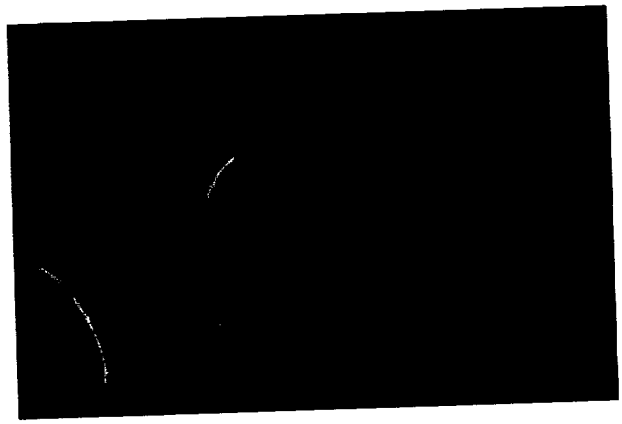
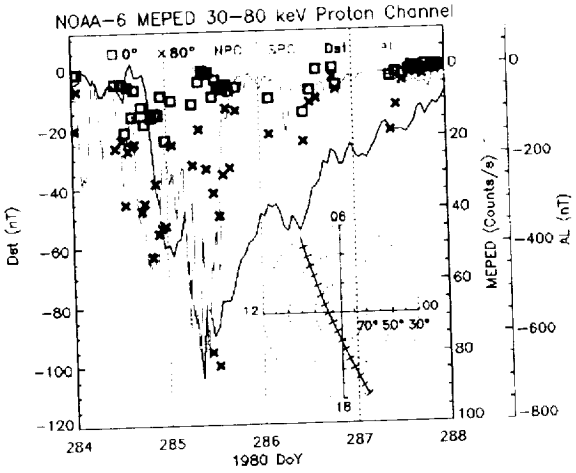
FINAL REPORT FOR THE NASA ISTP/SOLARMAX EXTENDED SCIENCE PROGRAM:

MULTIPOINT ENERGETIC NEUTRAL ATOM STUDIES WITH POLAR, GEOTAIL, AND TIROS

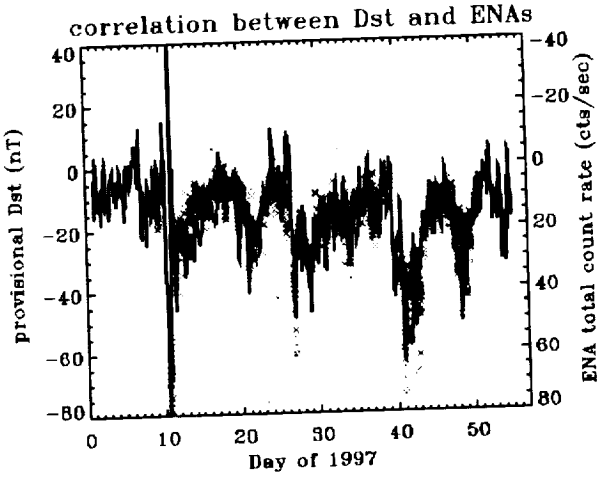
Principal Investigator: Harlan E. Spence
Associate Professor of Astronomy
Center for Space Physics and
Department of Astronomy
Boston University
725 Commonwealth Avenue
Boston, MA 02215

E-mail: spence@bu.edu
Phone: (617) 353-7412
Fax: (617) 353-6463





TIROS ENA Flux, Dst, and AL vs. time (Alothman et al., 2000)



POLAR ENA Flux and Dst vs.time (Jorgensen et al., 1997)

NASA Grant NAG5-8039
(BU Grant # 20-325-3894-5)
Period of Performance: 1/15/99-1/14/01

Final Report Summary of Research

This final report describes the efforts accomplished during the grant's period of performance, covering the period of 15 January 1999 to 14 January 2001, of a NASA ISTP/SolarMax Extended Science Program grant. We have completed many of the goals set forth in the proposed research objectives and our efforts in this research area continue in a related grant from NASA. Studies have been published and papers are being written, and numerous invited and contributed presentations of these studies have been presented at national and international meetings during the performance period. These studies are summarized below:

- **Multipoint Substorm ENA Analyses** – We have been excited by the ability of POLAR CEPPAD/IPS data to reveal new information about substorms. These early studies hinted at the power of using ENA data to image the elusive global substorm. We have continued modeling substorm ENA emissions in the context of increasingly sophisticated dynamic tail plasma models. This work was led by and reported in *Physics and Chemistry of the Earth* and *Advances in Space Research* by **Henderson et al. (1999; 2000)** with BU collaborations.

  The substorm ENA topic was also an essential component of the PhD thesis of BU graduate, Dr. Anders Jorgensen (now at LANL), who worked under my supervision. During the past year, he has completed additional studies on the temporal and spatial distribution of these emissions from a statistical approach, to complement the earlier case study approaches. A *Journal of Geophysical Research* paper supported by this effort (**Jorgensen et al., 2000a**) has recently been published. It demonstrates an unambiguous association of ENA emissions with classic substorm signatures measured by the vast suite of ISTP space-based and ground-based data. These include, for example, POLAR auroral images, ground magnetometer data, and geostationary particle data. The ENAs appear to be coming from the inner edge of the magnetotail (and its extension to low altitudes) during substorm expansion phase, produced through a combination of changes in the source ion distribution (temperature, density, and pitch angle) and possibly changes in the magnetic field topology.

  As a POLAR liaison to the IMAGE mission, I attended the August 1999 IMAGE Science Team Meeting and communicated early results of these now-published studies to that group. A project with Geotail investigator, Dr. Edmond Roelof, was identified at this meeting. That study was to explore further theoretical relationships between ENA fluxes measured by POLAR and the rate of change of Dst. This work capitalizes on the earlier work at BU reported by Jorgensen, A. M., H. E. Spence, et al. (Global energetic neutral atom (ena) measurements and their association with the Dst index, Geophys. Res. Lett., 24, 3173, 1997). That study has been completed and has recently appeared in the Journal of Geophysical Research (**Jorgensen et al., 2001**).

- **Low Altitude Imaging of ENAs** – We have continued a study of observations made by the low-altitude TIROS spacecraft, that we attribute to ENAs. BU graduate student, Mr. Mohamed Alothman, who completed his PhD degree last year, conducted the research on that project as part of his completed dissertation. We associated anomalous fluxes of energetic particles (>30 keV) observed when TIROS is in the polar cap and looking back toward the ring current, with ENAs. As was shown by Jorgensen et al. (1997), these fluxes track geomagnetic activity as measured by Dst and/or AL (see cover page for an example of this TIROS association). A paper summarizing these studies has been completed and was submitted to JGR. A revised version of that paper is still being worked by coauthors. This paper demonstrates the value of such low-altitude data to complement high-altitude ENA measurements. These data, using contemporary rather than archival TIROS measurements, could prove to be highly complementary to the IMAGE and TWINS missions. The low altitude data would add an

important dimension to the unambiguous deconvolution of the ENA images. A revised JGR manuscript of the TIROS study is nearing final stages for resubmission to the editor.

A second related effort involves the work of another recent BU PhD student, Dr. Andrew Stephan. His thesis used UV measurements from a low-altitude Navy satellite to infer ENA impacts of the upper atmosphere during recent geomagnetic storms. Several of these storms occurred during times when POLAR and GEOTAIL were in good positions for ENA imaging. A study based on that work is underway. We will show in that study the development of the ring current as a function of time and local time from high and low altitudes for the first time.

List of Inventions

No inventions were developed as a result of this research effort for the entire performance period covered in this report.

Publications

1. Henderson, M. G., G. D. Reeves, K. R. Moore, H. E. Spence, A. M. Jorgensen, J. F. Fennell, J. B. Blake, and E. C. Roelof, Energetic neutral atom imaging with the POLAR CEPPAD/IPS instrument: initial forward modeling results, Phys. and Chem. of the Earth, 24, 203, 1999.
2. Henderson, M. G., G. D. Reeves, A. M. Jorgensen, H. E. Spence, L. A. Frank, J. B. Sigwarth, J. F. Fennell, J. L. Roeder, J. B. Blake, K. Yumoto, S. Bourdarie, POLAR CEPPAD/IPS Energetic Neutral Atom (ENA) Images of a Substorm Injection, Adv. Space Res., 25 (12), 2407, 2000.
3. Jorgensen, A. M., L. Kepko, M. G. Henderson, H. E. Spence, G. D. Reeves, J. D. Sigward, and L. A. Frank, The association of energetic netural atom (ENA) bursts and magnetospheric substorms, J. Geophys. Res., 105, 18753, 2000.
4. Jorgensen, A. M., M. G. Henderson, E. C. Roelof, G. D. Reeves, and H. E. Spence, Charge exchange contribution to the decay of the ring current, measured by energetic neutral atoms, J. Geophys. Res., 106, 1931, 2001.
5. Alothman, M., T. A. Fritz, H. E. Spence, and R. B. Sheldon, Observations of energetic neutral atoms by the NOAA-Tiros satellites, submitted to JGR, 2000 (in review).