Connecting Mainstream Scenarios of Inflation and the MSSM

Daniel J. H. Chung
(University of Wisconsin – Madison)

Collaborators: Micha Berkooz (Weizmann Institute)
Tomer Volansky (Weizmann Institute)

Inflation is well motivated

- Natural paradigm from observational viewpt.
  - flat spatial section
  - scale invariant spectrum successful
- Slow-roll inflation may be ruled out through consistency condition [e.g. Sasaki, Stewart] (need B-mode measurement)
- An appealing way to solve the flatness problem
- No likely smoking gun yet: Need controlled experiment
- model building challenge: $N \sim 60$ $\frac{\delta\rho}{\rho} \sim 10^{-5}$ $n_s \sim 1$
- Wishful thinking: "part" of the inflaton is in the MSSM

since future colliders (such as LHC) may discover MSSM

Class of Models Considered

- want to connect MSSM with inflation +

need flat potential ⟶ involve flat direction of MSSM

For a comprehensive listing in MSSM, see [Kolda, Gherghetta, Martin '95]

e.g. $QQQL \to Q = Q = Q = L = \phi$

- flat direction lifted by (gravity med)

$$m_{3/2} \sim 1\ TeV \qquad U(\phi) = m_{3/2}^2 M_{pl}^2 U\left(\frac{|\phi|^2}{M_{pl}^2}, \frac{\phi^n}{M_{pl}^n}\right)$$

- flat direction field variation after the end of inflation is of order
  - Supergravity/string length scale M_{pl}
  - Enhanced symmetry point models

A Generic Situation

Starting point of our work [Berkooz, Chung, Volansky]:

ϕ is an MSSM flat direction (only one direc. on)

consequence: typically carries $U(1)_{B-L}, U(1)_{B+L}$

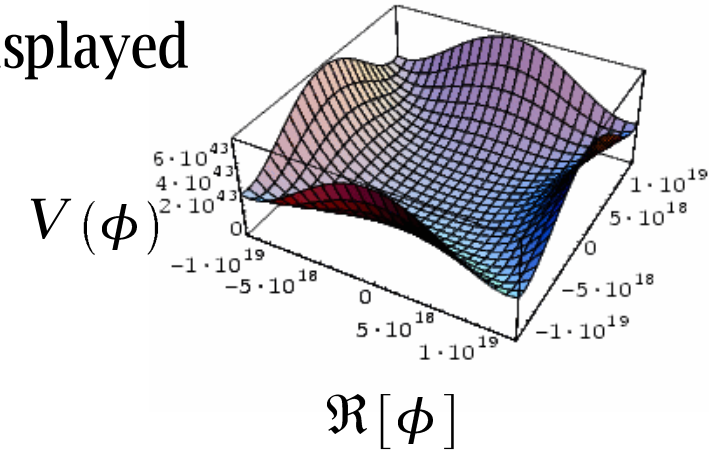
$$V(\phi) = m_\phi^2 |\phi|^2 \left(1 + K \ln\left[\frac{|\phi|^2}{M^2}\right]\right) + P(\phi, \overline{\phi})$$

computed in MSSM

$P(\phi, \overline{\phi})$ ← Generically U(1) violating

e.g. $\left(\frac{m_{3/2}}{M_{pl}}\right)^2 (\phi^4 + \overline{\phi^4})$

Note: bothreal and imaginary parts displayed



What is a Q-ball?

- Nontopological, time dependent soliton solution [Coleman; T.D. Lee; Rosen]
- source of quasi-stability:
  - almost conserved angular momentum in the U(1) direction
  - interaction is such that E/Q < m; $Min[U''(\phi_0)/\phi_0^2] \rightarrow \phi_0 \neq 0$
- Example: [Enqvist, Mcdonald]

$$V(|\phi|) = m_\phi^2 |\phi|^2 (1 + K \ln[\frac{|\phi|^2}{M^2}]) \qquad K < 0$$

$$\phi(t, r) = \phi_0 e^{-r^2/R^2} e^{i w t}$$

Large vev init cond = large charge!

$$R = \frac{\sqrt{2}}{m_\phi \sqrt{-K}} \qquad Q = \frac{\phi_0^2 \pi^{3/2}}{|K|^{3/2} m_\phi^2} \{1 - K(1 - \frac{1}{2} \ln[\frac{\phi_0^2}{M^2}])\}$$

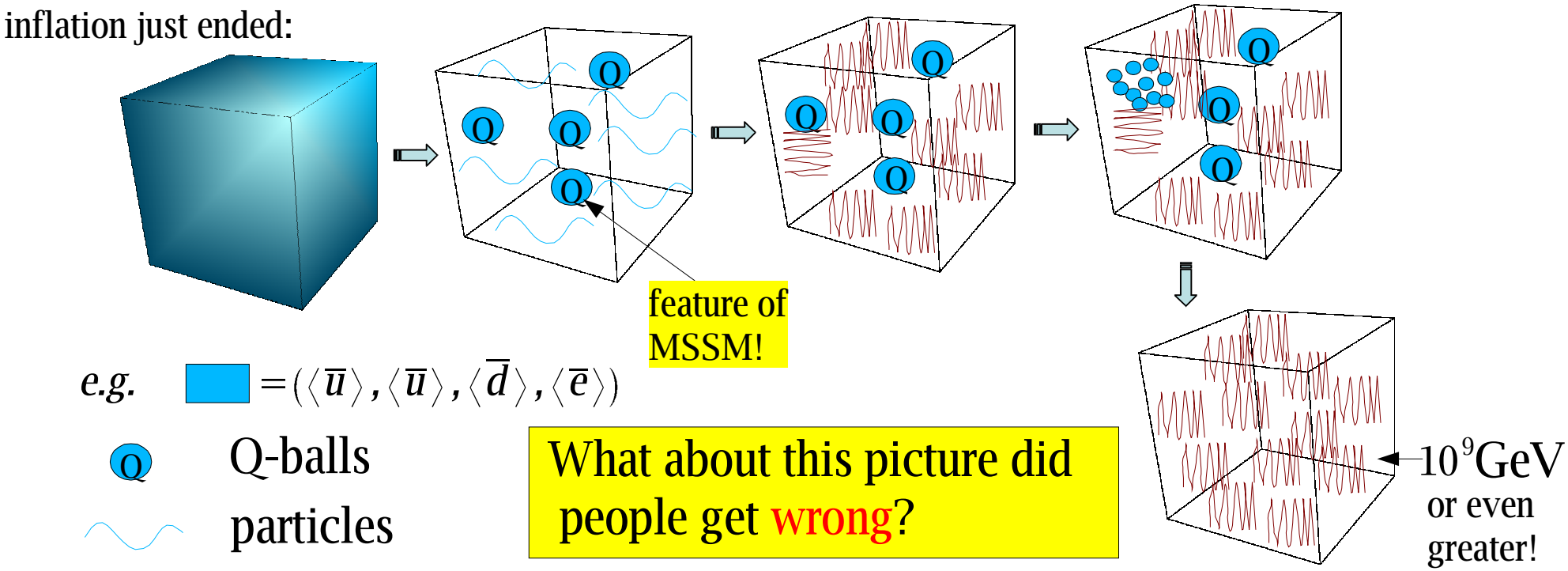
(subtlety comparing with free particle since RGE needs to be accounted)

Unique MSSM inflaton?

(hep-ph/0507218, hep-ph/0510186 [accepted to PRL])

For inflation to be compelling: need connection with colliders.

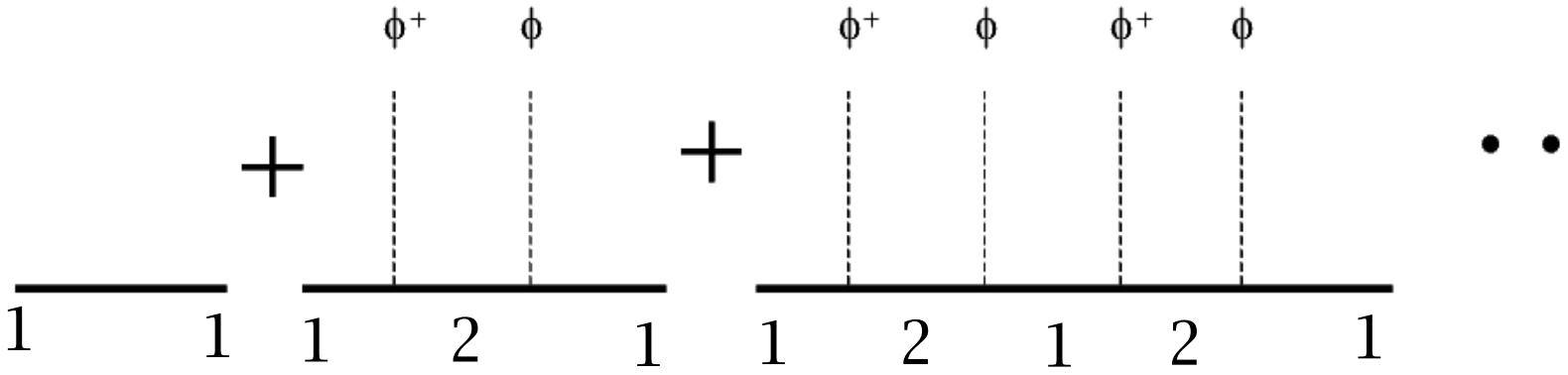
Testable current picture of physics beyond the Standard Model:
MSSM embedded into a perturbative string theory/supergravity framework



Finite density mass

- Q-ball charge is large → the density of particles between the Q-balls is also large!

e.g. $L_I = -g\,\phi\,\overline{\psi_1}\,\psi_2$ ← particles between the Q-balls



$$\delta m_{\psi_{1,2}} \approx \sqrt{g^2 \langle \phi^+ \phi \rangle} \sim g\,\phi_0 \left(\frac{a_i}{a}\right)^{3/2} \sim g\,O(M_{pl})\left(\frac{a_i}{a}\right)^{3/2} \gg m_\phi \sim m_{3/2}$$

Hence, $\phi \to \psi_1 \psi_2$ is suppressed (nearly forbidden, "kinematically")!
Similar result applies to bosons.

- Can show $\delta m_\phi < O(m_{3/2})$ corr. due to SUSY

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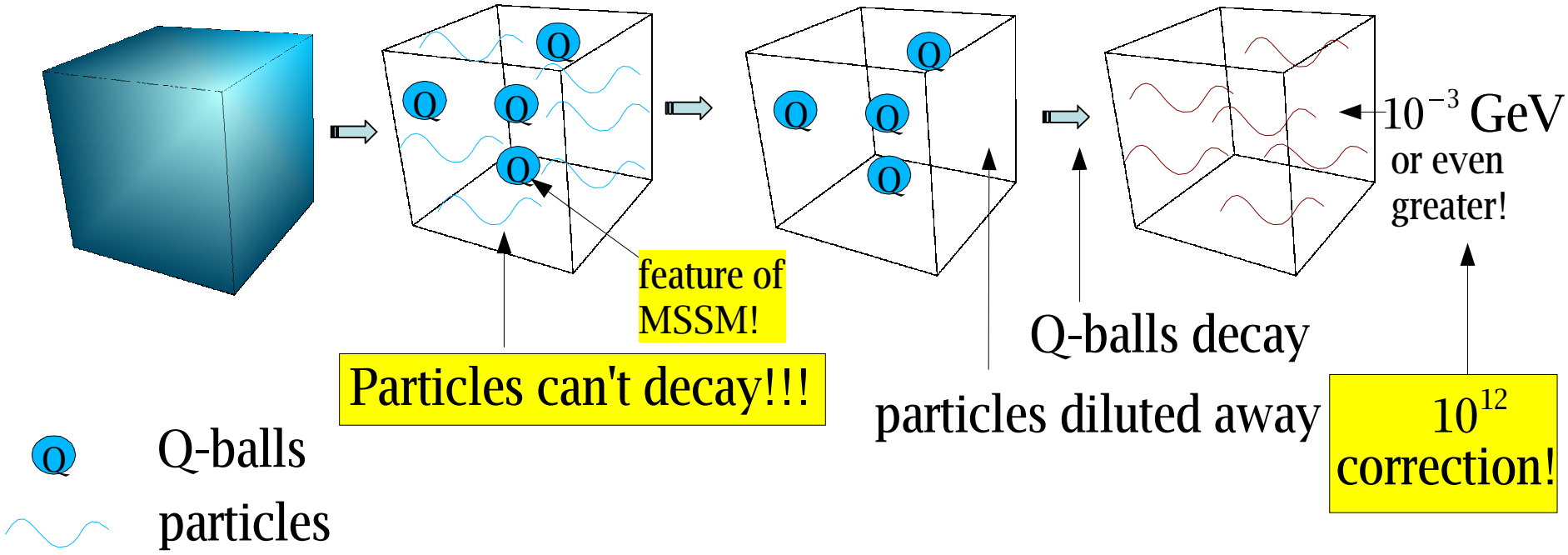

Consequences

- Since $T_{RH} < 10^{-3}\,GeV$ ruins BBN!

usual: inflation + MD -> RD (BBN) -> MD -> today
consequence of new Q-ball decay dynamics:

1) bad: inflation + MD -> RD (gas decay) -> MD (BBN?) ->
RD (Q-giant decay) -> MD -> today

2) bad: inflation+MD -> RD (gas decay) -> thermal inflation + MD ->
RD (BBN?) -> MD -> RD (Q-ball decay) -> MD -> today

Thermal inflation here requires significant engineering!

Conclusion

- If after inflation ends, a MSSM flat direction must roll a field length of order M_{pl}, the only likely viable flat direction is $H_u H_d$ because of large charge Q-ball leading to too low reheating temperature.
- Dissociating plasma temperature after Q-ball formation can be orders of magnitude lower than the current literature values if one properly accounts for the finite density mass corrections.

→ An effect that changes the reheat temperature by 10^{12}.