Study of cosmic expansion anisotropy with type Ia supernovae from ZTF.

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ZTF Meeting
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Motivation:

Isotropy (large-scale)

?

?

?

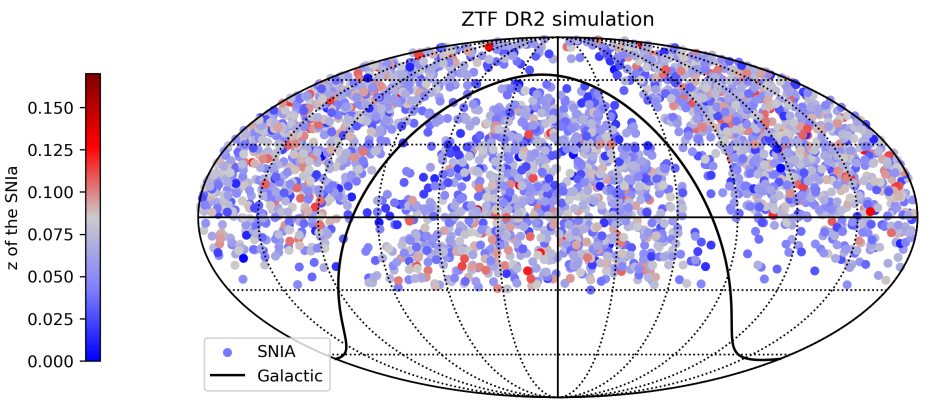
?

Cosmological principle

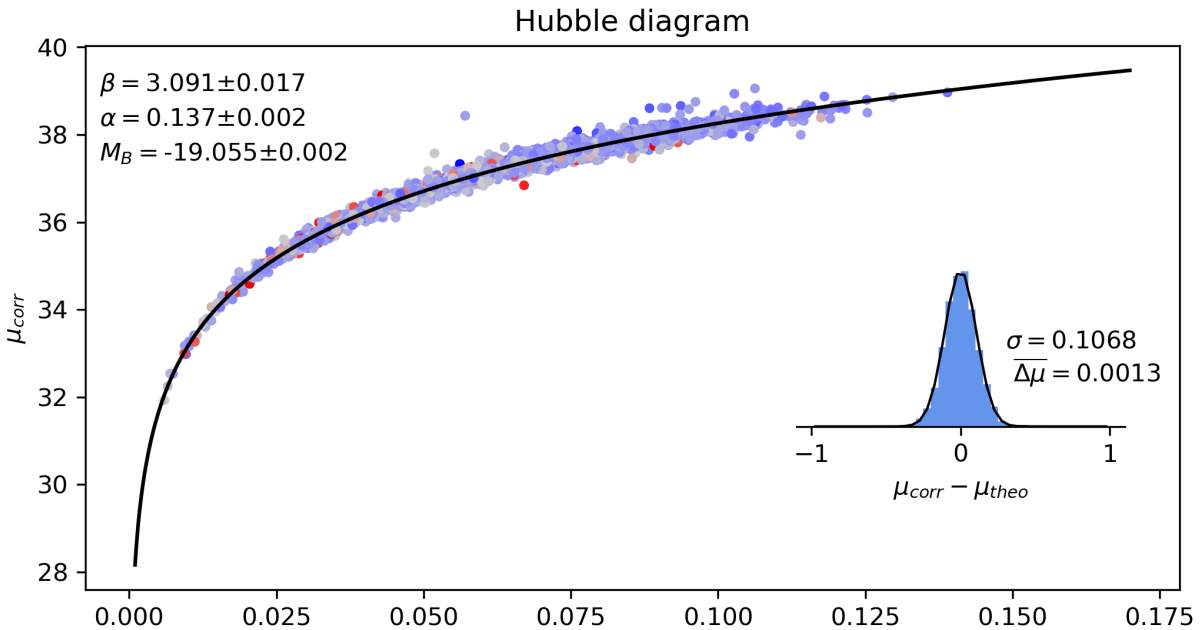
Homogeneity (large-scale)

- *This work :*
- *Study anisotropy of H_0*

- **Skysurvey :** Simulates astronomical targets as they would be observed by a survey



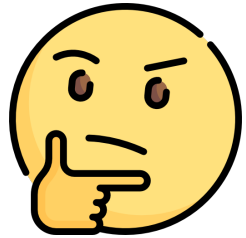
Hubble Diagram of a simulated survey after standardisation:



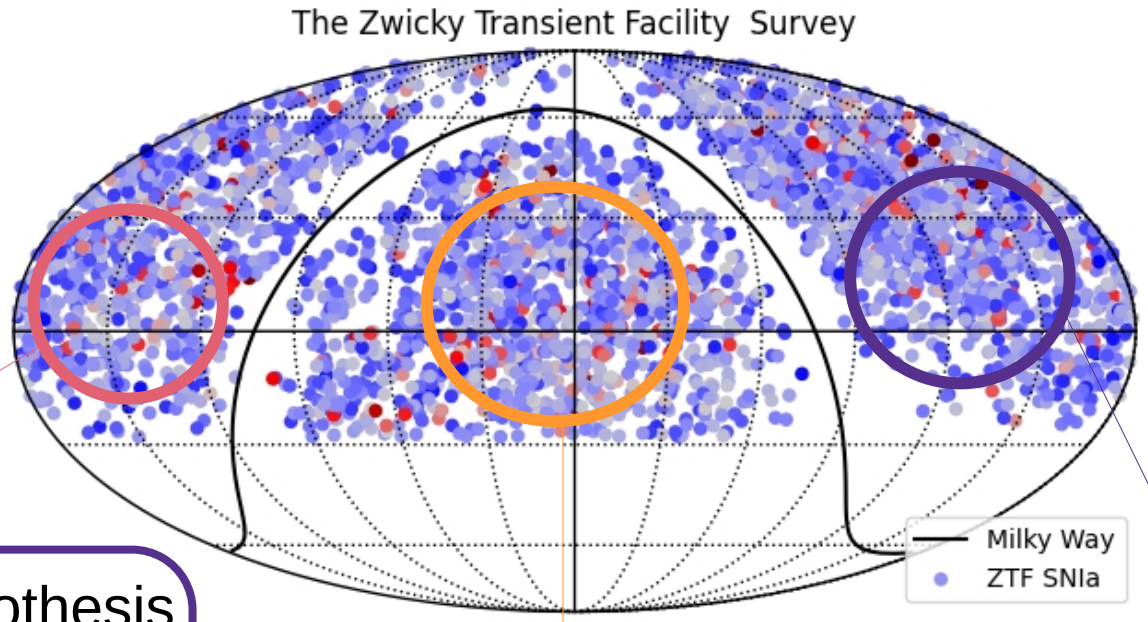
- Fit α, β, M_b for the survey

- With fixed cosmology :
  - Flat ΛCDM
  - $\Omega_m = 0.315$
  - $H_0 = 70$ km.s^{-1}.Mpc^{-1}

Anisotropy:



- With α, β, M_b and Ω_m fixed
- H_0 and σ free



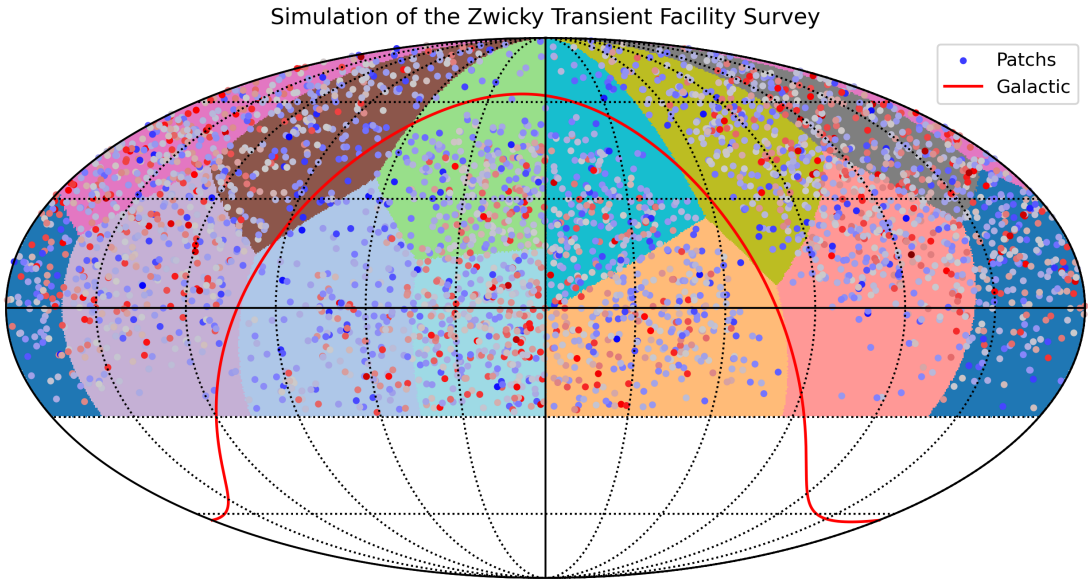
$H_0 = 68$ km.s^{-1}.Mpc^{-1} ?

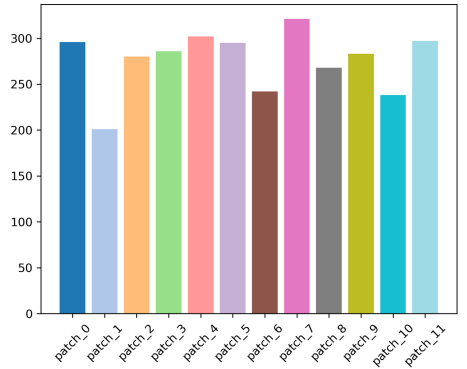
$H_0 = 73$ km.s^{-1}.Mpc^{-1} ?

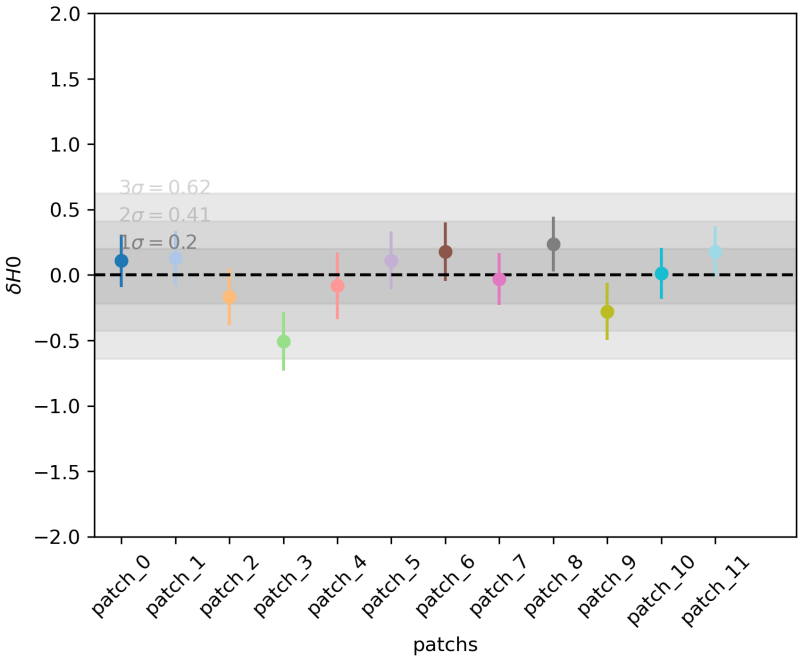
$H_0 = 70$ km.s^{-1}.Mpc^{-1} ?

- Divided skies : no hypothesis on anisotropies
- Anisotropic function (continous function) : best statistics

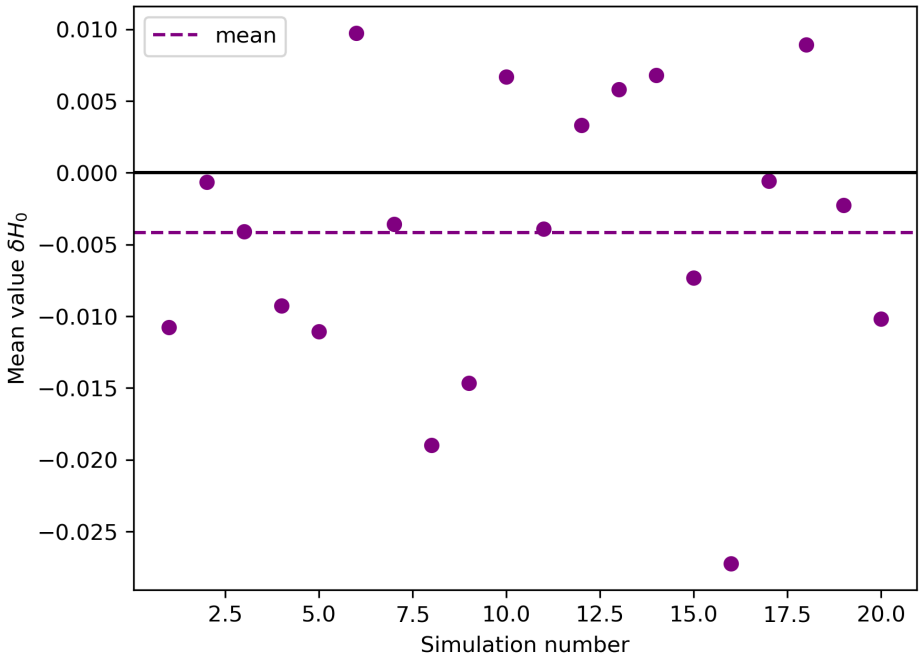
Cluster method (adapted patch):

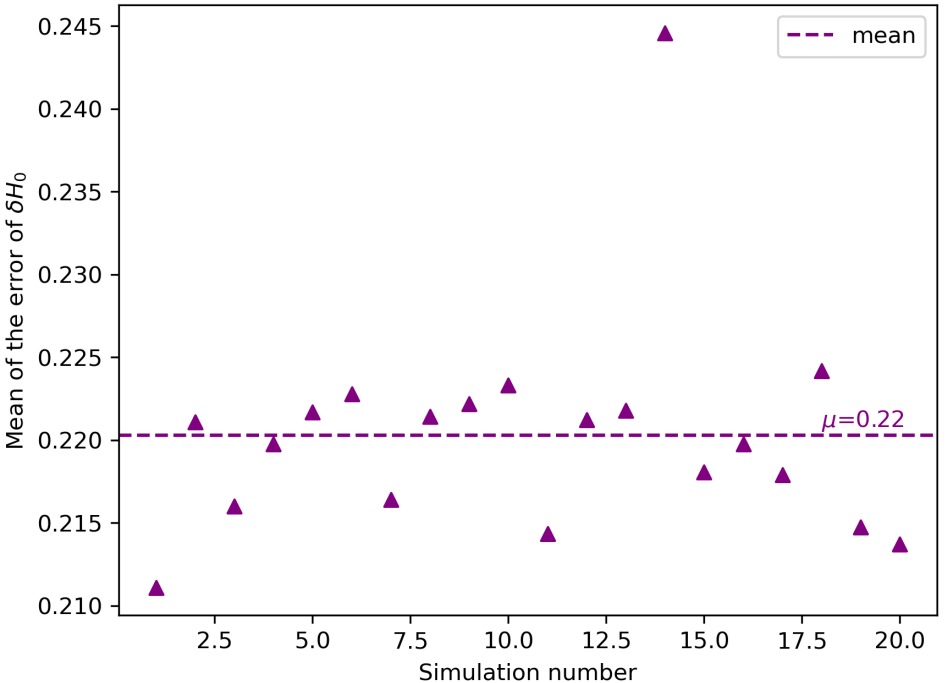






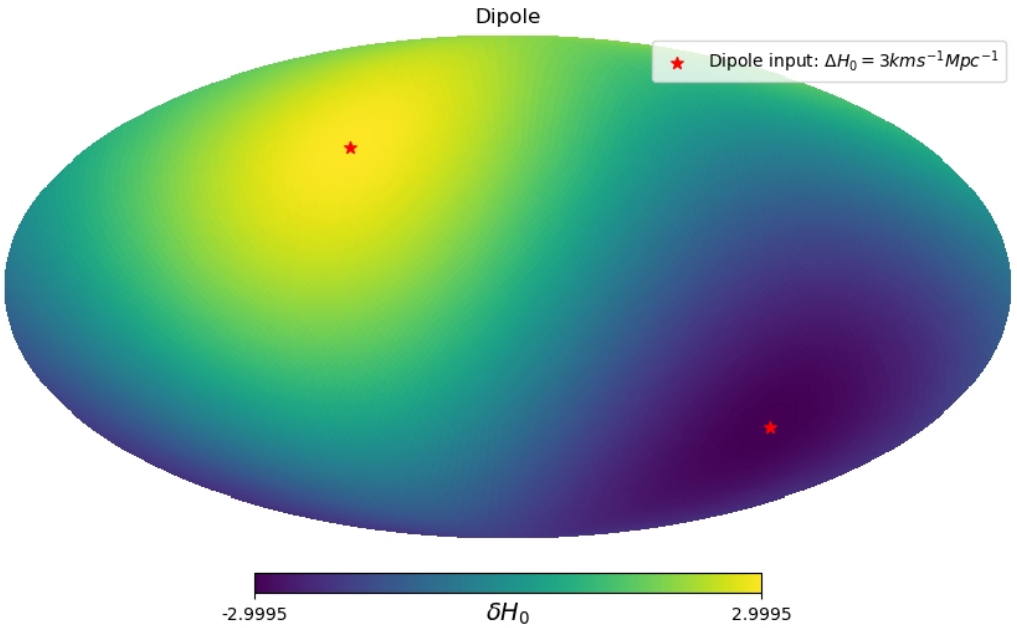
Several Simulation:





- Sensitivity of 0.22 km.s^{-1}.Mpc^{-1} at a confidence level of 1σ with no anisotropy effect in input.

Adding a dipole effect:



$H_0 = 70$ km.s^{-1}Mpc^{-1}

$\Delta\theta = \theta^{i}_{SNIa} - \theta_{dipole}$

$$cz' = H_0' d = \left(H_0 + \Delta H_0 \cos\left(\Delta\theta\right)\right) d$$

$$z' = \left(1 + \frac{\Delta H_0 \cos\left(\Delta\theta\right)}{H_0}\right) z$$

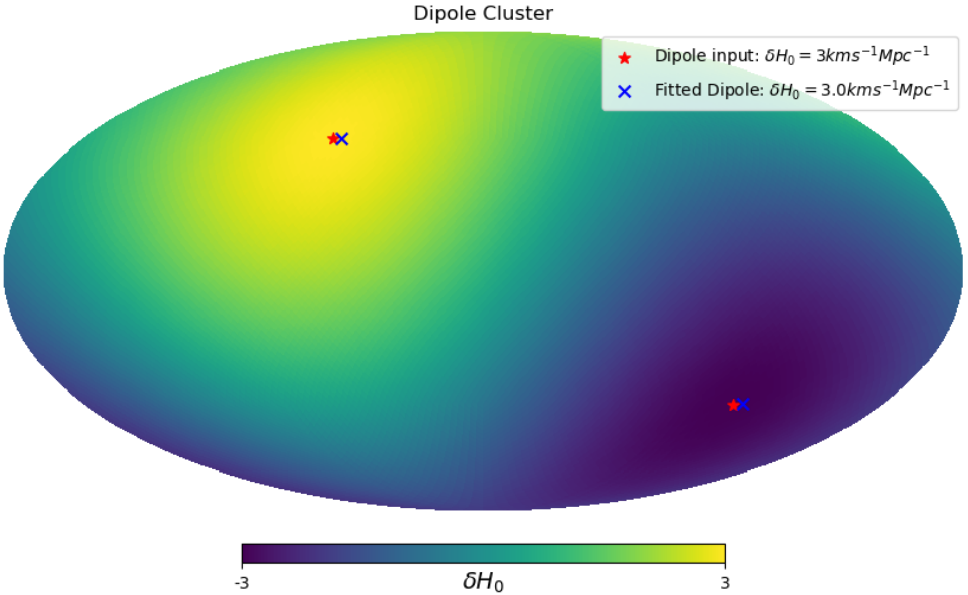
$\Delta H_0 = 3$ km.s^{-1}Mpc^{-1}

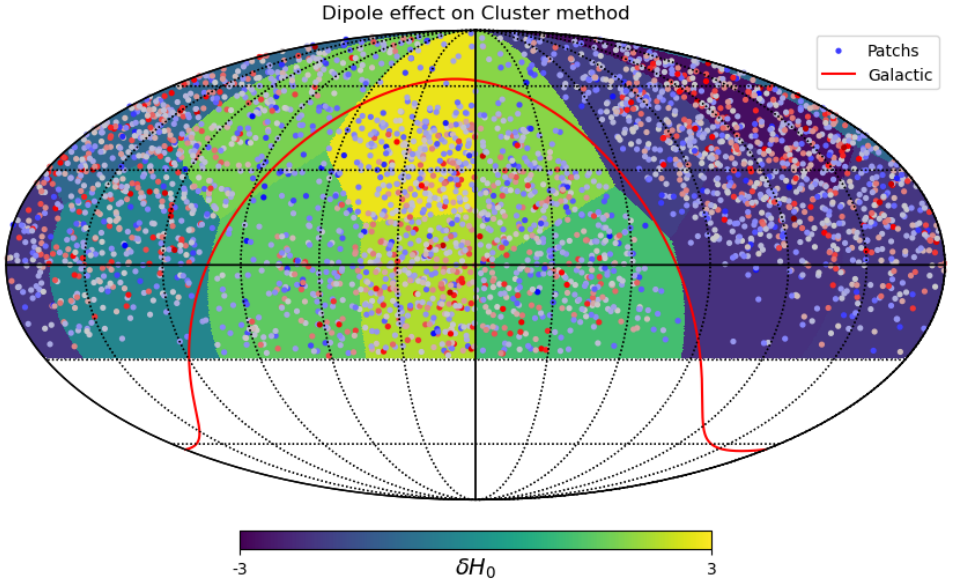
Fit a dipole for Cluster method :

Free

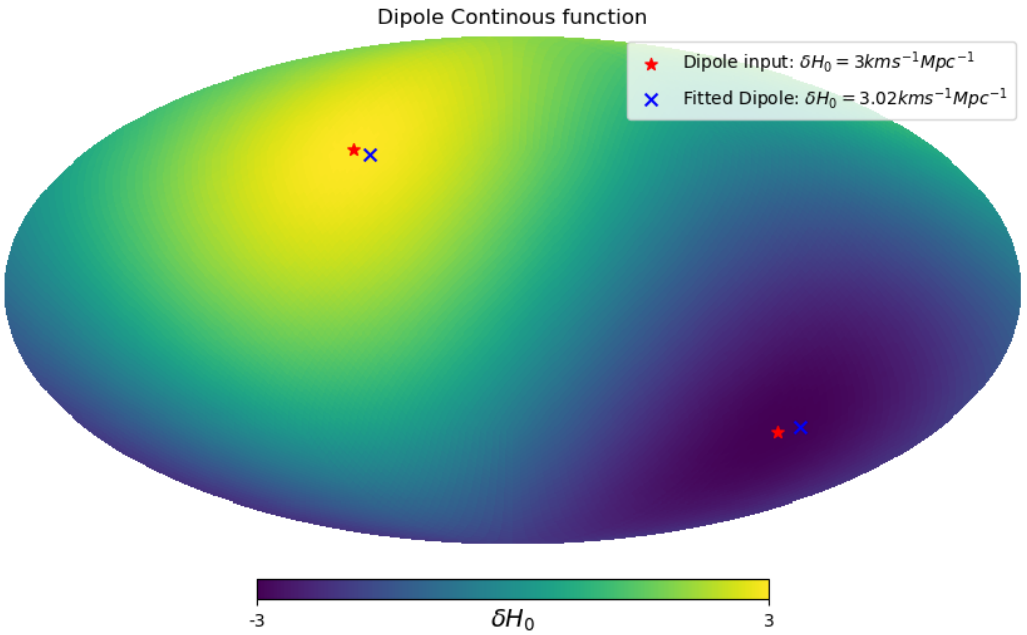
$$\chi^2 = \sum_{i=1}^{N_{patch}} \left(\frac{\delta H_0^i - \delta H_0^{th,i}(\theta_i, \theta_{dip}, \Delta H_0)}{\sigma_{\delta H_0^i}} \right)^2$$

$$\delta H_0^{th,i} = \Delta H_0 \cos(\theta_i - \theta_{dip})$$





Fit a dipole for Continous function :



Free

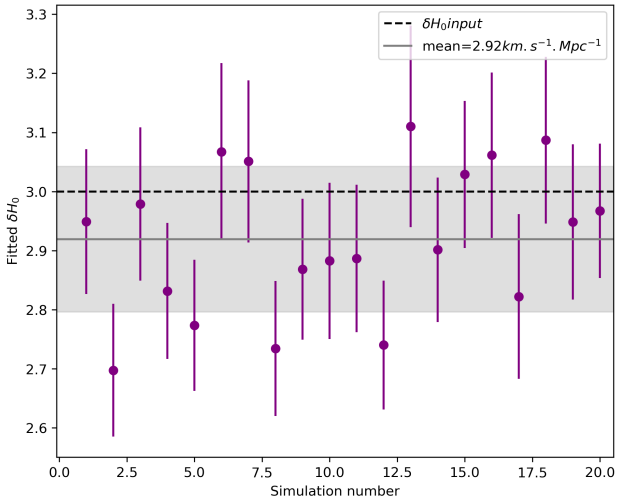
$$\chi^2 = \sum_{i=1}^{N_{SNeIa}} \left(\frac{\mu_i^{\exp} - \mu_i^{th}\left(z_i, \theta_i, \theta_{dip}, \Delta H_0\right)}{\sigma_{\mu_i}} \right)^2$$

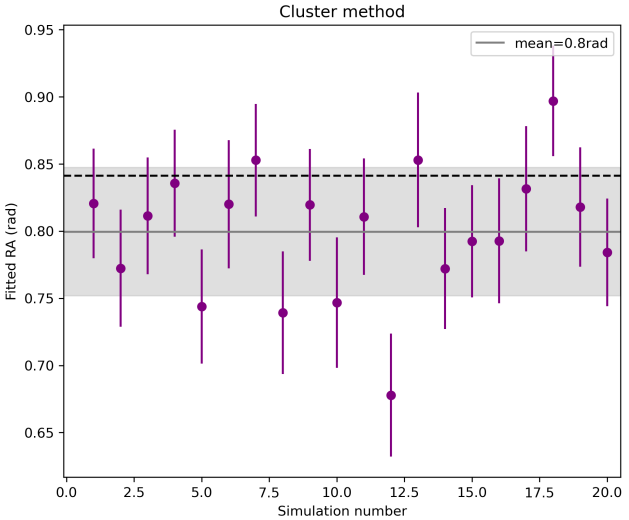
$$\mu_{th} = 5 \log\left(d_l(Mpc)\right) + 25$$

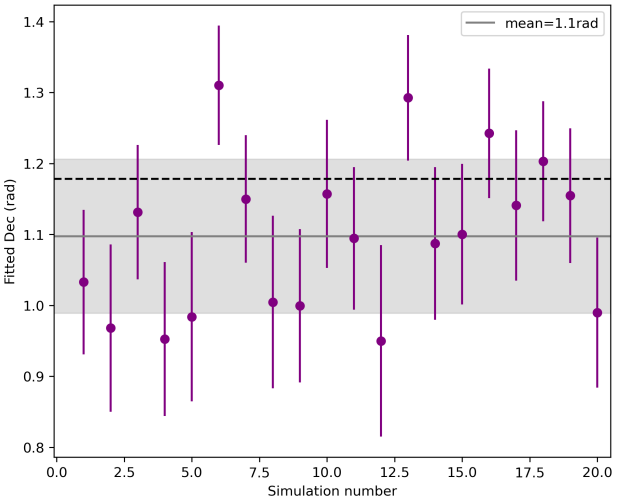
$$d_l = \frac{c(1+z)}{H_0} \int_0^{z_i} \frac{dz'}{\sqrt{\left((1+z)^3 - 1\right)\Omega_m + 1}}$$

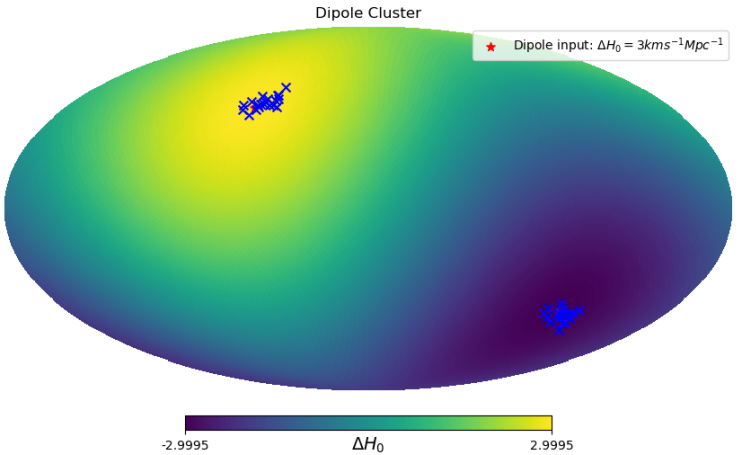
$$H_0 = \bar{H}_0 + \Delta H_0 \cos\left(\theta_i - \theta_{dip}\right)$$

Cluster fit dipole:



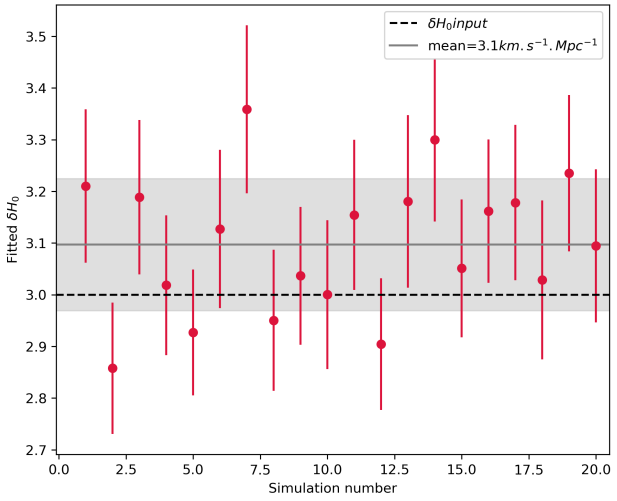


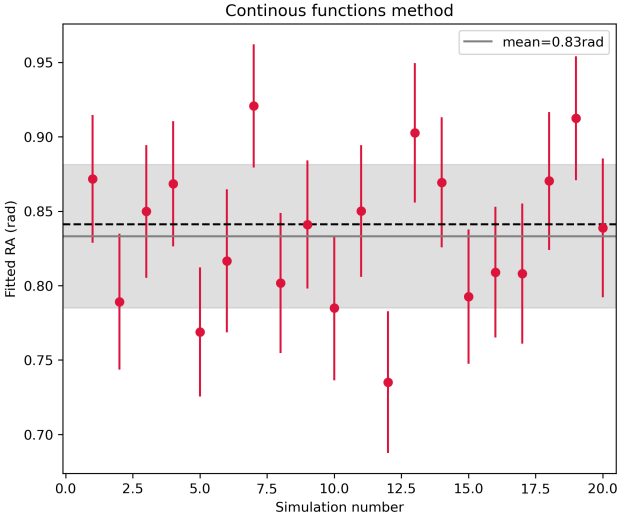


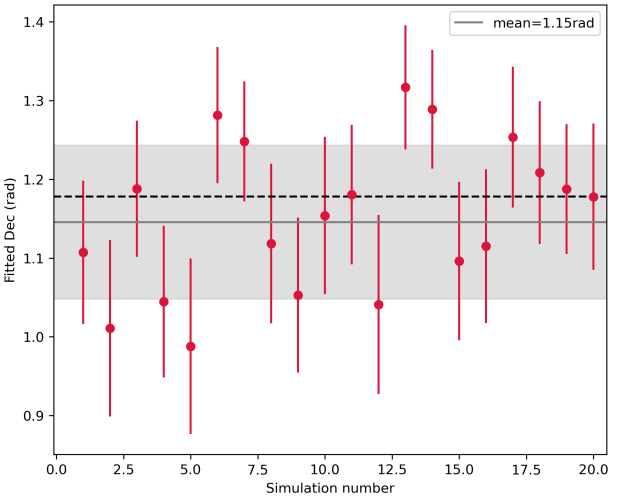


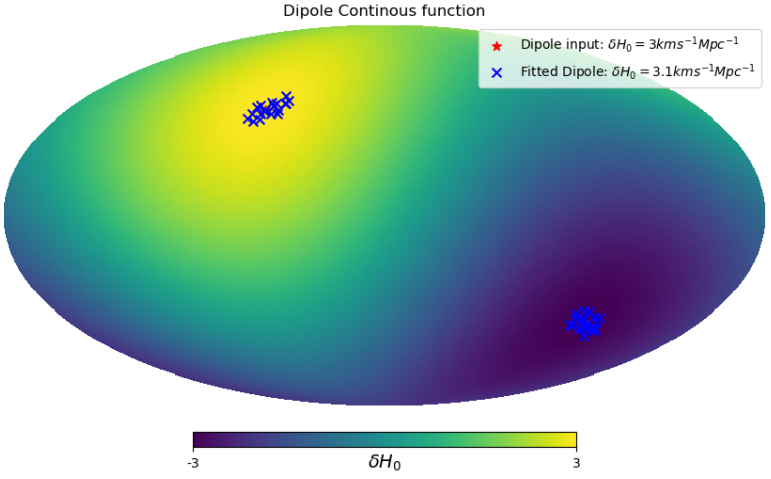
- No Systematic bias

Continous function fit dipole:



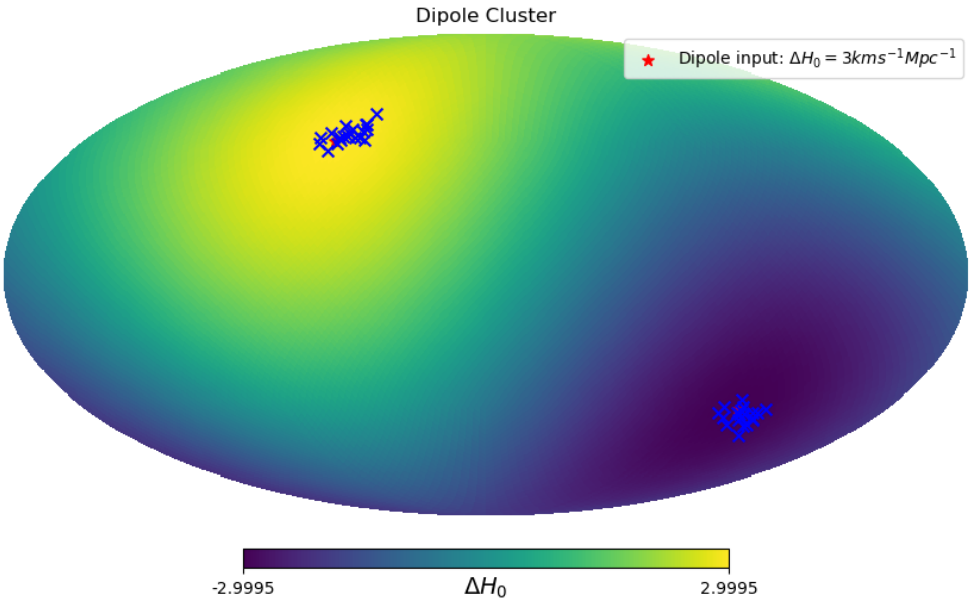


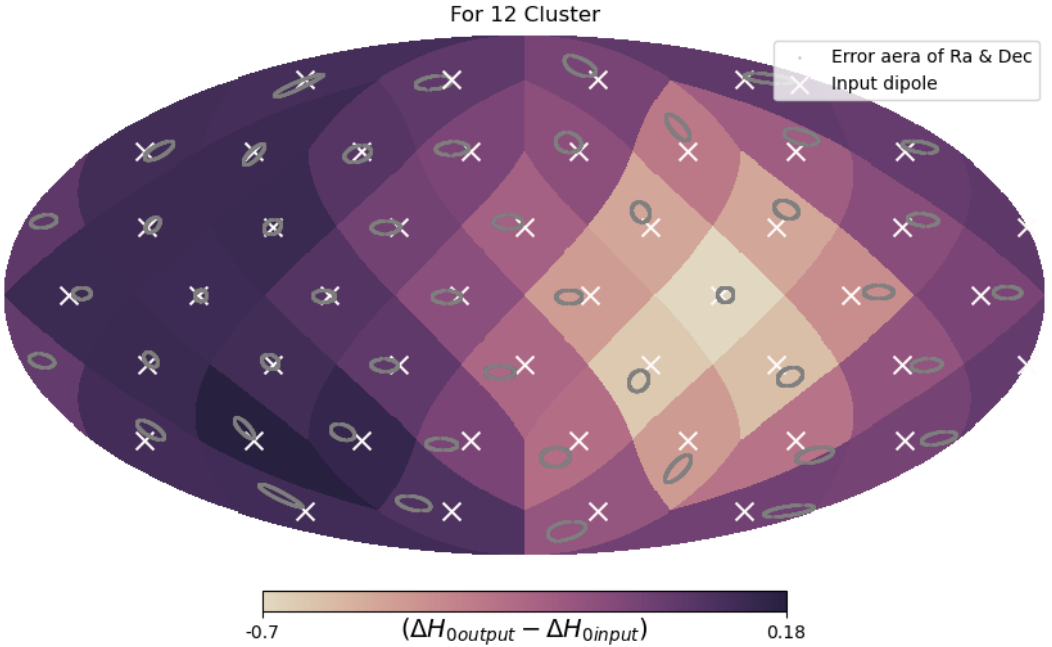




- Closer to the truth values.

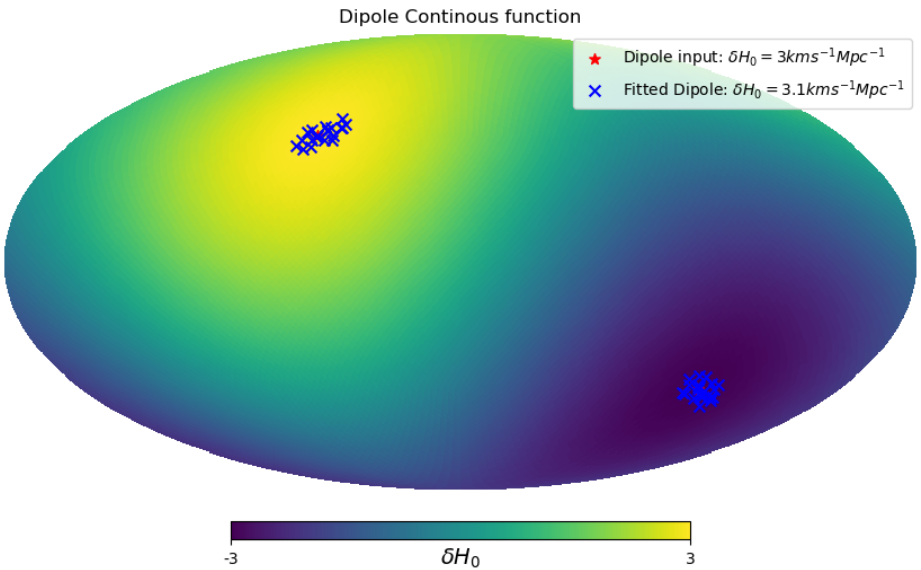
Cluster fit dipole:

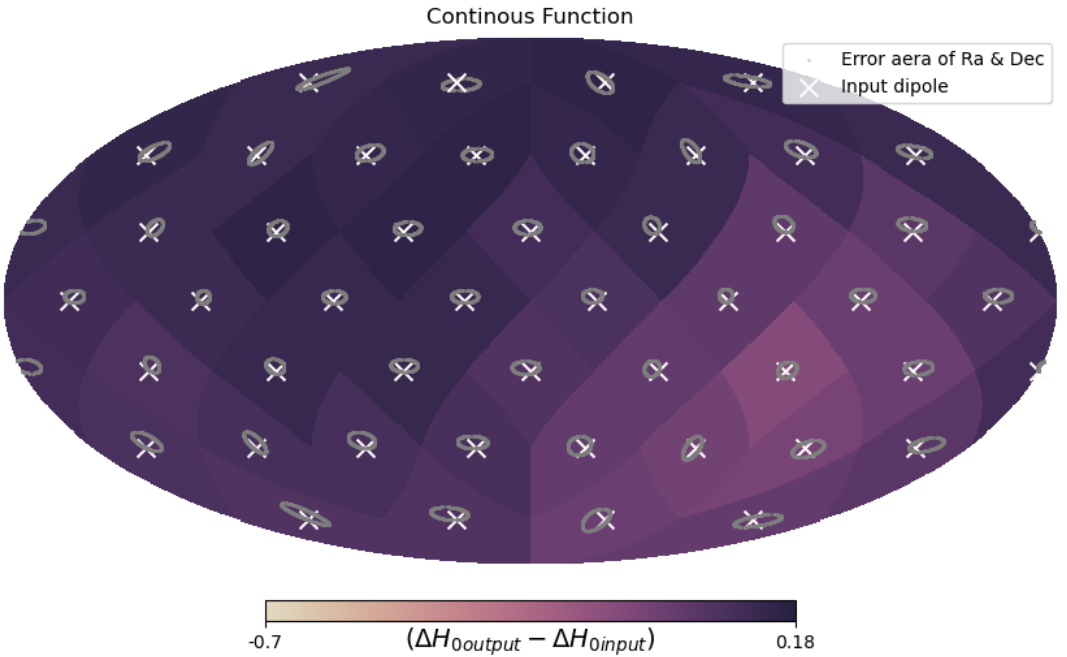




- Difficulty to fit the location of the input dipole close to the south celestial pole.
- Difficulty to fit the amplitude of the input dipole near to the right of the milky way.

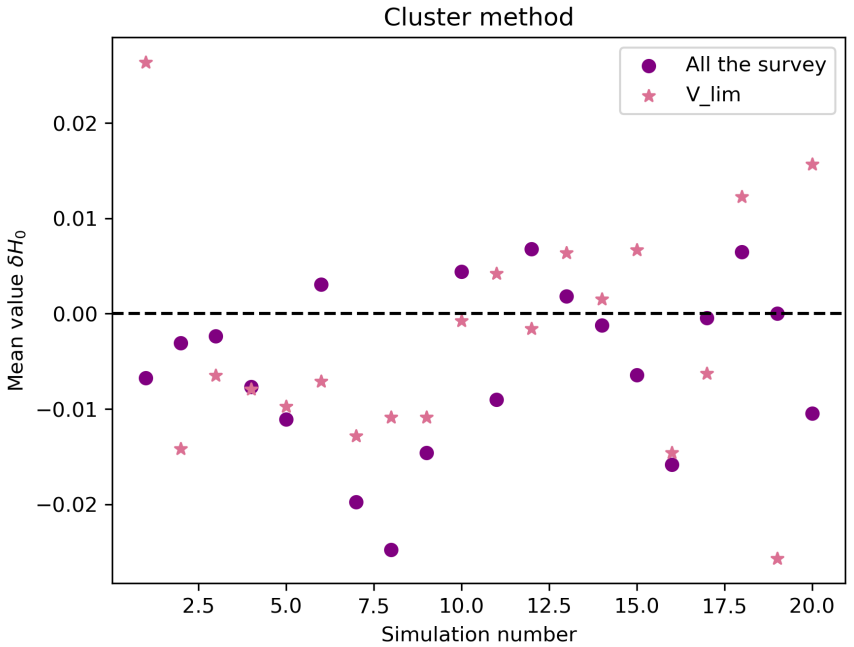
Continous function fit dipole:

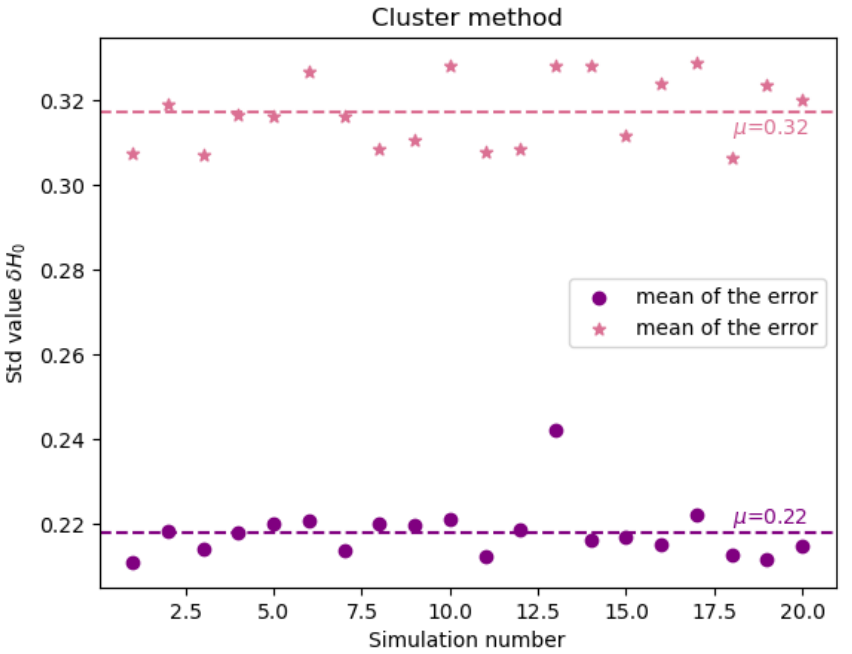




- Works better, no biais.

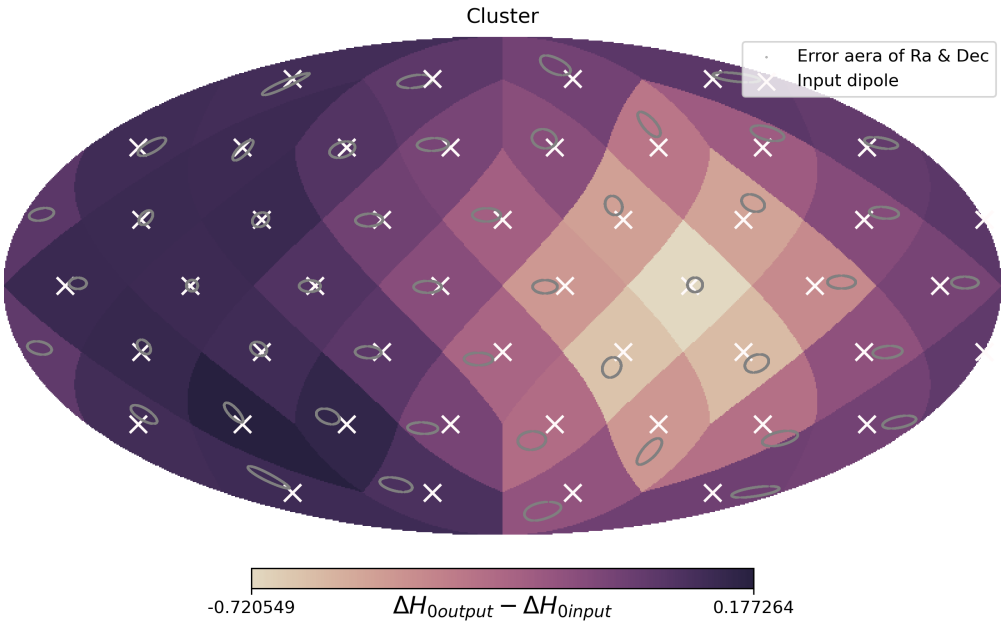
Volume limites (z<0.06) :

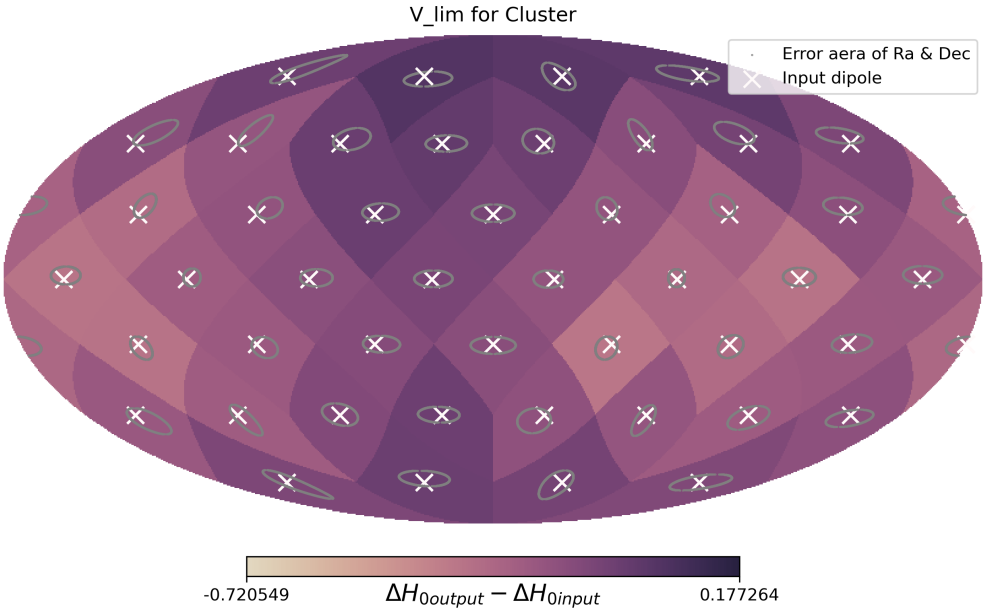




- Sensitivity of 0.32 km.s^{-1}.Mpc^{-1} at a confidence level of 1σ for the V_lim for the Cluster method with no anisotropy effect in input.

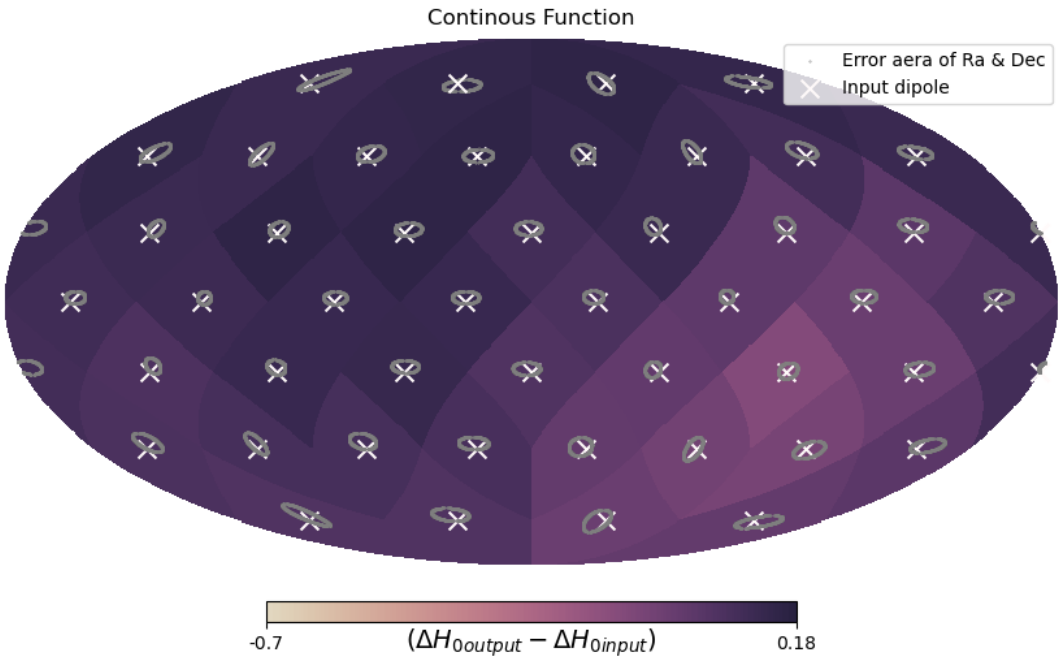
V_lim fit dipole (z<0.06):

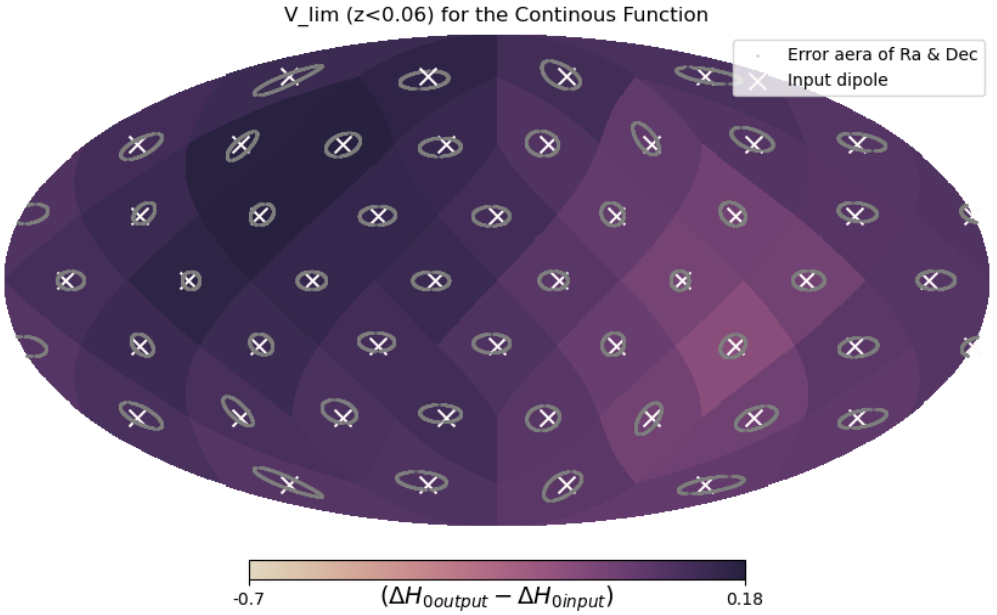




- Less biased with the volume limited with the cluster methods

V_lim fit dipole (z<0.06):





Largest ellipse for the continus function.

Conclusion:

- Summary :
  - Sensitivity of 0.22 $km.s^{-1}.Mpc^{-1}$ at a confidence level of 1σ for Cluster method with no anisotropy effect in input.
  - Closer to the truth value with the continous function.
  - Difficulty to fit the location dipole close to the south celestial pole and the amplitude near to the milky way.
  - Sensitivity of 0.32 $km.s^{-1}.Mpc^{-1}$ with the Volume limite and less biased.

- Perspective :
  - Anisotropy fit with MCMC.

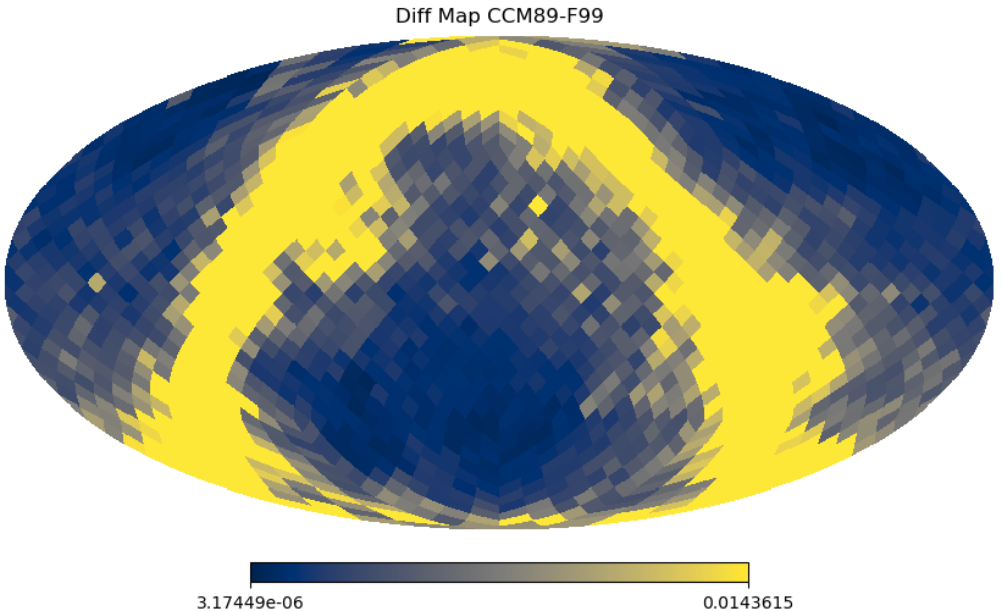
  - Test the impact of different Dustmaps.

  - More complexe anisotropy effects.

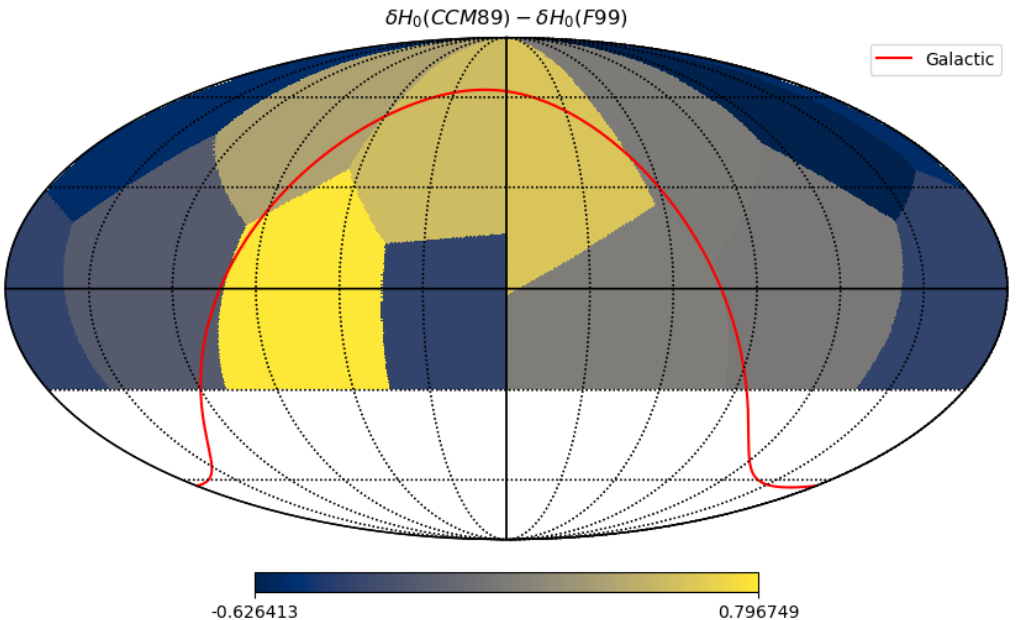
  - Adding large scale structure in the simulations.

  - ..

Backup- Impact Dustmaps :



$$mean\left(\left(\delta H_{0\,CCM} - \delta H_{0\,F\,99}\right)_{patch_i}\right)_{20\,simus}$$



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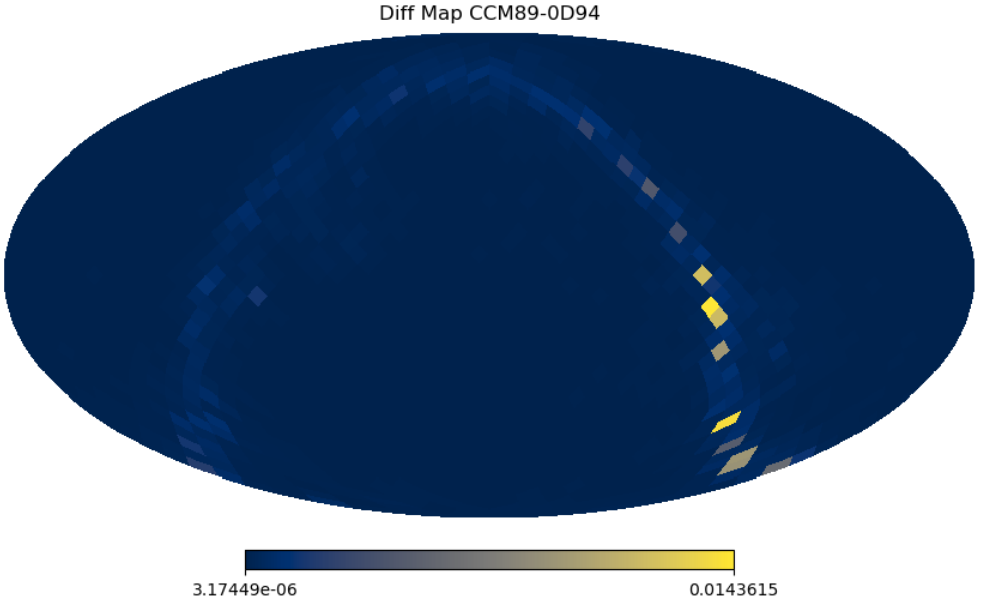
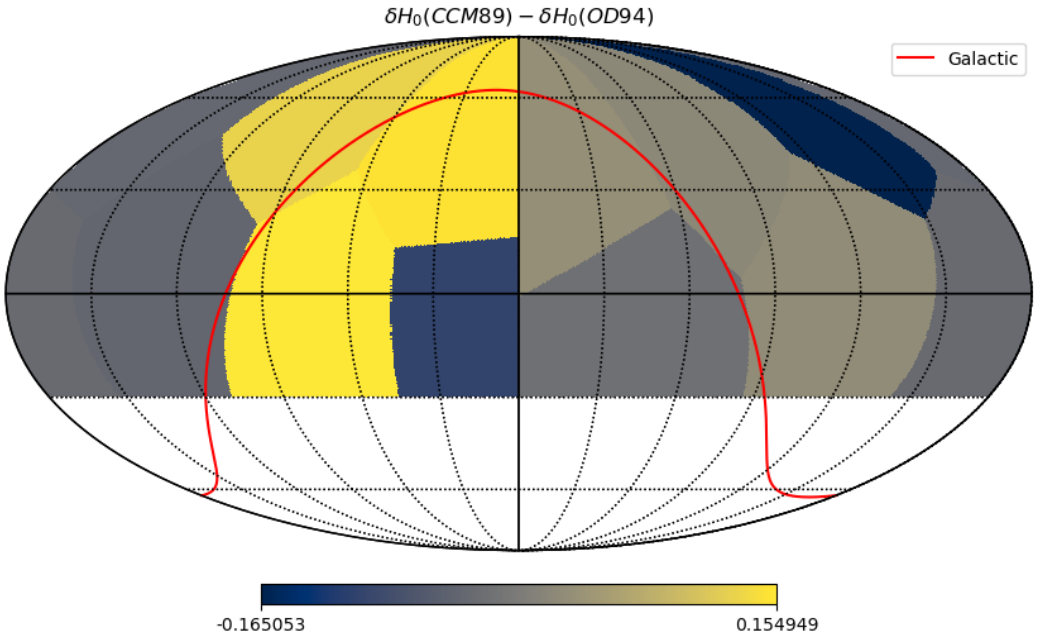
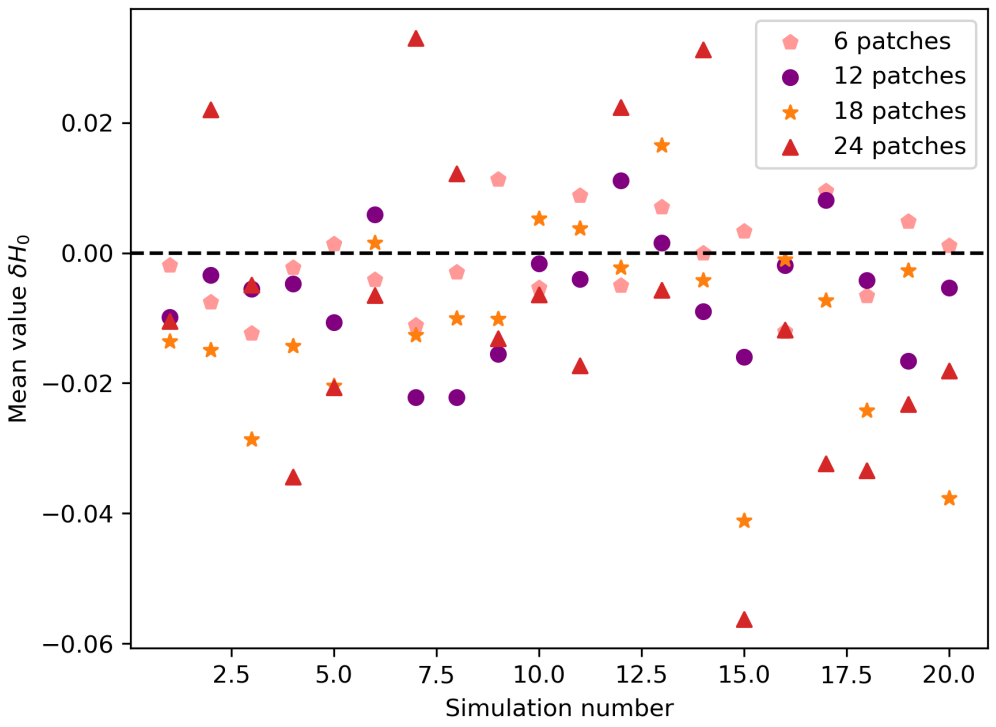
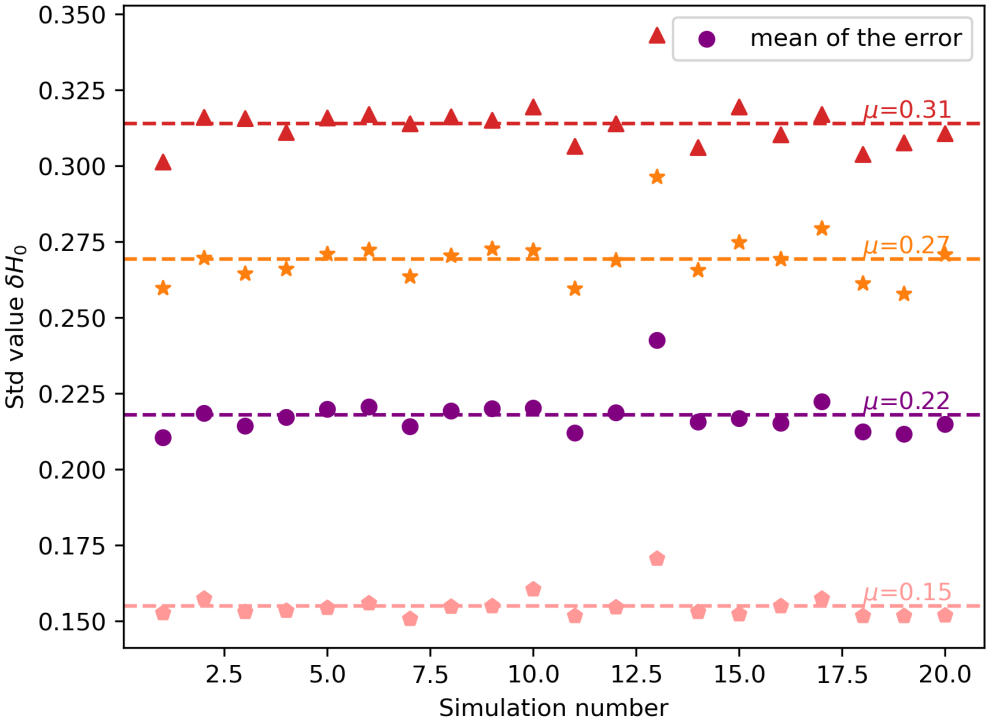


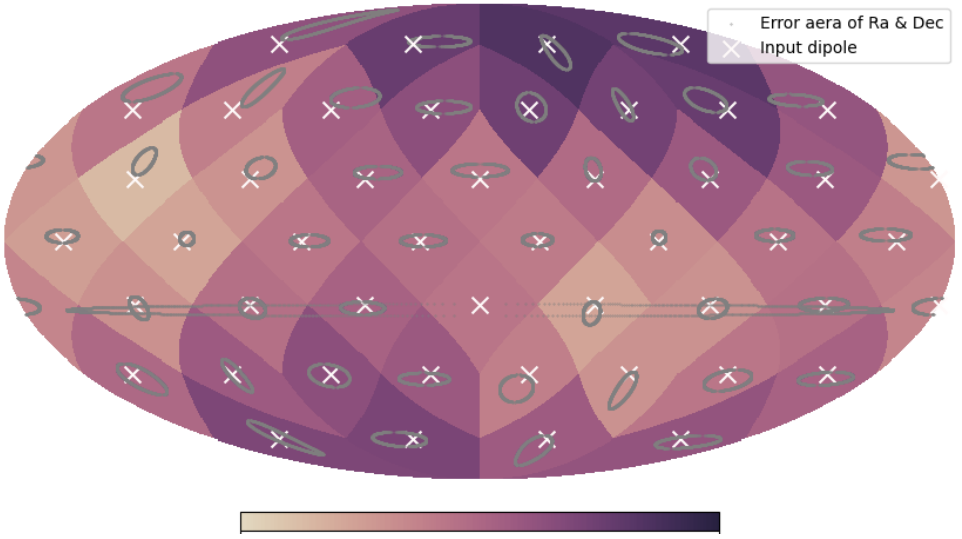


Backup- Comparaison nombre de patchs :

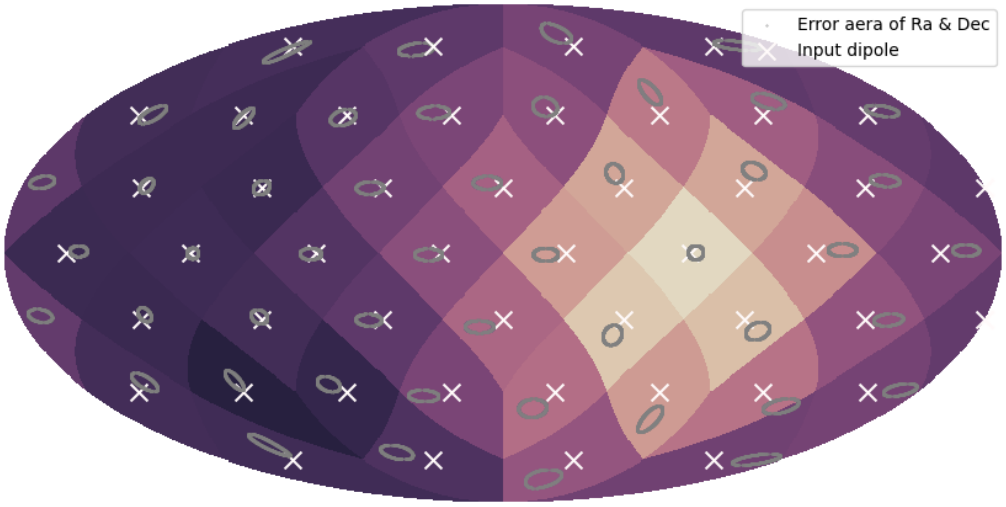




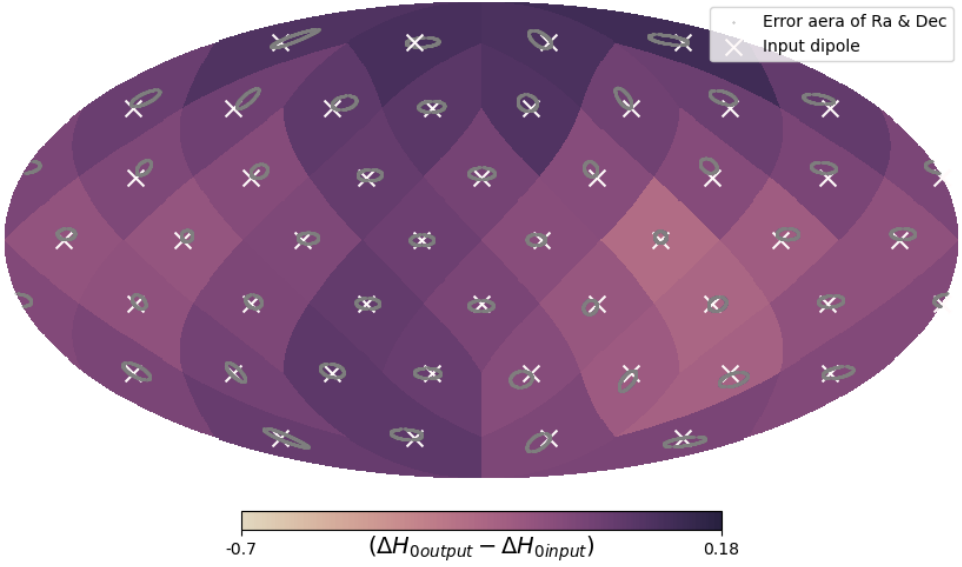
For 6 Cluster



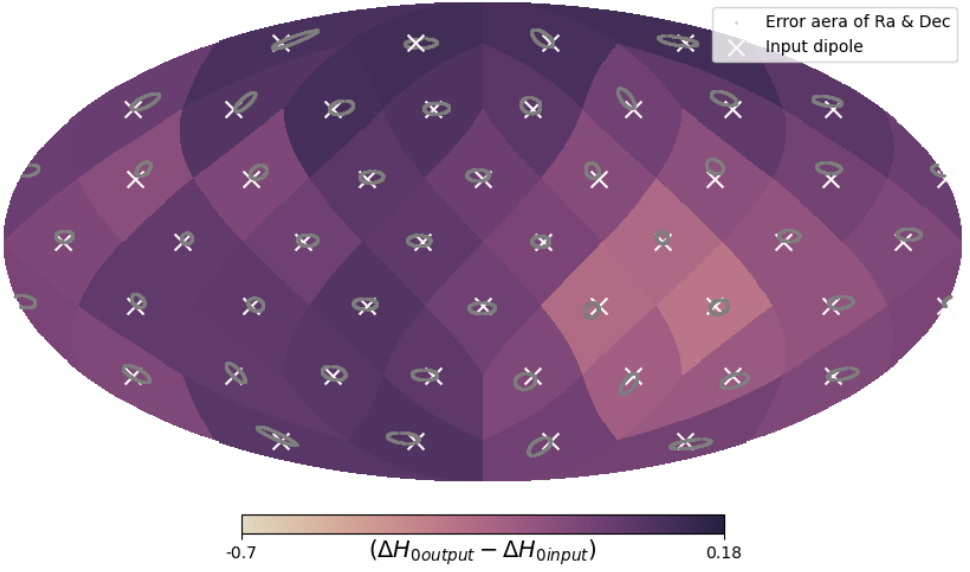
For 12 Cluster



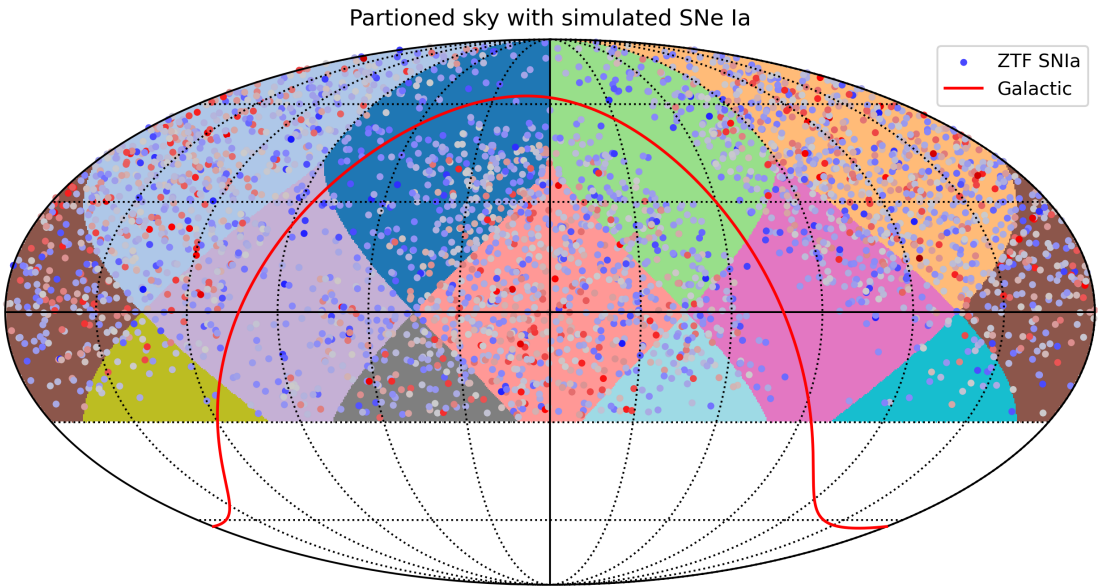
For 18 Cluster

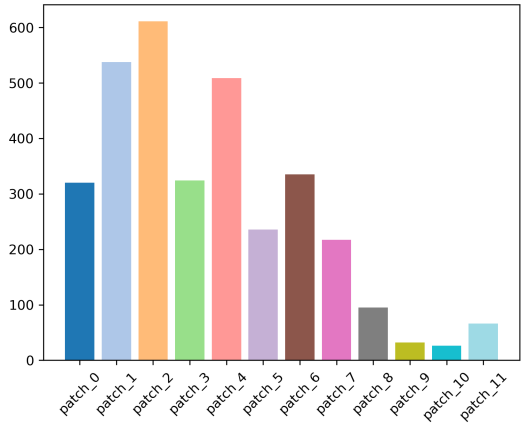


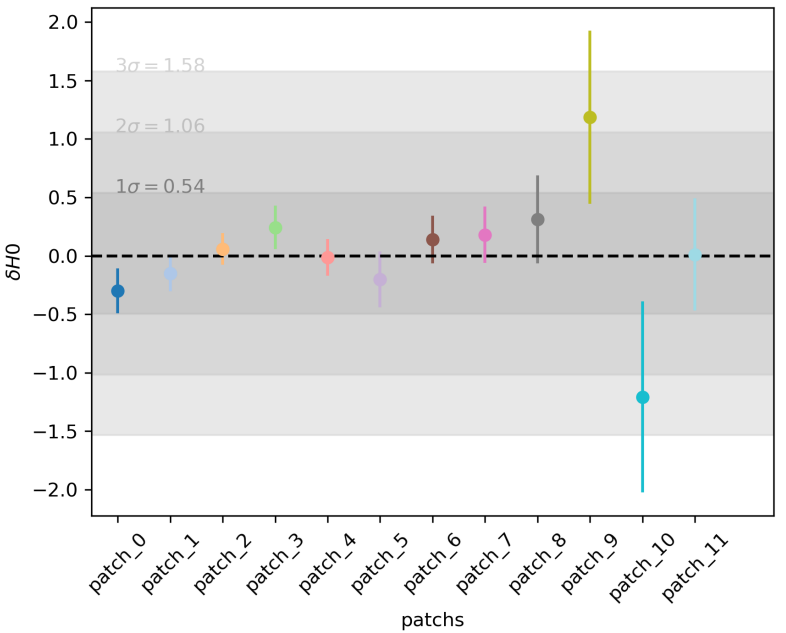
For 24 Cluster



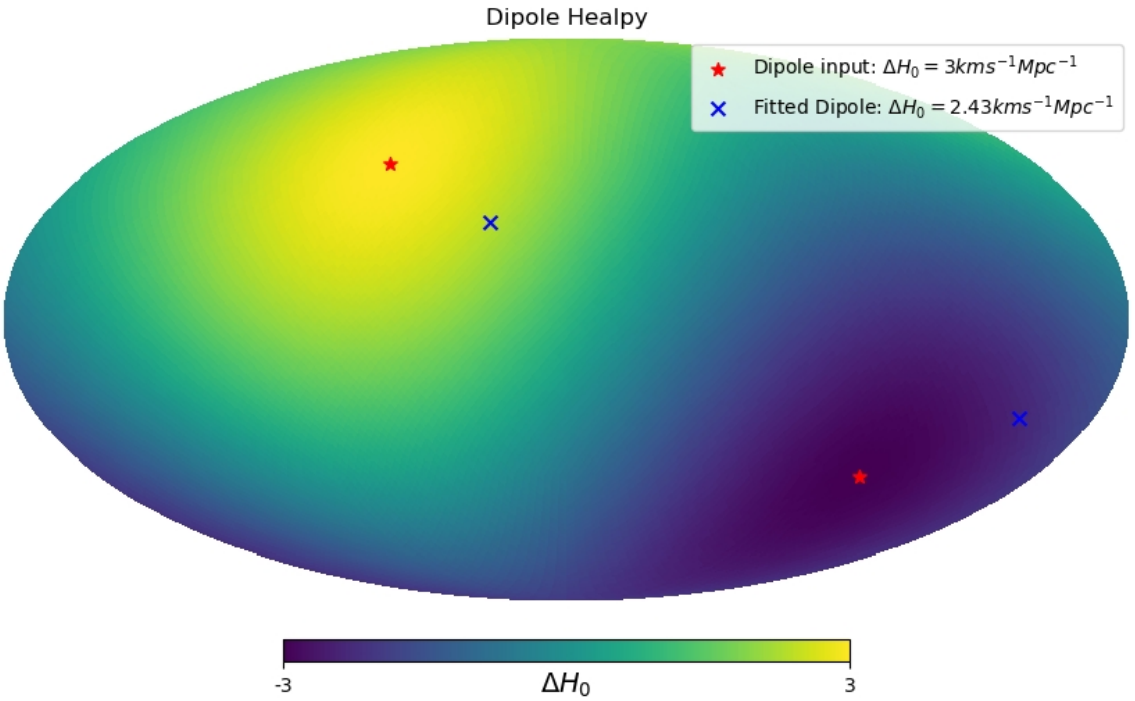
Backup : Healpy method (fixed patch):

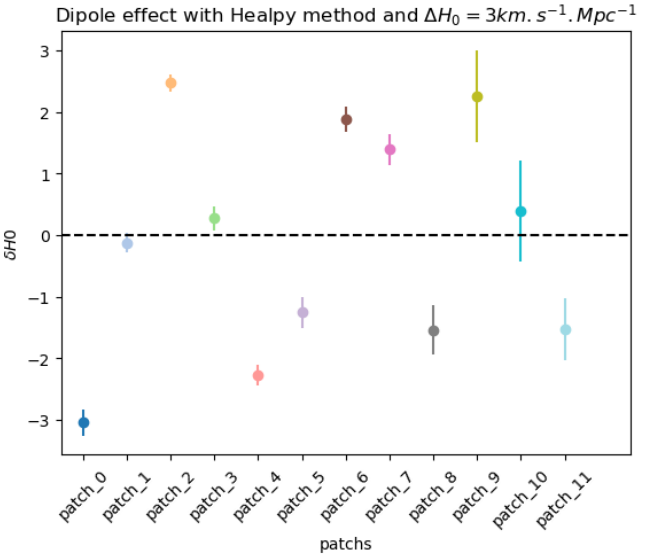


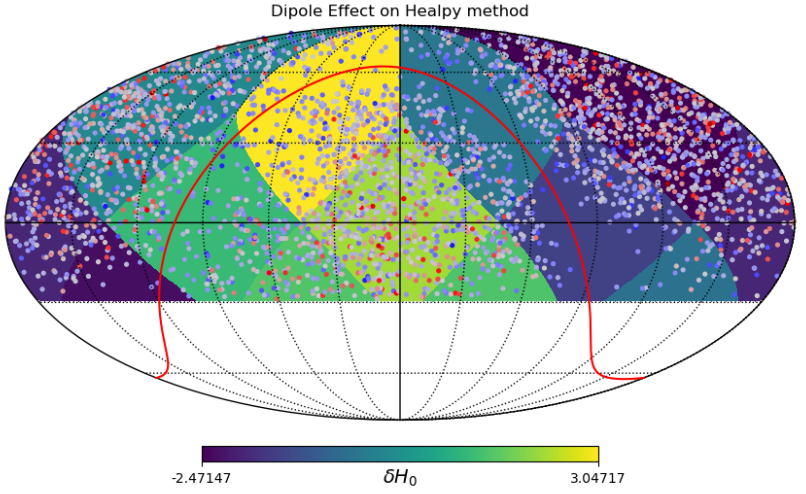




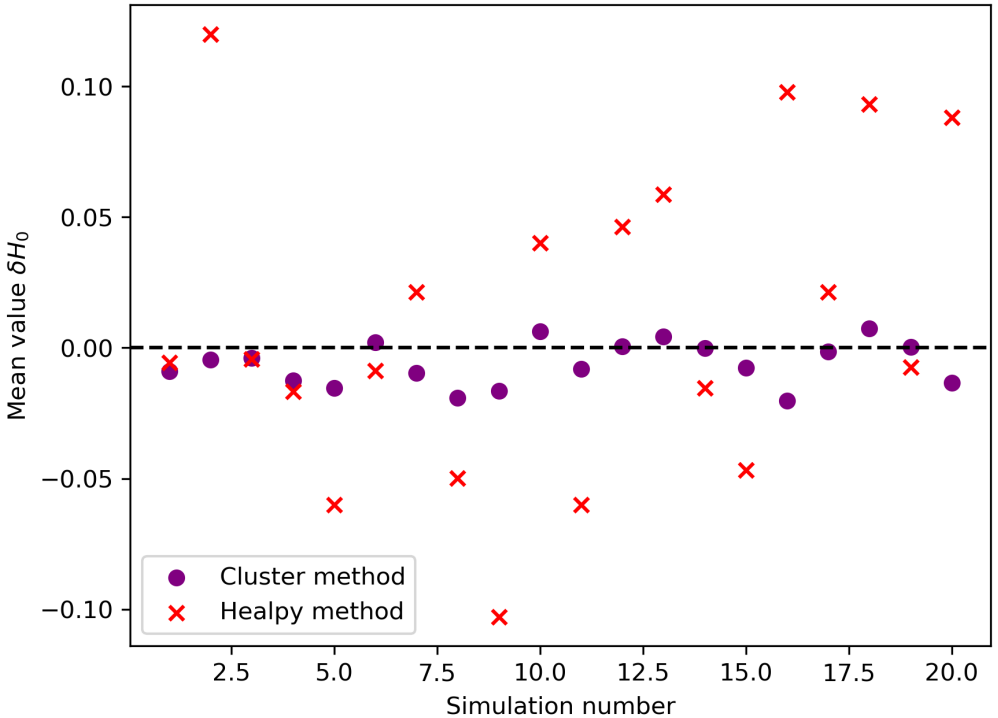
Backup- Fit dipole for Healpy method:

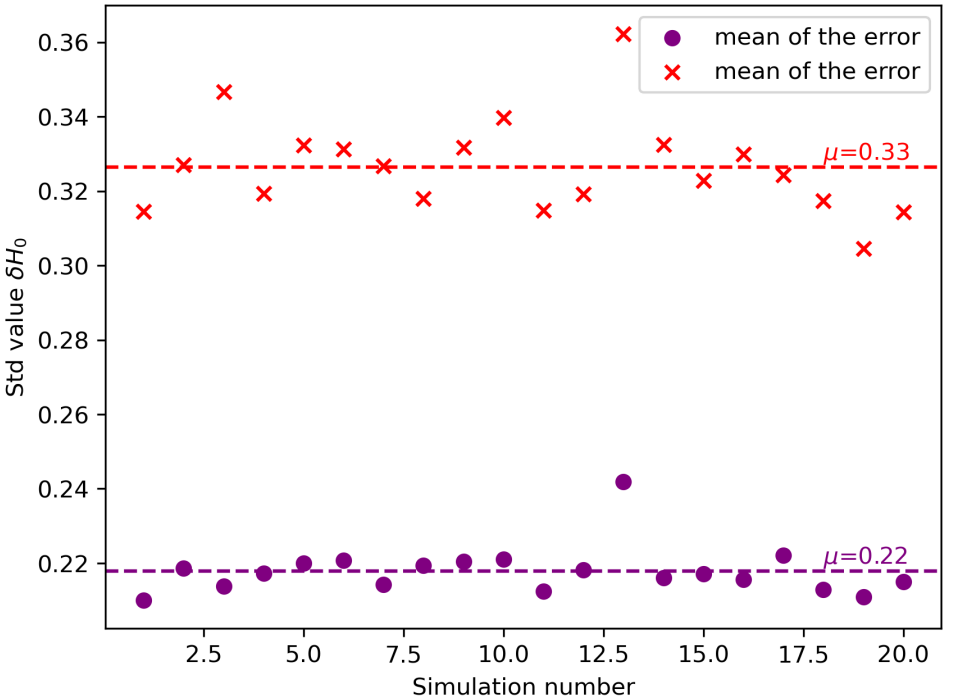






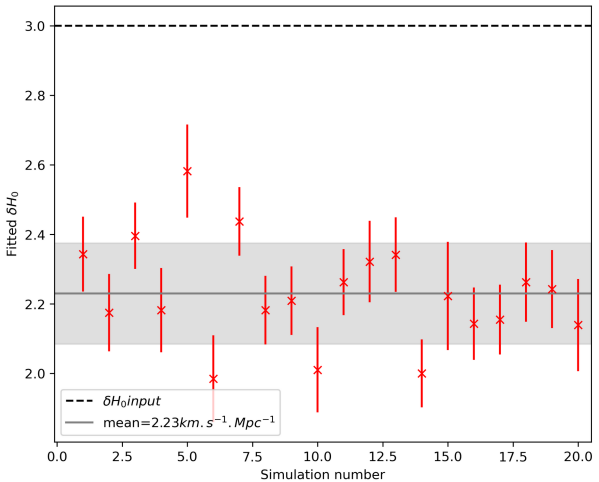
Several Simulation:

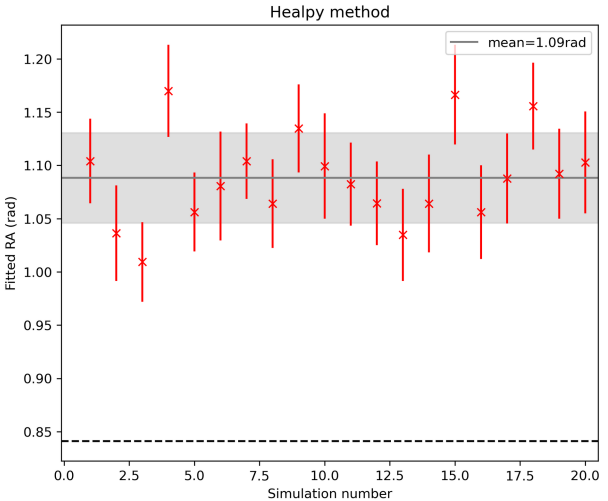


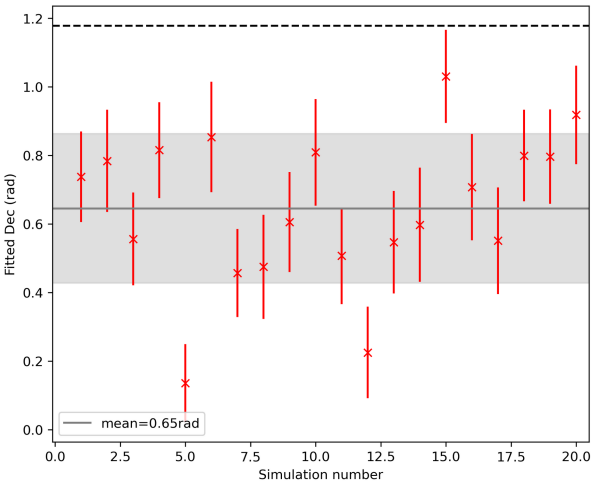


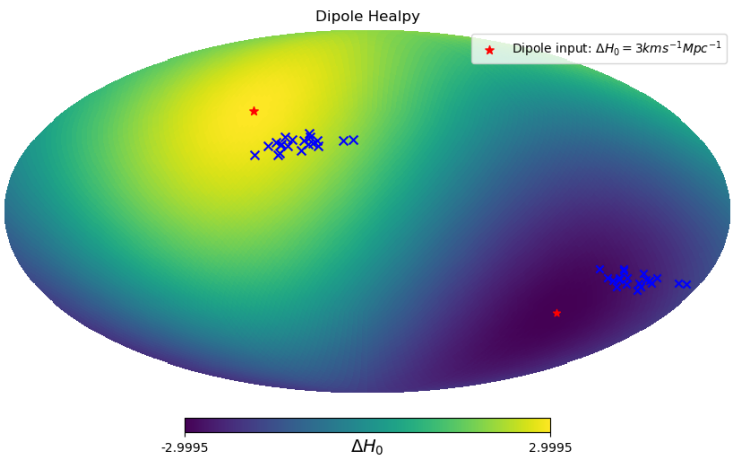
- Sensitivity of 0.22 km.s^{-1}.Mpc^{-1} at a confidence level of 1σ with for cluster method and no anisotropy effect in input.

Healpy fit dipole:



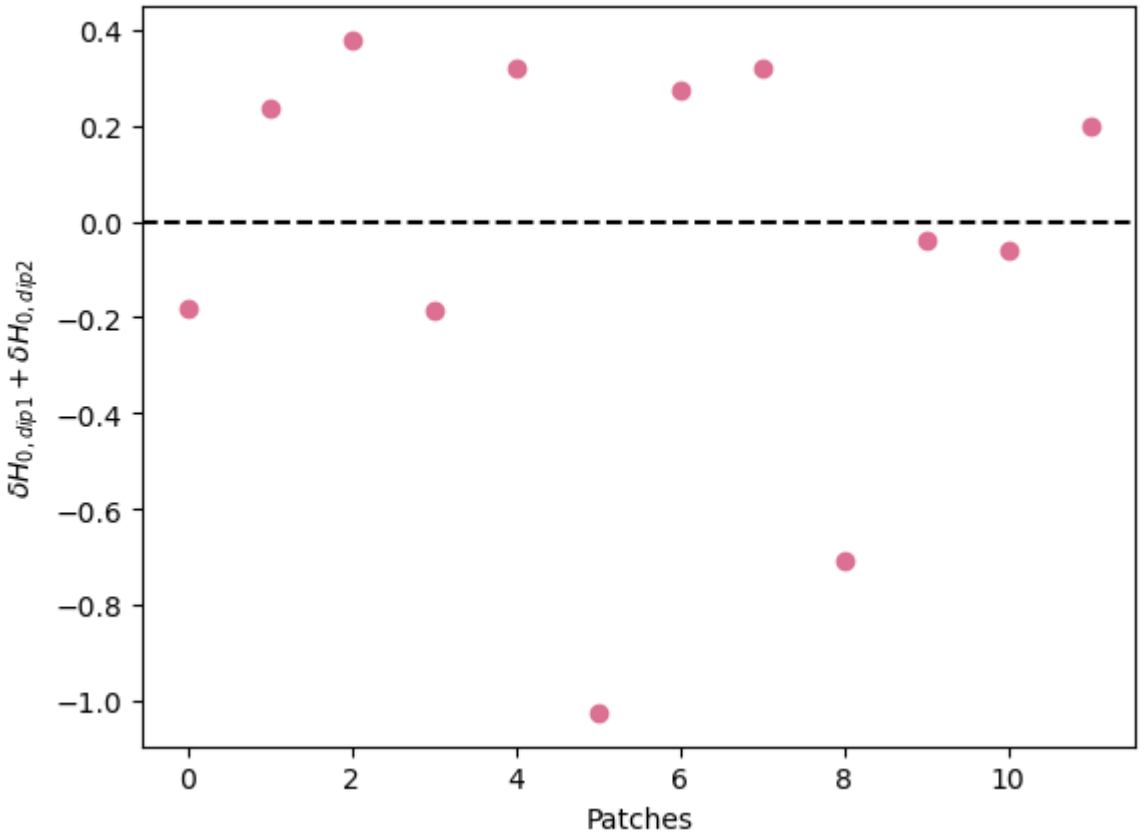




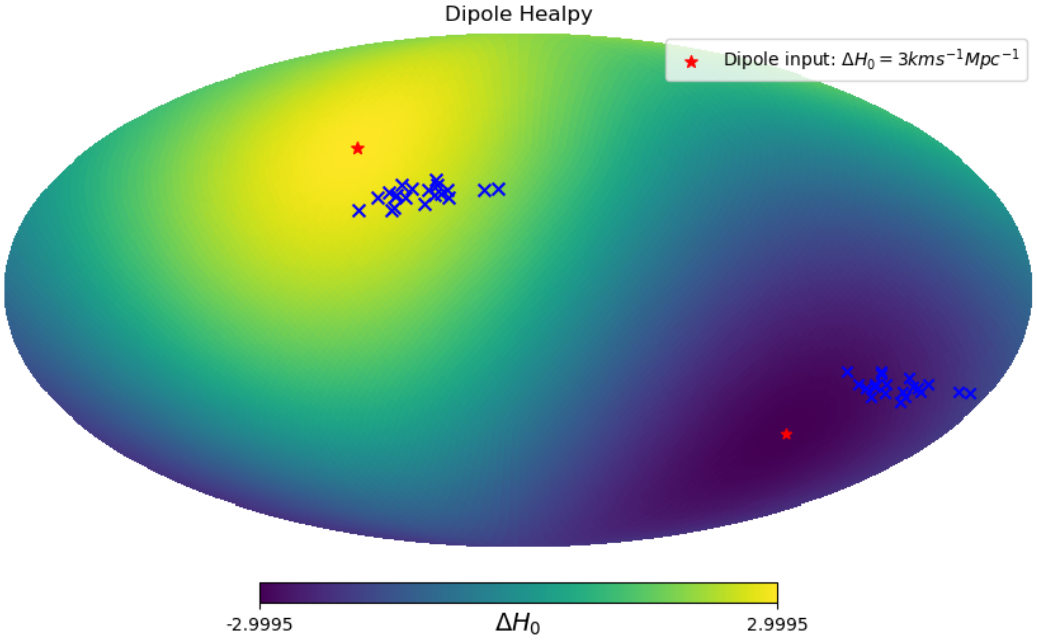


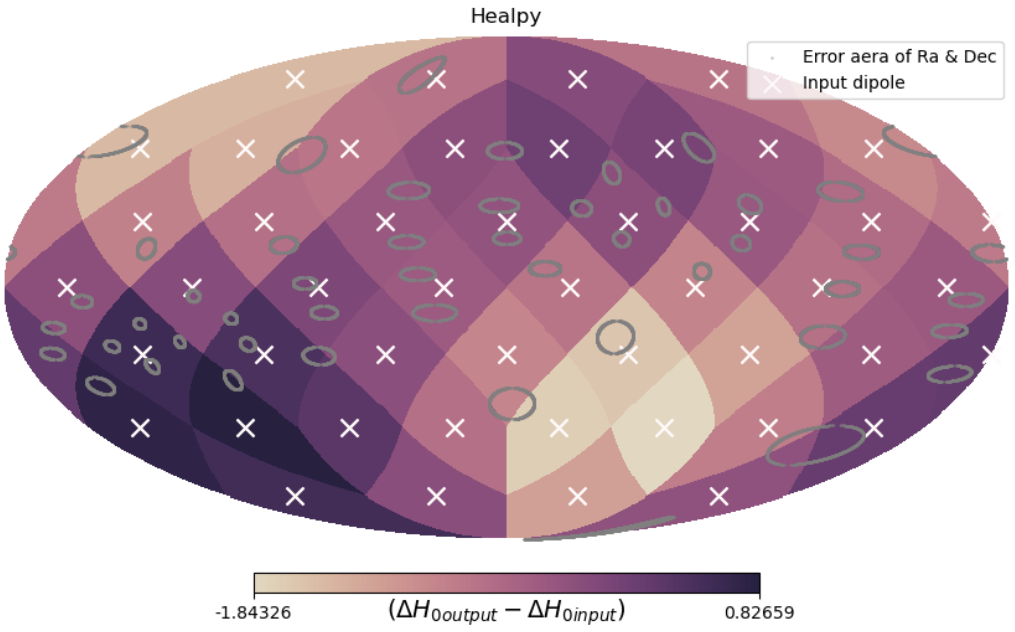
- Systematics bias

Backup-Symetrie :

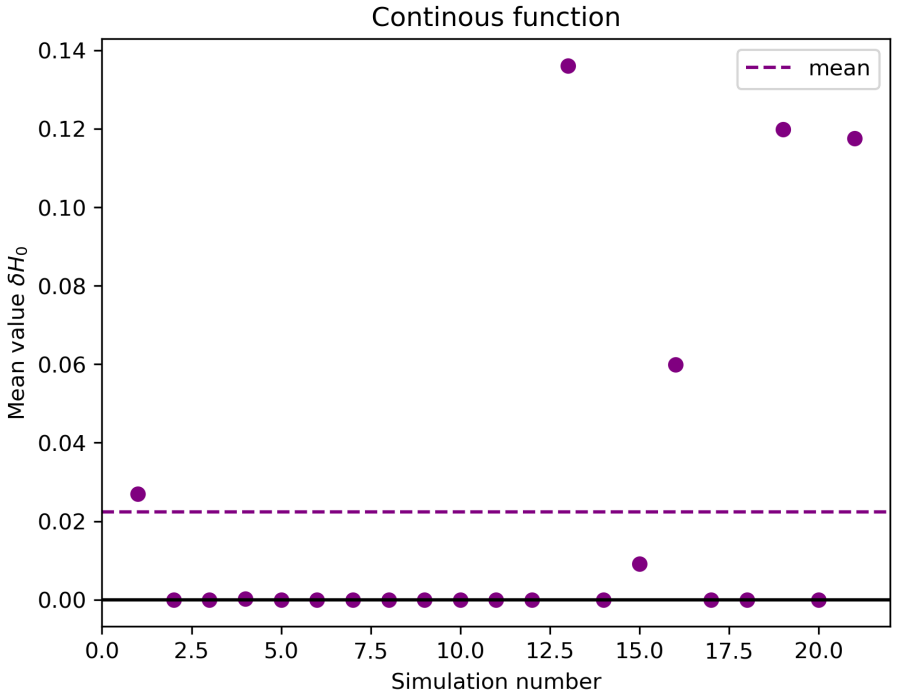


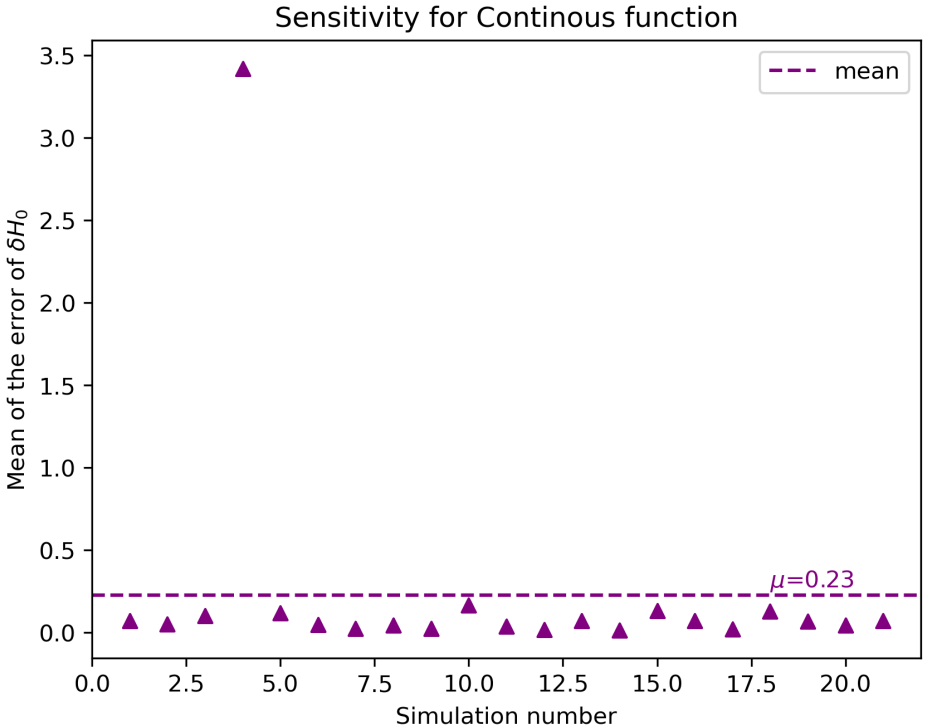
Backup-Dipole Healpy :





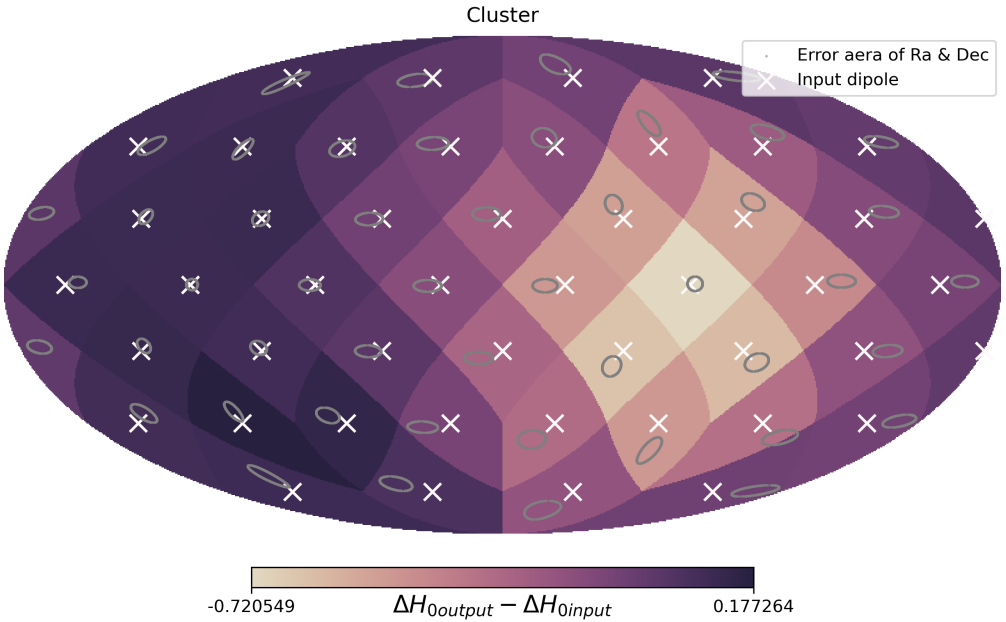
Backup -Sensitivity for continous function :

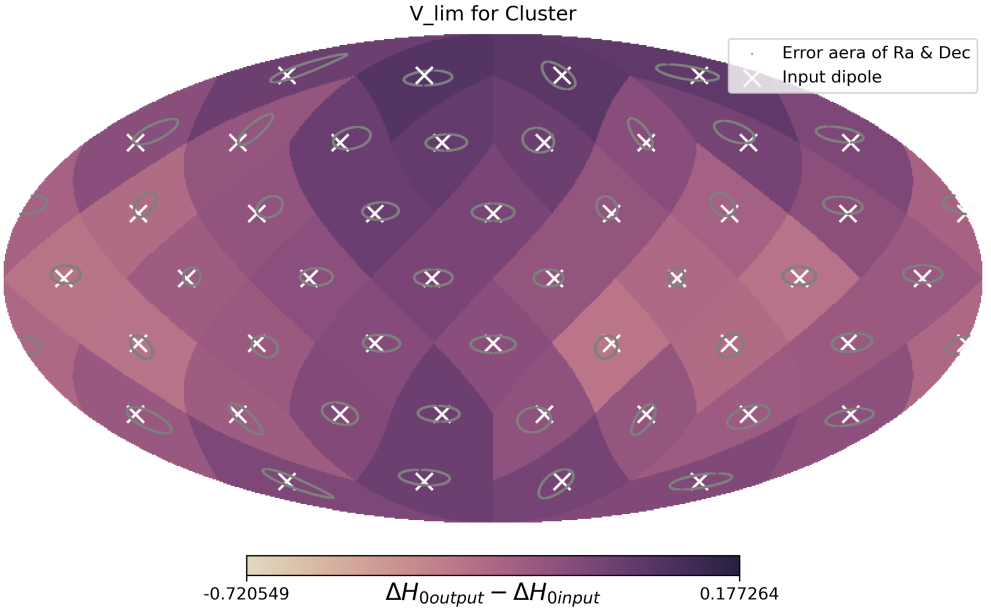




- Sensitivity of 0.23 km.s^{-1}.Mpc^{-1} at a confidence level of 1σ with no anisotropy effect in input with continous function.

V_lim fit dipole:





- Less biased with the volume limited

Backup- Selection cut:

BTS cut :
- Mpeak < 19
- ..

Quality cut :
- Mwebv <1
- -3<x1<3
- -0.2<c<0.8
- Fitproba>1e-7
- σ_{x1}<1 & σ_c<0.1