LSST Absolute Photometric Calibration

2022B-319184

Type: NOIRLab: Standard (NOIRLab 2022B)
Proprietary Period: 18 Months

Abstract:
This proposal is to identify the hot stellar component – in particular, pure hydrogen-atmosphere ("DA") white dwarfs – in the Southern sky. These objects proved vital for the absolute color calibration of the Dark Energy Survey (DES) and should be useful in the same manner for the Rubin-LSST effort.
Combining u-band imaging data with DES and other survey data allows identification of candidate hot stars for follow-on spectroscopy. A similar SOAR-4m program netted 120 spectroscopically confirmed and modeled DA white dwarfs for use in calibrating the DES. We intend to perform medium resolution spectroscopy with the SOAR telescope to classify candidates from existing imaging surveys, as well as candidates from other sources (e.g., from VST-ATLAS and from GAIA), to determine their effective surface temperature and surface gravity. 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.

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Scheduled Runs:

Run 1 (2022B): SOAR / Goodman *Classical*

2 scheduled nights

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.*

Vera C. Rubin Observatory systems engineering has recently approved opportunities for the community engagement with LSST commissioning effort[1] to be performed over the calendar years 2022 and 2023.

To meet its science goals, LSST imposes the following requirements on its photometric calibration[1]: photometric zeropoint uniformity across the sky of 10 mmag in *grizy* and 20 mmag in u, with color accuracy of 5 mmag for colors that do not involve u and 10 mmag for those that do. As a point of reference, the Dark Energy Survey has now achieved a photometric zeropoint uniformity across its 5000 sq deg footprint of σ<3 mmag (DES DR1 & DR2 [2,3]). This has been achieved using the FGCM approach[4], which LSST also plans to use. Additionally, DES absolute photometric calibration was tied to the AB system[2,3] based on DES observations of the HST CALSPEC standard star C26202[5] and a new, large sample of AB reference stars[3]: ∼450 DA White Dwarfs (DAWDs) in the DES footprint that have been spectroscopically observed with the ARC 3.5m, SOAR 4m, and Magellan 6.5 telescopes and subsequently modeled. Specifically, a "Golden Sample" (Fig. 3) of ∼150 relatively faint ($16.5<r<18$) DAWDs was used (Fig. 1), plus the HST CALSPEC spectrum c26202_stiswfcnic_002, to achieve absolute *color* calibration with systematic errors at the ≤10 mmag level (Table 2 of [3]).

DAWDs offer a unique opportunity for accurate absolute photometric calibration of large surveys[6,7,8]. This is due to the fact that their intrinsic SED can be accurately calculated given only the stellar parameters; temperatures T_{eff} and log(g), both of which can be determined from ground-based spectroscopy of the Balmer line profiles (Fig. 2). There are some issues that arise in putting this approach into practice for LSST commissioning. First, DAWDs are relatively rare. Using the Besançon model of the Galaxy[9], yields a rough estimate of one DAWD per LSST field[8] in an appropriate magnitude range ($16<r<19$). Furthermore, not all candidate DAWDs will be appropriate to use for absolute calibration, due to being variable (binaries or in the instability strip), due to poor fits to the model DAWD spectra, or due to high interstellar extinction. Therefore, as with the DES DAWD effort, many more candidates need to be observed than what finally constitute the final "Golden Sample." Depending on the area selected for LSST commissioning, there is a deep need to extend the DAWD sample and follow them up spectroscopically, and have their spectra modeled. Remote observing using SOAR is a key for enlarging the sample, and reducing the travel and accommodation costs. To aid in the proposed observations and analysis, several python code packages developed for DES Absolute calibration can be adopted for the use with LSST commissioning data-set (e.g. WD selection, on-the-fly spectroscopic reduction, synthetic photometry, etc.).

We request 6 nights during the 2022B semester, to obtain medium-resolution spectroscopy with the SOAR telescope to classify the candidate DAWDs from the publicly available DECam Local Volume Exploration (DELVE; [10]) survey imaging runs and other sources (e.g., from VST-ATLAS and from *GAIA EDR3*, SDSS Stripe 82[11]), in order to determine their effective surface temperatures and surface gravities. In particular, the goal of the proposed observation is to extend coverage in both the sky distribution and the effective temperatures of the sample of confirmed DAWDs inside and outside the DES footprint, to obtain additional observations of some of the previously targeted DAWDs to boost the S/N of their observed spectra, and to help with the calibration of LSST commissioning data.

[1] `https://sitcomtn-010.lsst.io/SITCOMTN-010.pdf`

References

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[5.] Bohlin, R. C. Gordon, K. D. & Tremblay, P.E. 2014, PASP, 126, 711
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[12.] Gentile Fusillo, N. et al. 2017, MNRAS, 469, 621
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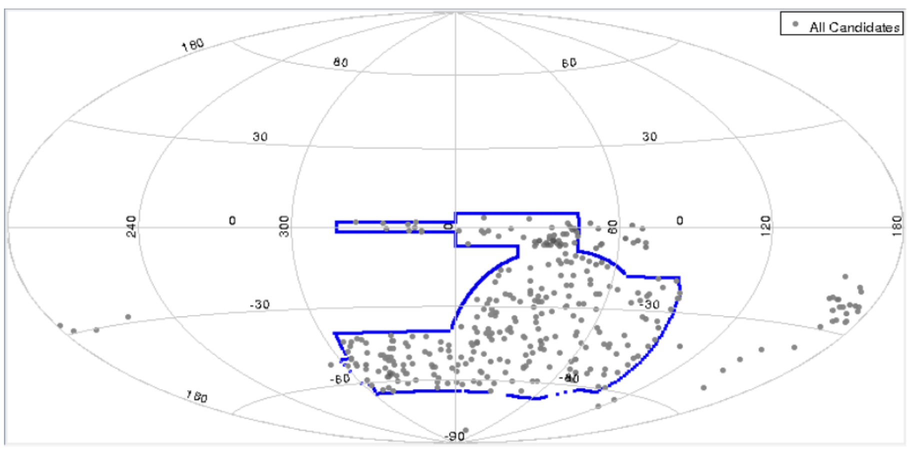

Figure 1: Shown are the sky positions of the final sample of DES DAWDs which were used to estimate the DES absolute color offset. The observed data were fit to model DA spectra to obtains synthetic DES AB colors for all the candidates. The DAWD stars were matched to Gaia DR2, with Gaia DR2 distance tables taken from (Bailer-Jones et al. 2018), and SFD98 E(B-V) maps corrected, then matched with FGCM Y6A1 standard star catalog, the Y6-Gold-v1 catalog, and the DES Y6Q1 variable star catalog. The blue outline shows the borders of the DES footprint.

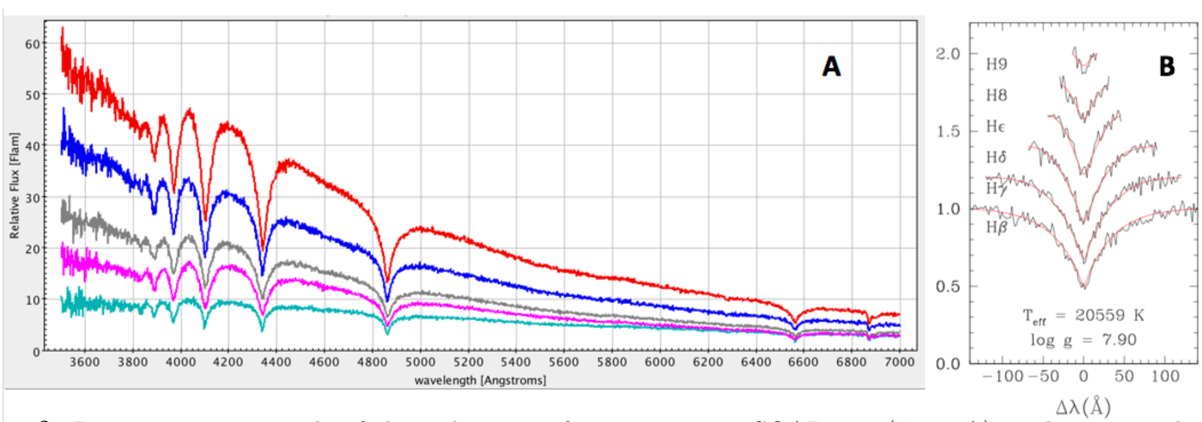

Figure 2: Representative sample of cleaned spectra from a previous SOAR run (Fig. 2A), and an example of one of the model fits (Fig. 2B). Note that all spectra from previous SOAR runs have been modeled.

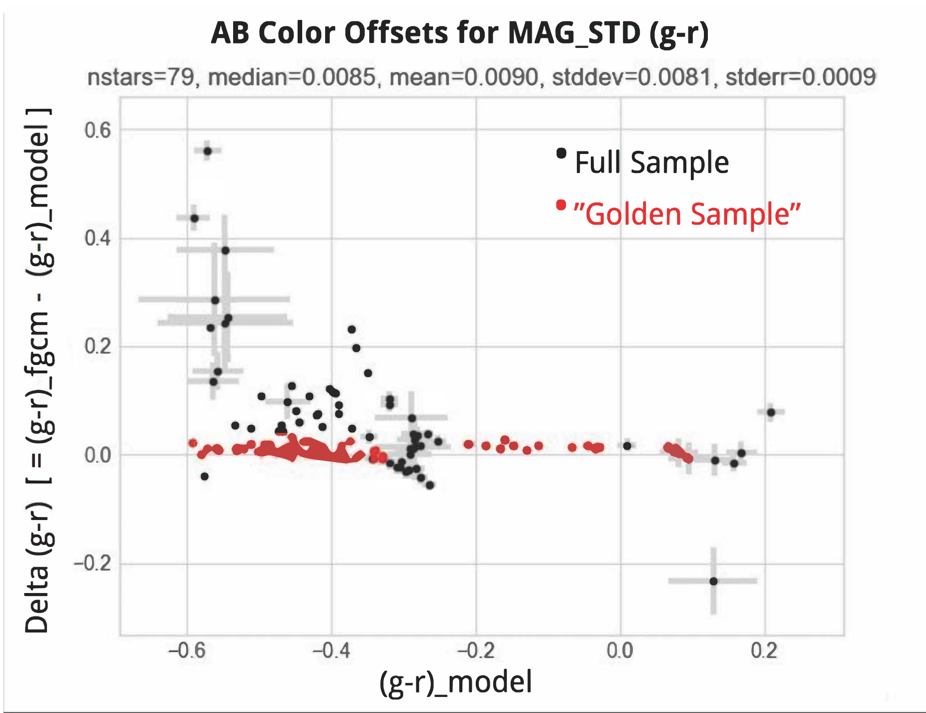

Figure 3: Plot of the DAWD sample matched to FGCM standard star catalogue. Some stars have large error bars due to variability and/or due to poor model fits. The locus bifurcates near the blue edge of the instability strip –i.e, bluewards of $(g-r)_{model} \sim$ -0.3. The "Golden Sample" on the main locus is identified by first removing the stars with large error bars and then performing iterated sigma-clipping. Marked in red are the "Golden Sample" stars that is used to estimate the DES AB color offsets. Details in the DES DR2 paper [3].

Experimental Design *Describe your overall observational program. How will these observations contribute toward the accomplishment of the goals outlined in the science justification?*

The design of the proposed observation is informed by successful spectroscopic programs from 2018B and earlier.

In 2014, a SOAR observation program targeted WD candidates of 16.5$\leq$ r mag $\leq$17.0 identified by their proper motions from the Rowell & Hambly (2011) SuperCOSMOS Sky Survey WDs catalog, supplemented with a handful of repeat targets from earlier CTIO-1.5m and ARC-3.5m programs. The 2014B observation yielded 51 of the 141 targets with the SOAR Goodman spectrograph; 30 of which were white dwarfs, 5 were possible white dwarfs, and 16 were not white dwarfs.

Then a 2017B observation expanded the magnitude range of the targets (16.5$\leq$ $rmag$ $\leq$17.5) and continued observing within the DES footprint – in particular, covering the extreme western edge (RA=20h to 24h) of the DES footprint, as well as the gap between the DES SPT area and the DES equatorial area (DEC=-40deg to -10deg). A subsample (mag$\approx$16–17.5) VST ATLAS high-confidence southern WD-sample within the DES footprint from Gentile Fusillo et al. (2017) was also targeted.

During 2018B, observations were designed to fill in remaining gaps in both the sky distribution and the effective temperature distribution of the sample of confirmed DAWDs within the DES footprint. Additional observations of some previously targeted DAWDs were obtained to boost the S/N of their observed spectra, to extend the original sample to include GAIA DR2 and GALEX-identified candidate white dwarfs, and to extend the sample to areas outside the DES footprint (to help with the calibration of other Southern surveys).

Drawing experience from those previous observations, we request the grating of 400 l/mm, working in 1st order with a slit size 1.5$''$ in the wavelength range 3500Å– 7500Å. There is no need for multi slit option. We prefer to use of blue camera for this run and the use of parallactic angle corrections to improve the observations. **The target range is from 0h to 24h, as this will be all-sky sample, and declination from -70 to +10.**