Appendix A Telescope Coating Systems

The comparison that has been presented in this report is between a new VRC and an old LX10. The difference in image brightness between these two scopes, once focal ratio has been accounted for, is due to the differences in the transmissive efficiency of each scope's optics. The SCT has four reflective surfaces (two sides of corrector plate, primary & secondary mirrors) at which some of the incoming light can be lost. The VRC has no corrector plate, and therefore only has two reflective surfaces to worry about. The two scopes also have different coating technologies applied, the SCT using traditional metallic aluminum coatings with a dielectric protective topcoat, and the VRC has purely dielectric reflective coatings. Finally the LX10 used in my testing is about 10 to 15 years old, so there has presumably been some degradation of the coatings. To fully understand the differences in performance between these two types of scope, it is necessary to examine the coating technologies in more detail.

I was able to easily find manufacturer published data from Meade and Celestron on their coating systems. Meade identifies two coating systems: standard, and Ultra High Transmission Coatings (UHTC). Today's "standard" Meade coating is equivalent to the EMC coating system on my LX10. Celestron also has two coating systems: Starbright, and Starbright XLT. On all SCT mirrors the coating providing the bulk of the reflectivity is an initial layer of pure metallic Aluminum. To protect the Aluminum from corrosion, and to improve its reflective properties, a thin dielectric coating is applied on top. Mirror top coat materials include various combinations of SiO, MgF_2, SiO_2, and TiO_2. Corrector plates also have coatings applied in order to reduce reflectivity. Corrector plate anti-reflection coating materials include various combinations of Al_2O_3, TiO_2, and MgF_2. Figure A-1 below shows the transmission data provided by each manufacturer for their coating systems. The plot shows the net percentage of light passed by the entire optic system. I have combined the manufacturer data with other information available on the web in order to extrapolate the performance graphs beyond just the visual band.

The VRC mirrors do not use a metallic coating to give them their reflectivity. They use a completely dielectric coating. A dielectric coating works much the same way as a band-pass filter made for light pollution. Many thin alternating layers of non-conductive material are applied to the glass substrate (in this case a mirror blank). A small percentage of the incoming light is reflected at each interface between layers. The thickness of each layer is selected very carefully so that each layer's reflection is in phase with the neighboring layer's reflection, resulting in constructive wave interference. The result is very high (99.9%) reflectivity for the design wavelength. Dielectric coatings are very hard and durable, making them easy to care for. They have been in use for several years on mirror diagonals, and now that the costs to apply are coming down, dielectric coatings are becoming popular on telescope optics as well. Figure A-1 shows a typical transmission curve for a VRC with dielectric coated mirrors. I was unable to find data specific to the VRC's actual mirrors, so the plot shown is an amalgamation of data from several different coating suppliers in North America. Note that outside the design wavelength band, dielectric mirrors have basically zero reflectivity. This was a surprise to me when I initially discovered it.

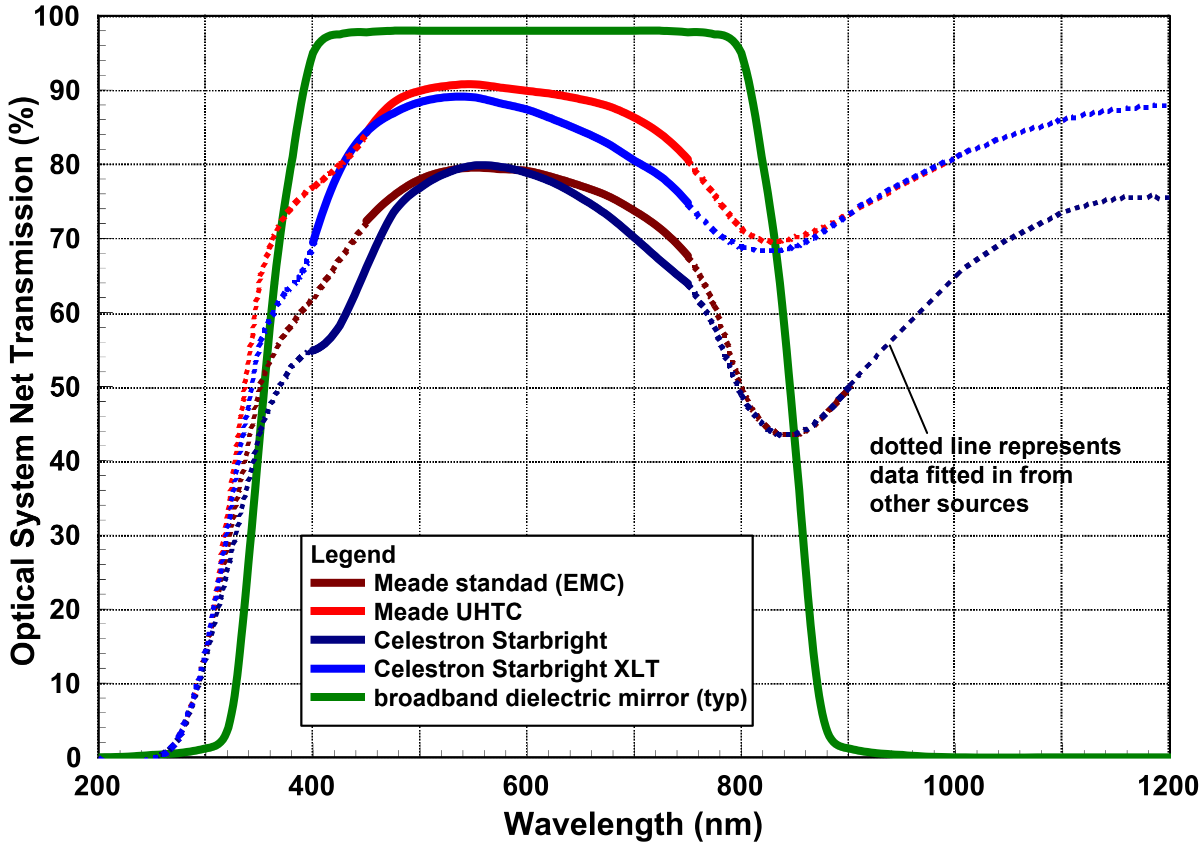

Figure A-1 **Optical System Spectral Transmission By Coating System**

To determine the impact of coating system on telescope performance I combined the data in Figure A-1 with the spectral data I have already on hand for the detector (human eye, Mallincam), light source (bright nebula, dim nebula, galaxy, Moon, light polluted sky), and filter (no filter, Astronomic UHC, Baader UV/IR, 680nm Pass). By stacking these four things together numerically, detector + filter + telescope + light source, I was able to predict the relative brightness of each coating system. Since the Celestron coating system seems to perform similarly to the Meade system, I have used the Meade system in my calculations only.

Figure A-2 shows the relative brightness of each coating system when the scopes are used visually. Regardless of light source, the more modern UHTC coating is about 16% brighter than the standard coating. The dielectric coated VRC perform even better, at about 27% brighter than the standard coated SCT.

Figure A-3 shows the relative brightness of each coating system when the scopes are used with a standard Mallincam Xtreme (Sony ICX418AKL). Relative scope performance on bright and dim nebulae is similar to what was found during visual use, but performance on infrared rich light sources like galaxies and the Moon varies significantly. To confirm my predictions of relative brightness, I went back to some of the images I collected during my comparison testing.

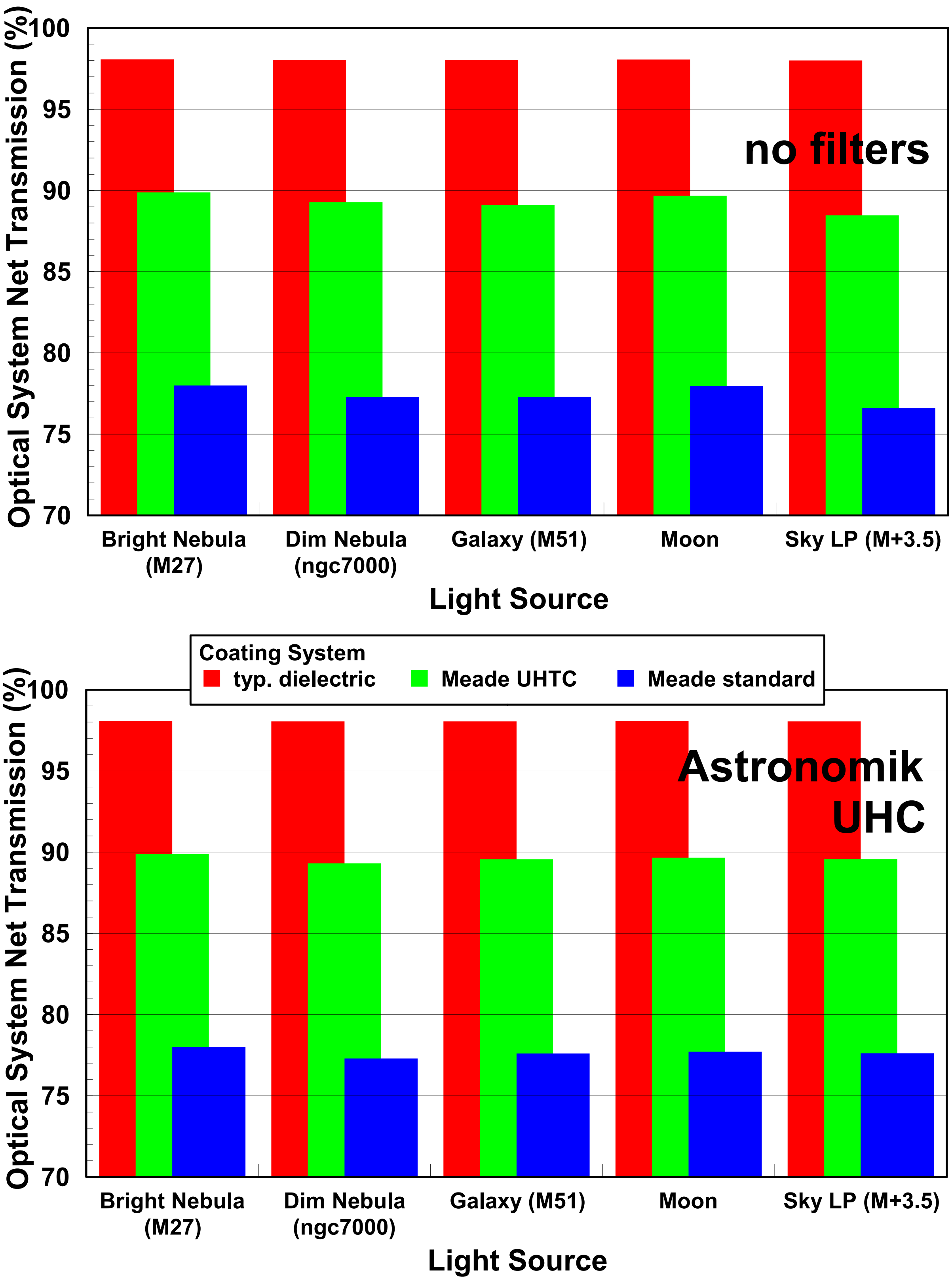

Figure A-2 **Predicted Optical System Net Transmission – Visual Use**

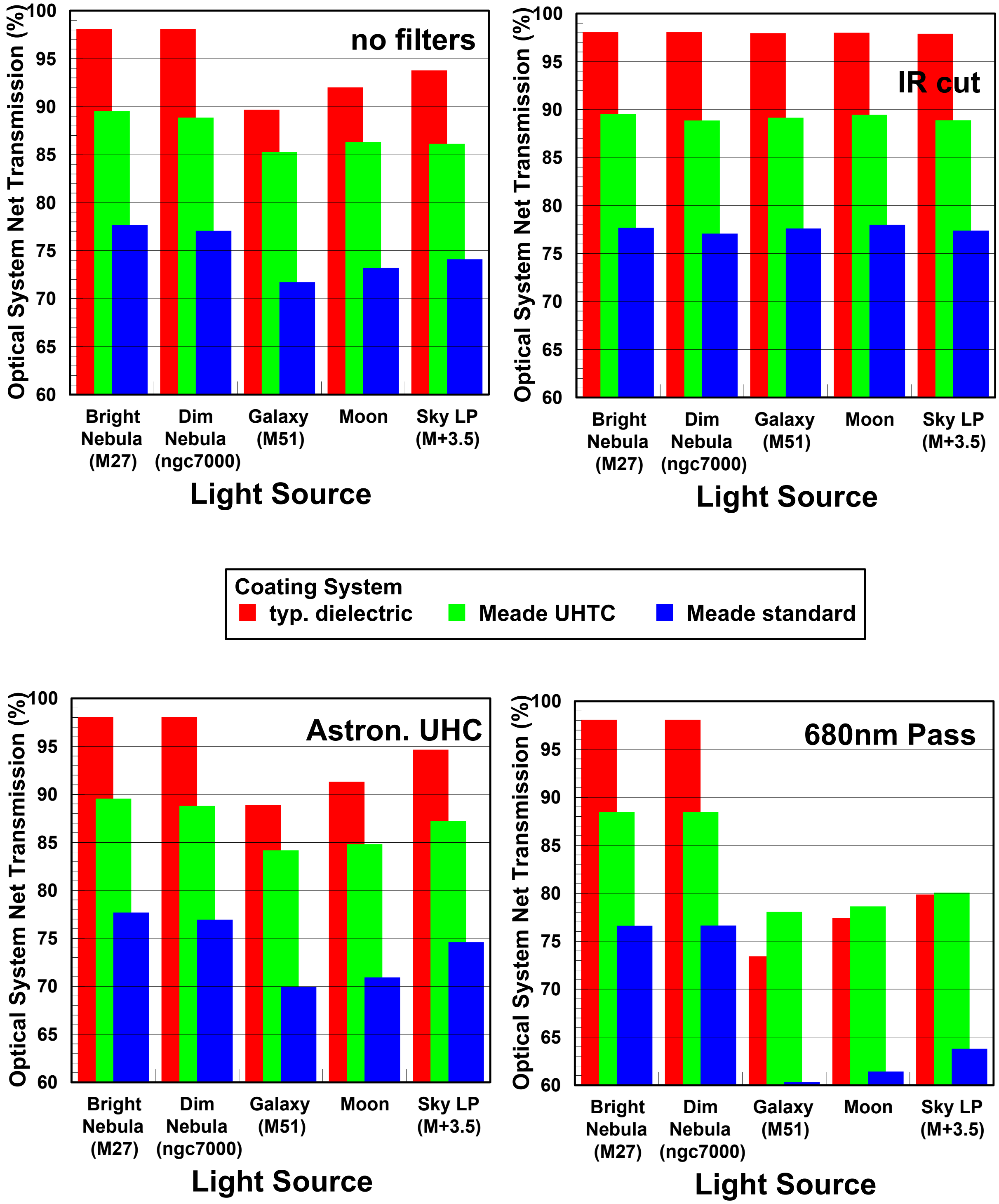

Figure A-3 **Predicted Optical System Net Transmission – Mallincam Use**

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Figure A-4 is screen captures of M42 from Test #1 taken with my SCT and a VRC, with no filters. Accounting for the focal ratio difference (f/10 versus f/8), the VRC image still took less time than required to get the same relative image brightness. The remaining difference in INT time translates into the VRC being about 26% brighter than the SCT. The predictions in Figure A-3 suggest that the VRC should be around 26 to 27% brighter, meaning that the optics in my LX10 don't seem to have degraded at all; a reasonable and entirely believable outcome. My LX10 may be 10 to 15 years old, but it has coatings that include a protective dielectric top coat which prevents degradation. I have also cleaned my mirrors and corrector plate within the last 12 months, so scope performance should be pretty close to on-spec.

8" LX10 @ f/10, 30 sec INT

VRC8 @ f/8, 14 sec INT

Figure A-4 Test #1 Comparison – M42, No Filters

Figure A-5 is screen captures from Test #5 taken with my SCT and a VRC, with the 680nm Pass filter. Based on the INT time and the difference in focal ratio, the VRC was approximately 20% brighter than the SCT. My predictions suggest the VRC should be about 21% brighter than the SCT. Again my direct observations are consistent with the predicted brightness of these different telescopes. Having two separate observations corroborate my predictions gives me a high level of confidence that the predictions are accurate. Continuing with that assumption, the following conclusions can be made about the performance of these different scopes when used with a Mallincam:

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8” LX10 @ f/5.3, 187 sec INT VRC8 @ f/4.1, 90 sec INT

Figure A-5 Test #5 Comparison – M51, 680nm Pass Filter

- On emission nebulae, the VRC is approximately 27% brighter than SCT’s with standard coatings, and 10% brighter than SCT’s with enhanced coatings like UHTC or Starbright XLT, regardless of filter used.
- On galaxies, the VRC is approximately 27% brighter than SCT’s with standard coatings, and 6% brighter than SCT’s with enhanced coatings, when using no filters or a typical LP filter.
- On galaxies, the VRC is approximately 21% brighter than SCT’s with standard coatings, and 6% dimmer than SCT’s with enhanced coatings, when using an IR high pass filter.
- On the Moon, the VRC is approximately 26% brighter than SCT’s with standard coatings, and 6% brighter than SCT’s with enhanced coatings.
- The VRC lets in 28% more light pollution than SCT’s with standard coatings, and 9% more than SCT’s with enhanced coatings.
- The VRC is probably not suitable for use with IR high pass filters that have cut-off wavelengths much above 700nm.

Thus, the bottom line is that by test and by calculation, the optical system of the VRC results in superior image brightness compared to modern SCT’s, regardless of coating technology.

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