# $f\sigma_8$ with SN Ia

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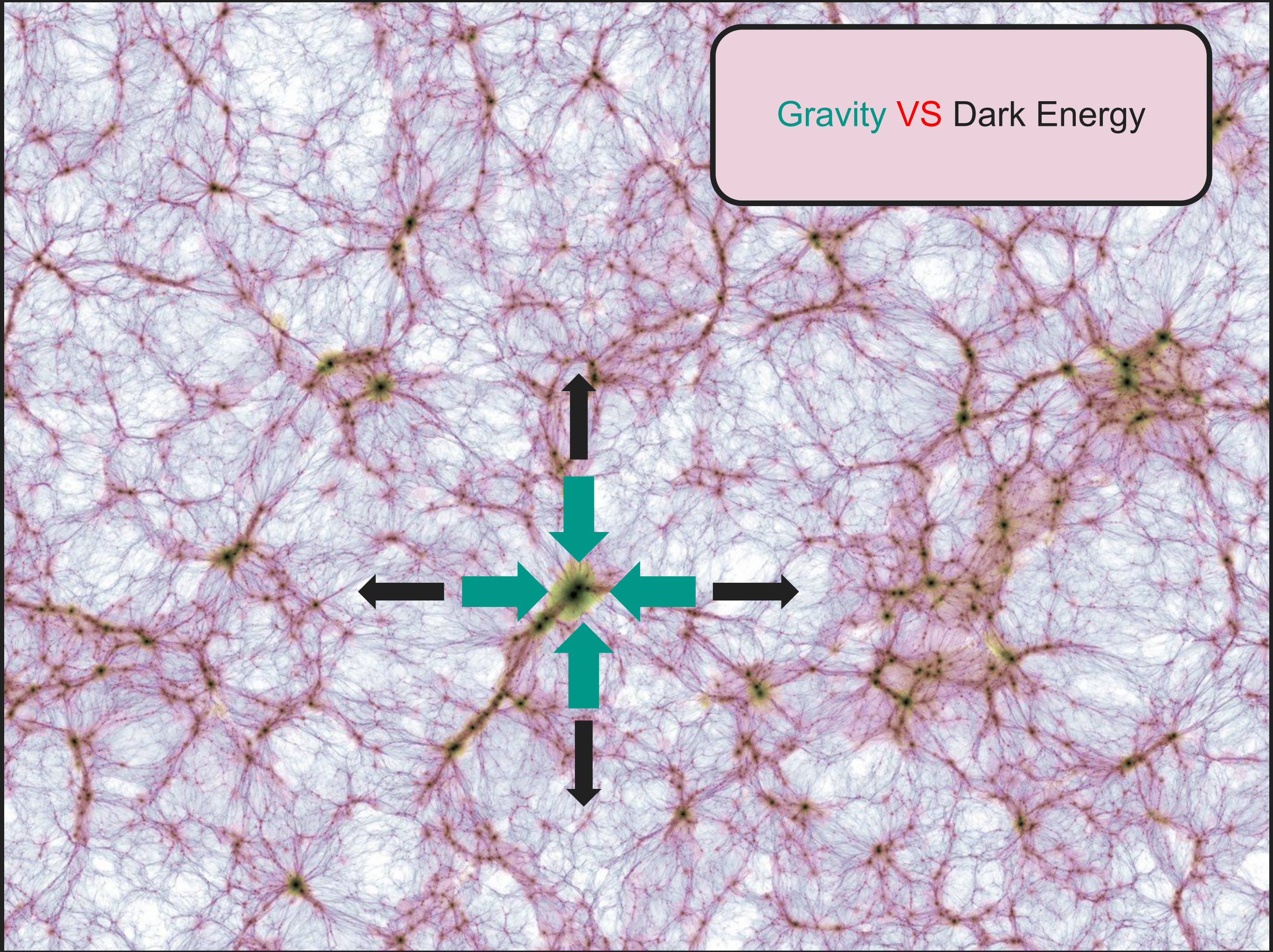
# What is $f\sigma_8$?

Growth factor

$$\delta_{\rm m} = \hat{\delta}_{\rm m}(\mathbf{x})\boxed{{\rm D}(t)}$$

Growth rate

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



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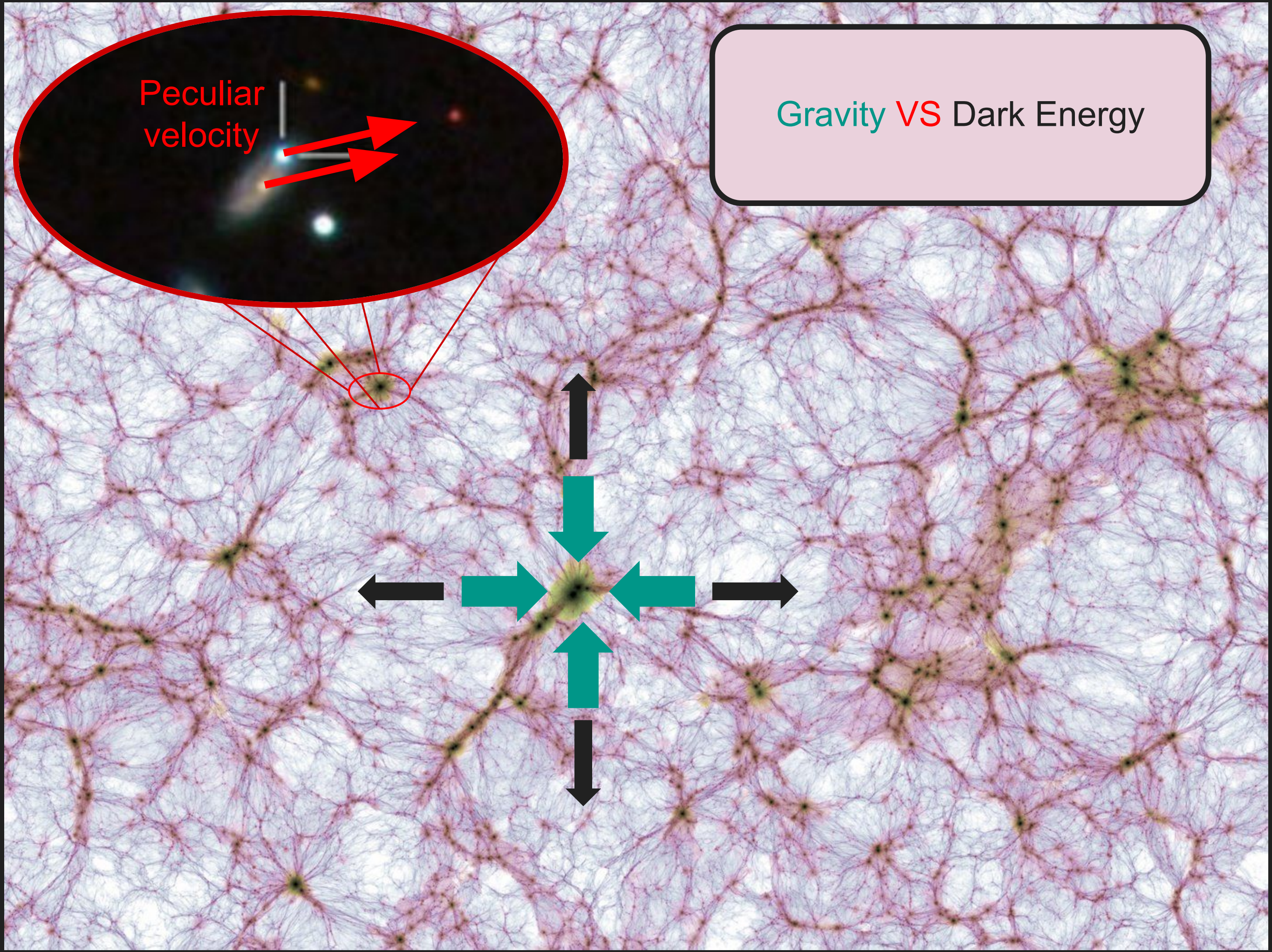
$$\nabla.\mathbf{v} \propto fD$$



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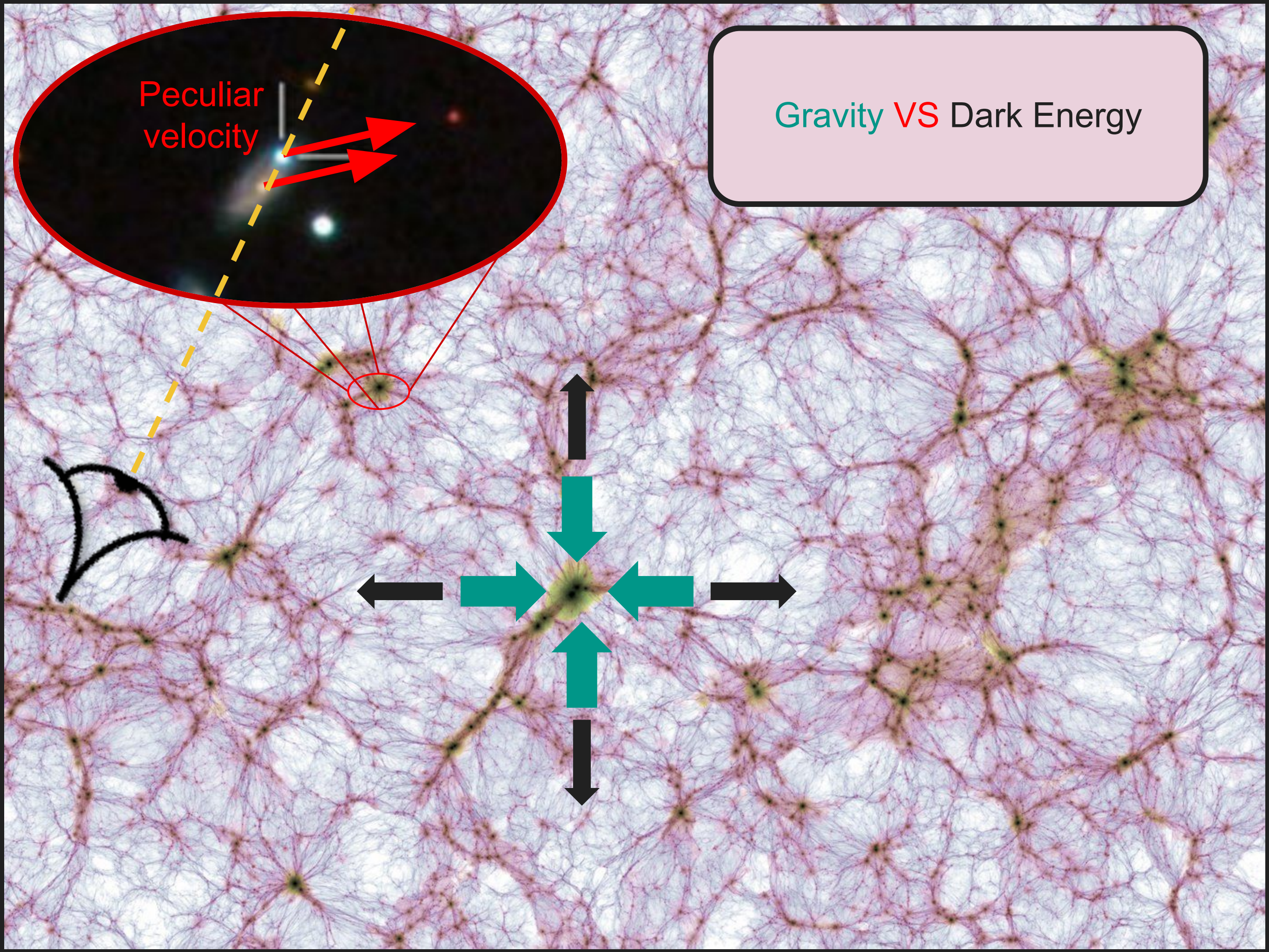
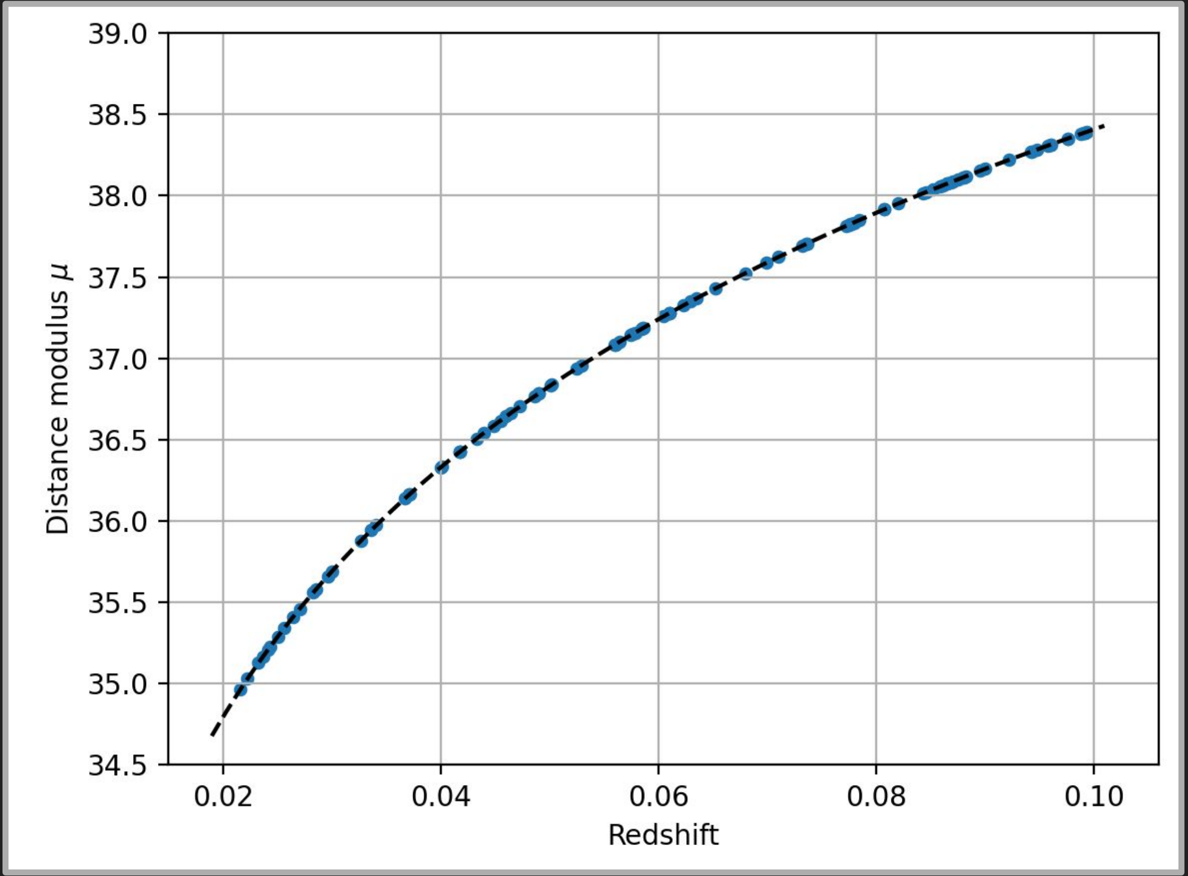


# The Hubble diagram with peculiar velocities



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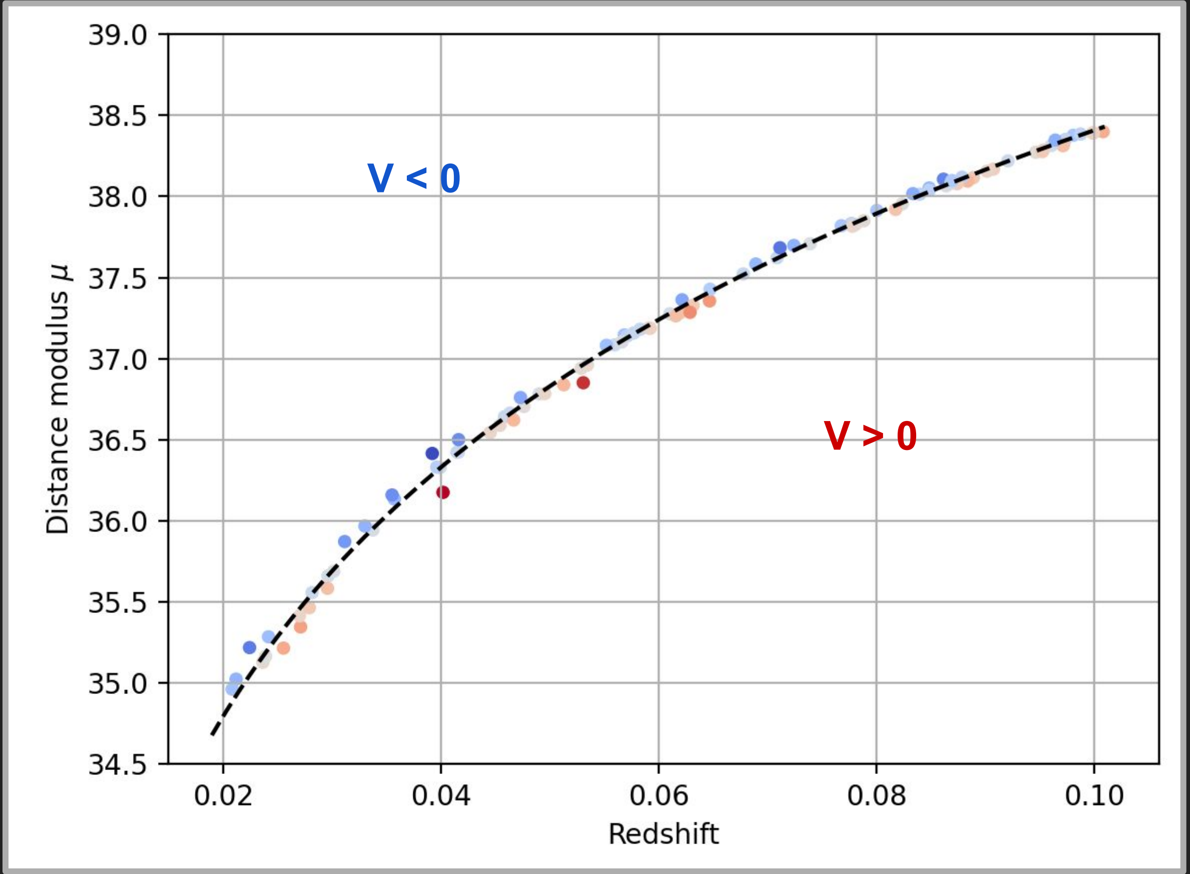
**Adding peculiar velocity :**

v ~ 300 km / s

Δz ~ 0.001

Δμ ~ 0.004 mag

Variation has the same sign as peculiar velocities



# The Hubble diagram with peculiar velocities

**Adding peculiar velocity :**

v ~ 300 km / s

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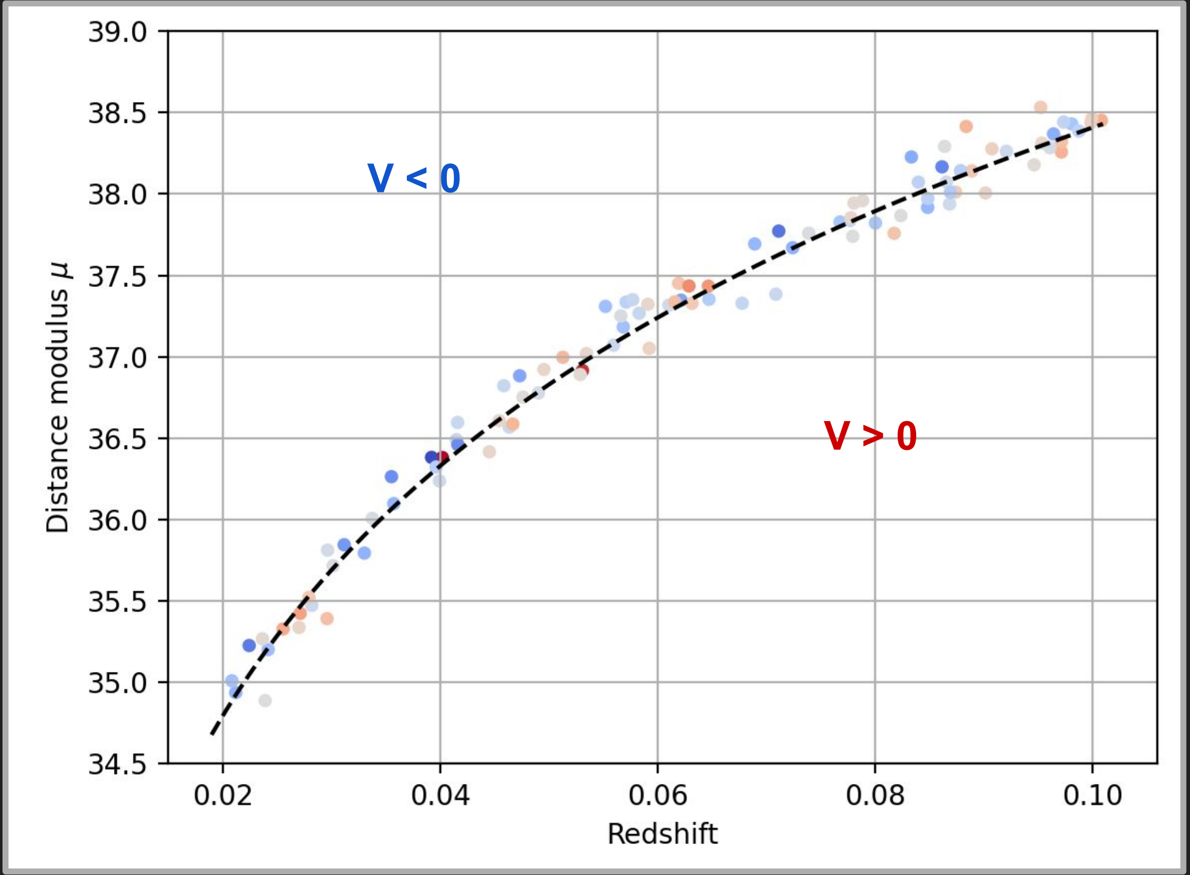
Variation has the same sign as peculiar velocities

**Adding intrinsic scatter :**

$\sigma_{int}$~ 0.12 mag

Lead to bad velocity estimation



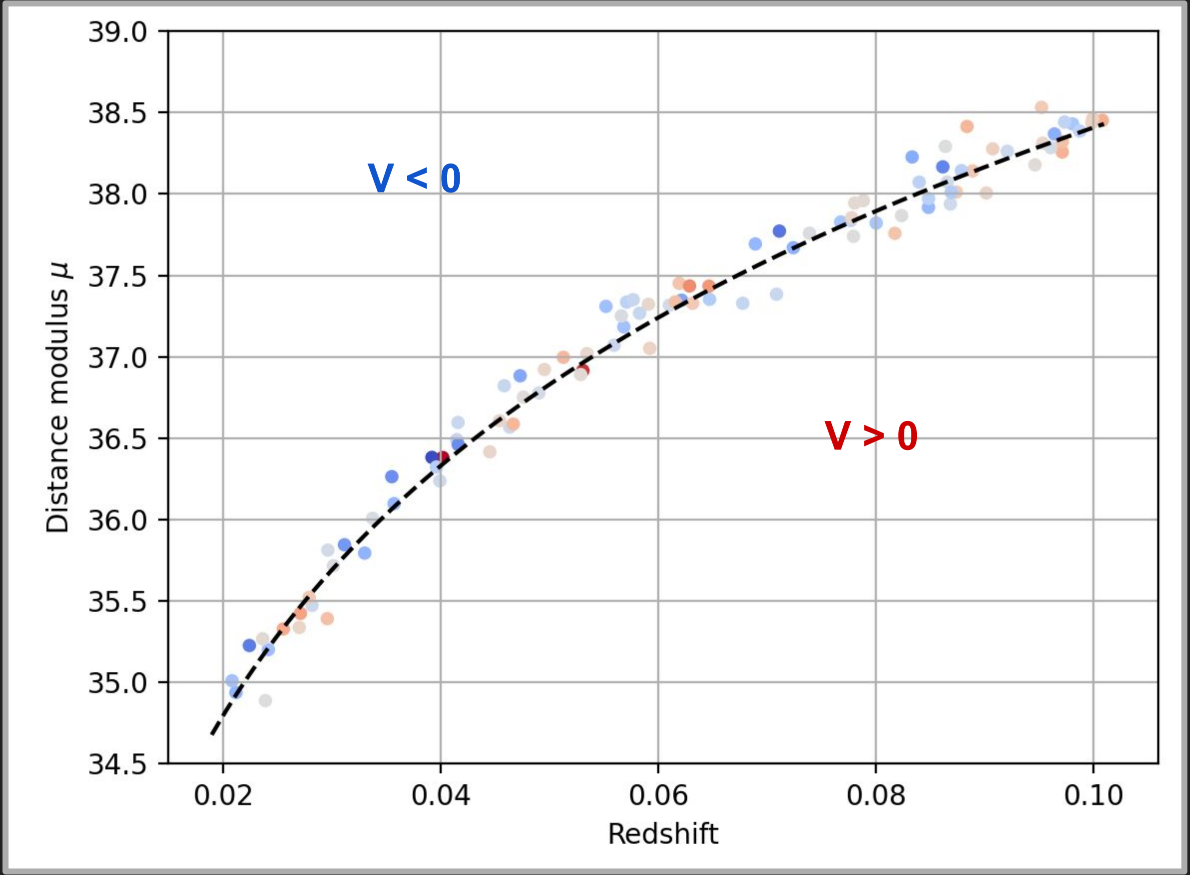
# The Hubble diagram with peculiar velocities

**Peculiar velocity estimator :**

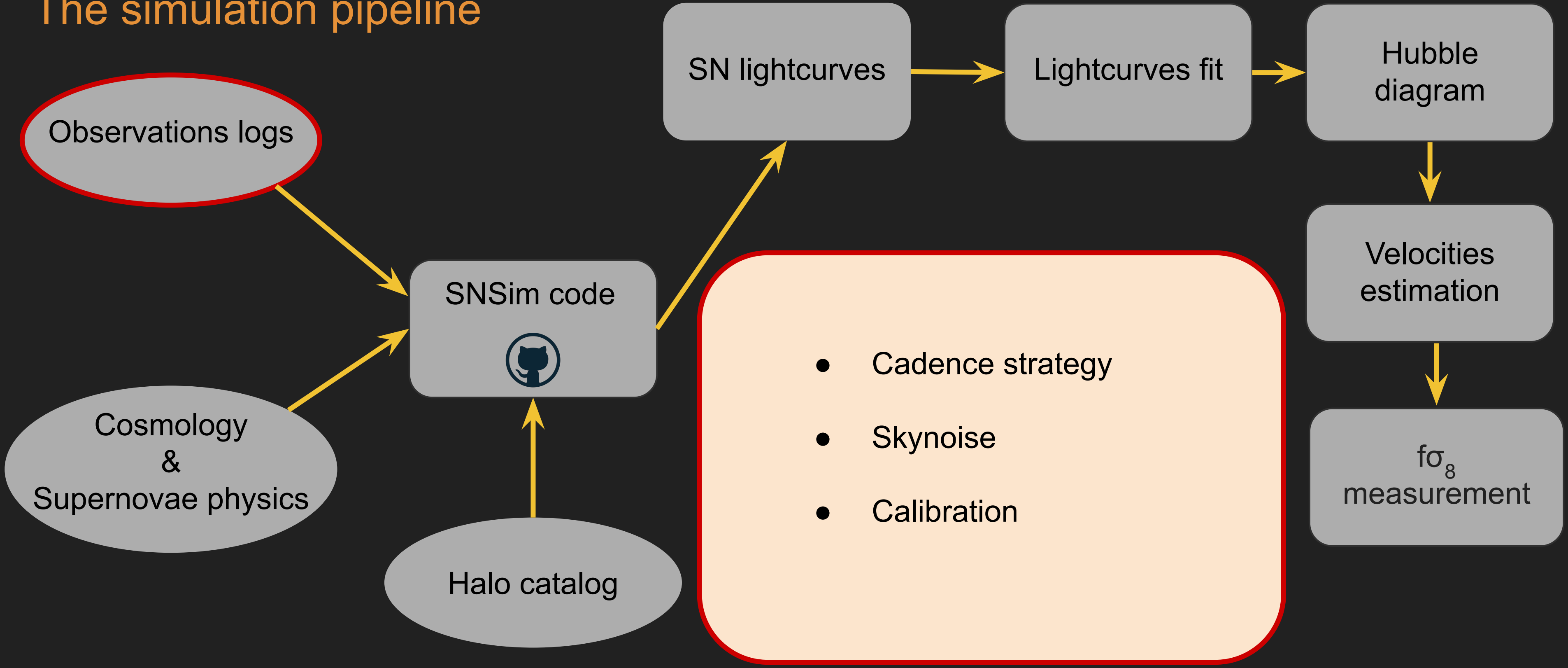
$$\chi^2 = \frac{\Delta\mu^2}{\sigma^2}$$

$$\Delta\mu = \mu_{obs} - \left[5\log\left((1+z_{obs})\left(1+\frac{v}{c}\right)r(z_{cos})\right) + 25\right]$$

$$z_{cos} = \frac{1+z_{obs}}{1+\frac{v}{c}} - 1$$



# The simulation pipeline



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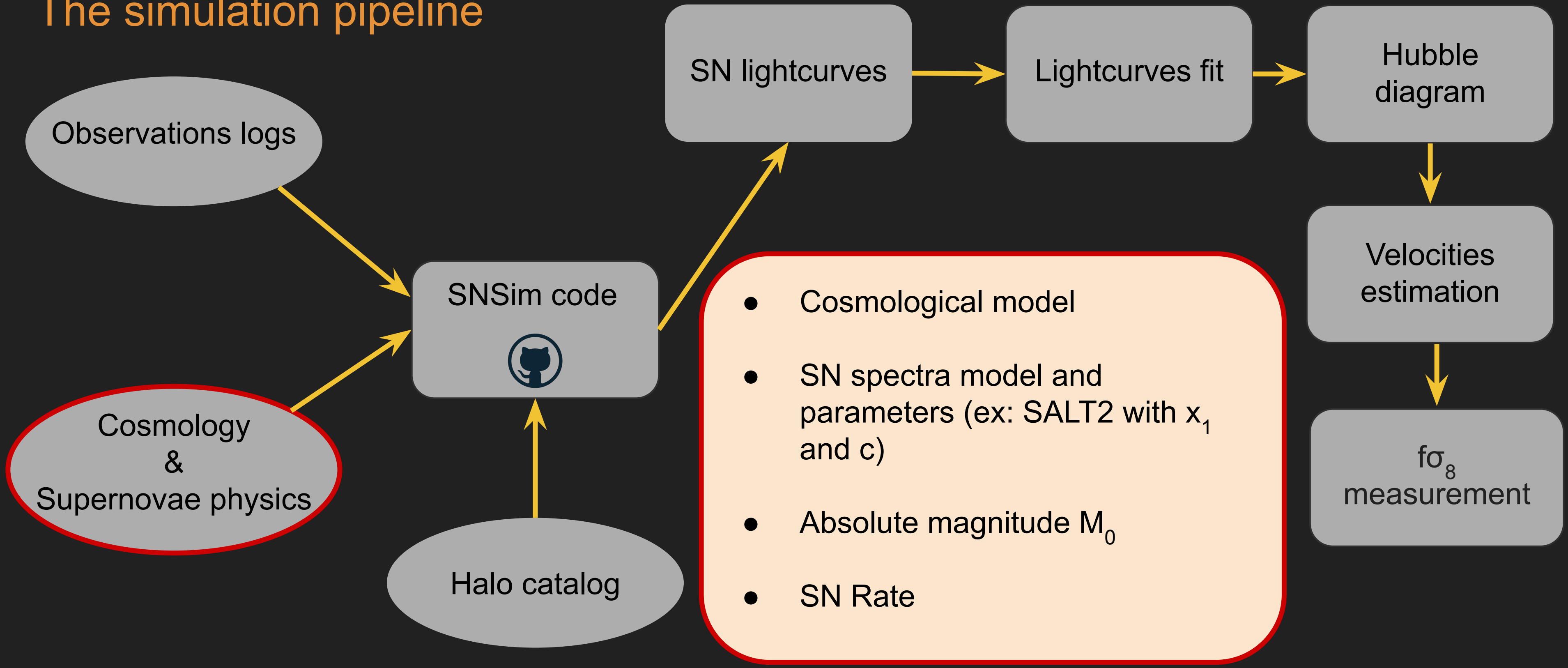

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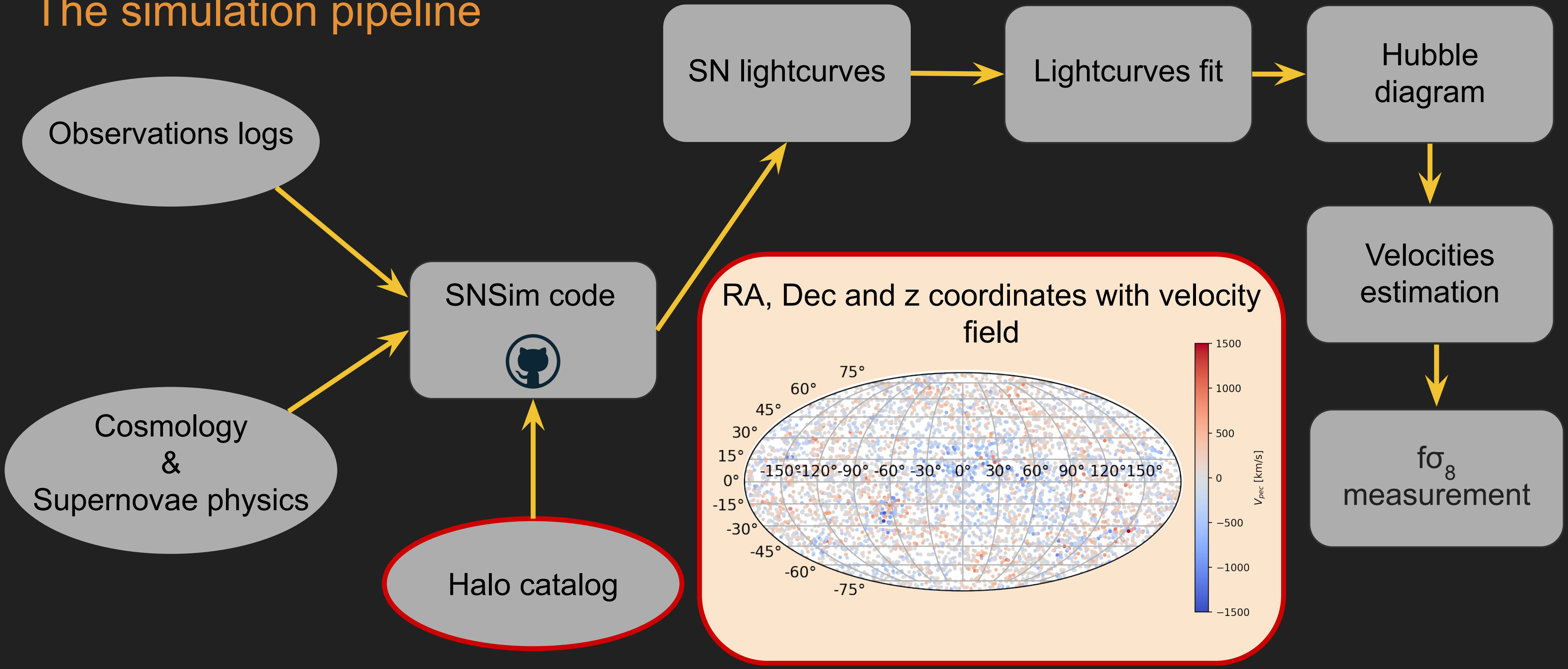

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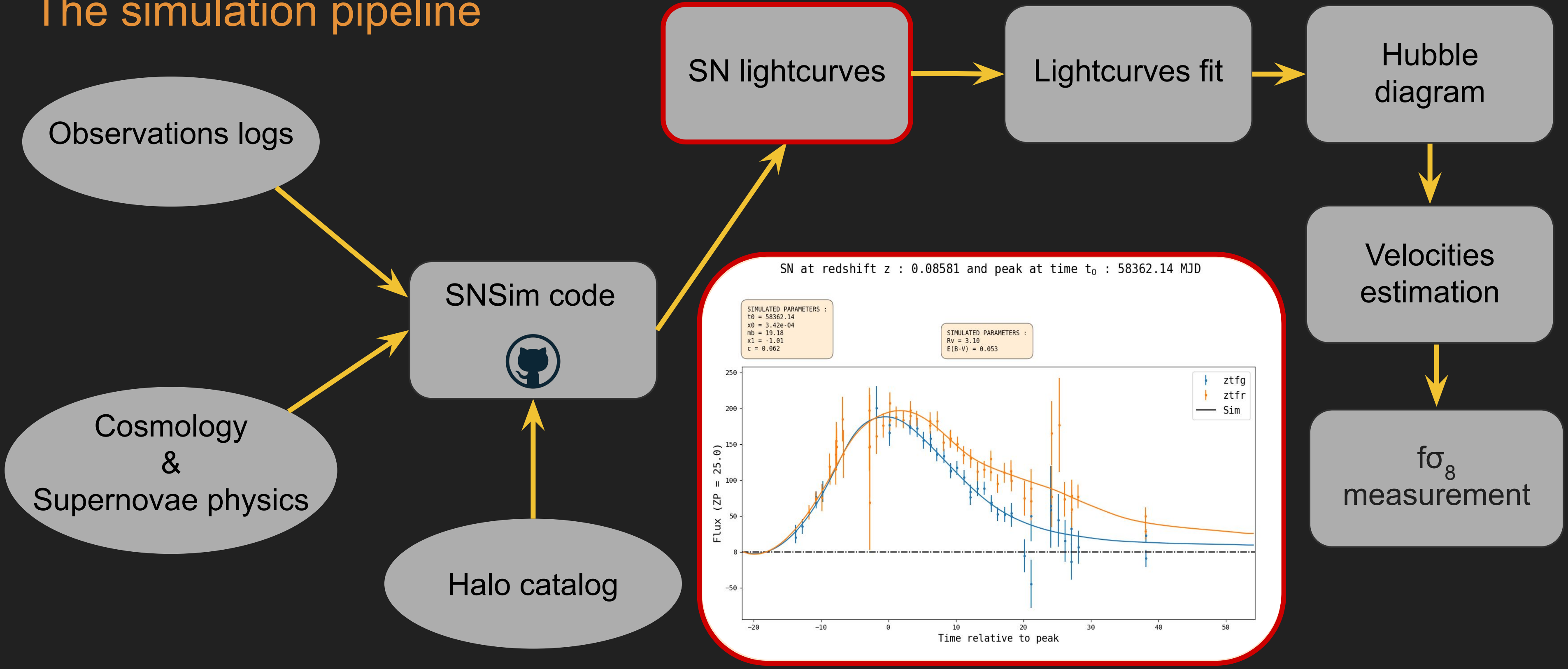

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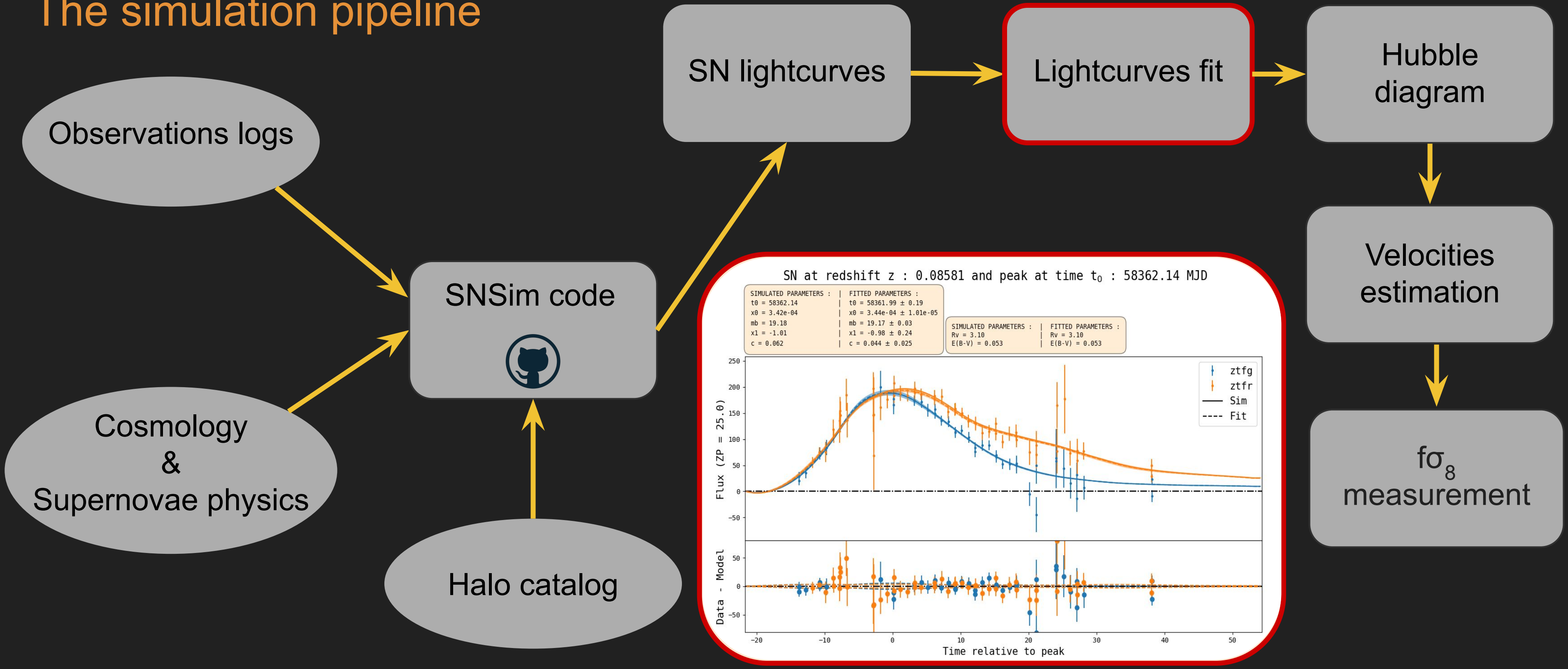

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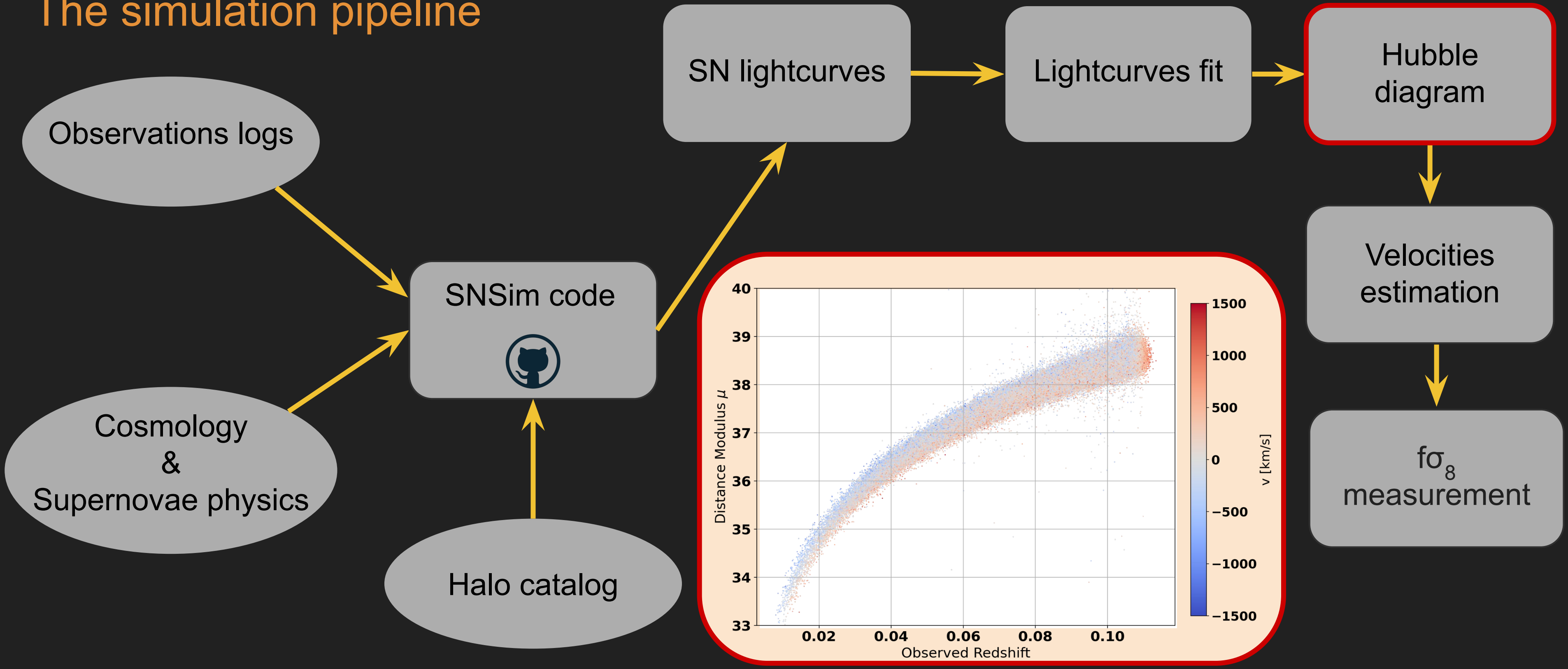

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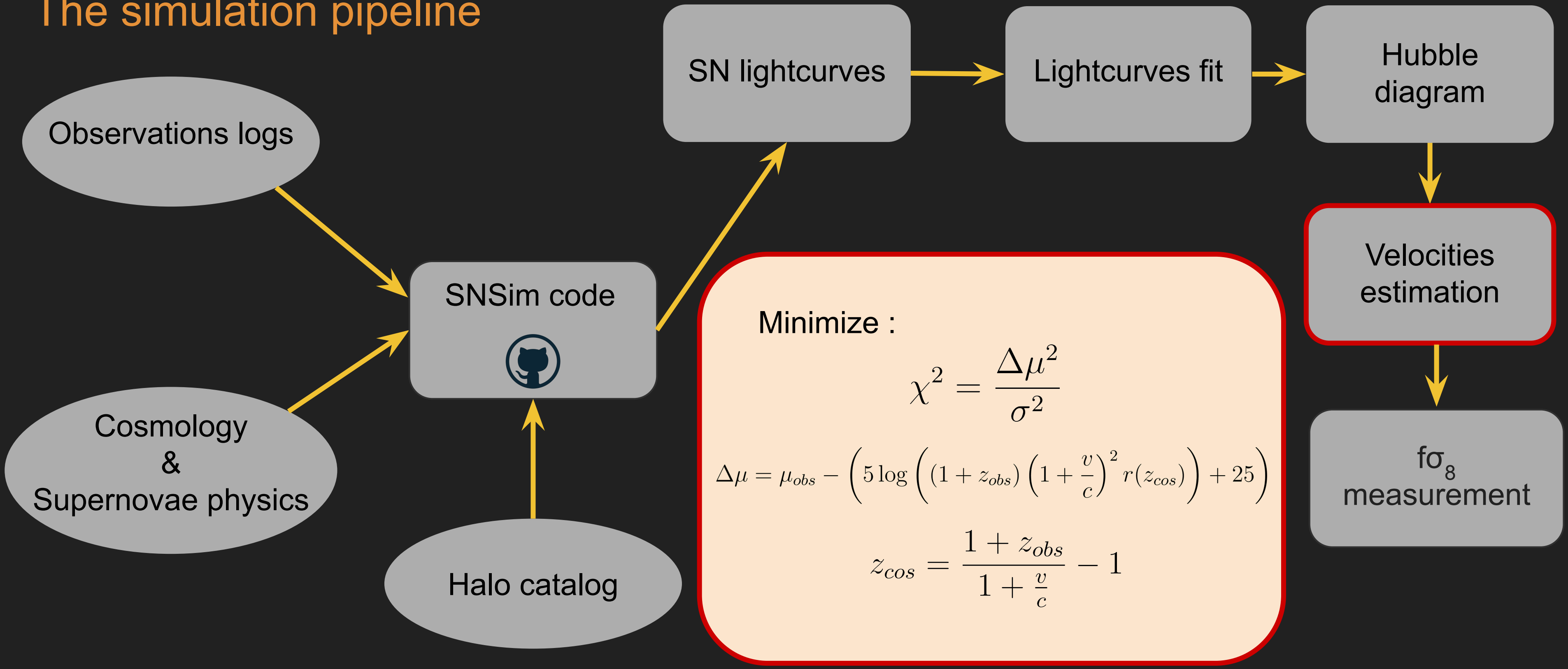

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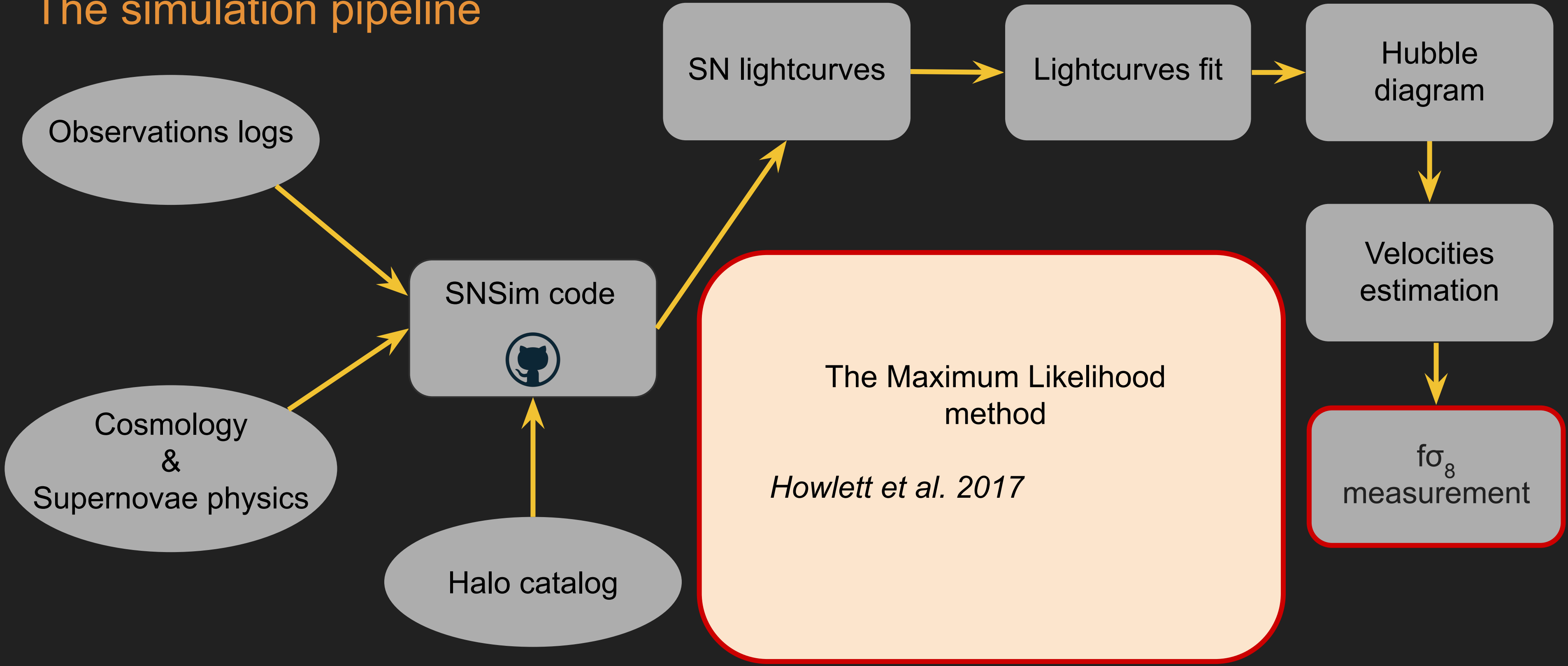
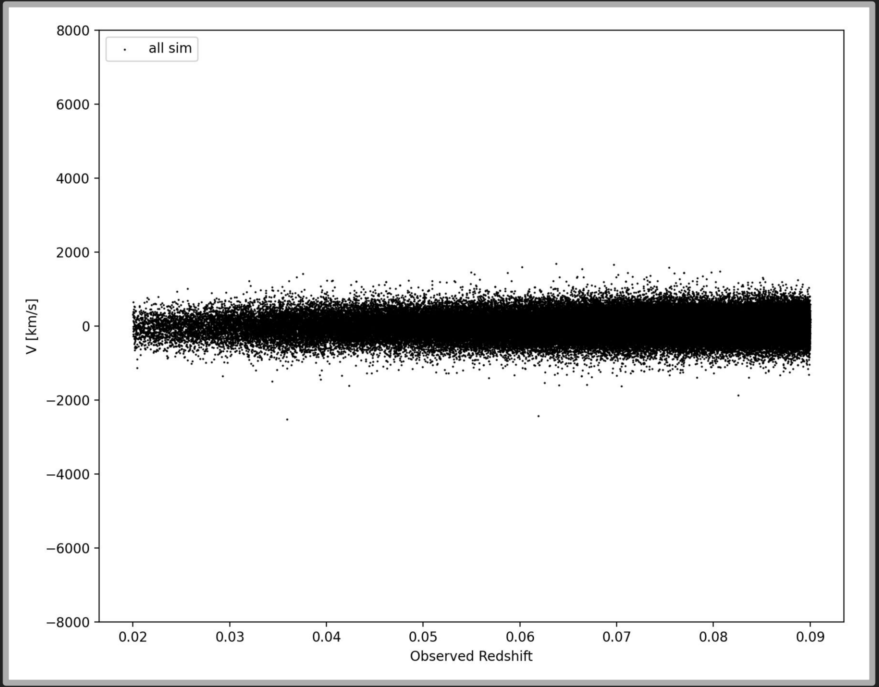


# Quantify biases that may affect $f\sigma_8$ analysis

Quality cut on SN can bias $f\sigma_8$ by changing peculiar velocities population.

Exemple : Malmquist bias

Initial velocities distribution



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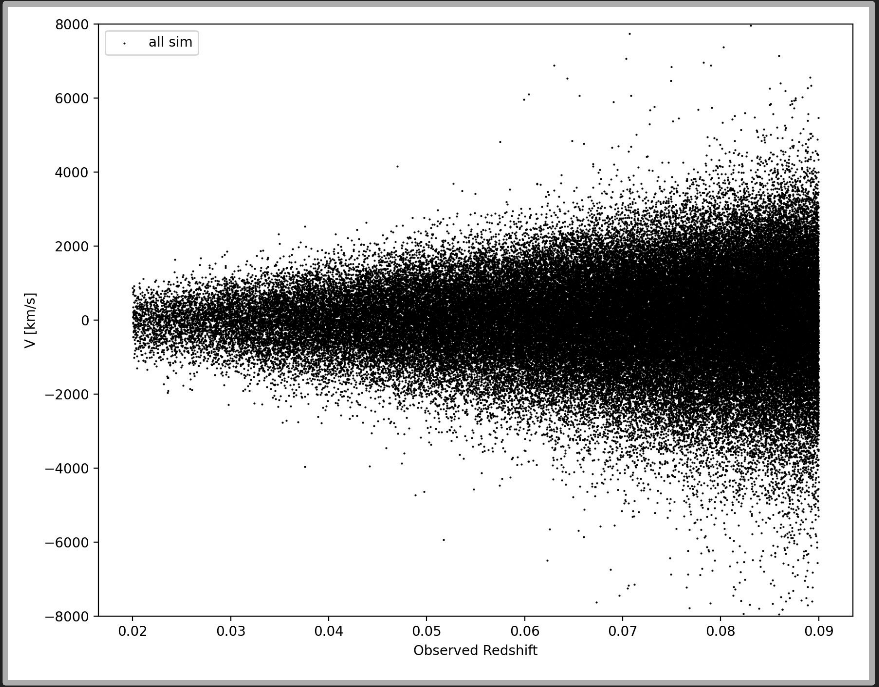

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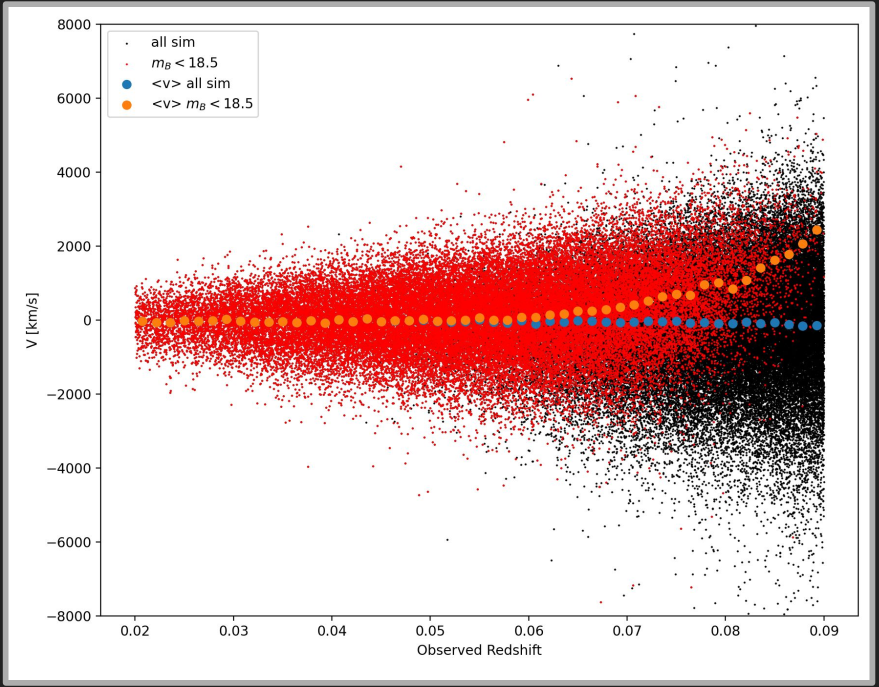

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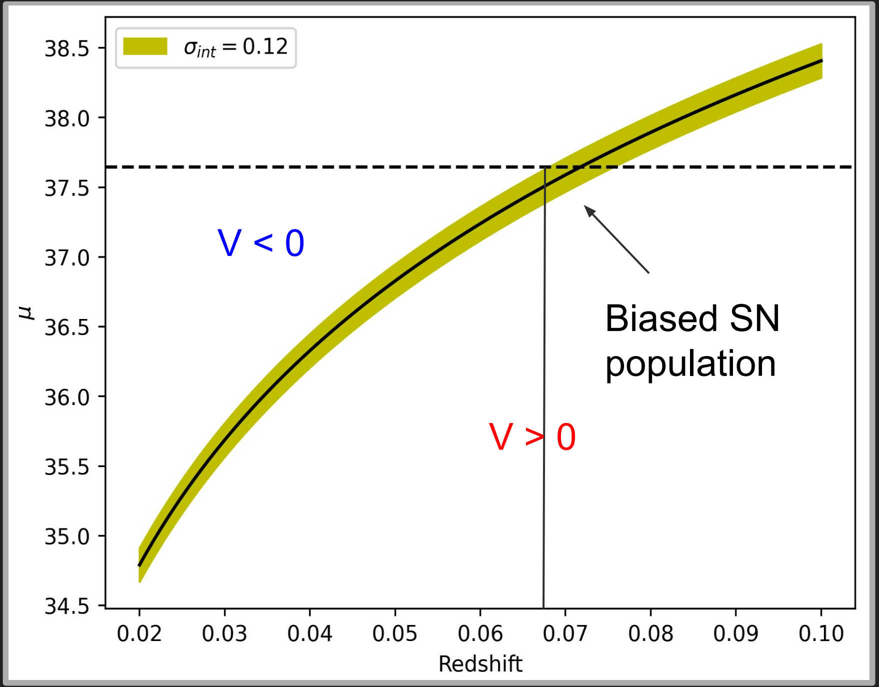
This effect is lead by the bias from intrinsic scattering on vpec estimation



# Method we want to test : the maximum likelihood

From Howlett *et al.* 2017

$$\mathcal{L} = \frac{1}{(2\pi)^{\frac{n}{2}}\sqrt{|\mathrm{C}_{\mathrm{tot}}|}} e^{-\frac{1}{2}\mathbf{v}^T \mathrm{C}_{\mathrm{tot}}^{-1}\mathbf{v}}$$

Peculiar velocities

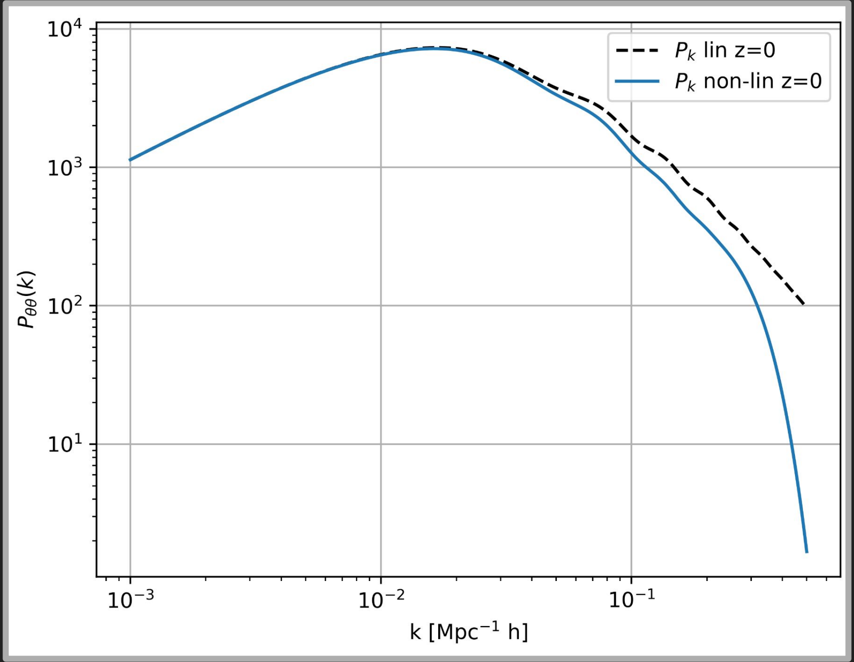
$$\mathrm{C}_{\mathrm{tot}} = (f\sigma_8)^2 \mathrm{C}_{\mathrm{cos}} + \mathrm{C}_{\mathrm{obs}}$$

# Method we want to test : the maximum likelihood

From Howlett *et al.* 2017

$$(\mathrm{C}_{\cos})_{ij} = \frac{1}{2\pi^2}\int dk\, P_{\theta\theta}(k) W(k, r_i, r_j)\Gamma^2(k)$$

Non-linear power spectrum computed with regpt (cf https://arxiv.org/abs/1208.1191)



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**Window function :**

Give the amplitude of each mode of the power spectrum in the covariance term.

Depends on position

# Method we want to test : the maximum likelihood

From Howlett *et al.* 2017

$$(\mathrm{C}_{\cos})_{ij} = \frac{1}{2\pi^2}\int dk P_{\theta\theta}(k) W(k, r_i, r_j) \boxed{\Gamma^2(k)}$$

**Bin window function :**

Take into account the binning of voxels.

Smooth the scales typically smaller than the voxels size.

# The dependence on grid size and kmax

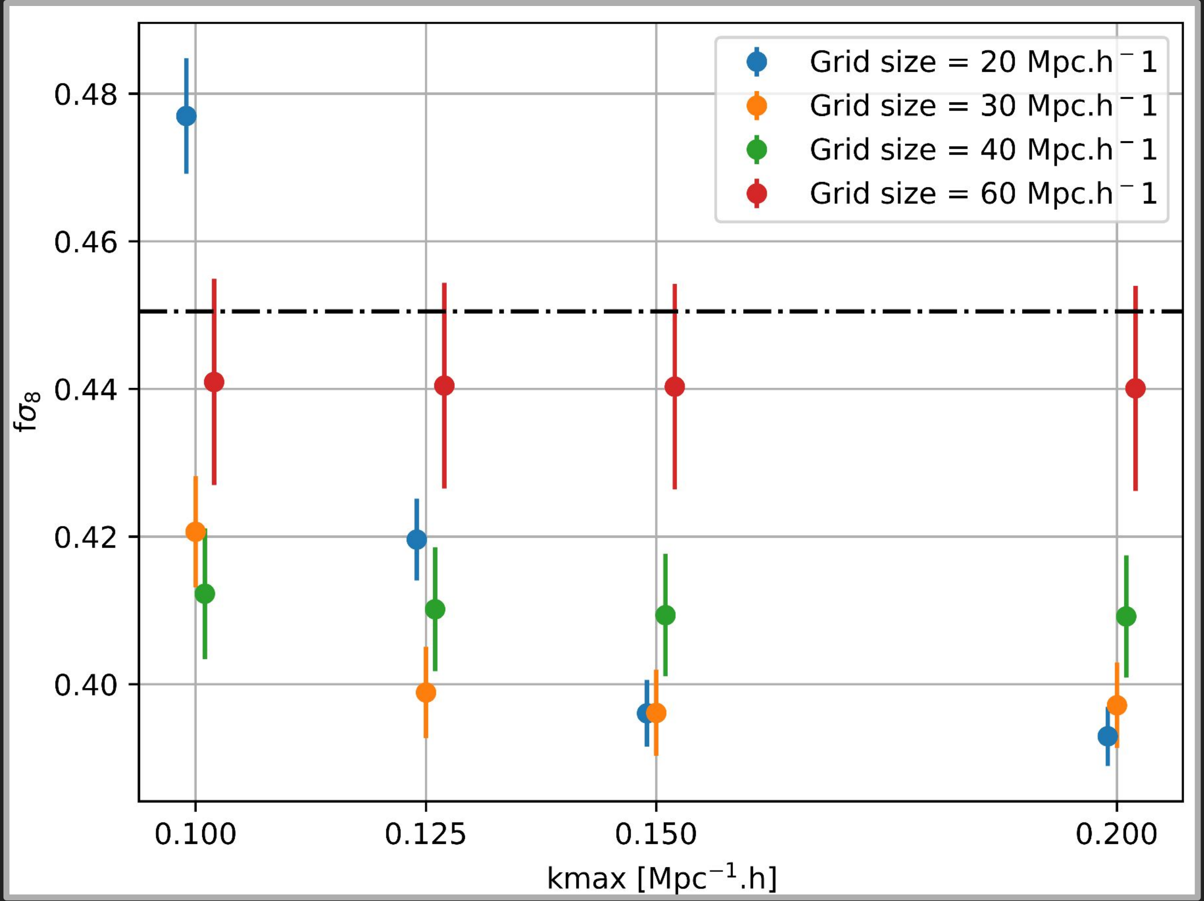
**Determine the mock $f\sigma_8$**

Use true velocities values

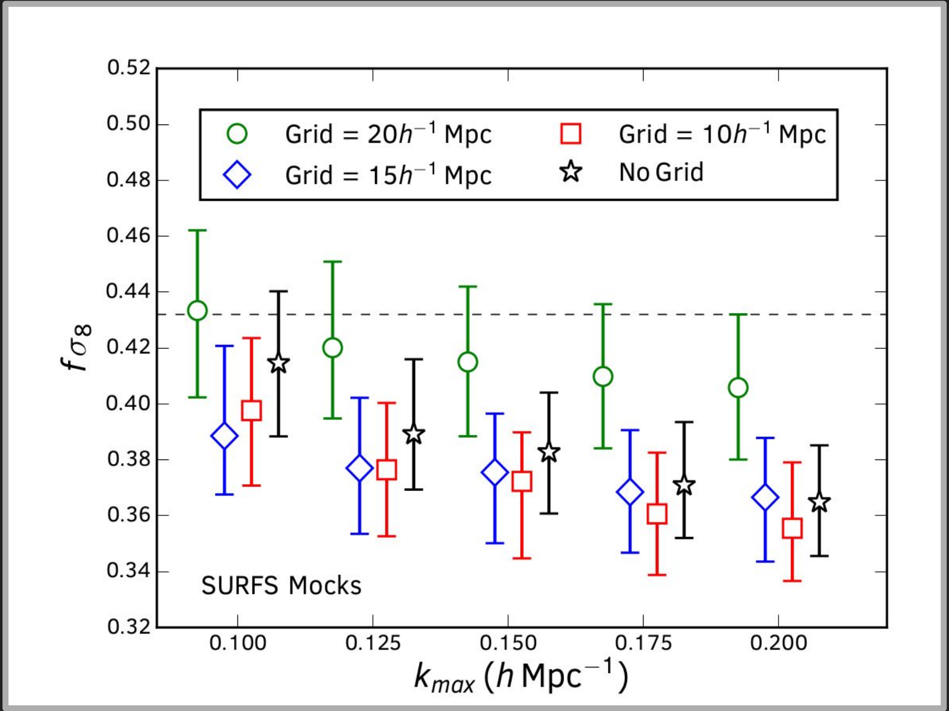
Only cosmological covariance :

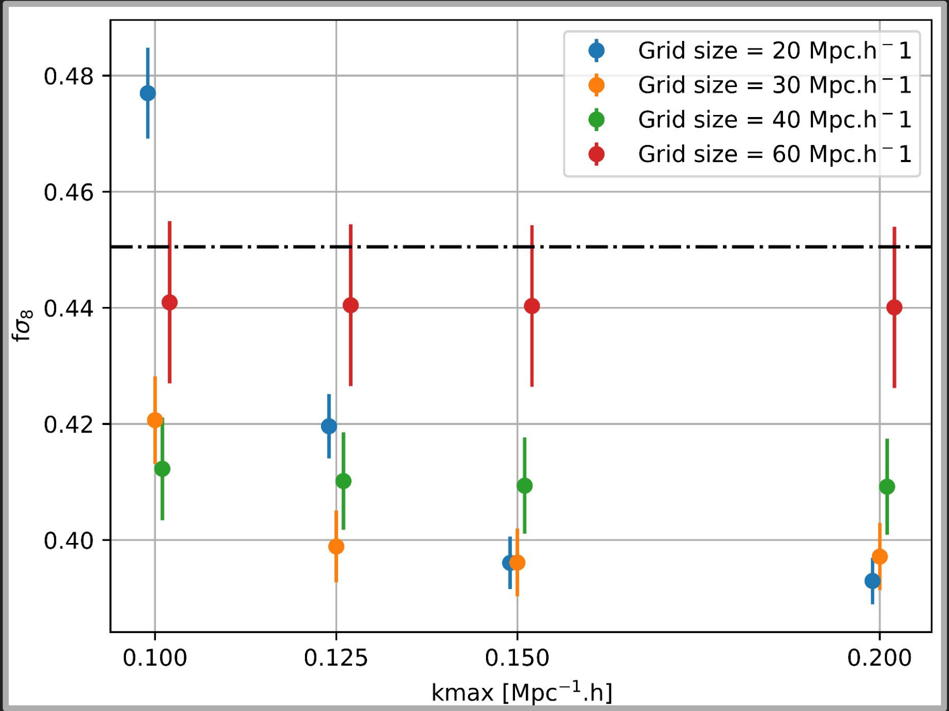
$$C_{obs} = 0$$

Fit using $k_{\min} = 0.007 \ \mathrm{Mpc.h}^{-1}$



# Comparison with *Howlett et al. 2017*




For the 20 Mpc.h$^{-1}$ our results seems to decrease faster with increase of kmax

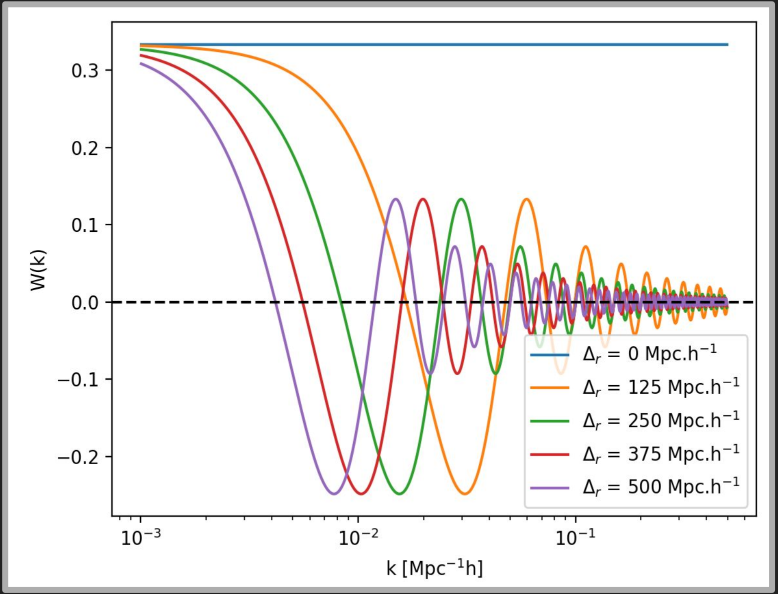
# Conclusion and future plan

- The instabilities with respect to kmax have to be investigated
- We plan to measure the $f\sigma_8$ of the box using standard RSD analysis
- Quantify the impact of SN selection biases on the estimates of $f\sigma_8$

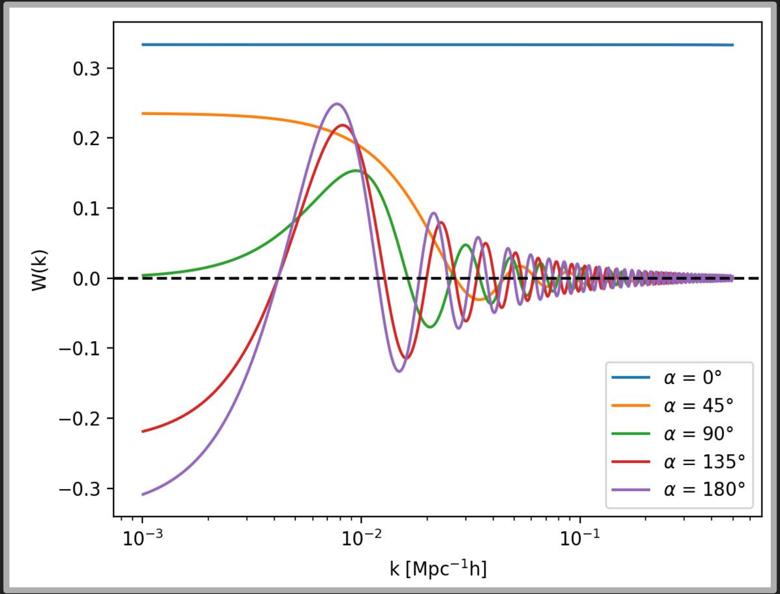
Thanks for your attention

# Appendix

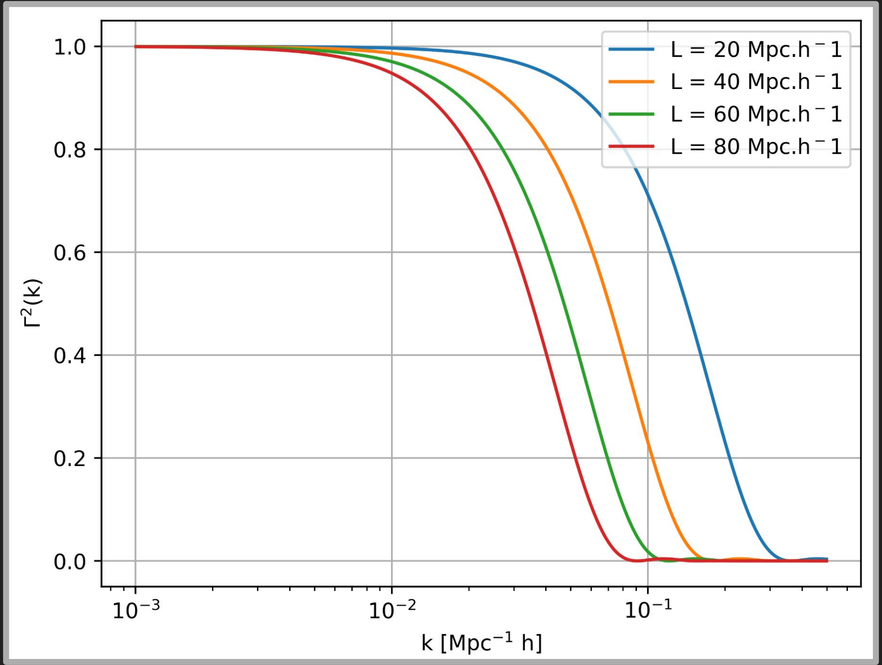
W(k) for α = 0°




W(k) for $r_i = r_j$ = 250 $Mpc.h^{-1}$



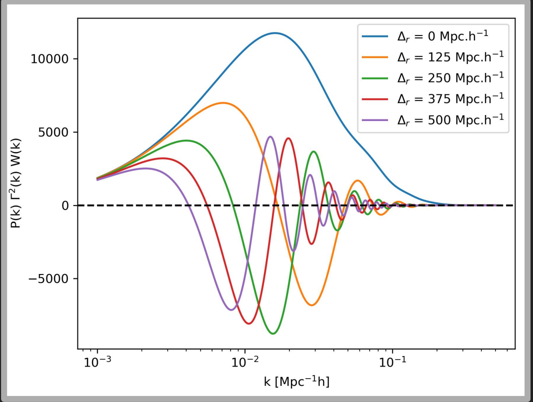
# Appendix

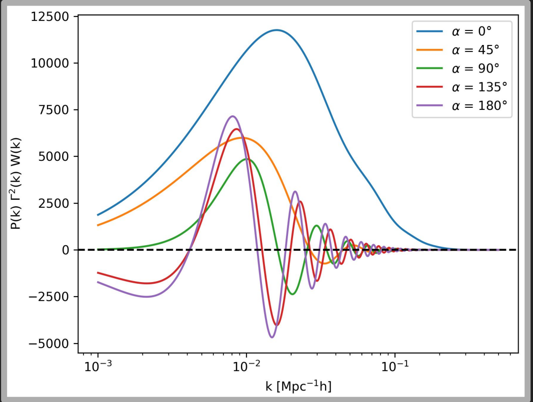


1.0
0.8
0.6
0.4
0.2
0.0
Γ²(k)
10⁻³
10⁻²
10⁻¹
k [Mpc⁻¹ h]
L = 20 Mpc.h⁻1
L = 40 Mpc.h⁻1
L = 60 Mpc.h⁻1
L = 80 Mpc.h⁻1

# Appendix

## L = 20 Mpc.h$^{-1}$




## L = 60 Mpc.h$^{-1}$