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A SPECTRAL ATLAS OF LANDOLT STARS FOR A RELIABLE MID-IR SPECTROPHOTOMETRIC CALIBRATION FOR LARGE TELESCOPES

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It is often stated that there is no point in obtaining mid-infrared data with $S/N > 20$, even in the best of cases, because it is impossible to obtain a calibration to better than 5%, although in many cases 10% or greater is a more accurate reflection of the true quality of calibration. Mid-infrared calibration is difficult because of the lack of measured standards and their generally poor quality and also because of the rapid variability of the atmospheric transparency that requires great care to be taken. The mid-infrared standards that have served for a generation of 3 m class telescopes are found to be inadequate for the new generation of 8–10 m class telescopes as the sensitivity of a telescope in the mid-IR goes as the fourth power of the increase in diameter. We describe our efforts to prepare a new set of mid-infrared standards adapted to the needs of 10 m class telescopes as a part of the photometric, spectrophotometric and polarimetric calibration for the CanariCam project (Martín-Luis et al. 2001).

1. STATING THE PROBLEM

Spectrophotometric calibration is a major astronomical problem that is often ignored or at least understated. Without a reliable calibration it may be difficult to compare time series of data, or data taken with different instruments. Calibration errors add to the uncertainties in the data and combine with the uncertainties in measuring the extinction to create a significant problem for the astronomer.

At present, the typical recommendation to obtain a good calibration is to spend some 30% of all observing time in measuring standard stars. With time on the GTC valued at $1 per second, this implies that in a 10-hour night, the equivalent of $10 800 ($4 million per year) of observing time is used on observations other than science.

Very few mid-infrared calibration stars have been published (Rieke et al. 1985; Tokunaga et al. 1986) and they are generally very bright (the UKIRT list has only one star fainter than $N = +3$)and poorly distributed in the sky.

For an efficient calibration of CanariCam we require stars mainly in the range $+6 < N < +8$ for broad band imaging and somewhat brighter stars for spectroscopy. However, it is also essential to have some much fainter stars ($+11 < N < +16$) of accurately known flux to test the data reduction pipeline and check instrument sensitivity on a regular basis.

CanariCam will have approximately 22 broad and narrow band filters and four spectroscopic configurations. Just calibrating twenty new stars for CanariCam would thus imply obtaining more than 500 sets of independent spectrophotometry. To obtain a reliable all-sky network of stars (several hundred stars with relative precision close to 1%) is prohibitively difficult and costly in telescope time using the traditional methods of calibration.

2. SOLVING THE PROBLEM

The method that we are using is one of stellar templates developed by Cohen (1999). We take stars of known spectral energy distribution (SED), or with a SED that may be calculated easily with current models. Rather than measure the star's flux in 26 passbands, we use observations in the visible, near IR and mid IR to fix the level of the known SED and then convolve this SED with the instrument's bandpasses and the atmosphere at the ORM and calculate fluxes for any passband that we require.

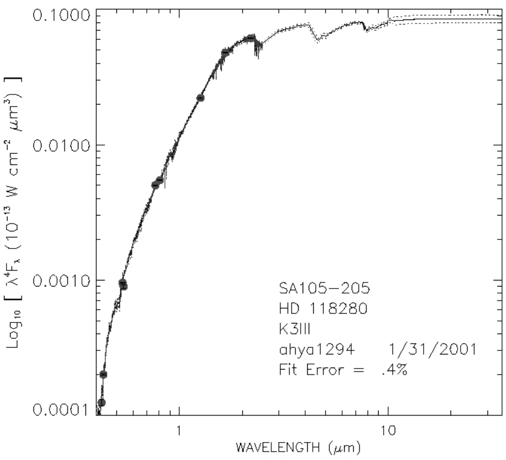

Fig. 1. Template generated for HD 118280.

Using high quality visible and near-IR (1% precision level) and mid-IR (*IRAS* and *MSX*) photometry and a well-determined spectral type, the SED may be determined with a high degree of accuracy (see Figures 1 and 2).

We use two classes of stars for the templates:

K giants These stars have a well-defined SED as a complete spectrum from 0.3–30 μm has been defined for a number of prototype stars from ground-based data and from *IRAS*, *ISO*, and KAO observations.

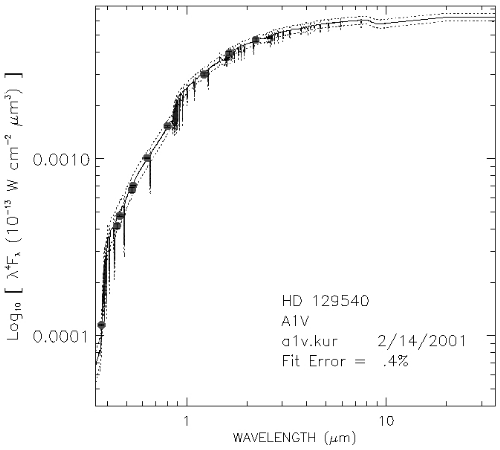

Fig. 2. Template generated for HD 129450.

Stars from K0 III to M2 III may be used. As red stars, they form the basis of the bright end of the CanariCam distribution with $V - N = 2$–4 magnitudes.

Early Main Sequence A Stars These stars have good atmospheric models, neutral colors and, up to A5 V, weak metal lines. This makes them suitable as faint standards, as to obtain a star of $N = +7$ a star of $V = +7$ is sufficient.

3. RESOLVING THE PROBLEM

An ideal set of accurately measured stars already exists in the Landolt stars. These have excellent *UBVRI* photometry, and many have been measured in *JHK*. The brighter and redder stars in the Landolt list also have *IRAS* 12 and 25 μm data. A second, and much larger, sample is the *Hipparchos*/Tycho stars. These have fewer bands measured, but the photometric precision is even higher than for Landolt stars. Unfortunately, few Landolt stars have high quality spectral types. The template fitting method allows a small shift in the assumed spectral class (e.g., from A1 V to A2 V) to be tested to see if it improves the fit, but this uncertainty introduces a dangerous free parameter.

We have thus carried out a program of spectral typing of Landolt stars with INT + IDS. Potential A V and K III/M III stars were selected by color. A total of 279 spectra were taken. Of these, 62 are identified as type A(0–5) V. The stars will typically be only 0.2 magnitudes brighter at 10 μm. Analysis is currently being carried out of the spectra of potential type K/M III stars, but we know that there are at least 90 in the sample observed, giving us a total of at least 150 templatable stars in the Landolt lists. Combined with other observing campaigns we now have >200 stars with sufficient data to be templated for CanariCam calibration.

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