THE LICK-INDEX CALIBRATION OF THE GEMINI MULTI-OBJECT SPECTROGRAPHS

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ABSTRACT

We present the calibration of the spectroscopic Lick/IDS standard line-index system for measurements obtained with the Gemini Multi-Object Spectrographs known as GMOS-North and GMOS-South. We provide linear correction functions for each of the 25 standard Lick line indices for the B600 grism and two instrumental setups, one with 0.5 slit width and 1 × 1 CCD pixel binning (corresponding to ∼2.5 Å spectral resolution) and the other with 0.75 slit width and 2 × 2 binning (∼4 Å). We find small and well-defined correction terms for the set of Balmer indices Hβ, Hγ, and Hδλ along with the metallicity sensitive indices Fe5015, Fe5270, Fe5335, Fe5406, Mg2, and Mgb that are widely used for stellar population diagnostics of distant stellar systems. We find other indices that sample molecular absorption bands, such as TiO1 and TiO2, with very wide wavelength coverage or indices that sample very weak molecular and atomic absorption features, such as Mg1, as well as indices with particularly narrow passband definitions, such as Fe4384, Ca4455, Fe4531, Ca4227, and Fe5782, which are less robustly calibrated. These indices should be used with caution.

Key words: methods: data analysis – techniques: spectroscopic

Online-only material: color figures

1. INTRODUCTION

The spectroscopic Lick index system was introduced by Burstein et al. (1984) in order to homogenize the study of low-resolution integrated-light spectra of elliptical galaxies and other extragalactic stellar systems. It is based on observations carried out with the Cassegrain image dissector scanner (IDS) spectrograph at the 3 m Shane telescope of the Lick Observatory and has been continuously updated and refined by several subsequent works (e.g., Worthey et al. 1994; Worthey & Ottaviani 1997; Trager et al. 1998). In its current form it defines 25 widely used line indices for specific atomic and molecular absorption features in the optical wavelength range from ∼4040 to ∼6420 Å. The precise definition of line index passbands allows a reproducible measurement and uniform interpretation of spectroscopic data, in particular of index combinations sensitive to luminosity-weighted stellar population age and various chemical abundances. Because the Lick system was initially devised to study the integrated-light spectra of massive early-type galaxies with high velocity dispersions (Burstein et al. 1984; Worthey 1994; Worthey & Ottaviani 1997), the spectral indices are defined for low spectral resolution at about R ≲ 700, which is equivalent to a spectral resolution of 8–11 Å in the optical (see Figure 7 in Worthey & Ottaviani 1997). However, higher resolution index definitions, which are formally more sensitive to the absorption feature of interest (e.g., Vazdekis et al. 2010), deliver lower signal-to-noise with the same instrumental setup and exposure time. In general, spectral resolution and integration times have to be traded for any index system to yield the most efficient observing program and most robust index measurements depending on the target luminosity.

That said, the great advantage of the Lick system is its comprehensive library of nearby-star stellar spectra covering a large parameter space in log g, Teff, and metallicity. This library is the foundation of many population synthesis models that use fitting functions computed from this library (Tripicco & Bell 1995) to model predictions of Lick index strengths as a function stellar-population age and chemical composition for simple and composite stellar populations (see, e.g., Trager et al. 2000; Thomas et al. 2003, 2004). One can then use such model predictions to derive ages and chemical makeups of distant stellar populations, such as galaxies (e.g., Thomas et al. 2005) and globular clusters (e.g., Puzia et al. 2005), provided the observed spectra match the spectroscopic characteristics of the IDS Lick spectrograph in terms of wavelength coverage, spectroscopic resolution, and continuum flux calibration. Calibrating spectroscopic index measurements onto the Lick system is usually done by re-observing stars from the Lick standard star library (Worthey et al. 1994) with the same instrumental configuration that is being used for science observations (see, e.g., Puzia et al. 2002). The purpose of this work is to provide such Lick index calibrations for the Gemini Multi-Object Spectrographs at the Gemini North and Gemini South Observatory for the most commonly used B600 grating and spectrograph setups.

2. OBSERVATIONS

All spectroscopic observations were collected using both telescopes of the Gemini Observatory. The first campaign was conducted with the Gemini Multi-Object Spectrograph (GMOS) on the 8.2 m Gemini-North telescope on Mauna Kea in Hawaii (hereafter GMOS-N) as part of the programs GN-2002A-Q-17, GN-2002B-Q-77, GN-2003A-Q-75, and GN-2004A-Q-94.
The selection criteria are (1) integral field spectrograph project (Kuntschner et al. 2006).
standard star list selected by H. Kuntschner for the SAURON telescope on Cerro Pachón in Chile (hereafter GMOS-S) as part of programs GS-2003B-Q-63 and GS-2004A-Q-62 (see Table 1 for a log of all GMOS observations).

2.1. Sample Selection
The stars observed by us are so-called “secondary Lick standards” that were used to derive the fitting functions in many population synthesis models (Worthey 1994; Faber et al. 1985; Trager et al. 1998). Since most of these sample stars were observed only 1–3 times at Lick observatory (except for HD184406 and HD165760, which were observed 64 and 40 times, respectively) part of the scatter in the calibrations will be associated with the uncertainties in the Lick measurements themselves. Our star sample is a subset of the total Lick/IDS standard star list selected by H. Kuntschner for the SAURON integral field spectrograph project (Kuntschner et al. 2006).

The selection criteria are (1) $-10^\circ < $ decl. $< 70^\circ$, (2) the star must be part of the Henry Draper (HD) Catalogue (see Nesterov et al. 1995, and references therein), and (3) the star must not be classified as peculiar. There are 233 stars in this subset spread across all R.A. coordinates. The SAURON project observed 73 of these stars as part of its survey of the dynamics and stellar populations of nearby early-type galaxies. Our subsample summarized in Table 1 facilitates therefore a comparison and cross-calibration option between SAURON and GMOS, and previous results from other instruments.

2.2. Spectrograph Configuration
At the time of our observations the twin GMOS instruments provided a wavelength coverage within 3600–9400 Å in long-slit and multi-slit mode over a 5.5′ × 5.5′ field of view. The instruments are equipped with three EEV CCDs with 2’8 gaps between the detector chips. Since the gaps run perpendicular to the dispersion direction, we took dithered sub-integrations with two different grating blaze angles (at $\lambda = 508$ and 510 nm) to cover the entire wavelength range. All standard star observations were performed in long-slit mode with the B600 grating with a wavelength coverage from 3800-6500 Å with a resolution of $R \approx 1500$. The “central spectrum” region of interest on the CCD detector was used to place the standard star along the spatial axis of the slit and to reduce the size of the corresponding files.

For the GMOS-N observations we used two instrumental setups with different detector chip binning factors and slit widths. In the following we refer to setting A as the configuration with 2 × 2 detector binning and 0’75 slit width (six stars with 13 individual observations) and to setting B with 1 × 1 binning and 0’5 slit width (11 stars with 35 individual observations). Most of the GMOS-N observations were conducted using the standard procedure of centering the target in the slit, however for GN-2003A-Q-75 the observations were unguided and the telescope was nodded such that the light from the stars moved across the narrow dimension of the slit aperture (perpendicular to the spatial axis and parallel to the dispersion axis). With this technique the light from the star fills the slit and the spectral resolution depends only on the slit width. The detectors were the original E2V devices EEV9273-16-03, EEV9273-20-04, and EEV9273-20-03. All observations at GMOS-S were conducted with the B setting (14 stars with 28 individual exposures). The detectors were E2V devices EEV 2037-06-03, EEV 8194-19-04, and EEV 8261-07-04. All the GMOS-S observations were carried out with the nodding method described above.

3. DATA REDUCTION
The data were reduced using common procedures for long-slit data. The Gemini GMOS IRAF package was used for most reduction steps. These scripts are mostly wrappers for standard IRAF9 tasks that handle the Gemini Multi-Extension FITS (MEF) data format. Differences from standard Gemini procedures are noted below.

3.1. Bias Subtraction and Flat Fielding
Bias subtraction was performed using average bias frames (0 s exposure time) taken the closest in time to a given Lick data set. It proved best to subtract the overscan from the average biases and the science data as the bias level drifts slowly with time. Care must be taken to use only the area of overscan that is farthest from the detector area so that the overscan is free from any contamination. This helps reducing artificial “jumps” in the spectra due to bias subtraction.

Flat field frames were created from quartz halogen lamp spectra taken before or after the Lick star exposures. The quartz lamp signature was removed using a wrapper script for the IRAF RESPONSE task. Since the effective slit length was shortened by using the “central spectrum” region of interest, twilight flats were not used to apply an illumination correction.

3.2. Wavelength Calibration
Wavelength calibration was done by fitting fourth-order Chebyshev polynomials to the positions of lines identified in CuAr arc lamp spectra, taken close in time of the stellar observations. The rms of the wavelength solutions was typically 0.2 Å. The wavelength solutions were measured on the two-dimensional spectra using the IRAF tasks AUTOIDENTIFY and REIDENTIFY and applied to the Lick standard star observations using the task TRANSFORM.

3.3. Scattered Light Subtraction
The three CCDs in each GMOS detector array were chosen to have similar quantum efficiency (QE) characteristics but there are still differences of a few percent that depend on wavelength. A method was developed to measure the relative QE curves of CCDs 1 and 3 relative to CCD 2. A correction to the QE differences as a function of wavelength can then be applied. This can further reduce or remove intensity jumps at the chip edges, with the result that the final spectra have a more uniform appearance and are easier to interpret.

3.4. Quantum Efficiency Corrections
Flat field frames were created from quartz halogen lamp spectra taken before or after the Lick star exposures. The quartz lamp signature was removed using a wrapper script for the IRAF RESPONSE task. Since the effective slit length was shortened by using the “central spectrum” region of interest, twilight flats were not used to apply an illumination correction.

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3.3. Scattered Light Subtraction
GMOS data suffer from scattered light, especially for central wavelengths shorter than 5200 Å. After the spectra were wavelength calibrated the IRAF task APSCATTER was used to fit the diffuse background light in each frame. Particular care was taken to fit and subtract the background light and not the light from the wings of the point spread function. Fit orders of 11 in X and 7 in Y gave good results. This step significantly improved the results for several of the stars, especially those of earlier spectral types. We point out that since the scattered-light component is a smoothly varying function of detector position that changes on spatial scales much larger than the individual absorption features measured by a Lick index, the contribution to the total Lick index uncertainty associated with this subtraction is negligible compared with variations in the sky subtraction.

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The three CCDs in each GMOS detector array were chosen to have similar quantum efficiency (QE) characteristics but there are still differences of a few percent that depend on wavelength. A method was developed to measure the relative QE curves of CCDs 1 and 3 relative to CCD 2. A correction to the QE differences as a function of wavelength can then be applied. This can further reduce or remove intensity jumps at the chip edges, with the result that the final spectra have a more uniform appearance and are easier to interpret.
the time of the observation there will be wavelength-dependent correctors so unless a slit is placed along the parallactic angle at a wavelength, both in units of Å.

The fitting functions give the spectral resolution in FWHM as a function of slit width), we observed 11 stars with 35 individual exposures. For the GMOS-S observations in setting B (1 x 1 binning and 0.5 slit width), we observed 10 stars with 20 individual exposures.

Note. For the GMOS-N observations setting A (2 x 2 binning and 0.75 wide slits), we obtained observations for 6 stars with 13 individual exposures, while for setting B (1 x 1 binning and 0.75 slit width), we observed 11 stars with 35 individual exposures. For the GMOS-S observations in setting B (1 x 1 binning and 0.5 slit width), we observed 10 stars with 20 individual exposures.

Table 2

Fitting Functions of GMOS Spectral Resolution

| Setup  | $a$ | $b \times 10^{-3}$ | $c \times 10^{-7}$ | rms |
|--------|-----|-------------------|-------------------|-----|
| GMOS-N/A | 8.86 ± 0.68 | −2.03 ± 0.27 | 1.95 ± 0.25 | 0.071 |
| GMOS-N/B | 5.17 ± 0.44 | −1.08 ± 0.17 | 1.06 ± 0.16 | 0.053 |
| GMOS-S/B | 5.17 ± 0.75 | −0.91 ± 0.30 | 0.82 ± 0.28 | 0.089 |

Note. The fitting functions give the spectral resolution in FWHM as a function of wavelength, both in units of Å.

3.5. Parallactic Angle Slit-loss Corrections

The GMOS instruments do not have atmospheric dispersion correctors so unless a slit is placed along the parallactic angle at the time of the observation there will be wavelength-dependent slit losses (Filippenko 1982). An IDL procedure was developed to calculate the slit losses based on the difference between the position angle of an observation and the parallactic angle and a correction applied to the spectra. While this does not restore the lost flux, it is important for making the continuum shapes from different observations similar enough that these spectra can be successfully averaged.

3.6. Flux Calibration

Relative flux calibrations were performed with observations of flux standard stars and analyzed with the IRAF tasks STANDARD and SENSFUNC (via the Gemini task GSTDNAND). The GMOS-N data were calibrated using observations of EG131 taken in 2002 June. The mean atmospheric extinction curve for Mauna Kea from the Gemini IRAF package was used. The GMOS-S data were calibrated using an observation of LTT 9239 from 2003 November. The atmospheric extinction curve for Cerro Paranal obtained from the ESO Web site was used for the GMOS-S data.

Each flux-calibrated spectrum was compared by eye with reference spectra of similar spectral type from the MILES library (Vazdekis et al. 2010) and duplicate observations of the same stars obtained with VLT/FORS (Puzia et al. 2005). We define the final sample of high-quality GMOS Lick standard-star spectra as those spectra for which we find flux discrepancies smaller than 20% between their final flux calibration and the reference spectra mentioned above. The final sample spectra
can be discarded as an outlier if its normal distribution probability is less than
12 Based on the mean and standard deviation of n data points, a measurement
can be discarded as an outlier if its normal distribution probability is less than

\((2\pi)^{-1}\) (see, e.g., Peirce 1852).

Figure 1. Comparison of the Lick/IDS spectral resolution, which is implicitly
hardwired in the Lick index system, and the corresponding resolutions for our
three GMOS instrument configurations.

(A color version of this figure is available in the online journal.)

Table 3

| Index | Feature Passband | Blue Continuum | Red Continuum | Units |
|-------|------------------|----------------|---------------|-------|
| H6_A | 4083.500 4122.250 | 4041.600 4079.750 | 4128.500 4161.000 | Å |
| H6_F | 4091.000 4112.250 | 4087.250 4088.500 | 4114.750 4137.250 | Å |
| CN1  | 4143.375 4178.375 | 4081.375 4118.875 | 4245.375 4285.375 | mag |
| CN2  | 4143.375 4178.375 | 4085.125 4097.625 | 4245.375 4285.375 | mag |
| CaT2 | 4223.500 4236.000 | 4212.250 4221.000 | 4242.250 4252.250 | Å |
| G4300| 4282.625 4317.625 | 4267.625 4283.875 | 4320.125 4336.375 | Å |
| H6_A | 4319.750 4363.500 | 4283.500 4319.750 | 4367.250 4419.750 | Å |
| H6_F | 4331.250 4352.500 | 4283.500 4319.750 | 4354.750 4384.750 | Å |
| Fe4383| 4370.375 4421.500 | 4360.375 4371.625 | 4444.125 4456.625 | Å |
| Fe4455| 4453.375 4475.875 | 4447.125 4455.875 | 4478.375 4493.375 | Å |
| Fe4531| 4515.500 4560.500 | 4505.500 4515.500 | 4561.750 4580.500 | Å |
| Fe4677| 4635.250 4721.500 | 4612.750 4631.500 | 4744.000 4757.250 | Å |
| Fe5015| 4977.750 5054.000 | 4946.500 4977.750 | 5054.000 5065.250 | Å |
| Mg1  | 5069.125 5134.125 | 4895.125 4957.625 | 5301.125 5366.125 | mag |
| Mg2  | 5154.125 5196.625 | 4895.125 4957.625 | 5301.125 5366.125 | mag |
| Fe5b  | 5260.125 5320.625 | 5142.625 5161.375 | 5191.375 5206.375 | Å |
| CaTb  | 5245.650 5285.650 | 5233.150 5248.150 | 5285.650 5318.150 | Å |
| Fe5353| 5312.125 5352.125 | 5304.625 5318.875 | 5353.375 5363.375 | Å |
| Fe5406| 5387.500 5415.000 | 5376.250 5387.500 | 5415.000 5425.000 | Å |
| Fe5709| 5698.375 5722.125 | 5674.625 5698.375 | 5724.500 5738.375 | Å |
| Fe5782| 5788.375 5798.375 | 5767.125 5777.125 | 5799.625 5813.375 | Å |
| NaD  | 5878.625 5911.125 | 5862.375 5877.375 | 5923.875 5949.875 | Å |
| TiO1  | 5938.375 5959.875 | 5981.375 5850.875 | 6040.375 6105.375 | mag |
| TiO2  | 6191.375 6273.875 | 6068.375 6143.375 | 6374.375 6416.875 | mag |

Notes. The above passband definitions are for the full set of 25 Lick indices that are used in this work. The index definitions were taken from Worthey (1994) and Worthey & Ottaviani (1997). The units of each index are given in the last column.

4. ANALYSIS

4.1. Spectral Resolution

The spectral resolution of our GMOS-N observations for the two instrument configurations was determined using the FWHM of wavelength-calibration lamp emission lines and found to be very well approximated by polynomial functions for the instrument setup A (2 × 2–0.75") and setup B (1 × 1–0.5"):

FWHM\(_i\)(\(\lambda\)) = a + b\(\lambda\) + c\(\lambda^2\)

where FWHM\(_i\)(\(\lambda\)) is for the \(i\)th setup, \(\lambda\) is in units of Å. Table 2 summarizes the coefficients and quantifies the fit quality for all instrumental setups. Note that for instrument setup B the spectral resolutions of GMOS-N and GMOS-S are relatively similar and that all three GMOS configurations are significantly smaller than the nominal spectral resolution of the Lick index systems.
(Worthy & Ottaviani 1997). The spectral resolutions of the various GMOS configurations and the Lick/IDS resolution are shown in Figure 1. These analytic functions serve as baseline to broaden the GMOS spectra to the Lick/IDS spectral resolution before applying the index measuring routines. The smoothing of our sample spectra is performed with a wavelength-dependent Gaussian kernel with

$$\sigma_{\text{smooth}}(\lambda) = \left( \frac{\text{FWHM}(\lambda)^2 - \text{FWHM}(\lambda)^2}{8 \ln 2} \right)^{1/2}.$$
Ca4455 − Mg1 0.03 0.01 0.05 0.9470 0.0279
Fe5015 H H
TiO1 0.01 0.01 0.02 0.7323 0.1210
Fe4383 0.85 0.36 1.31 0.5556 0.2616 2.3222 1.2843 0.4873
− G4300 − Ca4227
See Figure 5 for an illustration of the corresponding Lick index correction terms that are being used in Equations (5) and (6).

Hδ absorption features, which are calculated in Å. For molecular line index pseudo features of interest, as illustrated in Figure 2. To determine the absorption or emission features is the accurate definition of the λ continuum. From the distribution of index values the 1σ standard deviation defines the total Lick index uncertainty. Note that instead of transforming the spectrum to the rest frame the code shifts the index passbands to the observed redshift to avoid pixel noise correlation effects for narrowly defined indices.

where FWHM_{i} describes the spectral resolution of the corresponding instrument setup.

4.2. Lick Index Measurements

A crucial part of measuring the strength of spectroscopic absorption or emission features is the accurate definition of the adjacent continuum. The Lick system bypasses this complication by defining a pseudo-continuum around strong absorption features of interest, as illustrated in Figure 2. To determine the continuum level inside the feature passband a linear interpolation of the mean fluxes in two satellite passbands is performed, which defines the pseudo-continuum flux F_{c}. The feature and pseudo-continuum passband definitions are summarized in Table 3.

The ratio of the feature passband between the absorption line F_{1} and the pseudo-continuum F_{c} is then used to define the line index

I_{a} = \int_{\lambda_{min}}^{\lambda_{max}} \left(1 - \frac{F_{1}(\lambda)}{F_{c}(\lambda)}\right) d\lambda \tag{1}

in units of magnitudes,\textsuperscript{13} where \(\Delta_{\lambda} = \lambda_{\text{max}} - \lambda_{\text{min}}\). The transformation between the Å and magnitude scale can be performed with the following two equations

\begin{align*}
I_{a} &= \Delta_{\lambda}(1 - 10^{-0.4I_{m}}), \tag{3} \\
I_{m} &= -2.5 \log \left(1 - \frac{I_{a}}{\Delta_{\lambda}}\right). \tag{4}
\end{align*}

The Lick line index strengths for our sample stars, as defined by Equations (1) and (2) together with the passband definitions summarized in Table 3, were measured with the GONZO code that is described in detail in Puza et al. (2002, 2005). The GMOS science and variance spectra are used to generate the uncertainty of the Lick index measurements via Monte Carlo simulations. The indices are re-measured on the Poisson noise-altered spectra. From the distribution of index values the 1σ standard deviation defines the total Lick index uncertainty.

4.3. Lick Index-system Calibration

Using the full data set we determine the mean index correction terms to the Lick system for each instrument setup and calculate the corresponding rms. For each index, outliers are rejected

\textsuperscript{13} One exception is the G4300 index, which is traditionally measured in Å, although the strength of the dominant feature is driven by the CH molecule abundance.
using Chauvenet criteria as described above. From the selected data we derive the mean correction in the sense

\[ I_{\text{Lick}} = I_{\text{GMOS}} + \delta \]  

(see dashed lines in Figures 3, 4, and 5), the error of the mean correction, \( \Delta \delta \), and the dispersion, \( \sigma(\delta) \). The numerical values of these parameters are summarized in Columns 2–4 of Tables 4, 5, and 6. We also fit linear relations of the form

\[ I_{\text{Lick}} = a \times I_{\text{GMOS}} + b \]  

(6)
to the selected data (dotted lines in Figures 3, 4, and 5) and determine the uncertainties, \( \Delta a \) and \( \Delta b \), as well as the root mean square and the range over which the fit is valid. All parameter values are tabulated in Columns 5–11 of Tables 4, 5, and 6. Note that our Lick standard-star sample covers a large dynamic range in each index, allowing for a robust correction as a function of index strength. Figures 3, 4, and 5 illustrate the comparison between Lick index system and our measurements for the three instrument configurations. The plots show the overall quality of the Lick index calibration for the three spectroscopic settings. We point out that although the sampling range of each index varies from epoch to epoch the overall fit quality is not driven by any particular sub-sample. In particular, the most important Lick indices that are typically used in stellar population analyses.
Figure 3. Comparison plots between original Lick system measurements and Lick index measurements from our standard-star GMOS-N spectra obtained with setup A: 2 × 2 binning and 0.75″ slit width. In each panel, the solid lines are the identity relations, while dashed lines illustrate the mean linear offset corrections. Dotted lines are weighted least-square fits to the solid data points. Open circles mark data that were rejected using Chauvenet criteria (see text for details). The corresponding correction terms are summarized in Table 4. Note that very few data points have error bars larger than the symbol size.

(A color version of this figure is available in the online journal.)

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(A color version of this figure is available in the online journal.)

(5. SUMMARY)

We provide Lick index calibration functions for the GMOS-N and GMOS-S spectrograph using two instrumental configurations, namely with 2 × 2 binning and 0.75″ slit width (setup A).
Figure 4. Comparison plots similar to Figure 3, but this time for GMOS-N spectra obtained with setup B: $1 \times 1$ binning and 0.5″ slit width. The different color shadings indicate three different data sets from the observing periods 2002B, 2003A, and 2004A. The corresponding correction terms are summarized in Table 5.

(A color version of this figure is available in the online journal.)

and with $1 \times 1$ binning and 0.5″ slit width (setup B). The quality of the linear correction terms shows that widely used Lick indices such as the Balmer indices $H\beta$, $H\gamma_A$, and $H\delta_A$ along with metallicity sensitive indices $Fe5015$, $Fe5270$, $Fe5335$, $Fe5406$, $Mg_2$, and $Mgb$ can be robustly calibrated and thus used to derive stellar population parameters by comparison with predictions of stellar population synthesis models that use the exact same Lick index definitions. Indices that sample many weak features or molecular absorption bands, such as $Mg_1$, TiO$_1$, and TiO$_2$, with very wide wavelength coverage or indices with particularly narrow passband definitions, such as $Fe4384$, Ca4455, Fe4531, Ca4227, and Fe5782, are less robustly calibrated and should be used with caution.

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Figure 5. Comparison plots similar to Figure 3, but this time for GMOS-S spectra obtained with setup B: 1 × 1 binning and 0.5” slit width. The different color shadings indicate two different data set from the observing periods 2003B and 2004A. The corresponding correction terms are summarized in Table 6.

(A color version of this figure is available in the online journal.)

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ERRATUM: “THE LICK-INDEX CALIBRATION OF THE GEMINI MULTI-OBJECT SPECTROGRAPHS” (2013, AJ, 145, 164)

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Due to a typographical computer scripting issue, Equations (5) and (6) were not reproduced correctly in the original paper. The correct equations read

\[ I_{\text{GMOS}} = I_{\text{Lick}} + \delta \]  \hspace{1cm} (5)

and

\[ I_{\text{GMOS}} = a \times I_{\text{Lick}} + b. \]  \hspace{1cm} (6)

The corresponding tabulated parameters \( a \), \( b \), and \( \delta \) and the figures are correct. None of the results are affected.