

M-Dwarf BOT Procedures

COS UV Detectors

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Motivation

“M dwarfs are subject to irregular and unpredictable flaring outbursts, which may increase the FUV and NUV light by possibly large factors”

These training slides provide guidance for Pls on implementing policies on M-dwarf BOT clearance documented in COS ISR 2017-01 by R. Osten:

http://www.stsci.edu/hst/cos/documents/isrs/ISR2017_01.pdf

M-dwarf clearance procedures

Table 2: Maximum U band magnitude increases (ΔU) corresponding to flare energies listed in Table 1.

Activity level	Spectral Type				†
	M0-2		M3-5	M6-9	
inactive	$P=10^{-2}$	-0.07	$P=10^{-2}$	-0.07	...
	$P=10^{-3}$	-1.1	$P=10^{-3}$	-1.1	...
	$P=10^{-4}$	-2.3	$P=10^{-4}$	-2.3	...
active	$P=10^{-2}$	-1.8	$P=10^{-2}$	-1.8	$P=10^{-2}$... ‡
	$P=10^{-3}$	-2.3	$P=10^{-3}$	-4.6	$P=10^{-3}$ -1
	$P=10^{-4}$	-2.8	$P=10^{-4}$	-8.0	$P=10^{-4}$ -2.8

† Almost all late M dwarfs are considered active; West et al. (2008).

‡ ΔU for flare energy E_U too small, out of range of validity using data from larger flares.

This table shows the maximum U-band magnitude increase as a function of flare probability and spectral type.

Mid M-dwarfs (M3-5) have the largest flares, with $\Delta U=-8$

Information needed per star

In order to clear M-dwarf observations, start by gathering this information:

- **U-magnitude** (Johnson system)
 - If unavailable on SIMBAD calculate from B or V using the colors listed here for the given spectral type:
http://www.pas.rochester.edu/~emamajek/EEM_dwarf_UBVIJHK_colors_Teff.txt
 - **H α equivalent width**
 - EW(H α)>1 Å indicates magnetically active
 - Table 1 in Newton et al. (2017) has EW(H α) of ~3000 northern M-dwarfs. Check for your target:
<http://adsabs.harvard.edu/abs/2017ApJ...834...85N>
 - If unavailable, assume it is active
- If the observation covers Ly α , the following two items are also needed:
- **Distance to star in pc**
 - d[pc]=1/parallax ["]
 - **Stellar radius**
 - see table on next slide

Table of M-dwarf data

Sp. Type	Temperature (K)	Radius (R_{\odot})
M0	3800	0.62
M1	3600	0.49
M2	3400	0.44
M3	3250	0.39
M4	3100	0.26
M5	2800	0.20
M6	2600	0.15
M7	2500	0.12
M8	2400	0.11
M9	2300	0.08

from Kaltenegger & Traub (2009)

Note: $1 R_{\odot} = 6.96 \times 10^8 \text{ cm}$; $1 \text{ pc} = 3.09 \times 10^{18} \text{ cm}$

Overall procedure

The next slides describe how to clear M-dwarf COS observations. The following steps are used:

- 1a) clear ACQUISITION in quiescent case (magnitude U)
- 1b) clear SCIENCE in quiescent case (magnitude U)
- 2a) clear ACQUISITION in flaring case (magnitude U + ΔU)
- 2b) clear SCIENCE in flaring case with continuum only
- 2c) clear SCIENCE in flaring case with emission lines added

In each case the count rates are compared to the flight software limits.

Step 1: “Quiescent” ETCs

- ETCs with the quiescent magnitude need to be run for the acquisition (1a) and science (1b) exposures.
- For M-dwarf template in the ETC, *use actual data whenever available* (user-supplied spectrum)
 - make sure the input spectrum overlaps the passband of the chosen setting
- Otherwise use black body or Kurucz model (but these do not have chromospheric emission lines) normalized to GALEX NUV (or U) magnitude

Step 2: “Flare” ETCs

The Flare ETCs follow the guidelines in the ISR, which are:

- NUV observations:
 - Black body at $T=9000$ K normalized to $U=U_{\text{quiescent}}+\Delta U$
- FUV observations:
 - Black body at $T=9000$ K normalized to $U=U_{\text{quiescent}}+\Delta U$
 - add C IV and Si IV emission from equations 2 & 3 in ISR
 - add Ly α emission from equation 4 in the ISR

If any ETC calculation exceeds the flight software (FSW) local or global limits listed in the table on next slide (i.e. if there is a 10^{-4} chance of safing the detector), **the observation cannot proceed**.

Flare ETCs have to be performed separately for the acquisition (2a) and science exposures, with continuum (2b) and then with emission lines added (2c). See examples that follow

Flight Software (FSW) Limits

Detector	FSW global limit (cts/sec)	FSW local limit (cts/sec/pix)
COS/MAMA (NUV)	770 000	IMAGING: 104 SPECTROSCOPY: 180
COS/XDL (FUV)	60 000	2.7

Use these limits for comparing to all M-dwarf ETC calculations.

Note the FSW limits are higher than the standard screening limits.

Note the NUV local limits were updated in October 2017 following reanalysis of the brightest pixel fractions in NUV observations.

Example: HIP 17695

- target=HIP 17695 (M3.0V)
- $U=14.052$ B=13.048 V=11.537 (SIMBAD)
- No H α EW so assuming active case
- GALEX NUV=18.52
- $T_{\text{eff}}=3400$ K
- $U_{\text{flare}}=U+\Delta U$ where $\Delta U=-8.0 \rightarrow U_{\text{flare}}=6.05$
- $d=16$ pc, $R=0.39 R_{\odot}$

In the following slides we go through the ETC calculations for this target.

Requested Signal/Noise Ratio = 40.000
gives: Time = 2.4308 seconds
Exposure time calculation **HAD WARNINGS.**
WARNING MESSAGE: Total count rate per pixel 91.3762 exceeds bright limit 50.

1a) QUIESCENCE ACQ. ETC
(ASSUMING NUV IMAGING)

Plots

Detailed Information			
Counts (box of 9 x 9 pixels)			
Source	658.322	1,600.23	40.00
Background	0.095	0.23	0.48
Sky	0.028	0.07	0.26
Dark Current	0.067	0.16	0.40
Total in selected region	658.417	1,600.46	40.01
Brightest Pixel (single exposure)	91.376	222.12	
Count rate entire detector	1,531.731		

Extraction region box of 9 x 9 pixels	
Area (pixels)	81.00
Fraction of flux	1.00
Fraction of flux in brightest pixel	0.14
Effective Wavelength	3923.56 Å

Instrument name: COS

Mode: ACQ/IMAGE
Detector: NUV
Mirror: Mirror A
Aperture: Primary Science Aperture

Target: [point source]

Spectrum: Black body at 3400K
Extinction E(B-V): None
Normalization: Renormalized to abmag = 18.52 in filter Galex/NUV
Redshift: None
Emission Lines: None

USE USER-SUPPLIED SPECTRUM WHENEVER POSSIBLE

SWITCH TO MIRRORB NEEDED
SINCE LOCAL RATE IS >50

Exposure time (seconds) = 1,800.0000 at wavelength 1310.00 Å
gives: SNR = 0.0003 (per resolution element)

Table of Source and Noise Counts per Pixel

Plots			
<div>Total CountsSignal-to-noiseInput Target SpectrumThroughputObserved Target Spectrum</div>			
Detailed Information			
Counts (box 57 pixels high)			Count rate (counts/s)
Source	(1 pixel)		Total counts (counts)
Background	(8 pix resel)		Associated noise (counts)
Sky			
Dark Current			
Total in selected region			
Brightest Pixel (single exposure) (at 1306.70 Å)			
Brightest Pixel in Segment A (at 1306.70 Å)			
Brightest Pixel in Segment B (at 1191.09 Å)			
Count rate entire detector			
Count rate Segment A			
Count rate Segment B			

23,428

Buffer Time (sec)
For APT purposes, the recommended buffer time should be 2/3 of the buffer time calculated above. Please refer to Chapter 5.4 in the [COS Instrument Handbook](#) for more details.

Encircled energy fraction1.00

Instrument name: COS
Mode: spectroscopic
Detector: FUV
Central Wavelength: 1280
Grating: [G140L] Grating (R ~ 2000 - 5,000)
Aperture: Primary Science Aperture

Target: [point source]
Spectrum: Black body at 3400.0K
Extinction E(B-V): None
Normalization: Renormalized to abmag = 18.52 in filter Galex/NUV
Redshift: None
Emission Lines: None



USE USER-SUPPLIED SPECTRUM WHENEVER POSSIBLE

Requested Signal/Noise Ratio = 40.000
Exposure Time = 0.0006 seconds
WARNING MESSAGE: Observation countrate 2.55654e+06 exceeds NUV imaging global screening count rate limit of 1000000/sec
WARNING MESSAGE: Total count rate per pixel 354726 exceeds bright limit 50.

2a) FLARE ACQ. ETC
(ASSUMING NUV
IMAGING)

Plots

Input Target Spectrum Throughput Observed Target Spectrum

LOCAL & GLOBAL LIMITS VIOLATED

Detailed Information			
	Count rate (counts/s)	Total counts (counts)	Associated noise (counts)
Counts (box of 9 x 9 pixels)			
Source	2,555,662.571	1,600.00	40.00
Background	0.095	5.97e-05	7.73e-03
Sky	0.028	1.76e-05	4.20e-03
Dark Current	0.067	4.21e-05	6.49e-03
Total in selected region	2,555,662.666	1,600.00	40.00
Brightest Pixel (single exposure)	354,725.966	222.08	
Count rate entire detector	2,556,535.980		

Extraction region box of 9 x 9 pixels	
Area (pixels)	81.00
Fraction of flux	1.00
Fraction of flux in brightest pixel	0.14
Effective Wavelength	2533.23 Å

Instrument name: COS

Mode: ACQ/IMAGE
Detector: NUV
Mirror: Mirror A
Aperture: Primary Science Aperture

Target: [point source]

Spectrum: Black body at 9000.OK
Extinction E(B-V): None
Normalization: Renormalized to vegamag = 6.05 in filter Johnson/U
Redshift: None
Emission Lines: None

Requested Signal/Noise Ratio = 10.000 at wavelength 1310.00 Å (per resolution element)
gives: Time = 2.5611 seconds

Exposure time calculation: ~~Hit~~ **WARNINGS.**

WARNING MESSAGE: Buffer time 42.8531 is less than minimum 80 seconds.
WARNING MESSAGE: Total count rate per pixel 1.18744 exceeds bright limit 0.666667.

WARNING MESSAGE: Segment count rate 5.28e+04 will have a >5 percent reduction in detected count rate due to detector dead-time effects not included in the ETC. See section 4.1.5 of the COS Instrument Handbook for details.

WARNING MESSAGE: Segment count rate 52805.7153265 exceeds segment/stripe global count rate limit of 15000 counts per second for non-variable sources.

[Table of Source and Noise Counts per Pixel](#)

LOCAL & GLOBAL LIMITS VIOLATED

Plots

Total Counts Signal-to-noise Inout Target Spectrum Throughout Observed Target Spectrum

Detailed Information

Counts (box 57 pixels high)
Source
Background
Sky
Dark Current
Total in selected region
Brightest Pixel (single exposure) (at 1482.23 Å)
Brightest Pixel in Segment A (at 1482.23 Å)
Brightest Pixel in Segment B (at 1195.45 Å)
Count rate entire detector
Count rate Segment A
Count rate Segment B

**PLOT INPUT
TARGET SPECTRUM
AND READ OFF FLUX AT
3650 and 1500 Å, f_{3650}
and f_{1500} .**

Buffer Time (sec) 42

For APT purposes, the recommended buffer time should be 2/3 of the buffer time calculated above. Please refer to Chapter 5.4 in the [COS Instrument Handbook](#) for more details.

Encircled energy fraction 1.00

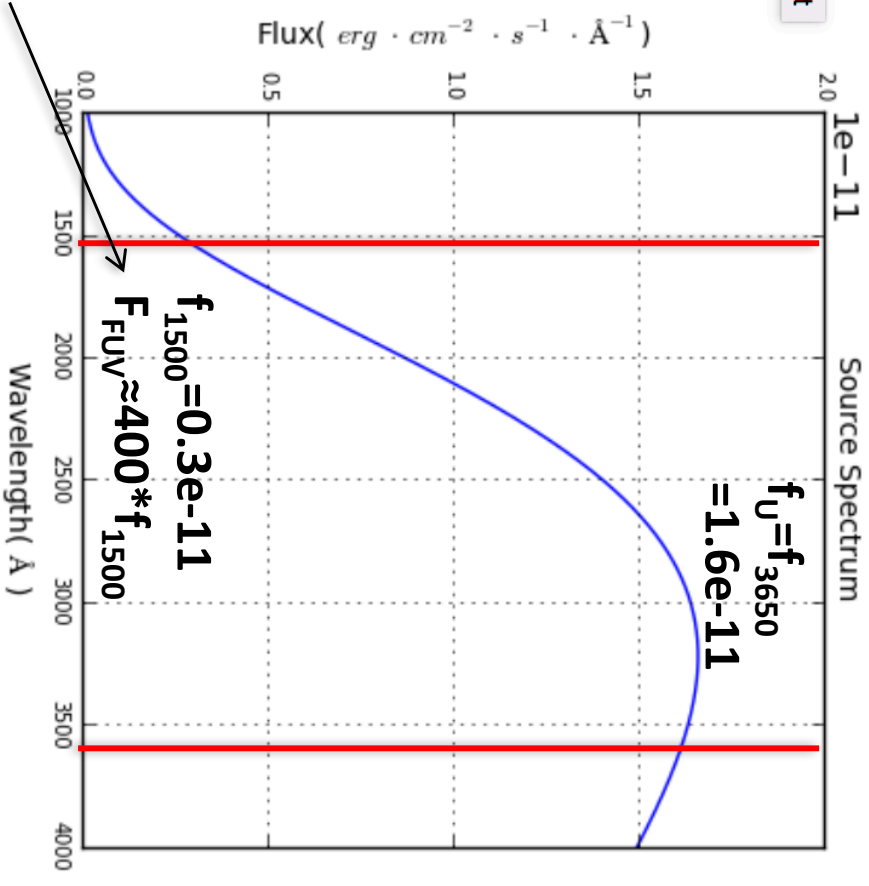
Instrument name: COS

Mode: spectroscopic
Detector: FUV
Central Wavelength: 1280
Grating: [G140L] Grating (R ~ 2000 - 5,000)
Aperture: Primary Science Aperture

Target: [point source]

Spectrum: Black body at 9000.0K
Extinction E(B-V): None
Normalization: Renormalized to vegamag = 6.05 in filter Johnson/U
Redshift: None
Emission Lines: None

2b) FLARE SCIENCE ETC (CONTINUUM ONLY)



Factor 400 is because GALEX FUV bandpass is 400 Å wide
Alternatively, integrate from 1350-1750 Å to get F_{FUV}

Calculating line flux (C IV, Si IV, Ly α)

See equations 2-4 in ISR

- $\log f_{\text{C IV}} = 0.32 + 0.92 \log f_{\text{U}}$
- $\log f_{\text{Si IV}} = 2.4 + 1.10 \log f_{\text{U}}$
- $\log f_{\text{Ly}\alpha} = 3.97 + 0.43 \log F_{\text{FUV}} - 1.14 \log (d/R_*)$

Line fluxes ($f_{\text{C IV}}, f_{\text{Si IV}}, f_{\text{Ly}\alpha}$) are in units of $\text{erg cm}^{-2} \text{ s}^{-1}$

F_{FUV} is integrated flux in GALEX FUV bandpass in units of $\text{erg cm}^{-2} \text{ s}^{-1}$

f_{U} is flux at 3650 Å in units of $\text{erg cm}^{-2} \text{ s}^{-1} \text{ Å}^{-1}$

d and R_* are in same unit

For HIP 17695:

- $\log f_{\text{C IV}} = -9.61$ \rightarrow $f_{\text{C IV}} = 2.4\text{e-}10$
- $\log f_{\text{Si IV}} = -9.48$ \rightarrow $f_{\text{Si IV}} = 3.3\text{e-}10$
- $\log f_{\text{Ly}\alpha} = -10.43$ \rightarrow $f_{\text{Ly}\alpha} = 3.7\text{e-}11$

Requested Signal/Noise Ratio = 10,000 at wavelength 1393.78 Å (per resolution element)
gives: Time = 2.564 seconds
Exposure time calculation **HAD WARNINGS.**
WARNING MESSAGE: Buffer time 31.0882 is less than minimum 80 seconds.
WARNING MESSAGE: Total count rate per pixel 432.505 exceeds bright limit 0.666667.
WARNING MESSAGE: Segment count rate 7.36e+04 will have a >5 percent reduction in detected count rate due to detector dead-time effects not included in the ETC. See section 4.1.5 of the COS Instrument Handbook for details.
WARNING MESSAGE: Segment count rate 73638.1317646 exceeds segment/strip global count rate limit of 15000 counts per second for non-variable sources.

2c) FLARE SCIENCE ETC
(CONTINUUM+LINES)

[Table of Source and Noise Counts per Pixel](#)

Plots

- Total Counts
- Signal-to-noise
- Inout Target Spectrum
- Throughout
- Observed Target Spectrum

LOCAL & GLOBAL LIMITS VIOLATED
BUFFER TIME ALSO TOO SHORT

Detailed Information			
Counts (box 57 pixels high)			
Source	Count rate (counts/s)	Total counts (counts)	Associated noise (counts)
Background	(1 pixel) 6.508	(6 pix resel) 100.00	10.00
Sky	1.585e-04	2.43e-03	0.05
Dark Current	2.389e-11	3.67e-10	1.92e-05
Total in selected region	1.585e-04	2.43e-03	0.05
Brightest Pixel (single exposure) (at 1393.78 Å)	6.508	100.00	10.00
Brightest Pixel in Segment A (at 1393.78 Å)	432.505	1,107.67	
Brightest Pixel in Segment B (at 1195.45 Å)	432.505		
Count rate entire detector	0.347		
Count rate Segment A	75,880.909		
Count rate Segment B	73,638.132		
	2,242.777		

Buffer Time (sec)
For APT purposes, the recommended buffer time should be 2/3 of the buffer time calculated above. Please refer to Chapter 5.4 in the [COS Instrument Handbook](#) for more details.

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Instrument name: COS

Mode: spectroscopic
Detector: FUV
Central Wavelength: 1280
Grating: [G140L] Grating (R ~ 2000 - 5,000)
Aperture: Primary Science Aperture

Target: [point source]

Spectrum: Black body at 9000.0K
Extinction E(B-V): None
Normalization: Renormalized to vegamag = 6.05 in filter Johnson/J
Redshift: None
Emission lines:
Line at Center 1215.7 Å FWHM 0.5 Å Flux 3.7e-11 FJ
Line at Center 1393.8 Å FWHM 0.2 Å Flux 3.3e-10 FJ
Line at Center 1548.2 Å FWHM 0.2 Å Flux 9e-11 FJ

3 lines added in ETC, note different
line width for Ly-a (0.5 Å)

If screening limits are exceeded

- If violation is with COS/NUV ACQ/IMAGE:
 - Investigate offset-star acquisition (if point source within 2 arcmin)
 - Investigate switch to MIRRORB, BOA, or spectroscopic ACQ.
 - Consider a blind pointing (no acquisition) if your observations do not require high flux or wavelength accuracy.
- If violation is with COS SCIENCE:
 - Investigate switch of grating (L to M)
 - Consider substituting a more distant target of same spectral type
 - Consider a switch to STIS. This requires a request to the Telescope Time Review Board (TTRB), submitted online via the Program Status Page under the “Request an observing change” link.
- Target substitutions that do not alter the science goals can be approved within the COS team as minor change requests if no duplication exists. This should be discussed with your Contact Scientist.

Further information that can be taken into account when calculating M-dwarf count rates

The following items can be used to clear targets, on a case-by-case basis:

- information about the flare frequency distribution for a particular target
- information about the ISM $N(\text{H I})$ for a particular target and how that can be used to reduce $L_{\gamma\alpha}$ intensity for a particular target
- information about why the width of the lines should be broader for a particular target

Pls should contact their CS if any of this information is relevant to their program.