Galactic Archaeology with Brown Dwarfs and the Nancy Grace Roman Space Telescope

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1 Science, Technical, and Management

1.1 Introduction

Since the first discovery of brown dwarfs nearly thirty years ago, in the Pleiades cluster (Rebolo *et al.* 1996) and orbiting the nearby star Gliese 229 (Nakajima *et al.* 1995), brown dwarfs have proven to be a rich and important population in stellar, exoplanetary, and galactic astrophysics. These low-mass compact objects ($M \leq 0.075\ M_{\odot}$) are incapable of sustained hydrogen fusion and supported from further collapse by electron degeneracy pressure, and hence steadily cool and dim as they age (Kumar 1963; Hayashi & Nokana 1963). They are an abundant population in the Milky Way, comprising $\gtrsim$ 20% of all "stars" in the Solar Neighborhood (Kirkpatrick *et al.* 2021b; Reylé *et al.* 2021) and found in young and old clusters; in thin disk, thick disk, and halo populations; and as the Sun's nearest neighbors. Their discovery *en masse* has been facilitated by wide-field red optical and infrared surveys such as 2MASS, SDSS, UKIDSS, PanSTARRS, and WISE, which have uncovered thousands of brown dwarfs down to effective temperatures $T_{eff} \approx 250$ K, and three new spectral classes: the L dwarfs, T dwarfs, and Y dwarfs. The diversity of these sources has generated new insights into star and exoplanet formation, the chemistry and dynamics of low-temperature atmospheres, and the properties of hydrogen-helium mixtures under extreme pressures. As wide-area surveys of ever-greater depth in the infrared are developed, these ubiquitous, long-lived, and evolving objects are also becoming an important tool for Galactic Archaeology studies.

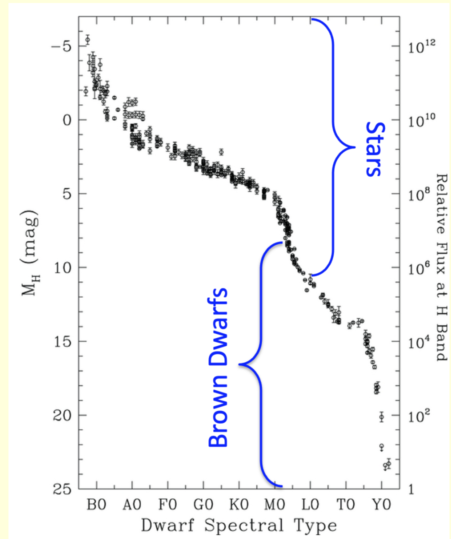

Fig. 1: Absolute H-band magnitudes of stars and brown dwarfs in the vicinity of the Sun as a function of spectral type. The latter have extended the "Main Sequence" by ~15 magnitudes. Figure adapted from (Kirkpatrick *et al.* 2012).

We propose a science case for the community-surveys with the Nancy Grace Roman Space Telescope that focuses on the lowest mass stars and brown dwarfs, develops new data reduction and analysis tools, and creates new population synthesis algorithms incorporating advanced evolutionary and atmospheric models. We will deliver our data products and software as value-added products to the community.

1.2 Galactic Archaeology with Brown Dwarfs

1.2.1 Brown Dwarfs as Standard Clocks and Galactic Chronometers

The steady cooling of brown dwarfs makes them a viable "clock" for population studies, a trait that has been exploited to date young clusters <200 Myr old via the lithium depletion boundary technique (Stauffer *et al.* 1998; Bell *et al.* 2015; Martín *et al.* 2018). In the broader Milky Way, brown dwarf cooling can also be used to date populations by comparing them to coeval low-mass stars, which undergo no evolution on the Main Sequence (lifetimes up to 10^{12} yr; Laughlin *et al.* 1997). Both stars and brown dwarfs born in the thin disk dynamically scatter over time via gravitational perturbations (i.e., disk heating; Spitzer *et al.* 1951), which increase their vertical velocity dispersions over time (e.g., Wielen 1977). The addition of brown dwarf cooling creates a dual metric for age-dating low-mass populations: young brown dwarf populations have typically warm temperatures ($\sim$2500 K) and small velocity dispersions, old brown dwarf populations typically cold temperatures ($\sim$1000 K) and large velocity dispersions. Across the hydrogen burning minimum mass (HBMM $\sim$ 0.075 $M_\odot$), models predict variations in velocity dispersions as we transition from predominantly long-lived stars (M dwarfs) to young warm brown dwarfs (L dwarfs) to evolved cold brown dwarfs (T and Y dwarfs; see Fig. 2). The present-day population of brown dwarfs in the Galactic disk is thus a convolution of star-formation history (SFH) and mass-dependent cooling evolution (Burgasser 2004). By combining both velocity and temperature measurements, it is possible to simultaneously probe the age and mass distributions of Galactic brown dwarfs.

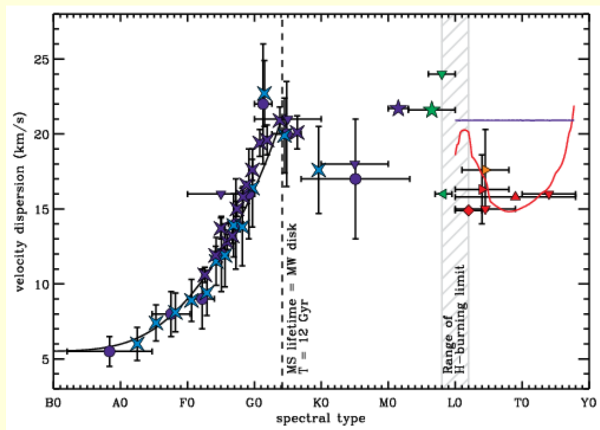

Fig. 2: Vertical velocity dispersion as a function of spectral type taken from Ryan *et al.* (2017). The colored symbols represent samples that are certainly above the hydrogen-burning limit (blue), likely straddling the limit (green), and likely below (red). The solid black line represents a kinematic model derived from solving the Fokker-Planck equation. The red/blue lines show simulations from Ryan *et al.* (2017) to predict kinematics of brown dwarfs with/without cooling, respectively. The decrease of $\sim$25% in the red curve exemplifies the importance of cooling in brown dwarf evolution, and how it transforms brown dwarfs into Galactic chronometers.

Kinematic studies of local low mass stars and brown dwarfs have sought to confirm these age- and temperature-dependent trends through various 2D and 3D velocity surveys (e.g., Zapatero Osorio *et al.* 2007; Faherty *et al.* 2009; Seifahrt *et al.* 2010; Schmidt *et al.* 2010; Blake *et al.* 2010; Burgasser *et al.* 2015; Hsu *et al.* 2021). These studies have shown considerable disagreement with predictions and each other, driven in large part by small sample biases induced by the sensitivity limits for radial velocity measurement (typically $N \lesssim 100$). Ryan *et al.* (2011) have proposed the use of deep number count studies of brown dwarfs to probe their Galactic vertical distribution (z_{scl}) as a proxy of age, since this distribution scales to the vertical velocity variance, $z_{scl} \propto \sigma_W^2$ (van der Kruit 1988). This approach has found some success in deep space-based imaging and spectroscopic surveys.s For example, Aganze *et al.* (2022b) identified 164 late-M, L and T dwarfs out to 1 kpc with low-resolution spectra in 0.6 deg^2 of sky covered by the largest HST surveys (Atek *et al.* 2010; Brammer *et al.* 2012), and inferred vertical scale-heights marginally consistent with a younger L dwarf population in the Galactic disk. Wide and deep imaging surveys from the ground have also begun to make constraints on brown dwarf scale-heights in the brown dwarf regime (Carnero Rosell *et al.* 2019; Sarohana *et al.* 2019), with considerably larger samples (10^{3-4} sources) but smaller distances ($\lesssim$200 pc) and more uncertain classifications.

Deliverable 1: Galactic Distributions

We will use number counts of brown dwarfs to measure their Galactic-scale distribution (e.g. vertical scale height) as a function of spectral type, to probe the macrophysics of disk heating and microphysics of brown dwarf cooling.

1.2.2 Brown Subdwarfs as Fossil Relics

Because they do not sustain core fusion, brown dwarfs never deplete their hydrogen stores and are supported from collapse by electron degeneracy pressure. Brown dwarfs cool but never die. As such, every brown dwarf ever formed exists today, including those formed early in the history of the Milky Way. These cool, low-mass objects preserve their natal chemical abundances, as well as a record of the efficiency of low-mass stellar and substellar formation in the metal-depleted environments of the early Milky Way and merged populations (Buser 2000; Bland-Hawthorne & Gerhard 2016; Gallart *et al.* 2019). Metallicity plays an important role in the evolution of brown dwarfs (Fig. 3), as the HBMM is itself metallicity dependent, ranging from 0.072 $M_\odot$ at solar metallicity to 0.090 $M_\odot$ for pure H/He (Saumon *et al.* 1994). Metallicity also influences the rate of cooling (Burrows *et al.* 2001, 2011) and the chemistry and spectral appearance of brown dwarfs (Lépine *et al.* 2007; Burgasser *et al.* 2007).

The efficiency of low-mass star and brown dwarf production in the early Milky Way is poorly determined, both observationally and theoretically. While the low-mass stellar and substellar initial mass function (IMF) is well-determined in young clusters (Bastian *et al.* 2010) and the immediate Solar Neighborhood (Kirkpatrick *et al.* 2021b), the IMF of the halo has only been measured down to $M \approx 0.2\ M_\odot$ (Reid *et al.* 1996; Digby *et al.* 2003). The shape of the halo IMF near or below the HBMM is unknown. Theoretically, it remains unclear whether low metallicity environments produce low-mass objects rarely (Bromm 2013), in excess (Chabrier *et al.* 2014), or proportional to the disk population (Bate 2005).

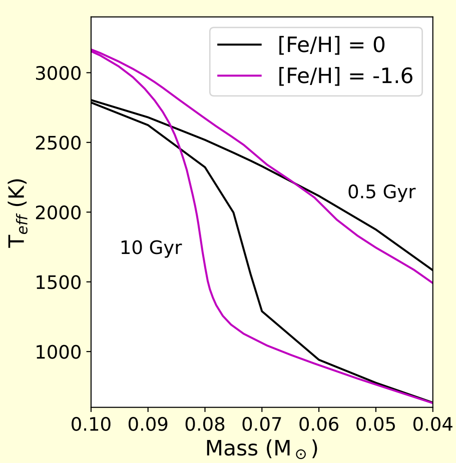

Fig. 3: Metallicity effects in the thermal evolution of low-mass stars and brown dwarfs. Metal-poor models (Gerasimov *et al.* 2022) (magenta lines) have higher stellar temperatures and transition to the evolved (10 Gyr) brown dwarf sequence ($T_{\rm eff} \lesssim 1000$ K) at higher masses than their solar-metallicity counterparts. These metallcity-dependent evolutionary effects, as well as the IMF, can be inferred from the temperature/luminosity distribution of evolved fossil brown dwarfs in the halo.

We do know low-temperature halo brown dwarfs exist (e.g., Burgasser *et al.* 2003), and they have been discovered recently in the form of low-metallicity T subdwarfs (Schneider *et al.* 2020). The unique spectra of these sources (see Fig. 4) reveal signatures of low temperature ($T_{\rm eff} \approx 1000$ K) and highly metal-depleted atmospheres ([Fe/H] $\lesssim -1$), although current models poorly reproduce observed spectra (Schneider *et al.* 2020; Lodieu *et al.* 2022). While several halo T-subdwarf candidates have now been identified (Meisner *et al.* 2020, 2021; Kirkpatrick *et al.* 2021a; Brooks *et al.* 2022), the samples remain too small, and individual sources too poorly characterized, to make better than order-of-magnitude estimates of their local space density, let alone concrete determinations of the halo brown dwarf IMF or metal-dependent evolution.

The two primary challenges in characterizing the fossil brown dwarf population are (1) the sparsity of halo stars in the Solar Neighborhood (disk:halo density ≈ 1:200; Jurić *et al.* 2008; Amarante *et al.* 2020); and (2) the long-term cooling of these objects over $\gtrsim 8$ Gyr causes them to be intrinsically faint and red at present-day temperatures ($T_{\rm eff} \lesssim 100$ K; Burgasser 2004). Halo stars outnumber disk stars at distance $\gtrsim$1 kpc out of the plan (Jurić *et al.* 2008); hence, detecting brown dwarfs well-beyond the disk would produce large enough samples to study early brown dwarf formation and evolution in a statistically robust matter.

The infrared sensitivity and coverage of the Roman High-Latitude Wide-Area and High-Latitude Time Domain Surveys will provide the first opportunity to study a statistically robust sample of halo brown dwarfs, sufficient to investigate their formation and evolutionary histories. The deepest infrared surveys conducted with *HST* (Ryan *et al.* 2011; Aganze *et al.* 2022a,b) and now *JWST* (Ryan *et al.* 2016) have insufficient areal coverage ($<1^\circ$) to detect large halo brown dwarf samples. Wide-area infrared surveys such as 2MASS, UKIDSS, VHS, and WISE lack sufficient depth. Combined wide and deep optical surveys such as PanSTARRS, DES, and (soon) LSST, despite producing large samples of late-M and L dwarfs (10^4 sources; Carnero Rosell *et al.* 2019; Sarohana *et al.* 2019), are insensitive to cold halo brown dwarfs beyond ∼100 pc. Roman's Wide-Area Survey provides the optimal combination of depth in the infrared to detect $T_{\rm eff}$ = 1000 K brown dwarf beyond 1 kpc (and importantly perpendicular to the Galactic disk) and areal coverage to build robust samples over many sight lines. In addition, the combination of multi-band photometry, low-resolution spectroscopy, and (for the Time Domain Survey), multi-epoch astrometry for proper motion selection, enable the construction and characterization of large, clean samples of low temperature, high velocity, halo brown dwarfs.

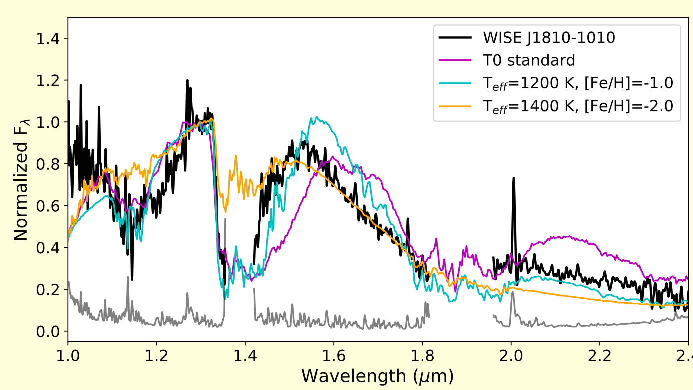

Fig. 4: Discovery spectrum of the first T subdwarf WISE J1810-1010 (Schneider *et al.* 2020) (black) compared to a T0 spectral standard (magenta) and two low-temperature, subsolar metallicity models (Gerasimov *et al.* 2020). The spectrum of the T subdwarf does not match any known T dwarf, indicating its unique nature as a metal-poor halo brown dwarf. In addition, its spectrum cannot be accurately reproduced by existing low-temperature and low-metallicity models.

1.2.3 Brown Dwarf Classification

The High-Latitude Wide-Area Survey (HLWAS) will be sufficiently cadenced to obtain trigonometric parallaxes for the brown dwarfs, which puts the utmost importance on accurate spectral types as a means of a *spectroscopic parallax* (wherein distances are inferred via a calibrated relationship between spectral type and luminosity). Therefore we plan to establish and test a methodology to identify brown dwarfs and very low-mass stars, and to obtain accurate classification (<0.5 subtypes) using a combination of photometry and spectroscopic. Previous studies have selected and classified thousands of brown dwarfs based on photometry in large-scale infrared surveys (e.g. WISE, 2MASS, UKIDSS, DES). Photometric selections are fast and efficient. However, they are affected by contamination from red extra-galactic sources (e.g. Ryan *et al.* 2005; Carnero Rosell *et al.* 2019). Additionally, rare populations (subdwarfs, young sources) can be overlooked, unless the methods are specifically tuned to pick out these unusual objects. Alternatively, spectroscopic selections are less susceptible to contamination by extragalactic sources, and spectrum-based selection and classification offer an improvement over using just photometry. Spectral classification is typically done by comparing objects to established spectral standards (Burgasser *et al.* 2006; Kirkpatrick *et al.* 2010; Cushing *et al.* 2011). In addition, metal-poor and young brown dwarfs can also be classified in a similar manner, and by measuring spectral indices that have been calibrated to bulk metallicities and ages of these sources (Allers *et al.* 2007; Burgasser *et al.* 2007).

With these competing issues in mind, we have developed a supervised machine learning methods as a complementary approach to traditional photometric and spectroscopic selections and classification. Machine learning methods can select brown dwarfs in large-scale imaging and spectroscopic surveys and provide accurate classification by type (Aganze *et al.* 2022a; Feeser *et al.* 2022; Yang *et al.* 2023), including young sources and subdwarfs. More generally, machine-learning-based models, and deep learning in particular, have been proven to reliably perform star/galaxy separation and to determine spectral types of main-sequence stars (e.g. Kim *et al.* 2017; Miller *et al.* 2017; Sharma *et al.* 2020).

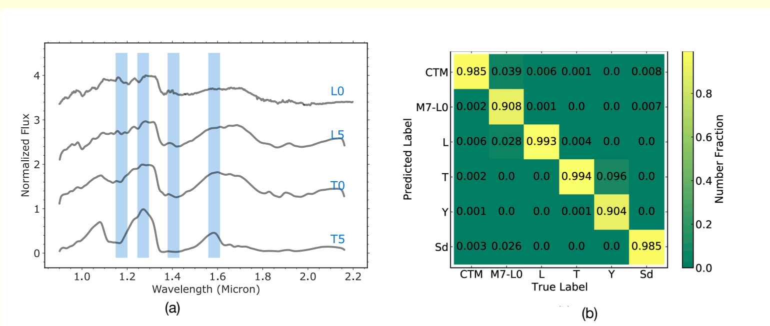

Fig. 5: Left: Spectral templates from the SpeX Prism Libary (Burgasser *et al.* 2014) smoothed to the Roman prism resolution. Blue regions indicate features that are most sensitive to classification by random forests based on the random forest model by Aganze *et al.* (2022a). Right: Predicted types vs true types of point sources based on WFC3 grism spectroscopy using a neural network.

Hence, we plan to use a combination of random forests (RF), artificial neural networks (ANNs), and convolutional neural networks (CNNs) to select objects and classify them. Fortunately, cold brown dwarfs are characterized by distinct broad molecular features dominated by their water and methane opacities in the Roman bands ($0.9-2$ μm, see Fig. 5). Aganze *et al.* (2022a) have demonstrated that random forests and neural networks can efficiently select brown dwarfs in HST/WFC3 grism surveys (3dHST & WISPs) with precision

$> 90\%$ (see Figure 5). As the Roman grism spectra will offer a similar resolution compared to the WFC3 grisms, we expect a comparable efficiency in selecting brown dwarfs.

Assuming accurate star/galaxy separation, we will provide spectral classifications of all the points sources. To train the RF, ANN and CNN models, we will utilize spectra and photometry catalogs compiled by the community from ground- and space-based data (e.g. Burgasser *et al.* 2014; Manjavacas *et al.* 2019; Best *et al.* 2020; Aganze *et al.* 2022a), supplemented by additional synthetic photometry in Roman bands based on atmospheric models (Line *et al.* 2015, 2017; Gerasimov *et al.* 2020; Phillips *et al.* 2020; Marley *et al.* 2021), and any available astrometric information.

Deliverable 2: Spectral-type classifications from deep learning

We will deliver a trained-deep learning network to spectrally classify brown dwarfs and very low mass stars and/or data for the first year of observations.

1.2.4 Stellar SED Modeling and Chemical Retrievals

The spectra of brown dwarfs contain a wealth of information regarding the molecular inventory, physical properties, and dominant chemical processes of sub-stellar atmospheres. The interpretation of spectra toward solving for these quantities requires both high fidelity atmospheric models that can replicate the thermal flux received from these objects as well as powerful statistical inference methods to estimate the parameters that make up the model. Near to mid infrared brown dwarf spectra contain prominent absorption features of H_2O, CH_4 and NH_3 as well as alkali metals for the coolest objects (Lodders 2003; Kirkpatrick 2005; Cushing *et al.* 2011). Measuring these species can help in uncovering the ratio of atmospheric C/O ratio as well as the overall metal-to-hydrogen level (M/H). To this end, there have been several studies using near-infrared (NIR) spectra that have coupled these facets in order to place robust constraints on key atmospheric quantities of brown dwarfs. Line *et al.* (2015) analyzed two brown dwarf spectra using a forward radiative transfer model parameterized by the volume mixing ratio of several key absorbers in the NIR, a partitioned temperature-pressure profile and additional physical parameters, combined this with the affine-invariant ensemble sampler (Foreman-Mackey *et al.* 2013) to retrieve the observables given by the spectra. This "atmospheric retrieval" framework yielded precise constraints on the abundances of aforementioned absorbers (~ 0.1 dex), the thermal structure, and data-model fits. Based on these results, atmospheric retrievals via parameter estimation inferences have provided insight into the physical and thermal properties of a large sample of brown dwarfs spanning the spectral types of early- to mid-L (Rowland *et al.* 2023), mid T (Line *et al.* 2017; Zalesky *et al.* 2022) and late-T to early-Y dwarfs (Zalesky *et al.* 2019). In Fig. 6,

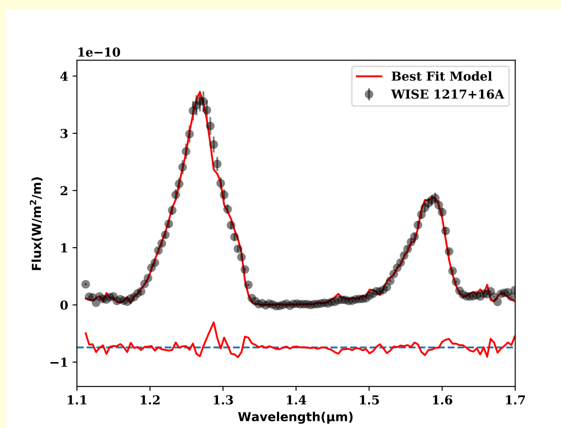

Fig. 6: Example model fitting for NIR grism data from Sanchez *et al.* (2023).

we show our modeling of a late-T dwarf (Sanchez *et al.* 2023) observed with HST/WFC3, which has a slightly reduced wavelength range ($1.08 - 1.7\ \mu$m) and resolution (45 Åpix^{-1}) compared to Roman. We plan to build on this Bayesian framework to model the spectra of the brown dwarfs to understand the microphysics of brown dwarf atmospheres.

Deliverable 3: Brown Dwarf Physical Properties

We will provide parameters for the thermal structure and molecular abundances of brown dwarfs as determined from our MCMC modeling of the HLWAS spectroscopy.

1.3 Roman Imaging and Slitless Spectroscopy to the Rescue

The wide-field Roman observations represent a Rosetta stone for decoding the history of the Milky Way and microphysics within brown dwarfs, but to frame the matter, we consider the reference survey presented by Wang *et al.* (2022). Here, the notional HLWAS and HLTDS will subtend $\gtrsim 2000$ deg^2 in four near-infrared imaging filters (F106 Y, F129 J, F158 H, and F184 HK) with grism/prism spectroscopy from $1.0 - 1.9\ \mu$m with a uniform dispersion of > 10.8 Å/pix. The slitless spectroscopy will be collected over four independent position angles of $\Delta\theta \in (5°, 175°, 185°, 355°)$ with respect to some fiducial angle that is driven by orbital or solar-avoidance considerations.

1.3.1 Linear Reconstruction of Slitless Spectroscopy

Slitless spectroscopy lacks a physical aperture to restrict the spatial extent of the dispersed light, which results in a complete spectroscopic view of an astrophysical scene, free of any major observational planning or targeting considerations (such as slit masks, fiber placements, *etc.*). However this advantage comes at a considerable cost, because the observed two-dimensional spectra is effectively a convolution between the source spectra and their spatial profiles. Although the advantage of this complete multiplexing is obvious, it brings a significant data analysis challenge: *How to handle overlapping traces and source confusion?* Traditional grism extraction methods are built on the notion of "contamination" to describe the flux from nearby, unrelated sources. Although it is often straight-forward to identify contaminated regions, it is far less obvious how to properly treat these pixels. The most basic option would be to simply mask such pixels in further analyses, since in the general case, there is no unique way to determine the contribution from each source. Obviously, this approach would leave "holes" in the extracted spectra, likely inhibiting further analyses. However if multiple position angles are available, then the additional data can break the degeneracy and "fill in" these holes. A slightly more advanced option would be to model the contamination based on ancillary data, often from broadband photometry (as with `aXe` or `grizli`), but then the spectroscopic quality will be limited by the photometry and modeling.

With these critical limitations and challenges in mind, Ryan *et al.* (2018) developed a novel technique to extract the optimal, contamination-free spectra when multiple position angles are available. Here, the flux measured in a dispersed image pixel as the sum over all sources and wavelengths, weighted by several scene-dependent (*e.g.* light distribution) and detector-dependent (*e.g.* flat field or sensitivity) factors:

$$\mathcal{I}_{x,y,i} = \sum_{\lambda} \sum_{j}^{N} W_{x,y,i,\lambda,j} f_{\lambda,j}. \tag{1}$$

This establishes a large system of sparse linear equations for an over-constrained integral problem, which can be solved by regularized least-squares (Paige & Saunders 1982):

$$\psi^2(f) = ||\mathcal{I} - Wf||^2 + \ell||W||_F^2||f||^2. \tag{2}$$

where ℓ and $||W||_F$ are the (dimensionless) regularization parameter and Frobenius norm, respectively (the first term is the canonical χ^2-term). However to establish the coefficients of this linear transform (ie. the W-matrix), the concept of "drizzling" had to be generalized, so that pixel transformations are explicit functions of wavelength.

Although this formalism was motivated by addressing the unavoidable issue of spectral contamination, it provides has an additional major advantage related to the spectral resolution. The spectral resolution achievable in slitless observations is related to the size of the source projected along the dispersion axis, in analogy to the relationship between resolution and slit width in long-slit spectroscopy. Consequently, if the source is extended, then the individual-orient spectra will have different resolutions, since they have different projected sizes (see Fig. 7), which significantly complicates *post facto* combination of the individual-orient spectra — as is the plan of the Science Support Center (SSC). Therefore, one chooses to either increase the signal-to-noise by combining the individual orients or increase the spectral resolution by analyzing the individual-orient spectra. However, the Ryan *et al.* (2018) method obviates this trade-off by providing the highest spectral resolution present in the source while approximately increasing the S/N as expected by the increased exposure time.

It is important to stress: While the SSC will provide one-dimensional spectra and value-added products (e.g. redshift, line fluxes, etc.), these spectra will be individual-orient extractions combined *post facto*. Further, the contamination model will be predicated on simple interpolation of the broadband photometry, which is effectively a highly-smoothed version of the spectra. Obviously, if this high-smoothed (broadband) spectra differs significantly from the slitless spectra (such as any source with strong emission lines or deep absorption features, like in Fig. 5), then it is natural to expect erroneous contamination corrections.

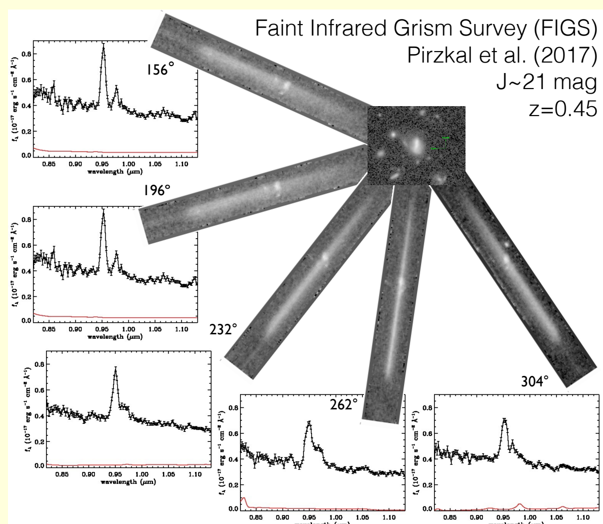

Fig. 7: Our analysis of the FIGS observations with WFC3/IR (Pirzkal *et al.* 2017). At the center, we show the J-band image of an extended galaxy with the two-dimensional grism spectra radiating at the angles specified. In each subpanel, we show the classic one-dimensional extractions (black data) with contamination model (red line). Since this object is extended, orients that disperse along the minor axis (156° or 196°) clearly have the highest spectral resolution, easily separating Hα and [S II]. Whereas the orients that disperse along the major axis (232° or 262°) have considerably lower spectral resolution, blending these emission lines. Although extended sources are not our foremost concern, this unique advantage of our approach reinforces the value of Deliverable 4.

For this reason and the description of extend-source spectral resolution, we insist our work represents a significant advancement beyond the default Roman program.

Deliverable 4: Linear reconstruction of 1d spectra

We will deliver our optimal, linear-reconstructed spectra for all sources brighter than a flux limit based on the final properties of the HLWAS.

1.3.2 Concluding Remarks

The Roman surveys will greatly expand these studies through greater depth, areal breadth, and classification reliability. The HLWAS has the capacity to image mid-L dwarfs out to 5 kpc and mid-T dwarfs to $1-2$ pc, sampling several scale heights down to low masses and temperatures. In addition, the wide area coverage of this survey will photometrically detect 100,000s of L and T dwarfs in the thin disk alone, eliminating small sample bias as an issue. Slitless grism spectroscopy in the HLWAS will reach distances of $\sim$500 pc and $\sim$200 pc for mid-L and mid-T, enabling detailed classification and characterization of 1000s to 10,0000s of brown dwarfs over a full scale height. The combination of multi-band photometry and (for a subset of the sample) grism spectroscopy will allow for robust separation of brown dwarfs from contaminating sources, facilitated by the point source/extended source separation afforded by Roman's $0\farcs1$ imaging resolution. Combined, the HLWAS will create by far the largest, cleanest, and best-characterized sample of Galactic disk brown dwarfs to date, enabling detailed examination of age variations as a function spectral type and subclass (e.g., unusually red vs. blue L dwarfs) along multiple sightlines. The HLTDS will provide a complementary dataset, where the benefit of multi-epoch astrometry enabling proper motion selection of sources and assessment of 2D kinematics to greater integrated depth and over areas $\gtrsim$50$\times$ larger than existing HST surveys.

1.4 Project Management Plan

Our team is comprised of scientific and technical experts in working with low-mass stars, Galactic evolution, slitless spectroscopy, infrared detectors, and the Roman mission in general. While we expect all team members to contribute to all areas, we have identified several subgroups that will lead the effort in five distinct categories below. Effort is largely distributed between three institutions: STScI, ASU, and UCSD, with senior team members at each institution will serve as immediate supervisors (R. Ryan, J. Patience, and A. Burgasser).

- **Object Classification:** The sample selection of brown dwarfs will be based on a deep-learning method developed by our team. *Aganze, Burgasser*
- **Spectral Modeling:** The spectroscopic modeling of brown dwarfs is critical to understanding their present-day energtics and birth-chemistry. *Sanchez, Patience, Line, Burgasser, Manjavacas*
- **Low-metallicity Subdwarfs:** These rare brown dwarfs are the true fossil relics of the Milky Way's early days, which Roman will find in droves. *Theissen, Schneider, Burgasser*
- **Slitless Spectroscopy:** The implementation, validation, and execution of the slitless spectroscopy based on the linear-reconstruction algorithms is the springboard for our entire study. *Ryan, Aganze, Sanchez, Hathi*
- **Infrared Detectors & Surveys:** A robust analysis of the slitless spectroscopy requires a detailed understanding of NIR detectors and artifacts. *Willmer, Ryan, Manjavacas, Patience*

2 Proposed Undergraduate Research

Training the Next Generation of Roman Astronomers: An Astronomy Science Process Skills Curriculum

There are chronic and well-documented disparities in the participation of underrepresented minorities (URMs) and women in STEM degree programs and careers. For example African and Hispanic Americans, Indigenous people, and Pacific Islanders make up 33% of the US population, but earn only 5% of Astronomy B.S. and Ph.D. degrees, and hold only 3% of Astronomy faculty positions (Mulvey 2012; Ivie 2014); an order-of-magnitude disparity that has existed for decades. The Joint Working Group on Improving Underrepresented Minority Persistence in STEM (Estrada *et al.* 2016) identifies four evidence-based strategies that reduce demographic disparities at the undergraduate level: (1) integrate curriculum change, particularly in skills-based learning; (2) invigorate students' creativity through research opportunities and community-based learning; (3) create strategic partnerships with successful programs; and (4) address student resource disparities.

In this program, we aim to apply all four of these strategies in the design, development, assessment and dissemination of an **Astronomy Science Process Skills (ASPS) research training curriculum.** Our curriculum aims to build students' technical, practical, and social-emotional skills in the context of astrophysical science, specifically the brown dwarf and Galactic archaeology research focus of this proposal. It is also specifically designed to increase and sustain STEM participation among students from underrepresented communities. The curriculum will be integrated into an annual summer research program focused on the primary research activities of this proposal, with participants recruited primarily through minority research program partners.

Our ASPS model arises from our collective experience in undergraduate research training, and the current literature on science process skill development. There is broad agreement among researchers that process skills such as experimental design, problem-solving, data analysis and interpretation, scientific writing and communication, critical analysis of primary sources, collaborative work, and metacognition are all essential for successful scientific practice (Coil *et al.* 2010). Standard undergraduate curricula rarely teach these skills; instead, faculty assume that students gain these skills through lab or research practicum. Numerous studies have shown that explicit instruction of science process skills results in statistically significant improvements in STEM academic success (e.g. Nicoll & Francisco 2001; McConnell *et al.* 2003; Veal *et al.* 2009).

We will create a coherent workshop series focusing on key science process skills implemented in both our summer research program and as academic-term workshops. We will consolidate, evaluate, and iterate on existing training, and develop a model by which these can be adapted and adopted across our partnering and peer institutions. Seventeen specific training modules will include: Content knowledge: stellar/substellar & Galactic astronomy; Programming: python, program design, debugging, testing, & documentation; Survey data: accessing open-source data, NOIRLab, SQL queries; Statistics: measurement, significance, distributions, and Monte Carlo methods; Principles of simulation: modeling, sampling, noise, & calibration; Machine learning: random forests, neural networks, `scikit-learn` package; Scientific reading: identifying primary sources, structured reading, literature review; Scientific writing: narrative structure, logical flow, editing, & writing practice; Scientific communication: speaking & presentation, effective visualizations; Growth mindset: developing self-reflective capacity & perseverance; Organization & self-care: time management, life/-work balance, self-care; and Advanced study & careers: UG/G applications, networking.

Materials developed for this program will include lecture slides, videos, curated readings, in-class exercises, Jupyter notebooks, and instructor facilitation guides. These will be made publicaly distrubted online and conducted during the academic term in partnership with regional community colleges (CCs) to engage these students in research practices and encourage participation in research opportunities and advanced study.

Our research and training program builds on existing partnerships at ASU and UCSD:

I. Cal-Bridge: This is a bridge-to-PhD program that provides financial support, faculty mentoring, professional development, and research opportunities for students from 60 CSUs and CCs, nearly all federally-designated HSIs. These programs have been highly successful in engaging URM students (60% of participants) and assuring advancement to graduate study (90% placement; Rudolph 2019). We will work with Cal-Bridge to bring funded summer CAMPARE scholars to UCSD and (with a new partnership to) ASU to participate in research and training activities, and return elements of our program to Cal-Bridge.

II. ENLACE: This bi-national summer research program between the U.S. and Mexico aims to increase the participation of high school and college students in STEM research while promoting cross-border partnerships in the Baja California/San Diego region. Students are paired with graduate students to foster peer mentoring, participate in professional development workshops, and attend talks by faculty mentors. Over 100 students participate in ENLACE each year, including many with interest in astronomy, physics, and computer sciences. We will host student teams from ENLACE at UCSD using institutional funding.

III. UCSD STARS: This 8-week summer research academy at UCSD provides workshops on undergraduate transfer and graduate application, fellowship application workshops focused on the NSF Graduate Research Fellowship, a graduate student mentor, and local educational, cultural, and social activities. STARS also provides logistical support for summer research participants at UCSD.

CoIs Patience and Burgasser commit to mentoring 2-4 summer undergraduate research students per year at ASU and UCSD, 2 supported by this grant and ≥ 2 supported by alternate funding sources. To ensure these students are part of a cohesive research cohort, joint hybrid training sessions will be alternately hosted at ASU and UCSD, and one "site visit" will occur each summer, alternating between ASU to UCSD. We also commit to conducting portions of the ASPS training curriculum at our home institutions and regional sites as independent workshops ($\lesssim 20$ participants each). We thus anticipate direct mentorship of ~ 10 undergraduate researchers and training of $\lesssim 100$ students over the course of this grant, with a specific focus on supporting URM populations.

We will evaluate the efficacy of our research and training curriculum using research-validated protocols that assess the development of science process skills, and use this evaluation to improve the curriculum during the funded period. This assessment will be based on existing research-validated protocols such as the Statistics Concept Inventory (Allen 2006), the Scientific Literature Test (Coil *et al.* 2010), the Quantitative Writing 4C Score (Ruscetti *et al.* 2018), the Lawson Classroom Test of Scientific Reasoning (Lawson 1978), and the Colorado Learning Attitudes about Science Survey (Adams *et al.* 2006). At the end of the grant, we will analyze the outcomes for program participants and publish results.

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4 Data Management Plan

4.1 Software Development

A cornerstone aspect of our WFS program is a re-analysis of the wide-field slitless spectroscopy obtained in the HLWAS, using the linear-reconstruction algorithm developed by Ryan *et al.* (2018). Although that work was prototyped and implemented for Wide-Field Camera 3 for HST, there is a significant additional development to extend to the Roman/WFI. To accomplish this task, we will adhere to principles of open-source development with continuous-integration/continuous deployment (CI/CD) for documentation, unit and regression testing, and automatic versioning. We will develop a suite of example usages for both simulated and observed Roman data. We anticipate releasing the software and example suite with the BSD-3 license.

In this regard, the Team has considerable experience developing and distributing code in accordance with modern software standards, having publicly released a significant amount of software and data (e.g. SPLAT, pyLINEAR, iGALFIT). Finally PI Ryan has served as the co-chair of the SOC-SIT Working Group for WFIRST that established algorithms and protocols for sharing and integrating community-led software and data products into the operational pipeline at the Science Oversight Committee (SOC).

4.2 Data Deliveries and Volume

We foresee having several data that would be returned to, and hosted in MAST in the timely fashion. To estimate the size of these data, which set our processing requirements and timelines.

- The notional HLWAS is expecting to spectroscopically observe $\gtrsim 10^9$ astrophysical sources. The G150 grism is expected to disperse at $\sim$10.8Å/pix between $1-1.93$ μm, which implies each spectrum will have $(1.93-1.0)/0.00108 \approx 900$ independent spectral elements. Assuming we need to store three floating-point arrays per source (wavelength, flux, and uncertainty), then the approximate dataset is $\sim$10 Tb.

- We will obtain spectral types and high-level spectral characteristics for the brown dwarfs and stellar sources. It is harder to establish the volume for these data, as it depends on the number of sources and inferred parameters (e.g. spectral type, effective temperature, surface gravity, etc.). Importantly, these would be just approximately a few floating point or string variables, which should be dwarfed by the spectroscopy (fewer measurements and only relevant to stars).

4.3 Processing Requirements

The most computationally expensive aspect of our work is the creation of the linear-reconstructed spectra, following the equations described above. In general, this requires defining a large system of sparse-linear equations as a coordinate-list sparse matrix format, and the computing requirements (e.g. RAM or processor) are driven by the size and density of this matrix, which are in turn set by astrophysical scene and array of position angles. While it is hard to predict the exact nature of the HLWAS scene, we do know that the notional plan has four relative position angles $\Delta\theta \in (-5°, 5°, 175°, 185°)$. This assortment of angles is effectively two pairs of angles, separated by 180°, which means that the effective contamination in $-5°$ and 175° will be the same (and similarly for the other pair). Therefore, there are effectively only two angles, separated by 10°; and in our experience with HST/WFC3IR observations, these imply fairly modest size matrices. With that, we will be using a Mac Studio computer (M1 Ultra, 20-core CPU, 128 Gb of RAM) to develop and execute much of our algorithm. We expect these algorithms, once finalized, can be integrated into the operational pipeline at the SOC and/or implemented in the Roman Science Platform, developed and maintained for the Roman mission at STScI.

5 Inclusion Plan

As an integral element in our roles as educators, research scientists, mentors, and students, the proposers are committed to centering diversity, equity, inclusion, and belonging in the research and training activities described in this proposal. One motivation for this focus is the recognition that diverse and inclusive teams do better science. Research across multiple fields has demonstrated that integrated, diverse teams are more productive and creative (Sommers *et al.* 2006; Levine *et al.* 2014; Smith-Doerr & Croissant 2016), produce more innovative work (Hofstra *et al.* 2020), are more likely utilize the expertise of all team members (Joshi *et al.* 2014), publish higher numbers of articles (Adams *et al.* 2013), and receive more citations per article (AlShebli *et al.* 2018). A more important motivation, however, is the need to reduce or eliminate the barriers to participation that are embedded in academic and research cultures that are experienced by women and gender minorities, racial and ethnic minorities, and other underrepresented groups. The barriers are evident in the chronic and systemic disparities in Science, Technology, Engineering, and Mathematics (STEM) degree programs and careers. For instance, women earn 30-40% of Astronomy Bachelor's and Ph.D. degrees, but hold only 20% of faculty positions Mulvey *et al.* (2014); Porter & Ivie (2019); while African and Hispanic Americans, Indigenous people, and Pacific Islanders, who make up 33% of the US population, earn only 5% of Astronomy Bachelor's and Ph.D. degrees, and hold only 3% of Astronomy faculty positions (Mulvey 2012; Ivie 2014). Such order-of-magnitude disparities in the participation of underrepresented groups signal the need for proactive measures to engage and support degree and career persistence, and ensure NASA's inclusion objective of "the full participation, belonging, and contribution of organizations and individuals."

Recognizing that our institutions (R1 research universities, government-supported research labs) are particularly susceptible to systematic barriers to broad inclusion, the proposers aim to achieve the following Inclusion goals over the course of this program:

- Full participation of all investigators in setting the priorities and responsibilities in achieving its technical and scientific objectives, including regular team meetings, asynchronous communication, accessible documentation, and inclusive decision making [metric: $>$60% participation in team meetings, full documentation of all priorities and processes];

- Proactive engagement with underrepresented and under-served communities through partnerships with minority-serving programs (MSPs) and engagement of student from diverse backgrounds [metrics: $>$70% student participants from MSPs; $\gtrsim$70% one or more underrepresented identity];

- Effective mentoring and career development of junior participants, including opportunities for leadership on research projects and outcomes [metric: dual mentorship of undergraduate researcher, collation of effective mentoring resources, $>$50% of publications led by students/postdoctoral scholars]

- Equitable access to resources for all investigators to conduct research, training, and mentoring activities, and support for development of additional resources for sustainability [metric: $>$90% approval of resource allocation, $\geq$3 new proposals generated from team to support activities];

- Public dissemination of research tools and resources through open-access portals, including appropriate documentation and tutorials [metric: 100% analysis tools documented, tutorials encompassing all major components of data reduction and analysis, all associated resources publicly accessible]
- Public dissemination of training tools and resources, and their assessment to facilitate adoption and adaptation [metric: public webpage/database hosting teaching resources; publication of assessment protocols and outcomes]

In support of these goals, the proposers are committed to working with Cal-Bridge and ENLACE minority research programs in support of the recruitment, mentoring, and professional development of traditionally underrepresented students in our research, training, and mentoring activities. In addition, CoIs Burgasser and Patience commit to working in partnership with faculty and students at regional community colleges to engage these students in research training and encourage participation in research opportunities and advanced study.

The proposers further commit to developing and sustaining a positive and inclusive working environment for all participating members by defining expectations for our collaboration. Specifically, the proposers commit to the collaborative creation of a team code of conduct (CC), modeled off of best practices (REF) and the CCs of similarly-sized teams. Our CC will encompass expectations for ethical research practices (including authorship), mentoring, distribution of resources, and appropriate behavior within and outside the collaboration, and processes to (anonymously) report and address CC violations. The CC will be clearly posted on our team webpage, and revisited annually to ensure it addresses contemporary norms and includes the voices of all participants, including students and external partners.

To assess the efficacy of the measures, and to provide accountability for our practices, the proposers commit to regular assessment of inclusion both with regard to the internal team culture and the success of student and junior researcher participants. In addition to regular team meetings to facilitate discussion and feedback, the PI/CoIs will create an annual, anonymized survey to assess participants' perceptions of inclusion in research, training, and mentoring activities; equitable access to resources; effectiveness in communication and leadership; and ability to participate fully in the collaboration. This survey will be modeled on comparable assessments in our home institutions (e.g., UCSD Campus Climate Survey; University of Arizona Campus Climate Survey), and composite results and feedback used to generate recommended changes to the team code of conduct and research, training, and mentoring practices.

The proposers further commit to documenting and publicly disseminating these inclusion practices and assessments for other organizations to adopt and adapt.

6 Biographical Sketches and Curriculum Vitæ

6.1 PI: Russell Ryan (Space Telescope Science Institute)

Biographical Sketch

PI Ryan is an associate scientist work supporting the Advanced Camera for Surveys (ACS), a third-generation imaging and imaging-spectrograph on the *Hubble Space Telescope* (HST). The primary and long-standing focus of PI Ryan has been to advance methods for analyzing slitless spectroscopy. To this end, he developed the novel paradigm for reconstructing spectra (Ryan *et al.* 2018) that mitigates contamination and preserves spectral resolution while improving signal-to-noise, trade-offs that have been historically necessary. He is a recognized expert in working with wide-field slitless spectroscopy, having directly reduced/extracted the spectra for countless publications, most notably the infrared spectra of the electromagnetic counterpart from the gravitational wave event detected by LIGO on August 17, 2017. This analysis conclusively revealed high-velocity lanthanide emission, which is consistent with the merging-neutron star hypothesis for the event.

PI Ryan has extensive experience working with the *Nancy Grace Roman Space Telescope* (Roman), where he has led or contributed to 7 technical publications on the detectors, grism wavelength calibration, or observational strategies. He chaired the working group that established the computing requirements and algorithms for the Science-Investigation Teams (SITs), and how these methods will be integrated in the operational pipeline at the Science Operations Center (SOC) at STScI. He has represented STScI at the AAS Townhall, various topical workshops at IPAC, Princeton, and Caltech, and Formulation Science Working Group (FSWG) meetings, and was the chair of the deep-field/galaxy evolution virtual conference.

PI Ryan has strong commitment to mentoring and training junior scientists, having worked with graduate, undergraduate, and high-school students on a wide array of topics from Python and computing techniques to data and image reductions. The most recent success-story is from his student Delondrae Carter, who is now a Goldwater Fellow at Arizona State University working with Prof. Rogier Windhorst.

Role in this WFS Program

PI Ryan is the scientific and administrative PI of this program, and as such, will lead the organization and management of the team. Additionally, he will supervise the to-be-determined (TBD) STScI postdoc, who will lead the spectroscopic reduction and contribute to the analysis. PI Ryan and the TBD postdoc will lead scientific papers describing the pipeline as well the analysis of the first year of Roman observations for the disk scale height and Milky Way properties. As the TBD postdoc will not be joining the team until Year 2 of this award, PI Ryan will lay the groundwork for the spectroscopic pipeline.

Employment History

Associate Scientist, Space Telescope Science Institute — 2019–present

WFC3-IR Detector Lead, develop grism extraction software, write Instrument-Science Report for UVIS software, serve as Contact Scientist and Science Liaison for HST and WFIRST programs, SOC-SIT Working Group Lead for WFIRST project, co-lead of slitless spectroscopy working group at STScI, mentor junior analysts

Support Scientist, Space Telescope Science Institute — 2014–2019 develop grism modeling software, write Instrument-Science Report on the infrared internal flat-field campaign, serve as Contact Scientist for HST general-observer programs, assist as HST panel support staff, contribute to Slitless-Spectroscopy Working Group

Postdoctoral Researcher, Space Telescope Science Institute 2011–2014

write scientific publications on high-redshift galaxies in CANDELS, mentor graduate, undergraduate, and high-school students, lead proposals for observations and grants

Postdoctoral Fellow, Unversity of California, Davis 2008–2011

lead scientific publications on high-redshift galaxies, mentor undergraduate students, develop a photometric pipeline for the Deep Lens Survey

Education

Ph.D., Arizona State University 2002–2008

Supervisor: Rogier Windhorst

B.S., Ohio University 1998–2002

Supervisor: Brian McNamara

Publication Summary

as First Author: 18 referred and unreferred publications, white papers, and technical reports
as Conbrituting Author: 107 referred publications
H-index = 38: as of February 12, 2023

Grants Summary and Highlights

PI of 4 HST or JWST programs
coI on $\gtrsim$22 HST, JWST, Spitzer, and NASA-ADP

Selected Relevant Publications

1. "A Self-consistent Model for Brown Dwarf Populations", **Ryan, R.**, *et al.* 2022, ApJ, 932, 96
2. "Linear: A Novel Algorithm for Reconstructing Slitless Spectroscopy from HST/WFC3", Ryan, R. E., Jr. ; Casertano, S. ; Pirzkal, N., 2018, PASP, 130, 034501
3. "FIGS—Faint Infrared Grism Survey: Description and Data Reduction" Pirzkal, N., Malhotra, S., **Ryan, R.**, *et al.* 2017, ApJ, 846, 84
4. "The Effect of Atmospheric Cooling on Vertical Velocity Dispersion and Density Distribution of Brown Dwarfs" **Ryan, R.**, *et al.* 2017, ApJ, 847, 53
5. "Hubble Space Telescope Observations of Field Ultracool Dwarfs at High Galactic Latitude" **Ryan, R.**, *et al.* 2011, ApJ, 739, 83

Scientific Collaborations

- Next-Generation Deep Survey (NGDEEP). PI: S. Finkelstein
- ATLAS-Probe. PI: Y. Wang
- Cosmic Evolution Early-Release Science (CEERS). PI: S. Finkelstein
- Prime Extragalactic Areas for Reionization and Lensing Science (PEARLS). PI: R. Windhorst
- RELICS of the Cosmic Dawn (RELICS). coPIs: M. Bradač & D. Coe
- The Faint-Infrared Grism Survey (FIGS). PI: S. Malhotra
- Spitzer UltRaFaint SUrvey (SURFS Up). PI: M. Bradač

6.2 Co-I: Christian Aganze (UC San Diego)

Professional Experiences

B.S. Physics, Morehouse College 2016
Ph.D. Physics, University of California, San Diego (Expected 2023)

Positions

Graduate Student, University of California, San Diego 2016-2023

Bibliography of Relevant Publications

1. "Beyond the Local Volume. I. Surface Densities of Ultracool Dwarfs in Deep HST/WFC3 Parallel Fields" **Aganze, C.**, Burgasser, A. J., Malkan, M., et al. 2022, *ApJ* 924, 114
2. "Beyond the Local Volume. II. Population Scaleheights and Ages of Ultracool Dwarfs in Deep HST/WFC3 Parallel Fields" **Aganze, C.**, Burgasser, A. J., Malkan, M., et al. 2022, *ApJ* 934, 73
3. "Characterization of the Very-low-mass Secondary in the GJ 660.1AB System" **Aganze, C.**, Burgasser, A. J., Faherty, J., et al. 2016, *AJ* 151, 46

Science, Technical, & Management Experience

Undergraduate Mentoring:

I have been a research mentor for several student teams composed of high school and undergraduate students focused on applying Machine Learning tools to brown dwarf research

Mentees: M. Desai (UCSD: 2022-2023), J. D. Draxl Giannoni (UCSD: 2022-2023), C. Dunning (UCSD: 2022-2023), E. G. Gutierrez (2022), G. Eduardo Gauna (2022), A. M. Maytorena (2022), Z. Gong (2022), C. Verdaguer (2022)

Training and Workshops:

Software Carpentry Instructor Training (2021), Summer School on Galactic Dynamics (2021), Big Data and Deep Learning Workshop (2020), LSST Data Science Fellowship (2018–2020), Kraft Observational Astronomy Workshop (2017), Scicoder Workshop (2017)

Scientific Leadership and Organizations:

Cool Stars 22 Local Organizing Committee (2022-present), LSST DP0 Delegate (2021-present), member of the American Astronomical Society (2016-present), member of the National Society of Black Physicists (2016-present)

6.3 Co-I: Adam Burgasser (UC San Diego)

Professional Experiences

B.S. Physics, UC San Diego	1996
M.S. Physics, California Institute of Technology	2001
Ph.D. Physics, California Institute of Technology	2001

Positions

Asst/Assoc/Full Professor, UC San Diego	2009–present
Hans Sigrist Visiting Professor, University of Bern	2019
Fulbright Scholar, University of Exeter	2017
Severo Ochoa Visiting Professor, Instituto de Astrofisica de Canarias	2014
Graduate Affiliate Faculty, University of Hawaii	2008-2011
Asst/Assoc Professor, Massachusetts Institute of Technology	2005-2010
Spitzer Postdoctoral Fellow, American Museum of Natural History	2004-2005
Hubble Postdoctoral Fellow, UC Los Angeles	2001-2004

Bibliography of Relevant Publications

(287 peer-review publications, 26,564 citations, h-index = 82 as of 2 March 2023)

1. "T Dwarfs and the Substellar Mass Function." **Burgasser, AJ**. 2004, *ApJS* 155, 191
2. "Spectrophotometrically Identified stars in the PEARS-N and PEARS-S fields." Pirzkal, N, **Burgasser, AJ**, Malhotra, S, et al. 2009, *ApJ* 695, 1591
3. "Beyond the Local Volume. I. Surface Densities of Ultracool Dwarfs in Deep HST/WFC3 Parallel Fields" Aganze, C, **Burgasser, AJ**, Malkan, M., et al. 2022, *ApJ* 924, 114
4. "Beyond the Local Volume. II. Population Scaleheights and Ages of Ultracool Dwarfs in Deep HST/WFC3 Parallel Fields" Aganze, C, **Burgasser, AJ**, Malkan, M., et al. 2022, *ApJ* 934, 73
5. "The HST Large Program on ω Centauri. V. Exploring the Ultracool Dwarf Population with Stellar Atmosphere and Evolutionary Modeling" Gerasimov, R, **Burgasser, AJ**, Homeier, D, et al. 2022, *ApJ* 930, 24

Science, Technical, & Management Experience

Undergraduate Mentoring: Mentor to >50 undergraduate researchers, co-Director of the UCSD-Morehouse-Spelman UC-HBCU program (2013-2017), Steering Committee member of CalBridge (2014-2016)

Graduate Student Mentoring: J. Faherty (PhD Astronomy, SUNY Stony Brook 2010), D. Looper (PhD Astronomy, U. Hawaii 2011), D. Bardalez Gagliuffi (PhD Physics, UCSD 2017), C.-C. Hsu (PhD Physics, UCSD 2022), C. Aganze (UCSD 2016-present), R. Gerasimov (UCSD, 2018-present), E. Softich (2022-present), P. Karpoor (2022-present)

Postdoctoral Mentoring: A. West (2008-2009), J. Bochanski (2008-2010), C. Melis (2009-2013), C. Nicholls (2011-2013), J. Rees (2018-2019), C. Theissen (2019-present)

Scientific Community Leadership: American Astronomical Society Board Trustee (elected, 2017-2019) and Vice President (elected, 2021-present); Panel Member, Astro2020 Decadal Survey (2019-2021); Science Organizing Committee for Cool Stars 16 (2009-2010), 19 (2015-2016), and 22 (co-Chair, 2022-present), Ringberg Conference on Brown Dwarf Binaries (2012), Keck Science Meeting (2012), and Inclusive Astronomy (2015)

6.4 Co-I: Elena Manjavacas (ESA Office for Space Telescope Science Institute)

Professional Experiences

B.S. Physics, Universidad Complutense de Madrid (Spain)	2010
M.S. Astrophysics, Universidad Complutense & Autónoma de Madrid (Spain)	2011
Ph.D. Astronomy, MPIA	2015

Positions

ESA/AURA Astronomer, Space Telescope Science Institute	2020-Present
Staff Astronomer at W. M. Keck Observatory	2019-2020
Postdoctoral Research Associate, Steward Observatory, University of Arizona	2016-2019
Postdoctoral Researcher at Instituto de Astrofísica de Canarias, Tenerife (Spain)	2015-2016

Bibliography of Relevant Publications

(37 peer-review publications (11 first-author), 799 citations, h-index = 17 as of 6 March 2023)

1. **Manjavacas, E**; Miles-Paez, P. A.; Karalidi, T; Vos, J. M; Galloway, M. L; Girard, J. H. *Time-resolved Optical Polarization Monitoring of the Most Variable Brown Dwarf*, 2023. Accepted for publication in AJ.

2. **Manjavacas, E.**; Karalidi, Theodora; Tan, Xianyu; Vos, Johanna M.; Biller, Beth A.; Lew, Ben W. P. *Tracing the Top-of-the-atmosphere and Vertical Cloud Structure of a fast-rotating late T-dwarfy*, 2022, AJ, 164, 65M.

3. **Manjavacas, E.**; Karalidi, Theodora ; Vos, Johanna M. ; Biller, Beth A. ; Lew, Ben W. P. *Revealing the Vertical Cloud Structure of a Young Low-mass Brown Dwarf, an Analog to the β-Pictoris b Directly Imaged Exoplanet, through Keck I/MOSFIRE Spectrophotometric Variability*, 2021, AJ, 162, 179M.

4. **Manjavacas, E.**; Lodieu, N.; Béjar, V. J. S.; Zapatero-Osorio, M.R.; Steve B.; Bonnefoy, M. *Spectral library of age-benchmark low-mass stars and brown dwarfs*, 2020, MNRAS, 491, 5925.

Science, Technical, & Management Experience

Founder and Leader of the Mentoring Program for Female Astronomers of the Spanish Society of Astronomy. Started in 2021 with ∼50 astronomers enrolled.
Commissioning of NIRSpec onboard the James Webb Space Telescope. January to June 2022.

6.5 Co-I: Jenny Patience (ASU)

Jenny Patience
ASU, School of Earth and Space Exploration
(480)727-8554, jpatienc@asu.edu

Professional Preparation

2000 Ph.D., Astronomy - UCLA
1994 M.S., Optics - University of Rochester
1992 B. S., Physics - Stanford University

Appointments

2012-present Associate Professor, Arizona State University
2007-2012 Lecturer, Senior Lecturer, Associate Professor, University of Exeter
2004-2006 Michelson Fellow (renamed Sagan Fellowship), Caltech
2002-2004 Postdoctoral Research Fellow, Caltech
2000-2002 Postdoctoral Researcher, Lawrence Livermore National Lab

Selected Recent Service

2020 *JWST* Master Class
2021 *JWST* Time Allocation Committee
2020-2021 NASA Keck Time Allocation Committee
2015-2017 ALMA Time Allocation Committee

Selected Publications: (* for supervised students/postdocs)

1 – *First Resolved Scattered-Light Images of Four Debris Disks in Scorpius-Centaurus with the Gemini Planet Imager*, Hom*, J., **Patience**, J., and 58 co-authors, 2020, *AJ,* 159, 31.
2 – *The Taurus Boundary of Stellar/Substellar (TBOSS) Survey. II. Disk Masses from ALMA Continuum Observations*, Ward-Duong*, K, **Patience**, J, Bulger*, J., van der Plas, G., Menard, F., Pinte, C., Jackson, A. P., Bryden, G., Turner, N. J., and 3 co-authors, 2018, *AJ,* 155, 54.
3 – *Characterizing 5J Eri b from J to 5 μm: A Partly Cloudy Exoplanet*, A. Rajan*, J. Rameau, R. J. De Rosa, M. S. Marley, J. R. Graham, B. Macintosh, C. Marois, C. Morley, J. **Patience**, & GPIES co-authors, 2017, *AJ,* 154, 10.
4 – *Discovery and spectroscopy of the young jovian planet 51 Eri b with the Gemini Planet Imager*, B. Macintosh & GPIES Team (inc. J. **Patience**), 2015 *Science*, 350, 6256
5 – *Direct imaging of an asymmetric debris disk in the HD 106906 planetary system*, P. G. Kalas, A. Rajan*, J. J. Wang, M. A. Millar-Blanchaer, G. Duchene, C. Chen, M. P. Fitzgerald, R. Dong, J. R. Graham, J. **Patience**, & GPIES co-authors, 2015, *ApJ,* 814, 32

Selected Synergistic Activities

1- *JWST* Master Class 2020 Lead organizer and instructor for a 2-day *JWST* planning workshop to train astronomers in ETC and APT interested in proposing for time
2 – Lecturer for 2015 Sagan Summer School for grad students/postdocs on *Exoplanetary System Demographics: Theory and Observation*, Pasadena, CA; topic: protoplanetary disks
3- Lecturer for 2014 MAD (Millenium ALMA Disk Nucleus) workshop for Chilean astronomers *Protoplanetary disks and the planets they form*, Santiago, Chile; topic: brown dwarf disks frequency and properties
4- Instructor/Activity Coordinator for 2016-2021 Sundial Program Intensive 2-week pre-semester class for students with backgrounds making it more likely they will struggle in college

6.6 Co-I: Jorge Sanchez (ASU)

Biographical Sketch

Co-I Sanchez is a PhD student at Arizona State University studying the atmo- spheres of exoplanets and brown dwarfs using both ground and spaced based facilities. He has experience in extraction of slitless spectroscopy, modeling and atmospheric retrieval analysis of sub-stellar objects as well as high performance computing.

Co-I Sanchez has expertise working with wide field slitless-spectroscopy from Near-Infrared facilities such as the Hubble Space Telescope Wield Field Camera 3 instrument, familiarizing himself with a variety of spectral extraction software as well as modifying some of them in order to fit custom spectral profiles. He also uses powerful radiative transfer tools to model the thermal emission spectra of brown dwarfs of varying spectral type.

Education

Ph.D., Arizona State University — expected 2027

Supervisor: Jenny Patience & Michael Line

B.S., University of Chicago — May 2001

Publication Summary

- **Sanchez** et al. 2023A, *High Resolution Cross Correlation Spectroscopy of an Ultra Hot Jupiter*, In Prep

- **Sanchez**, et al. 2023B, *Investigating Formation Pathways Through Abundance Measurements of Benchmark Late T/ Early Y Binary Systems*, In Prep

- Cerny, W., and co-authors including Sanchez, Jorge A., *Precise Photometric Measurements from a 1903 Photographic Plate Using a Commercial Scanner* 2021, PASP, 133, 4501

- Khullar, G., and co-authors including Sanchez, Jorge A., *COOL-LAMPS I. An Extraordinarily Bright Lensed Galaxy at Redshift 5.04* 2021, ApJ, 906, 107

Selected Proposals (Awarded Queue Telescope Time)

- *Getting the Full Picture: Building a 3D map of ultra-hot Jupiter day sides through post eclipse observations.* GEMINI South Observatory (IGRINS). Prin- ciple Investigator. 2023A semester. 14 hours.

- *Tracing the Day-Night Structure of WASP-121b with Multi-Phase High-Resolution Spectroscopy.* GEMINI South Observatory (IGRINS). Co-Investigator. PI: Emily Rauscher. 2023A semester. 12 hours

6.7 Co-I: Adam C. Schneider (USNO Flagstaff Station)

Professional Experiences

B.S. Physics & Astronomy, University of Georgia	2006
M.S. Astronomy, University of Georgia	2008
Ph.D. Astronomy, University of Georgia	2013

Positions

Astronomer, USNO Flagstaff	2022-Present
Research Scientist, George Mason University/USNO Flagstaff	2020-2022
Research Scientist, Arizona State University	2018-2020
Postdoctoral Research Associate, Arizona State University	2016-2018
Postdoctoral Research Associate, University of Toledo	2013-2016

Bibliography of Relevant Publications

(100 peer-review publications (18 first-author), 3,449 citations, h-index = 34 as of 6 March 2023)

1. "WISEA J041451.67-585456.7 and WISEA J181006.18-101000.5: The First Extreme T-type Subdwarfs?" **Schneider, A. C.**, Burgasser, A. J., Gerasimov, R., et al., 2020, *ApJ* 898, 77
2. "New Candidate Extreme T Subdwarfs from the Backyard Worlds: Planet 9 Citizen Science Project" Meisner, A. M., **Schneider, A. C.**, Burgasser, A. J., et al. 2021, *ApJ* 915, 120
3. "Discovery of CWISE J052306.42-015355.4, an Extreme T Subdwarf Candidate" Brooks, H., Kirkpatrick, J. D., Caselden, D., **Schneider, A. C.**, et al. 2022, *AJ* 163, 47
4. "Exploring the Extremes: Characterizing a New Population of Old and Cold Brown Dwarfs" Meisner, A. M., Leggett, S. K., Logsdon, S. E., **Schneider, A. C.**, et al. 2023, arXiv:2301.09817

Science, Technical, & Management Experience

Undergraduate Mentoring: Erik Dennihy (UGA: 2010-2012), James Windsor (U Toledo: 2014-2016), Emma Softich (ASU: 2020-2022)

Graduate Student Mentoring: Jennifer Greco (U Toledo: 2014-2017), Tyler Richey-Yowell (ASU: 2017-2020)

Co-I: Christopher A. Theissen (UC San Diego)

Professional Experiences

Ph.D. Astronomy, Boston University	2018
M.A. Astronomy, Boston University	2013
B.S. Physics, UC San Diego	2010
B.A. Mathematics, UC San Diego	2010

Positions

UC Chancellor's Postdoctoral Fellow, UC San Diego	2021–Present
NASA Sagan Postdoctoral Fellow, UC San Diego	2019–2022
Visiting Scholar, UC San Diego	2019
Postdoctoral Scholar, UC San Diego	2018–2019
Adjunct Professor, San Diego Mesa College	2017–2019

Bibliography of Relevant Publications

(35 peer-review publications (8 first-author), 1,392 citations, h-index = 13 as of 6 March 2023)

1. **Theissen, C. A.** *Parallaxes of Cool Objects with WISE: Filling in for Gaia*, 2018, AJ, 862, 173

2. **Theissen, C. A.**, Burgasser, A. J., Bardalez Gagliuffi, D. C., Hardegree-Ullman, K. K., Gagné, J., Schmidt, S. J., West, A. A. *2MASS J11151597+1937266: A Young, Dusty, Isolated, Planetary-Mass Object with a Potential Wide Stellar Companion*, 2018, ApJ, 853, 75

3. **Theissen, C. A.**, West, A. A. *Collisions of Terrestrial Worlds: The Occurrence of Extreme Mid-Infrared Excesses around Low-mass Field Stars*, 2017, AJ, 153, 165

4. **Theissen, C. A.**, West, A. A., Shippee, G., Burgasser, A. J., Schmidt, S. J. *The Late-Type Extension to MoVeRS (LaTE-MoVeRS): Proper Motion Verified Low-mass Stars and Brown Dwarfs from SDSS, 2MASS, and WISE*, 2017, AJ, 153, 92

5. **Theissen, C. A.**, West, A. A., Dhital, S. *Motion Verified Red Stars (MoVeRS): A Catalog of Proper Motion Selected Low-mass Stars from WISE, SDSS, and 2MASS*, 2016, AJ, 151, 41

Science, Technical, & Management Experience

Undergraduate Mentoring: Jessica Birky (UCSD: 2016–2019), Dennis H. Calderon (UCSD: 2018–2019), Roberto Tejada Arevalo (UCSD: 2018–2020), Chelsea Adelman (UCSD: 2020), Lexu Zhao (UCSD: 2023–present), Tianxing Zhou (UCSD: 2023–present)

Graduate Student Mentoring: Chih-Chun Hsu (UCSD: 2018–2022), Kielan Wilcomb (UCSD: 2018–2022), Christian Aganze (UCSD: 2018–present), Lingfeng Wei (UCSD: 2020–present), Aneesh Baburaj (UCSD: 2021–present), Preethi Karpoor (UCSD: 2023–present)

6.8 Co-I: Christopher N. A. Willmer (University of Arizona)

Biographical Sketch

Co-I Willmer is an Associate Research Professor at Steward Observatory and is part of the University of Arizona Near Infrared Camera (NIRCam) Instrument Team, having been involved in the construction, testing, and now, science operations of NIRCam. Prior to joining NIRCam in 2007, co-I Willmer was part of the Spitzer MIPS GTO team at the University of Arizona (2005-2007).

Employment History

Associate Research Professor, Steward Observatory, University of Arizona	2013-present
Assistant Astronomer, Steward Observatory, University of Arizona	2005-2013
Postdoctoral Researcher, Instituto de Astrofísica de Andalucia	2005
Postdoctoral Researcher: UCO/Lick Observatory, UCSC	1998–2005
Associated Researcher: CNPq/Observatório Nacional, Rio de Janeiro	1991-1998

Education

Ph.D.: CNPq/Observatório Nacional, Rio de Janeiro, Brazil Supervisor: Luiz da Costa	1986-1990
M.Sc.: CNPq/Observatório Nacional, Rio de Janeiro, Brazil Supervisor: Luiz da Costa	1981–1986
B.Sc.: Universidade Federal do Rio de Janeiro, Brazil	1976-1980

Grants Summary and Highlights

coI on 4 HST, JWST proposals.

Publication Summary

as First Author: 18 refereed and unrefereed publications
as Contributing Author: 181 refereed publications
H-index = 68: as of March 15, 2023

Selected Relevant Publications

1. "The Absolute Magnitude of the Sun in Several Filters" **C. N. A. Willmer**, 2018, ApJS, 236, 47
2. "Spitzer Observations of Cold Dust Galaxies." **C. N. A. Willmer**, G. H. Rieke, E. Le Floc'h, J. L. Hinz, C. W. Engelbracht, D. Marcillac, K. D. Gordon, AJ, 138, 146
3. 2006 "The DEEP2 Redshift Survey: The Galaxy Luminosity Function to $z \sim 1$." **C. N. A. Willmer**, S. M. Faber, C. Wolf, D. C. Koo, B. J. Weiner, J. A. Newman, A. L. Coil, A. J. Connolly, C. Conroy, M. C. Cooper, M. Davis, D. P. Finkbeiner, B. F. Gerke, P. Guhathakurta, J. Harker, N. Kaiser, S. Kassin, N. P. Konidaris, L. Lin, G. Luppino, D. S. Madgwick, K. G. Noeske, A. C. Phillips, R. Yan, ApJ, 647, 853
4. 1999 "Two Galaxy Clusters: A3565 and A3560." **C. N. A. Willmer**, M.A.G. Maia, S.O. Mendes, M.V. Alonso, L.A. Rios, O.L. Chaves, & D. F. de Mello. 1999, AJ, 118, 1131-1145
5. "Estimating Galaxy Luminosity Functions." **C. N. A. Willmer**, AJ, 114, 898-912

7 Table of Personnel and Work Effort

Below we present our work effort for funded (top), unfunded (middle), and their union (bottom) for all team members (as relevant) for all four years of our program.

Name	Role	Work Effort to be Funded				
		Y1	Y2	Y3	Y4	Total
A. Burgasser	Co-I	0.0425	0.0425	0.0425	0.0425	**0.1700**
J. Patience	Co-I	0.0425	0.0425	0.0425	0.0425	**0.1700**
R. Ryan	PI	0.3000	0.0000	0.0000	0.0000	**0.3000**
TBD ASU Grad	N/A	0.4375	0.4375	0.4375	0.4375	**1.7500**
TBD ASU Undergrad	N/A	0.1917	0.1917	0.1917	0.1917	**0.7667**
TBD STScI Postdoc	N/A	0.0000	1.0000	1.0000	1.0000	**3.0000**
TBD UCSD Grad	N/A	0.3750	0.3750	0.3750	0.3750	**1.5000**
Work Effort Funded Subtotal		**1.3892**	**2.0892**	**2.0892**	**2.0892**	**7.6567**

Name	Role	Work Effort to be Unfunded				
		Y1	Y2	Y3	Y4	Total
C. Aganze	Co-I	0.0425	0.0425	0.0425	0.0425	**0.1700**
A. Burgasser	Co-I	0.1250	0.1250	0.1250	0.1250	**0.5000**
N. Hathi	Collaborator	*de minimis*				**0.0000**
M. Line	Collaborator	*de minimis*				**0.0000**
E. Manjavacas	Co-I	*de minimis*				**0.0000**
J. Patience	Co-I	0.0417	0.0417	0.0417	0.0417	**0.1667**
R. Ryan	PI	0.1000	0.1000	0.1000	0.1000	**0.4000**
A. Schneider	Co-I	*de minimis*				**0.0000**
TBD ASU Grad	N/A	0.0000	0.0000	0.0000	0.0000	**0.0000**
TBD ASU Undergrad	N/A	0.2000	0.2000	0.2000	0.2000	**0.8000**
TBD STScI Postdoc	N/A	0.0000	0.0000	0.0000	0.0000	**0.0000**
TBD UCSD Grad	N/A	0.1250	0.1250	0.1250	0.1250	**0.5000**
C. Theissen	Co-I	0.0825	0.0825	0.0825	0.0825	**0.3300**
C. Willmer	Collaborator	*de minimis*				**0.0000**
Work Effort Unfunded Subtotal		**0.7167**	**0.7167**	**0.7167**	**0.7167**	**2.8667**

Name	Role	Work Effort to be Unfunded				
		Y1	Y2	Y3	Y4	Total
C. Aganze	Co-I	0.0425	0.0425	0.0425	0.0425	**0.17**
A. Burgasser	Co-I	0.1675	0.1675	0.1675	0.1675	**0.67**
N. Hathi	Collaborator	*de minimis*				**0**
M. Line	Collaborator	*de minimis*				**0**
E. Manjavacas	Co-I	*de minimis*				**0**
J. Patience	Co-I	0.0842	0.0842	0.0842	0.0842	**0.336667**
R. Ryan	PI	0.4000	0.1000	0.1000	0.1000	**0.7**
A. Schneider	Co-I	*de minimis*				**0**
TBD ASU Grad	N/A	0.4375	0.4375	0.4375	0.4375	1.7500
TBD ASU Undergrad	N/A	0.3917	0.3917	0.3917	0.3917	1.5667
TBD STScI Postdoc	N/A	0.0000	1.0000	1.0000	1.0000	3.0000
TBD UCSD Grad	N/A	0.5000	0.5000	0.5000	0.5000	2.0000
C. Theissen	Co-I	0.0825	0.0825	0.0825	0.0825	0.3300
C. Willmer	Collaborator	*de minimis*				**0**
Work Effort Unfunded Subtotal		**2.1058**	**2.8058**	**2.8058**	**2.8058**	**10.52333**

8 Current and Pending Support

Russell Ryan Current and Pending Support (as of 3 March 2023)

Current Support

Project Title: Galactic Archaeology with Brown Dwarfs in Medium-Deep JWST Observations
PI: Russell Ryan
Award: JWST-AR-02074.001-A
Sponsoring Agency: Space Telescope Science Institute
    Contact Name: Paula Sessa
    Contact Email: gms_mail@stsci.edu
    Phone: 410-338-4200
Performance Period: 1 Jul 2022 – 30 Jun 2025
Time Commitment: only unfunded effort

Project Title: SKY-SURF: Panchromatic constraints on the Extragalactic Background Light and Zodical Light sources through all-sky foreground measurements
PI: Rogier Windhorst — **Institutional PI**: Russell Ryan
Award: HST-AR-15810.012-A
Sponsoring Agency: Space Telescope Science Institute
    Contact Name: Paula Sessa
    Contact Email: gms_mail@stsci.edu
    Phone: 410-338-4200
Performance Period: 1 Dec 2019 – 30 Nov 2023
Time Commitment: only unfunded effort

Pending Support

Proposal Title: A *Roman* Project Infrastructure Team to Support Cosmological Measurements with Type Ia Supernovae
PI: Russell Ryan
Sponsoring Agency: NASA ROSES
Performance Period: 1 Oct 2023 – 30 Sep 2028
Time Commitment: 1.0 FTE distributed throughout years 1–5

9 Statements of Commitment and Letters of Resource Support, and Endorsement

STScI | SPACE TELESCOPE SCIENCE INSTITUTE

3700 San Martin Drive
Baltimore, MD 21218
(410) 338-4971
FAX: (410) 338-4796

14 March 2023

INSTITUTIONAL LETTER OF COMMITMENT

Proposal Title: Galactic Archaeology with Brown Dwarfs and the Nancy Grace Roman Space Telescope

Program/Solicitation: NNH22ZDA001N-ROMAN D.14 Nancy Grace Roman Space Telescope Research and Support Participation Opportunities

STScI PI: Dr. Russell Ryan

Dr. Russell Ryan
Space Telescope Science Institute
3700 San Martin Drive
Baltimore, MD 21218

Dear Dr. Ryan,

The Space Telescope Science Institute is pleased to endorse the participation of Dr. Elena Manjavacas and in the proposal entitled "Galactic Archaeology with Brown Dwarfs and the Nancy Grace Roman Space Telescope" that is submitted in response to the ROMAN D.14 solicitation. STScI will provide the appropriate support and institutional resources should the proposal be successful.

Dr. Manjavacas will make annual contributions to the project, supported by their individual research time as an AURA/ESA staff at STScI in support of the science operations of the James Webb Space Telescope.

Sincerely,

I. Neill Reid
Associate Director for Science
Space Telescope Science Institute

UNIVERSITY OF CALIFORNIA, SAN DIEGO UCSD

BERKELEY • DAVIS • IRVINE • LOS ANGELES • MERCED • RIVERSIDE • SAN DIEGO • SAN FRANCISCO SANTA BARBARA • SANTA CRUZ

CENTER FOR ASTROPHYSICS AND SPACE SCIENCES (CASS)
TEL: (858) 822-6958 / FAX: (858) 534-2294

9500 GILMAN DRIVE #0424
LA JOLLA, CALIFORNIA 92093-0424

INSTITUTIONAL LETTER OF COMMITMENT

Proposal Title: Galactic Archaeology with Brown Dwarfs and the Nancy Grace Roman Space Telescope

Program/Solicitation: NNH22ZDA001N-ROMAN D.14 Nancy Grace Roman Space Telescope Research and Support Participation Opportunities

PI: Dr. Russell Ryan

Dear Dr. Ryan,

The UC San Diego Cool Star Lab is pleased to endorse the participation of Dr. Christopher Theissen and Mr. Christian Aganze in the proposal entitled "Galactic Archaeology with Brown Dwarfs and the Nancy Grace Roman Space Telescope" that is submitted in response to the ROMAN D.14 solicitation. UCSD will provide the appropriate support and institutional resources should the proposal be successful.

Dr. Christopher Theissen will make annual contributions to the project, supported by their research time as an independent postdoctoral researcher. Mr. Christian Aganze will make annual contributions to the project, supported by his graduate research position in the Cool Star Lab.

Adam J. Burgasser, Ph.D.
Professor, Department of Physics
Director, UCSD Cool Star Lab
University of California San Diego

DEPARTMENT OF THE NAVY
NAVAL OBSERVATORY FLAGSTAFF STATION
10391 West Naval Observatory Road
FLAGSTAFF, AZ 86001-8521

20 March 2023

Institutional Letter of Commitment

Proposal Title: Galactic Archaeology with Brown Dwarfs and the Nancy Grace Roman Space Telescope

Program/Solicitation: NNH22ZDA001N-ROMAN D.14 Nancy Grace Roman Space Telescope Research and Support Participation Opportunities

STScI PI: Dr. Russell Ryan

Dr. Russell Ryan
Space Telescope Science Institute
3700 San Martin Drive
Baltimore, MD 21218

Dear Dr. Ryan,

The United States Naval Observatory endorses the participation of Dr. Adam Schneider in the proposal entitled "Galactic Archaeology with Brown Dwarfs and the Nancy Grace Roman Space Telescope" that is submitted in response to the ROMAN D.14 solicitation. USNO will provide the appropriate support and institutional resources should the proposal be successful. Dr. Schneider will make annual contributions to the project, supported by their individual research time.

Sincerely,

Jeffrey A. Munn
Acting Director
USNO, Flagstaff Station

10 Redacted Budget

Institution: Space Telescope Science Institute	**STScI PI:** Dr. Russell Ryan					
STScI Proposal #: **12259** **Proposal Type:** NNH22ZDA001N-ROMAN	Program Institution & PI (if different than above):					
	Proposal Title: Galactic Archaeology with Brown Dwarfs and the Nancy Grace Roman Space Telescope					
	Year 1: 10/01/23-09/30/24					
1. Direct Labor	**Monthly(or) Hourly Rate**	**No. of Months**	**Percent of Time**			**Amt. Charged to Project**
a. Russell Ryan	Redacted	12.00	30.00%			Redacted
b.						
Total	.					Redacted
Fringe Benefits	Rate	Base				Totals
Full Benefits	Redacted					Redacted
Partial Benefits	Redacted					Redacted
Total						Redacted
Total Loaded Labor Costs						
2. Other Direct Costs						
a. Subcontracts/Purchase Orders						Totals
1. Arizona State, Co-I J. Patience		See separate redacted budget from ASU			Redacted	
2. UC San Diego, Co-I A. Burgasser		See separate redacted budget from UCSD			Redacted	
Total						
b. Consultants						Totals
1.						**$0**
c. Equipment		Unit cost	Quantity			Totals
1. Mac Studio Computers		$5,497	1			$5,497
2.						$0
3.						$0
Total						**$5,497**
d. Supplies and Materials		Unit cost	Quantity			Totals
1. Apple MacBook Pro		$ 3,899	1			$3,899
2. Studio display		$ 1,599	1			$1,599
3. Central Storage 8TB		$ 250	8			$2,000
Total						**$7,498**
e. Travel Destinations	Transportation Costs	Lodging Costs	Subsistence Costs	Number of Nights		Totals
Foreign						
1.						$0
2.						$0
3.						$0
Domestic						
1.						$0
2.						$0
3.						$0
Total						**$0**
f. Other		Cost		No.		Totals
1. Publication Charges/figures/per Tier		$0			0	$0
2. Relocation		$0			0	$0
3. Conference Registration Fees/conference		$0			0	$0
Total						**$0**
3. Indirect Costs/Agreement: 11/21/22-NASA		IDC Rate		X Base =		Total
Overhead		Redacted				Redacted
General & Administrative (G&A)		Redacted				Redacted
Facilities & Administrative (F&A) 12/01/21		Redacted				Redacted
4. Other Applicable Costs						**$0**
5. Subtotal Estimated Costs						
6. Less Proposed Cost Sharing						**$0**
7. Carryover Funds (if any)						**$0**
a. Anticipated amount						**$0**
b. Amount used to reduce budget						**$0**
8. Total Project Costs						Redacted

Institution: Space Telescope Science Institute	**STScI PI:** Dr. Russell Ryan				
STScI Proposal #: **12259** **Proposal Type:** NNH22ZDA001N-ROMAN	Program Institution & PI (if different than above):				
	Proposal Title: Galactic Archaeology with Brown Dwarfs and the Nancy Grace Roman Space Telescope				
	Year 2: 10/01/24-09/30/25				
1. Direct Labor	**Monthly(or) Hourly Rate**	**No. of Months**	**Percent of Time**		**Amt. Charged to Project**
a. Russell Ryan	Redacted	0.00	0.00%		Redacted
b. STScI Postdoc (TBD)	Redacted	12.00	100.00%		Redacted
Total					Redacted
Fringe Benefits	Rate	Base			Totals
Full Benefits	Redacted				Redacted
Partial Benefits	Redacted				Redacted
Total					Redacted
Total Loaded Labor Costs					
2. Other Direct Costs					
a. Subcontracts/Purchase Orders					Totals
1. Arizona State, Co-I J. Patience	See separate redacted budget from ASU				Redacted
2. UC San Diego, Co-I A. Burgasser	See separate redacted budget from UCSD				Redacted
Total					Redacted
b. Consultants					Totals
1.					**$0**
c. Equipment					Totals
1.					$0
2.					$0
3.					$0
Total					**$0**
d. Supplies and Materials					Totals
1.					$0
2.					$0
3.					$0
Total					**$0**
e. Travel Destinations	Transportation	Lodging	Subsistence	Number of	
Foreign	Costs	Costs	Costs	Nights	Totals
1.					$0
2.					$0
3.					$0
Domestic					
1. National Harbor, MD - AAS Mtg. (#2 ppl.)	$534	$1,570	$742	4	$2,846
2.					$0
3.					$0
Total					**$2,846**
f. Other					
		Cost		No.	Totals
1. Publication Charges/figures/per Tier 2		$2,651		1	$2,651
2. Relocation		$5,000		1	$5,000
3. Conference Registration Fees/conference		$762		2	$1,524
Total					**$9,175**
3. Indirect Costs/Agreement: 11/21/22-NASA		IDC Rate		X Base =	Total
Overhead		Redacted			Redacted
General & Administrative (G&A)		Redacted			Redacted
Facilities & Administrative (F&A) 12/01/21		Redacted			Redacted
4. Other Applicable Costs					**$0**
5. Subtotal Estimated Costs					
6. Less Proposed Cost Sharing					**$0**
7. Carryover Funds (if any)					**$0**
a. Anticipated amount					**$0**
b. Amount used to reduce budget					**$0**
8. Total Project Costs					Redacted

Institution: Space Telescope Science Institute	**STScI PI:** Dr. Russell Ryan					
STScI Proposal #: **12259** **Proposal Type:** NNH22ZDA001N-ROMAN	Program Institution & PI (if different than above):					
	Proposal Title: Galactic Archaeology with Brown Dwarfs and the Nancy Grace Roman Space Telescope					
	Year 3: 10/01/25-09/30/26					
1. Direct Labor	**Monthly(or) Hourly Rate**	**No. of Months**	**Percent of Time**			**Amt. Charged to Project**
a. Russell Ryan	Redacted	0.00	0.00%			Redacted
b. STScI Postdoc (TBD)	Redacted	12.00	100.00%			Redacted
Total						Redacted
Fringe Benefits	Rate	Base				Totals
Full Benefits	Redacted					Redacted
Partial Benefits	Redacted					Redacted
Total						Redacted
Total Loaded Labor Costs						
2. Other Direct Costs						
a. Subcontracts/Purchase Orders						Totals
1. Arizona State, Co-I J. Patience		See separate redacted budget from ASU				Redacted
2. UC San Diego, Co-I A. Burgasser		See separate redacted budget from UCSD				Redacted
Total						Redacted
b. Consultants						Totals
1.						**$0**
c. Equipment						Totals
1.						$0
2.						$0
3.						$0
Total						**$0**
d. Supplies and Materials						Totals
1.						$0
2.						$0
3.						$0
Total						**$0**
e. Travel Destinations	Transportation Costs	Lodging Costs	Subsistence Costs	Number of Nights		Totals
Foreign						
1.						$0
2.						$0
3.						$0
Domestic						
1. Phoenix, AZ - AAS Mtg. (#2 ppl.)	$1,646	$1,610	$809	5		$4,066
2.						$0
3.						$0
Total						**$4,066**
f. Other		Cost		No.		Totals
1. Publication Charges/figures/per Tier 2		$2,651		1		$2,651
2. Relocation		$0		0		$0
3. Conference Registration Fees/conference		$779		2		$1,557
Total						**$4,208**
3. Indirect Costs/Agreement: 11/21/22-NASA		IDC Rate		X Base =		Total
Overhead		Redacted				Redacted
General & Administrative (G&A)		Redacted				Redacted
Facilities & Administrative (F&A) 12/01/21		Redacted				Redacted
4. Other Applicable Costs						**$0**
5. Subtotal Estimated Costs						
6. Less Proposed Cost Sharing						**$0**
7. Carryover Funds (if any)						**$0**
a. Anticipated amount						**$0**
b. Amount used to reduce budget						**$0**
8. Total Project Costs						Redacted

Institution: Space Telescope Science Institute	**STScI PI:**					
STScI Proposal #: **12259** **Proposal Type:** NNH22ZDA001N-ROMAN	**Institution/Principal Investigator (if different than above):**					
	Proposal Title: Galactic Archaeology with Brown Dwarfs and the Nancy Grace Roman Space Telescope					
	Year 4: 10/01/26-09/30/27					
1. Direct Labor	**Monthly(or) Hourly Rate**	**No. of Months**	**Percent of Time**			**Amt. Charged to Project**
a. Russell Ryan	Redacted	0.00	0.00%			Redacted
b. STScI Postdoc (TBD)	Redacted	12.00	100.00%			Redacted
Total						Redacted
Fringe Benefits	Rate	Base				Totals
Full Benefits	Redacted					Redacted
Partial Benefits	Redacted					Redacted
Total						Redacted
Total Loaded Labor Costs						
2. Other Direct Costs						
a. Subcontracts/Purchase Orders						Totals
1. Arizona State, Co-I J. Patience		See separate redacted budget from ASU				Redacted
2. UC San Diego, Co-I A. Burgasser		See separate redacted budget from UCSD				Redacted
Total						Redacted
b. Consultants						Totals
1.						**$0**
c. Equipment						Totals
1.						$0
2.						$0
3.						$0
Total						**$0**
d. Supplies and Materials						Totals
1.						$0
2.						$0
3.						$0
Total						**$0**
e. Travel Destinations	Transportation	Lodging	Subsistence	Number of		
Foreign	Costs	Costs	Costs	Nights		Totals
1.						$0
2.						$0
3.						$0
Domestic						
1. Seattle, WA - AAS Mtg. (#2 ppl.)	$1,487	$1,918	$947		5	$4,351
2.						$0
3.						$0
Total						**$4,351**
f. Other						
		Cost		No.		Totals
1. Publication Charges/figures/per Tier 2		$2,651			1	$2,651
2. Relocation		$0			0	$0
3. Conference Registration Fees/conference		$795			2	$1,591
Total						**$4,242**
3. Indirect Costs/Agreement: 11/21/22-NASA		IDC Rate		X Base =		Total
Overhead		Redacted				Redacted
General & Administrative (G&A)		Redacted				Redacted
Facilities & Administrative (F&A) 12/01/21		Redacted				Redacted
4. Other Applicable Costs						**$0**
5. Subtotal Estimated Costs						
6. Less Proposed Cost Sharing						**$0**
7. Carryover Funds (if any)						**$0**
a. Anticipated amount						**$0**
b. Amount used to reduce budget						**$0**
8. Total Project Costs						Redacted

BUDGET SUMMARY for RESEARCH PROPOSAL

Total Period of Performance: 10/01/23-09/30/27

		A	B (NASA USE ONLY)	C (NASA USE ONLY)
1	Direct Labor (salaries, wages, and	Redacted		
	fringe benefits)	Redacted		
2	Other Direct Costs:			
	a. Subcontracts/Purchase Orders	Redacted		
	b. Consultants	$0		
	c. Equipment	$5,497		
	d. Supplies	$7,498		
	e. Travel	$11,263		
	f. Other	$17,625		
3	Indirect Costs			
	Redacted	Redacted		
	Redacted	Redacted		
	Redacted	Redacted		
4	Other Applicable Costs:	$0		
5	Subtotal - Estimated Costs	Redacted		
6	Less Proposed Cost Sharing (if any)	$0		
7	Carryover Funds (if any)	$0		
	a. Anticipated amount: _______	$0		
	b. Amount used to reduce budget	$0		
8	Total Estimated Costs	Redacted		XXXXXXX
9	APPROVED BUDGET	XXXXXXX	XXXXXXX	

STScI PI: *Dr. Russell Ryan*

Proposal Title: Galactic Archaeology with Brown Dwarfs and the Nancy Grace Roman Space Telescope

STScI Proposal #: *12259*

Proposal Type: *NNH22ZDA001N-ROMAN*

Travel Details:

Location	Airfare	Mileage	# Days Parking	Airport Parking based on $8/day	Local Transportation/ Car Rental	Total Trans.	Hotel cost per night	# nights	Total Hotel Cost	Daily per diem (M&IE)	# days per diem at 100%	2 days per diem at 75%	Total M&IE	Total per person w/o regs.	Conf. Reg. Fee	Total Cost per person	# travelers	Total trip cost/per year
National Harbor, MD AAS meeting Jan. 2025	$ -	$ 79	5	$ 188	$ -	**$ 267**	$ 196	4	**$ 785**	$ 82	3	2	**$ 371**	**$ 1,423**	**$ 762.03**	**$ 2,185**	2	**$ 4,370**
Phoenix, AZ AAS meeting Jan. 2026	$ 623	$ 16	6	$ 51	$ 133	**$ 823**	$ 161	5	**$ 805**	$ 74	4	2	**$ 405**	**$ 2,033**	**$ 778.56**	**$ 2,812**	2	**$ 5,623**
Seattle, WA - Est. location AAS meeting Jan. 2027	$ 539	$ 16	6	$ 52	$ 136	**$ 743**	$ 192	5	**$ 959**	$ 86	4	2	**$ 473**	**$ 2,176**	**$ 795.46**	**$ 2,971**	2	**$ 5,942**
Grant total unloaded travel costs:														**$ 11,263.22**				**$ 15,935**

*Costs are escalated by 2.17% per year, costs in chart above are the FY23 baseline costs with escalation applied.

Arizona State University Redacted Budget

Cost Categories	Period 1 10/1/2023 9/30/2024	Period 2 10/1/2024 9/30/2025	Period 3 10/1/2025 9/30/2026	Period 4 10/1/2026 9/30/2027	Cumulative
Senior/Key Personnel:					
Jennifer Patience					
ERE:					
Effort (FTE Months	0.5	0.5	0.5	0.5	2 FTE months
Other Personnel:					
Graduate Student TBD01					
ERE:					
Effort (FTE Months	5.25	5.25	5.25	5.25	21 FTE months
Undergraduate Student TBD03					
ERE:					
Effort (FTE Months	2.308	2.308	2.308	2.308	9.23 FTE months
Total Number Other Personnel	2	2	2	2	
Total Salary, Wages and ERE:					
Equipment:	**$0**	**$0**	**$0**	**$0**	**$0**
Travel:	**$6,924**	**$15,608**	**$7,345**	**$6,305**	**$36,182**
1. Domestic	$6,924	$4,054	$7,345	$6,305	$24,628
2. Foreign	$0	$11,554	$0	$0	$11,554
Participant/Trainee Support Costs:	**$0**	**$0**	**$0**	**$0**	**$0**
1. Tuition/Fees/Health Insurance	$0	$0	$0	$0	$0
2. Stipends	$0	$0	$0	$0	$0
3. Travel	$0	$0	$0	$0	$0
4. Subsistence	$0	$0	$0	$0	$0
5. Other	$0	$0	$0	$0	$0
6. Number of Participants/Trainees	0	0	0	0	0
Other Direct Costs:	**$21,573**	**$14,451**	**$15,399**	**$16,423**	**$67,846**
1. Materials and Supplies	$8,000	$0	$0	$0	$8,000
2. Publication Costs	$2,600	$2,600	$2,600	$2,600	$10,400
3. Consulting Costs	$0	$0	$0	$0	$0
4. ADP/Computer Services	$0	$0	$0	$0	$0
5. Subaward/Consortium/Contractual	$0	$0	$0	$0	$0
6. Equipment or Facility Rentals/User Fees	$0	$0	$0	$0	$0
7. Alterations and Renovations	$0	$0	$0	$0	$0
8. Tuition Remission	$10,973	$11,851	$12,799	$13,823	$49,446

UCSD PROPOSAL BUDGET FORM

University of California San Diego

Budget Period: From 10/1/2023 Through 9/30/2024 Year 1 of 4

Direct Costs:

List Personnel Salary and Fringe Benefits

UCSD# **49535**

Name	Payroll Title	Monthly Salary	# of Months	% Effort	Person Months	Requested Salary	* Fringe Benefits %	* Fringe Benefits Amount	**Total**
			0.5	100.00	0.5				

Check box for additional personnel. List "Additional Personnel" on next page.

List Graduate Student Researchers (GSRs) Salary and Fringe Benefits

# of	Name	Payroll Title	Monthly Salary	# of Months	% Effort	Person Months	Requested Salary	Fringe Benefits %	Fringe Benefits Amount	Total
1				3	49.99	1.5				
1				3	100.00	3.0				

Fringe Benefit Rate % and Tuition Remission Calculation: $

* Enter the appropriate **Fringe Benefit Rate %**. For example: 17.0% enter 17 in the box.
The budget form will calculate the Fringe Benefit Amount and the Total automatically.

The "Totals" above also include Salary and Fringe Benefit amounts from the next page.

Tuition Remission: # of GSR's: 1 x # of Months 3 x Tuition Remission Rate:
Tuition Remission: # of GSR's: x # of Months x Tuition Remission Rate: =
Tuition Remission: # of GSR's: x # of Months x Tuition Remission Rate: =
Tuition Remission: # of GSR's: x # of Months x Tuition Remission Rate: =

$

Consultant(s)					$
Equipment					$
Supplies and Materials	Misc. Supplies	500			$ 3,690
	1 MacBook Pro Laptop	2,340			
	Printer	600			
	Monitor	250			
Travel	Collaboration travel	1,200			$ 1,200
Subaward(s)					$
Other Expenses	Next Generation Network (NGN)	56	Part. Costs 1 UG Student (salary redacted)	5,400	$ 8,320
	Physics Computing Facility (PCF)	264	Publications (1 article)	2,600	

Total Direct Costs **$**

Indirect Costs:

On Campus Federally-Negotiated Rate(s)	%	x	MTDC Base:	
	%	x	MTDC Base:	
Off Campus Federally-Negotiated Rate	%	x	MTDC Base:	=
Other Rate	%	x	Base:	=

Total Indirect Costs **$**

Total Costs Requested **$**

UCSD PROPOSAL BUDGET FORM

University of California San Diego

Budget Period: From 10/1/24 Through 9/30/25 Year 2 of 4

Direct Costs:

List Personnel Salary and Fringe Benefits UCSD# 49535

Name	Payroll Title	Monthly Salary	# of Months	% Effort	Person Months	Requested Salary	* Fringe Benefits %	Amount	Total
			0.5	100.00	0.5				

Check box for additional personnel. List "Additional Personnel" on next page.

List Graduate Student Researchers (GSRs) Salary and Fringe Benefits

# of	Name	Payroll Title	Monthly Salary	# of Months	% Effort	Person Months	Requested Salary	* Fringe Benefits %	Amount	Total
1				3	49.99	1.5				
1				3	100.00	3.0				

Fringe Benefit Rate % and Tuition Remission Calculation:

* Enter the appropriate **Fringe Benefit Rate %**. For example: 17.0% enter 17 in the box.
The budget form will calculate the Fringe Benefit Amount and the Total automatically.

The "Totals" above also include Salary and Fringe Benefit amounts from the next page.

Tuition Remission: # of GSR's: 1 x # of Months 3 x Tuition Remission Rate:
Tuition Remission: # of GSR's: x # of Months x Tuition Remission Rate:
Tuition Remission: # of GSR's: x # of Months x Tuition Remission Rate:
Tuition Remission: # of GSR's: x # of Months x Tuition Remission Rate:

Consultant(s)				-	$
Equipment					$
Supplies and Materials	Misc. Supplies	500			$ 500
Travel	Domestic (conference, 3 people)	7,150			$ 7,150
Subaward(s)					$
Other Expenses	Next Generation Network (NGN)	59	Part. Costs 1 UG Student (Salary redacted)	5,400	$ 8,424
	Physics Computing Facility (PCF)	235	Publications (1 article)	2,730	

Total Direct Costs $

Indirect Costs:

On Campus Federally-Negotiated Rate(s)	%	x	MTDC Base:	
	%	x	MTDC Base:	
Off Campus Federally-Negotiated Rate	%	x	MTDC Base:	
Other Rate	%	x	Base:	

Total Costs Requested $

UCSD PROPOSAL BUDGET FORM

University of California San Diego

Budget Period: From 10/1/25 Through 9/30/26 Year 3 of 4

Direct Costs:

List Personnel Salary and Fringe Benefits UCSD# 49535

Name	Payroll Title	Monthly Salary	# of Months	% Effort	Person Months	Requested Salary	* Fringe Benefits %	* Fringe Benefits Amount	Total
			0.5	100.00	0.5				

Check box for additional personnel. List "Additional Personnel" on next page.

List Graduate Student Researchers (GSRs) Salary and Fringe Benefits

# of	Name	Payroll Title	Monthly Salary	# of Months	% Effort	Person Months				
1				3	49.99	1.5				
1				3	100.00	3.0				

Fringe Benefit Rate % and Tuition Remission Calculation: $

* Enter the appropriate **Fringe Benefit Rate %**. For example: 17.0% enter 17 in the box.
The budget form will calculate the Fringe Benefit Amount and the Total automatically.

The "Totals" above also include Salary and Fringe Benefit amounts from the next page.

Tuition Remission: # of GSR's: 1 x # of Months 3 x Tuition Remission Rate:
Tuition Remission: # of GSR's: x # of Months x Tuition Remission Rate:
Tuition Remission: # of GSR's: x # of Months x Tuition Remission Rate:
Tuition Remission: # of GSR's: x # of Months x Tuition Remission Rate:

Consultant(s)				-	$
Equipment					$
Supplies and Materials	Misc. Supplies	500			$ 500
Travel	Collaboration travel	1,200			$ 1,200
Subaward(s)					$
Other Expenses	Next Generation Network (NGN)	62	Part. Costs 1 UG Student (salary redacted)	5,400	$ 8,571
	Physics Computing Facility (PCF)	242	Publications (1 article)	2,867	

Total Direct Costs **$**

Indirect Costs:

On Campus Federally-Negotiated Rate(s) % x MTDC Base:
% x MTDC Base:
Off Campus Federally-Negotiated Rate % x MTDC Base:
Other Rate % x Base:

Total Costs Requested **$**

UCSD PROPOSAL BUDGET FORM

University of California San Diego

Budget Period: From 10/1/26 Through 9/30/27 Year 4 of 4

Direct Costs:

List Personnel Salary and Fringe Benefits

UCSD# 49535

Name	Payroll Title	Monthly Salary	# of Months	% Effort	Person Months	Requested Salary	* Fringe Benefits %	* Fringe Benefits Amount	Total
			0.5	100.00	0.5				

Check box for additional personnel. List "Additional Personnel" on next page.

List Graduate Student Researchers (GSRs) Salary and Fringe Benefits

# of	Name	Payroll Title	Monthly Salary	# of Months	% Effort	Person Months	Requested Salary	Fringe Benefits %	Fringe Benefits Amount	Total
1				3	49.99	1.5				
1				3	100.00	3.0				

Fringe Benefit Rate % and Tuition Remission Calculation:

* Enter the appropriate **Fringe Benefit Rate %**. For example: 17.0% enter 17 in the box.
The budget form will calculate the Fringe Benefit Amount and the Total automatically.

The "Totals" above also include Salary and Fringe Benefit amounts from the next page.

Tuition Remission: # of GSR's: 1 x # of Months 3 x Tuition Remission Rate:
Tuition Remission: # of GSR's: x # of Months x Tuition Remission Rate:
Tuition Remission: # of GSR's: x # of Months x Tuition Remission Rate:
Tuition Remission: # of GSR's: x # of Months x Tuition Remission Rate:

Consultant(s)				-	$
Equipment					$
Supplies and Materials	Misc. Supplies	500			$ 500
Travel	Domestic (conference, 3 people)	7,150			$ 7,150
Subaward(s)					$
Other Expenses	Next Generation Network (NGN)	65	Participant Costs 1 UG Student	5,400	$ 8,724
	Physics Computing Facility (PCF)	249	Publications (1 article)	3,010	

Total Direct Costs **$**

Indirect Costs:

On Campus Federally-Negotiated Rate(s) % x MTDC Base:
% x MTDC Base:
Off Campus Federally-Negotiated Rate % x MTDC Base: =
Other Rate % x Base: =

Total Indirect Costs **$**

Total Costs Requested **$**

UCSD PROPOSAL BUDGET FORM

University of California - San Diego

Cumulative Budget

Cumulative Budget Period: From 10/1/2023 Through 9/30/26

UCSD# 49535

	Year 1	Year 2	Year 3	Year 4	Year 5	Cumulative
Salaries						
Fringe Benefits Tuition Remission						
Consultant(s)						
Equipment						
Supplies and Materials	3,690	500	500	500	-	5,190
Travel	1,200	7,150	1,200	7,150	-	16,700
Subaward(s)	-	-	-	-	-	-
Other Expenses	8,320	8,424	8,571	8,724	-	34,039
Total Direct Costs						
Total Indirect Costs						
Total Costs Requested	$				$ -	$

10.1 Budget Narrative

Budget Narrative – STScI

Title: Galactic Archaeology with Brown Dwarfs and the Nancy Grace Roman Space Telescope
STScI PI: Dr. Russell Ryan (proposal PI)
Lead Institution/PI: Space Telescope Science Institute/R. Ryan
NASA Solicitation: NNH22ZDA001N-ROMAN

Direct Labor:

Russell Ryan – Funded 0.3 FTE/0.0 FTE/0.0 FTE/0.0 FTE
Unfunded: 0.1 FTE/0.1 FTE/0.1 FTE/0.1 FTE

Here 0.1 FTE/yr will be from unfunded effort to support the project. The funding of 0.3 FTE for PI Ryan in year 1 will be used to lay the groundwork for the spectroscopic pipeline, which will be taken over by the TBD postdoc. Additionally, PI Ryan will begin validate the extensibility of the linear-reconstruction formalism to the Roman surveys. In years 2-4, we do not request funding for PI Ryan, as his role will transition to supervising and assisting the postdoc, who will be leading publications in the methods and analyzing the first year of data.

STScI Postdoc (TBD) – 0.0 FTE/1.0 FTE/1.0 FTE/1.0 FTE

The Postdoc will predominately be in charge of the implementation of the linear-reconstruction algorithms for the Roman WFS grism data. In year 2, we expect this will be significant development and extension of the methods (e.g. validating the methods for the unique characteristics of the Roman surveys), but also will require liaising with IPAC and STScI staff to understand the precise nature of the inputs and outputs of all the software and steps. In year 3, we expect the postdoc will being describing the methodologies and preparing work on the Galactic modeling toolkit. In year 4, we expect the postdoc will being writing papers on earliest generation of observations, which should start late 2026 or early 2027.

For budgeting purposes, postdoc salary is updated yearly commensurate with the number of months since date of PhD and escalated by 3.5% per year. Other salary is calculated based on current base salary escalated by 3.5% each fiscal year (Oct. – Sept.)

Equipment:

Mac Studio Computer: This workstation will be used by the postdoc and PI Ryan to prototype the spectroscopic pipeline that will be developed by STScI staff. An essential component is the linear-reconstruction algorithm, which centers around solving a large system of sparse linear equations. To achieve this, the computer requires a modest amount of RAM to store the coefficients of these equations.

- M1 Ultra, 20 core CPU, 48-core GPU, 32-core neutral engine
- 2TB SSD Storage
- 128Gb RAM
- keyboard & mouse

$5,497 based on estimate from Apple Store online.

Supplies and Materials:

#1 MacBook Pro 16" Z14X 2022: This laptop computer will be for the to-be-determined postdoc, who will also develop/prototype algorithms --- however these items require significantly less computing than the linear-reconstruction described above.

CPU: Apple M1 Max chip with 10-core CPU, 32-core GPU, and 16-core Neural Engine
Memory: 64 GB
Disk: 1 TB Flash Drive
Monitor: DELL ULTRASHARP 27 4K USB-C DELL HUB MONITOR
OS: macOS
Other: keyboard, mouse, assorted dongles

$3,899 (no monitor) based on estimate provided by STScI's IT department.

Studio Display: This studio display is meant as the monitor for the workstation above.

$1,599/ea. per the Apple Store online.

Central Storage:

We request funding for 8TB of space on STScI's central storage facility at a cost of $250/TB. These central storage space will provide a fast and efficient access for the STScI team to internally share data and codes, while providing backups.

Travel:

Domestic: Funding is requested for a portion of the STScI team members to the American Astronomical Society (AAS) winter meeting for some of the years.

Travel Pricing Details:

Transportation calculation includes: airfare, mileage, parking and local travel (bus, taxi, rental car, etc.). All Airfare and car rental estimates are based on competitive online agent estimates. Mileage costs are based on the standard published IRS mileage rates for 2023, see https://www.irs.gov/newsroom/irs-issues-standard-mileage-rates-for-2023-business-use-increases-3-cents-per-mile. Airport parking costs are based on the average cost ($8 per day) of parking BWI airport's long term lot, see https://www.bwiairport.com/to-from-bwi/parking/long-term-parking. Lodging & M&IE is based on the GSA per diem rates for each individual city (unless otherwise noted), see http://www.gsa.gov/portal/category/21287. See travel details spreadsheet included in the budget details for a breakdown of travel costs.

An escalation factor of 2.22% per year is applied to current travel costs per the IHS Global Insight index.

Publication Costs:

We plan to present the results of our study in a refereed paper and request support for 2-3 papers per year in years 2-4 priced based on the 2023 AAS article publication charge rates for the ApJ and AJ. https://journals.aas.org/article-charges-and-copyright/

Relocation costs:

Funding is included in the year 3 budget to support relocation costs for the TBD STScI postdoc in the amount of $5K. This is the standard relocation package offered to postdocs at STScI.

Indirect Costs:

The Association of Universities for Research in Astronomy (AURA), operating the Space Telescope Science Institute submitted FY23 provisional indirect rates to NASA on 8/13/22. NASA approved these provisional rates on 11/21/22. These rates are based upon the most cost effective and equitable manner of administering our programs and charging the appropriate share of indirect costs to all projects carried out at the Space Telescope Science Institute.

AURA is including a [redacted]% Facilities and Administrative rate (applied to total costs) to STScI projects to address appropriate reimbursement of AURA corporate office costs.

Cognizant Federal Agency Official contact information:
Rochelle Overstreet
National Aeronautics and Space Administration
300 E St SW
Washington, DC 20024

Telephone: 1-202-358-1279
E-mail: rochelle.n.overstreet@nasa.gov

Arizona State University Redacted Budget Justification

Personnel:

ASU lead Patience will supervise the ASU grad student to ensure that the simulations required for the research project are performed, analyzed, interpreted, and made available to the community within the timeline of the program. The work will also include training an undergraduate student on the research project and coordinating collaborative remote calls and in-person meetings with collaborators at UCSD and STScI. The work will include providing ample mentoring so that the students benefit from the project and are prepared to present results as part of collaborative telecons and at larger conferences such as the AAS and Extreme Solar Systems meetings.

The ASU Graduate Student will work on two main areas of the project – performing trial runs of the routines with the ASU Supercomputer and analyzing extracted simulated spectra. During Year 1 of the project, the ASU grad student will work with the STScI postdoc and PI to perform trial runs of components of the extraction routines on the ASU Supercomputer Agave to assist with the code development. ASU faculty and students have access to an allotted time on the supercomputer which can be used before the STScI team runs longer routines on the purchased cloud computing. The code-testing will continue in Year 2 and will be combined with building a set of empirical and model-generated brown dwarf spectra with a range of physical properties to be used in the simulations that will cover the wavelengths to be observable with *Roman*. In Years 3 and 4 the work will focus on determining the properties from extracted spectra from the tools developed at STScI and comparing with expected results.

Each year of the project, an undergraduate researcher will work on the research project with the ASU lead and ASU grad student. The student work will begin with training in technical skills such as python coding and astrophysics background on brown dwarfs and the *Roman* telescope. After the initial period of training, the student will work with python scripts to contribute to analyze the simulated *Roman* spectra. The student will be recruited from the diverse population of both in-person and online undergraduate majors at ASU. ASU is an Hispanic-serving institution, and the online degree program has significant population of students who are veterans.

Travel Costs: $36,182

Two types of travel funding are requested for the project – collaborative visits and conferences. During each year of the project, the ASU team (faculty member, grad student, and undergrad student) will travel to UCSD for a collaborative research visit with the UCSD team (5 days, 4 nights). During Years 1 and 3, the ASU lead and graduate student will travel to STScI for a collaborative research visit. During Years 2 and 4, the ASU team (faculty member, grad student, and undergrad student) will travel to conferences to present the results of the research project. In Year 2, the Extreme Solar System Conference will be held and is an ideal environment for this research topic, and Year 4 the AAS meeting will be held locally in Phoenix.

Destination: San Diego, California
3 travelers per year

Airfare: $200
Per Diem Rate: $61
# of days: 5
Lodging Rate: $174
# of nights: 4
Ground Transportation: $100
Misc. Costs: $11
Per Person Cost: $1,312
Total Cost: Year 1: $3,936, Year 2: $4,054, Year 3: $4,176, Year 4: $4,302

Destination: Baltimore City, Maryland
2 travelers in years 1 and 3
Airfare: $450
Per Diem Rate: $61
# of days: 5
Lodging Rate: $157
# of nights: 4
Ground Transportation: $100
Misc. Costs: $11
Per Person Cost: $1,494
Total Cost: Year 1: $2,988, Year 3: $3,169

AAS Conference:
3 travelers in year 4
Destination: Phoenix, Arizona
# of days: 5 (local conference $0 per diem/lodging requested)
Ground Transportation: $100
Registration Fee: $500
Misc. Costs: $11
Per Person Cost: $667
Total Cost: Year 4: $2,003

Destination: Christchurch, New Zealand
3 travelers in year 2
Airfare: $1,339
Per Diem Rate: $118.42
# of days: 7
Lodging Rate: $169
# of nights: 6
Ground Transportation: $103
Registration Fee: $515
Misc. Costs $52
Per Person Cost: $3,852
Total Cost: Year 4: $11,554

All lodging and per diem meal rates are based on maximum rates established by ASU's travel guide, which sets rates at or below those established by the GSA and Department of State.

ASU's travel system software provider, Concur Technologies, assesses a charge of $11/per person for each travel expense report submitted. The expense is a direct cost charged per trip, and is included in misc. costs.

Other Direct Costs: $67,846

Materials & Lab Supplies: $7,000 for two $3,500 computers, and $1,000 for computer accessories in year 1.

Publication/Page Charges: $10,400 for publications. $2,600 each year in years 1-4.

Tuition Remission: $49,446 in tuition for the graduate student. Tuition is included as a mandatory benefit and is charged in proportion to the amount of effort the graduate student will work on the project during the academic year. Summer tuition is provided in full if any effort is expended in the summer. Tuition charges are exempt from Facilities & Administrative costs, and are currently charged as such:

	Academic Term	**Summer Term**
2024	$19,418	$1,264
2025	$20,972	$1,365
2026	$22,650	$1,474
2027	$24,462	$1,592

Budget Narrative – UCSD

Title: Galactic Archaeology with Brown Dwarfs and the Nancy Grace Roman Space Telescope
UCSD PI: Dr. Adam Burgasser (proposal Co-I)
Lead Institution/PI: STScI/Dr. Russell Ryan
NASA Solicitation: NNH22ZDA001N-ROMAN

Direct Labor: Labor rates are estimated in person months and costs are assigned based upon employee classifications. Escalation for all personnel costs reflect range and merit increases in accordance with the primary institution's policies.

Proposing Institution PI: This grant requests one (1) month of summer salary at 50% effort (0.04 FTE) in each of Years 1-4 for the proposing institution PI, who will be responsible for student research training and mentoring, professional development training, directing development of population simulation and atmosphere and evolutionary models, and contributing to the scientific direction and publication/presentation of results. The institutional PI will be fully committed to the program during the funded period, and will contribute effort outside of the funded period.

TBN Graduate Student: This grant requests three (3) month academic term salary at 49.99% effort and three (3) months summer term salary at 100% effort (0.38 FTE) for one (1) TBN graduate student in each of Years 1-4 at the proposing institution. The graduate student will lead development of population simulations and/or atmosphere and evolutionary models, co-mentor summer undergraduate research students, and contribute to the scientific direction and publication/presentation of results.

Fringe Benefits: Fringe benefits are calculated at composite rates currently in effect for the proposing institution. Graduate student tuition remission during the academic term is included in the fringe benefits.

Proposing institution defines "year" as the fiscal year from July 1 – June 30

Supplies and Materials:

Funds are requested for the purchase of one (1) MacBook Pro 13" laptop computer for use by the TBN graduate student for the proposed project. Cost estimate is based on configuration of: MacBook Pro 13" with M2 chip, 8C CPU/10C GPU, 24GB RAM, 2TB SSD, and 3-Year Warranty. Estimated cost in Year 1 is $2,340 based on academic pricing.

Funds are requested for the purchase of one (1) HP LaserJet Pro Multifunction Color Laser Printer (M283FDW) for use by the institutional PI for the proposed project. Estimated cost in Year 1 is $600 based on academic pricing.

Funds are requested for the purchase of one (1) Dell 24" U2422H Monitor for use by the TBN graduate student for the proposed project. Estimated cost in Year 1 is $250 based on academic pricing.

Funds are requested for miscellaneous supplies necessary for the project, include mail services, photocopying, data storage, software fees, etc., and are estimated based on actual usage and historical costs on similar projects. These costs are estimated as $500 per year in each of Years 1-4.

Publications: Funds are requested for one (1) publication in each year, at an estimated cost of $2600 in Year 1 based on current AAS Journal charges, based on an average of ApJ Tier 2 and ApJL Tier 1 costs, and increasing by 5% in each of Years 2-4.

Sub Awards:

None

Other Direct Costs:

Next Generation Network (NGN) Communication charge: Communications (or Communications/Computing) costs have been included for telephone and associated voice and data communications charges which are directly related to the individuals working on the project. Rates are $64.89 for faculty and $31.93 for graduate students per month in Year 1, and a 3% annual rate increase is assumed for Years 2-4.

Computing Facility (PCF): supports computer requirements and maintenance, and is computed on a usage-based formula that has been negotiated with the primary institution administration and is charged at $31.96 per month for graduate students and $106.50/month for faculty in Year 1, and a 3% annual rate increase is assumed for Years 2-4.

Participant Costs**:** Funds are requested to support one (1) undergraduate summer research students in each of Years 1-4 of the program through the UCSD STARS program. Costs include a summer stipend of (redacted) (matched to NSF REU program stipends to account for 8 weeks of effort), travel to/from site ($800 including domestic airfare and ground transportation), graduate mentor (redacted), student training ($1200), housing ($3300), and health access ($100). These costs are not included in IDC.

Travel:

Domestic:

Funding is requested for collaboration travel for two (2) people in each of Years 1 and 2. Estimated costs per trip include airfare/ground travel between San Diego, CA and Phoenix, AZ ($200/person), shared local ground transportation ($50), shared accommodation ($125/day for 4 days), and meals ($31.25/day/person for 4 days).

Funding is requested for the principal investigator and two (2) students to attend a domestic conference in each of Years 3 and 4. Estimated costs per trip include airfare from San Diego, CA to a TBD ($700/person), ground transportation ($100/person), lodging ($150/person/day for 5 days), meals ($60/day/person for 5 days), and conference registration ($800 for PI, $400 each for students).

International:

None

Indirect Costs: The Primary Institution's indirect costs are calculated based on Modified Total Direct Costs (MTDC) as defined in 2 CFR Part 200.68 using Facilities and Administration (F&A) rates approved by the U.S. Department of Health and Human Services (DHHS). MTDC is comprised of total direct costs less capital equipment, alterations and renovations, patient care costs, rents, tuition and fee remission, scholarships and fellowships, participant support costs, and that portion of subcontract costs in excess of $25,000. Additionally, the total amount of subawards to other sister institutions are excluded. This project will be located at the Primary Institution. Rates established by Primary Institution's F&A rate agreement dated May 23, 2018.

11 Facilities & Equipment

STScI has developed and maintained a “Flexible Data Center” (FDC) for institute members that requires computing typically more demanding than a workstation can deliver but not as great as publicly available cloud-computing solutions (e.g. AWS). We expect the majority of our work can be achieved with the computing requested above, but will utilize the FDC as necessary.