The neutrino window to new physics

Salvador Centelles Chuliá

IFIC Newcomers Fest
12/12/2012

Neutrino oscillations are BSM physics

- Oscillations **need** BSM physics: the simplest solution is to have **massive neutrinos**.
- Immediately opening more questions than answers:
  - What is the **mass mechanism**? Is there a **symmetry structure** to it? Is lepton number conserved or broken (by 2 units or more)? Spontaneously or explicitly?
  - Are neutrinos **Dirac or Majorana**?
  - Why is the mass scale so small (~ 0.05 eV) compared to the electroweak scale?
- We have **complementary probes** to address these questions:
  - Oscillation experiments
  - Low-energy processes (e.g. rare flavour-violating decays)
  - Cosmological and astrophysical observations
  - Collider searches

Some research avenues

- **Dirac Seesaws**: Lepton number broken in $\Delta L > 2$, leading to small Dirac neutrino masses 1606.04543, 1802.05722, 1804.03181
- **Scotogenic connection**: Dark matter stabilized by Diracness symmetry 1901.06402, 1907.08630

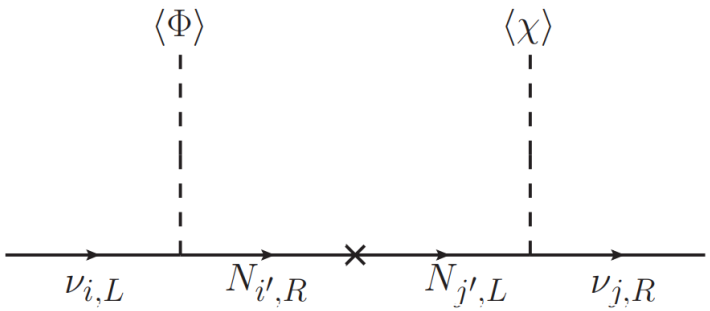
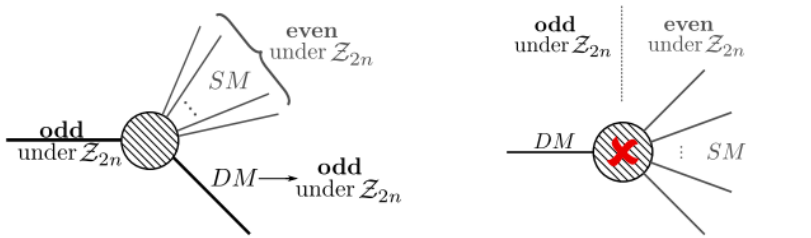


Figure 1. Dirac type-I seesaw mechanism.

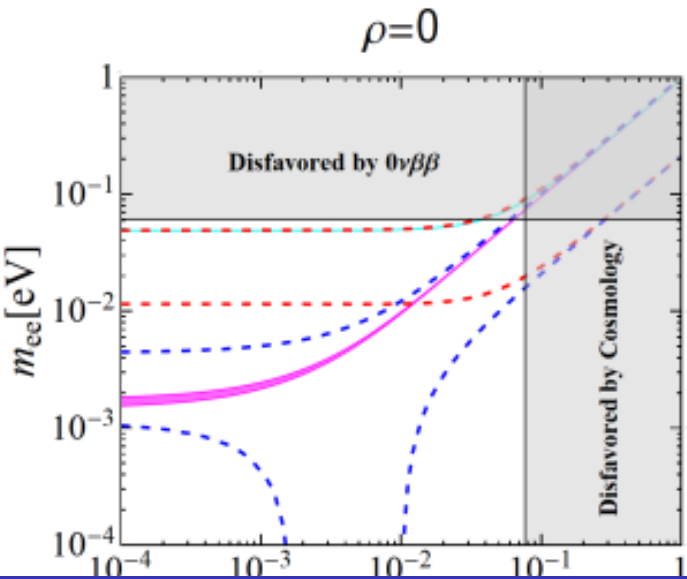


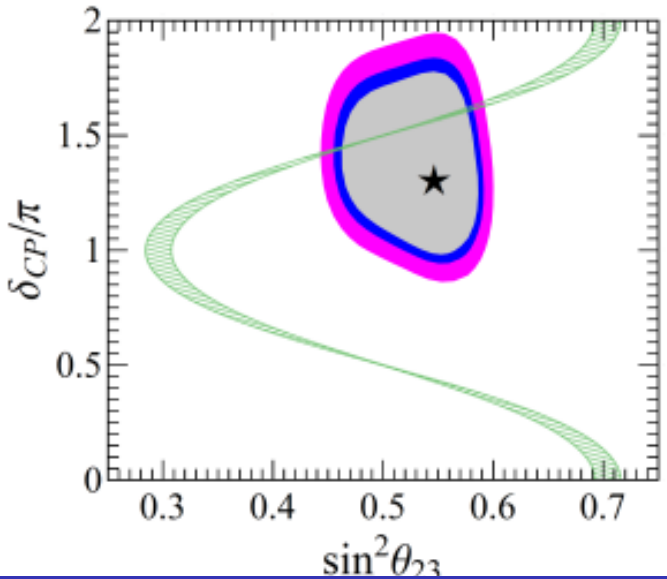
(a) The lightest of the odd fields under $\mathcal{Z}_{2n}$ will be the dark matter candidate.

(b) The decay of the dark matter to the Standard Model is forbidden by the residual symmetry.

Some research avenues

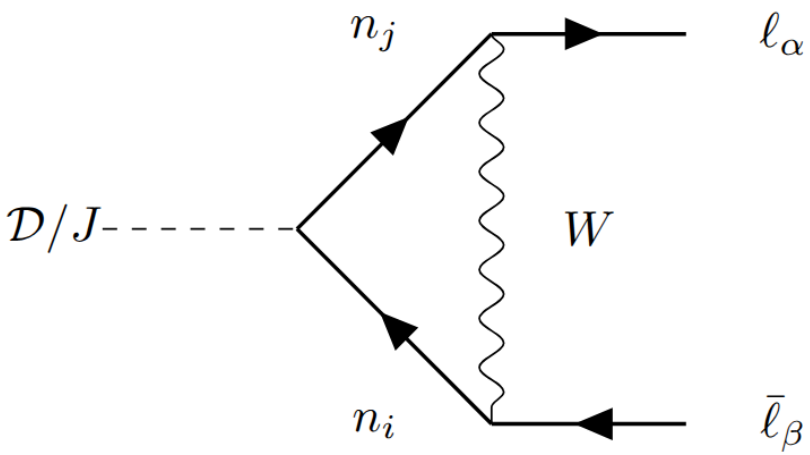
- **Flavour Symmetries**: Use non-abelian (modular or traditional) flavour symmetries to explain the structure of neutrino masses and mixings. Predictions for the absolute neutrino mass scale, mixing angles, charged lepton mass hierarchy, neutrinoless double beta decay, flavour decays... 1610.05962, 1706.00210, 1806.03367, 1911.06824, 1911.12043, 2204.12517 ...





Some research avenues

- **Goldstone-enhanced seesaws**: The pattern of lepton number breaking $U(1)$ symmetry can lead to enhanced interactions for the Goldstone bosons (Majoron or Diracon) 2404.15415, 2506.06449 and controls the phenomenology



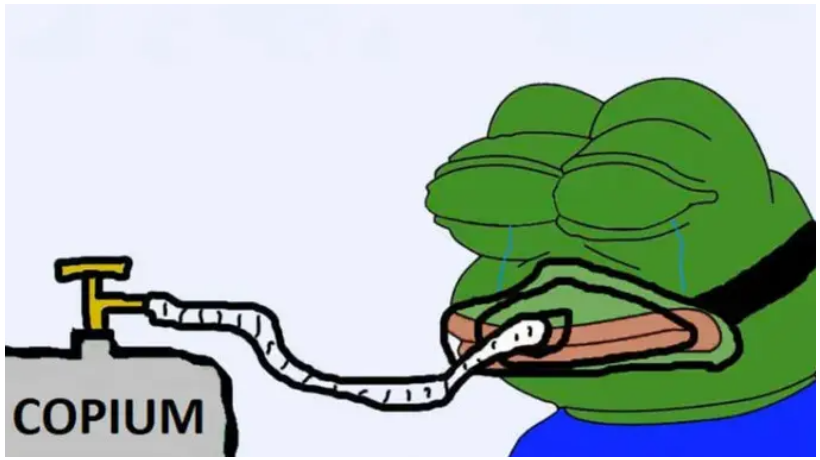
The $U(1)$ charges control the phenomenology!

Model	ν **nature**	cLFV	G-cLFV	ΔN_{eff}
Canonical IS	Majorana	🥇	❌	🥉
J-enhanced IS	Majorana	🥈	🥇	🥉
Canonical T-I DS	Dirac	🥈	❌	🥇
$\mathcal{D}$-enhanced T-I DS	Dirac	🥈	🥇	🥉

(IS = Inverse Seesaw, T-I DS = Type-I Dirac Seesaw, J = Majoron, $\mathcal{D}$ = Diracon)

Some research avenues

- **Gravity-assisted neutrino masses**: Gravity induced Planck-suppressed contributions to neutrino mass leading to a low scale seesaw with very rich phenomenology, to appear this month in arxiv.



Other directions

- Non-standard neutrino propagation 2402.00114, 2512.09027, overlooked possibilities in the phenomenology of the seesaw
- First order phase transition effect on large structure formation 2107.10283
- And more! Find me in office B-6-7. Happy to discuss these or other ideas at any time.
- Many of these projects have possible followups and **the bottleneck is manpower!**

See you around!