Evolution of dark currents in LYRA detectors

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In 2014, it was found that the level of dark currents in LYRA detectors did not stay constant on the 2010 post-launch levels as initially assumed, but changed with time of mission. This lead to artifacts in calibrated data and had to be corrected, see the report given at the Solar EUV Irradiance Working Group:
http://solwww.oma.be/users/dammasch/Dammasch_Brussels_Jun2014.ppt

The following report describes to what extent the initial estimate of this evolution in unit 2 can be confirmed, and to what extent the evolution also exists on other LYRA units.

At first sight, there is a confusing multitude of possible reactions of the various LYRA detectors:
- There are diamond detectors whose dark currents are almost independent of temperature and stay almost unchanged during mission time (PIN in all units: ch1-2, ch2-2, ch3-2).
- There are diamond detectors whose dark currents are heavily dependent on temperature but get “better” (i.e. the level diminishes) during mission time (MSM in unit 2: ch2-1, ch2-3, ch2-4).
- There are diamond detectors whose dark currents are heavily dependent on temperature but get “worse” (i.e. the level increases) during mission time (MSM in unit 1: ch1-1, ch1-3).
- There is a silicon detector whose dark current is slightly less dependent on temperature and gets only a little “worse” during mission time (Si in unit 1: ch1-4).
- There is a silicon detector whose dark current is heavily dependent on temperature and gets “worse” during mission time, but the post-launch levels are still much lower than what was measured in the laboratory before launch (Si in unit3: ch3-1).
- There are silicon detectors whose dark currents are slightly less dependent on temperature, but in a counter-intuitive way; the levels decrease with temperature, and more so during mission time (Si in unit3: ch3-3, ch3-4).

In detail: From the lab measurements before the launch in 2009 to a calibration campaign in July 2015, the dark currents of the PIN detectors changed as follows (all measured at around 45 deg C).
ch1-2 from 6.61 to 6.48 counts/ms
ch2-2 from 6.38 to 6.47 counts/ms
ch3-2 from 6.54 to 6.41 counts/ms

One could almost think that these values are a physical “constant” for the technology used; almost all detectors show dark currents between 6.10 and 6.98 counts/ms below +20 deg C. The only notable exception is ch3-1, but the dark-current measurement of this channel is also peculiar, because the values could not be reproduced after launch. Taking the first post-launch measurements of this channel into account, it behaves like the diamond and silicon detectors of unit 1.

Which leaves the strange behaviour of the Si detectors ch3-3 and ch3-4 whose dark currents seem to decrease with temperature. Assuming this dependence to result from a data processing or read-out error and mirroring the curve at the cold dark-current level, these channels would also behave like the diamond and silicon detectors of unit 1. <u>With all these assumptions, dark current levels decrease over mission time for unit 2, they increase for units 1 and 3, while the PIN detectors stay constant.</u>

In order to improve the calibration function for the LYRA channels (as a first step, dark currents have to be subtracted from the observed count rates) the time-dependence has to be estimated. This means that the development of the dark currents at various temperatures has to be observed during calibration campaigns (i.e., with closed covers) executed during the course of the mission and extrapolated into the future.

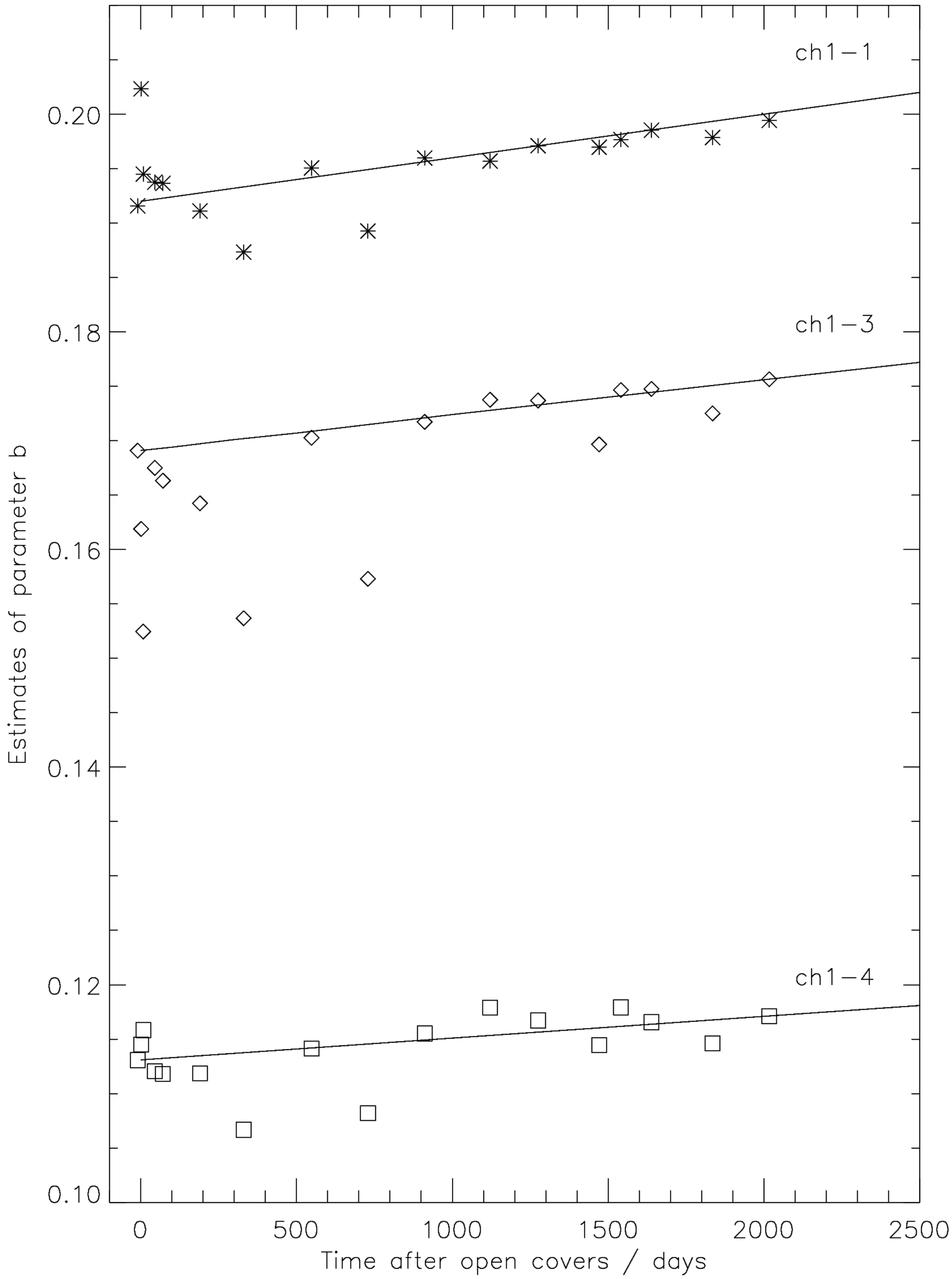
Except for the PIN detectors, the dark currents as a function of temperature appear to follow an exponential curve (compare the last nine figures at the bottom of this report):
$DC = f(T) = a + \exp(b*T + c)$
For all channels, parameter a is chosen as the dark current level below 20 deg C, measured pre-launch in the lab. When this value is subtracted and the logarithm of the rest is fitted with a linear polynomial, one observes large variations of parameters b and c, which do not appear to be independent from each other. As a solution, parameter c is chosen from the pre-launch data fit, and only parameter b is fitted. The resulting time series of parameter b is smoothed by hand, while

results observed with higher temperatures are given higher significance. The developments of parameter b for the three units are shown in the three figures below.

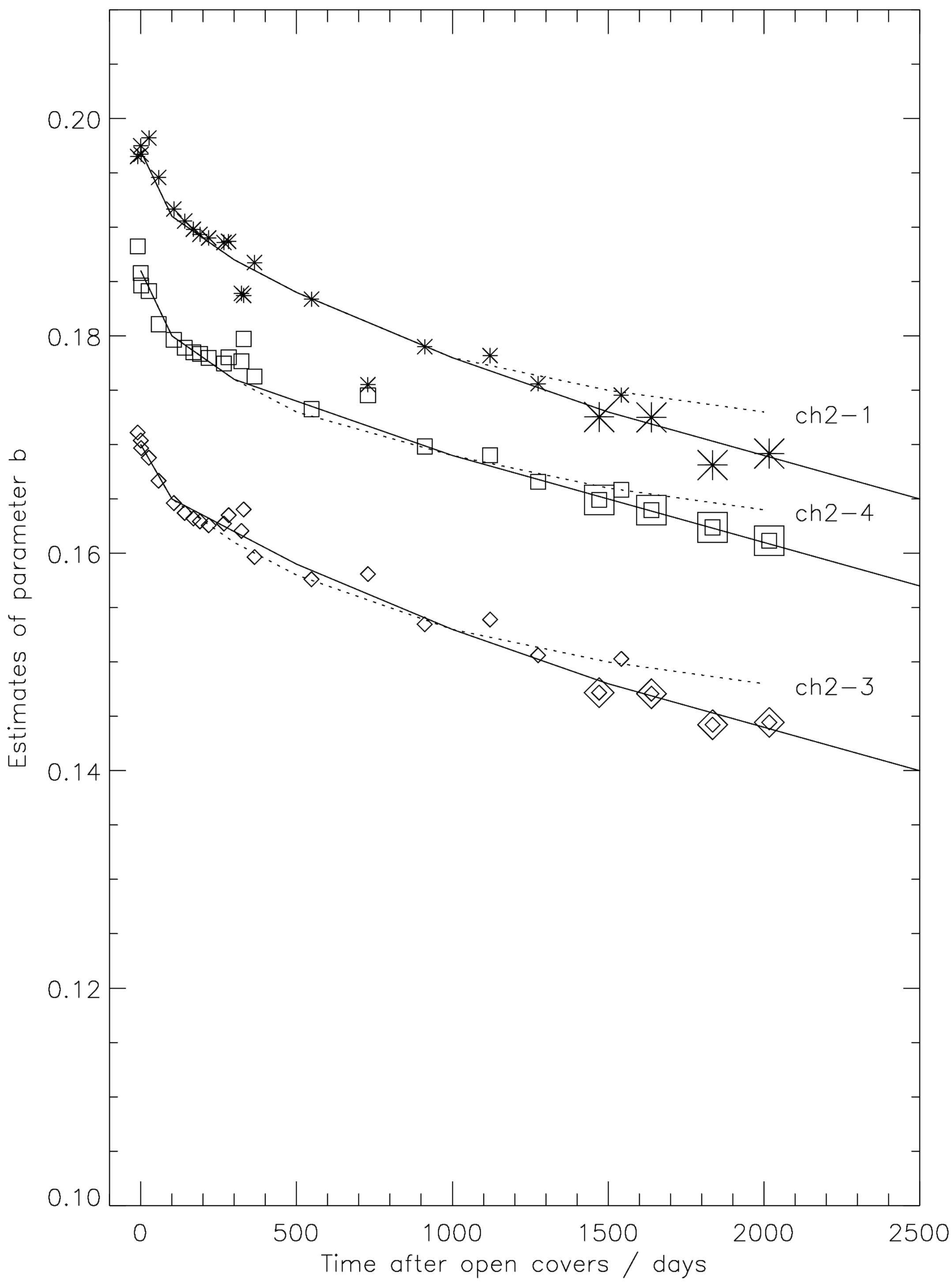
For unit 2 detectors, parameter b decreases over time of mission, leading to “better” (decreasing) dark currents. For unit 1 and unit 3 detectors, parameter b increases. One has to note, though, that ch3-1 initially drops from a higher value as observed pre-launch in the lab; ch3-3 and ch3-4 are calculated using their mirrored curve.

Changes for unit 1 appear to be smaller, maybe due to the fact that unit 1 is seldom used and less degraded. - For unit 2 and unit 3, last year's estimates are given by dotted lines while the latest values are marked with larger symbols. Obviously, the changes continue in most cases and were initially underestimated.

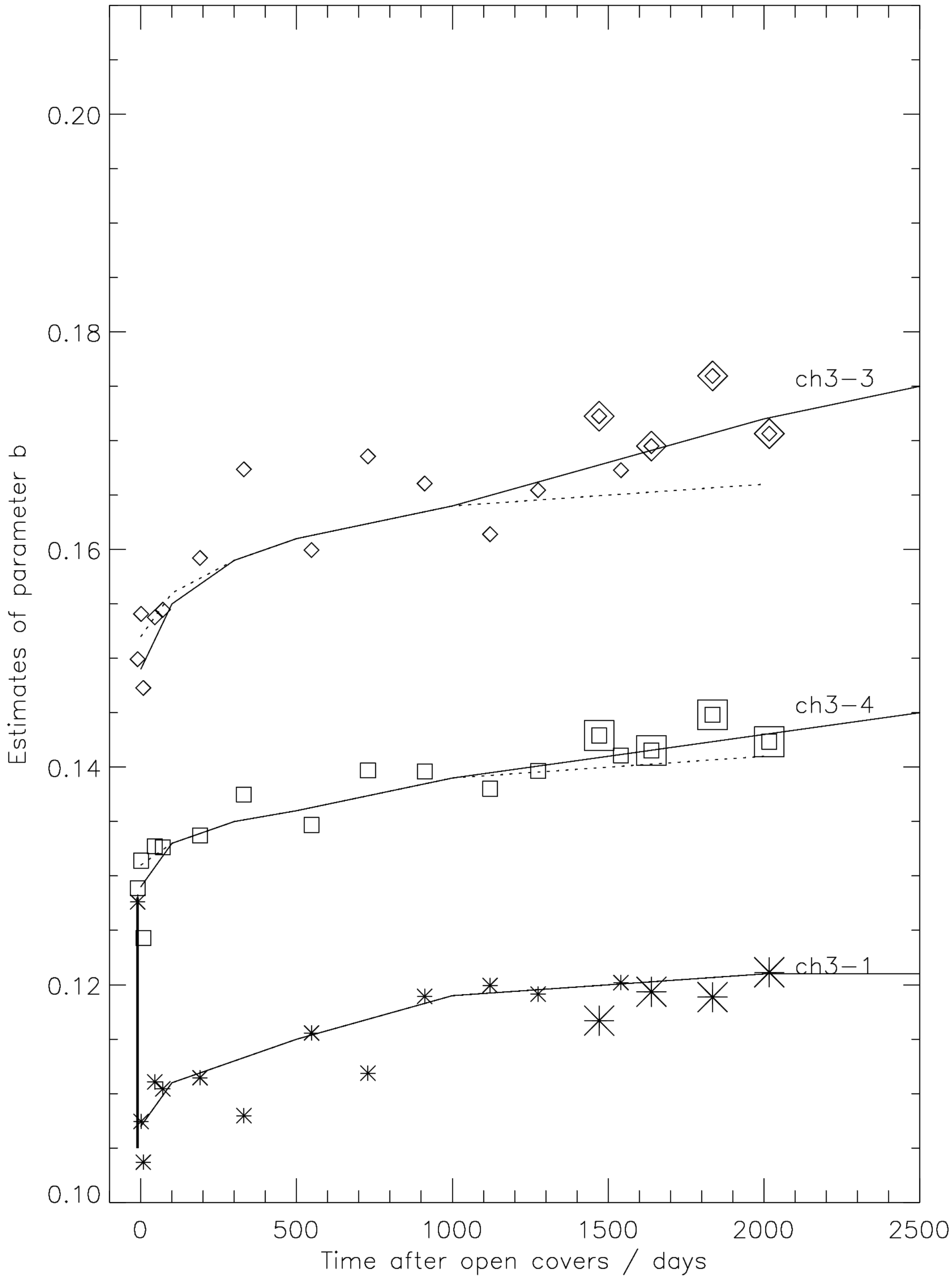
With the help of individual parameters a, b, and c, the behaviour of the dark currents over time were estimated and compared to the observed data: Many campaigns from 2010, only two campaigns per year (January and July) for 2011 to 2015. Data (points) and fits (curves) are marked by colour: Black for 2010, lighter gray towards 2015. The pre-launch lab results are shown with a thick black line and diamond symbols. Results are shown for the nine detectors (ch1-1, ch1-3, ch1-4, ch2-1, ch2-3, ch2-4, ch3-1, ch3-3, ch3-4) in the nine figures at the end. They give reason for hope that past and future development of dark currents can indeed be estimated with these functions. The calibration software was updated accordingly, and will be in the future.



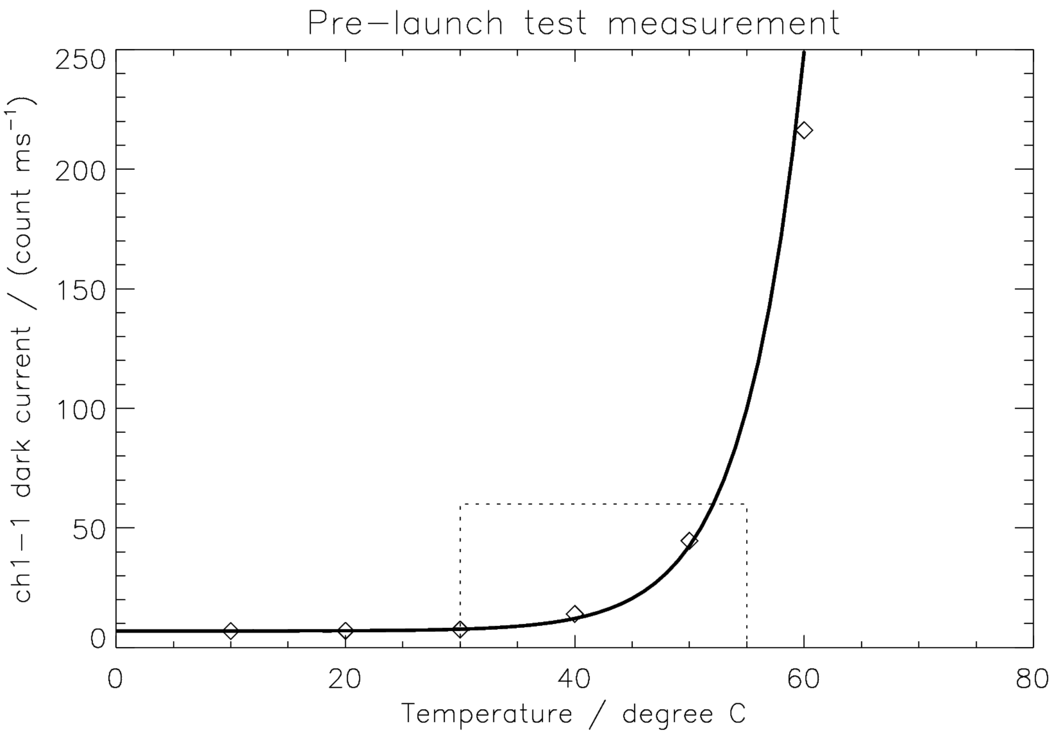
ch1−1
ch1−3
ch1−4
0.20
0.18
0.16
0.14
0.12
0.10
Estimates of parameter b
0
500
1000
1500
2000
2500
Time after open covers / days

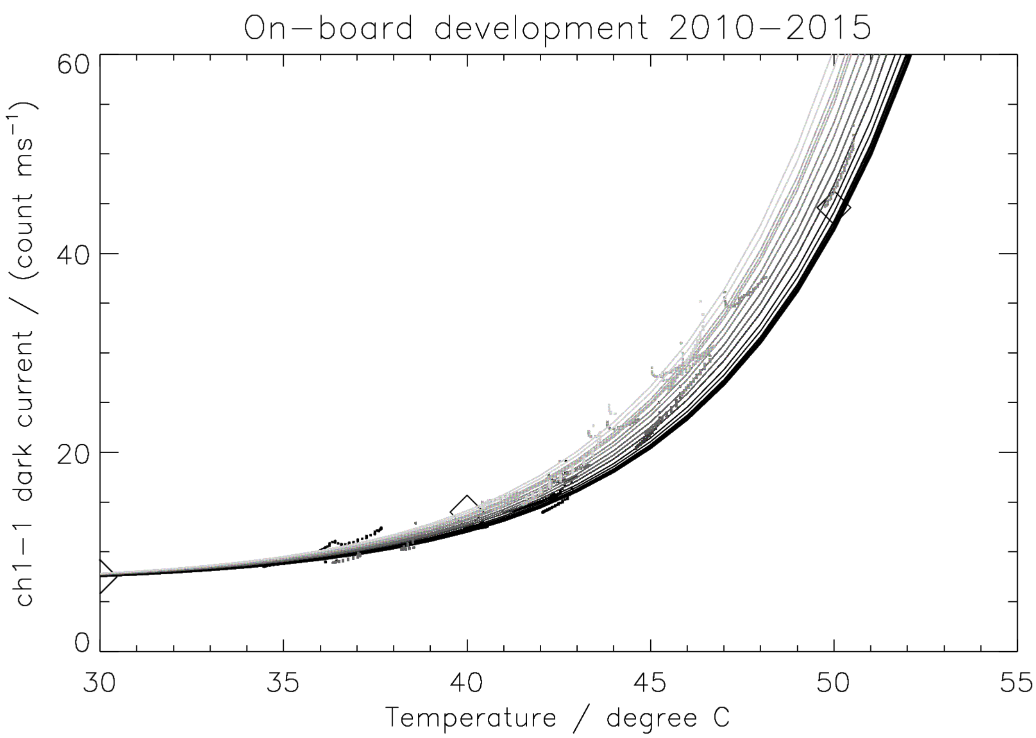


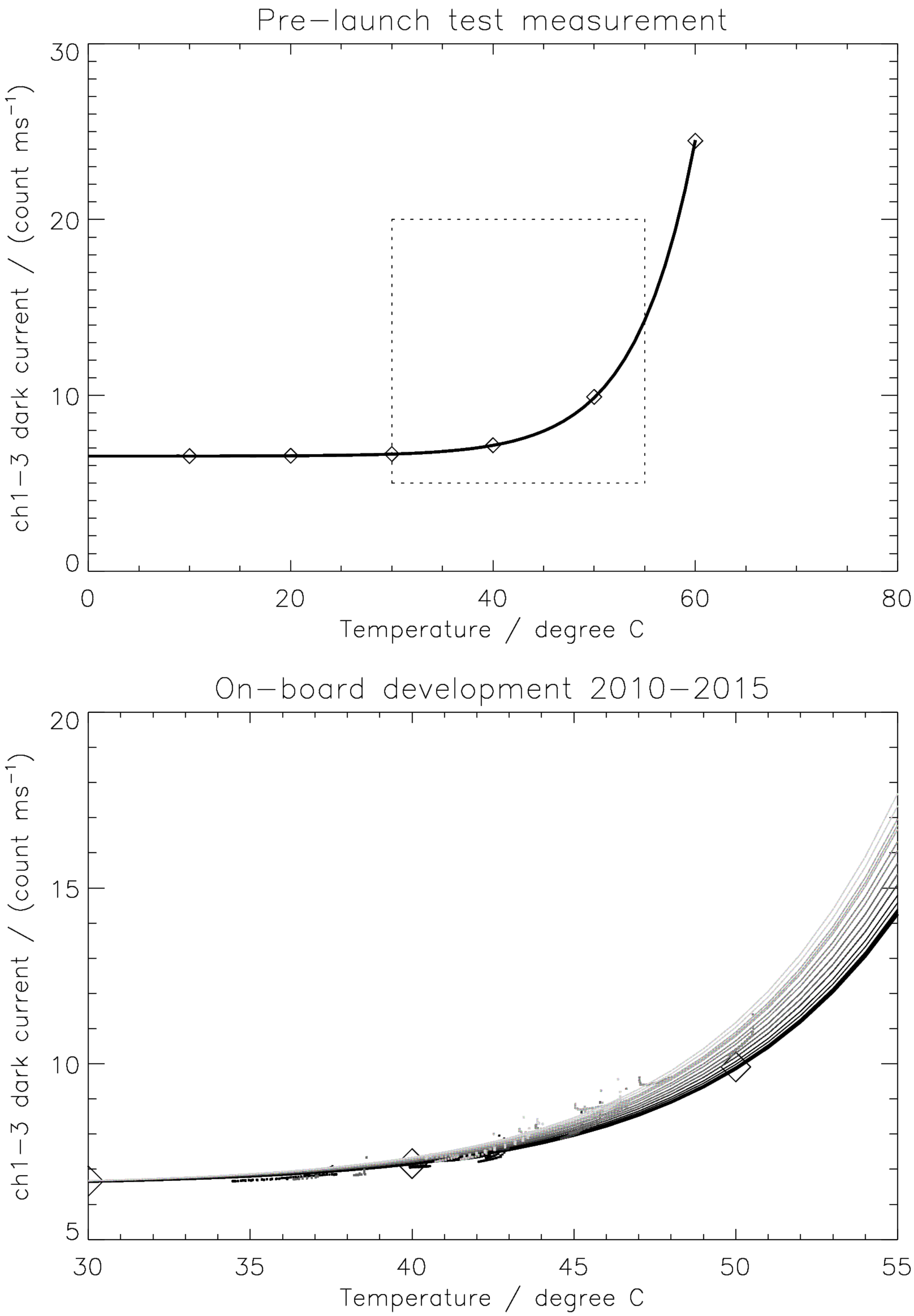
Estimates of parameter b
0.20
0.18
0.16
0.14
0.12
0.10
0
500
1000
1500
2000
2500
Time after open covers / days
ch2-1
ch2-4
ch2-3



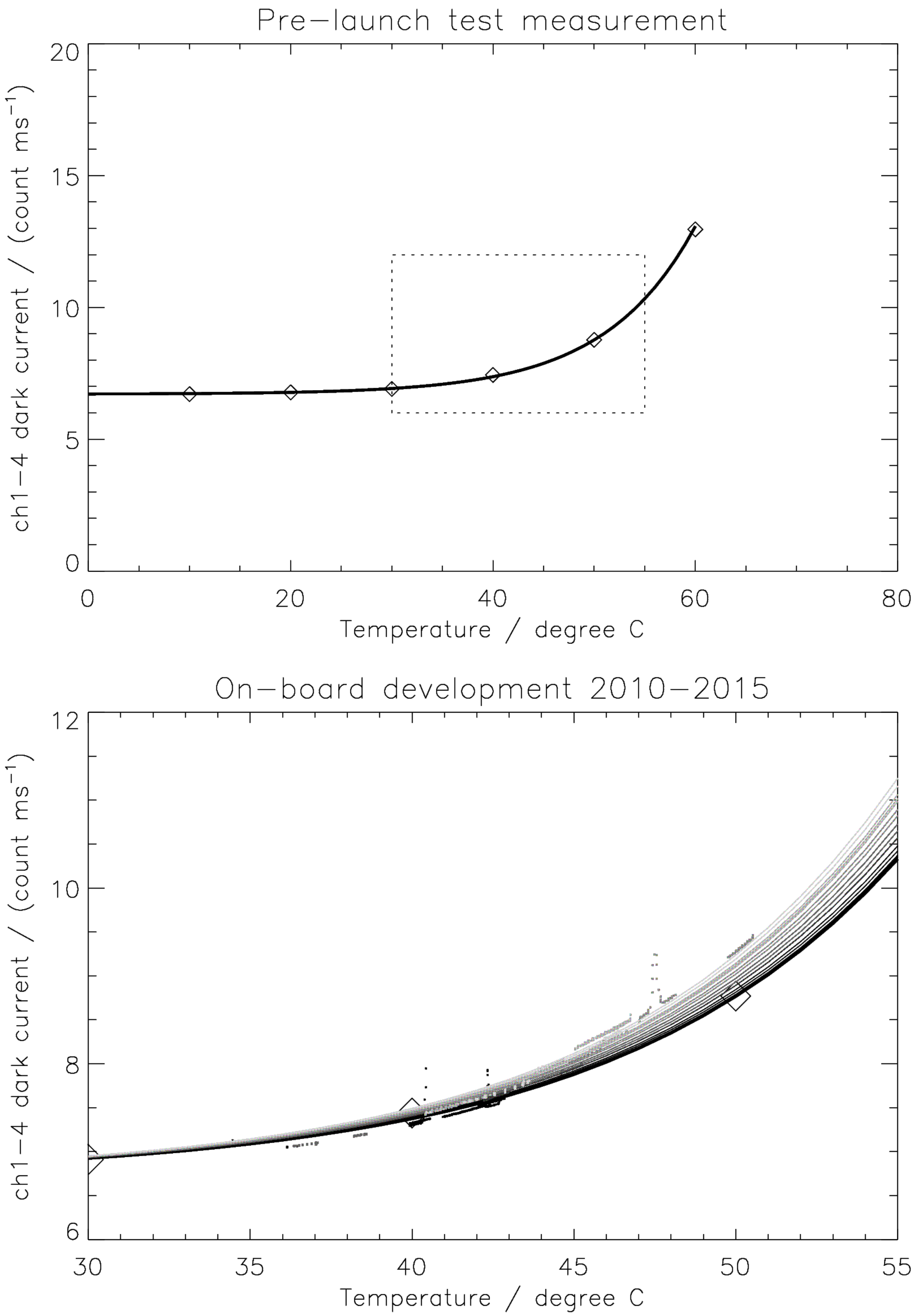
0.20
0.18
0.16
0.14
0.12
0.10
0
500
1000
1500
2000
2500
Estimates of parameter b
Time after open covers / days
ch3-3
ch3-4
ch3-1


Pre–launch test measurement
ch1–1 dark current / (count ms^{-1})
Temperature / degree C
0
50
100
150
200
250
0
20
40
60
80

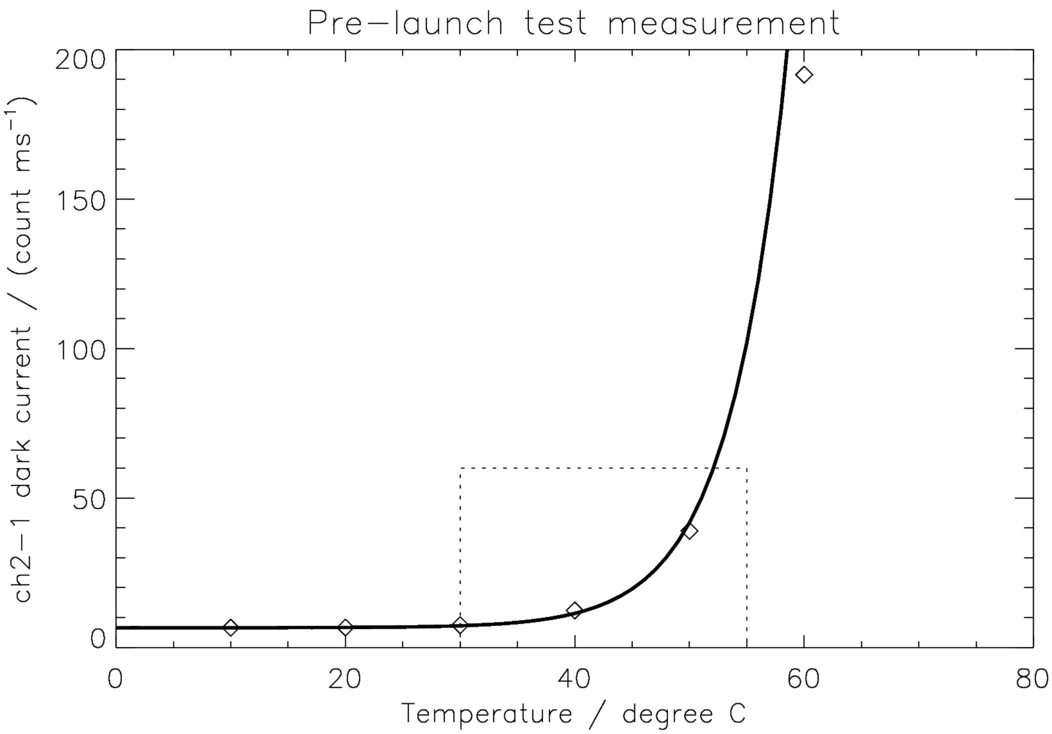

On–board development 2010–2015
ch1–1 dark current / (count ms^{-1})
Temperature / degree C
0
20
40
60
30
35
40
45
50
55

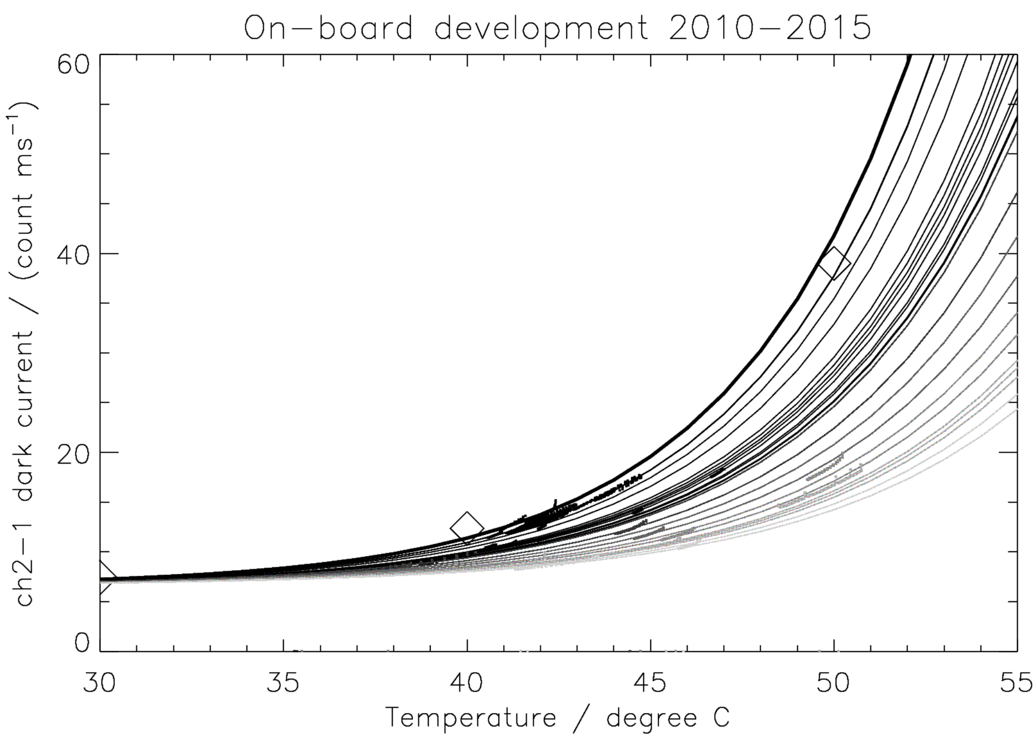


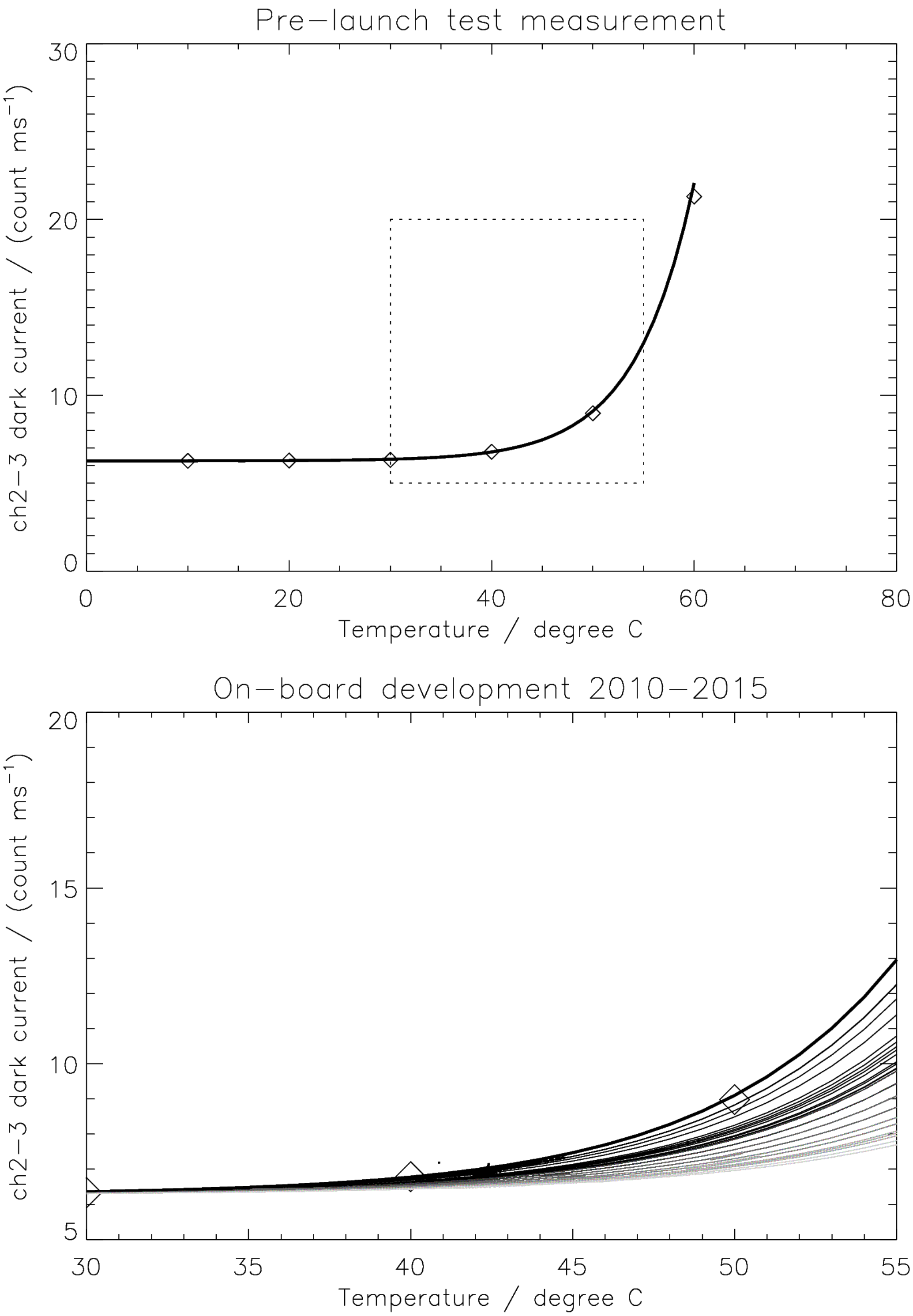
Pre–launch test measurement
ch1–3 dark current / (count ms⁻¹)
Temperature / degree C
0
10
20
30
0
20
40
60
80
On–board development 2010–2015
ch1–3 dark current / (count ms⁻¹)
Temperature / degree C
5
10
15
20
30
35
40
45
50
55

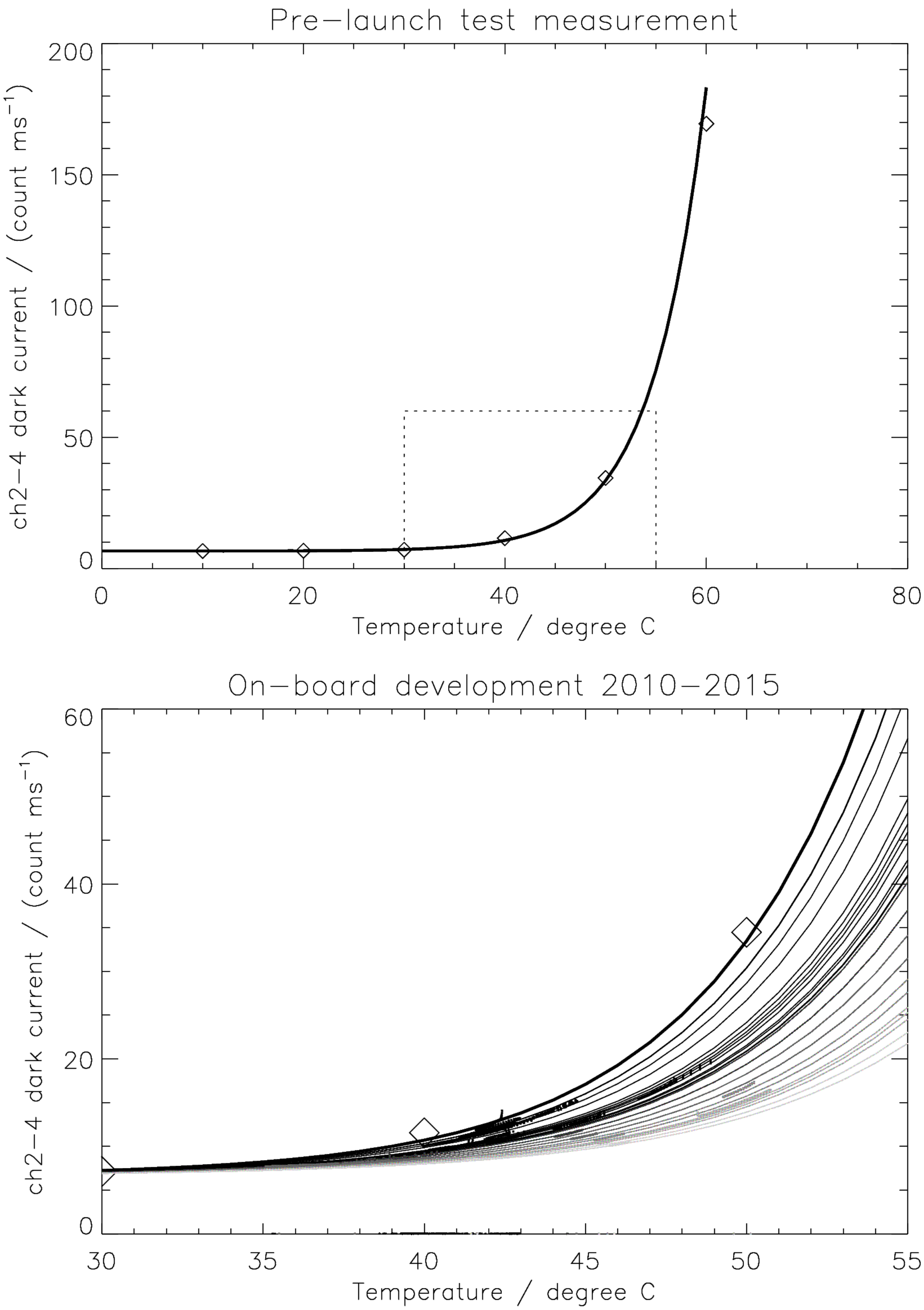


Pre-launch test measurement
ch1-4 dark current / (count ms^{-1})
Temperature / degree C
0
5
10
15
20
0
20
40
60
80
On-board development 2010-2015
ch1-4 dark current / (count ms^{-1})
Temperature / degree C
6
8
10
12
30
35
40
45
50
55

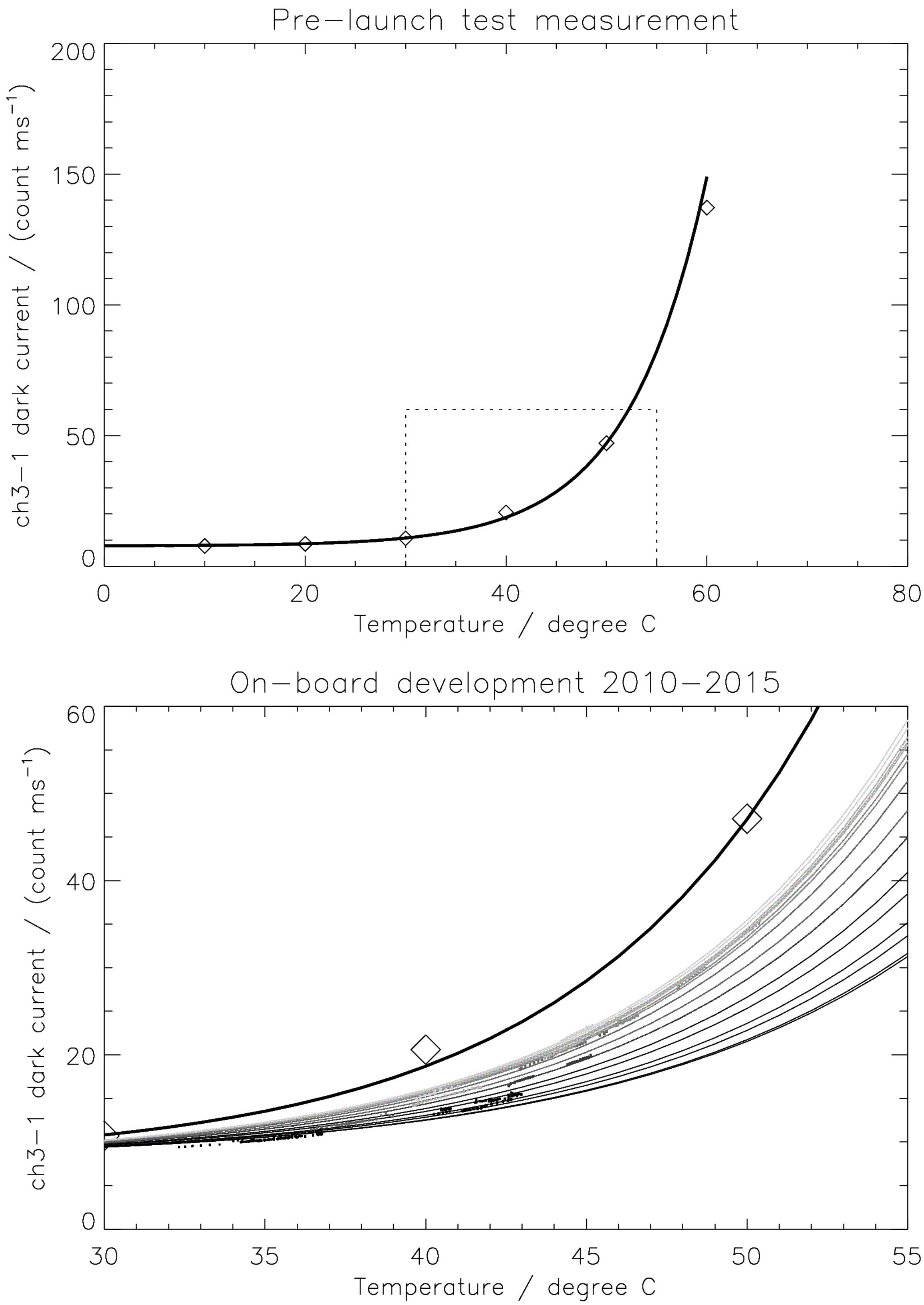

Pre–launch test measurement
ch2–1 dark current / (count ms⁻¹)
200
150
100
50
0
0
20
40
60
80
Temperature / degree C


On–board development 2010–2015
ch2–1 dark current / (count ms⁻¹)
60
40
20
0
30
35
40
45
50
55
Temperature / degree C

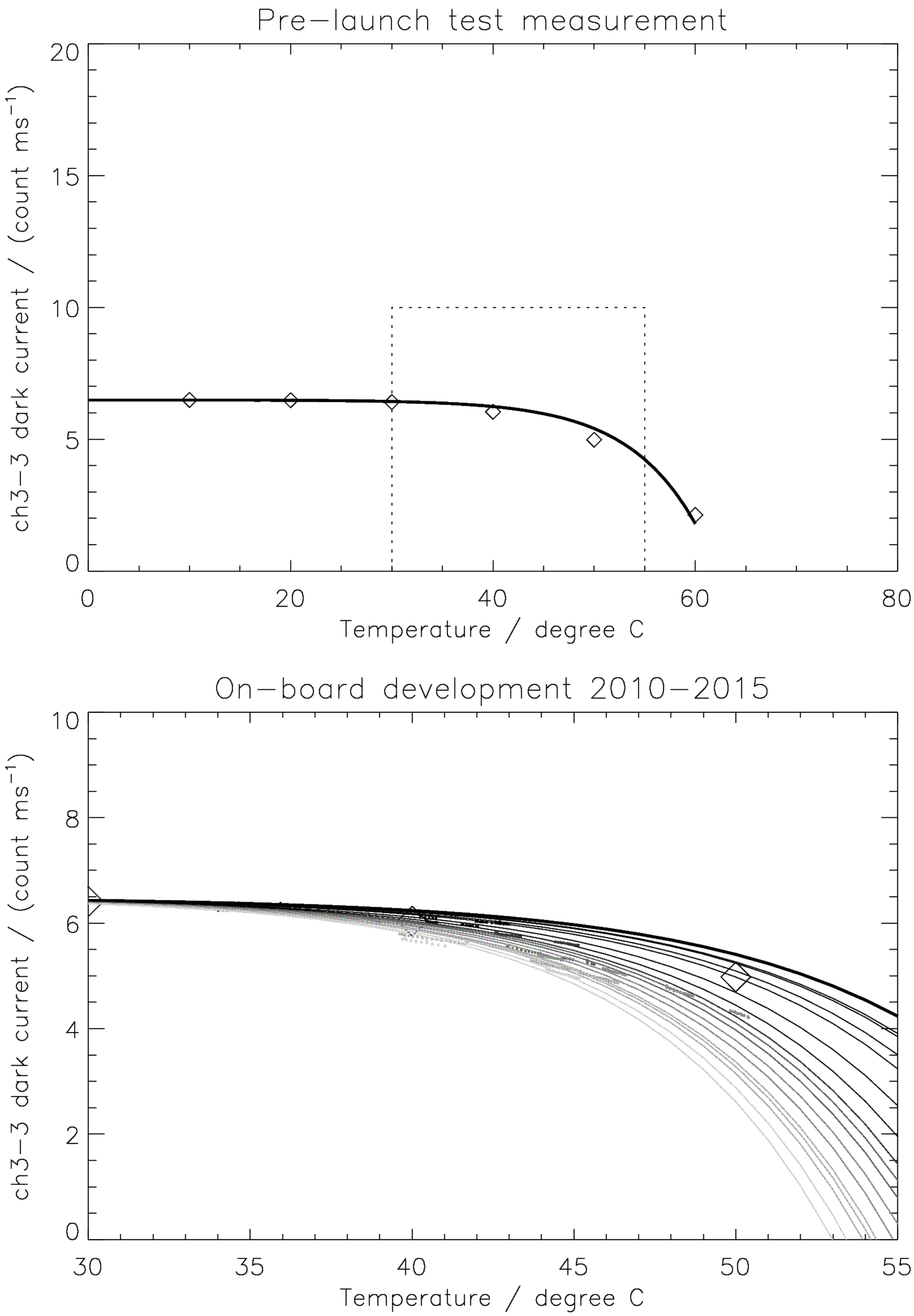

Pre−launch test measurement
ch2−3 dark current / (count ms^{-1})
Temperature / degree C
0
10
20
30
0
20
40
60
80
On−board development 2010−2015
ch2−3 dark current / (count ms^{-1})
Temperature / degree C
5
10
15
20
30
35
40
45
50
55

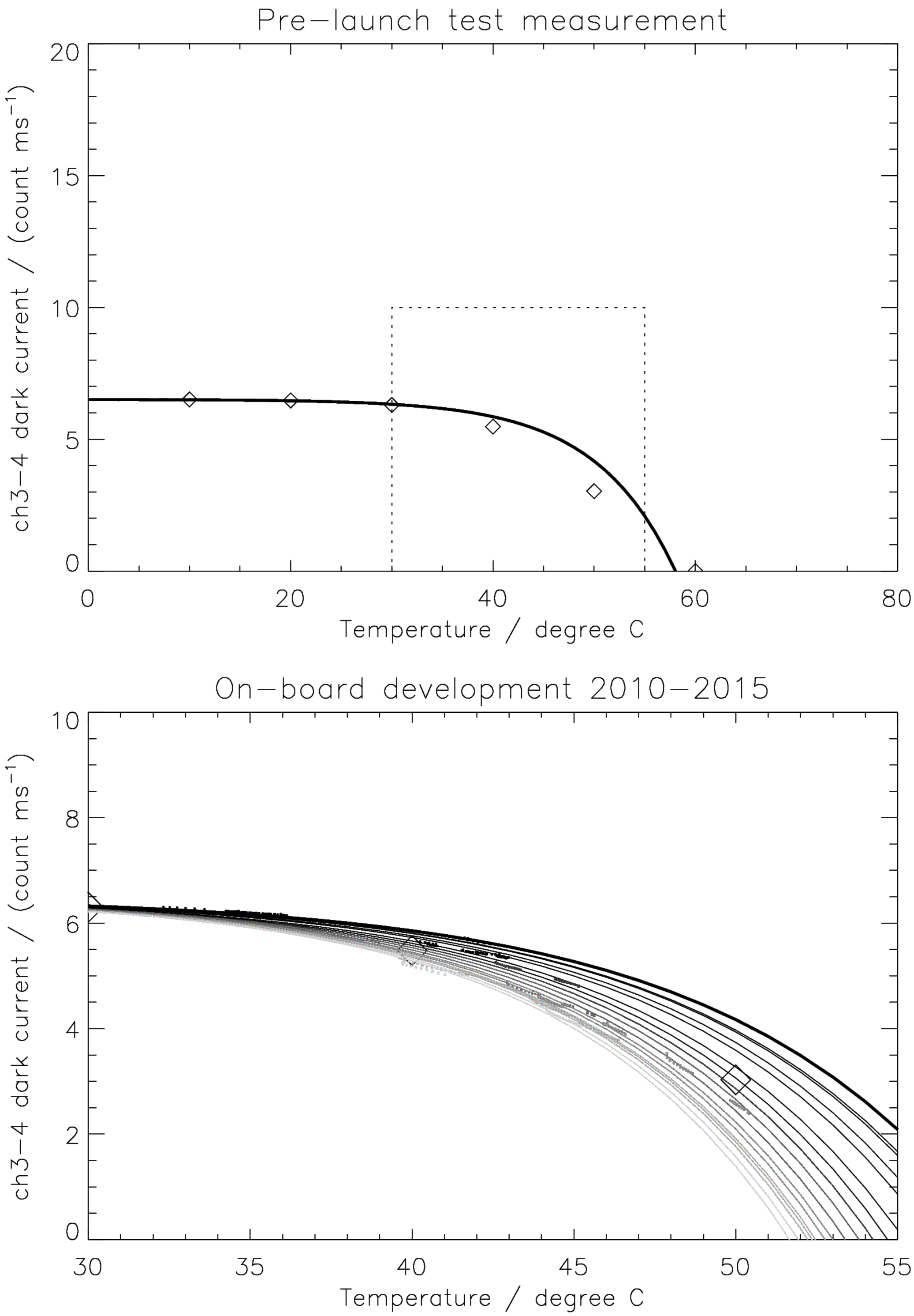


Pre−launch test measurement
ch2−4 dark current / (count ms⁻¹)
0
50
100
150
200
0
20
40
60
80
Temperature / degree C
On−board development 2010−2015
ch2−4 dark current / (count ms⁻¹)
0
20
40
60
30
35
40
45
50
55
Temperature / degree C



Pre−launch test measurement
ch3−1 dark current / (count ms^{-1})
0
50
100
150
200
0
20
40
60
80
Temperature / degree C
On−board development 2010−2015
ch3−1 dark current / (count ms^{-1})
0
20
40
60
30
35
40
45
50
55
Temperature / degree C


Pre−launch test measurement
ch3−3 dark current / (count ms⁻¹)
Temperature / degree C
0
5
10
15
20
0
20
40
60
80
On−board development 2010−2015
ch3−3 dark current / (count ms⁻¹)
Temperature / degree C
0
2
4
6
8
10
30
35
40
45
50
55



Pre–launch test measurement
ch3–4 dark current / (count ms⁻¹)
Temperature / degree C
On–board development 2010–2015
ch3–4 dark current / (count ms⁻¹)
Temperature / degree C