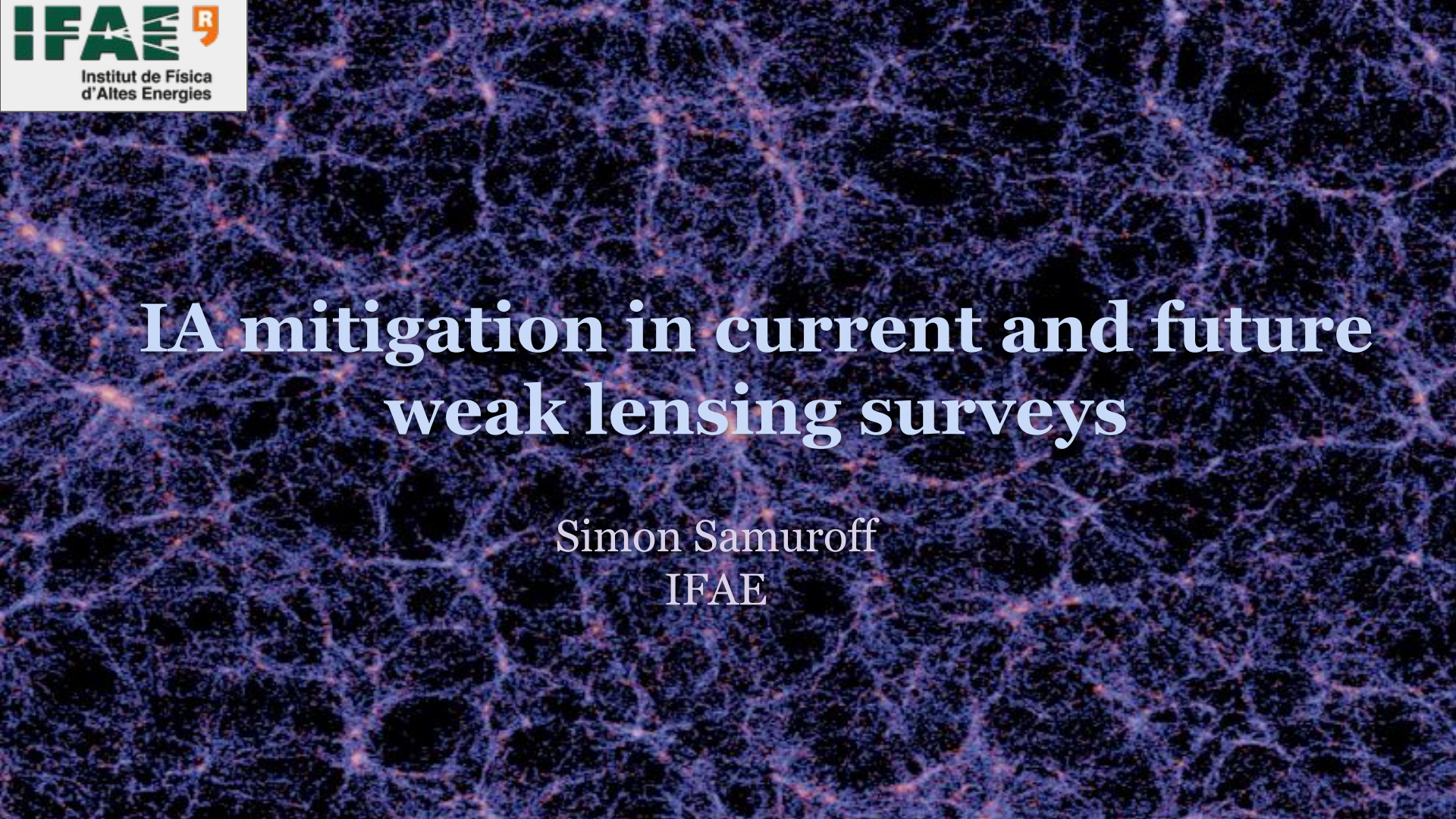

IA mitigation in current and future weak lensing surveys

Simon Samuroff
IFAE

Outline

1. Basic concepts and setup
2. IA mitigation approaches
3. Conclusions/the future

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1. **Basic concepts and setup**
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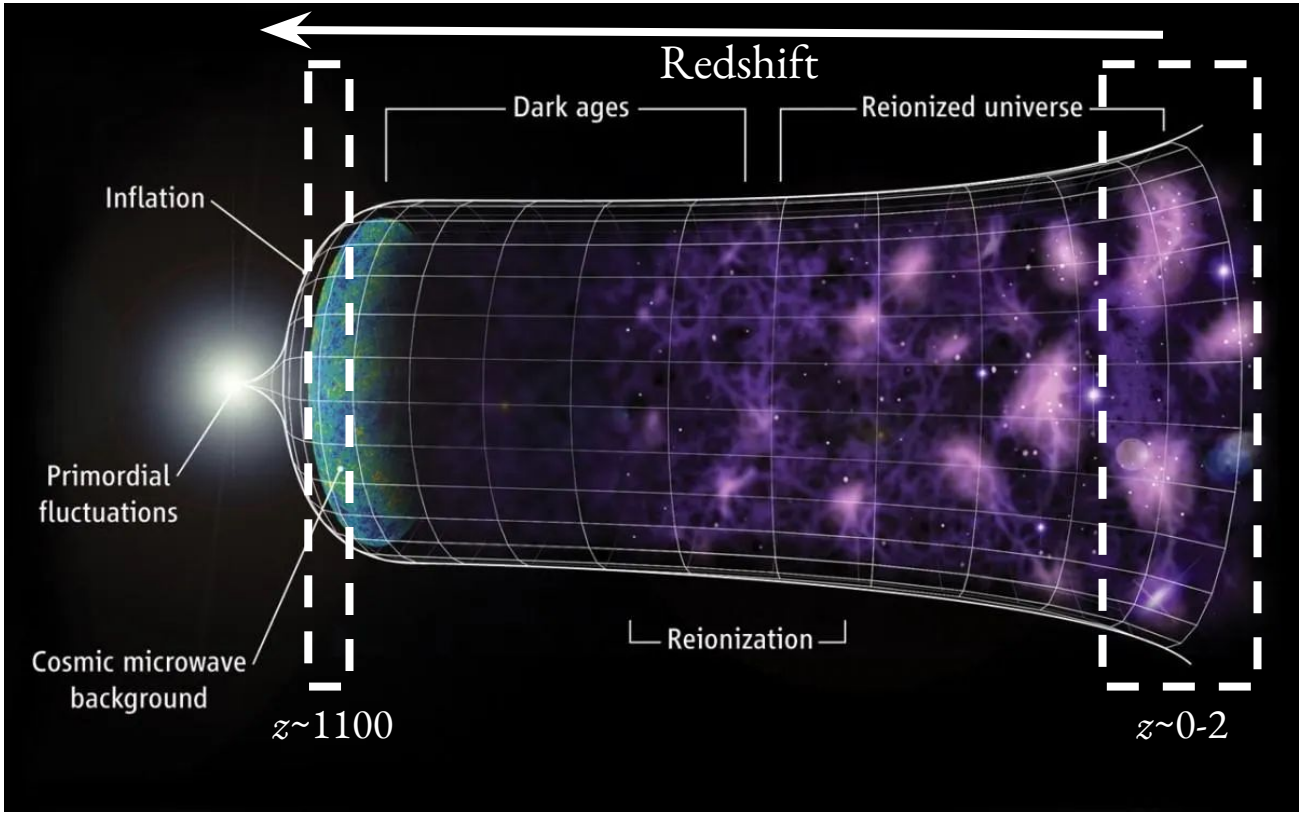
Cosmology with galaxy surveys



Galaxy imaging surveys really only probe the low-redshift part of the Universe

The CMB is sensitive to very high redshift (z~1100)

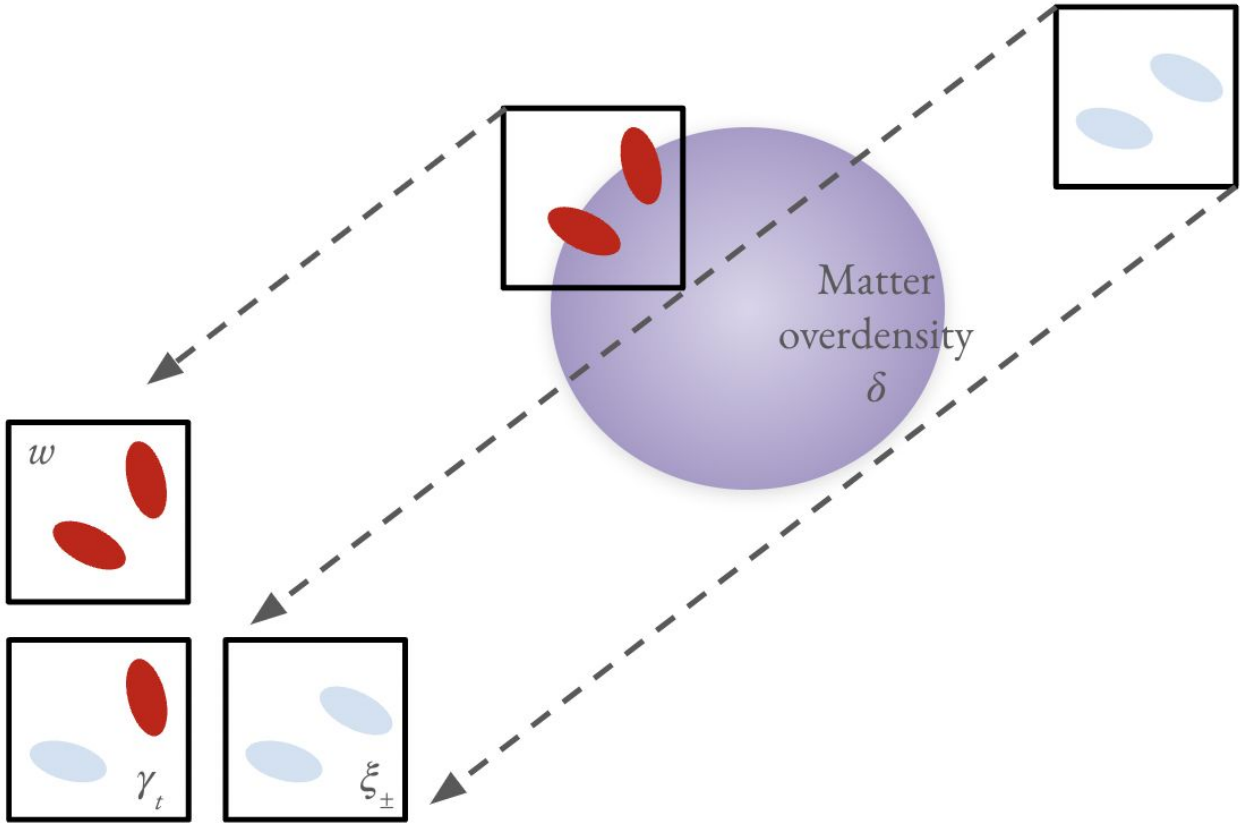
Comparing the two lets us test the consistency of ΛCDM

Cosmology with galaxy surveys

Three main ways galaxies can be used to constrain cosmology:

- shear-shear (cosmic shear)
- position-shear (galaxy galaxy lensing)
- position-position (galaxy clustering)

All three are ultimately sensitive to the low-redshift matter power spectrum $P(k)$

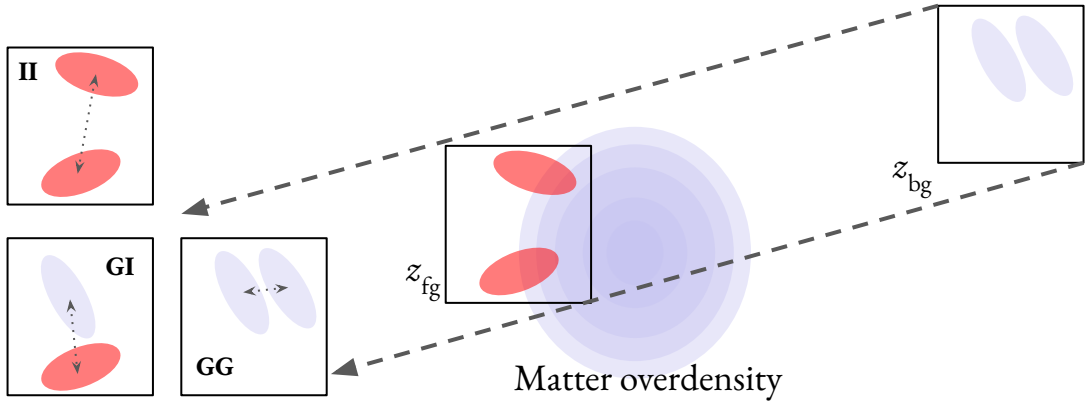


Intrinsic alignments

Intrinsic alignments are an astrophysical systematic, analogous to baryonic feedback and redshift error

IAs are fundamentally different, however, in that they do not modify the matter power spectrum, but are rather are an extra signal that can mimic lensing
They also appear across a range of physical scales, meaning cutting is not a workable option

Fortunately, we do have physically motivated models for IAs, so we can model/marginalise



Intrinsic alignments

Choice of IA model can have a significant impact on both the preferred S8 and the constraining power of a given dataset

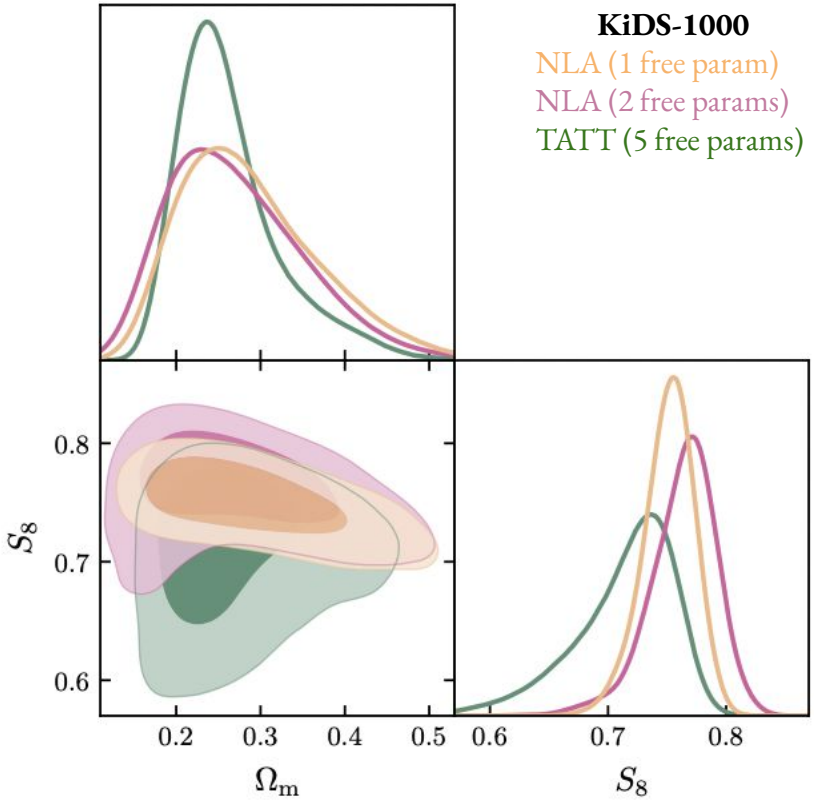


Figure from DES & KiDS Collab 2023

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IA mitigation

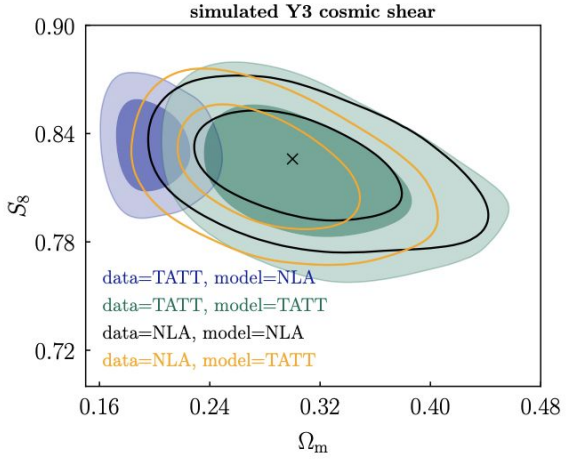
Let's define "mitigating" IAs as reaching a situation where they no do not dominate the overall error budget

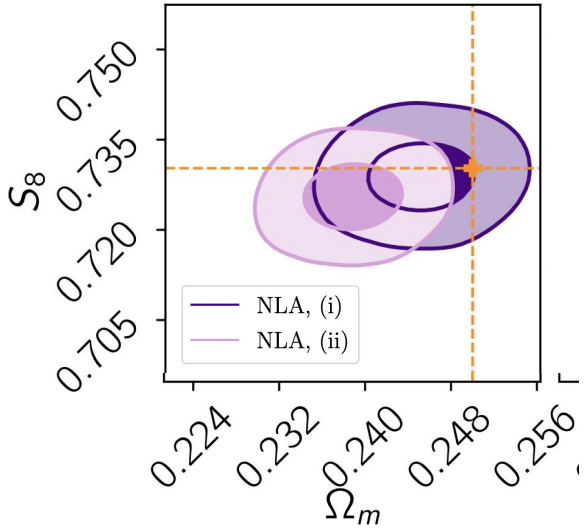
We have a few possibilities:

- **Model simplification:** find a subspace of IA parameters that do not degrade cosmological constraining power
- **Sample selection:** choose a subset of galaxies for which IAs are subdominant/non-existent
- **Priors:** keep our IA model relatively complex, but derive informative priors on its parameters somehow
- **(Hope things work out ok:** maybe better data will self calibrate itself...)

Opt 1: model simplification/selection

- The simpler the model, the less constraining power is lost to its parameters
- **But** the simpler the model, the more risk there is of bias due to mismodelling
- We can construct tests and make choices, but the results often reflect subjective preferences
- One way round this is data driven model selection (e.g. *Campos et al 2023*)
- Doesn't remove the possibility that the data need a complex IA model, but does reduce the chances of over-fitting

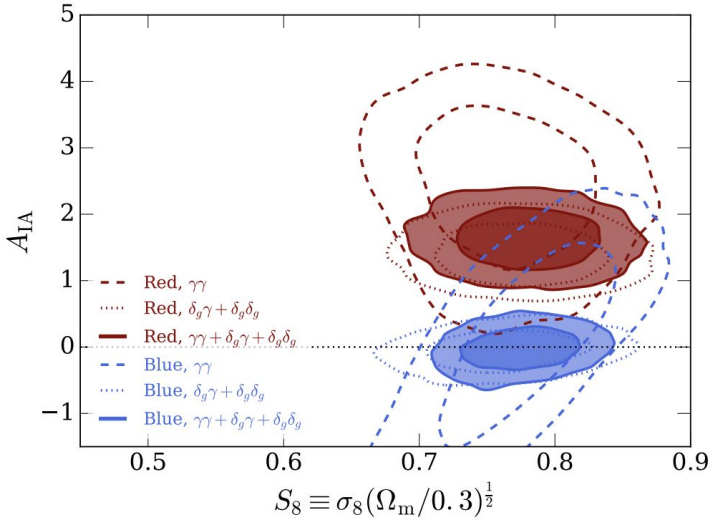


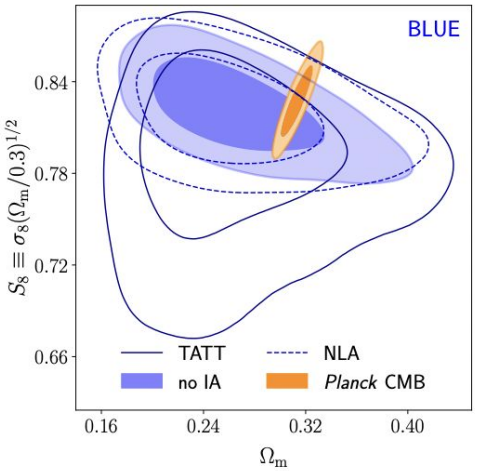


Figures from Secco & Samuroff et al 2022 (upper) and Fortuna et al 2020 (lower)

Opt 2: sample selection

- IAs are strongly dependent on galaxy properties
- We know that blue/spiral galaxy alignments are much weaker than in bright red galaxies, for example
- → colour/type cuts can be used to amplify/reduce the IA signal (or at least disentangle different types of alignment)
- → in principle a blue-selected lensing sample should be less affected by IAs, and so require less complicated modelling





Figures from Samuroff et al 2019, McCulloch et al 2024

Opt 3: calibrating priors

- Potentially more promising avenue is to use photometric-spectroscopic* cross correlations to measure IAs
- These are called *direct IA measurements* (see Christos' talk)
- Key thing to understand is that to do this you need both shapes and precise per-galaxy redshifts, which limits the kinds of samples one can use
- See e.g. *Hervas Peters et al 2024*, *Samuroff et al 2023*, *Fortuna et al 2022*, *Johnston et al 2019*, *Joachimi et al 2009, Mandelbaum et al 2008*

Opt 3: calibrating priors

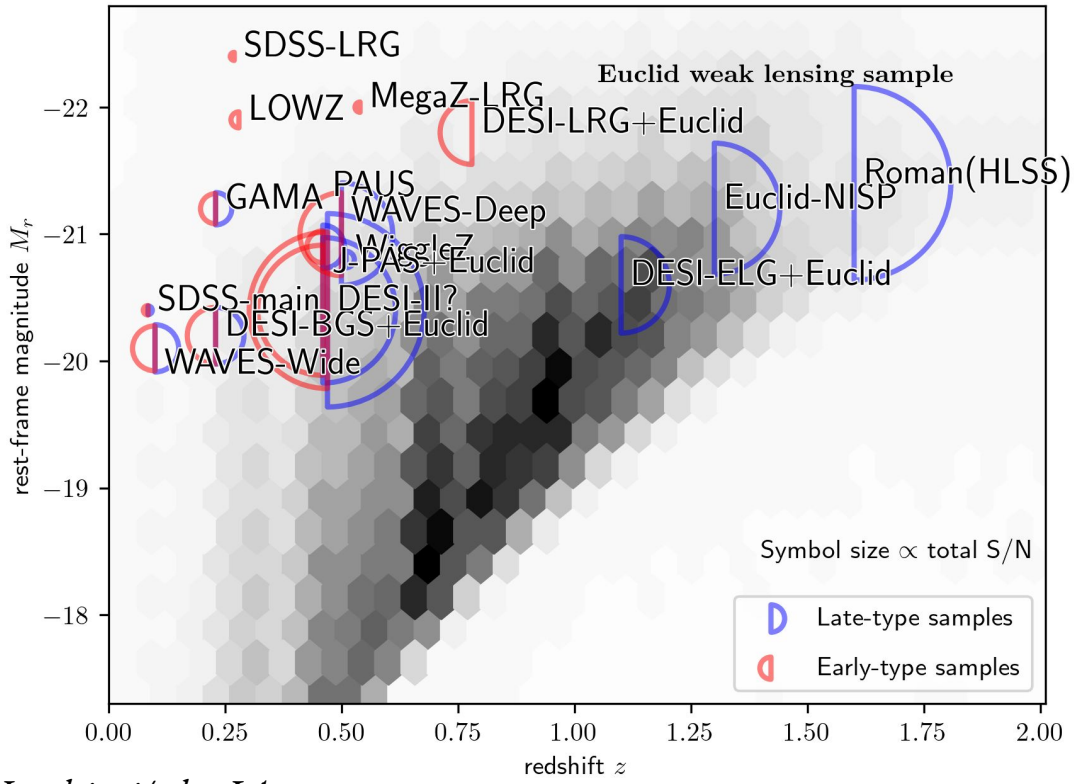


Figure credit: Benjamin Joachimi/echo-IA

Opt 4: hope things work out ok

- It's really difficult what will happen in future datasets – big gains in data power will constrain IA parameters better
- → much less messiness from projection effects, unconstrained tails etc
- Most recent lensing measurements also tend to prefer small IA amplitudes
- But any model inaccuracies will become more important as posteriors shrink, and data gets deeper

- **Ideally:** TATT model expansion is sufficient, no unexpected behaviour in blue high-z galaxies, IAs naturally become sub-dominant due to self-calibration

- **Realistically:** given the assumptions, it seems like a bad idea to rely on this

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Conclusions

- For current weak lensing datasets, IAs are a major part of the systematic error budget (implicitly or explicitly)
- No real consensus on how complicated an IA model is needed and how to interpret shifts between models
- Considerable amount of uncertainty in the nature and significance of IAs in future datasets
- But in principle we have mitigation techniques – though they rely on work on implementation and/or more calibration data

Institut de Física d'Altes Energies

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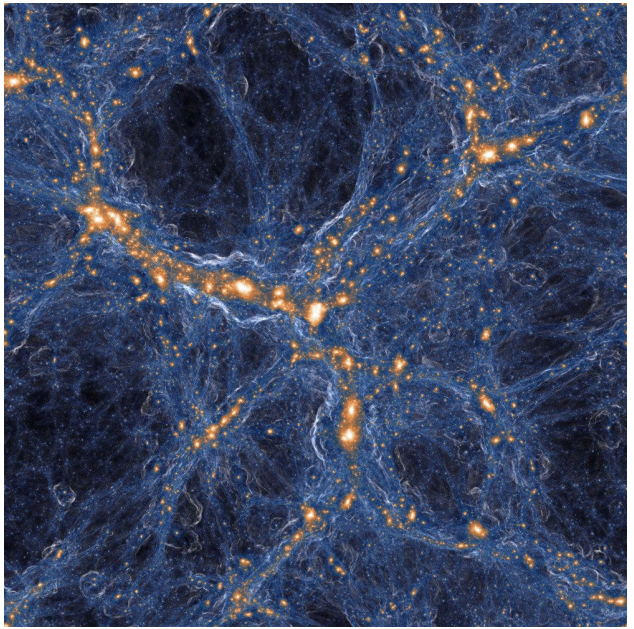
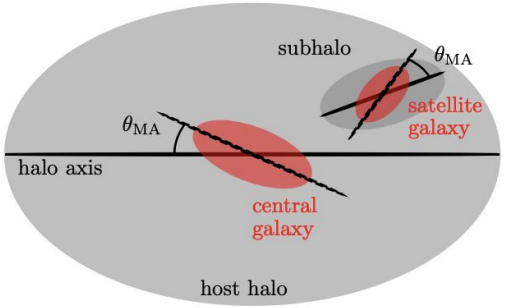
Simon Samuroff
IFAE

Opt 3: calibrating priors

- Various studies have tried to learn about IAs, using different hydrodynamic simulations
- It is, however, difficult to ensure a realistic galaxy sample
- Hydro sims are also typically fairly small, meaning statistical uncertainties are large - especially on large scales/small *k*
- The constraints are slightly limited by the extent to which we can trust the baryonic physics of the simulations (which is a notoriously difficult problem)





Figures from IllustrisTNG Collab. (upper) and Van Alfen et al 2024 (lower)