Rocky Worlds DDT: HST Scheduling Report for LHS 1140

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Rocky Worlds is a joint JWST and HST Director's Discretionary Program designed to implement the top recommendations from the Working Group on Strategic Exoplanet Initiatives with HST and JWST (Redfield et al., 2024). The HST side of the Rocky Worlds DDT focuses on ultraviolet (UV) characterization of the nearby M-dwarf hosts of the rocky planets observed with JWST. We use COS and STIS to measure the UV to blue-optical spectra of these stars, including UV flare monitoring and measuring the wings of the Ly-alpha profile where appropriate. With these observations we constrain the high-energy output of these host M dwarfs in the UV, which can be applied to planetary models of atmospheric escape, as well as photochemistry if a planetary atmosphere is present. As detailed below, the HST Target Scheduling Team has constructed a plausible SED for LHS 1140 (§1) and has used these values to calculate APT inputs (§2). LHS 1140 is faint in the NUV but the risk of flaring requires a less sensitive mode for COS NUV imaging target acquisitions, which we discuss in 3.

1 Stellar Parameters

We adopt parameters for LHS 1140 primarily from Ment et al. (2019), who provided detailed stellar parameters based on high resolution spectroscopy and SED fitting. The parameters are presented in Table 1.

Since LHS 1140 has archival HST observations, we assessed the utility of these exsiting observations. Table 2 lists the program IDs, PIs, Modes, and exposure times.

For our ETC calculations of LHS 1140, we used a combination of Hubble Advanced Spectral Products (HASP) coadds [1] of archival data to determine exposure times in the FUV and NUV. Table 3 has the estimated SNRs from archival data. For visible STIS observations and COS NUV acquisition exposure times, we used the default STScI ETC Phoenix M4.5V SEDs scaled to Gaia G=12.65 and U=17.11 respectively. The Rocky Worlds team assessed that the line SNRs would be sufficient for the goals of the Rocky Worlds project.

2 APT INPUTS

The goal for each target host star is to obtain a) flare monitoring in the FUV, b) UV coverage of as many emission lines as is feasible, c) an NUV-Visible spectral energy distribution (SED), and d) high enough SNR observations of the wings of the Lyman-α line to reconstruct the intrinsic Lyman-α profile.

For LHS 1140, we meet our science goals by scheduling 12 orbits of flare monitoring using COS/G130M/1222. Archival data provides complete UV coverage from 1070–1710 Å. We will additionally obtain NUV/Vis low resolution spectroscopy with STIS

[1] https://archive.stsci.edu/missions-and-data/hst/hasp

Parameter	Value
T_{eff} (K)	3216±40
log g	5.05
Radius ($R_\odot$)	0.21
Spectral Type	M4.5V
H-α EQW (Å)	0.20
RV (km s^{-1})	-13.21

Table 1: Adopted Stellar Parameters from Ment et al. (2019) for T_{eff} and gravity, Medina et al. (2020) for H-α and Lillo-Box et al. (2020) for radial velocity.

G230L, G430L, and G750L using the 52x0.2 slit for SED construction in concert with archival STIS/G230L observations. We determined that archival data was sufficient to measure the wings of the Lyman-α line in order to reconstruct the intrinsic line profile (Youngblood et al., 2017). We repeat STIS/G230L observations to verify that the Mg II 2800 Å lines have not significantly changed compared to the archival data.

3 Target Acquisition Strategy

LHS 1140 is faint in the NUV in quiescence, but could be bright enough if it flares to present safety issues for the COS NUV imaging modes during target acquisitions. Our proposed STIS observations circumvent this issue since all target acquisitions with STIS use the STIS CCD. Since both COS and STIS require extra considerations in case of a rare and bright flare condition, any NUV observation must not exceed flight software limits for local or global count rates, assuming a significant flare that occurs with a probability of 10^{-4} (Osten, 2017). If the most sensitive mode is not safe, the next most sensitive mode is required. For faint objects this can present a challenge where the object requires significant exposure time for a target acquisition due to needing a less sensitive mode.

LHS 1140is an inactive M4.5V spectral type with estimated U=17.11, so we assumed a flare with ΔU=-2.3 and a blackbody SED with T_{eff} = 9000 K. A flare of this magnitude exceeds the limits given in Osten (2017) for the NUV using MIRRORA/PSA, and we are forced to use MIRRORB/PSA for acquisitions. Unfortunately, LHS 1140's

Program ID	Instrument	Grating	T_{exp} (s)
15264, 14888	STIS	G140M	11600
15264	COS	G130M	9241
15264	COS	G160M	6430
15264	STIS	G230L	4288

Table 2: Archival observations of LHS 1140

Line	SNR	Grating
Lyman-α(1216Å)	23-15	STIS/G140M
Si II(1261Å)	0.5	COS/G130M
Si II(1264Å)	0.2	COS/G130M
Si III(1206Å)	9	COS/G130M
Si III(1294Å)	1	COS/G130M
Si IV(1393Å)	3	COS/G160M
Si IV(1402Å)	1	COS/G160M
C II(1334Å)	4	COS/G130M
C II(1335Å)	11	COS/G130M
C III(1175Å)	6	COS/G130M
C IV(1548Å)	12	COS/G160M
C IV(1550Å)	8	COS/G160M
O IV(1401Å)	–	COS/G160M
O V(1371Å)	–	COS/G160M
N V(1238Å)	6	COS/G130M
N V(1242Å)	5	COS/G130M
Mg II(2796)	14	STIS/G230L
Mg II(2803)	12	STIS/G230L

Table 3: Estimated Line SNR for key UV Lines, based on archival observations. Lines that are covered by G130M include the expected SNR from all flare monitoring visits.

faintness requires a long NUV exposure time to meet the basic SNR requirements for a target acquisition. Coupled with the new overheads at G130M for lifetime position 7[2], nearly a full orbit within a visit must be dedicated to the target acquisition.

The HST Scheduling team considered the possible advantage of using blind pointing. Current Observatory uncertainties with blind pointing are quoted to 100 mas, which is the positional uncertainty of the HST guide stars[3], as well as any FGS-to-COS uncertainties or any uncertainties in coordinates and proper motions. The COS aperture can tolerate small offsets, but these can also cause both flux and wavelength solution uncertainties.

With the above considerations in mind and the fact that the cost of a high quality acquisition was small relative to the science goals of this program, the HST scheduling team decided to replicate the successful acquisition strategy of GO #15264, which exposed with the NUV imager for 957s. Inspection of the NUV ACQ images for that program indicates an achieved SNR of ≈15 with final slews within the tolerance of typical acquisitions.

To date, the COS observations of GJ 3929 using Gaia DR3 coordinates and proper motions have had fairly repeatable blind pointings of <100 mas. If this is also true for LHS 1140, it may be possible to tolerate a blind pointing strategy. Once the first visit of COS observations is obtained with LHS 1140, the HST scheduling team may revise our decision for acquisitions.

References

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[2]See COS IHB Section 5.7.6

[3]See Target Acquisition without the Ground System Section, HST Primer