Dark Forces and Astrophysical Objects

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based on

arXiv:1303.7232, 1310.3826 [hep-ph] and work in progress

with Herbert K. Dreiner, Christoph Hanhart,
Jordi Isern and Lorenzo Ubaldi

Motivations: Dark forces with dark sectors

$$\mathscr{L} = \mathscr{L}_{\rm SM} + \mathscr{L}_{\rm D} + \mathscr{L}_{\rm SM\otimes D} \quad \text{where} \quad \mathscr{L}_{\rm SM\otimes D} = \frac{\varepsilon_{\rm SM}}{2} F^{\rm SM}_{\mu\nu} F^{\mu\nu}_{\rm D}$$

- Top-down considerations
  - SM extensions with extra (Higgsed) gauge groups
- Bottom-up considerations
  - (DM?) astrophysical anomalies (PAMELA, FERMI, AMS, etc.)
  - Muon anomalous magnetic moment
  - DM structure formation
- Expected parameters
  - ⇒ Small kinetic mixing $\varepsilon_{\rm SM} \sim 10^{-8} - 10^{-2}$
  - ⇒ Light dark photon $m_{A_{\rm D}} \sim 10^{-3} - 10^{0}$ GeV

Probe of dark forces with dark sectors ⇒ Intensity frontier

Astrophysical objects

- Low-energy high intensity objects
  - Temperatures between few tens of keV (WDs) to few tens of MeV (SN)
  - Density between $10^6\,\mathrm{g/cm^3}$ (WDs) to $10^{14}\,\mathrm{g/cm^3}$ (SN)

  $\Rightarrow$ Particularly suited for new light weakly-interacting particles
- Standard cooling processes
  - Photon and neutrino emissions

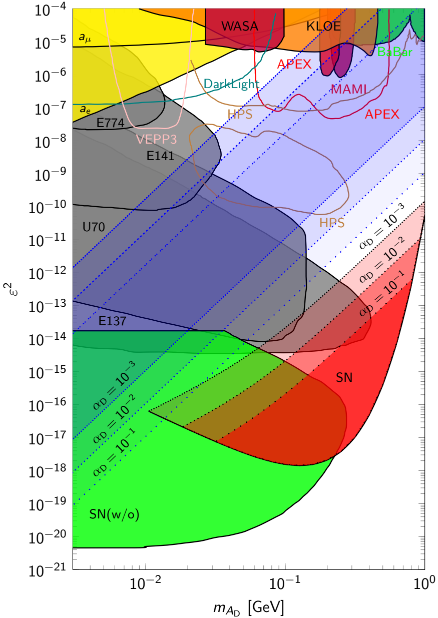
  $\Rightarrow$ Good (order of magnitude) agreement between theoretical models and observations
- Energy-loss argument for new light weakly-interacting particles
  - Extra energy losses altering standard cooling processes

  $\Rightarrow$ Competitive bounds on parameters

White dwarfs and supernovae

$$\mathscr{L}_{\mathrm{SM}\otimes\mathrm{D}} = \frac{\varepsilon}{2} F^{\mathrm{QED}}_{\mu\nu} F^{\mu\nu}_{\mathrm{D}} \to \mathscr{L}_{\mathrm{SM}\otimes\mathrm{D}} = -\varepsilon e J^{\mathrm{QED}}_{\mu} A^{\mu}_{\mathrm{D}}$$

- Competing effects
  - Large $\alpha_{\mathrm{D}}\varepsilon^2 \Rightarrow$ Large $\sigma_{\mathrm{SM}\to\mathrm{D}}$
  - Small $\alpha_{\mathrm{D}}\varepsilon^2 \Rightarrow$ Large λ_{D}
- White dwarfs $\Rightarrow E_{\mathrm{D}} \lesssim E_{\nu}$
  - keV dark sector particles
  - "Heavy" dark photon $\Rightarrow$ Four-fermion interactions
    $G_{\mathrm{D}} = 4\pi\varepsilon\sqrt{\alpha\alpha_{\mathrm{D}}}/m^2_{A_{\mathrm{D}}} \Rightarrow G_{\mathrm{F}} \lesssim G_{\mathrm{D}} \lesssim 400\,G_{\mathrm{F}}$ excluded
- Supernovae $\Rightarrow E_{\mathrm{D}} \lesssim \frac{1}{10} E_{\nu}$
  - MeV dark sector particles
  - "Light" dark photon



- Beam-dump experiments: E137, E141, E774 and U70
- $e^- e^+$ colliding experiments: BaBar and KLOE
- Fixed-target experiments: APEX, DarkLight, HPS, MAMI and VEPP-3
- Rare neutral pion decay measurements: WASA
- Anomalous magnetic moment measurements: a_e and a_μ
- Astrophysical constraints: SN(w/o), WD and SN

Interactions with nucleons

- One-pion-exchange approximation
  - Over-estimation of nucleon-nucleon interaction
  - $\Rightarrow$ Over-estimation of emissivity by factor 4
- Soft radiation approximation
  - Related to on-shell nucleon-nucleon amplitude
  - $\Rightarrow$ Model-independent data-based results

Thank you!