

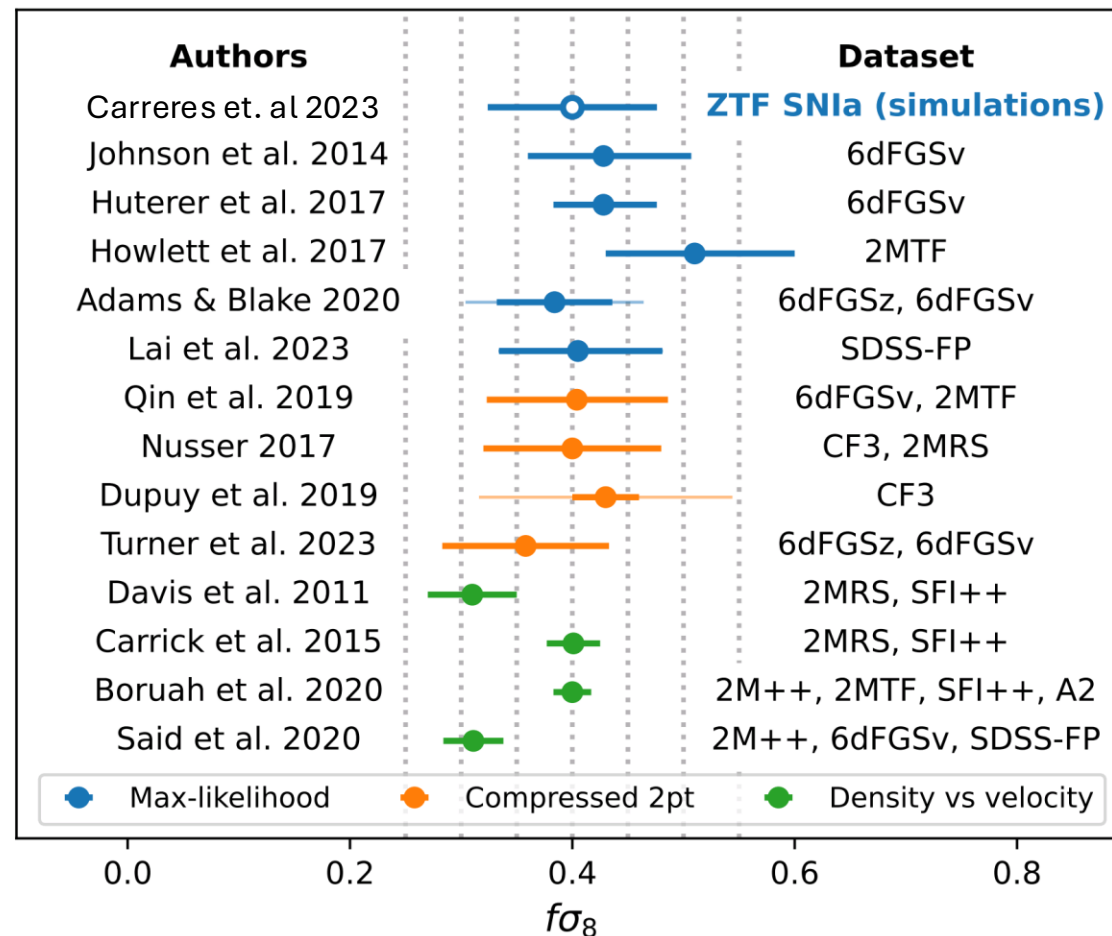
Reconstructing $f\sigma_8$ Cosmology with Theseus

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Measurements of $f\sigma_8$ at Low Redshifts

Carreres et. al (2023)

- Peculiar velocities: Galaxies and SNIa
- SNIa: velocity correlations
 - e.g. Carreres et. al (2023)
- SNIa: Density vs. Velocity measurements
 - This work: get a tighter grip on systematics affecting $f\sigma_8$ density v. velocity measurements



Theory & Pipeline

$$\vec{v}(\vec{r}) = \frac{H_0 \beta}{4\pi} \int d^3\vec{r}' \delta_g(\vec{r}') \frac{\vec{r}' - \vec{r}}{|\vec{r}' - \vec{r}|^3} + \vec{V}_{ext}$$

Where $\delta_g = b_{lin} \delta$ is the smoothed galaxy density and $\beta \equiv f/b$.

Theory & Pipeline

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Diagram illustrating the equation for the velocity field $\vec{v}(\vec{r})$. The terms $\vec{v}(\vec{r})$ and $\delta_g(\vec{r}')$ are circled in green and labeled "observable". The term $\frac{H_0 \beta}{4\pi}$ is circled in blue and labeled "measurable".

Where $\delta_g = b_{lin} \delta$ is the smoothed galaxy density and $\beta \equiv f/b$.

Theory & Pipeline

$$\vec{v}(\vec{r}) = \frac{H_0 \beta}{4\pi} \int d^3\vec{r}' \delta_g(\vec{r}') \frac{\vec{r}' - \vec{r}}{|\vec{r}' - \vec{r}|^3} + \vec{V}_{ext}$$

Pantheon+,
Union, ZTF

Theseus

2M++

Theory & Pipeline

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Pantheon+,
Union, ZTF

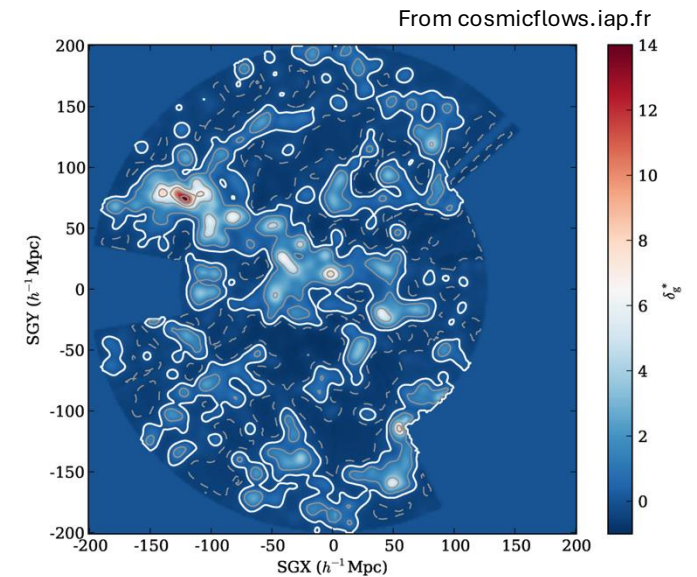
- **Pantheon+**
 - 601 Low-z SNe from 18 catalogs
 - Accounts for selection bias via corrections to m_B
- **Union**
 - 707 Low-z SNe from 24 catalogs
 - Accounts for selection bias via corrections to errors
- **ZTF DR2(.5)**
 - Homogenous and complete sample of 516 SNe below redshift 0.06, more without completeness
 - Simulations Available

Theory & Pipeline

$$\vec{v}(\vec{r}) = \frac{H_0 \beta}{4\pi} \int d^3\vec{r}' \delta_g(\vec{r}') \frac{\vec{r}' - \vec{r}}{|\vec{r}' - \vec{r}|^3} + \vec{V}_{ext}$$

2M++

- **2M++**
 - Density map of the local universe (<0.1) made through peculiar velocity measurements of galaxy peculiar velocities
 - “ β -independent measurement of the mass distribution in the local universe”



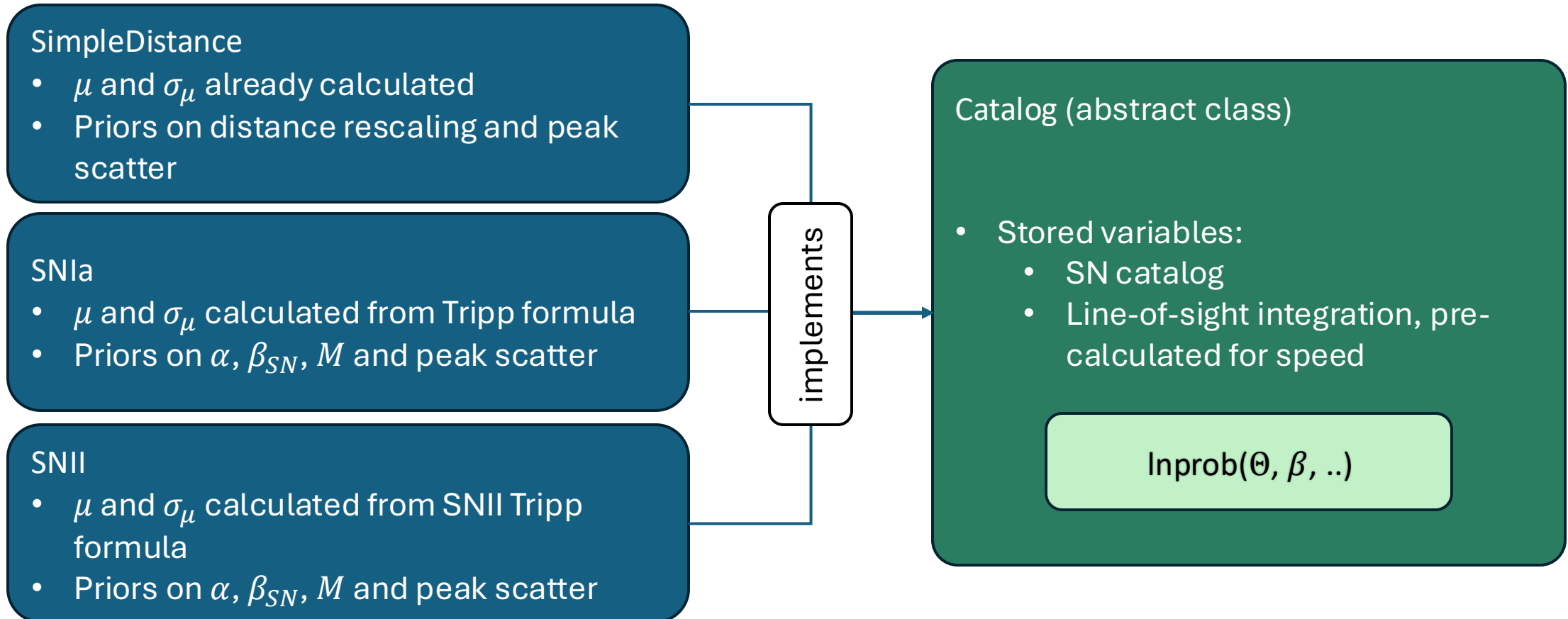
Theory & Pipeline

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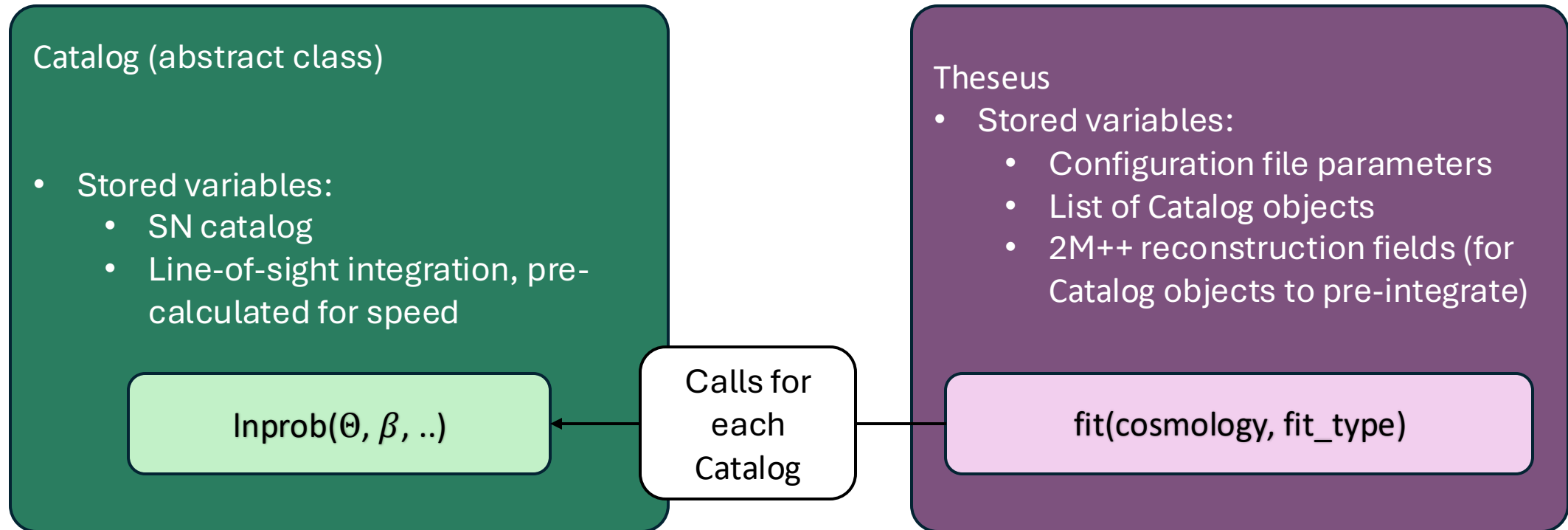
Theseus

- Maximum Likelihood Approach
- Assumes Gaussian likelihood for redshift measurements
- Accounts for:
 - Inhomogeneous Malmquist bias
 - Coming soon: correlations between the 2M++ velocities and the SNIa velocities (as per Blake & Turner (2024))

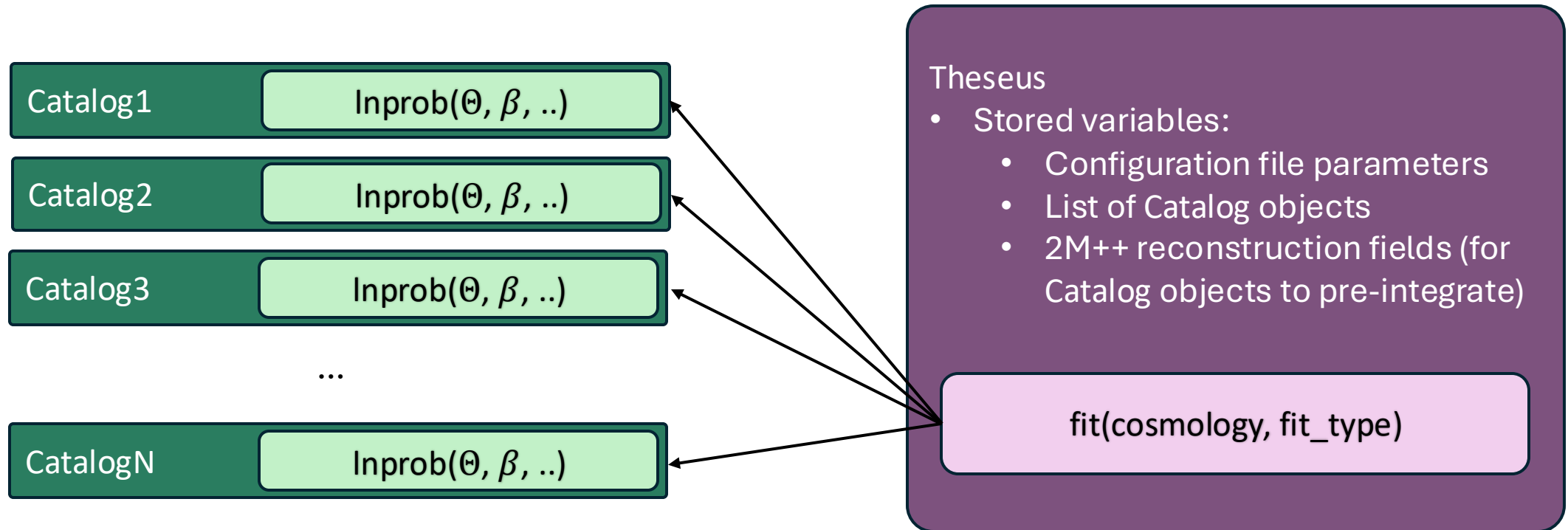
Implementation Details



Implementation Details



Implementation Details



Results - Pantheon

Single Catalog
with
Bias Corrections

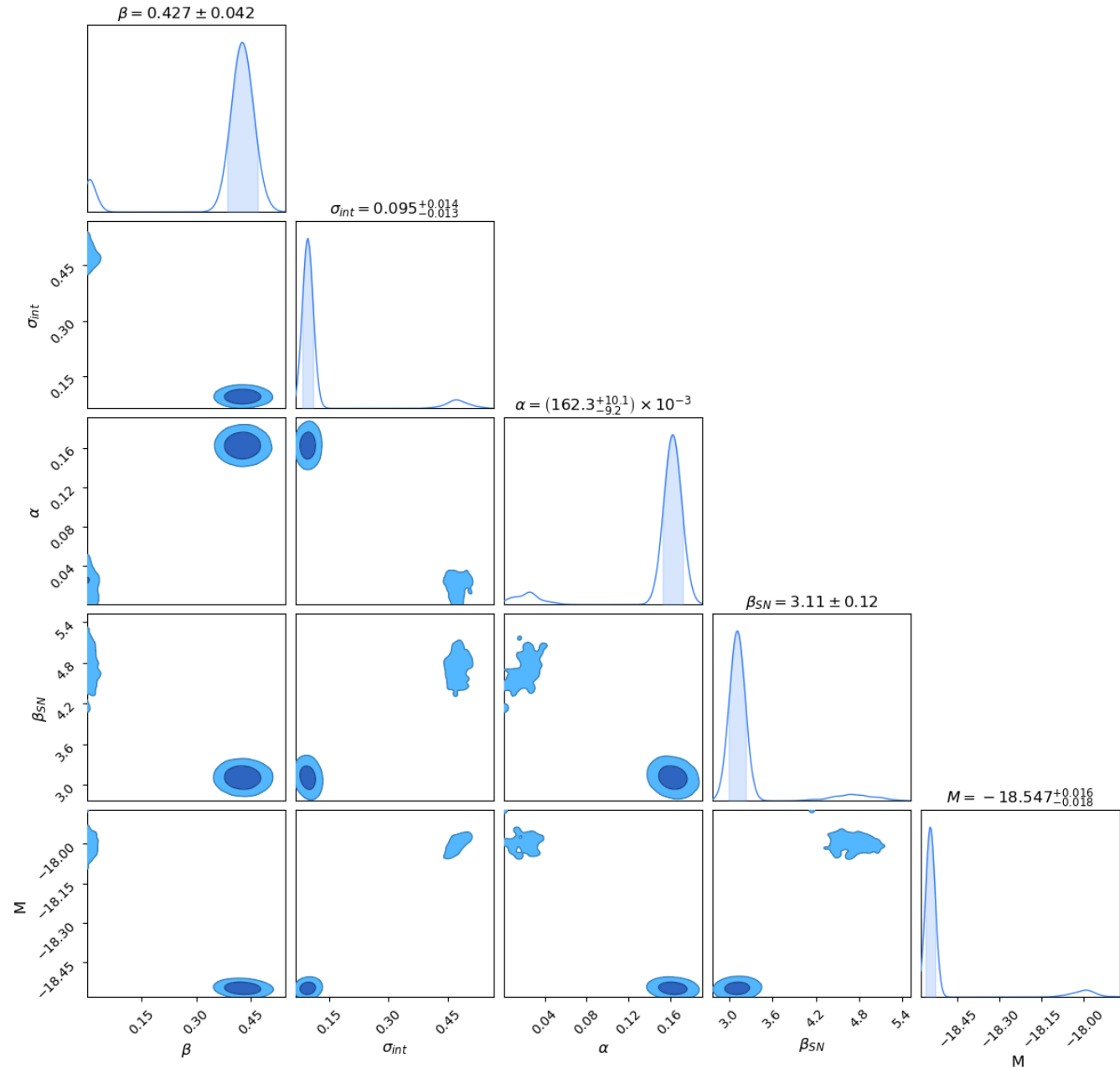
Single Catalog
without
Bias Corrections

Separate Catalogs
with
Bias Corrections

Separate Catalogs
without
Bias Corrections

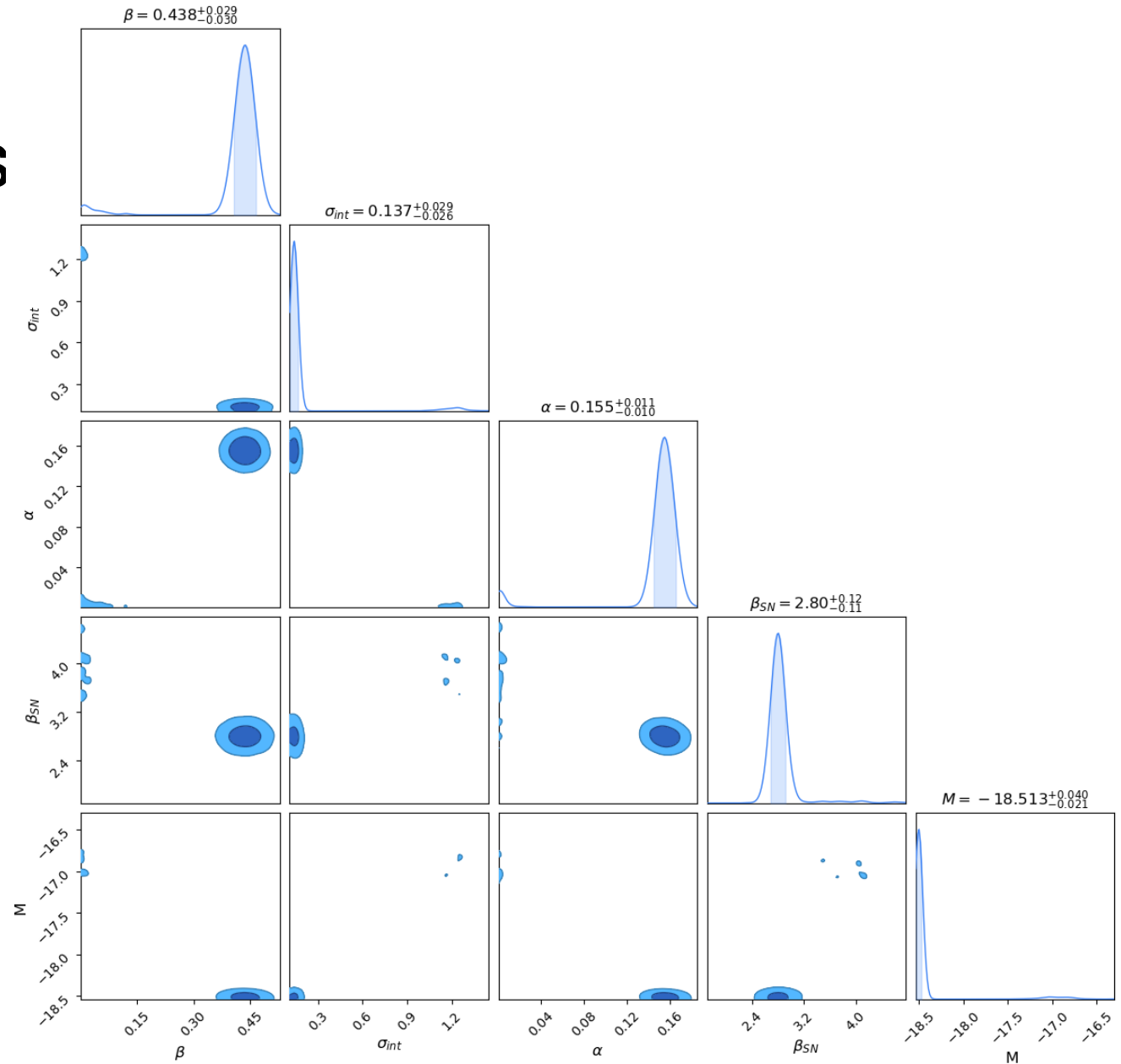
Results: Pantheon+ with bias corrections

- Small likelihood that $\beta = 0$
- Cosmology:
 $\beta = 0.427 \pm 0.042$
- Standardization params:
 $\alpha = .162 \pm 0.01$
 $\beta_{SN} = 3.11 \pm 0.11$
 $M = -18.547 \pm 0.02$



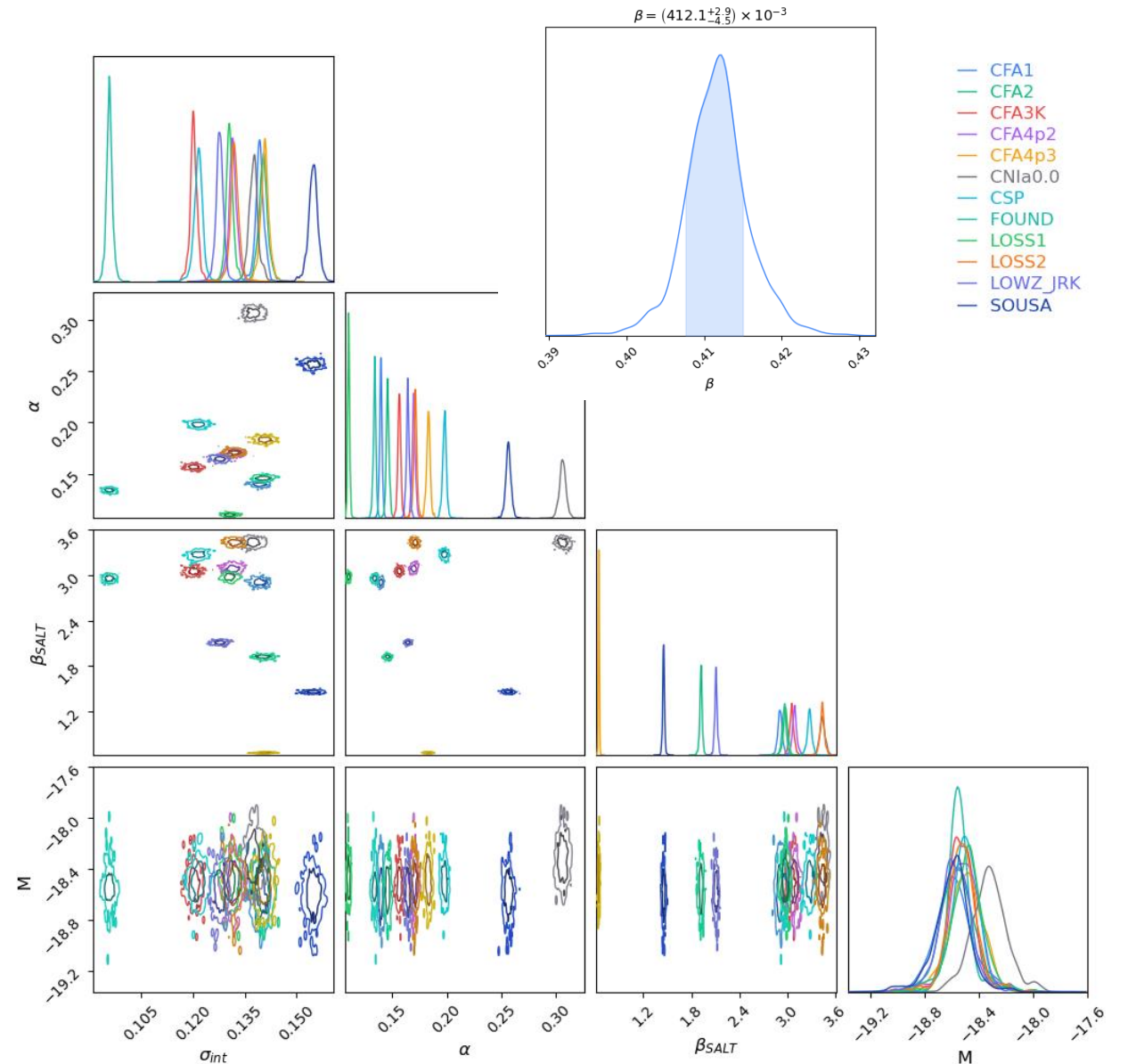
Results: Pantheon+ without bias corrections

- Small likelihood that $\beta = 0$
- Cosmology:
 - $\beta = 0.438 \pm 0.029$
 - Larger value than without bias corrections, smaller error
- Standardization params:
 - $\alpha = 0.155 \pm 0.01$
 - $\beta_{SN} = 2.80 \pm 0.12$
 - $M = -18.513 \pm 0.04$



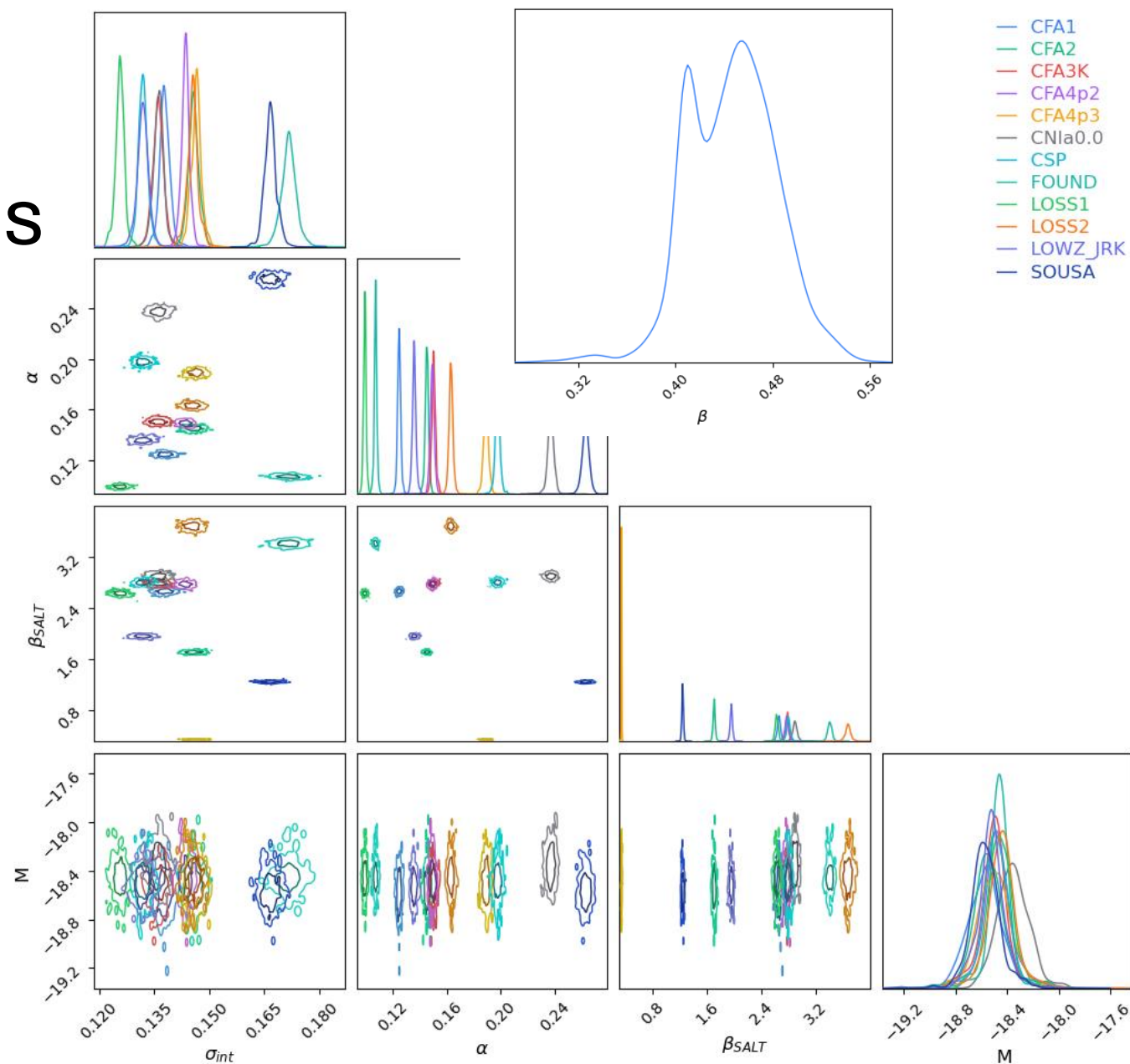
Results: Pantheon+ separated, with bias corrections

- No likelihood that $\beta = 0$
- Cosmology:
 - $\beta = 0.412 \pm 0.002$
 - Much smaller (value + error)
- Standardization params: various
- Overfitting?

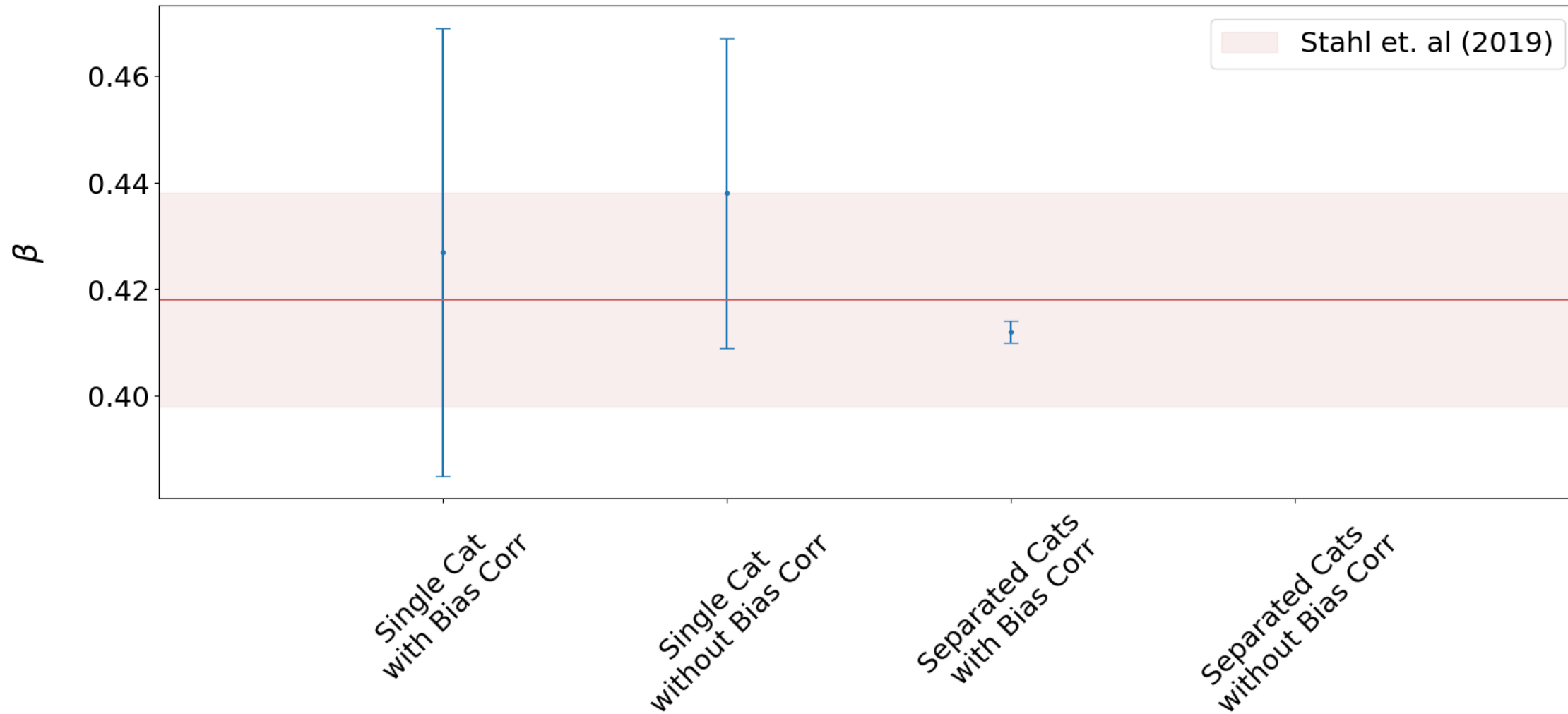


Results: Pantheon+ separated, **without** bias corrections

- No likelihood that $\beta = 0$
- Cosmology: β is unconstrained
- Standardization params: various
- Overfitting?



Pantheon+ Summary



Union3 results incoming

- Union3 does not do direct bias corrections, just adds to the error
- Direct comparison between Pantheon+ and Union3

ZTF & Simulations

- Homogeneous catalog
- Complete catalog: see how volume-limited Malmquist bias affects results
- Pocket effect
- Further project: testing this pipeline with simulations

Next Steps

- Apply analysis to Union3 (just released!) and ZTF cosmology data
- Examine the mass reconstruction procedure in depth
- Test pipeline with simulations

Summary

- Measurements of $f\sigma_8$ need to be consistent between data sets, so we are examining how different correction mechanisms between catalogs affect measurements
- Pantheon+ results alone are rather enlightening:
 - Treating compiled catalogs as fully homogenous might not be reliable
 - Selection bias could play a significant role in the final $f\sigma_8$ measurement
- Adding Union3 and ZTF will give us a better vantage point
- Further work in testing pipeline with simulations is underway