LoCo Lab EDGES Memo 167
Fitting Physical Foreground Model to Mid-Band Data with PolyChord

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February 5, 2020

1 Description

Here we compare the performace of the 'physical foreground model' — accounting for the astrophysical foreground and the ionosphere — relative to the generic 'powerlog' model, when using them to fit a 20-minute integration of Mid-Band data. The comparison is done considering the parameter estimates and the Bayesian evidence.

This memo continues the exploration of the physical foreground model, following LoCo memos 165 and 166, but now using real measurements.

2 Models

We use the following models:

- Model A (Parameters: T_0, β, γ)

$$T(\nu) = T_{\mathrm{CMB}} + T_0 \left(\frac{\nu}{\nu_0}\right)^{\beta+\gamma\log(\frac{\nu}{\nu_0})} \tag{1}$$

- Model B (Parameters: T_0, β, γ, δ)

$$T(\nu) = T_{\mathrm{CMB}} + T_0 \left(\frac{\nu}{\nu_0}\right)^{\beta+\gamma\log(\frac{\nu}{\nu_0})+\delta\left[\log(\frac{\nu}{\nu_0})\right]^2} \tag{2}$$

- Model C (Parameters: T_0, β, γ, τ_{ion}, T_e)

$$T(\nu) = \left[T_{\mathrm{CMB}} + T_0 \left(\frac{\nu}{\nu_0}\right)^{\beta+\gamma\log(\frac{\nu}{\nu_0})}\right] e^{-\tau_{ion}\left(\frac{\nu}{\nu_0}\right)^{-2}} + T_e\left[1 - e^{-\tau_{ion}\left(\frac{\nu}{\nu_0}\right)^{-2}}\right] \tag{3}$$

- Model D (Parameters: T_0, β, γ, δ, τ_{ion}, T_e)

$$T(\nu) = \left[T_{\mathrm{CMB}} + T_0 \left(\frac{\nu}{\nu_0}\right)^{\beta+\gamma\log(\frac{\nu}{\nu_0})+\delta\left[\log(\frac{\nu}{\nu_0})\right]^2}\right] e^{-\tau_{ion}\left(\frac{\nu}{\nu_0}\right)^{-2}} + T_e\left[1 - e^{-\tau_{ion}\left(\frac{\nu}{\nu_0}\right)^{-2}}\right] \tag{4}$$

We use data in the frequency range $60 - 120$ MHz, with a channel width of 0.39 MHz, and with a reference frequency $\nu_0 = 90$ MHz.

3 Input Data

The input data is a 20-minute integration centered at GHA = 0 hr, from day 2018-148. This GHA corresponds to the Galactic transit, in which the measured brightness temperature at 90 MHz is about 3000 K. The measurement was conducted at night.

4 Noise

The noise standard deviation as a function of frequency was obtained from the data integration itself.

5 Fit Priors

Nominally we use the following 'Relaxed' uniform priors:

- $T_0 = [-10^4, 10^4]$ K
- $\beta = [-3, -2]$
- $\gamma = [-10^4, 10^4]$
- $\delta = [-10^4, 10^4]$
- $T_e = [0, 10^4]$ K
- $\tau_{ion} = [0, 1]$

In some cases we change to 'Tight' uniform priors for T_0 and T_e:

- $T_0 = [2000, 4000]$ K
- $T_e = [400, 1200]$ K

6 Cases

CASE	Model	Priors	$\log(Z)$
1	A	Relaxed	-1087
2	B	Relaxed	-458
3	C	Relaxed	-475
4	C	Tight	-466
5	D	Tight	-460

7 Results

The results are presented in Figures 1 through 5, as well as in the $\log(Z)$ column of the Table, which corresponds to the Bayesian evidence.

8 Discussion

1. In Cases 3 and 4, which include the ionosphere terms but do not include δ, the estimated value of the spectral index is very high in absolute value ($|\beta| \approx 2.7$), the value of γ changes from negative to positive relative to Cases 1 and 2, and the ionospheric opacity also takes a very high value ($\tau_{ion} > 6\%$). In Case 5, when we incorporate δ while still including the ionospheric terms, the parameters β, γ, and τ_{ion} take values closer to expectations. In particular, the estimate for τ_{ion} is low ($< 1\%$).

2. The highest Bayesian evidence is obtained for Case 2 (-458), which includes δ but not the ionospheric terms, followed by Case 5 (-460). In both cases the estimate for δ is similar (≈ 0.1), which suggests that this estimate is robust.

3. Considering the above, for this spectrum it is not justified to use Model D (with 6 parameters). The inclusion of δ in the model has a more significant and 'beneficial' effect than including τ_{ion} and T_e which, on the contrary, reduces the evidence. The Bayesian evidence prefers Model B (with 4 parameters) to model these data.

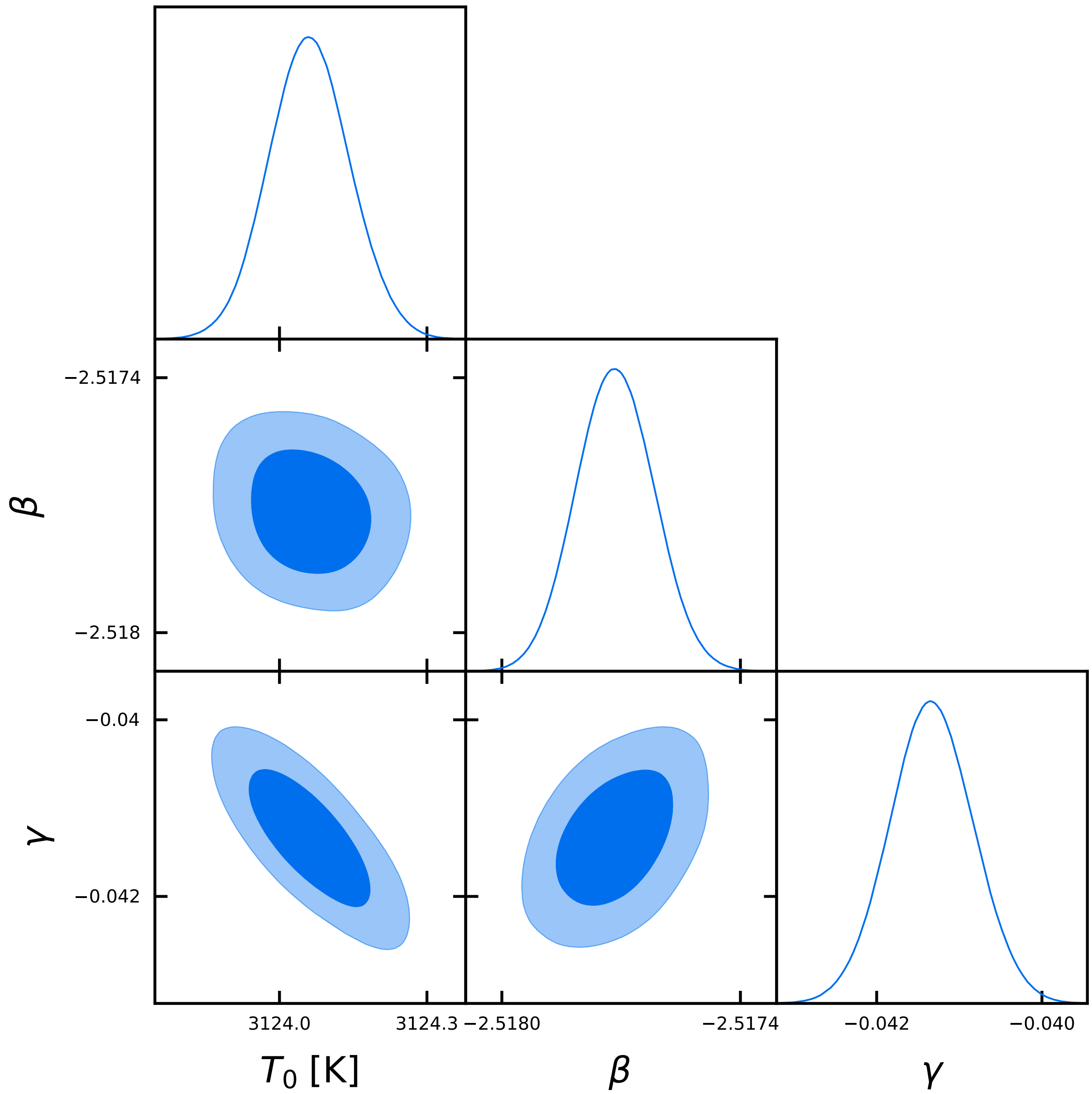

Figure 1: CASE 1. colors correspond to 68% and 95% confidence regions respectively.

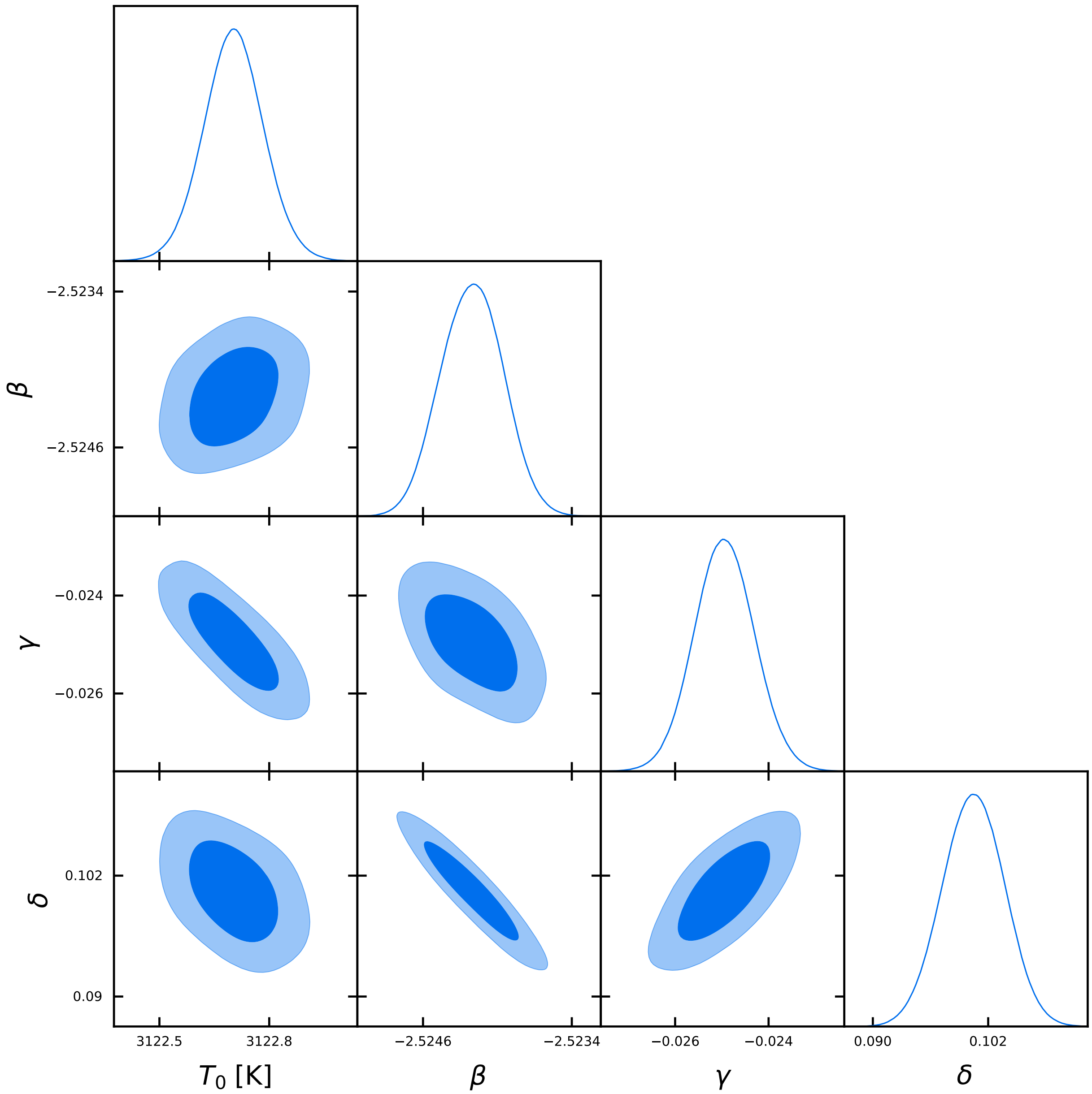

Figure 2: CASE 2. colors correspond to 68% and 95% confidence regions respectively.

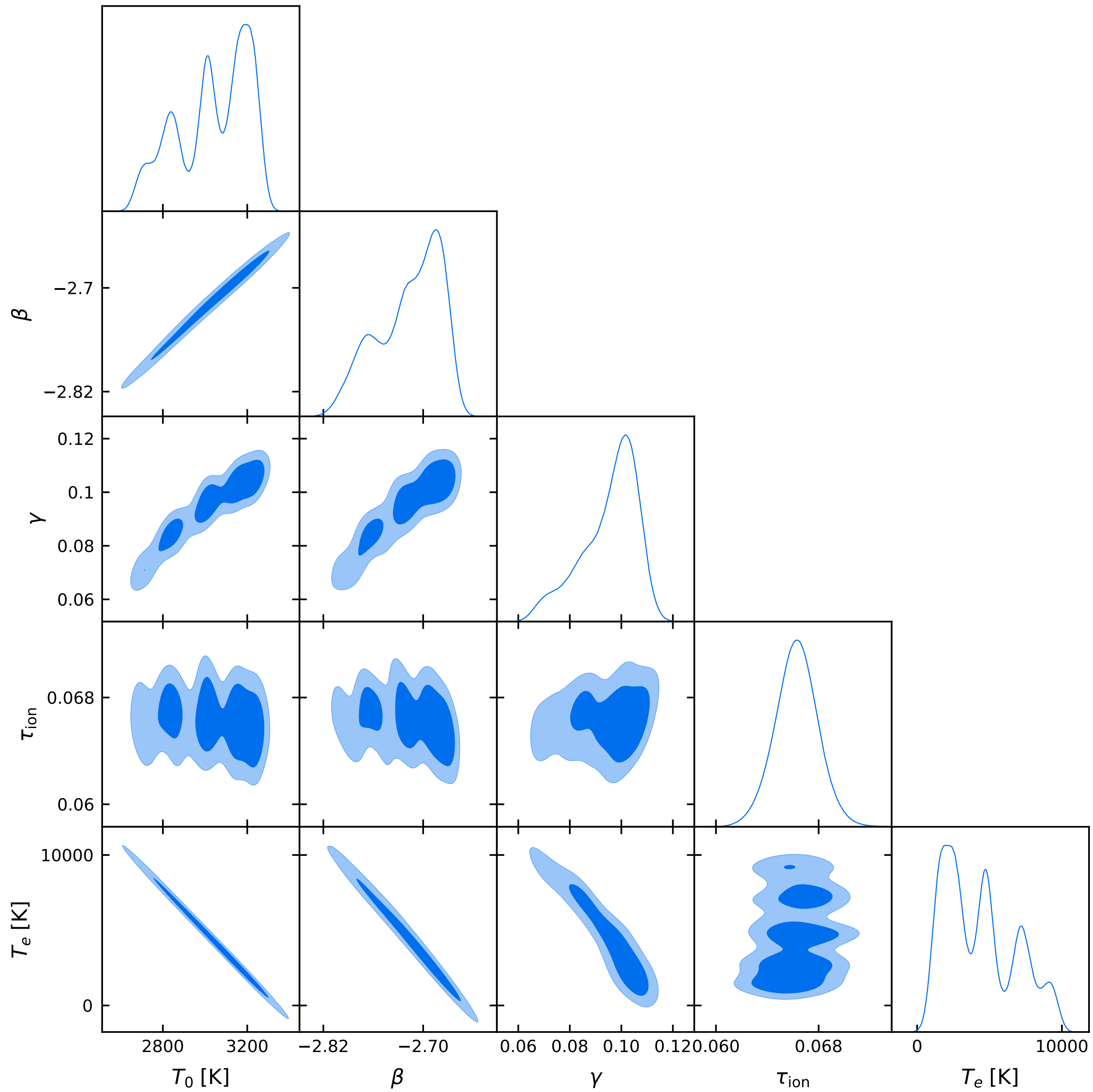

Figure 3: CASE 3. colors correspond to 68% and 95% confidence regions respectively.

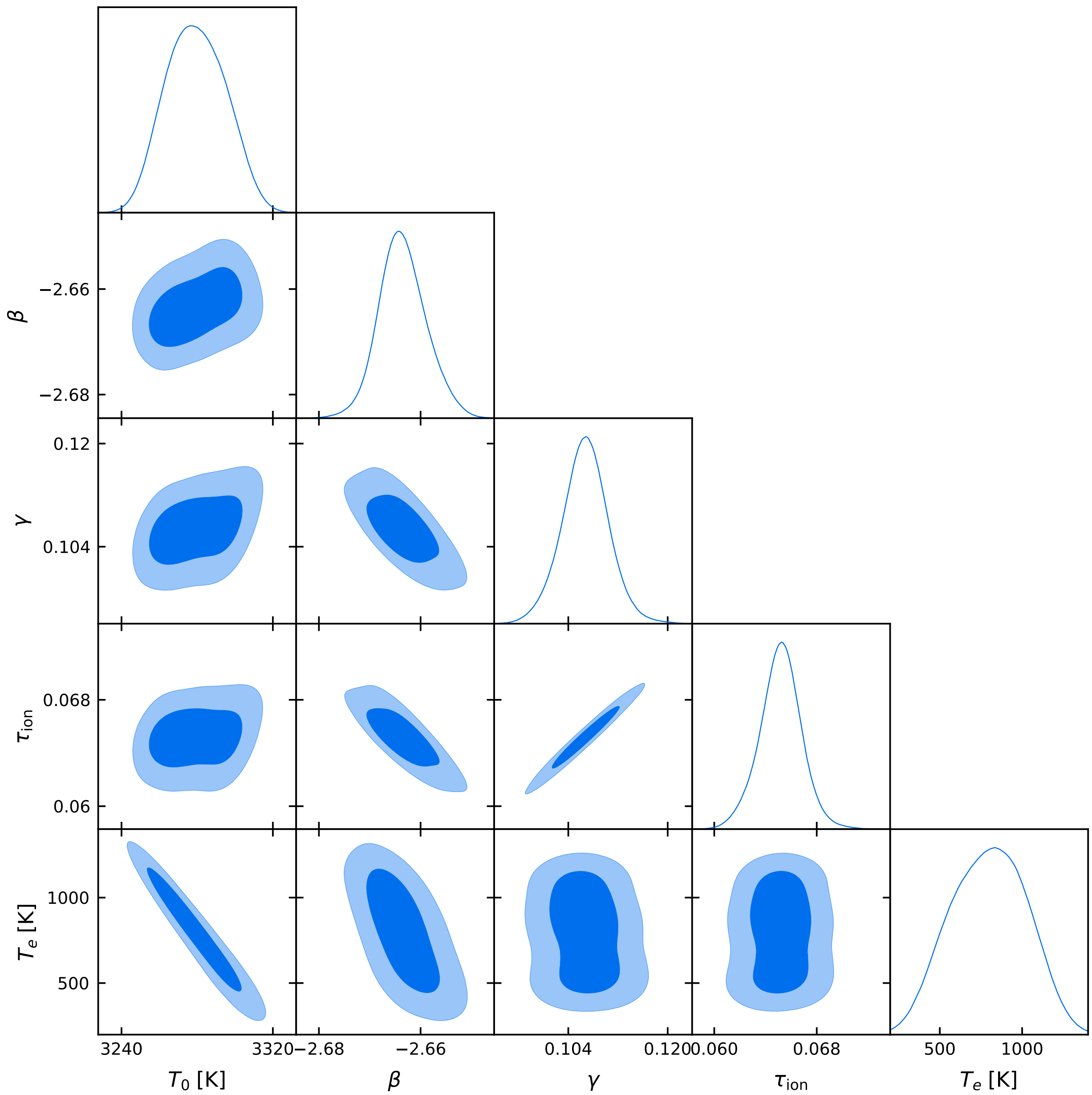

Figure 4: CASE 4. colors correspond to 68% and 95% confidence regions respectively.

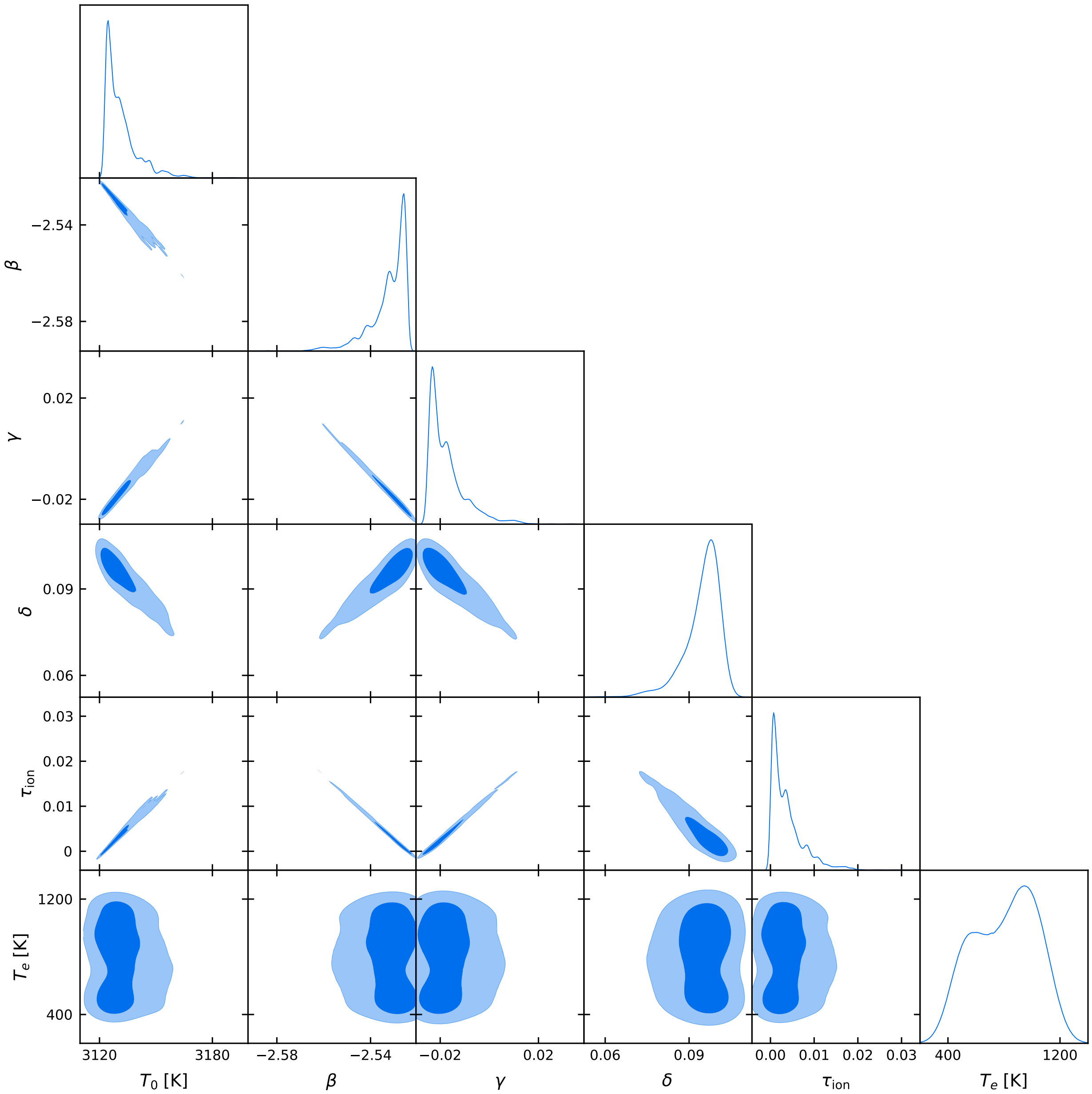

Figure 5: CASE 5. colors correspond to 68% and 95% confidence regions respectively.