

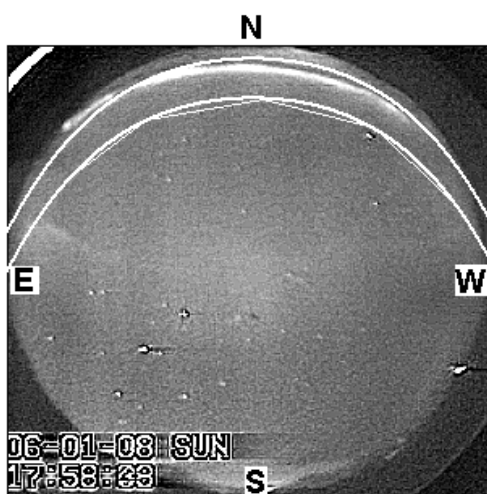
## NORTHERN AURORAL STRUCTURES BEFORE BREAKUP AND SOLAR WIND

I.A. Kornilov, T.A. Kornilova (*Polar Geophysical Institute, Apatity, Russia; kornilova@pgia.ru*)

**Abstract.** Rather bright auroral arcs usually appear at the northern horizon of TV imager field of view 30-40 minutes (substorm preliminary phase) before breakup development at the southern arc, and are projected to 20-30 Re in the tail (breakup arc projection is at 5-7 Re). Northern arc generates plasma fluxes and auroral structures moving eastward (so called BBFs and streamers), pumping inner magnetosphere by hot plasma, finally yielding a breakup development. Arc position (20-30 Re) is appropriate for magnetic reconnection, but northern arc development and luminosity variations definitely are not a breakup type explosive process. It should be also noted that if breakup is a result of explosive magnetic reconnection, there is a problem, how to stop this self-sustaining and all-sufficient process. We have measured integral arc luminosity variations (about 50 cases total), and compare them with solar wind parameters (magnetic field vector mostly) registered by ACE and WIND satellites with appropriate time shift (50-60 minutes). In many cases rather good correlation between arc luminosity variations and solar wind parameters were found. We can suppose that if northern auroral structures have magnetic reconnection nature, this reconnection is completely initiated and controlled by solar wind, and actually operates as some kind of converter, or transformer between external force (solar wind) energy, and energy of magnetospheric plasma.

### Introduction

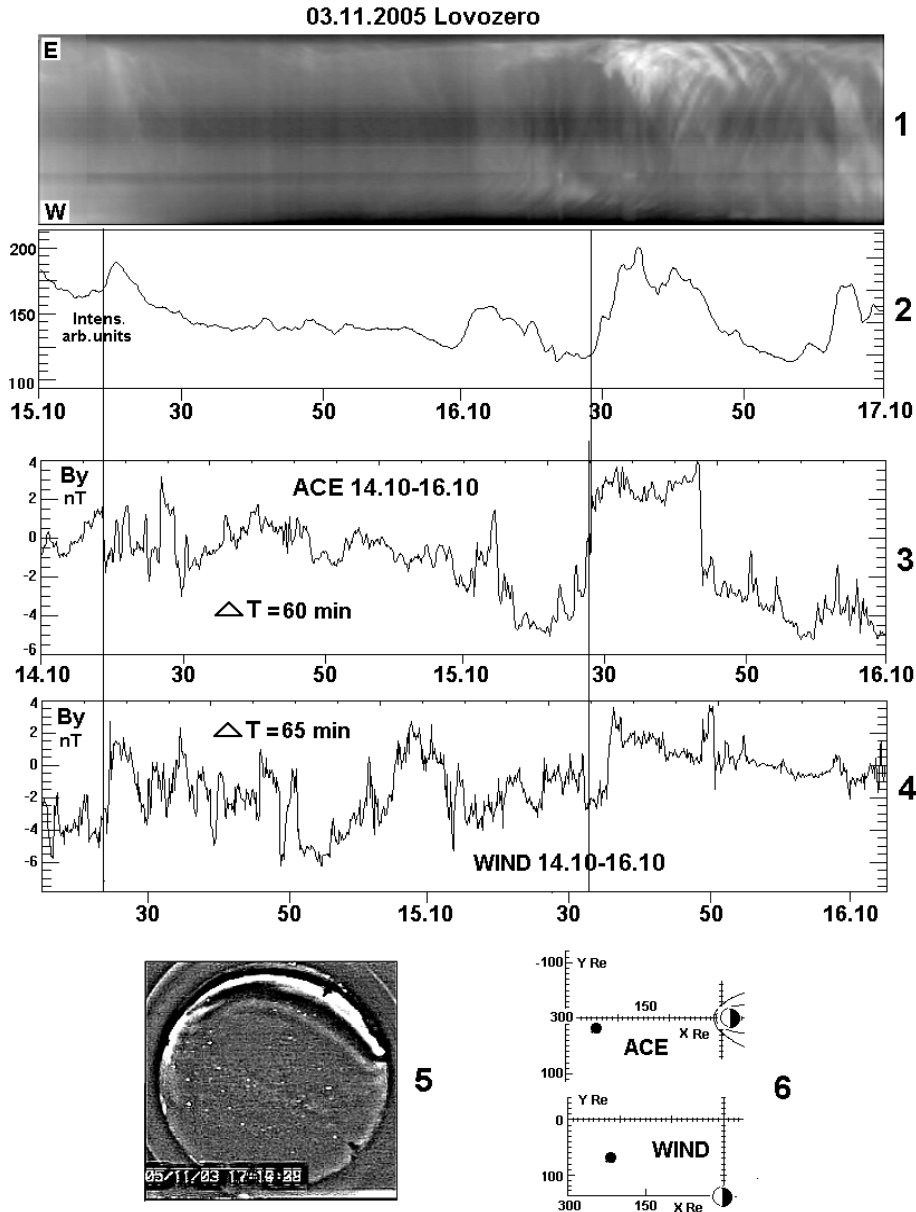
Study of different solar wind parameters interconnection with magnetospheric processes started in the very beginning of cosmic science, when the first satellites were launched, and solar wind and magnetospheric tail were discovered. These investigations are rather active and nowadays. Auroral oval size and configuration dynamics, ionospheric current variations, fine details of different period magnetic pulsations, global magnetospheric reaction on the sharp solar wind pressure pulses, changes in ionospheric convection, so on. [Boudouridis, 2004; Villante, 2004; Farrugia, 2007; Shue, 2009; Juusola, 2010; Boudouridis, 2011]. Important problem of modern geophysics is a magnetospheric breakup development. One of most popular conception of breakup is the model of explosive magnetic reconnection in the tail. But in compare with reconnection on the dayside magnetopause, where theory and experiment are in rather good agreement, night-side tail reconnection theory faces with two serious problems. First – it is difficult to explain extremely high speed of reconnection (all main, most energetic processes of breakup lasting couple minutes only). Second - how to stop this self-sustaining and all-sufficient process, in other words, why magnetospheric tail does not disappear at all [Akasofu, 2013]. In this paper we present some experimental results demonstrating that, like on the day-side, reconnection in the tail can also be driving by external force (solar wind). For this purpose we compare magnetic field variations measured by ACE and WIND satellites with northern auroral arc intensity variations.



**Figure 1.** Method of northern arc luminosity

### Experimental results

Fig. 1 demonstrates some details of northern arc luminosity variation measurements. In digital TV frame (240\*240 elements matrix) 6 key points are indicated by mouse cursor (for visual control they are connected by straight lines), and these six points are interpolated by four-degree polynomial. Resulting curve shifts along the frame 20-25 points northward, forming the area of integration. Frame elements are summarized cross this area along every matrix row, forming one-dimensional vector of arc luminosity in E-W detection, this procedure repeats for every frame of the time interval under study (usually 500-600 frames total), resulting 2-dimensional picture of arc luminosity temporal variations (keogram in E-W direction - Fig. 2 (1)). Rather broad integration area (usually 20-25 pixels) is useful in two aspects. First – strong noise reduction and significant dynamic range improving, second – arc can demonstrate some motion in N-S direction near northern horizon, and this fact will not change at all the result of arc luminosity integration. Summarization of all elements of every vertical keogram line (or, what is the same – integration of all frame elements inside the marked area, repeated for every frame) gives one-dimensional picture of arc integral luminosity variations (Fig. 2 (2)).

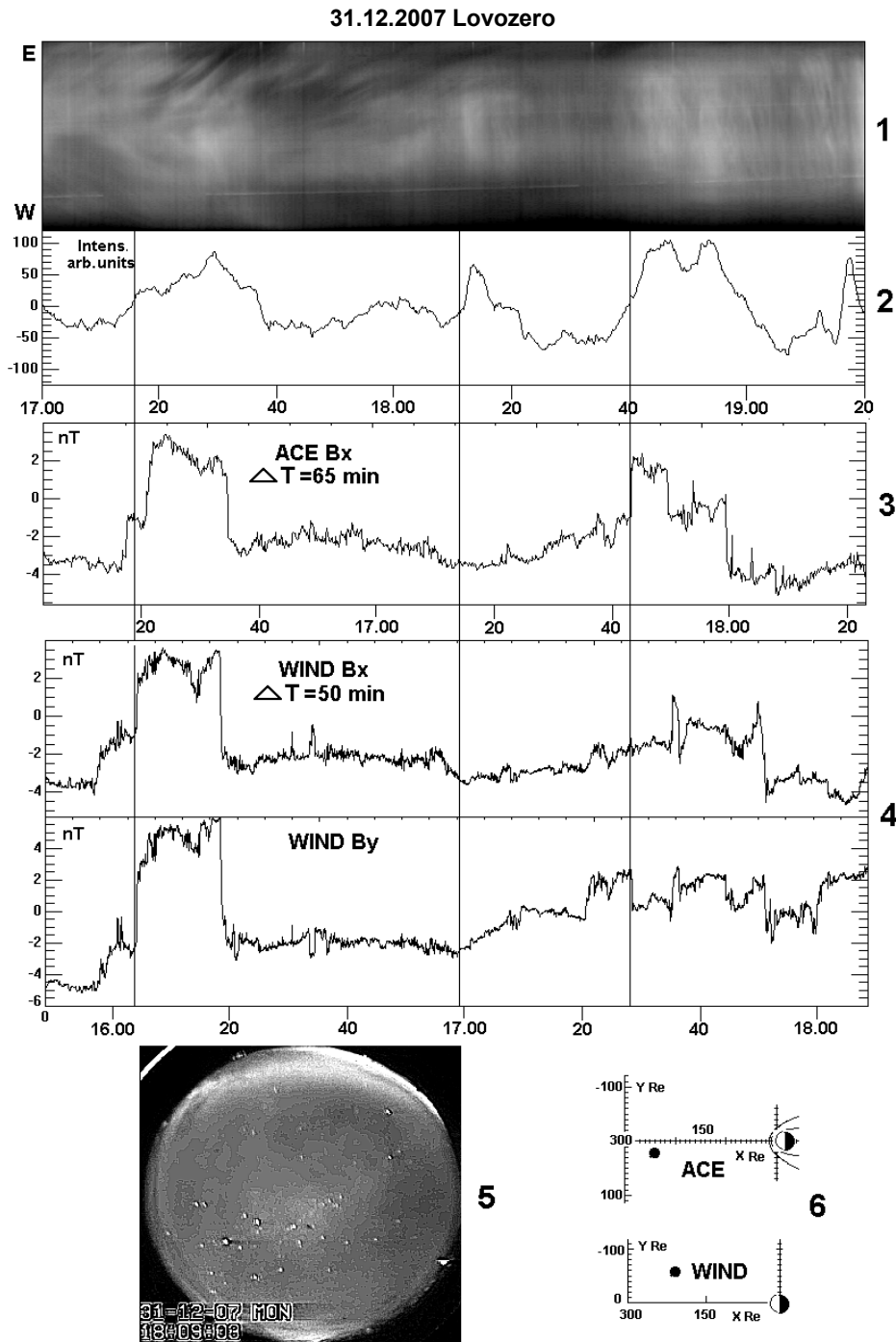


**Figure 2.** Auroral TV and solar wind magnetic data for 03.11.2005. Arc luminosity variations (1, 2),  $B_y$  – components of solar wind magnetic field (3, 4), TV frame example for this date (5) and satellites positions (6).

About 50 events total were analyzed on the base of Lovozero and Loparskaya TV data. For all data selected auroral structures were inside TV camera field of view (near the northern horizon). Two dates - 03.11.2005 and 31.12.2007 will be discussed in more detail.

Fig. 2 demonstrates E-W keogram of northern auroral arc luminosity variations (1), integral arc brightness (2), and  $B_y$  – components of solar wind magnetic field, measured by ACE and WIND. Northern arc position is shown at the bottom part of the picture (5). North is on the top, east on the left. For better revealing fine details frame is high-frequency filtered. WIND and ACE satellite positions are shown on (6). Semi-dark circle is the Earth. White part of it directed to the Sun, while dark part directed to the magnetospheric tail.

One can see obvious correlation (typical moments are marked by vertical lines) of solar wind magnetic field and northern arc luminosity variations. Satellite magnetic data shifted in time for about 60 minutes. This shift corresponds to the time of magnetic cloud irregularity motions from satellite position (250 Re) to the tail and arc projection on the tail borders (probably about  $-20$  Re). Time delay is in good agreement with direct measurement of solar wind speed by satellite detectors (about 480 km/s in this case). Somewhat surprising is the fact that time delay for WIND (65 min) is larger than for ACE (60 min) though WIND is closer to the Earth. But in E–W direction satellites are separated more than 60 Re, and comparison of satellite detected solar wind speed vectors reveals that solar wind moves not perpendicularly to magnetopause, but under some angle, and ACE detected it first.



**Figure 3.** Auroral TV and solar wind magnetic data for 31.12.2007. Arc luminosity variations (1, 2),  $B_y$  – components of solar wind magnetic field registered by ACE(3), WIND Bx and  $B_y$  components (4), TV frame example for this date (5) and satellites position (6).

The same data for 31.12.2007 are shown on Fig. 3. Good correlation of arc luminosity variations with solar wind magnetic field is quite visible as well, especially for the time interval of aurora activation about 17.15–17.40 UT. Correlation for 18.35–19.05 UT is rather good for satellite ACE, but not so good for WIND. Besides, aurora intensification at 18.05 UT (this moment marked by vertical line about 17.00 UT) is almost invisible in satellite data, though coincide with WIND  $B_y$  magnetic field component increasing. Obviously, all those details of correlation are because of the fact that magnetic field is measured locally, at the point of satellite position, but solar wind interaction with magnetosphere definitely has global integral character.

It is important that such correlation exists at all (as was mentioned earlier, objects are separated by ~ 2 million kilometers). It should be also noted, that though presented pictures do not conclude information about solar wind pressure variations (time resolution for these data is worse), magnetic field and pressure variations are usually in a very good correlation.

### Discussion

Data presented demonstrate obvious correlation between solar wind magnetic field variations and luminosity of the northern arc. Very probably, arc is an optical manifestation of magnetic reconnection process in the distant tail (possibly, about  $-20 R_e$ ). In this case we can conclude that reconnection is completely initiated and controlled by intensity of external force – namely, by solar wind magnetic field and pressure variations, and speed of reconnection is in direct correlation with intensity of this force. This approach allows us to avoid theoretical problems of explosive reconnection, and consider magnetospheric tail reconnection as a process converting, or transformation of solar wind energy into the energy of internal magnetospheric plasma.

**Acknowledgements.** The authors are grateful to PGI for TV auroral data, to CDAWeb site data providers N. Ness, A. Szabo and R. Lepping for ACE and WIND magnetic data. This work was supported by grant N 12-05-00273a of RBSR and by Programs 22II and 4II of the Russian Academy of Sciences.

### References

- Boudouridis A., Zesta E. et al. Magnetospheric reconnection driven by solar wind pressure fronts // *Annales Geophysicae*. 2004. V. 22. P.1367–1378.
- Villante U. and Giuseppe P. Some aspects of the geomagnetic response to solar wind pressure variations: a case study at low and middle latitudes // *Annales Geophysicae*. 2004. V. 22. P. 2053–2066.
- Farrugia C. J., Grocott A. The magnetosphere under weak solar wind forcing // *Annales Geophysicae*. 2007. V. 25. P.191–205.
- Juusola L., Andreeva K. et al. Effects of a solar wind dynamic pressure increase in the magnetosphere and in the ionosphere // *Ann. Geophys.* 2010. V. 28. P. 1945–1959.
- Shue J.-H., Kamide Y., and Gjerloev J. W. Effects of solar wind density on auroral electrojets and brightness under influence of substorms // *Ann. Geophys.* 2009. V. 27. P. 113–119.
- Akasofu S. I. The relationship between the magnetosphere and magnetospheric/auroral substorms // *Ann. Geophys.* 2013. V. 31. P. 387–394. doi:10.5194/angeo-31-387-2013.
- Boudouridis A. et al. Statistical study of the effect of solar wind dynamic pressure fronts on the dayside and nightside ionospheric convection.// *J. Geophys. Res.* 2011. V.16. A10233, doi 10.1029/2011JA16582.2011.