# TEMPORAL VARIATIONS OF THE ANOMALOUS OXYGEN COMPONENT, 1977 - 1984

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ABSTRACT

We present a survey of the long term temporal variations of 6.6-12 MeV/nucleon anomalous oxygen at 1 AU covering the period 1977-1984. This time interval included the recent solar maximum, with the recovery at neutron monitor energies beginning in 1982. During this time interval, 6.6-12 MeV/nucleon O fluxes decreased by at least a factor of 50, and indeed remained below our instrumental detection threshold after 1979. By late 1984, neutron monitors had recovered to roughly 1979 levels from the 1982 solar maximum, and anomalous O still remained below our detection threshold.

**1. Introduction.** The 1972 discovery of the anomalous components of He (4), N, O and Ne (1,5,8) added a new particle population to the set available to probe acceleration and transport processes in the heliosphere. Observed over the energy range from a few to a few 10s of MeV/nucleon during the 1972-77 solar minimum, these components display an unusual composition resembling neither galactic cosmic rays nor solar energetic particles. Of the many models suggested to explain the anomalous components, perhaps the most attractive is that by Fisk, Kozlovsky and Ramaty (3), who proposed that the particles begin as interstellar neutrals which are ionized and accelerated in the heliosphere, yielding a particle population in which high ionization potential elements are favored.

A key prediction of this model (3) is that the particles are singly ionized. However, a direct test of this prediction remains beyond the capabilities of any instruments flown to date. Temporal variations, however, may offer clues pertinent to this question. For example, a special temporal behavior has been predicted by Pesses, Jokipii and Eichler (10) in a model where the anomalous component is accelerated at the solar wind termination shock over the solar poles, and the particles subsequently flow down to the ecliptic plane. In this case, particle drifts yield a 22-year modulation cycle, and thus the component would not be expected to re-appear during the upcoming solar minimum. In order to probe these questions we present measurements of ~10 MeV/nucleon oxygen over the period 1977-1984, thus updating our previous report for the years 1974-79 (7).

**2. Instrumentation.** The measurements presented here were carried out in interplanetary space with the Ultra Low Energy Wide Angle Telescope (ULEWAT), which is part of the MPI/UMD experiments on the ISEE-1 and ISEE-3 spacecrafts. Figure 1 shows a cross sectional view of the ULEWAT, which identifies particle type and energy by the dE/dx versus residual energy method. For the particles discussed in this paper, the flow-through proportional counters P1 and P2 serve as dE/dx elements, and the silicon detector D1 is the residual energy detector. The

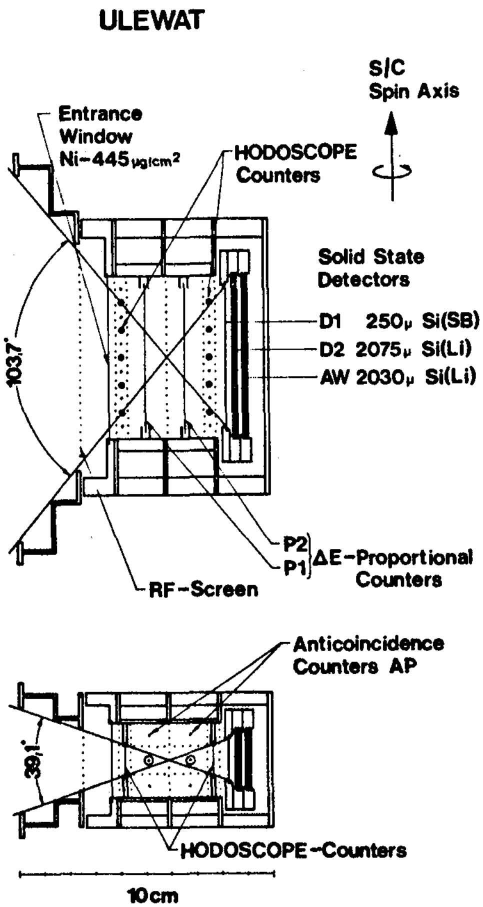


Figure 1

hodoscope detectors shown in the Figure permit correction of the ΔE signals for particles entering the telescope at different angles, thus allowing a wide opening angle while preserving instrument resolution. For the present study, particles with incident angles up to ~25$^{o}$ were accepted, resulting in a geometrical factor of ~1.3 cm$^2$ sr. A complete instrument description has been published elsewhere (6).

In order to remove the possibility of contamination by, e.g., solar flare particles, a strict criterion was adopted wherein observation times were used only if the counting rate channel for Z $\geq$ 6 particles above 300 keV/nucleon counted less than 30 particles in 24 hours of observing time. Assuming E$^{-3}$ spectra, this criterion extrapolates roughly to a level of 10$^{-4}$ particles/sec-m$^2$-sr-MeV/nuc at 10 MeV/nucleon, a factor of ~500 below anomalous O flux levels during solar minimum. Table 1 lists the observing time periods and number of hours observing time for each point. High levels of solar activity decreased the number of hours of quiet time in some intervals, and, after ISEE-3 was targeted for comet encounter, spacecraft tracking coverage was an important factor.

3. Observations. Figure 2 shows the fluxes and upper limits of 6.6-12 MeV/nucleon quiet time O during the survey period. Note that after the end of 1978, only upper limits are shown. In the figure, upper limit data points plotted with positive standard deviation bars indicate finite O measurements where the spectral information was not sufficient to conclusively identify the particles as part of the anomalous component. Points that are shown as upper limits only are 1-count upper limits. For comparison with the solar modulation at high energies, the lower panel shows 3-month averages of the Deep River neutron monitor as compiled from Solar-Geophysical Data. While the neutron monitor has been increasing since its 1982 minimum, by late 1984 it has not surpassed 1979 levels, and thus it is not surprising that even in 1984 anomalous O remained below our detection threshold.

Table 1

OBSERVATION PERIODS AND COLLECTION TIMES

| Spacecraft | Period | Hours | Spacecraft | Period | Hours |
|---|---|---|---|---|---|
| ISEE-1 | 10/26/77 - 12/30/77 | 343 | ISEE-3 | 7/01/81 - 12/31/81 | 635 |
| ISEE-1 | 01/01/78 - 08/08/78 | 368 | ISEE-3 | 1/01/82 - 06/30/82 | 734 |
| ISEE-3 | 08/14/78 - 12/30/78 | 784 | ISEE-3 | 7/01/82 - 12/31/82 | 758 |
| ISEE-3 | 01/01/79 - 06/30/79 | 709 | ISEE-3 | 1/01/83 - 07/01/83 | 1299 |
| ISEE-3 | 07/01/79 - 12/31/79 | 684 | ISEE-3 | 7/01/83 - 12/31/83 | 2058 |
| ISEE-3 | 01/01/80 - 06/30/80 | 1148 | ISEE-3/ICE | 1/01/84 - 06/30/84 | 418 |
| ISEE-3 | 07/01/80 - 12/31/80 | 686 | ISEE-3/ICE | 7/01/84 - 09/28/84 | 172 |
| ISEE-3 | 01/01/81 - 07/01/81 | 586 | | | |

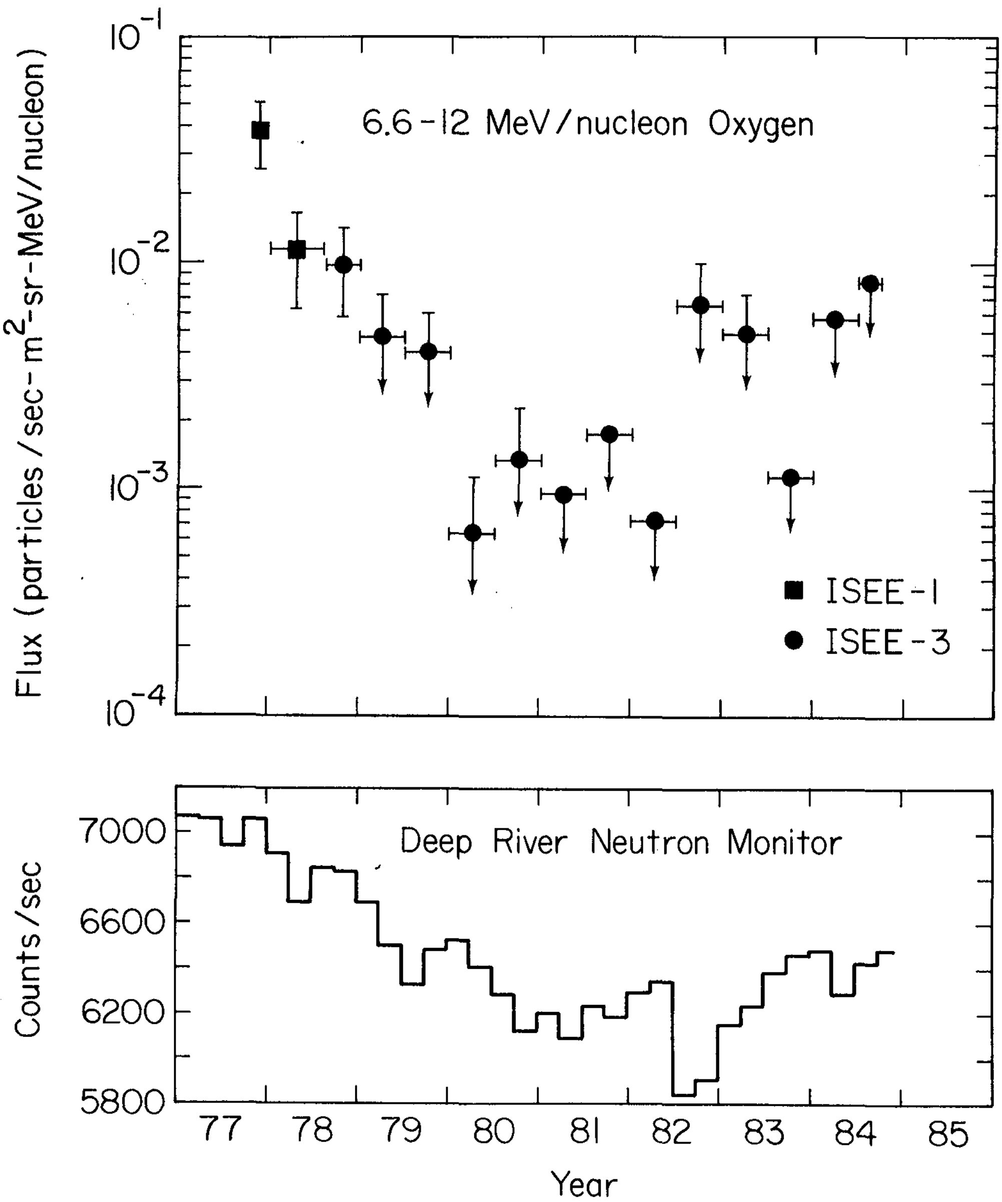


Figure 2

4. Discussion. From Figure 2 it is clear that at 1 AU anomalous O decreased by at least a factor of 50 between 1977 and solar maximum levels in 1981-82. This is much larger than the factor of ~10 observed for cosmic ray protons near 100 MeV (13), but is comparable to the factor of ~30 decrease in 10-20 MeV/nucleon anomalous He between 1977 and 1981 (9). The fact that the anomalous components show greater sensitivity to the solar cycle than galactic cosmic rays may be due to a combination of source (acceleration) and modulation effects; however, the unique spectral shapes of the anomalous components may also play an important role (11).

During the 1977-81 time period the ~10 MeV/nucleon O flux observed on the Voyager spacecrafts decreased also by a factor of ~50 (12), almost the same as the upper limits shown in Figure 2. However, since the Voyagers were at ~10 AU in 1981, the measurements cannot be directly compared with the results presented here. Indeed, since the anomalous He component has typically shown rather large positive radial gradients, the Voyager results could imply an anomalous O flux level at 1 AU a factor of 2 or more below our upper limits--yielding an overall modulation factor of >100 between 1977 and 1981.

Since the neutron monitors have not returned to levels at which our instrumental sensitivity would allow us to see anomalous O based on an 11-year cycle, we are not yet able to address the predictions of a 22-year cycle as in the model in reference (10). Recently, the anomalous O fluxes have been increasing at large distances from the sun (2), so it may be soon possible to address this question with measurements at 1 AU.

5. Acknowledgements. We are grateful to the MPI and UMD individuals responsible for the success of the ISEE instruments. This work was supported by NASA under contract NAS5-28704, grants NGR 21-002-224/316 and NAGW-101, by the NSF under grant ATM-84-07546, and by the Bundesministerium fur Forschung und Technologie, contract RV 14-B8/74.

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