



## 14479 - The global view of the ionized outflows in NGC 4051

Cycle: 24, Proposal Category: GO

(Availability Mode: SUPPORTED)

### INVESTIGATORS

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### VISITS

<i>Visit</i>	<i>Targets used in Visit</i>	<i>Configurations used in Visit</i>	<i>Orbits Used</i>	<i>Last Orbit Planner Run</i>	<i>OP Current with Visit?</i>
01	(1) NGC-4051	COS/FUV COS/NUV	4	15-Mar-2016 21:05:20.0	yes

4 Total Orbits Used

## **ABSTRACT**

We propose to observe the bright active galactic nucleus NGC 4051 for 120 ks jointly with HST and Astro-H. This source hosts one of the most extraordinary multi-phase ionized outflows. For the first time, we will acquire a high-resolution spectrum of the low, medium and highly ionized outflow in a low-mass black hole. We will study the connection between the X-ray and UV absorber and the disk winds mapping the ionization structure, kinematic behavior and relative abundance.

## **OBSERVING DESCRIPTION**

We will observe NGC 4051 simultaneously in the X-ray and the UV with a 120 ks observation using the RGS on XMM-Newton as the prime instrument combined with a an HST-COS observation of 4 orbits duration. We also ask to coordinate these observations with an expected Astro-H observation (with a net exposure of 100 ks) on a best effort basis. We will study the variability of the warm absorber in both the UV and the X-ray on short time scales, for the first time including HST, XMM-Newton and Astro-H. This source is one of the best cases for variability studies in the X-rays using both RGS and EPIC-pn. This will be done either through X-ray time resolved spectroscopy (Krongold et al. 2007) or the study of the continuum-lagging warm absorber using timing (Silva et al. 2015).

\* For the first time, we will have global, high-resolution, and simultaneous picture of the grand design of the ionized outflow and associated narrow emission lines: HST-COS will map the low ionization species (Si iii, Ciii, Si iv, Civ, Nv), possibly the long-distance tail of the disk wind.

\* XMM-Newton-RGS will bridge all the components: the low ionization ones (via the ions belonging to both the X-ray and UV band, Costantini 2010) and the intermediate ionization multi-layer gas, that is largely inaccessible to Astro-H. Finally, Astro-H-SXS, with 5 eV resolution, will provide an unprecedented coverage of the medium-hard energy band, opening an extraordinary discovery space.

\* The thorough census of the ionized gas will allow us to meaningfully test theoretical scenarios especially on the connection between high-velocity disk winds and the warm absorber: is the gas distributed in discrete components or a continuous flow? Would the initial energy be conserved throughout the flow?

NGC 4051 has a history of significant changes in both the underlying continuum and ionization structure. Simultaneous UV-X-ray observations will be key for a true understanding of any unexpected event (e.g. obscuration, appearance or disappearance of new components). This has been the case in the past for e.g. NGC 5548 (Kaastra et al. 2014), in Mrk 335 (Longinotti et al. 2013), and in NGC 985 (Ebrero et al., submitted)

We will observe NGC 4051 with HST-COS for 4 orbits using gratings G130M and G160M in order to observe the main absorption line transitions in C III\* 1176, Ly alpha, N V, Si IV, and C IV. Our previous observational campaigns on Mrk 279, Mrk 509, NGC 5548, and NGC 985 all achieved good results with a signal-to-noise ratio of 20 per resolution element in the continuum for these objects. To achieve a 4-fold diversity of grating settings for each grating, we use multiple central wavelengths for G130M and G160M to make sure we span the gap between segments A and B, and we use different FPPOS positions for each of those. For Ly alpha and N V using grating G130M, assuming a historical median flux of  $1.3e-14$  erg/cm<sup>2</sup>/s/A at 1368 A (Dunn et al. 2006) this requires a minimum of  $t=2000$  s, and for C IV in G160M,  $t=2000$  s. Including overheads, these observations therefore require a total of 4 orbits. We note that the high resolution afforded by COS makes our proposed observations robust to flux variations to fainter levels. The  $\sim 100$  km/s widths of the absorption troughs are spanned by 4 COS resolution elements. If NGC 4051 were half as bright, we could bin our spectrum up by a factor of two and still oversample the absorption troughs at the same S/N.

These observations pose no bright object concerns. All historical flux levels for NGC 4051 lie below the bright object limits for COS. Since NGC 4051 has been observed successfully before (see HST PID 11834), there are also no surrounding field objects that are too bright. NGC 4051 is faint enough that we can safely use an imaging target acquisition. Our ETC calculations use the ETC FOS quasar spectrum redshifted to  $z=0.002336$  with foreground extinction of  $E(B-V)=0.011$  and normalized to the historical minimum and maximum flux at 1368 A ( $flam\_min=0.57e-14$ ,  $flam\_max=2.2e-14$ , Dunn et al. 2006). In order to get our limiting cases and be absolutely sure that an imaging target acq is safe, we use a maximum flux that is twice the historical maximum:

- ACQUISITION -

Configuration	Flux	EXP time	Max cts/s/pix	Total rate	Buffer Time	COS ETC ID
G130M/1291	4.40e-14	5.3 s	42	1387	----	COS.im.768334
G130M/1291	0.57e-14	41 s	5.4	997	----	COS.im.768333

- EXPOSURES -

Configuration	Flux	EXP time	Max cts/s/pix	Total rate	Buffer Time	COS ETC ID
G130M/1291	1.30e-14	1000	0.11	1013 2327		COS.sp.768323
G130M/1291	2.20e-14	1000	0.12	1429 1650		COS.sp.768330
G160M/1600	1.30e-14	1000	0.004	414 5695		COS.sp.768326
G160M/1600	2.20e-14	1000	0.007	606 3889		COS.sp.768331

Proposal 14479 - Visit 01 - The global view of the ionized outflows in NGC 4051

Wed Mar 16 01:05:22 GMT 2016

<b>Visit</b>	<p><b>Proposal 14479, Visit 01, implementation</b></p> <p><b>Diagnostic Status: Warning</b></p> <p>Scientific Instruments: COS/FUV, COS/NUV</p> <p>Special Requirements: SCHED 100%</p> <p><i>Comments: Should be simultaneous with the coordinated XMM-Newton observation. To achieve a 4-fold diversity of grating settings for each grating, instead of using 4 FPPOS positions for each grating, we use multiple central wavelengths for G130M and G160M to make sure we span the gap between segments A and B, and we use different FPPOS positions for each of those.</i></p>																	
	<p>(Visit 01) Warning (Form): For the best data quality, it is strongly recommended that all four FP-POS positions be used when observing at a given COS CENWAVE setting.</p>																	
<b>Diagnosics</b>																		
<b>Fixed Targets</b>	<table border="1"> <thead> <tr> <th>#</th> <th>Name</th> <th>Target Coordinates</th> <th>Targ. Coord. Corrections</th> <th>Fluxes</th> <th>Miscellaneous</th> </tr> </thead> <tbody> <tr> <td>(1)</td> <td>NGC-4051</td> <td>RA: 12 03 9.6860 (180.7903583d) Dec: +44 31 52.54 (44.53126d) Equinox: J2000</td> <td>Redshift: 0.002336</td> <td>V=12.92+/-0.5 F(1368)=1.3e-14</td> <td>Reference Frame: ICRS</td> </tr> </tbody> </table>	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous	(1)	NGC-4051	RA: 12 03 9.6860 (180.7903583d) Dec: +44 31 52.54 (44.53126d) Equinox: J2000	Redshift: 0.002336	V=12.92+/-0.5 F(1368)=1.3e-14	Reference Frame: ICRS					
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<p><i>Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.</i></p> <p><i>Extended=NO</i></p>																		

Proposal 14479 - Visit 01 - The global view of the ionized outflows in NGC 4051

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit	
Exposures	1	(COS.im.76 8333)	(1) NGC-4051	COS/NUV, ACQ/IMAGE, PSA	MIRRORB			50 Secs (50 Secs) [==>]	[1]	
	<i>Comments: Exposure time is chosen for the faintest historical flux, 1.2e-14.</i>									
	2	(COS.sp.768 323)	(1) NGC-4051	COS/FUV, TIME-TAG, PSA	G130M 1291 A	BUFFER-TIME=47 5; FP-POS=3		1060 Secs (1060 Secs) [==>]	[1]	
	<i>Comments: We use BUFFER-TIMES much shorter than the 2/3*ETC value for brightest historical flux since this is even safer. They are optimized to be 110 s less than the exposure time to minimize the overhead between exposures.</i>									
	3	(COS.sp.768 323)	(1) NGC-4051	COS/FUV, TIME-TAG, PSA	G130M 1291 A	BUFFER-TIME=47 5; FP-POS=4		1065 Secs (1065 Secs) [==>]	[1]	
	<i>Comments: We use BUFFER-TIMES much shorter than the 2/3*ETC value for brightest historical flux since this is even safer. They are optimized to be 110 s less than the exposure time to minimize the overhead between exposures.</i>									
	4	(COS.sp.768 323)	(1) NGC-4051	COS/FUV, TIME-TAG, PSA	G130M 1327 A	BUFFER-TIME=59 2; FP-POS=1		1294 Secs (1294 Secs) [==>]	[2]	
	<i>Comments: We use BUFFER-TIMES much shorter than the 2/3*ETC value for brightest historical flux since this is even safer. They are optimized to be 110 s less than the exposure time to minimize the overhead between exposures.</i>									
	5	(COS.sp.768 323)	(1) NGC-4051	COS/FUV, TIME-TAG, PSA	G130M 1327 A	BUFFER-TIME=59 2; FP-POS=2		1296 Secs (1296 Secs) [==>]	[2]	
<i>Comments: We use BUFFER-TIMES much shorter than the 2/3*ETC value for brightest historical flux since this is even safer. They are optimized to be 110 s less than the exposure time to minimize the overhead between exposures.</i>										
6	(COS.sp.768 326)	(1) NGC-4051	COS/FUV, TIME-TAG, PSA	G160M 1600 A	BUFFER-TIME=59 2; FP-POS=3		1294 Secs (1294 Secs) [==>]	[3]		
<i>Comments: We use BUFFER-TIMES much shorter than the 2/3*ETC value for brightest historical flux since this is even safer. They are optimized to be 110 s less than the exposure time to minimize the overhead between exposures.</i>										
7	(COS.sp.768 326)	(1) NGC-4051	COS/FUV, TIME-TAG, PSA	G160M 1600 A	BUFFER-TIME=59 2; FP-POS=4		1294 Secs (1294 Secs) [==>]	[3]		
<i>Comments: We use BUFFER-TIMES much shorter than the 2/3*ETC value for brightest historical flux since this is even safer. They are optimized to be 110 s less than the exposure time to minimize the overhead between exposures.</i>										
8	(COS.sp.768 326)	(1) NGC-4051	COS/FUV, TIME-TAG, PSA	G160M 1623 A	BUFFER-TIME=59 2; FP-POS=1		1294 Secs (1294 Secs) [==>]	[4]		
<i>Comments: We use BUFFER-TIMES much shorter than the 2/3*ETC value for brightest historical flux since this is even safer. They are optimized to be 110 s less than the exposure time to minimize the overhead between exposures.</i>										
9	(COS.sp.768 326)	(1) NGC-4051	COS/FUV, TIME-TAG, PSA	G160M 1623 A	BUFFER-TIME=59 2; FP-POS=2		1296 Secs (1296 Secs) [==>]	[4]		
<i>Comments: We use BUFFER-TIMES much shorter than the 2/3*ETC value for brightest historical flux since this is even safer. They are optimized to be 110 s less than the exposure time to minimize the overhead between exposures.</i>										



