# 16919 - Ultraviolet spectroscopic confirmation of an active binary intermediate-mass black hole

Cycle: 29, Proposal Category: GO

(UV Initiative)

(Availability Mode: SUPPORTED)

**INVESTIGATORS**



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**VISITS**

| *Visit* | *Targets used in Visit* | *Configurations used in Visit* | *Orbits Used* | *Last Orbit Planner Run* | *OP Current with Visit?* |
|---|---|---|---|---|---|
| 01 | (1) J163159.59+243740.2 | COS/FUV<br>COS/NUV | 4 | 30-Aug-2022 11:00:46.0 | yes |
| 04 | (1) J163159.59+243740.2 | COS/FUV<br>COS/NUV | 4 | 30-Aug-2022 11:00:47.0 | yes |

| *Visit* | *Targets used in Visit* | *Configurations used in Visit* | *Orbits Used* | *Last Orbit Planner Run* | *OP Current with Visit?* |
|---|---|---|---|---|---|
| 05 | (1) J163159.59+243740.2 | COS/FUV<br>COS/NUV | 4 | 30-Aug-2022 11:00:48.0 | yes |
| 02 | (1) J163159.59+243740.2 | COS/NUV | 3 | 30-Aug-2022 11:00:49.0 | yes |
| 03 | (1) J163159.59+243740.2 | COS/NUV | 2 | 30-Aug-2022 11:00:49.0 | yes |

17 Total Orbits Used

**ABSTRACT**

The origin and evolution of supermassive black holes (SMBHs) in galaxy centers remain among the most important open questions of modern astrophysics. They grow from yet unidentified BH seeds by accreting gas in the active galactic nucleus (AGN) phase or via coalescences during galaxy mergers. Low-mass BH seeds (100s MSun) should leave behind a population of intermediate-mass black holes (IMBHs) holding the key for SMBH origin. SMBH binaries form at the pre-coalescence stage and then become the sources of gravitation waves, which will likely be detected at cosmological distances by the LISA space mission.

We present the first candidate active IMBH binary, J1631+24 (z=0.0433; 190Mpc) with the mass ratio of 10:1 (10^6 and 10^5 MSun) detected via double-peaked broad optical hydrogen lines separated in velocity by 300 km/s in a compact low-mass elliptical galaxy with morphology suggestive of a past merger. The two-component shape and the velocity separation have been persistent over 17 years. If confirmed, it will be the first example of such a system directly proving the hierarchical growth of SMBHs in the low-mass regime.

Alternatively, dust near the AGN can cover and extinguish the receding part of the broad line component. We propose to observe J1631+24 using Cosmic Origins Spectrograph in the low-resolution far/near-UV setups (G140L/G230L), which cover several broad emission lines (Mg, C, H), originating from different areas of the broad-line region and, hence, expected to have different widths. If the velocity separation of the components remains the same, we will confirm the binary IMBH. If the red broad component disappears, this will favor the dust scenario.

We will analyze spectral lines profiles for MgII, CIII, CIV, and Ly-alpha lines by recovering the narrow line shape from forbidden lines in the range (taking into account spectral resolution variations across the spectral range) and fitting it simultaneously with two broad components represented by Gauss-Hermite and/or Lorentzian profiles. The procedure is overall similar to how we analyzed SDSS, Keck, and Magellan optical spectra with the only difference that it will not include stellar population template because its contribution is expected to be negligible.

**OBSERVING DESCRIPTION**

HST ultraviolet spectroscopic capabilities are absolutely essential to achieve our goals. No other space observatories with UV spectroscopic capabilities and enough collecting area to observe a faint extragalactic source exist. NASA Neil Gehrels Swift Observatory has a UV grism slitless spectroscopic mode in its UltraViolet and Optical Telescope, however, its spectral resolution and sensitivity are far below what is required to achieve our goals. Moreover, Swift does not offer far-UV capabilities at all.

We propose to use the Cosmic Origin Spectrograph (COS), the only available instrument providing a sufficient combination of spectral resolution and wavelength coverage to fulfill the goals of our project. To successfully resolve two broad components separated by 300km/s, we need a spectral resolving power of at least R=1500-2000, similar to that provided by SDSS in the optical. If the "dust" scenario is true, we do not expect to see any red wings in broad lines, and the blue peak offset by -250km/s from the systemic velocity will be obvious at R=1500. We also want the highest possible sensitivity and a large simultaneous wavelength coverage to observe several emission lines (with different ionization potentials) in one setup. Taking into account these considerations, we strongly favor COS over STIS, as the low-resolution gratings in the MAMA mode provide lower spectral resolution than we require. The UV flux in our galaxy as measured by GALEX is dominated by the contribution of the AGN at the 85 and 94% level in the NUV and FUV channels, as estimated from the shape of the stellar population template -- therefore, we do not expect any substantial contamination from the underlying population in the COS aperture. Our primary target in the NUV is the MgII line lambda=2800A redshifted to 2920A); the secondary target is the CIII lines (lambda=1907,1909A redshifted to ~1990A). The G230L grating in the 3000A central wavelength setup will cover both of them; we choose 3000 over 2950 to have slightly better wavelength coverage when combined with the FUV data. Our targets in the FUV range are Ly-alpha (lambda=1216A redshifted to 1268A) and C IV (lambda=1550A redshifted to 1617A) lines. The G140L grating with the 800A central wavelength will cover both of them with the maximum efficiency. We will use the ACCUM mode as the more efficient option provided that we do not need high temporal resolution.

We ran COS ETC with the QSO template (FOS based) as the best representation of the expected spectral shape, despite weaker broad lines in J1631+24 compared to a typical QSO because of the lower M_ BH. We used the flux normalization in the GALEX FUV and NUV bands and the published GALEX photometry of the source. To reach the S/N ratio of 30 per resolution element in Ly-alpha required for the line profile decomposition, we need about 9,800sec of integration time, which corresponds to 4 orbits in the G140L setup. To reach the S/N ratio of 20 per resolution element at R=1500 in the MgII line or 14 at R=2900 (the line is expected to be narrower than Ly-alpha, therefore the components will be better resolved and lower S/N ratio is needed to perform the analysis) we need 12,500sec, which corresponds to 5 orbits in the G230L setup. The

C{\sc iii} line is then expected to have S/N~20 per resolution element. Based on these calculations, we request 9 orbits for the entire program.

# Proposal 16919 - 01FUV (01) - Ultraviolet spectroscopic confirmation of an active binary intermediate-mass black hole

## Visit

**Proposal 16919, 01FUV (01), failed**

Tue Aug 30 15:00:50 GMT 2022

**Diagnostic Status: No Diagnostics**

Scientific Instruments: COS/FUV, COS/NUV

Special Requirements: (none)

## Fixed Targets

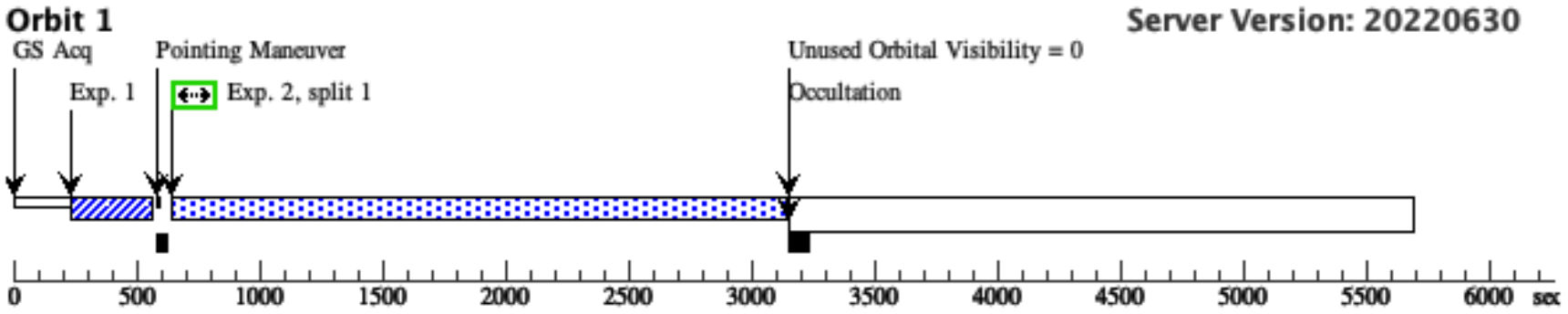
| # | Name | Target Coordinates | Targ. Coord. Corrections | Fluxes | Miscellaneous |
|---|---|---|---|---|---|
| (1) | J163159.59+243740.2 | RA: 16 31 59.5946 (247.9983108d)<br>Dec: +24 37 40.26 (24.62785d)<br>Equinox: J2000 | Proper Motion RA: 0<br>Proper Motion Dec: 0<br>Redshift: 0.0435 | V=17.5 | Reference Frame: ICRS |

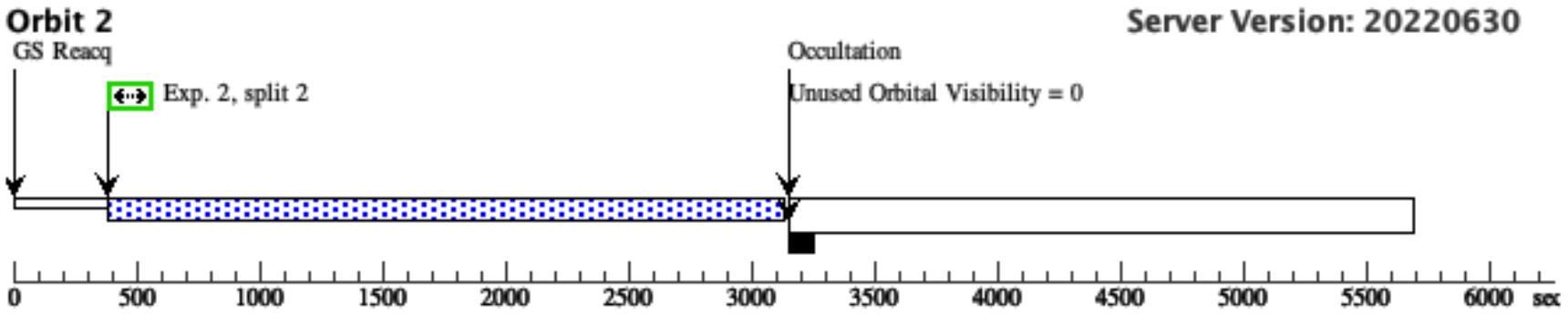
*Comments:*
*Category=GALAXY*
*Description=[DWARF ELLIPTICAL, SEYFERT]*
*Extended=NO*

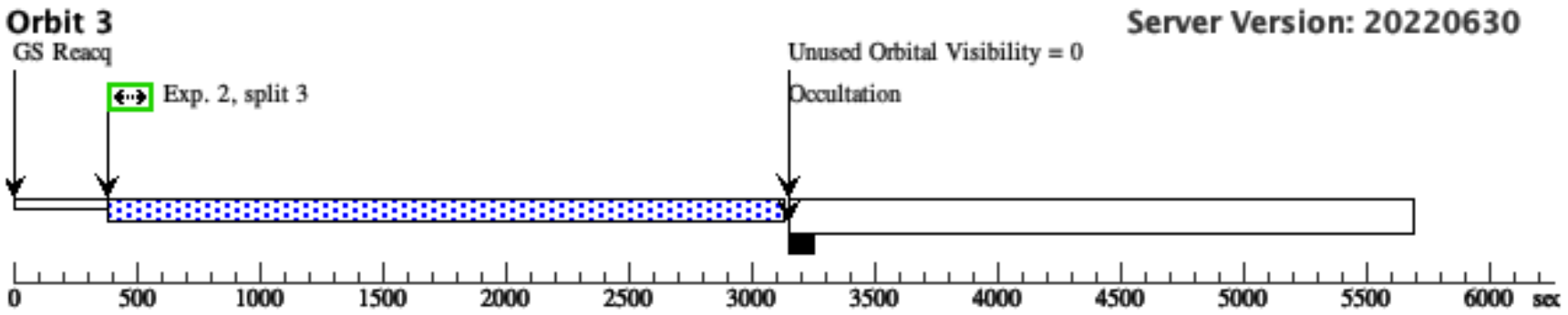
## Exposures

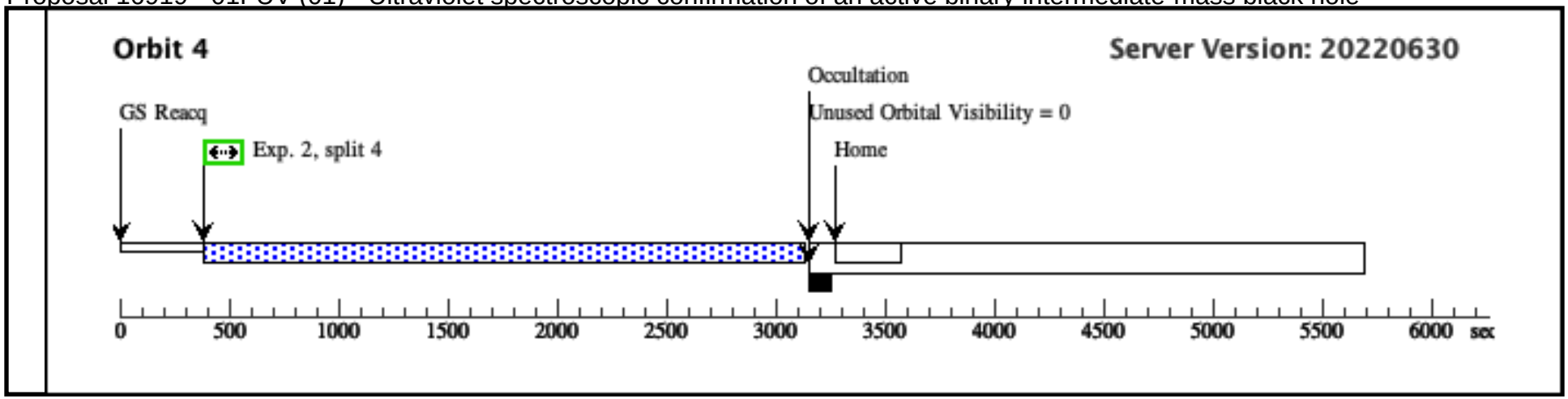
| # | Label (ETC Run) | Target | Config,Mode,Aperture | Spectral Els. | Opt. Params. | Special Reqs. | Groups | Exp. Time (Total)/[Actual Dur.] | Orbit |
|---|---|---|---|---|---|---|---|---|---|
| 1 | ACQ_01FUV (COS.sa.1742733) | (1) J163159.59+243740.2 | COS/NUV, ACQ/IMAGE, PSA | MIRRORA | | | | 60 Secs (60 Secs) | |
| | | | | | | | | *[==>]* | ***[1]*** |
| 2 | 01FUV_01 (COS.sp.1742569) | (1) J163159.59+243740.2 | COS/FUV, TIME-TAG, PSA | G140L<br>800 A | SEGMENT=A;<br>FP-POS=ALL;<br>BUFFER-TIME=3000;<br>FLASH=YES | | | 2448 Secs (10397 Secs) | |
| | | | | | | | | *[==>2294 Secs (Split 1)]* | ***[1]*** |
| | | | | | | | | *[==>2701.0 Secs (Split 2)]* | ***[2]*** |
| | | | | | | | | *[==>2701.0 Secs (Split 3)]* | ***[3]*** |
| | | | | | | | | *[==>2701.0 Secs (Split 4)]* | ***[4]*** |

Orbit Structure




Orbit 4
Server Version: 20220630
Occultation
GS Reacq
Unused Orbital Visibility = 0
Exp. 2, split 4
Home
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500
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sec

## Visit

**Proposal 16919, 01FUV (04), failed**

Tue Aug 30 15:00:50 GMT 2022

**Diagnostic Status: No Diagnostics**

Scientific Instruments: COS/FUV, COS/NUV

Special Requirements: (none)

*Comments: This is a duplicate of the failed visit 01 (FUV)*

## Fixed Targets

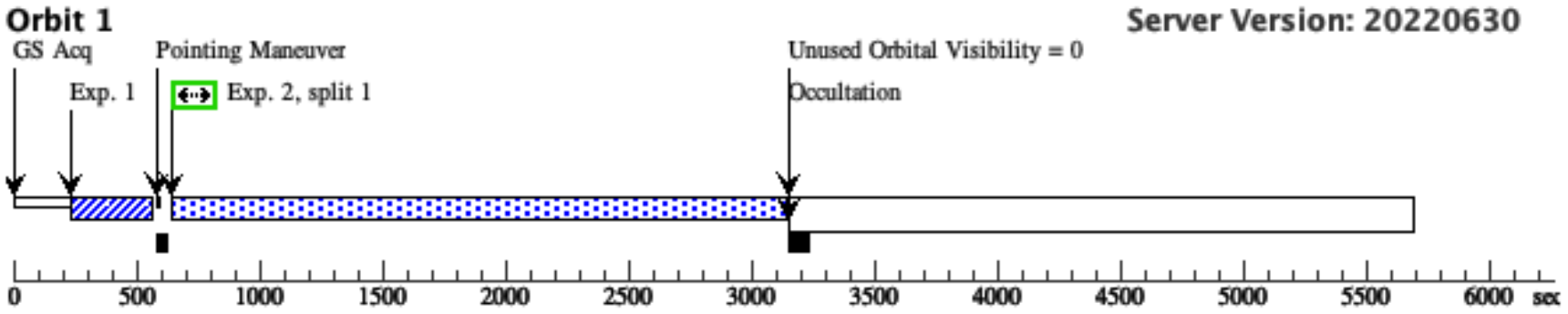
| # | Name | Target Coordinates | Targ. Coord. Corrections | Fluxes | Miscellaneous |
|---|---|---|---|---|---|
| (1) | J163159.59+243740.2 | RA: 16 31 59.5946 (247.9983108d)<br>Dec: +24 37 40.26 (24.62785d)<br>Equinox: J2000 | Proper Motion RA: 0<br>Proper Motion Dec: 0<br>Redshift: 0.0435 | V=17.5 | Reference Frame: ICRS |

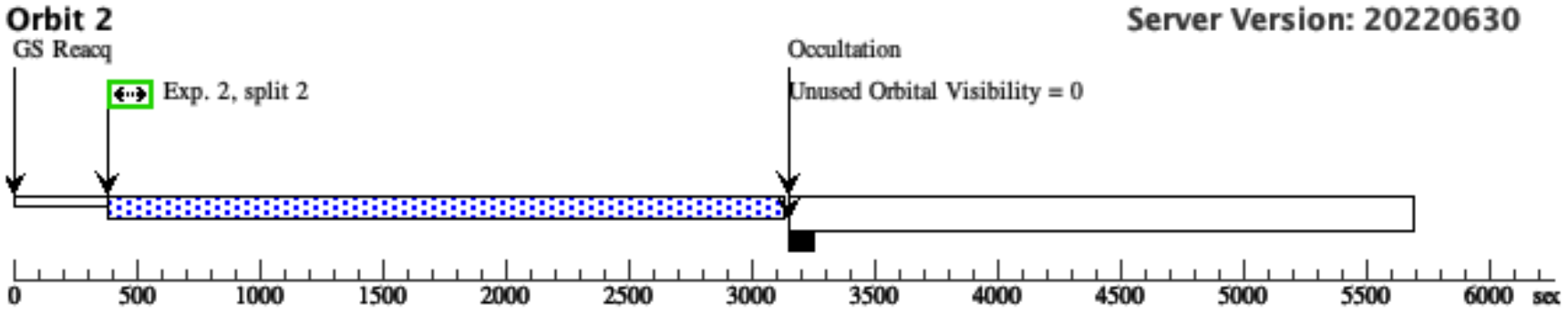
*Comments:*
*Category=GALAXY*
*Description=[DWARF ELLIPTICAL, SEYFERT]*
*Extended=NO*

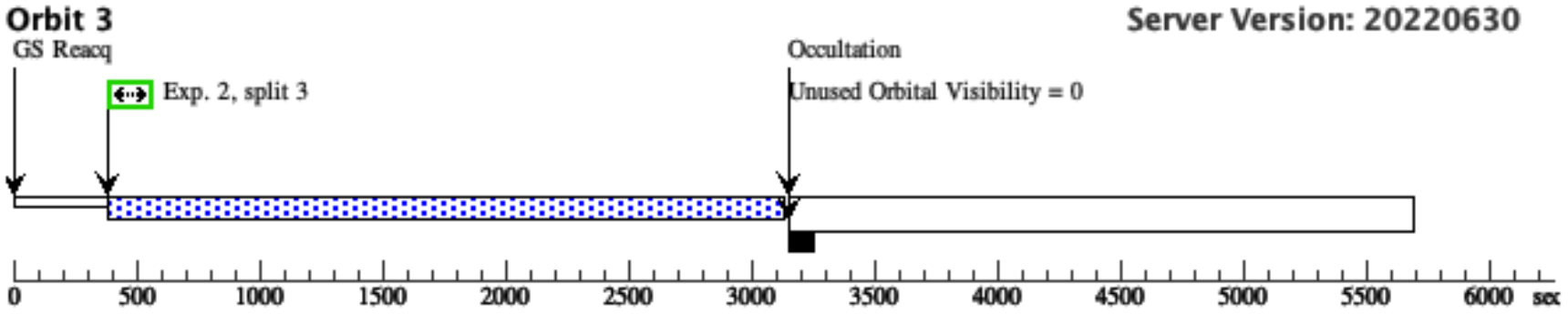
## Exposures

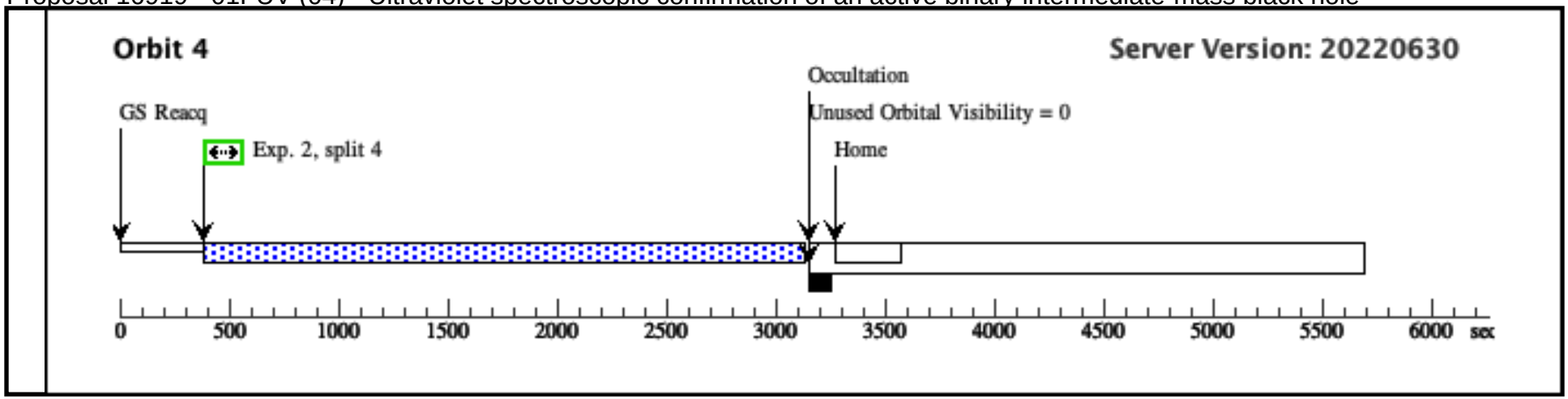
| # | Label (ETC Run) | Target | Config,Mode,Aperture | Spectral Els. | Opt. Params. | Special Reqs. | Groups | Exp. Time (Total)/[Actual Dur.] | Orbit |
|---|---|---|---|---|---|---|---|---|---|
| 1 | ACQ_01FUV (COS.sa.1742733) | (1) J163159.59+243740.2 | COS/NUV, ACQ/IMAGE, PSA | MIRRORA | | | | 60 Secs (60 Secs) | |
| | | | | | | | | *[==>]* | ***[1]*** |
| 2 | 01FUV_01 (COS.sp.1742569) | (1) J163159.59+243740.2 | COS/FUV, TIME-TAG, PSA | G140L 800 A | SEGMENT=A; FP-POS=ALL; BUFFER-TIME=3000; FLASH=YES | | | 2448 Secs (10397 Secs) | |
| | | | | | | | | *[==>2294 Secs (Split 1)]* | ***[1]*** |
| | | | | | | | | *[==>2701.0 Secs (Split 2)]* | ***[2]*** |
| | | | | | | | | *[==>2701.0 Secs (Split 3)]* | ***[3]*** |
| | | | | | | | | *[==>2701.0 Secs (Split 4)]* | ***[4]*** |

Orbit Structure




Orbit 4
Server Version: 20220630
Occultation
GS Reacq
Unused Orbital Visibility = 0
Exp. 2, split 4
Home
0
500
1000
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2000
2500
3000
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## Visit

**Proposal 16919, 01FUV (05)** Tue Aug 30 15:00:50 GMT 2022

**Diagnostic Status: No Diagnostics**

Scientific Instruments: COS/FUV, COS/NUV

Special Requirements: (none)

*Comments: This is a duplicate of the failed visit 04 (FUV)*

## Fixed Targets

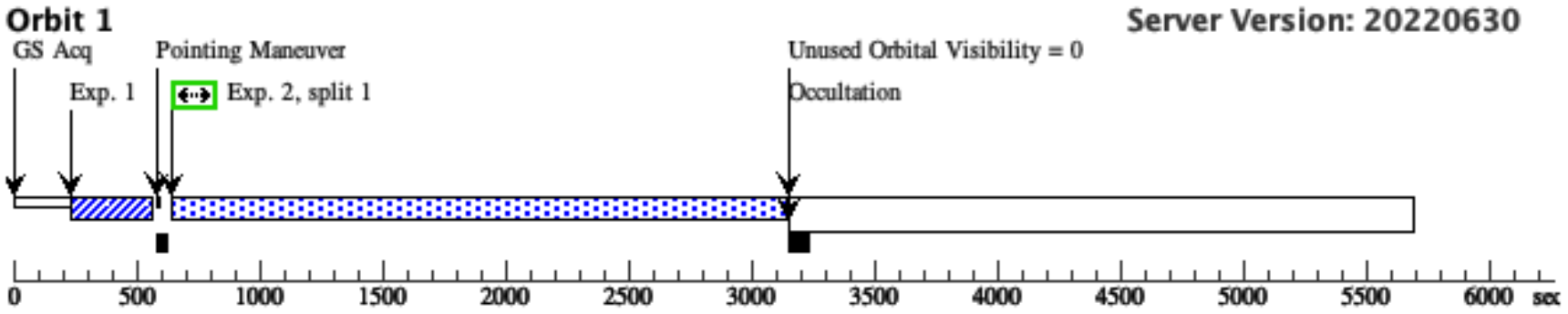
| # | Name | Target Coordinates | Targ. Coord. Corrections | Fluxes | Miscellaneous |
|---|---|---|---|---|---|
| (1) | J163159.59+243740.2 | RA: 16 31 59.5946 (247.9983108d)<br>Dec: +24 37 40.26 (24.62785d)<br>Equinox: J2000 | Proper Motion RA: 0<br>Proper Motion Dec: 0<br>Redshift: 0.0435 | V=17.5 | Reference Frame: ICRS |

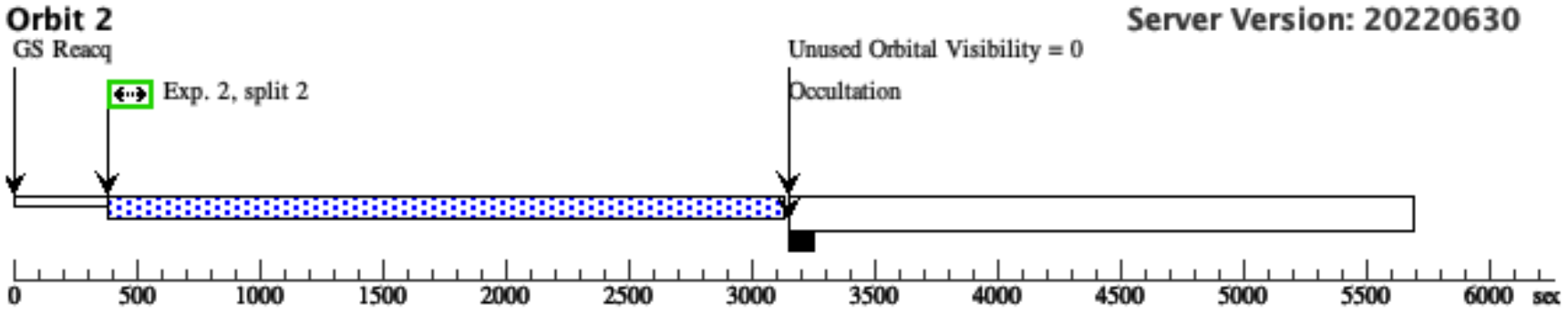
*Comments:*
*Category=GALAXY*
*Description=[DWARF ELLIPTICAL, SEYFERT]*
*Extended=NO*

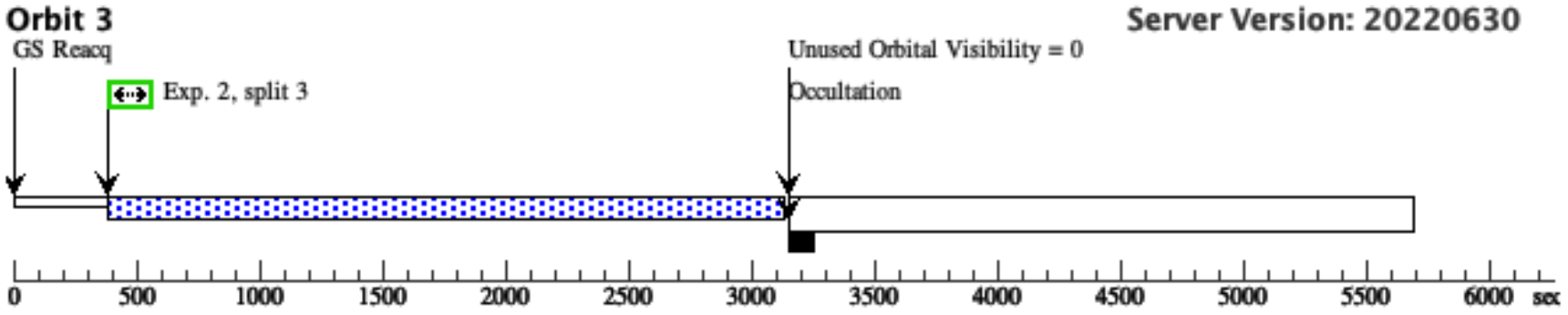
## Exposures

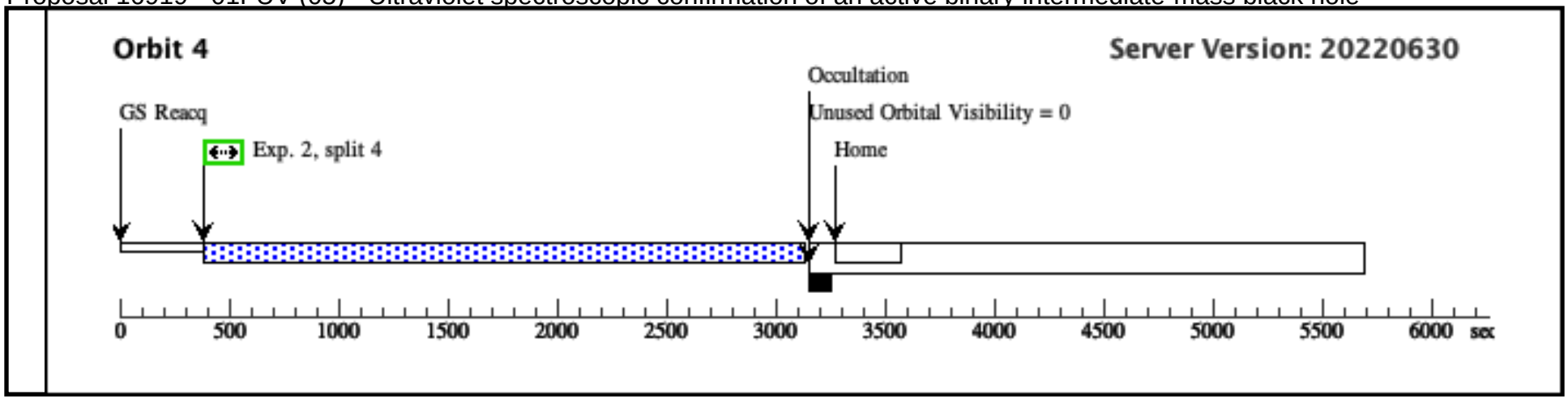
| # | Label (ETC Run) | Target | Config,Mode,Aperture | Spectral Els. | Opt. Params. | Special Reqs. | Groups | Exp. Time (Total)/[Actual Dur.] | Orbit |
|---|---|---|---|---|---|---|---|---|---|
| 1 | ACQ_01FUV (COS.sa.1742733) | (1) J163159.59+243740.2 | COS/NUV, ACQ/IMAGE, PSA | MIRRORA | | | | 60 Secs (60 Secs) | |
| | | | | | | | | *[==>]* | ***[1]*** |
| 2 | 01FUV_01 (COS.sp.1742569) | (1) J163159.59+243740.2 | COS/FUV, TIME-TAG, PSA | G140L 800 A | SEGMENT=A; FP-POS=ALL; BUFFER-TIME=3000; FLASH=YES | | | 2448 Secs (10397 Secs) | |
| | | | | | | | | *[==>2294 Secs (Split 1)]* | ***[1]*** |
| | | | | | | | | *[==>2701.0 Secs (Split 2)]* | ***[2]*** |
| | | | | | | | | *[==>2701.0 Secs (Split 3)]* | ***[3]*** |
| | | | | | | | | *[==>2701.0 Secs (Split 4)]* | ***[4]*** |

Orbit Structure




Orbit 4
Server Version: 20220630
Occultation
GS Reacq
Unused Orbital Visibility = 0
Exp. 2, split 4
Home
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
sec

## Visit

**Proposal 16919, 01NUV (02), completed** Tue Aug 30 15:00:50 GMT 2022

**Diagnostic Status: No Diagnostics**

Scientific Instruments: COS/NUV

Special Requirements: SAME ORIENT AS 01

## Fixed Targets

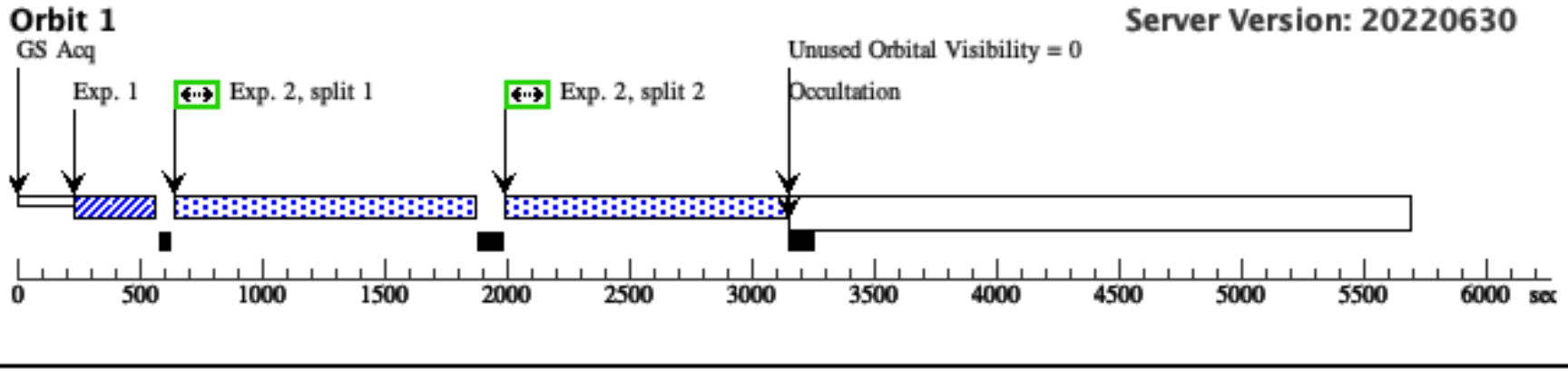
| # | Name | Target Coordinates | Targ. Coord. Corrections | Fluxes | Miscellaneous |
|---|---|---|---|---|---|
| (1) | J163159.59+243740.2 | RA: 16 31 59.5946 (247.9983108d)<br>Dec: +24 37 40.26 (24.62785d)<br>Equinox: J2000 | Proper Motion RA: 0<br>Proper Motion Dec: 0<br>Redshift: 0.0435 | V=17.5 | Reference Frame: ICRS |

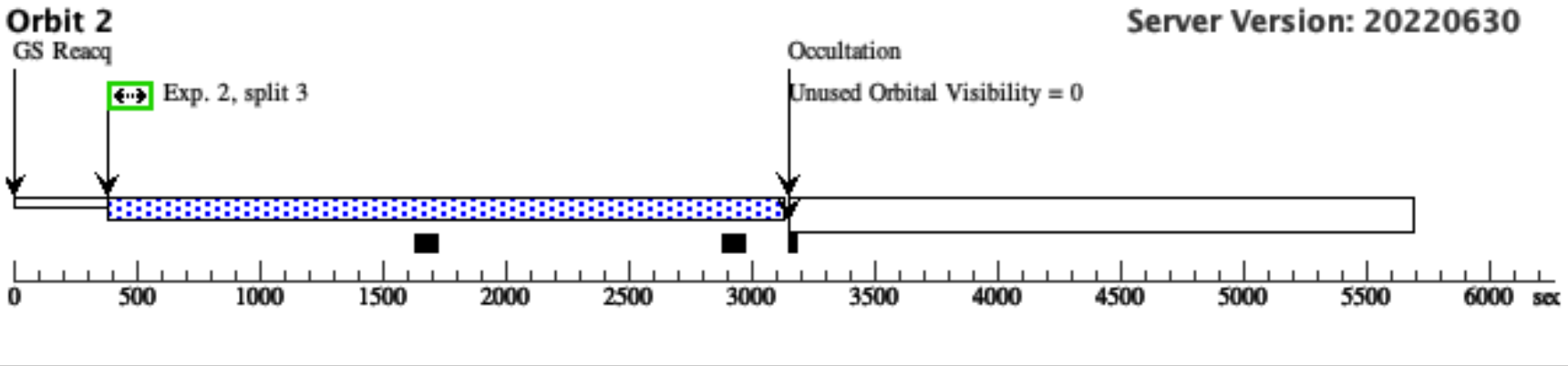
*Comments:*
*Category=GALAXY*
*Description=[DWARF ELLIPTICAL, SEYFERT]*
*Extended=NO*

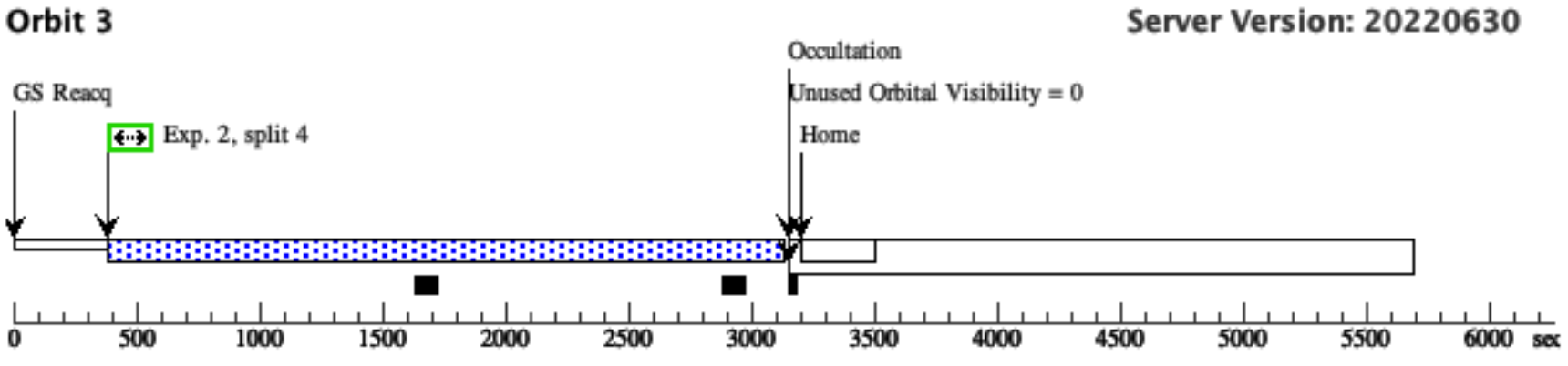
## Exposures

| # | Label (ETC Run) | Target | Config,Mode,Aperture | Spectral Els. | Opt. Params. | Special Reqs. | Groups | Exp. Time (Total)/[Actual Dur.] | Orbit |
|---|---|---|---|---|---|---|---|---|---|
| 1 | ACQ_01NUV (COS.sa.1742733) | (1) J163159.59+243740.2 | COS/NUV, ACQ/IMAGE, PSA | MIRRORA | | | | 60 Secs (60 Secs) | |
| | | | | | | | | *[==>]* | ***[1]*** |
| 2 | 01NUV_01 (COS.sp.1742570) | (1) J163159.59+243740.2 | COS/NUV, TIME-TAG, PSA | G230L 3000 A | FP-POS=ALL; BUFFER-TIME=1245; FLASH=YES | | | 2448 Secs (7718 Secs) | |
| | | | | | | | | *[==>1111.0 Secs (Split 1)]*<br>*[==>1131.0 Secs (Split 2)]* | ***[1]*** |
| | | | | | | | | *[==>2738.0 Secs (Split 3)]* | ***[2]*** |
| | | | | | | | | *[==>2738.0 Secs (Split 4)]* | ***[3]*** |

Orbit Structure



## Visit

**Proposal 16919, 02NUV (03), completed** Tue Aug 30 15:00:50 GMT 2022

**Diagnostic Status: No Diagnostics**

Scientific Instruments: COS/NUV

Special Requirements: SAME ORIENT AS 01

## Fixed Targets

| # | Name | Target Coordinates | Targ. Coord. Corrections | Fluxes | Miscellaneous |
|---|---|---|---|---|---|
| (1) | J163159.59+243740.2 | RA: 16 31 59.5946 (247.9983108d)<br>Dec: +24 37 40.26 (24.62785d)<br>Equinox: J2000 | Proper Motion RA: 0<br>Proper Motion Dec: 0<br>Redshift: 0.0435 | V=17.5 | Reference Frame: ICRS |

*Comments:*
*Category=GALAXY*
*Description=[DWARF ELLIPTICAL, SEYFERT]*
*Extended=NO*

## Exposures

| # | Label (ETC Run) | Target | Config,Mode,Aperture | Spectral Els. | Opt. Params. | Special Reqs. | Groups | Exp. Time (Total)/[Actual Dur.] | Orbit |
|---|---|---|---|---|---|---|---|---|---|
| 1 | ACQ_02NUV (COS.sa.1742733) | (1) J163159.59+243740.2 | COS/NUV, ACQ/IMAGE, PSA | MIRRORA | | | | 60 Secs (60 Secs) | |
| | | | | | | | | *[==>]* | ***[1]*** |
| 2 | 02NUV_01 (COS.sp.1742570) | (1) J163159.59+243740.2 | COS/NUV, TIME-TAG, PSA | G230L 3000 A | BUFFER-TIME=1245; FLASH=YES; FP-POS=ALL | | | 2448 Secs (4835 Secs) | |
| | | | | | | | | *[==>1062.0 Secs (Split 1)]*<br>*[==>1189 Secs (Split 2)]* | ***[1]*** |
| | | | | | | | | *[==>1320 Secs (Split 3)]*<br>*[==>1264 Secs (Split 4)]* | ***[2]*** |

Orbit Structure