

Dear Prof. Asantha Cooray,

Thank you very much for forwarding the referee report to us. Again, we are grateful to the referee for the helpful suggestions.

We have revised our manuscript carefully in terms of the referee report, with new revisions marked in boldface. We sincerely hope that this newly revised version is qualified to be accepted for publication in your journal.

For the reply to the referee report, please see below.

Best wishes,

Xiao-Lei Meng

Responses to the referee report is as follows,

Firstly, we thank the anonymous referee again for providing helpful suggestions. We have revised our manuscript cautiously in terms of the referee report, with new revisions marked in boldface. Below, we give a detailed description of our revisions.

COMMENT:

(1) First of all, the definition of  $\gamma'$  is unclear. Abstract and Introduction say  $\rho_{tot} \propto r^{-\gamma'}$  and an isothermal profile corresponds to  $\gamma' = 2$ . However this is inconsistent with Eq. (4.3) in which  $\gamma' = 1$  reduces to an isothermal case. This is important because the interpretation of  $\gamma_{out}/\gamma_{in}$  shown e.g., Fig. 7 is different between  $\gamma' = 2$  and  $\gamma' = 1$  (as  $\Delta\gamma' = 0.02$  translates into  $\Delta(\gamma'_{out}/\gamma'_{in}) = 0.01$  and  $0.02$ , respectively).

RESPONSE:

We thank the referee for catching this. We have fixed the inconsistent definition in Eq 4.3, which had caused erroneous labels on Figures 7-10. We have corrected the labels, and switched to absolute errors on  $\gamma'$  throughout the paper in order to avoid any confusion. Indeed, our target uncertainty is 0.02 on  $\gamma'$  (i.e. 2% on time-delay distance). The calculations were correct but the labels and part of the text were wrong.

COMMENT:

(2) It is mentioned that the Gaussian PSFs are adopted for Euclid, WFIRST, and LSST. I'm a little bit concerned about this, because PSFs are known to be more extended than Gaussian (particularly for space observations). They are better described by the Moffat profile. Is this difference of the PSF not important? In fact it looks straightforward to repeat the analysis for several different PSF shapes (different  $\beta$  in the Moffat profile for example) to check this effect.

RESPONSE:

We have simulated the effect of using a Moffat profile in the case of WFIRST. This is the most promising of the surveys where we are adopting Gaussian PSFs, and therefore the most likely where our conclusions could have been affected negatively. As one can see from the additional Table 6, the broader wings of a Moffat PSF decrease only slightly the precision on  $\gamma'$ . We thank the referee for pushing us to this further test, which improves our paper.

COMMENT:

(3) I should note that Kochanek et al. (2001) is among the first who emphasized the importance of lensed host galaxies for time delay cosmography and demonstrated how it breaks the degeneracy in lens mass models.

RESPONSE:

Thank the referee very much for pointing out this oversight. We have added this content in the 1st paragraph in the section of Introduction, which is marked by boldface.

COMMENT:

(4) Throughout the paper the authors ignore the PSF uncertainty and assume the perfect knowledge about the PSF. While I understand the authors' point that by doing so the results represent a lower limit of the total uncertainty, I'd like to see a more extensive discussion on how the PSF uncertainty would propagate into  $\gamma'$ , given the critical importance of accurate PSF characterizations for AO observations. In Introduction the authors mention Marshall et al. and Lagattuta et al., but these papers are not very relevant in this context as systems studied in those papers are more like galaxy-galaxy strong lensing. In the case of quasar lensing, there must be a degeneracy between the PSF wing (from quasar images) and surface brightness profile of a lensed host galaxy, which has to be carefully addressed. Agnello et al. mentioned in the paper did not fully take account of the PSF uncertainty. In a recent paper by Rusu et al. (2015) adopted a parametrized PSF model and marginalized over PSF parameters when deriving physical parameters, and thus should be helpful in discussing potential impacts of PSF uncertainties and possible future extensions of the present paper to address the propagation of PSF uncertainties to the final result.

RESPONSE:

This is of course an important issue. One, however, that cannot be quantitatively addressed using studies in the literature (The Rusu et al paper for example does not attempt to determine  $\gamma'$ , and furthermore the situation with Subaru might be completely different from Keck or TMT). Addressing the issue quantitatively would require a full suite of simulations that would be specific for every instrument configuration and well beyond the scope of the aims of this paper. While we agree that this is a worthwhile enterprise we think that this is best left for a future follow-up paper, so as not to detract from the main goal of this paper, that is the estimation of the random uncertainties. We clarified our goal of focusing on the random component of the error at several points in the paper, starting from the introduction and adding a full paragraph at the end.

COMMENT:

(5) In Sec. 3.1: “... of currently known lenses, selected from the Sloan Digital Sky Survey,” The current largest quasar lens sample comes from the SDSS Quasar Lens Search, containing more than 50 quasar lenses. It would be informative to give a quantitative description of the SQLS sample (typical magnitudes, quad/double ratio, etc), citing references.

RESPONSE:

According to the comment of the referee, we have added a brief account of the SDSS Quasar Lens Search at the end of the second paragraph in Section 3.1, including the typical magnitudes, the redshift range, quad/double ratio, selection algorithms, and so on, which is marked by boldface.

COMMENT:

(6) Also in Sec. 3.1: “As in the real-system used as inspiration”. This sounds a bit odd, because SLACS and SL2S (which that sentence is referring) are not quasar lens surveys but galaxy-galaxy strong lens surveys. For example typical redshifts can be quite different.

RESPONSE:

We rephrased the paragraph to clarify what we meant. We meant that the redshifts are reasonable and in the end it does not matter what they are exactly.

COMMENT:

(7) Sec 3.2: “... are listed in Table 2 and Table 3.” In fact light and lens models are described later in Sec. 4, so at this point readers have no idea what these parameters mean.

RESPONSE:

As the referee pointed out, we have clarified the meanings of these parameters and reminded the readers that there will be additional details about them in the next section.

COMMENT:

(8) The authors choose a quasar 1 mag brighter than the host galaxy in their simulations. It would be useful to check previous analysis of lensed quasar hosts to see how typical this assumption is compared with observed lensed quasar systems. For example Peng et al. (2006) analyzed a large sample of quasar lenses using HST. Rusu et al. (2015) mentioned above also added several more quasar lens systems with host detections.

RESPONSE:

Thanks a lot for the referee’s comment. We have investigated previous work of lensed quasar hosts and added their results in the last but one paragraph. These results reinforce the fact that the assumption in this paper is typical.

COMMENT:

(9) Is the quasar always placed at the center of the host galaxy? This may sound obvious, but looking at Fig. 4 lensed quasar host appears to be offsetted from the quasar image. Of course this is not impossible, as a nice example was given in Agnello et al., but this kind of configuration is also not very common.

RESPONSE:

Yes, the quasar is always at the center of the galaxy, within numerical accuracy. The quasar images are added directly in the image plane and their position, given the center of the host galaxy in the source plane, are computed using gravlens. The configuration in Figure 4 happens because the host surface brightness profile crosses into the inner caustic very close to the center of the galaxy, but not exactly.

COMMENT:

(10) It looks like lensing galaxies are not shown in Figs. 3-6, I guess this is just to better show quasar images and host galaxies. If so this point should be clearly mentioned in the paper. In practice a lensing galaxy is fitted simultaneously (if I understand correctly), so it may be helpful to show simulated images with lensing galaxies as well.

RESPONSE:

Yes, the referee is correct that the lensing galaxy is fitted simultaneously. Unfortunately, it is difficult to render the host galaxy at the same time as the host on a b/w image. So the images with the lens galaxies are not very informative, and would take up a lot of space, effectively doubling the real estate covered by figures 3-6. For the sake of conciseness we prefer to only show the figures that contain the most information.

COMMENT:

(11) In the non-linear fitting described in Sec. 4.2, is the sky level not included as a fitting parameter? Or the sky level is fixed to the true value during fitting?

RESPONSE:

In fitting process in our work, the non-linear parameters contain the necessary parameters for source and deflector brightness model, the deflector mass model, and point source's position in the image plane. The sky level is fixed to the true value in this process. Thanks for this comment from the referee, we have added a sentence to illustrate this point in the first paragraph in Section 4.2.

COMMENT:

(12) In Sec. 4.3 and 5 there are sentences like “determine  $\gamma'$  with 2% precision”. This is related to my first comment, suppose that the input  $\gamma'$  value is 2, “2% precision” is different from  $\gamma'$  uncertainties of 0.02. If one wants to determine  $H_0$  with 2% accuracy,  $\gamma'$  has to be determined with an accuracy of 0.02, which corresponds to 1% precision of  $\gamma'$  determination for the fiducial  $\gamma'$  value of 2. Please clarify.

RESPONSE:

Indeed, we are very thankful to the referee for catching this inconsistency. The confusion was due to the two definitions of  $\gamma'$  given in the previous version of the text. We have now fixed this throughout the manuscript.

COMMENT:

(13) In Sec. 5: “we generate 30 mock systems” These mock systems refer to different noise realizations of the same input image?

RESPONSE:

Yes. For each exposure time with each instrument, we generate 30 mock systems for most configurations and 10 mock systems for TMT with the view of saving

computing time. In each mock system, we use the standard normal distribution of the noise. So, for the 30 mock systems, they have different noise realizations with the same other input values. We have added an explication about this problem in the first paragraph of Section 5.

COMMENT:

(14) Figs. 7-10: I don't quite understand the insert in each panel. If I read the caption literally,  $x$  and  $y$  axes refer to the same quantity and therefore all the points lie exactly on the  $y = x$  line? Then what information does this plot carry?

RESPONSE: We have removed the inset with redundant information.

COMMENT:

(15) It would be very useful to add a summary table that lists all the estimated uncertainties on  $\gamma'$ , as it is sort of painful to read off those values from the Figures.

RESPONSE:

We have added the table.