## VLF Observations of Auroral Beams as Sources of a Class of Emissions

An interesting very low frequency (VLF) phenomenon which I shall call auroral V-emissions (AVEs) has been known for a number of years, although few reports have been published. The phenomenon has also been known informally as "short saucers" and "splashes". The dynamic spectra of a collection of AVEs are shown in Fig. 1*a*. The AVEs shown here have a fairly low frequency minimum, near 0·5 kHz, and have time scales of the order of 10 s. The broader form at the upper part of the record may perhaps be an example of an AVE, but in this paper it will not be considered as an AVE. The name auroral V-emission is based on the region of observation and the V-shaped or hyperbolic spectral appearance. The hyperbolic shape is often quite symmetrical, particularly for the AVEs with shorter time scales. AVEs have only been observed in satellites, usually near the auroral zone. Noise bands with distinct intensity minima at harmonics of the local proton frequency are often observed at the centre of an AVE, especially for observations at relatively high altitude (3,000 km) and for AVEs with a low frequency minimum. The phenomena reported here have a much shorter time scale and a more well defined spectral appearance than the "V-type VLF hiss"[1,2].

Certain features of AVEs suggest that the frequency versus time spectral form is the result of a spatial distribution of energy as a function of frequency rather than of a temporal variation resulting from dispersive propagation. The close association of AVEs with the auroral zone, the similarity of AVE forms from orbit to orbit and the time sequence of AVE appearance in the records over a limited time interval (usually in a range below one or two minutes) suggest the stationary spatial form. The natural suggestion for an AVE source is thus an auroral beam. The main features of the spectral shape of the auroral V-emissions can be explained by assuming a limited region of generation along the auroral beam (perhaps at the altitude of break-up of the beam) and propagation near the resonance cone to the satellite, each frequency having a unique ray path to the satellite.

It would, of course, be of interest to detect the presence of auroral beams directly from the VLF recordings. One possible advantage of such observations is that possible electrostatic beam modes could extend the range of observation so that the beam would not have to be intersected by the satellite in order to be observed. Because electrostatic modes might be involved, and because AVEs are observed more frequently from satellites with electric antennae, the Alouette satellite with its large electric antenna makes an ideal platform for such observations.

Fig. 1*b* shows a sequence in which a number of impulse-like forms appear, usually in conjunction with AVEs. In the sequence shown, most of the strong and broad impulses seem to be associated with AVEs. I shall interpret these impulses as beam modes. A possible beam mode is also seen in Fig. 1*a*, near the arrow. This beam mode is somewhat broader than most, lasting approximately 1 s. The minimum duration of observation of the beam mode is difficult to estimate from the records obtained so far, but is probably less than 0·05 s.

Examination of a number of AVEs shows that the beam modes are most frequently seen in conjunction with events whose minimum frequency is low. This is in accordance with a theoretical development which indicates that the frequency of the minimum of the AVE is an increasing function of the minimum distance from the satellite path to the source beam. When the satellite approaches the beam very closely, the frequency of the minimum of the AVE is thus quite low.

Sometimes a given AVE seems to show (presumably) spatial variations, with discontinuities at a sharply defined instant. Frequently an impulse is observed at the discontinuity. This impulse is probably from an auroral beam, but may result instead from a discontinuity of the electric field associated with a rapid electron density change. Fig. 1*c* shows an AVE with obvious proton harmonic bands and a number of beam modes. To the left of the beam marked by the arrow the upper frequency of the bands shows a rising characteristic, while the bands are very uniform to the right of the arrow.

Some of the beam modes seem to have a systematic broadening at the higher frequencies (see Fig. 1*a*, for example). If the beam modes are observable to a certain fraction of a wavelength from the beam itself, one might expect the wavelength to decrease with increasing frequency. The beam modes are, however, most likely

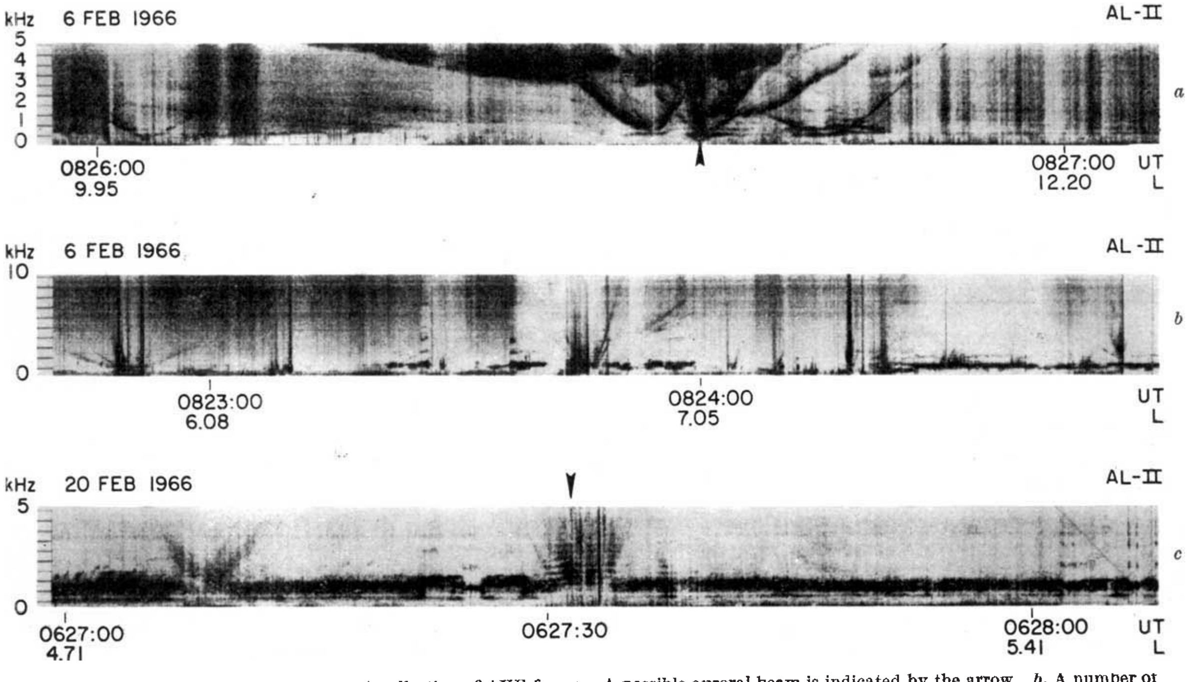


Fig. 1. Auroral V-emissions (AVE). *a*, A collection of AVE forms. A possible auroral beam is indicated by the arrow. *b*, A number of auroral beams associated with AVEs. *c*, An auroral V-emission with associated proton harmonic noise bands (harmonics occur at intensity minima). A discontinuity in the band structure appears at the beam indicated by the arrow.

connected with the resonance cone where the refractive index changes rapidly with frequency and propagation direction. By making the assumption that the beam is monoenergetic, one finds that the transverse wavelength actually increases with increasing frequency, especially for low plasma frequencies.

In any case, direct observations of an auroral beam with VLF electric field sensors in a satellite make possible measurements of an upper limit of the dimensions of auroral beams. For some of the impulses seen in Fig. 1 this upper limit is approximately 700 m.

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## Chromospheric Flare Enhancements in the Extreme Ultraviolet and their Relationship with Solar Abundances

Hall and Hinteregger[1] have discussed the enhancement of the extreme ultraviolet (EUV) intensities of spectral lines during the near-maximum stage of a class 3 flare. Here I suggest a relationship between the enhancement of a given line and the abundance of the element from which it is radiating.

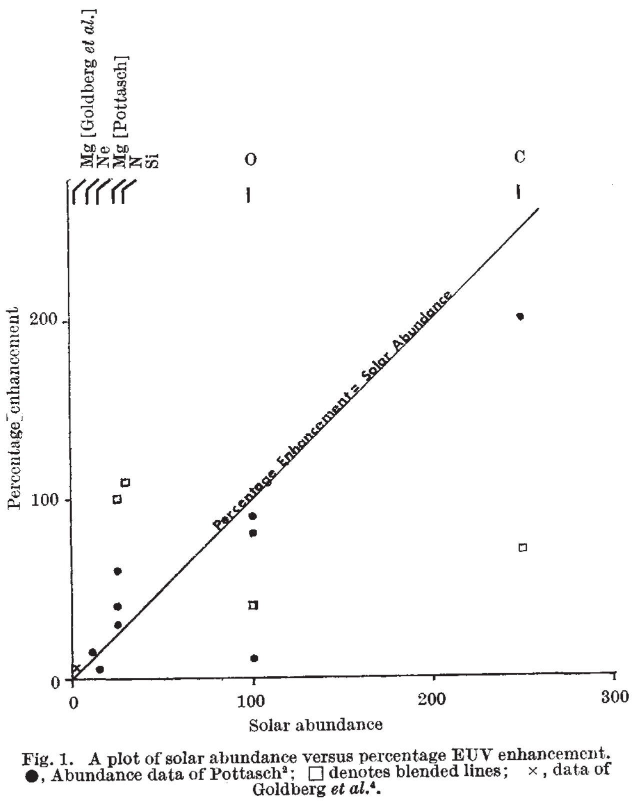


Fig. 1. A plot of solar abundance versus percentage EUV enhancement. ●, Abundance data of Pottasch[2]; □ denotes blended lines; ×, data of Goldberg *et al.*[4].

Table 1. LINES ENHANCED NEAR MAXIMUM OF 3-FLARE

| Wavelength (Å) | Ion | Per cent enhancement |
|---|---|---|
| 1238·8 | N V | 30 |
| 1215·7 | H I | 18 |
| 1206·5 | Si III | 110 |
| 1175 group | C III | 200 |
| 554 group* | O IV | 120 |
| 1085 group | N II | 60 |
| 1031·9 | O VI | 40 |
| 1025·7 | H I | 10 |
| 990 group | N III | 100 |
| 977·0 | C III | 70 |
| 972·5 | H I | 14 |
| 949·7 | H I | 13 |
| Contin. at 911 | H I | 20 |
| Contin. at 834 | H I | 30 |
| 833–835 group | O II, III | 90 |
| 790 group | O IV | 80 |
| 765·1 | N IV | 40 |
| 760 group | O V | 80 |
| 629·7 | O V | 10 |
| 584·3 | He I | 7 |
| 465·2 | Ne VII | 15 |
| 368·1 | Mg IX | < 5 |
| 303·8 | He II | 7 |

* Measurement made in second order.

Table 1 lists the measured enhancements. The data for hydrogen and helium are ignored, first because of their very high relative abundances and second because variations in hydrogen line intensities in flare regions are very small in comparison with the total output of hydrogen line radiation.

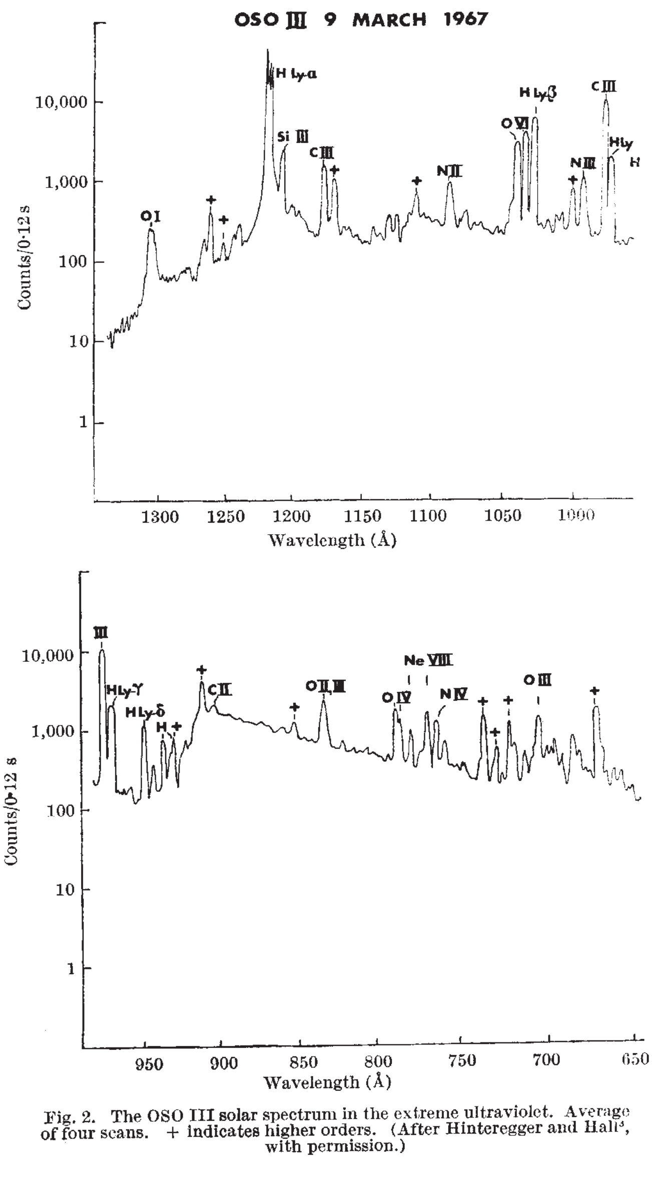


Fig. 2. The OSO III solar spectrum in the extreme ultraviolet. Average of four scans. + indicates higher orders. (After Hinteregger and Hall[1], with permission.)