MUSE ETC

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version 1.0 11-05-03
Inspired from Simon Morris mathcad and Ian Parry excel ETC

version 2.0 8-06-03 Take sky value (no OH) from Hanushik paper
add variation of ensquared energy with wavelength, use updated version 1.1 of throughput

version 3.0 02-10-03
Refurbish and simplify the presentation
updated version 2.1 of throughput
include also bad seeing conditions for AO performances and add effect of MUSE IQE on all PSFs
Problem found: we seems to be pessimistic about sky brignthness in the blue wrt to ESO ETC

version 3.1 09-10-03
Change z = 0.95 µm and B=0.44 µm traditional wavelength to the red and blue limits of MUSE (respectively 0.93 µm and 0.465 µm)

version 3.2 11-11-03
Add computation of accuracy needed in sky subtraction

version 3.3 1-12-03
Updated version 20/11/03 of throughput with VLT adaptative secondary AO system, typical curve. Added computation of surface line emission sensitivity.

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1. Units and Constant

Velocity of light in vacuum $c := 299792458 \cdot m \cdot s^{-1}$

Angstroem $A := 10^{-10} \cdot m$ microns $\mu m := 10^{-6} \cdot m$

Planck's constant (h) $hr := 6.6260755 \cdot 10^{-34} \cdot joule \cdot sec$

$phot := 1$ $arcsec := \frac{deg}{3600}$ $arcmin := \frac{deg}{60}$

$elec := 1$ $hour := 3600 \cdot s$

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2. Define a few useful functions

$$Mean(f,a,b) := \frac{\int_a^b f(x)\,dx}{b-a}$$

$$GAUSS(r,\sigma) := \frac{\exp\left(\frac{-r^2}{2 \cdot \sigma^2}\right)}{\sqrt{2 \cdot \pi} \cdot \sigma} \qquad E_{GAUSS}(a,\sigma) := \int_{-\frac{a}{2}}^{\frac{a}{2}} GAUSS(x,\sigma)\,dx$$

$$FWHM_{GAUSS}(\sigma) := 2\sqrt{2 \cdot \ln(2)} \cdot \sigma$$

$$\sigma_{GAUSS}(FWHM) := \frac{FWHM}{\left(2\sqrt{2 \cdot \ln(2)}\right)}$$

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3. Photometric System

3.1 UBVRIz System

Bessel, 1979, PASP 91, 589

$$\lambda_b := \begin{pmatrix} 0.36 \\ 0.44 \\ 0.55 \\ 0.64 \\ 0.79 \\ 0.95 \\ 1.25 \\ 1.65 \\ 2.2 \\ 3.5 \\ 4.8 \end{pmatrix} \cdot \mu m \qquad val\_Z_b := \begin{pmatrix} 7.3788 \\ 7.1804 \\ 7.4425 \\ 7.6408 \\ 7.9115 \\ 8.1101 \\ 8.4989 \\ 8.9706 \\ 9.4367 \\ 10.2649 \\ 10.2692 \end{pmatrix}$$

Magnitude central wavelengths and zero points from ESO web site http://www.eso.org/observing/etc/doc/g-en/formulaBook/node12.html

Central wavelengths to be used

Useful reference wavelength for MUSE

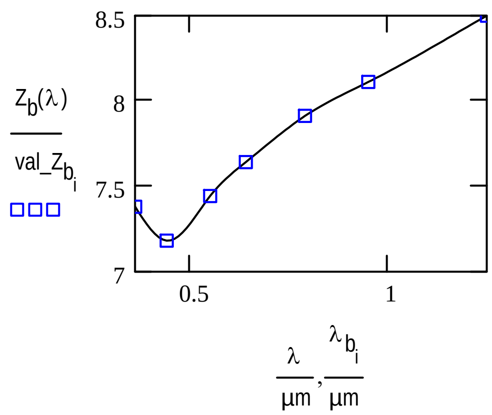
$\lambda_B := 0.465 \cdot \mu m \qquad \lambda_V := \lambda_{b_2} \qquad \lambda_R := \lambda_{b_3} \qquad \lambda_I := \lambda_{b_4} \qquad \lambda_z := 0.93 \cdot \mu m$

$$\lambda_{MUSE} := \begin{pmatrix} \lambda_B \\ \lambda_V \\ \lambda_R \\ \lambda_I \\ \lambda_z \end{pmatrix} \qquad Band_{MUSE} := \begin{pmatrix} "B" \\ "V" \\ "R" \\ "I" \\ "z" \end{pmatrix}$$

Note that B and z wavelength are set to the limit of MUSE wavelength range

$spline\_Z_b := lspline(\lambda_b, val\_Z_b) \qquad \lambda := 0.36 \cdot \mu m, 0.36 \cdot \mu m + 0.01 \cdot \mu m .. 1.25 \cdot \mu m$

$Z_b(\lambda) := interp(spline\_Z_b, \lambda_b, val\_Z_b, \lambda) \qquad i := 0..6$



Function to transform magnitude in flux

$$\mathrm{Mag2Flux}(mag,\lambda) := 10^{-0.4\cdot mag - Z_b(\lambda)}\cdot W\cdot m^{-2}\cdot \mu m^{-1}$$

$$\mathrm{SurfMag2Flux}(mag,\lambda) := 10^{-0.4\cdot mag - Z_b(\lambda)}\cdot W\cdot m^{-2}\cdot \mu m^{-1}\cdot arcsec^{-2}$$

$$\mathrm{Flux2Mag}(F,\lambda) := -2.5\cdot\left[\log\left[\frac{F}{\left(W\cdot m^{-2}\cdot \mu m^{-1}\right)}\right] + Z_b(\lambda)\right]$$

$$\mathrm{Flux2MagSurf}(F,\lambda) := \mathrm{Flux2Mag}(F,\lambda) - 2.5\cdot\log\left[(arcsec)^2\right]$$

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3.2 AB magnitude system

$$\mathrm{Flux2AB}\left(F_\lambda,\lambda\right) := -2.5\cdot\log\left[\frac{F_\lambda\cdot\lambda^2}{c\cdot\left(erg\cdot cm^{-2}\cdot sec^{-1}\cdot Hz^{-1}\right)}\right] - 48.60$$

$$\mathrm{AB2Flux}(AB,\lambda) := \frac{10^{-0.4\cdot(AB+48.60)}}{\lambda^2}\cdot c\cdot erg\cdot cm^{-2}\cdot s^{-1}\cdot Hz^{-1}$$

$$\mathrm{Flux2ABSurf}\left(F_\lambda,\lambda\right) := -2.5\cdot\log\left[\frac{F_\lambda\cdot\lambda^2}{c\cdot\left(erg\cdot cm^{-2}\cdot sec^{-1}\cdot Hz^{-1}\cdot arcsec^{-2}\right)}\right] - 48.60$$

$$\mathrm{SurfAB2Flux}(AB,\lambda) := \frac{10^{-0.4\cdot(AB+48.60)}}{\lambda^2}\cdot c\cdot erg\cdot cm^{-2}\cdot s^{-1}\cdot Hz^{-1}\cdot arcsec^{-2}$$

Test $\mathrm{Flux2AB}\left(\mathrm{Mag2Flux}\left(25,\lambda_R\right),\lambda_R\right) = 25.163$

$\mathrm{SurfAB2Flux}\left(25,\lambda_R\right) = 2.657\times10^{-19}\,erg\cdot cm^{-2}\cdot s^{-1}\cdot A^{-1}\cdot arcsec^{-2}$

$\mathrm{AB2Flux}\left(25,\lambda_R\right) = 2.657\times10^{-19}\,erg\cdot cm^{-2}\cdot s^{-1}\cdot A^{-1}$

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4. Sky brightness

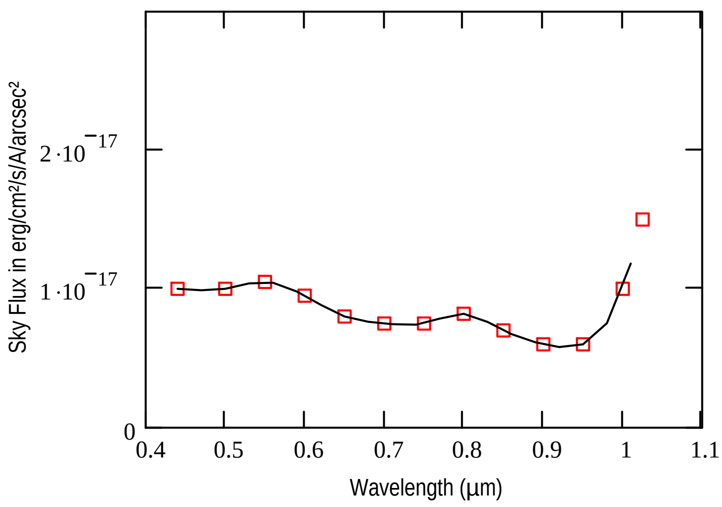
Sky brightness is taken from the Hanuschik paper, it doesnt include the OH lines

$$\lambda_{Sky} := \begin{pmatrix} 0.44 \\ 0.5 \\ 0.55 \\ 0.6 \\ 0.65 \\ 0.7 \\ 0.75 \\ 0.8 \\ 0.85 \\ 0.9 \\ 0.95 \\ 1.0 \\ 1.025 \end{pmatrix} \cdot \mu m \qquad TabFlux_{SkyNoOH} := \begin{pmatrix} 0.1 \\ 0.1 \\ 0.105 \\ 0.095 \\ 0.08 \\ 0.075 \\ 0.075 \\ 0.082 \\ 0.07 \\ 0.06 \\ 0.06 \\ 0.1 \\ 0.15 \end{pmatrix} \cdot 10^{-16} \cdot erg \cdot s^{-1} \cdot cm^{-2} \cdot A^{-1} \cdot arcsec^{-2}$$

$$Spline\_Flux_{SkyNoOH} := lspline\left(\lambda_{Sky}, TabFlux_{SkyNoOH}\right)$$

$$Flux_{SkyNoOH}(\lambda) := interp\left(Spline\_Flux_{SkyNoOH}, \lambda_{Sky}, TabFlux_{SkyNoOH}, \lambda\right)$$

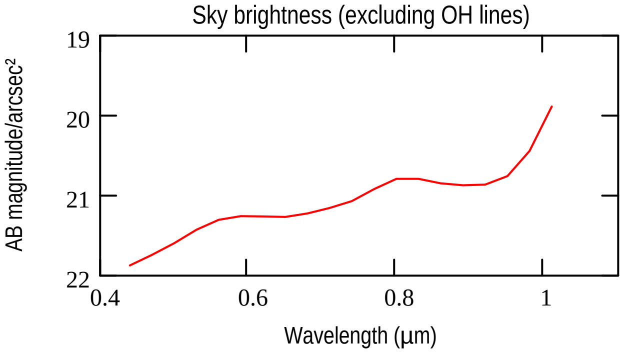
$$\lambda := 0.44 \cdot \mu m, 0.47 \cdot \mu m .. 1.025 \cdot \mu m$$



Checking

$\text{Flux2ABSurf}\left(\text{Flux}_{\text{SkyNoOH}}(\lambda_B), \lambda_B\right) = 21.766$	ESO ETC value 22.7
$\text{Flux2ABSurf}\left(\text{Flux}_{\text{SkyNoOH}}(\lambda_V), \lambda_V\right) = 21.337$	ESO ETC value 21.8
$\text{Flux2MagSurf}\left(\text{Flux}_{\text{SkyNoOH}}(\lambda_R), \lambda_R\right) = 21.109$	ESO ETC value 20.9
$\text{Flux2MagSurf}\left(\text{Flux}_{\text{SkyNoOH}}(\lambda_I), \lambda_I\right) = 20.441$	ESO ETC value 19.9
$\text{Flux2MagSurf}\left(\text{Flux}_{\text{SkyNoOH}}(\lambda_z), \lambda_z\right) = 20.378$	ESO ETC value 18.8

Note the difference in the red is fully explained by the OH suppression. There is also a large difference in the blue ... unexplained at the moment ... TBC



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5. Atmospheric extinction

tab_extinct :=

	0	1
0	440	0.26
1	450	0.25
2	460	0.22
3	470	0.21
4	480	0.21
5	490	0.18
6	500	0.17
7	520	0.16
8	540	0.14
9	560	0.13

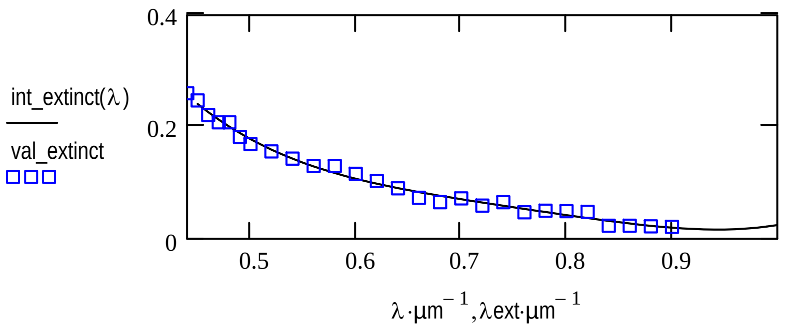
Reference: Paranal extinction - ESO VIMOS ETC

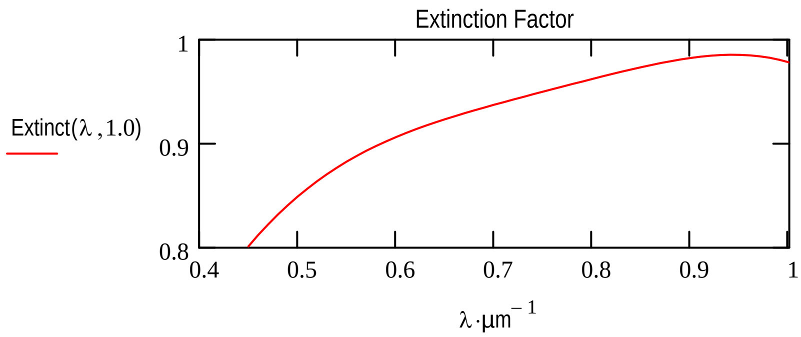
$\lambda ext := \left(10^{-3} \cdot \mu m \cdot tab\_extinct\right)^{\langle 0 \rangle}$ $val\_extinct := tab\_extinct^{\langle 1 \rangle}$

$pol\_extinct := regress\left(\frac{\lambda ext}{\mu m}, val\_extinct, 4\right)$

$int\_extinct(\lambda) := interp\left(pol\_extinct, \frac{\lambda ext}{\mu m}, val\_extinct, \frac{\lambda}{\mu m}\right)$

$Extinct(\lambda, Airmass) := 10^{-0.4 \cdot int\_extinct(\lambda) \cdot Airmass}$ $\lambda := 0.45 \cdot \mu m, 0.46 \cdot \mu m .. 1 \cdot \mu m$





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6. Telescope Effective Area

$Area_{VLT} := 485425.1 \cdot cm^2$ From ESO UVES ETC

Note: Useful surface is only $\frac{Area_{VLT}}{\pi \cdot (4 \cdot m)^2} = 0.966$

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7. MUSE throughput

7.1 MUSE throughput of WF mode

table_muse_throughput :=

	0	1
0	0.46	0.0784
1	0.48	0.1217
2	0.5	0.1681
3	0.52	0.2092
4	0.54	0.2452
5	0.56	0.273
6	0.58	0.2923
7	0.585	0.2973
8	0.59	0.3012
9	0.595	0.3046

Total throughput of MUSE, excluding atmosphere, version 20/11/03
Typical curve with Adaptive Secondary

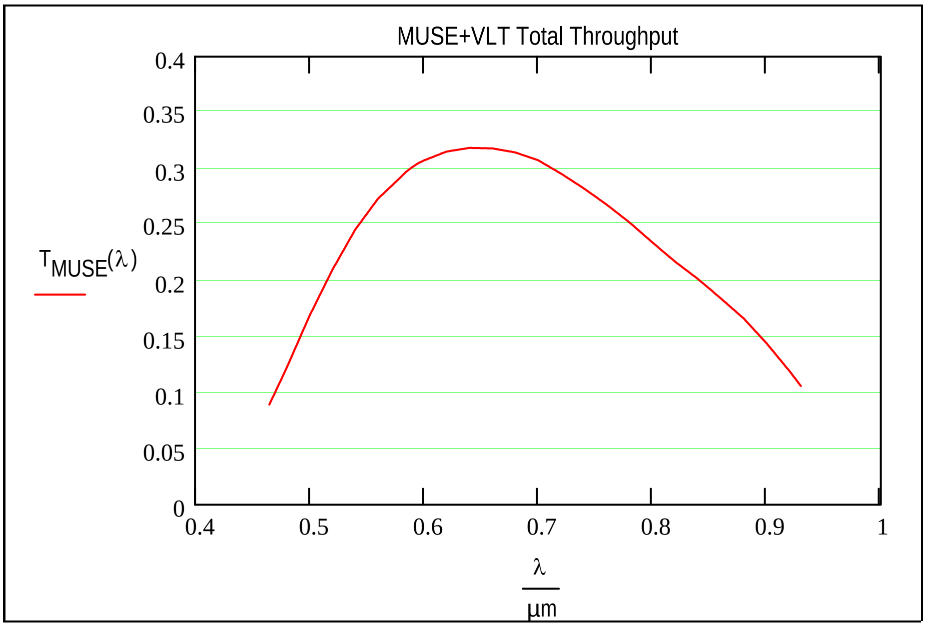
$\lambda\_table := \mu m \cdot table\_muse\_throughput^{\langle 0 \rangle}$

$val\_muse\_throughput := table\_muse\_throughput^{\langle 1 \rangle}$

$T_{MUSE}(\lambda) := linterp(\lambda\_table, val\_muse\_throughput, \lambda)$

$\lambda_{min} := 0.465 \cdot \mu m$ $\lambda_{max} := 0.93 \cdot \mu m$ $Mean(T_{MUSE}, \lambda_{min}, \lambda_{max}) = 0.239$

$\lambda := \lambda_{min}, \lambda_{min} + 0.001 \cdot \mu m .. \lambda_{max}$



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7.2 MUSE throughput of HR mode

8. MUSE CCD characteristics

$DN_{CCD} := 3 \cdot \frac{elec}{hour}$ Dark Current

$RN_{CCD} := 4 \cdot elec$ Readout noise *Note; This is for Fairchild CCD*

$Npix_{CCD} := 4096$

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9. MUSE spatial and spectral configurations

9.1 MUSE wide-field spatial mode

$\Delta_{WFspa} := 0.2 \cdot \text{arcsec}$

9.2 MUSE high spatial resolution mode

$\Delta_{HRspa} := 0.025 \cdot \text{arcsec}$

9.3 MUSE Spectral characteristics

$\lambda_{min} := 0.465 \cdot \mu m$ $\lambda_{max} := 0.93 \cdot \mu m$

$$\Delta_{spec} := \frac{(\lambda_{max} - \lambda_{min})}{Npix_{CCD}} \qquad \Delta_{spec} = 1.135\,A \qquad \lambda := \lambda_{min}, \lambda_{min} + \Delta_{spec} .. \lambda_{max}$$

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10. MUSE Spatial PSF

10.1 MUSE spatial PSF in WF mode

10.1.1 Seeing limited, poor seeing conditions

$TabEEnoao_{poor} :=$

	0	1	2	3	4	5	6
0	0.2	0.0303	0.0332	0.0344	0.0394	0.0421	0.04
1	0.4	0.1087	0.1174	0.1257	0.1345	0.1415	0.1525
2	0.6	0.2251	0.2412	0.2529	0.2724	0.2848	0.2926
3	0.8	0.3566	0.3725	0.3915	0.4109	0.4254	0.4377
4	1	0.4853	0.504	0.5281	0.546	0.5613	0.5764
5	1.2	0.5954	0.6133	0.6376	0.6514	0.6713	0.6795
6	1.4	0.6903	0.7062	0.7244	0.7385	0.7496	0.7576
7	1.6	0.7653	0.7778	0.7904	0.7998	0.8115	0.8187
8	1.8	0.8208	0.8295	0.8394	0.8475	0.8535	0.8593
9	2	0.8644	0.8698	0.8755	0.882	0.8861	0.8907

$i := 0..18$

$j := 1..6$

Note that MUSE IQE is now included in ensquared energy

$EE_i := submatrix(TabEEnoao_{poor}, i, i, 1, 6)^T$

$$\lambda_{EE} := \begin{pmatrix} 0.465 \\ 0.55 \\ 0.65 \\ 0.75 \\ 0.85 \\ 0.93 \end{pmatrix} \cdot \mu m$$

$D_{EE_i} := TabEEnoao_{poor_{i,0}}$

$k := 0..5$

$T_k := cspline(\lambda_{EE}, EE_k)$

$EEnoao_{poor}(\lambda, k) := interp(T_{k-1}, \lambda_{EE}, EE_{k-1}, \lambda)$

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10.1.2 Seeing limited, good seeing conditions

$TabEEnoao_{good} :=$

	0	1	2	3	4	5	6
0	0.2	0.067	0.0732	0.0757	0.0859	0.0913	0.0868
1	0.4	0.2249	0.2409	0.2557	0.2709	0.2824	0.3006
2	0.6	0.422	0.4458	0.4617	0.4879	0.5033	0.5125
3	0.8	0.598	0.6155	0.6351	0.6541	0.6672	0.678
4	1	0.7295	0.7445	0.7627	0.7749	0.7848	0.7944
5	1.2	0.8157	0.8261	0.8397	0.8464	0.8564	0.8598
6	1.4	0.8739	0.8805	0.888	0.8933	0.8972	0.8999
7	1.6	0.9112	0.9149	0.9185	0.921	0.9247	0.9267
8	1.8	0.9348	0.9363	0.9385	0.9403	0.9415	0.943
9	2	0.9516	0.9516	0.9521	0.9533	0.9539	0.9549

$i := 0..18$

$j := 1..6$

Note that MUSE IQE is now included in ensquared energy

$EE_i := submatrix(TabEEnoao_{good}, i, i, 1, 6)^T$

$$\lambda_{EE} := \begin{pmatrix} 0.465 \\ 0.55 \\ 0.65 \\ 0.75 \\ 0.85 \\ 0.93 \end{pmatrix} \cdot \mu m$$

$D_{EE_i} := TabEEnoao_{good_{i,0}}$

$k := 0..5$

$T_k := cspline(\lambda_{EE}, EE_k)$

$EEnoao_{good}(\lambda, k) := interp(T_{k-1}, \lambda_{EE}, EE_{k-1}, \lambda)$

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10.1.3 AO Gen I, poor seeing conditions

$TabEEgenI_{poor} :=$

	0	1	2	3	4	5	6	7
0	1	0.1	0.0554	0.0653	0.0734	0.0894	0.1009	0.1003
1	2	0.2	0.1839	0.2091	0.2365	0.2647	0.2893	0.3169
2	3	0.3	0.343	0.3777	0.4089	0.4478	0.4769	0.4968
3	4	0.4	0.4897	0.5182	0.5502	0.5804	0.6046	0.6233
4	5	0.5	0.6089	0.633	0.6607	0.6818	0.6998	0.715
5	6	0.6	0.6973	0.7152	0.7369	0.7504	0.7667	0.7746
6	7	0.7	0.7665	0.7789	0.7929	0.8037	0.8123	0.8184
7	8	0.8	0.8182	0.826	0.8343	0.8408	0.8486	0.8535
8	9	0.9	0.8558	0.8598	0.8655	0.8705	0.8744	0.8782
9	10	1	0.8857	0.8869	0.8894	0.8932	0.8957	0.8988

Note that MUSE IQE is now included in ensquared energy

$i := 0..18$

$j := 1..6$

$EE_i := submatrix(TabEEgenI_{poor}, i, i, 1, 6)^T$

$$\lambda_{EE} := \begin{pmatrix} 0.465 \\ 0.55 \\ 0.65 \\ 0.75 \\ 0.85 \\ 0.93 \end{pmatrix} \cdot \mu m$$

$D_{EE_i} := TabEEgenI_{poor_{i,0}}$

$k := 0..5$

$T_k := cspline(\lambda_{EE}, EE_k)$

$EEgenI_{poor}(\lambda, k) := interp(T_{k-1}, \lambda_{EE}, EE_{k-1}, \lambda)$

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10.1.4 AO Gen I, good seeing conditions

$TabEEgenI_{good} :=$

	0	1	2	3	4	5	6
0	0.2	0.1151	0.1325	0.1442	0.1688	0.1839	0.1789
1	0.4	0.3384	0.3732	0.4072	0.4393	0.4647	0.4939
2	0.6	0.5479	0.5828	0.6109	0.6447	0.6678	0.6828
3	0.8	0.6927	0.7134	0.7353	0.7551	0.7703	0.7819
4	1	0.7861	0.7996	0.8147	0.8256	0.8346	0.8426
5	1.2	0.8448	0.8529	0.8631	0.8686	0.8762	0.8794
6	1.4	0.8857	0.8904	0.8959	0.8999	0.9031	0.9054
7	1.6	0.9139	0.9163	0.9189	0.9208	0.9238	0.9255
8	1.8	0.9333	0.9341	0.9356	0.937	0.938	0.9393
9	2	0.9483	0.9479	0.9481	0.9491	0.9495	0.9505

Note that MUSE IQE is now included in ensquared energy

$i := 0..18$

$j := 1..6$

$EE_i := \mathrm{submatrix}(TabEEgenI_{good}, i, i, 1, 6)^T$

$$\lambda_{EE} := \begin{pmatrix} 0.465 \\ 0.55 \\ 0.65 \\ 0.75 \\ 0.85 \\ 0.93 \end{pmatrix} \cdot \mu m$$

$D_{EE_i} := TabEEgenI_{good_{i,0}}$

$k := 0..5$

$T_k := \mathrm{cspline}(\lambda_{EE}, EE_k)$

$EEgenI_{good}(\lambda, k) := \mathrm{interp}(T_{k-1}, \lambda_{EE}, EE_{k-1}, \lambda)$

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10.2 MUSE spatial PSF in HR mode

10.2.1 AO Gen II, good seeing conditions

$TabEEgenII_{good} :=$

	0	1	2	3	4	5	6
0	0.025	0.0735	0.1362	0.2195	0.3019	0.1954	0.2321
1	0.05	0.1848	0.2586	0.3131	0.4066	0.4835	0.4297
2	0.075	0.2183	0.3111	0.4008	0.4611	0.5327	0.5782
3	0.1	0.2468	0.3357	0.4319	0.505	0.557	0.6007
4	0.125	0.2628	0.3537	0.4422	0.5169	0.5721	0.6152
5	0.15	0.2787	0.3699	0.4597	0.5356	0.5931	0.6263
6	0.175	0.3032	0.3858	0.4753	0.5436	0.6014	0.6355
7	0.2	0.3201	0.4018	0.4902	0.5581	0.6089	0.6508
8	0.225	0.3375	0.4182	0.4976	0.565	0.6224	0.6574
9	0.25	0.3642	0.4349	0.5126	0.5786	0.6288	0.6636

Note that MUSE IQE is now included in ensquared energy

$i := 0..18$

$j := 1..6$

$EE_i := submatrix(TabEEgenII_{good}, i, i, 1, 6)^T$

$$\lambda_{EE} := \begin{pmatrix} 0.465 \\ 0.55 \\ 0.65 \\ 0.75 \\ 0.85 \\ 0.93 \end{pmatrix} \cdot \mu m$$

$D_{EE_i} := TabEEgenII_{good_{i,0}}$

$k := 0..5$

$T_k := cspline(\lambda_{EE}, EE_k)$

$EEgenII_{good}(\lambda, k) := interp(T_{k-1}, \lambda_{EE}, EE_{k-1}, \lambda)$

10.3 Number of spatial pixels

In the case of unresolved objects and in good seeing conditions we will sum up 3x3 spatial pixels to recover a fraction of the object flux, this correspond to 0.6x0.6 arcsec² in WF mode and 0.075x0.075 arcsec² in HR mode

$k_{spa\_good} := 3$

$EEnoao_{good}(\lambda_V, k_{spa\_good}) = 0.446$ $EEnoao_{good}(\lambda_I, k_{spa\_good}) = 0.496$

$EEgenI_{good}(\lambda_V, k_{spa\_good}) = 0.583$ $EEgenI_{good}(\lambda_I, k_{spa\_good}) = 0.655$

$EEgenII_{good}(\lambda_V, k_{spa\_good}) = 0.311$ $EEgenII_{good}(\lambda_I, k_{spa\_good}) = 0.489$

In the case of unresolved objects and in poor seeing conditions we will sum up 4x4 spatial pixels to recover a fraction of the object flux, this correspond to 0.8x0.8 arcsec² in WF mode and 0.1x0.1 arcsec² in HR mode

$k_{spa\_poor} := 4$

$EEnoao_{poor}(\lambda_V, k_{spa\_poor}) = 0.373$ $EEnoao_{poor}(\lambda_I, k_{spa\_poor}) = 0.417$

$EEgenI_{poor}(\lambda_V, k_{spa\_poor}) = 0.49$ $EEgenI_{poor}(\lambda_I, k_{spa\_poor}) = 0.563$

Note that this choice is somewhat arbitrary. It is a trade between S/N and spatial resolution. Optimum summation should allow increase of the S/N while keeping the spatial resolution.

11. MUSE spectral PSF

11.1 Shape of spectral PSF

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The spectral PSF is assumed to be Gaussian with 2*pixels FWHM

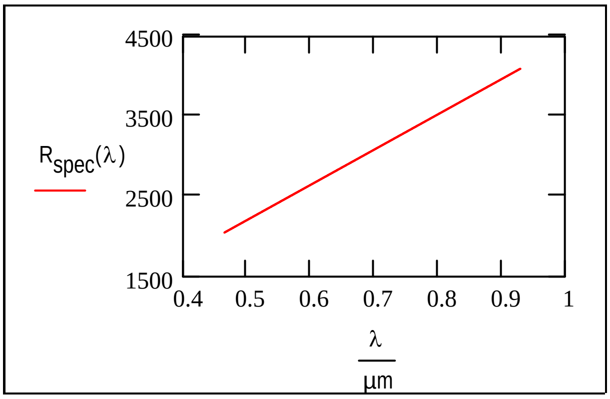
$FWHM_{spec} := 2 \cdot \Delta_{spec}$ $\quad R_{spec}(\lambda) := \frac{\lambda}{FWHM_{spec}}$

$R_{min} := R_{spec}(\lambda_{min})$

$R_{max} := R_{spec}(\lambda_{max})$

$R_{min} = 2.048 \times 10^3$

$R_{max} = 4.096 \times 10^3$



$R_{mean} := \frac{R_{min} + R_{max}}{2}$ $\quad R_{mean} = 3.072 \times 10^3$

Fraction of energy enclosed within n pixels :

$FracE_{spec}(n) := E_{GAUSS}(n, \sigma_{GAUSS}(2))$

$i := 2..4$ $\quad FracE_{spec}(i) =$

0.761
0.923
0.981

Low spectral resolution is obtained after summation of N spectral pixels

$N_{sumspec} := 10$

$\Delta_{lowspec} := N_{sumspec} \cdot \Delta_{spec}$ $\Delta_{lowspec} = 11.353\,A$

$$R_{lowspec}(\lambda) := \frac{\lambda}{2 \cdot \Delta_{lowspec}}$$

$R_{lowmin} := R_{lowspec}(\lambda_{min})$ $R_{lowmin} = 204.8$

$R_{lowmax} := R_{lowspec}(\lambda_{max})$ $R_{lowmax} = 409.6$

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$$R_{lowmean} := \frac{R_{lowmin} + R_{lowmax}}{2}$$ $R_{lowmean} = 307.2$

11.2 Number of spectral pixels

To recover major party of the fllux of an emission line we sum over 3 pixels in the spectral direction

$k_{spec} := 3$ $FracE_{spec}(k_{spec}) = 0.923$

Main ETC Formula

Signal to Noise SN

$$SN(F_O, n, t, F_S, RN, DC, K_O, K_S, K_{RN}, K_{DC}) := \sqrt{n} \cdot K_O \cdot F_O \cdot t \cdot \left(K_O \cdot F_O \cdot t + K_S \cdot F_S \cdot t + K_{RN} \cdot RN^2 + K_{DC} \cdot DC \cdot t\right)^{\frac{-1}{2}}$$

Object Flux F_O

$$F_O(SN, n, t, F_S, RN, DC, K_O, K_S, K_{RN}, K_{DC}) := \begin{vmatrix} a \leftarrow n\left(\dfrac{K_O \cdot t}{SN}\right)^2 \\ b \leftarrow K_O \cdot t \\ c \leftarrow K_S \cdot F_S \cdot t + K_{DC} \cdot DC \cdot t + K_{RN} \cdot RN^2 \\ \dfrac{b + \sqrt{b^2 + 4 \cdot a \cdot c}}{2 \cdot a} \end{vmatrix}$$

Integration time t

$$t(SN, n, F_O, F_S, RN, DC, K_O, K_S, K_{RN}, K_{DC}) := \begin{vmatrix} a \leftarrow n\left(\dfrac{K_O \cdot F_O}{SN}\right)^2 \\ b \leftarrow K_O \cdot F_O + K_S \cdot F_S + K_{DC} \cdot DC \\ c \leftarrow K_{RN} \cdot RN^2 \\ \dfrac{b + \sqrt{b^2 + 4 \cdot a \cdot c}}{2 \cdot a} \end{vmatrix}$$

Where F_O is the Object Flux $(erg \cdot s^{-1} \cdot cm^{-2})$

if it is a surface brightness, flux should be in $arcsec^{-2}$

if it is a continuum source, flux should be in A^{-1}

and F_S is the Sky Flux ($erg \cdot s^{-1} \cdot cm^{-2} \cdot A^{-1} \cdot arcsec^{-2}$)
and n is the number of exposures
and t is the integration time in sec of one exposure
and RN is the readout noise in electron per pixel
and DC is the dark current in electron per pixel and per hour
the coefficients K_O, K_S, K_{RN}, K_{DC} are defined below

The coefficient K_O transform the object flux in photons per second

$$K_O(f_s, f_a, \Delta_s, \Delta_a, \lambda, A_m) := f_s \cdot \Delta_s \cdot f_a \cdot \Delta_a^2 \cdot T_{MUSE}(\lambda) \cdot Area_{VLT} \cdot Extinct(\lambda, A_m) \cdot \frac{\lambda}{hr \cdot c}$$

Where f_s is the fraction of total flux enclosed in a spectral bin
and f_a is the fraction of total flux enclosed in a spatial bin
and Δ_s is the size of a spectral bin
and Δ_a is the linear size of a spatial bin in arcsec
and λ is the wavelength
and A_m is the airmass
and T_{MUSE} is the MUSE+VLT total throughput
and $Area_{VLT}$ is the effective collective area of VLT primary mirror
and $Extinct$ is the extinction absorption coefficient at Paranal

Note that when the flux is a flat continuum source (flux per A)
f_s must be set to 1 and Δ_s to the size of the spectral bin
and when the flux is an emission source (flux not per A)
f_s must be set to the flux fraction enclosed in the bin and Δ_s to 1
Note that when the flux is a surface brightness source (flux per arcsec²)
f_a must be set to 1 and Δ_a to the size of the spectral bin
and when the flux is a total flux (flux not per arcsec²)
f_a must be set to the flux fraction enclosed in the bin and Δ_a to 1

The coefficient K_S transform the sky flux in photons per second

$$K_S(\Delta_s, \Delta_a, \lambda) := \Delta_s \cdot \Delta_a^2 \cdot T_{MUSE}(\lambda) \cdot Area_{VLT} \cdot \frac{\lambda}{hr \cdot c}$$

The coefficient K_{RN} is the number of summed bin

The coefficient K_{DC} is the number of summed pixels

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Noise Statistics

$$FNoise\left(F_O, n, t, F_S, RN, DC, K_O, K_S, K_{RN}, K_{DC}\right) := \left| \begin{array}{l} V_O \leftarrow K_O \cdot F_O \cdot n \cdot t \\ V_S \leftarrow K_S \cdot F_S \cdot n \cdot t \\ V_{RN} \leftarrow n \cdot K_{RN} \cdot RN^2 \\ V_{DC} \leftarrow n \cdot K_{DC} \cdot DC \cdot t \\ V_{CCD} \leftarrow V_{RN} + V_{DC} \\ V_{Tot} \leftarrow V_O + V_S + V_{CCD} \\ \begin{pmatrix} \frac{V_O}{V_{Tot}} \\ \frac{V_S}{V_{Tot}} \\ \frac{V_{RN}}{V_{Tot}} \\ \frac{V_{DC}}{V_{Tot}} \\ \frac{V_{CCD}}{V_{Tot}} \end{pmatrix} \end{array} \right.$$

This function give the fraction of noise due to object (line 1), sky (line 2), readout (line 3), dark current (line 4), detector (ie readout + drak current, line 5)

back

13. ETC parameters

$SN_{lim} := 5$	Signal to Noise
$t_{exp} := 1 \cdot hour$	Exposure time
$n_{exp} := 80$	Number of summed exposures
$AM := 1$	Air mass of observations
$F_{Sky}(\lambda) := Flux_{SkyNoOH}(\lambda)$	Sky flux is taken outside OH lines

back

14. Limiting surface brightness

Estimation of limiting surface brightness for a continuum source with flat spectra. The computation is done by spectral and spatial pixels.

14.1 WF mode

back

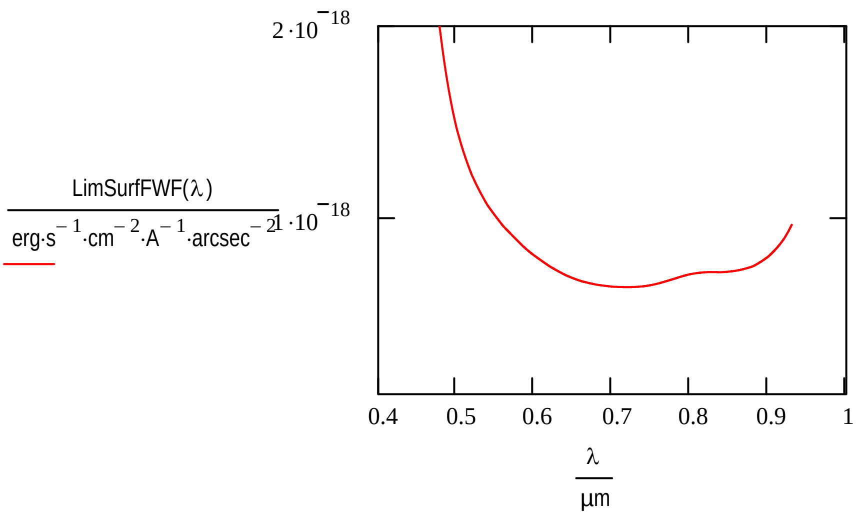
$K_{Obj}(\lambda) := K_O(1, 1, \Delta_{spec}, \Delta_{WFspa}, \lambda, AM)$

$K_{Sky}(\lambda) := K_S(\Delta_{spec}, \Delta_{WFspa}, \lambda)$

$K_{RN} := 1$

$K_{DC} := 1$

$LimSurfFWF(\lambda) := F_O(SN_{lim}, n_{exp}, t_{exp}, F_{Sky}(\lambda), RN_{CCD}, DN_{CCD}, K_{Obj}(\lambda), K_{Sky}(\lambda), K_{RN}, K_{DC})$



back

$i := 0..4$

$LimMagSurfWF_i := Flux2ABSurf(LimSurfFWF(\lambda_{MUSE_i}), \lambda_{MUSE_i})$

$$LimMagSurfWF = \begin{pmatrix} 23.228 \\ 23.87 \\ 23.928 \\ 23.479 \\ 22.778 \end{pmatrix} \qquad Band_{MUSE} = \begin{pmatrix} \text{"B"} \\ \text{"V"} \\ \text{"R"} \\ \text{"I"} \\ \text{"z"} \end{pmatrix}$$

back

$$FN(\lambda) := FNoise\left(LimSurfFWF(\lambda), n_{exp}, t_{exp}, F_{Sky}(\lambda), RN_{CCD}, DN_{CCD}, K_{Obj}(\lambda), K_{Sky}(\lambda), K_{RN}, K_{DC}\right)$$

$$FN(\lambda_V) = \begin{pmatrix} 0.061 \\ 0.712 \\ 0.191 \\ 0.036 \\ 0.226 \end{pmatrix} \quad FN(\lambda_R) = \begin{pmatrix} 0.058 \\ 0.734 \\ 0.175 \\ 0.033 \\ 0.208 \end{pmatrix} \quad FN(\lambda_z) = \begin{pmatrix} 0.083 \\ 0.499 \\ 0.352 \\ 0.066 \\ 0.418 \end{pmatrix}$$

Computing line emission sensitivity by arcsec

We sum the emission line over 3 pixels

$k_{spec} := 3$

$FracE_{spec}(k_{spec}) = 0.923$

$$K_{Obj}(\lambda) := K_O\left(FracE_{spec}(k_{spec}), 1, 1, \Delta_{WFspa}, \lambda, AM\right)$$

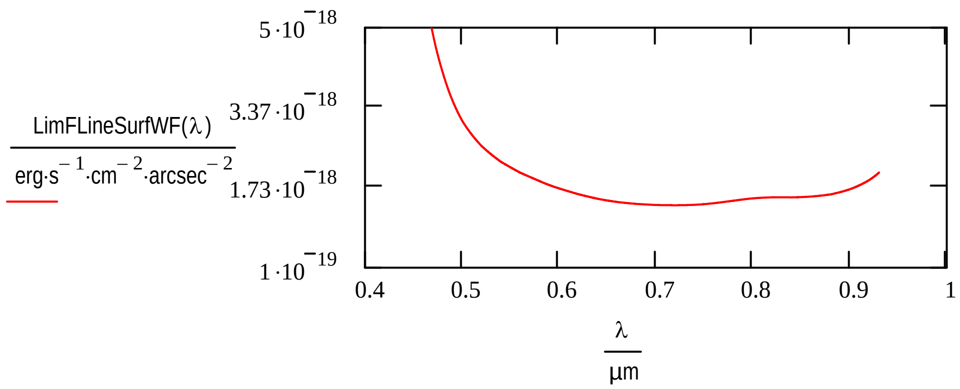
$$K_{Sky}(\lambda) := K_S\left(k_{spec} \cdot \Delta_{spec}, \Delta_{WFspa}, \lambda\right)$$

$K_{RN} := k_{spec}$

$K_{DC} := K_{RN}$

$$LimFLineSurfWF(\lambda) := F_O\left(SN_{lim}, n_{exp}, t_{exp}, F_{Sky}(\lambda), RN_{CCD}, DN_{CCD}, K_{Obj}(\lambda), K_{Sky}(\lambda), K_{RN}, K_{DC}\right)$$

$$LimFLineSurfWF(\lambda_B) = 5.38 \times 10^{-18} \, erg \cdot s^{-1} \cdot cm^{-2} \cdot arcsec^{-2}$$



$$LimVFLineSurfWF_i := LimFLineSurfWF\left(\lambda_{MUSE_i}\right)$$

$$LimVFLineSurfWF = \begin{pmatrix} 5.38 \times 10^{-18} \\ 2.143 \times 10^{-18} \\ 1.501 \times 10^{-18} \\ 1.489 \times 10^{-18} \\ 2.038 \times 10^{-18} \end{pmatrix} erg \cdot s^{-1} \cdot cm^{-2} \cdot arcsec^{-2} \qquad Band_{MUSE} = \begin{pmatrix} \text{"B"} \\ \text{"V"} \\ \text{"R"} \\ \text{"I"} \\ \text{"z"} \end{pmatrix}$$

back

14.2 HR mode

Nota that the computation is done for a single 1 hour integration

$K_{Obj}(\lambda) := K_O(1, 1, \Delta_{spec}, \Delta_{HRspa}, \lambda, AM)$

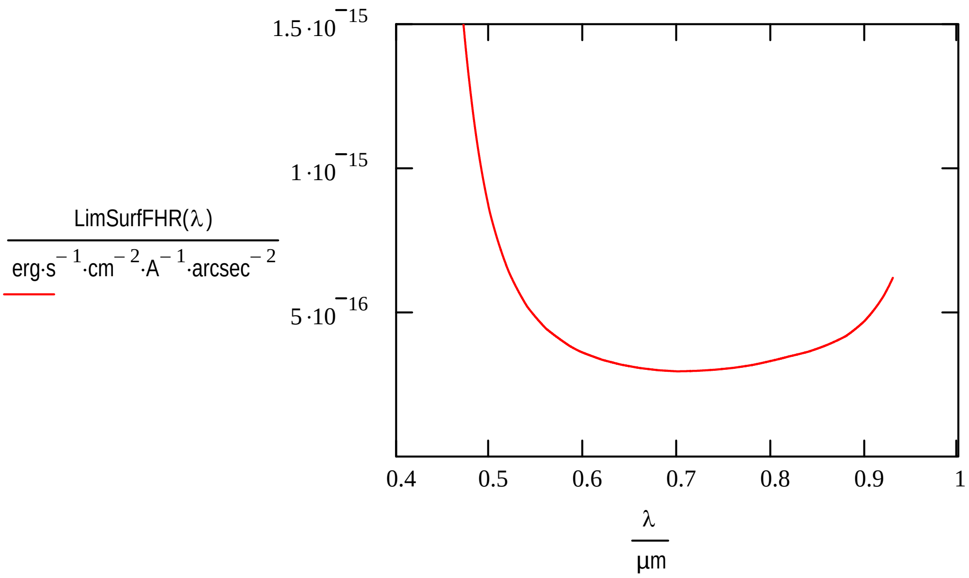
$K_{Sky}(\lambda) := K_S(\Delta_{spec}, \Delta_{HRspa}, \lambda)$

$K_{RN} := 1$

$K_{DC} := 1$

$F_{Sky}(\lambda) := Flux_{SkyNoOH}(\lambda)$

$LimSurfFHR(\lambda) := F_O(SN_{lim}, 1, t_{exp}, F_{Sky}(\lambda), RN_{CCD}, DN_{CCD}, K_{Obj}(\lambda), K_{Sky}(\lambda), K_{RN}, K_{DC})$



$LimMagSurfHR_i := Flux2ABSurf(LimSurfFHR(\lambda_{MUSE_i}), \lambda_{MUSE_i})$

back

$i := 0..4$

$$LimMagSurfHR = \begin{pmatrix} 16.126 \\ 17.175 \\ 17.278 \\ 16.803 \\ 15.76 \end{pmatrix} \qquad Band_{MUSE} = \begin{pmatrix} "B" \\ "V" \\ "R" \\ "I" \\ "z" \end{pmatrix}$$

$$FN(\lambda) := FNoise\left(LimSurfFHR(\lambda), 1, t_{exp}, F_{Sky}(\lambda), RN_{CCD}, DN_{CCD}, K_{Obj}(\lambda), K_{Sky}(\lambda), K_{RN}, K_{DC}\right)$$

$$FN(\lambda_V) = \begin{pmatrix} 0.656 \\ 0.016 \\ 0.276 \\ 0.052 \\ 0.327 \end{pmatrix} \quad FN(\lambda_R) = \begin{pmatrix} 0.655 \\ 0.018 \\ 0.275 \\ 0.052 \\ 0.327 \end{pmatrix} \quad FN(\lambda_z) = \begin{pmatrix} 0.661 \\ 6.201 \times 10^{-3} \\ 0.28 \\ 0.052 \\ 0.332 \end{pmatrix}$$

back

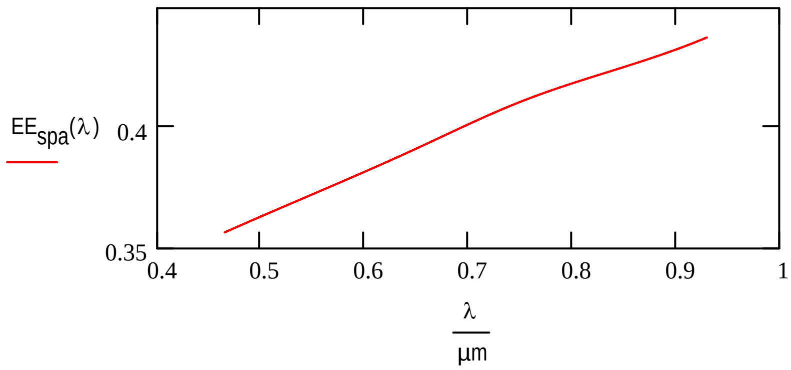
15. Limiting flux for an unresolved source

15.1 WF mode

15.1.1 Seeing limited, poor seeing conditions

$i := 0..4$

$EE_{spa}(\lambda) := EEnoao_{poor}(\lambda, k_{spa\_poor})$



back

15.1.1.1 Continuum source

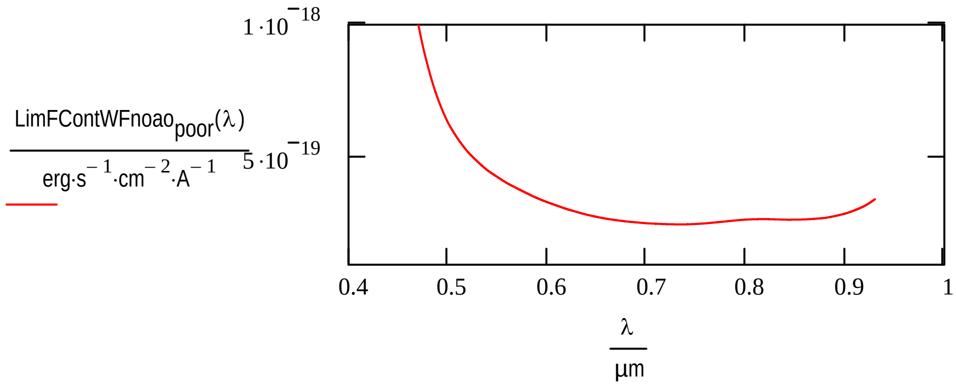
$K_{Obj}(\lambda) := K_O(1, EE_{spa}(\lambda), \Delta_{spec}, 1, \lambda, AM)$

$K_{Sky}(\lambda) := K_S(\Delta_{spec}, k_{spa\_poor} \cdot \Delta_{WFspa}, \lambda)$

$K_{RN} := k_{spa\_poor}^{2}$

$K_{DC} := k_{spa\_poor}^{2}$

$LimFContWFnoao_{poor}(\lambda) := F_O(SN_{lim}, n_{exp}, t_{exp}, F_{Sky}(\lambda), RN_{CCD}, DN_{CCD}, K_{Obj}(\lambda), K_{Sky}(\lambda), K_{RN}, K_{DC})$



$$LimMagContWFnoao_{poor_i} := Flux2AB\left(LimFContWFnoao_{poor}\left(\lambda_{MUSE_i}\right), \lambda_{MUSE_i}\right)$$

$$i := 0..4$$

$$LimMagContWFnoao_{poor} = \begin{pmatrix} 24.136 \\ 24.813 \\ 24.918 \\ 24.544 \\ 23.906 \end{pmatrix} \qquad Band_{MUSE} = \begin{pmatrix} \text{"B"} \\ \text{"V"} \\ \text{"R"} \\ \text{"I"} \\ \text{"z"} \end{pmatrix}$$

In case of lower dispersion we have

$$K_{Obj}(\lambda) := K_O\left(1, EE_{spa}(\lambda), \Delta_{lowspec}, 1, \lambda, AM\right)$$

$$K_{Sky}(\lambda) := K_S\left(\Delta_{lowspec}, k_{spa\_poor} \cdot \Delta_{WFspa}, \lambda\right)$$

$$K_{RN} := N_{sumspec} k_{spa\_poor}^{2}$$

$$K_{DC} := K_{RN}$$

$$LimFContWFnoao_{poor}(\lambda) := F_O\left(SN_{lim}, n_{exp}, t_{exp}, F_{Sky}(\lambda), RN_{CCD}, DN_{CCD}, K_{Obj}(\lambda), K_{Sky}(\lambda), K_{RN}, K_{DC}\right)$$

$$LimMagContLowWFnoao_{poor_i} := Flux2AB\left(LimFContWFnoao_{poor}\left(\lambda_{MUSE_i}\right), \lambda_{MUSE_i}\right)$$

$$i := 0..4$$

$$LimMagContLowWFnoao_{poor} = \begin{pmatrix} 25.395 \\ 26.069 \\ 26.174 \\ 25.8 \\ 25.164 \end{pmatrix} \qquad Band_{MUSE} = \begin{pmatrix} \text{"B"} \\ \text{"V"} \\ \text{"R"} \\ \text{"I"} \\ \text{"z"} \end{pmatrix}$$

back

15.1.1.2 Line emission source

We sum the emission line over 3 pixels

$k_{spec} := 3$

$FracE_{spec}(k_{spec}) = 0.923$

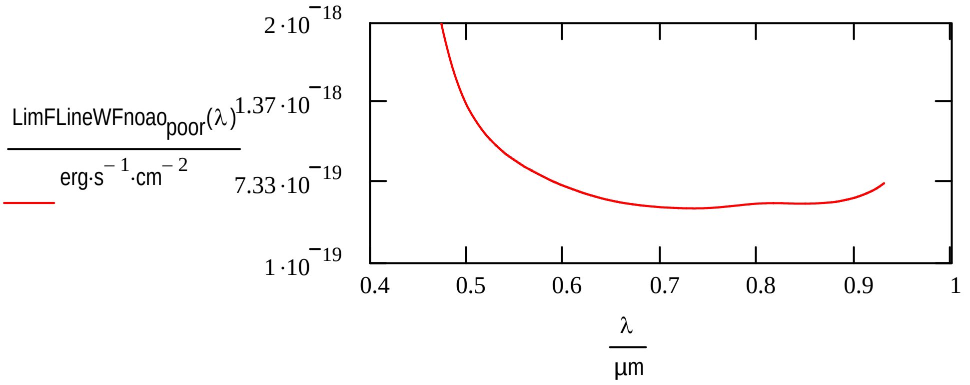
$K_{Obj}(\lambda) := K_O\left(FracE_{spec}(k_{spec}), EE_{spa}(\lambda), 1, 1, \lambda, AM\right)$

$K_{Sky}(\lambda) := K_S\left(k_{spec} \cdot \Delta_{spec}, k_{spa\_poor} \cdot \Delta_{WFspa}, \lambda\right)$

$K_{RN} := k_{spa\_poor}^{\ 2} \cdot k_{spec}$

$K_{DC} := K_{RN}$

$LimFLineWFnoao_{poor}(\lambda) := F_O\left(SN_{lim}, n_{exp}, t_{exp}, F_{Sky}(\lambda), RN_{CCD}, DN_{CCD}, K_{Obj}(\lambda), K_{Sky}(\lambda), K_{RN}, K_{DC}\right)$



$LimVFLineWFnoao_{poor_i} := LimFLineWFnoao_{poor}\left(\lambda_{MUSE_i}\right)$

$i := 0..4$

back

$$LimVFLineWFnoao_{poor} = \begin{pmatrix} 2.365 \times 10^{-18} \\ 9.082 \times 10^{-19} \\ 6.087 \times 10^{-19} \\ 5.636 \times 10^{-19} \\ 7.312 \times 10^{-19} \end{pmatrix} erg \cdot s^{-1} \cdot cm^{-2}$$

$$Band_{MUSE} = \begin{pmatrix} \text{"B"} \\ \text{"V"} \\ \text{"R"} \\ \text{"I"} \\ \text{"z"} \end{pmatrix}$$

$$FN(\lambda) := FNoise\left(LimFLineWFnoao_{poor}(\lambda), n_{exp}, t_{exp}, F_{Sky}(\lambda), RN_{CCD}, DN_{CCD}, K_{Obj}(\lambda), K_{Sky}(\lambda), K_{RN}, K_{DC}\right)$$

$$FN(\lambda_V) = \begin{pmatrix} 9.05 \times 10^{-3} \\ 0.752 \\ 0.201 \\ 0.038 \\ 0.239 \end{pmatrix} \quad FN(\lambda_R) = \begin{pmatrix} 8.661 \times 10^{-3} \\ 0.772 \\ 0.184 \\ 0.035 \\ 0.219 \end{pmatrix} \quad FN(\lambda_z) = \begin{pmatrix} 0.012 \\ 0.537 \\ 0.379 \\ 0.071 \\ 0.45 \end{pmatrix}$$

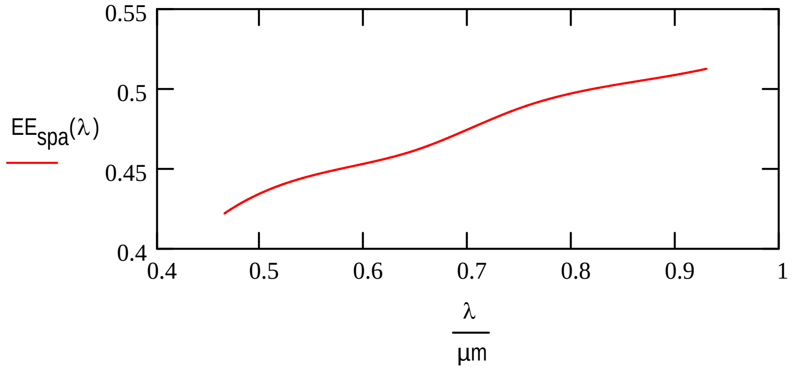
back

15.1.2 Seeing limited, good seeing conditions

back

$i := 0..4$

$EE_{spa}(\lambda) := EEnoao_{good}(\lambda, k_{spa\_good})$



back

15.1.2.1 Continuum source

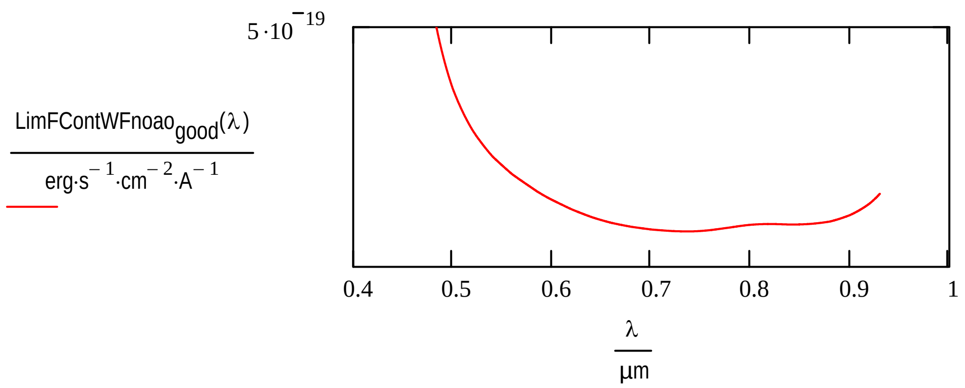
$K_{Obj}(\lambda) := K_O(1, EE_{spa}(\lambda), \Delta_{spec}, 1, \lambda, AM)$

$K_{Sky}(\lambda) := K_S(\Delta_{spec}, k_{spa\_good} \cdot \Delta_{WFspa}, \lambda)$

$K_{RN} := k_{spa\_good}^{2}$

$K_{DC} := k_{spa\_good}^{2}$

$LimFContWFnoao_{good}(\lambda) := F_O(SN_{lim}, n_{exp}, t_{exp}, F_{Sky}(\lambda), RN_{CCD}, DN_{CCD}, K_{Obj}(\lambda), K_{Sky}(\lambda), K_{RN}, K_{DC})$



$LimMagContWFnoao_{good_i} := Flux2AB(LimFContWFnoao_{good}(\lambda_{MUSE_i}), \lambda_{MUSE_i})$

$i := 0..4$

$$LimMagContWFnoao_{good} = \begin{pmatrix} 24.627 \\ 25.317 \\ 25.408 \\ 25.041 \\ 24.386 \end{pmatrix} \qquad Band_{MUSE} = \begin{pmatrix} \text{"B"} \\ \text{"V"} \\ \text{"R"} \\ \text{"I"} \\ \text{"z"} \end{pmatrix}$$

In case of lower dispersion we have

$$K_{Obj}(\lambda) := K_O\left(1, EE_{spa}(\lambda), \Delta_{lowspec}, 1, \lambda, AM\right)$$

$$K_{Sky}(\lambda) := K_S\left(\Delta_{lowspec}, k_{spa\_good} \cdot \Delta_{WFspa}, \lambda\right)$$

$$K_{RN} := N_{sumspec} k_{spa\_good}{}^2$$

$$K_{DC} := K_{RN}$$

$$LimFContWFnoao_{good}(\lambda) := F_O\left(SN_{lim}, n_{exp}, t_{exp}, F_{Sky}(\lambda), RN_{CCD}, DN_{CCD}, K_{Obj}(\lambda), K_{Sky}(\lambda), K_{RN}, K_{DC}\right)$$

$$LimMagContLowWFnoao_{good_i} := Flux2AB\left(LimFContWFnoao_{good}\left(\lambda_{MUSE_i}\right), \lambda_{MUSE_i}\right)$$

$i := 0..4$

$$LimMagContLowWFnoao_{good} = \begin{pmatrix} 25.889 \\ 26.575 \\ 26.665 \\ 26.299 \\ 25.647 \end{pmatrix} \qquad Band_{MUSE} = \begin{pmatrix} \text{"B"} \\ \text{"V"} \\ \text{"R"} \\ \text{"I"} \\ \text{"z"} \end{pmatrix}$$

back

15.1.2.2 Line emission source

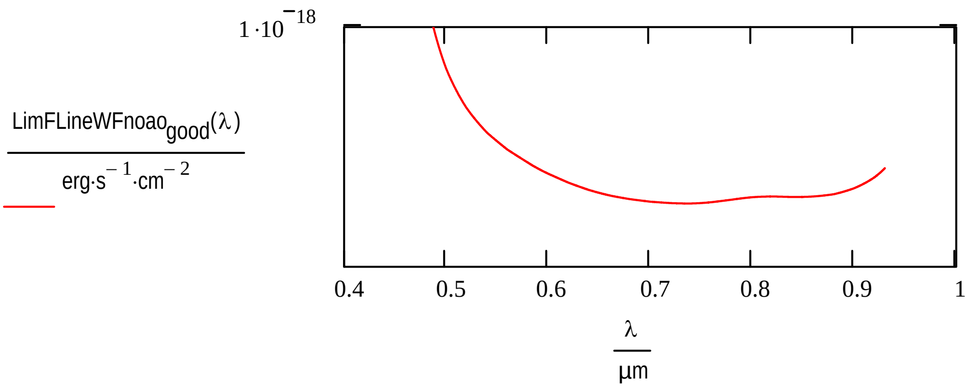
$K_{Obj}(\lambda) := K_O(FracE_{spec}(k_{spec}), EE_{spa}(\lambda), 1, 1, \lambda, AM)$

$K_{Sky}(\lambda) := K_S(k_{spec} \cdot \Delta_{spec}, k_{spa\_good} \cdot \Delta_{WFspa}, \lambda)$

$K_{RN} := k_{spa\_good}^{\ 2} \cdot k_{spec}$

$K_{DC} := K_{RN}$

$LimFLineWFnoao_{good}(\lambda) := F_O(SN_{lim}, n_{exp}, t_{exp}, F_{Sky}(\lambda), RN_{CCD}, DN_{CCD}, K_{Obj}(\lambda), K_{Sky}(\lambda), K_{RN}, K_{DC})$



$LimVFLineWFnoao_{good_i} := LimFLineWFnoao_{good}(\lambda_{MUSE_i})$

$i := 0..4$

back

$$LimVFLineWFnoao_{good} = \begin{pmatrix} 1.503 \times 10^{-18} \\ 5.7 \times 10^{-19} \\ 3.875 \times 10^{-19} \\ 3.563 \times 10^{-19} \\ 4.693 \times 10^{-19} \end{pmatrix} erg \cdot s^{-1} \cdot cm^{-2}$$

$$Band_{MUSE} = \begin{pmatrix} "B" \\ "V" \\ "R" \\ "I" \\ "z" \end{pmatrix}$$

$FN(\lambda) := FNoise(LimFLineWFnoao_{good}(\lambda), n_{exp}, t_{exp}, F_{Sky}(\lambda), RN_{CCD}, DN_{CCD}, K_{Obj}(\lambda), K_{Sky}(\lambda), K_{RN}, K_{DC})$

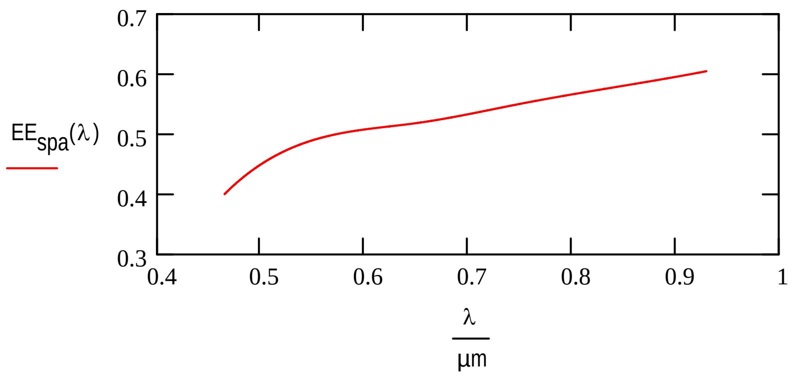
$$FN(\lambda_V) = \begin{pmatrix} 0.012 \\ 0.75 \\ 0.201 \\ 0.038 \\ 0.238 \end{pmatrix} \quad FN(\lambda_R) = \begin{pmatrix} 0.012 \\ 0.77 \\ 0.184 \\ 0.034 \\ 0.218 \end{pmatrix} \quad FN(\lambda_z) = \begin{pmatrix} 0.017 \\ 0.535 \\ 0.378 \\ 0.071 \\ 0.448 \end{pmatrix}$$

back

15.1.3 **AO Gen I, poor seeing conditions**

$i := 0..4$

$EE_{spa}(\lambda) := EEgenI_{poor}(\lambda, k_{spa\_poor})$



15.1.3.1 **Continuum source**

back

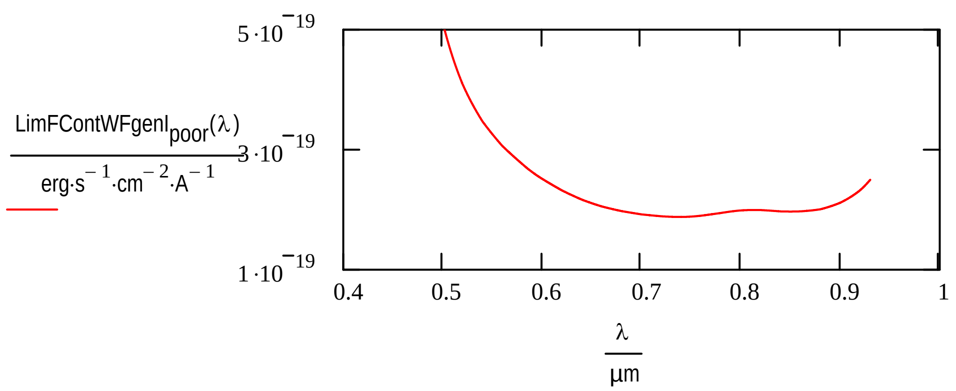
$K_{Obj}(\lambda) := K_O(1, EE_{spa}(\lambda), \Delta_{spec}, 1, \lambda, AM)$

$K_{Sky}(\lambda) := K_S(\Delta_{spec}, k_{spa\_poor} \cdot \Delta_{WFspa}, \lambda)$

$K_{RN} := k_{spa\_poor}^{2}$

$K_{DC} := k_{spa\_poor}^{2}$

$LimFContWFgenI_{poor}(\lambda) := F_O(SN_{lim}, n_{exp}, t_{exp}, F_{Sky}(\lambda), RN_{CCD}, DN_{CCD}, K_{Obj}(\lambda), K_{Sky}(\lambda), K_{RN}, K_{DC})$



$LimMagContWFgenl_{poor_i} := Flux2AB\left(LimFContWFgenl_{poor}\left(\lambda_{MUSE_i}\right), \lambda_{MUSE_i}\right)$

$i := 0..4$

$LimMagContWFgenl_{poor} = \begin{pmatrix} 24.261 \\ 25.11 \\ 25.223 \\ 24.87 \\ 24.257 \end{pmatrix}$ $Band_{MUSE} = \begin{pmatrix} "B" \\ "V" \\ "R" \\ "I" \\ "z" \end{pmatrix}$

In case of lower dispersion we have

$K_{Obj}(\lambda) := K_O\left(1, EE_{spa}(\lambda), \Delta_{lowspec}, 1, \lambda, AM\right)$

$K_{Sky}(\lambda) := K_S\left(\Delta_{lowspec}, k_{spa\_poor} \cdot \Delta_{WFspa}, \lambda\right)$

$K_{RN} := N_{sumspec} k_{spa\_poor}^{2}$

$K_{DC} := K_{RN}$

$LimFContWFgenl_{poor}(\lambda) := F_O\left(SN_{lim}, n_{exp}, t_{exp}, F_{Sky}(\lambda), RN_{CCD}, DN_{CCD}, K_{Obj}(\lambda), K_{Sky}(\lambda), K_{RN}, K_{DC}\right)$

$LimMagContLowWFgenl_{poor_i} := Flux2AB\left(LimFContWFgenl_{poor}\left(\lambda_{MUSE_i}\right), \lambda_{MUSE_i}\right)$

$i := 0..4$

$LimMagContLowWFgenl_{poor} = \begin{pmatrix} 25.52 \\ 26.366 \\ 26.479 \\ 26.126 \\ 25.515 \end{pmatrix}$ $Band_{MUSE} = \begin{pmatrix} "B" \\ "V" \\ "R" \\ "I" \\ "z" \end{pmatrix}$

15.1.3.2 Line emission source

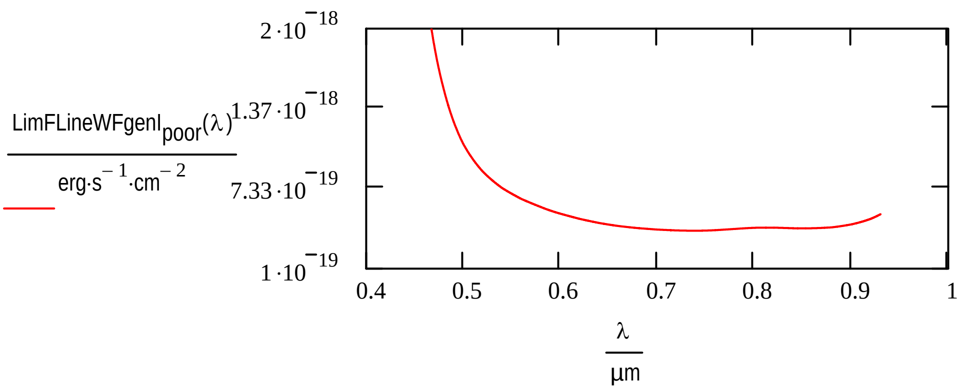
$K_{Obj}(\lambda) := K_O(FracE_{spec}(k_{spec}), EE_{spa}(\lambda), 1, 1, \lambda, AM)$

$K_{Sky}(\lambda) := K_S(k_{spec} \cdot \Delta_{spec}, k_{spa\_poor} \cdot \Delta_{WFspa}, \lambda)$

$K_{RN} := k_{spa\_poor}^{2} \cdot k_{spec}$

$K_{DC} := K_{RN}$

$LimFLineWFgenl_{poor}(\lambda) := F_O(SN_{lim}, n_{exp}, t_{exp}, F_{Sky}(\lambda), RN_{CCD}, DN_{CCD}, K_{Obj}(\lambda), K_{Sky}(\lambda), K_{RN}, K_{DC})$



$LimVFLineWFgenl_{poor_i} := LimFLineWFgenl_{poor}(\lambda_{MUSE_i})$

$i := 0..4$

back

$$LimVFLineWFgenl_{poor} = \begin{pmatrix} 2.109 \times 10^{-18} \\ 6.908 \times 10^{-19} \\ 4.596 \times 10^{-19} \\ 4.177 \times 10^{-19} \\ 5.293 \times 10^{-19} \end{pmatrix} erg \cdot s^{-1} \cdot cm^{-2} \qquad Band_{MUSE} = \begin{pmatrix} "B" \\ "V" \\ "R" \\ "I" \\ "z" \end{pmatrix}$$

$FN(\lambda) := FNoise(LimFLineWFgenl_{poor}(\lambda), n_{exp}, t_{exp}, F_{Sky}(\lambda), RN_{CCD}, DN_{CCD}, K_{Obj}(\lambda), K_{Sky}(\lambda), K_{RN}, K_{DC})$

$$FN(\lambda_V) = \begin{pmatrix} 9.05 \times 10^{-3} \\ 0.752 \\ 0.201 \\ 0.038 \\ 0.239 \end{pmatrix} \qquad FN(\lambda_R) = \begin{pmatrix} 8.661 \times 10^{-3} \\ 0.772 \\ 0.184 \\ 0.035 \\ 0.219 \end{pmatrix} \qquad FN(\lambda_z) = \begin{pmatrix} 0.012 \\ 0.537 \\ 0.379 \\ 0.071 \\ 0.45 \end{pmatrix}$$

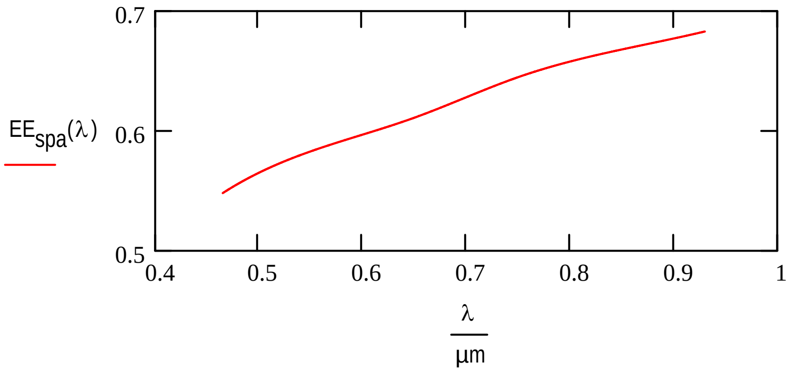
back

15.1.4 AO Gen I, good seeing conditions

back

$i := 0..4$

$EE_{spa}(\lambda) := EEgenI_{good}(\lambda, k_{spa\_good})$



15.1.4.1 Continuum source

back

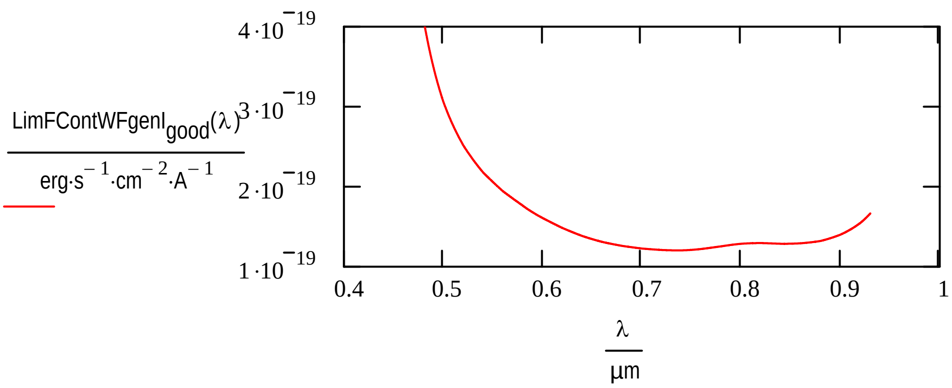
$K_{Obj}(\lambda) := K_O(1, EE_{spa}(\lambda), \Delta_{spec}, 1, \lambda, AM)$

$K_{Sky}(\lambda) := K_S(\Delta_{spec}, k_{spa\_good} \cdot \Delta_{WFspa}, \lambda)$

$K_{RN} := k_{spa\_good}^{2}$

$K_{DC} := k_{spa\_good}^{2}$

$LimFContWFgenI_{good}(\lambda) := F_O(SN_{lim}, n_{exp}, t_{exp}, F_{Sky}(\lambda), RN_{CCD}, DN_{CCD}, K_{Obj}(\lambda), K_{Sky}(\lambda), K_{RN}, K_{DC})$



$LimMagContWFgenI_{good_i} := Flux2AB(LimFContWFgenI_{good}(\lambda_{MUSE_i}), \lambda_{MUSE_i})$

$i := 0..4$

$$LimMagContWFgenl_{good} = \begin{pmatrix} 24.911 \\ 25.608 \\ 25.711 \\ 25.345 \\ 24.697 \end{pmatrix} \qquad Band_{MUSE} = \begin{pmatrix} "B" \\ "V" \\ "R" \\ "I" \\ "z" \end{pmatrix}$$

In case of lower dispersion we have

$$K_{Obj}(\lambda) := K_O\left(1, EE_{spa}(\lambda), \Delta_{lowspec}, 1, \lambda, AM\right)$$

$$K_{Sky}(\lambda) := K_S\left(\Delta_{lowspec}, k_{spa\_good} \cdot \Delta_{WFspa}, \lambda\right)$$

$$K_{RN} := N_{sumspec} k_{spa\_good}^2$$

$$K_{DC} := K_{RN}$$

$$LimFContWFgenl_{good}(\lambda) := F_O\left(SN_{lim}, n_{exp}, t_{exp}, F_{Sky}(\lambda), RN_{CCD}, DN_{CCD}, K_{Obj}(\lambda), K_{Sky}(\lambda), K_{RN}, K_{DC}\right)$$

$$LimMagContLowWFgenl_{good_i} := Flux2AB\left(LimFContWFgenl_{good}\left(\lambda_{MUSE_i}\right), \lambda_{MUSE_i}\right)$$

$i := 0..4$

$$LimMagContLowWFgenl_{good} = \begin{pmatrix} 26.172 \\ 26.866 \\ 26.968 \\ 26.602 \\ 25.958 \end{pmatrix} \qquad Band_{MUSE} = \begin{pmatrix} "B" \\ "V" \\ "R" \\ "I" \\ "z" \end{pmatrix}$$

back

15.1.4.2 **Line emission source**

$K_{Obj}(\lambda) := K_O(FracE_{spec}(k_{spec}), EE_{spa}(\lambda), 1, 1, \lambda, AM)$

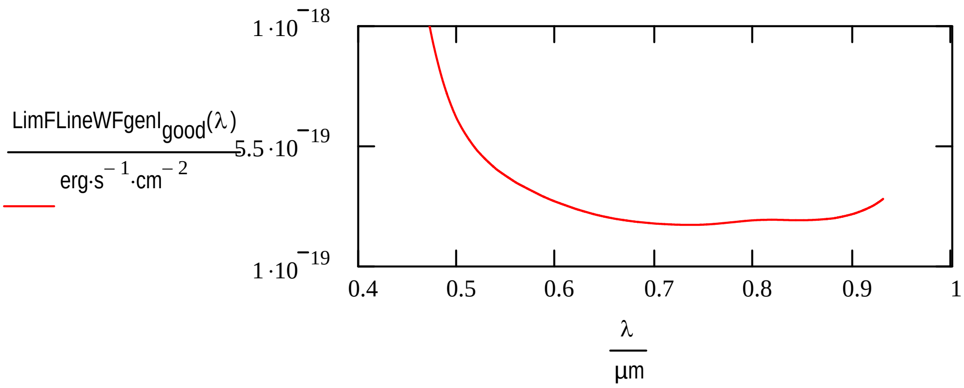
$K_{Sky}(\lambda) := K_S(k_{spec} \cdot \Delta_{spec}, k_{spa\_good} \cdot \Delta_{WFspa}, \lambda)$

$K_{RN} := k_{spa\_good}^{\;2} \cdot k_{spec}$

$K_{DC} := K_{RN}$

$F_{Sky}(\lambda) := Flux_{SkyNoOH}(\lambda)$

$LimFLineWFgenl_{good}(\lambda) := F_O(SN_{lim}, n_{exp}, t_{exp}, F_{Sky}(\lambda), RN_{CCD}, DN_{CCD}, K_{Obj}(\lambda), K_{Sky}(\lambda), K_{RN}, K_{DC})$



$LimVFLineWFgenl_{good_i} := LimFLineWFgenl_{good}(\lambda_{MUSE_i})$

$i := 0..4$

back

$$LimVFLineWFgenl_{good} = \begin{pmatrix} 1.157 \times 10^{-18} \\ 4.36 \times 10^{-19} \\ 2.93 \times 10^{-19} \\ 2.695 \times 10^{-19} \\ 3.523 \times 10^{-19} \end{pmatrix} erg \cdot s^{-1} \cdot cm^{-2} \qquad Band_{MUSE} = \begin{pmatrix} \text{"B"} \\ \text{"V"} \\ \text{"R"} \\ \text{"I"} \\ \text{"z"} \end{pmatrix}$$

$FN(\lambda) := FNoise(LimFLineWFgenl_{good}(\lambda), n_{exp}, t_{exp}, F_{Sky}(\lambda), RN_{CCD}, DN_{CCD}, K_{Obj}(\lambda), K_{Sky}(\lambda), K_{RN}, K_{DC})$

$$FN(\lambda_V) = \begin{pmatrix} 0.012 \\ 0.75 \\ 0.201 \\ 0.038 \\ 0.238 \end{pmatrix} \qquad FN(\lambda_R) = \begin{pmatrix} 0.012 \\ 0.77 \\ 0.184 \\ 0.034 \\ 0.218 \end{pmatrix} \qquad FN(\lambda_z) = \begin{pmatrix} 0.017 \\ 0.535 \\ 0.378 \\ 0.071 \\ 0.448 \end{pmatrix}$$

back

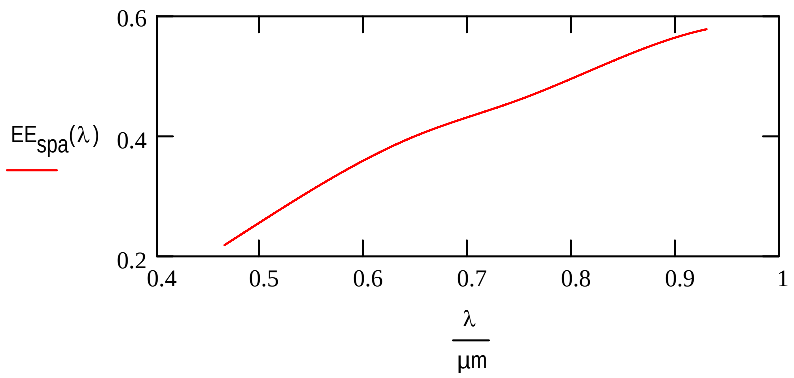
15.2 HR mode

15.2.1 AO Gen II, good seeing conditions

back

$i := 0..4$

$EE_{spa}(\lambda) := EEgenII_{good}(\lambda, k_{spa\_good})$



15.2.1.1 Continuum source

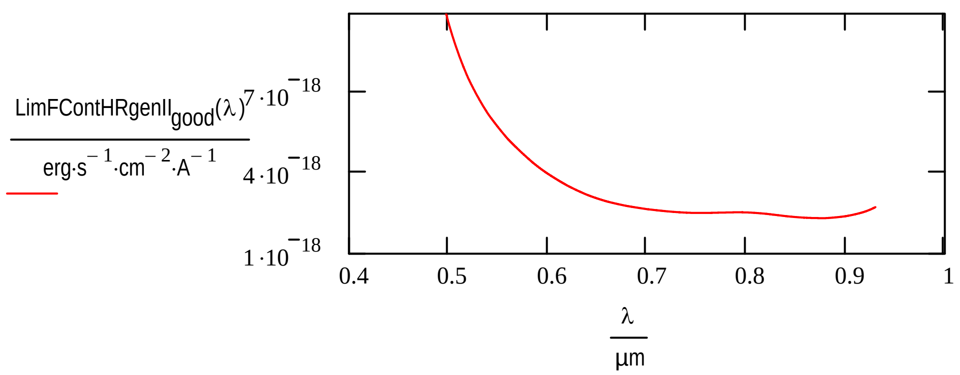
back

$K_{Obj}(\lambda) := K_O(1, EE_{spa}(\lambda), \Delta_{spec}, 1, \lambda, AM)$

$K_{RN} := k_{spa\_good}^{2}$

$K_{DC} := k_{spa\_good}^{2}$

$LimFContHRgenII_{good}(\lambda) := F_O(SN_{lim}, 1, t_{exp}, F_{Sky}(\lambda), RN_{CCD}, DN_{CCD}, K_{Obj}(\lambda), K_{Sky}(\lambda), K_{RN}, K_{DC})$



$LimMagContHRgenII_{good_i} := Flux2AB\left(LimFContHRgenII_{good}\left(\lambda_{MUSE_i}\right), \lambda_{MUSE_i}\right)$

$i := 0..4$

$$LimMagContHRgenII_{good} = \begin{pmatrix} 21.084 \\ 21.994 \\ 22.3 \\ 22.09 \\ 21.657 \end{pmatrix} \qquad Band_{MUSE} = \begin{pmatrix} \text{"B"} \\ \text{"V"} \\ \text{"R"} \\ \text{"I"} \\ \text{"z"} \end{pmatrix}$$

In case of lower dispersion we have

$K_{Obj}(\lambda) := K_O\left(1, EE_{spa}(\lambda), \Delta_{lowspec}, 1, \lambda, AM\right)$

$K_{Sky}(\lambda) := K_S\left(\Delta_{lowspec}, k_{spa\_good} \cdot \Delta_{HRspa}, \lambda\right)$

$K_{RN} := N_{sumspec} k_{spa\_good}^{2}$

$K_{DC} := K_{RN}$

$LimFContHRgenII_{good}(\lambda) := F_O\left(SN_{lim}, 1, t_{exp}, F_{Sky}(\lambda), RN_{CCD}, DN_{CCD}, K_{Obj}(\lambda), K_{Sky}(\lambda), K_{RN}, K_{DC}\right)$

$LimMagContLowHRgenII_{good_i} := Flux2AB\left(LimFContHRgenII_{good}\left(\lambda_{MUSE_i}\right), \lambda_{MUSE_i}\right)$

$i := 0..4$

$$LimMagContLowHRgenII_{good} = \begin{pmatrix} 23.065 \\ 24.491 \\ 24.848 \\ 24.608 \\ 23.755 \end{pmatrix} \qquad Band_{MUSE} = \begin{pmatrix} \text{"B"} \\ \text{"V"} \\ \text{"R"} \\ \text{"I"} \\ \text{"z"} \end{pmatrix}$$

back

15.2.1.2 Line emission source

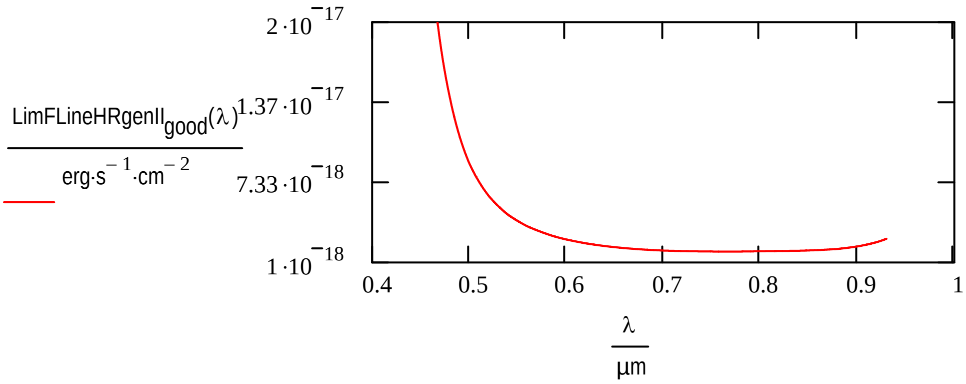
$K_{Obj}(\lambda) := K_O\left(FracE_{spec}\left(k_{spec}\right), EE_{spa}(\lambda), 1, 1, \lambda, AM\right)$

$K_{RN} := k_{spa\_good}^{2} \cdot k_{spec}$

$K_{DC} := K_{RN}$

$F_{Sky}(\lambda) := Flux_{SkyNoOH}(\lambda)$

$LimFLineHRgenII_{good}(\lambda) := F_O\left(SN_{lim}, 1, t_{exp}, F_{Sky}(\lambda), RN_{CCD}, DN_{CCD}, K_{Obj}(\lambda), K_{Sky}(\lambda), K_{RN}, K_{DC}\right)$



$LimVFLineHRgenII_{good_i} := LimFLineHRgenII_{good}\left(\lambda_{MUSE_i}\right)$

$i := 0..4$

back

$$LimVFLineHRgenII_{good} = \begin{pmatrix} 2.148\times10^{-17} \\ 4.261\times10^{-18} \\ 2.277\times10^{-18} \\ 1.858\times10^{-18} \\ 2.857\times10^{-18} \end{pmatrix} erg\cdot s^{-1}\cdot cm^{-2} \qquad Band_{MUSE} = \begin{pmatrix} "B" \\ "V" \\ "R" \\ "I" \\ "z" \end{pmatrix}$$

$FN(\lambda) := FNoise\left(LimFLineHRgenII_{good}(\lambda), 1, t_{exp}, F_{Sky}(\lambda), RN_{CCD}, DN_{CCD}, K_{Obj}(\lambda), K_{Sky}(\lambda), K_{RN}, K_{DC}\right)$

$$FN\left(\lambda_V\right) = \begin{pmatrix} 0.185 \\ 0.115 \\ 0.59 \\ 0.111 \\ 0.7 \end{pmatrix} \qquad FN\left(\lambda_R\right) = \begin{pmatrix} 0.183 \\ 0.127 \\ 0.581 \\ 0.109 \\ 0.69 \end{pmatrix} \qquad FN\left(\lambda_z\right) = \begin{pmatrix} 0.192 \\ 0.047 \\ 0.64 \\ 0.12 \\ 0.76 \end{pmatrix}$$

back

16. Accuracy requirements in sky subtraction

We compute the ratio of sky flux (outside OH lines) with the object flux

$$\mathrm{RatioSkyObj}_i := \frac{\mathrm{Flux}_{\mathrm{SkyNoOH}}\left(\lambda_{\mathrm{MUSE}_i}\right)\cdot\left(k_{\mathrm{spa\_good}}\cdot\Delta_{\mathrm{WFspa}}\right)^2\cdot k_{\mathrm{spec}}\cdot\Delta_{\mathrm{spec}}}{\mathrm{LimFLineWFgenl}_{\mathrm{good}}\left(\lambda_{\mathrm{MUSE}_i}\right)}$$

$$\mathrm{RatioSkyObj} = \begin{pmatrix} 10.487 \\ 29.526 \\ 34.47 \\ 37.174 \\ 20.095 \end{pmatrix} \qquad \mathrm{Band}_{\mathrm{MUSE}} = \begin{pmatrix} \text{"B"} \\ \text{"V"} \\ \text{"R"} \\ \text{"I"} \\ \text{"z"} \end{pmatrix}$$

Thus at most the sky is 40 times the object flux and sky subtraction to a precision of 1% should be OK in all cases.