

The widest contiguous field of view

$4 < \theta < 20$
arcminutes

Jeff Stoesz

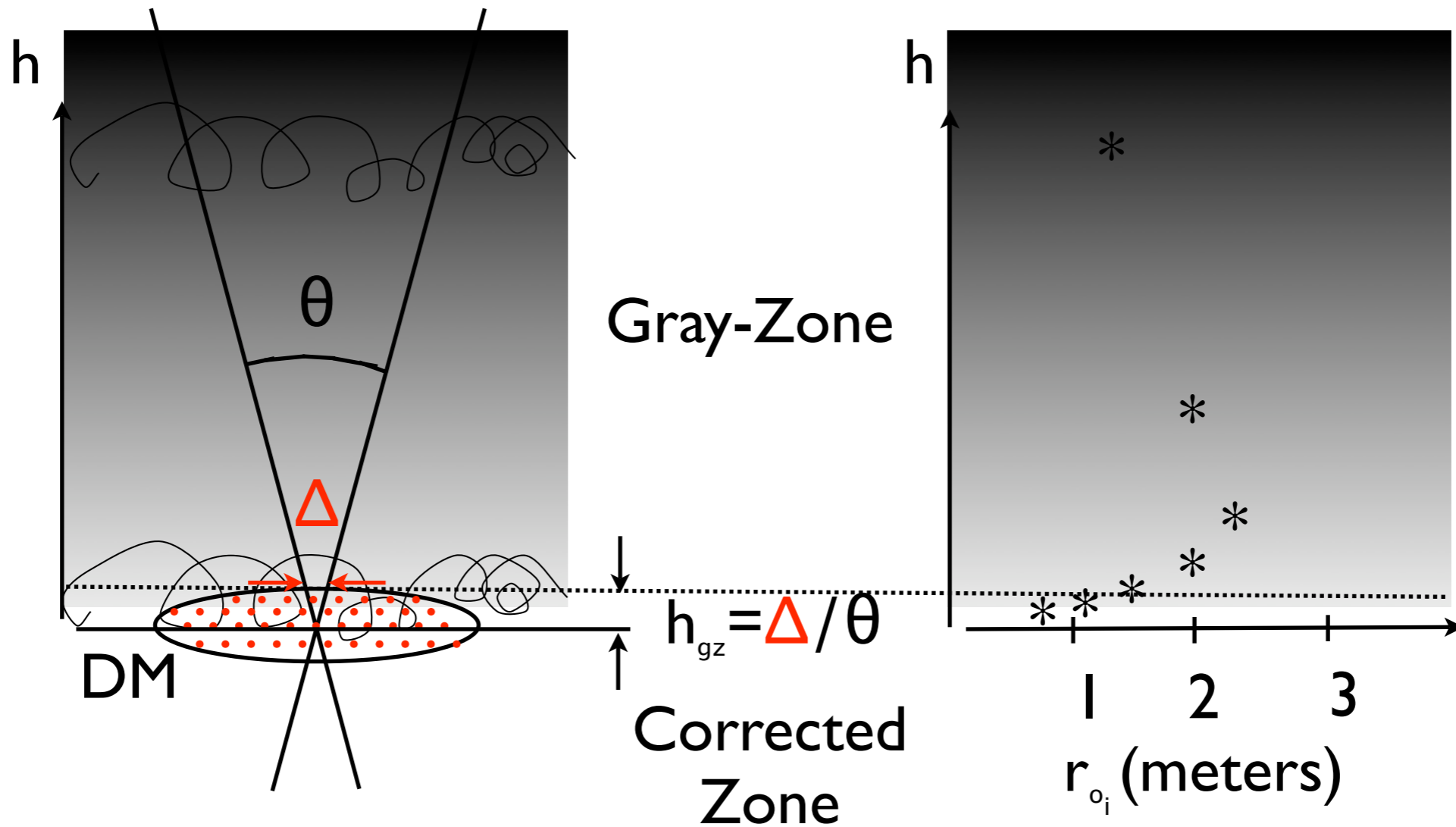
Susanna Hagelin, Elena Masciadri, Franck Lascaux



The widest contiguous field of view

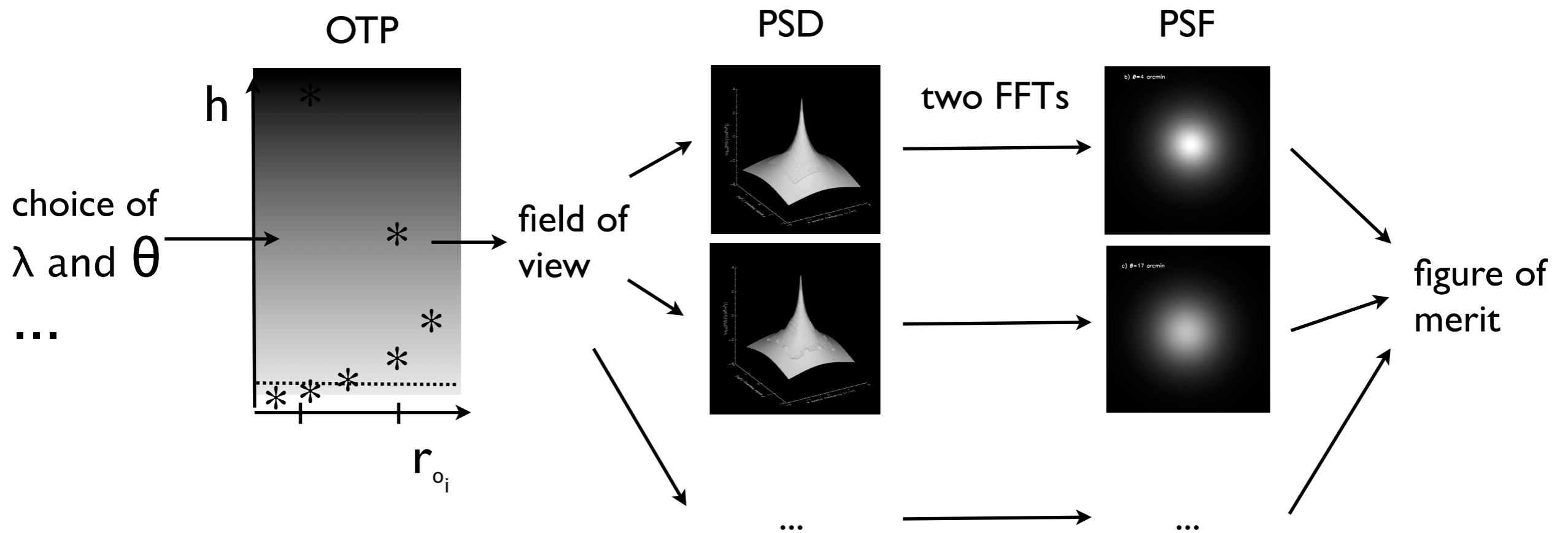
- Adaptive telescopes with one Deformable Mirror (DM) doing astronomy on contiguous fields of view $4 < \theta < 20$ arcminutes in diameter will have very interesting Point Spread function (PSF) morphology due to $C_n^2(h)$.
- Let us select two basic questions that should not be too difficult to answer given our current knowledge of $C_n^2(h)$ over **Mount Graham** and **Dome C**:
 - What will the PSF look like for $4 < \theta < 20$ in terms of a meaningful figure of merit?
 - What does the uncertainty in $C_n^2(h)$ imply for wide field astronomy?

The gray-zone of correction



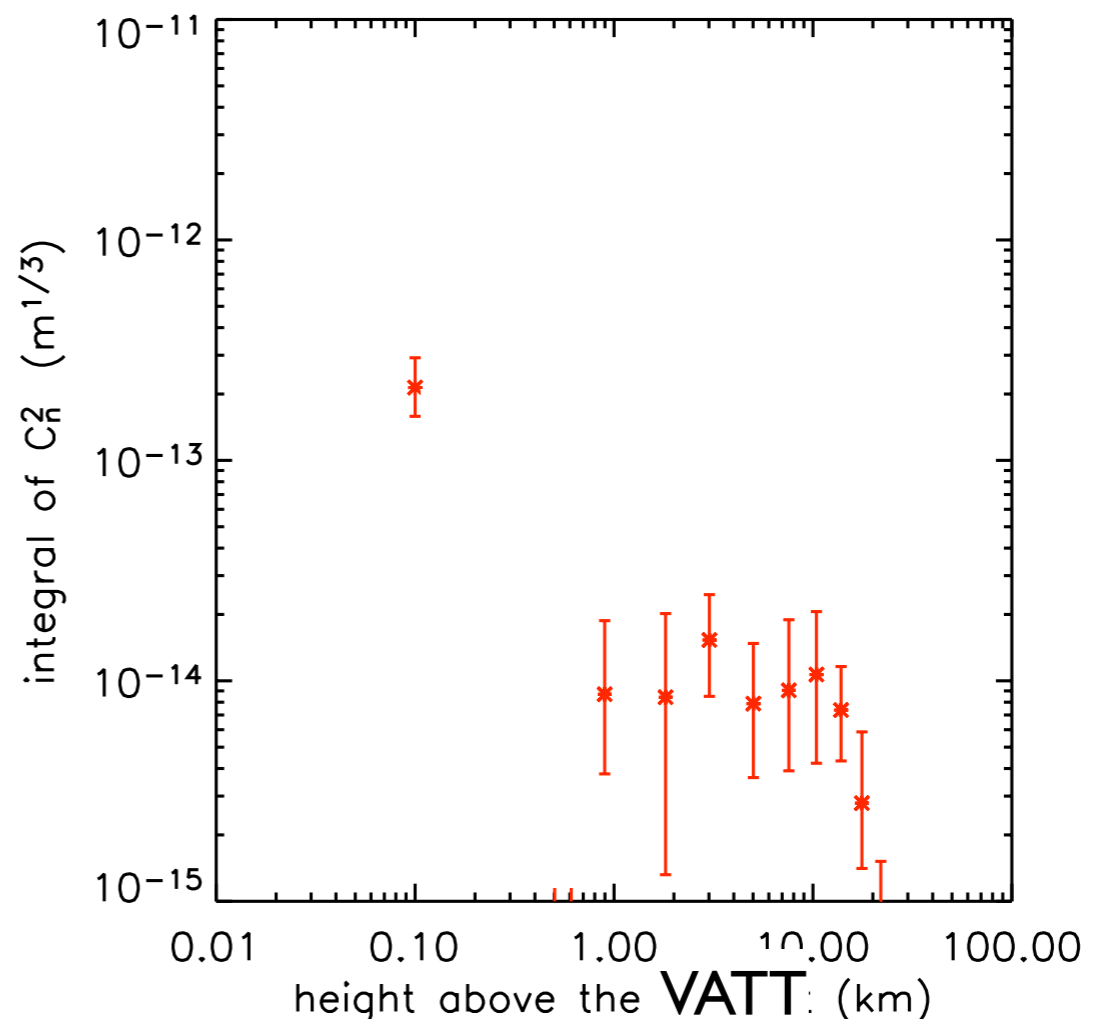
Modeling the effect of the Gray-Zone in the spatial frequency domain

- The partially corrected Gray-Zone has an effect in the focal plane: *quasi-uniform anisoplanatism*.
 - Given the Optical Turbulence Profile (OTP) and system parameters the Power Spectral Density of the phase (PSD) can be expressed analytically. The long exposure Point Spread Function (PSF) can be computed from that using a series of two Fast Fourier Transforms (FFT).



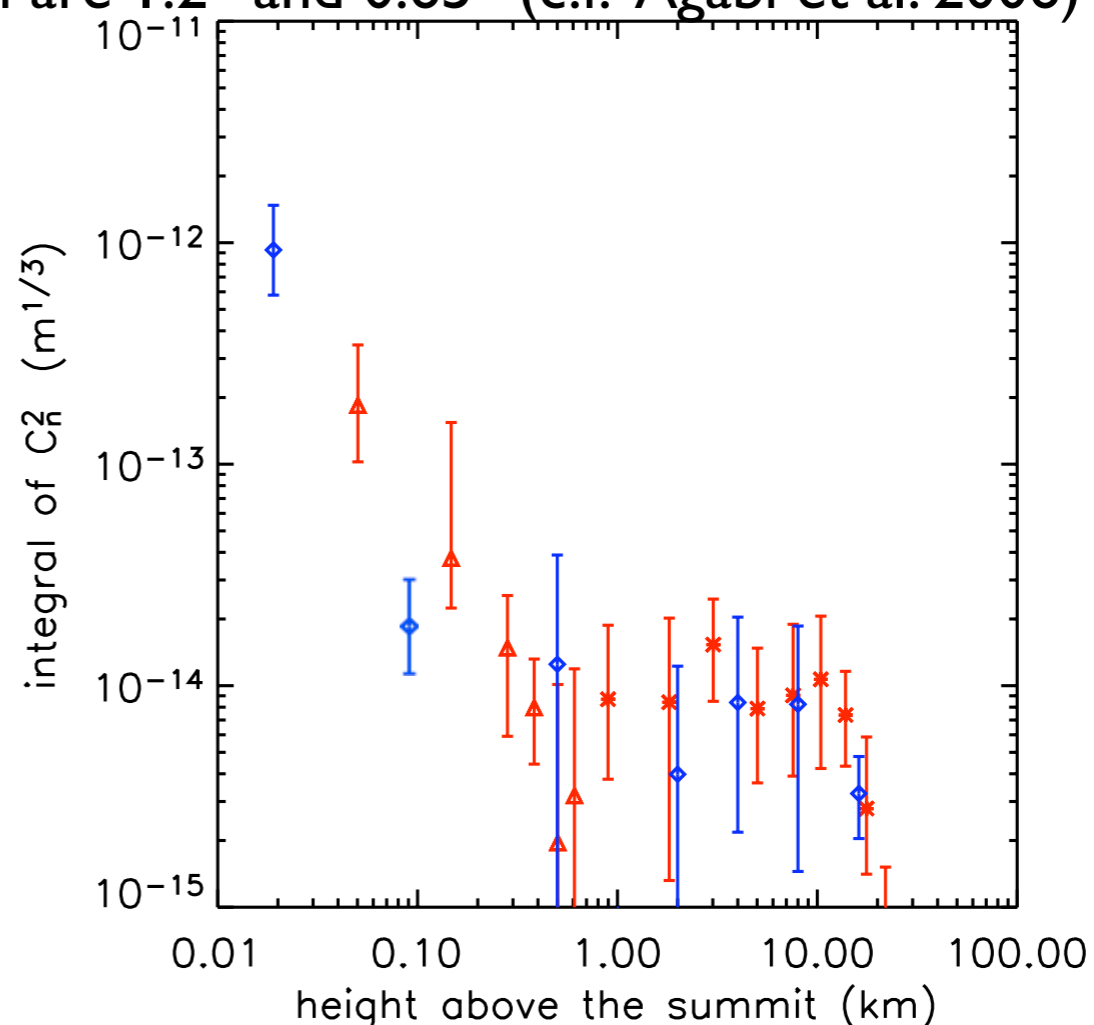
OTP monitoring at Mt. Graham

- Generalized SCIDAR at the Vatican Advanced Technology Telescope (VATT) near the Large Binocular Telescope (LBT).
 - 9911 profiles (16 nights) half in early winter half in early spring, measuring the whole atmosphere (Egner et al. 2007).
 - 851 profiles from binaries separated by 32 to 35 arcseconds indicate that half of the turbulence in the first 600 meters is concentrated below ~ 117 meters above the VATT.

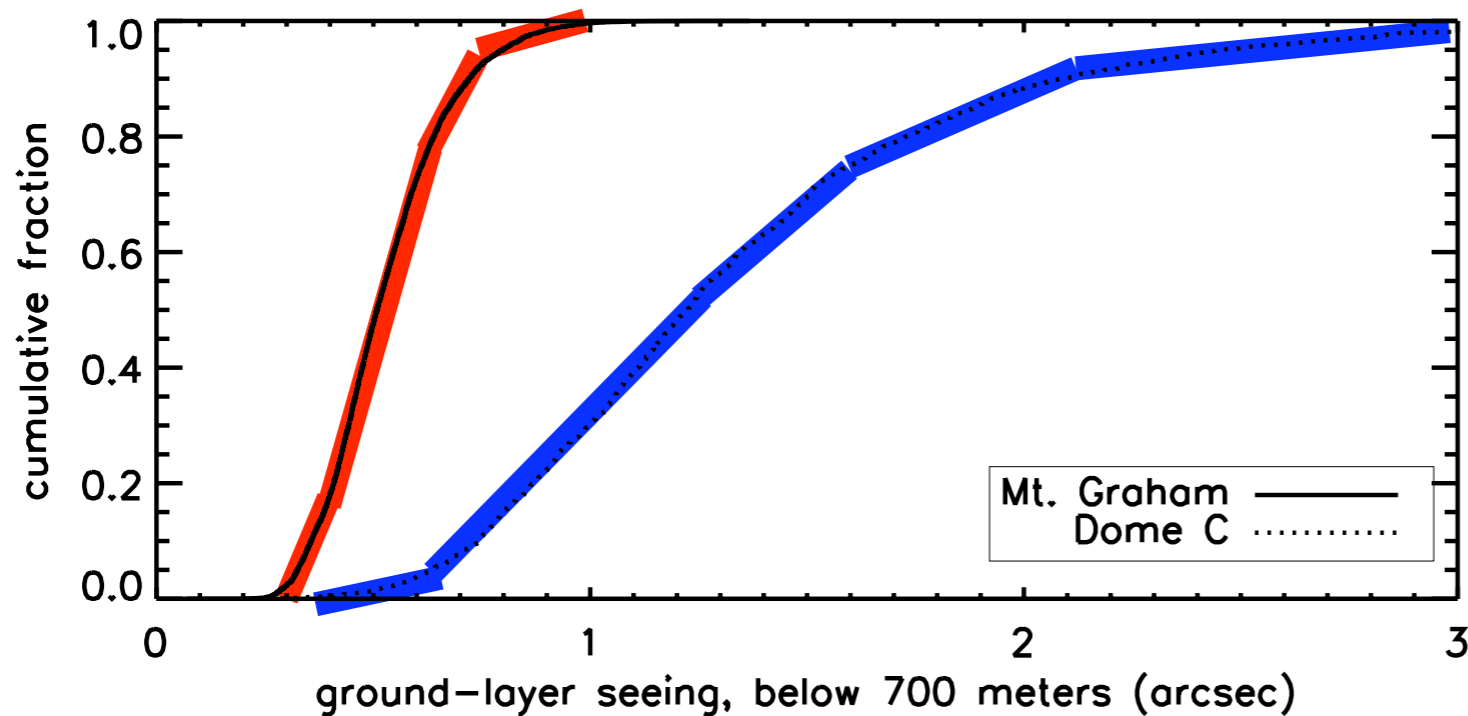
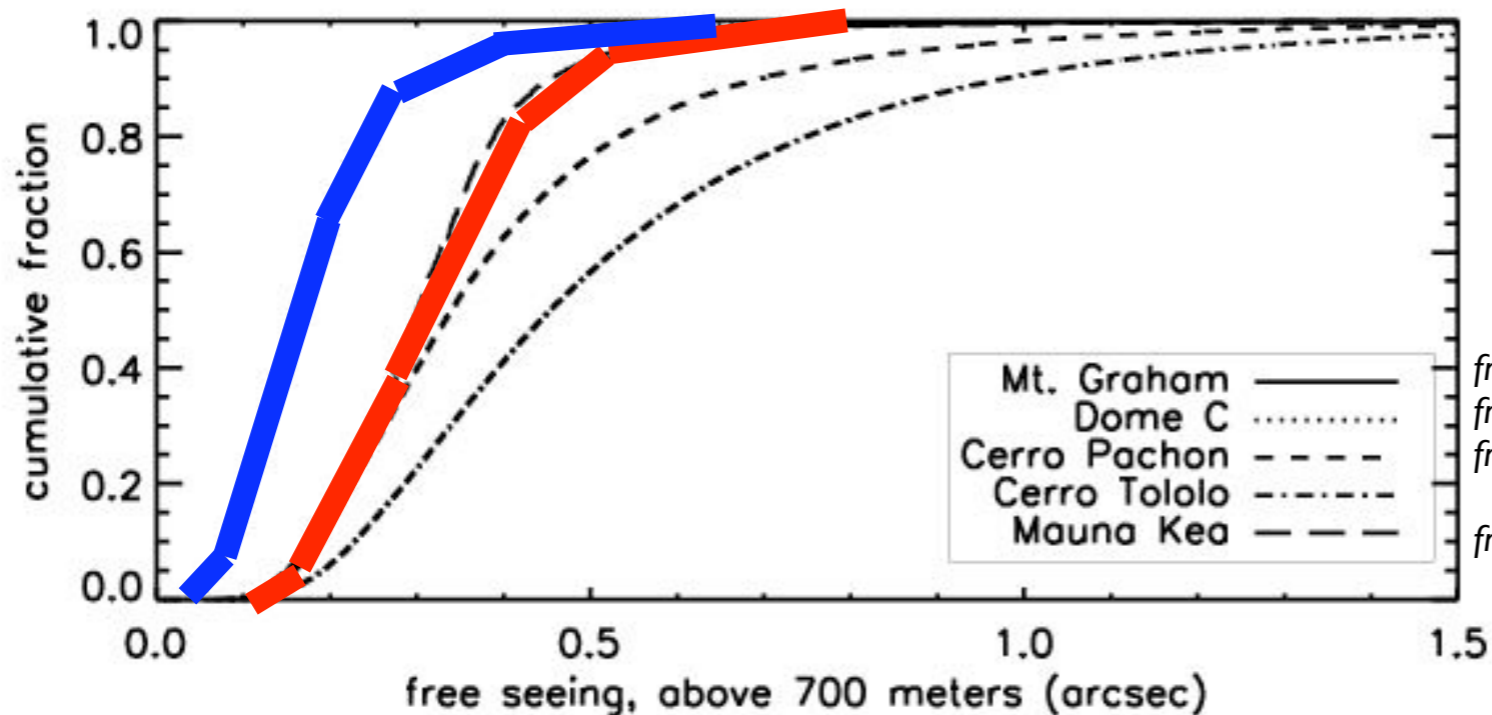


OTP monitoring at Dome C

- We selected the MASS+SODAR measurements of Lawrence et al. (2004) at Concordia station. The ground-layer is supplemented with synthesized bottom layer.
- 1701 $C_n^2\Delta h$ profiles (26 nights) from MASS+SODAR
- 1701 $C_n^2\Delta h$ values generated with a log-normal distribution of seeing. The median and standard deviation are 1.2" and 0.65" (c.f. Agabi et al. 2006)



Dome C and Mt. Graham



- The free atmosphere and ground-layer conditions at **Mt. Graham** is similar to other mid-latitude sites, while **Dome C** is unique.
- median seeing of **Mt. Graham** composite is 0.64''
- median seeing of **Dome C** composite is 1.2''

the other (less important) parameters

Atmosphere:

Von Kármán with 30 m outer scale.

composite of C_n^2 profiles.

10 m/s wind at the ground, increasing to 40 m/s wind at 12 km.

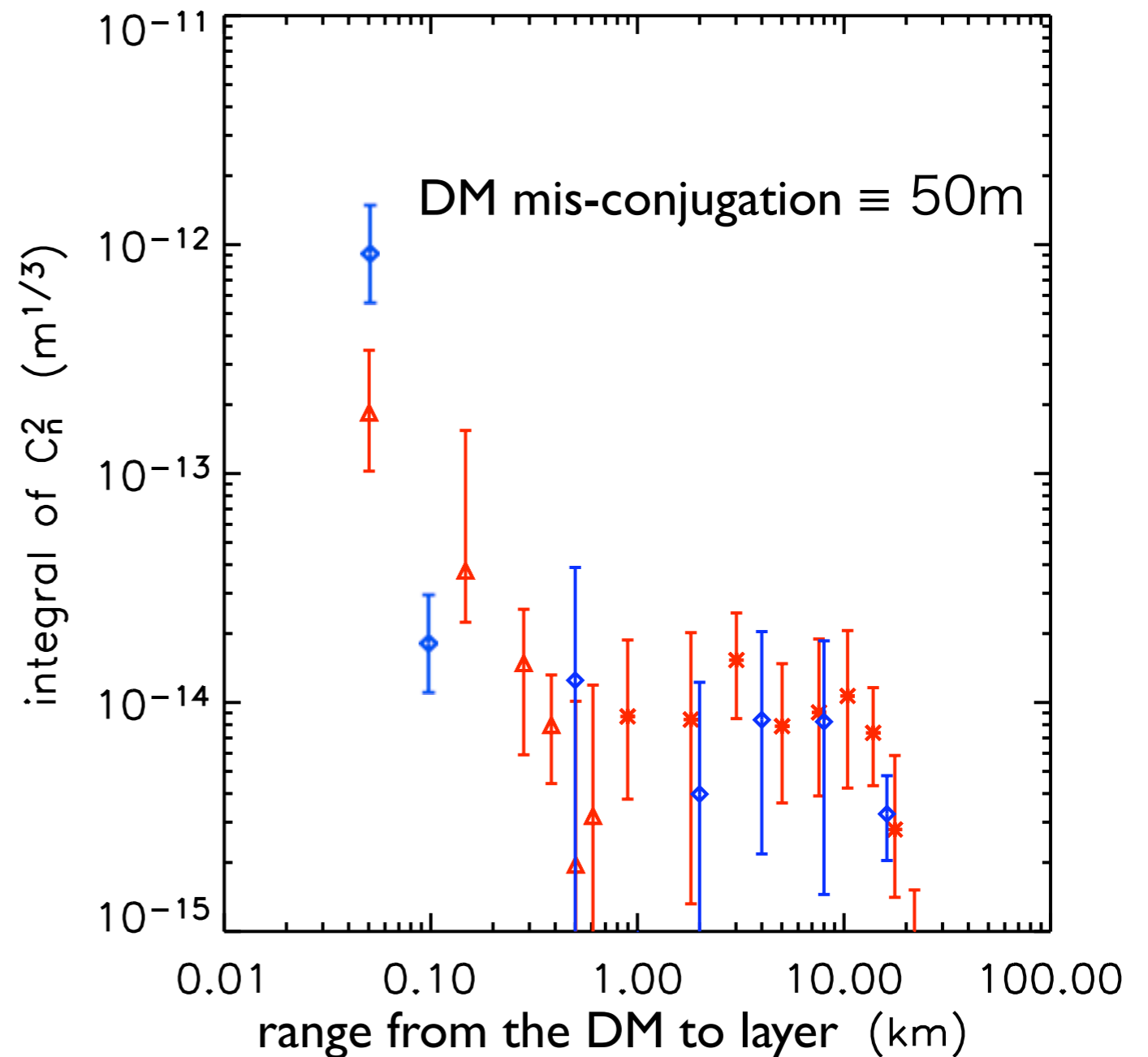
hypothetical GLAO:

8 m pupil

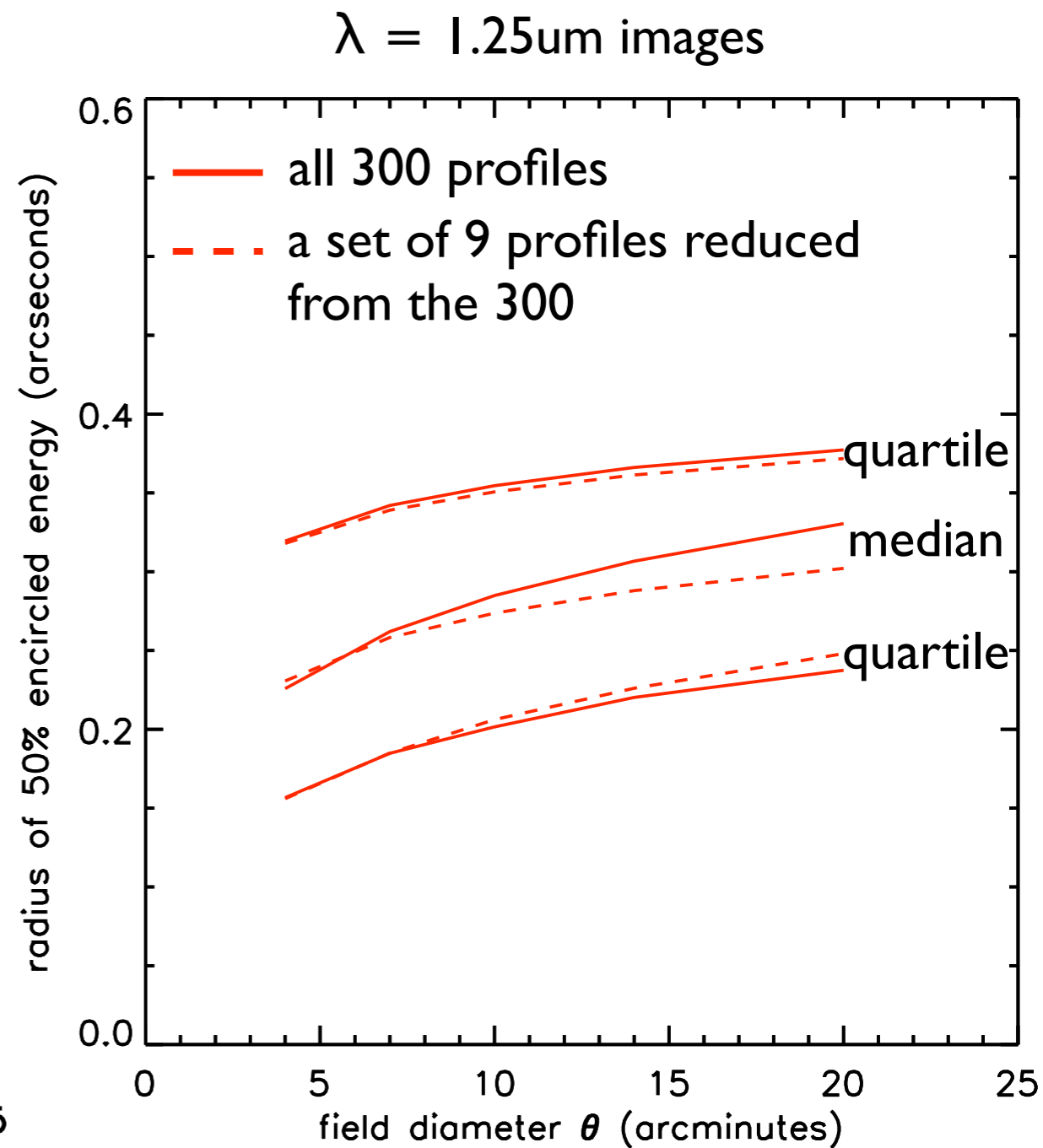
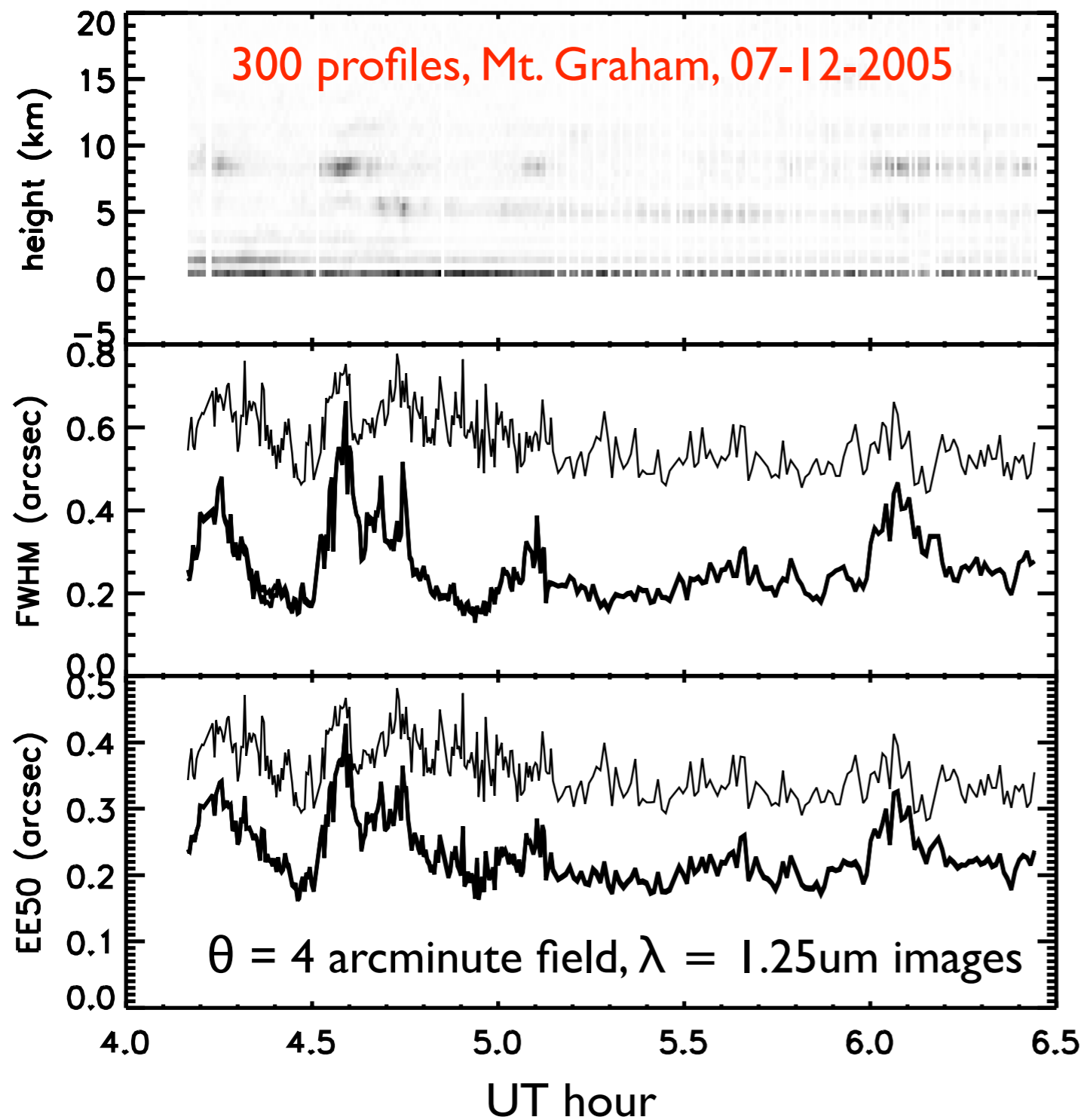
4 Na LGS surrounding the science field

WFSs integration = 0.004 s

WFSs pitch matches the pitch of the DM



Reduce the profile monitoring data? ...sure

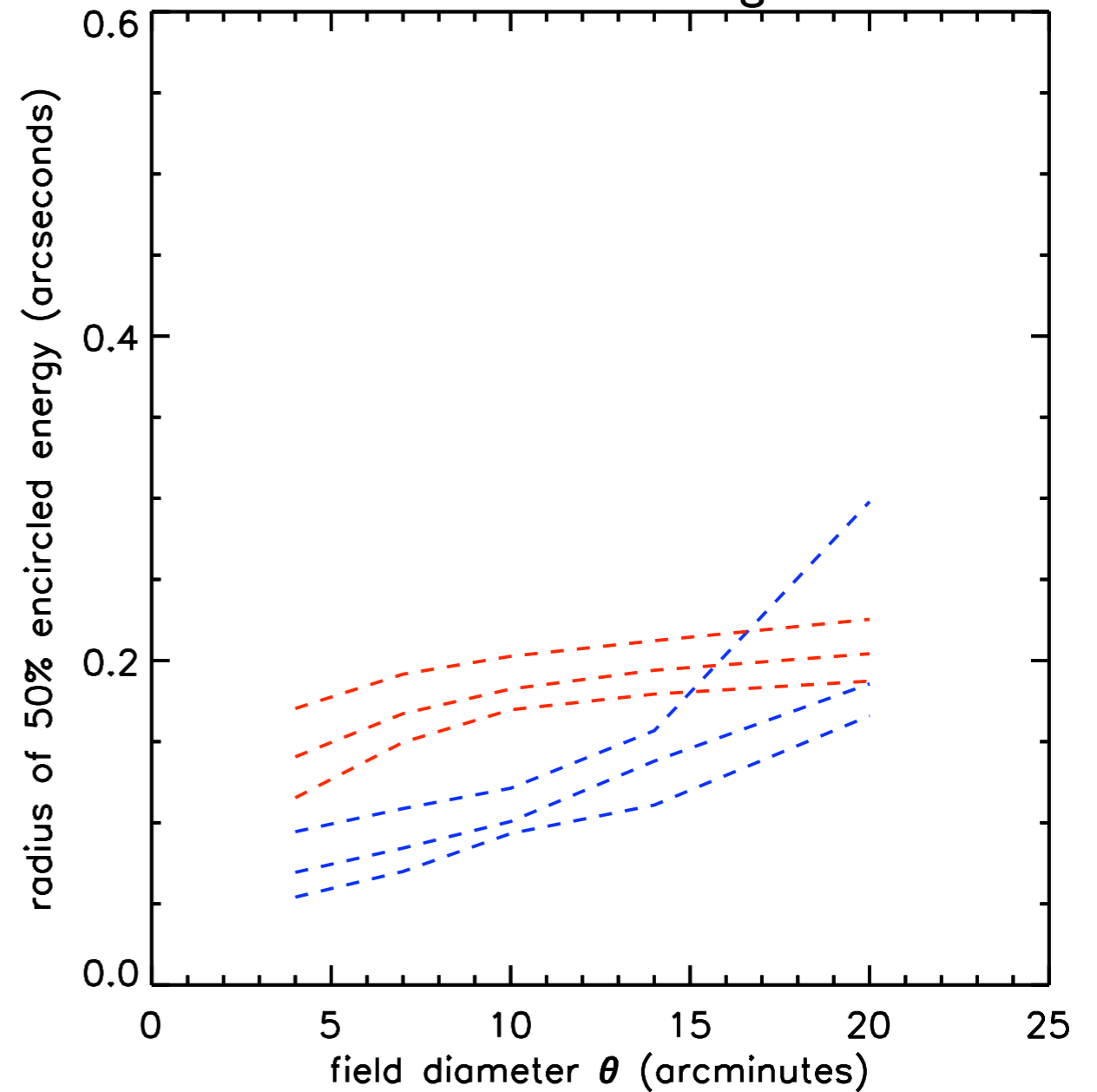
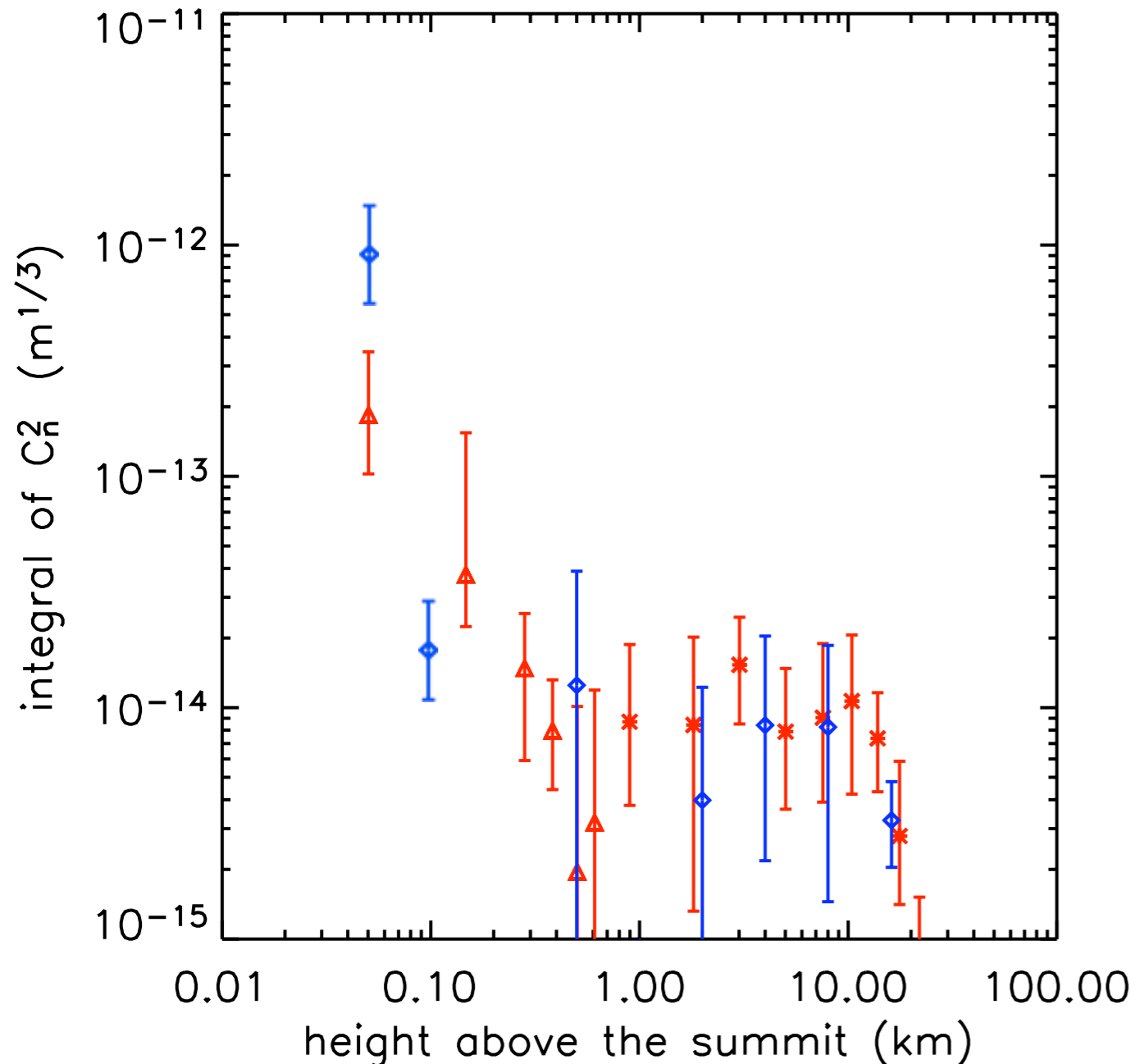


The EE50 from the whole set of reduced composite profiles

OTP

figure of merit

$\lambda = 1.25\mu\text{m}$ images

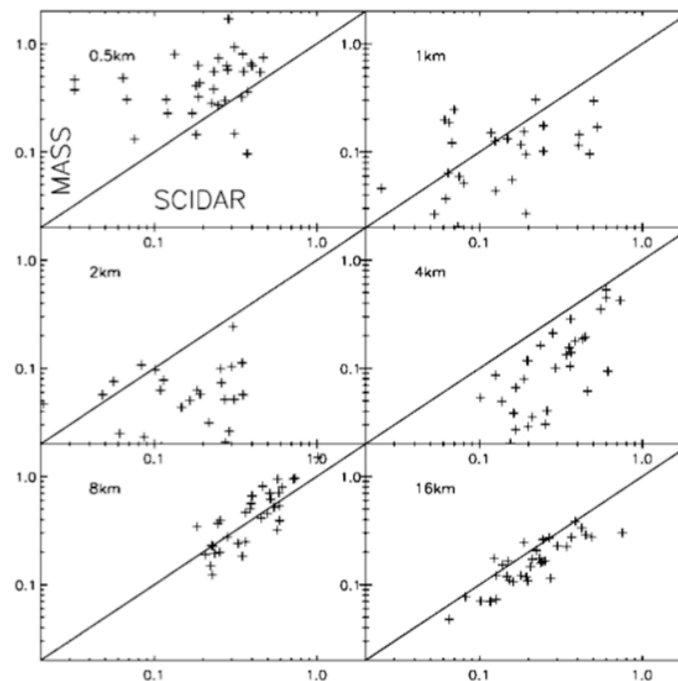


Measurement uncertainty

- Random errors are not an obstacle to this study. (SCIDAR: from weak autocorrelation signals at high altitudes and from dome seeing removal at the ground)
- MASS and SCIDAR: The total seeing (total Cn2) is well determined, hence systematic errors are in the distribution of Cn2(h).

- MASS vs. SCIDAR: systematic uncertainty in seeing in the

16km slab	}	small
8km slab		
4km slab	}	~25% to 75%
2km slab		
1km slab		
0.5km slab		



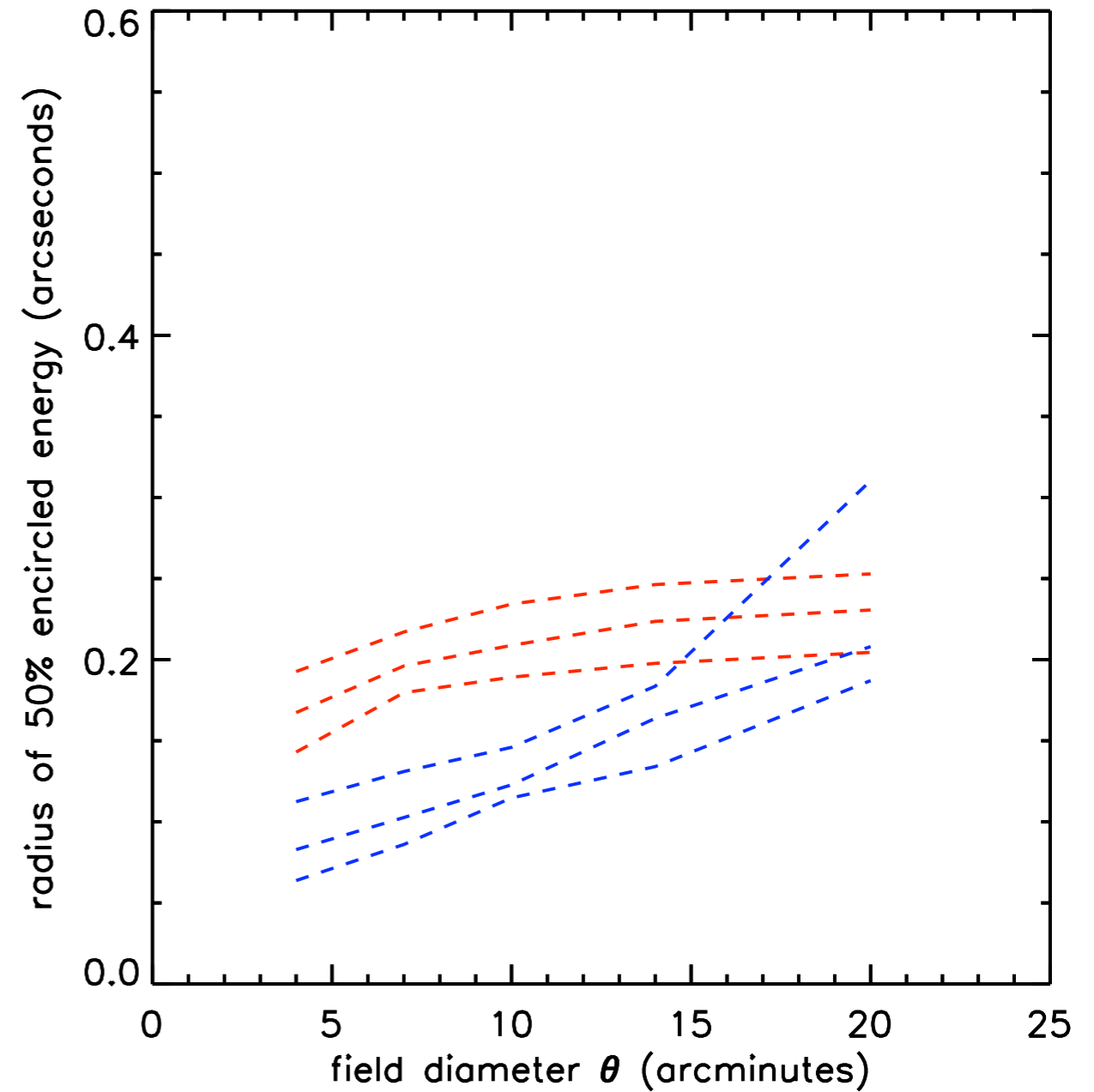
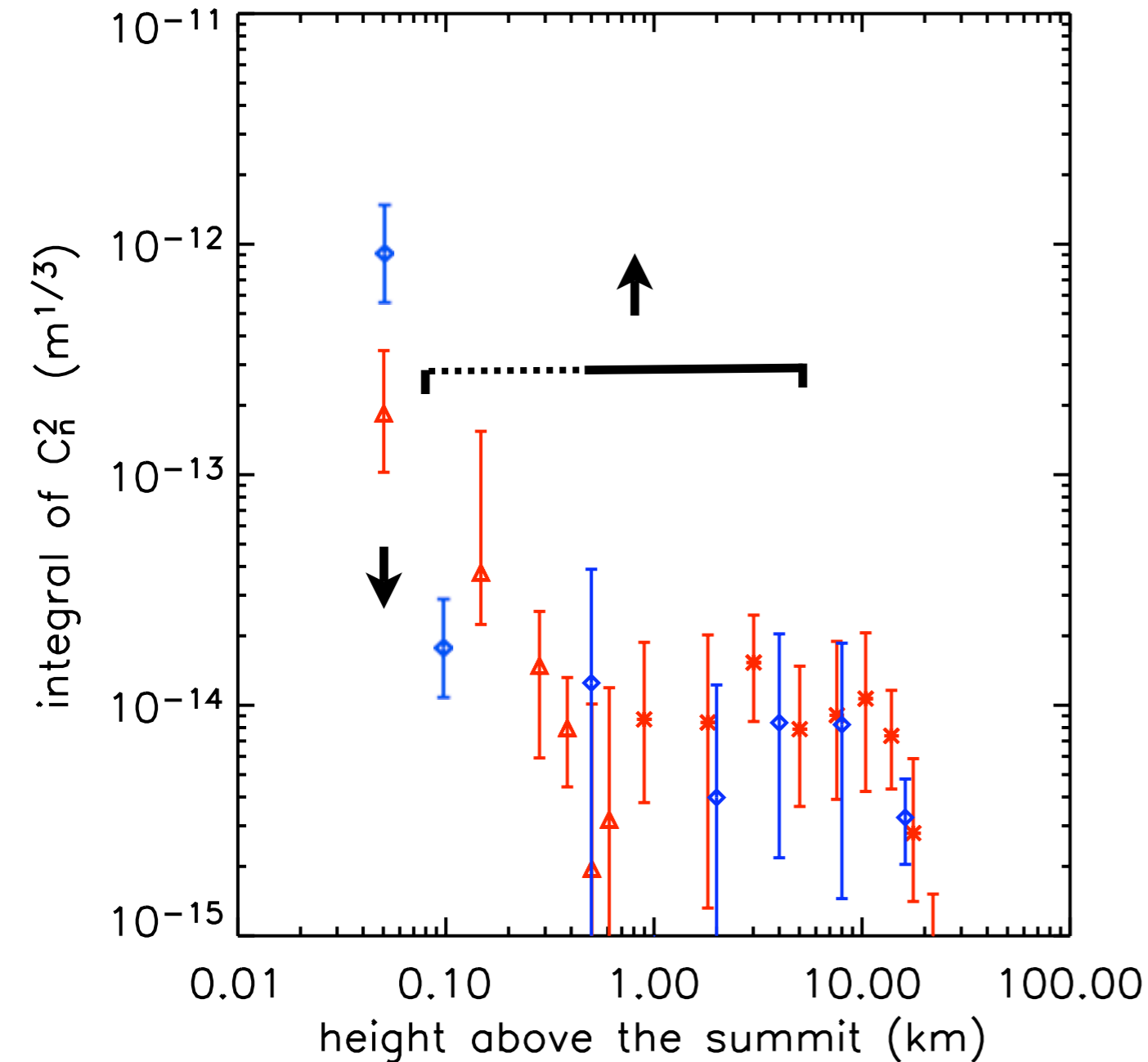
Tokovinin et al. (2005)

The EE50 from +50% Gray-zone turbulence

OTP

figure of merit

$\lambda = 1.25\mu\text{m}$ images

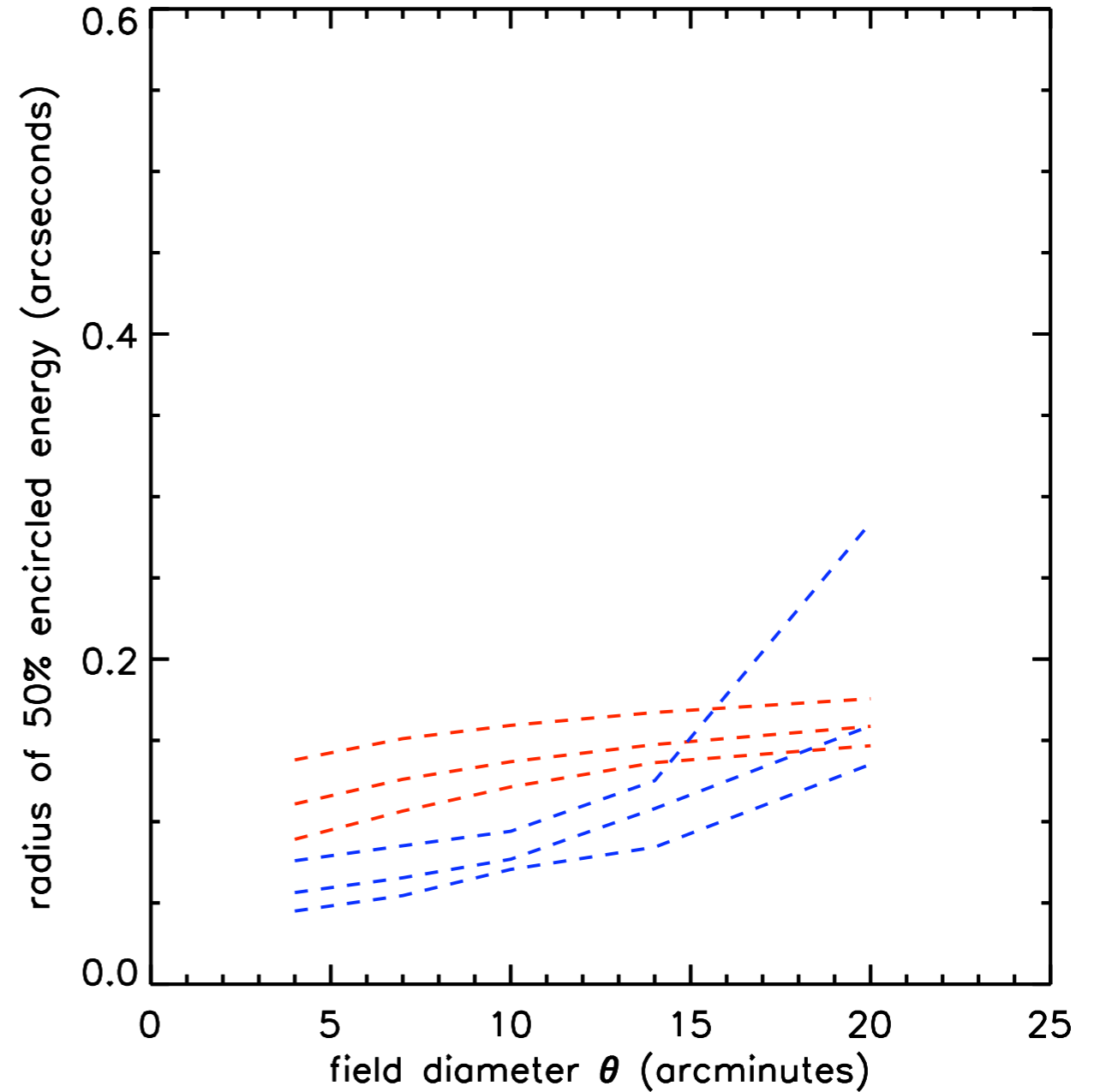
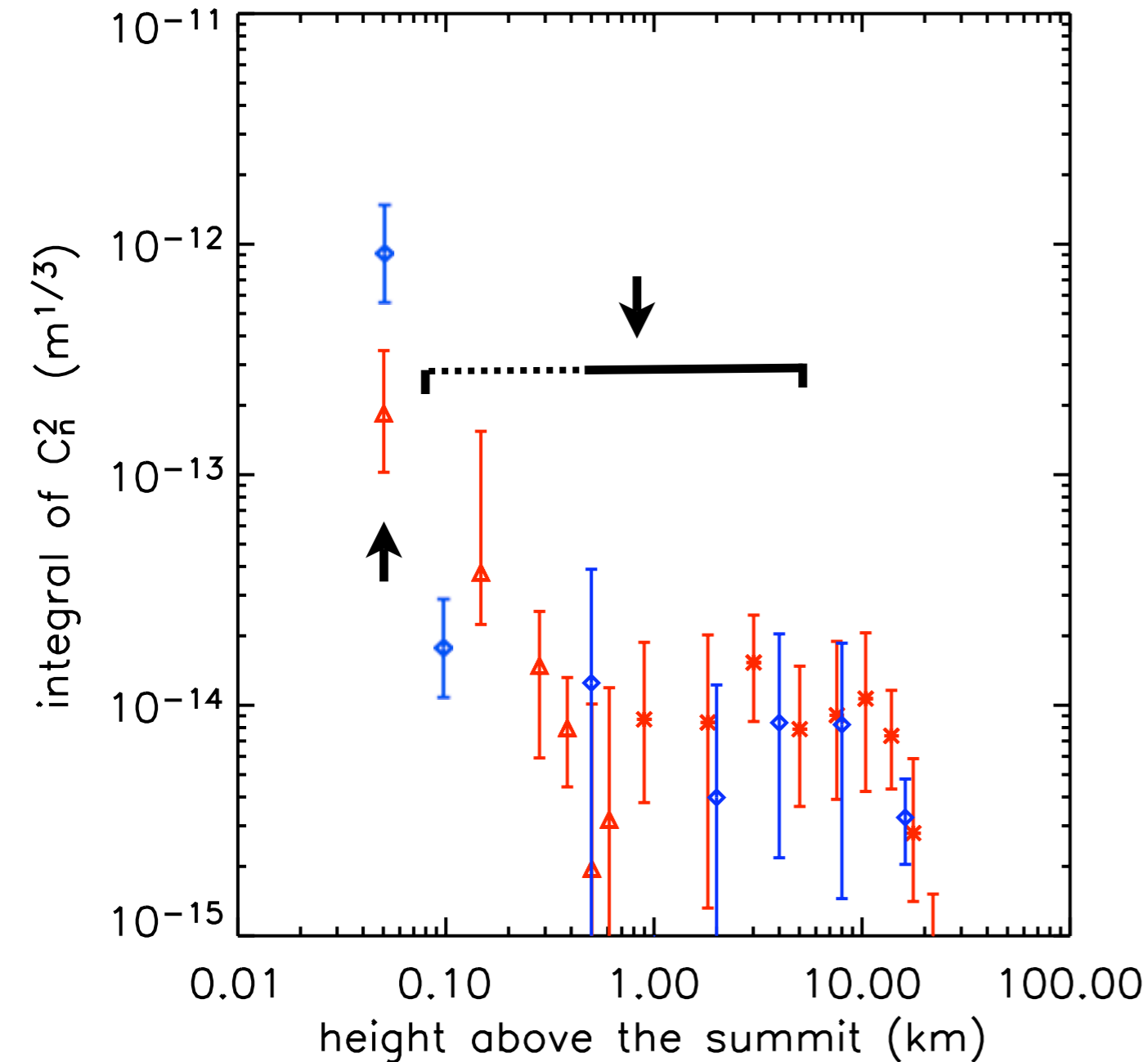


The EE50 from -50% Gray-zone turbulence

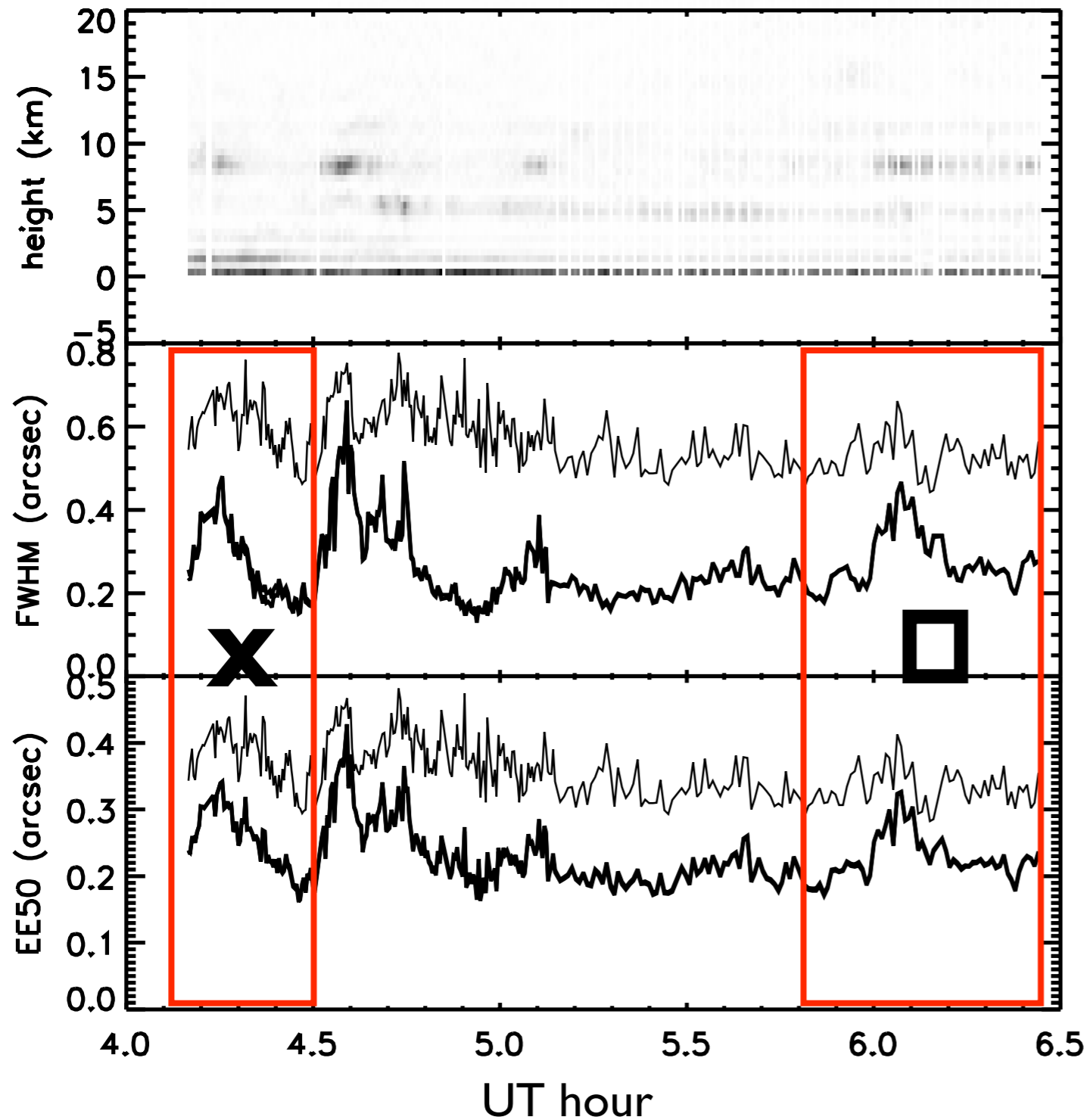
OTP

figure of merit

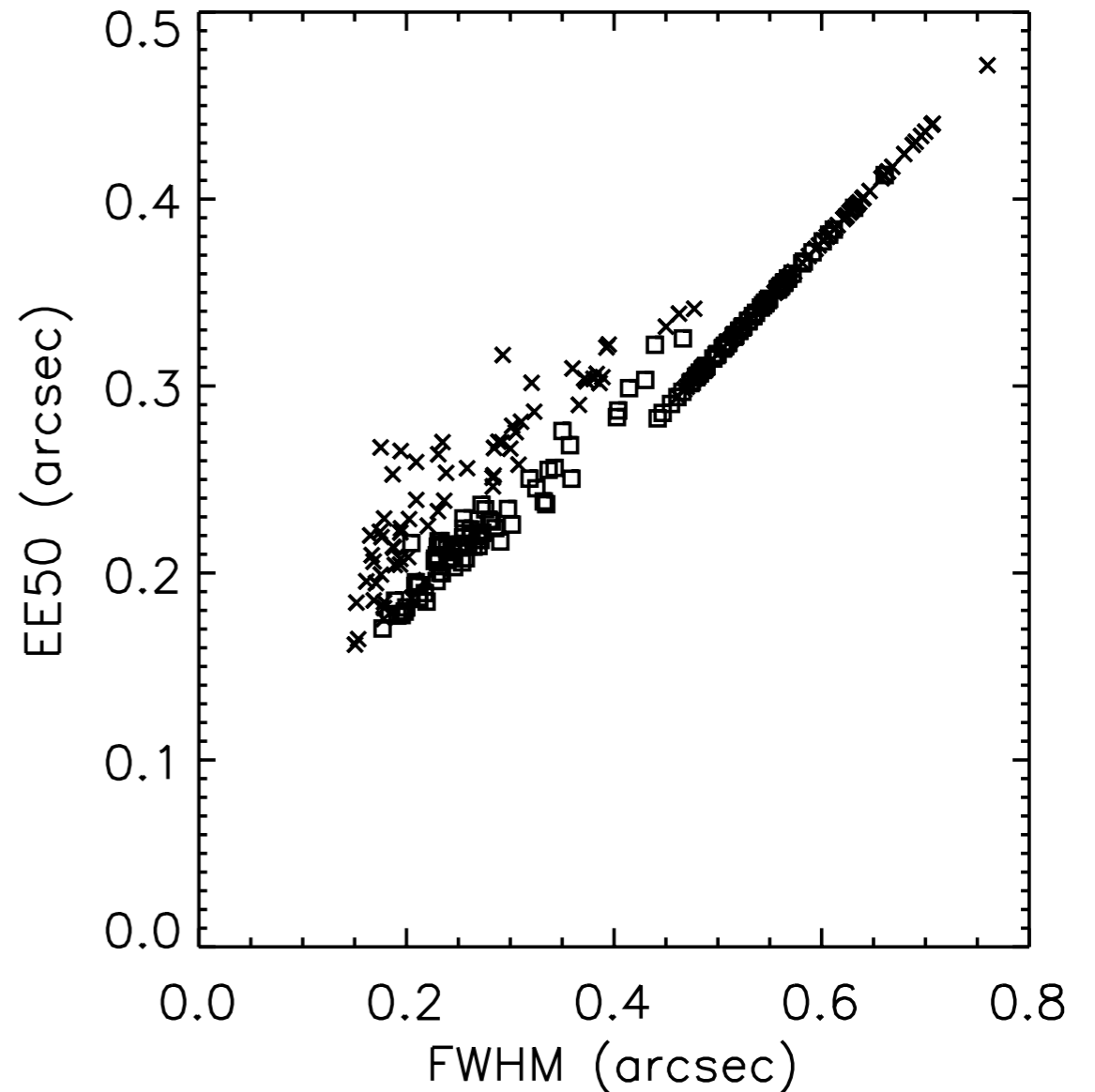
$\lambda = 1.25\mu\text{m}$ images



The PSF morphology

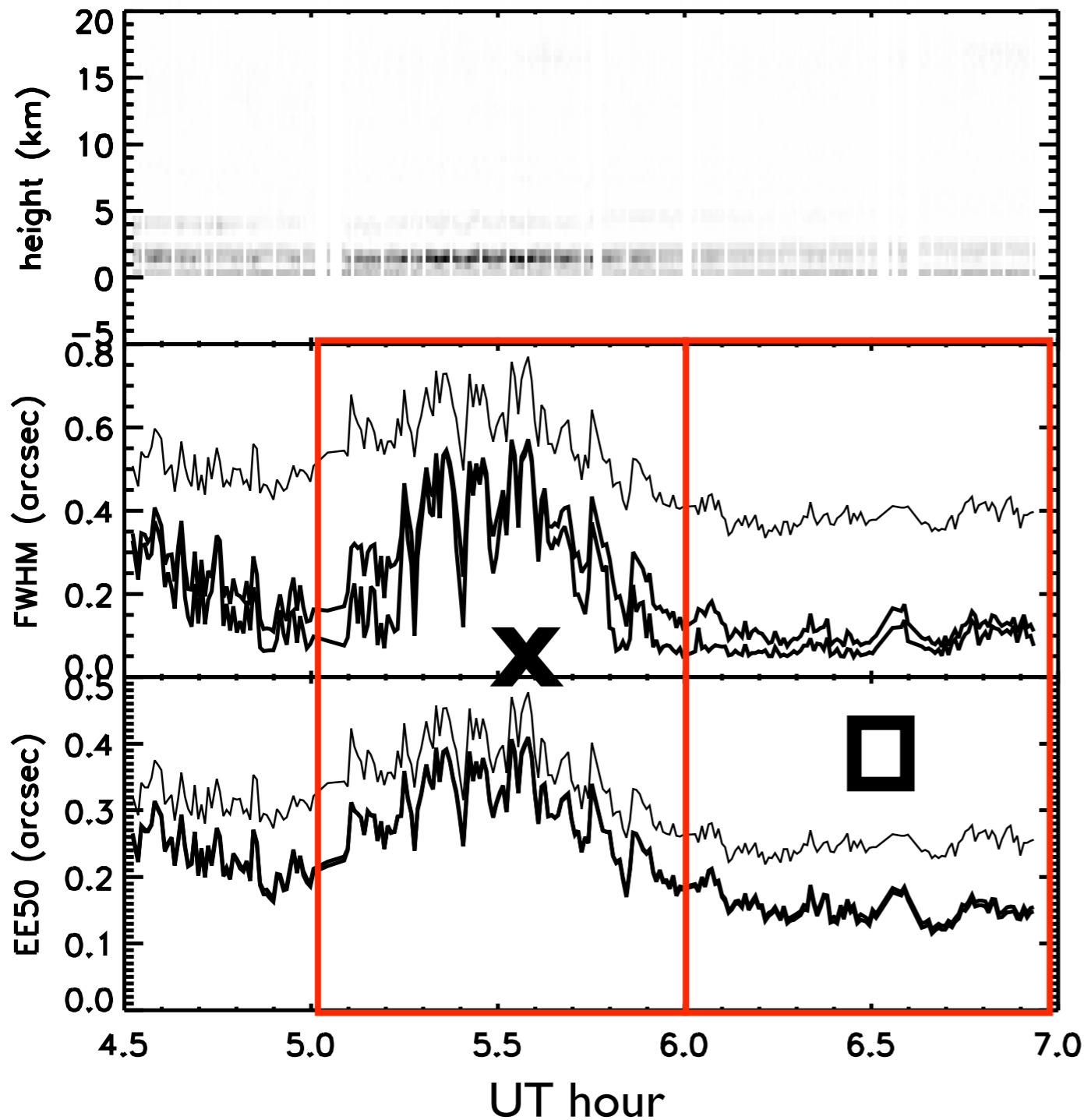


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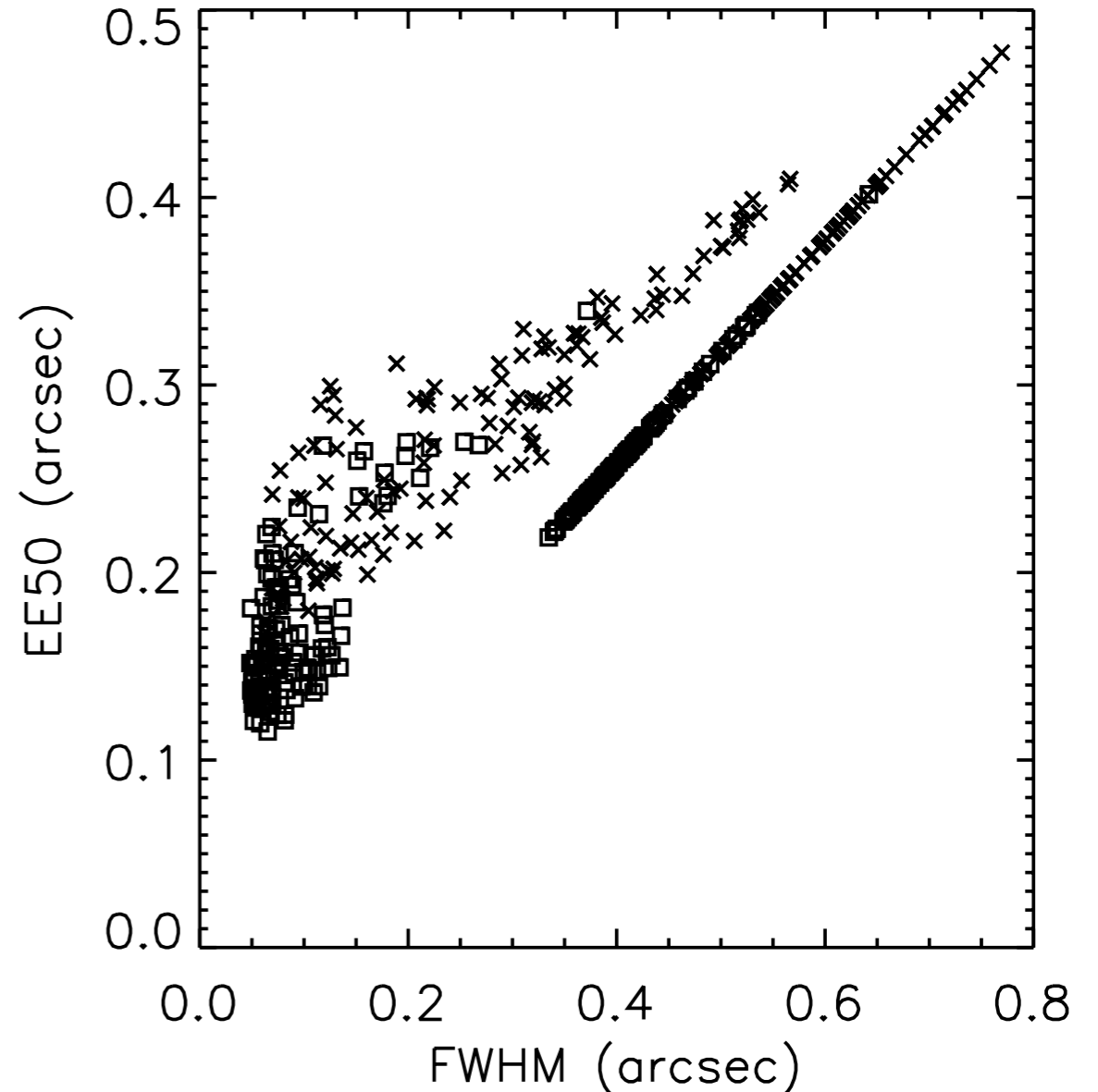


- The shape of the infrared GLAO PSF is highly variable, and sometimes has a small core with a broad halo...
- Radius of 50% encircled energy (EE50) and...

The PSF morphology



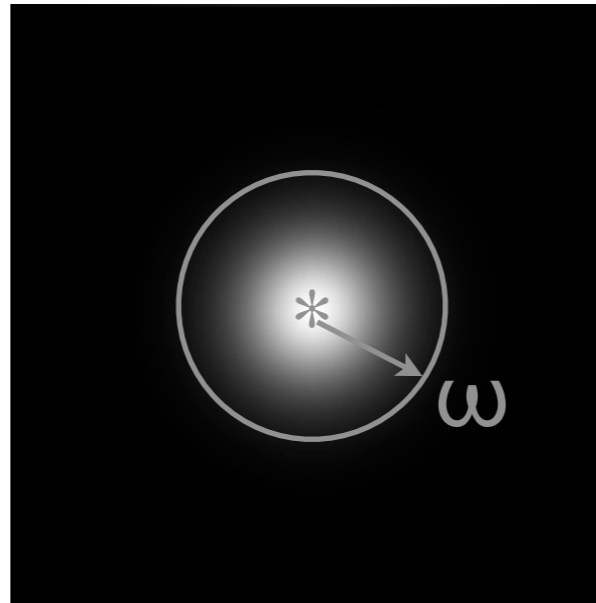
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- The shape of the infrared GLAO PSF is highly variable, and sometimes has a small core with a broad halo...
- Radius of 50% encircled energy (EE50) and...

Another figure of merit

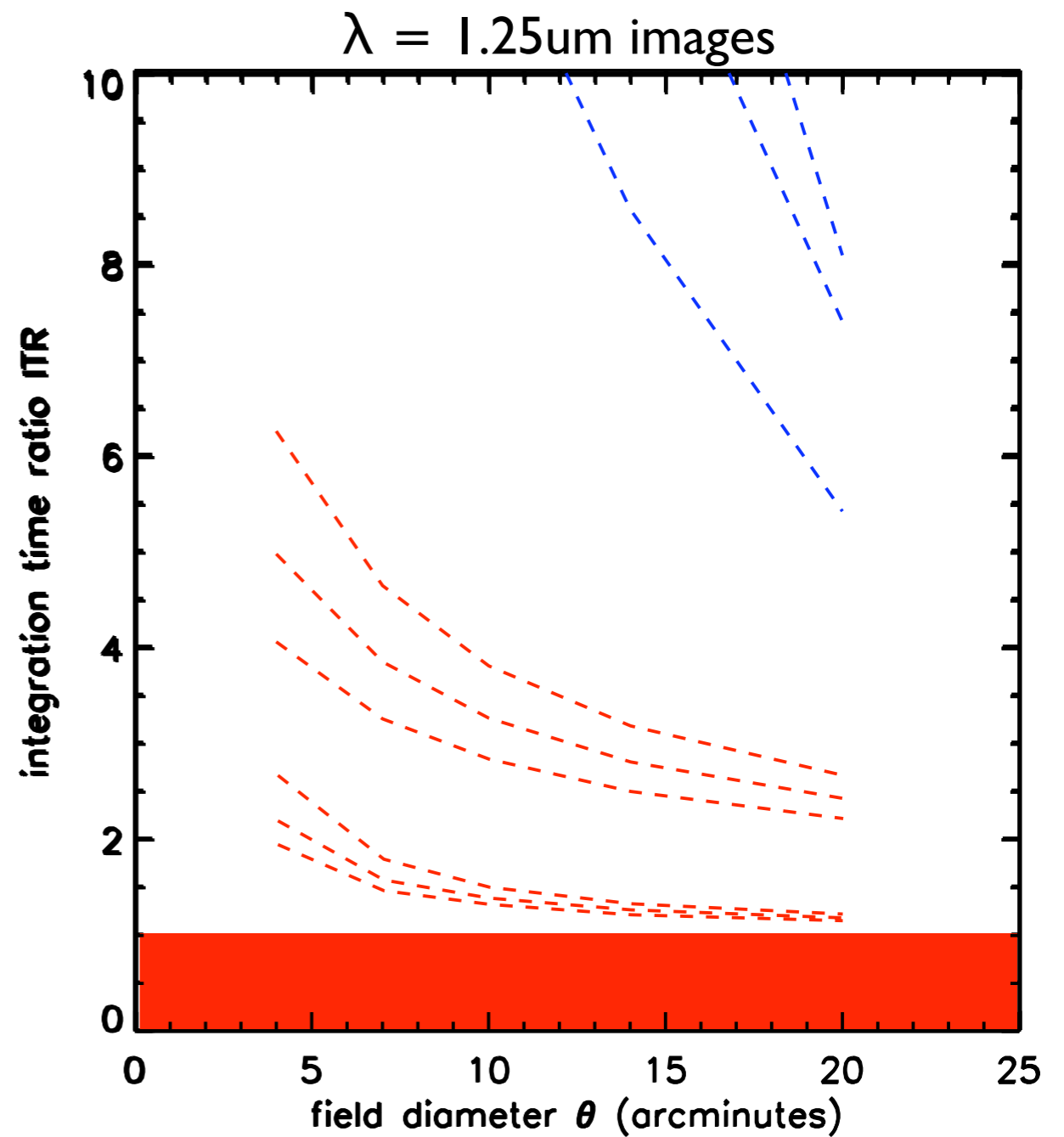
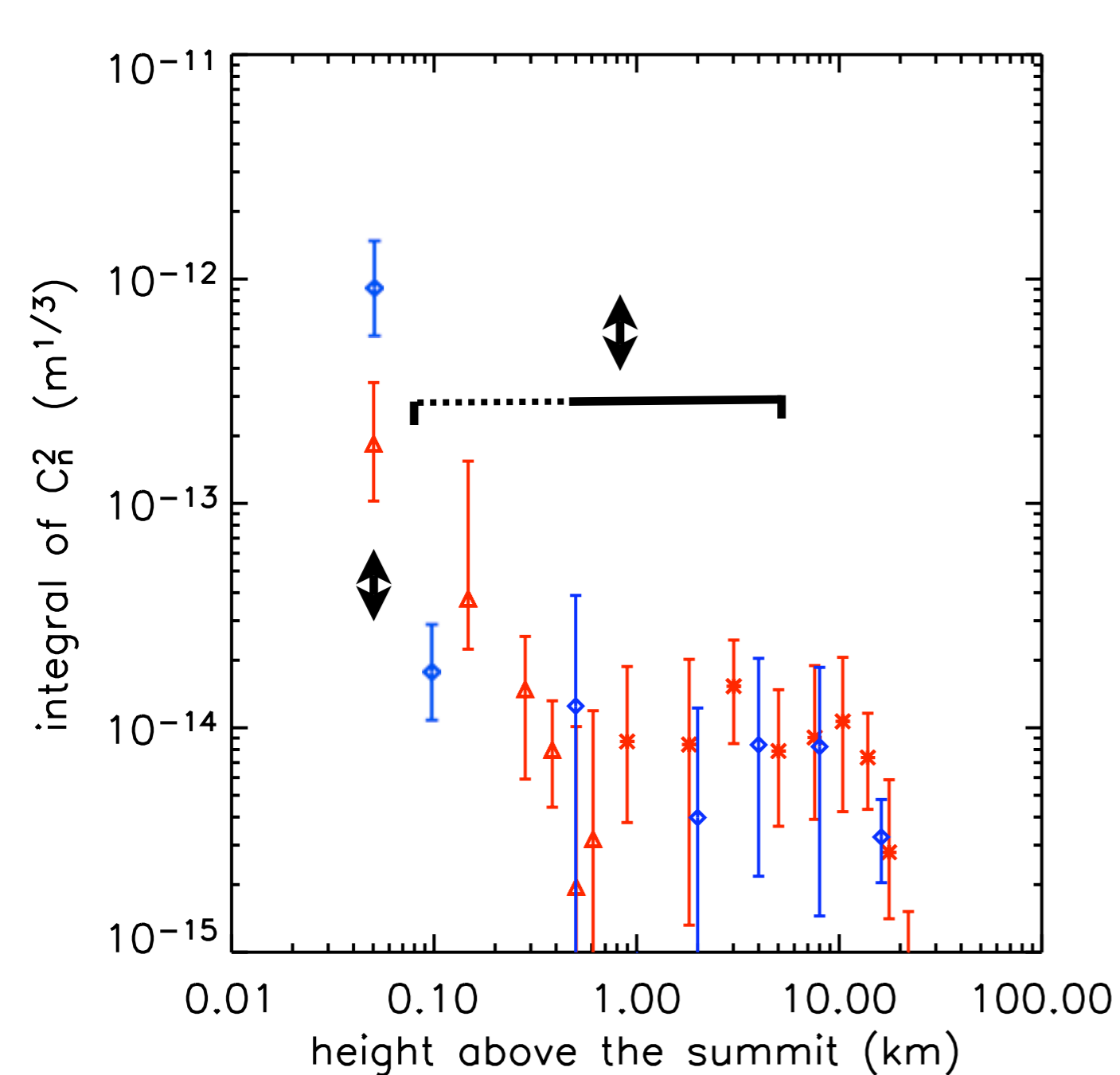
- FWHM \Leftarrow It tells us the resolving power
- Radius of 50% encircled energy (EE50) \Leftarrow Indicates how concentrated the image and more closely relates to the integration time.



- Integration time ratio (ITR) \Leftarrow For background-limited photometry to some signal to noise ratio.

The sky area of the field of view divided by the integration time can indicate the survey efficiency.

The ITR from +/-50% Gray-zone turbulence



Summary

- What will the PSF look like for $4 < \theta < 20$ using a meaningful figure of merit?
 - ⇒ The radius of 50% encircled energy of the PSF will be quasi-uniform across the field. The value squared and averaged in a field is related to integration time.
- What does the uncertainty in $C_n^2(h)$ imply for wide field astronomy?
 - ⇒ At **Mt. Graham** (and other mid-latitude sites) an underestimate of 50% in the C_n^2 of the Gray-Zone turbulence implies marginal Ground-Layer correction on fields greater than 10 arcminutes at J-band.
- New questions:
 - What are the important aspects of modelling marginal Ground-Layer correction?
 - What interesting information is lost when we statistically reduce the monitored C_n^2 profile set before we statistically reduce the PSFs?

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