A New Software Tool to Predict Astrometric Errors for ELTs

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1. Introduction

1. Existing 8-10 meter class telescopes demonstrated astrometric error capabilities of around 150 micro arcsec with the help of Adaptive Optics. Astrometry with ELTs is expected to improve upon these results and and enable a wide range of new discoveries.
2. To improve astrometric observations with the ELTs it is essential to estimate the precision to a few tens of micro arcsec.
3. A detailed astrometry error budget analysis for TMT-IRIS has previously been reported [1].
4. Using this astrometric error budget as a foundation, we developed a new web-based astrometry calculator that allows future telescope users to predict the astrometric error for their specific science case.
5. The calculator consists of a python script and a web interface where observation parameters can be fed based on an interactive Graphical User Interface (GUI) wherein the contributing parameters can be varied based on science interests to estimate the achievable precision.

3. Code Structure

1. The GUI is developed using the python Dash libraries. The calculator is made of simple function calls.
2. Python dictionaries are used to set inputs and outputs to the function calls.
3. The GUI sets the inputs for the calculator by modifying the input parameter dictionaries. Depending on the type of astrometry observation selected and the user inputs, the calculator functions calculate the astrometry error.
4. The TMT Exposure Time Calculator (ETC) is used to convert the magnitude and exposure time to the corresponding SNR for the observation field.
5. The calculator is self contained. It can be executed separately by invoking python in a terminal.

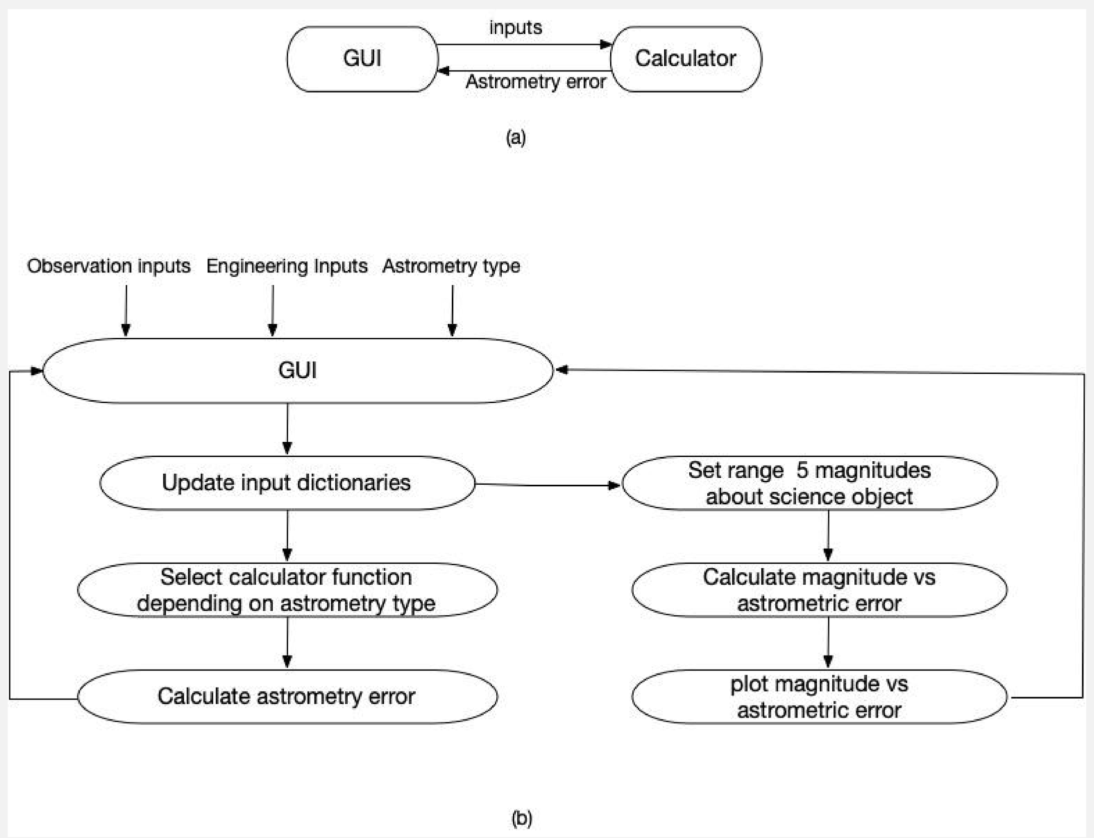

Figure 1: a) Block diagram of GUI and Astrometry calculator interaction b) Detailed block diagram representing the interaction between different parts of the code [2].

2.Software Input Overview

Type of astrometric observations

1. **Absolute Astrometry** The science object position is estimated in the sky coordinate system.
2. **Differential astrometry of science objects with respect to each other** This category estimates the variance in position of science objects with respect to each other.
3. **Differential astrometry with respect to reference objects** Applications that evaluate the variance in position of science objects in relation to reference stars fall under this group.

Observation Field

1. **Science Objects** These are the objects in the field for which the positions and motions are to be determined [1].
2. **Reference objects** These objects are objects with known coordinates that are available from other observations (e.g. the Hipparcos or Gaia catalogs, or the masers around the Galactic Center) and that are visible in the science field [1].
3. **Field Objects** Field objects are all objects that are visible in the field, in addition to but in particular also including science or reference objects[1].
4. **Separation between objects** The defines the average separation between the science and reference objects, amongst the reference objects or amongst the Natural Guide Stars.

Engineering Inputs These are secondary inputs and need not be changed once they are set for a telescope and its instrument. These are divided into 5 categories : 1) reference object catalogue errors, 2) refraction errors 3) atmospheric turbulence errors 4) opto-mechanical errors and 5) focal plane errors.

4. Web Interface

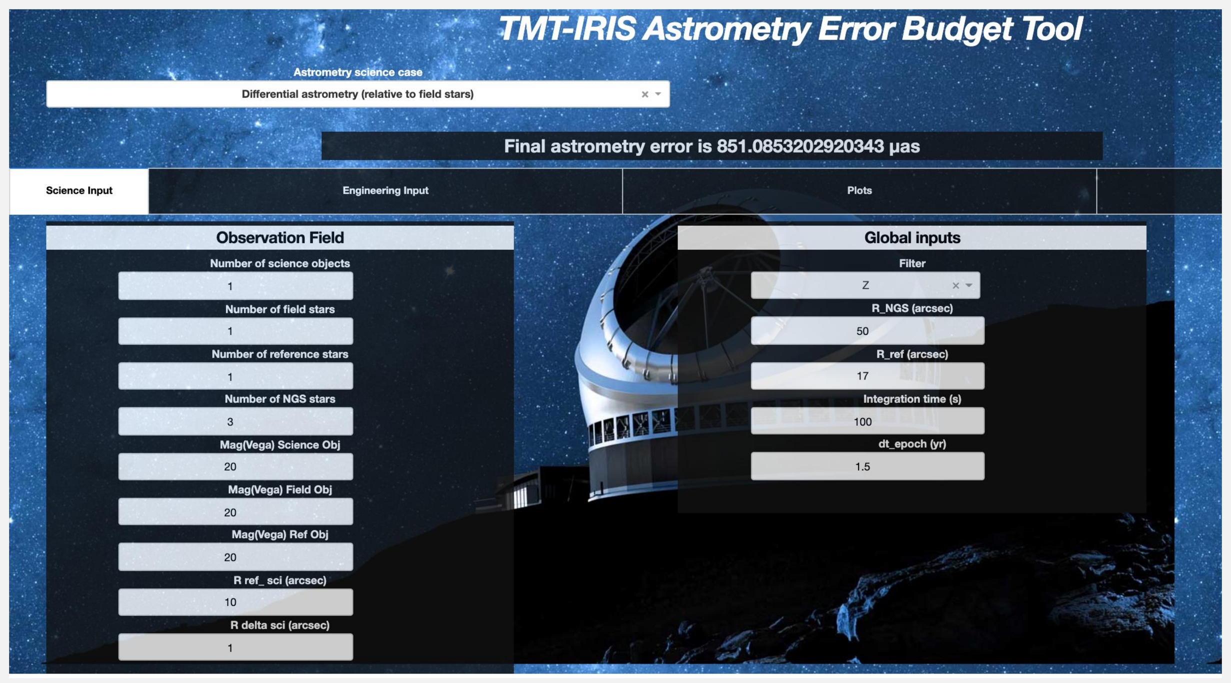

Figure 2: Observation field input panel

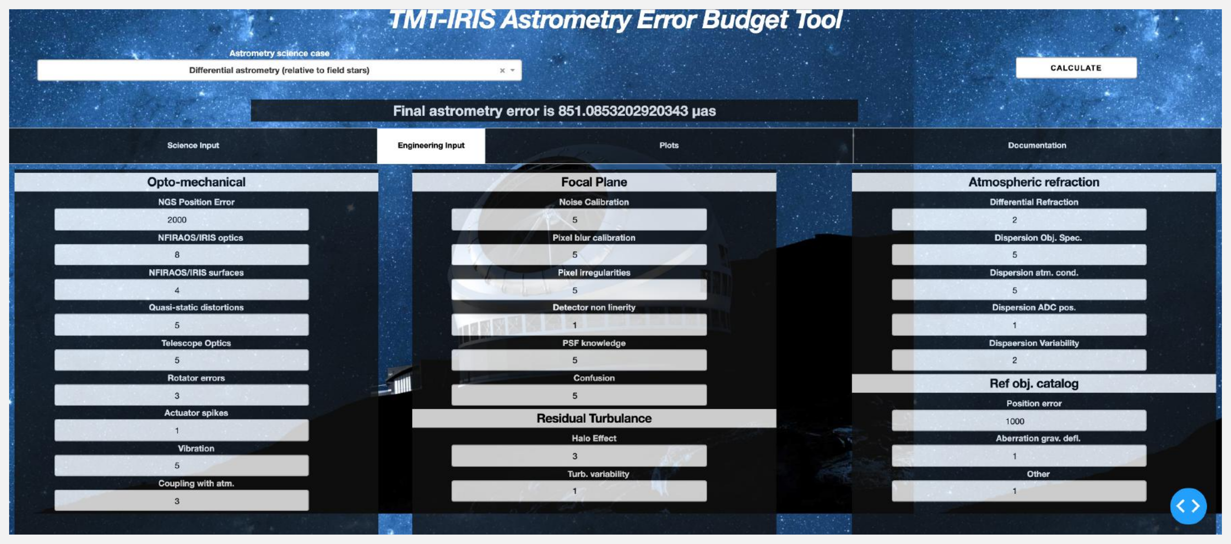

Figure 3: Engineering input panel

5. Galactic Center Astrometry Analysis

Science Inputs	
Field	***Value***
Number of science objects	1
Number of field stars	10000
Number of reference stars	10
Number of Natural Guide Stars	3
SNR of science object	200
SNR of field stars	680
SNR of reference stars	4800
Separation: science and reference objects (arcsec)	3
Relevant scale of the science object movement (arcsec)	1
Filter used	K
Average separation of Natural Guide Stars (arcsec)	50
Average separation of reference objects (arcsec)	17
Time since catalog reference epoch (year)	1.5
Integration time (seconds)	3600
Engineering Inputs	
All the engineering inputs are the default values used by IRIS	

Table 1: Observational field values used for astrometry error estimation[3]

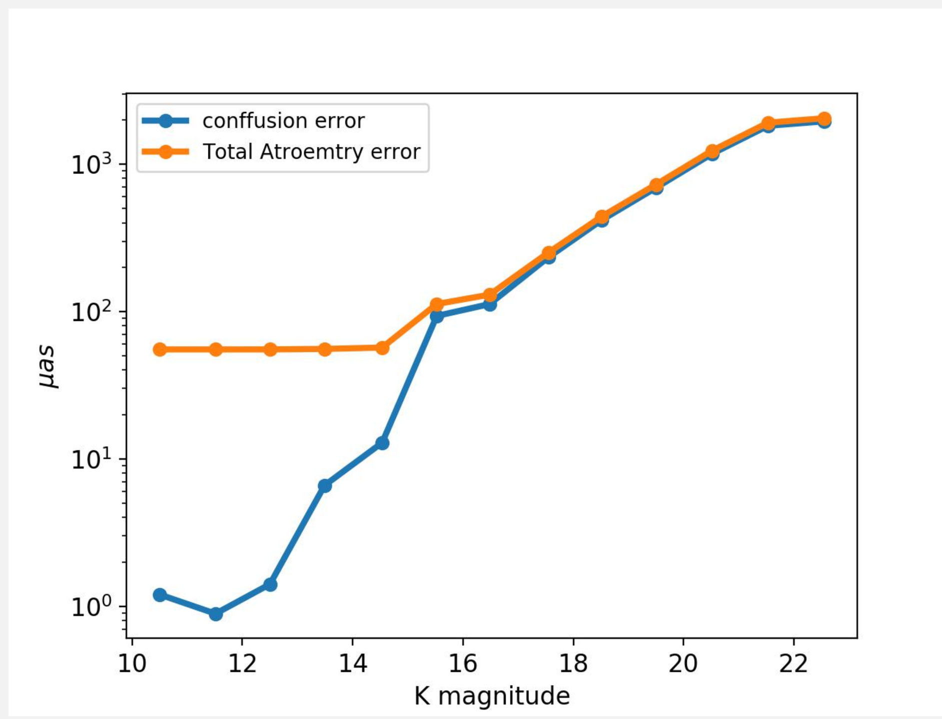

Figure 4: Astrometry error Vs magnitude in the K band for differential astrometry related to field objects.

References

[1] Schöck, M., Andersen, D., Rogers, J., Ellerbroek, B., Chisholm, E., Dunn, J., Herriot, G., Larkin, J., Moore, A., Suzuki, R., et al., “Flowdown of the TMT astrometry error budget (s) to the IRIS design,” in [*Ground-based and Airborne Instrumentation for Astronomy VI*], **9908**, 9908AD, International Society for Optics and Photonics (2016).

[2] Ranka, T., Chamarthi, S., and Surya, A., “TMT astrometry tool.” `https://github.com/chamarthisireesha/TMTAstrometry` (2019).

[3] Yelda, S., Meyer, L., Ghez, A., and Do, T., “Astrometry in the galactic center with the thirty meter telescope,” (10 2013).

Acknowledgements

This work was done in collaboration as part of the TMT Early Career Initiative (TECI). The authors would like to thank TECI, which is managed by the Institute for Scientist & Engineer Educators and funded by the Thirty Meter Telescope International Observatory and University of California Observatories.