The importance of redshift-space distortions for angular power spectra of galaxy number counts

Università degli studi di Torino
Konstantinos Tanidis [arXiv: 1902.07226]

COSMO'19
RWTH Aachen University
3rd September 2019

- How the incorporation of the redshift-space distortions on top of galaxy number counts affects the constraints on the cosmological parameters

- What is redshift-space distortions (RSD)?
- The background galaxies recede: expanding universe

- Galaxies also have their own peculiar velocities whose contributions are added to the main component of cosmological recession

- Result: Distribution of the galaxies in the redshift space is squashed and deformed

What is galaxy number counts or galaxy clustering?

- Distribution of galaxies studied with the 3D galaxy Fourier PS: Fourier mode of the 3D separation between pairs of galaxies in the sky at a given z

- Here use 2D or tomographic angular power spectrum : 2D angular separation of galaxies in different z slices

- Approximate sky as flat in small patches-Limber approximation

How to study galaxy clustering?

- With density fluctuations by computing galaxy bias. Also smaller contributions are neglected here (such as lensing, … etc).

$$\delta_g(\vec{n}, z) = b_g(z) \cdot \delta_m(\vec{n}, z)$$

Aim to see how the contribution or the ignorance of the RSD affects our analysis

$$\delta_g(\vec{n}, z) = b_g(z) \cdot \delta_m(\vec{n}, z) + \frac{1}{\mathcal{H}(z)} \partial_r(\vec{v} \cdot \vec{n})$$

Limber approximated angular power spectra: Galaxy clustering and RSD

$$C^{\mathrm{g}}_{\ell\gg 1}(z_i, z_j) = \int \mathrm{d}\chi \, \frac{W^i(\chi) W^j(\chi)}{\chi^2} P_{\mathrm{lin}}\left(k = \frac{\ell + 1/2}{\chi}\right)$$

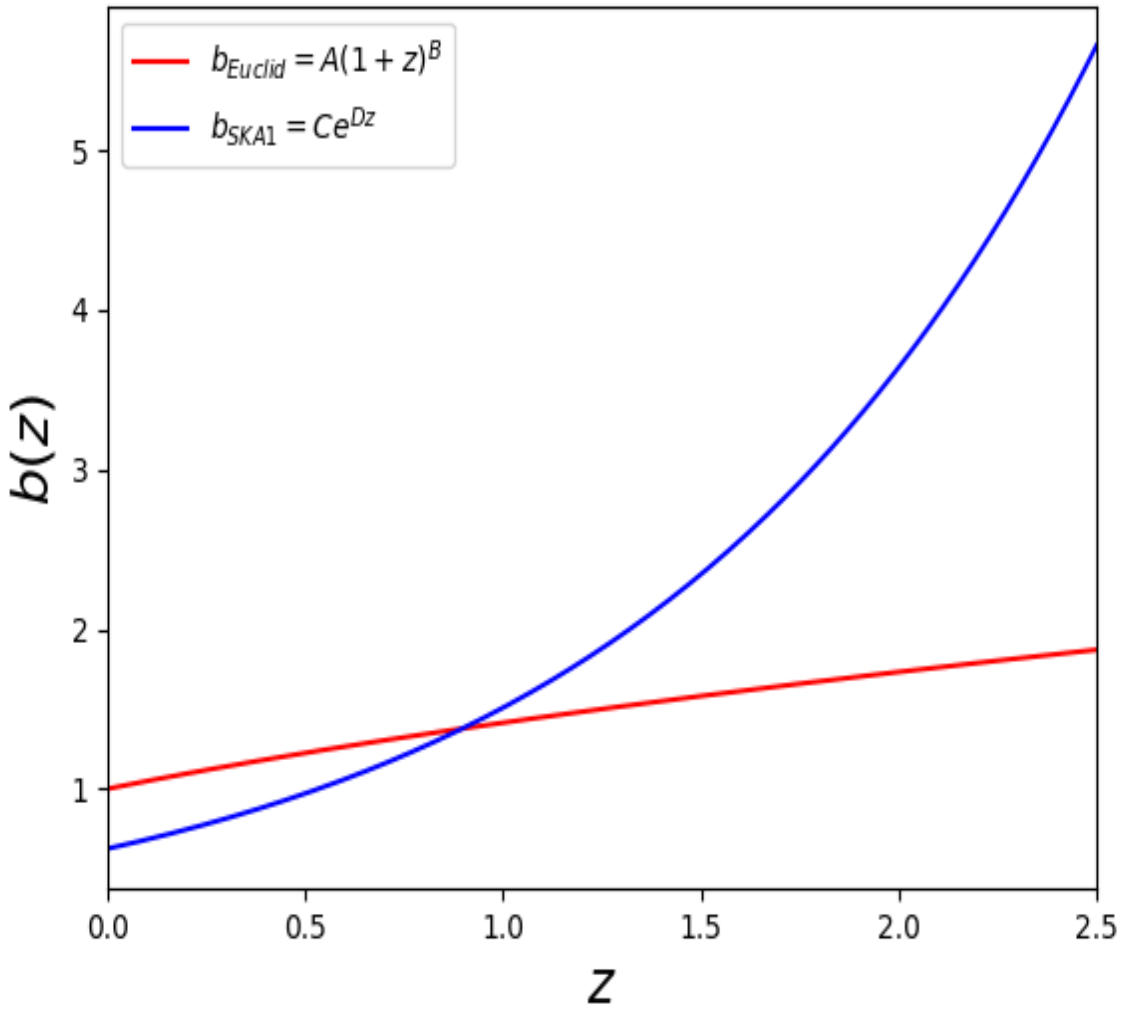
Density fluctuations

$$W^i_b(\chi) = n^i(\chi) b(\chi) D(\chi)$$

Density fluctuations + RSD

$$W^i_f(\chi) = n^i(\chi) f(\chi) D(\chi)$$

$$W^i(\chi) = W^i_b(\chi) + \frac{2\ell^2 + 2\ell - 1}{(2\ell - 1)(2\ell + 3)} W^i_f(\chi) - \frac{(\ell - 1)\ell}{(2\ell - 1)\sqrt{(2\ell - 3)(2\ell + 1)}} W^i_f\left(\frac{2\ell - 3}{2\ell + 1}\chi\right) - \frac{(\ell + 1)(\ell + 2)}{(2\ell + 3)\sqrt{(2\ell + 1)(2\ell + 5)}} W^i_f\left(\frac{2\ell + 5}{2\ell + 1}\chi\right)$$

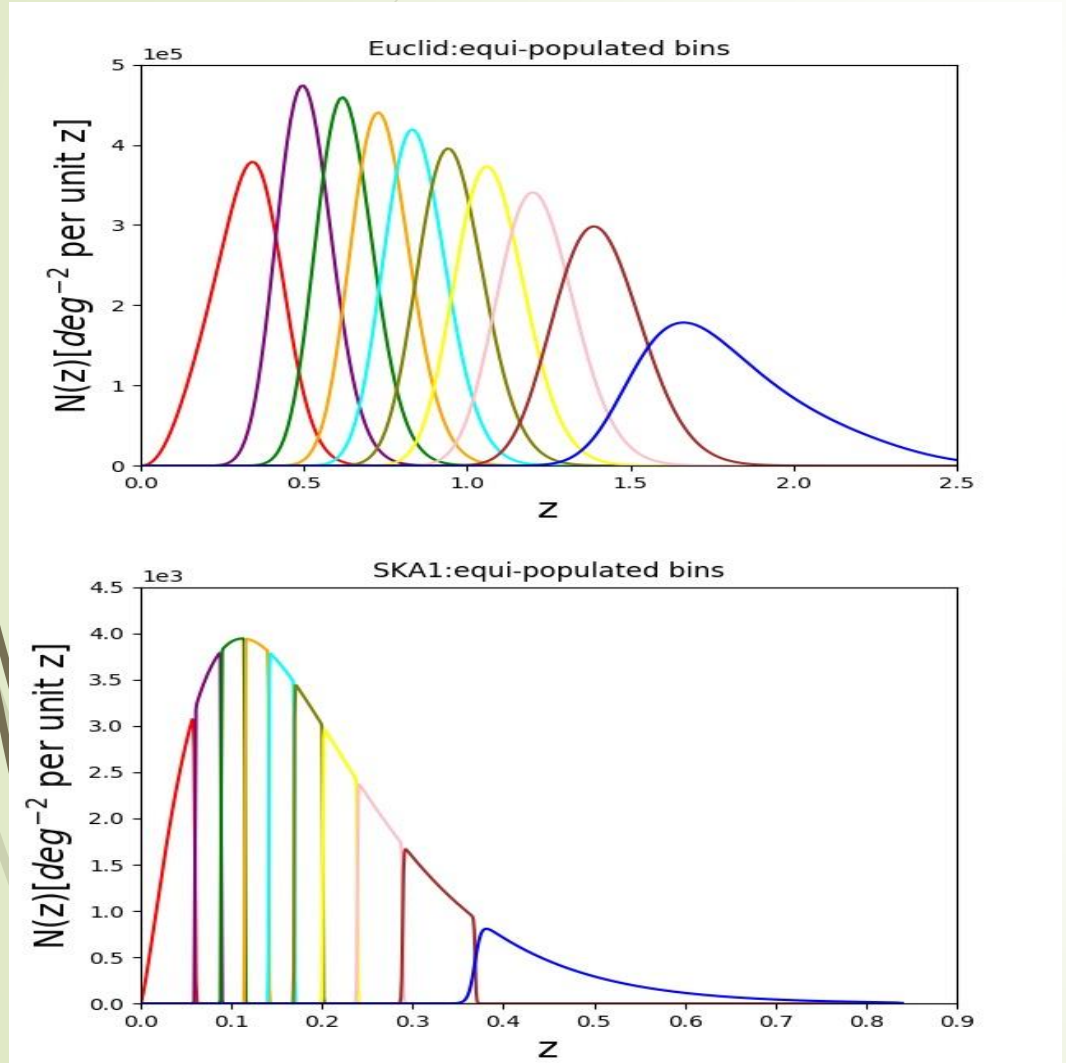


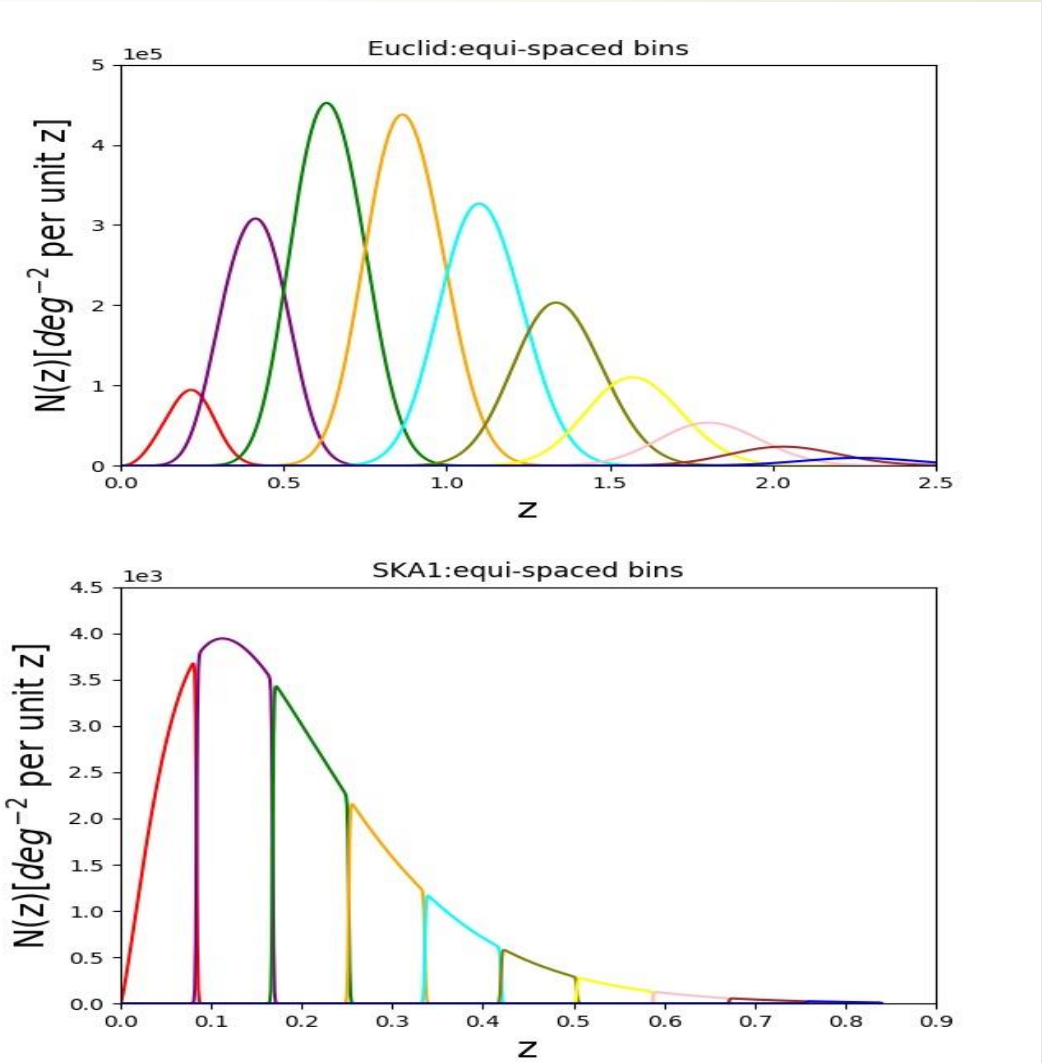
- In order to study galaxy clustering we make forecasts based on proxies with real experiment specifications:

- **Euclid** telescope in optical/NIR detecting a large number of galaxies and measuring their photometric redshifts
  - Sky coverage: $15000\ deg^2$
  - Scale independent galaxy bias with A=1.0 and B=0.5

- Square Kilometre Array phase 1 (**SKA1**) which is an HI galaxy survey in radio. Therefore, the redshift estimation is made with spectroscopy.
  - Sky coverage: $5000\ deg^2$
  - Scale independent galaxy bias with C=0.625 and D=0.881

- We choose 2 binning configurations for each proxy
- Equi-populated bins : The same number of galaxies in each bin
- Equi-spaced bins: Bins of equal size in redshift range





- For each bin, proxy, and binning configuration calculate the angular power spectra
- Want to see how the information based on the RSD on top of the density fluctuations change the results. In order to do so:
- Construct mock observables assuming perfect knowledge of the density fluctuation and RSD
- Then fit these data with 2 models:
  - Keep the same information
  - Neglect RSD
- Constrain 3 cosmological parameters: $\Omega_{\mathrm{m}}, h, \sigma_8$

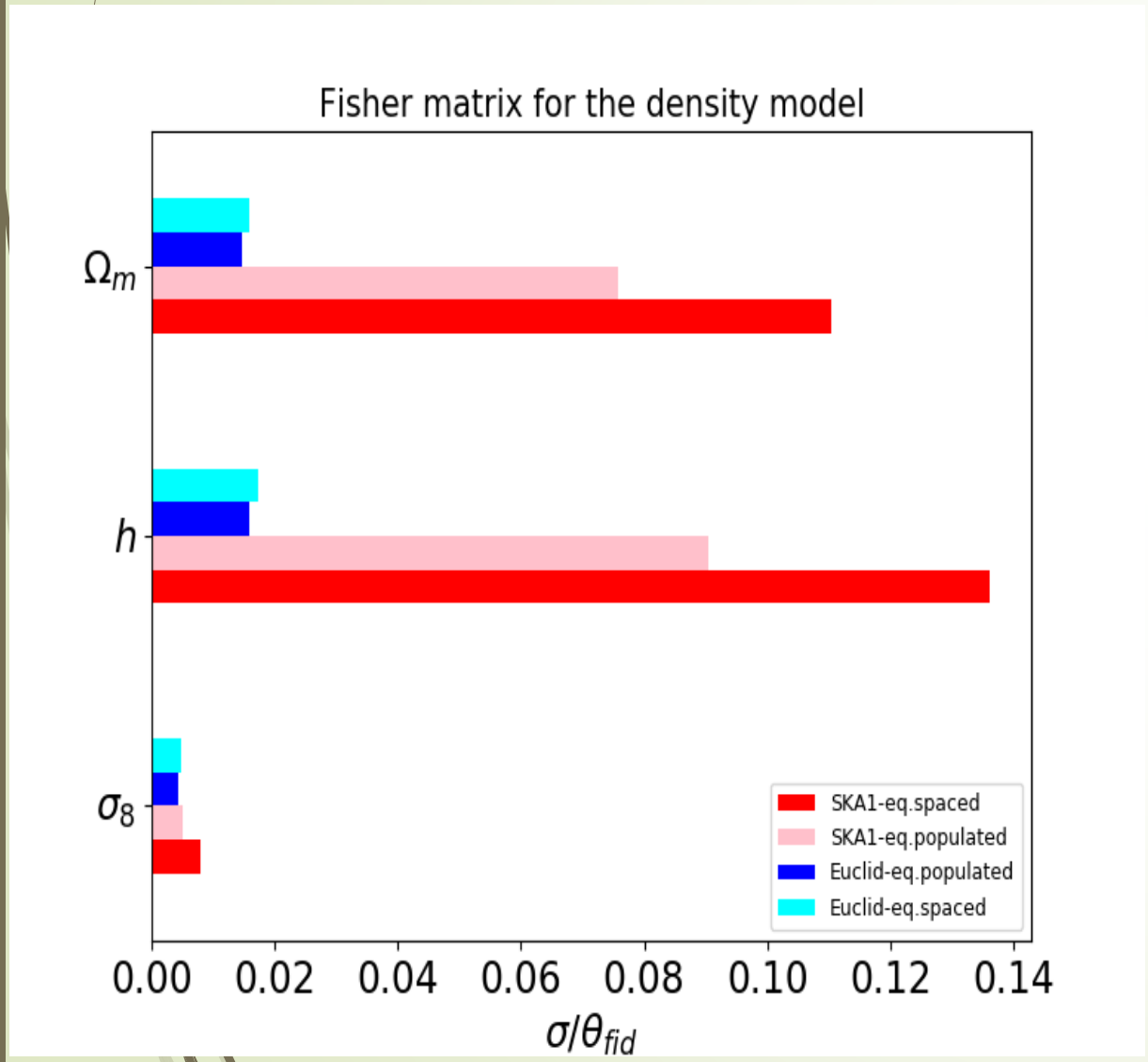
Multipole Range

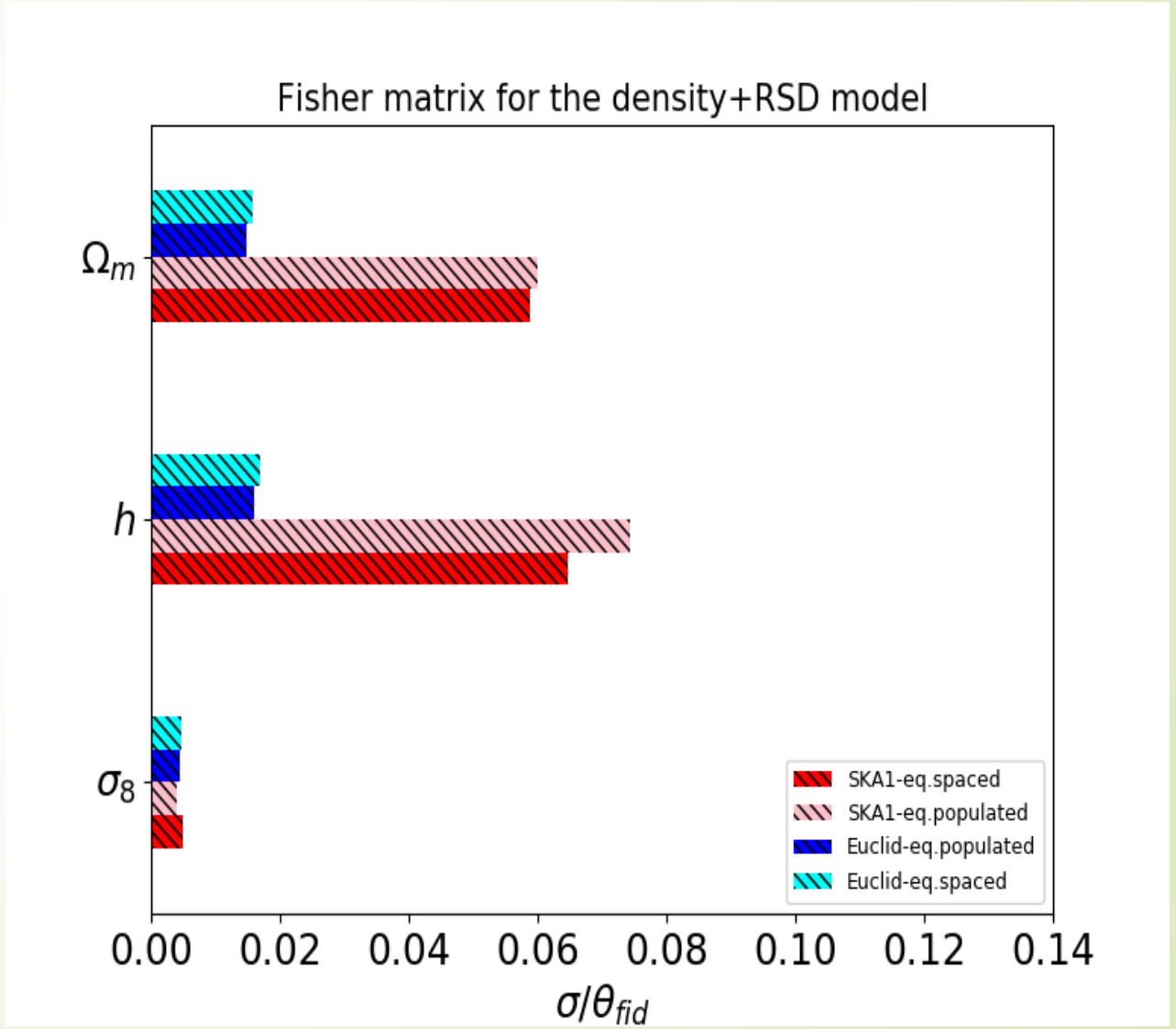
Table 1. Mininum and maximum multipoles for the two binning strategies. The former are set so that the relative error between angular spectra computed with `CosmoSIS` and `CLASS` is below 5%. The latter follow $\ell_{\rm max} = \chi(\bar{z}_i)k_{\rm max}$ in redshift bin i centred on $\bar{z}_i$.

Equi-spaced bins						Equi-populated bins					
Euclid			SKA1			*Euclid*			SKA1		
$\ell_{\rm min}$		$\ell_{\rm max}$	$\ell_{\rm min}$		$\ell_{\rm max}$	$\ell_{\rm min}$		$\ell_{\rm max}$	$\ell_{\rm min}$		$\ell_{\rm max}$
den	den+RSD		den	den+RSD		den	den+RSD		den	den+RSD	
2	2	133	3	13	45	4	3	348	2	7	32
8	6	373	1	13	134	10	7	480	7	30	80
12	9	581	14	26	218	12	9	576	11	78	109
16	11	759	29	40	299	15	10	659	13	77	136
22	13	913	33	60	375	17	12	733	15	80	164
28	17	1046	43	70	448	18	13	806	19	80	194
32	20	1162	63	73	518	20	14	880	22	91	228
36	22	1265	60	101	584	22	15	957	26	82	270
40	25	1356	70	110	647	24	17	1054	30	65	331
50	30	1437	80	120	707	25	19	1181	11	44	564

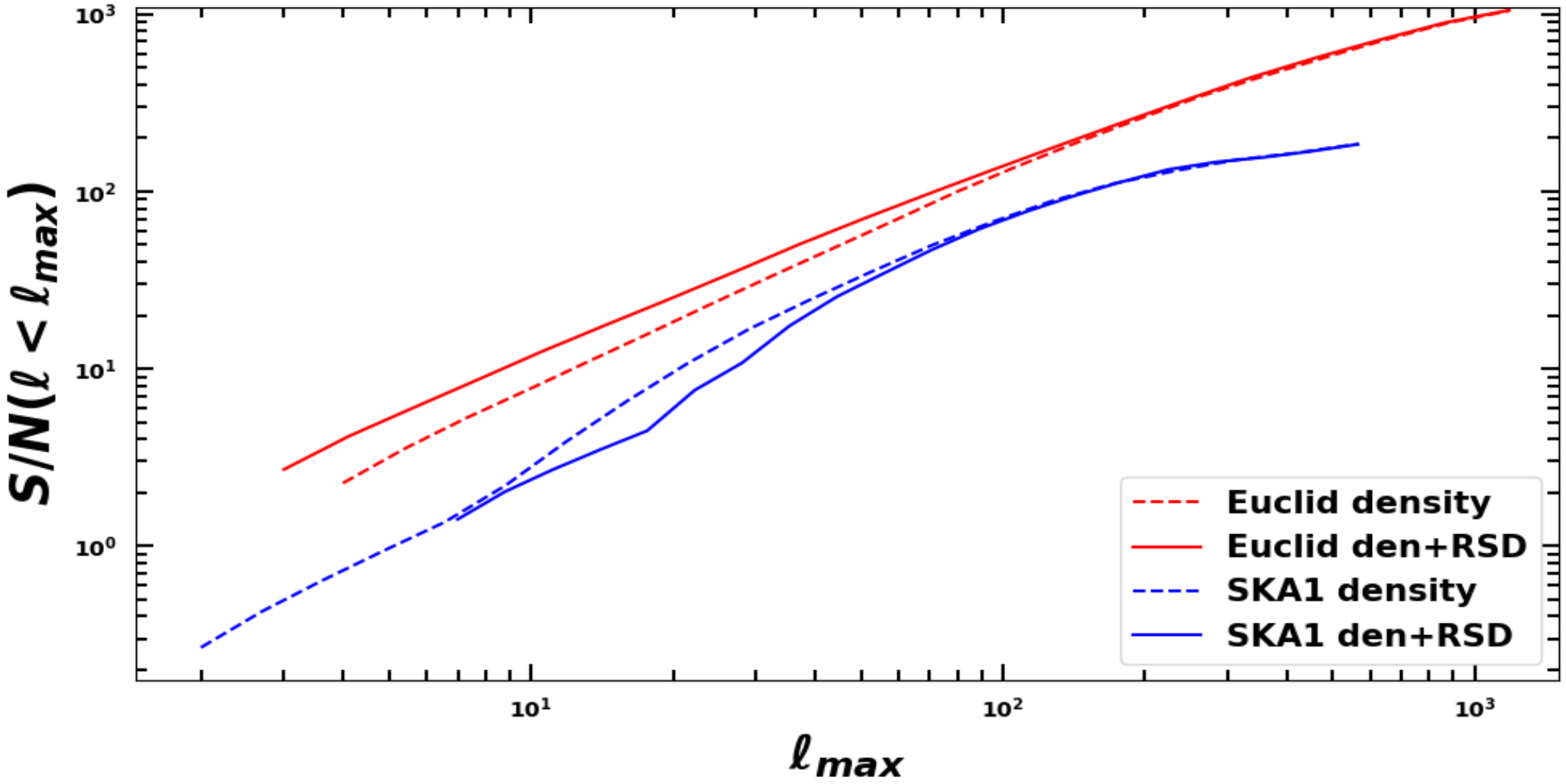
Fisher test: likelihood behaviour near the peak

- Which binning configuration is optimal





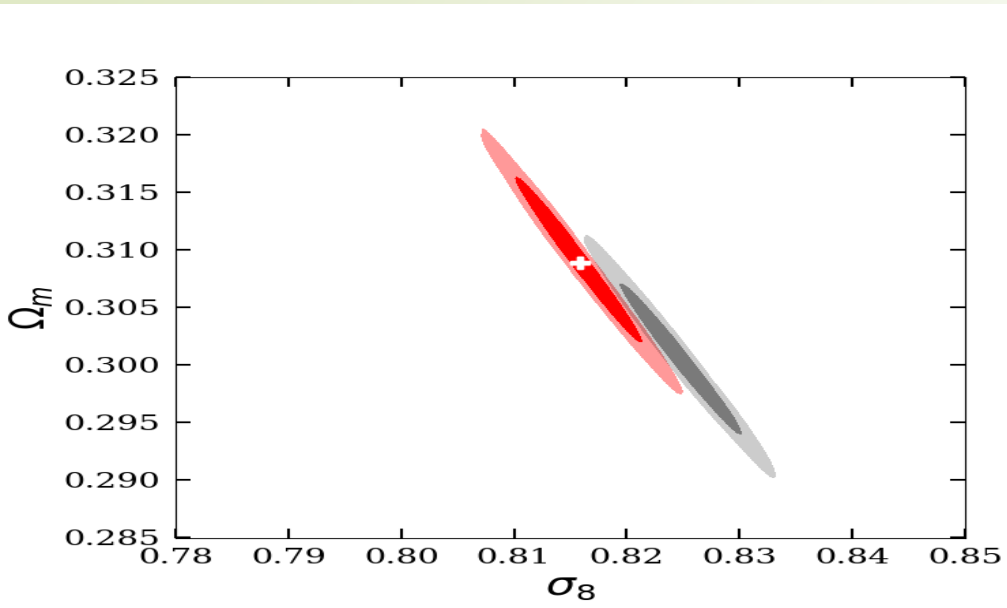
Signal-Noise-Ratio

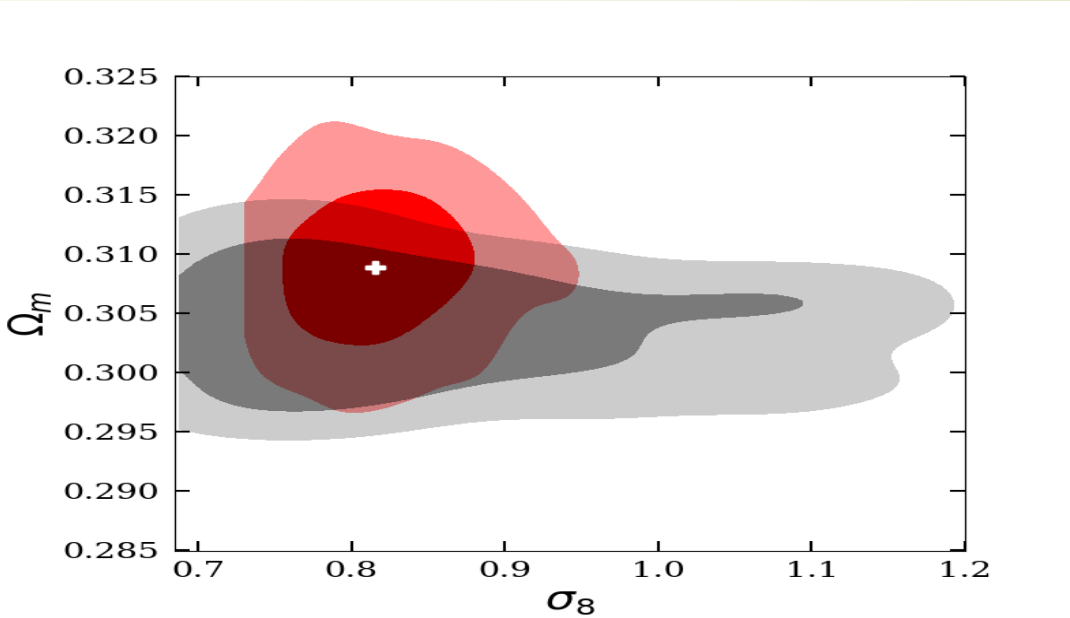


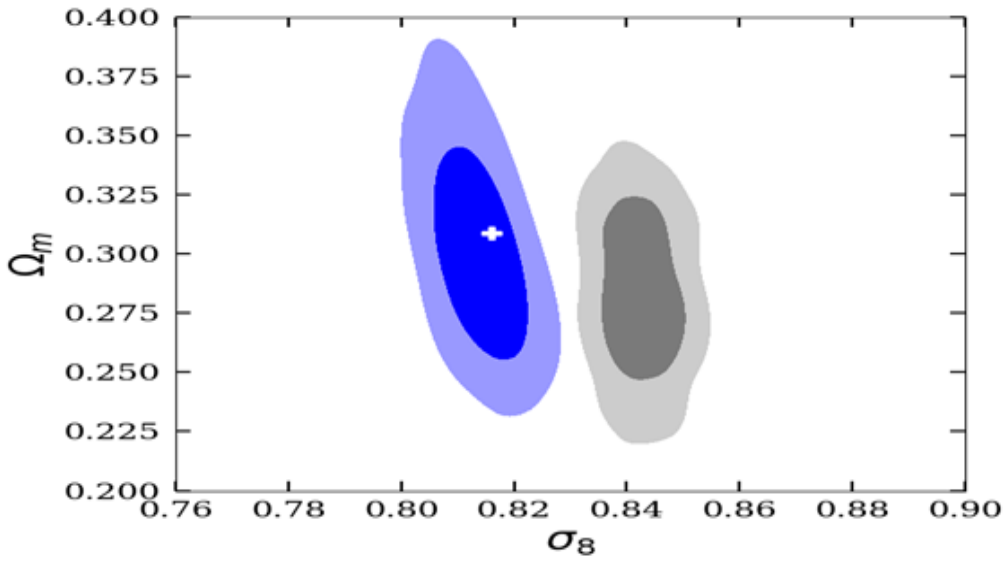
Three scenarios based on our knowledge of the galaxy bias

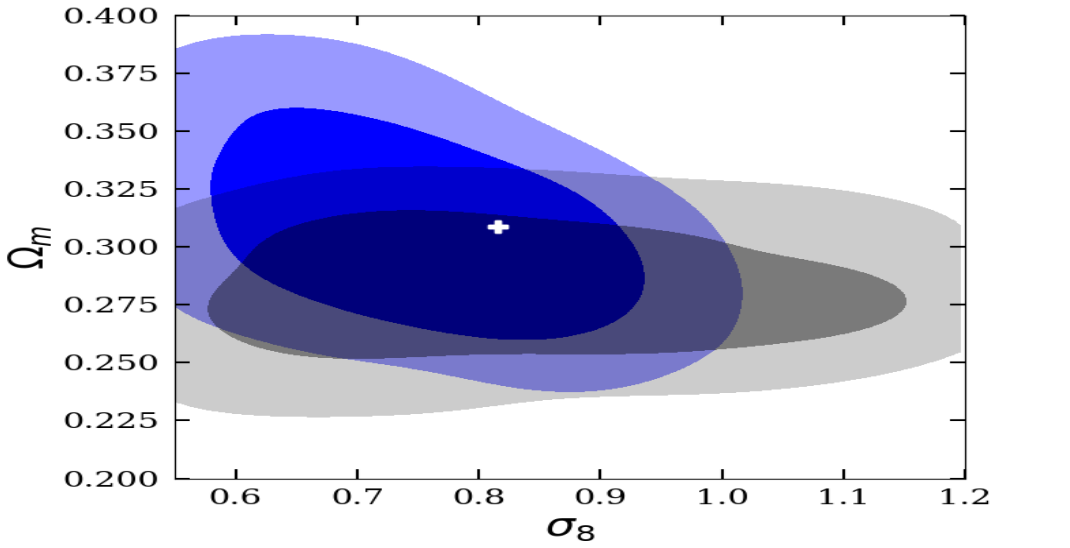
- Assume perfect knowledge of the galaxy bias
- An overall normalization and power-law unknown parameters at all redshifts (vary the bias parameters A,B,C,D)
- Unknown evolution of the galaxy bias with one parameter per z bin

Euclid: density, density+RSD. SKA1: density, density+RSD

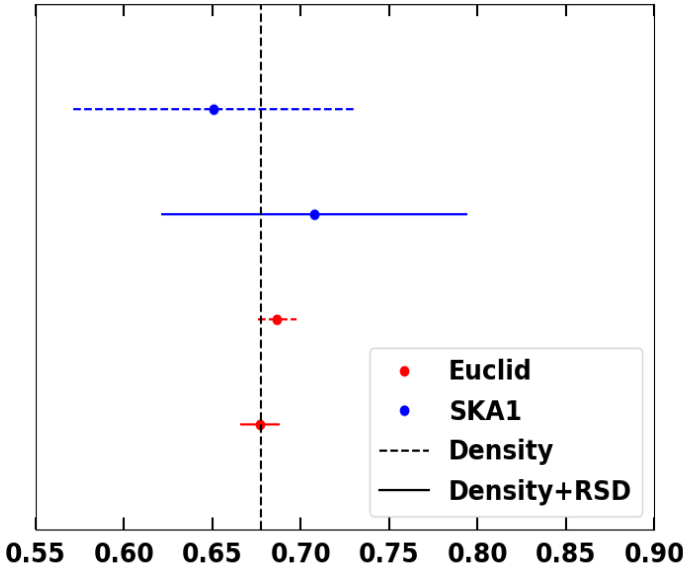


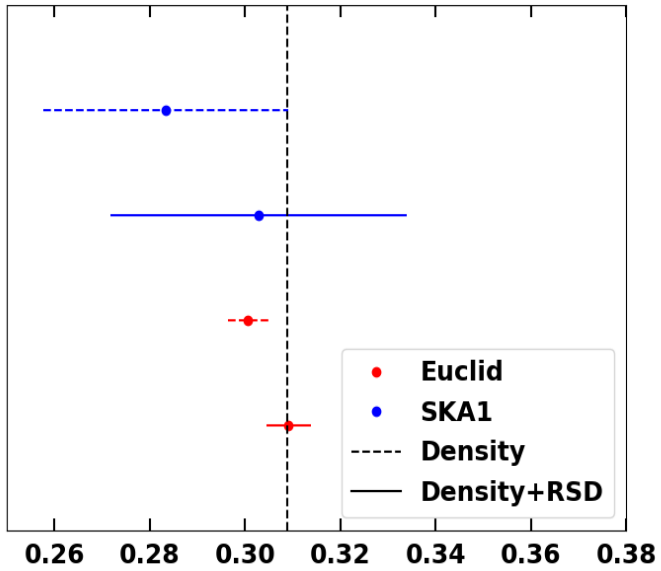


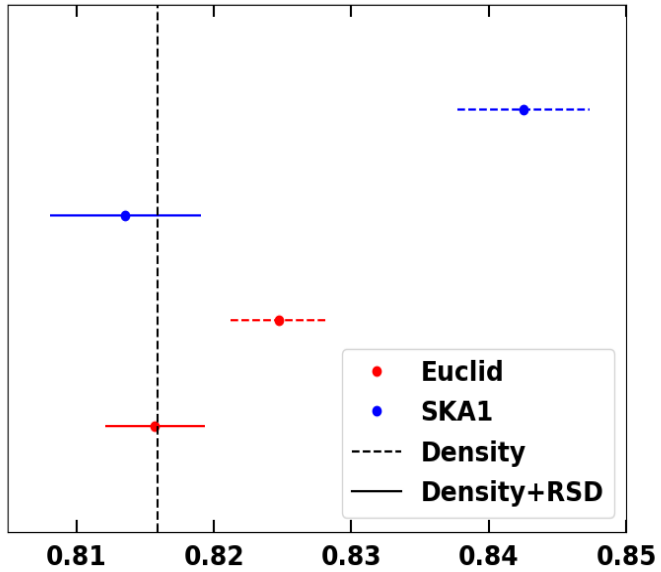




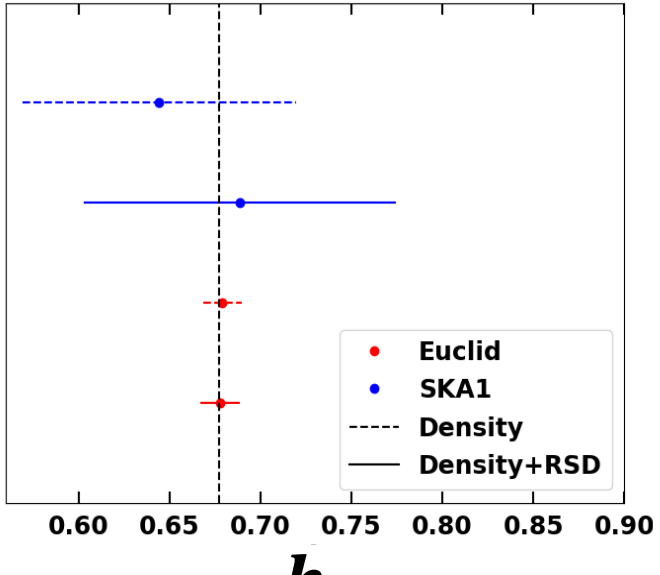
Results: Euclid, SKA1



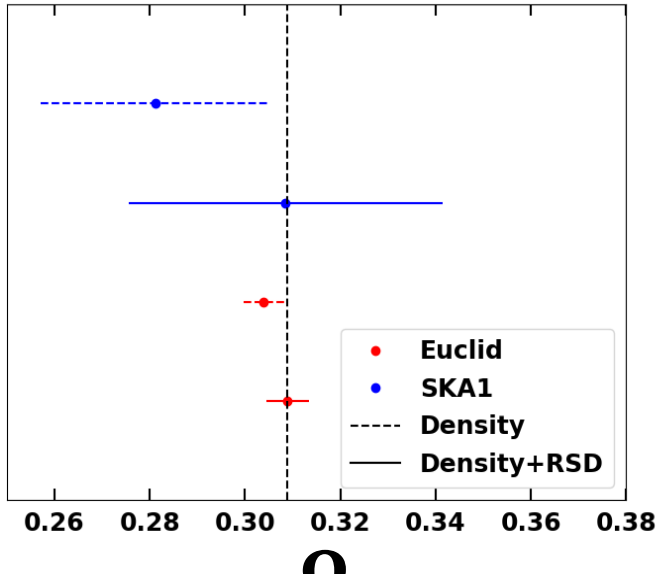




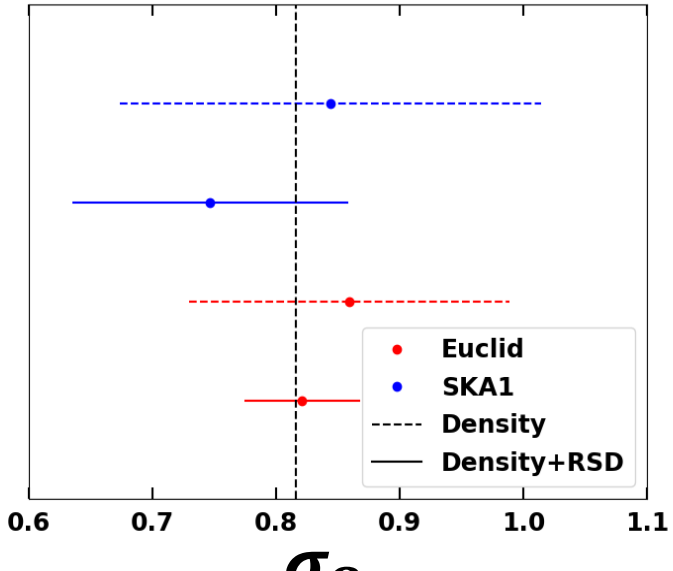
ideal



h



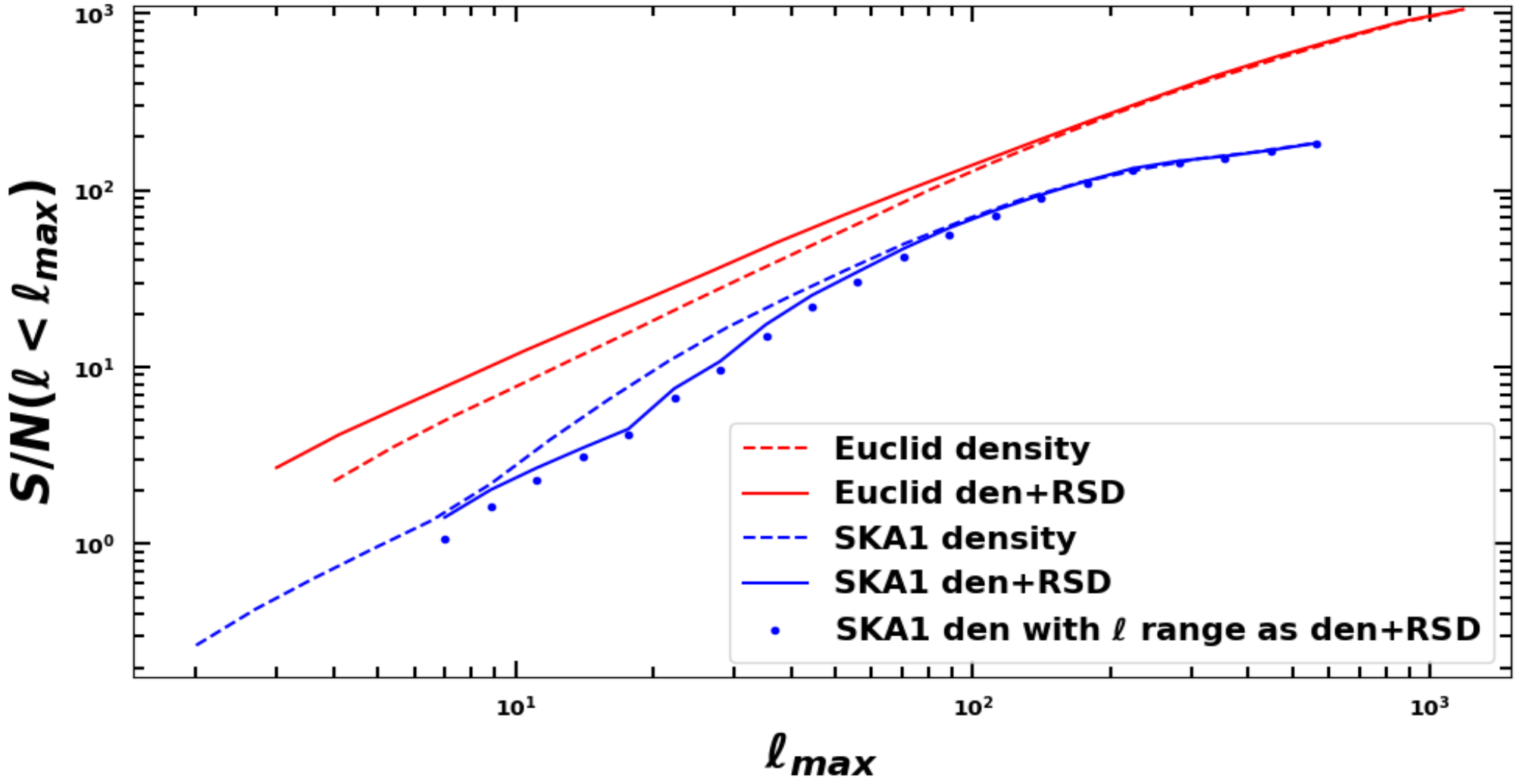
Ω_m



σ_8

conservative

Signal-Noise-Ratio



Conclusions

- The discrepancy on the estimated cosmological parameters mean values between an analysis with and without RSD is statistically significant for both proxies, especially for the matter parameters $\{\Omega_m, \sigma_8\}$. This is true for the ideal, the pessimistic and the conservative scenario

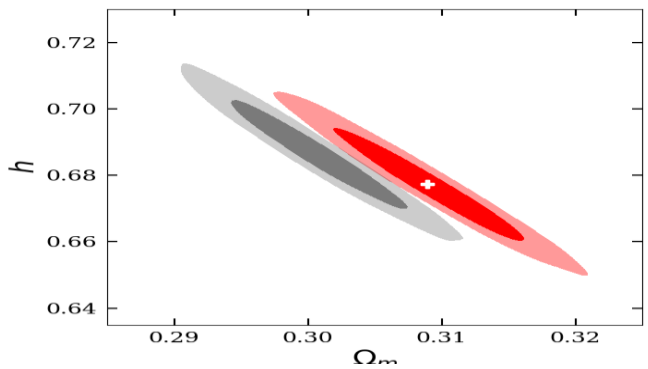
- The purely density model yields very degenerate results on σ_8 since it is the normalization of the PS. Partially broken when adding RSD which are insensitive to the galaxy bias

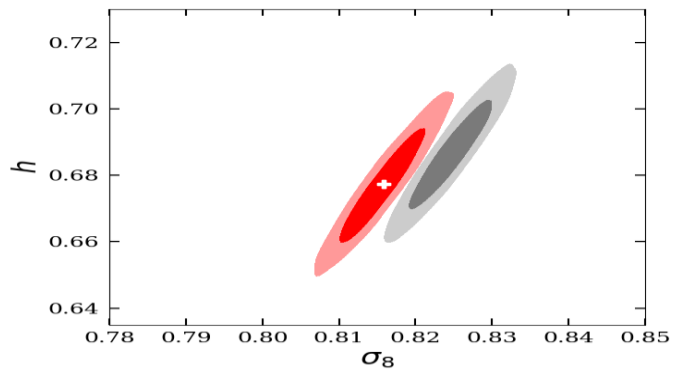
- SKA1 is not very informative due to the lower SNR compared to Euclid caused by the smaller multipole range and the shorter area coverage.

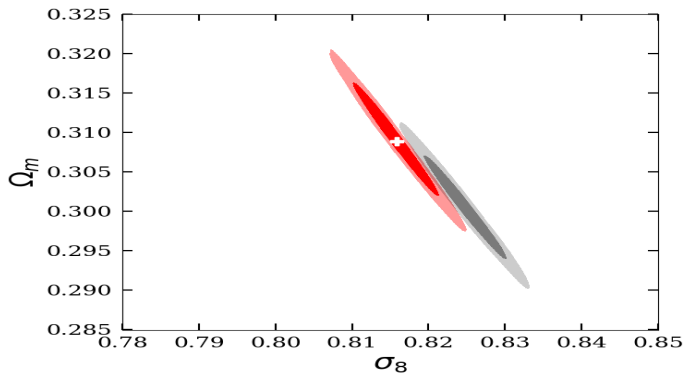
Thank you for your attention!

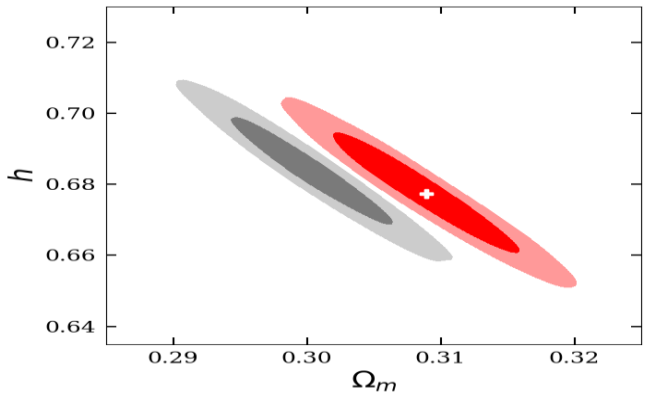
Extra Slides

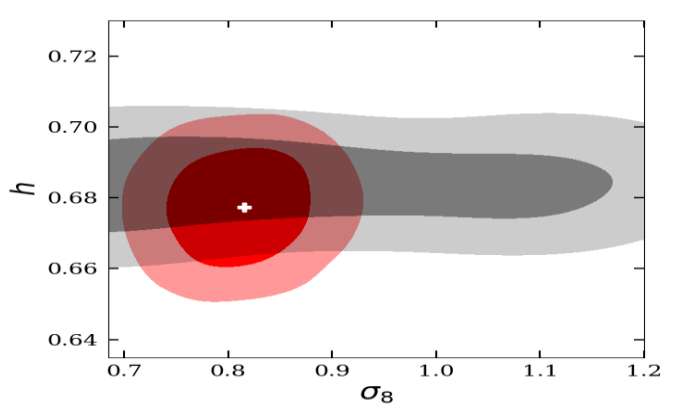
Results for Euclid: density, density+RSD

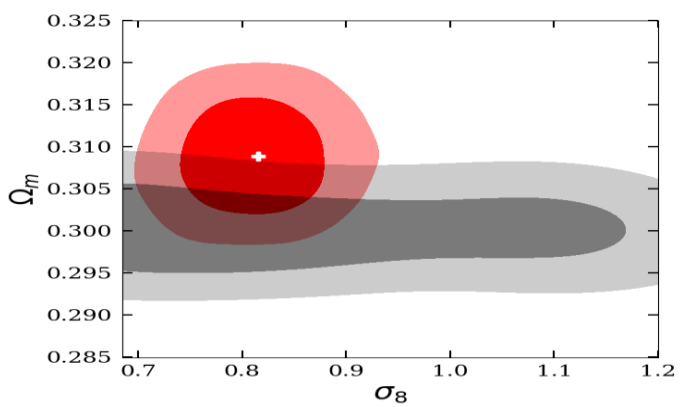


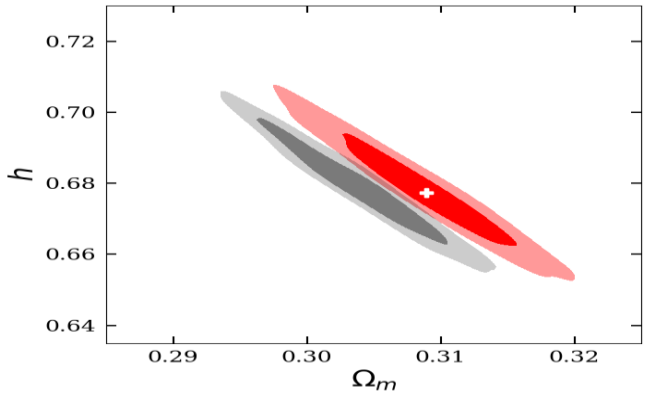


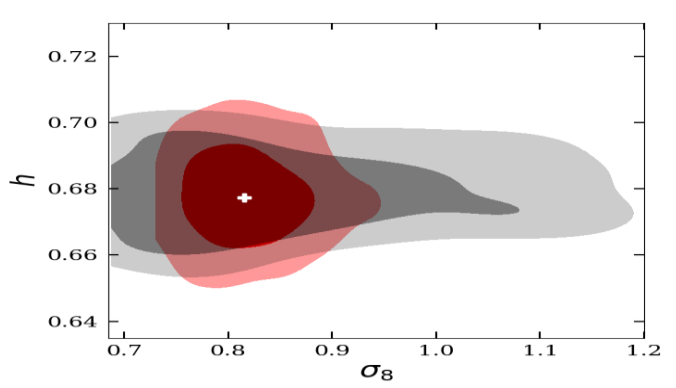


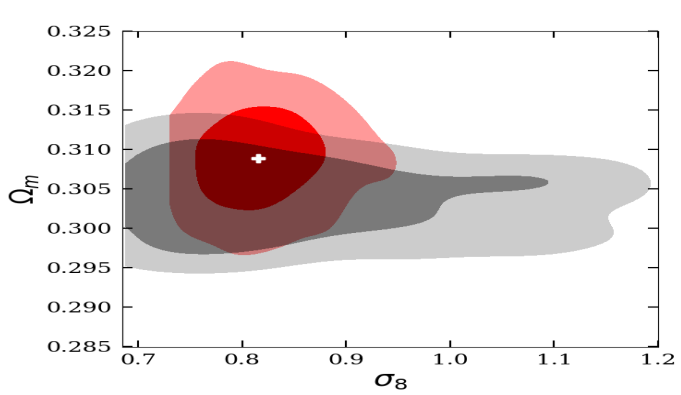




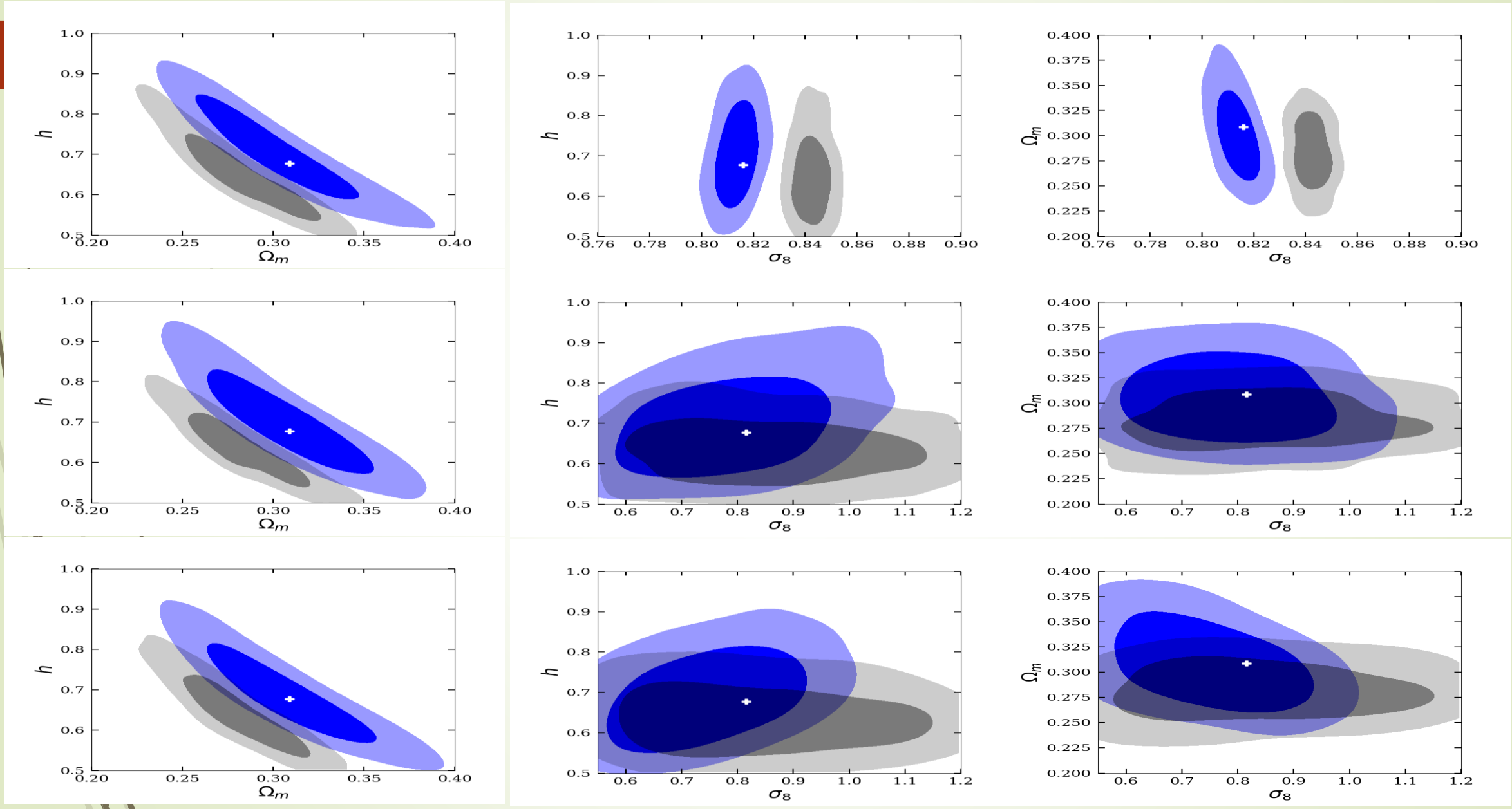




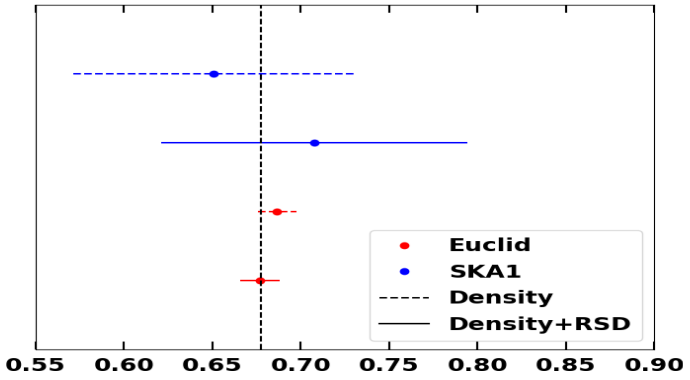


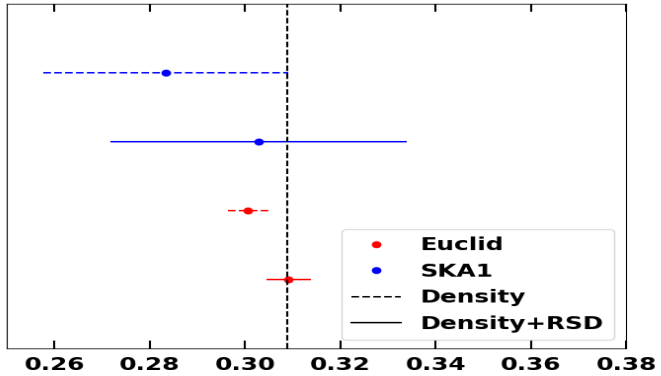


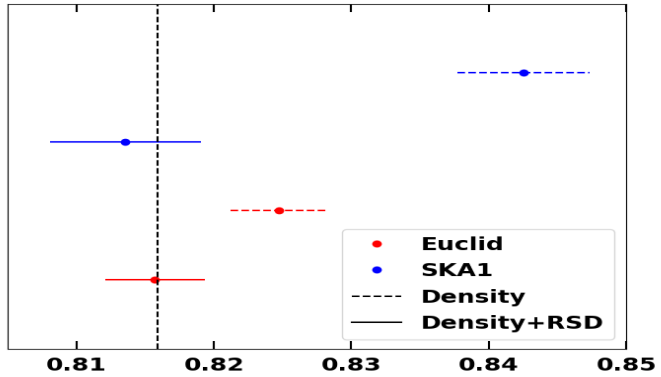
Results for SKA1: density, density+RSD



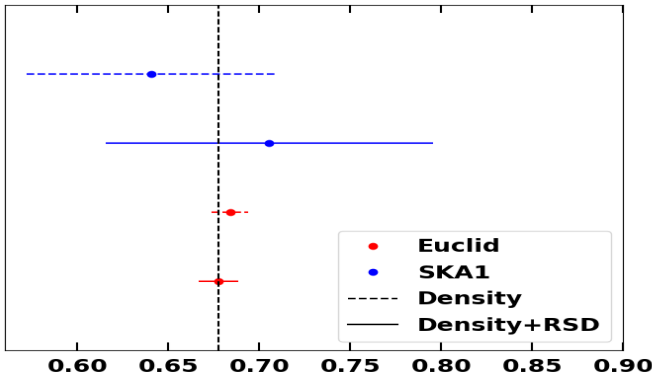
Results: Euclid, SKA1

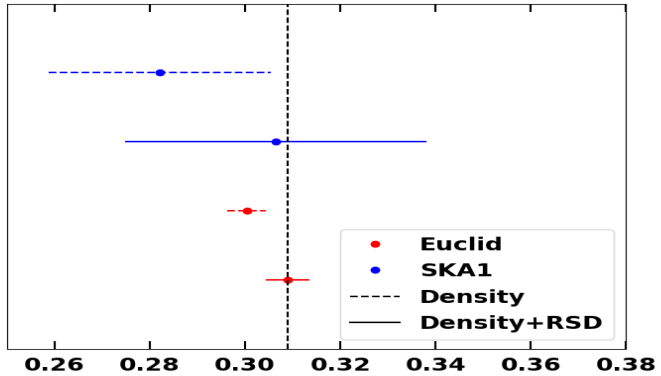


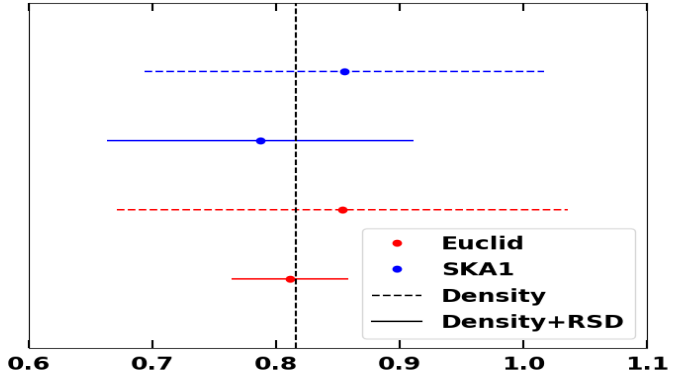




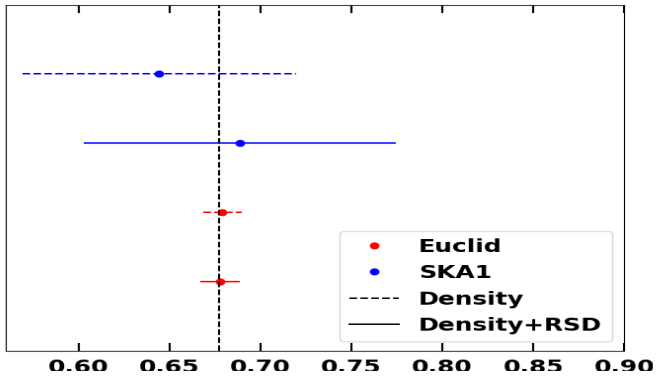
ideal



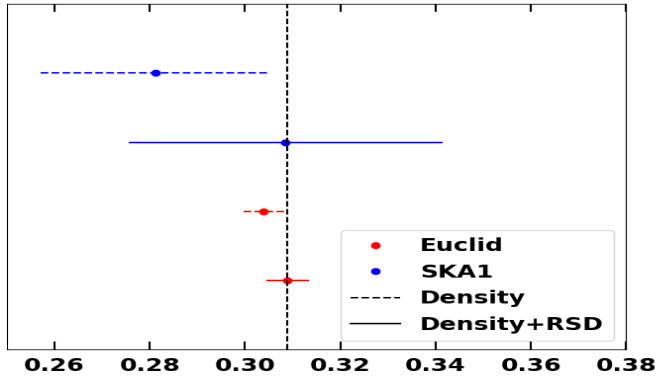




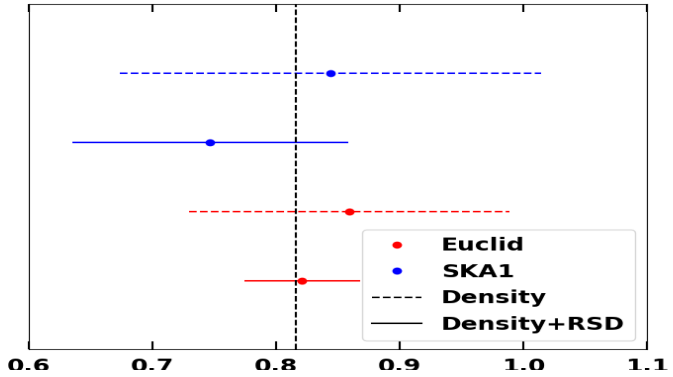
pessimis
tic



h



Ω_m



σ_8

conserv
ative