The Goldstini Variations

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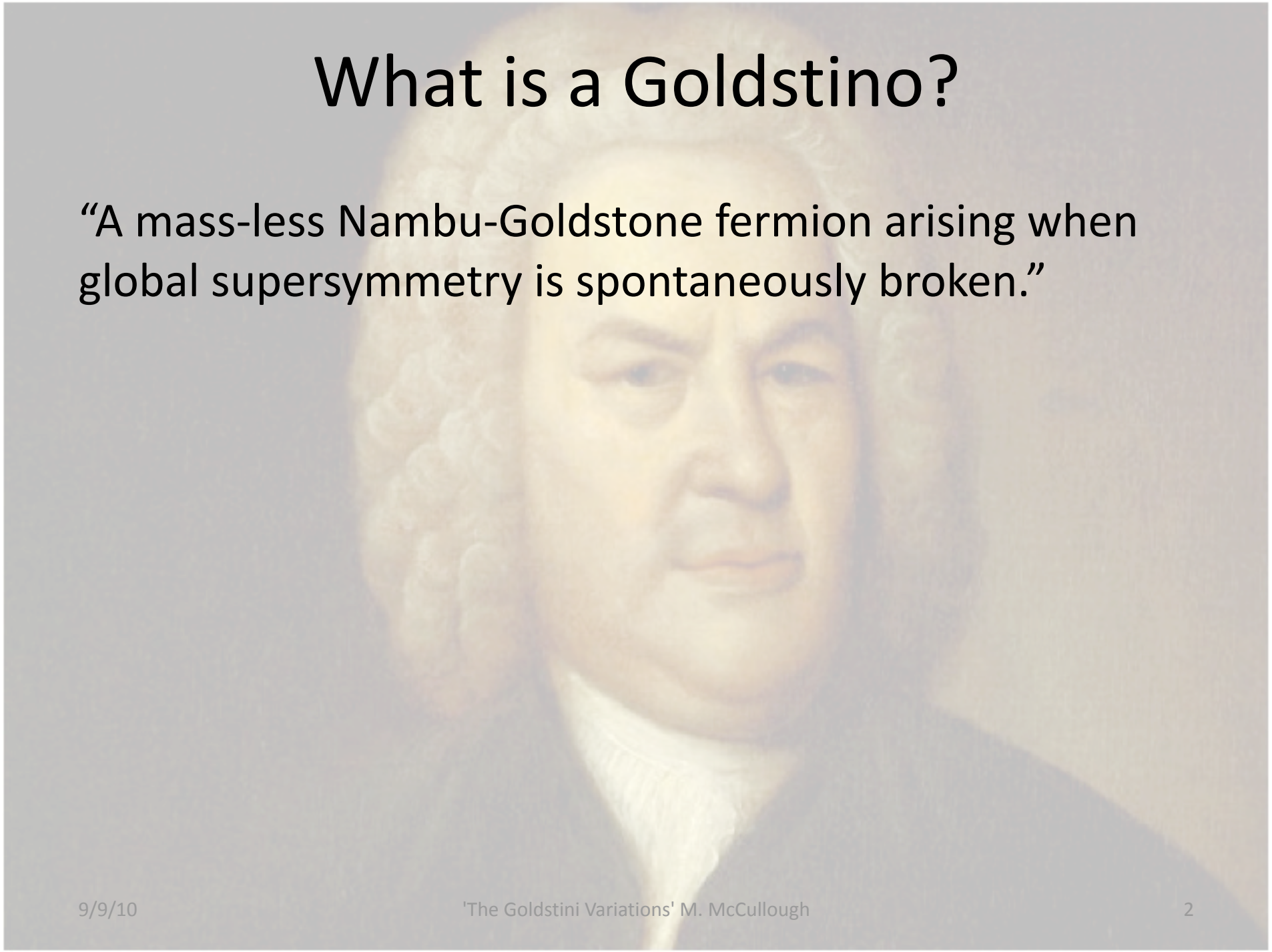
UniverseNet School 2010
Lecce, Italy

Based on: Cheung, Nomura & Thaler: JHEP 1003:073,2010
Cheung, Mardon, Nomura & Thaler: JHEP 1007:035,2010
Craig, March-Russell & McCullough: 1007.1239

What is a Goldstino?

"A mass-less Nambu-Goldstone fermion arising when global supersymmetry is spontaneously broken."



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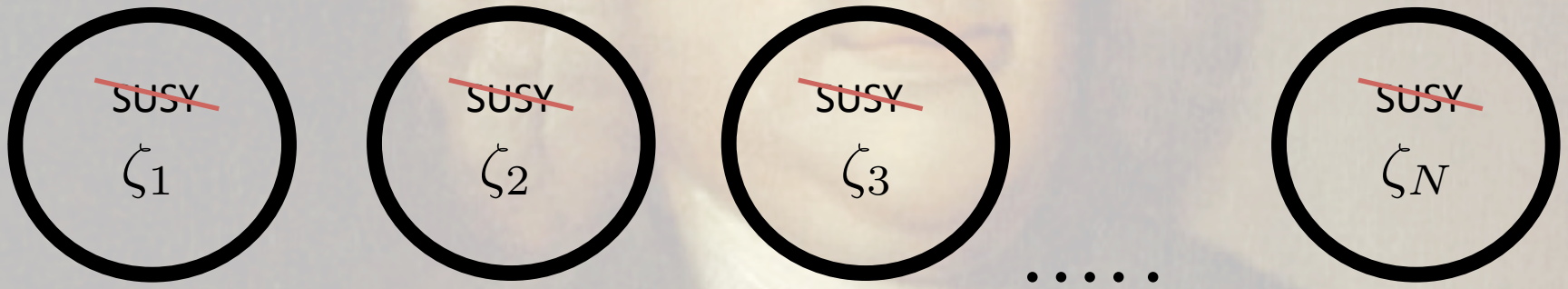
Imagine N completely decoupled sectors each breaking SUSY spontaneously (ignoring gravity).



Then we have N mass-less 'goldstini'!

What about gravity?

Embed this set-up in supergravity:

- One combination of goldstini 'eaten' to form massive spin-3/2 gravitino.
- Other combinations of goldstini become massive (Cheung, Nomura, Thaler) with:

$$m_\zeta = 2m_{3/2}$$

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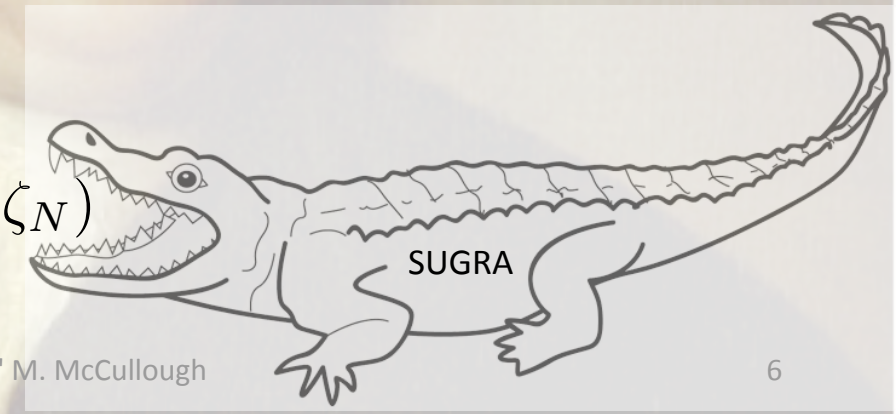
- If SUSY breaking in each sector is: F_i
- And: $F_{eff} = (F_1^2 + F_2^2 + ... + F_N^2)^{1/2}$
- Then 'eaten' linear combination is:

$$\zeta_{eaten} = \frac{1}{F_{eff}}(F_1\zeta_1 + F_2\zeta_2 + ... + F_N\zeta_N)$$



What about Particle Cosmology?

- If gravitino LSP then MSSM 'LOSP' can be long-lived.
- Could observe LOSP decays to gravitino at colliders, mass and lifetime measurements could confirm SUGRA, for:

$$m_{3/2} > O(0.1) m_{LOSP}$$

- But LOSP decays would have occurred after nucleosynthesis, spoiling BBN unless:

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- Gravitino coupling to LOSP: $C_G \sim \left(\sum_i \tilde{m}_i^2 \right) / F_{eff}$

- Goldstino coupling to LOSP: $C_{\zeta_i} \sim \tilde{m}_i^2 / F_i$

Therefore goldstino can couple to LOSP much more strongly, enabling LOSP to decay earlier, reheating to a higher temperature, and preserving BBN. (Cheung, Mardon, Nomura & Thaler)

What about Particle Cosmology?

Thermal leptogenesis typically requires a reheating temperature:

$$T_R \geq 10^9 GeV$$

Bounds from gravitino overproduction and successful BBN typically require:

$$T_R < 10^7 GeV \qquad (m_{3/2} = 100\mathrm{GeV})$$

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Dominant production of goldstino from non-renormalizable couplings to gauginos. Couplings forbidden if goldstino arises in a SUSY breaking sector with an R-symmetry.

Therefore thermal leptogenesis can be accommodated with gravitino LSP with mass in the range (Cheung, Mardon, Nomura & Thaler):

$$m_{3/2} > O(0.1) m_{LOSP}$$

How many Goldstini?

Possibly most plausible models that break SUSY dynamically are the ISS models. Simply SUSY QCD with N_c colours and N_f flavours of massive quarks, where:

$$N_c < N_f < \frac{3}{2} N_c$$

- Gauge coupling strong in the IR at a scale Λ. Quark masses satisfy:

$$m_f \ll \Lambda$$

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Embed in SUGRA and we find many goldstini, and even more 'modulini' with:

$$N_{Goldstini} = N_c \qquad M_{Goldstini} = 2m_{3/2}$$

$$N_{Modulini} = N_c^2 - N_c \qquad M_{Modulini} \geq 2m_{3/2}$$

Thus many goldstini can arise from within one SUSY-breaking sector! (Craig, March-Russell, MM)

Where from?

Smallness of FCNCs require that flavour-violating transmission of SUSY-breaking is suppressed. This is most readily achieved with:

- Conformal sequestering
- Geographical sequestering, i.e. 'warping'

Conformal sequestering occurs if scaling dimension of SUSY breaking field, Δ > 1. Writing this scaling dimension as: $\Delta = 1 + \gamma$

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Warping occurs if the SUSY breaking field resides at the end of a warped throat. The exponentially warped superfield is: $\omega = \phi \exp(-kT)$

Corresponding goldstino mass is: $m_\zeta = 2 f_\omega / \omega \neq 2 m_{3/2}$

Thus 'realistic' mediation of SUSY-breaking may significantly modify goldstini masses!

To conclude...

The idea of a hidden SUSY-breaking sector has been entertained for about 30 years. So why only one sector?

More than one sector leads to gravitino + goldstini, and:

- Goldstini are interesting, even appealing, for particle cosmology – BBN, thermal leptogenesis.

- Goldstini are potentially detectable at the LHC.

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The idea of a hidden SUSY-breaking sector has been entertained for about 30 years. So why only one sector?

More than one sector leads to gravitino + goldstini, and:

- Goldstini are interesting, even appealing, for particle cosmology – BBN, thermal leptogenesis.
- Goldstini are potentially detectable at the LHC.
- Many goldstini can arise from within one sector alone.
- Sequestering, whether conformal or geographical (warping), can lead to modifications of goldstini masses and couplings.

It's fun to play the Goldstini Variations…