MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

T a g u n g s b e r i c h t 36/1991

Klassifikation komplex-algebraischer Varietäten

25.8. bis 31.8.1991

Die Tagung fand unter der Leitung von Herrn K. Hulek (Hannover), Herrn T. Peternell (Bayreuth) und Herrn M. Schneider (Bayreuth) statt. Die Vorträge der teilnehmenden Mathematiker aus 10 Ländern behandelten folgende Gebiete: Klassifikation höher-dimensionaler Varietäten, Hodge-Theorie, Syzygien von projektiven Varietäten, Adjunktionstheorie, projektive Mannigfaltigkeiten kleiner Kodimension und analytische Methoden in der komplex-algebraischen Geometrie.

Vortragsauszüge

C. Birkenhake:

Exponents of abelian subvarieties

Joint work with H. Lange.

Let X be a principally polarized abelian variety. To any abelian subvariety Y of X one associates a positive integer e(Y), the exponent. The exponent is defined to be the exponent of the induced polarization on Y.

The set of abelian subvarieties of X is computed in terms of the endomorphism algebra $End_{\mathbb{Q}}(X)$.

This leads to the following arithmetic interpretation of the exponent: Given

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an abelian subvariety Y with symmetric idempotent ϵ_Y, then $e(Y) = \min\{ n\geq 1 : n\epsilon_Y \in \mathrm{End}(X) \}$. This allows to compute the exponent in many cases. As an example we compute the exponent of all abelian subvarieties of the Jacobian of the curve $C_a : y^2 = (x^2+1)(x^2-a)(x^2-1/a)$.

F. Bogomolov:

Stable vector bundles on surfaces

Consider a stable vector bundle E of rank r on a projective surface V. Stable means that in the cone of polarizations on V we can find a subcone V_E such that E is stable with respect to any element of V_E. I show in my talk that by the discriminant of E, $\Delta(E)=(r-1)/2r\cdot c_1^2-c_2$, and the rank r it is possible to define a subdomain $V_E(r,\Delta)\subset V_E$ such that E is stable being restricted to any curve X with $[X]\in V_E(r,\Delta)$. The result is based on the sharp version of the theorem on nonstability of vector bundles with $\Delta(E)>0$.

R. Braun:

Boundedness for non-general type 3-folds in $\mathbb{P}_5$

Joint work with G. Ottaviani, M. Schneider, F.-O. Schreyer.
We show the following theorem:

Thm.: There exist only finitely many families of 3-folds in $\mathbb{P}_5$, which are not of general type.

The proof consists of two parts. First using the semipositivity of the (-1)-twist of the normal bundle and the generalized Hodge Index Theorem we show that there exist only finitely many families of non-general type 3-folds in $\mathbb{P}_5$, which are not contained in a hypersurface of degree 12. In the second part we prove that in hypersurfaces of a fixed degree there exist only finitely many families of non-general type 3-folds; this is the main technical part and uses results of G. Ellingsrud and C. Peskine which they showed in the proof of the corresponding theorem for smooth surfaces in $\mathbb{P}_4$.

F. Campana:

Rational connectedness of Fano manifolds

Let X be an n-dimensional complex-projective manifold.

Def.: X is Fano $:\Longleftrightarrow$ $(-K_X)$ is ample

X is rationally connected $:\Longleftrightarrow \forall\ (x,y)\in X\times X\ \exists$ C: connected curve of X with rational irreducible components containing x and y.

Thm. (also obtained by Y. Miyaoka): X Fano $\Rightarrow$ X rationally connected.

The main step of the proof is a relative version of S. Mori's argument to produce rational curves on a manifold with K_X not nef.
The talk was devoted to a sketch of proof and to explain the relationship to the problem of boundedness of the family of Fano n-folds (A positive answer has recently been announced by Kollar-Miyaoka-Mori).

C. Ciliberto:

Endomorphism of Jacobians

Let $\mathcal{H}_g=\{A\in\mathcal{A}_g : \mathrm{End}(A)\supsetneq\mathbb{Z}\}$. General properties of $\mathcal{H}_g$ are needed (see Shimura). Some recent results of Ciliberto, v. d. Geer, Teixidor and of Ciliberto, v. d. Geer about the dimension of components of $\mathcal{H}_g\cap\mathcal{M}_g$ are discussed. Possible generalizations are proposed. The following theorem has been stated, proved and commented:

Thm.: Let S be a smooth complex-projective surface, $\mathcal{L}$ a linear system on S such that $\varphi_{\mathcal{L}}: S \longrightarrow F \subseteq \mathbb{P}^n$ is birational onto the image F and F is not a scroll, not with rational hyperplane sections. Let C be the normalization of the general element of $\mathcal{L}$. Then

$$\mathrm{End}(J(C)) \simeq \mathrm{End}(\mathrm{Alb}(S))\times\mathbb{Z}$$

The theorem, stated by Severi, has been recently proved by Ciliberto, v. d. Geer. A related result of Ciliberto, Harris, Teixidor on $G^1_d(C)$, $C\in\mathcal{M}_g$, $g=2d-3$ with C general in moduli, has been stated and commented.

L. Ein:

Syzygies of smooth projective varieties

Let X be a smooth projective n-fold and L be a very ample line bundle on X. We say that L satisfies the property N_0, if $|L|$ gives a projectively normal embedding. L satisfies N_1, if the homogeneous ideal is generated by quadrics etc. We consider a line bundle of the form $L_d=K_X\otimes A^{\otimes d}\otimes B$ where A is a very ample line bundle and B is a nef line bundle on X.

Thm. (Ein and Lazarsfeld): If $d\geq n+1+p$, then L_d satisfies N_p.

Cor.: Let X be a smooth 3-fold. Then

(a) If $Y\in|3K_X+16A+B|$ is a general element, then $\mathrm{Pic}(Y)\simeq\mathrm{Pic}(X)$.

(b) If $Y\in|K_X+8A+B|$ is a smooth surface, then the infinitesimal Torelli theorem holds for Y.

G. Ellingsrud:

The number of twisted cubics on a general quintic threefold

We calculate the number of twisted cubics on a general quintic threefold to be 317 206 375, thus verifying a prediction coming from string theory by Candelas-Ossa-Green and Porkes.

We identify this number as the degree of the top Chern class of a certain bundle on the Hilbertscheme of cubics in $\mathbb{P}^4$. Studying the cohomology of this space we arrive at computing this degree (with some help of computers).

H. Esnault:

Hodge type of projective varieties (and the number of $\mathbb{F}_q$ rational points)

Thm.: Let S be a complex projective subvariety of $\mathbb{P}^n$ defined by r equations of degrees $d_1 \geq d_2 \geq \ldots \geq d_r$. Then the Hodge-Deligne filtration of the de Rham cohomology verifies: $F^k H_c^{\cdot}(\mathbb{P}^n - S) = H_c^{\cdot}(\mathbb{P}^n - S)$, where k is the integral part of $(n - \sum_2^r d_i/d_1)$.

This theorem has been proved by

Deligne (SGA, 1970) for S a smooth complete intersection,

Deligne-Dimca (Annales de l'ENS, 1990) for r=1,

Esnault (Math. Ann., 1990) for $r \geq 1$, S a complete intersection,

Esnault-Nori-Srinivas (preprint, 1991) in general,

and answers positively a conjecture of Deligne based on the analogy with the following formula:

Thm. (Ax 1964, Katz 1971): Let S be a projective subvariety of $\mathbb{P}^n$ defined by r equations of degrees $d_1 \geq d_2 \geq \ldots \geq d_r$ over the finite field $\mathbb{F}_q$. Then

$$\# S(\mathbb{F}_q) = \# \mathbb{P}^n(\mathbb{F}_q) \mod q^k$$

M. Green:

Generic initial ideals of projective varieties

An invariant of a graded homogeneous ideal, the generic initial ideal, introduced by Grauert in his work in several complex variables, is very useful in the study of projective varieties. One can recover from this invariant of the ideal its regularity, whether it is saturated, etc. For varieties it is a finer discrete invariant than the Hilbert function. For points in $\mathbb{P}^2$ and curves in $\mathbb{P}_3$ this invariant was described and how to obtain from it the numerical character and genus. Some applications of Braun-Fløystad and Strano were described.

S. Katz:

Higher order neighborhoods of curves on threefolds

Adapting a method of Kollar, a procedure is given for describing canonical higher order neighborhoods of curves on threefolds. This procedure is good enough to deduce the theorem of D. Morrison and S. Katz that the only Gorenstein 3-fold singularities which can be resolved by $\mathbb{P}^1$ are of type cA_1, cD_4 or cE_n (Kollar's work is also good enough for this); in addition, a broader classification encompasses non-contractible (1,-3) curves as well. The beginnings of an obstruction theory are developed for deforming curves on threefolds. Using results of H. Clemens and J. Jimenez, necessary and sufficient conditions are given for curves with exactly one $\mathcal{O}(-1)$ quotient of the ideal sheaf to be exceptional.

Y. Kawamata:

Abundance Theorem for Minimal Threefolds

Thm.: Let X be a minimal threefold such that $K_X{}^3=0$ and $K_X{}^2\cdot H>0$ for an ample divisor. Then there exists a positive number m such that

$$\dim H^0(X, mK_X) \geq 2$$

This finishes the proof of the following abundance theorem when combined with previous works:

Thm.: Let X be a minimal threefold. Then there exists a positive integer m such that $|mK_X|$ is free.

R. Lazarsfeld:

Seshadri constants on smooth surfaces

We describe joint work with L. Ein concerning Seshadri constants on a smooth surface X. Let L be an ample line bundle on X. Define, following Demailly,

$$\epsilon(L,x) = \inf_{\substack{C \ni x \\ C \text{ red. irred.}}} \frac{L\cdot C}{\mathrm{mult}_x C}$$

These were introduced by Demailly to study adjoint linear series. We prove the elementary

Thm.: One has $\epsilon(L,x)\geq 1$ for all but countably many $x\in X$.

We propose an example where $\epsilon(L,x)\leq 1/2$.

Various open problems are discussed.

M. Levine:

K-theory as applied to 1^{st} order deformations of cycles

We consider the following problem:
What part of the "algebraic part" $H^d(X,\Omega^{d-1}_{X/\mathbb{C}})$ of the tangent space of the intermediate Jacobian $J^d(X)$ of a smooth projective variety X is parametrized by 1^{st} order deformations of cycles?
There is a 1^{st} order obstruction, namely all 1^{st} order deformations land in the subspace $H^d(X,\Omega^{d-1}_{X/\mathbb{C}})^{\delta} := \mathrm{Im}(H^d(X,\Omega^{d-1}_{X/\mathbb{Q}}) \longrightarrow H^d(X,\Omega^{d-1}_{X/\mathbb{C}}))$. For d=2, this is the same as $\ker(\delta : H^2(X,\Omega^1_{X/\mathbb{C}}) \longrightarrow H^3(\mathcal{O}_X)\otimes\Omega^1_{\mathbb{C}/\mathbb{Q}}))$ arising from the sheaf sequence $0 \longrightarrow \mathcal{O}_X\otimes\Omega^1_{\mathbb{C}/\mathbb{Q}} \longrightarrow \Omega^1_{X/\mathbb{Q}} \longrightarrow \Omega^1_{X/\mathbb{C}} \longrightarrow 0$. To attack this problem we first rephrase it as looking for a Chern class $c_d\colon T_0K_0(X) \longrightarrow H^d(\Omega^{d-1})$ defined via a modified Deligne cohomology.
Here $T_0K_0(X) = \ker(K_0(X[\epsilon]/\epsilon^2) \longrightarrow K_0(X))$. We then apply Thomason's spectral sequence and Goodwillie's computation of the K-theory of nilpotent ideals to prove

Thm.: Suppose dim(X)=3. Then

$$c_2\colon T_0K_0(X) \longrightarrow H^2(\Omega^1_{X/\mathbb{C}})^{\delta}$$

is surjective.

R. Miranda:

Applications of Gaussian maps

The Gaussian map for a variety X with a line bundle L is the map $\phi_{X,L}\colon \Lambda^2H^0(X,L) \longrightarrow H^0(X,L^2\otimes\Omega^1_X)$ defined locally by $\phi_{X,L}(f\wedge g) = fdg-gdf$. By analyzing the restriction maps for the situation of a curve C lying in a rational scroll S_n (with a section B of self-intersection -n) we have the following

Thm. (J. Duflot, R. Miranda): Suppose $C \sim pB+qF$ where B is the negative section of S_n, F is the fiber, $p\geq5$ and $n\geq3$ (C is smooth). Then the corank of ϕ_{C,K_C} is n+6.

As a corollary, if C lies in an S_n, $n\geq3$ and C is not hyperelliptic, trigonal or 4-gonal, then n is determined by C: C lies in at most one scroll.

S. Müller-Stach:

Algebraic cycles on odd dimensional varieties

Let (H_t) be a geometric family of mixed Hodge structures over the unit disk, which arises as a family of extensions $0 \longrightarrow A_t \longrightarrow H_t \longrightarrow B_t \longrightarrow 0$ with

A_t, B_t pure of weights a and b. The family of extension classes defines a section in a certain bundle of complex tori. In this talk we define an infinitesimal invariant δe for e and indicate how to apply this invariant to the study of algebraic cycles on Calabi-Yau 3-folds (Joint work with F. Bardelli Pisa).

S. Mukai:

Curves and Grassmannians

Let $G(6,2) \subset \mathbb{P}^{14}$ be the 8-dimensional Grassmannian embedded by Plücker coordinates. A transversal intersection $G(6,2) \cap \mathbb{P}^7$ is a canonical curve of genus g.

Thm.: A curve C of genus 8 is isomorphic to $G(6,2) \cap \mathbb{P}^7$ if and only if C has no g^2_7.

All curves of genus 8 and their canonical rings are classified as an application. Similar results are obtained in the case g=7 and 9 replacing $G(6,2) \subset \mathbb{P}^{14}$ by suitable homogeneous space $X^{24-2g}_{2g-2} \subset \mathbb{P}^{22-g}$. In the case g=9, $X^6_{16} \subset \mathbb{P}^{13}$ is the compact dual of the Siegel upper half space $\mathfrak{H}_3$ of degree 3.

Thm.: A curve C of genus 9 is isomorphic to $X^6_{16} \cap \mathbb{P}^8$ if and only if C has no g^1_5.

Cor.: Green's conjecture is true for $g \leq 9$.

C. Peskine:

Les surfaces lisses d'une hypersurface singuliere de $\mathbb{P}_4$

Let S be a smooth surface contained in a singular hypersurface Σ of $\mathbb{P}_4$ and let $\sigma = d^o\Sigma$. Consider the polynomial

$$P_\sigma = \frac{x^3}{6\sigma^2} + \frac{\sigma-5}{4\sigma} x^2 + \frac{2\sigma^2-15\sigma+35}{12} x$$

If Σ has only isolated singularities, there exists a constant $k(\sigma)$ such that

$$P_\sigma(d) - (\frac{d}{\sigma}+\sigma-4)k(\sigma) \leq \chi(\mathcal{O}_S) \leq 1+h^2(\mathcal{O}_S) \leq P_\sigma(d)$$

If Σ has a multiple curve, there exists a polynomial of $d^o 1$ Q such that

$$P_\sigma(d) - (\frac{d}{\sigma}+\sigma-4)Q(d) \leq \chi(\mathcal{O}_S) \leq 1+h^2(\mathcal{O}_S) \leq P_\sigma(d)$$

The result is a consequence of the two (easy) following remarks:

1) If N is the normal bundle of S in $\mathbb{P}_4$, we have $c_2N(-\sigma) \leq (\sigma-1)^4$ if Σ has isolated singularities and $c_2N(-\sigma) \leq (\sigma-1)^2d$ if it has a multiple curve.
2) If A is the graded integral ring of S in $\mathbb{P}_4$ and B the graded ring of a complete intersection $\Sigma \cap T$ with $d^oT = d/\sigma$, one has $rk(A_n) \geq rk(B_n)$ for all n.

F.-O. Schreyer:

Enriques surfaces in $\mathbb{P}_4$

Four families of smooth Enriques surfaces in $\mathbb{P}_4$ are known. In the talk I sketched the construction of two of these families. The first family due to Cossec and Verra consists of Enriques surfaces of degree 9 and sectional genus $\pi=6$. They arise as projection of Reye polarized Enriques surfaces in $\mathbb{P}_5$ from a point. our construction shows that the component $\mathcal{H}$ of the Hilbert-scheme containing these is birational to $\mathbb{G}(12,H^0(\mathbb{P}_4,\mathcal{O}(2)))$ which in turn is birational to $\mathbb{G}(3,H^0(\check{\mathbb{P}}_4,\mathcal{O}(2))) \approx \mathrm{Hilb}_{8t-4}(\check{\mathbb{P}}_4)$ the Hilbert-scheme of canonical genus 5 curves in the dual space. Taking quotients by PGL(5) we obtain a birational map $\mathcal{M}_5^0 \longrightarrow \mathcal{U}^0 \longrightarrow \mathcal{M}_E^0$ of the moduli space $\mathcal{M}_5$ of genus 5 curves to the universal surface $\mathcal{U}$ over an open part of the moduli scheme of Reye polarized Enriques surfaces.

Y.-T. Siu:

A variation of Demailly's method of constructing holomorphic sections of line bundles

Demailly used singular solutions of the complex Monge-Ampere equation to study the following conjecture of Fujita: For any ample line bundle L over a compact complex manifold X of complex dimension n the line bundle $(n+2)L+K_X$ is very ample. He proved the very ampleness of $\beta_n L+2K_X$. In his method the coefficient 2 for K_X is needed, because in using the exterior product of positive currents he had to use a meromorphic vector field to differentiate the defining function of an effective $\mathbb{Q}$-divisor approximating the current. In this talk we discussed the method of trying to remove the coefficient 2 by adding some ample divisor to move the effective $\mathbb{Q}$-divisor.

A. J. Sommese:

The Adjunction Theory of Projective Varieties

Let L be a very ample line bundle on a projective manifold X. Recently Beltrametti, Fania and Sommese showed that except for a short list of special pairs (X,L), it follows for $n=\dim X\geq 5$, that there is a well behaved birational morphism, $\phi: X \longrightarrow Y$ where Y has isolated, terminal, 2 factorial singularities, and $K_Y+(n-3)(\phi_* L)^{**}$ is nef and big. Partial results exist for n=3,4 and for $n\geq 6$ and L merely ample. It is likely that results like this can't be true for n-4 in place of n-3 without replacing ϕ by a mapping that isn't a morphism. The following conjecture - for which evidence was given - indicates what is truestably

Conjecture (Beltrametti and Sommese):

Let $u:=\sup\{ \frac{p}{q} \mid q>0,\ \mathrm{Kod.dim}(qK_X+pL)=-\infty \}$ be the unnormalized spectral value of (X,L). If $u>\sqrt{n/2+1}$, then u is a fraction, K_X+uL is nef, and the associated morphism $\phi:X \longrightarrow Y$ is the contraction of an extremal ray of fibre type.

J. Spandaw:

Hodge structures, abelian surfaces and their degenerations

Let $\bar{\mathcal{A}}$ be the Voronoi compactification of the moduli space $\mathcal{A}$ of abelian surfaces with (1,p)-polarization and level structure. Namikawa, Hulek and Weintraub gave examples of degenerating families of abelian surfaces associated to a general point q of the boundary surfaces of $\bar{\mathcal{A}}$. In this talk we investigate the uniqueness of this degeneration.

We use the interpretation by Carlson, Cattani and Kaplan of the boundary points as Mixed Hodge Structures and Persson's description of the possible degenerate abelian surfaces X_0 to show that at least 2 of the 4 parameters determining X_0 are determined by q. We have not yet used the polarization and level structure. We hope that these extra data suffice to determine the remaining parameters.

H. Tsuji:

Kähler-Einstein currents and pluricanonical systems

Recently I have constructed a Kähler-Einstein current on a projective manifold of general type. This current is a natural generalization of the Kähler -Einstein metric on a manifold of ample canonical bundle of Aubin-Yau.

The main purpose of this talk is to describe how to extract the information of the pluricanonical system from the Kähler-Einstein current, i.e. how to construct the Zariski decomposition of the canonical bundle. The main tools used here is the L^2-estimate of $\bar{\partial}$ of Hörmander and Yau's analysis of Monge-Ampere operators. The theory of d-closed positive currents is a proper language for the purpose. Actually we may consider every pseudoeffective divisor as a closed positive (1,1)-current and the current can be considered as a "weak" Zariski decomposition.

C. Voisin:

Zero-cycles on certain hypersurfaces

We give first a simple proof of the vanishing of the CH_0^0 group of a quintic Godeaux surface, as predicted by Bloch's conjecture. We turn then to the example of a 3-dimensional quintic threefold invariant under an involution acting trivially on $H^{3,0}$. We show again that for such X, $CH_0(X)^-=0$; in this last case, one step of the demonstration is the proof of the surjectivity of the Abel-Jacobi map ϕ_X: $CH_1(X)^- \longrightarrow JX^-$.

P. M. H. Wilson:

The Kähler Cone of Calabi-Yau threefolds

Let X denote a Calabi-Yau threefold and $\mathcal{K} \subset H^2(X,\mathbb{R})$ the Kähler Cone of Kähler classes. The closure $\bar{\mathcal{K}}$ of this cone (dual to the Mori Cone $\overline{NE}(X)$) turns out to be locally rational polyhedral away from the Cubic Cone $W^* = \{ D$ such that $D^3=0 \} \subset H^2(X,\mathbb{R})$. The codimension one faces of $\bar{\mathcal{K}}$ correspond to primitive birational contractions of X, and then fall into 3 given types. This has implications concerning the existence of rational curves on X, and also the behaviour of the Kähler Cone under deformations. Let π: $\mathfrak{X} \longrightarrow B$ denote the Kuranishi family for a Calabi-Yau threefold $X=X_0$, where B may be taken as a polydisc in $H^1(T_X)$.

Thm.: The Kähler Cone is invariant precisely over the locus of $b \in B$ for which X_b contains no elliptic ruled surfaces, this locus being the complement of at most countably many codimension one submanifolds.

Elliptic ruled surfaces on Calabi-Yau threefolds are very analogous to (-2)-curves on K3 surfaces, giving rise to elementary transformations and reflections of the cohomology.

J. Wisniewski:

Vector bundles, adjunction and Fano manifolds

Let X be a Fano manifold of dimension n. The index of X r(X) is defined as $r(X) = \max\{ k : -K_X = kL$, L ample line bundle$\}$; the pseudoindex $\tilde{r}(X)$ is defined as $\tilde{r}(X) = \min\{ -K_X \cdot C : C \subset X$ rational curve$\}$. Using generalized adjunction for vector bundles, the following result was proved

Thm.: 0) If $\tilde{r}(X)>n/2+1$, then $b_2(X)=1$.

1) If $r(X)=n/2+1$, then $b_2(X)=1$ unless $X \simeq \mathbb{P}^{r-1} \times \mathbb{P}^{r-1}$.

2) If $r(X)=(n+1)/2$, then $b_2(X)=1$ unless $X \simeq \mathbb{P}^{r-1} \times Q^r$, $X \simeq \mathbb{P}(T\mathbb{P}^r)$ or $X \simeq \mathbb{P}(\mathcal{O}(2) \oplus \mathcal{O}(1)^{r-1})$.

F. L: Zak:

Varieties with small monodromy and their tangent hyperplanes

Let $X^n \subset \mathbb{P}^N$ be a nonsingular projective algebraic variety, and let Y be a general hyperplane section of X. The image Γ of the representation $\{\pi_1(\mathbb{P}^{N*}\backslash X^*) \longrightarrow \mathrm{Aut}H^*(X,\mathbb{Q})\}$, where X^* is the dual variety, is called the monodromy group of X. We are interested in varieties for which Γ is finite. That means that either $\dim X^*<N-1$ and $\Gamma=1$ or n is even and $H_{n-1}(Y) \simeq H_{n-1}(X)$, $\Gamma=1$ or n is odd, $\ker\{H^{n-1}(X) \longrightarrow H^{n-1}(Y)\}^{\perp} \subset CH^{(n-1)/2,(n-1)/2}(Y)$, Γ is a Weyl group and vanishing cycles form a system of roots. Our approach to dealing with such varieties is to observe that their hyperplane sections may have only simple isolated singularities. In particular, if T is abelian, then the only isolated singularities are ordinary quadratic. Thus, if the second fundamental form has dimension $\geq n$, we can show that all points of X are equivalent with respect to tangential equivalence and X can be isomorphically projected to $\mathbb{P}^{2n}$. This approach allows to classify such varieties X if $\mathrm{codim}(X)>\dim(X)$, at least in small dimensions. For varieties X with $\dim(X^*)=N-1-\mathrm{def}(X)$, $\mathrm{def}(X)>0$ we show that $\mathrm{def}(X)>3n-2N$, so that X cannot have small codimension.

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