Effects of LIMRs on Nonlinear structure formation

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Ravi kumar sharma
(SRF,IIA Bangalore)

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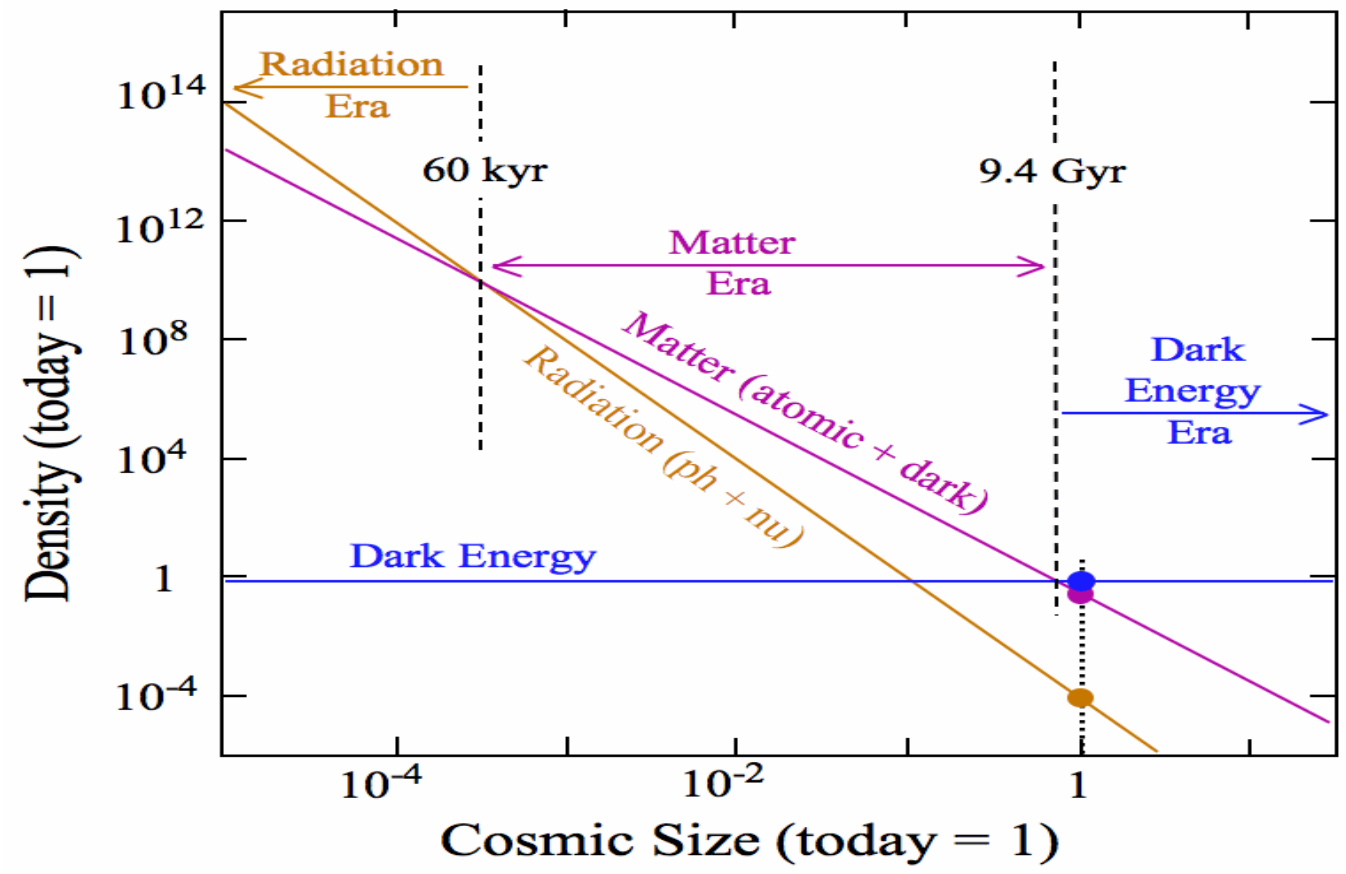
Contents of The Universe



Neutrino Properties

- Phase Space $$f\left(E, T_\nu\right) = \frac{1}{\exp\left(-\frac{p}{T_\nu}\right) + 1}$$
- Background Temp. $$T_{(\nu)} = \left(\frac{4}{11}\right)^{1/3} T_\gamma$$
- Energy density If Relativistic $$\rho_\nu = \left[\frac{7}{8}\left(\frac{4}{11}\right)^{4/3} N_{eff}\right] \rho_{CMB}$$
- If Non-relativistic $$\Omega_\nu h^2 = \frac{M_\nu eV}{93\, eV}$$

Free streaming

- Neutrino turns non-relatvistic at $1+z_{nr}=1890\left(\frac{m_\nu}{1eV}\right)$

- Nonrelativistic neutrino also have high velocity dispersion $\sigma_\nu=158\,(1+z)\left(\frac{1eV}{m_\nu}\right)km\,s^{-1}$

- Free streaming length $\lambda_{FS}\simeq 4.2\sqrt{\frac{(1+z)}{\Omega_{m,0}}}\left(\frac{1eV}{m_\nu}\right)h^{-1}\,Mpc$

$$k_{FS}=\frac{2\pi}{\lambda_{FS}}$$

New sterile Species and its cosmological effects

- Completely defined by three parameters

$$\Delta N_{eff}, \quad \omega_s, \quad .<\nu_s>.$$

- Only two independent parameters(Phys.Rev.D79:045026,2009).

$$\Delta N_{eff} = \frac{\rho_s^{rel}}{\rho_\nu} = \frac{\left[\frac{1}{\pi^2}\int dp\, p^3 f(p)\right]}{\left[\frac{7}{8}\frac{\pi^2}{15}T_\nu^{id\,4}\right]}$$

$$\frac{m_{sp}^{eff}}{94.05\,eV} = \omega_s = \Omega_s h^2 = \left[\frac{m_{sp}}{\pi^2}\int dp\, p^2 f(p)\right]\left[\frac{h^2}{\rho_c^0}\right.$$

$$.<\nu_s>. = 5.6\,x\,10^{-6}\,\frac{\Delta N_{eff}}{\omega_s}$$

Nonthermal-Distributions

- Nonthermal Limr from moduli decay(Phys.Rev.D 103 (2021) 6, 063503)

$$f(q)=\frac{32}{\pi \hat{E}^3}\frac{N(0)B_{sp}}{s^3(\theta^*)}\frac{e^{s^{-1}(y)}}{q^3 H(s^{-1}(y))}$$

$$T_{ncdm},0=0.418\left(\frac{m_\phi^2\,\tau}{M_{pl}}\right)^{\frac{1}{2}}\frac{T_{cmb}}{(1-B_{sp})^{\frac{1}{4}}}$$

- Dodelson Widrow

$$f_{DW}(p)=\frac{\chi}{\exp(\frac{p}{T_\nu})+1}$$

- Gaussian Distribution

$$f_g(\boldsymbol{p})=N\frac{T_\nu^3}{p^2}\exp(\frac{-(p-p_0)^2}{2\sigma^2})$$

$$N=4\pi\sqrt{2\pi\sigma^2}$$

What is S8 Tension

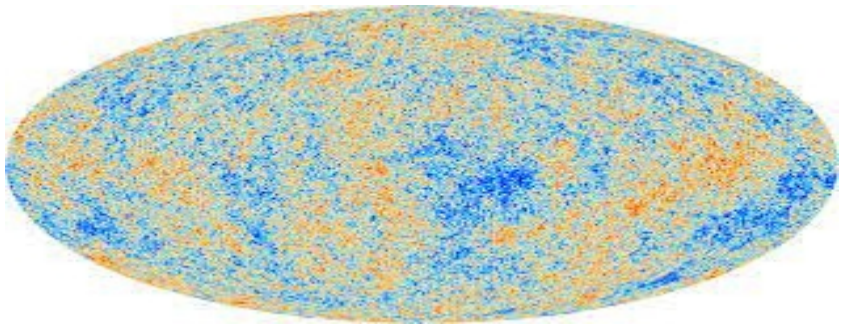
- S8 is define as

$$S8 = \sigma_8 \sqrt{\frac{\Omega_M}{0.3}}$$

Ω_M Total matter abundance

σ_8 root mean square of matter fluctuations on a 8 Mpc/h scale

Planck CMB



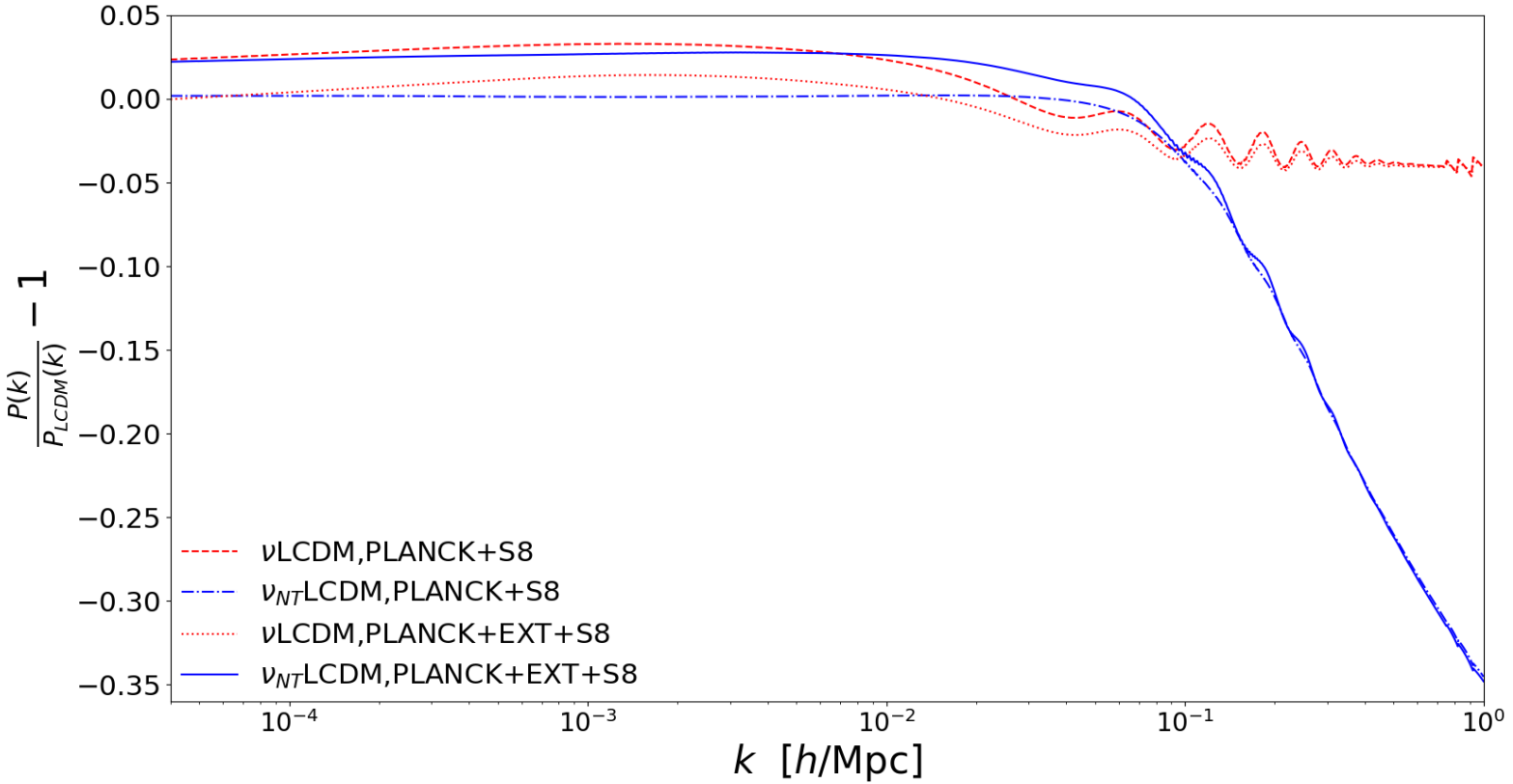
$$S_8 = 0.834 \pm 0.016$$

KIDS1000+DES

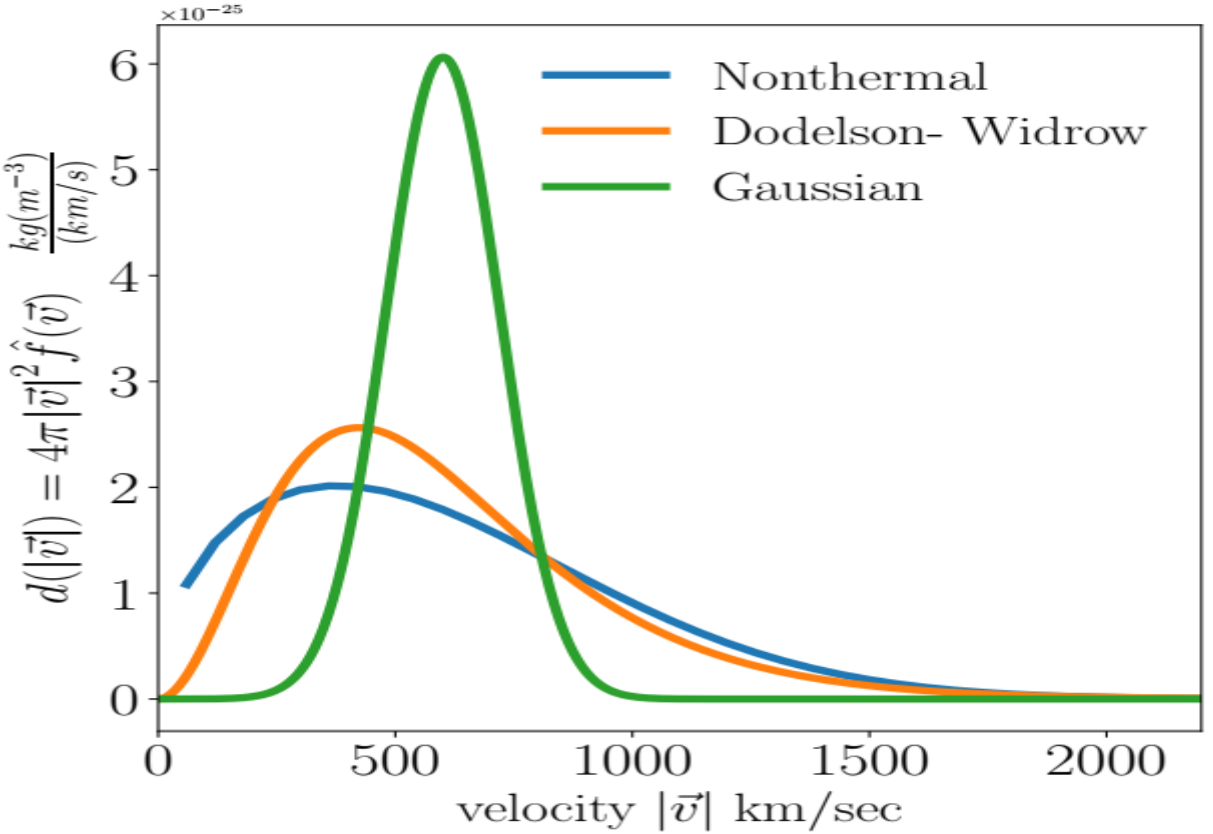
$$S_8 = 0.755^{+0.019}_{-0.021}$$

Residual Matter Power Spectra

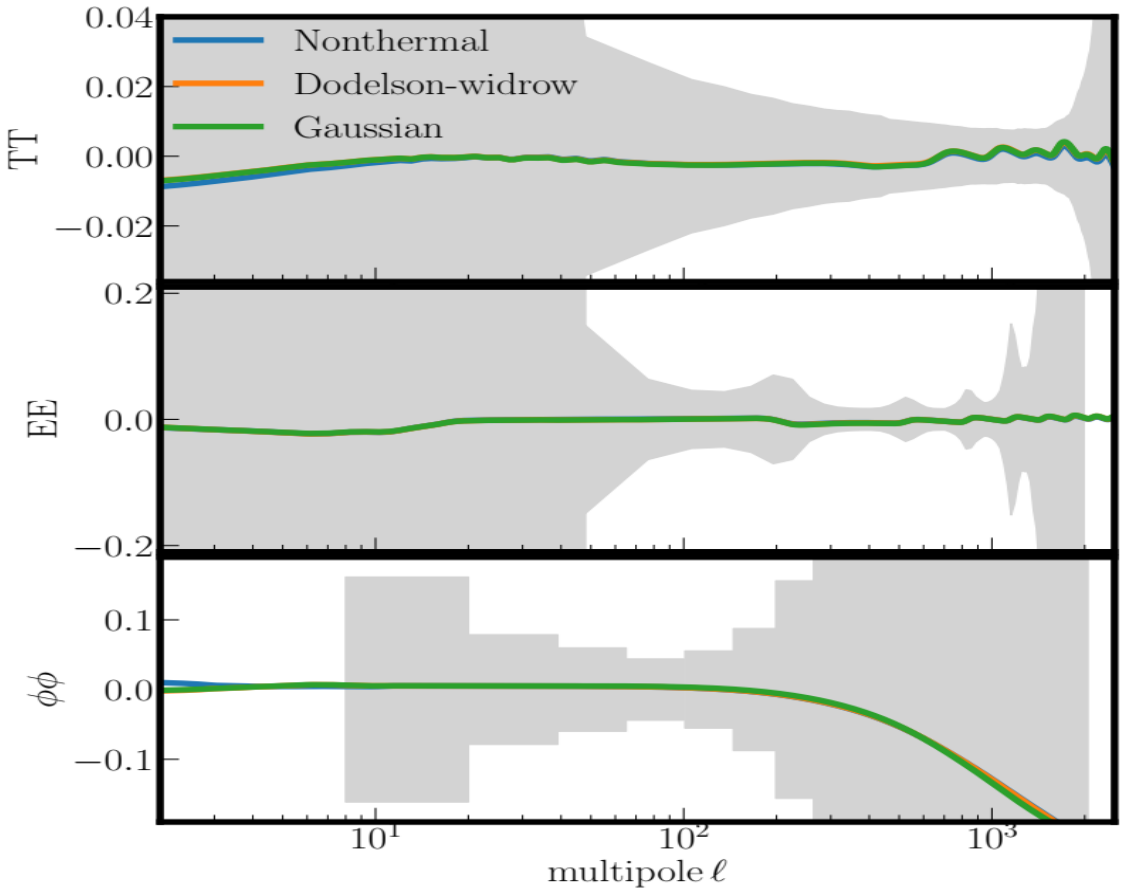
Phys.Rev.D 105 (2022) 10, 103503



Nonthermal-distributions



Compare using Linear cosmology



Simulation setup

- Gadget-2
- Box Size 1Gpc, particles 1024^3
- Two type particles: CDM+b,LiMRs
- Two sets of Simulation: Nonthermal,LCDM with matched sigma8
- Halo finder:Rockstar (uses only type1)

Initial Conditions

- CDM initial positions determined completely by Linear power spectra and growth rate.
- Limr velocity assignement:

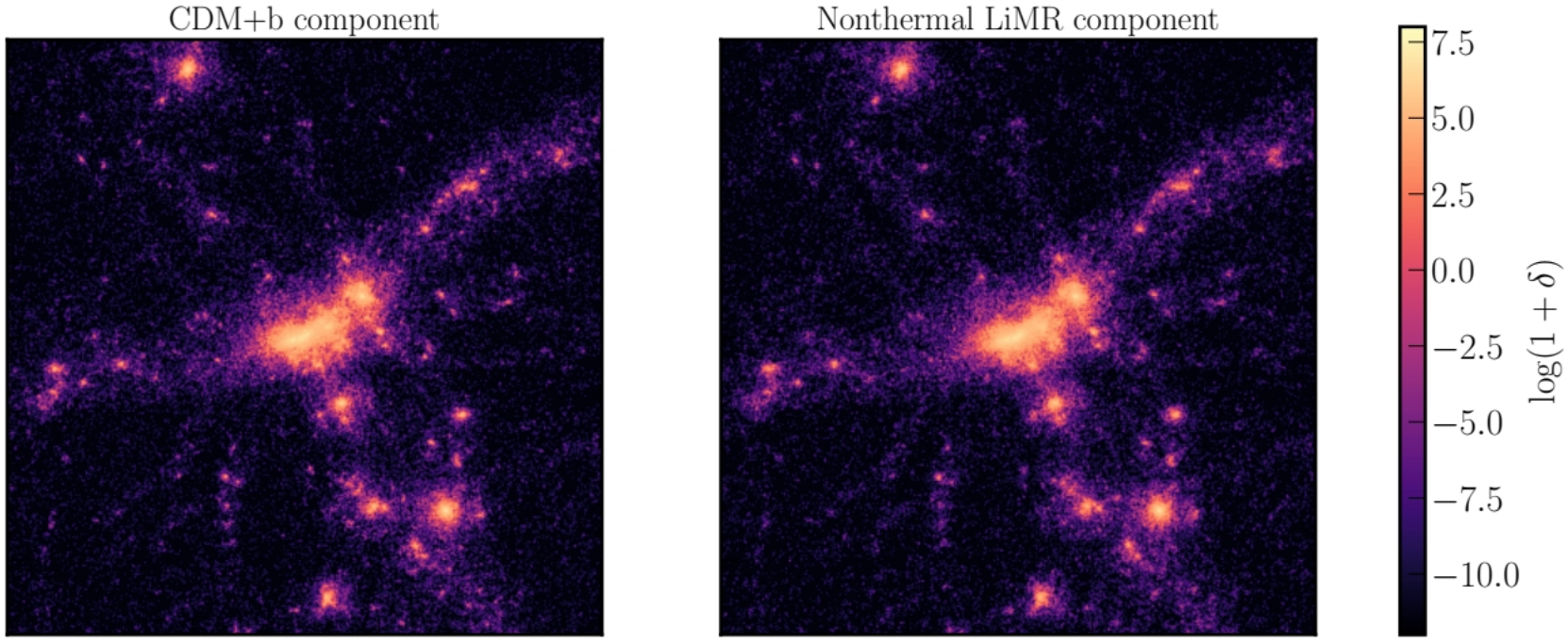
  1.From f(v) to CDF(v)

  2.Generate a random number between 0 to 1. lets say x

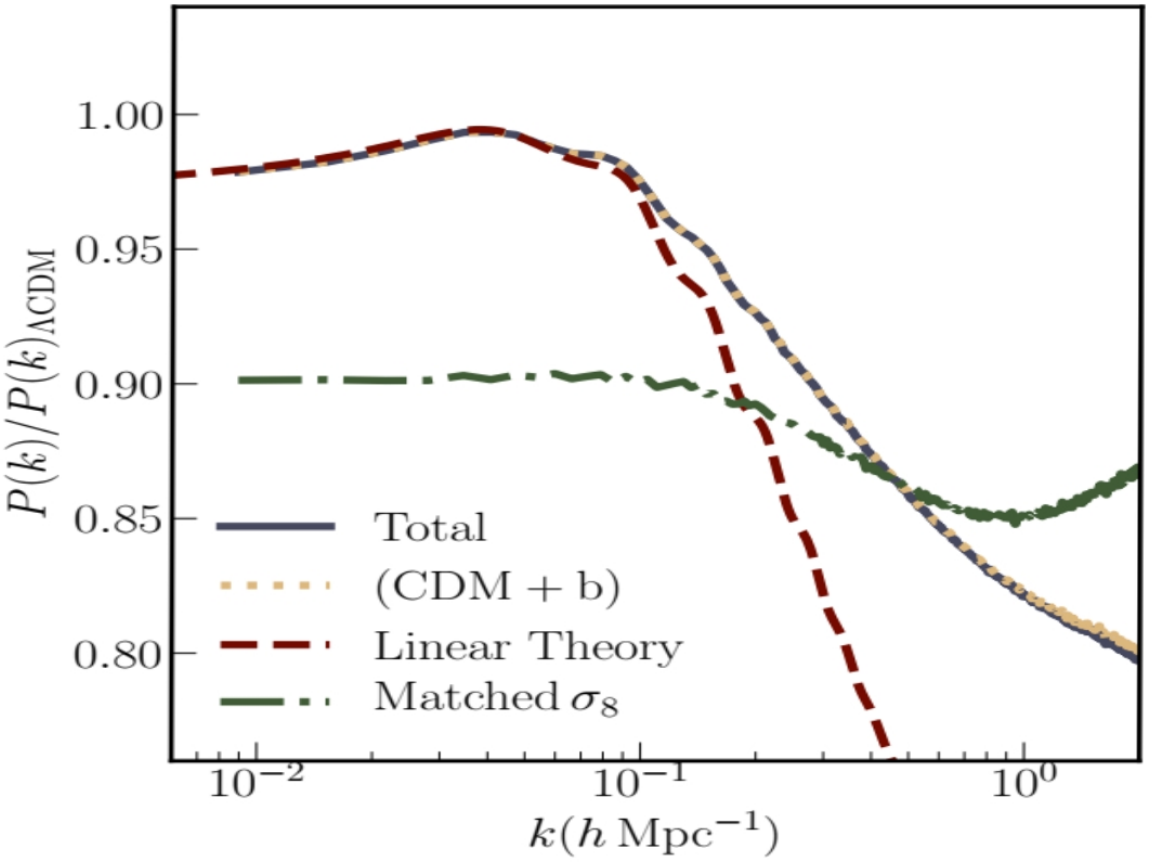
  3. assign velocity v* to that Limr for which CDF(v*)=x

  4.repeat for each limr particle

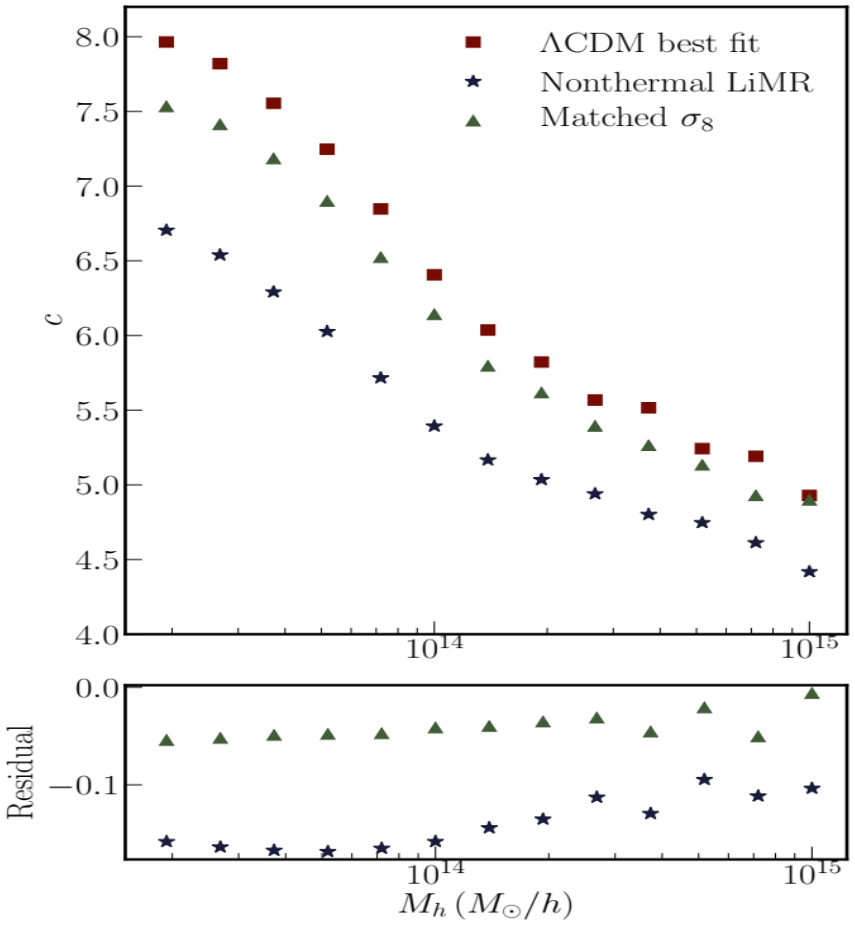
Results


CDM+b component
Nonthermal LiMR component
7.5
5.0
2.5
0.0
−2.5
−5.0
−7.5
−10.0
log(1 + δ)

1.*Matter Power Spectra*



2.*Mass concentration*



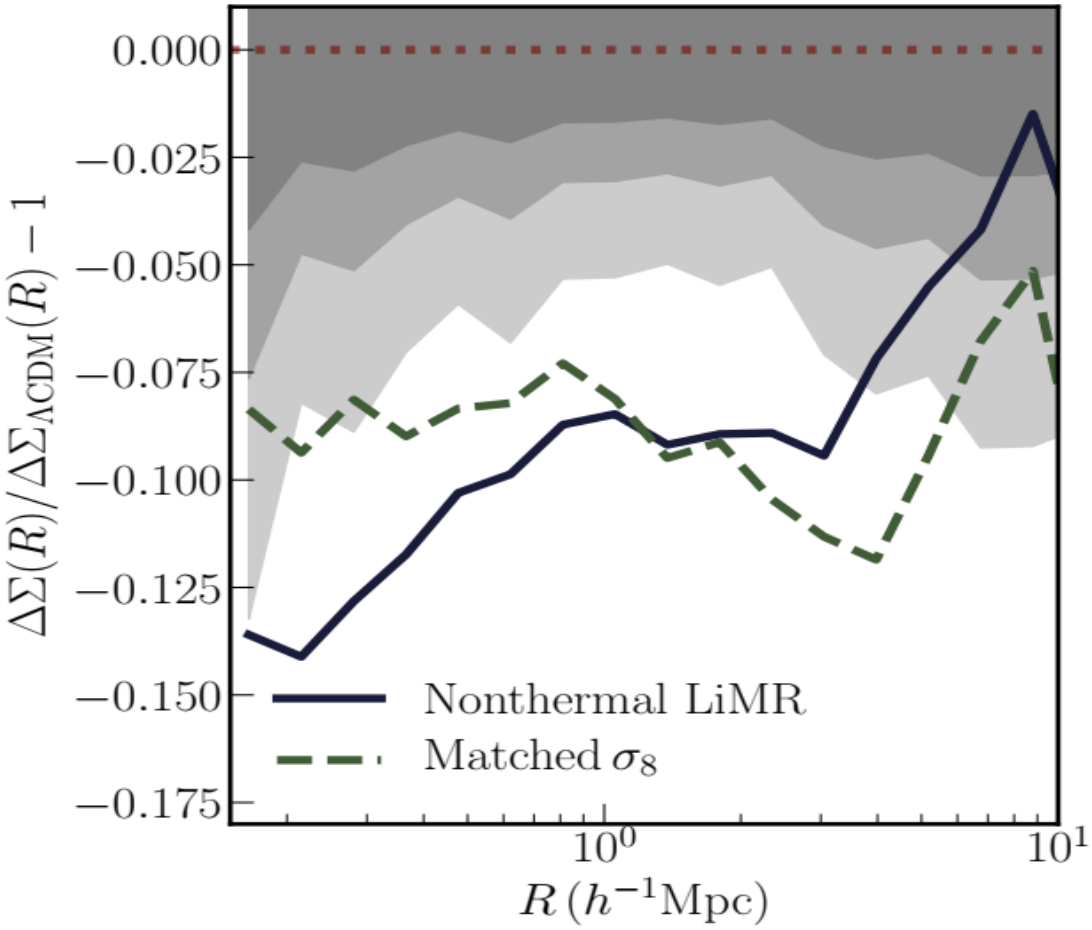
- The concentration $c = \frac{r_{vir}}{r_s}$

  virial radius of the halo(r_{vir}), and the scale radius of the halo (r_s)

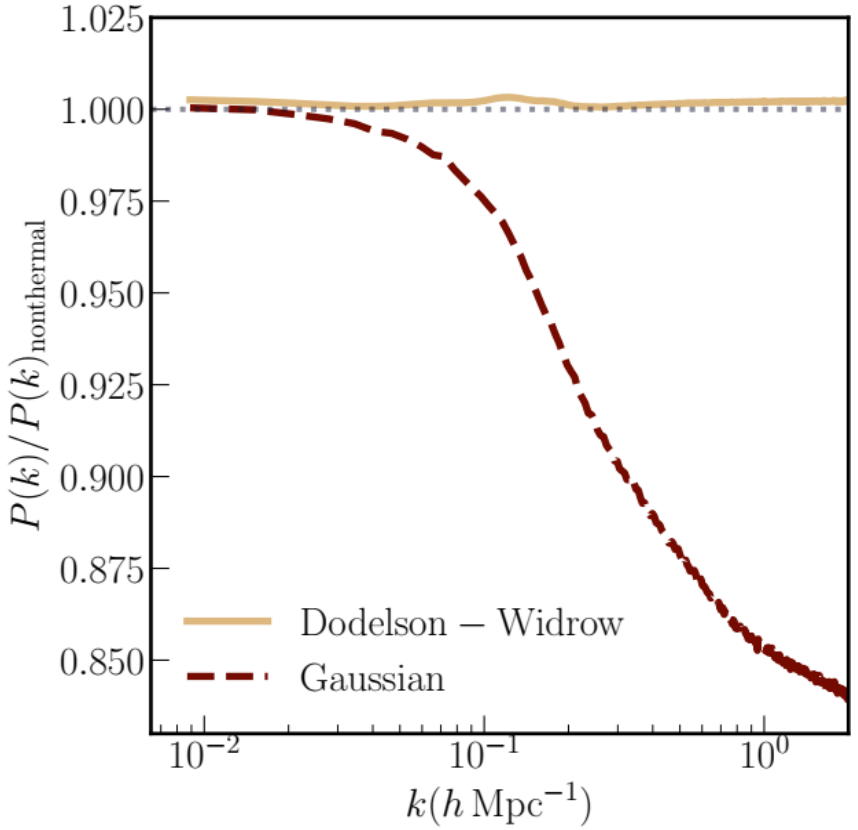
3. *Weak lensing around massive clusters*

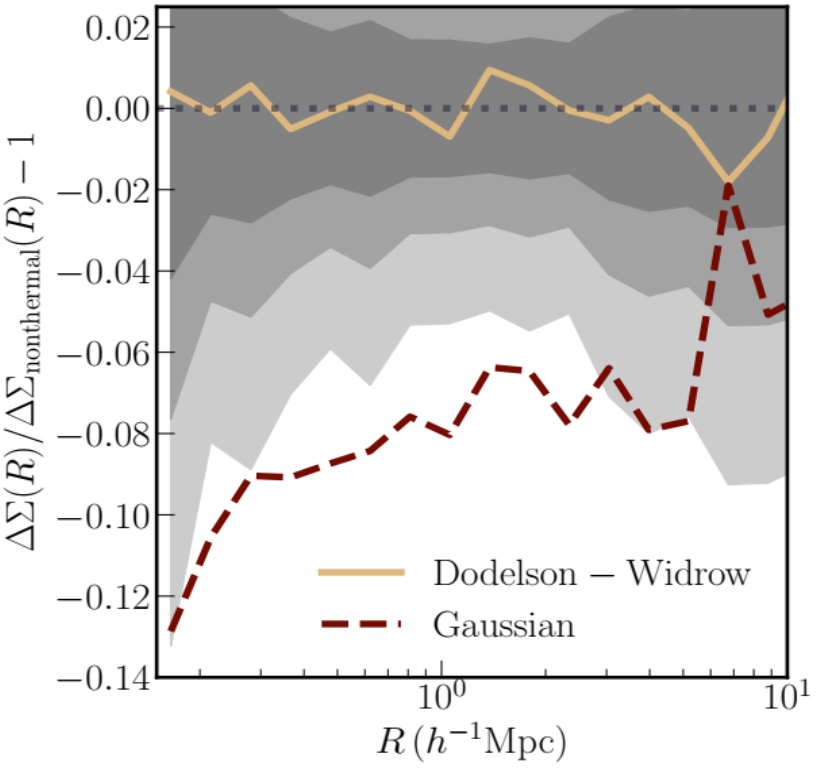
- The excess surface mass density
$\Delta\Sigma(R) = \Sigma(<R) - \Sigma(R)$

  R is the projected distance from the cluster centre



4.*EFFECT OF LIMR VELOCITY DISTRIBUTIONS ON NONLINEAR STRUCTURE FORMATION*





Conclusions

- *Effect on Matter power spectrum*: (shape and amplitude differ from linear prediction)
- we find that the non-thermal LiMR model produces an overall reduction in the mean concentration as a function of halo mass over the mass range $10^{13} M_s/h \leq M_h \leq 10^{15} M_s/h$, but remains roughly monotonic
- Expected level of signal-to-noise in these types of measurement expected in DES Y3, and especially LSST (VRO) should be sufficient to discriminate between the non-thermal LiMR model and the Planck best-fitting LCDM model at a high level of statistical significance.
- Completely indistinguishable at linear : Distinguishable at non-linear

Thank you all for listening

- This is work is done in guidence of Dr. Arka Banerjee, Dr. Anshuman Maharana, Dr. Subinoy Das .