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EXACT: A study of the Earth's aurora using a Cubesat

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Abstract

Despite the relationship between solar wind conditions and the Earth's auroral emissions, no systematic attempt has yet been made to correlate the two with in-situ coordinated particle and radiation measurements, and X-ray measurements in particular. We have studied how to do this with a **dedicated, low-cost, nano-satellite, a Cubesat, carrying miniaturised and yet very effective instrumentation**, which will open the way to a better targeted and global approach to planetary exploration. We are especially keen to observe the X-ray aurora, which is associated with the most energetic particles and has not been explored in detail yet, and to correlate its strength and variability with simultaneous particle and magnetic field measurements. This presentation will describe the aims of the mission and the strategy to carry it out.

1. Introduction

The infrared, visible and ultraviolet aurora is formed when ionospheric and solar wind particles collide with atmospheric atoms and molecules, and leave them in excited states, from which they subsequently decay; photons of specific energies characteristic of the emitting species are thus released, giving rise to a great number of spectral lines and bands. At the high energy end of the spectrum, auroral X-ray production can take place by electron bremsstrahlung (with electron energies of 10 – 100 keV), by electron excitation of atmospheric constituents, followed by line emission, and by 'charge exchange' (CX): in this case highly ionised solar wind ions (C, N, O) acquire an electron in collisions with atmospheric particles and subsequently de-excite, with characteristic X-ray line emission in the soft X-ray range (0.3 – 2 keV).
Electron bremsstrahlung of auroral origin has been observed at energies above 3 keV by the PIXIE experiment onboard *Polar* [4]; some evidence for soft X-ray Ka lines of N and O, following electron excitation, emerged from observations with *HEAO-1* [3], but CX has not been revealed yet; however, its typical signature of soft X-ray emission lines is expected to be present, by analogy with the strong emissions of the same origin identified in Jupiter's aurorae [2]: both planets have dense atmospheres and well developed magnetospheres, so similar physical processes are found, and are expected, to operate on both. Soft X-ray imaging [1] (see Fig. 1) has shown the Earth's aurora to be very variable in flux and morphology, with bright patches and arcs, changing aspect over timescales of minutes; however, the details of the spectrum below 2 keV are still unknown.

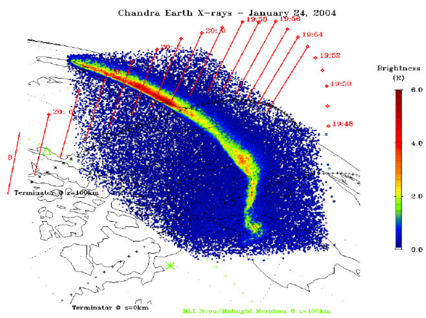

Figure 1: Example of soft X-ray terrestrial auroral arc detected with the *Chandra Observatory*.

Turning to the particles responsible for the aurora, in-situ measurements in the Earth's upper atmosphere reveal a dynamic space environment, characterised by a complex network of electric and magnetic fields governing the movement of charged particles towards and away from the terrestrial atmosphere (Birkeland current). Changes in magnetotail configuration, modulated by solar activity, drive the current system and accelerate the particles responsible for the auroral manifestations. So there is very significant scope for coordinated studies of auroral X-ray emissions and in-situ particle and magnetic field measurements.

2. The *EXACT* mission

***EXACT* (Earth X-ray Aurora Cubesat Telescope) is a Cubesat mission planned to make simultaneous observations of the Earth's X-ray aurora, of the charged particles likely to be**

responsible for it and of the magnetic field driving the auroral processes. Not only this will enable the first systematic and correlated study of terrestrial high energy auroral phenomena, but will also offer a testbed for new technology and imaginative hardware developments; especially the requirement to fit within very limited resources in terms of mass, size and power makes a Cubesat ideal for prototyping and testing in real space conditions novel, miniaturised technology, with the view of transferring it later to more ambitious planetary missions, and to wider industrial applications. Cubesat projects are also a very effective training ground for graduate students planning careers in space research, in an academic as well as an industrial context. Some of the preliminary study that has lead to the current mission plan was part of individual and team project work of UCL/MSSL Master-level students.

2.1 Scientific objectives

EXACT main scientific objectives are: a) To establish the role of magnetospheric ions, originally from the solar wind, in the production of the terrestrial X-ray aurora by making the first soft X-ray spectroscopic observations of it and by searching for charge exchange (CX) line emission in the band 0.3 – 2 keV; b) To study the X-ray aurora up 5 keV, thus probing the electron population expected to produce most of the higher energy emission via bremsstrahlung, and measure at the same time the magnetic field controlling the electron propagation; c) To make a systematic search for correlations between intensity and morphology of the X-ray aurora and particle fluxes, and generally with solar wind variability.

2.2 Development plan

Our plan is to design, construct, launch and operate in low-Earth polar orbit a compact global auroral observatory, based on a 3-unit Cubesat spacecraft and incorporating an X-ray telescope with spectroscopic capabilities, a plasma package and a magnetometer. The spacecraft will be three-axis stabilised by way of magnetorquers; power will be provided by solar panels mounted on the sides of the spacecraft and by batteries during peak consumption. The X-ray telescope is based on the principle of the pinhole camera, scaled to match the size and brightness of the X-ray features expected to be observed. Off-the-shelf Charge Coupled Devices detectors can provide adequate sensitivity and energy resolution according to our requirements, at very small size and mass. A novel, miniaturised plasma analyser is planned to be adopted, based on an advanced prototype developed at MSSL. The instrument will measure the ambient plasma densities of both electrons and ions simultaneously (Fig. 2).

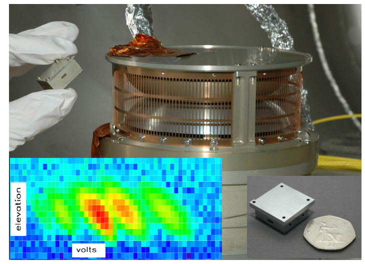

Figure 2: UCL/MSSL prototype miniaturised plasma analyser (between gloved fingers) compared to a normal size analyser (dominating the picture); inset: analyser response for 1 keV beam.

An off-the-shelf magnetometer completes the payload, with the sensor part mounted on a telescopic boom to avoid that currents circulating in the spacecraft may perturb the local magnetic field measurements. Details of the payload and the development plan and mission operations will be provided in the presentation.

3. Summary and Conclusions

The upper atmosphere region is the interface that connects the Earth's environment and space. As such, it plays a major role in the energy balance of the whole Earth's system, yet it remains the least explored region in the Earth's atmosphere. The *EXACT* mission is a first attempt at a new way of exploration, that ideally will evolve into a future mission with a number of Cubesats flying in formation in low-Earth orbit. This promises to be a very effective, affordable, educational and inspirational approach to more discoveries about our home planet.

References

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