

The Scientific Output of the *International Ultraviolet Explorer* during Its Lifetime

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The *International Ultraviolet Explorer* (IUE) was launched in 1978 and turned off in 1996. We measured the importance of its science by counting citations to the 3435 papers produced during that time. For fairness we counted citations for the same interval after the publication of each paper, namely six years. They show an increase of 61% during 1981-1994, indicating that the spacecraft was producing an increasing amount of important science until its operation was curtailed. Two-thirds of the increase is due to increasing numbers of papers and one-third to a partial shift toward extragalactic research.

1. INTRODUCTION

There are two general types of spacecraft. One is for a dedicated set of experiments, such as the lunar and planetary missions, which are operated by and for a team with specific goals. Another is for facilities open to all proposers, such as HST, Chandra, IUE, etc. The question arises as to how long spacecraft of the latter kind should be kept operational.

The *International Ultraviolet Explorer* (IUE) was a modest telescope of 0.45m aperture that illuminated a spectrograph having two wavelength bands at 1150-1950 Å and 1900-3200 Å, and a quantum efficiency of 10-15%. There were two dispersions in each band, one with a resolution of 6-8 Å and the other with 0.1-0.3 Å. It was operated jointly by the U.S. National Aeronautics and Space Administration (NASA), European Space Agency (ESA) and UK Science Research Council (SRC), which shared in the construction of the equipment. It was operated from the Goddard Space Flight Center for 16 hr of each day and the European ground observatory near Madrid for 8 hr. IUE was unique in being in a geosynchronous orbit and was operated in real time. During its lifetime it produced about 104,000 spectra of 10,000 different objects observed by about 1000 different astronomers. It was called the "People's Satellite;" it weaned many optical astronomers from ground-based to space astronomy.

The pertinent dates were:

Launch	26 Jan. 1978
First light	9 Feb. 1978
First non-NASA observer (J. Linsky)	1 Apr. 1978
Announcement of handover to ESA	5 Oct. 1995
Satellite turn-off	30 Sep. 1996

In 1994 the grants for travel, analysis, and publication costs were terminated and in 1995 it was decided to turn over full operation to ESA. Although several guidance sensors had failed, operation was terminated because, it was stated, NASA could not afford to continue operation at a cost of less than a half million dollars per year. The decision should not have been due to competition with the Hubble Space Telescope: IUE was purely a spectroscopic instrument while use

of HST was dominated by imaging except for a very high-dispersion Goddard High Resolution Spectrograph. We wonder whether the termination of IUE was due to a feeling that perhaps the most important science with it had been done after 18 years of observations.

2. ANALYSIS

We will use citation counts as an objective measure of the importance and/or usefulness of papers. Justification for that assumption was demonstrated by Abt (2000a). We obtained from NASA a list of the 3435 papers published in refereed journals during 1978-1997 and based on IUE data. The latter date was selected so that in fairness we could count citations for the same interval, chosen as six years, after the publication of each paper. The IUE archive is still being used actively as an international resource, so IUE papers will continue to be published. IUE spectra can be retrieved from the website <http://archive.stsci.edu/iue>. Please note that the dates of the papers referred to in this study are to dates of publication, not when the data were obtained.

We used the University of Arizona's access to the Web of Science, the on-line edition of the ISI Science Citation Index. We counted the citations for the six calendar years following the year of publication for each paper. Those averaged about half of the total citations to date. Without bothering to determine when during the year each paper was published, we engendered a random error of a partial year in the counting intervals. Ninety of the papers (2.6%) had zero citations. We left out three heavily cited technical papers by Boggess (1978a, 1978b) and Bohlin (1980) that describe the instrument and its calibration; they had 285, 205, and 161 citations, respectively.

The results from the counting are given in Table 1. The four columns are self-explanatory except to say that the dispersions given are dispersions of the means.

3. CONCLUSIONS

The annual total citations are plotted in Figure 1. They show a steep rise from the year of launch (1978) through 1980. After that there is a statistically linear increase of 4.7% per year for a total of 61% during those 14 years. That increase is shown by a least-squares line. The next year (1995) the total citations per year started a rapid decrease as funding

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TABLE 1. Citation Counts for IUE Papers

Year of Publication	Papers per Year	Total Citations per Year	Mean Citations per Paper
1978	13	305 ± 90	23.46 ± 6.93
1979	49	912 ± 145	18.61 ± 2.96
1980	113	2076 ± 177	18.37 ± 1.57
1981	160	2877 ± 259	17.98 ± 1.62
1982	190	3175 ± 247	16.71 ± 1.30
1983	189	2770 ± 212	14.66 ± 1.12
1984	200	2666 ± 188	13.33 ± 0.94
1985	178	2359 ± 194	13.25 ± 1.09
1986	174	2935 ± 249	16.87 ± 1.43
1987	171	2342 ± 174	13.70 ± 1.02
1988	205	3407 ± 367	16.62 ± 1.79
1989	171	2929 ± 455	17.13 ± 2.66
1990	214	3262 ± 265	15.24 ± 1.24
1991	228	3911 ± 347	17.15 ± 1.52
1992	219	3157 ± 230	14.42 ± 1.05
1993	262	4952 ± 474	18.90 ± 1.81
1994	232	3879 ± 336	16.72 ± 1.45
1995	175	2924 ± 280	16.71 ± 1.60
1996	138	1876 ± 219	13.59 ± 1.59
1997	64	837 ± 116	13.08 ± 1.81

for grants was eliminated, total transfer to ESA was announced in 1995, and closure was announced in 1996.

Our main conclusion is that the scientific output of IUE as measured by total citation counts was rising steadily until termination was announced and gave no indication that IUE was exhausting the important science that could be done with this equipment. The decision to terminate IUE was made at the peak of its productivity.

A contributing cause of the increase, but not the main one, for this rise was the realization by astronomers in the late 1980s that IUE could also be used for galaxies, quasars, and other extragalactic sources. Because extragalactic astronomy now contributes half of all astronomical research being done (Abt 2000b), those papers have been heavily referenced. Of the 34 papers that produced more than 100 citations each during six years after publication, 25 were extragalactic and nine were stellar.

If we plot the total citations per year for the total sample of 3345 cited papers minus the 34 with high citation counts (>100), the graph is similar to Figure 1 but with a smaller slope of 2.8% per year or 39% increase during 1981-1994.

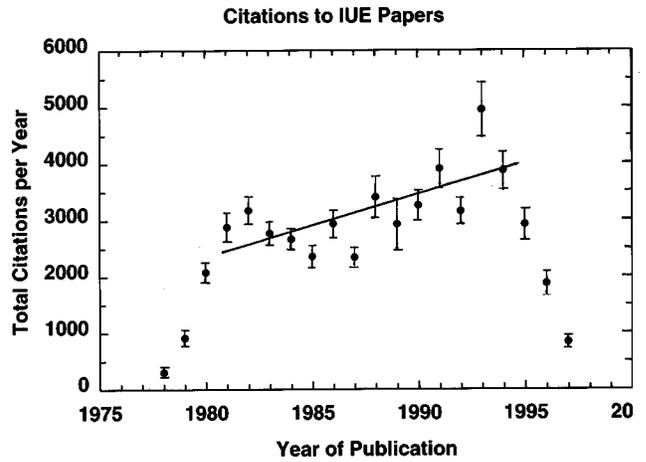


Fig. 1. The total citations per year accumulated by the 3345 cited papers published from IUE data during 1978-1997. After a rapid start during 1978-1980, there was an increasing number of citations until 1995 when closure of the spacecraft was announced. The straight line shows the least-squares relation during 1981-1994, giving an increase of 61%.

Therefore less than half of the increase is due to the heavily-cited papers that are mostly extragalactic.

The number of IUE papers published per year (second column of Table 1) shows a linear increase of 3.3% per year or 46% increase during 1981-1994. Thus two-thirds of the increase in citations in Figure 1 is due to an increase in numbers of papers per year and one-third is due to a shift toward extragalactic studies.

The mean number of citations per paper (last column of Table 1) seems to show a decline during 1978-1985, but overall the data fits a constant value of 16.3 ± 2.5 citations per paper in six years, or 2.7 citations per year. That average is higher than the average of 1.8 ± 0.3 citations per paper per year for papers in the AJ or ApJ (Abt 2000a). Thus IUE papers average more citations than average AJ and ApJ papers.

Abt, H. A. 2000a, *Scientometrics*, 48, 65
 Abt, H. A. 2000b, *BAAS*, 32, 937 (Table 2)
 Boggess, A. *et al.* 1978a, *Nat.*, 275, 372 (33 authors)
 Boggess, A. *et al.* 1978b, *Nat.* 275, 377 (34 authors)
 Bohlin, R. C., Holm, A. V., Savage, B. D., Snijders, M. A. J.,
 &
 Sparks, W. M. 1980, *A&A*, 85, 1