Large N Dark Matter

Chester Mantel

Work in progress with Graham Kribs

UNIVERSITY OF OREGON

PHENO 2022
indico.cern.ch/e/pheno22

Dark Matter Magnetic Moment

- Magnetic dipole provides strong probe on high mass DM
  - ↳ Lattice results found SU(3) DM to have $\mu_{DM} \sim \mu_n$
    Constrains $m_{DM} < 10$ TeV (2013, XENON100)
- Enhanced recoil energy spectrum
  - ↳ Used to constrain μ_{DM} as a function of mass

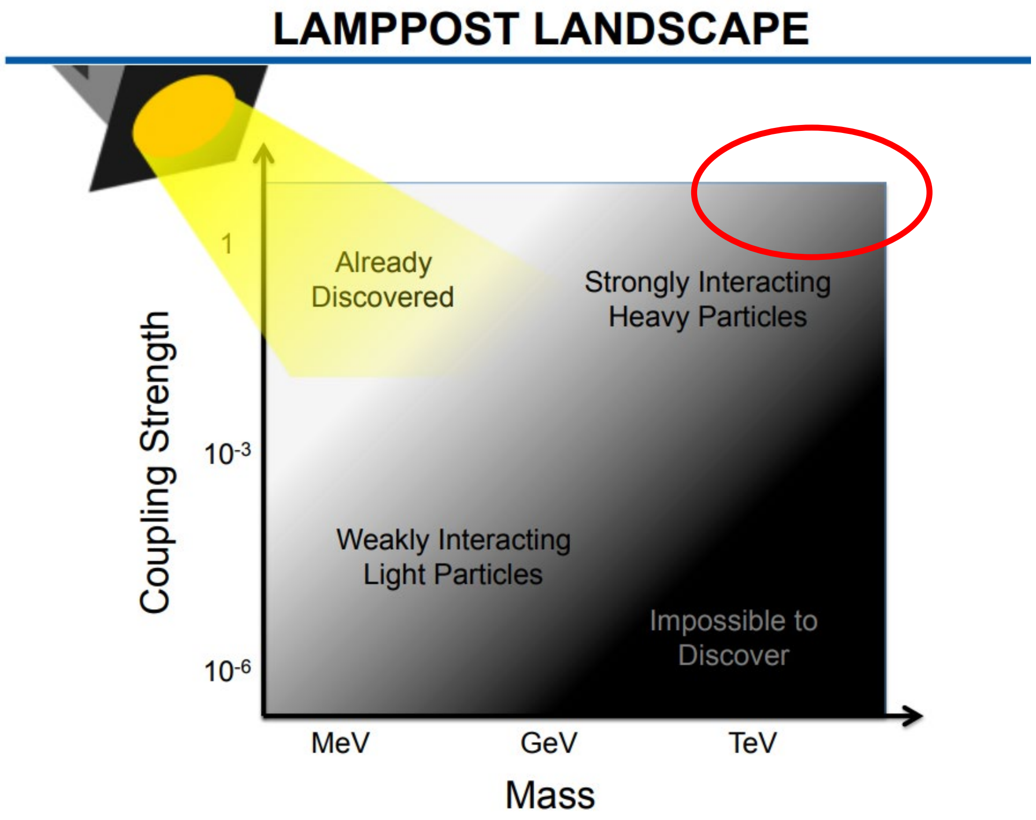
What can we get out of constraints on μ_{DM}?

Appelquist, et al. arXiv:hep-ph/1301.1693v2
Banks, et al. arXiv:hep-ph/1007.5515v1
Barger, et al. arXiv:hep-ph/1007.4345
Gresham, et al. arXiv:hep-ph/1401.3739v1

Composite Dark Matter

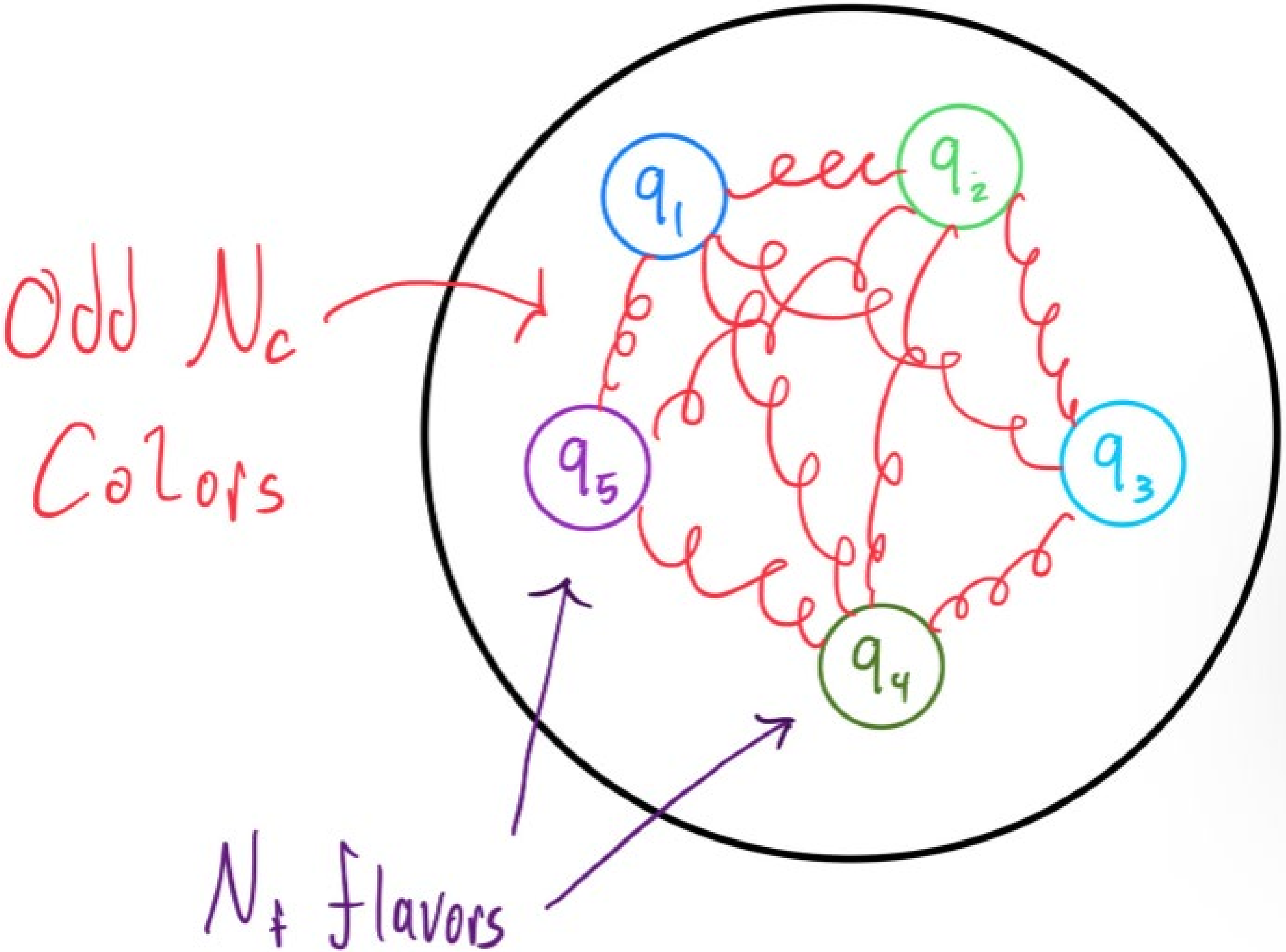
- Constraints of μ_{DM} → Heavy DM
  - ↳ Strongly coupled
- Dark quarks (duarks) confine
  - ↳ DM naturally stable

- Thermal relic → $U(1)_{EM}$ (for now)
- Dark hadrons (dadrons)
  - ↳ Neutral fermions with magnetic dipole moment



PHASER, *Phys. Rev. D* **97**, 035001 (2018)

Dadron → Wimp



How to Constrain N_c

Direct detection → m_{DM} lower bound

$1/N_c$ Expansion → N_c scaling of μ_{DM}

Cosmology → m_{DM} upper bound

How to Constrain N_c

Direct detection → m_{DM} lower bound

$1/N_c$ Expansion → N_c scaling of μ_{DM}

Cosmology → m_{DM} upper bound

What can be learned from direct detection?

Still much to be done!

Direct detection

$$\frac{\mathrm{d}\sigma_T}{\mathrm{d}E_\mathrm{R}} \overset{\mathrm{NR}}{=} \frac{1}{8\pi}\frac{m_T}{m_\mathrm{N}^2}\frac{1}{v^2}e^2\mu_\chi^2\left[\left(\frac{v^2}{E_\mathrm{R}} - \frac{m+2m_T}{2mm_T}\right)2\frac{m_\mathrm{N}^2}{m_T}F_M^{(p,p)}(q^2) + 4F_\Delta^{(p,p)}(q^2)\right.$$
$$\left. - 2\sum_N g_N F_{\Sigma'\Delta}^{(N,p)}(q^2) + \frac{1}{4}\sum_{N,N'} g_N g_{N'} F_{\Sigma'}^{(N,N')}(q^2)\right]$$

- Strongest constraints generally from xenon experiments (XENON1T, LUX)

del Nobile: arXiv:hep-ph/2104.12785v1

Toy Model

$$\delta\mathcal{L}_{\rm DM} = \overline{\psi}_i \left[i\gamma_\mu (D^\mu_{EM}) + i\gamma_\nu (D^\nu_{\rm DM})_{ij} - m\delta_{ij} \right] \psi_j - \frac{1}{4} (G_{\rm DM})^a_{\mu\nu} (G_{\rm DM})_a^{\mu\nu}$$

- ψ_i are duarks
- $i, j = 1, \ldots, N_c$
- $G_a^{\mu\nu}$ are dark gluons
- $a = 1, \ldots, N_c^2 - 1$
- Hold $N_f \sim N_c$ – Light degenerate masses
- Duarks charges: $q_{i,\ldots,N_f/3} = \frac{2}{N_c}$ $\quad q_{N_f/3+1,\ldots,N_f} = -\frac{1}{N_c}$

Large N_c

- $SU(N_c) \rightarrow 1/N_c$ Expansion

$$m_{\rm DM} \sim N_c \Lambda_{DM}$$

- Magnetic dipole scaling with N_c

$$\mu_{\rm DM}\sigma^j = -\frac{a_0 e}{m_{\rm DM}} \langle B|Q\sigma^j|B\rangle$$

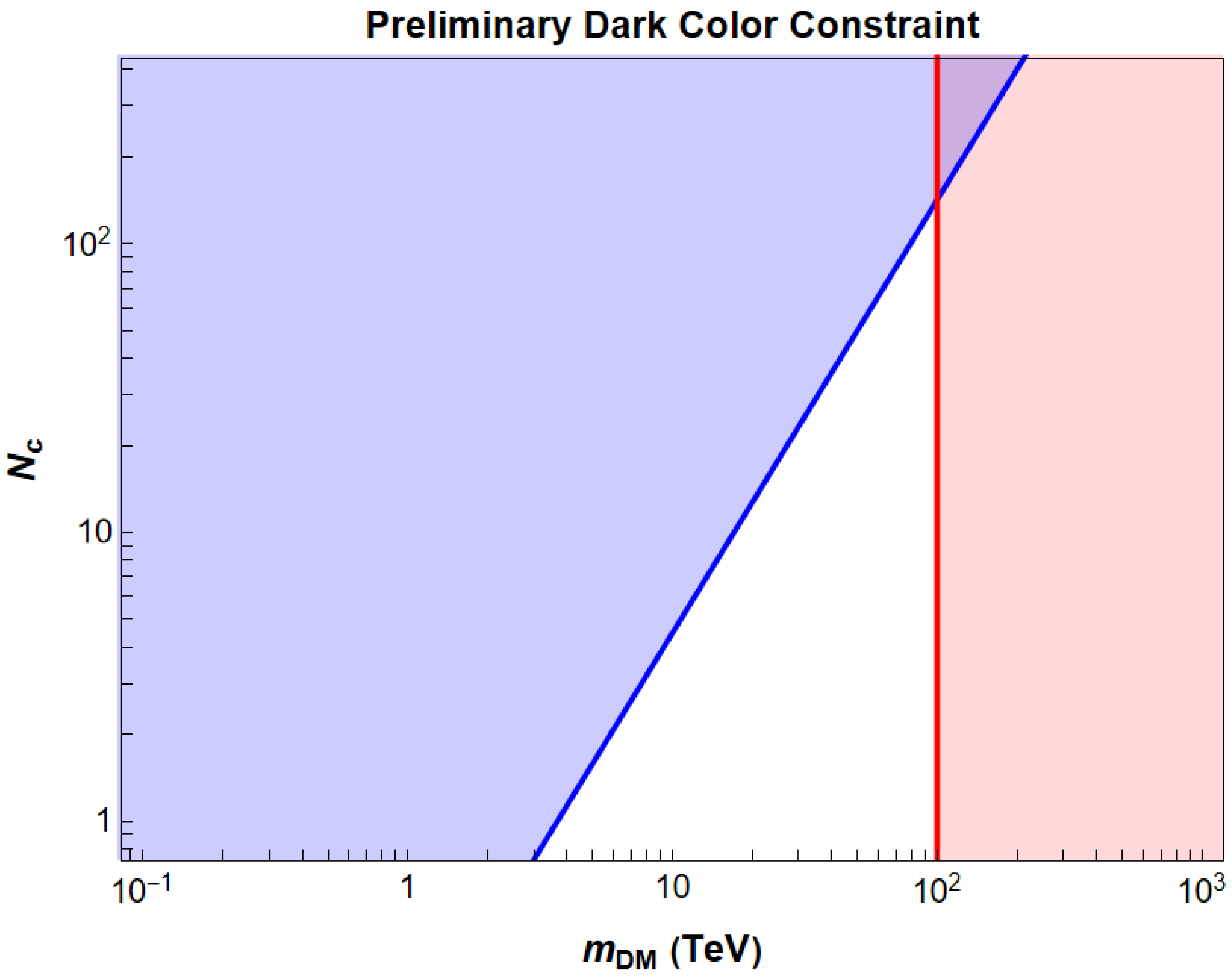
$$Q\sigma^j = \mathcal{O}(1)^*$$

- Interpret constraints on μ_{DM} as constraints on N_c

$$\mu_{\rm DM} = \mathcal{O}(N_c)$$

*Given $1/N_c$ normalization of duarks electric charge

Luty, March-Russell: arXiv:hep-ph/9405272



- Leading order in N_c
- Assuming $\Omega_{\text{dark baryon}} = \Omega_c$ and $\Lambda_{DM} < T_{\text{freeze out}}$
- $N_f \sim N_c$ light duarks with degenerate mass

Griest, Kamionkowski (1989)
XENON1T: arXiv:1207.5988v2

Ongoing investigations

1. Scaling
   1. More flavors → No confinement for $N_f >> N_c$
   2. Small charges → Smaller μ_{DM}
2. Light vs heavy duarks → Affects N_c scaling
3. Where is Λ_{DM} relative to $T \sim m_{DM}/25$?
4. $1/N_c$ corrections

Thank you!

Questions?

Acknowledgement:

Presidential Undergraduate Research Scholarships

UNIVERSITY OF OREGON | Office of the Vice President for Research and Innovation