Req 5.6.3

**Title:**
Photometric Calibration - Zeropoint key bands - doit

**Objective:**
Determine the zeropoint of the overall detector chain, separately for each CCD chip, in all four keybands (no composite filter) and the true atmospheric extinction at midnight by measuring standard stars in the 4 key passbands in one of the eight equatorial fields and the polar field. Do this every night whatever the science programme on the telescope may be. Optionally, add one observation of another equatorial standard field with higher airmass to obtain a redundant, classical, measurement of the atmospheric extinction.

The keybands plus the two-lens corrector form the standard for this requirement, the use of the ADC is considered as User mode (see req.564).

The zeropoint corresponding to the DQE of each of the 32 CCD chips will be determined on an individual chip basis \( g_{DQE}(0, N, X) \). Thus the composite filter can not be used for this. However, additional data will be acquired with the composite filter for redundancy. In case the relative gain variations of individual CCD chips appear small and well characterized by the overall flatfield (which is not really expected) then the req. might be fulfilled with only the composite filter, substantially relieving the data rate and workload.

The combination of the data of req. 562 Monitoring taken at the middle of the night with the present zeropoint data will be used to solve separately for the effect of the extinction and DQE at the middle of the night. A standard extinction curve will be used as a reference, for error analysis, and to support the derivation of the solutions in the pipeline processing.

As **primary standards** the Landolt equatorial fields will be used, possibly extended with preparatory programme results (Section 7 of CP). For each of the 8 equatorial fields a solution for **secondary standard** stars will be made for a larger, one degree, field of view. The acquisition of catalogues of secondary standards is discussed in req.569. These secondary standards data will be used for the nightly determination of the zeropoint.

During commissioning the reproducibility of the zeropoint determination should be verified for the different observing modes **Mode—jitter** \( N=5 \) and **Mode—dither** \( N=5 \). This also serves as an end-to-end-test.

In the case that composite filter data is used for the analysis, the transformation between composite and monolithic key band filters should be taken into account
Fulfilling or fulfilled by:
selfstanding, but uses data of req.562 at the middle of the night.

When performed/frequency:
Once in the middle of each night. The linking of external (primary) to internal
(secondary) standards will be done once during commissioning, and the first year
of operation for each standard field; after that to be determined by experience.
It is to be determined by experience (stability of the system) whether the nightly
zeropoint measurements can be relaxed as follows: in case the keyfilters are
not used for science observations in a particular night, it is sufficient to only
take an exposure with the composite filter.
During commissioning the Mode— dither N= and Mode— jitter N= have to be verified.

Sources, observations, instrument configurations:
Strategy— freq Mode— Stare N=1 OmegaCAM equatorial fields; exposures in
u’, g’, r’ and i’ and composite. Two lens corrector.

Inputs:
In pipeline data reduction, the req.563 reductions of a given night should pre-
ceed the req. 562 Monitoring reductions.

The inputs for deriving the photometry result tables are:
Fully calibrated image of equatorial standard field
CalFile— 569 Secondary Standard Catalog

The inputs for deriving the zeropoints for the night are:
List of photometry result tables
CalFile— 562 Extinction night report
CalFile— 564E Standard extinction curve

Outputs:
The output from deriving a photometry result table is the same as for req. 562.

The outputs from deriving the zeropoints for the night are:
CalFile— 563 Zeropoint + extinction - keybands (always) used by seq.— 636.

Required accuracy, constraints:
1% on the photometric scale
**Estimated time needed:**
Observation: 12 min. each night Reduction: 3 min/CCD/filter.

Detailed estimate of required integration time:
The secondary standard stars in the standard fields have a limiting magnitude $g' \sim 20$. The internal accuracy of the present task is set on the 2% level in order to achieve an overall end-to-end accuracy of better than 5% on the photometric scale. Given an airmass of 1.3 and an $S/N = 50$, we expect an integration time of:

- $u'$ band 110 sec but $S/N = 45$ for F0V
- $g'$ band 60 sec
- $r'$ band 75 sec
- $i'$ band 115 sec

As there will be many much brighter stars (than the $g'=20$ limiting mag for which this calculation is made) in the field of view, leading to much better $S/N$ these integration times will be sufficient for the goals, also at other moonphases (actually checked with ETC). The $u'$ band observations are on the limit and should be carefully checked during Commissioning. Thus a total sequence would last including readout of 42 sec:
- preset (100), $u'(110 + 42)$, $g'(60 + 42)$, $r'(75 + 42)$, $i'$ (115 + 42) = 628 sec

In addition, a composite filter image should be taken (100 sec) which in the long run might replace the $u'$, $g'$, $r'$, $i'$ sequence with monolithic filters.

**Priority:**
esential

**TSF:**

Strategy – freq
Mode – Stare $N=1$
(TSF – OCAM_img_obs_stare, $N=1$, filter=Key band)
= TSF – OCAM_img_obs_zpkey

**Recipe:**
For deriving a photometry result table:

```bash
PhotCal_Extract_Resulttable -i science_frame -s standard_catalog
[-t transformation_table]
```
science_frame : input frame that has been de-biased, flat-fielded and astrometrically calibrated. An il-

lumination correction (if needed) should also have been applied.

standard_catalog : standard star catalog.

transformation_table : transformation table containing color-
terms.

For deriving the zeropoints for the night:

```
PhotCal_Extract_Zeropoint -e <photometry_result_tables>
    -m monitoring_report
    -c extinction_curve
```

photometry_result_tables : list of photometry result tables as derived from a list of fully reduced images of a standard field.

monitoring_report : extinction night report.

extinction_curve : a standard extinction curve.

**Needed functionality:**

catalog - source extraction (SExtractor)
catalog - associate (LDAC prephotom)
catalog - select stars (LDAC filter)
The processing in the photometric part of the pipeline must be done for every key band separately and has two phases: 1) derive a photometry result table for every input chip, 2) use the photometry result tables in deriving the zeropoints for the night. The photometry result tables are derived in the same way as described in steps 1-8 of the relevant section of the CA from req. 562; these have to be derived first before the zeropoints for the night. The zeropoints for the night are derived from these photometric result tables as described in the steps 1-5 below. These steps are repeated for every separate input photometry result table.

1. Retrieve from the input extinction report (CalFile— 562) the atmospheric extinction for the middle of the night (see req. 562).
2. Multiply the retrieved extinction with the airmass contained in the input photometry result table.
3. Subtract the resultant value for the extinction from every raw zeropoint contained in the input photometry result table.
4. Derive the zeropoint from the resultant raw zeropoints by deriving the weighted average.
5. Store the derived zeropoint and the input extinction per unit airmass, together with the name of the chip for which the zeropoint was derived and the
name of the key band.

**CAP:**
Constant:


/* Step 1 : make photometry result tables

(1) create_empty_list_for_photometry_result_tables
(2) for every frame in the list of science frames:
(2.1) derive_source_catalog_from_frame:
       SExtractor.sextractor(frame_name)
(2.2) remove_saturated_stars_from_the_catalog:
       LDAC.filter(catalog_name, filter_criterium_1)
(2.3) associate_source_catalog_with_standard_star_catalog:
       LDAC.prephotom(catalog_name, refcat)
(2.4) remove_not_associated_sources_from_catalog:
       LDAC.filter(catalog_name, filter_criterium_2)
(2.5) create_empty_list_for_raw_zeropoints
(2.6) for every source in the source catalog:
       mag = take_magnitude_of_source_from_standard_catalog
(2.6.1) if composite_filter_data:
          apply_transformation_to_mag
          instmag = take_measured_magnitude_of_source
          raw_zeropoint = mag - instmag
          raw_zeropoint_err = sqrt(mag_err**2 + instmag_err**2)
          add_raw_zeropoint_and_error_to_list
(2.7) save_the_photometry_result_table
(2.8) add_photometry_result_table_to_list

/* Step 2 : make extinction

cwl = central_wavelength_of_key_band
extinction = value_from_extinction_curve_at_cwl
extinction += shift_from_input_report_at_middle_of_the_night

/* Step 3 : make zeropoints
(1) for every table in list of photometry_result_tables:
(1.1) ext = extinction * airmass_from_table
(1.2) ext_err = extinction_error * airmass_from_table
(1.3) create_empty_list_for_zeropoints
(1.4) for every raw_zeropoint in table:
    zeropoint = raw_zeropoint + ext
    zeropoint_err = sqrt(raw_zeropoint_err**2 + ext_err**2)
    add_zeropoint_and_error_to_list
(1.5) get_weighted_mean_and_error_of_zeropoint
(1.6) save_zeropoint_and_extinction