Chapter 1

Results

In this chapter, we present our forecast results for neutrino parameters and dark energy. Compared to our validation runs there are multiple differences in our parameters. Firstly the neutrino mass m_ν is no longer condensed into one massive neutrino but evenly split between three neutrino species. To differentiate this quantity from the neutrino mass from the last chapter we will call it $\sum m_\nu$. This is done by setting the number of degenerate non-cold dark matter particles '$\mathtt{deg_n cdm} = \mathtt{3}$'.
Because of this we also change our definition of N_{eff}. Before it could have been understood as a change in the temperature of the massless neutrinos and could vary freely to higher and lower values. Now all neutrinos have the same temperature of

$$T_\nu = T_{\text{CMB}} \left(\frac{3.044}{3}\right)^{1/4} \left(\frac{11}{4}\right)^{1/3}. \tag{1.1}$$

This parameter now just parametrises any additional massless relic particle. Typical models predict only additional species that contribute positively to N_{eff}. From this, we define a new parameter ΔN_{eff}. This parameter is essentially equivalent to the parameter N_{ur} inside of `CLASS`.
Our next change is, that we vary the parameter σ_v and σ_p now that govern the nonlinear corrections of the spectroscopic probe. In order to be more conservative we also stick to the pessimistic settings of the probes. We will also vary all 9 cosmological parameters for our MCMC.
For $\sum m_\nu$ and ΔN_{eff} we chose prior edges with a theoretical prior at 0 as a lower bound and a higher bound far enough away to not change our results. The dark energy parameters chose a bit tighter prior edges to not probe unphysical regions of the parameter space. These parameters are in reality only some approximation to a wider set of theories where dark energy has an equation of state that is slowly varying. When the posterior hits the prior edges for the dark energy parameters we will consider them as unconstrained. For the other cosmological and nuisance parameters we have chosen arbitrary priors that will not get hit but speed up convergence.
A summary of our cosmological parameters, their fiducial and their prior edges can be seen in the table 1.1. The results can be seen in figure 1.1. We see that the photometric and spectroscopic probes are sensitive to different cosmological parameters. The spectroscopic probe dominates the sensitivity for ΔN_{eff} and h. These are the parameters whose main effect is on the BAO. Since the spectroscopic probe is sensitive to that region, it measures these well. The spectroscopic probe is nearly insensitive to the amplitude of the power spectrum as it is multiplied by the galaxy biases. To break this it needs the redshift space distortions where the clustering parameter $f\sigma_8$ enters.

Figure 1.1: One and two-dimensional marginalized posteriors for the different *Euclid* probes. We depict the 68% and 95% confidence intervals for the cosmological parameters of the full nine-parameter model. We depict the photometric probe in purple, the spectroscopic probe in cream and the combined probe in red.

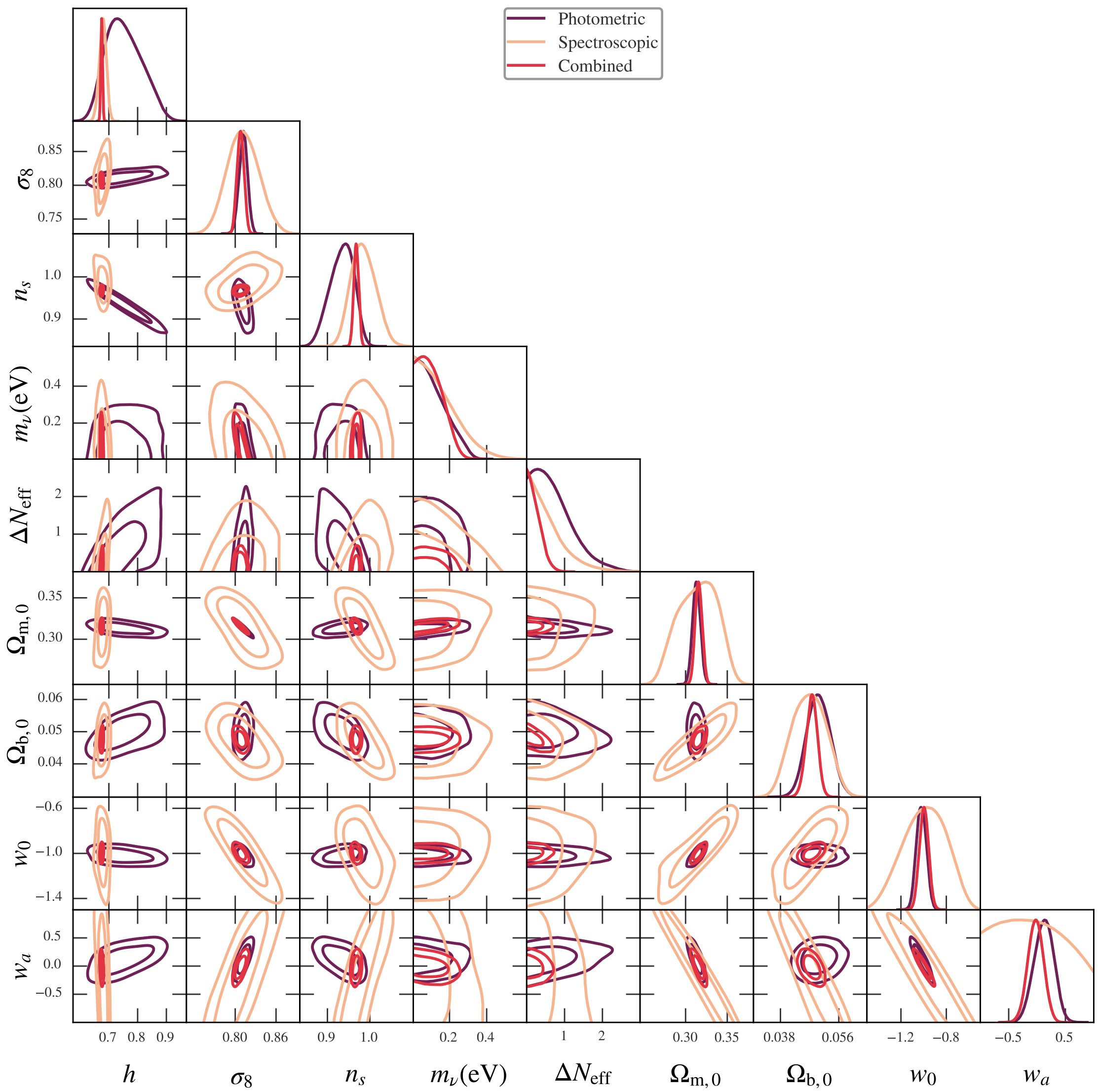

Table 1.1: Settings for the final forecast MCMCs. The fiducial values of the Nuisance parameters have been listed in the section for the respective probes.

Varied parameters								
Ω_{m}	$100 \times \Omega_{\mathrm{b}}$	h	n_{s}	σ_8	$\sum m_\nu(\mathrm{meV})$	ΔN_{eff}	w_0	w_a
Fiducal Value								
0.314571	4.92	0.6737	0.9661	0.81	60	0	0	-1
Prior Edges								
$[0.005, 1]$	$[0.5, 100]$	$[0.1, 1.5]$	$[0.8, 1.2]$	$[0.7, 0.9]$	$[0, 1000]$	$[0, 5]$	$[-1.5, -0.5]$	$[-1, 1]$

We also see that it alone is not able to constrain the time-dependent dark energy equation of state w_a. This parameter controls only slightly the time evolution of the amplitude of the matter power spectrum. Its sensitivity to the baryon density parameter Ω_b is greatly reduced by varying σ_v.
The photometric probe is very sensitive to the amplitude of the power spectrum and dominates thusly the dark energy parameters, the neutrino mass, Ω_m, and σ_8. Its sensitivity to Ω_b comes also from the BAO that leaves a small impact on the actual C_l. Since the scale of the BAO is fixed at around $5 \cdot 10^{-2}\mathrm{Mpc}^{-1}$ the imprint shows up at different multipoles ℓ for different redshift bins. This leaves a very clear signature of Ω_b. It loses its sensitivity to h and ΔN_{eff} for the same reason, as the actual scale of the BAO is washed out by the integration over z. Essentially the photometric probe loses its sensitivity to scales.
In that sense, both probes are very complimentary to each other. In the figure, one can see how the correlation directions of the different probes are often perpendicular to one another breaking correlation directions and drastically improving the constraints on h, n_s, and ΔN_{eff}.
Nevertheless judging from this forecast Euclid alone will not be able to detect the neutrino mass alone. This is why in our final forecasting results in tabel we can only give a 95% confidence interval. It should be noted that by adding CMB data to our forecast we can achieve a measurement of the neutrino mass on the 68% confidence level for this nine-parameter model. If we go to a smaller model with only ΛCDM+m_ν we can even achieve a 99% confidence detection. We will not discuss these results further in this work as we have not discussed the CMB as an additional probe.
The marginalized errors are found in the table 1.2. The constraints of *Euclid* for the cosmological parameters are tighter than for *Planck*. They never gave constraints on our nine-parameter model. We can compare the constraints on submodels though as the four parameters in our case are not too strongly correlated. This means that we expect similar errors for the parameters if we have run the smaller models. In an analysis of the $w_0 w_a$CDM *Planck* + BAO + Supernovae gives constraints on the dark energy parameters

$$w_0 = -0.957 \pm 0.08 \quad \text{and} \quad w_a = -0.29 \pm 0.3$$

This means that we can better constrain these parameters already with a bigger model. The main part of the constraints of *Planck* to these parameters are from contributions in additional late ISW effects, while *Euclid* we can see a redshift dependant reduction of the amplitude on all scales.
The parameters $\sum m_\nu$ and ΔN_{eff} are constrained by *Planck* +BAO+lensing to

$$\sum m_\nu < 0.12 \quad \text{and} \quad \Delta N_{\mathrm{eff}} < 0.34. \tag{1.2}$$

These are both tighter than in our *Euclid* forecast. The main sensitivity to these parameters comes from their background effects shifting the angular scale of recombination and the redshift of equality. Both of these parameters are very tightly constrained by the CMB measurements.
As both experiments measure probes that are very complimentary to one another as well as having additional Information in their cross-correlation, we believe that a combined analysis will bring us a new milestone in precision cosmology.

Table 1.2: Forecast 68% confidence levels for the different *Euclid* probes and the combined probe. For the parameters $\sum m_\nu$ and $\Delta N_{\rm eff}$ we only state the 95% upper limit as they are bound from below by their theoretical prior. The spectroscopic probe alone was not able to constrain w_a within our prior edges.

Forecast Results									
	$\Omega_{\rm m}$	$100 \times \Omega_{\rm b}$	h	$n_{\rm s}$	σ_8	w_0	w_a	$\sum m_\nu$(meV)	$\Delta N_{\rm eff}$
Probe	68% Sensitivity							95% confidence limit	
Photometric	0.0049	0.38	0.065	0.029	0.0065	0.05	0.18	$< 260.$	< 1.70
Spectroscopic	0.0258	0.56	0.013	0.031	0.024	0.20	–	$< 350.$	< 1.50
Combined	0.0043	0.18	0.0030	0.0060	0.0054	0.04	0.14	$< 220.$	< 0.57