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Comparative X-ray planetary aurorae: physical processes and diagnostic potential

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Abstract

This talk reviews observations of planetary X-ray aurorae carried out over the last decade by the two major orbiting X-ray observatory missions, *XMM-Newton* and *Chandra*. Particular emphasis is given to the interpretation of the physical processes leading to the X-ray production (e.g. ionic charge exchange and electron bremsstrahlung) and to the diagnostic potential of the X-ray data, in exploring the dynamics of the charged particles involved, their origin and the magnetic environment in which they radiate. Focus of the talk are the X-ray aurorae of Jupiter and Earth, their similarities and differences; the lack of detection of X-ray aurorae on Saturn is also examined, as well as the feasibility of observing them on Uranus and Neptune.

1. Introduction

Over the last decade the *XMM-Newton* and *Chandra* observatories have given a remarkable impetus to X-ray studies of the solar system by revealing how ubiquitous X-ray emission is among planets, moons, comets and asteroids (see [1] for a recent review of the subject). Both auroral and lower latitude disk emissions, with different spectral characteristics, are observed on planets. Disk emission is clearly produced in the scattering of solar X-rays in the planetary atmospheres (e.g. [2]), and as such mirrors the solar cycle variability very closely [3]. Topic of this talk are X-ray aurorae, observed on Jupiter and Earth, but not yet on Saturn, and unlikely to be detected on the other outermost planets.

2. Jupiter

Copious amounts of X-rays are produced in Jupiter's aurorae, via ionic charge exchange (dominating below 2 keV) and electron bremsstrahlung (emerging at higher energies – see Fig. 1, from [4]). The origin of the ions, which must be accelerated in the planet's magnetosphere, has been matter of debate, whether it may be in the solar wind, or from the inner Jovian magnetosphere, i.e. Io's volcanoes. The latter possibility is favoured by the most recent spectral results [4], [5]. Very interestingly, the morphology of the bremsstrahlung X-ray emission links the electrons producing it directly to those responsible for the FUV aurora (Fig. 2, from [6]), and dramatic changes in this emission have been associated with episodes of enhanced solar wind variability [4].

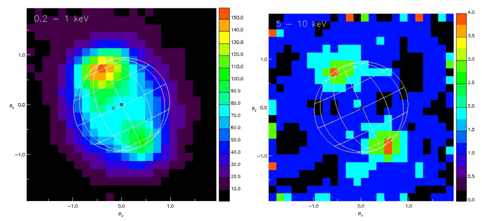

Figure 1: Smoothed *XMM-Newton* images of Jupiter (from [4]) showing the bright auroral spots, in the 0.2 – 1 keV band (left, due to ionic charge exchange) and the 5 – 10 keV band (right – electron bremsstrahlung). At the softer energies also the Jovian disk emission is clearly visible.

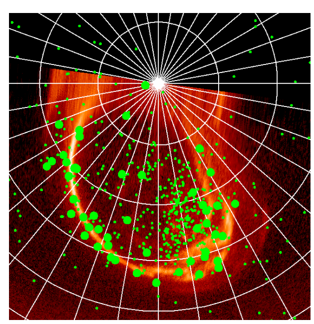

Figure 2: Polar projection of the Hubble STIS FUV image of Jupiter Northern aurora (in orange); overplotted are X-ray photons (large green dots: > 2 keV, from electron bremsstrahlung; small dots: < 2 keV, from ionic charge exchange) detected at the same time by *Chandra* (from [6]).

3. Earth

Unlike Jupiter, where rotation has a dominant role, Earth's auroral activity appears to be driven by solar wind variability. Here the hard X-ray aurora is generated by energetic electron bremsstrahlung; at energies below ~2 keV O and N emission lines are seen superimposed to this continuum, but good resolution soft X-ray spectra are not available to establish if, and to what extent, ionic charge exchange may be occurring. Imaging by the *Chandra* High Resolution Camera shows the Earth's soft X-ray aurora to be very variable, with intense arcs and diffused patches, at times absent [7]. Modelling of the emission shows it to be consistent with bremsstrahlung and line emission following electron precipitation.

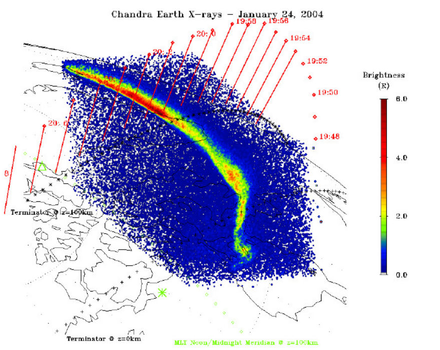

Figure 3: *Chandra* soft X-ray image of an auroral region on Earth, showing a bright arc of emission (from [7]).

4. Saturn

The lack of detection of X-ray aurorae on Saturn may be explained if they normally lie below the sensitivity threshold of current Earth-bound X-ray observatories [3]. This idea has been tested with *Chandra* very recently by attempting to search for Saturnian X-ray aurorae at a time when a solar wind enhancement is expected to have reached the planet.

5. Uranus and Neptune

X-ray aurorae are unlikely to be detectable from Uranus and Neptune with current and next generation X-ray observatories, by a simple scaling of the planetary parameters relevant to aurora production from those of Jupiter [3].

6. Summary and Conclusions

This presentation takes stock of the wealth of data and knowledge gathered in the last decade about X-ray emission from planetary aurorae. While studies in this high energy band are still considered a bit of a novelty by planetary scientists, the results so far demonstrate their potential in contributing a global view of the particle populations and their interactions in planetary magnetic environments. The next substantial step in advancing X-ray auroral research can only be realised with in-situ observations at the planets: that is when planetary X-ray astronomy will really come of age.

References

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