Eos



# How Did We Miss This? An Upper Atmospheric Discovery Named STEVE

*Captured unknowingly by scientific instruments for years, a sky phenomenon is finally brought to the attention of researchers by eagle-eyed citizen scientists.*

By **B. Gallardo-Lacourt**, **G. W. Perry**, **W. E. Archer,** and **E. Donovan**

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A strong thermal emission velocity enhancement (STEVE) captured by Alberta Aurora Chasers at Circle Lake in British Columbia on 11 May 2018. The dynamic green aurora is seen in the distant north, located at right in the photograph. Credit: Robert Downie

On 15 January 2016, highly skilled auroral photographers and citizen scientists of the Facebook group **Alberta Aurora Chasers** shared photographs of a unique optical form with Elizabeth MacDonald, a NASA space weather scientist and the creator of the aurora reporting website **Aurorasaurus**, and Eric Donovan, an expert in auroral physics at the University of Calgary. The pictures featured ribbons of white and mauve hues in the sky. Seen with the naked eye or through true-color imaging, the feature's emissions and morphology are striking in how they stand apart from any other optical phenomena in the region. The strange sight had been documented for decades by amateur auroral photographers but had not yet been noticed by the scientific community.

The Alberta group suggested to MacDonald and Donovan that what they'd captured was a type of aurora called a proton arc. However, Donovan knew that the intensity of a proton arc was too low to be detectable with the chasers' equipment, let alone with the naked eye. Despite their decades of shared experience studying auroras, neither MacDonald nor Donovan could identify the phenomenon. Nevertheless, they insisted that the unknown structure be given a name. A placeholder name was needed, one that would not carry any physical meaning. They called it Steve, a name proposed by one of the chasers in homage to the 2006 cartoon movie *Over the Hedge* in which the characters named an unidentified object "Steve."

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The chase was on to identify another Steve, this time with scientific instruments. On 26 June 2016, Brian Jackel at the University of Calgary found a wispy arc resembling a Steve-like feature in the overnight data from one of the university's redline cameras. Donovan asked the Alberta Aurora Chasers on Facebook if they had observed Steve on that night. Photographer Song Despins replied by **sending two images that she had captured of Steve**.

Serendipitously, one of the European Space Agency Swarm satellites orbited right through Steve that night, within the field of view of the same redline camera. The Swarm spacecraft measured intense plasma flows and significantly enhanced electron temperatures coincident with Steve [***MacDonald et al.***, 2018]. With the information from Swarm's measurements, Steve was converted into the backronym Strong Thermal Emission Velocity Enhancement: STEVE.

### Early-Career Scientists in the Middle of a Media Storm

One unique aspect of STEVE is the simplicity with which the research questions can be posed. When starting in a research field looking for topics, it can seem that all the big

questions have been answered, and often, the significance of scientific results is difficult to express to those outside of the research discipline. The appearance of STEVE was a rare and refreshing time when we could say, “See that mauve glow in the sky? We don’t know what it is, but we are looking into it.” Because of this accessibility, STEVE has become extremely popular and generated significant media attention.

> *Widespread reporting resulted in misinformation and, unfortunately, created the impression that the mystery of STEVE had already been solved.*

The attention had its advantages: STEVE was discussed on radio and television and even garnered a **write-up in the *New York Times***. What more could an early-career scientist ask for in terms of relevance and notoriety? However, the attention also had its disadvantages: Widespread reporting resulted in misinformation and, unfortunately, created the impression that the mystery of STEVE had already been solved. In some instances, the media coverage implied that scientists had acquired a deep understanding of STEVE from months of laborious research, which was not the case—there was still much about STEVE that scientists were trying to understand.

The media attention also added pressure to scientists investigating STEVE (including the authors of this article), who were busy poring over data from imagers, satellites, and radars in an effort to find more events to help understand the phenomenon and justify the media hype.

Nevertheless, focus remained on the science. Any delusions of grandeur arising from the hype were actively stifled. In one anecdote, after seeing a media article that, to some, gave the incorrect impression that STEVE’s mysteries had been solved, Gareth Perry sarcastically asked Bea Gallardo-Lacourt, “Why are you looking at pictures of STEVE? I thought that problem was already solved!”

## What Do We Know About STEVE So Far?

After 3 years of research, we have begun detangling the mysteries of STEVE. We now know that it tends to last about an hour and is only tens of kilometers wide (north–south) but spans thousands of kilometers in the east–west direction [*Gallardo-Lacourt et al.*, 2018a]. Although STEVE resembles an aurora, its origin appears to be completely different. A satellite that passed through a STEVE noted an absence of particle precipitation, suggesting that STEVE may instead be associated with extremely hot plasma moving rapidly equatorward of the auroral oval [*MacDonald et al.*, 2018].

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The first study, **published by MacDonald and her collaborators in *Science Advances***, reported that STEVE is an extremely narrow band of optical emission, situated equatorward of the auroral oval, in the subauroral region. Westward directed azimuthal plasma flows are commonly observed at these magnetic local times and latitudes. These flows are sometimes narrow (about 1° in latitudinal extent) and are then categorized as a subauroral ion drift (SAID) [*Spiro et al.*, 1979]. In MacDonald's paper, the authors observed a single STEVE event optically by a ground-based imager and sampled it in situ with a Swarm spacecraft. The spacecraft measurements showed a narrow westward plasma flow coincident with the optical emission, consistent with a SAID and an enhanced electron temperature signature. They concluded that STEVE could be an optical manifestation of an extreme SAID. However, they noted that more events needed to be analyzed to determine whether these two phenomena are indeed related.

Last August, **a second article about STEVE** was published in *Geophysical Research Letters* [*Gallardo-Lacourt et al.*, 2018a]. The authors analyzed a STEVE event observed by one of the **Time History of Events and Macroscale Interactions during Substorms (THEMIS) All-Sky Imagers** in conjunction with particle measurements from the Polar Operational Environmental Satellite (POES) 17. Their analysis revealed no evidence of electron or ion

precipitation during the event. Why is this significant? When a process has its origin in the magnetosphere, like an aurora, a satellite flying directly above a structure should observe particles precipitating down into Earth's upper atmosphere. This latest observation demonstrates that STEVE's optical emissions, more specifically, its white-mauve emissions, are not due to particle precipitation, suggesting that STEVE's emissions could be due to processes generated within the Earth's ionosphere-thermosphere system. This is a big clue that STEVE's emissions are most likely not an aurora, although future studies are needed to confirm this.

A **third study, published last November in the *Journal of Geophysical Research*** *: Space Physics* [***Gallardo-Lacourt et al.***, 2018b], presented the first statistical analysis of STEVE's optical characteristics using ground-based imagery. The authors also examined satellite data to determine the geomagnetic conditions favorable for the formation of the structure.

## What's Next?

The ability of many existing instruments to observe and collect data from STEVE events allows scientists to conduct research in many different ways, studying the numerous fundamental questions about the phenomenon that remain unanswered. Arguably one of the biggest is whether STEVE is the product of magnetospheric processes or ionosphere-thermosphere dynamics. We'll need more statistical studies and numerical simulations to completely elucidate this aspect of STEVE. In addition, the altitude at which STEVE is produced is still unknown. Scientists, together with the auroral photographers, are now working to obtain spectrographic and triangulation measurements that could help us understand how high STEVE is located.

## STEVE: A Lesson in Humility

It is remarkable that STEVE was only recently noticed by professional scientists, even though it has been in plain view of the THEMIS All-Sky Imager and its 20 cameras for many years. STEVE, we now know, is a common feature in the instrument's data archives. How we missed that is a fair question to ask. It took
the persistence and dedication of citizen

scientists to notice, distinguish, and catalog STEVE and a dissemination of knowledge from citizen to professional scientists to bring it to the fore.

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STEVE is one of many cases that validate the citizen scientist as a member of the scientific community. The Alberta Aurora Chasers noticed that STEVE was different from the other auroras. They made observations, categorized it, and attempted to identify it. In doing so, they made a hypothesis about its mechanism. They compared that hypothesis with existing knowledge (in place of experiment) when they contacted MacDonald and Donovan. The chasers' guess was shown to be wrong, but their actions made up the first iteration of the scientific method. It is a reminder for professional scientists—especially those early in their career—that a Ph.D. is not a prerequisite for being a scientist and that new discoveries can be made by anyone paying close enough attention.

## References

Gallardo-Lacourt, B., et al. (2018a), On the origin of STEVE: Particle precipitation or ionospheric skyglow?, *Geophys. Res. Lett., 45*(16), 7,968–7,973, **https://doi.org/10.1029/2018GL078509**.

Gallardo-Lacourt, B., et al. (2018b), A statistical analysis of STEVE, *J. Geophys. Res. Space Phys., 123*, 9,893–9,905, **https://doi.org/10.1029/2018JA025368**.

MacDonald, E. A., et al. (2018), New science in plain sight: Citizen scientists lead to the discovery of optical structure in the upper atmosphere, *Sci. Adv., 4*(3), eaaq0030, **https://doi.org/10.1126/sciadv.aaq0030**.

Spiro, R. W., R. A. Heelis, and W. B. Hanson (1979), Rapid subauroral ion drifts observed by Atmosphere Explorer C, *Geophys. Res. Lett., 6*(8), 657–660,

https://doi.org/10.1029/GL006i008p00657.

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**Ed Simonis**

6 years ago

As happens too often, I am confused. Where are the Sun, Moon, city lights at the place and time the picture was taken? I'm not sure if I should be looking at the right edge of the bright streak, or at the sunrise-like glow in the right part of the picture, but what really scared me was the headline: "How Did We Miss That: ...STEVE..." accompanied what I saw as a blank picture; I'm aging, so I thought my vision cannot detect that wave length of the mysterious light....

0 0 Reply

**ben** → Ed Simonis

6 years ago

Dude, Steve is the bright streak you mention. Your comment has broken my mind and now I'm not sure how to continue life.

1 0 Reply

This comment was deleted.

**Bea GL** → Guest

5 years ago

Hi guys, from this photograph STEVE is the bright mauve arc in the middle of the frame. If we talk about the color of the emission, very interestingly STEVE shows a continuos emission - excitation in many wavelengths (not like aurora for example, which we often see in green, one wavelength 557nm). Because of the continuous emission we see it sometimes as a white arc :)
We are still trying to understand how Earth's atmosphere is generating such a bright and particular emission at those latitudes

0 0 Reply