Classification of bad pixels of the Hawaii-2RG detector of the ASTROnomical NearInfraRed CAMera

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ABSTRACT

ASTRONIRCAM is an infrared camera-spectrograph installed at the 2.5-meter telescope of the CMO SAI. The instrument is equipped with the HAWAII-2RG array. A bad pixels classification of the ASTRONIRCAM detector is proposed. The classification is based on histograms of the difference of consecutive non-destructive readouts of a flat field. Bad pixels are classified into 5 groups: hot (saturated on the first readout), warm (the signal accumulation rate is above the mean value by more than 5 standard deviations), cold (the rate is under the mean value by more than 5 standard deviations), dead (no signal accumulation), and inverse (having a negative signal accumulation in the first readouts). Normal pixels of the ASTRONIRCAM detector account for 99.6% of the total. We investigated the dependence between the amount of bad pixels and the number of cooldown cycles of the instrument. While hot pixels remain the same, the bad pixels of other types may migrate between groups. The number of pixels in each group stays roughly constant. We found that the mean and variance of the bad pixels amount in each group and the transitions between groups do not differ noticeably between normal or slow cooldowns.

- Background

これまではdark frameを用いてbad pixelの評価を行うことが多かったが、H2RGは暗電流が小さく(< 0.03 [e-/s])normal pixelとdead pixel等のbad pixelの区別ができないことが多い(読み出しノイズ(~12[e-])に埋もれる)

⇨signal accumulation rateを用いたbad pixelの評価を行う

- Signal accumulation rate

Signal accumulation rateの測定にはsky backgroundを用いる

1. スカイフラットに16 pixのメジアンフィルターをかける
2. 隣接した読み出し間の信号強度の差を計算し、conversion gainを用いて電子数に変換
3. ディザリングして得た複数の画像についてメジアンをとり、宇宙線や星の影響を取り除く

サチらないようにup-the-rampの最初の3回までの読み出し結果のみを元に計算を行なっている。

- Signal accumulation rate

リセット電荷とsignal rateをプロットしたものが図5

1. いくつかの領域に大きく分かれている
2. NDR1-2の方がNDR2-3よりもsignal accumulation rateは高く、その傾向はNDR1が小さいところほど顕著
3. 同じsignal accumulation rateでもNDR1が倍違うところあり

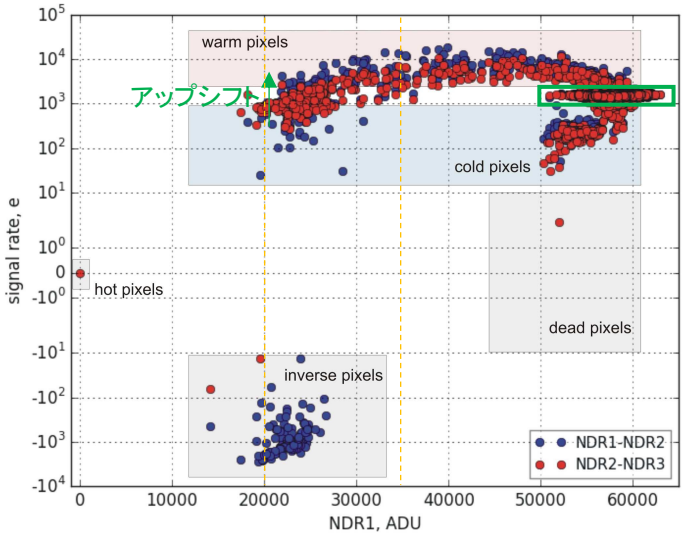

Figure 5.

Diagram of the dependence of the signal accumulation rate on the signal value in the 1-st NDR

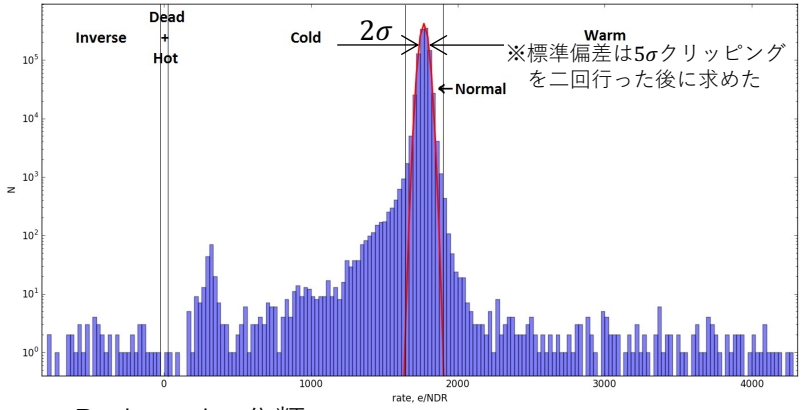

Figure 4.

A pixel distribution by the accumulation rate in a typical master-frame. The histogram bin width is 1 SD.

- Bad pixelの分類

1. Normal pixel
   signal rateの平均値からの乖離が5σ以下
2. Cold pixel
   signal rateが平均値より5σ以上低いが、読み出しノイズよりは大きい
3. Warm pixel
   Signal rateが平均値よりも5σ以上高い
4. Dead pixel
   (-RN, RN)の範囲(信号は全く蓄積されないが、読み出しノイズの存在により信号は0ではない)
5. Hot pixel
   Dead pixelと同様に信号は全く蓄積されないが、読み出しノイズに影響を受けず、signal rateは常に0

冷却率	<1[K/min]					< 0.3[K/min]
Dates	2016-05-22	2016-09-28	2016-11-14	2017-04-20	2017-05-30	2018-07-07
Hot (H)	H – 6	H – 6	H – 6	H – 6	H – 6	H – 6
Warm (W)	W – 441 C – 4 D – 0 I – 0 N – 191	W – 385 C – 4 D – 0 I – 0 N – 413	W – 372 C – 1 D – 0 I – 0 N – 84	W – 266 C – 5 D – 0 I – 0 N – 132	W – 262 C – 2 D – 0 I – 0 N – 71	W – 374 C – 2 D – 0 I – 1 N – 326
Cold (C)	W – 1 C – 2803 D – 0 I – 0 N – 472	W – 1 C – 2892 D – 1 I – 0 N – 814	W – 2 C – 2339 D – 1 I – 0 N – 153	W – 3 C – 1851 D – 0 I – 0 N – 142	W – 2 C – 1940 D – 0 I – 0 N – 360	W – 10 C – 1910 D – 2 I – 0 N – 1321
Dead (D)	W – 0 C – 1 D – 0 I – 0 N – 1	W – 0 C – 0 D – 0 I – 0 N – 1	W – 0 C – 1 D – 1 I – 0 N – 0	W – 0 C – 1 D – 0 I – 0 N – 1	W – 0 C – 0 D – 1 I – 0 N – 0	W – 0 C – 0 D – 1 I – 0 N – 0
Inverse (I)	W – 0 C – 0 D – 0 I – 89 N – 2	W – 0 C – 0 D – 0 I – 55 N – 2	W – 0 C – 0 D – 0 I – 87 N – 5	W – 0 C – 0 D – 0 I – 40 N – 55	W – 0 C – 0 D – 0 I – 57 N – 0	W – 0 C – 0 D – 0 I – 87 N – 2
Normal (N)	W – 150 C – 356 D – 1 I – 0	W – 90 C – 211 D – 1 I – 5	W – 210 C – 802 D – 0 I – 6	W – 98 C – 716 D – 1 I – 0	W – 91 C – 301 D – 0 I – 28	W – 195 C – 137 D – 0 I – 36

Table 2. Change of bad pixel types. The first column shows the pixel groups before the restore. The next columns show the number of pixels and the group to which they were transferred during a cooldown of the date indicated in the first row.

- バッドピクセル間の遷移

バットピクセルマップの比較(Table 2)により、

1. ホットピクセルは位置が一定でクールダウンの前後で変化しない
2. ゆっくり冷やしてもbad pixel数には有意な差は見られない
3. Warm, cold pixelはnormal pixelになったり戻ったりする

⇨本当に画素の種類が変化したのか、それとも統計的に遷移が起こっただけかを調べた(Table 3)

- WarmとNormalの遷移の場合、そのようなピクセルのうち40%が±σに、65%が±2σにあった。

⇨warmからNormalに変わったpixelのうち60%は実際に物理的な振る舞いを変えたことがわかる(cold→normalについても同様)。

Table 3. The number of normal pixels that turn to the warm or cold pixels group and vice versa. The columns indicate the number of pixels lying in the given range from all that changed the normal group to the warm (cold) group or vice versa.

Transition	Normal→Warm		Normal→Cold	
Date	$4\ SD < x < 6\ SD$	$3\ SD < x < 7\ SD$	$4\ SD < x < 6\ SD$	$3\ SD < x < 7\ SD$
2016-11-14	115/210 (54%)	175/210 (83%)	433/802 (54%)	699/802 (87%)
2017-04-20	30/98 (31%)	61/98 (62%)	364/716 (51%)	572/716 (80%)
2017-05-30	39/91 (40%)	57/91 (63%)	92/301 (31%)	195/301 (65%)
2018-07-07	60/195 (31%)	96/195 (49%)	78/137 (57%)	106/137 (77%)
Transition	Warm→Normal		Cold→Normal	
Date	$4\ SD < x < 6\ SD$	$3\ SD < x < 7\ SD$	$4\ SD < x < 6\ SD$	$3\ SD < x < 7\ SD$
2016-11-14	40/84 (48%)	58/84 (69%)	80/153 (52%)	133/153 (87%)
2017-04-20	13/132 (10%)	37/132 (28%)	63/142 (44%)	114/142 (80%)
2017-05-30	36/71 (51%)	49/71 (69%)	44/360 (12%)	133/360 (37%)
2018-07-07	224/326 (69%)	304/326 (93%)	445/1321 (34%)	823/1321 (62%)