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CCD DATA: THE *GOOD*, THE *BAD*, AND THE *UGLY*

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ABSTRACT The "art" of taking useful CCD data consists in large part of knowing what to look for and keeping one's eyes open for problems. We discuss some of our experiences in obtaining data during the CCD era at Kitt Peak, and offer suggestions which may improve your chances of obtaining useful rather than useless data.

"Some days the magic works. Some days it doesn't."
Little Big Man's grandfather.

INTRODUCTION

We will describe three kinds of data: *good data*, *bad data*, and *ugly data* (also known as "truth"). The first of these, *good data*, actually doesn't exist, but rather is an ideal to strive for in terms of what you would like your CCD data to be like. *Bad data* consists of data that you are better off throwing out—something went wrong; you either didn't notice or couldn't do anything about it, but just throw it out. *Ugly data* is what you get from *real* CCDs, and is just fine—just a little bit, well, ugly. It's our plan to help you distinguish between the last two cases.

In this paper we draw on various examples we've encountered during the CCD era at Kitt Peak which began in 1981. We have chosen to tailor this talk to a particular consumer, the Kitt Peak visitor, but our recommendations extend to observers at all observatories.

Good Data

Having told you that there is no such thing as *good data*, we are going to tell you what characteristics it would have if there were some. With *good data*, the "magic *always* works". Characteristics of *good data* include the following:

• **Linear:** *Good data* would be linear. Figure 1 illustrates this point. Over some range, the output values (ADUs, for analog digital units, or DN for data numbers) are proportional to the input number of photons. When there are zero photons, there is still some pedestal ("DC offset") level. We don't want to have zero ADUs if there are zero photons, because there is bound to be some "readnoise", and we don't want to have any values dipping below zero ADUs during the noise fluctuations. We assume that the detector has a 15-bit A to D (analog to digital) converter, and hence the highest output value you can have is 32,767. (At the time of the CCD School, we have not seen a single fully functional 16-bit A to D converter that does not display some data biases.) For the purposes of this illustration we show the detector saturating before the A-D converter saturates; i.e., beyond a certain limit we get the same output value no matter how many more photons we pour in.

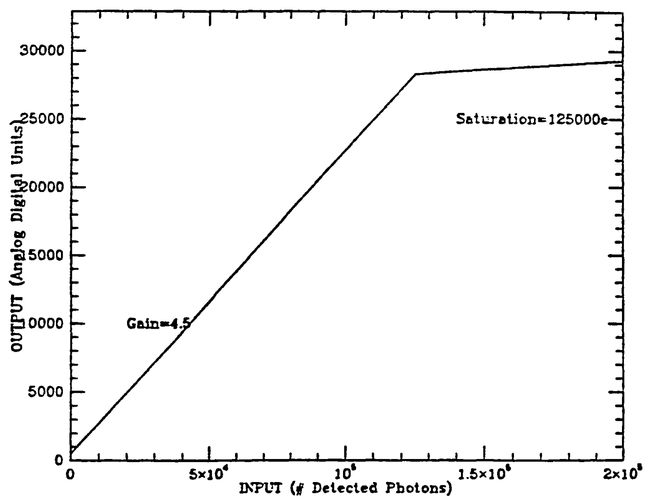

Fig. 1. *Good data* is linear over a substantial range.

• **Gaussian in bias** *Good data* show a Gaussian distribution (in a histogram, for example) in the absence of any input signal; the width σ_{ADU} of this Gaussian is related to the readnoise in electrons r_e as

$$\sigma_{ADU} = \frac{r_e}{gain}$$

where *gain* is the number of detected photons per ADU.

• **Gaussian in flat:** *Good data* show a Gaussian distribution whose width depends upon the signal level; for a flat-field exposure with level F_{ADU} this width will be

$$\sigma_{ADU} = \frac{\sqrt{F_{ADU} \times gain}}{gain}$$

where we have assumed that the signal level is so strong that the noise due to photon statistics is much greater than the readnoise, i.e.,

$$\sqrt{F_{ADU} \times gain} >> r_e$$

• **Flat:** Finally, *good data* would have the property that the gain is the same for each and every pixel (and that this value is **not** identically zero).

Bad Data

So what defines *bad data*? *Bad data* is lies. *Bad data* is when the magic is not working, and cannot, under any circumstances, be made to work. We will discuss more of this in a moment. For now, suffice it to say, "Throw it away!" No one is ever going to believe it no matter how clever you think you're being in trying to reduce it. (If you *can* fix it, it isn't *bad data*, it's merely *ugly data*. See below.) Some things that cause your data to be described as *bad* include:

• **Nonlinear:** If a region of a chip is nonlinear, there isn't a whole lot you can do about it. No one will ever believe any quantitative statement you make based upon objects in this region, as well they shouldn't. Just throw it away. This was often a problem with some old TI chips: they occasionally had image sections where the response of the chip was not linear. This problem manifests itself by an inability to flatten the data, in the sense that the number of counts in the flat-field must match the number of counts in the program data in order to work.

• **Non-Gaussian noise:** If the noise properties of the data are funny (e.g., non-Gaussian) something is wrong. This may be due to an electronics problem in the CCD control circuits.

• **Too flat:** Data that all has the same value is, let's face it, *bad*. Examples of this include cases where all the output is 32,767 (never a good sign) or 0 (also known as the "no detector case"). Another way of describing this malady has been immortalized by Craig Mackay (1986, ARAA 24, 255): "The only uniform CCD is a dead CCD."

Ugly Data

So what's *ugly data* you may well ask? *Ugly data* is "truth". *Ugly data* is when the "magic is mostly working", but you need to help it along. Characteristics of *ugly data* may include the following:

• **Pretty Linear:** *Ugly data* is linear almost everywhere; simply get rid of any subsections or columns or rows that aren't. Note that this is quite a different statement than saying that the chip is nearly linear everywhere. In the latter case, see the section on *bad data*.

• **Noise is close to Gaussian.** The noise in *ugly data* should be quite Gaussian in the bias, and *almost* Gaussian in a well-exposed flat-field exposure. If the gain were exactly the same for each pixel, the noise would be Gaussian. For *ugly data* (remember: *truth*), the gain is close, but not quite, the same for each and every pixel. Thus if you divide one flat-field exposure by another of similar intensity F_{ADU} (after subtracting off the pedestal level in each), you will find that the noise *is* Gaussian, and has amplitude

$$\sigma_{F_1/F_2}(ADU) = \frac{\sqrt{2 \times (F_{ADU} \times gain)}}{gain}$$

• **Not flat but flat-able:** The chip may be ugly, but large scale features and gradients disappear when divided by an appropriate flat-field exposure.

Summary of Introduction
1) *Ugly data* is **not** *bad data.*

2) The only cure for *bad data* is to either: (a) throw it away after your observing run, or (b) recognize it right away and get someone to fix it.

Hopefully the rest of this paper will encourage you to know how and when to do the latter. We will do this by walking you through some of our experiences at Kitt Peak, telling you what we look for, and weird things we've seen, in the hopes that we can prevent some of the things that have happened to us from happening to you.

ARRIVIAL AT THE TELESCOPE

The most critical time for your observing run may be those first few hours of the first afternoon. This is the time to keep your eyes and ears open, to be aware of what is going on around you. Don't be afraid to be assertive; after all, it's *your* data! Here are some things we think you should look for.

First Look
What are some things that you may want to check when you walk into the dome?

• **Dewar:** Is there a CCD attached to the telescope? Is it the right one?

• **Cables:** Does it look like more places you could stick a cable actually have a cable attached? Experience suggests that you not do anything about this yourself (yes, one of us has actually executed an otherwise useful and innocent CCD), but that you ask questions if they occur to you, such as "Should there be something connected to this 'CCD Video Out' connector?"

• **Dark slides:** Things that can get in the way include dewar covers, guider mirrors, and non-working shutters. It will usually be obvious when something this severe has occurred. However, a sticky shutter may be partially open, producing the most amazing flat-field patterns you can imagine.

• **Filters:** Are the correct filters in the correct slots? Are you sure they are not tilted? We recommend always checking this yourself. A tilted interference filter can result in a significant shift in the effective wavelength.

Your First Exposure: a Bias Frame

It is time for you to begin taking a few trial frames and to see what you might be up against. We suggest that you begin by taking a bias frame.

Examine the bias frame. Does it look normal? Make a histogram. Does the noise appear to be Gaussian? In Figure 2 we show examples of both good and bad histograms.

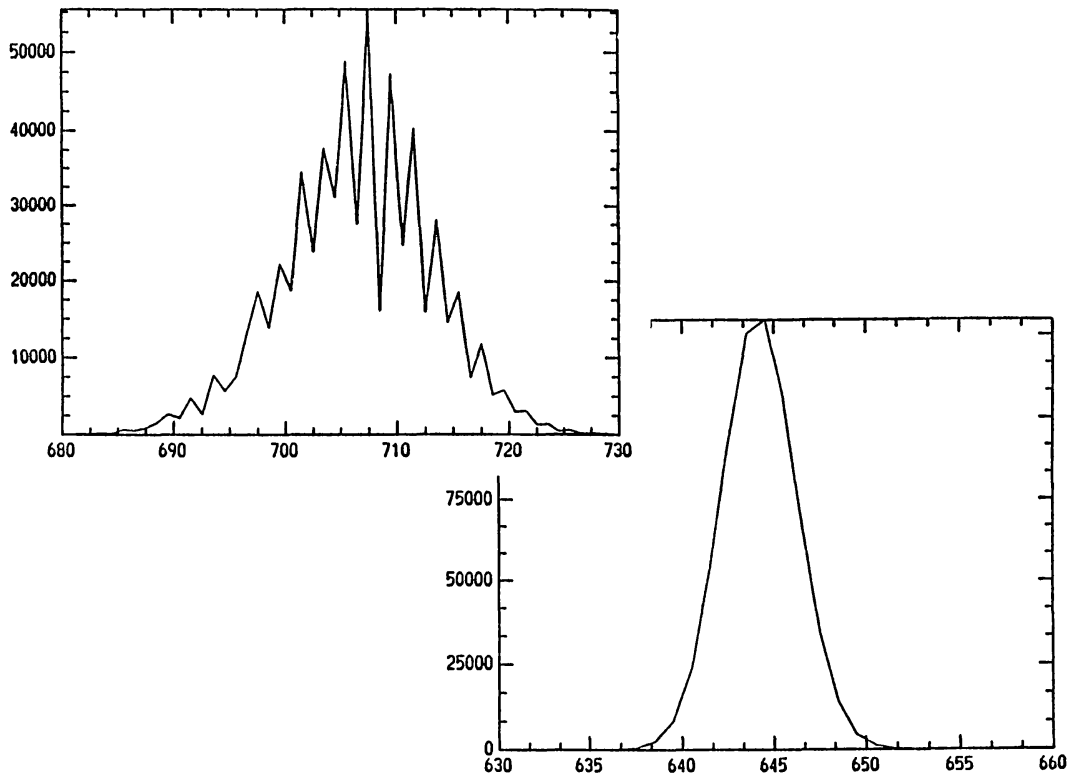

Fig. 2. Examples of histograms of bias frames from good and bad bias frames. In the example on the top, a stuck bit resulted in every other data value being low.

Are there ripples or moire (herring-bone) patterns visible? If so, what is their magnitude in ADUs? If they are greater than the read-noise, you may want to do something about this—sometimes there is a grounding problem. One of us once lost the better part of a 4m night owing to the fact that the CCD electronics box had been attached with long screws rather than short screws. Remember, there's no need to have *your* data screwed. (The long screws passed through the insulating block that the camera head attaches to, and contacted the telescope ground.) Sometimes, though, low-level patterns of this sort cannot be excised. At some point, you must accept the limits of real detectors on real telescopes.

Is there banding present in your data? We often have subtle (and not-so-subtle) electronics problems that lead to 20-100 pixel wide swaths of rows that are (slightly) elevated in level. These swaths extend into the overscan region. If the level is a few ADUs, you might want to simply live with it; if it is hundreds of ADUs, it might be time to call for help (see below). We note, however, that since these swaths *do* extend into the overscan region, it is possible to subtract them perfectly simply using the overscan data. We also have seen this as a temporary effect (with large amplitude) if a walkie-talkie is being used to transmit at the time the chip is being read down.

Plot a column. Is it nice and flat? Is the pedestal level reasonable (100-1000 ADU)? Or does the pedestal ramp? If so, it may simply be that the chip isn't uniformly cold yet. Is the pedestal level within a few ADUs of being zero? If so, call for help! If not repaired, the pedestal may drift low enough that some pixels will begin to fall below zero and get clipped at the zero level.

Plot a row. Is it nice and flat? Does the overscan region look reasonable? (a few ADUs lower than the rest of the chip, if that). Of course, if you a going to be preflashing your chip, you want the level to be higher than that, but probably not by more than about 20-40 ADUs.

Figure 3 illustrates a bias frame from one of the nicest, cleanest chips we own, a Tektronix 1024 × 1024. If your biases look like this, having absolutely no structure other than random pixel-to-pixel noise, there is no need to subtract the bias from your data frames. We strongly recommend taking biases daily anyway to assure yourself that they really do have no structure; then delete them.

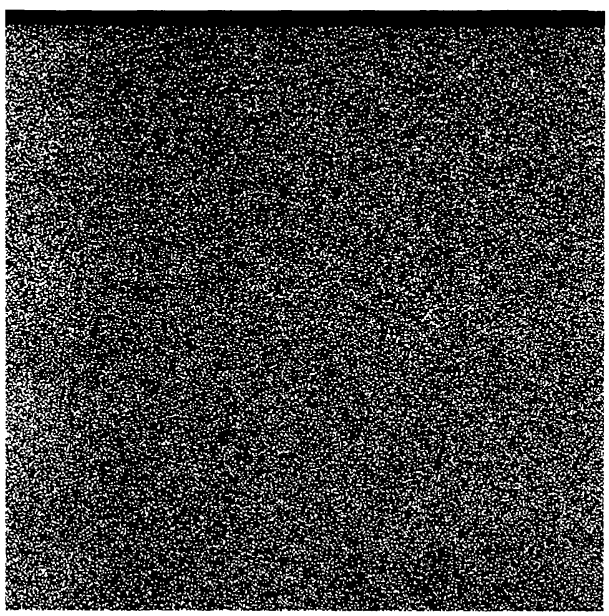

Fig. 3. A truely outstanding bias frame.

The Big Moment: A Flat-field Exposure

Before taking a test flat-field exposure, we suggest that you visually check the calibration target (aka "The White Spot") and the telescope. Is the mirror cover off? Are all the flat-field lamps working, or is one burned out? Are they properly aligned? Has the telescope been bulldozed? (Don't laugh; that actually happened to the meeting organizer once.)

Take a short exposure. Check the frame for (a) gradients, (b) dead columns, (c) charge traps. On a well-exposed flat-field, you may also want to check the status of the various bits. (There is a routine available in the CTIO package of IRAF for this called "bitstat".) Do you see any evidence for "stuck bits"? Better to determine this subtle but potentially devastating effect now rather than after your data has all been obtained! Examples of "bitstat" output is shown in Figure 4. Be forewarned that the output from this routine is not always easy to interpret. You should not go non-linear if this is your only evidence of a problem!

Bit	Total	1's	0's
0	163840	82192	81648
1	163839	82315	81524
2	163839	81965	81874
3	163839	81854	81985
4	163839	81590	82249
5	163839	81823	82016
6	163819	81105	82714
7	163577	84772	78805
8	163008	107019	55989
9	163008	21838	141170
10	163007	1089	161918
11	162729	162374	355
12	446	446	0
13	0	0	0
14	0	0	0
15	0	0	0

Bit	Total	1's	0's
0	278407	107523	170884
1	278407	112786	165621
2	278407	119585	158822
3	278407	128090	150317
4	278407	141982	136425
5	278407	160589	117818
6	278407	216900	61507
7	278407	217580	60827
8	278406	215868	62538
9	278405	231531	46874
10	47849	47342	507
11	798	637	161
12	303	238	65
13	166	143	23
14	98	98	0
15	0	0	0

Fig. 4. Two examples of "bitstat" output. In the example on the left we see that the lower-order bits (0-6) have roughly as many 1's as 0's. For higher order bits we begin to run out of data, and so the number of 1's and 0's are not equal. However, on the example on the right we see a real problem starting with bit 0: furthermore, there are always more 0's than 1's for the low-order bits. This example actually demonstrates a fairly subtle problem that required an adjustment of the clock voltages to fix; the data frame is shown in Figure 5 and discussed below.

Your First Measurements

With a couple of bias frames and flat-field exposures under your belt, you should now actually measure the gain and the readnoise using the following method. First, measure the average level in two similar dome-flats $(\overline{F_1}, \overline{F_2})$ and biases $(\overline{B_1}, \overline{B_2})$. Subtract one flat from another, and one bias from another, and determine the rms standard deviation σ of the resultant images $(\sigma_{F_1-F_2}, \sigma_{B_1-B_2})$. Then the CCD gain and readnoise (r_e) can be found from:

$$gain = \frac{(\overline{F_1} + \overline{F_2}) - (\overline{B_1} + \overline{B_2})}{\sigma^2_{F_1-F_2} - \sigma^2_{B_1-B_2}}$$

$$r_e = \frac{gain \times \sigma_{B_1 - B_2}}{\sqrt{2}}$$

Decision Time

There are two crucial decisions you should make at this point.

•**What Gain Do You Use?**. What *gain* do you wish to use? "How do I choose a gain setting?" is one of the most frequently asked questions. Many of the CCDs in use at Kitt Peak have gains which are adjustable by the software. Why would you want to adjust the gain? Our Tektronix chips, for example, all have a full-well capacity of >100,000 e^-, and some as high as 500,000 e^-, before there is any detectable deviation from linearity. However, the A-D converter cannot output data that is greater than 32,767. Thus to make full use of the dynamic range you would like the gain factor to be about 10. Why not simply set it to 10? Modern chips have very low read-noise (<$6e^-$), and thus if the gain is greater than the read-noise, you will be undersampling the read-noise; in effect, you will be increasing the read-noise to the level of the gain simply because of digitization noise. (You can't very well recover a read-noise of $6e^-$ if each data unit is equivalent to $10e^-$.) So like most things in life, there are trade-offs.

If you are attempting to do 1% stellar photometry of stars in a cluster, you are probably interested in covering as large a magnitude range as possible, and furthermore, your noise is going to be primarily photon-noise, not read-noise. Go for the largest value of e^- per ADU as you can without exceeding the linearity of the particular chip.

If you are doing surface brightness studies of objects through narrow-band filters, and the read-noise is significant but the dynamic range of your objects is limited, you may wish to opt for the lowest gain setting (the lowest number of e^-/ADUs).

•**How Many Pieces?** Your exposure time is dictated by how long you need to go to achieve the signal-to-noise ratio (SNR) that your program requires. For an exposure of that length, you may need to break the exposure into three or four pieces in order to be able to filter out radiation events (alias "cosmic rays", although only a fraction are usually attributed to cosmic sources—many, if not most, originate right there in the dewar). At this point in the afternoon you may wish to take a long dark exposure, with an integration time that is typical of the exposure time you will need on your program objects, and look at the image to see how many radiation events (and their size) you get with your particular chip.

Your First Maintenance Call

In the event that your chip flunked, you should consider making your first call for electronic assistance. Think about the following:

- How you are going to describe the problem?
- How big an effect (in ADUs) is this? Can you live with it?

• Should you panic now? Or later? This is one good reason for starting these tests at 1pm, and not 6pm.

THINGS TO LOOK FOR AND DO AT NIGHT

As the data begin to roll in, there are a multitude of things that you should be checking:

•**Too many counts:** Are you saturating the chip at the expected exposure level, i.e., the correct number of ADUs? Are you sure that you are not saturating objects of interest?

•**Not enough counts:** Are you getting enough counts in the faintest objects that you care about? If you are doing direct imaging for the purposes of precision photometry, then it behooves you to measure the integrated signal above sky to make sure there are sufficient counts to do the photometry at the level that you need to do.

However, the most serious question to ask is:

•**Does everything look ok?** Figure 5 shows one of the weirdest cases we've encountered: examining the data on this frame showed that there were "pairs" of pixels that were misbehaving. Our CCD guru subsequently had to fiddle with the clock voltages to get the chip to behave like a chip again (i.e., to start producing good/ugly data rather than bad). The "bitstat" results corresponding to this *bad data* was shown on the right side of Figure 4.

Most things to look for though, won't be quite this subtle, but they do require you to pay attention. When you run a focus frame, does the out-of-focus image look normal? Observers took direct CCD images with the the 2.1-m telescope for some unknown number of months before someone noticed that the out-of-focus image resembled that of Figure 6.

Shutters

The subject of shutters is enough to make you shudder. If you are interested in precision photometry, it behooves you to determine for yourself exactly how much the shutter open time resembles the exposure time you requested. We typically select a star that will give "lots o'counts" ($>40{,}000e^-$) in a 1 second exposure integrated over the stellar profile, but which will not saturate in its core in a 10 or 20 second exposure. We then take a series of eight exposures (1 sec, 20 sec, 20 sec, 1 sec, 1 sec, 20 sec, 20 sec, 1 sec) under photometric conditions. We then do quick-and-dirty aperture photometry through a reasonably large (15 pixel if the images have a fwhm <5 pixel) aperture. We average the results of the short and long exposures, checking to make sure that the variations are within the expected range (e.g., $<< 1\%$). Then the "extra" exposure time τ is related to the number of counts S in the short exposures (of length s seconds) and the number of counts L in the long exposures (of length l seconds) by

$$\tau = \frac{L \times s - S \times l}{S - L}$$

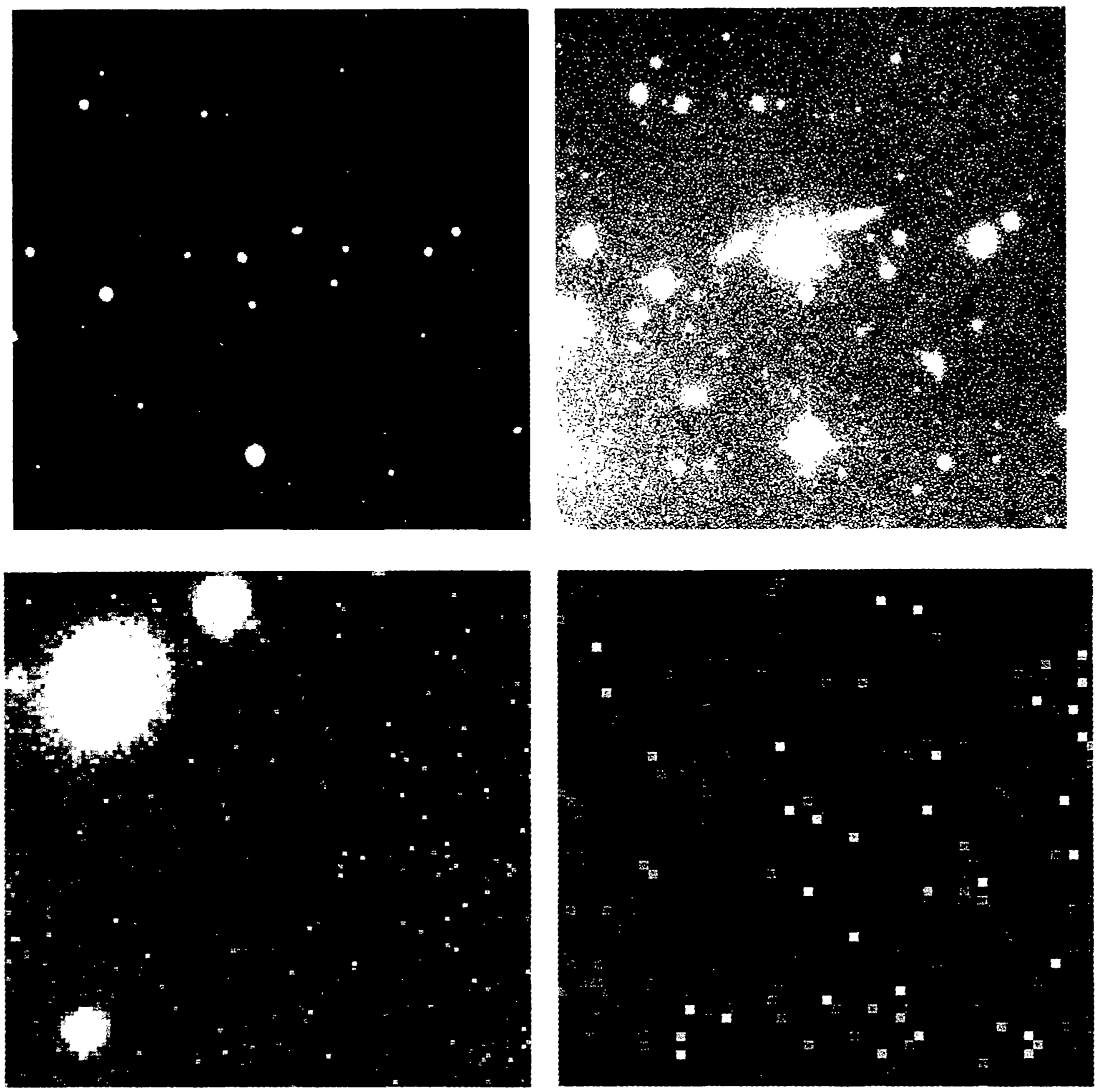

Fig. 5. One of the strangest examples of bad data that we successfully noticed is shown in this image of a cluster of galaxies. On the first of these images (top left), things look more-or-less all right. On the second of these images (top right) we have increased the contrast, and we begin to see a "salt-and-pepper" effect. The two bottom images show expanded views of this frame, and it is clear that there are pairs of low and high pixels.

For the "small" shutters in use at Kitt Peak, this time τ is about $+0.01$ seconds, and varies significantly from the center ($+0.013$ seconds) to the edge ($+0.004$ seconds). So you are safe ($< 1\%$) with a 1 second exposure of your standard stars *if* you place the star near the center of the chip and add 10ms to the logged exposure time when correcting your counts for exposure length. With our largest shutters, the actual exposure time is less than the requested time; $\tau = -0.050$ second. This shutter is a bi-directional focal-plane device, and the exposure time you obtain actually depends upon which direction the shutter is moving: when it flaps from left to right you get one value of τ and when it flaps from right to left you get a different value of τ; this was noticeable from the above sequence as every other value was a little bit high!

Other than the *normal* shutter behavior described above, you can also have shutter *problems*. Possibly the most confusing in its symptoms is that of the shutter which is stuck open. Reports of this usually begin with "There's something wrong with the charge transfer of this CCD...all the stars are bleeding." What is happening, instead, is that the shutter is still open as the charge is being clocked out, and so stars will smear along columns. If the charge transfer appears to suddenly have gotten bad, you should perhaps listen for the telltale "click" of the shutter closing before anyone begins to mess with the chip electronics! Turning on the dome lights for a moment and checking to see if the next frame is completely saturated will also tell the tale.

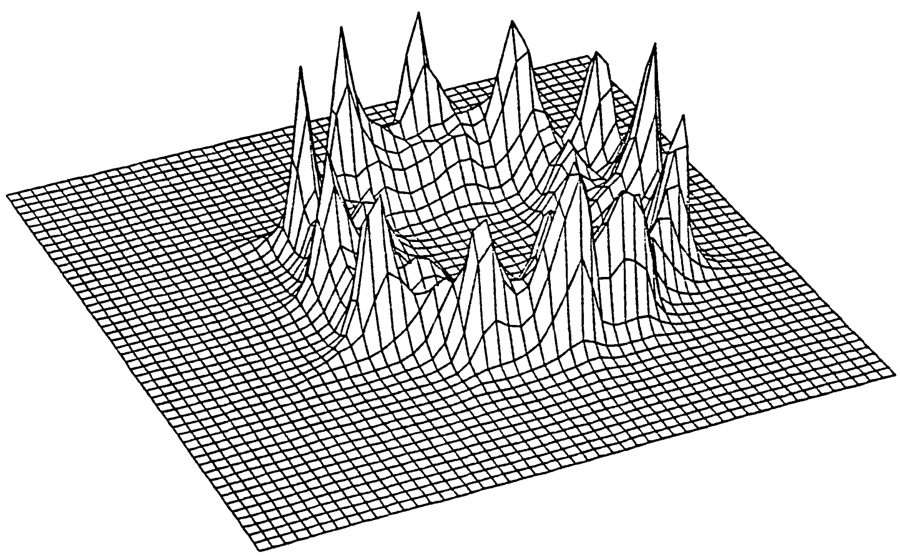

Fig. 6. Out of focus images with the 2.1m (shown in contour-relief) reveal print-through of the 18-point primary mirror support mechanism.

Flattening Magic

Two final things to check during your first few hours observing concerns the flat fielding:

•**Can this thing be made flat?** One reason for having real computers at the telescope is so you can make "trial" flat-field divisions of your data. Is the flattening magic working? On a long exposure with lots of sky counts, you can *see* if large scale features in your raw data go away after the data is properly reduced (i.e., pedestal [DC offset] subtracted and divided by a flat-field). Check to see if your flat-fielding is working at the 10%, 3%, or $\leq$ 1% level. Figure 7 shows a case where the flattening magic *wasn't* working: vignetting on the right side of the chip was not adequately removed by a dome-flat exposure. Figure 8, on the other hand, shows a case where the flat-field was anything but flat (i.e., the gain was substantially different depending upon what exact location you were at on the chip), and yet the flattening magic worked; large-scale features were properly removed by the flat-field division.

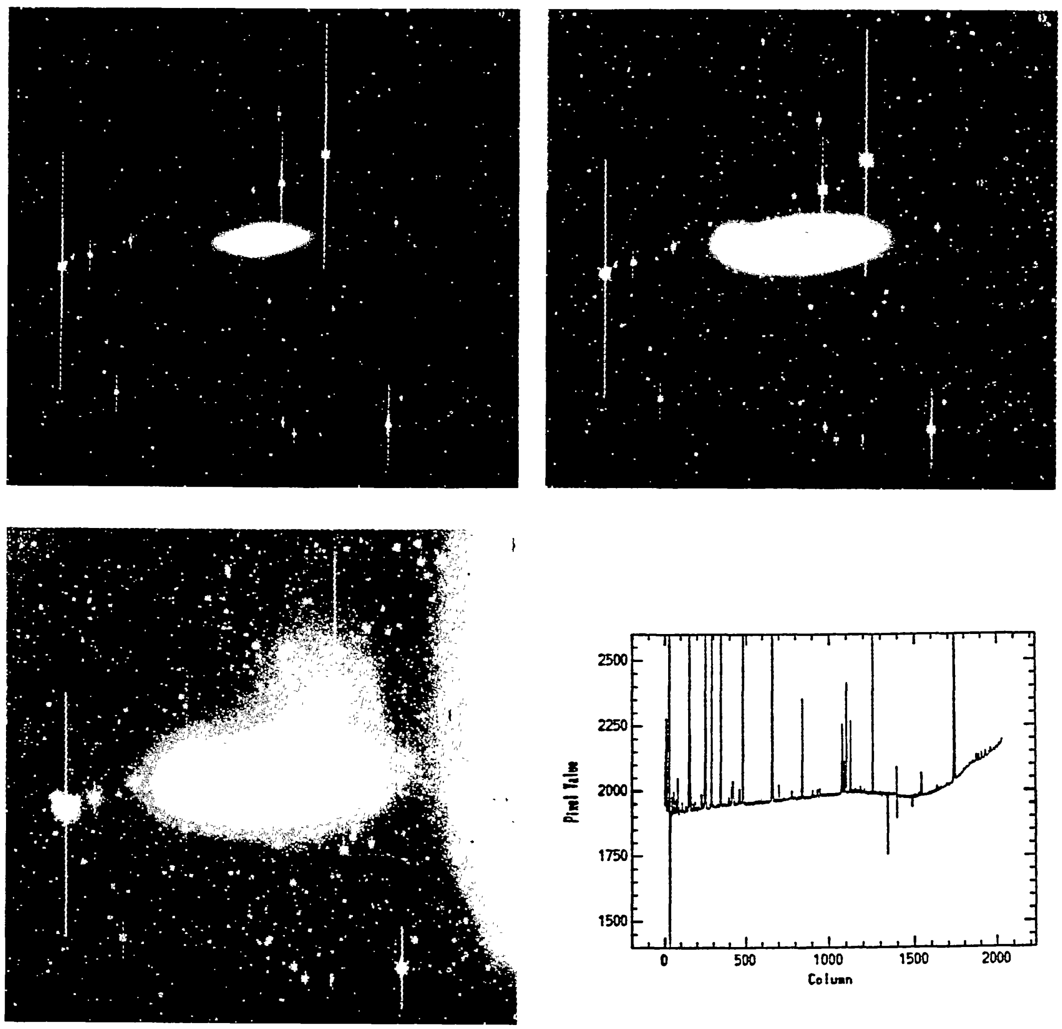

Fig. 7. An example of when the flattening magic did *not* work. The first image, that of the galaxy NGC1023 *after* flat-field division, shows only a hint of a problem on the right-hand edge. However, stretching the contrast makes it clear that there is a real problem. The plot shows that the level of non-flatness is roughly 250 out of 2000, or 12%.

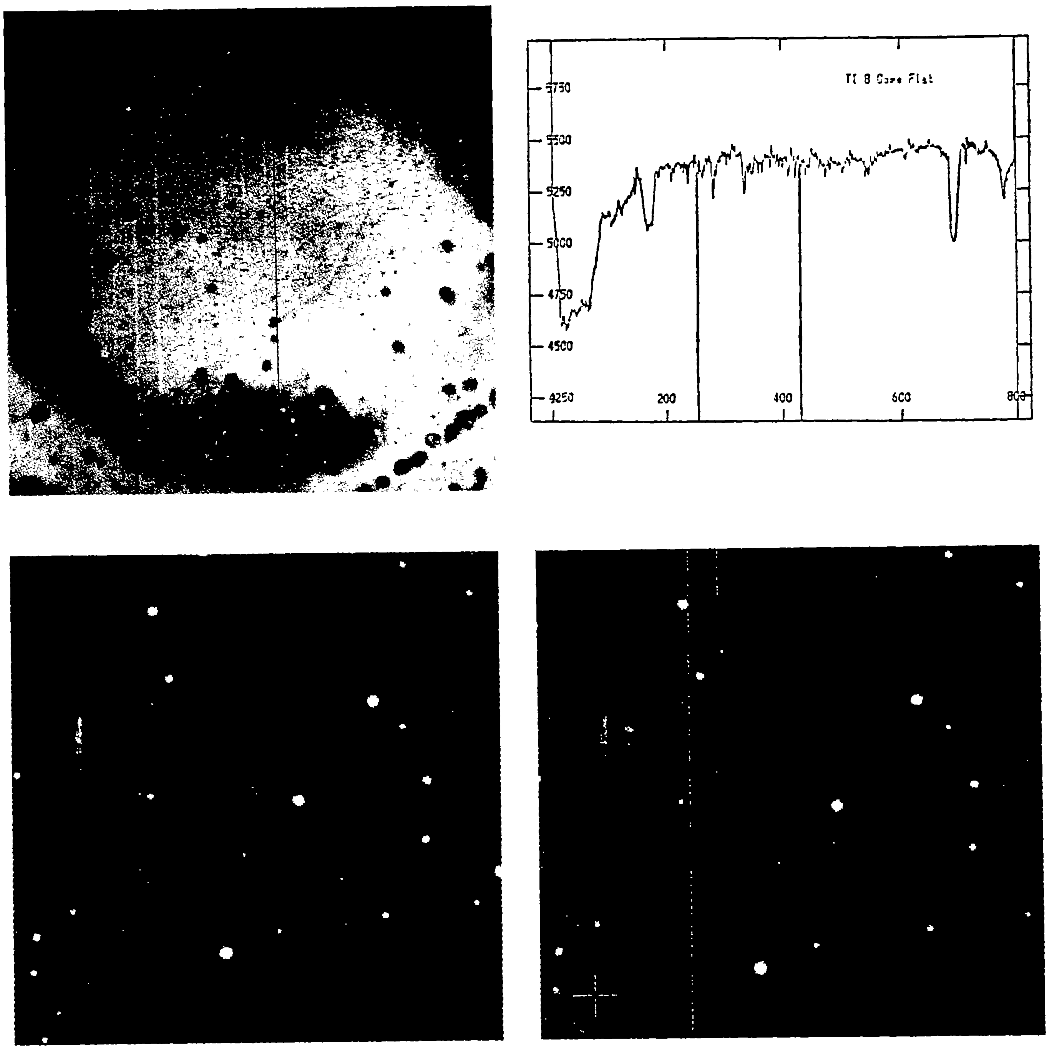

Fig. 8. An example of when the flattening magic does work. The top left image shows a dome-flat through a B filter taken with one of our TI chips. The plot next to it demonstrates that these irregularities are of large amplitude—some of the dips are $> 5\%$, and the large fall-off in sensitivity to the left is $> 10\%$. Unflattened data on the sky (bottom left) shows the same effect. However, once this data is divided by the flat-field, the result is the "perfect" image shown at lower right.

•**Don't put it there:** Consider the situation when the dome-flat in *U* looks very little like the dome flat at redder wavelengths. Figure 9 demonstrates this nicely for one of our TI chips (a different one than that pictured in Figure 8). If you think about it, you will realize that the color terms in the transformation equations will have a strong spatial dependence—surely the color terms in one of those holes (regions of low sensitivity) at *U* cannot be the same as in a region of the chip that looks similar both at *U* and *I*. Thus, we recommend not putting objects of interest in these regions! Note that the flat-field division will get rid of these large-scale regions (as shown in Figure 8) but that objects that are there will still have color terms which can be quite substantially different than in other regions of the chip.

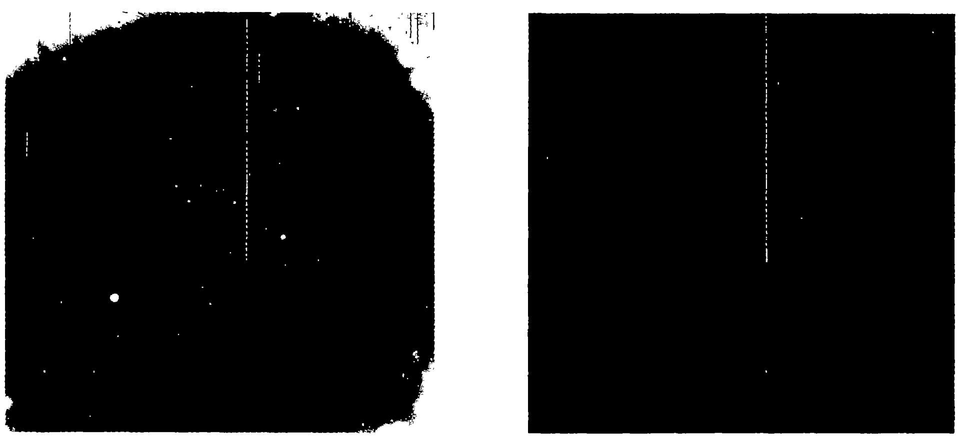

Fig. 9. Dome flats from another one of our TI chips at *U* (left) and *I* (right).

FINAL THOUGHTS

We leave you with these three pieces of advice:

• **Look** at your data.

• **Measure** what is going on. Use the tools available to verify the data quality (e.g., histograms, row and column plots).

• **Speak up** if you have questions! Remember, it's your data, and this may be your only clear night.

DISCUSSION

B. Fried: Can you briefly describe the lamps, fixtures and method of illuminating the dome flat screen?

G. Jacoby:

Flat-Fields - More Involved Than You Might Have Guessed
(To appear in NOAO Newsletter, December, 1991)

Over the last few years, we have received numerous requests for information describing our flat-field projectors and screens. The present scheme has evolved over time from shining a flashlight on the inside of the dome surface to the system described below. The projection system is used at the 0.9m, 1.3m, 2.1m, and 4m telescopes, while the screen is only at the 0.9m, and 2.1m; at the 4m telescope, a different and less satisfactory screen system is used because we haven't figured out how to build a good screen 4m in diameter, while the 1.3m science and instrumentation (IR) does not demand the "high-tech blue-sensitive" screen described below.

Projector and Lamps

Each telescope has 2 banks of 4 lamps each. Lamps are located in pairs (1 "high" and 1 "low" - see below) at the cardinal points around the top ring of the telescope. One bank is referred to as the "High Bank" and consists of 4 Cool-Lux FOS-4 12 volt 50 watt lamps. These have an average lifetime of 4000 hours as delivered from the factory. We modify them by applying an aluminum coating to the back; otherwise light from 8000-8500A would pass through the rear of the bulb housing, creating a dip in the spectral light distribution.

The "Low" bank has 4 Cool-Lux FOS-5 12 volt 25 watt lamps. The lifetime for these is also 4000 hours. [No one can remember any of these bulbs actually burning out, but we replace them every other year anyway. Note that the lifetimes correspond to about 10 years of use. We place a stack of filters in front of each of these lamps consisting of 4 mm of BG-34 blue color balancing glass (2 filters of 2mm each), and a 0.5 ND filter. The effect of the ND filter is to allow the voltage on the lamps to be raised, thereby running the bulbs at a high color temperature. The blue glass filters further reduce the color effects of the overly red (by astronomical standards) lamps.

The bulbs, projectors, and filter holders are all purchased from Cool-Lux Lighting Industries Inc, North Hollywood, California, 91606. The glass filters are obtained from Schott or another filter distributor.

Screens and Paint

Surprisingly, the screens required much more study than the lamps! Ideally, the screen should have a flat spectral response and a flat spatial response. Both are difficult, but the spectral character turned out to be the more difficult. Most white paints, for example, are really red paint. If your eye was sensitive down to 3200A, you would find that the familiar white domes (titanium oxide paint) are very red.

We adopted a paint first proposed for coating the inside of spot sensitometers used, coincidentally, for calibrating photographic plates. This is documented by WU et al (1972, AAS Photobulletin 1, 9) and is based on a barium sulfate mixture. The recipe for the paint is reproduced below for those who do not have access to old issues of this journal.

In order for this paint to adhere for a long period, the surface must be cleaned very well, and then primed with a white oil-based primer. The screen is masked so that the diameter of interest (several inches larger than the telescope aperture) is obstructed. The region exterior to the mask is then sprayed with flat black paint. After the black section dries, it is masked, and the central circle is sprayed with the white paint mixture. Use a spray gun capable of spraying coarse paint, and apply several coats very slowly, allowing a lot of drying time in between. If you rush it, the paint will run off the surface. It will take some 3 or 4 pints to cover a 4' diameter spot, plus a lot of practice with this strange paint. Once complete, handle the screen carefully, as the white paint is easily scratched and can flake.

The screen must be made of a stiff material which does not flex easily; otherwise the white paint will flake off. Thus, we found that plywood and fabrics don't work well. We have adopted a material called "Blue Seal Sandwich board" available from Hexcel corp, 7711 Center Ave Suite 305, Huntington Beach, California 92647 (714-898-3922). This board is a special light weight aluminum material honeycombed between two thin aluminum sheets. We used a 4' x 8' x 3/4" sheet (cut down to size) for the 0.9m telescope. Two sheets were carefully joined for use at the 2.1m telescope. Special clips and mounting frames are available from Hexcel, but the aluminum sheets are light enough that normal screws will hold it to a dome surface.

Contact one of us for further information.

George Jacoby,
Bill Schoening,
Jim De Veney

Here is the recipe for the high reflectance white paint, as taken from the paper by Wu et al (172, AAS Photobulletin 1, 9).

> "To make one pint, heat 50 ml of distilled water to 52-66 C (125-150 F) and slowly add 2.25 grams elvanol polyvinyl alcohol (Grade 72-60), mixing until all the alcohol dissolves. To this mixture add 150 ml of distilled water and 200 ml of 200 proof anhydrous ethyl alcohol. Then slowly add (stirring continuously) 227 gm of USP grade barium sulfate to the mixture.
>
> In practice it seems best to mix this paint just before use. We applied it to an undercoat of Krylon 1502 flat white paint using a Pace air brush with a No. 2 head."

<u>R. Rouse</u>: What should one do about non-linear regions in flat frames? Should they be removed? How? Will your answer apply even if I need to smooth the flat frame?

<u>G. Jacoby, P. Massey</u>: If non-linear (gain $\neq$ constant) regions exist, it is possible to devise a pixel-by-pixel mapping function to correct the region. It's a lot of effort to try to recover data that is really "bad." In the long

run, it is MUCH better to improve the CCD operation – this may require a new CCD!

M. Sitko: Are pictures available of the details of the defects of each NOAO chip so that a person can choose the proper one in their proposal?

G. Jacoby, P. Massey: We keep a "CCD Characteristics Manual" at each telescope, and several are available downtown (e.g., in the library). If you need advice on preparing a proposal, it is best to call someone at KPNO; we also try to include relevant details in the newsletter.

R. Gilliland: Why don't you correct the deferred charge?

G. Jacoby, P. Massey: One can correct for "deferred charge," or "charge traps," but most observers don't collect the necessary data. We recommend using the "Shift & Stare" mode of observing to circumvent this and other common CCD problems.

T. Balonek: Can you comment on the stability of flat fields from night to night, week to week, or month to month?

G. Jacoby, P. Massey: Flat-fields are not adequately stable, even over periods of a few days, so that you can skip taking them, but mostly the problem is dust specks falling on filters and dewar windows during the night. These affect the flat-field response from day to day. The overall structure is quite stable.

C. Wilton: Could you describe the distinction between overscan and bias? Should they be subtracted as scalars or arrays?

G. Jacoby, P. Massey: Overscan is a series of readouts of the CCD amplifier – it has nothing to do with any physical pixel on the chip, but rather provides a reading of the electrical offset level (a scalar). The bias is a picture taken for an exposure time of 0.000 seconds and represents any "zero point" structure across the physical pixels (an array).