

LCGTを用いた重力波ラジオメトリ

- 波源探索の実現性 -

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LCGT Collaboration

Osaka City Univ. Kanda-Lab

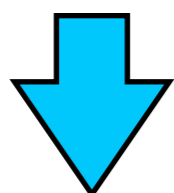
I. What's GW Radiometry

II. Spreading of point source

III. Summary and Future

Possible sources

- Astrophysical gravitational wave background
- Stochastic gravitational wave background

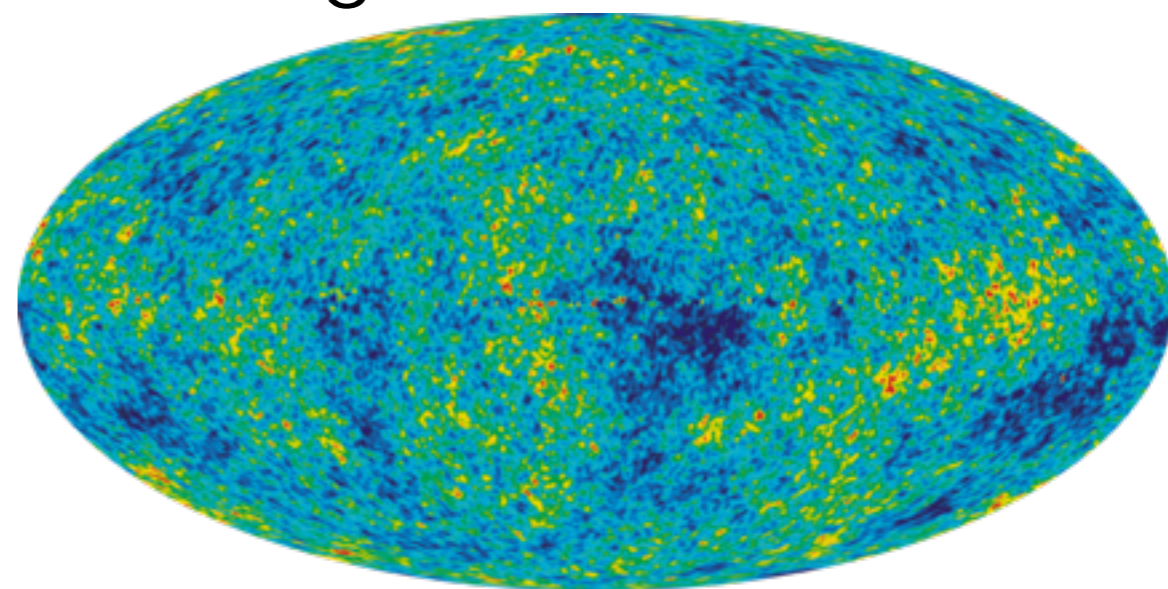


e.g.)
unresolved GW from pulsars of extra galaxies
or other cluster of galaxies

Stationary signal

We can extract the correlation between two of more detector outputs with appropriate time lag for particular direction.

We will be able to find GW hotspots or an anisotropy of GW background.



Radiometry Filter

$$Q = \lambda \frac{\gamma^*(f, \Omega) H(f)}{P_1(f) P_2(f)}$$

λ : normalization factor

$H(f)$: GW PSD

P_i : detector noise PSD

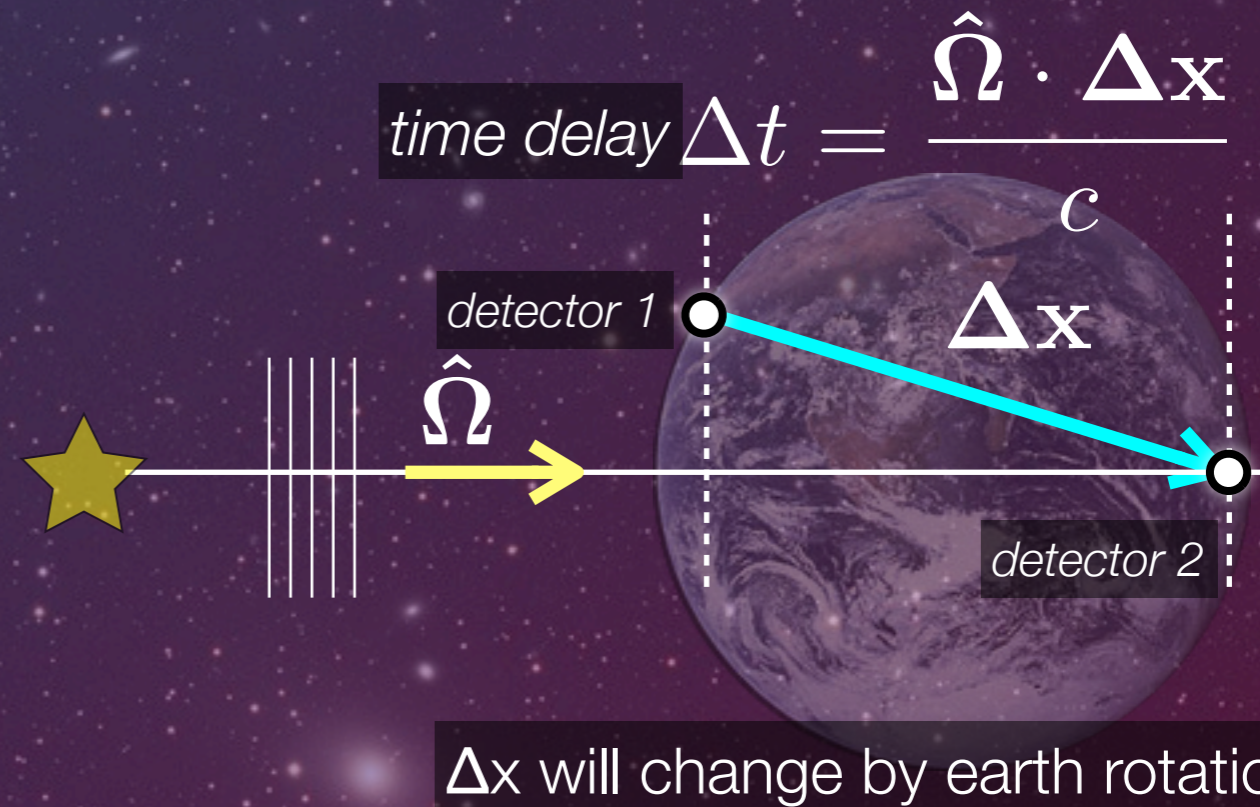
Antenna response

$$\gamma(f, \Omega) = \sum_{A=+, \times} F_1^A F_2^A e^{2\pi f i \hat{\Omega} \cdot \Delta \vec{x} / c}$$

$\Gamma(\hat{\Omega}, t)$

phase correction

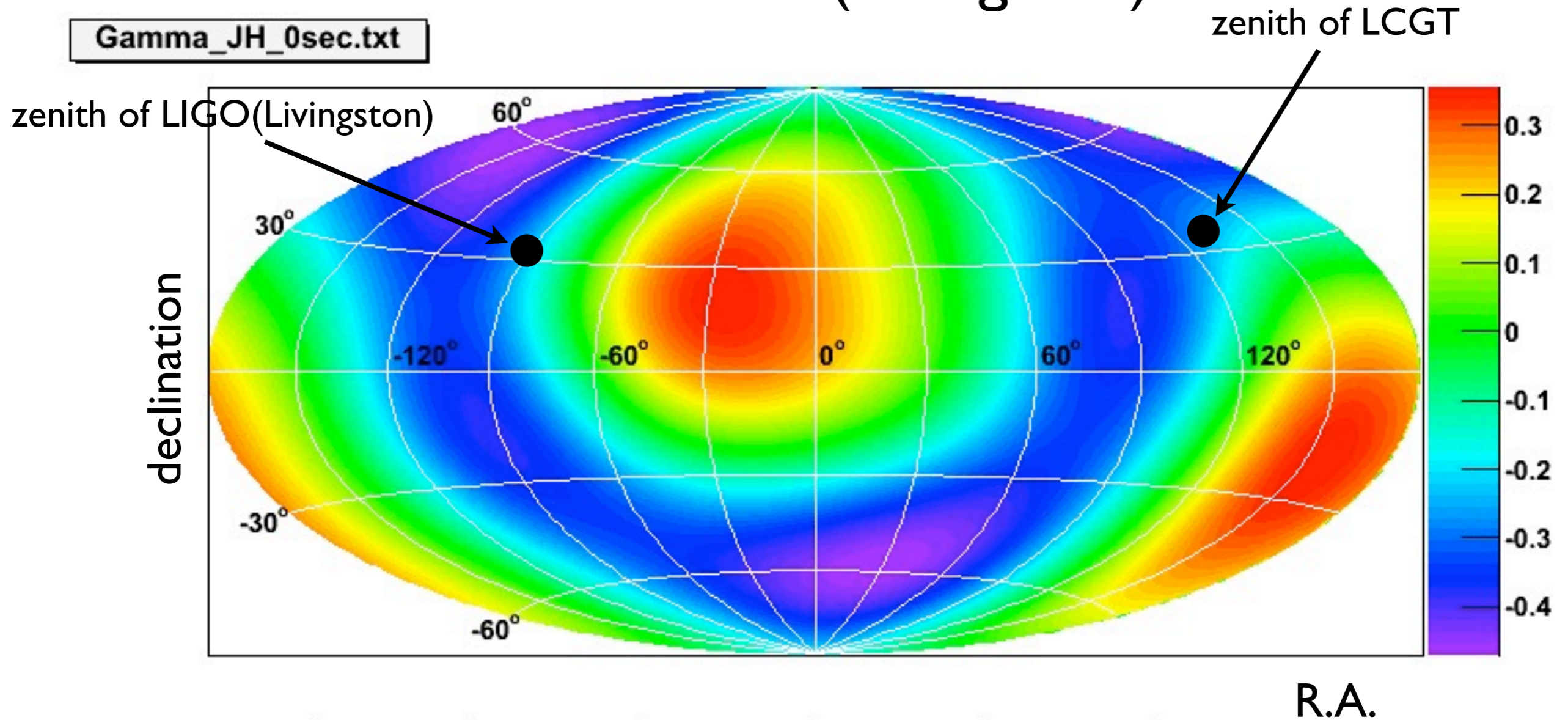
$$x_{1,2}(t) \text{ for } [t_k - \Delta t/2, t_k + \Delta t/2] \\ \Rightarrow \tilde{x}_{1,2}(t_k; f)$$



$$\Delta S_k(\hat{\Omega}) = \int_{-\infty}^{\infty} df \tilde{x}_1^*(t_k; f) \tilde{x}_2(t_k; f) \tilde{Q}(t_k, f, \hat{\Omega})$$

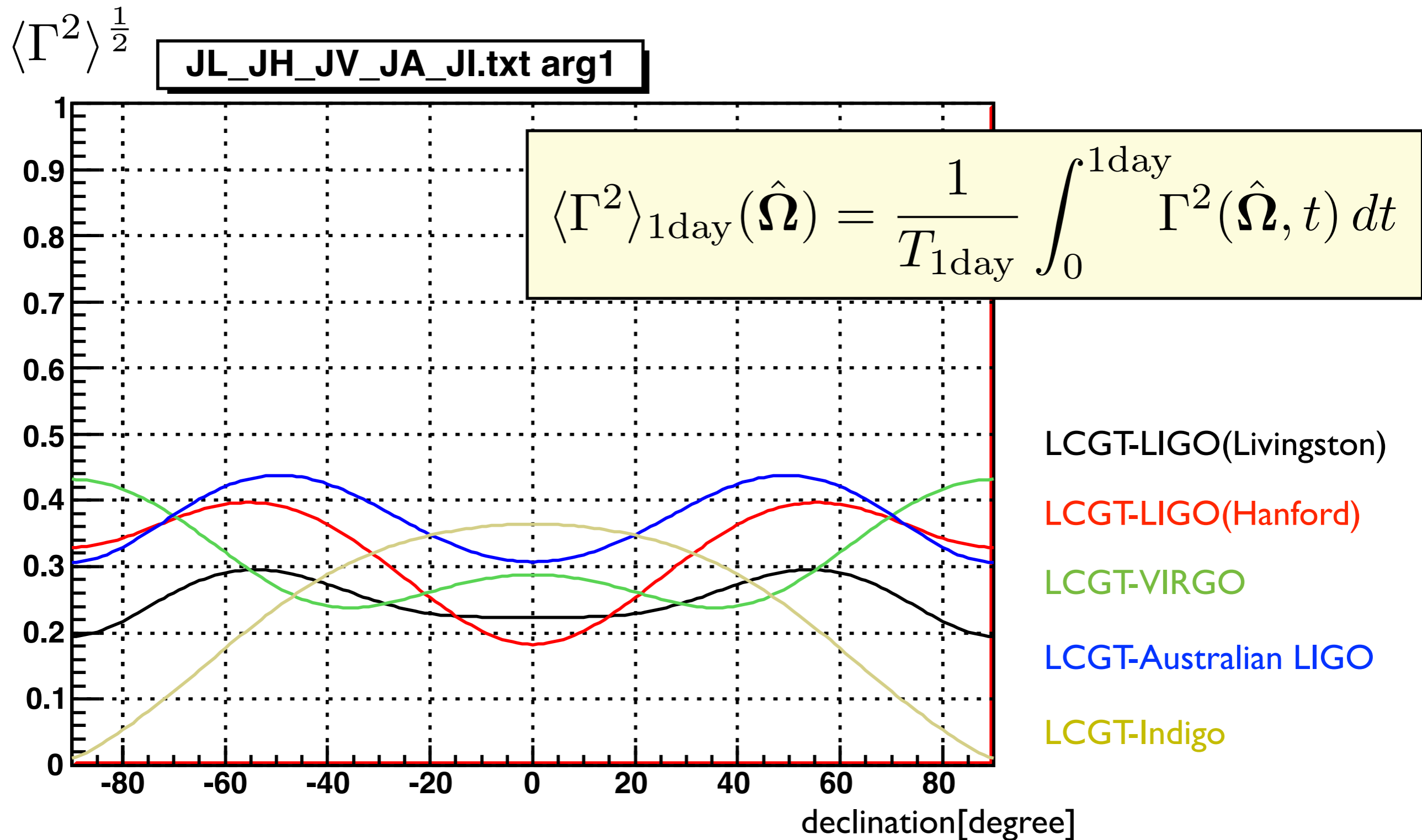
drawn by Nobuyuki Kanda

LCGT-LIGO(Livingston)



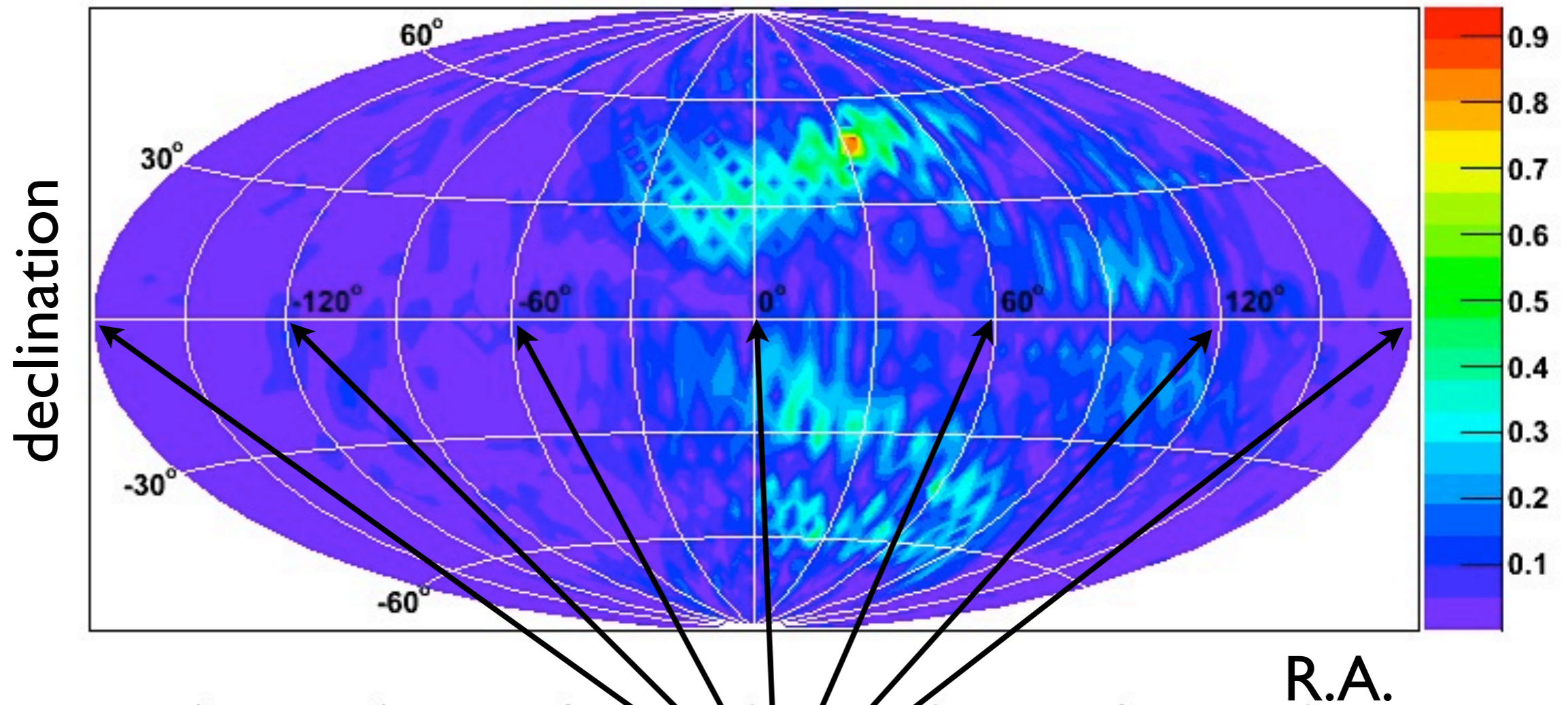
$$\Gamma(\hat{\Omega}, t = 0) \quad t : \text{GMT}$$

Spreading of point source



Spreading of point source

GW_radiometry.txt

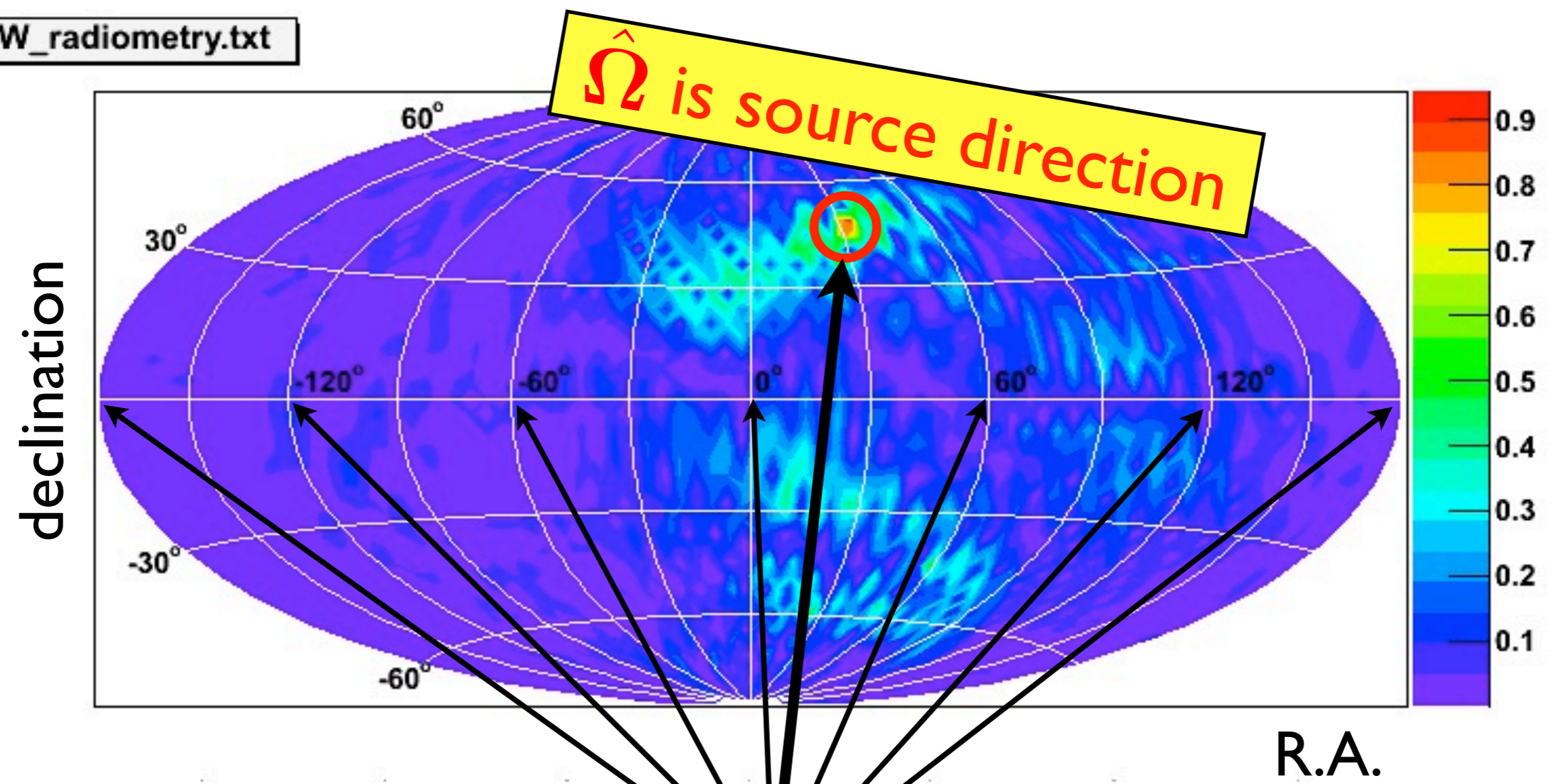


check for all sky by Ω changed

$\hat{\Omega}$

What's GW radiometry

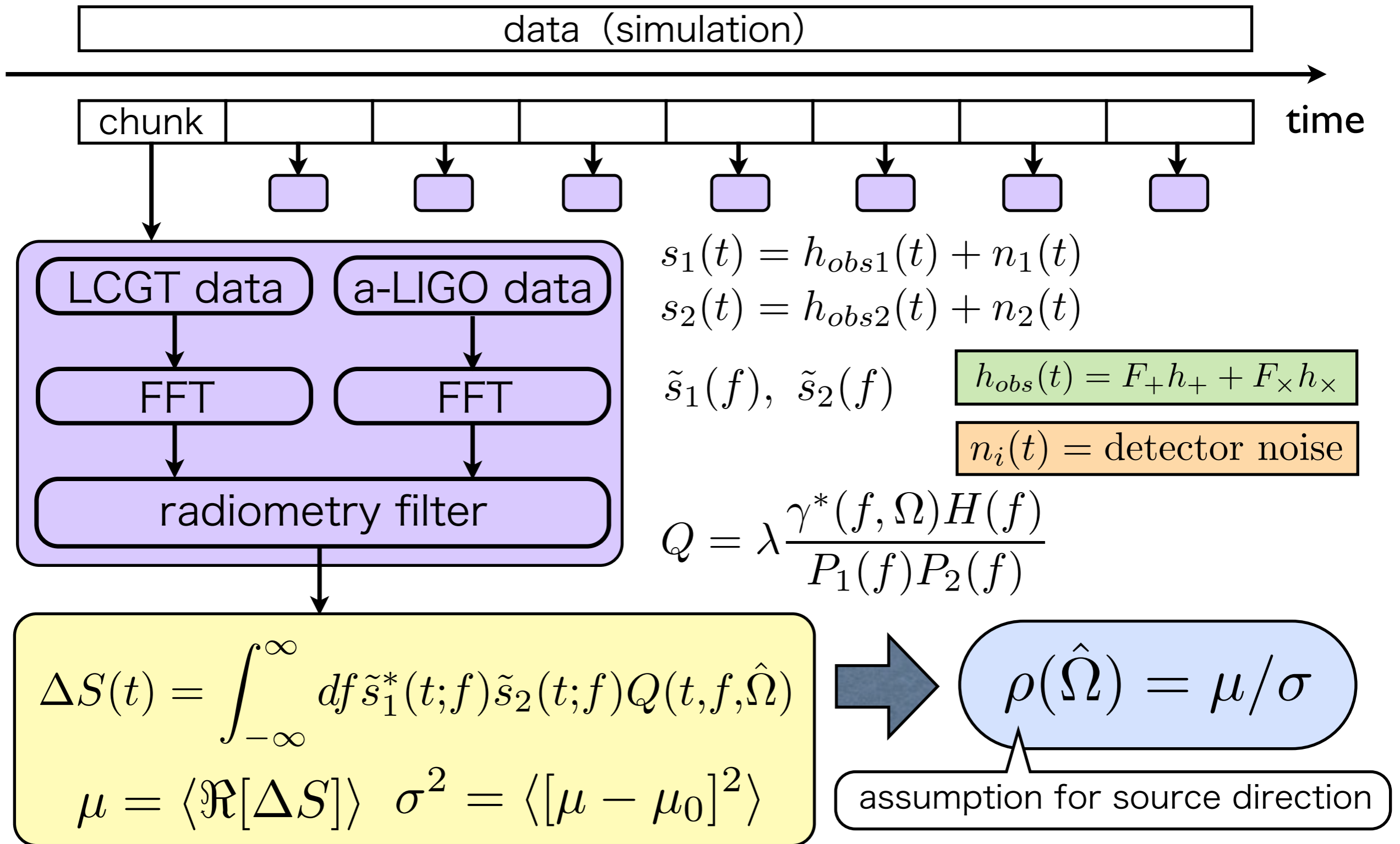
GW_radiometry.txt

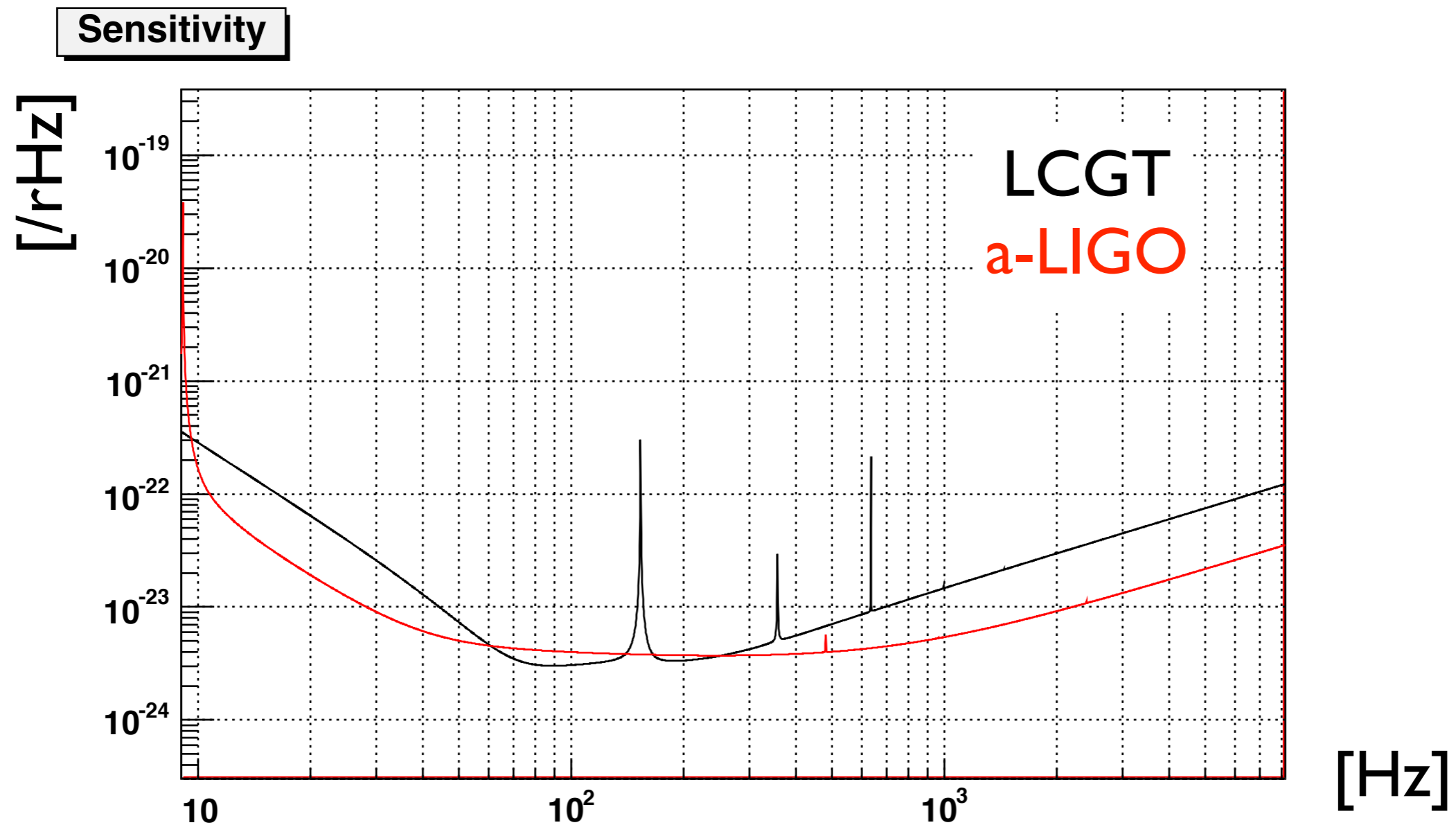


check for all sky by $\hat{\Omega}$ changed

$\hat{\Omega}$

What's GW radiometry





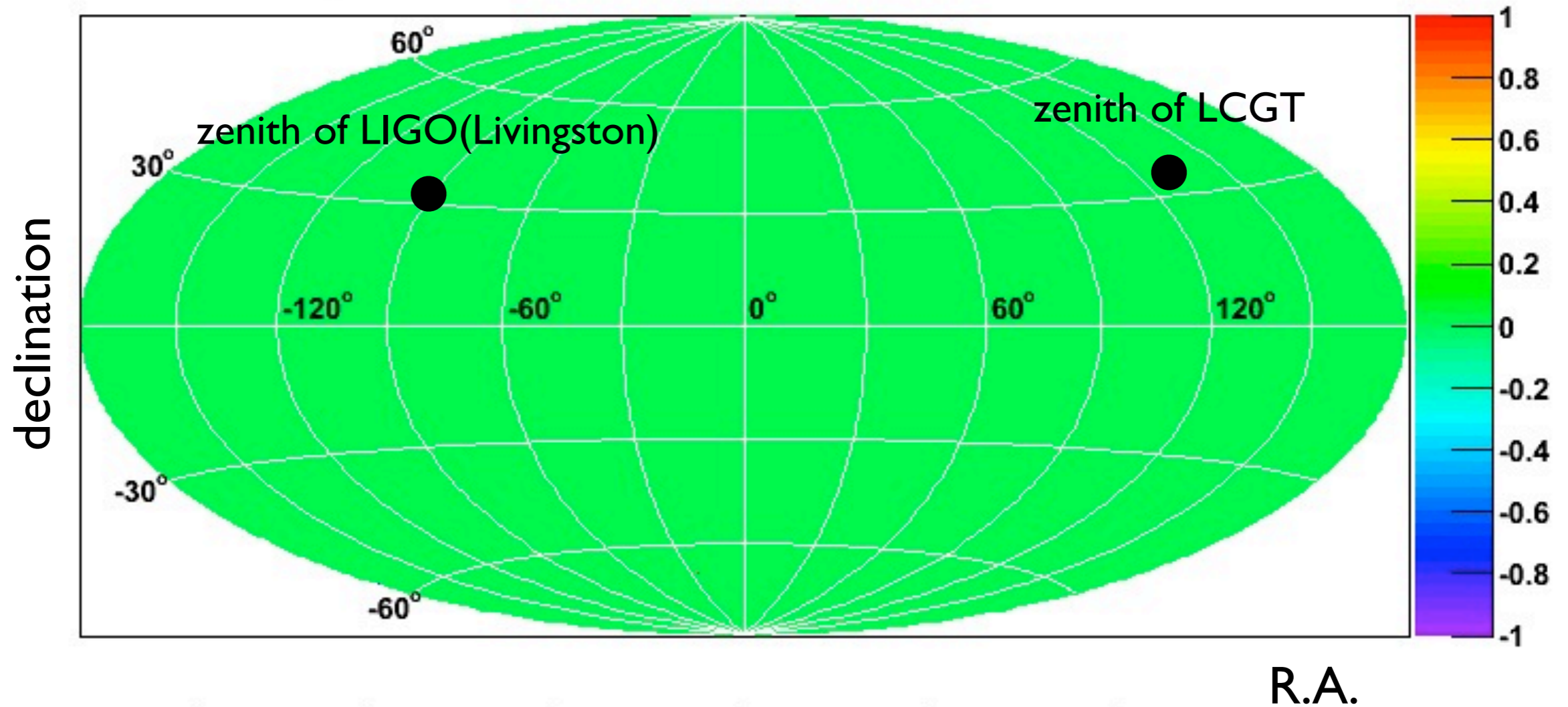
Detector's sensitivities which use to make noise in time series.

What's GW radiometry

- I. What's GW Radiometry
- II. Spreading of point source**
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LCGT-LIGO(Livingston)

background_aitoff.txt

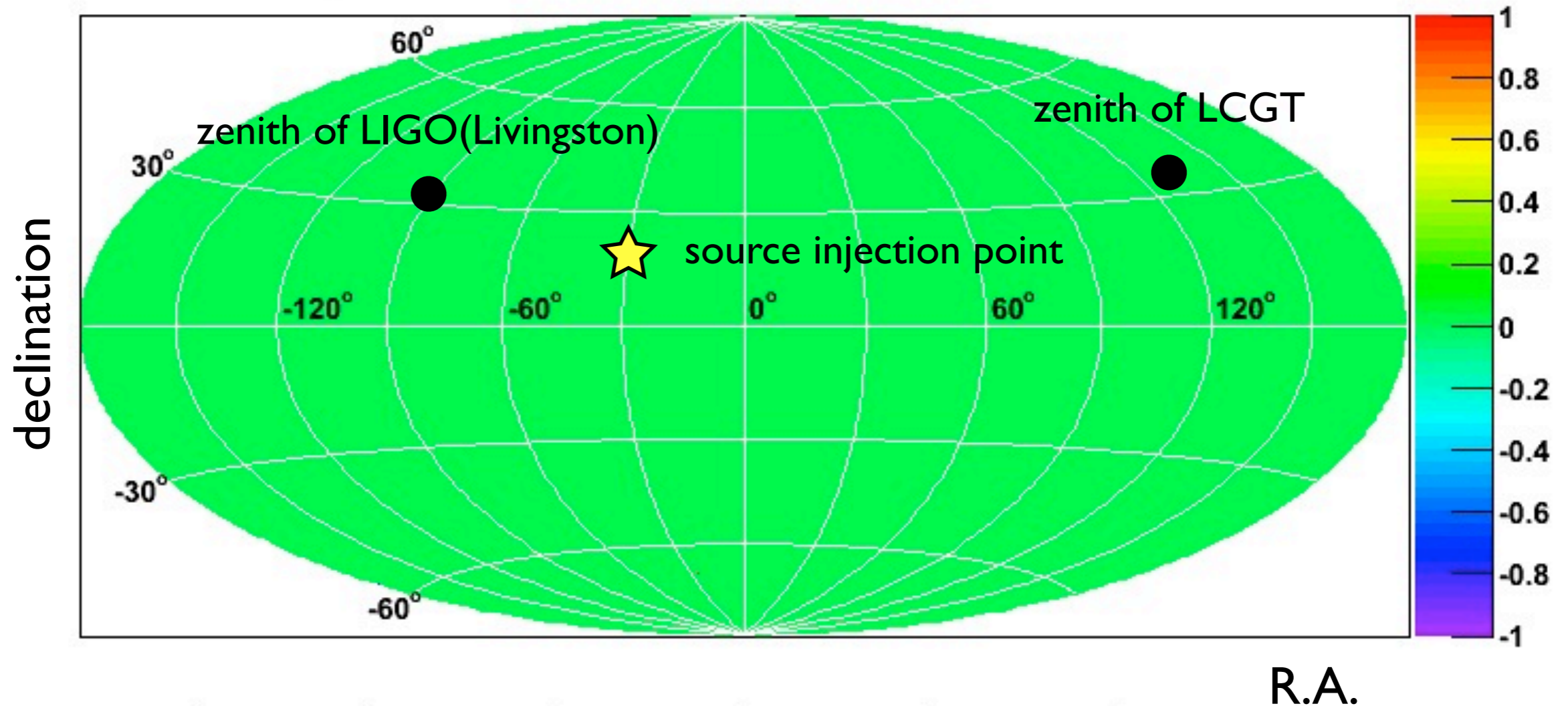


$$\Gamma(\hat{\Omega}, t = 0) \quad t : \text{GMT}$$

Spreading of point source

LCGT-LIGO(Livingston)

background_aitoff.txt

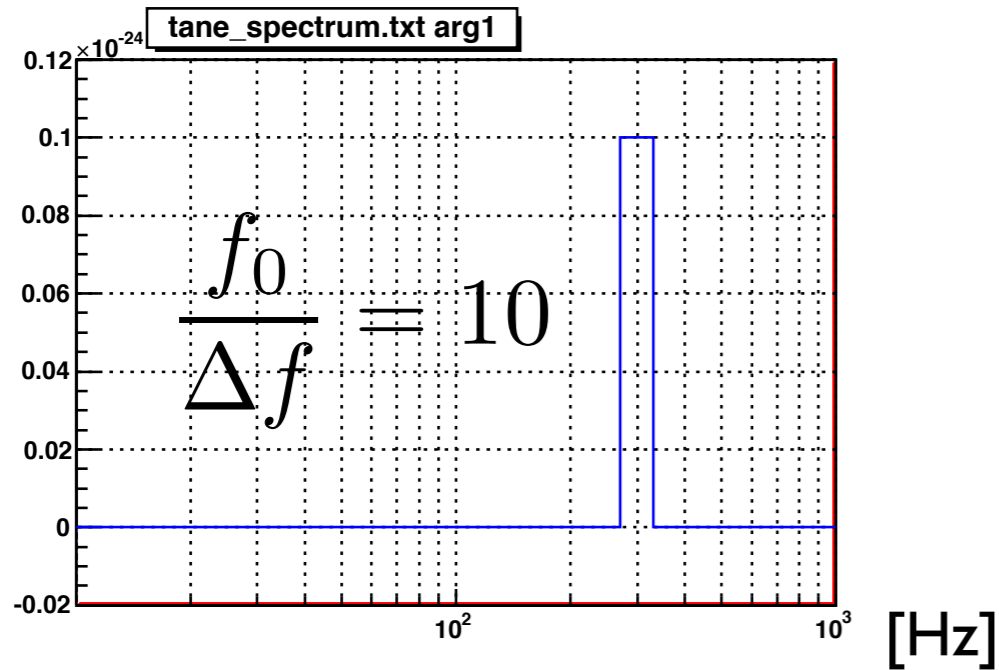


$$\Gamma(\hat{\Omega}, t = 0) \quad t : \text{GMT}$$

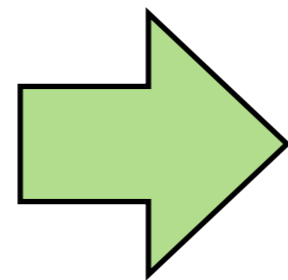
Spreading of point source

$f_0 = 10, 20, 30, 60, 100,$
 $200, 300, 600, 1000$ [Hz]

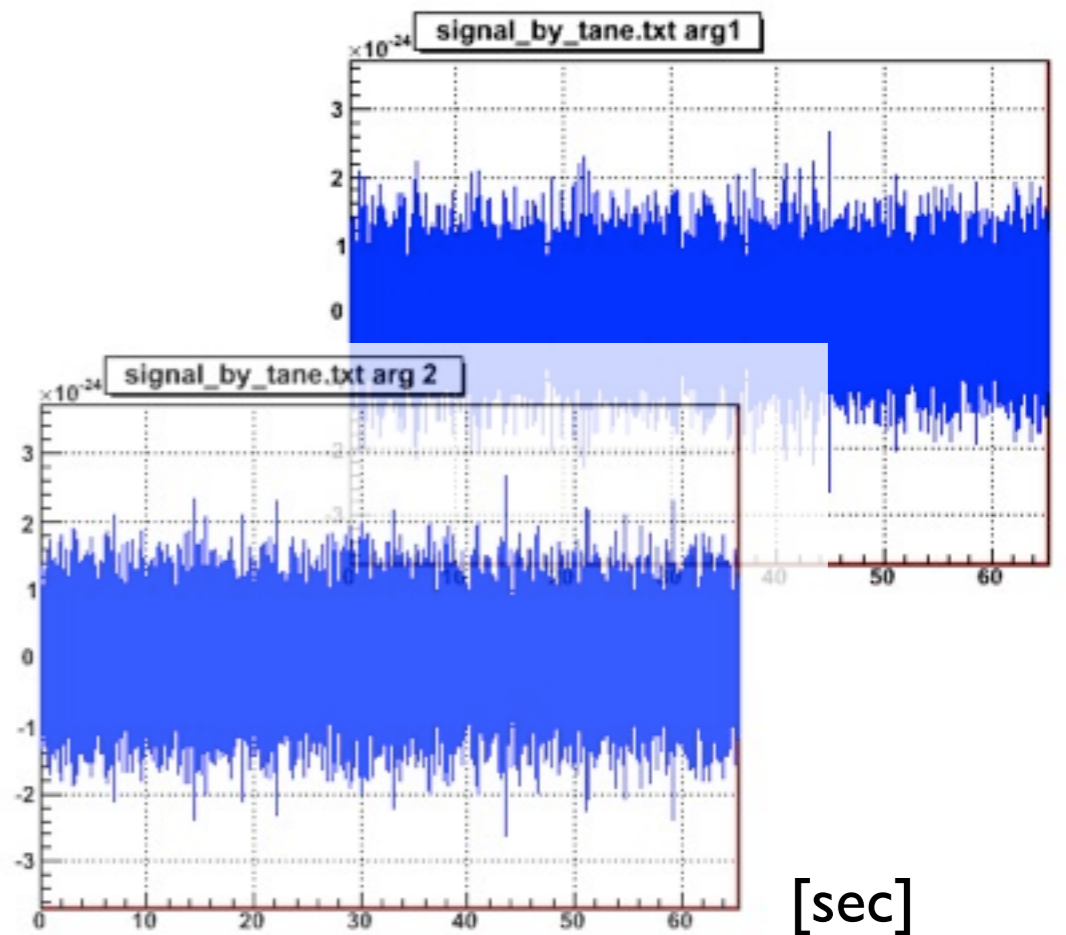
spectrum with constant power with random phase.



$\rightarrow \tilde{h}_1(f) \times e^{2\pi i f \frac{\hat{\Omega}_0 \cdot \Delta x}{c}}$
 $\rightarrow \tilde{h}_2(f)$

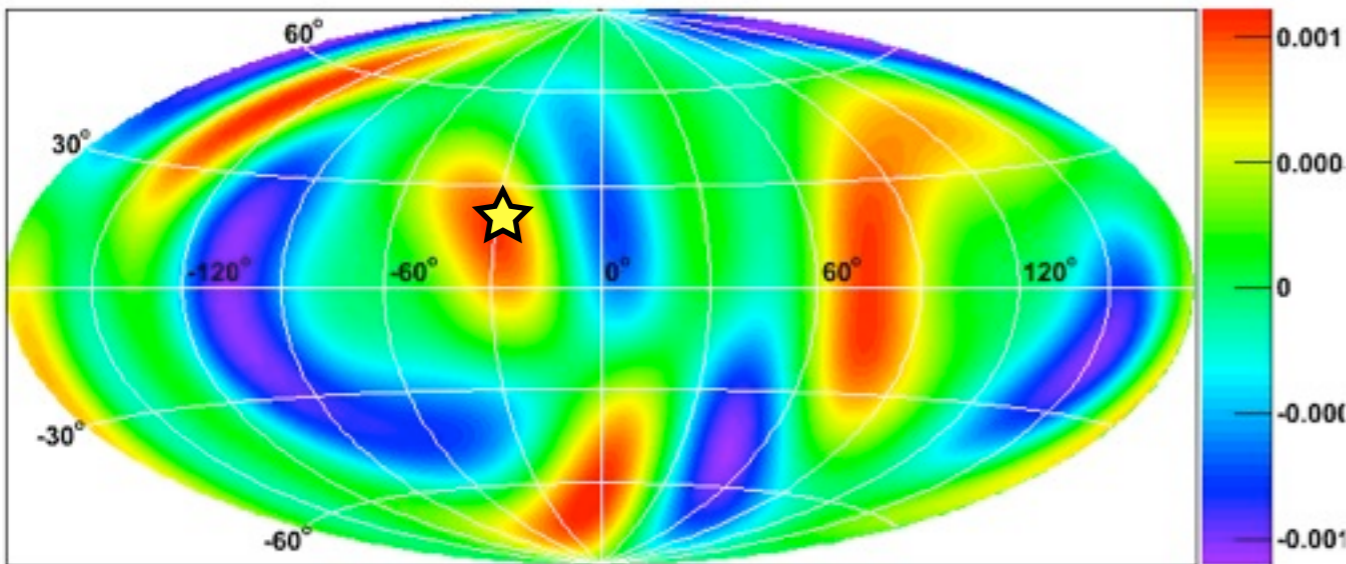


IFFT

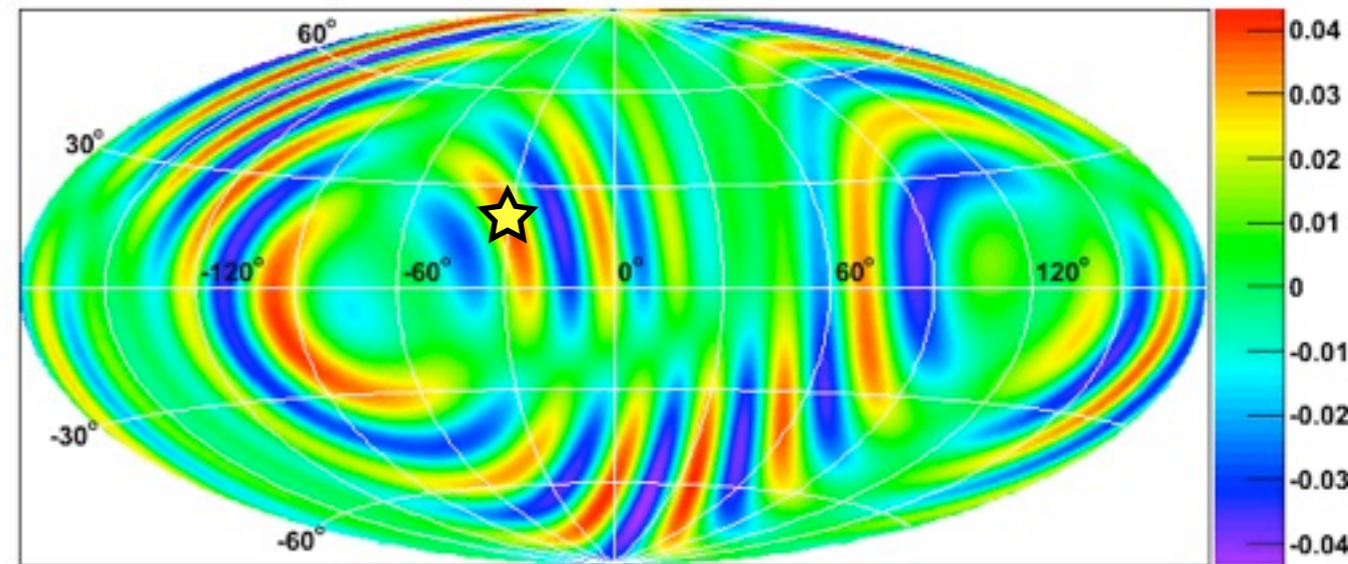


Spreading of point source

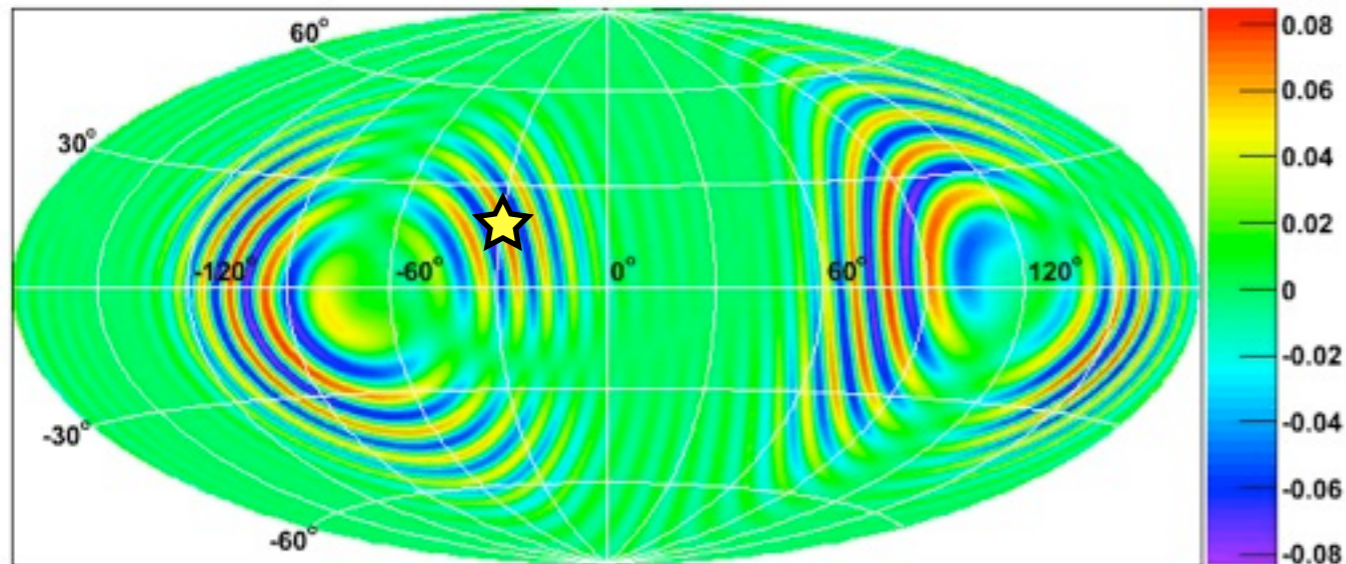
ΔS mapping for $t=0$



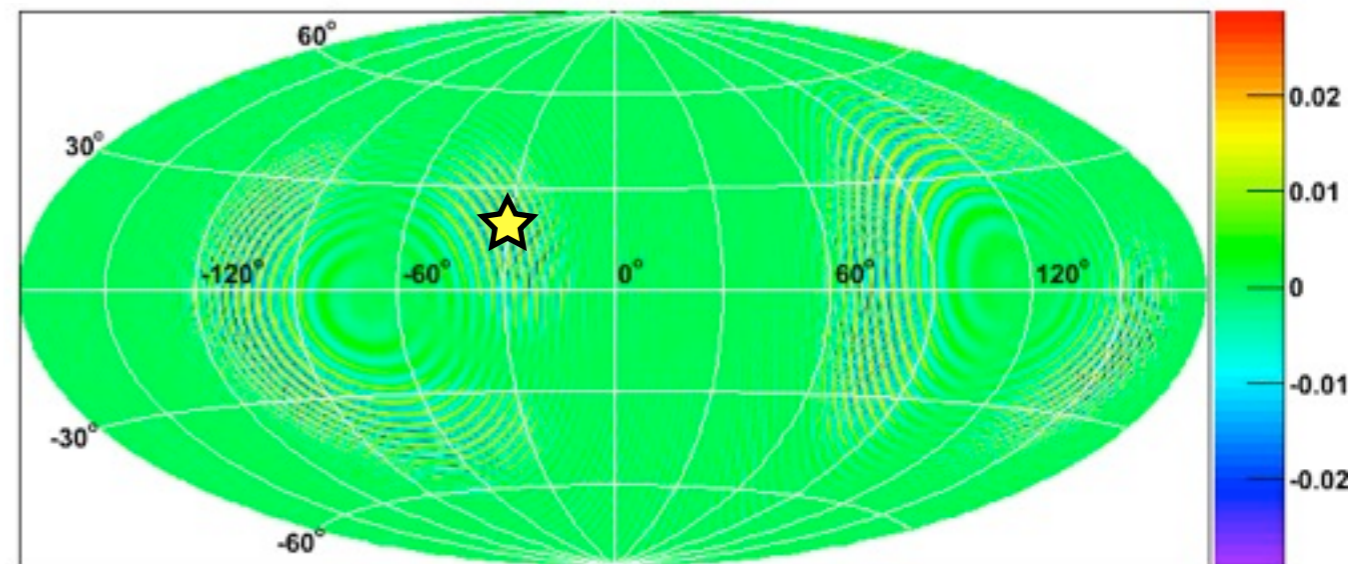
$$H(f) = \begin{cases} 10^{-25} & (27\text{Hz} \leq f \leq 33\text{Hz}) \\ 0 & (\text{else}) \end{cases}$$



$$H(f) = \begin{cases} 10^{-25} & (90\text{Hz} \leq f \leq 110\text{Hz}) \\ 0 & (\text{else}) \end{cases}$$



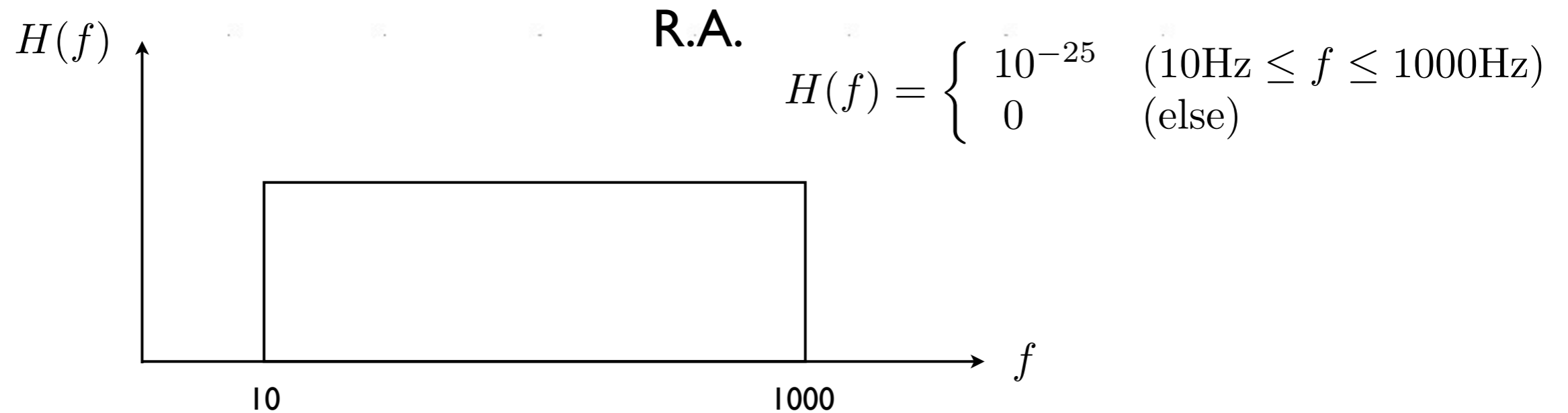
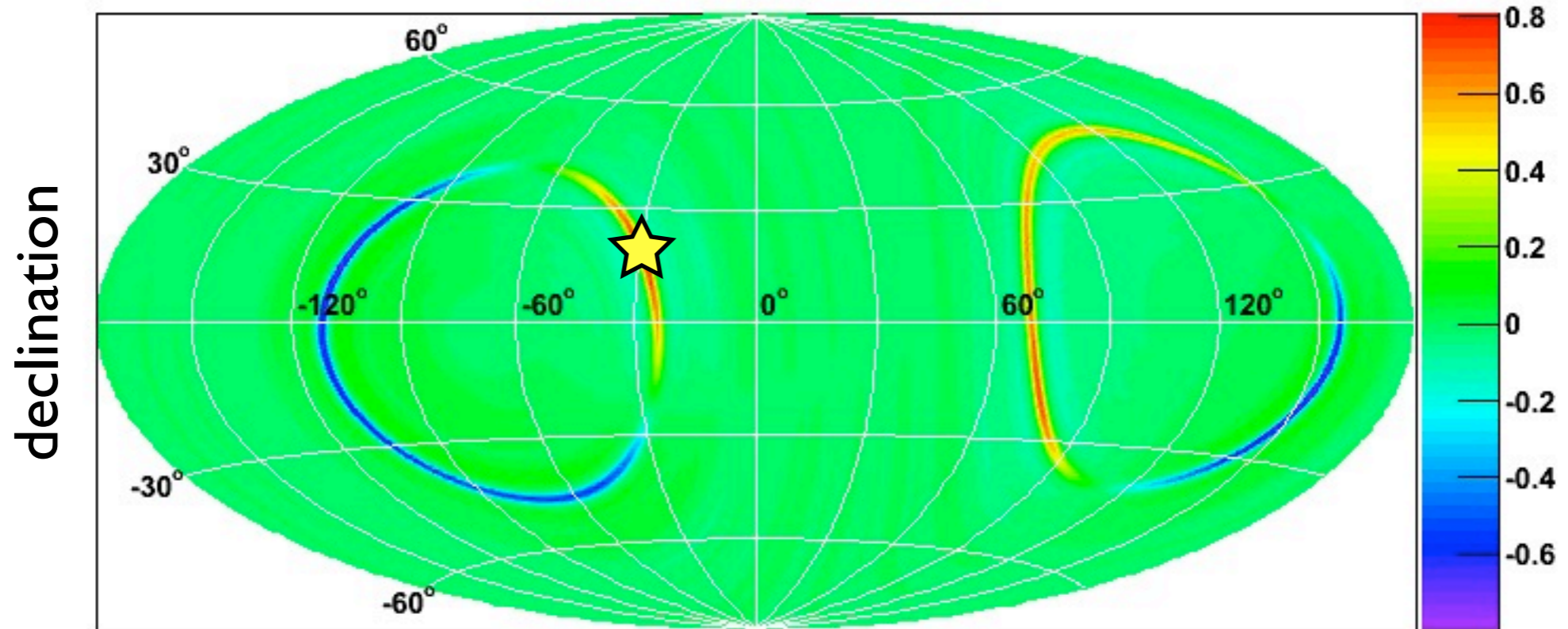
$$H(f) = \begin{cases} 10^{-25} & (270\text{Hz} \leq f \leq 330\text{Hz}) \\ 0 & (\text{else}) \end{cases}$$



$$H(f) = \begin{cases} 10^{-25} & (900\text{Hz} \leq f \leq 1100\text{Hz}) \\ 0 & (\text{else}) \end{cases}$$

Spreading of point source

dS_flat_t0.txt



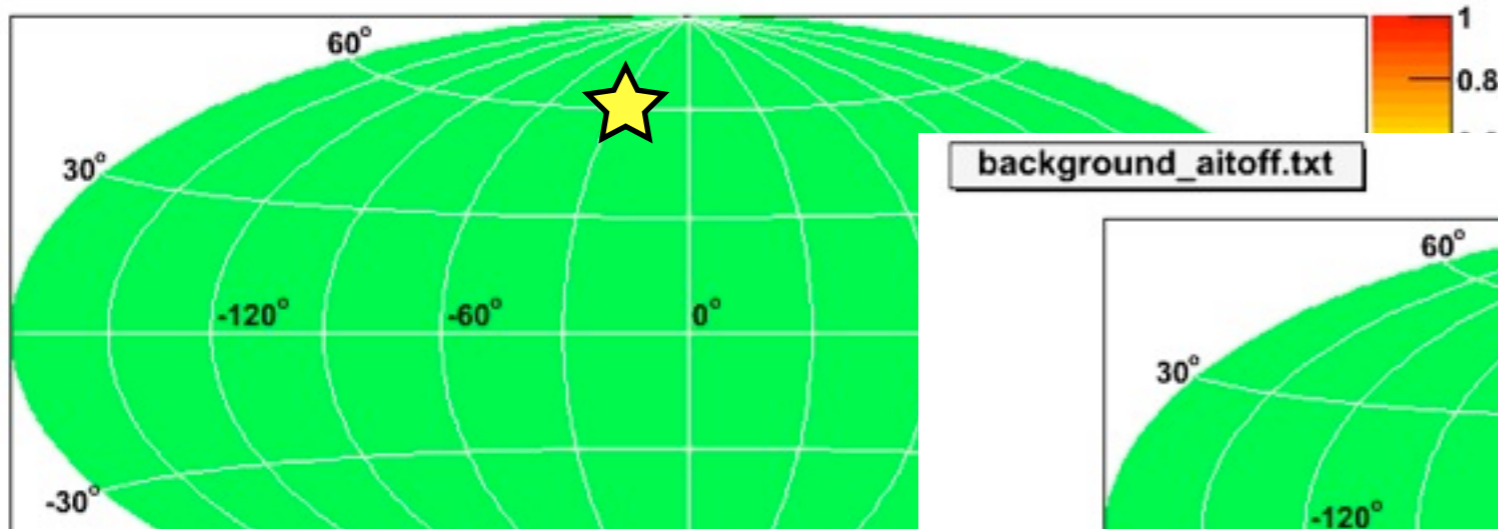
Spreading of point source

Stripe patterns of $\Delta S(\hat{\Omega})$ is changed by GW's frequency and source direction.

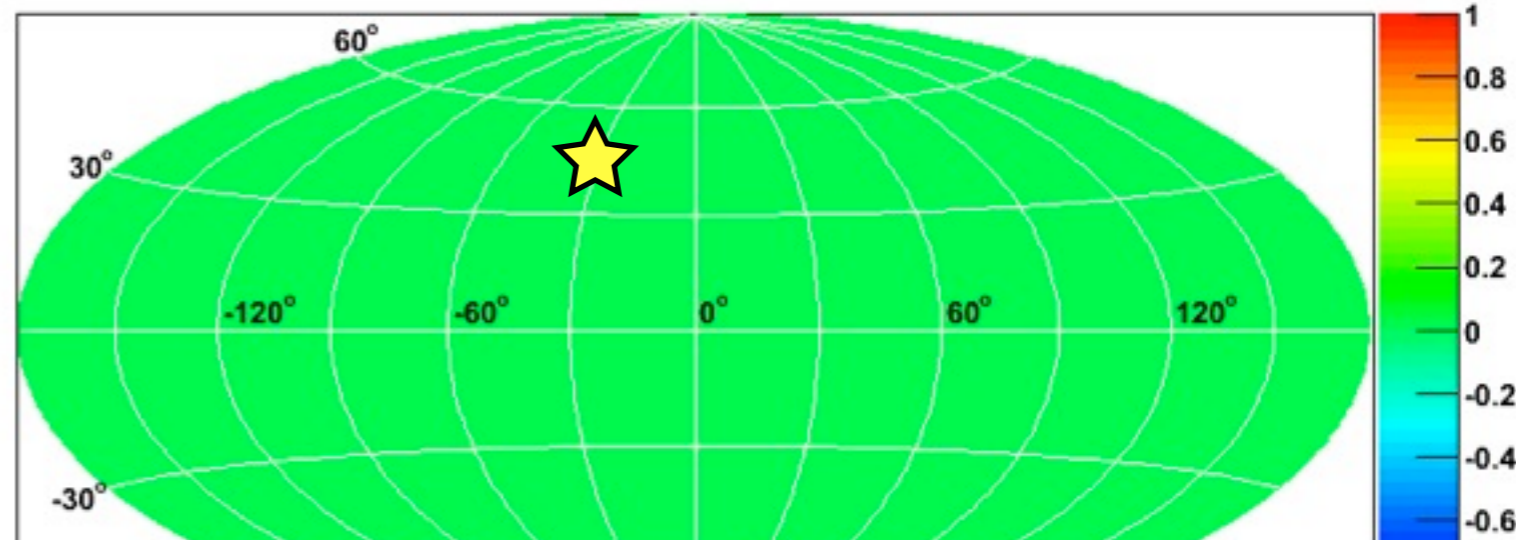
The output is the superposition of $\Delta S(\hat{\Omega})$.

We will observe for long span in practice, so it is effective that we consider the average for 1 day.

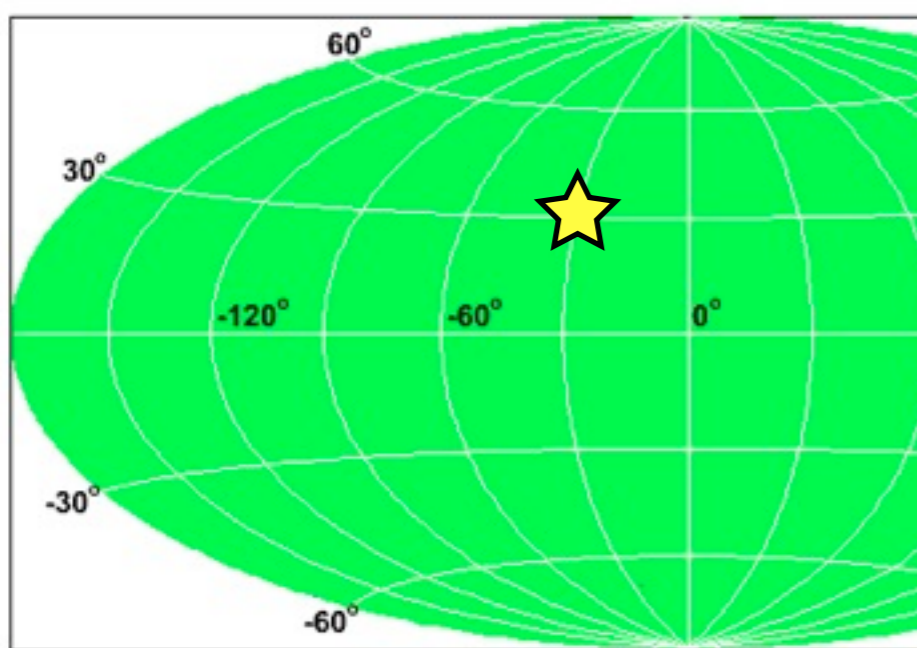
background_aitoff.txt



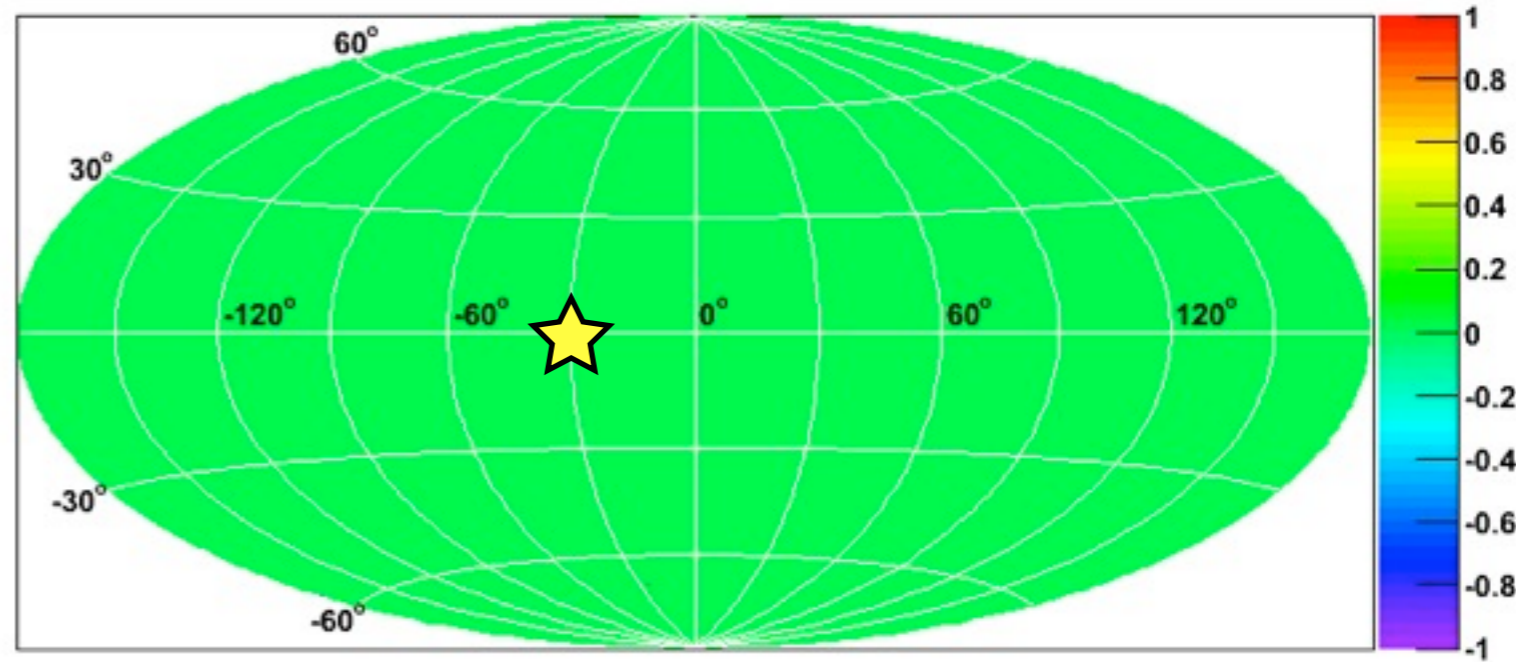
background_aitoff.txt



background_aitoff.txt



background_aitoff.txt



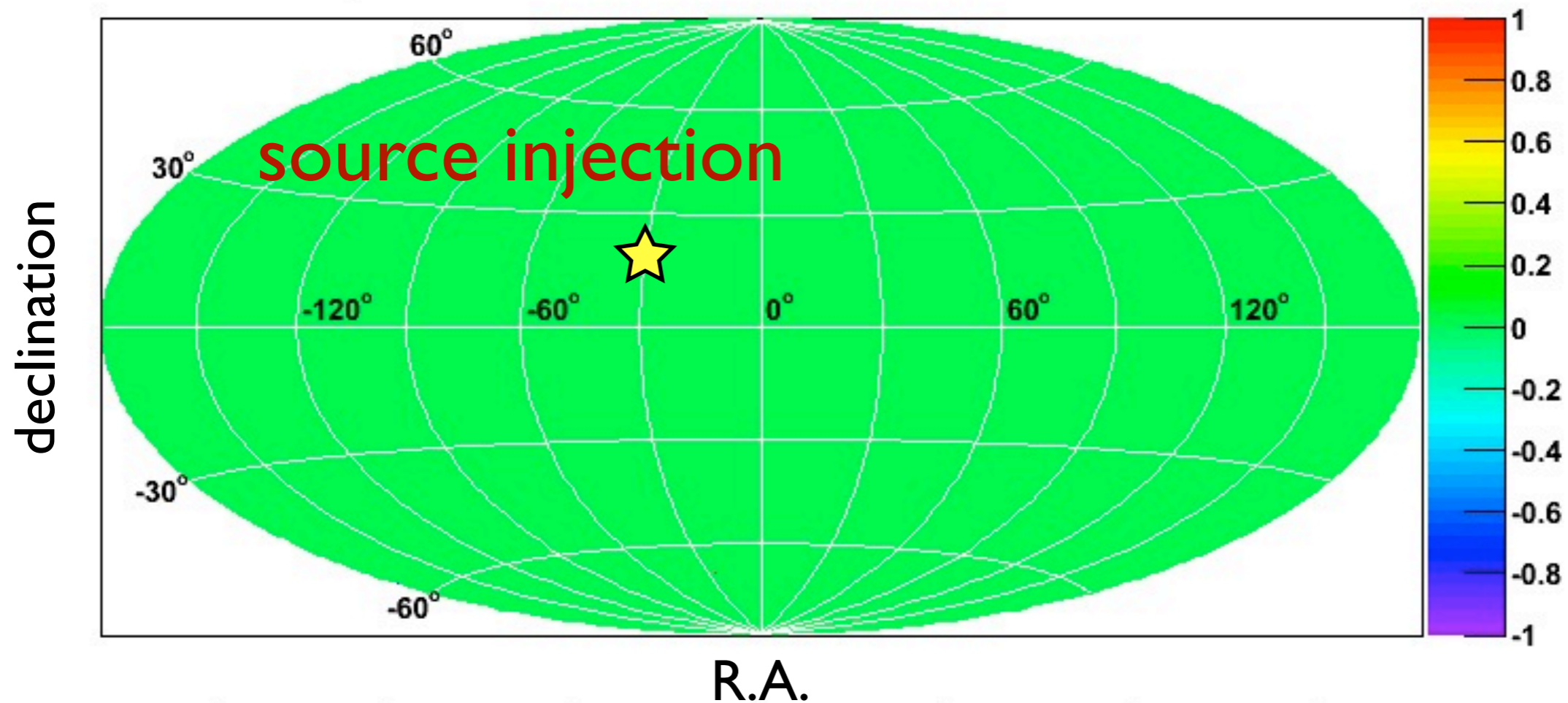
injection in various sky position.

Spreading of point source

example

one day average

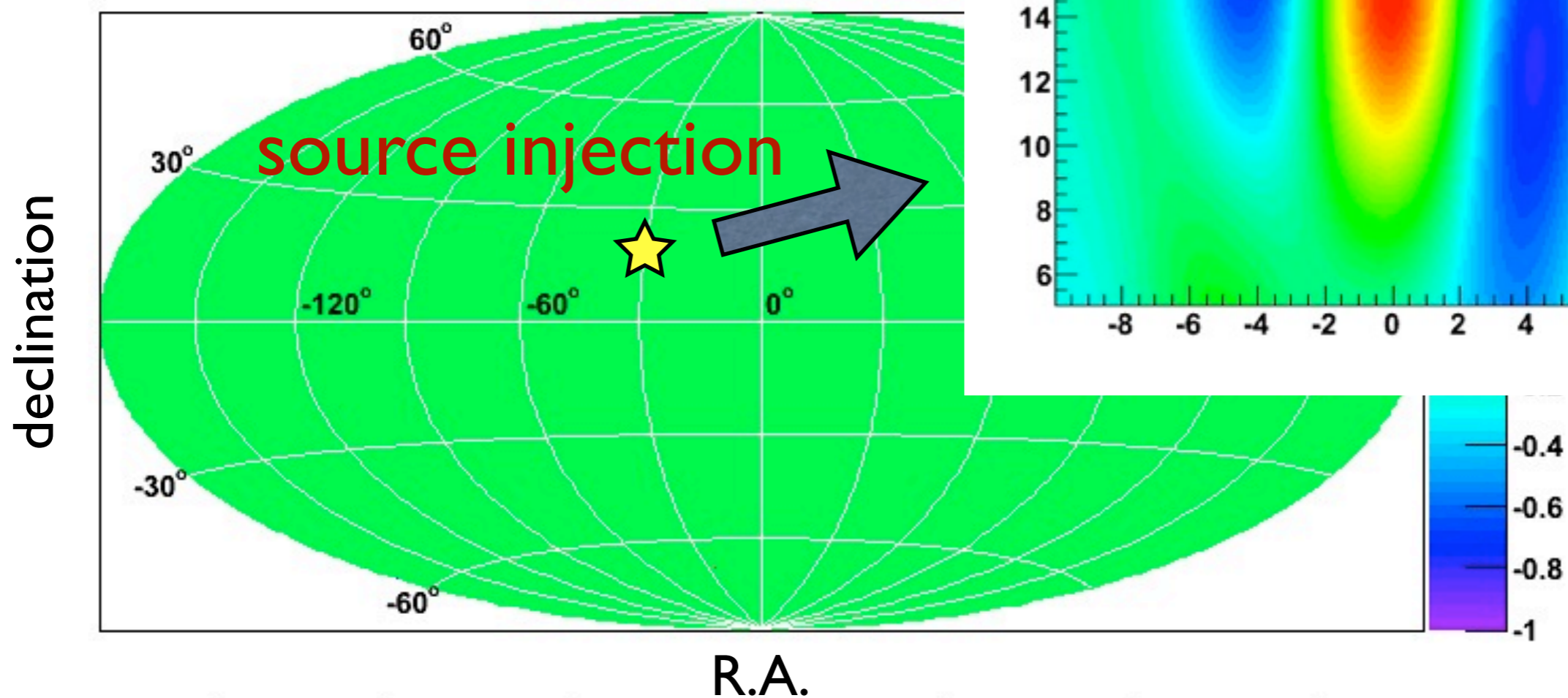
background_aitoff.txt



Spreading of point source

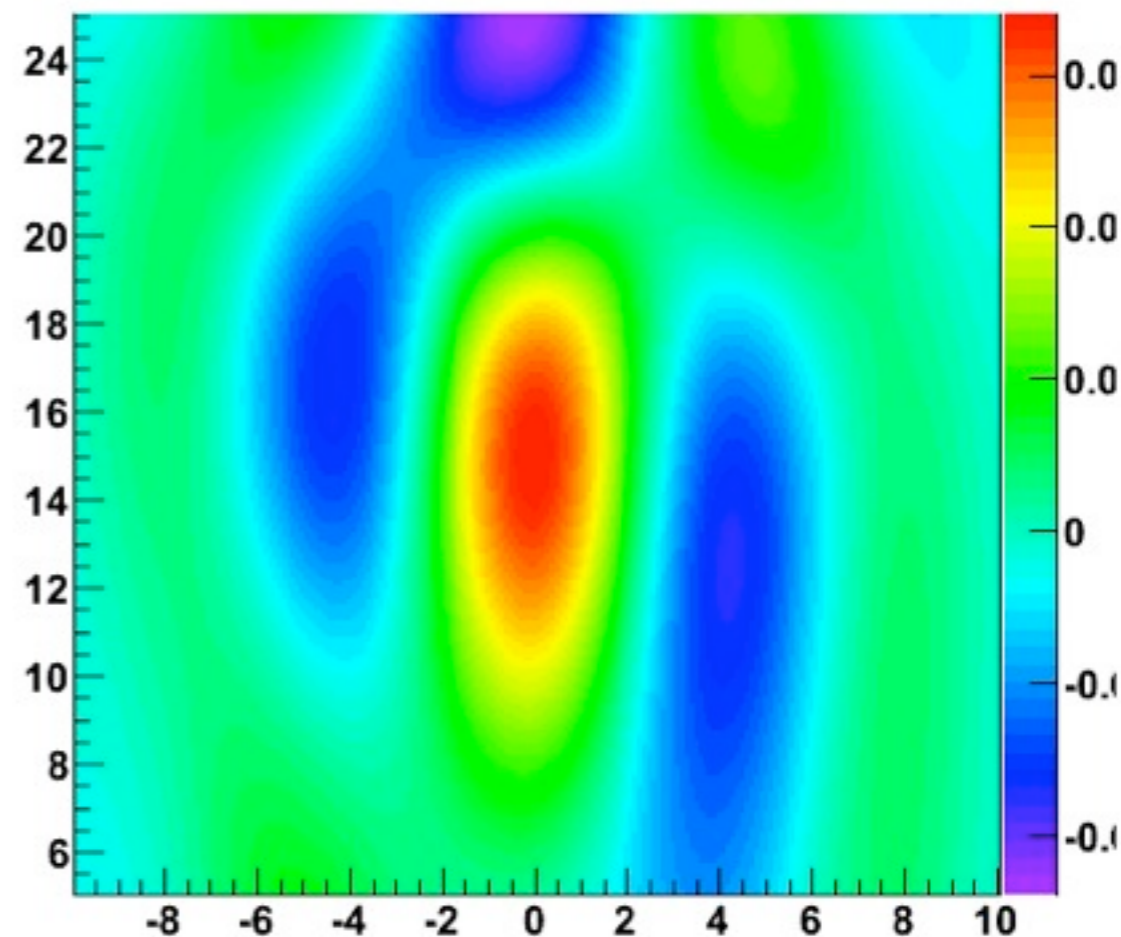
one day average

background_aitoff.txt



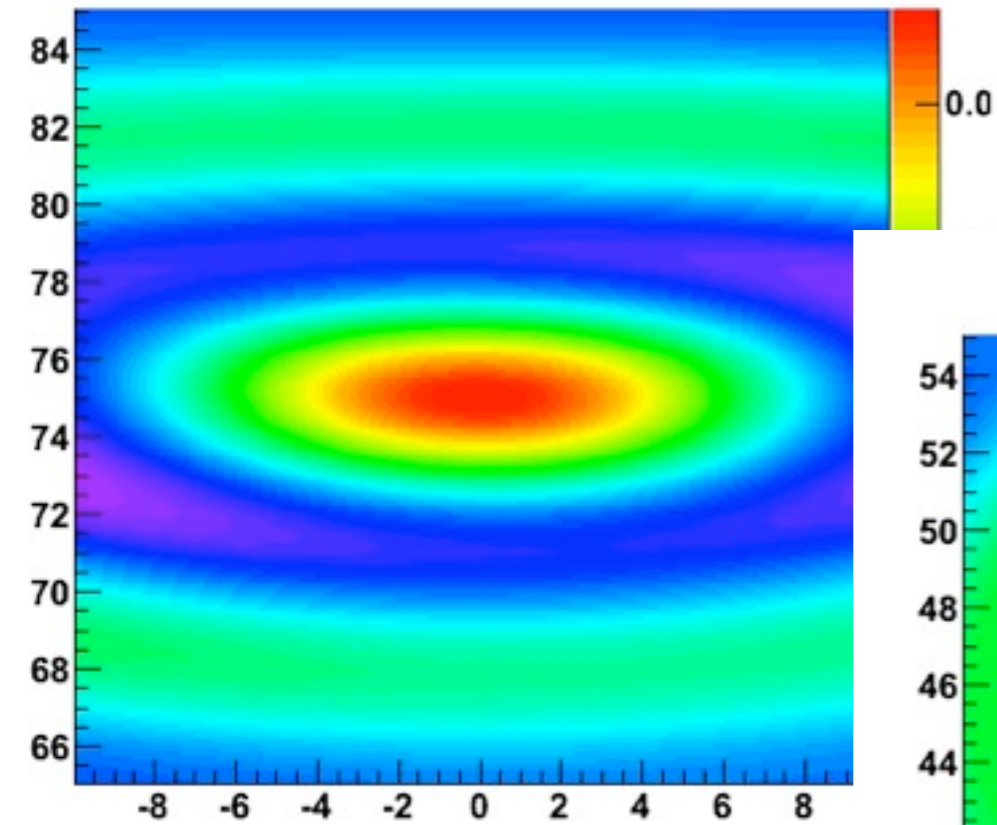
mu_f300_d15.txt

example



Spreading of point source

$$\delta = 75^\circ$$

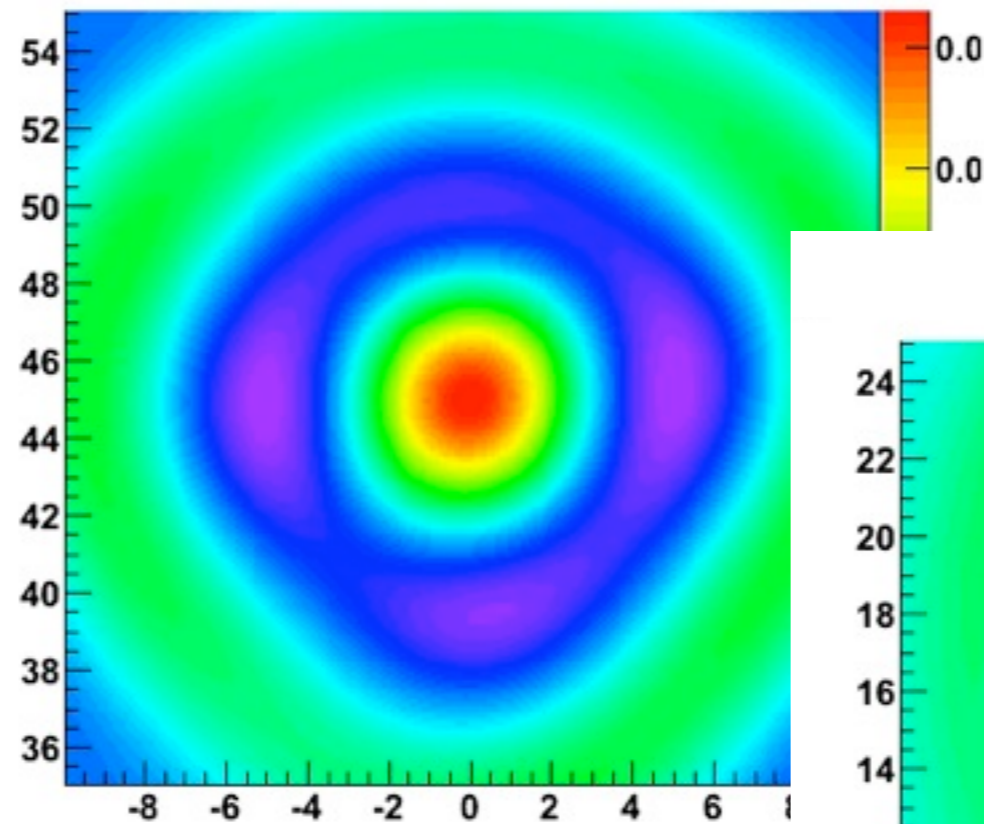


$\sim 10^\circ$

declination

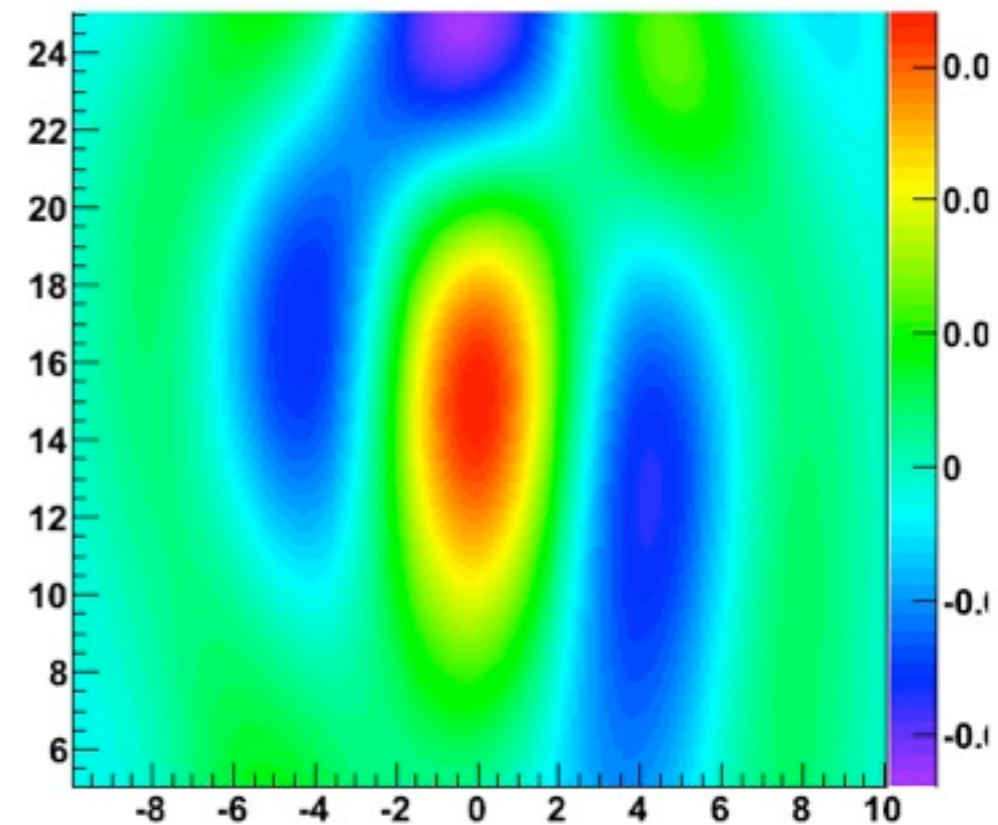
R.A.

$$\delta = 45^\circ$$



$\sim 4^\circ$

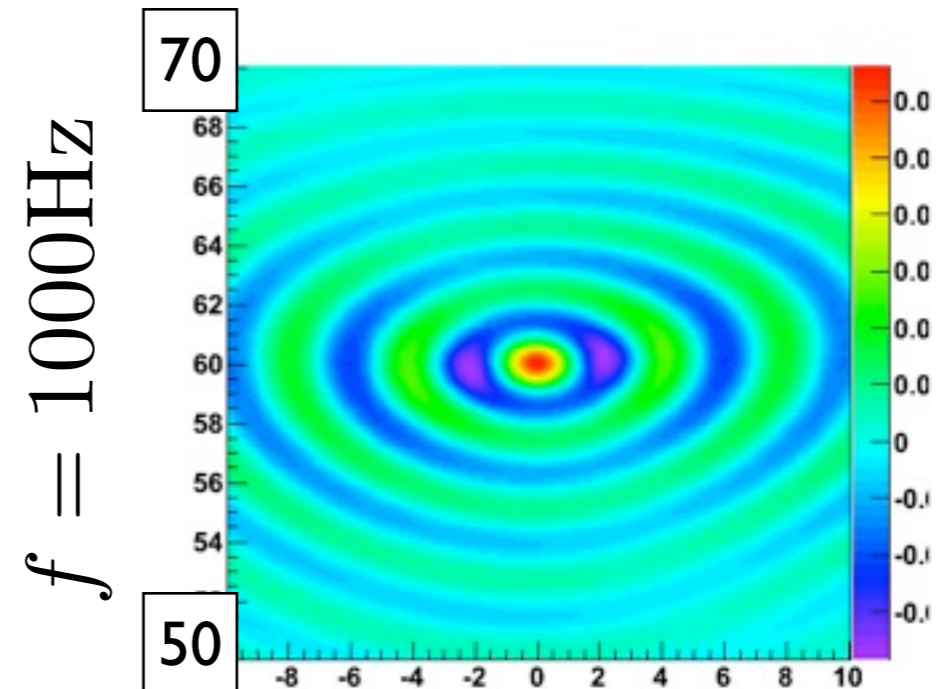
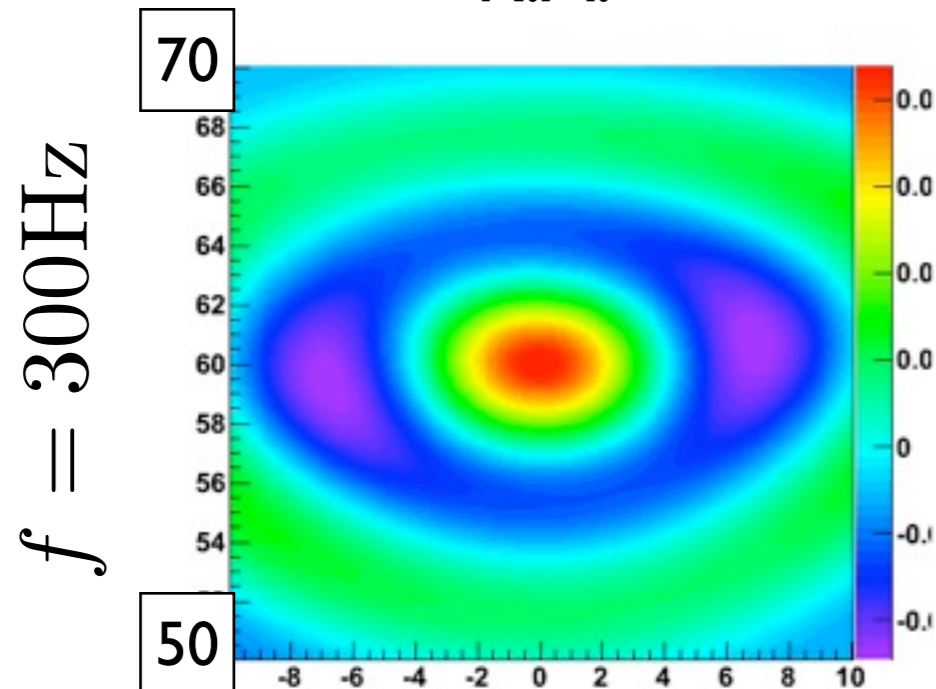
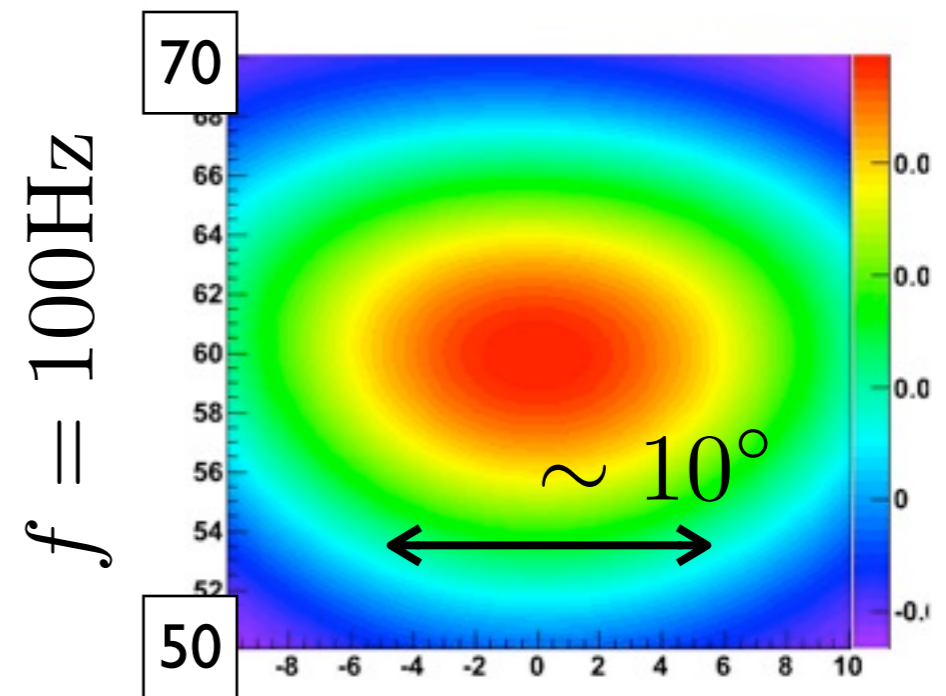
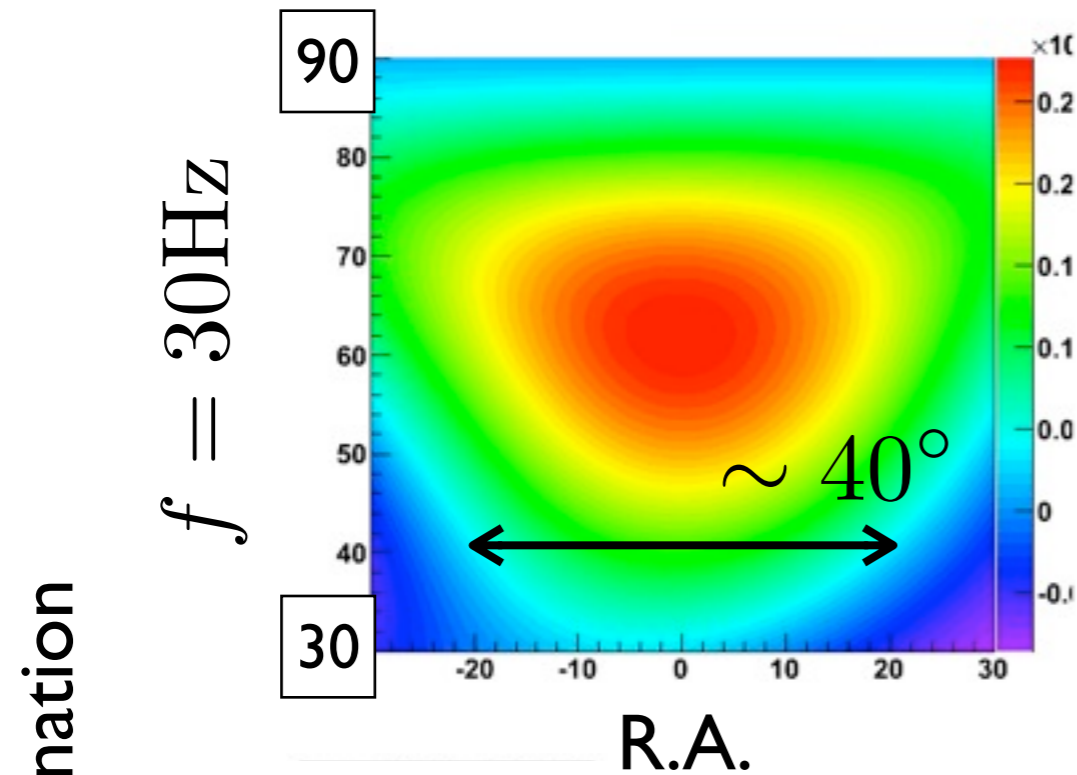
$$\delta = 15^\circ$$



$$f = 300\text{Hz}$$

Spreading of point source

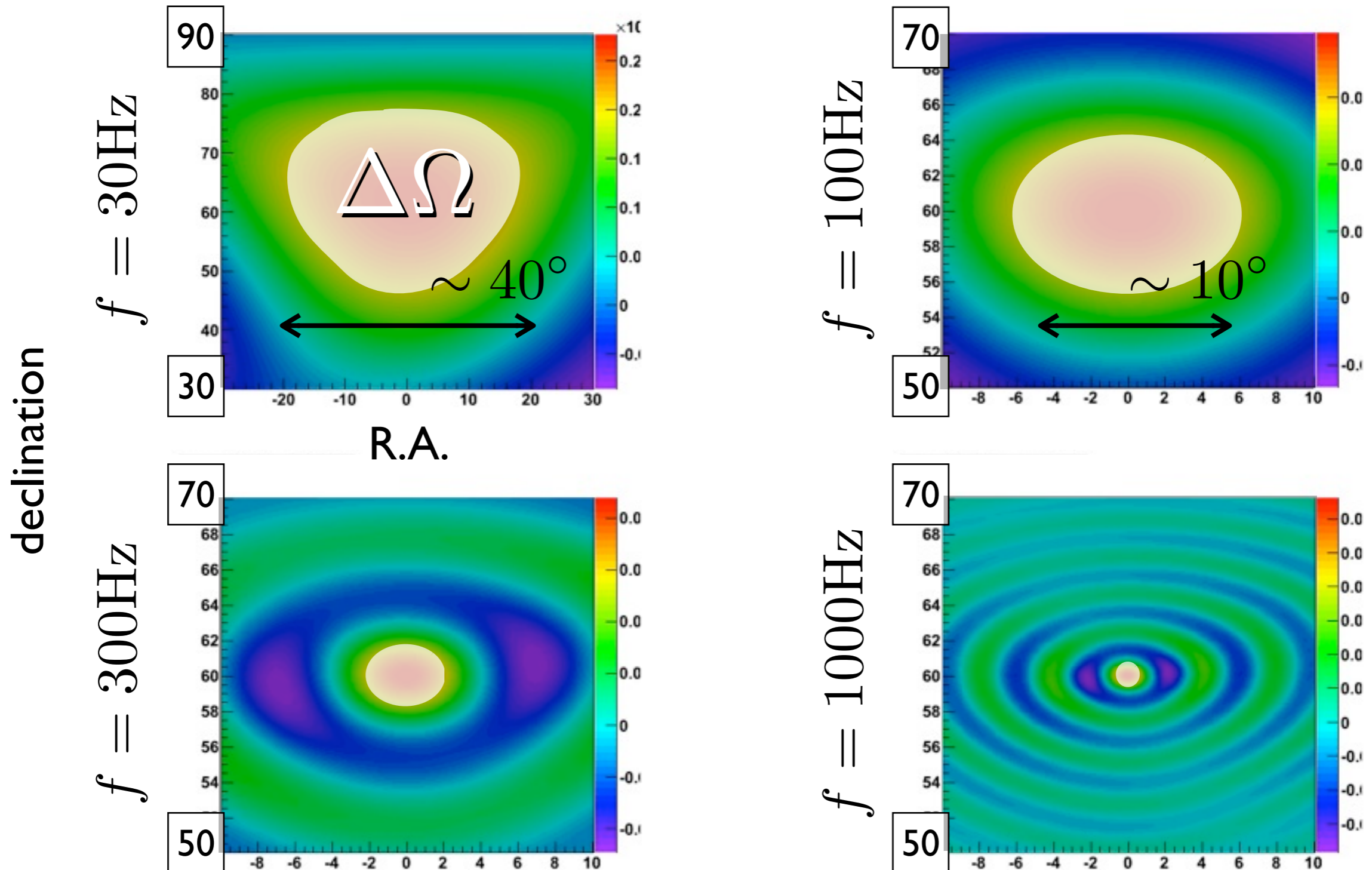
$$\delta = 60^\circ$$



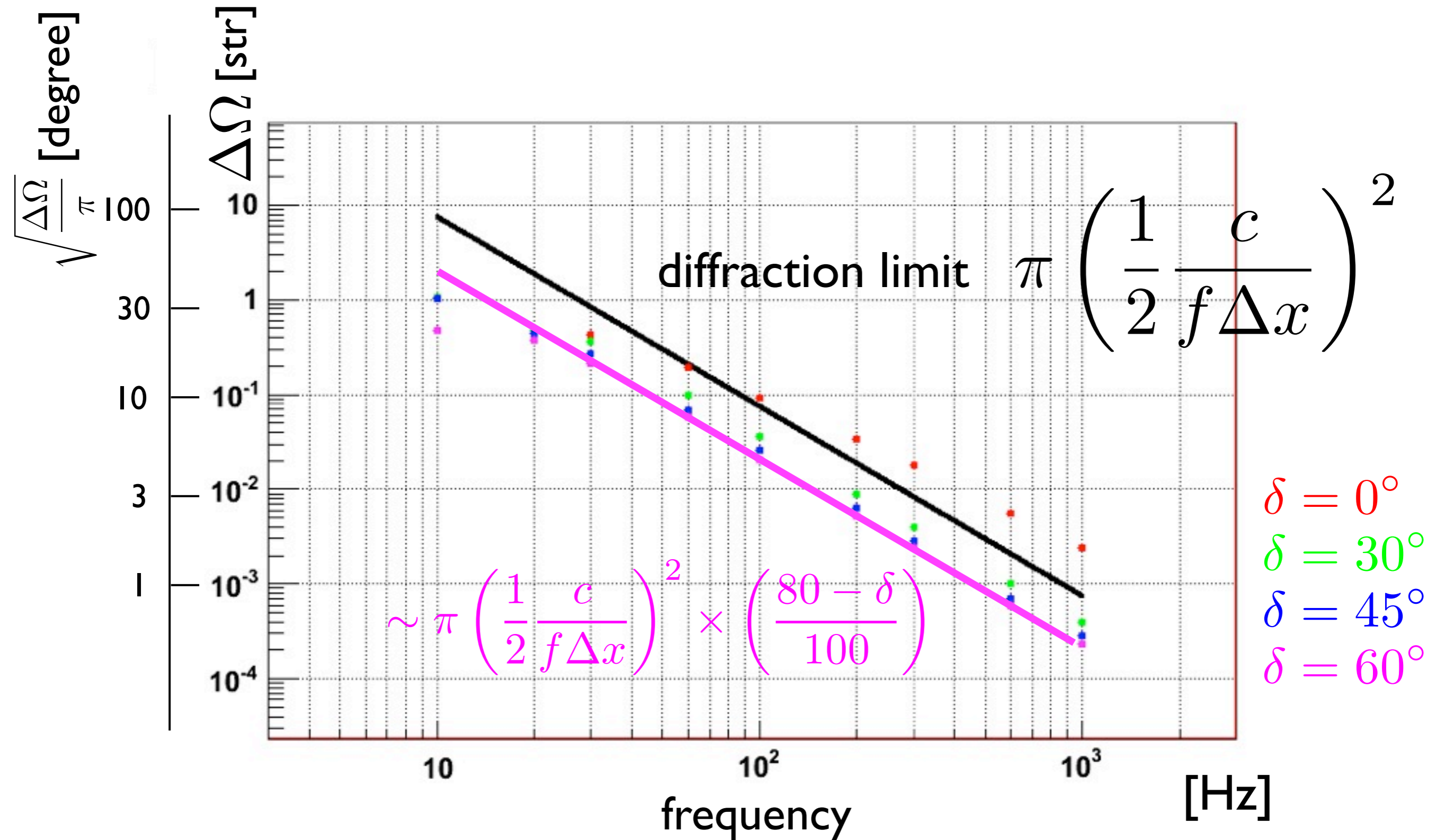
Spreading of point source

$$\delta = 60^\circ$$

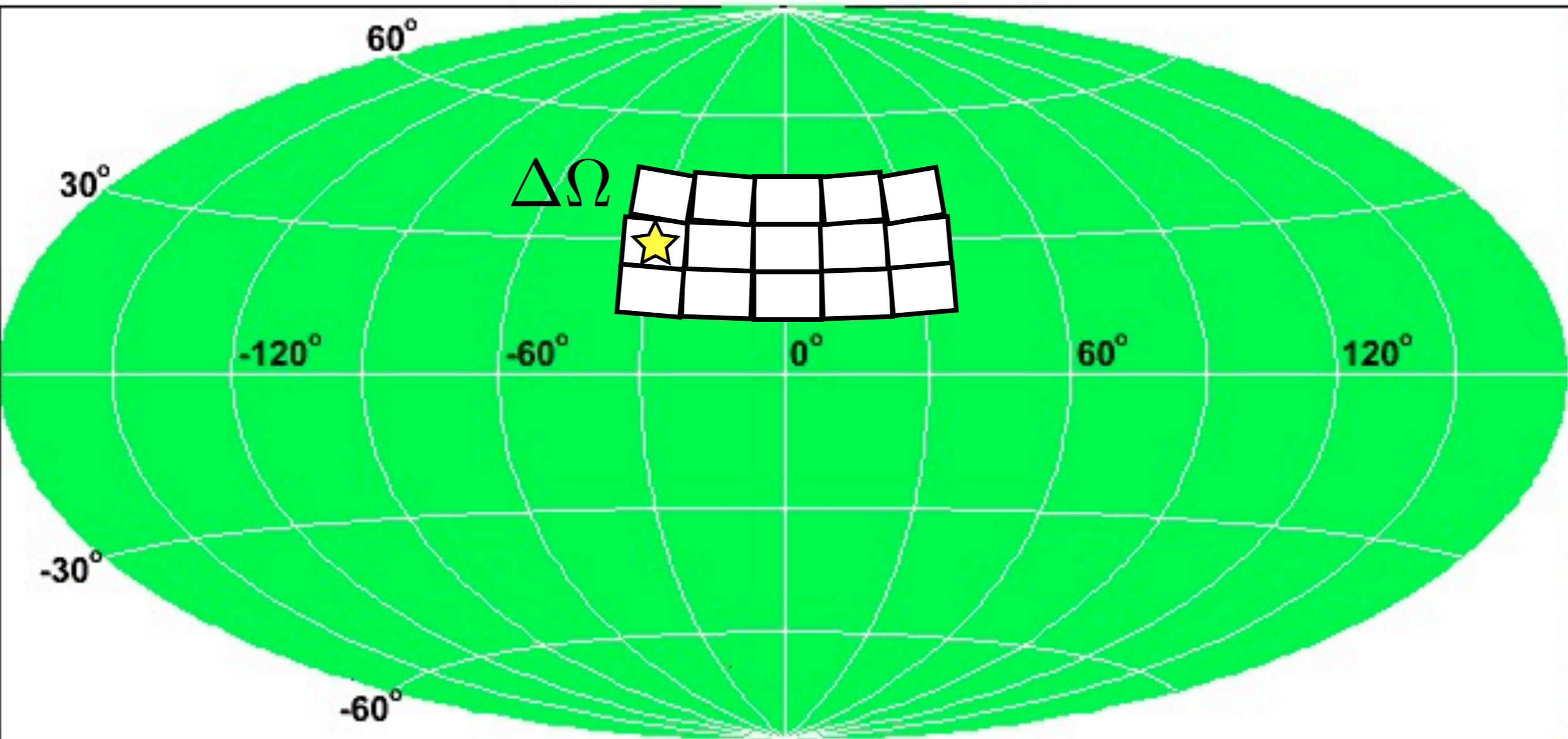
$\Delta\Omega$ is the area which $>$ FWHM



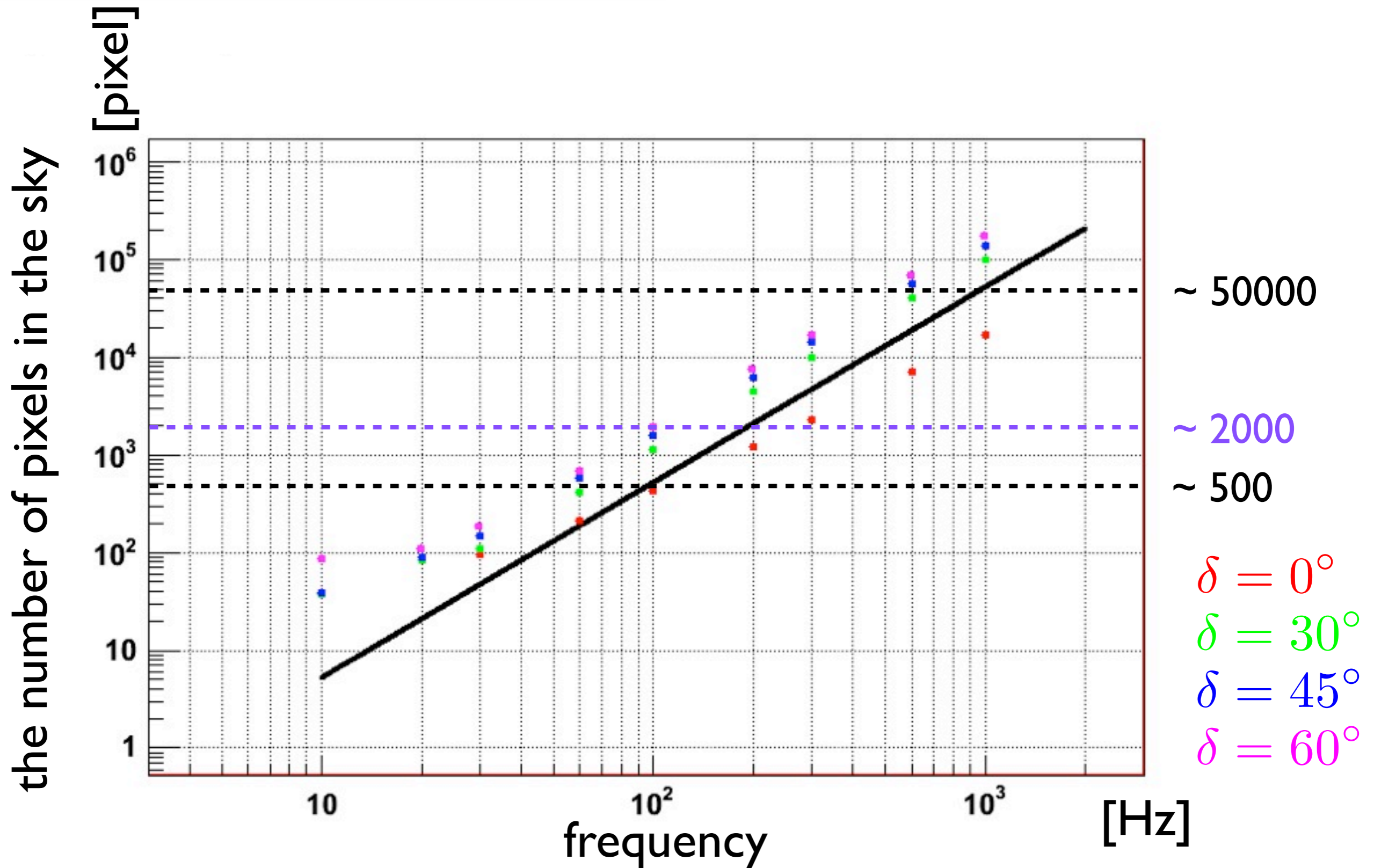
Spreading of point source



Spreading of point source



Spreading of point source



Spreading of point source

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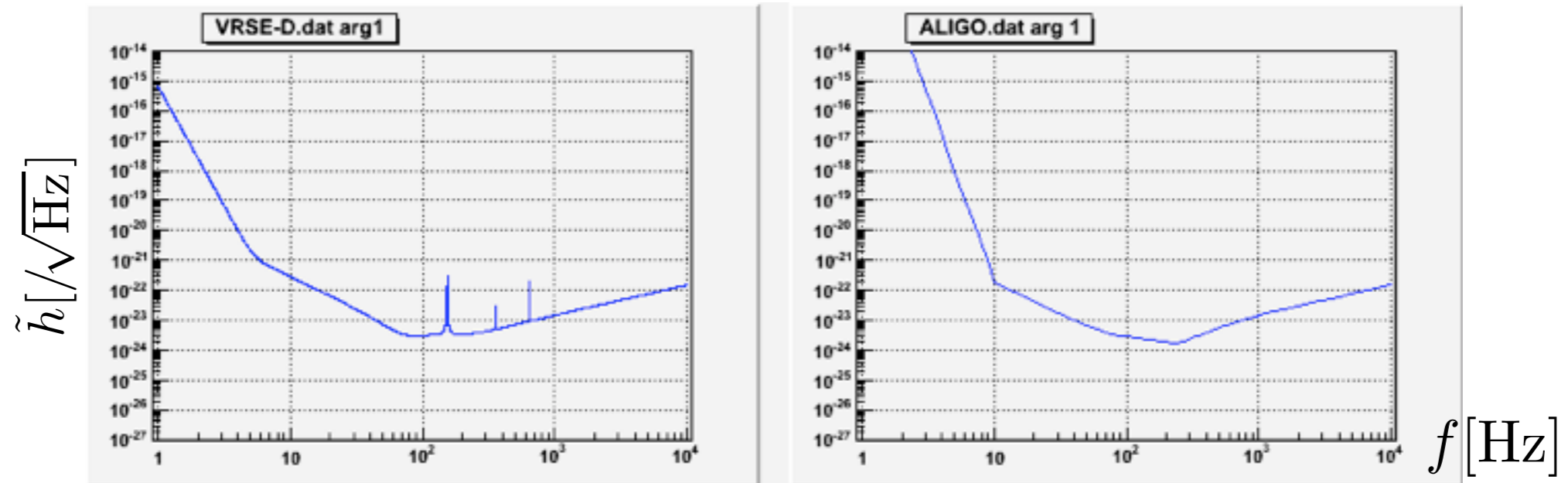
Summary

- We develop the radiometry analysis.
- We discuss how signal which is point injection spreads for frequency and declination.
- If signal's frequency is 100Hz, the number of pixels is ~2000.

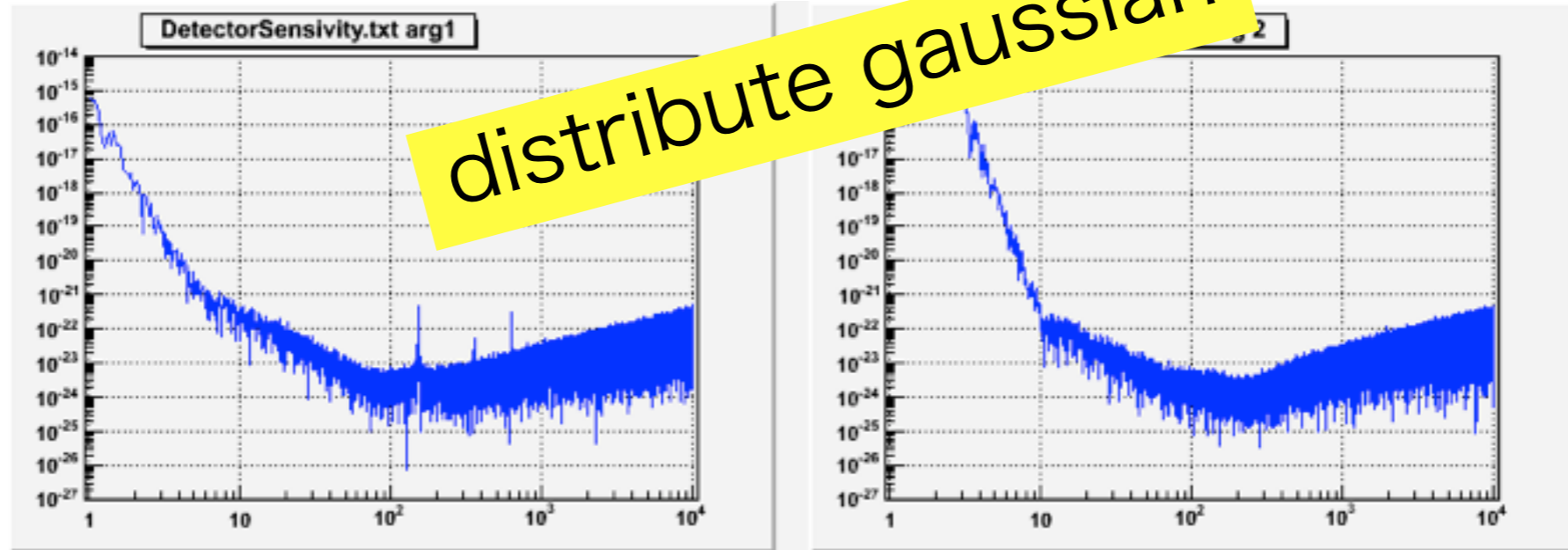
Future

- Study for more realistic sources.
- And study for non-point (area spread/distributed) sources.

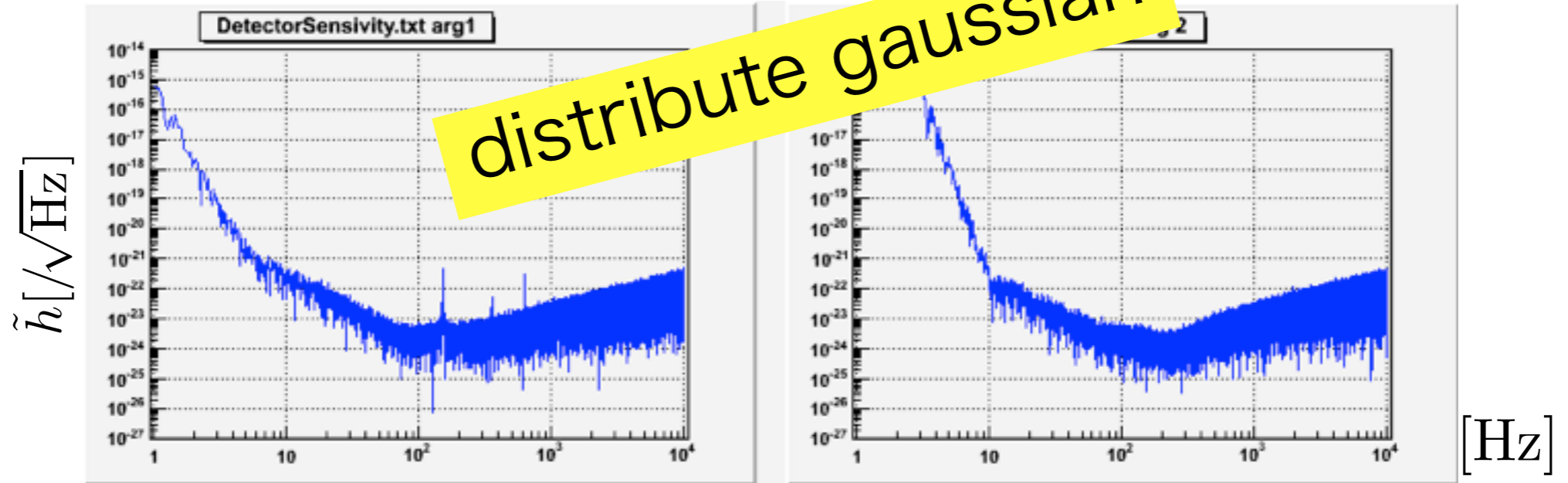
~ Fin ~



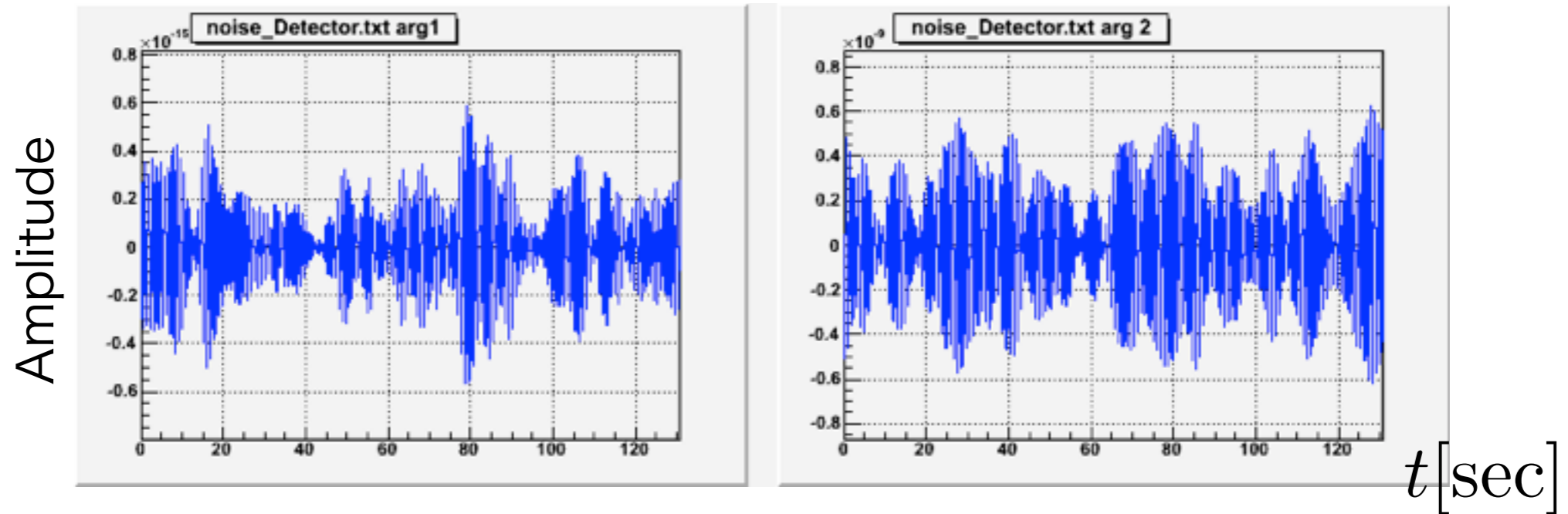
$\tilde{h}[\sqrt{\text{Hz}}]$



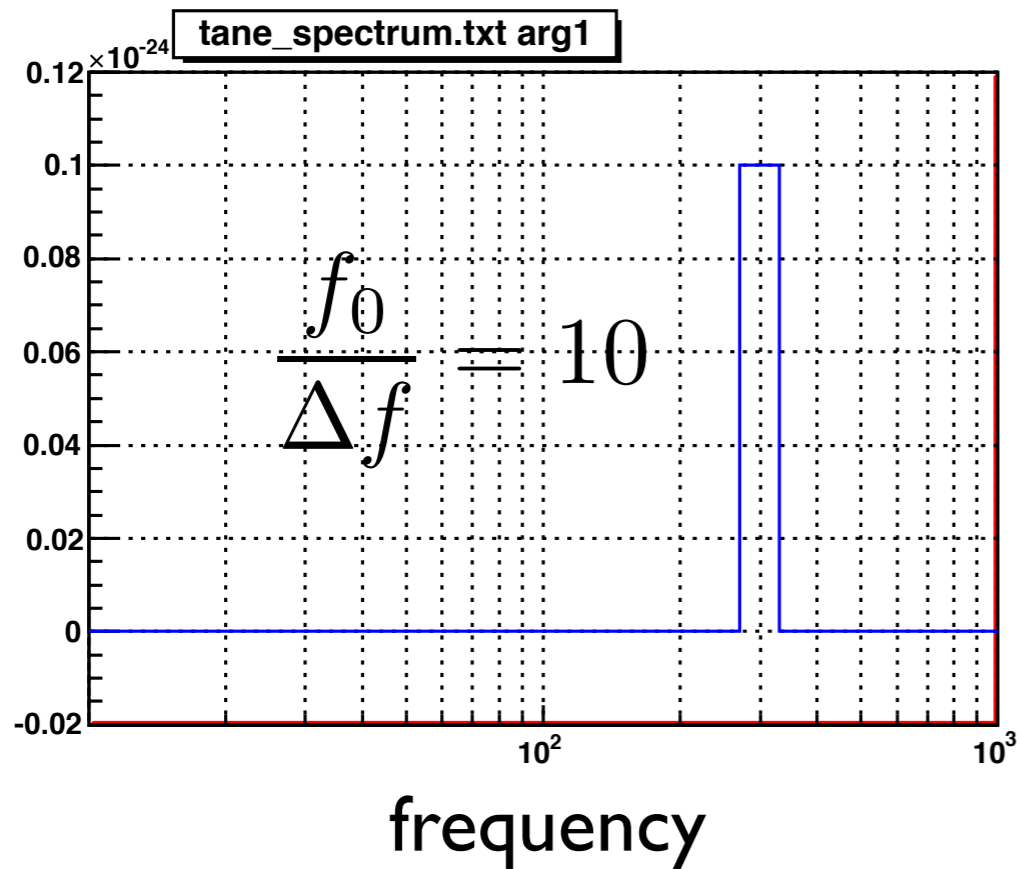
[Hz]



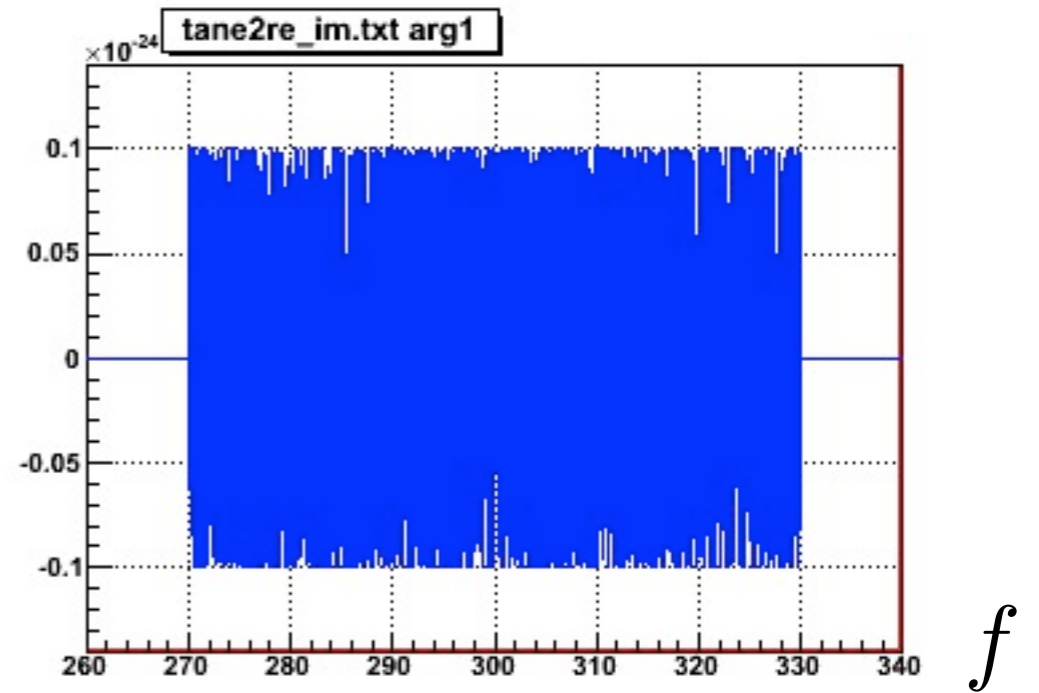
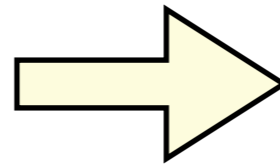
↓ Inverse FFT



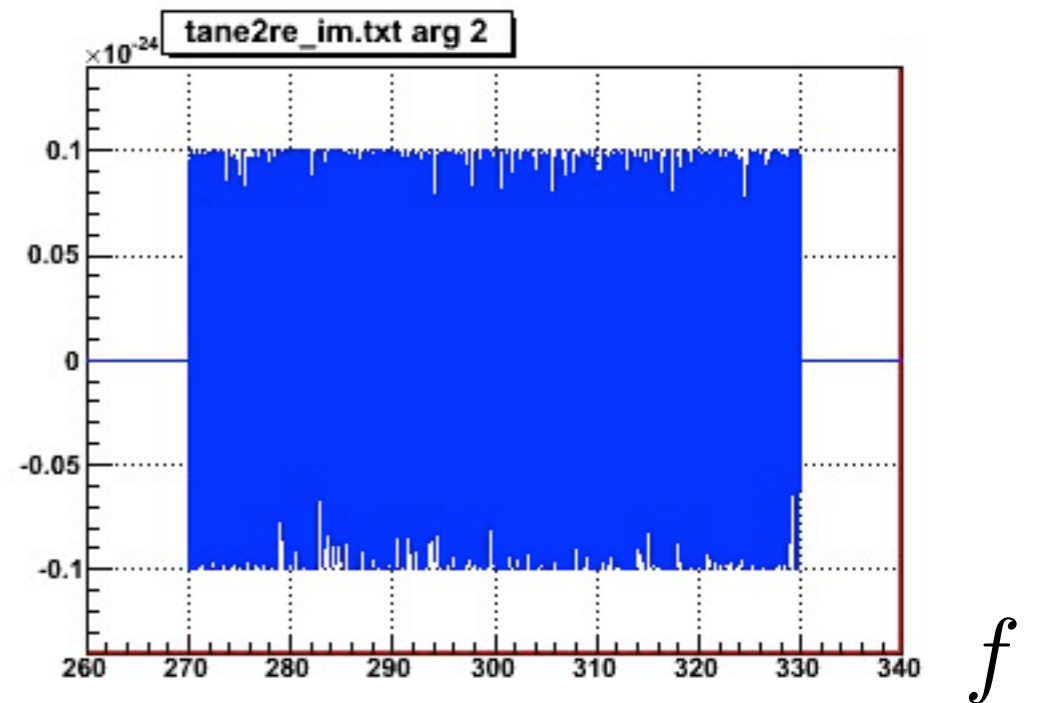
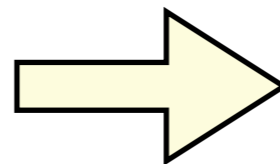
for detector 1



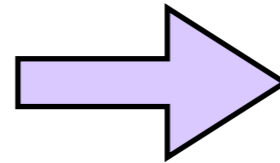
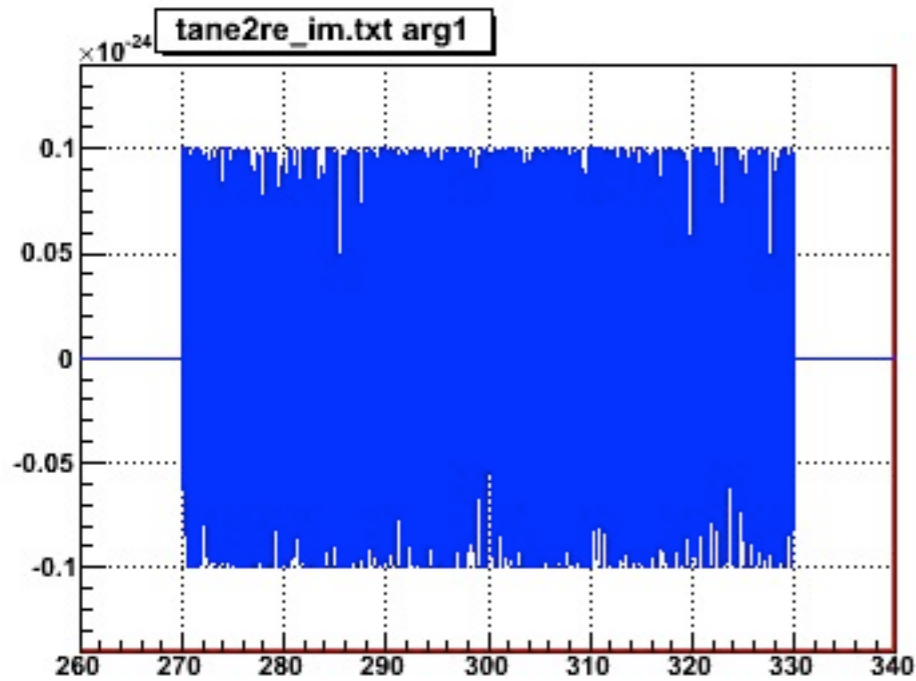
real



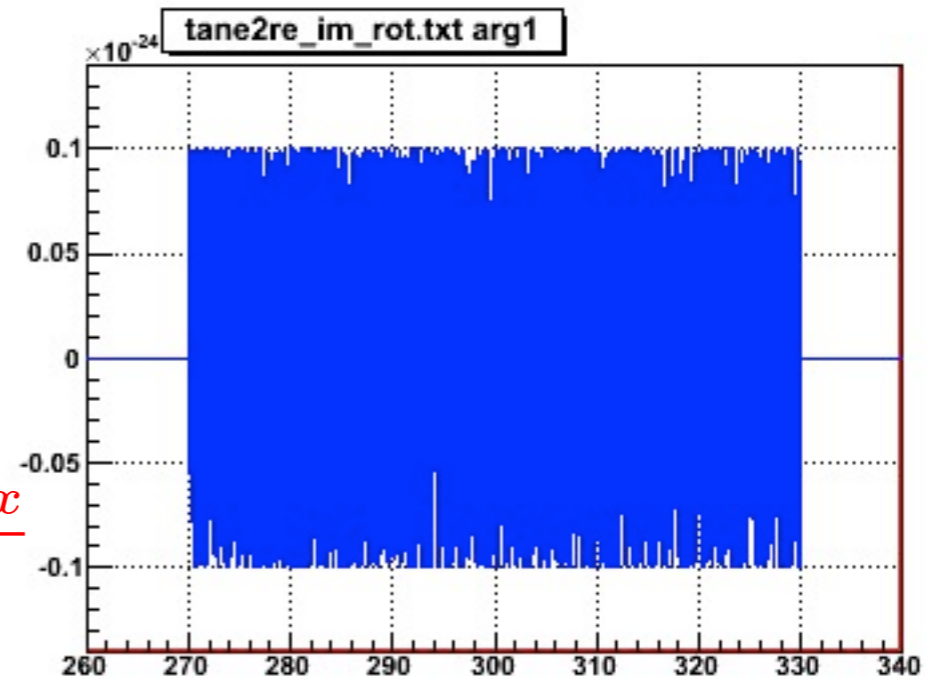
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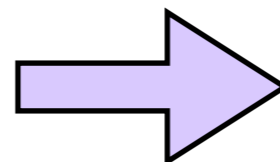
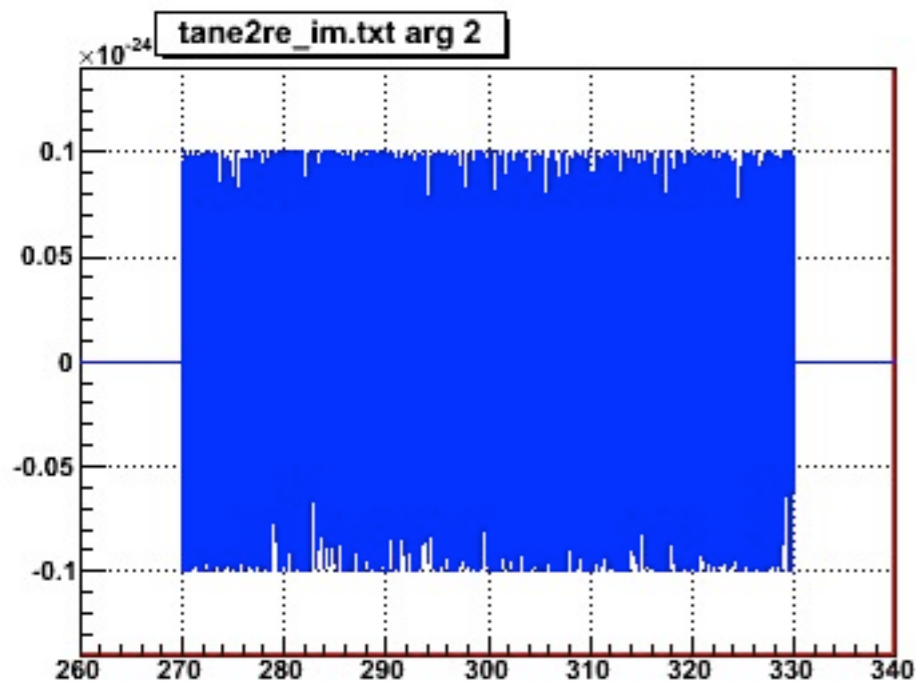
Spreading of point source



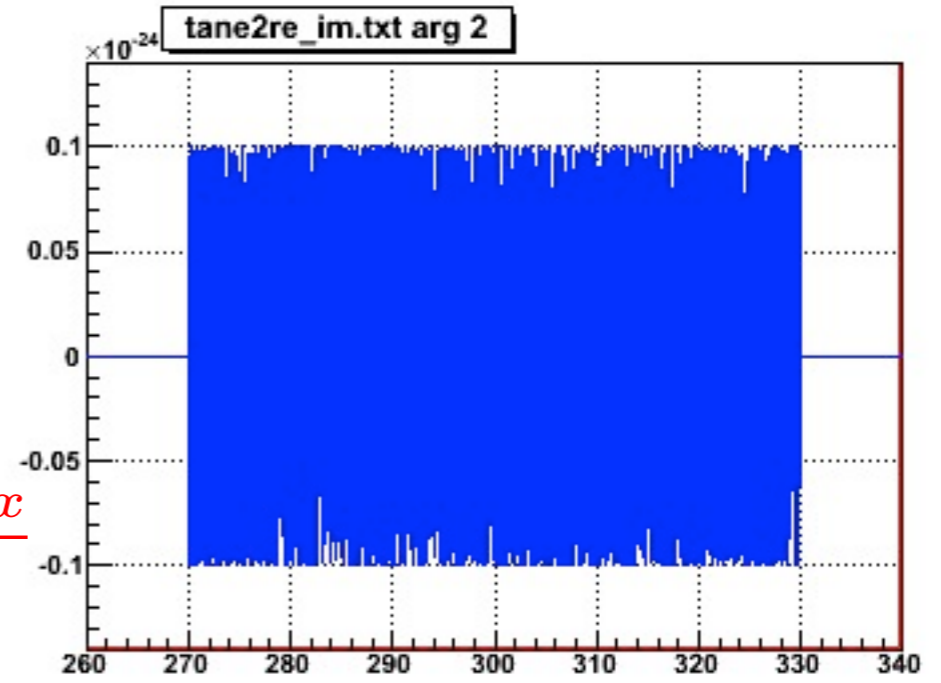
$$\times e^{2\pi i f \frac{\hat{\Omega}_0 \cdot \Delta x}{c}}$$



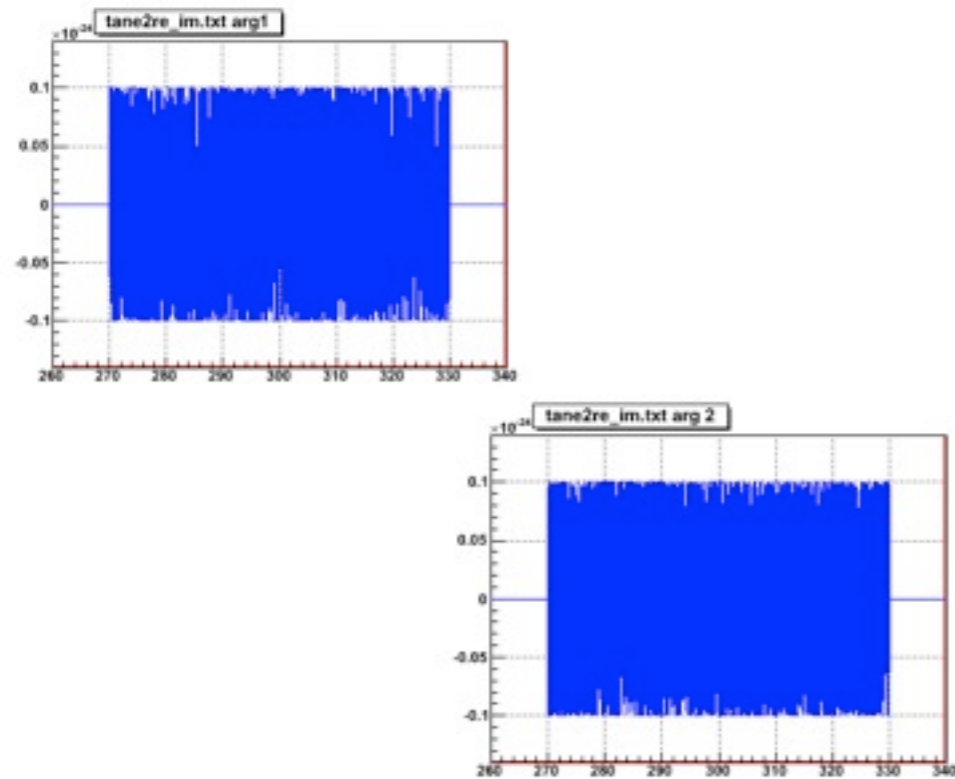
for detector 2



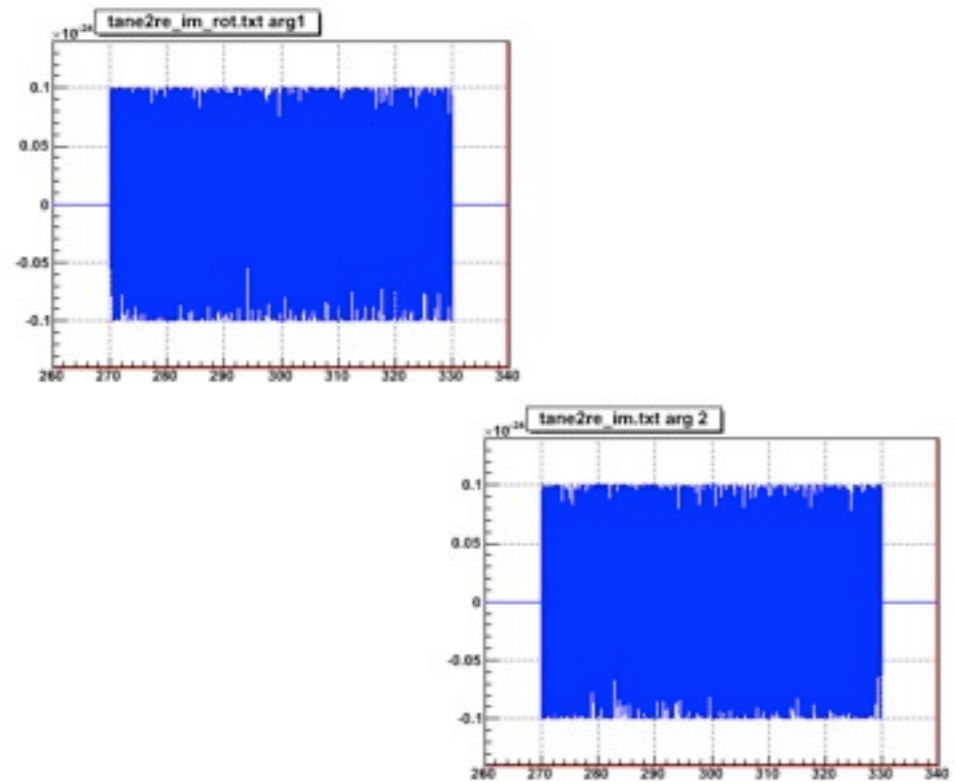
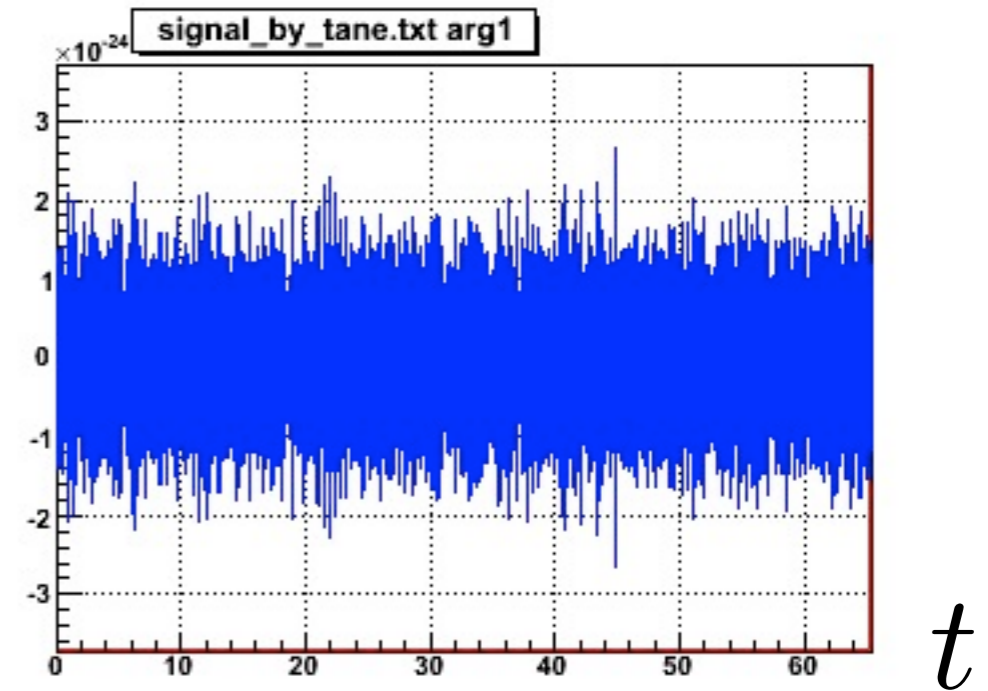
$$\times e^{2\pi i f \frac{\hat{\Omega}_0 \cdot \Delta x}{c}}$$



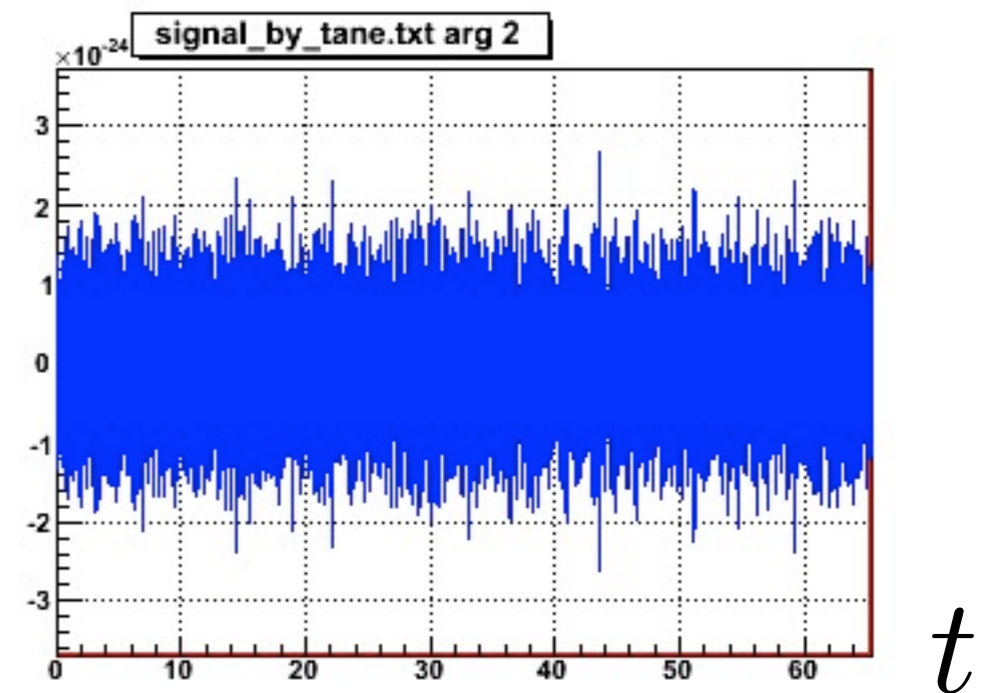
Spreading of point source



→
IFFT

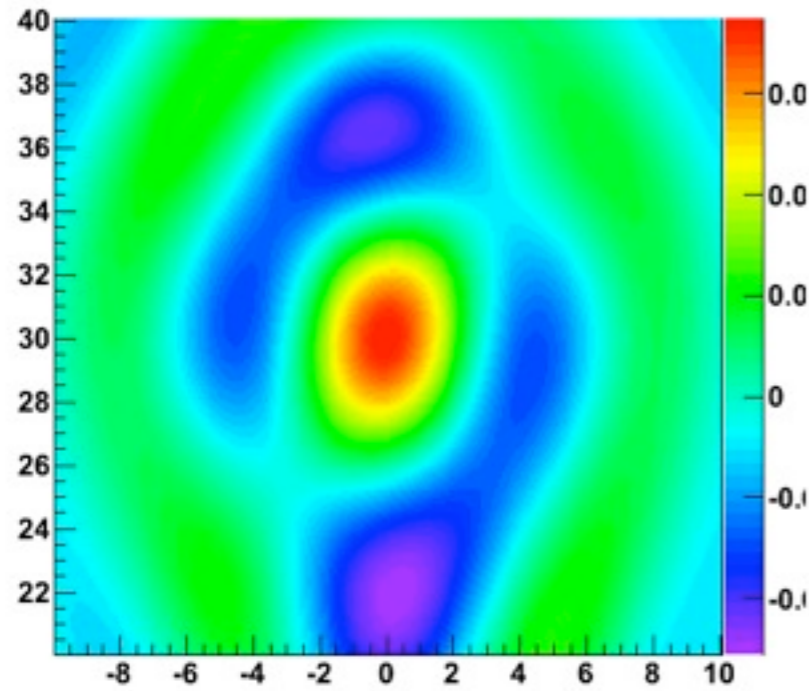


→
IFFT

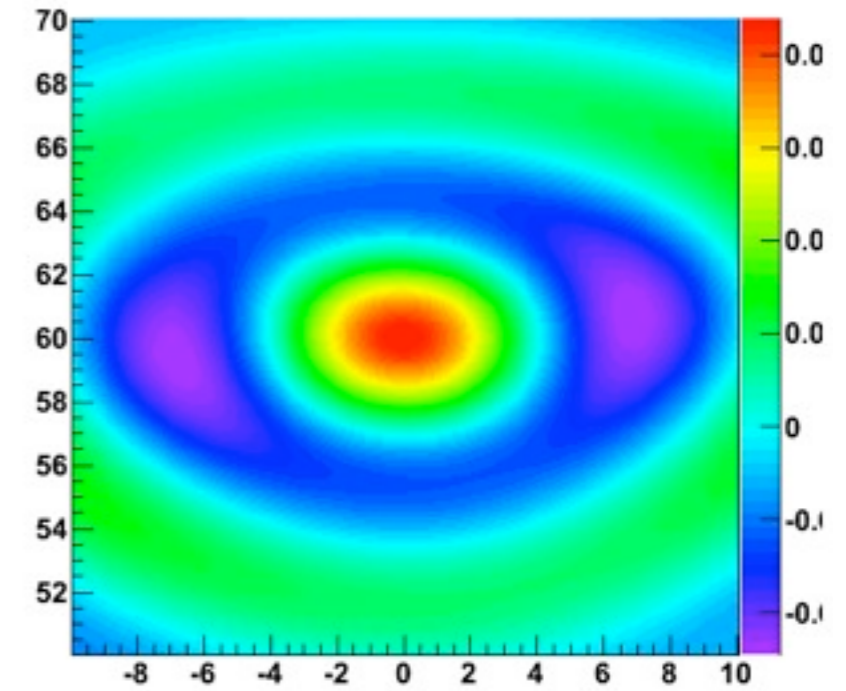


Spreading of point source

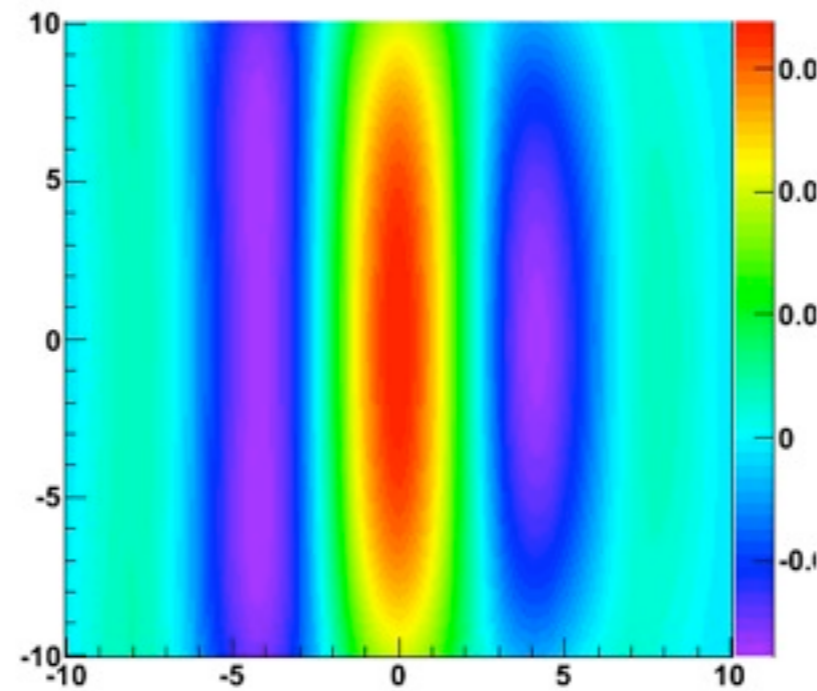
mu_f300_d30.txt



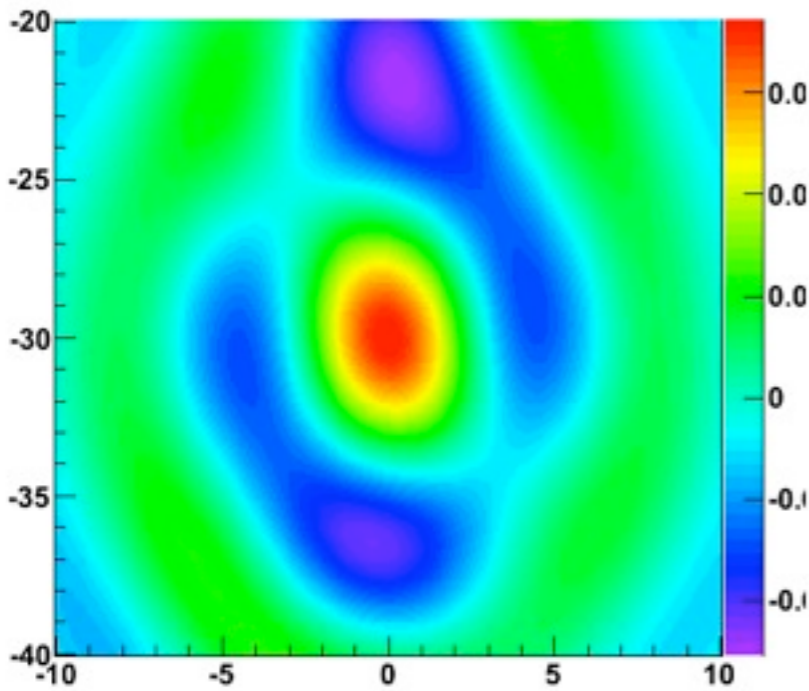
mu_f300_d60.txt



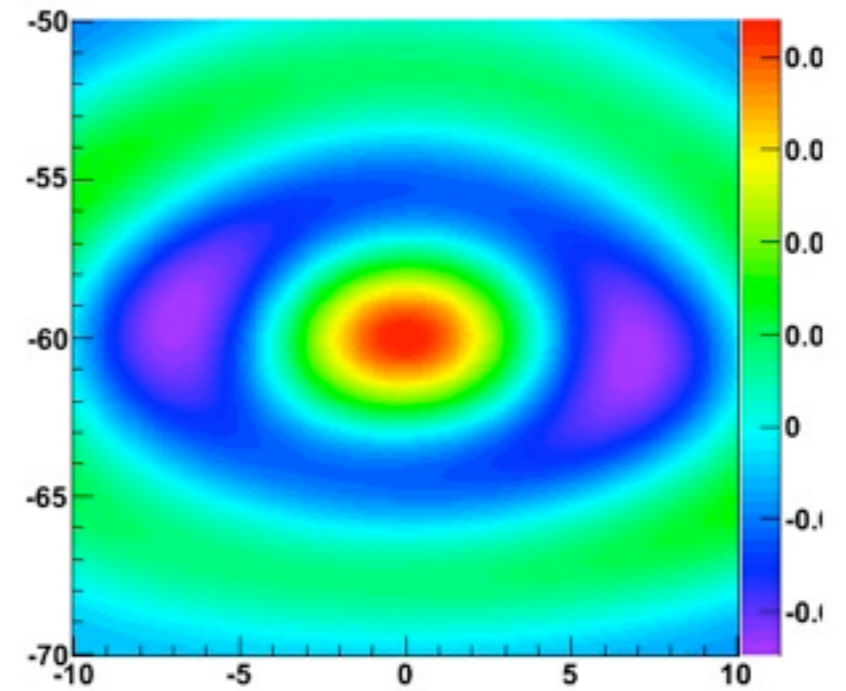
mu_f300_d0.txt



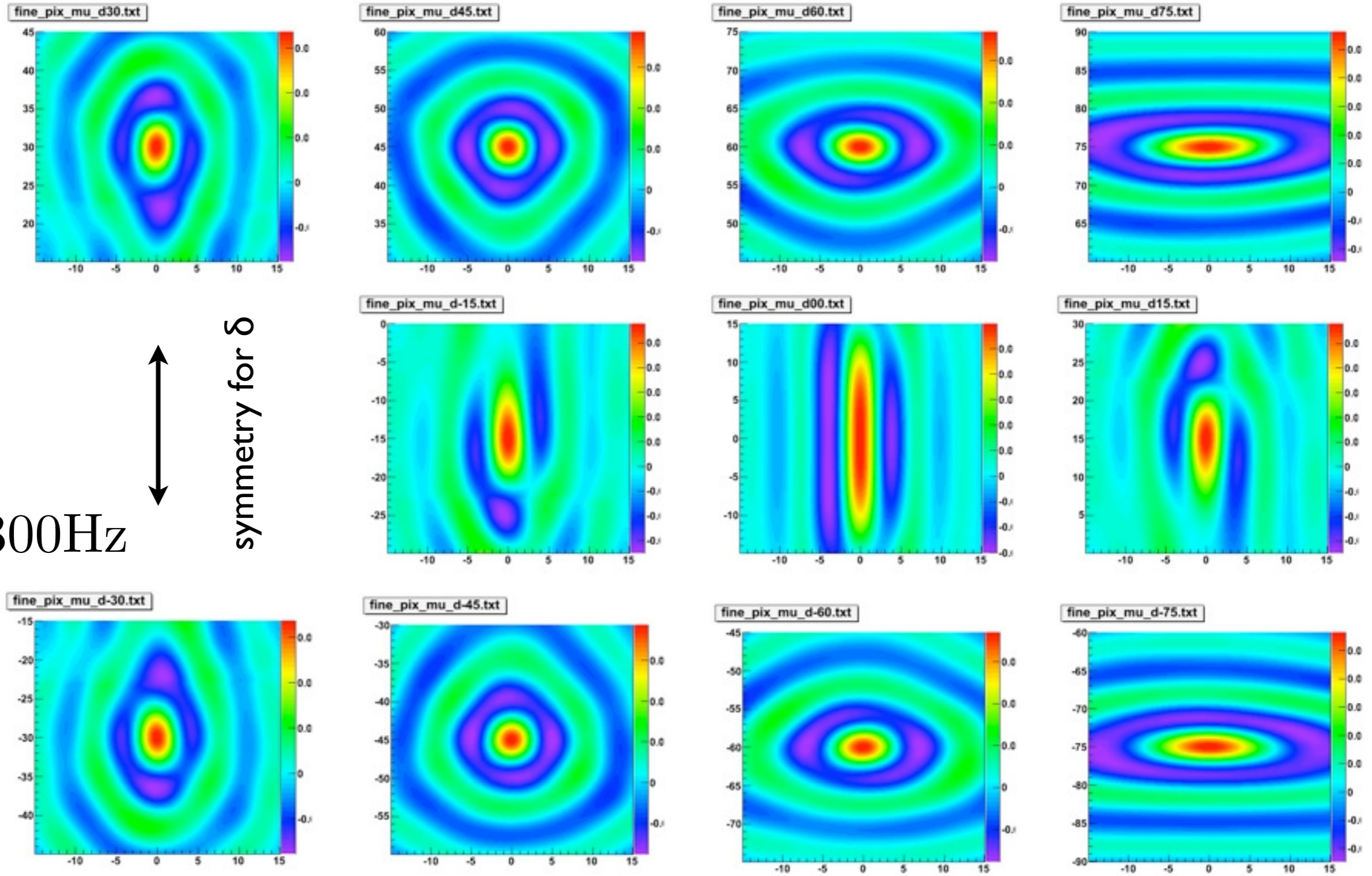
mu_f300_d-30.txt



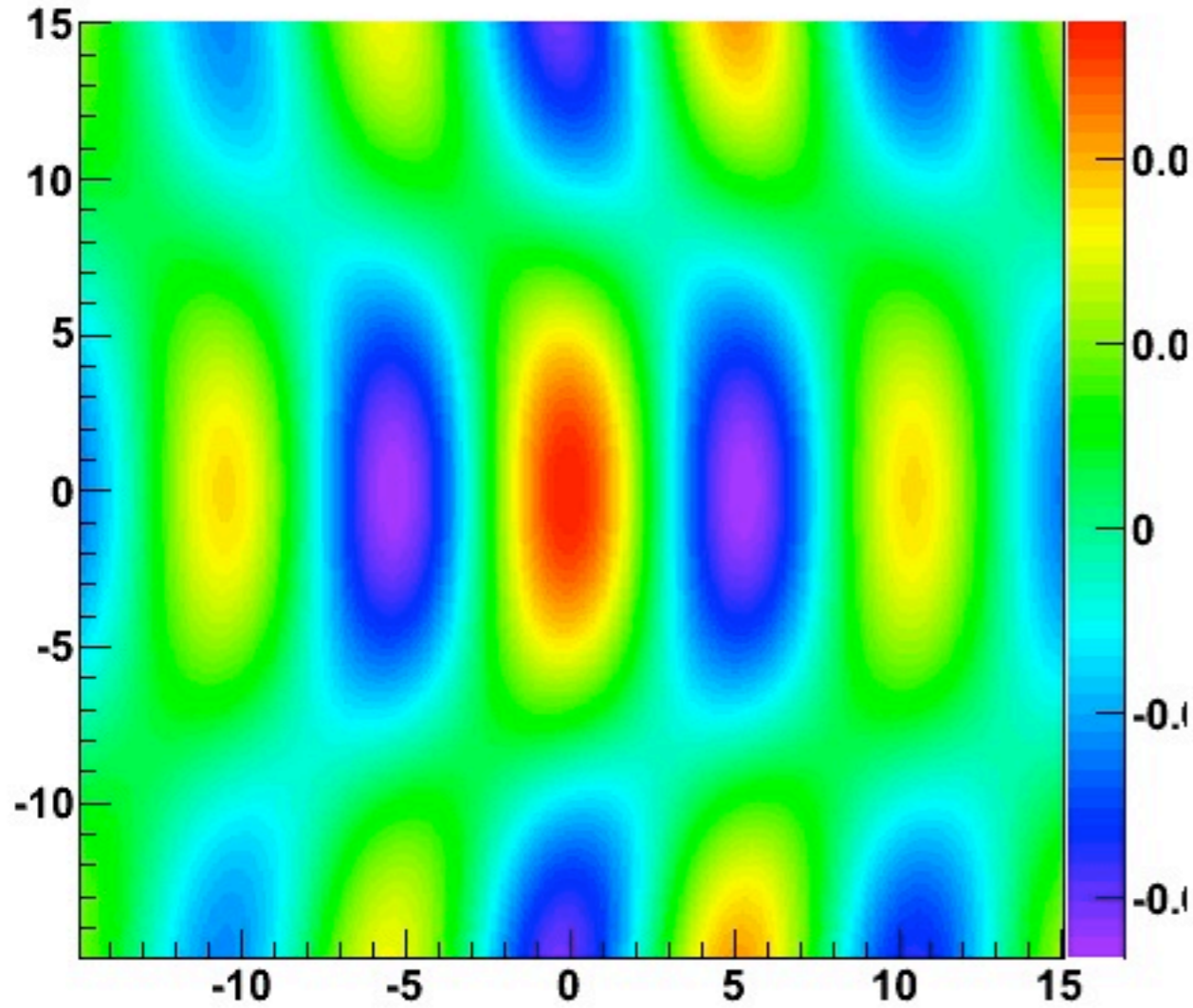
mu_f300_d-60.txt



$$f = 300\text{Hz}$$



LCGT-INDIGO_f300_d0_mu.txt



LCGT-INDIGO

LCGT-INDIGO_f300_d30_mu.txt

