A Sterile-Neutrino X-ray Target from the Finite-QEC Dark Sector: $m_{\nu_R} = 17.68\,\mathrm{keV}$ and $E_\gamma = 8.84\,\mathrm{keV}$

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Abstract

This note records the finite-QEC framework's sterile-neutrino X-ray target in the same pre-registration style as the dark-energy w_0, w_a note. The hard line-position claim is

$$m_{\nu_R} = \alpha_0^2 \Lambda_{\mathrm{QCD}} = 17.68\,\mathrm{keV}, \qquad E_\gamma = \frac{m_{\nu_R}}{2} = 8.84\,\mathrm{keV}.$$

The current dark-sector ledger also gives a conditional abundance,

$$\frac{n_{\nu_R}}{n_\gamma} = \frac{\alpha_0}{208}, \qquad \Omega_{\nu_R} h^2 = 0.02418, \qquad \Omega_{\mathrm{dark}} h^2 = 0.12089,$$

with the sterile state carrying one fifth of the paired zero-mode/sterile dark budget. This makes the line position and relic density sharp conditional targets. The line flux also becomes a single-number target if the local R4-enforcement branch is accepted. In that branch the finite register fixes the unique neutral $\nu_R \to \nu_L$ repair edge and its generation-singlet coefficient to one. The Schur sector then has only one remaining scalar, K_B, and the service-normalised one-denominator condition $K_B = 1/v_{R4}$ gives $\theta \simeq m_{\nu_R}/v_{R4}$, hence

$$\sin^2(2\theta) = 2.1 \times 10^{-14}, \qquad \Gamma_{\nu_R \to \nu\gamma} = 4.9 \times 10^{-33}\,\mathrm{s}^{-1}.$$

At that mixing the branch predicts a very faint 8.84 keV line — below near-term XRISM-class sensitivity [1], and probably below even Athena-class reach [2], so the flux is a long-term rather than near-term test. The robust near-term content is the line position and the prediction of *no* bright line at this energy. A much brighter 8.84 keV dark line would refute the $\kappa = 1$ service-normalised R4 reading; a sufficiently deep non-detection would refute that flux branch. If the $\kappa = 1$ premise is rejected, however, a non-detection should be read as a bound on the mixing, not as a refutation of the mass target alone.

Plain summary

Sterile-neutrino dark matter [3] has a simple observational signature. If a heavy sterile neutrino decays into an ordinary neutrino plus a photon, the photon has half the sterile-neutrino mass. This gives a narrow X-ray line. The much discussed 3.5 keV line is the standard example of this search strategy [4–6].

The finite-QEC framework gives a different line energy. Its sterile state is not a fitted warm-dark-matter particle; it is the passive ν_R state in the record code. The mass rule $m_{\nu_R} = \alpha_0^2 \Lambda_{\mathrm{QCD}}$ —

with $\alpha_0 \approx 1/137$ the fine-structure constant and $\Lambda_{\rm QCD} \approx 0.33\,\mathrm{GeV}$ the strong-interaction energy scale — puts it at about 17.7 keV, so the radiative decay line must be near 8.84 keV. That energy is the main target (its precision is set by the value of $\Lambda_{\rm QCD}$, as discussed below).

The branch is scientifically cleaner if the flux is also predicted. The framework now has a conditional abundance, but the flux also depends on the small active–sterile mixing angle. The one-denominator R4-enforcement branch fixes that angle at $\sin^2(2\theta) \simeq 2.1 \times 10^{-14}$. This makes the line faint. A detection near 8.84 keV would be important; a bright line would actually be bad for this branch, because it would require too much mixing. A very deep non-detection can eventually kill the full flux branch, but only once the mixing estimate is promoted from dimensional estimate to microscopic theorem.

1 The frozen line-energy target

The framework assigns the sterile state the mass

$$m_{\nu_R} = \alpha_0^2 \Lambda_{\rm QCD}. \tag{1}$$

Using $\alpha_0^{-1} = 137.035999$ and $\Lambda_{\rm QCD} = 0.332\,\mathrm{GeV}$,

$$m_{\nu_R} = 17.679\,\mathrm{keV}. \tag{2}$$

The radiative decay

$$\nu_R \to \nu + \gamma$$

is a two-body decay, so the photon energy is

$$\boxed{E_\gamma \simeq 8.84\,\mathrm{keV}}. \tag{3}$$

This is the hard observational target. For a source at redshift z, the observed energy is $\simeq 8.84/(1+z)\,\mathrm{keV}$.

Precision and its limiting input. The nominal value above uses the physical $\alpha_0^{-1} = 137.036$; the framework's bare $\alpha_0^{-1} = 137$ gives $8.844\,\mathrm{keV}$, so the α_0 convention is *not* the limiting input. That input is $\Lambda_{\rm QCD}$: the line scales linearly with it, and its value is scheme- and flavour-number-dependent. At the stated three-flavour $\Lambda_{\rm QCD} = 0.332\,\mathrm{GeV}$ the nominal line is $8.84\,\mathrm{keV}$ (8.8397 unrounded); a four-flavour value near $0.29\,\mathrm{GeV}$ would move it to $\simeq 7.8\,\mathrm{keV}$. The framework must fix which $\Lambda_{\rm QCD}$ definition it intends for the target to be sharp; until then the honest target is $E_\gamma \approx 8.8\,\mathrm{keV}$, and an X-ray search should scan a window of order a few percent around it rather than a single sub-eV bin.

The radiative decay rate is written in the standard sterile-neutrino convention [6, 7]

$$\Gamma_{\nu_R \to \nu\gamma} = 1.38 \times 10^{-32}\,\mathrm{s}^{-1} \left(\frac{\sin^2 2\theta}{10^{-7}}\right) \left(\frac{m_{\nu_R}}{\mathrm{keV}}\right)^5. \tag{4}$$

Thus the energy is independent of the mixing angle, but the flux is not.

2 Abundance and flux

The current dark-sector ledger gives the sterile abundance as a boot-QEC source law,

$$\frac{n_{\nu_R}}{n_\gamma} = \frac{\alpha_0}{208}. \tag{5}$$

At the CMB photon density this gives

$$n_{\nu_R} = 0.014410\,\mathrm{cm}^{-3}, \tag{6}$$

$$\Omega_{\nu_R} h^2 = 0.024177. \tag{7}$$

The paired zero-mode reservoir has four times the sterile density, so

$$\Omega_{\mathrm{dark}} h^2 = 5\Omega_{\nu_R} h^2 = 0.120885. \tag{8}$$

The sterile state is therefore one fifth of the paired dark ledger.

The active–sterile mixing is fixed in the current one-denominator R4-enforcement branch by

$$\theta \simeq \frac{m_{\nu_R}}{v_{R4}}, \qquad v_{R4} = 246\,\mathrm{GeV}, \tag{9}$$

then

$$\sin^2(2\theta) = 2.07 \times 10^{-14}, \qquad \Gamma = 4.92 \times 10^{-33}\,\mathrm{s}^{-1}. \tag{10}$$

This corresponds to a lifetime 2.0×10^{32} s, or 4.7×10^{14} Hubble times.

The finite part of this statement is not an order-of-magnitude guess. The R4 repair incidence has two local edges from each sterile source corner. The I_3 edge lands on e_R and is charged; it cannot be the radiative active-neutrino mixing channel. The χ/W edge lands on ν_L and is the unique neutral channel. Generation-blindness makes this edge the identity between the sterile and active generation triples, so the bright generation-singlet port has coefficient exactly one. Thus there is no hidden $\sqrt{2}$, $\sqrt{3}$, or three-port enhancement.

The Schur-complement premise can also be stated more tightly than "one microscopic virtual state". Let Q be the local R4-enforcement virtual sector and let q_B be the bright neutral service channel selected by the finite register. A generation-blind local Schur sector enters the bright sterile–active channel only through the scalar spectral moment

$$K_B = \langle q_B | (QHQ)^{-1} | q_B \rangle.$$

Hidden virtual microstates do not add a generation matrix or a multiplicity; they only alter the scalar $\kappa = v_{R4} K_B$. The named one-denominator branch is therefore the service-normalised condition

$$K_B = \frac{1}{v_{R4}}, \qquad \kappa = 1.$$

It may be realised by one virtual state of gap v_{R4}, or by an unresolved normalised multiplet with the same spectral sum. Under this condition Schur elimination gives

$$m_D = \frac{m_{\nu_R}^2}{v_{R4}}, \qquad \tan(2\theta) = \frac{2m_D}{m_{\nu_R}},$$

which is Eq. (10) at small angle.

For a local source with enclosed dark mass $M_{\rm dark}$ and distance D, the aperture-integrated photon flux is approximately

$$F_\gamma = 5.19 \times 10^{-12} \left(\frac{M_{\rm dark}}{10^{14} M_\odot}\right) \left(\frac{100\,{\rm Mpc}}{D}\right)^2 \left(\frac{\sin^2(2\theta)}{2.07 \times 10^{-14}}\right) \left(\frac{f_{\nu_R}}{0.2}\right) {\rm ph\,cm^{-2}\,s^{-1}}, \tag{11}$$

where f_{ν_R} is the sterile fraction of the relevant dark mass. This is the observer-facing form of the prediction. Real analyses must replace the simple M/D^2 factor by the appropriate projected dark-matter column density, energy response, aperture, background model, and redshift distribution.

3 Tier ledger

Quantity	Status	Comment
$E_\gamma \simeq 8.84\,{\rm keV}$	sharp conditional target	Follows from $m_{\nu_R} = \alpha_0^2 \Lambda_{\rm QCD}$ and two-body kinematics; absolute precision set by the $\Lambda_{\rm QCD}$ value/scheme.
$\Omega_{\nu_R} h^2 = 0.02418$	conditional density theorem	Uses the $\alpha_0/208$ boot source and the CMB photon bath.
$\Omega_{\rm dark} h^2 = 0.12089$	conditional paired dark ledger	Adds the directed R4 zero-mode reservoir at 4:1 relative to the sterile state.
$\sin^2(2\theta) = 2.1 \times 10^{-14}$	conditional Schur theorem	Finite algebra fixes the neutral edge and coefficient; the remaining scalar is $\kappa = v_{R4} K_B = 1$.
Flux, Eq. (11)	conditional target	Fixed inside the named one-denominator R4 branch.

4 Failure and success conditions

The line-energy claim fails cleanly if the framework's sterile state is identified with a radiative X-ray line at any energy other than

$$E_{\rm obs} \simeq \frac{8.84\,{\rm keV}}{1+z}.$$

The 3.5 keV line, for example, is not this state; it would require a sterile mass near 7 keV, not 17.68 keV.

The flux claim is branch-specific. If the service-normalised one-denominator R4 premise $\kappa = 1$ is accepted, then a sufficiently deep non-detection below the normalisation in Eq. (11) falsifies the full flux branch for the target analysed. A much brighter line at 8.84 keV would also be a failure of this branch, because it would imply $\sin^2(2\theta) \gg 2 \times 10^{-14}$. Conversely, a line at the right energy with an inferred mixing near 10^{-14} would be a strong positive result.

If the $\kappa = 1$ premise is rejected, however, a non-detection only tightens the mixing upper bound. It does not by itself falsify the mass rule in Eq. (1) or the density rule in Eq. (5). This is the central discipline of the note: energy and abundance are fixed conditional targets; flux is a hard prediction inside a named service-normalised R4 branch.

5 Reproducibility

The combined line, density, mixing, decay-rate, and flux ledger is produced by

`python_code/sterile_xray_prediction_audit.py`.

It also cross-checks the existing item-118 and item-123 scripts:

- `python_code/item118_nuR_xray_line.py`;
- `python_code/item118_nuR_mixing_theorem.py`;
- `python_code/item118_nuR_mixing_collapse.py`;
- `python_code/item123_omega_dark_absolute_chain.py`.

The script exits zero only when the line energy, abundance, stability, and reference flux normalization all land in the expected ranges.

6 Conclusion

The sterile branch is a strong near-term target, but it is not yet identical in status to the w_0, w_a dark-energy prediction. Its line energy is a sharp function of a single input:

$$E_\gamma \simeq 8.84\,\mathrm{keV} \quad (\Lambda_{\mathrm{QCD}} = 0.332\,\mathrm{GeV}).$$

Its abundance is also now a strong conditional prediction:

$$\Omega_{\nu_R} h^2 = 0.02418, \qquad \Omega_{\mathrm{dark}} h^2 = 0.12089.$$

The flux becomes a single-number prediction inside the service-normalised one-denominator R4 branch. That branch gives

$$\sin^2(2\theta) = 2.1 \times 10^{-14},$$

so the framework predicts a faint line, not a bright one. A microscopic derivation with $\kappa \neq 1$ would rescale the flux by κ^2, not reopen an arbitrary active–sterile mixing matrix. That makes the branch falsifiable in a staged way: energy first, abundance second, and flux in the service-normalised R4 branch.

References

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