

High Accuracy DIMM Measurements for the TMT Site Testing Program

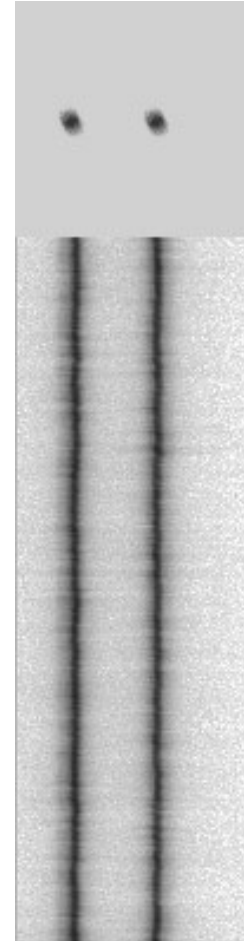
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TMT DIMM systems

- TMT DIMMs use ‘Drift scanning and binning mode’ data taking.
 - 6 ms (t_e) x 6000 frames = 36s
 - 1 dimensional stellar images
 - $2t_e$, $3t_e$, $4t_e$... seeing by binning
 - 6 ms/12 ms extrapolation used here (Tokovinin, 2002)
- Calculate 2-d equivalent Strehl ratio by assuming star images have radially symmetric Gaussian forms
- This Strehl ratio is consistent between all TMT DIMMs



Drift Scanning & Binning

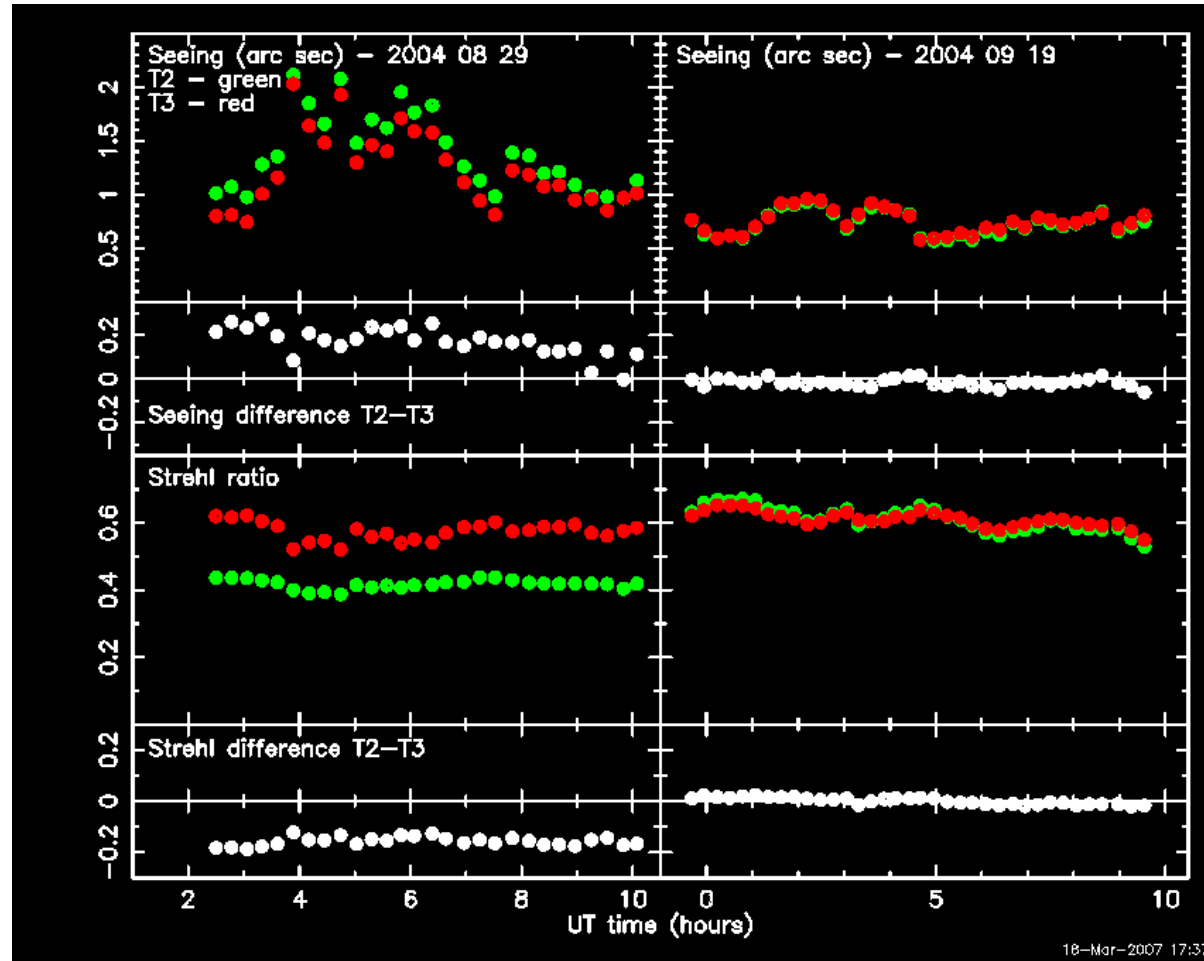
The cross comparison campaign

- August to October 2004 at Cerro Tololo (CTIO)
- 2 identical TMT DIMM systems, T2 and T3 on two towers
 - 7m above ground
 - 5m separation
- Both systems always pointed to the same star
- T2 and T3 acquisition are not synchronized. T3 seeing measurements interpolated to match T2 acquisition times



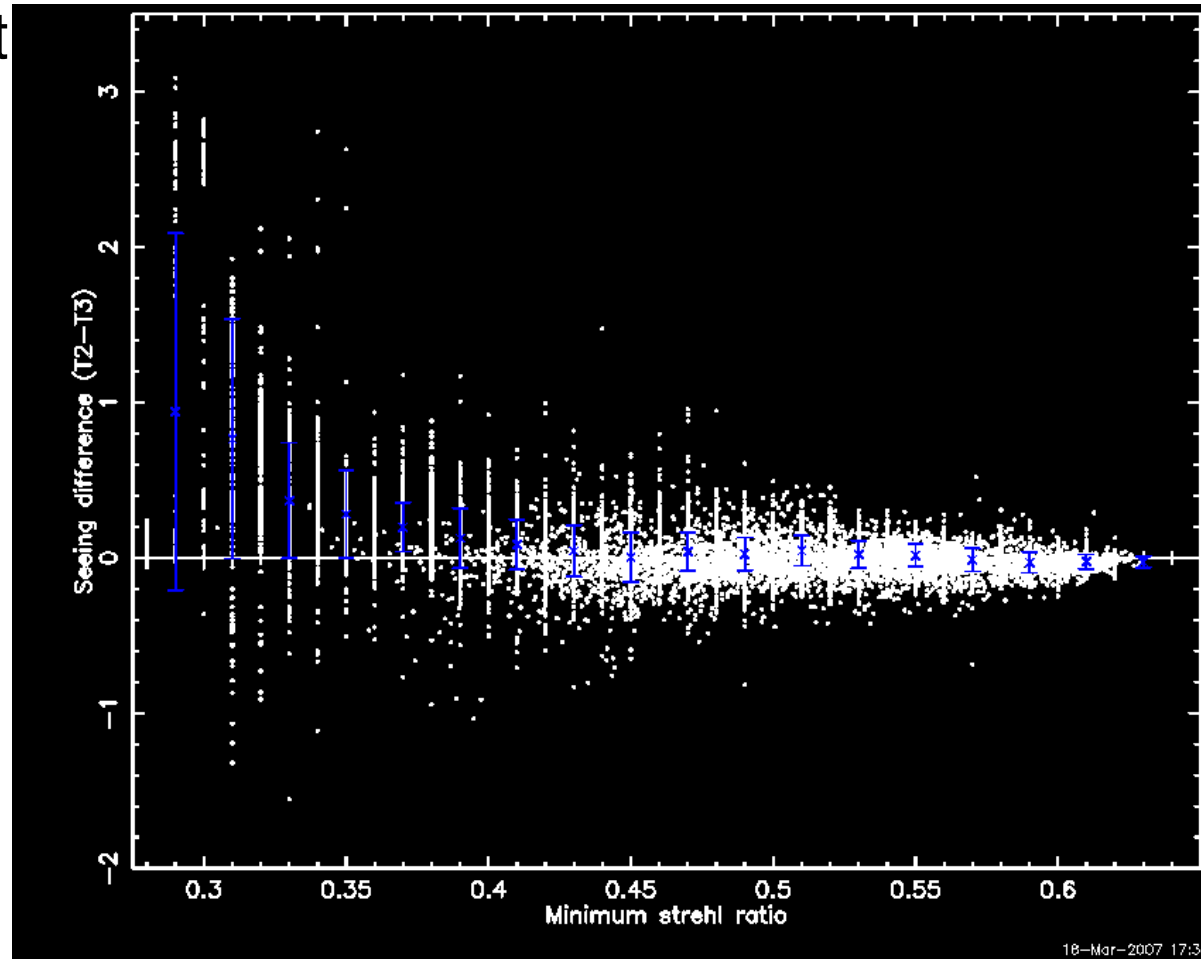
The cross comparison campaign

- Lower Strehls – higher measured seeing
- T2 discovered to have slight optical misalignment
- 15 min bins show 0.2 arc sec offset
- Magnitude of measured seeing very dependent on alignment/image quality



Results – Agreement related to Strehl ratio

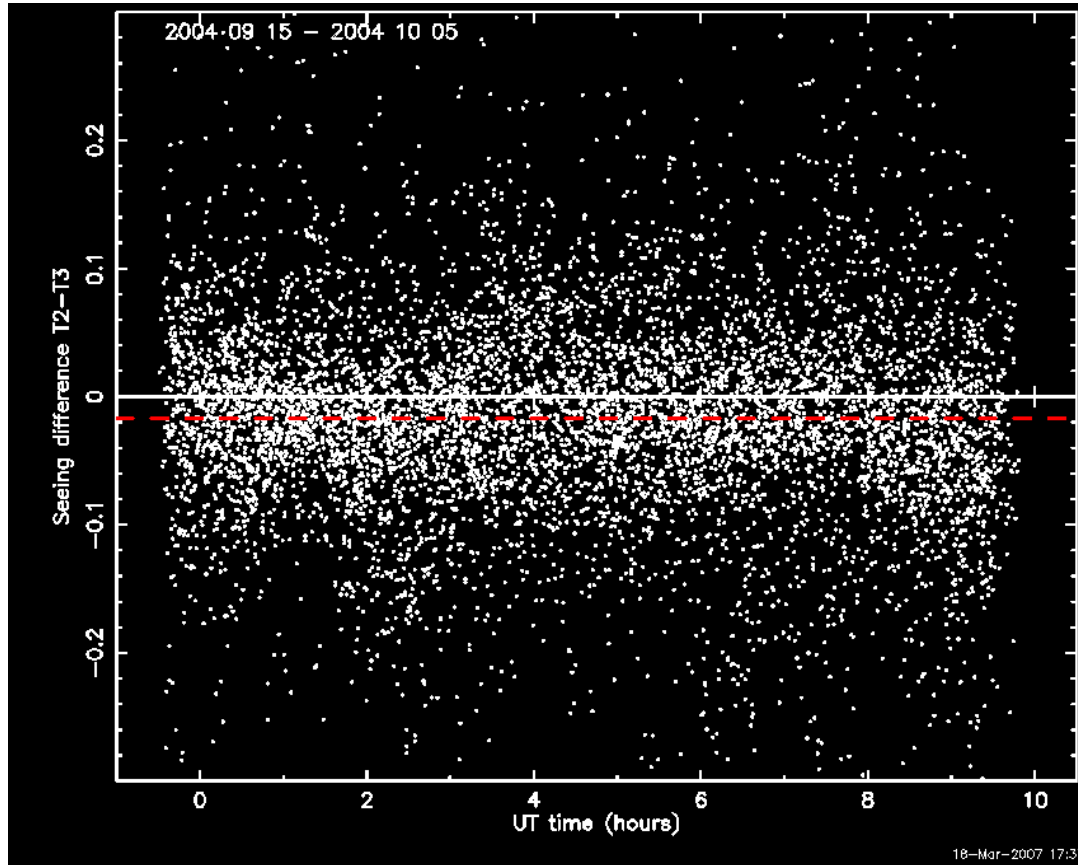
- ◆ Alignment constant and good for T3
- ◆ Alignment of T2 changed
- ◆ Systematic difference related to minimum Strehl ratio



Results – Average difference when well aligned

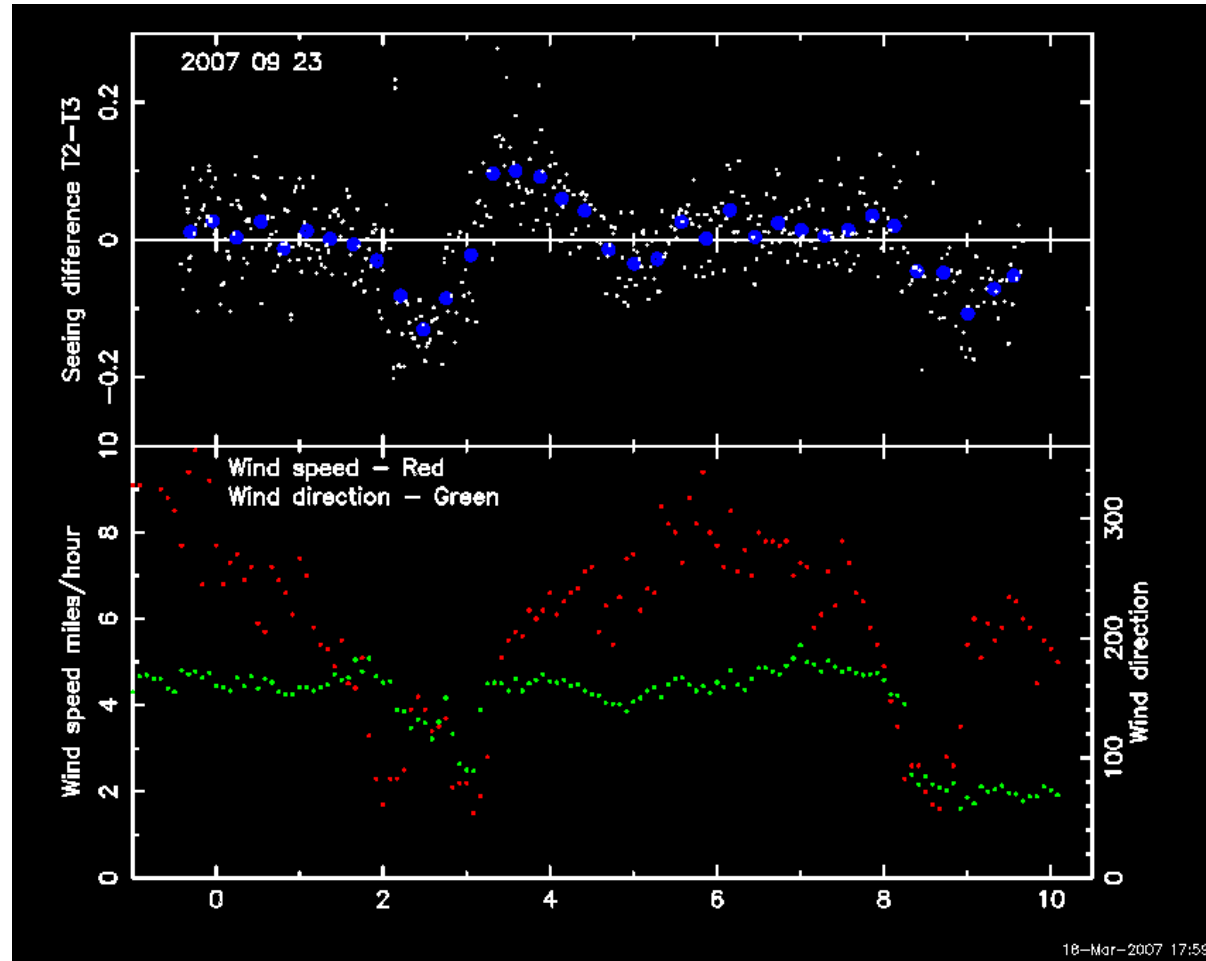
- 15th Sep. to 5th Oct 2004 has:

$$\overline{T2 - T3} = -0.017 \pm 0.001 \text{ arc sec} \quad \sigma = 0.10 \text{ arc sec}$$



Results – Local and temporal effects

- Local turbulence changes with wind speed and direction

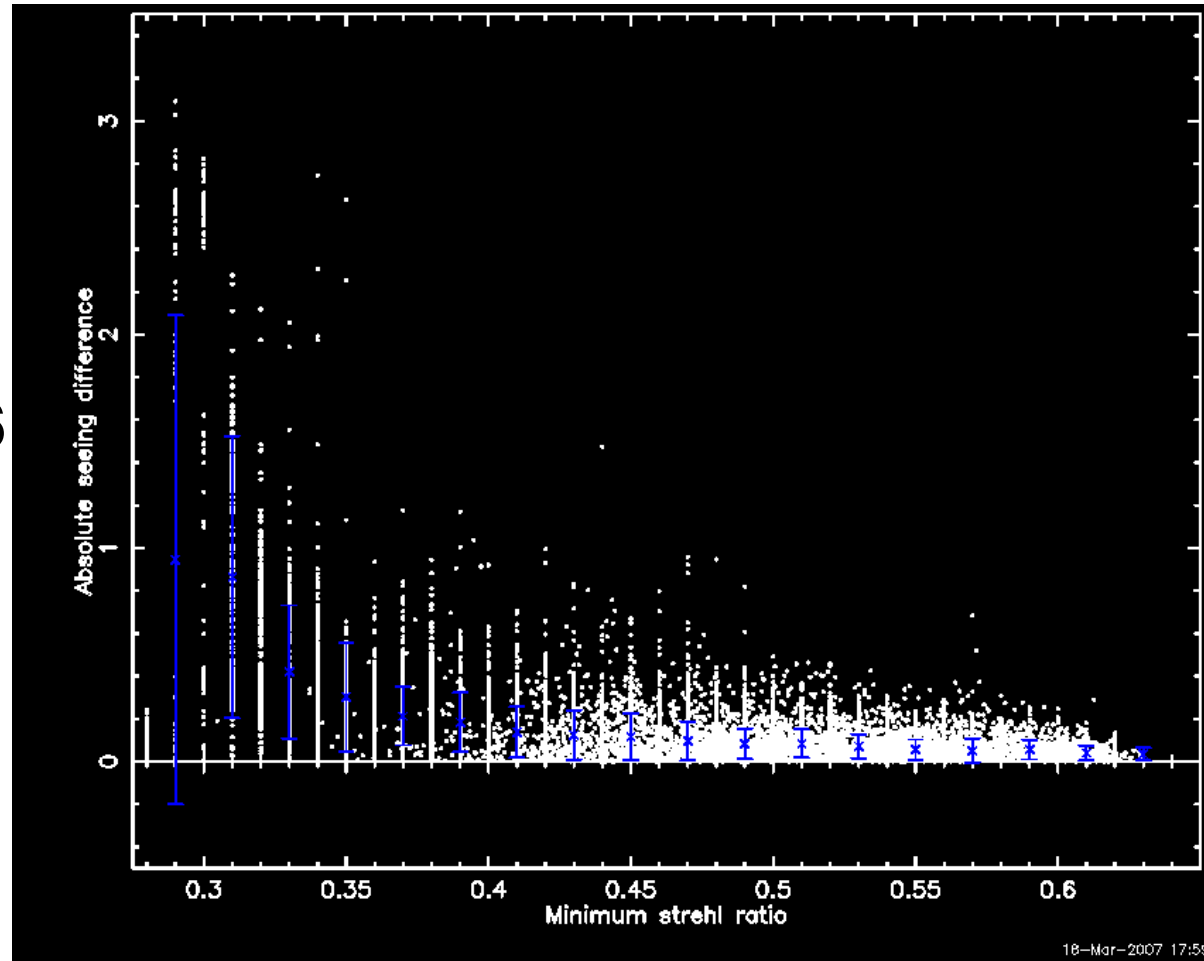


Results – estimate of DIMM measurement error

- Magnitude of differences gives estimate of DIMM measurement error
- For $0.5 < \text{Strehl} < 0.6$

$$\Delta \varepsilon = 0.045 \text{ arc sec}$$

$$\Delta \varepsilon = \frac{\sum |S_1 - S_2|}{(n \sqrt{2})}$$



Data quality control – Seeing dependent Strehl limit

- Simple Strehl limit not sufficient – bad seeing gives lower Strehls
- Cannot introduce a bias to our data
- Schöck developed seeing dependent Strehl metric

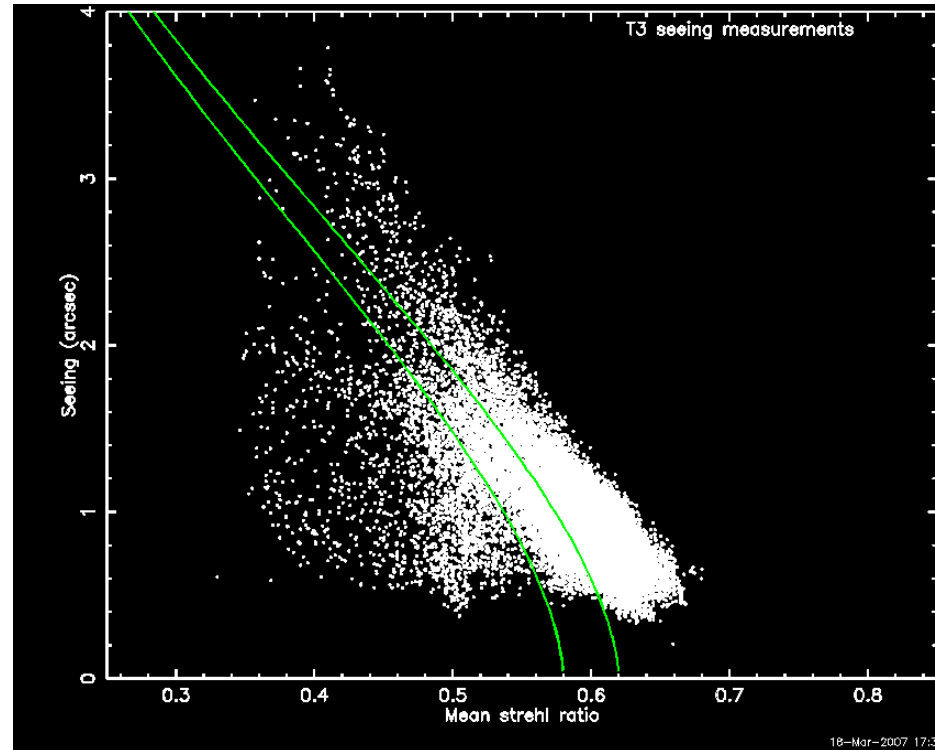
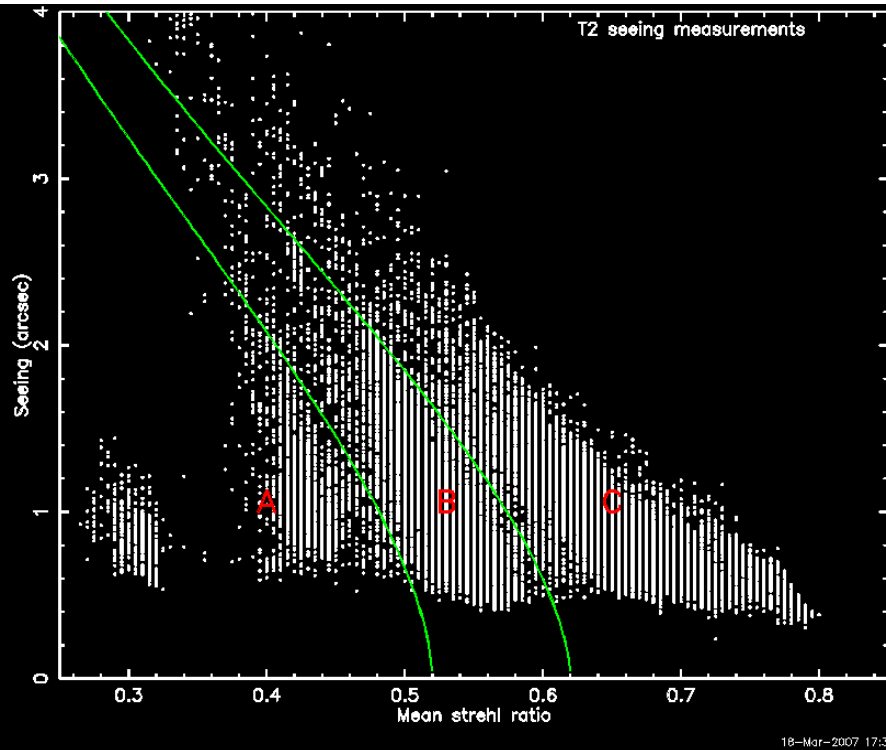
$$S_{limit} = S_{limit, seeing} \exp \left[\frac{-0.134}{f} \left(\frac{d \epsilon}{0.98 \lambda} \right)^{5/3} \right]$$

- where:

$d=10\text{cm}$, $\lambda=0.5\mu\text{m}$, ϵ is the seeing, $S_{limit, optics}$ is Strehl limit, f is an empirically determined factor = 1.7

Data quality control – Seeing dependent Strehl limit

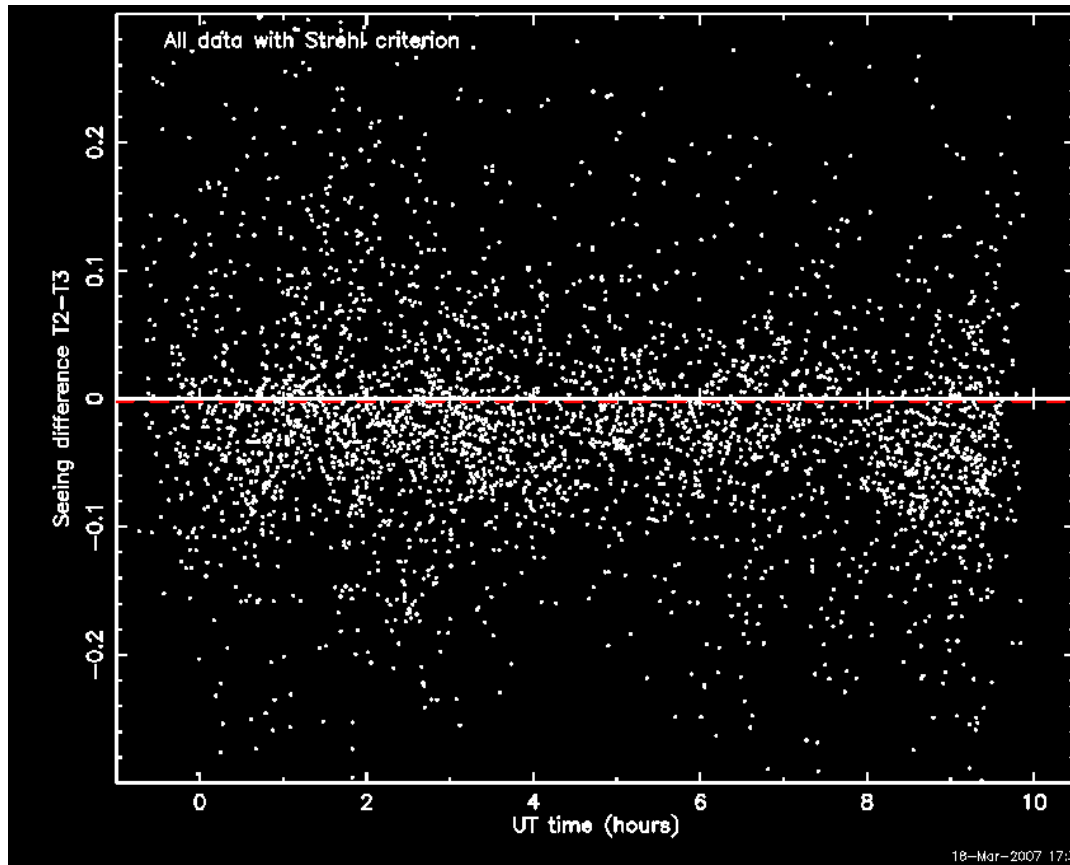
- T2 groups between $S_{\text{limit,optics}}$ 0.52 and 0.62
- T3 mainly above $S_{\text{limit,optics}}$ 0.58



Data quality control – Seeing dependent Strehl limit

- Apply limit with $S_{\text{limit,optics}} = 0.6$

$$\overline{T2 - T3} = -0.002 \pm 0.002 \text{ arc sec} \quad \sigma = 0.15 \text{ arc sec}$$



Conclusions

- Shown that well aligned TMT DIMMs have systematic differences of >0.02 arc sec
- High accuracy DIMM measurements strongly dependent on achieving good Strehl ratios
- Determined an upper limit for the size of the error bar on an individual TMT DIMM measurement.
- Derived simple seeing dependent Strehl criterion to ensure data quality

Paper: Wang et al., Applied Optics -
submitted