



13674 - A 1.05Msun Companion to PSR J2222-0137: The Coolest Known White Dwarf?

Cycle: 22, 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) PSR-J2222-0137	WFC3/UVIS	5	14-Aug-2015 21:18:09.0	yes
02	(1) PSR-J2222-0137	WFC3/UVIS	5	14-Aug-2015 21:18:14.0	yes
03	(1) PSR-J2222-0137	ACS/WFC	5	14-Aug-2015 21:18:19.0	yes

15 Total Orbits Used

ABSTRACT

The recycled pulsar PSR J2222-0137 is one of the closest known neutron stars, with a parallax distance of 267 ± 1 pc. Using radio Shapiro delay measurements, we determine a companion mass (1.05 ± 0.06 Msun) consistent with either a low-mass neutron star or a high-mass white dwarf (WD). However, the orbital eccentricity is too low to be the product of two supernovae and we are forced to conclude that the companion is a WD. And yet, despite deep optical and near-infrared searches with SOAR and the Keck telescopes we have not discovered the optical counterpart of the system and can limit its effective temperature to $< 3,000$ K, a limit that is robust to distance, mass, and atmosphere uncertainties. This would make the companion to PSR J2222-0137 the coolest WD ever observed. For the implied age to be consistent with the age of the Milky Way requires the WD to have already crystallized and entered the faster Debye-cooling regime.

We wish to identify the companion of PSR J2222 and measure its spectral-energy distribution. Atmosphere models in this regime are extremely poorly tested, with significant uncertainties in the equation-of-state. Cooling ages for these models are even less well-known, as the impacts of state changes, sedimentation, and chemical processes are not precisely known. Here we request 3 bands of imaging with HST (WFC3/UVIS for g, r, and ACS/WFC for i) designed to detect the companion under the most pessimistic scenario. This will measure the effective temperature and atmosphere, and constrain the radius. These models will then help calibrate the ages of the globular clusters, halo WDs, and millisecond pulsars.

OBSERVING DESCRIPTION

We propose to identify the companion of PSR J2222 and to begin to measure its spectral-energy distribution. This will help us measure the effective temperature and atmosphere, and constrain the radius/internal composition. If collisionally-induced absorption (CIA) is important in the atmosphere (i.e., there is some non-negligible amount of H), then the source will be considerably bluer than a blackbody, and so despite the cold temperatures we should focus on the optical regime rather than the near-infrared. We find that ACS/WFC/F625W (r-band) is the most sensitive band for most atmospheric compositions. Based on our faintest available models (considering a range of helium-to-hydrogen ratios for $M = 1.15$ Msun, which is 2σ above our best-fit value), we predict $r < 27.7$. We can reach this limit at S/N of 8 using 5 orbits of HST (total exposure time of 244 min, split into 4 dithered exposures per orbit).

We will complement the r-band search (effectively the deepest for most atmosphere models) with F475W (g) and F775W (i) observations using ACS/WFC (6 orbits each, giving $g = 28$ and $i = 27.5$ at 8σ). These data will give us some wavelength coverage, without moving too far from the optimal window where these ultra-cool WDs peak. We require three bands as there are three primary unknowns: T_{eff} , radius, and atmospheric composition. These don't reach quite the same radius limits, but in the event of a solid detection in one band the other bands will likely have at least 5σ detections that can help determine T_{eff} and the atmospheric composition. Again, we use 4 dithered exposures per orbit.

We will also use PSF photometry to improve the S/N. Our request is for 15 orbits total. If possible, we request that the different bands be scheduled in different visibility periods (separated by > 10 months) so that we can confirm any counterpart through a proper motion measurement ($\mu = 45$ arcsec/yr, or 1 WFC3 pixel/year, which should be detectable if the S/N is high enough) but this is not a requirement.

To be conservative, we will first take the r-band observations and examine them before moving to the other bands. If our expectations are completely wrong we will use the remaining orbits to go deeper in r-band rather than do the other bands.

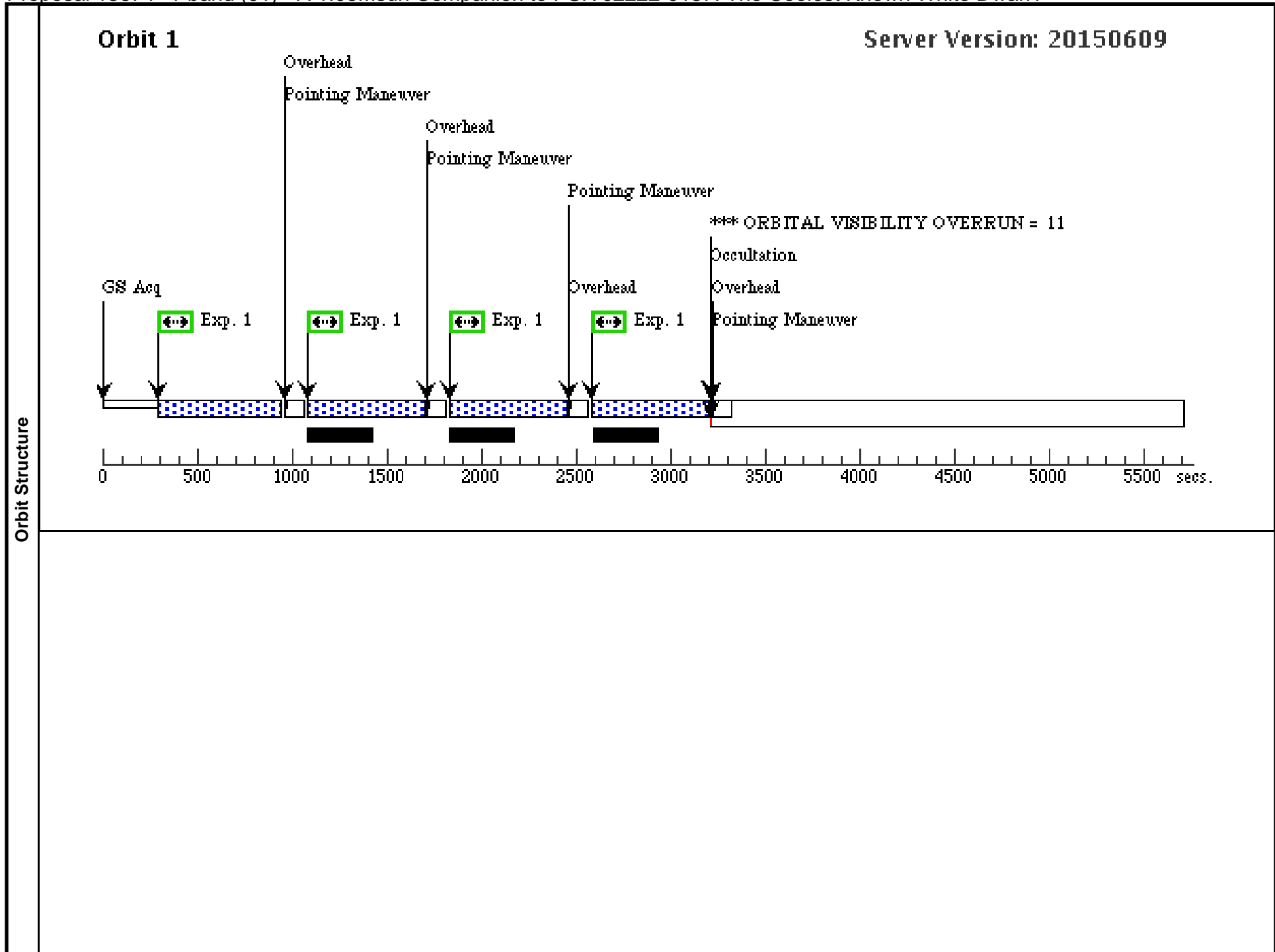
Proposal 13674 - r-band (01) - A 1.05Msun Companion to PSR J2222-0137: The Coolest Known White Dwarf?

Sat Aug 15 01:18:21 GMT 2015

Visit	Proposal 13674, r-band (01), completed Diagnostic Status: Warning Scientific Instruments: WFC3/UVIS Special Requirements: (none)				
	(r-band (01)) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN (r-band (01)) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN (r-band (01)) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN (r-band (01)) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN (r-band (01)) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN				
Diagnosics					
Patterns	#	Primary Pattern	Secondary Pattern	Exposures	
	(1)	Pattern Type=WFC3-UVIS-DITHER-BOX Purpose=DITHER Number Of Points=4 Point Spacing=0.173 Line Spacing=0.112	Coordinate Frame=POS-TARG Pattern Orientation=23.884 Angle Between Sides=81.785 Center Pattern=false		(1), (2), (3), (4), (5)
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes
	(1)	PSR-J2222-0137	RA: 22 22 5.9690 (335.5248708d) Dec: -01 37 15.72 (-1.62103d) Equinox: J2000		V=28
					Miscellaneous
					Reference Frame: ICRS

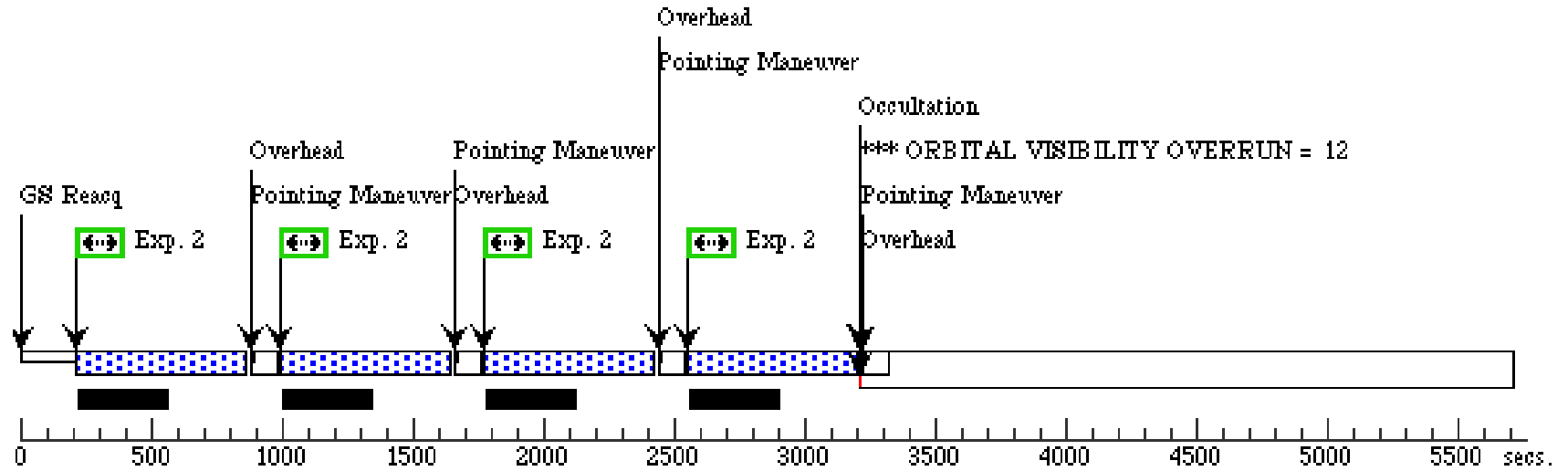
Proposal 13674 - r-band (01) - A 1.05Msun Companion to PSR J2222-0137: The Coolest Known White Dwarf?

Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1		(1) PSR-J2222-0137	WFC3/UVIS, ACCUM, UVIS2	F625W		POS TARG -41,-31	Pattern 1, Exps 1-1 i n r-band (01) (1)	620 Secs (2496 Secs)	
									[==>624.0 Secs (Pattern 1)]	[1]
									[==>624.0 Secs (Pattern 2)]	
									[==>624.0 Secs (Pattern 3)]	
									[==>624.0 Secs (Pattern 4)]	
2		(1) PSR-J2222-0137	WFC3/UVIS, ACCUM, UVIS2	F625W		POS TARG -37,-31	Pattern 1, Exps 2-2 i n r-band (01) (1)	620 Secs (2608 Secs)		
								[==>652.0 Secs (Pattern 1)]	[2]	
								[==>652.0 Secs (Pattern 2)]		
								[==>652.0 Secs (Pattern 3)]		
								[==>652.0 Secs (Pattern 4)]		
3		(1) PSR-J2222-0137	WFC3/UVIS, ACCUM, UVIS2	F625W		POS TARG -37,-27	Pattern 1, Exps 3-3 i n r-band (01) (1)	620 Secs (2608 Secs)		
								[==>652.0 Secs (Pattern 1)]	[3]	
								[==>652.0 Secs (Pattern 2)]		
								[==>652.0 Secs (Pattern 3)]		
								[==>652.0 Secs (Pattern 4)]		
4		(1) PSR-J2222-0137	WFC3/UVIS, ACCUM, UVIS2	F625W		POS TARG -41,-27	Pattern 1, Exps 4-4 i n r-band (01) (1)	620 Secs (2608 Secs)		
								[==>652.0 Secs (Pattern 1)]	[4]	
								[==>652.0 Secs (Pattern 2)]		
								[==>652.0 Secs (Pattern 3)]		
								[==>652.0 Secs (Pattern 4)]		
5		(1) PSR-J2222-0137	WFC3/UVIS, ACCUM, UVIS2	F625W		POS TARG -45,-35	Pattern 1, Exps 5-5 i n r-band (01) (1)	620 Secs (2608 Secs)		
								[==>652.0 Secs (Pattern 1)]	[5]	
								[==>652.0 Secs (Pattern 2)]		
								[==>652.0 Secs (Pattern 3)]		
								[==>652.0 Secs (Pattern 4)]		



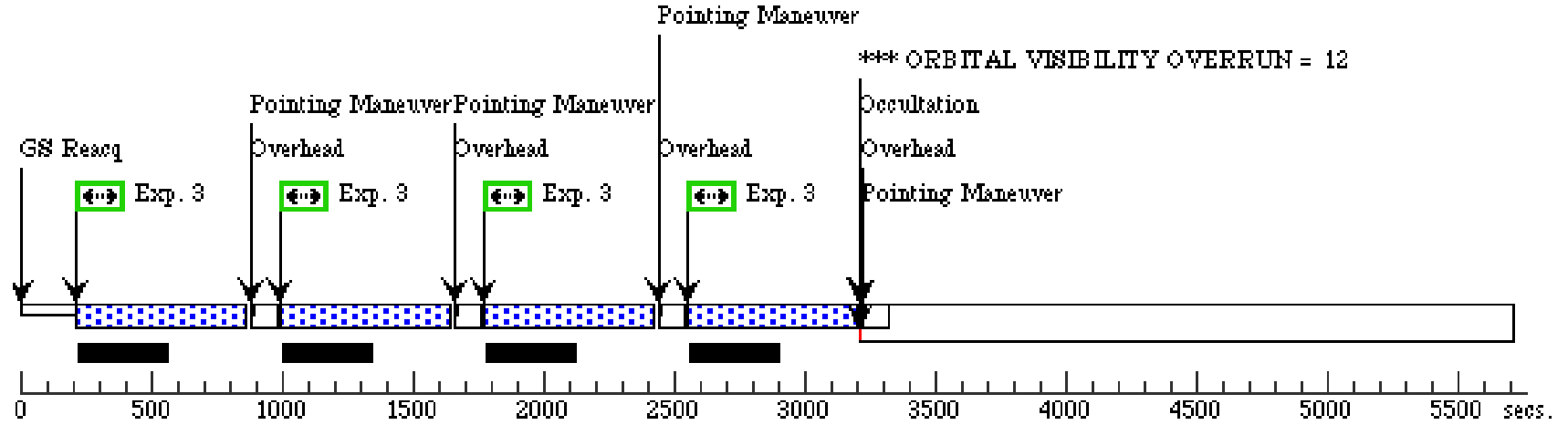
Orbit 2

Server Version: 20150609



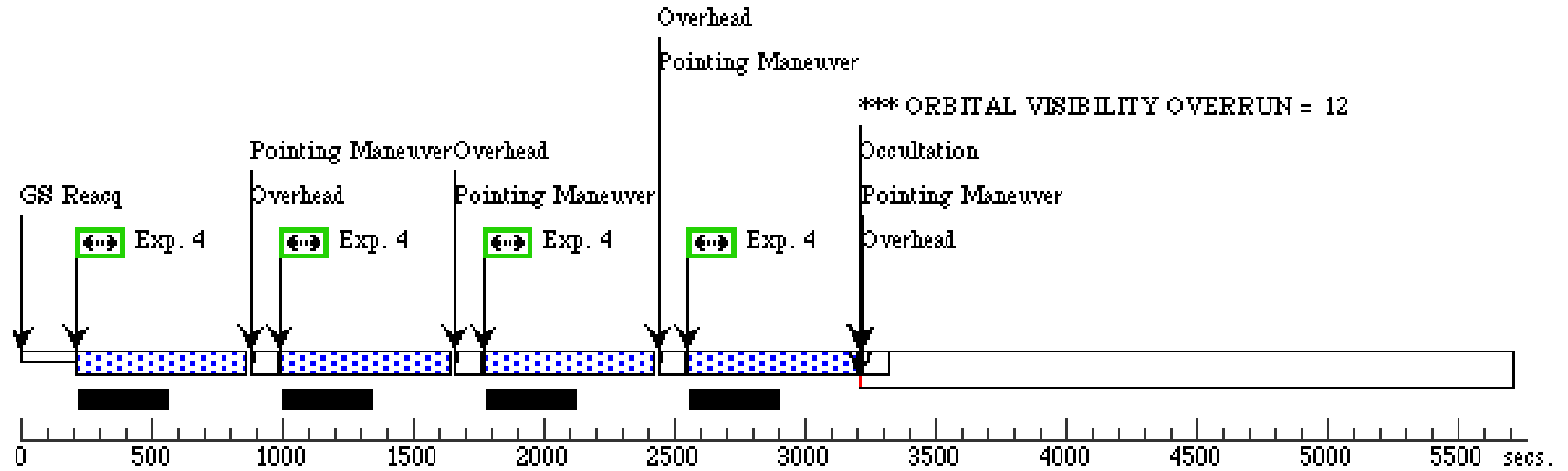
Orbit 3

Server Version: 20150609



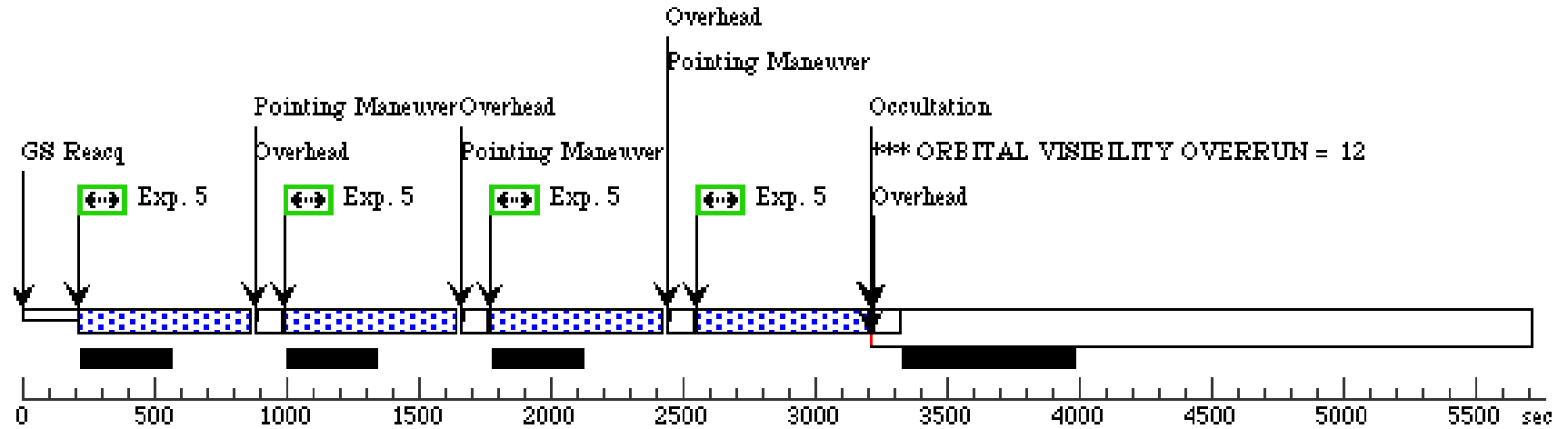
Orbit 4

Server Version: 20150609



Orbit 5

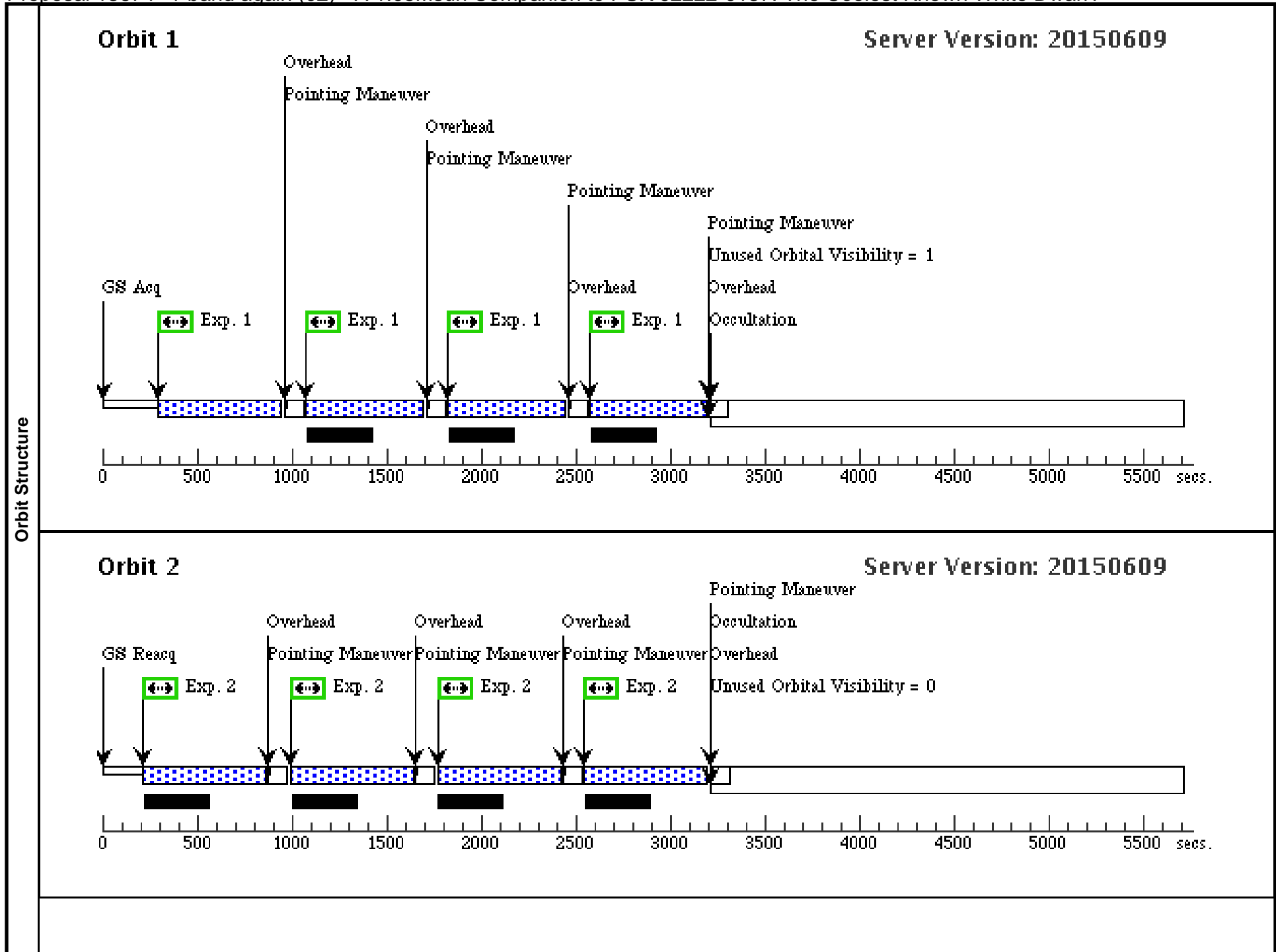
Server Version: 20150609



Proposal 13674 - r-band again (02) - A 1.05Msun Companion to PSR J2222-0137: The Coolest Known White Dwarf?

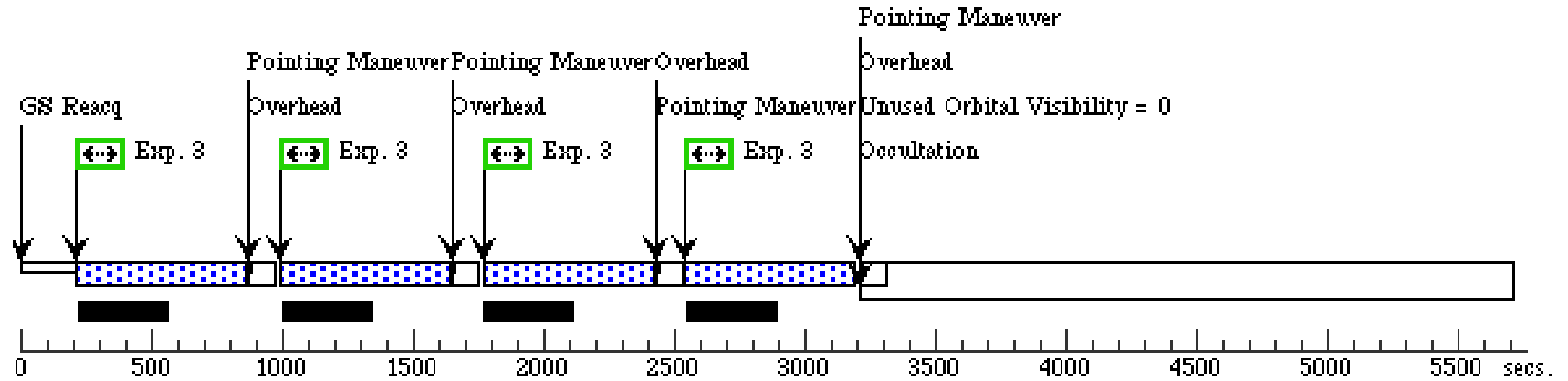
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Visit	Proposal 13674, r-band again (02), implementation Diagnostic Status: No Diagnostics Scientific Instruments: WFC3/UVIS Special Requirements: AFTER 01 BY 180 D TO 365.0 D									
	Patterns	#	Primary Pattern	Secondary Pattern	Exposures					
	(1)	Pattern Type=WFC3-UVIS-DITHER-BOX Purpose=DITHER Number Of Points=4 Point Spacing=0.173 Line Spacing=0.112	Coordinate Frame=POS-TARG Pattern Orientation=23.884 Angle Between Sides=81.785 Center Pattern=false		(1), (2), (3), (4), (5)					
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous				
	(1)	PSR-J2222-0137	RA: 22 22 5.9690 (335.5248708d) Dec: -01 37 15.72 (-1.62103d) Equinox: J2000		V=28	Reference Frame: ICRS				
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	(1) PSR-J2222-0137	WFC3/UVIS, ACCUM, UVIS2	F625W		POS TARG -41,-31	Pattern 1, Exps 1-1 in r-band again (02) (1)	624 Secs (2484 Secs)		
								[==>621.0 Secs (Pattern 1)] [==>621.0 Secs (Pattern 2)] [==>621.0 Secs (Pattern 3)] [==>621.0 Secs (Pattern 4)]	[1]	
	2	(1) PSR-J2222-0137	WFC3/UVIS, ACCUM, UVIS2	F625W		POS TARG -37,-31	Pattern 1, Exps 2-2 in r-band again (02) (1)	652 Secs (2596 Secs)		
								[==>649.0 Secs (Pattern 1)] [==>649.0 Secs (Pattern 2)] [==>649.0 Secs (Pattern 3)] [==>649.0 Secs (Pattern 4)]	[2]	
	3	(1) PSR-J2222-0137	WFC3/UVIS, ACCUM, UVIS2	F625W		POS TARG -37,-27	Pattern 1, Exps 3-3 in r-band again (02) (1)	652 Secs (2596 Secs)		
							[==>649.0 Secs (Pattern 1)] [==>649.0 Secs (Pattern 2)] [==>649.0 Secs (Pattern 3)] [==>649.0 Secs (Pattern 4)]	[3]		
4	(1) PSR-J2222-0137	WFC3/UVIS, ACCUM, UVIS2	F625W		POS TARG -41,-27	Pattern 1, Exps 4-4 in r-band again (02) (1)	652 Secs (2596 Secs)			
							[==>649.0 Secs (Pattern 1)] [==>649.0 Secs (Pattern 2)] [==>649.0 Secs (Pattern 3)] [==>649.0 Secs (Pattern 4)]	[4]		
5	(1) PSR-J2222-0137	WFC3/UVIS, ACCUM, UVIS2	F625W		POS TARG -45,-35	Pattern 1, Exps 5-5 in r-band again (02) (1)	652 Secs (2596 Secs)			
							[==>649.0 Secs (Pattern 1)] [==>649.0 Secs (Pattern 2)] [==>649.0 Secs (Pattern 3)] [==>649.0 Secs (Pattern 4)]	[5]		



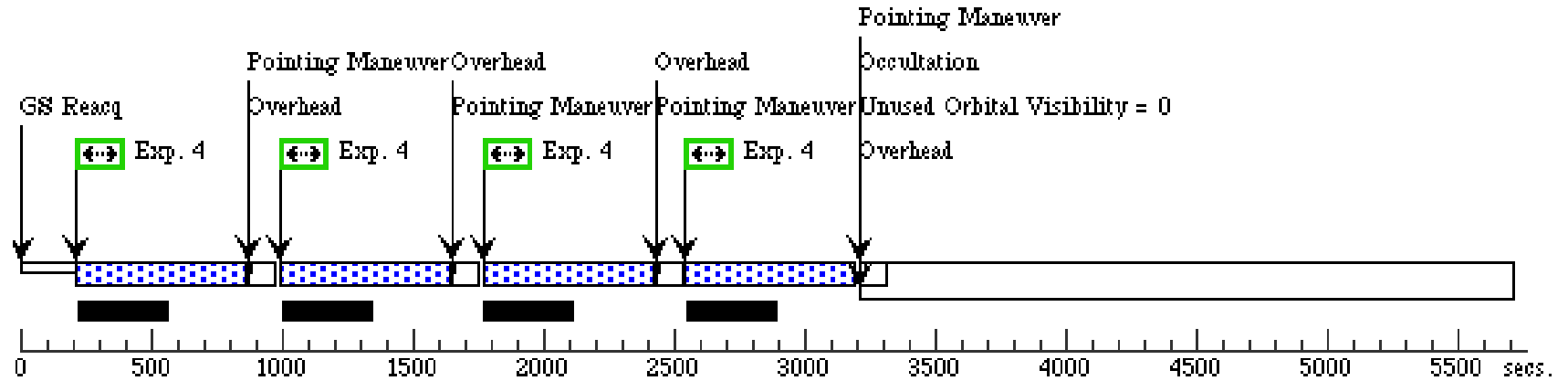
Orbit 3

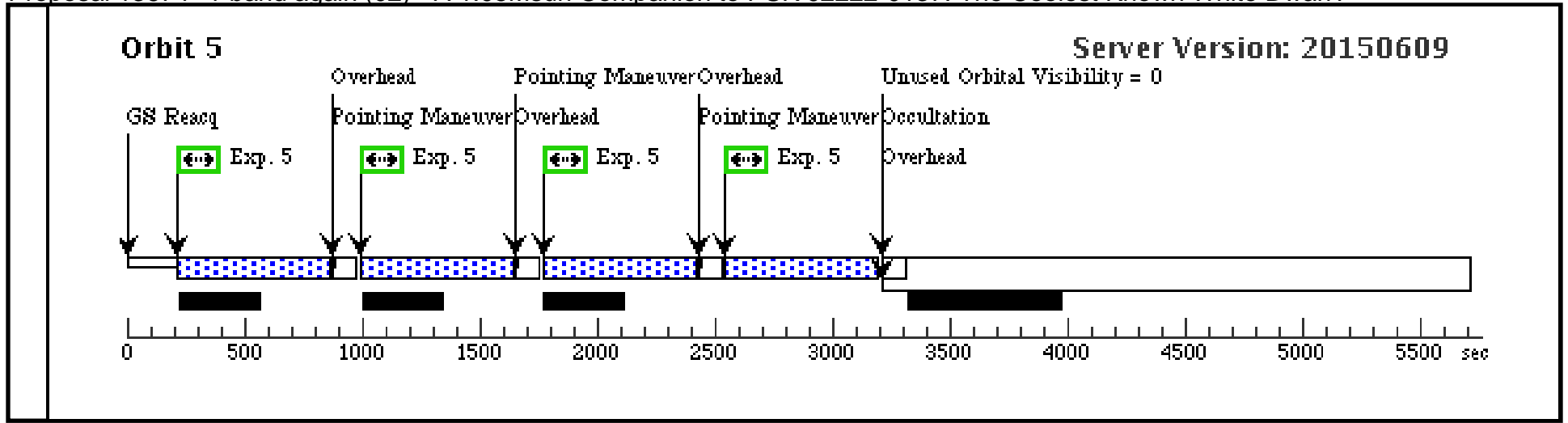
Server Version: 20150609



Orbit 4

Server Version: 20150609

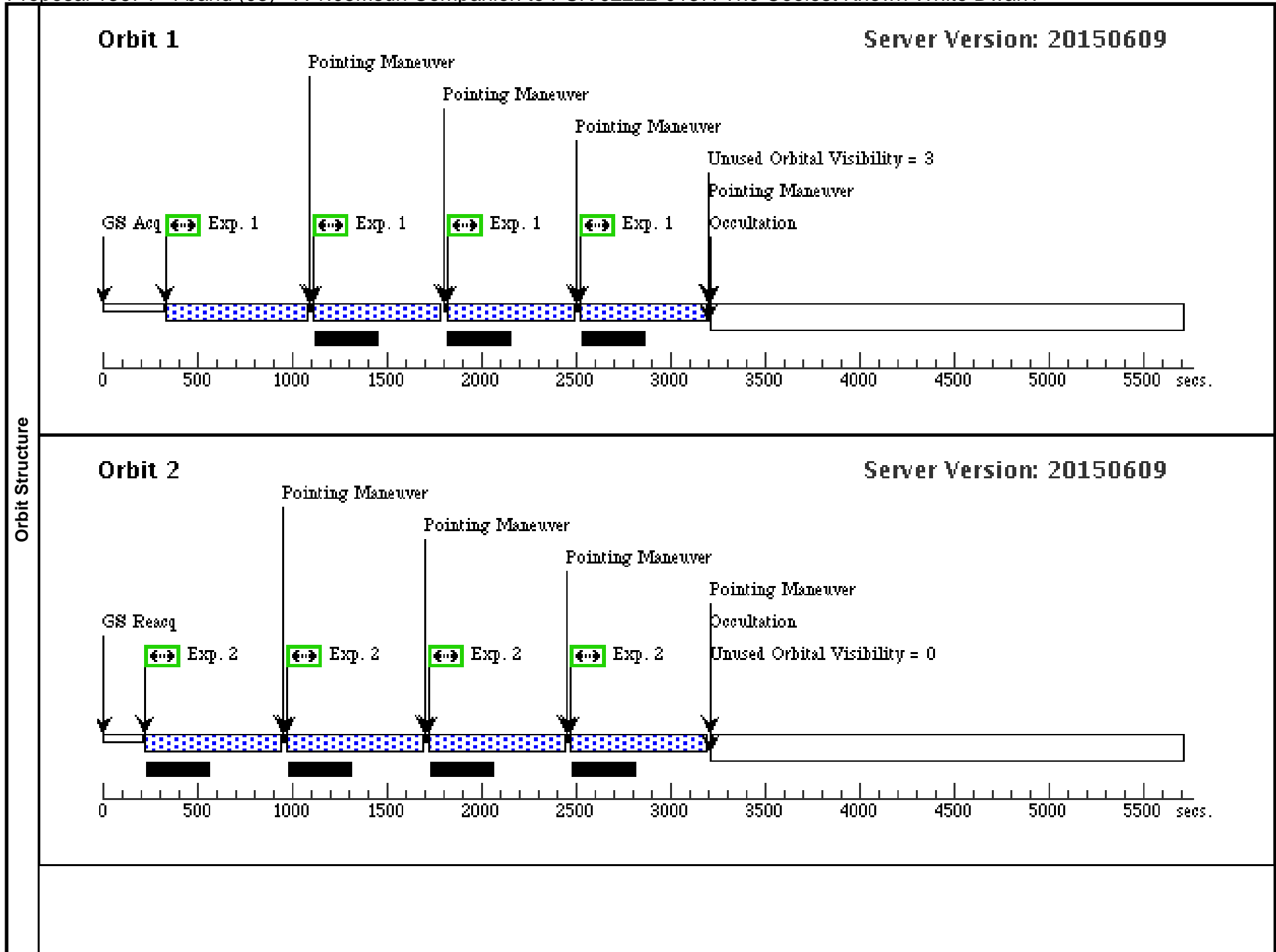




Proposal 13674 - i-band (03) - A 1.05Msun Companion to PSR J2222-0137: The Coolest Known White Dwarf?

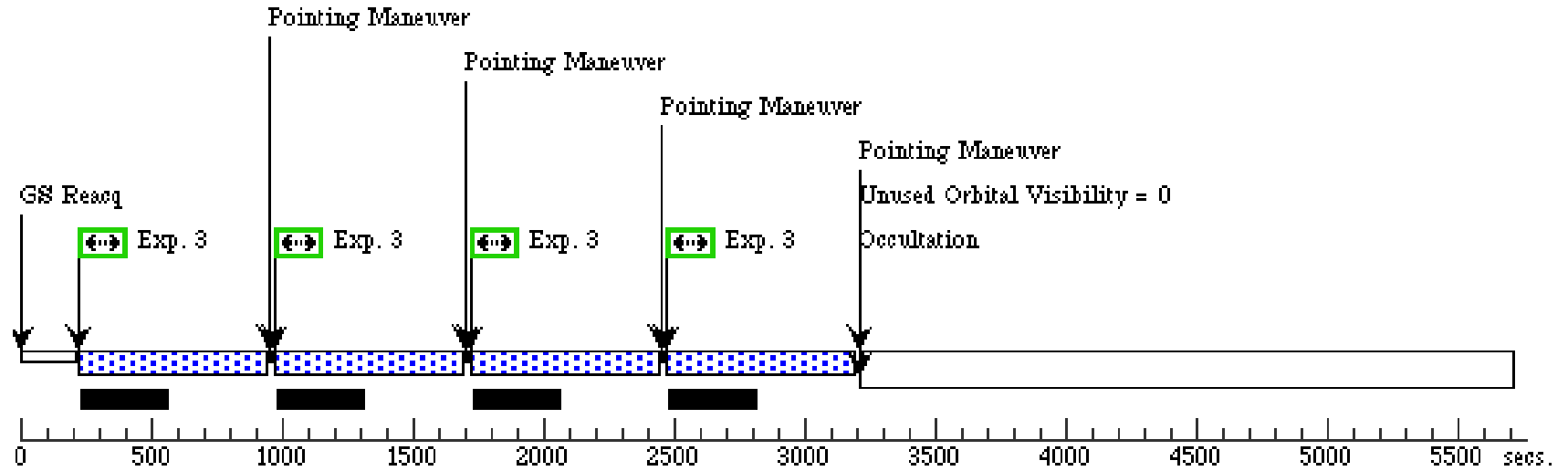
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Visit	Proposal 13674, i-band (03), implementation Diagnostic Status: No Diagnostics Scientific Instruments: ACS/WFC Special Requirements: AFTER 01 BY 180 D TO 365.0 D									
	Patterns	#	Primary Pattern	Secondary Pattern	Exposures					
	(2)	Pattern Type=ACS-WFC-DITHER-BOX Purpose=DITHER Number Of Points=4 Point Spacing=0.265 Line Spacing=0.187	Coordinate Frame=POS-TARG Pattern Orientation=20.67 Angle Between Sides=69.05 Center Pattern=false		(1), (2), (3), (4), (5)					
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous				
	(1)	PSR-J2222-0137	RA: 22 22 5.9690 (335.5248708d) Dec: -01 37 15.72 (-1.62103d) Equinox: J2000		V=28	Reference Frame: ICRS				
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	(1) PSR-J2222-0137	ACS/WFC, ACCUM, WFC1-CTE	F775W				Pattern 2, Exps 1-1 in i-band (03) (2)	548 Secs (2180 Secs) [==>545.0 Secs (Pattern 1)] [==>545.0 Secs (Pattern 2)] [==>545.0 Secs (Pattern 3)] [==>545.0 Secs (Pattern 4)]	[1]
	2	(1) PSR-J2222-0137	ACS/WFC, ACCUM, WFC1-CTE	F775W			POS TARG 4,0	Pattern 2, Exps 2-2 in i-band (03) (2)	597 Secs (2376 Secs) [==>594.0 Secs (Pattern 1)] [==>594.0 Secs (Pattern 2)] [==>594.0 Secs (Pattern 3)] [==>594.0 Secs (Pattern 4)]	[2]
	3	(1) PSR-J2222-0137	ACS/WFC, ACCUM, WFC1-CTE	F775W			POS TARG 4,4	Pattern 2, Exps 3-3 in i-band (03) (2)	597 Secs (2376 Secs) [==>594.0 Secs (Pattern 1)] [==>594.0 Secs (Pattern 2)] [==>594.0 Secs (Pattern 3)] [==>594.0 Secs (Pattern 4)]	[3]
	4	(1) PSR-J2222-0137	ACS/WFC, ACCUM, WFC1-CTE	F775W			POS TARG 0,4	Pattern 2, Exps 4-4 in i-band (03) (2)	597 Secs (2376 Secs) [==>594.0 Secs (Pattern 1)] [==>594.0 Secs (Pattern 2)] [==>594.0 Secs (Pattern 3)] [==>594.0 Secs (Pattern 4)]	[4]
	5	(1) PSR-J2222-0137	ACS/WFC, ACCUM, WFC1-CTE	F775W			POS TARG -4,-4	Pattern 2, Exps 5-5 in i-band (03) (2)	597 Secs (2376 Secs) [==>594.0 Secs (Pattern 1)] [==>594.0 Secs (Pattern 2)] [==>594.0 Secs (Pattern 3)] [==>594.0 Secs (Pattern 4)]	[5]



Orbit 3

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Orbit 4

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