Short overview of weights in the OmegaCAM pipeline software

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The weighting scheme in the Astro-Wise system is relatively elaborate as a result of the regridding performed. In the course of the image pipeline (seq631-seq636 as described in the Data Flow System) 3 different weights may be constructed, the first weight is described in the section 1 and the latter two are described in section 2.

1 Science frames and their weight

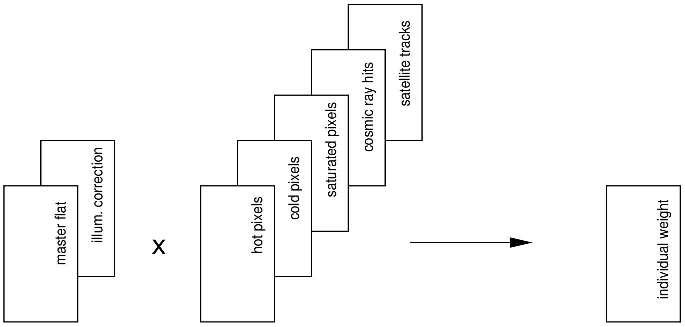

Figure 1: Individual weights

The science image is the end product of the pipeline for observations made in Stare mode, where no regridding operation is performed. Each science image has an associated weight.

The (normalized) flat-field describes the response of the telescope and instrument to a source of uniform radiation. In other words, it shows the relative amount of light received as a function of pixel position. This is a measure of the weight of a pixel relative to a pixel at a different position; the produced weights are relative weights.

Some pixels in an image are defect, counting too many or too few photons. These pixels are stored in hot- and cold pixel maps (values 1 for good, 0 for bad). In addition in a raw science image pixels may be unusable due to other causes. Pixel maps are created for saturated pixels, pixels affected by cosmic ray hits and pixels in satellite tracks. Saturated pixels are pixels whose counts exceed a certain threshold. In addition, saturation of a pixel may lead to 'dead' neighbouring pixels, whose counts lie below a lower threshold. Cosmic ray events can be detected using special source detections filters (retina filters), with Sextractor. These are essentially neural networks, trained to recognize cosmic rays, taking a set of neighbouring pixels as input. Satellite tracks can be discovered by a line-detection algorithm such as the Hough transform, where significant signal along a line produces a 'peak' in the transformed image. This peak can be clipped, and transformed back into a pixelmap that masks the track. The weight can therefore be written as:

$$W_{ij} \propto F_{ij} P_{hot} P_{cold} P_{saturated} P_{cosmic} P_{satellite} \tag{1}$$

It is possible that an illumination correction (photometric superflat) is used in the pipeline. As a result of stray light received by the detector the background of raw images is not flat. This effect is present both in science images and in flat-fields. In this case, dividing by the flat-field in the image pipeline results in a flat background, but in a non-uniform gain across the detector. In order to correct for this difference an illumination correction frame is made. This image is the result of the difference of the catalog magnitude of standard stars and their magnitude measured on reduced science frames, as a function of pixel position. The illumination correction can be viewed as a correction on the (incorrect) flat-field. Correctly applying the illumination correction therefore results in a non-flat background.

When an illumination correction is used the weight changes as follows:

$$W_{ij} \propto \frac{F_{ij}}{I_{ij}} P_{hot} P_{cold} P_{saturated} P_{cosmic} P_{satellite} \tag{2}$$

In terms of our code base the object oriented class hierarchy for calibrated science images is shown below (specifying only relevant class dependencies):

```
ScienceFrame                          (seq635)
 +-ReducedScienceFrame                (seq632)
     +-RawScienceFrame                (seq631)
     +-MasterFlatFrame                (req546)
     +-BiasFrame                      (req541)
     +-FringeFrame                    (req545)
     +-IlluminationCorrectionFrame    (req548)
 +-WeightFrame                        (seq633)
     +-MasterFlatFrame                (req546)
     +-IlluminationCorrectionFrame    (req548)
     +-ColdPixelMap                   (req535)
```

```
    +-DomeFlatFrame            (req535)
+-HotPixelMap                  (req522)
    +-BiasFrame                (req541)
+-SaturatedPixelMap
    +-RawScienceFrame (actually RawFrame, i.e. any raw image, to be fixed)
+-CosmicMap
    +-RawScienceFrame (actually BaseFrame, i.e. any image, to be fixed)
    +-HotPixelMap
    +-ColdPixelMap
    +-SaturatedPixelMap
    +-MasterFlatFrame
    +-IlluminationCorrectionFrame
+-SatelliteMap
    +-RawScienceFrame (actually BaseFrame, i.e. any image, to be fixed)
    +-HotPixelMap
    +-ColdPixelMap
    +-SaturatedPixelMap
    +-MasterFlatFrame
    +-IlluminationCorrectionFrame
```

2 Weights created by SWarp

Image coaddition is divided in two parts, resampling and combination. Image resampling addresses the problem that two independent observations of the same area of sky will, in general, result in images whose coordinate systems are different. Projection of these coordinate systems to a new coordinate system requires a mapping $x, y \Rightarrow \alpha, \delta \Rightarrow x', y'$. Since the area of sky covered by an input pixel will in general not map directly to an area of sky covered by a single output pixel, some sort of interpolation is required. Unfortunately interpolation will inevitably result in aliasing artifacts, hence, a careful choice of interpolation kernel is required.

Once all input images and their weights have been resampled onto the grid specified by the coordinate system of the coadded image, it is straightforward to compute the coadded image and its weight. Given resampled input images $1 \leq i \leq N$ entering co-addition, one can define for each pixel j:

- the local uncalibrated flux $f_{ij} = \overline{f_{ij}} + \Delta f_{ij}$, where $\overline{f_{ij}}$ is the sky background, and Δf_{ij} the contribution from celestial sources,

- the local uncalibrated variance $\sigma_{ij}^2 = \overline{\sigma_{ij}^2} + \Delta\sigma_{ij}^2$, where $\overline{\sigma_{ij}^2}$ is background noise and $\Delta\sigma_{ij}^2$ the photon shot noise of celestial sources,

- the local, normalized weight w_{ij},

- the electronic gain of the CCD g_i,

- the relative flux scaling factor p_i, deduced from the photometric solution, with $p_i \Delta f_{ij} = p_l \Delta f_{lj}$ for all i, l, j,
- the weight scaling factor k_i.

Optimal weighting is obtained using

$$k_i w_{ij} = \frac{1}{p_i^2 \overline{\sigma_{ij}^2}},$$

leading to a co-added flux (assuming the background of the input images has been subtracted),

$$f_j = \frac{\sum_i k_i w_{ij} p_i \Delta f_{ij}}{\sum_i k_i w_{ij}},$$

and variance

$$\sigma_j^2 = \frac{\sum_i k_i^2 w_{ij}^2 p_i^2 \sigma_{ij}^2}{(\sum_i k_i w_{ij})^2},$$

The software package SWarp, developed by E. Bertin (IAP) for Terapix provides a set of regridding and co-addition algorithms specifically optimized to handle large area CCD mosaics.

2.1 Regridded frames and their weights

Whenever a calibrated science image is created in Dither mode (seq635) it is resampled to one of a number of pre-defined field centers (part of seq636). This affects both the science and weight images.

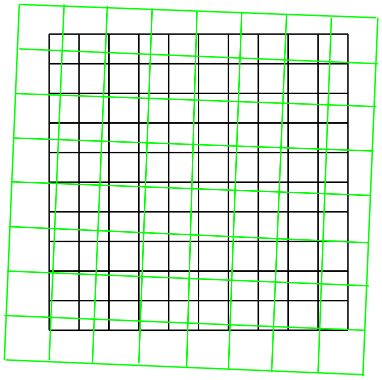

Figure 2: Regridded weights

The class hierarchy for regridded images is as follows:

```
RegriddedFrame
  +-WeightFrame       (produced by SWarp)
  +-ScienceFrame
      +-(see section 1)
```

2.2 Coadded frames and their weights

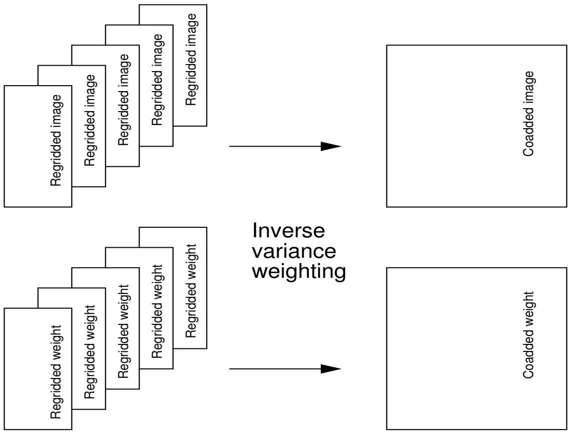

Figure 3: Coadded weights

When a collection of the regridded images described in the previous section are coadded a new weight is constructed by adding the (regridded) weights. In this step variance weighting is used to get a total weight.

The class hierarchy for coadded frames is as follows:

```
CoaddedRegriddedFrame
  +-WeightFrame       (produced by SWarp)
  +-RegriddedFrame(s)
      +-(see section 2.1)
```

3 Weights in quality control

Three methods are defined for most calibration files, subdividing the quality control. The *verify* method is used to provide internal checks, often this takes the form of sanity checks on parameters of e.g. a BiasFrame. The *compare* method compares aspects of e.g. a BiasFrame (standard deviation for example) with that of a previous instance. *Inspect* is intended to show plots or images so that after an interactive analysis a decision can be made on the quality of the object.

In particular, statistics in subwindows of all images are used. While determining these statistics it is possible to provide a pixelmap of acceptable pixels. Below is a table that shows which weights/pixelmaps are (can be) used.

Class	HotPixelMap	ColdPixelMap	SaturatedPixelMap	CosmicMap	SatelliteMap	Individual Weight
RawFrame	-	-	-	-	-	-
BiasFrame	-	-	-	-	-	-
DomeFlatFrame	+	+	-	-	-	-
TwilightFlatFrame	+	+	-	-	-	-
MasterFlatFrame	+	+	-	-	-	-
FringeFrame	+	+	-	-	-	-
ScienceFrame	+	+	+	+	+	+
RegriddedFrame	-	-	-	-	-	+

Table 1: Table of weights/pixelmaps and their application in quality control