Skyrmions in the Little Higgs Models: a new type of Dark Matter?

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(MG, A. von Manteuffel, P. Schwaller, D. Wyler, arXiv:1012.5288)

Outline

- What are Skyrmions?
- The Littlest Higgs Model
- Properties of the “Little Skyrmion”
- Can it account for the observed dark matter?
- Conclusions

Skyrmions are **topological solitons**

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Skyrmions are **topological solitons**

- classical static solution of the field equations
- finite size
- finite energy

$\Rightarrow$ they look exactly like **particles**

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- cannot be deformed into the vacuum by infinitesimal transformations

$\Rightarrow$ they are associated with a conserved topological quantity (**winding number**)

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Originally, they appear in the **Skyrme model**

(T.H.R. Skyrme, 1961)

$$\mathcal{L} = \frac{f_\pi^2}{4} \mathrm{Tr}\, \partial_\mu \Phi \partial^\mu \Phi^\dagger + \frac{1}{32e^2} \mathrm{Tr}\, \left| \left[\Phi^\dagger \partial_\mu \Phi, \Phi^\dagger \partial_\nu \Phi \right] \right|^2$$

where they describe baryons as bound states of mesons

(G.S. Adkins, C.R. Nappi, E. Witten, 1983)

In this case the topologically conserved quantity is the baryon number

$$-\frac{1}{24\pi^2} \epsilon_{ijk} \int d^3x\, \mathrm{Tr}\, (\Phi^\dagger \partial_i \Phi)(\Phi^\dagger \partial_j \Phi)(\Phi^\dagger \partial_k \Phi) \in \mathbb{Z}$$

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Little Higgs models:

(N. Arkani-Hamed, A.G. Cohen, H. Georgi, 2001)

- Higgs as a **Goldstone boson** of a spontaneously broken symmetry

  $\Rightarrow$ naturally lighter than the breaking scale

- Explicit **collective symmetry breaking**: at least 2 copies of the electroweak gauge group, breaking down to the diagonal subgroup

$$[SU(2) \times U(1)]^2 \to SU(2) \times U(1)$$

If any of the 2 gauge couplings is set to zero, there is no EW symmetry breaking

$$g = \frac{g_1 g_2}{\sqrt{g_1^2 + g_2^2}}$$

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The **Littlest** Higgs

(N. Arkani-Hamed, A.G. Cohen, E. Katz, A.E. Nelson, 2002)

Symmetry breaking pattern $SU(5) \to SO(5)$

$\Rightarrow$ 14 Goldstone bosons:
a scalar (the little Higgs), a complex triplet,
the other 7 are eaten by the gauge bosons

The low-energy theory is described by a **sigma-model** in terms of a SU(5) symmetric matrix Σ

$$\mathcal{L} = \frac{f^2}{4} \mathrm{Tr}\, D_\mu \Sigma D^\mu \Sigma^\dagger$$

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Higher derivative operators are naturally present, among them the Skyrme term

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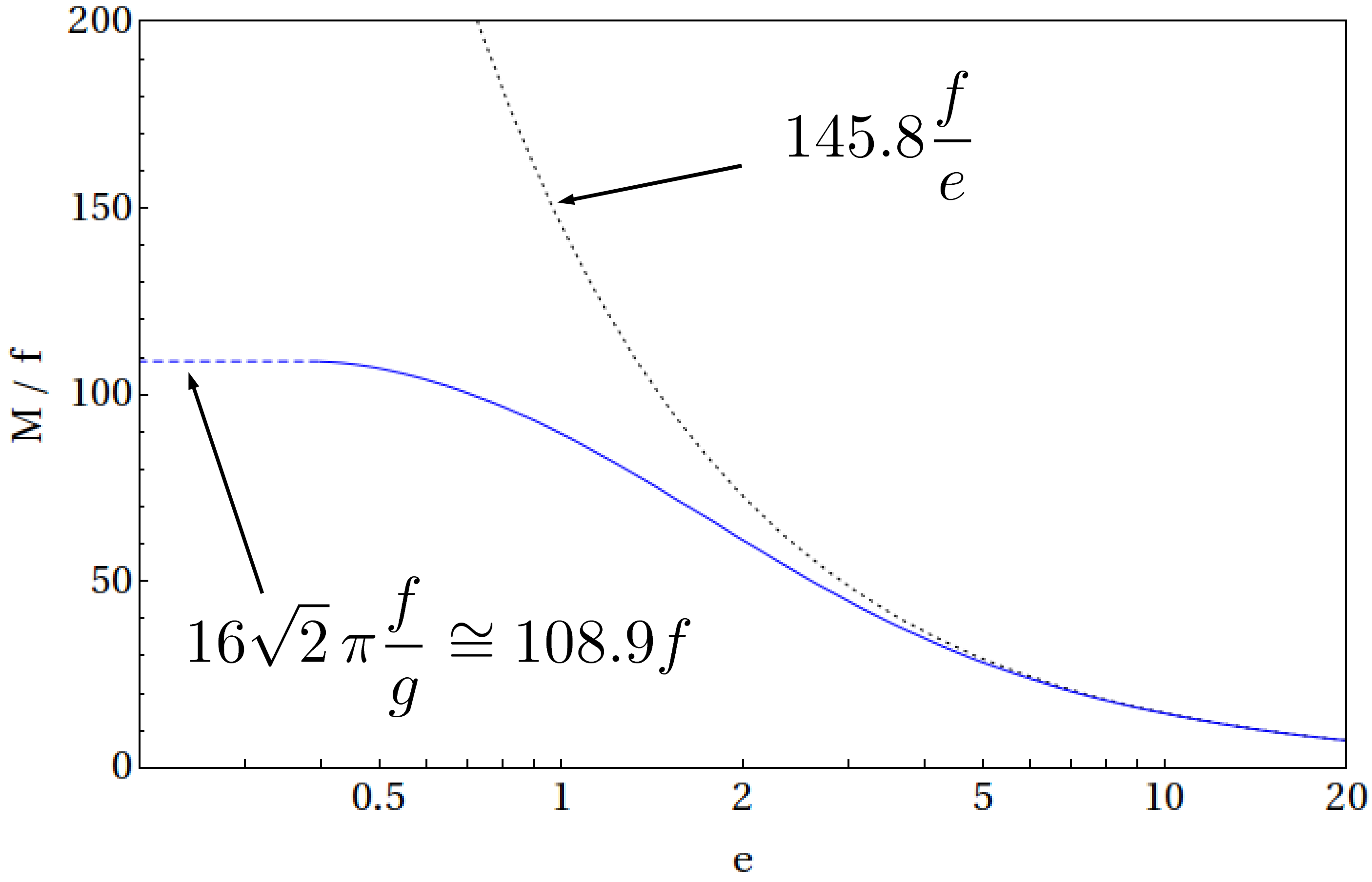
sym. breaking scale

Skyrme coupling

Mass:



Size:

$$\langle r^2 \rangle = \left(1.058\frac{1}{fe}\right)$$

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The little Skyrmion is:
- heavy
- stable (at least on cosmological timescales)

Can the dark matter be made of skyrmions?

Only if the skyrmion is
- interacting very weakly
- largely produced in the early universe

Problem: skyrmion production and annihilation are non-perturbative processes!

Naive cross-section estimate: $\sigma \sim \pi \langle r^2 \rangle$

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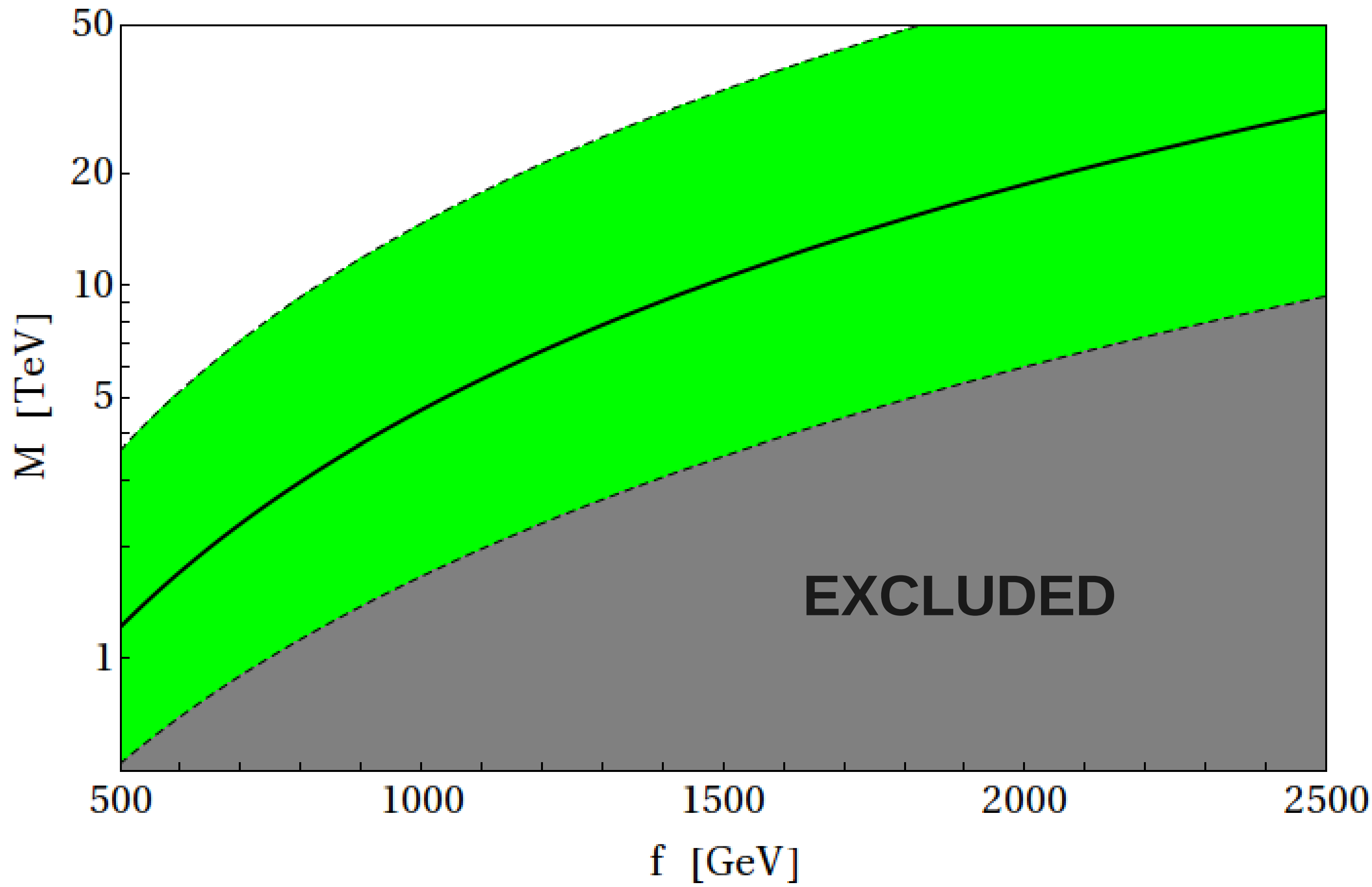
Computation of the relic density using microMEGAs

(Belanger, Boudjema, Brun, Pukhov, Rosier-Lees, Salati, Semenov, 2010)

(A. Belyaev, C.R. Chen, K. Tobe, C.P. Yuan, 2006)



Conclusions

- Skyrmions are present in little Higgs models
- They are heavy, but might interact only very little, hence are a **viable dark matter candidates**
- Still, computing the coupling of skyrmions to ordinary matter requires quantisation of the model (not an easy task)
- In general, topological objects appear in many other models, and their phenomenology should be studied

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