# *Look out, aurorae about!*

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According to a popular internet search engine, the phrase "aurora borealis" was among the top one hundred searched-for terms in the UK in 2005. At first glance, one might consider this surprising. After all, the British Isles are not typically associated with the beautiful auroral displays that are commonplace at more northerly locations. Why then is there so much interest in the so-called "northern lights"?

The aurora borealis, literally translated as the "northern dawn", has captivated onlookers for millennia. There are countless myths and beliefs that explain the dancing lights in the night sky. The indigenous people of North America believed that if you whistled at the aurora it would sweep down and take you from the Earth and only by clapping your hands you could force it to retreat. Several cultures associated auroral displays with the clashing of great armies in the sky or the restless spirits of the dead. Further south, where aurorae were observed much less frequently, people would have seen the northern lights only once or twice in their lives. In Europe, the strange lights in the sky, especially red aurorae, were usually interpreted as omens of impending death, war or the spilling of blood.

To modern-day observers, the aurora borealis is no less impressive. It is one of those phenomena that really must be seen first-hand as neither still or moving images can do it true justice. Judging by the number of aurora-watching holidays advertised in the travel sections of the Sunday papers, the aurora borealis still captivates those with an adventurous spirit as well as supporting a lucrative travel industry, but is it necessary to travel to the Arctic circle to witness the aurora first hand? Can the aurora borealis be seen from the UK? Perhaps it is this question that drives people to the internet search engines.

We now know that aurorae are a direct consequence of the magnetic coupling between the Sun and the Earth. Under certain interplanetary conditions, particles of solar origin are able to enter the magnetosphere, the region of near-Earth space dominated by the terrestrial magnetic field, from where they have access to the upper reaches of the Earth's atmosphere. Visible aurorae are created when energetic charged particles, mainly electrons, precipitate along magnetic field lines and collide with atmospheric atoms and molecules. The vast majority of auroral light consists of the emission lines of neutral or ionised O and $N_2$. Although Ångström demonstrated in 1866 that the dominant green emission had a wavelength of 557.7 nm, it was not until 1925 that McLennan and Schrum identified it as the metastable transition of atomic oxygen from the $^1S$ to the $^1D$ state. Another transition line of atomic oxygen ($^1D \rightarrow {}^3P$) results in red line emission from the 630.0 – 636.4 nm doublet. Ionised nitrogen molecules are responsible for violet and blue auroral emission lines at 391.4 nm and 427.8 nm.

The metastable or "forbidden" oxygen transitions have relatively long lifetimes (0.74 s and 110 s for the green and red lines respectively) and are most prominent in the upper atmosphere. At these high altitudes, the atmosphere is sufficiently rarefied that collision frequencies are low. Below about 200 km altitude the red line emissions are quenched by collisional de-excitation of the oxygen atom while green line emissions are quenched below approximately 120 km. Nitrogen transitions occur more or less spontaneously and, although weaker than the green and red line emissions from atomic oxygen, extend down to about 100 km altitude.

As well as the composition and density profile of the atmosphere, another key factor that determines the colour of auroral features is the energy of the precipitating particles. Typical auroral electron energies lie in the range 1-10 keV allowing to penetrate the atmosphere to between 150-100 km altitude. As such, the green line emission at 557.7 nm usually dominates the appearance of auroral features to the naked eye. Soft electrons (less than 1 keV) cannot penetrate far into the atmosphere and result in red emissions above about 200 km altitude. Fluxes of hard electrons with energy greater than 10 keV can travel deep into the atmosphere and produce a pink-red fringe at the lower edge of the aurora.

Typically, aurorae are observed within crown-like ovals that surround the northern and southern geomagnetic poles. Usually, the auroral ovals are about 5˚ of latitude in width and centred on about 70˚ magnetic latitude in the midnight sector and slightly further poleward in the dusk and dawn sectors. During intervals of high geomagnetic activity the auroral ovals expand equatorward whereas during quiescent periods they contract poleward. Consequently, the likelihood of observing the aurora at mid-latitudes varies according to the position within the 11-year solar cycle. Situated between about 47°-58° magnetic latitude, the UK usually resides within the sub-auroral zone located equatorward of the main auroral oval that surrounds the northern geomagnetic pole. However, on average we can expect to see visible aurora over the UK a couple of times per year, albeit with a preference toward the northern parts of the country.

The AuroraWatch programme is a real-time service that alerts subscribers when geomagnetic conditions are likely to result in aurora over the UK. Launched in September 2000, AuroraWatch operates under the auspices of SAMNET - the UK sub-auroral magnetometer network. SAMNET is a UK National Facility for Solar Terrestrial Physics funded by the Particle Physics and Astronomy Research Council. Originally deployed and operated by the University of York, SAMNET has been operated by Lancaster University since April 2003. Specifically, Lancaster University operates five stations equipped with fluxgate magnetometers which continuously record natural variations in the Earth's magnetic field at 1-second resolution. In addition, 1-second resolution data from five magnetometers of the International Monitor for Auroral Geomagnetic Effects (IMAGE) network and three British Geological Survey magnetometers are also archived. Thus, SAMNET comprises thirteen ground magnetometers spanning the sub-auroral zone and stretching approximately 2,000 miles from Borok in Russia to Hella in Iceland. These magnetometers are sensitive to magnetic field disturbances caused by electrical currents flowing in the ionosphere. As such they form a crucial component of the worldwide network of ground magnetometer stations used for the investigation of the complex interactions within the coupled solar wind-magnetosphere-ionosphere system. SAMNET’s mid-latitude location makes it particularly suitable for the investigation of ionospheric currents and characteristic wave pulsations associated with magnetospheric substorms – the explosive release of solar wind energy stored in the Earth's magnetotail that results in spectacular aurora in the high-latitude auroral zone.

AuroraWatch draws upon real-time data from the SAMNET magnetometer located at York (50.8˚ magnetic latitude). The components of the local magnetic field vector pointing toward magnetic north (H-component), vertically downward (the Z-component) and magnetic east-west (D-component) are measured at 1-second resolution and passed via the internet to the AuroraWatch system. From these data, a real-time activity plot is generated showing geomagnetic conditions over the preceding 24 hours(figure 1). These plots shows the H-component of the field as a black line, with a typical quiet day shown in blue. The difference between the observed field and a quiet day is plotted as a colour-coded bar chart: green for quiet, orange for active and red for stormy.

Various different stages of magnetic activity show up in H-component data. For example, as a coronal mass ejection (CME) hits the front side of the magnetosphere, the compression of the magnetic field produces an increase in the northward magnetic field measured at ground level. This gives a characteristic rise in the field and is known as a Sudden Storm Commencement (SSC). Not all SSCs are followed by auroral activity at mid-latitudes, but it is a good early indicator. If the solar wind speed and interplanetary magnetic field direction are favourable, energy will gradually build up in the magnetosphere resulting into a large geomagnetic storm, with the magnetic field decreasing and changing rapidly. It should be noted that the terminology of storms and substorms is somewhat misleading. Substorms are not small storms - storms may include several magnetospheric substorms as well as long quiescent periods. Nevertheless, geomagnetic storms probably present the UK aurora watcher's best chance for success.

AuroraWatch alerts correspond to the status colour coding indicated in Figure 1. A red alert indicates that geomagnetic conditions are sufficiently disturbed that aurorae are likely over the UK while an amber alert corresponds to moderate activity and a lower likelihood of aurora. When signing up for alerts, subscribers can elect to receive both amber and red alerts or red alerts only. The AuroraWatch alert takes the form of a short email with the alert status given in the subject line. As such, subscribers can take advantage of the free email forwarding services offered by most mobile phone networks and have AuroraWatch alerts forwarded as an SMS text messages directly to their mobile phone.

There is clearly huge public interest in the aurora within the UK and the AuroraWatch programme has been highly successful - in October 2005, AuroraWatch recorded its 20,000$^{th}$ subscriber. Of course, not every alert results in a spectacular auroral display and where you live can dramatically improve or reduced the chances of a successful night's aurora-spotting. Bright streetlights from large towns or cities will overpower faint aurora. However, as demonstrated by figures 2 and 3, it isn't necessary to travel far from urban areas in order to stand a good chance of spotting the northern lights given the right geomagnetic conditions (although aurora watchers who live in the rural north of the UK are more likely to see an auroral display than those inside the M25!). As we are currently, approaching a minimum in the 11-year cycle of solar activity it is expected that auroral displays over the UK will be at their most infrequent. Nevertheless, based upon photographs taken by AuroraWatch subscribers, it is known that clear aurorae were observed on at least two nights in 2005. The AuroraWatch gallery is full of images taken by AuroraWatch subscribers from as far north as the Shetland Isles to the south coast of England – all it takes is a fine night and a little luck!

More information can be found at the AuroraWatch website http://aurorawatch.lancs.ac.uk/

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**Quotations**

“I've wanted to see the northern lights all my life and thanks to your set up and red alert sent out, myself, my wife and our children went into the countryside not far from where we live in Ulverston last night and caught a wonderful display which will live long in the memory.”

Stephen Anderson-Bass

“Just seen the aurora for the first time, from the outskirts of Newcastle, absolutely fantastic!!!!“

Hilda Frost

“I was extremely fortunate to see a fine aurora in a country area outside Abergavenny, South Wales last night (10 November 04) at about 20:00 GMT - right when your display predicted one! It's not often we see such things so far south. Keep up the good work - I've subscribed to your e-mail alert service.”

Walter Daw

**Figures**

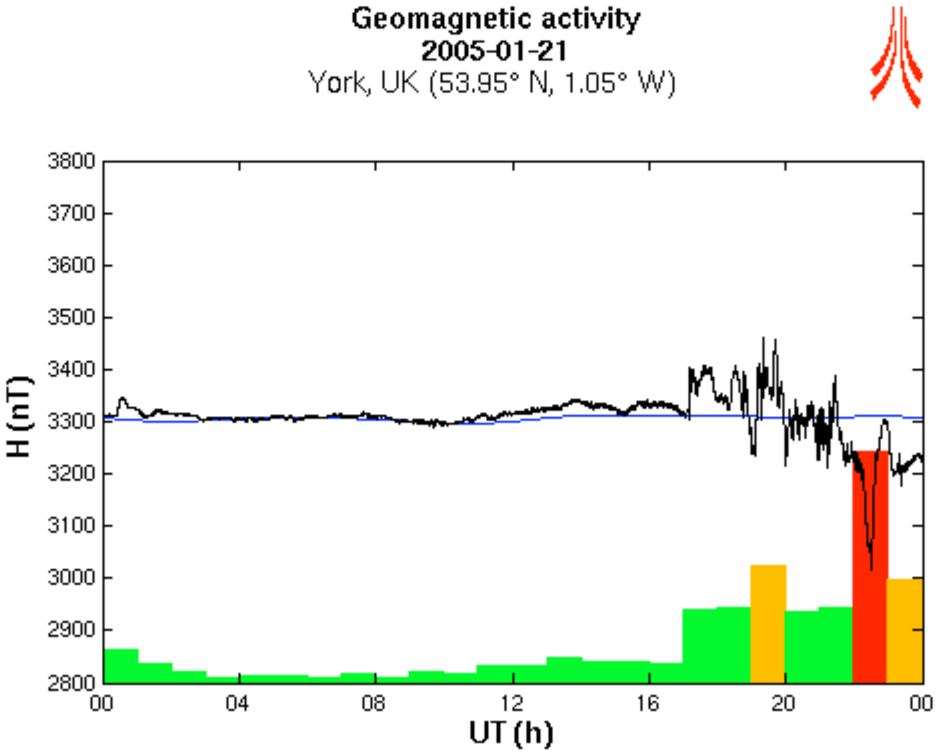


Figure 1: The AuroraWatch geomagnetic activity summary for the 21st January 2005

Figure 2: Red and green aurora over the Lancaster University campus on the night of 21st January 2005 (Photograph: Andrew Senior)

Figure 3: Green aurora over Insch, Aberdeenshire, on the night of 9th November 2004 (Photograph: Josta Vermeulen)