Ensquared Energy Budget

Donald Gavel

Keck Next Generation Adaptive Optics
Design Study Team Meeting #4, Waimea HI
January 23, 2007

Ensquared Energy Budget

- EE is an Important parameter for characterizing Integral Field Unit performance
- Is not necessarily tied to Strehl, for example the tip/tilt performance can be relaxed for large “spaxels”
- This presentation:
  - Ensquared energy as a function of
    - Spaxel size θ
    - Number of actuators across (d/r_0)
    - Science wavelength λ
    - Strehl S
    - Wavefront Error σ_ϕ^2 in nm
    - Tip/Tilt variance σ_{TT}^2 in mas
  - Comments on Sky Coverage

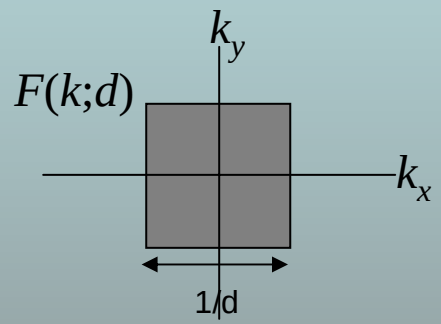
PSF Modeling

- Study is presently limited to fitting error and tip/tilt error
- Fitting error is modeled as filtered Kolmogorov turbulence:

$$S_{\tilde{\phi}}(k) = \left[1 - F(k;d)\right]^2 S_{\phi}(k)$$

$$S_{\phi}(k) = 0.027 r_0^{-5/3} k^{-11/3}$$

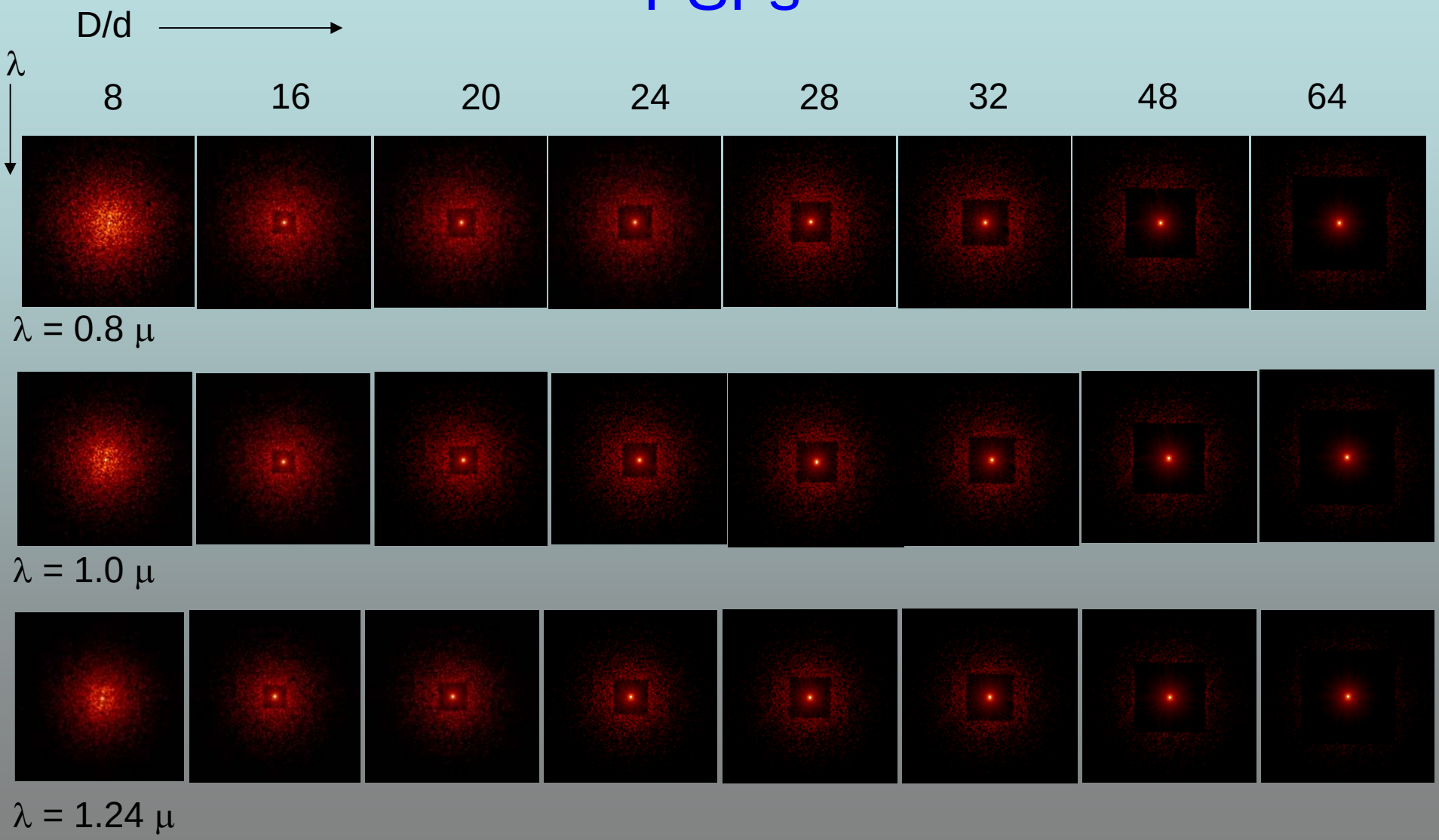
$$D_{\phi}(r) = FT\left\{S_{\phi}(k)\right\}$$



$$PSF(\theta) = \left[MTF(telescope) \times FT\left\{ e^{-\frac{1}{2} D_{\phi}(r)} \right\} \right]^2$$

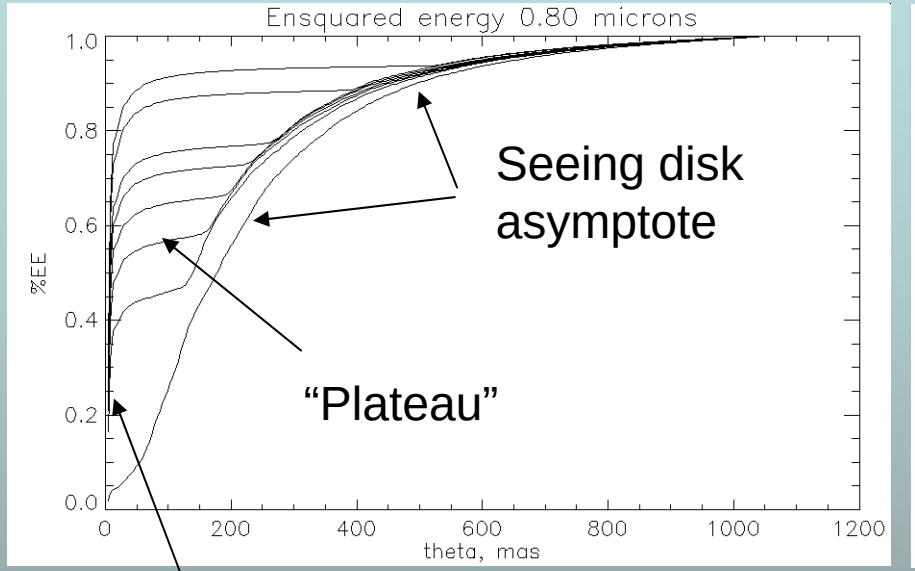
- Tip/Tilt error is modeled as a Gaussian blur of the AO-corrected PSF
- We use D = 10 m, r_0 = 16 cm

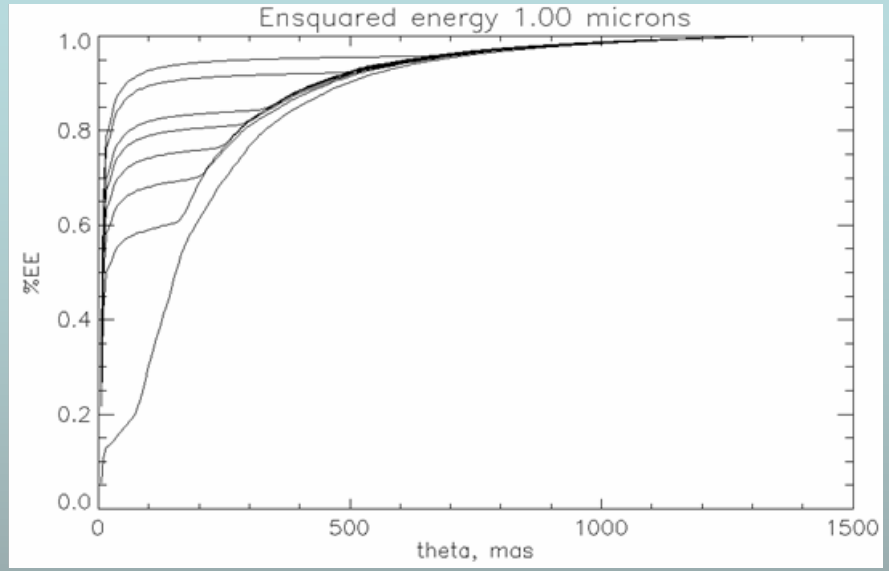
PSFs

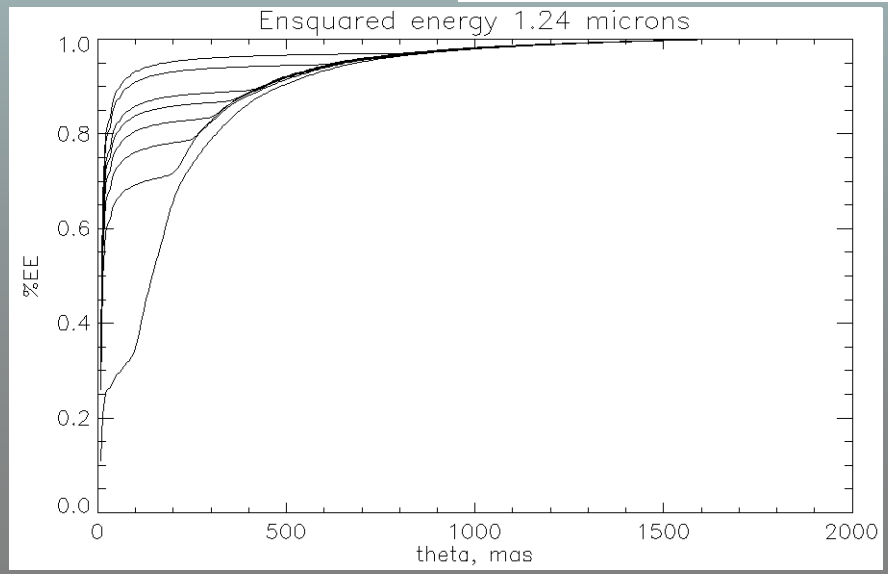


Ensquared Energy

Dominated by core, plateau, and then seeing disk

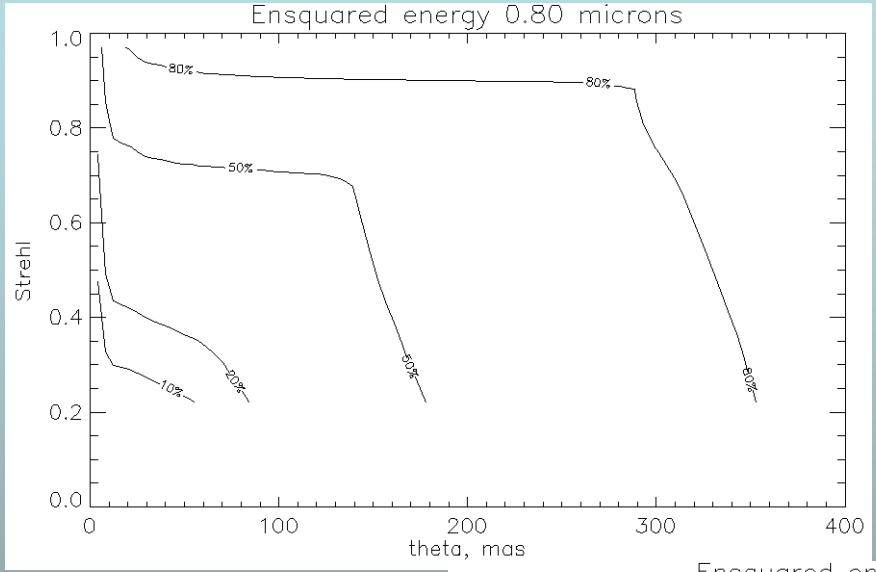


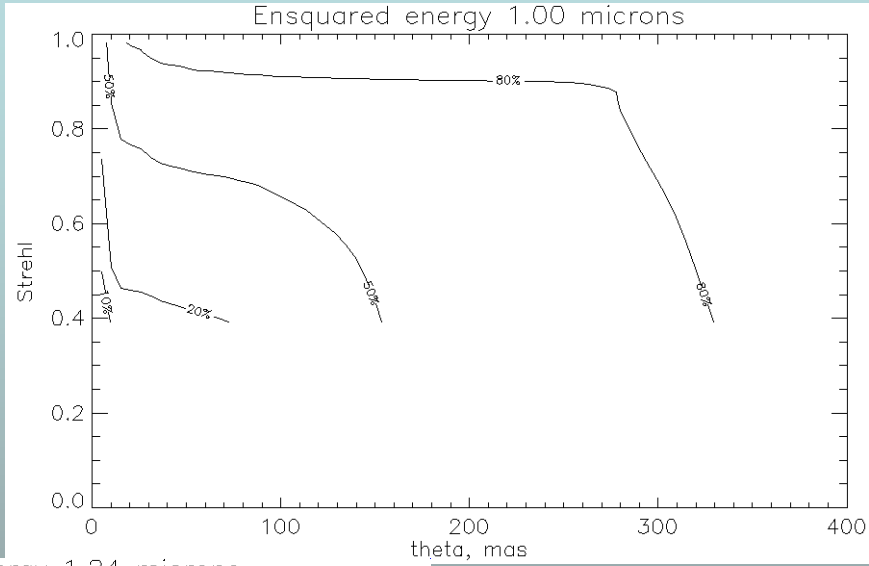


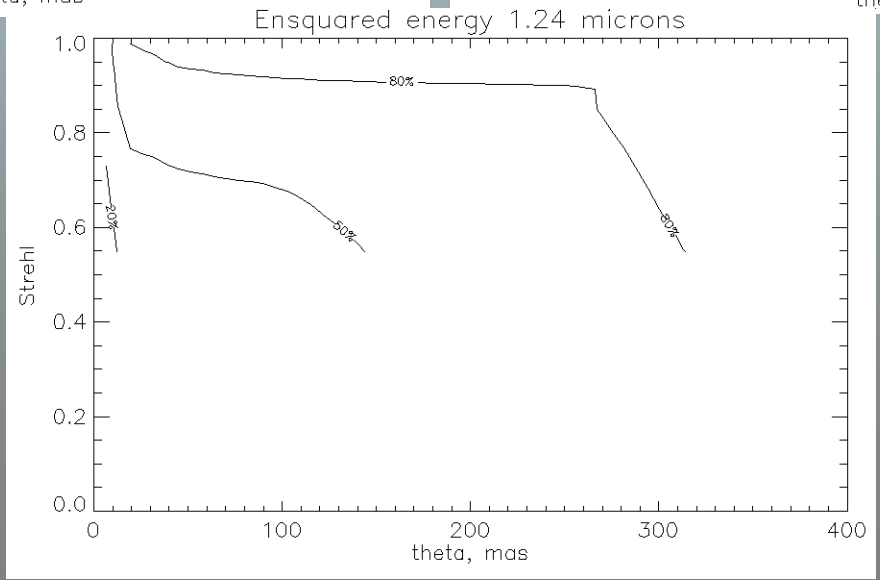


Contours of Ensquared Energy

plotted vs (Strehl,θ) – they're essentially insensitive to wavelength

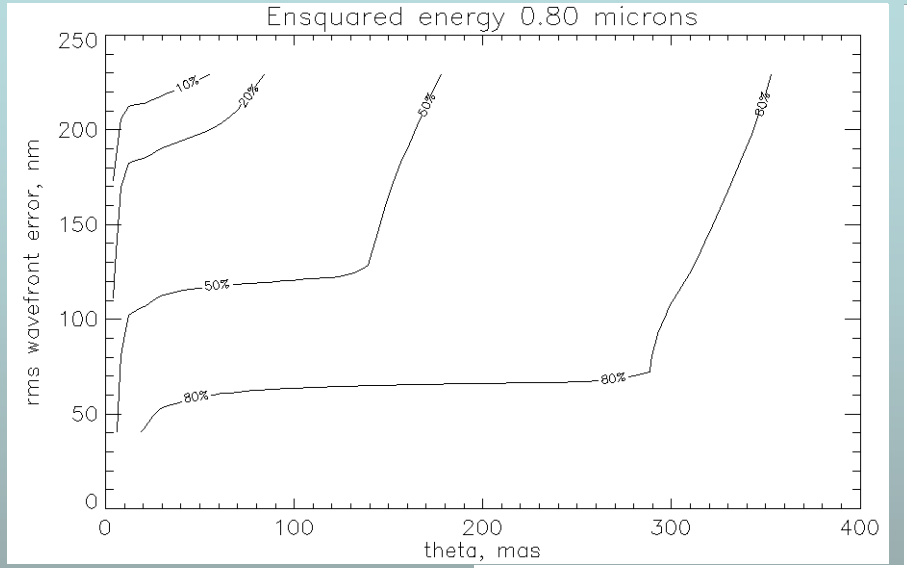


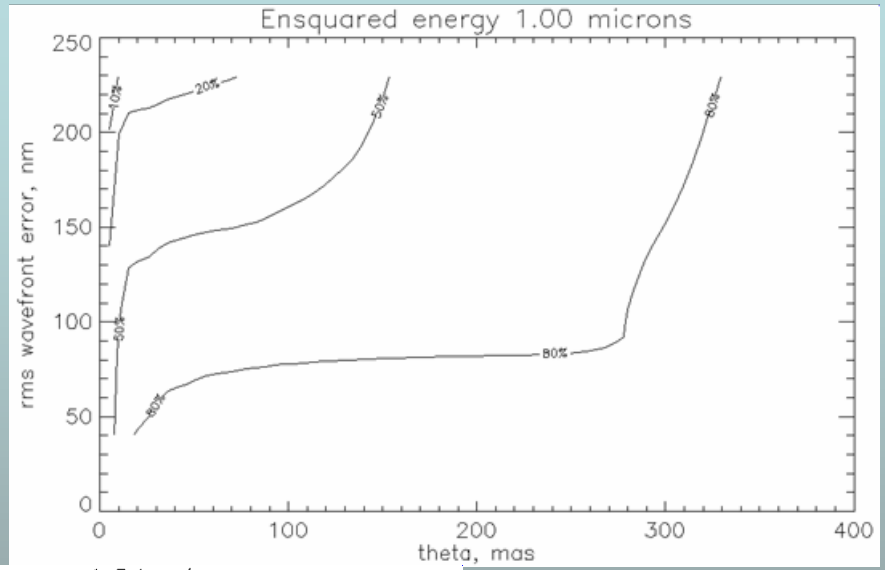


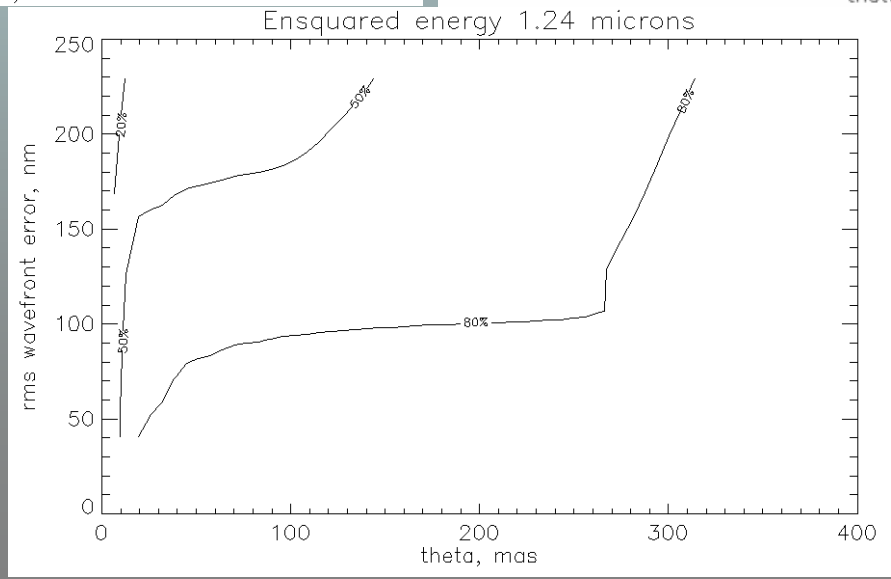


Contours of Ensquared Energy

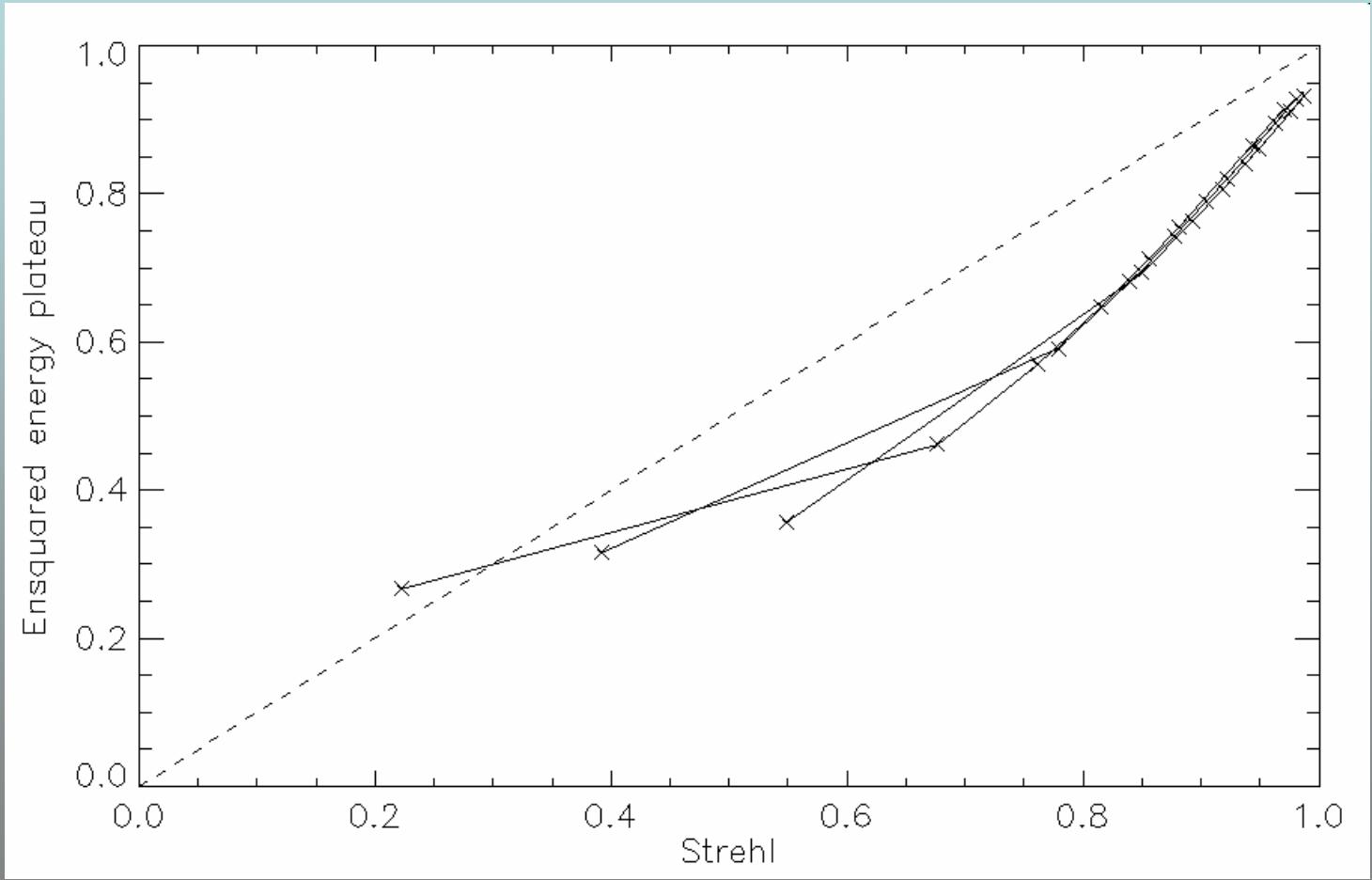
plotted vs (wfe,θ)







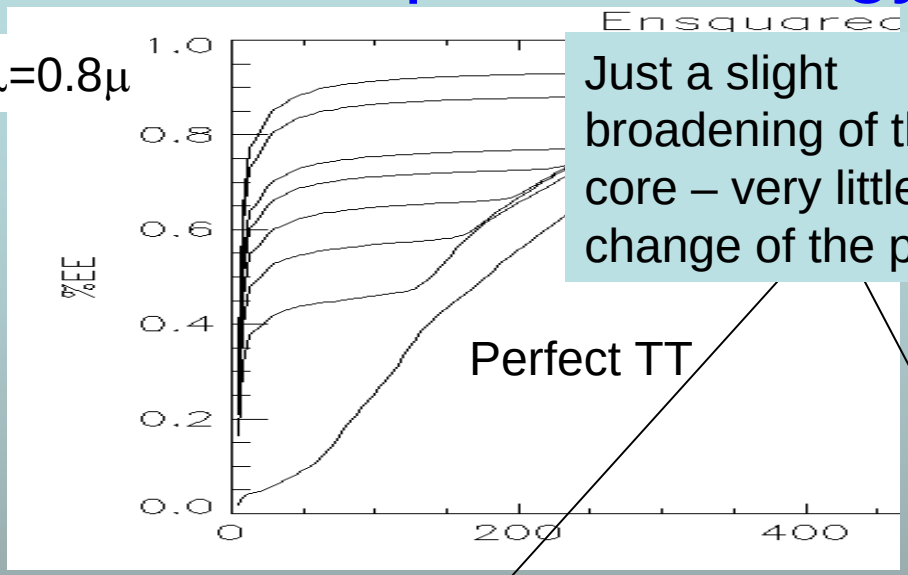
EE does not track Strehl
as closely as it did for a 30m aperture

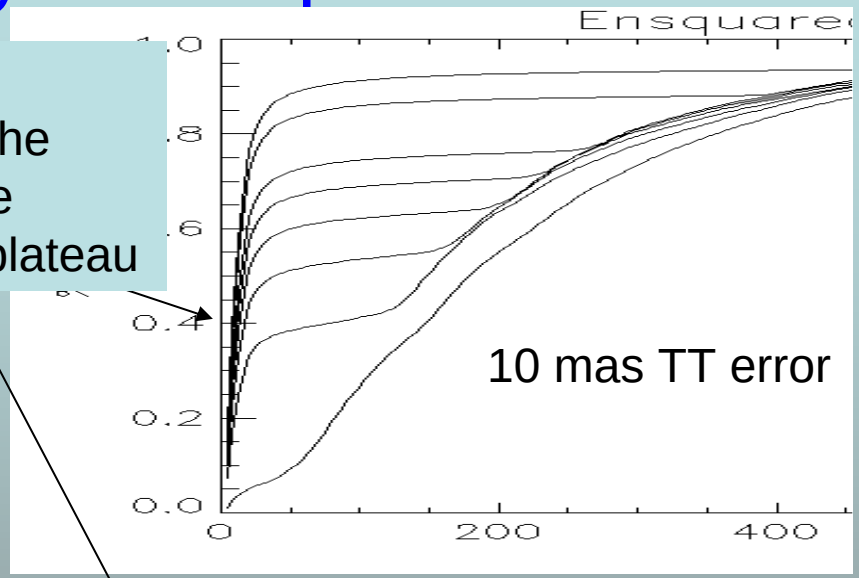


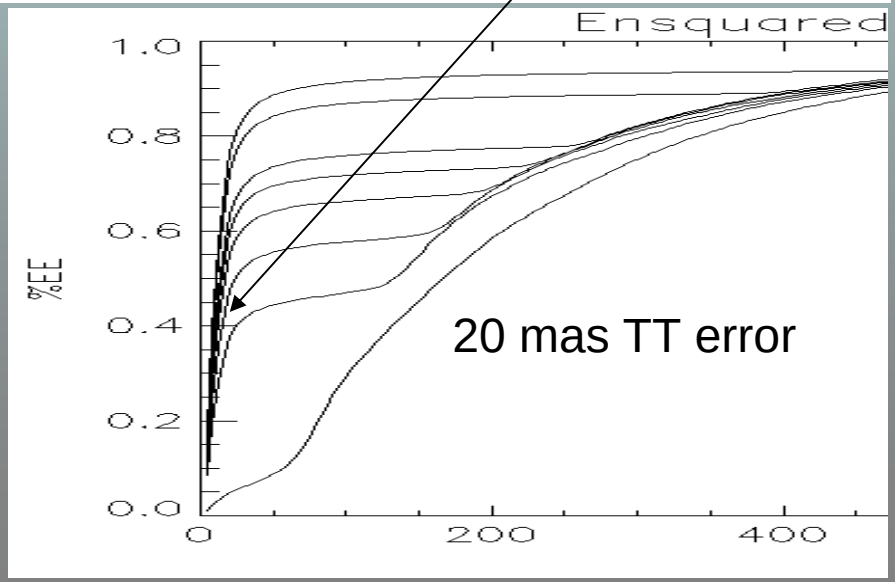
Ensquared Energy with Tip/Tilt Blur

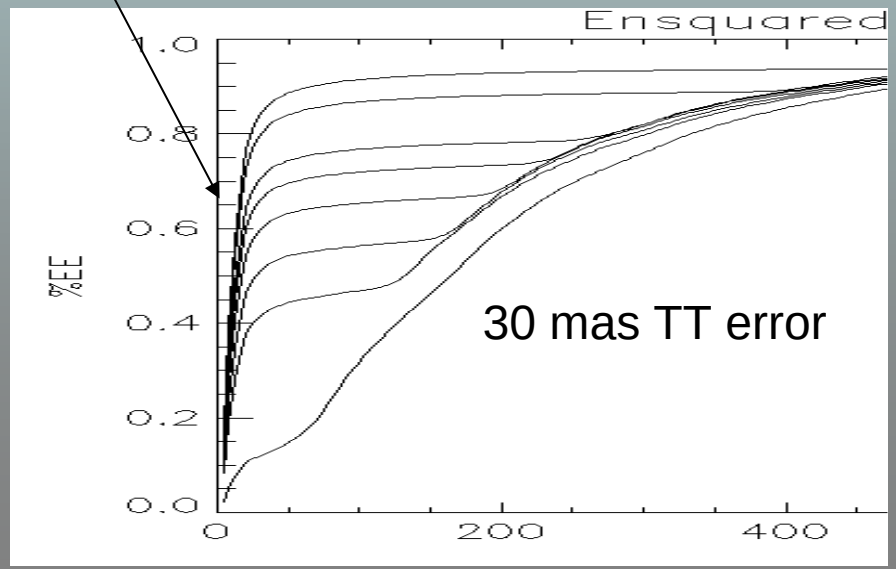
λ=0.8μ

Just a slight broadening of the core – very little change of the plateau





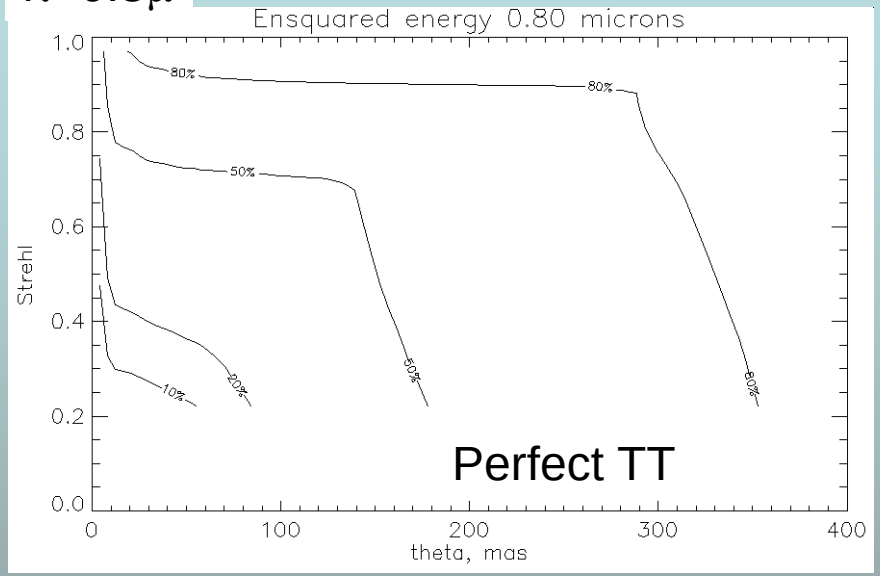


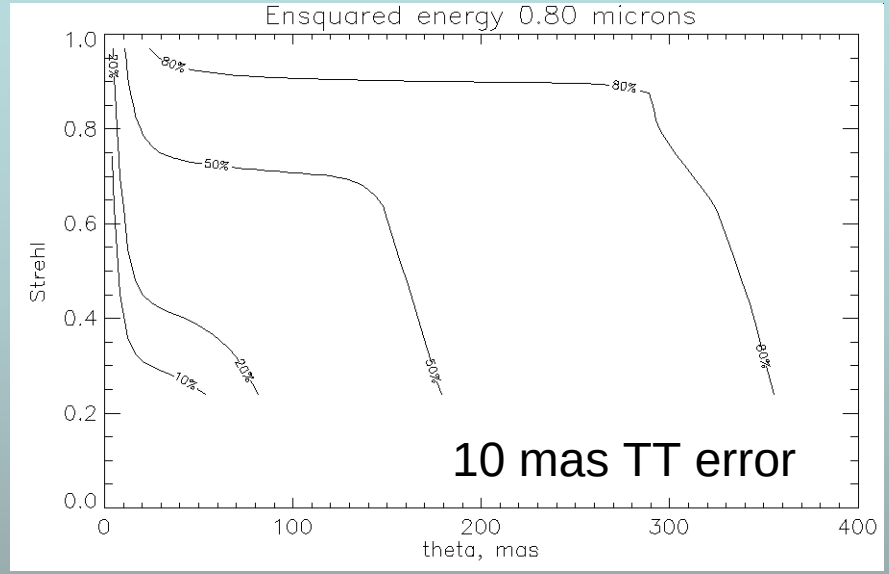


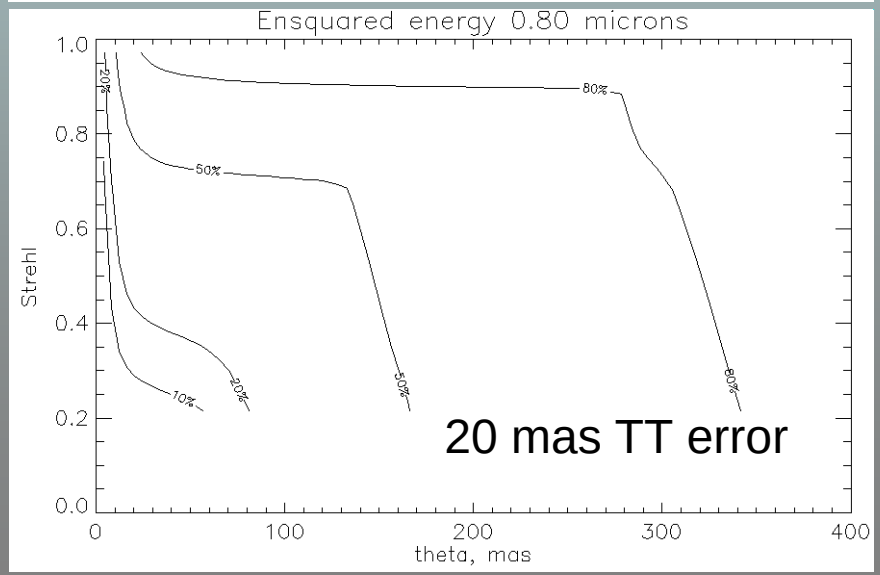
Ensquared Energy Contours

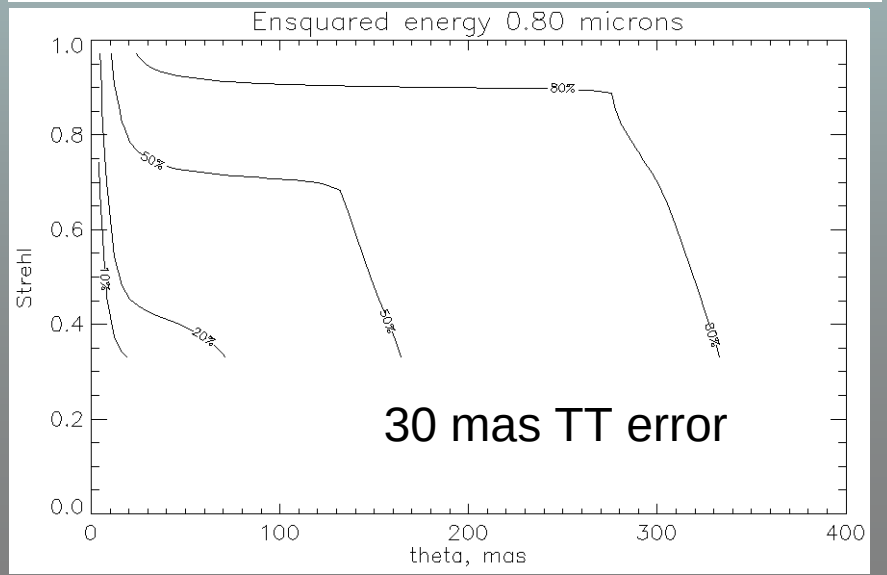
with Tip/Tilt Blur – hardly any effect in the plateau region

λ=0.8μ









Sky Coverage and Conclusions

- How do we condense all this information into a viable “ensquared energy budget”
- Need to do: budgets for specific science cases and/or incorporation into error budget spreadsheet
- Sky coverage:
  - If we are interested in 2 x DL spatial resolution of the IFU, then 30 mas tip/tilt is tolerable
  - From TT star statistics, this is about 40% sky coverage (if I’ve used Rich’s spreadsheet correctly) compared to 5% in a 142 nm [high-order] / 184 nm [High order + Tip/Tilt] error budget
- Consider: not precluding the future use of a *polychromatic guide star* in the NGAO system design

  for compatibility with further developments in tip/tilt sensing