Durham-Edinburgh eXtragalactic Workshop XIV

IfA Edinburgh

Cosmology with weak-lensing peak counts

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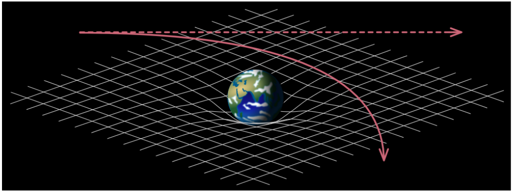
Outline

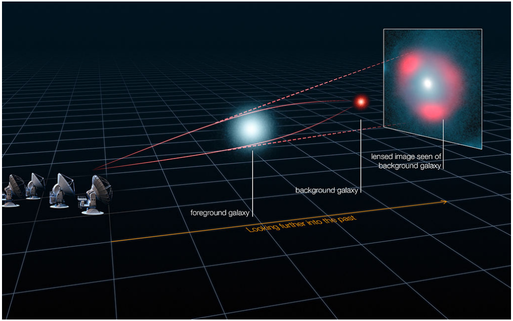
Motivation	Why do we study WL peaks?
Problems	How to model WL peaks?
Methodology	A stochastic approach
Results	Cosmological constraints and others
Perspectives	Improvements and new physics

Motivation

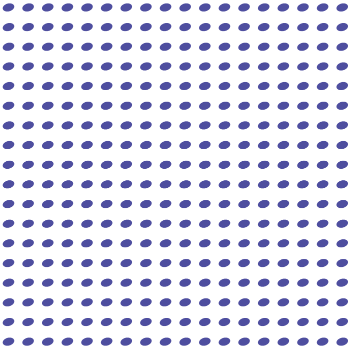
General relativity



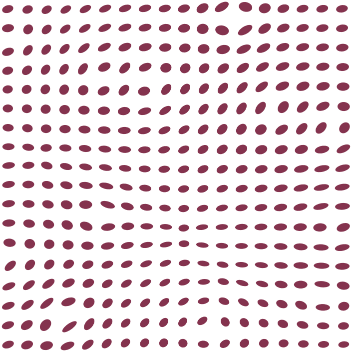
Gravitational lensing



(Source: ALMA)

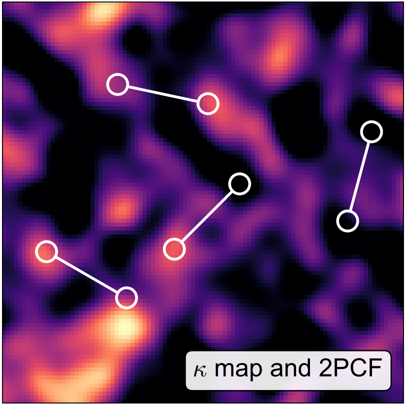


Unlensed sources



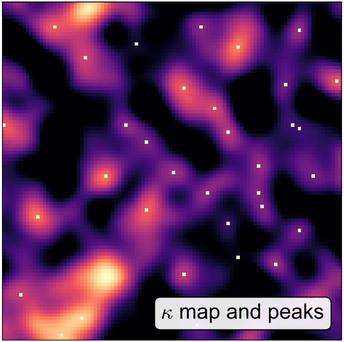
Weak lensing

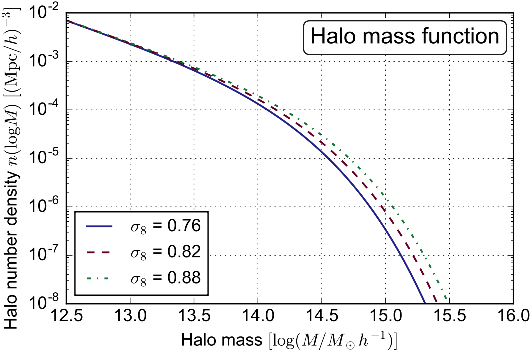
Gaussian information



But the lensing field is highly non-Gaussian

Weak-lensing peak counts





- Local maxima of the projected mass
- Probe the mass function
- Constrain cosmology

Problems

Dealing with selection function

Projection effects, irregular sampling, noise, ...

Early studies

Count only the true clusters with high S/N
(Kruse & Schneider 1999, 2000; Reblinsky et al. 1999)

Recent studies

Include the selection effect into the model

- Analytical formalism
- N-body simulations
- Fast stochastic model (this work)

Difficulties

Analytical models

- Fan et al. (2010) and series; Shirasaki (2017)
- Difficult to handle masks and photo-z bias
- Difficult to include baryons or intrinsic alignment
- Need external covariances

N-body simulations

- Dietrich & Hartlap (2010) and series; Kratochvil et al. (2010) and series
- Very expensive time costs

Challenges

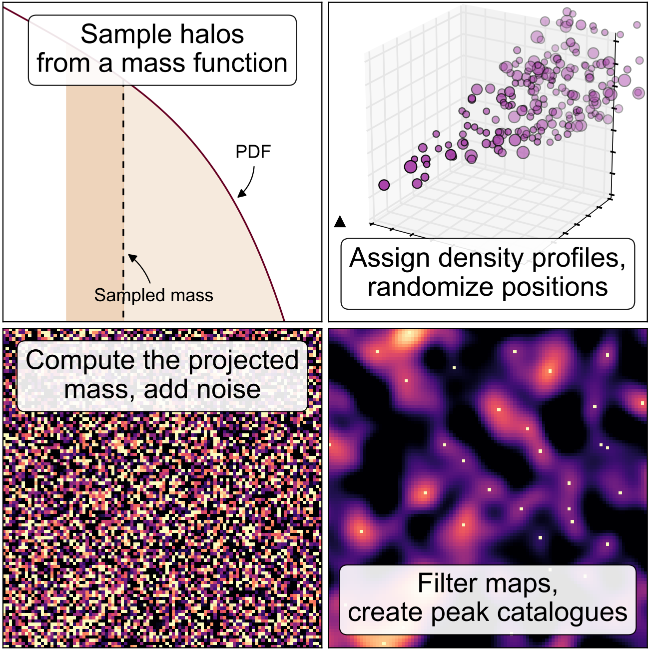
How to model properly weak-lensing peak counts?

How to resolve the trade off between flexibility and speed?

What cosmological information can we extract from peaks?

A new model

A stochastic model to predict weak-lensing peak counts



Lin & Kilbinger (2015a)

Advantages

Fast

Flexible

Full PDF information

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Only few seconds for creating a 25-deg^2 field, without MPI or GPU

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Full PDF information

Estimate covariances easily
Go beyond the Gaussian likelihood assumption

Validation

We compare the following four cases:

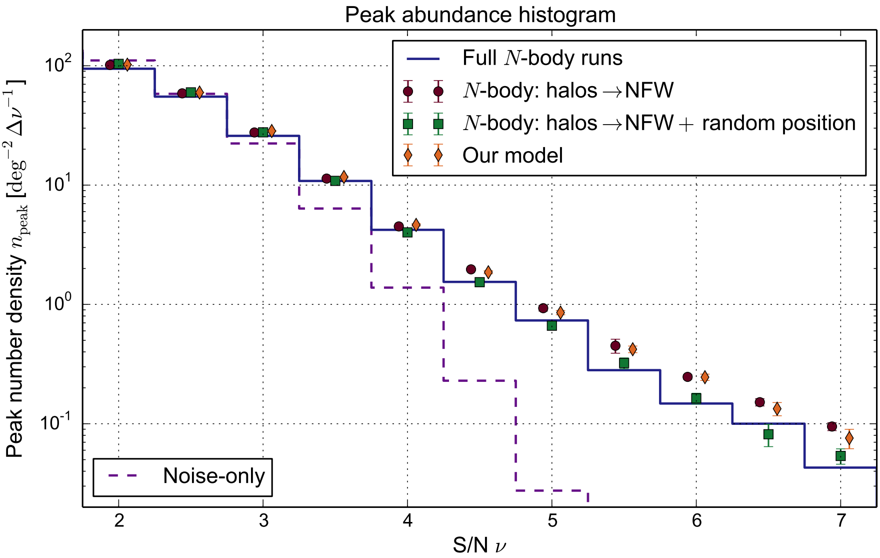
Case 1 — Full N-body runs
Case 2 — Replace N-body halos with NFW profiles of the same mass
Case 3 — Profile replacement and position randomization
Case 4 — Our model

to test two hypotheses:

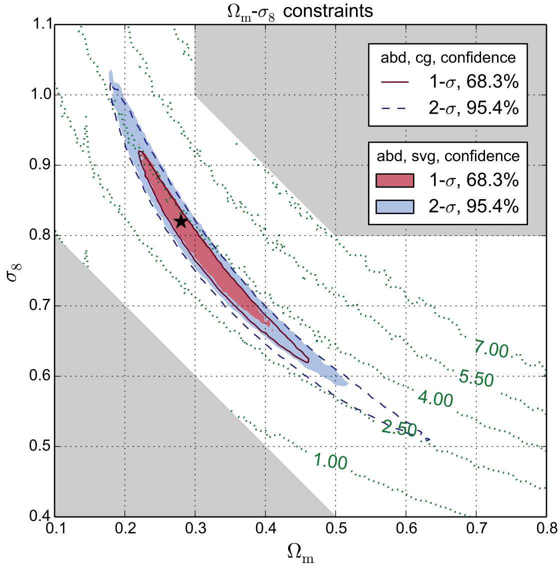
Comparison 1 & 2 — Ignore unbound matters & halo asphericity
Comparison 2 & 3 — Absence of the spatial correlation
Comparison 3 & 4 — Mass function

Lin & Kilbinger (2015a)

Validation



Results



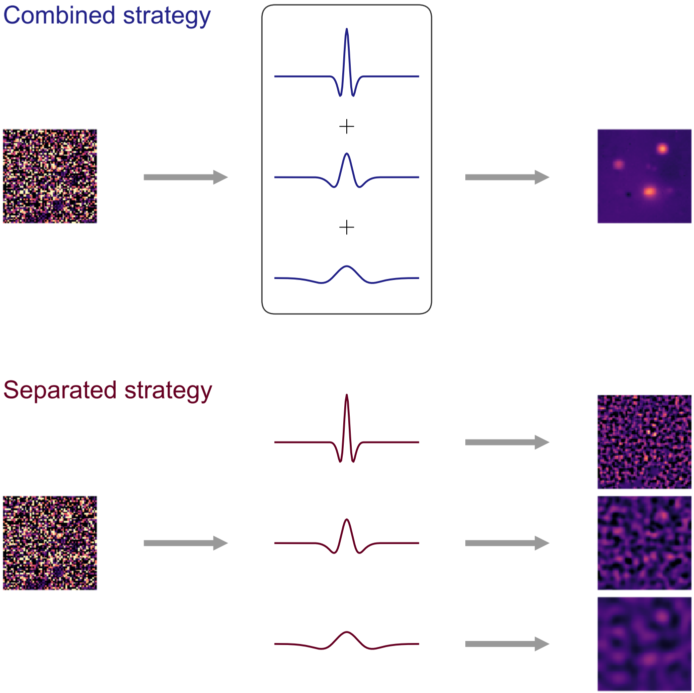
Cosmology-dependent covariance

$$L = \text{cst} + \Delta\boldsymbol{x}^T \boldsymbol{C}^{-1} \Delta\boldsymbol{x}$$

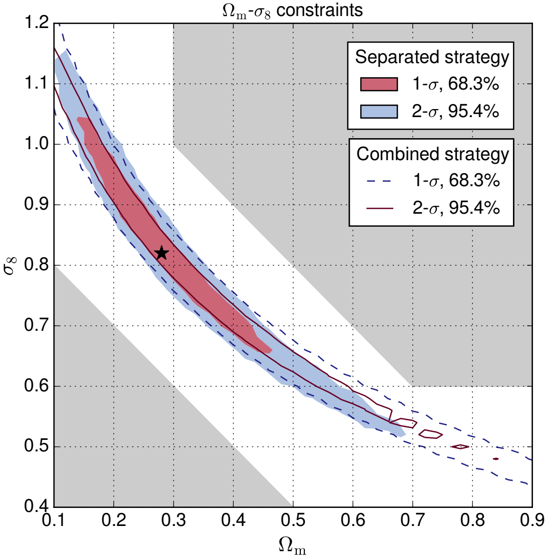
cg = constant covariance
svg = varying covariance

	cg	svg
FoM	46	57

Lin & Kilbinger (2015b)



Combined strategy
+
+
Separated strategy



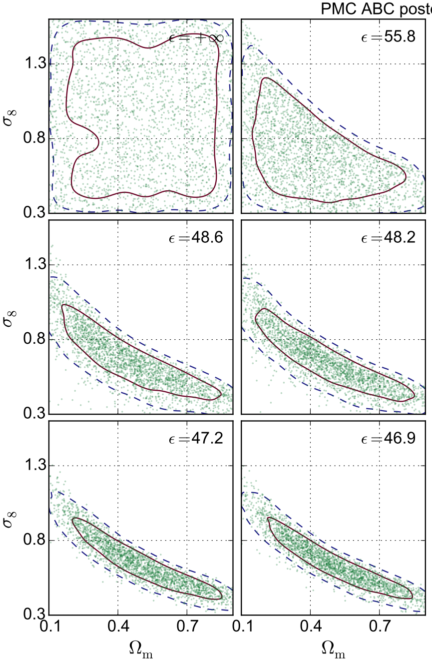
Combined vs separated

The combined map creates degeneracy which elongates the contours.

Lin et al. (2016)

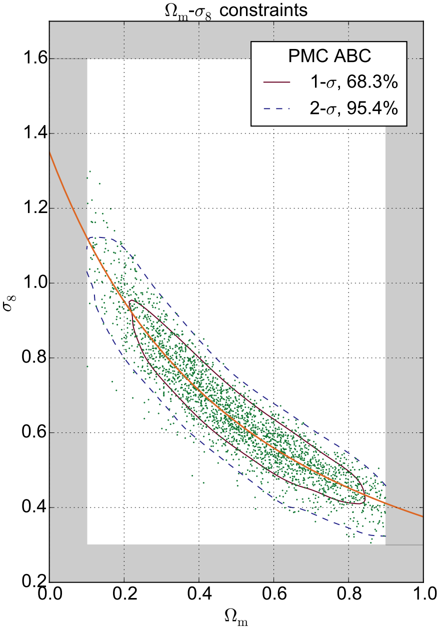
Data from three surveys

Survey	Field size [deg^2]	Number of galaxies	Effective density [deg^{-2}]
CFHTLenS	126	6.1 M	10.74
KiDS DR1/2	75	2.4 M	5.33
DES SV	138	3.3 M	6.65



Cosmological constraints

with
approximate Bayesian
computation (ABC)



Cosmological constraints

Width: $\Delta\Sigma_8 = 0.13$

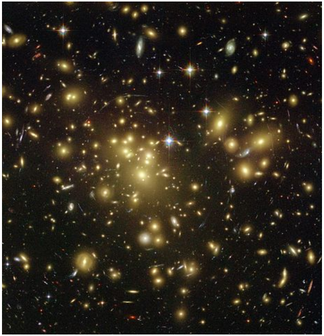
Area: FoM = 5.2

Lin (2016)

Perspectives

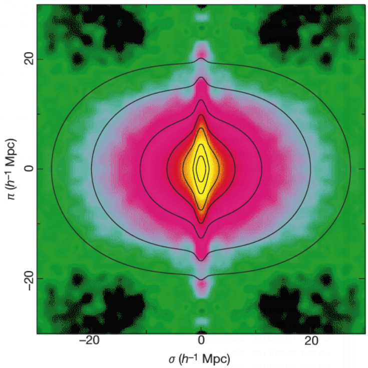
Improvements

Account for
halo clustering



(Source: HST)

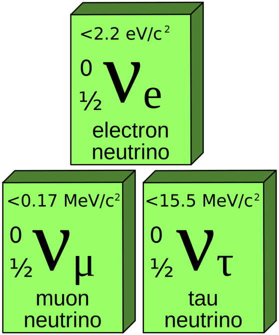
Extend to
redshift space distortions



Peacock et al. (2001)

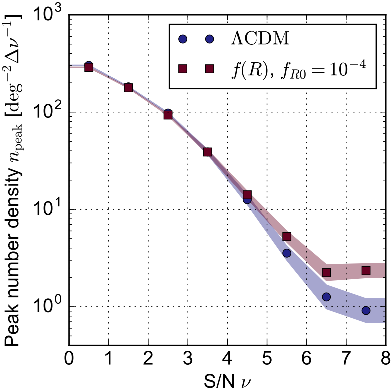
More physics

Massive neutrinos



(Source: MissMJ@Wikimedia/CC BY 3.0)

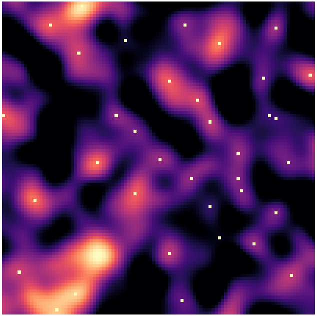
Modified gravity



(Preliminary)

Summary

- Peaks provide non-Gaussian information
- A stochastic model to predict WL peak counts
- Fast, flexible, full PDF information
- A public code: Camelus@GitHub



Collaborators:

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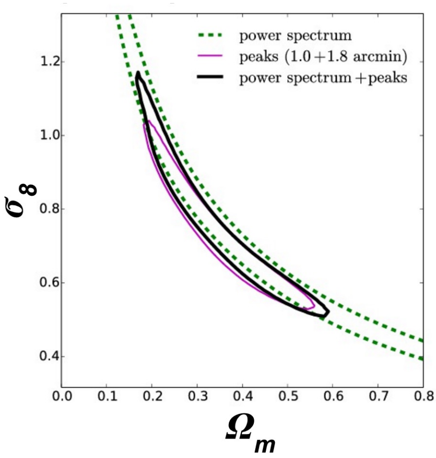
Sandrine Pires (CEA Saclay)

References:

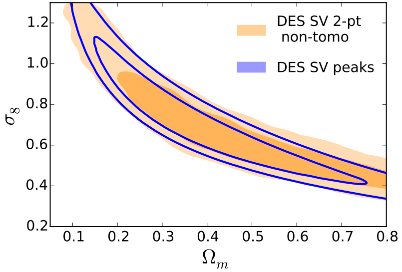
[1410.6955]	[1612.02264]
[1506.01076]	[1612.04041]
[1603.06773]	[1704.00258]
[1609.03973]	http://linc.tw

Backup slides

Peaks vs two-point statistics

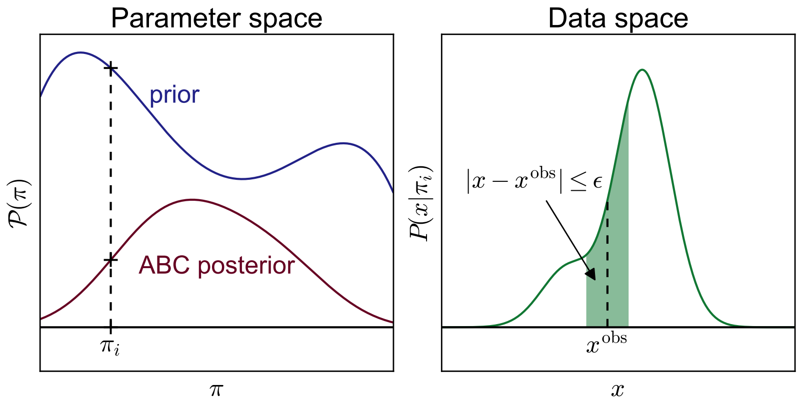


Liu J et al. (2015)



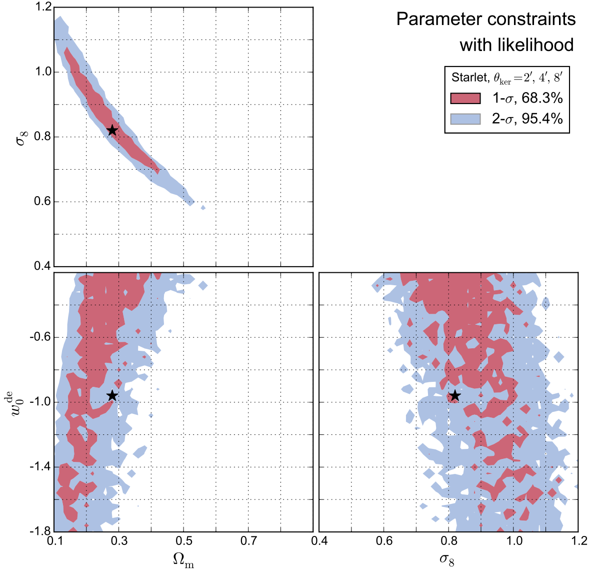
Kacprzak et al. (2016)

Approximate Bayesian computation



$$\begin{aligned} \text{Distribution of accepted } \pi &= \text{prior} \times \text{green area} \\ &\approx \text{prior} \times 2\epsilon \times \text{likelihood} \\ &\propto \text{posterior} \end{aligned}$$

Degeneracy with w_0^{de}



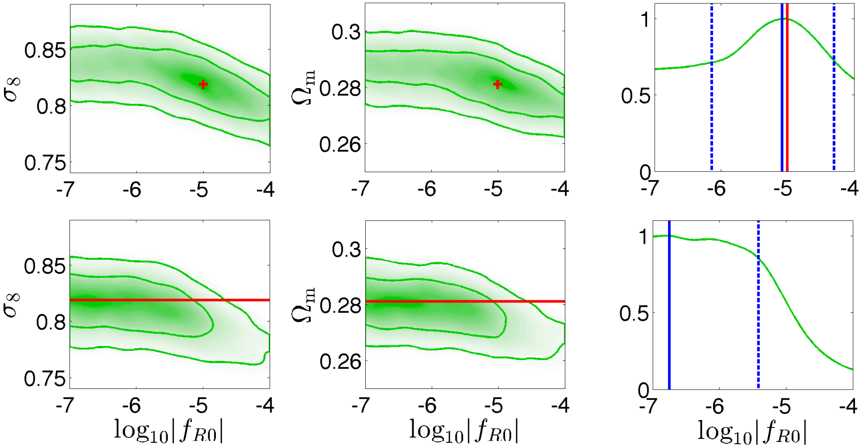
Parameter constraints with likelihood

Starlet, $\theta_{\mathrm{ker}} = 2', 4', 8'$
1-σ, 68.3%
2-σ, 95.4%

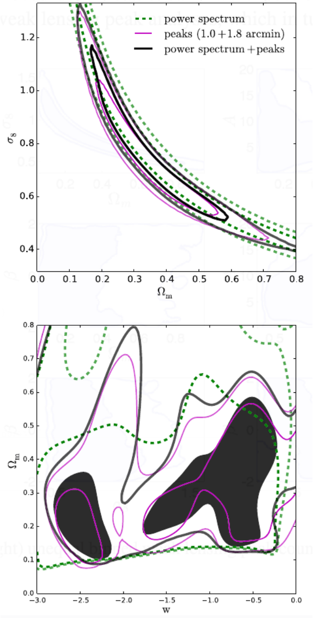
Lin et al. (2016)

Liu X et al. (2016)

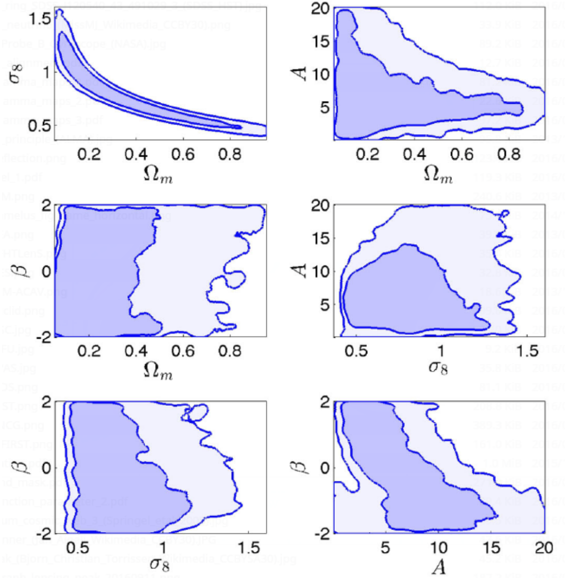
f_{R0} constraints



Other studies



Liu J et al. (2015)



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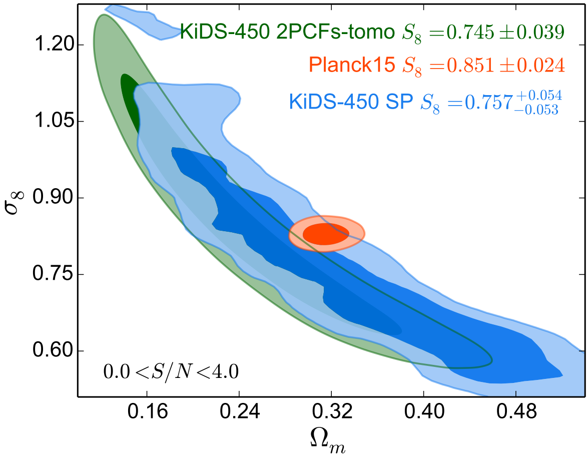

Other studies

Martinet et al. (2018)