PERGAMON

Journal of Atmospheric and Solar-Terrestrial Physics 64 (2002) 2013–2017

Journal of ATMOSPHERIC AND SOLAR-TERRESTRIAL PHYSICS

www.elsevier.com/locate/jastp

Argon auroral emissions

G.B. Burns[a,*], P.F.B. Williams[a], R.P. Lowe[b], W.J.R. French[a,c], P.A. Greet[a], D.P. Monselesan[d]

[a] *Space and Atmospheric Sciences, Australian Antarctic Division, Kingston, 7050, Australia*
[b] *Centre for Research in Earth and Space Technology, University of Western Ontario, London, Canada N6A3K7*
[c] *Institute of Antarctic and Southern Ocean Studies, University of Tasmania, Hobart, 7000, Australia*
[d] *IPS Radio and Space Services, Sydney, 2000, Australia*

Received 14 August 2001; received in revised form 16 January 2002; accepted 14 February 2002

Abstract

Argon is the third most abundant constituent of the atmosphere, but has not been previously detected by any ground-based optical remote sensing method. We report observation of argon emissions at λ840.82 and λ842.46 nm during intense aurora. These are most likely excited by direct electron impact. The maximum argon intensity observed is 270 R. Argon is the fifth elemental emission conclusively observed in geo-aurora, joining N, O, H and He.

Keywords: Argon aurora; Hydroxyl airglow

1. Introduction

Argon makes up, at the Earth's surface, 0.9% of the atmosphere by volume. Despite its relatively high abundance, argon has not been conclusively detected previously by any ground-based optical remote sensing method. Feldman et al. (2001) recently reported satellite observations of Far-Ultraviolet Ar lines in the dayglow at 104.8 and 106.7 nm, excited by resonant scattering of sunlight. A lack of spectral resolution in earlier FUV satellite, space-shuttle and rocket measurements had precluded separation of these lines from nearby N_2 and N emissions and led to doubt about attributing the features to Ar (Shefov, 1995). Only in situ measurements by mass spectrometers have been able to provide direct evidence of argon abundance throughout the atmosphere. In the altitude range from 90 to 150 km, the argon mixing ratio drops rapidly to below 0.13% due to a combination of two effects: diffusive separation above the turbopause and an increase in the fraction of atomic oxygen with altitude resulting from increasing photodissociation of molecular oxygen. Auroral electrons can excite atmospheric species in this altitude range. The higher the incident electron energy, the lower the atmospheric region principally excited.

Auroral emissions dominantly originate from N, N^+, N_2, N_2^+, O, O^+, O_2, O_2^+ and H (Vallance Jones, 1991). Excited states of these species are principally produced by electron impact or dissociative excitation of the major atmospheric constituents, except for the H emissions which are excited by proton precipitation. Helium auroral emissions have been observed, presumedly associated with weak He precipitation (Rees, 1989). Sodium emissions, which occur in airglow, have been reported with enhanced intensities associated with auroral particle precipitation although these observations remain controversial (Vallance Jones, 1974). The sodium atoms are deposited at auroral altitudes by meteor ablation. In the infrared spectral region, vibration-rotation spectra of NO, NO^+, O_3, etc. may be excited in aurora by energy transfer (Vallance Jones, 1991).

2. Observations and results

Since 1994, the infrared spectral region λ838–851 nm has been observed regularly at Davis, Antarctica (69.4°S,

* Corresponding author. Fax: +61-3-62323-496.
E-mail address: gary_bur@antdiv.gov.au (G.B. Burns).

1364-6826/02/$ - see front matter.
PII: S1364-6826(02)00077-9

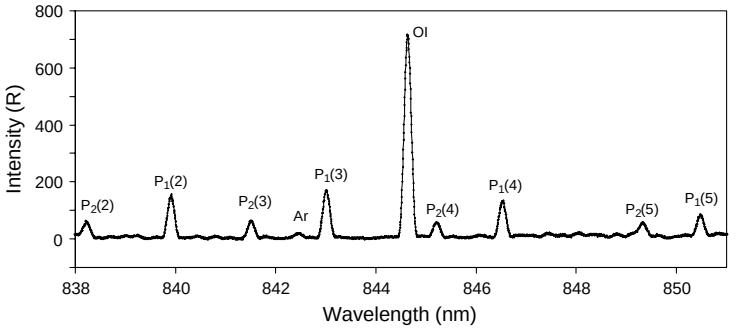

Fig. 1. Major emissions in the λ838–851 nm spectral region obtained by co-adding 45 spectra, each consisting of 5 scans, collected over intervals during which riometer measurements exceeded 1 dB absorption at 30 MHz thus ensuring energetic auroral precipitation in the vicinity of Davis.

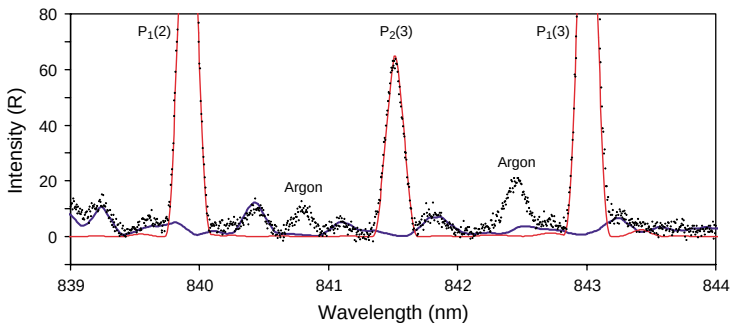

Fig. 2. Expansion of λ839–844 nm from Fig. 1, showing argon auroral emissions at λ840.82 and 842.46 nm. Synthetic fits to nitrogen aurora (blue line) and hydroxyl airglow (red line) are included. Nitrogen aurora across this spectral range is principally N_2^+ Meinel (4-2) band, with a minor contribution from N_2 1PG (3-2).

78.0°E) as part of a program for studying long-term trends in mesopause region temperatures through measurements of the hydroxyl 6-2 band night airglow emissions (Burns et al., 2002). A scanning, grating spectrometer of Czerny–Turner design is used for these measurements. Spectra presented here were collected during 1996 with 0.15 nm resolution, step-size of 0.005 nm and 6° field-of-view at the zenith. A co-located 30 MHz standard riometer with ~60° 'field-of-view' (defined by the −3 dB antenna pattern) measures cosmic noise absorption.

Fig. 1 shows the sum of 45 spectra, each consisting of five scans, collected when cosmic noise absorption in excess of 1 dB was measured during spectra acquisition. This noise absorption guarantees energetic auroral precipitation in the Davis vicinity. Co-adding is necessary to reduce the noise and background variability which results from the combined influences of scanning and rapid fluctuations in bright aurora. The absolute intensities of the recorded features are calculated by scaling the raw count rates based on the assumption that for the average 'clear sky' spectra collected at Davis during 1996 (a total of 1270 scans) $P_1(3)$ constitutes 11% of the total OH(6-2) band intensity of 1700 R (Krassovsky et al., 1962). Fig. 1 also shows that the auroral atomic oxygen multiplet at λ844.6 nm dominates the spectrum and that the airglow P-branch OH(6-2) emissions are significant.

Argon emissions at λ842.46 nm from the electronic transition $3p^5$ $(2P\langle 3/2\rangle)$ 4s–$3p^5$ $(2P\langle 3/2\rangle)$ 4p and λ840.82 nm from the electronic transition $3p^5$ $(2P\langle 1/2\rangle)$ 4s–$3p^5$ $(2P\langle 1/2\rangle)$ 4p are apparent in Fig. 2. Fig. 2 is an expansion of the λ839–844 nm wavelength region in Fig. 1. The background arises mainly from the N_2^+ Meinel (4-2) band with a minor contribution from N_2 first positive (3-2) band. These nitrogen bands are auroral features and are fitted by a synthetic spectrum, shown as a blue line (programs for synthetic auroral spectra by private communication, Gattinger; see also Gattinger and Vallance Jones, 1974). To fit accurately the measured experimental wavelengths, it was necessary to shift the theoretical values 0.12 nm toward longer wavelengths. A temperature of 300 K is used for the theoretical nitrogen auroral spectrum which has been convolved with a 0.15 nm full-width at half-maximum triangular instrument function with a rounded peak. It is quite apparent from Fig. 2 that the nitrogen auroral background features are well