Cosmic shear from KiDS: S_8 tension?

Konrad Kuijken
Leiden Observatory

Outline

- Main question: "***How much has the amplitude of large-scale density fluctuations grown since decoupling?***" Expected ΛCDM answer: a factor of ~ $(1+z_{CMB})$

- Weak lensing as probe of large-scale structure & cosmology
- KiDS and other surveys
- S_8 as a measure of LSS
- The importance of accurate redshifts
- Current results
- Next steps

    - See Hendrik Hildebrandt's talk on Tuesday for more on KiDS

tangential distortion around mass concentration

tangential distortion around mass concentration

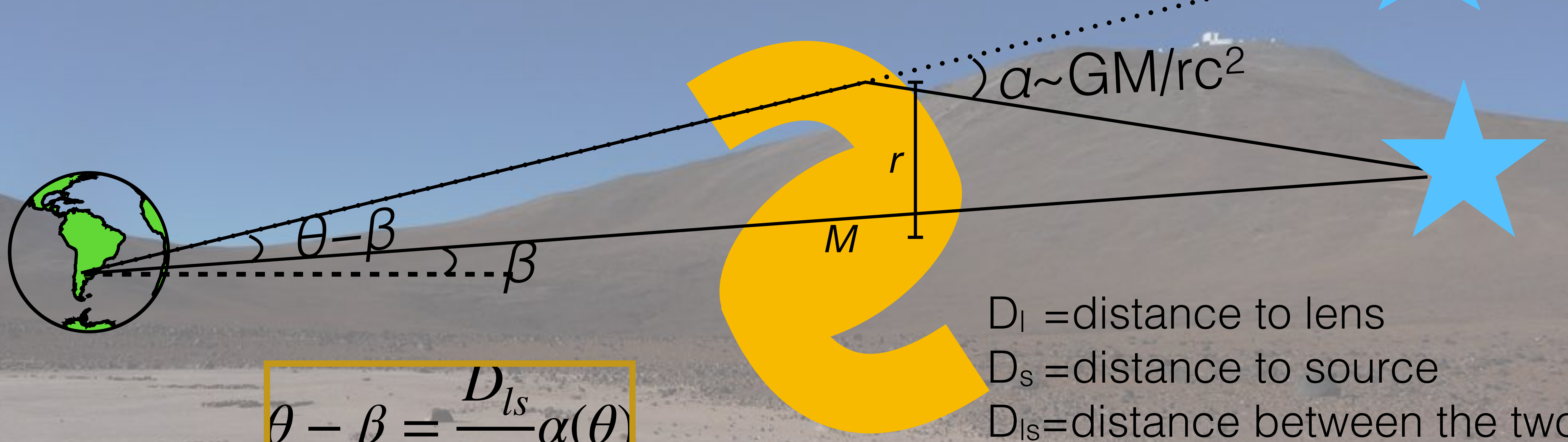
KiDS

wavelike density perturbation

KiDS

wavelike density perturbation

Weak lensing as probe of LSS



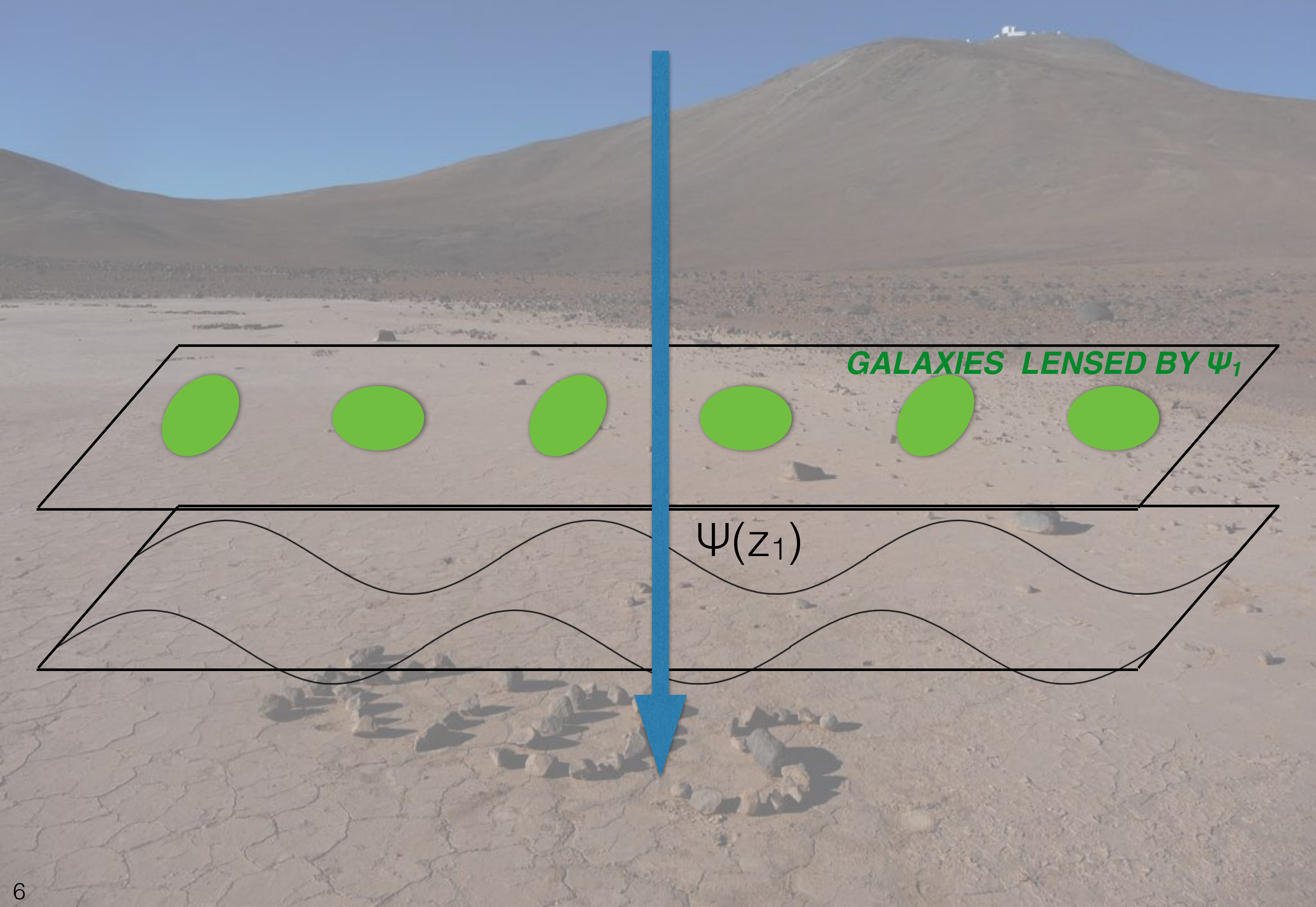
$$\boxed{\theta - \beta = \frac{D_{ls}}{D_s}\alpha(\theta)}$$

- Weak lensing measures the *distortion* of images = derivative of observed angle θ w.r.t. unlensed angle β:

$$\frac{d\theta}{d\beta} \simeq \left(1 - \frac{D_{ls}}{D_s}\frac{d\alpha}{d\theta}\right)^{-1} = \left(1 - \frac{D_{ls}D_l}{D_s}\frac{d\alpha}{dr}\right)^{-1}$$

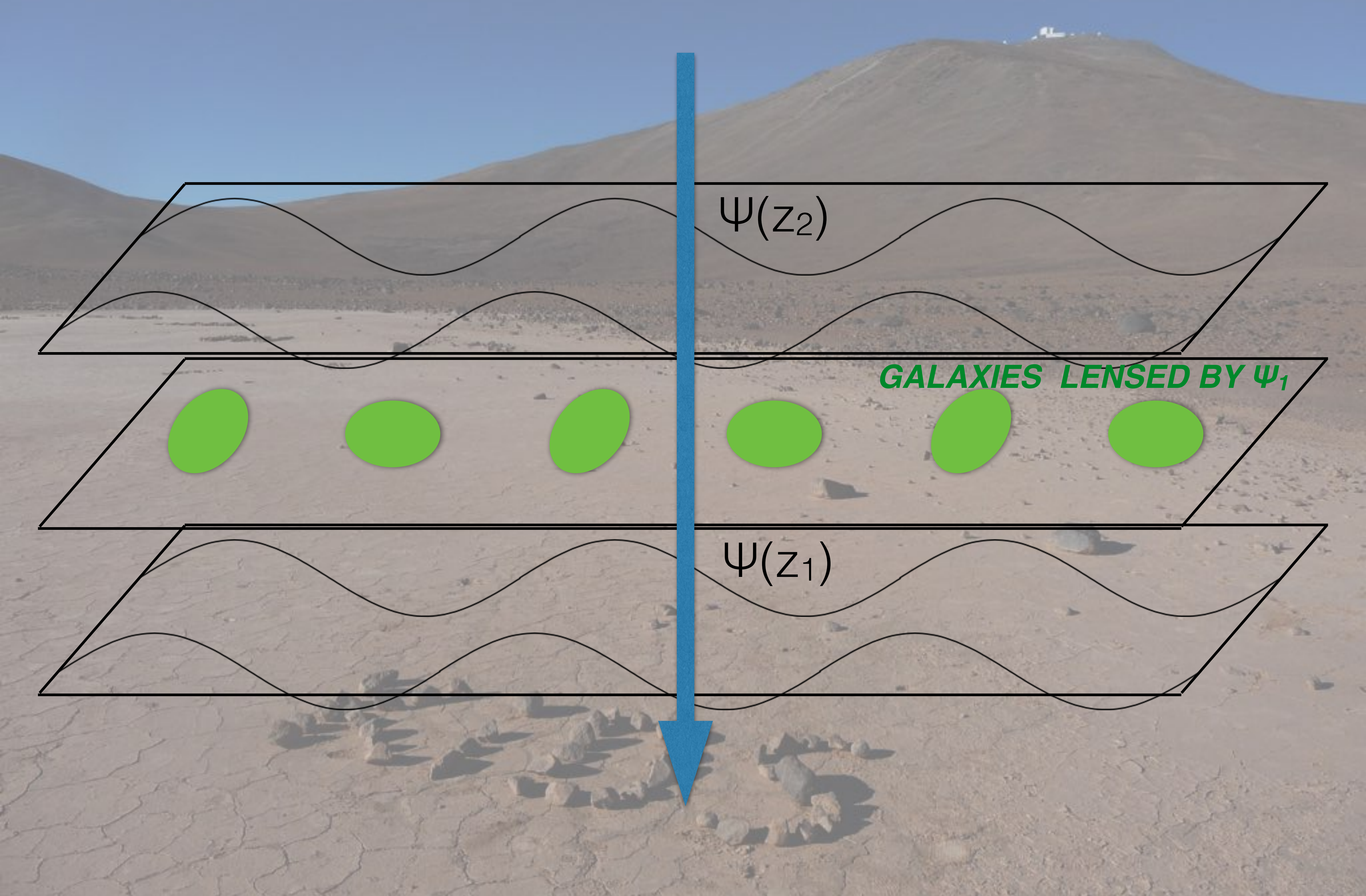
- Strongest effect for distant sources, and lenses ~ halfway

Tomographic lensing by large-scale structure

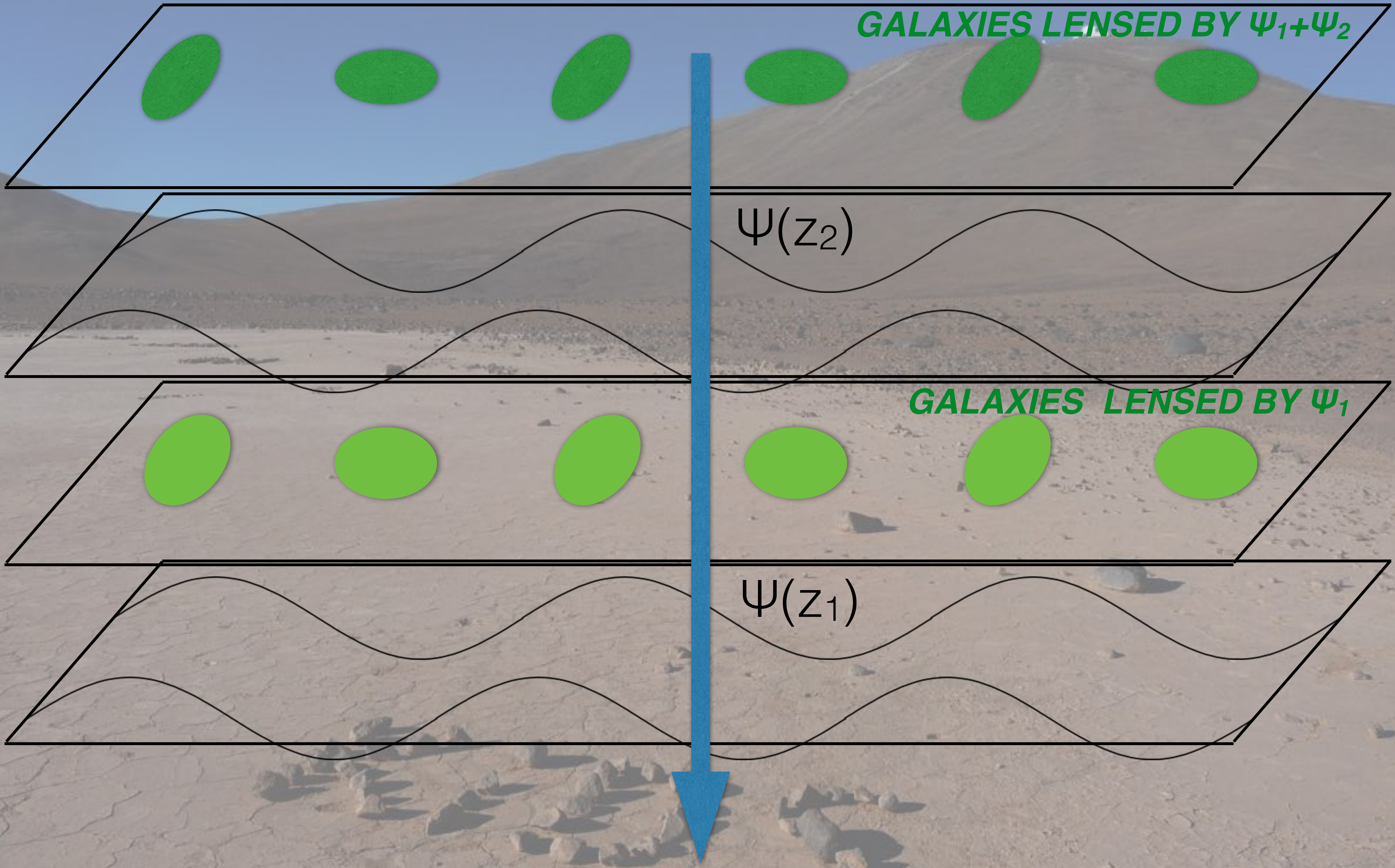


KiDS

Tomographic lensing by large-scale structure

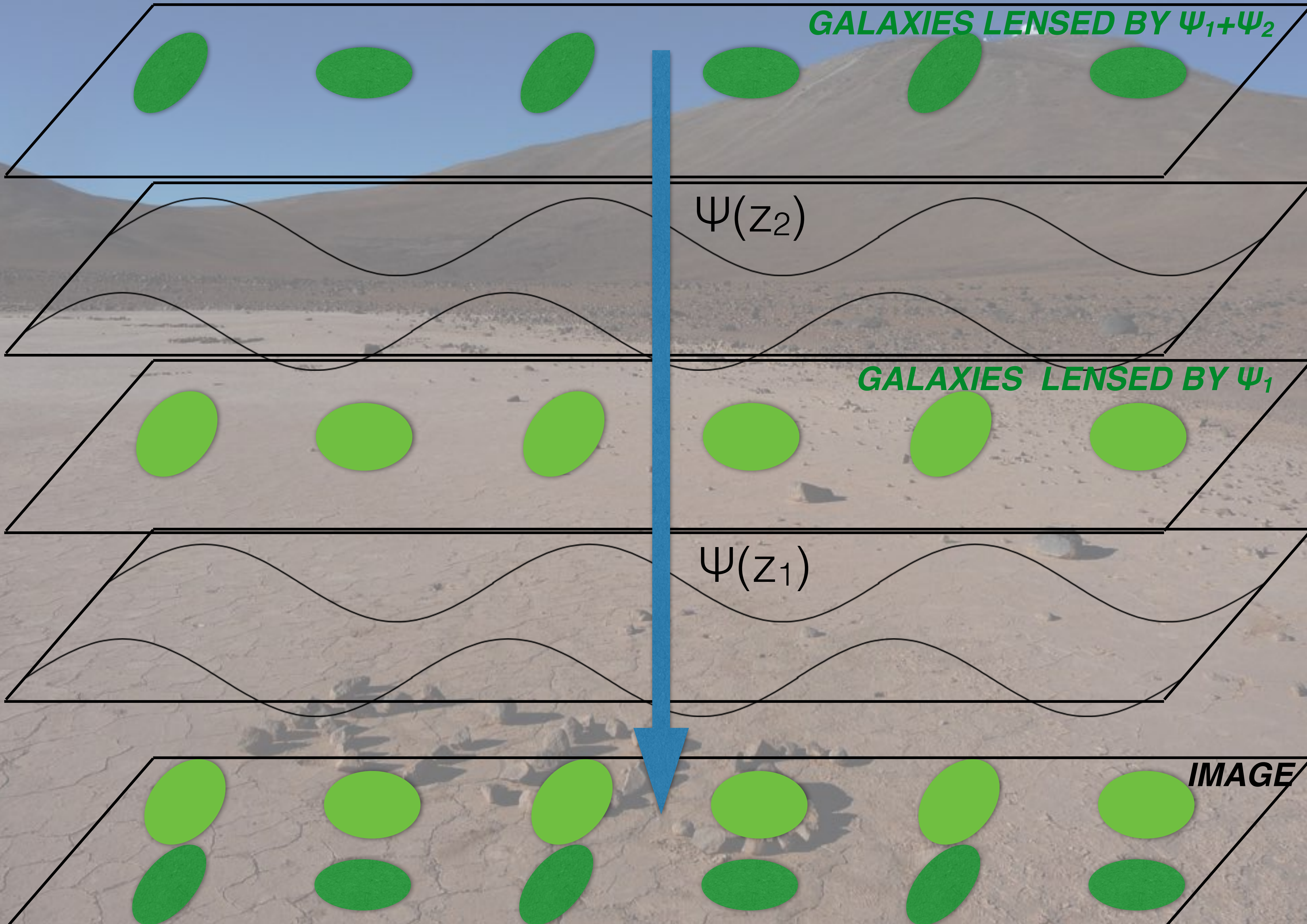


Tomographic lensing by large-scale structure

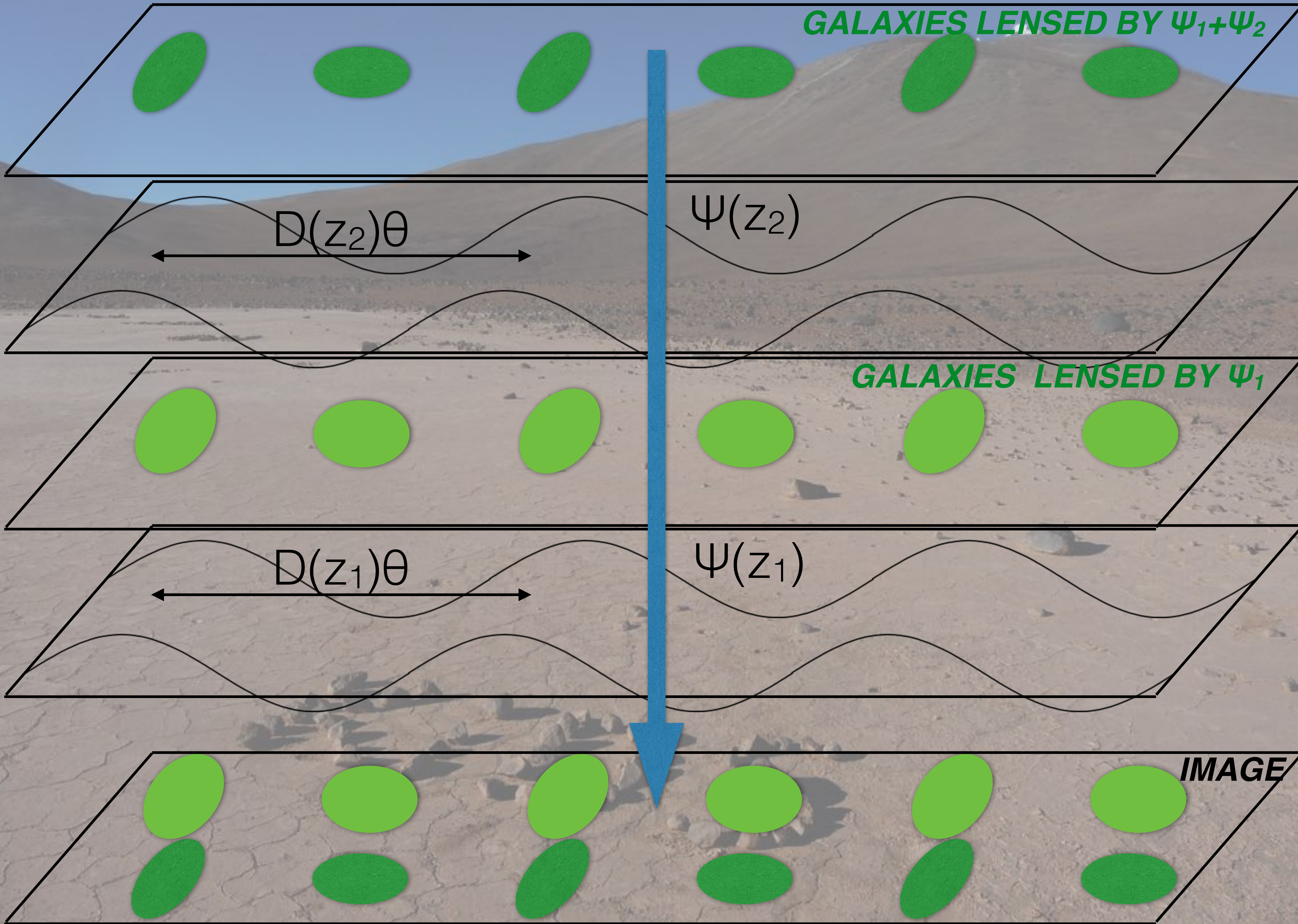


KiDS

Tomographic lensing by large-scale structure



Tomographic lensing by large-scale structure



KiDS

Tomographic lensing by large-scale structure

- Statistical effect only detectable by looking for correlations in galaxy shapes
- What do you need?

Many galaxies to cosmological distances

Sharp images to measure shapes

Good (photometric) redshifts to measure D_l, D_s, etc.

- Weak lensing is sensitive to **amount** of **clustered** matter
  - measure a combination of Ω_m and σ_8.

KiDS

Tomographic lensing by large-scale structure

- Statistical effect only detectable by looking for correlations in galaxy shapes

- What do you need?

Many galaxies to cosmological distances

Sharp images to measure shapes

Good (photometric) redshifts to measure D_l, D_S, etc.

- Weak lensing is sensitive to **amount** of **clustered** matter
    - mea

$$S_8 \equiv \sigma_8 \, (\Omega_m/0.3)^{1/2}$$

Three on-going weak lensing surveys

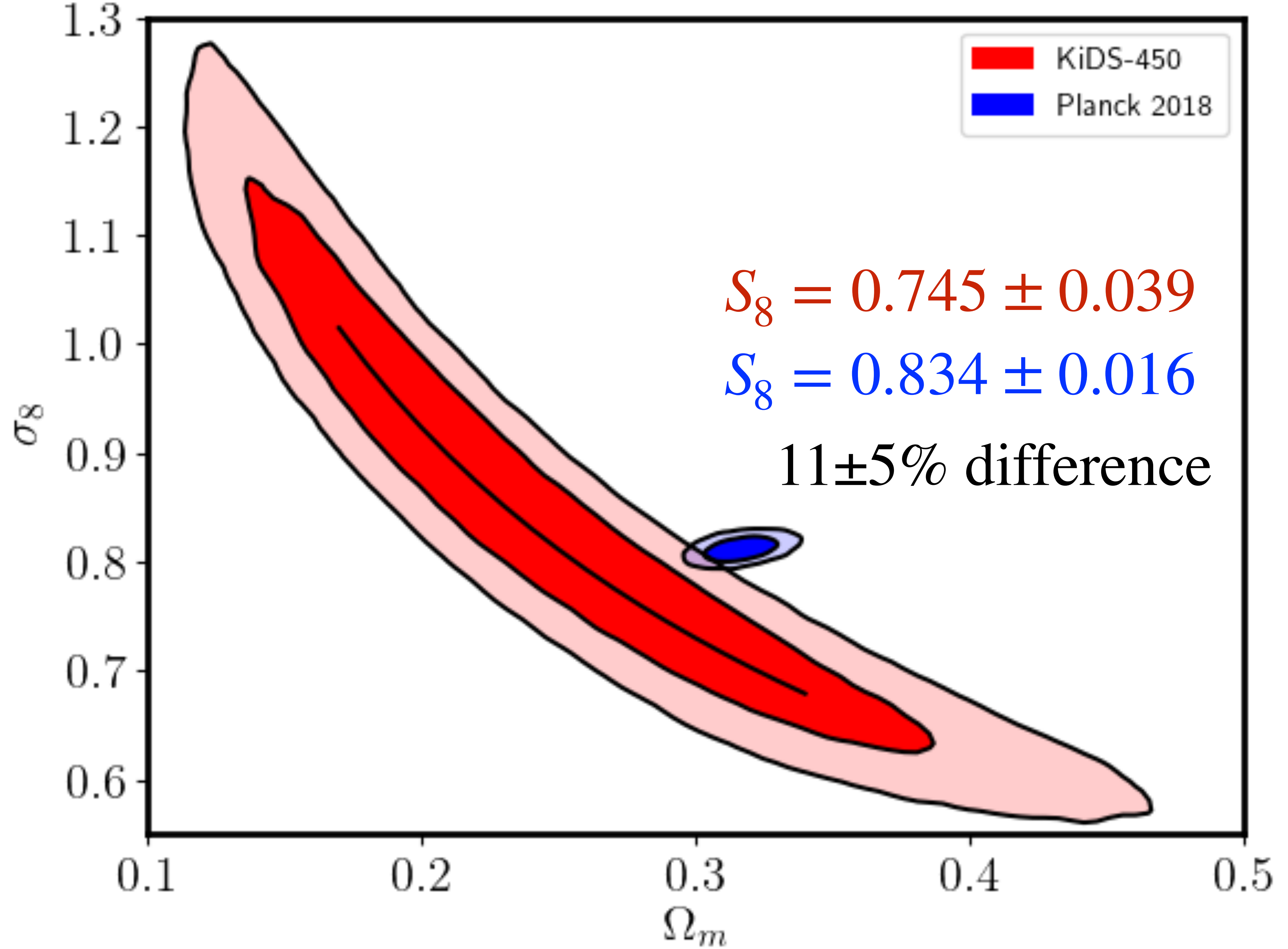
O(500) nights each!

	DES	KiDS	HSC
total area	5000	1350	1400
telescope	4m CTIO	2.6m VST (opt) 3.9m VISTA (IR)	8m SUBARU
image quality	0.9”	0.7”	0.6”
inverse shear var arcmin^{-2}	65-90	105	>200
bands	grizy	ugriZYJHK	grizy
mean z	0.7	0.77	~0.9
results so far	1300 deg^2 (yr 1)	450 deg^2	130 deg^2

2016: KiDS-450 cosmic shear results

$S_8 \equiv \sigma_8 (\Omega_m/0.3)^{1/2}$

Hildebrandt et al. 2017, MNRAS 465, 1454



KiDS

Tension?

- Statistical fluctuation

- Shear calibration error
  ✘ would have to be improbably high

- Model uncertainties in the power spectrum?
  - intrinsic alignment of galaxies (contaminates lensing)
  - baryonic effects on the matter distribution
  - non-linear effects poorly modelled

Model with nuisance parameters

- Redshift (z) calibration error
  - Empirical calibration to spec-z; base photo-z on wide λ range

- Focus of attention has shifted from shears to redshifts (for the current ground-based surveys)

KiDS

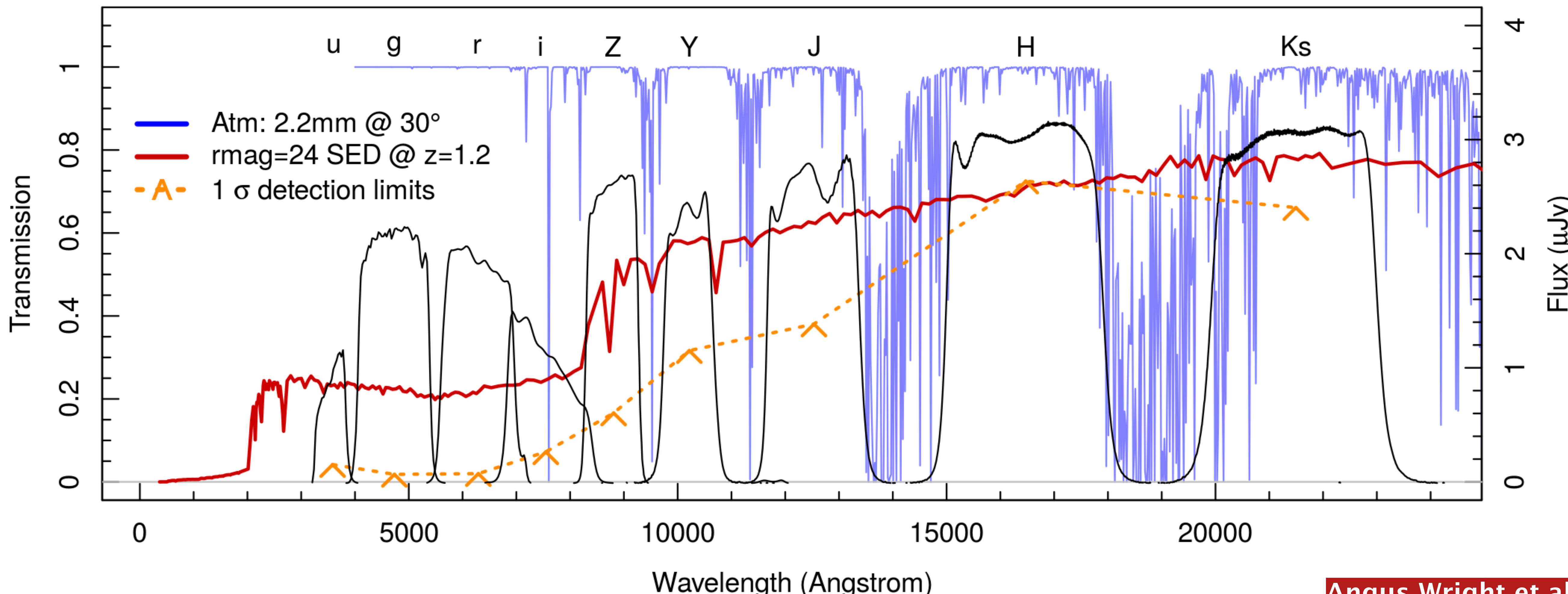
What if the redshifts are biased?

- If source galaxies are at higher z than you think
  - there is more LSS in front of them: shear ↗
  - they lens more efficiently than you think: shear ↗
- … so you infer a higher degree of clustering and S_8.

- Each effect scales as $z^{\sim 1-1.5}$
- 2% bias of redshift gives 5% error on S_8.

KiDS to KiDS+VIKING (KV)

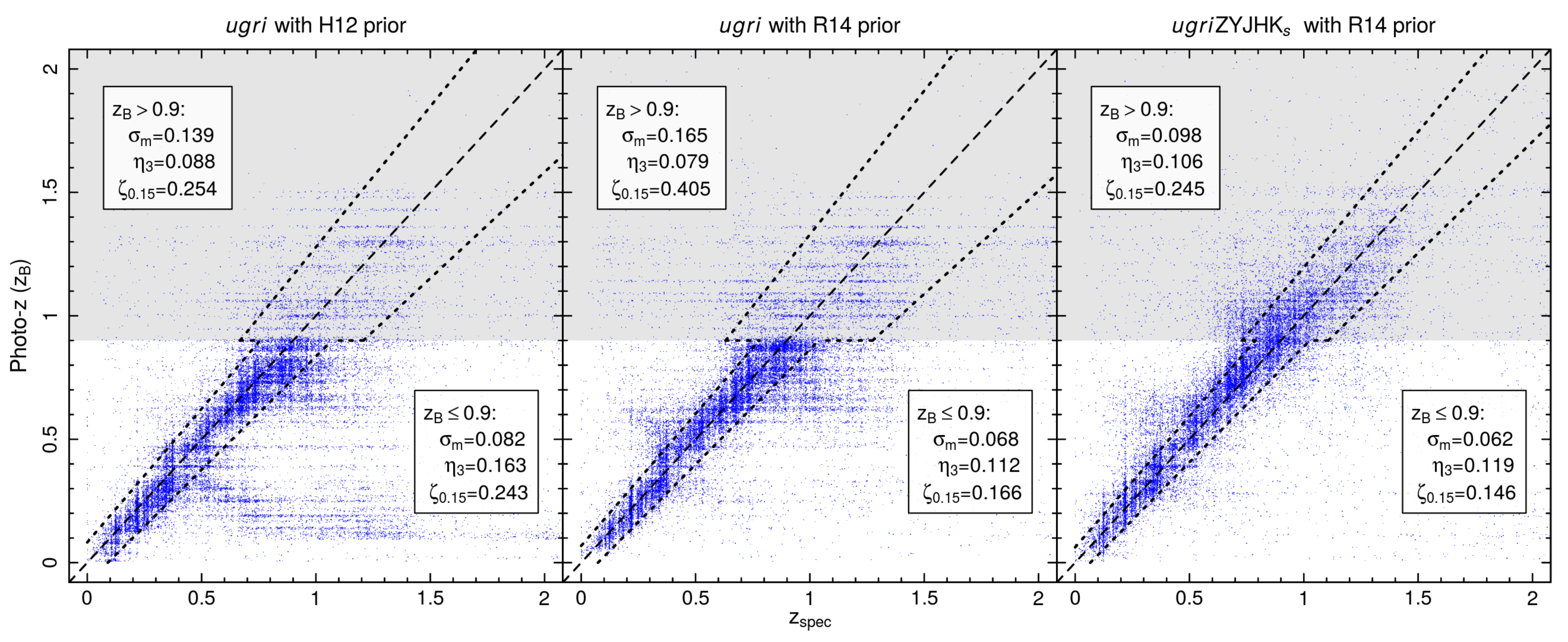
- KiDS was based on 4-band, *ugri* photometric redshifts
- KiDS+VIKING makes this 9 bands, *ugriZYJHK$_s$*.



Angus Wright et al.: arXiv:1812.06077

KiDS to KiDS+VIKING (KV)

- KiDS was based on 4-band, *ugri* photometric redshifts
- KiDS+VIKING makes this 9 bands, *ugriZYJHK_s*.



Results (see Hildebrandt talk tomorrow)

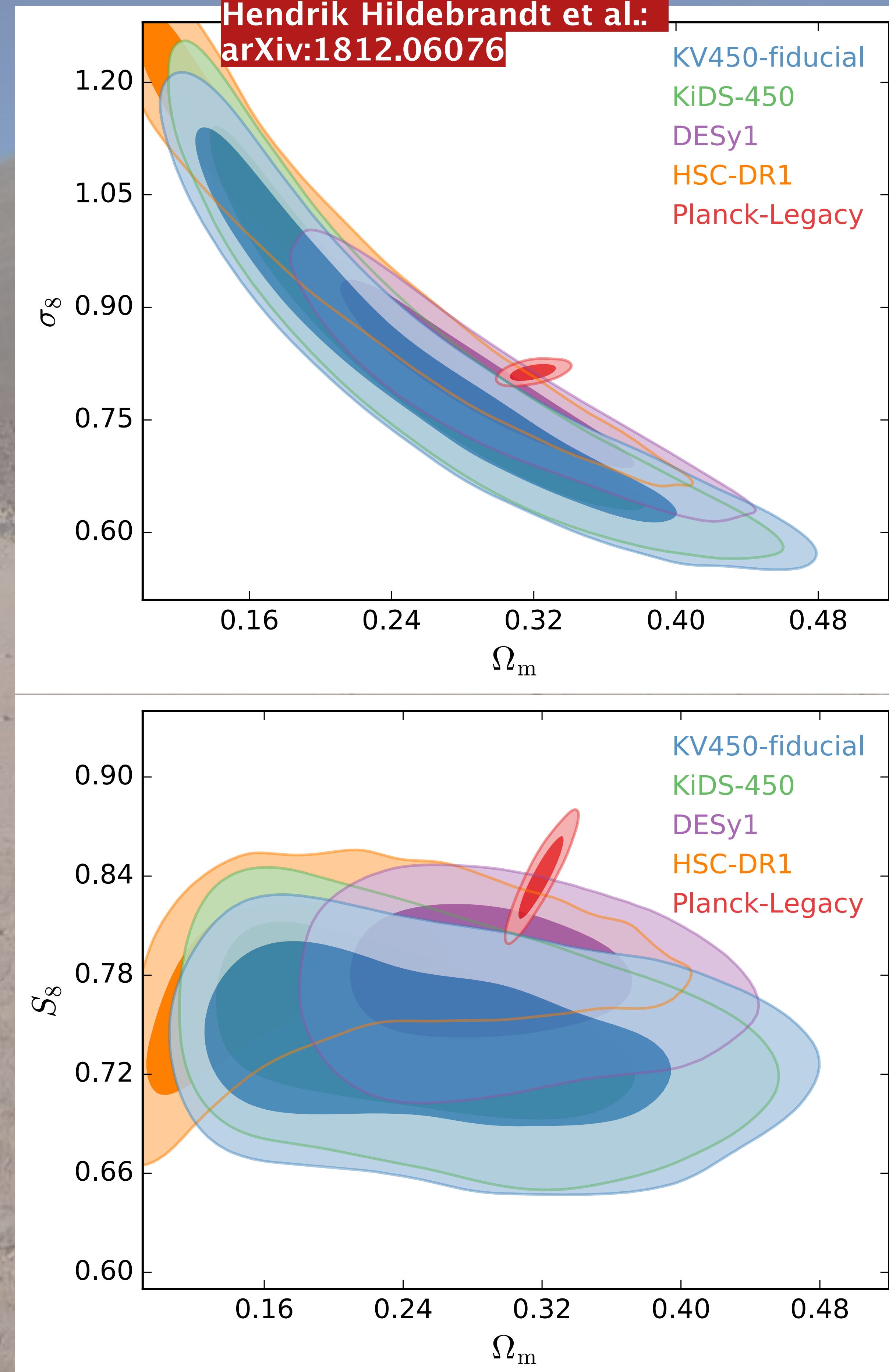
- Despite the changes, KV450 constraints very close to KiDS-450.

- Min. $\chi^2_{181} = 180.6$

- 2.3σ ‘tension’ with Planck:

$$S_8 = 0.737^{+0.040}_{-0.036}$$

- The other surveys also find results below Planck!



KiDS

Combined analysis with DES-Year 1

Shahab Joudaki et al.: arXiv:1906.09262

- KV450 cosmic shear result: $S_8 = 0.737^{+0.040}_{-0.036}$
- Allow z-dependence of intrinsic alignment: $S_8 = 0.734^{+0.043}_{-0.034}$

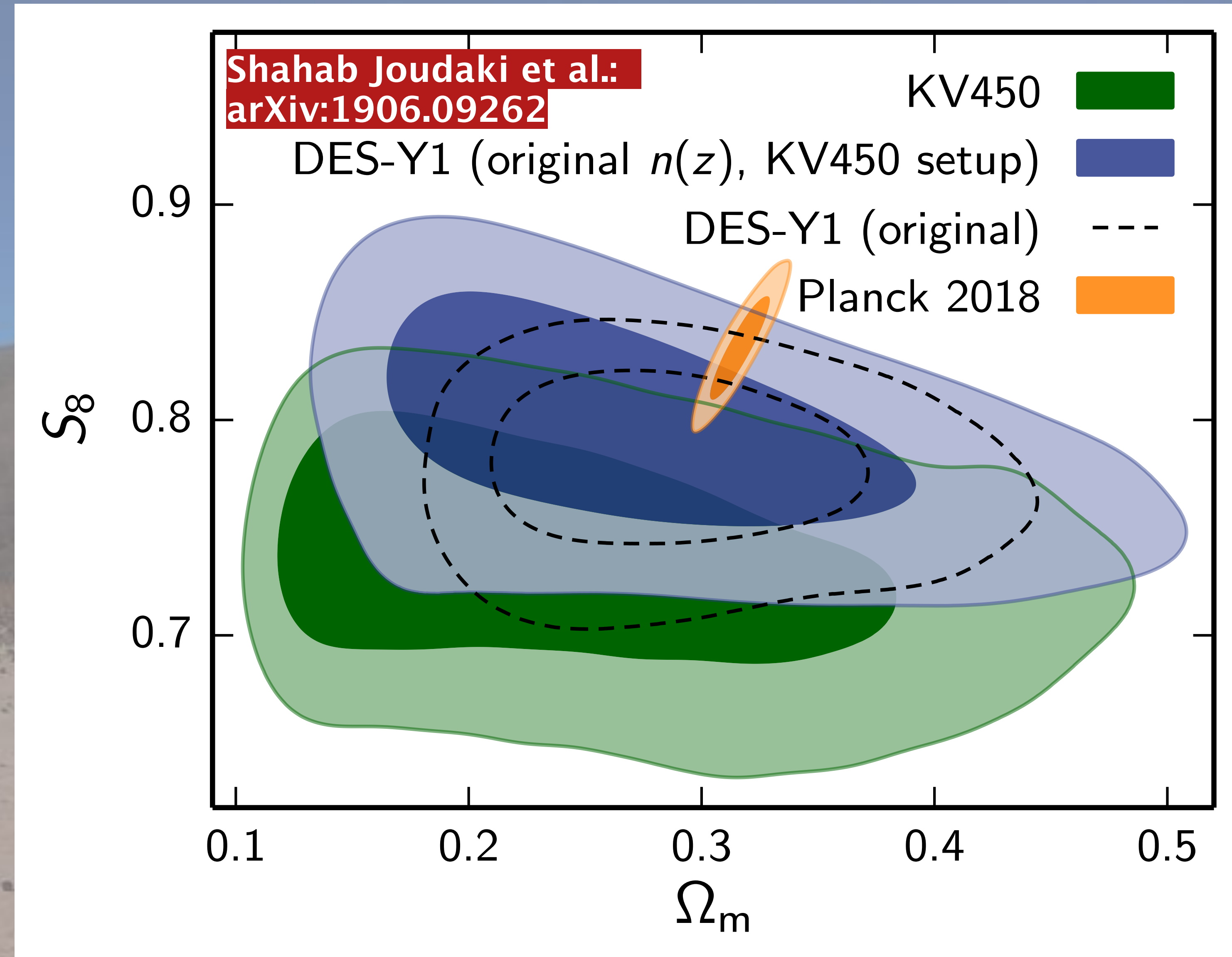
- Published DESY1 cosmic shear result: $S_8 = 0.778^{+0.030}_{-0.024}$
- DESY1 data using KV450 models, priors: $S_8 = 0.793^{+0.037}_{-0.034}$
- Replace DESY1 redshift calibrators (COSMOS2015) with spectroscopic sample used for KiDS: $S_8 = 0.763^{+0.037}_{-0.031}$

- Combined posterior of the joint data set $S_8 = 0.762^{+0.025}_{-0.024}$

- Planck is **9.5±3.9% (2.5σ)** higher

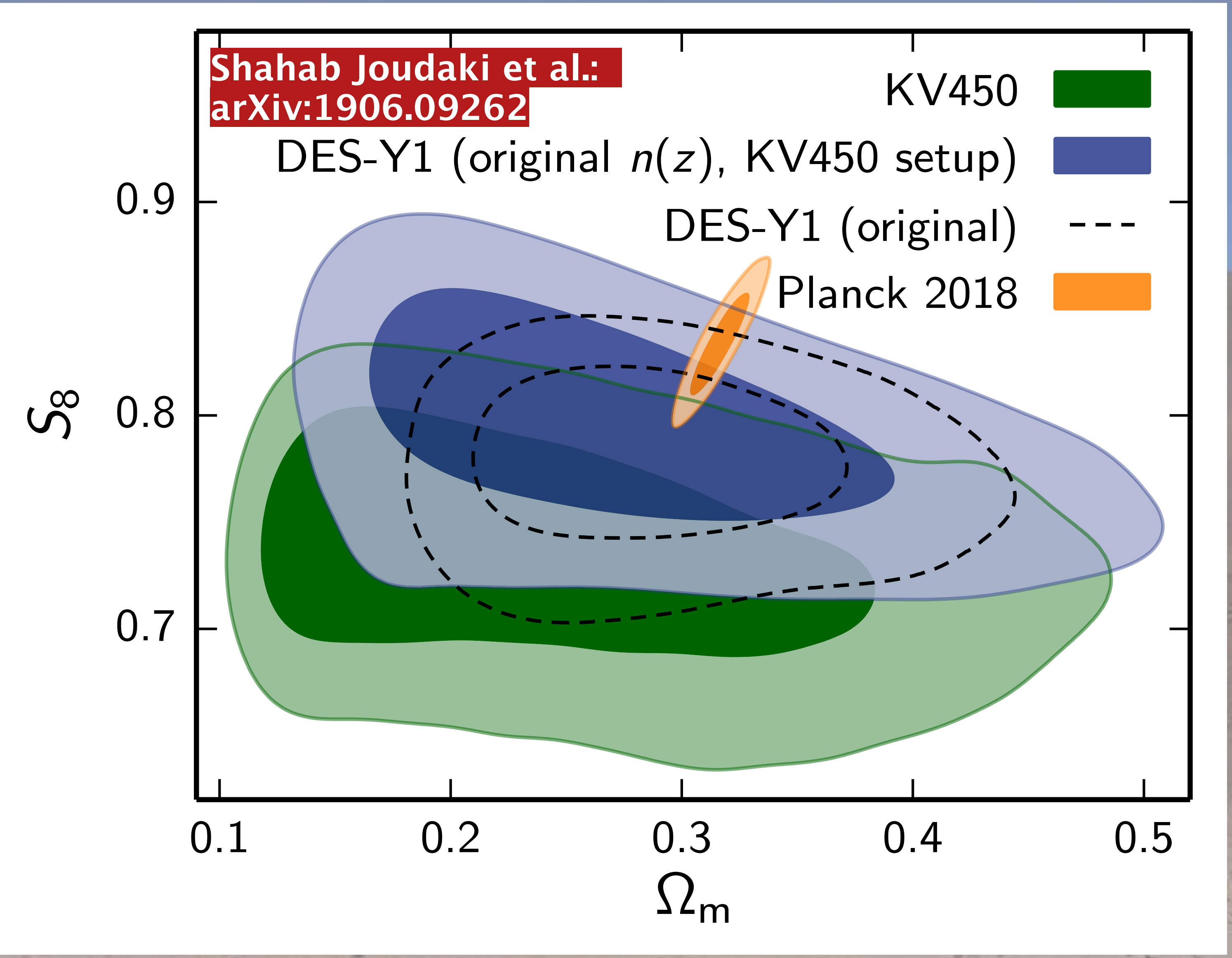
KiDS

In pictures:



In pictures:

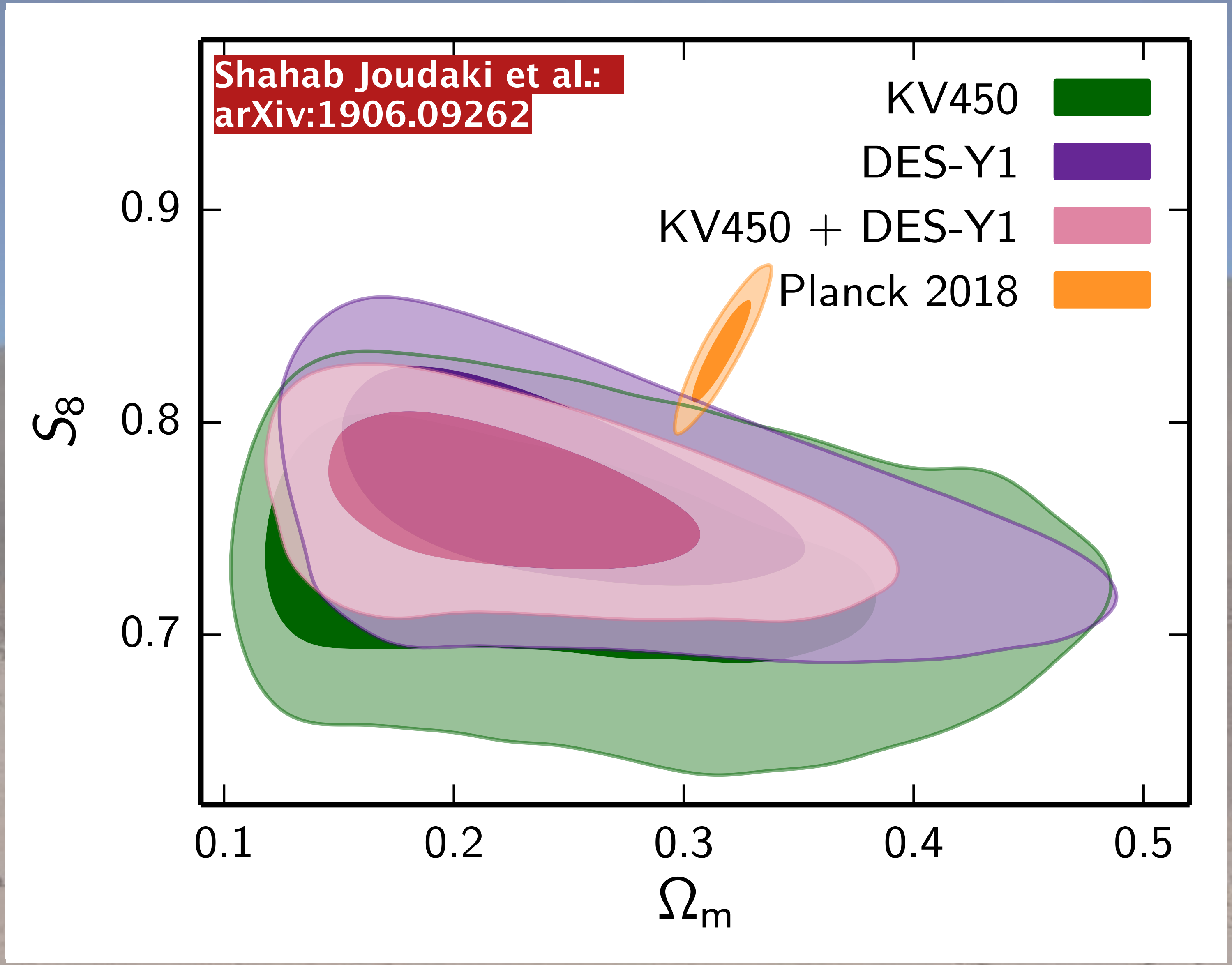
- KV450, DESY1 (same cosmology setup)



KiDS

In pictures:

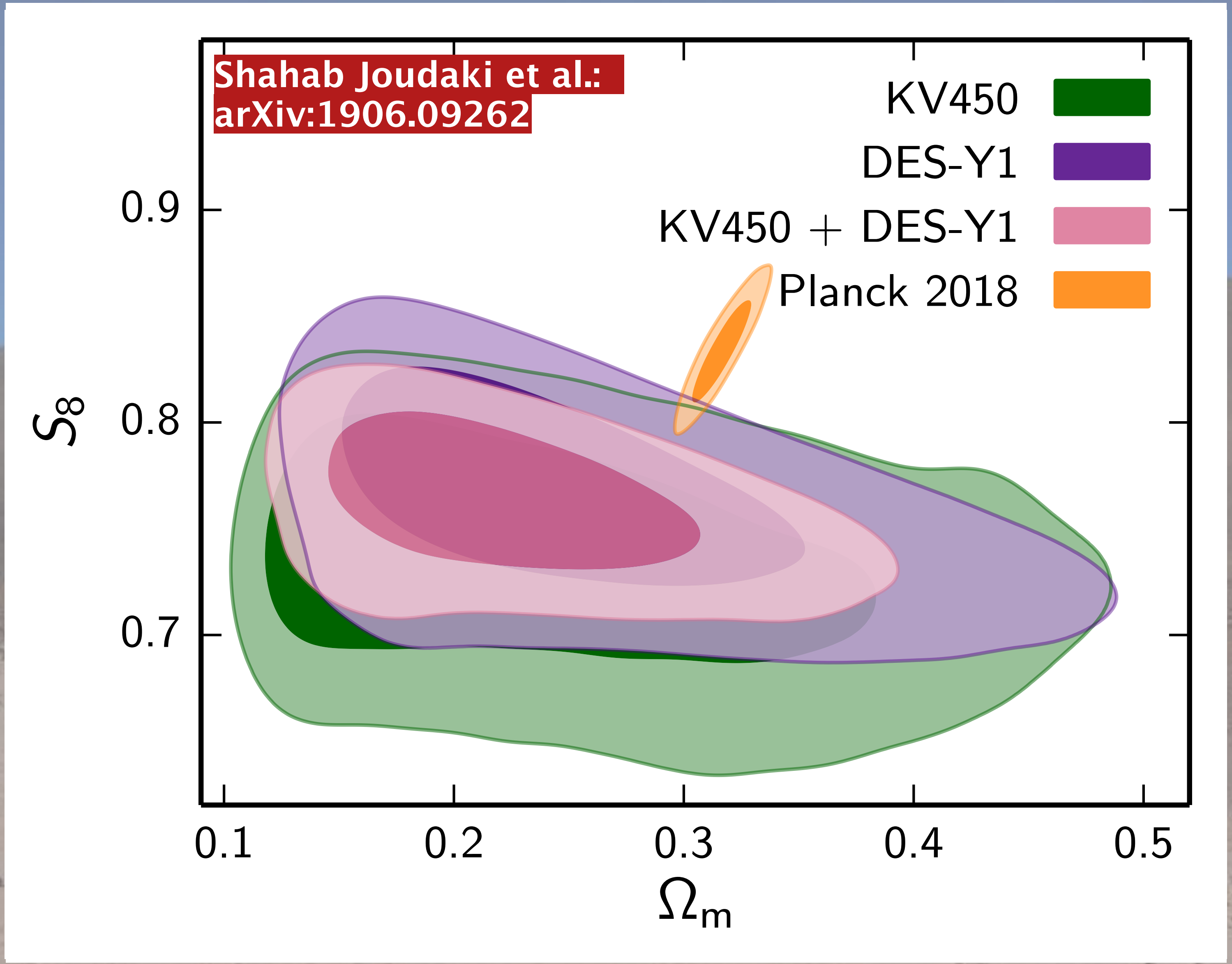
- KV450, DESY1 (same cosmology setup)
- KV450, DESY1 (using same z-calibration) & combined

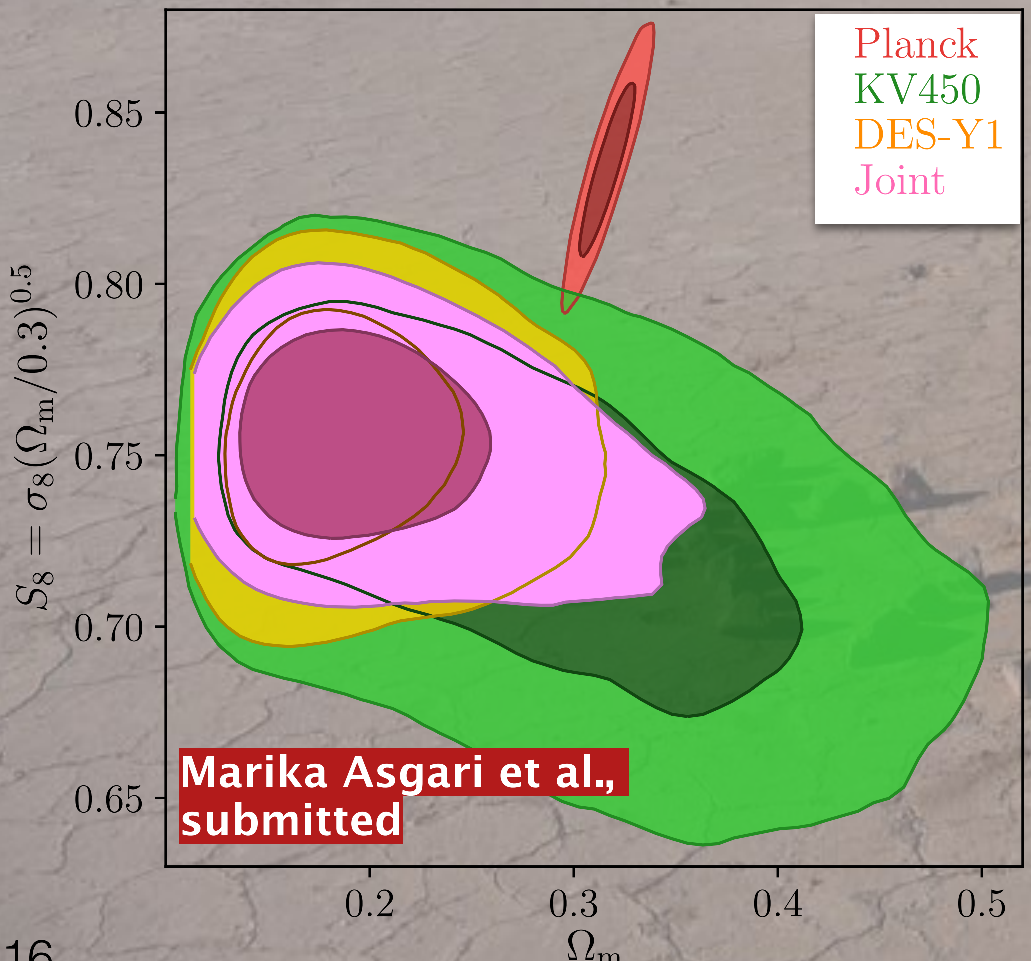


KiDS

In pictures:

- KV450, DESY1 (same cosmology setup)
- KV450, DESY1 (using same z-calibration) & combined





- Analysis using “COSEBI” (modified correlation functions that better separate k-scales, as well as E and B modes) gives **even tighter** constraints (and **3.2σ** significant tension, 10.5±3.4% below Planck)

$$S_8 = 0.755^{+0.019}_{-0.021}$$

KiDS

CONCLUSIONS

- Weak lensing cosmic shear is testing ΛCDM at the few percent level with surveys like KiDS, DES, HSC
  - and LSST, Euclid, WFIRST in future
- Intriguing discrepancies are getting persistent
  - S_8 values ~10% below Planck, at 2-3σ significance
- Photometric redshift biases are key (and hard!)
  - this will be a big challenge for deeper surveys

- This is still the beginning:
  - KiDS 450 → 1350 sqdeg
  - DES-Y1 → Y5
  - HSC 137 → 1400 sqdeg


KiDS
The KiDS Team
Konrad Kuijken
Massimo Viola
Henk Hoekstra
Marcello Cacciato
Maciek Bilicki
Andrej Dvornik
Christos Georgiou
MJ Vakili
Arun Kannawadi
Ricardo Herbonnet
Margot Brouwer
Cristobal Sifon
Ewout Helmich
Nancy Irrisari
Martin Borstad Eriksen
Arthur Jakobs
Fabian Köhlinger
Berenice Pila-Diez
Remco van der Burg
Elisabetta Semboloni
LEIDEN
Chris Blake
SWINBURNE
Catherine Heymans
Marika Asgari
Ami Choi
Alexandra Amon
Yanchuan Chai
Benjamin Giblin
Alexander Mead
Joachim Harnois-Deraps
John Peacock
Tilman Troester
Qianli Xia
EDINBURGH
Edo van Uitert
Benjamin Joachimi
Harry Johnston
Tom Kitching
Will Sutherland
LONDON
Catherine Heymans
Hendrik Hildebrandt
Angus Wright
BOCHUM
Lance Miller
Elisa Chisari
Julian Merten
Shahab Joudaki
Naomie Robertson
OXFORD
Ludovic van Waerbeke
Alireza Hojjati
VANCOUVER
Peter Schneider
Patrick Simon
Thomas Erben
Axel Buddendiek
Alexandru Tudorica
Reiko Nakajima
Chris Morrison
Douglas Applegate
Dominik Klaes
Oliver Cordes
Tim Schrabback
BONN
Alistair Edge
DURHAM
Kristian Zarb Adami
Ian Fenech Conti
MALTA
Edwin Valentijn
Jelte de Jong
Gijs Verdoes Kleijn
John McFarland
Hugo Buddelmeijer
Gert Sikkema
Kor Begeman
Andrey Belikov
Danny Boxhorn
Carlo Enrico Petrillo
Willem-Jan Friend
Leon Koopmans
Reynier Peletier
GRONINGEN
Mario Radovich
PADUA
Nicola Napolitano
Massimo Brescia
Massimo Cappacioli
Stefano Cavuoti
Giovanni Covone
Massimo Dall'Ora
Fedor Getman
Aniello Grado
Francesco La Barbera
Giuseppe Longo
Maurizio Paolillo
Emanuella Puddu
Agatino Riffato
Nivya Roy
Creszenzo Tortora
Zhuoyi Huang
NAPLES