CCD 芯片在 I 波段未明原因的一种退变

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提 要

上海天文台 1.56m 反射望远镜自 2002 年起安装了两架相同的 CCD 照相机，#1 和#2。所用芯片都是 Tek2048 × 2048。它们系在 Lick 天文台使用其控制电路组装。自 2004 年起，#1 CCD 发生了一种非常奇怪的退变，在其芯片上有许多小的区域的灵敏度下降，并呈现非线性（ < 3% ）。这些小区域的数目自 2004 年起逐年增加（现已基本稳定）。这种奇怪的退变只发生在 I 波段，B，V，R 波段都不受影响，也就是说，只涉及近红外光子。该现象在“CCD World”网页报道后引起注意，进行过许多讨论。这是整个 CCD 领域中未知的一种新毛病，但是找不出其病因。#2 CCD 没有这种退变。

主题词： 仪器 — 检测器 — CCD — 技术 — 测光
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UNSOLVED DETERIORATION OF THE CCD CHIP IN I WAVEBAND WITH UNKNOWN CAUSE

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Abstract

The CCD #1 camera has been attached to the 1.56-m reflector of Shanghai Observatory since 2002. It has suffered from a kind of strange deterioration since 2004: there are many local subregions on the CCD chip where the sensitivity has decreased and the non-linearity (< 3%) appeared. The number of these local subregions has increased since 2004. But the deterioration only appears in I, not in B, V and R. That is to say, only the near-infrared photons are involved, so it is a kind of new fault of CCD which is unknown to the whole CCD world.

Key words instrumentation — detectors — CCD — techniques — photometric

1. Introduction

There are two identical CCD cameras, #1 and #2, with the thinned back-illuminated Tek (normal

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name: SITe SI-424AB) 2048 × 2048 chips (pixel size 24 micron) attached to the 1.56-m of Shanghai Observatory. Both of them were integrated at Lick Observatory using their control electronics [1~3]. The #1 camera has been on routine use since 2002. However, strange deterioration of the #1 CCD chip has happened since 2004: there are many local small subregions on the CCD frames showing decrease in sensitivity, they look like watermarks but can hardly be understood. The number of these local subregions has increased since 2004, as shown in the Figs 1a ~ 1e. (Note that the figures shown here refer to negative images, the darker the image, the higher the pixel value). The Fig. 1a was obtained on 2003 May 8, the deterioration did not happen, it began to appear on the Fig. 1b obtained on 2004 January 7 (see the rectangular box at the lower left area) and afterwards (Fig. 1c on 2005 August 26; Fig. 1d on 2006 June 21; Fig. 1e on 2008 June 4).

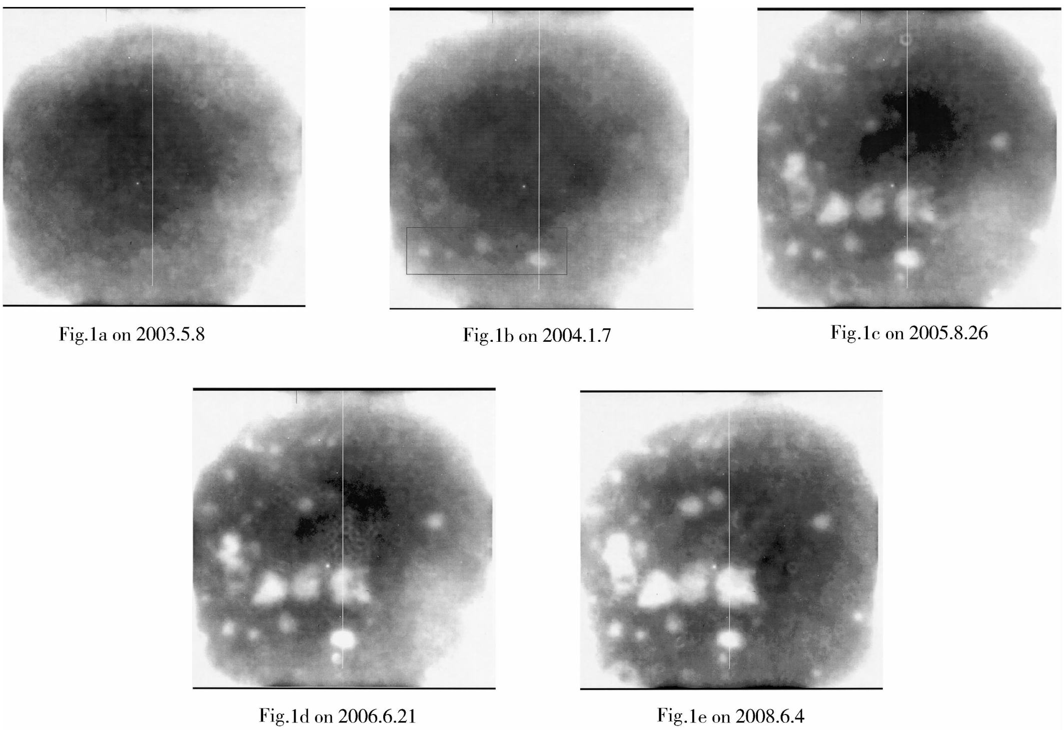

Fig. 1 Dome flat field for I filter at the 1.56-m, note the "watermarks" appeared first in fig. 1b, rectangular box at the lower left area

2. Features of the deterioration

(1) It only appears in the I waveband, the CCD frames obtained through the B, V and R filters do not show this fault. Fig. 2 shows the dome flat field in R and Fig. 3 in B, both of them are obtained in 2008. Here the filters are made up according to Bessell's prescription, so the short wavelength cut-off in I is at 700nm (by the glass filter RG9), and the long wavelength cut-off by the CCD itself. If the appearance of watermarks is really due to watermarks, why it only appears in the I waveband?

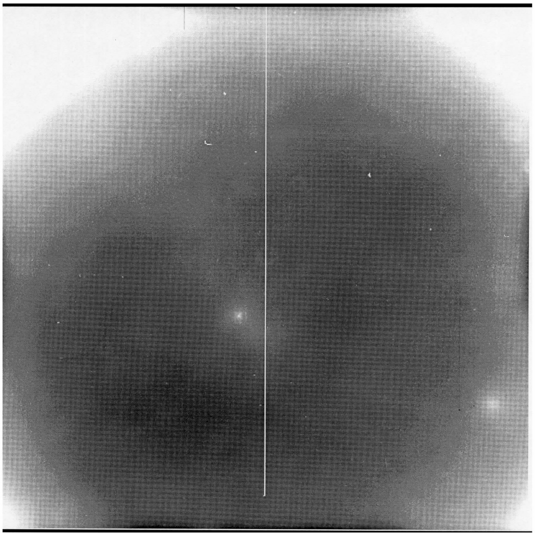

Fig. 2 Dome flat field for R filter at the 1.56-m on 2008.8.27

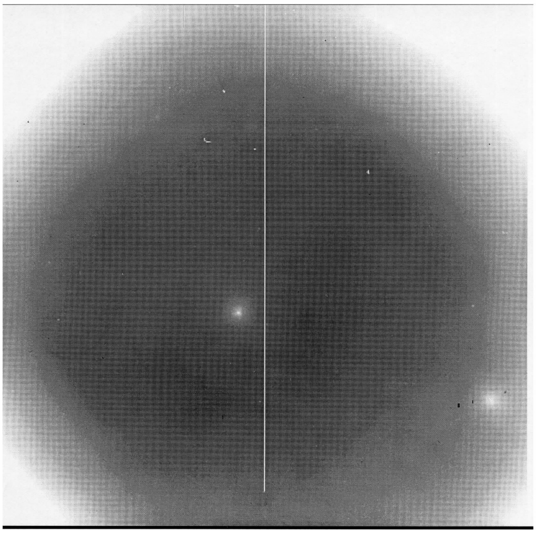

Fig. 3 Dome flat field for B filter at the 1.56-m on 2008.7.24

(2) The spectral sensitivity of this CCD was re-checked at the Chinese National Observatory in 2006 using several narrow-band filters including a 800nm one, all the CCD frames obtained through these filters did not show the deterioration. Therefore, we suppose the deterioration happens at some wavelength longer than 800nm.

(3) It has no relation to the interference of light. Because these local subregions keep their positions fixed on the CCD frames, no matter the frames are obtained by dome and twilight flat fields or night sky exposures. Our dome flat fields are obtained using the continuous light source, no emission lines.

(4) No relation to the possible fault of the I filter itself. Rotate the I filter relative to the CCD chip, the pattern of the deterioration keeps the same.

(5) At one night in July of 2008, the dome flat fields in I were obtained with the two CCD cameras one after another. The #2 camera did not show any deterioration, so it has no relation with any parts of the telescope itself or scattered light. The problem must be with the #1 CCD chip only.

(6) The pattern of the deterioration on the object frames can not be eliminated by flat fielding. Fig. 4 is the image of M92 which is only bias-subtracted. The scan along one of the subregions and its neighbourhood of Fig. 4 is shown in

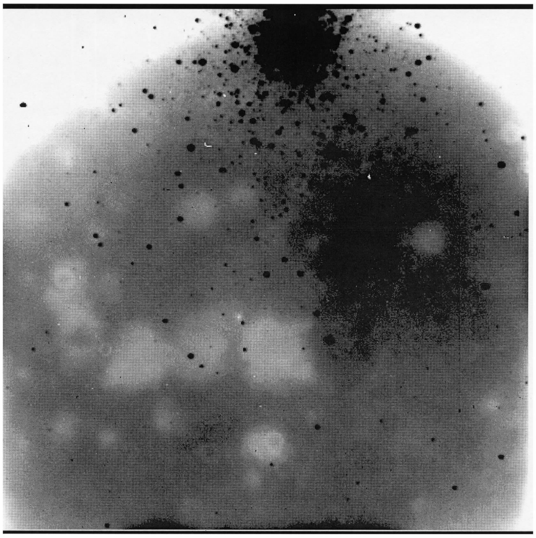

Fig. 4 The globular cluster M92 in I. Only bias subtracted

Fig. 5, here the decrease in sensitivity is about 9%. and Fig. 6 is bias-subtracted and twilight flat field divided. As shown in the figure, dividing the flat field from the object frame can not eliminate the appearance of the deterioration completely. The similar scan is shown in Fig. 7. Here the remained error is about 3%.

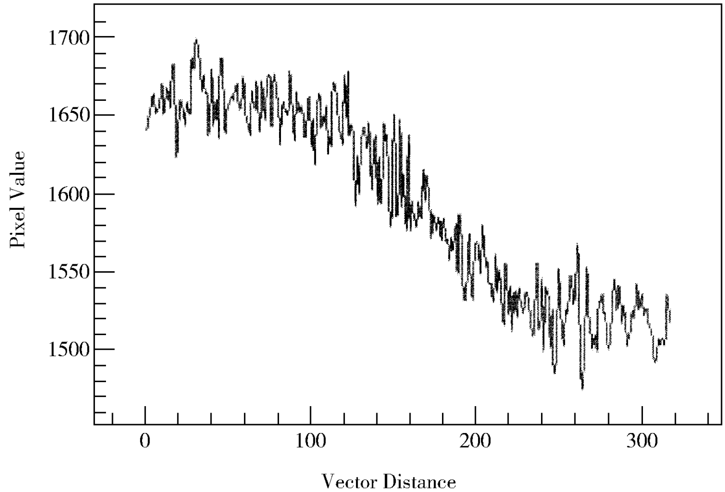

Fig. 5 Scan along one of the subregions and its neighbour of Fig. 4

It means a certain degree of non-linearity in these local deterioration subregions. Specifically, if the traditional transfer curve is plotted, the non-linearity (the sensitivity decrease) is more severe at the lower end of the transfer curve in these subregions.

The non-linearity is not very large, so it can not be shown clearly in the transfer curve because only limited number of points are used to plot the curve. But when a frame with low pixel value is divided by another one with high value (even the latter is normalized to 1.0), the non-linearity appears clearly.

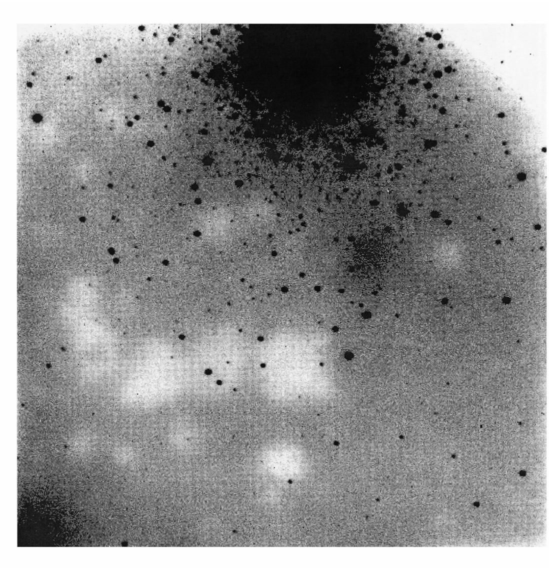

Fig. 6 The same image of M92, but also flat fielded

In Fig. 6 the object frame was divided by the normalized twilight flat field whose original average pixel value was about 5000 adu but the object frame has an average value of about 1500 adu, so the count at the "watermarks" in Fig. 6 is smaller than that at the nearby area. If the twilight flat field is obtained at an average value similar to that of the object frame, the appearance of the "watermarks" will become negligible.

(7) The Fig. 6 was obtained by dividing the twilight flat field. It has been asked whether "the pattern of the deterioration on the object frames

can not be eliminated by flat fielding" is due to the difference of the spectral distribution between the twilight flat field and the night sky exposure for the object frame?

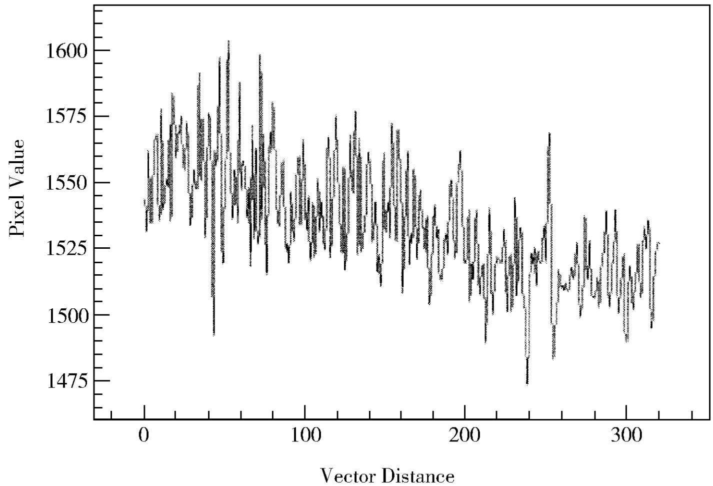

Fig. 7　Scan along one of the subregions and its neighbourhood of Fig. 6

What we can say for the time being is: if this is the cause, it can not be the only cause.

The Fig. 8 is the quotient of an I dome flat divided by another one, both of them were obtained on 2008 August 27 with exposure 5s (all of them were bias subtracted first), the local deterioration disappears, but a long exposure dome flat divided by a short one shows the deterioration (watermarks). The Fig. 9 is the quotient of a 15s exposure (average pixel value 22000adu) divided by a 1.5s (average value 2100 adu) one (the shutter influence was partly corrected for the 1.5s exposure). Here the same light source (the same spectral distribution) was used.

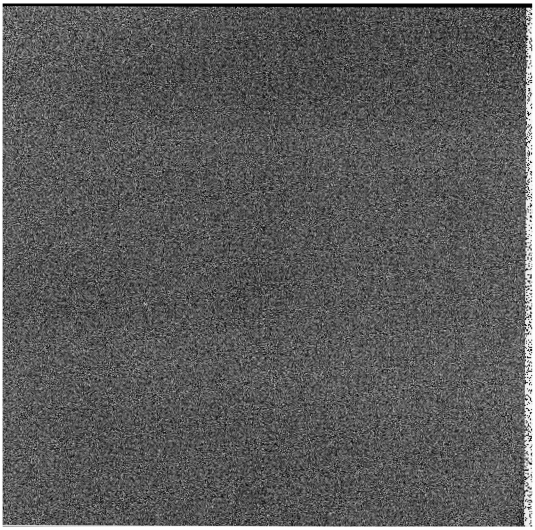

Fig. 8　Quotient of one I dome flat divided by another one with the same exposure

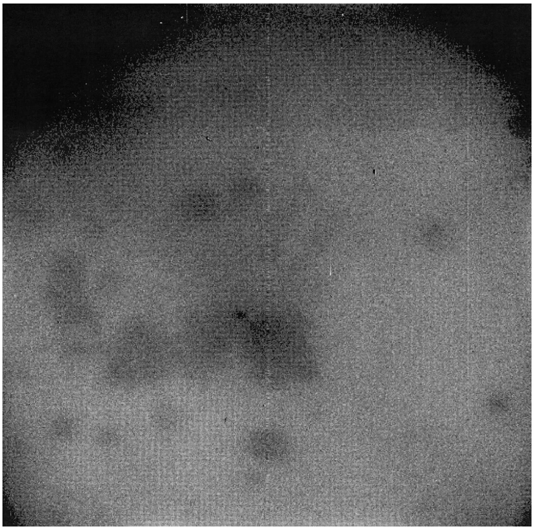

Fig. 9　Quotient of a 15s I dome flat divided by another one with 1.5s exposure

Contrary to Fig. 6, here the count of the quotient at the "watermarks" is larger than that at the nearby area (because the numerator of the quotient larger than the denominator), so it shows darker.

Obviously, the extended source (for example the comet tail) photometry suffers from this kind of deterioration. Accurate estimation of the error in point source (stars) has not been finished.

3. Why

The only difference between #1 and #2 is such: the cover glass of the CCD chip of #1 was removed away for some time at common room in 2002, so the moisture might be condensed on the surface of the chip. On the CCD frames obtained by us on 2002 September 12, there were many spots (maculae) with various diameters appeared. The appearance of these spots might be related to the unpleasant experience of the CCD chip. Fig. 10 shows the dome flat (through the R filter) on 2002 September 12. Note that the positions of the spots were fixed on the CCD frame, the frames obtained on 2002 October 1 through I filter also showed these fixed spots. Note the spots are dark in Fig. 10 (this is a negative image), i. e., their pixel values are higher than that of the surrounding areas. According to the size and appearance of the spots, they were not produced by the dust or condensed water drops on the window glass of the CCD dewar, neither on the cover glass of the CCD chip. Their positions on the CCD chip did not coincide with that of the later "watermarks". After long repeated vacuum, the CCD chip must be dry. All the above mentioned maculae disappeared on the CCD images. Note the deterioration (the "watermarks") did not happen in 2002, and since then the CCD has been always on routine use (keeps in vacuum).

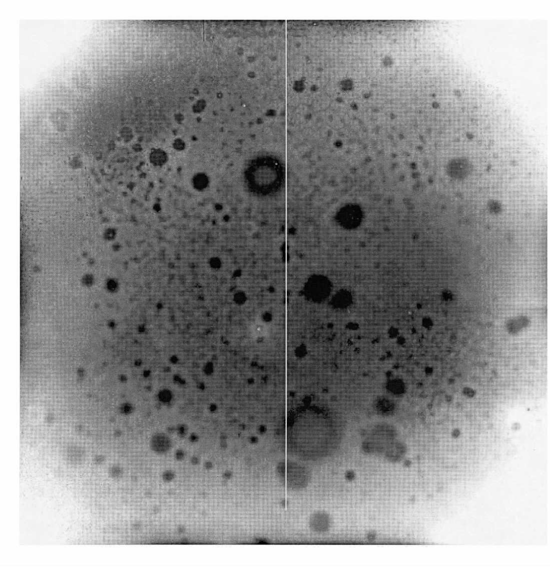

Fig. 10 The dome flat in R obtained on 2002. 9. 12

The simplest way to explain the deterioration is simply to say that the CCD becomes old. This kind of answer is equal to "no answer". There are so many CCD cameras in the world and no user has reported this kind of deterioration, and this CCD chip # 1 was not old when the "watermarks" appeared first in 2004.

Dr. Ye Binxun of Chinese National Observatory helped us to raise the question in the internet (the "CCD World") in order to get answers, because it is a new kind of deterioration which has never been found in the CCD community. To find out the cause of the deterioration is meaningful for the development of the CCD technique.

We got many suggestions and discussions from the internet, but no real cause has been found. Dr. Kasey Boggs among them pointed out that "if the backside process used a chemisorption coating prior to AR coating, one might be seeing a loss of backside charge, seen on other contaminated devices". (Kasey Boggs, 2008, private communication). It is hard to understand why the deterioration appears in I waveband only, i. e., only the near-infrared photon causes it.

Therefore, we publish the question here to expect explanations from CCD experts all over the world in the future.

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