# 14724 - Searching for a radio millisecond pulsar in a low-mass X-ray binary

Cycle: 24, 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) SAXJ1808.4-3658 | ACS/SBC | 2 | 29-Jul-2016 15:03:47.0 | yes |
| 02 | (1) SAXJ1808.4-3658 | WFC3/UVIS | 2 | 29-Jul-2016 15:03:49.0 | yes |

4 Total Orbits Used

**ABSTRACT**

Low-mass X-ray binaries (LMXBs) and millisecond radio pulsars (MSRPs) are two different manifestations of neutron stars in binary systems. Their evolution paths are thought to be linked, but many questions about their connection remain. Recently, three neutron stars have been discovered to transition back and forth between LMXB and MSRP states, opening a new vista to investigate the link between these different manifestations. The neutron star LMXB SAX J1808.4-3658 is a strong candidate to belong to this new class of transitional objects. Here, we propose to exploit the unique UV capabilities of the HST to search for the presence of an accretion disk in the quiescent state of this system. This gives insight into whether it can turn on as a MSRP when not accreting and hence if it is indeed a transitional object. In addition, we will search for thermal emission from the surface of the unusually cold neutron star in SAX J1808.4-3658, which has important implications for the physics of ultra-dense matter.

**OBSERVING DESCRIPTION**

Detecting a quiescent accretion disk or a hot neutron star in our target requires observations in the NUV/FUV bands. Observations with the Swift/UVOT in quiescence are not sensitive enough to detect the source in the NUV: u>20.5 mag (lambda_c~3465 A), and uvm2>21.5 mag (lambda_c~2246 A). This corresponds to NUV fluxes of <2E-17 erg/cm2/s/A (3465 A) and <1E-17 erg/cm2/s (2246 A), which is a factor of 5-20 above that expected for a quiescent accretion disk or a thermally emitting neutron star. Our science goals therefore require the unprecedented UV sensitivity of the HST. Given the unknown NUV/FUV magnitude of our target, we propose HST imaging observations.

To be able to determine the shape of the UV spectral energy distribution and to measure UV colors, we request observations using different NUV/FUV filters. To achieve the best sensitivity (our target is not in a crowded field), we chose the WFC3/UVIS for the NUV, and the ACS/SBC for the FUV. For the WFC3/UVIS we will use 3 filters: F336W (lambda_c~3355 A), F275W (lambda_c~2704 A), and F225W (lambda_c~2359 A). For the ACS/SBC we use 1 filter: F150LP (lambda_c~1500 A).

We used the online WFC3/UVIS and ACS/SBC exposure time calculators (v. 24.2). The distance to our target is 3.6 kpc, and the reddening is E(BV)= 0.23. Detecting a hot neutron star poses the strongest constraints on the science exposures. We assumed a black body of ~1E5 K (corresponding to the lowest neutron star temperatures in LMXBs), which yields a flux density of ~1E-18 erg/cm2/s/A. We aim for a SNR~10 at this flux density. For a remnant accretion disk we expect a higher UV flux and hence a higher SNR (a black body with a temperature of ~1E4 K, or a luminosity of ~8E30 erg/s, the coldest detected in quiescent LMXBs, would lead to FUV/NUV fluxes of ~5E-18 erg/cm2/s/A).

We used dither patterns for all science observations and for the WFC3/UVIS exposure time calculation we took into account lamp flashes to ensure that the minimum background for proper CTE is reached. We require 2 orbits of ACS/SBC observations, and 2 orbits of WFC3/UVIS observations, so 4 orbits in total. Little UV variability is expected for our targets and therefore the observations are divided into two visits (one per instrument) to ease the constraints on scheduling.

Our source is a transient X-ray source and can brighten to u~16.5 mag in outburst. The source is in outburst for ~1 month every ~2-5 years. The most recent outburst was in April 2015. Given the transient nature, we need to implement a safety procedure. We will obtain Swift observations (providing both X-ray and UV constraints) within 24 hr of the scheduled HST observations to ensure that our target is in quiescence.

## Visit

**Proposal 14724, Visit 01** Fri Jul 29 19:03:50 GMT 2016

**Diagnostic Status: No Diagnostics**

Scientific Instruments: ACS/SBC

Special Requirements: (none)

## Patterns

| # | Primary Pattern | | Secondary Pattern | Exposures |
|---|---|---|---|---|
| (1) | Pattern Type=ACS-SBC-DITHER-LINE<br>Purpose=DITHER<br>Number Of Points=3<br>Point Spacing=0.472<br>Line Spacing= | Coordinate Frame=POS-TARG<br>Pattern Orientation=44.4<br>Angle Between Sides=<br>Center Pattern=false | | (1) |

## Fixed Targets

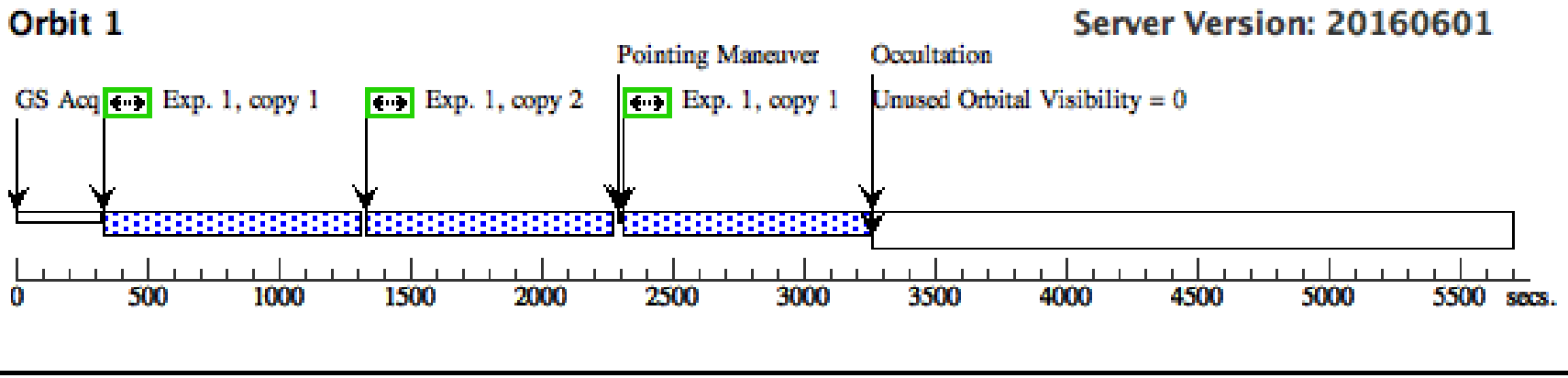
| # | Name | Target Coordinates | Targ. Coord. Corrections | Fluxes | Miscellaneous |
|---|---|---|---|---|---|
| (1) | SAXJ1808.4-3658 | RA: 18 08 27.5400 (272.1147500d)<br>Dec: -36 58 44.30 (-36.97897d)<br>Equinox: J2000 | | V=21 | Reference Frame: ICRS |

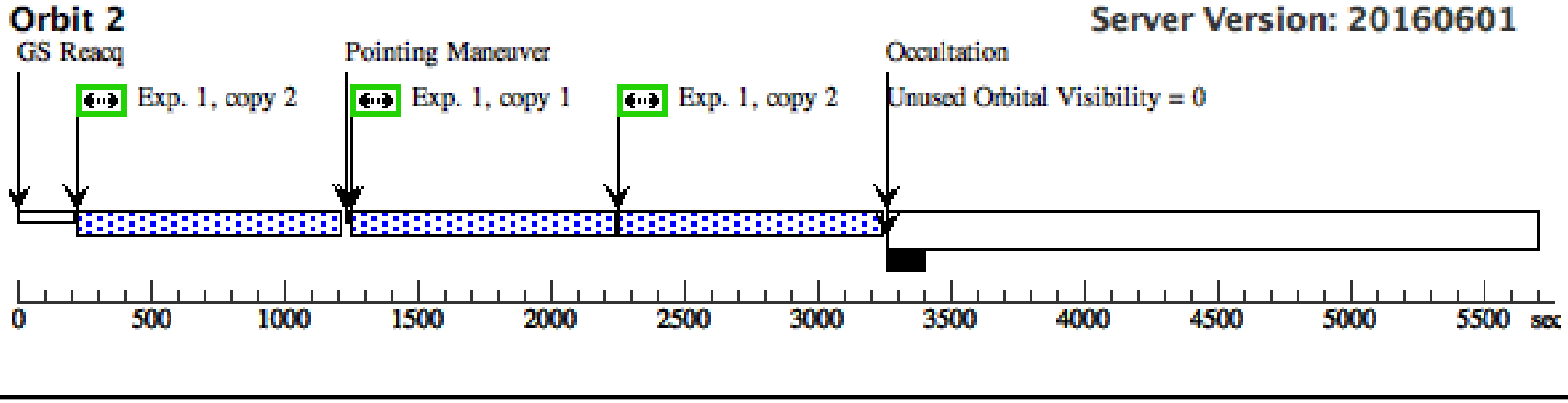
*Comments: Extended=NO*

## Exposures

| # | Label (ETC Run) | Target | Config,Mode,Aperture | Spectral Els. | Opt. Params. | Special Reqs. | Groups | Exp. Time (Total)/[Actual Dur.] | Orbit |
|---|---|---|---|---|---|---|---|---|---|
| 1 | (ACS.im.825418) | (1) SAXJ1808.4-3658 | ACS/SBC, ACCUM, SBC | F150LP | | | Pattern 1, Exps 1-1 in Visit 01 (1) | 917 Secs X 2 (5658 Secs) | |
| | | | | | | | | *[==>918.0 Secs (Pattern 1, Copy 1)]*<br>*[==>918.0 Secs (Pattern 1, Copy 2)]*<br>*[==>917.0 Secs (Pattern 2, Copy 1)]* | ***[1]*** |
| | | | | | | | | *[==>968.0 Secs (Pattern 2, Copy 2)]*<br>*[==>968.0 Secs (Pattern 3, Copy 1)]*<br>*[==>969.0 Secs (Pattern 3, Copy 2)]* | ***[2]*** |

Orbit Structure



## Visit

**Proposal 14724, Visit 02** Fri Jul 29 19:03:50 GMT 2016

**Diagnostic Status: No Diagnostics**

Scientific Instruments: WFC3/UVIS

Special Requirements: (none)

## Patterns

| # | Primary Pattern | | Secondary Pattern | Exposures |
|---|---|---|---|---|
| (2) | Pattern Type=WFC3-UVIS-DITHER-BOX<br>Purpose=DITHER<br>Number Of Points=4<br>Point Spacing=0.173<br>Line Spacing=0.112 | Coordinate Frame=POS-TARG<br>Pattern Orientation=23.884<br>Angle Between Sides=81.785<br>Center Pattern=false | | (1) |
| (3) | Pattern Type=WFC3-UVIS-DITHER-LINE<br>Purpose=DITHER<br>Number Of Points=2<br>Point Spacing=0.145<br>Line Spacing= | Coordinate Frame=POS-TARG<br>Pattern Orientation=46.84<br>Angle Between Sides=<br>Center Pattern=false | | (3) |
| (4) | Pattern Type=WFC3-UVIS-DITHER-LINE-3PT<br>Purpose=DITHER<br>Number Of Points=3<br>Point Spacing=0.135<br>Line Spacing= | Coordinate Frame=POS-TARG<br>Pattern Orientation=46.84<br>Angle Between Sides=<br>Center Pattern=false | | (2) |

## Fixed Targets

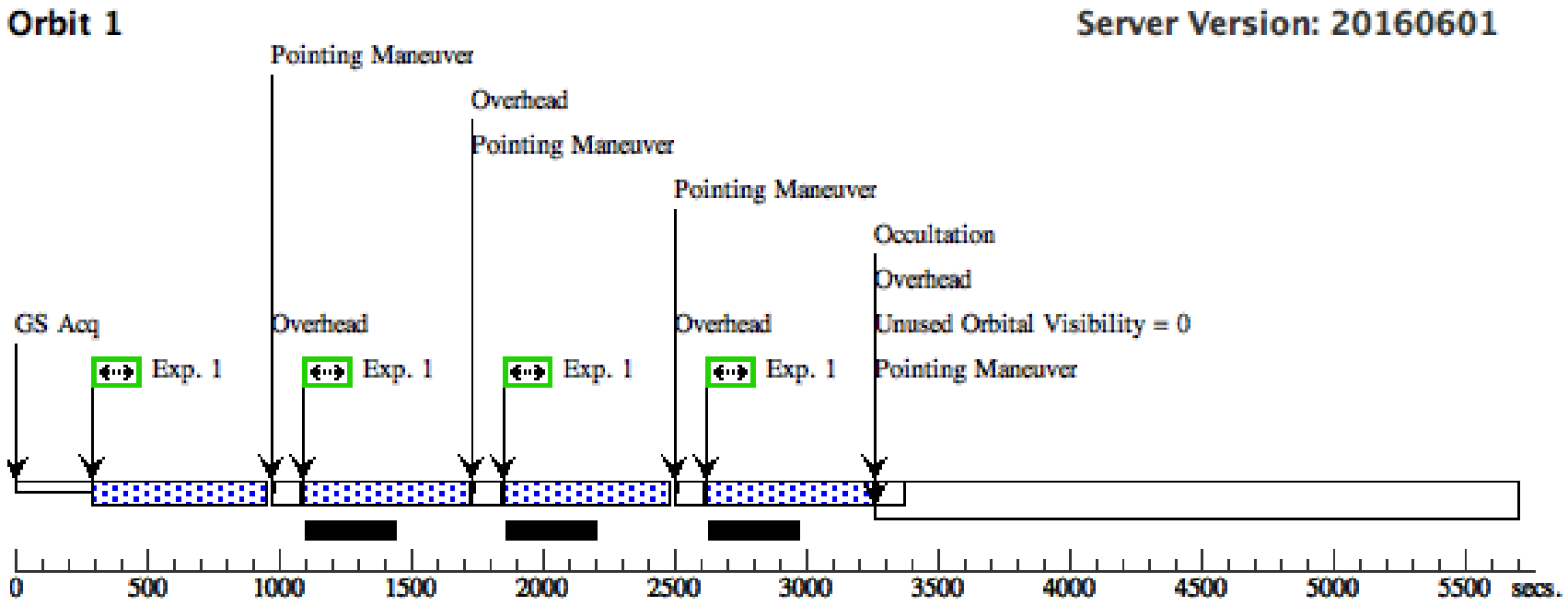
| # | Name | Target Coordinates | Targ. Coord. Corrections | Fluxes | Miscellaneous |
|---|---|---|---|---|---|
| (1) | SAXJ1808.4-3658 | RA: 18 08 27.5400 (272.1147500d)<br>Dec: -36 58 44.30 (-36.97897d)<br>Equinox: J2000 | | V=21 | Reference Frame: ICRS |

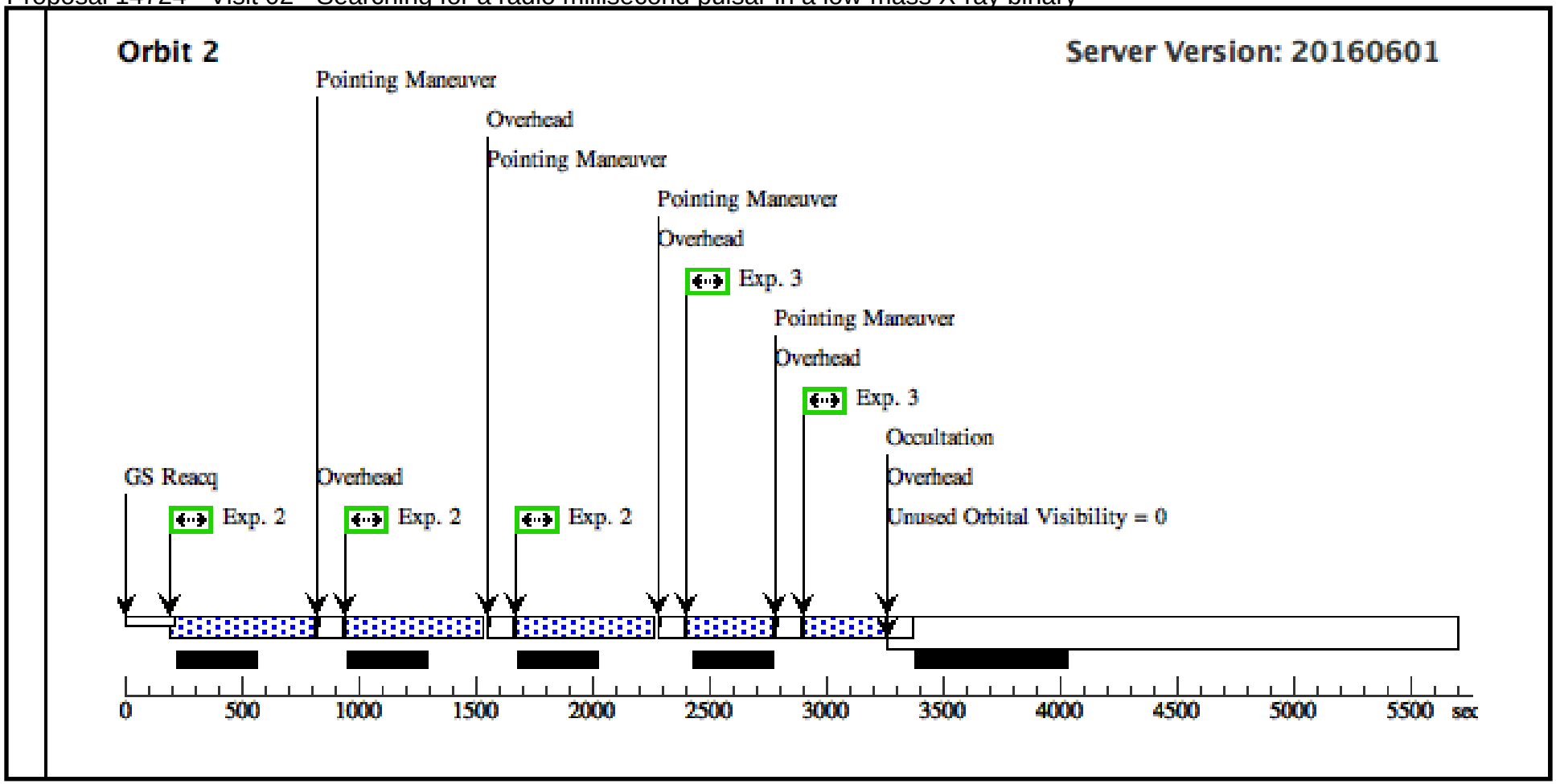
*Comments: Extended=NO*

## Exposures

| # | Label (ETC Run) | Target | Config,Mode,Aperture | Spectral Els. | Opt. Params. | Special Reqs. | Groups | Exp. Time (Total)/[Actual Dur.] | Orbit |
|---|---|---|---|---|---|---|---|---|---|
| 1 | (825540) | (1) SAXJ1808.4-3658 | WFC3/UVIS, ACCUM, UVIS | F225W | FLASH=10 | | Pattern 2, Exps 1-1 in Visit 02 (2) | 631 Secs (2524 Secs)<br>*[==>(Pattern 1)]*<br>*[==>(Pattern 2)]*<br>*[==>(Pattern 3)]*<br>*[==>(Pattern 4)]* | ***[1]*** |
| 2 | (825543) | (1) SAXJ1808.4-3658 | WFC3/UVIS, ACCUM, UVIS | F275W | FLASH=10 | | Pattern 4, Exps 2-2 in Visit 02 (4) | 594 Secs (1782 Secs)<br>*[==>(Pattern 1)]*<br>*[==>(Pattern 2)]*<br>*[==>(Pattern 3)]* | ***[2]*** |
| 3 | (825544) | (1) SAXJ1808.4-3658 | WFC3/UVIS, ACCUM, UVIS | F336W | FLASH=10 | | Pattern 3, Exps 3-3 in Visit 02 (3) | 348 Secs (696 Secs)<br>*[==>(Pattern 1)]*<br>*[==>(Pattern 2)]* | ***[2]*** |

Orbit Structure

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Overhead
Pointing Maneuver
Pointing Maneuver
Overhead
Exp. 3
Pointing Maneuver
Overhead
Exp. 3
Occultation
Overhead
Unused Orbital Visibility = 0
GS Reacq
Exp. 2
Overhead
Exp. 2
Exp. 2
0
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1000
1500
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sec