RESIDUAL IMAGES FROM PREVIOUS EXPOSURES *

1. INTRODUCTION

On quite a few IUE images with long exposure times faint residual spectra from previous (over)exposures have been noticed. There are two, entirely different sources of residual images: burnt-in signals in the SEC target and phosphorescence in the UV to optical converter. Virtually all practical problems for guest observers are due to phosphorescence during long exposures. In particular: how do you establish that the faint signal detected after a 7 hour exposure is due to the target studied and not to residual phosphoresence of a previous over-exposure? This problem has two aspects: how do you prevent it to happen and how do you assess the reliability of the images in the data bank.

2. SEC TARGET RESIDUALS

Spectra burnt-in in the SEC target are normally properly removed. The standard SPREP sequence cleans the SEC target satisfactorily after a normal exposure and executing XSPREP takes care of the burnt-in image after an over exposure. XSPREP has to be done immediately after an overexposure in excess of 8x. Residuals in the SEC target should then not present any serious problem.

Of course one should be aware that the high illumination level of the UVC in an XSPREP (800% + 200% + 50% vs. 200% + 50% for a normal SPREP) will give a higher background due to phosphoresence immediately following the PREP.

3. AFTERIMAGES DUE TO PHOSPHORESENCE

The P11 phosphor in the UV to optical converter (UVC) exhibits phosphorensence i.e. the conversion is not an instantaneous process and the integration capacity of the phosphor results in a decay slower then the incoming photon rate. A small fraction of the incident energy, typically 1%, is stored in the phosphor and later slowly released. The dynamic range of incoming flux accessed by IUE is ~10xx5, this is mainly obtained through differences in the integration time.Thus for integrations from 30min to 8hrs the cumulative effect of the phosphor decay can be important. From pre-launch measurements (Coleman et al., 1977) we know that during this period the phosphor decay signal, Fp(t), has

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a power-law dependance on the time interval, since the original excitation (Δt):

$$F_p(t) = k \times F_i \times (\Delta t)^{-n}$$

where k and n are camera dependant constants (table 1) and F(t) is the flux during the earlier exposure. An exposure between t1 and t2 of an object with signal strength, F_i , will result in a total incident flux on the camera of Fo =F_i x(t2-t1) where we have assumed that F(t) is time independent. The resultant phosphor decay signal during a later exposure from t3 to t4 will be:

$$F = \int_{t_1}^{t_2} \int_{t_3}^{t_4} k \times F_i \times (t-t')^{-n} \, dtdt'$$

$$= \frac{k \times F_o}{(t_2-t_1) \times p \times (1-n)} \times \{(t_4-t_1)^p-(t_4-t_2)^p+(t_3-t_2)^p-(t_3-t_1)^p\}$$

where p=2-n.In most cases of practical interest the original exposure between t1 and t2 is virtually instanteneous with respect to (t3 - t4) in which case a simpler formula can be used

$$F = \frac{k \times F_o}{(1-n)} \times \{(t_4-t_{12})^{(1-n)} - (t_3-t_{12})^{1-n}\}$$

Representative values for k and n are 2x10xx-4 and 0.75. Note that these formulae diverge for very large values of t4, eventually the phosphoresence should decrease faster than the t^{-n} power law predicts. The laboratory measurements by Coleman et al. were done over periods up to 8 hours. Practical experience with the cameras in orbit shows that for longer periods relations (2) and (3) overestimate the amount of phosphoresence. In fact I do not know of any example of noticable phosphor decay after 2 shifts (16 hours) have passed. If one calculates phosphor decay over periods longer then 8 hrs, the calculated decay is too large.

In table 1 we list the predicted phosphor decay signal during a 7 hour exposure, after a 10x overexposure 2 hours before the start of the 7 hour exposure. A 10x overexposure corresponds to a peak flux of 2000DN. 0.2% to 0.5% of the incident signal is emitted as a phosphorescent signal. The constants n and k are temperature sensitive (Coleman, 1978) the results in table 1 are valid for T = 20C. In orbit the phosphors operate in a slightly cooler environment: T = 6-17C; consequently n will be slightly lower and k slightly larger. The temperature dependence of the constants is not well known but over the temperature range of interest the changes are most likely less than 30%.

4. DISCUSSION

Phosphor decay is a problem because the IUE cameras are efficient at integrating weak signals over long periods. If a 6 min exposure to 200 DN is made 3 hrs after a 50x overexposure, the phosphor decay signal corresponds to 0.5 DN and can thus be ignored. However if you do a 7 hour exposure on a faint target which will result in a 25 DN signal, the equally large phosphor decay signal will be a major problem. A good example of such problems is SWP 14423 a low resolution 14h exposure of a faint object which has a high resolution decay signal, resulting from 4 images, 15x to 20x overexposed, superimposed on it (see figure 1). The decay and object signal have equal intensities and so far the unfortunate observers have not disentangled them succesfully.

Note that phosphorescence effects add up: a couple of small over exposures can be as bad as a single large one, in particular if they come from objects with the same type of spectra.

The precise level of an overexposure is often not known. Especially for early images retrieved from the data bank it is important to look for other images of the same star in the Merged Image Log and to obtain, if possible, reliable estimates of the overexposure level.

Camera operations without overexposures normally do not cause measurable phosphorescence. The only exception is an accumulation of optimum exposures in one shift (say a 200 DN exposure every hour) followed by a full shift exposure immediately afterwards. Provided the decay signals add up (same aperture, resolution and object types) a very faint 2.5 to 5 DN peak signal will be generated. I have seen two examples of this in the LWR camera (low resolution object spectrum and a high resolution decay signal). In both cases the decay signal was so faint that the observers simply ignored the high resolution remnant. Obviously the situation is very difficult if the previous overexpsures were made in the same spectrograph configuration as your long exposure. Then the observed signal can sometimes be completely due to the phosphor decay.

One trick, which has been tried by observers with a recently overexposed camera, is to do an XSPREP, expose the camera for half an hour during the slew to their target and read the camera after arrival. If this 30 min test image was completely blank they assumed that the effects of the overexposure could be ignored. This is incorrect: a 25x overexposure 3 hours before your 30 min test images gives rise to a ~1 DN phosphor decay signal, which is undetectable. If you follow this up with a 2 shift exposure a 10 to 15 DN decay signal is deposited by the phosphor and that is quite noticable. This test only shows that the XSPREP has effectively cleaned the SEC target. I was actually able to test this during a 2 shift LWR exposure. The SWP camera had been repeatedly overexposed during the previous shift on A and F stars. A 30 min and a 767 min SWP blank sky image were obtained during the 14 hour LWR exposure (SWP 8192 and SWP 8193). The 30 min exposure showed no detectable signal (a peak signal of about 1 DN was predicted to be present) but the 767 min blank sky image shows a 10 to 20 DN signal longward of 1700 A, a clear residual from the A and F type spectra.

Some practical points of interest should be noted: the 10 to 20 DN signal corresponded in this case to a flux level of 1 to 2x10xx-15 erg cm-2 s-1 A-1. This is a typical flux level (for phosphor decay) in the SWP camera after heavy overexposures followed by 7 to 14 hour integrations. The image log gives exposure levels in DN, but most guest observers think in physical fluxes. These numbers illustrate the phosphor decay in physical units. Typically one can measure fluxes down to 1x10xx-15 erg cm-2 s-1 A-1 during 7-14 hours exposures with the SWP camera for >1600 A without much problem. For fainter objects systematic errors (e.g.: background determination, phosphor decay and overlapping weak radiation hits) make measuring the signal or establishing its reality difficult (Hammerschlag- Hensberge et al. 1982, Snijders et al. 1982). For the LWR camera the corresponding numbers are: a minimum flux level of 5x10xx-16 erg cm-2 s-1 A-1 can be measured between 2600 A and 2900 A and a 10 DN peak phosphor decay signal in 7 hours corresponds to 7x10xx-16 erg cm-2 s-1 A-1.In summary: phosphor decay generates only a weak signal but during long exposures it can quite easily exceed the flux from a faint target. It might be good to point out at this stage that most of the problems with overexposed cameras are *not* due to errors in the calculated exposure time, but usually occur because an observer wants to study a very steep spectrum with a large dynamic range and is interested in the fainter parts of it (e.g. the 2200 A extinction maximum or F star continua below 1700 A). Such programs can be identified and it is therefore beneficial for the scheduling of IUE, when users notify the project of such conditions in their response to the scheduling questionnaires.

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TABLE 1

Phosphor decay parameters for the IUE cameras

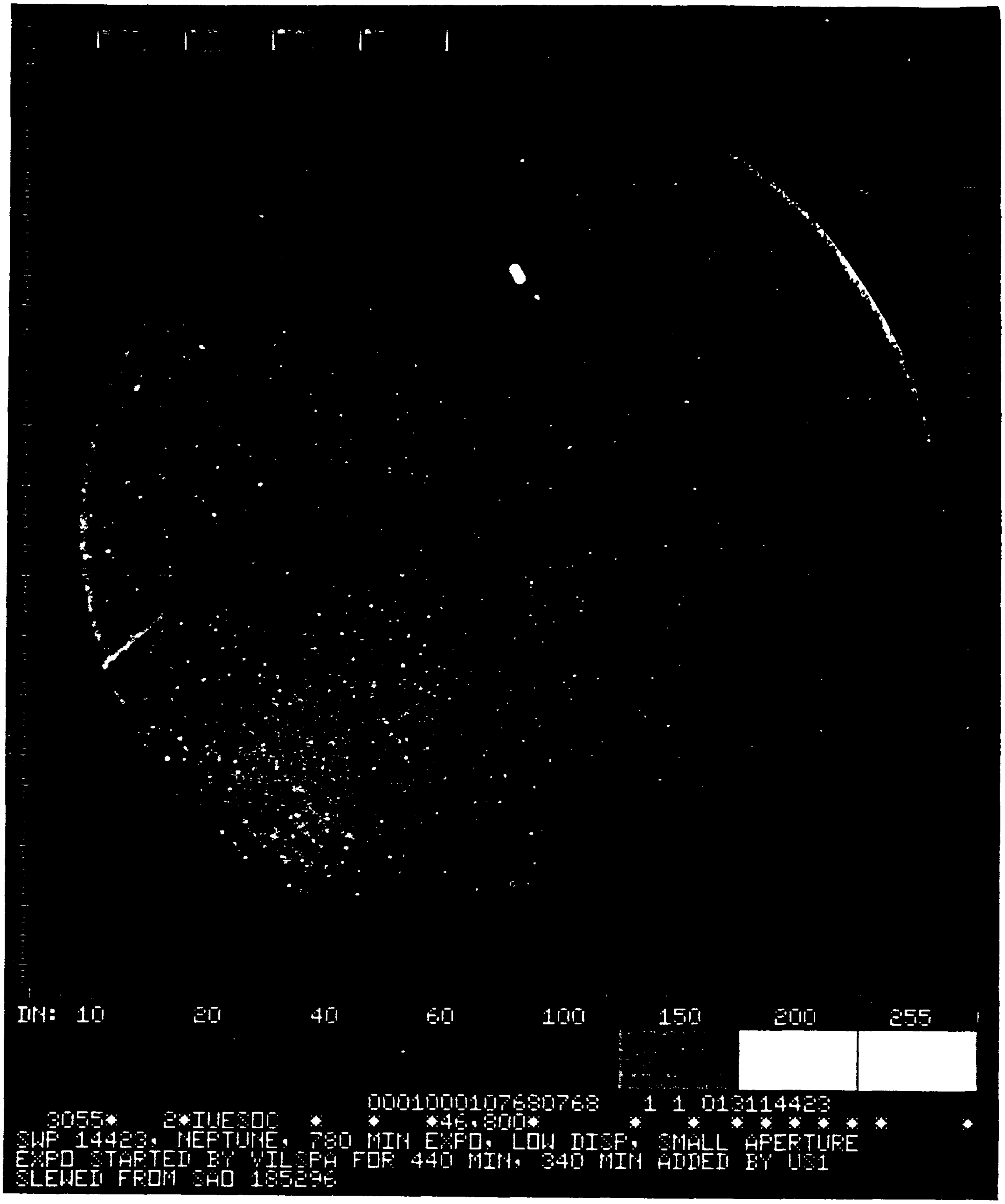
CAMERA	k(x10xx4)	n	DN PEAK
LWP	1.2	0.72	5.4
LWR	2.9	0.77	8.0
SWP	1.8	0.78	4.5
SWR	1.0	0.70	5.4

SOURCE

Coleman *et al*. (1977) for k and n (T ~ 20C); DN(peak) is the predicted decay signal during a 7 hour exposure which started 2 hours after a 10x overexposure. A 10x overexposure corresponds to peak fluxes which would give rise to 2000DN signal. k is the scale factor for phosphor decay; n is the exponent for the decay time dependence.

FIGURE 1:

The image SWP 14423 shows the target exposure (14hrs) of Neptune. Superposed one clearly distinguishes the high resolution spectra due to phosphorensence .



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                                   0001000107680768   1 1 01311442З
   3055*    2*IUESOC  *    *    *46,800*         *    *    *  *  *  *  *  *     *
SWP 14423, NEPTUNE, 780 MIN EXPO, LOW DISP, SMALL APERTURE
EXPO STARTED BY VILSPA FOR 440 MIN, 340 MIN ADDED BY US1
SLEWED FROM SAO 185296
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FIGURE 1