Signal and foreground inference for global 21-cm observations

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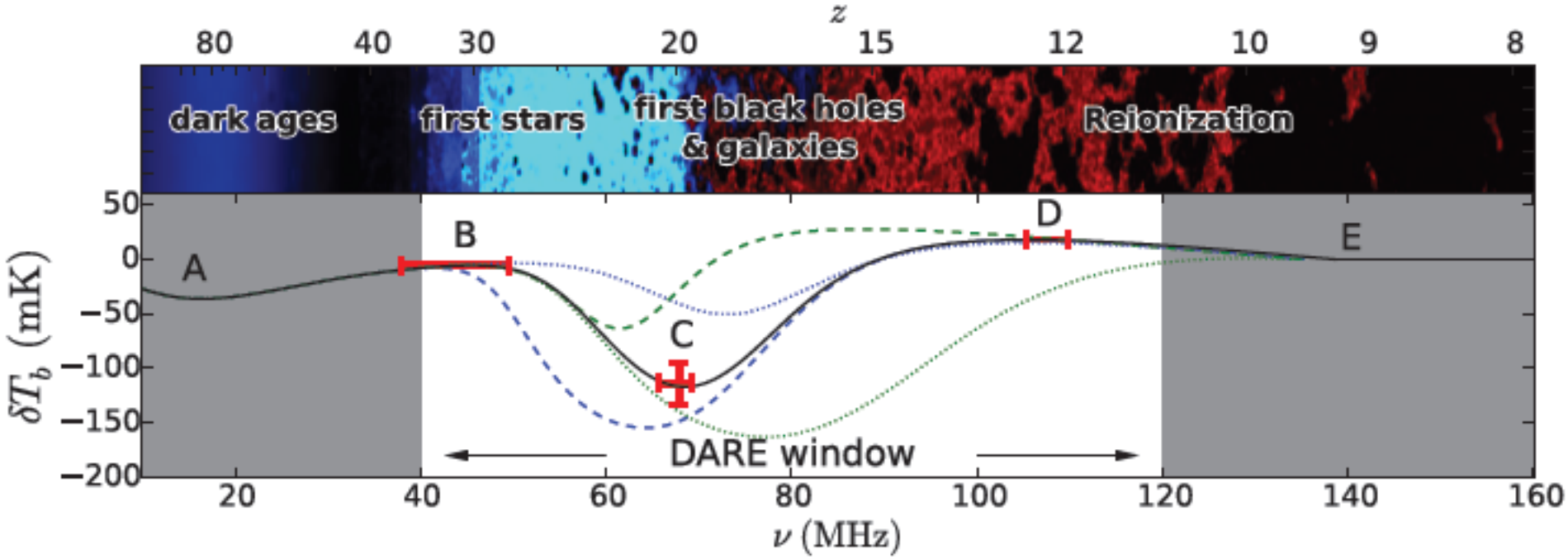
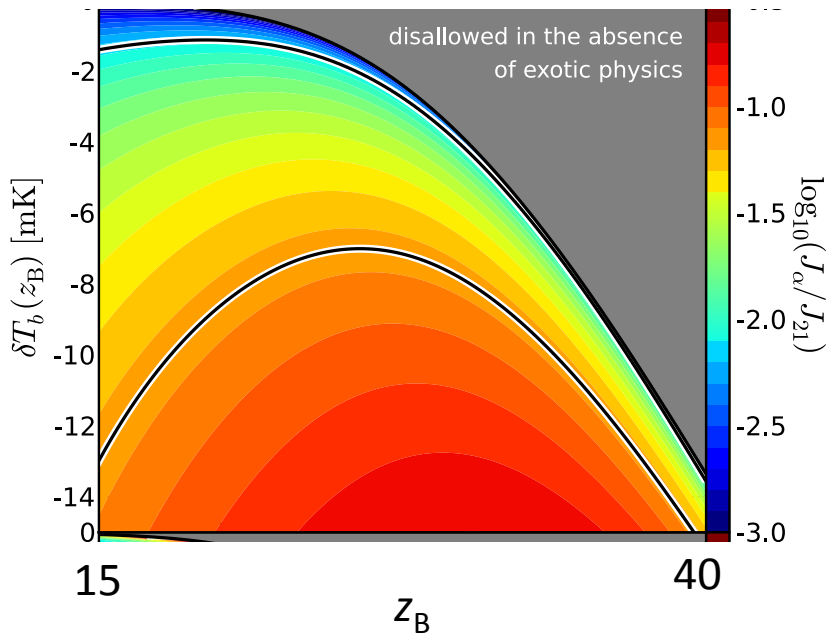
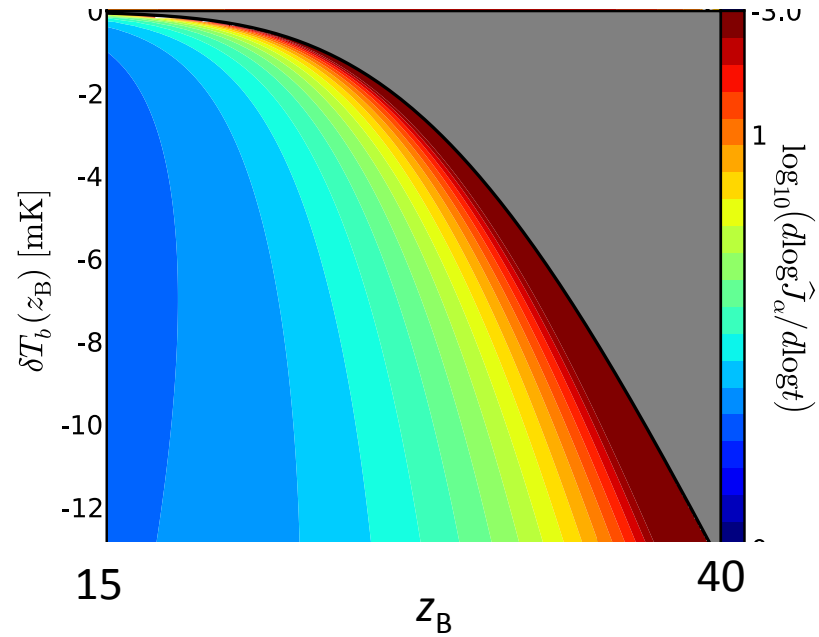
Global 21-cm signal, summarised by ‘turning points’



Turning point B

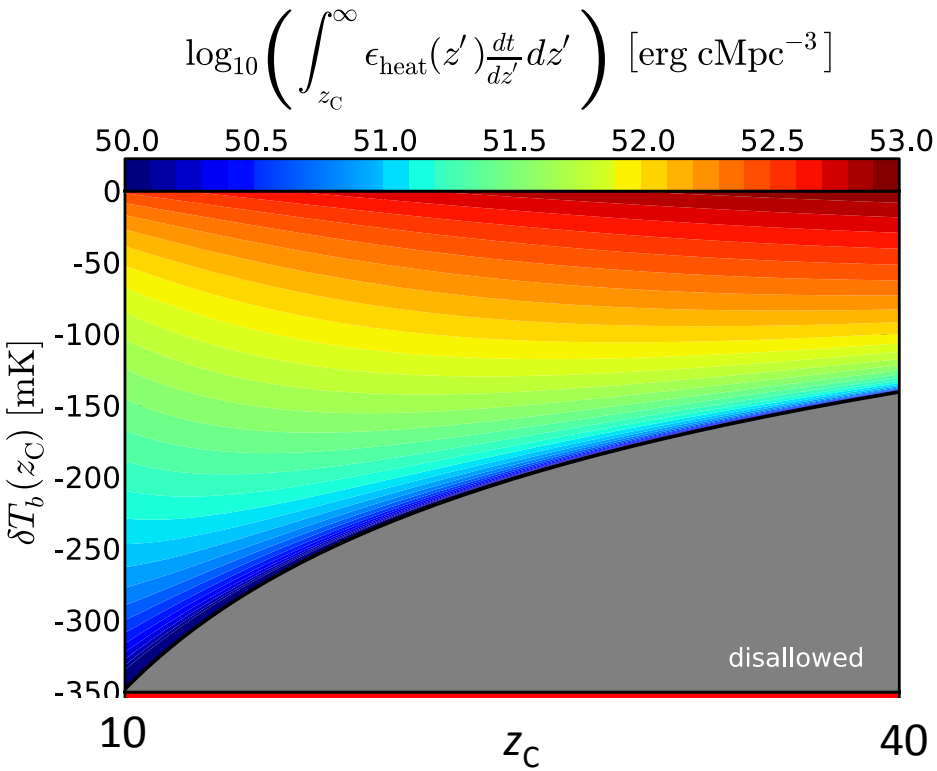


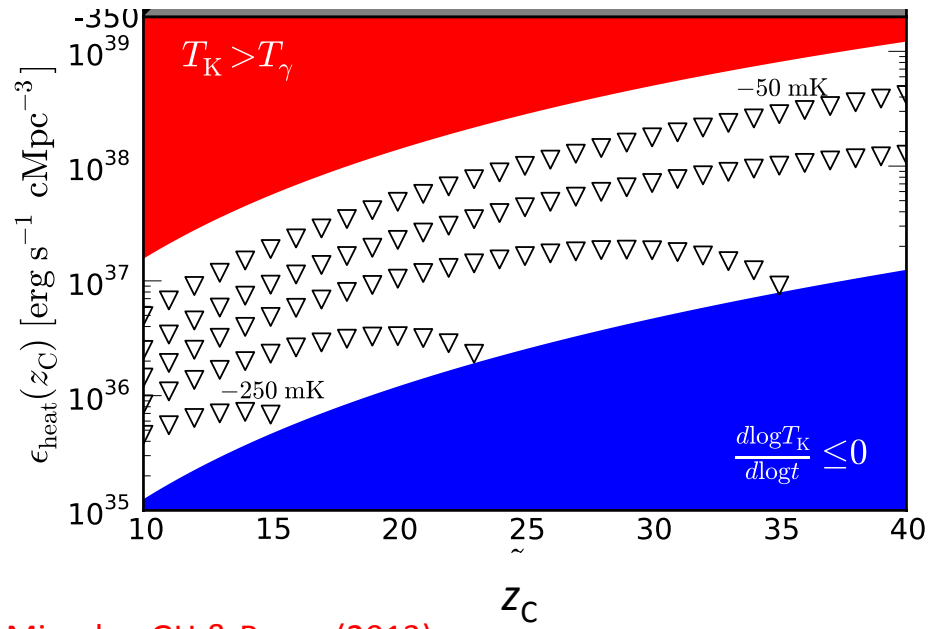


Mirocha, GH & Burns (2013)

Position of turning point B → constraints on global Lyman-alpha background

Turning point C



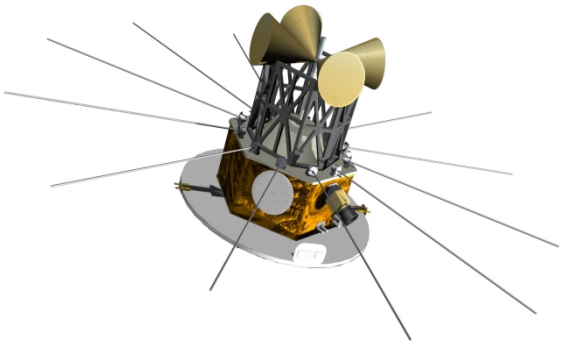


Mirocha, GH & Burns (2013)

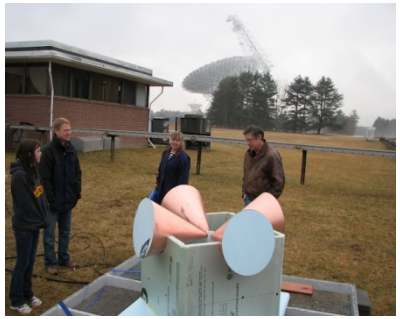
Position of turning point C → constraints on global heating rate (X-ray background)

The Dark Ages Radio Explorer

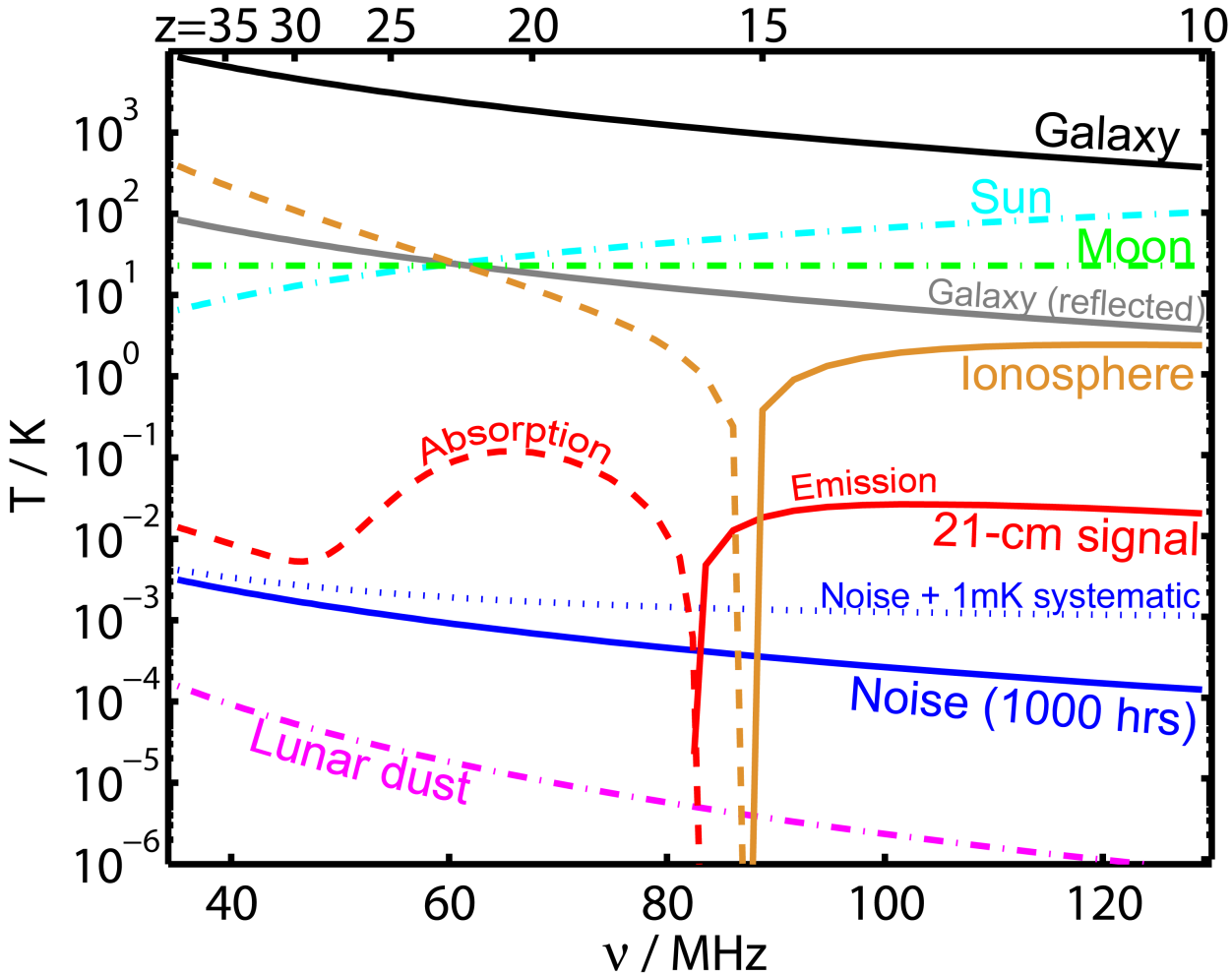
- Proposed:
  - Global 21-cm mission.
  - Low lunar orbit, collects science data over the far side at 40-120 MHz, shadowed from RFI from Earth.
  - Deemed selectable in the last Explorer round, was reproposed as a Small Explorer (SMEX) in December.



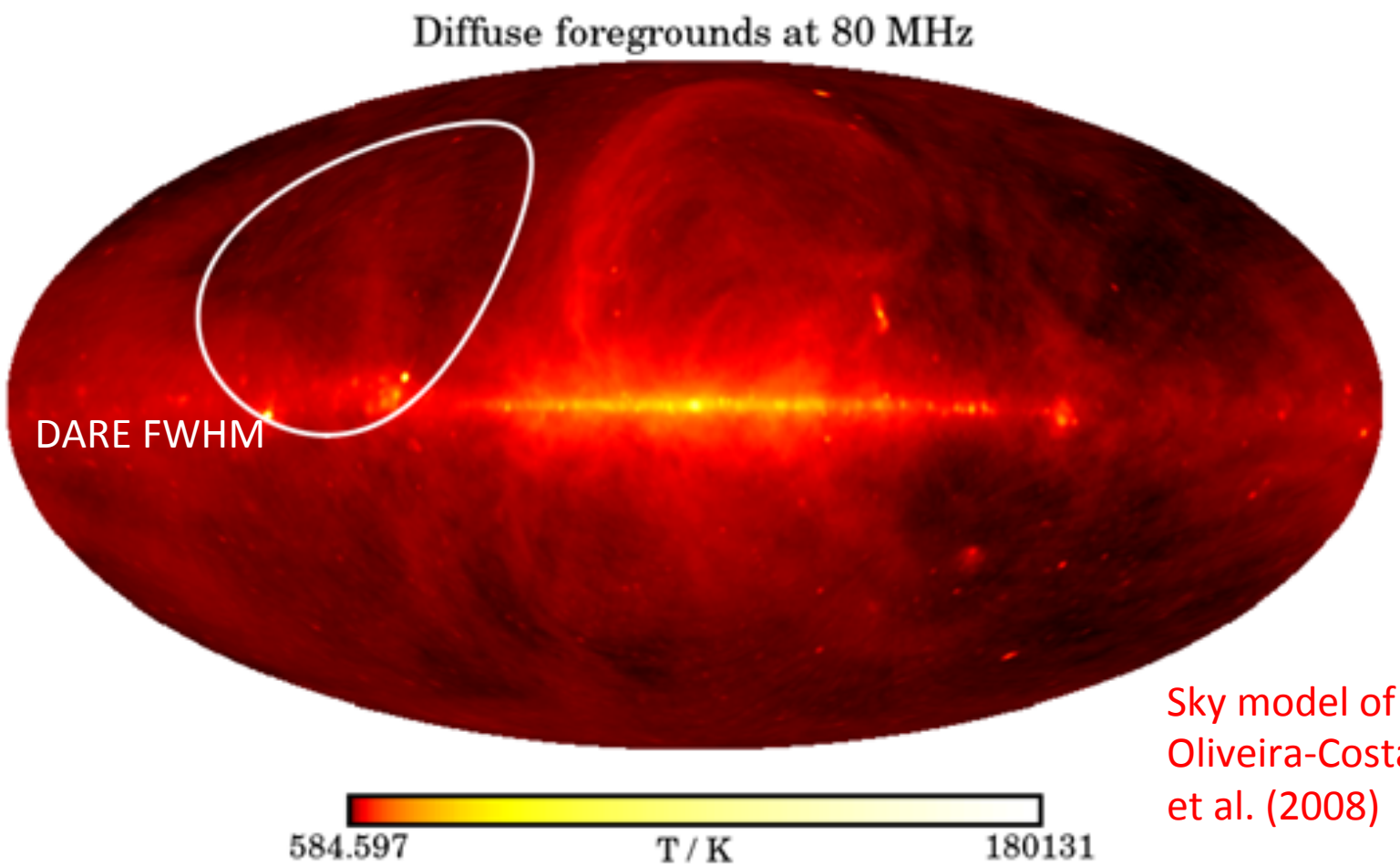
- Current status:
  - An initial field test of a *DARE*-like instrument in March 2012 showed effects of RFI and ionosphere.
  - We have deployed a next-generation prototype with an updated antenna and system, ready to test our new calibration approach, and study the ionosphere and low-frequency foregrounds in more detail.



Multiple strong foregrounds



Spatial structure of foregrounds



Sky model of de Oliveira-Costa et al. (2008)

Bayesian inference framework

Approach: parameterize 21-cm signal, foregrounds, instrument, ionosphere etc. and fit them all simultaneously

Can be computed given our model at a particular set of parameter values, Θ

Parameters

Data

Likelihood, (Θ)

Prior, π(Θ)

$$\Pr(\boldsymbol{\Theta}|\mathbf{D}, H) = \frac{\Pr(\mathbf{D}|\boldsymbol{\Theta}, H)\Pr(\boldsymbol{\Theta}|H)}{\Pr(\mathbf{D}|H)}$$

Posterior

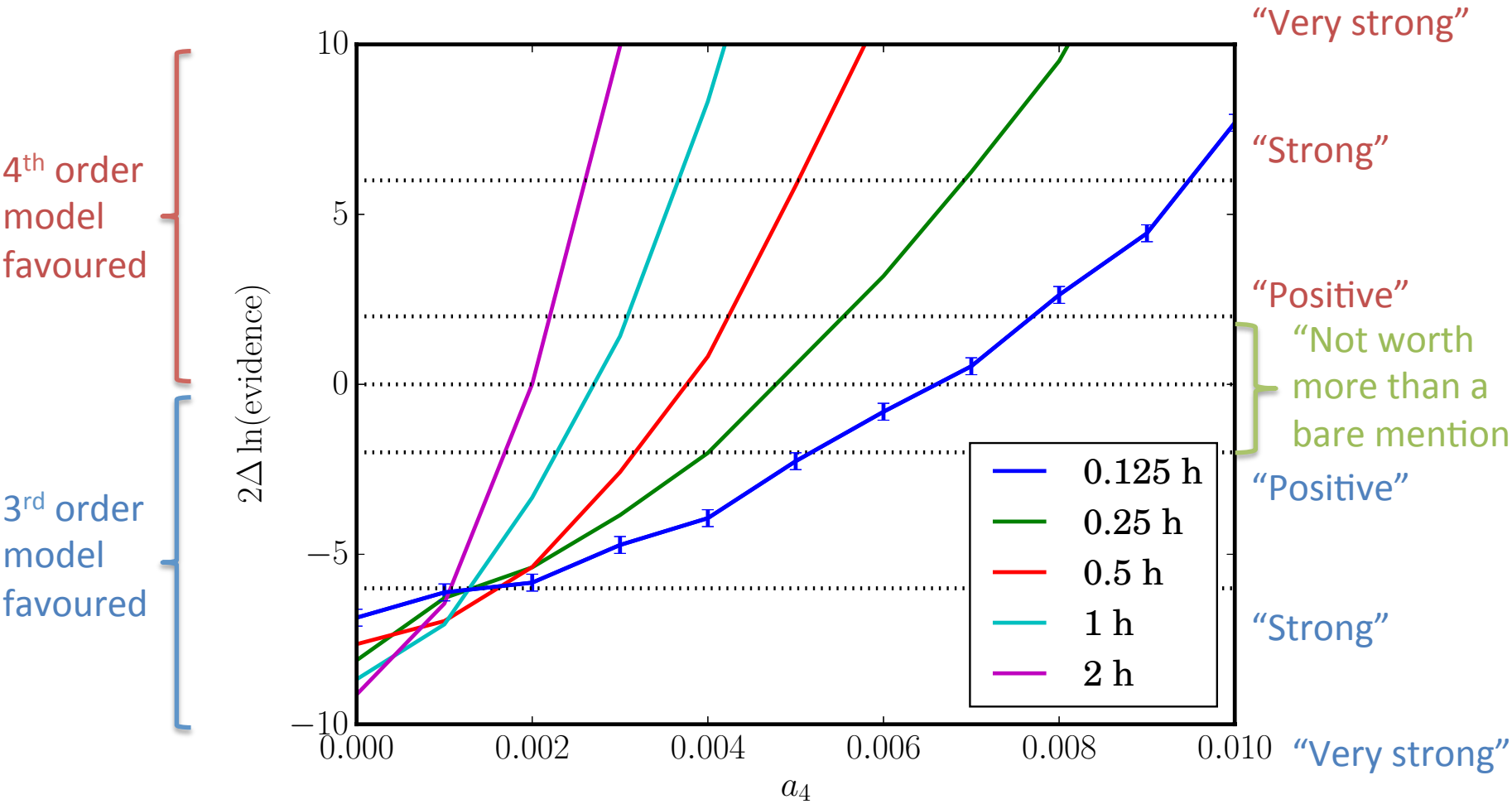
Evidence, *Z*

Hypothesis or model

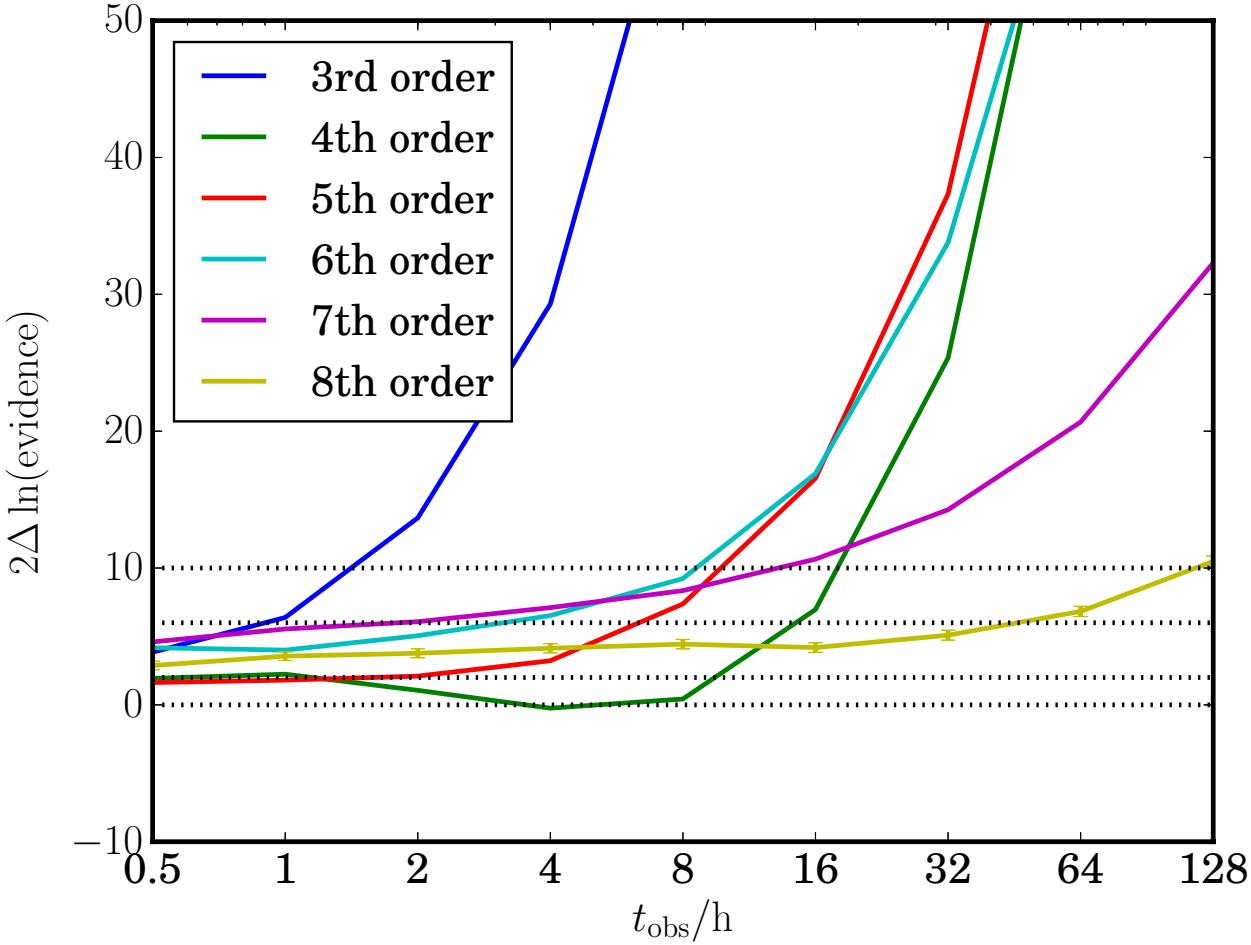
Computed as a function of Θ using Monte Carlo methods.

$$\mathcal{Z} = \int \pi(\Theta)\mathcal{L}(\Theta)\mathrm{d}^N\Theta$$

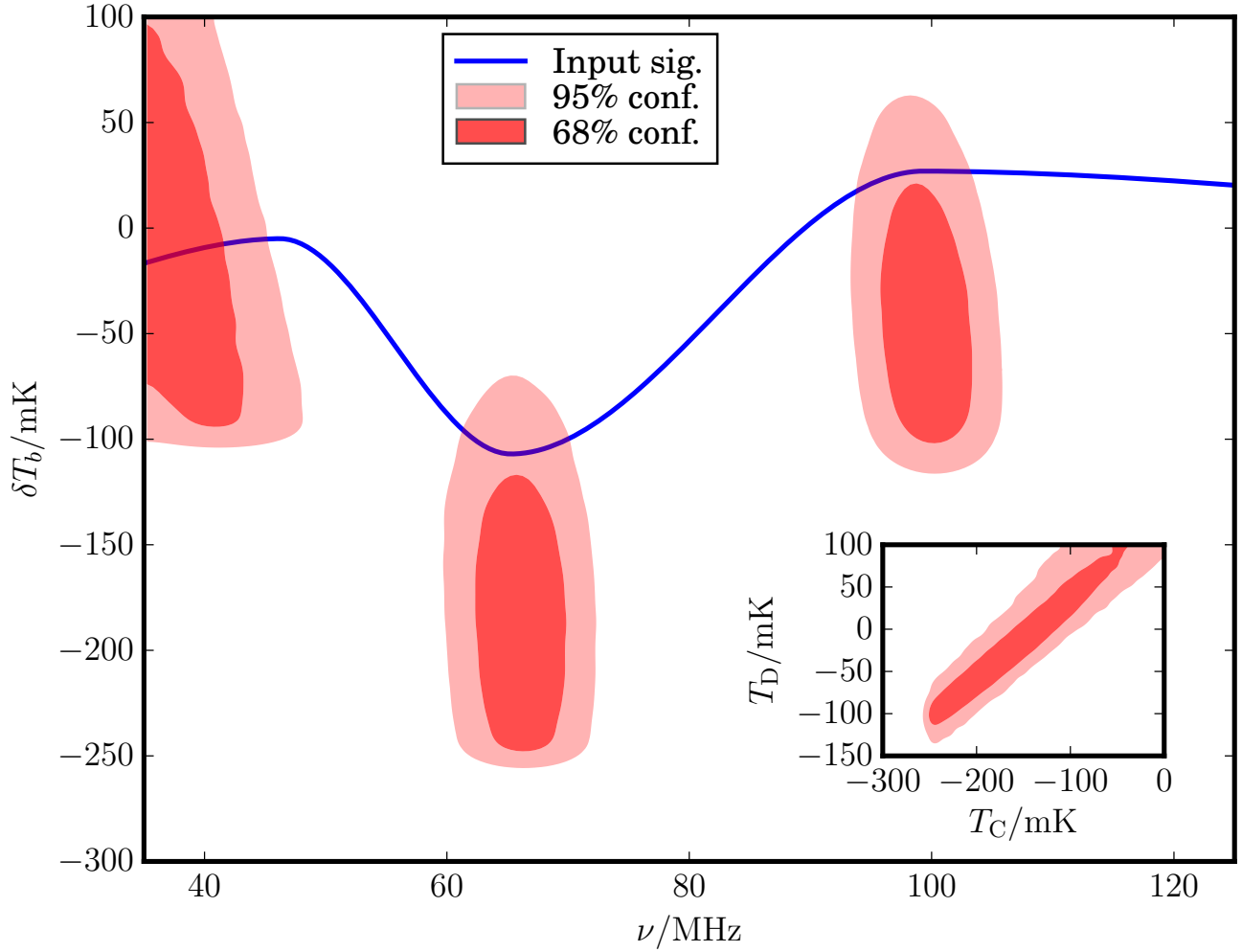
Trailblazer experiment: inferring foreground complexity



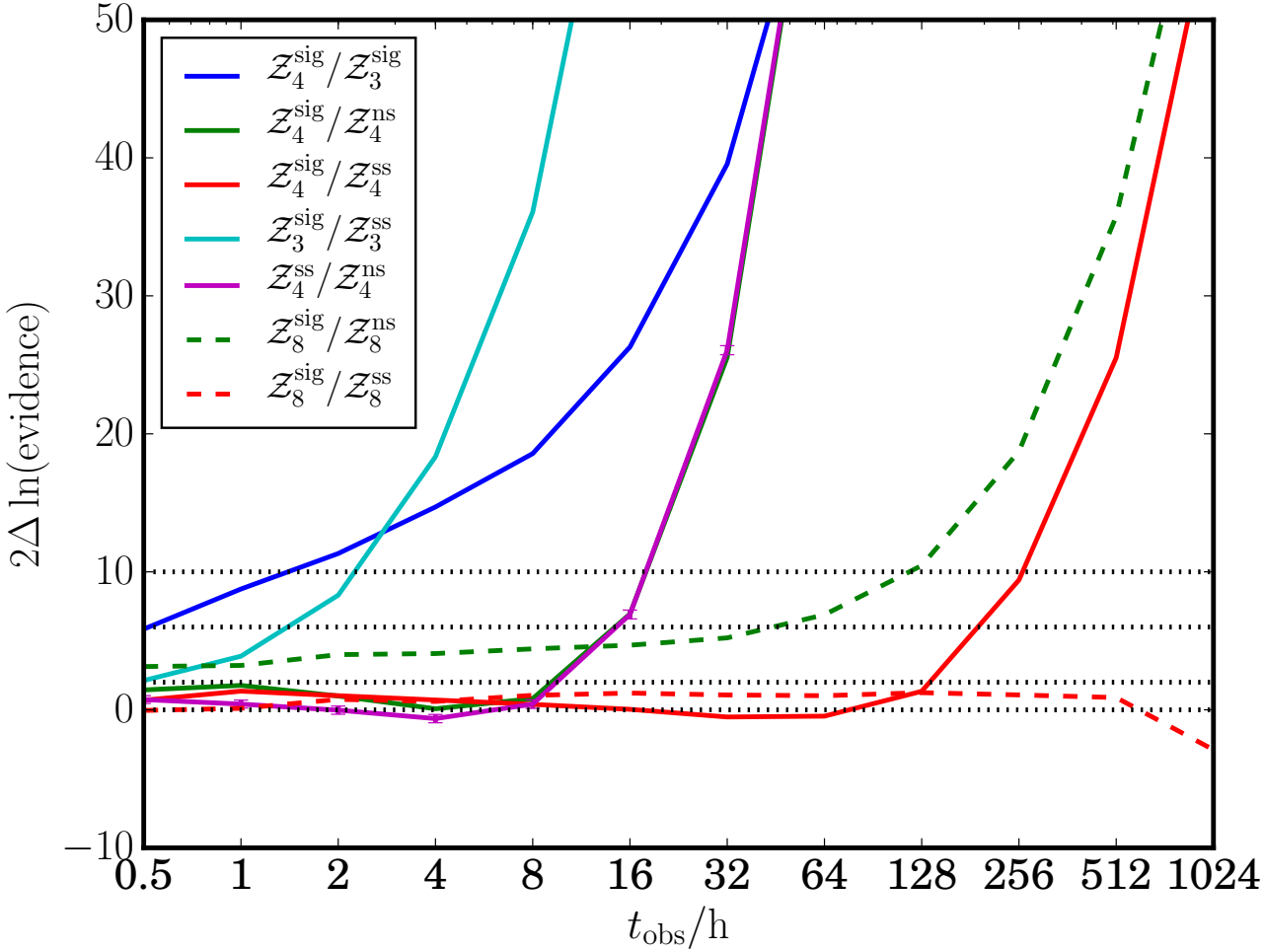
Higher order FGs make the signal harder to extract (but not impossible)



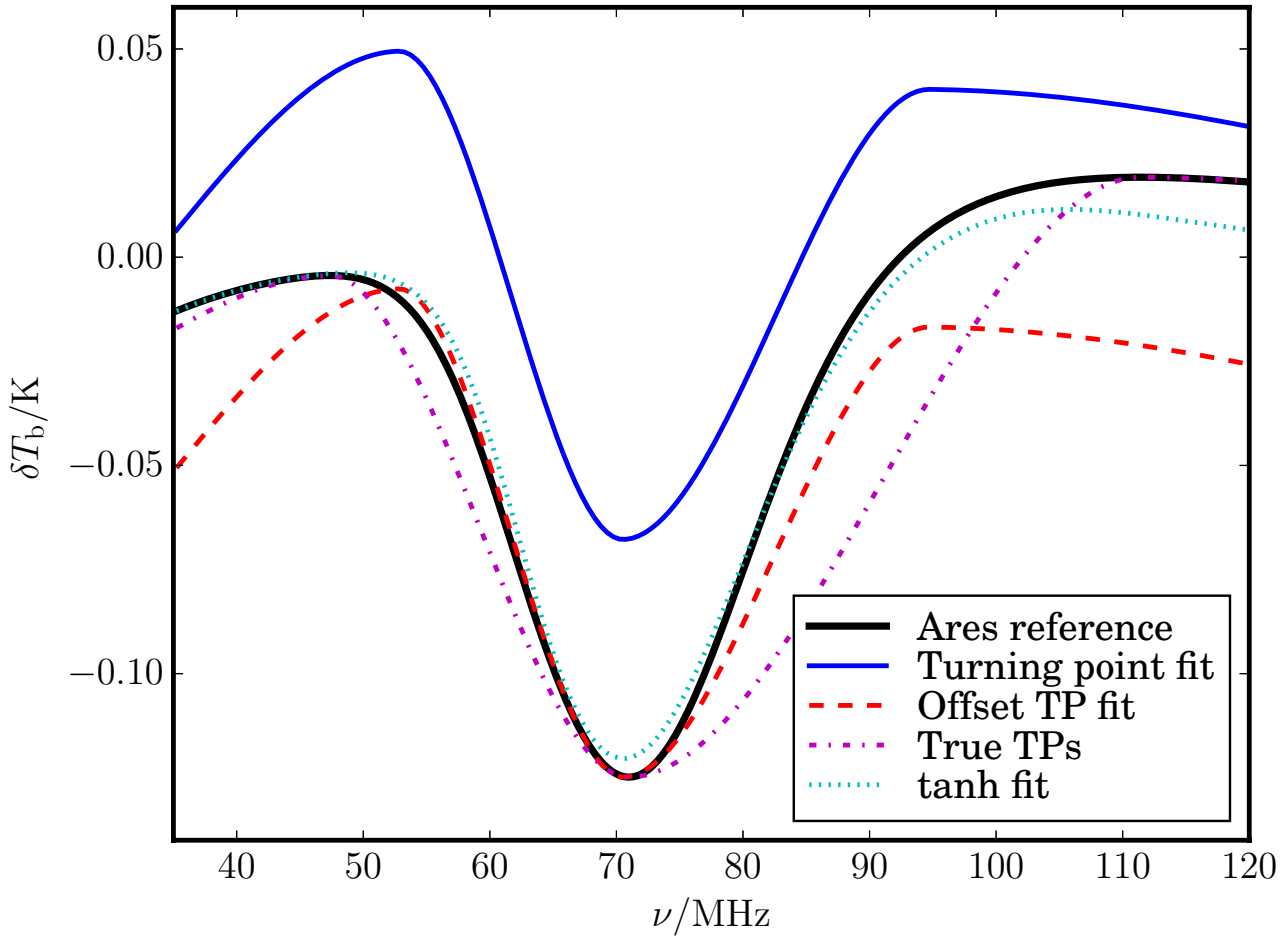
Shape constraints: 128 hr, 3rd-order foregrounds



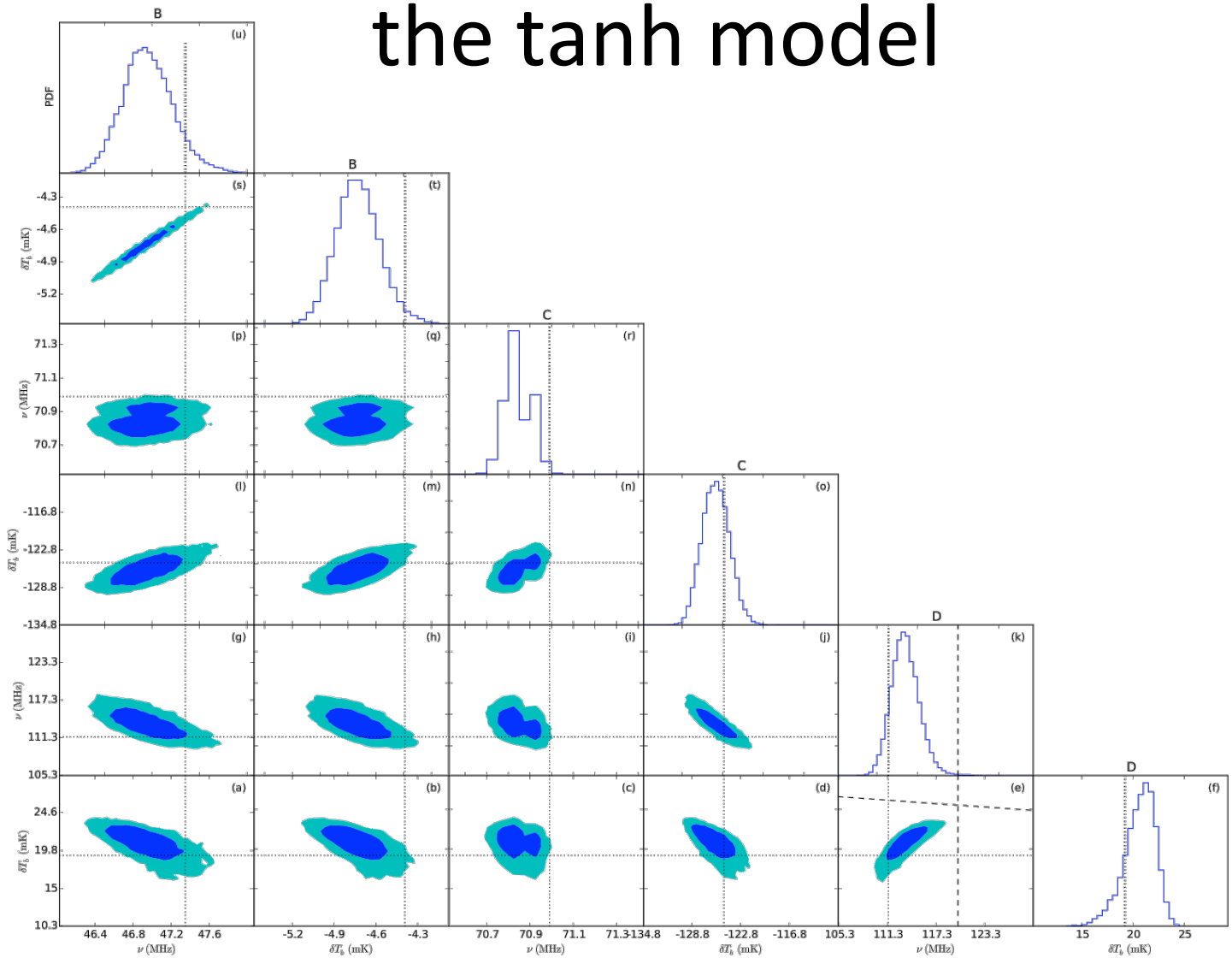
Effects of complex foregrounds



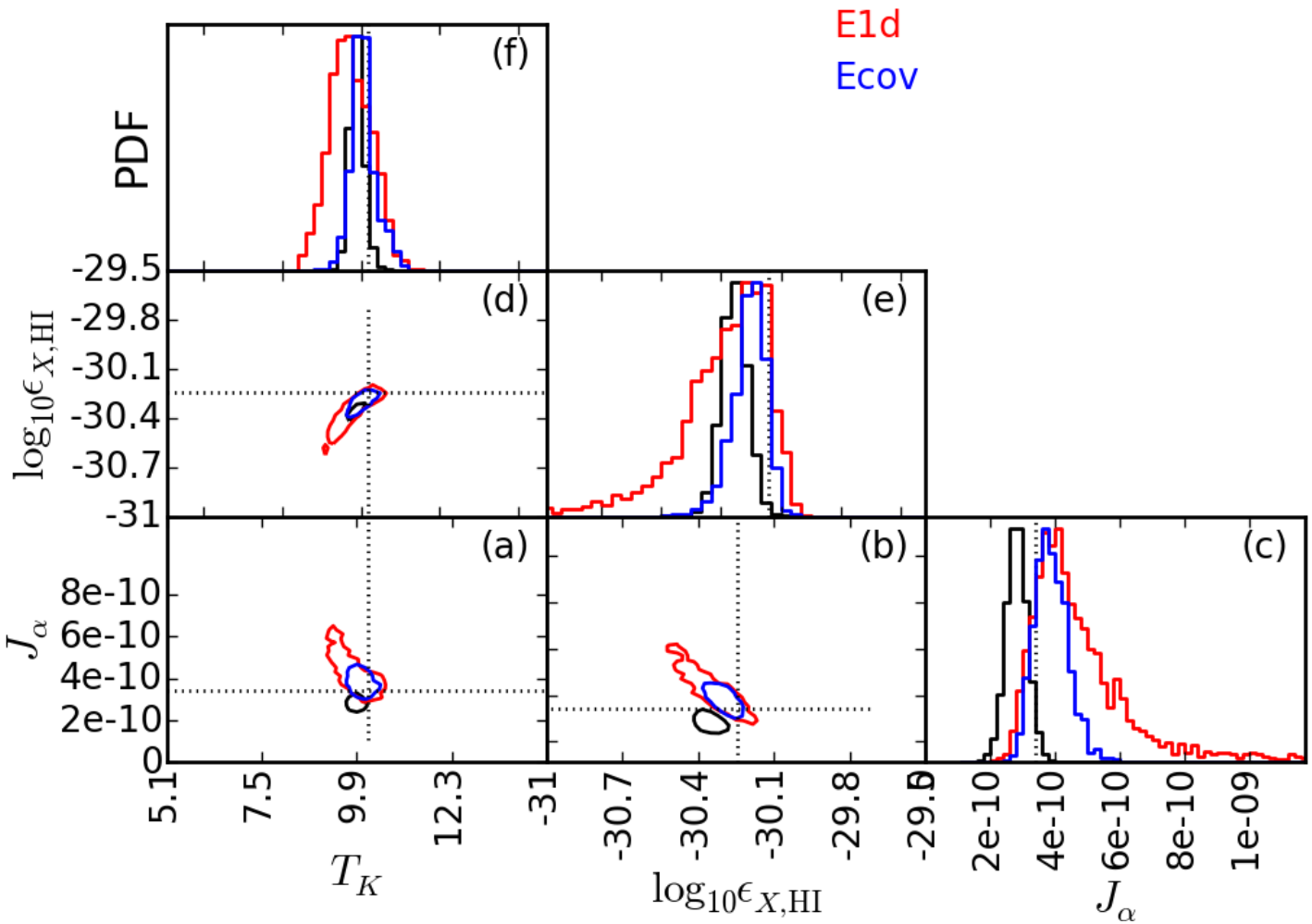
Other signal parametrizations may match the signal shape more easily



Turning points can be inferred from the tanh model



One-stage versus two-stage fitting



Conclusions

- Turning points encode robust information about IGM properties…
- …but their positions may be biased unless the model can capture the true shape of the signal.
- Can test for this, and for foreground complexity, using Bayesian model selection.
- Nested sampling seems to work well for this, but we need fast, scalable codes.