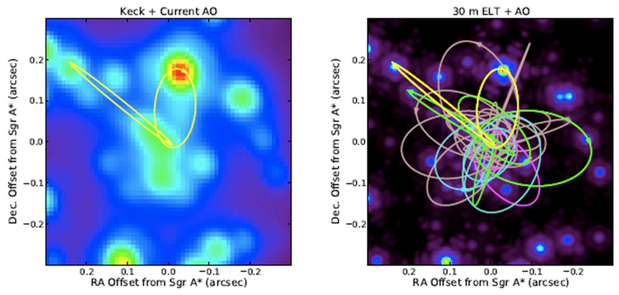
Current status of astrometry activities using TMT/IRIS

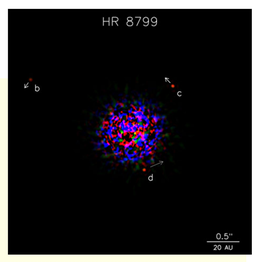
Ryuji Suzuki (TMT), Matthias Schoeck (TMT), David Crampton (NRC Canada), Brent Ellerbroek (TMT), Paul Hickson (Univ. BC), Andrew Phillips (UC CfAO), Luc Simard (NRC Canada), + TMT/IRIS astrometry team

1. We want to achieve ~10 uas relative astrometry with TMT/IRIS!

- There are exciting science cases which ~ 10 uas astrometry will open up (GC, Local dwarf galaxies, exoplanets, etc.)
- 10 uas can only be achieved by ELTs (because of the small PSF)
- Many error terms that are negligible for ~100 uas astrometry which is the limit of current 10 m class telescopes become important for ~10 uas astrometry.
- We tried to identify and quantify ALL effects that might influence astrometry to the best of our current knowledge.



Top : Image of Galactic Center obtained with Keck + AO system (left) and expected image with TMT (right) (from astro2010 Science White Paper)



Right : Multiple planet system around HR 8799 (Marois et al. 2008)

2. What should we consider?

Category	Examples
Reference star / Catalog errors	What if natural guide stars are at different positions than we expect?
Atmospheric refraction	What if the atmospheric dispersion correction is not perfect? What if the atmospheric dispersion changes over night?
Other atmospheric effect	How much is differential tip/tilt jitter? Is PSF uniform over the field? How does the uniformity affect?
Opto-mechanical errors	How does the optical distortion change over short/long periods?
Focal plane measurement errors	How accurately can we derive true PSF center? How much is the effect of confusion?
Observing condition	What if the observing conditions (transparency, seeing) vary during exposure?
Observing strategy	What is the best observing scenario to obtain the best astrometric accuracy?
Calibration strategy	How accurately can the optical distortion be calibrated?

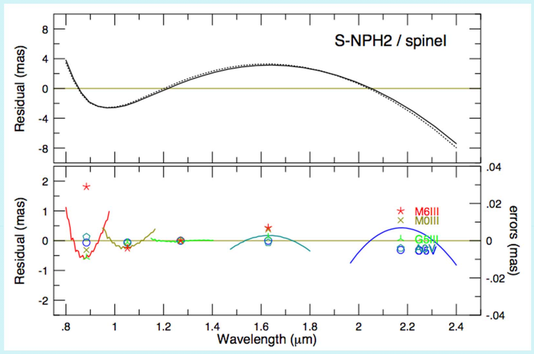
Item	Cases
Astrometry	Absolute? Relative?
Field	Crowded? Sparse?
Post analysis	Correctable? Or not?

→ 35 items and more for subcategories are listed in a spreadsheet.

3. What have we done?

3.1 Atmospheric dispersion correction errors

- The best material combination for the ADC is S-NPH2/Spinel.
- The ADC errors are ~10 uas in the worst case when the object SED is unknown.
- We need to know temperature and pressure to ~ 2 K and ~ 4mB, and adjust the ADC control accordingly.



Residuals of atmospheric dispersion after the correction by ADC

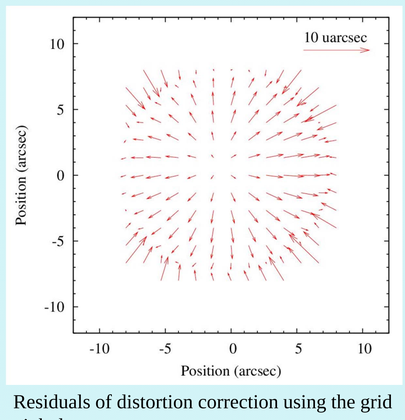
3.2 Differential tip/tilt jitter

- Tip/tilt being different between NGSs and target objects causes astrometric error.
- Residual tip/tilt errors computed for 7 x 7 stars in a 30 arcsec FoV at 800 Hz for 20 second exposure.
- Lower order terms can be removed using “field stars”
- Random measurement errors (S) contribute astrometry errors approximately as $S*(n_{modes}/n_{field})^{1/2}$

Order	Residual (uas)	Notes
0	167	Linear term
1	55	Linear term
2	16	
3	7	

3.3 Distortion correction errors

- Optical distortion of the IRIS imager is expressed by 7th order polynomials.
- Distortion pattern varies < 10 uas due to stability/ repeatability of moving parts in IRIS.
- We will use a grid pinhole placed on the telescope focal plane to correct the distortion.
- Correction accuracy using the grid pinhole is < 10 uas.
- Position of the grid pinhole must be known with ~20 nm accuracy.



Residuals of distortion correction using the grid pinhole

3.4 Transparency and Strehl variation

- Transparency variations and Strehl ratio variations during exposure coupled with any image motion will cause astrometric errors.
- Both variations will contribute astrometric errors on the order of 10 uas for the image drift of ~ 1 mas for short exposure (< 10 s).
- Astrometric errrors increase with exposure time.

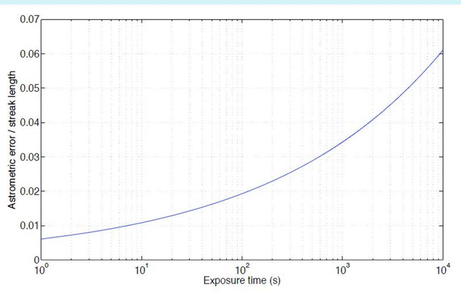


Figure 3.1. The ratio of astrometric error to streak length, σ_x/L, arising from transparency fluctuations, is plotted as a function of exposure time T.

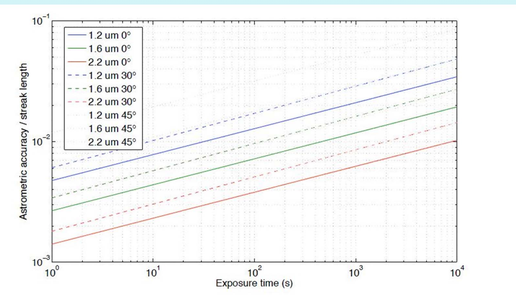


Figure 3.2. The ratio of Strehl astrometric error to streak length is plotted as a function of exposure time, for the indicated wavelengths and zenith angles.

4. What do we do next?

- Keep investigating remaining items in the list.
- We had the first astrometry workshop which put the people with a variety of backgrounds (astronomers, AO experts, instrumentation experts) together to share the understandings and draw a realistic scenario to achieve the unprecedented astrometric accuracy.

We welcome anyone who is interested in astrometry using TMT/IRIS. PLEASE JOIN US!!

Contact : Matthias Schoeck (mschoeck@tmt.org)