Institution: Lancaster University

Unit of Assessment: 9 Physics

Title of case study: AuroraWatch UK

1. Summary of the impact

Lancaster undertakes fundamental research into the space plasma environments. AuroraWatch UK, a spin-out of this research, provides a free service alerting when aurorae may be visible from the UK. The number of AuroraWatch subscribers has increased significantly from 22,000 in 2008 to over 109,000 at present. A survey by the Royal Astronomical Society suggests that AuroraWatch is very effective in promoting interest in science. As a result of subscribing to AuroraWatch, 3667 respondents watch science on television, 4437 read science magazines, websites and blogs, 524 now study science, 865 participate in citizen-science projects, and 1400 listed other changes in their behaviour (e.g. aurora sightseeing trips). The AuroraWatch School programme involves 1800 pupils across UK.

2. Underpinning research

Research into understanding the coupling between the solar wind, the magnetosphere and the ionosphere (the electrically charged upper portion on the Earth's atmosphere) reveals insights into the plasma physics of the space environment, in particular the temporal and spatial morphology of particle precipitation into the upper atmosphere which produce aurora and ionospheric currents.

The underpinning research is the dynamics and triggering of geomagnetic storms/substorms which result in particle precipitation into the atmosphere and the aurora. This is one of the main research areas conducted at Lancaster and has been supported by PPARC/STFC and now by NERC (RC1). Underpinning fundamental research into space plasmas, are a family of ground-based experiments developed and are operated by Lancaster space scientists which include ground-based magnetometers called SAMNET (the UK Sub-Auroral Magnetometer Network).

Magnetic field variations measured by magnetometers are predominantly a result of the coupling between the ionosphere, magnetosphere and solar wind. In order to understand this global-scale system, it is necessary to study magnetic field measurements spanning many hours of local time. In practice, this means combining measurements from magnetometers located in different locations, hence a need for operating a dense array of magnetometers. Operation of SAMNET magnetometers was funded by PPARC/STFC from 2003-2010 under UK solar-terrestrial physics (STP) national facilities. Following the transfer of ground-based STP from STFC to NERC, Lancaster has secured NERC funding.

One of SAMNET's scientific objectives is the detection of increased geomagnetic activity. In essence, during such intervals the coupling between the Earth's magnetic field and the interplanetary magnetic field (which is embedded in the solar wind) is enhanced. This activity gives rise to increased auroral activity in mid- and high-latitude regions. During particularly active periods, the Aurora Borealis can be seen from the UK. AuroraWatch UK (part of SAMNET's magnetometer network) is a free public outreach service which alerts subscribers by e-mail or via social media applications when the likelihood of aurorae appearing over UK is high.

Outputs from our fundamental research also contribute to a greater appreciation of the risk and hazards posed by space weather. The publications listed below in section 3 utilised SAMNET data to describe the triggering of substorms (Ref.1-3), and the particle precipitation dynamics during geomagnetic storm (Ref. 4-5). The sixth publication illustrates the geomagnetically induced currents in power transmission lines after the substorm onset. All publications are in leading peer-reviewed international journals.

3. References to the research

1. A. Keiling, M. Fujimoto, H. Hasegawa, **F. Honary**, V. Sergeev, V. S. Semenov, H. U. Frey,

O. Amm, H. Rème, I. Dandouras, and E. Lucek. Association of Pi2 Pulsations and Pulsed Reconnection: Ground and Cluster Observations in the Tail Lobe at 16 R_E. Annales Geophysicae - Atmospheres, Hydrospheres and Space Sciences. ISSN 0992-7689. 24 (12) pp. 3433-3449. doi:10.5194/angeo-24-3433-2006. 21st December 2006. http://www.ann-geophys.net/24/3433/2006/angeo-24-3433-2006.html.

2. V.A. Sergeev, S. V. Apatenkov, V. Angelopoulos, J.P, McFadden, D. Larson, J.W. Bonnell, M.Kuznetsova, N. Partamies, and **F. Honary**. Simultaneous THEMIS observations in the near-tail portion of the inner and outer plasma sheet flux tubes at substorm onset.; Journal of Geophysical Research , Vol 113, A00C02, doi:10.1029/2008JA013527, 2008.
3. K. Takahashi, D. Berube, D. H.Lee, J. Goldstein, H.J. Singer, **F. Honary**, and M.B. Moldwin. Possible evidence of virtual resonance in the dayside magnetosphere, Journal of Geophysical Research, Vol. 114, A05206, doi:10.1029/2008JA013898, 2009.
4. N. Longden, **F. Honary**, A. J. Kavanagh, and J. Manninen. The Driving Mechanisms of Particle Precipitation during the Moderate Geomagnetic Storm of 7 January 2005. Annales Geophysicae - Atmospheres, Hydrospheres and Space Sciences. ISSN 0992-7689. 25(9) pp. 2053-2068. doi:10.5194/angeo-25-2053-2007. October 2007. http://www.ann-geophys.net/25/2053/2007/angeo-25-2053-2007.html.
5. Z.C. Kale, I. R. Mann, C. L. Waters, M. Vellante, T. L. Zhang, and **F. Honary**. Plasmaspheric Dynamics Resulting from the Hallowe'en 2003 Geomagnetic Storms. Journal of Geophysical Research - Space Physics. ISSN 0148-0227. 114(A08204) pp. 1-12. doi:10.1029/2009JA014194. 11th August 2009.
6. K. L. Turnbull, **J. A. Wild**, **F. Honary**, A. W. P. Thomson, and A. J. McKay. Characteristics of Variations in the Ground Magnetic Field during Substorms at Mid Latitudes. Annales Geophysicae - Atmospheres, Hydrospheres and Space Sciences. ISSN 0992-7689. 27(9) pp. 3421-3428. SRef-ID:1432-0576/angeo/2009-27-3421. 1st September 2009.

4. Details of the impact

The aurorae captivate the public imagination and there is a great deal of interest in this beautiful and mysterious natural phenomenon. The impact of AuroraWatch was highlighted when Channel 4 contacted Farideh Honary (SAMNET PI) in 2006 mentioning that the phrase “aurora borealis” was in the top 100 of most searched-for terms in MSN’s UK search engine, and asked if they could visit Lancaster to produce a programme on aurorae. Since then, SPEARS scientists have given more than 20 national/regional radio interviews, have appeared on television to explain the auroral phenomena, such as the BBC’s Sky at Night (“The Merry Dancers”, 2009, ~200,000 expected audience) and Horizon (“Solar storms - the threat to Planet Earth”, 2012, 1,800,000 expected audience), and have delivered 32 talks to schools and 60 presentations to public audiences (~500 attendees). In addition to TV and radio programmes, AuroraWatch has featured in 10 newspaper/magazine articles since 2008 (RC2), and in the book “Field notes from a hidden city: An urban nature diary” (Esther Woolfson, 2013) (RC3). Lancaster’s auroral research was the subject of a short film (“Written in the sky: aurora borealis explained”) produced by the IOP in 2012 as part of the “Physics Lives” series, for A-level students. It won a British Universities Film and Video Council award in April 2013 and has over 16,960 viewings on YouTube (RC4).

The huge public interest is clear. AuroraWatch has over 109,000 subscribers, comprising 26,930 Twitter followers, 21,279 Facebook fans and 61,628 email subscribers. Users are encouraged to photograph the aurora and share via our Flickr group, which has 771 members and 1,239 aurora photographs since 2011. These numbers indicate a significant increase in public engagement compared to 2008 when AuroraWatch had 22,000 subscribers (RC5).

Professor Wild has delivered 12 enrichment lectures, to audiences of ~500 passengers, on board the Queen Victoria and Queen Mary cruise-liners between 2008 and 2011. He has also delivered lectures to aurora enthusiasts on four aurora pleasure flights (~130 passengers per trip). The repeated invitations testify to the interest and impact of these lectures (RC6).

The public support for AuroraWatch led to over 2500 individuals expressing their concern to PPARC following its decision not to fund SAMNET as a UK National Facility. At the time AuroraWatch had only 10,000 subscribers, hence the 2500 individual letters corresponds to 25% of

AuroraWatch subscribers. Their support letters constitute a four-volume document which was sent to PPARC's Chief Executive. To view all these letters, please see (RC7). Many AuroraWatch users are amateur astronomers and radio amateurs. Following the public outcry over concerns that the research council's decision might threaten the operation of SAMNET magnetometers and the AuroraWatch service, Robert Goodwill, MP for Scarborough and Whitby raised these concerns and questioned the Secretary of State for Trade and Industry in Parliament over PPARC's decision regarding SAMNET funding and the future of the AuroraWatch programme (RC8). Following Mr Goodwill's intervention, Ben Wallace, MP for Lancaster and Wyre, visited the SPEARS Group at Lancaster University in 2006 and lobbied STFC (PPARC's successor) for the decision to be reconsidered. The public support re-instated SAMNET's funding in 2007 (RC1).

According to a Royal Astronomical Society survey in October 2011, AuroraWatch has had a significant impact on public's interest and appreciation of science. The survey attracted 9971 responses (a response rate of 25%, total number of AuroraWatch subscribers were <40000 in 2011) and found a range of positive impacts. For example, as result of subscribing to AuroraWatch, 3667 respondents report that they watch more science on television, 1348 read more science magazines, 3089 read more science websites and blogs, 524 now study or plan to study science and 865 participate in citizen science projects. More than 1400 subscribers listed other changes in behaviour including an interest in amateur astronomy, buying a telescope or booking a cruise to the Arctic to see the aurora (RC9).

The RAS survey indicated that school pupils were the age group least-represented in the survey respondents. To increase participation by school pupils we developed a wireless, low-cost magnetometer and obtained funding from Lancaster University to construct ten magnetometers. A competition was launched to select ten schools that would best incorporate the magnetometer and its data into their teaching of STEM subjects. 164 applications from across the UK were received. The selected schools will involve 1800 pupils in AuroraWatch related activities, including projects for CREST awards, astronomy, science, physics, engineering, electronics and STEM clubs, and comparison with solar telescope, sunspot, VLF receiver, muon detector and high-altitude balloon radiation detector data (RC10). The impressive response has encouraged Lancaster to seek further funding to involve more schools in AuroraWatch.

5. Sources to corroborate the impact

RC1. The following research grants have supported the operation of SAMNET magnetometer network since 2003:

F. Honary, The UK Sub-Auroral Magnetometer Network (SAMNET) rolling grant, PPARC, ppa/g/2002/00482, 01/04/2003-31/03/2007, £284,069

F. Honary, SAMNET Operation, PPARC/STFC, 01/04/2007-31/03/2008, PP/E001963/1, £46,742

F. Honary, Fundamental Plasma Processes, STFC, ST/F003005/1, 01/04/2008-31/07/2010, £591,500

F. Honary, SAMNET data curation, STFC, ST/F008090/1, 01/12/2007-31/03/2008, £21,349.

J. Wild and F. Honary. A high-order model of the Earth's External and Induced Magnetic Field, NERC, NE/J021792/1, 01/01/2013-31/12/2015, £350,234.

RC2. For the list of media activities, including articles in newspapers and magazines please see http://aurorawatch.lancs.ac.uk/news-coverage

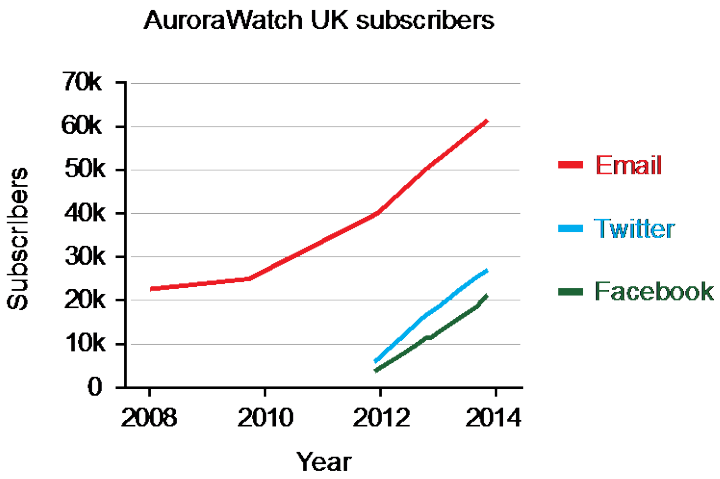
RC3. Field notes from a hidden city: An urban nature diary. Esther Woolfson. Published 7 March 2013 by Granta books,
http://grantabooks.com/Field-Notes-From-a-Hidden-City-2
AuroraWatch is featured on 3 occasions in this book (November 29th, July 20th and July 23rd). Below is an excerpt from November 29th which demonstrates the impact that AuroraWatch has on the general public: "Every morning as I sit down at my desk, before doing anything else - including work - I check a website that will inform me if the aurora borealis, the Northern Lights, may be seen later in the night skies above us. The site's called 'Aurora Watch', and is the website of the UK Sub-Auroral Magnetometer Network, SAMNET, the body that, on behalf of us all, keeps a usefully close eye on what's happening in the arcane universe of space weather and on the aurora

borealis, the only sign visible from earth of the astonishing turbulences above us."

RC4. "Physics Lives" film, made on behalf of the Institute of Physics, http://www.iop.org/education/higher_education/stem/showcasing/page_54368.html The film won the British Universities Film and Video Council Learning on Screen 2013 General Education Non Broadcast Award, http://bufvc.ac.uk/events/learningonscreen/winners

RC5. AuroraWatch UK website: http://aurorawatch.lancs.ac.uk/
Facebook page: https://www.facebook.com/aurorawatchuk
Twitter: https://twitter.com/aurorawatchuk
AuroraWatch UK Flickr group for subscribers photographs of aurora taken from the UK: http://www.flickr.com/groups/aurorawatch/

As a result of engaging with subscribers by social media the number of AuroraWatch followers has increased from 22,000 to 109,000 in the last 5 years despite the low geomagnetic activities.



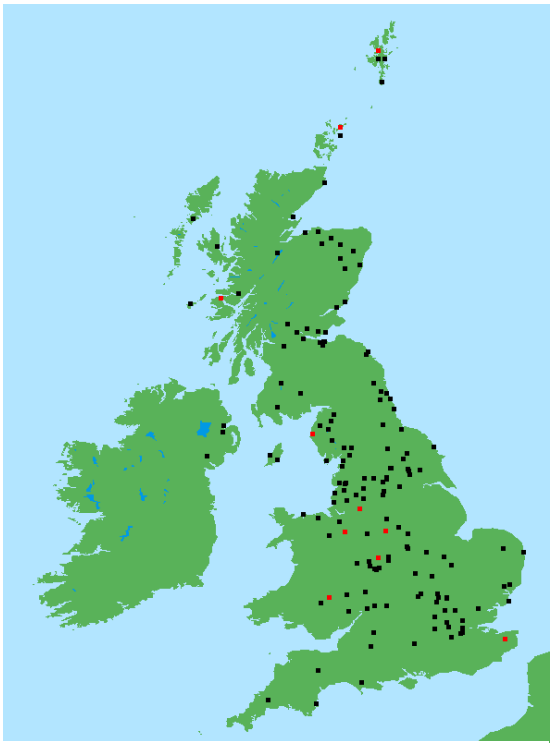
RC6. J. Wild. Astronomy at sea: Jim Wild's Cunard diary, Astronomy and Geophysics, Vol. 50 no. 1.

RC7. Public support letters constituting a four-volume document which was sent to PPARC's Chief Executive

RC8. House of Parliament: Questioning Secretary of State for Trade and Industry in the house of Parliament over PPARC's decision regarding SAMNET funding and the future of the AuroraWatch programme by Robert Goodwill, MP for Scarborough and Whitby. 12 May 2006. http://www.publications.parliament.uk/pa/cm200506/cmhansrd/vo060512/text/60512w0003.htm

RC9. Who watches aurora? Robert Massey, Astronomy and Geophysics (A&G) Feb. 2012, Vol.53, issue 1.

RC10. AuroraWatch magnetometer for schools competition entries.



Location of schools which entered the AuroraWatch schools magnetometer competition. Selected schools are highlighted in red.