to the wider public and educating and inspiring the next generation of scientists.

The Dutch Black Hole Consortium has funding initially for six years and officially started work in September 2021. More information about the consortium, its members, work-packages, meetings and regular updates on progress can be found on our website.

A brief overview of the work-packages

The astrophysics effort includes work related to black hole imaging and modelling and the progenitors of gravitational wave events, both from an observational and theoretical perspective (WP1-4). The consortium is also contributing to the Einstein Telescope (WP5,6), a new gravitational wave detector that will be built within the next decade. The consortium is developing new technologies required for the telescope design. One of the possible sites is in the very

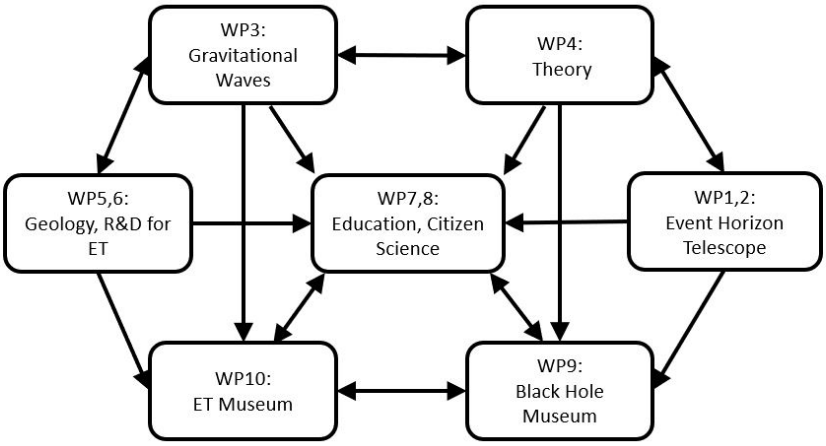

Figure 1: The Dutch Black Hole Consortium

south of the Netherlands, straddling the border with Belgium, however the geology of the area is currently not well understood. The consortium is therefore performing a detailed geological survey of the potential site.

The final 4 work-packages (WP7-10) are focused on education and outreach and will draw on and promote the other work-packages (Fig. 1). The consortium is creating new content for the interactive science centre Discovery Museum in Kerkrade and the Boerhaave Science Museum in Leiden. There will also be a large citizen science project related to the data from the BlackGEM telescope, whose main scientific goal is to identify optical counterparts of gravitational wave events. The test version is expected to ready in early 2023 with a public version later in the year. Alongside these activities is an extensive formal education package (see below).

Education at primary and secondary level

The formal education package includes three main goals. Figure 2 highlights how these goals are related to each other and the broader consortium:

1. A lesson package for upper primary level (10-12 yrs) to stimulate scientific thinking through hands-on – minds-on learning with an interactive digital tool.

2. Research internships for trainee physics teachers to give them experience of real scientific research to help them convey what it really means to be a scientist in the classroom.

3. A dedicated PhD project to research the impact of the educational programmes in both formal and informal settings. This research will provide important information for discussions at high level aimed at improving the visibility of cutting-edge science in school curricula and lesson materials in general.

Lessons for primary schools

The primary lessons will tackle relevant primary science goals and will assist teachers to teach science and support learners in developing scientific thinking skills. The lessons also aim to inspire children to be scientists of the future. The Dutch Black Hole Consortium provides an exciting context of cutting-edge science and technology.

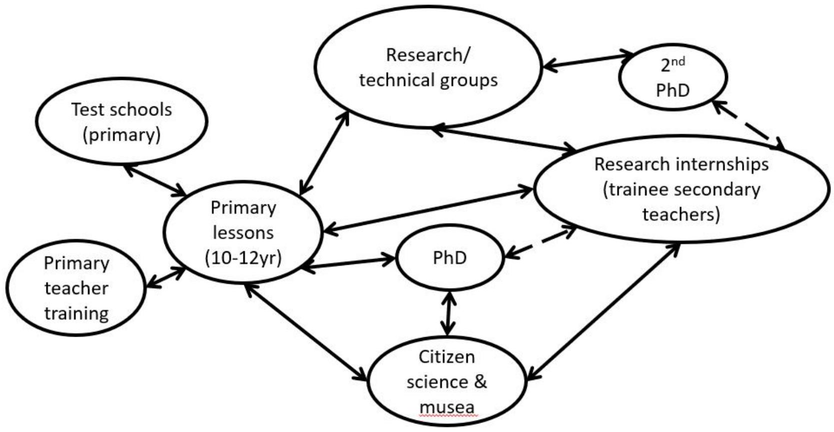

Figure 2: Formal education at primary and secondary level

In each lesson, a science concept will be combined with a scientific thinking skill. The science concepts will be drawn from the Dutch curriculum for upper primary. Whilst black holes and other topics from the consortium do not appear specifically in the primary curriculum, science concepts relating to them do, such as gravity and light. To address scientific thinking, each lesson will focus on one of the seven cross-cutting concepts[1] such as cause-and-effect reasoning, patterns or thinking in systems. Lessons will consist of short practical activities interspersed with an interactive concept diagram in a digital tool. Learners can, for the most part, work independently in the tool and receive automated feedback and interaction to stimulate the thought process. The lessons will build on the existing project Minds-On. Lessons will be evaluates using a suite of tools including pre- and post-tests, teacher and learner questionnaires and click-data from the tool.

Black holes in primary schools

Black holes do not appear in the primary school science curriculum, so why should we want to bring topics such as black holes into the primary classroom? It is now well known that astronomy topics are perceived as some of the most interesting science topics by both boys and girls though projects such as the Rose project. Practical experience of the Netherlands Research School for Astronomy (NOVA) Mobile Planetarium project also show that even the youngest children have heard about black holes and are curious to learn about these exotic objects.

Summary: The Dutch Black Hole Consortium is an interdisciplinary collaboration of scientists from the fields of astronomy, theoretical physics, technology, and earth sciences in which education lies at the heart.

[1]National Research Council (2012). A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Committee Conceptual Framework New K-12 Science Education Standards.

Using Authentic Exoplanet Data to Promote Active Learning of Physics and Mathematics in Schools

Speaker: Carla Hernández, Universidad de Santiago de Chile (USACH), Center for Interdisciplinary Research in Astrophysics and Space Science (CIRAS), Millennium Nucleus on Young Exoplanets and their Moons (YEMS), Chile

Collaborators: Fernanda Alarcón (USACH), Ignacia Benito (USACH), Irma Fuentes (YEMS) & Sebastián Pérez (USACH, CIRAS, YEMS)

Chile benefits from a favourable position to develop astronomy; however, teacher training in the area is low, and there are few opportunities for students to learn about frontier research. To address this challenge, we built a group of astrophysicists, science education specialists, and high school teachers to co-construct active-learning activities using exoplanet data for physics and mathematics classes. Our team worked with almost a hundred students from three schools to pilot our activities. The results show that teaching frontier astrophysics in school classrooms is possible and promotes students' interest in science. We believe this project contributes to bridging the gap between astrophysics research and teaching science in school.

Talk link: https://youtu.be/V9-XxgogS9I

Living in a privileged geographical area for astronomical observation allows this line of research to be one of Chile's most relevant areas of knowledge [1]. However, a review of the national educational curriculum reveals little astronomy content taught at the school level [2]. The limited curricula and the lack of updated content reflecting the latest findings in frontier astronomy represent an obstacle for students to learn about the diversity of astronomical phenomena and, particularly, what is investigated in Chile.

To address this challenge, we built a professional learning community [3] composed of astrophysicists, science education researchers, and high school teachers to co-construct active learning activities using exoplanet data for physics and mathematics classes. We implemented activities for more than 100 Chilean students aged 14 and 15.

We used the Open Exoplanet Catalogue to select information on the radius, mass, period, and semi-major axis, among others, for 800 exoplanets. The data were delivered to the students in Excel's .xls spreadsheet format in class. Students used them to learn about graphs, record populations in double-entry tables, build scatter plots, and draw trend lines, among other mathematics topics. In physics classes, the data was used to study Kepler's Laws and to establish comparisons between variables following the objectives of the national curriculum. In addition, using the NASA Eyes on Exoplanets platform, they could visualise different systems and access more information about the host stars, detection techniques, and habitable zone.

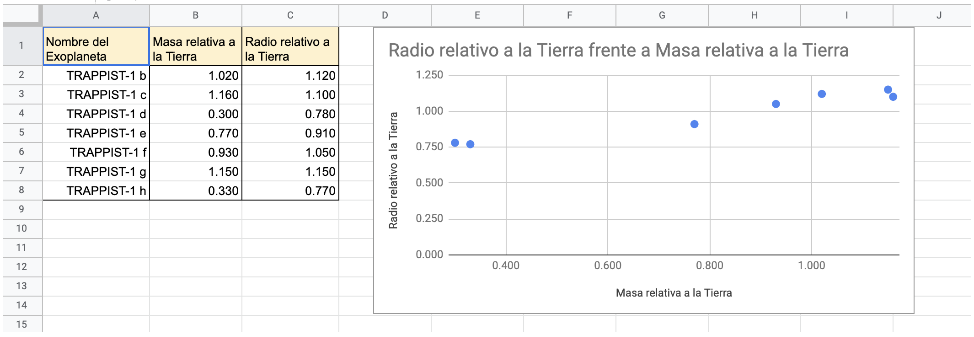

Figure 1: Graph made by a group of students on correlations and linear trend, with data from the Trappist-1 planetary system.

Figure 1 shows the graph obtained by the students when analysing mass and radius data (relative to the Earth) for the Trappist-1 system. Since each group of students worked with data from a different system, comparing results and formulating joint conclusions were encouraged. The process was repeated using data from our Solar System and a table with information on 800 exoplanets. Subsequently, their results were compared with a graph that we provided to the teacher for the more than 5000 exoplanets that had been detected to date (Fig. 2).

At the end of each activity, students were encouraged to formulate questions for the researchers based on the work done in class. We could identify questions formulated in categories [4], as shown in Table 1.

At an exploratory level, participants were asked about their perception of scientific activity and whether it had changed due to the work done in class. Some of the answers obtained were the following:
E2_3, "Yes, because I was able to know an area of science more in-depth than I knew."
E2_7, "Yes, in the aspect of knowledge and data processing, since these disciplines are very much related to mathematics and statistics."
E2_27, "Yes, because I thought that science was only one method, but with the work, I learned that science had several topics."
The answers obtained concerning perception suggest that the work carried out using actual data from frontier astrophysics favours the motivation and interest of students in astronomy and scientific work in general.

Based on the results, we consider that the possibilities and scope of this project are extensive. On the one hand, we realise that bridging the gap between research and the classroom is possible. Doing so implies collaborative work based on horizontality and mutual respect for

Table 1: Examples of questions asked by students at the end of the activities.

Category	Sample student question
Nature of Science	What is the benefit of discovering an extrasolar planet?
Scientific Knowledge	How likely is it that a planet like Earth exists? Are there habitable planets nearby?
Scientific Activity	What instruments and methods do you use to obtain data from planets?
Scientific Career	Why did you want to study astronomy? Is it fun to find a new world?

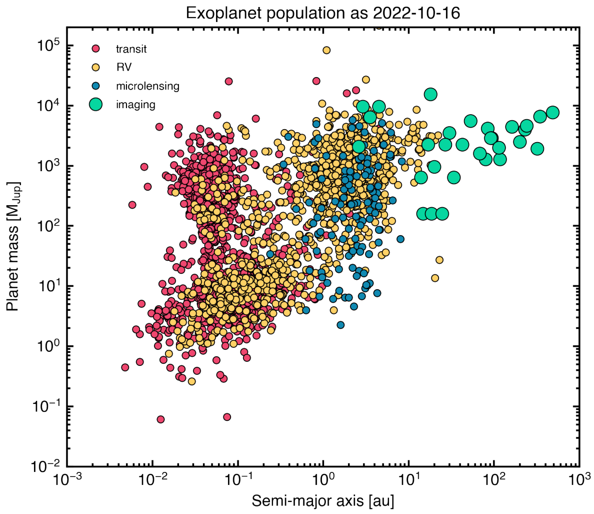

Figure 2: Plot showing the mass of exoplanets versus the size of their orbit. The colours of each data cloud indicate the method by which the exoplanets were detected. Plot prepared by Sebastián Pérez for teachers (in Spanish), from the data available in the Open Exoplanet Catalogue.

the training of teachers and scientists. We note that a limitation of this work is its reliance on technology. In some locations of our country, lack of technology access may hinder data use in the classroom. However, we propose alternatives for its use in the guidelines for teachers that accompany the activities.

As work prospects, we will also conduct a free training workshop for Chilean teachers who want to implement these proposals in their classrooms, with the support of the IAU-OAE Teacher Training Pilot Program. Also, this year we are part of the Global Sky Partner. We were assigned hours of astronomical observation at Las Cumbres Observatory to obtain light curves of the nova eruptions and develop activities to teach exponential and logarithmic functions. In addition, we will work with an amateur observatory in Chile to obtain actual data on southern star spectra. This way, we will add a chemistry teacher to create new activities. The designed activities will be published for open use through the `www.ciras.cl` website starting in 2023.

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4. France, B., & Bay, J. L. (2010). Questions students ask: Bridging the gap between scientists and students in a research institute classroom. International Journal of Science Education, 32(2), 173-194.

Incorporating Astronomy Research into the Classroom

Speaker: Fraser Lewis, Faulkes Telescope Project and National Schools' Observatory, UK

As part of my work with the Faulkes Telescope Project, I present examples of work done with students in various fields of astronomy research. Examples include studies of black hole X-ray binaries, open clusters, supernovae and exoplanets. In many cases, students follow the entire scientific process from target selection to observation to analysis and conclusions/reflection. While allowing students to learn, and be inspired by, astronomy, they are also able to practice implement transferable skills though the medium of astronomy. These skills are particularly prevalent in the fields of IT and maths.

Talk link: `https://youtu.be/If0_Rm1mowk`

The Faulkes Telescope Project provides telescope time free-of-charge on the Las Cumbres Observatory (LCO) robotic telescope network. In addition to telescope access, we provide resources on finding suitable targets, image processing and photometry. Here, I discuss some activities I have helped to design in the areas of exoplanets (especially transiting systems) and in black hole binary systems.

One of my exoplanet activities is part of a set of three inquiry-based activities produced using real astronomical data in the subject areas of exoplanets, supernovae and open clusters. In addition to this, I have been working since early 2021 with a group of astronomy educators and students in a project called GWAM (Gee Whizz Astronomy Modelling). This project has allowed us to collect several sample datasets on exoplanet transits as well as providing us with invaluable insight from our students into what properties make a suitable target for imaging with the LCO network.

Working with Dr. Rosa Doran (NUCLIO, Portugal) and capitalising on my research area of X-ray Binaries (XRB; binary systems comprising a compact object with a 'normal' star), I have also helped to develop an activity called Black Holes In My School. This involves the creation of a light-curve of a short orbital period XRB and via photometry and Kepler's Laws. It allows students to explore the mass of the compact object, which could only a neutron star or black hole.

Each of these activities harnesses the enthusiasm that students have in astronomy in general and in particular, in these areas which are still at the forefront of research. They include broader STEM skills such as graph plotting, uncertainties, logarithms and cover areas that are common to many physics curriculums across the world.

Sparking Imaginations with Black Hole Images

Speaker: Chi-kwan Chan, Steward Observatory and the Department of Astronomy, University of Arizona, USA

Black holes are regions of extremely distorted spacetime that not even light can escape. As predictions of Einstein's general theory of relativity a hundred years ago, black holes have captured the public's attention for many years and have influenced science friction, movie, music, and pop cultures. When we released the first ever images of black holes at the center of M87 in 2019 and our Milky Way earlier this year, students all across the world learned that black holes are real, and learned that through science, we can make predictions that were once beyond our imaginations. Using this opportunity, the EHT engages with students at all levels to promote astronomy, scientific thinkings, and mathematical reasonings. In this contribution, I will share the methods and lesson-learned from the EHT.

Talk link: https://youtu.be/4jP4UkQ6JAI

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The Event Horizon Telescope (EHT) project aimed to capture the first images of a black hole. When we released the first ever images of black holes at the center of M87 in 2019 and our Milky Way earlier this year, students across the world learned that black holes are real, and learned that through science, we can make predictions that were once beyond our imaginations. Using this opportunity, the NSF-funded Black Hole Partnerships for International Research and Education (PIRE) project engages with students at all levels to promote astronomy, scientific thinking, and mathematical reasoning.

We worked with different educators and passionate people on developing different education materials. With worked with an education major student who happened to enjoy astronomy to develop class modules for elementary and middle school students. These materials are short in-class modules with activities to engage young students. We describe basic concept such as force, speed of light, and black holes, but did not go into too much details and math. We learned that elementary and middle school education is completely different from University education. We heavily rely on our education major student to select content at the right level to match the students' ability.

We worked with Zoom to create the Zoom Classrooms "Chasing Black Hole" to provide additional science educations for high school students. This was set up before the pandemic so zoom was a new technology for everyone. For each classroom, two scientists from the EHT and one host from Zoom would connect to hundreds of classrooms across the US, where the EHT scientists provided a high-school level introduction to gravity and black holes. We also provided additional materials to teachers so they can set up activities and exercise to engage with the students. The exercise uses simple math to help the students understand the material they learn from the Zoom Classrooms. For this work, partnerships with high school teachers and technology company such as Zoom are essential. While material selection is less difficult compared to elementary and middle school, engaging high school students and exciting them in science is non-trivial. New technology itself is an interesting way to draw the students' attention. And at the end we need teachers to provide the follow up activities to ensure the students were able to learn something meaningful.

At University level, although there are astronomy courses (and we have helped creating education modules), to engage students who normally would not take a science course, we worked with the University outreach office to create additional activities. We drew an Einstein with chalk and put it on campus during new student visit. Hundreds of students and their parents walked by our chalk art, imagined what is on the other side of a black hole, wrote down their answers, and took pictures with the art. I personally answer questions raised by almost hundred people, and motivate about ten art students to take introductory science courses.

In short, the public is curious about black holes. Using it as a motivation, the Black Hole PIRE project successful engaged with the students at all level and public in black hole research. We collaborate with our colleagues and external partners to develop education materials at all levels, from elementary and middle school, to high school and even Universities level. We learned that 1) it is ok to leave out the details, 2) creativity is important, and 3) it is absolutely essential to work with educators and people who care about education.

Engaging Students and Teachers with the Exciting New Field of Gravitational-Wave Astronomy

Speaker: Martin Hendry, SUPA, School of Physics and Astronomy, University of Glasgow, UK

In just a few years the detection of gravitational waves has progressed from global breakthrough to almost routine occurrence. This exciting, young field offers excellent opportunities to engage and inspire STEM students and teachers through its combination of more advanced science topics which enjoy widespread popularity (black holes, general relativity, quantum physics) and more fundamental concepts (in mechanics, gas physics, lasers and materials) at the core of high school, college and university science and engineering courses. Here I highlight some of the approaches, adopted by the LIGO Virgo KAGRA Collaborations and the LISA Consortium, to convey the exciting science of gravitational-wave astronomy to STEM students and teachers across the globe.

Talk link: https://youtu.be/o3GRe2vEWyc

The discovery of gravitational waves (GWs), in 2015, marked the beginning of an exciting, new era in astrophysics that has opened a completely new window on the universe. In just over seven years since then, the LIGO, Virgo and now KAGRA (LVK) collaborations have made almost 100 confirmed detections of GW events, from collisions of pairs of black holes, neutron stars and black hole-neutron star systems, with the most recent catalogue of these events published in November 2021.

Long before the first GW detection, the LIGO Scientific Collaboration (LSC) had already been firmly committed to a programme of education and public outreach (EPO) – with the LSC EPO group first established in 2008 and a White Paper describing the Collaboration's activities written to guide the development of the group. The latest version of that White Paper, now evolved to become an inclusive document that sets out the strategic mission and collective EPO goals of the LVK Collaborations, reaffirms our commitment to harness the excitement generated by GW research to inspire and educate students and the general public in astronomy and fundamental science. We believe that the opportunity to discover the beauty of the cosmos should not be limited by age, culture or abode.

The EPO activities of the collaborations span a wide range of categories, and include:

- active visitor programmes at the various detector sites around the world;
- outreach in formal and higher education, particularly focused on providing online resources to support students and educators who wish to access and analyse GW data;

- informal education activities to multiple audiences – including the creation and curation of visual and audio multimedia, social media engagement across multiple platforms, educational games and apps, exhibitions on GW science and public lectures and discussions;

- outreach to other scientists, funding bodies, politicians and other stakeholders.

In this contribution I highlight a few examples of these activities that are particularly targeted at high school students and educators. Although my talk draws upon many years of leadership of LSC EPO efforts, I am not presenting formally on behalf of the LVK and instead am merely seeking to offer some brief, personal perspectives. I apologise in advance for any specific activities or contributions that I have overlooked due to lack of time/space. The interested reader can, of course, find out much more about LVK outreach programmes by following the links provided below.

Some Key EPO Resources for students and teachers
The essential launch-off points for students and educators wishing to learn more about GWs are our Collaboration websites (`https://www.ligo.org/`, `https://www.virgo-gw.eu/`, `https://gwcenter.icrr.u-tokyo.ac.jp/en/`). At `www.ligo.org` there is a section with resources about all of our main discovery announcements that includes animations, skymaps, visualisations, infographics and factsheets. You will also find links to our LIGO Magazine which has been produced twice yearly since 2012 and contains lots of articles written at the level of a high school audience; these describe not just the science we have learned but also the global family of scientists behind the discoveries.

Another flagship EPO resource is our science summaries: non-technical articles that accompany every one of our Collaboration papers and are written by the same scientists who lead the writing of the papers themselves. Again, they are aimed at a general audience: high School students, teachers, journalists as well as other scientists. We always seek to relate the content of our science summaries to the science topics that high school students are exploring in their classes, so they are an excellent tool for stimulating classroom discussion, supporting self-study or enhancing skills in science communication. We have produced over 160 summaries to date, and they have been translated into more than 20 languages.

The Gravitational-Wave Open Science Center
Our EPO team also helps to support and promote the GW Open Science Center (GWSOC). Here you can access actual data from previous LVK Observing Runs and explore tutorials and programming tools to help you analyse our GW detections for yourself. In recent years the LVK Collaboration, led by the GWOSC team, have hosted several online and in-person workshops that provide training in GW data analysis; these have been attend by thousands of participants and the most recent workshop (held in May 2022) is still available to be taken as an online self-directed course. Whilst these workshops have been very popular and attracted participants with very little prior knowledge or expertise, a key future EPO goal is to create a new version of the GWOSC tutorials that is tailored for high-school students and teachers – without requiring any prior programming experience.

As a first step towards such provision, our LSC Caltech colleague and GWOSC lead, Jonah Kanner, has already created a “learning path” on the GWOSC homepage that complements the existing GWOSC tools and workshop materials. The learning comprises two introductory videos and a simple, interactive tool (created by our LSC Cardiff colleague Chris North) to learn about the basic ideas of waveform fitting and matched filtering. Students can then dive a little deeper into the science behind the waveforms themselves and what they can tell us – drawing heavily on analogies with musical frequencies and harmonics – before applying this knowledge to find a secret sound hidden in noisy data: directly analogous to the actual process of analysing GW signals. Finally, students can use a simple graphical interface to plot and explore some real GW data, with a list of follow-up resources also available for further investigation.

In short, there are excellent resources available to help high school students and teachers learn about our GW discoveries – including interactive tools to let them explore the data directly. There are also multiple ways for students to reach out to the GW community to ask questions, such as our LVK discussion forum ask.igwn.org, our dedicated email address question[at]ligo[dot]org and our various social media platforms (Twitter: @ligo, @ego-virgo, @KAGRA_PR, @LIGOIndia; Facebook: @LigoScientificCollaboration, @EGOVirgoCollaboration, @kagra.pr, @LIGOIndia; Instagram: @ligo_virgo, @ligoindia).

So with our network of detectors set to begin the fourth LVK observing run in spring 2023, with the prospect of even higher detection rates and lots more discoveries, there has never been a better time to explore the exciting new field of GW astronomy.

Space Scoop

Speaker: Florian Seitz, Haus der Astronomie, Heidelberg, Germany

“Bringing news from across the universe to kids all around the world” is the claim of the Space Scoop project. Current astronomy press releases and publications are edited and presented especially for children. Interested children get insights in what is going on in astronomy right now. New Space Scoops are presented regularly. A translator network translates these Space Scoops in different languages.

Talk link: https://youtu.be/1Zfiivji7zc

Space Scoops (www.spacescoop.org) bring the latest astronomical research into the classroom. The short texts cover exciting astronomical topics in easy-to-understand language.

The Space Scoop partners are astronomical research institutions that send their press releases to Space Scoop. Some of these press releases are then edited for children and young people and published on the homepage. The design and operation of the homepage is adapted to the user group.

The texts are kept short, simple, and understandable. The tone is playful but serious enough. The Space Scoops are translated into over 30 languages by a network of volunteer translators. This way, many children in this world have access to fascinating new insights in astronomy.

Amateur Astronomer Magazine Provides Chinese Students with Cutting-Edge Science Contents

Presenter: Feng Chong, Beijing Planetarium, China

'Amateur Astronomer' magazine is the earliest and most influential astronomical science journal in China. The magazine has a monthly circulation of 16,000 copies, and the readers are young students. The magazine can be fast, accurate, and stable in terms of response speed, quality of content and topic continuity. First, the editors have been closely following the frontiers, keeping close contact with astronomers. Second, the professionalism and accuracy of the presented content is ensured by interviewing with astronomers. Third, many hot issues can be presented from the time they are proposed to that are confirmed. Finally, the magazine added current affairs to the annual Chinese National Astronomy Olympiad to guide students to pay attention to the progress of astronomical research.

Poster link: https://astro4edu.org/siw/p89

'Amateur Astronomer' was founded in 1958, and it is the earliest and most influential astronomical science magazine in China. The magazine mainly introduces the basic knowledge of astronomy, tracks the hot spots of astronomy, and cultivates the observation practice ability of young astronomy enthusiasts. The magazine has a monthly circulation of 16,000 copies, and the readers of the magazine are mainly young students in school.

For the frontier achievements of astronomy, the magazine can quickly respond, accurately interpret, and keep an eye on the topic. Based on actual data, the magazine had annual introductory articles in the field of black hole shadows, gravitational waves and exoplanets during recent years. Especially when the black hole shadow news first appeared, it was immediately featured in the magazine. In addition, the magazine added current affairs to the annual Chinese National Astronomy Olympiad held for school students to guide them to pay attention to the progress of astronomical research forwardly.

Taking the black hole shadow as an example, the magazine introduces both the basic background knowledge and the latest photos. From the initial prediction of the different black hole shadow forms that may be seen by the Event Horizon Telescope, to the first release of a photo of the black hole at the center of M87 in April 2019, to the release of an image of the M87 black hole in polarised light in March 2021, to the recent release of a photo of the black hole in Sgr A* at the center of the Milky Way in May 2022, the magazine has continued to give the fastest science interpretation. And the specific formats are varied, including cartoons, science pictures, and simplified articles on science to reduce reading difficulty and help students understand.

Taking the gravitational wave as an example, the magazine tracks the early theoretical studies of gravitational waves to the later actual observations of the signal. A complete history of the development of gravitational waves is presented for young readers. In addition to theoretical knowledge and actual observational progress, the magazine also introduces the scientific institutions conducting gravitational wave research, giving students a comprehensive understanding of this cutting-edge progress.

Taking the exoplanet as an example, the magazine starts with students' reading interests and combines distant celestial bodies with the familiar atmosphere, oceans and temperatures on Earth. Combining the latest astronomical knowledge with students' imagination, it helps them understand the wide variety of exoplanets. The magazine also publicises and promotes IAU's public-facing exoplanet naming programs. The event is a way to get students more interested in the topic of exoplanets and to learn more about the science involved. On the other hand, it also provided a place for teachers to exchange ideas, so that school teachers can also access more cutting-edge astronomical content.

Mimicking of Gravitational Lensing and Microlensing in a Classroom

Presenter: Jun Su and Jingcheng Zhu, Haian Senior School of Jiangsu Province, Jiangsu Province, China

When a point-like object passes between a background light source and an observer, the background illuminance fluctuates due to the gravitational microlensing effect. These objects are called massive astrophysical compact halo objects (MACHOs). In this project, an optical lens corresponding to a gravitational lens was printed using a 3D printer to demonstrate the images of an Einstein ring and a light source. Meanwhile, a process for searching for MACHOs and exoplanets was simulated based on the 3D printed lens, which could well present the total brightness change of the gravitational microlensing effect.

Poster link: https://astro4edu.org/siw/p90

Discussion summary

This session addressed the possibilities and strategies to bring cutting-edge science to the classroom and address topics such as gravitational waves, black hole shadows and exoplanets in a way that can be linked and ideally beneficiary to the curriculum. Due to the wide range and great importance of this topic, the session was split into two parts with a total of 11 talks and two posters. We thank the speakers for their inspiring contributions!

During the four different discussion sessions, it was repeatedly mentioned that breaking topics down into smaller units is key to make complex topics approachable by students. Looking at the curriculum will help to make a plan how to break things down, as the curriculum can provide pointers to what is known and what should be learned. But it will also depend on the look the teachers have: a mathematics teacher will look at it differently than a physics teacher as different aspects are important.

Breaking things down is also important when letting students use real data from telescopes. The educators are able to decide from which stage the data should be used: It can start with students taking their own raw data or prepared datasets that we know work, can be provided to the students. Providing a prepared data set, such as a catalogue rather than images, is possible also with a less stable internet connection. Either way, this data will look different than the images that we are used to from the news and we need to prepare students for the fact that the observations will not be a perfect graph just yet, but have bumps and glitches in them. Along this way, the students might also go on a different path with exploring the data than imagined by the scientist or teacher, and in an inquiry based approach we should not be afraid to let the students do so. The fact that images are not perfect, is often seen inspiring to students and interests them a lot, but the fact that not everything is complete yet, not every answer is there, also opens doors for them to think further. It also teaches students about the nature of science: it is evolving, and not perfect or finished.

The topic of cutting-edge science in the classroom is unique in the aspect that it is rapidly changing and thus (understandably) challenging for teachers to stay up to date. Therefore, text books can be outdated. It is recommended from several speakers that the teachers are provided with a handbook to be able to learn the necessary background information. Such a handbook can also include a lesson package for the teachers and should be structured in an interesting manner and that is accessible. The challenge is to find a middle-ground, with sufficient (but not too much) information given, ideally offering different levels of background for the more interested reader. Language is a barrier, as it takes time to translate new teaching concepts or materials into other languages, making access harder for teachers not fluent in English. Space Scoop is a project that provides cutting edge results in short texts, translated into many languages and written for students, in an appropriate level and this is a comfortable starting point of reading materials (also for foreign language classes).

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