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GALACTIC PLANE IMAGE SHARPNESS AS A CHECK ON COSMIC MICROWAVE BACKGROUND MAPMAKING

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Abstract. The largest uncollapsed inhomogeneity in the observable Universe is statistically represented in the quadrupole signal of the cosmic microwave background (CMB) sky maps as observed by the Wilkinson Microwave Anisotropy Probe (WMAP). The constant temporal offset of −25.6 ms between the timestamps of the spacecraft attitude and observational data records in the time-ordered data (TOD) of the WMAP observations was suspected to imply that previously derived all-sky CMB maps are erroneous, and that the quadrupole is in large part an artefact. The optimal focussing of bright objects in the Galactic Plane plays a key role in showing that no error occurred at the step of mapmaking from the calibrated TOD. Instead, the error had an effect when the uncalibrated TOD were calibrated. Estimates of the high-latitude quadrupole based on the wrongly calibrated WMAP maps are overestimated by about 15–60%.

Keywords: cosmic background radiation, galaxy: center, galaxy: disk, techniques: image processing

Although the primary aim of cosmic microwave background (CMB) all-sky observation missions is cosmological, the Galaxy constitutes a major component of the resulting data set. Liu & Li (2010) reconstituted all-sky maps from Wilkinson Microwave Anisotropy Probe (WMAP, Bennett et al. 2003) time-ordered data (TOD) and suggested that the quadrupole present in the official versions of the maps is mostly an artefact, since their own maps had a weaker quadrupole. They later traced this to a timing offset of −25.6 ms between the timestamps of the spacecraft attitude and observational data records in the calibrated TOD files (Liu et al. 2010). Since the offset is also present in the uncalibrated TOD files, it could have affected either (i) the calibration step or (ii) the mapmaking step.

The WMAP 3-year calibrated TOD were compiled into maps using Liu et al. (2010)'s publicly available data analysis pipeline*, and patched for using the GNU Data Language (GDL) and for two different timing error tests. In both cases, the timing offset, written as a multiple δt of an exposure time in a given waveband, where $\delta t = 0.5$ corresponds to the timing offset used by the WMAP collaboration, was varied in order to detect its effect on a relevant statistic of the maps. Testing an error at step (i) was done by creating low-resolution maps and finding the maps with the least variance per pixel (Roukema 2010b).† Testing an error at step (ii) was done by calculating high-resolution maps that included sub-cosmological objects, and finding the best focussed maps (Roukema 2010a).‡ The results, summarised in Table 1, showed to very high significance that the error affected the calibration step, but did not affect the mapmaking step directly. However, maps made from the wrongly calibrated data necessarily include the calibration error. For example, estimates of the high-latitude quadrupole based on the wrongly calibrated WMAP maps are overestimated by about 15–60% (Roukema 2010b). Figures 1 and 2 illustrate the sharpest focus test.

References

Bennett, C. L., Halpern, M., Hinshaw, G., et al. 2003, ApJSupp, 148, 1, [arXiv:astro-ph/0302207]
Liu, H., & Li, T. 2010, ArXiv e-prints, [arXiv:0907.2731]
Liu, H., Xiong, S., & Li, T. 2010, ArXiv e-prints, [arXiv:1003.1073]
Roukema, B. F. 2010a, A&A, 518, A34, [arXiv:1004.4506]
Roukema, B. F. 2010b, A&A, submitted, [arXiv:1007.5307]

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*http://cosmocoffee.info/viewtopic.php?p=4525, http://dpc.aire.org.cn/data/wmap/09072731/release_v1/source_code/v1/
†http://cosmo.torun.pl/GPLdownload/LLmapmaking_GDLpatches/LLmapmaking_GDLpatches_0.0.4.tbz
‡http://cosmo.torun.pl/GPLdownload/LLmapmaking_GDLpatches/LLmapmaking_GDLpatches_0.0.3.tbz

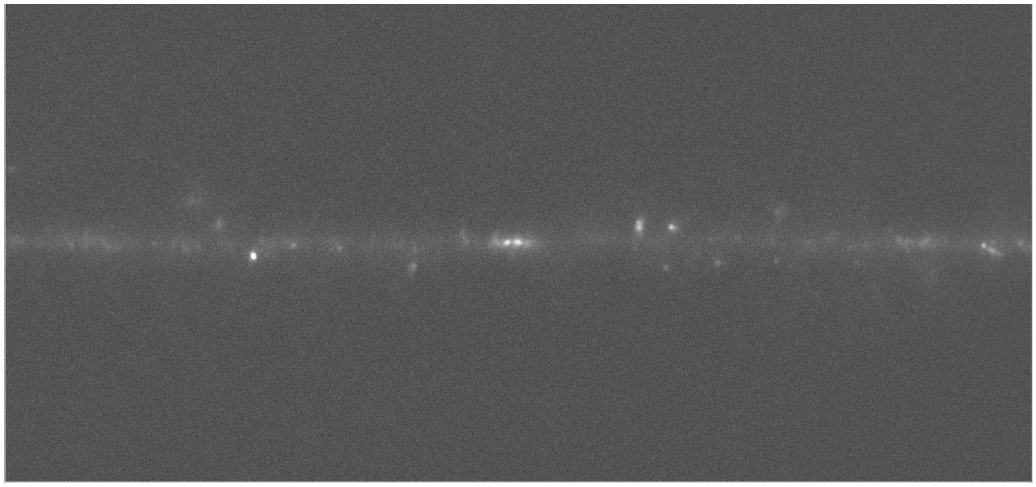

Fig. 1. Correctly focussed ($\delta t = 0.5$, Roukema 2010a) but wrongly calibrated (Roukema 2010b) WMAP W band (94 GHz) image of the $53.0^\circ \times 24.7^\circ$ region centred at the Galactic Centre (North up, East left), after monopole and dipole subtraction, on a grey scale ranging from black (-20 mK) to white (+40 mK). To zoom in, see Fig. 4, Roukema (2010a).

Table 1. Comparison of sharpest focus and minimum variance methods of testing for a timing offset error.

short name	minimum variance	sharpest focus
reference	Roukema (2010b)	Roukema (2010a)
step to understand	uncal. TOD $\rightarrow$ cal. TOD	cal. TOD $\rightarrow$ map
step analysed	cal. TOD $\rightarrow$ map	cal. TOD $\rightarrow$ map
planets & Gal. Plane	excluded	included
$N_{\rm side}$	8	2048
statistic	variance per pixel	brightness of 503-rd brightest pixel
max/min	min	max
rejected hypothesis	$\delta t = 0.5$ rejected at 8.5σ	$\delta t = 0$ rejected at 4.6σ
accepted hypothesis	$(\delta t - 0.5) \times 52.1$ ms $= -25.6$ ms	$\delta t = 0.5$
conclusion	calibration step wrong	mapmaking step right

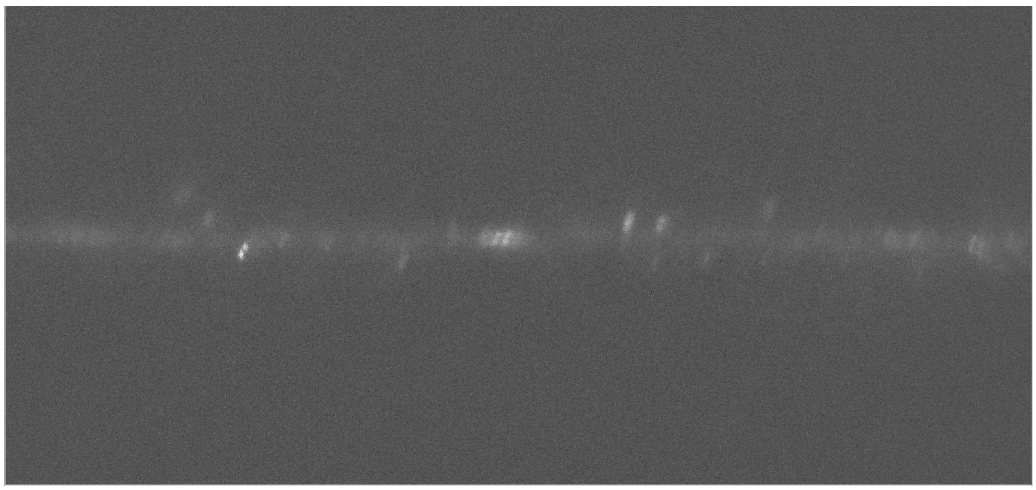

Fig. 2. Wrongly focussed, wrongly calibrated WMAP W band image, as for Fig. 1, with a timing offset $\delta t = -5$, i.e. exaggerated by a factor of ten beyond that which generated the calibration error. To zoom in, see Fig. 2, Roukema (2010a).