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Replacing the F093W Filter with the F140W

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ABSTRACT
The filter set of the WFC3 IR channel has until now included a filter with significant transmission in the optical, the F093W. The bandpass provided by that filter will extend well below 800 nm when the current IR flight detector (FPA64) is replaced by one with its substrate removed. The F093W filter was intended to allow alignment of the IR channel using an optical laser, but it has also been considered as a potential filter for science. Because the IR channel can now be aligned with an infrared laser, we revisit in this report the utility of the F093W filter for scientific observations. The science that can be performed with the F093W could in general be pursued with the F098M filter on the IR channel or one of the red filters on the UVIS channel, such as the F600LP. Thus, because the primary impetus for the F093W is gone, we are removing it and restoring the F140W filter, which was itself replaced by the F110W in 2002. The F140W filter provides an excellent complement to the F105W filter, straddles a gap in ground-based coverage (due to strong atmospheric absorption between J and H) and extant WFC3 filter coverage, and provides a useful direct image for the G141 grism.

Background

The Wide Field Camera 3 (WFC3) has 62 filters and 1 grism on its ultraviolet-visible (UVIS) channel, and 15 filters and 2 grisms on its infrared (IR) channel. The filter set on the IR channel was last changed in 2002, when the WFC3 Science Oversight Committee voted to replace the F140W filter with the F110W. We are currently replacing the 2 grisms on the IR channel (G102 and G141) with versions that better focus their spectral images on the IR detector. With the IR filter wheel disassembled, it is a good opportunity to revisit the IR filter set.

The IR filter set includes a filter with significant optical transmission, the F093W. The transmission curve for the F093W is shown in Figure 1. The original intent of this filter was to allow the use of a visible laser when aligning the IR channel optics. However, we have recently

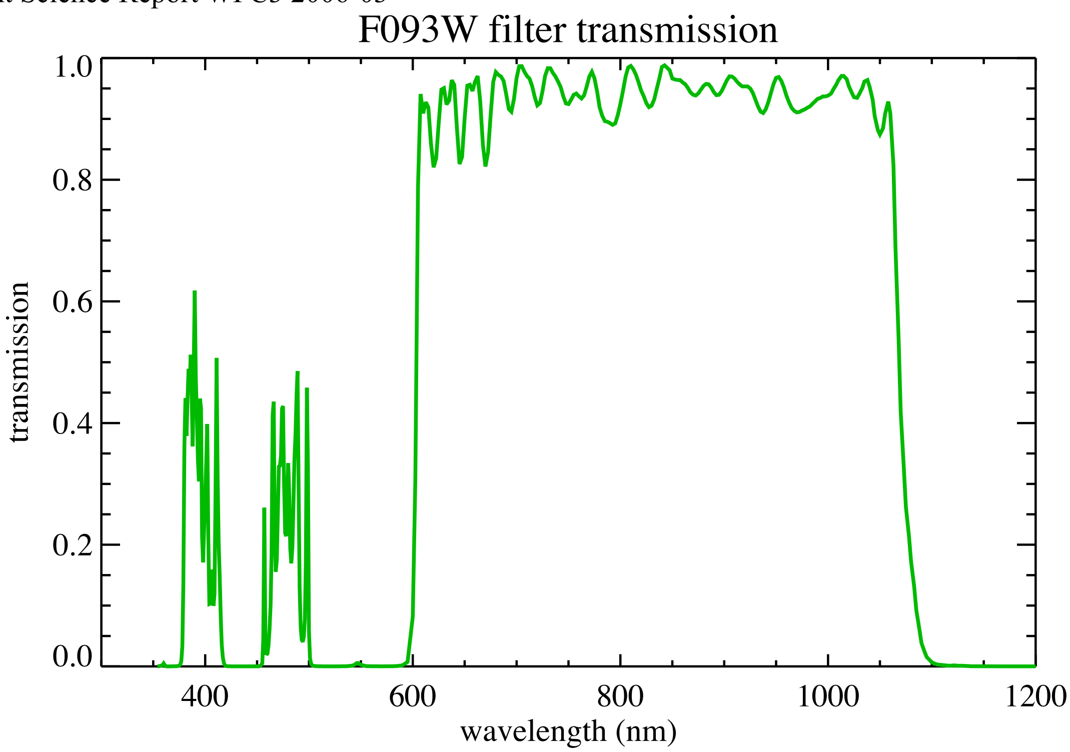

Figure 1: The transmission of the F093W filter (not including the throughput of the other IR channel components).

acquired an infrared laser for this alignment procedure. Thus, the utility of the F093W should be evaluated solely on its scientific merits, and those merits should be compared to those of the F140W filter, given that we have two F140W filters in hand that would make an appropriate flight and spare pair (Figure 2).

Data

The F093W filter is best judged as an F093W bandpass that includes the total system throughput of the WFC3 IR channel. Unfortunately, we do not have much data for the IR channel shortward of 800 nm, because the original IR detector (FPA64) has no sensitivity at those wavelengths. Now that we are replacing the IR detector with one that has its substrate removed, the IR detector will in fact have sensitivity all the way down to 300 nm. We can, however, make some reasonable assumptions about the IR channel optics to produce an approximation of the F093W bandpass shortward of 800 nm. The refractive corrector plate (RCP) and IR detector window are made of fused silica with an IR-optimized antireflection coating. This coating can have some significant structure in the optical, but if we want to be optimistic about the F093W bandpass, we can assume that the throughput at 800 nm (96% for the RCP and 97% for the detector window) is smoothly replicated all the way down to 200 nm. The pick-off mirror (POM) has been measured in the optical because it is also seen by the UVIS channel, so we do not need to make any assumptions for it. As for the remaining mirrors on the IR channel, the silver reflectivity should remain near 98% from 800 nm down to 550 nm, but somewhere between 350 nm

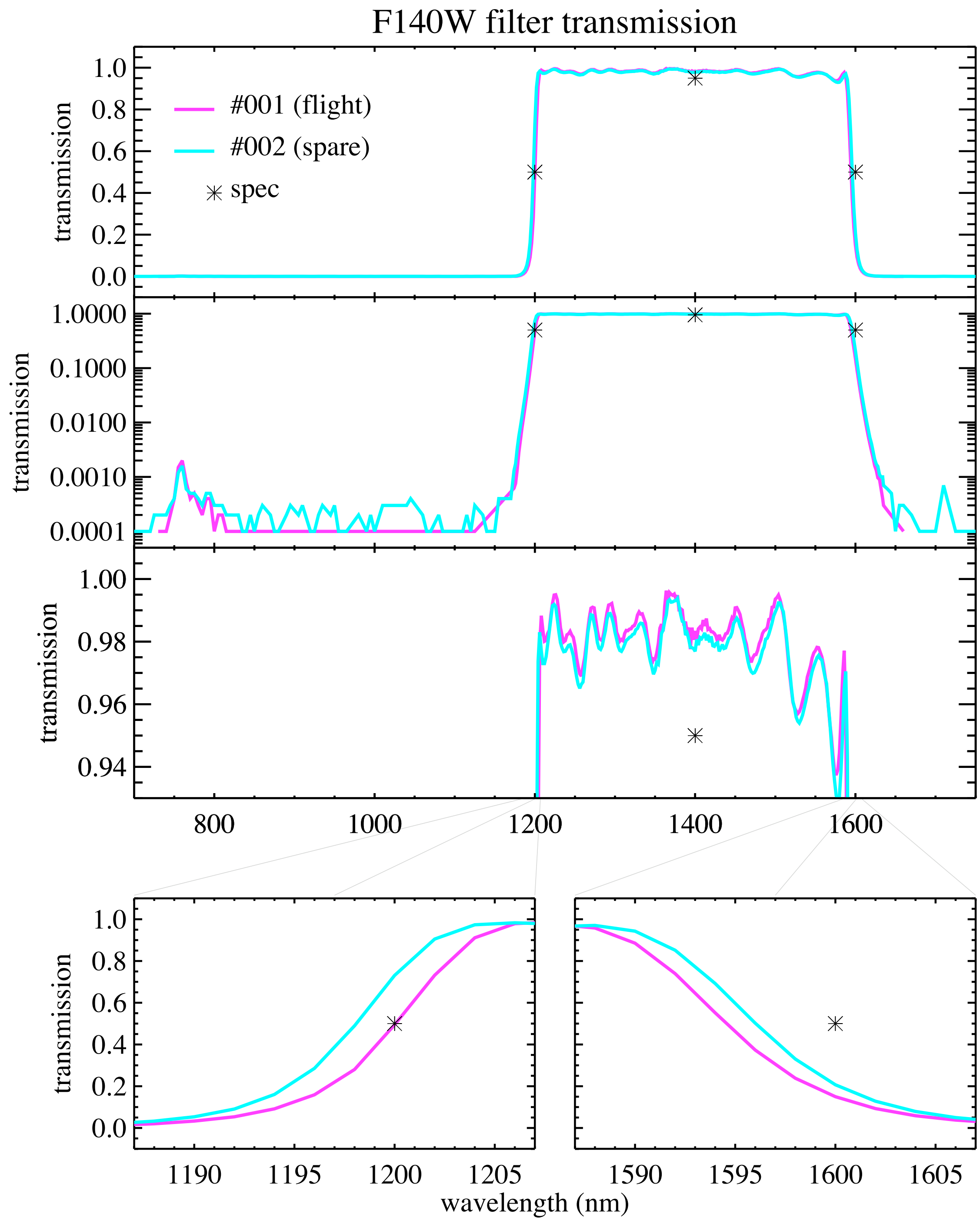

Figure 2: The transmission data for the two candidate F140W filters, shown at various stretches to highlight their similarities and differences. The F140W #001 exceeds the spec for transmission in the center of the bandpass, has slightly higher throughput than #002, matches the blue edge spec, and misses the red edge spec by 5 nm. The F140W #002 exceeds the spec in the center of the bandpass, and misses the blue and red edges by 2 nm and 4 nm, respectively. Both filters have slightly less out-of-band blocking at 760 nm than required, but the integrated area under this part of the transmission curve is 0.01% of the integrated area under the entire curve.

and 550 nm it will drop precipitously (with the exact wavelength depending upon the coating). We will assume it drops smoothly from about 98% at 400 nm to 0% at 350 nm. Finally, for the quantum efficiency (QE) of the IR detector, we will assume the QE curve of FPA129, a thinned-substrate detector which is one of the current possible candidates for flight; FPA129 still has significant response (about 18%) at 350 nm.

Using these assumptions, we plot the total system throughput in the IR/F093W bandpass in Figure 3. For comparison, we also show the total system throughput in the IR/F098M and the UVIS/F600LP; for the F600LP, we have extrapolated the QE curve of the UVIS channel CCD from its last measurement at 1000 nm down to a value of zero at 1100 nm. As evident from the figure, the F098M and F600LP bandpasses can perform much of the same science as the F093W. The red end of the F093W is well matched in throughput by the F098M, and the F098M does not include as much background (given the rising zodiacal spectrum to the blue). The blue end of the F093W is surpassed in throughput by the F600LP on the UVIS channel, which also has better spatial sampling, lower read noise and dark current, and a wider field of view (FOV). Both the UVIS/F600LP and the IR/F098M provide well-defined bandpasses, while the IR/F093W bandpass includes significant out-of-band peaks at very short wavelengths. If the IR-optimized antireflective coating of the IR channel RCP and detector window has significant structure in the visible, the IR/F093W bandpass will look worse than the idealized version shown in Figure 3.

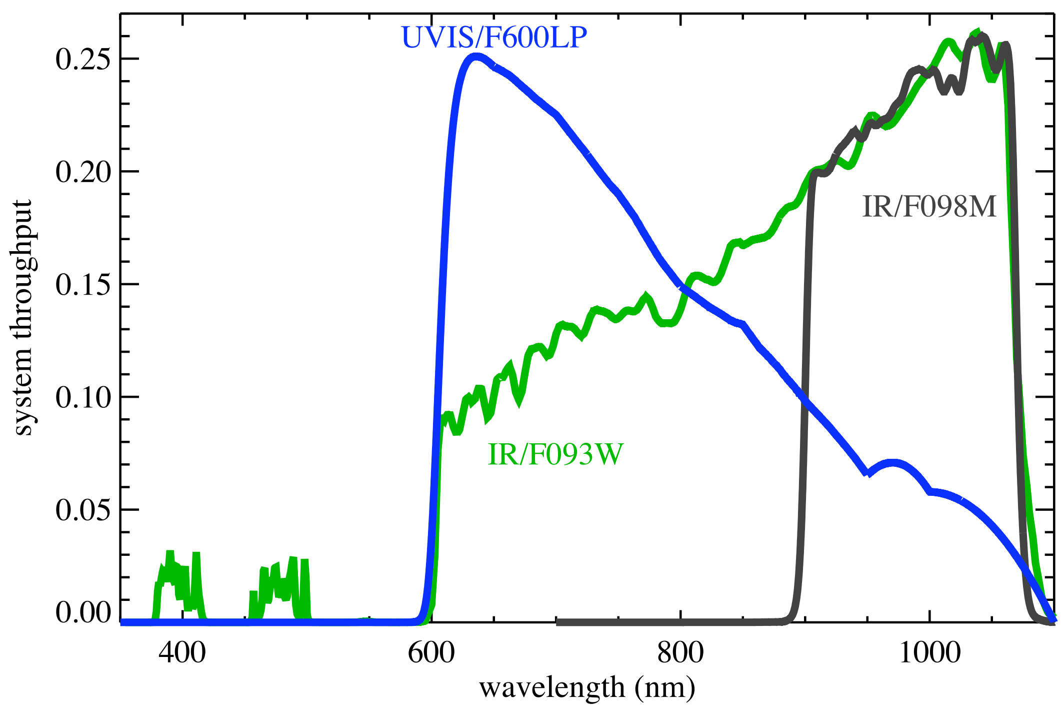

Figure 3: The total system throughput of the IR/F093W, IR/F098M, and UVIS/F600LP bandpasses. The F098M matches the throughput on the red end of the F093W. The F600LP surpasses the throughput on the blue end of the F093W, and provides the significant advantages of the UVIS channel (finer spatial sampling, lower read noise and dark current, wider FOV).

Compared to the F093W, the F140W bandpass provides a more useful option for science observations that is not replicated by other WFC3 filters or by ground observations (Figure 4). The F140W straddles the gap between ground-based *J* and *H* (caused by strong atmospheric absorption). Without the F140W, there are two natural pairs of wide filters available for two-color IR photometry on WFC3: the F125W-F160W, and the F110W-F160W. Both of these pairs replicate the same gap between ground-based *J* and *H*. Thus, F140W straddles a gap in the WFC3 filter set, too, and gives observers a third option for two-color photometry, because it makes a natural pair with the F105W. Finally, the F140W provides a useful direct image for the G141 grism, since the F140W bandpass is centered within the G141 wavelength range.

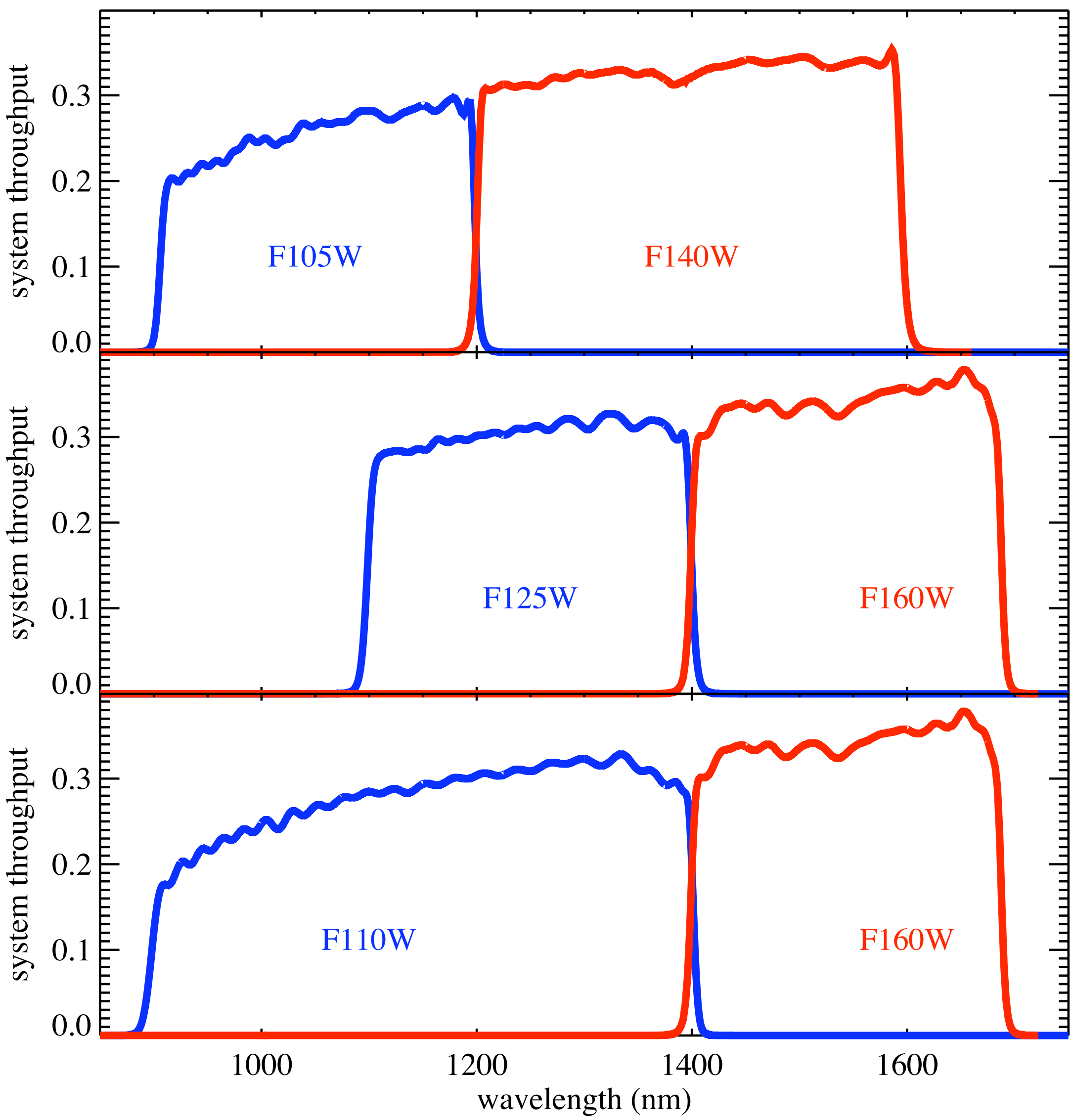

Figure 4: The F140W-F105W pair offers a third option for two-color wide-band photometry on the WFC3 IR channel. The F140W also straddles the gap at 1400 nm between F160W and F125W, F160W and F110W, and ground-based *J* and *H*.

Summary

We are replacing the F093W filter on the WFC3 IR channel with the F140W filter. The F093W filter is no longer needed for IR channel alignment, and for scientific observations, its utility can be reproduced (and often surpassed) by alternative filters on both the IR and UVIS channels. The F140W offers a natural complement to the F105W filter, straddles a gap that falls between the other bandpasses of WFC3 and ground observatories, and provides a direct image for the G141 grism. We have two suitable F140W filters in hand to serve as flight and spare candidates.