Aix*Marseille université
Socialement engagée

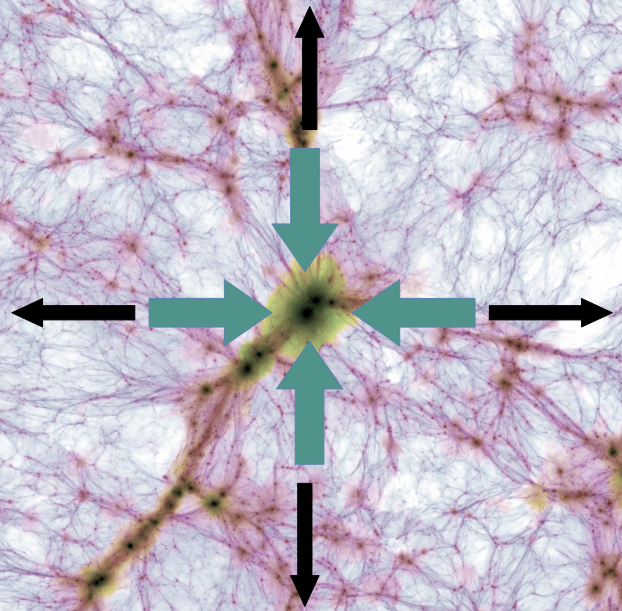
Cosmology with the growth rate using type Ia supernovae

Carreres Bastien

- Action Dark Energy 2022 -

CENTRE DE PHYSIQUE DES PARTICULES DE MARSEILLE
CPPM

Gravity VS Dark Energy

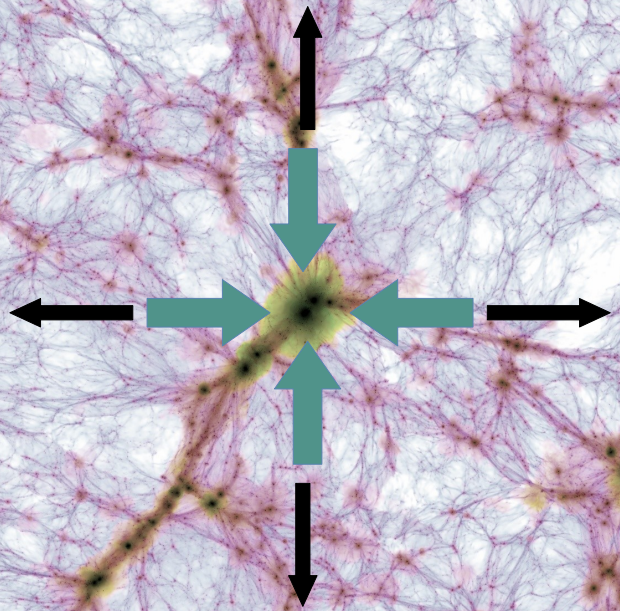


Credit : *Illustris TNG*

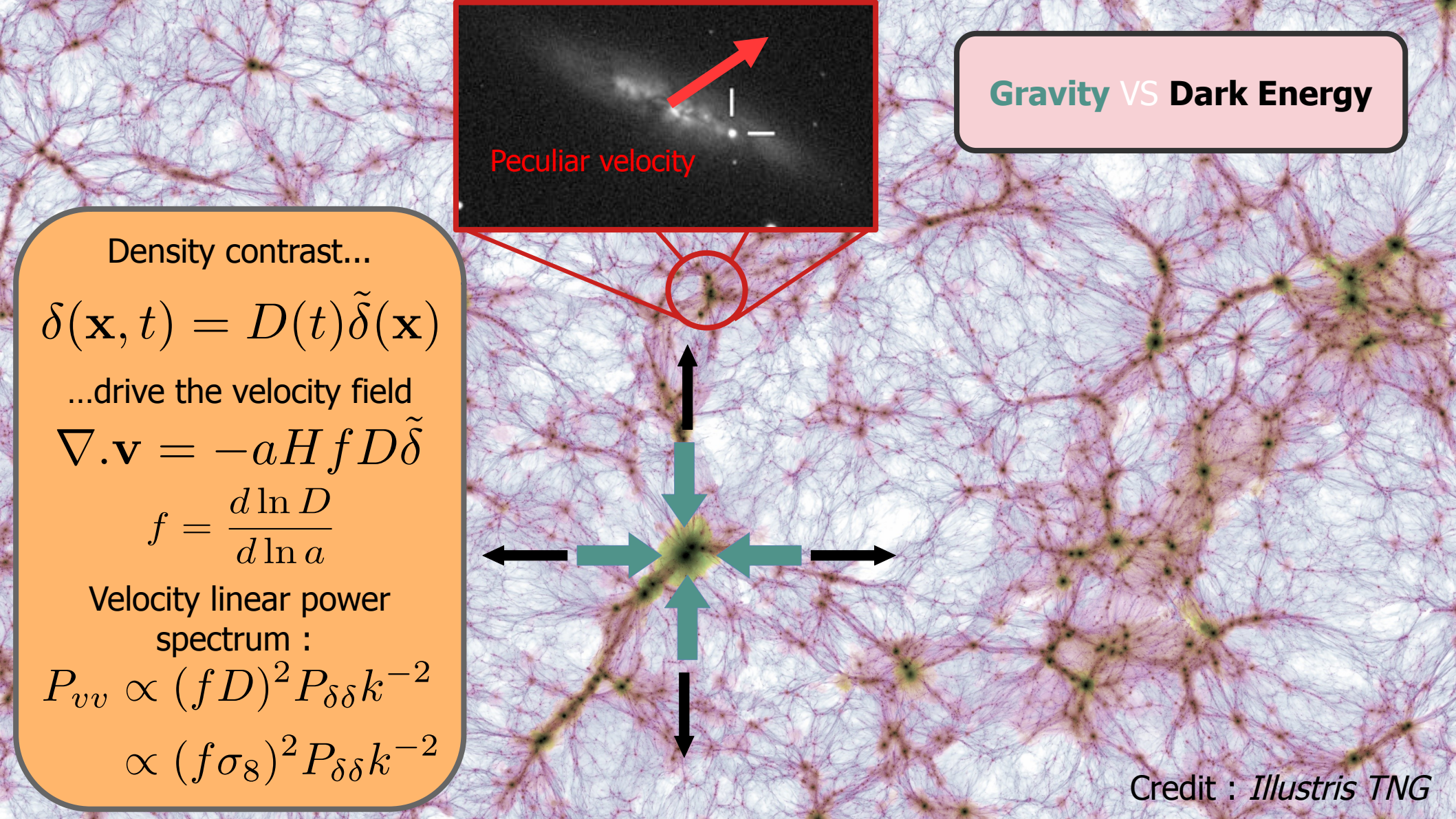
Gravity VS **Dark Energy**

Density contrast...

$$\delta(\mathbf{x}, t) = D(t)\tilde{\delta}(\mathbf{x})$$



Credit : *Illustris TNG*



Gravity VS **Dark Energy**

Density contrast...

$$\delta(\mathbf{x},t) = D(t)\tilde{\delta}(\mathbf{x})$$

...drive the velocity field

$$\nabla.\mathbf{v} = -aHfD\tilde{\delta}$$

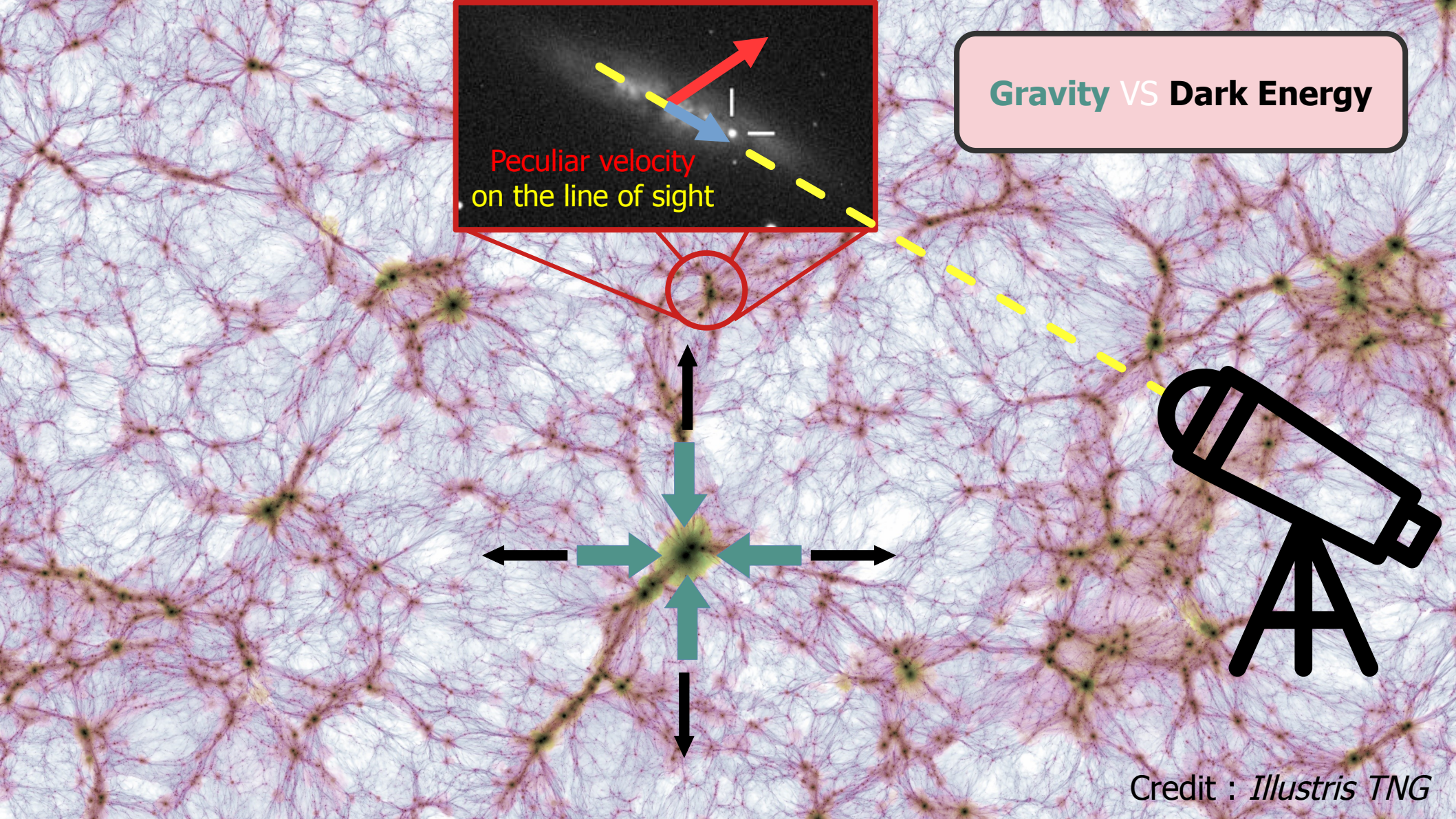
$$f = \frac{d\ln D}{d\ln a}$$

Velocity linear power spectrum :

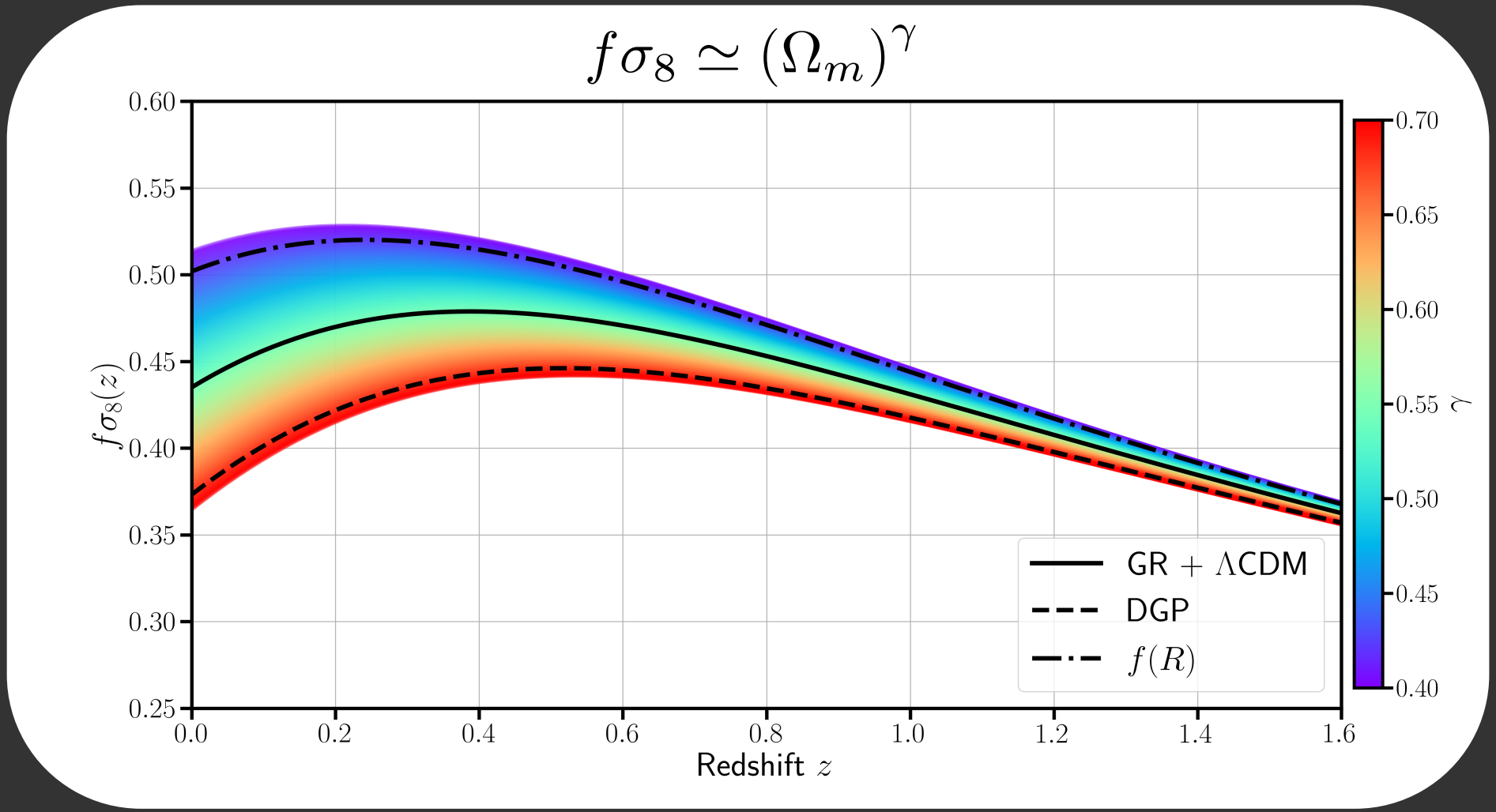
$$P_{vv} \propto (fD)^2 P_{\delta\delta} k^{-2}$$

$$\propto (f\sigma_8)^2 P_{\delta\delta} k^{-2}$$

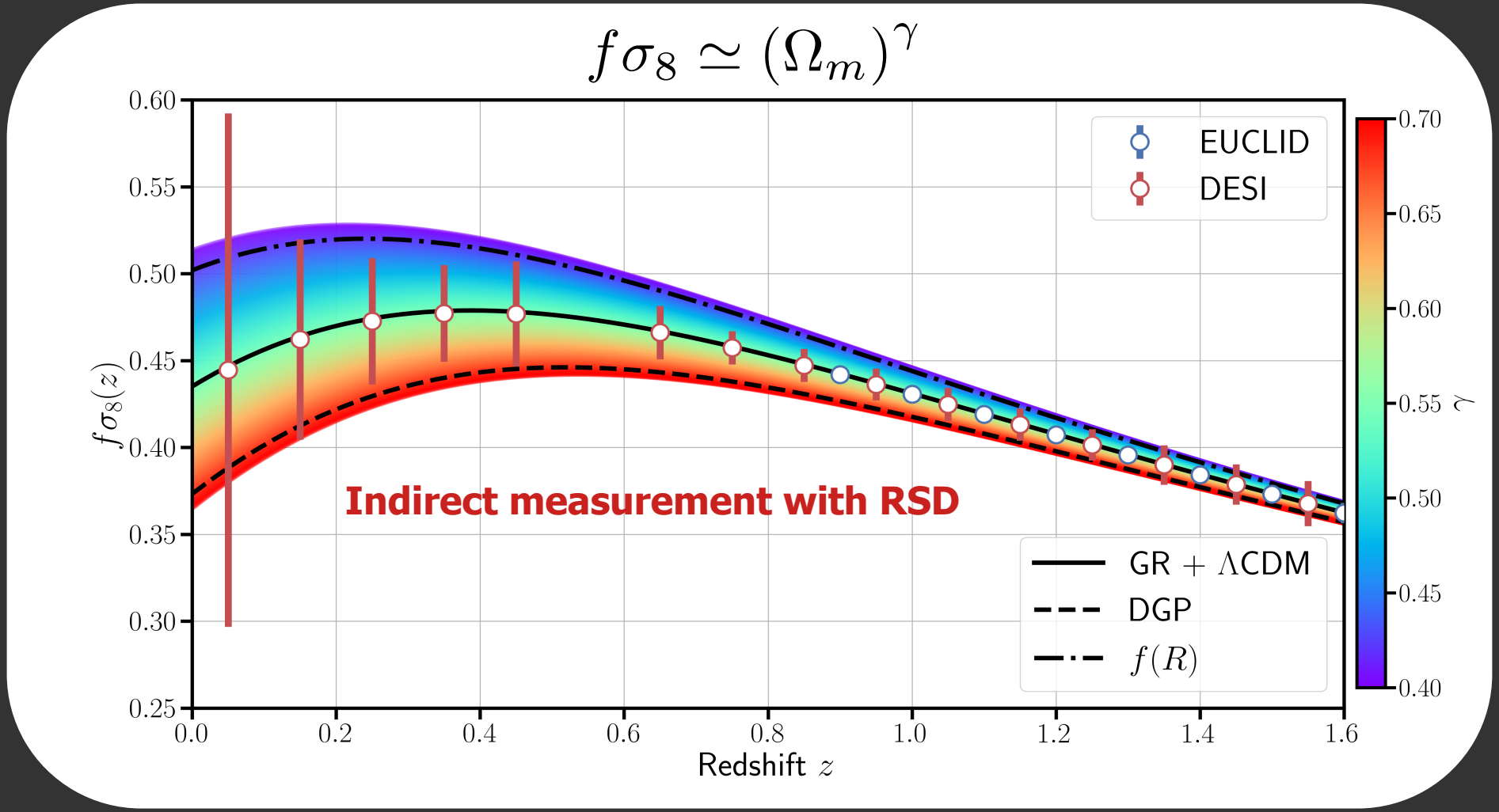
Credit : *Illustris TNG*


Peculiar velocity
on the line of sight
Gravity VS Dark Energy
Credit : *Illustris TNG*

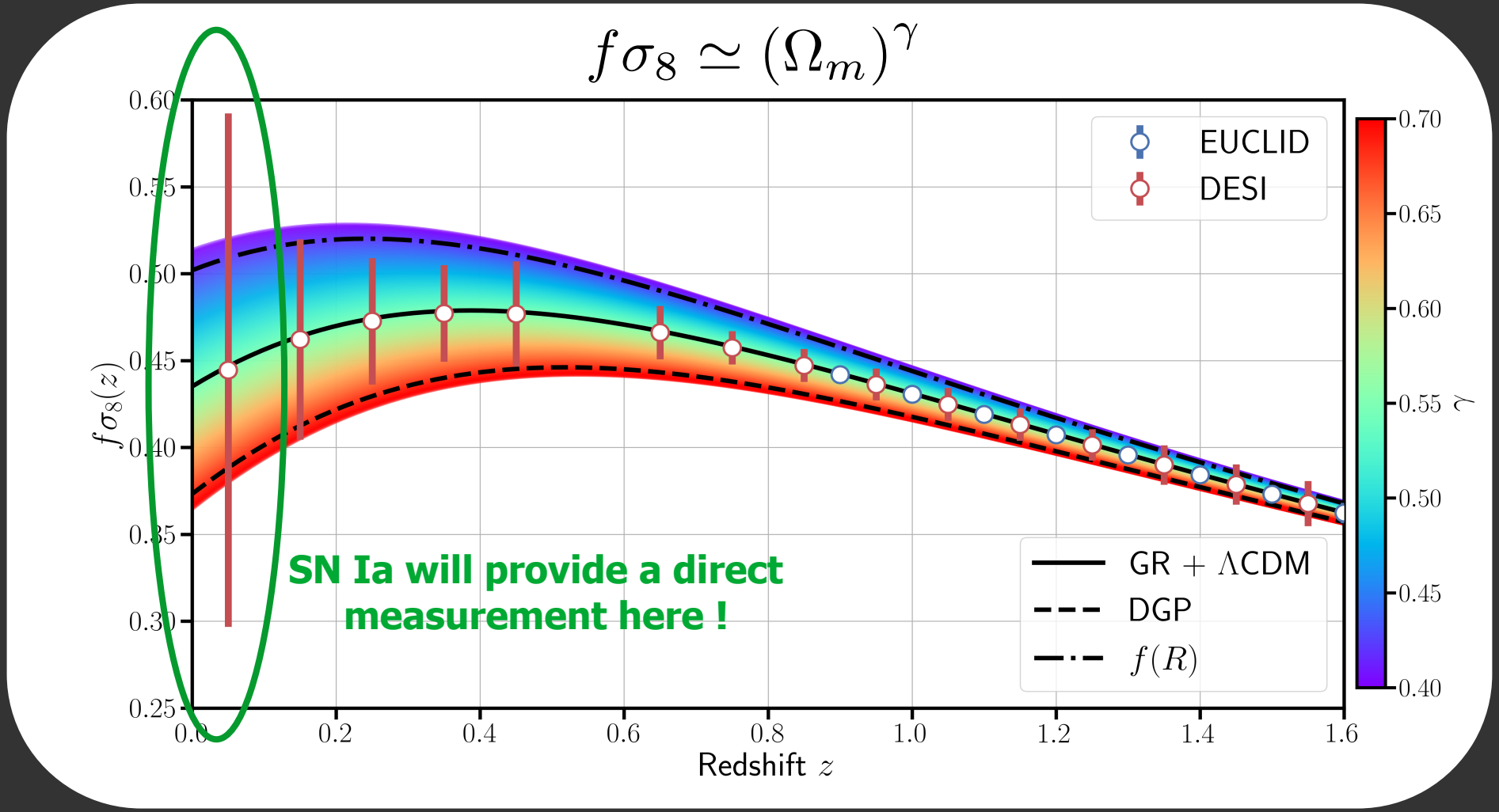
$f\sigma_8$: a probe of dark energy and general relativity



fσ8 : a probe of dark energy and general relativity



fσ8 : a probe of dark energy and general relativity



SN Ia : build the Hubble diagram

$$L \simeq cst$$

SN Ia : build the Hubble diagram

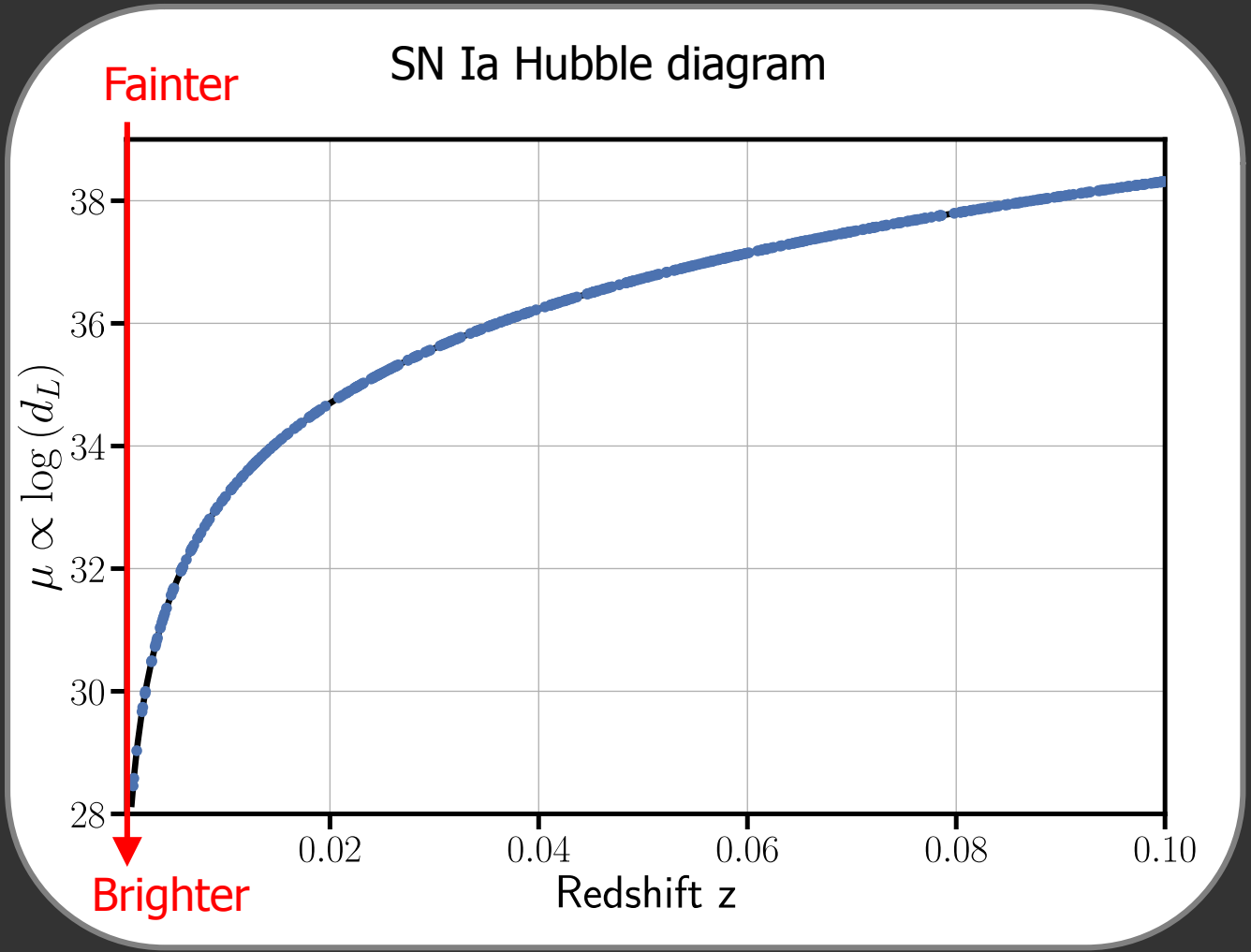
$$L \simeq cst$$

SN Ia : build the Hubble diagram

$$L \simeq cst$$

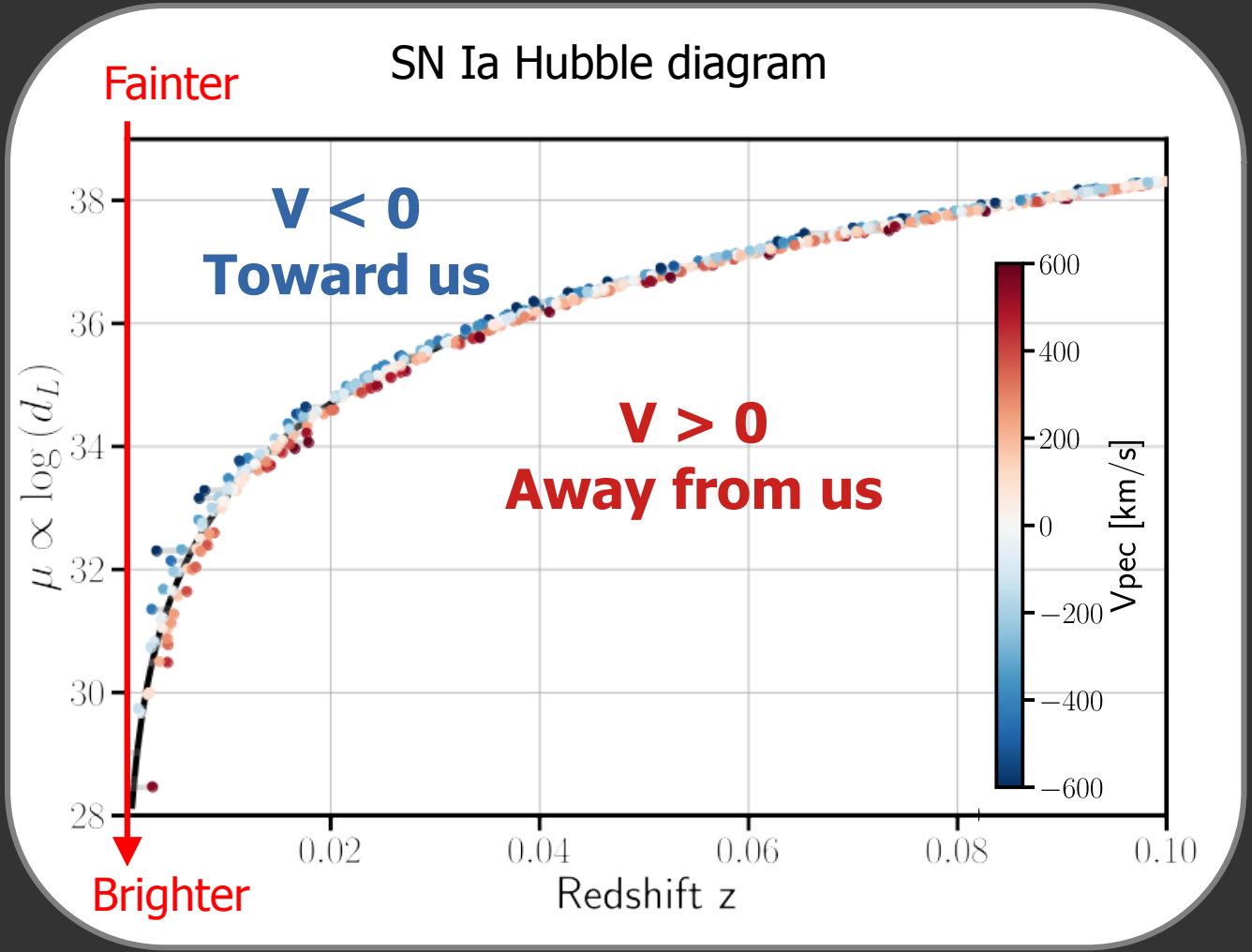
SN Ia : build the Hubble diagram

$$L \simeq cst$$



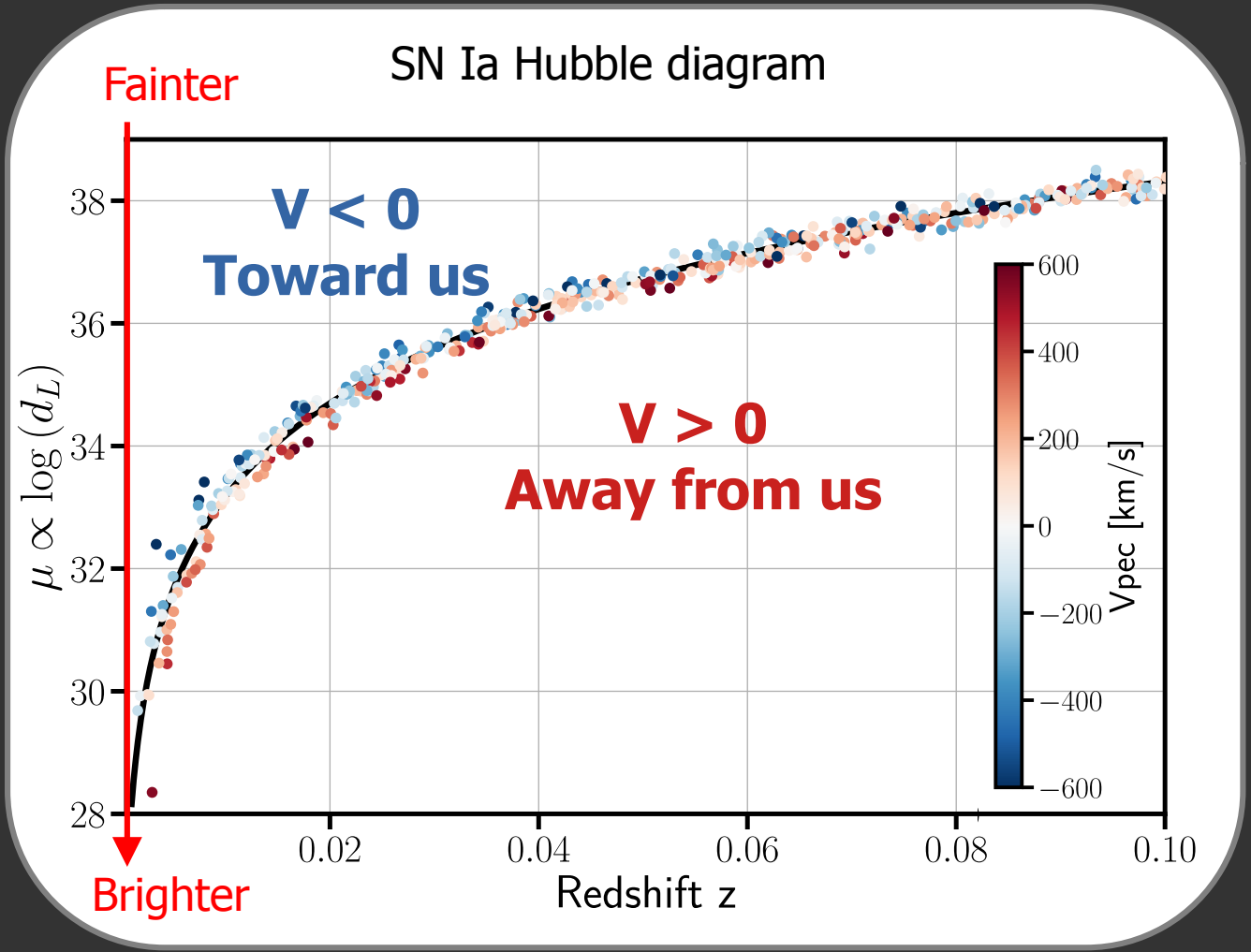
SN Ia : build the Hubble diagram

$$L \simeq cst$$

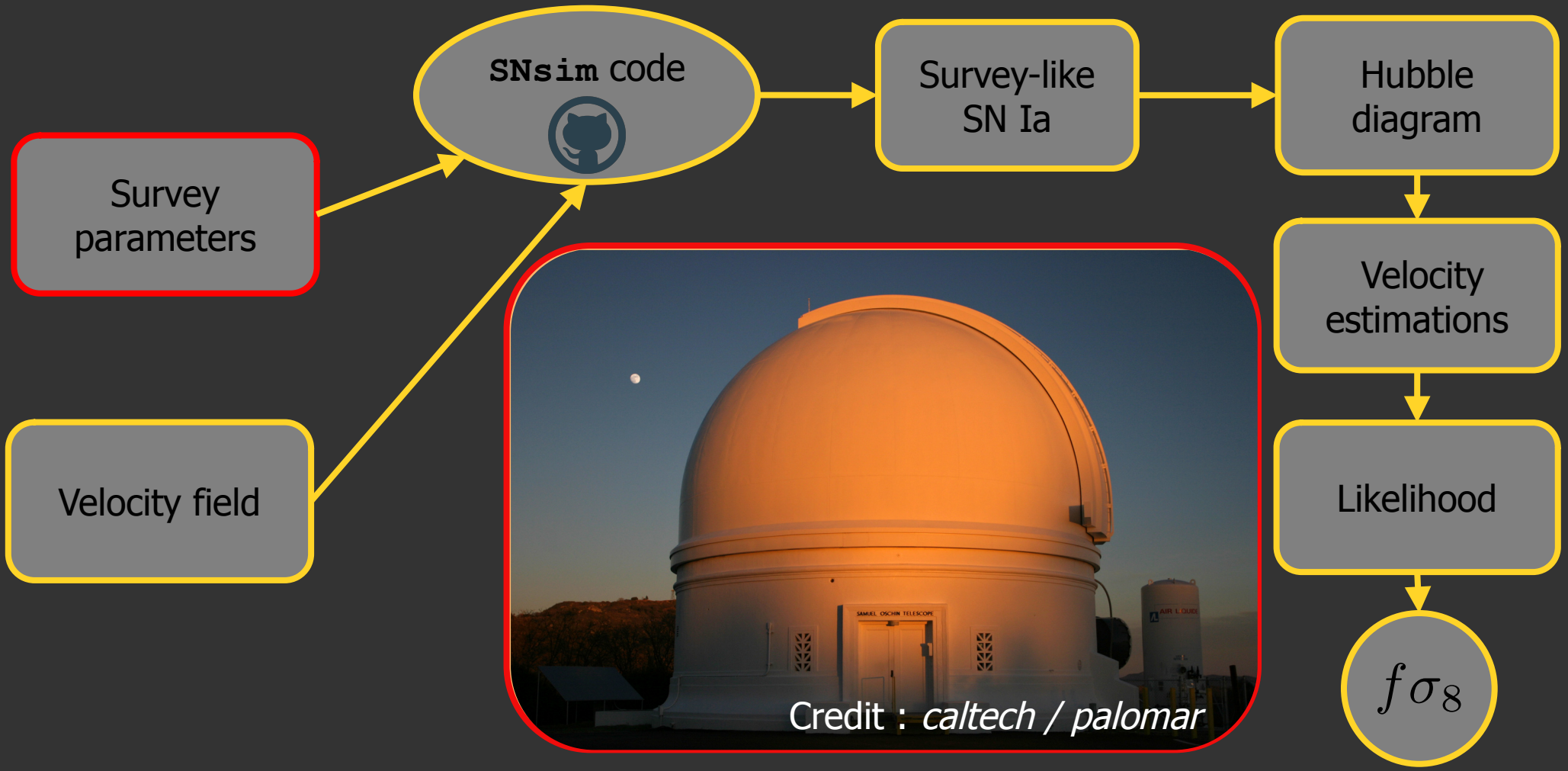


SN Ia : build the Hubble diagram

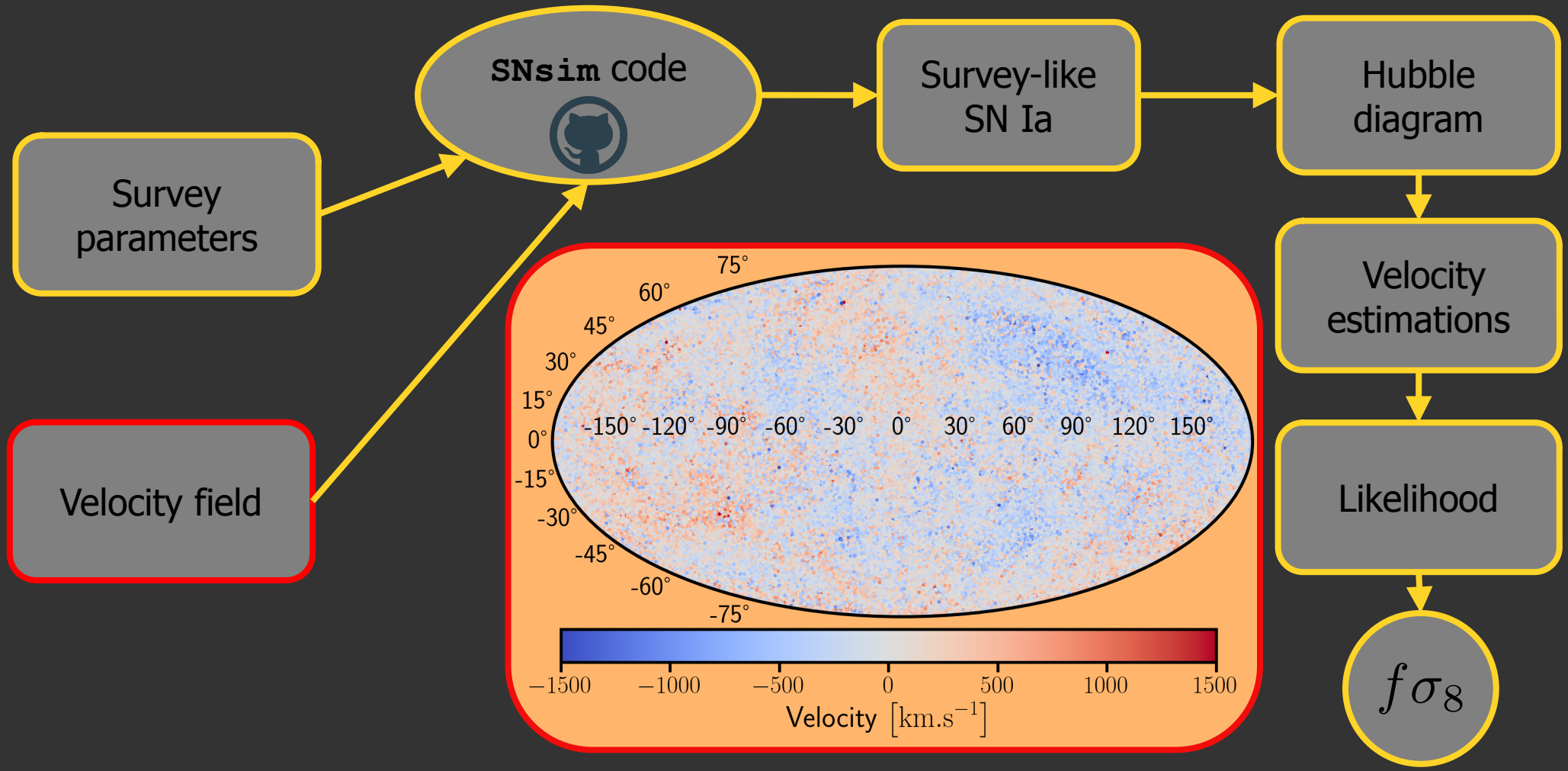
$$L \simeq cst$$



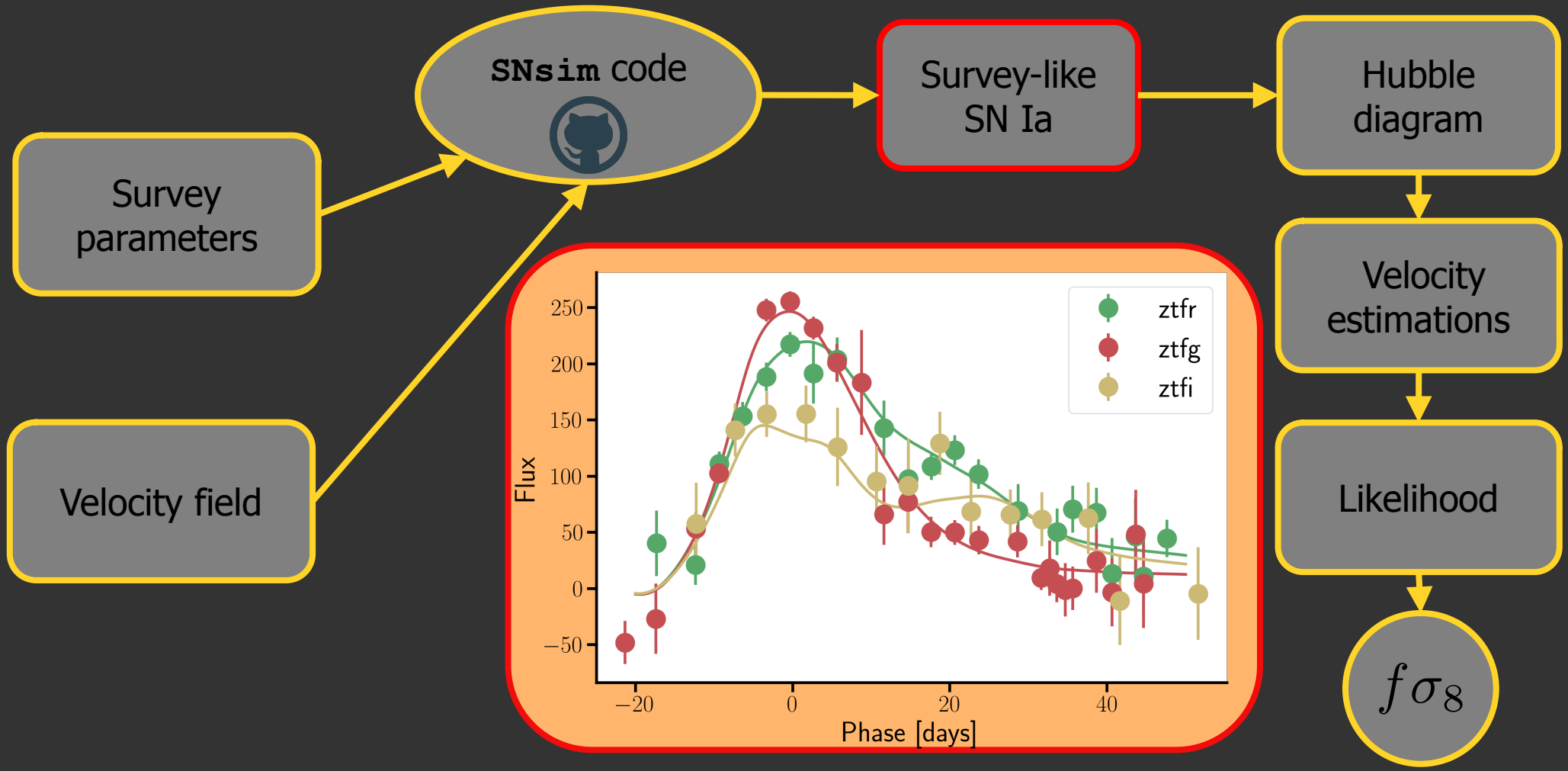
Using simulations to study bias and systematics



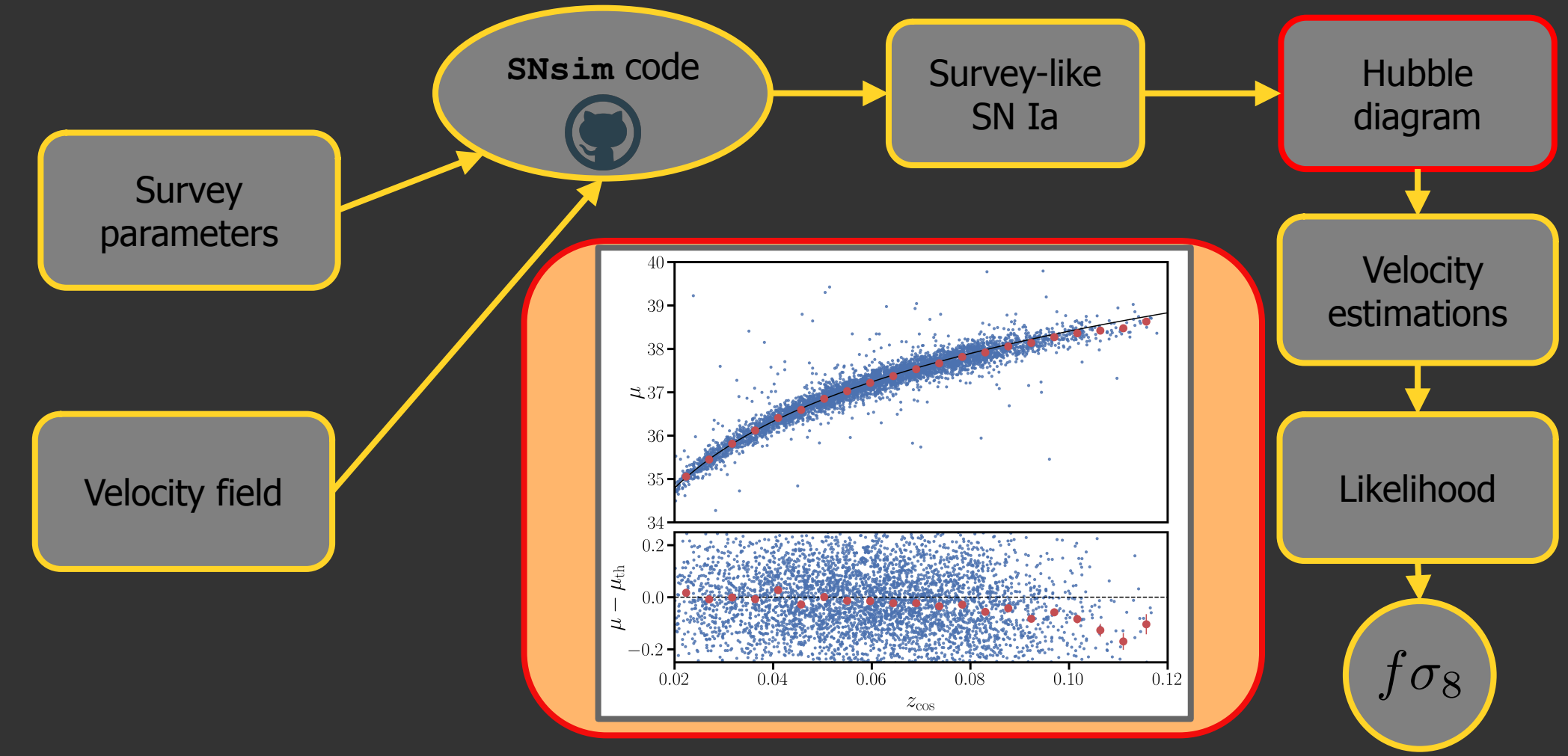
Using simulations to study bias and systematics



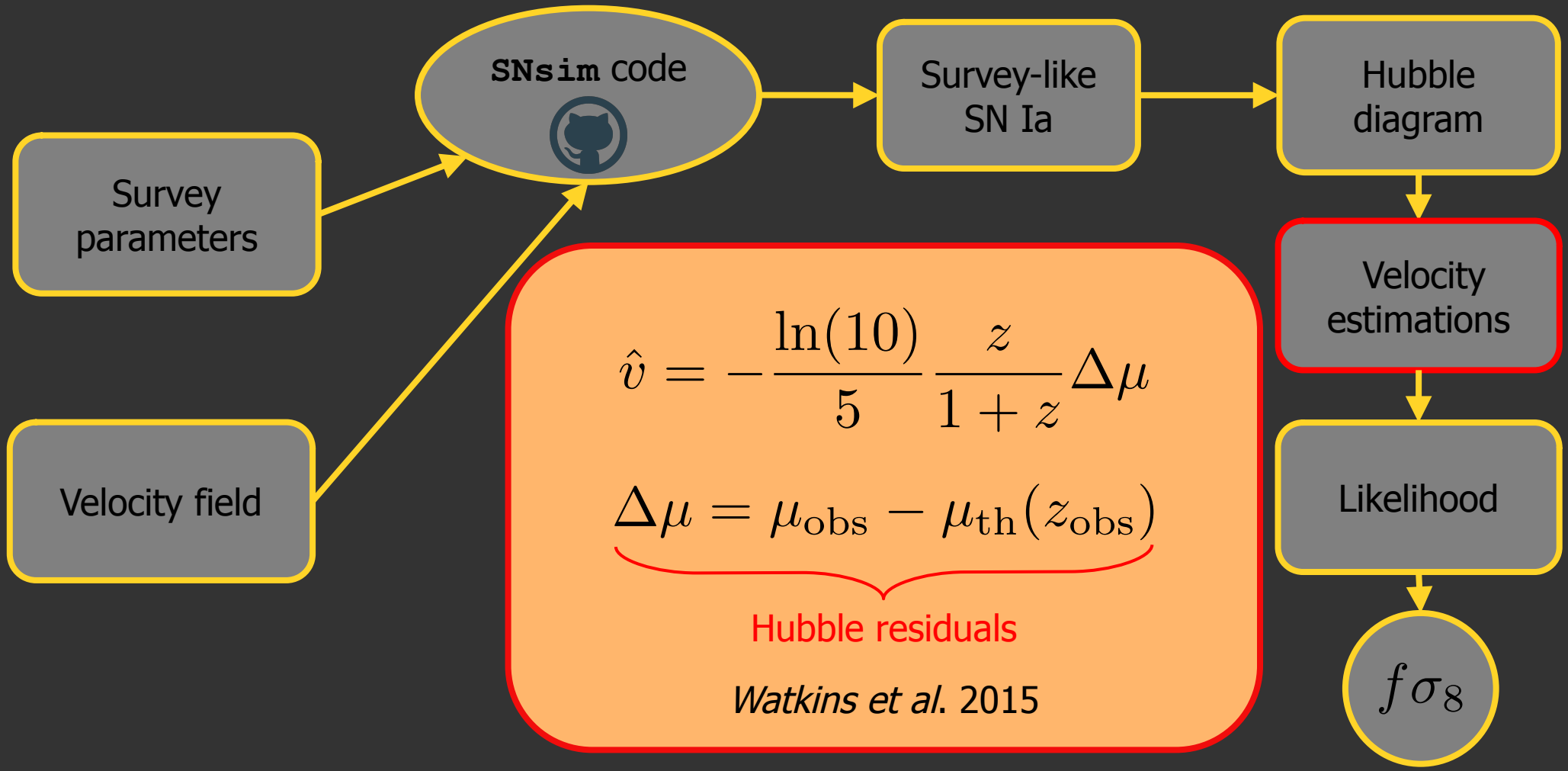
Using simulations to study bias and systematics



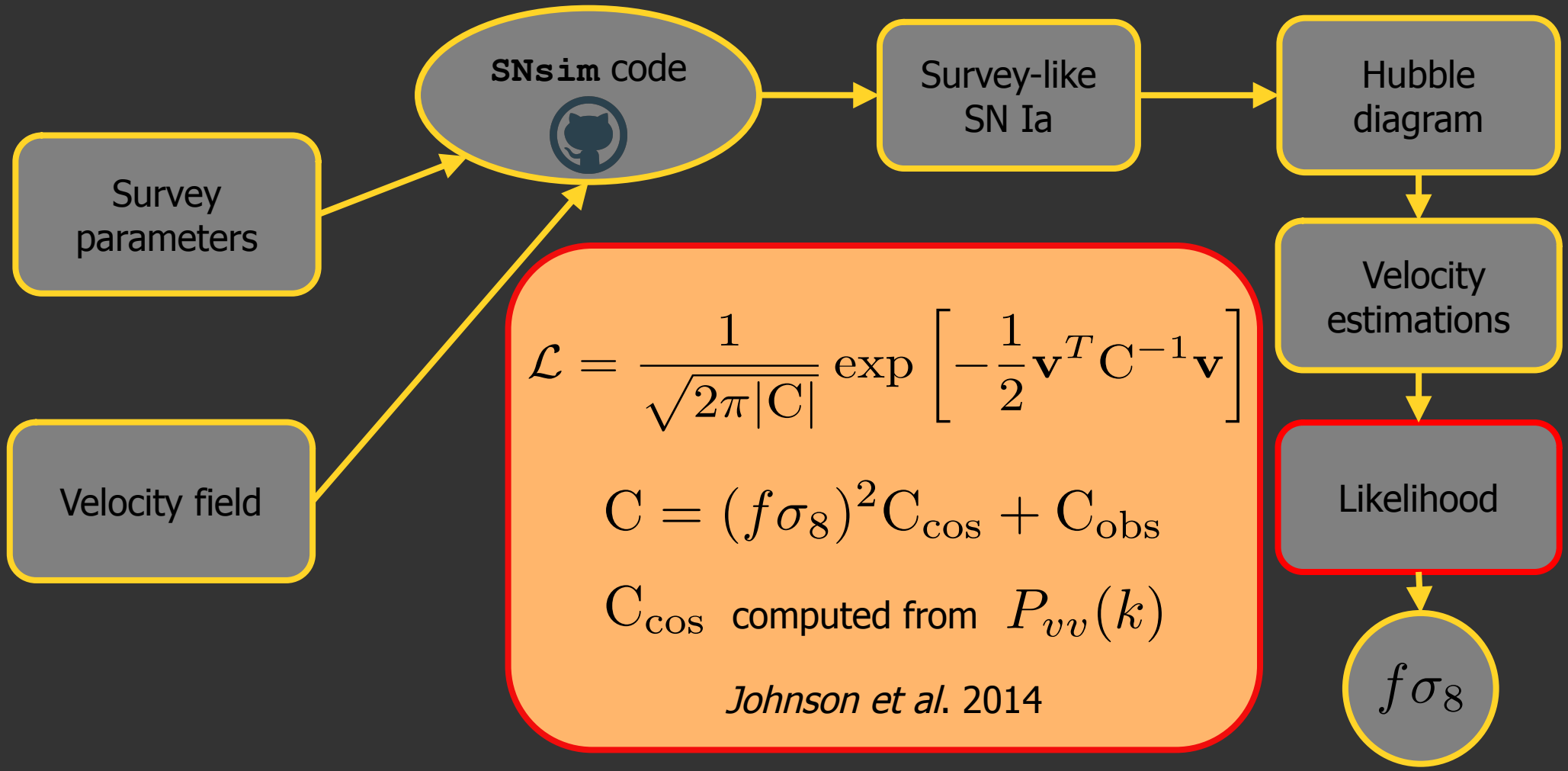
Using simulations to study bias and systematics



Using simulations to study bias and systematics



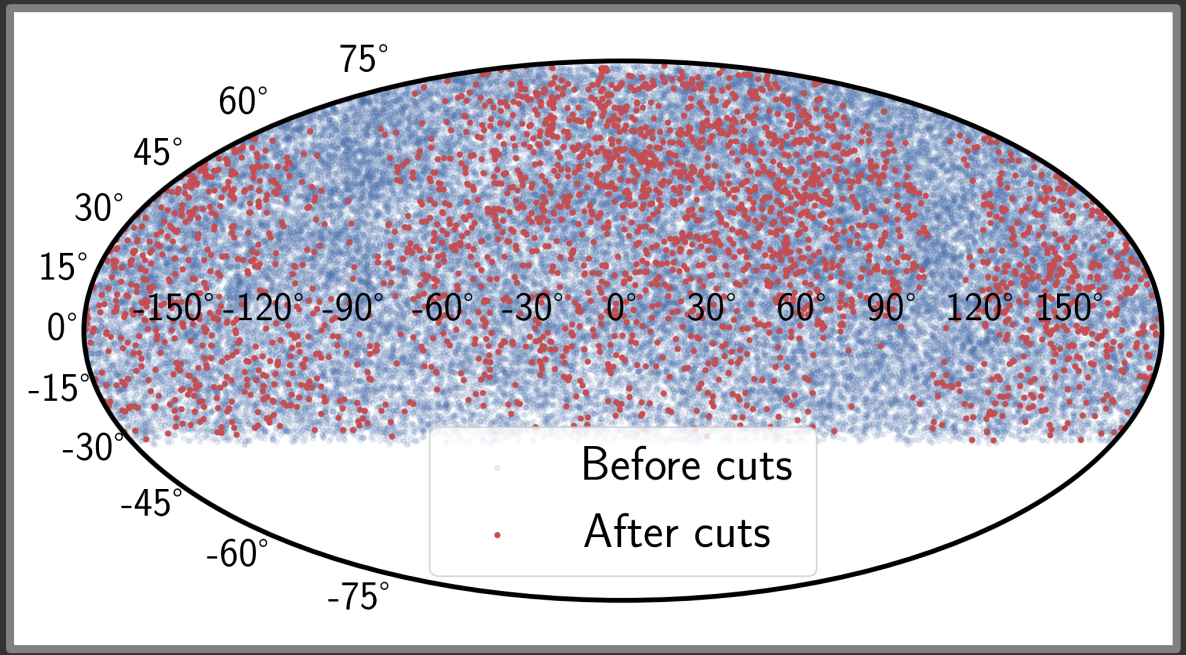
Using simulations to study bias and systematics



The sample selection bias

We reproduce the selection of data by applying 2 cuts :

- Detection cut : at least 2 epochs with a SNR > 5
- Typing cut : probability to be typed as a SN Ia

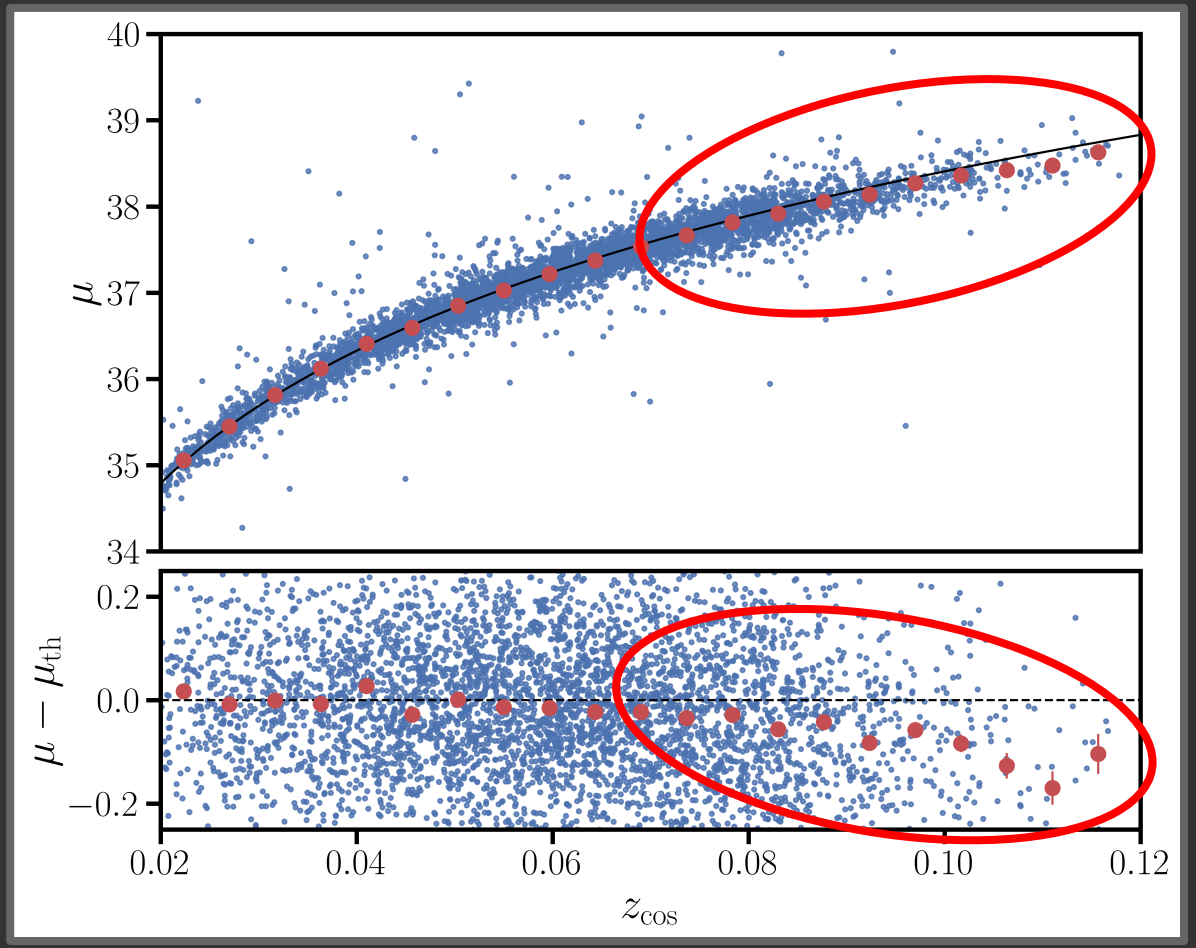


The sample selection bias

We reproduce the selection of data by applying 2 cuts :

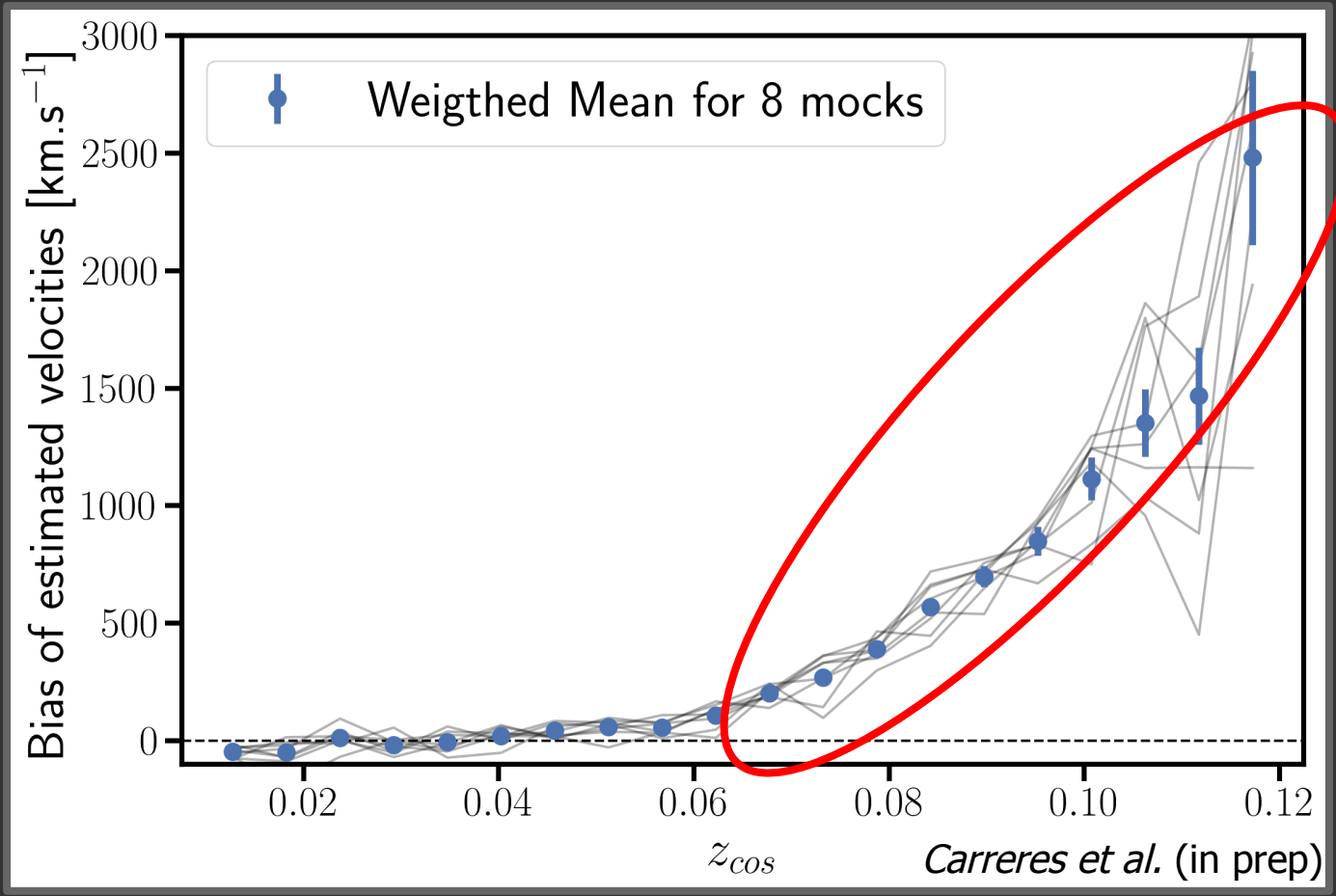
- Detection cut : at least 2 epochs with a SNR > 5
- Typing cut : probability to be typed as a SN Ia

Furthest objects : only the bright part of the sample is selected, leading to a **selection bias**



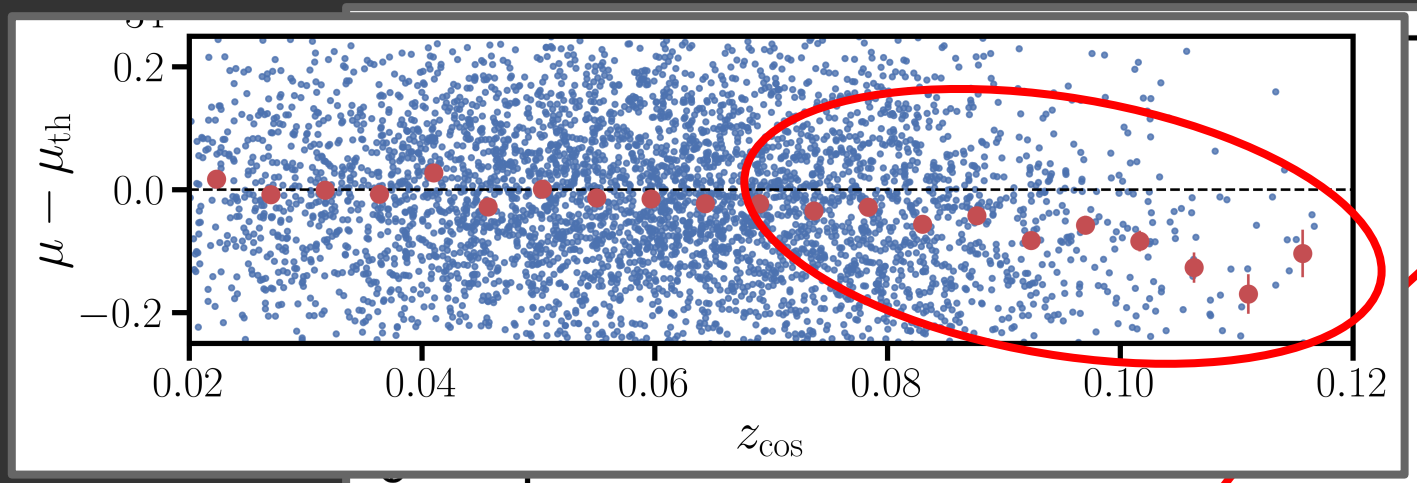
The sample selection bias : estimated velocities

The sample selection affect estimated velocities : bias after z ~ 0.06



The sample selection bias : estimated velocities

The sample selection affect estimated velocities : bias after z ~ 0.06

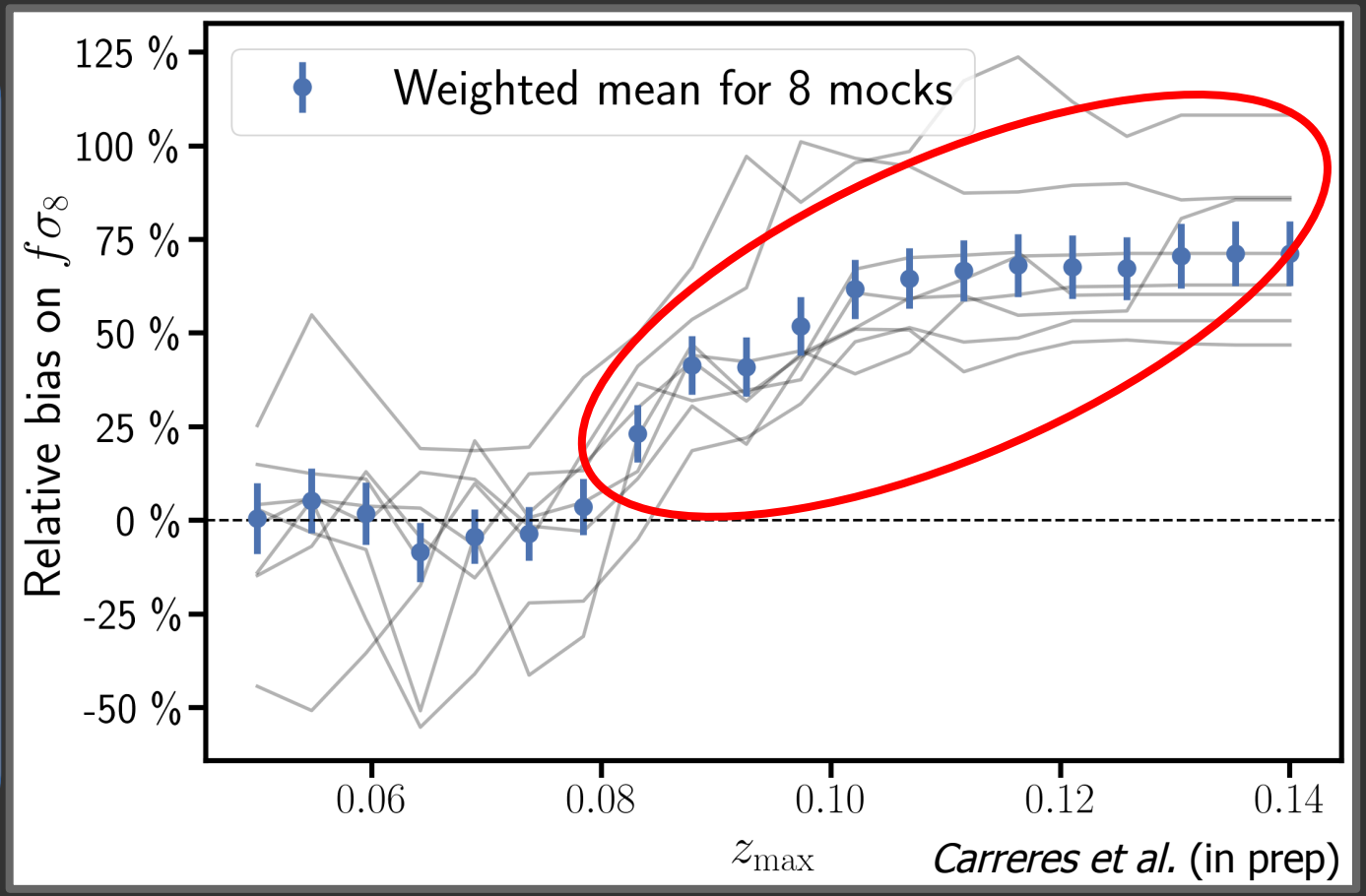


$$\hat{v} = -\frac{\ln(10)}{5}\frac{z}{1+z}\Delta\mu$$

The sample selection bias : growth rate results

Results for the **growth rate** :

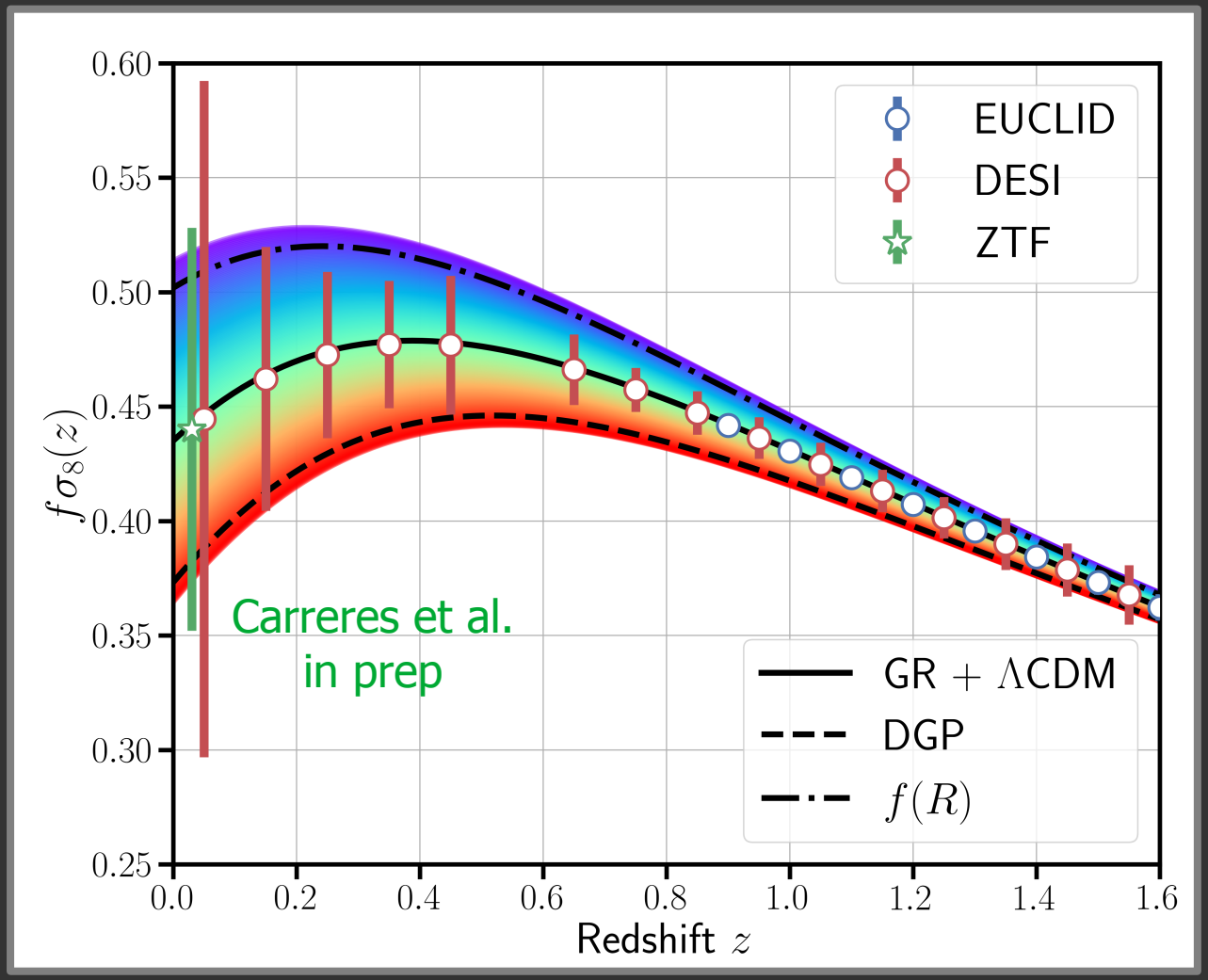
- Bias appear when including SN Ia with a redshift z > 0.08
- For z > 0.08 the relative bias increase up to ~ 70 %



The sample selection bias : growth rate results

Results for the **growth rate** :

- Bias appear when including SN Ia with a redshift z > 0.08
- For z > 0.08 the relative bias increase up to ~ 70 %
- With sample at z < 0.06 no bias and relative error of ~ 20 %

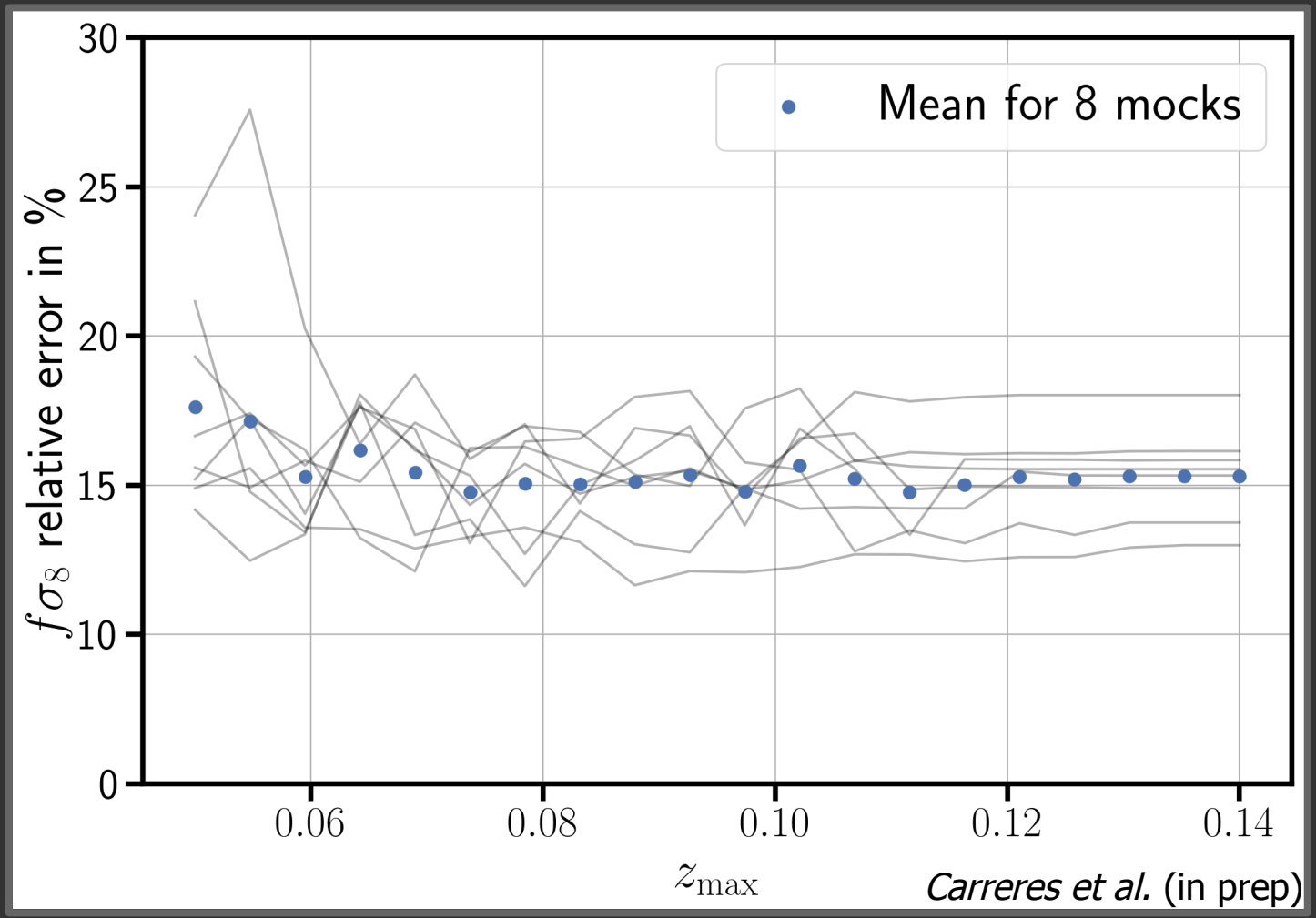


How much can we improve by unbiasing velocities ?

Unbias velocities for SN Ia with z > 0.06 obtained by drawing velocities as :

$$v \sim \mathcal{N}(v_{\rm true}, \sigma_v)$$

No improvement on the growth rate uncertainty

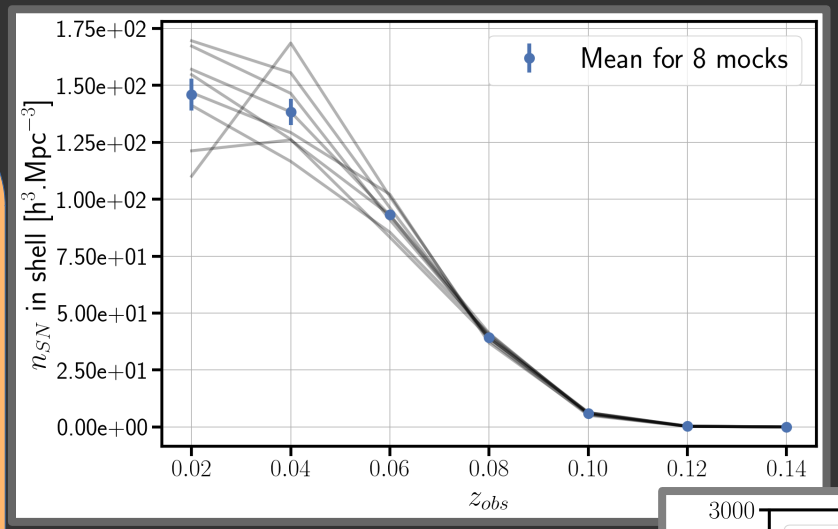


How much can we improve by unbiasing velocities ?

Unbias velocities for SN Ia with z > 0.06 obtained by drawing velocities as :

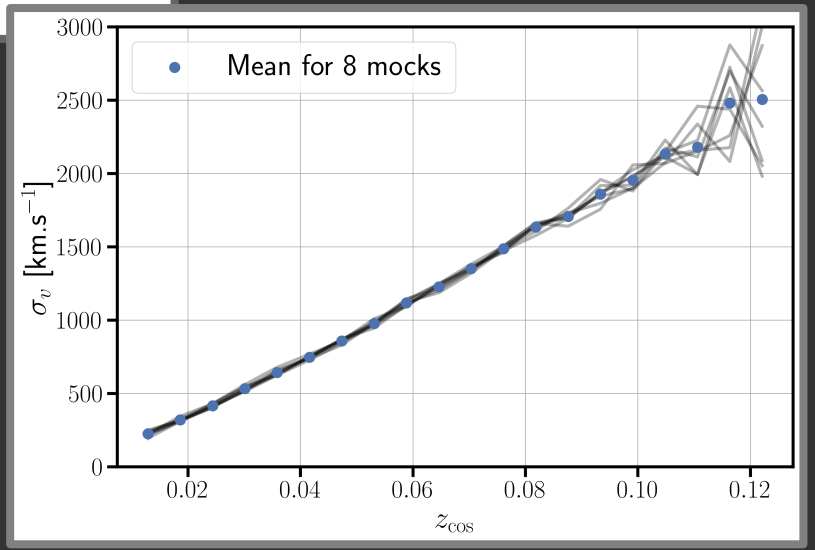
$$v \sim \mathcal{N}(v_{\mathrm{true}}, \sigma_v)$$

No improvement on the growth rate uncertainty



SN density decrease

Uncertainty on velocities increase



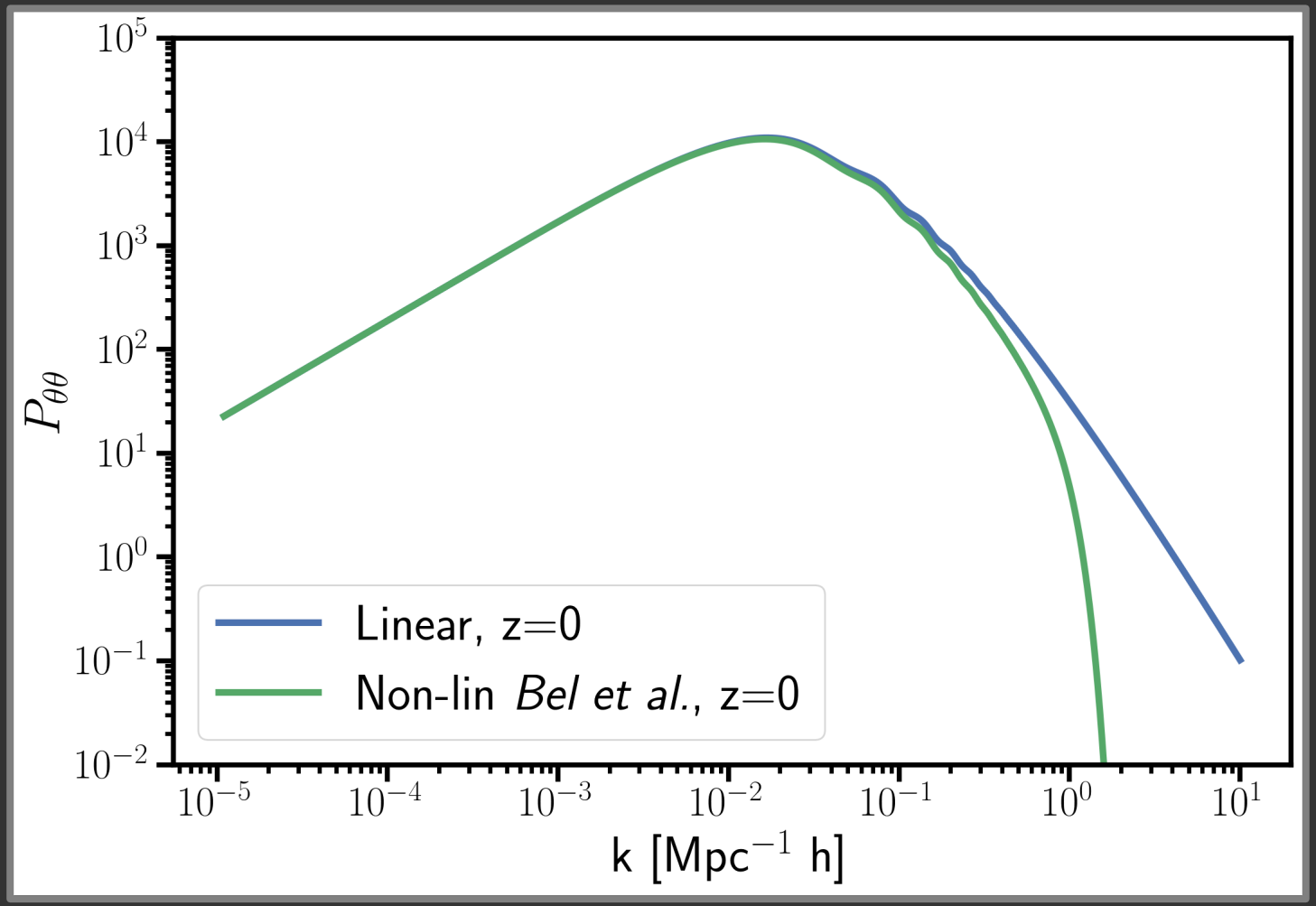
Conclusion

- The growth rate allows to test modified gravity and dark energy models
- SN Ia will provide a precise measurement of this parameter at low redshift with survey like ZTF and LSST
- The ZTF DR2 sample selection does not bias the result up to z ~ 0.06
- These results will be published soon !

Thanks for your attention

BACKUP

Power spectrum



Line of sight velocity covariance

$$C_{ij}^{vv} = \frac{(H_0 f \sigma_8)^2}{2\pi^2} \int P_{\theta\theta}(k) W_{ij}(k; \mathbf{r}_i, \mathbf{r}_j) dk$$

True velocities in simulated sample