11627 - Resolving the puzzling nature of the ultra-compact binary V407 Vul

Cycle: 17, Proposal Category: GO

(Availability Mode: SUPPORTED)

INVESTIGATORS

Name	*Institution*	*E-Mail*
Dr. Gijs Nelemans (PI) (ESA Member)	**Katholieke Universiteit Nijmegen**	**nelemans@astro.ru.nl**
Dr. Gijs Roelofs (CoI) (AdminUSPI)	Smithsonian Institution Astrophysical Observatory	groelofs@cfa.harvard.edu
Dr. Gavin Ramsay (CoI) (ESA Member)	Armagh Observatory	gar@arm.ac.uk
Dr. Danny Steeghs (CoI) (ESA Member)	The University of Warwick	D.T.H.Steeghs@warwick.ac.uk
Prof. Thomas R. Marsh (CoI) (ESA Member)	The University of Warwick	t.r.marsh@warwick.ac.uk
Prof. Paul Groot (CoI) (ESA Member)	Katholieke Universiteit Nijmegen	pgroot@astro.kun.nl
Ms. Susana Barros (CoI) (ESA Member)	The University of Warwick	s.c.barros@warwick.ac.uk

VISITS

Visit	*Targets used in Visit*	*Configurations used in Visit*	*Orbits Used*	*Last Orbit Planner Run*	*OP Current with Visit?*
04	(1) V407VUL	WFC3/UVIS	3	29-Jun-2009 22:20:28.0	yes

3 Total Orbits Used

ABSTRACT

Recently, three variable stars have been identified as likely accreting binary systems with ultra-short orbital periods of 10 minutes or less. This makes them the closest binaries known as well as strong sources of gravitational wave emission. These objects have thus been identified as crucial calibration sources for the LISA mission. V407 Vul diplays a 9.5 minute period at optical and X-ray wavelengths. Several different binary geometries have been proposed to explain this variable star with all but one scenario identifying the 9.5 minute period with the binary orbital period. Our time-

resolved spectroscopy and photometry from the ground revealed that the optical light is dominated by a stationary G9 star which would be inconsistent with the mass donor star of a compact binary. We propose ACS/HRC imaging in order to confirm the tentative 0.03" mis-alignment we have picked up between this G9 star and the underlying variable. Confirmation of a spatial separation between the variable and this field star would conclusively rule out that the G star is part of a low-inclination binary and thus verify it as a LISA source. In addition, we propose UV imaging that will allow us to determine the NUV luminosity of the variable star and thereby reliably infer the distance and the nature (and thus the gravitational wave signal) of the ultra-compact binary, as either mass transfer or magnetic interaction powers the X-ray source. Only HST imaging can provide rigorous proof for an ultra-compact binary interpretation for V407 Vul and thus validate it as LISA verification source

OBSERVING DESCRIPTION

We plan to employ the high resolution channel of ACS and obtain high-resolution images of the V407 Vul field in three filters. The plate-scale of 0.027”/pixel permits us to accurately measure the positions of our target as well as several reference stars within the HRC field of view (Fig. 3). Our goal is to compare the relative positions of the optical counterparts in the different filters with accuracies well below the pixel scale.

Given the 53 minute visibility window and the 6.1 minute guide star acquisition overhead, 46.9 minutes are available for ACS exposures in the first orbit. With two planned exposures in the first orbit, which each will be split into 3 to allow dithering, the ACS overheads amount to 9 minutes, leaving 37.9 minutes of effective exposure time. The second and third orbits will consist of sets of three exposures each (42.8mins of net exposure time).

Our ’red’ image will employ the F775W (i) filter. Using the ACS imaging ETC and R=19.2 for V407 Vul, we obtain a S/N of ~160 in 180s. This exposure will be completely dominated by light from the G9-star and will serve as the reference point for its position.

Our ’blue’ exposure will employ the F330W (U) filter. We chose the U filter to make sure that the G9-star contribution is very small compared to the underlying blue source which based on our ground-based observations is estimated to contribute more than 45% of the light in U. For

comparison, the variable only contributes 15% in the g-band, and thus we need to go bluer to measure its position accurately. The U-band exposures will span the remaining time left in the first orbit (38.9 min) as well as the second orbit of our visit, delivering a combined S/N of 60-100 for a 105K black-body that contributes 45% to the U flux. The range in S/N reflects the expected reddening range as derived from our Gemini observations ($0.6 < E(B V) < 1.4$). It is important to get a good S/N in this U-band exposure so as to be able to derive an accurate position for the blue variable and confirm the suggested separation of 0.03” relative to the G9 star. With the S/N of our exposures, we will be able to centroid our sources to better than 0.1 HRC pixels and can measure this separation directly.

Finally, we will use the third orbit of our visit to obtain a near-UV exposure using COS.

In one orbit we will achieve a S/N of 30-80 which depends on the actual reddening towards the variable and we have allowed for the full range of E(B-V). This third filter is mainly to constrain the reddening and temperature of the underlying variable.

With this strategy, we can achieve our two key goals in three HST orbits. The three images will allow us to measure the spatial separation between the blue variable and the G9 star as well as determine the reddening towards the blue variable, which is important for the implied luminosity of the system. These two measurements will finally settle the question of whether V407 Vul is a 9 minute ultra-compact binary accreting at high rates due to gravitational wave losses.

Visit

Proposal 11627, Visit 04 Tue Jun 30 02:20:33 GMT 2009

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/UVIS

Special Requirements: (none)

Patterns

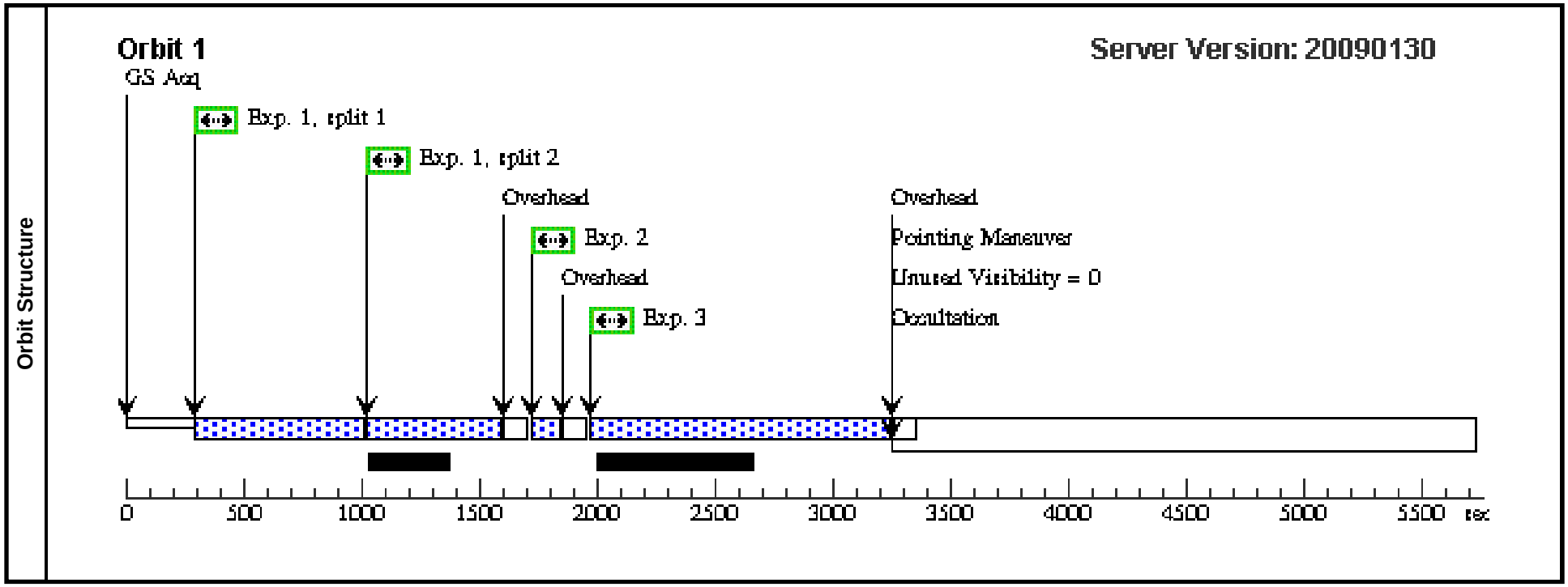
#	Primary Pattern		Secondary Pattern	Exposures
(2)	Pattern Type=WFC3-UVIS-DITHER-LINE Purpose=DITHER Number Of Points=3 Point Spacing=0.145 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=46.84 Angle Between Sides= Center Pattern=false		(1-3)

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	V407VUL Alt Name1: RXJ1914.3+2456	RA: 19 14 26.1000 (288.6087500d) Dec: +24 56 43.35 (24.94538d) Equinox: J2000		V=19.9 u'=21.5 g'=20.3	Reference Frame: ICRS

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
1		(1) V407VUL	WFC3/UVIS, ACCUM, UVIS	F390W	CR-SPLIT=2		Pattern 2, Exps 1-3 (2)	1138.8 Secs	
								[==>(Pattern 1, Split 1)] *[==>(Pattern 1, Split 2)]*	***[1]***
								[==>(Pattern 2, Split 1)] *[==>1138.8 Secs (Pattern 2, Split 2)]*	***[2]***
								[==>(Pattern 3, Split 1)] *[==>1138.8 Secs (Pattern 3, Split 2)]*	***[3]***
2		(1) V407VUL	WFC3/UVIS, ACCUM, UVIS	F775W	CR-SPLIT=NO		Pattern 2, Exps 1-3 (2)	100 Secs	
								[==>(Pattern 1)]	***[1]***
								[==>(Pattern 2)]	***[2]***
								[==>(Pattern 3)]	***[3]***
3		(1) V407VUL	WFC3/UVIS, ACCUM, UVIS	F225W	CR-SPLIT=NO		Pattern 2, Exps 1-3 (2)	569.4 Secs	
								[==>1245.4 Secs (Pattern 1)]	***[1]***
								[==>814.0 Secs (Pattern 2)]	***[2]***
								[==>814.0 Secs (Pattern 3)]	***[3]***


Orbit Structure
Orbit 1
Server Version: 20090130
GS Acq
Exp. 1, split 1
Exp. 1, split 2
Overhead
Exp. 2
Overhead
Exp. 3
Overhead
Pointing Maneuver
Unused Visibility = 0
Occultation
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
sec

Orbit Structure (continued)