Anomaly mediation and Seiberg Witten theory

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Big picture:

Understanding the IR structure of asymptotically free gauge theories

Example: chiral QCD

- Gauge group $SU(3)$
- 3 massless quarks.
- Global symmetry group $SU(3)_L \times SU(3)_R$
- Classically conformal

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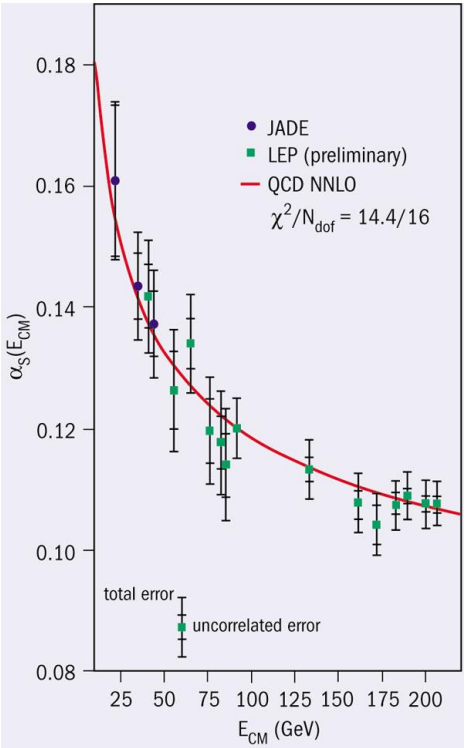
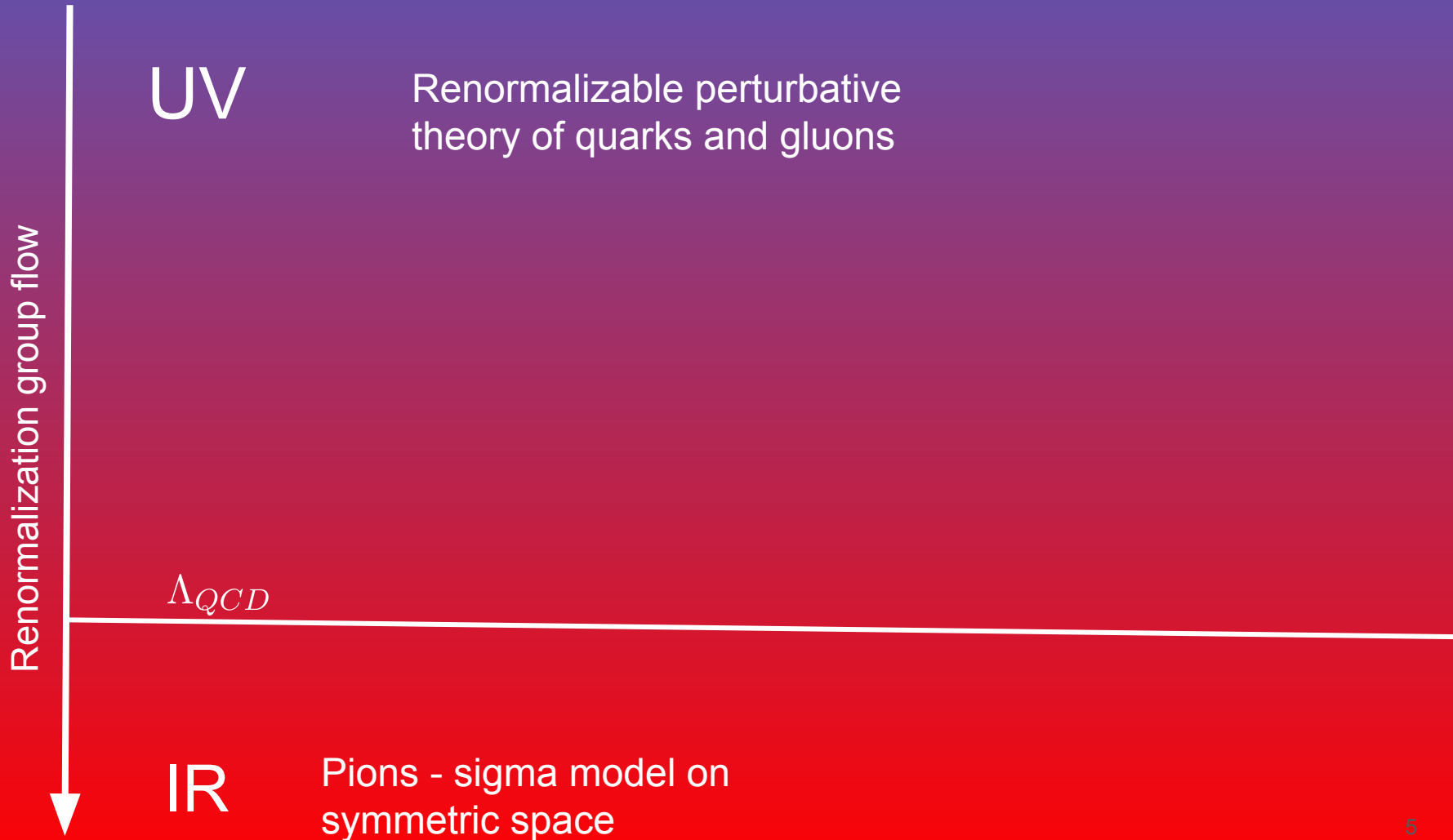
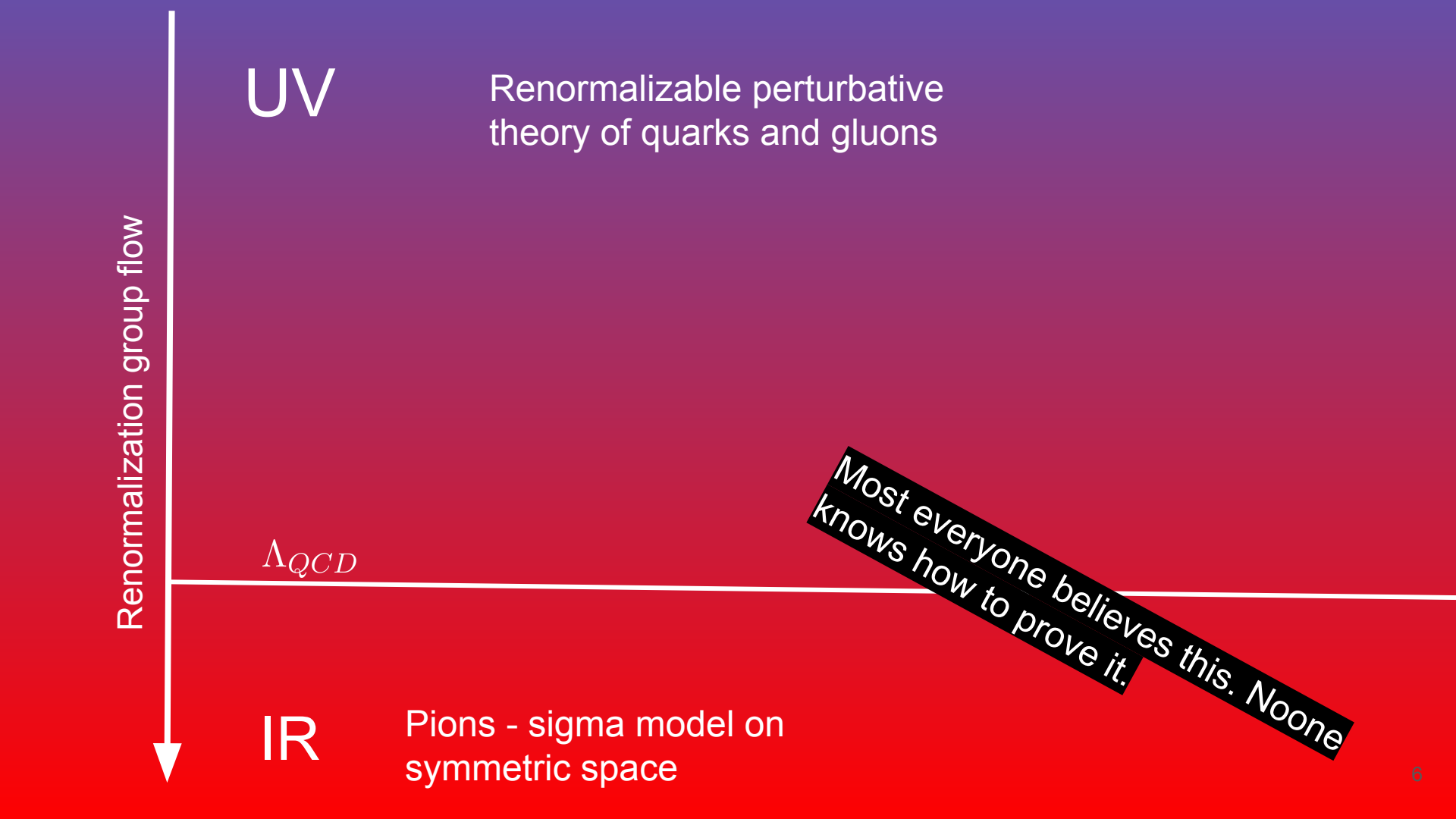
- Running coupling: conformal anomaly
- At Λ_{QCD}, perturbation theory breaks




UV
Renormalizable perturbative theory of quarks and gluons
Renormalization group flow
Λ_{QCD}
IR
Pions - sigma model on symmetric space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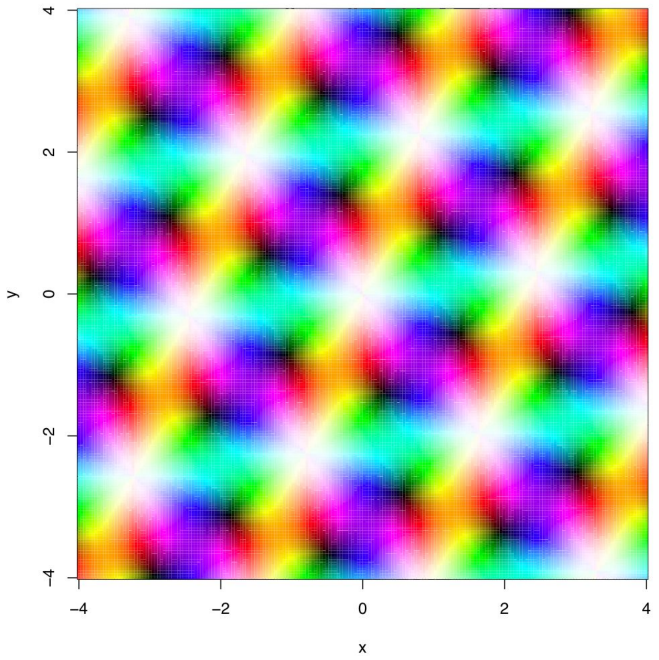
Most everyone believes this. Noone knows how to prove it.
IR
Pions - sigma model on symmetric space

Supersymmetry

- Lorentz invariance is powerful. SUSY is even more powerful.
- Allows derivation of exact, nonperturbative results.

- We'll see an example as we proceed.



SUSY = 0th order approximation. Can we get to 1st order?

Possible answer: Anomaly mediated supersymmetry breaking (AMSB)

Anomaly mediated SUSY breaking (AMSB)

- Rotate conformal anomaly into superspace: superconformal anomaly
- This is AMSB

- Only 1 parameter, $m_{3/2}$
- + Lagrangian + beta functions ->

$$V_{tree} = m_{3/2}\left(\partial_i W h^{i\bar{j}}\bar{\partial}_{\bar{j}}K - 3\,W\right) + \text{h.c.} + |m_{3/2}|^2\left(\partial_i K h^{i\bar{j}}\bar{\partial}_{\bar{j}}K - K\right)$$

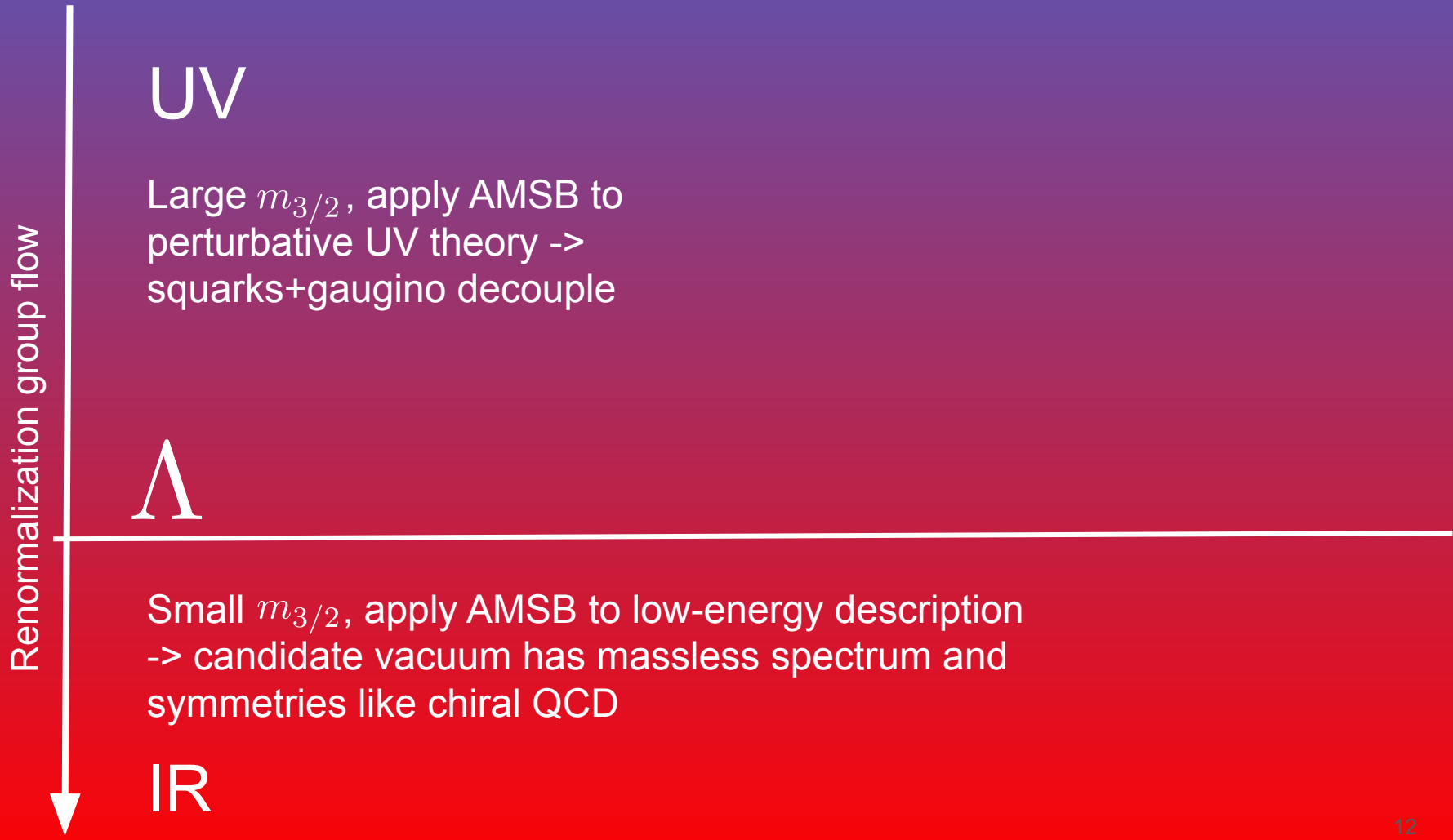
$$m_\lambda = \frac{-\beta(g)}{g} m_{3/2}$$

$$m_i^2 = \frac{-1}{4}\,\dot{\gamma}_i\,|m_{3/2}|^2$$

$$A_{ijk} = \frac{-1}{2}\,(\gamma_i + \gamma_j + \gamma_k)\,m_{3/2}$$

AMSB for non-SUSY gauge theory

- arXiv:2104.01179
- Hitoshi Murayama - Introduces AMSB to SQCD
- Many similar studies since.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Large $m_{3/2}$, apply AMSB to perturbative UV theory -> squarks+gaugino decouple
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Small $m_{3/2}$, apply AMSB to low-energy description -> candidate vacuum has massless spectrum and symmetries like chiral QCD
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$1,000,000 question:
Far IR at large SUSY-breaking

Phase transitions as $m_{3/2} \to \infty$

- arXiv: 211.11214
- Bai & Stolarski,
  Georgi-Glashow like SU(5)
  theory
- Phase transition guaranteed
  (t'Hooft anomaly matching)

Our project

- Seiberg Witten theory + AMSB
- arXiv:xxxx.xxxxx

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- Examine AMSB in a more controlled setting. What can we learn about the flow from small to large SUSY-breaking?

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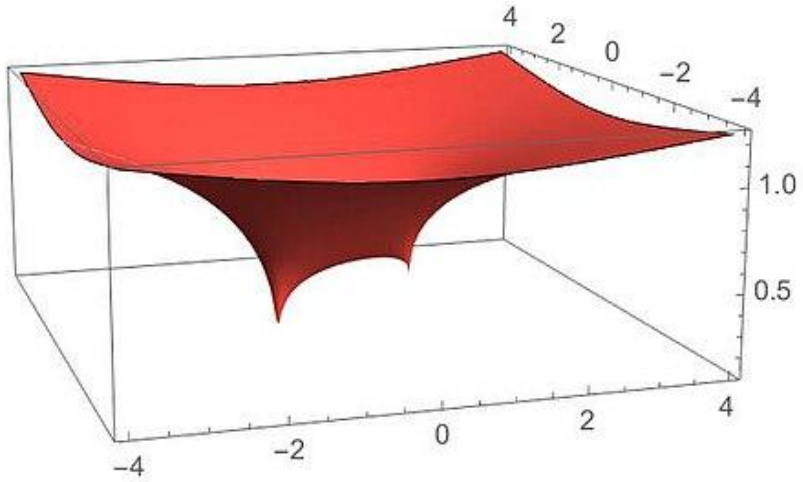
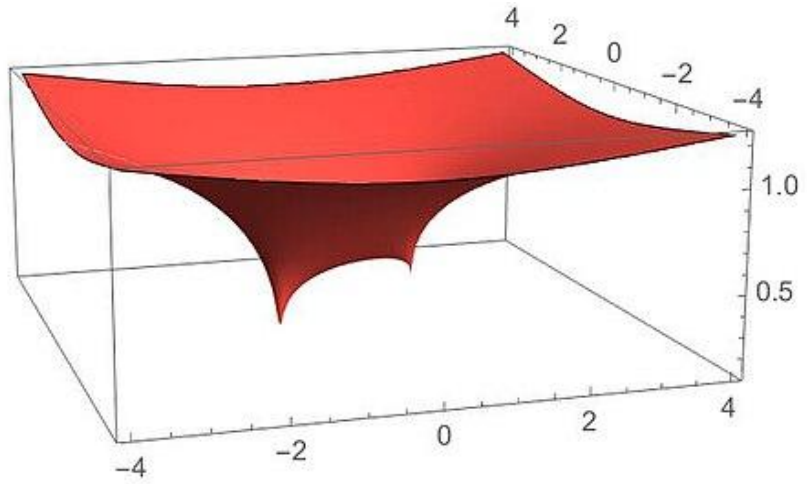
- Scalar potential -> VEV breaks $SU(2) \rightarrow U(1)$
- A moduli space of vacua (like goldstones, but space not symmetric)



Seiberg Witten theory

- Can exactly calculate metric



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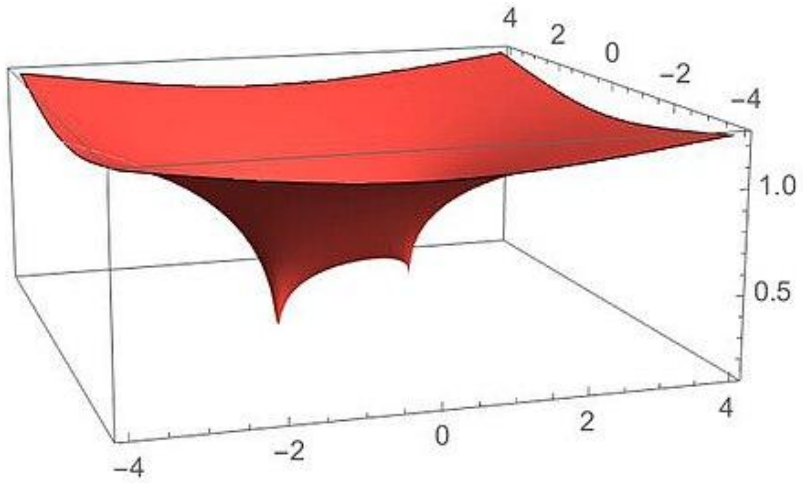

Seiberg Witten theory

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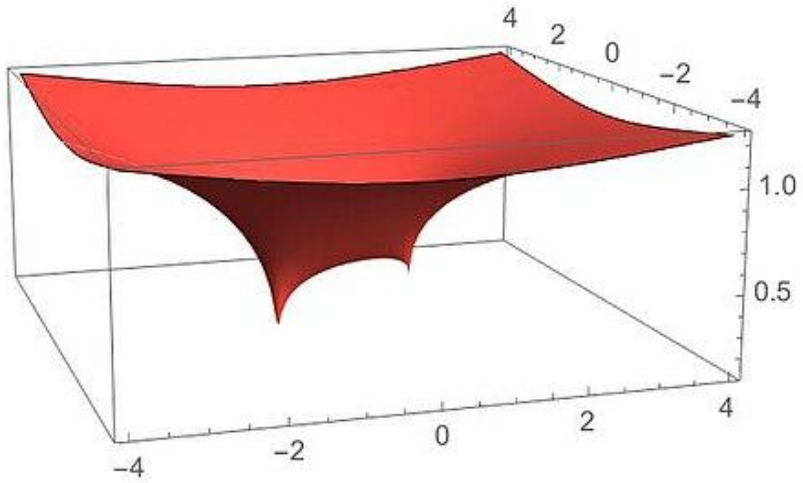
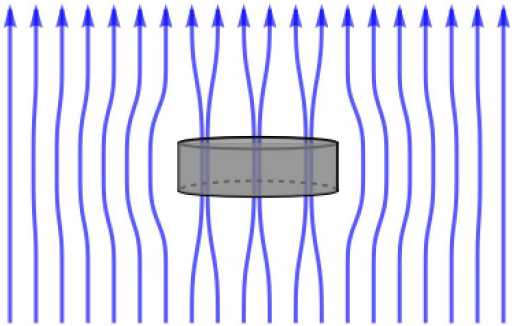
- Exact electromagnetic duality -> weakly coupled ‘elementary’ monopoles.



Seiberg Witten deformation

- N=1-preserving mass term
- Kills moduli space, but singularities survive



- Monopoles condense -> dual Meissner effect, confinement!!

AMSB + Seiberg Witten

- UV (large $m_{3/2}$) reproduces Seiberg Witten deformation in perturbation theory

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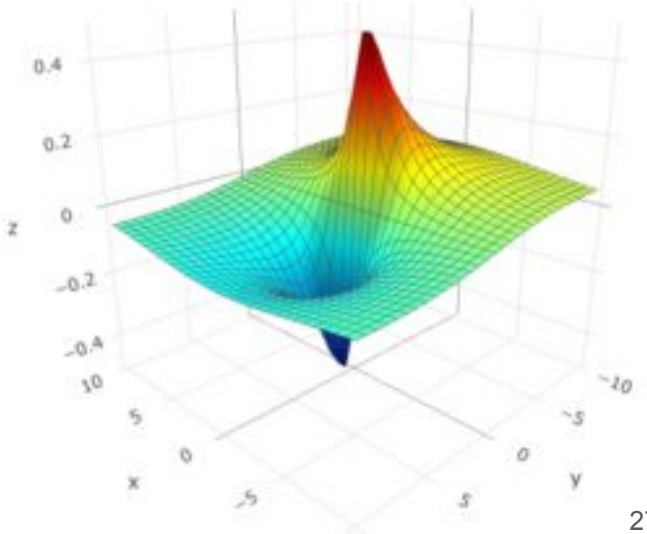
- UV (large $m_{3/2}$) reproduces Seiberg Witten deformation in perturbation theory
- IR is different! Coulomb branch still flows to singularities, and monopoles still condense. But SUSY is broken, condensate doesn’t match.

AMSB + Seiberg Witten

$$\beta = Ag^3 + B\exp(-\frac{8\pi^2}{g^2}) + \ldots$$

1 - loop

Instantons



AMSB mass-splitting -> all SUSY broken.

Renormalization group flow

UV

Large $m_{3/2}$ perturbative-> AMSB = Seiberg Witten

+Instantons =/= Seiberg Witten

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Renormalization group flow
AMSB->Seiberg Witten deformation
Flow of $m_{3/2}$
AMSB=/=Seiberg Witten deformation

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- Not a phase transition. Spectrum of massless particles and global symmetry breaking pattern do not change

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- But monopole condensate and spurious charge assignment do.

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- Regime involves interactions of mutually nonlocal degrees of freedom. No weakly coupled Lagrangian description.

A cautionary tale - hidden phase transitions?

- In this theory, there was no phase transition per se.
- But a VEV was altered, as were its spurious transformation properties.
- Easy to imagine this type of behaviour causing phase transitions

A cautionary tale - fictitious phase transitions?

- A global symmetry (N=1 supersymmetry) is broken at all $m_{3/2}$
- Invisible in UV perturbation theory, much clearer in IR.
- Could there be situations where nonperturbative breaking of a symmetry in UV makes e.g. anomaly matching arguments fail?

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- Valuable hints at how this all might work.
- Story for another time -> (chiral, super, conformal)
- Possibility of extending exact SUSY results to AMSB (nonperturbatively?)

Summary

- AMSB + SUSY = way to study non-SUSY
- Extrapolating from small to large SUSY breaking -> dangerous.
- We applied AMSB to Seiberg Witten
- Large AMSB = Seiberg Witten deformation + instanton corrections
- Small AMSB =\= Seiberg Witten deformation (but qualitatively similar)
- No phase transition, but change in VEV and spurion assignment
- Invisible in perturbation theory.
- Vague hints of potentially fruitful future lines of inquiry.