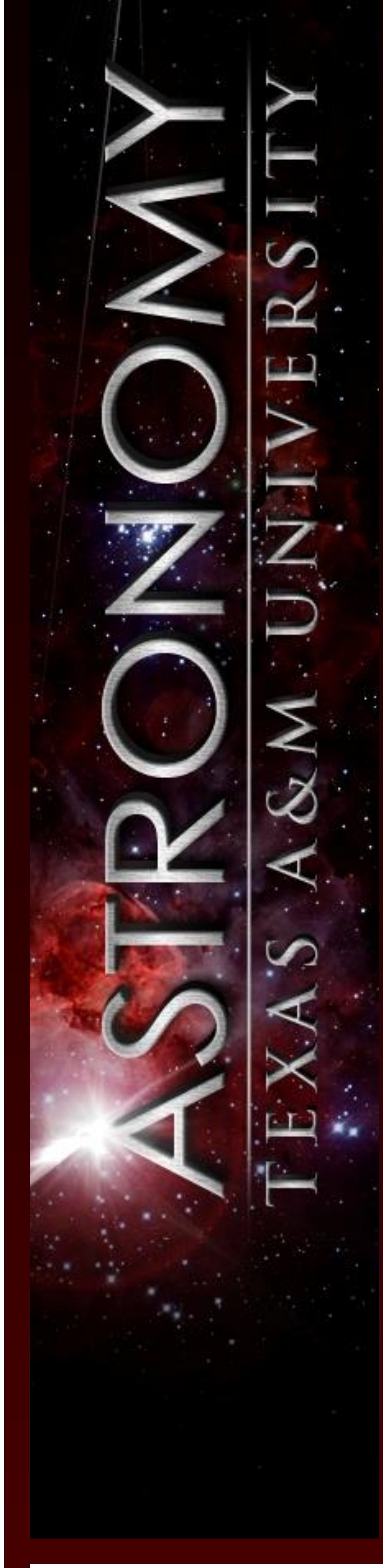

Total Reflectance of Black and White Materials

Doyeon Kim, Luke Schmidt, Jennifer L. Marshall, Travis Prochaska,
Marcus Sauseda, D. L. DePoy

Texas A&M University Department of Physics and Astronomy

Abstract

The Astronomical Instrumentation Lab at Texas A&M is compiling a library of total reflectance measurements of various materials commonly (and uncommonly) used to reduce or increase the amount of reflected light in optical systems. The total reflectivity of each material was measured over a wavelength range 250 nm < λ < 2500 nm using a Hitachi High-Tech U-4100 UV-Visible-NIR Spectrophotometer located in the Materials Characterization Facility (MCF). This ongoing project includes the work of many people which has in the past created several problems including inconsistent labeling, lost samples, and mistakes in the data reduction process. Our current work introduces improvements made to the sample organization and data processing pipeline along with a new user-friendly plotting method.

Introduction

Previously, many people have worked on this project with inconsistency, which created several problems, such as losing data from the lack of labeling, poor organization, poor sample handling, and creating mistakes in the data processing pipeline. Also, unlike only testing black materials previously, we also tested white materials for AstroCal, another project by Astronomical Instrumentation Lab that is a mobile spectrophotometric calibration system, to find the most highly reflective and dispersive (Lambertian) white material.

Method

We used the Hitachi High-Tech U-4100 UV-Visible-NIR Spectrophotometer in the Materials Characterization Facility (MCF) to obtain reflectance profiles for the samples [1]. The U-4100 dual beam spectrophotometer uses two different lamps to cover a wide range of wavelengths [1]. For the far-UV (λ<345 nm), the U-4100 uses a deuterium lamp; For UV, visible, and near-IR measurements, the system uses tungsten lamp [1]. The layout of the U-4100 includes monochromators, beam splitters, mirrors, focusing lenses, and detectors which can be used to analyze liquid or solid samples [1]. With this system we measured precise reflectance values at each wavelength (in 1 nm steps) for the wavelength range 250 < λ < 2500 nm [1].

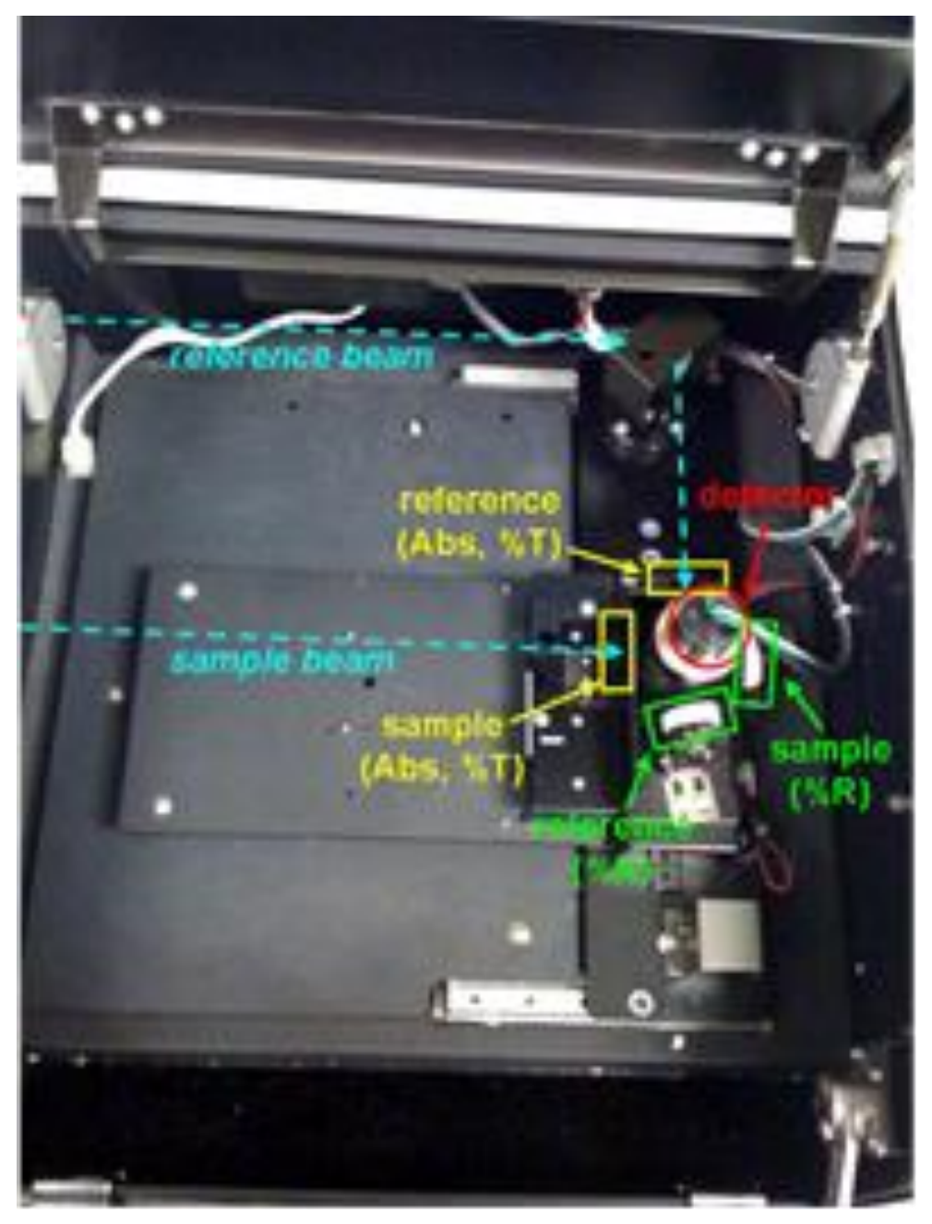

Figure 1. Instrumental setup of the Hitachi U-4100 spectrophotometer [1]

Figure 2. Organized samples in a tray

Materials Tested

We had difficulties with inconsistent labeling and poor organization of the samples and collected data. Therefore, several samples were lost and many collected data became unusable. Thus, we set the unified sample dimensions (Min: 1"x1", Max: 2"x2"), categorized the samples, and named them with a structured 3-4 letter code system, placing them into individual containers for easy accessibility and cleanness as in Figure 2. For instance, sample codes starting with F are fabrics, P are paints, T are tapes, and M are miscellaneous. Also, for the white materials, W is added in front of these codes as shown in Table 1. From this structured organization, we obtained 61 black materials and 9 white materials.

Category	Sample Code	Name
	SRS05	76188/ AS-01160-860 /SRS-05-010 / Labsphere
	LSRS	Pixelteq STAN SSL Low Specular Reflectance Standard
	BASO4	$BaSO_4$ -- MCF standard white material
	ABB	Aluminum.Beaded.Black
	ABH	Aluminum.Beadblast.Hardcoat
	AMB	Aluminum.Machined.Black
	AMH	Aluminum.Machined.Hardcoat
	SRN	Steel.Raw.Nickel
Fabric	F01-1	Optics Flock #55 on carboard
	F01-2	Flock 55
	F02	Edmund Optics flock #65
	F03	Black velcro on carboard (**Black Velcro**)
	WF01	Da-Lite Da-Mat
	WF02	Da-Lite High Contrast Matte White
	WF03	sample1blue
	WF04	sample2
Paint	P05	Rustoleum
	P07	Valspar
	P10	spray paint
	P11	black dry erase on cardboard (**Black Dry Erase**)
	WP01	Duraflect
	WP02	120 (hardness of the sandpaper) roughest
	WP03	180 (hardness of the sandpaper)
	WP04	240 (hardness of the sandpaper) smoothest
Tape	T01-1	Shurtape CP-743 Heat Shrink Tubing
	T01-2	Shurtape CP-743 Heat Shrink Tubing - shrunk
	T02-1	Polyken 510 Gaffer's Tape (**Black Duct Tape**)
	T02-2	Polyken 510 Gaffer's Tape(**Black Duct Tape**) outside from Aug 6 to March 4
	T03	black electrical tape on cardboard (**Black Electrical Tape**)
Miscellaneous	M01	Construction Paper
	M02	Black foam board
	M03	Thor Labs BKF12 (**Black Aluminum Foil**)
	M04	Thor Labs (unspecific) (**thorlabsfoil**)

Table 1. A portion of categorized tested materials

Process

Another difficulty we had was mistakes in the data reduction process. The order of data values of SRS-05 from Labsphere and MCF were in reversed order compared to the samples' MCF value. Thus, the comparison of the original plots and the corrected plots are shown in Figure 3.

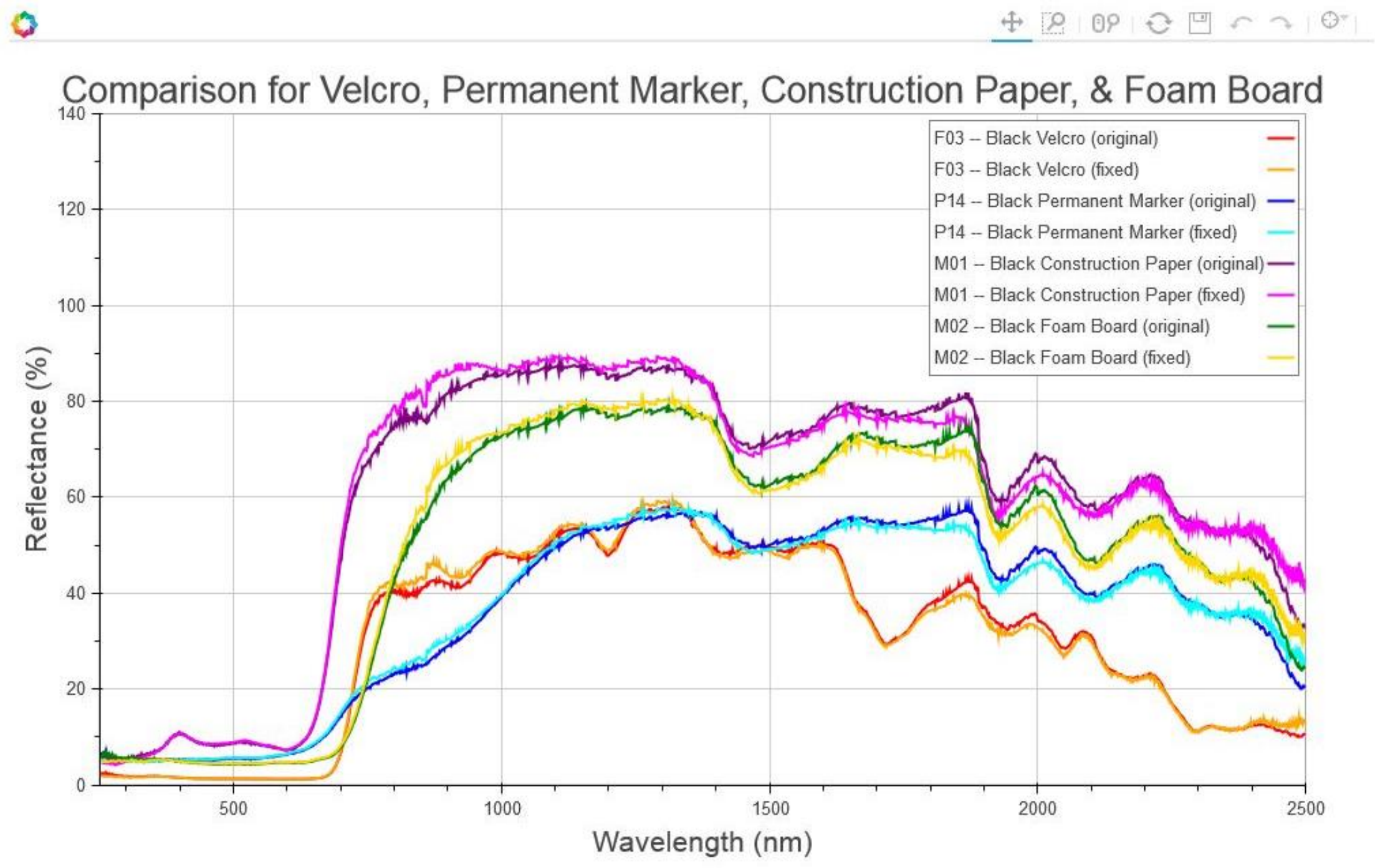

Figure 3. Comparison of the original plots and the corrected plots

Not only were the original plots recreated with the correct data reduction process but we also used a new user-friendly plotting method by Bokeh, a Python plotting library which includes pan, box select, box zoom, wheel zoom, undo, redo, reset, save, and hover with crosshair tools. The last collected data was in 2013, so before collecting new sample data sets, we collected the data of SRS-05, ABB, and AMB in order to see the reliability of Hitachi High-Tech U-4100 UV-Visible-NIR over a period of time (See Figure 4). The original and current data values were very similar, that the residuals were the range of [-2.1%, 1.3%] for ABB and [-2.4%, 3.5%] for AMB.

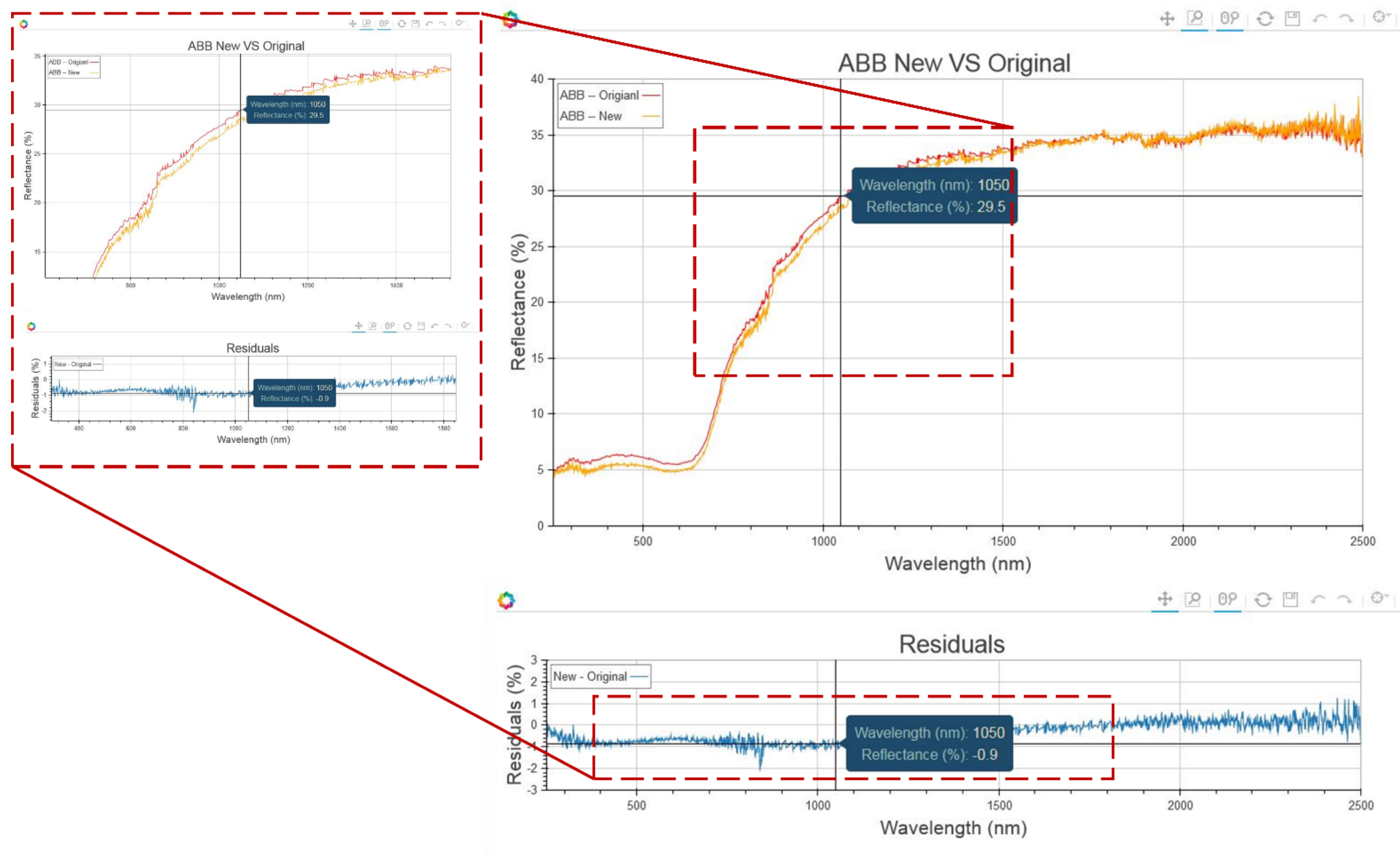

Figure 4. Comparison between ABB and AMB's original and new sets of data with new user-friendly plots method

Future Plans

We will make a structured experiment guide book that addresses the detailed appropriate sample handling methods and sample size regulations. Like black materials, we will also focus heavily on white materials and enlarge our white material sample collection. Moreover, we will gladly test samples for others if they submit the samples that they would like to be tested.

Conclusions

From the flaws and mistakes we have made in the past, we have presented the improvements made to the sample organization and data processing pipeline along with a new user-friendly plotting method on compiling a library of total reflectance measurements of various black and white materials. We note that some of the black materials' surfaces were not clean, including finger grease and scratches on the surfaces. We found the different durability of various samples from their damage degree. These unexpected mistakes we have made alarmed us that we have to be more careful on handling the samples and processing the data during the project. We will keep this in mind and continue the project.

Reference

[1] Marshall, J.L., Williams, P.D., Rheault, J.-P., Prochaska, T., Allen, R.D., DePoy, D.L. 2014, Proc. SPIE, Vol. 9147, 167

Texas A&M University Department of Physics and Astronomy is an institutional member of:

Munnerlyn Astronomical
Instrumentation Lab
Texas A&M University

GMT

HETDEX Illuminating the Darkness
Hobby-Eberly Telescope Dark Energy Experiment

LSST
Large Synoptic Survey Telescope

DARK ENERGY
SURVEY

Acknowledgments

Texas A&M University thanks Charles R. '62 and Judith G. Munnerlyn, George P. '40 and Cynthia Woods Mitchell, and their families for support of astronomical instrumentation activities in the Department of Physics and Astronomy. Also, thanks Amanda E. Henkes for training students to use Texas A&M University Materials Characterization Facility (MCF).