



SUBSTORMS OBSERVATIONS DURING GEOMAGNETIC ACTIVE PERIOD AT THE BEGINNING OF MARCH 2012

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Abstract. The period 7-17 March 2012 is one of the most geomagnetically active periods during the ascending phase of Solar Cycle 24. Magnetic storms occurred on 7, 9, 12, and 15 March, these are called the S1, S2, S3, and S4 events. These storms were caused by Sheath, MC and HSS, the detailed scenario for all four storms were different. Measurements of the Multiscale Aurora Imaging Network (MAIN) in Apatity and data of IMAGE magnetometers network have been used to verify the substorms onset and subsequent development. Substorms during the chain of 4 geomagnetic storms in the interval 7-17.03.2012 were studied and the characteristics of these substorms were compared to different interplanetary conditions. It was shown that substorms, originated during strong geomagnetic storms provoked by interplanetary shocks and magnetic clouds, near the Dst minimum, occurred to the South of Apatity, and substorm auroras expanded in North direction. For substorms during the late recovery phase, auroras were observed to the North of the Apatity station, and their motion from North to South was registered.

Introduction

Events of strong geomagnetic activity are of special interest because magnetic storms can affect the energetic systems, the space crafts or the ground based systems. That's why coordinated actions of the scientific community are needed to perform and gather observations, to create models of the whole chain of phenomena from the Sun to the Earth in order to make successful predictions of space weather and to prevent failures in the technologic infrastructure by reason of strong geomagnetic storms [1].

It is known that the following types of solar wind mainly generate the geomagnetic storms: interplanetary CORONAL MASS EJECTIONS (ICME) including Sheath- region and body of ICME (magnetic cloud, MC) and Corotating Interaction Regions (CIR) (e.g. [2], [3]). CIR is a region of the interaction of a high-speed recurrent stream with the undisturbed solar wind. CIR is determined as a region with magnetic field and plasma compression [4]. During a solar maximum, most common are the sporadic flows associated with coronal mass ejections (CME) [5]. Near the Earth they are observed as magnetic clouds (MC) (e.g. [6]). MC are characterized as regions, where the magnetic field strength is higher than the average, the density is relatively low, and the magnetic pressure strongly exceeds the ion thermal pressure, the magnetic field direction changes through the cloud by rotating parallel to a plane which is highly inclined with respect to the ecliptic [6]. Ahead of MC, a region of interaction with undisturbed solar wind (Sheath) is known to form, which is characterized by high density, increased pressure and strong IMF variability. It should be noted that there are differences between storms generated by Sheath, MC and CIR (in intensity, recovery phase duration, etc.) (e.g., [7], [8]; [9]).

However there are more complicated storm cases, when the magnetic storms are caused by several sources in the solar wind, coming consecutively one after the other or partly overlapping. Such an example is the event of strong geomagnetic activity 7-17 March 2012, which is one of the most disturbed periods during the ascending phase of Solar Cycle 24. This active interval was examined and the detected features were described ([10], [11], [12]). During this period four consecutive magnetic storms occurred on 7, 9, 12, and 15 March. The peak intensities are ~ -98 nT, -148 nT, -67nT, -79nT, respectively. These storms were caused by Sheath, MC and HSS, and the detailed scenarios for the storms were different. Each individual storm was discussed in some detail in previous papers [10], [11].

In our work three storm events during the strong geomagnetic activity period 7-17 March 2012 were considered. We have measurements from the Multiscale Aurora Imaging Network (MAIN) in Apatity during the first, the second and the third storms of this period. Below two events of substorms observations during the first and the second storms of this geomagnetic activity period are presented.

Data

Measurements from the Multiscale Aurora Imaging Network (MAIN) in Apatity during the strongly disturbed period in March 2012 have been used. The all-sky cameras observational system has been built in Apatity since 2008. The cameras characteristics, their mutual situation and the measurement process are described in detail in [12]. Solar wind and interplanetary magnetic field parameters were taken from OMNI database (http://sdaweb.gsfc.nasa.gov/cdaweb/istp_public/).

Substorm presence was verified by ground-based data of IMAGE magnetometers network (using the meridional chain NUR-NAL). To study the substorm development data from the Apatity all-sky camera (images and keograms) and the Guppy F-044C (GC) camera with a field of view $\sim 67^\circ$ (keograms) were used.

Results

The time interval 7 – 17 March 2012 (11 days) is one of the first major geomagnetically active periods of the ascending phase of SC24. An overview of the interplanetary conditions during this examined period is presented in Fig. 1.

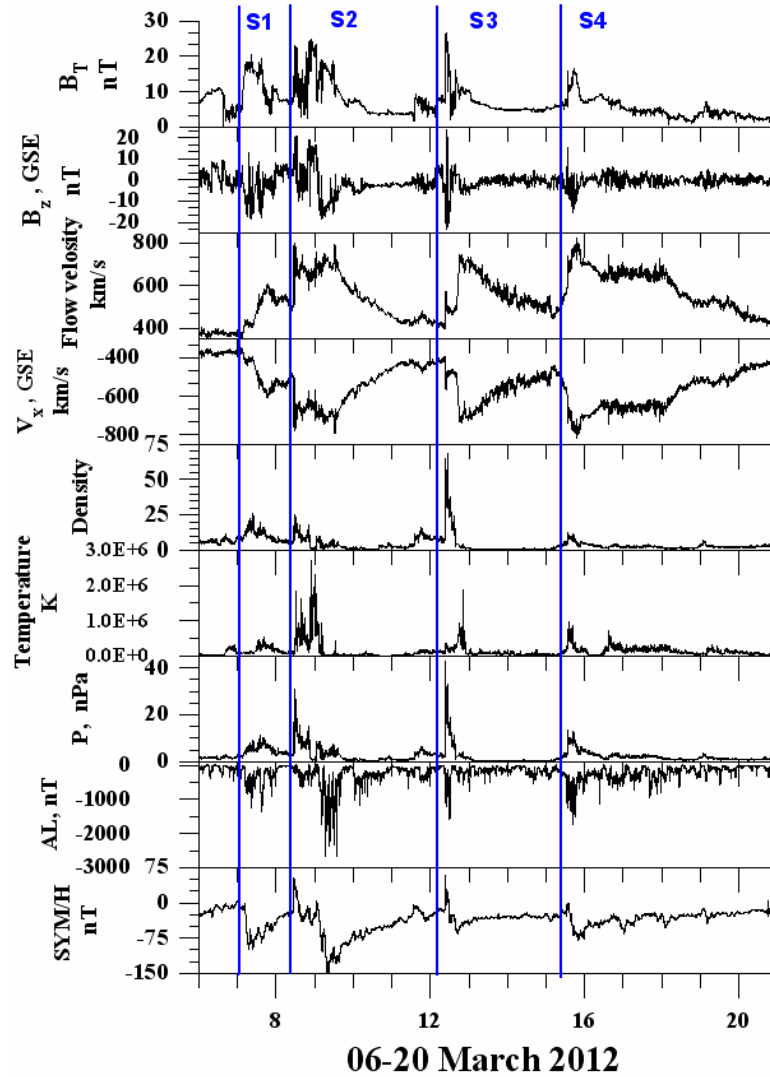


Figure 1. Solar wind and IMF parameters, AL and SYM/H indexes on March 7-20, 2012. Top-down: magnetic field magnitude and the IMF B_z component, the stream velocity V , the X component of the solar wind velocity, the density N , the temperature T , the solar wind dynamic pressure P , the geomagnetic index AL and the index SYM/H. The onset times of 4 events are marked by blue solid vertical lines and the symbols S1, S2, S3, S4, respectively.

It is seen, that magnetic storms occurred on 7, 9, 12, and 15 March, and the associated interplanetary events are called the S1, S2, S3, and S4 events. All storms are associated with high solar wind speeds and enhanced plasma densities and temperatures and interplanetary magnetic field strengths. All storms were initiated by different interplanetary causes (Sheath, MC and HSS). Below the first (S1) and the second (S2) storm events are considered, in relation with two substorm observations by the all-sky camera in Apatity as typical examples of substorm developments over Apatity.

The S1 storm was caused by the southward directed Sheath fields; the main phase of the storm starts at $\sim 02:00$ UT on 7 March and reaches a maximum at $\sim 05:15$ UT. The SYM-H peak intensity was ~ -98 nT. The S2 storm on 9 March had a different nature and a different interplanetary cause than the event S1. This storm was caused by the

southward directed magnetic field at the beginning of a solar wind magnetic cloud (MC). The storm reached a peak intensity of $SYM/H = -148$ nT at 07:58 UT on 9 March and had a more intense magnetic storm main phase.

7 March 2012

In Fig. 2 one substorm development during S1 storm was presented. The top panel shows selected images of the all-sky camera, the bottom panel shows keograms by all-sky camera (left) and by Guppy (GC) camera (right). The substorm was observed during the recovery phase of the S1 storm, near the maximal storm development. It is seen that substorm auroras appeared in the South part of the field of view in 18:45 UT. The auroras moved towards North, reached zenith in about 18:53 UT and after that auroras surpassed it.

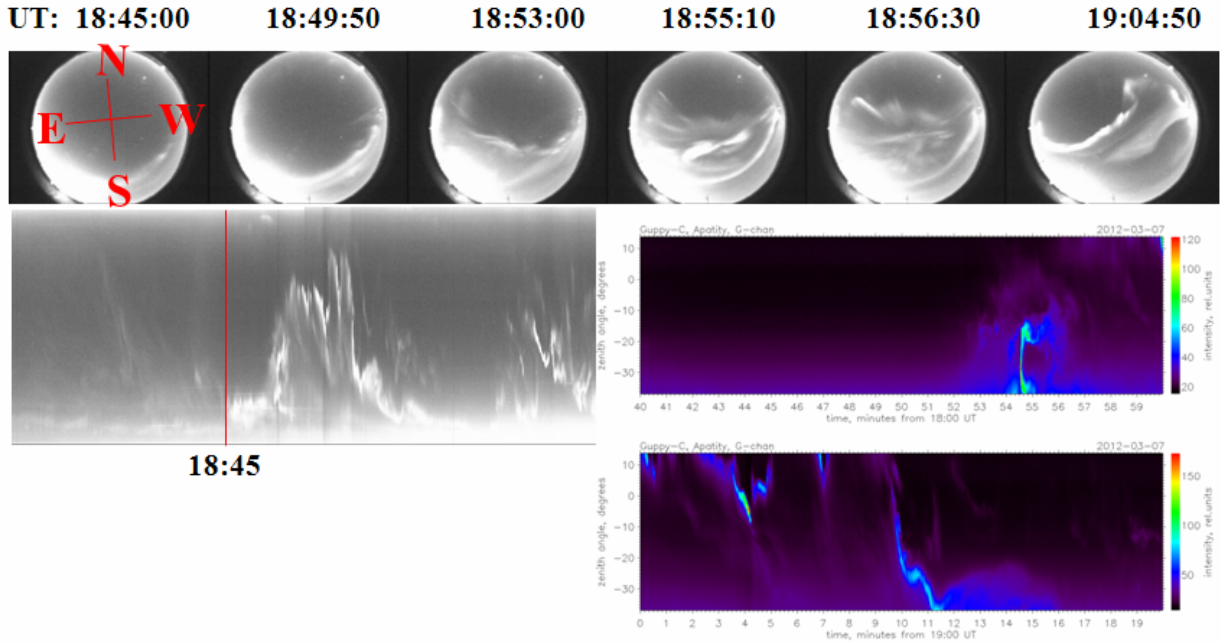


Figure 2. Development of the substorm on 7 March 2012 in 18:45:00 by chosen all-sky images (top panel), by all-sky keogram (left bottom panel) and Guppy (GC) camera keograms (right bottom panels).

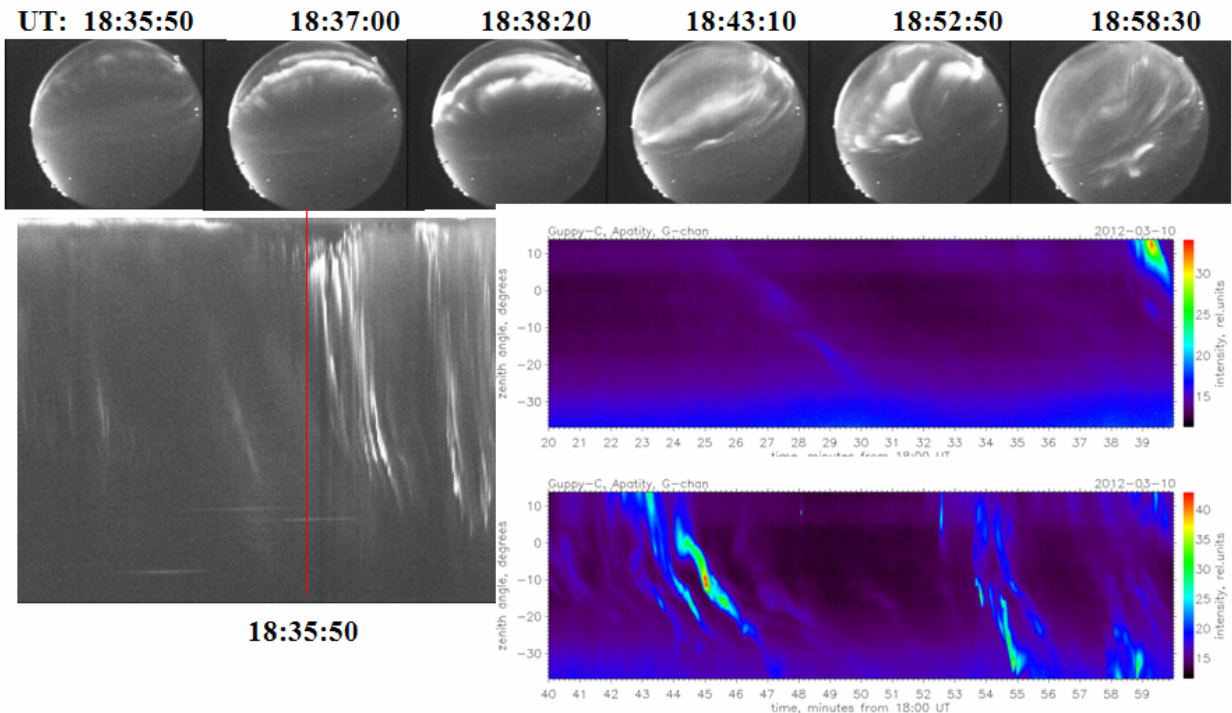


Figure 3. Development of the substorm on 10 March 2012 in 18:35:50 by chosen all-sky images (top panel), by all-sky keogram (left bottom panel) and Guppy (GC) camera keograms (right bottom panels).

10 March 2012

The substorm was observed during the second event of the period 7-17 March 2012, the S2 storm. This substorm occurred in the late recovery phase of the storm. The substorm development is presented in Fig. 3, where chosen all-sky images and all-sky and Guppy (GC) camera keograms are presented. The format of Fig. 3 is the same as in Fig. 2. The substorm onset in Apatity was in 18:35:50 UT on 10 March 2012 to the North of the station. It is seen that the auroras moved to South, reached zenith in 18:39 UT and moved further to South.

Conclusions

It is shown that:

1. Substorms, originated during the main storm phase or near the Dst minimum in the recovery phase, occurred to the South of Apatity, and substorm auroras expanded in North direction;
2. For substorms during the recovery phase or the late recovery phase, auroras were observed near the station zenith or to the North of the Apatity station, and their motion from North to South was registered.

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