Orbital Periods and Flare Rates of White Dwarf - Main Sequence Star Binaries with TESS

Proposal in Response to NASA ROSES 2022 NNH22ZDA001N-TESS (TESS General Investigator – Cycle 6)

PI: David Wilson

VARIOUS ID NUMBERS FOR THE UNIVERSITY OF COLORADO AT BOULDER
Unique Entity Identifier (UEI): SPVKK1RC2MZ3
Dunn & Bradstreet Number (DUNS): 00-743-1505
Taxpayer Identification Number (TIN): 84-6000555
Commercial and Government Entity (CAGE) Code: 4B475

Budget Justification

The attached proposal reflects the current standard indirect cost rate agreement provided to the University of Colorado by the Department of Health and Human Services (DHHS). The current rates are used for proposal pricing until a new rate agreement is negotiated with DHHS. The rate agreement in effect at the time of the initial award will be used throughout the life of the federal award. If there is an update to the rate agreement at the time of award, the costs will be updated accordingly during the award negotiation.

The University of Colorado is an accredited U.S. institution of higher education engaged in fundamental research in science and engineering. Our research is intended to be, and is, widely and openly published and made available to the scientific and academic community. LASP is submitting this commitment with the understanding that the work to be performed and the results generated are considered to be fundamental research, intended to be published and shared broadly within the scientific community. All costs are in U.S. dollars.

Direct Labor

Salaries are based on the employee's salary at the time of proposal, increased for inflation each year thereafter. In the event the person has not yet been identified, an equitable salary based on position requirements will be used as the estimate. CU Boulder's definition of a year is based on the University fiscal year, July 1 through June 30.

Fringe Benefits are calculated on requested salary per the University's federally negotiated Indirect Cost Rate Agreement with the Department of Health and Human Services (DHHS).

Personnel/Responsibility:
D. Wilson, PI (3.00 Work Months/Year, 0.25 Total Nominal Work Years)
Will manage the project and complete all of the major research tasks. The outline of Dr. Wilson's work effort is as follows, with an estimate of the time required given at the end of each distinct task:
New Periods of White dwarf binaries: The SDSS-WDMS catalog was used to create the target list of white dwarf-main sequence binaries for this program as part of the proposal process. The first stage of the investigation will be to refine the target list and carry out a careful literature search, identifying targets with measured/candidate periods not captured by the catalog and assembling the most up-to-date parameters for the component stars. The PI will also assemble an observing schedule, using the TESS targeting tool to record when each target is being observed and for how many sectors, and by extension the best times to carry out the post-observation stages of the work. *1 week*.

Concurrently with the above, the PI will retrieve data for all targets for all stars with existing reduced TESS light curves and perform a preliminary analysis. The PI will use the Lightkurve routines to measure candidate periods for the sample. For targets with known periods, periods measured from TESS will be compared with literature results to better assess the reliability of TESS for measuring new periods. Targets with remarkable light curves (e.g. multiple periods, eclipses, regular flaring etc.) will be flagged for particular attention when new TESS observations become available. *2 weeks*.

As new data for targets becomes available, the PI will retrieve the new light curves and vet them for quality, re-extracting light curves with Lightkurve if necessary. Where multiple sectors of data are available, the normalised multi-sector light curves will be combined. Period searches will be carried out on the entire sample using Lomb-Scargle periodograms, with false-alarm probabilities calculated using standard techniques. For each light curve, we will produce an inspection plot featuring the normalised light curve, periodogram and light curve folded onto the strongest signal in the periodogram (see the Phase 1 proposal for examples). *1 week*.

The PI will visually inspect each light curve. For systems where periods are detected, the visual inspection will ascertain the type of variation and whether the detected period is an alias of the true period. Precise periods will then be measured by fitting astropy models to the data. New periods will be assembled into a catalog to be part of the main publication. *2 weeks*.

Flares in close binaries: The second phase of the project is to measure the flare rates of close binaries and compare them with those of wide binaries and single stars, investigating whether the spin-up during the common envelope event increases the activity rate independent of age. Flares will be identified with the stella package and fitted with the Llamaradas Estelares flare model. The stellar flare identifications and flare fits will be visually inspected to ensure their reliability, and the fits for each star/flare tweaked as needs be. *2 weeks*.

With a collection of flares and flare energies for each target, the PI will calculate the Flare Frequency Distribution (FFD) for each star with the AltaiPony package. If statistics allow, we will compare the FFD as a function of orbital period (== the rotation period of the main-sequence star) to search for trends. We will then compare the FFDs of the close binaries with wide binaries and with FFDs for single stars samples found in the literature, exploring whether or not the binaries are more active than single stars as a function of rotation period, breaking the age-spin-activity degeneracy. We anticipate that the results of the flare survey will be published in the same paper as the new periods. *2 weeks*.

Notable single systems: Based on previous surveys, we expect many of the light curves to show features beyond their orbital variation. Throughout the survey the PI will keep track of notable light curves. For example, we may discover new eclipsing systems, which are vital tools for measuring the M dwarf mass-radius relationship. Systems that demonstrate spot modulation from the main sequence-star can test the standard assumption that the main sequence star is tidally locked to exactly the orbital period, by using the spot modulation to independently measure the rotation period of the main-sequence star. Other behavior modes may only become apparent during the survey due to its unprecedented size and data quality. *2 weeks*.

K. France, Unfunded Collaborator, LASP

Dr. France is the PI's line manager and will provide advice and scientific input across the course of the project. As part of being a faculty employee at the University of Colorado Boulder, a portion of Dr. France's time is to perform research as part of his/her employment.

Travel *Budgeted travel includes:*

(1) Trip to the TESS Science conference (or equivalent domestic scientific conference) for one project team member. At this conference, they will present research findings and collaborate with peers.

Airfare is based on an average of actual booking costs from the previous quarter recorded by Christopherson Business Travel, the booking agency for the University of Colorado. Travel costs are estimates. Upon contract award, actual travel costs will be billed pursuant to CU travel policy. *Per Diem* rates are taken from current government rate sites. *Car Rental* is estimated at $55/day, which is based on the State of Colorado's negotiated rates plus estimates for taxes and gasoline. Local ground transportation will be used in lieu of a car rental if available. *Ground Transportation* costs include daily parking at the airport and transportation to and from the airport and are estimated based on historical costs experienced. *Conference Registration Fees* are estimated using the most recent fee available on the conference web site or historical costs experienced.

Other Direct Costs: *Publications* are estimated using the AGU publication fee table and recent historical and actual costs from similar publications from other publishing houses.

Indirect Costs / Facilities and Administration (F&A) : Indirect costs are charged according to the University's federally negotiated rate per agreement dated 12/15/2022.

Inflation Rates: The University of Colorado's current budget planning parameters include an annual inflation factor of 3.00% for salaries of investigators, post-doctoral researchers, graduate research assistant, and 3.00% for hourly students. Tuition is estimated to increase 3.00% per year. Other direct costs such as travel, can be inflated at 2.50% per year (inflation of other direct costs is optional).

Current and Pending				
David Wilson				
Grant Title	**Agency (Program)**	**PI (Institution)**	**Performance Period**	**#mo/year**
Current:				
MEATS Cycle 28	STScI	Kevin France (LASP-CU)	10/01/2020-09/30/2023 $273,354	4
Mega-MEATS Cycle 29	STScI	Allison Youngblood (NASA Goddard)	10/01/21 –09/30/24 $535,763	6
(Mega) MEATS is obtaining UV+X-ray observations of JWST planet target host stars. Current work is to assemble full SEDs of the stars to high-level science product standard.				
Characterising the Soft X-ray Activity of the Metal-Rich White Dwarf GD 394	SAO	David Wilson (LASP-CU)	06/14/22-06/13/23 $48,820	1
Analysing X-ray and TESS photometric data to understand the unique UV variability of this hot metal-polluted white dwarf.				
Ultraviolet Photometry of TRAPPIST-1 during the next JWST Observing Window	STScI	David Wilson (LASP-CU)	6/01/2023 – 6/01/2024 $60,441	2
Have obtained three epochs of HST UV photometry of TRAPPIST-1 to track it's UV variability on ~ week long time scales, providing contemporaneous data with JWST observations.				
MANTIS (Monitoring Activity of Nearby sTars with uv Imaging and Spectroscopy)	NASA (APRA)	Briana Indahl (LASP-CU)	10/1/2023-9/30/2027 $8.5M	2
Multiwavelength cubesat mission to launch in 2026. I lead the science team.				
Stellar X-ray and Ultraviolet characterization of the Habitable Worlds Observatory habitable planet target sample	NASA (Astrophysics Decadal Survey Precursor Science)	David Wilson (LASP-CU)	10/1/23-9-30/26 $454, 085	4
Large project to catalog the available UV and X-ray data for the HWO target sample, assemble full SEDs where possible and make them available for community use.				

BUDGET

Orbital Periods and Flare Rates of White Dwarf - Main Sequence Star Binaries with TESS

Proposal in Response to NASA ROSES 2022 NNH22ZDA001N-TESS (TESS General Investigator – Cycle 6)

CU-LASP PI: David Wilson

			Year 1 1/1/2024 THROUGH 12/31/2024		Total 1/1/2024 THROUGH 12/31/2024
SALARIES	**Benefit Code**	**WM YR1**	**$ YR1**	**TOTAL WM**	**TOTAL**
		(WM = Work Months)			
PRINCIPAL INVESTIGATOR	P	3.00	$25,173	3.00	$25,173
SUBTOTAL: SALARIES		3.00	$25,173	3.00	$25,173
FRINGE BENEFITS	**Benefit Code**	Rate:			
PRINCIPAL INVESTIGATOR	P	61.60%	$15,507		$15,507
SUBTOTAL: BENEFITS			$15,507		$15,507
SUBTOTAL: LABOR (SALARIES + BENEFITS)			$40,680		$40,680
TRAVEL					
TRAVEL: Domestic (see Travel Detail)			$3,534		$3,534
CONFERENCE REGISTRATION COSTS: Domestic (see Travel Detail)			$623		$623
Subtotal Domestic Travel			*$4,157*		*$4,157*
SUBTOTAL: TRAVEL			$4,157		$4,157
OTHER DIRECT COSTS					
PUBLICATIONS			$3,632		$3,632
SUBTOTAL: OTHER DIRECT COSTS			$3,632		$3,632
TOTAL DIRECT COSTS			**$48,469**		**$48,469**
INDIRECT COSTS		Memo: MTDC Base		Memo: MTDC Base	
(MTDC ='s Modified Total Direct Costs)					
43.0% OF MTDC* (On est. MTDC effective 07/01/21)		$48,469	$20,842	$48,469	$20,842
TOTAL INDIRECT COSTS			**$20,842**		**$20,842**
TOTAL			**$69,311**		**$69,311**

*Indirect Cost rate of 43.0% used per DHHS agreement dated 12/15/2022. Rate effective 7/1/2021 to 6/30/2023. Starting 7/1/2023, the same indirect cost rates and conditions are used as those cited for fiscal year ending 6/30/2023.

BUDGET

Orbital Periods and Flare Rates of White Dwarf - Main Sequence Star Binaries with TESS

Proposal in Response to NASA ROSES 2022 NNH22ZDA001N-TESS (TESS General Investigator – Cycle 6)

CU-LASP PI: David Wilson

TRAVEL & CONFERENCE REGISTRATION DETAIL

	CURRENT COST	Period Ending--> 12/31/24 Inflated Year 1 Cost	TOTAL
TESS Science Conference (or domestic scientific equivalent)			
Boston, MA			
1 PERSON 7 DAYS			
AIRFARE @ $443 RT	$443		
PER DIEM: LODGING @ $309/DAY, MEALS & INCIDENTALS @ $79/DAY	$2,368		
CAR RENTAL @ $55/DAY	$385		
GRND TRANS @ $50.4/PERSON, PARKING @ $17/DAY/PERSON & UAL BAGGAGE FEES @ $40/BAG	$209		
	$3,405		
Travel Cost- 1 TRIP/YEAR (Inflated)		$3,534	$3,534
Est. Conference Registration- 1 person at $600 per person		$623	$623
DOMESTIC TRAVEL TOTAL		$3,534	$3,534
DOMESTIC CONFERENCE REGISTRATION TOTAL		$623	$623
DOMESTIC TOTAL		**$4,157**	**$4,157**
FOREIGN TRAVEL TOTAL		$0	$0
FOREIGN CONFERENCE REGISTRATION TOTAL		$0	$0
FOREIGN TOTAL		**$0**	**$0**
TRAVEL TOTAL FROM ABOVE		$3,534	$3,534
CONFERENCE REGISTRATION TOTAL FROM ABOVE		$623	$623
TOTAL TRAVEL AND CONFERENCE REGISTRATIONS		$4,157	$4,157

David J. Wilson

Professional Appointments

Laboratory for Atmospheric and Space Physics,
University of Colorado at Boulder — Boulder, USA
Research Associate — 2022–present

McDonald Observatory, University of Texas at Austin — Austin, USA
Postdoctoral Research Fellow — 2018–2022

Department of Physics, University of Warwick — Coventry, UK
Postdoctoral Research Fellow — 2017–2018

Education

University of Warwick — Coventry, UK
Ph.D. in Physics, Advisor: Boris Gänsicke — 2013–2017
- Thesis: "Observations of Remnant Planetary Systems at White Dwarfs"

Lancaster University/Michigan State University — Lancaster, UK/East Lansing, USA
MPhys (Hons) in Physics/Year Abroad — 2009–2013
- Thesis: "The Ever-Changing Sun: Multi-wavelength Solar Observations"

Selected Telescope Time Awarded as PI

- *HST*/WFC3/ACS (Cycle 30), Program ID 17282, 15 orbits: "Ultraviolet Photometry of TRAPPIST-1 during the next JWST Observing Window"
- *HST*/STIS (Cycle 28), Program ID 16449, 4 orbits: "Testing the Lyman Alpha reconstructions vital for stellar and exoplanet astronomy."
- Multiple *Swift* TOO awards for simultaneous observations with *HST*/*Chandra* visits, totaling ≈ 50 ksec.
- *Chandra* (Cycle 20), Program ID 20200610, 110 ksec: "Characterising the soft X-ray activity of the metal-rich white dwarf GD 394."
- *HST*/COS/STIS+*XMM Newton* (Cycle 25), Program ID 15189, 12 *HST* orbits + 43 ksec *XMM* time: "Post Common Envelope Binaries as probes of M dwarf stellar wind and habitable zone radiation environments."
- VLT/X-shooter (Period 99), Run ID 099.C-0811(A), 2 hours: "Confirmation of gaseous emission from a planetary debris disc at a white dwarf."
- *HST*/STIS (Cycle 22), Program ID 13719, eight orbits: "Accretion of planetary debris onto the unique white dwarf GD394."

Grants and Awards

- July 2023: $54k Astrophysics Decadal Survey Precursor Science Proposal 22-ADSPS22-0020
- March 2023: $ 60k research funding associated with *HST* proposal 17282.
- February 2021: $ 42k research funding associated with *HST* proposal 16449.
- December 2018: $ 65k research funding associated with *Chandra* proposal 20200610.

Professional Service

- July 2022 onwards: Organiser for LASP colloquium series.
- 2021-2022: Panelist for the *TESS* Cycle 4 and 5 reviews.
- October 2020: Panelist for the ADAP 2020 review.
- October 2020 onwards: ExoPAG SAG 22 working group member.
- December 2018: Panelist for the *Swift* Cycle 15 review.
- Ongoing: Regular external reviewer for *Hubble Space Telescope* proposals.
- July 2016: Member of LOC for the European White Dwarf Workshop, Warwick University.

Selected Publications

First Author

1. Wilson, D. J., Youngblood, A., Toloza, O., et al. (2022), *ApJ*, 936, 189: " Testing Ly α Emission-line Reconstruction Routines at Multiple Velocities in One System."
2. Wilson, D. J., Toloza, O., Landstreet, J. D., et al. (2021), *MNRAS*, 508, 561: "Discovery of a young pre-intermediate polar."
3. Wilson, D. J., Froning, C. S., Duvvuri, G. M., et al. (2021), *ApJ*, 911, 18W: "The Mega-MUSCLES Spectral Energy Distribution Of TRAPPIST-1."
4. Wilson, D.J., Hermes, J.J., and Gänsicke, B.T. (2020), *ApJL*, 897, L31: "Optical Detection of the 1.1 day Variability at the White Dwarf GD 394 with TESS."
5. Wilson, D. J., Gänsicke, B. T., Koester, D., et al. (2019), *MNRAS*, 483, 2941: "Multiwavelength observations of the EUV variable metal-rich white dwarf GD 394."
6. Wilson, D.J., Gänsicke, B.T., Farihi, J., & Koester, D. (2016), *MNRAS*, 459, 3282: "Carbon to oxygen ratios in extrasolar planetesimals."

Contributing Author

1. Lin et al. (2021), *MNRAS*, 505, 3562: "Differentiating modern and prebiotic Earth scenarios for TRAPPIST-1e: high-resolution transmission spectra and predictions for JWST."
2. Duvvuri et al. (2021), *ApJ*, 913, 40:"Reconstructing the Extreme Ultraviolet Emission of Cool Dwarfs Using Differential Emission Measure Polynomials."
3. France et al. (2020), *AJ*, "The High-Energy Radiation Environment Around a 10 Gyr M Dwarf: Habitable at Last?"
4. Linsky et al. (2020), *ApJ*, 902, 3, "The Relative Emission from Chromospheres and Coronae: Dependence on Spectral Type and Age"
5. Melbourne et al. (2020), *ApJ*, "Estimating the Ultraviolet Emission of M dwarfs with Exoplanets from Ca II and Hα"
6. Gaidos et al. (2020), *MNRASL*, 148, "Zodiacal Exoplanets in Time. XI. The Orbit and Radiation Environment of the Young M Dwarf-Hosted Planet K2-25b"
7. Wunderlich et al. (2020), *APJ*, "Distinguishing between wet and dry atmospheres of TRAPPIST-1 e and f"
8. Froning et al.(2019) *ApJl*, 871, L26: "A Hot Ultraviolet Flare on the M Dwarf Star GJ 674."