# 11725 - Eclipsing Binaries in the Local Group: III - Unprecedented Accuracy in Distance Determination to M33 and Calibration of the Cosmic Distance Scale

Cycle: 17, Proposal Category: GO

(Availability Mode: SUPPORTED)

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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) D33-J013346.2+304439.9 | COS/FUV<br>COS/NUV<br>STIS/CCD<br>STIS/NUV-MAMA | 4 | 18-May-2009 21:32:29.0 | yes |

4 Total Orbits Used

**ABSTRACT**

The Great Spiral Galaxy in Triangulum (M33) is a crucial calibrator for the Cosmic Distance Scale, and thus for determining the age and evolution of the Universe. M33 is viewed face-on, has a simple geometry, large and diverse stellar populations, and morphologies similar to our Galaxy and other more distant galaxies used for distance determinations. Yet currently the M33 distance (d ~ 830 +/- 120 kpc) still has measurement dispersions of 10-15%. Moreover, the distance to M33 derived from Cepheids, RR Lyrae stars, H2O masers, RGB stars, and EBs is currently discrepant by ~15% (Bonanos et al. 2006). In our work on the LMC and M31 distances we have demonstrated that double-line eclipsing binaries serve as excellent "standard candles." Distances derived from eclipsing binaries are basically geometric and essentially free from many assumptions and uncertainties that plague other less direct methods, such as metallicity differences and calibration zeropoints. The absolute radii of the component stars of eclipsing binaries can be determined to better than a few percent from the time-tested analyses of their light and radial velocity curves. With accurate determinations of radii, temperatures, and ISM absorption it is possible to determine reliable distances. In Cycle 15 we extended our program of using eclipsing binaries as standard candles to M33 using ACS/SBS and WFPC/2 spectrophotometry of a well suited ~19th mag O7+O7 eclipsing binary system. Although insightful, ACS/SBC data alone do not provide sufficient accuracy for the unambigous determination of individual temperatures, [Fe/H], and ISM extinction, which are central to distance determination. We propose a 4 orbit follow-up spectrophotometry with the newly installed HST/COS G140L and the repaired HST/STIS G230L and G430L to obtain the single missing key element of this program. These quantities, when combined with the results from existing light and radial velocity curves for the target (cf. Bonanos et al. 2006), yield stellar masses, radii, luminosities and, most importantly, the distance. Based on our previous experience, we expect to reduce the uncertainty of the M33 distance to less than 5%, thereby leading to a resolution of the currently irreconcilable distances to M33 derived by different methods, and a firm calibration of the Cosmic Distance Scale and the zeropoint of the Hubble Constant (Ho).

**OBSERVING DESCRIPTION**

In this study we are requesting observations of the M33 EB target that has existing ground-based light and radial velocity curves, and extremely valuable WFPC/2 V and R fields for spectral anchoring that were acquired in Cycle 15. For Cycle 17, 4 HST orbits are requested. Having WFPC/2 images of the field, we guarantee that there is no overexposure danger to any of the detectors. According to the HST orbital constraints and the declination of our target, a maximum visibility of 3180s is available per orbit. The optimum times for observing our target are in the months of July and September. The simulations indicate that 2 orbits are needed for HST/COS, 1 orbit for STIS G230L and G430L each, totalling 4 orbits, to reach

S/N>=20 for all exposures.

We will use three different grism setups to obtain a broad spectrophotometric coverage from 123 to 570nm: FUV COS/G140L, NUV-MAMA STIS/G230L, and CCD STIS/G430L. As discussed by Fitzpatrick & Massa (1999, ApJ, 525, 1011), this extended wavelength coverage uniquely disentangles the stellar and interstellar parameters, yielding the quantities: Teff, log(g), [Fe/H], E(B-V), and extinction. The near UV includes the ~220nm ISM dust absorption feature that permits a firm determination of the ISM reddening of the target. Presently, the determination of extinction for this star is one of the major contributions to the error budget.

Exposure estimates were carried out using the latest version of the spectroscopic and imaging online exposure time calculators. We assumed the intrinsic energy distribution of an O7V type star and an extinction corresponding to E(B-V)~0.14, estimated from ground-based B and V photometry of the target. We estimate that S/N in excess of 20 is necessary to secure a spectrum with sufficient quality to allow an accurate determination of the stellar and interstellar parameters. The target is relatively faint (~19.45mag) and has a few faint nearby companions.

**ADDITIONAL COMMENTS**

Ideal observing conditions for the proposed EB require an out-of-eclipse phase, close to the orbital quadratures (phases 0.15-0.35 or 0.60-0.85). At these phases, where both components of the system are fully visible, the target is brighter and the achieved S/N ratio is maximized. Because of the EB morphology, no significant light variation exists over the exposure time during these phases. The target has an eccentric orbit and so the actual quadratures differ somewhat from phases 0.25 and 0.75. However, since light curves are available, the optimum phases to execute the spectrophotometric observations can be carefully selected. The ephemeris and orbital phases of the primary and secondary minimum for the target are given by:

Min I (J013346.2+304439.9) = HJD 2451451.4040 + 4.89380 E,
Min II (J013346.2+304439.9) = HJD 2451453.7041 + 4.89380 E.

In addition to this soft time constraint, we are also proposing to define a roll angle exclusion interval. This is because the target has a number of fainter companions several arcsecs away that could possibly contaminate the spectrum in case of overlap. Inspection of the available imaging of the

region near the targets indicates that any possibility of contamination will be precluded by just avoiding a narrow ~40deg orientation interval.

## Visit

**Proposal 11725, Visit 01, implementation** Tue May 19 01:32:34 GMT 2009

**Diagnostic Status: No Diagnostics**

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

Special Requirements: Period 4.8938 D AND ZERO-PHASE HJD2451451.4040

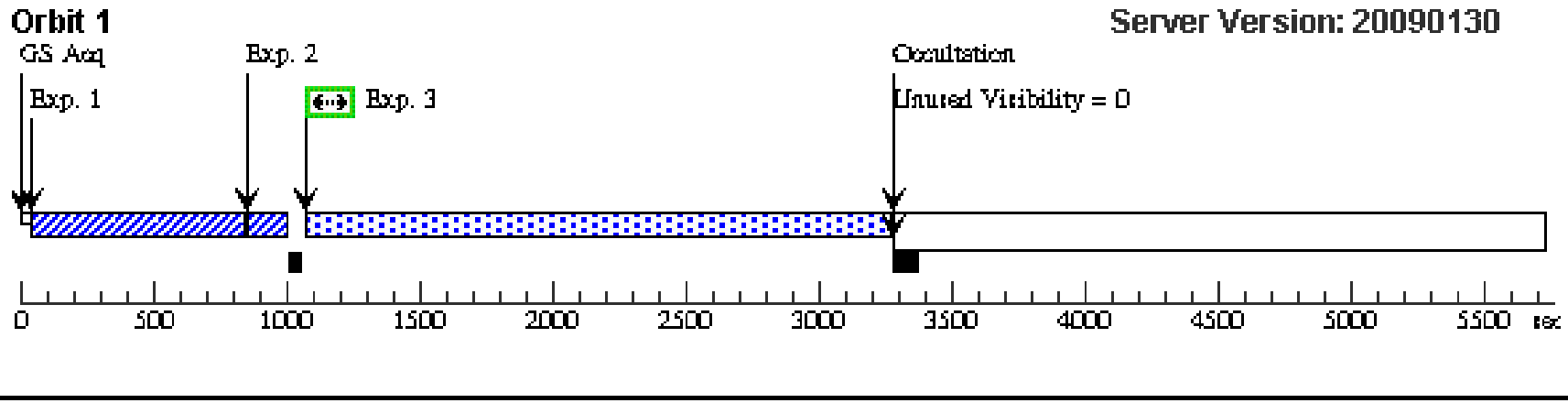
## Fixed Targets

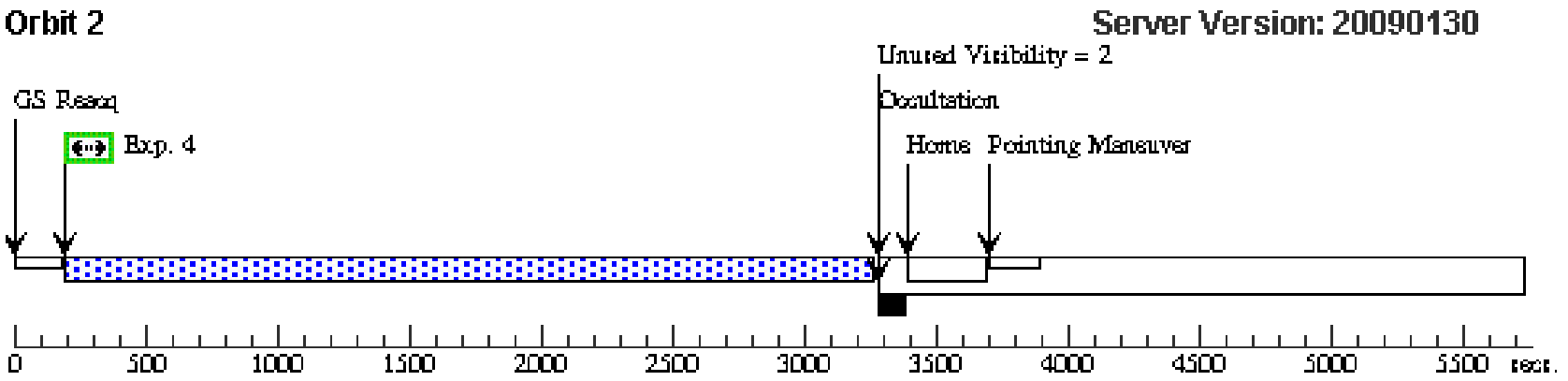
| # | Name | Target Coordinates | Targ. Coord. Corrections | Fluxes | Miscellaneous |
|---|---|---|---|---|---|
| (1) | D33-J013346.2+304439.9 | RA: 01 33 46.1700 (23.4423750d)<br>Dec: +30 44 39.90 (30.74442d)<br>Equinox: J2000 | | V=19.45+/-0.05 | Reference Frame: ICRS |

## Exposures

| # | Label | Target | Config,Mode,Aperture | Spectral Els. | Opt. Params. | Special Reqs. | Groups | Exp. Time/[Actual Dur.] | Orbit |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | (1) D33-J013346.2+304439.9 | COS/NUV, ACQ/SEARCH, PSA | MIRRORA | SCAN-SIZE=3 | PHASE 0.62 TO 0.88 | | 25 Secs<br>*[==>]* | <br>***[1]*** |
| 2 | | (1) D33-J013346.2+304439.9 | COS/NUV, ACQ/IMAGE, PSA | MIRRORA | | | | 25 Secs<br>*[==>]* | <br>***[1]*** |
| 3 | | (1) D33-J013346.2+304439.9 | COS/FUV, TIME-TAG, PSA | G140L<br>1230 A | BUFFER-TIME=2590;<br>FLASH=YES | | | 2590 Secs<br>*[==>2024.0 Secs ]* | <br>***[1]*** |
| 4 | | (1) D33-J013346.2+304439.9 | COS/FUV, TIME-TAG, PSA | G140L<br>1230 A | FLASH=YES;<br>BUFFER-TIME=3022 | | | 3022 Secs<br>*[==>]* | <br>***[2]*** |
| 5 | | (1) D33-J013346.2+304439.9 | STIS/CCD, ACQ, 50CCD | MIRROR | | | | 30 Secs<br>*[==>]* | <br>***[3]*** |
| 6 | | (1) D33-J013346.2+304439.9 | STIS/CCD, ACCUM, 52X0.5 | G430L<br>4300 A | CR-SPLIT=2 | | | 2282 Secs<br>*[==>(Split 1)]*<br>*[==>(Split 2)]* | <br>***[3]*** |
| 7 | | (1) D33-J013346.2+304439.9 | STIS/NUV-MAMA, ACCUM, 52X0.5 | G230L<br>2376 A | | | | 2965 Secs<br>*[==>3037.0 Secs ]* | <br>***[4]*** |

Orbit Structure



Orbit Structure (continued)