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1. THE AGT CORRESPONDENCE WITH SURFACE OPERATORS: 5/22/18

Today Shehper spoke about the AGT correspondence, following earlier lectures I wasn't in town for. The reference papers are [AGG⁺10] and [FGT16].

The AGT correspondence is a correspondence between

- the instanton partition function of a class-S field theory on a Riemann surface $\Sigma_{g,m}$ with gauge group a product of copies of SU_2 , and
- conformal blocks of Liouville theory on $\Sigma_{g,m}$.

This requires choosing a pair-of-pants decomposition of $\Sigma_{g,m}$.

This arises from a compactification of the A_1 (2, 0) 6D theory; the gauge group (specifically, the number of copies of SU_2) depends on the number of punctures and the genus in a way which can be seen from the Dynkin diagram. The 4D theory (i.e. the class-S theory) also has an SU_2^n flavor symmetry.

But today, we're going to focus on the AGT correspondence when surface operators are inserted. When you write down the 6D (2, 0) supersymmetry algebra, it has central charges that suggest the possibility of 2D and 4D defects. That is, instead of scalar central charges, which correspond to worldlines of particles, these central charges live in higher-dimensional representations of the Poincaré algebra. It will also be possible to introduce these defects in the 4D theory — there's no *a priori* reason to do it, just that it's possible and interesting. The 2D defect will be realized by an M5-M2 brane system, and the 4D defect by an M5-M5 brane system.

Since an Md -brane is a $(d + 1)$ -dimensional object, we can get a line operator in the 4D theory by taking the M2-brane to intersect C (in $C \times \mathbb{R}^4$, where the 6D theory is formulated) in a loop. Similarly, we can get a surface operator by having it intersect only at a single point; we'll call these operators of type A . For the 4D defects, have the two M5-branes intersect on $C \times \mathbb{R}^2 \subset C \times \mathbb{R}^4$; thus we obtain another kind of surface operator, called type B .

From string theory considerations that I'm not familiar with, one can deduce that type A operators correspond to type 2D-4D coupled systems, and type B operators to singularities in coupled fields.

- First, what's a 2D-4D coupled system? For concreteness, let's suppose the 4D theory is $\mathcal{N} = 2$ pure super-Yang-Mills, and suppose the surface operator $D \simeq \mathbb{R} \cdot \{x_0, x_1\} \subset \mathbb{R}^{1,3}$ (i.e. Minkowski space). Then, consider a 2D theory on D with flavor symmetry SU_2 ; the coupling is the idea that this is the same as the gauge symmetry in the bulk¹. Specifically, the "coupling" of the 2D-4D coupled system arises from adding a background connection for the 4D gauge group.

The boundary theory can be any theory which makes this work; since SU_2 acts on \mathbb{CP}^1 , we can take the σ -model with target \mathbb{CP}^1 on D , for example. There is a subtlety, though; you need to integrate out the x_2 - and x_3 -directions of the SU_2 -connection. Conceptually, this seems reasonable, but there are details that have to be justified: why is it that when you restrict the connection to D , you get the global SU_2 -symmetry of the boundary theory? Keep in mind that the SU_2 symmetry is a background symmetry, and is not gauged; for example, for the σ -model, the gauge group is U_1 .

¹There is a generalization where the flavor symmetry is replaced with another global symmetry.

- Next, the type B defects, which we claimed are singularities in 4D fields. Choosing $D = \text{span}_{\mathbb{R}}\{x_0, x_1\}$ again, let's introduce polar coordinates (r, θ) on $\text{span}_{\mathbb{R}}\{x_2, x_3\}$. If A is a connection of the form $A = \alpha d\theta + \dots$, then there will be a singularity at the origin, as

$$(1.1) \quad d\theta \sim \frac{1}{r} dx \pm \frac{1}{r} dy.$$

Explicitly, the curvature is a δ -function: $F = 2\pi\alpha\delta_D$.

If A is an SU_2 -gauge field, then we take $\alpha \in U_1$, for reasons which are unclear.

Our goal is to establish the AGT correspondence for both cases, and to understand if there's a relationship between the 4D theories with these two kinds of defects.

To do this, we'll have to modify the instanton partition function. For the type A defects, we'll take the 2D theory to be a σ -model with target \mathbb{CP}^1 . Therefore we want to consider maps $\phi: \mathbb{R}^2 \rightarrow \mathbb{CP}^1$ which vanish at infinity,² hence extend to maps from the one-point compactification: $\phi: S^2 \rightarrow \mathbb{CP}^1$ which are 0 at the basepoint. When we take homotopy classes, we get $[S^2, \mathbb{CP}^1] \cong \mathbb{Z}$, which sends a map to its degree $m \in H_2(\mathbb{CP}^1; \mathbb{Z}) \cong \mathbb{Z}$. Let $\mathcal{M}_{k,m}$ denote the moduli space of solutions (to the instanton equations?) with instanton number k in 4D and soliton number m in 2D.

This theory arises as the low-energy theory of a U_1 -gauge theory with two chiral superfields of type $\mathcal{N} = (2, 2)$ in 2D, and monopoles in the UV flow down to maps $S^1_{\infty} \rightarrow U_1$ with the prescribed winding number. It's stated in a somewhat different way in the physics, but the idea is to look at what happens to a large circle.

From this perspective, the correct instanton partition function is

$$(1.2) \quad Z = \sum_{k=0}^{\infty} \sum_{m \in \mathbb{Z}} q^k e^{itm} \int_{\mathcal{M}_{k,m}} \text{dvol}.$$

The surface operators are inserted at a point $z \in \Sigma$, and z is related to t in some way. t is called an *FI parameter*, and appears as a term in the action:

$$(1.3) \quad S_{\text{GLSM}} = \dots + \int d^2\tilde{\theta} (-tS).$$

This has something to do with a weakly coupled system, and when it flows to the IR, the M5-branes flow to just a single M5-brane wrapping around the Seiberg-Witten curve in \mathbb{R}^4 . This is not completely understood, but there is a lot of evidence for this argument.

The other side of the AGT correspondence, on conformal blocks of the Liouville theory, now has an insertion of a vertex operator $e^{-b/2\phi(z)}$ inserted. In this case the four-point function

$$(1.4) \quad \langle V_1(0)V_2(1)V_3(q)V_4(\infty) \rangle$$

is replaced with

$$(1.5) \quad \langle V_1(0)V_2(1)V_b(z)V_3(q)V_4(\infty) \rangle,$$

where $V_3(z) := e^{-b/2\phi(z)}$.

Now let's discuss what happens for the operators of type B . Suppose $A = \alpha d\theta + \dots$, so $F = 2\pi\alpha\delta_D + \dots$. Then $\oint F \in 2\pi\mathbb{Z}$, and the instanton partition function is

$$(1.6) \quad Z^{\text{inst}} := \sum_{m \in \mathbb{Z}} \sum_{k=0}^{\infty} q_1^k q_2^m \int_{\tilde{\mathcal{M}}_{k,m}} \text{dvol}.$$

There is a WZW model conformal field theory associated to the Kac-Moody algebra called affine \mathfrak{sl}_2 ; the AGT correspondence says that the instanton partition function should correspond to conformal blocks of this CFT. There are a bunch of subtleties going into this.

Anyways, we now have two kinds of surface defects, and get AGT correspondences with two different CFTs. One can ask whether these CFTs are related, or dually, whether these 4D theories are related.

The answer is yes: if $Z^{\text{WZW}}(x, \tau)$ denotes the WZW conformal block, where $x \in \text{Bun}_{SU_2}(\Sigma)$ and $\tau \in \mathbb{H}$, and Z^L denotes the Liouville conformal block, then

$$(1.7) \quad Z^{\text{WZW}}(x, \tau) = \int du \kappa(x, y) Z^L(u, \tau).$$

²Or more accurately, which have a finite limit at infinity.

This is an example of separation of variables! See the referenced papers for details; since conformal blocks are mathematically understood, there's a good chance this is rigorously proven!

For the relations between the 4D theories, we can rewrite the instanton partition function in terms of an *effective twisted superpotential* \tilde{W} :

$$(1.8) \quad Z^{\text{inst}} = \exp\left(-\frac{F}{\epsilon_1 \epsilon_2} - \frac{\tilde{W}}{\epsilon_1} + \dots\right).$$

For the two theories we have two superpotentials \tilde{W}^L and \tilde{W}^{WZW} , and they're related by

$$(1.9) \quad \tilde{W}^{\text{WZW}}(a, u, \tau) = \tilde{W}^L(a, u, \tau) + \tilde{W}^{\text{SOV}}(x, u, \tau).$$

In the IR, these two describe the same physics, hence one says they have IR duality.

2. DIFFERENTIAL COHOMOLOGY AND GERBES VIA ČECH COHOMOLOGY: 6/1/18

Today, Ivan spoke about differential cohomology and gerbes from as concrete of a perspective as possible, following Hitchin [Hit99]; then he talked about higher abelian gauge theory and examples, including the usual Maxwell theory. If time permits, we'll also see U_1 -gerbes with connection, which appear in the next nontrivial example.

Let M be a smooth n -manifold, and for $p \geq 0$ let $C_p(M)$ denote the abelian group of *singular p -chains*, i.e. the free abelian group on the set of smooth maps $\Delta^p \rightarrow M$, where Δ^p is the p -simplex. That is, a singular p -chain is a finite linear combination of such maps, where the coefficients are integers.³ There's a boundary map $\partial: C_p(M) \rightarrow C_{p-1}(M)$; the kernel of this map is called the space of p -cycles and denoted $Z_p(M)$.

Definition 2.1. For $p \geq 1$, the p^{th} Cheeger-Simons differential cohomology group, denoted $\check{H}^p(M)$, is the subgroup $\chi \in \text{Hom}_{\text{Ab}}(Z_{p-1}(M), U_1)$ such that there is an $\omega \in \Omega^p(M)$ such that for all $\sigma \in C_p(M)$,

$$\chi(\partial\sigma) = \exp\left(i \int_{\sigma} \omega\right).$$

We'll see that ω is uniquely determined from χ ; if χ is a field, ω will represent its field strength, and hence will sometimes also be denoted F_{χ} . Here are a few other nice facts coming from this definition: ω is in fact a closed p -form, and has integer periods, meaning $i \int_{\sigma} \omega \in 2\pi\mathbb{Z}$ for all cycles σ . The abelian group of p -forms with integral periods is denoted $\Omega_{\mathbb{Z}}^p(M)$; de Rham cohomology with these forms recovers the torsion-free part of $H^*(M; \mathbb{Z})$.

The map $F: \chi \mapsto (1/2\pi)F_{\chi}$ is a linear map $F: \check{H}^p(M) \rightarrow \Omega_{\mathbb{Z}}^p(M)$. There's also a *characteristic class map* $c: \check{H}^p(M) \rightarrow H^p(M; \mathbb{Z})$ sending $\chi \mapsto (1/2\pi)[F_{\chi}]$, much like the first Chern class.

$\check{H}^p(M)$ is uniquely characterized as the group that fits into the following short exact sequences.

$$(2.2a) \quad 0 \longrightarrow H^{p-1}(M; U_1) \xrightarrow{i_1} \check{H}^p(M) \xrightarrow{F} \Omega_{\mathbb{Z}}^p(M) \longrightarrow 0$$

$$(2.2b) \quad 0 \longrightarrow \Omega^p(M)/\Omega_{\mathbb{Z}}^{p-1}(M) \xrightarrow{i_2} \check{H}^p(M) \xrightarrow{c} H^p(M; \mathbb{Z}) \longrightarrow 0.$$

This means that if you come up with a group which admits injective maps as in (2.2a) and (2.2b), with the same quotients, then it must be $\check{H}^p(M)$. We're going to use this to identify $\check{H}^p(M)$ in a higher gauge theory.

Remark 2.3. There is a description of differential cohomology in terms of a cochain complex, but it's much more complicated (involving hypercohomology of a complex of sheaves), which is why it was left out. ◀

Anyways, physics!

Definition 2.4. A *higher abelian gauge theory* is a field theory in the classical sense (so, fields and equations of motion), and in particular a U_1 -gauge theory whose gauge equivalence classes of fields are $\check{H}^p(M)$ for some p specific to the theory.

Example 2.5. The first interesting example is when $p = 2$. We claim that $\check{H}^2(M)$ is in bijection (natural with respect to pullback) with the set of equivalence classes of principal U_1 -bundles on M with connection A (which is the electromagnetic potential of the theory), which is in bijection with the set of equivalence classes of Hermitian line bundles on M with connection ∇ .

³The p -simplex is not a manifold; by a smooth map we mean a map from the p -simplex which extends to a smooth map of a neighborhood of the p -simplex in \mathbb{R}^p .

Let $\text{Pic}_\nabla(M)$ denote the abelian group of isomorphism classes of Hermitian line bundles L on M with connection ∇ . Then there are maps $F: \text{Pic}_\nabla(M) \rightarrow \Omega_{\mathbb{Z}}^2(M)$ sending $F(L, \nabla) \mapsto F_\nabla$, and $c: \text{Pic}_\nabla(M) \rightarrow H^2(M; \mathbb{Z})$ sending $(L, \nabla) \mapsto c_1(L)$.

These will be the maps in (2.2); now we need to define i_1 and i_2 . The former is “the holonomy map of a flat connection,” which sounds nonsensical but has meaning. Namely, $H^1(M; U_1) \cong \text{Hom}(H_1(M); U_1)$ by the universal coefficient theorem, and the monodromy map of a flat connection gives you something in $\text{Hom}(H_1(M), U_1)$.⁴ Conversely, if $P \in \text{Hom}(H_1(M); U_1)$, one can construct a line bundle $L \rightarrow M$ and a connection ∇ for L with $F_\nabla = 0$, and whose monodromy map is P . Therefore if you replace $\check{H}^2(M)$ with $\text{Pic}_\nabla(M)$, (2.2a) is exact.

For (2.2b), the argument is similar: if you’re in $\ker(c)$, the first Chern class of L is trivial, so L is trivial. Therefore up to gauge equivalence, ∇ can be represented by $d + A$ for some one-form $A \in \Omega^1(M; i\mathbb{R})$. Thus if $[A] \in \Omega^1(M)/\Omega_{\mathbb{Z}}^1(M)$, then $i_2([A]) := [\mathbb{C}, d + A]$. The quotient is needed for i_2 to be injective: up to gauge, monodromy suffices to distinguish line bundles, and integral periods aren’t seen by this. Thus (2.2b) is exact when $\text{Pic}_\nabla(M)$ replaces $\check{H}^2(M)$.

Therefore $\check{H}^2(M) = \text{Pic}_\nabla(M)$. ◀

Example 2.6. The $p = 1$ case is less interesting: $\check{H}^1(M) \cong \Omega^0(M; U_1)$. You can prove this in a similar way, showing that $\Omega^-(M; U_1)$ fits into (2.2a) and (2.2b). In this case, F measures whether the function is locally constant, and c measures whether the function lifts to an \mathbb{R} -valued function. Explicitly, a $\chi \in \check{H}^1(M)$ is a homomorphism $Z_0(M) \rightarrow U_1$, hence defines a map $\bar{\chi}: M \rightarrow U_1$. Then one has $d\bar{\chi} = i\bar{\chi}F_{\bar{\chi}}$, which allows us to define F , and $c\bar{\chi} = \chi^*[d\theta]$, where $d\theta \in \Omega^1(S^1)$ is the usual generator. One has to check that this all works out, of course. ◀

When $p = 3$, we get something new, a higher abelian gauge theory. Explicitly, $\check{H}^3(M)$ will be isomorphic to the set of equivalence classes of U_1 -gerbes with connection over M . We’re going to define what these things are, and what F and c are, from a Čech cohomology viewpoint.

Fix a good cover \mathcal{U} of M indexed by an ordered set J .

Definition 2.7. The Čech p -cochain group $C^p(\mathcal{U}; U_1)$ is the abelian group of sets of collections of smooth maps

$$g_{\alpha_1 \dots \alpha_{p+1}}: U_{\alpha_1} \cap \dots \cap U_{\alpha_{p+1}} \rightarrow U_1$$

indexed over all $(p + 1)$ -fold intersections in \mathcal{U} ; the group structure is pointwise multiplication.

There is a coboundary operator $\delta: C^p(\mathcal{U}; U_1) \rightarrow C^{p+1}(\mathcal{U}; U_1)$: if $g = \{g_{\alpha_1 \dots \alpha_{p+1}}\}$, then

$$(2.8) \quad (\delta g)_{\alpha_1 \dots \alpha_{p+2}} = \prod_{i=1}^{p+2} g_{\alpha_1 \dots \hat{\alpha}_i \dots \alpha_{p+2}}^{(-1)^i},$$

If we were using additive notation (e.g. with a target \mathbb{R} instead of U_1) then this is take the alternating sum of evaluating g on the $(p + 1)$ -fold intersection where $U_{\alpha_{p_i}}$ is removed.

Then we proceed as usual: a Čech cocycle is a cochain with $\delta g = 1$, and a Čech coboundary is a cocycle in the image of δ . Then the p^{th} Čech cohomology group is the group of cocycles modulo coboundaries, and is denoted $H^p(M; C^\infty(U_1))$.⁵

When $p = 0$, 0-cocycles are locally constant functions, because given a cocycle $f: U_\alpha \rightarrow U_1$, $(\delta f)_{\alpha\beta} = f_\alpha f_\beta^{-1}$, so we can glue f_α and f_β . Therefore $H^0(M; U_1) = \Omega^0(M, U_1)$.

A 1-cocycle is a collection of maps $g = \{g_{\alpha\beta}\}$, where $g_{\alpha\beta}: U_\alpha \cap U_\beta \rightarrow U_1$, subject to the condition $1 = (\delta g)_{\alpha\beta\gamma} = g_{\alpha\beta}g_{\beta\gamma}g_{\alpha\gamma}^{-1}$. This is the cocycle condition for the transition functions for a line bundle, and since they land in U_1 , this is a Hermitian line bundle. Therefore a Čech 1-cocycle determines a Hermitian line bundle. If you mod out by coboundaries, you recover equivalence classes of Hermitian line bundles.

The next step, $p = 2$, will have to do with gerbes. There are various other definitions of gerbes, such as those involving sheaves of categories, but using Čech cohomology will make it easier for us to work with them.

Definition 2.9. A U_1 -gerbe on a manifold M , denoted $\mathcal{G} \rightarrow M$, is a class in $H^2(M; C^\infty(U_1))$.

That is, it’s defined to be a collection of smooth functions $g_{\alpha\beta\gamma}: U_\alpha \cap U_\beta \cap U_\gamma \rightarrow U_1$ such that

$$(2.10) \quad (\delta g)_{\alpha\beta\gamma\delta} := g_{\beta\gamma\delta}g_{\alpha\gamma\delta}^{-1}g_{\alpha\beta\delta}g_{\alpha\beta\gamma}^{-1} = 1.$$

⁴Normally, you would consider maps $\pi_1(M) \rightarrow U_1$, but since U_1 is abelian, this factors through the abelianization of $\pi_1(M)$, which is $H_1(M)$.

⁵As the notation might suggest, Čech cohomology can be described more generally, with coefficients in a *sheaf* of abelian groups. Our notation comes from this perspective, but ultimately we won’t need to worry about that level of generality.

Remark 2.11. You might be uncomfortable requiring a choice of cover, but this is just like defining smooth functions on a smooth manifold: when making a definition, you use the maximal atlas of a manifold for the sake of avoiding choices, but when computing with stuff, you choose some atlas with only a few charts. \blacktriangleleft

Next we'll define the trivialization of a gerbe, again by analogy with the Čech perspective on line bundles. Suppose f is a trivialization of a line bundle. Then, it's equivalent data to a section, which we can specify by functions $f_\alpha: U_\alpha \rightarrow U_1$ for all $\alpha \in J$ together with transition functions $g_{\alpha\beta}: U_\alpha \cap U_\beta \rightarrow U_1$ such that $\{g_{\alpha\beta}\}$ is a Čech coboundary. In particular, given two trivializations f and f' , there's a global function $h: U_\alpha \cup U_\beta \rightarrow U_1$ which is f_α/f'_α on U_α and f_β/f'_β on U_β , because on $U_\alpha \cap U_\beta$, $f_\alpha/f'_\alpha = f_\beta/f'_\beta$: the two trivializations are related by something in $\Omega^0(U_1 \cup U_2, U_1)$. So the point is: trivializations realize $g_{\alpha\beta}$ as a coboundary in $U_1 \cup U_2$.

For gerbes, we'll do this one level up.

Definition 2.12. Let $\mathcal{G} = \{g_{\alpha\beta\gamma}\}$ be a U_1 -gerbe. A *trivialization* of \mathcal{G} over $U_\alpha \cup U_\beta \cup U_\gamma$ is a representation of $\{g_{\alpha\beta\gamma}\}$ as a coboundary in $U_\alpha \cup U_\beta \cup U_\gamma$, i.e. a choice of $\{f_{\alpha\beta}, f_{\beta\gamma}, f_{\gamma\alpha}\}$ such that

$$g_{\alpha\beta\gamma} = f_{\beta\gamma} f_{\alpha\beta} f_{\gamma\alpha}.$$

Two trivializations f and f' over $U_\alpha \cup U_\beta \cup U_\gamma$ are related by a line bundle: let $h_{\alpha\beta} := f_{\alpha\beta}/f'_{\alpha\beta}$, and define $h_{\beta\gamma}$ and $h_{\gamma\alpha}$ similarly. Then since $g = \delta f = \delta f'$, then

$$(2.13) \quad h_{\alpha\beta} h_{\beta\gamma} h_{\gamma\alpha} = 1,$$

so these are the transition functions for a Hermitian line bundle on $U_\alpha \cup U_\beta \cup U_\gamma$.

Remark 2.14. There is a notion of “higher gerbes:” the next step up represents elements of $H^3(M; C^\infty(U_1))$, and a two trivializations of such a higher gerbe are related by a gerbe. These correspond to 2-form U_1 -symmetries. \blacktriangleleft

Now we'll talk about connections on gerbes. Again we'll start by seeing how to realize connections on line bundles from the Čech perspective. Specifically, if L is a line bundle with connection ∇ and transition functions $g_{\alpha\beta}$, then $\nabla|_{U_\alpha} = d + A_\alpha$ for some 1-form A_α , and the cocycle condition forces

$$(2.15) \quad A_\alpha = A_\beta + g_{\alpha\beta}^{-1} dg_{\alpha\beta}$$

on $U_\alpha \cap U_\beta$. Then, the curvature is just $F|_{U_\alpha} = dA_\alpha$. By Chern-Weil theory, $F/2\pi i$ has integer periods; conversely, any closed 2-form F such that $F/2\pi i$ has integer periods is the curvature of some connection; you can choose A_α such that $dA_\alpha = F|_{U_\alpha \cap U_\beta}$, and then check the transition functions.

Now we'll do this for gerbes. Everything is shifted up one, so a connection is locally a 2-form whose curvature is a 3-form. Let $G \in \Omega^3(M; i\mathbb{R})$ with $dG = 0$ and $(1/2\pi)G \in \Omega^3_{\mathbb{Z}}(M; i\mathbb{R})$, which we'll think of as the curvature. Locally we can choose $F_\alpha \in \Omega^2(U_\alpha, i\mathbb{R})$ with $G|_{U_\alpha} = dF_\alpha$ such that $F_\alpha - F_\beta = dA_{\alpha\beta}$ for $A_{\alpha\beta} \in \Omega^1(U_\alpha \cap U_\beta, i\mathbb{R})$ such that on triple intersections,

$$(2.16) \quad A_{\alpha\beta} + A_{\beta\gamma} - A_{\alpha\gamma} = df_{\alpha\beta\gamma}$$

for some $f_{\alpha\beta\gamma} \in \Omega^0(U_\alpha \cap U_\beta \cap U_\gamma, i\mathbb{R})$, and this defines a cocycle which is a gerbe. Then $A = \{A_{\alpha\beta}\}$ defines its connection.

The analogues of the maps in (2.2a) and (2.2b) are the map $F: \check{H}^3(M) \rightarrow \Omega^3_{\mathbb{Z}}(M)$ sending a gerbe to $1/2\pi$ times its curvature, and $c: \check{H}^3(M) \rightarrow H^3(M; \mathbb{Z})$ sending a gerbe to $1/2\pi$ times the equivalence class of its connection.

REFERENCES

- [AGG⁺10] Luis F. Alday, Davide Gaiotto, Sergei Gukov, Yuji Tachikawa, and Herman Verlinde. Loop and surface operators in $\mathcal{N} = 2$ gauge theory and Liouville modular geometry. *Journal of High Energy Physics*, 2010(1):113, Jan 2010. <https://arxiv.org/pdf/0909.0945.pdf>. 1
- [FGT16] Edward Frenkel, Sergei Gukov, and Jörg Teschner. Surface operators and separation of variables. *Journal of High Energy Physics*, 2016(1):179, Jan 2016. <https://arxiv.org/pdf/1506.07508.pdf>. 1
- [Hit99] Nigel Hitchin. Lectures on special Lagrangian submanifolds. 1999. <https://arxiv.org/pdf/math/9907034.pdf>. 3