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CALIBRATION FOR LARGE TELESCOPES: STATUS AND PROSPECTS

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We discuss the status of the calibration programme for CanariCam and related initiatives that aim to provide quality calibration facilities for users of the GTC and other telescopes. We have Visible and IR photometry of >300 stars apt for the calibration of CanariCam giving an initial density of ∼1 star per 100 square degrees of sky. The uncertainties in the visible data are typically ≤0.01mags and somewhat better in the near-IR. A revised catalogue of photometry of field stars of 26 AGNs has been produced with 43 000 observations of 437 stars, adding some 5000 additional visible measures. We have collaborated actively in the calibration of IRAC on SIRTF, providing the largest submission of input data received by the IRAC calibration team. Our data quality is excellent, exceeding that of any other submission by a significant factor.

Introducción

Calibration is an increasingly important problem and is now one of the major limitations on the science that can be obtained with large telescopes. At longer wavelengths obtaining a high-quality calibration becomes increasingly difficult due to the importance of both the two-dimensional structure and variability of the sky background. In the mid-IR a major crisis in calibration has occurred as the combination of new, large telescopes and highly sensitive instruments has led to a huge increase in sensitivity. CanariCam + GTC will be 5 mags (2 orders of magnitude) more sensitive than OSCIR + IRTF. The mid-IR standards that have been used for many years are both extremely bright and sparsely distributed in the sky.

In the visible large telescopes create new calibration problems as the majority of Landolt stars are brighter than V=12 and thus totally unsuitable even for 2-m class telescopes. Similarly, the distribution of stars is unsuitable as Landolt stars are mainly limited to the celestial equator. Even in the near-IR the density of faint standards on the sky is poor.

An instrument such as CanariCam is especially difficult to calibrate as it has many filters and observing modes.

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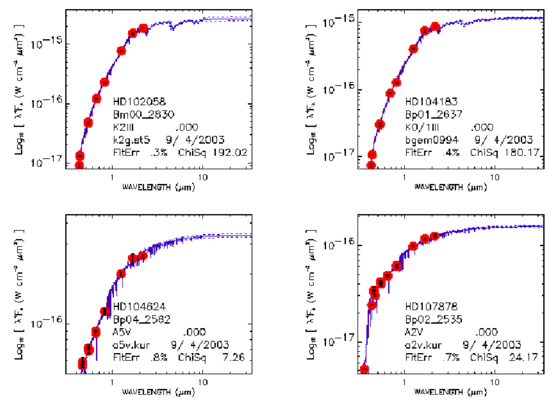

Fig. 1. A sample of template spectra for stars of different spectral types.

Requirements

IRAC and CanariCam have similar requirements: well-calibrated and well-understood stars that are non-variable in the IR and have no significant pathology that would affect their use.

• IRAC requires stars at the two ecliptic poles (the regions of continuous visibility) and coverage around the ecliptic (2 stars per hour of RA).

• CanariCam requires stars to be evenly distributed around the whole sky visible to the GTC. For Day 1 we have set a requirement of calibrating one star per 10×10° of sky -300 stars in total.

• Both require a distribution of fluxes adapted to the sensitivity of the instrument. For CanariCam, stars with magnitude typically in the range 5<N<8, giving s/n>100 in 100s of integration. IRAC has a similar flux requirement. Both need both brighter stars (for high-resolution and narrow-band measurements) and fainter ones (for engineering trials).

We require a dense and homogeneous spatial distribution of stars for CanariCam due to the condition of the IR sky. As the sky transparency and flux is dominated by water vapour which is highly variable over scales of a few degrees, while the sky background varies on timescales of minutes and less, it is strongly preferred that calibration should be carried out against a nearby flux standard, observed as near in time as possible to the source to be calibrated.

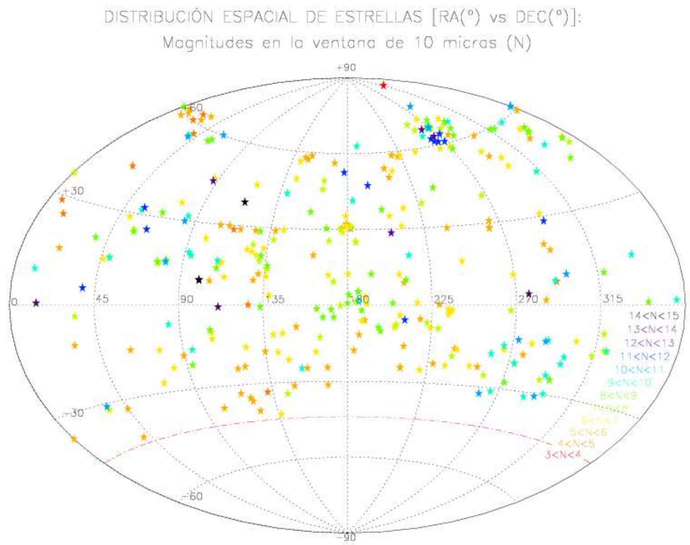

Fig. 2. The spatial distribution of all observed stars by magnitude N.

How do we do it?

Traditional calibration methods are slow and labour intensive. To calibrate CanariCam we would need to observe some 300 stars at multiple epochs using each filter and spectroscopic resolution that is to be calibrated. This would require some 400 000 individual integrations and ∼20 years to carry out.

Instead, we use a powerful method using templates and stellar atmospheric models.

- We use **KIII stars** (well measured empirical spectra from 0.3-30μm from ground-based and satellite photometry) and **A0-5V stars** (relatively simple atmospheric models and weak metal lines).
- We combine an accurate spectral type (to ±1 sub-type), with precise photometry of the star to be modelled. The more bands covered and the more precise the photometry, the better the results.
- We select a template or model for the appropriate spectral type that gives us the expected distribution of flux from 0.3-30μm.
- We calculate the extinction from the (B-V) colour excess for the star to be calibrated and apply this extinction to the template.
- We fit the reddened template to the photometric data to calibrate the absolute level of flux.
- The fitted template is then convolved with the filter profiles and instrument response to give the flux at the detector.
- The selected stars are observed at Teide Observatory in the 82-cm IAC-80 (BVRI) and 1.5-m CST (JHK) and with the 1-m JKT in the Roque de los Muchachos Observatory.
- Confirmation of the spectral type is obtained using observations with the IDS on the 2.5-m INT, or with ALFOSC on the 2.56-m NOT.

Results

- **Observations -** We have observed more than 300 stars in the visible and IR. Most have been observed at multiple epochs. Spectral types have been measured for 316 stars. Further stars will be observed in the NOT in September 2004. 43 000 measures of AGN field stars have also been made on ∼100 nights.
- **Uncertainties -** The uncertainties in the magnitudes of programme stars are typically $<$0.01mags over the range 7.5$<$V$<$12. For the stars in AGN fields they are typically $<$0.01mags to V=15. Even at V=19 we obtain uncertainties of ∼0.05mags. For bright stars in JHK they are $<$0.005mags.

125 high-quality templates have been generated to date. These are the basis for the IRAC calibration and will form the nucleus of the CanariCam calibration. More than 600 templates already exist, mainly for bright stars of interest for calibration of narrow-band photometry and spectroscopy.

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