Low-latitude aurorae

Low-latitude aurorae are a storm time phenomena, in which particles originating from the ring current (and/or which are energized by the ring current) enter the lower thermosphere of the Earth's atmosphere, causing optical emission. It has been suggested (Rassoul et al., 1993) that four "pure" types of such auroras exist, as shown in table below, where LEE = low energy electron aurora, and HP = heavy particle aurora. Many auroral events are a mixture of these "pure" types. For example, type d aurorae is considered to be a subset of type A aurorae.

	*LEE (lowest)	LEE	HP Neutral	HP Ion	Non-pure types
Primaries	<10 eV el.	~10-1000 eV el.	~1-100 keV HP	~1-100 keV HP	mixed el. and HP
Auroral names	SAR arc	type d	neutral atom	ion, proton	low-latitude, type A, type I, great
Dominant emission	[OI] 630 nm	[OI] 630 nm	N2+1N (vib. exc.)	N2+1N (vib. exc.)	[OI] 630 nm or N2+1N (vib. exc.)
Red/green ratio r	>10	1 < r < 10	-	-	-
Location	near plasmapause	near plasmapause	equator to 40° ML	>40° ML	-
Emission rate	<10 kR	<1000 kR	<100 R	<10 kR	-
Time scale	~10 hours	~1 hour	~1 hour	~1 hour	-

* Here excitation by heat conducted from the magnetosphere is included

Low energy electron (LEE) aurora

Low energy electrons produce red aurora where the 630.0 nm oxygen O(1D) emission is stronger than other emissions. Because of the nature of the O(1D) emission these auroras are located at very high altitudes (200-1000 km). One should thus not confuse them with other red emissions from much lower altitudes. Two "pure" types exist, SAR arcs and type d auroras. They can be observed on field lines where the plasma sheet ove rlaps the plasmasphere.

Visually the most notable low-latitude aurorae are the type A red auroras which can be seen during the main phase of some magnetic storm s (and which is not a "pure" type, but is related to type d). The strongest events are referred to as great aurora. Type A red aurora resemble the SAR arcs because they most likely share the same energy source, the ring current (Robinson *et. al*., 1985; the whole scenario below is from this source). However, fundamental differences between the arc types can be seen, and they are due to the difference in the energy of the precipitating electrons (lower for SAR arcs). The type A red aurora is caused by a short-lived (5-10 min) burst of an intense flux of low energy (about 30 eV) precipitating electrons that is also capable of ionizing ionospheric plasma near 400 km altitude (and producing also other emissions than 630.0 nm). However, because of the time constants for heating of electron gas are short compared to the buildup of the ionization, initially the heat is distributed among fewer electrons and very high electron temperatures result. The temperatures can be thousands of degrees higher near the peak than those normally associated with SAR arcs (30 eV is a high energy when compared to, e.g., 5 eV!), and consequently also 630.0 nm emission becomes visible. As the ionization builds up, the heat is distributed among a larger and larger electron population and Te begins to drop. The 630.0 nm intensity, however, falls of only slowly because it is linearly proportional to the electron density. This partially offsets the decrease that would result from the lower temperature. When the burst of precipitation is over, the electron gas very quicly cools, but the ionization lingers for tens of minutes, resulting in enhanced 630.0 nm intensity with a comparable time constant. The very existence of 30 eV electron precipitation indicates more complicated mechanism to draw the energy from the ring current than with the SAR arcs, and acceleration by oblique ion cyclotron waves have been suggested (Robinson *et. al*., 1985).

A word of caution has been raised by Collis *et al.* (1991) and Rietveld *et al.* (1991) in connection with incoherent scatter radar measurements of **hi gh electron temperatures** during red auroras. They point out that the emissions are produced by intense field aligned fluxes of low energy electrons that create parallel electric fields in the horizontally poorly conducting F-region. These in turn produce thermal electron fluxes that carry strong (> 1000 mA/m-2) field-aligned currents (FAC). As it happens, the electron drift term describing the FACs is usually neglected in standard radar analysis. The authors show that the currents can be estimated from the asymmetric enhancement of ion-acoustic shoulders in the spectra. This finding does not, however, argue against the heating properties of described electron fluxes in the F-region.

Note also that although the high latitude dayside auroras exhibit also 630 nm red emission, they are related to precipitation of electrons of magnet osheath origin near local magnetic noon (cusp region).

Heavy particle (HP) aurora

The precipitation of energetic (~ keV) neutral atoms, originating from charge exchange between storm-time ring current ions and geo-coronal H and O, is found to be important from equatorial to mid geomagnetic latitudes (0-40°). In addition, the direct field-aligned precipitation of energetic ions from ring current is found to be important at magnetic latitudes above ~ 40°. Both the neutrals and ions produce emissions from states requiring excitation energies above 10 eV such as (OI) 777 nm and give rise to the vibrational/rotational development of the N2+ first negative band system.

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