# 14790 - Investigating the binary nature of active asteroid 288P/300163

Cycle: 24, Proposal Category: GO

(Availability Mode: SUPPORTED)

**INVESTIGATORS**



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|---|---|---|
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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) 288P | WFC3/UVIS | 1 | 29-Jul-2016 15:42:51.0 | yes |
| 02 | (1) 288P | WFC3/UVIS | 1 | 29-Jul-2016 15:42:52.0 | yes |
| 03 | (1) 288P | WFC3/UVIS | 1 | 29-Jul-2016 15:42:53.0 | yes |
| 04 | (1) 288P | WFC3/UVIS | 1 | 29-Jul-2016 15:42:54.0 | yes |
| 05 | (1) 288P | WFC3/UVIS | 1 | 29-Jul-2016 15:42:54.0 | yes |

5 Total Orbits Used

**ABSTRACT**

We propose to study the suspected binary nature of active asteroid 288P/300163. We aim to confirm or disprove the existence of a binary nucleus, and - if confirmed - to measure the mutual orbital period and orbit orientation of the compoents, and their sizes. We request 5 orbits of WFC3

imaging, spaced at intervals of 8-12 days. 288P belongs to the recently discovered group of active asteroids, and is particularly remarkable as HST images obtained during its last close approach to Earth in 2011 are consistent with a barely resolved binary system. If confirmed, 288P would be the first known active binary asteroid. For the first time, we would see two important consequences of rotational break-up in a single object: binary formation and dust ejection, highlighting the importance of the YORP-effect in re-shaping the asteroid belt. Confirming 288P as a binary would be a key step towards understanding the evolutionary processes underlying asteroid activity. In order to resolve the two components we need 288P at a geocentric distance comparable to or less than we had in 2011 December (1.85 AU). This condition will be fulfilled for the first time since 2011, between mid-July and mid-November of 2016. The next opportunity to carry out such observations will be in 2021.

**OBSERVING DESCRIPTION**

We request 5 orbits to observe active asteroid 288P close to its perigee. The orbits should be spaced at intervals of 8-12 days, covering a total time span of 32-48 days. We know from our 2011 observations that 8 days is a suitable time interval to detect the morphological changes we target. We also know that, if 288P is a binary system, the mutual orbital period will be between 60 and 300 days (Agarwal et al., 2016). Given the uncertainty of the period, the unknown orientation of the mutual orbital plane, and the unknown phase (i.e. we do now know when the two components will be in conjunction), we devise a strategy that is robust enough to achieve our goals for mutual orbital periods in the whole range between 60 and 300 days, and independently of the time of conjunction. To constrain the orbital period of the system, we need a total time coverage of about 40 days. If the mutual orbital period is of order 60 days, we will observe at least one opposition characterized by circular isophotes (assuming that the mutual orbital plane of the system is close to the heliocentric orbital plane of 288P, as suggested by our 2011 data), and at least three configurations with the isophotes elongated by 2 pixels, allowing us to constrain the orientation of the system's orbital plane. If the mutual orbital period is of order 300 days, we will cover only a short fraction of the total orbit, but expect to detect a clear binary signature regardless of phase: Near opposition, we will see the isophotes change between circular and elongated by up to 4 pixels, while far from opposition, we will see a near-constant component distance of 4-5 pixels. The most dicult scenario to derive the mutual orbital period will arise if the central visit out of our five coincides with opposition. But even in that case we would be able to distinguish between a 60 day period, characterized by component separations of 2,2,0,2,2 pixels in the five visits, and a 300 day period, characterized by a more continuous 2,1,0,1,2. For this reason, we request a total of five visits. We expect the combined magnitude of both components to be of order V=21, thus a single component will be at V'22. The orbital visibility for a solar system target near the ecliptic plane is 54 min (Section 6.3 of the HST Primer document). In each orbit, we will take 8 exposures of 225 s using the 2k subarray of WFC3 and perform a subsampling dither box pattern, obtaining 2 exposures at each dither point. We will carefully drizzle our subsampled images to a finer output pixel scale to extract the extra spatial information gathered by our subsampling strategy. This enhanced resolution will give us the best chance to separate the two components of the binary system. The dithering will also enable us to reject hot pixels and cosmic ray hits. This strategy gives us a total

exposure time of 1800 s = 30min, and estimated overheads of 6 min for guide-star acquisition, 2.6 min for the first exposure, a total of 14.7 min for the subsequent 7 exposures, and 1.5 min for the three spacecraft maneuvers required for dithering, which adds up to a total execution time of 54 min per orbit. We will use the wide bandpass filter F606W for an optimum trade-off between sensitivity and highest resolution: the bandpass (475-700 nm) covers the maximum of the solar spectrum, and is in the wavelength range where the PSF is smallest (FWHM<0.07 arcsec, from the WFC3 instrument handbook for Cycle 24), such that we can optimally exploit our subsampling dither strategy. In addition, F606W is the same filter we used to observe 288P in 2011, enabling a direct comparison of both data sets. The WFC3 exposure time calculator returns for a solar-spectrum point source at V=22, an exposure time of 225 s, and F606W a signal-to-noise-ratio of 79 within a circle of 0.08 arcsec (ETC Request ID: WFC3UVIS.im.796928). The small aperture is needed to separate the fluxes from the two components as far as possible given the expected overlapping of the PSFs. A point source at V=26.5 will be detectable at SNR=5 in a single image, and SNR=14 after stacking all eight exposures, allowing us to search for additional satellites down to a diameter of 170m (for an assumed geometric albedo of 0.04). The decisive parameter for the success of our program is the angular separation of the binary components, which scales linearly with the geocentric distance, in addition to the 5 intrinsic periodic variability we aim to measure. During our 2011 observations, 288P was at a geocentric distance of 1.85AU, such that one 0.04 arcsec pixel of WFC3 corresponded to 54km at the distance of the asteroid. In order to confirm the binary nature of 288P, we need at comparable resolution or better, which will be given in the time interval between 2016 mid-July and mid-November: The geocentric distance will be 1.85AU in mid-July (54km per pixel), decrease to 1.45AU (42km per pixel) in mid-September, and again increase to 1.85AU (54km per pixel) in mid-November. Our strategy involves 5 orbits at a cadence of 8-12 days, spanning a total period of 32-48 days. We therefore require the observations to be carried out in the first weeks of the regular Cycle 24, between Oct-01 and November-15. The highest spatial resolution (42km per pixel) will be reached already in mid-September, such that the program would benefit from early implementation a few weeks prior to the beginning of Cycle 24. This would have the additional advantage of minimizing the risk of dust contamination, as in late October, 288P will return to the orbital position (at true anomaly of 354 degrees) where it is known to have started ejecting dust in 2011.

## Visit

**Proposal 14790, Visit 01** Fri Jul 29 19:42:55 GMT 2016

**Diagnostic Status: Warning**

Scientific Instruments: WFC3/UVIS

Special Requirements: SCHED 50%; BETWEEN 15-AUG-2016:00:00:00 AND 30-AUG-2016:00:00:00

## Diagnostics

(Exposure 1 (Pattern 1, Exps 1-1 in Visit 01)) Warning (Form): FLASH level may be too low for this exposure or a short subexposure. See extended explanation in the diagnostic browser

## Patterns

| # | Primary Pattern | | Secondary Pattern | Exposures |
|---|---|---|---|---|
| (1) | 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) |

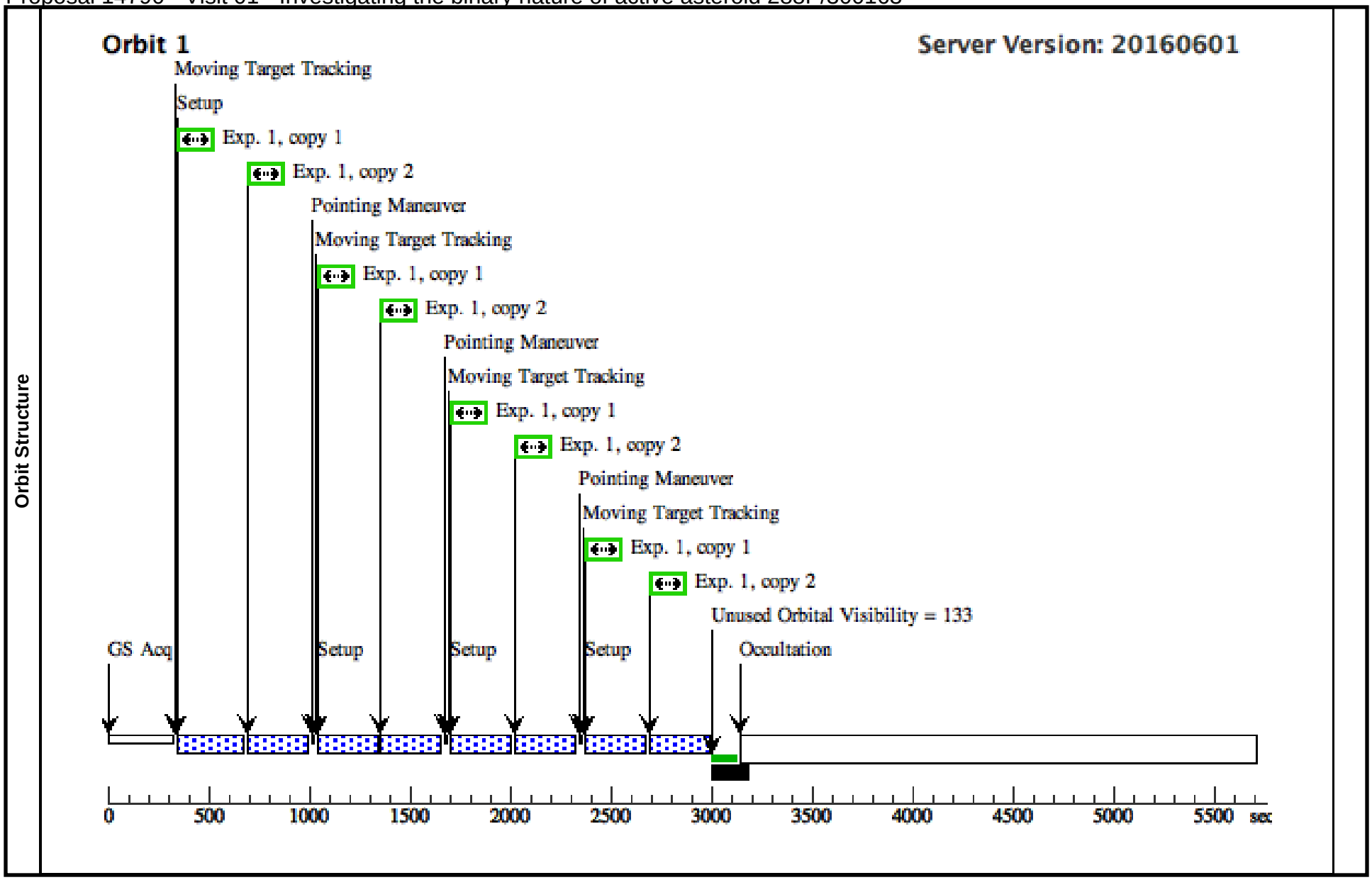
## Solar System Targets

| # | Name | Level 1 | Level 2 | Level 3 | Window | Ephem Center |
|---|---|---|---|---|---|---|
| (1) | 288P | TYPE=COMET,Q=2.439882181529367,E=.1999209058788649,I=3.238859149229396,O=83.22939688201053,W=281.8902871519682,T=18-JUL-2011:23:10:22,TTimeScale=UTC,EQUINOX=J2000,EPOCH=06-JUN-2009:00:00:00,EpochTimeScale=TDB | | | | EARTH |

*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 | (WFC3UVIS.im.823668) | (1) 288P | WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB | F606W | CR-SPLIT=NO | | Pattern 1, Exps 1-1 in Visit 01 (1) | 230 Secs X 2 (1840 Secs)<br>*[==>(Pattern 1, Copy 1)]*<br>*[==>(Pattern 1, Copy 2)]*<br>*[==>(Pattern 2, Copy 1)]*<br>*[==>(Pattern 2, Copy 2)]*<br>*[==>(Pattern 3, Copy 1)]*<br>*[==>(Pattern 3, Copy 2)]*<br>*[==>(Pattern 4, Copy 1)]*<br>*[==>(Pattern 4, Copy 2)]* | ***[1]*** |


Orbit 1
Server Version: 20160601
Orbit Structure
Moving Target Tracking
Setup
Exp. 1, copy 1
Exp. 1, copy 2
Pointing Maneuver
Moving Target Tracking
Exp. 1, copy 1
Exp. 1, copy 2
Pointing Maneuver
Moving Target Tracking
Exp. 1, copy 1
Exp. 1, copy 2
Pointing Maneuver
Moving Target Tracking
Exp. 1, copy 1
Exp. 1, copy 2
Unused Orbital Visibility = 133
GS Acq
Setup
Setup
Setup
Occultation
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
sec

## Visit

**Proposal 14790, Visit 02** Fri Jul 29 19:42:55 GMT 2016

**Diagnostic Status: Warning**

Scientific Instruments: WFC3/UVIS

Special Requirements: SCHED 50%; AFTER 01 BY 8 D TO 12 D

## Diagnostics

(Exposure 1 (Pattern 1, Exps 1-1 in Visit 02)) Warning (Form): FLASH level may be too low for this exposure or a short subexposure. See extended explanation in the diagnostic browser

## Patterns

| # | Primary Pattern | | Secondary Pattern | Exposures |
|---|---|---|---|---|
| (1) | 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) |

## Solar System Targets

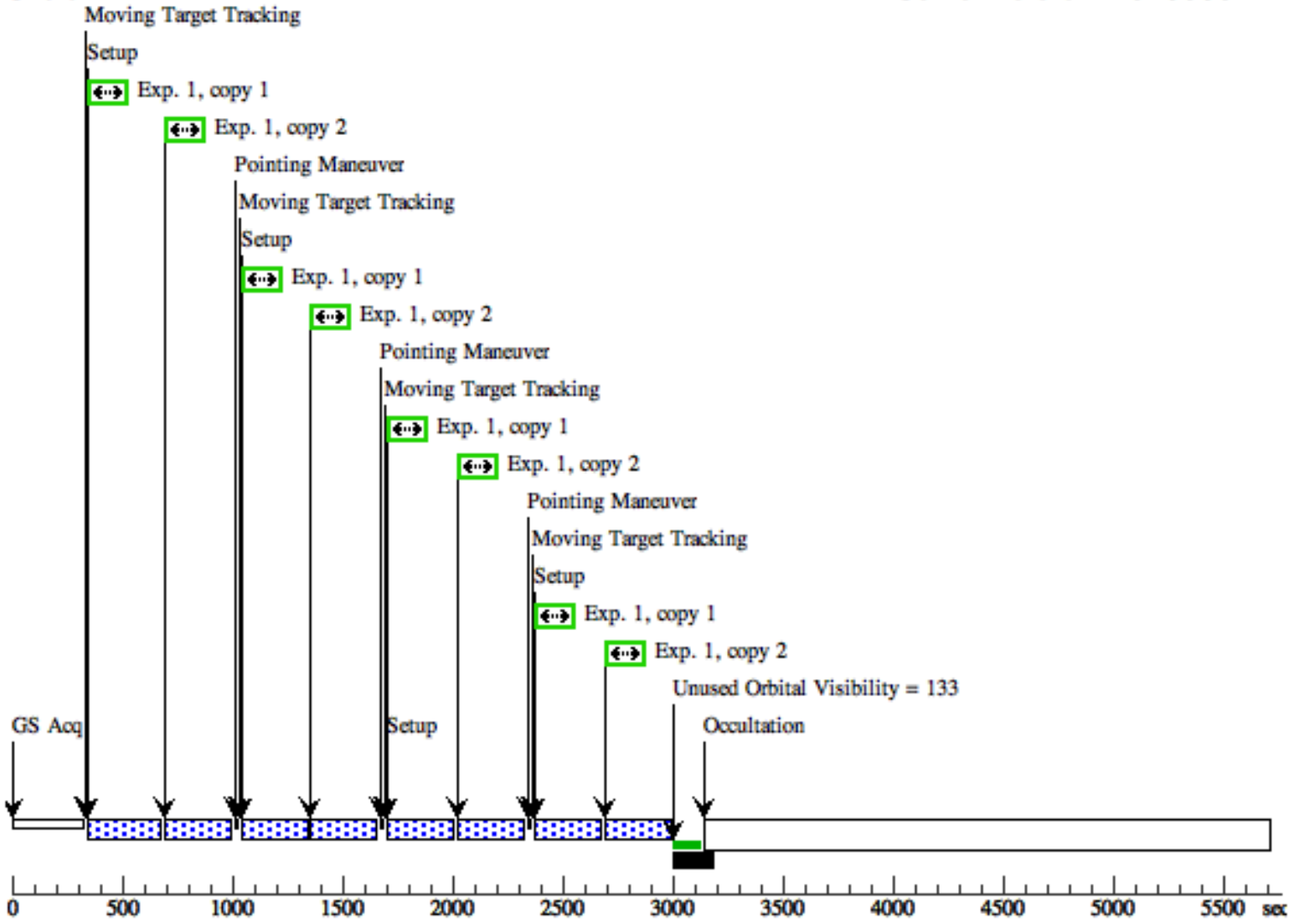
| # | Name | Level 1 | Level 2 | Level 3 | Window | Ephem Center |
|---|---|---|---|---|---|---|
| (1) | 288P | TYPE=COMET,Q=2.439882181529367,E=.1999209058788649,I=3.238859149229396,O=83.22939688201053,W=281.8902871519682,T=18-JUL-2011:23:10:22,TTimeScale=UTC,EQUINOX=J2000,EPOCH=06-JUN-2009:00:00:00,EpochTimeScale=TDB | | | | EARTH |

*Comments: Extended=NO*

## Exposures

| # | Label | Target | Config,Mode,Aperture | Spectral Els. | Opt. Params. | Special Reqs. | Groups | Exp. Time (Total)/[Actual Dur.] | Orbit |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | (1) 288P | WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB | F606W | CR-SPLIT=NO | | Pattern 1, Exps 1-1 in Visit 02 (1) | 230 Secs X 2 (1840 Secs) | |
| | | | | | | | | *[==>(Pattern 1, Copy 1)]* | ***[1]*** |
| | | | | | | | | *[==>(Pattern 1, Copy 2)]* | |
| | | | | | | | | *[==>(Pattern 2, Copy 1)]* | |
| | | | | | | | | *[==>(Pattern 2, Copy 2)]* | |
| | | | | | | | | *[==>(Pattern 3, Copy 1)]* | |
| | | | | | | | | *[==>(Pattern 3, Copy 2)]* | |
| | | | | | | | | *[==>(Pattern 4, Copy 1)]* | |
| | | | | | | | | *[==>(Pattern 4, Copy 2)]* | |

Orbit Structure



## Visit

**Proposal 14790, Visit 03** Fri Jul 29 19:42:55 GMT 2016

**Diagnostic Status: Warning**

Scientific Instruments: WFC3/UVIS

Special Requirements: SCHED 50%; AFTER 01 BY 18 D TO 22 D

## Diagnostics

(Exposure 1 (Pattern 1, Exps 1-1 in Visit 03)) Warning (Form): FLASH level may be too low for this exposure or a short subexposure. See extended explanation in the diagnostic browser

## Patterns

| # | Primary Pattern | | Secondary Pattern | Exposures |
|---|---|---|---|---|
| (1) | 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) |

## Solar System Targets

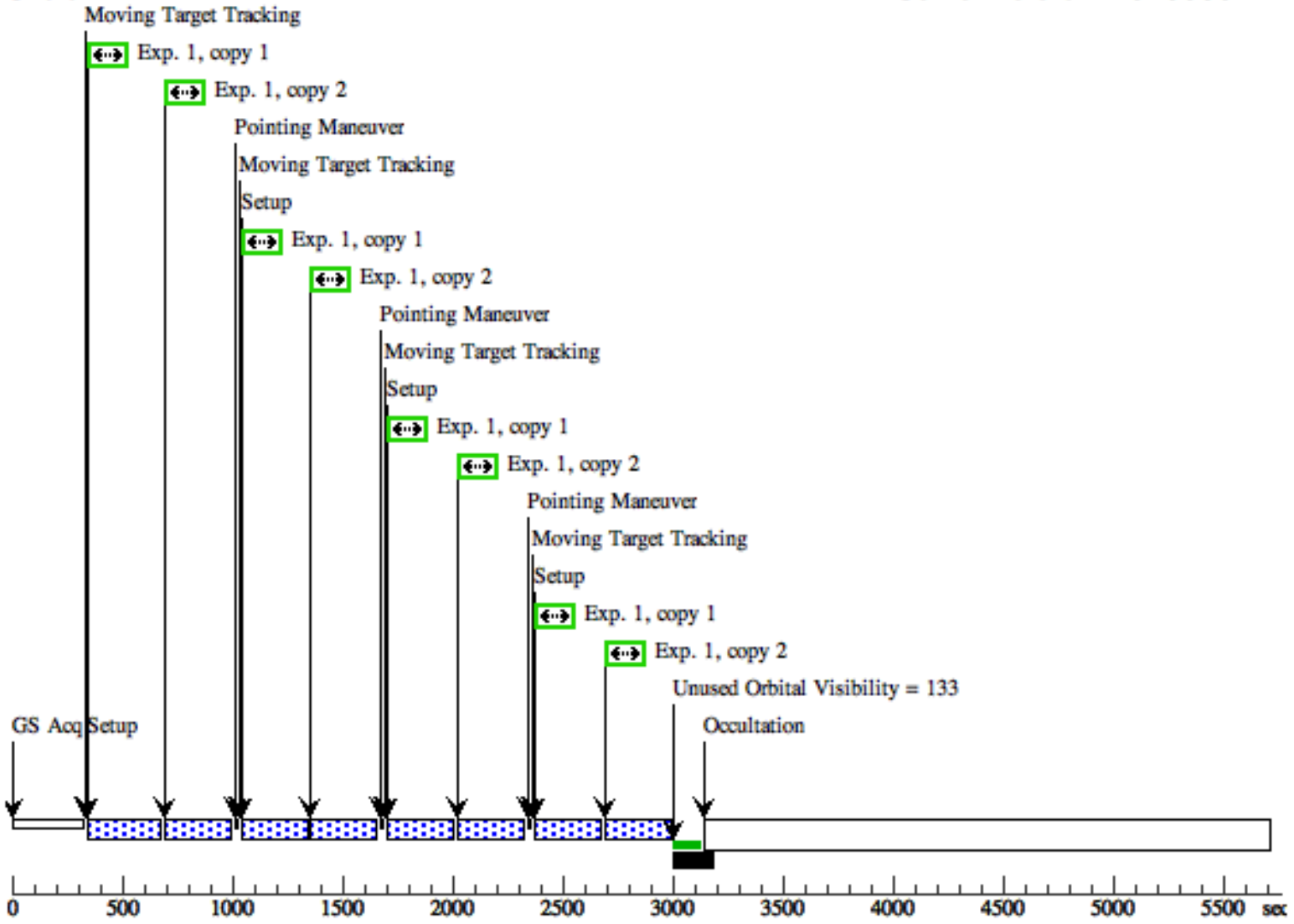
| # | Name | Level 1 | Level 2 | Level 3 | Window | Ephem Center |
|---|---|---|---|---|---|---|
| (1) | 288P | TYPE=COMET,Q=2.439882181529367,E=.1999209058788649,I=3.238859149229396,O=83.22939688201053,W=281.8902871519682,T=18-JUL-2011:23:10:22,TTimeScale=UTC,EQUINOX=J2000,EPOCH=06-JUN-2009:00:00:00,EpochTimeScale=TDB | | | | EARTH |

*Comments: Extended=NO*

## Exposures

| # | Label | Target | Config,Mode,Aperture | Spectral Els. | Opt. Params. | Special Reqs. | Groups | Exp. Time (Total)/[Actual Dur.] | Orbit |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | (1) 288P | WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB | F606W | CR-SPLIT=NO | | Pattern 1, Exps 1-1 in Visit 03 (1) | 230 Secs X 2 (1840 Secs) | |
| | | | | | | | | *[==>(Pattern 1, Copy 1)]* | ***[1]*** |
| | | | | | | | | *[==>(Pattern 1, Copy 2)]* | |
| | | | | | | | | *[==>(Pattern 2, Copy 1)]* | |
| | | | | | | | | *[==>(Pattern 2, Copy 2)]* | |
| | | | | | | | | *[==>(Pattern 3, Copy 1)]* | |
| | | | | | | | | *[==>(Pattern 3, Copy 2)]* | |
| | | | | | | | | *[==>(Pattern 4, Copy 1)]* | |
| | | | | | | | | *[==>(Pattern 4, Copy 2)]* | |

Orbit Structure



## Visit

**Proposal 14790, Visit 04** Fri Jul 29 19:42:55 GMT 2016

**Diagnostic Status: Warning**

Scientific Instruments: WFC3/UVIS

Special Requirements: SCHED 50%; AFTER 01 BY 28 D TO 32 D

## Diagnostics

(Exposure 1 (Pattern 1, Exps 1-1 in Visit 04)) Warning (Form): FLASH level may be too low for this exposure or a short subexposure. See extended explanation in the diagnostic browser

## Patterns

| # | Primary Pattern | | Secondary Pattern | Exposures |
|---|---|---|---|---|
| (1) | 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) |

## Solar System Targets

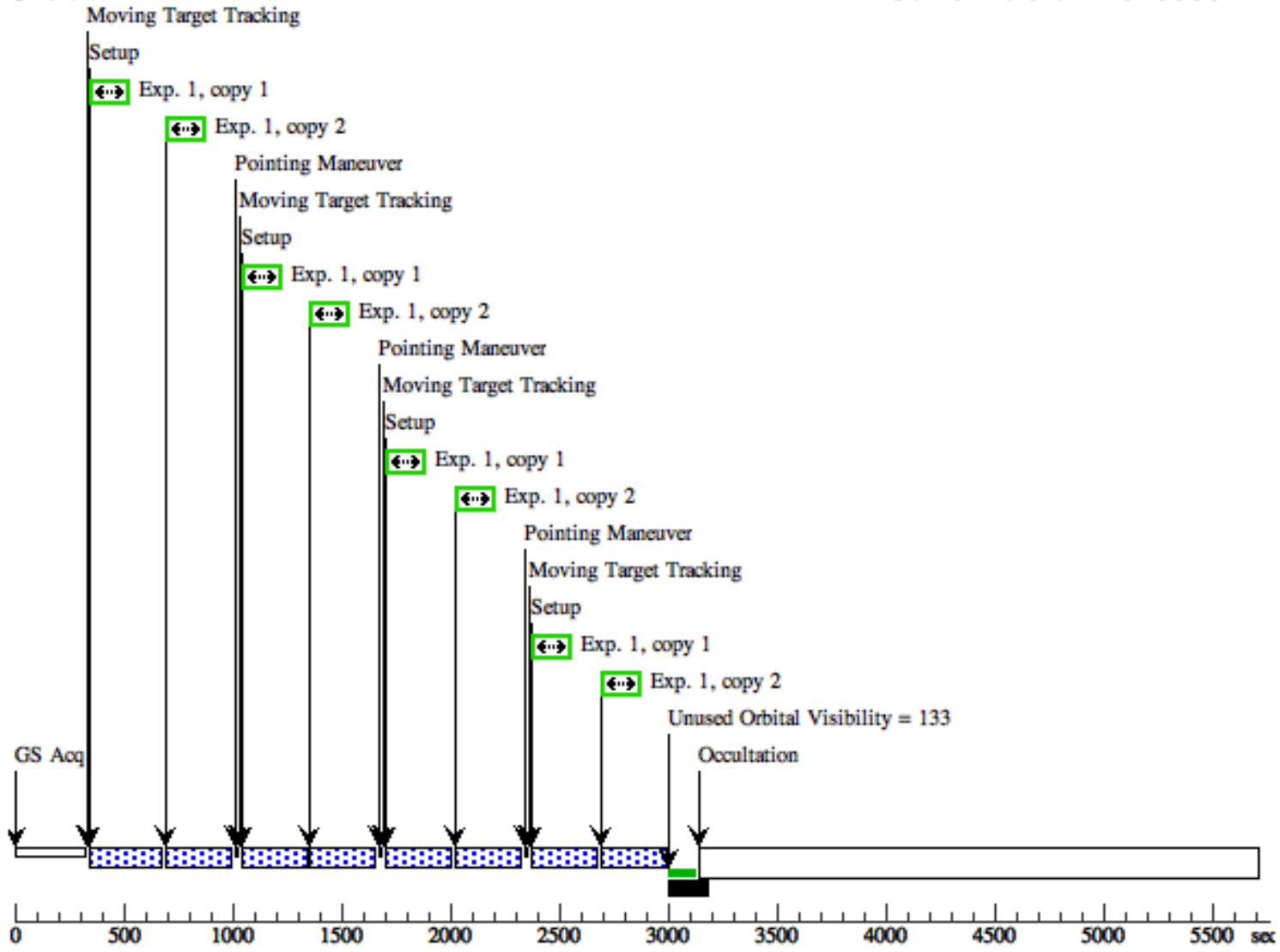
| # | Name | Level 1 | Level 2 | Level 3 | Window | Ephem Center |
|---|---|---|---|---|---|---|
| (1) | 288P | TYPE=COMET,Q=2.439882181529367,E=.1999209058788649,I=3.238859149229396,O=83.22939688201053,W=281.8902871519682,T=18-JUL-2011:23:10:22,TTimeScale=UTC,EQUINOX=J2000,EPOCH=06-JUN-2009:00:00:00,EpochTimeScale=TDB | | | | EARTH |

*Comments: Extended=NO*

## Exposures

| # | Label | Target | Config,Mode,Aperture | Spectral Els. | Opt. Params. | Special Reqs. | Groups | Exp. Time (Total)/[Actual Dur.] | Orbit |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | (1) 288P | WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB | F606W | CR-SPLIT=NO | | Pattern 1, Exps 1-1 in Visit 04 (1) | 230 Secs X 2 (1840 Secs) | |
| | | | | | | | | *[==>(Pattern 1, Copy 1)]* | ***[1]*** |
| | | | | | | | | *[==>(Pattern 1, Copy 2)]* | |
| | | | | | | | | *[==>(Pattern 2, Copy 1)]* | |
| | | | | | | | | *[==>(Pattern 2, Copy 2)]* | |
| | | | | | | | | *[==>(Pattern 3, Copy 1)]* | |
| | | | | | | | | *[==>(Pattern 3, Copy 2)]* | |
| | | | | | | | | *[==>(Pattern 4, Copy 1)]* | |
| | | | | | | | | *[==>(Pattern 4, Copy 2)]* | |

Orbit Structure



## Visit

**Proposal 14790, Visit 05** Fri Jul 29 19:42:55 GMT 2016

**Diagnostic Status: Warning**

Scientific Instruments: WFC3/UVIS

Special Requirements: SCHED 50%; AFTER 01 BY 38 D TO 42 D

## Diagnostics

(Exposure 1 (Pattern 1, Exps 1-1 in Visit 05)) Warning (Form): FLASH level may be too low for this exposure or a short subexposure. See extended explanation in the diagnostic browser

## Patterns

| # | Primary Pattern | | Secondary Pattern | Exposures |
|---|---|---|---|---|
| (1) | 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) |

## Solar System Targets

| # | Name | Level 1 | Level 2 | Level 3 | Window | Ephem Center |
|---|---|---|---|---|---|---|
| (1) | 288P | TYPE=COMET,Q=2.439882181529367,E=.1999209058788649,I=3.238859149229396,O=83.22939688201053,W=281.8902871519682,T=18-JUL-2011:23:10:22,TTimeScale=UTC,EQUINOX=J2000,EPOCH=06-JUN-2009:00:00:00,EpochTimeScale=TDB | | | | EARTH |

*Comments: Extended=NO*

## Exposures

| # | Label | Target | Config,Mode,Aperture | Spectral Els. | Opt. Params. | Special Reqs. | Groups | Exp. Time (Total)/[Actual Dur.] | Orbit |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | (1) 288P | WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB | F606W | CR-SPLIT=NO | | Pattern 1, Exps 1-1 in Visit 05 (1) | 230 Secs X 2 (1840 Secs) | |
| | | | | | | | | *[==>(Pattern 1, Copy 1)]* | ***[1]*** |
| | | | | | | | | *[==>(Pattern 1, Copy 2)]* | |
| | | | | | | | | *[==>(Pattern 2, Copy 1)]* | |
| | | | | | | | | *[==>(Pattern 2, Copy 2)]* | |
| | | | | | | | | *[==>(Pattern 3, Copy 1)]* | |
| | | | | | | | | *[==>(Pattern 3, Copy 2)]* | |
| | | | | | | | | *[==>(Pattern 4, Copy 1)]* | |
| | | | | | | | | *[==>(Pattern 4, Copy 2)]* | |

Orbit Structure