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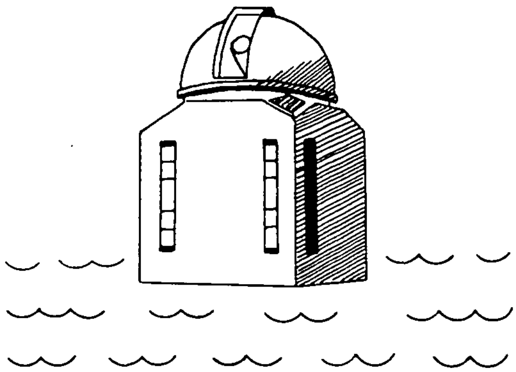
BIG BEAR SOLAR OBSERVATORY



ULTRAVIOLET RESPONSE OF FILM CANDIDATES FOR THE SOLAR OPTICAL TELESCOPE PHOTOMETRIC FILTERGRAPH

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ABSTRACT

This report summarizes measurements of UV response between 2000 and 3000 A of Kodak films 2415, Aerocon II 3412, and SO-415. The short wavelength cutoff of the response of all films studied lies near 2100 A, occurring as a gentle falloff starting near 2500 A. The sensitivity of the films appears to remain roughly constant from 2500 to 3000 A. Estimates of UV Gamma for 2415 and the effect of hard UV on the optics in the experiment are also discussed.

I. Introduction

This report summarizes the results of a series of measurements of the UV response in the wavelength range 2000-3000 A of film candidates for the Photometric Filtergraph of the Coordinated Instrument Package for the Solar Optical Telescope. Kodak films Technical Pan 2415, Aerocon II 3412, and High Definition Aerial SO-415 were investigated. The experiment described below was intended in the first instance to determine the low-wavelength cutoff of the candidate films, but was extended to obtain some tentative measurements of UV film sensitivity. Section III presents results of exposure tests at various UV wavelengths. Section IV describes briefly the effect of hard UV on MgF_2 windows, a topic on which an unintended experiment was performed as well. Finally, Section V presents conclusions.

II. The Experiment

Film tests were performed with a McPherson Model 630 Hinteregger discharge lamp as the source of UV, a McPherson Model 235 vacuum UV monochromator as the dispersing element, and a lenseless Minolta X-700 camera loaded with candidate films.

Hydrogen gas at a pressure of about 0.08 psi bled into the hollow cathode of the discharge lamp while an AC current of 15 kV and 60 ma was applied. The lamp pressure was dictated by a compromise between the desire for maximal continuum emission (best at low pressures) and the need to maintain gas flow through the lamp (stagnant at or near the limiting pressure of the lamp mechanical pump ca. .04-.05 psi) in order to avoid contamination of the lamp window and pyrex vessel.

UV radiation from the lamp passed through a magnesium fluoride window into the monochromator. The grating chamber was kept at a pressure of 110-140 microns of mercury, as indicated by a thermocouple gauge. All results presented in this report were obtained with a 600 ruling/mm grating which gave a dispersion of 34 A/mm.

Two detectors were used to monitor the spectrometer output. At first, the output of an EMI 9514b photomultiplier with a Na Salicylate frosted window for UV conversion drove a strip chart recorder to provide lamp spectra for later comparison with the film. Light from the monochromator exit slit passed through a LiF window into a light-proof chamber at atmospheric pressure which contained both the camera and the PMT. The camera was mounted on a table which rode on a shaft directly in front of the PMT housing so that PMT spectra could be easily obtained in alternation with film exposures. As the lamp was a relatively bright light source, a bias of only 500 volts on the PMT was adequate to obtain good spectra. However, the PMT mounting required long path lengths from the exit window for both camera and PMT, leading to long exposures (up to 10 minutes). Although long exposures did not seem objectionable for the task of locating the short-wavelength cutoff of the film gelatin, since reciprocity failure is wavelength-independent (Mees, 1954), they were far too long for a meaningful study of UV film sensitivity. This arrangement was later abandoned in favor of alternately mating camera and a photodiode detector directly to the exit window housing in order to obtain short exposure times. Mating the camera more directly to the exit window housing precluded use of the PMT, which was replaced by a United Detector Technology Schottky-barrier photodiode with a frosted Na Salicylate window.

III. Results of Film Exposures

A. Short Wavelength UV Cutoff

The result of a typical set of exposures appears in Fig. 1. The lamp output peaked at 2400-2500 A, at a value of between 0.3 and 0.5 erg/cm**2/s, and fell to about 25% of its peak value by 2000 A. For wavelengths longer than 2500 A, the output fell off more slowly. Film exposures were made at 100 A intervals for exposure times varying from 1/8 s to more than 10 minutes (for the original setup). In all cases, the film density consistently fell to fog levels between 2000 A and 2100 A. The effect is illustrated in Fig. 2, where the film density is divided by the detector output. The fog density intercept appears to lie near 2100 A for all films tested, at which wavelength the lamp output is approximately 50% of its peak value.

In order to eliminate the possibility that scattered light from longer wavelengths contributed to the film response below 2400 A, 2415 was exposed through Acton narrowband filters. The exit window was replaced by filters with peak transmission at 2020, 2200, and 2380 A. While densities above fog of order unity at 2560 A, and of 0.4 at 2260 A, were obtained with exposures of 10 s, no density above fog resulted at 2060 A (very nearly the peak of the 2020 A filter bandpass), and exposures of 100 s at this wavelength resulted only in D = 0.08 above fog. In this case, the light passed by the filter at 2060 and 2260 A was about 20% greater than at 2560 A. The resultant plot of (density above fog)/(detector output) appears as Fig. 2d, and confirms the falloff determined above.

B. UV Film Sensitivity

A limited amount of information on UV film sensitivity of 2415 and Aerocon II 3412 could be extracted from the film exposures. Fig. 3 shows the exposure in ergs/cm**2 required to reach various densities.

The photodiode/Na Salicylate detector was calibrated for film sensitivity measurements in the following way. 2415 film was exposed for .25 sec. at about 3000 A, and developed in HC-110 (Dilution D) to a nominal (visual) gamma of 2.0. The resulting exposure had a density D ~= 0.3. The sensitivity curve in the Kodak data sheet for 2415 (Kodak, 1981) then gave the approximate exposure, which was used to calibrate the detector intensity scale at that wavelength. The photodiode response vanishes for wavelengths below 3000 A, so the response at this and shorter wavelengths is provided by Na Salicylate fluorescence. For wavelengths greater than about 3400 A, Na Salicylate ceases to fluoresce, and the photodiode responds directly. The relative sensitivity of the detector at a number of wavelengths was checked directly with a Pen-Ray Hg lamp, using the intensity scale of Childs (1962). At 3000 A, the detector sensitivity is 20% of that at 4000 A.

The resulting sensitivity measurements are very approximate. The main sources of uncertainty lie in the use of film response for the overall calibration of the intensity scale, changes in lamp output during runs (kept as short as possible to conserve the optics), and spatial nonuniformity of the exposures on film caused by an imperfection in the exit window. Of these sources, the second seems to have the greatest effect, which enters twice (once in the original calibration, and once during each run). However, lamp spectra were taken before and after each run, and in each case the intensity leading to a given density was taken to be the greater so as to systematically overestimate the exposure required. The uncertainty introduced by this procedure is estimated to be of order 10-15%.

C. Additional Remarks

It has been found that in the UV, gamma tends to decline markedly from its value at visible wavelengths (Mees, 1954, and references cited). Some tentative indications of this effect were found by taking exposures of varying length, 1/8 to 1 second. Reciprocity failure effects in this range of exposure time cause changes in D of less than 8% (for D near unity) for constant I X t (Fig. 4). For 2415, estimates of gamma for wavelengths less than 3000 A, although very crude, seem to be of order unity or less (Table 1). If confirmed by a more detailed investigation, this effect would mean that, while the candidate films have a useful sensitivity in the UV, they may not be able to produce high contrasts. In this event, an alternative approach to UV imaging, such as the use of downconverting phosphors like coronene, becomes more attractive.

IV. Effects of Lamp Environment on MgF2 Windows

All exposures in this series of tests were performed with the original LiF exit window, but more than one MgF2 window was used with the lamp. When a fresh window was placed in the lamp, a steady decline in the stabilized output occurred for wavelengths between about 2400 and 3000 A. On inspection, the windows showed a yellowish discoloration after several hours of lamp operation. This discoloration could not be removed to any significant extent by washing in Chromerge, but could be abraded away with Polygrit. Lamp UV output with a refurbished window showed considerable recovery, but never to levels attainable with a pristine window. MgF2 is known to suffer from the formation of color centers when exposed to hard radiation (Heath and Sacher, 1966), resulting in decreased transmission in a broad band centered at 2500 A. As the discoloration appeared to occur in a thin surface layer of the window, it is not clear whether the loss of transmission was caused by radiation damage or by contamination from the lamp discharge, which builds up very rapidly if vaccuum oil backstreams into the lamp vessel (for this reason the lamp mechanical pump was isolated from the lamp by a liquid nitrogen cold trap). It is suggestive, however, that Chromerge proved incapable of washing the discoloration away, as this method has been used quite successfully to clean the Pyrex lamp vessel.

MgF2 and LiF are the only commercially available window materials which will transmit UV down to Lyman alpha. LiF is very radiation sensitive (Harshaw, 1967), in addition to being water-soluable and very soft, leaving MgF2 as the window material of choice for any transmitting optical intensity calibration in place of normalizing sensitivity results to the properties of 2415 at 3000 A. The latter problem may be attacked more directly by exposing film to an Hg discharge lamp through a narrowband filter near 2537 A together with appropriate colored glass filters (Schott UG-5 and UG-11). In the near UV, it may be possible to establish film characteristic curves in passbands relevant to SOT by direct solar observing.

Acknowledgements

I wish to thank Professor Aron Kuppermann for providing me with laboratory facilities. This study was supported by the NASA under grant NAS5-27269.

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Table 1

Estimates of 2415 Gamma in the UV (HC-110 dev.)

Wavelength	D(0.5 s)	D(1.0 s)	Est. Gamma
2464 A	0.66±.02	0.88±.02	0.73±.07
2560 A	0.65 "	0.78 "	0.43±.04
2658 A	0.62 "	0.80 "	0.60±.06
3060 A	0.64 "	0.82 "	0.60±.06

Captions

Fig. 1 - A. Film densities and lamp output as a function of wavelength for 2415. B. As A, for Aerocon II 3412. C. As A, for SO-415.

Fig. 2 - A. Film density above fog divided by lamp output as a function of wavelength for 2415. B. As A, for Aerocon II 3412. C. As A, for SO-415. D. As A, for 2415 exposed through narrowband filters.

Fig. 3 - A. Film sensitivity required to read D = 1 above fog for 2415 exposed 1 second (D-19 development). B. Film sensitivity required to reach D = 0.65 above fog for Aerocon II 3412 exposed 1 second (D-19). C. Film sensitivity required to reach D = 0.3 above fog for 2415 exposed .25 second (HC-110, dilution D).

Fig. 4 - Reciprocity failure data for 2415 exposed to an 18% grey scale under fluorescent lighting. Densities produced for various I X t = constant.

Figure 1a. 2415 (1 sec. exp.)

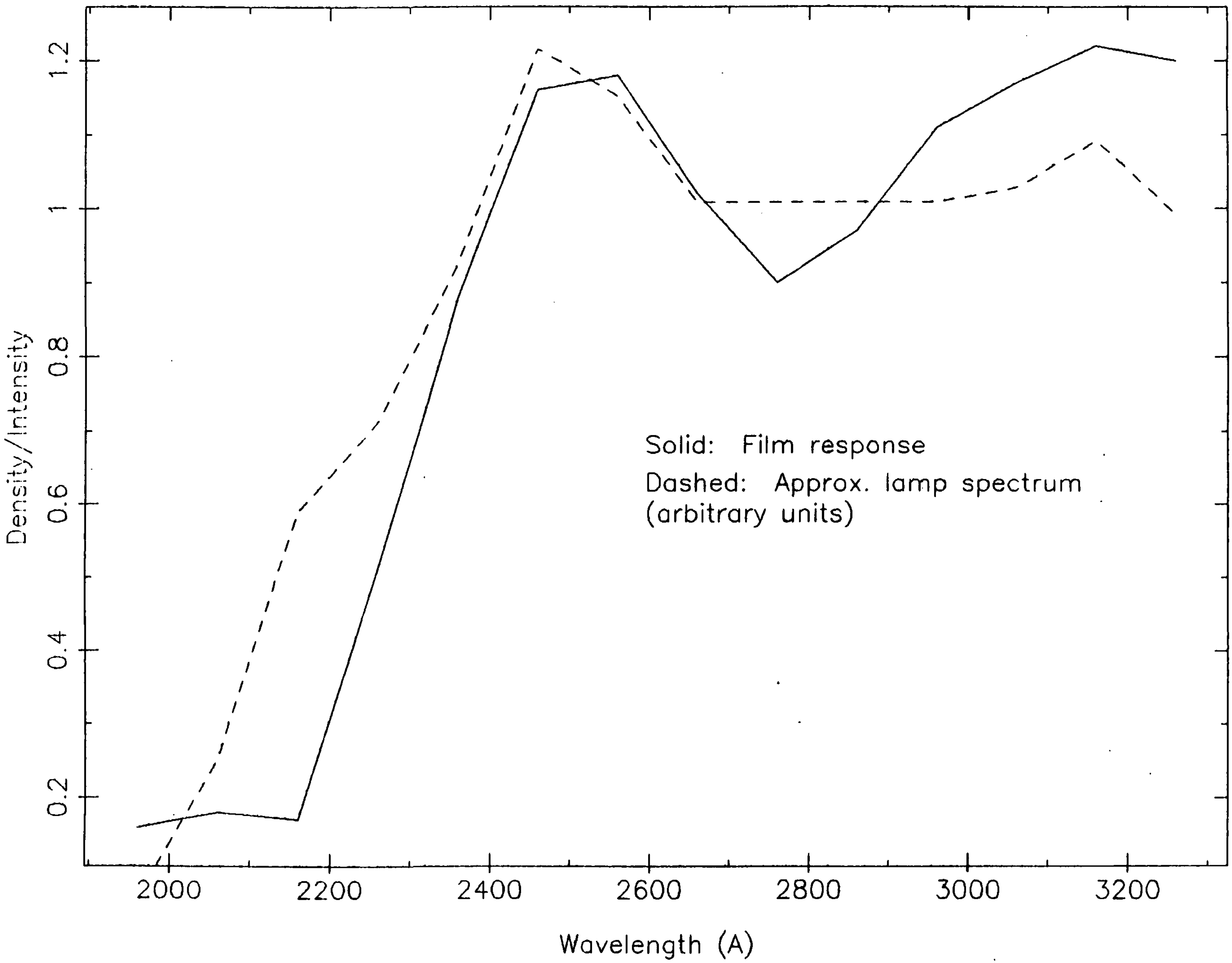

Figure 1b. As Fig. 1a, for Aerocon II 3412 (10 min. exp.)

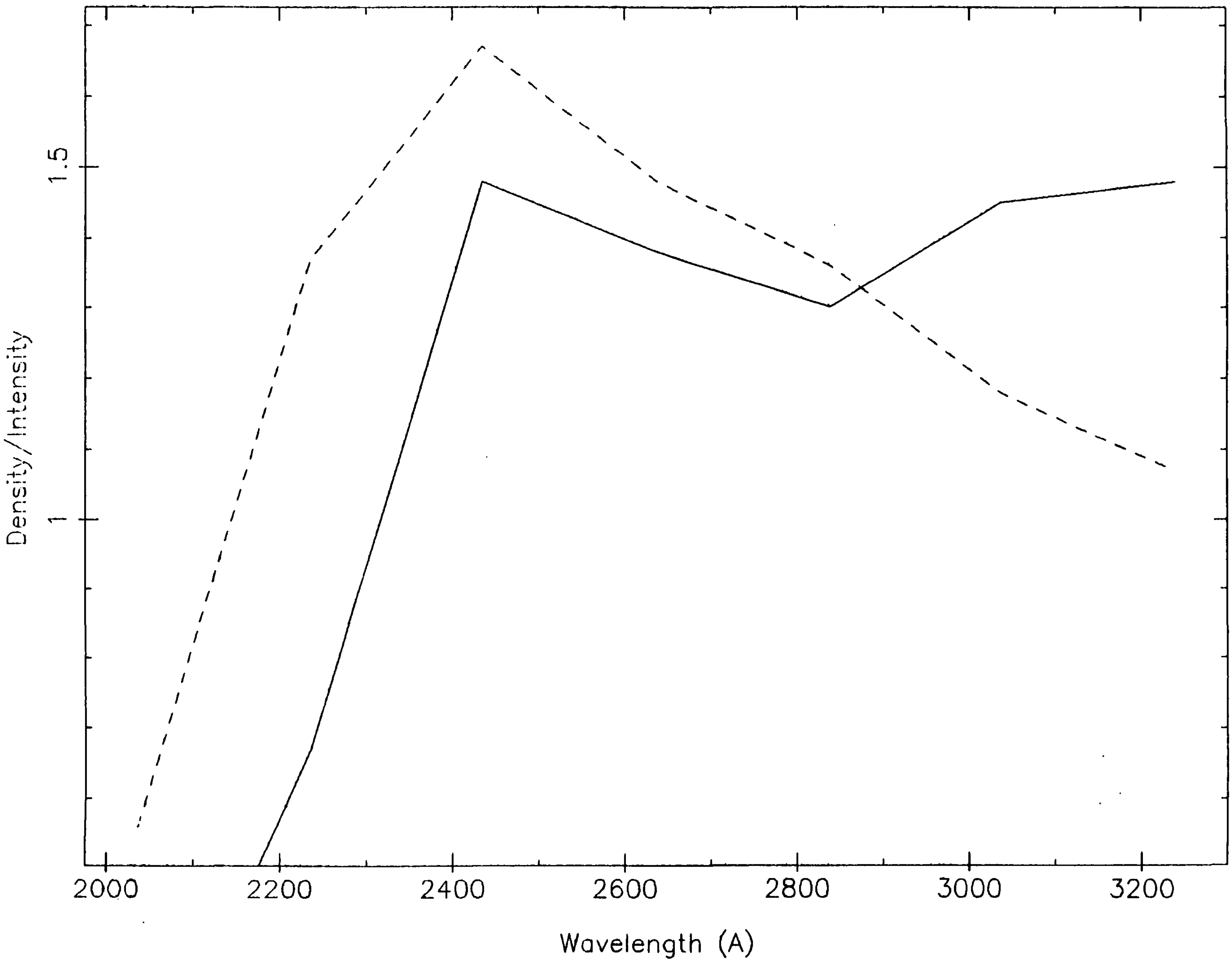

Figure 1c. As Fig. 1a, for SO-415 (10 min. exp.)

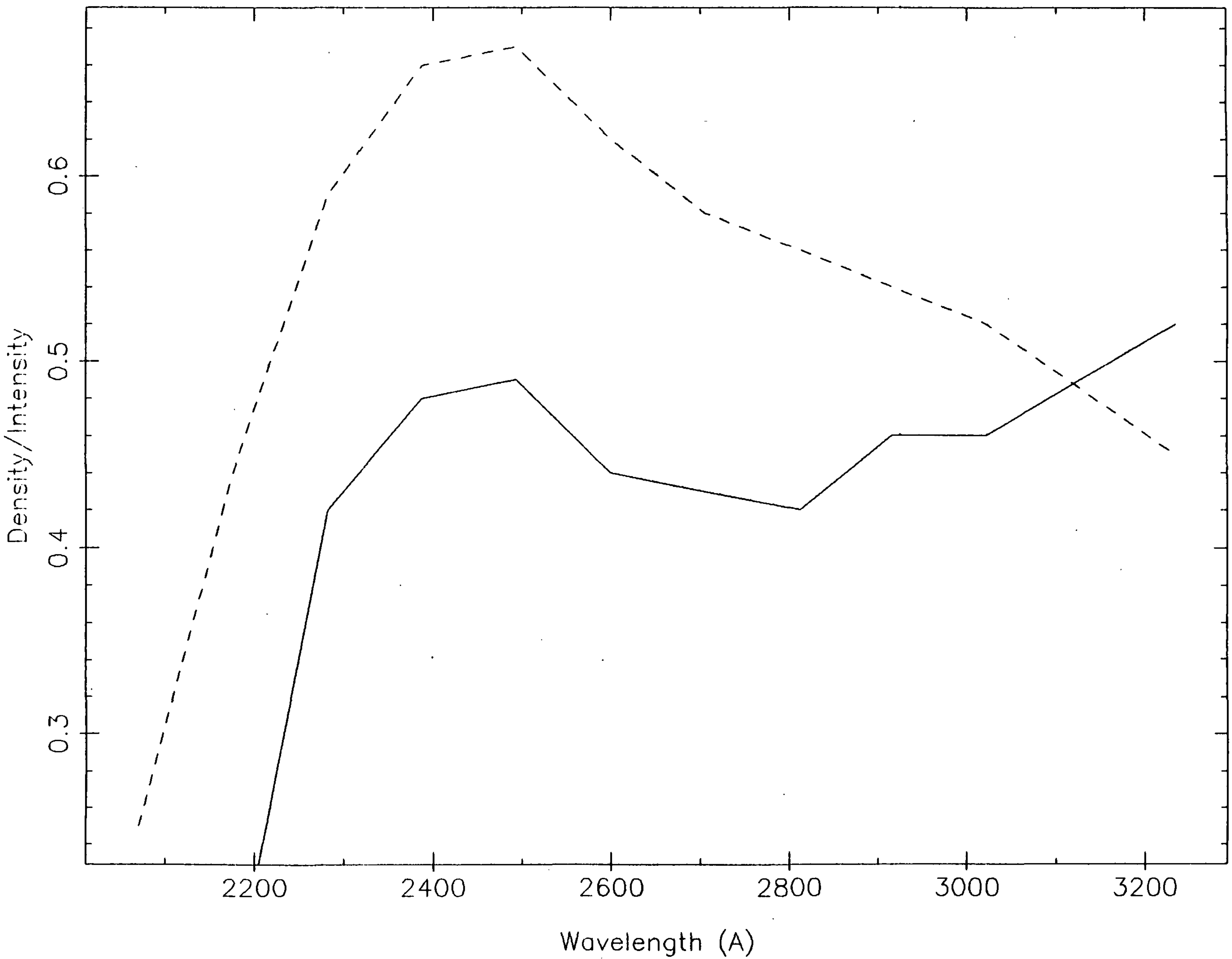

Figure 2a. 2415 density above fog divided by lamp intensity

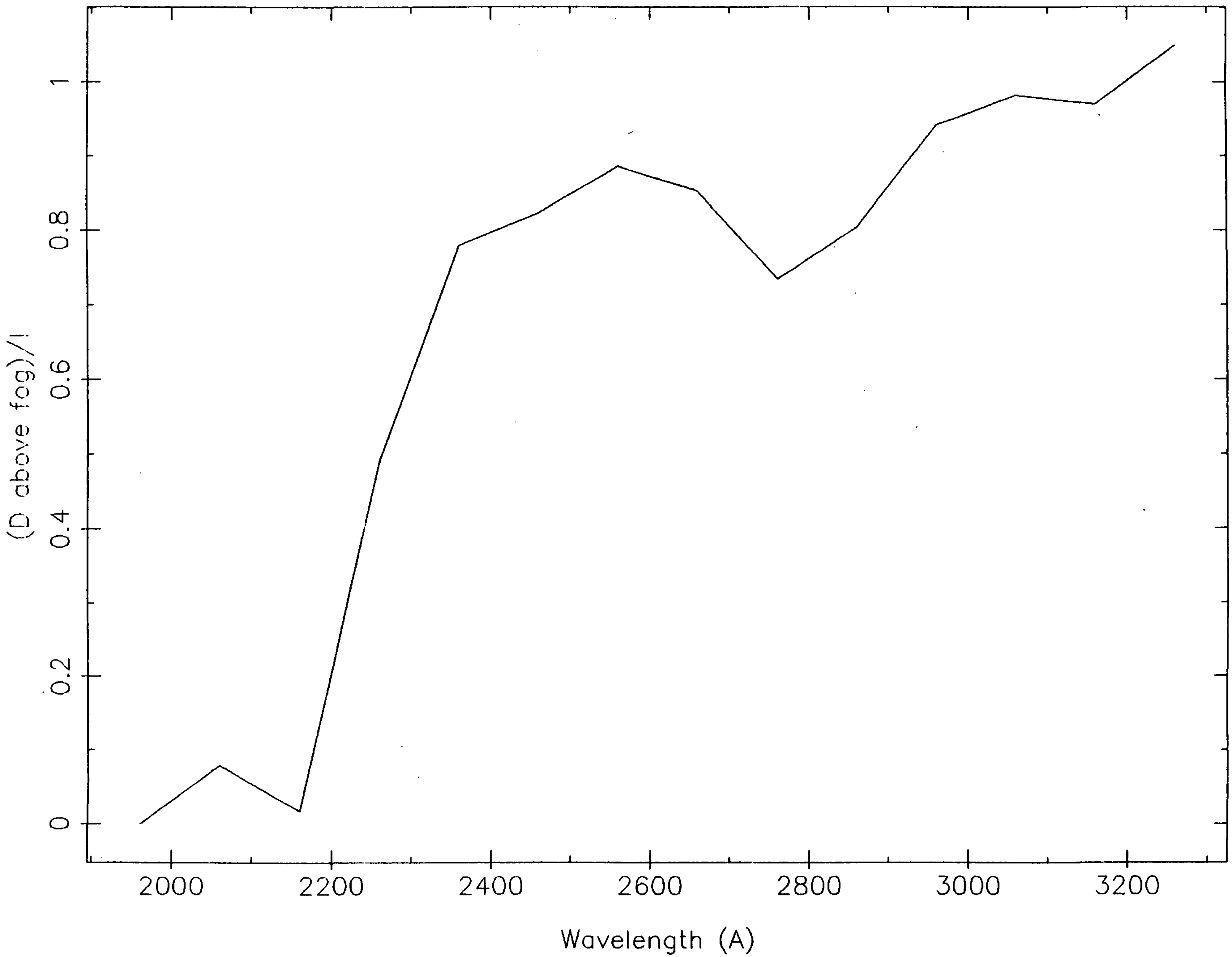

Figure 2b. As Fig. 2a, for Aerocon II 3412

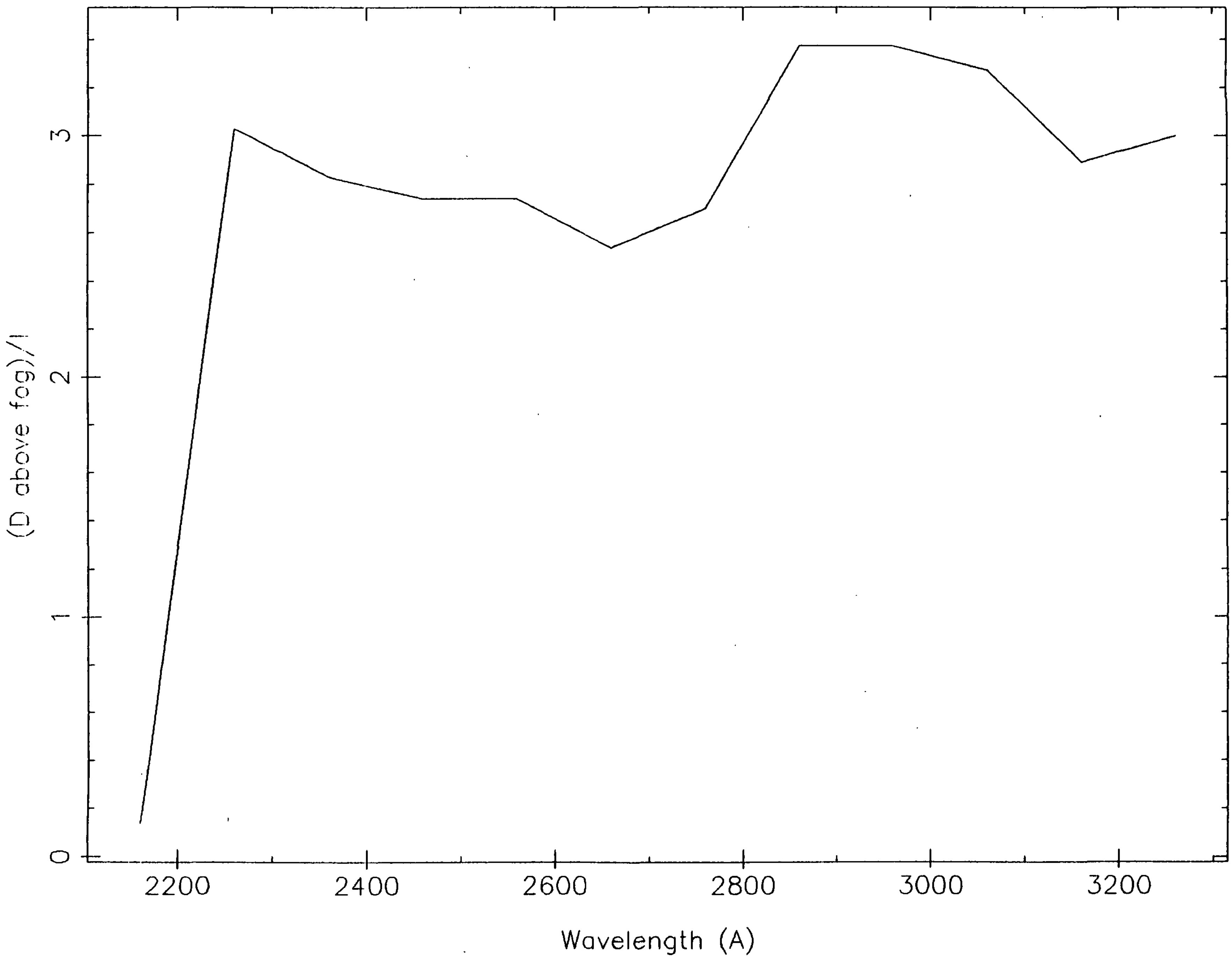

Figure 3b. Aerocon II 3412 UV Sensitivity

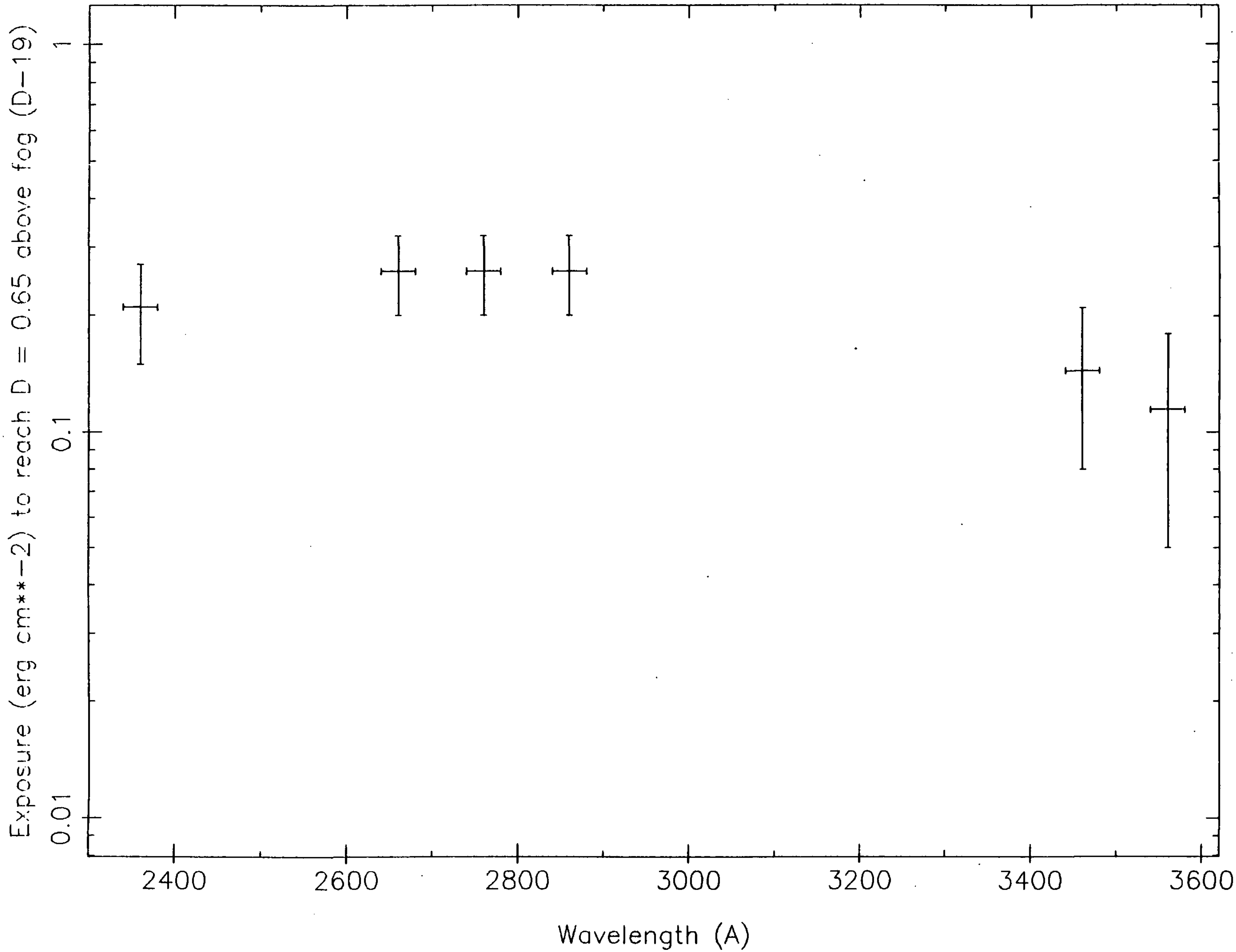

Figure 2d. As Fig. 2a, for 2415 exposed through UV filters

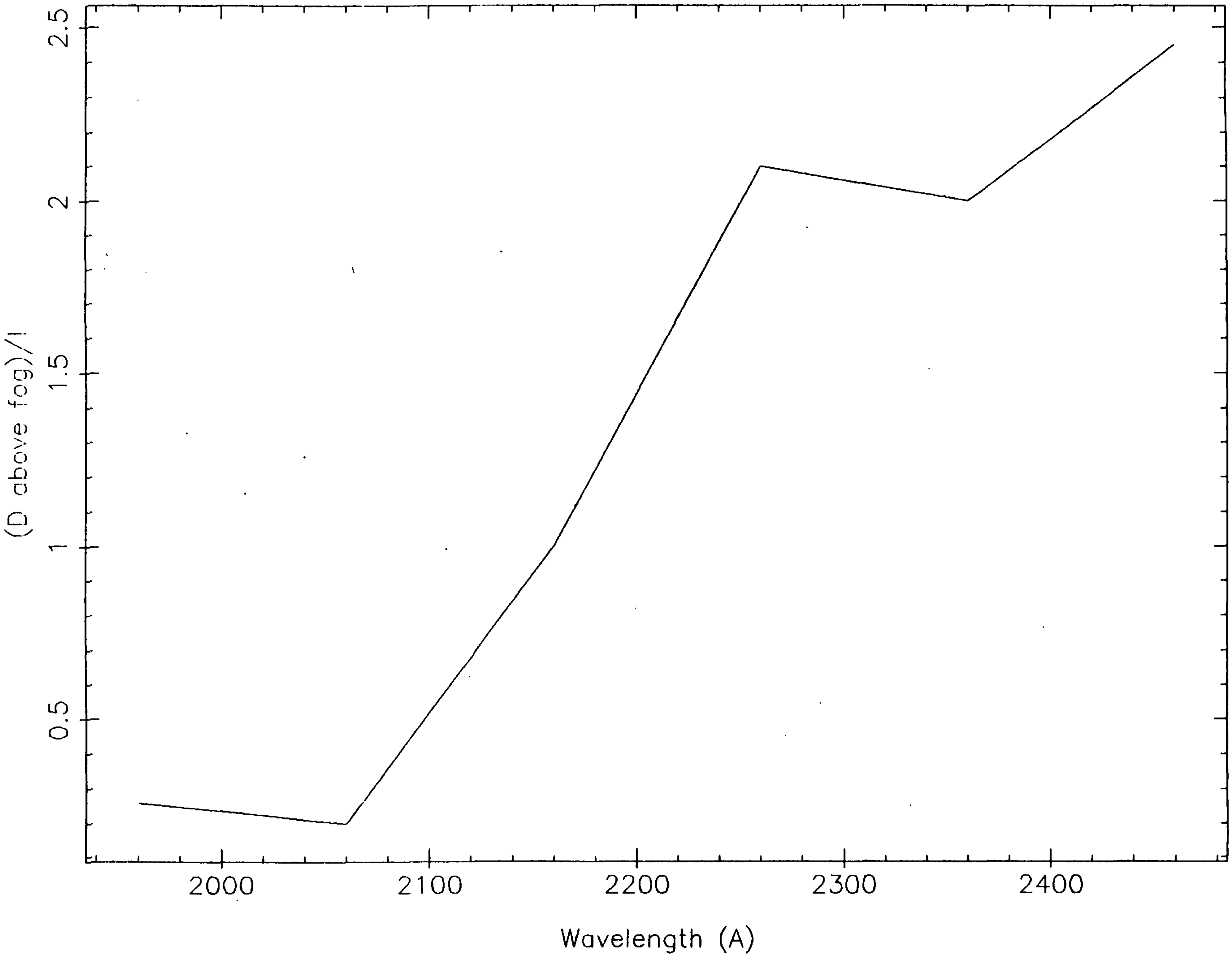

Figure 3a. 2415 UV Sensitivity

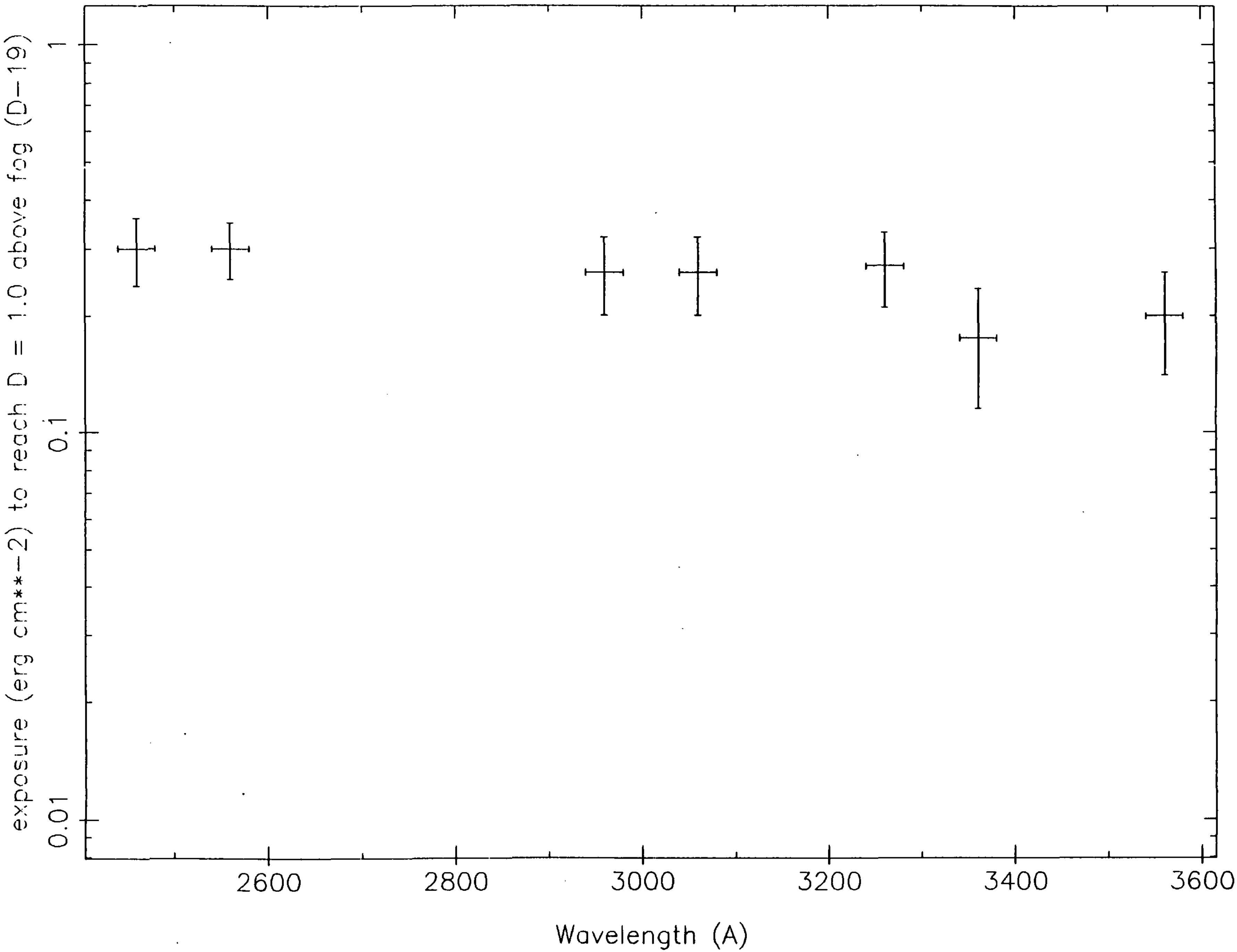

Figure 3b. Aerocon II 3412 UV Sensitivity

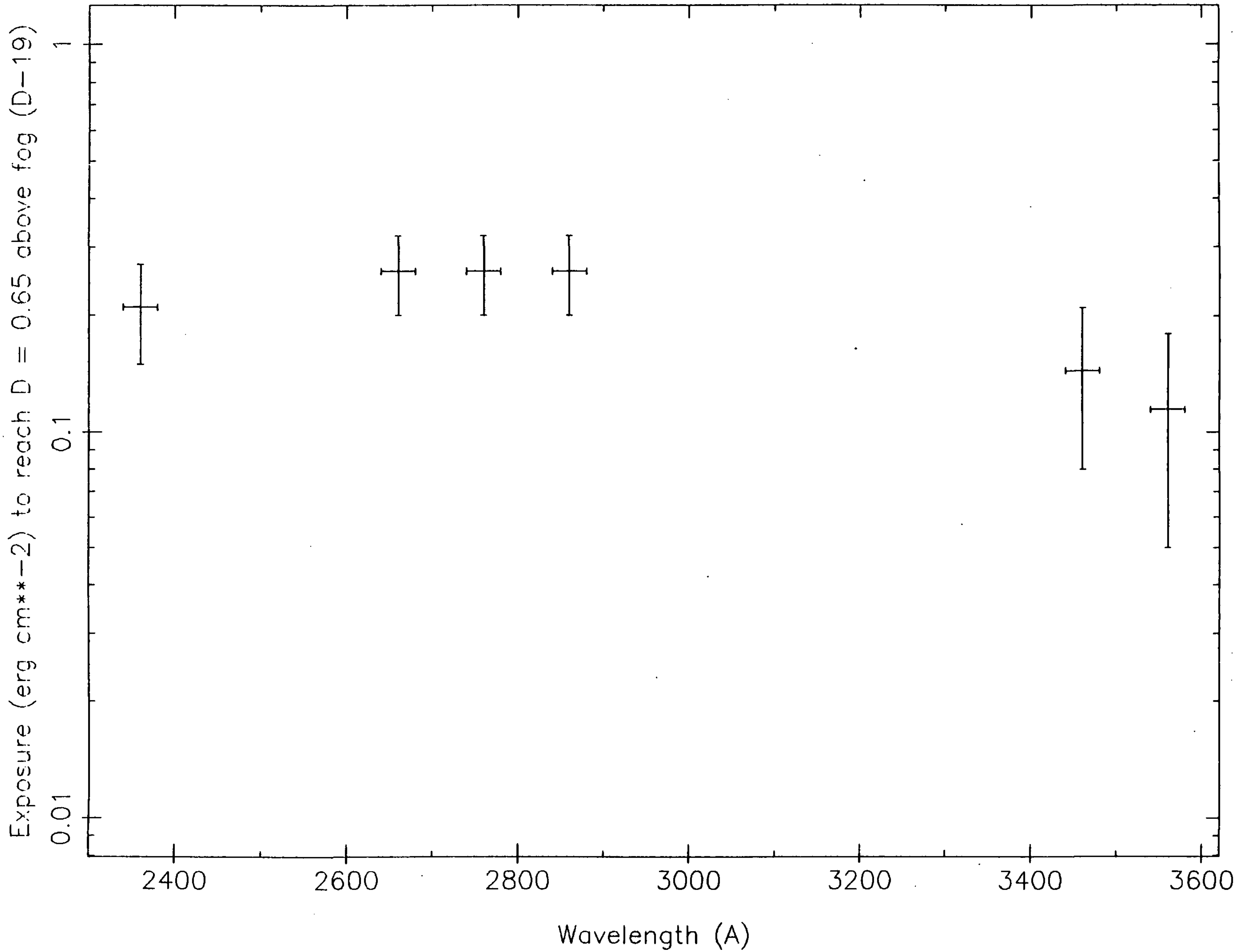

Figure 3c. 2415 UV Sensitivity

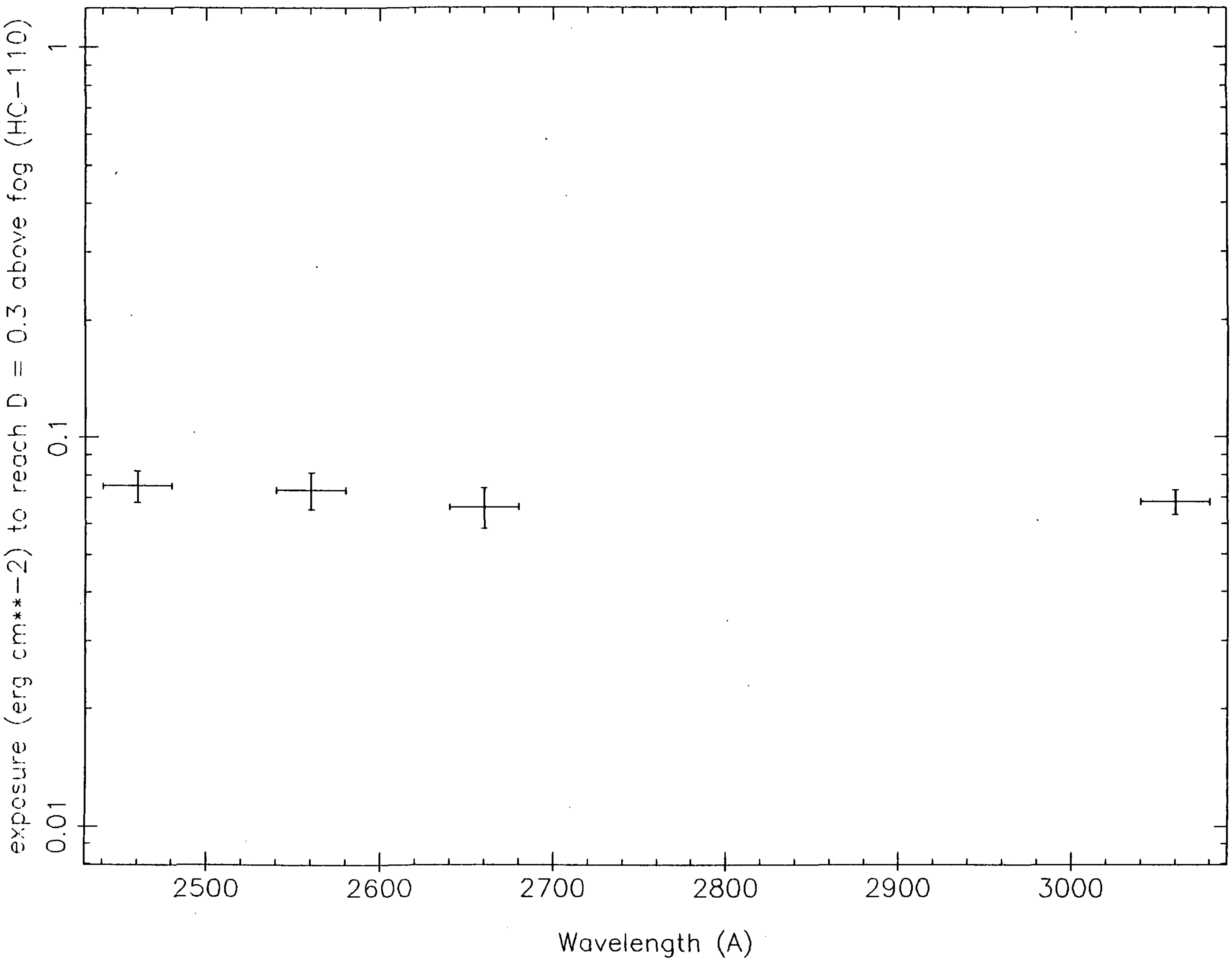

Figure 4. 2415 reciprocity failure