Gain

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LSST : small CCD amplifiers but gain under control

Specific issue with LSST :

amplifier surface on sky is small and

, even if mirror large , exposure time is

short .

Instrument	nb pixels per amp	pixel size arc sec**2	amplifier size arc min**2	nb amplifie r/CCD	CCD size arc min**2	mirror*exp_time m**2 s
HSC	512 * 4096	.168**2	**16.4**	**4**	**65.67**	**8.2**2*200=13448**
DES	1024 * 4096	.28**2	**91.3**	**2**	**182.7**	**3.9**2*90=1369**
LSST	512 * 2000	.20**2	**11.4**	**16**	**182**	**6.423**2*30=1238**

- ==> limited number of stars per amplifier :
  - inter-amplifier normalisation using star = bad idea… but for inter-calibration between CCD ok .
  - So issue for an uniform sky subtraction per CCD
  - the clame : it can be fixed by gain & linearity measurement using PTC data (once in a while) , gain rescaled per exposure using temperature and gain monitored (corrected) per night using flats

Why we should consider gain correction/normalisation as a better tool than ever ?

- Following the work on brighter fatter , we can measure gain in PTC data with a precision with a few .01 % …before this work , the apparent non-poissonian behavior of the PTC curve was preventing to extract a gain with precision. (For a Poissonian “noise” we expect variance_ADU = nb_ADU / gain , with nb_ADU % exposure time …)

- The gain is observed stable / easy to correct in real time in LSST cam : at first order only the temperature has an impact on the gain in LSSTcam :
  - the REB/ASPIC temperature
  - the CCD temperature

  Both are stable (we are in a stabilized temperature environment / cryostat) , and stability after T correction better than .01% should be easy to reach (in highly controled environement we achieved relative gain control at ~ 0.002% in Paris over days) …
  Also per nigth flats can be used to monitor / correct gain if needed. (no need to take PTC often)

- remark : the point above is a ~ (small) lie : for some ITL device there is a random gain glitch < .1% between 2 values for different exposures …we should be able to correct this based on overscan information … this is still under investigation

- Also these temperatures change should affect in the same way all amplifiers of a given CCD : the 2 ASPIC’s (8 channels each) of a given CCD are at the same location (on both side of the board) , and we can expect no strong temperature gradient change over a given CCD. ==> so at first order , even in case of a temperature change , the relative gain change among the different channels of a CCD should be tiny

- ==> to correct the gain in real time : 2 temperatures per image per CCD (1 per REB , 1 per CCD) + 3 (4?) corrections coef for the full focal plane (cte , estimated once for ever ? 1 gain vs T CCD_e2v , 1 gain vs T CCD_itl , 1 gain vs T REB , 1 gain vs T corner REB (should not be needed))

- What really matter to have a “in CCD flat sky” , is to control the non-linearity between high flux (flats) and low flux (sky) . For these flats are useless . What we propose is to measure the gain and non-linearity (+ CTI + BF coef) , all together in a precise PTC measurement. The non-linearity measured (and the associated correction) in ADU & gain measured are 100% linked in the PTC measurement , and should be used together.

A few remarks

Does the calibration of the temperature probe/ADC is an issue ? ==> NO !

- There is many temperature probes on the focal plane (10 per REBs 2 are close to the ASPICs and can be taken as references , 1 per ASPIC but with a poor resolution , 1 per CCD)
- To get a precise absolute temperature measurement , all the ADC should be calibrated … but we don't really care as the gain correction with the temperature , will be at first order only function of the relative temperature change !

What we will not correct with gain…or flat ?

- the "pre-tearing" effect in e2v which affect a few columns at the boundary of the CCD correspond to electrostatic distortion "à la" brighter fatter due to holes at the amplifiers boundaries. The effect size is sensitive to the flux like brighter fatter …so it cannot be corrected by flat … or gain … something else will have to be done (brighter/fatter like correction ?)
- Same difficulties for the sensor edges (4 boundaries and middle line)

What flat field are good at / should be used for ?

- smooth the sky level , and allow extrapolation below stars / galaxy : after flats pixels size variation et al. are not a problem and indeed after sky subtraction you may change your mind about the flat ;-)
- remove quantum efficiency variation between pixels & small dust transparencies issue

What flat field are bad for ?

- Correct non-uniformity in pixels size : corrupt astrometry and photometry
- In print on the CCD response the non-uniformity of the flat illumination / ghost … this is a high price to pay if you can uniformise the CCD response between amplifiers by a direct gain correction

What we should be worried about ?

- **Good non-linearity & gain measurement** = **precise ptc measurement** from saturation (150 ke-) down to the lowest expected sky level (~ 50-100 e-) , I do have a proposal for that see : **https://lsstc.slack.com/archives/CCQBHNS0K/p1661966200669859** (I hope we will use something like this for run 6 …for camera run 5 the PTC were not optimal in this respect)

What may not be a problem ?

- Part of the non-linearity is from the CCD , Part is from the ASPIC REB , a change in T_CCD or T_ASPIC will change the gain but also may/will slightly shift the associated non-linearity … is it a problem ? For T_CCD (non-linearity smooth) certainly not . For T_ASPIC (much sharper) , Pierre Astier says "no !" … if we have 10 deg change in REB ? it will I think .

Que faire ? Proposition :

- Prendre un jeu de données pour lesquelles on a une valeur des gains et une non linéarité mesurée ==> Run 1344 analysé par P.Astier

- appliquer ces corrections sur des flats à haut et bas flux de ce même run et voir si on a des effets de “frontière” entre ampli :
    - en excluant ~3 lignes au centre , 3 colonnes sur les bord des amplis , on peut mesurer des 2 cotés d’une frontière le niveau de flux en <les pixels> sur quelques (4?) ligne (ou colomne) des 2 cotés de la frontière. ==> on doit pouvoir contrôler le gain à bien mieux que le .001 entre ampli
    - la mesure   <amp1_frontière > / <amp2_frontiére > = gain 1 / gain2   = gain ratio +/- sqrt (2 / signal_moyen / nb_pixels)   , ainsi pour une moyenne sur 4 colonnes ~ 8000 pixels on a pour
        - un signal de 50000 e- , une mesure du gain ratio à +/- 7 10^-5 !!!
        - un signal de 1000 e- , une mesure du gain ratio à +/- 4 10^-4
        - un signal de ~500 e- (~sky) , une mesure du gain ratio à +/- 7 10^-4
        - un signal de ~100 e- (~sky en U) , une mesure du gain ratio à +/- 1,5 10^-3 ==> 2x plus de pixels nécessaires
        - Remarque la difficulté en particulier à bas flux est de faire une bonne correction de biais : à priori correction 2D + super biais

- voir si on peut voir / mesurer la dependance en T , en comparant cette fois le niveau pour un même CCD - ampli mais pour des poses avec des # temperatures … la on peut utiliser la totalité des pixels du CCD ==> pas facile à faire car source de lux pas stable et photo-diode pas terrible non-plus … une idée ? …Ceci dit on peut faire un truc en pratique plus important : vérifier que même si TASPIC ou CCD change (chercher des flats avec des var de T de plusieurs degrés) , le niveau entre ampli n’est pas affecté (gain_ratio= toujours 1 , les gains ont changé de la même façon pour le 2 amplis) …et ce pour # flux (==> la linéarité reste ok)