The Effect of Systematic Redshift Biases in BAO Cosmology

Aaron Glanville

Cosmology from Home
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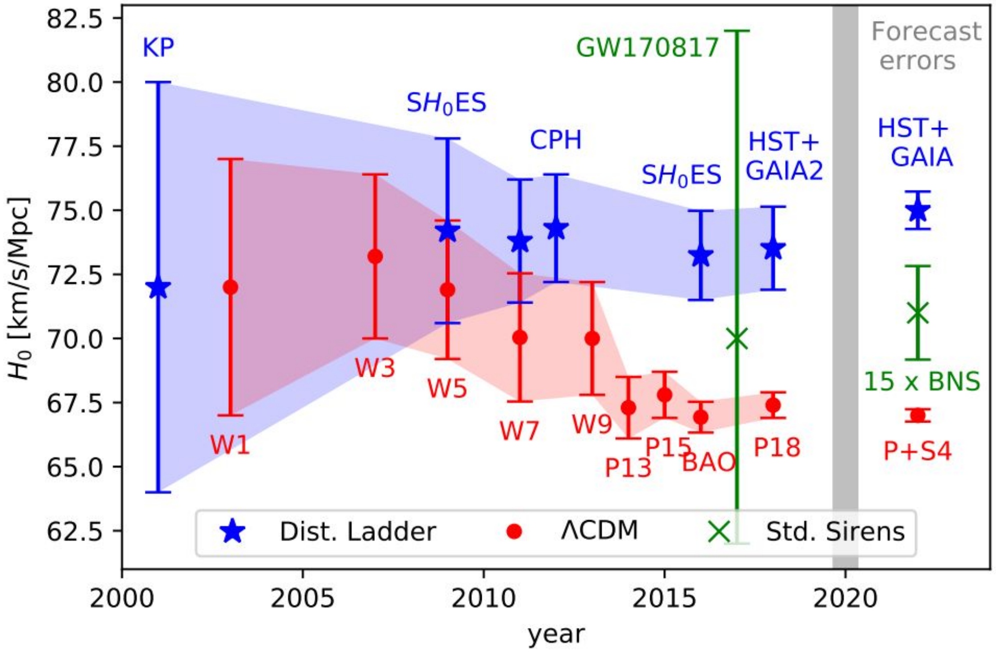
Institution: University of Queensland
E-mail: a.glanville@uq.edu.au

The Hubble Tension

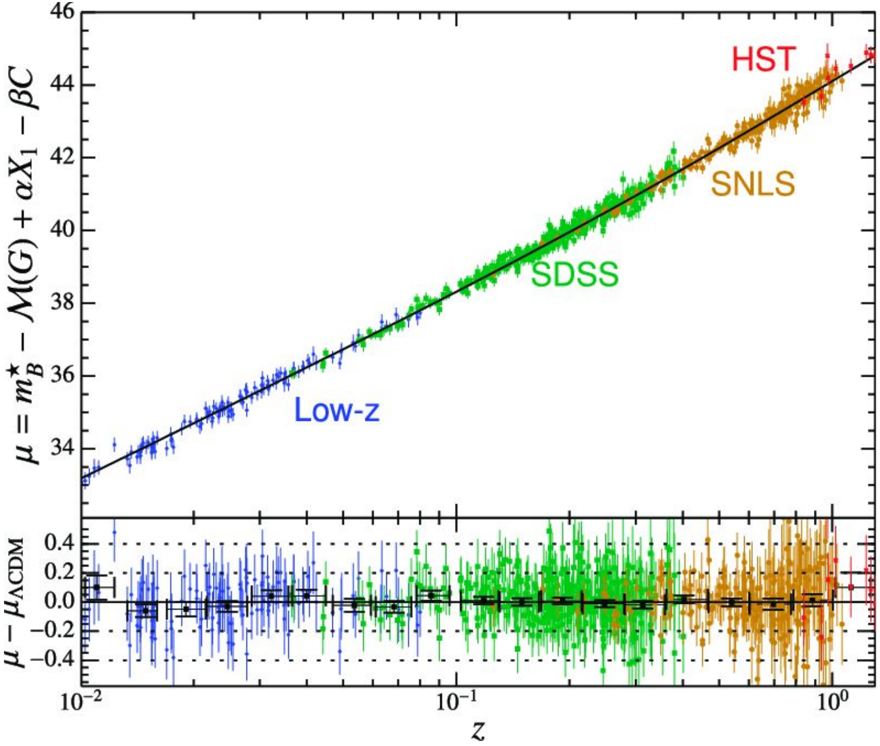


Tension in H_0 using local standard candles, and global standard rulers

Discrepancy at 4-6σ level

Figure: Taken from Ezquiaga and Zumalacarregui (2018) arxiv:1807.09241, adapted from Beaton et. al (2016) arxiv:1604.01788 and Freedman et. al, (2017) arxiv: 1706.02739

The Hubble Tension



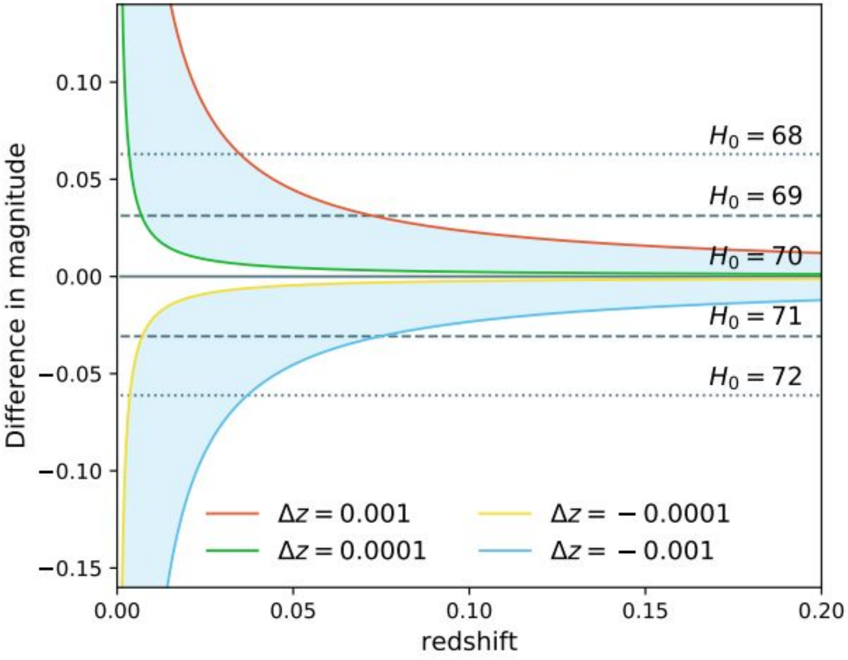
Most of our efforts have gone into distance measurement errors- but what about z?

Figure: *Improved cosmological constraints from a joint analysis of the SDSS-II and SNLS supernova samples.* Betoule et. al (2014), arxiv: 1401.4064

Small Systematics Make a Big Difference

Small systematic offsets in redshift ($\Delta z \approx 10^{-3}$ - 10^{-4}) can bias Supernovae H_0 by ~1% [1]

Similar systematic biases also significantly offset cosmological parameters like Ω_m and w [2]



Ref: [1] and Figure: *Can redshift errors bias measurements of the Hubble Constant?*, Davis et. al (2019), arxiv: 1907.12639

[2]: *Local gravitational redshifts can bias cosmological measurements*, Wojtak et. al, arxiv: 1504.00718

Not All Distances are Created Equal...

Standard rulers (CMB/BAO) and standard candles (SNe, TRGB, etc.) probe different distances:

$$D_A(1+z) = D_L/(1+z)$$

Angular Diameter Distance (std ruler)

Luminosity Distance (std candle)

Could previously undetected systematic redshift offset be responsible for a significant bias in constraints of H_o?

What Kind of Effects?

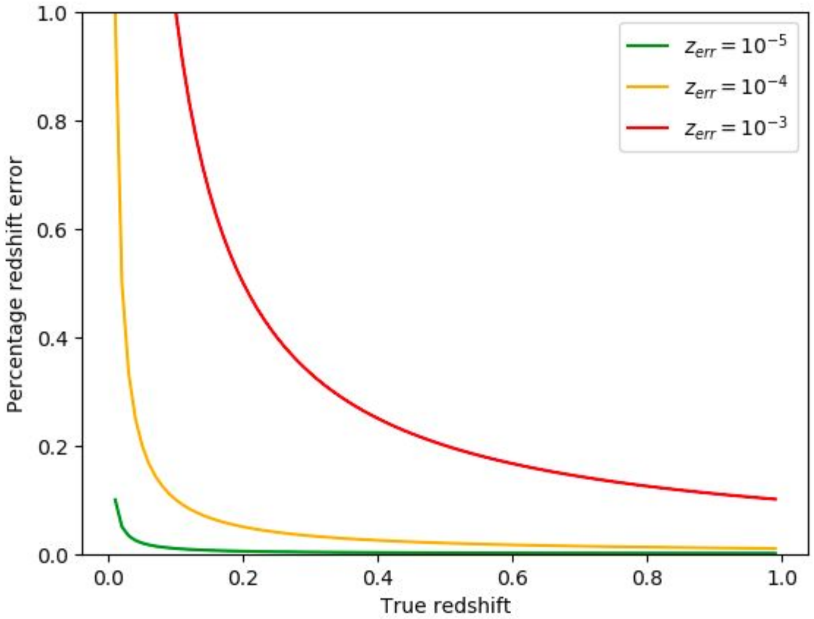
What kind of effects are we interested in?

Low-Z approximations ($z = z_{obs} - z_{pec}$, rather than

$$1 + z = \left(\frac{1+Z_{obs}}{1+Z_{pec}}\right) \longrightarrow z_{err} \approx 10^{-3} - 10^{-4}$$

Physical effects (e.g. living in an over/under density)

$$\longrightarrow \quad z_{err} \approx 10^{-5}$$



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Methodology (or: Plan of Attack)

We are interested in observational level biases which may have previously been negligible

Inject a systematic bias of known magnitude into benchmark sample, and review impact on final cosmology

Mock Survey → (Inject systematic bias) → Biased Power Spectrum → Biased Alpha → Final Cosmology

Mock Cosmology

We use the MultiDark Patchy mock dataset, generated for SDSS-DR12

Replicates data used in BOSS 2-point clustering statistics, over 0.2<z<0.75

Points populated with fixed cosmology

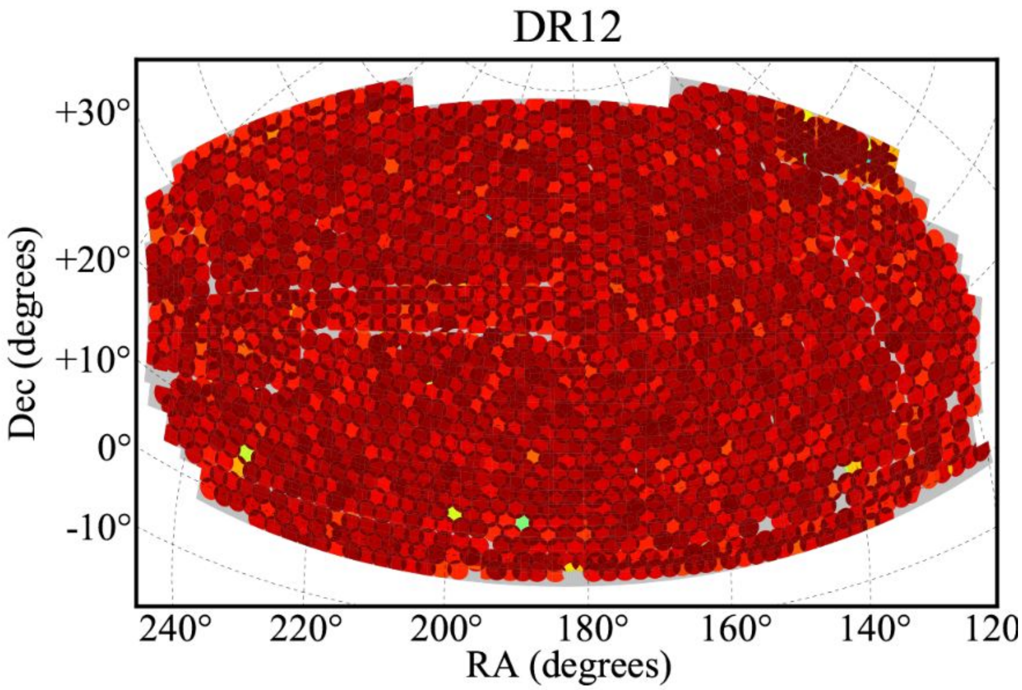


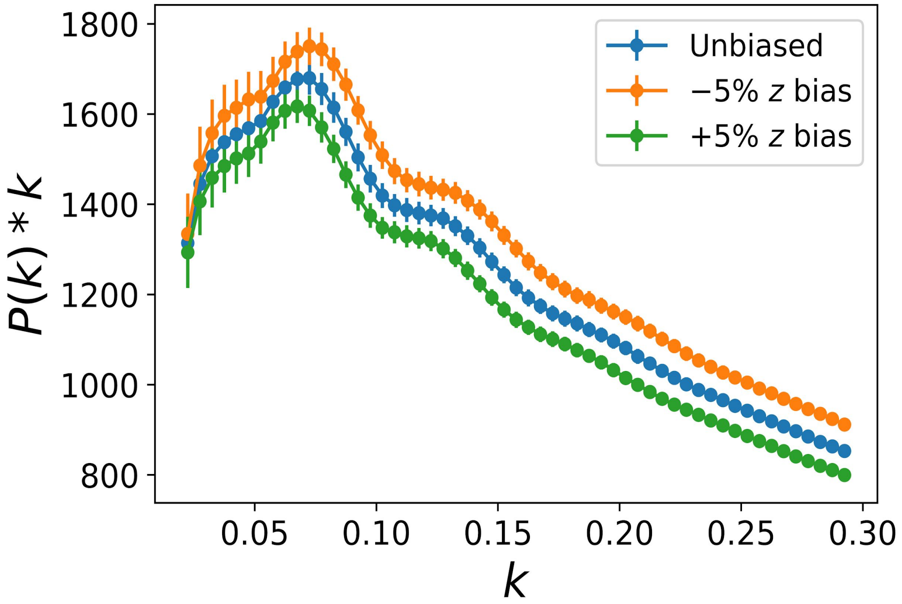
Figure: *SDSS-III Baryon Oscillation Spectroscopic Survey Data Release 12: galaxy target selection and large-scale structure catalogues*, Reid et. al (2015),

From Survey to Power Spectrum

Must measure the convolved power spectrum from these mocks:

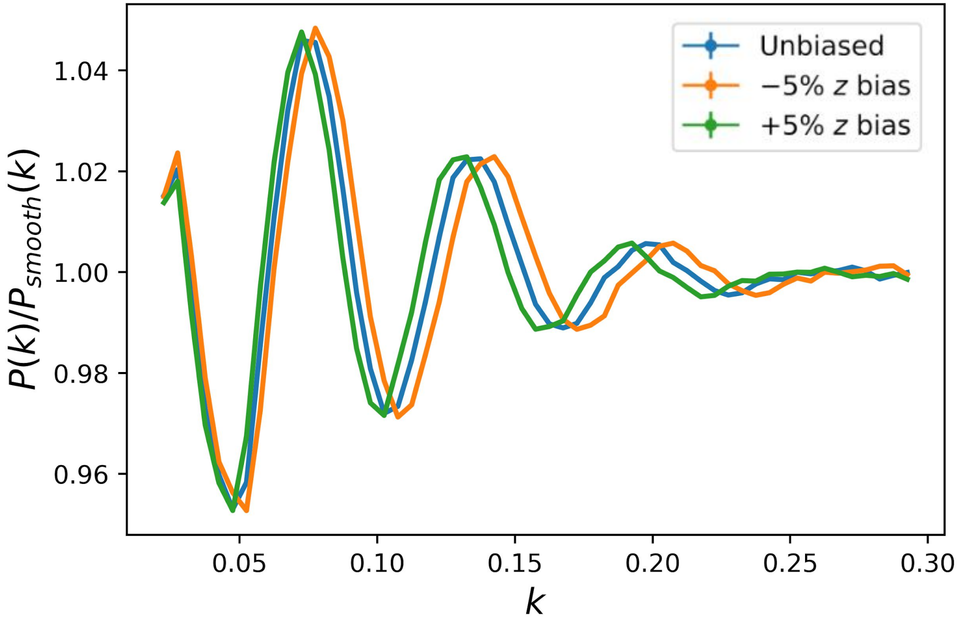
1) Project our redshift sample to Cartesian space (using underlying cosmology as fiducial)
2) Measure 1D power spectrum convolved with supplied randoms

Use nbodykit code suite in both steps



Extracting the BAO Feature

Extract BAO features from 1D power spectrum using modular BAO fitting code “Barry”

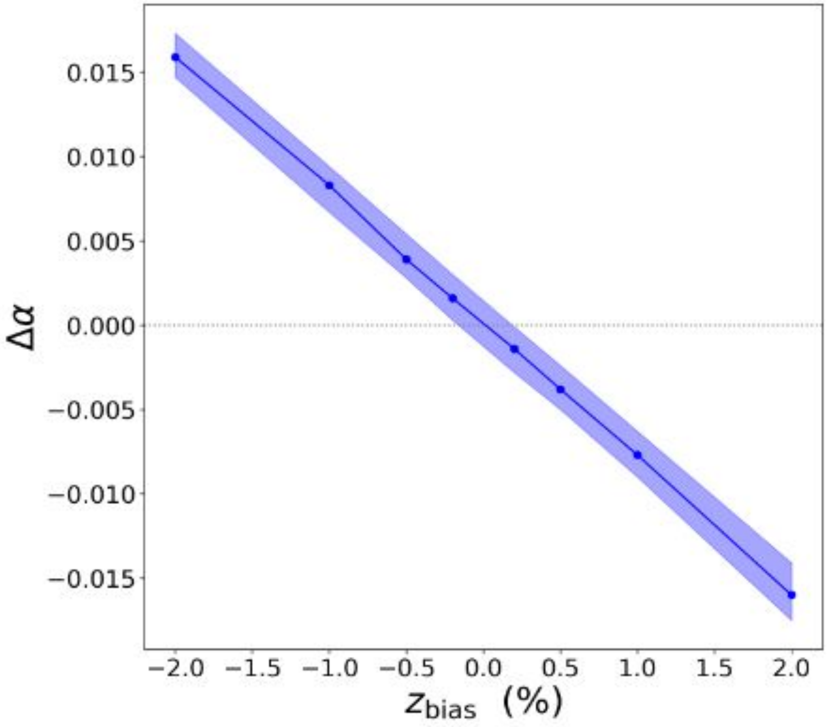


Extracting the BAO Feature

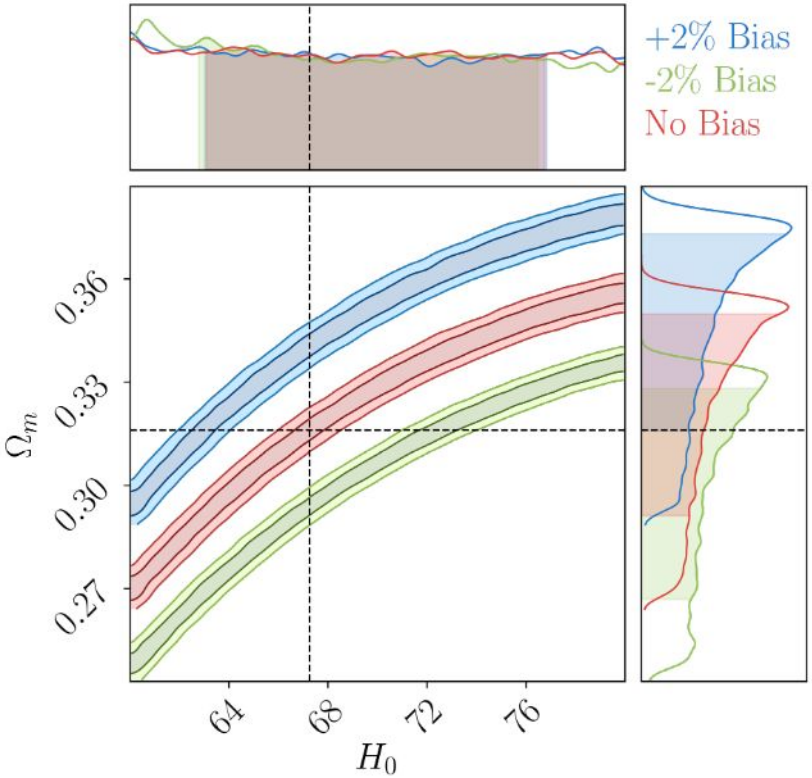
Fit α using the average power spectrum of all 500 mocks

We find a consistent trend in Δα with injected bias, and across BAO models

Fitting for Δα allows us to avoid over-reliance on any specific BAO model



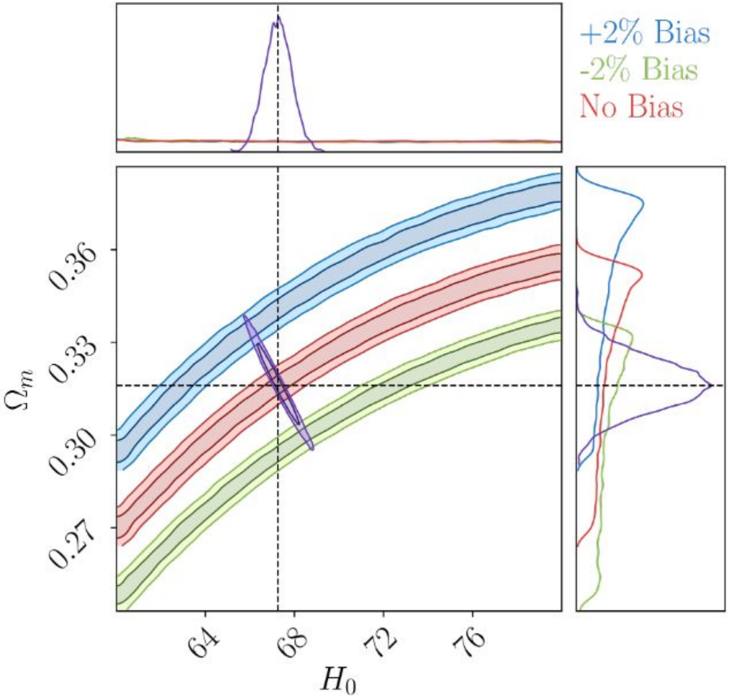
Cosmology Fits With Injected Bias

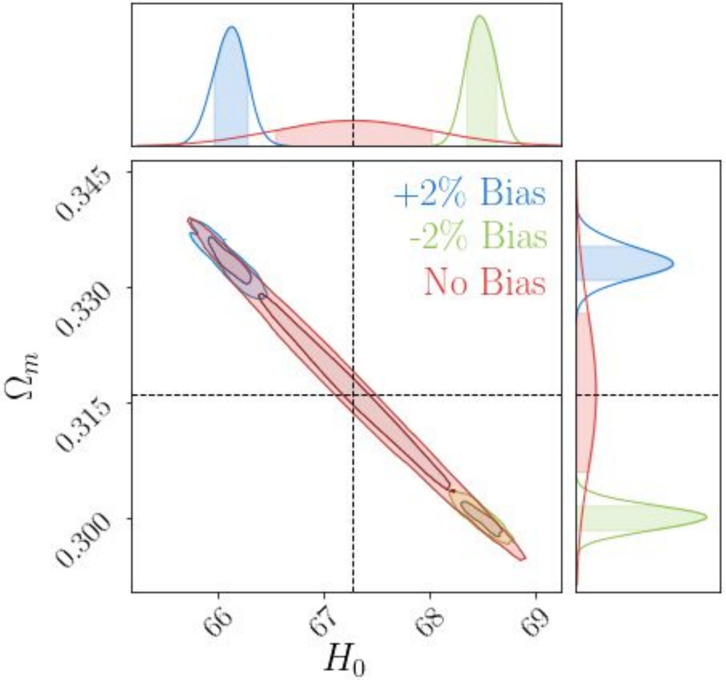


Fit cosmology using this α using MCMC analysis

Varying α shifts BAO contours along Ω_m - Need additional information to constrain further

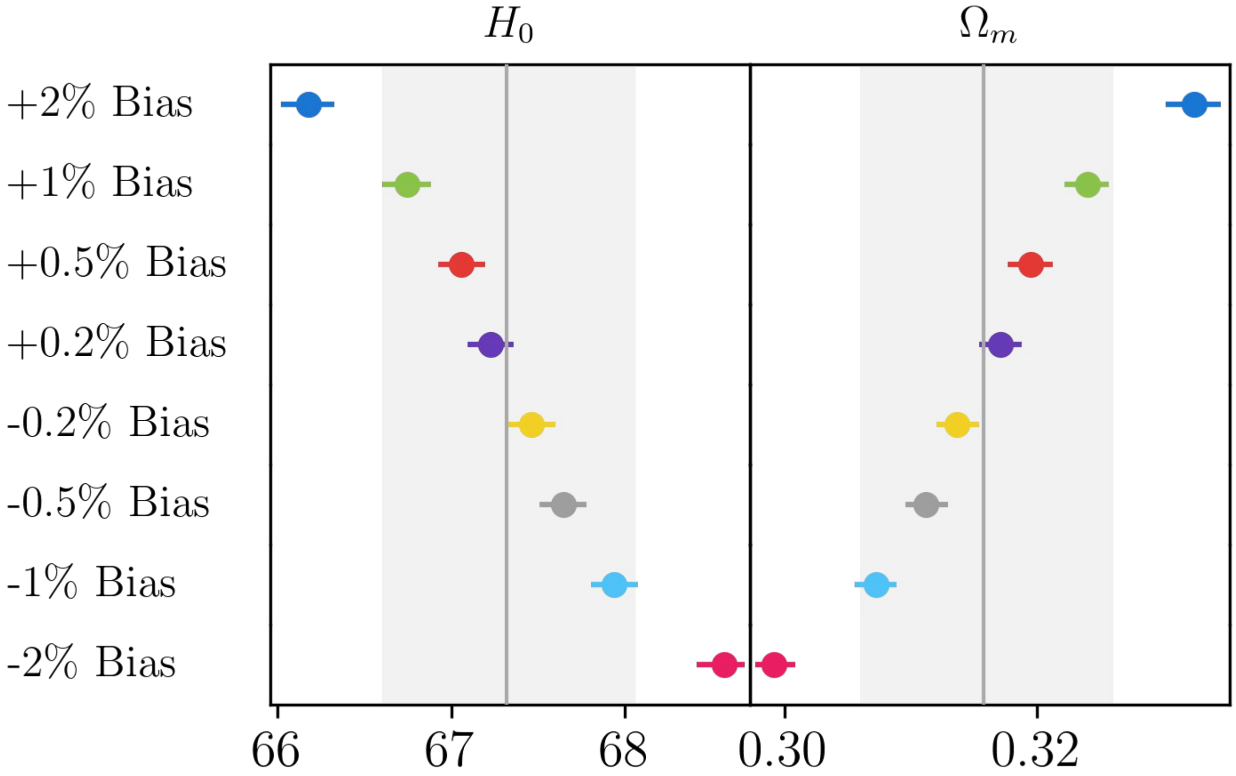
Combined Cosmological Fits





Summary of Importance Sampling

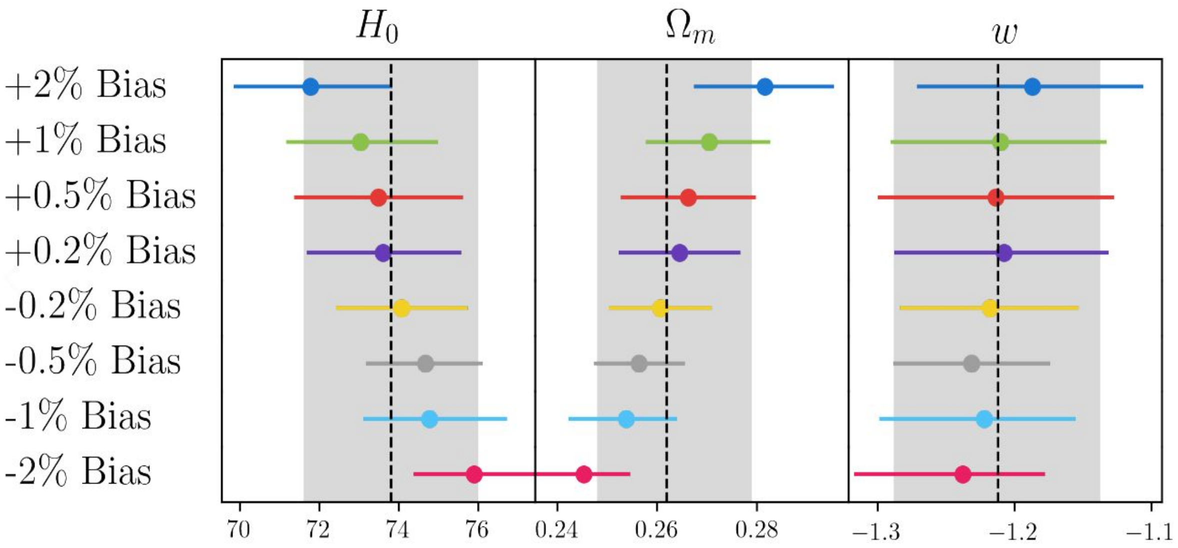
Naive Heliocentric correction (largest effect): ±0.1% bias



Alternate Fits (wCDM Cosmology)

CMB alone weakly constrains H_o in wCDM cosmology, and BAO is an important tool

Does this reliance make wCDM model constraints more susceptible to BAO systematics?



Takeaway Message

Are systematic redshift offsets responsible for the Hubble tension…

Probably not

As statistical errors reduce, potentially unresolved systematics could play larger role in characterising accuracy