Constraining Foreground Models Using Time- and Antenna-Dependent Data

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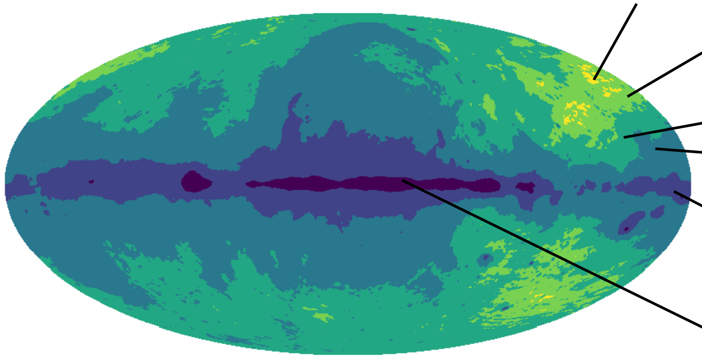
On behalf of the REACH collaboration

Summary of REACH Pipeline



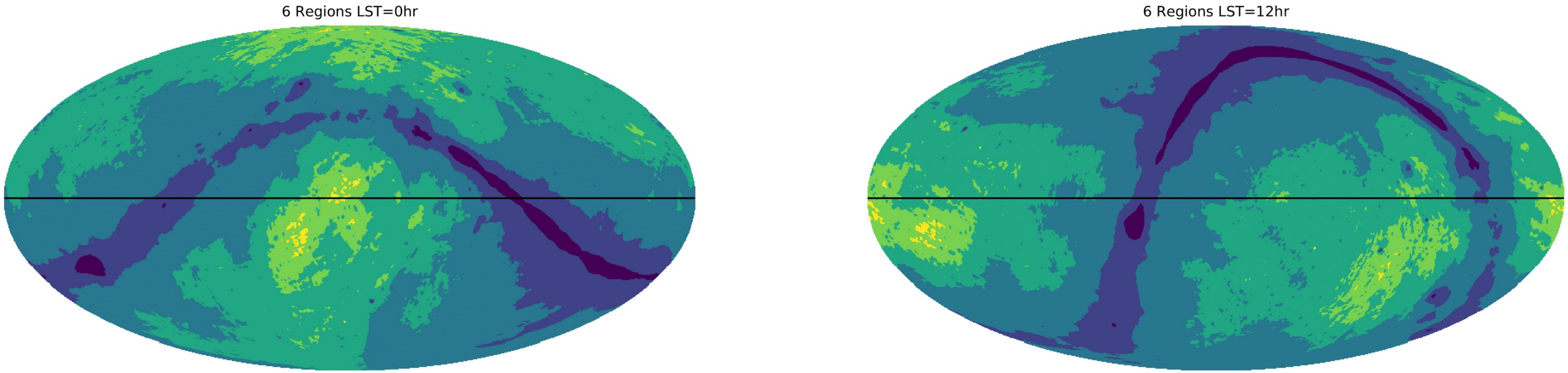
$$T_{\mathrm{F}}\left(\nu,\theta_{\mathrm{F}}\right)=\frac{1}{4\pi}\int_{0}^{4\pi}D\left(\theta,\phi,\nu\right)\times\int_{t_{\mathrm{start}}}^{t_{\mathrm{end}}}\sum_{i=1}^{N}M_{i}\left(\theta,\phi\right)\left(T_{230}\left(\theta,\phi\right)-T_{\mathrm{CMB}}\right)\left(\frac{\nu}{230}\right)^{-\beta_{i}}dt\,d\Omega+T_{\mathrm{CMB}}$$

$$\log\mathcal{L}=\sum_{i}-\frac{1}{2}\log\left(2\pi\sigma_{\mathrm{n}}^{2}\right)-\frac{1}{2}\left(\frac{T_{\mathrm{data}}\left(\nu_{i}\right)-\left(T_{\mathrm{F}}\left(\nu_{i},\theta_{\mathrm{F}}\right)+T_{S}\left(\nu_{i},\theta_{\mathrm{S}}\right)\right)}{\sigma_{\mathrm{n}}}\right)^{2}$$

Anstey et al. 2021

Time-Separated Fitting

$$\log\mathcal{L} = \sum_i -\frac{1}{2}\log\left(2\pi\sigma_\mathrm{n}^2\right) - \frac{1}{2}\left(\frac{\frac{1}{n_j}\sum_j\left[T_\mathrm{data}\left(\nu_i, t_j\right)\right] - \left(\frac{1}{n_j}\sum_j\left[T_\mathrm{F}\left(\nu_i, t_j, \theta_\mathrm{F}\right)\right] + T_S\left(\nu_i, \theta_\mathrm{S}\right)\right)}{\sigma_\mathrm{n}}\right)^2$$



Time-Separated Fitting

$$\frac{1}{n_j}\sum_j \left[T_{\text{data}}\left(\nu_i, t_j\right)\right]$$

$$\frac{1}{n_j}\sum_j \left[T_{\text{F}}\left(\nu_i, t_j, \theta_{\text{F}}\right)\right]$$

$$\theta_{\text{F}}$$

$$T_{\text{data}}\left(\nu_i, t_1\right)$$

$$T_{\text{F}}\left(\nu_i, t_1, \theta_{\text{F}}\right)$$

$$T_{\text{data}}\left(\nu_i, t_2\right)$$

$$T_{\text{F}}\left(\nu_i, t_2, \theta_{\text{F}}\right)$$

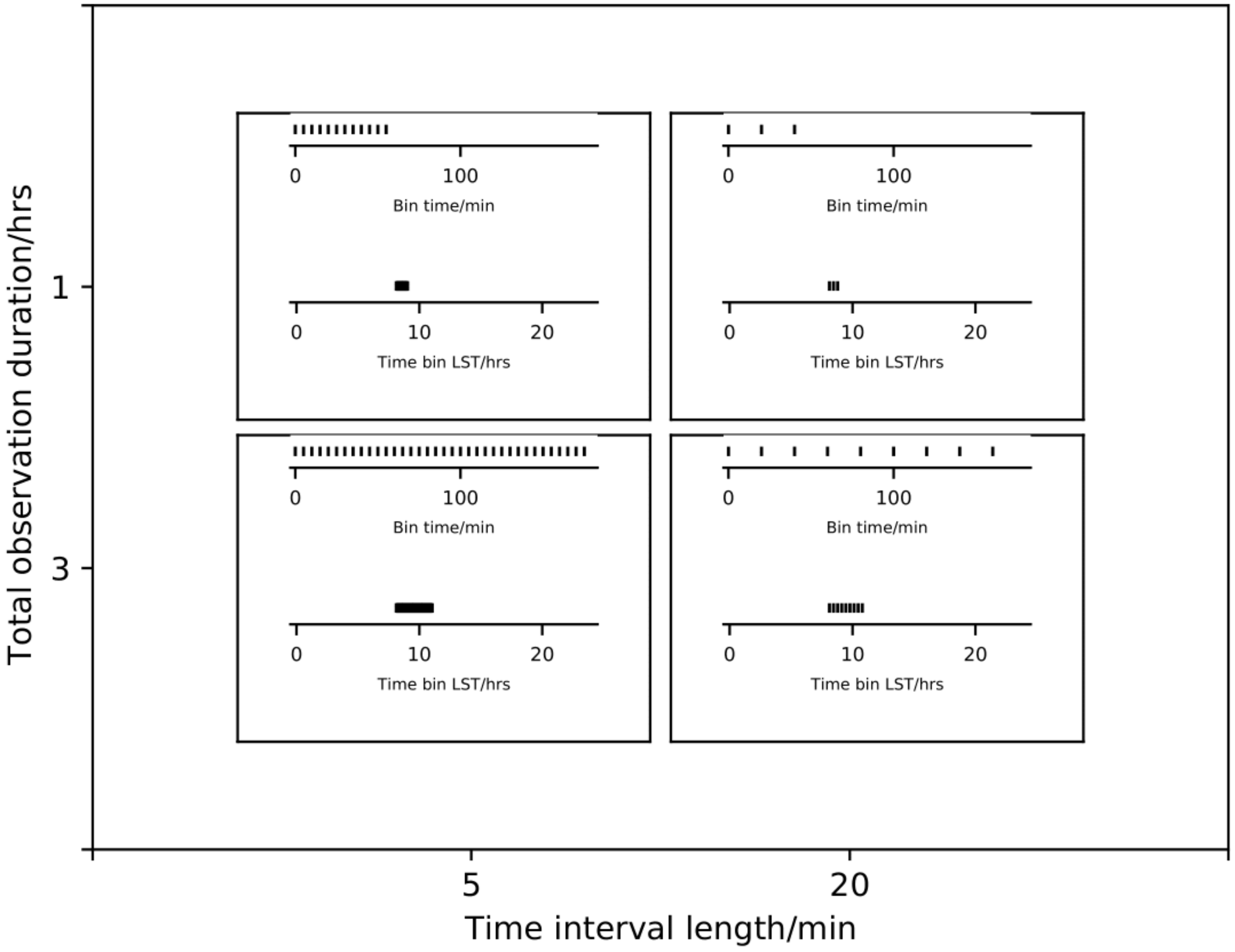
$$T_{\text{F}}\left(\nu_i, t_3, \theta_{\text{F}}\right)$$

$$T_{\text{data}}\left(\nu_i, t_3\right)$$

(…)

$$\log \mathcal{L} = \sum_i \sum_j -\frac{1}{2}\log\left(2\pi\sigma_{\text{n}}^2\right) - \frac{1}{2}\left(\frac{T_{\text{data}}\left(\nu_i, t_j\right) - \left(T_{\text{F}}\left(\nu_i, t_j, \theta_{\text{F}}\right) + T_S\left(\nu_i, \theta_{\text{S}}\right)\right)}{\sigma_{\text{n}}}\right)^2$$

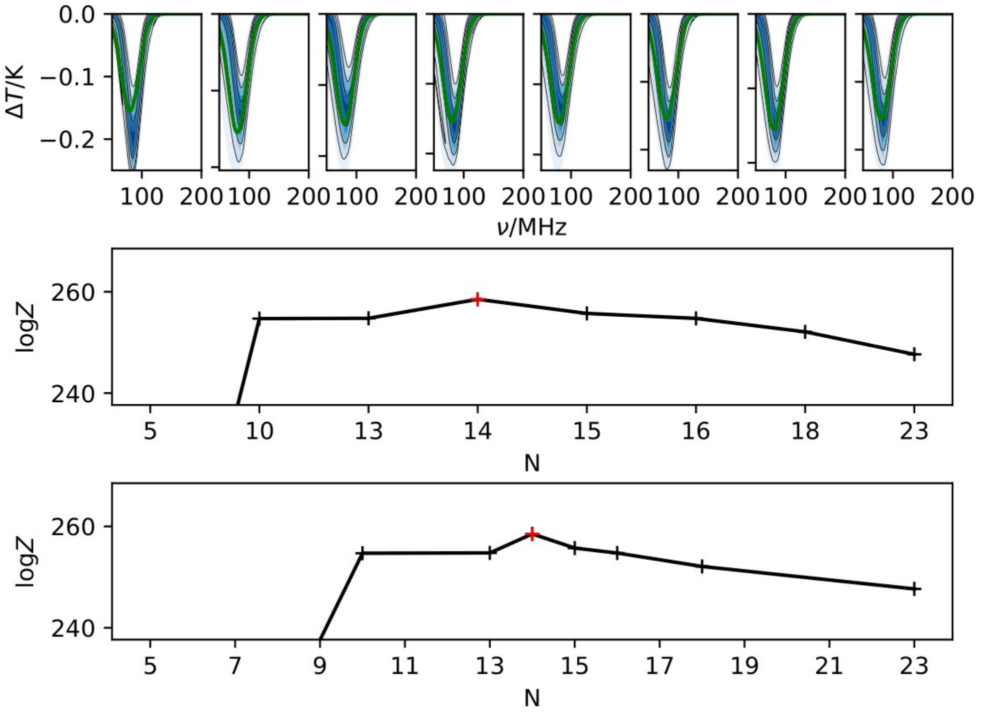
Comparison of Time-Averaged and –Separated Fitting



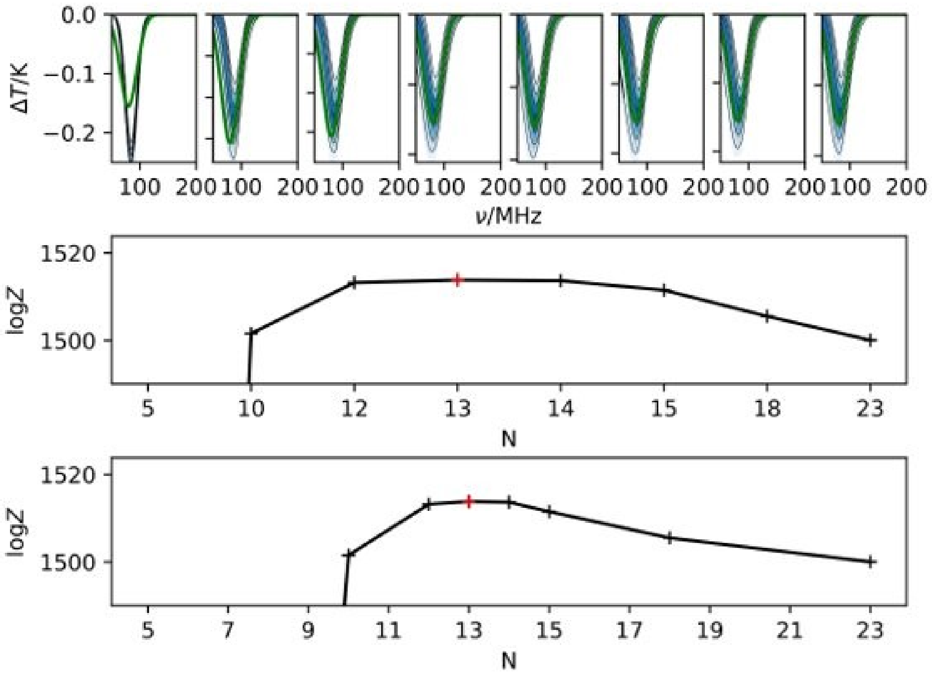
Comparison of Time-Averaged and – Separated Fitting

1 Hour 5 Minute Divisions

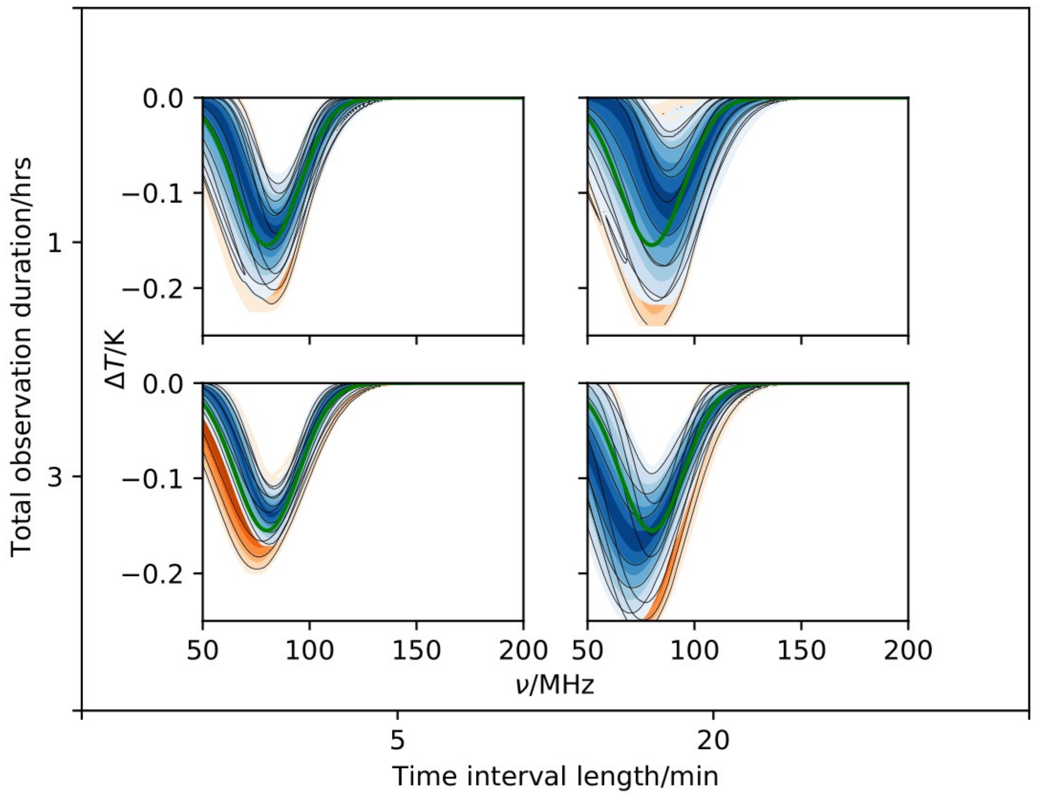
Time-Averaged

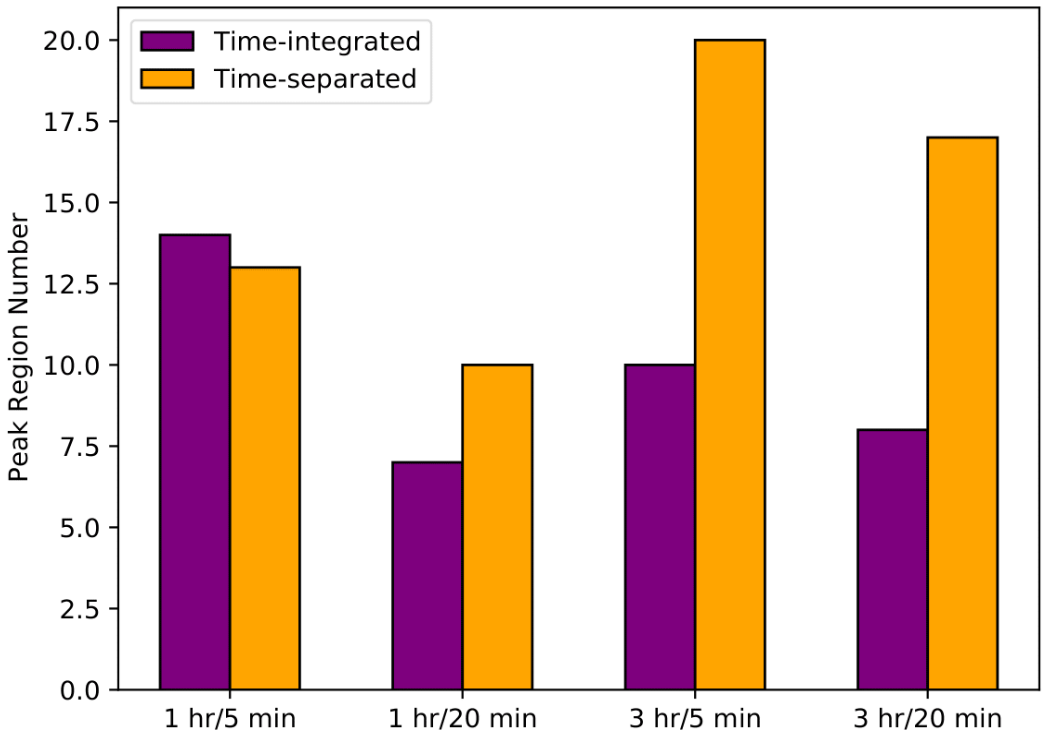


Time-Separated



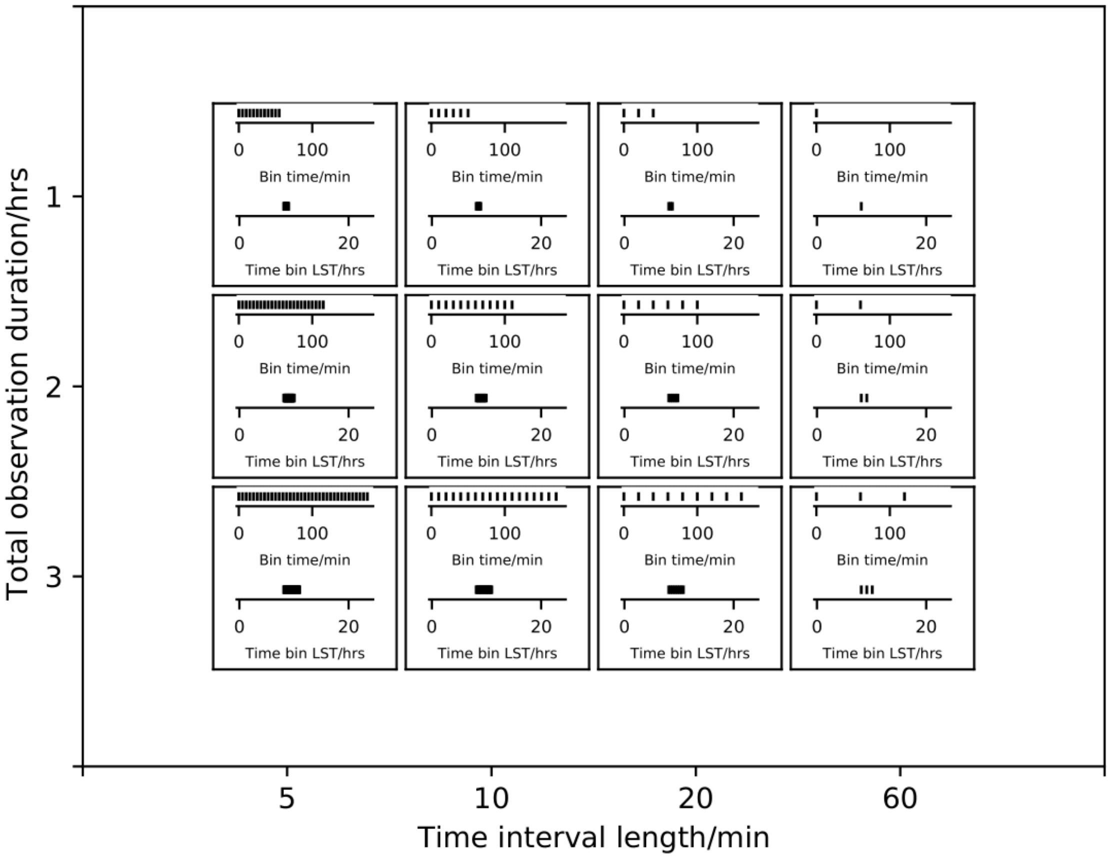
Result Comparison



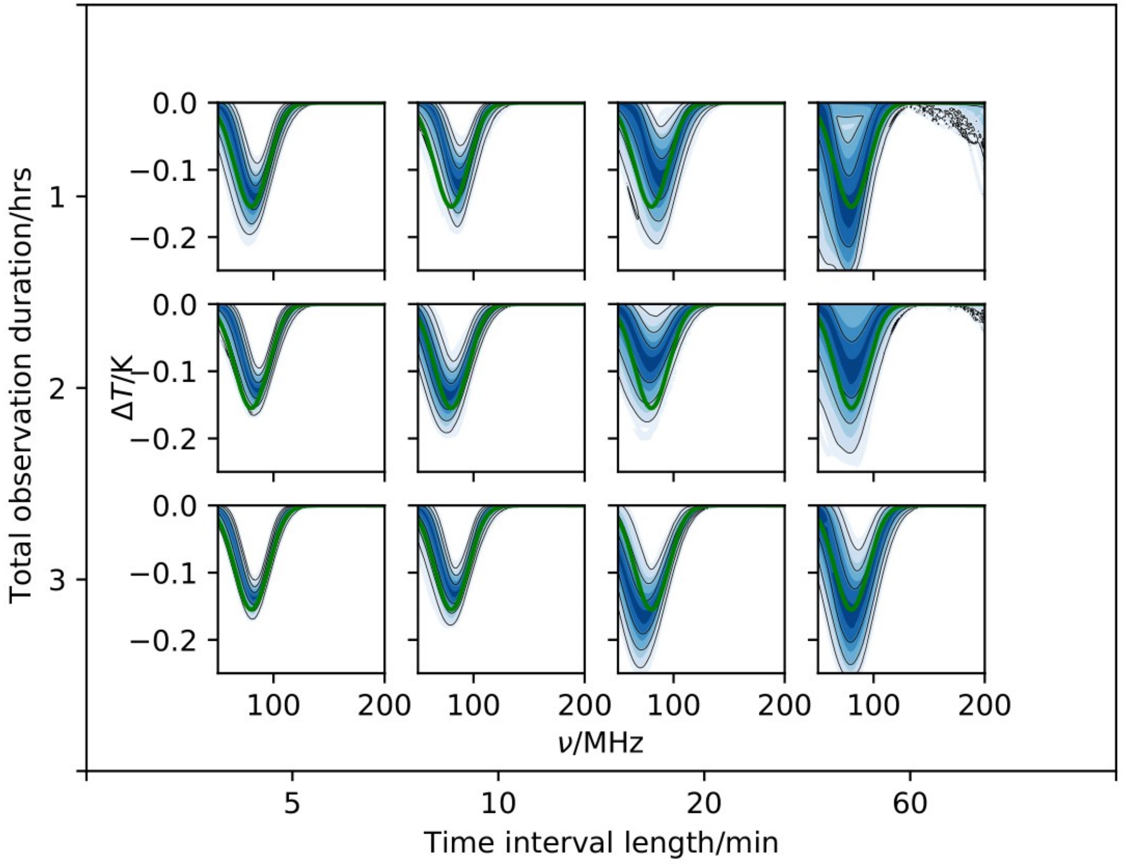


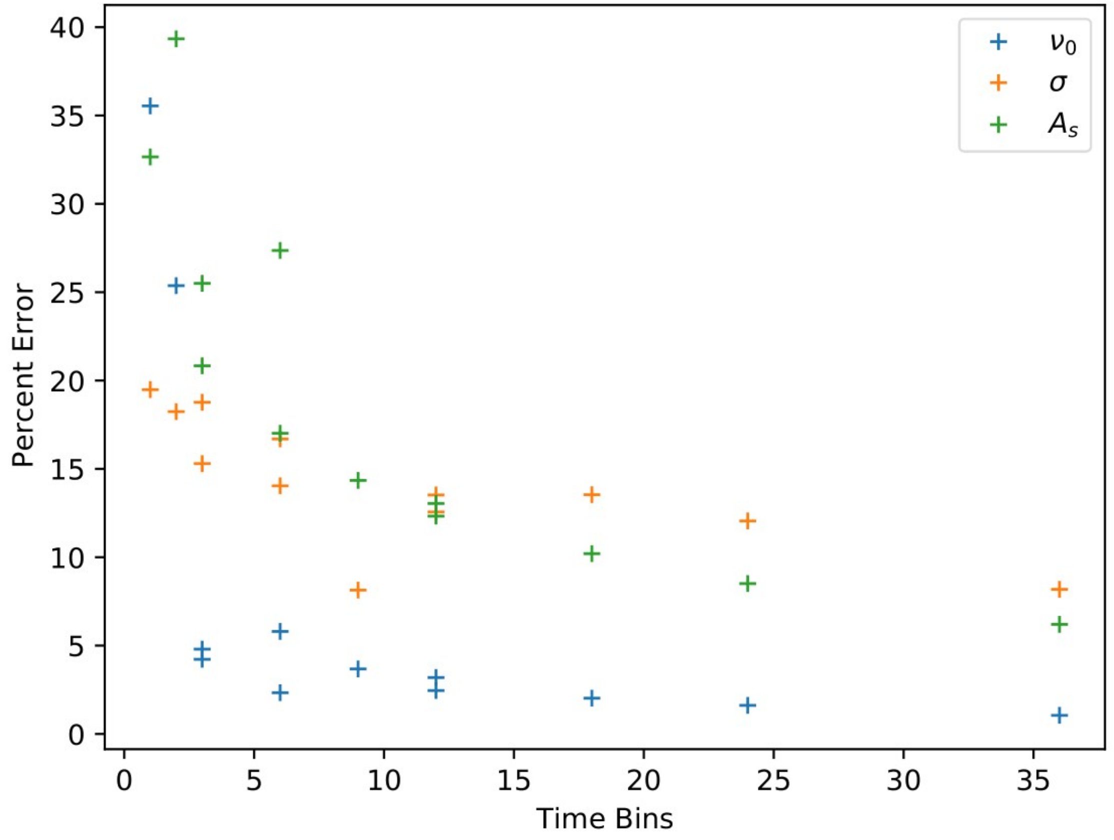
Tests of Time-Separated Analysis

- Scan over observation lengths and time-bin separations

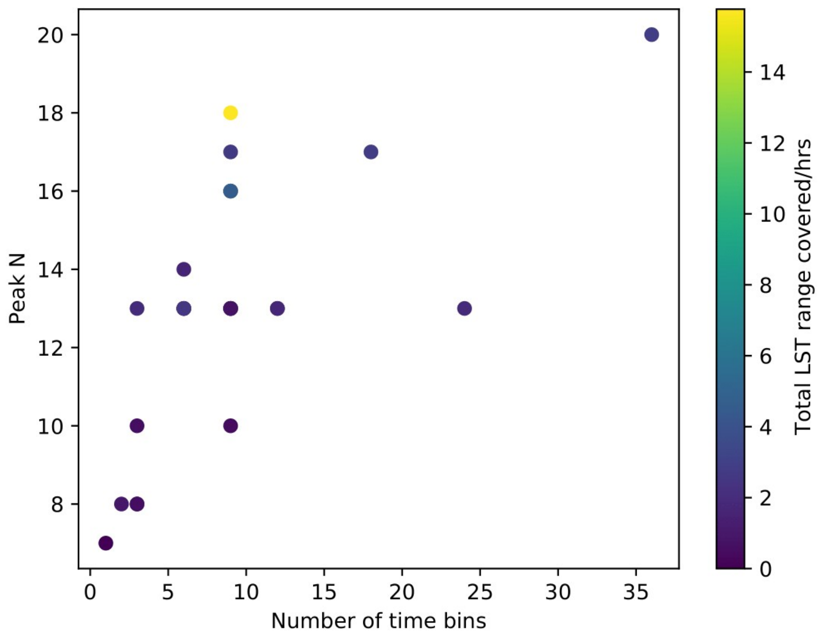


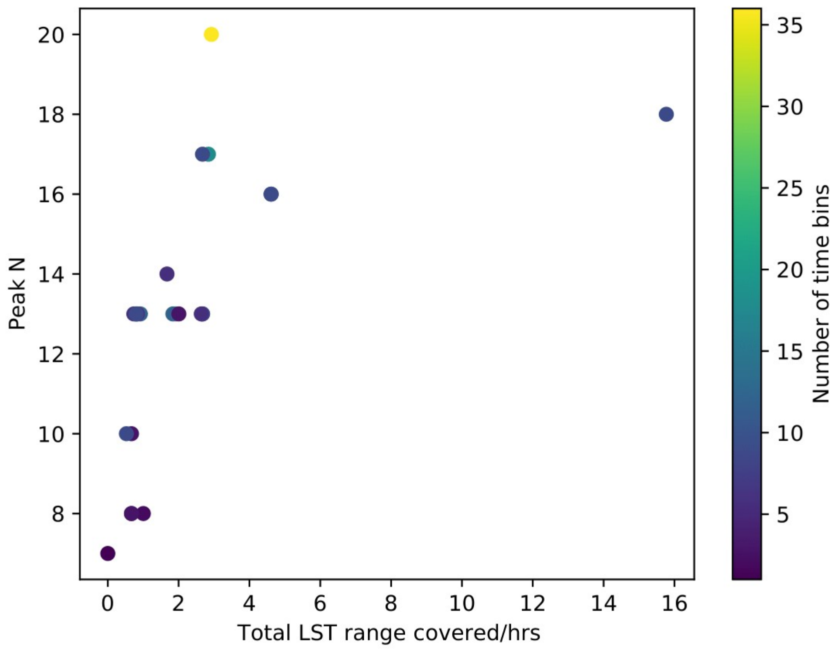
Scan Results





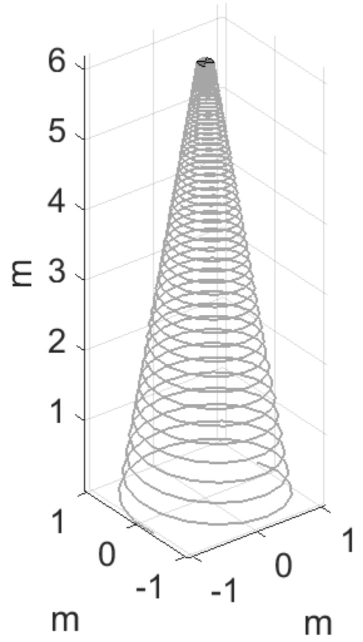
Variation in Peak Parameter Numbers

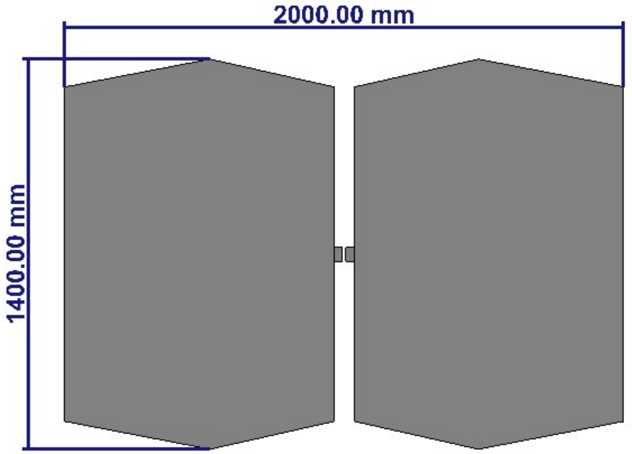




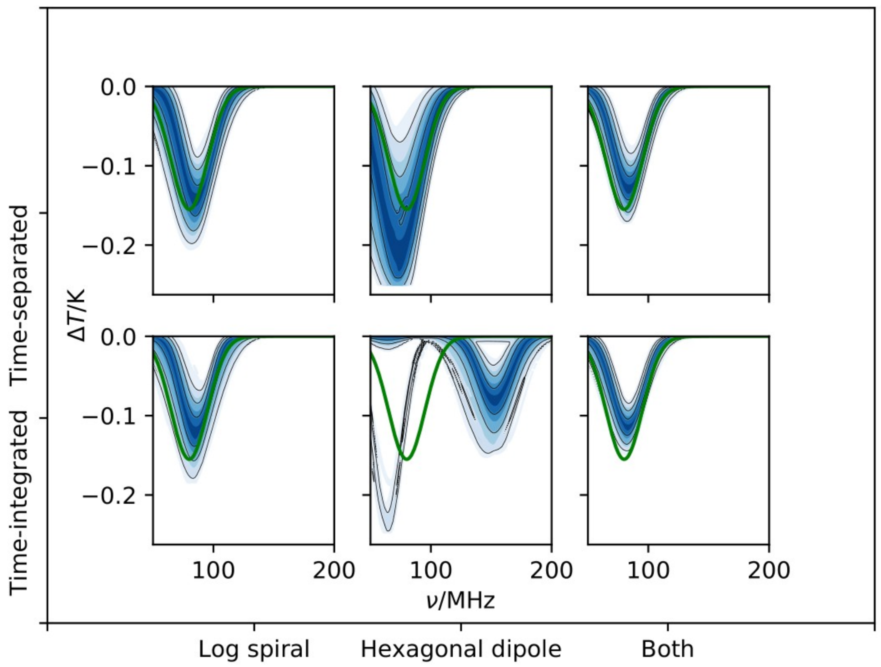
Multiple Antennae

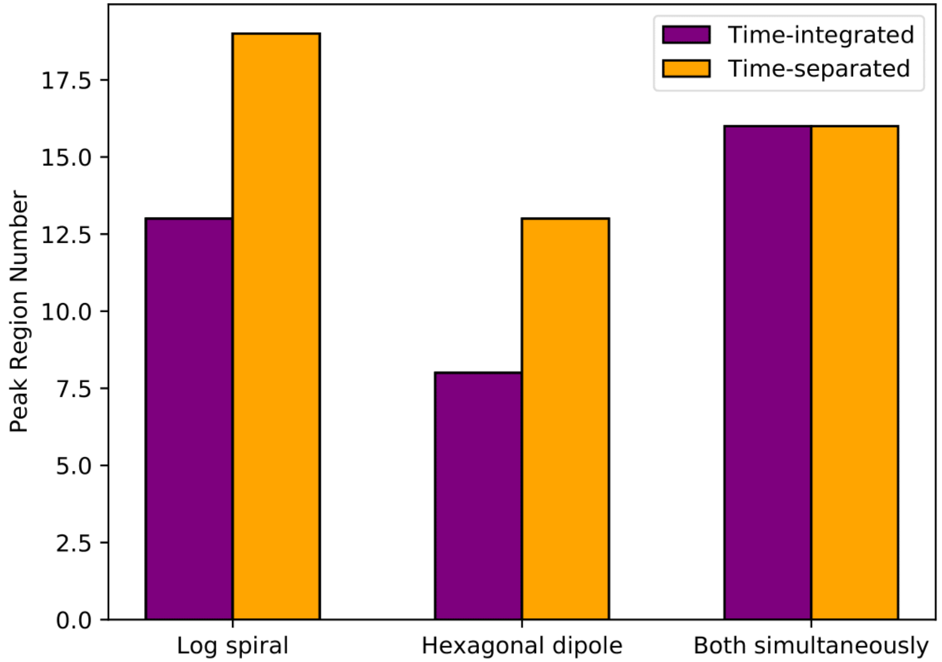
$$\log \mathcal{L} = \sum_i \sum_j \sum_k -\frac{1}{2}\log\left(2\pi\sigma_{\mathrm{n}}^2\right) - \frac{1}{2}\left(\frac{T_{\mathrm{data}\,k}\left(\nu_i, t_j\right) - \left(T_{\mathrm{F}\,k}\left(\nu_i, t_j, \theta_{\mathrm{F}}\right) + T_S\left(\nu_i, \theta_{\mathrm{S}}\right)\right)}{\sigma_{\mathrm{n}}}\right)^2$$





Multiple Antennae Results





Conclusions

- Using a physical property for the foreground parameters allow multiple time-dependent data sets to be fit simultaneously
- This produces a significant improvement in signal reconstuction over a single model fit to integrated data
- Signal recovery accuracy improves with increasing number of time bins and increasing LST range covered by them
- Number of parameters in the foreground model required to achieve an optimal model fit also increases with increasing number of time bins and increasing LST range
- Method extends to allowing data from multiple antennae to be fit simultaneously, which gives further improvement in signal recovery

Antenna EM simulations provided by John Cumner and Quentin Gueuning

Plots produced using fgivenx tool: Handley, 2018

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