ARCTIC Reductions Cookbook

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February 6, 2017
DRAFT

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1.2.1 Notes Before Reduction

There are a few native peculiarities to ARCTIC that are addressed in the following walkthrough. Some have been resolved and some have not. We will walk through the data reduction for broadband photometry of a face-on galaxy and a standard star. We will be using IRAF for our data reduction, so it is assumed the user has relative familiarity in this regard.

The first peculiarity one will run into with ARCTIC will happen straight away. A $\sim$20 count gradient builds up very quickly on the CCD from the bottom up. If the instrument has been idle for only 5 seconds, this gradient is present on all future images. However, taking a bias flushes the chip, removing the gradient from the next image. Waiting any amount of time between images will cause this gradient to return. One has two options when it comes to dealing with this gradient:

1. Create a 'flat' (i.e. gradient-free) master bias. Take around 20 or more biases and ignore the first couple and combine the rest. However, a bias will need to be taken **before every science image** in order to flush out the gradient.

2. Create a 'gradient' master bias. Take as many as desired biases with a minimum of 5 seconds between each bias. This way, no bias is required before each science image, as the gradient will be present in the master bias.

We strongly recommend the second option, as it greatly reduces wasted time later in the night, particularly if your science exposures are short. Both types of master biases are shown in Figure 1.

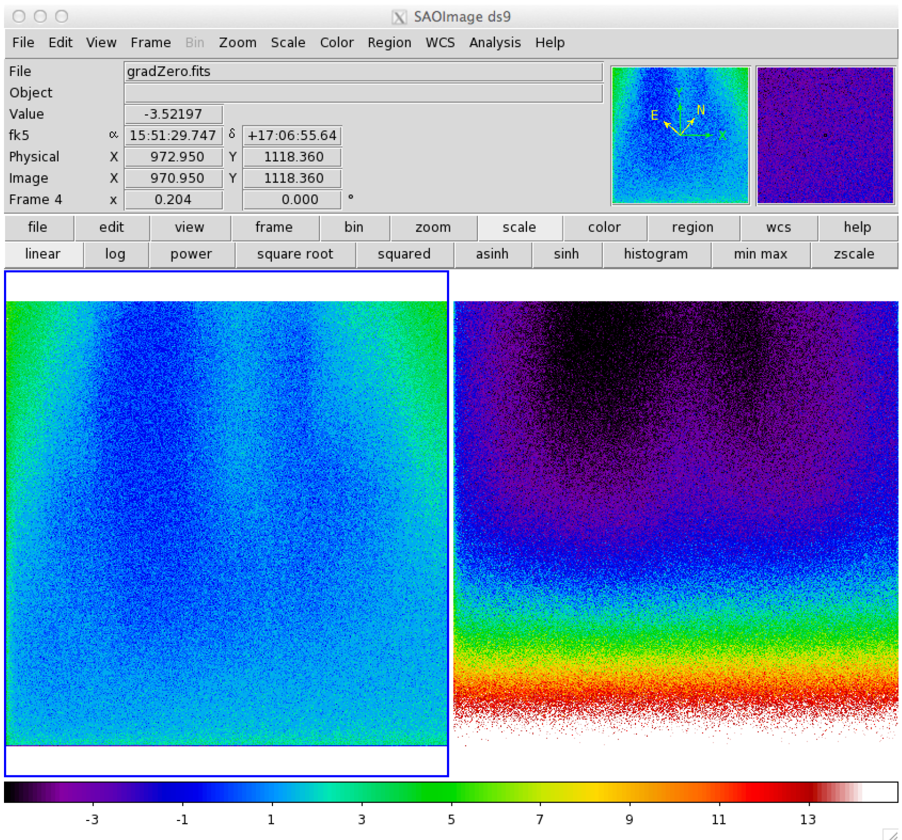

Figure 1. Master biases. *Left*: 'Flat' bias. *Right*: 'Gradient' bias. Notice the ∼20 count increase toward bottom of the CCD.

1.2.2 Reduction with the Gradient Bias

We will run through the reduction on a standard star as well as a face-on galaxy. Our raw images are below in Figure 2. The gradient is quite obvious in both of these images.

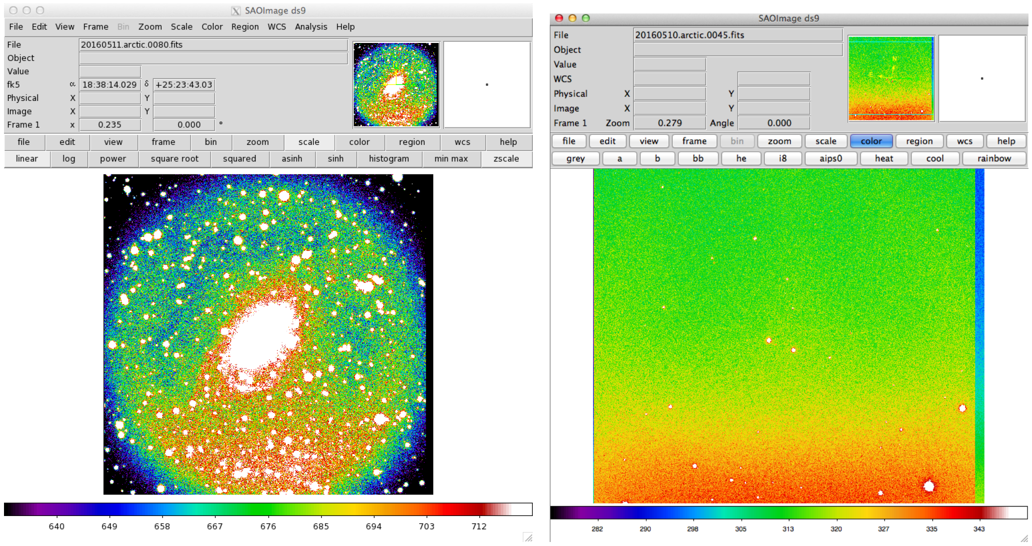

Figure 2. Raw images for our reduction example. Galaxy is on the left, standard star on the right. Because a bias was not taken immediately prior to either science image, the gradient is obvious.

1.2.3 Overscan, Trim and Bias Subtraction

The header on ARCTIC images lists overscan as *BSEC11* and the trim as *DSEC11*. You cannot use these keywords in IRAF's ccdproc; you must type in the BSEC11 and DSEC11 values. For example, if DSEC11 = [3:2050,1:2048] and BSEC11 = [2053:2100, 1:2048] you would enter the following parameters in ccdproc:

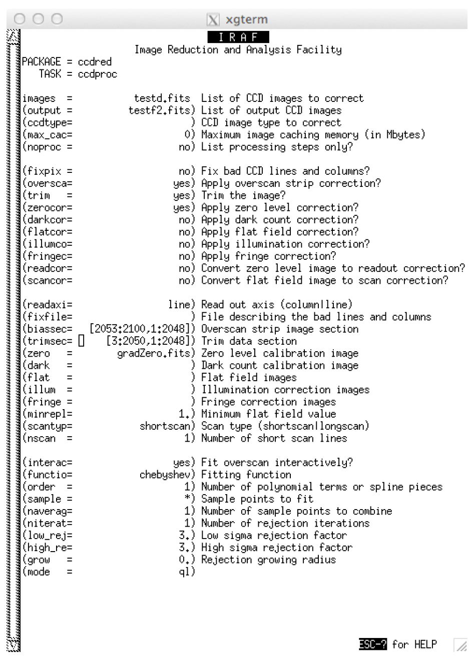

Figure 3. Entering trim and overscan values for ccdproc.

IRAF may give you a warning about setting CD1_1 and CD2_2 to 1 for bias, dome flat, and dark images. This means that CD1_1 and CD2_2 cards in the header have NaNs instead of numbers. If this warning shows up on a bias, dome flat, or dark image, it does not affect your science images. The CD1_1 and CD2_2 NaN value on these images could be a result of the dome being closed while taking calibrations, or if you were taking bias or darks while the telescope was slewing.

Another important note: when using IRAF on a number of images (i.e. creating your master bias) you cannot use the ccdtype keyword (i.e. **zero**). An example of the error is shown in Figure 4. The solution is simply to create lists of the images you wish to work with and leave the ccdtype keyword blank in IRAF.

Figure 5 shows our bias-subtracted images. Note how the gradient has been removed.

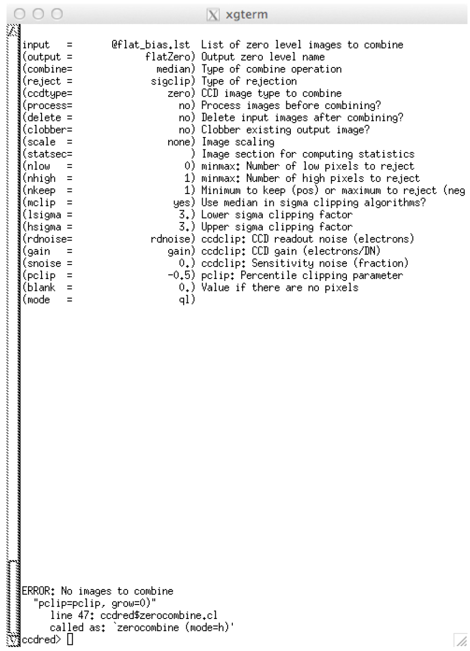

Figure 4. Error message received when entering ‘zero’ in ccdtype in the IRAF routine zerocombine.

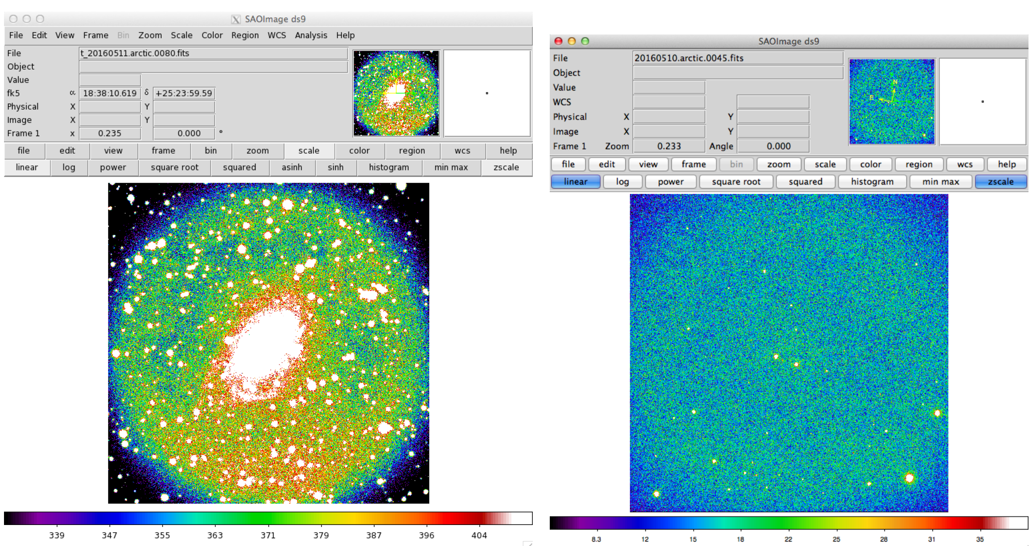

Figure 5. Bias-subtracted images using the ‘gradient’ master bias. Note the successful removal of the gradient.

1.2.4 Dark

Your darks (if you have them) should be relatively flat around zero if you are using a bias with a gradient (which you should). In our case, we have darks for our galaxy but not for our standard star, as our exposure time for the standard star was too short to warrant a dark.

In ccdproc, change *darkcor* to yes and enter the file name for your dark in *dark*.

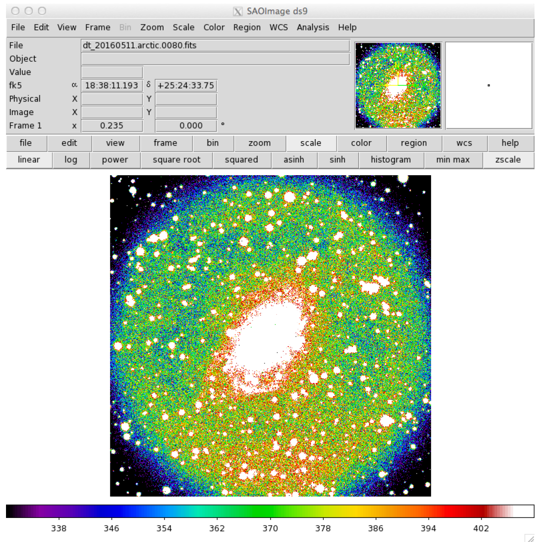

Figure 6. Dark-corrected galaxy image.

1.2.5 Flat

You *need* sky flats for the reduction regardless of which bias you took. For those observing remotely, it may be necessary for you to request the observing specialist to take sky flats for you at the beginning of dusk or dawn. Combine your bias-subtracted, dark-corrected flats using flatcombine in IRAF. In Figures 7 and 8 we compare the results of flattening with dome vs. sky flats.

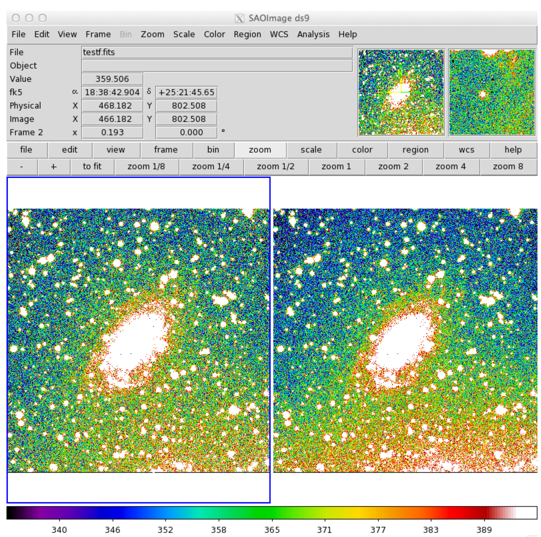

Figure 7. *Left*: Final, reduced galaxy image with sky flat. *Right*: Final, reduced galaxy image with dome flat.

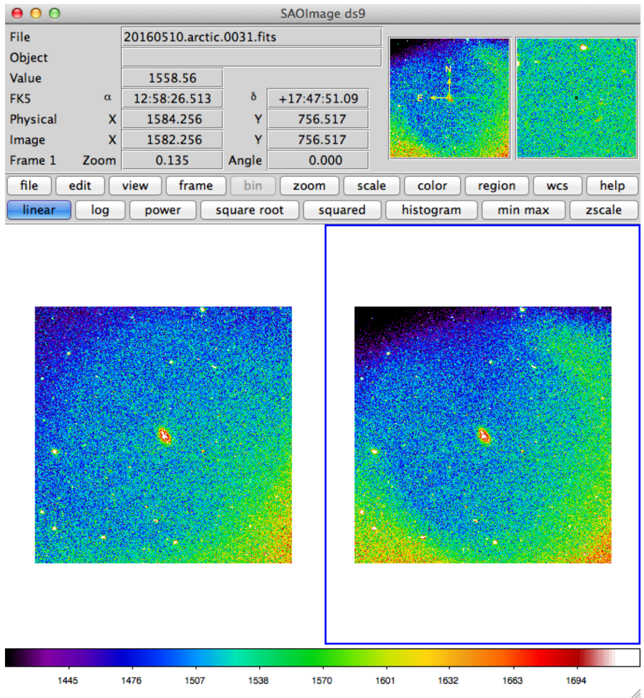

Figure 8. *Left*: Final, reduced different galaxy image with sky flat. *Right*: Final, reduced different galaxy image with dome flat.

1.2.6 Effect of the Gradient: Reducing Data with a 'Flat', Gradient-Free Bias

If one chooses to reduce images with a flat master bias, the above procedures still apply. *However*, the flat bias will not remove the gradient from the images. One can expect results similar to the following:

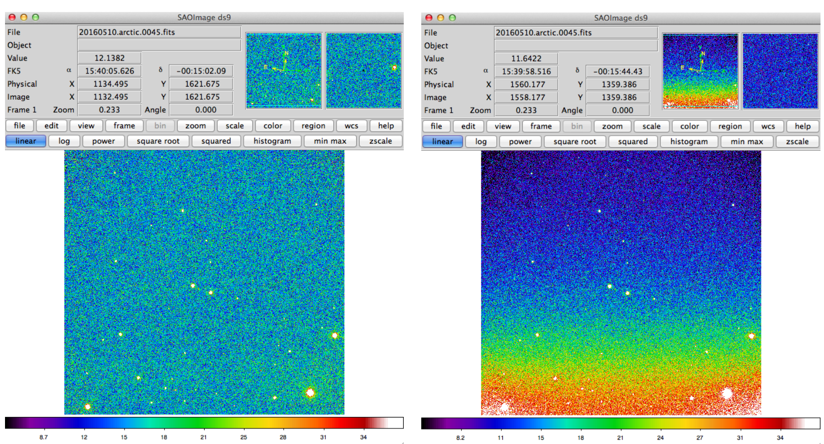

Figure 9. *Left*: Final std. star image with gradient bias and sky flats used. *Right*: Final std. star image with flat bias and sky flats used. Notice the ∼20 count gradient has not been removed from the image on the right.

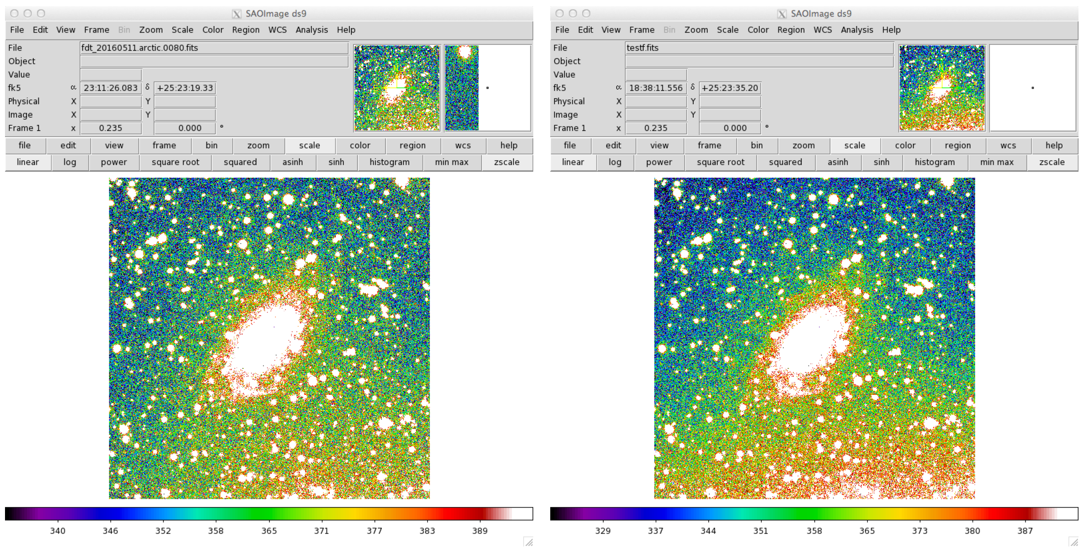

Figure 10. *Left*: Final galaxy image with gradient bias and sky flats used. *Right*: Final galaxy image with flat bias and sky flats used. Notice the ∼20 count gradient has not been removed from the image on the right.

The gradient is much more obvious in the standard star image (Figure 9), likely due to the low level of counts for the sky. However, the gradient is still present in the galaxy image (Figure 10).

1.2.7 I-Band Weirdness

There is an additional complication for the I-band. Our raw I-band images have, for lack of a better term, "squiggles" that are not removed by our flats, as illustrated in Figure 11. It is possible that the large difference in counts between our I-band galaxy (∼1,800 counts) and our I-band flat images (∼16,500 counts) prevents the I-band features from being removed from our galaxy images. It may be that the "squiggles" get washed out in our I-band flats as a result of such high counts (Figure 12). However, in order to test this, we would require sky flats of similar count levels to our objects.

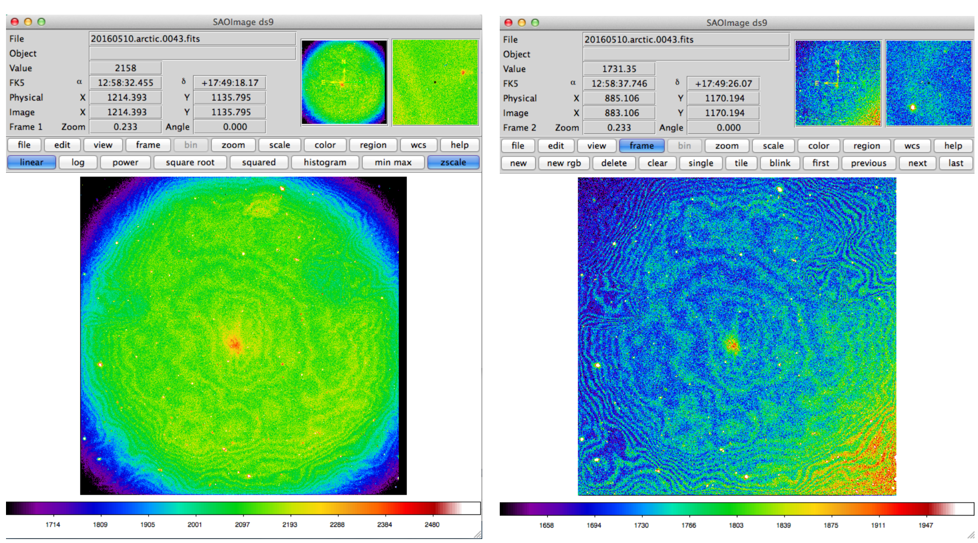

Figure 11. I band "squiggles" present in a science image. Both images are the same, the image on the right has been rescaled to show the "squiggles" more clearly.

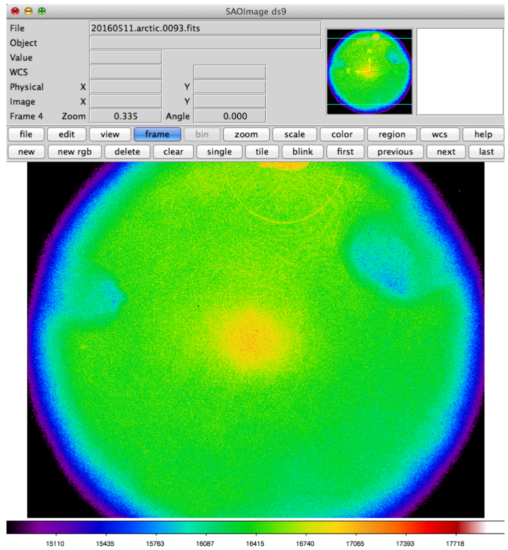

Figure 12. I band sky flat. Squiggles not visible.

1.2.8 Combining Images

Do not combine images using imcombine without first mapping coordinates using ccmap and ccsetwcs.

The coordinates output by the instrument appear to be affected by the time the image is taken. For example, Figure 13 shows the combination of two V-band images taken ∼3.5 hours apart. The galaxy is far too bright to notice the effect, but there are numerous stars surrounding it that show how the coordinates do not line up. Resolving this is still a work in progress.

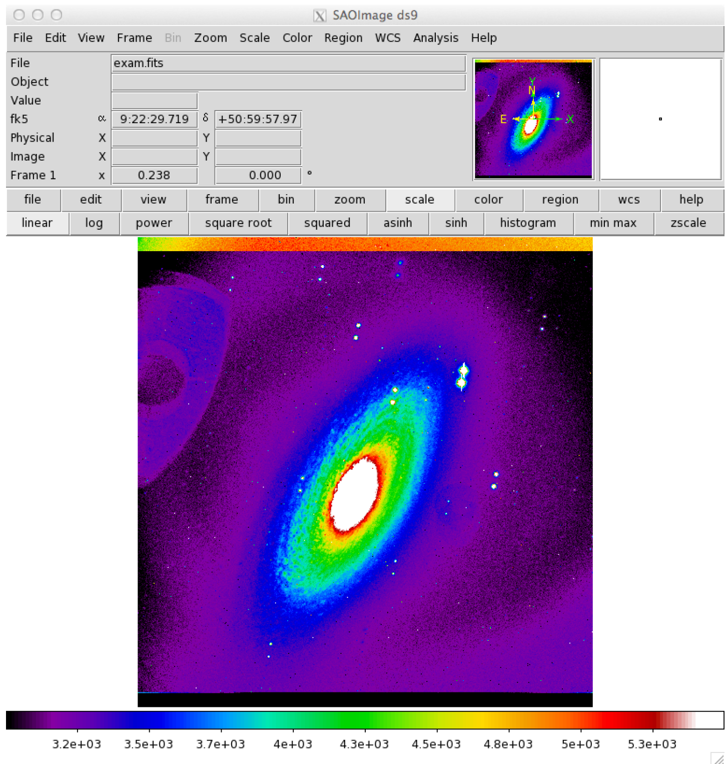

Figure 13. Combined galaxy image with native wcs coordinates from ARCTIC. The coords written into the header are wrong and must be corrected by the user with the IRAF task ccmap.

2. PYTHON