Recent Advances in Pulsating Aurora

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Typical Characteristics

1. Typical periods and patch sizes:

   From a few seconds to a few tens of seconds; from 10 to 200 km in horizontal extent [Royrvik and Davis, 1977; Oguti, 1978; Yamamoto, 1988].

2. Patch thicknesses:

   A few km. [Stenbaek-Nielsen and Hallinan, 1979] or ~15-25 km [Jones et al., 2008]

3. Typical brightness:

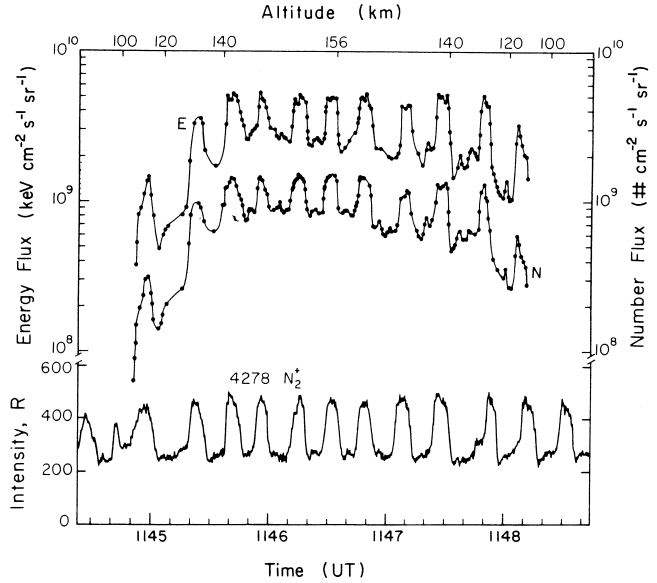
   A few kR at 428 nm [Jones et al., 2008]

4. Context:

   A: Substorm recovery phase *and/or* dawn sector,
   B: Consistently embedded in regions of diffuse aurora;
   C: Confirmed using cameras on a 10 km baseline to measure the altitude of emissions [Brown et al., 1976].

Rocket Observations

1. Several rockets consistently observed pulsations in energetic electron precipitation. Example To the right from McEwen et al. [1981].



2. Energies from a few keV to several tens of keV, with *more pronounced modulations occurring at higher energies* (typically 30 keV or higher up to 80 keV?) [Bryant et al., 1969; Whalen et al., 1971; Bryant et al., 1975; Sandahl et al., 1980; McEwen et al., 1981]

3. Velocity dispersion in the energetic electrons indicate *they originate from near the equator* [Bryant et al., 1971, 1975; Smith et al., 1980; Yau et al., 1981].

Occurrence Distributions

1. J. P. Heppner [Thesis, 1954]: occurrences between near-midnight and dawn; occurrence frequency peaks near 64 ILAT; quite low poleward of 66 ILAT and equatorward of 60 ILAT (from College, Alaska) [Cresswell,1972],

2. Kvifte and Pettersen [1969]: occurrences from pre-midnight to 0900 MLT (between 65 and 68 ILAT); occurrence rates ranging from less than 25% to greater than 75%.

3. Oguti et al. [1981]: observed 61.5 to 74.3 ILAT – probabilities of approximately 30% near midnight, increasing to 100% near 0400 MLT (central Canada)

4. Royrvik and Davis [1977]: "all-sky camera data from Byrd Station demonstrate that the pulsating aurora can extend eastward from the darkside auroral oval around to the noon meridian or even beyond", although they provide no citation for this information.

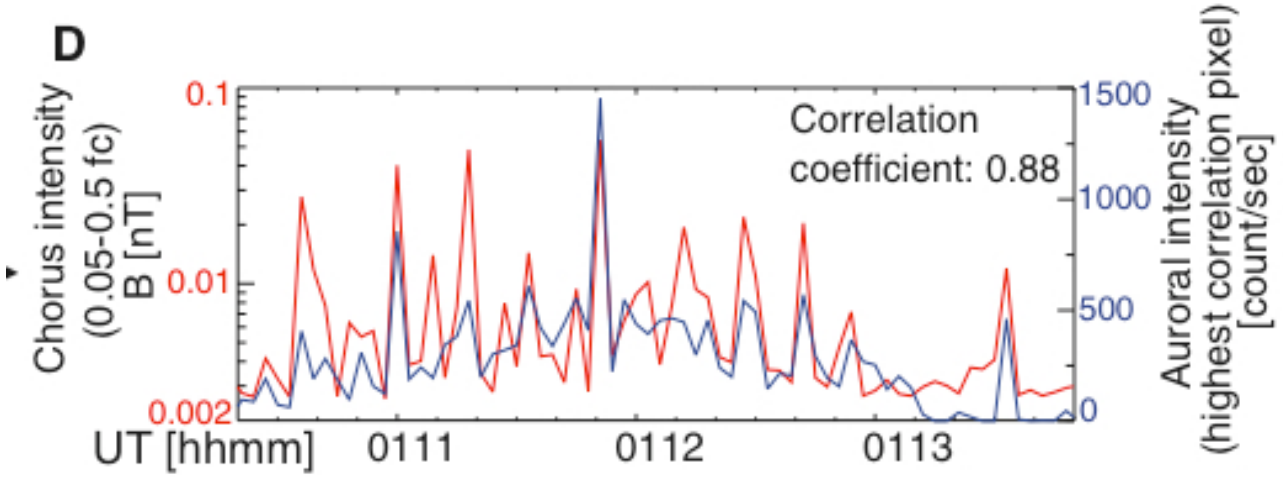
5. Berkey [1978]: photometric and riometer observations obtained just after twilight (1300-1600 MLT, College, Alaska); occurrence of pulsating auroras in the afternoon sector. Half dozen events during 1967-68.

Recent Results

Oyama et al., [2010]: Thermospheric (FPI) observations of clear horizontal and vertical fluctuations in neutral winds (at 558 nm); fluctuations occurred in darker areas of patches.

Wilson et al., [2005]: Infrasonic observations correlated with pulsating aurora near College, AK. Not cited in Oyama, but similar result.

Nishimura et al., [2010]: Correlates lower-band chorus observed by THEMIS satellites with ground-based observations of pulsating aurora.



Recent Results – "worms" (P. Fernandes, Senior thesis)

1. Used an intensified video (Xybion) camera at Poker Flat in 2007. Camera outfitted with 45x34 deg FOV (83x60 km spot at 100 km alt).
2. Total of 26 events acquired in 7 nights of observing. Net occurrence rate (of the worms observed in P.A. events of 5%.
3. Worms were aligned east-west in 24 of 26 events.
4. Average width of 3 km and length of 54 km.
5. Durations from 8 secs to 2.5 mins,, with 38 secs ave.

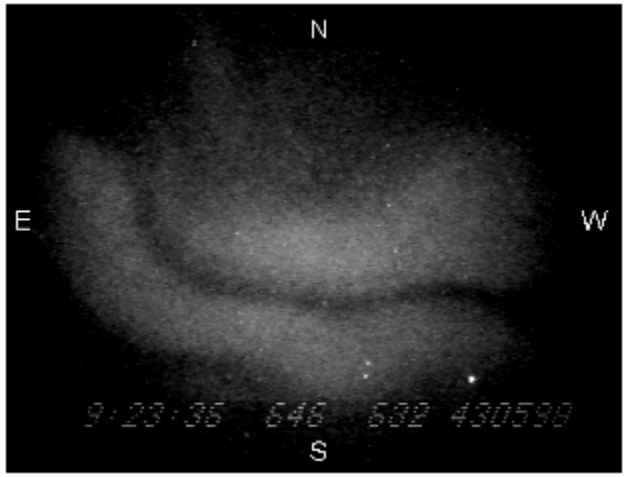


Figure 12: Typical example of a black auroral form in pulsating aurora. The top of the field of view is north, while east is to the left. Image taken January 18, 2007.

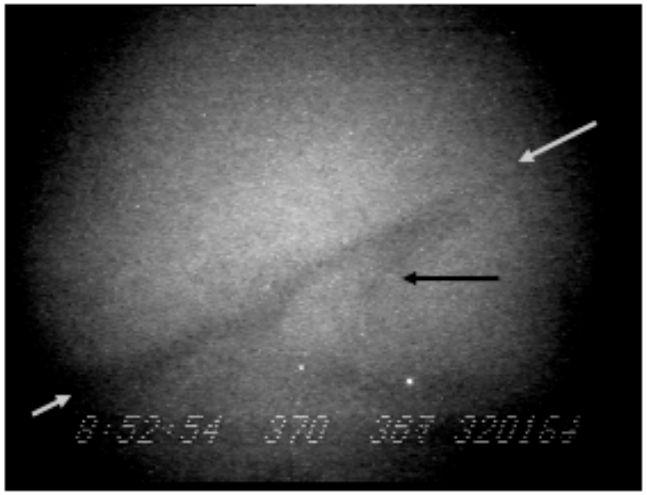


Figure 15: Example of black aurora (grey arrows) located at the boundaries of pulsating patches. The pulsating patches above and below the form were observed to pulsate with different frequencies. The black arrow indicates a region in which the pulsating patch is off, obscuring the boundary of the black aurora. Brightness and contrast have been modified. Image taken January 18, 2007.

Recent Results – large scale

Jones et al., [2011], using THEMIS data from Gillam and Fort Smith (similar ILAT, separated by 1.5 hours in MLT)

1. Source region of pulsating aurora drifts or expands westward, away from magnetic midnight, for pre-midnight onsets; the spatial evolution is more complicated for post-midnight onsets.

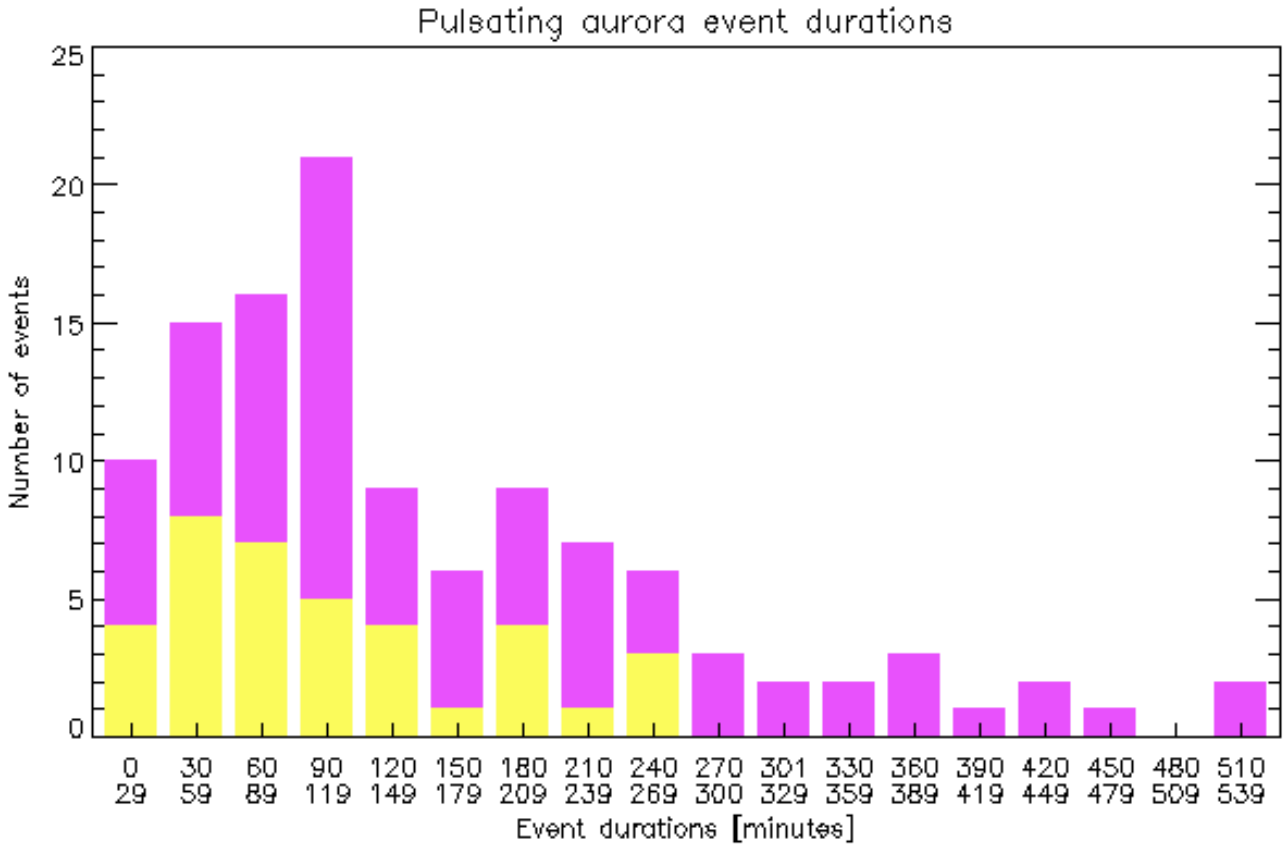
2. The spatial extent of pulsating aurora events averages 7.3 in MLT, based on 25 clear events.

3. Only observed occurrence rates of 31% in clear optical data; 69% of all pulsating aurora onsets at Gillam occur post-substorm breakup. Far greater likelihood of observing pulsating aurora after magnetic midnight (54% probability versus a 14% probability before midnight).

Recent Results – large scale

Jones et al., [2011], using THEMIS data from Gillam and Fort Smith (similar ILAT, separated by 1.5 hours in MLT)

4. Durations (Gillam) are highly variable; most probable duration of 90-120 min, but many events with durations the order of several hours.



Outstanding problems

1. What is the relationship between pulsating aurora and substorms? Do substorms provide the seed populations of energetic electrons as originally suggested by S. Akasofu?

2. What is the total energy involved in pulsating aurora events? How does this compare to substorm expansion phases?

3. What is the spatial extent of occurrences of pulsating aurora? Does it occur throughout the dayside?

4. What is the role of the ionosphere? How do the patches remain so incredibly persistent in terms of their shape and location during an event?

5.Do “worms” represent black aurora (i.e., does it represent a signature of current closure? How do currents close in individual patches?

References

Berkey, F. T., Observations of pulsating aurora in the day sector auroral zone, *Planet. Space Sci*, 26, 635–650, 1978.

Brown, N. B., et al., Altitude of pulsating aurora determined by a new instrumental technique, *Geophys. Res. Lett*., 3 , 403–+, 1976.

Bryant, D. A., et al., Modulation of auroral electrons at large distances from the earth, *J. Atmos. Terr. Phys*., 31 , 579, 1969.

Bryant, D. A., G. M. Courtier, and G. Bennett, Equatorial modulation of electrons in a pulsating aurora*, J. Atmos. Terr. Phys*., 33 , 859, 1971.

Bryant, D. A., et al., Distant modulation of electron intensity during the expansion phase of an auroral substorm, *Planet. Space Sci*., 23 , 867, 1975. .

Cresswell, G. R., The morphology of displays of pulsating auroras, *J. Atmos. Terr. Phys,* 34, 549–554, 1972.

Jones, S. L., M. R. Lessard, K. Rychert, E. Donovan, and E. Spanswick, Large-scale aspects and temporal evolution of pulsating aurora, *J. Geophys. Res.*, 116, A03214, doi: 10.1029/2010JA015840, 2010.

Jones, S.L., et al., PFISR and ROPA observations of pulsating aurora*, J. Atmos. Solar Terr. Phys*, doi:10.1016/j.jastp.2008.10.004, 2008.

Kvifte, G. J., Pettersen, H., Morphology of the pulsating aurora, *Planet. Space Sci,* 17, 1599–1607, 1969.

McEwen, D. J., Yee, E., Whalen, B. A., Yau, A. W., Electron energy measurements in pulsating auroras. *Can. J. Phys*. 50, 1106. 167, 1981.

Nishimura et al., Identifying the Driver of Pulsating Aurora*, Science,* DOI: 10.1126/science.1193186, 81, 2010.

Oguti, T., et al., Statistics of pulsating auroras on the basis of all-sky TV data from five stations. I. Occurrence frequency, *Can. J. Phys*. 59, 1150, 1981.

Oyawa et al., Lower-thermospheric wind fluctuations measured with an FPI during pulsating aurora at Tromsø, Norway, *Ann. Geophys*., 28, 1847–1857, 2010.

Royrvik, O., Davis, T. N., Pulsating Aurora: Local and Global Morphology*, J. Geophys. Res*. 82, 4720, 1977.

Smith, M. J., D. A. Bryant, and T. Edwards, Pulsations in auroral electrons and positive ions*, J. Atmos. Terr. Phys*., 42 , 167, 1980.

Stenbaek-Nielsen, H.C., Hallinan, T.J., Pulsating auroras: evidence for noncollisional thermalization of precipitating electrons. *J. Geophys. Res,* 84, 3257, 1979.

Wilson et al., High trace-velocity infrasound from pulsating auroras at Fairbanks, Alaska, *GRL*, 32, 14810, 10.1029/2005GL023188,2005

Yau, A. W., et al., Rocket–Borne Measurements of Particle Pulsation in Pulsating Aurora, *J. Geophys. Res*., 86 , 5673, 1981.