> Report #1
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> The authors addressed my points and I think the article can be published
> in its present form. The article presented an interesting set of auroral
> observations and the discussion of physical mechanisms is very deep.

Reply: Thank you.

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> Report #2
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> The authors have completely changed their discussions, retracting their
> initial discussions on the SAR arcs and SAG arcs. The abstract is completely
> rewritten too. In the previous round, the authors' manuscript was severely
> debated in the open discussion forum by two experts. In my humble opinion,
> it's fair to let the authors resubmit this manuscript as a new submission
> and post this manuscript to the open discussions so that these experts
> can also assess whether their comments have been properly incorporated.

Reply: Sorry, this is not correct. All of the observational results and conclusions from our initial submission remain intact. In response to your first set of comments, we no longer use the terms SAR and SAG arcs (but please note that Kataoka et al. 2024b has used the term SAR arc to describe their results). That is essential all the changes that we have made. We now have added citizen science auroral results from this magnetic storm in the Introduction section (as requested by the referee).

The main import of our results remains the same. The continuous streaks in the red and green auroras tell us that the physical cause of the bright streaks in the red aurora are caused by precipitating energetic electrons. This is a new and breakthrough result.

> Besides, I am slightly unimpressed with the authors' referencing style.
> They are so inclined to the self citation and have not properly addressed
> the scientific achievements of other teams. As the authors also agree,
> we have more than a hundred of articles for the May 2024 storm.
> Quite a few articles discussed about the aurorae of this storm.
> The author keeps silence on their novelty against such previous studies.
> I believe this article is reviewed as a regular paper of Annales Geophysicae.
> If that's the case, the authors have to properly contextualise their
> study to the previous studies, rather than pretending as if the scientific
> developments stopped for decades outside of their team.

Reply: Done. We have now referenced many of the papers on auroras taken by citizen scientists on the 10-11 May 2024 superstorm. We have deleted some of our references, but you should note that Hajra et al. (2024 and 2025) were the only publications that have gone into detail on the superstorm. The storm and substorm details are highly important for understanding the mechanism for the energetic electron precipitation.

Also please note that there are no auroral papers that deal with the specific physics discussed in our paper. Our paper is the first to show details of a red/green aurora, the continuous streaks and the implication that it is precipitating energetic electrons causing the bright portions of the red aurora.

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> Report #3
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> Review of: "High Temporal- and Spatial-Resolution Photographs
> of the "Christmas" Red-Green Auroras Taken Over Germany
> During a Main Phase of the 10–11 May 2024 SYM-H = -518 nT
> Superstorm" by Tsurutani et al.
>
> The paper presents ground-based imaging of red-green auroras over
> central Germany during the second main phase of the May 2024 superstorm,
> and offers morphological arguments about auroral generation mechanisms.
> The event is of great interest, and the high temporal and spatial resolution
> of the images constitutes a genuine observational contribution, namely
> distributed imaging by help of consumer cameras. The central morphological
> finding, that field-aligned brightness rays are continuous from the red into
> the green emission below, is visually compelling and physically meaningful
> as a constraint on generation mechanisms, and is, ironically, likely not discernible
> in conventional scientific all-sky-imagers that point straight upwards.
> The paper is original in this respect and merits publication. However, in its
> current form it falls short of what is required for a convincing scientific case,
> for two principal reasons.

Reply: Thank you.

> 1) The manuscript does not currently read as a unified work. The introductory
> paragraph, the kinetic Alfvén wave discussion, and the core observational
> sections are written in distinct registers and do not cohere into a single argument.
> It is apparent that substantive additions were made at the revision stage
> without integrating them into the existing text. The paper needs to clarify,
> at the outset, its main preoccupation, or purpose, whether it is an observational
> report or a demonstration of citizen-science instrumentation capability, and the
> subsequent narrative should progress accordingly. In the present form the reader
> is left to infer the central thesis.

Reply: Done. We have now added a paragraph at the beginning of the paper mentioning that this citizen science paper that is addressing the physical causes of the red aurora observed over Braunschweig and Goettingen, Germany during the second main step of the 10-11 May 2024 magnetic storm main phase. These observations occurred during substorms.

The purpose of this paper is to understand the physics of the red aurora. None of the published citizen science reports discuss this topic, only that red (or green) auroras were seen. The observation of blue auroras is perhaps a different type of aurora involving a different topic.

> 2) The data interpretations advanced in the Discussion and Final Comments
> sections are not adequately supported by the data presented: The paper rests
> entirely on ground-based photographs taken with consumer cameras.
> No supporting ground-based or in-situ particle or wave data are brought to
> bear, and while the authors are not obligated to present a comprehensive
> multi-instrument study, the gap between the observations and the conclusions
> currently drawn is wide enough to undermine the paper's credibility.

Reply: The beginning paragraph addresses this situation. These measurments have never been made by scientific instrumentation. Red auroras are rare and we have to make do with citizen science reports until better facilities are set up. There are very few rocket ranges in middle latitudes and having a rocket ready for launch when a red aurora is overhead is highly improbable.

> Two specific cases illustrate this:
> a) The kinetic Alfvén wave acceleration discussion is physically reasonable
> but entirely qualitative. No wave or particle observations from the relevant
> L-shell and MLT sector during the substorm intervals are cited or analysed.
> If the authors do not wish to bring in new datasets, some contemporary
> investigations may be worth citing, e.g., by Zhang et al., which may
> stimulate discussion.

Reply: This has been checked and double checked. There were no spacecraft flying over this area to check for energetic particle precipitation, Alfvén waves, etc. Spacecraft and rocket instrumentation are probably incapable to measure thermal and suprathermal electrons and ions at 800 to 200 km altitude. This is the reason why the physical mechanisms of red aurora have been a mystery for such a long time. This is now stated explicitly in the Introduction section to help give the paper more coherence.

There were no scientific calibrated instruments in the Braunschweig and Goettingen areas to do spectral studies of the aurora.

> Zhang, Anxin, Suping Duan, Lei Dai, et al. ‘Observations of the Magnetopause
> Reconnection Ion Diffusion Region With High-Density O+ Ions During the
> May 2024 Superstorm’. Geophysical Research Letters 53, no. 8 (2026):

> e2025GL121449. https://doi.org/10.1029/2025GL121449.

Reply: We believe this is a misunderstanding of the referee. Zhang et al. (2026) discuss the magnetic reconnection observation (particularly sampling from the ion diffusion region) with kinetic Alfvén waves. The reconnection was observed at the dayside (and morning side) magnetopause, and has nothing to do with our auroral observations in the pre-midnight to midnight sector.

> b) More critically, the paper's most physically specific and novel inference,
> namely that the spatially separated red and green aurorae in Figure 4 reside
> on field lines inside and outside the plasmapause respectively, is stated in
> a single sentence and left entirely unsubstantiated. This interpretation is
> testable and, I would argue, worth testing. The empirical plasmapause location
> during the second main phase can be estimated from the Kp time series already
> in the authors' dataset, using, e.g., the O'Brien & Moldwin (2003) expression
> for the plasmapause L-shell, referencing statistical studies (e.g., Verbanac et al.,
> 2015). This can be mapped to magnetic latitude and compared to the observations,
> and I suspect the location would be favourable to the Braunschweig and
> Göttingen sites. If the red and green auroral centroids in Figure 4 straddle this
> boundary, the inside/outside-plasmasphere interpretation gains merit.
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> O'Brien, T. P., and M. B. Moldwin. 'Empirical Plasmapause Models from
> Magnetic Indices'. Geophysical Research Letters 30, no. 4 (2003).
> https://doi.org/10.1029/2002GL016007.
>
> Verbanac, G., V. Pierrard, M. Bandić, F. Darrouzet, J. L. Rauch, and P. Décréau.
> 'The Relationship between Plasmapause, Solar Wind and Geomagnetic
> Activity between 2007 and 2011'. Annales Geophysicae 33, no. 10 (2015):
> 1271–83. https://doi.org/10.5194/angeo-33-1271-2015.

Reply: We now cite the paper by O'Brien and Moldwin (2003). The model by O'Brien and Moldwin (2003) and the preceding model by Carpenter and Anderson (1992) were indeed very helpful. In fact, the L-shell values of Braunschweig (L=2.69) and Goettingen (L=2.61) agree reasonably with the model prediction using the Dst index (predicting the L-shell in a range from 2.56 to 2.66. This is now included in the paper.

The model by Verbanac et al. (2015) is not useful in our case, because of the lack of the data points, for example Dst within -40 nT (Dst in our case is -339 nT). We do not cite Verbanac et al. (2015) for concise manuscript writing.

THEMIS-A and THEMIS-E spacecraft were flying the night side of the inner magnetosphere, but a clear identification of the plasmapause is not possible because of the lack of electron density measurement using the wave instrument. The Arase spacecraft was on the dayside, and we cannot link Braunschweig and Goettingen to the plasmapause by tracing the geomagnetic field lines.

> Lastly, the authors may wish to discuss what consumer-grade instruments
> actually provide to the field, which I believe is morphological coverage
> at high cadence and broad geographic distribution. The density of capable
> amateur imagers now enables event documentation at spatiotemporal
> sampling unachievable by dedicated networks. For comparison, this was
> not possible during the 2003 superstorm. This point pertains to the citizen
> science analyses of this same storm by Grandin et al. (2024) that authors
> already reference.

Reply: Yes, absolutely. We address the spatio-temporal resolution by citizen-science in the paper now (Grandin et al., 2014, Kataoka et al. 2024b, 2025). Further studies of red auroras looking for streaks will verify/help confirm our present results. It will also be interesting to find if red auroral occur during magnetic storms without streaks. This will imply a different physical mechanism for creating red auroras.