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Stray Radiation Issues in Astronomical Systems with Adaptive Optics

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Abstract. The prevention and removal of stray radiation in adaptive optics systems is critical. The range of potential issues is large; they must be addressed early in the system design of the astronomical telescope / adaptive optics / instrument system. After potential problems are identified, a systems level analysis using stray light analysis software can identify the most important problems and assess the magnitude of the effect on system performance.[i]

Key Words: adaptive optics, instrumentation, stray light, black surfaces, baffles, contamination, scattering, bidirectional reflectance distribution function, points source normalized irradiance transmittance.

Outline

1. Introduction: What is Stray Light?

In this paper I will give a brief introduction to stray light issues in astronomical systems with adaptive optics. I will discuss the problem from a qualitative point of view as there are very few quantitative studies of stray light in such systems or stray light models that have been produced. Fortunately (or unfortunately, depending on your perspective) many of the first-order stray light problems that affect astronomical telescopes must be well controlled in order for the adaptive optics system to work effectively. Therefor, much of this paper will be a review of some general stray light problems that are very important but not peculiar to adaptive optics systems.

In my lecture, I had three items that I used to symbolize the key concepts of stray light. My flashlight, tinted swim goggles, and hat are indicative of the approaches we use in the field of stray light analysis. The flashlight represent our approach to understanding how radiation propagates in an optical system. We shine rays figuratively and literally through the system to understand the paths unwanted off-axis radiation or thermal radiation can take. The tinted swim goggles represent filtering, the spectrally selective removal of radiation. We shall see that this is extremely important in adaptive optics systems. And my hat represents the most fundamental approach to stray light removal, the blocking of out-of-field radiation which can create dynamic range problems. This glare can scatter through the system, reducing the contrast. In the extreme case, glints are produced by this off-axis radiation.

What is stray light? I like to define it in a very general way, as any radiation that reduces the performance of an optical system. One way of thinking about optical design is that there are two types of electromagnetic radiation or photons propagating through the system - the 'wanted' part and the 'unwanted' part. The wanted radiation comes from the objects of interest and are imaged on the detector. In general, they are controlled by the 'idealized' optical system, which contains the optical elements that you can describe in an optical design code. The ensemble of elements defined in the design code is a simplified and highly idealized subset of the finished optical system. Many mechanical and structural components are missing.

There is also ’unwanted’ radiation which is propagated and generated by the actual optical system. This can include radiation from an unwanted source (say a source outside of the field-of-view) or radiation from thermally emissive objects inside or outside of the optical system. It may also include radiation that is diffracted, scattered due to microroughness and contamination of optical surfaces, or scattered from inhomogeneities in transmissive elements.

You will notice that I often use the word "system". It is a very important concept for stray light. A system is the whole arrangement of things that have been placed together to perform a ftmction. Although the primary fimction of an optical system is to collect, direct, and focus light, there will be many other components that have important functions from a stray light point of view even if they have no role in forming an image. For example, motors that move filter wheels emit radiation that can reach the detector. In the case of adaptive optics, it is the telescope / adaptive optics / instrument system that is important, and which must be made to work. Actually, the *system* is even more complex. Included in this system are the various telescope and atmospheric components that the AO system must work with. Since all of these aspects must work together to give the desired performance, we must consider stray light factors in each part of the system. Considering the’optical system’ alone would yield a very narrow perspective.

Let me illustrate the concept of system performance and wanted and unwanted radiation with a simple example - the overhead projector. We know what the desired optical performance is,