

# What will we learn about DE in the 2020's?

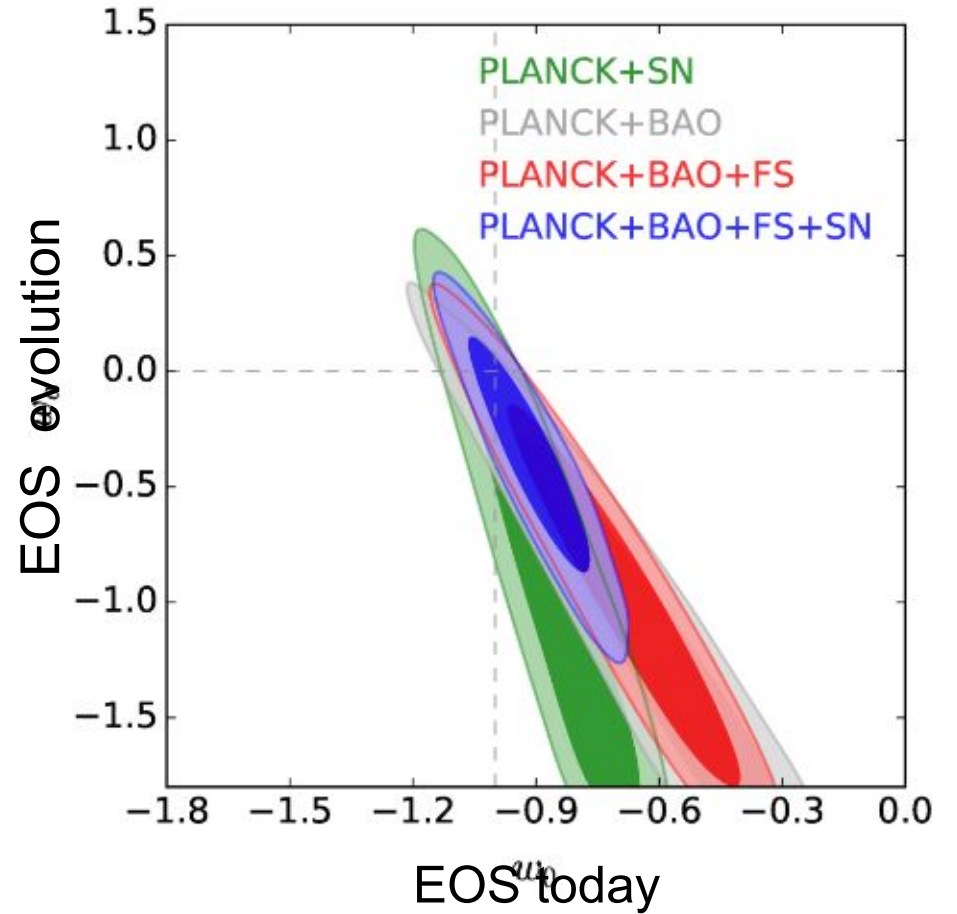
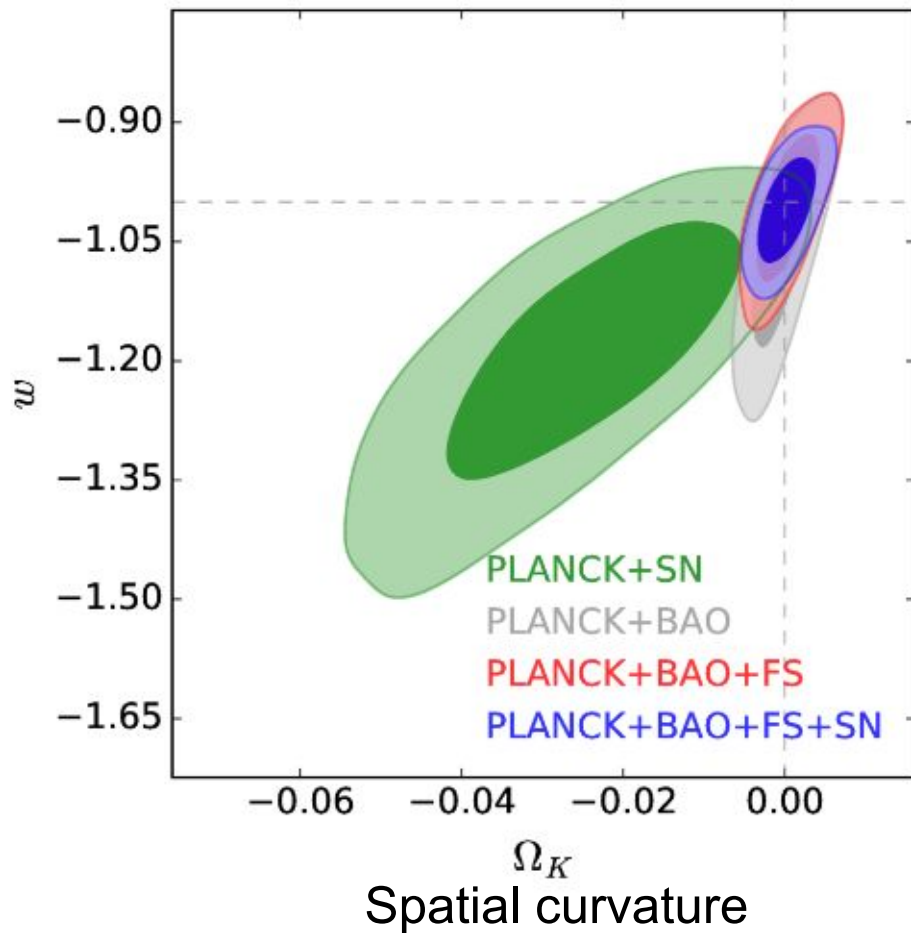
Martin White, Eric Linder, Joe DeRose  
and other interested parties!

# Current status

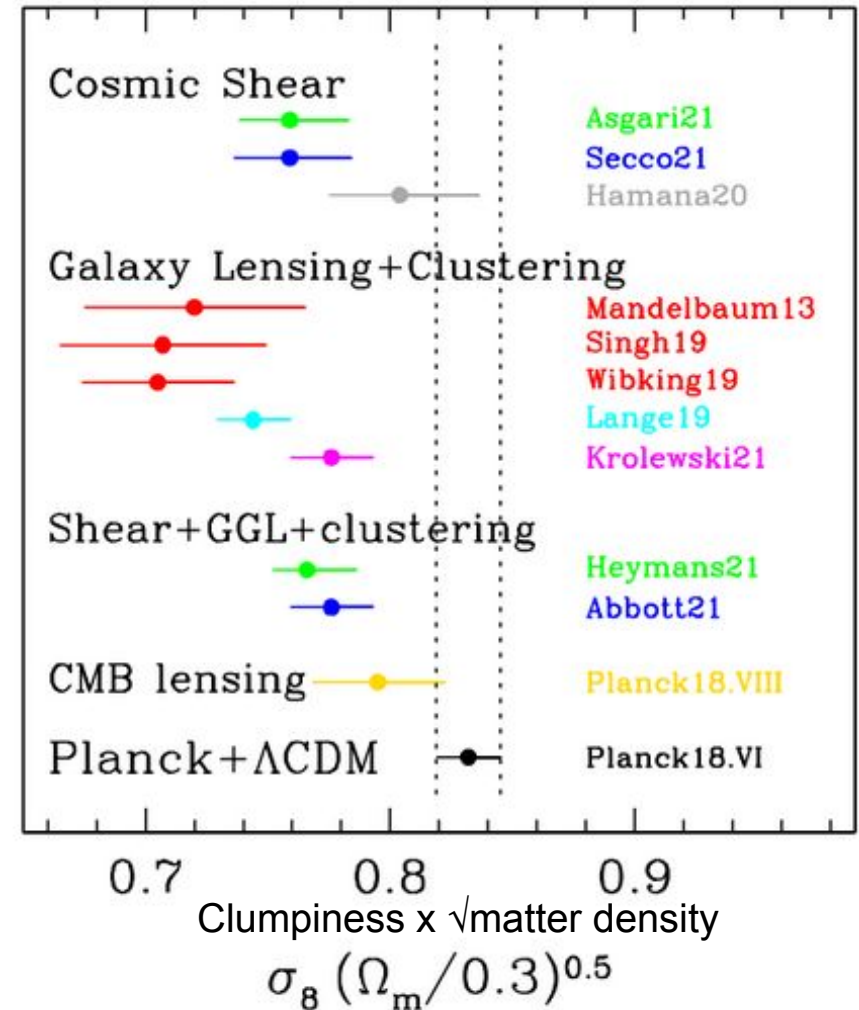
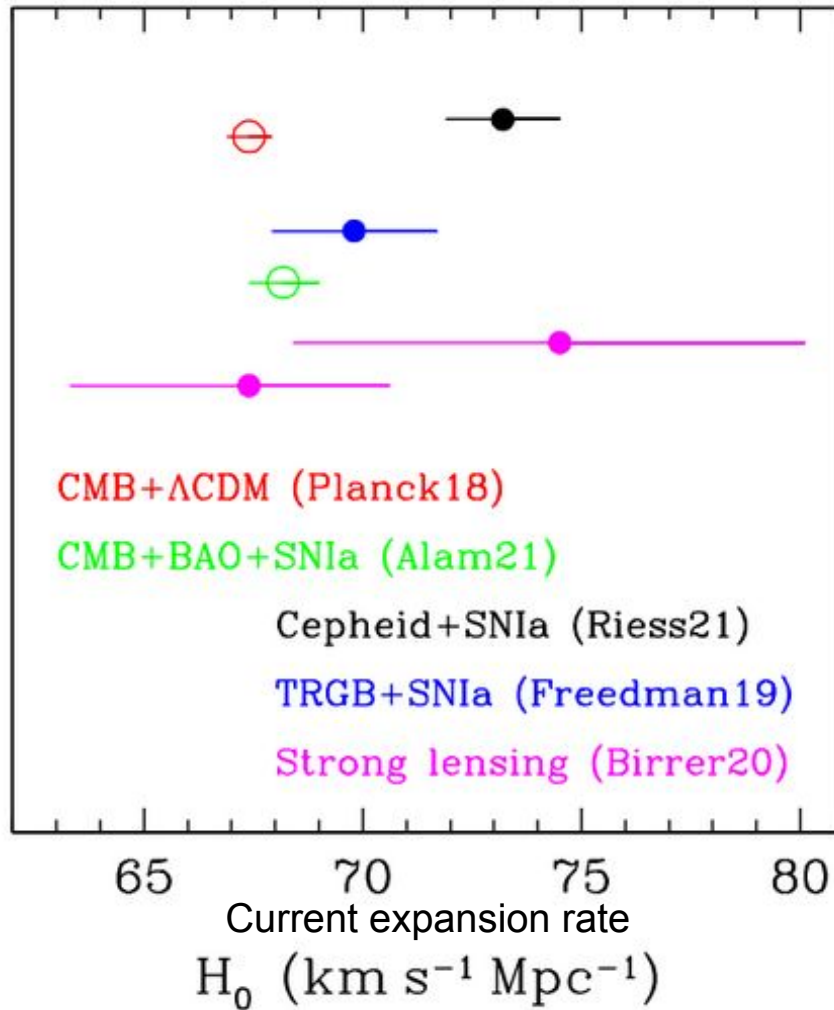
- The  $\Lambda$ CDM model, with vacuum energy, fits the majority of the existing data.
  - Odd tensions in measurements have arisen. Maybe they are systematics, but people will work on comparing these different probes in the 2020s.
- The tests of dark energy evolution, and comparison of expansion to growth, that were proposed in the 2000s have still not been carried out to the level expected to give insight.
  - We have sharpened the “why now” problem, but quantitative constraints on dark energy evolution are weak:  $dw/d(Ht)$  constrained to  $O(1)$  not  $O(0.1)$ .
- Measurements done in the 2020s to higher redshift, and new more precise techniques at low redshifts, will push on  $\Lambda$ CDM in untested places, and could reveal new physics.
- Many outstanding theoretical questions and a model that is purely phenomenological.
- Better theoretical understanding of many classes of modified gravity.
- Arguments have been made for
  - Studying dark energy at low redshift (“thawing” models).
  - Studying dark energy as we approach the matter dominated era.
  - Studying “early” dark energy.
  - Mapping gravity as a function of time and scale.

# Current state-of-the-art

Constraints on the spatial curvature ( $\Omega_K$ ) and the equation of state of dark energy ( $w_0, w_a$ ).



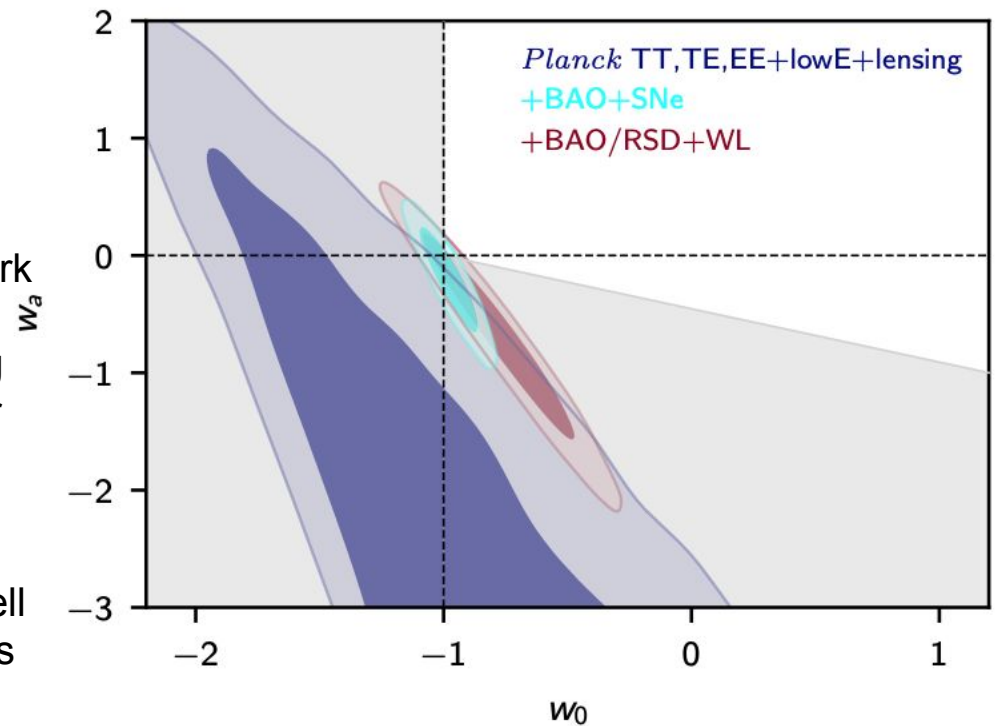
Tensions (from pdg.lbl.gov review; possibly unconnected with DE!)



# Combining Imaging, Spectroscopy and CMB data optimally will be key

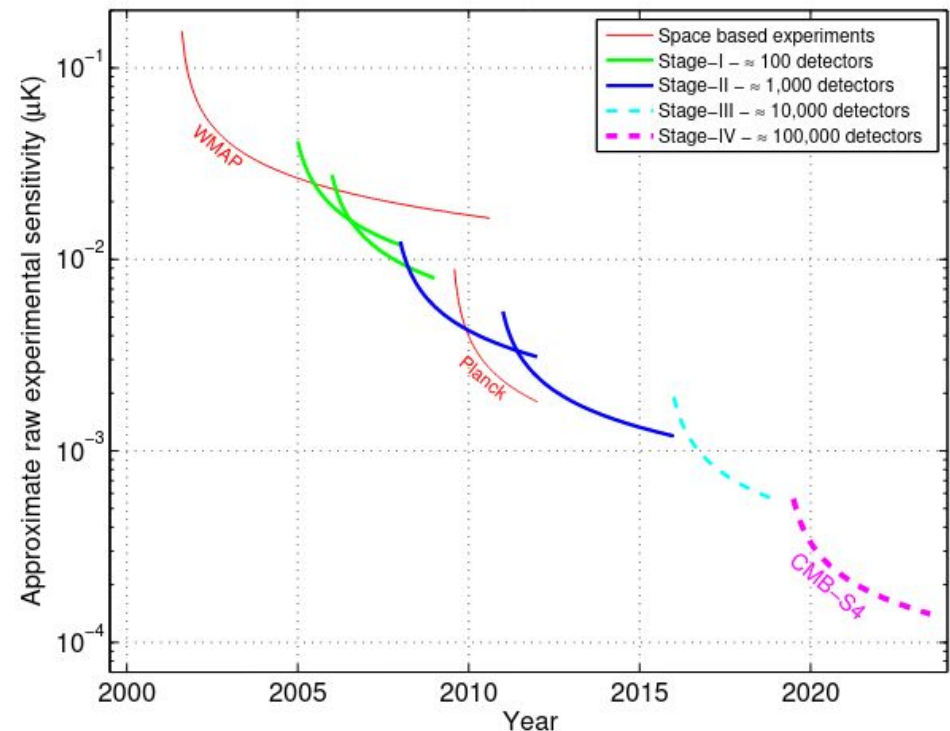
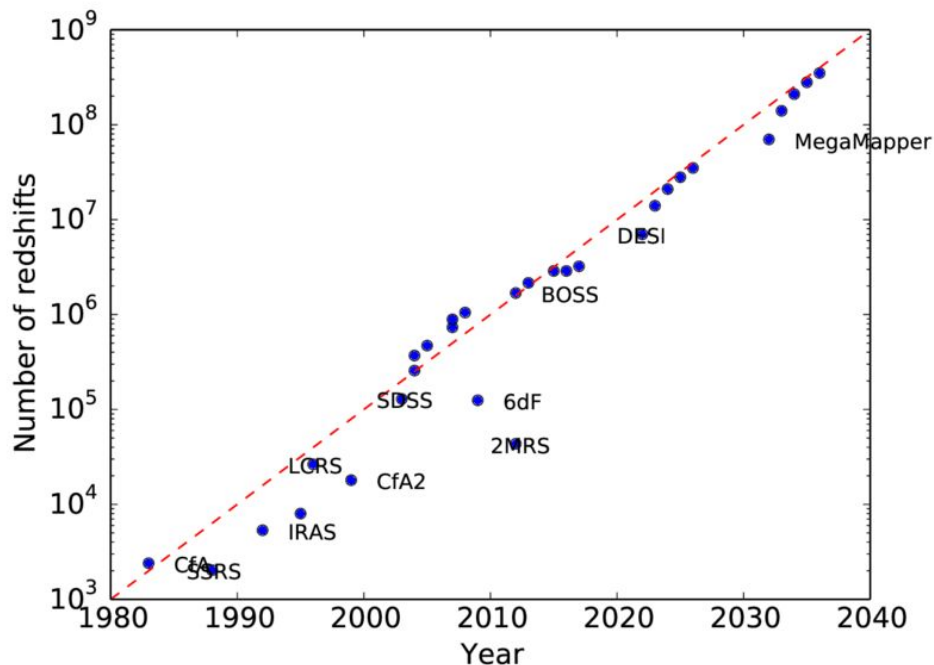
Galaxy clustering measured from spectroscopic surveys combined with lensing from deep imaging in combination with CMB constraints will provide a key tool for understanding dark energy.

- Analyses using stage III imaging and spectroscopic surveys have provided the tightest constraints to date on time evolving dark energy models.
- Joint analysis methods will be key to mitigating systematics and optimizing constraining power
  - Will require significant investment in theoretical modeling and simulation.
- LBL is already leading ongoing/upcoming spectroscopic and CMB experiments and is well positioned to lead development of joint analysis efforts.



# The 2020s will see a dramatic increase in cosmology data!

Several major surveys and facilities, for which we have been waiting a decade or more, are scheduled to come online during the 2020s!



Plus very deep optical imaging data from the LSST/VRO.

We need to be clever enough to use it to test cosmic expansion+growth+gravity.