Ageing of the CoRoT CCDs

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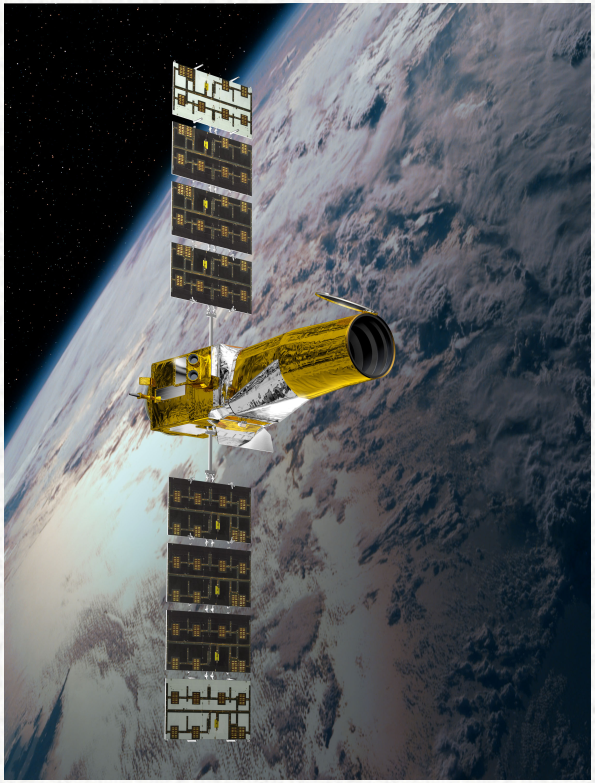
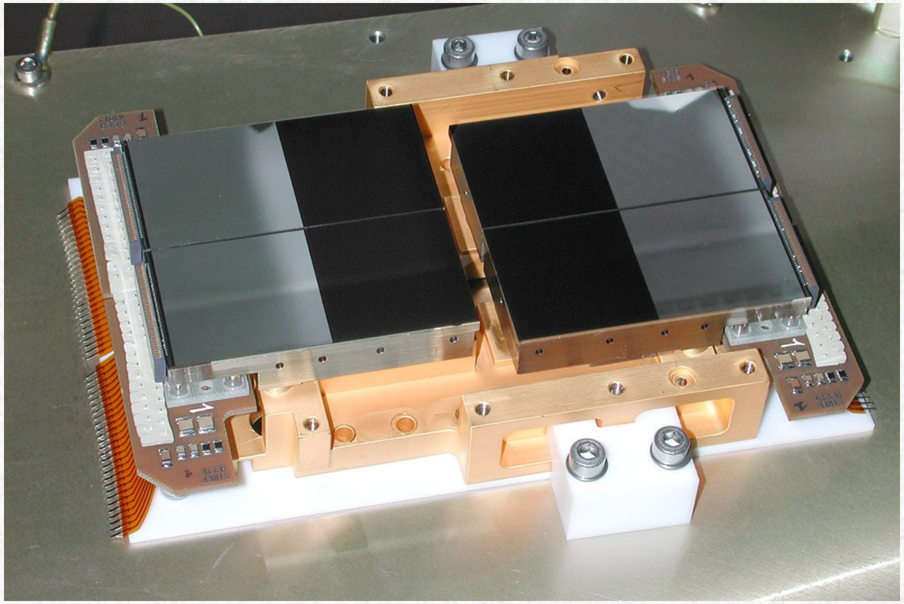
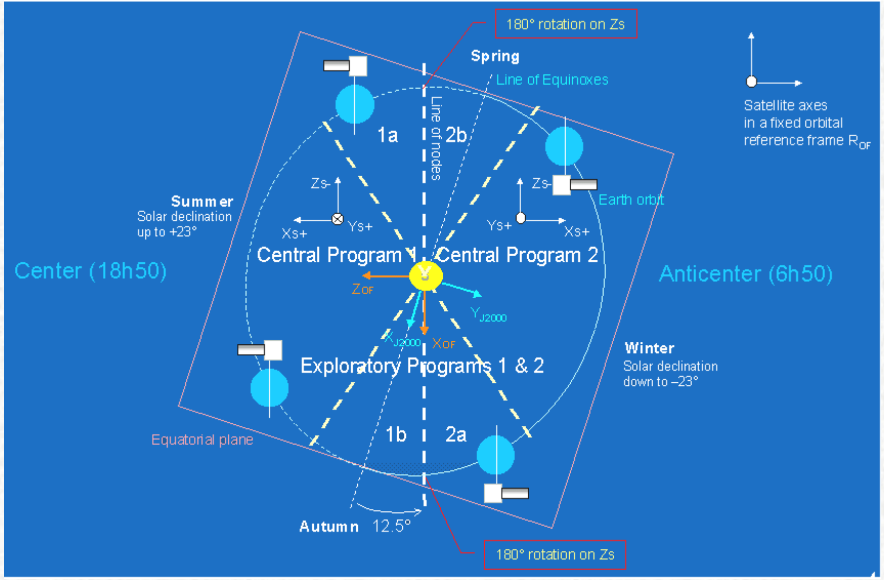




CoRoT focal plane
Frame transfer CCDs, E2V 2kx2k, 13.5micron pix
2 Asteroseismology CCDs (larger aperture, ~900 pix)
2 Exoplanet CCDs (smaller aperture, <100pix total)

CoRoT's Orbit



- Polar orbit w nearly constant axis
- Altitute: 830km
- Flight phase: 28 Dec 2006 - 2 Nov 2012 (5.85 yrs)
- Reversed every 6 months to point in opposite direction.
- Approx locaction of 'CoRoT-eyes':
  - crossings of galactic plane with dec=0°
  - near Galactic Center resp. Anti-Center
- Each 6-month block: one (later two) Long Runs of 150 days (or 2x~70d), complemented by several shorted runs.

Data analyzed

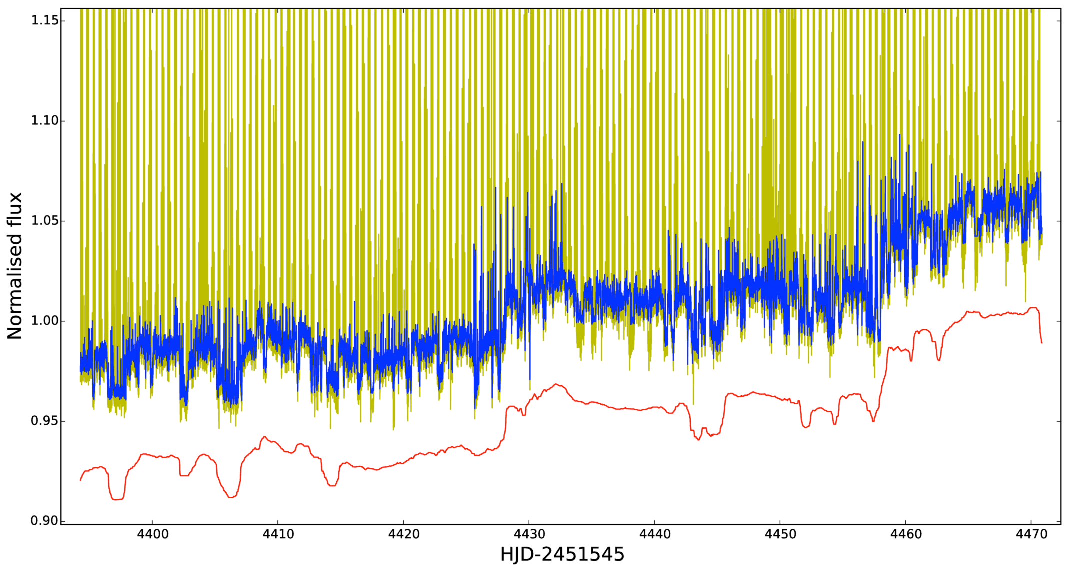
- 4 Long runs: Two near begin, one from middle, one from end of mission

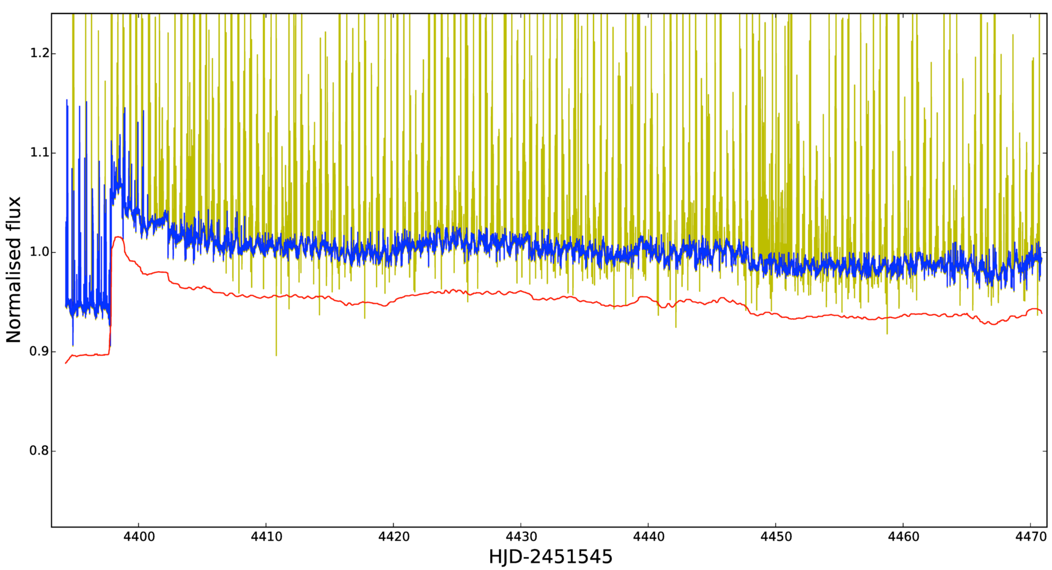
time in space (since launch)

Run ID	Start	End	D(d)	TS(yr)	
IRa01	2007-01-18	2007-04-03	75	0.16	
LRa01	2007-10-15	2008-03-03	140	0.99	two 56d sections analyzed
LRa03	2009-09-30	2010-03-01	152	2.97	two 56d sections analyzed
LRa06	2012-01-10	2012-03-29	79	5.14	

- For consistency, only 'anti-center' runs (less psf overlap / background contamination).
- Full data-sets from Exoplanet CCDs:
    - ~6000 stars/CCD
    - 2 CCDs in IRa01, LRa02; 1 CCD in LRa03, LRa06.
- Analyzed sections of 56days lenght from end of runs (two sections in LRa01, LRa03).
- IRa01, LRa01 also analyzed in Aigrain et al. 2009; adapted their analysis procedure

2 Representative Lightcurvces





Corot raw data (Yellow):

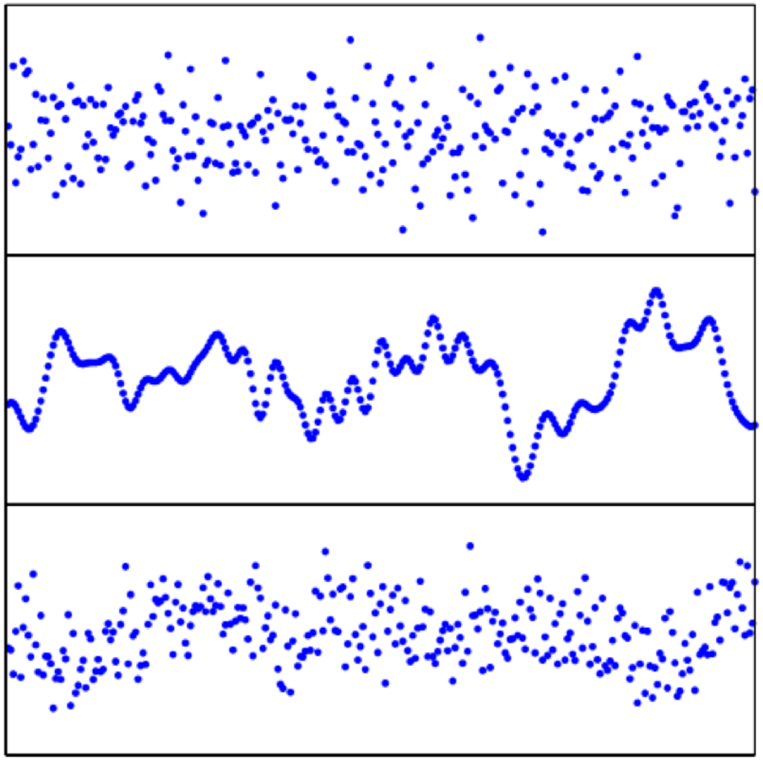
- CCD hit by energetic particles, mainly during SAA crossing. Hot pixel events!

Reduction steps

- 3 sigma clipping: 5-point boxcar filter + Median filter with baseline of 1h (-> Blue)
- Removal of variations longer than a day obtained by means of the same filter with baseline of 1 day (-> Red)
- Analyzed light curves are Blue - Red

Analyzed noise on 2h time-scales:
combination of uncorrelated (white) and correlated (red) noise

2h: time-scale of transit events

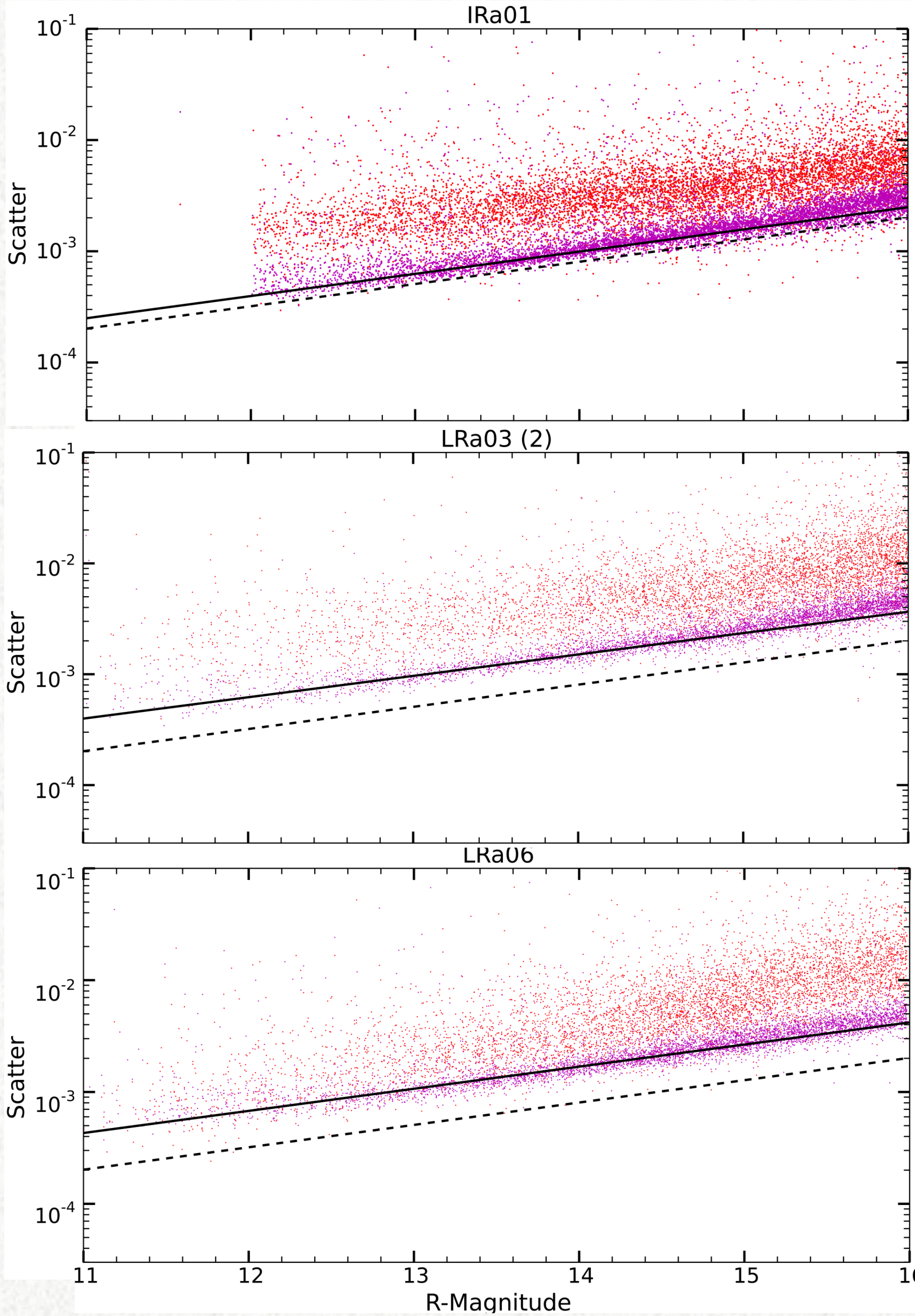


simulated data, Pont et al. 2006

Figure: Effect of red correlated noise on light curves.
-Top figure: light curve with only white noise. Middle figure: light curve with only red noise. Bottom figure: light curve with both white and red noise

- Noise is correlated due to a combination of factors such as orbital motion, telescope tracking, stellar activity...
- $\sigma_{2h} > \frac{\sigma_{pp}}{\sqrt{14}}$ σ_{pp} : pt-to-pt noise
- $\sigma_{2h} = \sqrt{\sigma^2_{uncorrelated} + \sigma^2_{correlated}}$
- σ_{2h} obtained from the MAD of the median points of each 2h block

Evolution of noises with time



- rms over 1 day
- rms point to point (every 512sec)

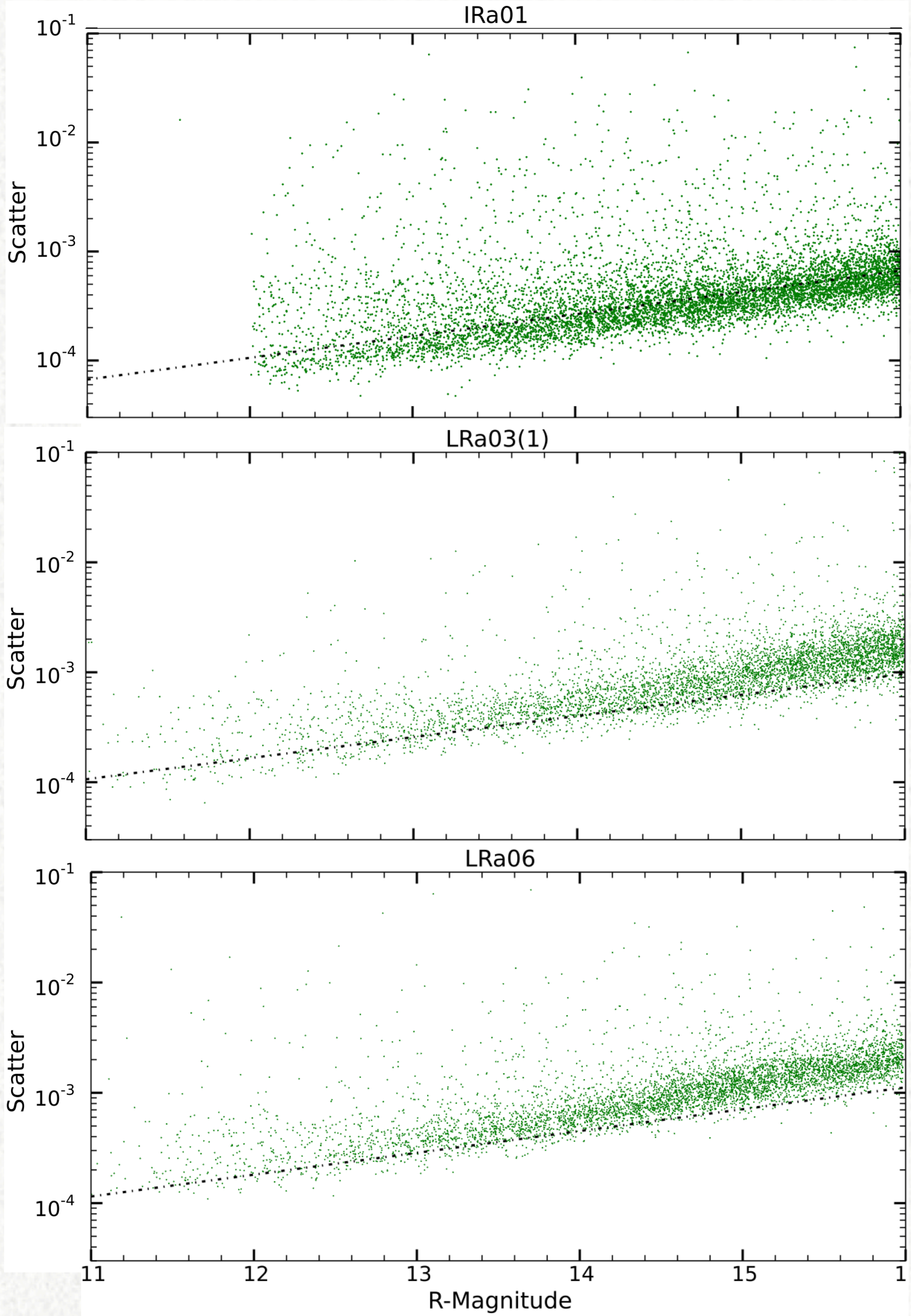
— fit to lower 20% percentile of pt-to-pt

-- theo. photon-noise over 512sec

IRa01 (0.2yr) : pt-to-pt slope ~ 1.3x phot.-noise

LRa06 (+5 yr) : pt-to-pt slope ~ 2.0x phot.-noise

White Noise versus 2h Red N.



- Red noise over 2h

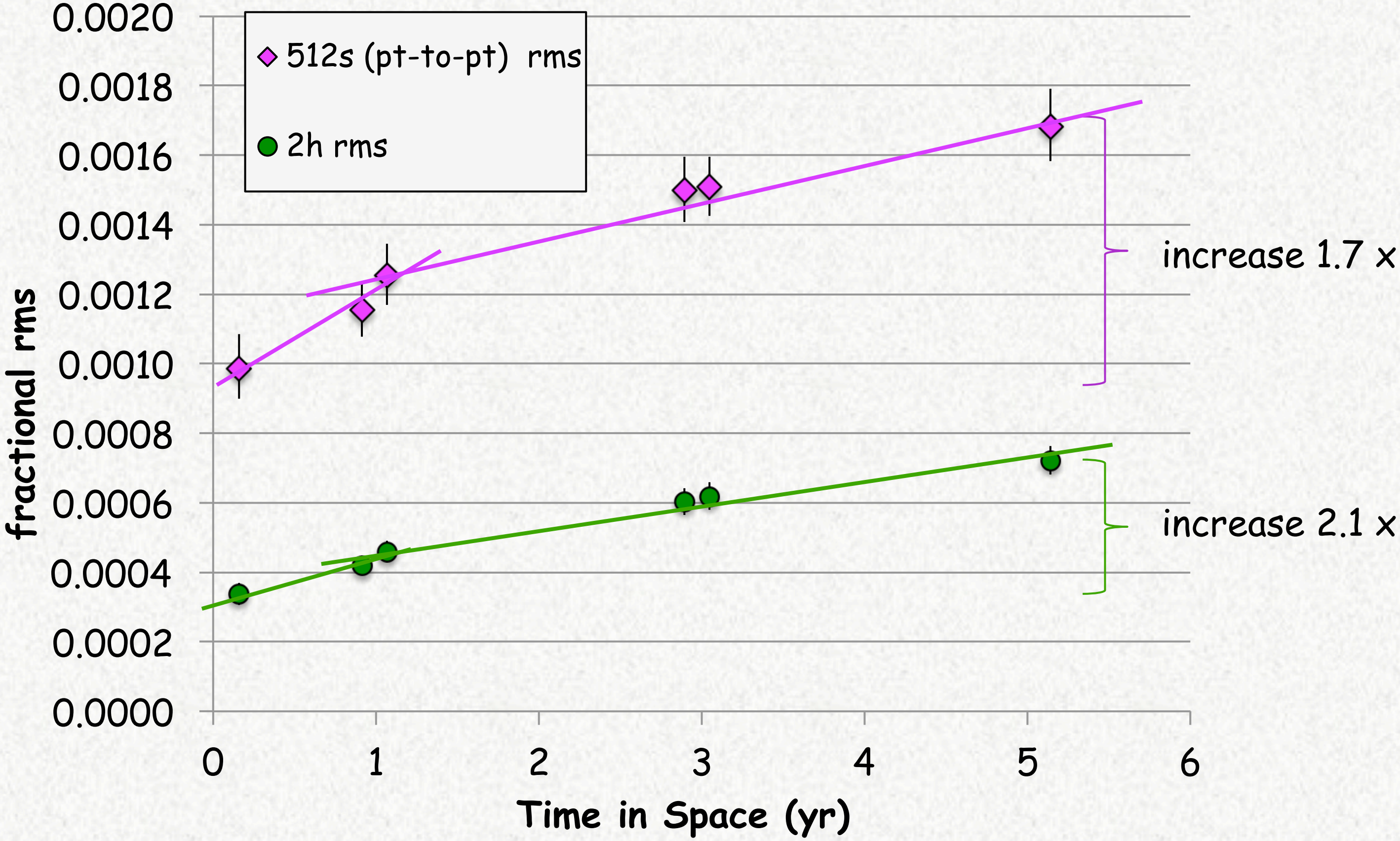
····· 20% percentile of pt-to-pt noise *scaled to 2h* = WN over 2h

IRa01 (0.2yr) : 2h-RN ~ 0.8x WN

LRa06 (+5 yr) : 2h-RN ~ 1.8 x WN

Red noise increased much more than WN

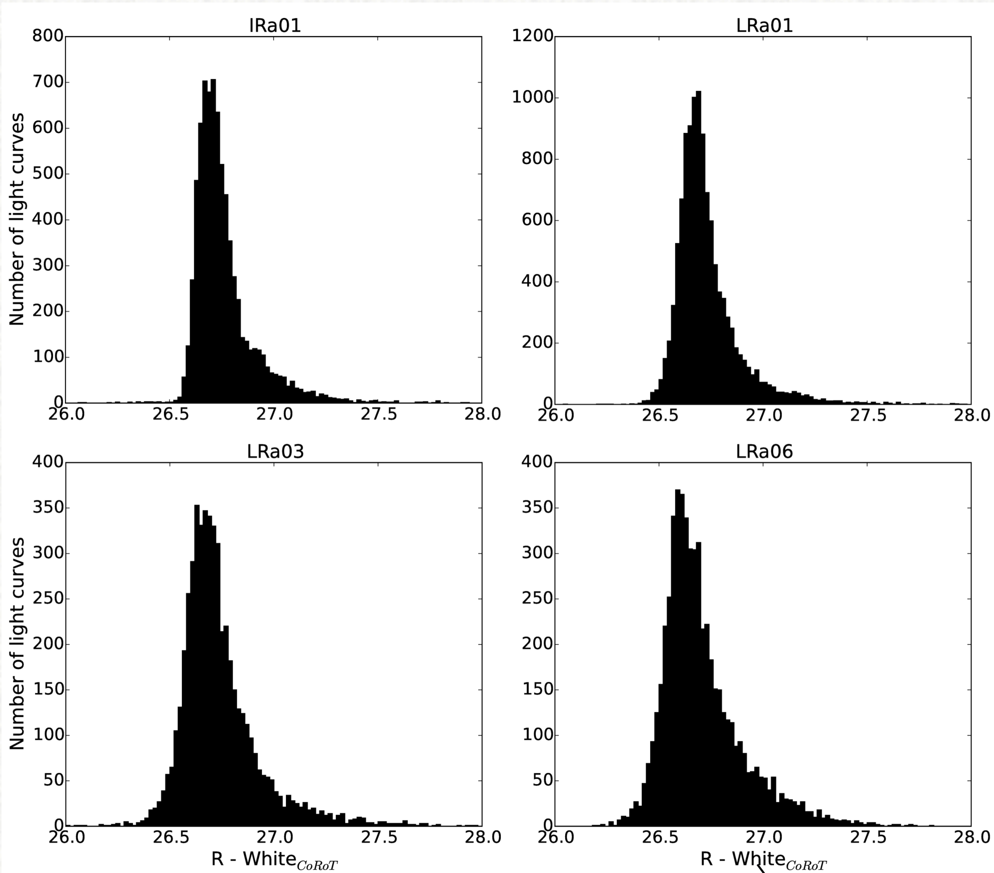
Total Noises for R=14 mag



two time-scales of ageing?
first yr: rapid aging ('burn-in'), ~30% noise increase
1-5yrs: noises increase with 10-20% /yr.

Photometric Zero-points

Zero-point = Catalog_mag – Instrum_mag



Indicates instrument efficiency
- optical transmission efficiency,
- CCD quantum efficiency,

and amplifier gain.

Across CoRoT flight-phase:
Variations in ZP are
- -small (<5% in flux)
- -not systematic

Zero-points of individual lightcurves

Conclusions

Significant increase (~2x) of CCD noises during 5yr flight-phase:
Likely caused by increasing numbers of pixels with permanent low-level ('warm') excitation, probably as reminder of CR hit.

Data taken during Southern Atlantic Anomaly (SAA) crossings strongly degraded: Likely main source of radiation damage. SAA will also affect CHEOPS (also polar orbit, slightly less altitude)

Strongest degradation in first year (~30% noise increase) ;
Noises on short times scales (512sec/8min) increase slightly less than on few-hr time-scale.

All or *nearly all* CoRoT-apertures are affected (due to increase of lower envelope of pt-to-pt rms)

With smallest apertures: 35 pixels, up to ~100 pix:

-> Affected are at least ~5% of pixels

No relevant effects on instrument throughput/gain during flight phase

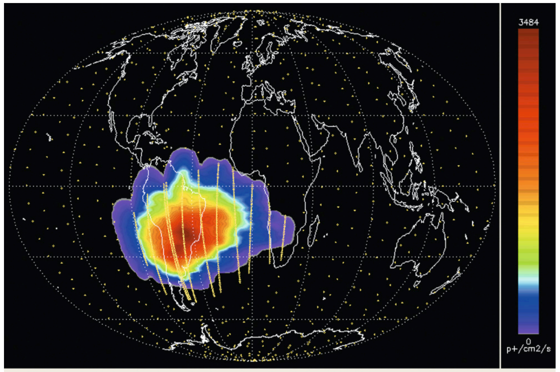


Fig. 4. Radiation flux p$^+$/cm^2/s map. The yellow points are the moment of image acquisition.The oscillations on the edges come from a poor time sampling.

Auvergne et al. 2009