Comparison of STIS and SNAP Spectrograph Throughputs

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This is a comparison of the measured throughput of STIS on HST versus what we might expect from the spectrograph on SNAP. The principle reference is Woodgate et al. (1998) PASP, 110, 1183. Additional material was taken from the STIS Handbook, available on-line at www.stsci.edu. The goal is to demonstrate that there are sound reasons to expect better performance for a SNAP spectrograph (even one with a grating) than would be expected by scaling from HST+STIS.

In Table 1 I attempt to reverse-engineer the STIS system throughput at $0.77\ \mu\text{m}$ by using published or assumed efficiencies for constituent STIS optical components. In particular, the CCD efficiency is given Table 10 of Woodgate et al and the Al efficiency is the textbook value for fresh Al. The grating efficiency, and the dewar window throughput are assumed quantities. The behavior with wavelength of several STIS components is shown in Figure 1. The HST OTA throughput is not included in Table 1. The reference wavelength of $0.77\ \mu\text{m}$ was chosen since Woodgate et al quote their efficiency at this wavelength.

Table 1: STIS Efficiency @ $0.77\ \mu\text{m}$

Component	Component efficiency	Cumulative efficiency	Notes
4 Al reflections	0.55	0.55	aberration corr+coll+cam each 86% reflectivity at peak, including 86% reflectivity from Table 10 of Woodgate et al.
grating	0.65	0.36	
dewar window	0.98	0.35	
CCD	0.51	0.18	

The measured throughput for the G750L grating at $0.77\ \mu\text{m}$ given in Table 1 of Woodgate et al 1998 is 10.0%, while the G750M gratings has a measured throughput of 14.8%. (The lower efficiency of G750L compared to G750M is due to a Lyot stop) The value of 14.8% is in good agreement with the *ab initio* estimate of 18% in Table 1. Indeed, the STIS efficiency in the G750M grating at $0.77\ \mu\text{m}$ given by the HST calibration pipeline tables (i.e. in SYNPHOT) is 17.6% — slightly higher than the value published in Woodgate et al. and in excellent agreement with the *ab initio* estimate. This suggests that the assumed efficiencies of the spectrograph components are plausible.

In Table 2 I show how a similar spectrograph on SNAP would fare relative to STIS at $0.77\ \mu\text{m}$. Here the OTA efficiencies for both telescopes are included. Basically, we should expect SNAP+spectrograph to be roughly $4\times$ more efficient than HST+STIS.

Fig. 1.— Efficiency of key STIS components, plus the total system throughput including the optical telescope assembly.

SNAP’s spectroscopy advantage arises from better efficiency for each of the key components: OTA, spectrograph optics, disperser efficiency, and detector efficiency. These efficiency advantages come about in a traceable fashion and for many components derive from the specific trades allowed by SNAP’s dedicated SN program relative to a generic observing program.

One interesting point to note is the lower OTA throughput for HST. This is not strongly dependent on wavelength. The HST mirror is 2.4m with a 0.6m diameter hole, but a 0.79m diameter shadow from the secondary baffle. This gives a geometrical throughput of 89%. This is actually better than for SNAP, where the aperture is only 84% unobscured due to the large field of view. Two reflections off Al at 86% each should then give a total throughput of 66% for HST, in fair agreement with the published value of 61%. Despite the greater number of mirrors in the SNAP OTA, the efficiency is higher than for HST because the losses from Ag are so much smaller than for Al.

Table 2: STIS vs. SNAP-like Spectrograph @ 0.77 μm

Component	STIS	SNAP	
OTA	0.61	0.77	2 Al reflections vs 4 Ag reflections + obs
spectro. optics	0.55	0.83	4 Al reflections vs 9 Ag reflections
grating/prism	0.65	0.81	grating on blaze vs prism for SNAP
instrument window	0.98	0.98	
CCD	0.51	0.92	
	0.11	0.47	

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