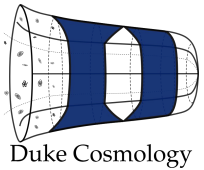
Status of PV cosmology in LSST-DESC

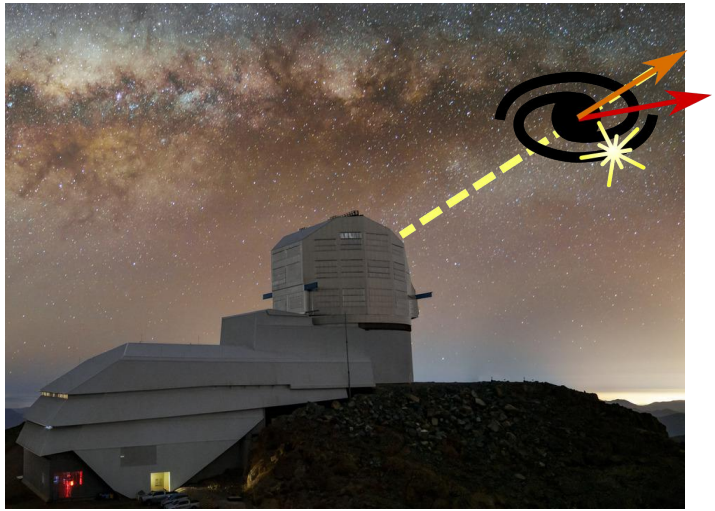
Bastien Carreres, Damiano Rosselli, Corentin Ravoux et al.



PV cosmology with Rubin-LSST

Main objective:
Measurement of the **Growth Rate of Structure ($f\sigma_8$)**

Focused on the **Maximum Likelihood** method for now



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- Density X Velocity (c.f Dane and Mahmoud talks)
- Forward modelling
- Simulation Based Inference
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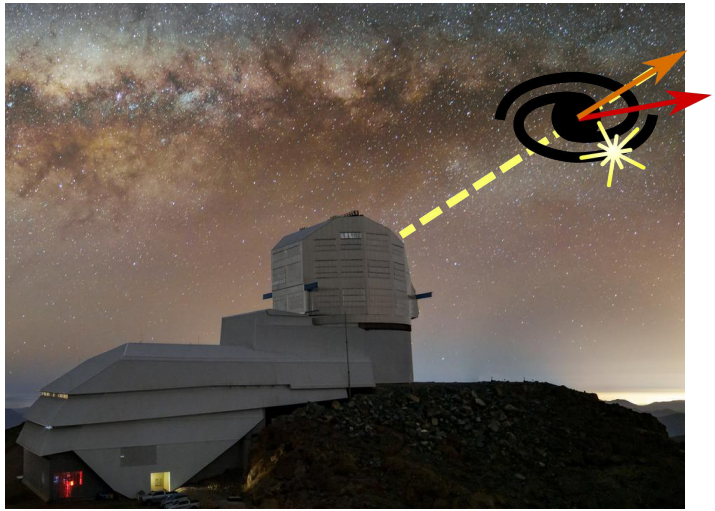

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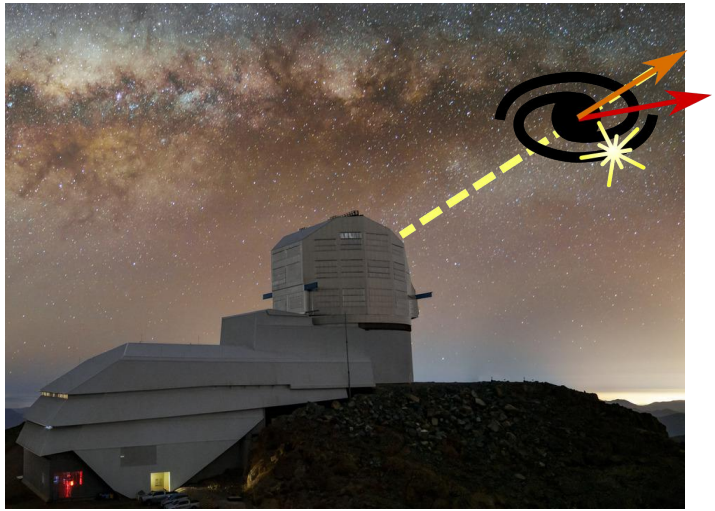

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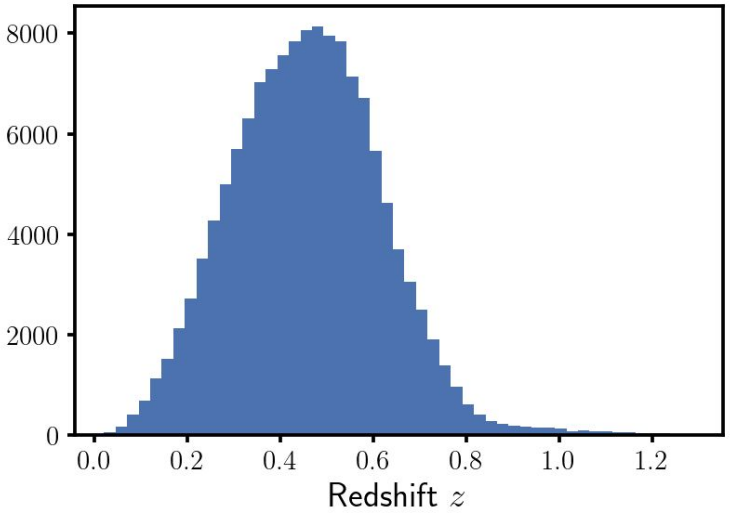
Other sciences:

- Reconstruction and Cosmography (see Farnik's talk)
- H_0 (see Davide's talk)
- PV corrections for w0 – wa
- …

The future sample from the Rubin-LSST

Rubin-LSST: ~1 000 000 SNe Ia, ~200 000 cosmological-grade (Lochner et al. 2022, Gris et al. 2023)



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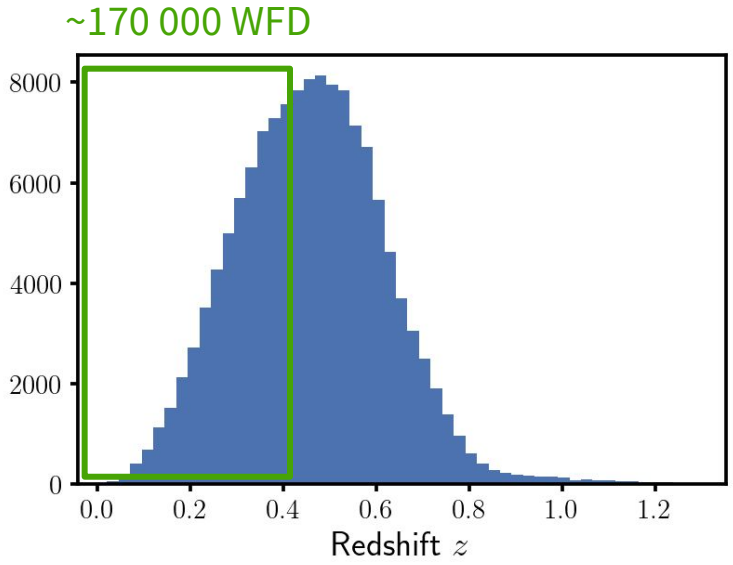

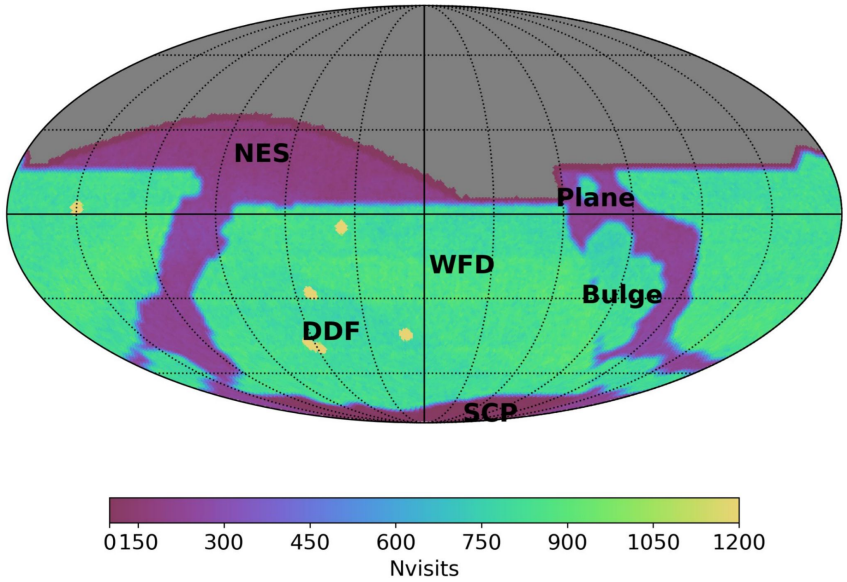

Credit: Lynne Jones, Federica Bianco, Peter Yoachim

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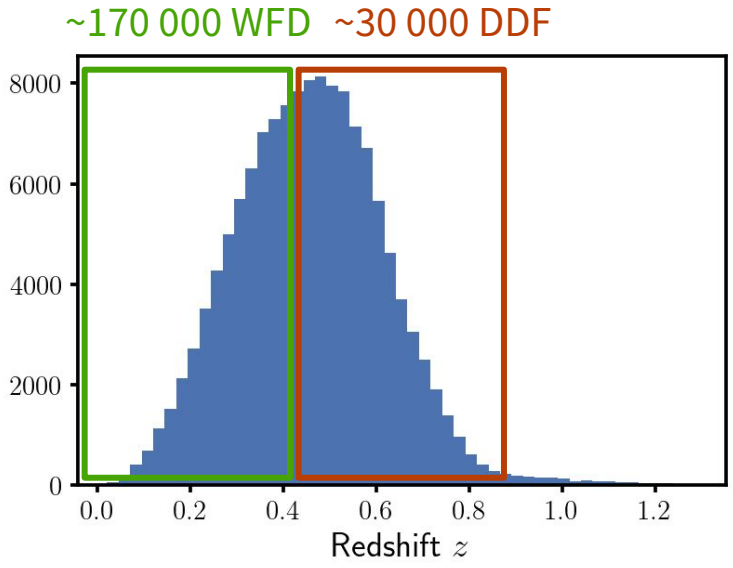

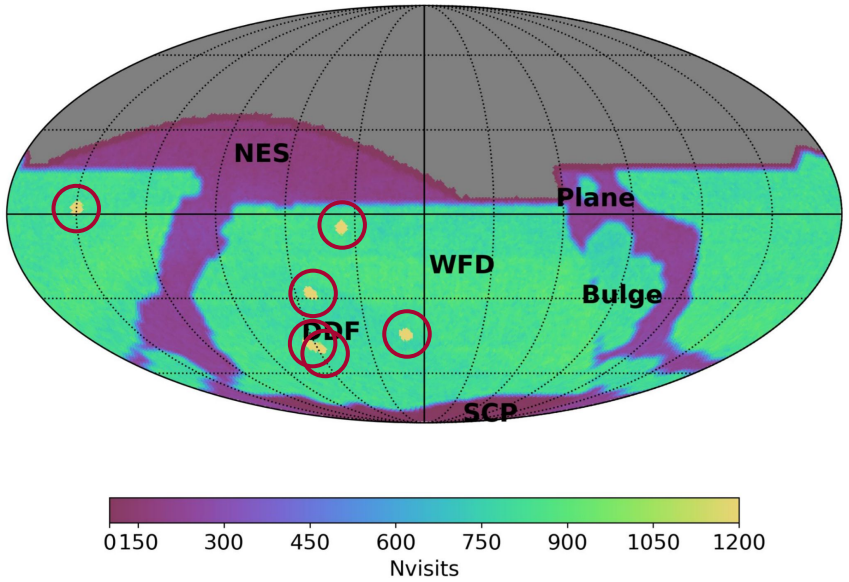

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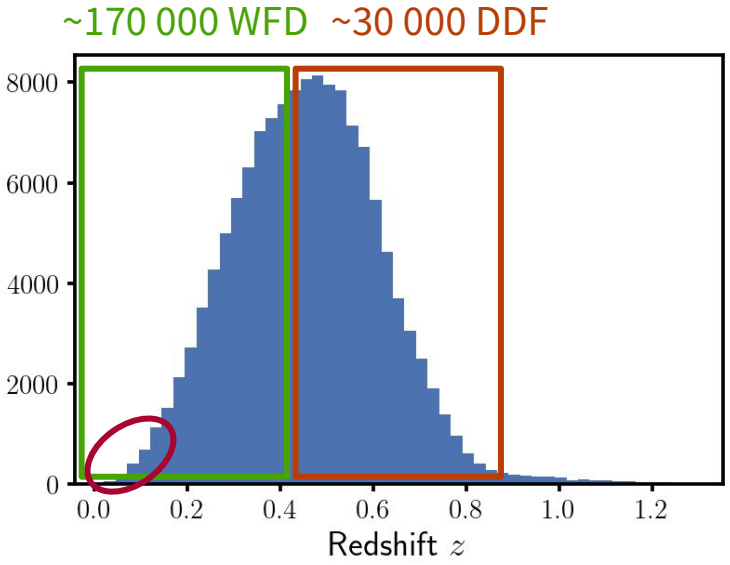
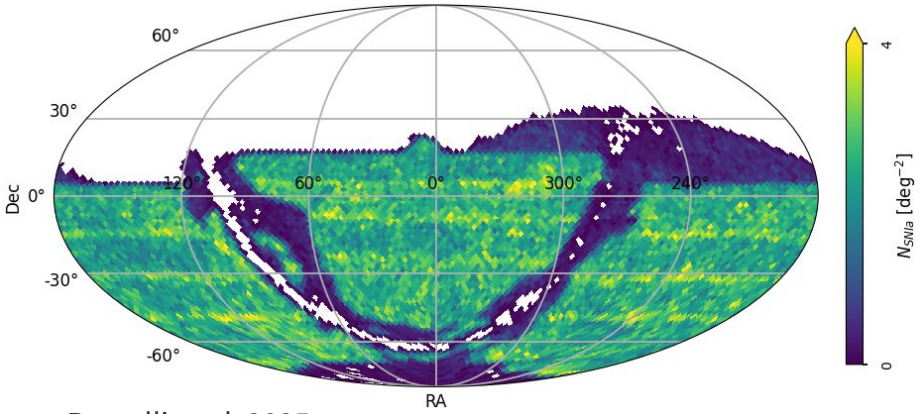
The future sample from the Rubin-LSST

Rubin-LSST: ~1 000 000 SNe Ia, ~200 000 cosmological-grade (Lochner et al. 2022, Gris et al. 2023)

PV sample: ~30 000 SNe Ia at $z \leq 0.15$

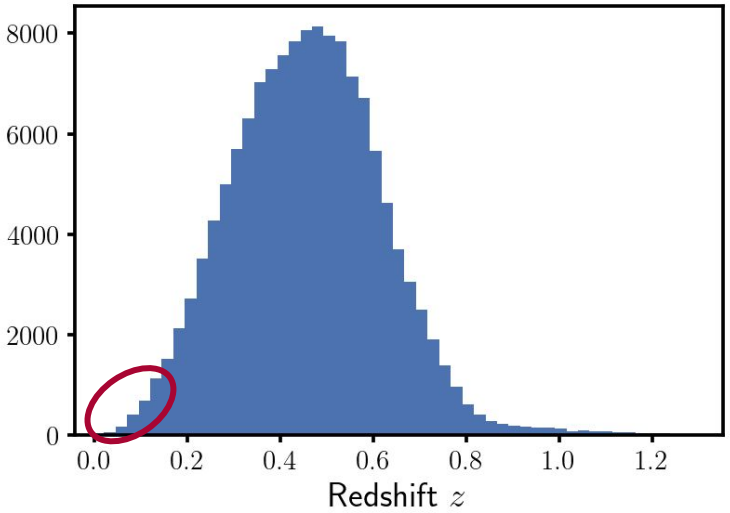


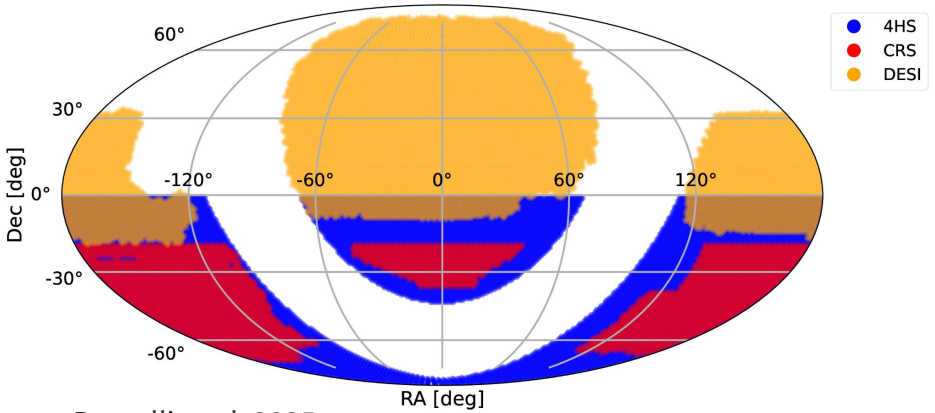


Rosselli et al. 2025

The future sample from the Rubin-LSST

Spectroscopic redshift are needed !!!
Host-z from 4MOST (4HS, TiDES-Host, CRS) & DESI (DESI, DESI-Ib & DESI-II)





Rosselli et al. 2025

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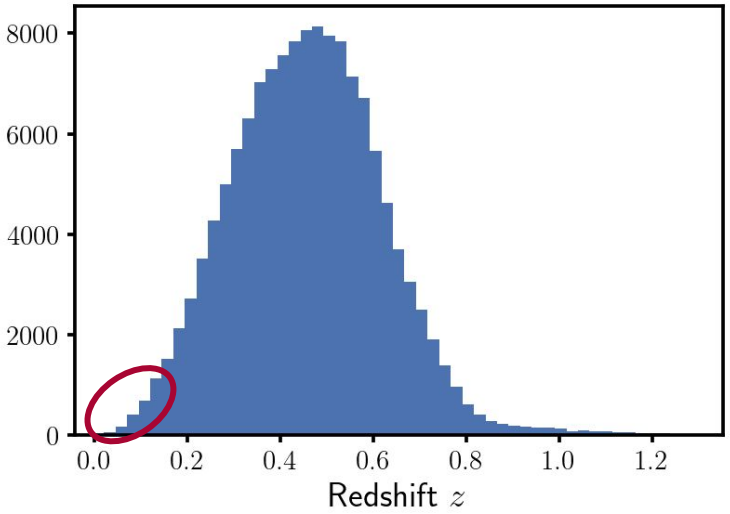
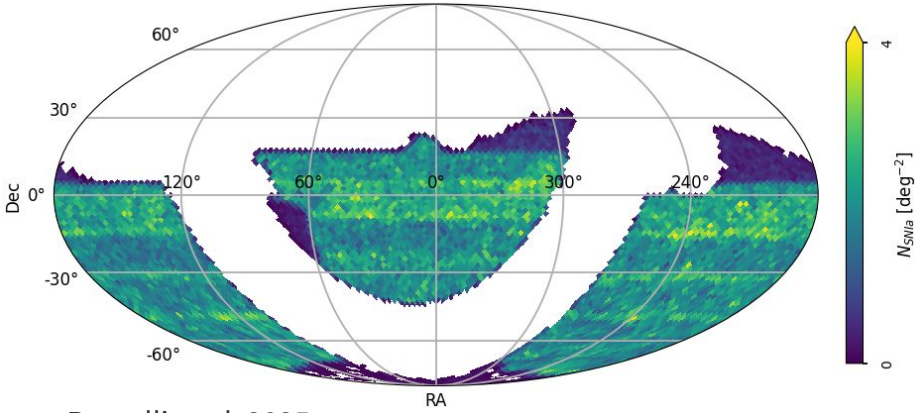
Spec-z sample ~ 20 000 SNe Ia





Rosselli et al. 2025

Growth rate pipeline: what do we have?

N-body simulations

- OuterRim (DM halo)
- Uchuu UM (Gal)

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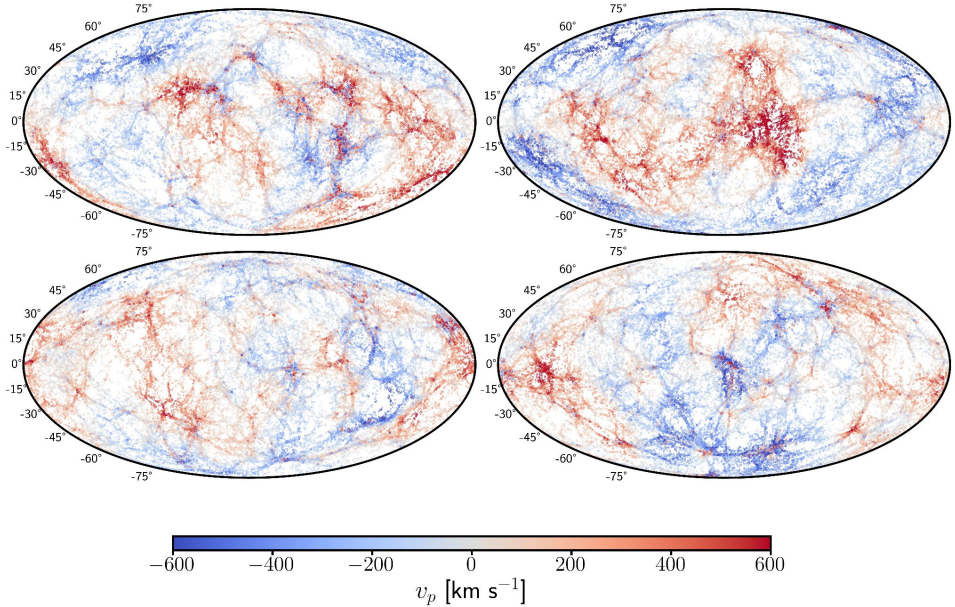
Uchuu `UniverseMachine` (Ishiyama et al. 2021; Aung et al. 2023)

One mock contains ~O(50 000 000) galaxies !
(including SFR and Stellar Mass)



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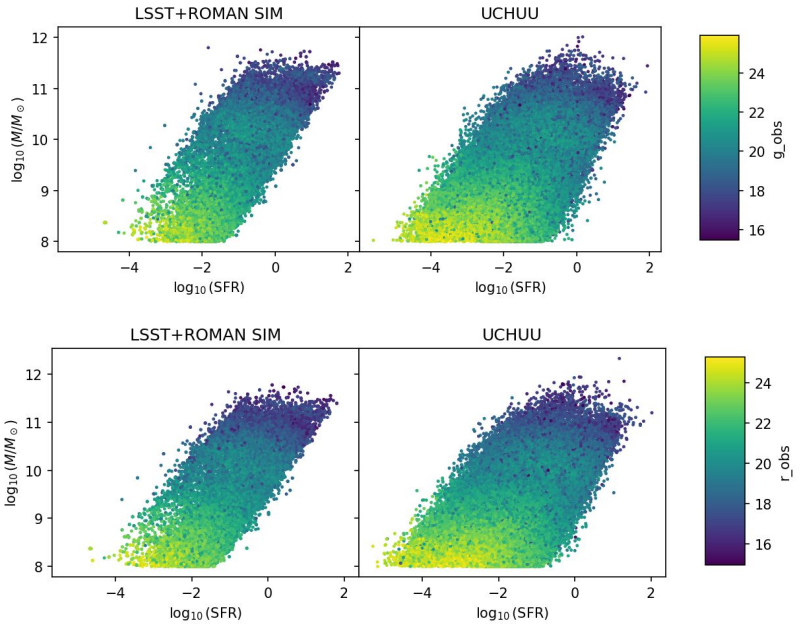
Uchuu `UniverseMachine` (Ishiyama et al. 2021; Aung et al. 2023)

LSST and Roman magnitudes and sersic parameters added by interpolating on OpenUniverse simulations using **Stellar Mass** and **SFR** parameters

8 mocks covering z ~ 0–0.17 are available on NERSC



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Survey cadence

`OpSim` db + `OpSimSummaryV2`

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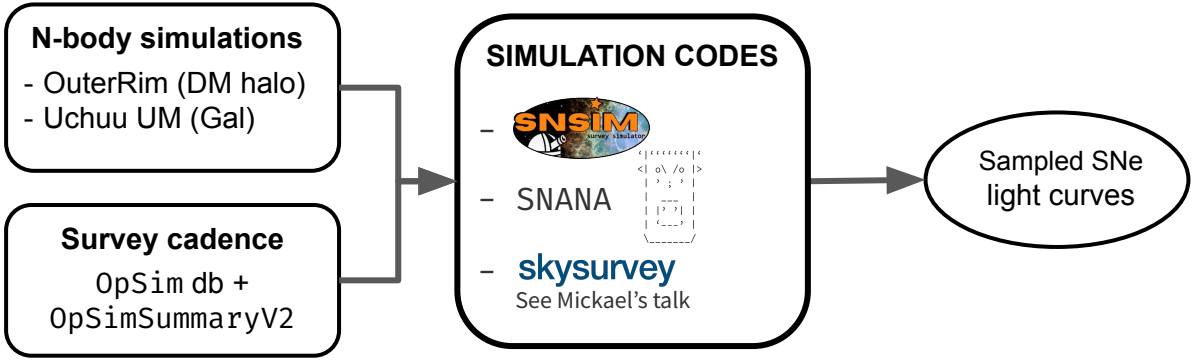
SIMULATION CODES

- SNSIM
- SNANA
- skysurvey

See Mickael's talk

Growth rate pipeline: what do we have?



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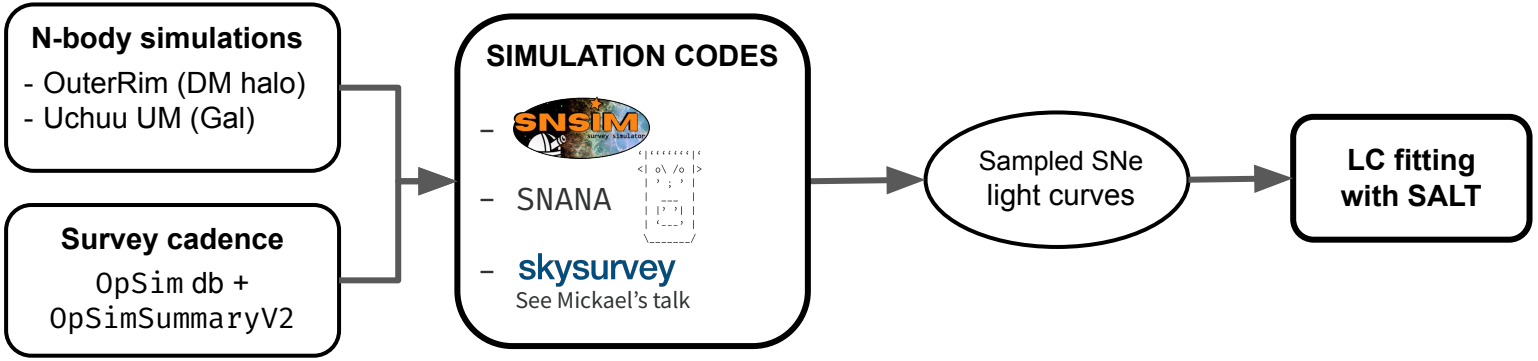

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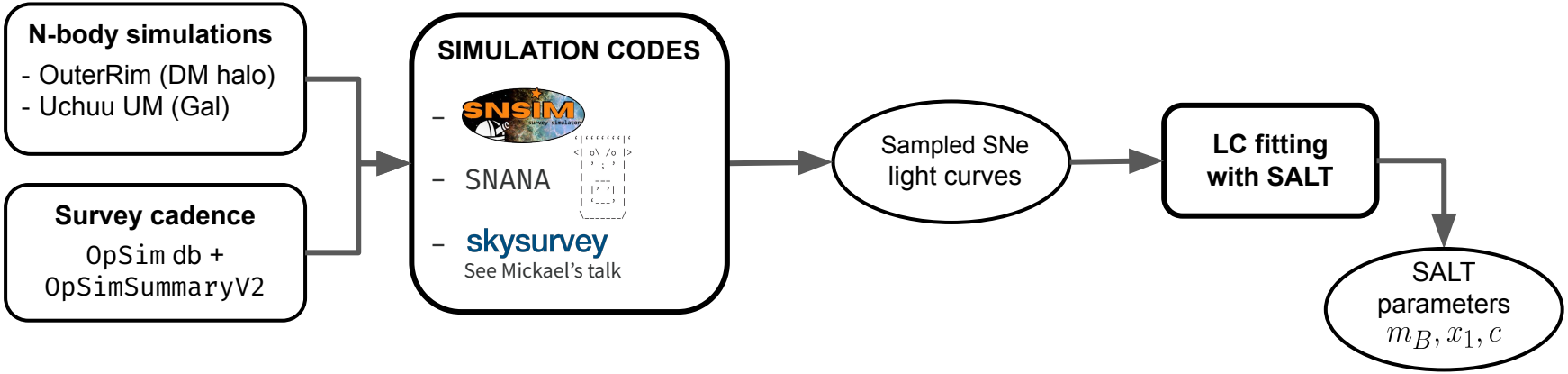

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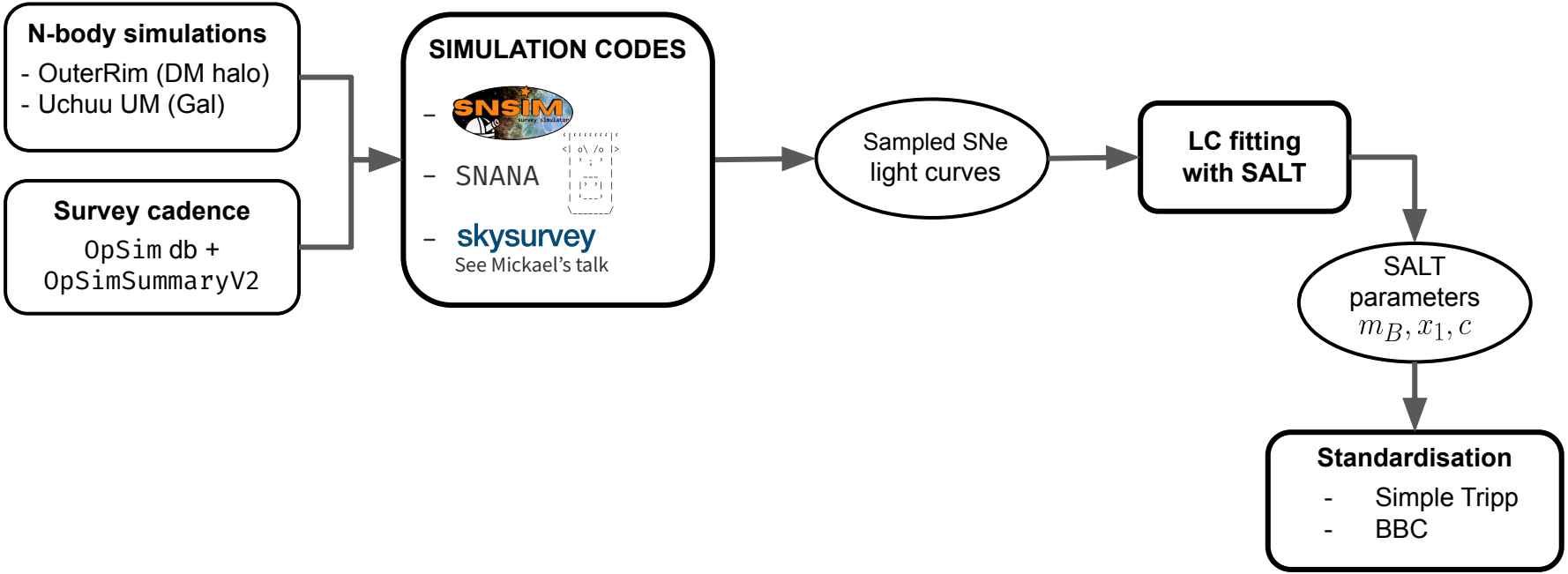

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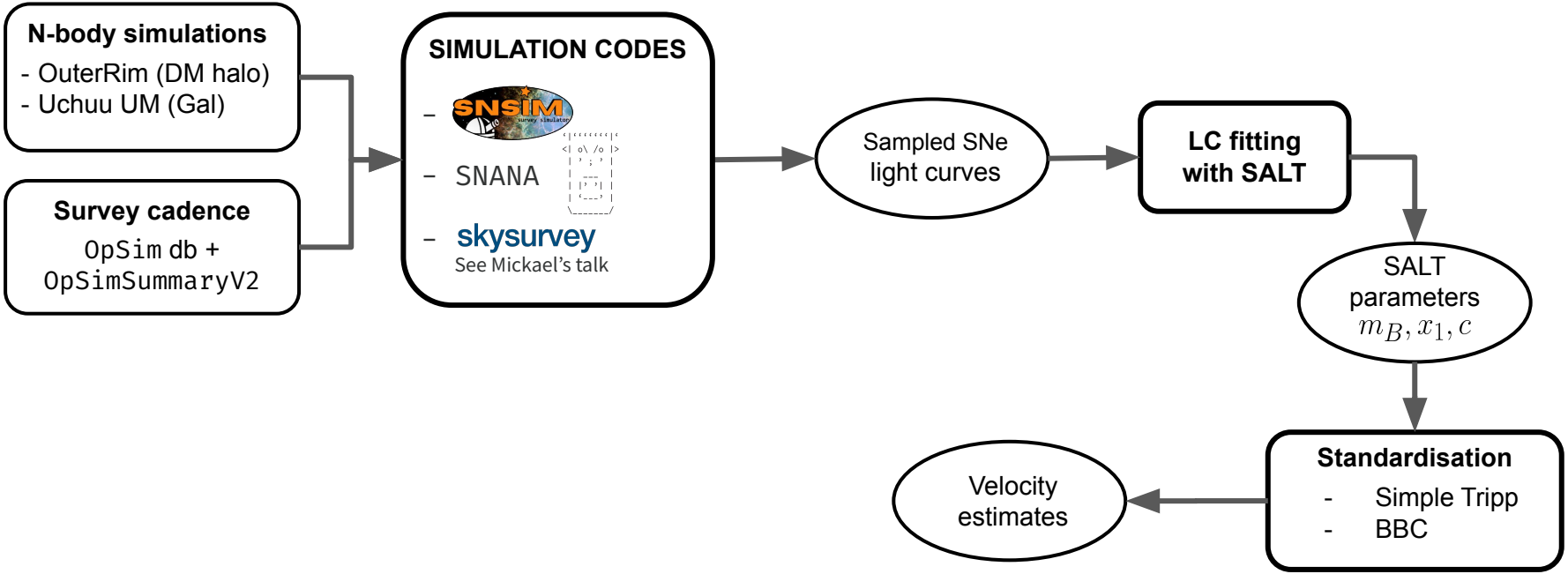

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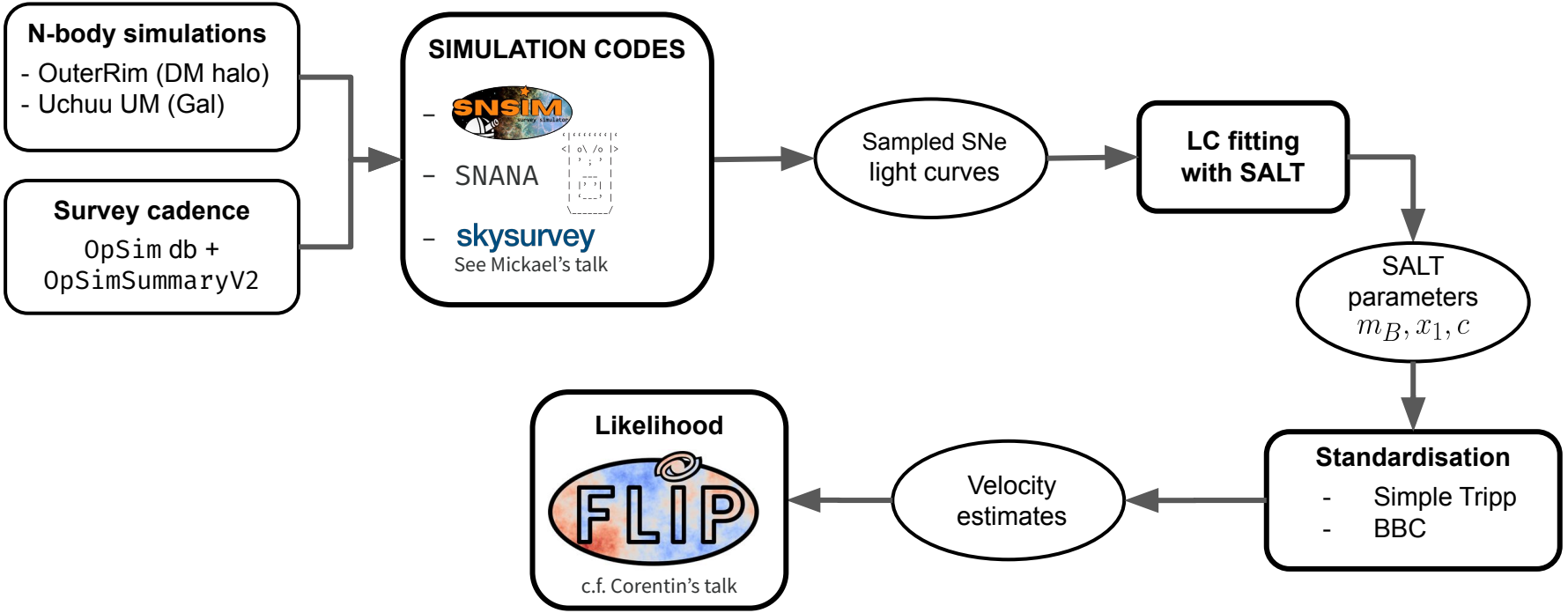

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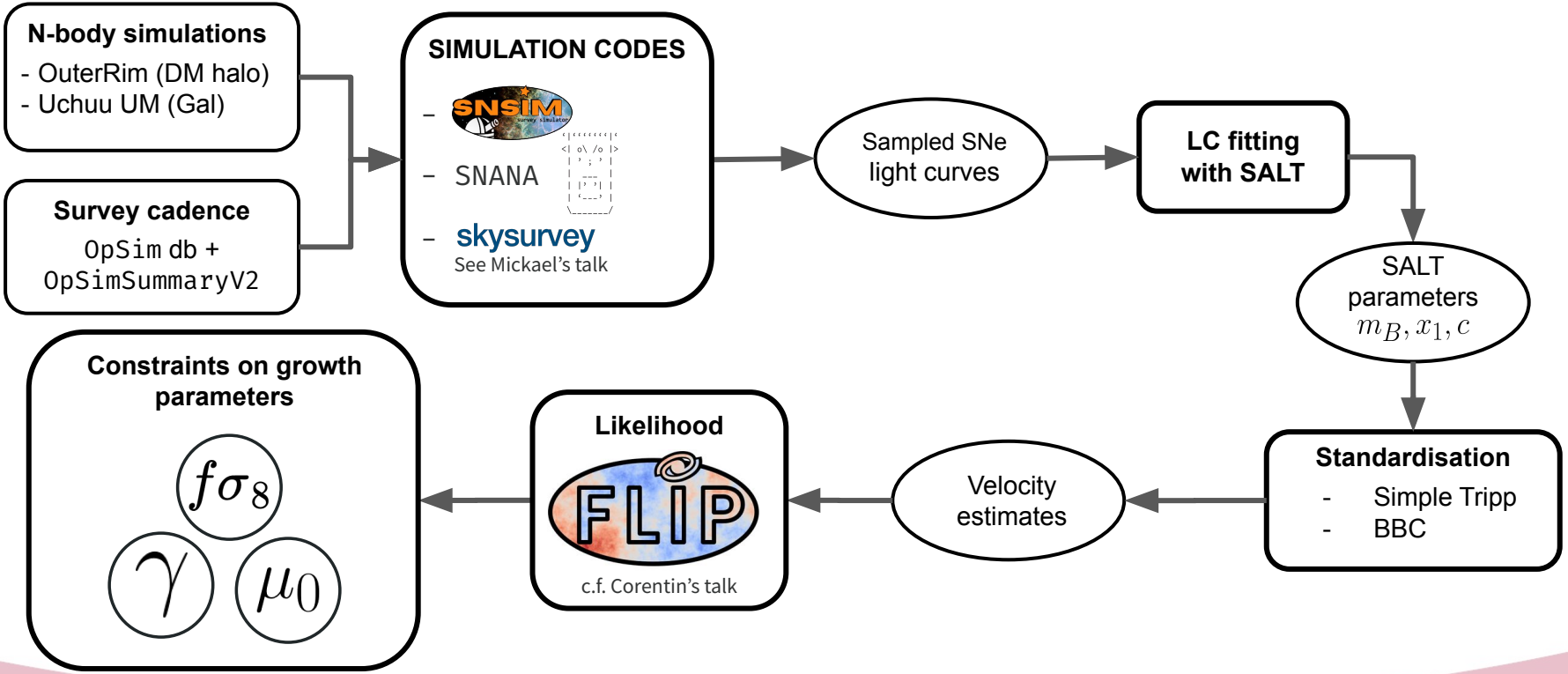

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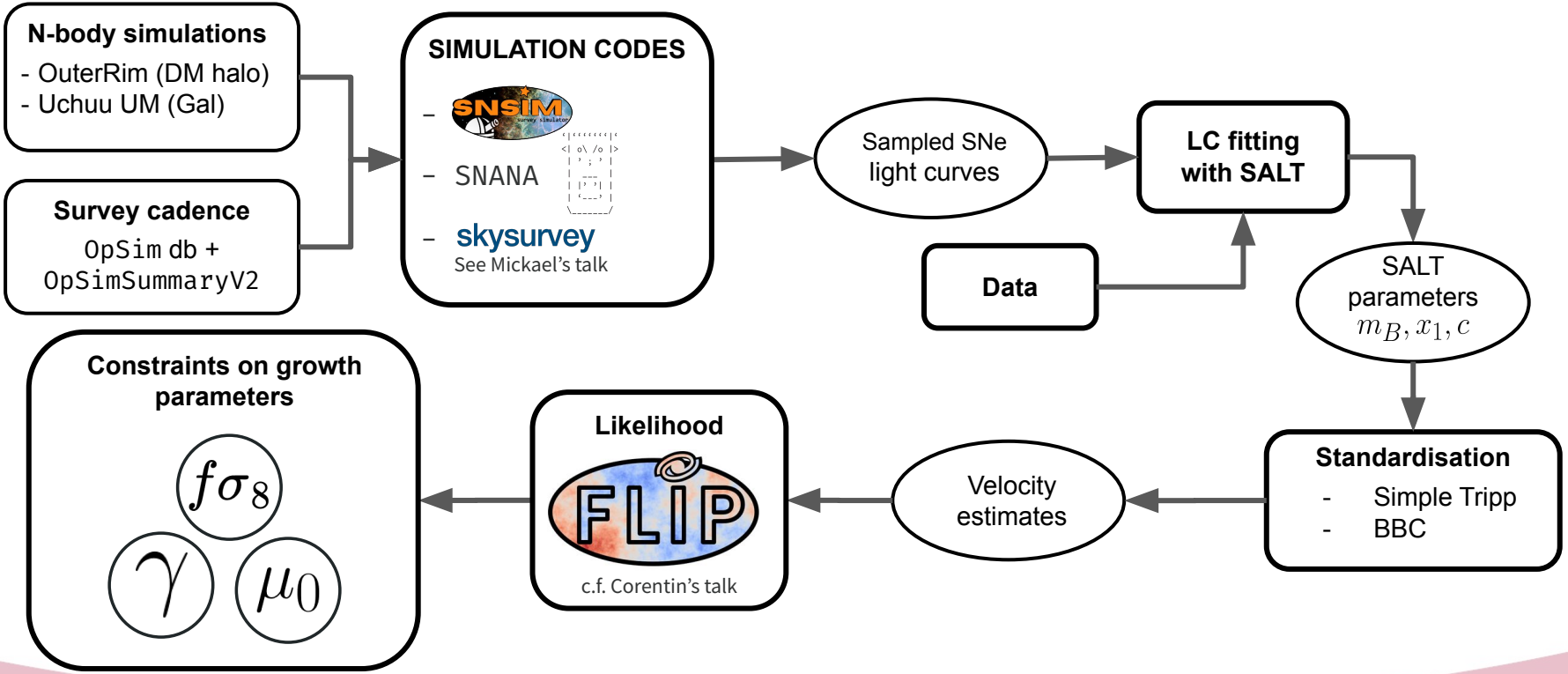


PV cosmology DESC working group

2 papers published this year within DESC:

- **Rosselli et al. 2025**, *Forecast for growth rate measurement using peculiar velocities from LSST supernovae*
- **Carreres et al. 2025**, *Type Ia supernova growth-rate measurement with LSST simulations: intrinsic scatter systematics*

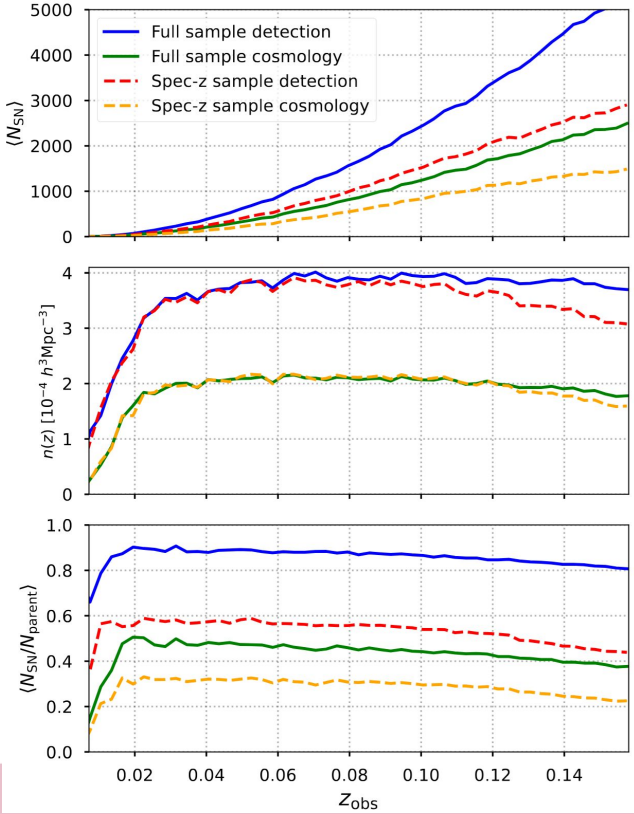
Growth rate: forecasts (Rosselli et al. 2025)

Simulation of the 10-years sample of the Rubin-LSST using `snsim` for the 8 Uchuu mocks

SN Ia scatter of ~0.12 mag

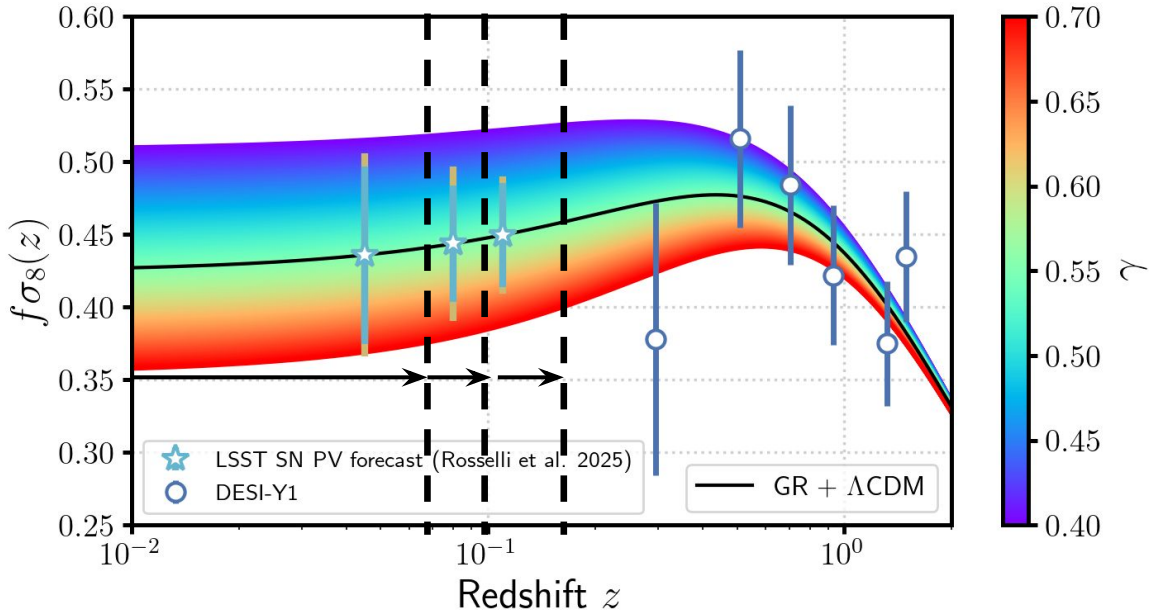
Rubin-LSST detection efficiency from Sánchez et al. 2022

Spec-z sample based on 4MOST and DESI efficiencies



Growth rate: forecasts (Rosselli et al. 2025)

$z_{\rm min}$	$z_{\rm max}$	$\langle z_{\rm obs}\rangle$	$\langle N_{SN}\rangle$	$\left\langle \frac{f\sigma_8}{f\sigma_{8,\rm fid}} \right\rangle$	$\left\langle \frac{\sigma_{f\sigma_8}}{f\sigma_{8,\rm fid}} \right\rangle$
Full sample					
0.02	0.06	0.05	2,969	1.02	0.14
0.02	0.10	0.08	14,091	0.97	0.09
0.02	0.14	0.11	36,599	1.01	0.08
Spec-z sample					
0.02	0.06	0.05	1,989	1.01	0.16
0.02	0.10	0.08	9,500	0.99	0.12
0.02	0.14	0.11	24,194	1.01	0.09



<10% precision over the redshift range 0.02 < z < 0.14

Growth rate: forecasts (Rosselli et al. 2025)

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0.02	0.06	0.05	2,969	1.02	0.14
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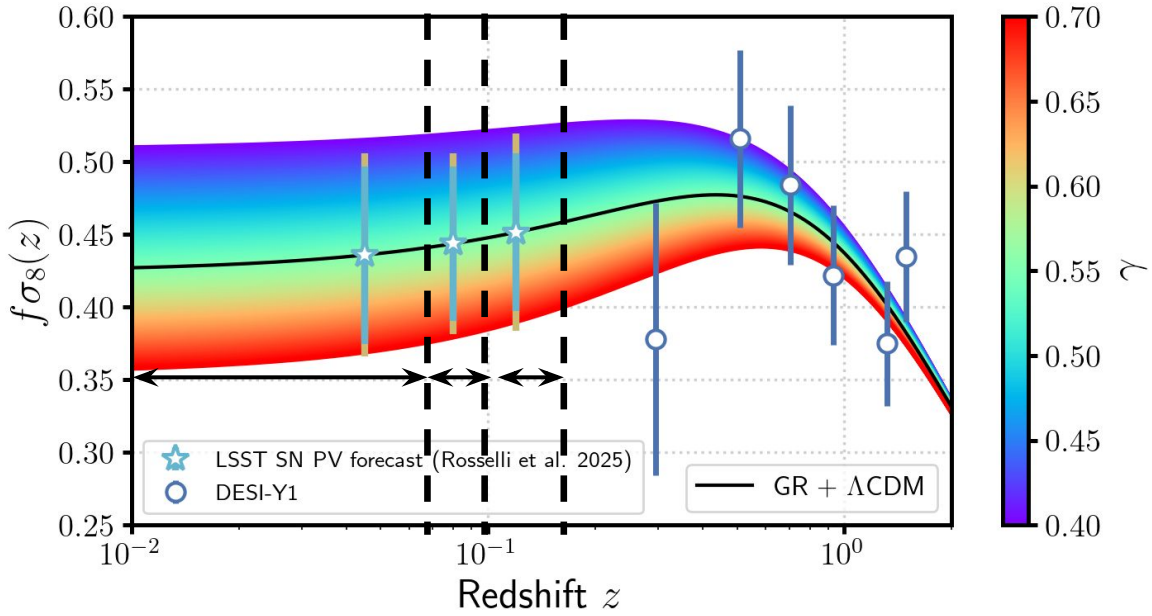
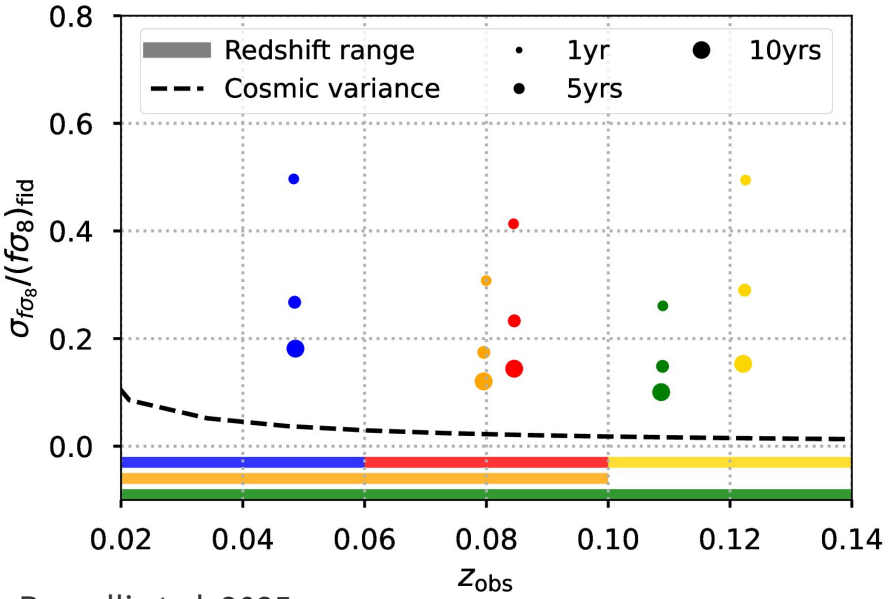
0.10	0.14	0.12	22,507	1.05	0.12
Spec-z sample					
0.02	0.06	0.05	1,989	1.01	0.16
0.06	0.10	0.08	7,511	0.94	0.14
0.10	0.14	0.12	14,693	1.01	0.15



12–14 % precision in the 3 redshift bins
0.02–0.06, 0.06–0.1, 0.1–0.14

Growth rate: forecasts (Rosselli et al. 2025)



Rosselli et al. 2025

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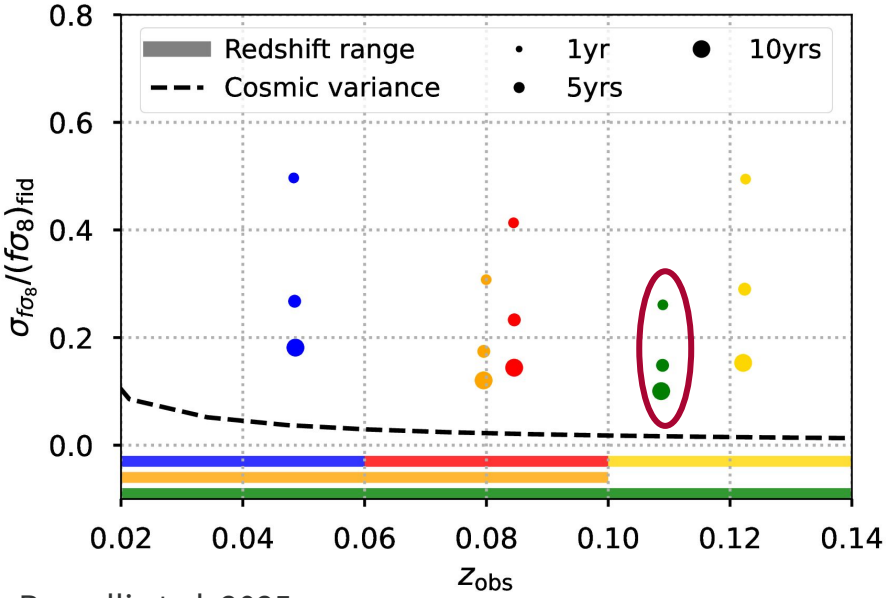

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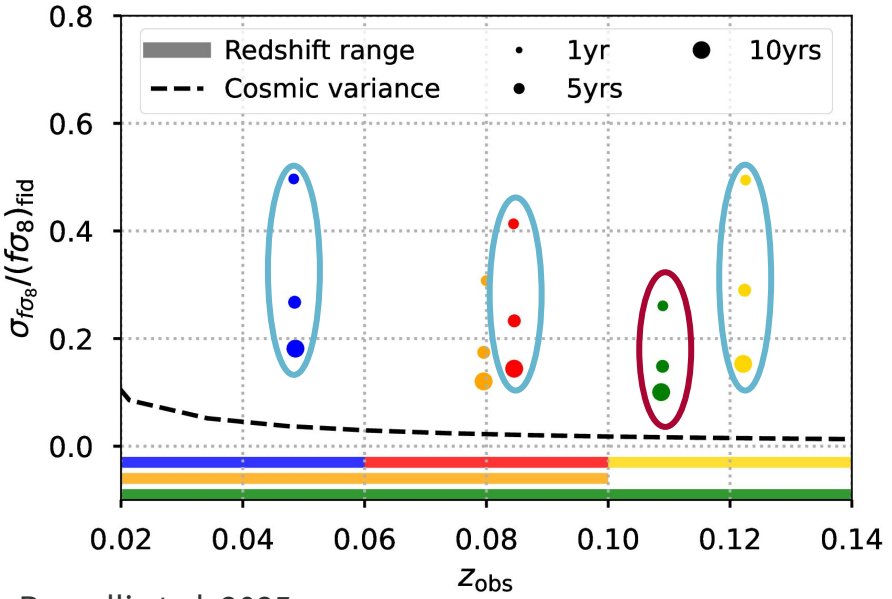

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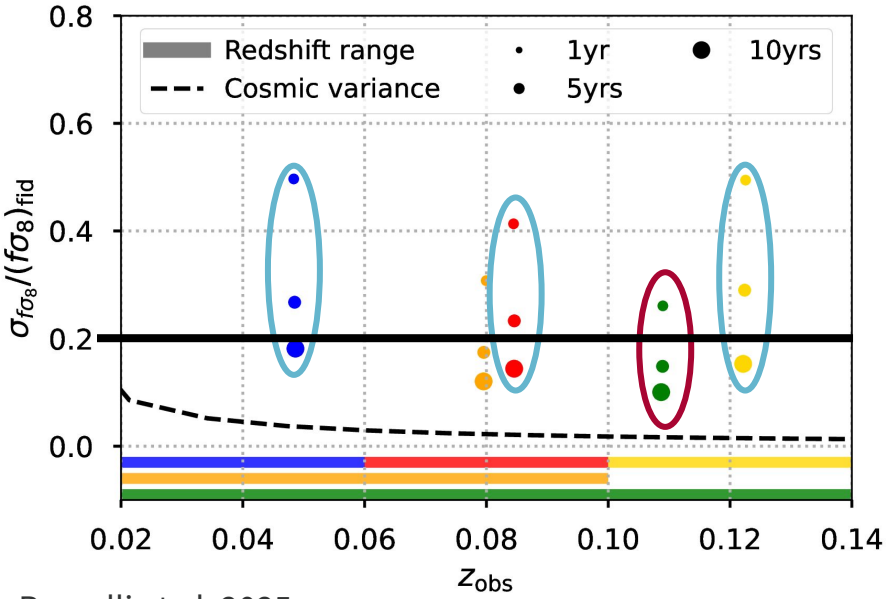

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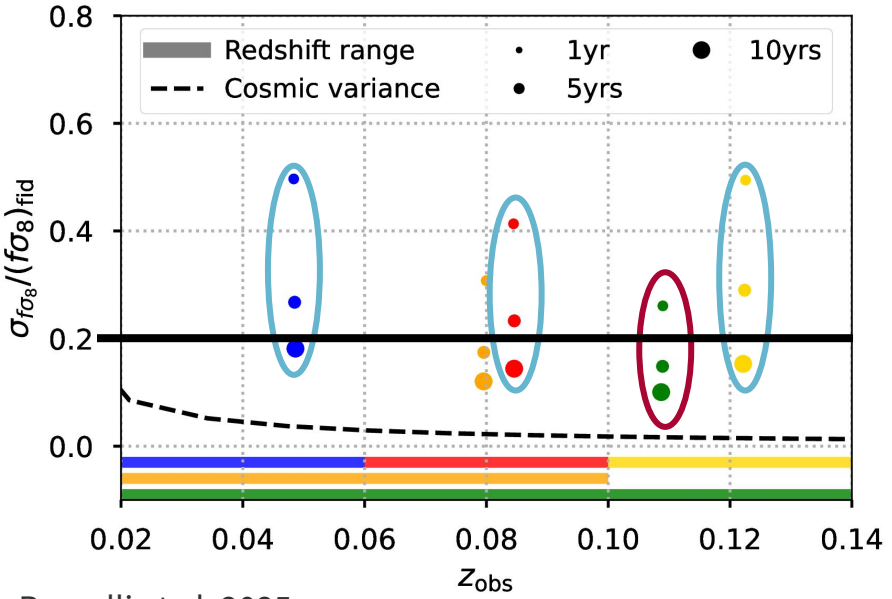

Rosselli et al. 2025

Additional details on Damiano's work will be given on Thursday during his PhD defense !!!

Growth rate: systematics (Carreres et al. 2025)

Simulation of 10 years of LSST using SNANA for the 8 Uchuu mocks and different models of intrinsic scatter

Growth rate: systematics (Carreres et al. 2025)

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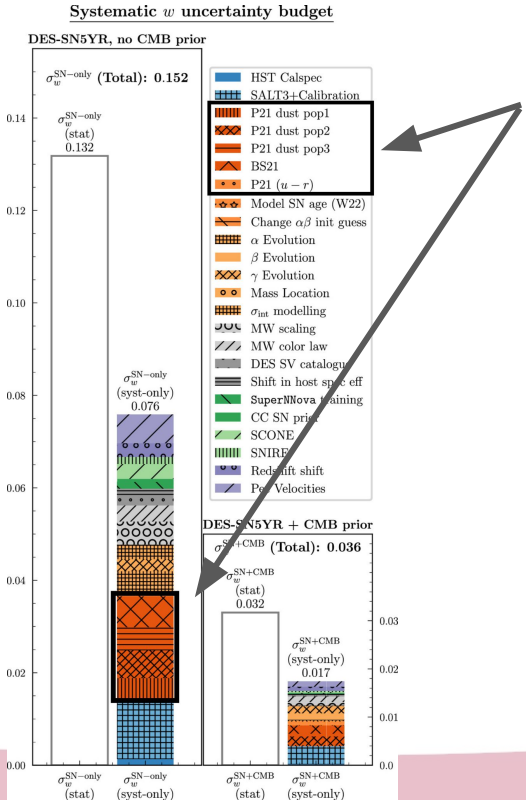

Major systematic in the DES-5years analysis (Vincenzi et al. 2024)

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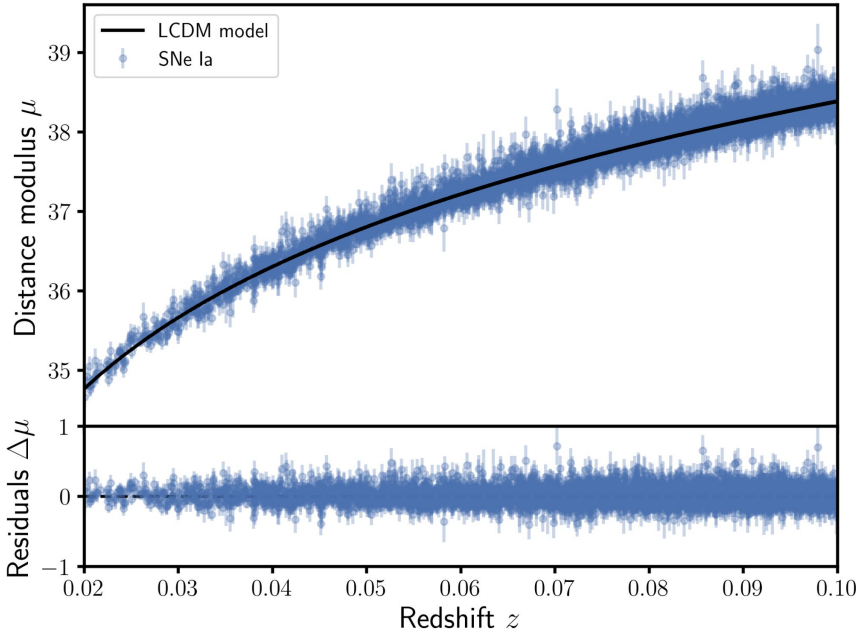
SN Ia systematics: Intrinsic scatter



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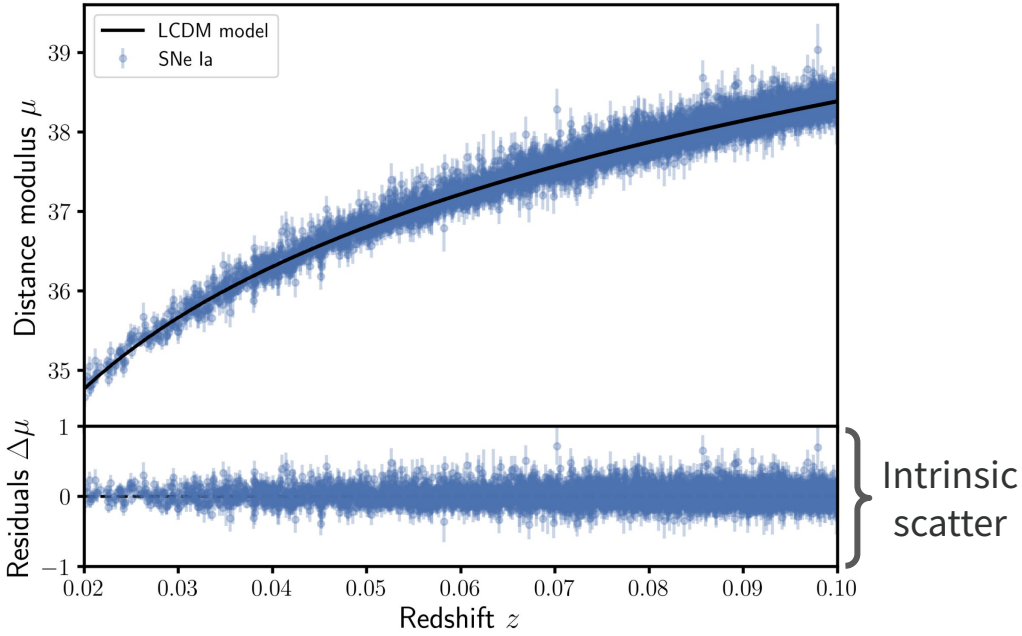

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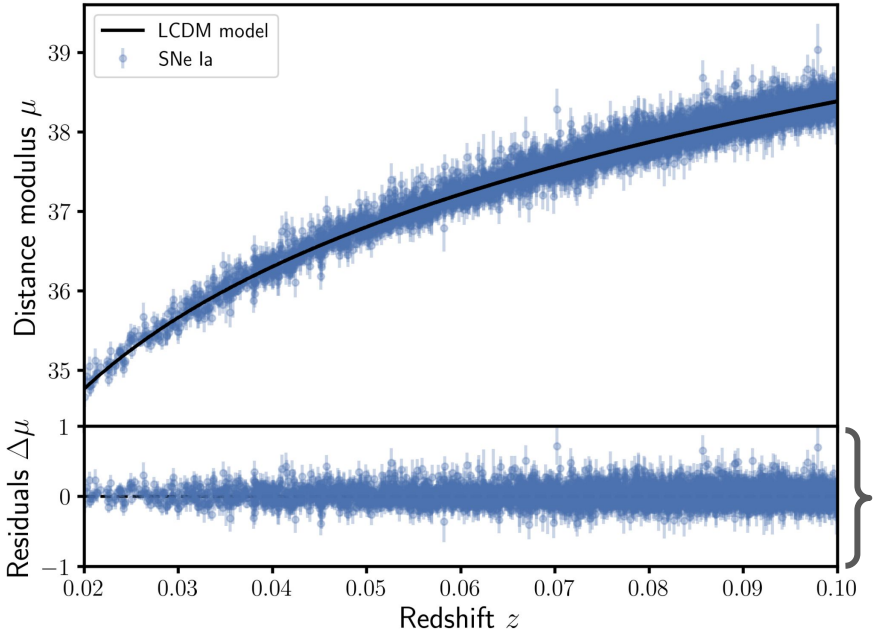

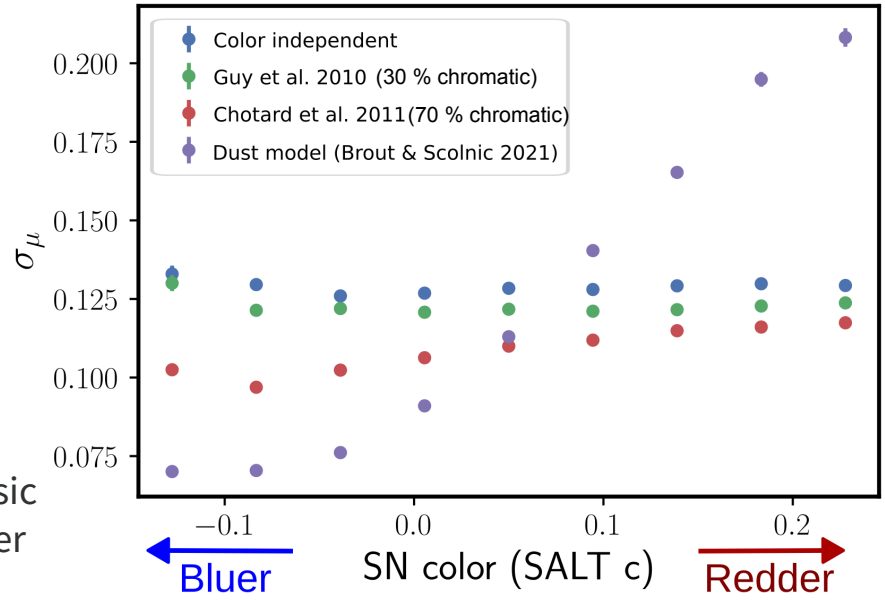

Growth rate: systematics (Carreres et al. 2025)

Test fit of the $f\sigma_8$ using simple standardisation:

$$\mu = m_B + \alpha x_1 - \beta x_1 - M_0$$

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$$\mu = m_B + \alpha x_1 - \beta x_1 - M_0$$

And Bias Correction method (BBC):

$$\mu = m_B + \alpha x_1 - \beta x_1 - M_0 + \delta(x_1, c, \beta, \alpha, M_{\rm host})$$

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Computed using large simulation (~40 times LSST)

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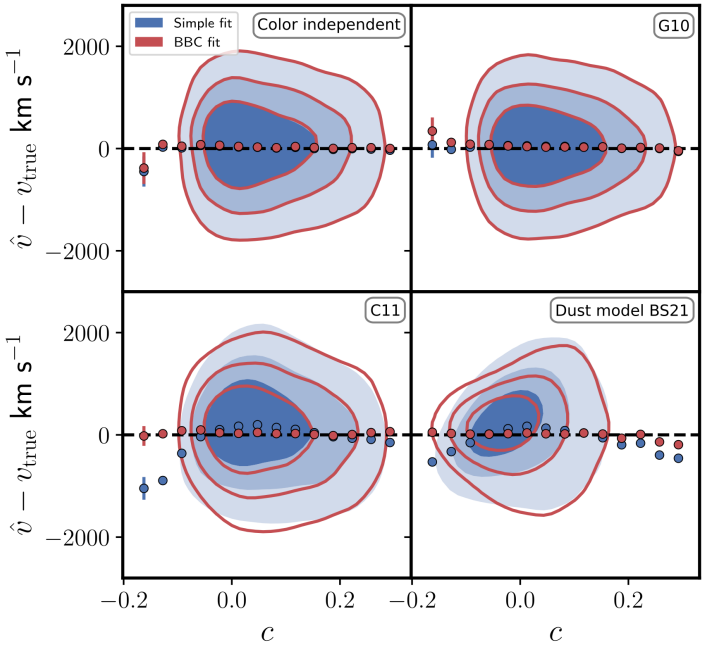
The “bias corr” simulations reproduce realistic intrinsic scatter and survey selection effects

Growth rate: systematics (Carreres et al. 2025)

SN Ia systematics: Intrinsic scatter



Growth rate: systematics (Carreres et al. 2025)

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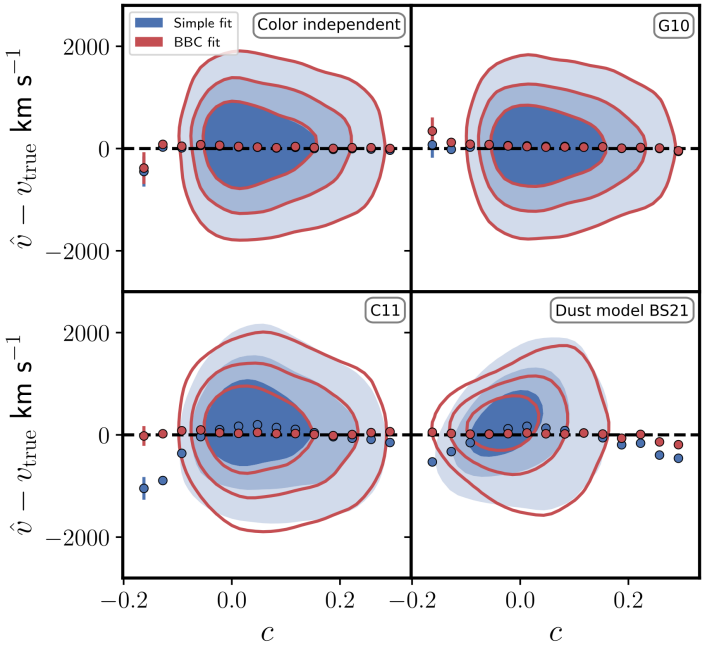

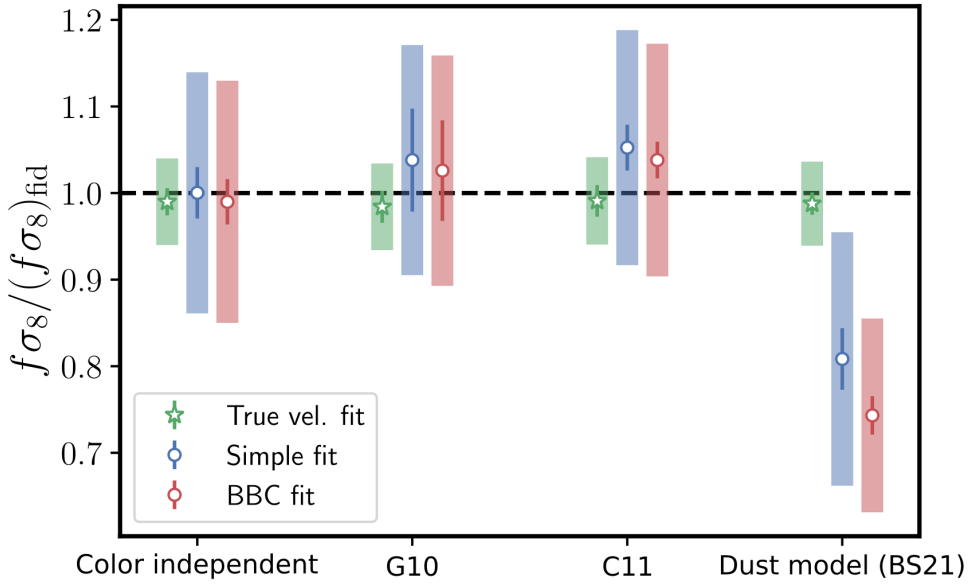

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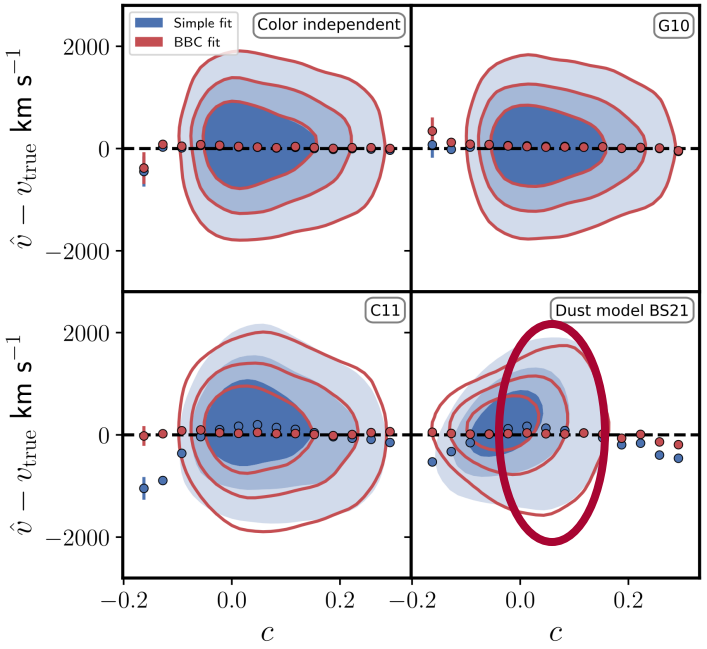

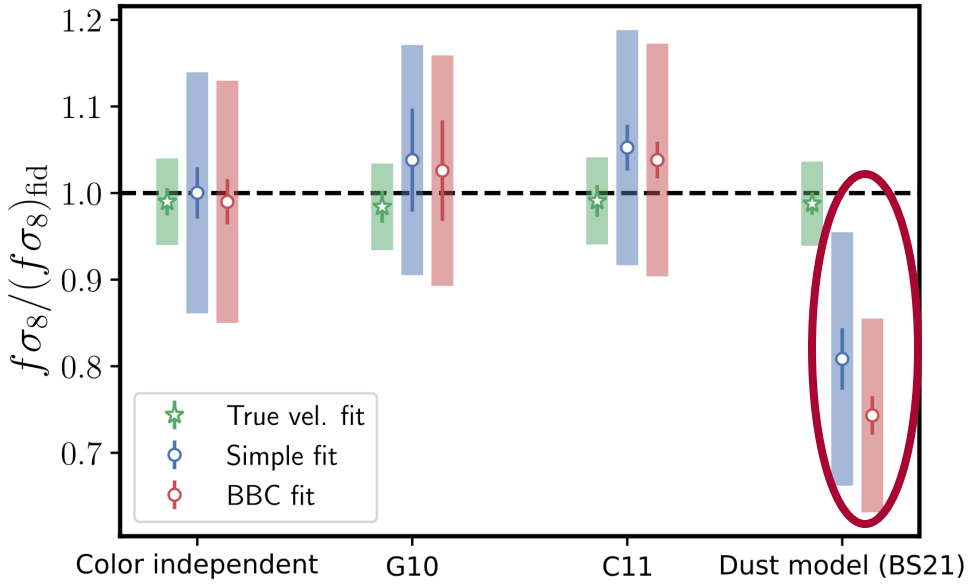

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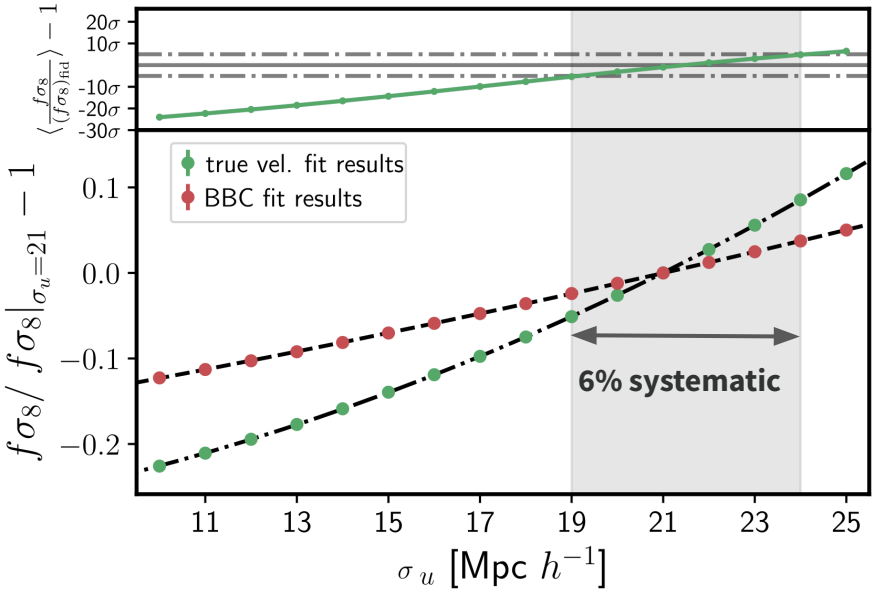

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Systematics such as intrinsic scatter and RSD models needs to be mitigated

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Improvement of power spectrum modelling (Shi-Fan and Massimo talks)

Thank you for your attention