二、申請補助經費：

（一）請將本計畫申請書之第四項(表 C004)、第五項(表 C005)、第六項(表 C006)、第七項(表 C007)、第八項(表 C008)所列費用個別加總後，分別填入「研究人力費」、「耗材、物品及雜項費用」、「研究設備費」、「國外或大陸地區差旅費」及「出席國際學術會議差旅費」欄內。

（二）若有申請國際合作研究計畫費用者，請將表 I002 之「C 類經費合計」欄金額填入「國際合作研究計畫國外學者來臺費用」欄內，「A 類經費與 B 類經費合計」欄金額填入「國際合作研究計畫出國差旅費」欄內。

（三）管理費為申請機構配合執行本計畫所需之費用，其計算方式係依本會規定核給補助管理費之項目費用總和及各申請機構管理費補助比例計算後直接產生，申請人不須填寫「管理費」欄。

（四）「貴重儀器中心使用額度」係將第九項(表 C009)所列使用費用合計數填入。

（五）請依各年度申請博士後研究之名額填入下表。

（六）申請機構或其他單位（含產業界）提供之配合項目，請檢附相關證明文件。

金額單位：新台幣元

執行年次 / 補助項目		第一年 (99 年 8 月~100 年 7 月)	第二年 (100 年 8 月~101 年 7 月)	第三年 (101 年 8 月~102 年 7 月)	第四年	第五年
業務費		**608,000**	**608,000**	**608,000**		
研究人力費		528,000	528,000	528,000		
耗材及雜項費用		80,000	80,000	80,000		
國際合作研究計畫國外學者來臺費用		0	0	0		
研究設備費		**118,000**	**107,000**	**0**		
國外差旅費		**100,000**	**100,000**	**100,000**		
國外或大陸地區差旅費		0	0	0		
出席國際學術會議差旅費		100,000	100,000	100,000		
國際合作研究計畫出國差旅費		0	0	0		
管理費		**108,900**	**107,250**	**91,200**		
合計		**934,900**	**922,250**	**799,200**		
貴重儀器中心使用額度		0	0	0		
博士後研究	國內、外地區	共 0 名	共 0 名	共 0 名	共名	共名
	大陸地區	共 0 名	共 0 名	共 0 名	共名	共名

申請機構或其他單位（含產業界）提供之配合項目（無配合補助項目者免填）

配合單位名稱	配合補助項目	配合補助金額	配合年次	證明文件

三、主要研究人力：

（一）請依照「主持人」、「共同主持人」、「協同研究人員」及「博士後研究」等類別之順序分別填寫。

類 別	姓名	服務機構/系所	職稱	在本研究計畫內擔任之具體工作性質、項目及範圍	＊每週平均投入工作時數比率(%)
主持人	陳榮凱	國立臺灣大學 數學系暨研究所	教授	研究探討	100%

※註:每週平均投入工作時數比率係填寫每人每週平均投入本計畫工作時數佔其每週全部工作時間之比率，以百分比表示（例如：50%即表示該研究人員每週投入本計畫研究工作之時數佔其每週全部工時之百分五十）。

（二）如申請博士後研究，請另填表 CIF2101 及 CIF2102（若已有人選者，請務必填註人選姓名，並將其個人資料表併同本計畫書送本會)。

四、研究人力費：

（一） 類別/級別欄請依專任助理(含碩士、學士、三專、五(二)專及高中職)、兼任助理(含博士生、碩士生、大專學生、講師及助教)及臨時工等填寫。

（二） 專任助理及兼任助理之每月工作酬金標準，不得超過本會補助專題研究計畫專任助理人員工作酬金參考表及本會補助專題研究計畫兼任助理人員工作酬金支給標準表之規定。

（三） 申請專任助理者，除依工作月數填列工作酬金及至多 1.5 個月年終工作獎金外，須另填列投保勞保及健保之「雇主應負擔之勞、健保費」（於線上填列工作酬金時，系統會自動列入勞、健保費）。

（四） 請分年列述。

金額單位：新台幣元

第 1 年

（一）專任助理、講師及助教級兼任助理、臨時工資						
類別/級別	人數	姓 名	工 作 月 數	月支酬金（含勞健保費）	小計	請述明：1.最高學歷 2.曾擔任專題研究計畫專任助理之經歷 3.在本計畫內擔任之具體工作性質、項目及範圍
合 計（一）						

（二）博士班研究生、碩士班研究生及大專學生兼任助理					
級別／姓名	人數（1）	每人每月單元數(2)	獎助月數(3)	小計 (4)＝$ 2000×(1)×(2)×(3)	在本研究計畫內擔任之具體工作性質、項目及範圍
合計（二）					
總計（三）＝合計（一）＋合計（二）					

第 2 年

（一）專任助理、講師及助教級兼任助理、臨時工資						
類別/級別	人數	姓 名	工 作 月 數	月支酬金（含勞健保費）	小計	請述明：1.最高學歷 2.曾擔任專題研究計畫專任助理之經歷 3.在本計畫內擔任之具體工作性質、項目及範圍
合 計（一）						
（二）博士班研究生、碩士班研究生及大專學生兼任助理						

級別／姓名	人數（1）	每人每月單元數(2)	獎助月數(3)	小計 (4)＝$ 2000×(1)×(2)×(3)	在本研究計畫內擔任之具體工作性質、項目及範圍
碩士班研究生研究助學金	3	3	12	216,000	協助執行計畫
大專學生研究助學金	2	2	12	96,000	協助執行計畫
博士班研究生獎助金(博士候選人)	1	13	12	312,000	協助執行計畫
合計（二）				624,000	
總計（三）＝合計（一）＋合計（二）				624,000	

第 3 年

（一）專任助理、講師及助教級兼任助理、臨時工資						
類別/級別	人數	姓 名	工 作 月 數	月支酬金（含勞健保費）	小計	請述明：1.最高學歷 2.曾擔任專題研究計畫專任助理之經歷 3.在本計畫內擔任之具體工作性質、項目及範圍
合 計（一）						

（二）博士班研究生、碩士班研究生及大專學生兼任助理					
級別／姓名	人數（1）	每人每月單元數(2)	獎助月數(3)	小計 (4)＝$ 2000×(1)×(2)×(3)	在本研究計畫內擔任之具體工作性質、項目及範圍
碩士班研究生研究助學金	3	1	12	72,000	協助執行計畫
博士班研究生獎助金	2	13	12	624,000	協助執行計畫
合計（二）				696,000	
總計（三）＝合計（一）＋合計（二）				696,000	

五、耗材及雜項費用：

（一） 凡執行研究計畫所需之耗材及雜項費用，均可填入本表內。
（二） 說明欄請就該項目之規格、用途等相關資料詳細填寫，以利審查。
（三） 若申請單位有配合款，請於備註欄註明。
（四） 請分年列述。

第 1 年 金額單位：新台幣元

項 目 名 稱	說明	單位	數量	單價	金額	備註
消耗性器材	電腦耗材、投影片、文具等	1	1	20,000	20,000	
電腦使用費	硬體維護、軟體更新	1	1	20,000	20,000	
資料檢索費	學術論文查詢	1	1	10,000	10,000	
論文發表費	論文發表所需之費用	1	1	10,000	10,000	
電郵費	國內外郵寄、通訊所需之費用	1	1	10,000	10,000	
打字費	打字、印刷	1	1	10,000	10,000	
合 計					80,000	

第2年

項 目 名 稱	說明	單位	數量	單價	金額	備註
消耗性器材	電腦耗材、投影片、文具等	1	1	20,000	20,000	
電腦使用費	硬體維護、軟體更新	1	1	20,000	20,000	
資料檢索費	學術論文查詢	1	1	10,000	10,000	
論文發表費	論文發表所需之費用	1	1	10,000	10,000	
電郵費	國內外郵寄、通訊所需之費用	1	1	10,000	10,000	
打字費	打字、印刷	1	1	10,000	10,000	
合 計					80,000	

第3年

項 目 名 稱	說明	單位	數量	單價	金額	備註
消耗性器材	電腦耗材、投影片、文具等	1	1	20,000	20,000	
電腦使用費	硬體維護、軟體更新	1	1	20,000	20,000	
資料檢索費	學術論文查詢	1	1	10,000	10,000	
論文發表費	論文發表所需之費用	1	1	10,000	10,000	
電郵費	國內外郵寄、通訊所需之費用	1	1	10,000	10,000	
打字費	打字、印刷	1	1	10,000	10,000	
合 計					80,000	

六、研究設備費：

（一） 凡執行研究計畫所需單價在新台幣一萬元以上且使用年限在二年以上之各項儀器、機械及資訊設備（含各項電腦設施、網路系統、週邊設備、套裝軟體：如作業系統軟體，以及後續超過 2 年效益之軟體改版、升級與應用系統開發規劃設計）等之購置裝置費用及圖書館典藏之分類圖書等屬之，此項設備之採購，以與本研究計畫直接有關者為限。各類研究設備金額請於金額欄內分別列出小計金額。

（二） 購置設備單價在新臺幣二十萬元以上者，須檢附估價單。

（三） 若申請機構及其他機構有提供配合款，請務必註明提供配合款之機構及金額。

（四） 儀器設備單價超過六十萬元(含)以上者，請詳述本項設備之規格與功能(諸如靈敏度、精確度…等)，其他重要特性與重要附件，以及申購本設備對計畫執行之必要性。本項設備若獲補助，主持人應負維護保養之責，並且在不妨礙個人研究計畫或研究群計畫之工作下，同意提供他人共同使用，以避免設備閒置。

（五） 請分年列述。

第 1 年　　金額單位：新台幣元

類別	設備名稱(中文/英文)	說　明	數　量	單　價	金　額	經費來源：本會補助經費需求	經費來源：提供配合款之機構名稱及金額
其他設備	軟體(Mathematica、GrindEq)/	數值計算、文書編寫	1	20,000	20,000	20,000	
儀器及資訊設備	電腦 螢幕及周邊/	高階數值計算。參閱共同契約 LP5-970060 第二組 14 項	1	60,000	60,000	60,000	
儀器及資訊設備	印表機/	參閱共同契約 LP5-970061 第 1 組 6.02 項	1	38,000	38,000	38,000	
合計					118,000	118,000	

第 2 年

類別	設備名稱(中文/英文)	說　明	數　量	單　價	金　額	經費來源：本會補助經費需求	經費來源：提供配合款之機構名稱及金額
其他設備	軟體(matlab)/	數值計算	1	12,000	12,000	12,000	
儀器及資訊設備	筆記型電腦/	高階計算、文書編輯。參閱共同契約 LP5-970060 第 3 組第 3 項	1	60,000	60,000	60,000	

圖書設備	圖書/	詳見書單 #1.　Flips for 3-folds and 4-folds (Oxford Lecture Series in Mathematics and Its Applications) [Hardcover] Alessio Corti (Editor) •　Hardcover: 184 pages •　Publisher: Oxford University Press, USA (August 23, 2007) •　Language: English •　ISBN-10: 0198570619 •　ISBN-13: 978-0198570615 $99.00 #2.　Methods of Algebraic Geometry in Control Theory: Multivariable Linear Systems and Projective Algebraic Geometry Part II [Hardcover] Peter Falb $109.00 •　Hardcover: 404 pages •　Publisher: Birkhäuser Boston；　1 edition (February 1, 2000) •　Language: English •　ISBN-10: 0817641130 •　ISBN-13: 978-0817641139	1	6,500	6,500	6,500	
儀器及資訊設備	電腦螢幕及硬碟/	電腦螢幕 15000 硬碟 8000	1	23,000	23,000	23,000	
合			計		29,500	29,500	

第 2 年

七、赴國外或大陸地區移地研究差旅費：

（一）類別分為「實驗」、「研究」、「田野調查」等。
（二）請詳述預定各出國人員之出國行程、預估經費、天數及地點。
（三）生活費、機票費及其他費用之標準，請依照行政院頒布之「中央各機關（含事業機構）派赴國外進修、研究、實習人員補助項目及數額表」規定填列（網址 http://web1.nsc.gov.tw/public/Data/02912191571.pdf）。
（四）請將所列各項費用換算為新台幣，並註明估算匯率。
（五）請分年列述。

第 1 年　　金額單位：新台幣元

申　請　補　助　費　用		
經　費　類　別	預　估　經　費	詳述預定各出國人員之類別、出國行程、預估經費、天數及地點 （類別包括實驗、研究、田野調查）
赴國外	100,000	主持人預計於 2011 暑假或 2012 寒假 訪問 Princeton 大學 Kollar 教授 約 14 日 預估經費約 100000
赴大陸	0	
合　計	100,000	

第2年

申　請　補　助　費　用		
經　費　類　別	預　估　經　費	詳述預定各出國人員之類別、出國行程、預估經費、天數及地點 （類別包括實驗、研究、田野調查）
赴國外	100,000	主持人預計於 2012 暑假或 2013 寒假 訪問 Utah 大學 Hacon 教授 約 14 日 預估經費約 100000
赴大陸	0	
合　計	100,000	

第3年

申　請　補　助　費　用

八、出席國際學術會議差旅費：

（一）計畫內之研究人員得申請本項經費。

（二）請詳述預定參加國際學術會議之性質、預估經費、天數及地點。

（三）請詳述申請人近三年參加國外舉辦之國際學術會議論文之發表情形。(包括會議名稱、時間、地點、發表之論文題目、補助機構，及後續收錄於期刊或專書之名稱、卷號、頁數、出版日期)。

（四）請分年列述。

第 1 年

出席國際學術會議差旅費			
博士生人數	共 0 名	金 額	100,000 元
費用說明	預訂於 2011 年前往德國 Oberwolfach 參加會議 預計 12 日 預估經費約 100000		
近三年論文發表情形	1. Oberwolfach Conference-Komplex Geometrie, Germany 08/2008 2. Analytic and algebraic aspects of the MMP and higher dimensional classification, Grenoble, France 11/2008 3. Classification of Algebraic Varieties, Schiermonnikoog, Netherlands 05/2009 (proceeding to appear) 4. Arithmetic Geometry and Moduli Spaces in Algebraic Geometry, Hangzhou, China 08/2009 5. Algebraic Geometry on Varieties and Manifolds, Fudan Univ., China 05/2010 6. 5th Pacific Rim Conference on Mathematics, Stanford, USA 06/2010 7. International Congress of Chinese Mathematicians, Beijing, China 12/2010 (proceeding to appear)		

第 2 年

出席國際學術會議差旅費			
博士生人數	共 0 名	金 額	100,000 元
費用說明	預訂於 2012 年前往美國參加 Western Algebraic Geometry Symposium 預計 14 日 預估經費約 100000		
近三年論文發表情形	1. Oberwolfach Conference-Komplex Geometrie, Germany 08/2008 2. Analytic and algebraic aspects of the MMP and higher dimensional classification, Grenoble, France 11/2008 3. Classification of Algebraic Varieties, Schiermonnikoog, Netherlands 05/2009 (proceeding to appear) 4. Arithmetic Geometry and Moduli Spaces in Algebraic Geometry, Hangzhou, China 08/2009 5. Algebraic Geometry on Varieties and Manifolds, Fudan Univ., China 05/2010 6. 5th Pacific Rim Conference on Mathematics, Stanford, USA 06/2010 7. International Congress of Chinese Mathematicians, Beijing, China 12/2010 (proceeding to appear)		

第 3 年

出席國際學術會議差旅費			
博 0 士生人數	共名	100,000 金 額	元
費用說明	預訂於 2014 年 6 月前往法國參加 Complex Algebraic Geometry 相關之會議 預計 14 日 預估經費約 100000		
近三年論文發表情形	1. Oberwolfach Conference-Komplex Geometrie, Germany 08/2008 2. Analytic and algebraic aspects of the MMP and higher dimensional classification, Grenoble, France 11/2008 3. Classification of Algebraic Varieties, Schiermonnikoog, Netherlands 05/2009 (proceeding to appear) 4. Arithmetic Geometry and Moduli Spaces in Algebraic Geometry, Hangzhou, China 08/2009 5. Algebraic Geometry on Varieties and Manifolds, Fudan Univ., China 05/2010 6. 5th Pacific Rim Conference on Mathematics, Stanford, USA 06/2010 7. International Congress of Chinese Mathematicians, Beijing, China 12/2010 (proceeding to appear)		

第 4 年

出席國際學術會議差旅費			
博士生人數	共 0 名	金 額	100,000 元
費用說明	預訂於 2014 年 8 月前往韓國參加 ICM 及 Satellite Conference in Algebraic Geometry 預計 14 日 預估經費約 100000		
近三年論文發表情形	1. Oberwolfach Conference-Komplex Geometrie, Germany 08/2008 2. Analytic and algebraic aspects of the MMP and higher dimensional classification, Grenoble, France 11/2008 3. Classification of Algebraic Varieties, Schiermonnikoog, Netherlands 05/2009 (proceeding to appear) 4. Arithmetic Geometry and Moduli Spaces in Algebraic Geometry, Hangzhou, China 08/2009 5. Algebraic Geometry on Varieties and Manifolds, Fudan Univ., China 05/2010 6. 5th Pacific Rim Conference on Mathematics, Stanford, USA 06/2010 7. International Congress of Chinese Mathematicians, Beijing, China 12/2010 (proceeding to appear)		

十一、研究計畫中英文摘要：請就本計畫要點作一概述，並依本計畫性質自訂關鍵詞。

（一）計畫中文摘要。（五百字以內）

於本計畫中，我們打算探討高維度極小模型理論以及相關的雙有理幾何問題。第一年我們希望能夠處理極小模型理論中的基本雙有理映射的分解問題，希望能對三維時的基本雙有理映射有完全具體的描述。第二年我們希望能夠處理四維或更高維的商奇異點。第三年我們希望能夠討論 extremal neighborhood 上的局部不變量，以期進一步探討 flip 的存在性及有限性。於第四年，我們將利用所發展出來的工具與方法應用至各式各樣的雙有理幾何問題上。

十一、研究計畫中英文摘要：請就本計畫要點作一概述，並依本計畫性質自訂關鍵詞。

（二）計畫英文摘要。（五百字以內）

In this project, we propose to study various aspects circling around higher dimensional minimal model program and its birational geometry.

In the first year, we will mainly study the classification problem of elementary maps of birational maps in minimal model program. In the second year, we will study quotient terminal singularities in dimension 4 and higher. We shall try to work on local invariants on extremal neighborhood in higher dimensional settings. This is considered to be helpful to the problem of existence and termination of flips. In the fourth year, we will seek for various applications on explicit birational geometry of minimal varieties of the theory we developed in the past three years.

十二、研究計畫內容：

（一）近五年之研究計畫內容與主要研究成果說明。（連續性計畫應同時檢附上年度研究進度報告）

1. Birational Geometry of threefolds.

Given a variety of general type, it is natural and important to ask when the pluricanonical map is birational. This was previously known only for curves and surfaces to be 3-canonical and 5-canonical respectively. Only quite recently, Hacon and McKernan show that there exist a constant c_n, depending only on dimension n, such that the m-th canonical map is birational for m greater than c_n. This leads to the boundedness for varieties of general type. However, their result is non-explicit.

The standard approach uses natural geometric fibration such as Albanese map or canonical map. Therefore the remaining difficult cases are the varieties with small birational invariants that there is no natural fibration structure and their minimal model is singular. In my series of joint work with Meng Chen (cf. [1,2,5]) we obtained a breakthrough on threefolds of general type by the study of three dimensional terminal singularities. We introduced a notion called *"packing of baskets of singularities"* (cf. [5]). We also introduce a canonical sequence of prime packings, which is some sort of approximation of baskets of singularities. The theory of basket we developed led to many important effective results for threefolds of general type. For example, we prove that

Theorem

Let X be a complex projective threefold of general type, then

1. $P_{12}>0$,
2. $P_{24}>1$
3. *the canonical volume* $Vol \geq 1/2660$
4. *m-th canonical map is birational for* $m \geq 73$.

The worst known example is the following:

Example

Let $X=X_{46}$ *be a general hypersurface of degree 46 in the weighted projective space* $P(4,5,6,7,23)$. *Then* $Vol=1/420$ *and 26-th canonical map is not birational*.

One sees that the bound we obtained is not only the first explicit bound ever but also not too far from being sharp. We would like to mention that the techniques also applicable to Fano threefolds (cf. [2]) and other threefolds, for example, weighted complete intersections. In fact, we have the following result for Fanos.

Theorem

Let X be a complex projective weak Q-Fano threefold, then

1 $P_{-6}>0$,

2 $P_{-8}>1$

3 *the canonical volume* $Vol \geq 1/330$, *which is sharp due to the following example.*

Example

Let $X=X_{66}$ *be a general hypersurface of degree 66 in the weighted projective space* $P(1,5,6,22,33)$. *Then* $-K^3=1/330$.

With the better understand of three dimensional singularities, we the turn our attention to the singularities in birational maps in minimal model program. In [6], we prove that flips and divisorial contraction to a curve can be decomposed into simpler elementary maps by an inductive argument using partial resolution of singularities on extremal rays.

2. <u>Varieties with Kodaira dimension zero.</u>

The classification theory of varieties usually reduced to the study of varieties of the following three types: varieties of general type, varieties with Kodaira dimension zero and varieties with negative Kodaira dimension. For varieties with Kodara dimension zero, it is conjecture by Ueno that they are decomposed into product of abelian varieties and Calabi-Yau up to etale and birational morphisms. In [4], we gave a partial answer to Ueno’s conjecture. In fact, in our recent preprint, we proved the second statement of Ueno’s conjecture. We also have some application to the famous Iitaks’s Conjecture Cnm.

十二、研究計畫內容：

（二）研究計畫之背景及目的。請詳述本研究計畫之背景、目的、重要性及國內外有關本計畫之研究情況、重要參考文獻之評述等。本計畫如為整合型研究計畫之子計畫，請就以上各點分別述明與其他子計畫之相關性。

The most challenging problems in algebraic geometry are the existence of minimal model program and the birational geometry of such minimal models. In the case of dimension less than two, then all of these problems are well-known. During the year of 80s and early 90s, various results along this direction are obtained. First of all, by Mori's work (cf. [Mo82]), it is known that one needs to allow at least terminal singularities in order for minimal model program to work. Reid and Mori classified three dimensional terminal singularities as isolated cyclic quotient of compound DuVal singularities (cf. [Mo85, YPG]). Mori then studied extremal neighborhood extensively, and showed that the flip of a small extremal contraction always exists in dimension three (cf. [Mo88, KM92]). Together with Shokurov's work on termination of flips, this proved the existence of minimal model in dimension three.

This approach turns out to be extremely difficult in higher dimension in many aspects. First of all, there is no known classification for terminal singularities in dimension four or higher. In fact, it's known that the embedded dimension of four dimension terminal singularities could be arbitrarily large. Therefore, it is difficult to classify singularities as in three-dimensional case. On the other hand, the termination of flips relies on associating to individual singularities invariants, which is also difficult in higher dimensions.

The recent break rough of Birkar, Cascini, Hacon and McKernan [BCHM] and some of the subsequent works proceed in a different approach. The new approach is an inductive approach that reduces the existence of minimal model into a non-vanishing theorem. By using this approach, they successfully showed the existence of minimal model for varieties of log general type. Even though the existence of minimal model is quite promising, very little is known about explicit birational geometry of minimal models even in dimension three. For example, the classification of divisorial contractions to a point is classified by Hayakawa (cf. [HaI, HaII]) and Kawakita (cf. [Kk01], [Kk05]) only quite recently. However, there is almost no result for divisorial contraction to a curve in dimension three. It is tempting to understand the birational maps explicitly.

Moreover, given a three dimensional terminal singularities, there is a deformation into terminal quotient singularities. The collection of these quotient singularities is called the "basket of singularities". In [YPG], Reid derived a singular Riemann-Roch formula that the contribution of terminal singularities can be computed by its basket. By using this formula and introduced the concept of "packing of baskets", we are able to derive many useful inequalities among Euler characteristics. These lead to various effective results of birational geometry of threefolds (cf. [CC1, CC2]). It is then interesting to see whether the singularities between elementary birational in minimal model program are connected by packing of baskets. By the classification of Kawakita and Hayakawa, the singularities between divisorial contraction to a point are connected by a packing. As a by product, we proved a factorization theorem for flips and divisorial contractions to a curve in [CH].

[BCHM] C. Birkar, P. Cascini, C. Hacon, J. McKernan, *Existence of minimal models for varieties of log general type*. J. Amer. Math. Soc., to appear. arXiv:math/0610203v2

[CC1] J. A. Chen, M. Chen, *Explicit birational geometry of threefolds of general type, I*, Ann. Sci. \'Ec. Norm. Sup\'er (4) 43 (2010), no. 3, 365--394.

[CC2] J. A. Chen, M. Chen, *Explicit birational geometry of threefolds of general type, II*, J. of Diff. Geom. (to appear). ArXiv: 0810.5044

[CH] J. A. Chen, C.D. Hacon, *Factoring 3-fold flips and divisorial contractions to curves.* Jour. Reine Angew. Math., to appear, arXiv 0910.4209

[HaI] T. Hayakawa, *Blowing ups of 3-dimensional terminal singularities*, Publ. Res. Inst. Math. Sci. 35 (1999), no. 3, 515--570.

[HaII] T. Hayakawa, *Blowing ups of 3-dimensional terminal singularities*. II, Publ. Res. Inst. Math. Sci. 36 (2000), no. 3, 423--456.

[Kk01] M. Kawakita, *Divisorial contractions in dimension three which contract divisors to smooth points*, Invent. Math. 145 (2001), no. 1, 105--119.

[Kk05] M. Kawakita, *Three-fold divisorial contractions to singularities of higher indices*, Duke Math. J. 130 (2005), no. 1, 57--126.

[KM92] J. Koll\'ar S. Mori, *Classification of three-dimensional flips*, J. Amer. Math. Soc. 5 (1992), no. 3, 533--703.

[Mo82] S. Mori, *Threefolds whose canonical bundles are not numerically effective*, Ann. Math. 116 (1982), 133--176.

[Mo85] S. Mori, *On 3-dimensional terminal singularities*, Nagoya Math. J. 98 (1985), 43--66.

[Mo88] S. Mori, *Flip theorem and the existence of minimal models for 3-folds*, J.Amer. Math. Soc. 1 (1988), no.1, 117--253.

[YPG] M. Reid, *Young person's guide to canonical singularities*, Proc. Symposia in pure Math. 46 (1987), 345-414.

（三）研究方法、進行步驟及執行進度。請分年列述：1.本計畫採用之研究方法與原因。2.預計可能遭遇之困難及解決途徑。3.重要儀器之配合使用情形。4.如為整合型研究計畫，請就以上各點分別說明與其他子計畫之相關性。5.如為須赴國外或大陸地區研究，請詳述其必要性以及預期成果等。

（四）預期完成之工作項目、成果及績效。請分年列述：1.預期完成之工作項目。2.對於學術研究、國家發展及其他應用方面預期之貢獻。3.對於參與之工作人員，預期可獲之訓練。4.預期完成之研究成果及績效（如期刊論文、研討會論文、專書、技術報告、專利或技術移轉等質與量之預期績效）5.本計畫如為整合型研究計畫之子計畫，請就以上各點分別說明與其他子計畫之相關性。

In this project, we propose to study various aspects circling around higher dimensional minimal model program and its birational geometry.

Year One:

In the first year, we will mainly study the classification problem of elementary maps of birational maps in minimal model program. It is known that most of the divisorial contraction to a point can be realized by certain weighted blowup. One might wonder whether all divisorial contractions to a point can be realized by weighted blowups or not. Once we have a better understanding of these maps, we are able to have explicit description of flips, flops and divisorial contraction to a curve in dimension three. An explicit description of these maps might leads to various applications in birational geometry of threefolds.

However, the difficulty is that a weighted blowup depends on embedding of a singularity and also on the choice of weights. Unfortunately, there is no canonical choice of coordinates and neither is canonical choice of weights. A possible way to attack the problem is to study the exceptional divisor and singularities on the exceptional divisor. The exceptional divisor itself is a singular Del Pezzo surface. There are too many Del Pezzo surfaces to be completely classified. We expect that one can at least study Del Pezzo surfaces with given anticanonical volume. This will provide certain information of the exceptional divisor, and hopefully to the weights if it is a weighted blowup.

We will study resolution of Gorenstein terminal singularities in dimension three as well. We expect that there exists a canonical way to construct a canonical sequence of partial resolution such that each map allows us to play the “two-rays game”. This will lead to a factorization of birational maps with only Gorenstein terminal singularities, and hopefully to a factorization of flop as well. We would like to remark that there is a recent result of Kawamata showing the any two birational minimal models are connected by a sequence of flops. Moreover, the quantum cohomology between simple flop can be computed due to the seminar article of Lee, Lin and Wang (cf. [LLW]). Therefore, it would be very interesting to factorize flops into elementary maps and simple flops.

Year Two:

It is essential to study singularities in minimal model program. In the second year, we will study quotient terminal singularities in dimension 4 and higher. This type of singularities can be considered as toric singularities and hence are considered to be relatively easy than terminal singularities in general. We are interesting in the singular Riemann-Roch formula that taking the contribution of quotient terminal singularities. We hope that there is a generalized notion of “baskets of singularities” such that there is an explicit form of Riemann-Roch formula. This formula will be extremely useful for various effective and boundedness problem as we did in dimension three. In particular, one can expect to classified quasi-smooth weighted complete intersections in dimension four and higher. This work will be a starting point to provide many examples in higher dimensions.

The difficulty is that singular locus might be of positive dimension. Even though we start with an isolated point, a partial resolution might create a variety with non-isolated singularities. Therefore, it seems that the geometry of the locus must come into play. Moreover, even we have a toric description of a quotient singularity; one can expect to have a resolution by appropriate subdivision of cones. However, there is no canonical way to subdivide a cone and the combinatorics involved could be very complicated. In general, the combinatorics of cones and lattices in dimension four and higher are a lot complicated than those of dimension three or less.

A possible solution is to consider resolution, i.e. subdivision of cones, guided by Euler characteristics. Recall that in the lower dimension case, we always have that Euler characteristic increased for each map of the resolution. In other words, the Poincare series increased in some suitable sense. Therefore, one can try to pick a subdivision among all subdivisions with largest Poincare series. This might provide a better way to study the quotient terminal singularities.

Another possible way-out is the choice of weights. Notice that a subdivision of cones corresponds to a weighted blowup. In the case of dimension three, there is a unique choice of weight such that the weighted blowup is an extremal extraction. Now we have many different choices of weight in higher dimensions.

We have one more remark. In dimension three, given a singularity P in X of index r, there is a canonical cover Y→X such that the preimage of P consists of a sinple point Q, which is Gorenstein. In other words, being Gorenstein is the same as having index one in dimension three. However, this is no longer the case in dimension four. Take a quotient singularity 1/5(1,4,2,3) for example, one imagines that it has index 5 but it is Gorenstein. Therefore, being Gorenstein seems not to be a good notion in higher dimension.

Year Three:

In the third year, we will turn our attention to minimal model program in dimension four or higher. The classification of Mori and Kollar on extremal neighborhood depends on the careful studies of local invariants on extremal neighborhood. We shall try to work on this in higher dimensional settings. The main tasks are to formulate a partial ordering on the set of local invariants and to find a partial resolution of extremal neighborhood into an extremal neighborhood with controllable singularities. This is considered to be helpful to the problem of existence and termination of flips as what we have done in [CH].

The difficulty is that so far we don't have good description of the terminal singularities that might involve in a given extremal neighborhood. Therefore, one can not expect to have a complete classification of extremal neighborhood according the type of singularities contained in it (cf. [Mo88], [KM92]). An even more serious problem is that in the situation of dimension 4 or higher, the singular locus might be positive dimensional. Could it happen that the whole extremal curve is contained in the singular locus? Or can one deform the extremal curve into another one which contained only isolated points?

A possible solution is instead of classifying extremal neighborhood by the type of singularities contained in it, one might be able to classify local invariants. One needs to study the extremal contraction when local invariants are trivial, as people did in threefolds. If all these can be worked out, is there a reasonable way to discuss the possible derived flip and divisorial contractions? A positive answer to the above question will be very useful to the existence and terminal of flips. We hope to at least work this out in dimension four by our explicit understanding of threefolds.

Year Four:

In the fourth year, we will seek for various applications on explicit birational geometry of minimal varieties of the theory we developed in the past three years. The first type of question is the effectiveness of pluricanonical maps. Recall in the case of surfaces, a beautiful theorem of classical Italian school asserts that

Theorem

Let X be a complex algebraic surface , then

$k=-\infty$ iff $P_{12}=0$,

$k=0$ iff $P_{12}=1$,

$k=1$ iff $P_{12}=2$ and $K^2=0$

$k=2$ iff $P_{12}=2$ and $K^2>0$

In general with intermediate Kodaira dimension, there is a theoretic bound thanks to the result of Fujino-Mori. Together with Kawamata's result on threefold with k=0, Viehweg and Zhang's result on threefolds with k=2 and our previous result on threefolds of general type, the remaining non-explicit case is the case when k=1. By using the technique of explicit birational geometry, one expects to have a similar unified result for threefolds and even fourfolds as in the two-dimensional case.

Another possible application is some explicit aspects of Fano-type varieties. For example, it is known that weak Q-Fano threefold is bounded. It is known that the lower bound of anticanonical volume is 1/330, which is sharp. The known example with highest anticanonical volume is 72. However, it is not known whether 72 is optimal or not. We expect that our explicit description of birational map will be helpful to determine the upper bound of anticanonical volume. We hope that our work in the first three years will make it possible to study Fano 4-folds. .

十三、近三年內執行之研究計畫

（請務必填寫近三年所有研究計畫）

計畫名稱 （本會補助者請註明編號）	計畫內擔任之工作	起迄年月	補助或委託機構	執行情形	經費總額
數統學門數學組研究發展及推動計畫 (100-2114-M-002-001-)	主持人	2011/1/1 ~ 2011/12/31	行政院國家科學委員會	執行中	238,000
以代數幾何方法研究控制理論及相關問題 (99-2221-E-019-003-)	共同主持人	2010/8/1 ~ 2011/7/31	行政院國家科學委員會	執行中	614,000
中華民國數學會學術研究發展計畫 (99-2114-M-310-001-)	主持人	2010/1/1 ~ 2010/12/31	行政院國家科學委員會	執行中	2,000,000
數統學門數學組研究發展及推動計畫 (99-2114-M-002-002-)	主持人	2010/1/1 ~ 2010/12/31	行政院國家科學委員會	執行中	238,000
中華民國數學會期刊出版及學術推廣業務計畫 (98-2114-M-310-001-)	主持人	2009/1/1 ~ 2009/12/31	行政院國家科學委員會	已結案	1,600,000
數統學門數學組研究發展及推動計畫 (98-2114-M-002-005-)	主持人	2009/1/1 ~ 2009/12/31	行政院國家科學委員會	已結案	238,000
高維流形中的奇點之研究 (97-2115-M-002-013-MY3)	主持人	2008/8/1 ~ 2011/7/31	行政院國家科學委員會	執行中	2,468,000
中華民國數學會學術研究發展計畫 (97-2114-M-310-001-)	主持人	2008/1/1 ~ 2008/12/31	行政院國家科學委員會	經費報銷審核中，報告已繳	1,600,000
高維流形中的奇點之研究 (97-2115-M-002-013-MY3)	主持人	2008/8/1 ~ 2011/7/31	行政院國家科學委員會	執行中	2,468,000
合　　計					11,464,000

100 年度自然處專題計畫主持人近五年研究成果

（修正：99/10/07）

姓名：　　　　　　　　　職稱：　　　　　　　服務機關系所：

一、近五年內(2006/1/1～2010/12/31)已出版之最具代表性研究成果至多六篇，擇其中五篇電子檔上傳。(請依序填寫：姓名,著作名稱,發表年份,期刊,卷數,頁次,IF,▲：被引用次數，並以＊號註記該篇所有的通訊作者)

1. J. A. Chen, M. Chen, D.Q. Zhang, *The 5-canonical system on 3-folds of general type*, J. Reine Angew. Math., 603, (2007), 165-181.
2. J. A. Chen, M. Chen, *An optimal boundedness on weak $\bQ$-Fano threefolds*, Adv. Math., 219, (2008), 2086-2104.
3. F. Campana, J. A. Chen, T. Peternell, *On strictly nef divisors*, Math. Ann., 342, (2008), 565-585
4. J. A. Chen, C. D. Hacon, *On Ueno's Conjecture K*, Math. Ann., 345, (2009), 287-296. arXiv 0802.1060.
5. J. A. Chen, M. Chen, *Explicit birational geometry of threefolds of general type I*, Ann. Sci. Ecole Norm. Sup., (43) 2010, 365-394.. arXiv 0810.5041
6. J. A. Chen, C.D. Hacon, *Factoring 3-fold flips and divisorial contractions to curves*. Jour. Reine Angew. Math., to appear, arXiv 0910.4209

二、近五年內研究成果統計表（請務必更新個人資料表 C302-C303，未來審查時將以該表之內容為準）

統計類別	2006		2007		2008		2009		2010		以上合計		2010 已接受但 2011 以後出版者	
	總篇數	IF 總和	總篇數	IF 總和	總篇數	IF 總和	總篇數	IF 總和	總篇數	IF 總和	總篇數	IF 總和	總篇數	IF 總和
SCI 期刊論文（含共同作者）	1	0.443	3	2.133	3	2.845	2	1.51	1	1.109	10	8.037	3	3.012
SCI 期刊論文（限通訊作者）														
僅物理學門填寫 SCI 期刊論文（限非屬通訊之第一作者）														

說明：

1. SCI (Science Citation Index) 之 Impact Factor 係以 **2009** 年版本為準。請至有購買 Journal Citation Reports on the Web（JCR Web）資料庫之各大學圖書館或財團法人國家實驗研究院科技政策研究與資訊中心(http://cdnet.stpi.org.tw/db_search/01_isi.htm)進行查詢。
2. IF 總和：係該年度論文所刊載期刊之 Impact Factor 總和。

1. J.A. Chen, C. D. Hacon, *An example of a surface of general type with* $p_g=q=2$ *and* $K_X^2=5$, Pacific Jour. Math., 223, (2006), 219-228.
2. J. A. Chen, M. Chen, D.Q. Zhang, *The 5-canonical system on 3-folds of general type*, J. Reine Angew. Math., 603, (2007), 165-181.
3. J.A. Chen, C.D. Hacon, *Pluricanonical systems on irregular 3-folds of general type*, Math. Zeit, 255, (2007),343-355.
4 J. A. Chen, M. Chen, *On projective threefolds of general type*. Elec. Res. Announc. Math. Sci., 14, (2007), 69-73.
5. F. Campana, J. A. Chen, T. Peternell, *On strictly nef divisors*, Math. Ann., 342, (2008), 565-585.
6. J. A. Chen, M. Chen, *An optimal boundedness on weak $\bQ$-Fano threefolds*, Adv. Math., 219, (2008), 2086-2104.
7. J.A. Chen, M. Chen, *The canonical volume of threefolds of general type with X<1,* J. London Math. Soc., 78, (2008), 693-706. arXiv 0704.1702
8. J. A. Chen, C. D. Hacon, *On the geography of threefolds of general type*, J. Alg., 321, (2009), 2500-2507. arXiv 0802.0884.
9. J. A. Chen, C. D. Hacon, *On Ueno's Conjecture K*, Math. Ann., 345, (2009), 287-296. arXiv 0802.1060.
10. J. A. Chen, M. Chen, *Explicit birational geometry of threefolds of general type, I*, Ann. Sci. École Norm. Sup. (43) 2010, 365-394. arXiv 0810.5041
11. J. A. Chen, M. Chen, *Explicit birational geometry of threefolds of general type, II*, Jour.Diff. Geom, to appear, arXiv 0810.5044
12. J Chen, J. A. Chen, M. Chen, *On quasismooth weighted complete intersections*, Jour. Alg. Geom, to appear. arXiv 0908.1439
13. J. A. Chen, C. D. Hacon, *Factoring 3-fold flips and divisorial contractions to curves.* Jour. Reine Angew. Math., to appear, arXiv 0910.4209
14. J. A. Chen, C. D. Hacon, *Kodaira dimension of irregular varieties*, arXiv 1008.2404

三、近五年內獲獎情形及重要會議邀請演講至多五項。

1. 中華民國數學會青年數學家獎 2007
2. 國科會傑出研究獎 2009-2012
3. 世界華人數學家大會晨興數學獎銀獎 2010
4. 中華民國數學年會大會主講 Plenary speaker 2010
5. 世界華人數學家大會大會主講 Plenary speaker 2010

四、近五年內其他資料：擔任國際重要學術學會理監事、國際知名學術期刊編輯或評審委員等。

Referee for journals include: Duke Math Jour, Comp. Math., Math. Ann., Jour. Alg Geom., Nagoya Math. Jour., Math. Zeit., etc.

五、請簡述上述代表性研究成果之個人重要貢獻（至多一頁）。

1. Birational Geometry of threefolds.

Given a variety of general type, it is natural and important to ask when the pluricanonical map is birational. This was previously known only for curves and surfaces to be 3-canonical and 5-canonical respectively. Only quite recently, Hacon and McKernan show that there exist a constant c_n, depending only on dimension n, such that the m-th canonical map is birational for m greater than c_n. This leads to the boundedness for varieties of general type. However, their result is non-explicit.

The standard approach uses natural geometric fibration such as Albanese map or canonical map. Therefore the remaining difficult cases are the varieties with small birational invariants that there is no natural fibration structure and their minimal model is singular. In my series of joint work with Meng Chen (cf. [1,2,5]) we obtained a breakthrough on threefolds of general type by the study of three dimensional terminal singularities. We introduced a notion called *“packing of baskets of singularities”* (cf. [5]). We also introduce a canonical sequence of prime packings, which is some sort of approximation of baskets of singularities. The theory of basket we developed led to many important effective results for threefolds of general type. For example, we prove that $P_{12}>0$, $P_{24}>1$ and m-th canonical map is birational for m ≥ 73.

We would like to mentioned that the techniques also applicable to Fano threefolds (cf. [2]) and other threefolds, for example, weighted complete intersections.

With the better understand of three dimensional singularities, we the turn our attention to the singularities in birational maps in minimal model program. In [6], we prove that flips and divisorial contraction to a curve can be decomposed into simpler elementary maps by an inductive argument using partial resolution of singularities on extremal rays.

2. Varieties with Kodaira dimension zero.

The classification theory of varieties usually reduced to the study of varieties of the following three types: varieties of general type, varieties with Kodaira dimension zero and varieties with negative Kodaira dimension. For varieties with Kodara dimension zero, it is conjecture by Ueno that they are decomposed into product of abelian varieties and Calabi-Yau up to etale and birational morphisms. In [4], we gave a partial answer to Ueno’s conjecture. In fact, in our recent preprint, we proved the second statement of Ueno’s conjecture together with some application to the famous Iitaks’s Conjecture Cnm.

行政院國家科學委員會專題研究計畫申請書

一、基本資料： 申請條碼：94WFA0102432

本申請案所需經費(單選)	A 類(研究主持費及執行計畫所須經費)				
計畫類別(單選)	一般型研究計畫				
研究型別	個別型計畫				
計畫歸屬	自然處				
申請機構/系所（單位）	國立臺灣大學 數學系暨研究所				
本計畫主持人姓名	陳榮凱	職稱	教授	身分證號碼	*******681
本計畫名稱 中文	代數流形的雙有理分類				
本計畫名稱 英文	Birational Classification of Algebraic Varieties				
整合型總計畫名稱					
整合型總計畫主持人				身分證號碼	
全程執行期限	自民國 95 年 08 月 01 日起至民國 98 年 07 月 31 日				
研究學門(請參考本申請書所附之學門專長分類表填寫)	學門代碼	名稱(如為其他類，請自行填寫學門)			
	M2	數學			
研究性質	基礎研究				
本年度申請主持國科會各類研究計畫(含預核案)共 1 件。(共同主持之計畫不予計入) 本件在本年度所申請之計畫中優先順序(不得重複)為第 1 。					
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本計畫是否申請海洋研究船：否					
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傳真號碼	(02)23914439	E-MAIL：	jkchen@math.ntu.edu.tw		

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（二）若有申請國際合作研究計畫費用者，請將表 I002 之「C 類經費合計」欄金額填入「國際合作研究計畫國外學者來臺費用」欄內，「A 類經費與 B 類經費合計」欄金額填入「國際合作研究計畫出國差旅費」欄內。

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（四）「貴重儀器中心使用額度」係將第九項(表 C009)所列使用費用合計數填入。

（五）請依各年度申請博士後研究之名額填入下表。

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金額單位：新台幣元

補助項目 \ 執行年次		第一年 (95 年 8 月~96 年 7 月)	第二年 (96 年 8 月~97 年 7 月)	第三年 (97 年 8 月~98 年 7 月)	第四年	第五年
業務費		**946,000**	**946,000**	**946,000**		
研究人力費		816,000	816,000	816,000		
耗材及雜項費用		130,000	130,000	130,000		
國際合作研究計畫國外學者來臺費用		0	0	0		
研究設備費		**90,000**	**0**	**40,000**		
國外差旅費		**150,000**	**150,000**	**150,000**		
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出席國際學術會議差旅費		50,000	50,000	50,000		
國際合作研究計畫出國差旅費		0	0	0		
管理費		**155,400**	**141,900**	**147,900**		
合計		**1,341,400**	**1,237,900**	**1,283,900**		
貴重儀器中心使用額度		0	0	0		
博士後研究	國內、外地區	共 1 名	共 1 名	共 1 名	共名	共名
	大陸地區	共 0 名	共 0 名	共 0 名	共名	共名

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配合單位名稱	配合補助項目	配合補助金額	配合年次	證明文件

五、耗材及雜項費用：

（一） 凡執行研究計畫所需之耗材及雜項費用，均可填入本表內。

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合　計					130,000	

第2年

項 目 名 稱	說明	單位	數量	單價	金額	備註
雜支	影印、文具、資料檢索、國內差旅等。		1	130,000	130,000	
合　計					130,000	

第3年

項 目 名 稱	說明	單位	數量	單價	金額	備註
雜支	影印、文具、資料檢索、國內差旅等。		1	130,000	130,000	
合　計					130,000	

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						本會補助經費需求	提供配合款之機構名稱及金額
儀器及資訊設備	筆記型電腦及週邊配件/	筆記型電腦 ~70000 週邊配件 ~20000	1	90,000	90,000	90,000	
合		計			90,000	90,000	

第 2 年

類別	設備名稱 (中文/英文)	說　　明	數　量	單　價	金　額	經費來源	
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合		計					

第 3 年

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						本會補助經費需求	提供配合款之機構名稱及金額
儀器及資訊設備	電腦設備局部更新/	工作主機升級 ~20000 列印單元升級 ~15000 其他附件升級 ~5000	1	40,000	40,000	40,000	
合		計			40,000	40,000	

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第 1 年　　　　金額單位：新台幣元

申請補助費用		
經費類別	預估經費	詳述預定各出國人員之類別、出國行程、預估經費、天數及地點 (類別包括實驗、研究、田野調查)
赴國外	100,000	擬利用寒暑假期間前往國外訪問研究 1 至 4 週。可能地點有美國、德國、日本、法國等。
赴大陸	0	
合計	100,000	

第2年

申請補助費用		
經費類別	預估經費	詳述預定各出國人員之類別、出國行程、預估經費、天數及地點 (類別包括實驗、研究、田野調查)
赴國外	100,000	擬利用寒暑假期間前往國外訪問研究 1 至 4 週。可能地點有美國、德國、日本、法國等。
赴大陸	0	
合計	100,000	

第3年

申請補助費用		
赴大陸	0	

十一、研究計畫中英文摘要：請就本計畫要點作一概述，並依本計畫性質自訂關鍵詞。

（一）計畫中文摘要。（五百字以內）

（二）計畫英文摘要。（五百字以內）

我們計畫利用未來三年時間探討代數流形的雙有理分類理論。主要圍繞在以下的三個子計畫：1. k=0 的代數流形的結構。 2. 代數叢流形的結構。3.弧空間的幾何與奇點。這個計畫的成功將對雙有理分類理論有具體且基本的貢獻。

十一、研究計畫中英文摘要：請就本計畫要點作一概述，並依本計畫性質自訂關鍵詞。

（一）計畫中文摘要。（五百字以內）

（二）計畫英文摘要。（五百字以內）

In this three-years project, we are going to investigate birational classification theory of algebraic varieties. It will consist of the following three related subprojects: 1. Structure of varieties with k=0. 2. Algebraic fiber spaces. 3. Geometry of space of arcs and singularities. We hope that people will better understanding of birational classification theory once we succeed in this project.

十二、研究計畫內容：

（一）近五年之研究計畫內容與主要研究成果說明。（連續性計畫應同時檢附上年度研究進度報告）

The classification of algebraic varieties is one of the main theme in algebraic geometry. Our research was mainly around the birational classification problem. From Iitaka's point of view, the building blocks of varieties consists of the following three categories: varieties of general type, varieties with k=0, and varieties with k=-∞.

Varieties of general type.

It's well-known that mK_X defines a birational map for m sufficiently large. It's natural to ask whether one can determine m effectively. For dim X =1,2, these bounds are known to be 3 and 5 respectively. There is a recent work by Hacon and McKernan asserts that there is a theoretical bound m(n) depends on dim X =n. However, the number m(n) is far from being optimal in any way. On my joint work with Meng Chen and DeQi Zhang, we obtained that 5K is birational for minimal Gorenstein threefolds with at worst canonical singularities. This bound is optimal. In a joint previous joint work with Hacon, we show that $7K_X$ is birational for irregular threefolds. Our method can also be applied to certain higher dimensional irregular varieties.

Vareities with k=0.

In a series of joint work with Hacon, we first characterize abelian varieties as the varieties with P_2=1 and q= dim X. And then we can also characterize varieties with q= dim X and P_m is small. Basically, these are going to be certain covering over abelian varieties. We can completely describe varieties with $P_3 \leq 4$ and q= dim X.

Miscellaneous Results.

We have the following results which are also related to classification theory.

1. Irregularity of image of Iitaka fibration.
   Iitaka fibration is obtained by pluricanonical maps. In general, there is no good control of the geometry of its image except dimension. We can determine the irregularity of the image via the cohomological support loci of the original variety.
2. Effective non-vanishing on surface.
   It's a conjecture by Kawamata that if D is nef and D-K is nef and big. Then D is effective. We prove a non-vanishing theorem for Q-divisors on surface.
3. Strictly nef divisors.
   A strictly nef divisor is a divisor such that C.D > 0 for all curves C. A conjecture of Serrano asserts that K+tD is ample for t>dimX+1. In a joint work with Peternell and Campana, we verified this conjecture for threefolds unless one exception.

ON PROJECTIVE THREEFOLDS OF GENERAL TYPE

JUNGKAI A. CHEN AND MENG CHEN

Abstract. Let Y be a complex nonsingular projective 3-fold of general type. We show that $P_{12}(Y) \geq 1$, $P_{24}(Y) \geq 2$, the canonical volume $\mathrm{Vol}(Y) \geq 1/2660$ and that the pluri-canonical map φ_m is birational for all $m \geq 77$. Details will appear in [2].

1. Introduction and known results

Let Y be a non-singular complex projective variety of dimension n. It is said to be of general type if the pluricanonical map $\varphi_m := \Phi_{|mK_Y|}$ corresponding to the linear system $|mK_Y|$ is birational into a projective space for all $m \gg 0$. It is thus natural and important to ask whether one can find a practical constant $c(n)$ so that φ_m is birational for all $m \geq c(n)$ and for all varieties of general type of dimension n.

When $\dim Y = 1$, it was classically known that $|mK_Y|$ gives an embedding of Y into a projective space if $m \geq 3$. When $\dim Y = 2$, Bombieri's theorem [1] says that φ_m gives a birational map onto the image for $m \geq 5$. When $\dim Y \geq 3$, a recent remarkable result of Hacon and M^{c}Kernan [7], Takayama [16] and Tsuji [17] affirms the existence of $c(n)$. However no explicit numerical bound of $c(3)$ was known. Kollár [11] studied both irregular 3-folds and 3-folds with $P_k \geq 2$ for a certain positive integer k and found a constant $c(3)$ for those 3-folds. Kollár's results have been considerably improved respectively in [5] and [4] where nearly sharp $c(3)$ were found. For regular 3-folds of general type, Luo [13] has proved some partial bounds for $c(3)$.

We are interested in finding a concrete $c(3)$ for all 3-folds of general type. A possible approach is to use the cohomological method via vanishing theorems. This requires estimates on the positivity of the canonical divisor which is usually measured in terms of the singularities of any minimal model and the canonical volume

$$\mathrm{Vol}(Y) := \limsup_{\{m \in \mathbb{Z}^+\}} \left(\frac{n!}{m^n} \dim_{\mathbb{C}} H^0(Y, \mathcal{O}_Y(mK_Y))\right).$$

Lower bounds for the canonical volume are useful in producing lower bounds for the plurigenus $P_m(Y) := \dim_{\mathbb{C}} H^0(Y, mK_Y)$. The volume

The first author was partially supported by TIMS, NCTS/TPE and National Science Council of Taiwan. The second author was supported by both the Program for New Century Excellent Talents in University (#NCET-05-0358) and the National Outstanding Young Scientist Foundation (#10625103).

十二、研究計畫內容：

（二）研究計畫之背景及目的。請詳述本研究計畫之背景、目的、重要性及國內外有關本計畫之研究情況、重要參考文獻之評述等。本計畫如為整合型研究計畫之子計畫，請就以上各點分別述明與其他子計畫之相關性。

（三）研究方法、進行步驟及執行進度。請分年列述：1.本計畫採用之研究方法與原因。2.預計可能遭遇之困難及解決途徑。3.重要儀器之配合使用情形。4.如為整合型研究計畫，請就以上各點分別說明與其他子計畫之相關性。5.如為須赴國外或大陸地區研究，請詳述其必要性以及預期成果等。

（四）預期完成之工作項目及成果。請分年列述：1.預期完成之工作項目。2.對於學術研究、國家發展及其他應用方面預期之貢獻。3.對於參與之工作人員，預期可獲之訓練。4.本計畫如為整合型研究計畫之子計畫，請就以上各點分別說明與其他子計畫之相關性。

In the coming three years, we plan to investigate more on the birational classification theory. This is going to contain many related subprojects:

In this first year, we are going to study the following topics:

1. Structure of varieties with k=0.
   A conjecture of Ueno asserts that varieties with k=0 will splits into product of abelian varieties and Calabi-Yau varieties after finite etale coverings and birational morphisms. We have some partial result toward this direction. We hope that we can have some more progress on this using the new technique of multiplier ideals and some new results on algebraic fiber spaces.
2. Algebraic fiber spaces.
   There are various situation that we are led to the study of algebraic fiber spaces. For example, Iitaka fibration, Albanese morphism, and Mori fibration. It worth to have a more systematical study of algebraic fiber spaces. It's well-known that the push-forward of relative canonical sheaves is semipositive in some sense. However, in the application we are considering, we need a more precise measurement of positivity of relative canonical sheaves.
3. Geoemtry of space of arcs and singularities.
   We expect that many more geometric properties can be decoded from the geometry of space of arcs. To be more precise, we hope to consider a "change of variable formula" for finite morphisms. And we expect to have a reintepretaion of Fulton's connectedness theorem. All this is going to be relative with Carrel's conjecture concerning varieties whose cotangent bundle has global sections.

In the second year, we are going to study a conjecture of Miles Reid which says that $P_{-2}(X)>0$ for almost all $\bQ$-Fano 3-folds. There are already several known examples with $P_{-2}=0$ by Iano-Fletcher and Altinok and Reid. Another question that we are interested in is the boundedness of $\bQ$-Fano 3-folds, which is equivalent to the boundedness of the anti-canonical volume $-K^3_X$. Kawamata first showed the
boundedness of $-K^3$ for terminal $\bQ$-Fano 3-folds with Picard
number 1. Koll\'ar, Miyaoka, Mori and Takagi then gave the boundedness for all canonical $\bQ$-Fano 3-folds.

In the third year, we are going to do the same.