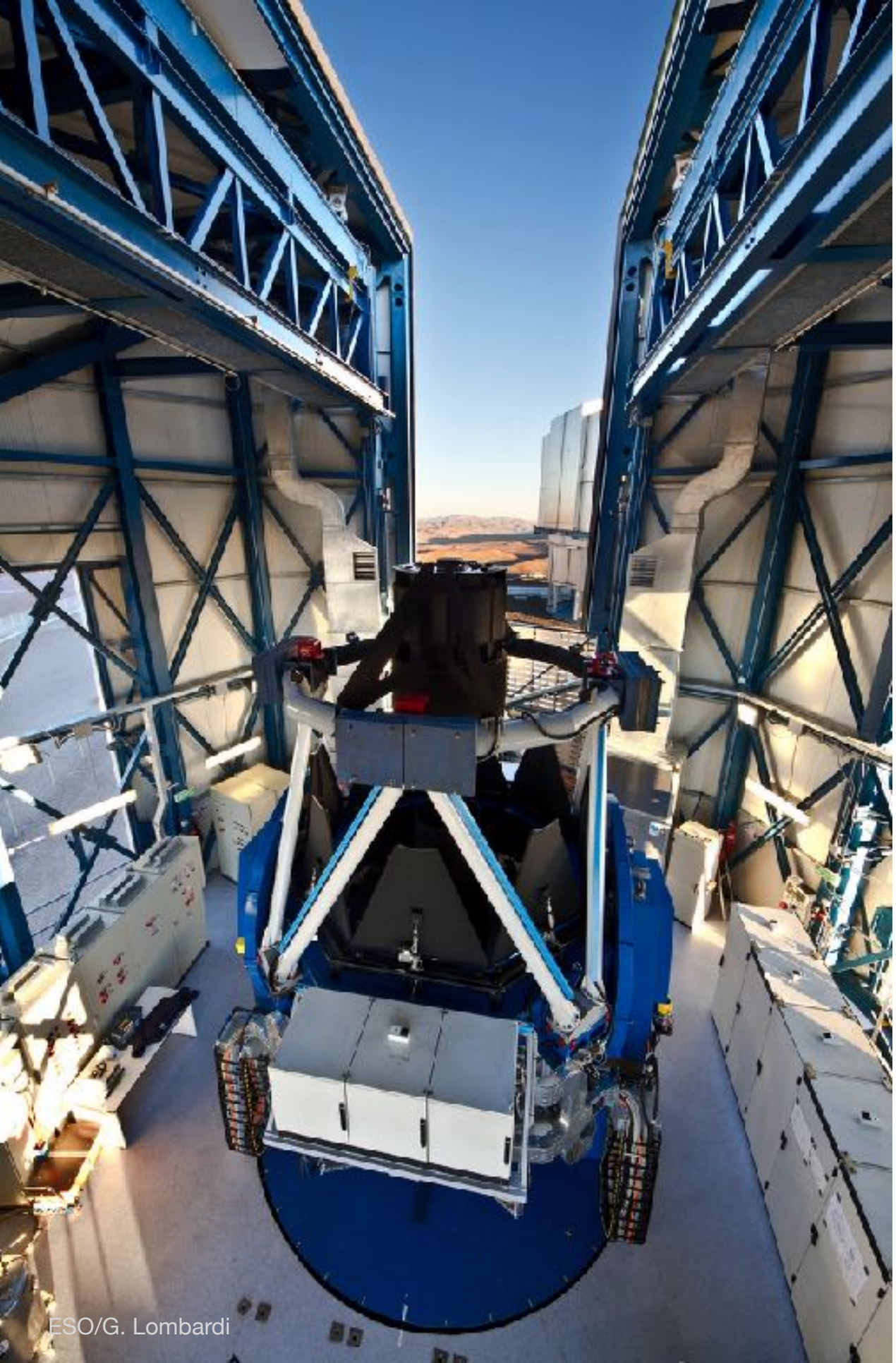
Cosmology with the Kilo-Degree Survey

Tilman Tröster

LineA webinar
1 Apr 2021



KiDS

Optimised for weak lensing

- 1000 deg^2 analysed
  - Full survey: 1350 deg^2
- 21 million galaxies

Overlap with VIKING

- 9 photometric bands

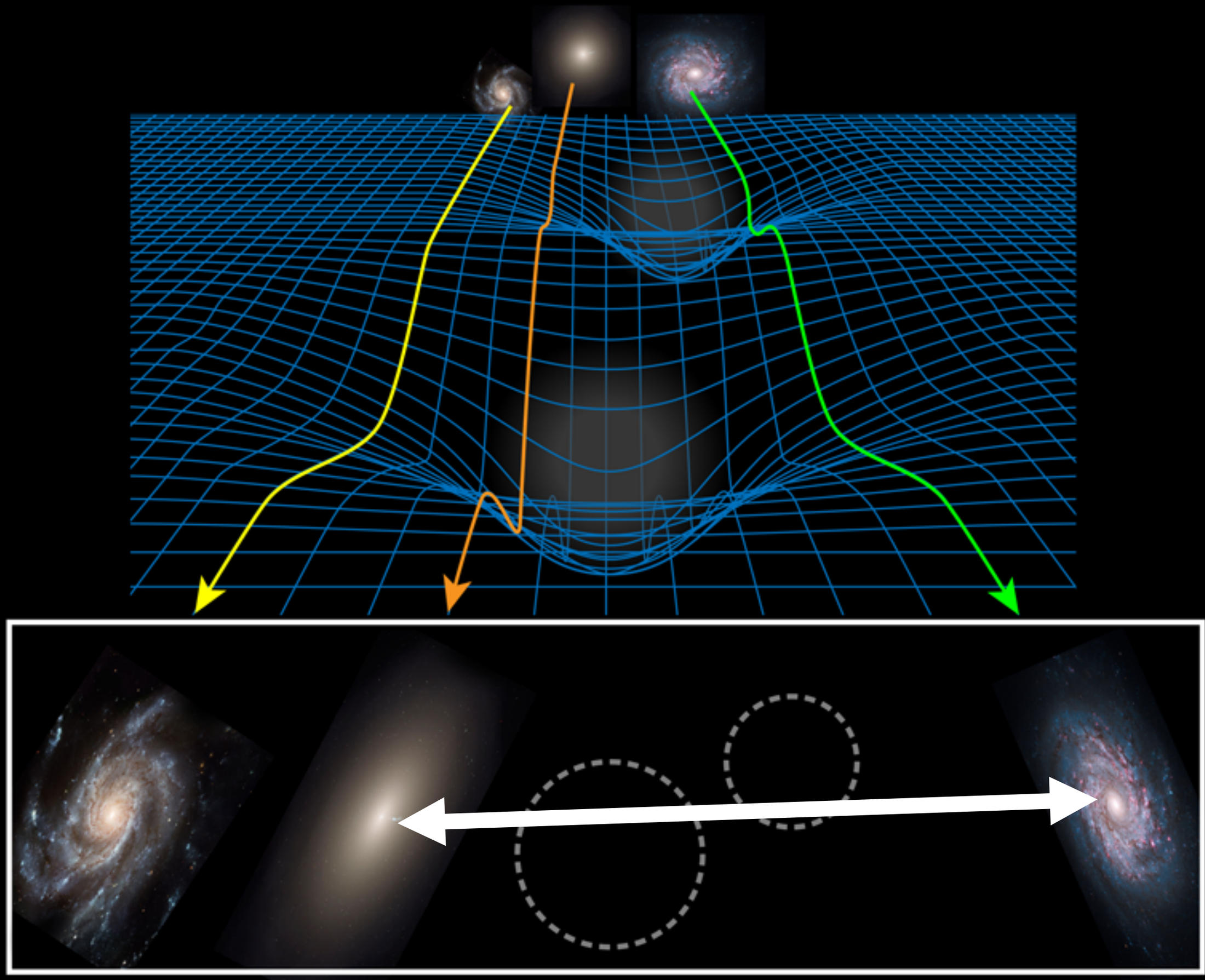
Cosmic probes

Cosmic shear

Cosmic probes

Cosmic shear

- correlation between galaxy shapes



APS/Alan Stonebraker; galaxy images from STScI/AURA, NASA, ESA, and the Hubble Heritage Team

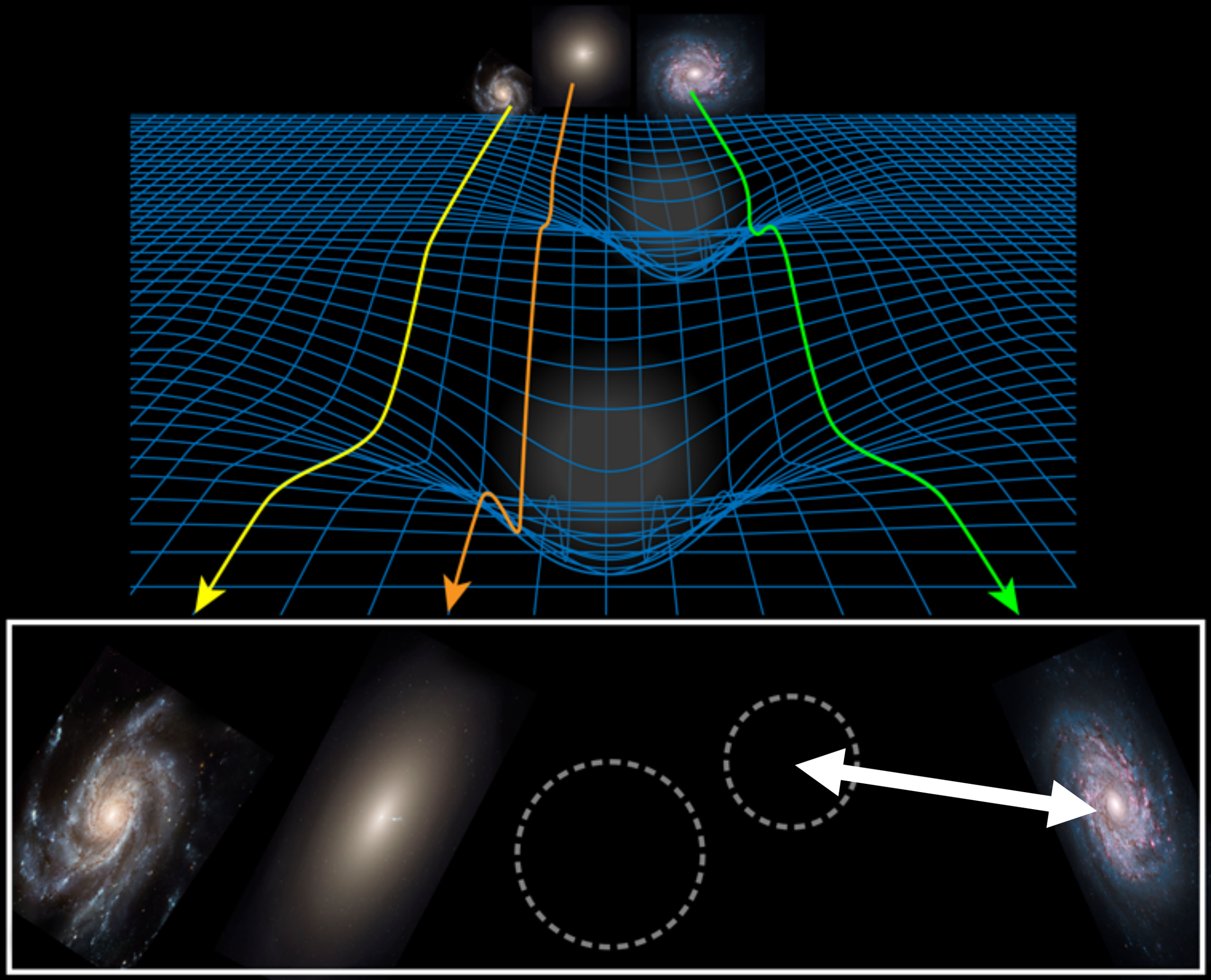
Cosmic probes

Cosmic shear

- correlation between galaxy shapes

Galaxy-galaxy lensing

- correlation between galaxy positions and galaxy shapes



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Cosmic probes

Cosmic shear

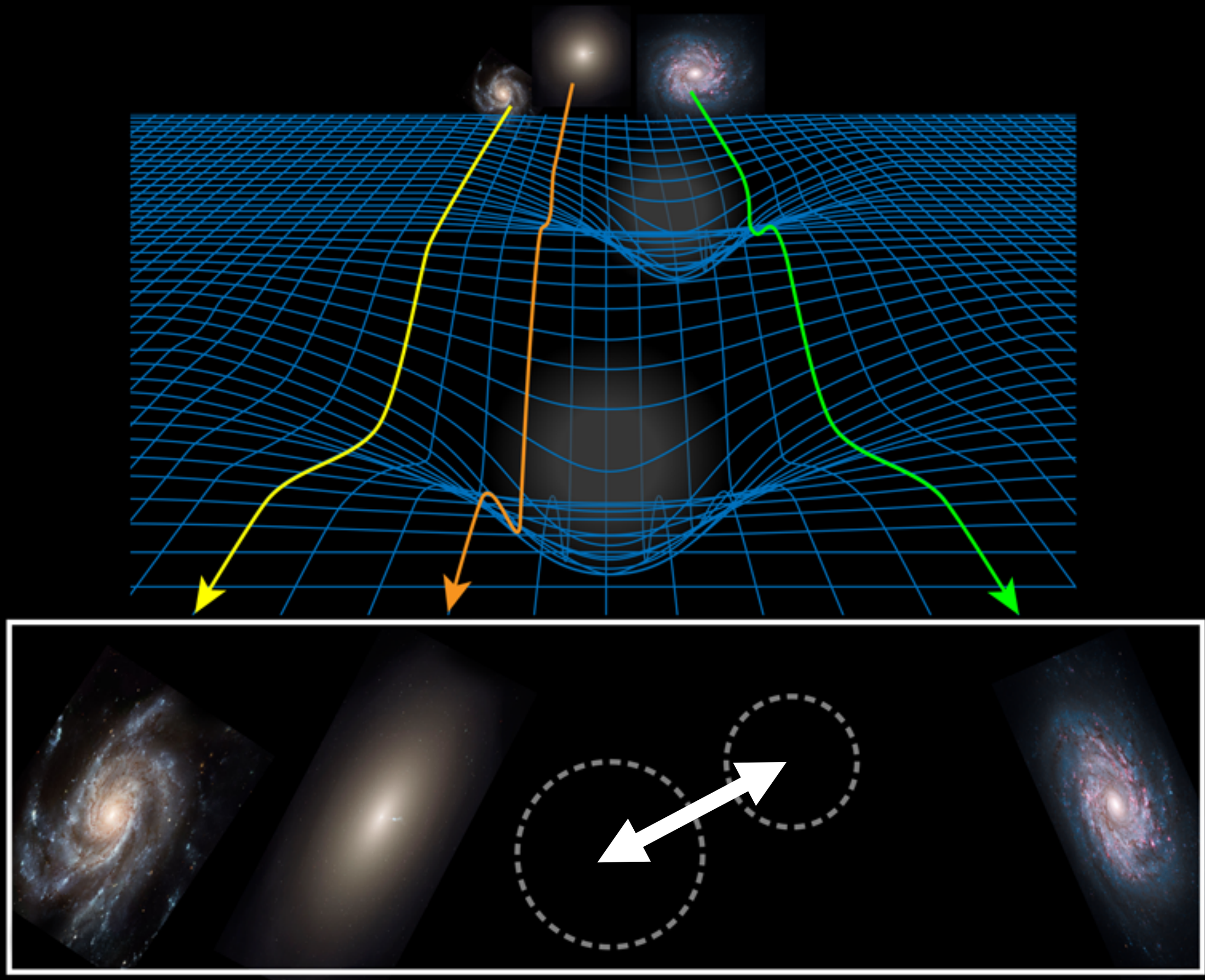
- correlation between galaxy shapes

Galaxy-galaxy lensing

- correlation between galaxy positions and galaxy shapes

Galaxy clustering

- correlation between galaxy positions



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Cosmic probes

3x2pt

- Joint analysis of
  - Cosmic shear
  - Galaxy-galaxy lensing (GGL)
  - Galaxy clustering

Data

Cosmic shear

- Kilo-Degree Survey (KiDS-1000)

Galaxy-galaxy lensing

- Foreground galaxies
  - BOSS DR12
  - 2dFLenS
- Background shapes
  - KiDS-1000

Galaxy clustering

- BOSS DR12

KiDS-N

5°
0°
-5°
-135°
180°
135°

KiDS-S

-30°
-40°
30°
0°
-30°

$r_{\rm lim}$

25.75 26 26.25 26.5 26.75

60°
30°
-30°
-60°
-120°
180°
120°
60°
0°
-60°
RA
DEC

BOSS
2dFLenS
KiDS
Overlap

Survey footprints

Joachimi, Lin+ 2021

KiDS-1000 core papers

Cosmic Shear Cosmology

- Asgari, Lin, Joachimi et al. (arXiv: 2007.15633)

Combined Probe Cosmology

- Heymans, Tröster et al. (arXiv: 2007.15632)

Beyond flat ΛCDM

- Tröster et al. (arXiv:2010.16416)

Methodology

- Joachimi, Lin, Asgari, Tröster, Heymans et al. (arXiv: 2007.01844)

Photometric Redshifts

- Hildebrandt, van den Busch, Wright et al. (arXiv: 2007.15635)

Shear Measurements

- Giblin, Heymans, Asgari et al. (arXiv: 2007.01845)

KiDS-1000 core papers

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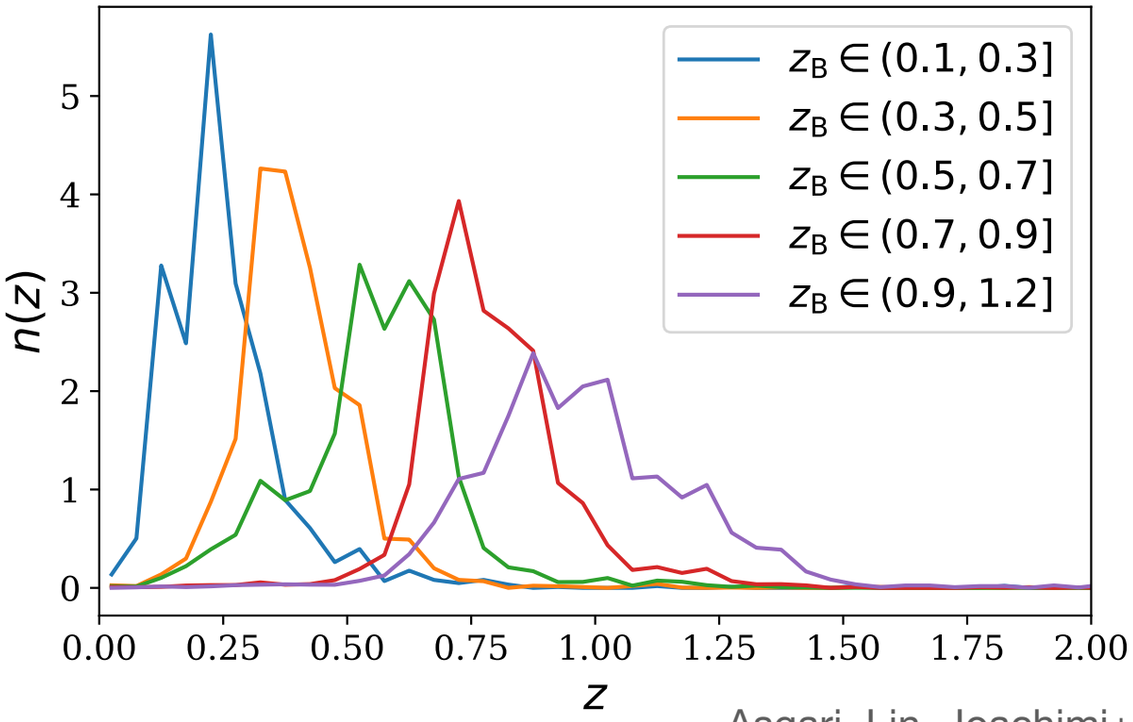
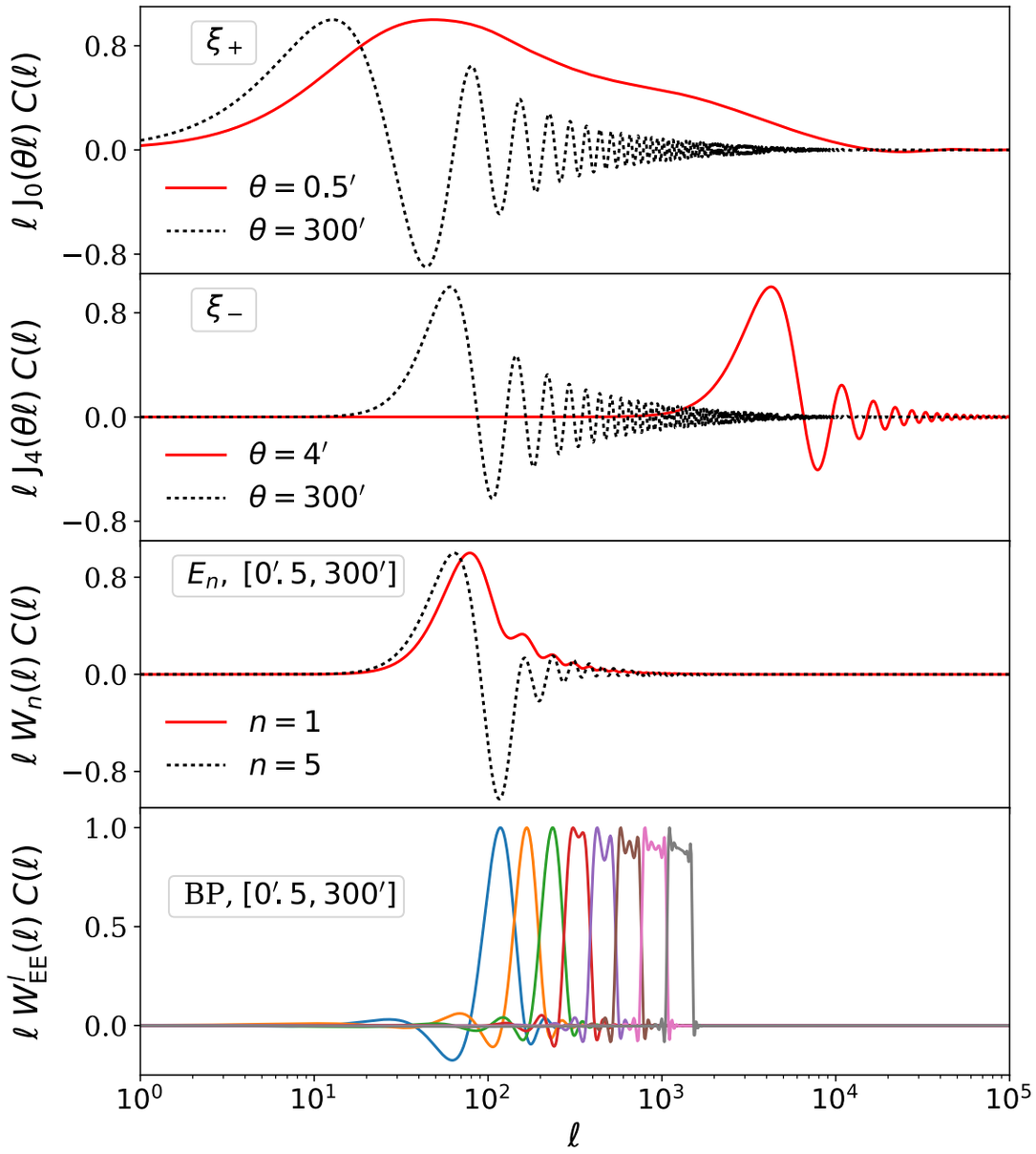


Asgari, Lin, Joachimi+ 2021



5 tomographic bins

- 0.1 < z < 1.2

3 two-point statistics

- Correlation functions
- COSEBIs
- Band powers (C_l)

Cosmic shear model

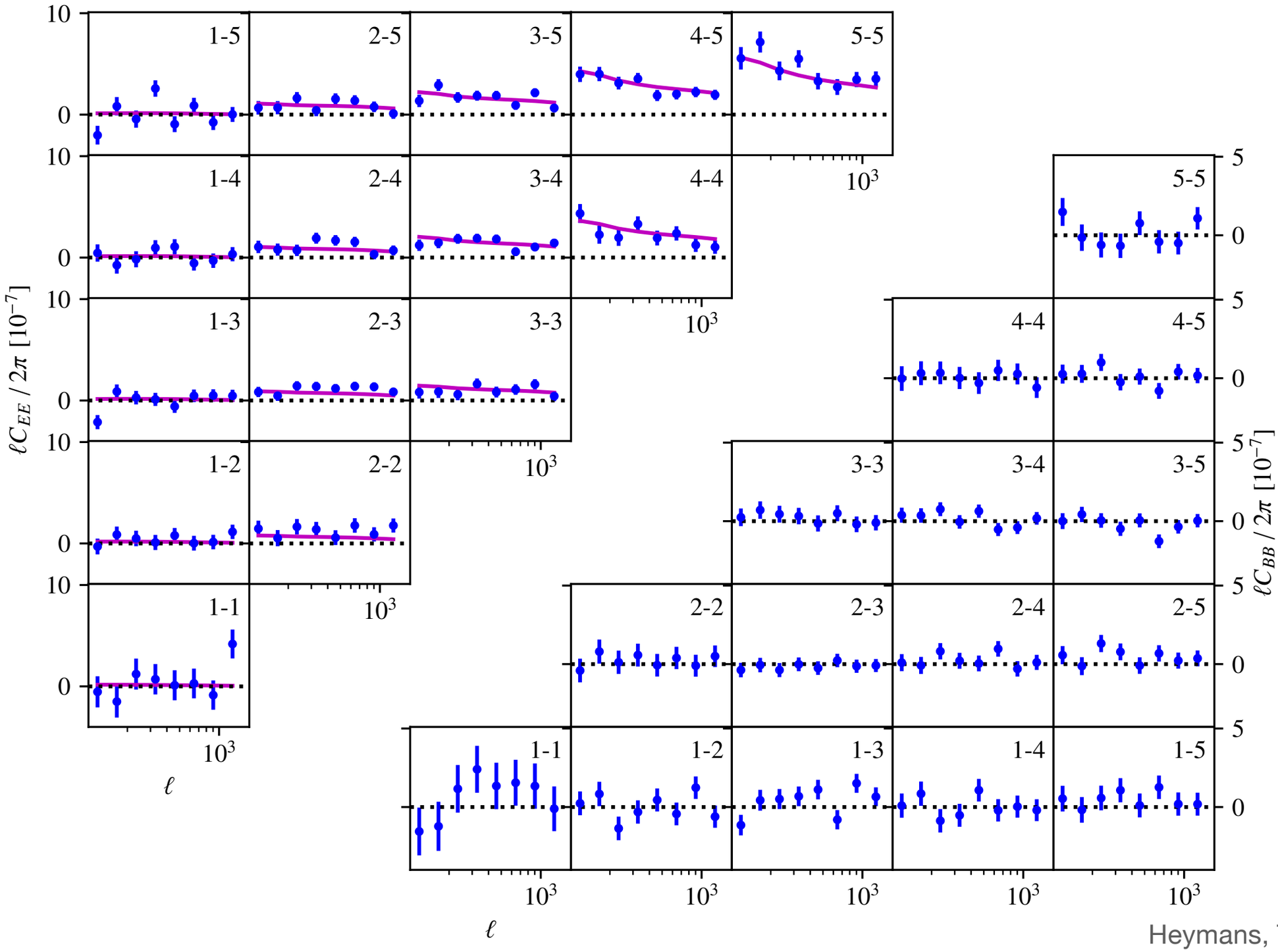
Baseline cosmological model

- Flat ΛCDM, fixed neutrino mass
- Nonlinear modelling with HMCode

Systematics

- Baryon feedback
- Intrinsic alignment
- Photometric redshift calibration uncertainty
- Shear calibration uncertainty

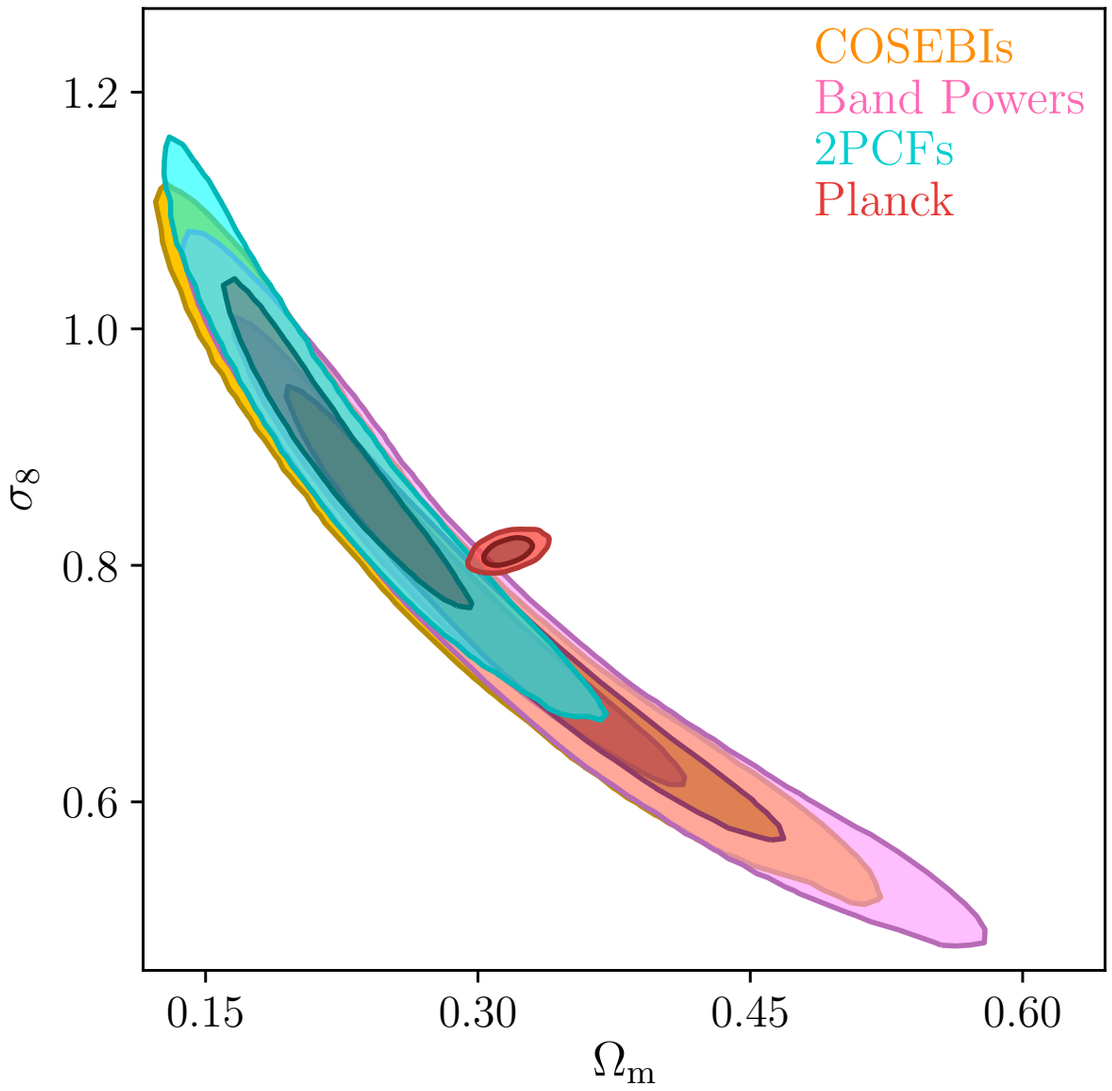
Cosmic shear band powers

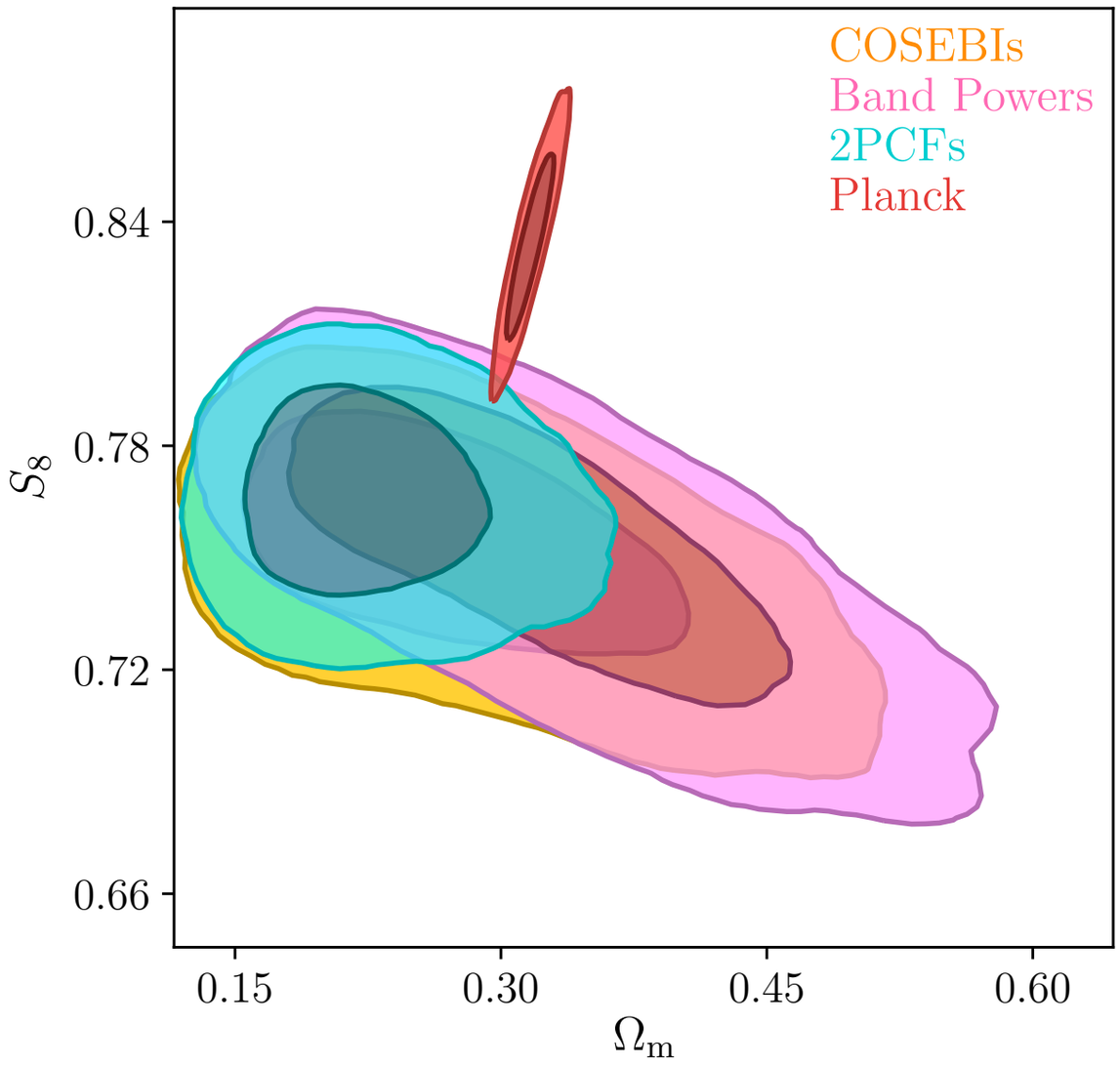


Heymans, Tröster+ 2021

Cosmic shear cosmology constraints

$$S_8 = \sigma_8\sqrt{\Omega_\mathrm{m}/0.3}$$





Asgari, Lin, Joachimi+ 2021

3x2pt model

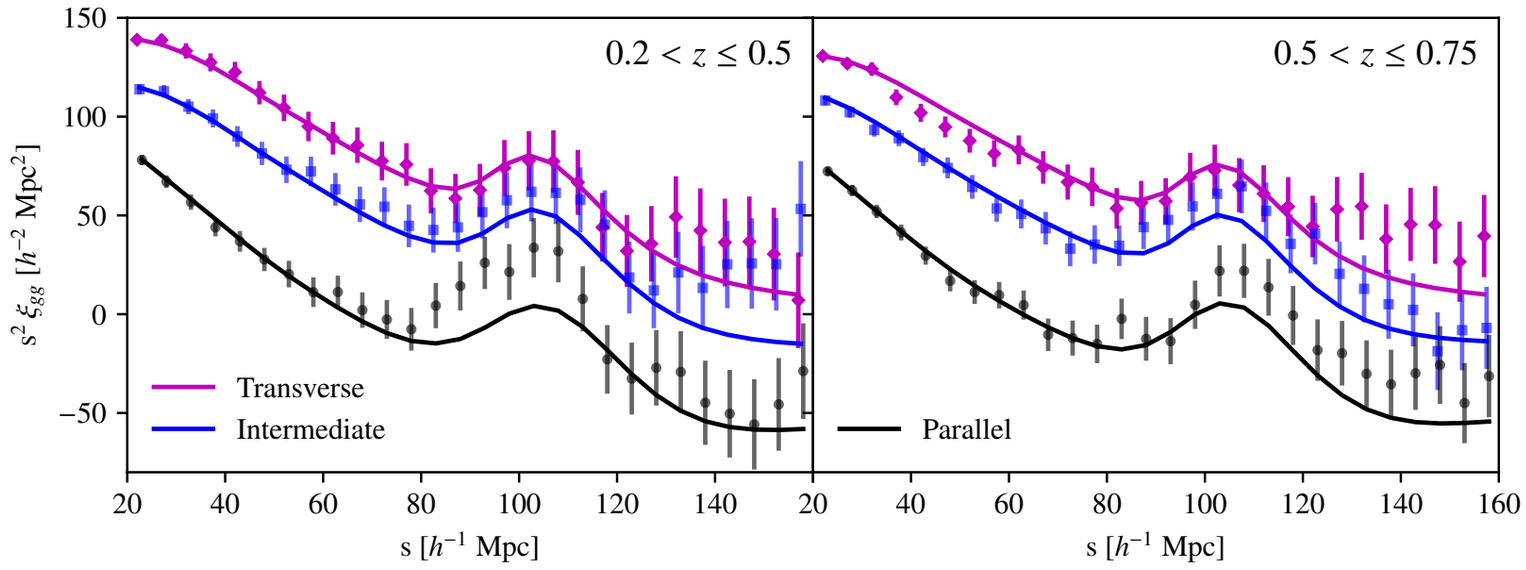
Baseline cosmological model

- Same as cosmic shear
- Full-shape perturbative model for BOSS galaxies

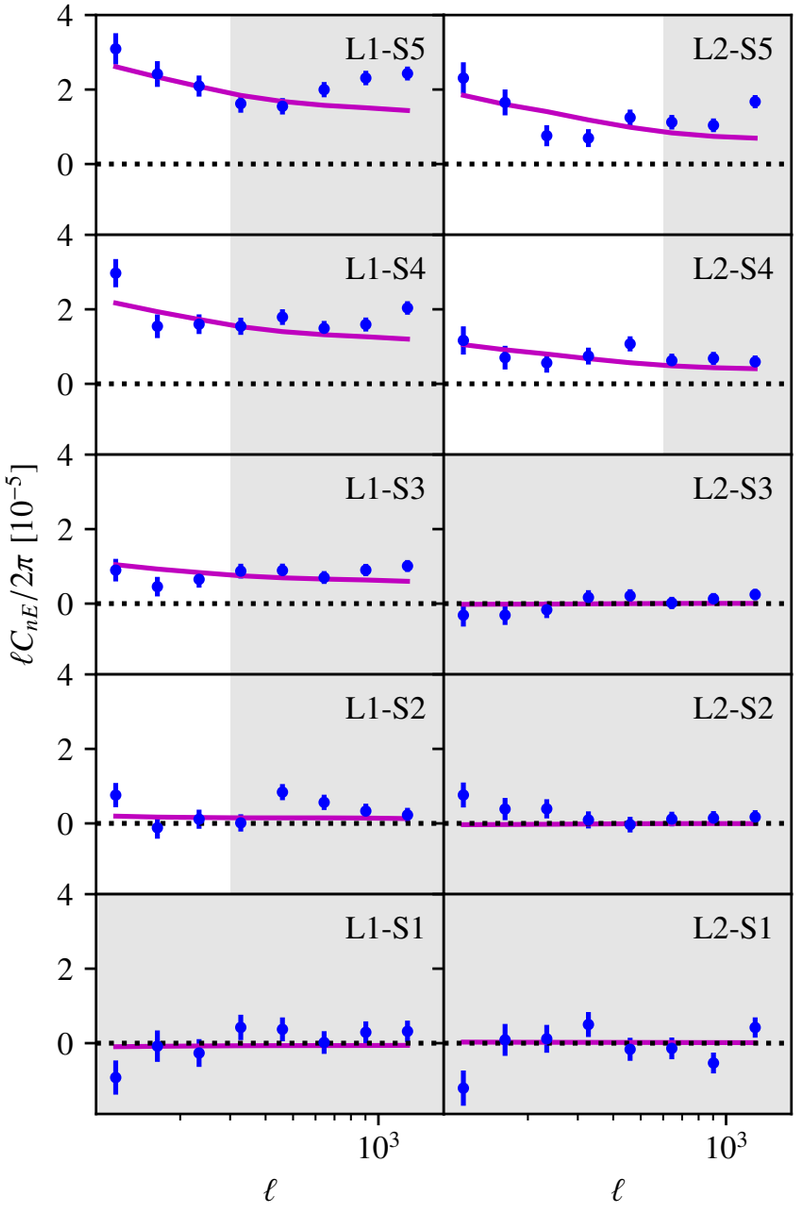
Systematics

- Same as cosmic shear +
  - Non-linear bias model
  - Redshift-space distortions
  - Magnification

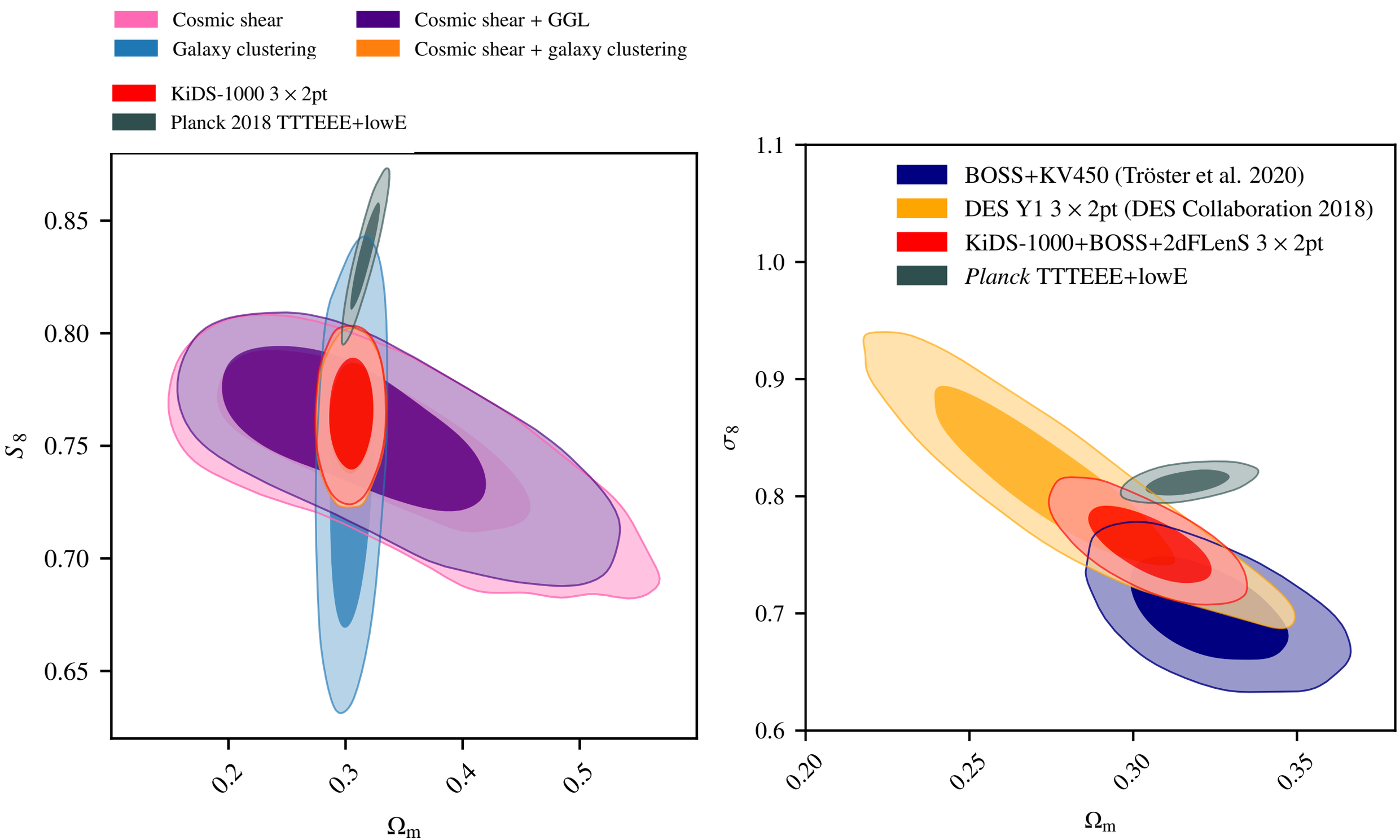
BOSS DR12



KiDS-1000 x BOSS + 2dFLenS



Heymans, Tröster+ 2021



Heymans, Tröster+ 2021

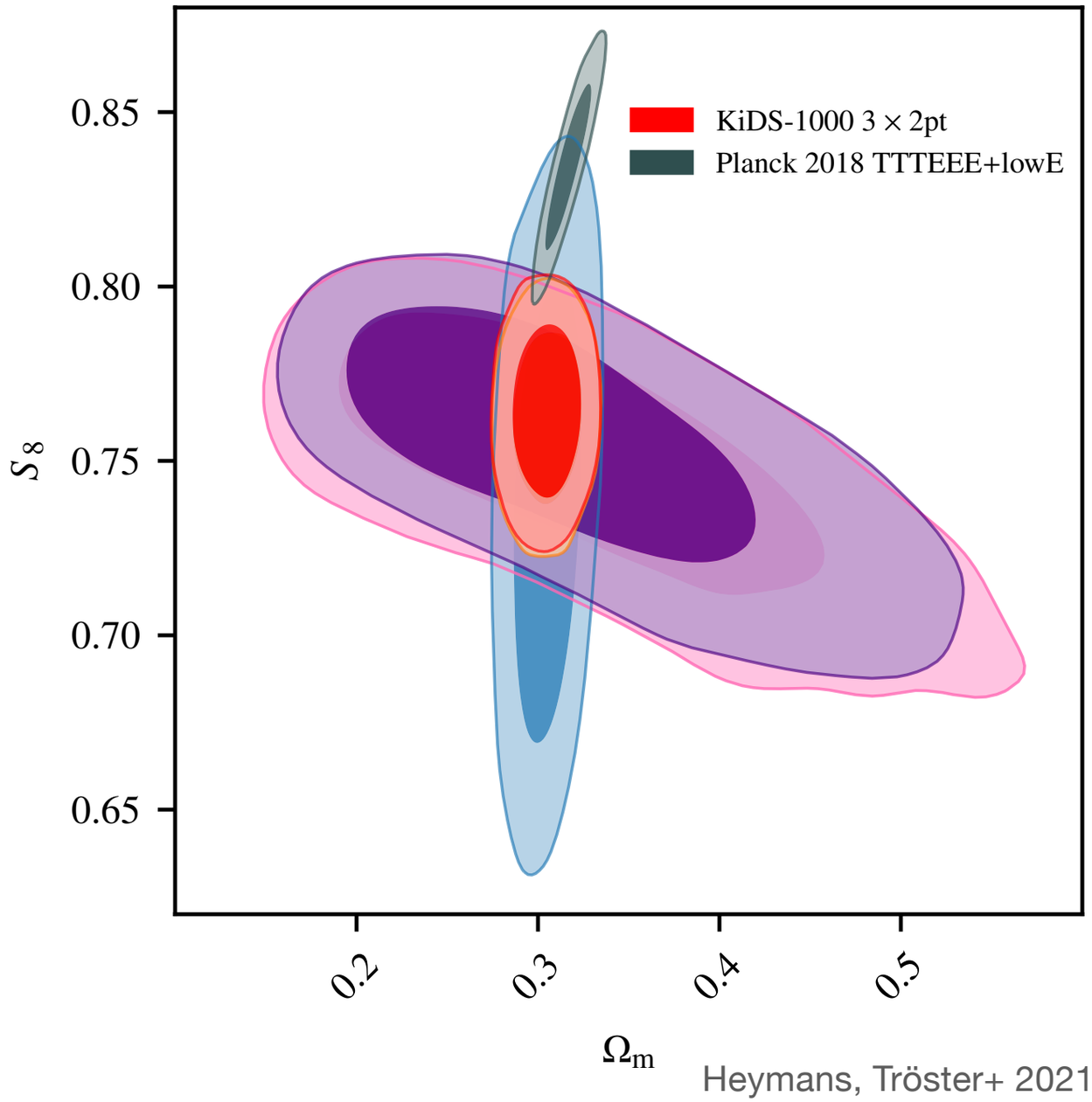
(Dis)agreement with Planck?

Tension with Planck

- Same overall precision as Planck for the structure growth parameter S_8

- S_8 from KiDS is 8.3 ± 2.6 % lower than Planck: ~3σ

- Full parameter space: ~2σ

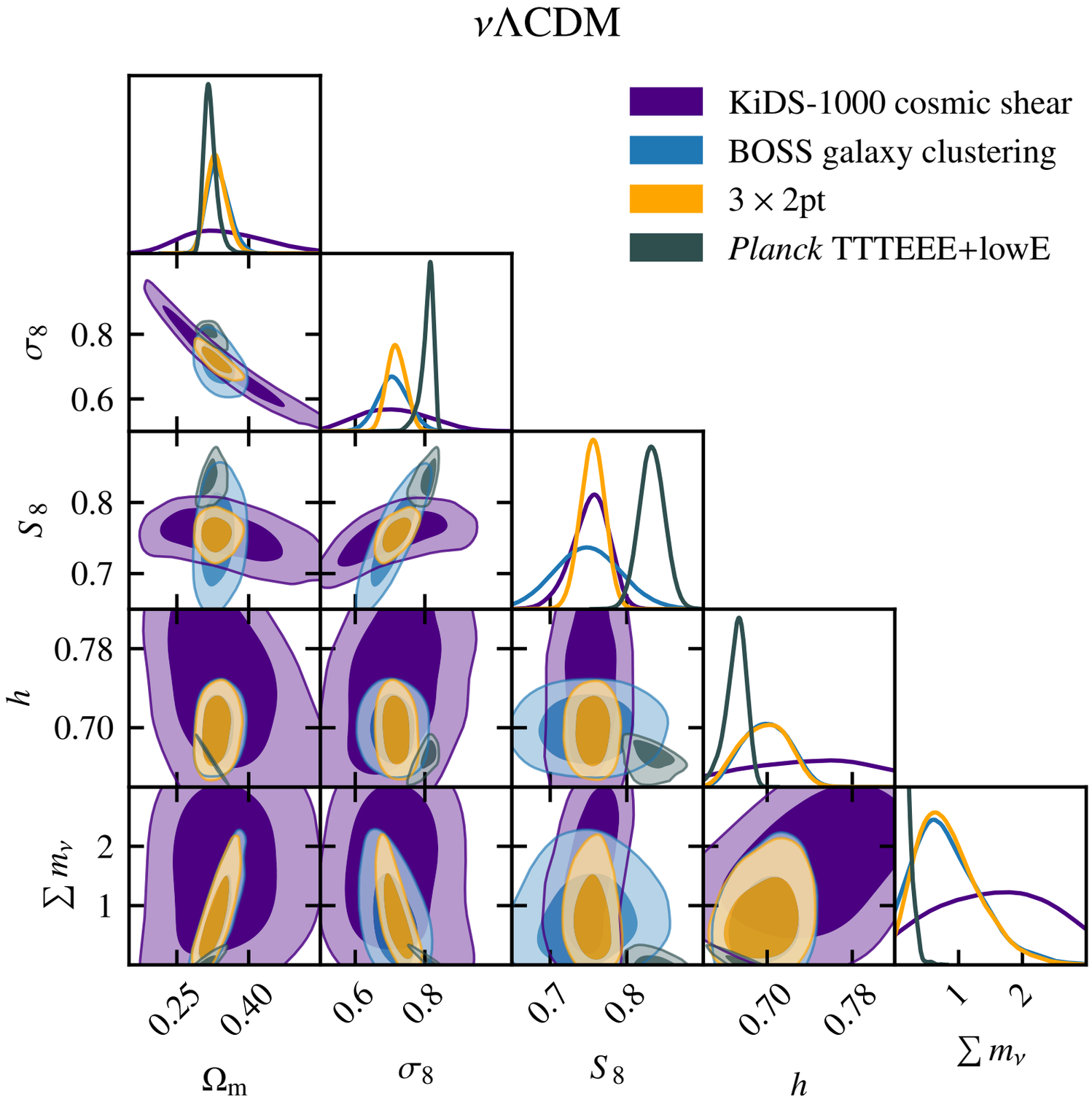


Heymans, Tröster+ 2021

Standard model of cosmology

- Minimal neutrino mass
- Spatially flat Universe
- Cosmological constant
- General relativity

Massive neutrinos



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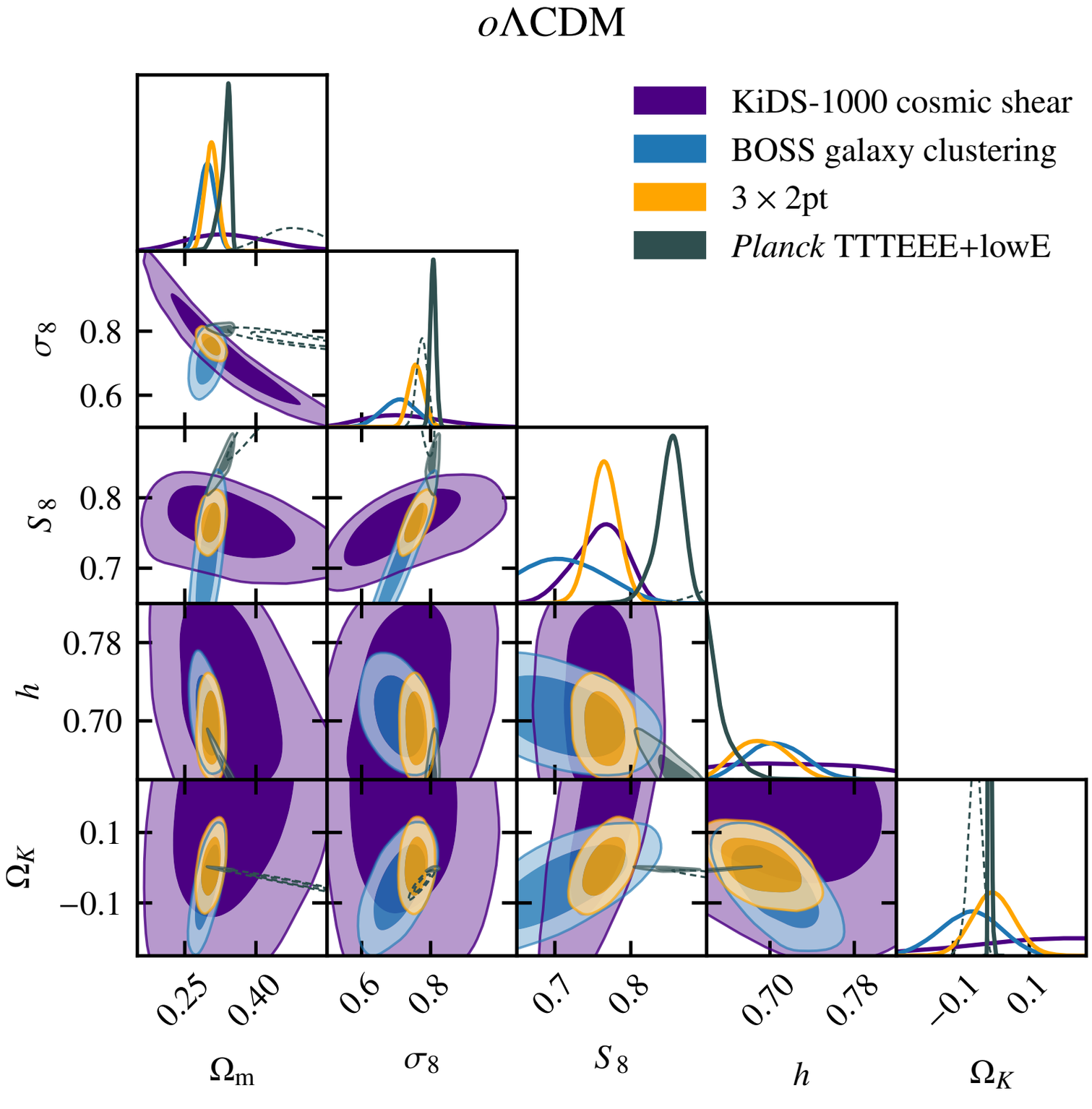
Curvature



- H_0 priors matter!

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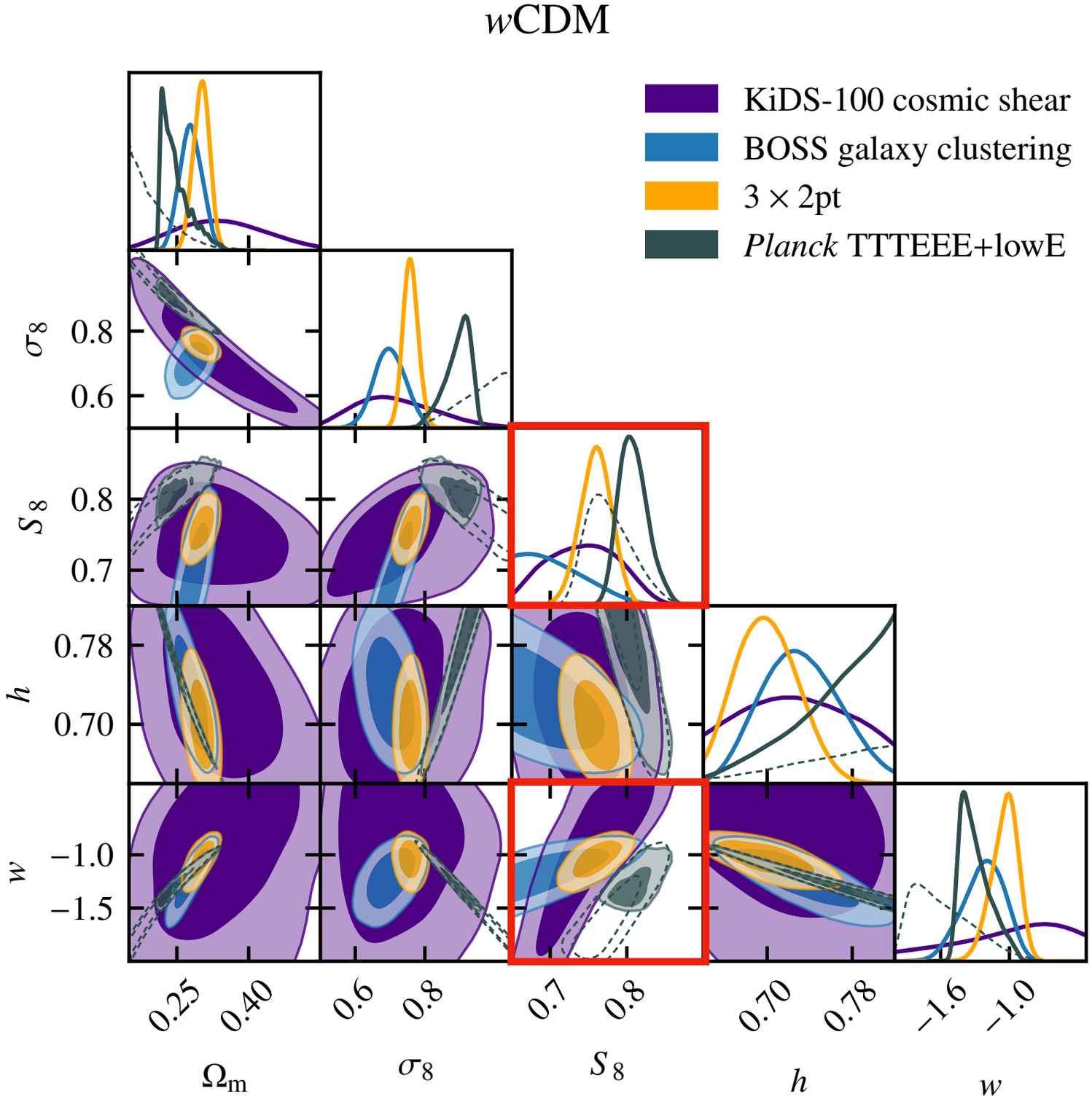
Dark energy equation of state



- H_0 priors matter!

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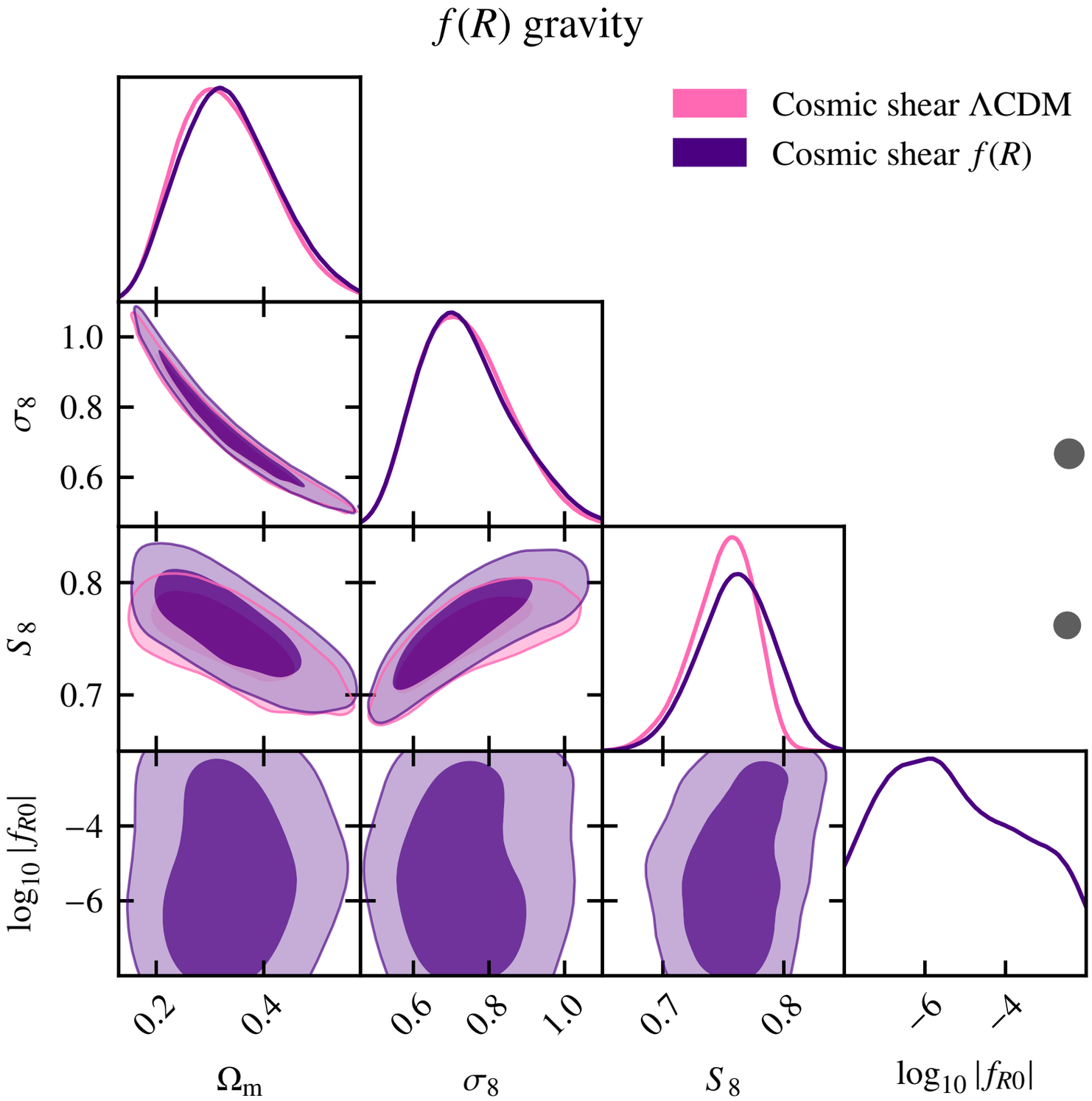
Modified gravity - f(R)



- Full non-linear modelling using reaction formalism
- github.com/nebblu/ReACT, arXiv:2005.12184

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Summary

Data well described by a model of the Universe with

- Minimal neutrino mass
- Spatially flat
- Cosmological constant
- General relativity

Tension with Planck in S_8 persists*

Fix amplitude to Planck

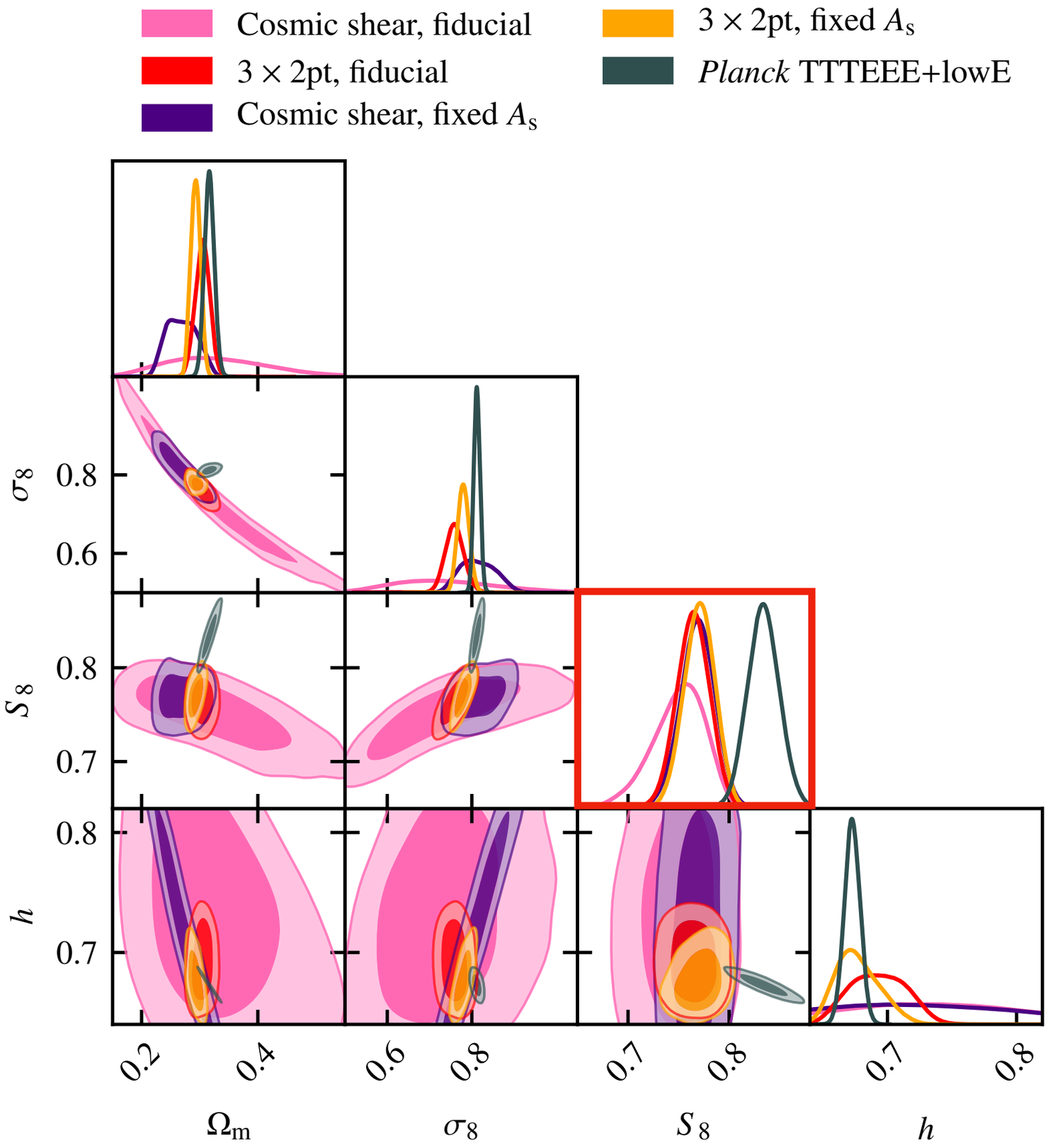
Planck constrains amplitude of the matter power spectrum in the early Universe

- Parametrised by A_s

Lensing constrains $S_8 = \sigma_8\sqrt{\Omega_m/0.3}$

- σ_8 is a complicated function of A_s and other parameters
- Poor constraints on A_s

Fix amplitude



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Model selection

Do the data prefer any of the models?

Model selection criteria

Deviance information criterion (DIC)

- Compares improvement in best-fit χ^2 with increase in model complexity

Watanabe-Akaike information criterion (WAIC)

- Similar to DIC
- Does not rely on point estimates

Evidence ratio

- Compares the Bayesian evidences

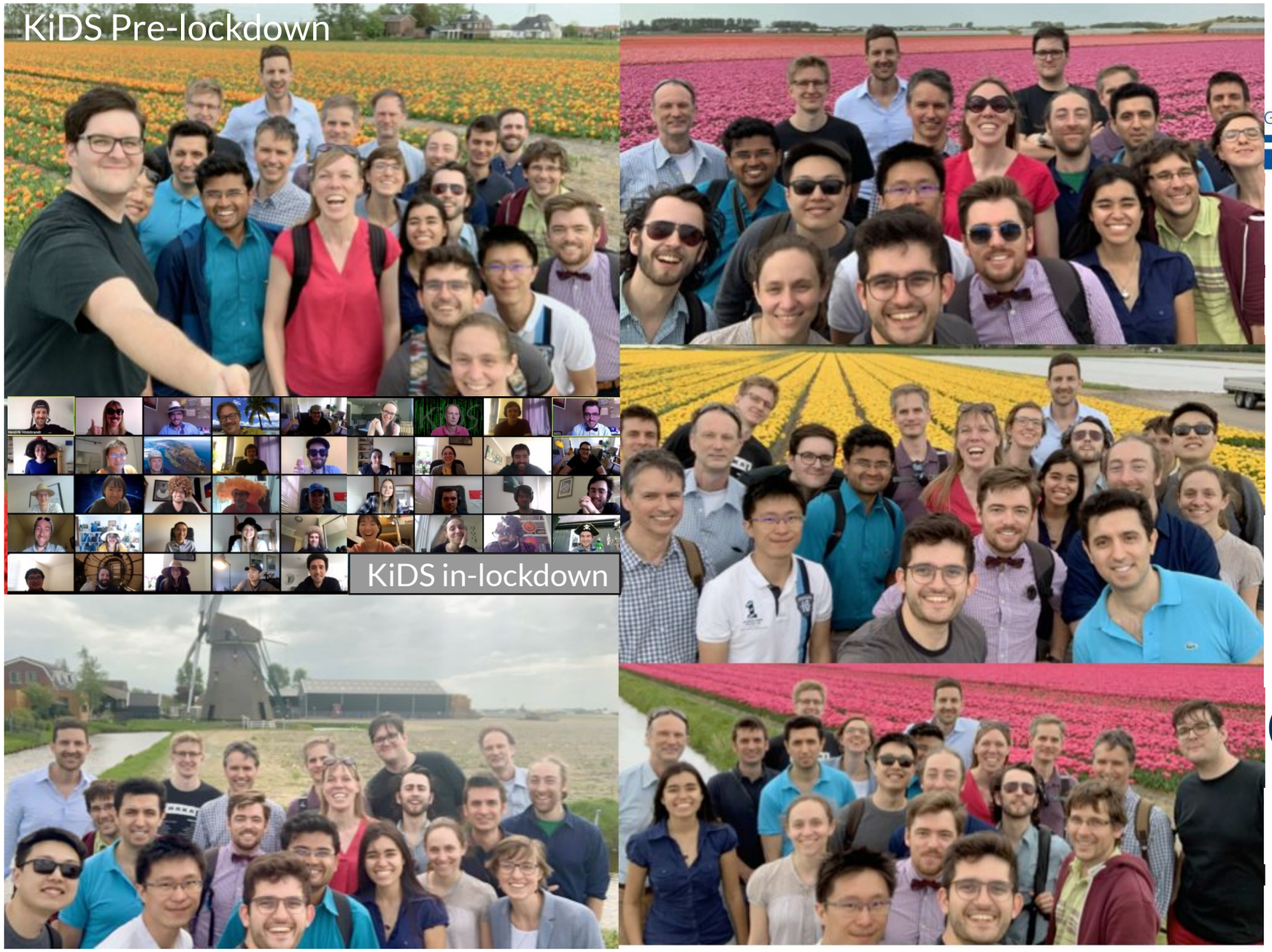
Summary

No indication for physics beyond flat ΛCDM

No preference for or against any of the models considered

S_8-tension with Planck remains at ~3σ

Thanks to KiDS and all our funders!



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