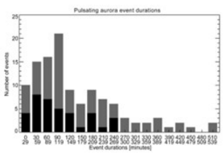
GEM Tutorial Poster – San Diego 2023

Pulsating Aurora: A common diffuse-like and dynamic auroral type

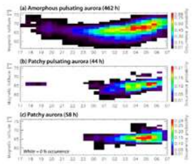
WHAT ARE PULSATING AURORA (PA)?

Appearance & Morphology

- Dim and diffuse (barely visible to naked eye) patches that blink on/off in a variety of sizes (400 to 3000 km^2) [1], shapes, and periods (<1s to 30s) [2, 3].
- Blinking is quasi-periodic and patches are not necessarily synced with neighbors.
- Common (>75%), especially after substorms, and usually at a lower latitude than other aurora [4, 5].
- On average PA lasts 1.5 hours, but can continue for many hours [6].
- On average PA extends 4 hours of MLT, but can be spread over a much wider area [7].
- PA occurs at lower altitudes than other aurora [8][9].



Distribution of PA event durations from Jones+ 2011. The gray bars include all observed events, while the black only include events with clear start and stop times [6].



Occurrence rates of different PA forms from Grono & Donovan 2020. During amorphous PA a single patch doesn't last for more than a few periods, for patchy PA they do, and for patchy aurora the patches are continuous [5].

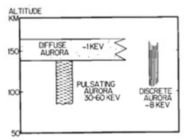
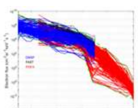


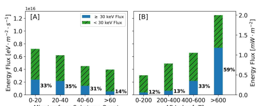
Figure from Brown+ 1976 showing the approximate altitude of different types of aurora. PA tends to be at a lower altitude than discrete or the non-pulsating diffuse aurora [8]

Energy

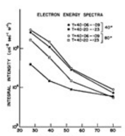
- Wide range of energies that are more energetic than discrete aurora
  - (1 keV to >100 keV) [10, 11, 12].
- Varies based on MLT, most energetic events during 3 to 6 MLT [13].
- More energetic when occurring soon after substorms [14].
- Amorphous PA less energetic than patchy PA and patchy aurora [5, 15].
- ON phase more energetic than OFF phase [9, 10].



Energy spectrum from Tesema+ 2020 measured during PA over 137 DMSP, 9 FAST, and 240 POES overpasses [11].



Average high and low energy flux of PA associated with substorms from Troyer+ 2022. More energetic events occur close in time to substorms and during high AE periods [14].



PA energy flux measured via sounding rocket during the ON (circles) and OFF (squares) phases, showing a softening of the spectrum when the patch is OFF [10].

Source

- PA electrons originate in the outer radiation belt region [16, 17].
- Magnetically trapped electrons precipitate due to changing mirror point caused by wave induced pitch angle scattering [18, 19, 20].
- Specific PA events have been directly associated with modulated lower-band chorus waves in the radiation belt region [21, 22].

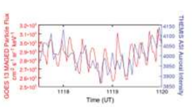


Figure from Jaynes+ 2013 showing strong correlation between electron flux in the equatorial radiation belt region and pulsations in cameras at the magnetic footprint of the satellite [16].

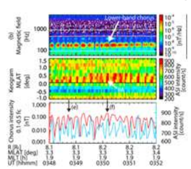
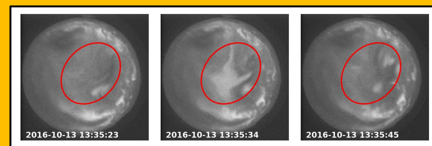


Figure from Nishimura+ 2013 showing strong correlation between lower-band chorus waves in the radiation belt region and pulsations in cameras at the magnetic footprint of the satellite [21].

Compared to discrete aurora, PA occur at lower L-shells, which map to lower latitudes. In this image you can see the north-south boundary between the discrete and more diffuse PA.

Pulsating aurora are diffuse-like, dynamic, energetic, and very common. They originate from magnetospheric waves that pitch angle scatter electrons magnetically trapped in the outer radiation belt region. The potential for high energies (up to 100 keV), combined with their long lasting and widespread nature, mean that pulsating aurora are important to magnetosphere-ionosphere coupling.



HOW DO WE STUDY PULSATING AURORA?

- **All-sky imagers (ASI)** – Used to study widescale dynamics and statistics. They can derive energy from wavelength filters, and height via triangulation. There are various networks across Alaska, Canada, and Scandanavia [13, 23, 24].
- **Satellites** – Often used in conjunction with imagers to deduce field and particle information in radiation belt region or low earth orbit that could be responsible for PA [11, 17].
- **Incoherent scatter radar (ISR)** – Capable of remote sensing electron density, temperature, and velocity in upper atmosphere [9, 18, 25].
- **Other radio instruments** – Can use various atmospheric absorption and back scattered signals to detect when energetic electron precipitation is occurring [7, 26].
- **Rockets** – Like the LAMP mission shown here, they conduct case studies, with direct measurements from within the aurora region, of fields and particles. Often combined with ground-based instruments [10, 18, 27].

WHY DO WE STUDY PULSATING AURORA?

- Can produce NO_x (N, NO, NO_2) and HO_x (H, HO, HO_2) molecules, which get convected to lower altitudes and deplete ozone [28, 29].
- Enhances conductivity in the atmosphere [30].
- Frequently associated with energetic electron precipitation [7, 14].
- Because they occur at lower latitudes, PA are often seen in the continental US during strong geomagnetic storms, making them engaging to amateur aurora watchers, helping to promote the field [31].

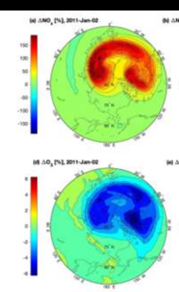


Figure from Verronen+ 2021 showing the increase in NO_x and resulting decrease in ozone during a modeled PA event [29].

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OPEN QUESTIONS?

- What causes the pulsating behavior, both large and small scales?
- What causes the patchy appearance?
- Are microbursts associated with PA?
- Are modulation periods related to energy in any way?
- What are the role of different wave types?
- Question references and general overview papers: [32, 33, 34]

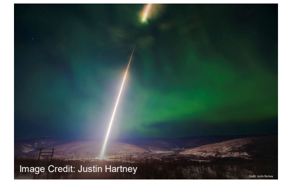

Image of the Loss Through Auroral Microburst Pulsations (LAMP) rocket, which was launched on March 5, 2022 to study how PA are connected to microbursts and the energy composition of the precipitating electrons [18].

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