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

Chloé Barjou-Delayre,
Under the direction of Philippe Rosnet

UNIVERSITÉ Clermont Auvergne

LPC Particules pLasmas Univers applicationS
Laboratoire de Physique de Clermont

Action Dark Energy
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Motivation:

Cosmological principle

Homogeneity (large-scale)

Isotropy (large-scale)

?

?

?

?

- *This work : Study anisotropy of H_0*

Zwicky Transient Facility (ZTF):

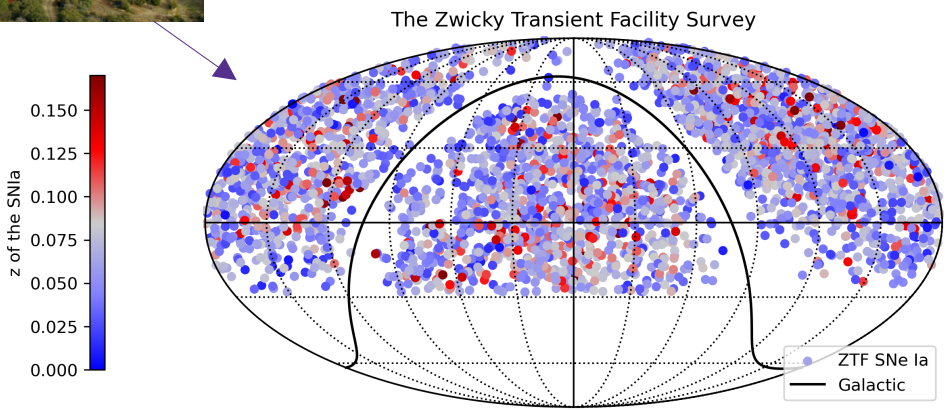
- Survey of the Northern sky begun in 2018 in California

- Unique survey of low redshift Sne Ia

- *M.Rigault et al. arXiv:2409.04346 (submitted)*

- Observe in three bands : g, r, i

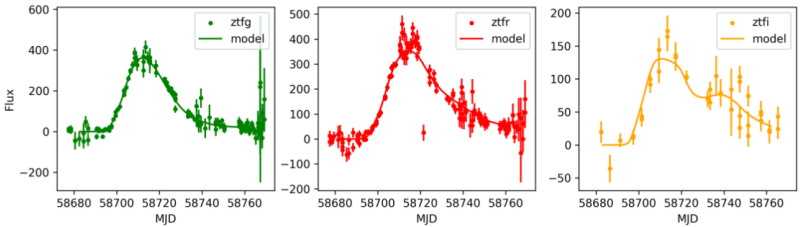
- DR2 : second data release contains 3628 spectroscopically Sne Ia, between 2018-2020



Simulation:

- Contains all observation information : maglim, field of observation, possible technical problem

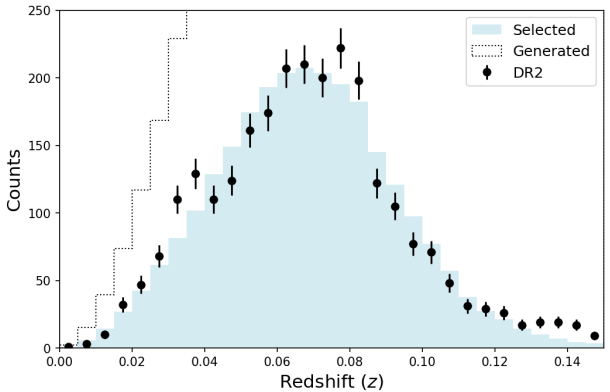
ZTF observing logs



M.Amenouche et al., arXiv:2409.04650 (submitted)

Skysurvey

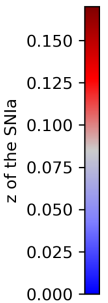
- Simulates astronomical targets as they would be observed by a survey

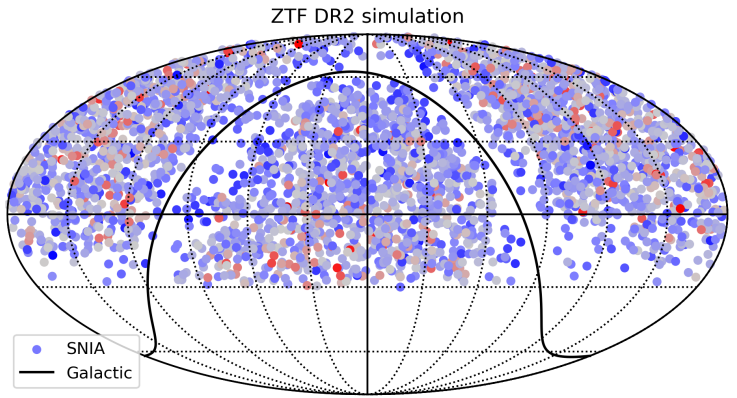


M.Amenouche et al., arXiv:2409.04650 (submitted)

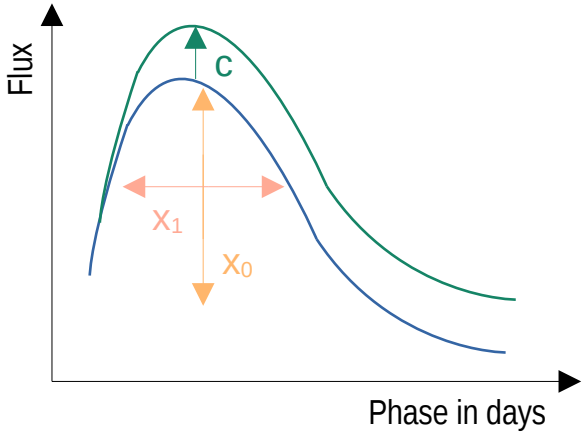
SN Ia model

- Sncosmo : SALT2





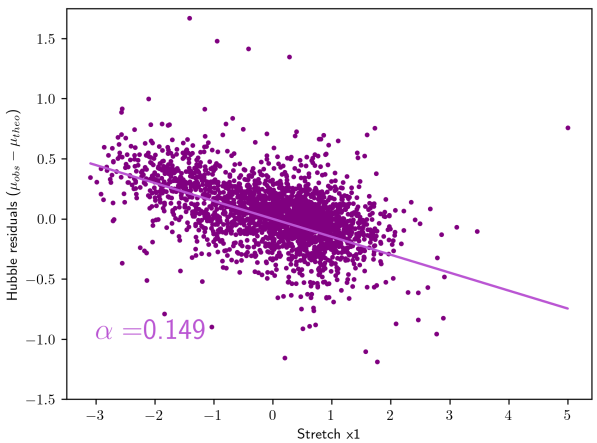
SNe Ia - Standardisation:

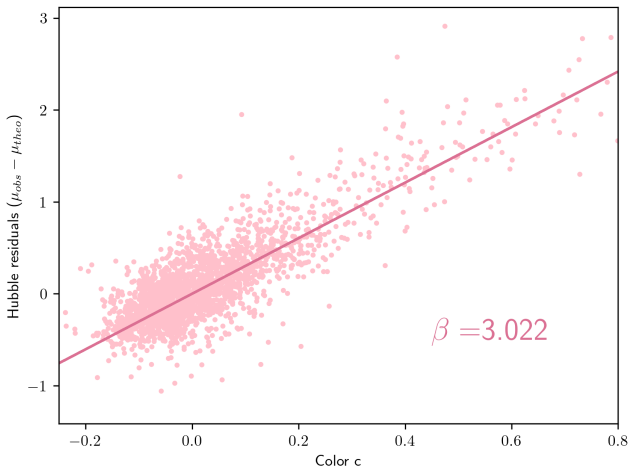


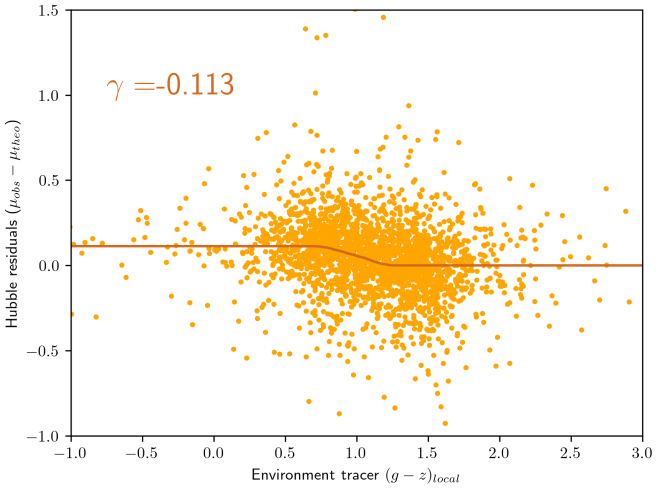
Tripp relation :

$$m_B = -2.5\log_{10}(x_0) + 10.635$$

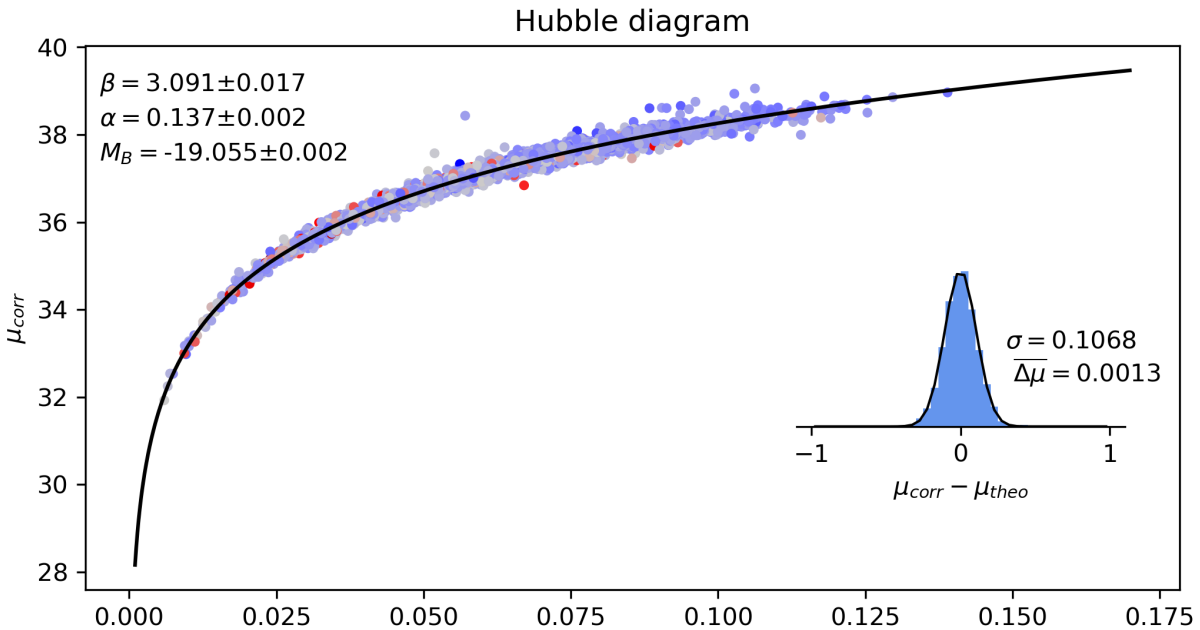
$$\mu = m_B - M_B + \alpha x_1 - \beta c + p\,\gamma$$







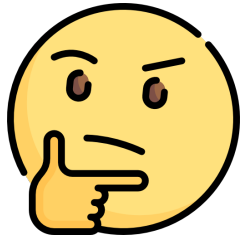
Hubble Diagram of a simulated survey after standardisation:



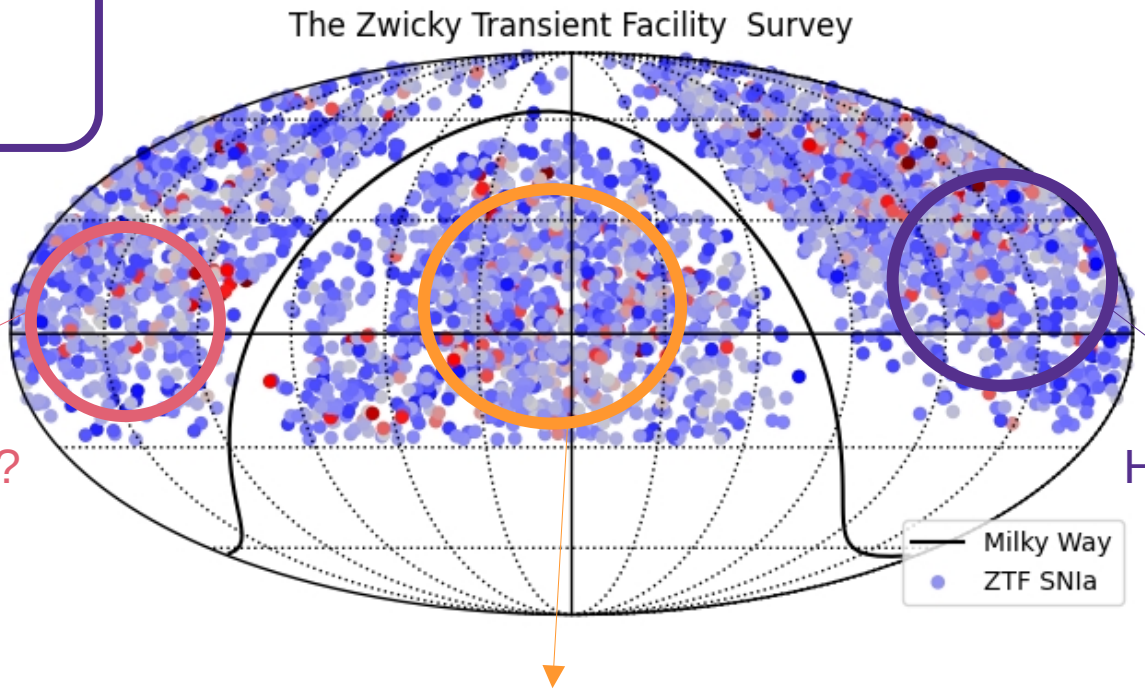
- Fit α, β, M_b for the survey

- 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

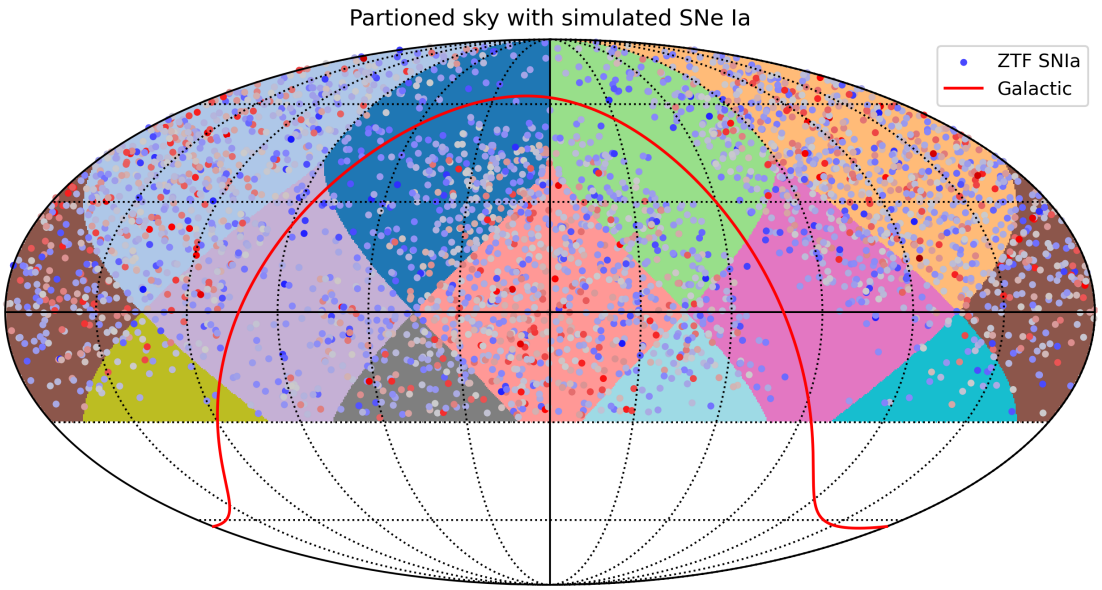


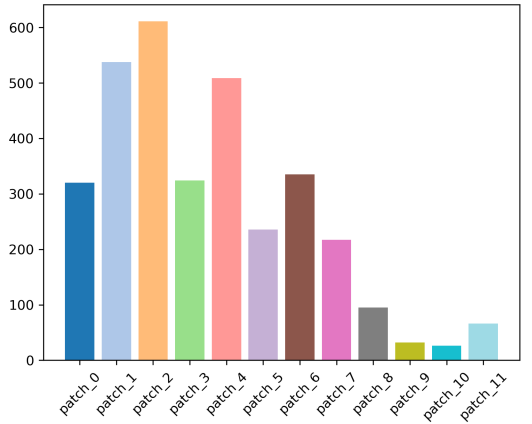
$H_0 = 68$ km.s^{-1}.Mpc^{-1} ?

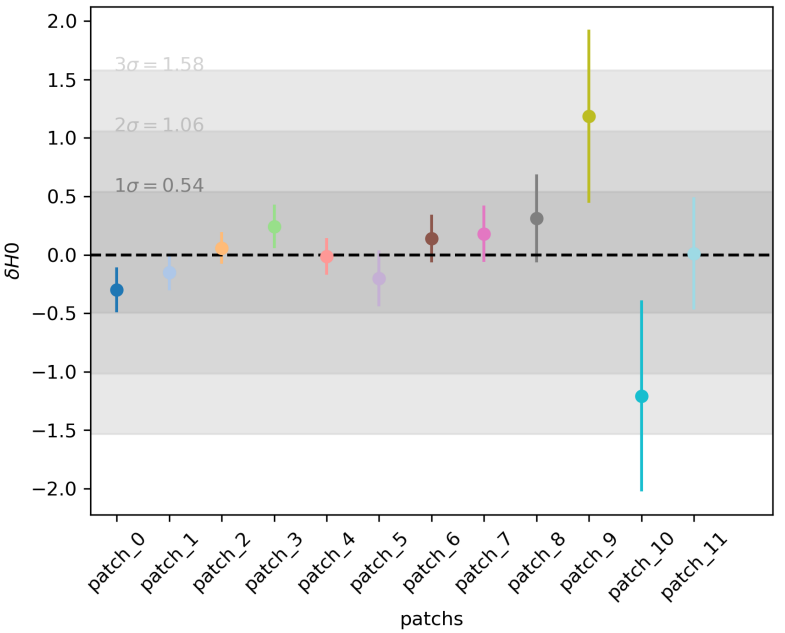
$H_0 = 73$ km.s^{-1}.Mpc^{-1} ?

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

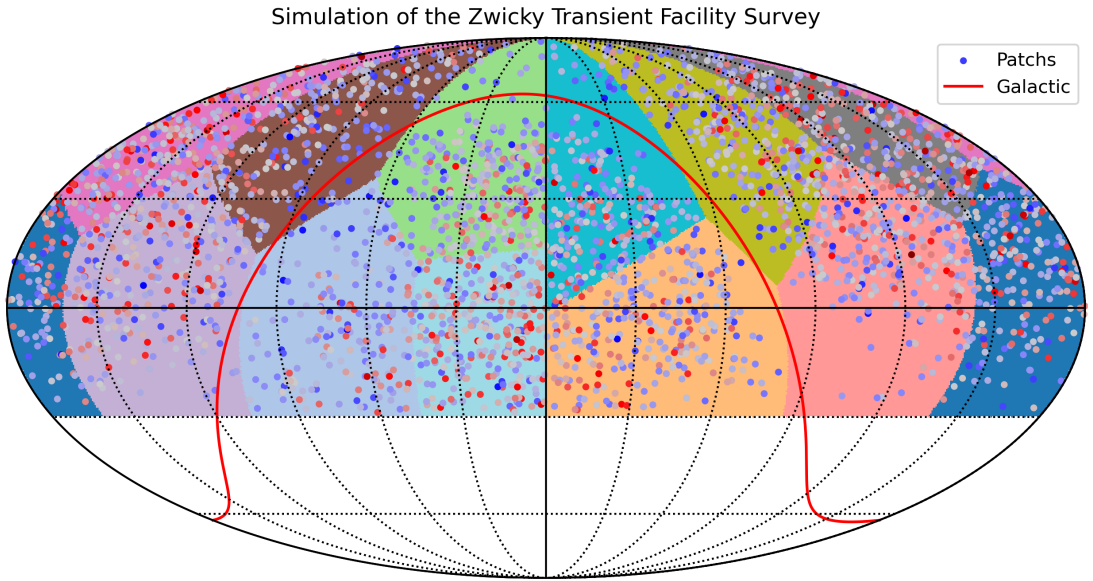
Healpy method (fixed patch):

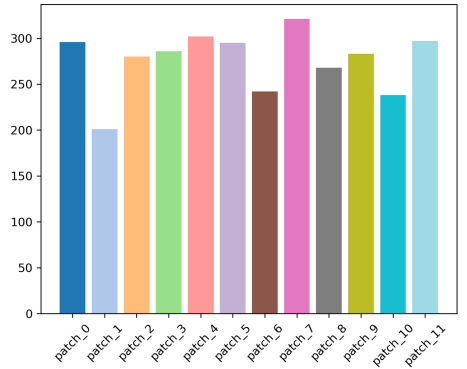


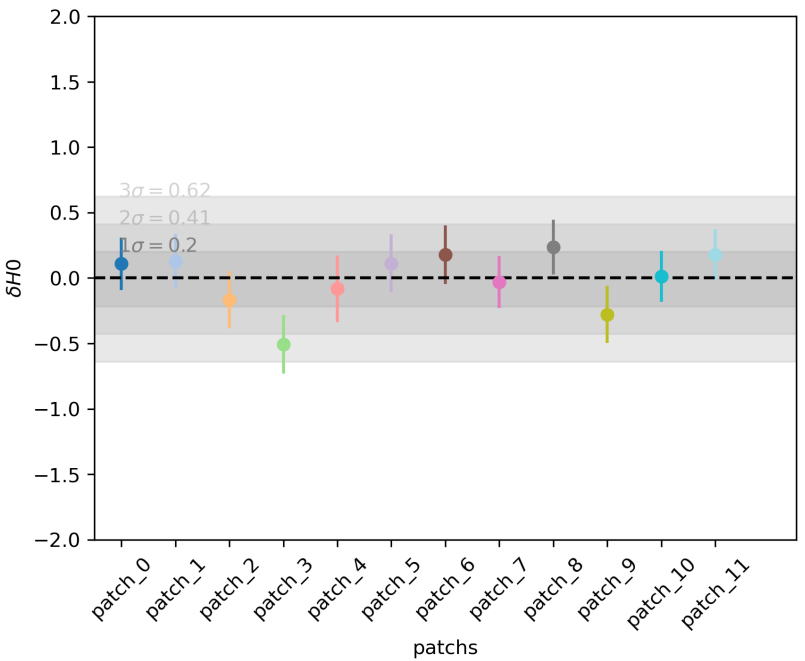




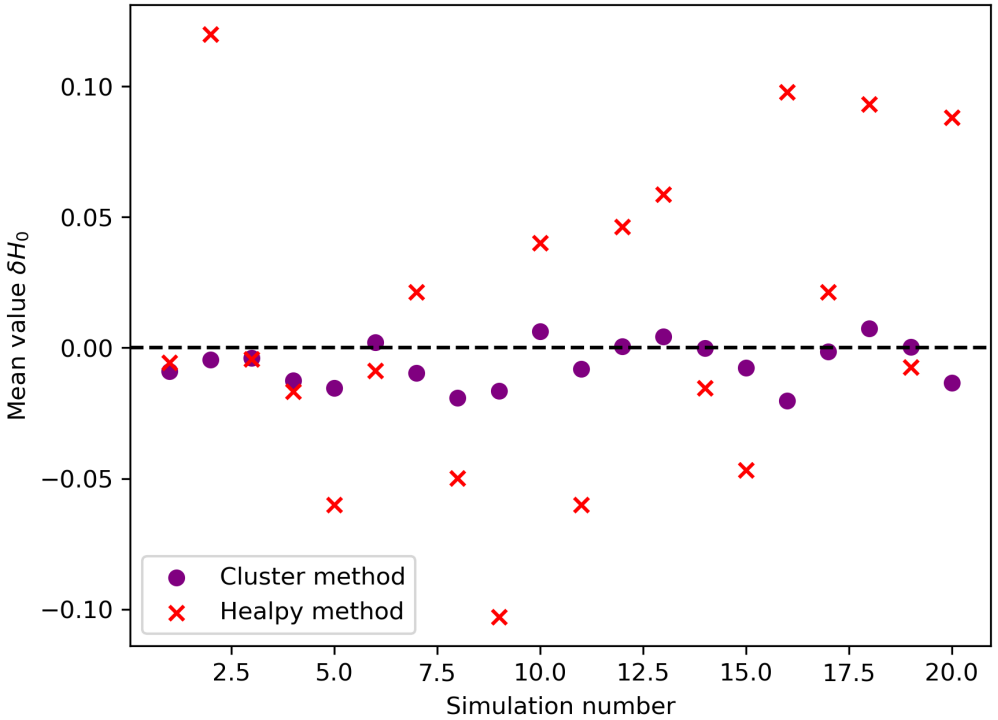
Cluster method (adapted patch):

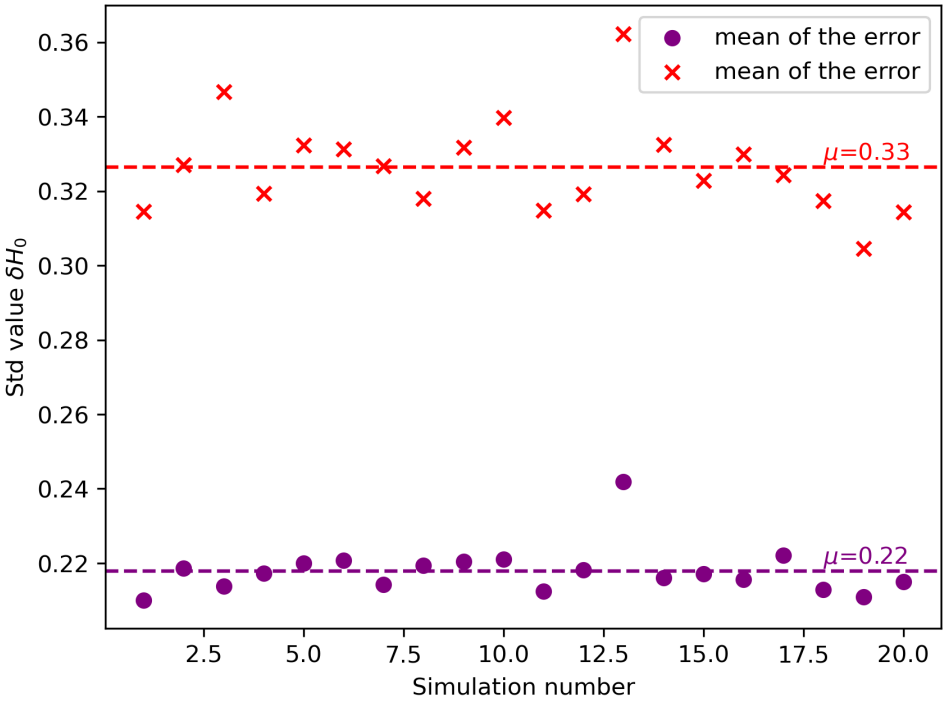






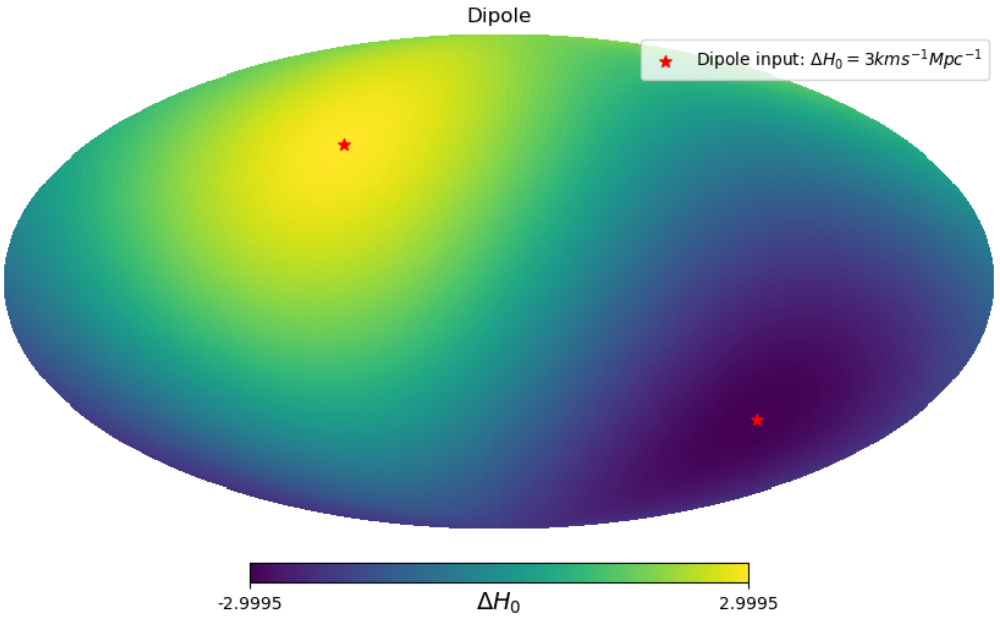
Several Simulation:





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

Adding a dipole effect:



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

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

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

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

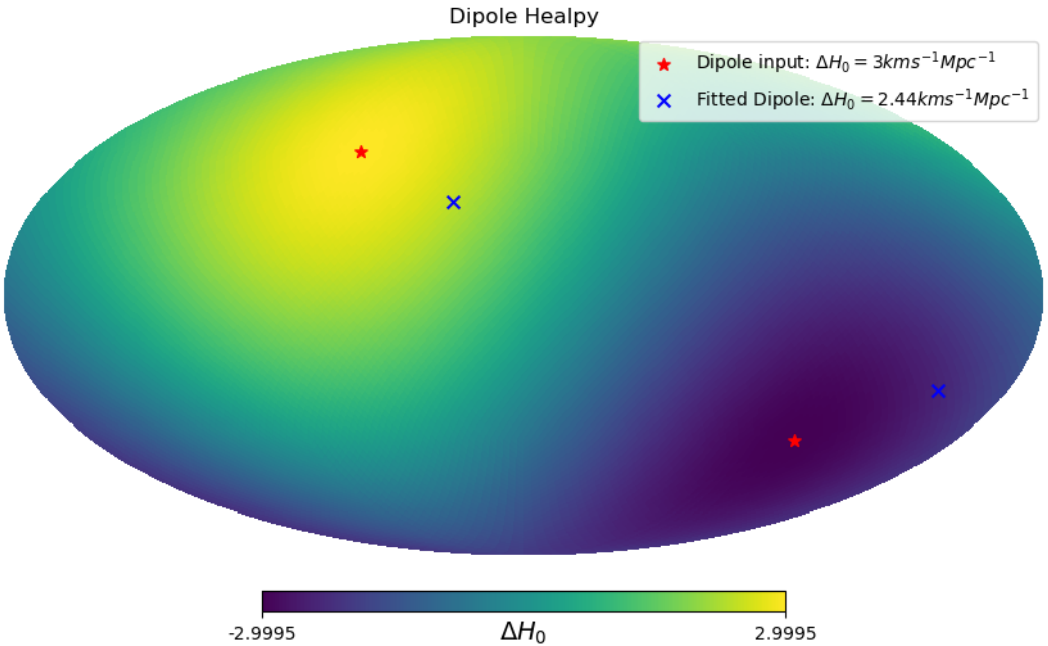
$\Delta H_0 = 3$ km.s^{-1}Mpc^{-1}

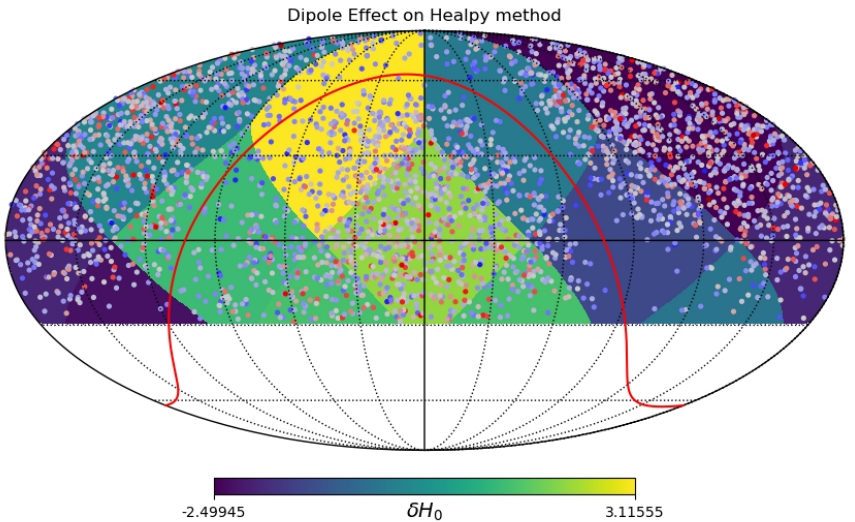
Fit a dipole for the Healpy method:

Free

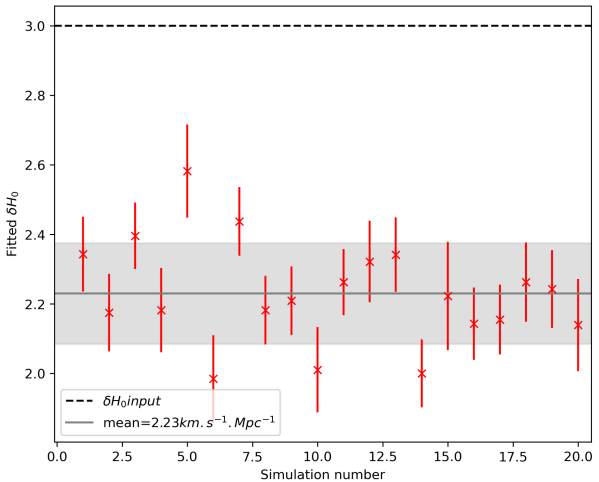
$$\chi^2 = \sum_{i=1}^{N_{patch}} \left(\frac{\delta H_0^i - \delta H_0^{th,i}(\theta_i, \theta_{dip}, \Delta H_0)}{\sigma_{\delta H_0^i}} \right)^2$$

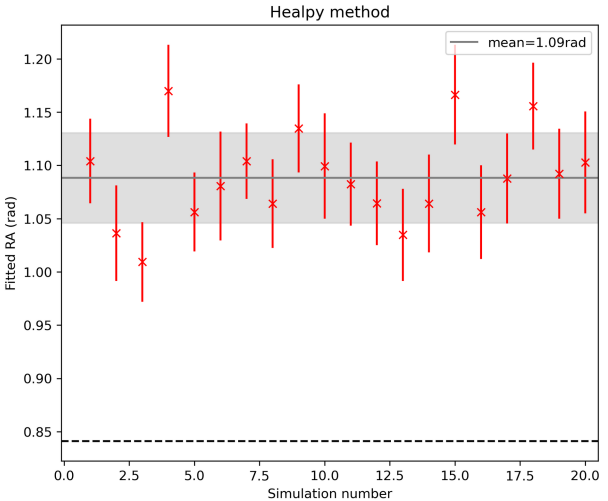
$$\delta H_0^{th,i} = \Delta H_0 \cos(\theta_i - \theta_{dip})$$

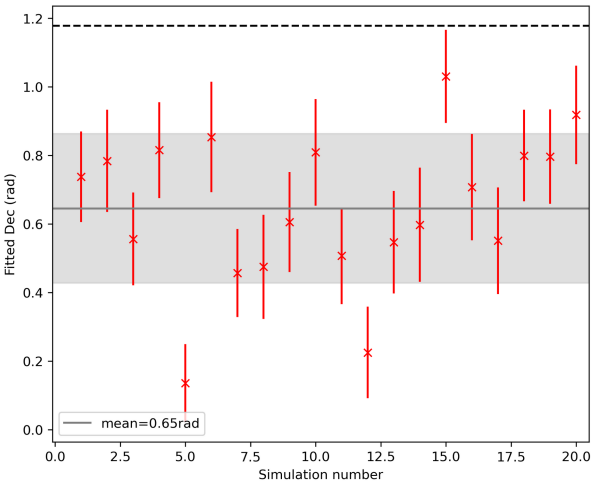


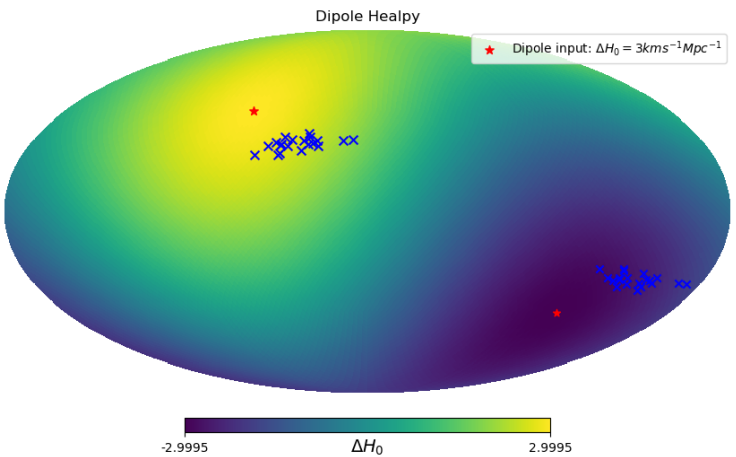


Healpy fit dipole:



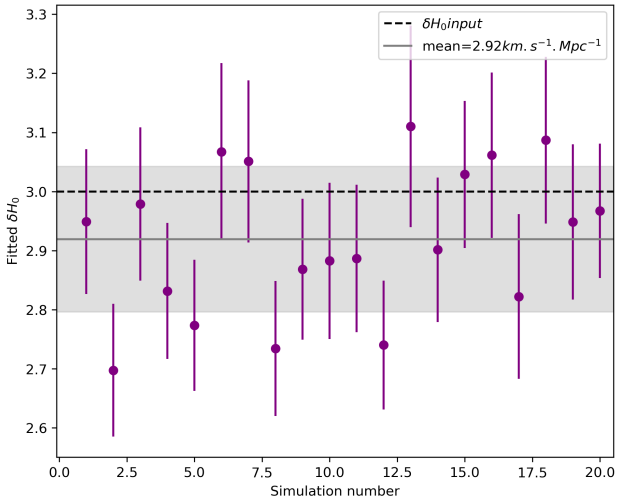


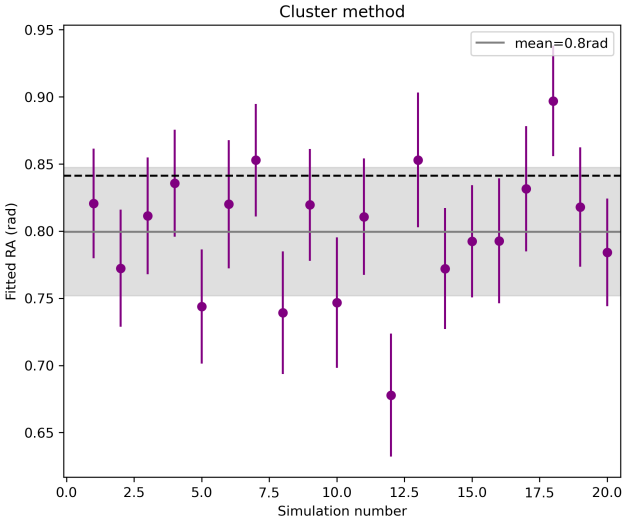


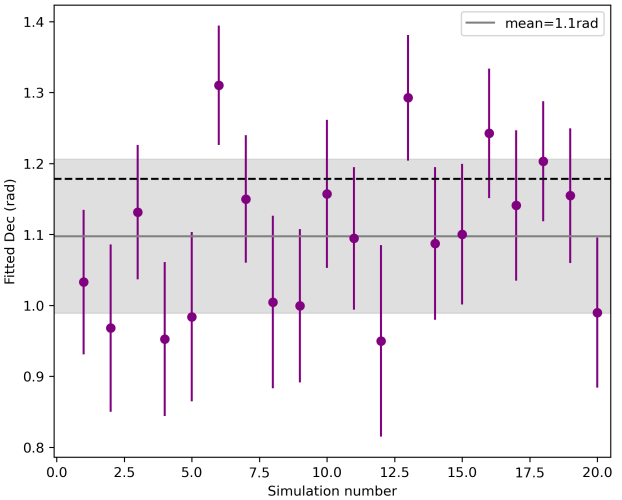


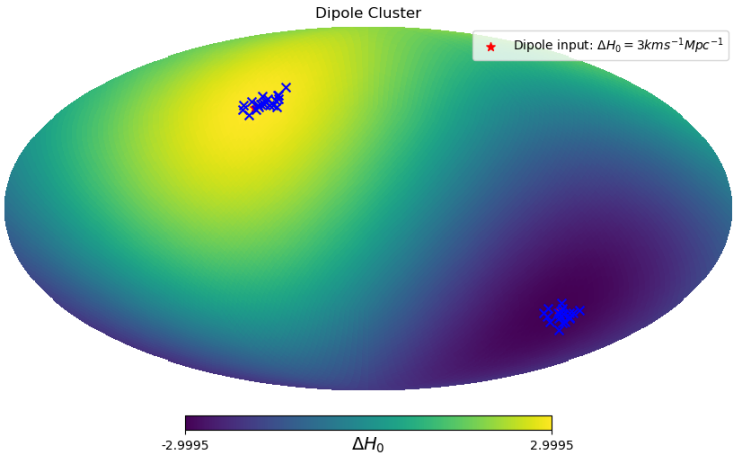
- Systematics bias

Cluster fit dipole:



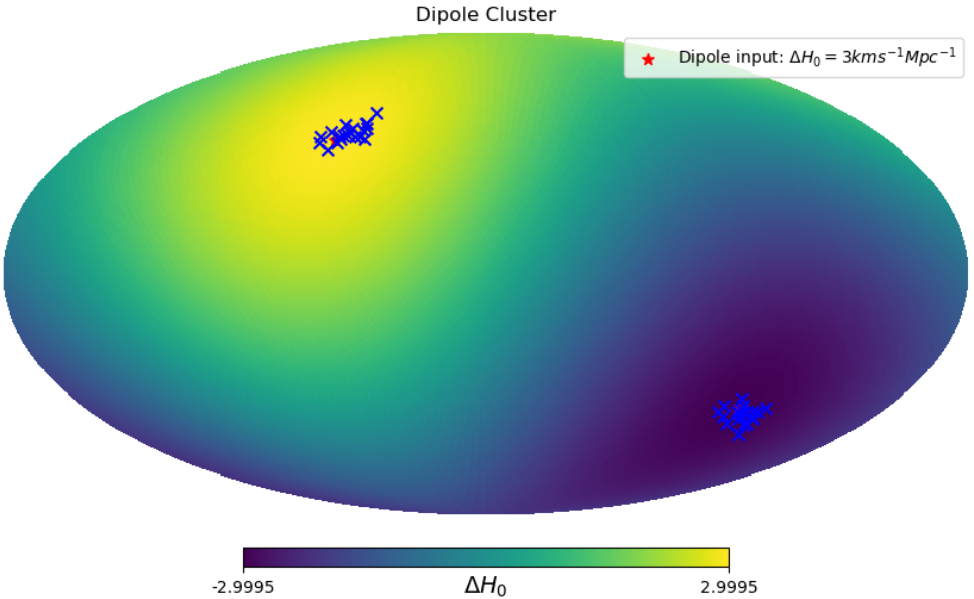


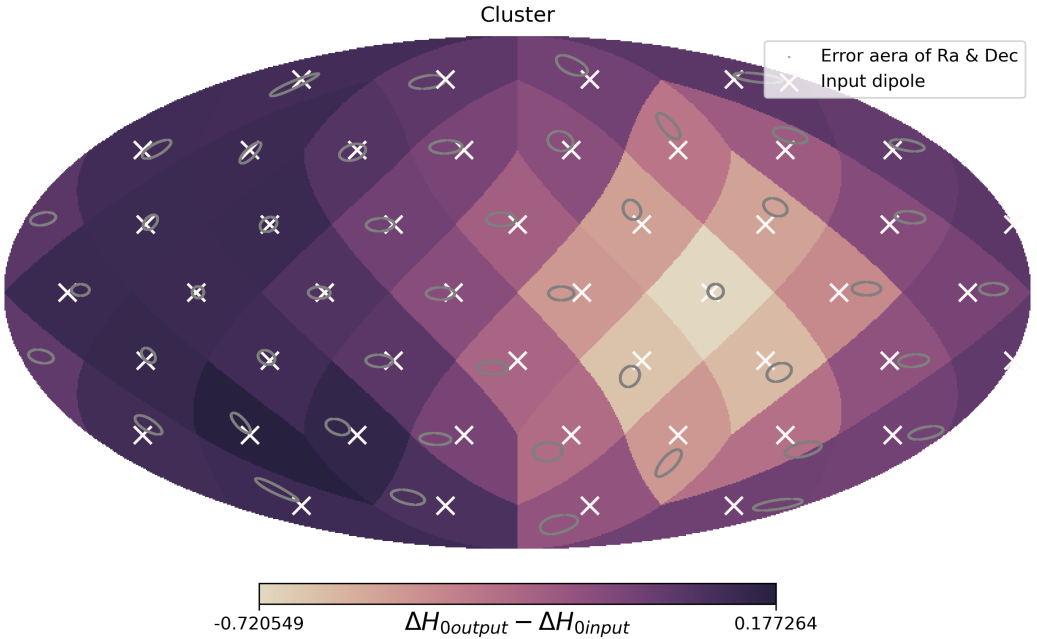




- No Systematic bias

Cluster fit dipole:





- More difficulty to fit the input dipole close to the south celestial pole.

Conclusion:

- Summary :
  - The clustering method is more precise and sensitive than Healpy methods.
  - Sensitivity of 0.22 $km.s^{-1}.Mpc^{-1}$ at a confidence level of 1σ for Cluster method with no anisotropy effect in input.
  - The healpy method introduce a bias in the reverse fit dipole.

- Perspective :
  - Test the impact of using the volume limited (z<0.06).

  - Anisotropy fit with MCMC.

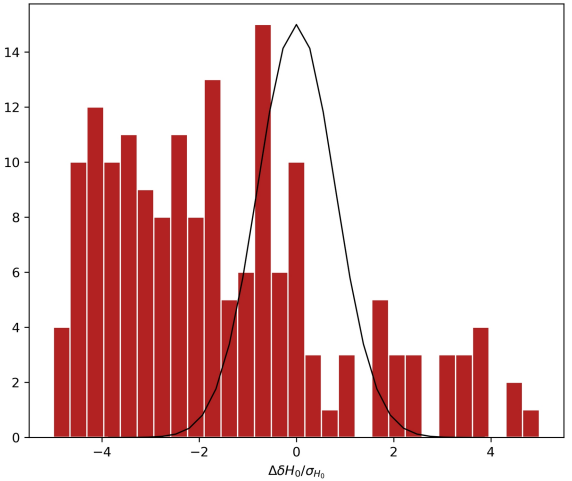
  - Test the impact of different Dustmaps.

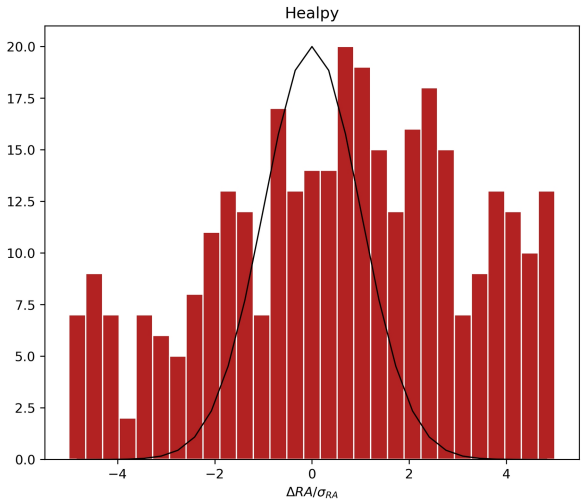
  - More complexe anisotropy effects.

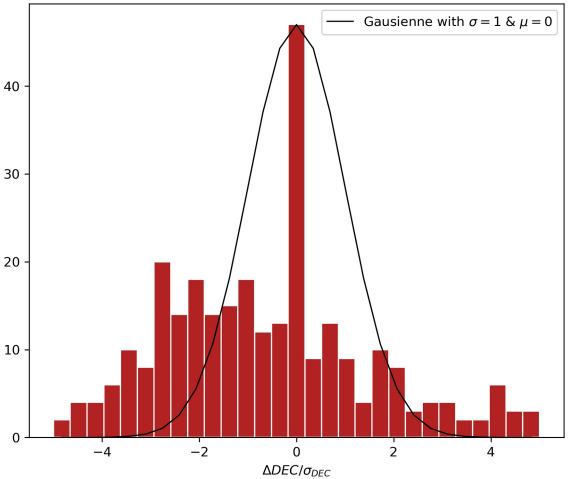
  - Adding large scale structure in the simulations.

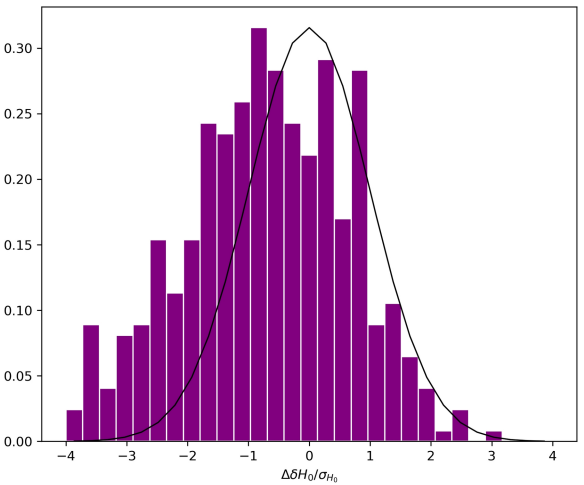
  - ...

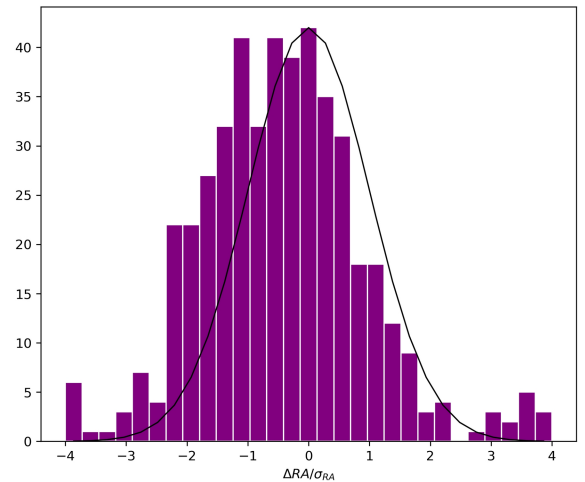
Backup - Several dipoles in several simulations :

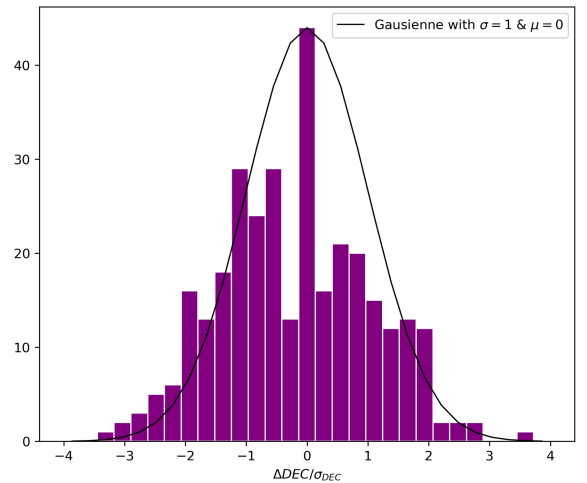




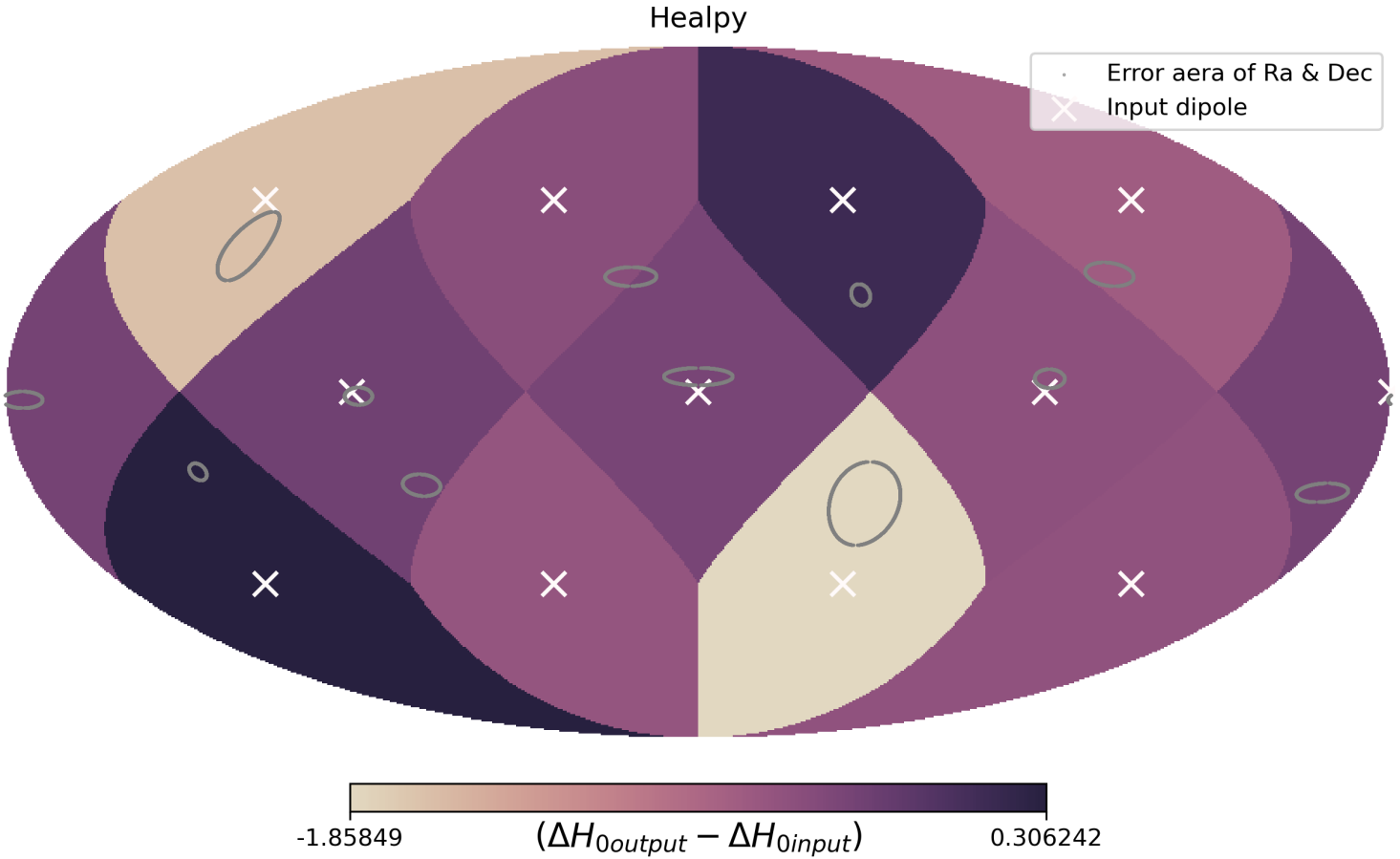




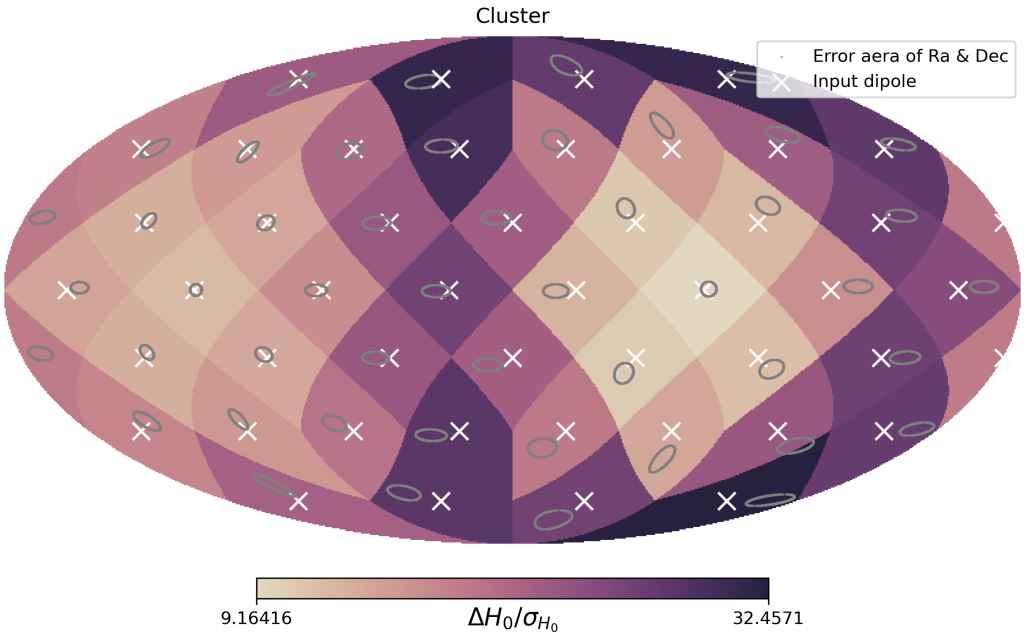


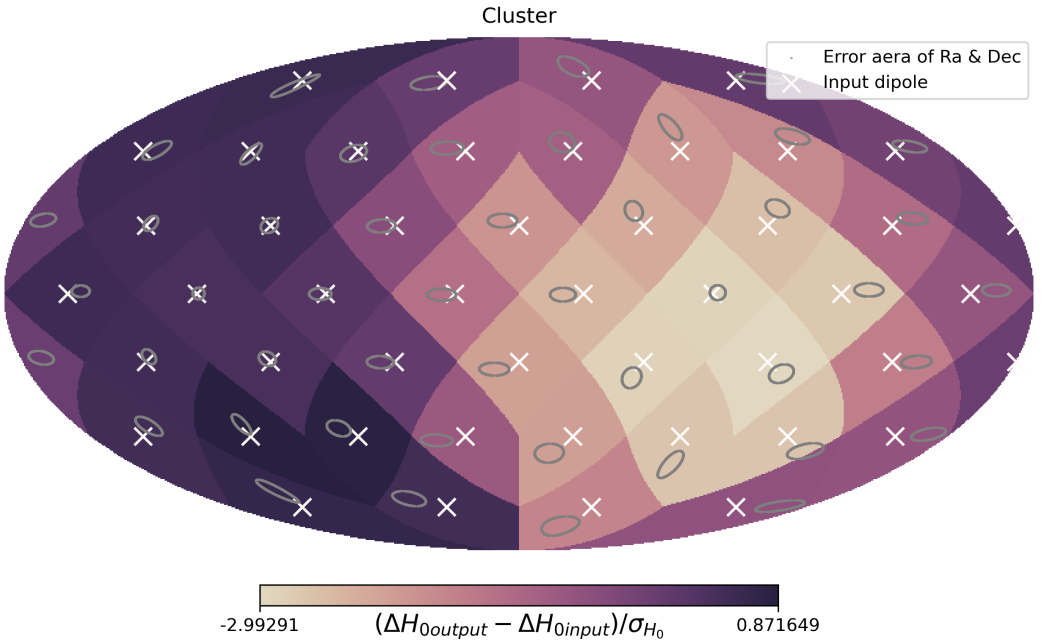


Back-up : Several dipoles in several simulations :

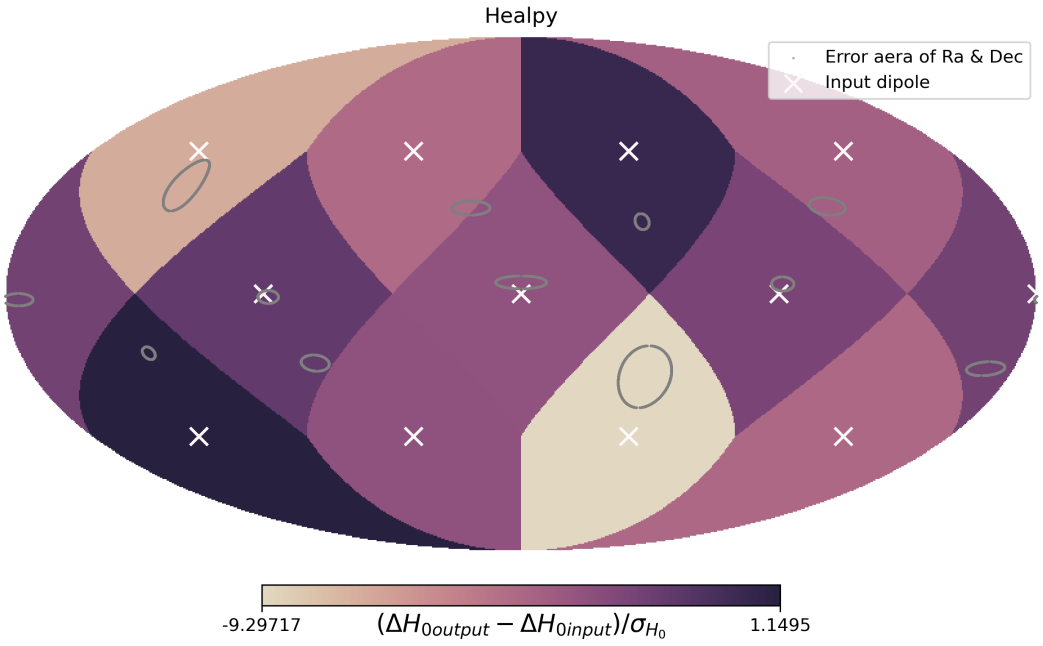


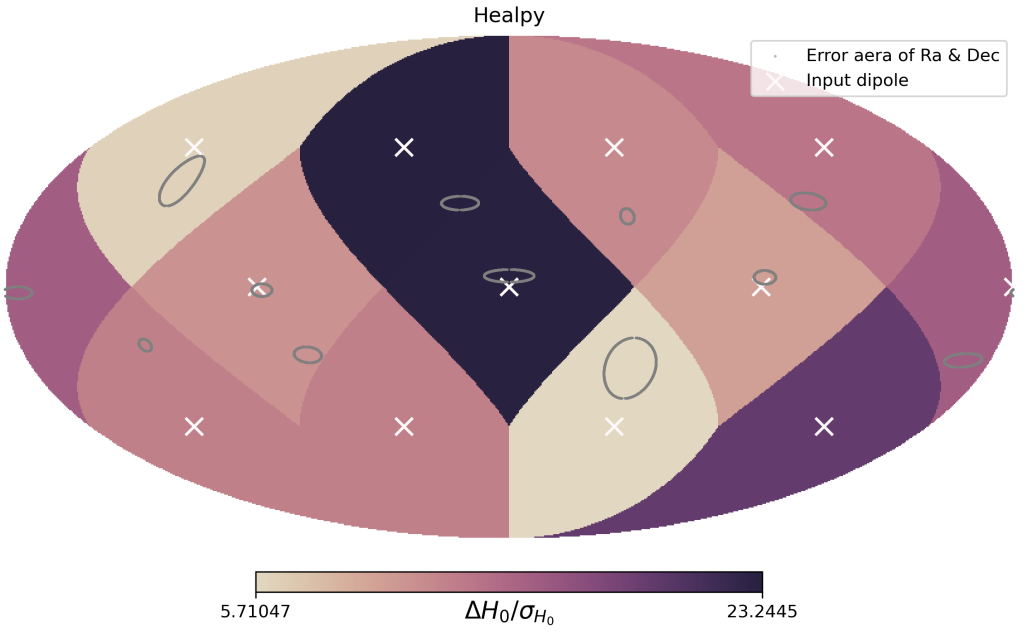
Back-up : Several dipoles in several simulations Cluster method:



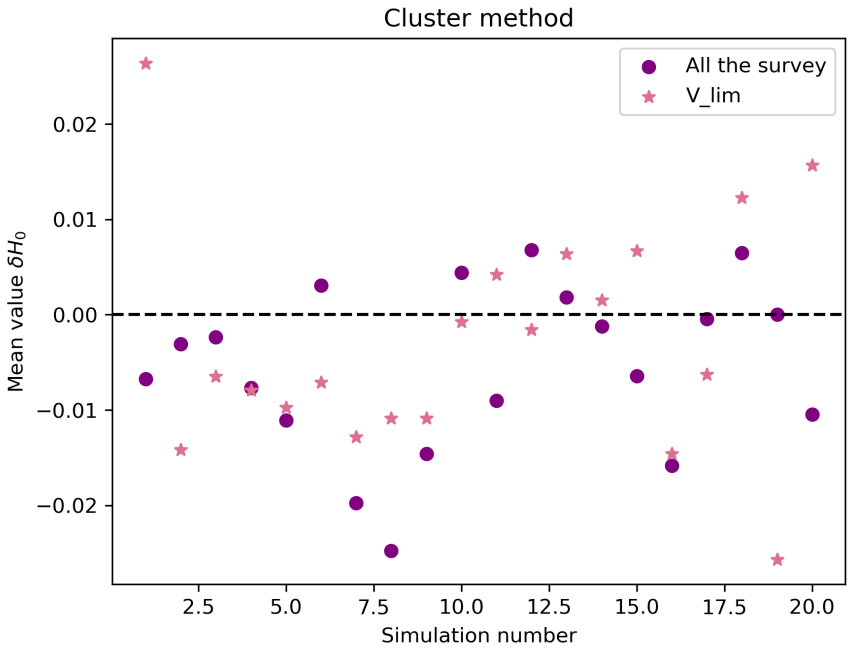


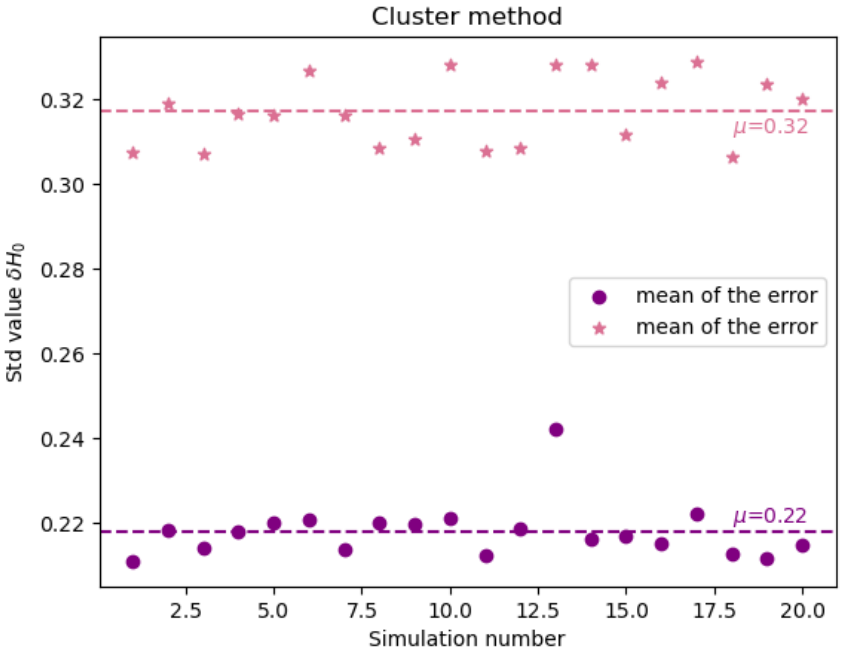
Back-up : Several dipoles in several simulations Healpy method:



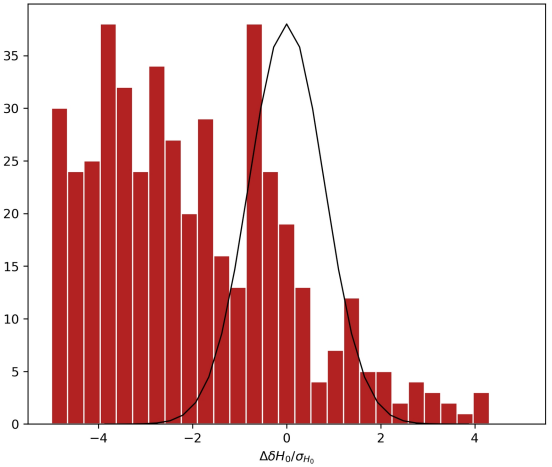


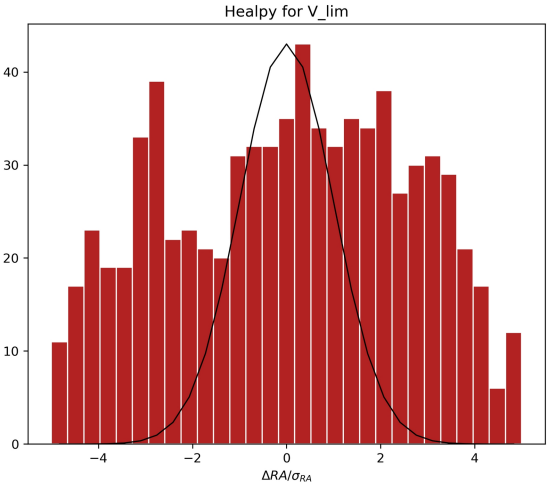
Backup-Volume limites :

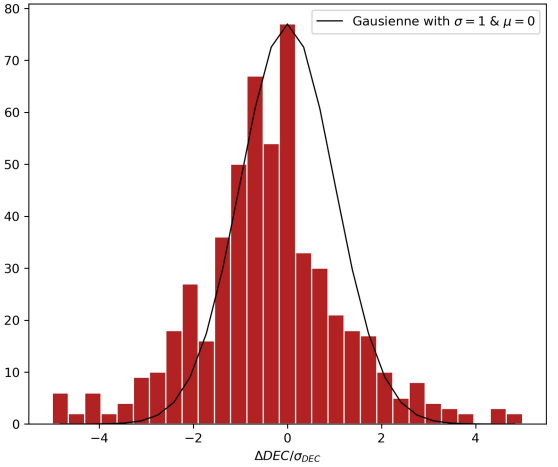


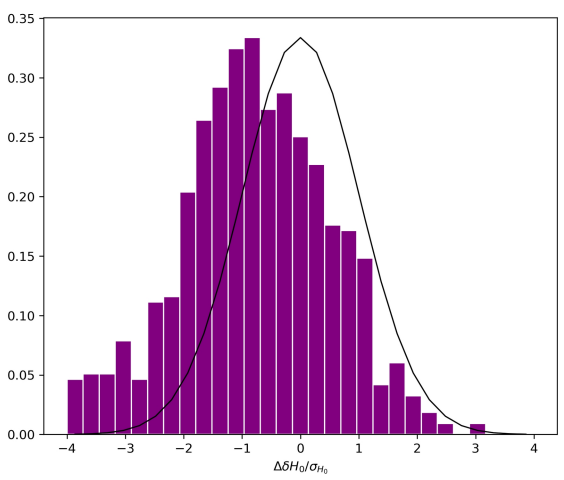


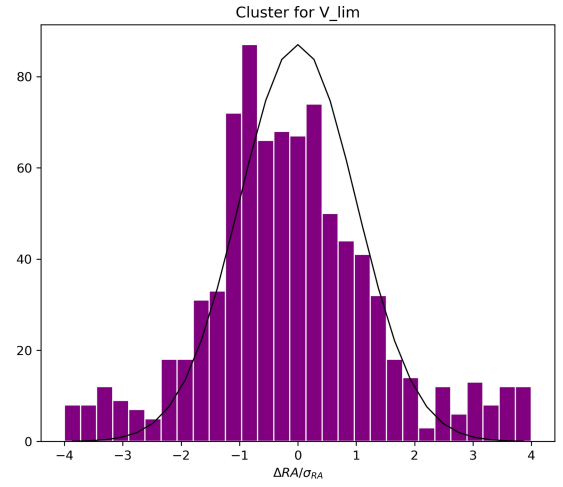
Backup-Volume limites :

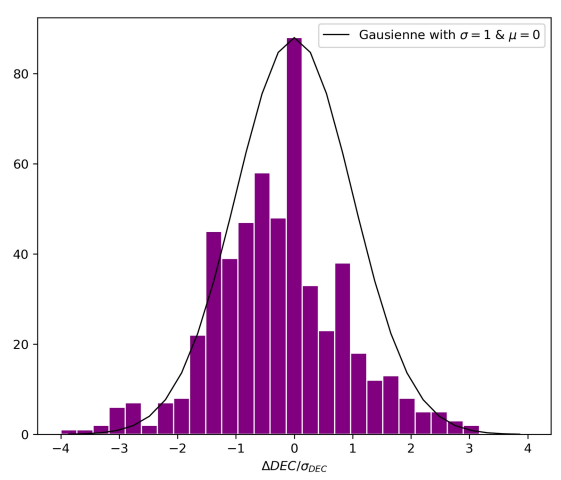












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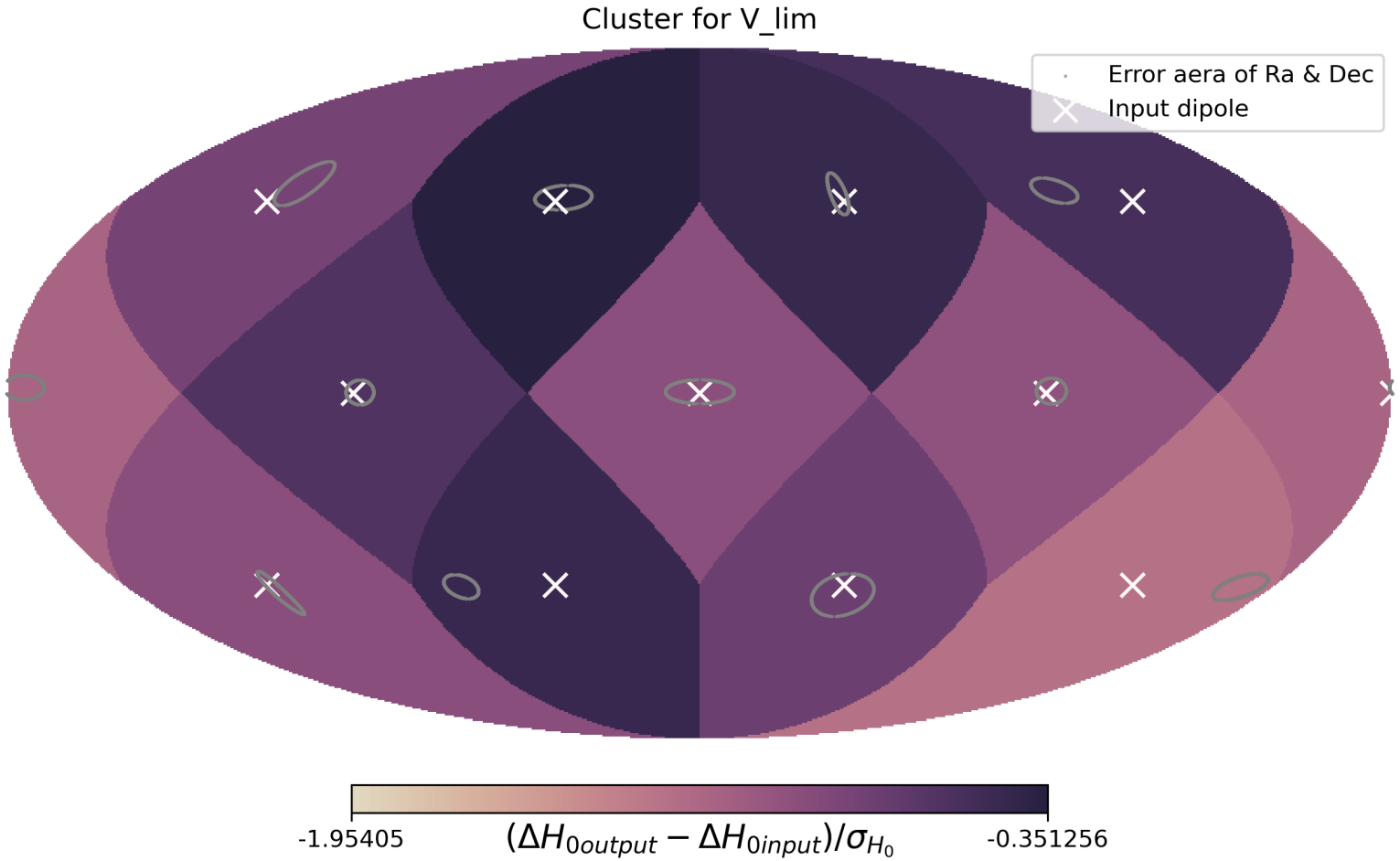
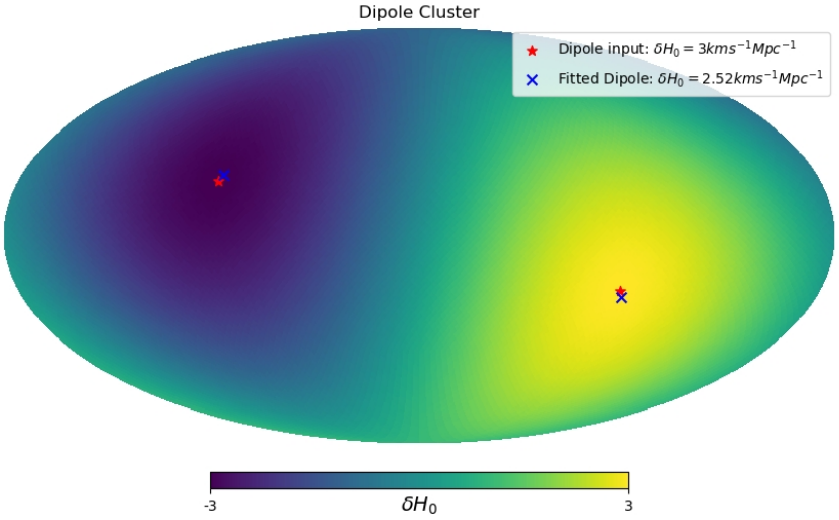
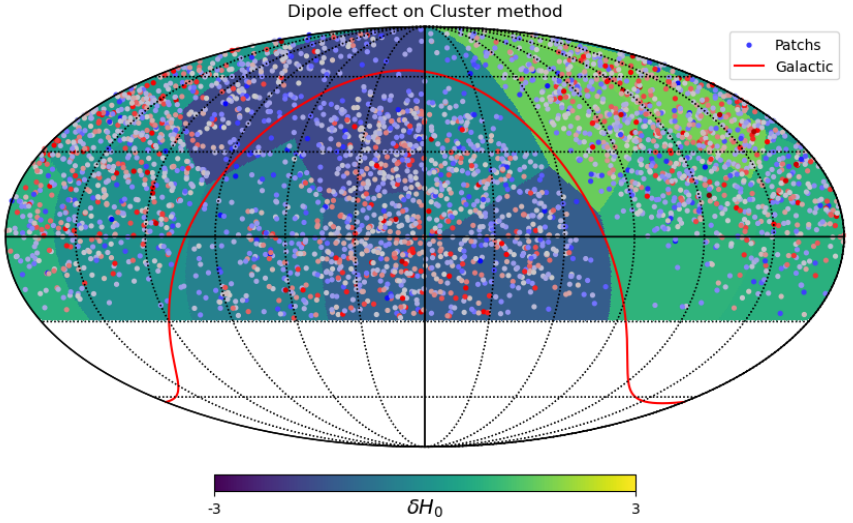
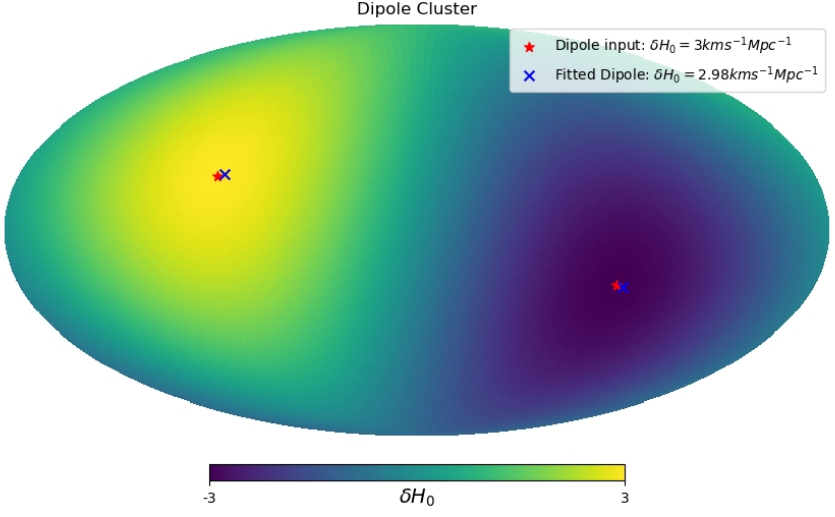
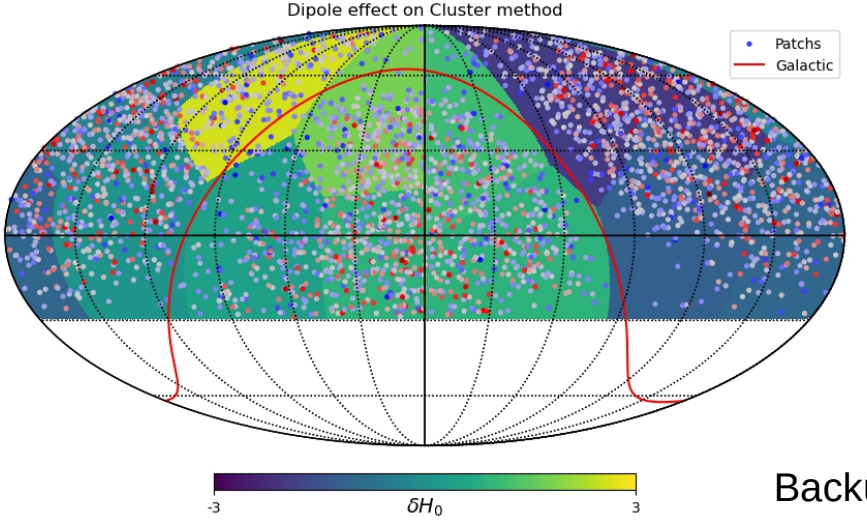


Backup-Symetrie :



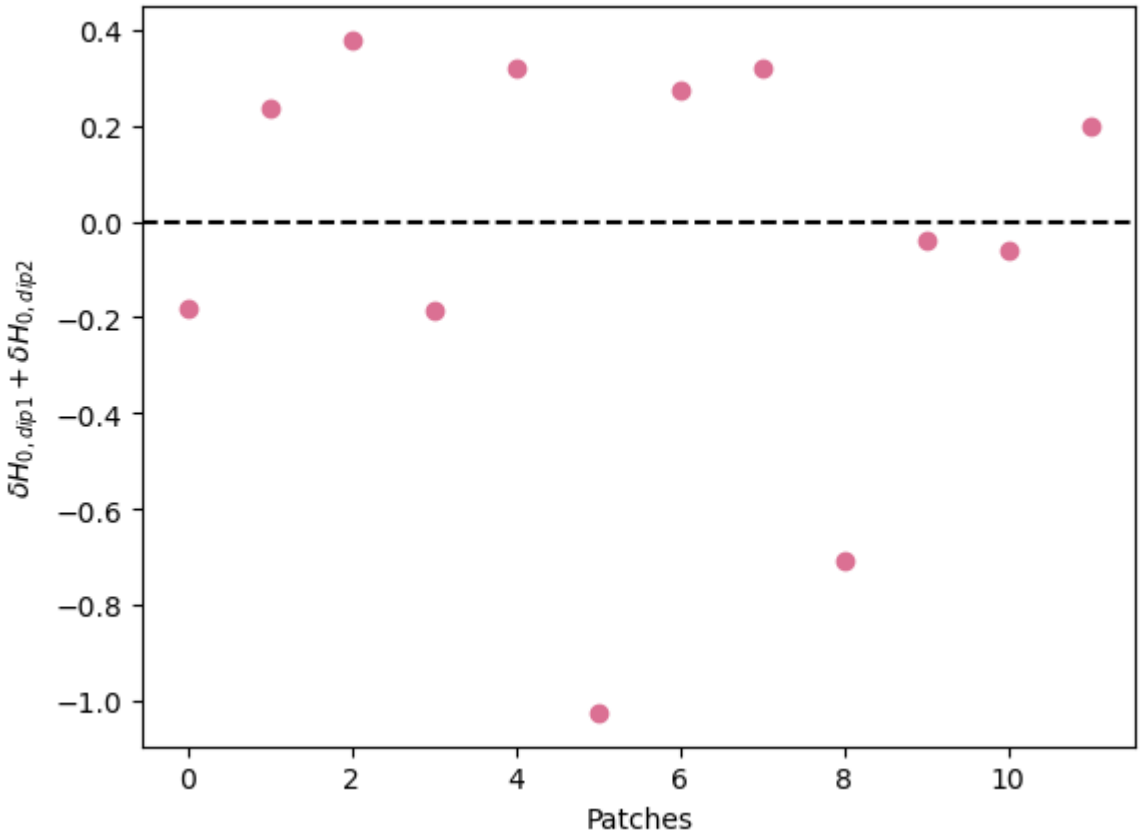




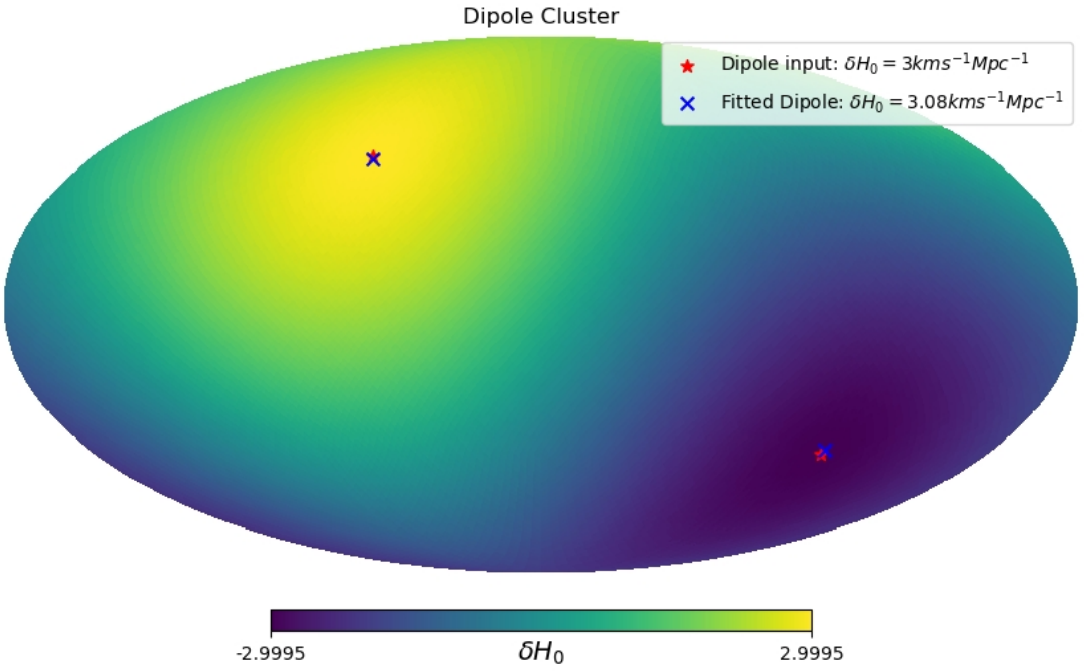


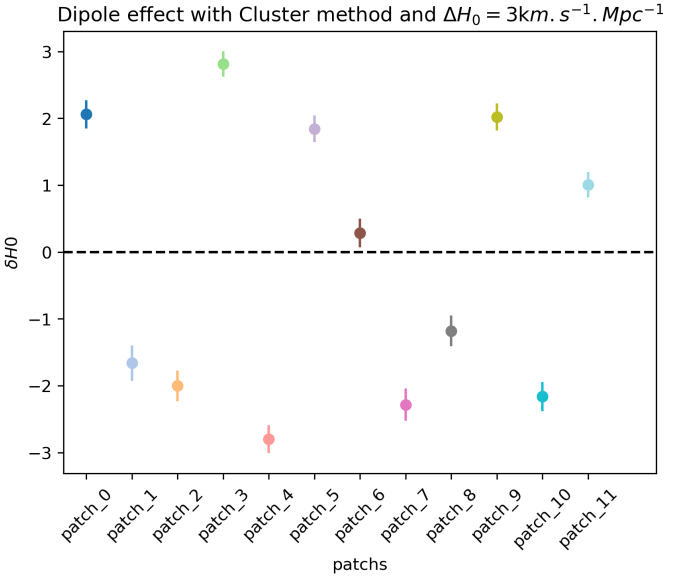
Backup

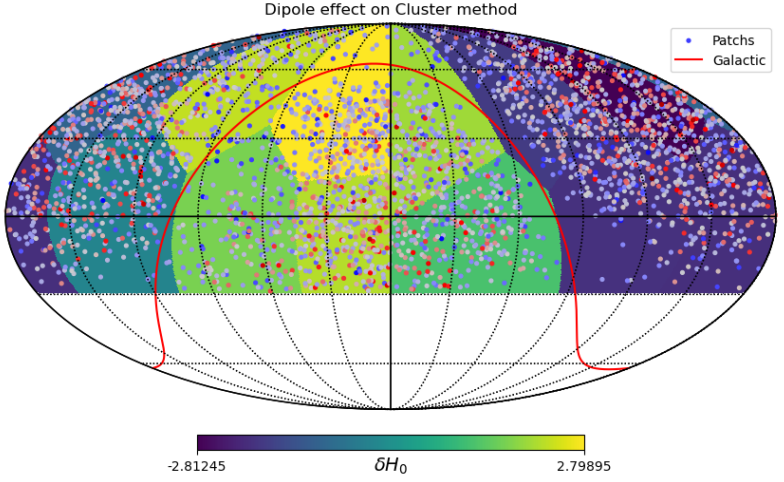
Backup-Symetrie :



Backup- single Cluster Dipole :







Backup SALT2

Sncosmo : A Python Library for Supernova Cosmology analysis.

Usefull for :

- Supernovae modelisation
- Light curve representation
- Simulation
- ...

sncosmo
A Python Library for Supernova Cosmology

Salt2 (T21) Spectral Adaptive Lightcurve Template version 2 : one supernovae model to modelize ligth curve parameters

$$F(p,\lambda) = X_0 \times [M_0(p,\lambda) + X_1 M_1(p,\lambda)] \times \exp[C\,\mathrm{CL}(\lambda)]$$