Structure of Black Aurora Associated With Pulsating Aurora

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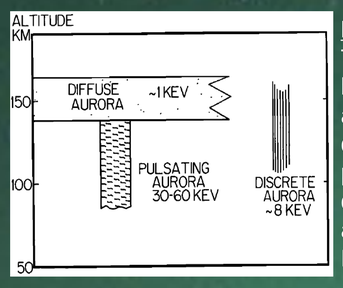
Abstract

Morphological behavior of black aurora as it relates to pulsating aurora is investigated by examining a collection of ground-based observations from January 2007 in support of the ROPA rocket campaign. Images were sampled from video recorded by a Xybion intensified camera (30 fps) at Poker Flat Research Range, AK. The primary observations of black aurora recorded during the substorm recovery phase were between separate patches of pulsating aurora as well as pulsating aurora separated from diffuse aurora. In these observations the black aurora forms an apparent firm boundary between the auroral forms in a new behavior that is in contrast with previously reported observations. Also presented for the first time are black curls in conjunction with pulsating aurora. Curl structures that indicate shear plasma flows in the ionosphere may be used as a proxy for converging/diverging electric fields in and above the ionosphere. This new subset of black auroral behavior may provide visual evidence of black aurora as an ionospheric feedback mechanism as related to pulsating aurora.

Background



Diffuse vs. Pulsating Aurora

There is a distinct difference between diffuse and pulsating aurora due to the significant energy difference between the precipitating particle populations that cause diffuse (~1 keV) and pulsating aurora (typically >10 keV).

Left: Figure from Brown et al [1976]

Scattering waves modes in the magnetosphere

- ❖ Pulsating aurora -- LB Chorus waves
- ❖ Diffuse aurora -- UB Chorus and ECH waves

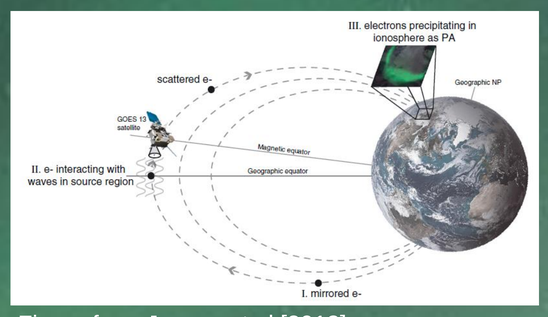
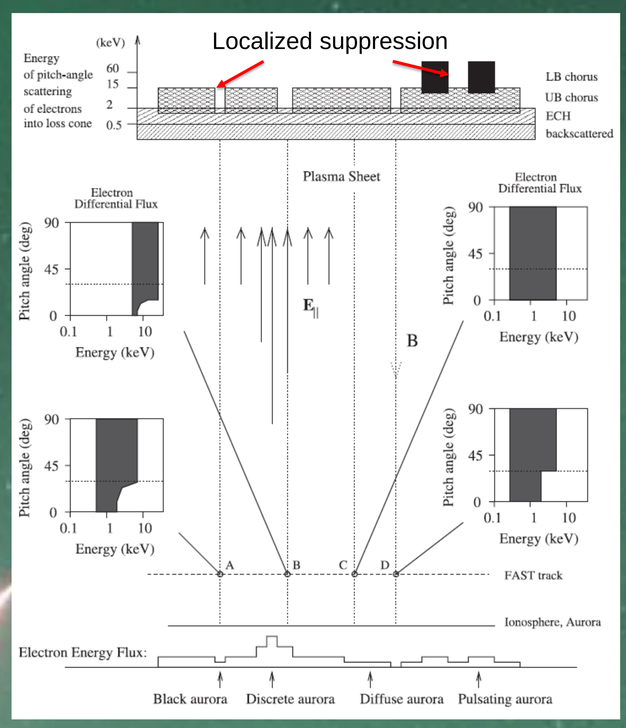


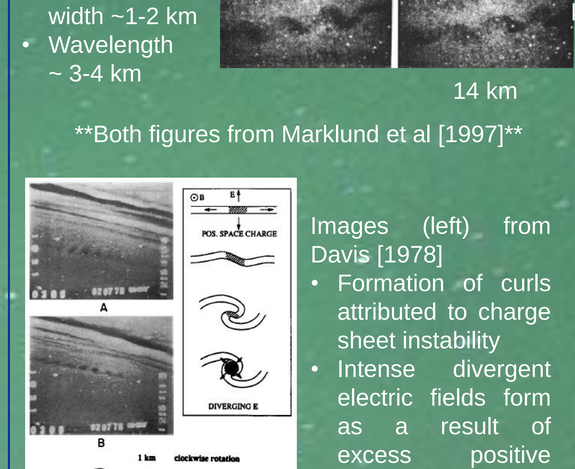
Figure from Jaynes et al [2013]



Black aurora

Fine structure within diffuse or pulsating aurora that is characterized by a distinct lack of visible emission with two popular explanations:

1. Localized suppression of pitch angle scattering in the equatorial magnetosphere (Peticolas et al [2002], left)
2. Intense field aligned structures form and accelerate electrons upward in a downward current region (Marklund *et al* [1997], below)

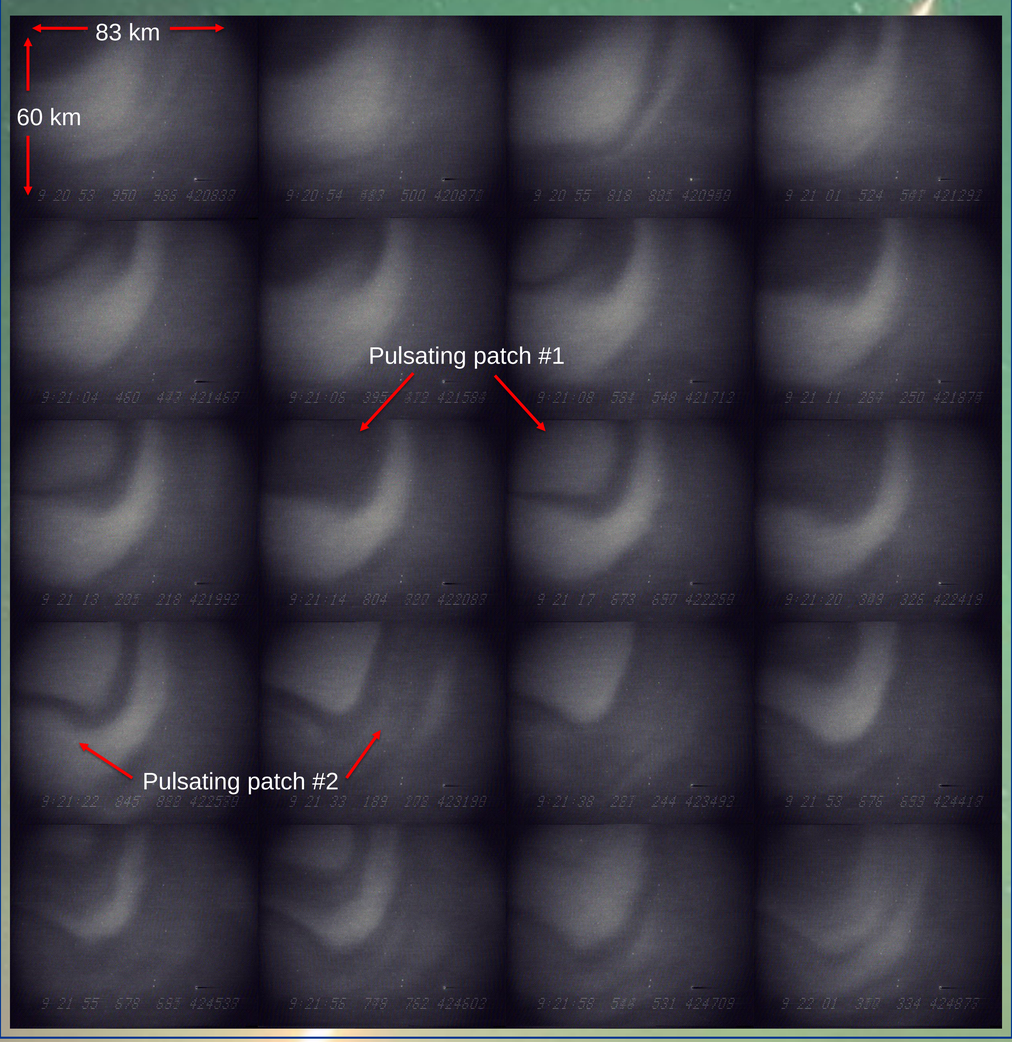


Black Aurora Between Pulsating Patches

In this event from 18 January 2007,12:21:11 MLT, two separate, slowly drifting pulsating patches are spatially defined by black aurora.

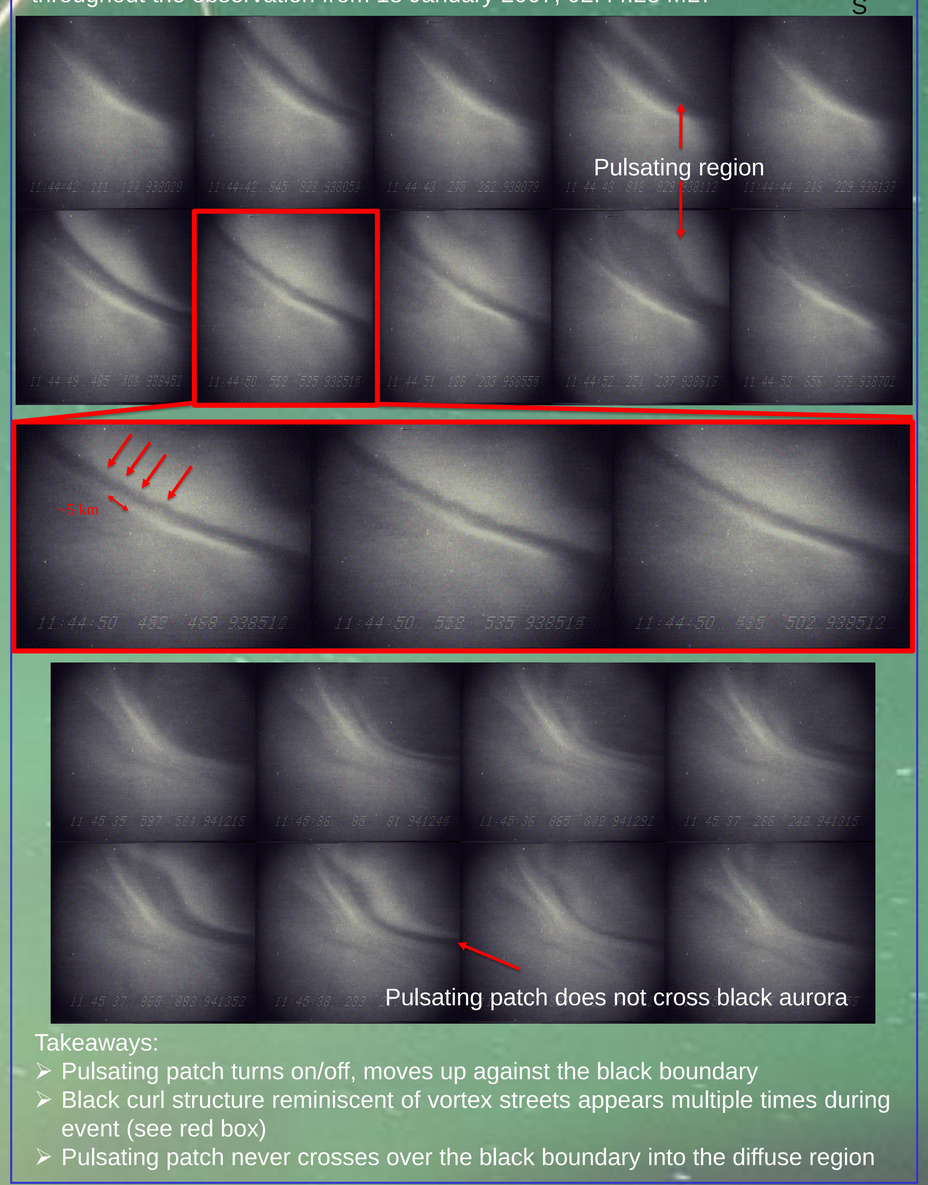
Takeaways:

- ➢ Two patches that are pulsating with different periods of pulsation (similar to observations by Nishiyama et al [2012])
- ➢ Patches evolve in shape but the black aurora maintains the border between patches
- ➢ Implies a morphological interaction between the pulsating patches and the black aurora



Black Aurora Between Pulsating and Diffuse Aurora

The majority of the frame is filled by diffuse aurora that stays constant for ~150 sec. The boundary is clearly defined and maintained throughout the observation from 18 January 2007, 02:44:28 MLT



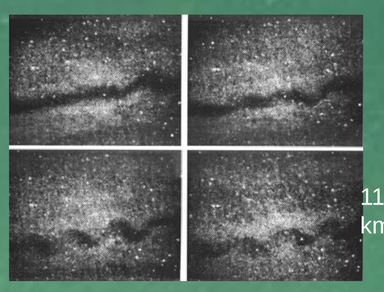
Takeaways:

- ➢ Pulsating patch turns on/off, moves up against the black boundary
- ➢ Black curl structure reminiscent of vortex streets appears multiple times during event (see red box)
- ➢ Pulsating patch never crosses over the black boundary into the diffuse region

Black Curls

Images (right) taken by Trond Trondsen

- Black curls in diffuse background
- Horizontal width ~1-2 km
- Wavelength ~ 3-4 km



Both figures from Marklund et al [1997]

Images (left) from Davis [1978]

- Formation of curls attributed to charge sheet instability
- Intense divergent electric fields form as a result of excess positive space charge

Summary

A collection of observations from the ROPA rocket campaign is presented and supports the widely held notion that black aurora are commonly seen in the midnight sector late recovery phase. The noteworthy observations include:

- ➢ ***Black aurora between patches of pulsating aurora that pulsate with different periods***
- ➢ ***Black aurora between diffuse and pulsating aurora***
- ➢ ***The first reported observation of black curls in conjunction with pulsating aurora***

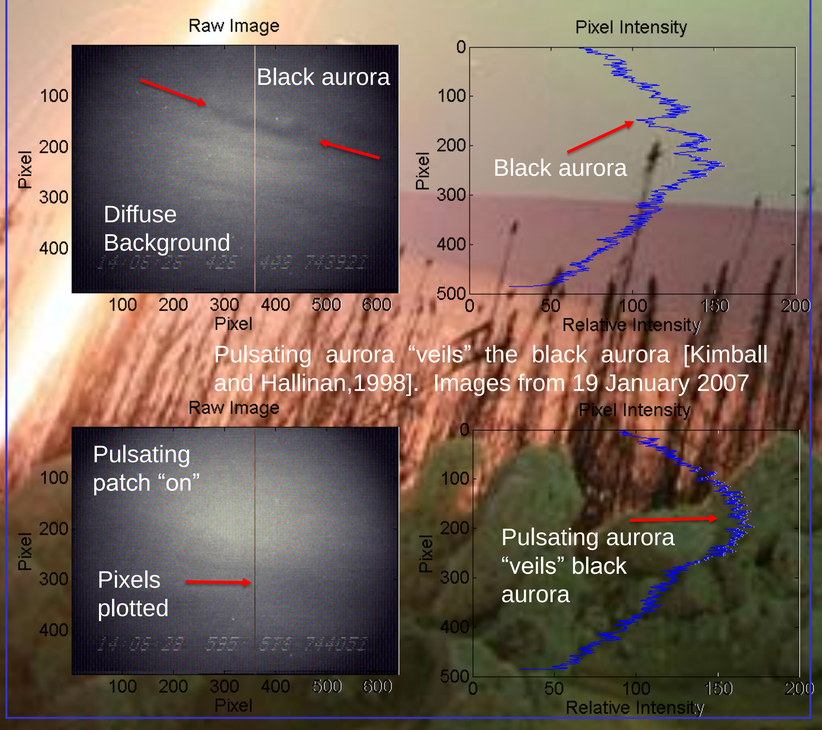
The observations shown here suggest that the ionosphere may play an active role in defining the behavior of black aurora in conjunction with pulsating aurora.

- ➢ Black curl structure in conjunction with pulsating aurora supports the notion of a return current structure in the ionosphere
- ➢ Black aurora separating diffuse aurora and pulsating aurora shows that black aurora can separate two events occurring at different altitudes

**It is important to note that this new behavior would not preclude the many other generating mechanisms of black aurora. This new behavior would be a driver of black aurora and other fine structure in the ionosphere in addition to previously reported mechanisms, not in place of them.

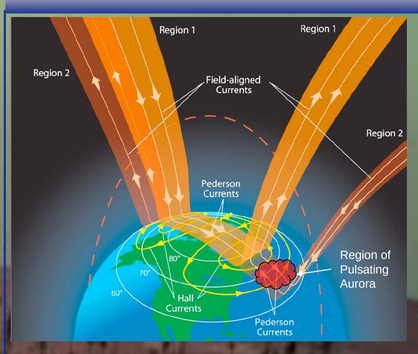
For more detail, full source list, please see Fritz *et al* [2015, accepted]

Veiling



Pulsating aurora "veils" the black aurora [Kimball and Hallinan,1998]. Images from 19 January 2007

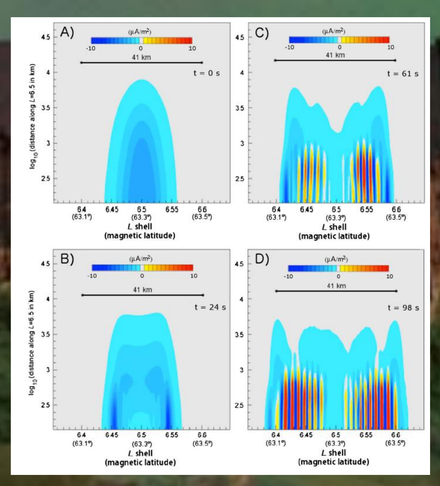
Ionospheric Feedback



Pulsating aurora is capable of producing enhanced conductivity in the ionosphere:

1. Energetic electrons flow along Region 2 FAC lines in pairs of current sheets [*Fujii et al.*, 1985]
2. Electric field will be modified if PA deposits enough energy [*Hosokawa et al.*, 2008]
3. Pedersen currents will flow in the D-region [*Hosokawa et al.*, 2010]

- ❑ Ionospheric feedback instability model [Atkinson, 1970] could provide a mechanism for fine structure in aurora
- ❑ Small-scale intense electric fields and currents resulting from ionospheric feedback may be found in density-depleted ionospheric regions accompanying downward FAC [*Streltsov and Lotko*, 2004]
- ❑ Results based on Streltsov and Lotko [2004] or similar models show the ability to reproduce fine-scale field structures measured by Cluster [*Streltsov and Marklund*, 2006] as well as sounding rocket measurements [*Cohen et al.*, 2013].



Model results from Cohen *et al.* [2013]

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