Education and Heritage in the era of Big Data in Astronomy
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IBSE-Type Astronomy Projects Using Real Data

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Abstract. I present three examples of IBSE (Inquiry-Based Science Education) type activities for students and teachers using data and resources from the Faulkes Telescope Project and the National Schools' Observatory. Both projects have recently celebrated their 15th anniversary and both provide free access via the internet to 2-metre robotic telescopes to educational users throughout the World. Each activity contains supporting material and sample datasets in several aspects of astronomy as well as instructions on how to analyse data. These activities are designed to be 'teacher-free', extended projects for students.

They include the study of open clusters via astronomical images and population studies of exoplanets. I also present a Citizen Science project using data from Type Ia supernovae as discovered by the Gaia Alerts consortium. These data allow citizen scientists to develop their own Hubble Plot and begin to understand the link between Type Ia supernovae and the age of the Universe.

Keywords. Astronomy Education, IBSE (Inquiry Based Science Education), Big Data, Robotic Telescopes

1. Introduction

Based in South Wales, the Faulkes Telescope Project (FTP; http://www.faulkes-telescope.com/) provides free access to schools and other educators, via both queue-scheduled and real-time observations, to a global network of 2-metre, 1-metre and 0.4-metre telescopes. FTP was originally conceived by Dr Martin 'Dill' Faulkes as a way of promoting the teaching of STEM subjects (especially though the medium of astronomy) in schools in UK and Ireland.

Two 2-metre aperture telescopes of Richey-Chretien design were built by Telescope Technologies Ltd (TTL), a spin-off company of Liverpool John Moores University (LJMU). These two f/10 robotic telescopes are located at Haleakala on Maui, Hawai'i (FT North; FTN) and Siding Spring in New South Wales, Australia (FT South; FTS).

In 2006, FTN and FTS were bought by Las Cumbres Observatory (LCO) and since then, FTP has been an educational partner of LCO.

The LCO network now has a further nine 1-metre telescopes along with ten 0.4 metre telescopes. FTP provides free access (via the internet) to all of these telescopes via LCO's queue-scheduler and real-time exclusive access to two metre and 0.4 metre telescopes in both Hawai'i and Australia. This access is exclusively for educational users, predominantly in the UK and Ireland but also including educators and schools from other parts of the World.

FTP also provides resources (http://resources.faulkes-telescope.com/) on its website giving users information on what targets are suitable to observe, when they are visible, how to analyse the data and access the data archive. It currently has approximately 1200 registered users.

Complementary to the FTP is the work of the National Schools' Observatory (NSO; http://www.schoolsobservatory.org.uk/), which uses time on the 2-metre Liverpool Telescope (LT). The LT is based at the Instituto de Astrofísica de Canarias (IAC) at Observatorio del Roque de los Muchachos on La Palma in the Canary Islands, Spain. Also built by TTL, the LT features a broader range of instrumentation than FTN/FTS and is run by the Astrophysics Research Institute (ARI) at Liverpool John Moores University.

Established in 2004, the NSO provides schools in the UK and Ireland with access to the Liverpool Telescope through a guided observing system, using 10% of the LT's time. Its website contains astronomy related content, news and learning activities. With over 16,000 active users, including 13,000 school students, the NSO also allows non-UK/Ireland based schools and teachers to register affording free access to both the observing portal and resources.

2. The Activities

Since 2013, my work with the NSO as Operations Officer, was based around developing online resources which, to a large extent, would be teacher-free. As older school pupils develop independent learning skills, it was felt that we could provide activities which are based around aspects of astronomy that are both interesting and relevant to the curriculum. Astronomy is the perfect vehicle to explore science and STEM (especially Mathematics) and the existence of astronomical data collected by the Faulkes and Liverpool Telescopes presented a perfect opportunity to create useful, educational activities.

These activities are developed broadly in the Inquiry Based Science Education (IBSE; see https://allea.org/portfolio-item/aemase-inquiry-based-science-education-ibse/ for further details) format so that students are not presented with a series of numbered tasks to work through sequentially. Rather, they are presented with a set of webpages (in our activities, between 20 and 40 separate pages) which provide introductory and background material, as well as instructions on data analysis, sample datasets (and results) and an opportunity to reflect and share results. To give students some structure, navigation of the webpages is by a side bar menu. We firmly believe that this format provides users with an insight into the full scientific process from data collection, through analysis to presentation of and reflection on their results. We have recently introduced forums for students to share their work, accessible only via a login and moderated by NSO staff.

Depending on students' experience, we envisage that these resources will best serve students of 16 years and older, but it may be possible that younger students (i.e. 14 years +) will also enjoy and learn from participation in these activities, perhaps with additional teacher support.

We use real astronomical data, allowing students to explore the science of these objects as well as associated STEM (Science, Technology, Engineering, Mathematics) topics such as graph plotting and the measurement of uncertainties. These activities also aim to encourage the exploration of data archives. There is no requirement for specialist software - all our resources use software that is available free-of-charge and is generally usable across different platforms (e.g. MS Windows, Linux, macOS).

The first activity (http://www.schoolsobservatory.org.uk/discover/projects/clusters/main) was created in 2017. It allows students to learn about open clusters and HR diagrams as well as the technique of photometry. Including screenshots and screencasts, this activity teaches students how to analyse their data using the photomtry package, Makali'i (https://makalii.mtk.nao.ac.jp/) and e.g. Excel and to upload their results in the form of a CMD with the aim of encouraging them to discuss their findings with other students. A template spreadsheet is provided along with a finder chart, to get students confident with a sample dataset.

Students can then choose between 28 datasets (Bessel-B and -V images from the FTP) of different open clusters but participants may wish to take their own observations of a suitable cluster of their choice with FTP or NSO. These datasets represent a subset of approximately 600 open clusters in our Galaxy that have not been intensively studied. There are even the opportunities here to go further and use either the FLOYDS (FTN/FTS) or SPRAT (LT) spectrographs to follow-up any object of particular interest, such as extremely bright stars or those which appear to be very red or blue. This gives a true flavour of IBSE in that initial studies can be seen as the launchpad to further, more in-depth research.

Our second activity focuses on population studies of currently known exoplanet systems (https://www.schoolsobservatory.org/discover/projects/exoplanets/main). It encourages students to explore the properties of exoplanets (such as radius, mass, orbital period) and investigate these to search for correlations between these properties. Students are encouraged to plot these data to search for correlations and grouping of data and to watch out for selection effects which may lead them to incorrect conclusions. By utilising the exoplanet.eu website, we are able to ensure that the list of exoplanets to explore remains up-to-date. As with our open clusters activity, extensive use is made of screenshots within our instructions.

Finally, I present a third activity which has been created as a crossover between IBSE and Citizen Science (https://www.schoolsobservatory.org/discover/projects/supernovae). This activity was funded by a grant from UK Research and Innovation (UKRI) as a pilot project using real data in Citizen Science. We recognise the huge success of the Zooniverse project (https://www.zooniverse.org/) and were keen to investigate whether users could participate more fully in the science, with both learning and enjoyment along the way. It uses data collected by FTP from Type Ia supernovae as discovered by Gaia Alerts (http://gsaweb.ast.cam.ac.uk/alerts/alertsindex). Users are instructed on how to perform browser-based photometry using an online browser-based photometry tool called JS9. From this photometry, users can add additional data-points to the Hubble Plot, enabling them to measure the expansion rate (the Hubble Parameter) and age of the Universe. Templates are provided in .xls format to allow users to plot their photometry and to create their Hubble Plot. Within the background material, students will see that their work replicates that which contributed to the Nobel Prize in Physics as recently as 2011 (https://www.nobelprize.org/uploads/2018/06/advanced-physicsprize2011.pdf).

3. Results

Since publishing these activities online (from 2017 onward), we have seen several hundred unique users working their way through the activities. We are keen to disseminate this work further via e.g. this symposium and the IAC's Astronomy Adventures in the Canary Islands (http://galileoteachers.org/astronomy-education-adventure-in-the-canary-islands-2020/), Global Hands-On Universe (GHOU; https://handsonuniverse.org/ghou2020/) and the ESA/Galileo Teacher Training Program (GTTP) (http://galileoteachers.org/esa-gttp-2020-a-journey-to-space-exploration-mission/) annual workshops and conferences.

One recent example of a student and teacher working with us is that of our follow-up imaging of Gaia Alerts targets. In 2018, the student (Jorgen Kolgjini, Eastbury Community School, London) assisted us with collecting data on the target, Gaia18aen, which was later found to be Gaia's first detection of a symbiotic star. We were delighted

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when Jorgen's contribution to this study (along with that of his teacher, Megan Greet) as an observer of the system using FT South, was recognised and they were both included as authors in a peer-reviewed paper in 2020 (Merc *et al.* 2020).

4. Conclusions

Each of these activities is available on the NSO website, each one using real data. This allows students to explore the science of these objects as well as the broader scientific process. It provides an insight into the idea of Big Data and incorporates STEM topics such as graph plotting, trend-lines and the measurement of uncertainties. The move toward online resources has sped up in light of the Covid-19 pandemic and we believe that resources such as those detailed here can contribute to increased understanding of astronomical techniques and how they sit within STEM.

It is envisaged that additional IBSE-type resources will be developed in coming years. From discussions with teachers, educators and students, we intend to base these resources on topics such as variable stars, black holes and spectroscopy. We always encourage interested parties to contact us with feedback and suggestions.

Reference

Merc et al., Gaia18aen: First symbiotic star discovered by Gaia, 2020, A&A, 644A, 49M