

The Angular Power Spectrum measurement using TGSS survey

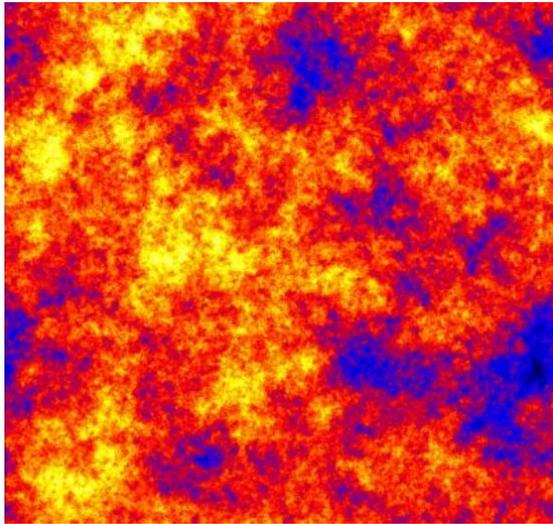
Samir Choudhuri
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with

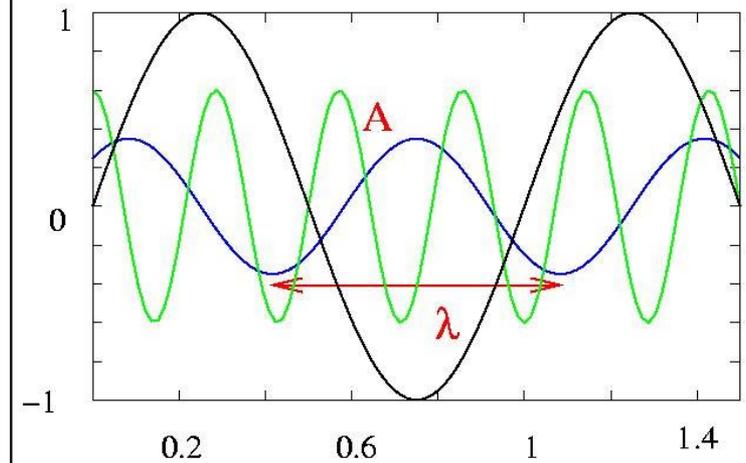
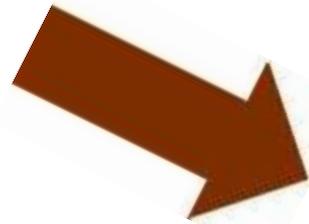
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Nirupam Roy, Prasun Dutta, Huib Intema



Angular Power Spectrum



a particular realization of a statistically homogeneous and isotropic Gaussian Random Field

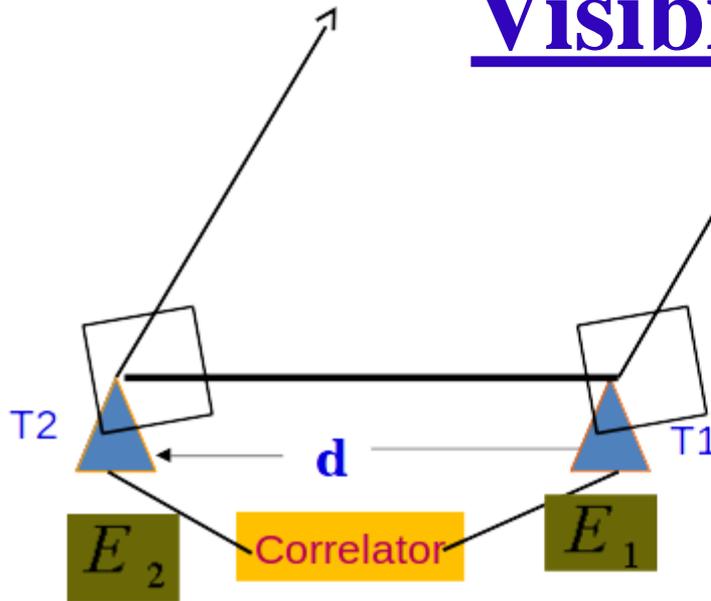


comoving wave number $k=2 \pi / \lambda$

$$\langle \Delta \tilde{T}(\mathbf{U}) \Delta \tilde{T}^*(\mathbf{U}') \rangle = \delta_D^2(\mathbf{U} - \mathbf{U}') C_{2\pi U}$$

Radio Interferometers:

Visibilities



$$V(\mathbf{U}, \nu) = \iint A_\nu(\boldsymbol{\theta}) I_\nu(\boldsymbol{\theta}) e^{-2\pi i \mathbf{U} \cdot \boldsymbol{\theta}} d^2 \boldsymbol{\theta}$$

Antenna beam pattern \downarrow \searrow **Sp. Intensity**

$$V(\mathbf{U}, \nu) = S(\mathbf{U}, \nu) + \mathcal{N}(\mathbf{U}, \nu)$$

How are they related?

$$\mathcal{V}(\mathbf{U}, \nu) = \mathcal{S}(\mathbf{U}, \nu) + \mathcal{N}(\mathbf{U}, \nu)$$



Entire Sky Signal

Two Visibility Correlation:

$$V_{2ij} \equiv \langle \mathcal{V}_i \mathcal{V}_j^* \rangle = V_0 e^{-|\Delta \mathbf{U}_{ij}|^2 / \sigma_0^2} C_{\ell_j} + \delta_{ij} 2\sigma_n^2$$

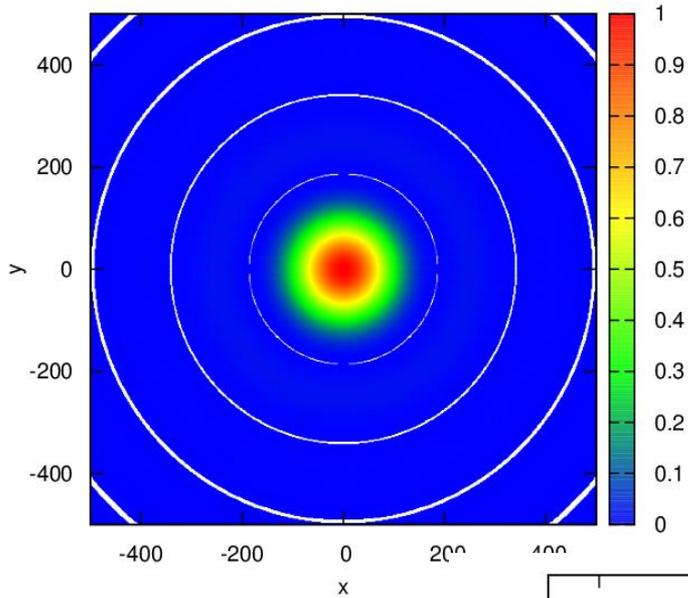
Noise bias can be avoided by excluding self-correlation term.

Estimator

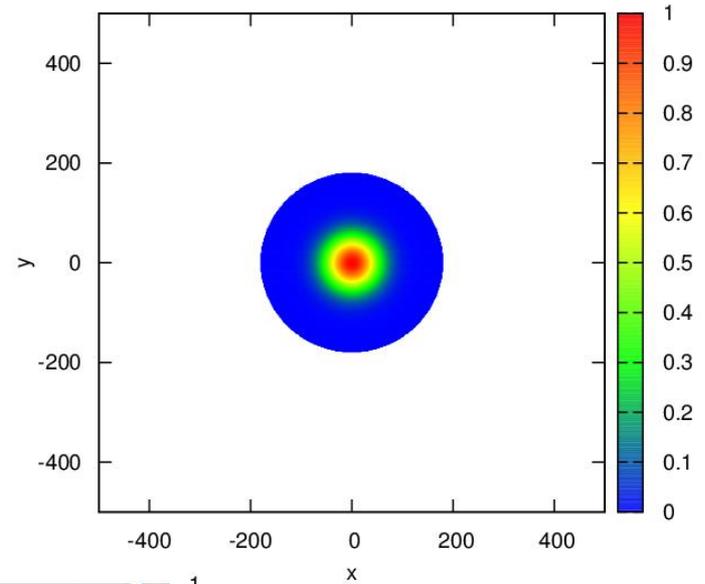
Tapered Gridded Estimator

- Gridded Estimator
- Suppress Side-lobe Response
- Remove Noise Bias

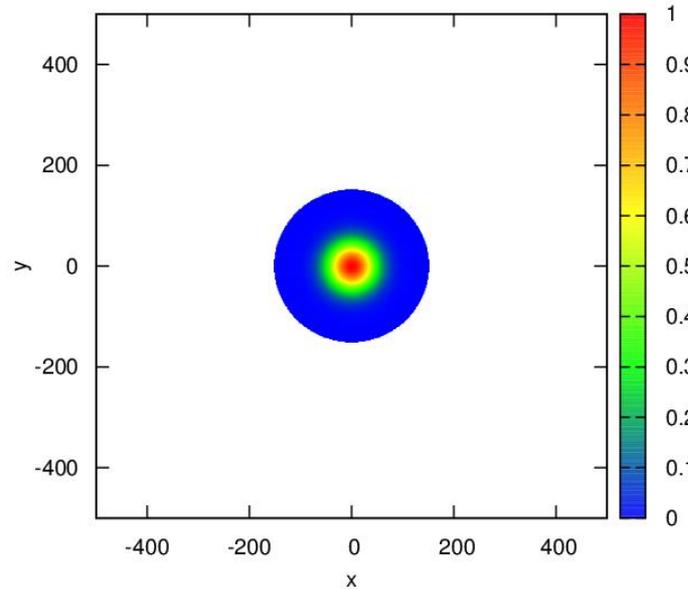
Tapered Gridded Estimator



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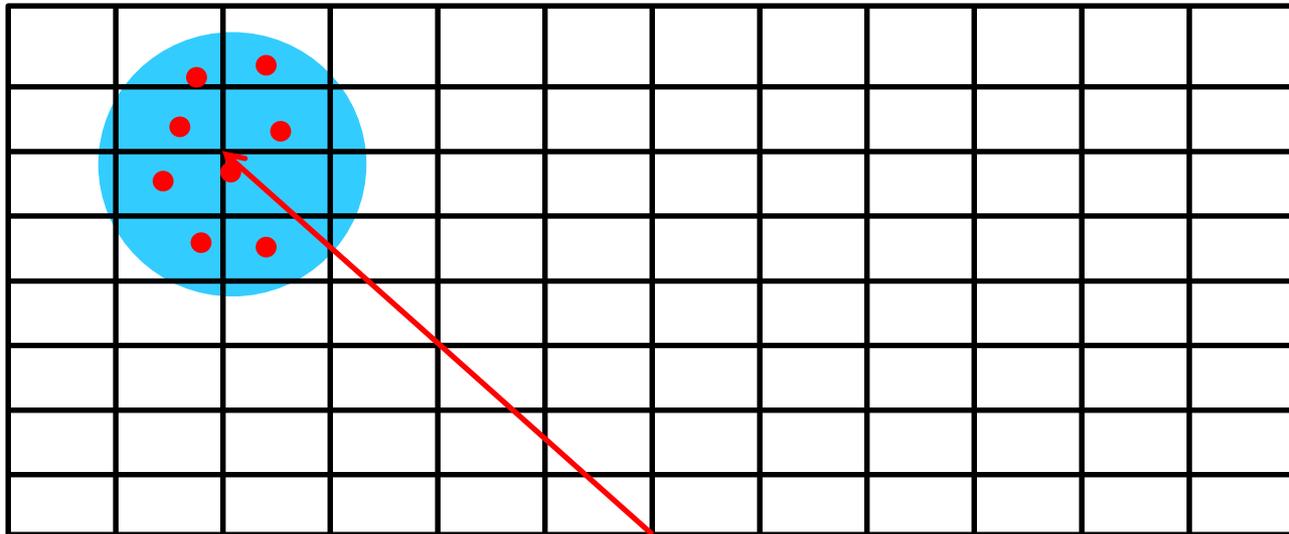


Primary Beam



Taper Window

Tapering and Gridding



$$\mathcal{V}_{cg} = \sum_i \tilde{w}(\mathbf{U}_g - \mathbf{U}_i) \mathcal{V}_i$$

Tapered Gridded Estimator

$$\left\langle \left(|\mathcal{V}_{cg}|^2 - \sum_i |\tilde{w}(\mathbf{U}_g - \mathbf{U}_i)|^2 |\mathcal{V}_i|^2 \right) \right\rangle = M_g C_{2\pi U_g}$$

$$\hat{E}_g = M_g^{-1} \left(|\mathcal{V}_{cg}|^2 - \sum_i |\tilde{w}(\mathbf{U}_g - \mathbf{U}_i)|^2 |\mathcal{V}_i|^2 \right)$$

$$\langle \hat{E}_g \rangle = C_{\ell_g}$$

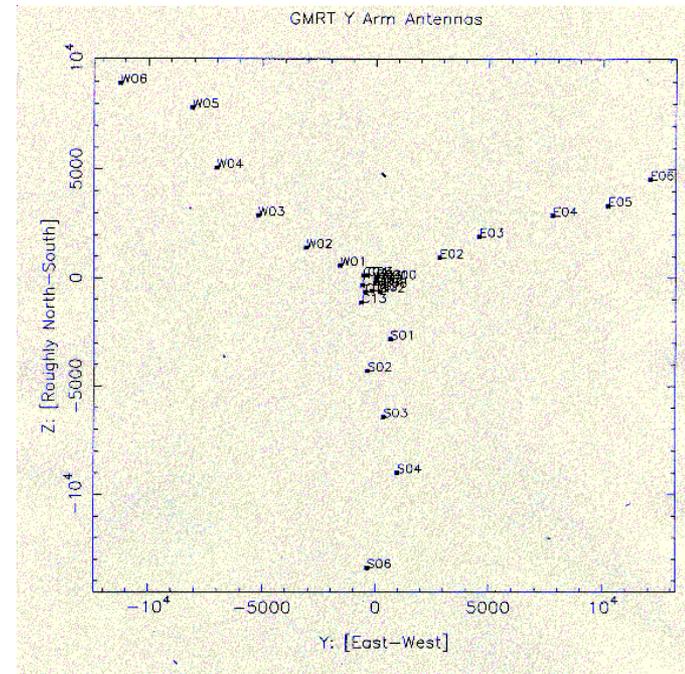
Validation

GMRT @ 150 MHz Simulations



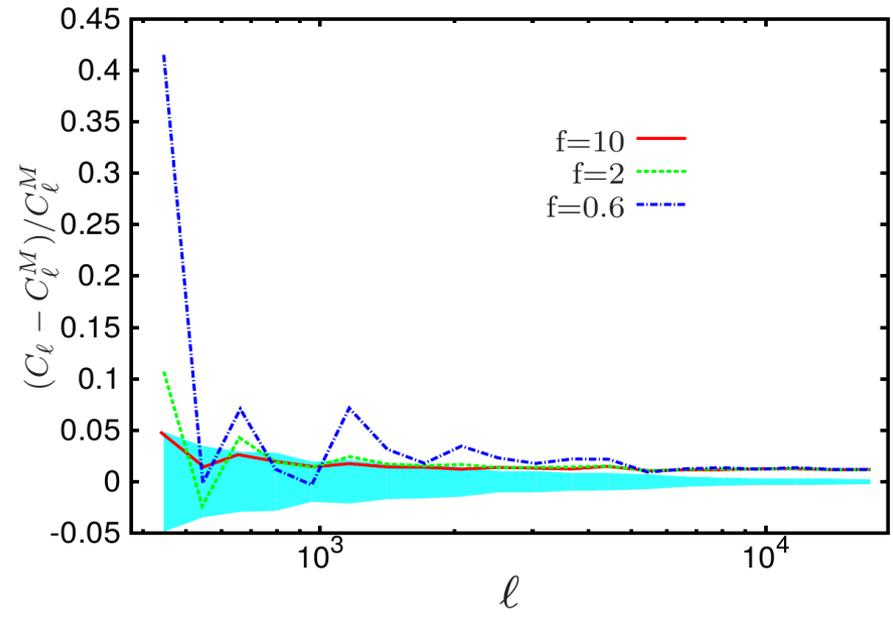
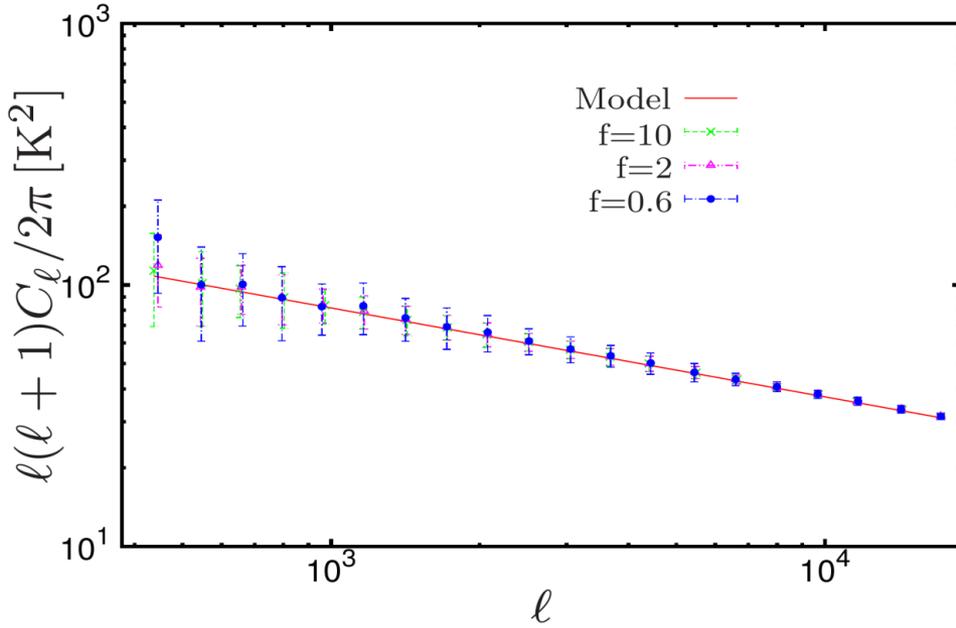
GMRT

30 antennas 45m diameter



Frequency MHz	153	235	325	610	1420
z	8.3	5.0	3.4	1.3	0

Results:



Application

TIFR GMRT Sky Survey-ADR Data

Frequency	147.5 MHz
Bandwidth	16.7 MHz
Number of Fields	5336
Integration per field	15 min
Total survey time	2000 hrs
Sky coverage	36,900 deg ²
RMS noise (median)	3.5 mJy beam ⁻¹
Resolution (DEC > 19°)	25'' × 25''
Resolution (DEC < 19°)	25'' × 25'' / cos (DEC – 19°)
Number of sources	640,017

We have used two data sets:

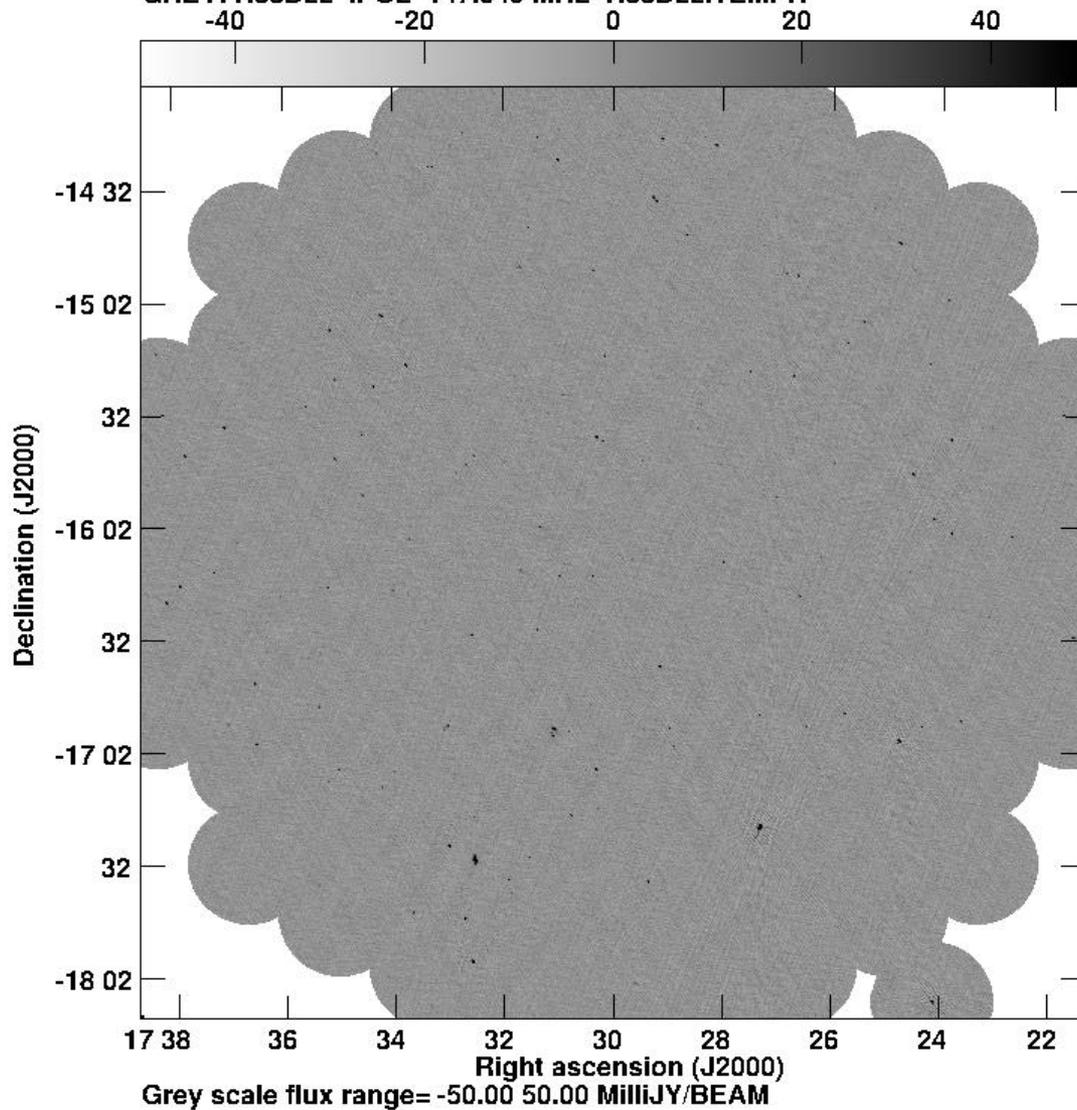
Galactic coordinate:

Data1:(+9deg, +10deg)

Data2:(+15deg, -11deg)

Data1:

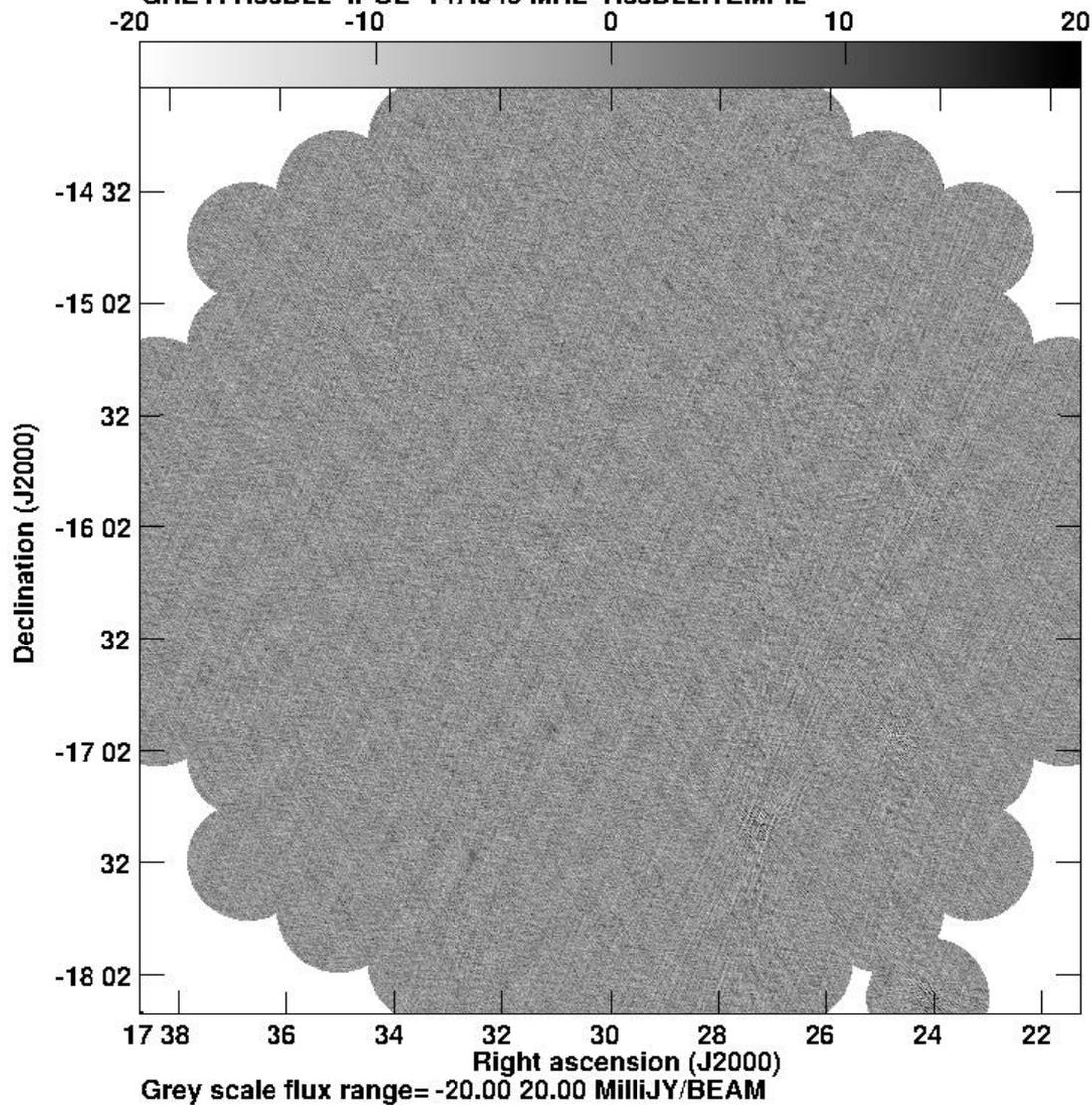
PLot file version 1 created 24-JAN-2017 18:03:20
GREY: R53D22 IPOL 147.049 MHZ R53D22.TEMP.1



Before

Data1:

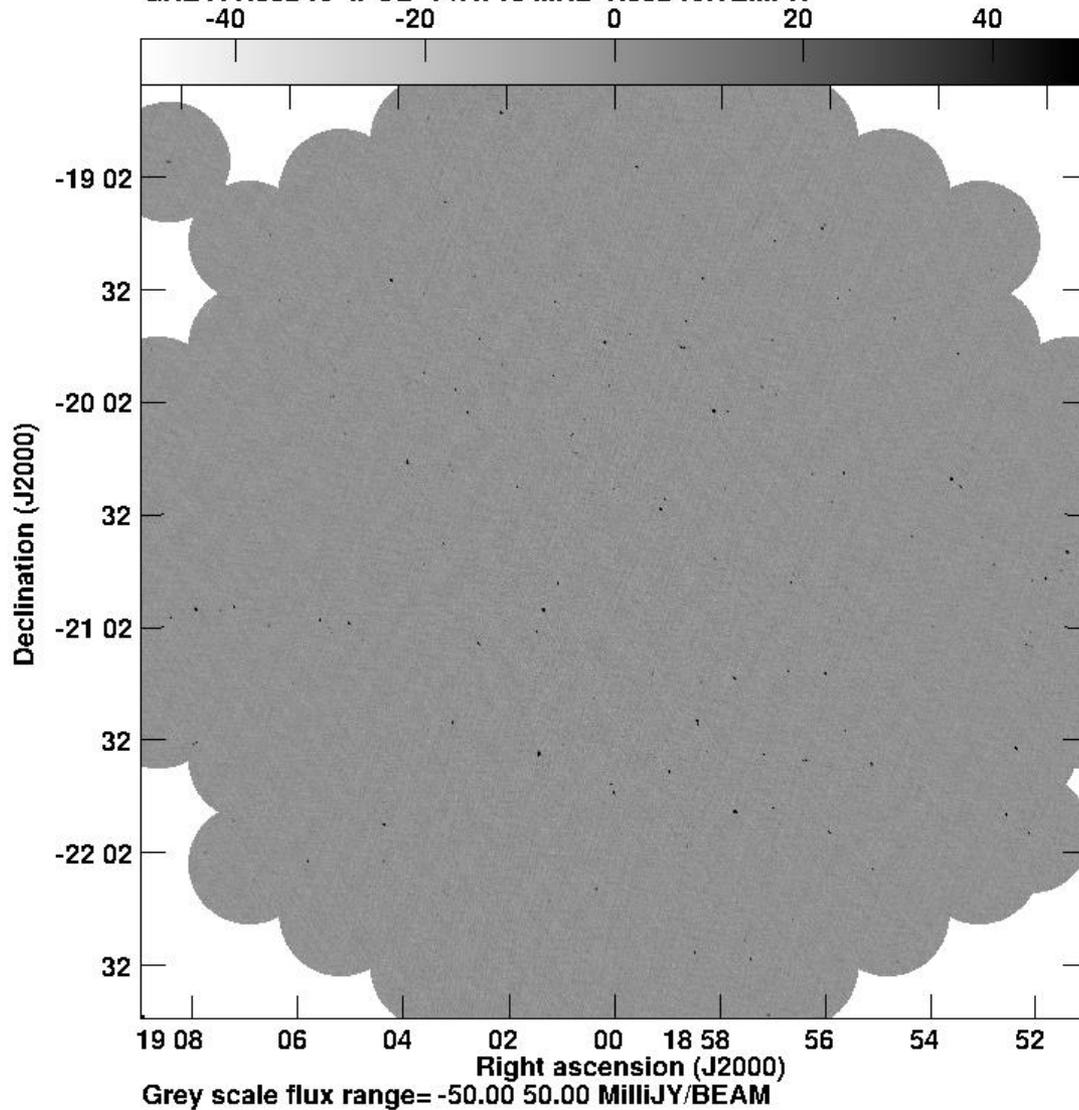
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GREY: R53D22 IPOL 147.049 MHZ R53D22.TEMP.2



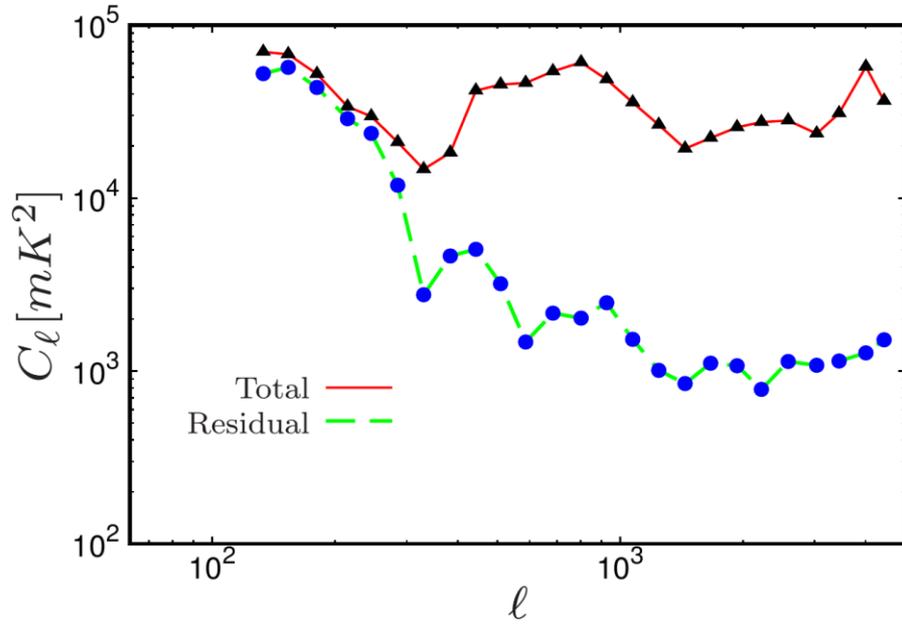
After

Data2:

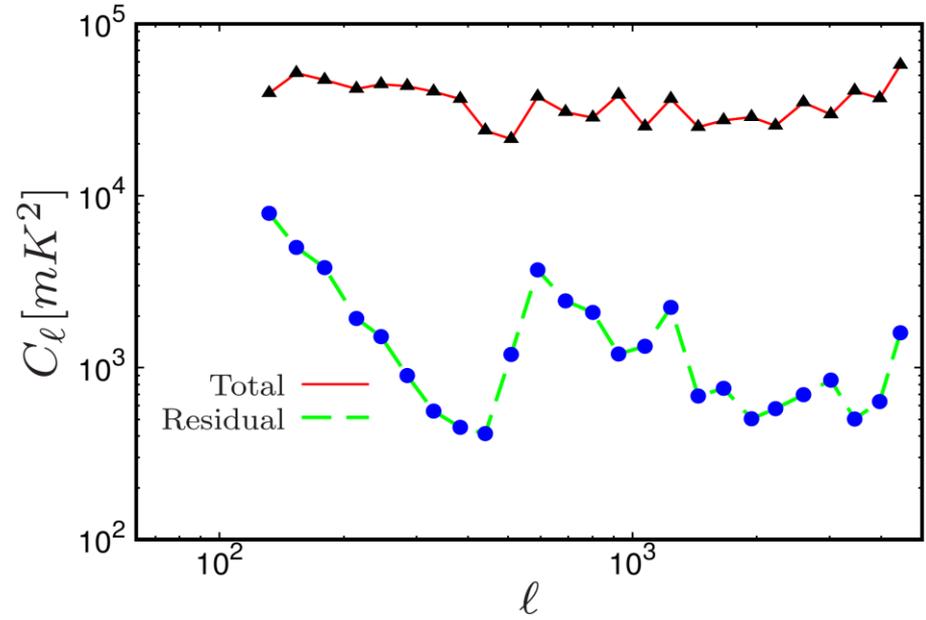
PLot file version 1 created 24-JAN-2017 18:14:11
GREY: R58D19 IPOL 147.716 MHZ R58D19.TEMP.1



Angular power spectrum measurement



Data1



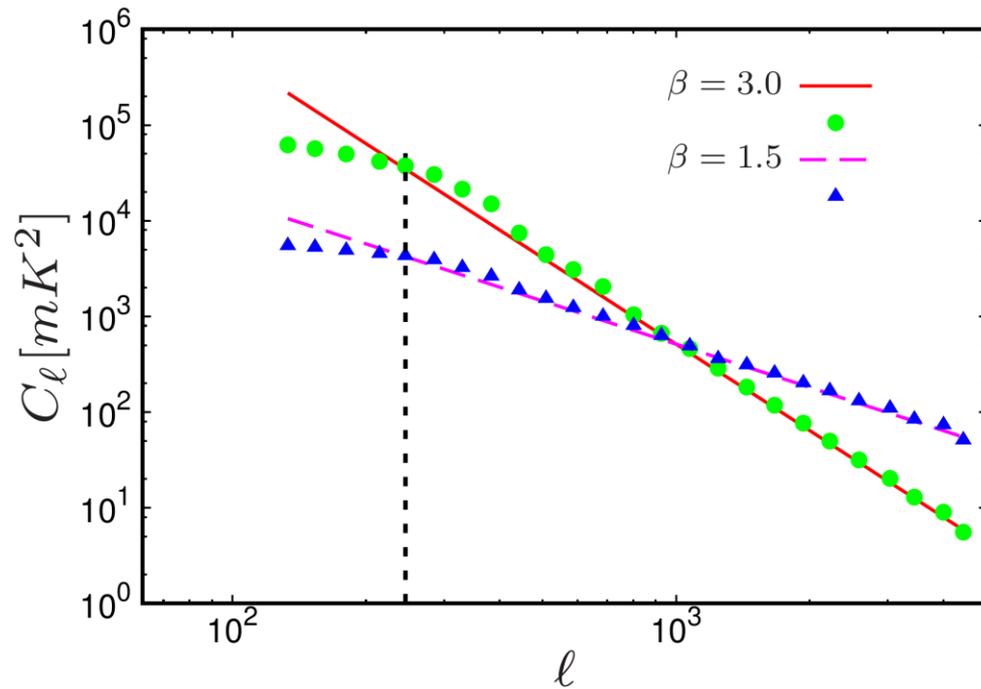
Data2

Convolution effect

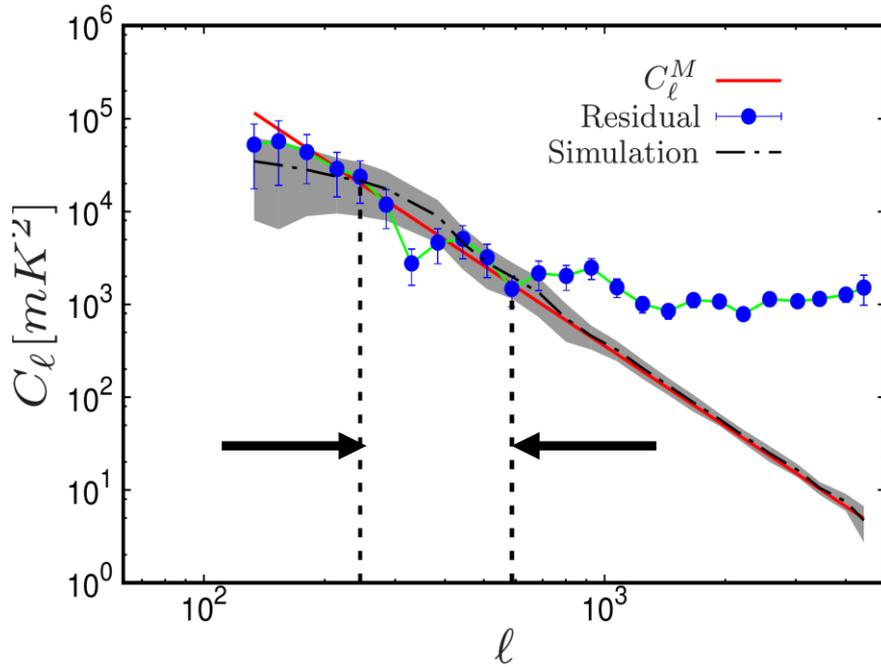
$$\langle | \mathcal{S}_i |^2 \rangle = \left(\frac{\partial B}{\partial T} \right)^2 \int d^2 U \tilde{a}(\mathbf{U}_i - \mathbf{U}) \tilde{a}^*(\mathbf{U}_i - \mathbf{U}) C_{2\pi U_i}$$

$$\langle | \mathcal{S}_i |^2 \rangle = V_0 C_{2\pi U_i}$$

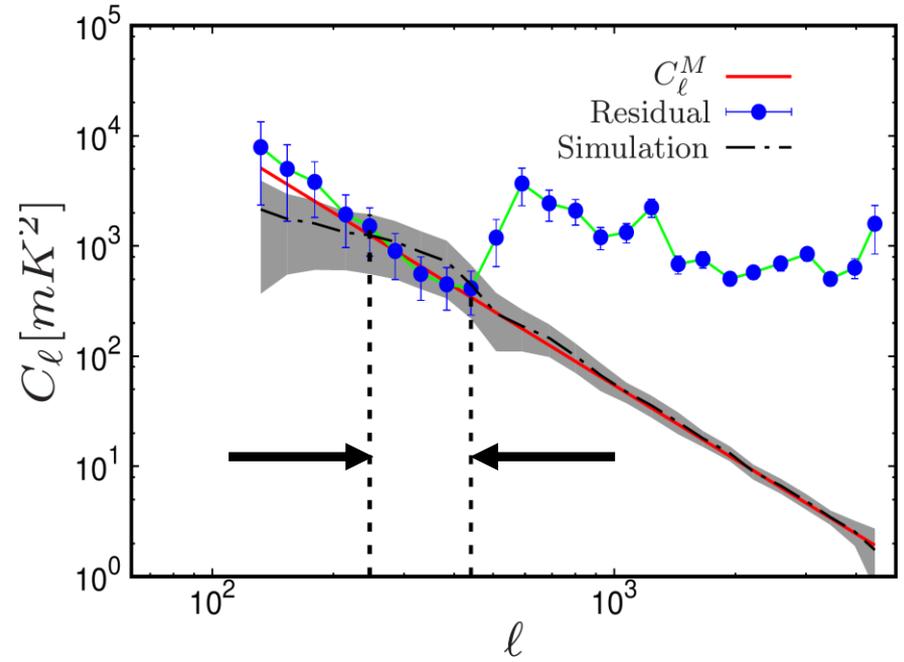
$$V_0 = \left(\frac{\partial B}{\partial T} \right)^2 \int d^2 U | \tilde{a}(\mathbf{U}_i - \mathbf{U}) |^2$$



Angular power spectrum measurement

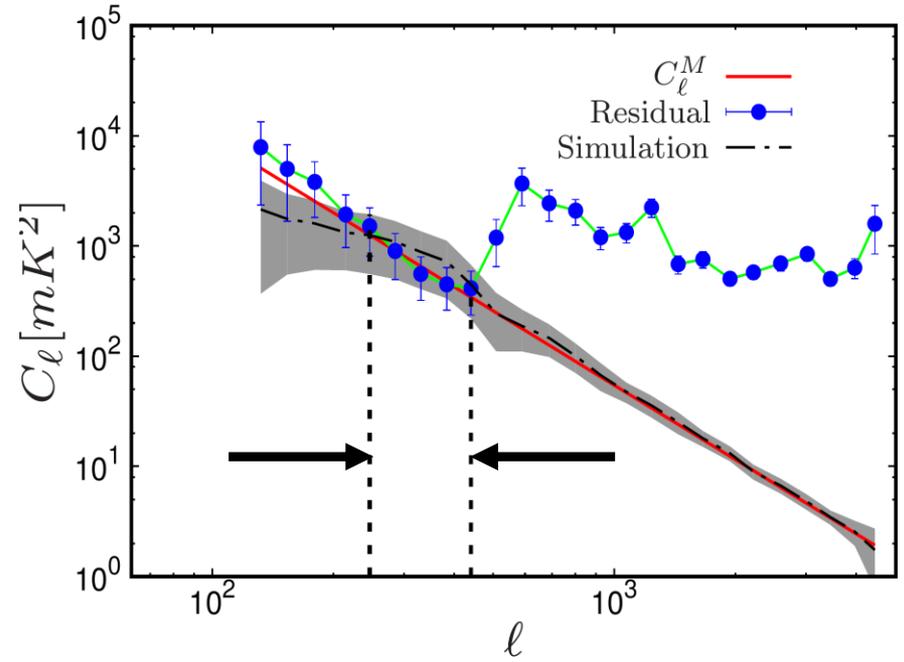
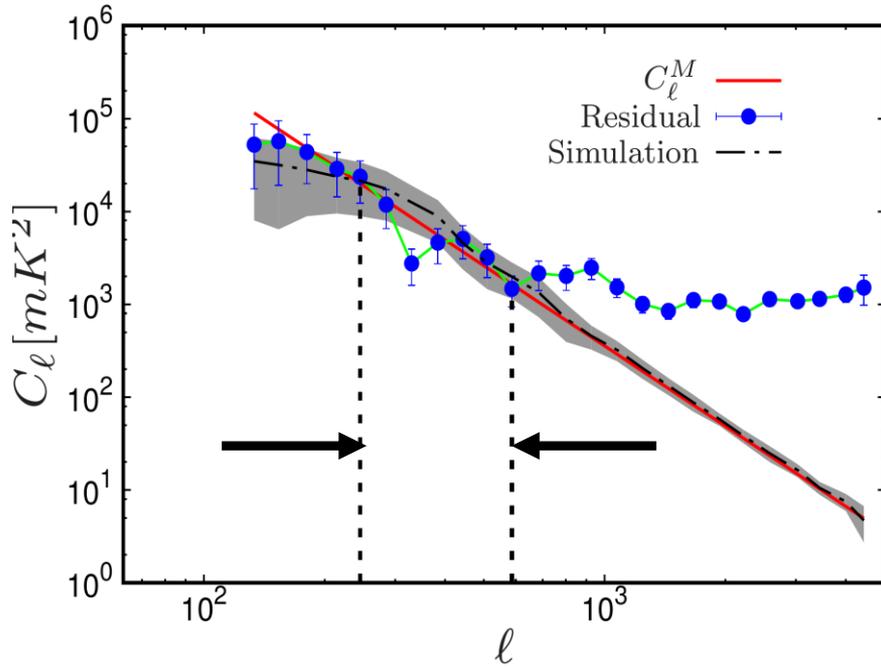


Data1



Data2

Angular power spectrum measurement



	Galactic Co-ordinate (l, b)	l_{min}	l_{max}	A (mK^2)	β
Data1	($9^\circ, +10^\circ$)	240	580	356 ± 109	2.8 ± 0.3
Data2	($15^\circ, -11^\circ$)	240	440	54 ± 26	2.2 ± 0.4

consistent with earlier measurements Bernardi et al. (2009); Ghosh et al. (2012); Iacobelli et al. (2013)

Summary

- We have developed the Tapered Gridded Estimator (TGE) to estimate the angular power spectrum and validated using GMRT 150MHz simulations.
- We have applied the TGE to real GMRT (TGSS) data.
- We found the sky signal, after subtracting the point sources, is likely dominated by the diffuse Galactic synchrotron radiation across the angular multipole range $240 \leq \ell \leq 500$.

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Thank You