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Interactive comment on "An Early Low Latitude Aurora Observed by Rozier (Beziers, 1780)" *by* Chiara Bertolin et al.

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Dear Editor, The authors want to thank the reviewers for their work on the submitted paper. In the following, specific answers to the comments are reported and all changes in the new revised manuscript are highlighted in yellow.

Reviewer #1: R1: I have carefully read the paper titled "An Early Low Latitude Aurora Observed by Rozier (Beziers, 1780)". The authors present a suspected aurora observed by Francois Rozier on 15 August 1780 in Beauséjour, close to Beziers (at MLAT= 50.18 N, according to the authors). It should be noted that the observation was made under adverse weather conditions (presence of a lightning storm). In section 4, the authors indicates that at the same time an aurora was also observed at Ratisbon

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Discussion paper

(Germany, 49 N), 5.5 further north than Beziers, and recorded in Angot's catalogue (Angot, 1897). If this article is selected for publication, I suggest some revisions to the manuscript and other small suggestions before it can be published in ANGEO.

A: Many thanks for your detailed review. We have taken into account all your suggestions and the manuscript has improved a lot.

R1: 1 Background and Introduction Line 20: For the physical mechanism of the aurora origin, (Vazquez et al. 2014) is not the appropriate reference (see e.g., Brekke, 2013, Physics of the Upper Polar Atmosphere, 2nd edn. Springer, Heidelberg).

A: We agree with the referee, We have deleted the cite of Vazquez et al. 2014 and included two more appropriate cites i.e. Brekke 2013 and Gonzalez et al., 1994.

Brekke, A.: Physics of the Upper Polar Atmosphere, 2nd Ed., (Springer) 2013.

Gonzalez, W. D., Joselyn, J. A, Kamide, Y., Kroehl, H. W., Rosoker, G., Tsuruani ,B. T. and Vasyliuna, V. M.: What is a geomagnetic storm?, J. Geophys. Res., 99, 5771-5792, doi.org/10.1029/93JA02867, 1994.

R1: Lines 25-26: The three articles cited relate to the Carrington event. It is interesting to point out other exceptional events, such as that of 1921 (Silverman, S.M., Cliver, E.W.: 2001, J. Atmos. Solar-Terr. Phys. 63, 523), as well as that which occurred in 1770 (Hayakawa, H., et al.: 2017, Astrophys. J. Lett. 850, L31).

A: We have included the events proposed by the referee and other important and well-studied events. Moreover we have updated some references of the Carrigton storm in accordance with referee 2. "This was the case of well studied extreme space weather events as those occurred on September 1770 (Hayakawa et al. 2017a); the Carrington event in August/September 1859 (Green and Boardsen, 2006; Green et al., 2006; Humble 2006; Tsurutani et al., 2003; Cliver and Dietrich, 2013; Hayakawa et al., 2019a); the storm on 1872 February (Hayakawa et al. 2018; Silverman, 2008); the extreme event on September 1909 (Hayakawa et al., 2019b); May 1921 (Hapgood,

2019; Silverman and Cliver, 2001; Love et al., 2019) or March 1989 (Allen et al., 1989) resulting in extreme magnetic disturbances and auroral displays at very low latitudes .".

Hayakawa H., Tamazawa H., Ebihara Y., Miyahara H., Kawamura A. D., Aoyama T. and Isobe H.: Records of sunspots and aurora candidates in the Chinese official histories of the Yuán and Míng dynasties during 1261–1644, Publ. Astron. Soc. Jpn 69, 65, doi: 10.1093/pasj/psx045, 2017a.

Green, J. L. and Boardsen, S.A.: Duration and extent of the great auroral storm of 1859, Adv. Space Res. 38, 130–135, 10.1016/j.asr.2005.08.054, 2006.

Green, J.L., Boardsen, S. A, Odenwald, S., Humble, J. and Pazamickas, K.A.: Eyewitness reports of the great auroral storm of 1859, Adv.Space Res. 38-2, 145-154, doi.org/10.1016/j.asr.2005.12.021, 2006.

Humble, J.: The solar events of August/September 1859 – Surviving Australian observations, Adv. Space Res. 38, 155–158, 10.1016/j.asr.2005.08.053, 2006.

Tsurutani B. T., Gonzalez W. D., Lakhina G. S., Alex S. (2003) The extreme magnetic storm of 1–2 September 1859, J. Geophys. Res., 108, 1268, doi:10.1029/2002JA009504.

Cliver, E. W. and Dietrich, W. F.: The 1859 space weather event revisited: limits of extreme activity, J. Space Weather Space Clim. 3, A31, doi: 10.1051/swsc/2013053, 2013.

Hayakawa, H., Ebihara, Y., Willis, D.M., Toriumi, S., Iju, T., Hattori, K., Wild, M. N., Oliveira, D. M., Ermolli, I., Ribeiro, J. R., Correia, A.P., Ribeiro, A. I. and Knipp, D. J: Temporal and Spatial Evolutions of a Large Sunspot Group and Great Auroral Storms Around the Carrington Event in 1859, Avd. Space Res, 17, 1553–1569. https://doi.org/10.1029/ 2019SW002269, 2019a.

Hayakawa, H., Ebihara, Y., Cliver, E. W., Hattori, K., Toriumi, S., Love, J. J., Umemura, N., Namekata, K., Sakaue, T., Takahashi, T., and Shibata, K.: The extreme space

weather event in September 1909. Monthly Notices of the Royal Astronomical Society, 484, 3, 4083-4099. DOI: 10.1093/mnras/sty3196, 2019b.

Hapgood, M.: The Great Storm of May 1921: An Exemplar of a Dangerous Space Weather Event, Adv. Space Res., 17, 950–975. https://doi.org/10.1029/2019SW002195, 2019

Love, J. J., Hayakawa, H. and Clive, E. W.: Intensity and Impact of the New York Railroad Superstorm of May 1921, Avd. Space Res, 17, 1281–1292. doi.org/10.1029/2019SW002250, 2019.

Silverman, S.M. and Cliver, E.W.: Low-latitude auroras: the magnetic storm of 14 –15 May 1921, J. Atmos. Sol-Terr. Phys. 63, 523–535, doi.org/10.1016/S1364-6826(00)00174-7, 2001

Allen, J., Frank, L., Sauer, H. and Reiff, P.: Effects of the March 1989 Solar Activity, EOS, 70, 1479-1488. doi: 10.1029/89EO004090, 1989.

R1 Line 26: About LLA, the authors state that "and have been considered a proxy of solar activity". This needs to be correctly documented. Overall, I think that this section needs to be improved and expanded with more background information.

A: We have rewritten and expanded the Background and Introduction section including an important amount of references to clarify some aspects. About the use of aurora night as a proxy we have included: “Low and mid latitude auroras nights show an association with solar activity indices as sunspot records. This link has been observed during the telescopic era (Silverman, 1992; Lockwood and Barnard, 2015; Lockwood et al., 2016) but also in pre-telescopic era from the comparison with naked-eye sunspot reports (Hayakawa et al. 2017a; Bekli and Chadou, 2019). This relationship is due mainly to the highest frequency of LMLAs during the maximum and the decaying phase of the solar cycle (Gonzalez et al., 1994). Therefore, the mid-latitude aurorae, being footprints of solar CMEs, can be considered as proxies for the long-term solar activity.

Nevertheless, LMLAs sometimes occurred in periods of low solar activity (Silverman 2003; Willis et al. 2007; Vaquero et al., 2007 and 2013; Garcia and Dryer, 1987 and Hayakawa et al., 2020). These auroras are called “sporadic auroras””.

2 Methodology 2.1. The Observer

R1: The subsection (2.1), which is a biography of F. Rozier, is unnecessary and the text should be reduced considerably.

A: The text has been shortened a 25%.

R1: Lines 35-39: please refer to reliable sources for accurate information and remove the links.

A: A new reference: Gutton, J.P. and Bonnet, J. C., Guton J. P. (Ed): Les Lyonnaises dans l’Histoire, Privat, 1991 has been added and the links eliminated as required.

2.2. The Documentary Source and the Observation description

R1 : Lines 65-66: The book’s title should be rectified as follow: Observations sur la physique, sur l’histoire naturelle et sur les arts, avec des planches en taille-douce

A: The title has been amended ad indicated.

R1 : Lines 66-67: The subtitle should be rectified as follow: Observation sur une Nuée rendue phosphorique par une surabondance de l’électricité, vue de Beauséjour près de Beziers, le 15 Août

A: The subtitle has been modified as required.

R1: Lines 82-83: bad translation: The sentence "avant-coureurs de l’orage" means "before the storm" not "before it was orange colored"

A: The translation has been amended

R1: Line 93: The sentence "l’orage s’éloigna de Beziers" means "the storm moved away from Beziers”, not "the orange moved away from Beziers"

A: The translation has been amended

R1: Line 101: why the author uses the term "explosion"?

A: The literary translation for Âń il n'y eut point d'explosion Âż is Âń there was no explosion". It can be also interpreted as "there was no thunder" but in those cases Rozier utilized other terms as "tonnerre".

R1: Page 2: Footnote 1: The reference must be written correctly as indicated in "Manuscript preparation guidelines for authors" of ANGEO (Publisher, Location: : :). Also, please indicate the relevant pages.

A: The footnote has been removed and the reference has been added to the reference list.

3 Analysis

R1: of the Observation Line 105: Please specify how you obtained the two values of solar depression angle (13 and 14.9).

A: The paragraph has been updated and the calculation carefully checked with the HORIZONS NASA web interface that has been quoted in the text as follows: The calculation of the solar depression angle for the geographical coordinates in Béziers and the day of the observation has been performed using the HORIZONS Web-interface of the American National Aeronautics and Space Administration (NASA) (https://ssd.jpl.nasa.gov/horizons.cgi?s_type=1#top).

R1: Lines 113-121: Color: as I said before, the orange color is not specified by the author. Therefore, this paragraph must be corrected.

A: The quote to the orange color has been cancelled and the section has been modified accordingly.

R1: Lines 133-134: There is no exact definition of the low latitude, but for me the present event must be classified as a mid-latitude aurora!

A: There is no exact definition where that boundary lies, but we agree with the referee about it is more accurate to consider the Rozier aurora as mid latitude. We have changing the text accordingly.

4 Discussion

R1: Lines 138 and 140: (Angot, 1897) not (Angot, 1896)

A: The reference has been amended: Angot A.: The Aurora Borealis, (D. Appleton & Co) 326 pp, 1897.

R1: Lines 157-160: A similar phase opposition and anti-correlation between auroral occurrence and sunspot were reported by some authors. It is an important point which must be well documented (see e.g., Silverman, S.M., 1992, Secular variation of the aurora for the past 500 Years, Rev. Geophys. 30, 333–351).

A: We have included this anticorrelation between auroral night and sunspot in the background section: “Low and mid latitude auroras nights show an association with solar activity indices as sunspot records. This link has been observed during the telescopic era (Silverman, 1992; Lockwood and Barnard, 2015; Lockwood et al., 2016) but also in pre-telescopic era from the comparison with naked-eye sunspot reports (Hayakawa et al. 2017a; Bekli and Chadou, 2019). This relationship is due mainly to the highest frequency of LMLAs during the maximum and the decaying phase of the solar cycle (Gonzalez et al., 1994). Therefore, the mid-latitude aurorae, being footprints of solar CMEs, can be considered as proxies for the long-term solar activity. Nevertheless, LMLAs sometimes occurred in periods of low solar activity (Silverman 2003; Willis et al. 2007; Vaquero et al., 2007 and 2013; Garcia and Dryer, 1987 and Hayakawa et al., 2020). These auroras are called “sporadic auroras””.

Moreover we have modify this paragraph also the paragraph commented by the referee:

“Figure 3 shows the sunspot number during the period 1766-1800. Rozier’s observa-

tion was in the declining phase of the solar cycle 3, 2-years after the maximum. This is a good moment to see LMAA because long-lived coronal holes - source of high ionized particles in the solar wind - occur more frequently in the declining phase of the sunspot cycle (Verbanac et al., 2011; Lefèvre et al., 2016). It is important to note that the Rozier's observation occurred in a period with few sunspot records. As we can see in Figure 4 the solar observations during the 1780's are rare, frequently below the 30 observations per year. For this reason, any contribution to the knowledge of the geomagnetic activity in this period is very beneficial".

R1: Overall, a more extended state of the art is needed. Some articles relating to the present work should be viewed and cited (e.g., Ordaz, J., 2010, Auroras boreales observadas en la Península Ibérica, Baleares y Canarias durante el siglo XVIII, Treb. Mus. Geol. Barcelona 17, 45-110; Legrand, J. P., & Simon, P. A., 1987, Two hundred years of auroral activity (1780-1979), AnGeo 5, 161-167; : : :)

A: The state of the art has been improved reorganizing and expanding the Background and introduction section. Both references have been included in the new version of the section.

Conclusions

R1: I think the conclusion is too short and it does not summarize the work in sufficient detail.

A: The conclusions have been rewritten as follows: "We have found a record of an atmospheric phenomenon observed on 15 August 1780 in Beausejour, close to Béziers (43° 19âĂš N, 3° 13âĂš E), France, by the abbot Francois Rozier described as a "big white cloud ... whitish color of phosphorus burning in the open air". Rozier was not an astronomer and it is clear that he did not fully understand the phenomenon he was recording. Probably for this reason he recorded the event with minute details to later discuss it with other academicians of his time. Thanks to this accuracy, we have been able to analyse quantitative information and facts that contribute to confirm that

Francois Rozier observed a Mid latitude aurora that night. The aurora was observed during the nautical and astronomical twilight, it was white, enough brilliant to not be overshined by the full moon which however was above the horizon in ESE direction. It showed two bands and some rays which could fit with the class of auroral forms of both homogeneous arcs/uniform diffuse surface, and homogenous bands. Its temporal evolution could also resemble an auroral sub-storm expansion. This auroral event contributes to enlarge the geomagnetic knowledge of the late 18th century period in which the geomagnetic and the solar activity have high uncertainties due to few sunspots and LMLA observations reported from primary sources. The Rozier record is a clear case of how, a scientist from a research field far from Astronomy or Meteorology in the 18th century, could record and publish descriptions on atmospheric phenomena that he did not fully understand but however he considered worth to be documented. These sources are very valuable because they report details of infrequent and/or partially unknown atmospheric phenomena. In this case the Rozier's report had contributes to enlarge the geomagnetic knowledge of a period with low information. "

References

R1: Line 237: The source of the data (WDC-SILSO) must be cited properly as indicated on their website. I think: SILSO data/image, Royal Observatory of Belgium, Brussels. In addition, you can also indicate the version.

A: The reference has been amended.

R1: Figure 1 is not cited in the text. Furthermore, Figure 1 (b) hides part of Figure 1 (a); I think it is better to remove Figure 1 (b).

A: Figure 1 has been modified following the suggestions

Figure 1: (a) Photographic portrait of Abbot Francois Rozier (photo in public domain) (Library of Congress Prints and Photographs Division Washington; http://loc.gov/pictures/resource/ppmsca.02227/). (b) The two printed pages reporting

the aurora observation made by Abbot Francois Rozier, on 15 August 1780 in Beziers, France (Rozier, 1781).

Please also note the supplement to this comment:
https://www.ann-geophys-discuss.net/angeo-2020-1/angeo-2020-1-AC1-supplement.pdf

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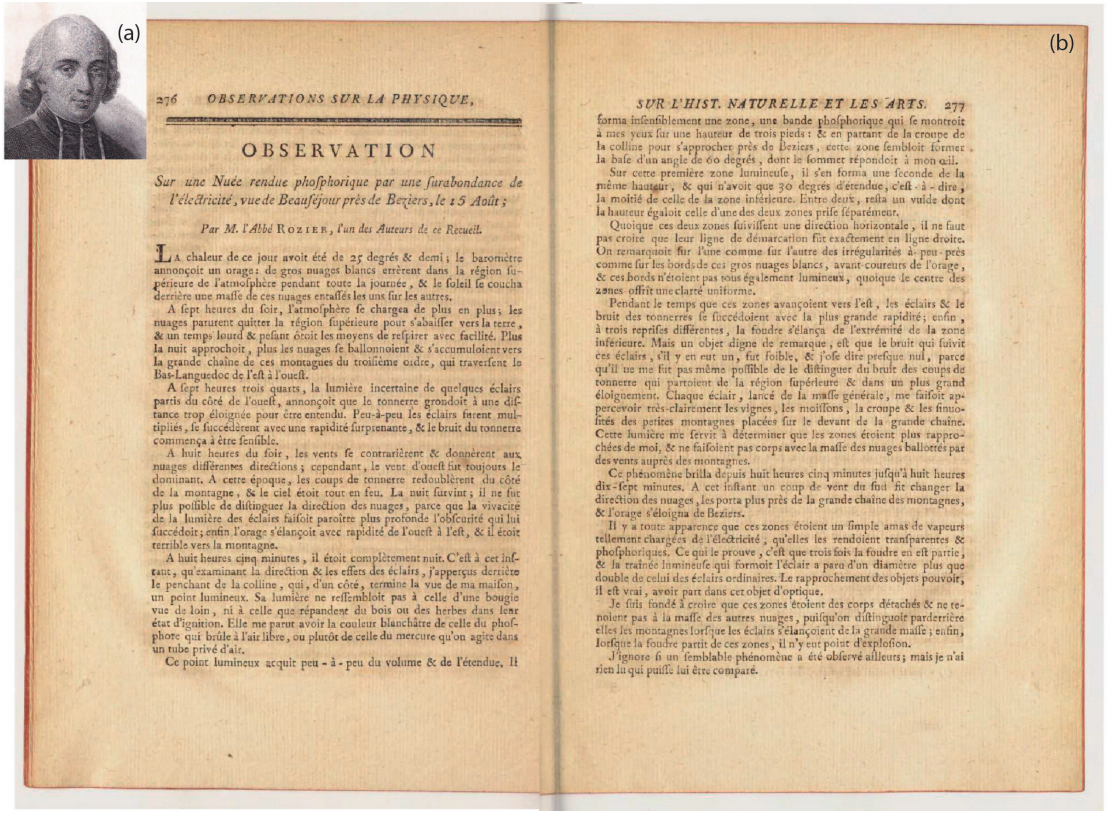
(a)
276 OBSERVATIONS SUR LA PHYSIQUE,
OBSERVATION
Sur une Nuée rendue phosphorique par une surabondance de l'électricité, vue de Beauséjour près de Beziers, le 15 Août;
Par M. l'Abbé ROZIER, l'un des Auteurs de ce Recueil.
LA chaleur de ce jour avoit été de 25 degrés & demi; le baromètre annonçoit un orage: de gros nuages blancs errèrent dans la région supérieure de l'atmosphère pendant toute la journée, & le soleil se coucha derrière une masse de ces nuages entassés les uns sur les autres.
A sept heures du soir, l'atmosphère se chargea de plus en plus; les nuages parurent quitter la région supérieure pour s'abaisser vers la terre, & un temps lourd & pesant ôtoit les moyens de respirer avec facilité. Plus la nuit approchoit, plus les nuages se ballonnoient & s'accumuloient vers la grande chaîne de ces montagnes du troisième ordre, qui traversent le Bas-Languedoc de l'est à l'ouest.
A sept heures trois quarts, la lumière incertaine de quelques éclairs partis du côté de l'ouest, annonçoit que le tonnerre grondoit à une distance trop éloignée pour être entendu. Peu-à-peu les éclairs furent multipliés, se succédèrent avec une rapidité surprenante, & le bruit du tonnerre commença à être sensible.
A huit heures du soir, les vents se contrarièrent & donnèrent aux nuages différentes directions; cependant, le vent d'ouest fut toujours le dominant. A cette époque, les coups de tonnerre redoublèrent du côté de la montagne, & le ciel étoit tout en feu. La nuit survint; il ne fut plus possible de distinguer la direction des nuages, parce que la vivacité de la lumière des éclairs faisoit paroître plus profonde l'obscurité qui lui succédoit; enfin, l'orage s'élançoit avec rapidité de l'ouest à l'est, & il étoit terrible vers la montagne.
A huit heures cinq minutes, il étoit complètement nuit. C'est à cet instant, qu'examinant la direction & les effets des éclairs, j'apperçus derrière le penchant de la colline, qui, d'un côté, termine la vue de ma maison, un point lumineux. Sa lumière ne ressembloit pas à celle d'une bougie vue de loin, ni à celle que répandent du bois ou des herbes dans leur état d'ignition. Elle me parut avoir la couleur blanchâtre de celle du phosphore qui brûle à l'air libre, ou plutôt de celle du mercure qu'on agite dans un tube privé d'air.
Ce point lumineux acquit peu-à-peu du volume & de l'étendue. Il
(b)
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forma insensiblement une zone, une bande phosphorique qui se montroit à mes yeux sur une hauteur de trois pieds: & en partant de la croupe de la colline pour s'approcher près de Beziers, cette zone sembloit former la base d'un angle de 60 degrés, dont le sommet répondoit à mon œil.
Sur cette première zone lumineuse, il s'en forma une seconde de la même hauteur, & qui n'avoit que 30 degrés d'étendue, c'est-à-dire, la moitié de celle de la zone inférieure. Entre deux, resta un vuide dont la hauteur égaloit celle d'une des deux zones prise séparément.
Quoique ces deux zones suivissent une direction horizontale, il ne faut pas croire que leur ligne de démarcation fût exactement en ligne droite. On remarquoit sur l'une comme sur l'autre des irrégularités à-peu-près comme sur les bords de ces gros nuages blancs, avant-coureurs de l'orage, & ces bords n'étoient pas tous également lumineux, quoique le centre des zones offrît une clarté uniforme.
Pendant le temps que ces zones avançoient vers l'est, les éclairs & le bruit des tonnerres se succédoient avec la plus grande rapidité; enfin, à trois reprises différentes, la foudre s'élança de l'extrémité de la zone inférieure. Mais un objet digne de remarque, est que le bruit qui suivit ces éclairs, s'il y en eut un, fut foible, & j'ose dire presque nul, parce qu'il ne me fut pas même possible de le distinguer du bruit des coups de tonnerre qui partoient de la région supérieure & dans un plus grand éloignement. Chaque éclair, lancé de la masse générale, me faisoit apercevoir très-clairement les vignes, les moissons, la croupe & les sinuosités des petites montagnes placées sur le devant de la grande chaîne. Cette lumière me servit à déterminer que les zones étoient plus rapprochées de moi, & ne faisoient pas corps avec la masse des nuages ballottés par des vents auprès des montagnes.
Ce phénomène brilla depuis huit heures cinq minutes jusqu'à huit heures dix-sept minutes. A cet instant un coup de vent du sud fit changer la direction des nuages, les porta plus près de la grande chaîne des montagnes, & l'orage s'éloigna de Beziers.
Il y a toute apparence que ces zones étoient un simple amas de vapeurs tellement chargées de l'électricité, qu'elles les rendoient transparentes & phosphoriques. Ce qui le prouve, c'est que trois fois la foudre en est partie, & la traînée lumineuse qui formoit l'éclair a paru d'un diamètre plus que double de celui des éclairs ordinaires. Le rapprochement des objets pouvoit, il est vrai, avoir part dans cet objet d'optique.
Je fus fondé à croire que ces zones étoient des corps détachés & ne tenoient pas à la masse des autres nuages, puisqu'on distinguoit parderrière elles les montagnes lorsque les éclairs s'élançoient de la grande masse; enfin, lorsque la foudre partit de ces zones, il n'y eut point d'explosion.
J'ignore si un semblable phénomène a été observé ailleurs; mais je n'ai rien lu qui puisse lui être comparé.

Fig. 1.