Hot Dark Matter in Cosmology

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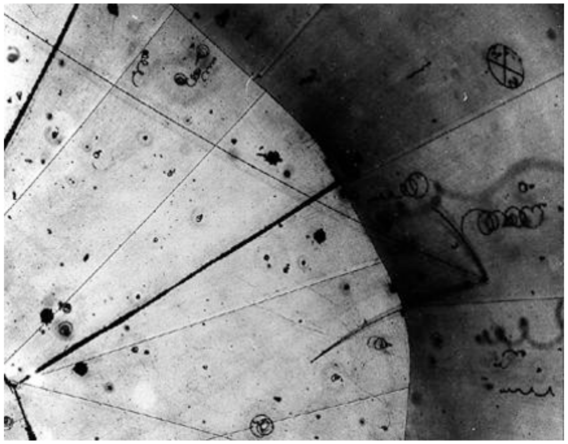
Historical Summary

- In 1979-83, Neutrinos were the most popular Dark Matter candidate.
- In the early 80’s neutrino mass was not known precisely.
- Cold Dark Matter is the standard model today, but some current models include both hot and cold dark matter.

Hot, Warm, and Cold Dark Matter

- Hot dark matter refers to particles moving at close to the speed of light in the early universe.
- Possible candidates besides neutrinos include super symmetry particles such as the gravitino and neutralino.



Problems with HDM model (mass)

- Number density of neutrinos is comparable to that of CMB photons, implying neutrino mass of ~10 eV in HDM models, conflicting with current upper bound on (electron) neutrino mass of < 1 eV.
- Due to exclusion principle, mass of neutrinos must be > 500 eV to reproduce observed rotational velocities of galaxies.
- Numerical simulations show that baryonic matter cannot form galaxies with neutrino halos.

$$n_\nu(p) = \frac{g_\nu}{h^3}\left[1 + \exp\left(\frac{pc}{kT_\nu(z)}\right)\right]^{-1}$$

Problems with HDM model (structure formation)

- The free streaming of HDM particles will tend to smooth out small scale fluctuations in matter density.
- In HDM model, super clusters form early, and galaxies form late (which is the opposite of what we observe)

Cold plus Hot Dark Matter

- A small amount of HDM can slow growth of density inhomogeneities in CDM model.
- CDM model predicts galaxy scale density inhomogeneities which are too large.
- Numerical simulations favor a mixed CDM+HDM model with a cosmological constant.

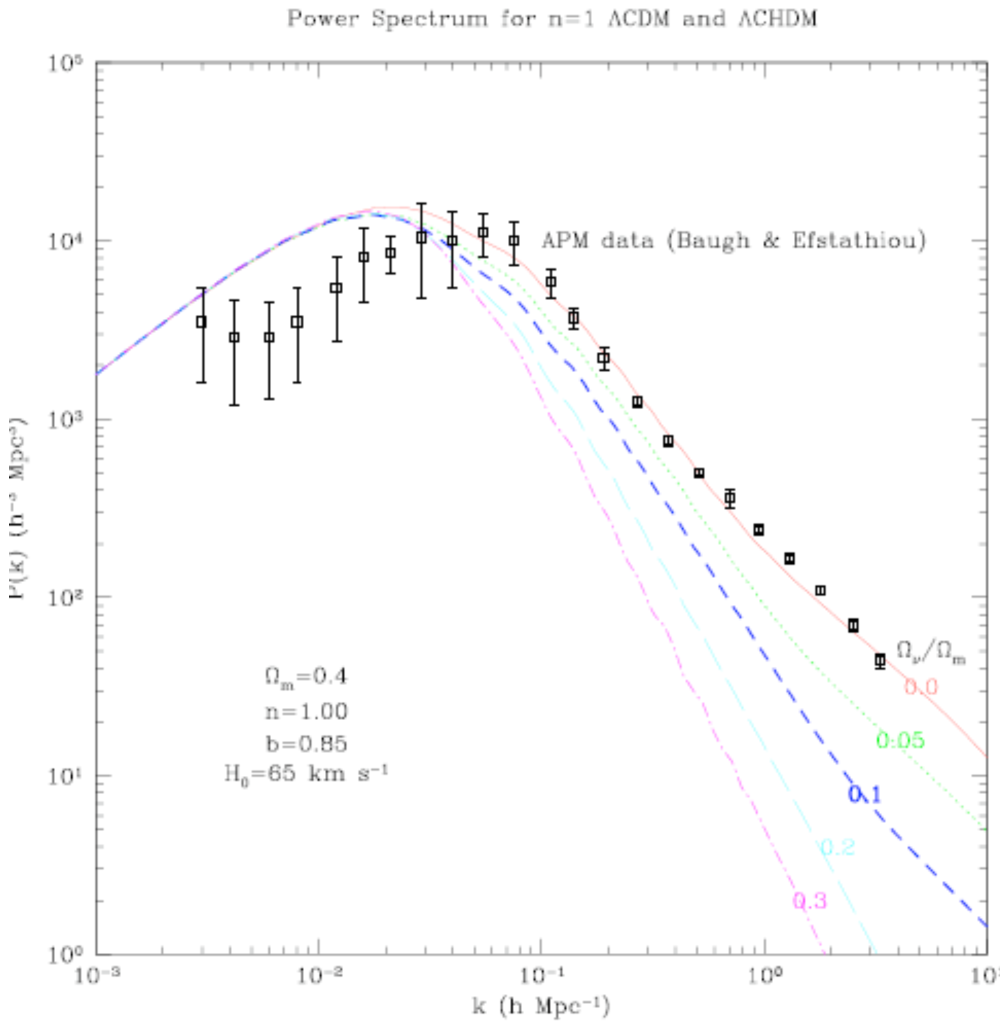


Fig. 1. Nonlinear dark matter power spectrum vs. wavenumber for ΛCDM and ΛCHDM models with $\Omega_\nu/\Omega_m = 0.05, 0.1, 0.2, 0.3$. Here $\Omega_m = 0.4$, the Hubble parameter $h = 0.65$, there is no tilt (i.e., $n = 1$), and the bias $b = 0.85$. Note that in this and the next Figure we "nonlinearized" all the model power spectra [103], to allow them all to be compared to the APM data (the small "wiggles" in the high-Ω_ν power spectra are an artifact of the nonlinearization procedure).

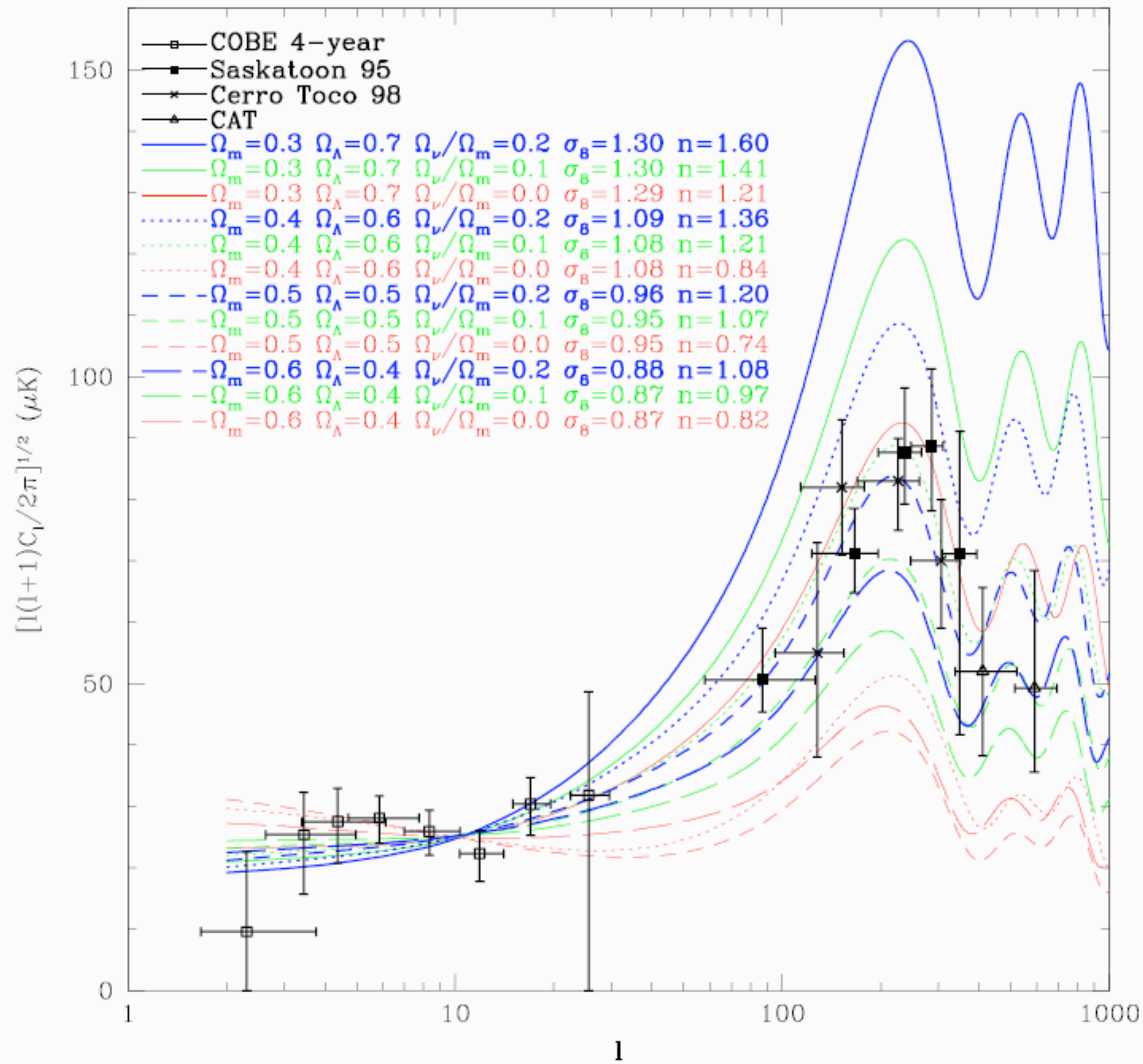


Fig. 3. CMB anisotropy power spectrum vs. angular wave number for the same models as in Figure 2. The data plotted are from COBE and three recent small-angle experiments [104,105,106,107].