Proposal for a Stray Light Analysis of the Apache Point 3.5-m Telescope

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Introduction

We desire to have improvements made in our ability to do photometry on the APO 3.5m telescope. The majority of measurements on the 3.5m telescope are still made at the Nasmyth focus. It is likely that this will continue to be true for some time. On the 3.5m a large portion of the photometry is accomplished using SPIcam at visible wavelengths. This instrument has a total field of view (FOV) of 0.08° x 0.08° and is situated on the telescope's optical axis. A considerable amount of work is also done with GRIM at near infrared wavelengths (from 1 to 3 μm) but we will be focusing in this proposal on the visible wavelength characteristics of the telescope. Since GRIM's sensitivity does not extend very far into the thermal infrared we do not think that this focus is a major limitation to the usefulness of this study for the current telescope instrumentation.

It is suspected by many that the flat fielding difficulties that are encountered when trying to do photometry using SPIcam on the 3.5-m are caused by scattered stray light falling on the telescope focal plane. Features in dark sky frames have been seen which appear to be 20% of the sky and which extend over 50% of SPIcam's FOV.

The Stubbs group at UW is actively building a large field imager for use on the 3.5-m telescope. This camera may see first light as early as summer of 2001. We will refer to this instrument as the Stubbs Big Camera (SBC). It will have a rectangular FOV with an angular coverage of 0.32° x .80° when used on the 3.5-m telescope. This camera will also be used for photometry. Our collective experience with the smaller field camera makes us anxious to minimize the scattered light problems that we may have in the current telescope optics. This proposal includes a significant start towards our understanding of the scattered light problems that we will encounter in this wide field imager.

Statement of Work Goals

We are proposing here that we hire Pompea and Associates to build and run a stray light model of the 3.5-m telescope. The goals of this work will be to identify where modifications of the 3.5-m would improve the off-axis rejection characteristics of the telescope and to assess the effectiveness of those modifications. The main focus of this work will be to improve the on-axis performance of the telescope. However, in light of our development efforts on the SBC, a second goal of this project is to evaluate the off-axis scattering in a wide field of view and to make sure that we understand the impact that the suggested modifications will have on the performance of wide field detectors.

There will be four stages to this effort. First, we must build the model. This early part of the effort will require approximately two weeks worth of concentrated attention on my part. We will need to supply the vendor with a prescription of the optical system, a description of all coatings used in the optical system (or our best efforts in this regard), and drawings of the current support structures and baffles. Either during this period, or before, we also need to collect a set of stray light measurements from the telescope for use in comparisons with the model.

The second stage will be to compare results of the model with on-axis measurements in order to understand the limitations of the model and to make best effort attempts to improve the model. It is important to the vendor that the measurements for this work do not impede the time line of finishing the work in this proposal. If the off-axis data are not available in a timely manner, then the analysis will proceed without the benefits of this comparison. The goal of this second stage of work will be to produce model estimates of both the average level of scattered light and contour plots showing the variation of scattered light within SPIcam's FOV. We will make these estimates for several off-axis angles of a bright source. We will detail below the steps that we plan on using to acquire the comparison data and the steps we will use to compute the model data used for the comparisons.

The third stage of this effort will be to use the model to evaluate the stray light rejection characteristics of the telescope under variable conditions. These calculations will be used to determine off-axis angles instructive to the stray light performance of the system. The vendor will then use knowledge of these angles of interest to suggest modifications to the telescope baffling. At this time we will, of course, be required to give the vendor guidance on the extent of modifications that we are willing to make in the pursuit of improved stray light performance of the telescope. The suggested modifications could include any range from a complete redesign of the baffle system to simple modifications of the present design. The extent of this evaluation will depend mostly on our willingness to consider significant changes to the telescope.

An important part of the third stage of this effort will be to evaluate what effects the proposed baffling modifications will have on the SBCs FOV. For this we will require model estimates of the stray light across the SBCs FOV in two orientations of the instrument rotator. For each rotator position we will compute the stray light analysis before and after the suggested baffling modifications. These calculations will be done at a reduced spatial resolution for angles of interest of the off-axis source.

The forth stage of this effort will consist of documenting all the model calculations including the assumptions used in the analyses and the results in a final written report.

Statement of Work Details

In this section we show our intended steps toward obtaining the goals listed in the previous section. We anticipate that some changes to these steps may be desired in the course of this work. Such changes will be discussed between the vendor and an APO representative at the time that they are deemed necessary.

Stage 1

1) The customer will supply the following data to the vendor in a timely fashion
    - Prescription of the optical system
    - Description of all coatings (AR, reflective, etc.) used in the optical system
    - Drawings of main baffling including locations of the vanes, vane aperture dimensions, vane edge description, etc.
    - Scatter properties of the coating used in the baffling members. If these data are not available, then the customer shall identify the material and/or process and Pompea and Associates shall make reasonable assumptions about these surface coatings.
    - Pinhole images made from the Nasmyth focal plane of the telescope of scattered light from bright off-axis sources
2) The customer will make the following series of measurements using SPIcam at the Nasmyth focus on the 3.5-m telescope for use in the evaluation of the scattered light model:

- A bright star (> 3rd magnitude) will be placed at 1° intervals from the boresight of the telescope and approximately 10 minute exposures will be taken of a nearly empty field through a V filter. If a good empty field cannot be easily found, then dithering of the telescope with several exposures of shorter duration may be made and median filtered. A series of these measurements will be taken to cover a total range of 15° of off-axis source angle.
- At least a single on-axis exposure will be made of the source star in order to normalize the off-axis exposures to the source brightness. It is understood that a neutral density filter will have to be used for this on-axis exposure and that the on-axis exposure time will be considerably different from the off-axis exposures. It will be up to the customer to make appropriate corrections in the data analysis for these effects.
- Flat-field exposures will be taken with SPIcam using both twilight sky flats as well as dome flats.
- The flat-fielded (and possibly median filtered) telescope exposures will then be smoothed to an effective angular resolution of 0.008° x 0.008°. This is equivalent to a boxcar smoothing of approximately 200 x 200 pixels in each SPIcam image. These smoothed data will be used to evaluate the scattered light model calculations.
- Pinhole images of the NA2 optical path will be made using either Jupiter or the moon at 1° intervals. The range of source angles to be covered will depend on the signal level available at the time of data acquisition, but our goal will be to span a range of approximately 20° with these measurements.

3) The vendor, after receipt of the information detailed above will construct an initial stray light model of the telescope.
   - For each off-axis source angle observed, this model will be used to calculate the Point Source Transmittance (PST) of the telescope for a 10 x 10 array of focal plane positions which will cover a total angular extent which matches that of the SPIcam FOV (i.e. 0.08° x 0.08°). The PST is a unit-less number defined by the ratio.

     $$PST(\theta) = (\text{ detector irradiance }) / (\text{ entrance aperture irradiance})$$

     where θ = the off-axis angle of the point source. These calculations will be used to compute contour maps of the scattered light variations in the telescope's focal plane. These contour maps will be used to compare the model calculations with the scattered light model.
   - For source angles between 15 and 60°, at 1° intervals the vendor will compute single point, on-axis scattered light PST ratios using the initial 3.5-m scattered light model. These calculations will be used to look for angles of interest for future calculations and modeling of the telescope.

Stage 2

1) The customer will supply the vendor with contour plots of the smooth, flat-fielded scattered light measurements taken earlier. Note that if this data is not available in a timely manner, then the vendor will proceed with the next stage of the analysis without the benefits of these measurements. The vendor will give the customer approximately 1-week notice when he will require this comparison data.
2) The vendor will supply the customer with contour plots of the small angle PST calculations. A full written report is not required at this time, but the vendor will supply brief descriptive comments describing circumstances required to interpret the calculations (such as contour levels used in the plots, any scaling calculations that

were made on the data, and spatial scales used in the plots). Electronic versions of these data are appreciated, but not required.

3) The vendor will supply the customer with pertinent plots describing the large angle PST calculations.
4) The vendor will then evaluate the model by use of the measured data and the supplied pinhole images. If significant discrepancies are found, the vendor will make a best effort attempt to modify the model to correct for these differences. The vendor will supply the customer with a best effort estimate of the errors in the model based on this comparison.

Stage 3

1) The vendor will use the improved model (or the initial, best effort model if comparison data are not available) to search for "angles of interest". These are source angles, which appear to be major contributors to the telescope's overall scattered light. Approximately 10 angles of interest will be examined in detail.
2) The vendor will use the model to produce contour maps of the scattered light variations in the SBCs FOV. Two SBC orientations will be considered: at rotator angles of 0 and 90°. Spatial resolutions of only 0.04° x 0.04° will be required for these calculations.
3) The vendor will use the model to suggest changes that can be made to the baffling on the 3.5-m. These changes will take into account the effects on the SGCs wide field FOV.
4) The customer will supply input to the vendor as to the magnitude of the changes that we are willing to undertake to improve telescope scattered light performance.

Stage 4

The vendor will produce a written report documenting the model calculations including the assumptions used in the analyses and the results in a final written report.

1) The vendor will produce a written report documenting the model calculations. Included in this report will be the assumptions used in the model analysis, the comparison of the model with the available observational data, the suggested changes to the baffling, and the effects that these changes will have on the SBCs FOV.

Schedule

Customer supplied data shall be furnished in complete form as soon as possible and no later than close of business day on January 15, 2001. The estimated time for completion of this project is 4 weeks from the time set-up data is provided for the system.

Cost Proposal

This is a firm, fixed price contract proposal. The vendor has agreed to do this work for a total cost of $15,000. Thirty percent of the cost will be paid to Pompea and Associates at the issuance of the Purchase Order. A second payment of 30% will be made at the end of stage 3. A final payment of 40% will be due upon delivery and acceptance of the final report.

Choice of Vendor

Pompea and Associates have been chosen for this proposal based on several criteria. First, among the different vendors contacted they were willing to offer to do this work as a fixed price contract rather than through per hour charges. Second, they are available to accomplish the work in a time scale that is commensurate with our needs. Third, these folks already have prior experience with the telescopes at APO.