Placement of the SNIFS Pick-Off Prism & Support

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Abstract

This is a short note discussing the possible choices for the location of the SNIFS pick-off prism and support structure with respect to the imager and guider. A figure illustrating the recommended choice is presented.

Introduction

There are four main issues associated with the placement of the SNIFS spectrograph pick-off prism (POP). They are

- Cross-calibration of the imager and the spectrograph
- Optimal location for automated acquisition
- Size and location of the shadow
- Differential refraction between the guide star and the SN

Cross-calibration

The cross-calibration of the imager and the spectrograph simply requires that the flat-field exposure have a known *relative* intensity ratio between any location on the imager and the POP, at all wavelengths. That is, changes in the flat-field ratio

$$\frac{I_{imager}(x,y,\lambda,t)}{I_{spectrograph}(\lambda,t)} = c(x,y,\lambda,t)$$

must be known, or the ratio must be constant by design.

Ideally one would like the flat-field intensity ratio to be unity, but this is not essential since only changes in flux ratios between the imager and spectrograph are of interest (see memo "SNfactory Spectrophotometry Requirements Document"). Since the light (e.g., from a flat-field lamp or the twilight sky) hitting the probe cannot also hit the imager or guider, there is no way to monitor $c(x,y,\lambda,t)$ directly. However, since the illumination should not have fine spatial structure, it should be possible to infer relative changes in $c(x,y,\lambda,t)$ by interpolation. Interpolation requires that the POP be in front of a filtered CCD so that the wavelength dependence can be monitored. If the POP is in front of the guider, the guider must have a filter capability so that $c(x,y,U,t)$ ... $c(x,y,Z,t)$ can be measured. If the guider is not filtered, then the POP must be in front of the imager CCD; this will lead to annoying shadows when SNIFS is used for imaging.

Acquisition

Acquisition requires recognition of the star field and the ability to accurately infer the SN location relative to the surrounding stars. Interpolation of the geometrical transformation is the most robust approach for accurately placing the SN on the POP. Moreover, on average the overlap of the NEAT discovery images and the SNIFS acquisition image should be greatest when the POP is centered on the imager or guider (or both if they are used in tandem). Note that it may be possible to extrapolate the SN location if the geometric transformation is nearly linear, but it is probably dangerous to rely on that case.

Both of these considerations lead to the conclusion that *the POP should be located in front of the guider or imager CCD.*

Shadow Impact

However, if the POP is centered on the imager or guider, the POP and it's support structure will cast a significant shadow. This probably has a minor impact on our main program - resulting in a loss of less than $\sim 10\%$ of the imaging area. However for direct-imaging applications using SNIFS, this shadow is a serious nuisance, requiring extra observations for programs which require contiguous areal coverage, and necessitating the use of an areal mask during data processing.

Differential refraction

Differential refraction between the guide star and the SN can cause slight trailing of the SN image at the IFU as the airmass of the field changes. SNIFS is most susceptible to this effect for blue SN light when the guider observes at red wavelengths for a field at high airmass when the SN and guider star angular separation is not small. To minimize the differential refraction the SN and guide star should be as close as possible and the guider should work at an intermediate effective wavelength. Note that differential refraction acts along the object-to-zenith vector so the above effect is reduced by the dot-product of the SN-to-zenith vector and the SN-to-guidestar vector.

The largest possible angular separation between two objects observable with SNIFS — along the diagonal between the far corners of the imager and the guider — is about 0.24 degrees. At an airmass of $X = 2$ the maximum difference in airmass between two objects is therefore about $\Delta X = 0.015$, while the change in airmass is about 0.26 in a 15 minute exposure. According to my calculations (Filippenko, 1982) using the temperature and pressure at the summit of Mauna Kea, the total differential refraction between the most distant guide star observed at 10000Å and a SN observed at 3500Å is about 3.5 arcseconds. The change in this value in 15 minutes at $X = 2$ is about 0.7 arcseconds — the blue channel alone will suffer almost all of this source of image degradation. For the proposed POP location shown in Figure 1 the worst-case change would be 0.5 arcseconds. This can be reduced to about 0.3 arcseconds by guiding at an effective wavelength of 5000Å. The change in atmospheric dispersion with wavelength is so strong that the guider would have to operate at an impractically blue effective wavelength of 3700Å to equalize the guiding error between blue and red.

The above discussion would suggest that locating the POP in the center of the guider field would be the best choice for reducing the effects of atmospheric dispersion, but this would only reduce the worse-case image degradation to 0.3 arcseconds and the 5000Å effective wavelength case to 0.2 arcseconds. This slight improvement doesn't seem worth the considerably greater area obscured by the POP support incurred by centering the POP in the guider. Allowing the POP to enter the guider field-of-view from right-center in Figure 1 would be almost as effective in terms of reducing the worse-case guiding error.

Discussion

The above considerations suggest having the POP overlap the CCD's just enough to allow illumination and geometric interpolation but no more than necessary so that there is little additional impact from the shadow of the POP support. This suggests the configuration in Figure 1, or configurations with similar penetration of the POP into the field-of-view but rotated by multiples of 90^o. An alternative to the configuration to Figure 1 which reduces the shadow impact on the total field-of-view by increasing the gap between CCD's does not seem attractive since it will result in gaps in the illumination and geometric transformation functions.

Under the assumption that the imager and the guider CCD's are similarly filtered, and given the ability of reading the top and bottom each 2k$\times$4k CCD independently, there is really little practical difference between 90^o multiples of the configuration shown in Figure 1. In practice it could be necessary to use a slightly inferior CCD for the guider than for the imager. Therefore there is some merit to ensuring that the POP is positioned near the imager CCD, as in Figure 1.

Conclusion

If the imager and guider have the same filter, then the simplest solution satisfying the above constraints is to locate the POP as in Figure 1. In this case the POP intrudes just far into the field to allow reasonable interpolation of the illumination distribution and the geometric transformation at the location of the POP, while giving only modest degradation in the image quality for the worse-case guiding error due to atmospheric dispersion. Also, at least some of the support shadow falls on the (2–3 mm) gap between the CCD's

References

Filippenko, A. V. 1982, PASP, 94, 715

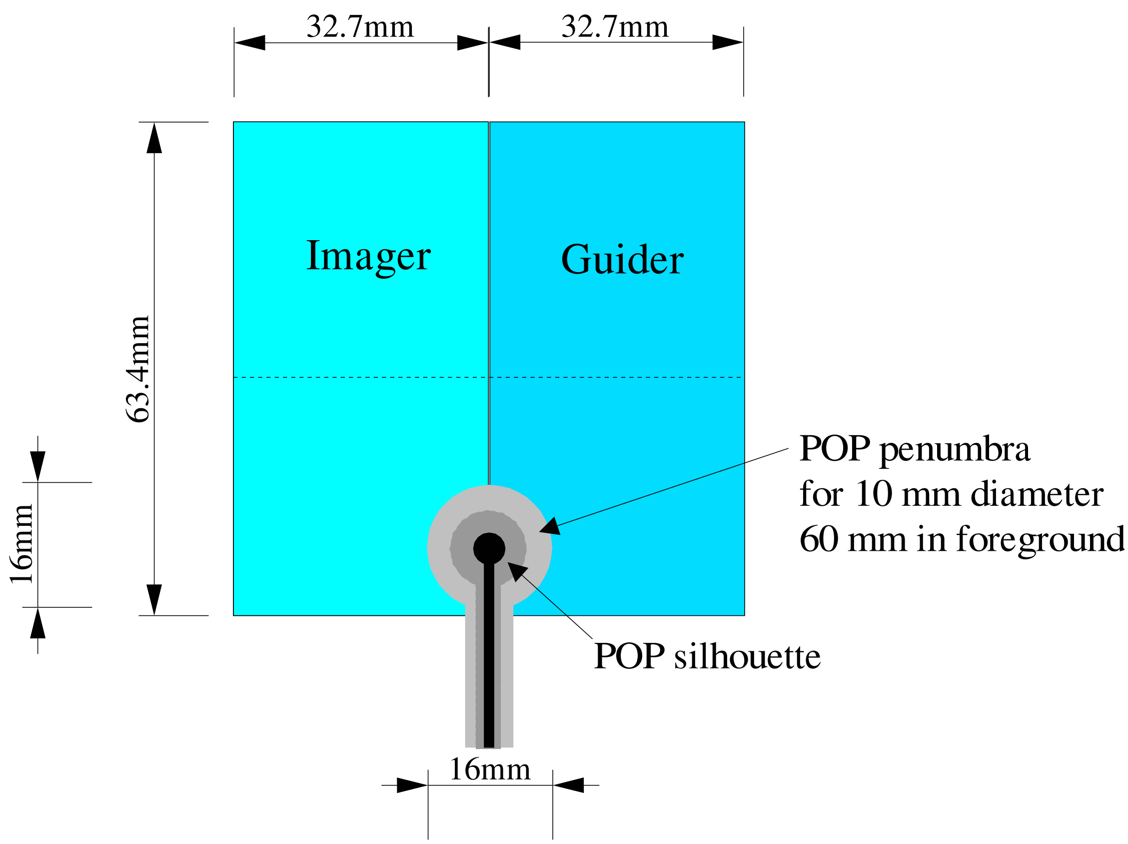

Figure 1: Suggested POP location with respect to Imager and Guider CCD's. The umbra (black), silhouette (medium-gray), and penumbra (light-gray) of the POP and it's support are illustrated. A 10 mm diameter was assumed for the POP, and the POP was placed 60 mm in front of the focal plane. The area lost within the shadowed region is about 5%. The horizontal dashed lines across the CCD's represent the boundary between upper and lower readout amplifiers.