Error analysis for one Sérsic parameters

In fitting two-dimensional galaxy light profiles, faint galaxies are well known to suffer from large systematic and random uncertainties in the recovered galaxy magnitudes, sizes, Sérsic indices and ellipticities. The relation between the measured value and the true value for a given parameter is defined as:

$$p_{\rm m} = p_{\rm t} + b \pm \sigma \tag{1}$$

where $p_{\rm m}$ and $p_{\rm t}$ are measured and true parameter values, respectively, b is systematic bias (uncertainty), while σ stands for random/statistical uncertainty (i.e., the confidence limits).

It is well known that Galfitm/Galfit software considerably underestimates the true errors on the fitted parameters. The standard errors reported by Galfitm (typically of $\sim$ few per cent) are purely statistical and are derived from covariance matrices during the least-squares minimization, , by assuming that the uncertainties of the fitted parameters are entirely dominated by the Poisson noise. However, in reality, the true uncertainties are often dominated by various sources, including uncertainties due to sky determinations, object S/N, the choice of the model profiles, improper masking, flux contamination by neighboring objects, such as other galaxies or stars, how the PSF is made, etc. Therefore, more realistic and meaningful (reliable) error bars for the individual parameters need to be estimated.

To make this complicated problem tractable, we 'decompose' the full error budget into multiple error components. This strategy is analogous to what we have adopted in measuring galaxy parameters in previous sections (i.e., we subtract the ICL and bCGs in advance in order to boost the source detection and measurement). For parameter errors of the galaxy sample in the processed image, we will consider four dominant contributors, i.e., local background treatment, object S/N, contamination by nearby objects and potential influences from the subtraction of ICL+bCGs (since they are genuine light distribution in the original image, their contributions must be taken into account). These decisions are made based on the actual source crowding situations in the processed image, as well as the way we process the image. We assume that these error components are independent of each other, hence the final errors are calculated by adding in quadrature all the individual error components.

In the following sections, we will characterize in succession the error contributions from the aforementioned effects: (1) sky background determination, (2) source S/N, (3) neighboring contamination in the crowded field (i.e., processed image), and (4) influence from the subtractions of ICL+bCGs, in which the fainter galaxy sample are originally embedded. The analysis of the first three factors will be conducted solely on the processed image, while the

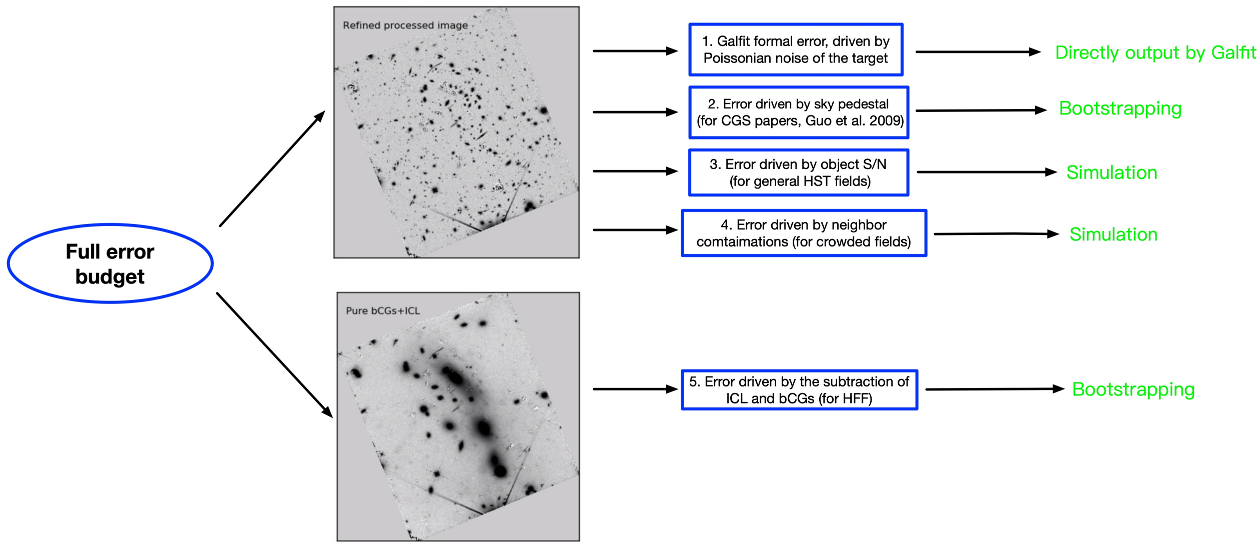

Figure 1: A schematic diagram outlining dominant error components in the HFF field. The total error budget consists of four components, with their origins briefly described in the blue rectangulars. We also show the corresponding solution of deriving the error bars.

last one will also necessitate the reprocessing of original image. A schematic diagram describing the classification of error contributions is shown below in Figure 1. Each kind of error contribution was quantified with different methods, as indicated with green font texts in the right side of Figure 1. We begin by describing the derivation of parameter uncertainties due to sky background determination.

1 Uncertainties driven by sky determination

Accurate sky background estimation is critical in the fitting of galaxy surface brightness profiles, especially for the photometric studies of faint extended objects whose derived parameters are highly sensitive to the estimation of the background. We consider this as the one of the major potential contributions because measuring local background is an important step in our pipeline. As described previously, Galapagos2 uses an accurate and efficient way to measure the background and background uncertainty for each source from the full mosaic, and then the background level is considered as a fixed component during the Galfitm run.

In order to derive the contribution from background uncertainty $\sigma_{\rm sky}$, we run a bootstrapping analysis on a subset of our galaxy sample, that is to say, for each source we randomly perturbed the inferred background value 100 times by using Gaussian sampling with $\sigma_{\rm sky}$ as the standard deviation. Then we repeat the profile fitting process 100 times, adopting those modified background values by following the exact same procedures as described above, which produces a distribution of fitting parameters caused by the variation of the sky background. The uncertainties in best-fitting Sérsic parameters are then taken as the 16th and 84th percentiles of the 100 realizations. We perform this approach by selecting a subsample of relatively isolated galaxies spanning a wide range of structural parameters. This exercise shows that the parameter uncertainties additionally introduced by the sky background for a

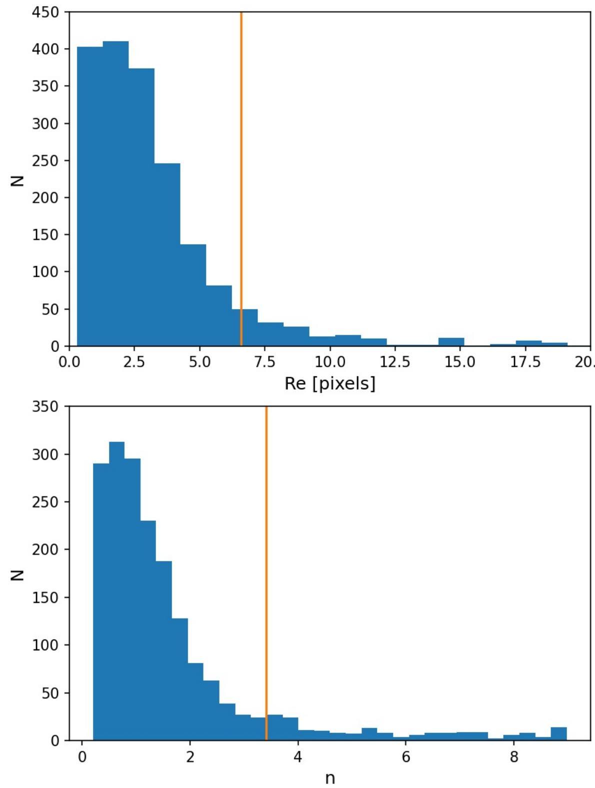

Figure 2: Histograms of Sérsic parameters r_{e}(top panel) and n (bottom panel) for the sample with 'good' fits (see text for definitions). Two solid vertical lines indicate the 90th percentiles of the distribution, i.e., $r_{\mathrm{e}} \sim 6.5$ pixels and n ~ 3.5, respectively.

typical isolated galaxy (e.g., mag=23.02, r_{e}=3.45 pixels, n=2.54) are $\delta m = 0.002$, $\delta r_{\mathrm{e}} = 0.01$, and $\delta n = 0.012$, which are quite insignificant in comparison with the GalfitM formal error of the same galaxy, $\delta m = 0.004$, $\delta r_{\mathrm{e}} = 0.0213$, and $\delta n = 0.041$. This suggests that uncertainties due to the sky background level is merely one of the minor sources of errors for our fittings.

There are two reasons for the negligible error contributions owing to sky uncertainties. First, the situation where the sky measurement becomes crucial is typically encountered for objects with larger outer isophotes, i.e., large r_{e} and n. However, our detected sample mainly consists of intermedia redshift and background high redshift galaxies that are barely resolved. Their estimated r_{e} and n are generally small and thus much less sensitive to the background uncertainties. In Figure 1, we show the histograms of r_{e} (top panel) and n (bottom panel) for sample with 'good' fitting results (the 'good' fits means that none of the measured parameters have run into the fitting constrains). It is evident that r_{e} and n peak around 1.8 pixels and 0.7, respectively, with sharp declines towards the higher ends. The 90% percentile of the sample is at approximately $r_{\mathrm{e}} \sim 6.5$ pixels and n ~ 3.5. Second, the sky uncertainties delivered from Galapagos2 are small. This is because our image processing method has produced a globally flattened background, which is better than previous methods. We therefore exclude this error component from the final catalog.