Phenomenology of scalar sequestering

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TR, Schmaltz (arXiv:0708.3593)
Murayama, Nomura, Poland (arXiv:0709.0775)
Perez, TR, Schmaltz (arXiv:0811.3206)

Weak scale supersymmetry (MSSM)

- solves the hierarchy problem in the standard model
- gauge coupling unification for free
- provides dark matter candidates

Weak scale supersymmetry (MSSM)

137 free parameters

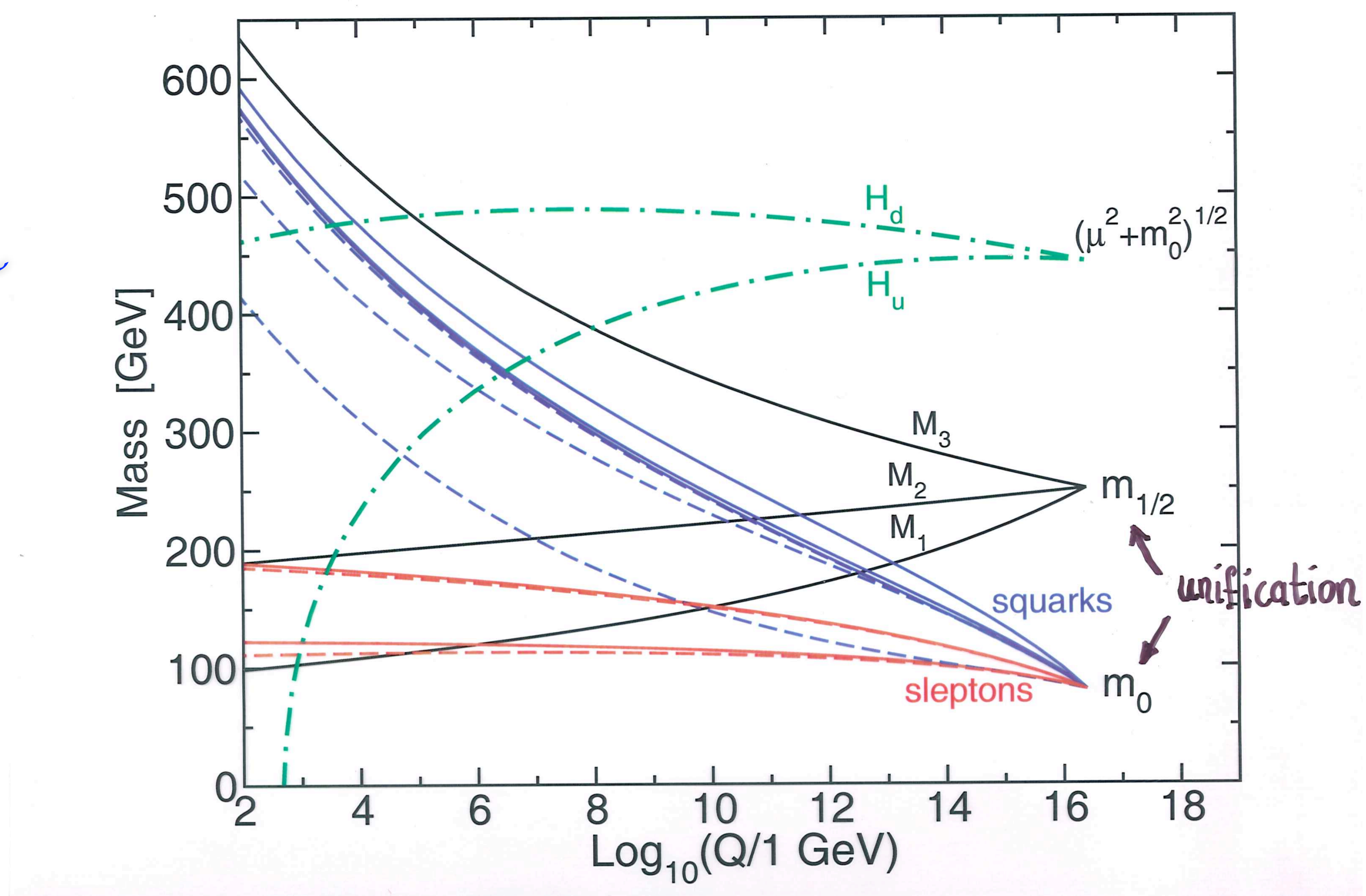
with further assumption of
superpartner mass unification
no. of parameters is reduced drastically

Superpartner Mass unification

e.g. SO(10)

State of the art MSSM running

- 2 loop running
- 1 loop matching at 1 TeV and at GUT
- automated
    - Isajet
    - Softsusy
    - Suspect
    - -
    - -



we missed a
potentially very large
effect and our scalar
mass predictions
may be totally wrong

Cohen, TR, Schmaltz (hep/ph 0612100)

soft masses are also renormalized due to susy breaking interactions

Cohen, TR, Schmaltz (hep/ph 0612100)

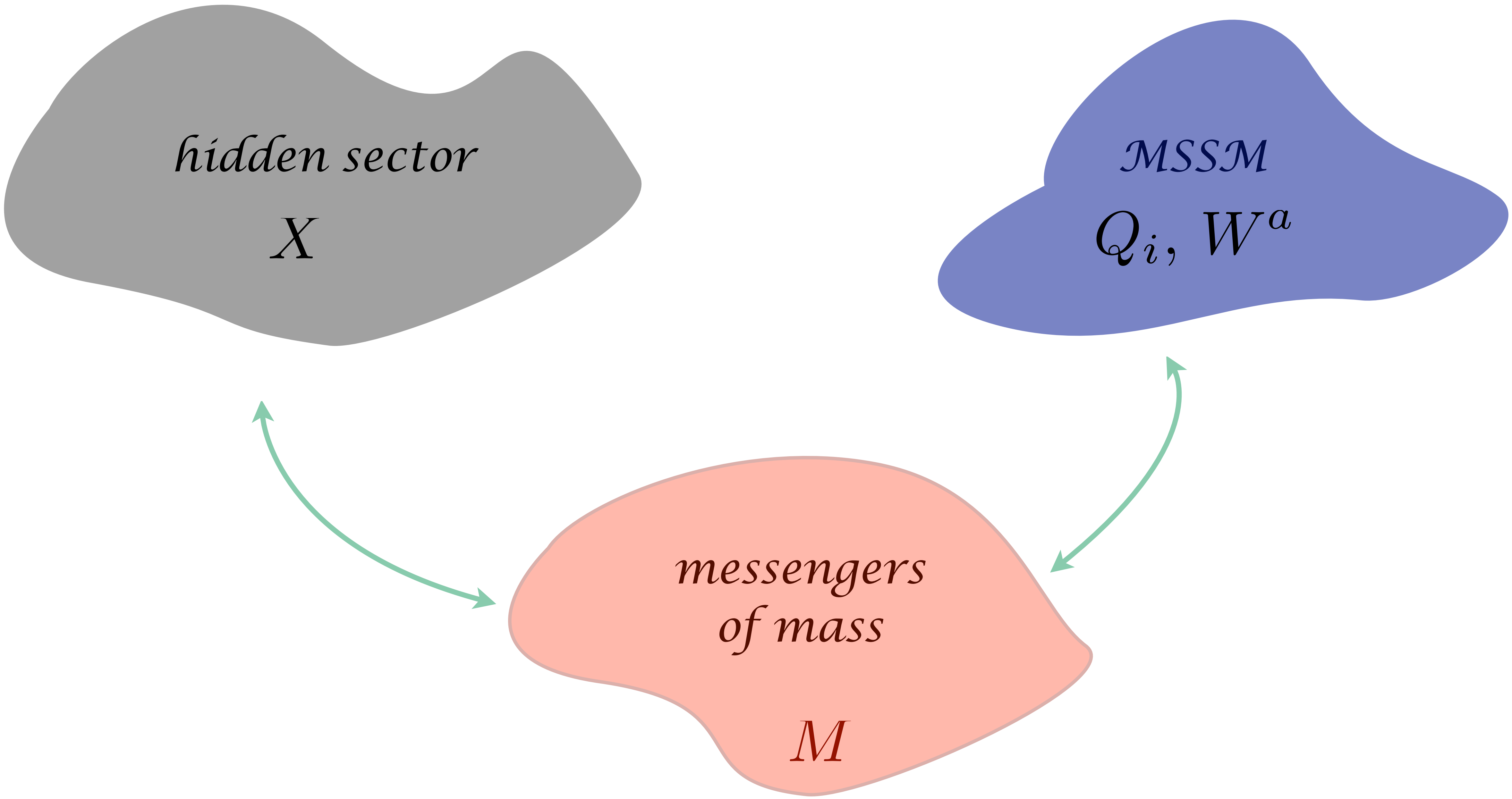
Outline

1. Physics of soft masses and an intrinsic problem of all mediation mechanisms.

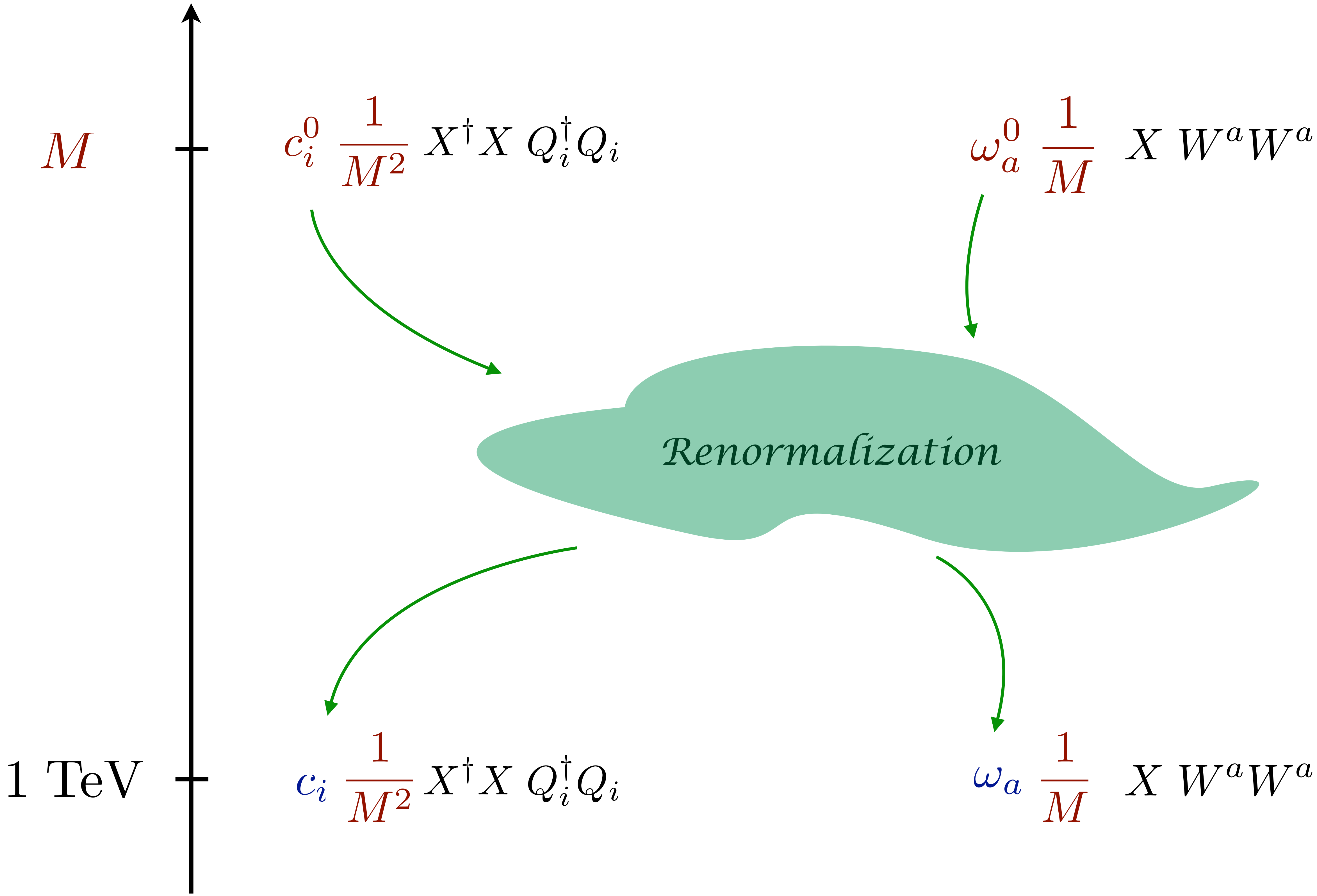
2. Corrections of soft masses due to hidden sector dynamics and a natural solution.

3. Scalar Sequestering
    - definition
    - phenomenology and model independent predictions

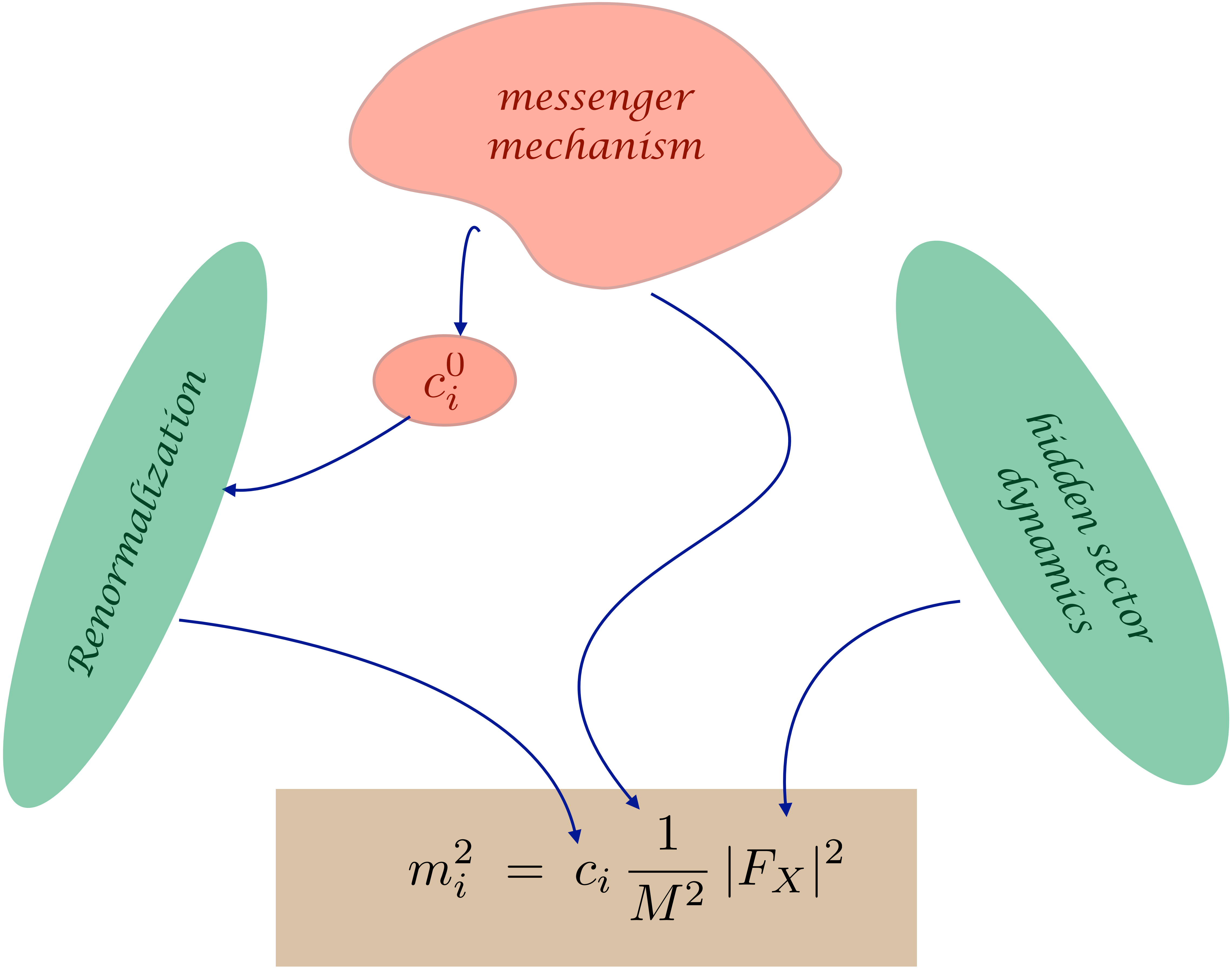
Physics of soft masses



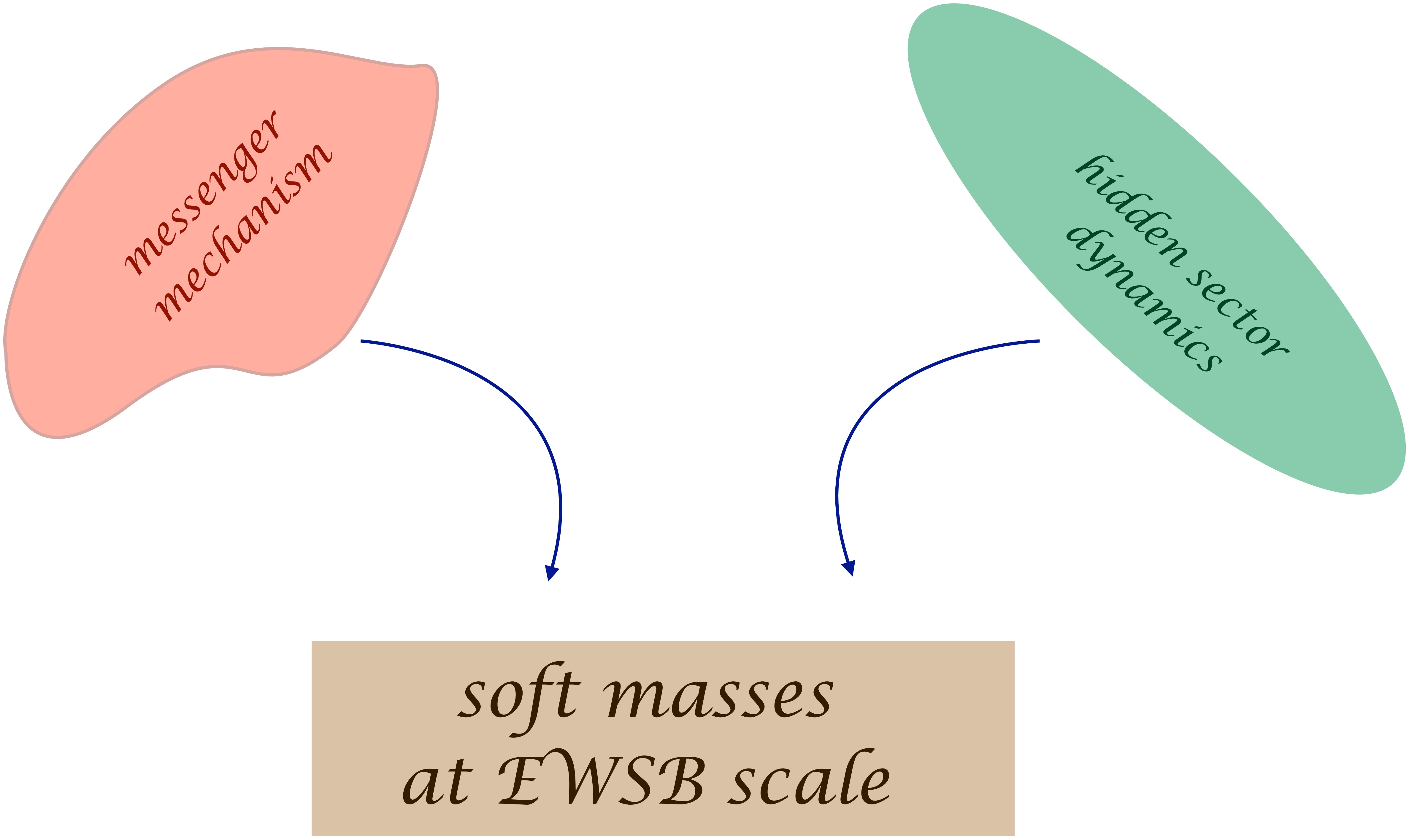
$$c_i^0 \frac{1}{M^2} \; X^\dagger X \, Q_i^\dagger Q_i \qquad\qquad \omega_a^0 \frac{1}{M} X \, W^a W^a$$



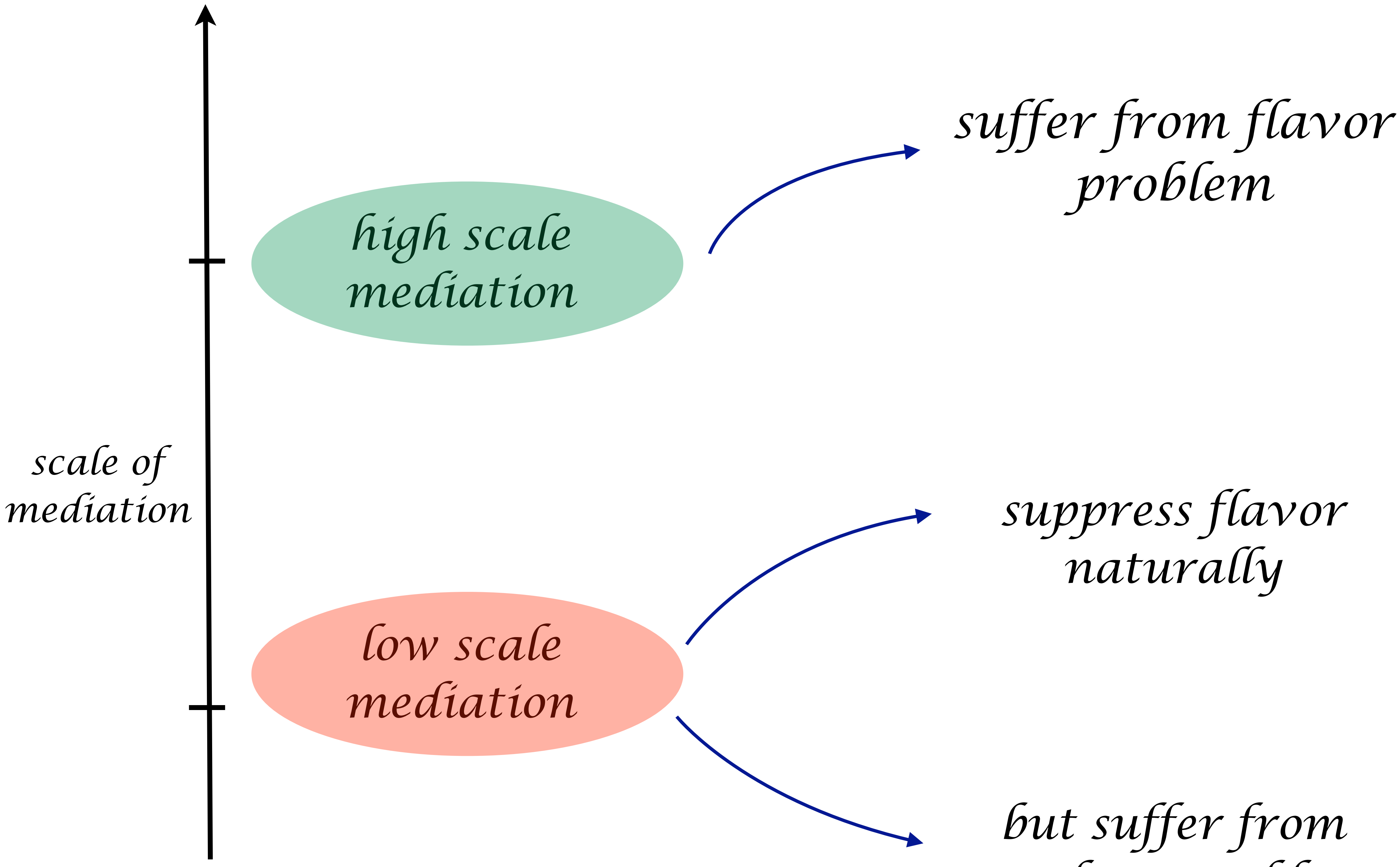
M
1 TeV
$c_i^0 \frac{1}{M^2} X^\dagger X \, Q_i^\dagger Q_i$
$\omega_a^0 \frac{1}{M} \, X \, W^a W^a$
Renormalization
$c_i \frac{1}{M^2} X^\dagger X \, Q_i^\dagger Q_i$
$\omega_a \frac{1}{M} \, X \, W^a W^a$



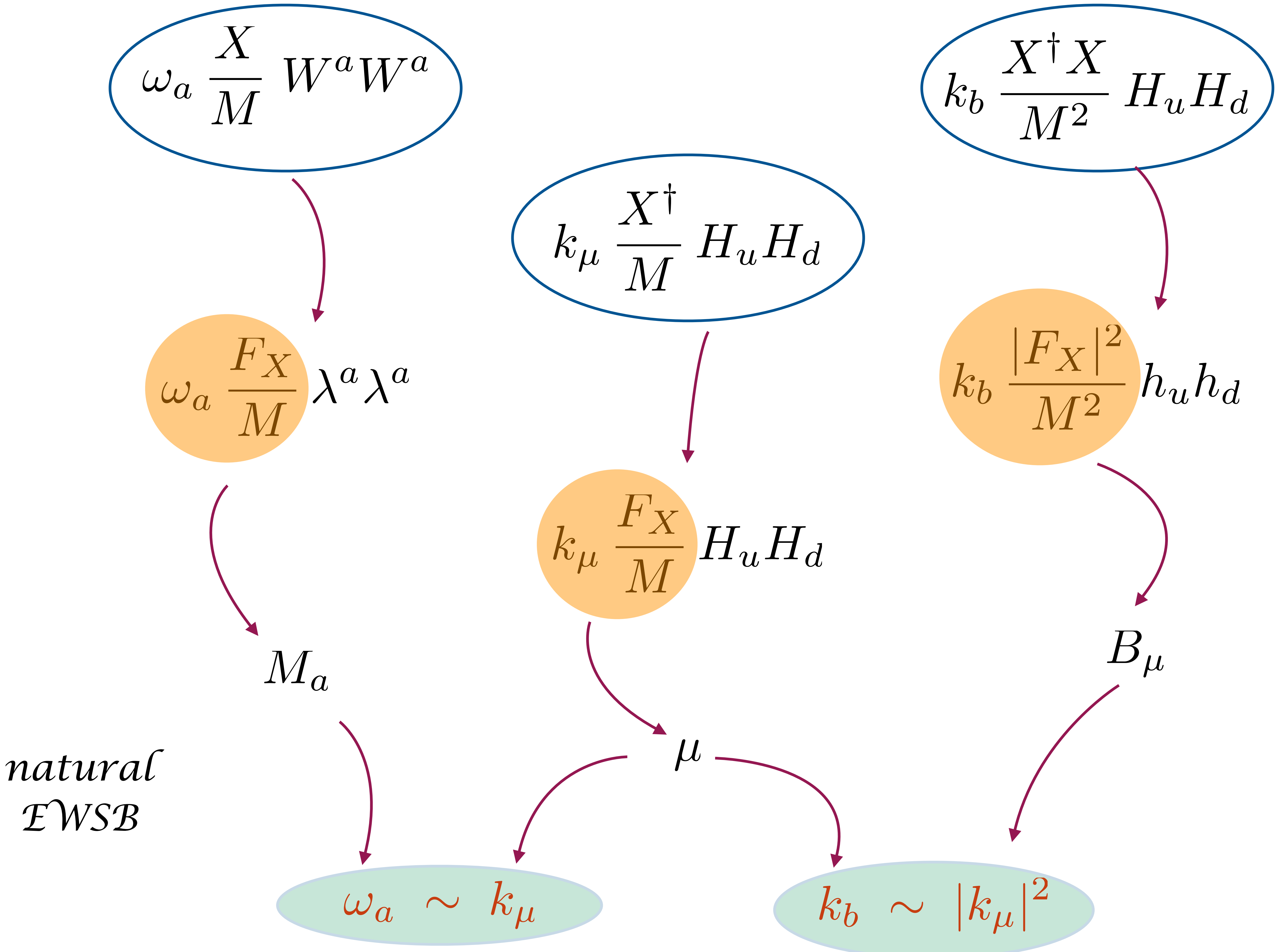
messenger mechanism
c_i^0
Renormalization
hidden sector dynamics
$m_i^2 = c_i \frac{1}{M^2} |F_X|^2$


messenger mechanism
hidden sector dynamics
soft masses at EWSB scale

summary of intrinsic problems of all messenger mechanism



more about the mu-bmu problem



more about the mu-bmu problem

$$k_b \sim k_\mu \sim \delta$$

$$k_b \sim \frac{|k_\mu|^2}{\delta}$$

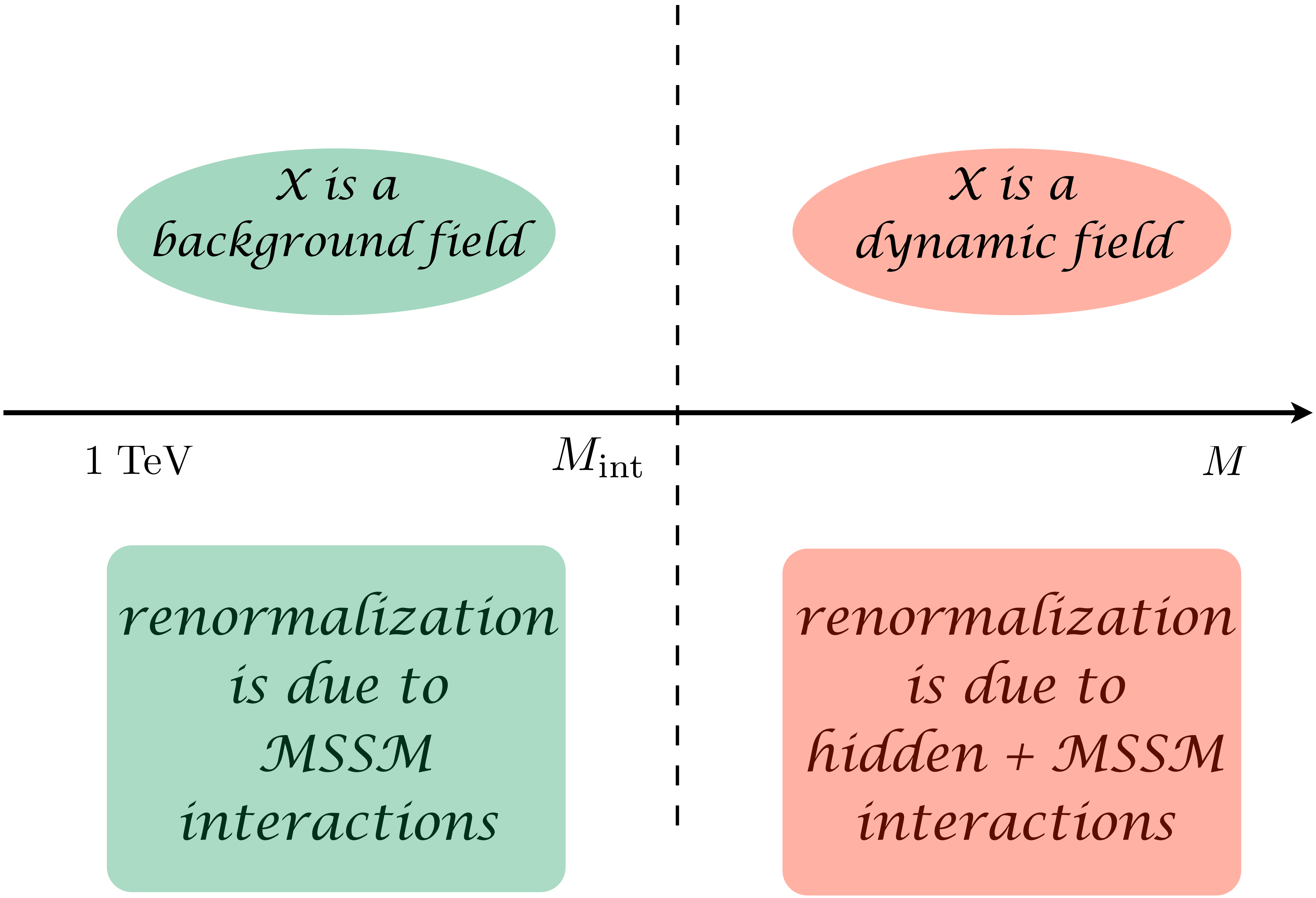
$$B_\mu \sim \frac{|\mu|^2}{\delta}$$

$$\delta \ll 1$$

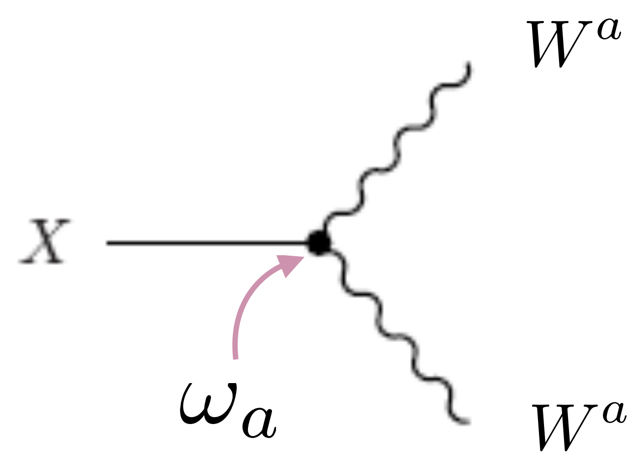
for low scale of mediation

mu-bmu both can not have natural size

Scales in renormalization



Renormalization



$\omega_a \, \frac{1}{M} \, X W^a W^a$ *is a superpotential coupling*

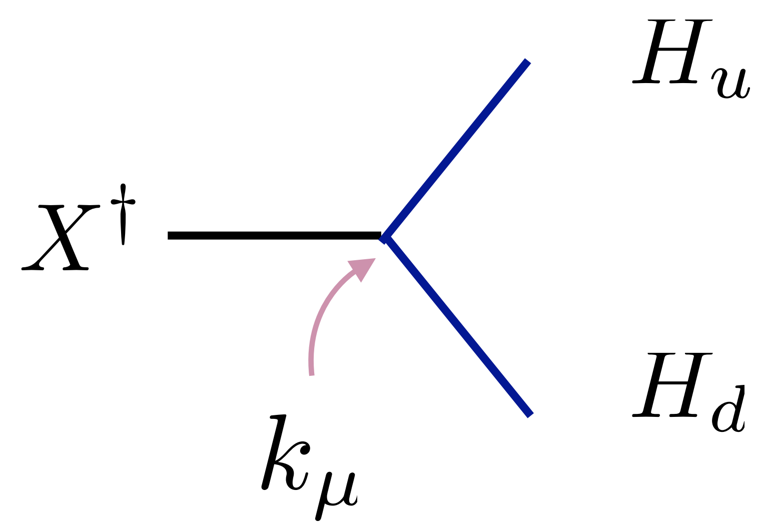
↓

ω_a *does not renormalize*

↓

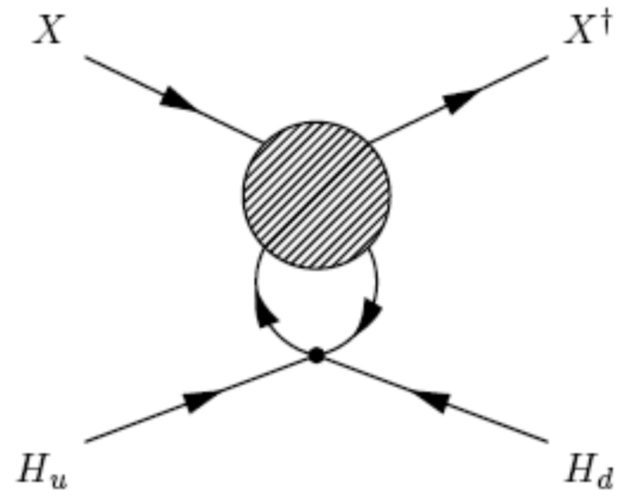
$$\omega_a = \omega_a^0$$

Renormalization



k_μ *does not renormalize*

$$k_\mu = k_\mu^0$$



$$\frac{dk_b}{dt} = \gamma\, k_b$$

$$k_b = e^{-\int \gamma} \quad k_b^0$$

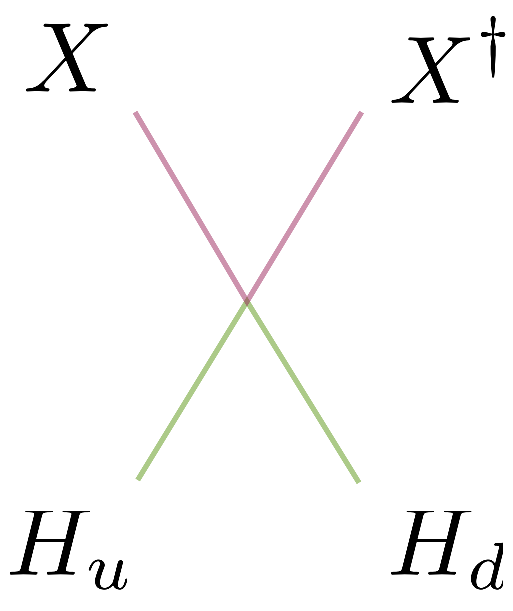
If γ *is constant :*

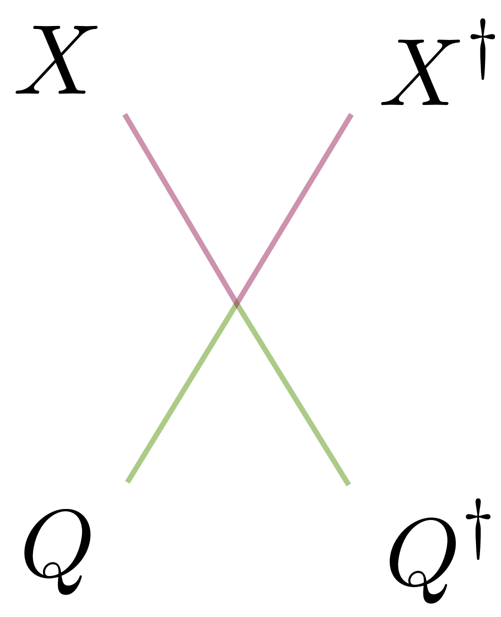
$$k_b(M_{\rm int}) = \left(\frac{M_{\rm int}}{M}\right)^{\gamma} \quad k_b^0$$

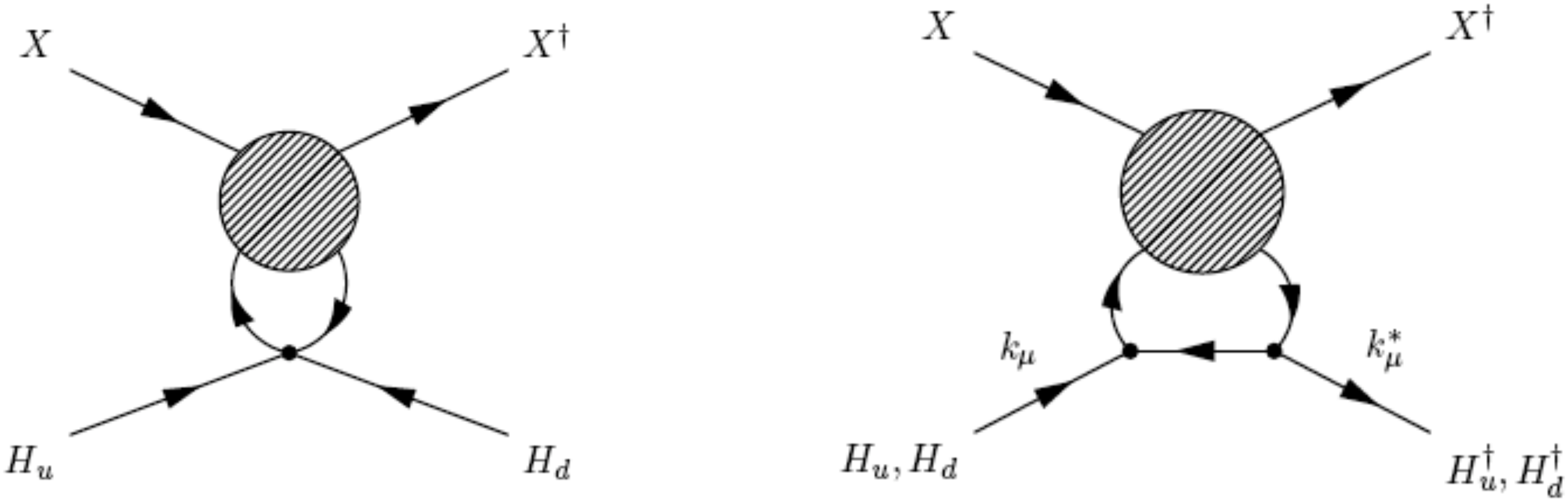
The hidden sector

1. supersymmetry is broken in the hidden sector.
2. hidden sector dynamics is due to a super-conformal field theory.
3. SCFT is such that $\gamma > 0$

hidden sector renormalization of scalar mass operators and the bmu operator is identical







$$\frac{dC_H}{dt} = \gamma\, C_H + \gamma\, |k_\mu|^2$$

$$C_H^{\text{fixed}} = -\,|k_\mu|^2$$

$$m_H^2(M_{\text{int}}) = -\,|\mu|^2$$

Spectrum at the intermediate scale

$$\mu \sim M_a$$

$$B_\mu = 0$$

$$m_i^2 = 0$$

$$m_{H_u}^2 = m_{H_d}^2 = -|\mu|^2$$

in particular: Higgs mass matrix

$$\begin{pmatrix} m_{H_u}^2 + |\mu|^2 & B_\mu^* \\ B_\mu & m_{H_d}^2 + |\mu|^2 \end{pmatrix}$$

in particular: Higgs mass matrix

$$\begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}$$

Scalar sequestering

scalar sequestering

is characterized by the spectrum
at the intermediate scale

All scalars including
scalar Higgses
are massless

The spectrum is independent of
details of messenger model
and hidden sector model

only
gauginos and Higgsinos
are massive

Parameters of scalar sequestering

$$\mu$$

$$M_1 \; M_2 \; M_3$$

$$a_t \; a_b \; a_\tau$$

$$\log \frac{M_{\rm int}}{M_{\rm susy}}$$

$$\tan \beta$$

Parameters of scalar sequestering

$$\mu$$

$$\frac{M_1}{g_1^2} = \frac{M_2}{g_2^2} = \frac{M_3}{g_3^2} \equiv M_u$$

$$a_t \;\; a_b \;\; a_\tau$$

$$\log \frac{M_{\rm int}}{M_{\rm susy}}$$

$$\tan \beta$$

Parameters of scalar sequestering

$$\mu$$

$$\frac{M_1}{g_1^2} = \frac{M_2}{g_2^2} = \frac{M_3}{g_3^2} \equiv M_u$$

$$\frac{a_t}{\lambda_t} = \frac{a_b}{\lambda_b} = \frac{a_\tau}{\lambda_\tau} \equiv A_u$$

$$\log \frac{M_{\rm int}}{M_{\rm susy}}$$

$$\tan\beta$$

two equations of constraints at the EWSB scale

$$\frac{|m_{H_u}^2 - m_{H_d}^2|}{\sqrt{1-\sin^2\beta}} - \left(m_{H_u}^2 + m_{H_d}^2 + 2|\mu|^2\right) \quad = m_Z^2$$

$$B_\mu - \frac{\tan\beta}{1+\tan^2\beta}\left(m_{H_u}^2 + m_{H_d}^2 + 2|\mu|^2\right) \quad = 0$$

we can eliminate two more parameters

Scalar sequestering + unification spectrum is determined only in terms of 3 parameters

for example:

input parameters

$$\tan\beta, \quad \log\frac{M_{\rm int}}{M_{\rm susy}}, \quad \hat{\mu} = \frac{\mu}{M_u}$$

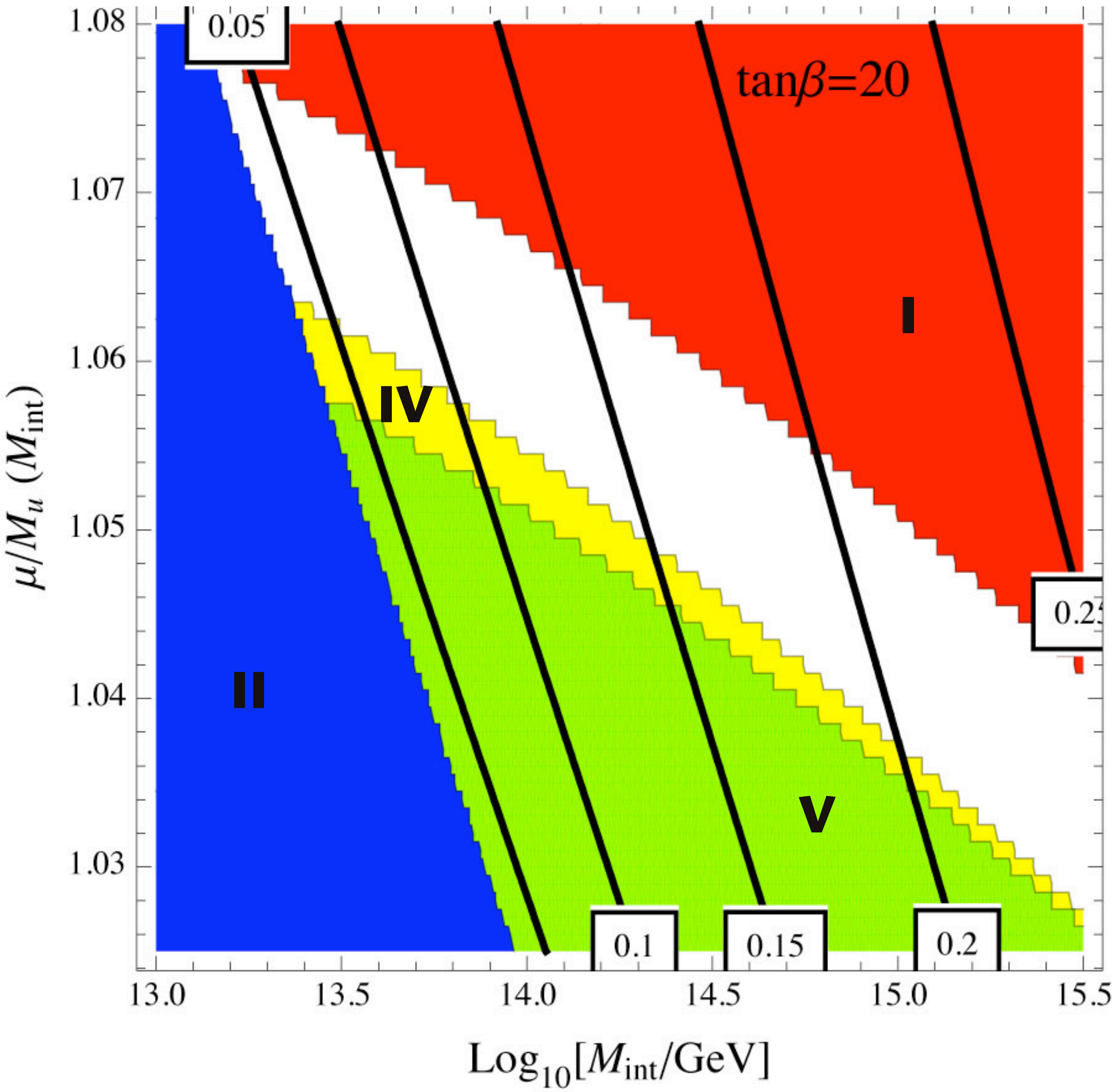
$$\hat{A} = \frac{A_u}{M_u}, \quad M_u$$

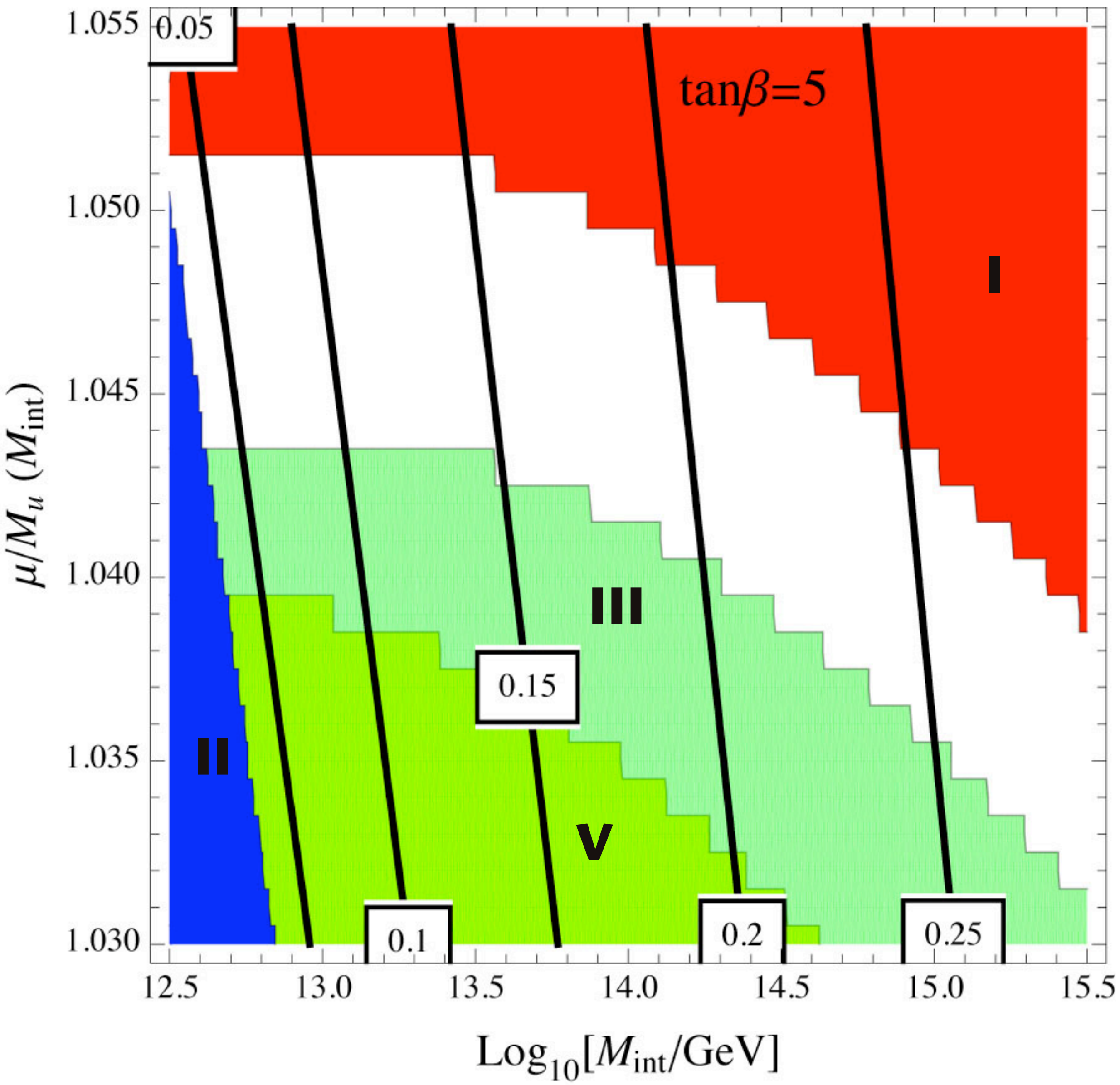
determined by EWSB conditions

the parameter space in
scalar sequestering + unification
is the most minimal

it is more minimal than even MSUGRA
and actually have theoretical foundation

there are regions of parameter space open for scalar sequestering + unification





features of scalar sequestering at the EWSB scale

- all scalar Higgses are much lighter that the Higgsinos

$$m_A^2 \ll |\mu|^2$$

- third generation scalars receive additional positive contribution due to large and negative Higgs soft masses.

We predict:

$$\left(m_{\tau_1}^2 + m_{\tau_2}^2\right) > \left(m_{L_i}^2 + m_{E_i}^2\right) \qquad i \in \{1, 2\}$$

other features of the spectrum are shared with gaugino mediation

Conclusion

- Soft masses are sensitive to hidden sector physics.
- Scalar sequestering is an extreme example where the effect due to the hidden sector dominates those due to the visible sector.
- Scalar Sequestering solves non-trivial problems in susy model building using hidden sector dynamics
  - the spectrum is independent of details of messengers or hidden sector interactions
  - with further assumption of unification, the entire spectrum is determined in terms of only three parameters.
  - unique predictions
    - Higgsinos are far heavier than all scalar Higgses
    - staus are generically heavier than smuons and selectrons