So You're Looking to Run a Research in Schools Project?

Practical Tips from the Evaluation of a Pilot Programme

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Abstract

Research in Schools (RiS) projects offer school students opportunities to experience scientific research over prolonged periods within their school environment. The School of Physics and Astronomy at Queen Mary University of London has piloted such a programme over the past two years in five London schools across two research areas: cosmic ray muons and magnetospheric ultra-low frequency waves. Through the evaluation of this programme, findings and recommendations towards good practise are presented which could be applied to other RiS programmes.

Evidence towards the positive impact RiS can have on participating students is shown, including raising awareness of current scientific research, increased understanding of the scientific method, and developed skills. Teachers are also found to benefit from RiS, reconnecting them with their subject at an academic level, challenging them and aiding towards their professional development. However, we report that teachers and students benefit greatly through supervision from current researchers. We find that the structure of the projects is very important and recommend a framework containing initial prescribed activities followed by independent research. Recommendations on the accompanying resources provided to both students and teachers are also given. Finally, we stress the importance of piloting RiS projects allowing for evaluation and iteration of the projects before expanding, whilst also bearing in mind the large workloads associated with RiS.

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1 Introduction

School students typically have limited opportunities to experience science in the way that researchers do. For this reason a number of organisations and institutions support student-led project work in science. According to a recent report commissioned by the Wellcome Trust [Bennett et al., 2016, Holman et al., 2016], independent research projects in science *"usually involve hands-on investigations, in which students or groups of students work independently, supervised by a teacher and/or other adults, on a scientific problem over an extended period"*. They found that globally these projects are still only done by a small minority of students and only sometimes are these supported by a "mentor" from university or industry.

Research in Schools (RiS) is the term often used to describe such projects which have direct links to current academic scientific research. Examples of this area include CERN@School, a scheme that brings technology from CERN into the classroom, and HiSparc, a cosmic ray shower detector network originating in the Netherlands which now runs regionally in the UK from Bristol and Birmingham. While there is much interest on RiS at present, largely because they are unlikely to suffer the same limitations upon impact as one-off outreach interventions given their protracted nature, little in terms of practical advice into how best to setup and run RiS projects has been disseminated.

2 Physics Research in Schools at QMUL

The outreach programme from Queen Mary University of London's (QMUL) School of Physics and Astronomy have been piloting a RiS programme for the past two years. The overall aims of this programme are as follows:

1. To raise awareness of current Physics research questions with 14–18 year old school students.
2. To enable students to develop a better understanding of how scientific research works by conducting sustained independent research projects.
3. To provide students with a framework to develop their own lines of enquiry around the subject material in collaboration with QMUL research and outreach staff.

The programme runs during the first two terms of the academic year culminating in a student conference where participants present their research findings. So far two projects have been developed, based around the academic research being undertaken within the department's research groups: one on cosmic ray muons and another on magnetospheric ultra-low frequency (ULF) waves.

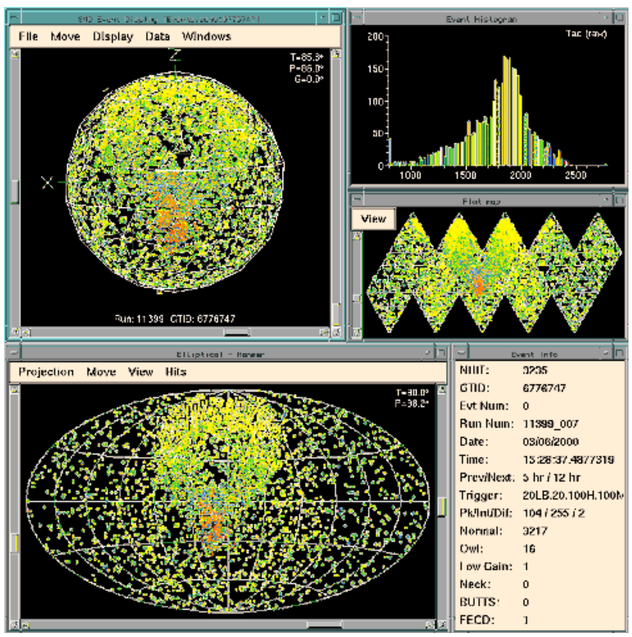

Figure 1: A cosmic ray muon event detected by the Sudbury Neutrino Observatory, courtesy of Chris Kyba.

Cosmic Ray Muon Project: Current neutrino experiments, such as T2K and Super-Kamiokande in Japan and SNO+ in Canada which QMUL particle physicists are involved with, use large volumes of scintillating material surrounded by photomultiplier tubes to detect the light produced by the very rare interactions of neutrinos with matter. These are constructed deep underground to reduce the number of background events due to highly penetrating cosmic ray muons (an example muon event is shown in Figure 1). The RiS project based around this topic utilises a fundamentally similar scintillator – photomultiplier tube detector setup which is able to identify and study these cosmic ray muons. Students initially undertake a lifetime measurement involving equipment calibration, data collection and statistical analysis and then may pursue their own independently-motivated studies using the capabilities of the detector, which may include topics such as antimatter, special relativity, the Higgs boson, or the origins of cosmic rays. Due to the availability and cost of the equipment, so far this project has only been run in one independent public school for boys in Dulwich, South London over the past two years. This limits what can be learned about this specific project at present due to only one type of school participating.

Magnetospheric ULF Wave Project: One area of study in space weather research is that of ultra-low frequency waves in Earth's magnetosphere (see Figure 2 for an illustration) since it is thought these can create "killer electrons" in the Van Allen radiation belts. These waves are routinely measured by satellites in orbit around the Earth, however, because these observations do not provide a full picture throughout the magnetosphere of the wave activity at any given time and due to the variability of the magnetosphere itself there remain a large number of questions surrounding these waves. The RiS project provides students with the satellite data in the form of audible sound files, a conversion process which turns a year's worth of data into under six minutes of audio. Students can then listen to the waves and analyse them in audio software such as Audacity. This activity was initially piloted during a week-long summer school and then rolled out to four London schools last year.

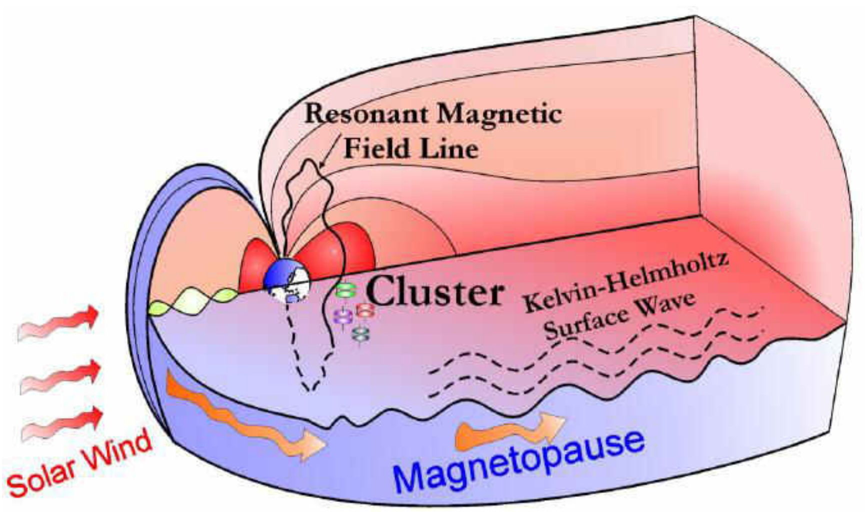

Figure 2: Schematic of ultra-low frequency waves in Earth's magnetosphere courtesy of Q. Zong.

The two projects are therefore quite different in a number of ways. The link to current research is much stronger with the magnetosphere ULF wave project, leading to the possibility of co-creation of new research between students and researchers, whereas the cosmic ray muon project is unlikely to result in any novel outputs. On the other hand, some students may find the relative familiarity of particle physics topics and the hands-on use of equipment more engaging than strictly analysing data in an unfamiliar area with a wide scope of potential studies possible. It is not yet clear if one approach is better overall.

3 Stakeholders

3.1 School Students & Teachers

Five schools were involved in the two-year pilot of QMUL's RiS programme, the names of which are shown shown in Table 1. Suffice it to say they represent a variety of school types from different areas and backgrounds within London. Students involved typically were in Year 12 (16–17 years-old / studying A-Level qualifications) and all students in that year participated in at least the first RiS session, apart from at Dulwich College and Newham Sixth Form College where teachers had surveyed student interest beforehand and selected the students. Dulwich College also encouraged a small number of high-ability Year 10–11 students (14–16 years-old / studying GCSE qualifications) to participate.

The teachers became involved with RiS in different ways. The RiS programme was created after a consultation in summer 2014 with Physics teachers at Dulwich College, of particular interest to QMUL for student recruitment, to ask what Physics outreach opportunities they would be interested in. This discussion highlighted the desire for bespoke content with repeated interventions and ongoing activities. The school were offered three potential projects based on the academic research at QMUL. In contrast, the magnetospheric ULF wave project was initially developed for a Physics summer school and then rolled out for a RiS pilot by inviting teachers to get involved via the QMUL teachers' newsletter in October 2015.

School	Post Code	Type	FSM (%)	Partner	RiS Project
Dulwich College	SE21 7LD	Independent	N/A	SR	Muon
Bishop Challoner Catholic Federation of Schools	E1 0LB	Voluntary Aided	31.0	SPN	ULF
Newham Sixth Form College	E13 8SG	Sixth-Form	20.7	WP	ULF
Ockendon Academy & Studio School	RM15 5AY	Academy Converter	21.1		ULF
St Gregory's Roman Catholic Science College	HA3 0NB	Voluntary Aided	15.8		ULF

Table 1: Participating schools in QMUL's Physics RiS pilot programme between 2014-2016. FSM denotes the percentage of students eligible for free school meals. QMUL student recruitment (SR) and widening participation (WP) target schools are indicated along with Stimulating Physics Network partner schools. For further information see Edubase.

3.2 University Staff

QMUL academic and outreach staff have been involved in the RiS pilot. Prof Jeanne Wilson, a Reader in Particle Physics who works on neutrino experiments became academic lead on the cosmic ray muon project, with her chief involvement being an introductory talk on her research area and how it related to muons. It was planned that the Outreach Officer would support the project from then on. However, after the first initial session in September 2014 a number of staff changes occurred leaving the department without an Outreach Officer until December 2014 when I joined. From January 2015 onwards my role in the RiS programme has been somewhat of a mix between research and outreach - drawing on my research background in devising project resources, providing support and suggestions to students, and in developing the magnetospheric ULF wave project around my current research interests. It should be stressed that this combination of roles is by no means necessary and that a combination of both researchers and outreach staff can deliver RiS projects e.g. with the HiSparc project.

4 Findings

From evaluating QMUL's Physics RiS programme we can identify some elements of good practice which are relevant to other RiS projects. The programme will continue to be evaluated as it evolves. In this section a number of practical findings are presented based on the results of before and after surveys of students, anonymous feedback forms from both students and teachers, and the lessons learned through running the programme.

4.1 Is Research in Schools Worth Doing?

An important question is whether RiS activities are worth the significant amount of time and effort required by all parties involved: the researchers, teachers and students. A complete assessment of the worthiness of such an emerging field is beyond the scope of this report; for a start the aims and objectives of these activities can and do vary amongst both projects and institutions. Therefore, this report concerns only the outcomes of QMUL's pilot RiS programme, which are tested against the specific aims of the programme (as detailed in section 2) and the students' and teachers' experiences.

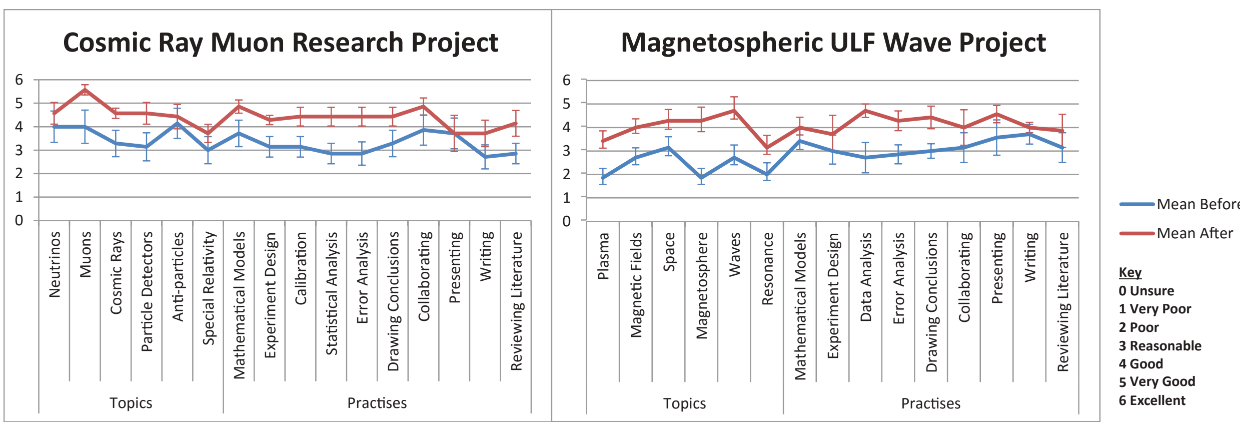

Figure 3: Average student understanding in relevant scientific topics and methods before (blue) and after (red) undertaking the two projects. The standard error in the mean is also shown.

Two of the main aims of the research projects were for students to better understand current research topics and the scientific practises through which these are tackled. One of the methods used to evaluate the programme against these aims was asking students to quantify (on the Likert scale) their understanding of scientific topics and practises relevant to the project. This was done both pre- and post- project and in the case of the latter students were also asked to reassess their understanding before having taken part. No statistically significant difference in the "before" data was found between the pre- and post- project surveys, thus only post-project survey data is used henceforth.

Figure 3 shows the average results before and after undertaking the projects. Almost across the board the results show significantly greater understanding after having been involved in the projects. The students' responses for each category were on average 1.1±0.1 and 1.2±0.1 points higher after the projects than before for the two projects respectively. From the data, we can reject the notion that the projects did not increase the students' overall understanding in the relevant research topics and methods with 85±3% and 92±4% confidence. Therefore, the success from this pilot demonstrates that RiS projects, more generally, can indeed raise awareness of current scientific research topics and increase understanding of the scientific method through first hand experience.

> *"students have gained... a better appreciation of real science"*
>
> Tony Dunn, Physics Teacher, Newham Sixth Form College

Overall Experience **Skills Gained**

Figure 4: Student and teacher responses to the research projects overall (left) and the skills they helped the students develop (right). The size indicates the total number of each response.

More qualititatively, students and teachers were surveyed for adjectives describing their experience of the projects overall and the skills (if any) they think it helped to develop. They were free to use any words they wanted and were not given a pre-selected list. These results are presented in Figure 4. All of the adjectives are of a positive nature with *"interesting"*, *"challenging"* and *"inspiring"* being the top three most-quoted, suggesting that students were engaged with the projects throughout and found them a rewarding experience.

"the hard work paid off"
Student, Dulwich College

"kept my students busy and motivated"
Tony Dunn, Physics Teacher, Newham Sixth Form College

"provided a pure physics outlet for many students"
Simon Whittaker, Head of Physics, Dulwich College

The identified skills developed by the students through undertaking the projects cover a wide range of those applicable to real scientific research e.g. team-work, presentation, analysis and working with data were the most commonly recognised. The treatment of these four areas at a university and research level are arguably quite different from at school, thus the exposure to new ways of working has had a positive impact on the students.

"The autonomous group work, with very little input from me, was great to see. They have become more confident in communicating their ideas and realised that they are not too young to do research. The production of results and posters was a challenge which required real group work."
Dr. Alexandra Galloni, Physics Teacher, Dulwich College

While the projects are relatively self-contained, there are some very relevant (and some less so) links to the current curriculum e.g. particle physics and waves topics respectively. Students were asked whether working on the projects had helped with their studies. 78% responded they had been "very useful" or "useful" and tended to feel that either the projects had either enhanced their understanding of specific topics

"after researching for our project, it was easier for me to understand the waves topic when we studied it in class with our teachers"
Student, Newham Sixth Form College

or that the projects had at least broadened their knowledge and equipped them with transferable skills that would be useful in the future.

"[the project] has enhanced my ability to understand new topics in Physics"
Student, Newham Sixth Form College

However, some students were unable to see where curriculum links might be present or simply felt that the projects didn't enhance what they learned in class. While the aim of the projects is not to contribute to the formal education of students with their studies, one teacher (Simon Whittaker of Dulwich College) said that efforts like this were *"essential for contextualising Physics"* in the classroom.

Having run RiS projects for only two years, it is too early to say whether running such activities has any lasting impact on students, changing their aspirations. However, one teacher (Tony Dunn of Newham Sixth Form College) believed that these RiS efforts were *"excellent for motivating students"* and from the feedback one student thought participating had *"increased my interest in space"* while another said it had *"convinced me I would like to pursue Physics"*. Furthmore, the Wellcome report on independent research projects [Bennett et al., 2016], of which RiS is a subset, does support their benefits to students. By tracking RiS students who take part in projects, we hope to be able to comment in the future on the potential impact RiS can have. Nonetheless, all evidence here suggests that **RiS projects can have significantly positive results on students' understanding and appreciation of science, as well as equipping them with vital skills**. The potential impacts of RiS projects on teachers and researchers are discussed later.

4.2 Project Structure

Over the course of the programme development and pilot we have created a framework for RiS, a two-term model which we present in Table 2.

Oct	Nov	Dec	Jan	Feb	Mar	Apr
Kick-Off Event						Student Conference
Prescribed Project		Independent Research Project				
					Writing Up	
		School Visit		School Visit	School Visit	

Table 2: Annual Structure of RiS programme.

Under this structure, projects start with some sort of kick-off event early to mid-way through the Autumn term, whereby students learn about the field of scientific research they will be working on and some specifics of the project itself. This takes the form of a talk followed by a workshop, which may be held at the school or at the place of research e.g. university campus.

The students form mini research groups of around five to work on the projects. The initial tasks given to these groups is a prescribed experiment or activity e.g. measuring the lifetime of a muon, as laid out in the provided resources (see section 4.3). This stage incorporates elements of scientific research, namely calibration, data collection, data analysis, error analysis, critical discussion and drawing conclusions. The idea is that students (and teachers) build confidence with the theory and methods before they are asked to conduct their own independently motivated research.

The independent research occupies the majority of the project time. These are supervised and supported by the teachers (see section 4.4) and through visits by researchers (see section 4.5) throughout, culimating in the presentation of results at a student conference before Easter holidays. This timescale was chosen because the majority of students in our target age-range will have exams in the summer, thus finishing the project at this time should not add stress on top of their revision and exam preparation. Most teachers agreed that this timescale was good.

We have found that **the projects' structure is very important in students' successful engagement and progression** over the sixth months. The first year of the cosmic ray muon project, a different structure was implemented which set students a literature review and report followed by experimental project work. Because the literature review was given a specific title, *"Is measured muon lifetime consistent with the predictions of special relativity?"*, students became too fixated on this particular aspect rather than exploring

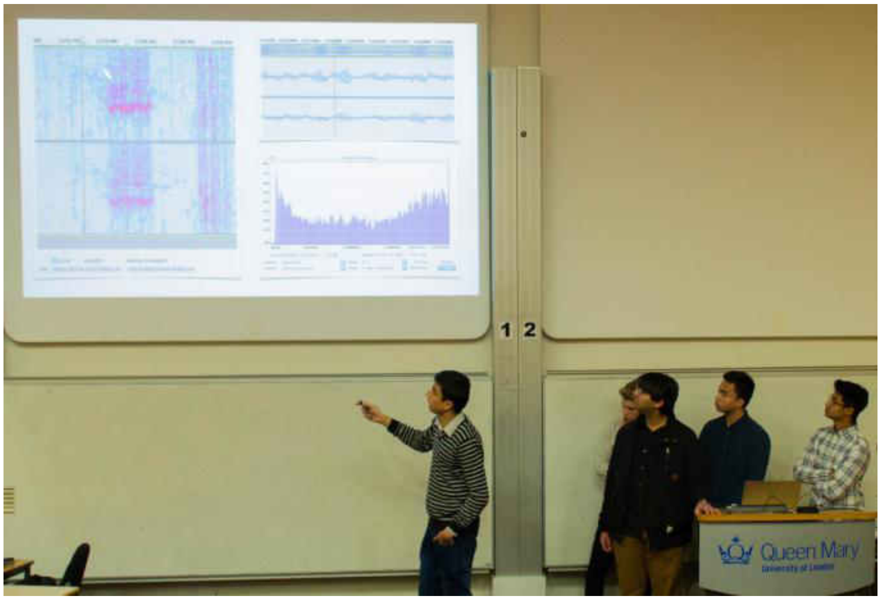

Figure 5: A group of Year 12 students giving a presentation on their research at the Cosmic Con 2016 student conference.

other possible avenues, even with interjections to the contrary during the late-stage researcher visits (see section 4.5). Students were also not exposed to the experimental and analysis techniques until a relatively late stage. This unfortuantely resulted in near-identical posters being produced by all groups in the end. The structure outlined in Table 2 implemented in the second year showed an improvement throughout. Each group completed the prescribed activity along with the accompanying exercises and discussion questions within the timeline, moving on to pursue different research topics using the cosmic ray detector and applying appropriate techniques to arrive at results.

We have also learned that **it is vital for the prescribed activity to be carefully structured with easily followed steps**. In the pilot year of the magnetospheric ULF wave project, the initial activities were only loosely prescribed since a step-by-step method did not feel reflective of an observational research area like space plasma physics. However, this lead to some students and teachers struggling at first due to the wide range of possibilities open to them, despite some hints or suggestions in the resources provided. One teacher (Mary Wood of St. Gregory's Sixth Form College) noted that *"most are still daunted by the whole thing"* midway through the project.

> *"I am having difficulty understanding the project fully and also with how to analyse the audio files"*
> Student, The Ockendon Academy and Studio School

To address this, changes have been made to this particular project for the coming year with more structured preliminary activities presented and clearer ideas of how to progress into the independent research. We have found that there is no one form of prescribed activity that will suit all RiS projects, thus these activities will be highly dependent on the specific details of the project and need to be thoughtfully designed accordingly.

Our student scientific conference, Cosmic Con 2016, saw 21 students come to QMUL to present a total of 2 talks and 6 posters. Both teachers and parents were encouraged to attend, given the influence both can have on students' aspirations [Archer et al., 2013] and it was well attended by both (7 teachers and 8 parents). Prizes were awarded to the top 3 research groups, which were spread across the different schools showing that **students from various different types of schools can succeed at RiS projects**.

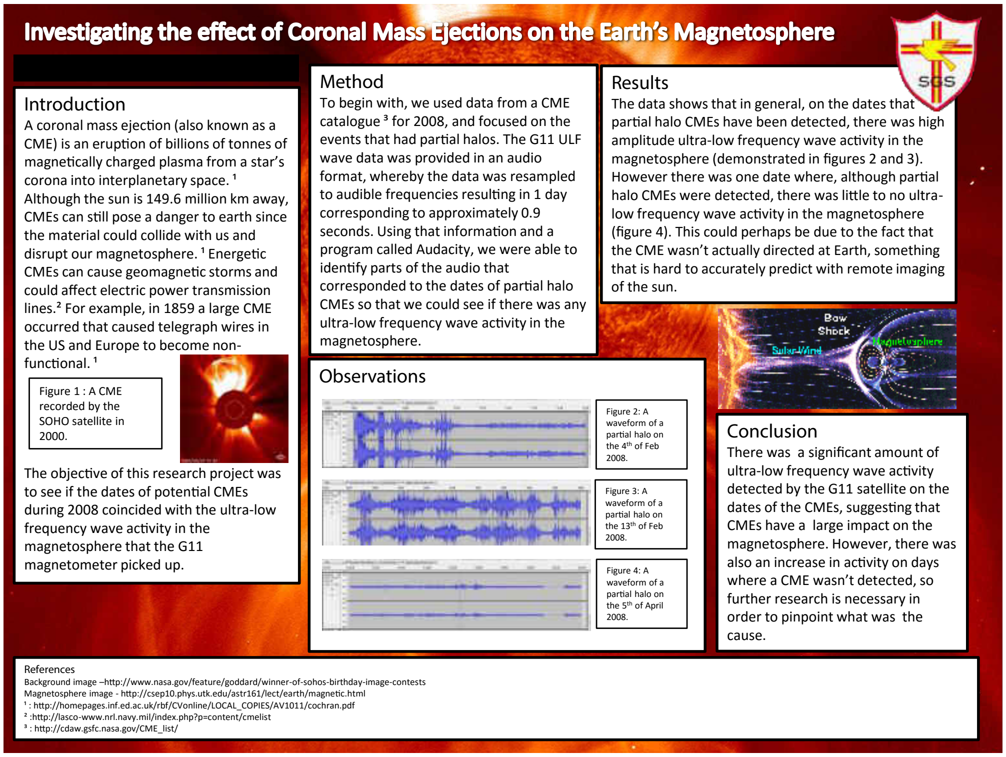

Figure 6: First Prize winning poster from the magnetosphere ULF wave project by one female (first author) and two male Year 12 students (names redacted) from a coeducational Roman Catholic secondary school in Harrow, North-West London.

> *"I attended Cosmic Con 2016, the conference where participating students gave talks and presented posters based on the research. The standard of presentations was high, in some cases better than some academic conferences I have attended in the past! The posters were all clear, informative and worked as prompts for the students themselves to discuss their work. What was also fantastic about the event was the presence of families and teachers. The pride was palpable. The role that itself will play in building the aspirations of the students is incalculable."*
>
> Dr Dominic Galliano, SEPnet Director of Outreach

We found that interest in schools signing up to take part in RiS projects is dependent on the time of year. Little reponse was received using our teacher mailing list (covering $\sim$ 200 Physics teachers) in September time, at the start of the academic year. Teachers were more receptive at the end of the summer term for the coming year. This is when teachers start planning the upcoming academic year, whereas by September it is more difficult for them to build the RiS activities into their existing plan. Furthermore, we received much more interest from both word of mouth amongst teachers and via a Stimulating Physics Network coach ($\sim$20 teachers) than via our teacher mailing list ($\sim$5 teachers). We therefore **recommend that schools are contacted about involvement before the summer using existing teacher networks**.

4.3 Project Resources

To enable the students to take part in our RiS projects, the students and teachers were provided with a number of resources including equipment, data and software. We also provided students with a written guide to the project.

For the cosmic ray muon project, a TeachSpin Muon Physics was lent to the school (see Figure 7) with an agreement signed primarily stipulating that the detector be placed on the school's insurance policy, making the school liable for the expensive ($\sim$ £4000) equipment in case of damage or theft. We also provided a dedicated PC/laptop along with any equipment provided to alleviate potential software or institutional IT issues with using school computers with the detector. Technical manuals for the detector were also provided to teachers. This proved important since the muon kit's manual detailed how the data was stored, which was vital when going beyond simply using the software package for the students' research projects. In similar cases of lending equipment, we **recommend that a complete solution to equipment be provided with no expectations of what schools can provide additionally** and that **insurance of equipment is considered**.

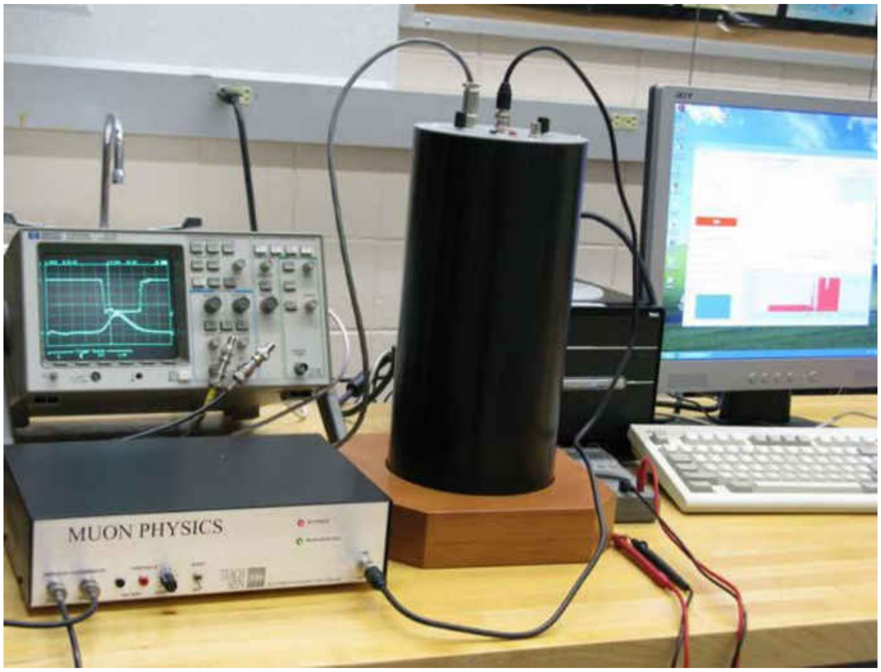

Figure 7: TeachSpin Muon Physics kit provided to schools including scintillator - photomultiplier tube, detector electronics and accompanying software.

The magnetospheric ULF wave project, on the other hand, had no equipment but instead required supplying data in the form of audio files. These were provided to students on USB sticks along with a portable version of Audacity to be used for the analysis (see Figure 8). Most schools were able to either use the provided software or get a version of the free software installed on their system by their IT department. While students were instructed to record the wave events they found and analysed in a spreadsheet, many of them struggled with this, particularly in applying some of the routine formulas required such as reliably converting between times in the audio files to either real times or spacecraft local times (a measure of location). This coming year we have decided to provide a set spreadsheets for students' data logging which should not only aid students' progression with the project but may prove useful for use by researchers due to the standardised format. Therefore, for computer-based projects we **recommend portable software be used where possible** and that a **standard format of data logging is provided**.

For analysis, students were able to use any package they chose. However, for some tasks such as non-linear curve fitting and error estimation we found that Excel, the most widely available and familiar tool for the students, was insufficient. It was recommended that students use Plot.ly, a free online analytics and data visualization tool based on Python, a programming language which is increasingly used in scientific research nowadays particularly for data analysis. Figure 9 shows the use of this tool in the cosmic ray muon's prescribed experiment of a lifetime measurement.

In the first year of the RiS programme, students were given a barebones guide which had been written by an undergraduate. This gave instructions for to the muon equipment, but did not cover much of the scientific field, theory, or how the detector worked. This seemed to limit students' progress: they did not sufficiently

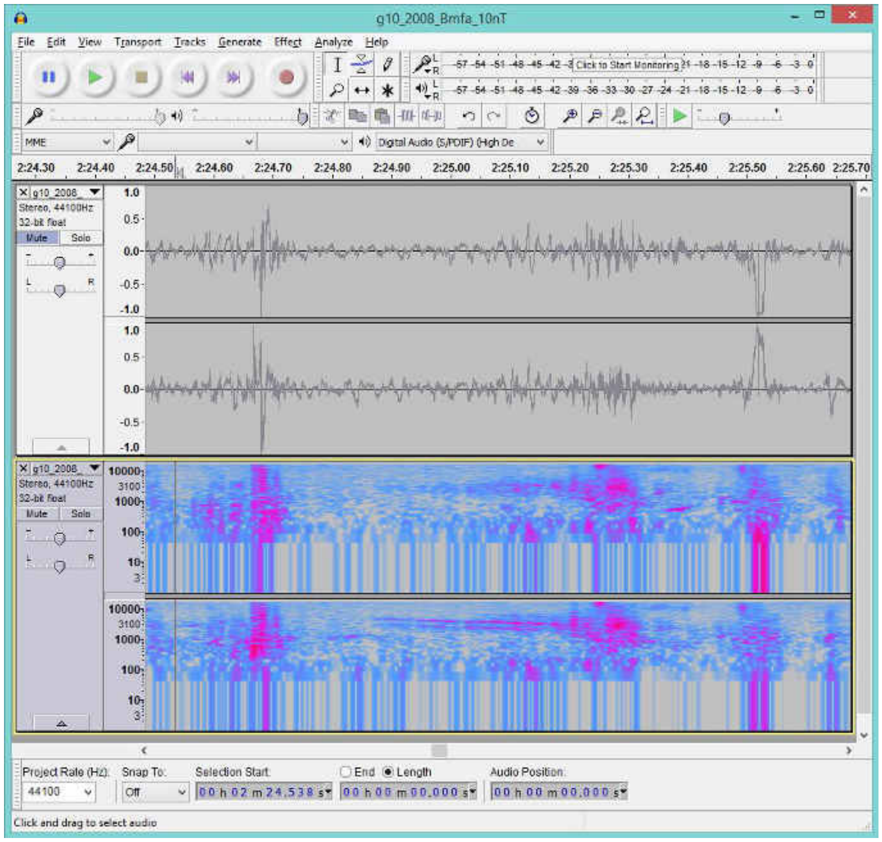

Figure 8: Students used the portable version of Audacity to analyse magnetospheric ULF waves, utilising features such as waveform (top) and spectrogram (bottom) views.

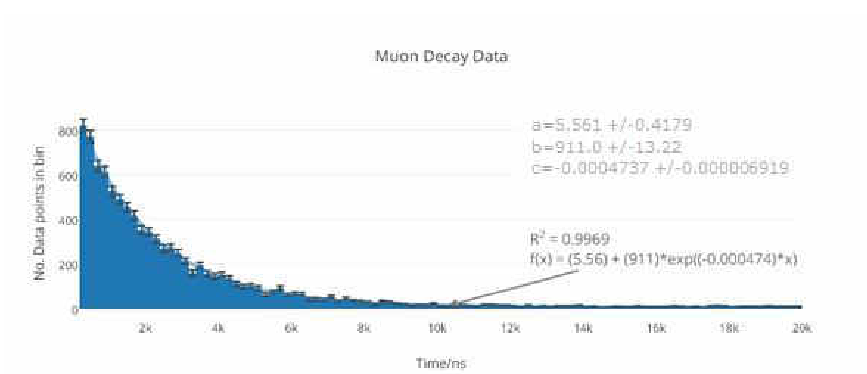

Figure 9: Muon decay time histogram with Poisson error bars and an exponential fit with associated in fit parameter errors using plot.ly

understand when questioned during their poster presentations what they had measured, why they had used the methods they did, and what the significance of their results were.

For the second year of RiS projects more comprehensive student and teacher guides were created. These guides, presented in the style of an academic paper (see Figure 10), were designed to serve as an introduction, providing enough information for students to start working on the project and refer back to but also requiring them to read additional materials as they progressed. The content covered:

- Introduction to the scientific field
- Relevant theory
- Explanation of the equipment/data
- Analysis techniques
- Details of the initial prescribed activity
- Suggested avenues of exploration for independent research

Throughout this material, a number of exercises were present requiring either mathematical calculations or critical discussions designed to get students thinking about the project and/or motivating their activities, rather than blindly following instructions.

> *"The students need and needed to think about the work"*
>
> Mary Wood, Physics Teacher, St Gregory's Roman Catholic Science College

Teachers were provided with the same guide, but with extra guidance including answers to the exercises, hints and tips about different methods, common pitfalls of students etc. All teachers strongly agreed in the feedback that sufficient resources had been provided to them for the projects. Given this feedback and the improved student progress and understanding in the case of cosmic ray muon project, we **recommend that a comprehensive introductory resource to the project is given to students with teachers given additional guidance**.

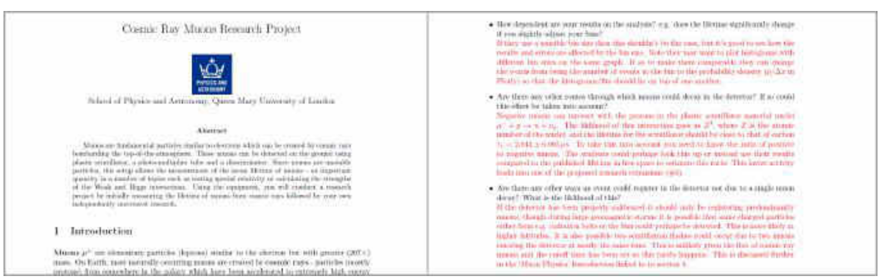

Figure 10: Students are given resources in the style of a scientific paper (left) while teachers receive the same but with extra guidance notes (right).

4.4 Role of the Teacher

Teachers played an important role in arranging and supporting their students with these RiS projects. They acted as the students' first point of call when discussions within their research group are insufficient. While students generally seemed to work almost autonomously on the projects, most teachers felt they were able to support their students. However, one felt hampered by time constraints whilst another felt they could provide *"a little but only through Martin's support"*, highlighting the importance of additional researcher involvement as well (see the next section). Qualitatively it appeared that students made more progress between researcher visits when their teacher appeared confident with the material compared to those that showed outward uncertainty.

We believe that how the **RiS projects are incorporated into a school is best decided by the supervising teacher**. The majority of the RiS activities will be an extra-curricular activity, undertaken in the students' own time. However, teachers often arranged lunchtime or after school sessions within which to run activites surrounding the projects. Other teachers utilised a mixture of both classroom, particularly in the introductory stages of the project, and extra-curricular sessions. From the researcher side, some flexibility is therefore required for successful involvement of a school with the project.

With that being said, not all schools were able to maintain involvement with our RiS projects. One teacher reported back that *"The students are concerned about fitting in all of their A level content"* resulting in only one student continuing with it from that school whereas another stated *"sadly competing activities... plus their work concerns"* meant they were ultimately unable to get involved quoting *"it is the time of year"*. However, both teachers were interested in trying to work the RiS projects into their schedule differently the following year.

One teacher was interested in incorporating the British Science Association's CREST Awards or Extended Project Qualifications into the RiS programme. There is also the possibility of students publishing their work in a growing number of journals designed for young researchers e.g. Young Scientist Journal. We feel that teachers are again best placed to determine whether these activities are worth doing beyond our RiS programme structure, though the recently formed Institute for Research in Schools may be able to provide teachers with support for these endeavours.

Similar to the Wellcome Trust's review, we also find that **RiS projects can have a positive impact on the teachers** themselves.

> *"It has reconnected me with university level physics and reminded me how to mentor a research project [as] I was very rusty. [The project has] given my teaching a boost"*
>
> Dr. Alexandra Galloni, Physics Teacher, Dulwich College
>
> *"Made me spend extra time in school with my students. It has been interesting science too so I have learnt some more Physics."*
>
> Mary Wood, Physics Teacher, St Gregory's Roman Catholic Science College

Given the important role that teachers play on students' aspirations [e.g. Archer et al., 2013] reconnecting them with their subject at an academic level, challenging them and helping them develop their skills should reflect positively on their students - both those undertaking RiS and more generally.

4.5 Role of the University

One of the aspects of this RiS programme which differs from some of the existing ones is the active supervision and support from Physics researchers. This encompassed a number of roles to ensure the students' success with the projects including:

- Delivering a presentation/workshop providing an academic introduction to the scientific field and the project itself to students.
- Contact with and managing the teachers e.g. arranging school visits, soliciting updates on progress, providing links to resources, setting deadlines etc.
- School visits where aspects of methods, analysis techniques, errors, and scientific presentation are discussed with students.
- Listening to and providing comments on students' progress with suggestions for continuation within the timeframe of the projects.
- Contextualising the students' work in terms of current and past research, highlighting the motivations within the field etc.
- Providing comments on students' produced draft posters and talks for the conference.

Figure 11: Photo of a school visit to supervise students working on the cosmic ray muon project.

As was highlighted in the previous section, **most teachers did not feel confident enough to fully support their students' project work alone**. This is where the skills and experience of researchers may prove incredibly invaluable in tackling students' problems.

> *"One research group working on the direction of cosmic ray muons were worried that their results of the muon detection rate with angle didn't fit their theoretical model based on the cross-sectional area of the cylindrical detector. They wanted a result that they could present at the conference and their teacher wasn't sure how to help them. My research experience helped in identifying the assumptions that had gone into their model, that all muons came from a single direction, and thus how their result showed this assumption could not be true given the data - a result which they then presented. It's in areas like this where support from an experienced researcher is vital in making these projects succeed."*
>
> Dr. Martin Archer

In the first year of the cosmic ray muon project, due to staffing issues, the project was left unsupervised from the academic side for many months. When such supervision was introduced, it was found that the students had adopted a large number of misconceptions and hadn't made much in terms of progress. While the late-stage supervision meant that the students were able to produce results and associated research posters based on the prescribed activity, when questioned on their presentations the students were not always confident and some misconceptions still remained.

In contrast, during the second year of the muon project, where researcher supervision was present throughout, the students made much greater progress. It was made clear from the get go that researcher visits should be treated as a step-change in the terms of the projects, cultivating an expectation that they meet deadlines and not waste researchers' valuable time with excuses, as had been the case sometimes in the previous year.

> *"They usually feel re-inspired by any visit you make, so I'm looking forward to seeing how they got on."*
>
> Dr. Alexandra Galloni, Physics Teacher, Dulwich College

This approach seemed to work, as the students progressed beyond the prescribed activities with each group addressing very different lines of enquiry, utilising different methods and analysis techniques to arrive at results and conclusions that were confidently presented at the conference.

Activity	**Time (days)**
Project Development	
Design of Pilot Project (may vary)	15
Writing Project Resources	5
Preparation of Introductory Session	2
	22
Project Delivery (per school)	
Contact with Teacher	2
Introductory Session Admin	0.5
Introductory Session Delivery	0.5
Project Supervision (4 sessions)	2
Providing poster/talk comments	0.5
	5.5
Student Conference Organisation	
Date Organisation through Teachers	0.5
Location & Catering Admin	3
Ticketing and Registration Admin	1
Poster Production	0.5
Student Conference	0.5
	5.5
Project Evaluation	
Production of Evaluation Forms	0.5
Analysis of Evaluation Data	3
Iterative redevelopment of project	5
	8.5
TOTAL	
	41.5

Table 3: Estimates on amount of university staff time required for a RiS project.

"I was very impressed and very pleasantly surprised about the quality of work that was on show at Cosmic Con. It was very clear to me that almost all of the student groups had fully engaged with the research tasks assigned to them, and produced work that was significantly above what I had expected to be possible from sixth form school students. It just goes to show what a mixture of inspiration, hard work, high quality mentorship and well thought through research tasks can lead to. Of particular note was the fact that some student groups really excelled in the presentation side of the task, producing visually eye-catching posters with clear explanations of the underlying motivation and physics that they were exploring. For others, it was clear that they were primarily motivated by the challenge of scientific research and exploration, and produced excellent results and insights from their independent research without necessarily hitting the heights in artistic poster presentation. That's one of the positive aspects of Research in Schools: it allows different people to demonstrate their flair and originality in different ways."

Prof. Richard Nelson, Head of Astronomy Unit, QMUL

Since the evidence suggests that **supervision from the academic side was a key aspect towards the success of this RiS pilot**, a practical guide to the academic time involved is presented in Table 3. Since many elements of project development, organisation and evaluation are independent of the number of schools participating, RiS projects become more time-effective as more schools get involved. Furthermore, it should be mentioned that this time does not necessarily have to come from just one researcher. Indeed a model of **sharing out responsibility amongst a research group** (research/academic staff and PhD students) as well as administrative and outreach/public engagement support would seem most sensible, particularly once projects progress beyond the pilot stage (see next section). How the different roles are shared out between researchers and outreach/public engagement staff will depend on their experience and availability. Such a collaborative model may be a way of effectively embedding a culture of public engagement within a research group.

Due to the early stage of this RiS programme, we have little evidence of the impact RiS may have on researchers. However, there is potential that RiS may feed back into the research in the future.

4.6 Piloting Projects

The final finding relates to piloting projects before expanding them. The cosmic ray muon project was run for two years with the same school, with many changes made to the structure and resources throughout, as has been discussed. The magnetospheric ULF wave project was first trialled over a week-long summer school, with again necessary changes being identified, and then rolled out to pilot with 4 schools of different types. This first year in schools highlighted further required changes which have been made for the coming year.

The process of piloting these projects has allowed our researchers and outreach team to discover what aspects of the projects work, which need more work, and provided some limited insight into how these are affected depending on different types of schools or different teachers and/or students. Indeed, all of the findings presented in this report were only possible through the piloting process and it would have proven difficult to implement any of the necessary changes along the way had we attempted to start out with a wide-reaching RiS programme. We have thus found that the **evaluation and iterative redevelopment of RiS projects should be something which is planned for at least for the first few years of any new RiS project**. We believe that the reach of these projects should be kept within the reasonable workloads of the university stakeholders involved as they expand, since we have found that RiS really benefits from the support both from the academic and teacher sides.

"Thanks so much - your outreach and the launch has been great and much appreciated. We felt very privileged."

Dr. Alexandra Galloni, Physics Teacher, Dulwich College

5 Conclusions and Recommendations

Here the conclusions of our evaluation into QMUL's pilot RiS are summarised along with recommendations to those looking to conduct RiS projects.

1. Is Research in Schools Worth Doing?

a. RiS projects can raise awareness of current scientific research topics and increase understanding of the scientific method through first hand experience.

b. RiS projects can be positive and rewarding experiences for students.

c. RiS projects can help develop students' skills.

2. Project Structure

a. RiS projects' structure is very important in students' successful engagement and progression.

b. We recommend a two-term model with a prescribed initial activity followed by independent research.

c. Any prescribed activities should be carefully structured with easily followed steps.

d. Students from various different types of schools can succeed at RiS projects.

e. We recommend that schools are contacted about involvement before the summer using existing teacher networks.

3. Project Resources

a. We recommend that a complete solution to any project equipment needs is provided (including computers, software and documentation) with no expectations of what schools can provide additionally.

b. We recommend insurance of any loaned equipment be placed on school insurance policies for liability against damage or theft.

c. We recommend portable software be used where possible to prevent against possible IT issues.

d. We recommend that a standard format of data logging is provided.

e. We recommend that a comprehensive introductory resource to the project is given to students with teachers given additional guidance.

4. Role of the Teacher

a. Teachers play an important role in arranging and supporting their students with RiS projects.

b. Not all teachers will feel confident enough to support their students without additional support.

c. We recommend teachers decide how to incorporate RiS projects into their school.

d. RiS projects can have a positive impact on the teachers reconnecting them with their subject at an academic level, challenging them and helping them develop their skills.

5. Role of the University

a. Supervision from the academic side was a key aspect towards the success of this RiS pilot

b. We recommend research groups share out the responsibilities associated with this support across research, outreach and administrative staff

6. Piloting Projects

a. Piloting RiS projects allows universities to evaluate and change aspects of projects were necessary.

b. We recommend that the evaluation and iterative redevelopment of RiS projects should be something which is planned for at least for the first few years of any new RiS project.

c. We recommend that RiS projects be kept within the reasonable workloads of research groups as the projects expand.

6 Future Aspirations

For the academic year 2016/17 the QMUL RiS programme will grow beyond the pilot stage. Thanks to an STFC Public Engagement Small Award we have been able to purchase additional muon detectors, enabling us to offer the cosmic ray muon project to 5 schools in 2016/17. The magnetospheric ULF wave project has expanded to 15 schools, with new data added and revised resources created. Furthermore, a new project is being piloted in 4 schools concerning analysis of data from the Kepler mission, enabled through an introduction to coding in Python. This project was conceived by Prof. Richard Nelson and has been developed by a post-doc, funded to work on this one day per week thanks to Open Access Agreement Grant at QMUL that we secured. Like the ULF project the year before, this project was trialled initially during a summer school with supervision from the post-doc and in the forthcoming pilot we plan to trial using PhD students studying exoplanets as part of the project's supervision.

There are a number of areas we anticipate to study with the continuation of this RiS scheme. This year we will be trialling a mentoring scheme at some schools whereby student participants from previous years' projects can provide assistance to the current students in addition to the teachers. We also hope to find out if RiS is an effective outreach tool by tracking students a number of years after participating to see whether they have ultimately pursued a scientific subject, or indeed Physics in particular, and whether the sustained engagement with research and researchs over the course of the projects changed aspirations or played any part in their decision making processes. We therefore plan to release future supplements to this report in due course.

List of Supplementary Material

The following documents are provided as supplementary material:

- Teacher/student project guides
- Schools Collaboration Agreement

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