Dark Energy with future z > 2 surveys

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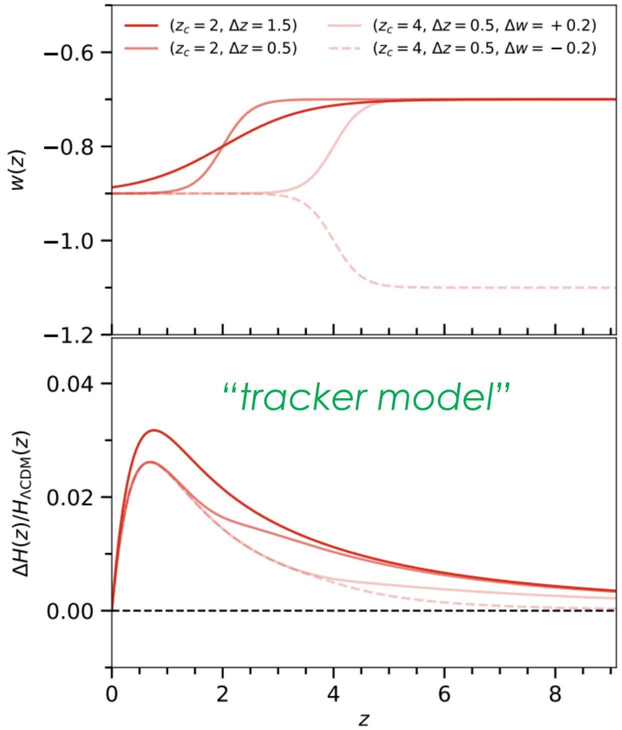
Why Dark Energy at z > 2?

- Large classes of dynamical DE models have "*freezing*" behavior at low z (w = -1), while transitioning to "*tracking*" behavior (w ~ 0) in matter domination.
- Detectable if we can measure DE density at 2 < z < 6.
- Dark Energy FoM (area of ellipse in the w_0-w_a plane) has been useful for current/upcoming experiments, but doesn't capture the complexity of general DE models.
- In absence of firm guidance from fundamental physics, optimization of model-independent quantities becomes important. E.g. require <u>large redshift lever arm</u>.
- Can indirectly probe "Early Dark Energy" (EDE)

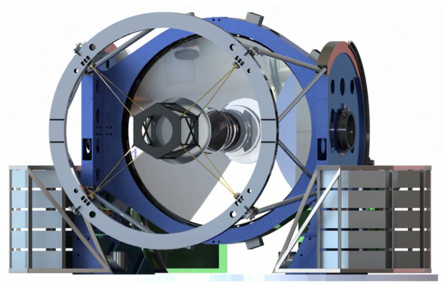


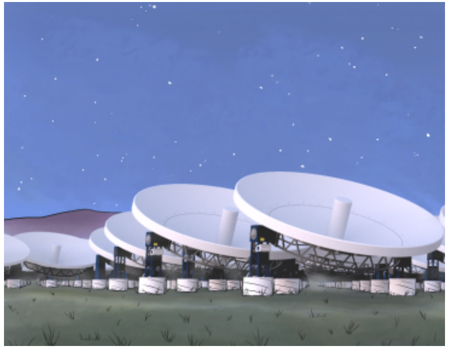
Bull, White & Slosar (2020)
Raveri et al (2017)
Linder (2006)

LOIs: link, link

Observational opportunities at z > 2

- The volume on the past lightcone increases dramatically. A $2 < z < 6$ survey can quadruple the observed volume → smaller cosmic variance and access to larger scales.
- Smaller degree of non-linearity and less affected by astrophysical processes → high precision perturbative inspired by high-energy particle physics become increasingly applicable.
- High-redshift target galaxies are dense enough to have $n \sim 10^{-4}$ $[h/\mathrm{Mpc}]^3$ to $z = 5$ (LBGs and LAEs) – see Wilson & White (2019). Several proposed experiments: MegaMapper, SpecTel, MSE, ATLAS, DESI-2…
- Intensity mapping (21cm, CO, [CII], other lines): low shot noise to high redshift. Proposals: PUMA, HIRAX, SuperSpec, …





Dark Energy from high-z observations

High-z surveys will probe Dark Energy in 3 ways:

1) Direct measurement of DE over the observed redshift range. Broad classes of dynamical DE exhibit "tracking behaviour" with respect to the dominant energy density at a given redshift → *measure DE all the way deep into matter domination*.

2) Degeneracy breaking: parameter sensitivity varies with redshift, breaking degeneracies internally. E.g. dynamical DE vs neutrinos.

3) Indirect measurement of Early DE (EDE): through measurement of the shape of the matter PS (with much reduced cosmic variance) can constrain the fraction of EDE to be below 1% all the way to $z \sim 10^5$ → *precision DE probe throughout most of cosmic history*.

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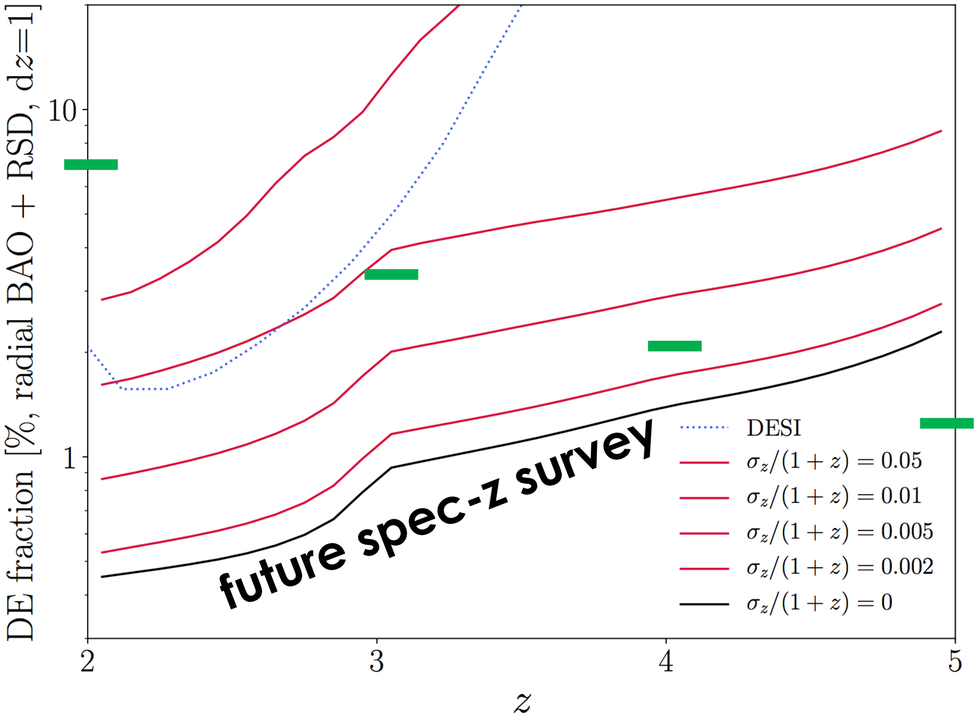
Direct measurement of expansion history



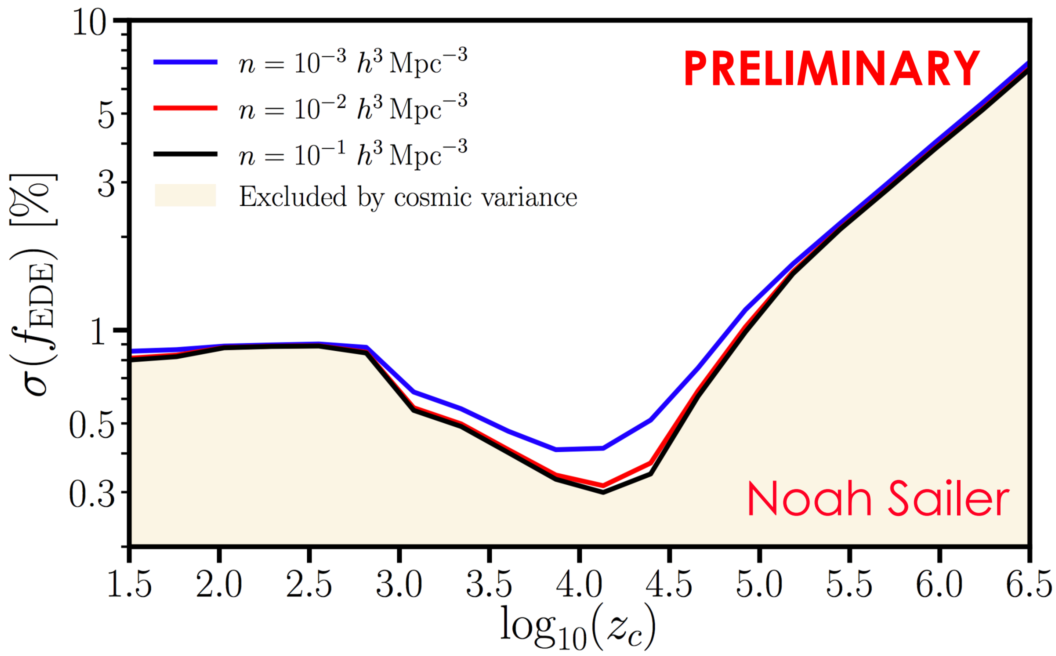
S.F., Mike Wilson et al (2019). Plot by Pat McDonald

= LCDM prediction

KEY POINTS:

- Can measure the DE fraction to ~1% up to z = 4.
- "Detect" DE to z > 4.
- "lever arm" well matched to Horndenski/Quintessence models.

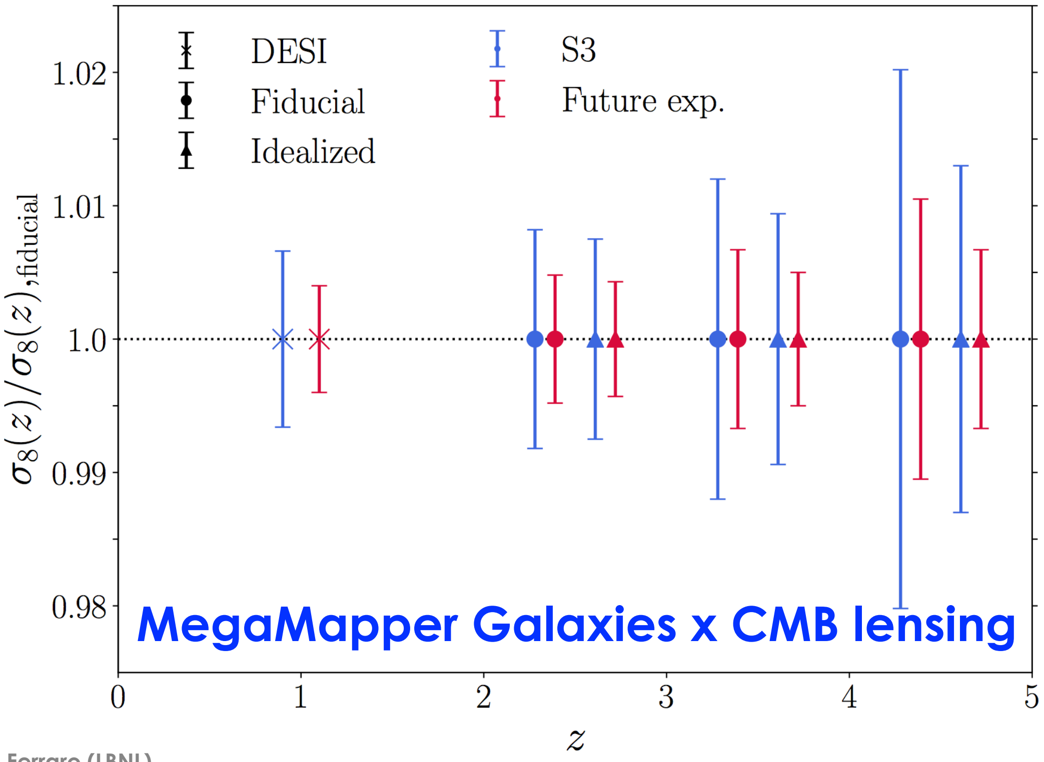
(Early) Dark Energy to z ~ 10^5



Detailed shape of the matter PS → **percent level measurement of expansion history to z ~ 10^5** → tight bounds on EDE and other non-standard components.

CMB cross-correlations: Mapping the growth of structure

CMB



- ~1% constraint on amplitude up to z ~5.
- Neutrino mass without CMB optical depth.
- Tests of gravity.

S.F., Mike Wilson et al (2019)
B. Yu et al (2018)

Conclusions

- Exciting opportunities for DE science at high redshift!
- Feasible in the next decade: spectrocopic galaxies and/or intensity mapping.
- 3 complementary tools: direct expansion, shape of the transfer function, internal degeneracy breaking with z.
- Large redshift lever arm is important. Cross correlations with CMB provide robustness and tests of gravity.

Thanks!