15946 - Towards a 1% local determination of the Hubble constant: quantifying stellar association bias in the supernova-host galaxy M101

Cycle: 27, Proposal Category: GO

(UV Initiative)

(Availability Mode: SUPPORTED)

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) M101-F1	WFC3/UVIS	1	07-Feb-2020 12:00:11.0	yes
02	(2) M101-F2	WFC3/UVIS	1	07-Feb-2020 12:00:12.0	yes
03	(1) M101-F1	WFC3/UVIS	1	07-Feb-2020 12:00:13.0	yes
04	(2) M101-F2	WFC3/UVIS	1	07-Feb-2020 12:00:13.0	yes

4 Total Orbits Used

ABSTRACT

The growing tension among recent measurements of the present-day value of the Hubble Constant (H0) is one of the potentially most consequential open problems in astrophysics. The value of H0 inferred from early-Universe Cosmic Microwave Background measurements assuming the lambdaCDM Cosmological Concordance Model differs by 9.4 +/- 2.1 % (4.4 sigma) from H0 measured directly in the late Universe using a well-

calibrated distance ladder that is free from such assumptions. It is now crucial to push the measurement accuracies to the extreme in order either to identify previously unrecognized or underestimated systematic observational error, or to demonstrate a need to modify lambdaCDM, which would place fundamental physics at the verge of a breakthrough.

This proposal seeks to exploit HST/WFC3's unique UV capabilities to increase the accuracy of the late-Universe H0 measurement based on Cepheid variable stars and type-Ia supernovae (SNIa). The requested F300X passband observations of Cepheids in the closest SNIa host galaxy M101 will enable: a) direct measurements of the blending frequency of Cepheids with physically associated hot, early-type stars; b) direct measurements of the photometric bias incurred by such blending; c) improved selection criteria for extragalactic Cepheid searches that will help to further reduce the impact of this bias in upcoming late-Universe H0 measurements. The proposed observations are particularly urgent since a) Gaia astrometry and HST photometry of Local Group Cepheids increase the need to correct for this bias and b) the currently applied bias correction, based on SNIa host analog M31, requires a sanity check as well as greater precision.

OBSERVING DESCRIPTION

We plan to observe two fields known to host Cepheid variable stars in the nearby galaxy M101 using WFC3/UVIS. The F300X observations are intended to detect the presence of hot, UV-bright cluster stars that are not otherwise detectable. The two fields have been selected to match the positions of previous optical and near-infrared observations made using ACS/WFC and WFC3/UVIS and WFC3/IR.

In summary, the idea is to:
- observe two fields of M101 using WFC3/UVIS F300X passband during two visits per field, 1 orbit per visit
- leave between 69 days and 120 days between visits of the same field in order to average over Cepheid variability
- apply a box dithering pattern during each visit
- use the same orientation for both visits of each field
- use orientations that avoid the chip gap falling onto priority objects of interest

More details as follows.

We seek to detect the presence of (unknown) star clusters near (known) Cepheids and to measure the average contrast between Cepheids and their

host clusters in the closest SNIa host galaxy M101. To improve the SNR and measure an averaged cluster-Cepheid contrast, we adopt a two-visit observing strategy. The Cepheids in M101 have mean variability period of 27 d, with 68% of Cepheids having P between 16 d and 46 d (cf. Fig. 6 in Riess et al. 2016, ApJ 826, 56 and Table 5 of Hoffmann et al. 2016, ApJ 830, 10). In F300X passband, a Cepheid may vary by more than 2 mag (peak-to-peak) throughout the cycle.

We request to observe each field during two visits, as this will provide two random variability phase measurements per Cepheid. For the Cepheids of interest (periods less than 46 days), we estimate that a duration between 69 days and 120 days between two visits of the same field achieves a suitable balance between scheduling flexibility and variability phase diversity (maximized variance).

We require maximum spatial resolution (hence best possible PSF sampling) in order to detect and characterize the light contribution from the nearly unresolved host star clusters. Host clusters are detectable via the high UV flux emitted by their hot B-star members and we plan to apply a curve-of-growth following Anderson & Riess (2018, ApJ, 861, 36). To this end, we will apply a 4-point box dithering to densely sample the PSF (UVIS PSF FWHM is 1.87 pixel at 300nm). The exposure times are adopted such as to divide up the orbital visibility into four equally long exposures.

We must avoid certain orientations in order to prevent many known Cepheids from falling onto the chip gap. Suitable orientations have been determined using the known positions of Cepheids in M101. Maximizing the number of Cepheids in the FOV of WFC3 is crucial, since only a few percent of Cepheids are expected to reside in clusters. Assuming the 2.5% clustered Cepheid fraction from M31, we expect detecting on the order of 13 host clusters associated with the 538 Cepheids in M101.

F300X will provide a sensitive diagnostic for the hot (T > 10000K) cluster stars. The filter's red leak is no cause for concern, since most stars cooler than 6000K have negligible flux levels in our observational setup. The rare exception, such as yellow hypergiant stars, will be easily discernible from the existing multi-band photometry (F555W, F814W, F160W).

There are no bright sources in the field of view and there are no limitations for using WFC3/UVIS.

Visit

Proposal 15946, Visit 1 Field 1 (01), scheduling Fri Feb 07 17:00:14 GMT 2020

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/UVIS

Special Requirements: ORIENT 142.0D TO 180 D

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(2)	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)

Fixed Targets

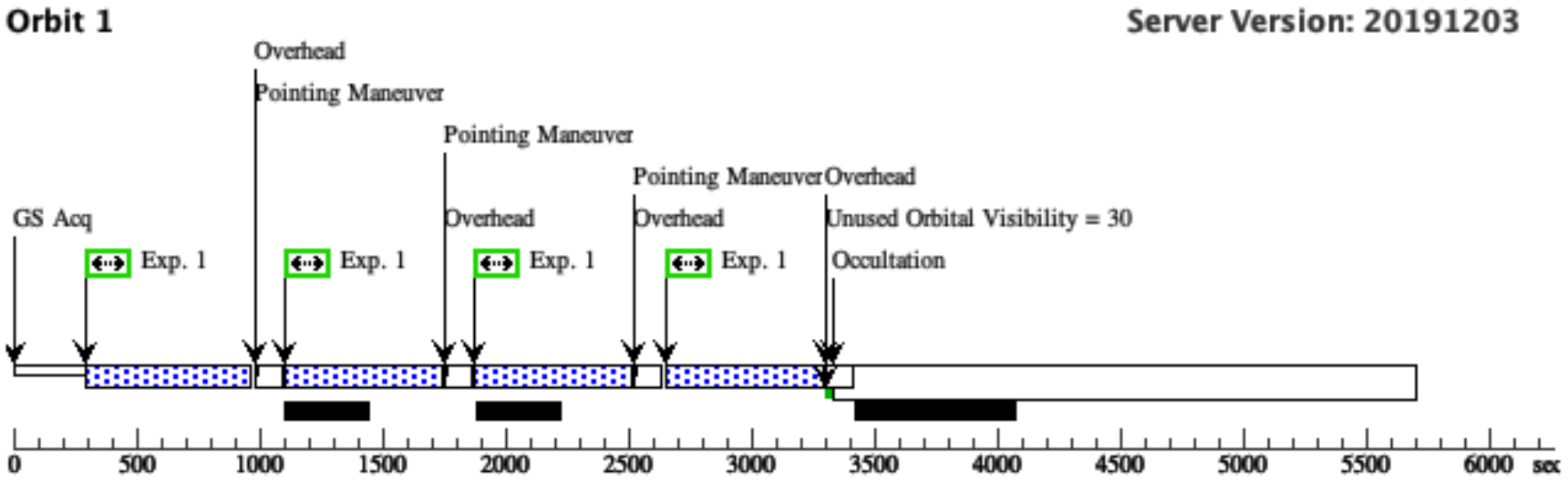
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	M101-F1	RA: 14 03 29.9190 (210.8746625d) Dec: +54 21 7.02 (54.35195d) Equinox: J2000	Epoch of Position: 2000	V=7.86	Reference Frame: ICRS

Comments: This target is centered on the same position as ACS/WFC observations for field M101-F1 in Proposal ID 10918
Category=GALAXY
Description=[DISK, DUST LANE, SPIRAL, SPIRAL ARM]

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1		(1) M101-F1	WFC3/UVIS, ACCUM, UVIS-CENTER	F300X	FLASH=10		Sequence 1-1 Non-Int in Visit 1 Field 1 (01) Pattern 2, Exps 1-1 in Sequence 1-1 Non-Int in Visit 1 Field 1 (01) (2)	640 Secs (2560 Secs) *[==>(Pattern 1)]* *[==>(Pattern 2)]* *[==>(Pattern 3)]* *[==>(Pattern 4)]*	***[1]***

Orbit Structure



Visit

Proposal 15946, Visit 1 Field 2 (02), scheduling Fri Feb 07 17:00:14 GMT 2020

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/UVIS

Special Requirements: ORIENT 197.22D TO 199.58 D

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(2)	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)

Fixed Targets

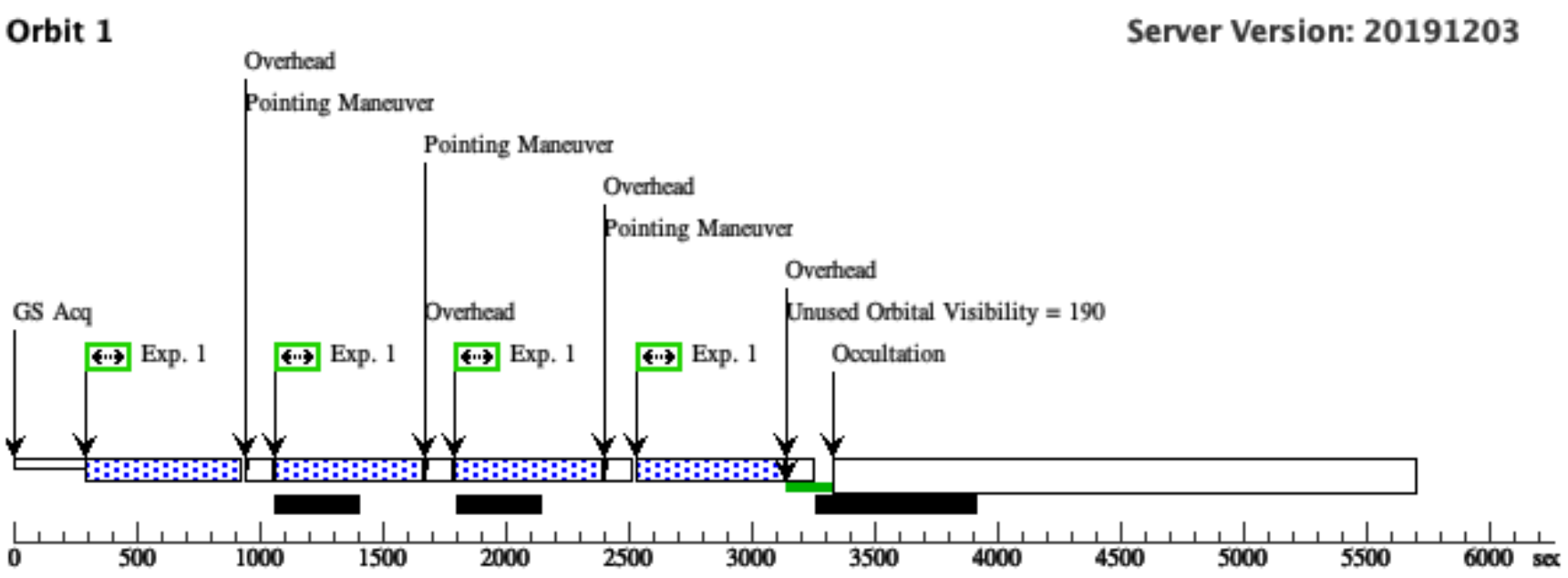
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(2)	M101-F2	RA: 14 02 55.5934 (210.7316392d) Dec: +54 20 13.69 (54.33714d) Equinox: J2000	Epoch of Position: 2000	V=7.86	Reference Frame: ICRS

Comments: This target is centered on the same position as ACS/WFC observations for field M101-F2 in Proposal ID 10918
Category=GALAXY
Description=[DISK, DUST LANE, SPIRAL, SPIRAL ARM]

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1		(2) M101-F2	WFC3/UVIS, ACCUM, UVIS-CENTER	F300X	FLASH=10		Sequence 1-1 Non-Int in Visit 1 Field 2 (02)	600 Secs (2400 Secs)	
								[==>(Pattern 1)] *[==>(Pattern 2)]* *[==>(Pattern 3)]* *[==>(Pattern 4)]*	***[1]***
							Pattern 2, Exps 1-1 in Sequence 1-1 Non-Int in Visit 1 Field 2 (02) (2)		

Orbit Structure



Visit

Proposal 15946, Visit 2 Field 1 (03), scheduling Fri Feb 07 17:00:14 GMT 2020

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/UVIS

Special Requirements: SAME ORIENT AS 01; AFTER 01 BY 45 D TO 120 D

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(2)	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)

Fixed Targets

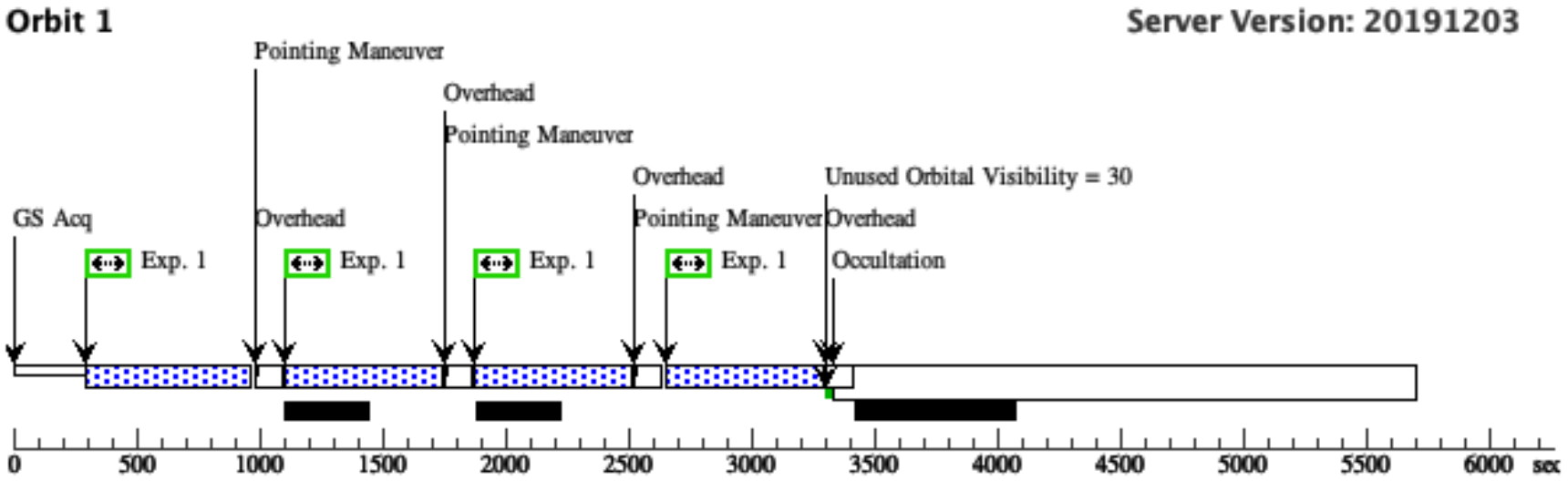
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	M101-F1	RA: 14 03 29.9190 (210.8746625d) Dec: +54 21 7.02 (54.35195d) Equinox: J2000	Epoch of Position: 2000	V=7.86	Reference Frame: ICRS

Comments: This target is centered on the same position as ACS/WFC observations for field M101-F1 in Proposal ID 10918
Category=GALAXY
Description=[DISK, DUST LANE, SPIRAL, SPIRAL ARM]

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1		(1) M101-F1	WFC3/UVIS, ACCUM, UVIS-CENTER	F300X	FLASH=10		Sequence 1-1 Non-Int in Visit 2 Field 1 (03) Pattern 2, Exps 1-1 in Sequence 1-1 Non-Int in Visit 2 Field 1 (03) (2)	640 Secs (2560 Secs) *[==>(Pattern 1)]* *[==>(Pattern 2)]* *[==>(Pattern 3)]* *[==>(Pattern 4)]*	*[1]*

Orbit Structure



Visit

Proposal 15946, Visit 2 Field 2 (04), scheduling Fri Feb 07 17:00:14 GMT 2020

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/UVIS

Special Requirements: SAME ORIENT AS 02; AFTER 02 BY 12 D TO 120 D

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(2)	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)

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(2)	M101-F2	RA: 14 02 55.5934 (210.7316392d) Dec: +54 20 13.69 (54.33714d) Equinox: J2000	Epoch of Position: 2000	V=7.86	Reference Frame: ICRS

Comments: This target is centered on the same position as ACS/WFC observations for field M101-F2 in Proposal ID 10918
Category=GALAXY
Description=[DISK, DUST LANE, SPIRAL, SPIRAL ARM]

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1		(2) M101-F2	WFC3/UVIS, ACCUM, UVIS-CENTER	F300X	FLASH=10		Sequence 1-1 Non-Int in Visit 2 Field 2 (04) Pattern 2, Exps 1-1 in Sequence 1-1 Non-Int in Visit 2 Field 2 (04) (2)	600 Secs (2400 Secs) *[==>(Pattern 1)]* *[==>(Pattern 2)]* *[==>(Pattern 3)]* *[==>(Pattern 4)]*	***[1]***

Orbit Structure