



ExoClock Newsletter

Dear ExoClock participants,

Hope you are all well and safe. April has been the most productive month so far in terms of observations, well done everyone! Many thanks also for participating in the recent meetings; we will continue organising more such discussions in the future, as they are very fruitful. For those who did not have the chance to join so far, the recorded meetings, as well as all newsletters are accessible through your account at:

<https://www.exoclock.space/users/material/>

Note that this material is only available to registered participants and thus, it is not allowed to use it for external purposes or share it with others.

In this newsletter, we share briefly key points of the latest meeting and also some new educational material on reduction frames explaining some more details on why they are important for every single observation. We have developed also a new feature that allows you to upload transit times from previous literature publications on the website.

Updates on the website - Mid-time literature upload

We have already discussed that for the refinement of any target's ephemeris, we will combine literature observations with any ExoClock current or past observations. This is very important in order to decrease the errors as much as possible. At the same time, it is a chance to collect the literature observations and use them efficiently.

Since we are approaching the first publication date, we have started collecting all these literature mid-time points (each of them corresponding to a single observation). As some of you are not able to do observations due to weather or accessibility issues, we have decided to open up this process to you, too, in order to give you the opportunity to contribute from a different perspective.

If you are interested and you have time, all you have to do is to choose a target and upload the transit times of observations from past publications. Simple guidelines are given on the website about accessing the publications and identifying the transit times.

You can access it from here:

https://www.exoclock.space/upload/literature_mt

The following screenshots show an example for a target and what you need to upload.

This is only optional, of course, but if you decide to do it, it is important that you upload all the relevant publications for your chosen target. This should be finished until the end of May, as it is a necessary element for the publication.

Upload Literature Mid-time

Planet: KELT-1b

Suggested papers

- **Spitzer Phase Curves of KELT-1b and the Signatures of Nightside Clouds in Thermal Phase Observations**
 Beatty et al. 2019 Bibcode: 2019AJ....158..166B
- **Planet-Star Interactions with Precise Transit Timing. I. The Refined Orbital Decay Rate for WASP-12 b and Initial Constraints for HAT-P-23 b, KELT-1 b, KELT-16 b, WASP-33 b and WASP-103 b**
 Maciejewski et al. 2018 Bibcode: 2018AcA....68..371M
- **Revised Exoplanet Radii and Habitability Using Gaia Data Release 2**
 Johns et al. 2018 Bibcode: 2018ApJS..239...14J
- **The Broadband and Spectrally Resolved H-band Eclipse of KELT-1b and the Role of Surface Gravity in Stratospheric Inversions in Hot Jupiters**
 Beatty et al. 2017 Bibcode: 2017AJ....154..242B
- **Near-infrared Thermal Emission Detections of a Number of Hot Jupiters and the Systematics of Ground-based Near-infrared Photometry**
 Croll et al. 2015 Bibcode: 2015ApJ...802...28C

Upload

Transit mid-time*
 ←

Transit mid-time error*
 ←

Time format*
 ←

Paper bibcode*
 ←

Upload Literature Mid-time

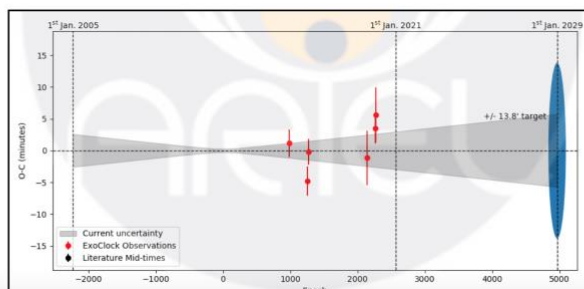
As soon as you have selected the target, there is a list with suggested papers. Note that for this process, only peer-reviewed publications are acceptable and this list includes only refereed papers. When you access one of these papers, four elements are important to report before clicking upload (indicated with the four coloured arrows). This is an example for the first publication of the list. When you access the paper, you should look for the transit mid-time (sometimes mentioned as T_c or T_0). Next to the mid-time, you will find the transit mid-time error, which is also required. It is very important to note the time format, which should be mentioned in each publication. If not, assume it as UTC. Finally, make sure you have included the paper bibcode, which you can find in the list as well (highlighted with the blue).

The website also includes some straightforward guidelines to facilitate you with the process (screenshot below):

- **Spitzer and z' Secondary Eclipse Observations of the Highly Irradiated Transiting Brown Dwarf KELT-1b**
 Beatty et al. 2014 Bibcode: 2014ApJ...783..112B
- **KELT-1b: A Strongly Irradiated, Highly Inflated, Short Period, 27 Jupiter-mass Companion Transiting a Mid-F Star**
 Siverd et al. 2012 Bibcode: 2012ApJ...761..123S

Guidelines:

1. Not all the papers include transit observations, check those that have transits observed.
2. The most important thing is the time basis (HJD/BJD/UT, UTC/TDB). If UTC/TDB is not specified, assume it is UTC. You can replace TT with TDB.
3. If the uncertainties are not symmetric (e.g. $2400054.4^{+0.002}_{-0.001}$) report the largest.
4. Report the uncertainty in days (in some cases you will find them in seconds or minutes in the papers).
5. More recent papers usually include data from previous ones, cite the original paper (the old one).



Key points from the second web meeting

During the second online meeting, these were the main topics discussed.

➤ *Observing during twilight*

Since we are approaching the Summer time and days become longer, fewer transits are observable, especially at northern latitudes. Twilight can last for a long time but if you use a red filter, the observations would not be highly affected. The scheduler has a limit for the Sun altitude of -10 degrees instead of -18 degrees, which means that some part of your observations can be conducted during twilight.

➤ *Binning*

It has been asked whether it is possible to use binning 2x2 instead of 1x1. Usually we recommend using binning 1x1 when conducting transit observations because it allows you to increase the exposure time and therefore the total SNR of the observation. However, this depends on the overheads. If you have short overheads, it is fine to have shorter exposure times by using binning 2x2. If your overheads are longer than your exposure times, it is preferable to use binning 1x1. This is something you can try with your own equipment. For example: If you have 40s overheads, an exposure time of 40s (binning 1) will result in 50% efficiency, while an exposure time of 10s (binning 2) will result in 20% efficiency, making the first setup preferable. As a general rule, binning 2 is acceptable only for faint target and as far as you don't have to decrease the exposure time.

➤ *Main steps to evaluate the results*

Many of you have asked how to simply evaluate the results before uploading them to the system. This can be done in the fitting preview.

First of all, check the agreement between the transit depth detected and the literature value. This is the main reason we usually return observations to the observers for reanalysis. Such differences occur either from unsuitable comparison stars or from problematic Flat Frames.

At a second stage, check the Auto-correlation of the residuals, if this value is higher than 0.4, it means that there is remaining signal that cannot be modelled. This can be due to unsuitable comparison stars but also due to bad weather conditions (in the latter case there is not much to do!)

Lastly, if you have processed the data with different sets of comparison stars that give consistent results and you want to decide which one is better, check for the lowest STD and the lowest AutoCorr of the residuals.

If you are still facing problems, it is suggested to upload the results and we will further explore what the issue might be. Always it is important to upload your results, and we will let you know if they can be improved or if they cannot be used due to low their quality.

Survey on creating profile pages

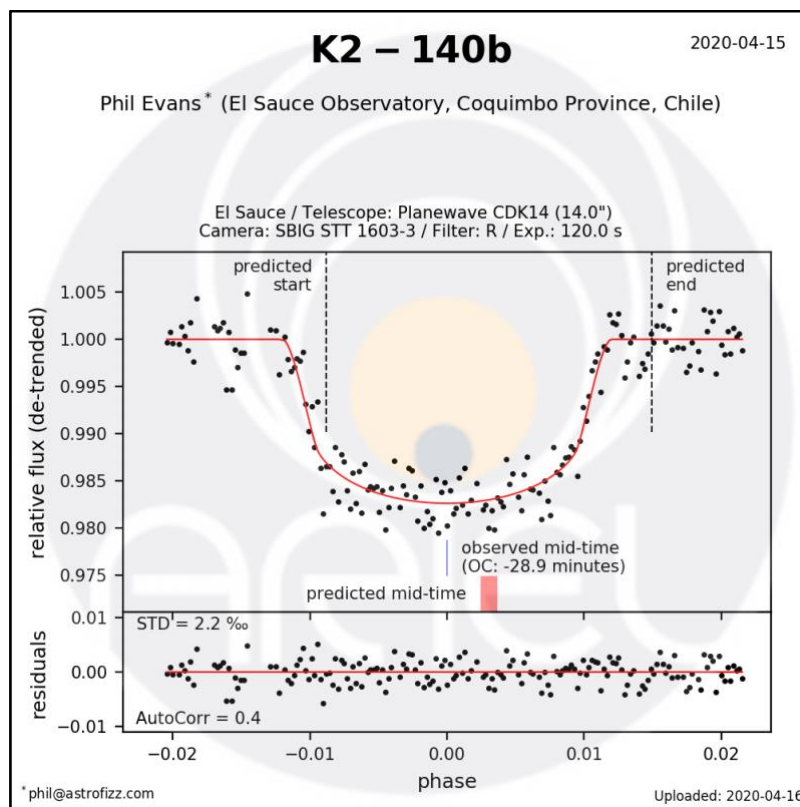
Many thanks to those that have already filled the survey for creating profile pages. If you haven't filled it yet, we would really appreciate it if you could share your opinion by filling the following survey. Since many of you have asked for having a form of discussion in order to get useful information and share best practices, we would like to ask your opinion on creating a profile page where you, the observers, can share information about your equipment, location, sky conditions etc. This would help other observers contact each other to ask questions or

share useful information. This at the moment just an idea, and before we start working on this, we would like you to fill this very short survey, it is simple and straightforward:

https://docs.google.com/forms/d/e/1FAIpQLSdtiNNEr5llsoAVEOromKDjxemVlySQQC1jKNweUBudByJmgw/viewform?usp=sf_link

Highlighted observations

This month has been the busiest so far with more than 100 new observations which is an incredible result. This is extremely important, as different targets are observable every season and from different locations. Thus, it leads to getting results for as many targets as possible and making the best use of resources. As an example for this newsletter, we showcase the light curve of K2-140b, observed by Phil Evans from Chile. K2-140b is a target that is only observable from places around the Equator (DEC $\sim -10^\circ$) and it has a long duration (total 6 hours) and thus, it is quite challenging to observe. The target was marked with medium priority and did not have any other observations. As you can see in the plot, the observed time has a difference of -28.9 minutes from the predicted value. Again, this observation is an example highlighting the importance of allocating the targets to different locations and different equipment.



Congratulations Phil for the great result!

ALERTS

Thanks to everyone who observed some of the **Alert targets** during the last month. HAT-P-22b was a target in the Alert system and now we have enough observations to refine the ephemeris and this is thanks to your vigorous activity. The following targets (including old and new ones) are in the **alert system** at the moment. Please check your personalised alert schedule and if you get a clear sky, observe them!

<https://www.exoclock.space/schedule/alerts>

- K2-140b
- WASP-54b
- KELT-18b
- KELT-15b
- HAT-P-41b
- WASP-83b
- HAT-P-17b
- WASP-107b

We remind you to send us at exoclockproject@gmail.com:

- Your feedback on the website
- Suggestions for new features
- Questions on the observations or the analysis
- Ideas for topics you would like to see in the newsletters

Stay well and healthy!

Clear Skies,
the ExoClock team

CHECK this out!

ExoWorlds Spies is now available in Portuguese! <https://www.exoworldsspies.com/pt/observers/>
Share it with any interested Portuguese-speaking audiences!

Many thanks to **Cédric Pereira** who translated all the material (only by himself!) to Portuguese, in an effort to expand the project to Portuguese-speaking people. Cédric is also the ExoClock national contact point for Portugal. If you are interested in translating material in your language, send us an email and check the Citizen Science Translation Hub website for details:

<https://citscitranslate.wixsite.com/citscitranslate/exoworlds-spies>

An overview of the data reduction process

why is it important to obtain reduction frames?

Every kind of measurement is usually affected by a number of unwanted factors. In astronomical photometry these are related to either the instrument or the sky conditions. Here we discuss about the most important instrument factors that can affect our observations. The process of correcting our observations (Science Frames) for these factors is known as the reduction process.

The reduction process requires three types of reduction frames known as the Bias, the Dark and the Flat Frames. It is important to obtain more than one frame from each type in order to minimise the effect of uncertainties (noise) during the reduction process.

Bias Frames

Bias Frames are frames with zero exposure time (practically), taken with the camera covered to avoid any external illumination. Covering the camera is just for safety, as any external source practically will not affect a frame with zero exposure time.

Bias Frames are used to remove the bias signal – i.e. signal produced by the electronics of the camera during the read-out process. The bias signal is present and constant in all frames, regardless of the exposure time.

Dark Frames

Dark Frames are frames of the same exposure time as the Science Frames (or longer), taken with the camera covered to avoid any illumination. Here, covering the camera is extremely important due to the non-zero exposure time.

Dark Frames are used to remove the dark signal – i.e. signal produced by the pixels themselves. As from every material at a temperature above absolute zero (-273°C), electrons are freed from the silicon of the CCD, escaping from the valence band. The dark signal is present in all frames with a non-zero exposure time, and it is linear with exposure time.

Flat frames

Flat Frames are frames of non-zero exposure time (typically of a few seconds) capturing a uniformly illuminated area. This area could be an illuminated panel or wall, or the sky during twilight (sky flats). It is important to keep the signal in the Flat Frames high (about 2/3s of the full pixel capacity) to achieve more precise results. In the case of sky flats, it is important to capture the sky while it is still bright, to void capturing stars, too.

Flat Frames are used to correct the flat field – i.e. non-uniformities in the illumination of the CCD, caused by the geometry of the telescope and by dust on the optical elements or on the CCD itself. The flat field is present in all frames with a non-zero exposure time that capture external light sources, regardless of the exposure time.

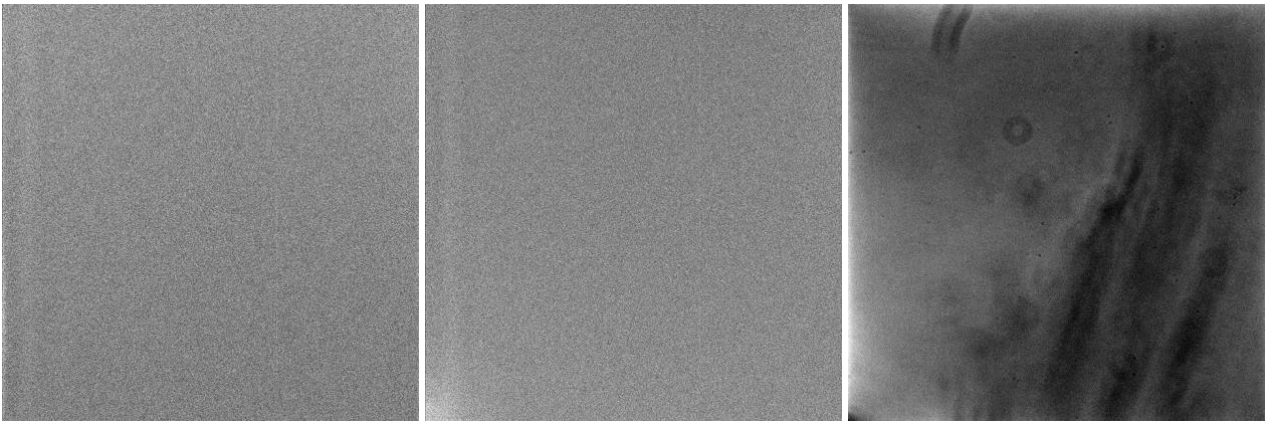


Figure 1. Examples of Bias, Dark and Flat Frames (from left to right).

Processing

There are a few steps involved in the reduction process:

1. The Master Bias is calculated as the median of all the bias frames.
2. The Dark Frames contain the bias signal, so the Master Bias is subtracted from every Dark Frame.
3. The Master Dark is calculated as the median of all the corrected Dark Frames, divided by the exposure time of the Dark Frames (effectively giving the dark signal per second).
4. The Flat Frames contain bias signal, too, so the Master Bias is subtracted from every Flat Frame.
5. The Flat Frames contain also dark signal, so a scaled version of the Master Dark (Master Dark \times exposure time of the Flat Frame) is subtracted from every Flat Frame.
6. The Master Flat is calculated as the median of all the corrected Flat Frames, and divided by its median.
7. The Science Frames contain the bias signal, so the Master Bias is subtracted from every Science Frame.
8. The Science Frames contain also dark signal, so a scaled version of the Master Dark (Master Dark \times exposure time of the Science Frame) is subtracted from every Science Frame.
9. The Science Frames are also distorted by the flat field, so every Science Frame is divided by the corrected Flat Field.

Note: the median is preferred over the mean, because it is less sensitive to extreme values (outliers) that may appear in one of the reduction frames.

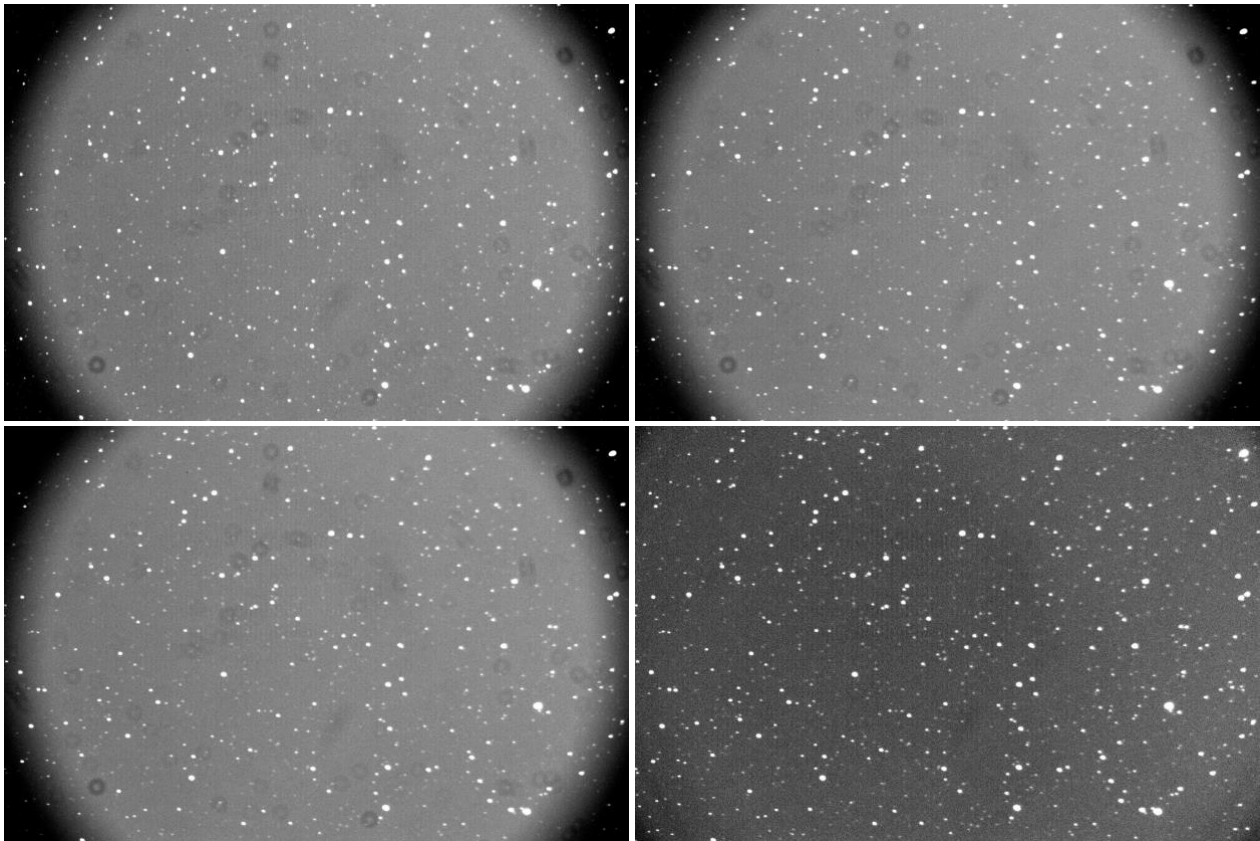


Figure 2. Different stages of the reduction process. Top-left: A raw Science Frame. Top-right: The same frame corrected for bias (after step 7). Bottom-left: The same frame corrected for bias and dark (after step 8). Bottom-right: The same frame corrected for bias, dark and flat (after step 9 – final product).

What to avoid while obtaining reduction frames?

As we can see from the above, the reduction frames require a very specific treatment to be implemented correctly. For this reason, we need to be careful and avoid common mistakes when obtaining or using them.

General:

- We should not obtain reduction frames at different temperatures. In this case, the reduction process will not remove the correct dark signal from the Flat Frames and the Science frames.
- We should not process a dataset without Bias Frames. In this case the Dark Frames will not be free of the bias signal and this signal will be scaled with exposure time (while it should not), leading to a wrong correction of the Flat Frames and of the Science frames.

Dark Frames:

- We should not uncover the camera when obtaining the Dark Frames. In this case, external illumination can affect them, leading to a wrong correction of the Flat Frames and of the Science frames.

Flat Frames:

- We should not obtain sky flat of long exposure. In this case, stars will become detectable in the Flat Frames, causing anomalies in the final reduced Science Frames.
- We should not obtain Flat Frames of low signal. In this case, the non-uniformities are not recorded with high enough precision.

How many reduction frames?

As mentioned earlier, it is important to obtain more than one reduction frame of each kind. This is to reduce the effect of the camera's readout noise on the reduction process. By obtaining two, five, ten or twenty reduction frames of each kind, the readout noise is reduced by approximately 30%, 50%, 65% or 75%, respectively. This means that five is a reasonable number, but if the camera used has a very high readout noise, we should obtain a higher number of frames, to minimise the effect.

In summary

	Dos	Don'ts
Bias Frames	<ul style="list-style-type: none">• Cover the camera / telescope	<ul style="list-style-type: none">• Don't forget them!
Dark Frames	<ul style="list-style-type: none">• Cover the camera / telescope	<ul style="list-style-type: none">• Don't use an exposure time shorter than the Science Frames
Flat Frames	<ul style="list-style-type: none">• Aim to a uniformly illuminated area.• Aim to the 2/3s of the full pixel depth	<ul style="list-style-type: none">• Don't observe stars (for sky flats)• Don't change filter
Overall	<ul style="list-style-type: none">• Set the same temperature and binning as for the Science Frames• Obtain at least five reduction frames of each kind	<ul style="list-style-type: none">• Don't obtaining the reduction frames under different conditions (e.g. during day time)

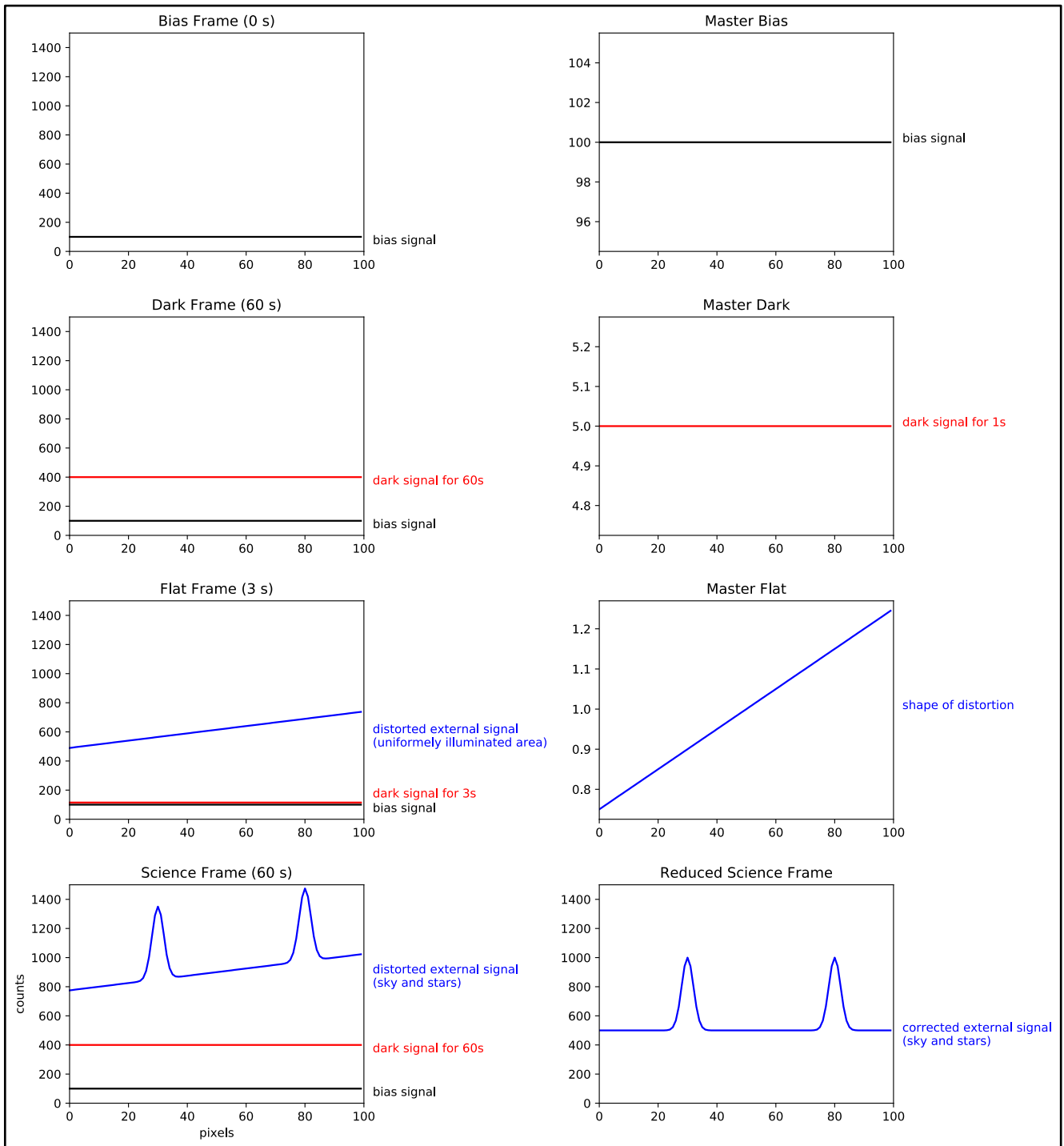


Figure 3. Schematic overview of the data reduction process. All plots show the profile of one line of a CCD (counts vs. pixel number). Left: Raw Reduction and Science frames. Right: Processed Reduction and Science frames.