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Space Weather Prediction in the Solar System

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Abstract

Space weather phenomena at the Earth or other planets are caused by activities on the solar surface. These are accompanied by intensified Lyman alpha radiation which can be used to monitor active solar regions even when they move behind the Sun as seen from Earth. Using the Lyman alpha mapper SWAN on SOHO one can follow the development of these active regions and thereby predict their state long before they re-appear around the limb of the Sun. This information can be used to prepare for possible adverse effects on infrastructures up to 15 days before the solar wind particles start interacting with the near-Earth environment. In a similar way the space weather situation can be predicted for the environment around other planets in the Solar system.

1. Introduction

Since 1989 the Solar Heliospheric Observatory SOHO [1] was designed and realized in cooperation between ESA, NASA and research institutes of many countries. In cooperation between the French Service d'Aeronomie in Paris (SA) and the Finnish Meteorological Institute in Helsinki the Solar Wind ANisotropy monitor SWAN [2] was designed and built. Principle Investigator was Jean-Loup Bertaux, SA. The French team was responsible for the detectors, integration and testing of the instrument, the Finnish side as cooperation between VTT Espoo, VTT Oulu, FMI Helsinki and several Finish companies designed and built the electronics, the flight software and the ground segment.

Since the launch on December 6, 1995, SOHO and SWAN are nearly continuously operational up to now, generating a completely new understanding of the Sun. SWAN was designed to map the solar wind intensity and velocity distribution in the solar system as a function of the solar activity. Using interstellar hydrogen atoms passing through the solar system as tracers, the solar Lyman alpha photons scattered by them into the SWAN detector are an indirect measure of the solar wind protons. Any collision between the protons and these hydrogen atoms makes scattering of Lyman alpha photons impossible. Soon it was discovered that the solar Lyman alpha radiation varied significantly with the solar activities. Active regions were accompanied by intensified UV radiation, resulting in an increase of scattered photons detected by SWAN, even if the active regions themselves were not visible from Earth or SOHO. Removing other influences like UV stars and solar wind anisotropies, a full sky distribution of Lyman alpha radiation could be derived. [3] This process was automated and provides now every day a UV flux distribution map of the solar system as seen from the vantage point at the Lagrange Point 1 at roughly 1 AU.

2. UV-flux in the vicinity of planets

The following table shows an example of the monitoring of interaction between the Sun and the planets the SWAN instrument is providing. For each direction towards a planet location at a given day the solar Ly_{α} flux is calculated from the SWAN full-sky UV distribution maps. The values are normalized for the distance of 1 AU from the sun. To get the actual UV flux at the planets the given values have to be scaled by the square of their distance from the Sun in AU.

Table 1: Lyman alpha flux at the planets
Observation: 2012-08-22

Planet	Ly alpha (photons/cm^2/sec)
Mercury	4.284e+11
Venus	4.175e+11
Earth	4.275e+11
Mars	4.609e+11
Jupiter	4.056e+11
Saturn	4.609e+11
Uranus	3.854e+11
Neptune	4.000e+11
Pluto	4.455e+11

These tables are calculated once per day since January 1996 and are accessible through the web-site http://swan.projet.latmos.ipsl.fr/ via the menu link “Solar Ly-alpha flux for planets at 1 AU”

3. Space weather forecast

Dividing the full sky map of the UV radiation into two halves with one representing the area behind the Sun, the other centered on the direction towards Earth, one can easily predict the development of space weather relevant areas by comparing subsequent daily images.

The high intensity of the far-side picture on the left seen in figure 1 corresponds to the high kp-values in the beginning of March. Figure 2 for March 31 shows the same intensity peak in the right image approaching the direction towards Earth. As the Sun is rotating from the left to the right in these images each 30° longitude line corresponds to roughly 2.5 days. The direction marked by a cross in the right hand picture points directly toward Earth. Roughly 3 days later one should expect an increase of auroral activity. And in fact there was a strong kp peak in the early morning hours of April 4 associated with active auroras in Northern Lapland.

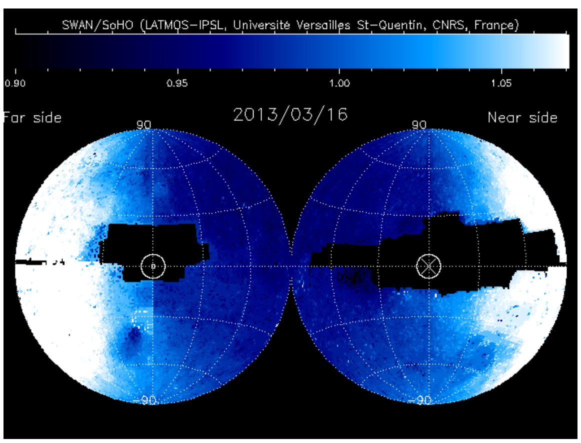

Figure 1: UV intensity distribution mid of March.

The daily images can be downloaded from the left column on the web page page http://swan.projet.latmos.ipsl.fr/images

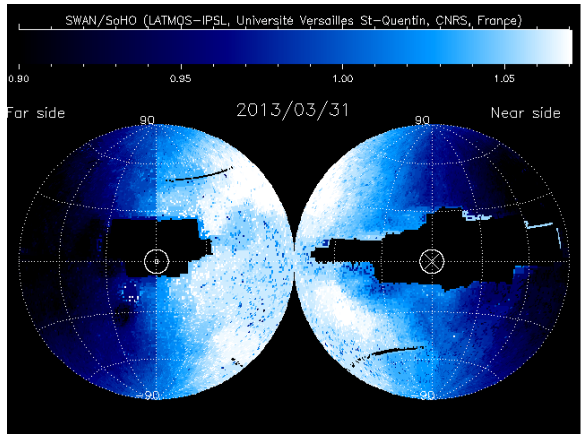

Figure 2: UV intensity distribution end of March.

Acknowledgements

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References

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