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The HST Set of Absolute Standards for the 0.12 μm to 2.5 μm Spectral Range

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ABSTRACT

A proposal to create a homogeneous set of absolute calibration standards covering for the first time the 0.12 μm to 2.5 μm spectral range is described. Observations to obtain medium resolution (R~ 200 - 500) near-infrared spectra (0.8 μm to 2.5 μm) of HST standard stars with next generation HST instruments (STIS and NICMOS) are planned. The proposed observations would extend into the near-infrared the present set of ultraviolet and optical HST absolute calibration stars. The set of standards would be used in the absolute calibration of present and future HST instruments, i.e. WFPC2, STIS, NICMOS, and ACS. This proposal will be submitted as part of the Calibration Plan for cycle 7 and as such, approval will be required prior to execution.

1. Introduction

Instruments onboard HST have spectroscopic and imaging capabilities over the entire 0.12 μm to 1 μm range. Next generation HST instruments (STIS and NICMOS) will extend these capabilities into the near-infrared, up to 2.5 μm. The ability to obtain the most quantitative astrophysical results with the new instruments relies on the accuracy achieved in the absolute calibration of the instruments. A complete, homogeneous, accurate set of primary and secondary absolute calibration stars form the basis of precise absolute calibrations.

The present set of HST standards (Bohlin 1996) consists of 26 stars with spectra covering the 0.115 μm - 0.920 μm wavelength range that are calibrated on the white dwarf scale (Bohlin, Colina, & Finley 1995), and are corrected for Oke's absolute flux uncertainties in the optical (Colina & Bohlin 1994). Three solar analog stars have recently been added to the list of HST standards. FOS observations of these solar analogs are scheduled for the second half of 1996 (Colina et al. in preparation). The FOS spectra will cover the 0.22 - 0.85 μm spectral range and will be used to assess the accuracy of NICMOS solar analog calibration method by direct comparison with the solar reference spectrum (Colina, Bohlin, & Castelli 1996).

In this document, we explain the plans to extend the wavelength coverage of HST standards spectra up to 2.5 μm, using STIS and NICMOS. The justification for such an extension is in section 2, while the list of targets is in section 3. Section 4 explains the observational strategy and technical feasibility of the project.

2. The Need for a Set of UV-NIR Absolute Standards

With the installation in February 1997 of STIS and NICMOS, HST will for the first time in Astronomy be a multifrequency observatory covering, without discontinuity, the ultraviolet to near-infrared spectral range, i.e. from 0.12 μm to 2.50 μm. The second generation of HST instruments require spectrophotometric standard stars for flux calibration to 1.1 μm for the imaging spectrograph (STIS), and to 2.5 μm for the near-infrared camera (NICMOS).

At the time of this writing there is a lack of spectrophotometric standards for which absolute calibrated spectra covering the full ultraviolet to near-infrared wavelength range are available. Except for model spectra of the four pure hydrogen white dwarf primary standards, the spectra of HST standards cover only the spectral range up to 0.9 μm. Beyond that wavelength, and up to 1.1 μm, only low resolution model spectra are available. These model spectra are generic, i.e. they were not customized to fit the spectral features of individual stars. Therefore new observations are needed to extend the spectral coverage of HST spectrophotometric standards towards the near-infrared, up to 2.5 μm.

To date, there are no spectrophotometric standards available beyond 1.0 μm. The two most widely used set of near-infrared standards (bright CIT set: see Elias et al. 1982; faint UKIRT set: see compilation by Courteau 1994) are broad-band photometric standards only.

Accuracy in the cross-instrument absolute calibration is a high priority for HST. The quality and homogenity in the absolute calibration of all HST instruments depends on the existence of a homogeneous set of standards. These standards should be based on the same system , i.e. the white dwarf scale, and have absolute fluxes known with the highest available precision, i.e ~3% up to 1 μm and ~10%-20% beyond.

The absolute calibration of present and future HST cameras (WFPC2, ACS) will also benefit from the existence of a set of UV-NIR standards. For example, better accuracy of the near-infrared (> 0.85 μm) absolute flux and shape (including absorption lines) of the standard spectral energy distributions will lead to an improved precision in the absolute calibration of the WFPC2 near-infrared filters (F814W, F953N, and F1042M), and future ACS filters.

3. The HST Set of Absolute Standards

The proposed list of standards consists of 29 stars (see Table 1 for a complete listing): 26 Oke standards for which ultraviolet and optical spectra on the white dwarf scale are already available (Bohlin 1996), plus three new solar analog standards selected for the absolute calibration of NICMOS, and for which FOS spectra are being obtained in the second half of 1996.

All stars in Table 1 have accurate ground-based broad-band photometry obtained by A. Landolt (white dwarfs and hot early-type stars), and by M. Rieke (solar analogs). Stars with priority 1 (7 in total) form the core of the HST set of absolute standards. This group consist of the four primary pure hydrogen white dwarfs (G191B2B, GD71, GD153, and HZ43), and the three solar analogs (P041C, P177D, and P330E). Ten more standards (priority 2 in Table 1) are widely used in the absolute calibration and photometric monitoring of HST instruments. Stars with priority 3 (12 in total) form the complementary set of HST absolute standards needed to cover a wider range in apparent magnitude and to extend the sky coverage.

Table 1. List of HST Absolute Spectrophotometric Standards

Name	V	B-V	Priority
AGK+81D266	11.936	-0.340	2
BD+25D4655	9.69	-0.31	3
BD+28D4211	10.509	-0.341	2
BD+33D2642	10.828	-0.166	2
BD+75D325	9.548	-0.334	2
Feige110	11.831	-0.304	3
Feige34	11.181	-0.343	2
Feige66	10.509	-0.289	3
Feige67	11.822	-0.343	3
G191B2B	11.781	-0.326	1
G93-48	12.739	-0.008	3
GD108	13.561	-0.215	3
GD153	13.346	-0.286	1
GD50	14.063	-0.276	3
GD71	13.032	-0.249	1

Name	V	B-V	Priority
GRW+70D5824	12.773	-0.091	2
HD93521	7.04	-0.27	2
HZ21	14.688	-0.327	2
HZ2	13.881	-0.092	3
HZ43	12.643	-0.092	1
HZ44	11.673	-0.291	2
HZ4	14.506	+0.086	2
LB227	15.323	+0.055	3
LDS749B	14.677	-0.044	3
LTT9491	14.100	+0.026	3
NGC7293	13.527	-0.366	3
P041C	11.99	+0.62	1
P177D	13.50	+0.63	1
P330E	13.03	+0.63	1

4. Observational Strategy and Technical Feasibility

The core proposal involves NICMOS and STIS observations of the 17 standards listed as priority 1 and 2 in the table above. Priority 1 stars are the primary standards for the absolute calibration of STIS (white dwarfs), and NICMOS (solar analogs). STIS and NICMOS observations of these stars are planned early in cycle 7 to establish the inverse sensitivity curves of STIS and NICMOS. Priority 2 stars are not directly needed for the calibration of the new instruments but near-infrared observations are recommended (for specific reasons see section 2).

Observations with NICMOS grisms provide low resolution spectra (resolving power ~ 200) of the standard stars over the 0.8 µm to 2.5 µm spectral range. The 0.8 µm to 1.1 µm range will be covered by STIS low resolution mode (resolving power ~ 500).

NICMOS observations will use the three available grism settings, G096, G141, and G206. For a S/N of at least 30, typical on-source observing times would be 1 to 25 minutes per setting. Overheads including guide star acquisition, instrument setup, readouts and ditherings account for about 10 additional minutes. Therefore, NICMOS observations of a target, covering the 0.8 µm to 2.5 µm spectral range, can be packed in one single orbit.

STIS observations will use the G750L grating with an effective resolution of about 15Å. Typical exposure times per target will be 10 to 30 minutes, for a S/N of 30. Overheads including guide star and target acquisition as well as crsplit account for about 20 additional minutes. Thus, one orbit per target would be required to obtain a medium resolution 0.8 μm to 1.1 μm spectrum.

NICMOS G096 and STIS spectra of the standards will provide a direct cross-instrument calibration check, although neither of the two instruments has its optimal sensitivity in the spectral region of overlap.

As in previous calibration proposals (FOS observations of white dwarfs and solar analogs), two visits per target separated by at least two weeks are required to establish reliable standards by verifying the repeatability of the observations and to check for stellar variability. All priority 1 & 2 standards are bright enough to obtain a high quality spectrum (S/N > 30, spectral coverage 0.8 μm to 2.5 μm) in two orbits, one for STIS and one more for NICMOS. During the first year (cycle 7), a total of 34 orbits would be needed to obtain the complete 0.8 μm to 2.5 μm spectra for all 17 standards. During the second year, NICMOS and STIS observations of the same stars would be repeated.

A few additional faint (m_V ~ 13.5 - 15.5) standards, selected from the priority 3 stars listed in table 1 (see section 3), would be observed in future cycles. The combined STIS and NICMOS observations for priority 3 stars would require no more than 30 orbits per year, for a period of two years.

5. Accuracy of the Near-infrared Absolute Flux of the Standards

The present set of HST standards are calibrated on the white dwarf scale. Calculated model atmosphere flux distributions (Koester 1995) for four pure hydrogen white dwarfs (G191B2B, GD71, GD153, & HZ43) provide the fundamental basis for the set of spectrophotometric standards. Since the model calculations extend to 3.0 μm and cover the long-wavelength limits of STIS and NICMOS, these models can also be used as the basis for the extension to the near-infrared of the present set of absolute standards.

In addition to Koester's models, independent NLTE model atmospheres have been computed by Hubeny for the same temperatures and gravities. If the models are normalized at V, the largest differences in the continuum fluxes of the two independent calculations are for the hottest white dwarf (G191B2B) where Hubeny flux is ~0.5% lower below 0.35 μm and up to 3.5% higher at 2.5 μm (Bohlin 1996) . Thus, the use of pure hydrogen white dwarf model atmospheres as the basis for the set of spectrophotometric standards, introduces an uncertainty of about 3% in the absolute flux beyond ~ 2 μm.

The absolute flux distribution of the standard stars in the near-infrared can also be obtained using the solar analog method (Campins, Rieke, & Lebofsky 1985) . The final accuracy in the absolute flux using this method relies on (1) the uncertainty in the absolute calibrated near-infrared spectrum of the Sun (Colina, Bohlin, & Castelli 1996), (2) on the uncertainty in the differences between the selected solar analog spectral energy distributions and the solar spectrum (Colina et al. in preparation), and (3) on the uncertainty in the near-infrared photometry of the solar analogs (Rieke et al. in preparation). The combination of these uncertainties is unlikely to be less than 4%.

In summary, the near-infrared absolute flux derived using either the white dwarf scale or the solar analog scale will have intrinsic uncertainties of 3% to 4%. Additional uncertainties in NICMOS observations will increase the final uncertainty in the flux of our standards and could be as high as ~ 20% in the near-infrared, i.e. beyond 1.1μm .

6. Results of the Program

The results of the present program will be a complete set of absolute calibrated spectra of standards covering the 0.8 μm to 2.5 μm spectral range. These spectra will be combined with the already available ultraviolet and optical spectra of these stars. As a result, a homogeneous set of absolute calibrated spectra of spectrophotometric standards for the 0.12 μm to 2.5 μm wavelength range will be generated for the first time. The resulting spectra will be made available electronically for a wide and easy access by HST users and by the entire astronomical community.

7. Summary

This report describes a proposal to create a homogeneous set of absolute calibration standards in the 0.12 μm to 2.5 μm spectral range by obtaining STIS and NICMOS spectra of the present set of HST absolute calibration stars. This proposal will be submitted as part of the Calibration Plan for Cycle 7 and as such, approval will be required prior to execution. Inputs from the community regarding the content of the proposal are appreciated.

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