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Balloon-Borne FIREBall-2 UV Spectrograph Stray Light Control Based on Non-Sequential Reverse Modeling of On-Sky Data

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ABSTRACT

We present a comprehensive stray light analysis and mitigation strategy for the FIREBall-2 UV telescope. Using non-sequential optical modeling, we identified the most problematic stray light paths which impacted telescope performance during the 2018 flight campaign. After confirming the correspondence between the simulation results and post-flight calibration measurements of stray light contributions, a system of baffles was designed to minimize stray light contamination. The baffles were fabricated and coated to maximize stray light collection ability. Once completed, the baffles will be integrated into FIREBall-2 and tested for performance preceding the upcoming flight campaign. Given our analysis results, we anticipate a substantial reduction in the effects of stray light.

Keywords: Stray light analysis, opto-mechanical design, non-sequential ray tracing

1. INTRODUCTION

The Faint Intergalactic-medium Redshifted Emission Balloon (FIREBall-2) is a balloon-borne, ultra-violet (UV) multi-object spectrograph (MOS) designed to observe faint emission from the halos of galaxies. FIREBall-2 is an international collaboration between the United States (Caltech, JPL, Columbia University, University of Arizona, University of Iowa) and France (Centre National d'Études Spatiales and Laboratoire d'Astrophysique de Marseille). This suborbital astronomical balloon telescope, jointly funded by NASA and CNES, is designed to explore the forefront of modern extra-galactic astronomy through the discovery and mapping of faint emission from the intergalactic medium (IGM) and circumgalactic medium (CGM) around moderate-redshift galaxies ($z \sim 0.7$). FIREBall-2 helps to improve our understanding of the vast diversity of nearby galaxies through the study of galactic feedback, including matter and energy outflows. By exploiting a convenient balloon window between the atmospheric O₂ and O₃ absorption bands above 37 km altitude, FIREBall-2 observes line emission in the $\lambda = 1980 - 2130 \text{ \AA}$ band. FIREBall-2 is uniquely positioned as the only MOS to have ever flown on a balloon and the only UV MOS currently operating.

The FIREBall optical design is described in more detail in Hamden et al., 2020,¹ and includes multiple components. A 1.2m diameter siderostat mirror provides field selection and angular altitude control, directing light to a 1-m parabolic primary mirror. This primary focuses light through a hole in the siderostat and into the spectrograph tank, which is kept at vacuum to allow the CCD detector to cool to -105 C. The siderostat has a small field correcting lens which allows light from the parabola through. There are two field correcting mirrors, which improve the field of view from 10" (in the original FIREBall²) to allow 4".5 resolution over the 30' field of view. At the field corrector focus is a slit mask carousel, which allows one of up to 9 masks to be selected

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for use in flight. The masks are curved to match the spherical focal plane. Each mask is custom laser cut for a particular field of view. After the mask, the spectrograph optics consist of two spherical Schmidt mirrors, a grating, and two folding flats for compactness. The detector is a Teledyne e2v CCD201-20, an EMCCD for photon counting.³

This complex system requires a sophisticated baffling strategy, which we describe in § 3 and § 4.

2. STRAY LIGHT IN THE 2018 FIREBALL-2 FLIGHT

2.1 Flight Characteristics

FIREBall-2 last flew on September 22, 2018 from Fort Sumner, NM, during the fall Columbia Scientific Balloon Facility (CSBF) campaign. Unfortunately, the flight suffered an anomaly, significantly impacting the science goals. A hole in the balloon, discovered when the balloon reached float altitude of 128,000 ft, caused the balloon to descend after only three hours at the float altitude. The payload remained above the minimum allowable science altitude for about one hour after astronomical twilight. The atmospheric transmission for the FIREBall-2 bandpass is highly dependent on altitude, with about a 10% reduction for every 3 km of altitude lost. As the altitude decreased over the course of the flight, the UV throughput dropped sharply, negatively impacting the ability to observe faint targets as planned.

2.2 Stray Light Problem

During the flight, FIREBall-2 suffered from severe stray light contamination, which compromised the observational effectiveness of the spectrograph. The cause of observed stray light is primarily attributed to moonlight scattered or reflected from the partially deflated balloon directly into the spectrograph. This problem was exacerbated by launch timing which forced the flight to take place during a full moon, drastically increasing the stray light background.

Following the abrupt touchdown of FIREBall-2 and an inventory of damage sustained, the team conducted post-flight calibrations, during which the primary stray light paths were confirmed.^{4,5} Based on the results of the post-flight calibration, a preliminary baffling strategy was proposed. We present the work done since to implement the proposed strategy and expand the scope and effectiveness of stray light control measures.



Figure 1. (Left) The damaged balloon was bathed in bright lunar illumination during the 2018 FIREBall-2 flight campaign. (Right) The resultant lunar stray light produced a veiling glare on the detector.

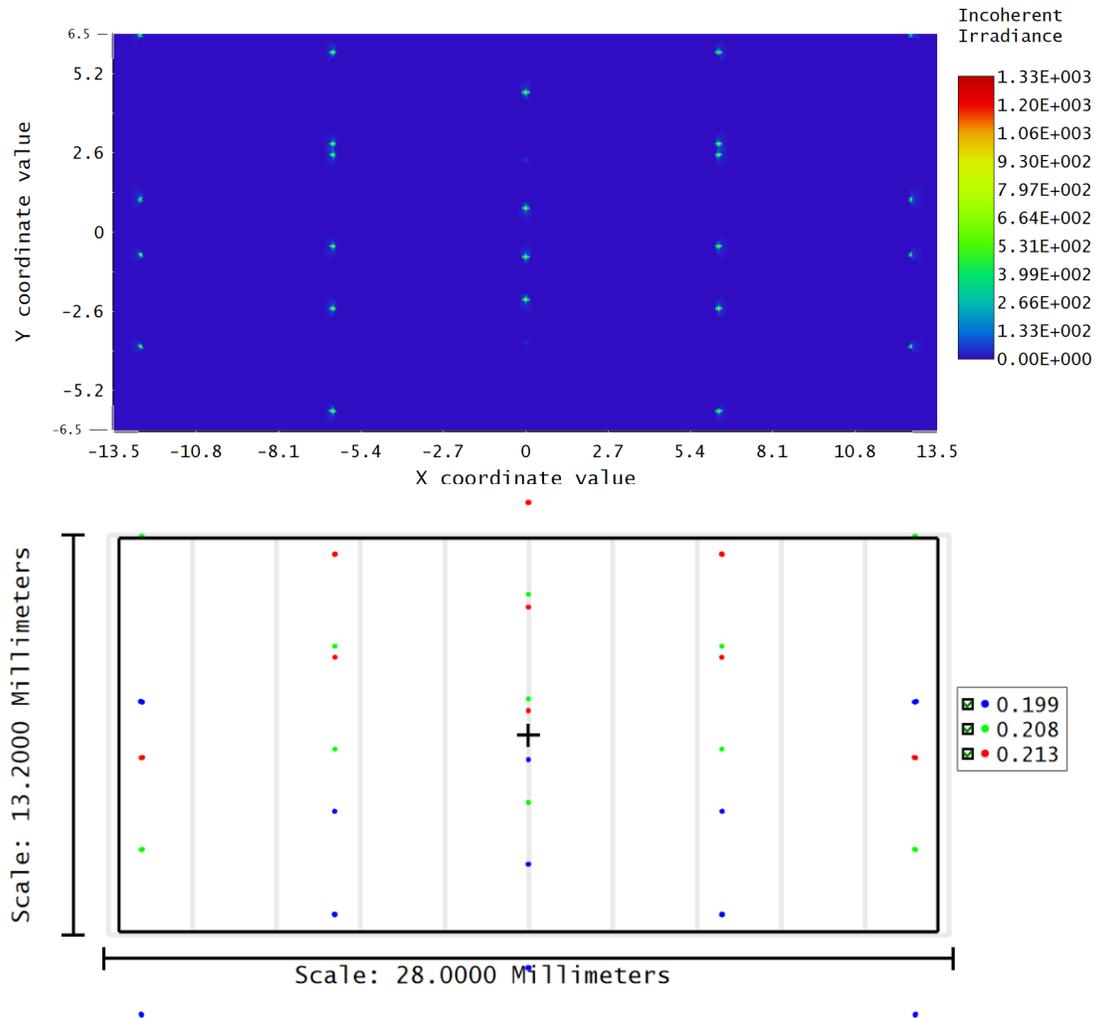


Figure 2. (Upper) Detector irradiance distribution produced with the non-sequential optical model. (Lower) Footprint diagram generated with the sequential optical model.

3. STRAY LIGHT ANALYSIS OF A UV BALLOON TELESCOPE

3.1 Stray Light Signature

During the 2018 flight campaign, FIREBall-2 suffered from severe stray light contamination, which substantially degraded optical performance. The main source of stray light was determined to be moonlight scattered and reflected off of the partially deflated balloon overhead. A hole caused the balloon shape to deviate from the nominal spherical shape to a teardrop shape, which directed and focused light into the telescope and directly into the spectrograph tank. The orientation and brightness of the full moon exacerbated the problem, scattering visible light into a direct path from the top of the spectrograph tank onto the back surface of the PCB mount, which then reflected onto the detector surface. This stray light path was not controlled for in optical analyses, and is believed to be the most problematic source of background light reducing detector performance. The scattered light background was $\sim 100\times$ more than expected. The photon counting capability of the EMCCD detector was not used during flight because of an excess of scattered light, resulting in higher than expected count rates on the detector ($>1/\text{event}/\text{pix}/\text{frame}$).

In addition to the elevated background levels, flashes of light were observed at certain orientations where moonlight was focused directly into the system by conical sections of the lower part of the teardrop-shaped

balloon. These flashes were many times higher in flux than the expected background or CGM signal. The flash was so severe that any images containing flashes were discarded from analysis. There is also a possibility that some of these flashes were caused by specular reflections from the support structure holding the primary mirror and the gondola doors.

More recently, a glint was discovered on the edge of the first Schmidt corrector mirror (SC1). Sneak paths through the medium bench assembly between the first folding flat (FF1) and the second folding flat (FF2) illuminate the rough edge of the mirror, scattering light up towards the detector through the hole in FF2.

3.2 Non-Sequential Optical Modeling

To correct the stray light contamination problem, FIREBall-2 was modeled in detail using Zemax OpticStudio®. By incorporating all of the optical features specified in the sequential optical model, a non-sequential model was constructed which closely matched the optical performance of the nominal system. By comparing the full-field point spread function of the sequential and non-sequential models, we demonstrated the near equivalence in performance between the two models.

Apertures were modeled accurately, along with the as-built optical surface specifications. Positioning and orientation of all optical components was carefully checked and rechecked to ensure the validity of results derived using the model. Mechanical objects were added as necessary to accurately characterize the possible stray light paths. A balance was struck between detail and simplicity to optimize ray tracing performance. All critical limiting apertures were included and surfaces known to be involved in producing the stray light were considered. Scattering properties were applied to critical surfaces using both built-in and measured scatter distributions.

Stray light baffles from the 2018 flight campaign were included in the original design. As new baffles were designed and tested, they were added in one by one to replace the original baffles. Performance with and without the proposed baffle solutions was characterized qualitatively and quantitatively.

4. STRAY LIGHT MITIGATION STRATEGY

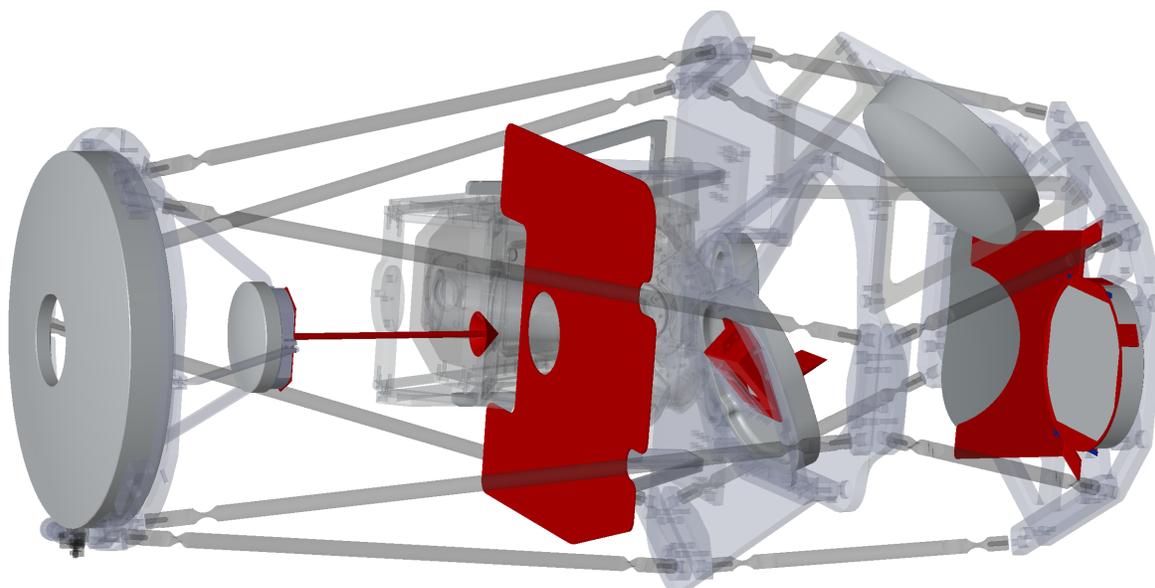


Figure 3. The FIREBall-2 spectrograph with newly added baffles highlighted in red.

A comprehensive system of baffles was designed and fabricated for installation on FIREBall-2, highlighted in Figure 3. By considering all previously identified stray light paths as well as new paths discovered during detailed analysis, baffles were implemented at locations best-suited to block any and all unwanted light from making its way to the sensitive EMCCD detector.

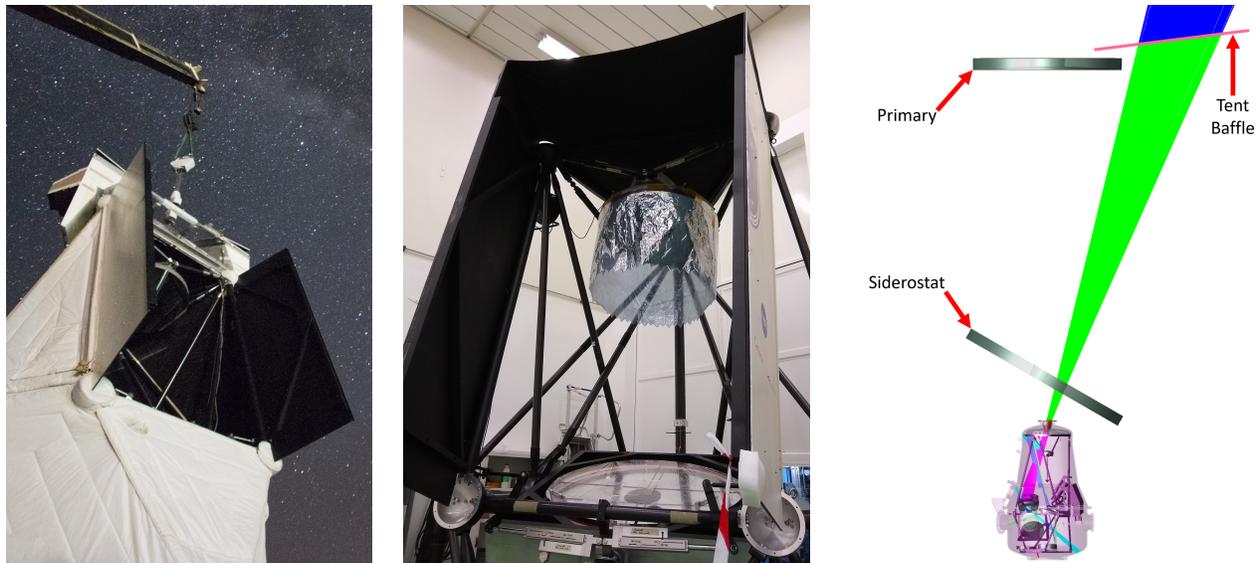


Figure 4. (Left) An upwards view of the FIREBall-2 gondola doors open, allowing light to enter the gondola structure from above. (Center) The tent baffle situated atop the gondola doors blocks balloon-emitted light from entering the spectrograph tank through the siderostat hole. (Right) Simulation of the tent baffle blocking stray light emanating from the balloon (blue rays from balloon turn green when blocked).

4.1 Tent Baffle

The first baffle introduced on the FIREBall-2 telescope following the 2018 flight campaign was the tent baffle. As the most problematic stray light path was quickly determined to originate at the balloon, the tent baffle was the logical first choice for implementation. Attached to the top of the gondola doors, the tent baffle extends 50 cm from the top of the gondola and allows unobscured observations up to a 65° elevation angle. Made out of black, flexible fabric, this baffle is deployed upon opening of the gondola doors, as demonstrated in Figure 4. With the primary source of stray light being traced to the balloon, this baffle is poised to make significant difference in the stray light background.

4.2 Conical Baffle

One of the stray light paths previously identified involves double and triple bounce ray paths on the field corrector mirrors at the top of the spectrograph tank. A conical baffle positioned below the first focal corrector mirror (FC1) was used to capture ray bundles following these unwanted paths and redirect them away from the mask/guider system, as shown in Figure 5. The original baffle was fabricated with a thin sheet of black anodized aluminum and included a shiny edge exposed to the unwanted irradiance. This baffle was damaged beyond repair during the 2018 flight campaign.

The conical baffle was redesigned to improve its durability and its effectiveness at capturing stray light. The walls of the cone were thickened and diameter of the opening aperture slightly expanded to contain more of the offending ray paths at the edge of the focal corrector optics. The new baffle is coated with Avian-S to minimize scattering off of surfaces inclined towards the detector and maximize light trapping.

4.3 Pupil Plane Baffle

One of most significant stray light paths identified during the 2018 post-flight calibrations involved light propagating from the top of the spectrograph tank onto surfaces in close proximity to the detector. The 2018 flight hardware included a baffle situated near the intermediate pupil plane between the focal corrector optics and the field mask, implemented to permit passage of only light which is contained within the nominal pupil ellipse. A proposal was made to extend the outer diameter of this pupil plane baffle to block any stray light which might

follow the unwanted ray paths described above. The redesigned baffle is shown at right in Figure 6 alongside the old baffle. The outer diameter of the baffle has been extended to effectively separate the upper part of the spectrograph tank from the lower part, with the pupil plane as the dividing interface. This new design isolates the lower region of the tank from receiving any unwanted light and greatly increases the chances of a successful observational campaign.

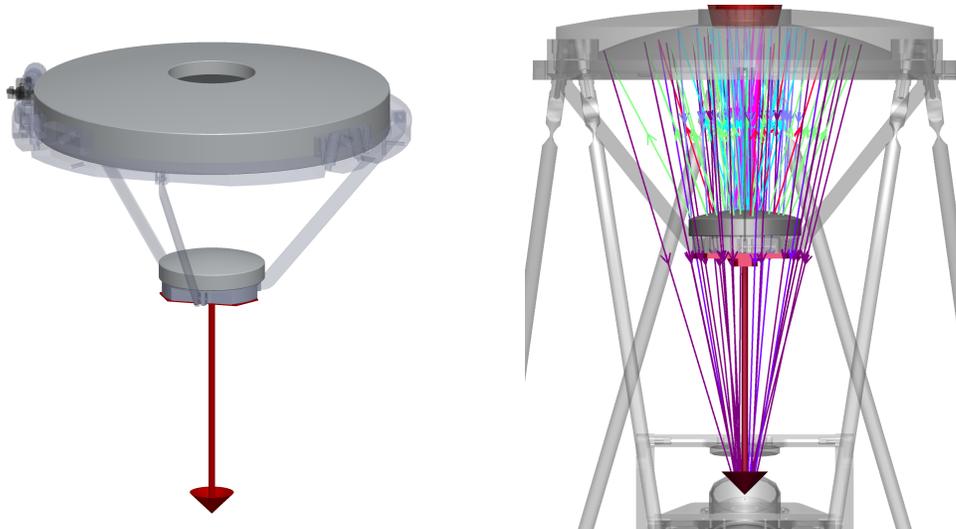


Figure 5. (Left) The conical baffle (red) situated beneath the focal corrector optics catches double and triple bounce paths between FC1 and FC2, as indicated at right by the per-segment coloration of ray paths. (Right) Each ray path sequentially evolving through violet, cyan, periwinkle, green, and purple constitute a double bounce path which is captured by the baffle.

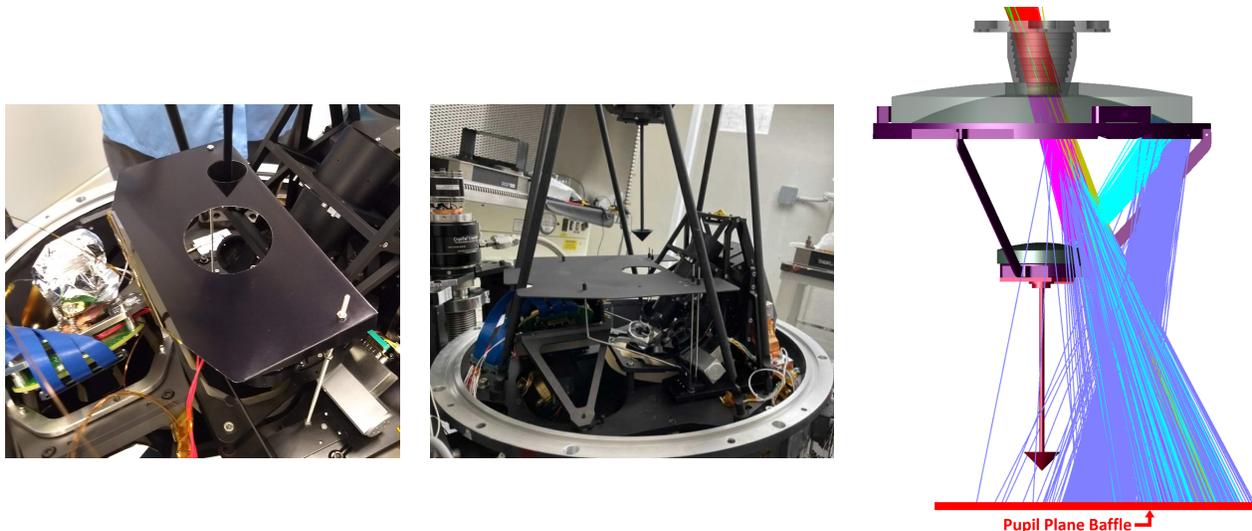


Figure 6. (Left) The old pupil plane diaphragm was constructed of thin, metal foil and mounted on threaded posts. (Center) The new pupil plane diaphragm is fabricated from sheet metal and mounted to the guider camera bench with six aluminum gussets. (Right) The new pupil plane diaphragm with significantly improved coverage isolates the upper part of the spectrograph tank from the lower bench.

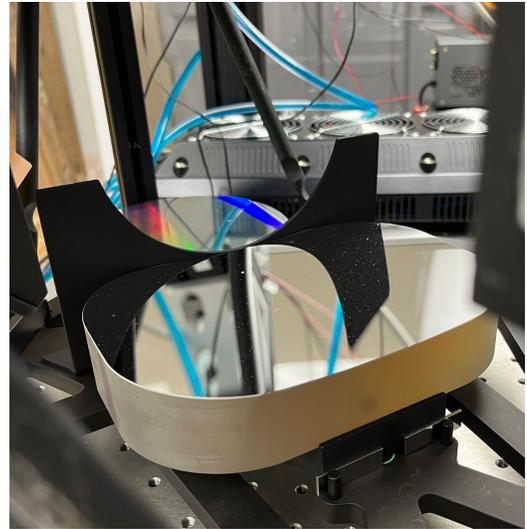
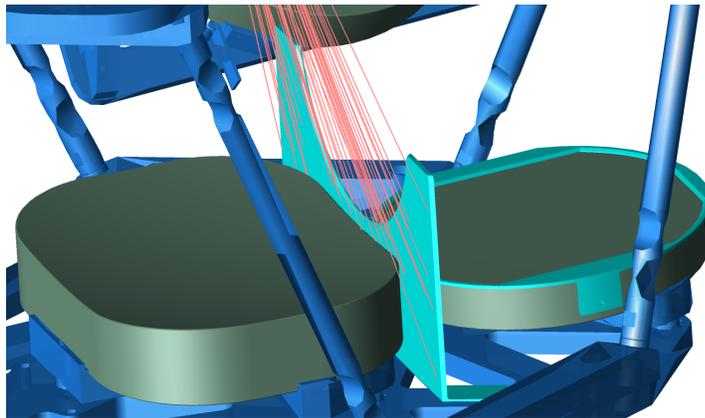


Figure 7. (Left) The SC1 glint baffle blocking rays which illuminate the unpolished, chamfered edge of the SC1 mirror. This mirror edge scatters light directly towards the detector, as observed in the laboratory. (Right) The installed baffle, coated with Avian-S, mounted to the bottom bench in between the SC1 mirror and the colorfully illuminated grating.

4.4 SC1 Glint Baffle

An unexpected stray light path was discovered by observation during lab testing. Glints of light reflecting off of the edge of the SC1 mirror after traversing a sneak path through the medium bench assembly between the FF1 and FF2 mirrors have the potential to send light towards the detector and increase the background. A barrier attached to the bottom of the spectrograph tank obscuring the edge of the Schmidt corrector from illuminating downstream optics prevents these potential ray paths from reaching the detector, as demonstrated in Figure 7. The barrier is coated with Avian-S to maximize absorption.

4.5 Grating Mask

The mask affixed to the grating, blocking the region outside the clear aperture of the elliptical grating surface, was badly damaged during the 2018 flight campaign. For the upcoming flight campaign, a new mask was designed and fabricated. With an emphasis on robustness and stray light mitigation, this new mask shown in Figure 8

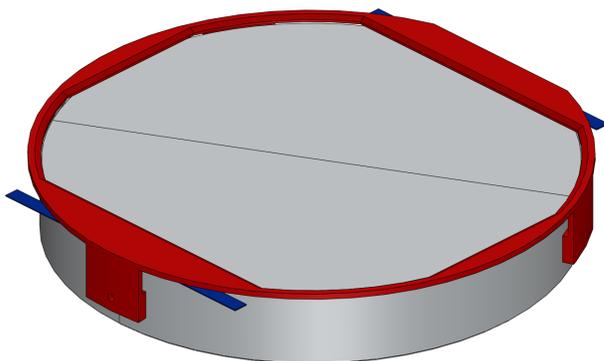


Figure 8. (Left) The grating mask with fixed to the outer face of the grating blank. Spacers shown in blue are used during mask installation to prevent damage to the grating surface and then removed after the adhesive sets. (Right) The coated grating mask during a fit check on the flight grating. The mounting mechanism was later updated as shown in § 6.6.

presents significant improvements over the previous mask, which was fabricated with a thin foil taped to the grating surface. Our new mounting solution using tabs and adhesive to fix the mask to the outer edge of the grating blank will reduce the risk of damaging the fragile grating surface. Considering the close proximity of the grating surface to the detector plane, the performance of this mask is crucial for mitigating out-of-field stray light.

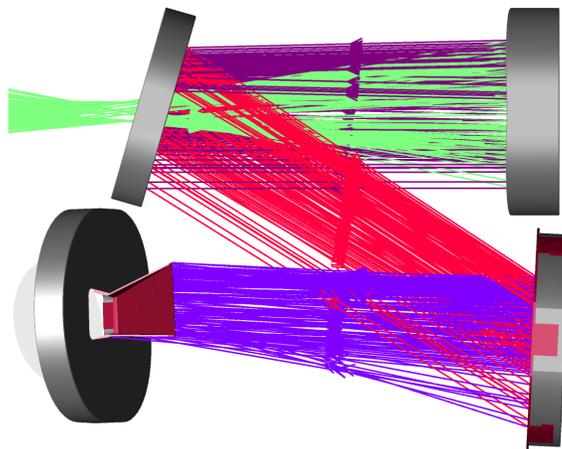


Figure 9. Unwanted direct-to-detector ray paths are blocked by the tongue baffle. The tongue baffle also blocks light just outside of the waveband of interest.

4.6 Tongue Baffle Improvements

A baffle attached to the FF2 mirror and extending down towards the grating was incorporated into the 2018 flight hardware. The baffle was included for two reasons: to prevent light from proceeding directly from the diffraction grating onto the detector without first reflecting off of FF2 and SC2, illustrated in Figure 9; and to block diffraction orders outside of the sole +1-order for which the system was designed. However, the baffle was designed with a smooth top surface oriented at a high angle of incidence to the chord connecting the grating and the detector, allowing for a significant portion of light contacting the black anodized surface to specularly reflect or scatter onto the detector plane.

The tongue baffle, shown in Figure 10 was redesigned with threading on the top face of the tongue surface to prevent unwanted light from reflecting and scattering into the vicinity of the detector. The thread orientation is



Figure 10. (Left) The tongue baffle upon receipt from ProtoLabs post manufacturing. (Center) The baffle was later coated with Avian-S optical black at Caltech to minimize scattering near the detector. (Right) The tongue baffle installed onto the FF2 mirror hole.

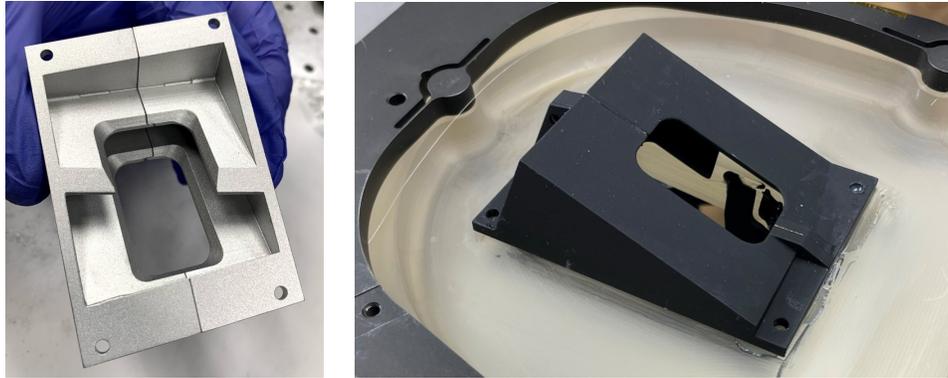


Figure 11. (Left) The front view of the ProtoLabs-fabricated detector baffle with respect to the sequential optical path. The vanes are designed to redirect rays away from the detector plane and capture unwanted light scattered from the FF2 central hole into the inter-vane cavity. (Right) The baffle was later coated with Avian-S at Caltech and transported to Columbia University for integration into the FIREBall-2 spectrograph. The image shows the baffle fixed to the backplane of the FF2 mirror.

orthogonal to the plane of incidence of the majority of rays intercepting the front face after diffracting, thereby redirecting light away at a steep angle. The baffle was coated with Avian-S polyurethane coating chosen for its success in aerospace applications, its low outgassing in high vacuum environments, and its durability.

4.7 Detector Baffle

To mitigate the risk of light scattering from the unpolished backplane of FF2 or the inner walls of the center hole in mirror FF2 from interacting with the detector, the detector baffle shown in Figure 11 was developed. It is believed that sneak paths allowed stray light to illuminate the backplane of FF2 and scatter onto the detector during the 2018 flight campaign. The baffle encapsulates the ray cones across the field converging onto the detector plane and fills the gap between the inclined detector package and the back of FF2. The space between the FF2 backplane and the detector plane was identified as the most likely source of much of the scattered stray light observed in 2018. Vanes trap and redirect unwanted light in spectrograph tank away from the focal plane. The baffle is coated in Avian-S to reduce scattering. The vanes were designed geometrically, using principles described in Ref. 6. Proximity to the detector and the high risk of near-to-detector stray light renders this baffle critical for mission success.

5. EFFECTIVENESS OF IMPLEMENTATION

To ensure the effectiveness of the stray light mitigation plans, verification testing was conducted for each baffle. Non-sequential ray tracing with and without each baffle showed marked improvements in the stray light rejection with the inclusion of the baffles. Non-sequential analysis results were compared with on-sky images highlighting stray light features. A comparative study of the distribution of stray light across the detector plane was used to quantitatively analyze the validity of the developed model.

Figure 12 demonstrates the effectiveness of the baffle implementation at mitigating stray light. The image at left depicts a typical stray light distribution from the 2018 FIREBall-2 flight campaign. The most notable features are the density of irradiance in the bottom right diagonal of the detector plane, which is replicated in center left figure containing detector irradiance results from a non-sequential ray tracing analysis. The source of stray light in this simulation comes from a radial source spanning 13.5° to 24° from vertical, modeled as an analog to lunar radiation redirected from a fully illuminated balloon above FIREBall-2. This source configuration was identified as the most problematic stray light contribution during the 2018 flight and was therefore the most pressing issue to overcome.

When the detector baffle is added to the optical model, stray light in the upper portion of the detector is reduced, but there is still substantial irradiance streaming into the detector at high angles after scattering off

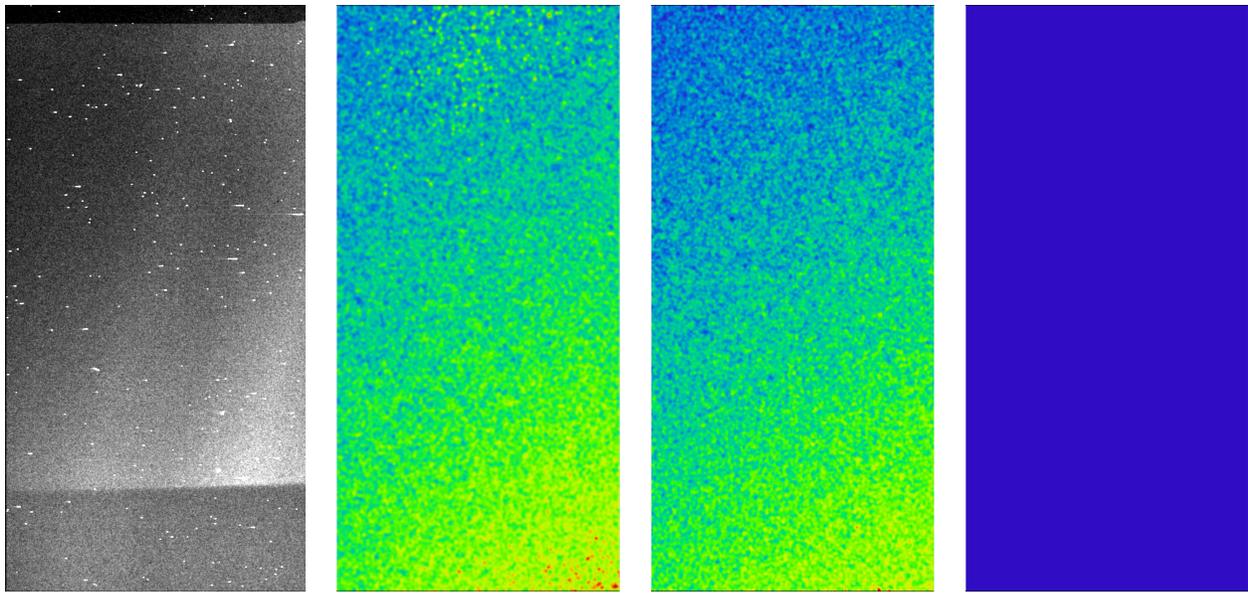


Figure 12. (Left) On-sky image of stray light observed during the 2018 flight campaign. (Center Left) Detector irradiance from a non-sequential ray trace simulating the stray light distribution from on-sky with no baffles installed. (Center Right) Marginal reduction in stray light with the inclusion of the detector baffle. (Right) Complete mitigation of stray light with both the detector baffle and the pupil plane baffle included. The inclusion of the tent baffle alone is also able to affect this sharp reduction in stray light.

of the rear surface of the FF2 mirror. It should be noted that the detector baffle was designed with substantial margin between the detector plane and the mechanical surface to minimize the risk of interference, and this margin reduces the baffle's ability to block high angle stray light. However, when the pupil plane baffle is included, the stray light from the source described above is entirely blocked, as shown at far right. Moreover, if only the tent baffle is included, all stray light from this source configuration is blocked. Redundancy in baffling solutions is essential to promote mission success, as there is a small risk of tearing the tent baffle or other possible failure modes.

The FIREBall-2 team is testing the stray light performance of the spectrograph with the newly added baffles at the CSBF facility in Fort Sumner, NM. Final results are pending, but early indications show excellent stray light rejection for the noted problematic ray paths. Figure 13 demonstrates preliminary results of a stray light test conducted using a flashlight pointed into the spectrograph tank. When contrasted with the stray light test results from a similar test presented in Hoadley et al., 2019,⁷ the new results show a marked improvement in stray light rejection. With confirmation of the effectiveness of our comprehensive system of baffles at mitigating stray light in the FIREBall-2 spectrograph, we move to a discussion of the baffle integration campaign.

6. BAFFLE INTEGRATION

A plan for integrating the system of baffles developed for FIREBall-2 was developed by Aafaque Khan and Simran Agarwal in conjunction with colleagues at Columbia University. Multiple baffles were fixed in place using 3M™ EC 2216 B/A Scotch-Weld™ Epoxy Adhesive, while others were bolted onto the upper and lower spectrograph benches. The epoxy was mixed by volume with syringes and de-gassed with a vacuum pump in a bell jar. The biggest challenge of the integration process was that the spectrograph optics had already been aligned, meaning that baffles had to be installed in situ with the mirrors in place. This was particularly problematic for the grating mask, but the team made effective use of protective tents to prevent optics from being damaged while baffles were positioned.

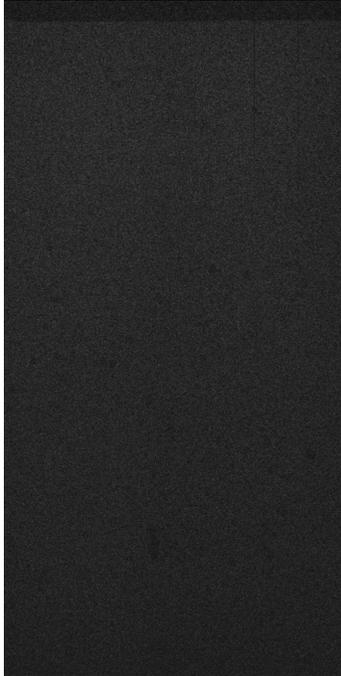


Figure 13. Stray light testing image from the test campaign in Fort Sumner, NM taken on July 25th.

6.1 Tongue Baffle Integration

Before installation of the tongue baffle, leftover epoxy on FF2 from the 2018 campaign required that parts of the baffle tabs be removed manually, as chipping off epoxy could have damaged the mirror. The baffle was sent back to Caltech for re-coating after the interfering regions were removed. The tongue baffle was fixed to the inner hole of the FF2 mirror with adhesive and a 3D-printed "casquette" tool to press the tabs onto the mirror edge, as illustrated in Figure 14. The baffle tabs first catch the edge of the mirror during by-hand installation, then the casquette tool precisely positions and orients the baffle as pressure is applied. A shim and kapton tape were inserted at the edge of the tool to ensure a tight fit during epoxy curing.

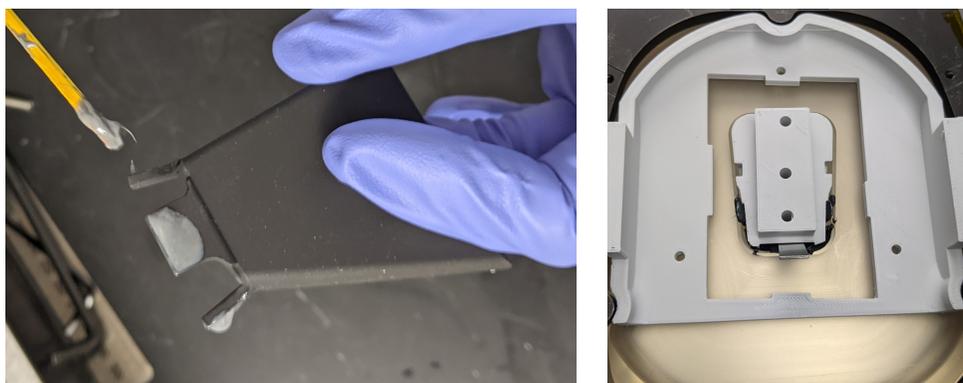


Figure 14. (Left) A view of the bottom side of tongue baffle with epoxy being applied to the mounting tabs. (Right) A rear view of the casquette tool inserted into the FF2 hole and pressed onto the baffle tabs. The 3D-printed tool ensures that the baffle is positioned and oriented correctly.

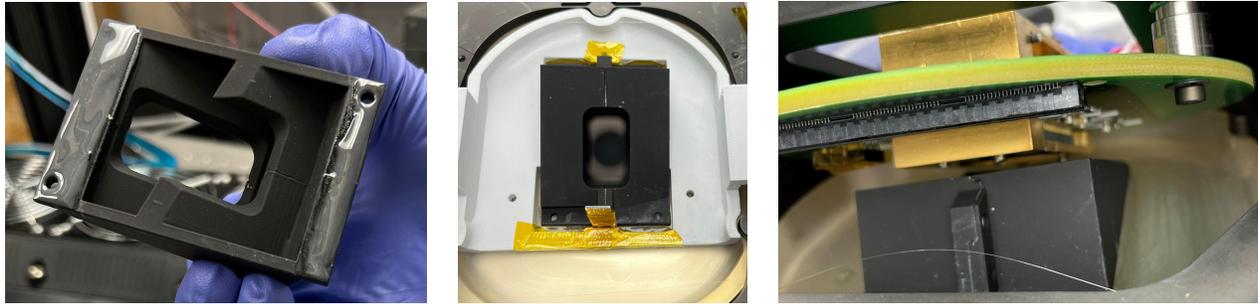


Figure 15. (Left) Detector baffle with epoxy on the bottom. (Center) Detector baffle installed onto the backplane of FF2. The 3D-printed jig for baffle alignment was removed after the epoxy cured. (Right) A view showing the proximity of copper detector clamp to the detector baffle.

6.2 Detector Baffle Integration

Next, the detector baffle was installed onto the back of the FF2 mirror using a 3D-printed jig and shims for positioning as shown in Figure 15. With the jig placed on FF2 and adhesive applied to bottom of the baffle, the baffle was pressed onto FF2 and shims were applied to the top and bottom along with kapton tape to fix the baffle in place during epoxy curing. Once the epoxy cured, the jig was removed and the detector assembly was installed for a fit check.

6.3 Thermal Analysis of Detector Baffle

There was a mild concern that the proximity of the detector baffle to the cold detector and copper cold clamp connected to the detector, as shown at right in Figure 15, could cool the baffle via radiative heat transfer. This cooling could induce thermal gradients in the FF2 mirror and potentially stress the adhesive bonding contacts past the point of failure.

To ensure that these thermal gradients did not pose a mission critical risk, we conducted a thermal simulation involving the Zerodur FF2 mirror, the detector baffle, and the radiating copper detector clamp. The detector clamp has the largest view factor to the detector baffle, so this was the only cold surface used in the model. Direct thermal contact was assumed between the baffle and FF2, as the thickness of the adhesive bond would have an insignificant effect on steady state thermal gradients. Various cases for mirror temperature boundary conditions and emissivity of the 110 Kelvin copper clamp were used in the model.

By analyzing the radiative transfer from the 110 Kelvin clamp to the detector baffle, the worst case scenario indicates that a thermal gradient of no greater than 0.1 Kelvin from the coldest to the hottest spot on the baffle. We inferred that the high thermal mass of the mirror and the high conductivity and low thermal mass of the baffle average out the temperature. With these findings, we successfully confirmed that radiative transfer does not pose any risk of inducing failure in the baffle bond.

6.4 SC1 Baffle Integration

The SC1 glint baffle was bolted to the bottom bench of the spectrograph. Originally, the plan was to fix this sheet of metal in place with adhesive, but the team reconsidered this decision and decided to implement a clamping mechanism instead. Figure 16 shows a side view and an underside view of the mechanical clamping mechanism used to fix the baffle in place between SC1 and the grating.

6.5 Conical Baffle Integration

The conical baffle was one of the simplest baffles to install. Three threaded holes in the FC1 mounting ring on the field corrector assembly were used to install the baffle in 2018, and these same holes were for this installation. The baffle, coated with Avian-S, hangs beneath the field corrector optics as shown in Figure 17.

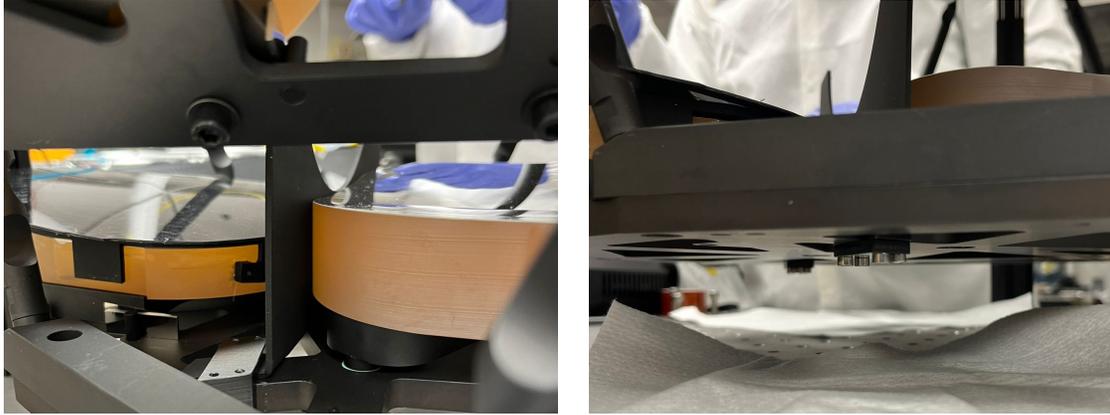


Figure 16. (Left) Side view of the SC1 baffle mounted onto the bottom bench. (Right) Underside view showing the mounting components under the bottom bench.



Figure 17. The conical baffle is fastened onto the FC1 mounting ring and sits beneath the field corrector assembly.

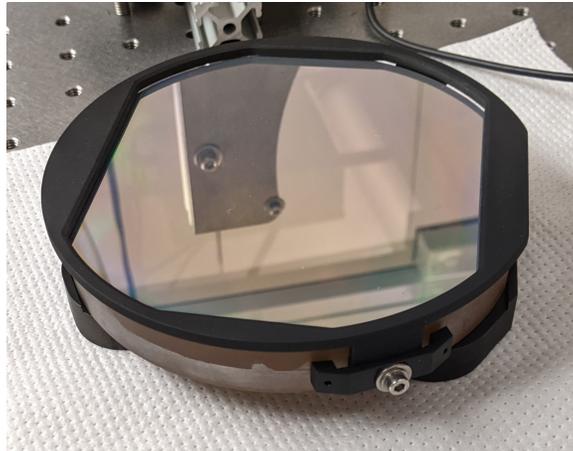


Figure 18. The grating mask is attached to the grating blank through a set of three bonded clamps to which the mask tabs are bolted.



Figure 19. (Left) The pupil plane baffle positioned above the spectrograph medium bench during a fit check. (Right) The installed pupil plane baffle after detector shimming. Thin rods are used to hold the pupil plane baffle in place.

6.6 Grating Mask Integration

The grating mask posed significant challenges during integration, not the least of which was the tight space into which it had to be installed. Originally, the mask was to be installed with three simple tabs contacting the outer edge of the blank. However, there was a mismatch between the size of the actual grating blank and the grating blank in the FIREBall-2 CAD model. This mismatch left too great a gap between the tabs and the edge of the blank for the adhesive to hold.

As such, a new mounting method was developed by the team which used three additional clamping bars to which the original mounting tabs were attached. The new mounting solution is demonstrated in Figure 18, where mounting clamps are bonded to the grating blank and the mask tabs are bolted onto these clamps.

6.7 Pupil Plane Baffle Integration

The pupil plane baffle is the last baffle to be installed. The baffle was mounted using a system of vertical gussets, metal rods attached to the mask guider bench atop the spectrograph medium bench. Thin rods are used for mounting because of tight constraints on added mass. Structural support is provided almost entirely by four gussets, while two extra gussets are included to prevent flapping of thin metal sheet. A fit check of the baffle and a demonstration of the mounting scheme are shown in Figure 19.

7. CONCLUSION

We have developed and implemented a stray light mitigation system on the FIREBall-2 UV balloon telescope. Comprehensive stray light analysis via non-sequential optical modeling, paired with on-sky stray light images enabled a unique and effective strategy for providing a comprehensive solution. Baffles were designed and fabricated, and are planned for integration onto the telescope in the near future. With the proposed system of baffles, the next FIREBall-2 flight campaign will exhibit superior stray light rejection and maximize scientific impact.

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