Growth Rate Measurement using Peculiar Velocities From LSST SNe Ia

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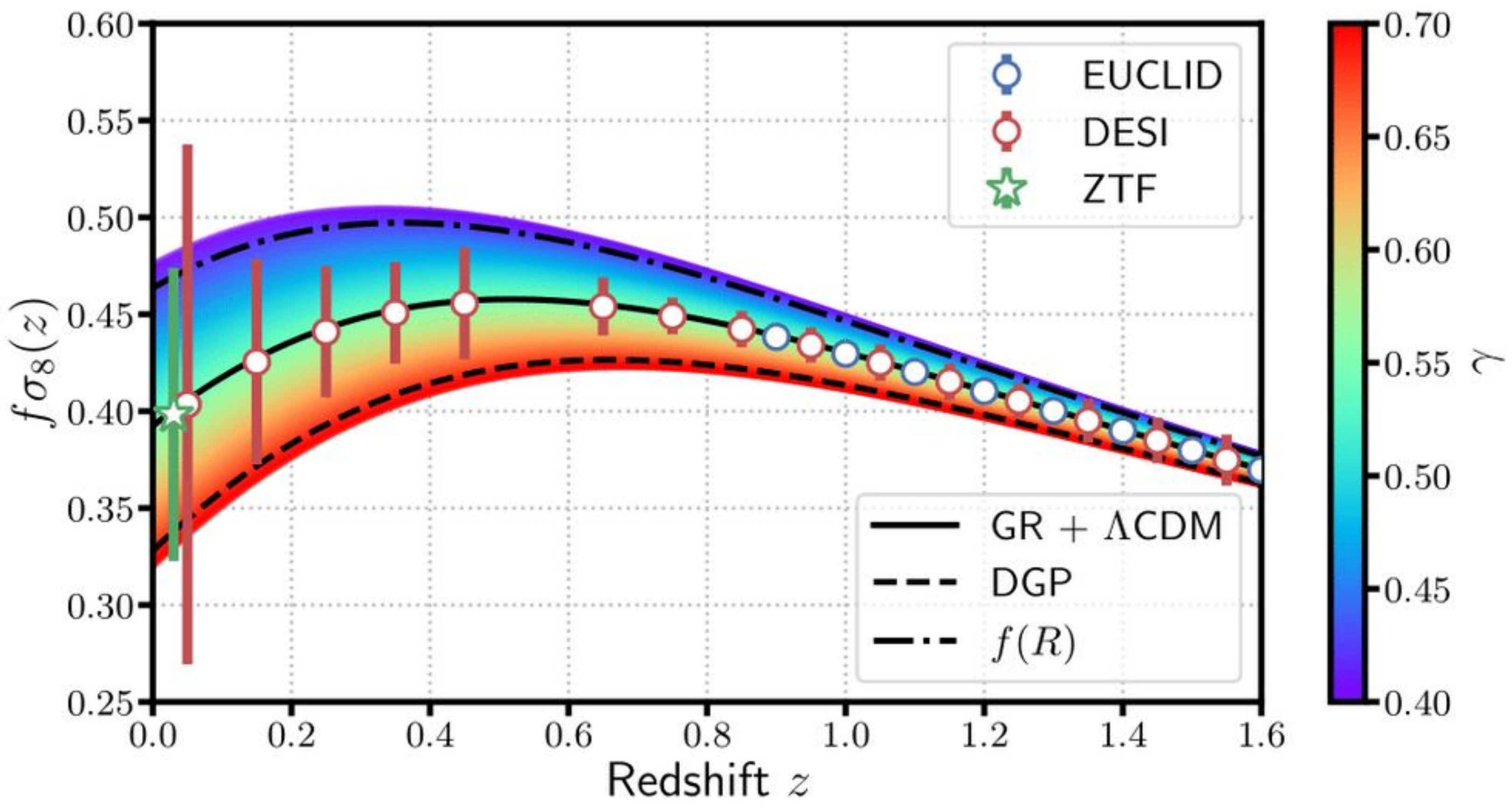


ZTF: Carreres et al 2023
DESI: DESI collaboration 2016a
Euclid: Amendola et al. 2018

Why the growth rate?

The **growth rate** of structures, f, is the logarithmic derivative of the growth factor, D(t) with respect to the **scale factor *a***.

$$f = \frac{d\ln D}{d\ln a}$$

Velocity fields are governed by the growth rate, through the relation (valid in linear theory)

$$\nabla_r \cdot v = -fH\delta$$

and the growth rate is parametrized as

$$f(z) = \Omega_m(z)^\gamma$$

where **γ=0.55 in ΛCDM (General Relativity).**
Thus velocities great probes of **Gravity** and **Dark Energy**.

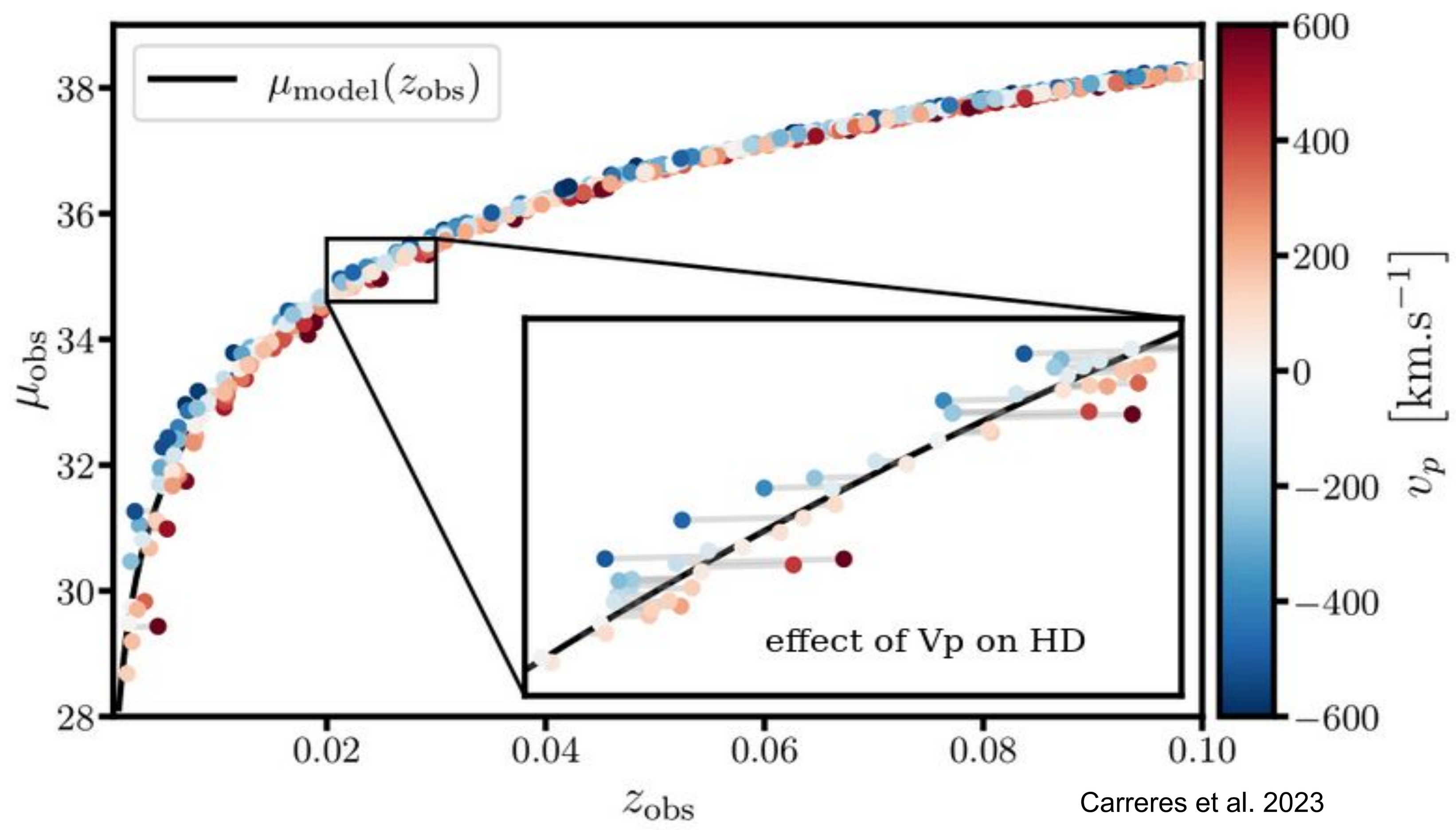
SNe Ia as a probe

We measure the peculiar velocities (PVs) by using their contribution to the **Hubble diagram residuals**. PVs (~300 km/s) have two effects on the SNe Ia Hubble diagram :

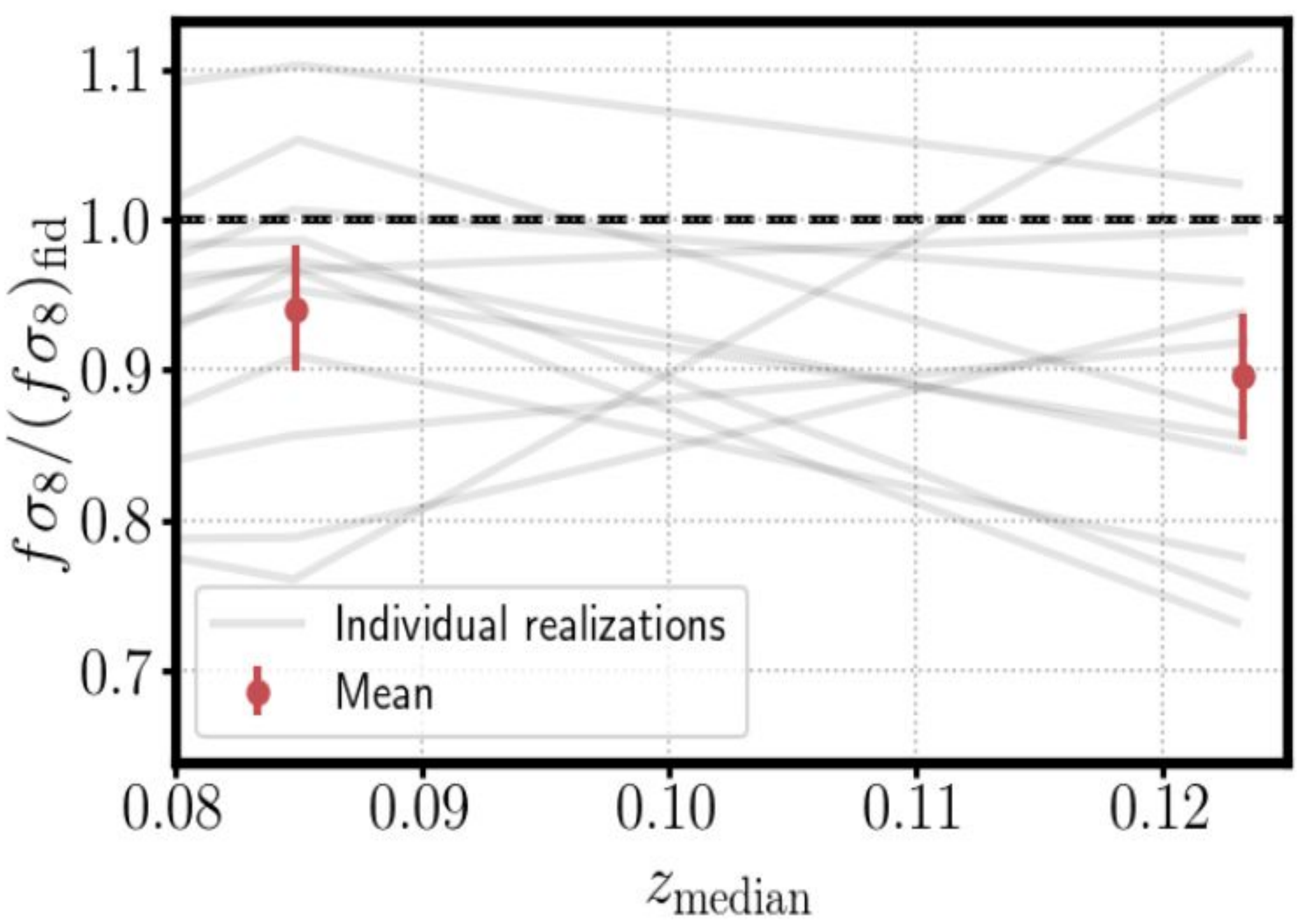
- **Change in redshift** (Δz~0.001) due to Doppler effect.
- **Change in apparent distance modulus** (Δμ ~ 0.004 mag) due to relativistic beaming.

Thus we can measure the PVs using the formula:

$$\hat{v}_i(\mathbf{p}_{\mathrm{HD}}) = -\frac{\ln(10)c}{5}\left(\frac{(1+z_i)c}{H(z_i)r(z_i)} - 1\right)^{-1}\Delta\mu_i(\mathbf{p}_{\mathrm{HD}}).$$



Carreres et al. 2023



Growth rate measurement from simulated LSST SNe Ia

We have produced **12** LSST survey realizations. We have used **Outer Rim** (Heitmann et al. 2019) box at **z=0,** as input for the large-scale structure. Using **LSST simulated observations** and ***SNsim*** survey simulator (Carreres et al. 2023), we have generated realistic SNe Ia light curves.
On the simulated sample we have applied the **selections** described in Sanchez et al. (2022). We have fitted the light curves using the **SALT2 model** (Guy et al. 2010) and we have applied some quality cuts on the fit results. We fit $f\sigma_8$ in 2 redshift bins using a **gaussian likelihood** with a covariance matrix computed as

$$C_{ij}^{vv} = \frac{H_0^2}{2\pi^2}\frac{(f\sigma_8)^2}{(f\sigma_8)^2_{\mathrm{fid}}}\int_0^{+\infty} f^2_{\mathrm{fid}}P_{\theta\theta}(k)D_u^2(k)W_{ij}(k;\mathbf{r}_i,\mathbf{r}_j)\mathrm{d}k.$$

$f\sigma_8$ measurement results bias in the highest redshift bin due to **Malquist bias.** The error on the measurement is about **14%** in both redshift bins.

Preliminary work with simple selection function: **perfect typing** and **spectroscopic redshift** available for all the SNe host galaxies.
Future:

- Include selection function in the likelihood.
- Use of **4MOST** footprint/selection function for the **SNe host redshifts**.
- **Phototyping** for SNe Ia characterization.

Velocity systematics on the Hubble diagram fit of the ZTF DR2 sample

(B. Carreres, D. Rosselli et al. in prep.)

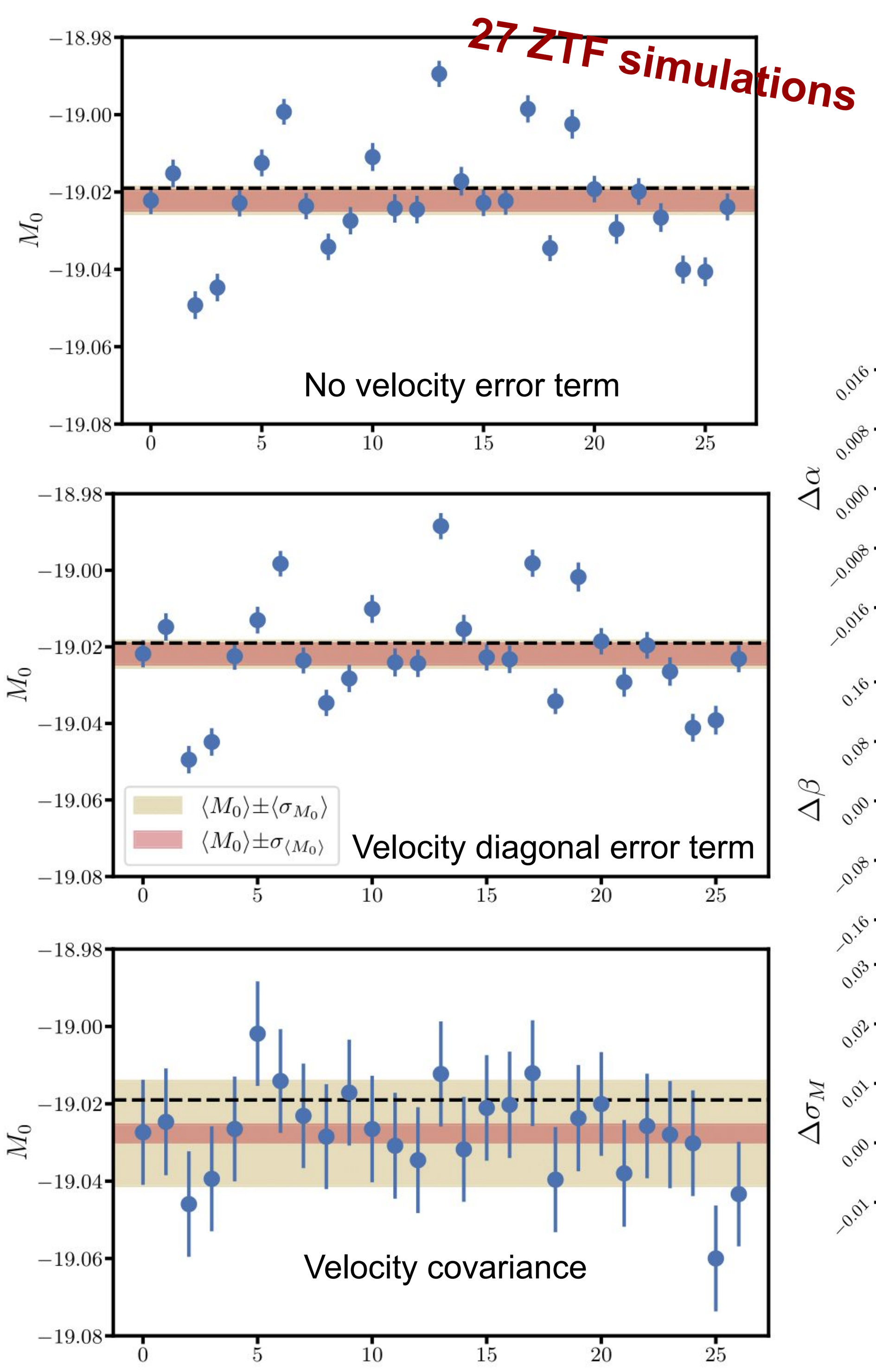
Type Ia supernovae (SNe Ia) host galaxy peculiar velocities (PVs) impact the measurement of cosmological parameters when SNe Ia are used to determine distances, especially in low redshift samples.
We have study the impact of neglecting galaxy PVs and their correlations in the **standardization of the SNe Ia Hubble diagram,** given by

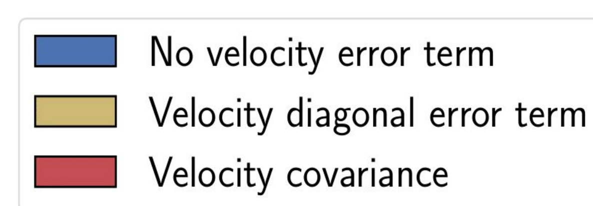
$$\mu_i = m_{B,i} + \alpha x_{1,i} - \beta c_i - M_0,$$

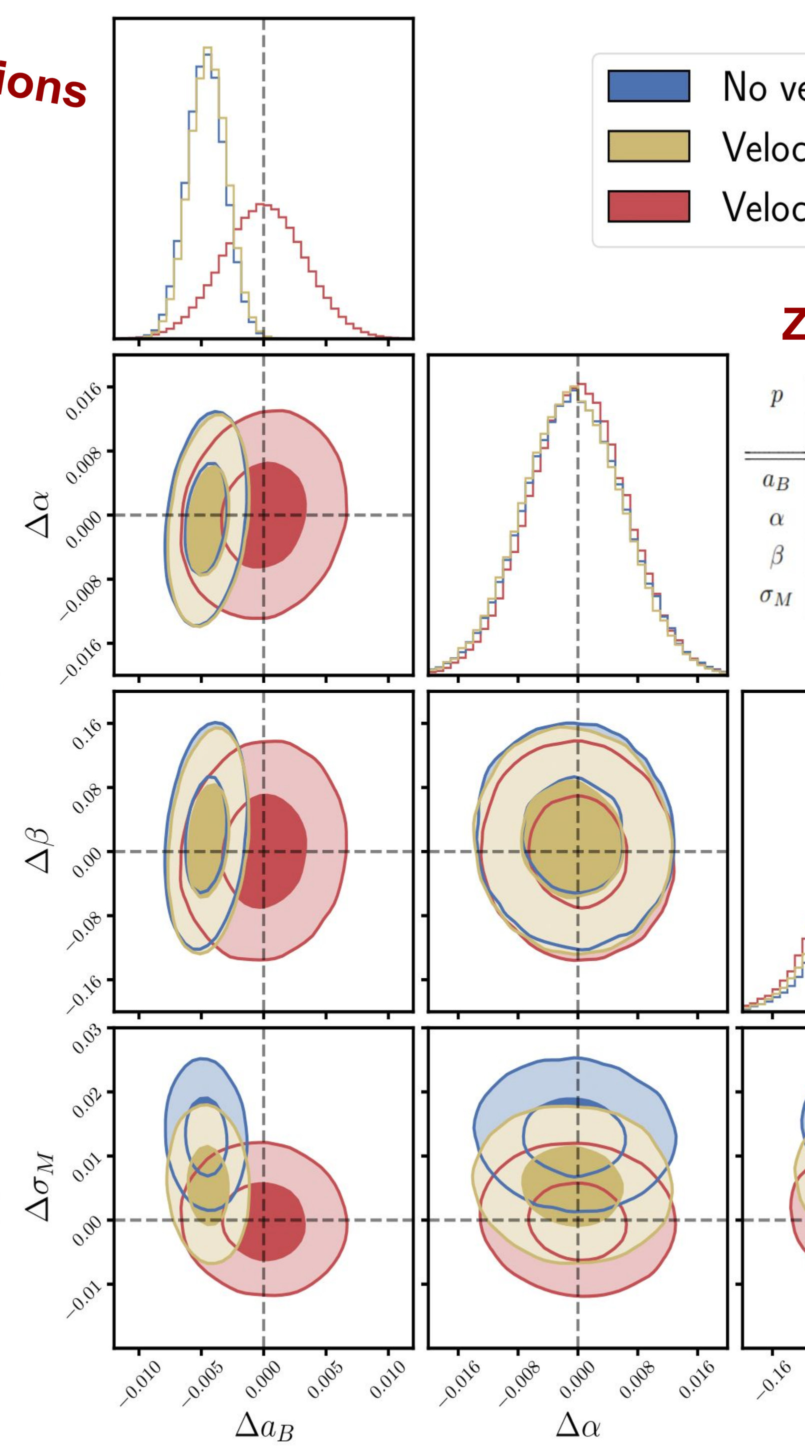
We have used realistic simulations of SNe Ia observed by the Zwicky Transient Facility (ZTF) to investigate the effect of different methods to take into account PVs. We have found that it is necessary to use the PV **full covariance matrix computed from the velocity power spectrum to take into account the sample variance**.
We have determined the PVs systematic effects in the context of the **ZTF DR2 SNe Ia sample**. We have investigated the PVs impact on the intercept of the Hubble diagram, $\mathbf{a_B}$, which is directly linked to the measurement of H_0 by the relation

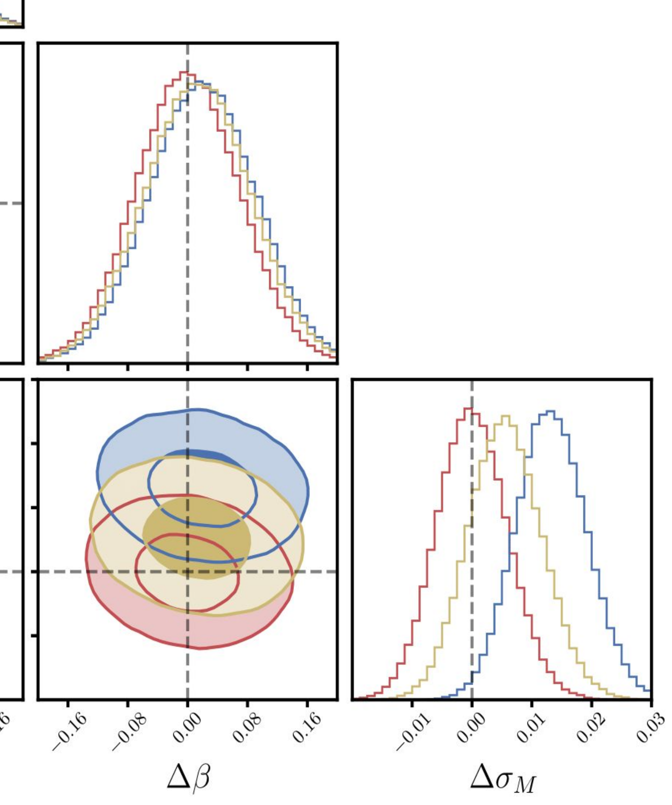
$$\log H_0 = \frac{M_B + 5a_B + 25}{5}.$$

Not taking into account PVs correctly causes a **shift on H_0 value of about 0.7 km.s^{-1}.Mpc^{-1}** and a **slightly underestimation of the final measurement error.**









ZTF DR2 Sample

p	Vel. full cov.	No vel. error		Vel. diagonal error	
	σ_p	Δp	σ_p	Δp	σ_p
a_B	± 0.0033	-0.0046	± 0.0015	-0.0044	± 0.0015
α	± 0.0065	-0.0005	± 0.0067	-0.0007	± 0.0066
β	± 0.069	0.020	± 0.071	0.013	± 0.071
σ_M	± 0.0059	0.0132	± 0.0059	0.0055	± 0.0061