Machine Learning the Nature of Dark Matter with 21cm Tomography

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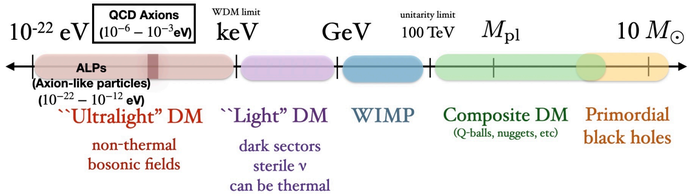
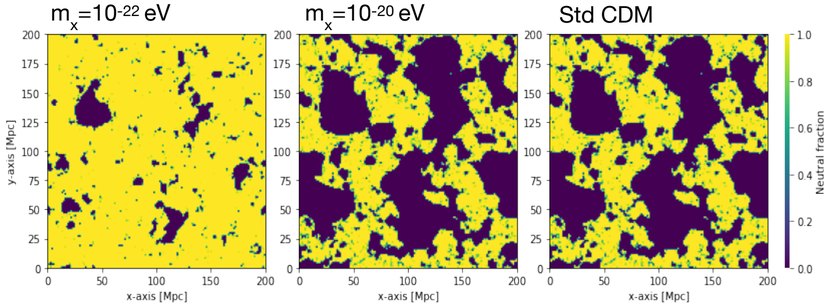
Abstract:

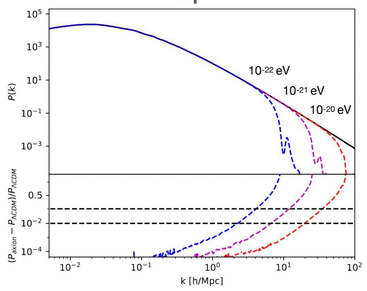
The nature of Dark Matter is still a missing piece if the cosmic ontology. In this work we look at the possibility of future 21cm radio intensity mapping experiments detecting ultra light axion like particle dark matter.



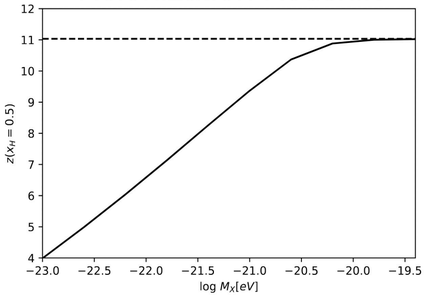
- ★ We use AxionCAMB to generate initial power spectra, P(k)
- ★ We use 21cmFAST to generate ionisation fields and 21cm brightness temperature fields from the P(k) with various axion masses



Power Spectrum

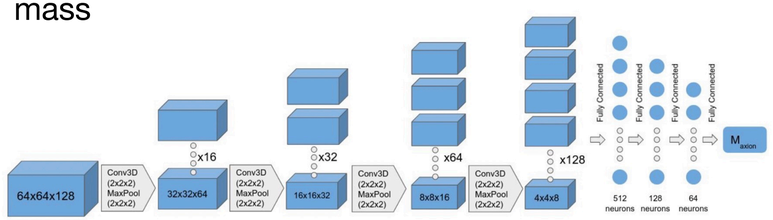


Reionization Redshift



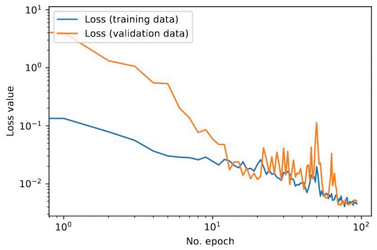
Machine Learning

- ★ We build a convolutional neural network which takes as input a 64,64,128 voxel brightness temperature field and outputs a single prediction of the axion mass

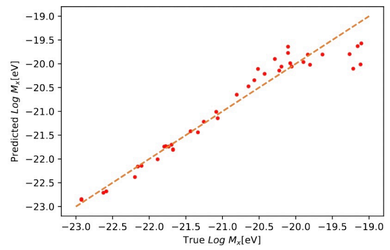


- ★ The testing predictions track the truth up until logM_X ~ -20, this is because heaver axion masses behave similar to std CDM.

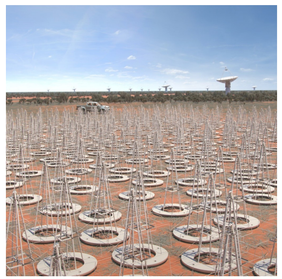
Training

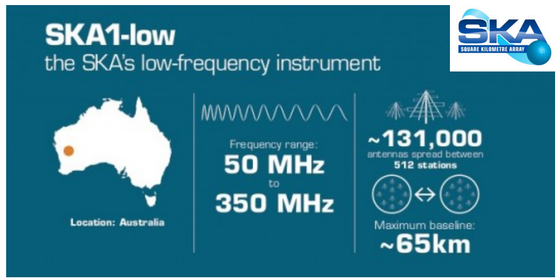


Testing



- ★ We generate semi realistic observations of the SKA-1 LOW design



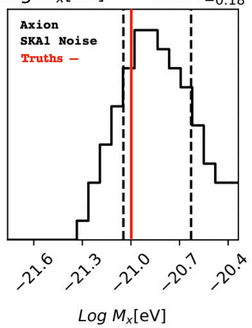


Results and Summary

- ★ We made realistic SKA-1 LOW images of the 21cm signal in an axion DM scenario.
- ★ We created 400 simulations with fiducial PLANCK 2015 parameters but varying the axion mass, m_x, and two astrophysical parameters T_{vir} and ζ, the minimum halo temperature to produce ionising photons and the ionising efficiency, respectively.
- ★ We applied a machine learning approach using convolutional neural networks and found that the trained network could constrain the axion particle mass
- ★ Marginalising over a wide range of nuance parameters we were able to constrain the **axion mass to ~20%** using a modest SKA1-Low design while assuming a fiducial Planck 2015 cosmology.
- ★ The axion can be detected with SKA at if the axion is $M_X < 1.86 \times 10^{-20}$eV although this can decrease to $M_X < 5.25 \times 10^{-21}$ eV if we relax our assumptions.

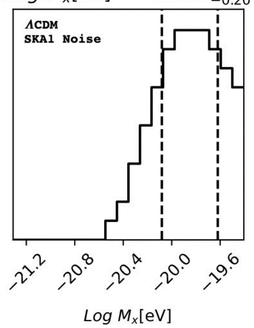
Axion Model

$Log\ M_x[\mathrm{eV}] = -20.87^{+0.24}_{-0.18}$



Standard CDM

$Log\ M_x[\mathrm{eV}] = -19.88^{+0.26}_{-0.20}$



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https://arxiv.org/abs/2108.07972