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Interactive comment on "Sporadic Aurora near Geomagnetic Equator: In the Philippines, on 27 October 1856" *by* Hisashi Hayakawa et al.

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Dear Dr. Tiera Laitinen,

We thank your consideration upon our manuscript. We found your comments are quite constructive and helpful. We will revise our manuscript according to your comments. We hope our revision should satisfy the criteria of publication in Annales Geophysicae.

As of the "white" colour of this phenomenon, as you suggested, we believe it is quite likely that the human eyes perceived auroral light as apparently whitish due to Purkinje Effect (Purkinje, 1825, p.109; Minnaert, 1993, p.133). Indeed, this phenomenon is described "a faint but weak white light on that horizon". Therefore, we can confirm that its brightness was "faint but weak". Accordingly, we will clarify in the new version of the

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Discussion paper

manuscript that the human eyes frequently perceive weak lights as apparently whitish, as they are insensitive to color with weak brightness.

We will also clarify that Figure 3 shows the timing of the sporadic aurora around 21:00-21:15 LT (12:56-13:11 UT) at Manila. It is roughly corresponding with the descending phase of the negative excursion in the magnetic observation at Helsinki up to 15:00 UT, considering that the differences of time zones between Manila (N14°35', E120°58'), Helsinki Observatory (N60°10âĂš, E24°57âĂš), and Greenwich are roughly 7.07h and 8.06h respectively, taking into consideration they are based on the local mean time (e.g. Nevanlinna, 2004, 2006).

We also thank your suggestion on the timing of negative excursion at Helsinki. We will add the following sentences. "The sporadic aurora occurred around 21:00-21:15 LT (12:56-13:11 UT) at Manila, which is roughly corresponding to the descending phase of this negative excursion at Helsinki, by considering that the differences of time zones between between Manila (N14°35', E120°58'), Helsinki observatory (N60°10âĂš, E24°57âĂš), and Greenwich are roughly 7.07h and 8.06h on the basis of local mean time (e.g. Nevanlinna, 2006, 2008)." We will also clarify that the negative excursion $\sim$140 nT is not categorized as an daily variation in the magnetic observations at Helsinki, especially in its local afternoon, while the negative excursion down to -140 nT is not related with a major geomagnetic storm. Then, it might be plausible that this negative excursion could be related to the interplanetary shock explained above and the peak of this effect may have been missed at Helsinki as it has only an hourly resolution, as the referee suggested.

We also thank your suggestion on the nature of the negative excursion of -140 nT. As you suggested, the peak effect of the interplanetary shock itself was not likely recorded here as because of its 1-hour resolution, but the nature of this magnetic excursion is indeed intriguing. We found similar variations in the magnetic field data from the Lovö observatory and added it into Figure 3. With the newly added data, we will add the following paragraph: "Figure 3c shows ΔH at the Lovö observatory on 17-21 January

2002. The variation of ΔH on 19 January 2002 resembles that observed on 27 October 1856 in terms of the negative excursion and subsequent variation. The negative excursion starts at ∼12 UT, and peaked at ∼16 UT on 19 January 2002. According to the OMNI solar wind data (King and Papitashvili, 2005), the negative excursion is associated with a southward turning of the interplanetary magnetic field (IMF) and a rapid increase in the solar wind dynamic pressure (data not shown). The sudden increase in the solar wind dynamic pressure resulted in the sudden increase in ΔH, which is visible in the one-minute resolution data at Lovö (dotted line in Figure 3c). The southward IMF continued until ∼15 UT, which could result in the intensification of the ring current, and the negative variation of ΔH. ΔH is highly fluctuating throughout this period, which is caused by fluctuations of the solar wind and IMF. The solar wind speed and density increased gradually, starting at ∼05 UT on 19 January 2002, and the strength of IMF peaked at ∼9 UT on 19 January 2002. These characteristics may correspond to a corotating interaction region (CIR) (Denton et al., 2006). The Dst index did not reach −30 nT on 19-20 January 2002. The amplitude of the negative excursion (∼140nT) observed in 1856 is roughly 5 times larger than that observed in 2002 (∼-30nT). This might indicate that the IMF Bz and/or solar wind velocity in 1856 was larger than those in 2002." We also clarified "the magnetic disturbance associated with an interplanetary shock lasts for just a few minutes ∼ a few tens of minutes depending on solar wind dynamic pressure (Araki et al., 2004) and orientation angle of the shock front (Takeuchi et al., 2002)" in the discussion of shock wave hypothesis too.

As of the Figure 3, we consider that typical precision of a magnetometer in the second half of the 19th century is around 1' (e.g. Batlló, 2005) and may have caused apparently larger pseudo-random variations than those in the modern time.

The report does not necessarily provide us enough information. However, Llanos describes "At this moment [at 9 o'clock at night], observing the cloudscape of the atmosphere, I noticed on the NW side, with a short difference there was a faint but weak white light on that horizon...". This means there have been breaks of cloud in the

NW. Moreover, in his early part (before the description of this “sporadic aurora”), he described “SW, it was getting worse, as well as the rain” (Llanos, 1856, p.223). Therefore, it is considered the rain was coming from SW and the sky in NW and later NE should have been relatively free from the rain.

Of course, we will correct Lovo to Lovö as it is much more appropriate to spell the place name in their original language.

We will also correct the numbering of sections accordingly.

Thank you very much for your consideration on our manuscript. We hope our revision should satisfy the criteria of publication in Annales Geophysicae.

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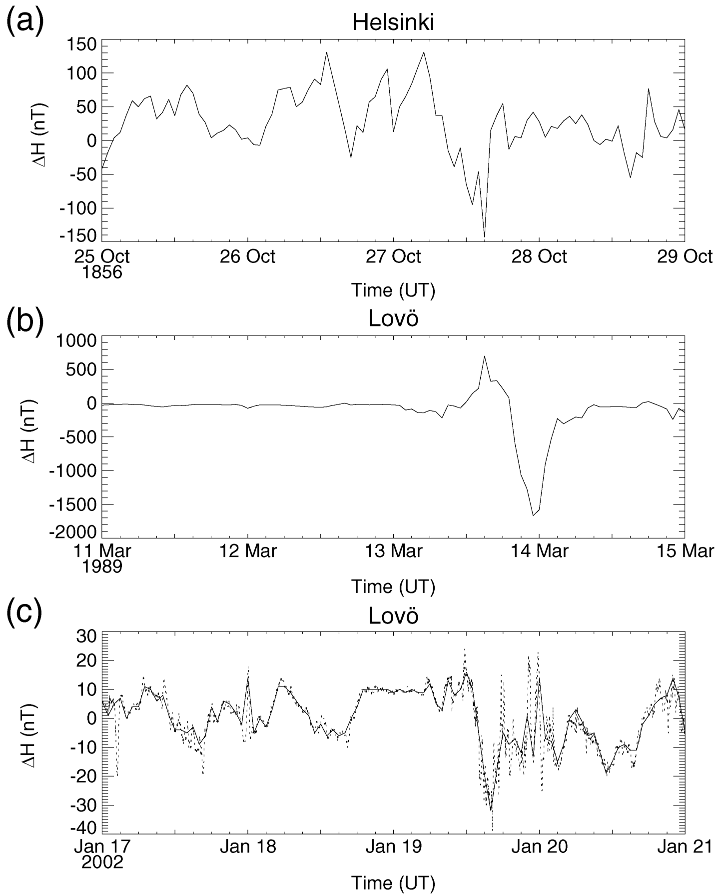

Fig. 1. Additional Figure 3c