Peculiar velocities with SNela

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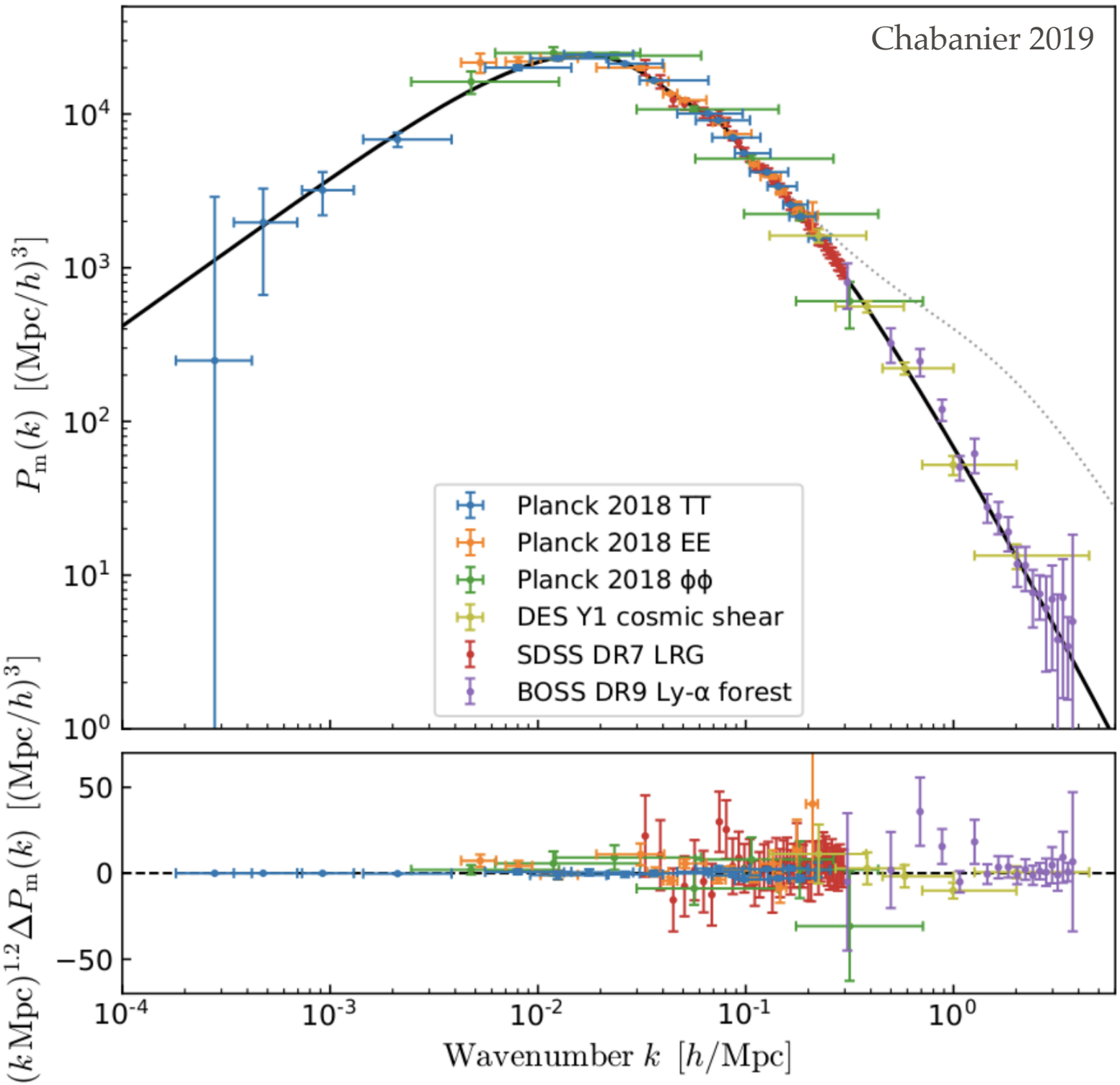
Peculiar velocities



$$\langle \delta^2 \rangle = \sigma_8^2 P_0(k)$$

$$\vec{\nabla}\vec{v} = -H_0 f \delta$$

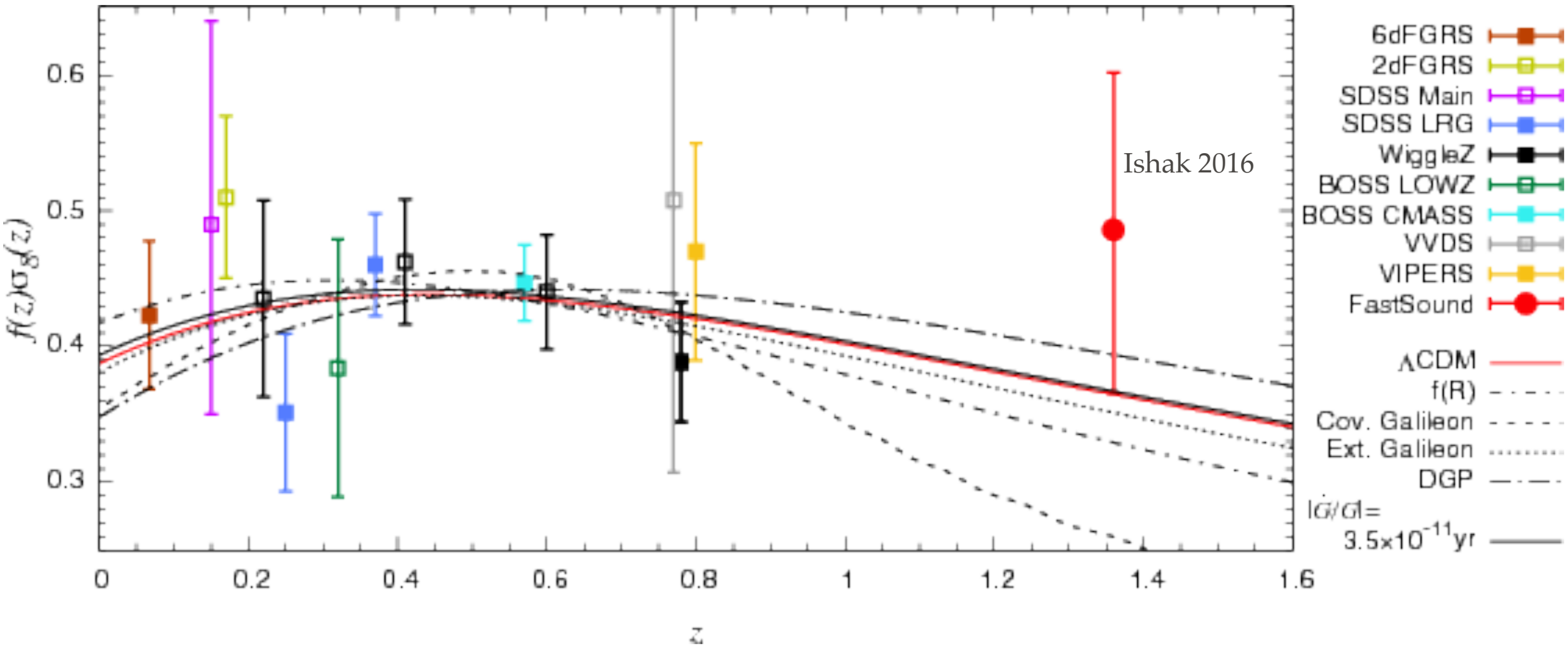
$$\langle v_\alpha^2 \rangle = (f\sigma_8)^2 \frac{k_\alpha^2}{k^4} P_0(k)$$

Pros / cons

Pros	Cons
- NO galaxy bias	- Poor S/N
- Probes GR	- Systematics not well studied
- Low redshift	- So far assumes linear regime
- New* and fancy	- Computationally expensive

*ly possible

Goal



State of the art: >15% measurement with peculiar velocities

The idea

Observed supernova magnitude:

$$z \sim z_H(m_{SN}) + z_{pec}$$

LCDM predicts :

$$< z_{pec}(m_1) z_{pec}(m_2) >= f(P(k), m_1, m_2)$$

The likelihood looks like :

$$\mathcal{L} = -\frac{1}{2(f\sigma_8)^2}(z - z_H)^T \mathrm{C}^{-1}(z - z_H)$$

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Note that we need the host redshift

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Note that there is a NxN matrix to invert (at least once)

Note that we need the host redshift

My approach

$$\mathcal{L} = -\frac{1}{2(f\sigma_8)^2}(z - z_H)^T \mathrm{C}^{-1}(z - z_H)$$

m_{SN}

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How to propagate uncertainties, selection effects, systematics effects etc. in this likelihood ?

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→ **MCMC**

Other approach

$$\mathcal{L} = -\frac{1}{2(f\sigma_8)^2}(z - z_H)^T \mathrm{C}^{-1}(z - z_H)$$

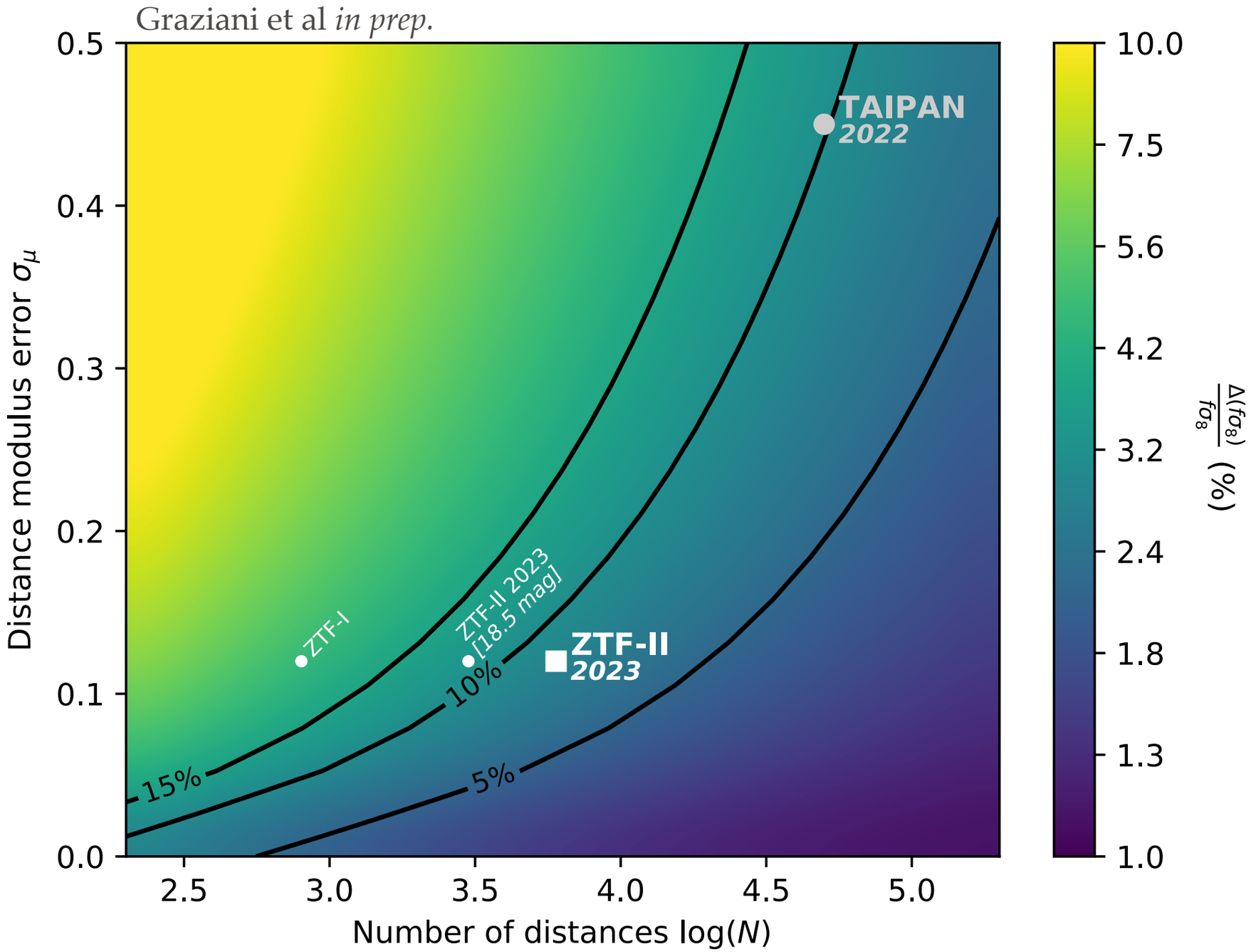
m_{SN}

How to propagate uncertainties, selection effects, systematics effects etc. in this likelihood ?

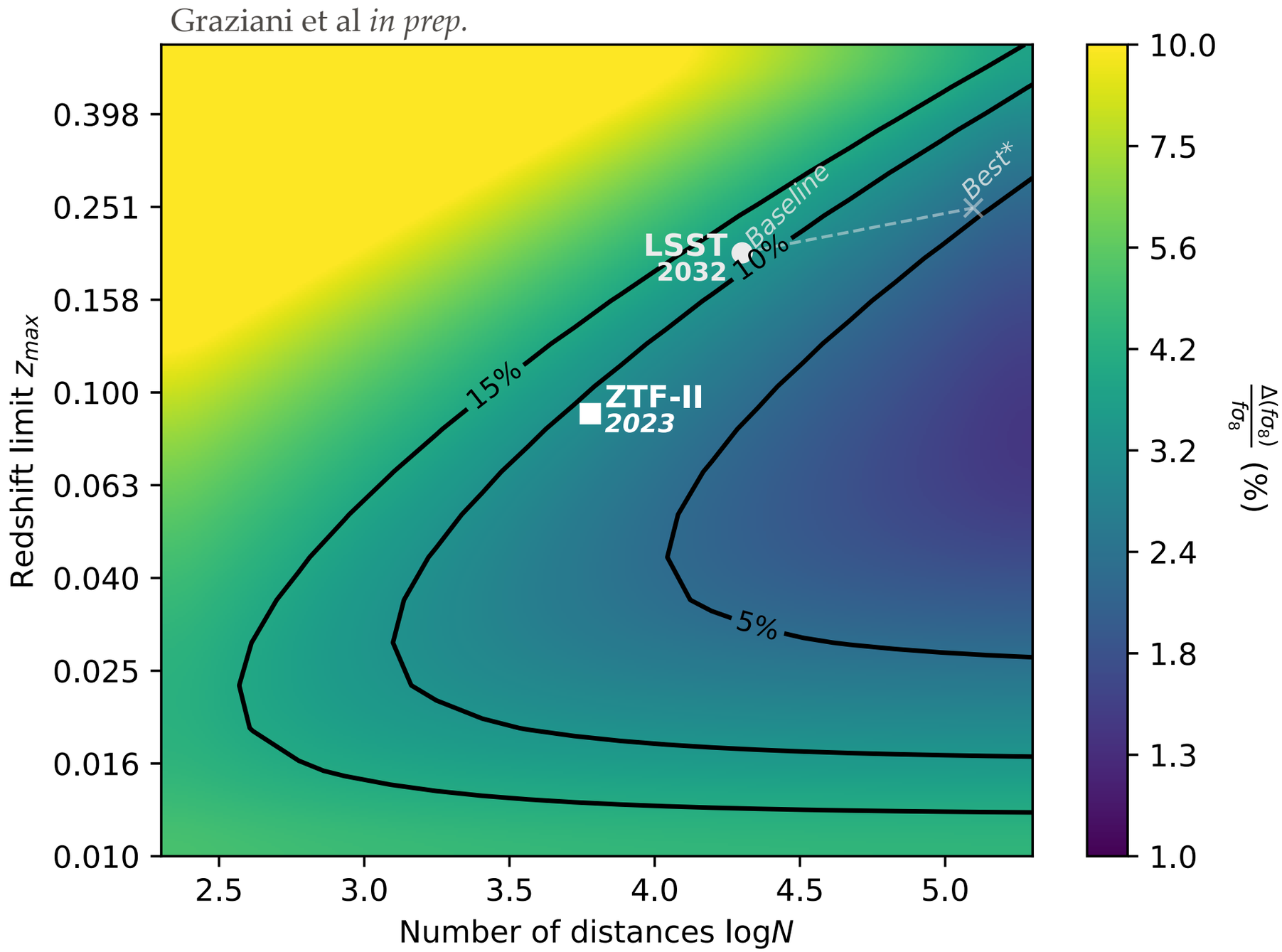
- Covariance does not depend on magnitude
- Empirical modeling of covariance matrix
- Gaussian error approximation
- Binning
- No selection nor systematics nuisance parameters
- I assume it is OK for a >15% measurement

Fisher matrix

Forecasts


Graziani et al *in prep.*
Distance modulus error σ_μ
Number of distances log(N)
$\frac{\Delta(f\sigma_8)}{f\sigma_8}$ (%)
TAIPAN 2022
ZTF-II 2023
ZTF-I
ZTF-II 2023 [18.5 mag]
15%
10%
5%
0.0
0.1
0.2
0.3
0.4
0.5
2.5
3.0
3.5
4.0
4.5
5.0
10.0
7.5
5.6
4.2
3.2
2.4
1.8
1.3
1.0

Forecasts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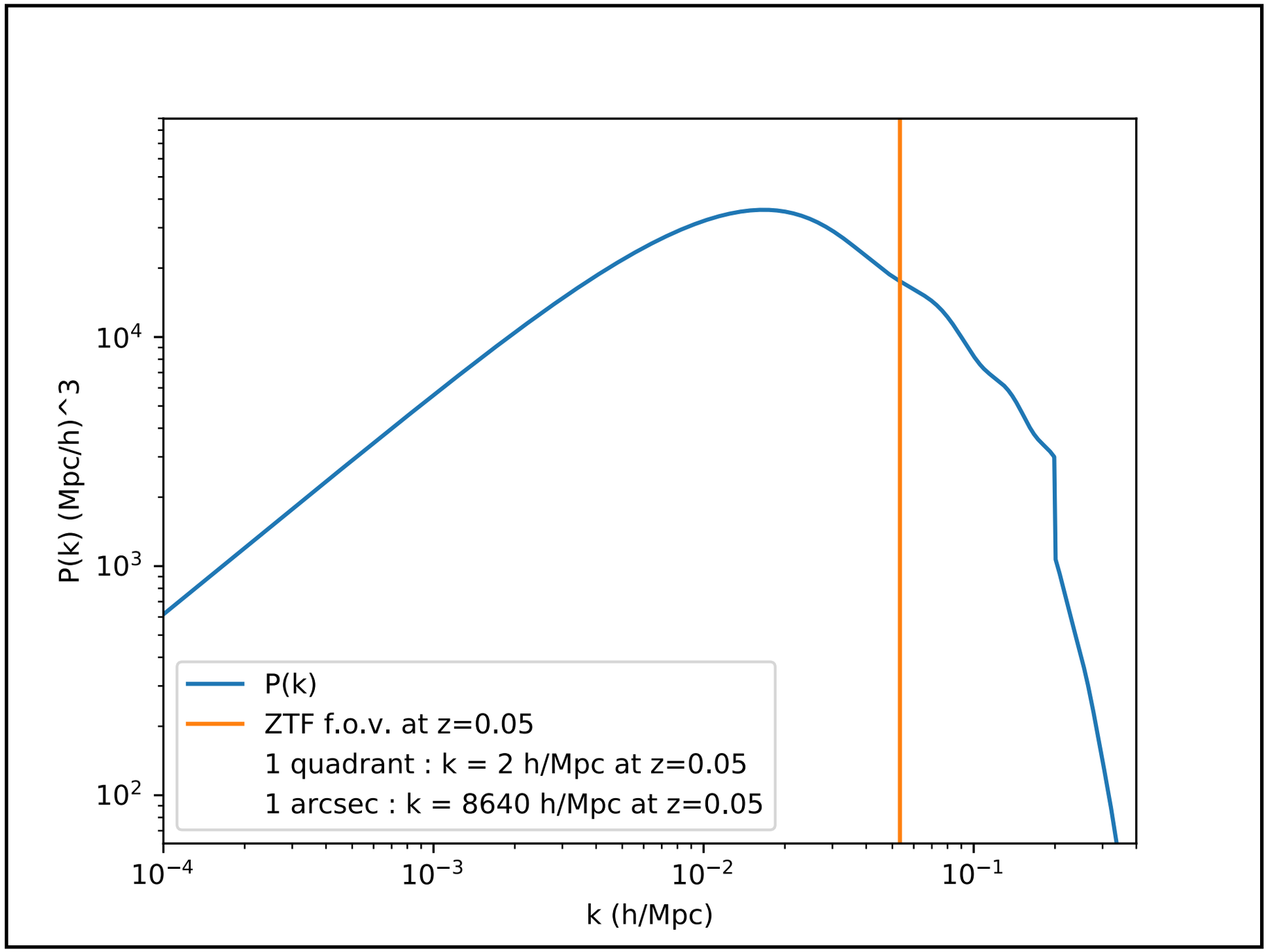
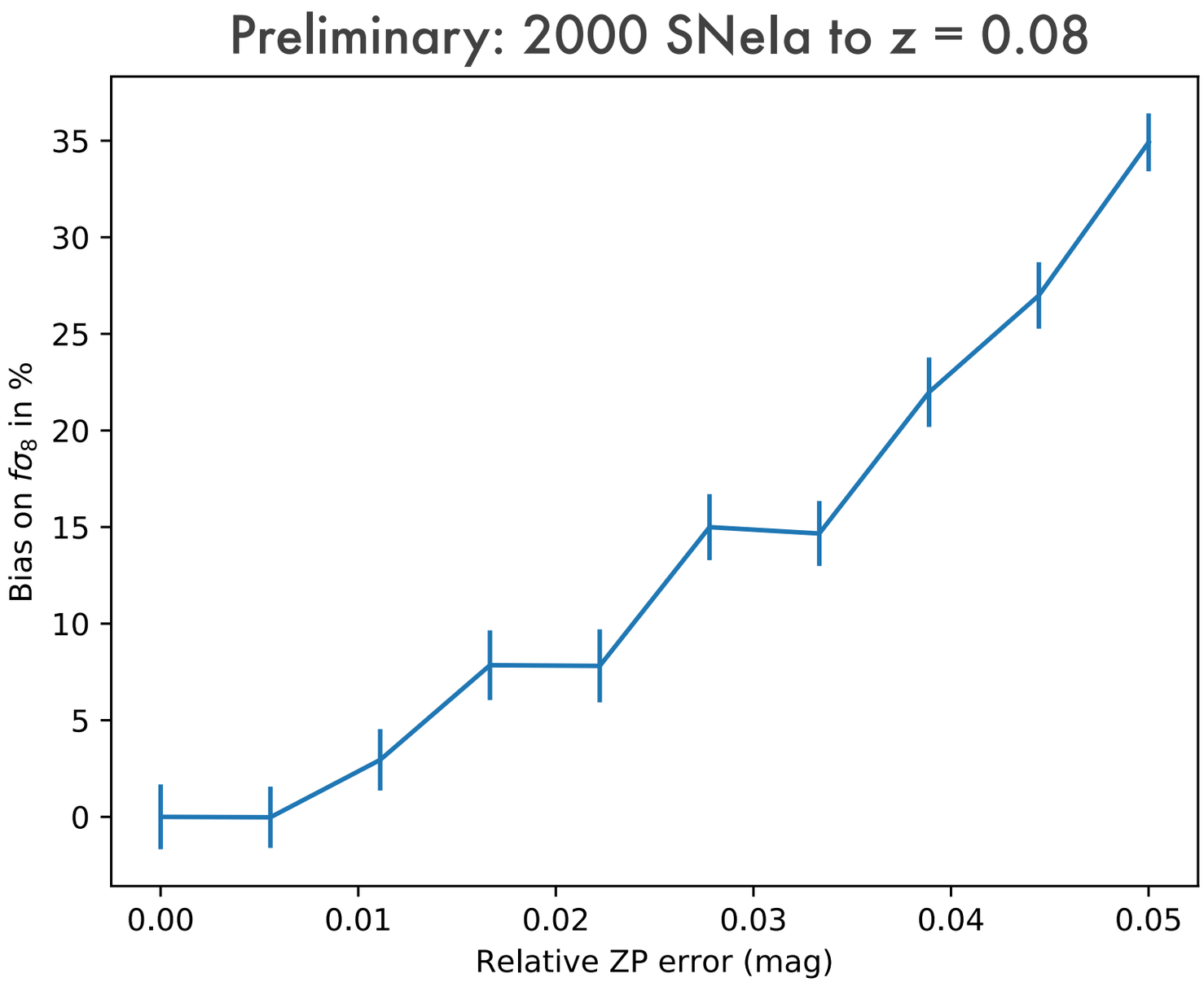
0.398
0.251
0.158
0.100
0.063
0.040
0.025
0.016
0.010
Redshift limit z_{max}
2.5
3.0
3.5
4.0
4.5
5.0
Number of distances log$N$
LSST
2032
Baseline
Best*
10%
15%
5%
ZTF-II
2023
10.0
7.5
5.6
4.2
3.2
2.4
1.8
1.3
1.0
$\frac{\Delta(f\sigma_8)}{f\sigma_8}$ (%)

Systematics

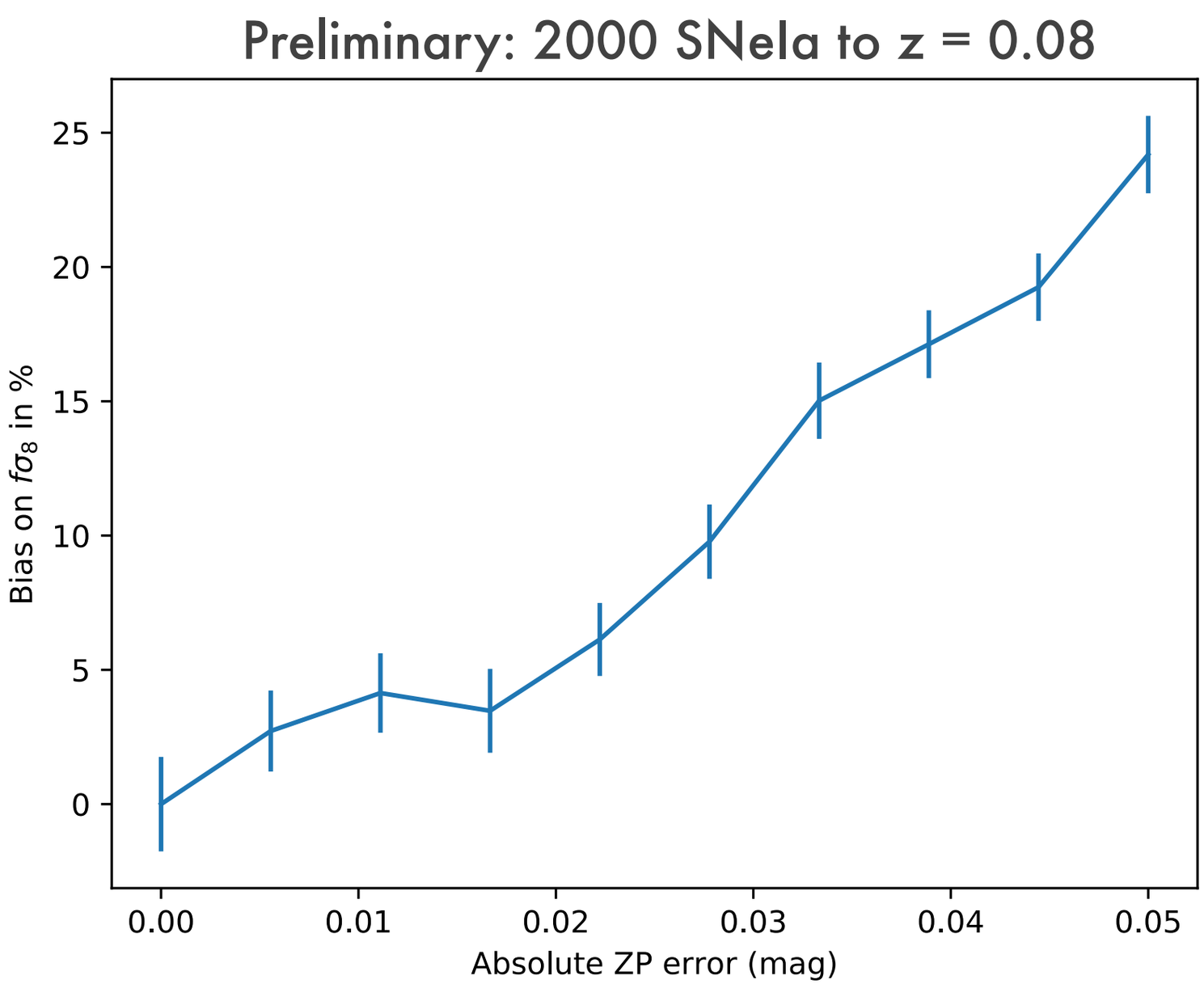
Example of systematic



Relative calibration



Absolute calibration



Overview of systematics effects

Effect	If not modeled	Full Bayesian model	Empirical model
Non Gaussian uncertainties	**Significant**	Included - no bias	Empirical model Syst < 15%
Non-linear effects	**Significant**	Included - no bias, noise	Empirical model Syst < 15%
Inhomogeneous MB	**Complicated…**	In progress	Empirical model Syst < 15%
Absolute calibration	**White noise term**	Included - no bias, noise	Included - no bias, noise
Relative calibration	**>5% for 0.02 mag**	Not included	Not included
Selection effects	**Unknown (high?)**	Included - unknown	Not included
Saturation	**Unknown (small?)**	Not Included	Not included
Contamination	**Unknown (small?)**	Included - no bias, noise	Not included

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Questions

- Disentangle density of datapoint and range
- Should we include the density-velocity correlations in the analysis ?
- Cross-correlation between ZTF and LSST ?
- … ?