13450 - Separating the Spectral Components of the Massive Triple Star System Delta Orionis

Cycle: 21, Proposal Category: GO

(UV Initiative)

(Availability Mode: AVAILABLE)

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) ADS-4134-A (2) ADS-4134-A-2 WAVE	STIS/CCD STIS/FUV-MAMA	1	23-Jan-2015 21:00:57.0	yes
02	(1) ADS-4134-A (2) ADS-4134-A-2 WAVE	STIS/CCD STIS/FUV-MAMA	1	23-Jan-2015 21:00:59.0	yes

2 Total Orbits Used

ABSTRACT

The multiple star system of delta Orionis represents one of the closest examples of a luminous O-star with a strong stellar wind, and it was the target of a recent multi-wavelength campaign to determine the source of the wind X-ray emission. It consists of a close eclipsing binary with a more distant tertiary, and all the components are massive stars. Investigations of the radial velocity curves of the eclipsing system are made difficult by severe line blending with the spectral lines of the tertiary star, and the resulting mass estimates range by a factor of two. We propose that the solution to this problem is to isolate the flux of the tertiary through high angular resolution spectroscopy with HST/STIS, and we show how a two visit program of ultraviolet and spatially resolved spectroscopy will provide us with the means to characterize the spectra of all three stars in the triple. This will allow us to reassess a large body of existing optical and UV spectroscopy and determine reliable radial velocity curves for the components in the close binary. By then fitting a new high precision light curve from MOST photometry, we will derive accurate masses, temperatures, radii, and projected rotational velocities for all the components. The inner binary also has a measured apsidal period, and the new results will form a key test of models of interior structure. The analysis will also provide secure estimates for the geometry and size of the inner binary and the radius of the secondary, the parameters required to analyze the orbital phase variations and sites of origin of the wind X-ray emission documented in a recent Chandra/HETGS program.

OBSERVING DESCRIPTION

Our primary goal in this proposal is to obtain spatially resolved, FUV spectra of both of the Aa1,Aa2 and Ab components. HST/STIS has the angular resolution to produce echelle spectra of each component that can be almost completely isolated from the flux of the other component. Furthermore, by making two visits to the target at times corresponding to both the radial velocity maximum and minimum of Aa1, we will be able to measure the radial velocities of both Aa1 and Aa2 and then extract their individual FUV spectra using a Doppler

tomography algorithm (Bagnuolo et al. 1994). A comparison of the extracted spectra with model spectra will then yield estimates of the effective temperature, gravity, rotational line broadening, and flux fraction contribution for each of Aa1, Aa2, and Ab. The FUV spectrum is ideal for these purposes because this spectral range is rich in temperature-sensitive transitions and records the luminosity-sensitive stellar wind lines (Harvin et al. 2002).

Discovering the spectral nature of Ab will allow us to reassess the radial velocities from the large number of spectra in the IUE archive (68 high resolution, SWP spectra obtained between 1979 and 1991). The HST/STIS spectra of Ab would be transformed to the resolution of the IUE spectra (R=10,000), and then we would subtract out the Ab spectral contribution and renormalize the resulting Aa1,Aa2 spectrum. These would be measured for radial velocity as a straight forward, double-lined spectroscopic binary, allowing us to determine reliably the mass ratio and (with the inclination from the light curve) masses of the inner binary. This would finally resolve the large discrepancies between the results from Harvin et al. (2002) and Mayer et al. (2010).

These results would also offer critical support to two recent observational programs on Ori. Co-I Michael Corcoran completed a program of Chandra/HETGS observations in 2012 December to follow the X-ray variability with orbital phase. One goal of this program was to map the sites of X-ray emission in the close binary by analyzing how the secondary occults different regions with the changing orientation of the orbit. The new HST/STIS observations would support this effort by determining the mass ratio and radius of the Aa2 secondary, so that the occultation effects are reliably estimated. A second program of high accuracy photometry with the Canadian MOST satellite took place at this time (directed by Co-I Anthony Moffat) to determine an extremely accurate binary light curve, and this was accompanied by an extensive program of ground-based spectroscopy. Once again, the derivation of radial velocity data from these new observations will require a careful treatment of the line profile contributions of the Ab component, and the proposed HST/STIS observations will provide the needed characterization of the spectrum of Ab (temperature,

gravity, line broadening, radial velocity, and flux contribution).

Finally, the determination of the orbital parameters of Aa1,Aa2 will provide the basis for high angular resolution program of optical long baseline interferometry with the Center for High Angular Resolution Astronomy (CHARA) Array. Recent observations of another triple, the Algol system, by Baron et al. (2012) demonstrates that the CHARA Array can resolve binary systems with separations below 0.5 milli-arcsec. This is the estimated angular separation of Ori Aa1,Aa2 at the orbital elongations. Thus, a re-determination of the orbital elements of Aa1,Aa2 using the proposed results from HST/STIS would be combined with the angular orbit from CHARA observations to arrive at an independent and accurate estimate of the distance, a key parameter for estimates of the radii and luminosities. This will help us develop a three-dimensional sense of the position of delta Ori among the young stars in the Orion association.

Visit

Proposal 13450, Visit 1 (01), completed Sat Jan 24 02:01:00 GMT 2015

Diagnostic Status: No Diagnostics

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

Special Requirements: ORIENT 55.55D TO 115.55 D; ORIENT 235.55D TO 295.55 D; BETWEEN 28-DEC-2014:00:00:00 AND 06-JAN-2015:00:00:00; Period 5.732436 D AND ZERO-PHASE HJD2456473.0502

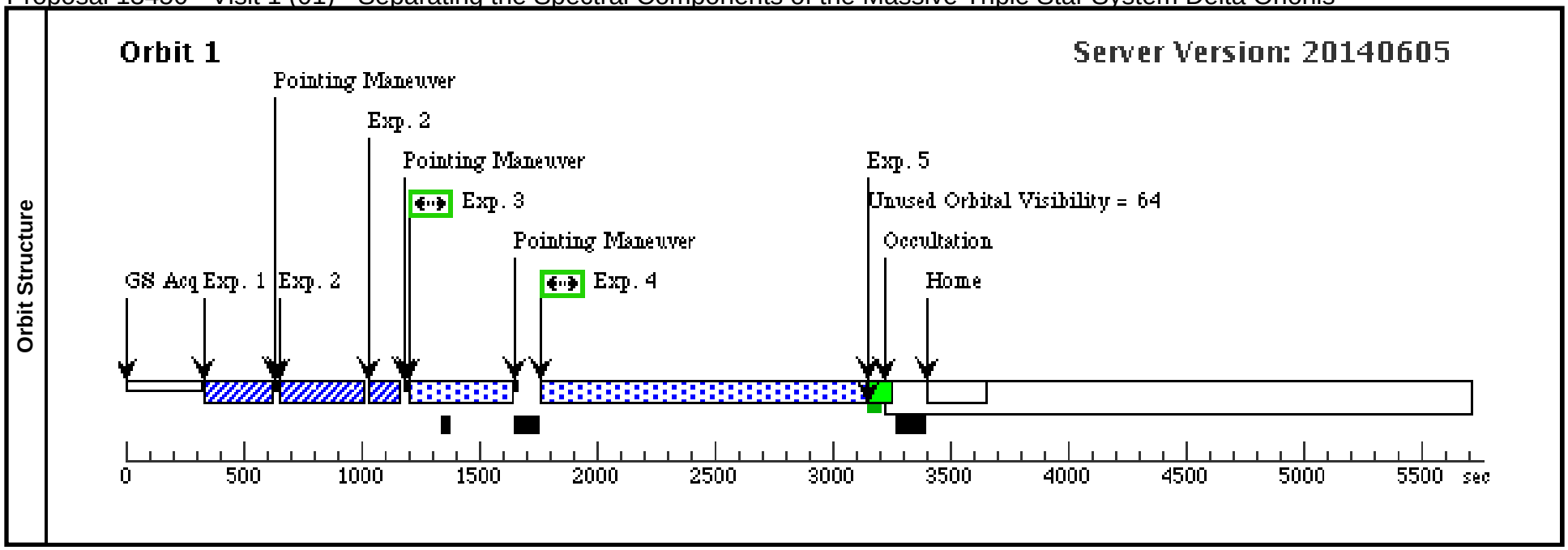
Comments: We want to isolate the flux from each star in the binary. Consequently, the Orientation is set so that the slit long (spatial) axis is perpendicular to the axis joining the stars. We estimate that the binary PA (east from north) is 130.55 deg in Cycle 21 (2014 June; from new orbital solution by Brian Mason, USNO, private communication), so the orthogonal direction is 130.55 - 90 = 40.55 deg (with a tolerance of +/- 30 deg). We set ORIENT = PA(orthogonal) + 45 deg as given in the STIS Handbook Section 11.4, and we give the supplementary (+180 deg) range as well. Visit 1 should occur during the upper 20% of the radial velocity range of orbit of the primary in the 5.7 d binary. The orbital period and ephemeris were taken from Mayer et al. (2010, A&A, 520, A89), and the epoch set here corresponds to phase 0.9 where periastron occurs at phase 0.0. This was done to avoid a working phase range that crosses 0.0.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	ADS-4134-A	RA: 05 32 0.4001 (83.0016671d)		V=2.21+/-0.02	Reference Frame: ICRS
	Alt Name1: DEL-ORI-A	Dec: -00 17 56.74 (-.29909d)			
	Alt Name2: HD36486-A	Equinox: J2000			
Comments: This object was generated by the target selector and retrieved from the SIMBAD database. O 9.5 II					
(2)	ADS-4134-A-2	Offset from ADS-4134-A		V=3.56+/-0.02	Offset Position (ADS-4134-A-2)
	Alt Name1: DELORI	RA Offset: 0.01665 Secs			
		Dec Offset: -0.21369 Arcsec			
Comments: This object was generated by the targetselector and retrieved from the SIMBAD database. B0.5 III					

Exposures

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	ACQ Delta Ori Aa (STIS.ta.514237)	(1) ADS-4134-A	STIS/CCD, ACQ, F25ND5	MIRROR		PHASE 0.49 TO 0.82		0.2 Secs (0.2 Secs) *[==>]*	***[1]***
	Comments: O9.5II								
2	ACQ/PEAK Delta Ori Aa (STIS.sp.514476)	(1) ADS-4134-A	STIS/CCD, ACQ/PEAK, 0.3X0.05ND	G230LB 2375 A				0.6 Secs (0.6 Secs) *[==>]*	***[1]***
	Comments: ETC run utilized 0.2x0.2 aperture. *Ratio of 0.2x0.2/0.2x0.05ND thruput is 1382 (C Proffitt 2013-06-19 email to T Gull);* *1.33x10^8/1382=9.5x10^4 (for t=0.2 sec; no adjustment for extinction E(B-V)=0.02).* *Multplied by factor of 3 for careful peak up (C Proffitt 2013-06-26 email to D Gies).*								
3	FUV E140M Delta Ori Aa (STIS.sp.488161)	(1) ADS-4134-A	STIS/FUV-MAMA, ACCUM, 0.3X0.05ND	E140M 1425 A	WAVECAL=NO			300 Secs (300 Secs) *[==>]*	***[1]***
4	FUV E140M Delta Ori Ab (STIS.sp.488161)	(2) ADS-4134-A-2	STIS/FUV-MAMA, ACCUM, 0.3X0.05ND	E140M 1425 A	WAVECAL=NO			1360 Secs (1360 Secs) *[==>]*	***[1]***
	Comments: No peak up here; just rely on accurate offsets. *Please increase the exposure time above 1360 sec if any time remains in the orbit.*								
5	WAVECAL in Earth Shadow	WAVE	STIS/FUV-MAMA, ACCUM, 0.2X0.06	E140M 1425 A				*[==>]*	***[1]***
	Comments: WAVECAL moved to earth shadow to maximize exposure time on Ab. *Narrow aperture is close to that used with observations (0.3X0.05ND).*								


Orbit Structure
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Server Version: 20140605
Pointing Maneuver
Exp. 2
Pointing Maneuver
Exp. 3
Pointing Maneuver
Exp. 4
Exp. 5
Unused Orbital Visibility = 64
Occultation
Home
GS Acq
Exp. 1
Exp. 2
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
sec

Visit

Proposal 13450, Visit 2 (02), scheduling Sat Jan 24 02:01:01 GMT 2015

Diagnostic Status: No Diagnostics

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

Special Requirements: SAME ORIENT AS 01; AFTER 01 BY 14 D TO 45 D; BETWEEN 09-FEB-2015:00:00:00 AND 18-FEB-2015:00:00:00; Period 5.732436 D AND ZERO-PHASE HJD2456473.0502

Comments: We want to isolate the flux from each star in the binary. Consequently, the Orientation is set so that the slit long (spatial) axis is perpendicular to the axis joining the stars. We estimate that the binary PA (east from north) is 130.55 deg in Cycle 21 (2014 June; from new orbital solution by Brian Mason, USNO, private communication), so the orthogonal direction is 130.55 - 90 = 40.55 deg (with a tolerance of +/- 30 deg). We set ORIENT = PA(orthogonal) + 45 deg as given in the STIS Handbook Section 11.4, and we give the supplementary (+180 deg) range as well.

As we need to confirm offset to Ab from Aa, we desire a delay of 14 to 45 days to allow for astrometry check.

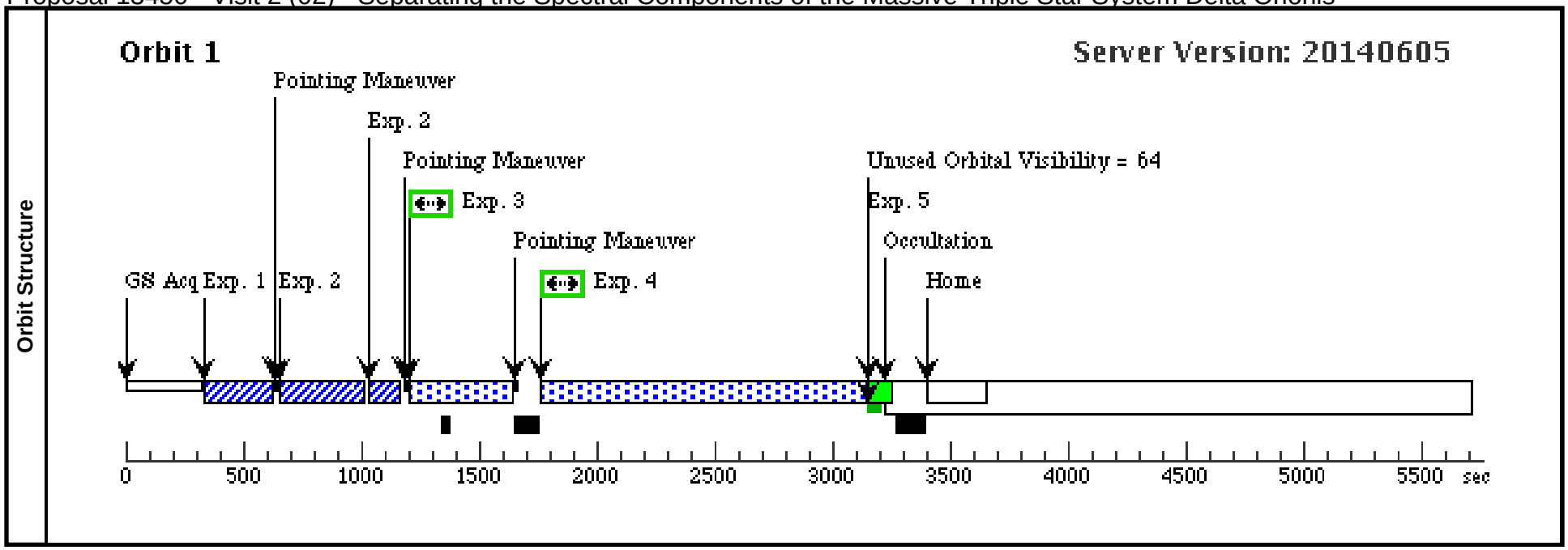
Visit 2 should occur during the lower 20% of the radial velocity range of orbit of the primary in the 5.7 d binary. The orbital period and ephemeris were taken from Mayer et al. (2010, A&A, 520, A89), and the epoch set here corresponds to phase 0.9 where periastron occurs at phase 0.0. This was done to avoid a working phase range that crosses 0.0.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	ADS-4134-A	RA: 05 32 0.4001 (83.0016671d)		V=2.21+/-0.02	Reference Frame: ICRS
	Alt Name1: DEL-ORI-A	Dec: -00 17 56.74 (-.29909d)			
	Alt Name2: HD36486-A	Equinox: J2000			
Comments: This object was generated by the target selector and retrieved from the SIMBAD database. O 9.5 II					
(2)	ADS-4134-A-2	Offset from ADS-4134-A		V=3.56+/-0.02	Offset Position (ADS-4134-A-2)
	Alt Name1: DELORI	RA Offset: 0.01665 Secs			
		Dec Offset: -0.21369 Arcsec			
Comments: This object was generated by the targetselector and retrieved from the SIMBAD database. B0.5 III					

Exposures

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	ACQ Delta Ori Aa (STIS.ta.514237)	(1) ADS-4134-A	STIS/CCD, ACQ, F25ND5	MIRROR		PHASE 0.02 TO 0.27		0.2 Secs (0.2 Secs) *[==>]*	***[1]***
	Comments: O9.5II								
2	ACQ/PEAK Delta Ori Aa (STIS.sp.514476)	(1) ADS-4134-A	STIS/CCD, ACQ/PEAK, 0.3X0.05ND	G430L 4300 A				0.6 Secs (0.6 Secs) *[==>]*	***[1]***
	Comments: ETC run utilized 0.2x0.2 aperture. *Ratio of 0.2x0.2/0.2x0.05ND thruput is 1382 (C Proffitt 2013-06-19 email to T Gull);* *1.33x10^8/1382=9.5x10^4 (for t=0.2 sec; no adjustment for extinction E(B-V)=0.02).* *Multplied by factor of 3 for careful peak up (C Proffitt 2013-06-26 email to D Gies).* *Update: 01/13/15* *The G230LB exposure was about 10DN above background with G230LB. As the FUV flux was* *3X less that anticipated and the brighter star spectrum double, G430L is being substituted.* *Expected fluxes should be about 160 DN above backgrounD(See STIS.sp.656004 and STIS.sp.656005a)* *Brightest pixel should be at 2971.50 A at 300 DN.*								
3	FUV E140M Delta Ori Aa (STIS.sp.488161)	(1) ADS-4134-A	STIS/FUV-MAMA, ACCUM, 0.3X0.05ND	E140M 1425 A	WAVECAL=NO			300 Secs (300 Secs) *[==>]*	***[1]***
4	FUV E140M Delta Ori Ab (STIS.sp.488161)	(2) ADS-4134-A-2	STIS/FUV-MAMA, ACCUM, 0.3X0.05ND	E140M 1425 A	WAVECAL=NO			1360 Secs (1360 Secs) *[==>]*	***[1]***
	Comments: No peak up here; just rely on accurate offsets. *Please increase the exposure time above 1360 sec if any time remains in the orbit.*								
5	WAVECAL in Earth Shadow	WAVE	STIS/FUV-MAMA, ACCUM, 0.2X0.06	E140M 1425 A				*[==>]*	***[1]***
	Comments: WAVECAL moved to earth shadow to maximize exposure on Ab. *Narrow aperture is close to that used with observations (0.3X0.05ND).*								


Orbit Structure
Orbit 1
Server Version: 20140605
Pointing Maneuver
Exp. 2
Pointing Maneuver
Exp. 3
Pointing Maneuver
Exp. 4
Unused Orbital Visibility = 64
Exp. 5
Occultation
GS Acq
Exp. 1
Exp. 2
Home
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
sec