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Cosmoglobe IV. Spatial variations in the polarized synchrotron spectral index from *WMAP* and *Planck* LFI sky maps

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ABSTRACT

We estimate the spectral index, β, of polarized synchrotron emission from the *WMAP* and *Planck* LFI sky maps from the Cosmoglobe data release. Similar to an earlier study, we partition the sky into 24 regions, and compute β in each region using the T-T plot method based on linear regression. We do the analysis on two cases; *WMAP* 23 GHz versus *WMAP* 33 GHz and *WMAP* 23 GHz versus *Planck* 30 GHz. For each case we compare the results using legacy maps to the results using Cosmoglobe maps. In the data products from Cosmoglobe we have many samples, instead of just one mean map, which enables us with an improved T-T plot method with a better handle on the uncertainties. For the *WMAP* 23 GHz versus *WMAP* 33 GHz case, the Cosmoglobe results is in good agreement with the legacy results, but in general we can see somewhat flatter spectral indices toward higher latitudes in the Cosmoglobe case. For the *WMAP* 23 GHz versus *Planck* 30 GHz ...

Key words. ISM: general – Cosmology: observations, polarization, cosmic microwave background, diffuse radiation – Galaxy: general

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1. Introduction

bla bla bla,

2. Data products

In this paper, we investigate the spatial variation of the polarized synchrotron spectral index, and specifically, we want to compare the results using the legacy maps against the results using the Cosmoglobe maps. The data products used are the *WMAP* and *Planck* maps in the 23-33 GHz regime. These frequencies are low enough so we can treat them as synchrotron tracers and hence ignore thermal dust and CMB, but not so low as we need to take into account effects like Faraday rotation (Fuskeland et al. 2021). The legacy data products and the data products from the Cosmoglobe *WMAP* reanalysis (cite Watts et al. 2023), are described in the two following sections.

2.1. WMAP and Planck legacy data products

The *WMAP* data products are available on the lambda archive[1]. As in Fuskeland et al. (2014), we use the *WMAP* K and Ka band Stokes Q and U parameter maps at 23 GHz and 33 GHz. The respective effective frequencies used are 22.45 GHz and 32.64 GHz. The maps originally at a HealPIX pixelization of $N_{\mathrm{side}} = 512$ are downgraded to $N_{\mathrm{side}} = 64$ and smoothed to a common resolution of $1\circ$ FWHM.

The *Planck* data products used are the Ka band Stokes Q and U maps at 30 GHz. We use an effective frequency of 28.4 GHz. Both the products from the *Planck* 2018 release (cite), and from the DR4? (cite-npipe) release are used, available on lambda. The products are natively at $N_{\mathrm{side}} = 1024$??, but as for the *WMAP* products, the maps are downgraded to $N_{\mathrm{side}} = 64$ and smoothed to $1\circ$ FWHM.

(Show maps?)

2.2. The Cosmoglobe data products

Cosmoglobe is a project? to do end-to-end analyses on several data sets jointly. Doing this can help to break the degeneracies of the different data sets, and in general improve on systematical effects. Being a end-to-end analysis means it goes all the way from Time ordered data (TOD) to cosmological parameters using the Bayesian Gibbs sampler, `Commander3`. For more de-

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[1] http://lambda.gsfc.nasa.gov

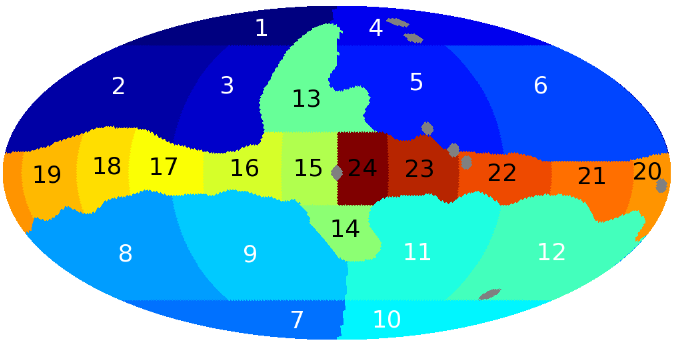

Fig. 1. The sky is split into the same 24 regions as in Fuskeland et al. (2014). The most prominent point sources are masked out and shown as the grey circular areas.

tails, see Watts et al 2023 and BeyondPlanck 2023. (Perhaps a bit short...)

What is relevant for this paper is some of the Cosmoglobe end products produced by the reanalysis of the *WMAP* and *Planck* LFI time ordered data (TOD) (cite Watts 2023). This analysis produced new (improved?) *WMAP* and *Planck* LFI maps, which we will use in an analysis to compare to the legacy data. In particular, we are interested in exactly the same set of maps as in the previous section in order to be able to do a comparision study. So we use the maps in the 23-33 GHz regime, namely the *WMAP* 23 and 33 GHz and the *Planck* 30 GHz data. The pixelization and angular scale is the same as for the legacy products ($N_{\rm side}$ = 64, 1○ FWHM). The Cosmoglobe end products consists of a series of many samples from the Gibbs chain, instead of just one mean sample as has been the normal case for previous data releases.

(Show maps? or do the other papers show a comparision of legacy vs cosmoglobe maps??)

3. Methods

3.1. T-T plot method

Short about the main T-T plot method here, but mainly refer to previous papers.

3.2. T-T plot method with an ensable of samples

Much better propagation of uncertainties with a whole suite of maps.

4. Results for 23/30 GHz

The uncertainty is calcuted as the minimum of the uncertainties in each rotation angle, and region. As in the Fuskeland 2021 paper, an systematic uncertainty that takes into account the variation of beta over rotation angle; $[max(beta_alpha) - min(beta_alpha)]/2$ is added in quadrature to the statistical uncertainty. For the Cosmoglobe analyses the standard deviation of the spectral indices for all samples is also added in quadrature to represent an additional systematic uncertainty.

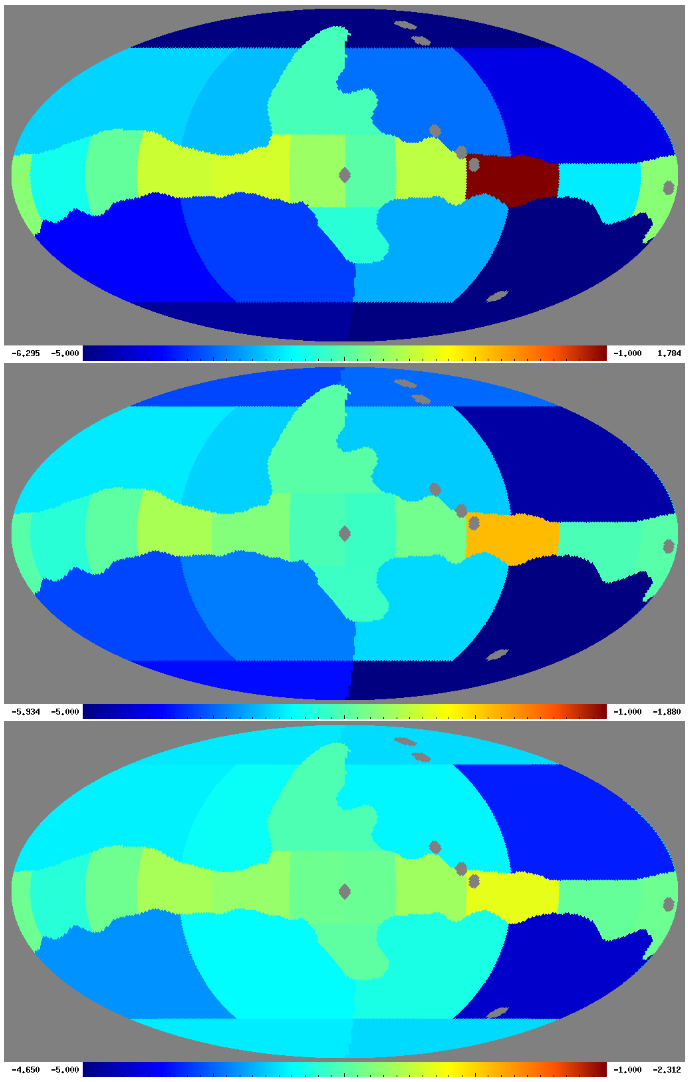

Fig. 2. The spatial variation of the synchrotron spectral index, computed using T-T plot between the *WMAP* 23 GHz and *Planck* 2018 30 GHz (top), *WMAP* 23 GHz and *Planck* DR4 30 GHz (middle) and Cosmoglobe 23 GHz and Cosmoglobe 30 GHz (bottom). The spectral index is inverse variance weighted over rotation angle, and in the Cosmoglobe case also samples. Fix style of maps. Bottom figure will be updated using more samples.

5. Results for 23/33 GHz

6. Discussion and conclusion

References

Fuskeland, U., Andersen, K. J., Aurlien, R., et al. 2021, A&A, 646, A69
Fuskeland, U., Wehus, I. K., Eriksen, H. K., & Næss, S. K. 2014, ApJ, 790, 104

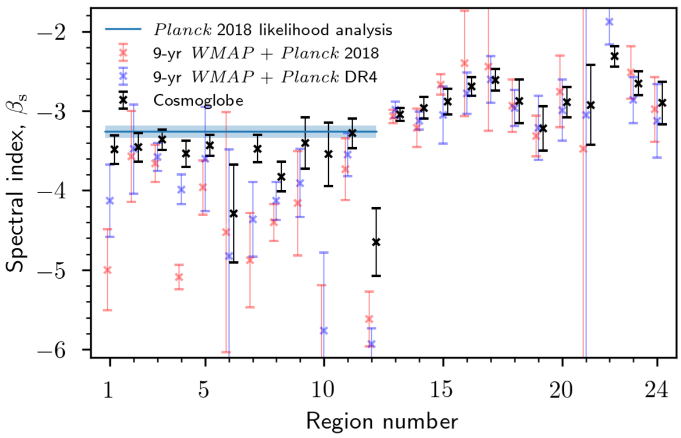

Fig. 3. The synchrotron spectral index as a function of region number, computed using T-T plot between the 9-yr *WMAP* 23 GHz and *Planck* 2018 30 GHz (red), 9-yr *WMAP* 23 GHz and *Planck* DR4 30 GHz (blue) and Cosmoglobe 23 GHz and Cosmoglobe 30 GHz (black). The spectral index is inverse variance weighted over rotation angles, and samples. The horizontal line in the high latitude regions corresponds to the estimated spectral index values from the *Planck* 2018 likelihood analysis. cite?? Figure will be updated using more samples.

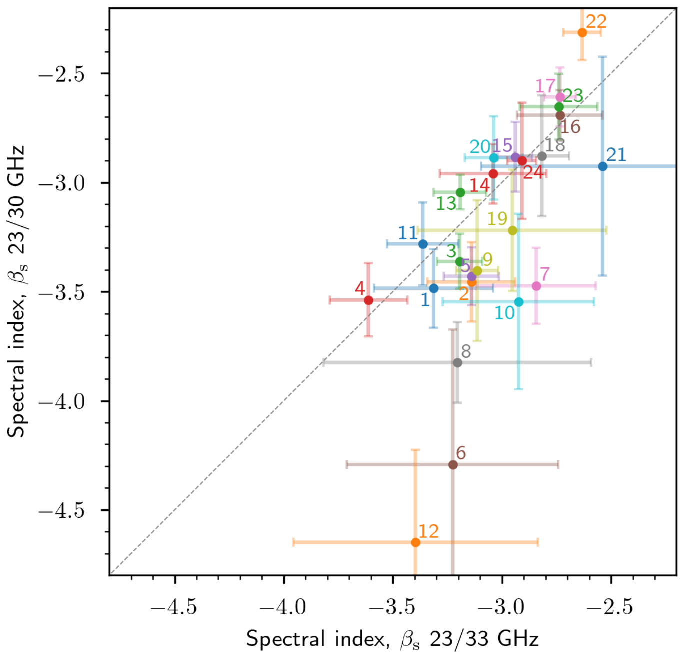

Fig. 4. The synchrotron spectral index computed using T-T plot with the Cosmoglobe 23 GHz and 30 GHz data versus Cosmoglobe 23 GHz and 33 GHz data for the 24 regions. Figure will be updated using more samples.

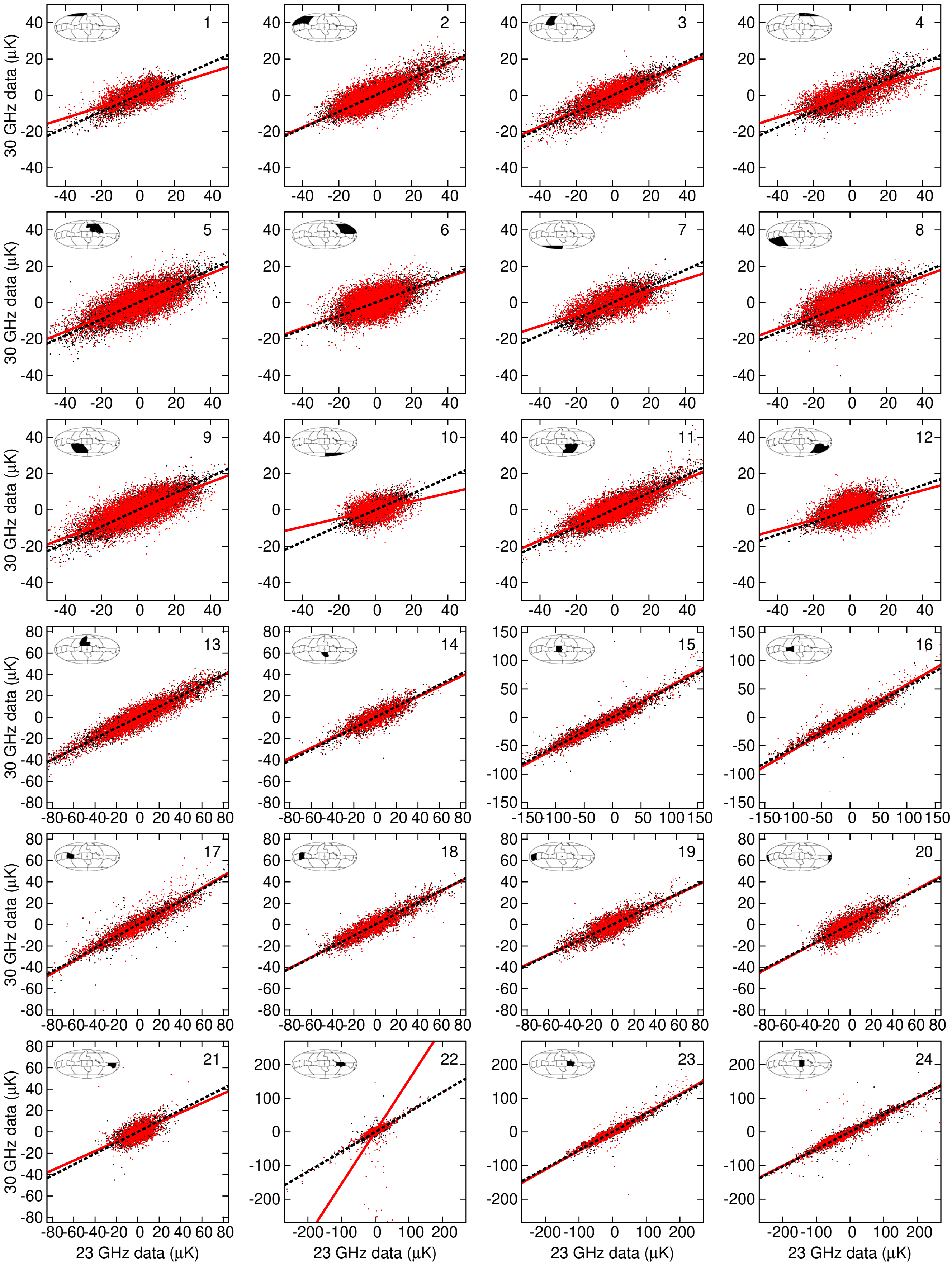

Fig. 5. T-T plots for Stokes Q and U maps of the Cosmoglobe 23 GHz versus the Cosmoglobe 30 GHz (black) and the 9 yr *WMAP* 23 GHz versus *Planck* 2018 30 GHz (red) for all regions. The horisontal (solid and dotted) lines indicates the corresponding inverse variance weighted values of the spectral index, averaged over rotation angle. Figure will be updated using more samples.

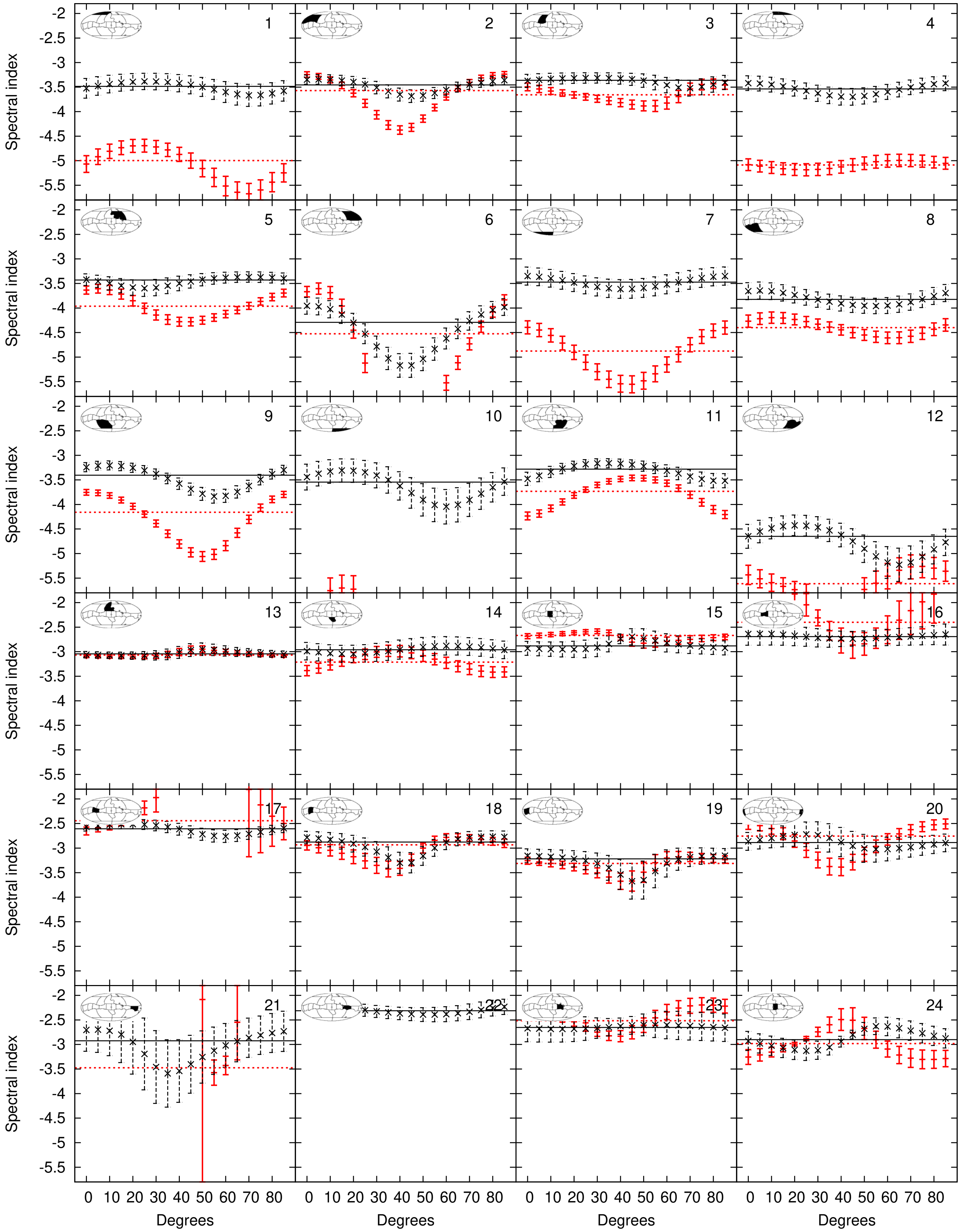

Fig. 6. The synchrotron spectral index as a function of rotation angle, computed using T-T plot between the Cosmoglobe 23 GHz and the Cosmoglobe 30 GHz (black) compared to the spectral index using the 9 yr *WMAP* 23 GHz and *Planck* 2018 30 GHz (red) for all regions. The horisontal (solid and dotted) lines indicates the corresponding inverse variance weighted values of the spectral index. Figure will be updated using more samples.

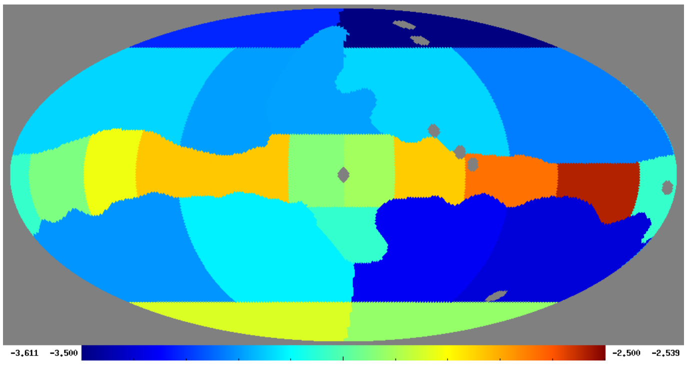

Fig. 7. The spatial variation of the synchrotron spectral index, computed using T-T plot between the Cosmoglobe WMAP K band and Ka band. The spectral index is inverse variance weighted over rotation angle, and samples. Fix style of maps. Figure will be updated using more samples.

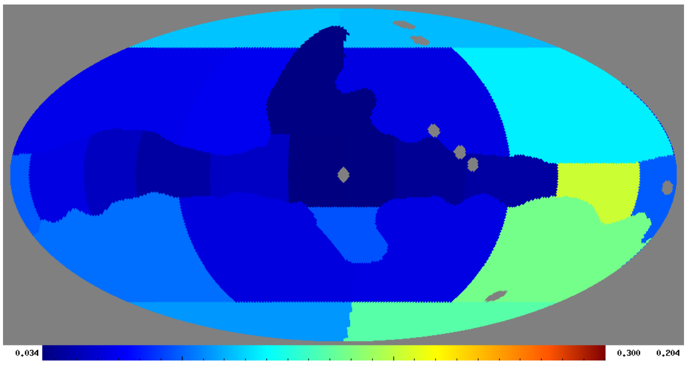

Fig. 8. The uncertainty of the synchrotron spectral index, computed using T-T plot between the Cosmoglobe WMAP K band and Ka band. REMOVE? Figure will be updated using more samples.

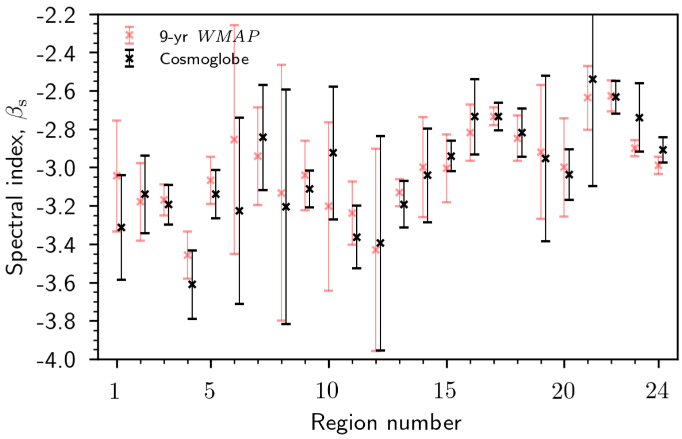

Fig. 9. The synchrotron spectral index, computed using T-T plot between the Cosmoglobe WMAP K band and Ka band (red) compared to the spectral index using the original 9 yr WMAP data (black) as a function of region number. The spectral index is inverse variance weighted over rotation angles, and samples. Figure will be updated, adding larger final uncertainty and using more samples.

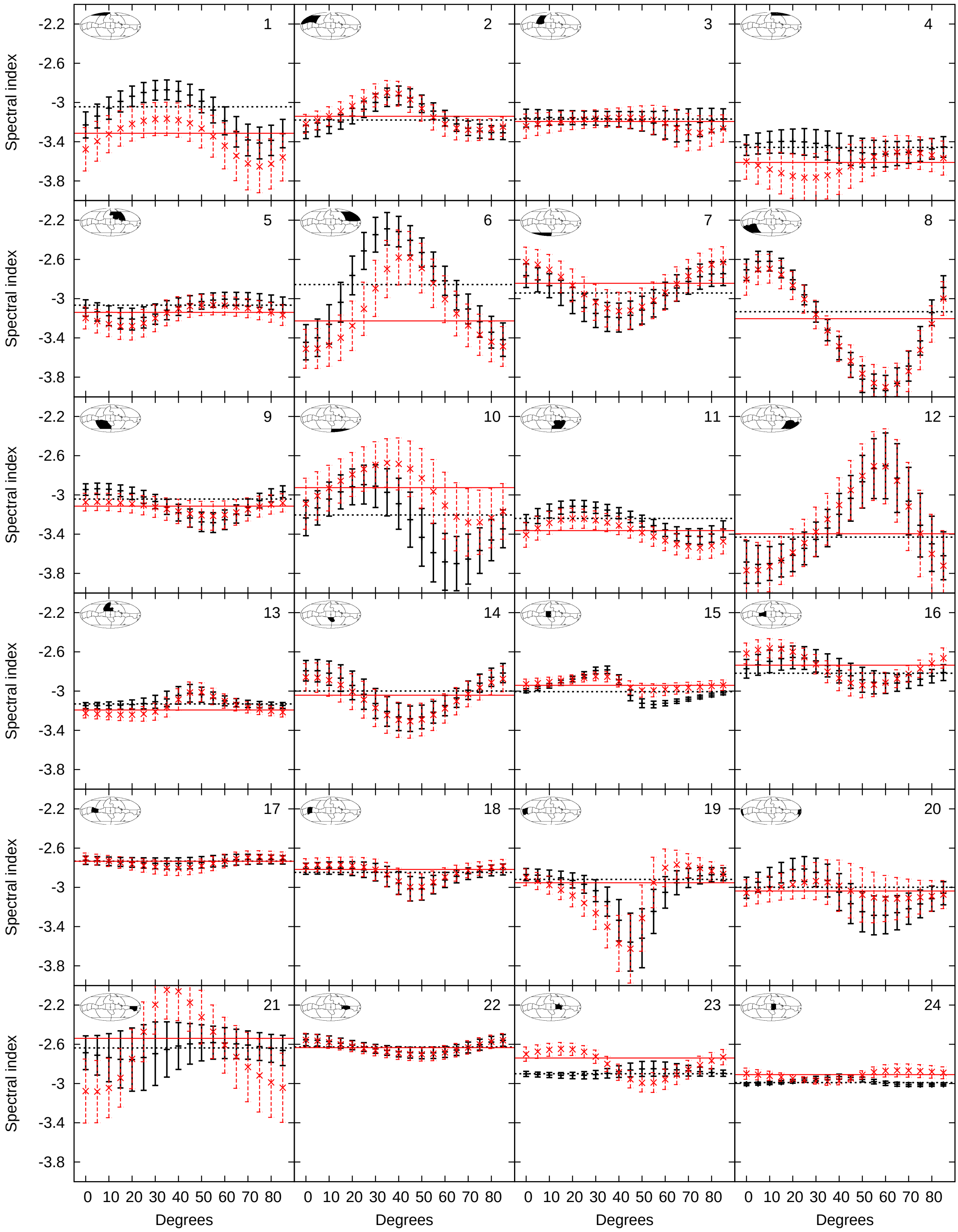

Fig. 10. The synchrotron spectral index as a function of rotation angle, computed using T-T plot between the Cosmoglobe WMAP K band and Ka band (red) compared to the spectral index using the original 9 yr WMAP data (black) for all regions. The horisontal lines indicates the corresponding inverse variance weighted values of the spectral indiex. Figure will be updated using more samples.