Journal of Atmospheric and Terrestrial Physics, 1973, Vol. 35, pp. 2289-2291. Pergamon Press. Printed in Northern Ireland

SHORT PAPER

The effect of conjugate photoelectron impact ionization on the pre-dawn ionosphere

A. F. NAGY
Space Physics Research Laboratory, The University of Michigan,
Ann Arbor, Michigan 48105, U.S.A.

J. D. WINNINGHAM
The University of Texas, Dallas, Texas 75230, U.S.A.

and

P. M. BANKS
Department of Applied Physics and Information Science,
The University of California, San Diego,
LaJolla, California 92037, U.S.A.

(*Received* 28 *February* 1973)

Abstract—Theoretical calculations using photoelectron fluxes measured by a soft particle spectrometer on ISIS-2 as input data show that impact ionization by photoelectrons arriving from the sunlit conjugate region is insignificant in the ionization balance of the nighttime ionosphere.

SHAWHAN *et al.* (1970) suggested in this journal that photoelectrons arriving from a sunlit conjugate hemisphere may play a significant role in maintaining the ionization balance of a locally dark ionosphere. They arrived at the conclusion by calculating the arriving photoelectron flux (using the method of NISBET, 1968), which was then used to deduce the electron impact ionization rate. These calculations gave a height-integrated ionization rate in the range of 1–3 $\times$ 10^8 electrons cm^{-2} sec^{-1}.

The role of secondary ionization by photoelectrons arriving from the sunlit conjugate region was also studied by NAGY and BANKS (1970). In their study a height-integrated ionization rate of about 5–6 $\times$ 10^6 electrons cm^{-2} sec^{-1} was calculated, indicating that the photoelectron ionization process may be much less important than suggested by SHAWHAN *et al.* (1970).

Both of these works relied upon theoretically deduced photoelectron fluxes for the energy range above about 20 eV; however, it is primarily this energy range which controls impact ionization. Direct measurements of photoelectron fluxes for energies greater than 5 eV are now available from a soft particle spectrometer on ISIS-2 (WRENN and HEIKKILA, 1972a, b). In this note we use the measured photoelectron fluxes to show that ionization by photoelectrons is not sufficiently large to affect significantly the nighttime ionosphere. The measured downward photoelectron flux used in the present calculations is shown in Fig. 1. This flux was measured on 9 December 1971 at an altitude of 1400 km, when the local zenith angle was 159° and the conjugate zenith angle was 85·2°. The Solar Local Time of the measurement was 2342 and the subsatellite point was at +50·1°N and −99·7°W geographic

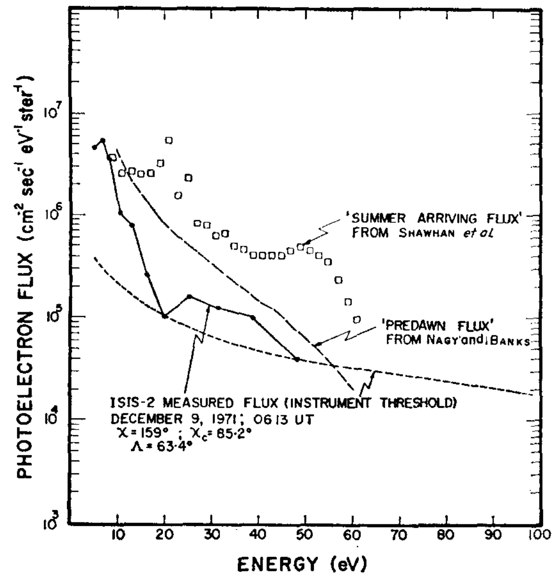

Fig. 1. Measured and calculated photoelectron fluxes.

coordinates. The corresponding fluxes used in the calculations of SHAWHAN *et al.* (1970) and NAGY and BANKS (1970) are also shown in Fig. 1 for comparison.

The flux measured by the ISIS-2 soft particle spectrometer was combined with topside sounder data (C. Pike, personal communication) and the BANKS and KOCKARTS (1973) 1000°K model atmosphere to calculate, in the manner of NAGY and BANKS (1970), the altitude variation of the predawn photoelectron flux and the resulting height-integrated impact ionization rate. The ionization rate was found to be $4{\cdot}7 \times 10^6$ electrons $cm^{-2} sec^{-1}$, which is too small to have any significant role in the ionization balance of the nighttime ionosphere.

Before any conclusions can be reached, the following points should be noted. The measured flux used in this calculation escaped from a conjugate hemisphere where the solar zenith angle was 85·2°, so one needs to establish that the flux does not increase significantly as the zenith angle becomes smaller. Calculations by FONTHEIM *et al.* (1968, see Fig. 1(a)), and SHAWHAN *et al.* (1970, see Fig. 4), as well as observations by WICKWAR and CARLSON (1971), indicate that changes in the conjugate flux are relatively small as χ becomes smaller than 90°. WRENN and HEIKKILA (1972b) give direct experimental evidence from ISIS-1 that the $\chi < 90°$ dependence is small.

It is also necessary to establish that this measured flux is 'typical'. To make such a decision one needs a large collection of relevant data which does not yet exist. However, based on the results of WRENN and HEIKKILA (1972b), there was nothing unusual about these results so they should be accepted as not atypical.

Finally, if this measured flux is accepted as typical, the question arises: why did the theoretical calculations predict much higher fluxes? Recent publications (SANATANI and HANSON, 1970; CICERONE and BOWHILL, 1971a, b; CICERONE *et al.*, 1972) have indicated that if only energy degradation by Coulomb collisions is considered in calculating the transport of photoelectrons from one hemisphere to the other, the arriving flux will be significantly over-estimated. The incorrect formulation of the effect of Coulomb collisions (SCHUNK and HAYS, 1971) and the neglect of pitch angle scattering by thermal electrons and wave-particle interactions could account for this overestimation. WRENN and HEIKKILA (1972b) using ISIS-2 data, indicate that loss to the protonosphere occurs predominantly at energies less than 20 eV.

In conclusion we find, using experimentally measured conjugate photoelectron fluxes, that the height-integrated ionization rate is so small that these secondary electrons cannot play a significant role in the ionization balance of the nighttime ionosphere.

Acknowledgements—The work reported herein was partially supported by NASA Grant NGR-23-005-015 and NASA Contract NAS5-11011 and Air Force Cambridge Research Laboratories Contract F 19628-72-C-0230.

REFERENCES

BANKS P. M. and KOCKARTS G.	1973	*Aeronomy* (in press).
CICERONE R. J. and BOWHILL S. A.	1971a	*J. geophys. Res.* **76**, 8299.
CICERONE R. J. and BOWHILL S. A.	1971b	*Radio Sci.* **6**, 957.
FONTHEIM E. G., BEUTLER A. E. and NAGY A. F.	1968	*Annls geophys.* **24**, 489.
NAGY A. F. and BANKS P. M.	1970	*J. geophys. Res.* **75**, 6260.
NISBET J. S.	1968	*J. atmos. terr. Phys.* **30**, 1257.
SANATANI S. and HANSON W. B.	1970	*J. geophys. Res.* **75**, 769.
SCHUNK R. W. and HAYS P. B.	1971	*Planet. Space Sci.* **19**, 113.
SHAWHAN S. D., BLOCK L. P. and FALTHAMMAR C.-G.	1970	*J. atmos. terr. Phys.* **32**, 1885.

Reference is also made to the following unpublished material:

CICERONE R. J., WICKWAR V. B., HEIKKILA W. H., CARLSON H. C, JR. and EVANS J. V.	1972	Paper presented at the Spring Annual Meeting of the AGU, Washington, D.C.
WICKWAR V. B. and CARLSON H. C.	1971	Paper presented at the 1971 Spring Meeting of URSI, Washington, D.C.
WRENN G. L. and HEIKKILA W. J.	1972a	Mullard Space Science Lab. Preprint.
WRENN G. L. and HEIKKILA W. J.	1972b	Paper presented at the Spring Annual Meeting of the AGU, Washington, D.C.