14070 - A Red Supergiant Mass Accurate to 1%

Cycle: 23, Proposal Category: GO

(UV Initiative)

(Availability Mode: AVAILABLE)

INVESTIGATORS

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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) V-V695-CYG WAVE	STIS/CCD STIS/FUV-MAMA	2	27-Aug-2015 21:13:40.0	yes

2 Total Orbits Used

ABSTRACT

Red supergiants (RSGs) are massive, evolved stars that are among the brightest stars in the near infrared, and often serve as useful ``standard candles'' for extragalactic and cosmological studies. But this use of RSGs is hampered by the lack of fundamental mass and luminosity calibrations tying these objects to the theoretical H-R diagram. Theoretical evolutionary models are not very useful because of mass loss due to stellar winds in the RSG stage. Mass loss in RSG stars is not well understood, and is incorporated using various parameterizations. No accurate observationally-determined RSG masses are available. More than anywhere else in the H-R diagram, there is a pressing need for accurate stellar masses of red supergiants.

The determination of an accurate RSG mass is a priority. We propose to determine the mass of the K supergiant in the bright, well-studied, eclipsing binary system 31 Cygni (K4 Ib + B3 V). The orbital solution of the optically-dominant K supergiant has been accurately determined. Given this, a complete solution for both stellar masses can be found from a small number of radial velocity observations of the companion star. For 31 Cyg, archival STIS/E140H observations from 2001-02 (program GO-9109) are well-suited for this purpose. The orbital configuration of 31 Cyg in Cycle 23 is ideally separated by ~0.5 in phase from the archival observations (thereby maximizing the RV difference). We propose to obtain additional STIS/E140H observations in Cycle 23, and use these two sets of FUV observations to determine the mass of the 31 Cyg K supergiant to ~1%. These observations must be done soon, or the optimal phase window for doing so will be lost.

OBSERVING DESCRIPTION

We request a total of 2 orbits at a single visit in Cycle 23 to re-observe the eclipsing binary system 31 Cygni with the STIS E140H echelle at an orbital phase differerence of about 0.5 from that of the archival 2001 and 2002 GO-9109 STIS observations (approximately 1.5 orbits ago). This phase difference maximizes the radial velocity difference between the proposed Cycle 23 observation and the archival observations of GO-9109. Since the orbital period of 31 Cyg is long (10.36 yr), suitable phase differences will remain favourable trhoughout the nominal 2015-2016 duration of Cycle 23. These E140H echelle observations will be acquired for the spectral region from 1150 to 1400 A at a high signal-to-noise ratio of S/N ~ 50. The target is a UV-bright, non-variable, early-type star (B3 V), and therefore we will use the 0.4 dex neutral density aperture 31X0.05NDA to keep the proposed global count rates (of 90,000 to 140,000 counts/s for the various E140H exposures) below the MAMA detector global count rate limit of 200,000 counts/s. Note that the variable star designation of this target refers to the low-amplitude photometric and radial velocity variability of the K supergiant primary star, and NOT to the B-star companion. In the FUV, only the B star makes a significant contribution to the flux, and this star is not varaible. A careful examination of large aperture IUE observations of this binary out-of-eclipse (which should be reasonably photometric) confirms that FUV fluxes vary by < 5-10%, and this small variation is probably due to the limitations of the IUE flux calibration, and not to instrinsic variability of the B star. The target is a bright, point source object, and so the use of the long slit should not present any difficulty in separating the echelle orders. The proposed high S/N ~ 50 E140H spectra, in combination with the two available archival visits from program GO-9109, should suffice to determine relative velocity shifts from spectral cross-correlation to an accuracy of about 0.4 km/s. Because of the favorable orbital phase differences, these observations will sample nearly the full range of orbital velocities of this binary (= 2*K_2 ~ 46 km/s, where K_2 is the B star's radial velocity semi-amplitude). The multiplex advantage of using three pairs of correlations (from the three observations) should further reduce the error on 2*K_2 to about 0.2 km/s. Therefore, we expect to determine K_2 to ~0.1 km/s. The primary orbit of the K4 Ib supergiant is very well determined: K_1 is known to an accuracy of 0.04 km/s. Therefore, an accurate determination of K_2 of this eclipsing binary will yield an accurate solution of the binary. We expect the proposed STIS/E140H observation to determine the masses of the K supergiant accurate to ~1%.

We have received approval to use the "AVAILABLE" modes option in APT, specifically the use of WAVECAL=NO and of user-specified GO wavecals (TARGET=WAVE) for each of the science exposures of the (single) Visit 1. The science objective requires accurate wavelength calibrations, because the orbital solution depends directly upon the accuracy to which the B-star secondary's radial velocity semi-amplitude K_2 can be determined from the proposed STIS/E140H echelle observations. The value of K_2 will be found by cross-correlation of the observed FUV spectrum with that observed by the PI's previous program GO-9109, when the B star was on the opposite side of its orbit.

Tom Ayres (University of Colorado, Boulder) has offered the investigators the use of his ASTRAL-II software to carry out a custom reduction and wavelength calibration of these observations. He recommended that (1) we use the 0.2X0.09 aperture for the lamp (wavecal) exposures to improve wavelength accuracy, and (2) we use longer wavecal (100 s) exposures to increase the S/N of the lamp spectrum, which is weak shortward of 1300 A. The region from 1150-1300 A is the region of focus for the science objectives of the program because this is the spectral region where the B star is most heavily line-blanketed (as needed for accurate radial velocity measurements). We use four CENWAVE configurations of E140H: 1234, 1271, 1307, and 1343 to improve the line spread function by dithering as provided by the substantial overlap of spectral coverage from these exposures. We have also broken all science exposures into subexposures of maximum length of ~300 s in order to minimize spacecraft Doppler smearing, and provide additional wavelength dithering of the observations.

The science exposures have been arranged so that the shortest wavelength observations (CENWAVE=1271 and 1234) occur as the last science exposures of orbits 1 and 2 respectively, immediately prior to Earth occultation. The calibration lamp is very weak at these short wavelengths, and in order to improve the S/N of the lamp spectrum obtained in this short-wavelength region of the FUV, we have scheduled *two* back-to-back GO-wavecals in Earth occultation immediately following each of the E140H/1271 and 1234 science exposures, in consultation with our Contact Scientist, Charles Proffitt. The first wavecal is of length 100s, whereas the second is a longer 500 s exposure. Both are taken with the identical optical configuration. The second of each of these GO-wavecals produces one warning (of high WAVECAL expsoure time > 300 s) and one error (of illegal STIS wave exposure sequence). However, we have been assured by our CS that these back-to-back wavecals are technically feasible, even though they are flagged as errors in APT. We request that these wavecal observations be carried out as submitted.

Update of Aug 25, 2015: Charles Proffitt requested that the double back-to-back wavecals at the end of each orbit be replaced by single user wavecal of length 300s, so that it will not generate errors in APT and can be put into the long range plan. This has been done in the latest version of this Phase II Proposal.

Visit

Proposal 14070, Visit 01, implementation Fri Aug 28 01:13:42 GMT 2015

Diagnostic Status: Warning

Scientific Instruments: STIS/CCD, STIS/FUV-MAMA

Special Requirements: (none)

Diagnostics

(Visit 01) Warning (Orbit Planner): GAP IN NON-INT SEQUENCE DUE TO ORBIT-NUMBER

(Visit 01) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN

(Visit 01) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN

Fixed Targets

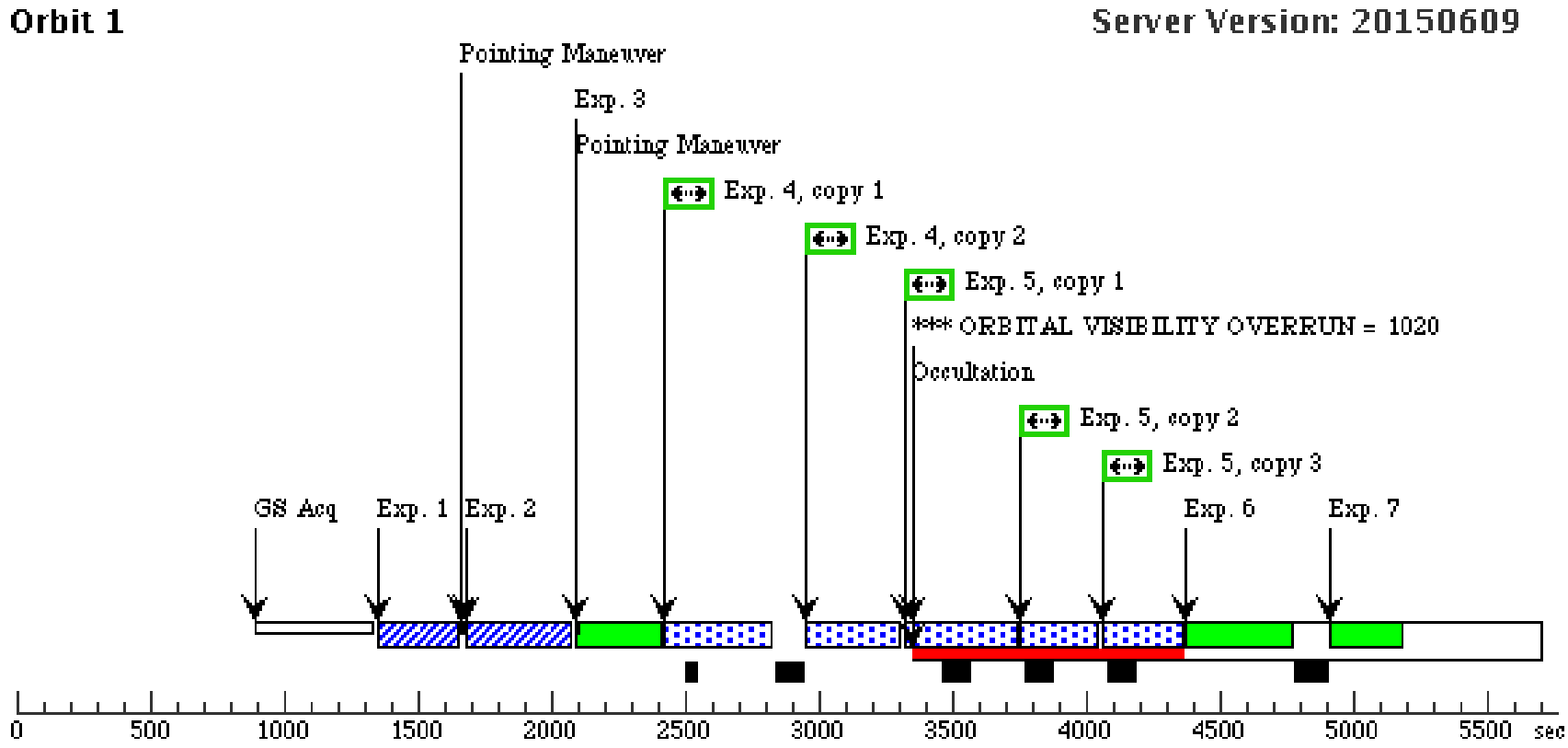
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	V-V695-CYG	RA: 20 13 37.9065 (303.4079437d)	Proper Motion RA: 4.78 mas/yr	V=3.8+/-0.1	Reference Frame: ICRS
	Alt Name1: HD192577	Dec: +46 44 28.78 (46.74133d)	Proper Motion Dec: 1.21 mas/yr	F_lam(1270 A)= 1.7e-10 ergs/cm2/s/A (not variable,	
	Alt Name2: 31-CYG	Equinox: J2000	Parallax: 0.00369"	except during eclipse every 10.3 yrs -- NOT variable in Cycle 23)	
			Epoch of Position: 2000		

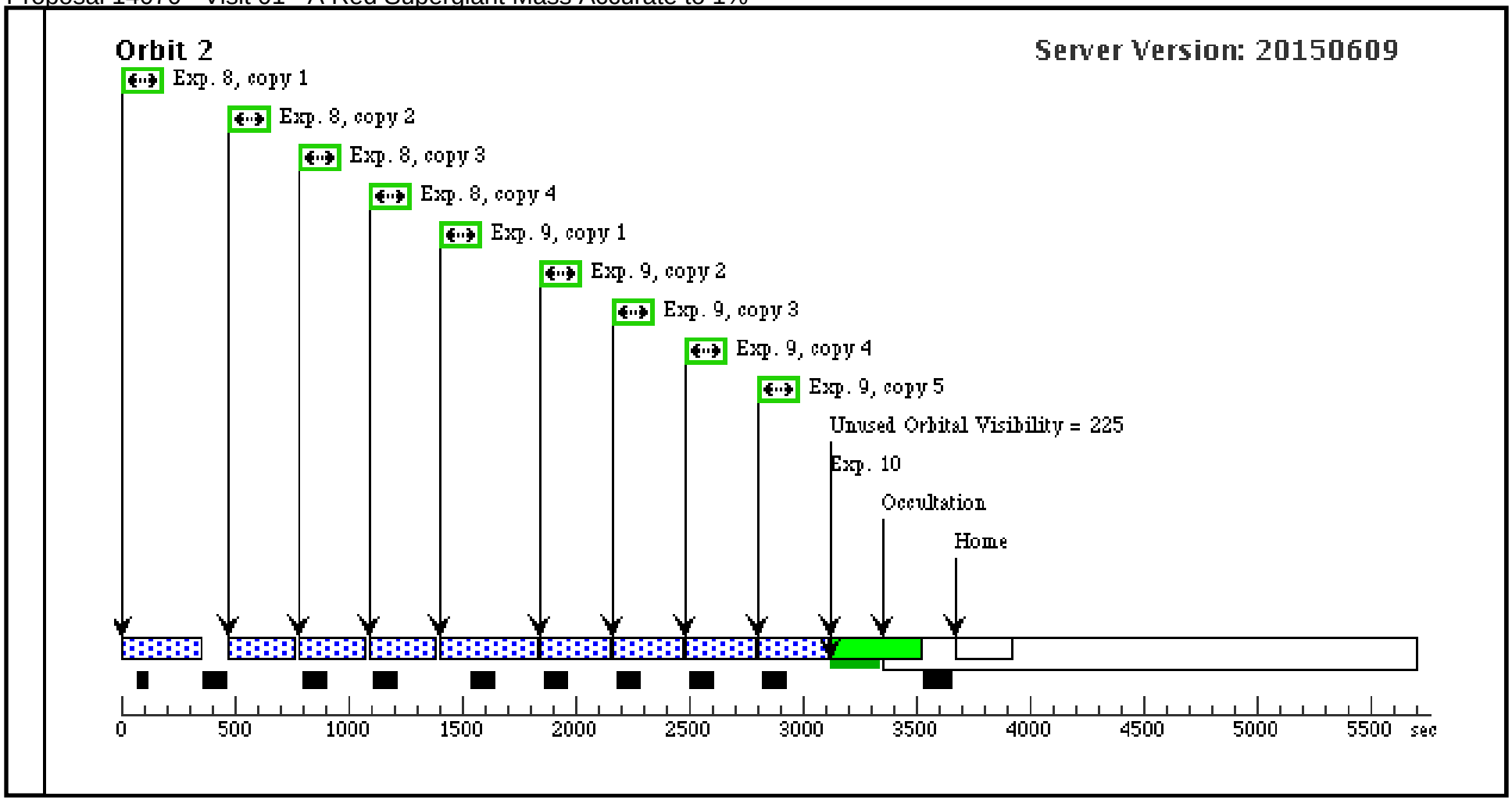
Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.

Exposures

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	(732858)	(1) V-V695-CYG	STIS/CCD, ACQ, F25ND5	MIRROR			Sequence 1-6 Non-Int in Visit 01	2.0 Secs (2 Secs) *[==>]*	 ***[1]***
2	(732887)	(1) V-V695-CYG	STIS/CCD, ACQ/PEAK, 31X0.05NDA	G230LB 2375 A			Sequence 1-6 Non-Int in Visit 01	1.0 Secs (1 Secs) *[==>]*	 ***[1]***
3		WAVE	STIS/FUV-MAMA, ACCUM, 0.2X0.09	E140H 1343 A			Sequence 1-6 Non-Int in Visit 01	100 Secs (100 Secs) *[==>]*	 ***[1]***
4	(732944)	(1) V-V695-CYG	STIS/FUV-MAMA, ACCUM, 31X0.05NDA	E140H 1343 A	WAVECAL=NO		Sequence 1-6 Non-Int in Visit 01	339 Secs X 2 (678 Secs) *[==>(Copy 1)]* *[==>(Copy 2)]*	 ***[1]***
5	(732911)	(1) V-V695-CYG	STIS/FUV-MAMA, ACCUM, 31X0.05NDA	E140H 1271 A	WAVECAL=NO		Sequence 1-6 Non-Int in Visit 01	285 Secs X 3 (855 Secs) *[==>(Copy 1)]* *[==>(Copy 2)]* *[==>(Copy 3)]*	 ***[1]***
6		WAVE	STIS/FUV-MAMA, ACCUM, 0.2X0.09	E140H 1271 A			Sequence 1-6 Non-Int in Visit 01	300 Secs (300 Secs) *[==>]*	 ***[1]***
7		WAVE	STIS/FUV-MAMA, ACCUM, 0.2X0.09	E140H 1307 A			Sequence 7-10 Non-Int in Visit 01	100 Secs (100 Secs) *[==>]*	 ***[1]***
8	(732926)	(1) V-V695-CYG	STIS/FUV-MAMA, ACCUM, 31X0.05NDA	E140H 1307 A	WAVECAL=NO		Sequence 7-10 Non-Int in Visit 01	285 Secs X 4 (1140 Secs) *[==>(Copy 1)]* *[==>(Copy 2)]* *[==>(Copy 3)]* *[==>(Copy 4)]*	 ***[2]***
9	(732906)	(1) V-V695-CYG	STIS/FUV-MAMA, ACCUM, 31X0.05NDA	E140H 1234 A	WAVECAL=NO		Sequence 7-10 Non-Int in Visit 01	296 Secs X 5 (1480 Secs) *[==>(Copy 1)]* *[==>(Copy 2)]* *[==>(Copy 3)]* *[==>(Copy 4)]* *[==>(Copy 5)]*	 ***[2]***
10		WAVE	STIS/FUV-MAMA, ACCUM, 0.2X0.09	E140H 1234 A			Sequence 7-10 Non-Int in Visit 01	300 Secs (300 Secs) *[==>]*	 ***[2]***

Orbit Structure




Orbit 2
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Exp. 8, copy 3
Exp. 8, copy 4
Exp. 9, copy 1
Exp. 9, copy 2
Exp. 9, copy 3
Exp. 9, copy 4
Exp. 9, copy 5
Unused Orbital Visibility = 225
Exp. 10
Occultation
Home
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
sec