Professor Lars Vegard’s Contribution to Auroral Research

A sixty year odyssey of curiosity, patience, and determination

by

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The Span of Years

- Lars Vegard
- Born 1880
- Died 1963
- 8 Sunspot Cycles
- Nos. 12 – 16 at turn-of-century low.
- Nos. 17, 18 & 19 grew to largest observed.
Preparations
Gjøahavn, 31 Oct. 1903

- As Vegard Birkeland and Størmer watched the great aurora of 31 Oct., Amundsen no doubt stared in amazement at the first magnetogram at Gjøahavn.
E-mail from the Solar System

• The particles from the sun activate the magnetosphere to accelerate magnetospheric particles to make aurora.
A series of events began on July 10, 2000, culminating in the large flare of July 14. The X-ray flux was large enough to disturb the imagers on the SOHO satellite.
A halo coronal mass ejection (CME) was associated with the flare and the ejecta near the sun were spectacular.
The wide angle coronagraph followed the ejecta even farther from the sun. This material propagated an invisible shock wave toward Earth.
A model of the solar wind shows the interplanetary shocks associated with the events of July 10 - 19, 2000. The Sun is at the center and the Earth is the green dot.
Auroral Sequence on July 15th

The aurora in the northern hemisphere is visible here in the ultraviolet observation from the IMAGE satellite. Watch for the pressure pulse aurora after 1600 UT.
The Biggest Show on Earth
Geographic Pattern of the Aurora

Discrete Aurora

Morning

Diffuse Aurora

Evening
Color from the Earth’s Atmosphere

Auroral Spectrum

Solar Spectrum

Professor Lars Vegard’s Contribution to Auroral Research
Classify According to Color

- Type A - crimson upper border
- Type B – magenta lower border
- Type c – green arc
- Type d – red overall
- Type e – magenta and green lower border
- Type f – blue or purple
Classify According to Color

Type B
Magenta
Lower Border

(c)2003 Jeff Pederson
Classify According to Color

Type c
Normal
Green, Gray
Classify According to Color

Type d
Great
Red
Aurora
Classify According to Color

Type e Magenta Moving Ahead Of Green
Classify According to Color

Type f
Blue or Purple
Sunlit Aurora
Vegard defined the first two classifications.

Type A is associated with Solar maximum and low latitude aurora.

Type B is associated with Solar minimum and high latitude aurora.

Professor Lars Vegard’s Contribution to Auroral Research
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Vegard’s Auroral Research

Monthly Average Sunspot Numbers

- Latitudinal Variations of Auroral Emissions/Birkeland-Stoermer Theory
  ">500 lines & bands identified in the auroral emission spectrum"
- Hydrogen Emission in Aurora
  Red Line = 6300 Å
- Vegard - Kaplan Bands in Lab (by Kaplan)
  'Green Line = 5577.35 Å
- N2+ Rotational Temperature of Aurora
- N2 Epsilon Bands in Aurora
- N2 Epsilon Bands in Lab
- Auroral lat., long., alt., & penetration
- Green Line close to 5577 Å

Professor Lars Vegard’s Life

1880 1890 1900 1910 1920 1930 1940 1950 1960 1970
Bossekop Field Trip, Winter 1912-13

• Vegard and Krogness spent the winter of 1912-13 at Bossekop and Haldde to measure the aurora using parallactic photography.
Bossekop, The Field Trip

- The Bossekop – Halde baseline for parallactic photography is 12.4 km
Bossekop, The Field Trip

• Vegard’s station was at the Bossekop field station.
• It had been part of the International Polar Year network.
Bossekop, The Field Trip

- Krognness held forth at the Haldde field station.
- It was more exposed and not as good for spectrographic work as Bossekop.
Parallactic Photography

- Two cameras located 5 to 50 km apart
- Communications between photographers
- Photographers agree on exposure time and direction
- Line up star fields
- Measure distance between points on auroral form.
Parallactic Photography

- Showing photograph pair number 348 with stars superimposed and distances between forms marked at parts of the images that are recognizable from both stations.
Arc Altitude

- Distance to the aurora is measured from two photographs.
- Altitude above ground is found by trigonometry from angles and distance.
• Distance on pictures between two points is proportional to distance from observer to aurora.

• Vegard wanted to know if he could reproduce the various arc lengths with different energetic particles.
Charged Particle in Magnetic Field

- Vegard understood the motion of charged particles in magnetic fields.
- He calculated how far the particles would penetrate the atmosphere and compared it to his measurements of arc lengths.
Vegard compared the observed arc lengths with what would be expected from different particles of different energy. Unfortunately he had relatively few sources of energetic particles available to him so it was impossible to differentiate any one of them as the cause of the aurora.

- **Alpha particles**: Ionized He atoms
- **Beta particles**: Electrons
- **Gamma rays**: EM waves
- **Kathode strahlen**: Electrons
- **Kanal strahlen**: Ions
Auroral Arc Alignments

- The Birkeland – Størmer theory, however, suggested that the auroral precipitation zone would have a spiral shape.
Auroral Arc Alignments

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Auroral Arc Alignments

- The Birkeland – Størmer theory, however, suggested that the auroral precipitation zone would have a spiral shape.
- So Vegard measured arc alignments.
International Polar Year

- Because Bossekop was an IPY station, there was a data set that included measurements from all around the pole.
- Bossekop was a candidate for Nordlysobservatoriet.
IPY Dirunal Occurrence Frequency

- Vegard gathered the data from around the pole and determined the average diurnal variation of the occurrence and arc alignment.
- It was not conclusively in support of the Birkeland – Størmer theory.
IPY Auroral Arc Alignment

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THE POSITION IN SPACE OF THE AURORA POLARIS
FROM OBSERVATIONS MADE AT THE HALDDE-OBSERVATORY
1913–14

BY
L. VEGARD AND O. KROGNESS

IN MEMORY OF OUR TEACHER
KR. BIRKELAND

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Professor Lars Vegard’s Contribution to Auroral Research
Vegard’s laboratory work revolved around reproducing the auroral emission spectrum.
Vegard in the Laboratory

• His trips to various laboratories in Europe led him to use the most advanced techniques.
• He was able to reproduce many of the emissions he observed in the aurora.
Vegard in the Laboratory

- His success in reproducing the auroral spectrum and in discovering the Vegard-Kaplan bands of $\text{N}_2$ by bombarding nitrogen crystals with electrons led him to believe that there was a layer of solid nitrogen particles in the atmosphere.
Vegard in the Laboratory

- Vegard discovered a forbidden band system of $N_2$.
- He called it the epsilon band (emission from the A state to the ground state $X$).
Vegard – Kaplan Bands

- Vegard observed the epsilon bands in the aurora.
- 2 years later, Joe Kaplan documented the exact level distribution in the laboratory.
Tromsø Geophysical Observatory

- Tromsø Meteorological Institute

Professor Lars Vegard’s Contribution to Auroral Research
New spectrographs with larger dispersion and aperture were designed and constructed for the establishment of a spectrographic auroral observatory in Tromsø.
• Access to the observation platform on the roof of the geophysical observatory was too small for the large instruments.

• The large spectrographic equipment had to be lifted up to the platform from below.
Tromsø Meteorological Institute

- The spectrographs could not be taken in out of the weather.
- Large canvas covers were fabricated to protect them.
• Vegard was enthusiastic about the possibilities for observing from Tromsø.
Professor Lars Vegard’s Contribution to Auroral Research

Latitude Variations: Oslo-Tromsø

- Vegard measured the difference in aurora between Oslo and Tromsø
- He found the red and green oxygen lines brighter in Oslo than farther north.
In 1925, Vegard received a grant from the Rockefellers to set up Nordlysobservatoriet. It was established in 1930.

Vegard headed the steering committee called Norsk Institute for Kosmisk Fysikk.
• Vegard and Einar Tønsberg pose with the new observing instruments on the platform at Nordlysobservatoriet
Nordlysobservatoriet I Tromsø

- A double wall was built to keep the large spectrograph warm
Fig. 1 c. Observation Platform with “stand” and instruments.
Auroral Spectrographs

• Vegard used various spectrographs throughout his career.
• He designed many new and faster instruments, but basically the only new technology he had at hand was the use of a new film for long astronomy exposures in the 1930s.
Changes in scientific instrumentation in the second half of the 20th century were not imaginable in Vegard’s time.
Temperature of the Aurora from $\text{N}_2^+$

- Vegard was the first to measure the temperature of the atmosphere in which the aurora occurs.
- He used the rotational structure of nitrogen bands.
- His long exposures prevented him from finding the variation with height.
Auroral Hydrogen Emission

- The detection of the hydrogen emission at 4861 Å was the first confirmation of the theory that the aurora was caused by energetic particles in electrically neutral rays.
Auroral Hydrogen Emission

- Horizon observations broaden but do not shift.
- Zenith measurements broaden and shift.
Auroral Hydrogen Emission

- Vegard had seen the Doppler effect since 1939, but did not have the sensitivity and resolution to see the Doppler shift.
Auroral Hydrogen Emission

- Carl Gartlein (shown with his assistant, Mrs. Gartlein) observed H emission in the September 1950 aurorae.
• Gartlein had the same problem as Vegard. His spectrographs were looking at the horizon so he measured Doppler broadening, but not Doppler shift.
Auroral Hydrogen Emission

- Aden Meinel used the new gratings blazed to reflect more light into a single order.
- He was able to record H emission in the zenith from Wisconsin in August, 1950.
“>500 Auroral Emissions”
Norway at the Turn of the Century

• Lars Vegard was a world-class scientist.
• He was at the same time *helnorsk.*