11629 - Far-UV Phase-resolved Spectroscopy of PSR B0656+14

Cycle: 17, Proposal Category: GO

(Availability Mode: SUPPORTED)

INVESTIGATORS

Name	*Institution*	*E-Mail*
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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) PSR-B0656+14	WFC3/UVIS	1	09-Dec-2009 21:21:38.0	yes
02	(2) PSRB0656-OFFSET (3) PSRB0656+14	COS/FUV COS/NUV	4	09-Dec-2009 21:21:44.0	yes
03	(2) PSRB0656-OFFSET (3) PSRB0656+14	COS/FUV COS/NUV	4	09-Dec-2009 21:21:50.0	yes

9 Total Orbits Used

ABSTRACT

X-ray observations of the brightest middle-aged pulsar PSR B0656+14 have shown a Wien tail of thermal emission from the neutron star surface in soft X-rays and magnetospheric emission at higher X-ray energies. Optical/near-UV observations of this pulsar have shown that its emission is predominantly magnetospheric in this range and indicated that the Rayleigh-Jeans thermal component could dominate in the far-UV. This hypothesis has been confirmed by our STIS/FUV observation, which, however, was too short to separate and study the thermal emission (only 2 of 8 allocated

orbits were executed before the STIS failure). Using the superior sensitivity of COS/FUV, we will perform phase-resolved spectroscopy and wavelength-resolved timing of the pulsar radiation in the 1105-1900 A band. The results of this observation, combined with the optical-UV and X-ray data, will allow us to firmly separate the thermal and magnetospheric components and infer the temerature and radius of the neutron star, which is important for understanding the thermal evolution of neutron stars and constraing the composition and equation of state of their superdense interiors.

OBSERVING DESCRIPTION

To collect enough source counts with sufficiently good time resolution for a useful phase-resolved spectroscopy and frequency-resolved timing in the FUV range, we will observe the pulsar with COS/FUV, using G140L grating in TIME-TAG mode. The 32 ms time resolution of COS/FUV will provide about 12 independent phase bins for studying the pulse shape, sufficient for our purposes. As the shorter wavelengths in the 1100-2000 A COS/FUV range are particularly important for our observation, we choose the 1105 A setting to image the whole spectrum on one detector segment; the geocoronal Ly-alpha and oxygen lines background will be cut off during the data analysis. The source count rate for the phase-integrated spectrum is expected to be 408 counts/ks in the 1105-1880 A band (minus a 20 gap around the Ly-alpha line and 10 A gaps around the 1306 A and 1356 A lines). The background count rate in the same wavelength range is 324 counts/ks, mostly from the dark current.

The minimum requirement for the phase-resolved spectroscopy is to measure the spectra in phase bins corresponding to the peaks and the minima of the pulsar's light curve with an accuracy sufficient to distinguish between the spectral slopes in these bins at a >3 sigma confidence level. Based on the previous STIS/FUV data, we performed a series of simulations for various frequency-phase binning schemes and several models for frequency-phase dependence of the FUV radiation and determined that a 20 ks scientific exposure is needed to reach the required accuracy for any models compatible with the STIS/NUV results. The slopes of the simulated spectra can be measured with an accuracy of 0.22 and 0.34 in the pulse peak and minimum, respectively, which means they can be distinguished with the 3.7 sigma confidence. When we get the actual data, we will, of course, perform a much more detailed analysis in the whole frequency-phase space using more realistic models for the thermal and magnetospheric components.

In the 20 ks scientific exposure (8 HST orbits with account for overheads), we will collect 8100 source photons. This will allow us to obtain pulse

profiles with 12 phase bins in, e.g., 8 frequency bands with the average S/N= 9 per bin and investigate the evolution of the pulse shape with frequency (e.g., to examine the expected decrease of pulsed fraction with frequency).

The pulsar is too faint to use it for direct acquisition with COS/NUV. We have checked that there are several nearby stars with precisely known offsets from the pulsar appropriate for offset acquisition. However, as these stars have not been observed with UV detectors, their NUV fluxes are unknown. Since extrapolations from the known optical/NIR magnitudes to the COS/FUV band are very uncertain, the estimates of the aquisition time are very uncertain, too. Therefore, to choose the most appropriate acquisition target and optimize acquisition time, we will image this field with WFC3/UVIS F225W filter (one HST orbit) prior to carrying out the spectroscopic observations.

Visit

Proposal 11629, Visit 01, completed Thu Dec 10 02:21:53 GMT 2009

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/UVIS

Special Requirements: BETWEEN 01-AUG-2009:00:00:00 AND 31-DEC-2009:00:00:00

Comments: UVIS imaging to choose optimal COS/NUV acquisition target and acquisition time. This one-orbit visit should be taken first (in the beginning of Cycle 17 if possible).

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=LINE	Coordinate Frame=POS-TARG		(1)
	Purpose=DITHER	Pattern Orientation=46.840		
	Number Of Points=3	Angle Between Sides=		
	Point Spacing=2.0	Center Pattern=false		
	Line Spacing=			

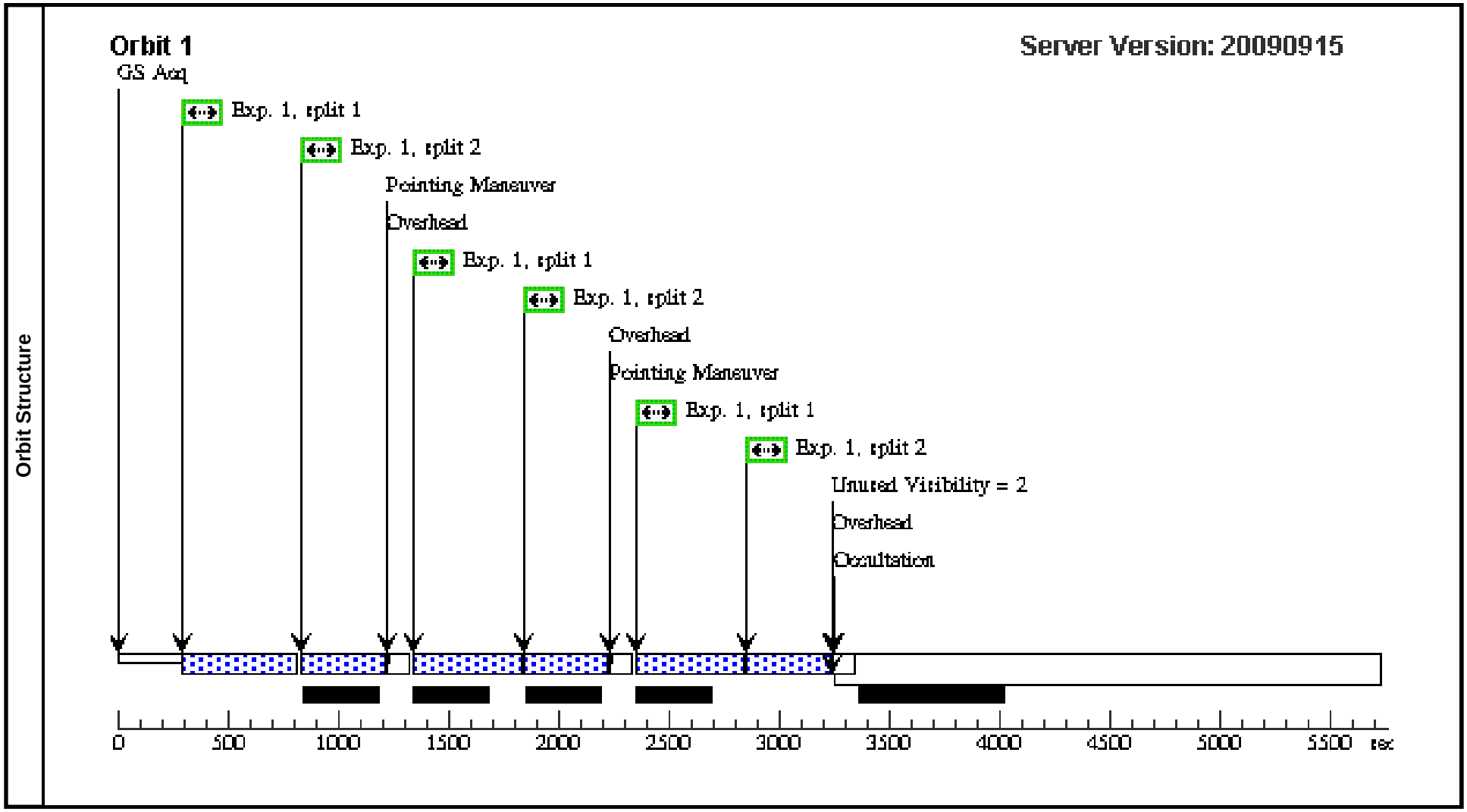
Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	PSR-B0656+14	RA: 06 59 48.1300 (104.9505417d)		V=24.9+/-0.1	Reference Frame: ICRS
		Dec: +14 14 21.50 (14.23931d)			
		Equinox: J2000			

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
1		(1) PSR-B0656+14	WFC3/UVIS, ACCUM, UVIS-CENTER	F225W	CR-SPLIT=2	GS ACQ SCENARIO BASE1B3	Pattern 1, Exps 1-1 (1)	750 Secs	
								[==>378.0 Secs (Pattern 1, Split 1)]	***[1]***
								[==>378.0 Secs (Pattern 1, Split 2)]	
								[==>378.0 Secs (Pattern 2, Split 1)]	
								[==>378.0 Secs (Pattern 2, Split 2)]	
								[==>378.0 Secs (Pattern 3, Split 1)]	
								[==>378.0 Secs (Pattern 3, Split 2)]	


Orbit Structure
Orbit 1
Server Version: 20090915
GS Acq
Exp. 1, split 1
Exp. 1, split 2
Pointing Maneuver
Overhead
Exp. 1, split 1
Exp. 1, split 2
Overhead
Pointing Maneuver
Exp. 1, split 1
Exp. 1, split 2
Unused Visibility = 2
Overhead
Occultation
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
sec

Visit

Proposal 11629, Visit 02, implementation Thu Dec 10 02:21:54 GMT 2009

Diagnostic Status: No Diagnostics

Scientific Instruments: COS/NUV, COS/FUV

Special Requirements: (none)

Comments: This visit was 'on hold' until the data from Visit 01 are analyzed to choose an optimal exposure time for the acquisition exposures. This analysis has been done, and the original parameters for Exposure 1 and Exposure 2 of this visit and Visit 03 have been changed.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(2)	PSRB0656-OFFSET Alt Name1: N8NG000499 Alt Name2: N2233030499	RA: 06 59 49.5820 (104.9565917d) Dec: +14 14 2.73 (14.23409d) Equinox: J2000		V=13.63+/-0.2 J=12.44+/-0.02, H=11.980+/-0.02, K=11.938+/-0.02, Flam=0.8 FEFU in WFC3/F225W filter	Reference Frame: ICRS

Comments: Based on the optical/NIR information available, this is the most appropriate acquisition target. Its coordinates and V magnitude are taken from GSC2.3, the NIR magnitudes are from 2MASS. We observed this field with WFC3/UVIS/F225W in Visit 01 and measured its spectral fux in this filter: 183 electrons/s for an infinite aperture, which corresponds to the average F225W spectral flux Flam = 0.81 FEFU, or Fnu = 0.15 mJy. We have fit the broadband spectrum with the Kurucz models and found that a model with Teff=6500 K (F5V) and E(B-V)=0.2 gives the best fit.

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(3)	PSRB0656+14	Offset from PSRB0656-OFFSET by RA Offset: -1.398 Secs Dec Offset: 18.36 Arcsec		V=24.9+/-0.1	Offset Position (PSRB0656+14) Reference Frame: ICRS

Comments: This pulsar has a proper motion of (42, 0) mas/yr. The offset from the acquisition target PSRB0656-OFFSET was measured from ACIS/WFC images of 2005.93 and computed for 2010.2. We have checked that this offset differs by <0.04 arcsec from the separation between the acquisition star and the pulsar in the WFC3 observation of 2009.8. The offset values are the target (pulsar) position minus the position of the acquisition star.

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
1		(2) PSRB0656-OFFSET	COS/NUV, ACQ/SEARCH, PSA	MIRRORA	SCAN-SIZE=2			12 Secs *[==>]*	 ***[1]***

Comments: First acquisition exposure (we start from ACQ/SEARCH following the unstructions in Phase II Update for Cycle 17 Users of COS). The exposure time and spectral element have been changed based on the data from Visit 01.

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
2		(2) PSRB0656-OFFSET	COS/NUV, ACQ/IMAGE, PSA	MIRRORA				12 Secs *[==>]*	 ***[1]***

Comments: This is second acquisition exposure (ACQ/IMAGE after AQCQ/SEARCH). The exposure time and spectral element have been changed based on the data from Visit 01.

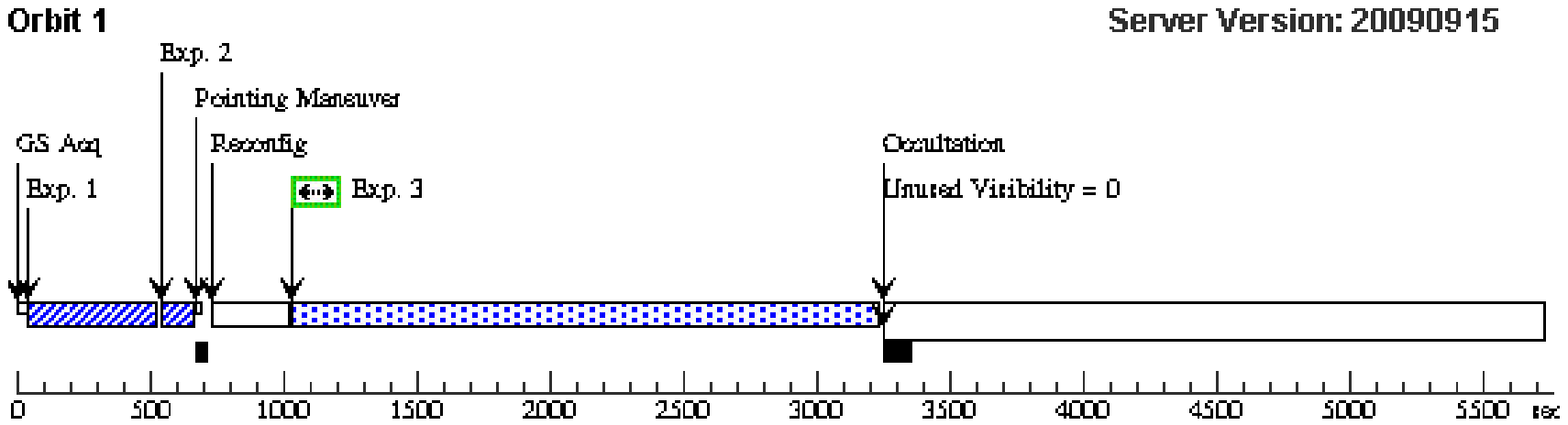
#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
3		(3) PSRB0656+14	COS/FUV, TIME-TAG, PSA	G140L 1105 A	SEGMENT=A; BUFFER-TIME=2031; EXTENDED=NO; FLASH=YES; FP-POS=3			2031 Secs *[==>2031.0 Secs]*	 ***[1]***

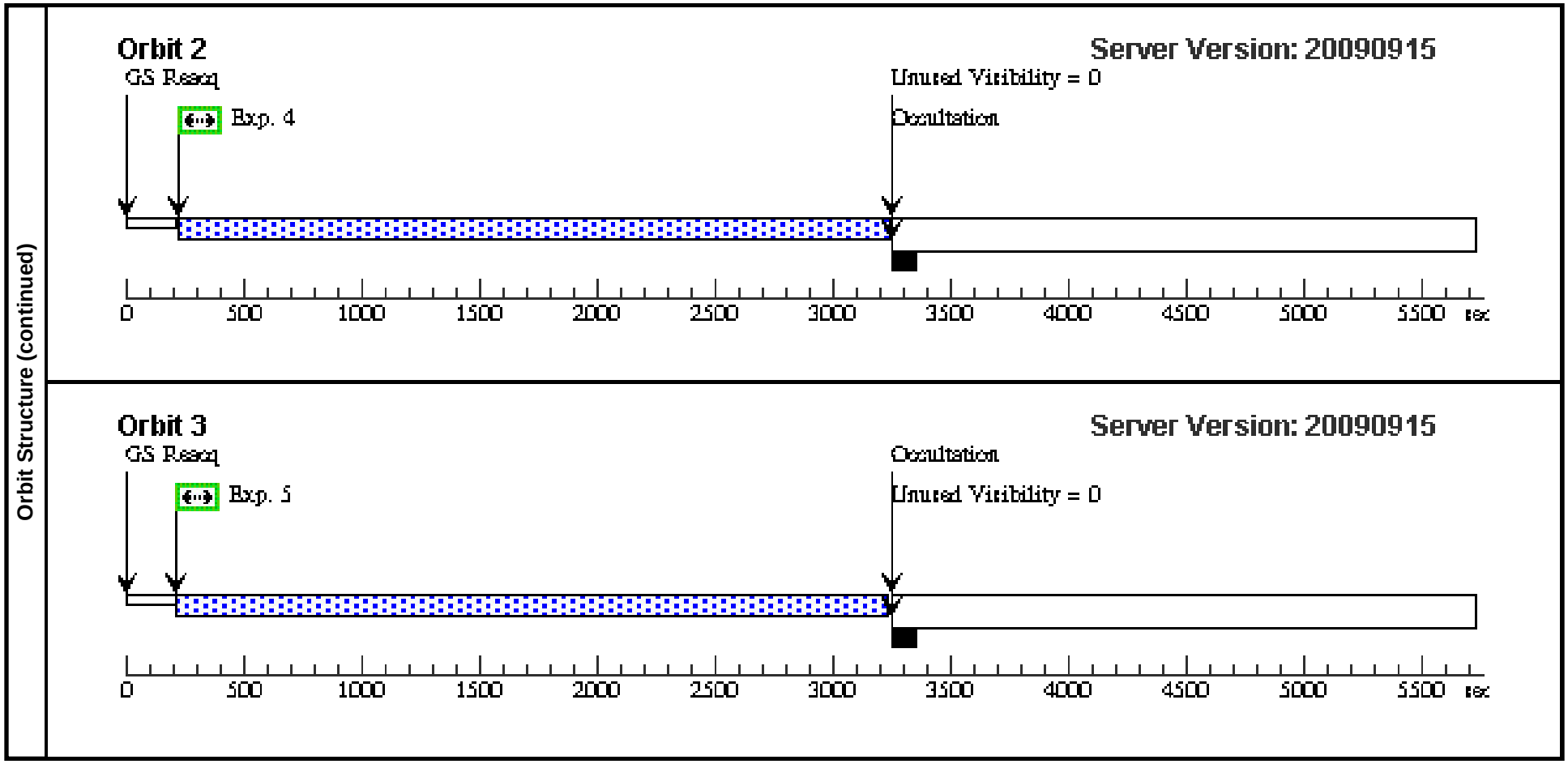
Comments: This is first spectroscopic exposure, taken after the offset acquisition (Exposures 1 and 2).

Exposures (continued)

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
4		(3) PSRB0656+14	COS/FUV, TIME-TAG, PSA	G140L 1105 A	SEGMENT=A; BUFFER-TIME=2965; EXTENDED=NO; FLASH=YES; FP-POS=3			2965 Secs *[==>2965.0 Secs]*	***[2]***
Comments: Second spectroscopic exposure (Orbit 2).									
5		(3) PSRB0656+14	COS/FUV, TIME-TAG, PSA	G140L 1105 A	SEGMENT=A; BUFFER-TIME=2965; EXTENDED=NO; FLASH=YES; FP-POS=4			2965 Secs *[==>2965.0 Secs]*	***[3]***
Comments: Third spectroscopic exposure (Orbit 3).									
6		(3) PSRB0656+14	COS/FUV, TIME-TAG, PSA	G140L 1105 A	SEGMENT=A; BUFFER-TIME=2965; EXTENDED=NO; FLASH=YES; FP-POS=4			2965 Secs *[==>2965.0 Secs]*	***[4]***
Comments: Fourth spectroscopic exposure (Orbit 4).									

Orbit Structure

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3000
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4000
4500
5000
5500
sec
Orbit 3
Server Version: 20090915
GS Reacq
Exp. 5
Occultation
Unused Visibility = 0
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1000
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4000
4500
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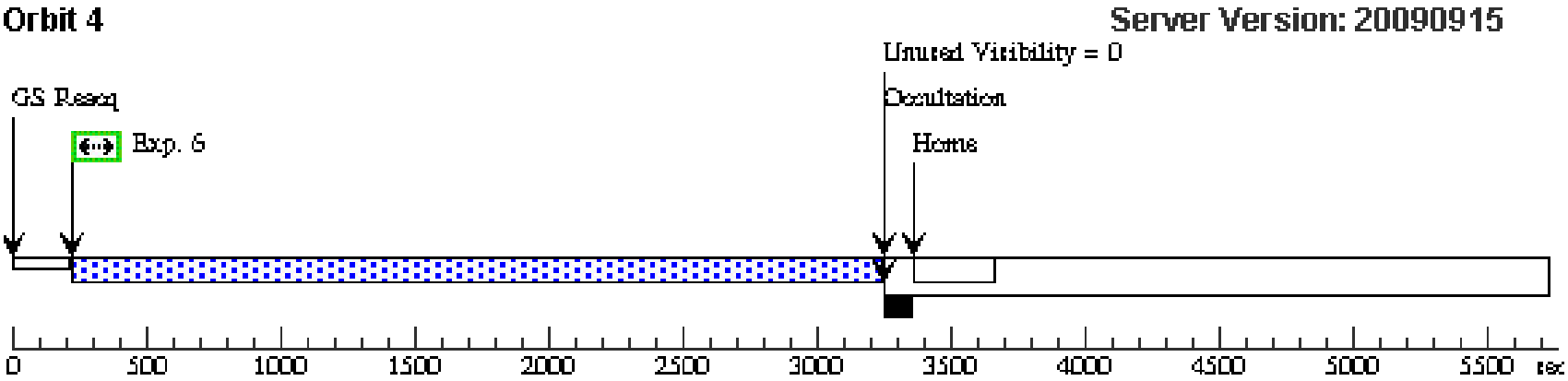
5500
sec

Orbit Structure (continued)



Visit

Proposal 11629, Visit 03, implementation Thu Dec 10 02:21:55 GMT 2009

Diagnostic Status: No Diagnostics

Scientific Instruments: COS/NUV, COS/FUV

Special Requirements: (none)

Comments: This visit was 'on hold' until the data from Visit 01 are analyzed to choose an optimal exposure time for the acquisition exposures. This analysis has been done, and the original parameters for Exposure 1 and Exposure 2 of this visit and Visit 02 have been changed.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(2)	PSRB0656-OFFSET Alt Name1: N8NG000499 Alt Name2: N2233030499	RA: 06 59 49.5820 (104.9565917d) Dec: +14 14 2.73 (14.23409d) Equinox: J2000		V=13.63+/-0.2 J=12.44+/-0.02, H=11.980+/-0.02, K=11.938+/-0.02, Flam=0.8 FEFU in WFC3/F225W filter	Reference Frame: ICRS

Comments: Based on the optical/NIR information available, this is the most appropriate acquisition target. Its coordinates and V magnitude are taken from GSC2.3, the NIR magnitudes are from 2MASS. We observed this field with WFC3/UVIS/F225W in Visit 01 and measured its spectral fux in this filter: 183 electrons/s for an infinite aperture, which corresponds to the average F225W spectral flux Flam = 0.81 FEFU, or Fnu = 0.15 mJy. We have fit the broadband spectrum with the Kurucz models and found that a model with Teff=6500 K (F5V) and E(B-V)=0.2 gives the best fit.

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(3)	PSRB0656+14	Offset from PSRB0656-OFFSET by RA Offset: -1.398 Secs Dec Offset: 18.36 Arcsec		V=24.9+/-0.1	Offset Position (PSRB0656+14) Reference Frame: ICRS

Comments: This pulsar has a proper motion of (42, 0) mas/yr. The offset from the acquisition target PSRB0656-OFFSET was measured from ACIS/WFC images of 2005.93 and computed for 2010.2. We have checked that this offset differs by <0.04 arcsec from the separation between the acquisition star and the pulsar in the WFC3 observation of 2009.8. The offset values are the target (pulsar) position minus the position of the acquisition star.

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
1		(2) PSRB0656-OFFSET	COS/NUV, ACQ/SEARCH, PSA	MIRRORA	SCAN-SIZE=2			12 Secs *[==>]*	 ***[1]***

Comments: First acquisition exposure (we start from ACQ/SEARCH following the unstructions in Phase II Update for Cycle 17 Users of COS). The exposure time and spectral element have been changed based on the data from Visit 01.

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
2		(2) PSRB0656-OFFSET	COS/NUV, ACQ/IMAGE, PSA	MIRRORA				12 Secs *[==>]*	 ***[1]***

Comments: This is second acquisition exposure (ACQ/IMAGE after AQCQ/SEARCH). The exposure time and spectral element have been changed based on the data from Visit 01.

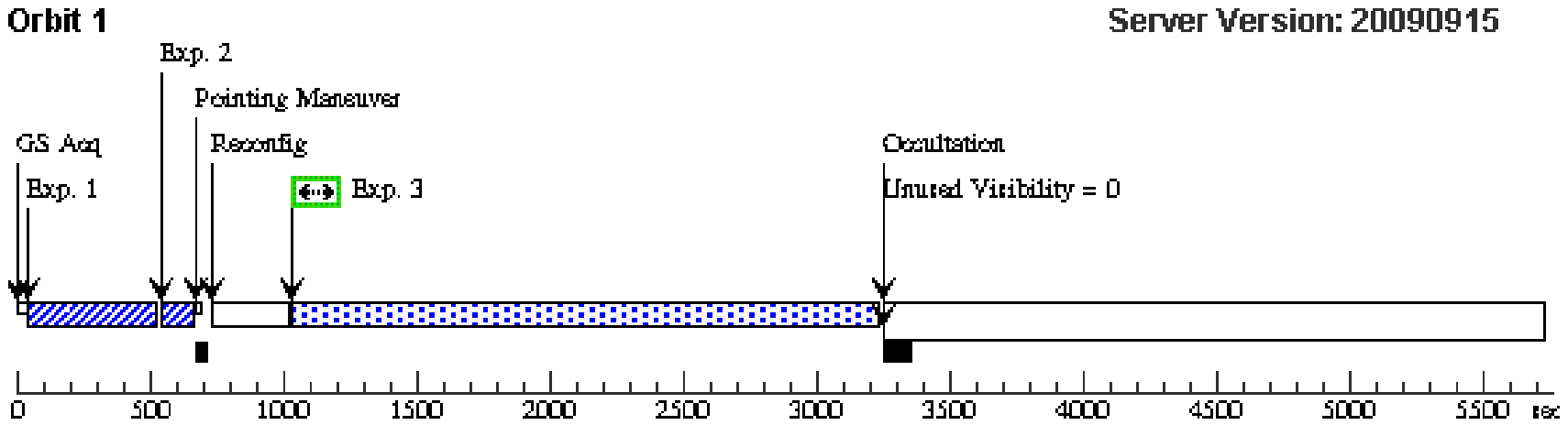
#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
3		(3) PSRB0656+14	COS/FUV, TIME-TAG, PSA	G140L 1105 A	SEGMENT=A; BUFFER-TIME=2031; EXTENDED=NO; FLASH=YES; FP-POS=3			2031 Secs *[==>2031.0 Secs]*	 ***[1]***

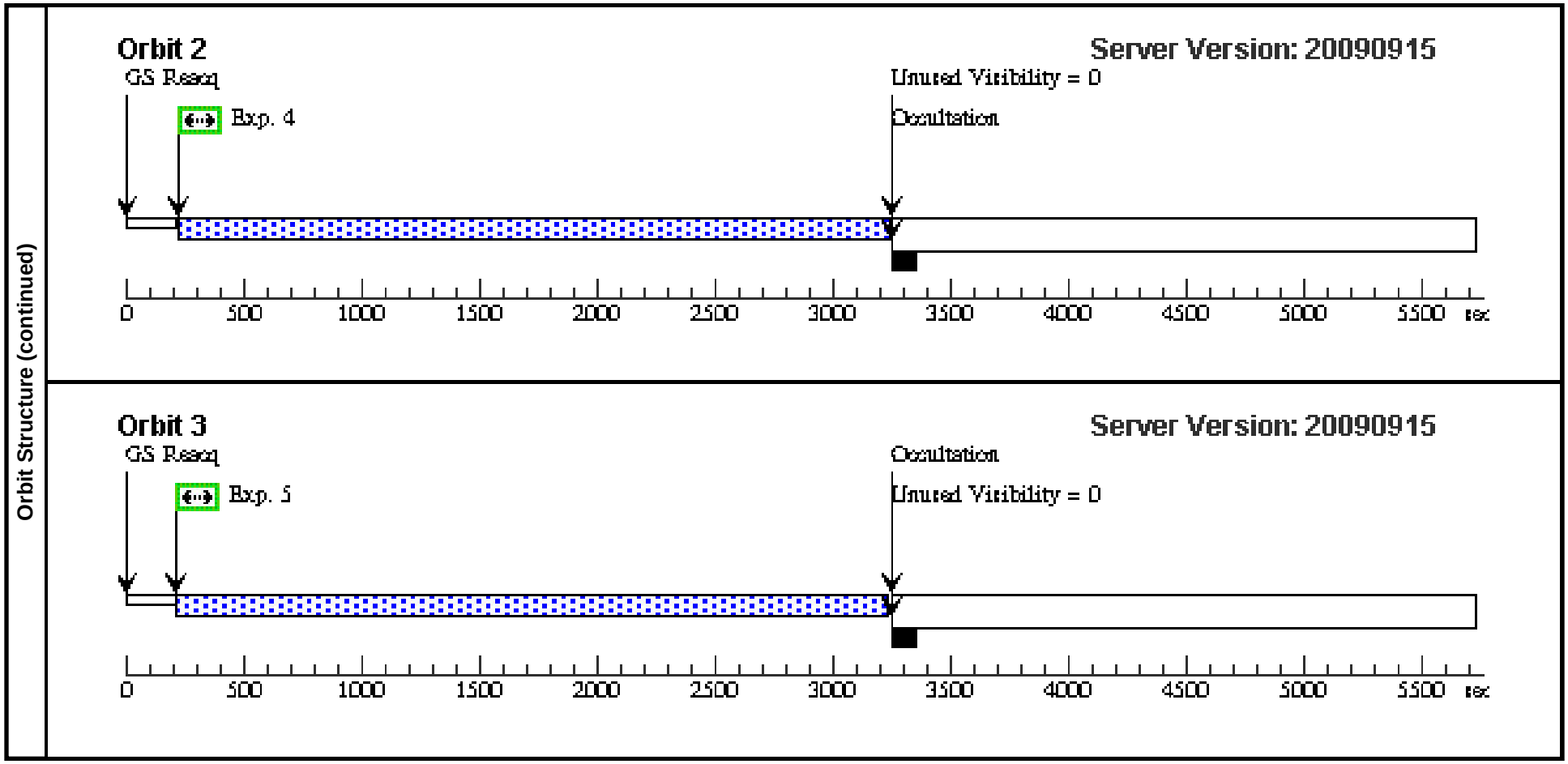
Comments: This is first spectroscopic exposure, taken after the offset acquisition (Exposures 1 and 2).

Exposures (continued)

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
4		(3) PSRB0656+14	COS/FUV, TIME-TAG, PSA	G140L 1105 A	SEGMENT=A; BUFFER-TIME=2965; EXTENDED=NO; FLASH=YES; FP-POS=3			2965 Secs *[==>2965.0 Secs]*	***[2]***
Comments: Second spectroscopic exposure (Orbit 2).									
5		(3) PSRB0656+14	COS/FUV, TIME-TAG, PSA	G140L 1105 A	SEGMENT=A; BUFFER-TIME=2965; EXTENDED=NO; FLASH=YES; FP-POS=4			2965 Secs *[==>2965.0 Secs]*	***[3]***
Comments: Third spectroscopic exposure (Orbit 3).									
6		(3) PSRB0656+14	COS/FUV, TIME-TAG, PSA	G140L 1105 A	SEGMENT=A; BUFFER-TIME=2965; EXTENDED=NO; FLASH=YES; FP-POS=4			2965 Secs *[==>2965.0 Secs]*	***[4]***
Comments: Fourth spectroscopic exposure (Orbit 4).									

Orbit Structure




Orbit Structure (continued)
Orbit 2
Server Version: 20090915
GS Reacq
Exp. 4
Unused Visibility = 0
Occultation
0
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1000
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3000
3500
4000
4500
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5500
sec
Orbit 3
Server Version: 20090915
GS Reacq
Exp. 5
Occultation
Unused Visibility = 0
0
500
1000
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4500
5000
5500
sec

Orbit Structure (continued)