Roberto Sartori
roberto.sartori@gmail.com

Weighted Batch Preprocessing

an improved version of PixInsight Batch Preprocessing

This project is the result of a collaboration with

Tommaso Rubechi

(www.tommasorubechi.it).

This document reports the motivations behind this extension and the technical changes made to the initial BatchPreprocessing script.

SUMMARY

Why this update?

Many astrophotographers don't use BatchPreprocessing (**BPP**), they prefer to run the whole master light generation process manually in order to have full control of each step. Indeed, shrewd astrophotographers tune parameters at each step trying to get the best from each of it. Despite the effectiveness of this manual approach, Batch Preprocessing is capable of generating a master light image which overall quality is, in general, quite close if not undistinguishable from the manual process. Nevertheless, manual execution allows to deviate from a standard integration workflow interposing intermediate steps functional to obtaining a precise desired result. One additional step of those, commonly performed before the light frame registration, consist in running the Subframe Selector script in order to measure light frames FWHM, eccentricity and SNR to discard poor frames that do not match some acceptance criteria (requiring for example that FWHM must be lower than a certain value) and to generate a meaningful weight for the remaining to be used during the Image Integration process aiming to improve one or a combination of the mentioned properties.

The purpose of this script is to embed this extra step into the current BPP in order to cover the most common missing gap between manual and batched master light frame generation process.

This project is a collaboration with **Tommaso Rubechi** which is deeply involved as a supervisor responsible of defining the weighting presets, being the principal tester and the main results analyst.

We named this script Weighted Batch Preprocessing (**WBPP**) in order to highlight its capability of automating the mentioned light frame weighting.

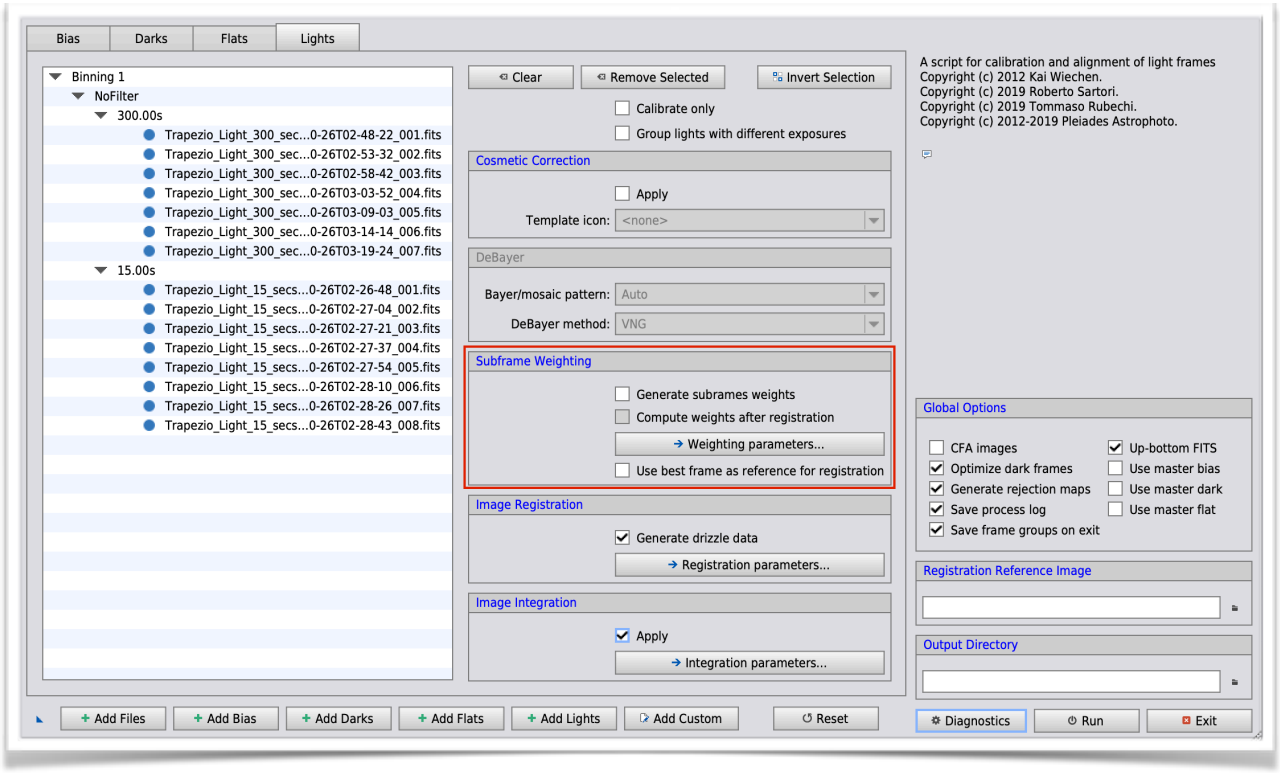
New Features

Several new features has been implemented to address the feedbacks and requirements pulled by the testers. The full features list is the following:

- automatic light frames weight computation based on a combined contribution of FWHM, eccentricity and SNR measurements
- automatic selection of the best reference frame for registration
- extended frame grouping strategy
- smart calibration of light frames
- new "auto" rejection option
- smart file/folder naming
- enhanced diagnostic
- smart reporting
- new "Save frame groups on exit" option

Each feature is described and detailed in the following chapter.

Light Frames Weighting and Best Reference Frame Selection



These two features works in synergy. Both are based on the measurement of the so-called **image descriptors**: FWHM, eccentricity and SNR. The JS code that performs these measurements has been extracted directly from the SubframeSelection script in order to provide precisely the same measurements.

The weighting formula

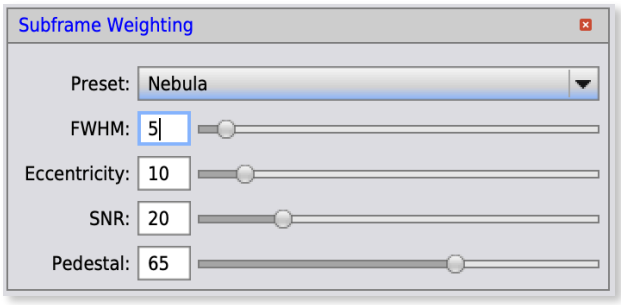
Light Frames Weighting is executed for each group of light frames. The principle is to compute light frames descriptors first and extract FWHM, eccentricity and SNR min/max values. Once the analysis is completed each weight is computed using the well known formula:

$$w = a\cdot\left(1 - \frac{FWHM - FWHM_{min}}{FWHM_{max} - FWHM_{min}}\right) + b\cdot\left(1 - \frac{ecc - ecc_{min}}{ecc_{max} - ecc_{min}}\right) + c\cdot\left(\frac{SNR - SNR_{min}}{SNR_{max} - SNR_{min}}\right) + P$$

where **w** is the final light frame weight, **(a, b, c)** are tunable coefficients to balance the FWHM, eccentricity and SNR contributions and and **P** is a tunable pedestal value added to the weight.

Usually, descriptors are computed on light frames **before** their registration; nevertheless, we decided to provide the option to postpone the measurement **after** the registration by flagging the new option "*Compute weights after registration*", in case the user would take into account the subsequent and unavoidable changes on the descriptor values of a registered frame.

The following image shows the interface to be used to assign descriptor's contributes and the pedestal value. The more a contribution is high, the more it will be taken into account to determine the weight (so better values will generate higher weights). To simplify the setup, we provided three templates that worked well in the general case, each of which is addressing a specific type of target: **Nebula** (which weights more the SNR due to the main presence of nebulosity details), **Globular Cluster** (which weights more the star properties since stars are the kind of objects we're willing to highlight) and **galaxy** (which sets a compromise between SNR and stars).



Best frame selection

The selection of the best reference frame works on the basis of finding the light frame with the "most suitable stars" to become the reference for the others i.e. the light frame with the smallest and roundest stars. The reference frame is always selected among the whole set of light frames provided despite their grouping, such that strategy is to measure

the descriptors for all light frames and pick the frame with the highest weight that combines FWHM and eccentricity only. The weighting function used in this step, thus, adopts the following coefficients:

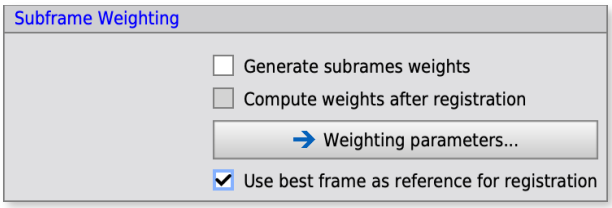
(a: 50, b: 50, c: 0, P: 1)

The best reference frame selection must be performed before the registration in order to provide the reference frame to that step. Because of that, all the light frame groups need to be calibrated, cosmetic corrected and debayered first and then, once the whole set of debayered images are measured and best frame is chosen, the registration and integration steps will continue. This change required to restructure the sequence of operations performed by the standard BPP as explained in the following section.

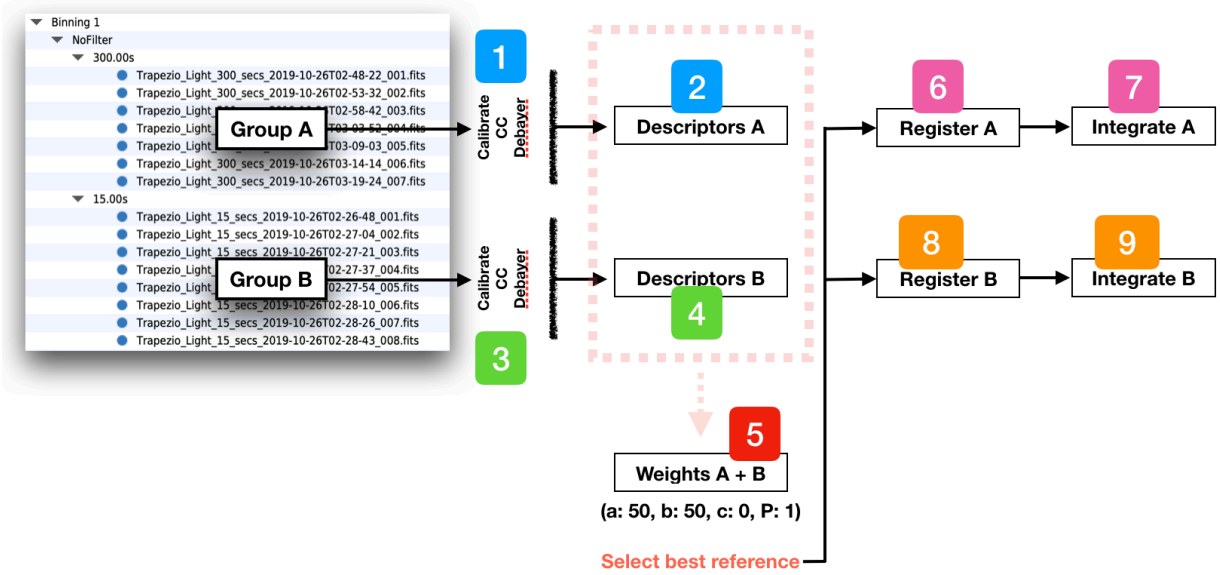
A new light frames processing flow

While the standard BPP processes each group one by one executing the entire processing flow from the initial calibration to the final integration (with the precedence of the group that contains the reference frame) the WBPP needs to work differently, preparing the whole light frame images by applying calibration, cosmetic correction and debayer to subsequently select the best frame among the whole set of prepared images. Moreover, depending on the settings, light frame weights needs to be eventually computed before or after the registration step. As a consequence, the processing flow of WBPP needs to be different and follows a precise sequence that may change depending on the configuration selected by the user.

All the possible cases are detailed below taking as an example the integration of two groups of light frames with different exposures.



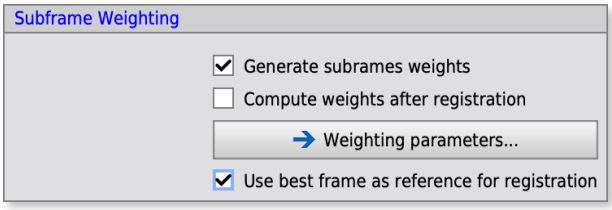
Auto-selection of reference frame, no weights computed



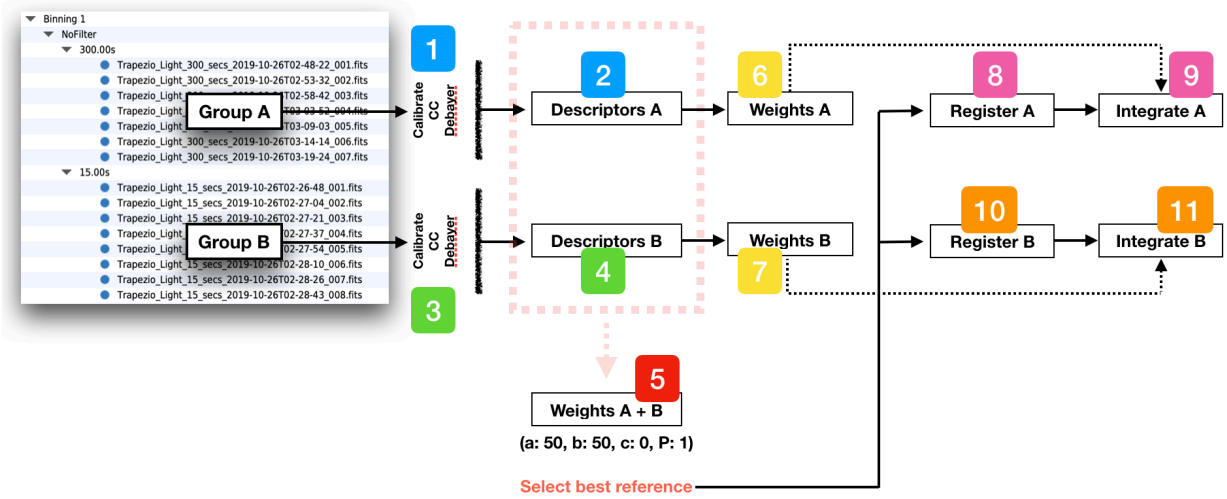
Every light frame group is calibrated, cosmetic corrected and debayered and frames descriptors are measured (step **1-2**, **3-4**).

Subsequently, the descriptors of all groups are grouped together and weights of all light frames are computed taking into account only stars properties. The best reference frame is the one with the highest weight (step **5**).

The process continues registering and integrating each light frame group (step **6-7**, **8-9**).



Auto-selection of reference frame, weights computed before registration

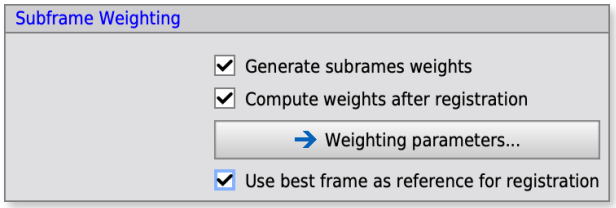


Every light frame group is calibrated, cosmetic corrected and debayered and frames descriptors are measured (step **1-2**, **3-4**).

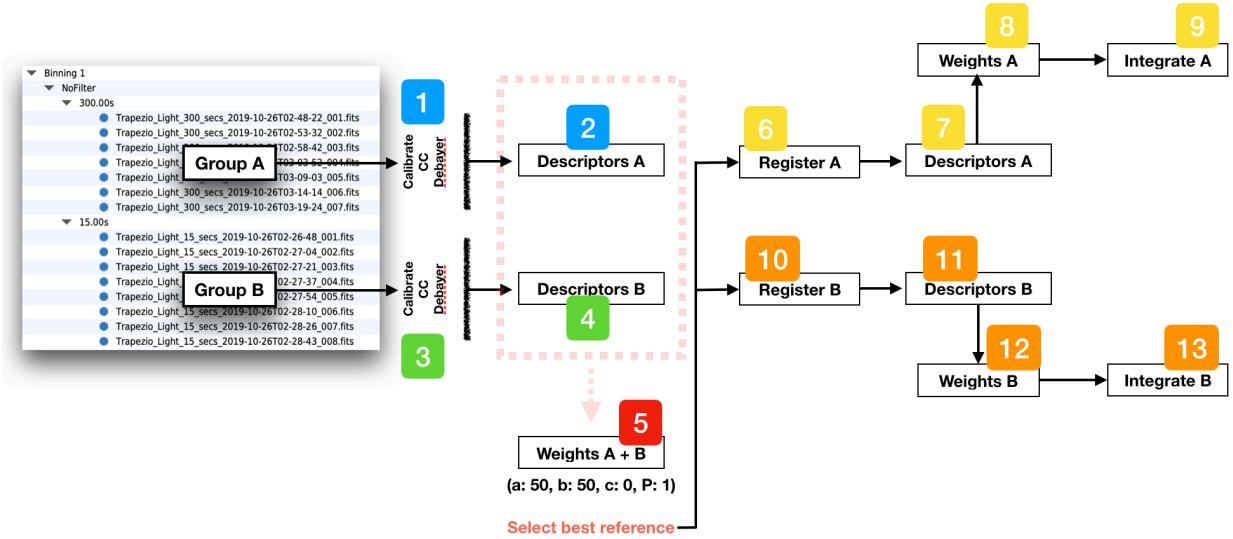
Subsequently, the descriptors of all groups are grouped together and weights of all light frames are computed taking into account only stars properties. The best reference frame is the one with the highest weight (step **5**).

Then, weights are computed for each group of light frames (step **6-7**).

The process continues registering and integrating each light frame group (step **8-9**, **10-11**) taking into account the previously computed weights.



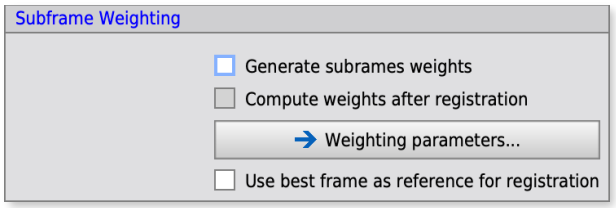
Auto-selection of reference frame, weights computed after registration



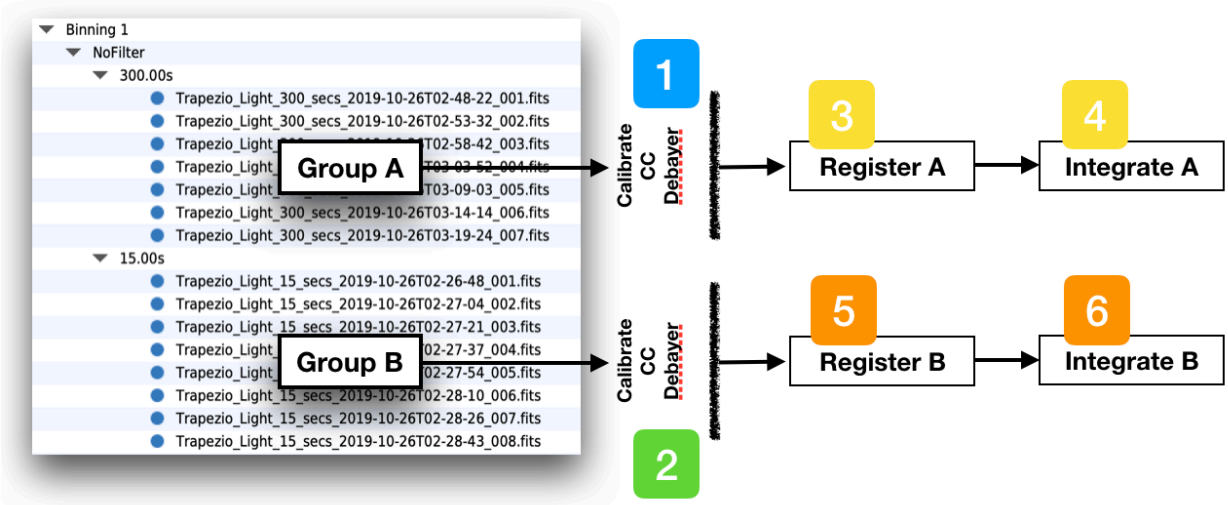
Every light frame group is calibrated, cosmetic corrected and debayered and frames descriptors are measured (step **1-2**, **3-4**).

Subsequently, the descriptors of all groups are grouped together and weights of all light frames are computed taking into account only stars properties. The best reference frame is the one with the highest weight (step **5**).

The process continues registering, computing descriptors and weights of registered images and integrating each light frame group (step **6-7-8-9**, **10-11-12-13**).

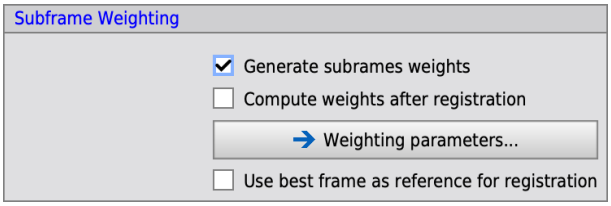


NO Auto-selection of reference frame, no weights computed

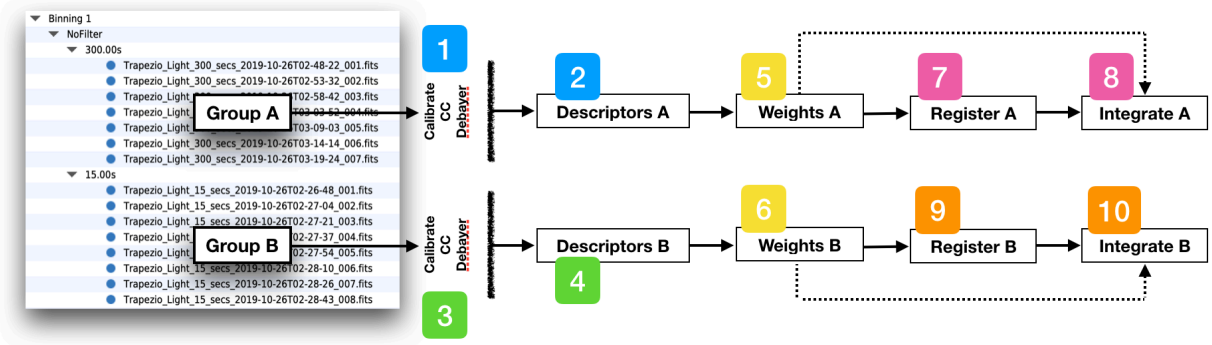


Every light frame group is calibrated, cosmetic corrected and debayered (step **1**, **2**).

The process continues registering and integrating each light frame group (step **3-4**, **5-6**).



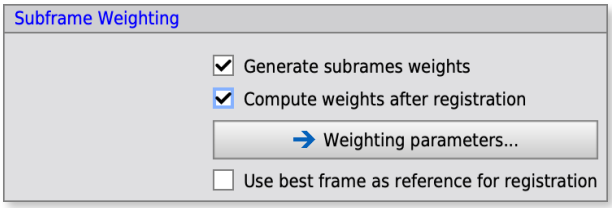
NO Auto-selection of reference frame, weights computed before registration



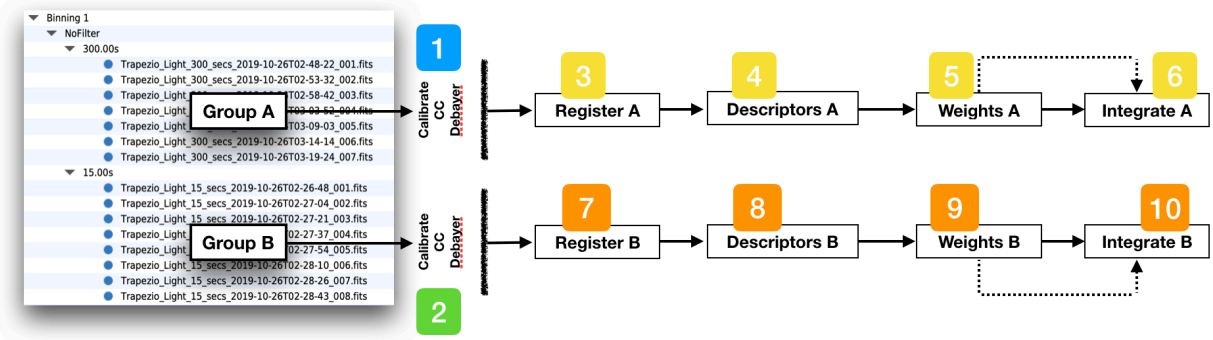
Every light frame group is calibrated, cosmetic corrected and debayered and frames descriptors are measured (step **1-2**, **3-4**).

Then, weights are computed for each group of light frames (step **5-6**).

The process continues registering and integrating each light frame group (step **7-8**, **9-10**) taking into account the previously computed weights.



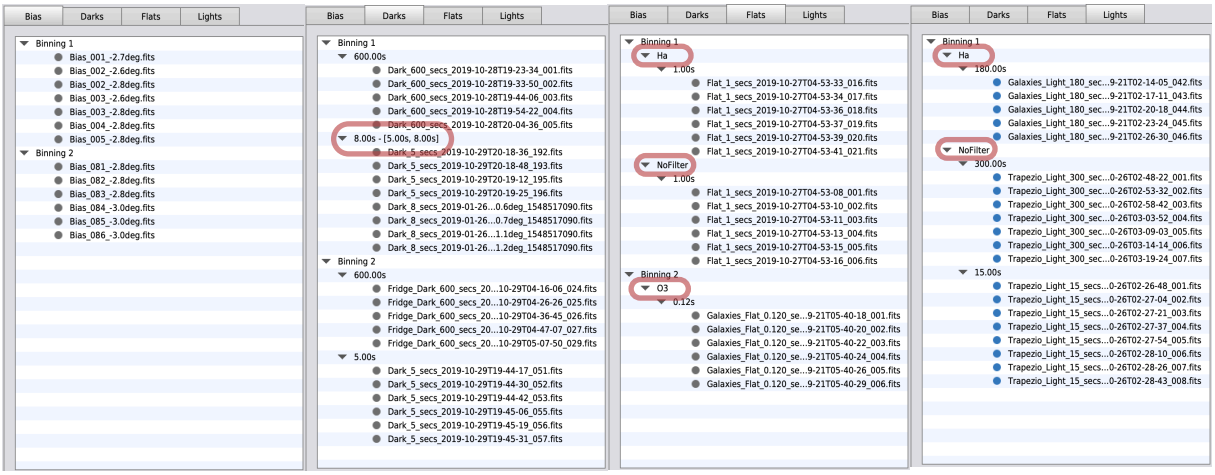
NO Auto-selection of reference frame, weights computed after registration



Every light frame group is calibrated, cosmetic corrected and debayered (step **1**, **2**).

The process continues registering, computing descriptors and weights of registered images and integrating each light frame group (step **3-4-5-6**, **7-8-9-10**).

New frames grouping



Frame grouping has been improved in order to take into account not only **BINNING** and **exposure** but also the **filter name**. This approach has the advantage of making WBPP capable of integrating an entire session of narrowband or HDR images in a single run. Frame grouping works with the following rules:

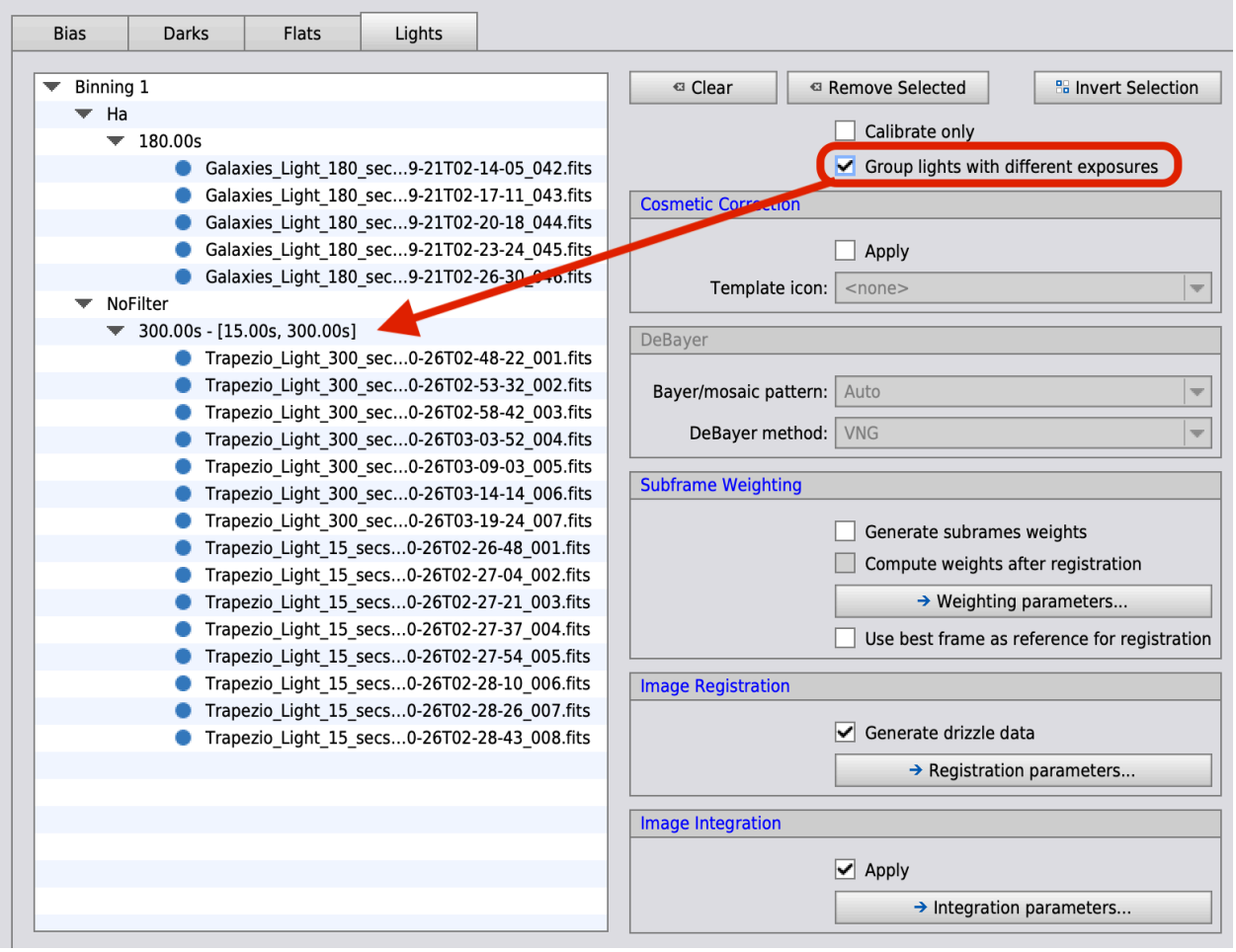
BIAS: grouped by BINNING (ascendant).

DARK: grouped by BINNING (ascendant)-> EXPOSURE (descendant). By setting the exposure tolerance, dark frames with different exposures are grouped together accordingly and, by convention, the dark group's exposure is taken a the max amigos the frames. In this case the new WBPP shows the main exposure assigned to the group and the set of the different exposures of its grouped frames using the following notation:

MAIN EXPOSURE - [exposure 1, exposure 2, exposure 3]

FLAT: grouped by BINNING (ascendant) -> FILTER (alphabetical) -> EXPOSURE (descendant). Frames will be grouped if they exactly match all three parameters (given a tolerance on the exposure of 10 milliseconds)

LIGHTS: grouped by BINNING (ascendant) -> FILTER (alphabetical) -> EXPOSURE (descendant). Frames will be grouped if they exactly match all three parameters (given a tolerance on the exposure of 10 milliseconds). If the new option "*Group lights with different exposure*" is selected then light frames will be grouped only by BNINNNG (ascendant) -> FILTER (alphabetical) only: light frames with different exposures will be grouped together and group exposure will be shown adopting the same notation as for dark frames group as shown below:



The reason why this flag has been introduced is that it could be desired to integrate together light frames with different exposures.

Moreover, as mentioned, a tolerance of 10 milliseconds is always taken into account when grouping by exposure since some softwares like APT do not save the exposure

precisely and a small difference between light frames of about one / two milliseconds has been seen during out tests.

Smart Calibration

Calibration in BPP works by matching the master dark exposure with the default exposure of a light frame group. Considering that the WBPP now allows to group by filter name and to merge light frames with different duration into a single group we need to make this matching smarter. In WBPP the calibration is smart since it extends the capability to find the proper master calibration files taking into account these new capabilities.

The master files matching works as follows:

	Master Calibration Files		
	master BIAS	**master DARK**	**master FLAT**
FLAT FRAMES	use the master bias with the same binning	use the master with the closest exposure. If “calibrate with flat dark only” is flagged then exposure cannot be different more than = 0.5s otherwise no master dark are be used.	
LIGHT FRAMES	use the master bias with the same binning	use master dark with same binning and closest exposure	use master flat with same binning and same filter name

When calibration is performed on a light frame group, light frames are always **sub-grouped by exposure** and the most suitable master dark frame is chosen for each subgroup of frames. This is mandatory to calibrate properly each light frame with the master dark that best matches the each light frame exposure.

New “auto” rejection option

Pixel rejection strategy should be selected depending on the number of frames to integrate. Standard BPP allows to set only one pixel rejection algorithm to be used for all groups of the same type (bias, dark, flat and light). Considering the amount of grouping possibility WBPP can manage it would be worth to have different pixel rejection strategies depending on each group’s number of frames. This new option solves this problem by letting WBPP to select the most suitable rejection algorithm depending on each group size.

The algorithm selection adopts the following criteria:

N < **8**: Percentile Clip

N < **11**: Average Sigma Clip

N < **20**: Winsorized Sigma Clipping

N < **25**: Linear Fit Clipping

N >= **25**: Generalized Extreme Studentized Deviate

Smart Naming

In order to group light frames by BINNING, EXPOSURE and FILTER, WBPP needs to identify these three properties for each file.

The default approach is to read them from the FITS file header reading the standard keys where binning, exposure and filter name are stored but depending on the software and the settings used to shot the images some of these information still could be missing from the file. Moreover, many image formats do not contain this standard metadata at all.

Smart naming is the possibility for the user to properly name folders and file names in order to let WBPP to retrieve these information from the file path when they are missing from the file’s metadata.

It’s worth to highlight that the proper naming of folders or file names **do not override the image FITS data** so any property stored into the header file will be used despite any

file/folder naming convention. Moreover, when looking the global file path if more than one valid matching keyword is found for the same keyword, the last one in the posistion found will override the previous values.

Naming convention follows the conventions described next.

Binning

Binning is extracted by searching one keyword among **XBINNING**, **CCDBINX** or **BINNING** followed by a space, an underline or a dash character and next a sequence of numerical digits.

Examples are :

FILE PATH	BINNING
/Users/ME/2019-09-21_Galaxies/Dark **xbinning 1**/dark_01.fits	**1**
/Users/ME/2019-09-21_Galaxies/Dark **BINNING 04**/dark_02.fits	**4**
/Users/ME/2019-09-21_Galaxies/DarkS/dark_**ccdbinx_1**_078.fits	**1**
/Users/ME/2019-09-21_Galaxies/DarkS/master_dark_**XBINNING-2**.fits	**2**

Filter

Filter is extracted by searching one keyword among **FILTER** or **INSFLNAM** followed by a space, an underline or a dash character and next a sequence of alphanumeric digits.

Examples are:

FILE PATH	FILTER
/Users/ME/NGC2903/FLAT **FILTER Halpha**/flat_01.fits	**Alpha**
/Users/ME/NGC2903/LIGHT **INSFLNAM O3**/light_02.fits	**4**
/Users/ME/NGC2903/LIGHT/light_**FILTER-SII**_078.fits	**1**
/Users/ME/NGC2903/FLAT/master_flat_**ISFLNAM-UHCS**.fits	**2**

Exposure

Exposure is extracted in two steps:

1. by searching one keyword among **EXPTIME** or **EXPOSURE** followed by a space, an underline or a dash character and next a valid integer or float number representation.
2. by searching a valid integer or float number representation not preceded by any alphabetic character and followed by **s**, **sec** or **_secs** if the previous step failed.

Examples are:

FILE PATH	EXPOSURE
/Users/ME/NGC2903/LIGHT **180s**/flat_01.fits	**180 sec**
/Users/ME/NGC2903/LIGHT **2.4_secs**/light_02.fits	**2.4 sec**
/Users/ME/NGC2903/LIGHT/light_**EXPTIME-60**_078.fits	**60 sec**
/Users/ME/NGC2903/FLAT/master_flat_**EXPOSURE-20.0**.fits	**20 sec**

Extended diagnostic

Providing an extended flexibility in terms of grouping and processing light frames by duration and filter, there are many scenarios where an improper set of bias dark flat and light frames could mismatch and generate master lights with issues. For this reason, the diagnostic has been extended in order to warn the used from the very beginning about potential masters mismatches and configuration errors. In particular, the new issues detected and reported by WBPP are:

Generic configurations

- **a group has less than 3 frames**: this is a blocking error since ImageIntegration needs at least 3 frames to proceed. WBPP will not continue.

• **a group contains CFA images but “CFA Images” flag is not set**: this is a ignorable warning if user is intentionally running WBPP with this purpose, otherwise CFA images needs always to be debayered so the flag bust be selected.

Flat frames checks

• **neither matching master bias nor master dark flat found**: this is a ignorable warning reported when no suitable master bias and master dark have been found to calibrate flat frames. The master flat frame will be generated by integrating uncalibrated flat frames. This could be the way the user decided to proceed otherwise he should investigate why there is a binning and/or exposure mismatching between flat groups and bias/dark groups.

• **matching master bias but no matching master dark found**: this is a ignorable warning in this case flat frames are calibrated with master bias only, discarding any dark calibration.

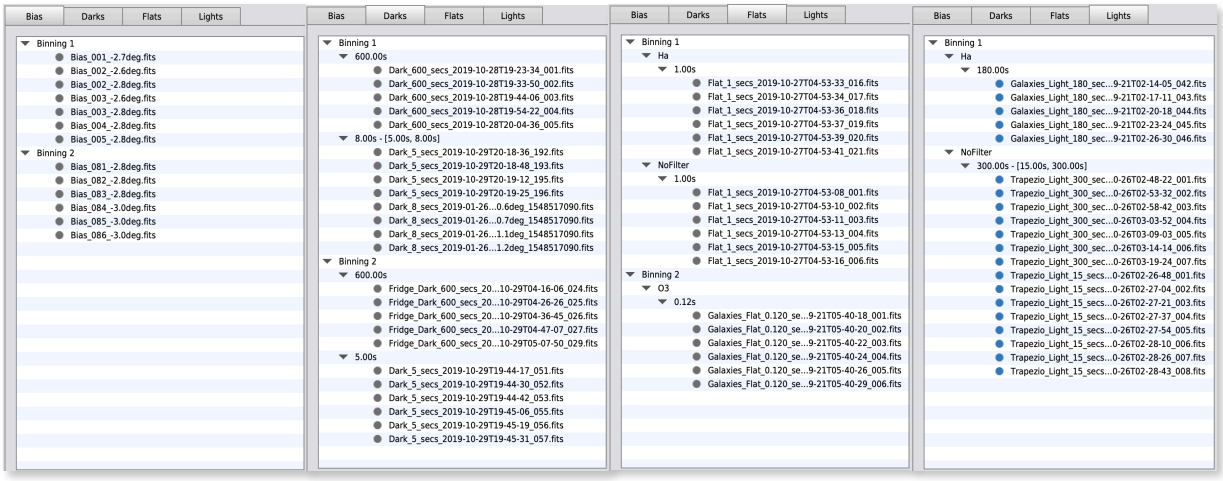
• **selected master dark frame has different exposure**: this is a ignorable warning reporting that the master dark used to calibrate flat frames has a different exposure time. Depending on the case, the user could decide to proceed or investigate on the reason of this binning and/or exposure mismatching.

Light frames checks

• **selected master dark frame has different exposure**: this is a ignorable warning reporting that the master dark used to calibrate a subgroup of light frames has a different exposure time. Depending on the case, the user could decide to proceed or investigate on the reason of this binning and/or exposure mismatching.

• **no master flat frame has been found**: this is a ignorable warning reporting that WBPP did not found any suitable master flat frame to calibrate light frames. The user could proceed if this was expected (for example i f no flat frames have been provided) or investigate on the reason why the provided master flat mismatches the light frame binning and/or filter name.

As an example, given the following set of frames:



We assume that “Calibrate with flat dark only” is selected for Flats so only a perfect matching master dark can be selected to calibrate flat frames. WBPP inspects the matching between the following masters:

1. master Bias
    1.1. BINNING 1
    1.2. BINNING 2
2. master Dark
    2.1. BINNING 1, 600 sec
    2.2. BINNING 1, 8 sec
    2.3. BINNING 2, 600 sec
    2.4. BINNING 2, 5 sec
3. master Flat
    3.1. BINNING 1, Ha, 1 sec: **no master dark matching 1 sec exposure is found**
    3.2. BINNING 1, NoFilter, 1 sec: **no master dark matching 1 sec exposure is found**
    3.3.BINNING 2, O3, 0.12 sec: **no master dark matching 0.12 sec exposure is found**
4. master Light

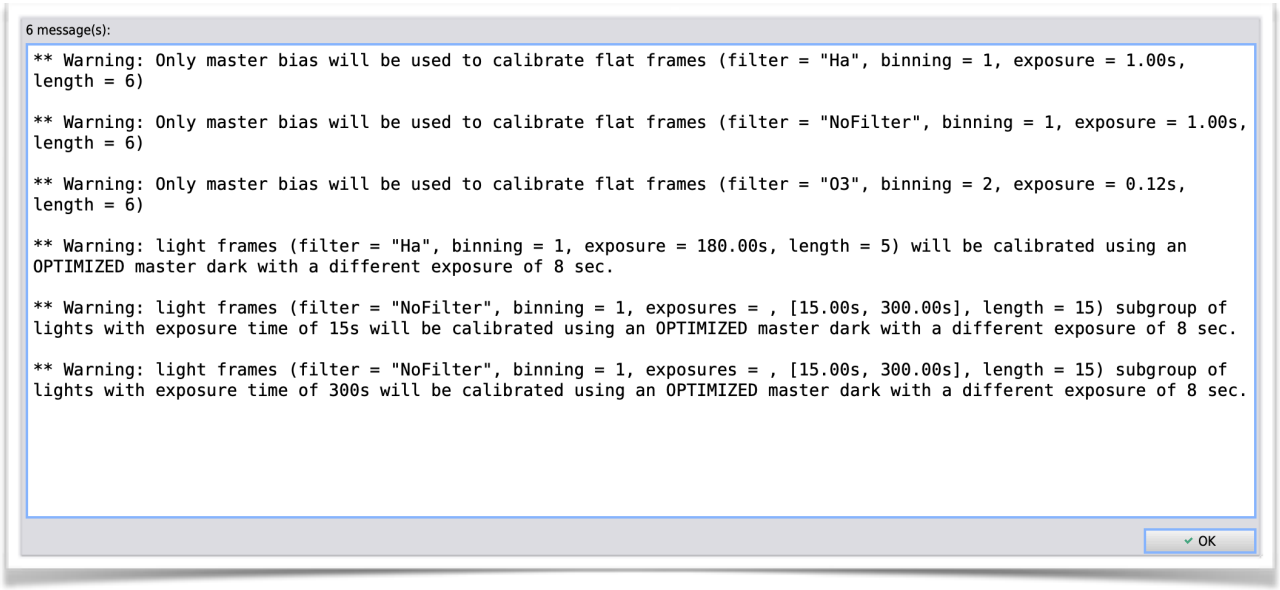
4.1.BINNING 1, Ha, 180 sec: master flat of (BINNING 1, Ha) is found but **master dark with BINNING 1 and closest exposure to 180 sec has a different exposure of 8 sec**

4.2. BINNING 1, Ha, 300 sec: this group is divided into two subgroups

4.2.1. BINNING 1, Ha, 15 sec: master flat of (BINNING 1, Ha) is found but **master dark with BINNING 1 and closest exposure to 15 sec has a different exposure of 8 sec**

4.2.2. BINNING 1, Ha, 300 sec: master flat of (BINNING 1, Ha) is found but **master dark with BINNING 1 and closest exposure to 300 sec has a different exposure of 8 sec**

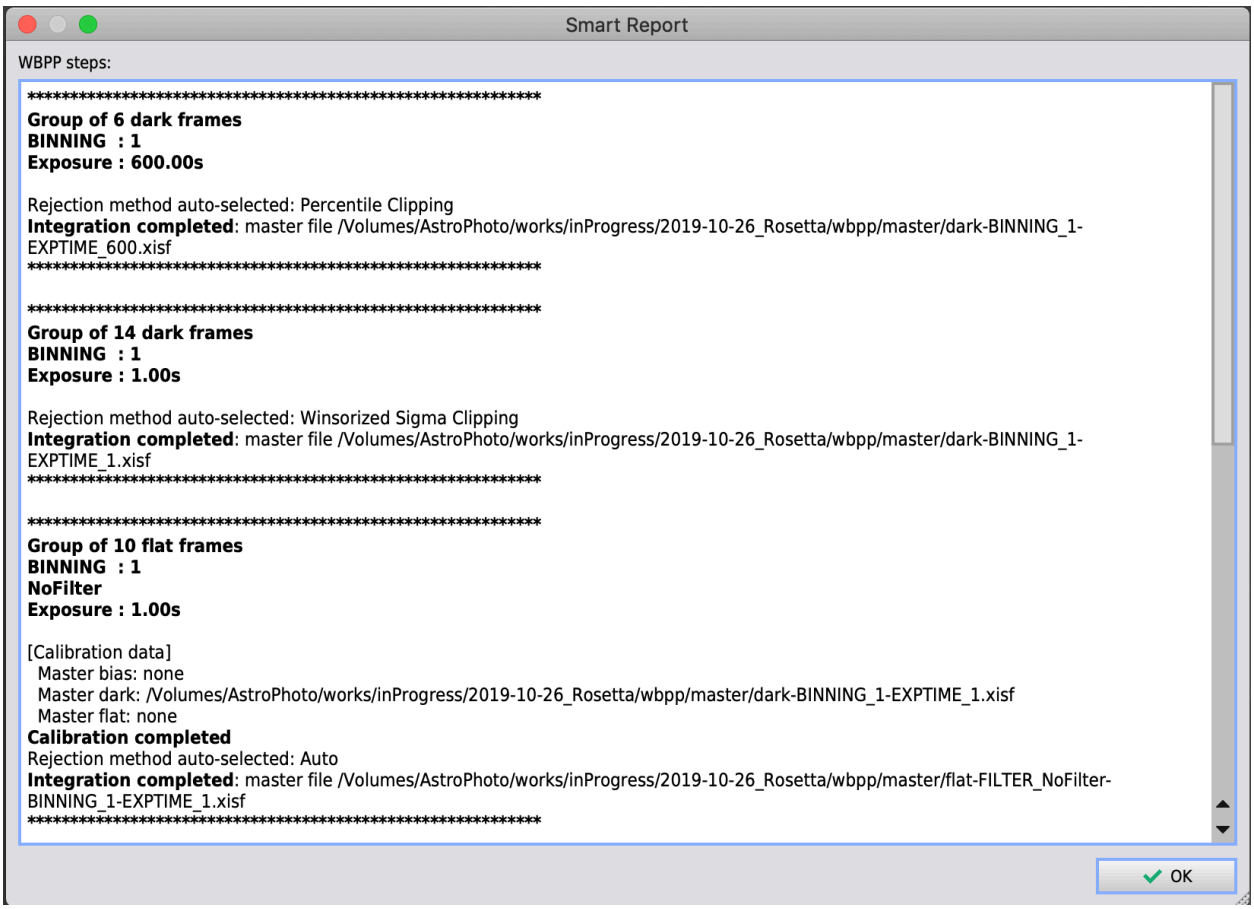
All these warnings are reported in the improved diagnostic screen.

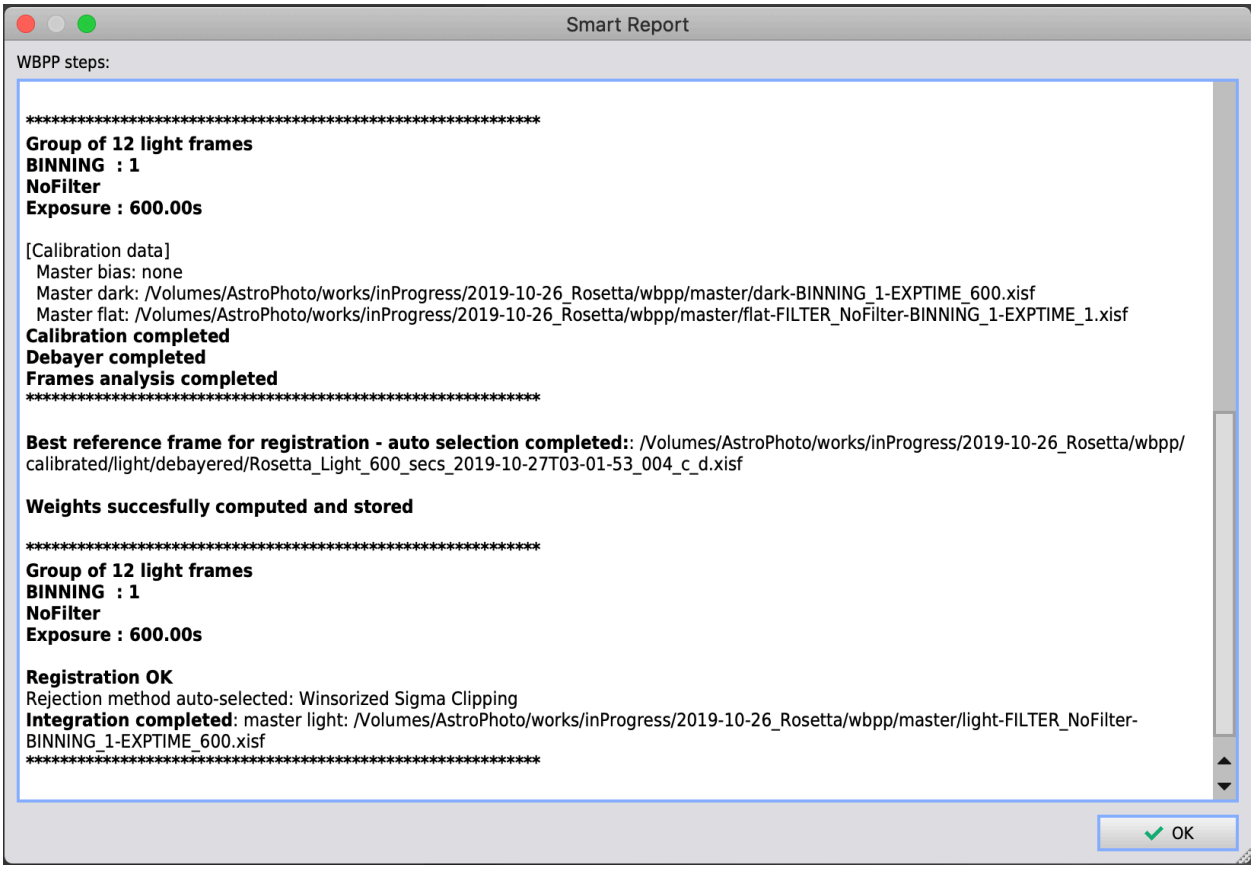


Smart Reporting

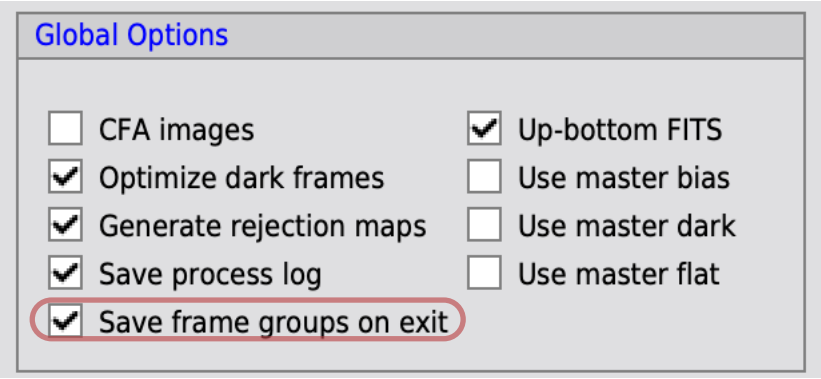
Standard BPP prints a verbose logging on the console during its execution and inspecting the log file eventually generated to overview the execution means flowing through thousands of text lines. This is awkward and we decided to provide a high-level overview reporting called **Smart Reporting** shown at the end of the WBPP execution. This screen resumes in a human-readable fashion the steps executed on each frame group and few significant details about calibration, registration and integration such as the calibration master files used, which reference frame have been selected for the registration, which rejection algorithm has been selected and the location of master files

Below as an example the smart





Save frame groups on exit



It is foreseeable that given a set if images to integrate, the first weights applied by WBPP are not generating the best possible master light that can be achieved by an iterative fine tuning of the weighting parameters.

Presets helps to get to a good result in general but an advanced or just curious user will be probably willing to do more than one integration changing the weighting parameters.

To inspect the master lights generated, the WBPP dialog window needs to be closed in order to load the masters in PixInsight and inspect them before executing a new integration with different parameters. Since standard BPP does not remember the files loaded in the previous session, the user needs to reload every time the entire set of bias, dark, flat and light frames (eventually using the masters from the second run).

This flat addresses this use case and if active lets the WBPP to reload the whole set of images (including the masters if they was generated) on the next launch such that there is no need to manually reinsert all files during this iterative weight tuning process.