

PARTIAL SYMPLECTIC RESOLUTIONS OF THE NILPOTENT CONE VIA HAMILTONIAN REDUCTION - TALK NOTES

TOM GANNON

The main theorem I'm going to present today is joint with Gwyn Bellamy.

0.1. Notation and Setup. Let G be a complex reductive group, and $\mathfrak{g}$ denote its Lie algebra. Our running example will be $G = \mathrm{GL}_n$ which acts on the vector space of $n \times n$ matrices $\mathfrak{gl}_n$ by conjugation. Let's recall the following Proposition, in part to set notation:

Proposition 0.1. A given $M \in \mathfrak{gl}_n$ is nilpotent (as a matrix) if and only if its image under the GIT quotient map $\mathfrak{gl}_n \rightarrow \mathfrak{gl}_n // \mathrm{GL}_n := \mathrm{Spec}(\mathrm{Fun}(\mathfrak{gl}_n)^{\mathrm{GL}_n})$ is the same as the image of the zero matrix.

Definition 0.2. The *nilpotent cone* $\mathcal{N}_{\mathfrak{g}}$ of $\mathfrak{g}$ is the scheme theoretic product $\mathcal{N}_{\mathfrak{g}} := \mathfrak{g} \times_{\mathfrak{g} // G} \{0\}$.

Example 0.3. It's an elementary exercise to show that a 2×2 matrix is nilpotent if and only if its trace and determinant vanish. Therefore

$$\mathcal{N}_{\mathfrak{gl}_2} \cong \left\{ \begin{pmatrix} a & b \\ c & d \end{pmatrix} : a + d = 0 = ad - bc \right\}.$$

Choose a Borel subgroup B , let $U := [B, B]$ denote its unipotent radical, and let T denote a maximal torus of B . Let $\mathfrak{b}, \mathfrak{u}, \mathfrak{t}$ denote their corresponding Lie algebras. The following result is due to Springer:

Theorem 0.4. [Spr69] The adjoint action map $G \times^B \mathfrak{u} \rightarrow \mathcal{N}_{\mathfrak{g}}$ from the balanced product (i.e. $(gb, t) \sim (g, b \cdot t)$) is a *resolution of singularities*, that is, a projective morphism from a smooth variety which is an isomorphism over the smooth locus of the codomain.

0.2. Hikita Conjecture for the Nilpotent Cone. We call the map in Theorem 0.4 the *Springer resolution*. A fundamental observation in the field is that the Springer resolution (in particular, its domain and codomain) admit an interpretation in terms of symplectic geometry. As a first hint of this, once we choose a G -invariant isomorphism $\mathfrak{g} \xrightarrow{\sim} \mathfrak{g}^*$ of vector spaces, we can identify

$$G \times^B \mathfrak{u} \cong G \times^B (\mathfrak{g}/\mathfrak{b})^* \cong T^*(G/B)$$

which obviously has a symplectic form. Since techniques in symplectic geometry can be useful and we saw that working with the dual Lie algebra aligns more closely with symplectic geometry, we hereafter work with the *dual nilpotent cone* $\mathcal{N}_{\mathfrak{g}^*} := \mathfrak{g}^* \times_{\mathfrak{g}^* // G} \{0\}$ and do *not* choose such a G -invariant identification.

The following theorem, which is essentially due to Borel [Bor53], is a (non-traditional) starting point to a field known as *symplectic duality*:

Theorem 0.5. There is an algebra isomorphism $\mathrm{Fun}(\mathcal{N}_{\mathfrak{g}^*}^T) \cong H^*(T^*(G^\vee/B^\vee), \mathbb{C})$ where $G^\vee$ is the Langlands dual group to G , $B^\vee$ is the corresponding Borel subgroup, and $\mathcal{N}_{\mathfrak{g}^*}^T$ is the scheme-theoretic fixed point locus, i.e. the closed subscheme cut out by homogeneous functions in nonzero weight.

Proof. Observe that

$$\mathcal{N}_{\mathfrak{g}^*}^T = (\mathfrak{g}^* \times_{\mathfrak{g}^* // G} \{0\})^T = (\mathfrak{g}^*)^T \times_{\mathfrak{g}^* // G} \{0\} \cong \mathfrak{t}^* \times_{\mathfrak{t}^* // W} \{0\}$$

and so functions on $\mathcal{N}_{\mathfrak{g}^*}^T$ are given by the *coinvariant algebra* $\mathrm{Sym}(\mathfrak{t}) \otimes_{\mathrm{Sym}(\mathfrak{t})^W} k \cong \mathrm{Sym}(\mathfrak{t})/\mathrm{Sym}(\mathfrak{t})_+^W$. Observe that

$$\mathrm{Sym}(\mathfrak{t})/\mathrm{Sym}(\mathfrak{t})_+^W \cong \mathrm{Sym}(\mathfrak{t}^*)/\mathrm{Sym}(\mathfrak{t}^*)_+^W$$

and Borel's theorem [Bor53] says that there is an algebra isomorphism

$$\mathrm{Sym}(\mathfrak{t}^*)/\mathrm{Sym}(\mathfrak{t}^*)_+^W \xrightarrow{\sim} H^*(G^\vee/B^\vee, \mathbb{C})$$

extending the first Chern class map. Now our claim follows since $T^*(G^\vee/B^\vee)$ is a vector bundle over $G^\vee/B^\vee$ so there's an algebra isomorphism

$$H^*(G^\vee/B^\vee, \mathbb{C}) \xrightarrow{\sim} H^*(T^*(G^\vee/B^\vee), \mathbb{C})$$

given by pullback. □

0.3. Symplectic Duality, Symplectic Resolutions, and Symplectic Singularities. Roughly speaking, the goal of the *symplectic duality* program is to give a systematic framework for identifying and proving generalizations of theorems for $\mathcal{N}_{\mathfrak{g}^*}$. For example, here is a conjecture, known as the *Hikita conjecture*, (which introduces a bunch of terms that I'll define shortly) which generalizes Theorem 0.5:

Conjecture 0.6. [Hik17] If $\tilde{X} \rightarrow X$ and $\tilde{X}^! \rightarrow X^!$ are dual *conical symplectic resolutions*, then there is a torus T acting on X for which $\mathrm{Fun}(X^T) \cong H^*(\tilde{X}^!, \mathbb{C})$ as algebras.

The first matching is that the Springer resolution $\tilde{\mathcal{N}}_{\mathfrak{g}^*} \rightarrow \mathcal{N}_{\mathfrak{g}^*}$ should be dual to the Springer resolution $\tilde{\mathcal{N}}_{\mathfrak{g}} \rightarrow \mathcal{N}_{\mathfrak{g}}$. Next, I'd like to say a little more about why the term symplectic appears. I've already mentioned above that $\tilde{\mathcal{N}}_{\mathfrak{g}^*}$ can be identified with the cotangent bundle of a smooth variety, but it's also the case that $\mathcal{N}_{\mathfrak{g}^*}$ is, roughly speaking, symplectic: by this I mean that there exists a Poisson algebra structure on $\mathrm{Fun}(\mathcal{N}_{\mathfrak{g}^*})$ (known as the *KKS* or *Kostant-Kirillov-Souriau* structure) which gives a symplectic form on the smooth locus. It also turns out that the Springer resolution intertwines these symplectic structures in the most natural possible sense. We will axiomatize this setup in the following definition:

Definition 0.7. Let X denote a normal Poisson variety such that the Poisson bracket restricts to a symplectic form on X^{sm} . A *symplectic resolution* is a projective map $p : Y \rightarrow X$ from a smooth variety Y which is an isomorphism when pulled back to X^{sm} and such that the induced symplectic form on $p^{-1}(X^{\mathrm{sm}})$ extends to a symplectic form on Y .

Now, an obvious question is, for X as in the definition, must a symplectic resolution exist? Work of Fu [Fu10] shows that, even for certain nilpotent orbit closures, the answer is no! This suggests a modification of Definition 0.7, which was originally discovered by Beauville:

Definition 0.8. [Bea99] For X as in Definition 0.7, we say that X has *symplectic singularities* if there exists a projective map $p : Y \rightarrow X$ from a smooth variety Y which is an isomorphism when pulled back to X^{sm} and such that the induced symplectic form on $p^{-1}(X^{\mathrm{sm}})$ extends to a (not necessarily symplectic) *2-form* on Y .

Remark 0.9. Observe that the nilpotent cone also has a *conical* $\mathbb{G}_m$ -action: that is, an action of $\mathbb{G}_m$ which corresponds to a grading on $\mathrm{Fun}(\mathcal{N}_{\mathfrak{g}^*})$ by non-negative weights such that $\mathrm{Fun}(\mathcal{N}_{\mathfrak{g}^*})_0 = \mathbb{C}$. There are obvious notions of *conical symplectic resolutions* and *conical symplectic singularities*, which we won't define formally in this talk.

Experience suggests that varieties with conical singularities are a natural object of study in the symplectic duality program. But not every variety with conical symplectic singularities admits a symplectic resolution. This suggests a tradeoff: desingularizing a variety can help us understand it better, but if we desingularize too much, this resolution won't be symplectic. We'd like to stay in the world of symplectic geometry, and so we introduce the following definition:

Definition 0.10. For X as in Definition 0.7, we say that a projective map $p : Y \rightarrow X$ of normal varieties which is an isomorphism over X^{sm} is a *partial resolution*. If, in addition, the symplectic form on X^{sm} extends to a symplectic form on all of Y^{sm} , we say that p is a *partial symplectic resolution*.

Remark 0.11. If X has a partial symplectic resolution $Y \rightarrow X$, then it's possible to show (see [Mal25]) that Y itself has symplectic singularities if X does. Moreover, if X has symplectic singularities, then a partial resolution is symplectic if and only if it is crepant in the sense that the pullback of the canonical bundle on X is the canonical bundle on Y [Fu03] [Mal25].

Of course, the identity is a partial symplectic resolution. But the idea is that there's a 'sweet spot' in this tradeoff: in other words, there exists a partial symplectic resolution which is maximal, and such maximal resolutions can be characterized explicitly:

Theorem 0.12. [Bir+10] [Mal25][Los21] [Nam15] Any variety X with symplectic singularities admits a partial symplectic resolution $Y \rightarrow X$ by a variety Y with $\mathbb{Q}$ -factorial terminal singularities. Such resolutions can be characterized as a maximal partial symplectic resolution of X . For such Y , $\text{codim}_Y(Y^{\text{sing}}) \geq 4$.

Remark 0.13. In fact, Namikawa's result [Nam15] states that a variety X with symplectic singularities has terminal singularities if and only if the codimension of its singular locus is at least 4.

0.4. Classification of All Partial symplectic Resolutions of All Conical Symplectic Singularities? Now we can state a major goal of a program originated by Bellamy-Craw-Schedler: the complete classification of all partial symplectic resolutions of conical symplectic singularities: in particular, the classification of all varieties with conical symplectic singularities X ! Roughly speaking, they propose to do this in three steps:

- (G1) Directly classifying all X which have $\mathbb{Q}$ -factorial conical terminal singularities.¹
- (G2) Proving that, for any X , there is some algebraic variety, known as the *Hamiltonian-Cox variety* $\text{Spec}(\text{HCox}(X))$ equipped with a Hamiltonian T -action for some torus T such that all partial symplectic resolutions of X are given by Hamiltonian reduction of $\text{Spec}(\text{HCox}(X))$ by varying the characters of T .
- (G3) Proving $\text{Spec}(\text{HCox}(X))$ has $\mathbb{Q}$ -factorial terminal conical symplectic singularities for all X .

Let us mention that such a classification is possible by a result of Namikawa [Nam16] which says that, informally speaking, such a classification is theoretically possible. (More precisely, it says that there are only finitely many conical symplectic singularities with a fixed dimension and fixed bound on the weights of a homogeneous generating set.)

0.5. The Program for the Nilpotent Cone. For a few minor technical reasons, we now assume G is semisimple and simply connected. In this case, it's easy to say what this Hamiltonian-Cox ring is with the notation we described above. Specifically, observe that the variety $\tilde{\mathcal{N}}_{\mathfrak{g}}^*$ is the zero fiber of the (dual) *Grothendieck-Springer resolution* $\tilde{\mathfrak{g}} := G \times^B (\mathfrak{g}/\mathfrak{u})^*$. Observe that the projection map onto

$$(\mathfrak{g}/\mathfrak{u})^* \rightarrow (\mathfrak{b}/\mathfrak{u})^* = \mathfrak{t}^*$$

naturally induces a map

$$\tilde{\mathfrak{g}} \rightarrow \mathfrak{t}^*$$

¹In fact, this step is a bit of an oversimplification: really, the idea is to directly classify all varieties with $\mathbb{Q}$ -factorial terminal conical symplectic singularities for which the fundamental group of the smooth locus is trivial, and then classify all $\mathbb{Q}$ -factorial conical terminal singularities by passing to a universal cover.

and this is ‘half’ of the Hamiltonian T -action we’re interested in. Now, we’re interested in producing an affine variety with an action of a torus out of this data, and one way to do this is via the *Cox ring*

$$\mathrm{HCox}(\mathcal{N}) := \mathrm{Cox}(\tilde{\mathfrak{g}}) := \bigoplus_{\mathcal{L} \in \mathrm{Pic}(\tilde{\mathfrak{g}})} \Gamma(\tilde{\mathfrak{g}}, \mathcal{L});$$

it’s not too difficult to show that $\mathrm{Pic}(\tilde{\mathfrak{g}}) \cong X^\bullet(T)$. In this case, a more explicit description for the ring $\mathrm{HCox}(\mathcal{N})$ exists:

Proposition 0.14. [GR15] The variety $G \times^U (\mathfrak{g}/\mathfrak{u})^* \cong T^*(G/U)$ is quasi-affine, and thus is an open subset of its affinization $\overline{T^*(G/U)} := \mathrm{Spec}(\mathcal{O}(T^*(G/U)))$. There is an isomorphism $\overline{T^*(G/U)} \cong \mathrm{Spec}(\mathrm{HCox}(\mathcal{N}))$.

In this case, (3) is a strengthening of a conjecture of Ginzburg and Kazhdan [GK] and was proved a few years ago by me, building on an idea in the proof of the SL_n case proved by Boming Jia [Jia21]

Theorem 0.15. ([Gan24], [Jia21] for $G = \mathrm{SL}_n$) If $X = \mathcal{N}_{\mathfrak{g}^*}$ then (G3) holds, i.e. $\overline{T^*(G/U)}$ has $\mathbb{Q}$ -factorial terminal conical symplectic singularities.

The main result of this talk is that (G2) holds for the nilpotent cone as well:

Theorem 0.16. [BG26] If $\mu : \overline{T^*(G/U)} \rightarrow \mathfrak{t}^*$ is the moment map for the Hamiltonian T -action, then the GIT quotients $\mu^{-1}(0) //_{\theta} T$ as θ varies over the dominant characters of T exhausts all partial symplectic resolutions of $\mathcal{N}_{\mathfrak{g}^*}$.

Remark 0.17. The content of Theorem 0.16 is exactly as I am stating it: that all resolutions have this *specific* form and are given by geometric invariant theory. Specifically, a construction of these resolutions were already known [BM83] (if we choose a G -invariant linear identification $\mathfrak{g} \xrightarrow{\sim} \mathfrak{g}^*$ then we show that $\mu^{-1}(0) //_{\theta} T \cong G \times^P (\mathfrak{p} \cap \mathcal{N}_{\mathfrak{g}})$ where P is the parabolic corresponding to θ) and the fact that these varieties give all partial symplectic resolutions of the nilpotent cone was first proved in [Mal25].

0.6. Analogue for $T^*(G/P)$. As we’ve already discussed, the Springer resolution is a map from the cotangent bundle of G/B . One natural way to generalize this is to take the cotangent bundle from G/P for a parabolic subgroup P we now fix.

Proposition 0.18. [BK94] We have $\mathcal{O}(T^*(G/B)) \cong \mathcal{O}(\mathcal{N})$. More generally, the scheme $\mathrm{Spec}(\mathcal{O}(T^*(G/P)))$ has conical symplectic singularities and the affinization map $T^*(G/P) \rightarrow \mathrm{Spec}(\mathcal{O}(T^*(G/P)))$ is a symplectic resolution of singularities; in particular, it is a $\mathbb{Q}$ -factorial terminalization.

(There is an analogue of the Springer map for $T^*(G/P)$, but it isn’t always a resolution of singularities since the analogue of the Springer map need not be one to one. In general, we can realize $\mathrm{Spec}(\mathcal{O}(T^*(G/P)))$ as the normalization of $\mathcal{O}(\overline{\mathbb{O}})$ in $\mathcal{O}(T^*(G/P))$, where $\mathbb{O}$ is the Richardson orbit corresponding to P .)

Now, the idea is to fit $T^*(G/P)$ in a similar scheme as we did $\tilde{\mathcal{N}} = T^*(G/B)$. We find a ‘universal Poisson deformation’ of this space, which in this case turns out to be $T^*(G/[P, P])/T_P$ for some torus $T_P := P/[P, P]$. We then take the Cox ring which, similar to the above discussion, turns out to be analogously the affinization $\overline{T^*(G/[P, P])}$ of the cotangent bundle of $G/[P, P]$, which, as before, contains $T^*(G/[P, P])$ as an open subset.

Theorem 0.19. [FL26] The variety $\overline{T^*(G/[P, P])}$ has $\mathbb{Q}$ -factorial symplectic singularities.

Using this theorem, we can show:

Theorem 0.20. ([GG26] for $G = \mathrm{SL}_n$, [Gan]) The variety $\overline{T^*(G/[P, P])}$ has terminal singularities.

0.7. A Fun Bonus: The Geometry of $\mu^{-1}(0)$. Let's go back to the setting of the Hamiltonian-Cox space $\overline{T^*(G/U)}$ for the nilpotent cone $\mathcal{N}$. We also prove some fun facts about the geometry of $\mu^{-1}(0)$, where $\mu : \overline{T^*(G/U)} \rightarrow \mathfrak{t}^*$ is the moment map from the Hamiltonian T -action. In general, taking the preimage of zero under some moment map can have seriously bad behavior: for example, it need not be reduced, integral, or normal. But, oddly enough, in this case, we show that it is!

Theorem 0.21. [BG26] The scheme $\mu^{-1}(0)$ is an integral, normal, Cohen-Macaulay variety.

0.8. Sketch of Proof. Given a torus T acting on some affine scheme X and a character λ , in GIT one can define the notion of the λ -semistable points, an open subscheme of X . We restrict our attention to the *effective* λ , that is, those λ for which the semistable points is a nonempty open subset. From this, we can form a partial order on the set of rationalized characters: one character is ' $\leq$ ' another character if the semistable locus of one is contained in the semistable locus of another. Two characters are said to be *GIT equivalent* if they are both $\leq$ each other. The GIT equivalent characters for $\mu^{-1}(0)$ give a partition of $\mathfrak{t}^*(\mathbb{R}) = X^\bullet(T)_{\mathbb{R}}$. We prove directly that these regions are given by the expected ones: the regions determined by whether the coroots are positive, negative, or zero. This breaks $\mathfrak{t}^*(\mathbb{R})$ into the expected collection of chambers. Now, it's not difficult to argue that there is an isomorphism

$$X^\bullet(T) \xrightarrow{\sim} \text{Pic}(\tilde{\mathcal{N}})$$

given by the so called *linearization map* which takes a character $\lambda : T \rightarrow \mathbb{G}_m$, views it as a character of B , and constructs the associated bundle over $\tilde{\mathcal{N}} \cong G \times^B (\mathfrak{g}/\mathfrak{b})^*$ up to a minus sign. In particular, we get an isomorphism

$$\mathfrak{t}^*(\mathbb{R}) \cong X^\bullet(T)_{\mathbb{R}} \xrightarrow{\sim} \text{Pic}(\tilde{\mathcal{N}})_{\mathbb{R}}.$$

We prove directly that this isomorphism identifies the dominant weights with the called *movable cone* of the resolution $\tilde{\mathcal{N}} \rightarrow \mathcal{N}$. Moreover, we prove directly that the various vanishing and non-vanishing of the simple coroots give rise to the *Mori fan* decomposition of the moving cone, which is known to classify partial symplectic resolutions [Mal25].

REFERENCES

- [Bea99] Arnaud Beauville. “Symplectic singularities”. In: *Inventiones mathematicae* 139 (1999), pp. 541–549.
- [BG26] Gwyn Bellamy and Tom Gannon. *Crepant partial resolutions of the nilpotent cone via Hamiltonian reduction*. 2026. arXiv: 2608.25994 [math.AG]. URL: <https://arxiv.org/abs/2608.25994>.
- [Bir+10] Caucher Birkar, Paolo Cascini, Christopher D. Hacon, and James McKernan. “Existence of minimal models for varieties of log general type”. In: *J. Amer. Math. Soc.* 23.2 (2010), pp. 405–468. ISSN: 0894-0347,1088-6834. DOI: 10.1090/S0894-0347-09-00649-3. URL: <https://doi.org/10.1090/S0894-0347-09-00649-3>.
- [BK94] Ranee Brylinski and Bertram Kostant. “Nilpotent orbits, normality and Hamiltonian group actions”. In: *J. Amer. Math. Soc.* 7.2 (1994), pp. 269–298. ISSN: 0894-0347,1088-6834. DOI: 10.2307/2152759. URL: <https://doi.org/10.2307/2152759>.
- [BM83] Walter Borho and Robert MacPherson. “Partial resolutions of nilpotent varieties”. en. In: *Analyse et topologie sur les espaces singuliers (II–III) – 6–10 juillet 1981*. Astérisque 101–102. Société mathématique de France, 1983, pp. 23–74. URL: https://www.numdam.org/item/AST_1983__101-102__23_0/.
- [Bor53] Armand Borel. “Sur la cohomologie des espaces fibrés principaux et des espaces homogènes de groupes de Lie compacts”. In: *Ann. of Math. (2)* 57 (1953), pp. 115–207. ISSN: 0003-486X. DOI: 10.2307/1969728. URL: <https://doi.org/10.2307/1969728>.
- [FL26] Baohua Fu and Jie Liu. *The affine closure of cotangent bundles of horospherical spaces*. 2026. arXiv: 2502.06383 [math.AG]. URL: <https://arxiv.org/abs/2502.06383>.

- [Fu03] Baohua Fu. “Symplectic resolutions for nilpotent orbits”. In: *Invent. Math.* 151.1 (2003), pp. 167–186. ISSN: 0020-9910. DOI: 10.1007/s00222-002-0260-9. URL: <https://doi.org/10.1007/s00222-002-0260-9>.
- [Fu10] Baohua Fu. “On $\mathbb{Q}$ -factorial terminalizations of nilpotent orbits”. In: *J. Math. Pures Appl. (9)* 93.6 (2010), pp. 623–635. ISSN: 0021-7824. DOI: 10.1016/j.matpur.2009.08.010. URL: <https://doi.org/10.1016/j.matpur.2009.08.010>.
- [Gan] Tom Gannon. In preparation.
- [Gan24] Tom Gannon. “Proof of the Ginzburg-Kazhdan conjecture”. In: *Adv. Math.* 448 (2024), Paper No. 109701. ISSN: 0001-8708, 1090-2082. DOI: 10.1016/j.aim.2024.109701. URL: <https://doi.org/10.1016/j.aim.2024.109701>.
- [GG26] Tom Gannon and Nikolay Grantcharov. *Cohomology on Cotangent Bundles of Partial Flag Varieties in Type A - Appendix*. 2026. arXiv: 2609.04670 [math.AG]. URL: <https://arxiv.org/abs/2609.04670>.
- [GK] Victor Ginzburg and David Kazhdan. “Differential operators on G/U and the Gelfand-Graev action”. In: (). URL: <https://arxiv.org/abs/1804.05295v3>.
- [GR15] Victor Ginzburg and Simon Riche. “Differential operators on G/U and the affine Grassmannian”. In: *J. Inst. Math. Jussieu* 14.3 (2015), pp. 493–575. ISSN: 1474-7480. DOI: 10.1017/S1474748014000085.
- [Hik17] Tatsuyuki Hikita. “An algebro-geometric realization of the cohomology ring of Hilbert scheme of points in the affine plane”. In: *Int. Math. Res. Not. IMRN* 8 (2017), pp. 2538–2561. ISSN: 1073-7928, 1687-0247. DOI: 10.1093/imrn/rnw115. URL: <https://doi.org/10.1093/imrn/rnw115>.
- [Jia21] Boming Jia. *The Geometry of the affine closure of $T^*(\mathrm{SL}_n/U)$* . 2021. DOI: 10.48550/ARXIV.2112.08649. URL: <https://arxiv.org/abs/2112.08649>.
- [Los21] Ivan Losev. “Derived equivalences for symplectic reflection algebras”. In: *International Mathematics Research Notices* 2021.1 (2021), pp. 442–472. DOI: 10.1093/imrn/rnz178.
- [Mal25] Alberto San Miguel Malaney. *Partial Resolutions of Affine Symplectic Singularities*. 2025. arXiv: 2311.13593 [math.RT]. URL: <https://arxiv.org/abs/2311.13593>.
- [Nam15] Yoshinori Namikawa. “Poisson deformations and birational geometry”. In: *J. Math. Sci. Univ. Tokyo* 22.1 (2015), pp. 339–359. ISSN: 1340-5705.
- [Nam16] Yoshinori Namikawa. “A finiteness theorem on symplectic singularities”. In: *Compos. Math.* 152.6 (2016), pp. 1225–1236. ISSN: 0010-437X, 1570-5846. DOI: 10.1112/S0010437X16007387. URL: <https://doi.org/10.1112/S0010437X16007387>.
- [Spr69] Tonny A. Springer. “The unipotent variety of a semi-simple group”. In: *Algebraic Geometry (Internat. Colloq., Tata Inst. Fund. Res., Bombay, 1968)*. London: Oxford University Press, 1969, pp. 373–391. ISBN: 978-0-19-635281-7.

Email address: tom.gannon@ucr.edu