4MOST – 4m Multi-Object Spectroscopic Telescope

ETC algorithms and assumptions

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The ETC

- Provides the user with some idea of how long the exposure times would be
- Assumptions based on the Top Of the Atmosphere to Detector (TOAD) instrument simulation software.

The survey nature of 4MOST implies that…

- User cannot choose specific sky conditions
- User cannot choose airmass
- User cannot choose seeing
- User cannot choose time of observations
- User cannot choose sky positions

Can the user choose anything at all?

- User must choose targets ☺
- User must provide required S/N

Some key 4MOST features

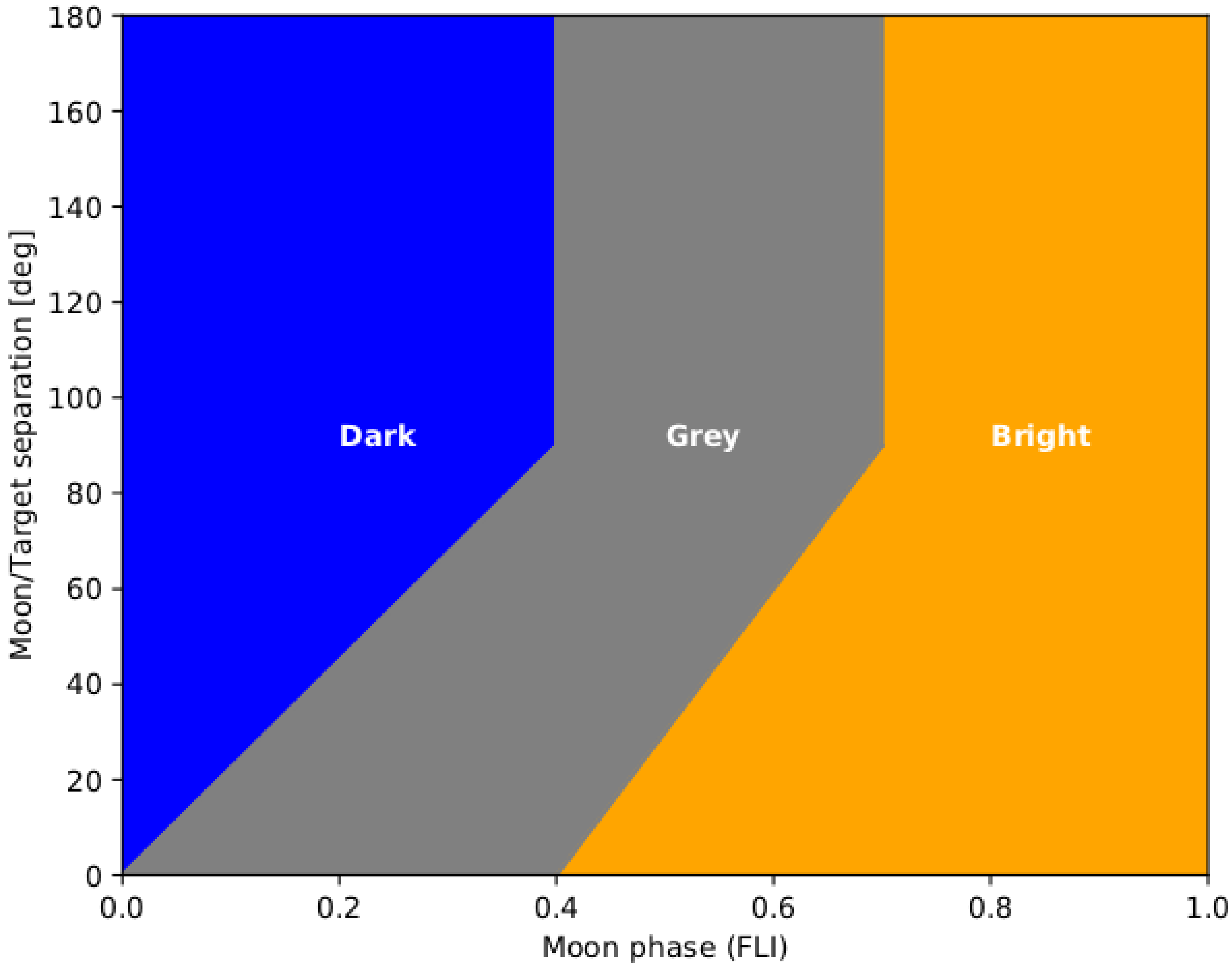
- FoV 4.2 deg^2
- Minimum distance between fibers: 15 arcsec
- 2436 fibers (LRS 2x812; HRS 812)
- LRS 370 – 950 nm
- HRS 392 – 435 nm; 516 – 573 nm; 610 – 679 nm

ETC assumptions:

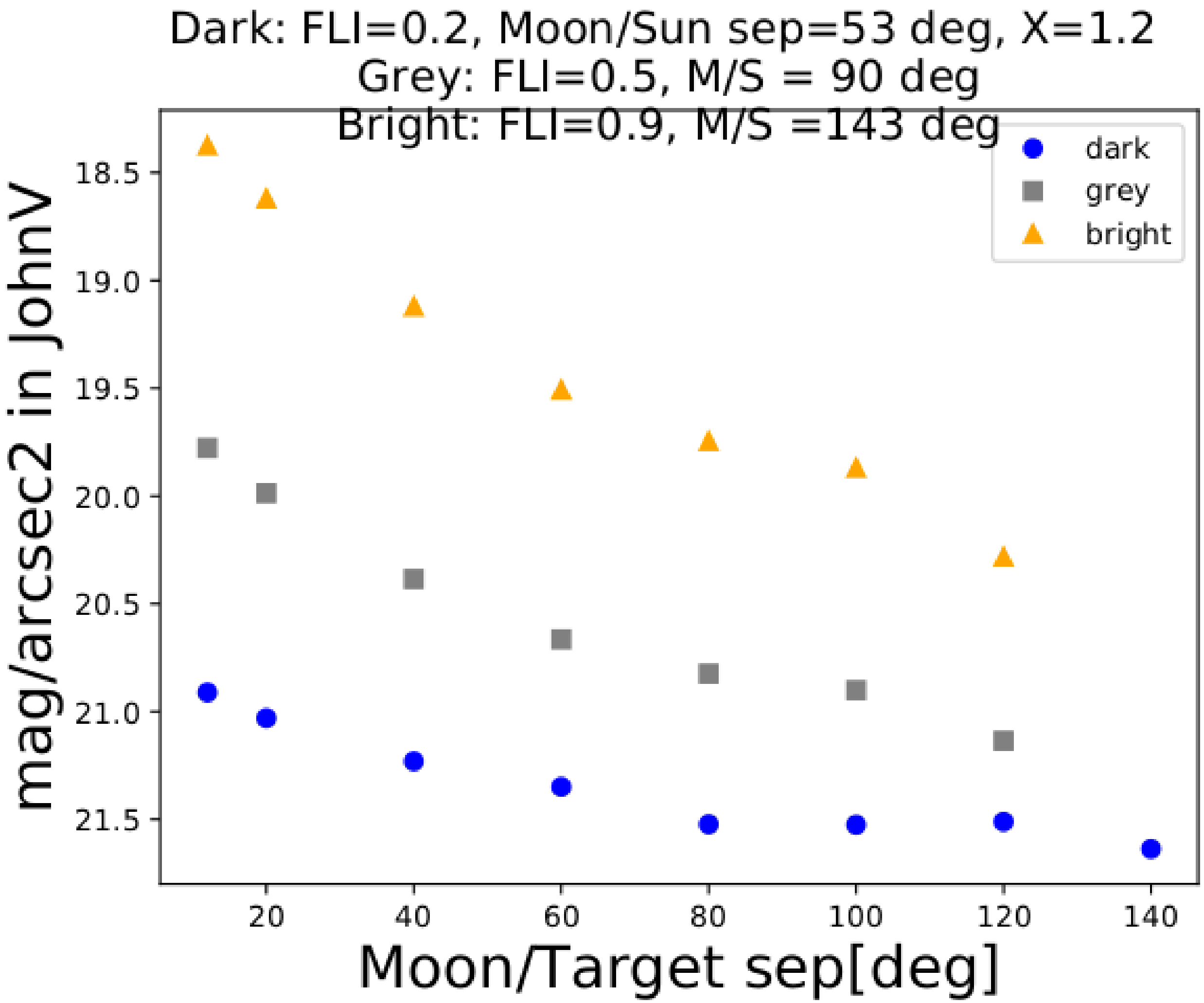
- 4MOST key features – ETC must use some representative fiber properties
- User cannot choose observing conditions – ETC must use typical observing conditions

The ETC uses time-averaged fiber-averaged properties

Representative Sky



Representative Sky



Representative Sky

- ESO’s SkyCalc models
- Default SkyCalc parameters
  - Moon/target separation 60 deg
  - Moon/Sun separation (53; 90;143 deg)
  - Moon altitude 45 deg
  - 350 – 1000 nm at fixed spectral resolution of 100 000

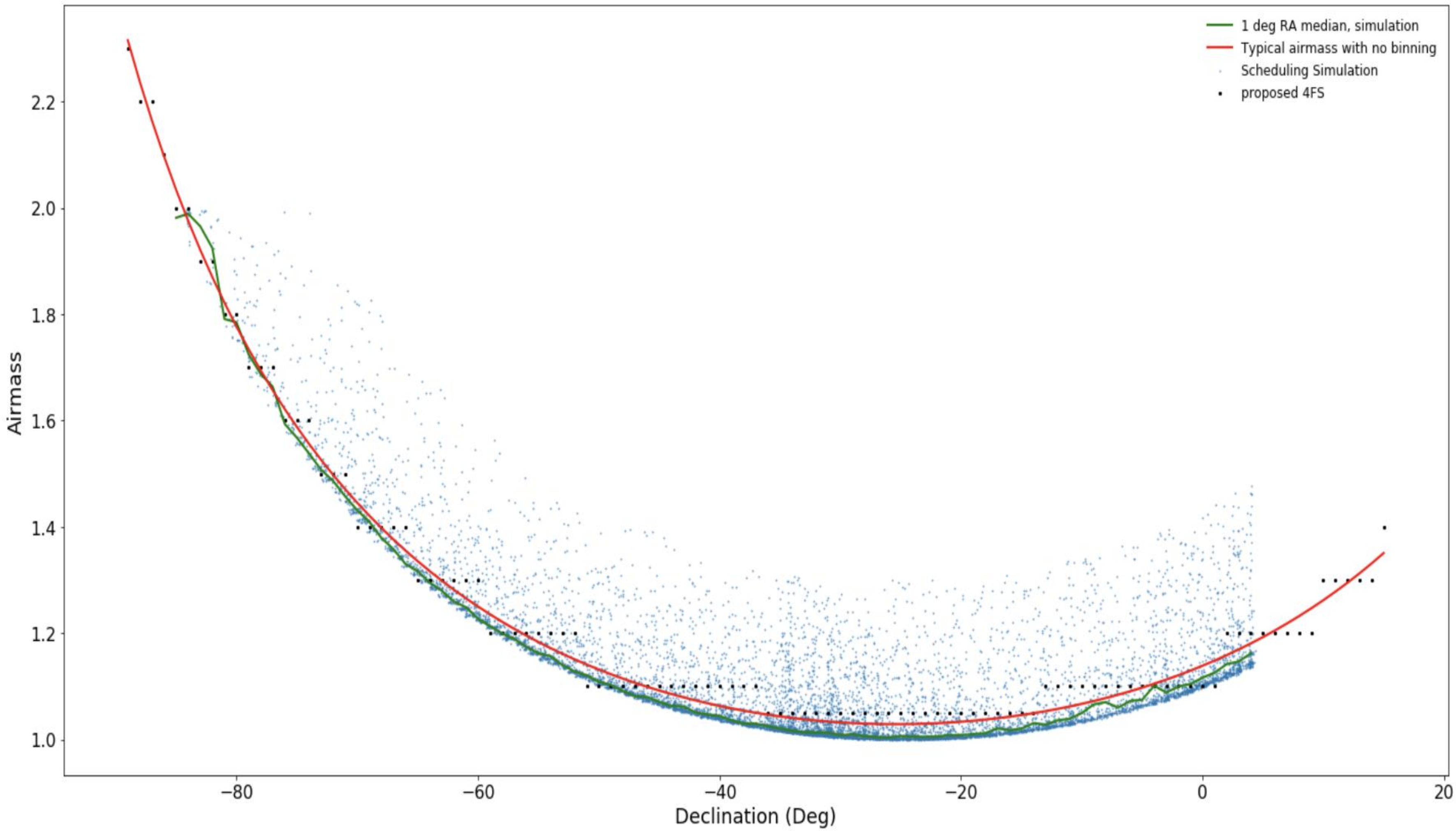
Representative Airmass:

- User provides target coordinates
- ETC converts DEC to representative airmass:
  - ±15 degrees away from the meridian, i.e. Hour Angle =1h. → target altitude a
  - AM = $\left\{\frac{1}{\cos(a)}\right\}$
  - Circumpolar targets (DEC ≤ -79.6) at AM≥ 1.74 (ZD ~55 deg) → limit of the ADC

Airmass + Sky

- Airmass bins [1.05, 1.1, …,2.0]
- Each bin – Dark, Grey, Bright sky

Airmass + Sky



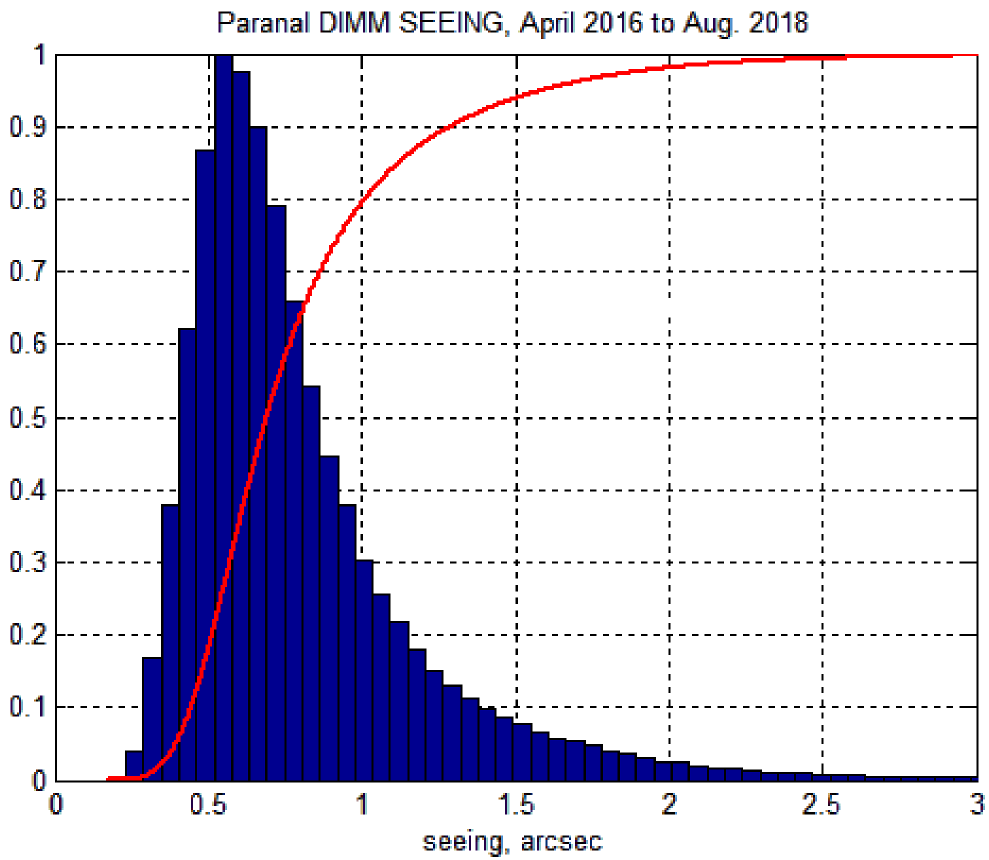
1 deg RA median, simulation
Typical airmass with no binning
Scheduling Simulation
proposed 4FS
Airmass
2.2
2.0
1.8
1.6
1.4
1.2
1.0
−80
−60
−40
−20
0
20
Declination (Deg)

Airmass + Seeing

- Reference seeing values are scaled with airmass and wavelength:
- $S(X) = \sqrt{\left(S_{ref} \cdot \left(\frac{X}{X_{ref}}\right)^{0,6}\right)^2 + S_{Vista}^2}$
- $S(\lambda) = S_{ref} \cdot \lambda^{-0.2}$

Reference Seeing

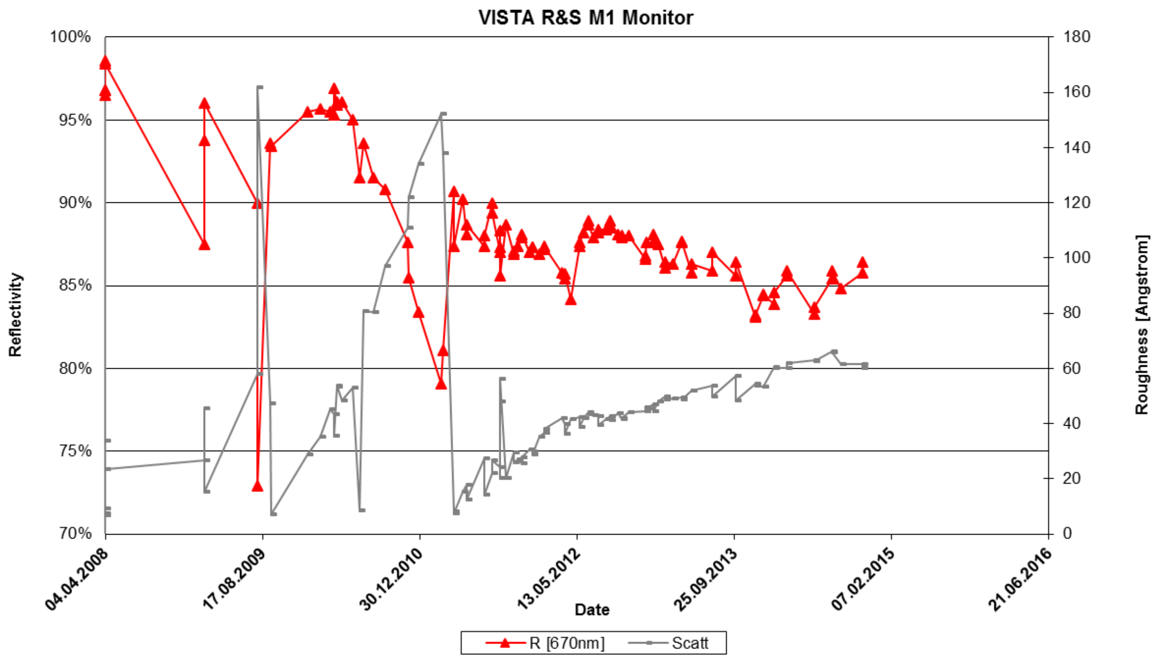
- Reference seeing = 0.8 arcsec



Based on old statistics of DIMM June 2014- Sept 2017.
New statistics show smaller Median seeing of 0.7 arcsec.
ETC uses a slightly pessimistic Value of 0.8 arcsec.

Mirror reflectivity

- A function of wavelength and time
- ETC assumes 86% reflectivity (as a function of λ)

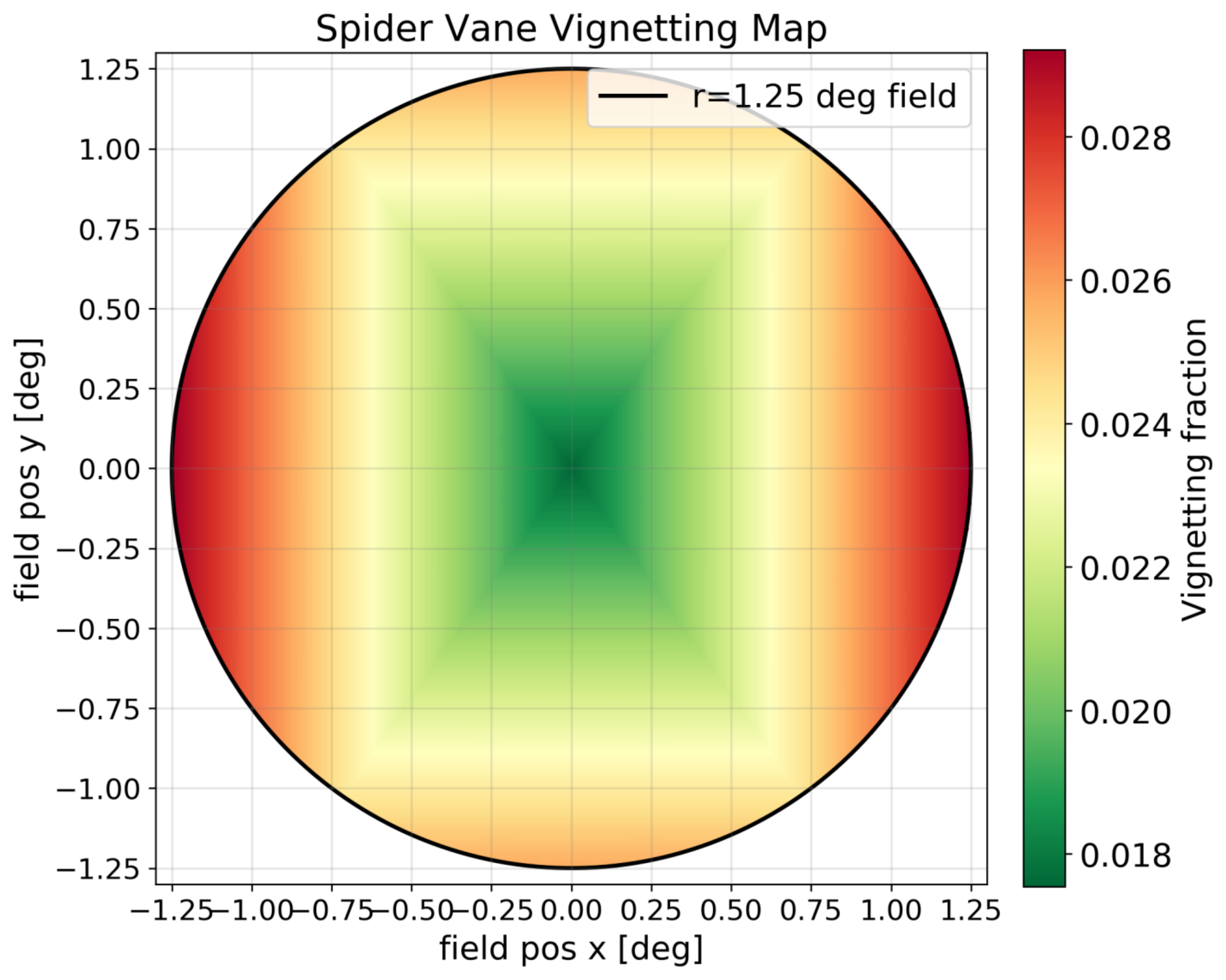


Telescope vignetting

- TOAD model contains vignetting due to
  - Central obstruction
  - Spider vanes of the M2 holding cell
  - The M2 mirror is undersized
  - The Wide field corrector optics
  - The atmospheric dispersion compensator

- ETC uses field centre.

Telescope vignetting



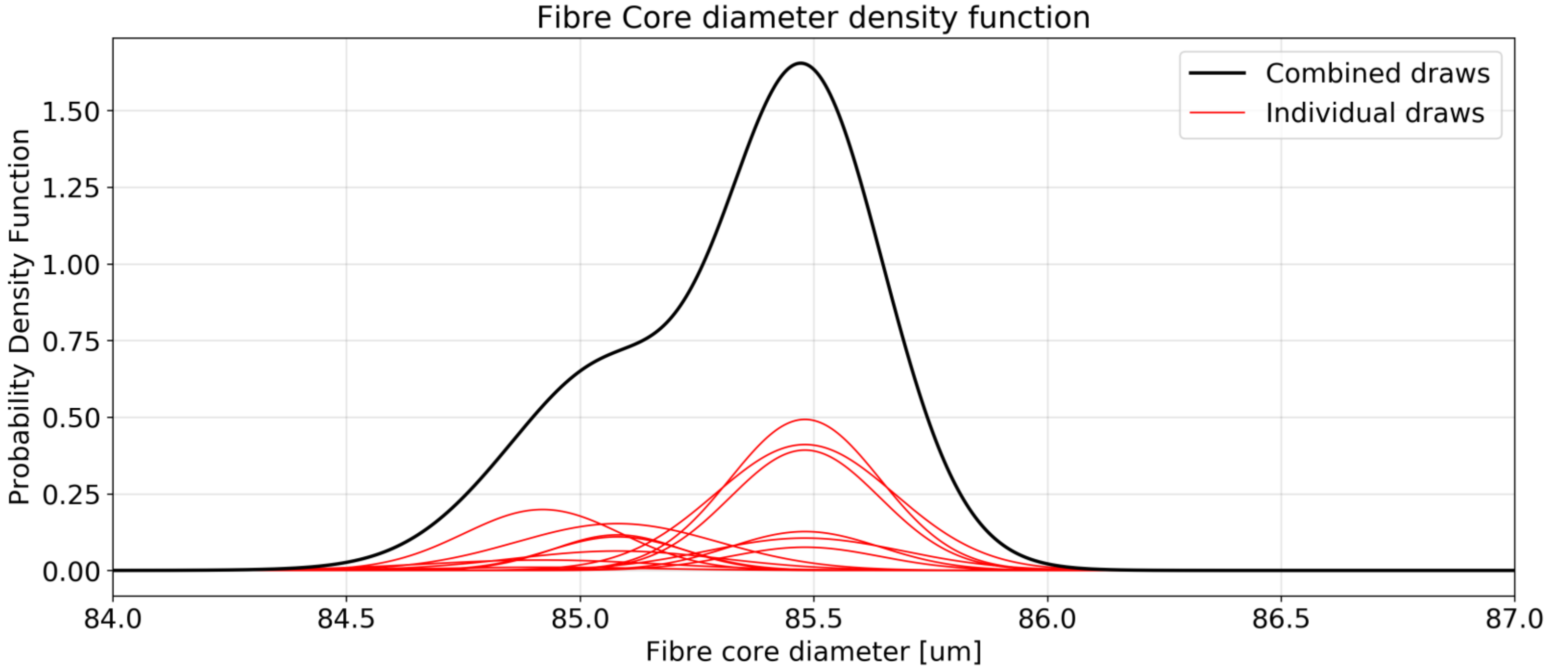
Light loss as a function of field position

2-3% of the flux lost to vignetting

1% loss (ETC)

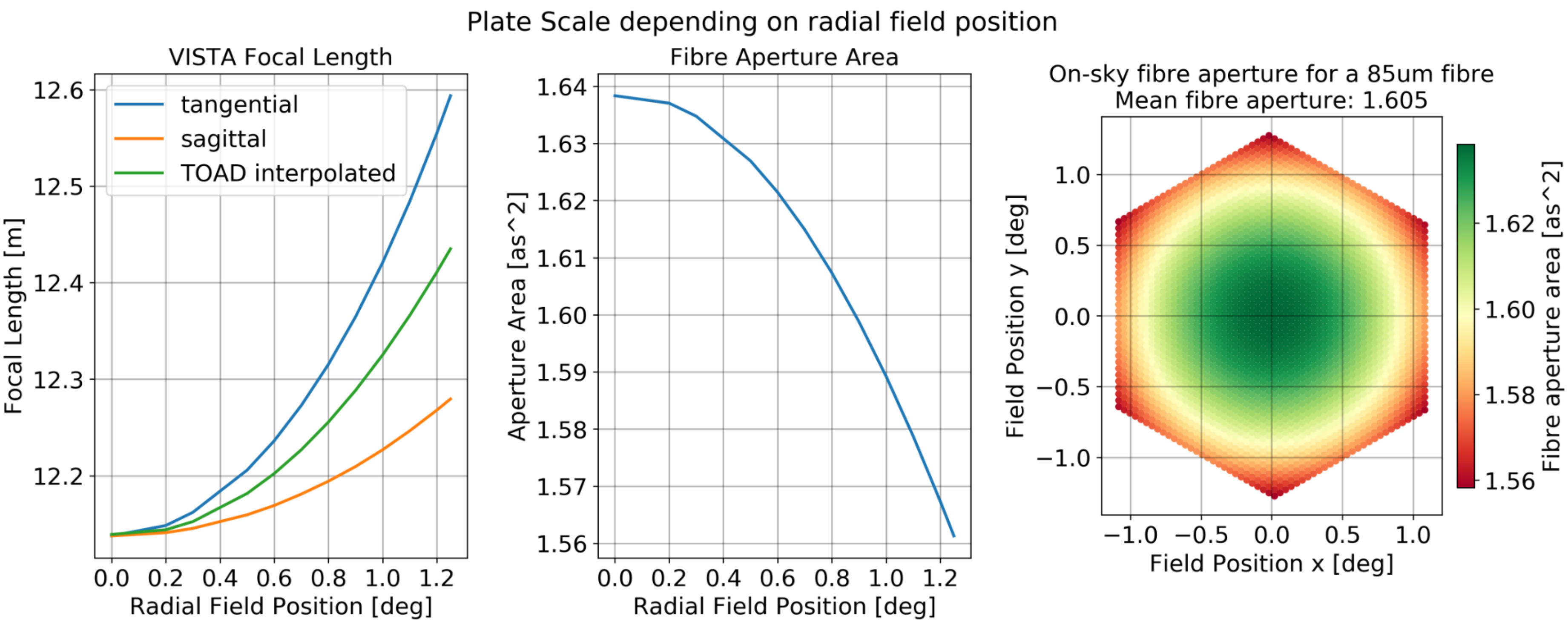
Telescope PSF and fiber size

- ETC uses telescope PSF at field center (function of λ)
- ETC uses a fixed fibre core diameter of 85μm



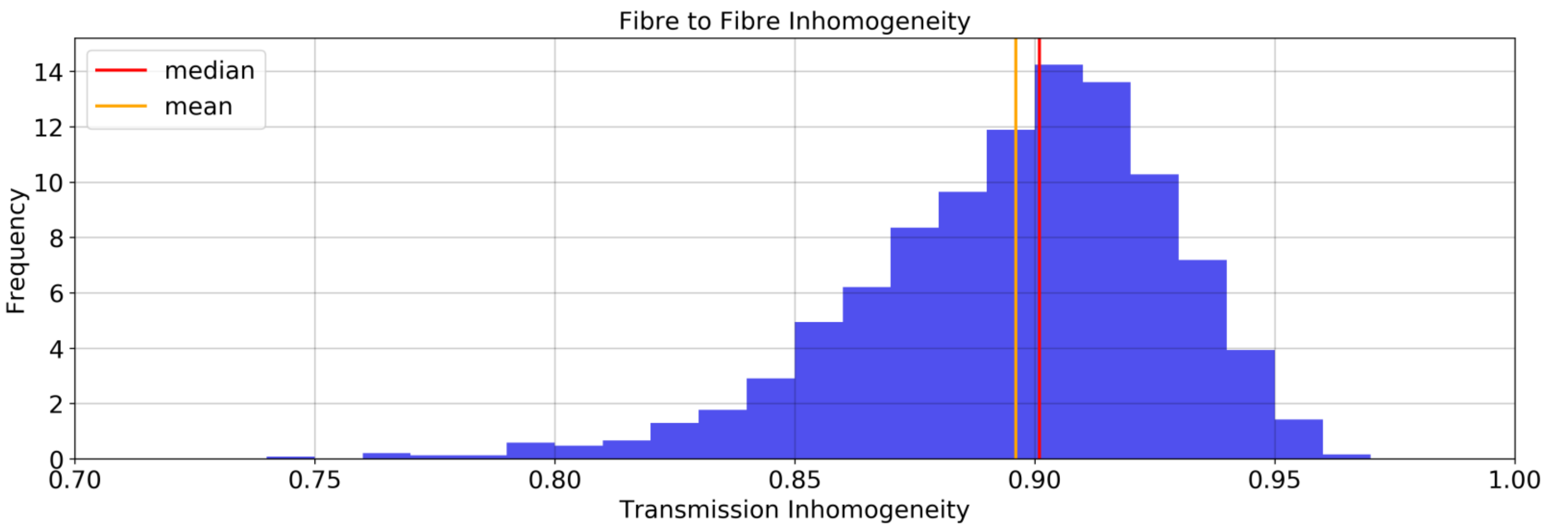
Fiber aperture size on sky

- Is a function of field position for fixed fiber core size
- 1.56’’2 – 1.63’’2 ; ETC – 1.605 ’’2



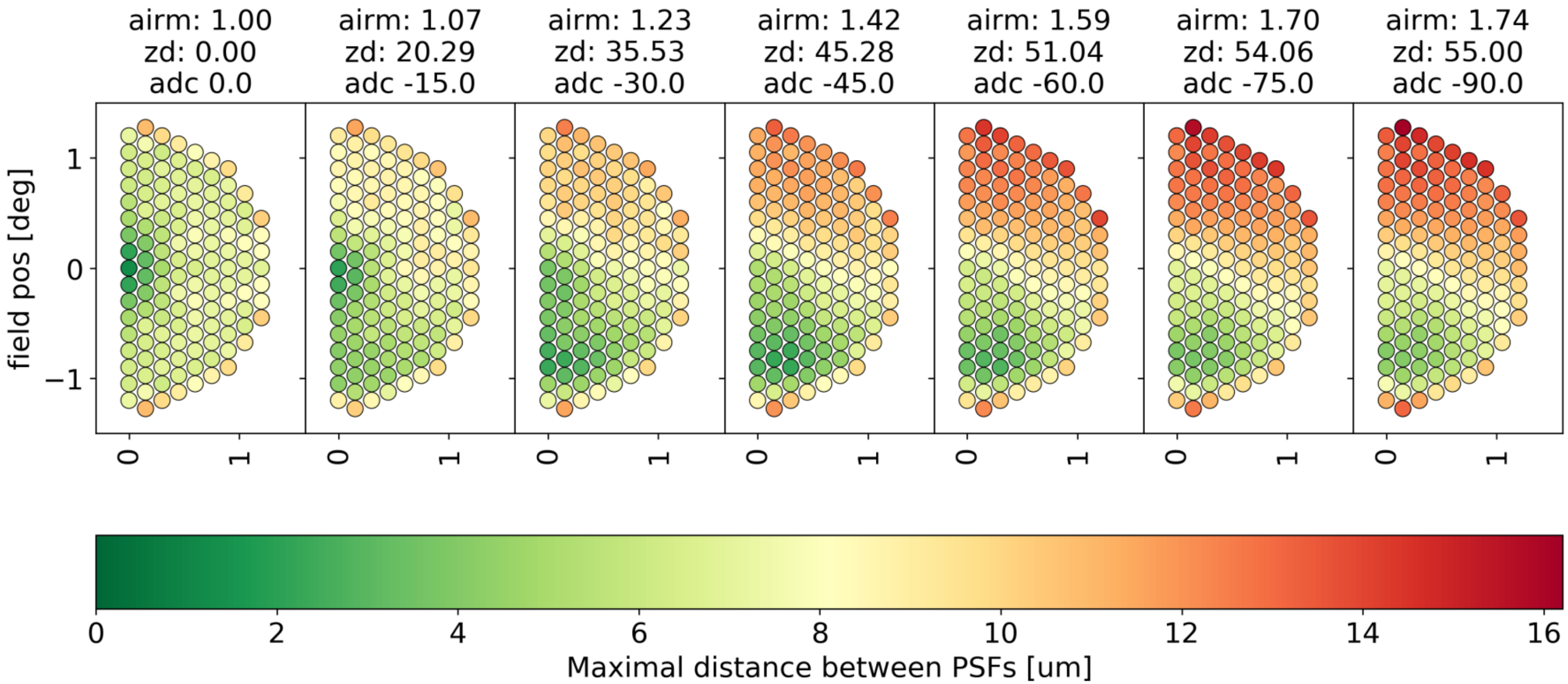
Intrinsic fiber transmission efficiency

- Relatively stable for each fiber
- ETC uses the mean fibre transmission efficiency of 0.895



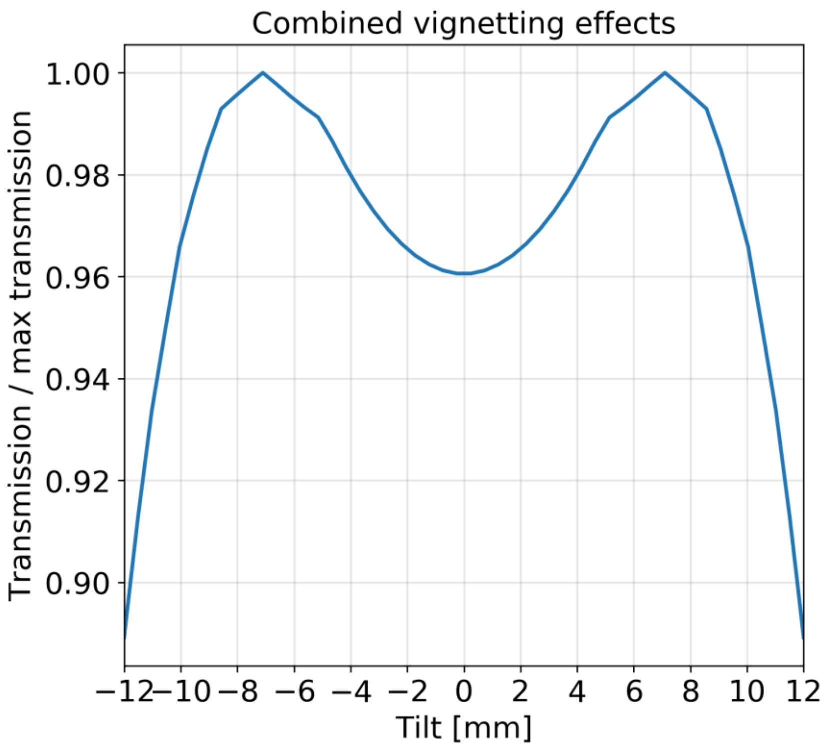
Residual atmospheric dispersion

- Residual between 0'' (field center, zenith) and 0.25'' (field edge, ZD = 55 deg)
- ETC takes (field center, zenith)



Fiber tilt-induced vignetting losses

- 2 effects:
  - Fiber entrance: focus shift, changes the PSF seen by the fiber
  - Fiber output: broadening of the light beam, which is then vignetted by the spectrographs
- ETC assumes a non-tilted fiber
  - Minimum losses due to the broadening of the beam
  - But Non-optimal due to slight de-focus



Detector characteristics

- Detectors have 4 quadrants, each with a RON, DC, Gain.
- ETC uses the mean of all quadrants for all 3.
  - E.g. DC = 2.288 e-/h
  - E.g. RON = 2.5 e-
  - E.g. Gain = 1.06875 e-/ADU

Charge transfer efficiency

- ETC uses position close to center of slit (~0.99)

Other effects/assumptions

- Fiber-to-target alignment accuracy of 0.1'' (between fiber center and target position).
- ETC uses a single Focal Ratio Degradation model (based on lab measurements).
- Spectrograph image quality
- Material transmission efficiency

S/N calculation

- On-detector binning only in dispersion direction
- No binning in cross-dispersion direction – (pipeline limitations)
- Per-pixel S/N converted to per-Å S/N using:
  - $SNR_{spec} = \sqrt{N_{pix}} \cdot SNR_{pixel}$

N_{pix}(λ, LRS/HRS, red/green/blue) = # pixels that make up 1 Å

Reddening

- ETC does not apply any reddening internally
- User templates must have reddening applied already!

Magnitudes

- User provides total Pogson magnitudes of target
- AB or Vega
- Available filters (next slide)
- ETC internally calculates the magnitude inside the aperture of the fiber

Filters

- GAIA DR2r: G_{BP}, G_{RP}, G
- DECam (CTIO): g,r,i,z
- VISTA: Z, Y, J, H, Ks
- Standard filters:
  - Bessel U
  - Johnson B,V
  - Cousins R,I
- All filter transmission is photon-counting curves!

Target Shape

- Point source - ETC assumes Moffat with $\beta=2.5$
- Extended source - ETC assumes Sersic profile, user provides R_{eff} and n

SED shape: Templates

- ESO standard templates:
  - MARCS
  - Kinney- Calzetti
  - HII region
  - Kuruzc
  - Pickles
  - QSO
  - PNe
- User-defined spectrum

Templates

Target model could be a power law spectrum:

- $F(\lambda) = F_0 * \left(\frac{\lambda}{\lambda_c}\right)^p$

where

λ – wavelength

F_0 – continuum flux level @ λ_c

p – powerlaw index

- $F_0 = 10^{-(0.4 * M_{obs} + ZP)}$

Where

M_{obs} – apparent magnitude

ZP – zero point of the observing band

Scaling of Input Source Templates

- User provides total magnitude $m_{Vega}(k)$ (or AB)
- Filter *k* (with transmission T_λ)
- Source template F^{temp}
- $F_k^{temp} = \frac{\int \lambda * T_\lambda F^{temp} d\lambda}{\int \lambda * T_\lambda d\lambda}$
- $f = 10^{-0.4(m_{Vega}(k) - 2.5 \log_{10} ZP_k^{Vega})}$
- Scaling factor $\xi = \frac{f}{F_k^{temp}}$
- $F_k^{scaled} = \xi F^{temp}$

Take-away message

- The ETC takes a number of shortcuts
- The virtual fiber used in the ETC does not exist
- But averaged over the survey lifetime, the ETC predictions will give correct results!

Thank you very much for your attention!