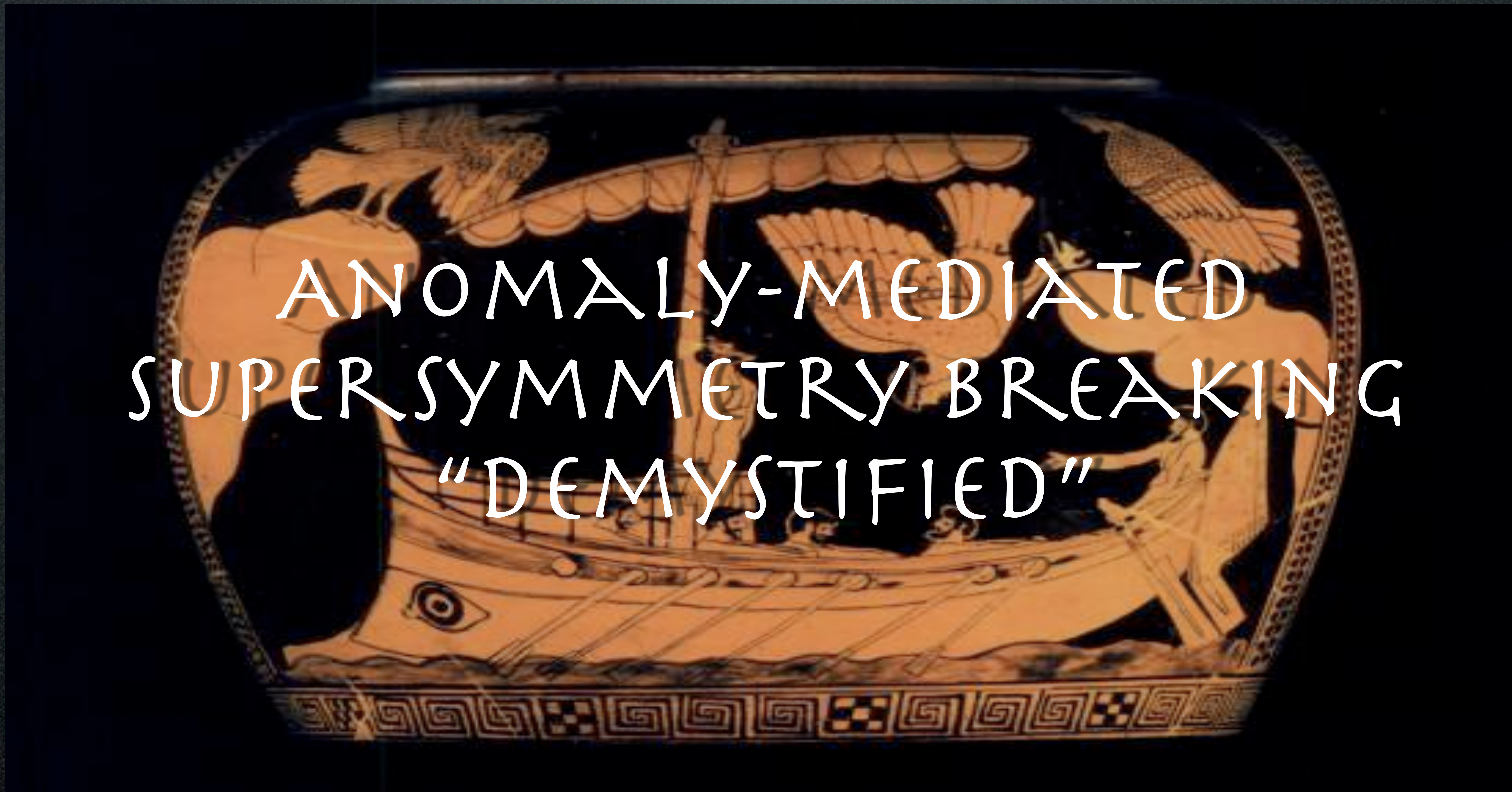

Anomaly-Mediated Supersymmetry Breaking "Demystified"

based on JHEP03(2009)123 (arXiv:0902.0464)

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PHENO 2009 SYMPOSIUM

OUTLINE

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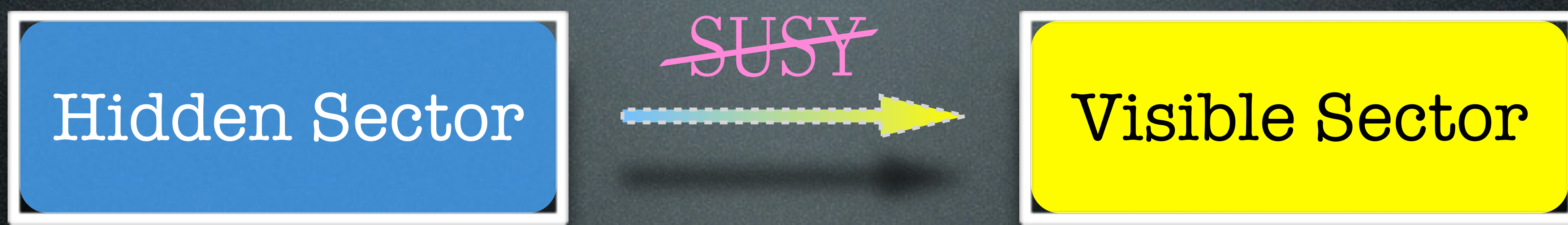
- Conformal symmetry, gravity and anomaly
- Superconformal symmetry and anomaly
- Chiral anomaly supermultiplet (CASM) and chiral compensator
- Anomaly-mediated SUSY breaking in MSSM
- Conclusion

Introduction



SUSY breaking by (superconformal) anomaly-mediation

Randall, Sundrum ('98); Giudice, Luty, Murayama, Rattazzi ('98)

- Chiral compensator χ in Einstein supergravity

$$\langle \chi^3 \rangle = 1 + \theta\theta m_{3/2}$$ $m_{3/2}$: gravitino mass

- gaugino mass, sfermion mass, A-term $\propto\ m_{3/2}$

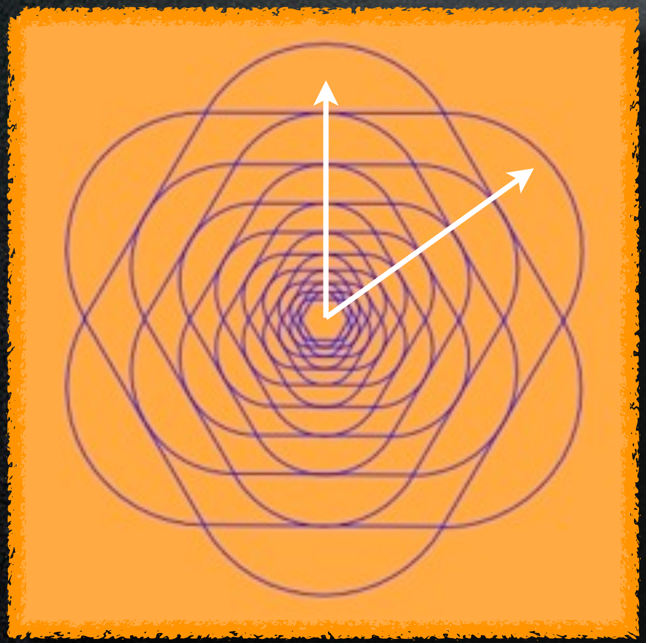
Conformal symmetry, gravity, and anomaly

conformal (or scale) transformations

$$x^m \quad \longrightarrow \quad e^{\varrho} x^m$$
$$p^m \quad \longrightarrow \quad e^{-\varrho} p^m$$

renormalization scale transforms as

$$\mu \longrightarrow e^{-\varrho}\mu .$$



The ρ is

- a real parameter for shifting the scale.
- the Nambu–Goldstone Boson (NGB), if conformal symmetry is “spontaneously” broken.
- contained in Einstein gravity where the matter Lagrangian couples to the integral measure $\sqrt{g}$ with $\rho = \ln\sqrt{g}$.
- brought in at loops along with the renormalization scale μ in quantum theory.

$$\supset \ln \mu^2 \to \ln \mu^2 - 2\varrho$$

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$$\supset \ln \mu^2 \rightarrow \ln \mu^2 - 2\varrho$$

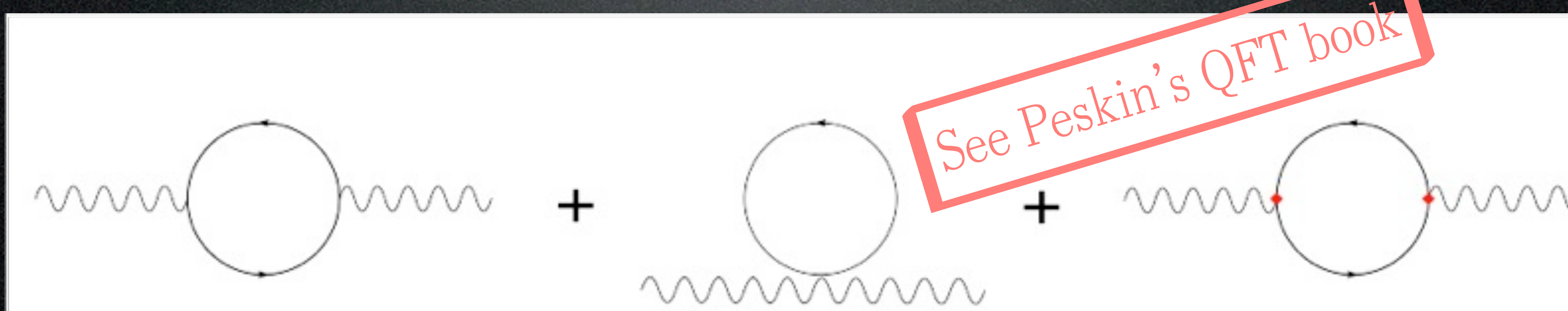
coupling of dilaton to conformal anomaly

Example: massless QCD theory

$$S_{\text{eff}} = \int d^4x \, \varrho \, T^m_m \, , \qquad \text{Coupling}$$

$$T^m_m = \frac{\beta_{\text{QCD}}(g)}{2g} F^a_{nl} F^{anl} \qquad \text{Trace (or conformal) anomaly}$$

- Fugikawa's path-integral method
- Feynman diagrams with background field method



See Peskin's QFT book

coupling of dilaton to conformal anomaly

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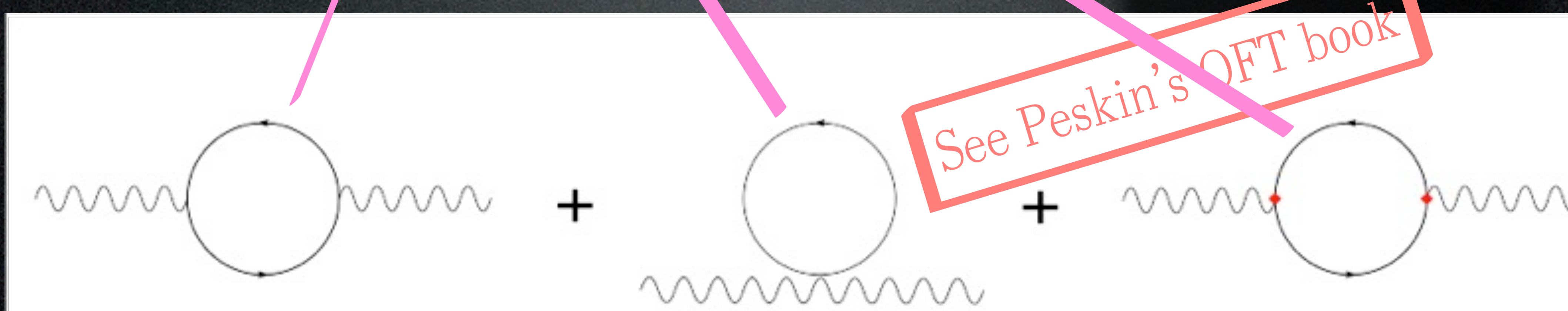
$$Z_g Z_A^{1/2} = 1$$



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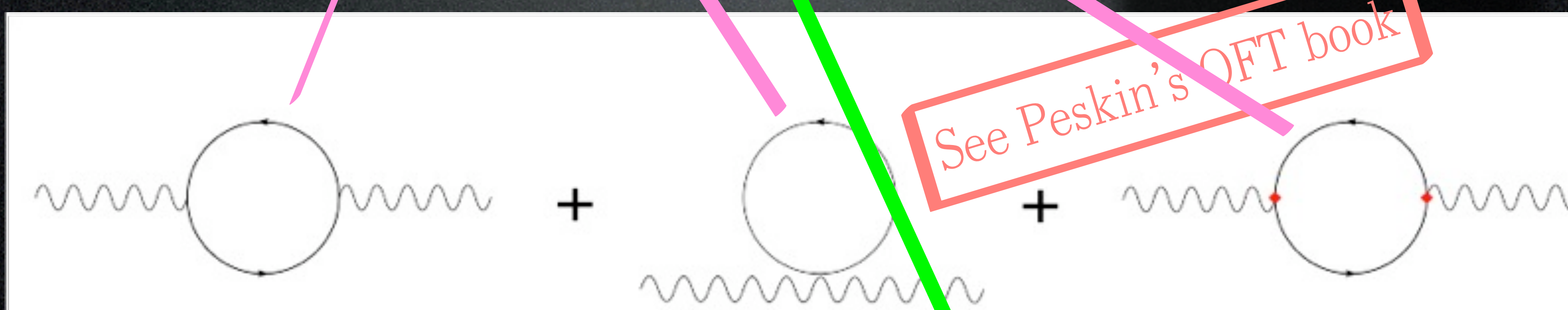
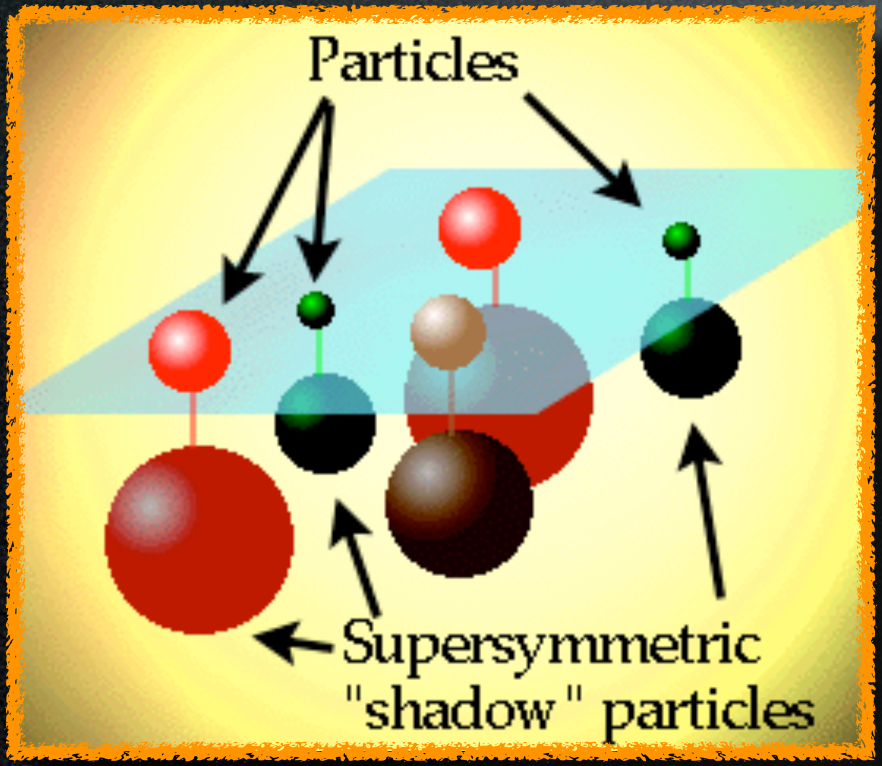


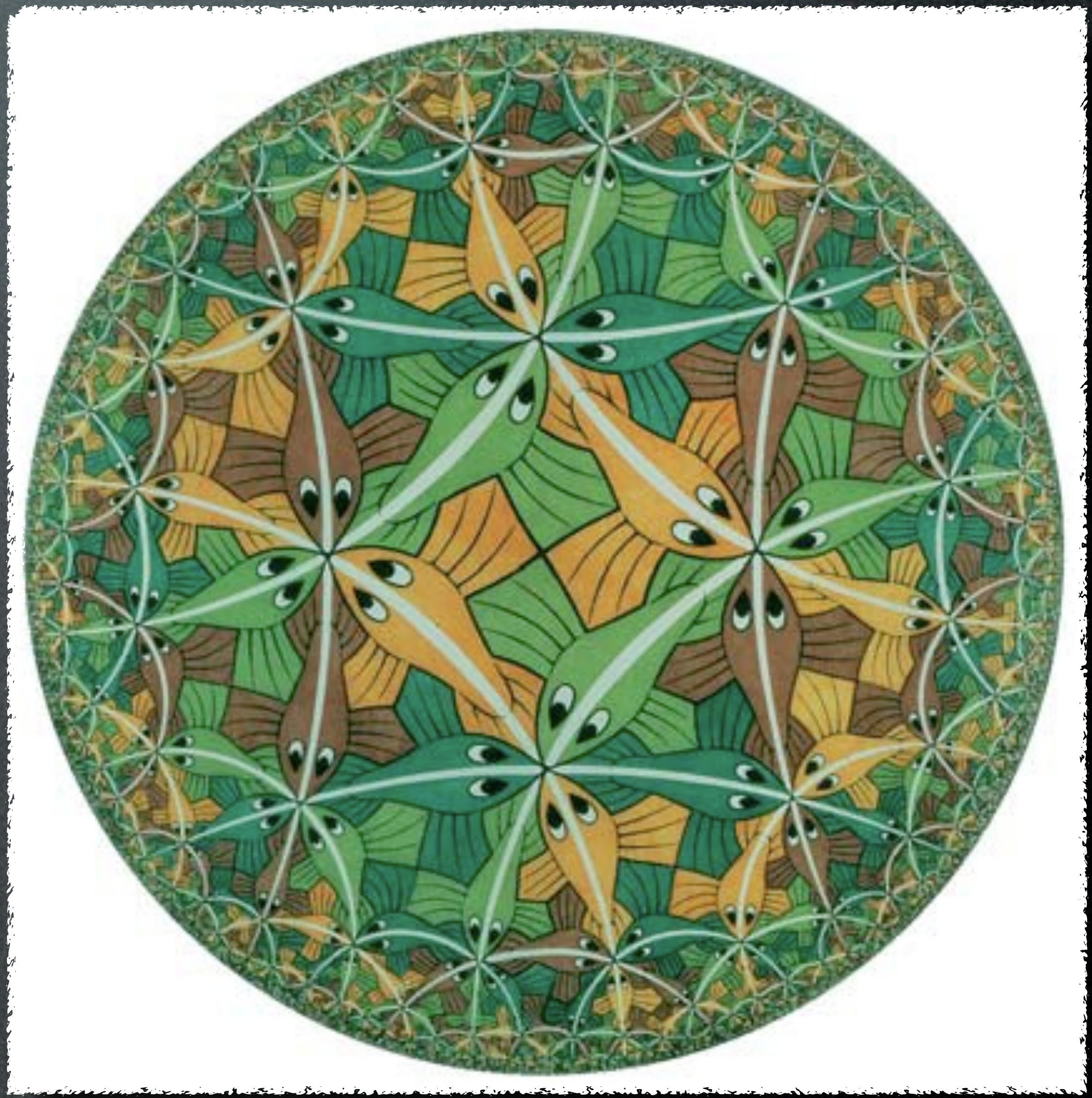
$$\ln \mu^2 \to \ln \mu^2 - 2\varrho$$

Superconformal symmetry and anomaly

Supersymmetry



Conformal symmetry



Conformal supergravity

$$\mathcal{H}^m(x,\theta,\bar\theta) = \theta\sigma^a\bar\theta e_a^m(x) + \frac{i}{2}\bar\theta\bar\theta\theta\psi^m(x) - \frac{i}{2}\theta\theta\bar\theta\bar\psi^m(x) + \frac{1}{4}\theta\theta\bar\theta\bar\theta\hat\nu^m(x)$$

U(1)_R gauge	gravitino	vierbein
$\hat\nu^m$	ψ_α^m	e_a^m
3=4-1	8=16-4-4	5=16-6-4-1

(Matter) Supercurrent

R−current	SUSY current	Energy−momentum tensor
j_m^R	S_α^m	T_n^m
$\partial^m j_m^R = 0$	$\gamma_m S_\alpha^m = 0$	$T_m^m = 0$

Conformal supergravity

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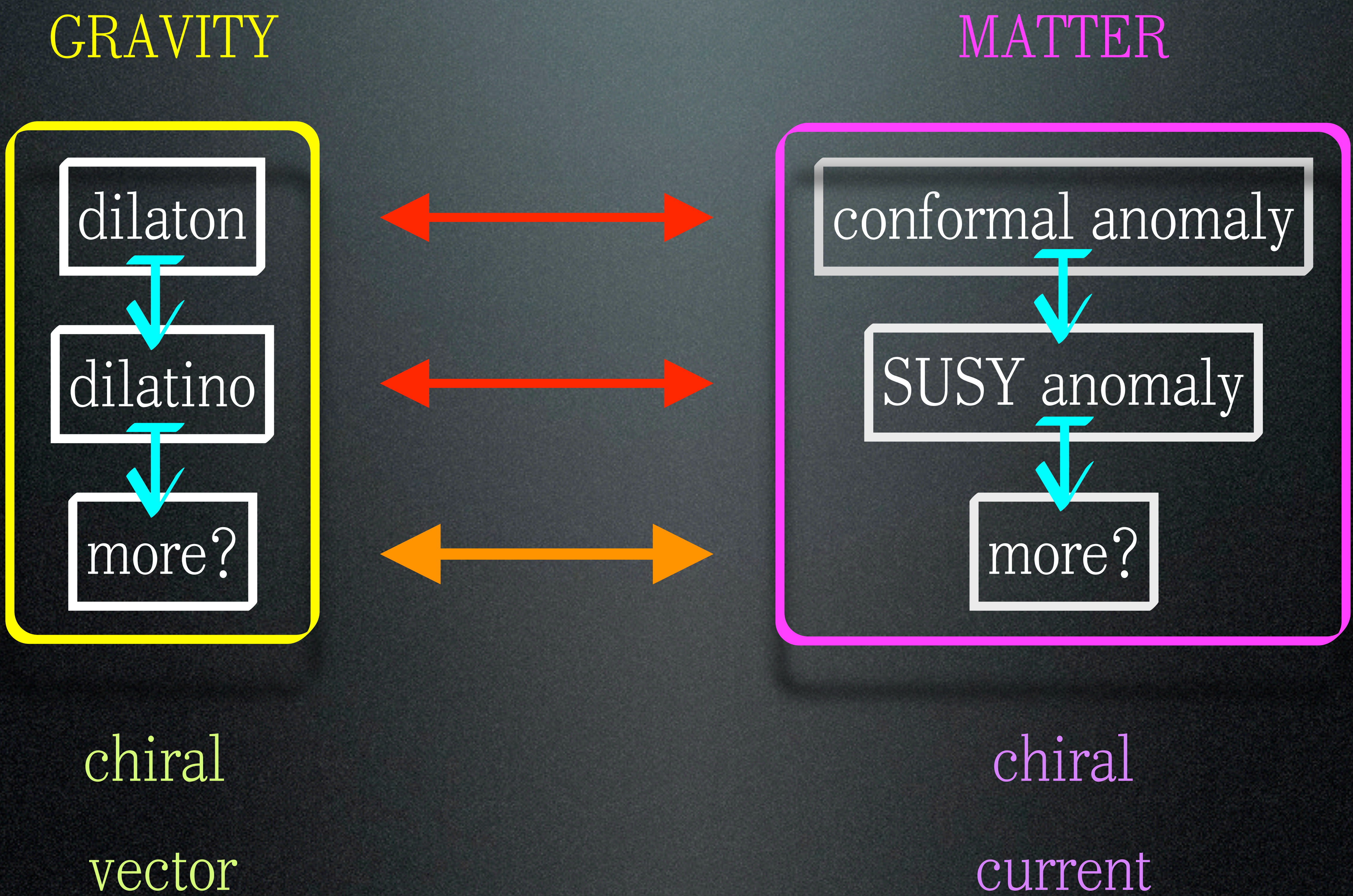
Gravity and Matter Anomaly



Chiral anomaly supermultiplet and chiral compensator

Suppose that all the three symmetries are "anomalous".

$\mathring{r} \equiv \partial^m j_m^R$	$\xi_\alpha \equiv \gamma_m S_\alpha^m$	$\mathring{t} \equiv T_m^m$
1	4	1

a, b
2

$$\begin{aligned} \mathcal{X}(x,\theta) &\equiv \mathcal{A}(x) + \sqrt{2}\theta\xi(x) + \theta\theta\mathcal{F}(x), \quad \bar{D}\mathcal{X} = 0 \\ \mathcal{A} &= a + ib \\ \mathcal{F} &= \mathring{t} + i\mathring{r} \end{aligned}$$

Chiral anomaly supermultiplet (CASM)

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$\hat{\nu}^m$	ψ^m_α	e^m_a
3=4-1	8=16-4-4	5=16-6-4-1

M^*
2

$$\chi^3(x,\theta) \equiv e^{2\varrho(x)+2i\delta(x)}[1 + \sqrt{2}\theta\bar{\Psi}(x) + \theta\theta M^*(x)]$$

Chiral compensator

$\bar{\Psi}_\alpha \sim \sigma^{\alpha\dot{\alpha}}_m \bar{\psi}^m_{\dot{\alpha}}$ (Nambu-Goldstino = dilatino)

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Coupling of the CASM to the chiral compensator

$$S_{\mathcal{X}} = \int d^4x\, d^2\theta\, \chi^3(x,\theta)\mathcal{X}(x,\theta) + h.c.$$

in components, $$S_{\mathcal{X}} = \int d^4x\, [e^{2\varrho+2i\delta}(M^*\mathcal{A} + \bar{\Psi}\xi + \mathcal{F}) + h.c.]$$

soft susy breaking terms

conformal anomaly

$$\begin{aligned} \langle M^* \rangle &= m_{3/2}, \\ \mathcal{A} &= \text{the lowest comp. of CASM} \end{aligned}$$

for example, $\mathcal{X} = W^a_\alpha W^{a\alpha} \Rightarrow \mathcal{A}| = \lambda_a\lambda_a$

$$M^*\mathcal{A} \Rightarrow m_{3/2}\lambda^a\lambda^a$$

gaugino mass term

Anomaly-mediated SUSY breaking in MSSM

$$S = \int d^4x\, d^2\theta d^2\bar{\theta}\, \phi_i{}^+ e^{2gV} \phi_i$$

(Simplified MSSM action)

$$+ \left[\int d^4x\, d^2\theta \left(\frac{1}{4} W^{a\alpha} W^a_\alpha + \frac{1}{3!}\, y^{ijk}\, \phi_i \phi_j \phi_k \right) + h.c. \right]$$

interaction	CASM $\mathcal{X}$	soft term
$\frac{1}{4} W^{a\alpha} W^a_\alpha$	$\frac{\beta(g)}{2g} W^{a\alpha} W^a_\alpha$	$M_\lambda = \frac{\beta(g)}{g} m_{3/2}$
$\frac{1}{3!}\, y^{ijk}\, \phi_i \phi_j \phi_k$	$-\frac{1}{3!}\, (\gamma_i + \gamma_j + \gamma_k)\, y^{ijk} \phi_i \phi_j \phi_k$	$A_{ijk} = -(\gamma_i + \gamma_j + \gamma_k) y^{ijk} m_{3/2}$

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β-function

γ-function

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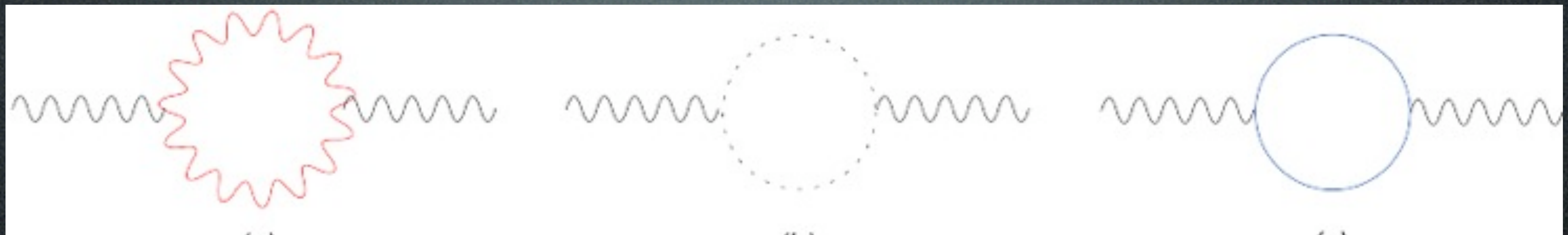
$\frac{1}{3!} y^{ijk}\, \phi_i \phi_j \phi_k$	$-\frac{1}{3!} (\gamma_i + \gamma_j + \gamma_k)\, y^{ijk} \phi_i \phi_j \phi_k$	$A_{ijk} = -(\gamma_i + \gamma_j + \gamma_k) y^{ijk} m_{3/2}$

$$\beta(g) = -\frac{g^3}{16\pi^2} [3C_A(\text{adj.}) - \sum_i T_A(\phi_i)]$$

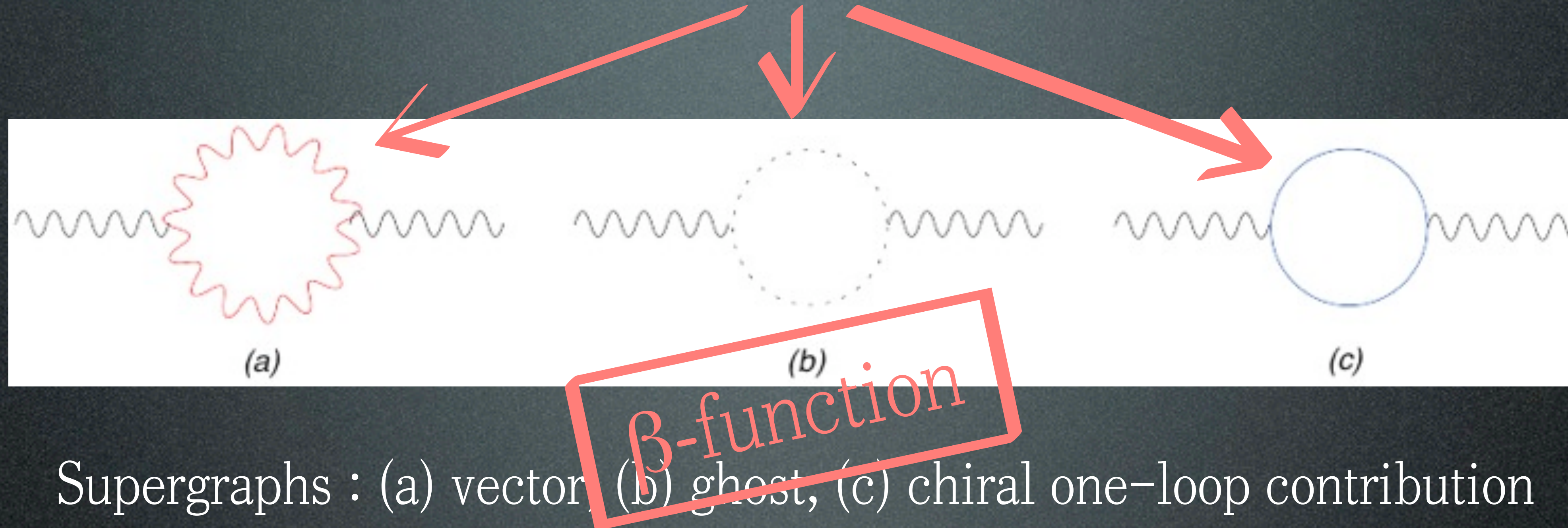
$$\gamma_i^j = -\frac{1}{32\pi^2} [y^*_{ikl} y^{jkl} - 4g^2 \delta_i^j C_A(\phi_i)]$$

$$\ln \mu^2 \to \ln \mu^2 - 2\varrho$$



Supergraphs : (a) vector, (b) ghost, (c) chiral one−loop contribution to the vector superpropagator.

$$\ln \mu^2 \to \ln \mu^2 - 2\varrho$$



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Supergraphs : one–loop contribution to the Yukawa term.

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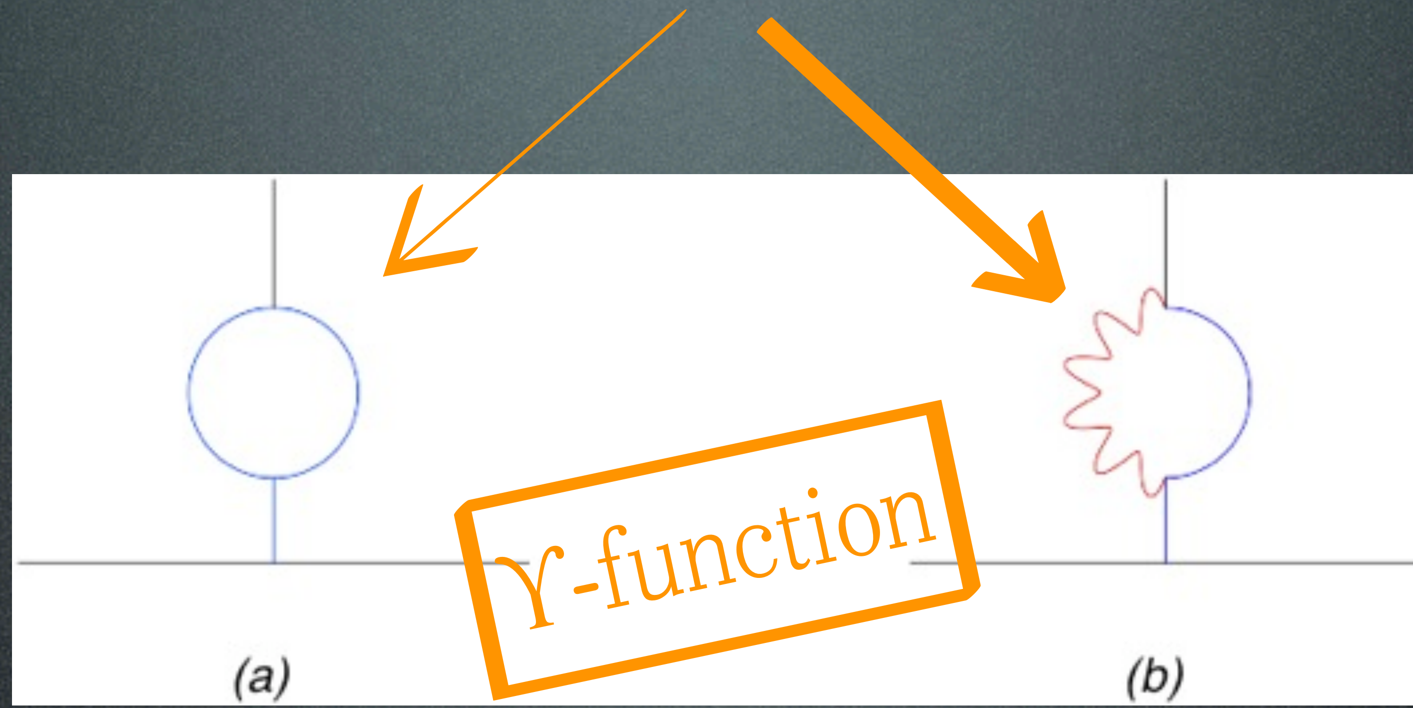

Supergraphs : one–loop contribution to the Yukawa term.

$$\gamma_i^j = -\frac{1}{32\pi^2}[y^*_{ikl}y^{jkl} - 4g^2\delta_i^j C_A(\phi_i)]$$

$$A_{ijk} = -(\gamma_i + \gamma_j + \gamma_k)y^{ijk}m_{3/2}$$

Supergraphs : these one-loops do NOT contribute to the Yukawa term.

Due to the non-renormalization theorems

Conclusion

- We have reviewed SUSY breaking of anomaly mediation from a field-theoretical perspective, using superspace perturbation theory and supergraphs.
- This approach is physically more understandable in comparison with the conventional spurion technique.
- We can even adopt this scheme to study the connection between the hidden sector and Einstein supergravity.
- We can/may systematically study various SUSY breaking mediation scenarios at once using this scheme. (i.e. GMSB+AMSB)

– The End –

Thanks for listening!