EPSC Abstracts
Vol. 6, EPSC-DPS2011-1251, 2011
EPSC-DPS Joint Meeting 2011

Searching for Saturn's X-ray aurorae: a novel strategy

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Abstract

After a decade of X-ray observations of Saturn, evidence for X-ray aurorae on the planet is still eluding us. In this presentation we describe a novel approach that we have adopted in searching for them. By analogy with Jupiter, we expect that Saturnian X-ray auroral emissions may originate from charge exchange of solar wind ions with the planet's atmospheric neutrals; the emission is expected to be brightest during episodes of enhanced solar wind. Our approach is to apply sophisticated codes that have been developed to propagate solar wind parameters measured near the Earth to the giant planets, and trigger X-ray observations at the time solar wind enhancements reach the planets. We have attempted this for Saturn in April-May 2011 with the *Chandra* X-ray Observatory, and here we report the results of these observations.

1. Introduction

Saturn's X-ray emission has been observed several times by *Chandra* and *XMM-Newton* over the years 2002 – 2005 [5], [1], [2], [3]. The X-ray spectrum of the planetary disk is well fitted by an optically thin coronal model with an average temperature of ~0.6 keV [3]. In addition, X-ray emission in the form of a fluorescent oxygen emission line at ~0.53 keV is detected from a 'hot spot' on the Eastern ansa of Saturn's rings [2] (see Fig. 1).

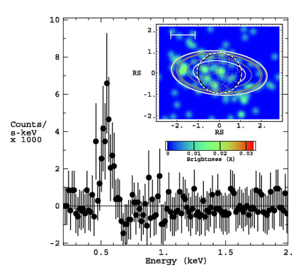

Figure 1. *Chandra* X-ray image (inset) and spectrum of the emission from the rings of Saturn (from [2]).

The disk coronal component is generally interpreted as emission produced by the scattering of solar X-rays in Saturn's upper atmosphere, which implies that the disk emission is directly controlled by the Sun (see Fig. 2).

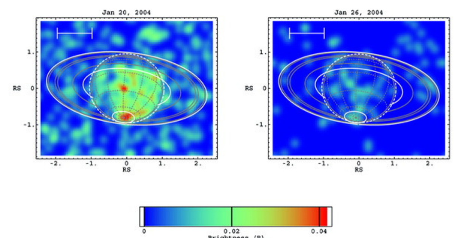

Figure 2. *Chandra* X-ray images of Saturn (from [1]). The disk emission is bright during the first observation (when an X-ray flare took place on the Sun) and much dimmer a week later.

The strength of the disk X-ray emission is seen to decrease over the period 2002 – 2005, following the decay of solar activity [3] towards the extended minimum in the solar cycle from which the Sun is now emerging. The oxygen line from the rings has also been interpreted as due to scattering of solar X-rays, in this case by the icy water particles that are thought to make up the rings [2]. However, by comparing the relative strengths of the disk emission and the oxygen line it appears that the disk flux does not vary over the years as the line flux does. An alternative possibility for the origin of the X-ray line relates to electron beams injected by Saturnian thunderstorms, which may excite the ring particles, subsequently producing the fluorescent oxygen line [3]. In addition to all this, there is the expectation that, similarly to Jupiter's case, Saturn may exhibit auroral X-ray emissions, due to the charge exchange process between solar wind ions and the neutrals in the planet's atmosphere. X-ray aurorae may have gone undetected so far if they generally lay below the sensitivity threshold of current Earth-bound X-ray observatories. However, by choosing to observe at a time when enhancements in the solar wind reach Saturn we would maximise the opportunity to detect them. The validity of this approach has been demonstrated [6] in the particular case of the propagation of a series of CMEs to Jupiter and then to Saturn, in Nov. – Dec. 2000, at a time when both planets were practically aligned with the Earth. The shocks associated with the CMEs took about a month to reach Saturn, where they are thought to have been responsible for a very unusual auroral FUV display. We have adopted this same approach, as described in the next section.

2. A novel observing strategy

Following an extended solar minimum, the Sun has now started to become more active, and has showed significant Earth-bound Coronal Mass Ejections and >C flares in mid Feb. and March 2011. We have used the mSWiM code [7], [8] to predict the solar wind propagation from Earth to Saturn, using OmniWeb data. The code uses solar wind parameters at Earth going back several months, so that their cumulative effects are taken into account, and predicts their values at later times on arrival at Saturn. Predictions are most accurate (+/– 10-15 hours) for times within +/–75 days of the planet's opposition, one of which occurred for Saturn on 4 April 2011. Charge exchange X-ray emission depends on solar wind density x speed [4]; the mSWiM code predicted that a strong solar wind enhancement in terms of these parameters would arrive at Saturn right at the end of April – beginning of May 2011; this was deemed as a good case for triggering Target of Opportunity observations with *Chandra*. Two observations of 80 ks each were carried out starting on 30 April, 05:48 UT, and on 2 May, 08:30. The planet was clearly detected on both occasions, and significant variability is found to have occurred between the two datasets. This presentation will report on the results of the on-going data analysis, including simultaneous radio and solar wind measurements in situ by the *Cassini* spacecraft.

6. Summary and Conclusions

We present the results of a novel strategy in the search for Saturn's X-ray aurorae, which involves propagating solar wind data from near Earth to the planet in order to identify periods of enhanced solar wind reaching it. Because charge exchange emission, known to be responsible for Jupiter's X-ray aurorae, depends on speed and density of the solar wind at the planet, we have used dedicated software to establish that an enhancement in solar wind properties reached Saturn around the end of April 2011, and then we triggered Target of Opportunity observations with the *Chandra* X-ray Observatory. This presentation reports on the results of our investigation.

Acknowledgements

We would like to thank Scott Wolk of the *Chandra* X-ray Center for his expert help with setting up the observations, and Deb Baker of the Mullard Space Science Laboratory for the real-time information she provided about Coronal Mass Ejections and solar activity phenomena.

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