Intensity Variations of Auroral Hydrogen Lines and the Influence of the Solar Proton Radiation on the Auroral Luminescence

BY

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1. Introductory Remarks.

The geographical and diurnal distribution of auroae and polar magnetic storms shows conclusively, that the solar electric ray bundles forming them must be magnetically active and from distances, which are great compared with the diameter of the Earth, they must be deflected in the Earth's magnetic field essentially in the way shown by Birkelands experiments and Størmers theory of the motion of an electrified particle in the magnetic field of the Earth.

As shown in previous papers, dating back to 1916 (1, 2, 3), these conditions are fulfilled by a solar bundle composed of electrons neutralized by positive ions of great spezific charge (preferably protons), and it seems to be the only way in which the conditions can be fulfilled by a system consistent with physical laws and observed facts.

A direct proof of the correctness of this constitution of the solar ray bundles was given, when in 1939 it was found at Oslo that hydrogen lines occationally appeared strong on the auroral spectrograms and when in 1940—41 spectrograms were obtained at Tromsø showing the H_β line broadened and displaced towards shorter waves through Doppler effect (3, 4, 5, 6, 7, 8). *This means that protons form part of the solar ray bundles.* These results have been confirmed by later spectrograms combining a great light power with considerable despersion (9.10, 11, 12, 15). The results have also been confirmed in 1951 by Meinel (13) and by Gartlein (14).

It is evident, that the study of the aurorae and magnetic disturbances must be based on solar bundles composed of moving electrons, electrostatically neutralized by protons (and possibly other positive ions eg. highly ionized sodium atoms).

2. Properties of the Neutralized Solar Bundle.

In the paper from 1916 referred to (1. p. 871) it was found, that if the solar bundles were composed of particles with the same signofcharge, the *mutual electromagnetic attraction between the moving* elctrified particles could not compensate the *mutual electrostatic repulsion*. Only if the ray velocity approached that of light the electromagnetic attraction might be nearly of the same order of magnitude as the electrostatic repulsion. *Thus the stabilisation requived that the bundle was composed of a mixture of positure and negative particles.*

In later papers (e. g. 3. p. 612) it was stated, that the electrostatically neutraliced solar bundles were constituted like the long narrow election ray bundles produced in vacuum tubes, c. g. like those used by Brüche (30) for illustration of Størmers auroral Theory. The bundle is electrostalically mentralized by positive ions, and we know, that the mutual electromagnetic attraction is essential for the formation and maintenance of its small cross section, *and thus this electromagnetic focussing effect is a property attached to the neutralized solar bundles.*

We consider the simplest bundle composed of electrons and protons. In a neutral bundle unit volume contains an equal number (n) of electrons and protons.

Let ν_p and ν_e be the number of protons and electrones crossing unit are a perpendicular to the

* A summary of this paper was given at the Xth General Assembly of I.U.G.G. at Rome Sept. 18th, 1954.

direction of the bundle (the proton and electron flux) with velocities V_p and V_e, then:

$$\left.\begin{array}{l} \nu_p = n\ V_p \\ \nu_e = n\ V_e \end{array}\right\} \qquad (1)$$

and:

$$\nu^p/\nu_e = V_r/V_e \qquad (2)$$

Now the intensity of the hydrogen lines relative to the other auroral lines and bands, which are mainly due to electron excitation, will vary in about the same way as ν_p/ν_e.

This means that the great variability shown by the intensity of the H-lines is due to the variation of the proton velocity relative to that of the electrons.

The fairly irregular intensity fluctuations of H-lines from time to time no doubt are to be referred to the variability to be expected in the processes on the sun, which cause the emission of the ray bundles.

Statistically, however, we may expect that the relative proton flux (or the relative intensity of auroral H-lines) varies in some regular way with solar activity and the solar cycle. In free space the protons and electrons must stick together. The electric current (I) carried by the bundle may be expressed by intigrating the current density i over the cross-section of the bundle or:

$$\mathrm{I} = \int i do \qquad (3)$$

$$i = en\,(V_e - V_p)$$

The diviating force (K) acting on unit volume in a magnetic field of strength F is expressed by the formula:

$$K = en\,(V_e - V_p)\ F \sin\varphi = iF \sin\varphi \qquad (4)$$

where φ is the angle between F and the direction of the bundle.

Thus the neutralized bundle is magnetically active and is deviated in the magnetic field of the earth in a similar way as a single electrified particle or a current element.

From studies of the height and structure of aurorae it follows, that the electron-velocity is much greater than the proton-velocity (16,11), and thus *the magnetic field produced by the bundle, the electromagnetic contraction and the deviating force is dominated by the electron flux.*

In free space the condition of neutralization must be fulfilled and the protons must keep within the limits of the bundle. Consequently the protons will influence the magnetic deviability (or stiffness) of the bundle. Suppose protons with a velosity V_p and electrons with a velocity V_e were free to move perpendicular to the lines of force of a homogeneous magnetic field, then:

$$\varrho_p/\varrho_e = \frac{M_p\ V_p}{M_e\ V_e} = 1800\ V_p/V_e \qquad (5)$$

where ϱ_p and ϱ_e is the radius of curvature of the protons and the electrons respectively. Thus if V_p is greater than $V_e/1800$, ϱ_p will be greater than ϱ_e. For ordinary aurorae coming down to about 100 km ν_e is equal to about $6\ 10^9$ cm/sec. (Cfr. papers 11 and 16) and $\frac{V_e}{1800} \approx 3\ 10^6$ cm/sec.

The Doppler displacements of the auroral H-lines give proton velocities of the order 1—3 10^8 cm/sec. and the magnetic stiffness of the protons may be as much as a-hundred times greater than that of the electrons.

Thus, while the magnetic field produced by the bundle, the contraction or focussing effect and the deviating force is mainly due to the electrons, the magnetic stiffness is dominated by the protons.

3. The Enhancement of Auroral H-lines with Increasing Distance from the Magnetic Axis Point.

According to Størmers theory the distance from the magnetic axis point to the spot, where the electric ray passes into the atmosphere increases with magnetic stiffness. Thus an increase of proton velocity should increase the magnetic polar distance of the aurora. On the other hand increased velocity means increased proton influx and increased relative intensity of the auroral hydrogen lines.

From 1939—41, when the auroral hydrogen lines and their Doppler-displacements were detected and up to 1952 a number of strongly exposed auroral spectrograms were obtained both at Tromsø and at Oslo.

The intensities of the H_β-lines were found relative to the negative nitrogen band 4709. The mean value of the ratio $I(H_\beta)/I_{4709}$ was found to be 1,01 for Oslo and 0,15 for Tromsø. (17, 27)

During the last two winters spectrograms were taken at Oslo and at Tromsø with practically indentical spectrographs. The results were resently published by Vegard and Kvifte (28) and agreed with those given in the first papers referred to.

The relative intensity of the H-lines thus shows a very pronounced latitude effect in the way predicted by theory.

The same effect was found at Tromsø by means of spectrograms taken with the same spectrograph and on the same sort of plates(18). It was found that H_a might appear quite distinctly from aurorae on the southern while it was absent or faint from the northern sky.

4. Phenomena Connected with the Passage of Solar Ray-Bundles through the Ionosphere.

As soon as a ray bundle enters the upper atmosphere, where there are plenty of electrons and positive ions. the protons and electrons of the bundle will be free to move and to be absorbed independently of each other. The absorption of electron rays and various types of positive rays in the upper atmosphere have been treated in previous papers (Cfr. e.g. 16, and 11).

The two types of rays will as a rule be completely absorbed and stop at different altitudes. The distribution of light along the auroral streamers will be different, and the spectral composition of the luminescence they produce will also be different.

It will be understood that the passage of a neutralized bundle of electric rays will account for many of the numerous variability effects which have been previously detected.

In the following we are going to deal with certain variability effects, which may be due to the proton rays contained in the solar bundles.

The range in the atmosphere (stopping height) of electron and proton rays for different velocities and energies were given in the table III and IV of paper 11. It appears from these that in order to reach down to a certain height the protons require a much greater energy than the electrons.

Thus in order to reach down to a height of 100 km the protons would require an energy of about $19{,}10^4$ electron volts while the electrons only need about 10^4 e.v.

At the same time the electron-velocity would be 10 times as great as that of the protons. Thus in the equations 1—5 we can safely assume, that the electron velocity is much greater than that of the protons. Suppose -- what comes probably nearer to the truth — that the electrons and protons in the bundle have about the same energy. In the case of an aurora with its lower limit at 100 km the electron energy would be about 10^4 e.v., and with this energy the protons would stop at an altitude of about 130 km.

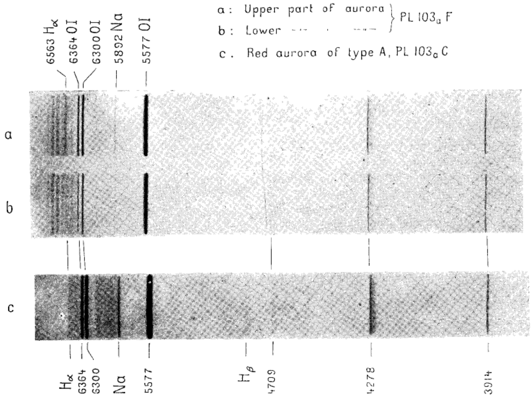
This separation of the protons and electrons in the bundle will greatly influence the distribution of ions in the upper atmosphere and produce ionospheric storms. Electric fields will be formed with the result, that protons will draw in electrons — and repulse positive ions, and the electrons, which reach down to lower levels, will draw in positive ions and drive away electrons. This will have a disturbing influence on the F_2 layer, which may be driven towards greater altitudes and even be made to disappear.

On account of the greater velocity of the electrons in the bundle, the electron flux (eq.1) is much greater than that of the protons, and during the auroral display and polar magnetic disturbance negative electricity is accumulating in the upper atmosphere, and may possibly account for the fact, that the earth on an average is negatively charged.

Through the combined effect of the electron and proton flux electric currents with corresponding magnetic fields will be produced in the conductive layers. They will be spread out over great areas and accompanied by mass transport, which may account for the ionospheric winds.

5. The Distribution of the Intensity of the Hydrogen Lines with Altitude.

The Hydrogen lines are emitted after the proton of the solar bundle has been neutralized by the attachment of an electron, and in this state the motion of the proton is no longer controlled by the magnetic field. The neutral light-emitting-protons are moving in all directions. The broadening of the H-lines through Doppler effect shows, that the maximum velocity perpendicular



to the magnetic lines of force is of the order of 10^8 cm/sec., indicating that many of the protons before neutralization are moving in screw lines round the magnetic lines of force. For we know from the study of canal rays, that they are continually neutralized and rechanged without any essential loss of energy.

If we follow the proton rays downwards from the extreme upper limit of the atmosphere, the intensity of the H-lines pro unit length of path first increases to a maximum and then decreases to the height h_p, where the rays stop. It is, however, to be remembered that the height h_p, the height of the maximum of the H-emission and details with regard to the intensity distribution of the H-lines upwards, will depend on the velocity distribution of the protons and the way in which their orbits in each special case is influenced by the earth's magnetic field.

Apart from details we have good reason to believe, that for most aurorae the stopping height (h_p) of the protons is considerably greater than that of the electrons. If this is so, we should find, that the intensity of the H-lines on an average increases with altitude along the auroral streamers.

By means of a new large spectrograph combining the high light power of $F : 0{,}65$ with fairly good despersion and sharpness of lines, we have taken spectrograms in rapid succession from the lower and from the upper part of the auroral streamers, and we find, that even at Tromsø somewhat strongly exposed spectrograms from the upper part show the H-lines (usually H_a-) very marked, while spectrograms from near the bottom edge show either no H-lines or they are extremely weak.

A series of such spectrograms showing both the enhancement of H_a with increasing altitude and decreasing latitude were described in a note to Nature (18).

The altitude effect of H_a is also shown on the figure, where spectrograms (a) and (b) correspond to the upper and lower part of an aurora.

Since these preliminary results were published a considerable number of spectrograms have been obtained at Tromsø, showing a very pronounced enhancement of the hydrogen lines with altitude. Details with regard to these spectrograms and the conclusions to be drawn will be given in a paper, which is soon ready for publication.

6. The Influence of the Solar Proton Radiation on the Composition of the Auroral Lumniescence.

It is well known from laboratory experiments, that the spectra produced by positive rays (Canal rays) differ essentially from those produced by electron rays. Thus the nitrogen canal ray spectrum shows more and stronger atomic lines than a nitrogen spectrum excited by electrons. (19).

In connection with the method of measuring the ionospheric temperature by means of the intensity distribution of rotational nitrogen bands appearing in the auroral spectrum, it is of interest to notice, that proton-spectra also differ from those excited by electrons with regard to intensity distribution of vibrational and rotational series of nitrogen bands.

Up to the present our measurements of ionospheric temperatures have been based on nitrogen bands belonging to the 1st negative group, which we indicate by (N_2^+ $1N$).

The influence of the excitation process on the intensity distribution of vibrational and rotational band series of (N_2^+ $1N$) has been the subject of investigations by Vegard and collaborators (20, 21, 22).

The Influence of protonexcitation on the Intensity Distribution of Vibrational Bands of the (N_2^+ $1N$) System.

The investigations referred to showed that the intensity distribution of the vibrational bands of (N_2^+ $1N$) excited by positive rays, differed considerably from that of bands excited by electrons. Thus the intensity of the bands of a sequence was found to deminish much more slowly with increasing quant number with positive-ray excitation.

In certain cases auroral spectrograms have been obtained, which showed a similar slow dimution with increasing quant number within a sequence of vibrational bands. One was taken by Lord Raylegh in 1922, one by Størmer in 1938, both at fairly low latitudes (23,24). Størmers spectrogram was obtained at Oslo from blue rays situated at the great altitudes from 400 to 650 km. The intensities were measured for the two sequences n''—n' = 1 and 2, and compared with the usual intensity distribution found by Vegard at Tromsø. The results, which are given in table 1, show that Størmers spectrograms deviates considerably from the usual ones in the way indicated.

TABLE 1.

Wavelenggth	$n' - n''$	Relative Intensity	
		Blue rays (Størmer)	Usual types (Vegard)
4708	0 — 2	100	100
4652	1 — 3	97	59
4596	2 — 4	85	44
4551	3 — 5	70	26
4278	0 — 1	100	100
4236	1 — 2	59	24
4200	2 — 3	35	8

Being now familar with the enhancement of the H-lines with increasing altitude and towards lower latitudes, and that excitation with protons enhance the bands of higher vibrational quant, numbers it is legitimate to draw the conclusion, that the peculiar intensity destribution in Størmers auroral spectrogram, as mentiones in a previous paper (22), simply means, that protons have played a prominent part by the excitation process.

The Influence of Proton Exictation on the Rotational Energy of the N_2^+ Ions and on the Apparent Band Temperature.

Among the results obtained by our investigations on the determination of gas temperatures by means of band-spectra (20) we may call attention to the following facts:

When the N_2-molecules were excited by electron rays at varying known gastemperatures, it was found that the temperature derived from the rotational R-branches of (N_2^+1N) bands—within the limit of error — was equal to the temperature of the gas surrounding the electron beam.

Excitation with positive rays, however, produced a considerable increase in the rotational energy of the molecular ions (N_2^+) with the result that the band temperature was found to be about 100° higher than that of the surrounding gas.

When the auroral spectrograms were taken from parts near the lower limit of ordinary aurorae, reaching down to about 100 km, most of the luminescence is due to electron excitation and thus the «band temperature» should give very nearly the temperature in the unexcited ionosphere at the height considered.

But taking into account that electron-excitation may slightly increase the rotational energy and that the auroral luminescence may be partly excited by protons, the band temperature should at any rate give an *upper limit* of the true ionospheric temperature.

In a paper recently published W. Petrie (25) deals with spectrograms of a similar unusual type as that obtained by Størmer at Oslo from an aurora situated at very great altitudes. The reproduction Petrie gives of the rotational R-branch of the ((0—0) band of (N_2^+ $1N$) shows at a glanse, that the intensity distribution corresponds to a much greater rotational energy and «apparent band-temperature» than that of the bands obtained by us at Tromsø.

This unusual intensity distribution is no doubt to be explained in the same way as that of the spectrogram taken by Størmer. The Petrie spectrogram is probably also taken at fairly *low latitudes and great altitudes*, which give great probability for intensive proton influx. The unusual type of spectrogram obtained by Petrie will be explained, if we assume that the luminescence is mainly due to proton excitation, which is shown to increase the rotational energy and give too high «ionospheric temperature».

Thus the spectrograms of Petrie does not interfere with or violate the correctness of the measurement of ionospheric temperature undertaken by us at Tromsø.

The quite extraordinary character of the Petrie auroral spectrograms is also shown by the unusually great intensity of the Vegard-Kaplan bands, indicating that these bands are enhanced by proton excitation.

Proton Excitation and Red Aurorae of Type (A).

The red colour shown by the red aororae of type (A) is due to the enhancement of the forbidden doublet OI ($^3P_{2,1}$ — $^1D_2$). It has been shown (26) that if the metastable state OI $^1D_2$ was only reached through the transitation OI ($^1D_2$ — $^1S_0$) — leading to the green auroral line (5577) — the ratio of the intensity of the red line OI (P_2 — $^1D_2$) (6300) to that of the green one could not exceed about 0,68. Under certain circumstances, however, the intensity of 6300 may be many times greater than that of the green line and we get a red aurora of type A, where the red colour extends to the very top of the ray-streamers.

When the ratio I_{6300}/I_{5577} is greater than 0,68 it means that an excitation process is operating, which brings the oxygen atom from the ground state $^3P_2$ directly to the $^1D_2$ state.

Now it has been found, that the red OI doublet is greatly enhanced towards lower latitudes and greater altitudes, and as previously mentioned the proton flux also increases towards lower latitudes and with increasing altitude. This very marked correlation suggests that the enhancement of the red OI-doublet producing red aurora of type A is due to proton excitation.

This explanation was confirmed in a striking way by a spectrogram taken at Tromsø 14th Nov. 1952 of a red aurora of type A.

At Tromsø the H-lines are usually very weak or absent and red aurorae of type A are very rare. *But the spectrogram shows at the same time the enhanced red OI-doublet and unusually strong hydrogen lines.*

Now it was previously found that the frequency of red aurorae of type A increases with solar activity. If our interpretation of the enhancement of the red OI doublet is right it means that also the average intensity of the proton flux increases with sunspot frequency. It is also of interest to notice hat the sodium D-line appears with considerable intensity, and we have reason to believe that also highly ionized sodium forms part of the solar electric ray bundles.

In this connection it is of interest to mention, that already in 1933 (29 p. 58). I suggested, that the red colour might be due to some change of properties of the cosmic electric rays.

On the spectrogram from the red aurora of type A (spectrogram (c) on the plate) the red doublet and the green line is too strongly exposed for accurate intensity measurements. Only for the weakest line 6364 of the red doublet the intensity can be estimated. But the intensity of the H-lines and the D-line were measured relative to that of the strongest (N_2^+ $1N$) bands.

The results are given in table 2.

TABLE 2.

Wavelength	Origin	Intensity
6561	H_a	39
6364	$OI\ (^3P_1 - {}^1D_2)$	600
6300	$OI\ (^3P_2 - {}^1D_2)$	Overexposed
5892	$NaI\ (D_1D_2)$	55
5577	$OI\ (^1D_2 - {}^1S_0)$	Overexposed
4862	$H\beta$	5,1
4709	$(N_2{}^+1N)\ 0 - 2$	7,6
4278	» $0 - 1$	24,4
3914	» $0 - 0$	38,4

Besides this spectrogram of red aurora of the *A*-type, we have obtained a great number of auroral spectrograms, which show a striking correlation between the intensity of the red *OI* doublet and that of H_a, which may be taken as an approcimate measure of the relative proton flux in the solar bundle.

In this connection it is also of interest to mention that the great intensity of the Vegard-Kapland bands on the Petrie spectrogram is most probably due to protonexcitation. As we know *the Vegard-Kapland bands correspond to a transition from the lowest metastable state to the ground state of the N_2-molecules.*

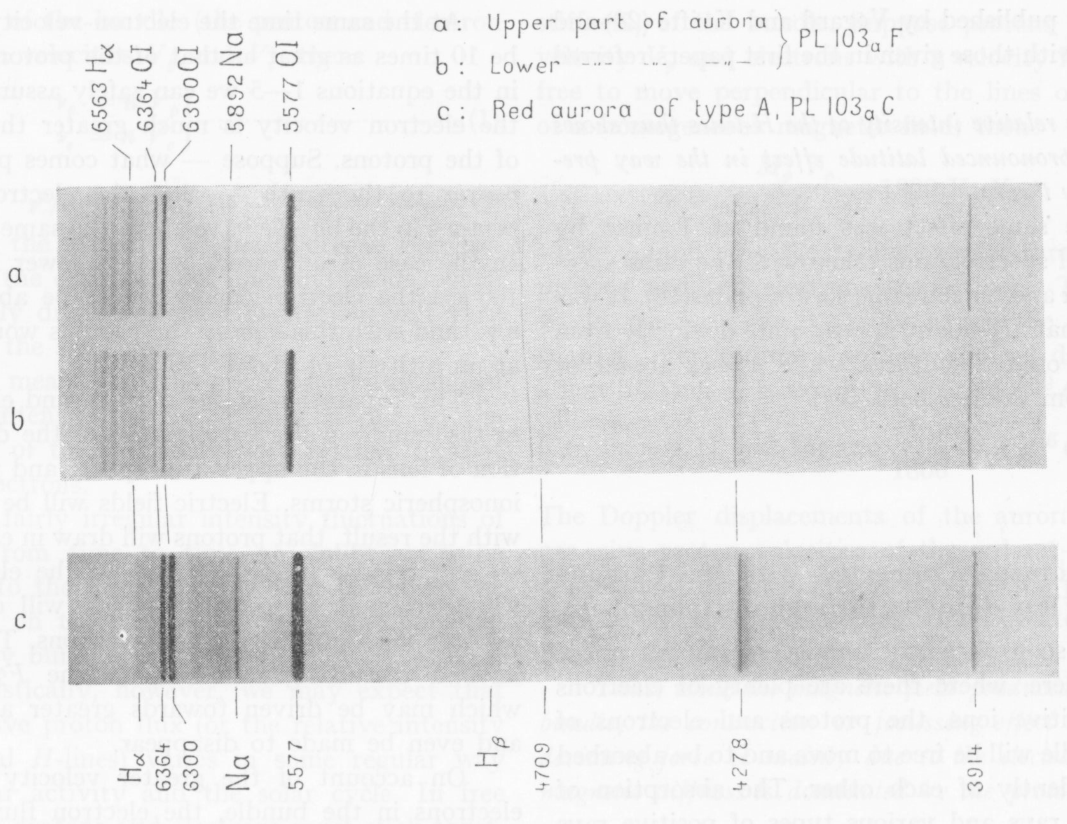
We also know that the forbidden *NI* doublet (5201, 5198), resulting from the transition from the metastable states $NI\ ^2D$ to the normal state ^4S of the neutral nitrogen atom, is greatly enhanced towards lower latitudes (15 p. 15), and probably also this enhancement may be due to proton excitation.

It seems as if proton excitation gives a great chance for transferring neutral atoms of oxygen and nitrogen or neutral molecules *from the normal state to the lowest metastable state,* and that the probability of transferring to the highest metastable states is much smaller.

These possibilities call for further investigations; but at any rate the results described show that *the great variability of the proton flux in the solar ray bundles may account for many of the numerous variability effects present in the auroral luminescence.*

List of papers.

1. L. Vegard: Ann. d. Phys. IV, 50, p. 853, 1916.
2. L. Vegard: Det Norske Vid. Akad. Skr 1928, No 2.
3. L. Vegard: Physics of the Earth. (Ed. by J. A. Fleming.) Vol. VIII, p. 573, 1939.
4. L. Vegard: and E. Tønsberg, Geofys. Publ. Vol. XIII No. 5, 1941; Vol. XVI, No. 2, 1944.
5. L. Vegard: Nature Vol 144, p. 1089, 1939.
6. L. Vegard: Phys. Soc. Gassiot Committee, Report, p. 82, 1948.
7. L. Vegard: Proc. of the Meeting at Brussels of the Mixed Comm. on Ionosphere July 1948, p. 111.
8. L. Vegard· Transactions of the Oslo Meeting of I.U.G.G. 1948, p. 189, 484.
9. L. Vegard: C R. Vol. 230, p. 1884, May 1950.
10. L. Vegard: Ann. d. Geophys. Vol. 6, p. 157, 1950.
11. L. Vegard: Doppler displacement of Auroral Hydrogen Lines and its Bearing on the Theory of Aurora and Magnetic Disturbances. Geof. Publ. XVIII, No. 5, 1951.
12. L. Vegard and G. Kvifte· Geof. Publ. XVIII, No. 3, 1951.
13. A. B. Meinel: Doppler-shiftet Auroral Hydrogen Emission. Astr. Journ. Vol. 13, No. 1, 1951.
14. C. W. Gartlein: Phys. Rev. Vol. 81, No. 3, p. 463, 1951.
15. L. Vegard and E Tønsberg: Geof. Publ. XVIII, No. 8, 1952.
16. L. Vegard: Phil. Mag. 42, p. 47, 80, 81, 1921.
17. L. Vegard: Nature, 170, p. 1120, 1952.
18. L. Vegard: Nature, 170, p. 536, 1952.
19. L. Vegard. Ann. d. Phys. 39, p. 111, 1913, and 41, p. 625, 1913.
20. L. Vegard; On the Determinitaon of Temperature by means of Band Spectra. Det Norske Vid. Akad. Avh. 1934, I, No. 12.
21. L. Vegard, Th. Ringdal, and A. Benedicks: Det Norske Vid. Akad., Avh. 1943, I, No. 13.
22 L. Vegard and H. Raastad: Geof Publ.. Vol. XVII, No. 7, 1949.
23. Lord Rayleigh: Proc. Roy. Soc. 101, p. 114 and 312, 1932.
24. C. Størmer: Nature, 1942, p. 1034, 1938 Terr Magn. 44, No. 1, 1939.
25. W. Petric: Journ. of Atmosph and Terrestrial Phys. Vol. 4, No 1/2, 1953.
26. L. Vegard: Geof. Publ Vol XII, No. 14, 1940.
27. L. Vegard: Procced. of the 3rd Meeting of the Mixed Commis. on the Ionosphere at Canberra (Australia). Aug. 1952. p. 135. Bruxelles.
28. L Vegard and G. Kvifte· Geof. Publ. Vol. XIX, No. 2, 1954.
29. L. Vegard: Geof. Publ. Vol. X. No. 4. 1833.
30. E. Brüche: Størmers Polarlichttheorie in Experimenten. Zs. Astroph., 2, 30 - 69, 1931.



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