Resubmission of 16B-0113

NOAO Observing Proposal *Standard proposal* **Panel:** *For office use.*
Date: March 31, 2017 **Category:** Stellar Pops (GAL)

Targeted Samples of the Hot Stellar Content in the Southern Sky

Abstract of Scientific Justification *(will be made publicly available for accepted proposals)*:
This proposal is a continuation of our program to identify the hot stellar component – in particular, pure-hydrogen-atmosphere ("DA") white dwarfs – in the Southern sky. These objects will be vital for the absolute color calibration of current and future Southern Sky CCD-based imaging surveys and facilities, such as the Dark Energy Survey (DES) and the Large Synoptic Survey Telescope. In our earliest runs, we primarily identified candidate hot stars by performing u, g-band imaging within the Blanco Cosmology Survey and PreCam Survey fields. Our current effort, which we plan to continue for 2017B, focuses on the following: (1) use the CTIO-0.9m telescope to obtain full *ugriz* imaging for potentially hot WDs from the SuperCOSMOS survey (Rowell & Hambly, 2011) within the DES footprint; and (2) perform medium-resolution spectroscopy with the SOAR telescope to classify our candidates from our previous imaging runs, as well as candidates from other sources (e.g. the McCook & Sion WD Catalog and the SDSS DR-10 catalog), and determine their effective surface temperatures and surface gravities. In addition to providing calibration stars for future surveys and facilities, this data set will permit studies of the white dwarf luminosity function and of Galactic structure.

Summary of observing runs requested for this project

Run	Telescope	Instrument	No. Nights	Moon	Optimal months	Accept. months
1	CT-0.9m	CFIM + 2K	10	grey	Sep - Nov	Sep - Jan
2	SOAR	Goodman	4	grey	Sep - Oct	Sep - Jan
3	SOAR	Goodman	3	grey	Dec - Jan	Oct - Jan
4						
5						
6						

Scheduling constraints and non-usable dates *(up to six lines)*.

Investigators *List the name, status, and current affiliation for all investigators. The status code of "P" should be used for all investigators with a Ph.D. or equivalent degree. For graduate students, use "T" if this proposal is a significant part of their thesis project, otherwise use "G".*

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CoI: Deborah J. Gulledge **Status:** U **Affil.:** Austin Peay State University
CoI: William Wester **Status:** P **Affil.:** Fermilab
CoI: Jacob M. Robertson **Status:** U **Affil.:** Austin Peay State University
CoI: Jamin Welch **Status:** U **Affil.:** Austin Peay State University
CoI: John P. Marriner **Status:** P **Affil.:** Fermilab

Scientific Justification *Be sure to include overall significance to astronomy. For standard proposals limit text to one page with figures, captions and references on no more than two additional pages.*

This proposal is a continuation of our program to identify and characterize the hot stellar component – in particular, pure-hydrogen-atmosphere ("DA") white dwarfs – in the Southern sky. These objects will be vital for the absolute color calibration of future Southern Sky CCD-based imaging surveys and facilities, notably the Dark Energy Survey (DES) and the Large Synoptic Survey Telescope (LSST). In previous campaigns we focused on identifying candidate hot stars via u-band imaging within the fields of the Blanco Cosmology Survey (BCS) and the DES precursor PreCam Survey (Kuehn et al. 2013). In 2012B we also began targeting members of the Rowell & Hambly (2011) SuperCOSMOS WD candidates. Here, we propose to continue our program in three ways: (1a) continuing the u, g-band imaging with the CTIO-0.9m telescope within the footprint of the PreCam and BCS surveys to continue identifying candidate hot stars; (1b) obtain u, g-band data for potential WDs identified in the DES data set; (2) obtain full $ugriz$ imaging for potentially hot WDs from the SuperCOSMOS survey (Rowell & Hambly, 2011); and (3) perform medium-resolution spectroscopy using the SOAR telescope to classify our candidates from our previous imaging runs, as well as candidates from other sources, and determine their effective surface temperatures and surface gravities. *The primary goal of this program is to identify white dwarfs (WD) within the DES footprint and obtain spectra for the hot ones.*

Hydrogen envelope WDs (DA) are of primary importance as calibrators for the upcoming DES and, later, the LSST. DA white dwarfs are the currently preferred spectrophotometric standards, as they have very simple spectra, they tend not to be variable, and they are relatively abundant (c. 1/sq deg down to $r \approx 17$) (Harris et al. 2006). Based on LSST simulations (Ivezić, private communication) we expect this number to grow to 35-40 per square degree (to $g = 24.5$) depending on thick disk scale height, yielding a sample of over 20,000 WDs in the $\sim$5000 sq deg survey area of the DES. These observations will also allow us to test WD identification procedures for use in the DES. The u&g-band photometry will permit efficient identification of DA white dwarf candidates based upon color selection (see, e.g., Fig. 1 of Kleinman et al. 2004) and thus supply an important set of absolute calibrators for future Southern hemisphere imaging surveys (e.g., the DES & LSST). *The primary goal of this program is to identify the hot (14,000 – 45,000K) WDs which will form the basis of the absolute calibration for the DES which began in 2012B.*

This proposal will obtain u, g observations of proper motion selected stars which have ($griz$) colors suggestive of hot stars. In photometric structure studies of the halo, the u band is essential for discriminating between blue stars (BHB, RR Lyr, dA, blue stragglers and F turnoff spectral types) and moderate redshift QSOs (redshift less than 2). These classes of objects have nearly identical $g - r$ and $r - i$ colors. Only the near-UV Balmer absorption, present in stars but absent in QSO spectra, can be used as a powerful photometric discriminator. When u-band photometry is available, this discriminator takes the form of a simple color cut in $u - g$ (Yanny et al. 2000; 2009). Without u data, contamination of photometric samples by QSOs can reach higher than 50% for BHB samples fainter than $g \sim 19$th mag (Yanny et al. 2000). See Figure 1. Furthermore, Ivezić et al. (2006, 2008) illustrate a connection between spectroscopic and photometric metallicity. This relies heavily on the u-band photometry, especially for A & F stars with $u - g$ between 0.8 and 1.5 (where the $g - r$ color doesn't help determine metallicity at all). Proper motion data (from various sources) allow sub-selection of white dwarfs with minimal contamination from other stellar classes. Spectroscopic observations of the WDs allow us to verify the hydrogen envelope stars (DAs) and to calibrate the surface gravities and effective temperatures (Bergeron et al. 1992) which are required for use as absolute calibration sources. Preliminary targets from our prior work and other sources (Rowell & Hambly, 2011; McCook & Sion, 1999) cover the entire sky and are plentiful in the DES footprint. See Figure 3.

References

Allende Prieto, C., Hubeny, I, & Smith, J.A. 2009, MNRAS, 396, 759.
Bergeron, P., et al. 1992, ApJ, 394, 228.
Harris, H.C., et al. 2006, AJ, 131, 571.
Ivezić, Z., et al. 2006, MmSAIt, 77, 1057.
Ivezić, Z., et al. 2008, ApJ, 684, 287.
Kleinman, S., et al. 2004, ApJ, 607, 426.
Kuehn, K., et al. 2013, PASP, 125, 409.
McCook, G.P., & Sion, E.M. 1999, ApJS, 121, 1.
Rowell, N., & Hambly, N.C. 2011, MNRAS, 1407.
Yanny, B., et al. 2000, ApJ, 540, 825.
Yanny, B., et al. 2009, AJ, 137, 4377.

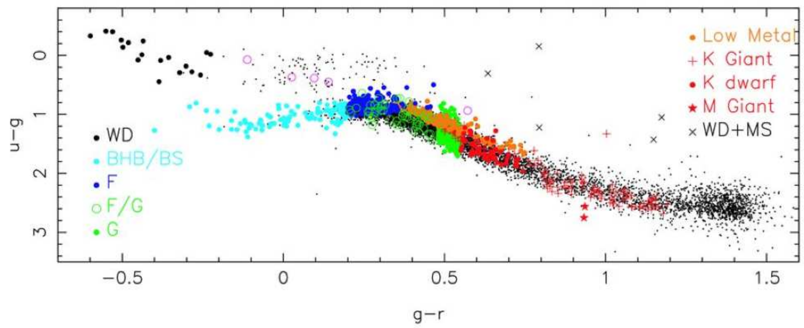

Figure 1: Fig. 3 of Yanny et al. (2009) - target selection categories for SEGUE. $(u-g)_0$,$(g-r)_0$ color-color plot showing the different SEGUE target categories. Note the 'Low Metal' category hugs the blue side of the stellar locus in $(u-g)_0$. (©AAS)

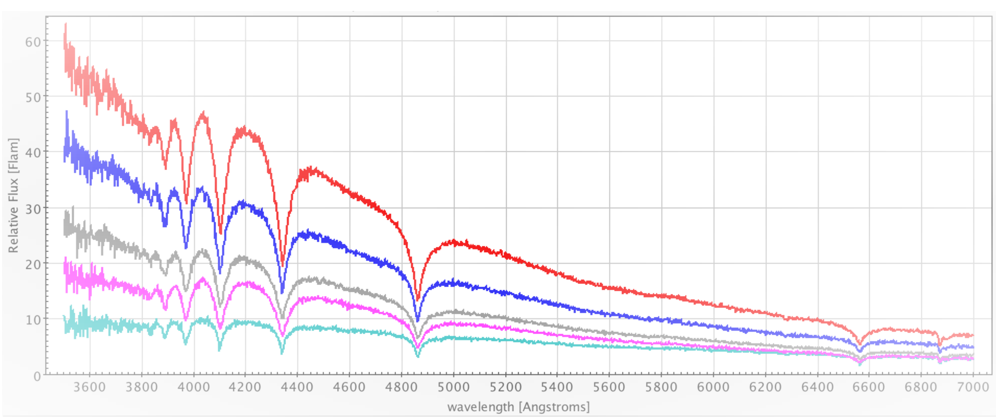

Figure 2: Representative cleaned spectra from the Dec. 2014 SOAR run. Fits to obtain log-g and T_{eff} values are underway.

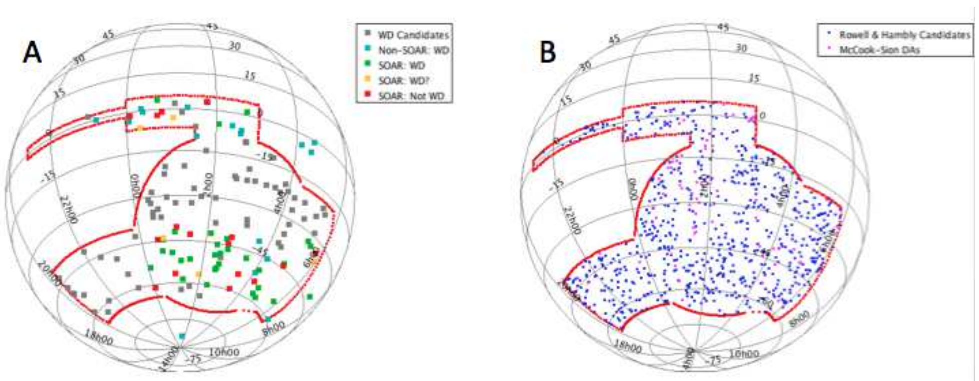

Figure 3: 3D spherical representations of the sky in RA, DEC. The red outline shows the borders of the DES footprint. (a) Current status from our 2014B SOAR spectroscopic followup program. Targets were drawn from the sample of mag=16.5−17.0 white dwarf candidates from the Rowell & Hambly catalog, plus a sampling of repeats from our CTIO-1.5m and ARC-3.5m programs. Green, Yellow, and Red squares: targets spectroscopically classified as white dwarfs, maybe white dwarfs, and non-white dwarfs, respectively, during our December 2014 SOAR run. Cyan squares: 2014B targets previously classified as white dwarfs from our earlier CTIO-1.5m and ARC-3.5m programs. Gray squares: 2014B targets from our Rowell & Hambly mag=16.5−17.0 white dwarf candidate sample still requiring spectroscopic followup. (b) Enhanced goal spectroscopic target sample. Blue squares: mag=16−18 white dwarf candidates from the Rowell & Hambly catalog. Magenta squares: mag=16−18 DA white dwarfs from the McCook-Sion catalog.

Experimental Design *Describe your overall observational program. How will these observations contribute toward the accomplishment of the goals outlined in the science justification? If you've requested long-term status, justify why this is necessary for successful completion of the science. (limit text to one page)*

This proposal is to obtain both *ugriz* imaging to identify additional white dwarf candidates and to obtain medium resolution spectroscopy to verify and classify of our brighter candidates from other sources. We will address the imaging and the spectroscopy in turn.

Imaging: Our goal here is to add to the list of DA white dwarfs which could be used as spectrophotometric standards *and which lie within the DES footprint*. As noted in the Scientific Justification, $u - g$ colors are an efficient filter for extracting DA white dwarfs from the general background of stars. We plan to make use of the full DES data set (Years 1-4), which already has *grizY* imaging to help with photometric classification and covers the full intended DES 5-year footprint. Most of the DES area has been observed at least 6 times in all 5 filters, which helps weed out variables. In addition, we will continue targeted *ugriz* imaging of potential hot DAs from the SuperCOSMOS survey.

Spectroscopy: For spectroscopy, we would like to continue our successful spectroscopic programs from 2014B and before. In 2014B, our targets were primarily drawn from mag=16.5−17.0 candidates from the Rowell & Hambly (2011) SuperCOSMOS Sky Survey white dwarf catalog, supplemented with a handful of repeat targets from our earlier CTIO-1.5m and ARC-3.5m programs (Fig. 3a). (Our CTIO-1.5m program targeted mag<16.0 candidates, and our ARC-3.5m program tended to target equatorial candidates.) We note that the Rowell & Hambly catalog contains no spectroscopic information: it is merely a catalog of candidate white dwarfs identified by their proper motions. For 2014B, we were able to observe 51 of our 141 targets with the SOAR Goodman spectrograph; of the 51 observed targets, we were able to classify 30 as white dwarfs, 5 as possible white dwarfs, and 16 as not white dwarfs. See Figure 2.

For 2017B, we intend to observe most or all of our remaining 90 targets from 2014B – in particular, covering the extreme western edge (RA=20h to 24h) of the DES footprint, as well as the gap between the DES SPT area and the DES equatorial area (DEC=-10deg to -40deg). If observing runs smoothly and time is available, we would also like to extend our program to fainter targets (mag=17–18) and to targets from the McCook-Sion white dwarf catalog (McCook & Sion 1999) (see Fig. 3b) Although the McCook-Sion catalog has only sparse coverage across the DES footprint, it does have numerous white dwarfs already classified as "DA". Most of these McCook-Sion DAs, however, do not have the log $T_{\rm eff}$, log g information that is critical for determining the best-fit spectrophotometric model for a DA white dwarf (and it is these best-fit models that are used for absolute calibration of photometric systems, not the observed spectrum of these stars).

Based on the success of our 2014B SOAR Goodman spectrograph observations, we believe a similar setup will be ideal for continuing this program though will will follow through with the 2016B TAC suggestion to use the Goodman Acquisition Camera.

Proprietary Period: 18 months

Use of Other Facilities or Resources *(1) Describe how the proposed observations complement data from non-NOAO facilities. For each of these other facilities, indicate the nature of the observations (yours or those of others), and describe the importance of the observations proposed here in the context of the entire program. (2) Do you currently have a grant that would provide resources to support the data processing, analysis, and publication of the observations proposed here?"*

APSU is a 5% partner in the WIYN 0.9m observatory at KPNO. The PI will use a portion of the allocated time on that telescope to support the imaging portion of this project for the WD candidates north of declination -20 degrees. However, none of our team has access to spectroscopic instruments other than through NOAO facilities.

Previous Use of NOAO Facilities *List allocations of telescope time on facilities available through NOAO to the PI during the last 2 years for regular proposals, and at any time in the past for survey proposals (including participation of the PI as a Co-I on previous NOAO surveys), together with the current status of the data (cite publications where appropriate). Mark with an asterisk those allocations of time related to the current proposal. Please include original proposal semesters and ID numbers when available.*

⋆ 2015B-0245: We were awarded one 10-night run on the 0.9m for u, g, r, i, z-band imaging to support this program. This run was completed and the data have been reduced. The hot WDs from this run have been added to our spectroscopy list. We were not awarded additional SOAR time due to the scattered light issue. We now have a plan to deal with the scattered light developed in consultation with the Goodman Instrument Scientist (Sean Points). Preliminary results from these programs were presented at the January 2016 AAS meeting. A publication combining all imaging data to date is in preparation for submission a refereed journal. – New from 2015B, the spectra have now been fit to atmospheric models to produce temperature and gravity data. Preliminary results were presented at the 2014 European White Dwarf Workshop meeting.

⋆ 2016B-0113: We were awarded one 5-night run in October 2016 on the 0.9m for u, g, r, i, z-band imaging but no spectroscopic time. This run was only marginally successful, 4 of the 5 nights were non-photometric; one was only open for a half-night.

2016B-0261: We were awarded a four half-night run in September 2016 on the WIYN 3.5m for u, g, r, i, z-band imaging and HYDRA spectroscopy for exo-planet studies of the open cluster Dolidze-35. This run was only marginally successful, the half-night of image was successful and those data are being reduced. The first 2 hours of the remaining three half-nights were successful for obtaining spectra of the brightest cluster members; Hurricane Newton claimed the rest of the time.

2017A-0241: We were awarded a two night run in June 2017 on the WIYN 3.5m for HYDRA spectroscopy to continue the exo-planet studies of the open cluster Dolidze-35 which were claimed by weather in 2016B. This run has not occurred yet.

⋆ : Smith, Tucker, & Allam are co-Is and observers on the PreCam Survey project (Kuehn et al. 2013, Allam et al., in prep).

Observing Run Details for Run 1: CT-0.9m/CFIM + 2K

Technical Description *Describe the observations to be made during this observing run. Justify the specific telescope, the number of nights, the instrument, and the lunar phase. List objects, coordinates, and magnitudes (or surface brightness, if appropriate) in the Target Tables section below (required for queue and Gemini runs).*

The primary objective of this run is to continue the photometric measurement and monitoring of the proper motion selected WDs in the SuperCOSMOS survey. These data will allow photometric selection of hot WDs and a rough atmosphere selection (DA vs. non-DA) for potential spectroscopic follow-up and modeling. The well modeled spectra will then provide excellent calibration sources for the DES and later the LSST. There are roughly 1100 candidates in the DES footprint between $r = 16$ and $r = 18$. For this run, we wish to focus on 300 of our better and brighter candidates in the DES footprint, especially those which are not visible from Kitt Peak (which we follow-up using APSU time on the WIYN-0.9m).

Based on previous experience on the CTIO-0.9m, we find exposure times of (450, 120, 120, 120, 180) seconds in (u, g, r, i, z) provide adequate S/N for a typical $r \approx 16.5$ white dwarf. Since we already have *griz* photometry for most of these candidates from either the DES itself or other sources, we plan to focus primarily on u, g imaging for this run, although we will obtain full *ugriz* imaging for a small subset for quality control purposes.

Assuming an readout overhead of 20 seconds per exposure and a typical between-target slew of 110 sec, we calculate a total time per target of 450sec(u) +120sec(g) + 20sec + 20sec + 110sec = 720sec (12 min). So, for all 300 targets, we arrive at a total time of 12min×300=3600min. To perform good photometry, we want to add 33% overhead for standards, yielding 3600min×1.33=4800min=80 hours, or ten 8-hour nights.

Instrument Configuration

Filters: ugriz	Slit:	Fiber cable:
Grating/grism:	Multislit:	Corrector:
Order:	λ_{start}:	Collimator:
Cross disperser:	λ_{end}:	Atmos. disp. corr.:

R.A. range of principal targets (hours): 20 to 06

Dec. range of principal targets (degrees): -20 to -65

Special Instrument Requirements *Describe briefly any special or non-standard usage of instrumentation.*

Observing Run Details for Run 2: SOAR/Goodman

Technical Description *Describe the observations to be made during this observing run. Justify the specific telescope, the number of nights, the instrument, and the lunar phase. List objects, coordinates, and magnitudes (or surface brightness, if appropriate) in the Target Tables section below (required for queue and Gemini runs).*

This run allows us to reach targets in the vital western portion of the DES footprint where we have nearly no spectroscopy to support survey calibration. We will select targets primarily in the magnitude range $16 < r < 18$ – too faint for our earlier CTIO-1.5m+RC Spectrograph program, but faint enough to avoid the saturation limit of a typical DES science exposure ($r \approx$16.0) – focusing on those ≈90 targets in the 16.5−17.0 range that we were unable to observe during our 2014B SOAR+Goodman Spectrograph run (see Fig 3). Our primary source for targets is the SuperCOSMOS proper motion database of candidate white dwarfs by Rowell & Hambly (2011), supplemented by a set of known DA white dwarfs from the McCook-Sion catalog that need improved measurements of $\log T_{eff}$ and $\log g$ to make them useful absolute calibration standards. The highest priority targets from these sources will be those for which we have have obtained *ugriz* imaging using the CTIO-0.9m, CTIO-1.0m or WIYN-0.9m and which lie within the DES footprint. With input from the Goodman Instrument Scientist and from other sources, Fermilab scientist John Marriner has resolved our earlier issues with the scattered light in the Goodman spectrograph, yielding a well-calibrated set of spectra from our 2014B run. See Figure 2.

Based on the GHTS ETC, and our experience during our 2014B run, we expect to achieve our goals ($S/N \approx 30$) with total integration times between 180 sec (for r =16.0) and 1200 sec (for r =18.0). To help with cosmic ray rejection, we plan to break each target total integration time into 3 exposures each. Based on our experience from our 2014B SOAR+Goodman Spectrograph run, we expect that we can observe ∼15−20 targets per night, weather permitting. At this rate, we should be able to hit at total of 60−80 targets over a 4-night run. This would not only potentially let us complete the remaining ≈90 targets from our 2014B run, but also permit us to extend our sample to some stars fainter than mag≈17.0. As suggested by the TAC last year, we will consider using the Goodman Acquisition Camera rather than pre-imaging.

Our end goal is a Golden Sample of 30-100 well-observed and modeled DAs spread over the DES footprint to push the absolute color calibration to the 0.5% level (note: the absolute color calibration of the SDSS was at ∼ 1% level, using ∼ 10 spectrophotometric standards). Having a large sample over this area of the sky (5000 sq deg) permits additional cross-checks to test the calibrations. Previous work (e.g., Allende Prieto et al. 2009; Eisenstein, private communication) indicates that substantial culling is required to attain such a Golden Sample; so the larger the initial set, the better. In the end, we estimate we will need an initial sample of at least 300 WDs.

Instrument Configuration

Filters: None	Slit: 1.5	Fiber cable:
Grating/grism: 400 l/mm	Multislit: no	Corrector:
Order: 1st	λ_{start}: 3500	Collimator:
Cross disperser:	λ_{end}: 7500	Atmos. disp. corr.: yes

R.A. range of principal targets (hours): 20 to 06

Dec. range of principal targets (degrees): -10 to -70

Special Instrument Requirements *Describe briefly any special or non-standard usage of instrumentation.*

We prefer the blue camera for this run.

Observing Run Details for Run 3: SOAR/Goodman

Technical Description *Describe the observations to be made during this observing run. Justify the specific telescope, the number of nights, the instrument, and the lunar phase. List objects, coordinates, and magnitudes (or surface brightness, if appropriate) in the Target Tables section below (required for queue and Gemini runs).*

This run allows us to reach remaining targets in the eastern portion of the DES footprint, as well as in the "connector" region at intermediate southern declinations. We will select targets primarily in the magnitude range $16 < r < 18$ – too faint for our earlier CTIO-1.5m+RC Spectrograph program, but faint enough to avoid the saturation limit of a typical DES science exposure ($r \approx 16.0$) – focusing on those ≈90 targets in the 16.5−17.0 range that we were unable to observe during our 2014B SOAR+Goodman Spectrograph run (see Fig 3). Our primary source for targets is the SuperCOSMOS proper motion database of candidate white dwarfs by Rowell & Hambly (2011), supplemented by a set of known DA white dwarfs from the McCook-Sion catalog that need improved measurements of log T_{eff} and log g to make them useful absolute calibration standards. The highest priority targets from these sources will be those for which we have have obtained *ugriz* imaging using the CTIO-0.9m, CTIO-1.0m or WIYN-0.9m and which lie within the DES footprint. With input from the Goodman Instrument Scientist and from other sources, Fermilab scientist John Marriner has resolved our earlier issues with the scattered light in the Goodman spectrograph, yielding a well-calibrated set of spectra from our 2014B run. See Figure 2.

Based on the GHTS ETC, and our experience during our 2014B run, we expect to achieve our goals ($S/N \approx 30$) with total integration times between 180 sec (for $r = 16.0$) and 1200 sec (for $r = 18.0$). To help with cosmic ray rejection, we plan to break each target total integration time into 3 exposures each. Based on our experience from our 2014B SOAR+Goodman Spectrograph run, we expect that we can observe ∼15−20 targets per night, weather permitting. At this rate, we should be able to hit at total of 45−60 targets over a 3-night run. This would not only potentially let us complete the remaining ≈90 targets from our 2014B run, but also permit us to extend our sample to some stars fainter than mag≈17.0. As suggested by the TAC last year, we will consider using the Goodman Acquisition Camera rather than pre-imaging.

Our end goal is a Golden Sample of 30-100 well-observed and modeled DAs spread over the DES footprint to push the absolute color calibration to the 0.5% level (note: the absolute color calibration of the SDSS was at ∼ 1% level, using ∼ 10 spectrophotometric standards). Having a large sample over this area of the sky (5000 sq deg) permits additional cross-checks to test the calibrations. Previous work (e.g., Allende Prieto et al. 2009; Eisenstein, private communication) indicates that substantial culling is required to attain such a Golden Sample; so the larger the initial set, the better. In the end, we estimate we will need an initial sample of at least 300 WDs.

Instrument Configuration

Filters: open	Slit: 1.5	Fiber cable:
Grating/grism: 400 l/mm	Multislit: no	Corrector:
Order: 1st	λ_{start}: 3500	Collimator:
Cross disperser:	λ_{end}: 7500	Atmos. disp. corr.: yes

R.A. range of principal targets (hours): 20 to 06

Dec. range of principal targets (degrees): -10 to -70

Special Instrument Requirements *Describe briefly any special or non-standard usage of instrumentation.*

We prefer the blue camera for this run.

NOAO observing proposal LaTeX macros v3.0.