Req 5.6.2

Title:

Photometric Calibration - monitoring

Objective:

Monitor any **short term** variability related to the transparency of the atmosphere (atmospheric extinction) or due to instrumental instabilities (e.g. effective DQE) with a minimum sampling of at least 3 times/night. This provides a **daily overall health check** of the instrument and detectors. A further trend analysis has to provide information on **long term** stability.

The variation (r.m.s.) of the flux detected by the autoguider shall also be used as an indicator (put in the FITS header) of the sky conditions. This is to be done for each science observation.

This monitoring is done on a standard **polar field**, which will be repeatedly observed at the beginning, middle and end of the night with the **composite key filter** (u', g', r' and i' band), irrespective of the passbands used for the science observations. The observations are done in the standard configuration, with the two-lens corrector. A comparison of the measured intensity of the stars with reference values is used to qualify the overal conditions of instrument and atmosphere, the actual zeropoint (both unit airmass extinction and instrument DQE) being determined by **req.**563.

The comparison of the observed signal with the expected signal from standard stars in each of the four quadrants will lead to the determination of the product of the atmospheric extinction and the overall effective DQE of the detector system including the optics, i.e. $g_e(t) \times g_e(0) \times g_{st.e}(X) \times g_{DQE}$, with $g_{st.e}(X)$ the gain of the standard extinction curve at passband X, and g_{DQE} the overall effective DQE. As **req.**563 solves for g_{DQE}, a comparison with these measures gives $g_e(t) \times g_e(0) \times g_{st.e}(X)$, the variation of the gain during the night. The thus derived values of $g_e(t) \times g_e(0) \times g_{st.e}(X)$ at $t =$ beginning, middle, and end of the night (could be more if the observer so wishes) provides the required monitoring. Note that in this scheme, $g_e(t) = 1$ by definition for the middle of the night ($t = 0$). Excursions from the standard extinction curve due to extraordinary meteorological conditions, can be traced by computing the standard deviation of observed minus standard curve values in the various bands.

The repetitive measurements on the same field and with the same filter will also be used in trend analysis to monitor the overall long term stability of the instrumentation and atmosphere. The redundancy of these measurements with **req. 563** *zeropoint* and **req. 542** *Flat field -dome* will be used as a cross-check on the validity of the photometric system.

The data taken through the composite filter will provide a simultaneous measurement of the sky brightness in the four different **key bands**; this data will thus give a spectrum of the sky with a resolution R of roughly 5. This sky spectrum shall be derived on-line from the data. This serves as a quality check on the health of the instrument and on the clearness of the atmosphere, as clouds or cirrus will be immediately noticable in the spectral shape. Reference tables containing the expected sky brightness (and thus colour) as function of lunar phase will be used in the evaluation of the data.

Note that small differences exist between the monolithic key-band filters and the composite filter (see **req.**565). This might lead to small color terms that should be taken into account if needed.

Fulfilling or fulfilled by:

Selfstanding; a corresponding requirement on detector level is
req. 547 *Quick detector responsivity check-doit*

When performed/frequency:

beginning, middle and end of each night; any moment atmospheric conditions are suspect.

Sources, observations, instrument configurations:

The **OmegaCAM** polar field, key composite filter, two lens corrector; short (about 20 sec) integration **Strategy– freq**

Inputs:

The inputs for deriving the photometry result tables are:
Fully calibrated image of the polar standard field
CalFile– 569 *Secondary Standard Catalog*
CalFile– 565C *composite -> monolithic*

The inputs for deriving the transparency of the atmosphere are (Category I recipe):
List of photometry result tables
CalFile– 563 *Zeropoint + extinction - keybands* (g_{DQE} and $g_e(0) \times g_{st.e}(X)$)
CalFile– 564E *Standard extinction curve*

The inputs for the **on-line** monitoring of the sky spectrum are (Category III recipe):
List of input raw images of the polar standard field

List of input masterbias frames
List of input masterflat frames
CalFile– 562Su *Sky brightness-u'* Reference values u'
CalFile– 562Sg *Sky brightness-g'* Reference values g'
CalFile– 562Sr *Sky brightness-r'* Reference values r'
CalFile– 562Si *Sky brightness-i'* Reference values i'

Outputs:

The output from deriving a photometry result table is:
CalFile– 562T *Photom + Sky*

The output from deriving the transparency of the atmosphere is:
CalFile– 562 *Extinction - night report* ($g_e(t) \times g_e(0) \times g_{st.e}(X)$ at var. t)

Series of output files will be used for trend analysis

Required accuracy, constraints:

all photometry better than 1-2% on the photometric scale.

Estimated time needed:

Observation: 3 times 4 min. (100 sec preset + 100 sec integration + 42 sec readout) totalling 12 min/night each night. Reduction: 10 min./CCD.

Detailed estimate of required integration time:
The secondary standard stars in the standard field have a limiting magnitude g'~ 20. The internal accuracy of the present task is set on 1-2% level in order to achieve an overall end-to-end accuracy of better than 5% on the photometric scale. Clearly, for the composite filter the desired exposure time will be dominated by the response in the u' band. Using the WFI2.2m ETC, corrected for the VST optics and estimated CCD spectral responsivity, we estimate a S/N= 20 after 100 sec integration for a V=20 F0V star at airmass 2 (South Pole) with nominal 1.0 arcsec seeing. Thus, most secondary standard stars will have a S/N better than 20 in the u' band in a 100 sec integration. This would just match to the wanted 5% overall photometric accuracy in the u' band, but would lead simultaneously to higher S/N in the other bands. We compute for a V=20 GoV star S/N=90 in i' new moon, S/N=70 in r' new moon, S/N=45 in r' full moon and S/N =80 in g' new moon. Thus an integration time of 100 sec for the composite filter appears reasonable, but clearly the u' band data give lower photometric accuracy, and the final value will depend on the achieved responsivity in the u' band. The final number has to be determined

by experience and depends on the distribution and colours of the stars in the u' quadrant of the field of view.

Priority:

night monitoring: essential, long-term trend analysis : important

TSF:

Strategy– freq
Mode– Stare N=1
(**TSF– OCAM_img_obs_stare,**N=1, filter=composite)
= **TSF– OCAM_img_obs_monit**

Recipe:

For deriving a photometry result table:

```
  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 transparency of the atmosphere:

```
  PhotCal_Monitoring -i <photometry_result_tables> -z <zeropoints>
                     -c extinction_curve

  photometry_result_tables : list of photometry result tables as
derived
```

```
                             from a list of fully reduced images
of a
                             standard field.
  zeropoints               : list of zeropoints, one for every com-
bination
                             of photometric band and chip.
  extinction_curve         : a standard extinction curve.
```

For the on-line monitoring of the sky spectrum:

```
  PhotCal_Monitoring_Sky -iu <raw_science_frames_sloanu_kwadrant>
                         -ig <raw_science_frames_sloang_kwadrant>
                         -ir <raw_science_frames_sloanr_kwadrant>
                         -ii <raw_science_frames_sloani_kwadrant>
                         -fu <masterflat_frames_sloanu_kwadrant>
                         -fg <masterflat_frames_sloang_kwadrant>
                         -fr <masterflat_frames_sloanr_kwadrant>
                         -fi <masterflat_frames_sloani_kwadrant>
                         -b  <masterbias_frames>
                         -s  <skybrightness_tables>
                         -lp lunar_phase
                         [-zu zeropoint_sloanu]
                         [-zg zeropoint_sloang]
                         [-zr zeropoint_sloanr]
                         [-zi zeropoint_sloani]
                         [-oc OVERSCAN_CORRECTION]

  raw_science_frames_sloanu_kwadrant : list of raw science frames
from the
                                       Sloan u kwadrant.
  raw_science_frames_sloang_kwadrant : list of raw science frames
from the
                                       Sloan g kwadrant.
  raw_science_frames_sloanr_kwadrant : list of raw science frames
from the
                                       Sloan r kwadrant.
  raw_science_frames_sloani_kwadrant : list of raw science frames
from the
```

```
                                      Sloan i kwadrant.
  masterflat_frames_sloanu_kwadrant  : list of masterflat frames
for the
                                      chips of the Sloan u kwad-
rant.
  masterflat_frames_sloang_kwadrant  : list of masterflat frames
for the
                                      chips of the Sloan g kwad-
rant.
  masterflat_frames_sloanr_kwadrant  : list of masterflat frames
for the
                                      chips of the Sloan r kwad-
rant.
  masterflat_frames_sloani_kwadrant  : list of masterflat frames
for the
                                      chips of the Sloan i kwad-
rant.
  masterbias_frames                  : list of masterbias frames.
  skybrightness_tables               : list of skybrightness ta-
bles.
  lunar_phase                        : lunar phase in days after
new moon
                                      (integer). Default: 0
  zeropoint_sloanu                   : overall zeropoint of the
detector
                                      block for Sloan u (float).
                                      Default: 0.00.
  zeropoint_sloang                   : overall zeropoint of the
detector
                                      block for Sloan g (float).
                                      Default: 0.00.
  zeropoint_sloanr                   : overall zeropoint of the
detector
                                      block for Sloan r (float).
                                      Default: 0.00.
  zeropoint_sloani                   : overall zeropoint of the
detector
                                      block for Sloan i (float).
```

Default: 0.00.

OVERSCAN_CORRECTION (integer). : overscan correction mode

Description of allowed values:

0: apply no overscan correction
(this is the default)

1: use median of the prescan in
the x-direction

2: use median of the overscan in
the x-direction

3: use median of the prescan in
the y-direction

4: use median of the overscan in
the y-direction

5: use the per-row value of the
prescan in the x-direction

6: use the per-row value of the
overscan in the x-direction

Needed functionality:

catalog - source extraction (Sextractor)
catalog - associate (LDAC prephotom)
catalog - select stars (LDAC filter)
misc - regression (minimal least-squares fit)

CA:

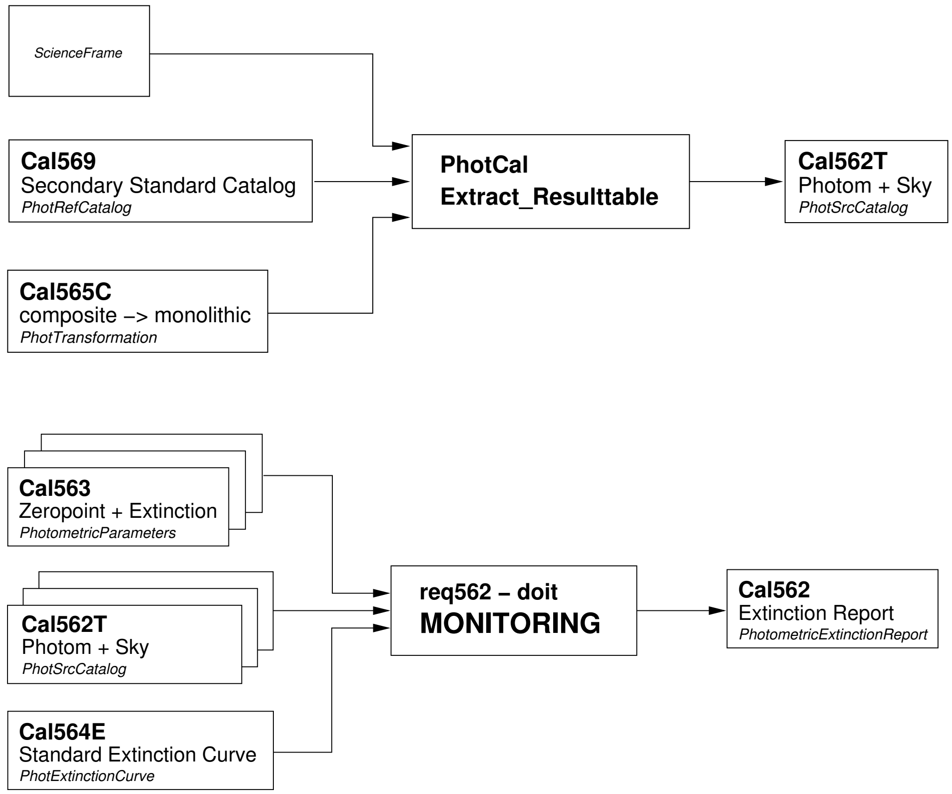

Fig 5.6.2 Dataflow and object class names for req562, monitoring the atmosphere.

The description given in the following paragraphs refers to the procedure used in deriving **photometry result tables**. The procedure can be run on the complete set of monitoring data, but also on a subset of the pointings for the night. The creation of the photometry result tables requires the secondary standard star catalog (**CalFile– 569,** see **req.** 569 for accuracy and constraints). In the creation of the photometry result tables, great care is taken to remove sources from the catalog unsuitable for the photometric calibration (see the steps outlined below).

1. De-bias, flatfield and astrometrically calibrate the input chips. Apply illumination correction (if needed).

The following steps are performed on every separate input chip as reduced in step 1:
2. Derive a source catalog from the input chip (Sextractor).
3. Remove saturated sources and blended sources from the source catalog. Re-

move sources from the catalog with clipped or otherwise deformed apertures.
4. Associate the source catalog with the standard star catalog (LDAC).
5. Remove all the sources from the source catalog that have not been associated with a source from the standard star catalog.
6. Subtract the measured magnitude of the identified standard stars from their magnitude as known from the standard star catalog. If a correction for color-terms is needed, the latter magnitudes have to be transformed first. The numbers resulting from the subtraction will further be referred to as raw zeropoints.
7. Measure the skybackground from the input chip.
8. Store in a photometry result table (**CalFile– 562T**): 1) the list of raw zeropoints, 2) the skybackground measured from the chip, 3) the airmass of the chip, 4) the observation date of the chip from which the sources where extracted, 5) the name of the key-band, 6) the central wavelength of the filter, 7) the name of the chip.

The description given in the following paragraph refers to the procedure used in **monitoring the transparency** of the atmosphere. The monitoring report for the night is obtained from all the photometry result tables derived previously in the steps 1-8 described above.

1. Sort the set of photometry result tables by the observation time. Sort the tables in these subsets further by key-band. Every combination of time/key-band is one subset of photometry result tables.
2. Sort the set of input zeropoints by key-band.
3. Derive the atmospheric extinction for every single combination of time/key-band. These extinctions are all converted to a value per unit airmass.
4. Sort the derived atmospheric extinctions for the separate key-bands into subsets based on the observation time.
5. Fit the standard extinction curve to each subset of derived atmospheric extinctions.
6. Derive the difference between the fit of the extinction curve to the measured extinctions and the extinction curve itself. This is the shift of the curve.
7. Store for every observation time : 1) the observation time, 2) the calculated shift of the standard extinction curve and its uncertainty, 3) the derived extinction for every key-band and their uncertainties, 4) the difference between the derived extinction and the standard extinction curve for every key-band.

Verification monitoring report (verify):
Quality flags can be raised

The description in the following paragraph refers to the procedure used in the on-line **monitoring of the sky spectrum**. The procedure is run on one single image of the polar field at a time.

1. De-bias and flatfield every chip.
2. Derive the median sky background from the input chips. This will give 32 values, 8 for each kwadrant of the composite filter.
3. Determine the colors from the median skybackground values, and visualize these colors together with the values derived from the input tables of skybrightness.

CAP:

```
The description given in this section refers to the procedure used
in
monitoring the transparency of the atmosphere. Any small differ-
ences
between the composite filter and the monolithic key-band filters
(if any) are not taken into account in this description.

Constants:
  DETECT_THRESH  : Sextractor processing parameter (float). Value:
10.0.
  SIGCLIP_LEVEL  : for sigma-clipping in deriving the atmospheric
                   extinctions (float). Value: 3.0.
  MAX_REL_ERROR  : maximum allowed relative error in the extinc-
tion

/* Step 1 : make photometry result tables

(1)      for every frame in the list of science frames:
(1.1)      derive_source_catalog_from_frame:
             Sextractor.sextractor(frame_name)
(1.2)      remove_saturated_stars_from_the_catalog:
             LDAC.filter(catalog_name, filter_criterium_1)
```

```
(1.3)     associate_source_catalog_with_standard_star_catalog:
            LDAC.prephotom(catalog_name, refcat)
(1.4)     remove_not_associated_sources_from_catalog:
            LDAC.filter(catalog_name, filter_criterium_2)
(1.5)     create_empty_list_for_raw_zeropoints
(1.6)     for every source in the source catalog:
(1.6.1)     mag = take_magnitude_of_source_from_standard_catalog
(1.6.2)     instmag = take_measured_magnitude_of_source
(1.6.3)     raw_zeropoint = mag - instmag
(1.6.4)     raw_zeropoint_err = sqrt(mag_err**2 + instmag_err**2)
(1.6.5)     add_raw_zeropoint_and_error_to_list
(1.7)     measure_skybackground_from_frame
(1.8)     save_the_photometry_result_table

/* Step 2 : make monitoring report

(1)     result_table_subsets_date = group_result_tables_by_observing_dat
(2)     zeropoint_subsets_key_band = group_zeropoints_by_key_band

(3)     create_empty_list_for_report_entries
(4)     for every result_table_subset in result_table_subsets_date:
(4.1)     result_table_subsets_key_band = group_result_table_subset_by_k
(4.2)     create_empty_list_for_atmospheric_extinctions
(4.3)     for every result_table_subset in result_table_subsets_key_band
(4.3.1)     get_zeropoint_subset_for_this_key_band
(4.3.2)     derive_the_atmospheric_extinction_for_this_keyband:
              create_empty_list_for_separate_extinctions
              for every raw zeropoint in result_tables:
                  subtract_zeropoint_from_raw_zeropoint
                  add_result_to_list
              sigma_clip_the_separate_atmospheric_extinctions
              derive_average_atmospheric_extinction
(4.3.3)     add_atmospheric_extinction_to_list
(4.4)     fit_extinction_curve_to_atmospheric_extinctions:
            least_squares_fits(atmospheric_extinctions, extcurve)
(4.5)     make_entry_in_extinction_report_for_this_catalog_subset
(4.6)     add_entry_to_list
(5)     save_the_monitoring_report
```