Prime Focus Spectrograph (PFS): Development of the 2D sky subtraction algorithm

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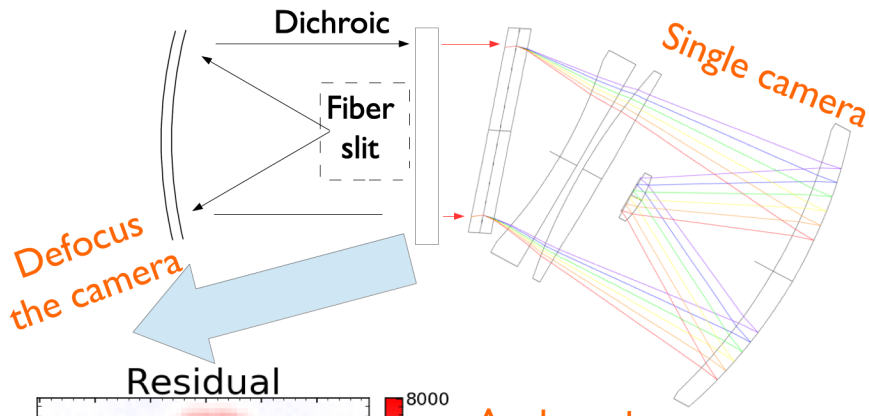
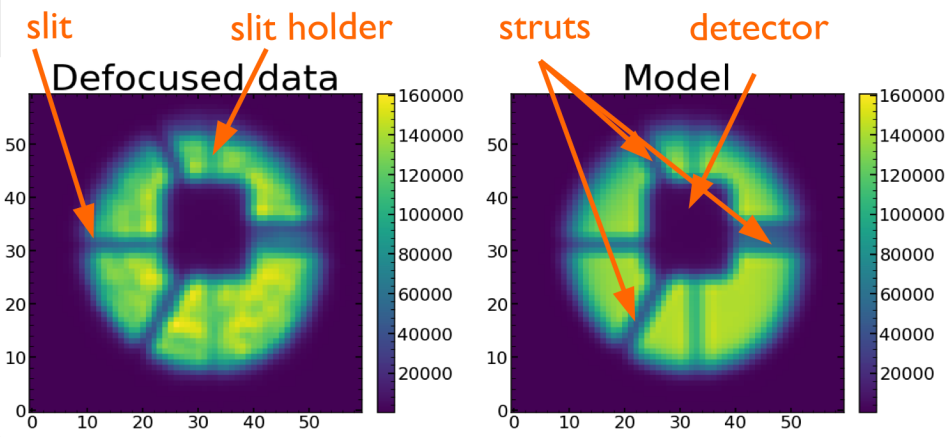
SuMIRe — Prime Focus Spectrograph

SPIE.

The point spread function (PSF) of the Prime Focus Spectrograph is affected by three different components: telescope pupil illumination, focal ratio degradation in the fibers, and the optical aberrations in the spectrographic cameras. The goal of the project is to understand and characterize these contributions. We are analyzing strongly defocused images where the effect of the optical aberrations and pupil obscurations is more readily seen. The data has been taken by the red arm camera of the spectrograph at the optical bench, and at the Subaru telescope. We compare the data with the custom-generated model in order to estimate coefficients describing the wavefront aberration and pupil illumination parameters. During telescope operation, pupil illumination of each exposure will change due to flexure of fibers and misalignments of fiber positioners in a predictable manner, while the wavefront aberrations are expected to be stable. With the full pupil illumination and wavefront information, we can predict and precisely model the PSF for any possible observation configuration!

Defocusing the spectrographic camera enables us to analyze the details of the optical setup in detail. Below we can see an example of the defocused data and our modeling. We can see clearly see various components of the obscurations along the light path, noted with arrows in orange. Residual is shown in the right panel. Note the small-angle, speckly, nature of the residual. This is the consequence of the fact that we are modeling only relatively low-order wavefront aberrations (up to Zernike order 56) that cannot fully capture small-angle distortions. Improvement can be achieved by considering higher-order wavefront corrections.

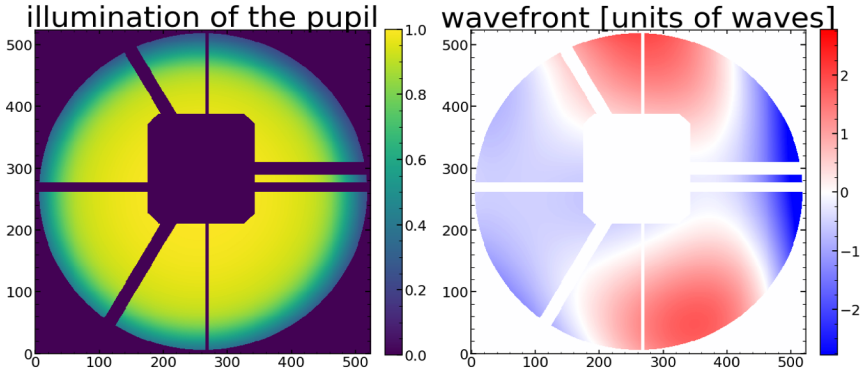


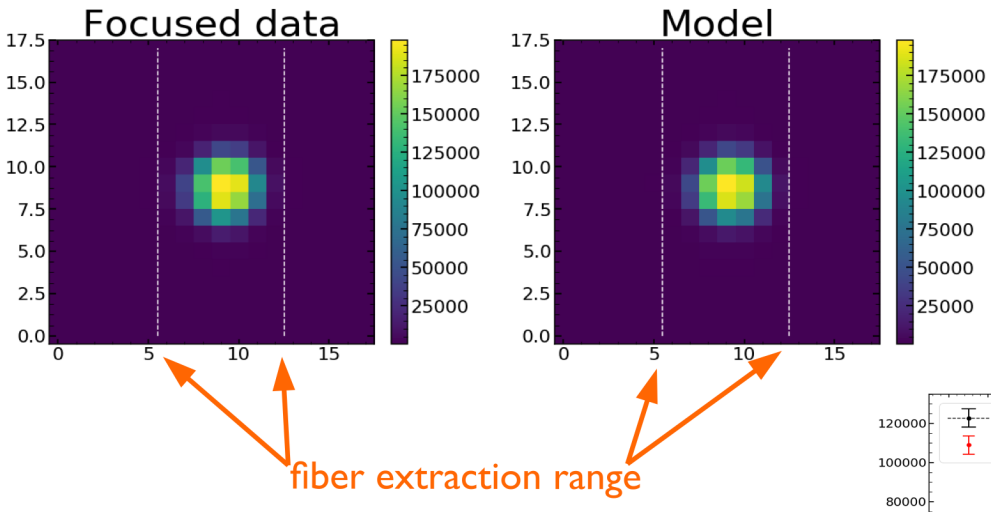


Analyze the images and infer the illumination and the wavefront

We apply the analysis demonstrated above on many images on both sides of the focus and with different amounts of defocus. We the interpolate the results so1 that we can deduce the illumination of the pupil and wavefront aberrations in focus. These are shown on the right. Note the decrease of flux towards the edges of the pupil, a consequence of the focal ratio degradation (FRD) in the fibers.

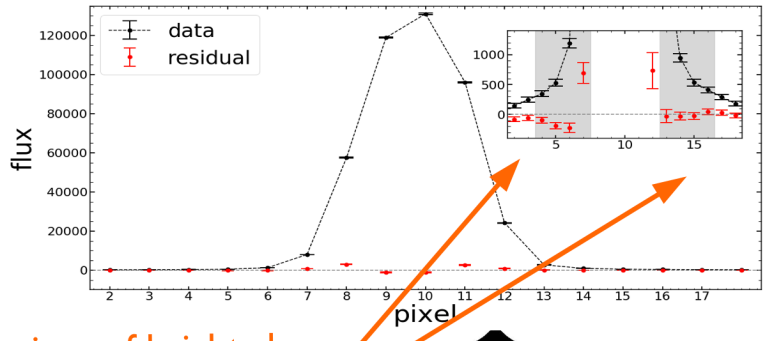
Use this information to predict PSF of in-focus images





Subtract the model and extract 1d spectrum

fiber extraction range



Using the pupil illumination and wavefront information, we create a 2d model of the PSF, which can be subtracted from the data. This is the same procedure that we will use to eliminate the bright skylines from the scientific data during a typical observing operation. We plan to improve existing residuals by better modeling of the defocused data and the employing the post-processing algorithm characterizing the residuals with the PCA methods.
After the 2d subtraction, in order to create a 1d spectrum, we extract the flux along the fiber with a standard ``optimal extraction''. We show the result on the right, with a zoomed-in central region in the inset.
We are primarily concerned about the good quality of the subtraction in the wings of the PSF. This is because, for very bright skylines, the Poisson noises will make it impossible to remove the central cores of these lines fully.

wings of bright sky lines – the most important region

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