Axion(-like) Dark Matter

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✓ Axion : Overview

  Radio (SKA-like) survey : axion-photon conversion

✓ Axion(-like) Particle : Ultra light particle

  Radio (SKA-like) survey : 21cm
QCD axion as a CDM candidate: mass range $\mu$eV $\sim$ meV (0.1GHz $\sim$ 100GHz)

Previous works: CDM axions converted into photons in the labs.

New works: How about the astrophysically sourced magnetic fields?

Non-resonant conversion: Kelley and Quinn (2017), Sigl (2017)


Line-like radio signal for non-relativistic axion conversion:

$$f \sim \frac{ma}{2\pi} \sim 240 \left( \frac{ma}{\mu eV} \right) \text{MHz}$$
Australia: SKA low: 50-350 MHz
S. Africa: SKA mid: 350 MHz-14GHz
Axion mass: 0.2~60 \(\mu eV\)

QCD axion as a CDM candidate:
Mass \(\mu eV \sim meV (0.1GHz \sim 100GHz)\)
The magnetic field is turbulent on small scales and all-sky flux at a central frequency of 495 MHz to be around the Galactic Centre.

In the rest frame of the Galaxy, is the most appropriate to magnetic field display net rotation with respect to the conservative position, that neither the dark halo nor the environment conversion occurs in a remote region where distribution of the axion. However, in the astrophysical conversion, photons with two distinct frequencies, defined by the energy of the magnetic field modes contributing to the interaction. We saw that only those modes with energy of the magnetic field, the properties of the Galactic Centre that would be expected the flux at the central frequency of 50 MHz to dominate the all-sky signal. There are also 10⁻⁸ to 10⁻⁷ Jy. In determining this flux we have assumed that the all-sky signal is produced will be 522.6 MHz and 783.9 MHz based on an axion of mass 2 x 10⁻²⁶ kg and 2 x 10⁻²⁷ kg.

In observing such coherent fields that are perpendicular to the radial vector with Earth, in addition to along the spiral arms, this could practically one would expect the flux at the central frequency of 50 MHz to dominate the all-sky signal. There are also 10⁻⁸ to 10⁻⁷ Jy. In determining this flux we have assumed that the all-sky signal is produced will be 522.6 MHz and 783.9 MHz based on an axion of mass 2 x 10⁻²⁶ kg and 2 x 10⁻²⁷ kg.

Figure 2

Kelley and Quinn (2017)

Hook, Kahn, Safdi and Sun (2018)
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Model: ALP (Axion-like particles) i.e. Ultra-light scalars

- Ultra-light mass:
  
  \[ m_u \sim H_0 \sim 10^{-33} \text{eV} \]
  \[ m_u \sim 10^{-22} \text{eV} \]
  \[ m_u \sim 10^{-22} \text{eV} - 10^{-10} \text{eV} \]

  \[ m_u, f_u = \Omega_u / \Omega_m \sim O(0.01) \]
  \[ m_u \leq H(t) : \rho_u = \text{const} \]
  \[ m_u > H(t) : \rho_u \propto 1 / a^3 \]

DE (Barbieri et al (2005),...)
Fuzzy DM (Hu (2000),...)
String axiverse (Arvanitaki et al (2009),...)

KK, Mao, Ichiki, Silk (2014)
21 cm signals
1420 MHz

TIDAL INTERACTIONS IN M81 GROUP

Stellar Light Distribution

21 cm HI Distribution
Brief History of Universe

- **Big Bang**: the Universe is filled with ionized gas
- **Recombination**: The gas cools and becomes neutral

<table>
<thead>
<tr>
<th>Years since the Big Bang</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td><del>300,000 (z</del>1000)</td>
<td></td>
</tr>
<tr>
<td><del>100 million (z</del>20-40)</td>
<td>The first structures begin to form.</td>
</tr>
<tr>
<td><del>1 billion (z</del>6)</td>
<td>Reionization starts (z ~12)</td>
</tr>
<tr>
<td>~13 billion (z=0)</td>
<td>Reionization is complete</td>
</tr>
</tbody>
</table>

Today's structures

Kenji Kadota (IBS) ICHEP 2018, Seoul
What can we do with 21cm?

High precision on small-scale power spectrum

$$\Delta P / P \sim 1 / \sqrt{N}$$

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Oyama+ (2013)

ICHEP 2018, Seoul

KK, Mao, Ichiki, Silk (2014)
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Conclusion
Let us be open minded.
Can go beyond the electroweak scale dark matter mass range.
Can go beyond CDM paradigm in LambdaCDM.