Institution:
University of Cambridge

Unit of Assessment:
UoA10

Title of case study:
Solar Space Research and Sun|trek

1. Summary of the impact (indicative maximum 100 words)

Research carried out by Dr Helen Mason, University of Cambridge, on solar space projects such as SoHO, Hinode and the Solar Dynamics Observatory (SDO), led to increased public interest in astronomy, space science, physics and mathematics, and has inspired school students to study science subjects, which should ultimately enhance the UK's technical and scientific expertise. This impact was achieved via sustained engagement activities including public lectures, work with the media and the Sun|trek project. Sun|trek (www.suntrek.org) is an educational website informed by Dr Mason's research targeted at UK teachers and school students about the Sun and its effect on the Earth's environment. Sun|trek also attracted a large user base in the USA, Australia, India and worldwide.

2. Underpinning research (indicative maximum 500 words)

Dr Helen Mason, University of Cambridge's Department of Applied Mathematics and Theoretical Physics (DAMTP), Assistant Director of Research throughout the period, has been invited to become an active researcher on many solar space projects, including Skylab, the Solar Maximum Mission, the Solar and Heliospheric Observatory (SoHO), Hinode and the Solar Dynamics Observatory (SDO). Using SoHO, Dr Mason studied many solar phenomena and was responsible for identifying the origin of the fast solar wind in 1999, which was one of SoHO's key objectives. Since 1998 the focus of her research has been on the nature of the heating in active regions and flares, together with studies of jets and micro-flares which can trigger filament eruptions and Coronal Mass Ejections (CMEs). Dr Mason has worked on Hinode, a joint UK/Japanese/NASA solar satellite from the time of its launch in 2006. She and her group, including postdoctoral researchers G. Del Zanna (STFC Advanced Fellow from 2008 to 2012,Senior Research Associate from 2012 to present) and D. Tripathi (Research Associate from 2008 to 2011), combined observations from Hinode/EIS (EUV Imaging Spectrometer) with those from SDO, launched in 2010, to investigate some key questions in solar physics. As members of the Hinode/EIS Science Team, Dr Mason and her group have planned, carried out and analysed many Hinode observations. This research work has been internationally significant. For example, it has provided important insights on the nature of heating in solar active regions and flares, by comparing the analysis of observations with theoretical models (Del Zanna et al, 2011, Tripathi et al, 2010, Tripathi et al, 2009). Their work has favoured the impulsive (nano-flare) heating model, where they have produced many high profile publications (see sample references below). Dr Mason now co-leads a team of researchers at the International Space Science Institute in a workshop series on the *Heating of Coronal Loops*.

Since 1998, Dr Mason and her group also studied the initiation (trigger) for energetic events on the Sun, such as jets, solar flares and CMEs. They found that the emergence and submergence of magnetic field plays a key role (Chifor et al, 2008). This area of research was particularly important for understanding and predicting space weather events, with possible damaging effects on the terrestrial environment.

Drs Mason and Del Zanna have also developed (with colleagues in the USA) a State-of-the-Art atomic database, called CHIANTI (Dere et al, 2009). First launched in 1997, CHIANTI is now universally used for the analysis of solar space observations. The latest release, v7, was in 2012. Drs Mason and Del Zanna have provided new atomic data (wavelengths, radiative data and electron collision data) for several ions, in particular those observed in the spectrum from the solar corona, for example from Hinode/EIS. These data are a crucial component in CHIANTI.

3. References to the research (indicative maximum of six references)

Del Zanna, G.; Mitra-Kraev, U.; Mason, H.E. et al, 2011, *The 22 May 2007 B-class flare: new insights from Hinode observations*, A&A, 526, 1, DOI: 10.1051/0004-6361/201014906
Tripathi, D.; Mason, H.E.; Klimchuk, J.A., 2010, *Evidence of Impulsive Heating in Active Region*

Core Loops, ApJ, 723, 713, DOI: 10.1088/0004-637X/723/1/713

*O'Dwyer, B.; G. Del Zanna; H. E. Mason et al, 2010, *SDO/AIA response to quiet Sun, coronal hole, active region and flare plasma*, A&A, v. 521, A21, DOI: 10.1051/0004-6361/201014872 (44 citations)

*Tripathi, D., H. E. Mason et al 2009, *Active Region Loops – Hinode/EIS Observations*, ApJ, v.694, p1256, DOI: 10.1088/0004-637X/694/2/1256 (45 citations)

*Dere, K. P.; Landi, E.; Young, P. R.; Del Zanna, G.; Landini, M.; Mason, H. E., 2009, *CHIANTI - an atomic database for emission lines. IX. Ionization rates, recombination rates, ionization equilibria for the elements hydrogen through zinc and updated atomic data*, A&A, v. 498, p915, DOI: 10.1051/0004-6361/200911712 (578 citations)

Chifor, C.; ; Mason, H.E.; Del Zanna, G. Et al, 2008, *Magnetic flux cancellation associated with a recurring solar jet observed with Hinode, RHESSI, and STEREO/EUVI*, A&A, 491, 279, DOI: 10.1051/0004-6361:200810265

*References which best represent the quality of the underpinning research.

This research has been supported by STFC (formerly PPARC):
2012-2014, STFC, Dr G. Oglvie (co-i's, Dr Mason, Dr Del Zanna), £615,415;
2009-2012, STFC, Pi Prof. J. Papaloizou (co-i's Dr Mason, Dr Del Zanna), £1,713,063;
2006-2011, PPARC, Pi Prof. J. Papaloizou (co-i Dr Mason, PDRA – Dr Tripathi), £971,014. Prior to this Dr Mason held a series of individual PPARC Standard Grant awards.

An international conference was held in 2010: '*Solar Plasma Spectroscopy - Achievements and Future Challenges: Celebrating the Career of Dr Helen Mason',* in recognition of Dr Mason's contribution to solar research, in particular her work with SoHO, Hinode and CHIANTI.
Furthermore, in 2010, the CHIANTI team was awarded the *RAS Group Achievement Award*. Dr Mason was a founder member of the CHIANTI team, first released in 1997, and this project has been largely dependent on her research contribution. Three out of five members of the Chianti team are from Dr Mason's group. The CHIANTI papers have had almost 600 citations in the past 5 years.

4. Details of the impact (indicative maximum 750 words)

Since 2008, Dr Mason has given over 15 public lectures at teachers' conferences (Institute of Physics, IoP, Association of Science Educators, ASE), schools and astronomy societies, in which she discussed solar space observations (SoHO, Hinode, SDO) and her research results, including those on the Sun's magnetic field, solar wind, active regions, flares and CMEs, and how CHIANTI has been used to analyse the UV observations.

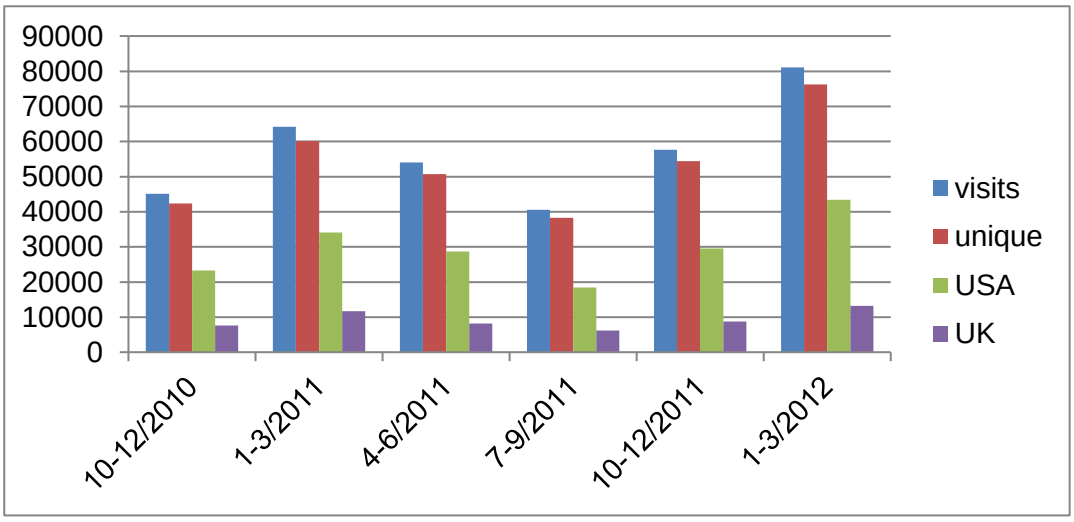
It is clear from the positive feedback that Dr Mason's engagement activity has informed and inspired teachers, students and the general public. Sample feedback includes: 'Thanks again for a brilliant talk. I've had some great feedback and you could tell by the questions how engaged the audience was!' (teacher, Kesgrave High School, Ipswich, 2013, 50+)[7]. In July 2013, IoP Director of Science and Education wrote of Dr Mason, "Her talks have helped improve student and teacher understanding of solar physics; and in particular the solar space projects, SoHO and Hinode. Teachers were also given supporting materials and ideas to help them teach this topic in the classroom. He also adds "We believe that the future of physics is very much in the hands of physics teachers and so are committed to providing all the support we can. It is particularly pleasing when we can do this in partnership with colleagues such as Dr Mason who has such a wealth of experience in the field of solar space projects."[6]

Since 2008, Dr Mason has also given several high profile public lectures, including a Friday Evening Discourse on 'Our Dynamic Sun' at the Royal Institution. This detailed her solar research with Hinode/EIS, SDO and CHIANTI (82% enjoyed the lecture, 73% learnt something new, 64%

wanted to find out more about her research, 2013, 250+)[1]. She also gave a Rutherford Appleton Laboratory *Talking Science* lecture (65% Strongly agreed that the talk was enjoyable and interesting 2013, 80+) [2]. She has lectured twice at the INTECH Science Centre (2009, 120+; 2011, 170+; 'Dr Mason's talks are ideal for our Space Lecture series... bringing in up-to-the-minute research and developments', INTECH Manager) [3].

Dr Helen Mason launched Sun|trek, an educational website about the Sun and its effect on the Earth's environment, in 2007. The site is directly underpinned by the research carried out by Dr Mason and her group described above. It features sections on solar space observatories (SoHO, Hinode, SDO) and CHIANTI. Key research results which feature on Sun|trek include: the heating of solar active regions and flares studied with SDO and Hinode (e.g. iSun|trek 'The Sun gets active with X-class Flares' and the Sun|trek Hinode section). New Sun|trek Classroom projects released in 2012 use real solar space data (e.g. '*Spectra: Solar fingerprints'* contains spectra from Hinode/EIS, with CHIANTI spectral identifications).

The impact of the Sun|trek project has by 2012 been far reaching - around 300,000 individuals per annum. Below are sample stats from Google Analytics for the Sun|trek website in 3 month groups from October 2010 until March 2012 (i.e. 10-12 2011 is Oct-Dec 2011 etc.). Visits denotes all visits, unique visits are separate individuals.



The 2012 enhancement, iSun|trek (**www.suntrek.org/blog**) links to modern social communication networks (Facebook, YouTube, Twitter etc.). The Sun|trek Facebook site, has topical information highlighting research achievements (e.g. with SoHO, Hinode, SDO), reaching 2,500 individuals per week by mid-2013. Since 2008, Sun|trek has been linked to many other educational websites (e.g. STEM, RAS, STFC, ASE, IoP, International Year of Astronomy (2009/10), SunEarthPlan, Schoolscience, ESERO, BBC Science).

Dr Mason has presented her research themes through her work with the media (BBC TV and radio). She featured in the BBC4 programme *Seven Ages of Starlight* (with recent observations from SDO), which was nominated for a BANFF Rockie award. This was broadcast in 2012 (reaching 795,000) and again in June 2013. The Audience Appreciation Index was 87, significantly higher than the average score for a factual programme [4]. The Times wrote: 'Everyone who isn't an astronomer or a theoretical physicist should watch Gaby Hornsby's incredible film... It is one of the richest and most informative science programmes I have ever seen'. Dr Mason also worked on *Science Britannica* (BBC2, 2013).

In 2010, Dr Mason was named as one of the UKRC's Women of Outstanding Achievement for 'her inspirational work in communication within SET and her contribution to discovery in her field' [5]. The prize, a photo portrait of Dr Mason, hangs at the IoP headquarters as an inspiration to young females. She was awarded an STFC Science in Society Fellowship (Oct. 2011 – March 2012) in

recognition of the high profile and impact of her outreach work.

5. Sources to corroborate the impact (indicative maximum of 10 references)

[1] Statement from the Director of Science and Education, Royal Institution regarding Friday Evening Discourse, April 2013
[2] Feedback Sheet, STFC, RAL Talking Science, May 2013
[3] Statement from INTECH Science Centre and Planetarium Manager regarding Space Science lectures: 2009, 2011
[4] Seven Ages of Starlight, BBC4, producer
[5] RAS feature on Helen Mason, 2010, Women of Outstanding Achievement Award: http://www.ras.org.uk/news-and-press/157-news2010/1743-dr-helen-mason-named-as-one-of-the-uks-outstanding-women
[6] Statement from IoP Director of Science and Education, including details of feedback on Dr Mason's talks
[7] Statement from Teacher, Kesgrave High School, Ipswich