



16310 - Interstellar Comet 2I/Borisov

Cycle: 28, 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) 2I-BORISOV	WFC3/UVIS	2	15-Mar-2021 12:01:16.0	yes
02	(1) 2I-BORISOV	WFC3/UVIS	2	15-Mar-2021 12:01:17.0	yes
03	(1) 2I-BORISOV	WFC3/UVIS	1	15-Mar-2021 12:01:17.0	yes
04	(1) 2I-BORISOV	WFC3/UVIS	1	15-Mar-2021 12:01:18.0	yes
05	(1) 2I-BORISOV	WFC3/UVIS	1	15-Mar-2021 12:01:18.0	yes
06	(1) 2I-BORISOV	WFC3/UVIS	1	15-Mar-2021 12:01:18.0	yes

8 Total Orbits Used

ABSTRACT

C/2019 Q4 (Borisov) is the first interstellar comet and only the second interstellar object (after 'Oumuamua) ever identified within the solar system. We propose high resolution observations with WFC3 and HST in order to probe the development of this body in Cycle 28. During this time we will use HST and WFC3 to constrain the nucleus and dust properties. Observation as the Earth passes through the projected orbit plane early in the Cycle will provide a model-free estimate of the dust extent and velocity perpendicular to the plane. Additional, spaced observations provide perspectives as the object recedes from about 9 to about 13 AU. The high resolution of HST is needed to resolve faint near-nucleus structures (jets, fans) and fragments at the growing distance to the comet. The proposed observations extend the temporal coverage of the evolution of this unique object and take advantage of new perspectives.

OBSERVING DESCRIPTION

We request 8 HST orbits spread over Cycle 28. The proposed observations span the outbound heliocentric distance range 9.0 AU to 13.7 AU. 2I emerges from the HST Sun-exclusion zone on 2021 January 28, at $r_H = 9.0$, $\Delta = 9.5$ AU, and with phase angle 5 deg. This date also corresponds to orbit plane crossing, needed to detect ultra-low surface brightness trail material consisting of the largest, most slowly moving particles. In this geometry, the direction of trailing of field objects is parallel to the direction of the extended dust emission, placing especially stringent constraints on the need for accurate background removal. For this reason, we request four orbits with WFC3 and the F350LP filter to image 2I on the plane-crossing date at the highest sensitivity using the broad F350LP filter (effective center 6230Å, FWHM 4760Å). These four orbits will be dithered and combined to optimize the rejection of field object trails, especially from hard-to-remove low surface brightness galaxies. Subsequent visits will be used to measure the brightness and morphological evolution of 2I, as well as to obtain sub-arcsecond astrometry. These single-orbit visits will secure six 270s integrations each, with dithering to provide protection from chip defects. According to the WFC3 ETC, a single exposure of this length reaches $V = 26.5$ at $SNR = 5$. Combining 6 images from one orbit will take us 1 magnitude fainter and will also provide protection from cosmic ray strikes on individual images. Combining data from 4 orbits will give us another 0.6 magnitudes, taking us to a point-source sensitivity $V = 28.1$ for the plane-crossing V1. As noted above, the expected apparent magnitude of a 0.5 km radius nucleus (albedo 0.04) is $V = 28$ AU at V1, so that detection of the nucleus will be challenging. We do expect to find the largest, slowest particles aligned in a trail behind the nucleus; the 0.04 arcsec PSF of HST projects to 300 km at the comet. Sub-pixel astrometry will assist with orbit fitting and the determination of non-gravitational acceleration. The currently predicted 1 arcsec ephemeris uncertainty (from JPL Horizons) is 2 arcsec on UT 2021 January 28. This is already small enough compared to the WFC3 field of view that ephemeris uncertainty poses no threat to the proposed observations. Moreover, as with all high profile targets, continuous additions to the astrometric database by astronomers around the world will shrink this uncertainty month-by-month up

until the comet reaches elongations < 50 degree (in 2020 October). Astrometry from this work will also be used to update the orbit. The ephemeris accuracy for HST observations is expected to be of no concern to these observations. All observations are with WFC3 and the F350LP (effective center 6230Å, FWHM 4760Å) filter to provide the highest sensitivity. The division of the requested orbits is as follows.

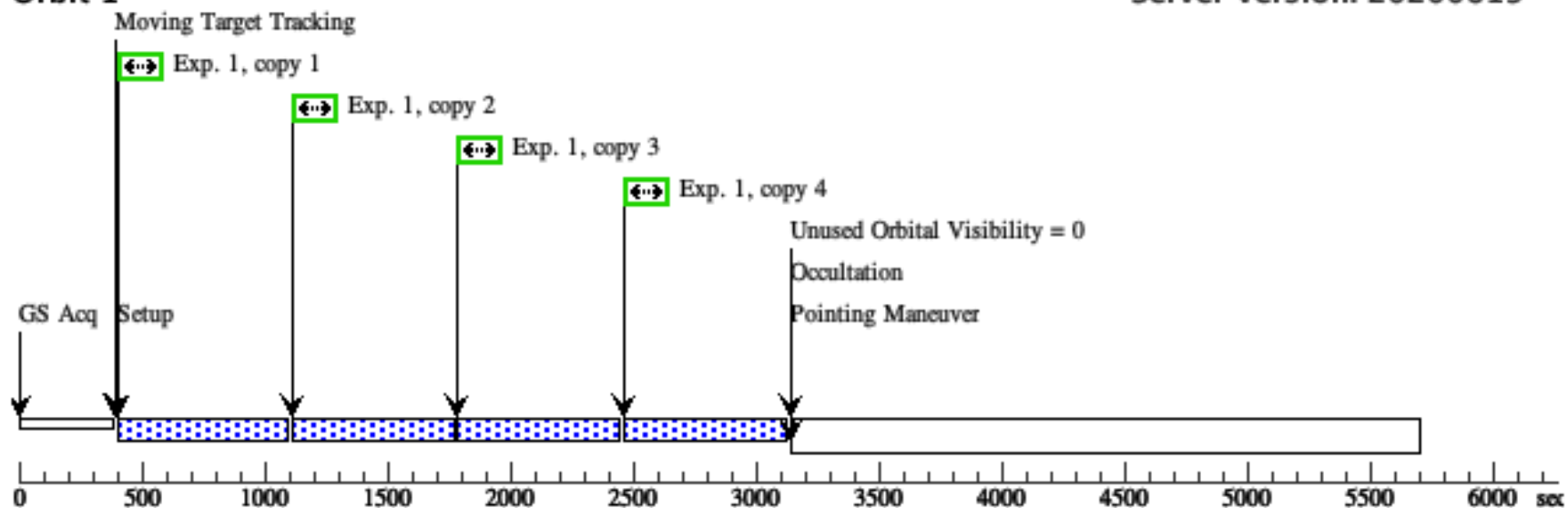
For visits V1 and V2, 2I emerges from the 55 deg HST exclusion zone on UT 2021 January 28 at $r_H = 9.0$, $\Delta = 9.5$ AU and with phase angle 5 deg. Fortunately, the Earth will pass through the orbit plane on this date providing us with the maximum sensitivity to large particles confined to the orbit plane of the body. Thus, early observation of 2I in Cycle 28 provides our best chance to detect a large particle trail. In this geometry, the direction of trailing of field objects is parallel to the direction of the extended dust emission, placing especially stringent constraints on the need for accurate background removal. For this reason we request three orbits to be dithered and combined to optimize the rejection of field object trails. The four orbits in V1 and V2 should be as close together as possible, although they do not need to be consecutive. (We realize that no more than two consecutive orbits are possible on a moving target because of the gyro problem). In fact, spaced orbits would be an advantage by giving enough time for background objects to completely leave the field of view. Image alignment between two consecutive HST orbits is excellent but alignment after a dither or other alignment change is less secure, particularly on a faint target that might not be readily identified in a single, heavily cosmic-ray impacted orbit. From experience, we feel confident in achieving good alignment in four plane-crossing orbits separated by a gyro gap. The in-plane angle changes by about 0.08 deg/day near plane crossing. Therefore, we need to be within 2 to 3 days of January 28 in order to attain the in-plane geometry and the closer to this time the better. Visit V3 is a single orbit visit near UT 2021 April 1 ($r_H = 10.1$ AU), requested to sample the changing morphology and photometry of the comet. Visit V4 is a single orbit visit near UT 2021 June 1 ($r_H = 11.4$ AU), requested to sample the changing morphology and photometry of the comet. Visit V5 is a single orbit visit near UT 2021 August 1 ($r_H = 12.6$ AU), requested to sample the changing morphology and photometry of the comet. The Earth again passes through the orbital plane of 2I at this time but the increased distance will substantially reduce our sensitivity to a large particle trail. Therefore, we have focused our in-plane attention primarily on V1 and V2. Visit V6 is a single orbit visit within 2 weeks of the end of Cycle 28 (UT 2021 September 30, $r_H = 13.7$ AU), requested to complete the study. The end of Cycle 28 is followed by entry of 2I into the Sun exclusion zone from 2021 October 26 - 2022 February 7. V6 marks the likely end of any possible observations of 2I/Borisov. We understand that we will have essentially no control over the spacecraft roll angle, which means that we will not be able to optimize the orientation of the dust coma on the CCD (e.g., to orient the tail along the longest dimension of the detector). However, the field-of-view of the camera is large enough and the target coma small enough that we should obtain excellent data, no matter what spacecraft roll angle is used.

Proposal 16310 - Visit 01 - Interstellar Comet 2I/Borisov

Visit	Proposal 16310, Visit 01, completed										Mon Mar 15 16:01:19 GMT 2021
	Diagnostic Status: No Diagnostics										
	Scientific Instruments: WFC3/UVIS										
	Special Requirements: BETWEEN 31-JAN-2021:00:00:00 AND 31-JAN-2021:21:00:00; BETWEEN 01-FEB-2021:05:00:00 AND 02-FEB-2021:06:00:00; BETWEEN 02-FEB-2021:14:00:00 AND 03-FEB-2021:21:00:00; GROUP 01,02 WITHIN 18H										
Solar System Targets	#	Name	Level 1	Level 2	Level 3	Window	Ephem Center				
	(1)	2I-BORISOV	TYPE=COMET,Q=2.0065818938403 75,E=3.356215101434632,I=44.05257 068647377 ,O=308.1487262895379,W=209.12367 864468,T=08-DEC- 2019:13:04:54,TTimeScale=TDB,EQ UINOX=J2000,EPOCH=01-AUG- 2020:00:00:00,EpochTimeScale=TDB, R0=2.808 ,DT=87.2916 ,A1=7.093444347382E-8,A2=- 1.443811535835E- 8,A3=6.534734368324E-10 ,ALN=0.1112620426,NM=2.15,NN=5. 093,NK=4.6142,AMRAT=0.	EARTH							
	Comments: Description=interstellar comet Extended=NO										
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit	
	1		(1) 2I-BORISOV	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F350LP			Sequence 1-1 Non-In t in Visit 01	500 Secs X 4 (2000 Secs) [==>(Copy 1)] [==>(Copy 2)] [==>(Copy 3)] [==>(Copy 4)]	[1]	
	2		(1) 2I-BORISOV	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F350LP		POS TARG 0.4,0.4	Sequence 2-2 Non-In t in Visit 01	500 Secs X 4 (2000 Secs) [==>(Copy 1)] [==>(Copy 2)] [==>(Copy 3)] [==>(Copy 4)]	[2]	

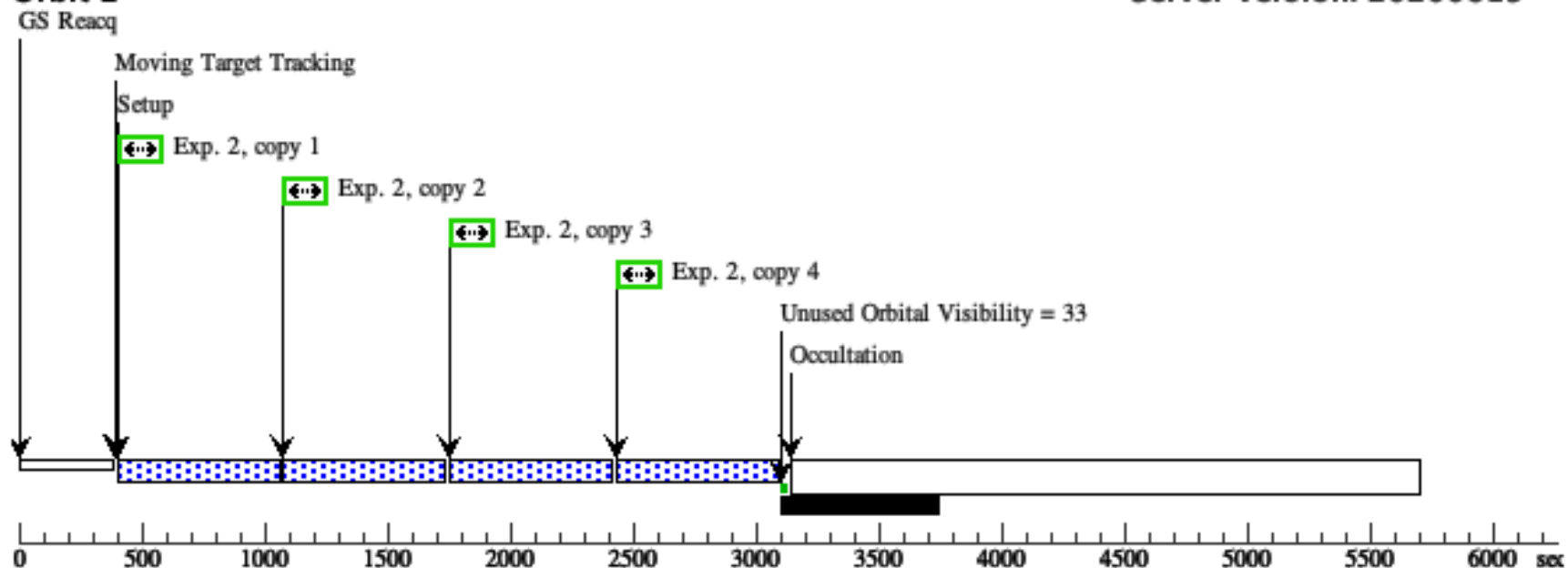
Orbit 1

Server Version: 20200619



Orbit 2

Server Version: 20200619

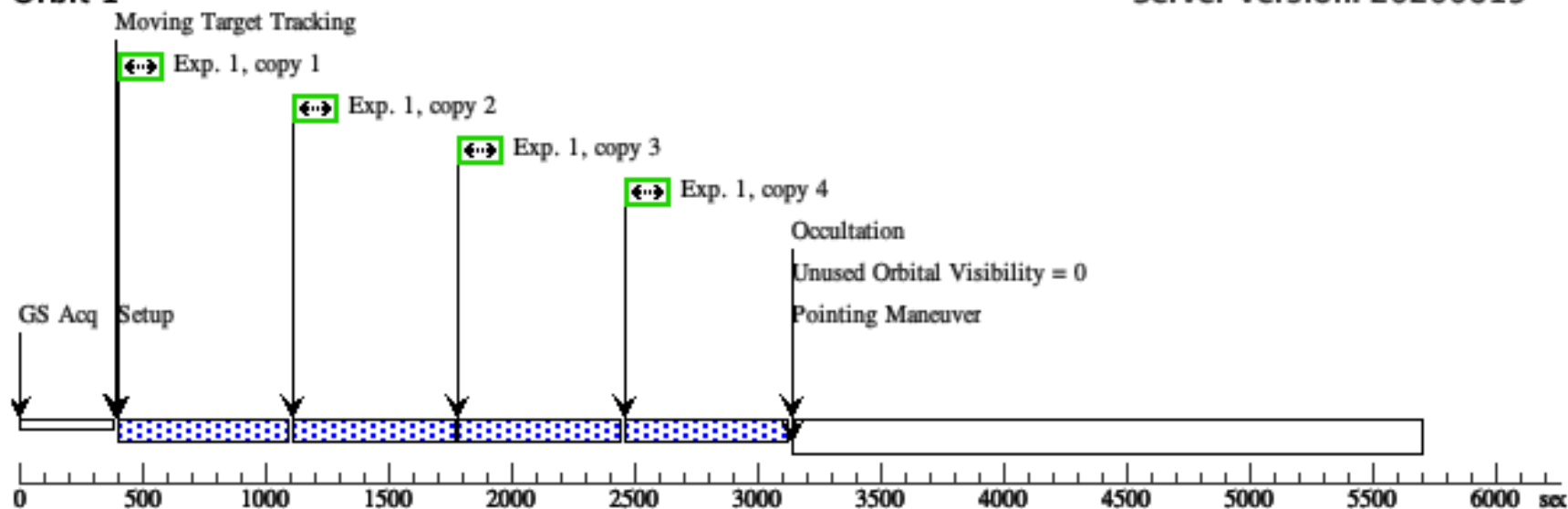


Proposal 16310 - Visit 02 - Interstellar Comet 2I/Borisov

Visit	Proposal 16310, Visit 02, completed										Mon Mar 15 16:01:19 GMT 2021
	Diagnostic Status: No Diagnostics										
	Scientific Instruments: WFC3/UVIS										
	Special Requirements: BETWEEN 31-JAN-2021:00:00:00 AND 31-JAN-2021:21:00:00; BETWEEN 01-FEB-2021:05:00:00 AND 02-FEB-2021:06:00:00; BETWEEN 02-FEB-2021:14:00:00 AND 03-FEB-2021:21:00:00										
Solar System Targets	#	Name	Level 1	Level 2	Level 3	Window	Ephem Center				
	(1)	2I-BORISOV	TYPE=COMET,Q=2.0065818938403 75,E=3.356215101434632,I=44.05257 068647377 ,O=308.1487262895379,W=209.12367 864468,T=08-DEC- 2019:13:04:54,TTIMEScale=TDB,EQ UINOX=J2000,EPOCH=01-AUG- 2020:00:00:00,EpochTimeScale=TDB, R0=2.808 ,DT=87.2916 ,A1=7.093444347382E-8,A2=- 1.443811535835E- 8,A3=6.534734368324E-10 ,ALN=0.1112620426,NM=2.15,NN=5. 093,NK=4.6142,AMRAT=0.								EARTH
	Comments: Description=interstellar comet Extended=NO										
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit	
	1		(1) 2I-BORISOV	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F350LP		POS TARG 0.8,0.8	Sequence 1-1 Non-In t in Visit 02	500 Secs X 4 (2000 Secs)		
									[==>(Copy 1)] [==>(Copy 2)] [==>(Copy 3)] [==>(Copy 4)]	[1]	
	2		(1) 2I-BORISOV	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F350LP		POS TARG 1.2,1.2	Sequence 2-2 Non-In t in Visit 02	500 Secs X 4 (2000 Secs)		
									[==>(Copy 1)] [==>(Copy 2)] [==>(Copy 3)] [==>(Copy 4)]	[2]	

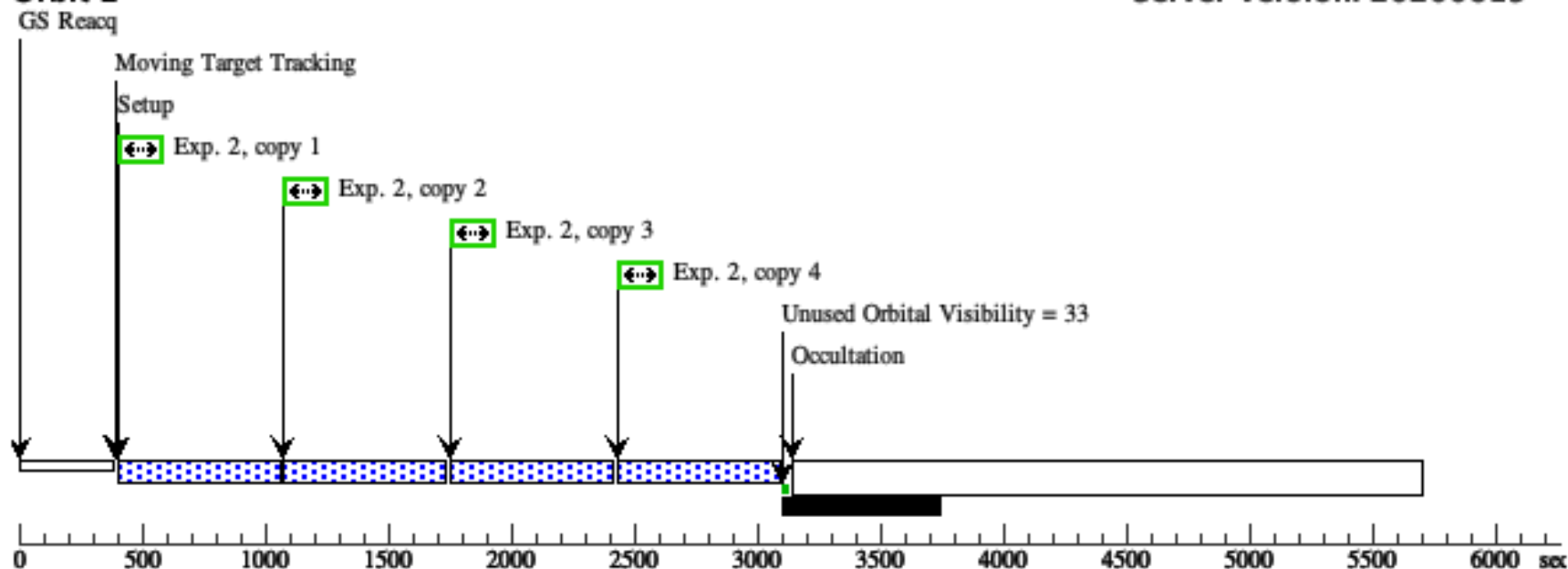
Orbit 1

Server Version: 20200619



Orbit 2

Server Version: 20200619



Proposal 16310 - Visit 03 - Interstellar Comet 2I/Borisov

Visit	Proposal 16310, Visit 03, implementation										Mon Mar 15 16:01:19 GMT 2021	
	Diagnostic Status: No Diagnostics											
	Scientific Instruments: WFC3/UVIS											
	Special Requirements: BEFORE 24-MAR-2021:00:00:00; GROUP 03,04,05,06 WITHIN 18H											
Solar System Targets	#	Name	Level 1	Level 2	Level 3	Window	Ephem Center					
	(1)	2I-BORISOV	TYPE=COMET,Q=2.0065818938403 75,E=3.356215101434632,I=44.05257 068647377 ,O=308.1487262895379,W=209.12367 864468,T=08-DEC- 2019:13:04:54,TTimeScale=TDB,EQ UINOX=J2000,EPOCH=01-AUG- 2020:00:00:00,EpochTimeScale=TDB, R0=2.808 ,DT=87.2916 ,A1=7.093444347382E-8,A2=- 1.443811535835E- 8,A3=6.534734368324E-10 ,ALN=0.1112620426,NM=2.15,NN=5. 093,NK=4.6142,AMRAT=0.					EARTH				
	Comments: Description=interstellar comet Extended=NO											
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit		
	1		(1) 2I-BORISOV	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F350LP			Sequence 1-1 Non-In t in Visit 03	700 Secs X 3 (2100 Secs)			
									[==>(Copy 1)] [==>(Copy 2)] [==>(Copy 3)]	[1]		
Orbit Structure	Orbit 1 Server Version: 20200619 Moving Target Tracking GS Acq Setup Exp. 1, copy 1 Exp. 1, copy 2 Exp. 1, copy 3 Occultation Unused Orbital Visibility = 77											

Proposal 16310 - Visit 04 - Interstellar Comet 2I/Borisov

Visit	Proposal 16310, Visit 04, implementation										Mon Mar 15 16:01:19 GMT 2021
	Diagnostic Status: No Diagnostics Scientific Instruments: WFC3/UVIS Special Requirements: BEFORE 24-MAR-2021:00:00:00; GROUP 04,05 WITHIN 18H										
Solar System Targets	#	Name	Level 1	Level 2	Level 3	Window	Ephem Center				
	(1)	2I-BORISOV	TYPE=COMET,Q=2.0065818938403 75,E=3.356215101434632,I=44.05257 068647377 ,O=308.1487262895379,W=209.12367 864468,T=08-DEC- 2019:13:04:54,TTimeScale=TDB,EQ UINOX=J2000,EPOCH=01-AUG- 2020:00:00:00,EpochTimeScale=TDB, R0=2.808 ,DT=87.2916 ,A1=7.093444347382E-8,A2=- 1.443811535835E- 8,A3=6.534734368324E-10 ,ALN=0.1112620426,NM=2.15,NN=5. 093,NK=4.6142,AMRAT=0.				EARTH				
Comments: Description=interstellar comet Extended=NO											
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]		Orbit
	1		(1) 2I-BORISOV	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F350LP		POS TARG 0.4,0.4	Sequence 1-1 Non-Int in Visit 04	700 Secs X 3 (2100 Secs) [==>(Copy 1)] [==>(Copy 2)] [==>(Copy 3)]		[1]
Orbit Structure	Orbit 1 Server Version: 20200619 Moving Target Tracking GS Acq Setup Exp. 1, copy 1 Exp. 1, copy 2 Exp. 1, copy 3 Occultation Unused Orbital Visibility = 77										

Proposal 16310 - Visit 05 - Interstellar Comet 2I/Borisov

Visit	Proposal 16310, Visit 05, implementation										Mon Mar 15 16:01:19 GMT 2021	
	Diagnostic Status: No Diagnostics											
	Scientific Instruments: WFC3/UVIS											
	Special Requirements: (none)											
Solar System Targets	#	Name	Level 1	Level 2	Level 3	Window	Ephem Center					
	(1)	2I-BORISOV	TYPE=COMET,Q=2.0065818938403 75,E=3.356215101434632,I=44.05257 068647377 ,O=308.1487262895379,W=209.12367 864468,T=08-DEC- 2019:13:04:54,TTTimeScale=TDB,EQ UINOX=J2000,EPOCH=01-AUG- 2020:00:00:00,EpochTimeScale=TDB, R0=2.808 ,DT=87.2916 ,A1=7.093444347382E-8,A2=- 1.443811535835E- 8,A3=6.534734368324E-10 ,ALN=0.1112620426,NM=2.15,NN=5. 093,NK=4.6142,AMRAT=0.					EARTH				
	Comments: Description=interstellar comet Extended=NO											
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit		
	1		(1) 2I-BORISOV	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F350LP		POS TARG 0.8,0.8	Sequence 1-1 Non-Int in Visit 05	700 Secs X 3 (2100 Secs) [==>(Copy 1)] [==>(Copy 2)] [==>(Copy 3)]	[1]		
Orbit Structure	Orbit 1 Server Version: 20200619 GS Acq Setup Exp. 1, copy 1 Exp. 1, copy 2 Exp. 1, copy 3 Occultation Unused Orbital Visibility = 77 050010001500200025003000350040004500500055006000 sec											

Proposal 16310 - Visit 06 - Interstellar Comet 2I/Borisov

Visit	Proposal 16310, Visit 06, implementation										Mon Mar 15 16:01:19 GMT 2021
	Diagnostic Status: No Diagnostics										
	Scientific Instruments: WFC3/UVIS										
	Special Requirements: (none)										
Solar System Targets	#	Name	Level 1	Level 2	Level 3	Window	Ephem Center				
	(1)	2I-BORISOV	TYPE=COMET,Q=2.0065818938403 75,E=3.356215101434632,I=44.05257 068647377 ,O=308.1487262895379,W=209.12367 864468,T=08-DEC- 2019:13:04:54,TTimeScale=TDB,EQ UINOX=J2000,EPOCH=01-AUG- 2020:00:00:00,EpochTimeScale=TDB, R0=2.808 ,DT=87.2916 ,A1=7.093444347382E-8,A2=- 1.443811535835E- 8,A3=6.534734368324E-10 ,ALN=0.1112620426,NM=2.15,NN=5. 093,NK=4.6142,AMRAT=0.				EARTH				
Comments: Description=interstellar comet Extended=NO											
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]		Orbit
	1		(1) 2I-BORISOV	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F350LP		POS TARG 1.2,1.2	Sequence 1-1 Non-Int in Visit 06	700 Secs X 3 (2100 Secs) [==>(Copy 1)] [==>(Copy 2)] [==>(Copy 3)]		[1]
Orbit Structure	Orbit 1 Server Version: 20200619 Moving Target Tracking GS Acq Setup Exp. 1, copy 1 Exp. 1, copy 2 Exp. 1, copy 3 Unused Orbital Visibility = 77 Occultation 050010001500200025003000350040004500500055006000 sec										