hcam-finder Documentation

Release 1.2.2

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Contents

Observation planning and finding charts for HiPERCAM, ULTRACAM and ULTRASPEC

The `hcam_finder` package provides Python scripts `hfinder`, `ufinder` and `usfinder` for observation planning with HiPERCAM on the WHT and GTC, ULTRACAM on the NTT and ULTRASPEC on the TNT, respectively.

These tools allow you to generate finding charts as well as specify the instrument setup you require, whilst providing an estimate of observing cadence, exposure time and S/N estimates.

Note: Creating a finding chart and instrument setup for the above instruments are more tightly connected than is usually the case with CCD imagers. To avoid errors in phase II setups, you **must** use the tools above to generate finding charts. By doing so, and reading the instrument-specific documentation below, you will avoid the non-optimal phase II setups that arise from a lack of awareness of the peculiarities of imagers designed for high time resolution.

`hcam_finder` is written in Python and is based on TKinter. It should be compatible with Python2 and Python3.

CHAPTER 1

Installation

The software is written as much as possible to make use of core Python components. It requires my own hcam_widgets module. It also relies on the third party libraries astropy for astronomical calculations and catalog lookup, as well as ginga for image display. Optionally, you can also use astroquery to expand the range of surveys one can download images from.

Installing using `pip` should take care of these dependencies. Simply install with:

```
pip install hcam_finder
```

or if you don't have root access:

```
sudo pip install hcam_finder
```

or:

```
pip install --user hcam_finder
```

- Free software: MIT license

- Documentation: https://hcam-finder.readthedocs.io.

CHAPTER 2

Bugs

`hfinder` is of course entirely bug free! However, if you do find an issue, please raise it at the github page.
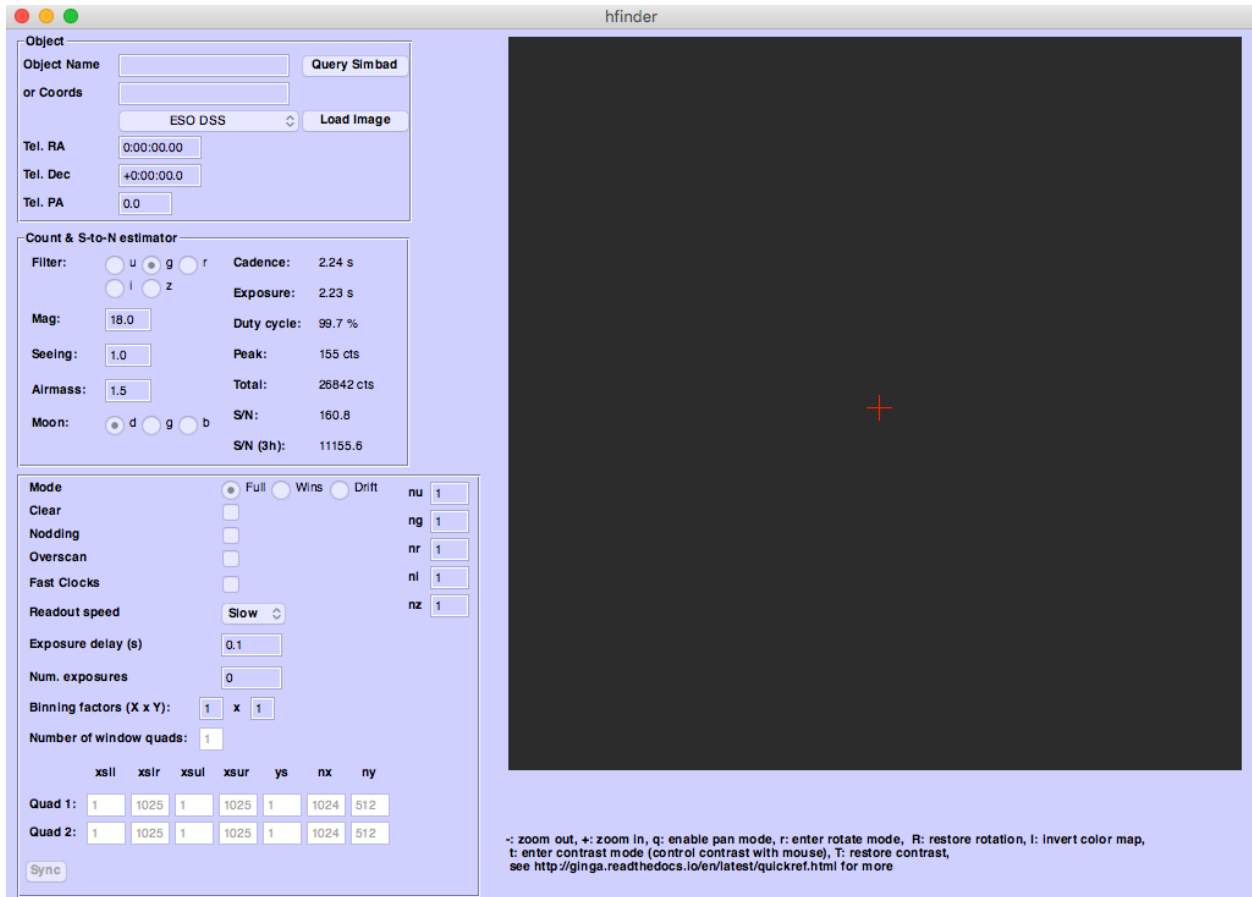
Usage

Please see the *detailed usage instructions*

3.1 Usage

To start `hfinder`, simply type:

```
hfinder
```

Other finding chart tools are started in a similar way, e.g. `ufinder` to start the ULTRACAM tool and `usfinder` for the ULTRASPEC tool. The main GUI window will display, shown below (windows for all tools are similar).

3.1.1 Telescope Selection

Before proceeding any further, make sure the correct telescope is selected using the *Telescope* menu item. If you wish to make your selection permanent, see *Changing the config file*.

3.1.2 Target Setup

Enter your Object Name in the appropriate box. You can query SIMBAD using your entered target name by pressing the *Query Simbad* button. If SIMBAD lookup fails, you can enter your target coordinates by hand.

Select a sky survey to grab images from and press the *Load Image* button. If an image is available in the selected sky survey it will be downloaded and displayed, along with the HiPERCAM field of view (FoV).

3.1.3 Manipulating the FoV

You can change the telescope pointing either by click-dragging the FoV, or by changing the values in the *Tel. RA* and *Tel. Dec* fields. Like all numerical entry boxes in hfinder the right and left arrow keys will increment or decrement the values. Holding Shift whilst pressing the arrow keys will make larger changes.

The Sky PA can be click-dragging on the corner of the displayed FoV. This will rotate the FoV. Alternately, edit the value in the *Tel. PA* field.

3.1.4 Interacting with the displayed image

Basic instructions for manipulating the displayed image (pan, zoom etc) are displayed below the image itself. `hfinder` uses the ginga package for image display. For a fuller reference about interacting with the image area, see the Ginga Quick Reference.

3.1.5 Choosing an Instrument Setup

Each finding chart tool includes a panel that is used to configure the instrument. For example, the instrument panel for `hfinder` is shown below:

As you make changes to this panel, the displayed FoV will update to reflect your choices of readout mode and window settings. The exposure time, cadence and signal-to-noise estimates in the panel above will also update.

Use this panel to select an instrument setup that best suits your observing needs. For more details of the different settings, and a guide to using each instrument, see:

- *Using HiPERCAM*
- *Using ULTRACAM*
- *Using ULTRASPEC*

Once you've got a setup and a pointing you are happy with, you can save a finding chart and export an instrument configuration file. To do this, select *Save → Finding Chart*. For HiPERCAM, you should also save a JSON copy of

your instrument setup by selecting *Save → Inst. Setup File* respectively. This will create two files which you should upload as part of your phase II submission.

> **Warning:** The JSON files produced by *hfinder* should not be edited by hand. Many of the mistakes observed in phase II submissions arise from hand-edited JSON files.

3.1.6 Changing the config file

A default configuration is written to `.hfinder/config` in the user's home directory. This has many settings in it, the vast majority of which should not normally be changed by the user. Two which are of interest are `telins_name`, which sets the default telescope. Set this to `GTC` or `WHT` as required.

The other option which may be useful is the `font_size`. Change this setting to increase or decrease the font size if the GUI does not fit well on your screen.

3.2 HiPERCAM

Because HiPERCAM is optimised for high time resolution, there are a number of peculiarities to it's use. You should read this document in full before creating a phase II submission.

If you are already familiar with HiPERCAM, there is a handy *Checklist* you can use to check your setups before submission.

The primary consideration when observing with HiPERCAM is to realise that its frame-transfer CCDs have no shutter. Instead, an image is rapidly moved into the storage area, which begins a new exposure in the image area. The image continues to expose whilst the storage area is reading out. As a result there is very little deadtime between exposures. However, one cannot start a new exposure whilst the storage area is being read out; this sets a *minimum exposure time* equal to the time needed to readout an image.

Obtaining a desired exposure time involves selecting a readout mode (binning/windows), which sets the *minimum* possible exposure, and optionally adding a delay to get the desired exposure time and cadence.

3.2.1 Cadence / exposure time

Therefore, the first thing you should decide is what cadence your science requires. The longer it is, the easier things tend to be. A key feature of HiPERCAM, if you are trying to go fast, is that there is a trade off between how fast you can go and how much of the CCDs you read out and/or what binning you use. If you try to go very fast, e.g. less than 3 second cadence, you will need to use *Windowed mode*, or bin the readout. For extremely fast observations (more than 10Hz frame rate) there is a special option (*Drift mode*) to reduce readout overheads further. For observations where even shorter exposures are needed, there is a special mode (*Clear mode*), which can be used at the expense of dead time overheads. Therefore, the exposure time can define multiple other aspects of the setup.

For any given setup (binning, window sizes, readout mode), there is an absolute minimum exposure time which is set by the time taken to readout the storage area. One can expose for longer than this minimum by adding an arbitrary "exposure delay"; this is a key parameter of the `hfinder` setup. So perhaps your setup can be readout in 3 seconds, but for reasons of signal-to-noise perhaps you add 7 seconds exposure delay. Then your exposure time (and cadence, as dead time is negligible in this case) will be 10 seconds. If you set the exposure delay to 0 however, your exposure will be 3 seconds and you wouldn't be able to go faster without altering the setup.

If your objects are not variable, then, as usual for CCD imaging, you should consider:

1. the signal-to-noise you need,

2. the avoidance of saturation of your target and possibly comparison stars,

3. allowing enough time for the sky background to dominate over readout noise for faint sky-limited targets especially, and

4. whether you want to divide up exposures perhaps for dithering the position, or to enable exploitation of brief periods of best sky conditions, e.g. seeing.

For time-series observations of variable targets, considerations 1, 2 and 3 may still apply, but you also need to decide on the timescale you aim to sample. Because of the dependence of the minimum exposure time on the setup described earlier, this timescale may drive later decisions. For instance, HiPERCAM's full frame, unbinned readout time is about 3 seconds. If you need to go faster than this, you will need to bin or window. This is a trivial but common example of the interplay between exposure time and CCD setup.

3.2.2 Spatial sampling / binning

It is quite common to see setups with 1x1 binning selected. However, in most cases 1x1 binning is not the best choice, and sometimes it is a very bad choice. There are three reasons for this:

1. HiPERCAM's native unbinned pixel size on the GTC is just 0.081 arcseconds, which significantly oversamples all but the very best seeing. Thus if you bin 2x2, 3x3 or even 4x4, you might not lose much resolution at all.

2. Binning substantially reduces the amount of data. This can allow you to readout the CCD faster. This could mean for example that you can read the entire CCD binned, whereas you would have to sub-window if unbinned. This can make observing easier, and ensure that objects are not too close to the edge of the readout windows.

3. Binning reduces the impact of readout noise. CCD binning occurs on chip before readout, so readout noise is incurred per binned pixel, not per native CCD pixel. This is often very important gain, depending upon target and sky brightness. You should, if possible, define a setup that ensures that the peak target counts per binned pixel are substantially in excess of R^2G where R is the RMS readout noise in counts (ADU) and G is the gain in electrons per ADU. **For HiPERCAM this means one wants if possible at least 100 counts/pixel at peak**, and preferably higher than this. There is a caveat to this in that if the sky counts are greater than this level, then there is less to be gained since binning increase the target and sky counts per pixel by the same factor, but when going fast, the sky can often be quite low level (especially in CCDs 1, 2 and 3, i.e. ugr). This means it can make sense sometimes to use very large binning factors when going fast and sky noise is low. It is this sort of case when binning can quite dramatically improve your data, and if you are not worried about spatial resolution at all, 8x8 or even 16x16 binning might make sense.

Binning has downsides of course; resolution is the obvious one. If you need to exploit good seeing, then you may not want to go beyond 2x2 binning (0.162 arcseconds/pixel). The other one is that you make saturation. However, points 2 and 3 above mean that more often than not you should bin, and you should think twice before simply selecting 1x1. To understand more about how one guard against readout noise, see the section below on condition-tolerant setups.

Note: The binning is the same for all CCDs. There is another option for accounting for differences between CCDs. See the discussion of `nskips` below.

Note: The peak counts per binned pixel are displayed by `hfinder` if you set the correct magnitude for the target and selected filter. This is a very good way to judge your setup.

3.2.3 Readout modes

Outputs

HiPERCAM has four seperate outputs, or channels, per CCD. The division between these outputs is clearly shown in the FoV in `hfinder`.

> **Warning:** Each output has a different gain and bias level. You **must** avoid putting critical targets on the boundary between outputs.

Windowed mode

To enable higher frame rates, HiPERCAM can use one or two windows per output. Since there are four outputs, we refer to *window quads* to define window settings. You can enable windowed mode by selecting *Wins* for the *Mode* option in the instrument setup panel.

A window quad is defined by the x-start positions of the four quadrants, the size of the windows in x and y, and a y-start value. All windows in a quad must be the same shape, and all share the same y-start value. Increasing y-start moves the windows in from the edges of the CCD towards the centre.

If there are two window quads, they cannot overlap in y.

Synchronising windows

If on-chip binning is enabled, it is possible to define windows that do not align with the boundaries of the binned pixels. This means that one cannot use calibration frames taken with 1x1 binning (such as sky flats) to match the windowed data. If windows are not synchronised in this manner, the *Sync* button will be enabled. Clicking this will align the windows with the boundaries of binned pixels.

> **Warning:** Unless you have requested special calibrations for your data, e.g binned sky flats, you should make sure your setup is synchronised.

Clear mode

Sometimes extremely short exposures are needed, even with full frame data. Sky flats would be one example. It is possible to *clear* the image area of the CCD, just after the storage area is read out. This allows exposure times as short as 10 microseconds. These short exposures come at the expense of efficiency, since the charge accumulated whilst the storage area was reading out is lost.

For example, if the storage area takes 2s to read out, clear mode is enabled and the exposure delay is set to 1s, then an image would be take every 3s with a duty cycle of 30%.

As a result, if the user needs short exposure times to avoid saturation, it is often preferable to use a faster readout speed, *Windowed mode* or *Drift mode* to achieve this without sacrificing observing efficiency.

Clear mode is enabled by selecting the *Clear* checkbox.

Drift mode

Drift mode is used to enable the highest frame rates. Instead of shifting the entire image area into the storage area at the end of each exposure, only a small window at the bottom of the CCD is shifted into the storage area. This

minimises the dead time involved in shifting charge to the storage area and allows frame rates of ~1 kHz for relatively small windows.

In drift mode, a number of windows are present in the storage area at any one time. At the same time, any charge in pixels above the windows is eventually clocked into the windows, and becomes part of that frame. To prevent bright stars from contaminating the drift mode data, a blade is inserted into the focal plane, blocking off most of the image area of the CCD. Because the windows in drift mode spend longer on the chip, they accumulate dark current; drift mode should only be used for frame rates faster than ~10 Hz as a result.

For more information about drift mode, see the ULTRACAM instrument paper and it's appendix.

3.2.4 Exposure multipliers (nskips)

The instrument setup will determine the exposure time and cadence of your data. It is unlikely that this exposure time will be optimal for your target in all bands. Many objects will need longer exposures at the blue or red extremes. HiPERCAM supports *exposure multipliers*. These allow a CCD to be readout once every N exposures, and can be changed in the fields labelled *nu*, *ng*...

For example, consider a target of magnitude g=20, u=20. In one second, and with 4x4 binning, `hfinder` reports 262 counts at peak in g, but only 40 in u, so the u band is below the readout threshold discussed earlier. If one is happy instead to use 3 second exposures in u, then this can be fixed by setting nu = 3, which will mean the u-band CCD will read out every three frames.

> **Warning:** The peak counts reported by `hfinder` do *not* account for the nskip values, so you need to take them into account when judging the peak count level. You should check values for all CCDs.

> **Note:** It is usual to run with at least one of the nskip values set = 1, so that at least one CCD is read out every time. One could in principle set values like 5,4,3,2,2,3 to deliver fractional exposure time ratios. It is not advised though, because (i) there should be enough dynamic range between readout-limited data and saturated data that integer ratios are OK, (ii) each CCD is always readout each cycle, but nskip-1 of the readouts are dummy readouts producing junk data. Thus with a minimum nskip of 2, at least 50% of the data for each CCD is junk. The software is designed to ignore this, but it is wasteful of disk space. A set of nskip values like 9,6,3,3,3 i.e. with a common divisor, is a mistake as it could be changed to 3,2,1,1,1 and the exposure delay adjusted to triple the cadence. This would deliver identical data but cut down the overall size by a factor of 3.

3.2.5 Comparison stars

If you have to use windows, their exact definition very much depends upon the field of your target. At minimum one should include at least one and preferably two or more comparison stars if possible. They should be brighter than your target. It often helps to have one that is quite significantly brighter for the u-band, particularly for blue targets, as the average comparison is red, and it can quite often be the case that a comparison that is moderately brighter than the target in the redder bands is scarcely visible in u. Remember one does not need to use the same star as comparison in each filter and its OK for a comparison used in u to saturate in all other bands, as long as there is a backup comparison for those bands.

> **Warning:** Avoid setups in which a bright star is on the same column (i.e. same X position) and same quadrant as a faint target. This is because the frame transfer leaves a low level vertical streak that could be problematic if there is a very bright star lined up with your target.

> **Warning:** Do not place your target or comparisons close to the half-way point in either X or Y in full frame mode because the HiPERCAM CCDs are read out at the 4 corners and you risk your target being divided across multiple *Outputs*.

3.2.6 Miscellaneous settings

The remaining settings you can change are described below:

Num. exposures The number of exposures to take before stopping. Most HiPERCAM users will want to take a continuous series of exposures and stop after an alloted time. In which case this field should be set to 0. If you want your OB to have a specific duration, the correct number of exposures is found by dividing the time required by the cadence reported by `hfinder`.

Readout speed Fast readout speed reduces the minimum exposure time in full-frame readout from 2.9s to 1.2s. This comes at the expense of increased readout noise. The impact of this on the S/N of your target is shown in `hfinder`.

Fast clocks Users wanting the ultimate in high speed performance can enable this option. This increases the rate at which charge is clocked in the CCDs. It will have an impact on charge transfer efficiency. As of today, this impact has not been well characterised, but we do not think it is serious.

Overscan Enable the recording of the overscan regions at the left and right edges of the chip. Can be useful if precise measurement of the bias in each frame is needed. This is important for the highest levels of photometric precision, so consider this option for, e.g. exoplanet transit observations.

3.2.7 Dithering the Telescope

It is possible to dither the telescope between frames. This can be useful if, for example, you want to make a flat-field directly from the night sky observations themselves. *Clear mode* is always enabled when dithering the telescope, to avoid trails from bright stars appearing in the image.

The overheads involved in moving the telescope mean that there is little point in using any mode other than full-frame readout with this option.

If you wish to dither the telescope, check the *Nodding* checkbox. You will be prompted for a plain text file specifying the offset pattern you require. The format of this file is a simple list of *absolute* RA, Dec offsets in arcseconds as shown below:

```
0   0
0   20
20  20
20  0
0   20
```

This offset pattern will be repeated until your exposures are finished. `hfinder` will estimate the impact of nodding on your cadence and overal signal-to-noise.

If you wish to visualise the dithering pattern on the sky, pressing the `n` key will cycle through the dithering pattern.

3.2.8 Condition-tolerant setups

If you are sure that your target will only observed with seeing close to 1.2" and during clear conditions, you'll have a relatively easy job defining a setup. Much more difficult is if the seeing could be anything from 1.2 to 2.5", the reason being that the peak counts could vary by more than a factor of 4. The key point here is probably the binning. It should

definitely be at least 4x4, and arguably 6x6 to 8x8, otherwise you could end up swamping the target with readout noise during poor seeing. One way to think about readout noise is as the equivalent of R^2G counts from the sky in each binned pixel. If you use 1x1 rather than 8x8, you have just increased this contribution by a factor of 64. Sometimes this won't matter; sometimes it will be a disaster. As always, the thing to do is try different setups and seeing values in `hfinder`, and the key to using it is to understand the signal-to-noise values hfinder reports.

S/N vs S/N (3h)

If you look at `hfinder` you will see two values of signal-to-noise. One, "S/N", is the signal-to-noise of one frame. The other, "S/N (3h)", is the total signal-to-noise after 3 hours of data. The latter can reach unrealistically large values (e.g. 14584 in the screenshot) which are meaninglessly high in practice, nevertheless, the "S/N (3h)" value is one of the best ways to compare different setups as it accounts for the issue of shorter exposures versus a larger number of exposure and also deadtime. One way to find a condition tolerant setup is to find one where the "S/N (3h)" value does not respond dramatically to the exact setup.

As an example, consider a star of g=18 being observed at high speed in dark time, seeing 1", airmass 1.5. With 1x1 binning and windows of 92x92, I find a cadence of 0.101, a duty cycle of 92.3% and an "S/N (3h)" value of 3772. This is not obviously bad, but the peak counts are listed as just 10! This will be heavily read noise affected. This becomes obvious if I add 0.1 seconds to the exposure delay giving 0.201 cadence, 96.1% duty. The S/N (3h) becomes 5306. That's the equivalent of $(5306/3772)^2 = 1.98$ times longer exposure, but the duty cycle only increased by a factor of 1.04. The large improvement is because I have halved the number of readouts.

What if I still want the 0.1 seconds? Then I should bin. So, the same target and conditions, but now with binning 4x4 and cadence 0.1 seconds, I find again a 92% cadence, but the S/N (3h) value is now 9970 and I have gained a factor of 7 in effective exposure time! So the first setting was really a disaster. To judge how much further there is to go, I make the cadence 10 sec, and find S/N (3h) = 13400, but of course 10 seconds may be unacceptably long, but still it shows what one should be aiming at.

What about the impact of seeing? If I set seeing to 2", the S/N (3h) for the 4x4, 0.1-sec mode drops to 6265, equivalent to dropping the exposure down by a factor 0.4. The 1x1 version drops to 1937, equivalent to just 0.26 of the exposure, so not only is it a bad setup, but it gets worse more quickly.

> **Warning:** These are not small effects, and you need to think about them for all CCDs. CCD 1 (the u-band) is almost always the most sensitive of all to readout noise issues. "nskip" is your friend then. If possible try to find the sweet spot between being well above the readout noise, but not in danger of saturation. Peak counts (factoring in any nskips) from 1000 to 15000 are what you might want to aim for, although they won't always be possible.

3.2.9 Checklist

1. Have you chosen your binning to give the spatial sampling you need? 1x1 binning is very rarely the best choice, and can increase readout noise dramatically. HiPERCAM's native pixel size is only 0.081" on the GTC, so you can resolve typical seeing discs with 3x3 or 4x4 binning.

2. Could your setup lead to saturation in good seeing? If so, is there leeway for the observer to reduce the exposure time (a relatively easy change) without the need to change the setup (time consuming)?

3. Have you checked the peak counts per pixel in *all* CCDs, especially CCD 1 (u-band)? Is it comfortably above readout? (100 counts or more). The nskip parameters (nu, ng, nr, ni, nz) may help.

4. Is your target away from the edges of the CCD outputs in both X and Y to avoid a split readout and consequent data reduction problems?

5. Have you ensured that no very bright objects are aligned along the Y direction and in the same quadrant as your target?

6. For blue targets, have you included a bright comparison star (if available) for the u-band, even if it looks too bright for the griz bands?

7. For variable targets, have you considered the impact of the full range of their variability in terms of possible saturation or readnoise?

8. Is the duty cycle of your setup what you expect? For most observations it should be above 95%.

9. Is your setup tolerant of the full range of conditions you have specified for it? Variations in seeing especially, can cause dramatic variations in peak count levels and may veer you towards either saturation or readout noise limitations.

10. Does the product of the number of exposures and the cadence match the times you want to follow your target?

11. Do you need to dither your observations for optimum background subtraction?

3.3 ULTRACAM

The primary consideration when observing with ULTRACAM is to realise that its frame-transfer CCDs have no shutter. Instead, an image is rapidly moved into the storage area, which begins a new exposure in the image area. The image continues to expose whilst the storage area is reading out; this sets a *minimum exposure time* equal to the time needed to readout an image.

For a full-frame image with slow readout speed, this minimum exposure time is around 2.1 seconds. Longer exposures can be obtained by entering an *Exposure Delay*, but shorter exposures will require the use of *Windowed mode*, *Drift mode* or *Clear mode*.

3.3.1 Outputs

ULTRACAM has two seperate outputs, or channels, per CCD. Each of these outputs has slightly different gains and bias levels; **avoid putting critical targets on the boundary between outputs**.

3.3.2 Windowed mode

To enable higher frame rates, ULTRACAM can use up to three windows per output channel. Since there are two outputs, we refer to *window pairs* to define window settings. You can enable windowed mode by selecting *Wins* for the *Mode* option in the instrument setup panel.

A window pair is defined by the x-start positions of each window, the size of the windows in x and y, and a y-start value. Both windows in a pair must be the same shape, and all share the same y-start value. Increasing y-start moves the windows in from the edges of the CCD towards the centre.

If there are two window pairs, they cannot overlap in y.

Synchronising windows

If on-chip binning is enabled, it is possible to define windows that do not align with the boundarys of the binned pixels. This is fine, but it does mean that one cannot bin calibration frames taken with 1x1 binning (such as sky flats) to match the windowed data. If windows are not synchronised in this manner, the *Sync* button will be enabled. Clicking this will align the windows with the boundaries of binned pixels.

3.3.3 Clear mode

Sometimes extremely short exposures are needed, even with full frame data. Sky flats would be one example. It is possible to *clear* the image area of the CCD, just after the storage area is read out. This allows exposure times as short as 10 microseconds. These short exposures come at the expense of efficiency, since the charge accumulated whilst the storage area was reading out is lost.

For example, if the storage area takes 6s to read out, clear mode is enabled and the exposure delay is set to 1s, then an image would be take every 7s with a duty cycle of 14%.

As a result, if the user needs short exposure times to avoid saturation, it is often preferable to use a faster readout speed, *Windowed mode* or *Drift mode* to achieve this without sacrificing observing efficiency.

Clear mode is enabled by selecting the *Clear* checkbox.

3.3.4 Drift mode

Drift mode is used to enable the highest frame rates. Instead of shifting the entire image area into the storage area at the end of each exposure, only a small window at the bottom of the CCD is shifted into the storage area. This minimises the dead time involved in shifting charge to the storage area and allows frame rates of ~1 kHz for relatively small windows.

In drift mode, a number of windows are present in the storage area at any one time. At the same time, any charge in pixels above the windows is eventually clocked into the windows, and becomes part of that frame. To prevent bright stars from contaminating the drift mode data, a blade is inserted into the focal plane, blocking off most of the image area of the CCD. Because the windows in drift mode spend longer on the chip, they accumulate dark current; drift mode should only be used for frame rates faster than ~10 Hz as a result.

For more information about drift mode, see the ULTRACAM instrument paper and it's appendix.

3.3.5 Exposure multipliers

The instrument setup will determine the exposure time and cadence of your data. It is unlikely that this exposure time will be optimal for your target in all bands. Many objects will need longer exposures at the blue or red extremes. ULTRACAM supports *exposure multipliers*. These allow a CCD to be readout once every N exposures, and can be changed in the fields labelled *nu*, *ng*...

With, for example, nu=2, the u-band CCD will read out every two frames. This allows you to double the exposure time for the u-band CCD only. Note that the S/N estimates in `hfinder` do *not* take account of the exposure multipliers.

3.3.6 Miscellaneous settings

The remaining settings you can change are described below:

Num. exposures The number of exposures to take before stopping. Most HiPERCAM users will want to take a continuous series of exposures and stop after an alloted time. In which case this field should be set to 0.

Readout speed Higher readout speeds reduce the time taken to read the storage area and increase the frame rate. This comes at the expense of increased readout noise. The impact of this on the S/N of your target is shown in `ufinder`.

Overscan Enable the recording of the overscan regions at the left and right edges of the chip. Can be useful if precise measurement of the bias in each frame is needed. This is important for the highest levels of photometric precision, so consider this option for, e.g. exoplanet transit observations.

3.4 ULTRASPEC

NEEDS WRITING.

Indices and tables

- genindex
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