

## A SHORT DESCRIPTION OF [\[ACLLa\]](#)

As a complex manifold, a genus-2 curve  $\Theta_\tau$  is a hypersurface in its Jacobian variety  $V_\tau$ , which is a principally polarized abelian surface. The parameter  $\tau$  is an element of the genus-2 Siegel space

$$(0.1) \quad \mathcal{H}_2 := \{\tau = B + i\Omega \text{ a } 2 \times 2 \text{ complex matrix : } \tau \text{ symmetric, } \Omega \text{ positive definite}\},$$

which is the moduli space of 2-dimensional principally polarized abelian varieties with Torelli structure (i.e. a choice of integral symplectic basis). In other words, we can describe  $\Theta_\tau \subset V_\tau = (\mathbb{C}^*)^2 / \tau \mathbb{Z}^2$  as the image of the hypersurface

$$(0.2) \quad \tilde{\Theta}_\tau = \left\{ \vartheta(\tau, x) = \sum_{m=(m_1, m_2) \in \mathbb{Z}^2} x_1^{m_1} x_2^{m_2} e^{\pi i n^T \tau n} = 0 \right\} \subset (\mathbb{C}^*)^2$$

under the covering map  $(\mathbb{C}^*)^2 \rightarrow V_\tau = (\mathbb{C}^*)^2 / \tau \mathbb{Z}^2$ , where  $\tau \mathbb{Z}^2$  acts multiplicatively on  $(\mathbb{C}^*)^2$ . In the above formula,  $\vartheta : \mathcal{H}_2 \times (\mathbb{C}^*)^2 \rightarrow \mathbb{C}$  is the Riemann theta function.

In her thesis, Cannizzo [\[Can20\]](#) proved a HMS result for genus two curves and their candidate mirrors constructed by [\[AAK16\]](#) in a generalized SYZ [\[SYZ96\]](#) mirror symmetry framework. The mirror to a genus two complex curve  $\Theta_\tau$  is a Landau-Ginzburg model  $(Y_\tau, W)$ , where  $Y_\tau$  is a 6-dimensional symplectic manifold that is a locally toric Calabi-Yau 3-fold, and  $W : Y_\tau \rightarrow \mathbb{C}$  is a symplectic fibration with a singular fiber above  $0 \in \mathbb{C}$ . See [Figure 1](#) for a description of this fibration. In the singular fiber, the critical locus is a “banana” configuration of three 2-spheres. Note that in a Lefschetz fibration for which Fukaya-Seidel category was first constructed, the critical locus consists of points, so the critical locus in this example is more complicated. This work by [\[Can20\]](#) is the first construction and computation of a Fukaya-Seidel category for a non-exact, non-monotone, and non-Lefschetz symplectic fibration, using some of the ideas from [\[AA\]](#).

The Kähler form on  $Y_\tau$  constructed in [\[Can20\]](#) requires that the three spheres in the critical locus to all have the same symplectic area. This one area parameter gives rise to a 1-parameter family of symplectic structures which is mirror to a 1-parameter family of complex genus-2 curves, i.e. the family where  $\tau = \frac{i}{2\pi} \log t \begin{pmatrix} 2 & 1 \\ 1 & 2 \end{pmatrix}$  with  $t > 0$  large. In [\[ACLLa\]](#), we extend this construction to prove a global HMS result that covers the 3 complex dimensional moduli space  $\mathcal{H}_2$  of complex structures on the genus-2 curve. Below are the two main ingredients of [\[ACLLa\]](#) that are not present in [\[Can20\]](#).

- (1) We need to use more general Kähler structures on  $Y_\tau$  where the areas of the three 2-spheres in the critical locus may vary independently instead of all being the same, as well as doing Floer theory computations with these symplectic structures.
- (2) The complex moduli space  $\mathcal{H}_2$  and the global Kähler moduli space of the mirror should match, however the global stringy Kähler moduli space cannot be covered by a single Kähler cone in this case, so we need to describe how it is glued from the individual Kähler cones and how the structure maps of the Fukaya-Seidel category changes through the transitions.

Below we discuss these two points in a bit more detail.

When the symplectic areas  $A_j$ ,  $j = 1, 2, 3$ , of the three spheres can vary independently, they give rise to a 3-parameter space of symplectic structures on  $Y_\tau$ , which via mirror symmetry corresponds to a 3-parameter space of  $\Omega = \text{Im } \tau$ 's in  $\mathcal{H}_2$ . (The other 3 parameters of  $B = \text{Re } \tau$ 's in  $\mathcal{H}_2$  correspond to what is known as the  $B$ -fields, which complexify the symplectic structure and play a role in the Floer theory for  $(Y_\tau, W)$ . We also incorporate these in [\[ACLLa\]](#).) The hexagon drawn in [Figure 1](#) is a representative example of what the moment polytope of the singular fiber looks like when

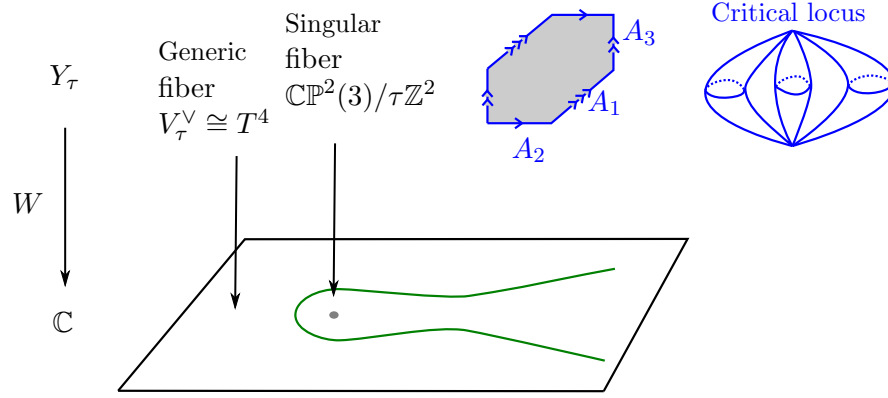


FIGURE 1. The symplectic fibration  $W : Y_\tau \rightarrow \mathbb{C}$ . Each generic fiber is a 4-torus isomorphic to the mirror  $V_\tau^\vee$  of  $V_\tau$ . The singular fiber above  $0 \in \mathbb{C}$  is a blow-up of  $\mathbb{CP}^2$  at 3 points, quotiented by  $\tau\mathbb{Z}^2$ . The moment polytope for  $\mathbb{CP}^2(3)$  is a hexagon and the quotient by  $\tau\mathbb{Z}^2$  is depicted as having the edges of the hexagon identified as shown in the figure. The critical locus corresponds to the boundary of the hexagon, drawn in blue, which is a union of three line segments with ends identified. This is the moment polytope for a “banana” configuration of three spheres as depicted in the picture of the critical locus, where each edge of the hexagon is the moment polytope for one sphere. The symplectic areas,  $A_1$ ,  $A_2$ , and  $A_3$ , of these spheres are labelled next to their respective moment polytopes. The Lagrangian objects in  $Y_\tau$  that we consider are of the form  $\cup \ell$ , which is the Lagrangian obtained by parallel transport of a Lagrangian  $\ell$  in the fiber  $T^4$  above  $-\epsilon \in \mathbb{C}$  along the  $U$ -shaped curved in the base drawn in green.

$\Omega_{12} = \Omega_{21} > 0$ ,  $\Omega_{11} - \Omega_{12} > 0$ , and  $\Omega_{22} - \Omega_{12} > 0$ . In this case, we have the identification

$$(0.3) \quad \begin{pmatrix} \Omega_{11} & \Omega_{12} \\ \Omega_{21} & \Omega_{22} \end{pmatrix} = \begin{pmatrix} A_1 + A_2 & A_1 \\ A_1 & A_1 + A_3 \end{pmatrix} \iff \begin{aligned} A_1 &= \Omega_{12} = \Omega_{21} \\ A_2 &= \Omega_{11} - \Omega_{12} \\ A_3 &= \Omega_{21} - \Omega_{12} \end{aligned}.$$

From this identification, one can see that simply varying the symplectic areas will not completely cover all the possible  $\Omega$ 's to give us a global correspondence with the complex moduli space. It'll only cover the part where the areas  $A_j > 0$  for  $j = 1, 2, 3$ . As  $A_j \rightarrow 0$  for example, we go through transitions known as Atiyah flops into different chambers of the moduli space where hexagons change shapes by actions of  $\text{GL}(2, \mathbb{Z})$ . Formally,  $\text{GL}(2, \mathbb{Z})$  acts on the tropical Siegel space (i.e. the space of  $\Omega$ 's), which is the moduli space of principally polarized tropical abelian varieties with Torelli structure; this was defined and studied in [CMV13, Cha12].

In fact, by writing

$$(0.4) \quad \Omega = \begin{bmatrix} \Omega_{11} & \Omega_{12} \\ \Omega_{21} & \Omega_{22} \end{bmatrix} = \begin{bmatrix} z + y & x \\ x & z - y \end{bmatrix},$$

we can identify the space of positive definite real symmetric  $2 \times 2$  matrices with

$$(0.5) \quad C = \{(x, y, z) \in \mathbb{R}^3 \mid z > \sqrt{x^2 + y^2}\},$$

which is a cone over  $C' \times \{1\} \subset \mathbb{R}^3$ , where  $C' \subset \mathbb{R}^2$  is the open unit disk centered at the origin:

$$(0.6) \quad C' = \{(x, y) \in \mathbb{R}^2 \mid x^2 + y^2 < 1\}.$$

Indeed, this space cannot be covered by a single top-dimensional Kähler cone, which we call a chamber. Each chamber is in fact a cone over a triangular region in  $C'$ . There are infinitely many of them and their corresponding triangles form a triangulation of the disk  $C'$ . All of them are in the same  $\mathrm{GL}(2, \mathbb{Z})$  orbit. Figure 2 shows 6 different chambers and how they fit together.

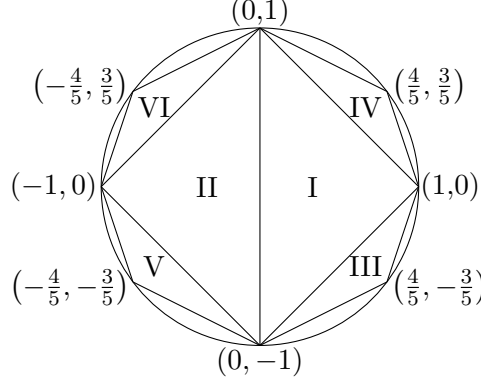


FIGURE 2. The open disk  $C'$  and six different chambers, I-VI. There are actually infinitely many chambers that form a triangulation of the disk.

The manifold  $Y_\tau$  can be described as  $\tilde{Y}'_\tau / \tau \mathbb{Z}^2$ , where  $\tilde{Y}_\tau$  is a toric variety of infinite type (i.e. its moment polyhedron has infinitely many facets) and  $\tilde{Y}'_\tau \subset \tilde{Y}_\tau$  is a small neighborhood of the singular fiber. We use the construction by [KL19] (based on the finite type construction of [Gui94]) for the Kähler structure on  $\tilde{Y}_\tau$ , which descends to a Kähler structure on the quotient  $Y_\tau$ . Then we write the superpotential  $W : Y_\tau \rightarrow \mathbb{C}$  in terms of the action-angle coordinates on  $Y_\tau$  to do computations such as studying the monodromy of a fiber around a circle in the base enclosing the critical point. The monodromy computation is needed for computing the differentials in the Floer theory for  $(Y_\tau, W)$ .

The precise concluding HMS statement is the completion of the following commutative diagram, with [Can20] proving it for a 1-parameter family of  $\tau$ 's and [ACLLa] proving it for all  $\tau \in \mathcal{H}_2$ ,

$$(0.7) \quad \begin{array}{ccc} D_{\mathcal{L}}^b \mathrm{Coh}(V_\tau) & \xrightarrow{\iota^*} & D_{\mathcal{L}}^b \mathrm{Coh}(\Theta_\tau) \\ \text{[Fuk02]} \downarrow & & \downarrow \text{[Can20, ACLLa]} \\ H^0(\mathrm{Fuk}(V_\tau^\vee)) & \xrightarrow{\cup} & H^0(FS(Y_\tau, W)) \end{array} .$$

The vertical maps are fully-faithful embeddings. The  $B$ -model  $D_{\mathcal{L}}^b \mathrm{Coh}(\Theta_\tau)$  is a full subcategory of the bounded derived category of coherent sheaves generated by powers of an ample line bundle  $\mathcal{L}$  on the genus-2 two curve  $\Theta_\tau$ . The  $A$ -model is the cohomological Fukaya-Seidel category  $FS(Y_\tau, W)$ . The left vertical arrow in this diagram is HMS for abelian varieties due to Fukaya [Fuk02]. The top arrow is the restriction functor given by the pullback of the inclusion  $\iota : \Theta_\tau \rightarrow V_\tau$ . The bottom  $\cup$  operator is given by parallel-transporting Lagrangian objects in the fiber  $V_\tau^\vee$  along a  $U$ -shaped curve in the base of  $W$  (the green curve in Figure 1) to obtain Lagrangian objects in  $Y_\tau$ .

For a hypersurface that is a theta divisor

$$(0.8) \quad \Theta_\tau = \left\{ \vartheta(\tau, x) = \sum_{m \in \mathbb{Z}^g} \prod_{j=1}^g x_j^{m_j} e^{\pi i n^T \tau n} = 0 \right\} \subset V_\tau = (\mathbb{C}^*)^g / \tau \mathbb{Z}^g$$

in a principally polarized abelian variety  $V_\tau$  of any dimension  $g \geq 2$ , where  $\tau$  is an element of the genus- $g$  Siegel upper half space  $\mathcal{H}_g$ , we will establish the right vertical map in (0.7) and show that

the diagram commutes in [ACLLb] for this higher dimensional generalization. In this case, the mirror manifold  $Y_\tau$  is a toric Calabi-Yau  $(g+1)$ -fold.

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