White Paper In Response To NSPIRES RFI For The Next Generation Space UV-Vis Space Observatory (NG-SUVO)

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In a SPIE paper (Ulmer, 2009, Proc SPIE, 7222, 33) Ulmer outlined a 8-m telescope proposal with upgraded detectors and coating that would, in the UV range, be $\sim 100\times$ more sensitive than HST. However, funding circumstances have changed such that it would appear that a 2.4 m class telescope is about as "good as it gets." Thus, here we de-scope that mission to a 2.4m that would probably cost about \$2G in today's dollars. The main point of the technology discussion that I present first is that vast improvements can be had in the optics and detectors such that a new mission, although not our "dream machine" would bring a factor of > 10 improvement. Second, I demonstrate that plenty of science can be done with a $> 10\times$ improvement.

1 Improvements With Technology Enhancements

For the details of the HST optics see Ford et al 1998 (Proc SPIE, 3356, 234 and references therein). From Ford et al we note that the transfer mirrors **IM2** and **IM3** produce net 34% efficiency at 350 nm. Then by removing the correcting **IM2** and **IM3** mirrors we can greatly improve optics efficiency over the HST system by about $3\times$. The optical telescope assembly (OTA) itself is only 62% @350 nm such that assuming an improvement to 70% is plausible. Then, let us improve by $\sim 2\times$ over the QE of WFC (about 40%) to give us a net gain of about 7 at 350nm. Thus, there is plenty of headroom for the UV even if a CCD is used.

In comparison, the microchannel plates (MCPs) on the HST only about about 5% net QE. The equivalent single photon detectors that will become available (*if NASA ever finds enough money to fund them from TRL3 to TRL6 or above*) that are GN based will be $\sim$ 70%. The gain over the HST would be at least 15 just with a detector advance! Then this system would allow us to do in 40 orbits what it takes HST 600. *Note in comparing with the MCP to the GaN APD, we are comparing zero read noise devices.* Having zero read noise vs CCDs with (say 3 electron read noise) *is important*, however, as shown in Fig 1 taken from web posted presentation given by Don Figer of RIT.

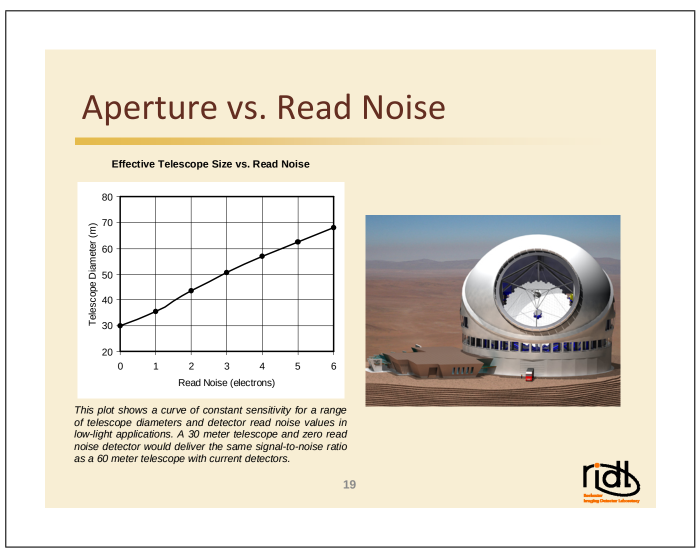

Figure 1: Read noise versus effective aperture

We see in Fig 1 that going from ~ 3 electrons (the WFC3 UV-Vis) camera to a zero-read-noise one gives us a boot of 50/30. Therefore, if we compare with an avalanche photodiode (APD) GaN zero-read-noise camera to a 40% QE CCD vs the 5% MCP we still get a gain of 50/30 by going to zero read noise. Including the 70%/40% gain in QE for the APD vs the CCD, the net is nearly 3. We are being conservative here in that the GaN does not require the severe blocking filters needed for cameras that are sensitive in the visible. Remember, we gain another factor of 3 by removing the transfer mirrors to then yield a gain of 9 over the current ACS/WFC in the near UV. Assume a 10% improvement in the OTA reflectivity to give an overall factor of 10 improvement; so in 100 orbits the next generation space UV-visible observatory (NG-SUVO) would be equivalent to the 1,000 orbits with HST!

Turning now to the Vis channels on HST: These only cover a field of view of about 3 arc min $\times$ 3 arc min. Yet, it should possible to gain a sky coverage factor of 4 with a 6 arc min $\times$ 6 arc min FOV. Then, combining zero read noise with the effective increase in étendue of the new mission would yield and improvement of about 6 total. This assumes no improvement in the reflectivity of the OTA, but a 10% improvement is possible. Also the current cameras have such slow readouts that for efficiency, the number of dithers and exposures is typically limited to 2-4. As CMOS advance, readouts can improve the observing duty cycle efficiency by ~ 1.5. Also it is plausible to gain of almost another factor of ~ 2 in efficiency with a zero read noise nearly 100% QE device. Therefore, even in the visible, gains can be made such that observations that benefit from a higher efficiency read outs, a 6 arc min $\times$ 6 arc min FOV (versus 3×3), zero-read-noise, and improved OTA reflectivity, the net gain will be 1.5 x 4 x 2 x 1.1 = 13!

All in all then significant advances can be made in the UV-Vis such that a 2.4 m telescope with modern detectors and coating will be a significant advance of HST even if it is not commensurate with our dreams of a 8 m or 16 m class UV-VIS mission.

Bottom line: Put significant funding into technology development to bring the key new detectors and coatings to at least TRL6, and we can then have a wonderful mission However, arguing for a new start without these improvements in hand will likely lead to either a new start being declined, or if accepted, not having the technology in hand such that a premature new start will likely lead to huge cost overruns.

2 Some Science Drivers

In order to keep this document short we simply enumerate some science drivers. As noted above see Ulmer, 2009, Proc SPIE, 7222, 33 for details:

2.1 Mainly UV

1. A study of the hot intracluster medium of rich clusters of galaxies: The concept is to use background QSOs along the line of sight to clusters to search for absorption lines due to gas as intermediate temperatures of about 10^5K to 10^6K. This gas *ought to be detectable* and detections will give us a link to the overall missing baryon question. However $\sim 50-100$ sight lines are needed to be assured of detections, and the necessity of about 50-100 targets then requires the increased sensitivity of the NG-SUVO.

2. He II absorption and the ionization history of the Universe out to z of 4.

3. Observing metals in intergalactic filaments

4. Observing the warm hot intergalactic medium (WHIM) and the relationship between galactic winds and metal enrichment of the WHIM.

5. Detecting metals in planetary disks leading toward an understanding the relationship between the metallicity in proto-planetary disks and planet formation.

6. Detecting the water absorption and perhaps even DNA-protein-like absorption features in the atmospheres of extra-solar planets (or extra-solar moons such as Europa or Enceladus).

7. Imaging aurorae on solar system planets, e.g. Jupiter

2.2 Mainly The Visible Band

1. Weak lensing mapping of Dark Matter.

2. Weak Lensing as a probe of the nature of Dark Energy.

3. Larger Deeper GOODs and UDFs (also UV as well).

4. With a coronagraph, imaging of planets (also in the UV as well).

5. Extending the catalog of Legacy images of nearby galaxies.