Why Do I Believe IN SUSY More Strongly Than Before The LHC ?

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Kavli IPMU July in 2012

ATLAS and CMS Experiments at the LHC Showed :

No Evidence for SUSY-particle production

Strong Indication for the SM Higgs Boson of mass ~125 GeV

The SUSY Standard Model Predicts the Higgs Boson Mass

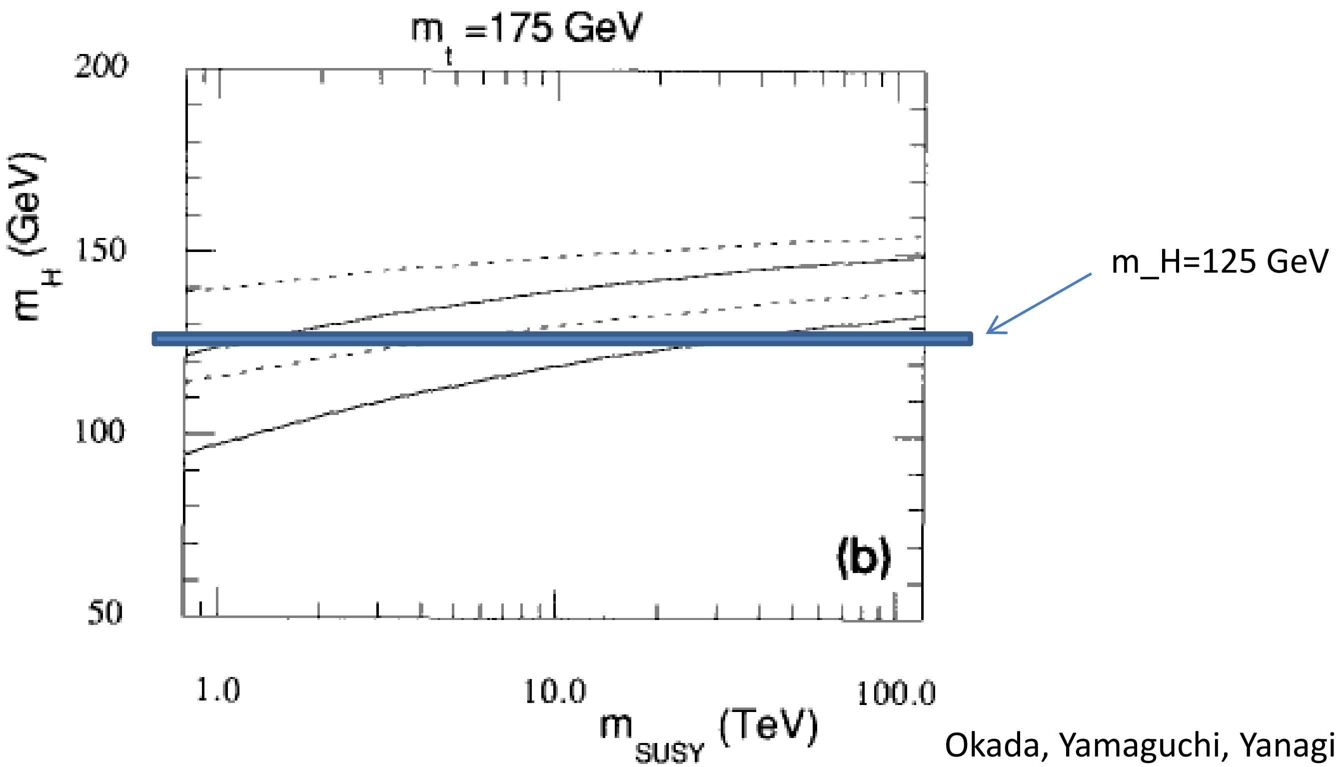
$m_H < m_Z = 91$ GeV

at the classical level

Why Do I Believe in the SUSY SM ?

Higher order corrections to m_H are non-negligible

Okada, Yamaguchi, Yanagida (1990)
Ellis et al (1990)
Haber et al (1990)



Okada, Yamaguchi, Yanagida (1990)

125 GeV Higgs ⟹ m_SUSY > O(10) TeV !!!

A large SUSY breaking scale > O(10) TeV has already been considered

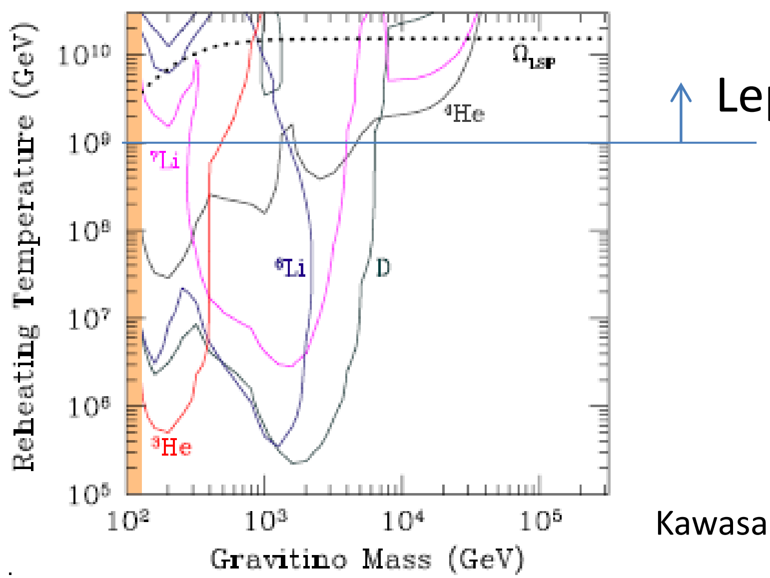
I. Gravitino over-production problem
II. Polonyi (Moduli) problem
III. Flavor-changing neutral current problem
IV. CP-violation problem
V. Proton decay problem

Solutions to all problems suggest

→ m_SUSY=m_sfermions = O(m_3/2) > O(10) TeV !!!

I. Gravitino over-production problem

The gravitinos are produced by particle scattering in thermal bath in the early universe. They decay after the BBN. Not to disturb the BBN we have constraints on T_R and m_3/2.



Leptogenesis

Fukugita, Yanagida (1986)

Kawasaki, Moroi, Yotsuyanagi (2008)

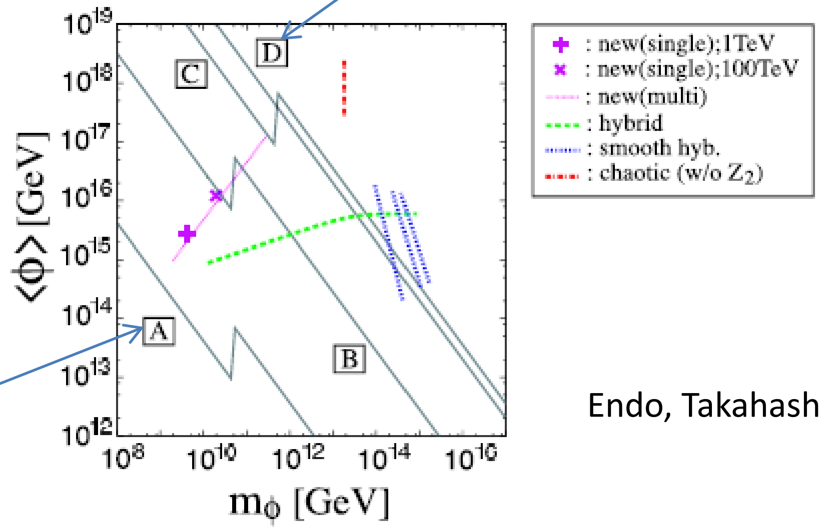
The Leptogenesis predicts m_3/2 >O(10)TeV !!

Even if T_R << 10^{9} GeV, we have a gravitino overproduction problem

Too many gravitinos are produced by inflaton decays

Kawasaki, Takahashi, Yanagida (2006)

m_3/2=100 TeV



m_3/2=1 TeV

Endo, Takahashi, Yanagida (2007)

m_3/2 > O(10) TeV is required

II. Cosmological Polonyi (Moduli) problem

Gravity mediation SUSY breaking model assumes a Polonyi field Z
to give masses for gauginos and Higgsino

The Z has a SUSY-breaking F term;

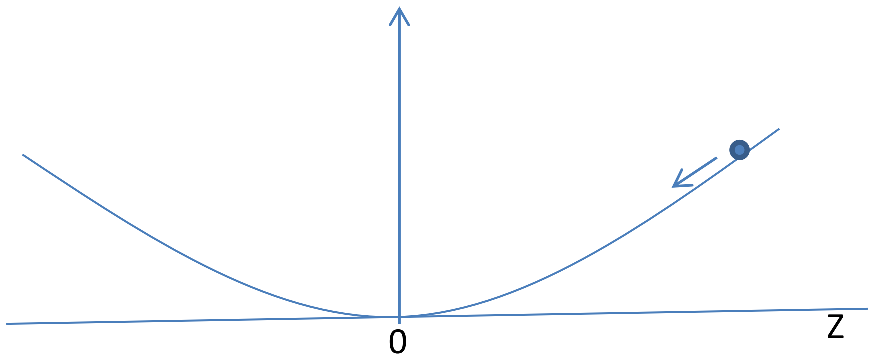
Then, ZWW ; Z^dagger H_uH_d

give the gaugino masses and the Higgsino mass

The Polonyi field Z is completely neutral
and has a mass of O(m_3/2)

During inflation the Z sits nearly at the Planck scale, Z=O(M_PL)
After the inflation the expansion rate of the universe decreases and becomes smaller than the Polonyi mass m_Z

Then, the Z starts its coherent oscillation which dominates quickly the universe's energy density



The Z decays after the BBB if m_Z=O(1) TeV destroying the light elements

For the successful BBN we should require m_Z > 100 TeV

⟹ m_3/2 > O(10) TeV !!!

Even for $m_Z=100$ TeV we have a serious problem

The decay temperature is $T_d = O(10)$ MeV and hence there is no BBN problem

But, the decay produces a huge entropy and the baryon asymmetry is diluted by a factor $T_d/T_R = O(10^{-11})$

The observed baryon asymmetry is
$n_B/s = 10^{-10}$

Can we take out the Polonyi field Z ?

→ Yes !!!

The minimal Gravity Mediation of SUSY breaking needs the Z field since it is very important

The gaugino masses and the Higgsino mass are given by the interactions with the Polonyi field Z

But, two important observations were known already

I. The Higgsino mass can be generated by the supergravity effects without the Polonyi field

Inoue, Kawasaki, Yamaguchi, Yanagida (1992)

II. The gaugino masses can be generated by quantum corrections without the Polonyi field in supergravity

Murayama et al (1998)
Randall, Sundrum (1999)

$$
\begin{aligned}
m_{\rm bino} &\simeq 10^{-2} m_{3/2}\,, \\
m_{\rm wino} &\simeq 3 \times 10^{-3} m_{3/2}\,, \\
m_{\rm gluino} &\simeq (2-3) \times 10^{-2}\, m_{3/2}\,.
\end{aligned}
$$

The LHC bound, m_{gluino} > 900 GeV

→ m_3/2 = 20-30 TeV

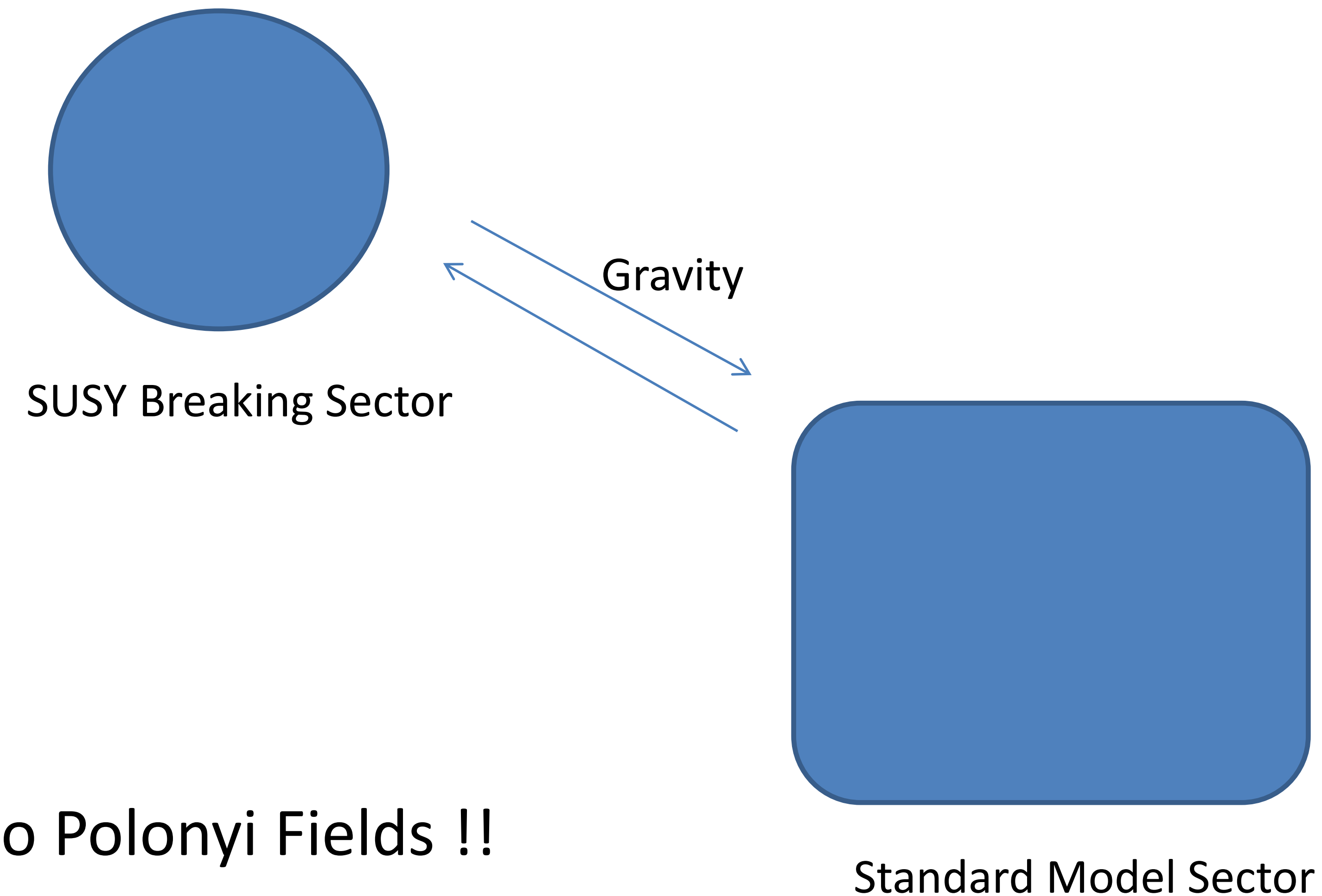
Motivated by the LHC indication of the Higgs boson mass about 125 GeV we have proposed a conjecture on the SUSY breaking mediation

Ibe, Yanagida (2011)
Ibe, Matsumoto, Yanagida (2012)

Pure Gravity Mediation

At Kavli IPMU

Pure Gravity Mediation



No Polonyi Fields !!

Gravity mediation of SUSY breaking at the tree level :

m_squraks =m_sleptons = O(m_3/2)

m_Higgsino = O(m_3/2)

The gaugino masses are generated at the one-loop level :

m_gluino = 0.03 m_3/2

m_bino = 0.01 m_3/2

m_wino = 0.003 m_3/2 + ……… < m_bino

The wino is the dark matter

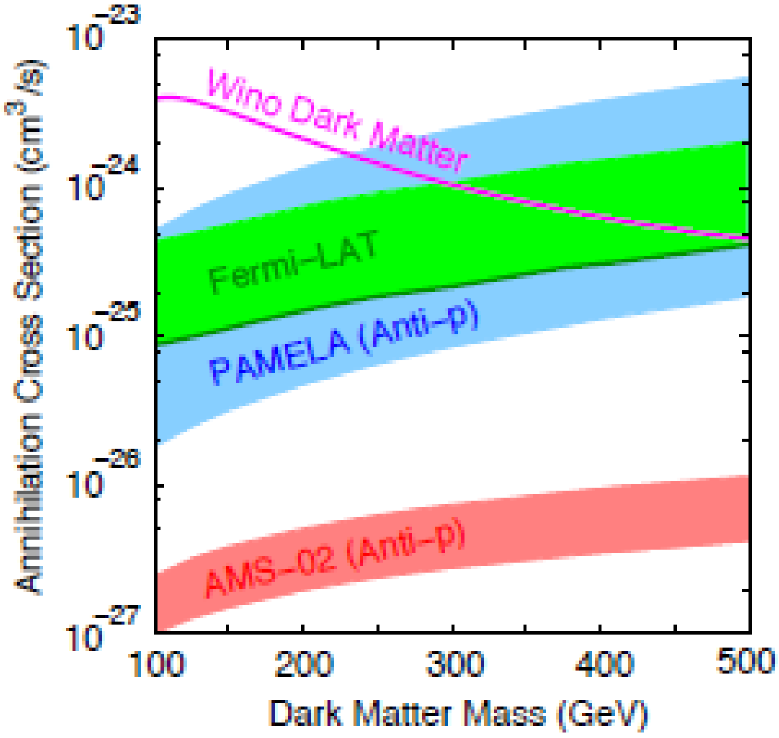
The pair annihilation cross section is too large
and hence thermal wino can not be the DM

The DM wino may be produced by the gravitino decay and
its abundance is determined by the reheating temperature T_R

Using the lower bound for the Leptogenesis $T_R > 10^{9}$ GeV,
we predict $m_{wino} < 1$ TeV to explain the DM density

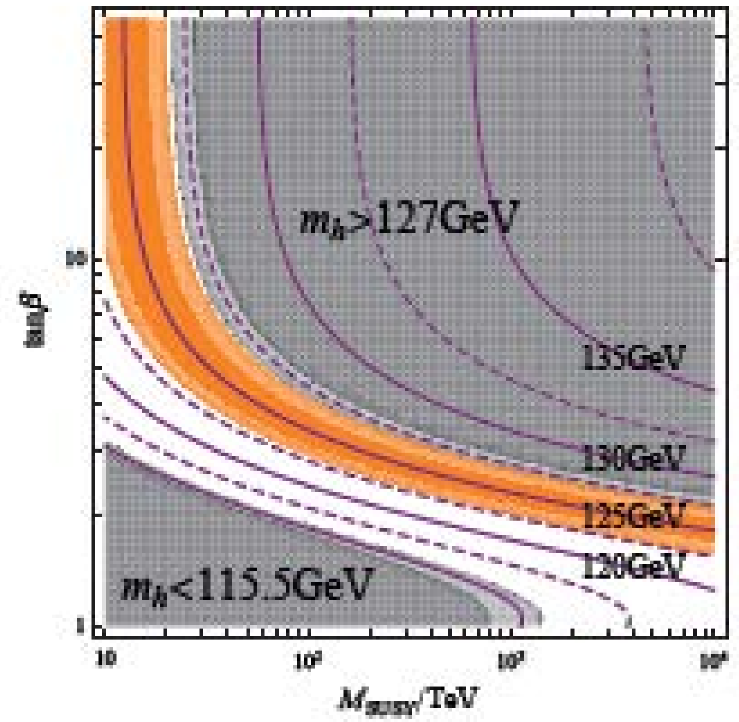
A cosmic ray experiment, AMS, may test this
prediction soon (in several years)

Anti-proton detection in CR



Ibe, Matsumoto, Yanagida (2012)

Higgs boson mass ~ 125 GeV is explaind for m_3/2 =O(100) TeV



Ibe, Matsumoto, Yanagida (2012)

Why the gluino mass is so heavy ?

If the SUSY breaking is biased to low energy,
why the gluino mas is NOT 100 GeV ?

I need a reason,
otherwise I can not believe in SUSY

Maybe, an answer is in Inflation of our universe !!

Consider the Chaotic Inflation

The inflaton mass is $m=10^{13}$ GeV

The reheating temperature T_R = a few 10^{9} GeV

To explain the DM density we need m_{wino} > a few 100 GeV

⇒ m_{gluino} > a few $\times$ 300 GeV ~ 900 GeV !!!

We may understand why SUSY has not been observed at LHC

Summary

	Minimal GM	Standard Model	Pure GM
Why m_SUSY>1 TeV ?	✗	☺	△
125 GeV Higgs Boson	△	☺	☺
Polonyi Problem	✗	☺	☺
Gravitino Problem	✗	☺	☺
FCNC /CP Problem	✗	☺	☺
Dark Matter	☺	△	☺
GUT Unification	☺	✗	☺
Fine Tuning Problem	△	✗ ✗ ✗	✗