Opening the window to the co-genesis with Affleck-Dine mechanism in gravity mediation

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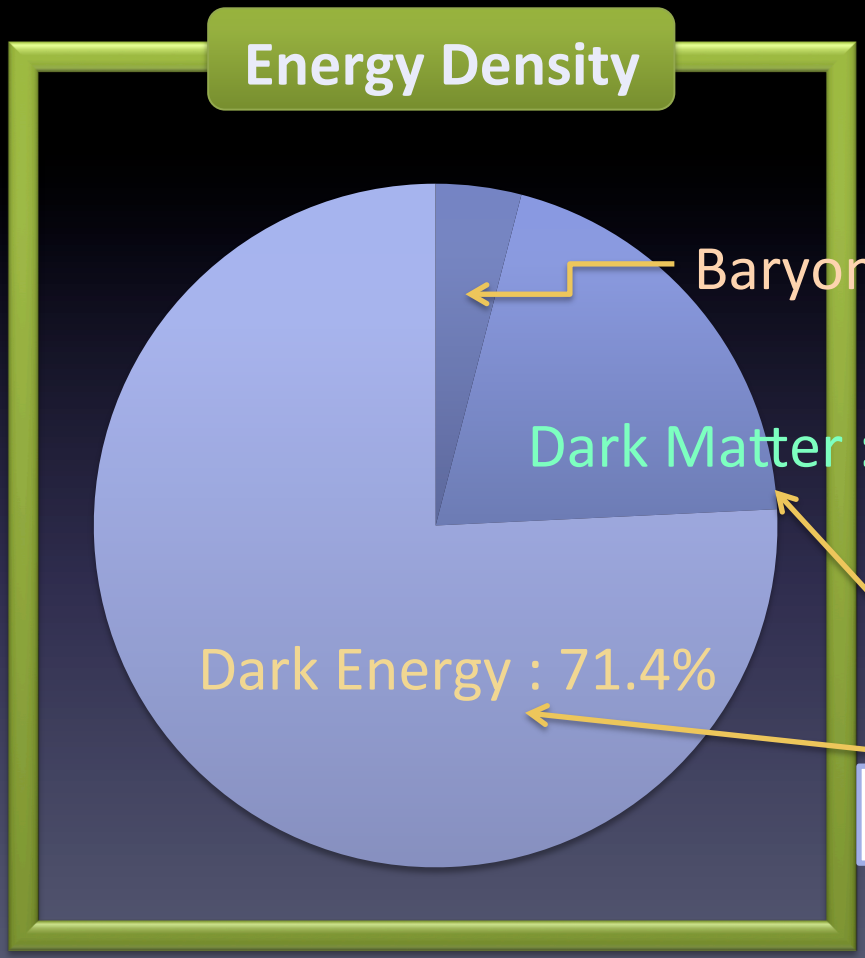
Cosmological Problems



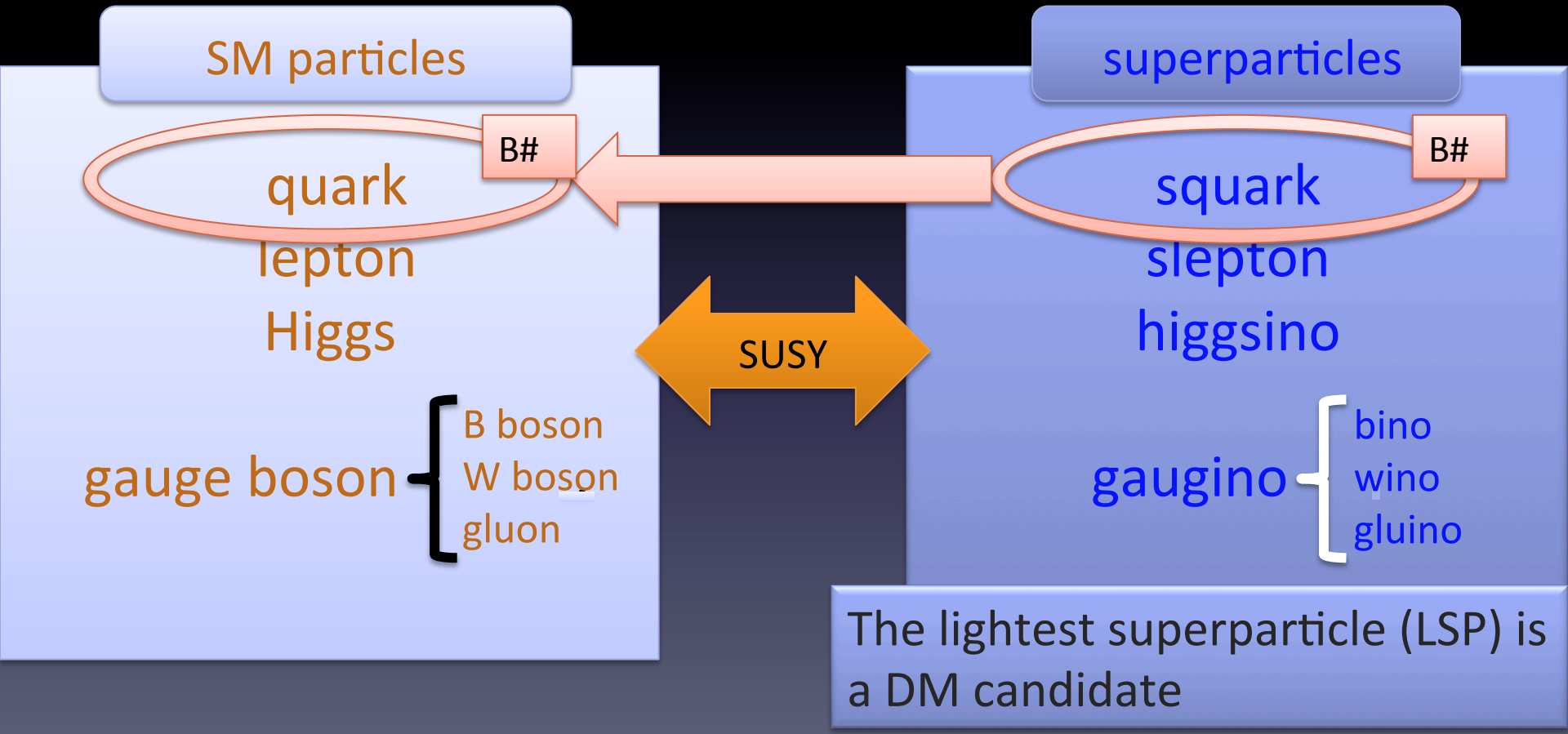
Deficiencies of the Standard Model

WMAP9 (2012)

Beyond the SM
→ Supersymmetry (SUSY)

New symmetry that relates bosons and fermions

← Solution of the hierarchy problem, GUT…



Affleck-Dine baryogenesis

Affleck, Dine, Nucl. Phys. B 249 (1985) 361.
Dine, Randall, Thomas, Nucl. Phys. B 458 (1996) 291.

SUSY

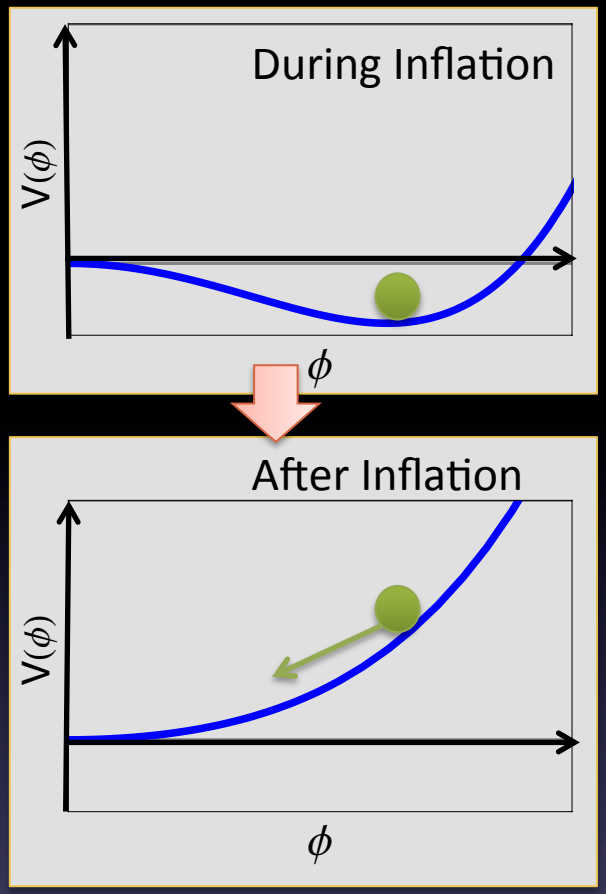
Many Flat Directions
(scalar fields with a shallow potential)

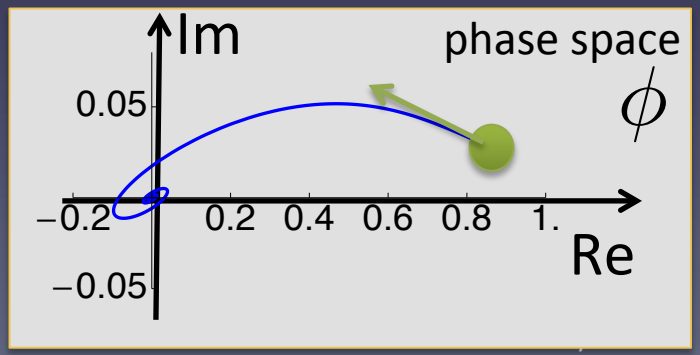
ex) $\tilde{\bar{u}}_1^R = \frac{1}{\sqrt{3}}\phi \qquad \tilde{\bar{d}}_1^G = \frac{1}{\sqrt{3}}\phi \qquad \tilde{\bar{d}}_2^B = \frac{1}{\sqrt{3}}\phi$

Squarks → with B#

- During Inflation, acquire large VEVs
- After Inflation, rotate in phase space

(= generate B#) $\boxed{B = \int \mathrm{d}V \mathrm{Im}\left(\phi \partial_0 \phi^*\right)}$





Q ball

Coleman, Nucl. Phys. B262 (1985) 263.

AD baryogenesis → Coherent oscillation with B#

↳ spatially unstable

⇒ fragment into non-topological solitons

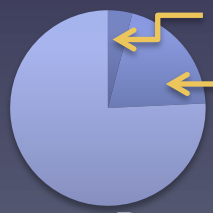
: Q-balls (with B#)

Eventually (before the BBN),

Q-balls decay into { quarks (→ Baryon)
superparticles (→ DM)

Baryon and DM have the same origin

→ naturally explain

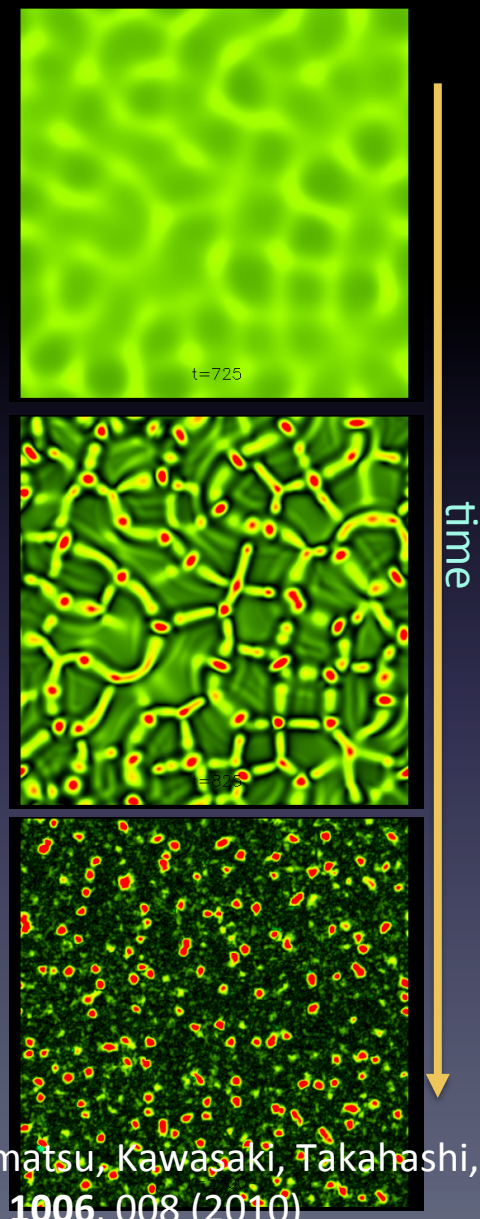


Baryons : 4.6%

DM : 24%

$$\frac{1}{5} = \mathcal{O}(1)$$

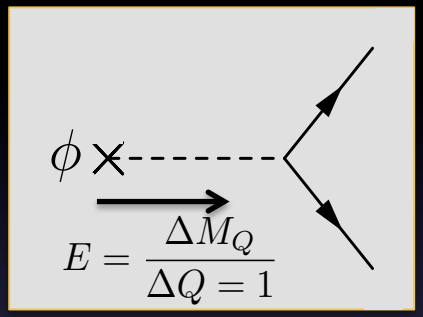
Energy Density



Hiramatsu, Kawasaki, Takahashi,
JCAP **1006**, 008 (2010)

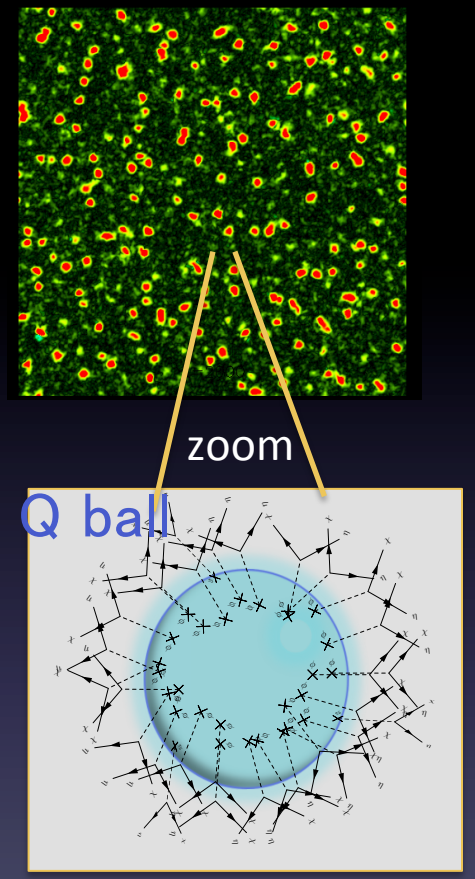
Q-ball decay rates

Basically, Q-ball decay can be regarded as



$\times Q$

(B# carried by the Q ball)



However,
fermion production rates are
determined by the Pauli exclusion principle
(= phase space volume per unit time)

$$\frac{\mathrm{d}N}{\mathrm{d}t} \simeq 4\pi R^2 \times \frac{E^3}{96\pi^2}$$

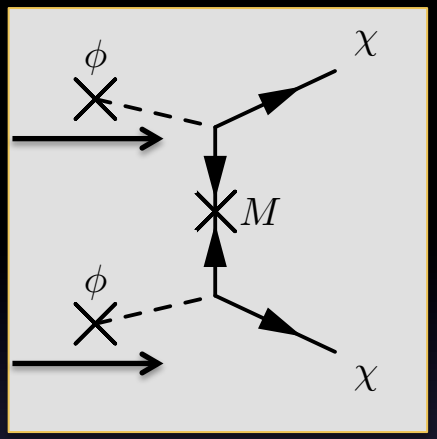
= gaugino production rate

(In massless limit)

Cohen, *et. al*, Nucl. Phys. B **272**, 301 (1986)

Q ball decay rates into quarks

Decay into quarks via gluino exchange



- $E = 2 \times \dfrac{\Delta M_Q}{\Delta Q = 1}$

  → × 8 for quark production rate

- color, flavor, Left-Right handed

  → × n_q (possible degrees of freedom of quarks) for total quark production rate

max $\boxed{n_q = 3 \times 2 \times 6 \times \dfrac{3}{4} = 27}$

color, LR, flavor, neutrality

Kawasaki and M.Y.
Phys. Rev. D **87**, (2013) 023517

Baryon and DM co-genesis

in gravity mediation

Kamada, Kawasaki and M.Y., Phys. Lett. B **719** (2013) 9

Set up:

wino LSP

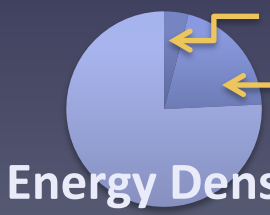
udd flat direction Q-ball

- Q-ball can not decay into
  - winos and sleptons (no interaction)
  - squarks (which constitute Q-balls)
  - higgsinos and gluinos (heavy (assumption))

decay

quarks (→ Baryon) : bino (→ wino DM)

$8 \times n_q \leqq 8 \times 27$: $n_{susy} = 1$ (In massless limit)



$\frac{1}{5}$

$$m_{\tilde{w}} \leq 360 \text{ GeV}$$

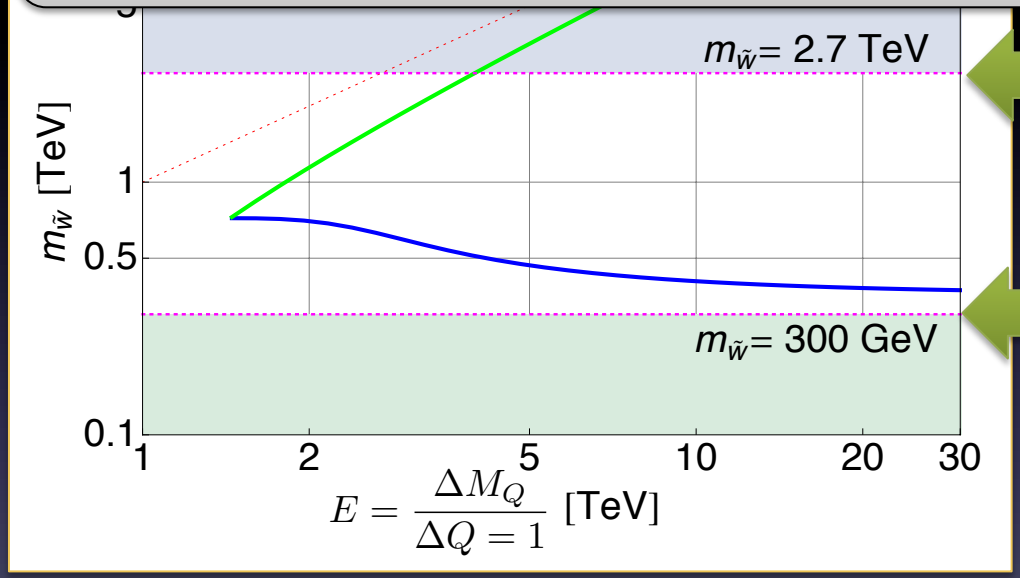
(If no DM annihilation)

Baryon and DM co-genesis

in gravity mediation

When we take into account bino mass,

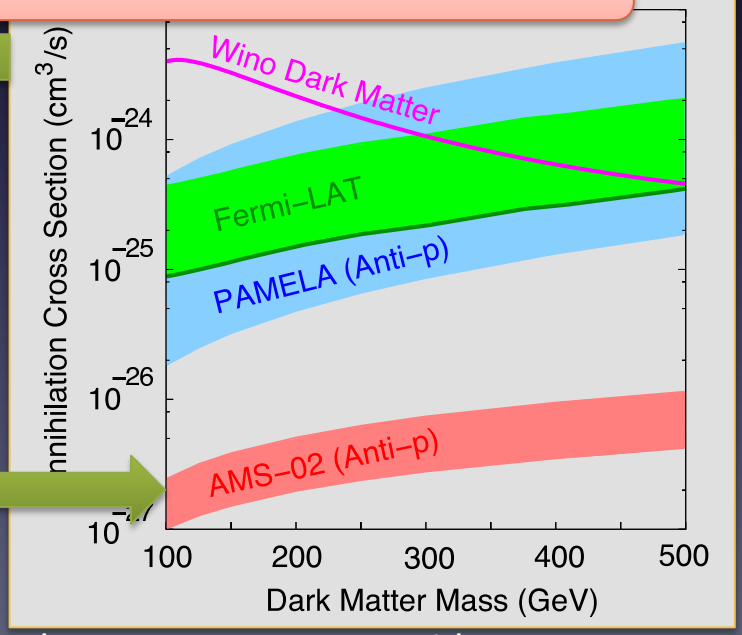
$$m_{\tilde{w}} = 400 - 600 \text{ GeV}$$



Kamada, Kawasaki and M.Y., Phys. Lett. B **719** (2013) 9

DM density = thermal relic density of the wino

Constraints on wino LSP

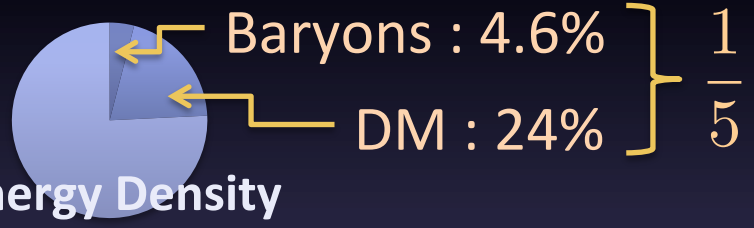


Ibe, Matsumoto, Yanagida
Phys. Rev. D **85** (2012) 095011

Future sensitivity
→ 400-600 GeV will be fully tested by AMS-02

Conclusion

- Gravity mediation with wino LSP
- Consider "udd" flat direction Q-ball



$$\frac{1}{5} \Leftrightarrow m_{\tilde{w}} = 400 - 600 \ \mathrm{GeV}$$

This will be fully tested by AMS-02

Assumption

no DM annihilation

→ Q-ball must decay lately (after DM freeze out)

→ Charge of Q-balls need to be very large

→ B# is produced too much

→ B# have to be diluted

Kamada, Kawasaki and M.Y., Phys. Lett. B **719** (2013) 9