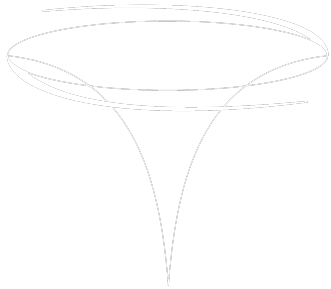
euclid



Euclid-Roman Cosmic Shear Synergies

Tom Kitching (UCL, MSSL)

Synergies between Roman and Euclid shear

- Here I will focus on cosmic shear only – combination of 3x2pt statistics including shear and photometric clustering

- Very few joint Roman-Euclid studies. Here proposed programme of possible synergies

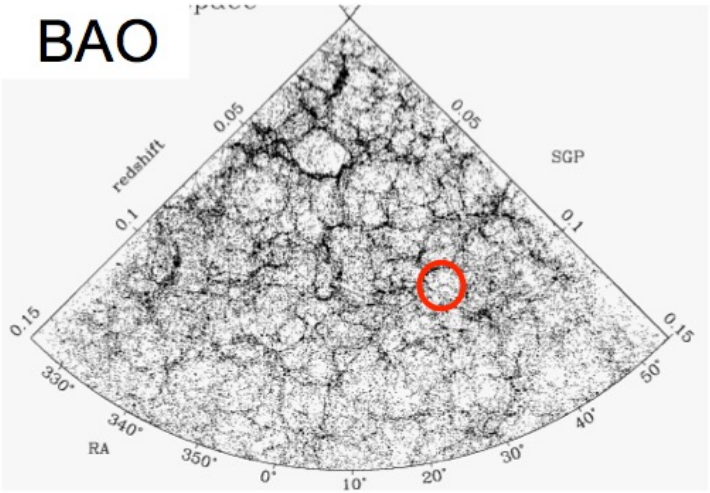
- Review some well-known synergies and propose some unexplored ones

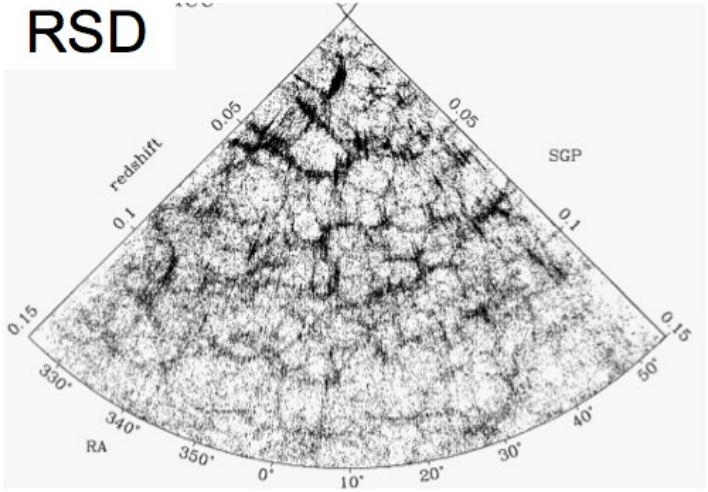
What is Euclid ?

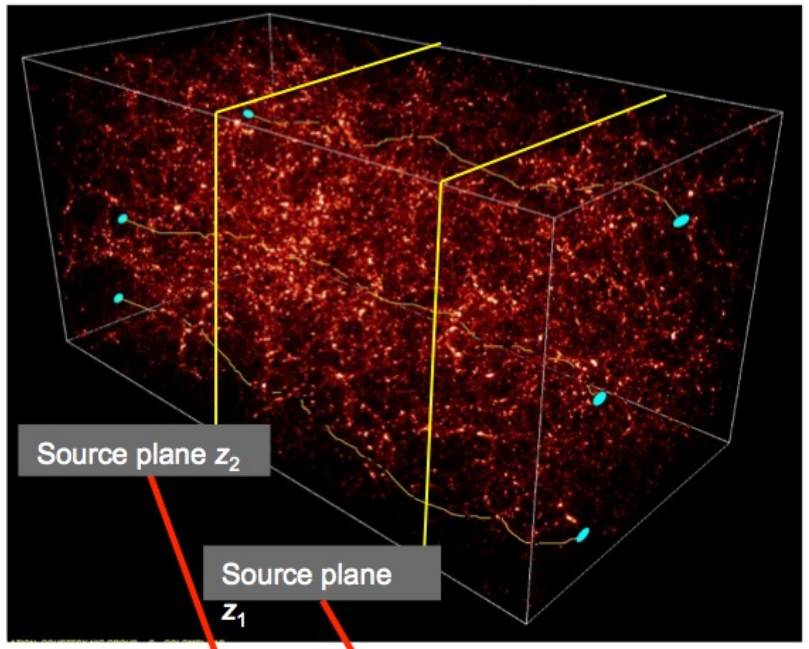
BAO, RSD and WL

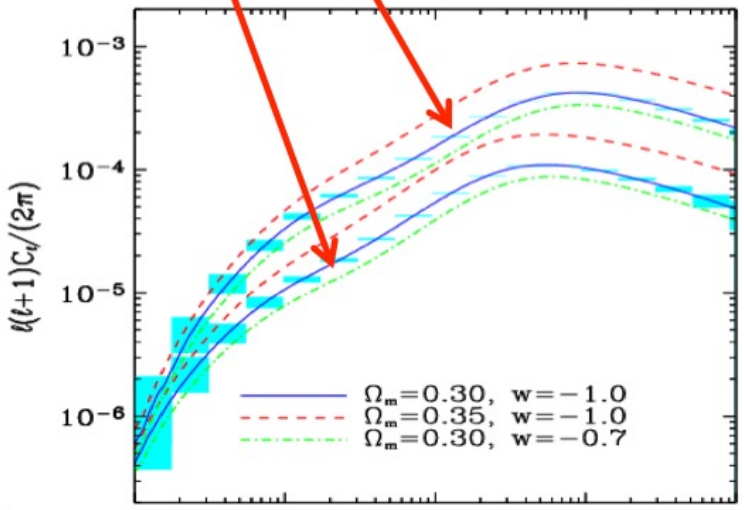
~30 million galaxies with redshifts

1.5 billion sources with shapes, 10 slices



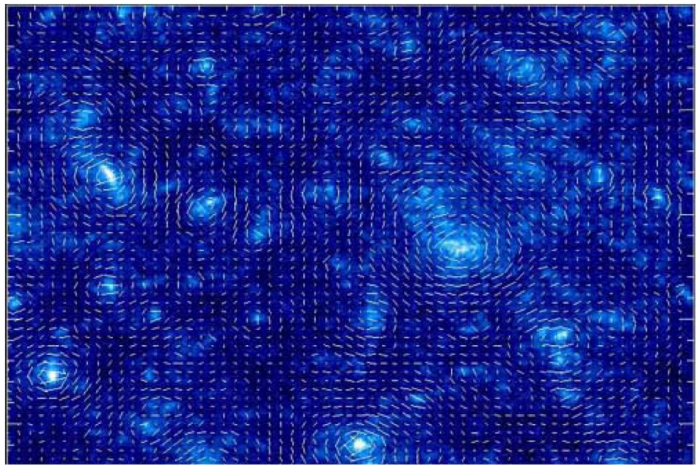






Slide from Y. Mellier

Weak Lensing



Simulation of cosmic shear in a CDM model. Line segments represent amplitude and direction of lensing shear produced by over-densities (light blue) and voids (dark blue). (B. Jain, U. Seljak, & S. White 2000, ApJ, 530, 547)

https://www.stsci.edu/files/live/sites/www/files/home/roman/_documents/cosmology-with-roman.pdf

Roman will enable measurements of millions of galaxy shapes with high signal-to-noise in four bands, providing the best controlled weak-lensing experiment: unique in depth, detail, and control of measurement and astrophysical systematics. The high density of lensed galaxies will make it possible to produce high-resolution maps of dark matter with redshift that can be used to better understand the growth of large-scale structures and provide additional constraints on key cosmological parameters. In addition to mapping galaxy distributions, Roman's potential High-Latitude Survey will enable:

- Wide-area, 4-NIR-band imaging of 170 deg²/month, with a possible total yield of 4×10^8 weak-lensed shapes (40 – 50 galaxies per square arcminute in the stacked images)
- 4-band photometric redshifts for all of the galaxies, complemented with slitless spectroscopy (1.0 – 1.93 μm) for the same areas of sky
- Detection of >20,000 galaxies/month at $z > 8$, and 1,500 galaxies/month at $z > 10$
- Imaging depth of 26.9 in Y, J, H bands

Ground based Photometry and Spectroscopy (photo-z)

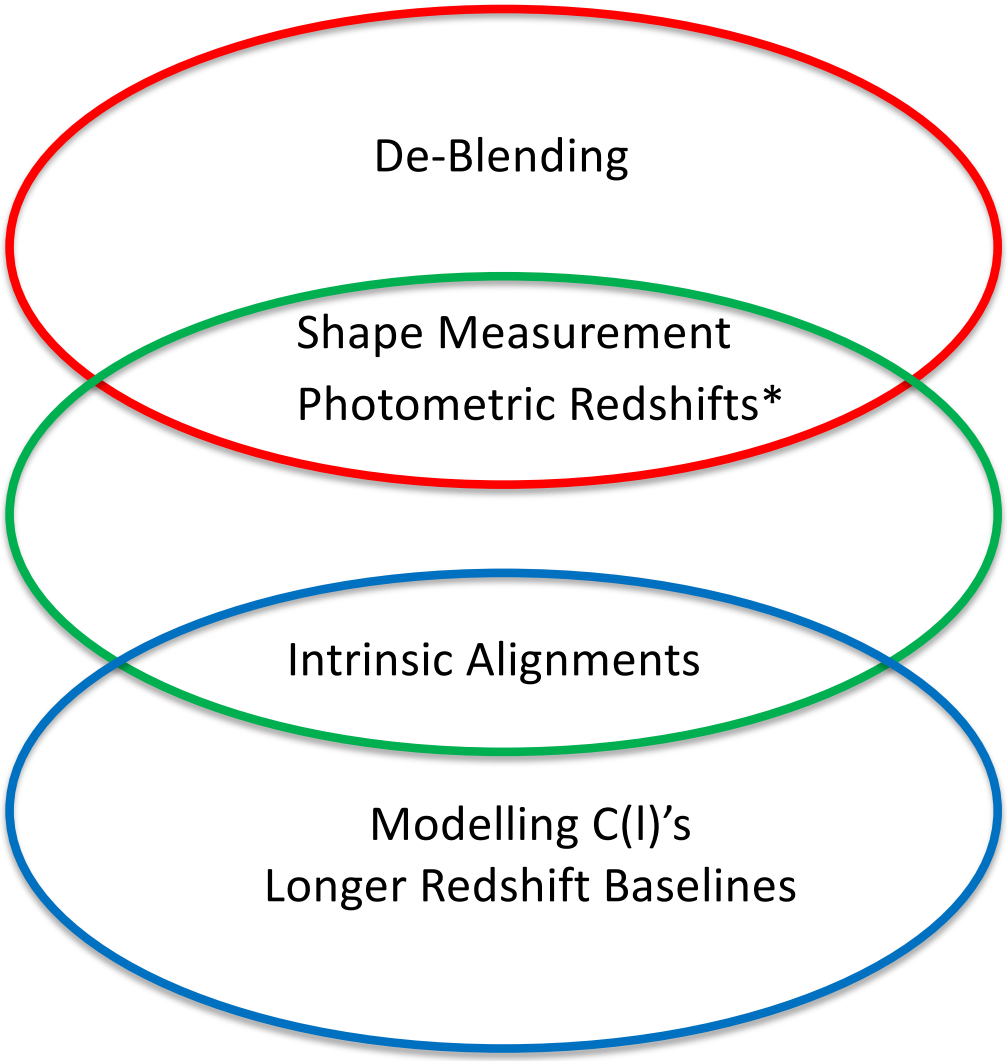
SURVEYS In ~6 years		
	Area (deg2)	Description
Wide Survey	**15,000 deg²**	Step and stare with 4 dither pointings per step.
Deep Survey	**40 deg²**	In at least 2 patches of > 10 deg² 2 magnitudes deeper than wide survey

PAYLOAD					
Telescope	1.2 m Korsch, 3 mirror anastigmat, f=24.5 m				
Instrument	VIS	NISP			
Field-of-View	0.787×0.709 deg²	0.763×0.722 deg²			
Capability	Visual Imaging	NIR Imaging Photometry			NIR Spectroscopy
Wavelength range	550– 900 nm	Y (920-1146nm),	J (1146-1372 nm)	H (1372-2000nm)	1100-2000 nm
Sensitivity	24.5 mag 10σ extended source	24 mag 5σ point source	24 mag 5σ point source	24 mag 5σ point source	$3\ 10^{-16}$ erg cm-2 s-1 3.5σ unresolved line flux
	Shapes + Photo-z of $n = 1.5 \times 10^9$ galaxies			z of $n=2.5 \times 10^7$ galaxies	

Possibility other surveys: SN and/or μ-lens surveys, Milky Way (TBC): **after Mission PDR**

Ref: Euclid RB Laureijs et al arXiv:1110.3193

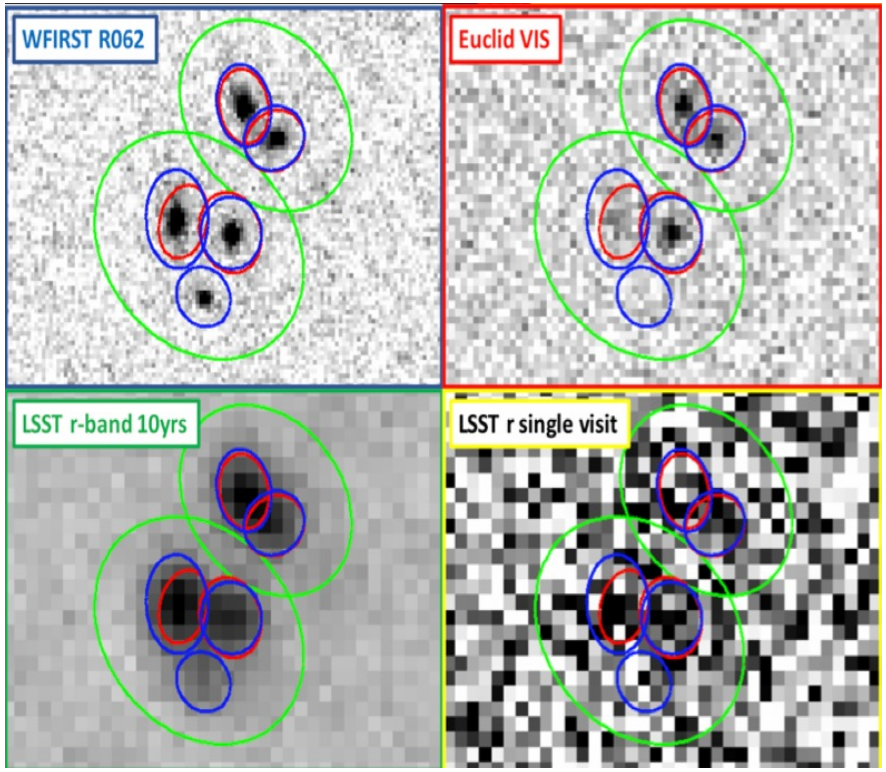
Roman+Euclid can improve all systematic effects in both surveys



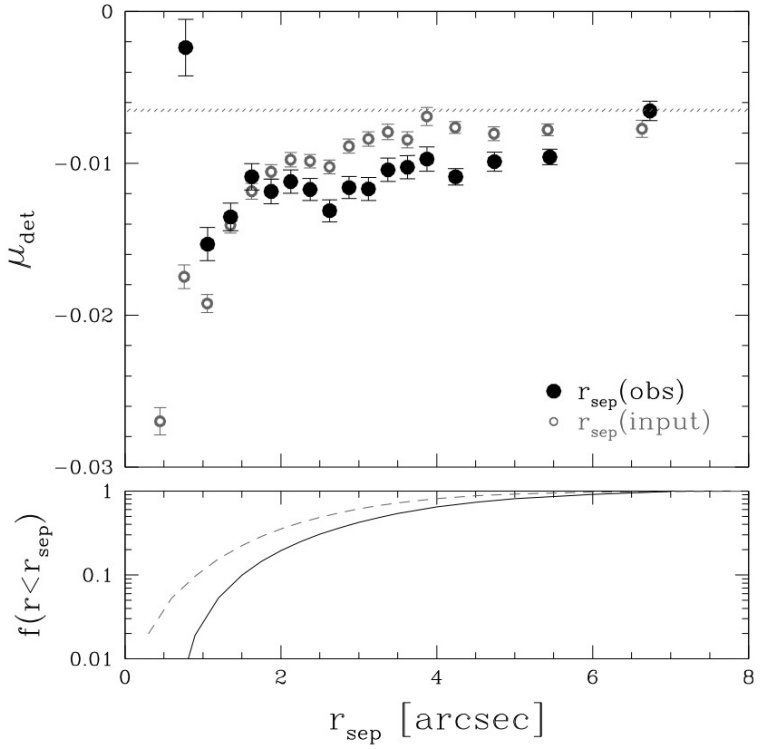
*won't discuss in this talk

Deblending

- Dominant source of bias



Reference: LSST Synergy With Euclid and WFIRST; Rhodes (2019)

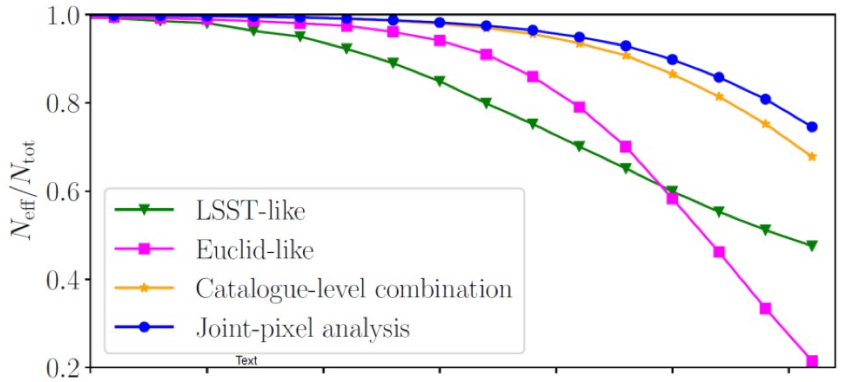


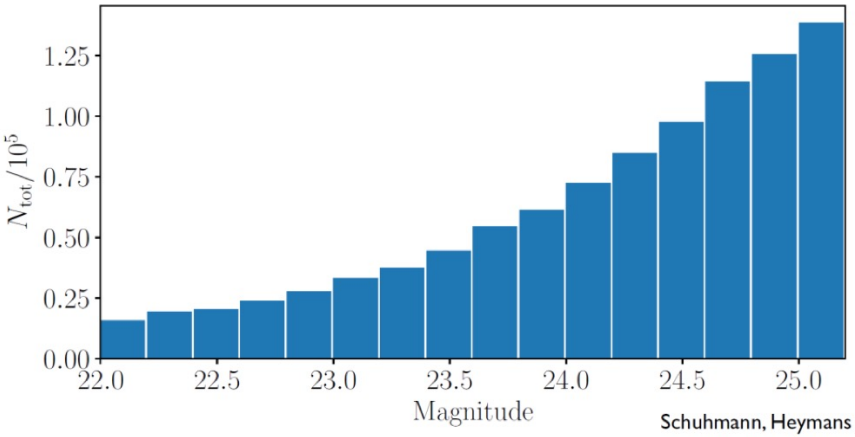
Reference: Hoekstra, Kannawadi, Kitching (2021), 2010.04178

- Possible to calibrate, or use Metadetect, but more data (bands) is better

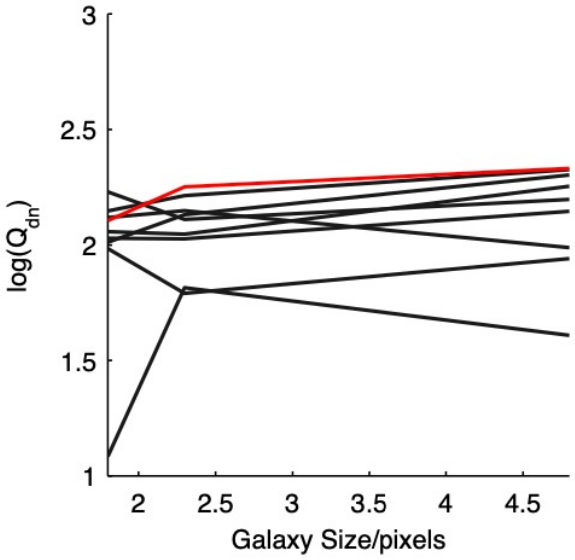
Shape Measurement

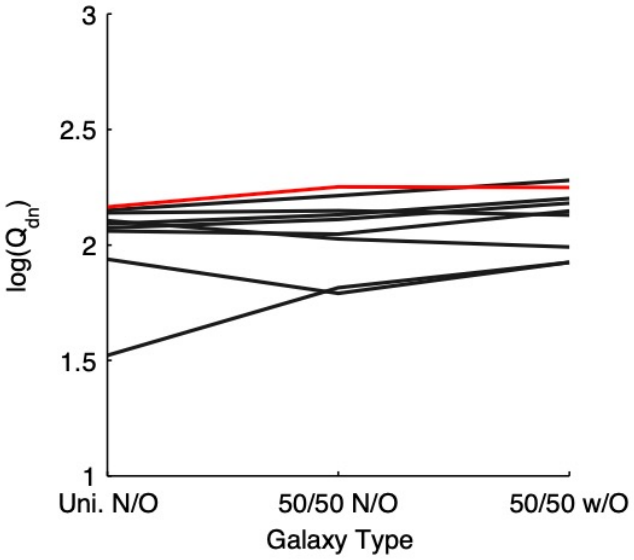
- Pixel level shape measurement from multiple surveys/methods in general leads to better accuracy



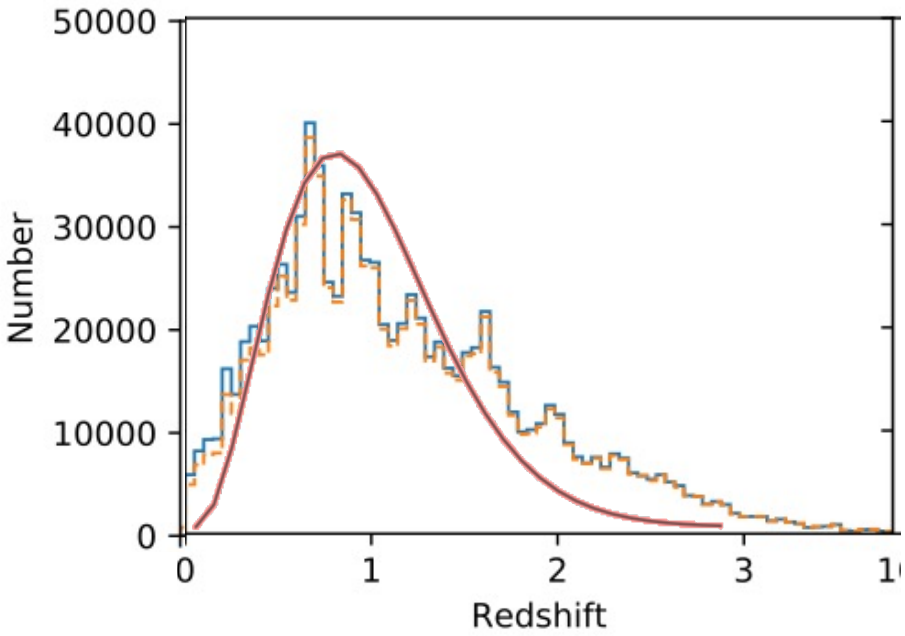


Schuhmann, Heymans and Zuntz 2019





Kitching et al. (2012) 1202.5254



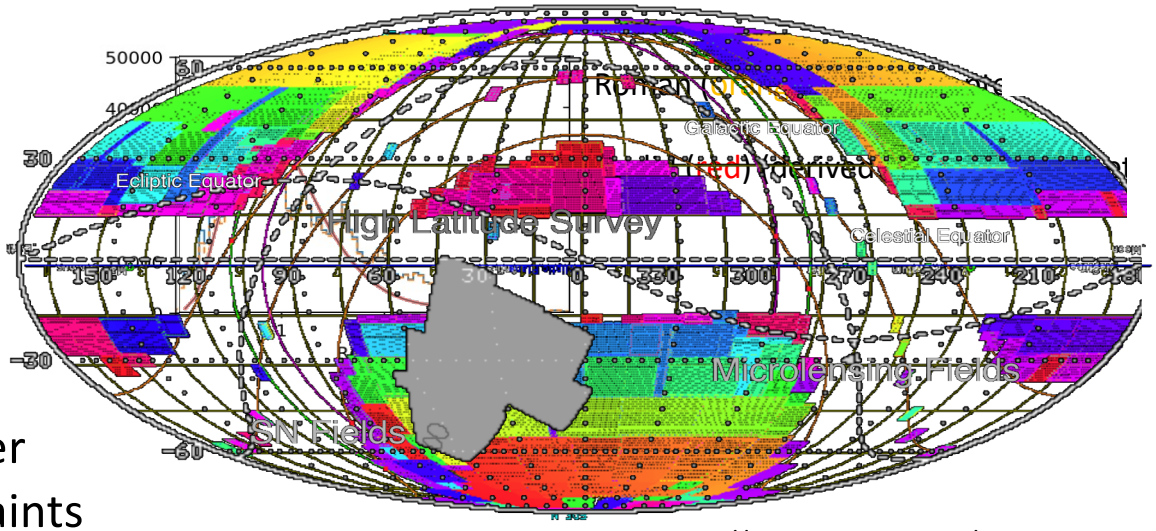
Roman (orange, blue) (adapted from Troxel et al., 2020; 1912.09481)

Euclid (red) (derived from Blanchard et al., 2020, 1910.09273)

Summary:

- Euclid wider and shallower
  -> better low-z constraints

- Roman HLS deeper and narrower
  -> better high-z source constraints

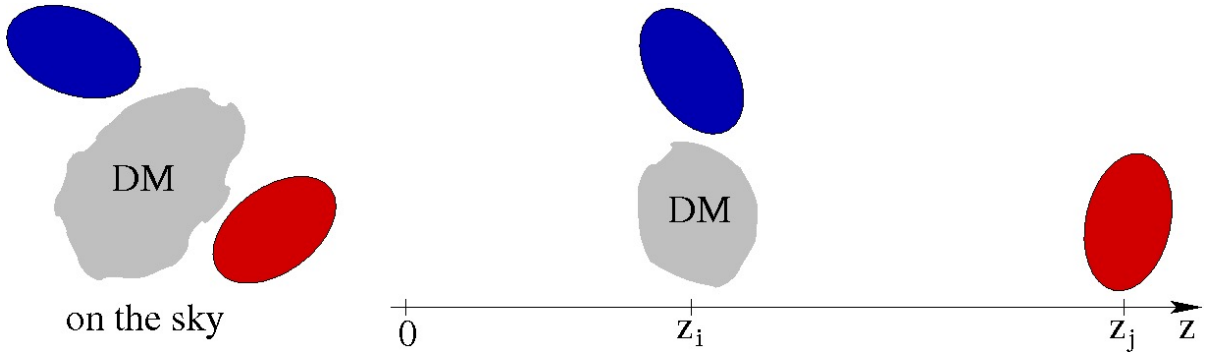


https://www.euclid-ec.org/?page_id=2581

https://drive.google.com/file/d/1UpzkjMGUNkietkdXbLwKiehI_2uwbUul/view (credit: Hirata)

Astrophysical Systematics

- Main astrophysical systematic effect is intrinsic alignments



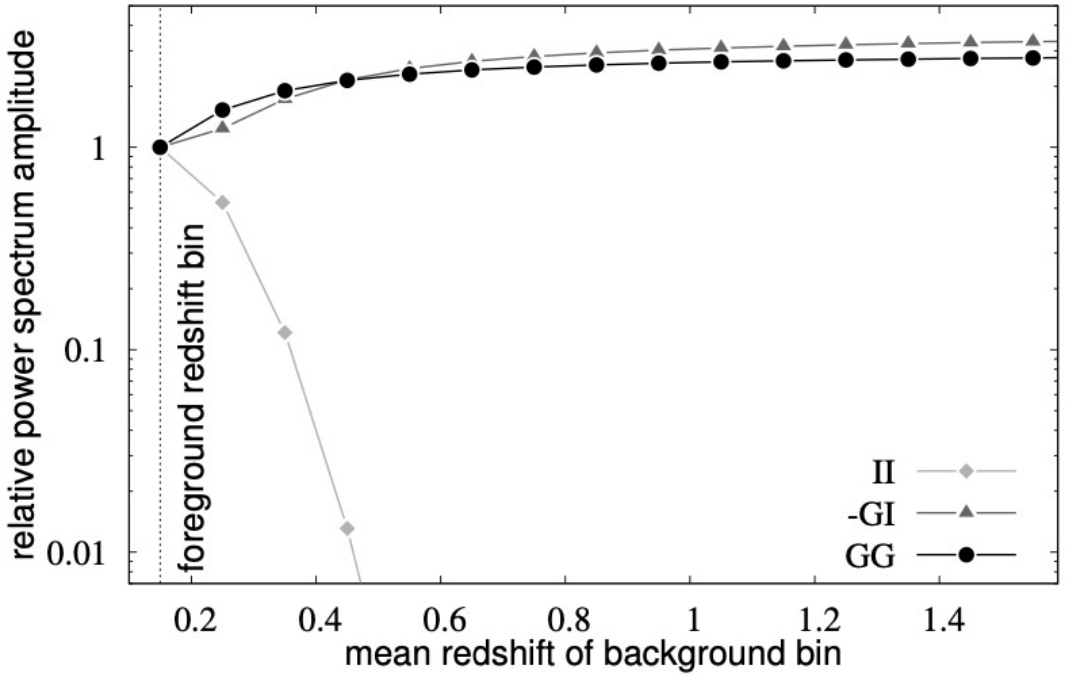
Joachimi et al. (2016); 1504.05456

Dominant model – (non)-linear alignment (Hirata & Seljak, 2004) assumes primordial alignment followed by growth factor scaling: Higher redshift is better (for measuring IA)

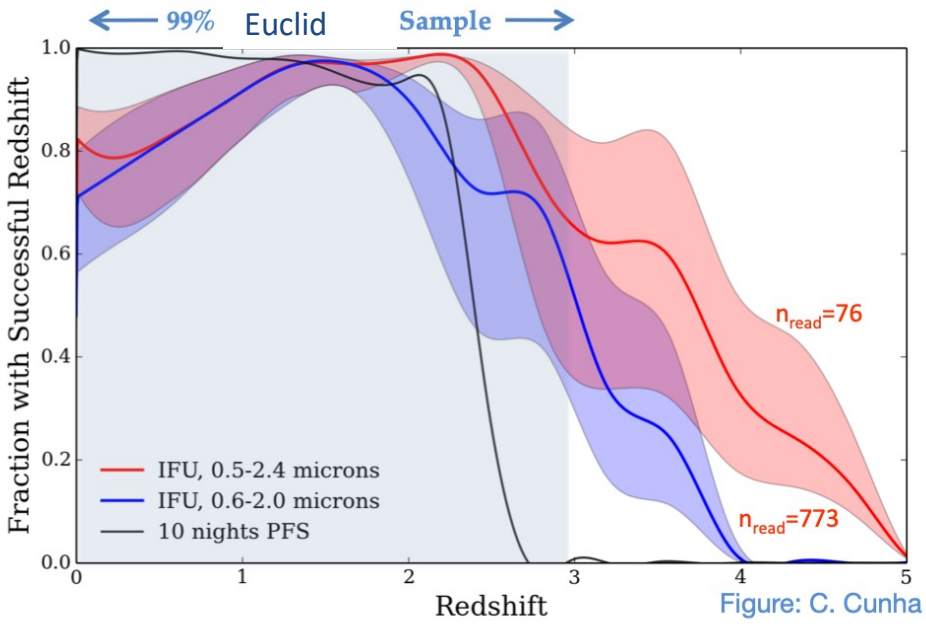
Roman – better IA constraints, but lower overall signal-to-noise

Euclid more contaminated but higher signal-to-noise.

Expectation that combination of the two would yield best of both – needs investigation

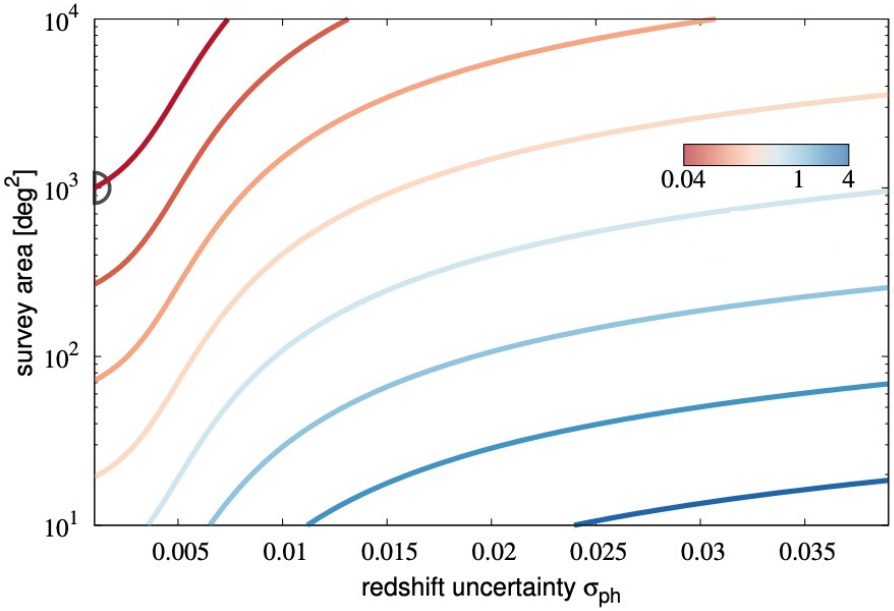


Joachimi et al. (2016); 1504.05456



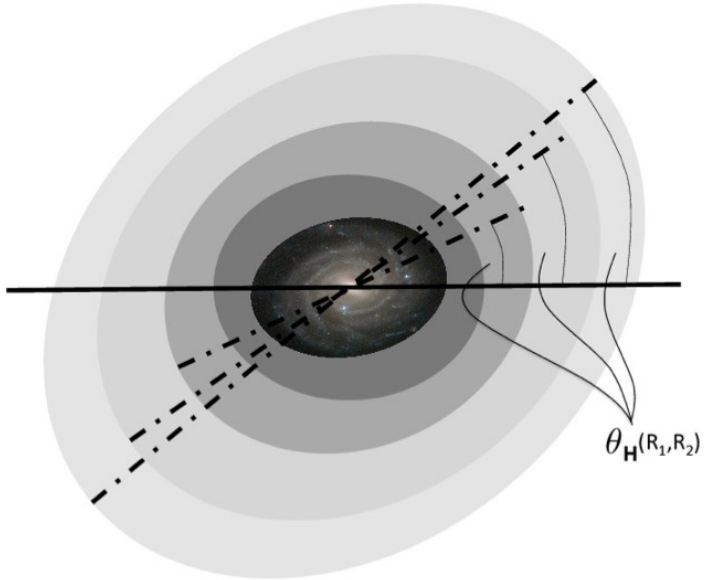
Predictions of the fraction of LSST weak lensing sample objects that would yield a secure (multiple-confirmed-feature) spectroscopic redshift, based either on 1440-second exposure time with Roman (coloured regions)

Roman spectroscopy with Euclid shapes could measure IA function with same S/N as current combinations of BOSS+KiDS over twice the area (from space)

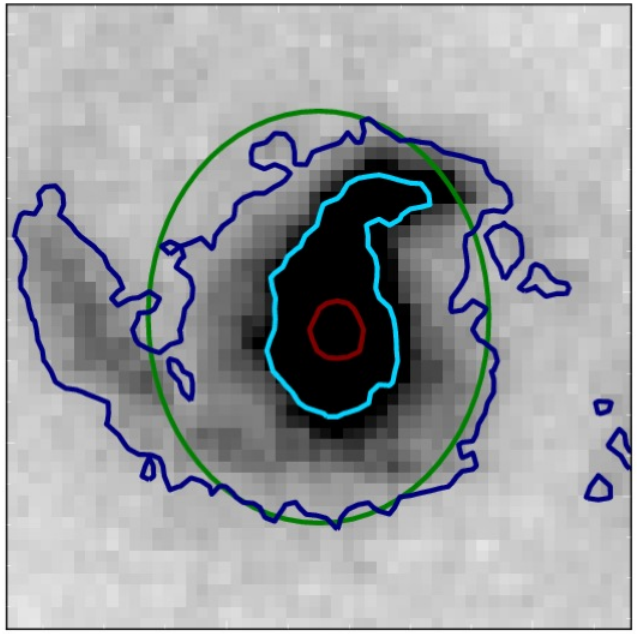


Astrophysical Systematics

- Alignment changes as a function of radius from a galaxy and SED



Kiessling et al. (2015): 1504.05546



Kirk et al. (2015): 1504.05465.

Multiple alignment measurements of the same population could be to mitigate cosmic variance (Chisari et al. 2016; 1607.05232)

Or can use multiple shear estimates to improve constraints on IA in the nonlinear regime (Leonard et al. 2018; 1802.08263)

Precise Roman-Euclid predictions need investigation

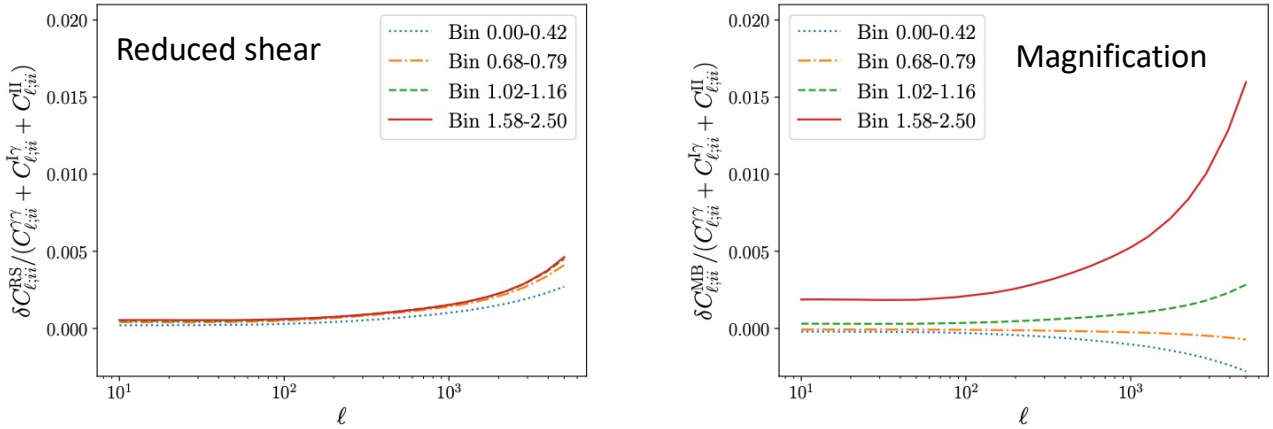
Theoretical Systematics

- Most complex systematics are at high source redshift. Euclid+Roman -> better cross-redshift calibration

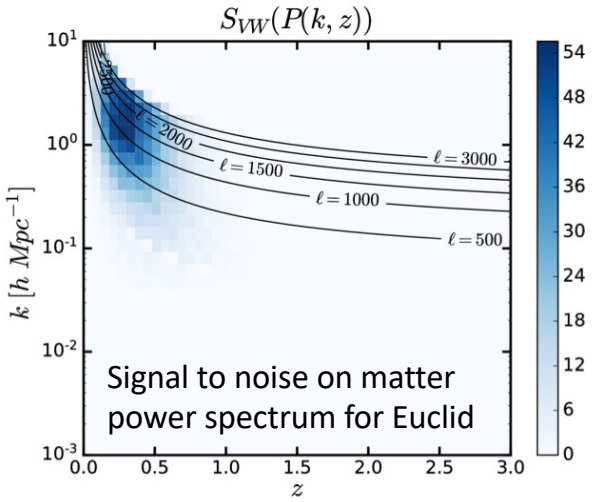
For a fixed ell-mode Roman high-z will be less contaminated by high-k (small scale effects), but raw shot-noise lower.

Euclid more contaminated but higher signal-to-noise.

Expectation that combination of the two would yield best of both – needs investigation



Deshpande et al (2020); 1912.07326



Taylor et al (2018); 1804.03667

- Science Synergy

- <u>More than the sum of the parts</u>

- Euclid & Roman can both measure
  - Weak lensing shear *g*,
  - Weak lensing magnification;
    - Including size *s* and flux (*n*(*z*))
  - Galaxy positions θ, both photometric and spectroscopic

- At least 3 measurements per galaxy
  - Over 10 redshift bins
  - 30 observable maps per experiment -> 60 for two experiments
  - ***<u>>1500 auto and cross-correlations / power spectra !</u>***

- Some will help with systematics

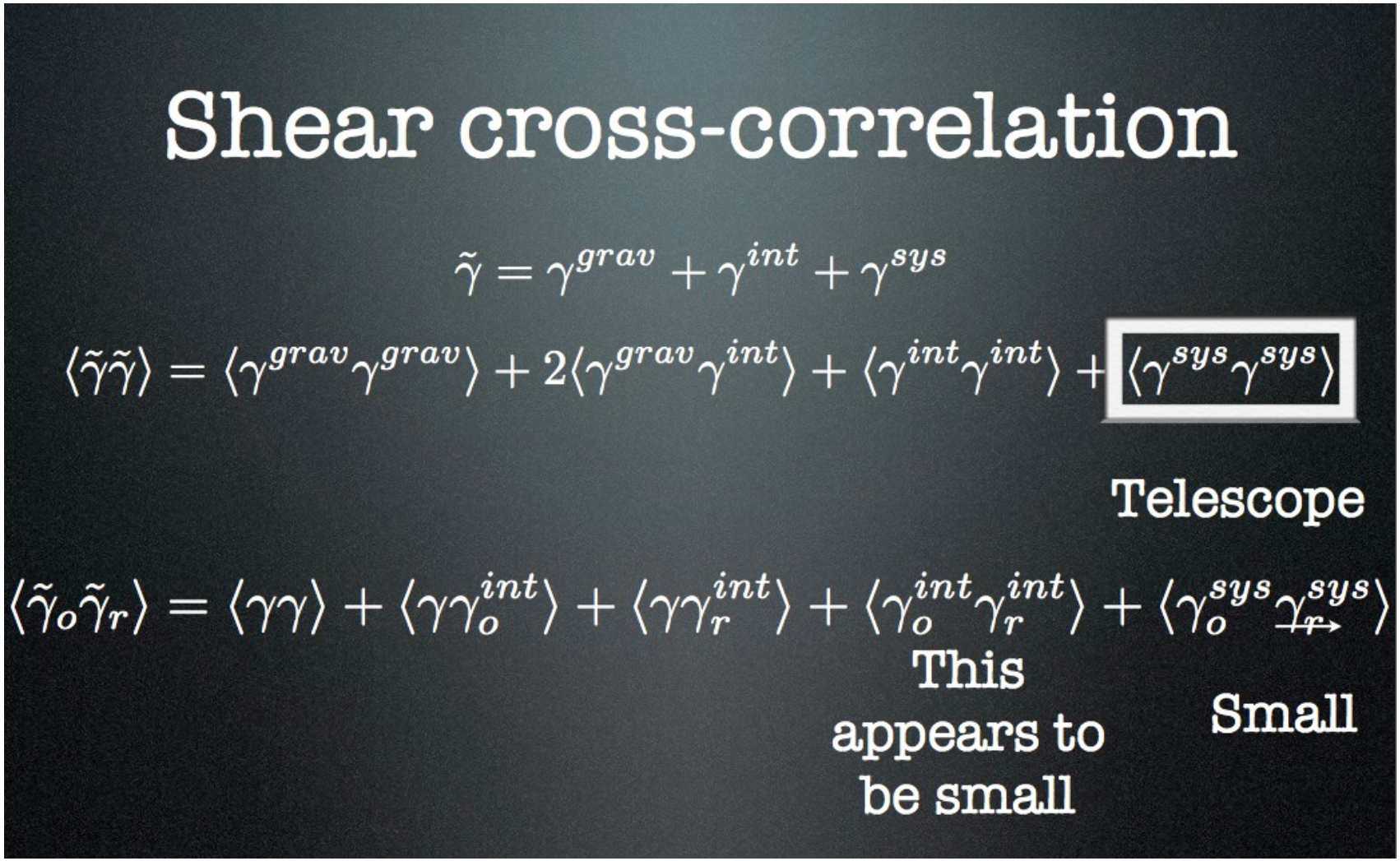
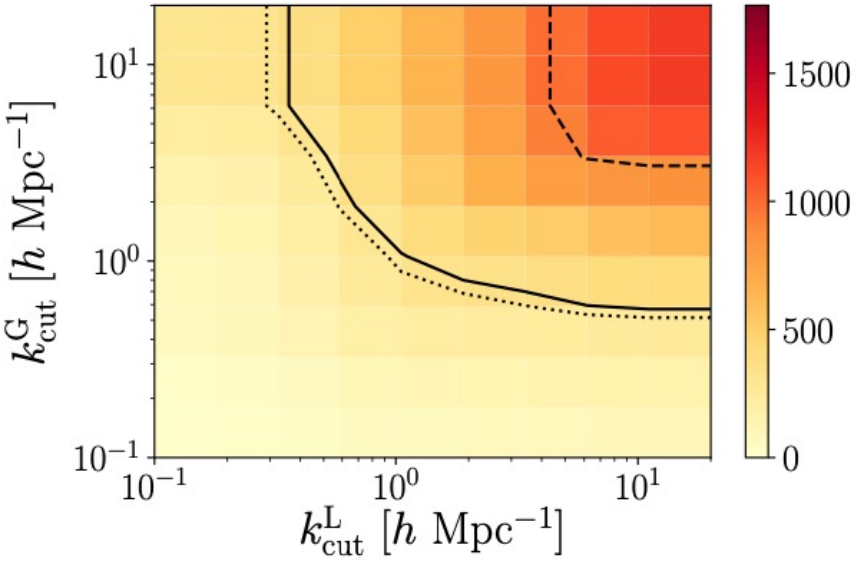
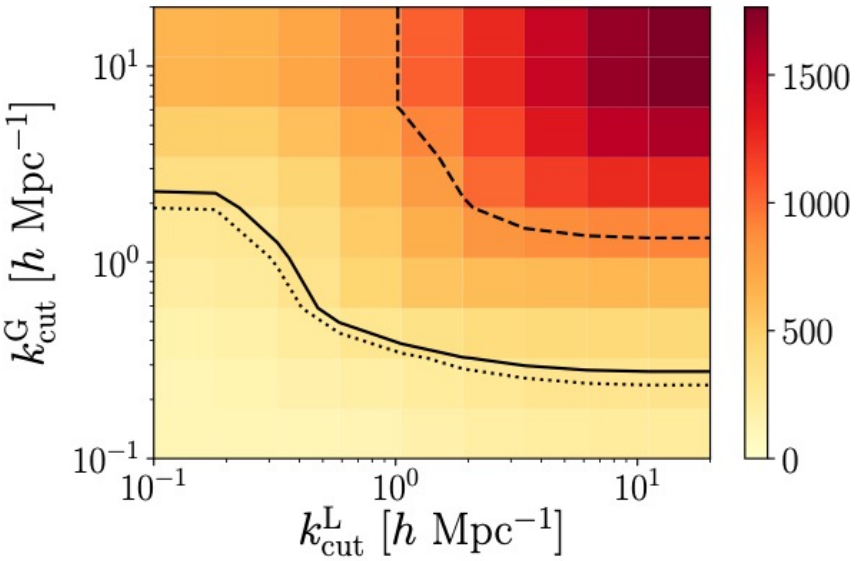


Figure from D. Bacon

Theory

For a fixed area spectroscopic redshifts in a 3x2pt analysis (cosmic shear+photometric clustering) will allow for lower (cleaner) k-cuts or equivalently much higher dark energy FoM





Taylor et al. (2020); 2012.04672

Trade off between Euclid wider area, higher FoM but more high-k contamination

Versus Roman smaller area, lower FoM, but less high-k contamination

Expectation that combination of the two would yield best of both – needs investigation

- Very few joint Roman-Euclid studies on cosmic shear: mainly to date focussed on data analysis (photo-z, blending)

- Here proposed programme of further possible synergies – more investigation is warranted

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