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Early Galaxy Formation and the Hubble Constant Tension

Stacy S. McGaugh[1]

[1] *Department of Astronomy, Case Western Reserve University, Cleveland, OH 44106, USA*

ABSTRACT

Tension between local determinations of the Hubble constant and the value found in fits to the cosmic microwave background (CMB) acoustic power spectrum have emerged as finer angular scales (higher multipoles ℓ) have been measured in the latter. Independent observations indicate that massive galaxies emerged at higher redshift than anticipated in the standard ΛCDM structure formation paradigm. If genuine, these early galaxies would cause excess gravitational lensing of the CMB, adding an anomalous source of power at high ℓ. I suggest that accommodating this anomalous source of power in multiparameter fits might be the root cause of the Hubble tension rather than systematics in local measurements.

THE HUBBLE TENSION

Early results in precision cosmology obtained estimates of the Hubble constant[1] $h = 0.73 \pm 0.03$ (Spergel et al. 2007) that were in good agreement with contemporaneous local estimates ($h = 0.72 \pm 0.08$: Freedman et al. 2001). Since that time, a tension has emerged as accuracy has improved. Precise local measures give $h = 0.73 \pm 0.01$ (Riess et al. 2021) while CMB fits give $h = 0.6736 \pm 0.0054$ (Planck Collaboration et al. 2020a).

Given the history of the distance scale, it is tempting to presume that local measures are at fault. However, it is the value of h from CMB fits that has diverged from the concordance region (Fig. 1). This occurred as progressively finer scales (higher ℓ) were incorporated into the fits, so perhaps the issue resides there.

Photons must traverse the entire universe to reach us from the surface of last scattering (Peebles 1993). Along the way, they are subject to 21 cm absorption by neutral hydrogen, Thomson scattering by free electrons after reionization, energy shifts from traversing gravitational potentials (the ISW effect), and deflection by gravitational lensing. Lensing blurs the surface of last scattering and adds a source of fluctuations not intrinsic to it.

EARLY GALAXY FORMATION

JWST observations evince the early emergence of massive galaxies at $z \approx 10$ (Finkelstein et al. 2022). This came as a great surprise theoretically, but the empirical result extends previous observations that galaxies grew too big too fast (Steinhardt et al. 2016; Franck & McGaugh 2017). Taking the data at face value, more structure appears to exist in the early universe than expected. This would cause excess lensing and an anomalous source of power on fine scales.

If excess lensing by early massive galaxies occurs but goes unrecognized, fits to the CMB data would be subtly skewed (Fig. 1). Fitting extra power at high ℓ would drive up Ω_m. In response, it would be necessary to reduce h to maintain a constant $\Omega_m h^3$ (Fig. 1). This would explain the temporal evolution of the best fit values, so I posit that this effect may be driving the Hubble tension.

The early formation of massive galaxies would represent a real, physical anomaly. This is unexpected in ΛCDM but not unanticipated. Sanders (1998) explicitly predicted the formation of massive galaxies by $z = 10$. Excess gravitational lensing by these early galaxies is a natural consequence, along with early reionization (McGaugh 1999), an enhanced ISW effect (McGaugh 2004; Granett et al. 2008), and high redshift 21 cm absorption (McGaugh 2018).

[1] $h = H_0/(100\ \mathrm{km\,s^{-1}\,Mpc^{-1}})$.

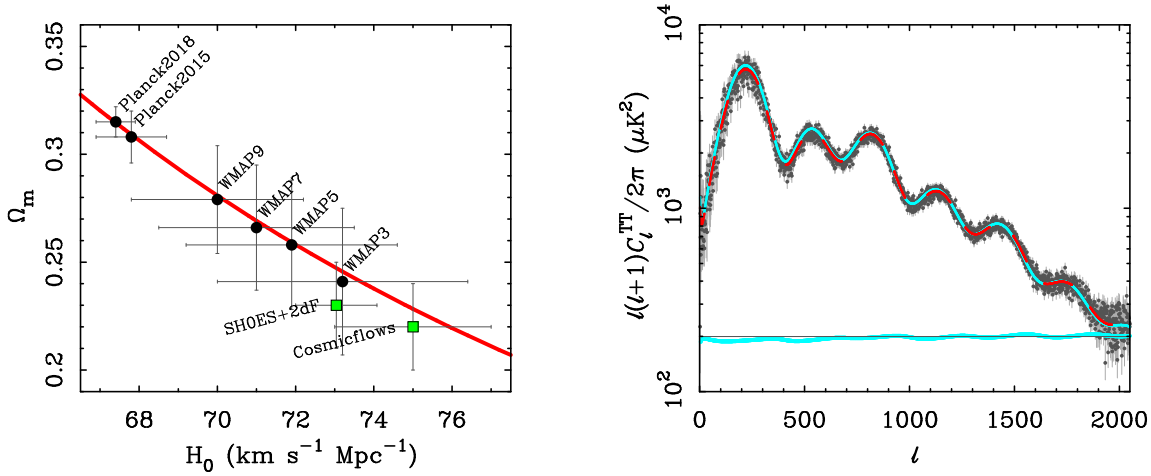

Figure 1. Left: The covariance between the density parameter and Hubble constant in CMB fits, $\Omega_m h^3 = 0.09633 \pm 0.00029$ (Planck Collaboration et al. 2020a, red line). Also shown are best-fit values from CMB experiments over time, as labeled. These all fall along the line of constant $\Omega_m h^3$, but have diverged from concordance with local data (examples from Cole et al. 2005; Mohayaee & Tully 2005; Tully et al. 2016; Riess et al. 2021) as higher multiples ℓ have been observed. **Right:** Unbinned Planck data (Planck Collaboration et al. 2020b, points) with the best-fit power spectrum (red line) and a model (blue line) with $h = 0.73$ and Ω_m adjusted to maintain constant $\Omega_m h^3$. The ratio of the models is shown at bottom, illustrating the subtle need for slightly greater power with increasing ℓ than provided by the model with $h = 0.73$.

The new physics driving the prediction of Sanders (1998) is MOND (Milgrom 1983). This is the same driver of anomalies in galaxy dynamics (McGaugh 2020; Banik & Zhao 2022), and apparently of the Hubble tension. These predictive successes highlight the need for a deeper theory (e.g., Skordis & Złośnik 2021).

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