

REDUCIBLE SUBGROUPS OF EXCEPTIONAL ALGEBRAIC GROUPS

ALASTAIR J. LITTERICK AND ADAM R. THOMAS

ABSTRACT. Let G be a simple algebraic group over an algebraically closed field. A closed subgroup H of G is called G -completely reducible (G -cr) if, whenever H is contained in a parabolic subgroup P of G , it is contained in a Levi factor of P . In this paper we complete the classification of connected G -cr subgroups when G has exceptional type, by determining the L_0 -irreducible connected reductive subgroups for each simple classical factor L_0 of a Levi subgroup of G . As an illustration, we determine all reducible, G -cr semisimple subgroups when G has type F_4 and various properties thereof. This work complements results of Lawther, Liebeck, Seitz and Testerman, and is vital in classifying non- G -cr reductive subgroups, a project being undertaken by the authors elsewhere.

1. INTRODUCTION

The subgroup structure of linear algebraic groups is a theory with applications throughout algebra and beyond. When working over $\mathbb{R}$ or $\mathbb{C}$, close connections with compact Lie groups give direct applications in geometry and physics. Over local fields and global fields, important applications are found in number theory, for instance in the Langlands program. Over finite fields and their algebraic closures, the subgroup structure has direct applications to the study of finite simple groups, for instance the subgroup structure of exceptional simple algebraic groups has been heavily used in understanding maximal subgroups of the corresponding finite groups of Lie type [18, 9, 8, 16].

Reductive subgroups of reductive groups are an important special instance of this problem. On the one hand, a result of Borel and Tits [5] states that for a reductive group G , a connected subgroup of G is either itself reductive, or contained ‘canonically’ in a proper parabolic subgroup of G . Thus the problem reduces to understanding parabolic subgroups and reductive subgroups, for instance a maximal connected subgroup of G is either parabolic or reductive. On the other hand, understanding reductive subgroups is equivalent to understanding affine homogeneous spaces for G , since for a closed subgroup $H \leq G$, the coset space G/H is an affine variety precisely when H° is reductive [23].

Let G be a connected reductive algebraic group over an algebraically closed field. Following [25], a closed subgroup H of G is said to be G -completely reducible (G -cr) if whenever H is contained in a parabolic subgroup P of G , it is contained in a Levi factor of P , and non- G -cr otherwise. Similarly, H is called G -irreducible or just *irreducible* if H is not contained in any proper parabolic subgroup of G , and *reducible* otherwise. The G -cr subgroups of G are precisely the L -irreducible subgroups of L , as L ranges over the Levi subgroups of G [4, Corollary 3.5], allowing $L = G$ to account for G -irreducible subgroups.

In the present work we classify the L_0 -irreducible connected subgroups as L_0 varies over those simple algebraic groups of classical type which occur as factors of Levi subgroups of a simple algebraic group G of exceptional type. Together with work of the second author and many others [1, 13, 14, 16, 28, 27, 29, 30, 31], the results here effectively complete the classification of G -cr

2010 *Mathematics Subject Classification.* 20G07 (Primary), 20G41, 20G10 (Secondary).

The first author is supported by the Alexander von Humboldt Foundation. Both authors thank the anonymous referee for their careful reading and numerous suggestions that have improved the paper.

Reductive Subgroups Of Exceptional Algebraic Groups

David A. Craven



Reductive Subgroups Of Exceptional Algebraic Groups:

Reductive Subgroups of Exceptional Algebraic Groups Martin W. Liebeck, 1996 *Reductive Subgroups of Exceptional Algebraic Groups* Martin W. Liebeck, Gary M. Seitz, 1996 The theory of simple algebraic groups is important in many areas of mathematics The authors of this book investigate the subgroups of certain types of simple algebraic groups and obtain a complete description of all those subgroups which are themselves simple This description is particularly useful in understanding centralizers of subgroups and restrictions of representations

The Irreducible Subgroups of Exceptional Algebraic Groups Adam R. Thomas, 2021-06-18 This paper is a contribution to the study of the subgroup structure of exceptional algebraic groups over algebraically closed fields of arbitrary characteristic Following Serre a closed subgroup of a semisimple algebraic group G is called irreducible if it lies in no proper parabolic subgroup of G In this paper we complete the classification of irreducible connected subgroups of exceptional algebraic groups providing an explicit set of representatives for the conjugacy classes of such subgroups Many consequences of this classification are also given These include results concerning the representations of such subgroups on various G modules for example the conjugacy classes of irreducible connected subgroups are determined by their composition factors on the adjoint module of G with one exception A result of Liebeck and Testerman shows that each irreducible connected subgroup X of G has only finitely many overgroups and hence the overgroups of X form a lattice We provide tables that give representatives of each conjugacy class of connected overgroups within this lattice structure We use this to prove results concerning the subgroup structure of G for example when the characteristic is 2 there exists a maximal connected subgroup of G containing a conjugate of every irreducible subgroup A_1 of G

On Non-Generic Finite Subgroups of Exceptional Algebraic Groups Alastair J. Litterick, 2018-05-29 The study of finite subgroups of a simple algebraic group G reduces in a sense to those which are almost simple If an almost simple subgroup of G has a socle which is not isomorphic to a group of Lie type in the underlying characteristic of G then the subgroup is called non generic This paper considers non generic subgroups of simple algebraic groups of exceptional type in arbitrary characteristic

A_1 Subgroups of Exceptional Algebraic Groups Ross Lawther, Donna M. Testerman, 1999 This book is intended for graduate students and research mathematicians interested in group theory and generalizations

Maximal PSL_2 Subgroups of Exceptional Groups of Lie Type David A. Craven, 2022-04-08 View the abstract

Algebraic Groups and their Representations R.W. Carter, J. Saxl, 2012-12-06 This volume contains 19 articles written by speakers at the Advanced Study Institute on Modular representations and subgroup structure of algebraic groups and related finite groups held at the Isaac Newton Institute Cambridge from 23rd June to 4th July 1997 We acknowledge with gratitude the financial support given by the NATO Science Committee to enable this ASI to take place Generous financial support was also provided by the European Union We are also pleased to acknowledge funds given by EPSRC to the Newton Institute which were used to support the meeting It is a pleasure to thank

the Director of the Isaac Newton Institute Professor Keith Moffatt and the staff of the Institute for their dedicated work which did so much to further the success of the meeting The editors wish to thank Dr Ross Lawther and Dr Nick Inglis most warmly for their help in the production of this volume Dr Lawther in particular made an invaluable contribution in preparing the volume for submission to the publishers Finally we wish to thank the distinguished speakers at the ASI who agreed to write articles for this volume based on their lectures at the meet ing We hope that the volume will stimulate further significant advances in the theory of algebraic groups

The Maximal Subgroups of Positive Dimension in Exceptional Algebraic Groups Martin W. Liebeck, Gary M. Seitz, 2004 Intends to complete the determination of the maximal subgroups of positive dimension in simple algebraic groups of exceptional type over algebraically closed fields This title follows work of Dynkin who solved the problem in characteristic zero and Seitz who did likewise over fields whose characteristic is not too small

The Reductive Subgroups of GF_4 David I. Stewart, 2013-04-22 Let G be a simple algebraic group defined over an algebraically closed field K of characteristic $p \geq 0$ A subgroup X of G is said to be G completely reducible if whenever it is contained in a parabolic subgroup of G it is contained in a Levi subgroup of that parabolic A subgroup X of G is said to be G irreducible if X is in no proper parabolic subgroup of G and G reducible if it is in some proper parabolic of G In this paper the author considers the case that $G = F_4(K)$ The author finds all conjugacy classes of closed connected semisimple G reducible subgroups X of G Thus he also finds all non G completely reducible closed connected semisimple subgroups of G When X is closed connected and simple of rank at least two he finds all conjugacy classes of G irreducible subgroups X of G Together with the work of Amende classifying irreducible subgroups of type A_1 this gives a complete classification of the simple subgroups of G The author also uses this classification to find all subgroups of GF_4 which are generated by short root elements of G by utilising and extending the results of Liebeck and Seitz

Maximal Subgroups of Exceptional Algebraic Groups Gary M. Seitz, 1991 Let G be a simple algebraic group of exceptional type over an algebraically closed field of characteristic p The subgroups of G maximal with respect to being closed and connected are determined although mild restrictions on p are required in dealing with certain simple subgroups of low rank For $p = 0$ we recover the results of Dynkin

Representations of Reductive Groups Roger W. Carter, Meinolf Geck, 1998-09-03 This volume provides a very accessible introduction to the representation theory of reductive algebraic groups

Linear Algebraic Groups and Finite Groups of Lie Type Gunter Malle, Donna Testerman, 2011-09-08 Originating from a summer school taught by the authors this concise treatment includes many of the main results in the area An introductory chapter describes the fundamental results on linear algebraic groups culminating in the classification of semisimple groups The second chapter introduces more specialized topics in the subgroup structure of semisimple groups and describes the classification of the maximal subgroups of the simple algebraic groups The authors then systematically develop the subgroup structure of finite groups of Lie type as a consequence of the structural results on

algebraic groups This approach will help students to understand the relationship between these two classes of groups The book covers many topics that are central to the subject but missing from existing textbooks The authors provide numerous instructive exercises and examples for those who are learning the subject as well as more advanced topics for research students working in related areas

Irreducible Subgroups of Exceptional Algebraic Groups Donna M. Testerman, 1988 Let Y be a simply connected simple algebraic group of exceptional type defined over an algebraically closed field k of prime characteristic $p > 0$ The main result describes all semisimple closed connected subgroups of Y which act irreducibly on some rational $k[Y]$ module V This extends work of Dynkin who obtained a similar classification for algebraically closed fields of characteristic 0 The main result has been combined with work of G Seitz to obtain a classification of the maximal closed connected subgroups of the classical algebraic groups defined over k

Centres of Centralizers of Unipotent Elements in Simple Algebraic Groups Ross Lawther, Donna M. Testerman, 2011 Let G be a simple algebraic group defined over an algebraically closed field k whose characteristic is either 0 or a good prime for G and let $u \in G$ be unipotent The authors study the centralizer $C_G(u)$ especially its centre $Z(C_G(u))$ They calculate the Lie algebra of $Z(C_G(u))$ in particular determining its dimension they prove a succession of theorems of increasing generality the last of which provides a formula for $\dim Z(C_G(u))$ in terms of the labelled diagram associated to the conjugacy class containing u

Unipotent and Nilpotent Classes in Simple Algebraic Groups and Lie Algebras Martin W. Liebeck, Gary M. Seitz, 2012-01-25 This book concerns the theory of unipotent elements in simple algebraic groups over algebraically closed or finite fields and nilpotent elements in the corresponding simple Lie algebras These topics have been an important area of study for decades with applications to representation theory character theory the subgroup structure of algebraic groups and finite groups and the classification of the finite simple groups The main focus is on obtaining full information on class representatives and centralizers of unipotent and nilpotent elements Although there is a substantial literature on this topic this book is the first single source where such information is presented completely in all characteristics In addition many of the results are new for example those concerning centralizers of nilpotent elements in small characteristics Indeed the whole approach while using some ideas from the literature is novel and yields many new general and specific facts concerning the structure and embeddings of centralizers

The Finite Irreducible Linear 2-Groups of Degree 4 Dane Laurence Flannery, 1997 This memoir contains a complete classification of the finite irreducible 2 subgroups of $GL(4, C)$ Specifically the author provides a parametrized list of representatives for the conjugacy classes of such groups where each representative is defined by generating a set of monomial matrices The problem is treated by a variety of techniques including elementary character theory a method for describing Hasse diagrams of submodule lattices and calculation of 2 cohomology by means of the Lyndon Hochschild Serre spectral sequence Related questions concerning isomorphism between the listed groups and Schur indices of their defining characters are also considered

$\mathbb{Z}_2$ Functions for the Orthogonal Group David

Ginzburg, Il'ia Iosifovich Piatetskiĭ-Shapiro, Stephen Rallis, 1997 In this book the authors establish global Rankin Selberg integrals which determine the standard L function for the group GL(r, G) where G is an isometry group of a nondegenerate symmetric form The class of automorphic representations considered here is for any pair of dyadic Kronecker tensor product symbols Π_1 and Π_2 where Π_1 is generic cuspidal for GL(r, G) and Π_2 is cuspidal for G The construction of these L functions involves the use of certain new models of local representations these models generalize the usual generic models The authors also compute local unramified factors in a new way using geometric ideas [Multiplicity-free Representations of Algebraic Groups](#) Martin W. Liebeck, Gary M. Seitz, Donna M. Testerman, 2024-03-18 View the abstract [The Fundamental Lemma for the Shalika Subgroup of \$GL\(4\)\$](#) Solomon Friedberg, Hervé Jacquet, 1996 The authors establish the fundamental lemma for a relative trace formula The trace formula compares generic automorphic representations of GS_4 with automorphic representations of GS_4 which are distinguished with respect to a character of the Shalika subgroup the subgroup of matrices of 2 x 2 block form $\begin{pmatrix} g & 0 \\ 0 & g \end{pmatrix}$ over superscript g The fundamental lemma giving the equality of the orbital integrals of the unit elements of the respective Hecke algebras amounts to a comparison of certain exponential sums arising from these two different groups [Conjugacy of \$\mathrm{Alt}_5\$ and \$\mathrm{SL}\(2, 5\)\$ Subgroups of \$E_8\(\mathbb{C}\)\$](#) Darrin D. Frey, 1998 Exceptional complex Lie groups have become increasingly important in various fields of mathematics and physics As a result there has been interest in expanding the representation theory of finite groups to include embeddings into the exceptional Lie groups Cohen Grieser, Ryba, Serre and Wales have pioneered this area classifying the finite simple and quasisimple subgroups that embed in the exceptional complex Lie groups This work contains the first major results concerning conjugacy classes of embeddings of finite subgroups of an exceptional complex Lie group in which there are large numbers of classes The approach developed in this work is character theoretic taking advantage of the classical subgroups of E_6 The machinery used is relatively elementary and has been used by the author and others to solve other conjugacy problems The results presented here are very explicit Each known conjugacy class is listed by its fusion pattern with an explicit character afforded by an embedding in that class

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