MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

T a g u n g s b e r i c h t 18/1984

Gruppen, Graphen und Kammernsysteme

22.4. bis 28.4.1984

Obige Tagung unter Leitung von M. Aschbacher (Pasadena), D. Goldschmidt (Berkeley) und F. Timmesfeld (Gießen) hatte sich die Aufgabe gestellt, den Zusammenhang zwischen graphentheoretischen (Operation von amalgamierten Produkten auf den entsprechenden Bäumen) und geometrischen Methoden (Tits'sche Theorie der Gebäude, Theorie endlicher Tits Geometrien und ihren Überlagerungen) und der Theorie der endlichen einfachen Gruppen zu untersuchen. Insbesondere wurden Anwendungen obiger Methoden auf einem (teilweisen) Neuzugang zur Klassifikation der endlichen einfachen Gruppen erörtert.

Um dieser speziellen Themenstellung Rechnung zu tragen, wurde die Tagung durch 2 Übersichtsvorträge eröffnet. Delgado - Stellmacher referierten über die Amalgammethoden, J. Tits über die Klassifikation der affinen Gebäude vom Rang ≥ 4 und Anwendungen auf die Theorie der endlichen Gruppen und Geometrien. Auch die übrigen Vorträge zeigten, daß hier ein neues Arbeitsgebiet entstanden ist, das einen befruchtenden Zusammenhang zwischen

1) endlicher Gruppentheorie,
2) der Theorie alg. Gruppen über lokalen Körpern,
3) geometrischen Objekten, wie Gebäuden und Tits Geometrien (auch Rang 2 Objekten, wie Bäumen!)

herstellt.

Gefördert durch DFG Deutsche Forschungsgemeinschaft

Vortragsauszüge

F. Buekenhout:

On p-geometries for the finite simple groups

We introduce the concept of a good prime contributor p to the order |G| of a finite simple group G and we determine these primes for all G but $L_2(q)$, $L_3(q)$, $U_3(q)$. Given G and p, we define a canonical geometry $\Gamma_p(G)$ whose elements are the maximal subgroups of G and whose incident pairs are those whose intersection contains a p-Sylow subgroup of G. The geometries we look really for, are all truncations of $\Gamma_p(G)$ which are firm, residually connected, on which G acts chamber transitively with a solvable chamber stabilizer and whose non-trivial residues reproduce these conditions for some simple group involved in their G-stabilizer or for a solvable group.
We get a full classification: mainly building geometries, a series of sporadic geometries and some truncations. Each sporadic group has some geometry of rank 2 at least. Almost all alternating groups have no geometry. Most geometries which are produced are known by the work of Ronan-Smith, Ronan-Stroth, the author and others.

A. Chermak:

Index-p Systems

Let B be a finite p-group, B_1 and B_2 a pair of maximal subgroups of B, $r_i \in Aut(B_i)$ (i = 1,2). What can be said about the structure of B (and about the action of r_1 and r_2) if no non-identity subgroup of $B_1 \cap B_2$ is both normal in B and invariant under both r_1 and r_2?

This question can be investigated via the methods of "Amalgams", much in the spirit of Goldschmidt's work. Here however the "universal completion" $G = \langle B, r_1, r_2 \rangle$ acts on a type of geometric object (a grove) which may be thought of as a sheaf of trees over a tree.

A.M. Cohen

Local recognition of buildings of spherical type

Let Δ be the shadow space of a finite building of type F_4 on an end node r (lines are the shadows of flags of cotype r). Then there is a subspace (i.e. lineclosed subset) $\Delta^{(1)}$ such that for each $x \in \Delta$ we have $x^{\perp} \simeq \Delta^{(1)}$, where $x^{\perp} = \{y \in \Delta \mid y \text{ collinear with } x\}$.

Suppose that Γ is a space (of points and lines) such that for each point x, the set $x^{\perp}$ is a subspace isomorphic to $\Delta^{(1)}$. Assume that

(*) For each path x,y,z,u in Γ where x,z and y,u are non-collinear pairs, the size of $x^{\perp} \cap y^{\perp} \cap z^{\perp} \cap u^{\perp}$ is either ≤ 1 or equal to the size of $x^{\perp} \cap y^{\perp} \cap z^{\perp}$.

Then $\Gamma \simeq \Delta$.

In the "thin" case, there is a (unique) counterexample (work of Buset). The above result is obtained in joint work with B.N. Cooperstein.

A. Delgado, B. Stellmacher

Rank 2 groups I, II

A rank 2 amalgam consists of a triple of groups P_1, B, P_2 and embeddings $\varphi_i : B \to P_i$ (the information is typically depicted by $P_1 \supseteq B \subseteq P_2$).

A general method for the analysis of the structure of amalgams was discussed which we have applied to the proof of the following

Theorem: Let G be a group generated by two finite subgroups P_1, P_2 with $B = P_1 \cap P_2$. Assume there exists a prime p such that for $i = 1,2$:

(i) $O^{p'}(P_i/O_p(P_i)) \simeq (S)L_2(p^{n_i}),\ (S)U_3(p^{n_i}),\ Sz(p^{n_i}),\ Ree(p^{n_i})$.

(ii) $B = N_{P_i}(S),\ S \in Syl_p(P_1 \cap P_2)$

(iii) No non-trivial normal subgroup of G is contained in B.

(iv) $C_{P_i}(O_p(P_i)) \leq O_p(P_i)$

Then $P_1 \supseteq B \subseteq P_2$ is isomorphic to the amalgam $X_1 \supseteq Y \subseteq X_2$, where X_i are the maximal parabolic subgroups of a rank 2 group of Lie type (possibly decorated by some automorphisms) and Y is the corresponding Borel subgroup, or where the amalgam corresponds to one of the groups M_{12}, $Aut(M_{12})$, J_2, $G_2(2)'$, ${}^2F_4(2)'$ (in all of which p = 2) or Th (in which case p = 3).

O. Diawara

Some facts about the McLaughlin group

We investigate geometries for $G = M^c$, consisting of a set Ω of points on which G acts primitively and of a G-invariant family of subsets of Ω, whose maximal members are orbits of maximal subgroups of G. This leads to various questions about the subgroup structure of G. We obtain in particular two new geometries whose diagrams are as follows:

4, 7, (N)

o————————o

2	125
1	3
7128	299376
$U_3(5)$	$5^{1+2}.3.8$

$B = 5^{1+2}.8$

N undetermined but $N \in \{7,8\}$

c (between the third and fourth nodes), 3,4,4 (between the fourth and fifth nodes)

o————o————o————o————o

1	1	1	7	2
1	2	3	4	11
275	22275	779625	12474000	113400
$U_4(3)$	$M_{21}.2$	$(24A_4).S_3$	$3.S_4$	M_{11}

B = {1}

A. Dress

Chamber systems and tesselations, or how to construct Escher-like pictures

If one interprets the barycentric subdivision of a tessellation of a manifold as a thin chamber system, one can reconstruct the tessellated manifold from the quotient of that chamber system, taken with respect to the action of the symmetry group of the tessellation, once one keeps in mind the degree of ramification along each face of codimension 2, which can be done by associating to each orbit of the original chamber system a certain Coxeter matrix.
Applications with respect to the enumeration of (combinatorial types of) tilings of the euclidean plane with pregiven degrees of transitivity of the symmetry group on the tiles are indicated.

P. Fan

Amalgams of prime index

Set G to be a group of automorphisms of a tree Γ such that G_δ is a finite group acting transitively on the vertices adjacent to δ. We are motivated by the so called Goldschmidt-Sims problem, i.e. to find a constant m such that for all possible G and Γ, $G_\alpha^m = 1$ (no non-identity element fixes all vertices of distance m from α).
This is easily seen to be false if Γ has valence (n_1,n_2), where n_1, n_2 are not both prime. So one naturally asks what happens if the valence of Γ is given by a pair of prime numbers. In this case, we actually classify all possible amalgams $G_\alpha \supseteq G_{\alpha,\beta} \subseteq G_\beta$ where α and β are adjacent, and there are just 17 "interesting" ones. Further, our analysis shows that $m \leq 4$. However, the Goldschmidt-Sims problem under the general hypothesis of "primitivity" $G_\alpha \supseteq G_{\alpha,\beta} \subseteq G_\beta$ is far from being resolved.

D. Goldschmidt

Towards a generalization of the Sims conjecture

Let G be a primitve, edge-transitive group of automorphisms of a tree Γ with $G_\alpha^{(2)} \neq 1$ of Thompson-Wielandt characteristic p.
Assume that no non-identity p-element of G fixes infinitely many elements of Γ.
Then $|O_p(G_\alpha)| \leq q^6$, where

$$q = \frac{\max_\alpha |G_\alpha|_p}{\min_\alpha |O_p(G_\alpha^{(2)})|} .$$

D. Gorenstein

Revising the classification of the finite simple groups

I shall describe the plan which Richard Lyons, Ronald Solomon, and I have been developing for revising the classification of the finite simple groups. I shall first outline our approach to the study of centralizers of involutions, the aim of which is to show that a minimal counterexample is necessarily a group of even type, a somewhat weaker concept than that of a group of characteristic 2 type, and hence more easily attained. After that, I shall describe the role we foresee for the theory of Goldschmidt amalgams in classifying the simple groups of even type.

J.I. Hall

A symplectic geometry for the Hall-Janko group

It is known that the double cover of the Hall-Janko group, 2·HJ, is a subgroup of $Sp_6(9)$. I discuss the construction of 2HJ in this context and some of the geometric consequences.

G. Hanssens

A characterisation of buildings of spherical type in terms of points and lines

A result of Buekenhout (An approach to building geometries based on points, lines and convexity) is improved and extended. It concerns a characterisation of buildings of type $C_{n,1}$; $D_{n,1}$; $E_{4,1}$; $E_{5,1}$;...;$E_{8,1}$; $F_{4,1}$, using axioms talking about points and lines only. Moreover, in the finite case the axioms can be weakened to enclose also most of the buildings of type $A_{n,j}$; $C_{n,j}$; $D_{n,j}$; $E_{n,j}$; $F_{4,1}$.

V. Mazurov (Novosibirsk)

On the wide subgroups of finite groups

Let $n(X)$ denote the minimum of indices of proper subgroups of a finite group X. A subgroup A of a finite group G is said to be wide subgroup of G if A is maximal under inclusion in the set $\{X \mid X < G,\ X \text{ is simple and } n(X) = n(G)\}$. If A is a wide subgroup of a simple group G then $C_G(A) \leq A$ and $N_G(A)$ is a maximal subgroup of G.

THEOREM (V.Mazurov, A.Fomin). If all wide subgroups of all known finite simple groups are known simple groups then all finite simple groups are known.

Almost all known sporadic groups have no wide subgroups.

Th. Meixner

Some chamber systems with diagram of affine type

Let G be a group with finite subgroups $S, X_1,\ldots,X_n$ such that $C(G;S;X_1,\ldots,X_n)$ is a chamber system with affine type M. Some remarks were given indicating that rank at least 4 almost never occurs, since one can show (using Tits' classification of affine buildings, Tits' "Universal 2-cover Theorem" and a theorem of Feit-Tits on projective representations of extensions of finite simple groups) that the "kernel" of the stabilizer of a special vertex has to be trivial in most cases. Examples of rank 3 with diagrams  over GF(8), o══o══o over GF(2) and o══o══o over GF(3) and their universal 2-covers were given.

A. Neumaier

<u>The known distance regular graphs</u>

In joint work with A. Cohen (Amsterdam), a compilation and classification of the distance regular graphs known to us is presented. Apart from covers of complete graphs, the known graphs of diameter $d \geq 3$ fall into at least one of the following classes.

1. Pseudo classical graphs, with intersection array

   $b_i = \left(\begin{bmatrix} d \\ 1 \end{bmatrix} - \begin{bmatrix} i \\ 1 \end{bmatrix}\right)\left(\beta - \alpha\begin{bmatrix} i \\ 1 \end{bmatrix}\right)$, $c_i = \begin{bmatrix} i \\ 1 \end{bmatrix}\left(1 + \alpha\begin{bmatrix} i-1 \\ 1 \end{bmatrix}\right)$,

   where $\begin{bmatrix} i \\ 1 \end{bmatrix} = 1 + b + \ldots + b^{i-1}$ for a suitable basis b.

2. Pseudo partition graphs, with intersection array

   $b_i = (m-i)(1 + \alpha(m-1-i))$, $c_d = \gamma d(1 + \alpha(d-1))$

   $c_i = i(1 + \alpha(i-1))$ for $i < d$, $(m,\gamma) \in \{(2d,2),(2d+1,1)\}$

3. Pseudo near polygons, with intersection array satisfying

   $b_o \geq sc_d$, $b_o - b_i = sc_i$ for $i = o,\ldots,d-1$.

4. One further infinite family (d=3) and 18 sporadic graphs.

A. Pasini

On certain geometries of type C_n and F_4

We prove the following result:

Let Γ be a geometry in one of the following diagrams

```
o—o—o═o   (q > 1)
q q q q

o—o═o—o   (q > 1)
q q q q
```

Then there is at least one point a such that Γ_a is a building. Then, as a corollary, we get that, if Γ belongs to

```
(C_n)   o—o—o ... o—o═o   (q > 1, n ≥ 4)
        q q q     q q q

or to (F_4)   o—o═o—o   (q > 1)
              q q q q
```

then Γ is a building if Aut(Γ) is flag-transitive. Moreover, let Γ be a geometry in

```
     o—o—o═o   (q > 1)
     q q q q

or   o—o═o—o   (q > 1)
     q q q q
```

then Γ is a building if (LL) or, respectively, (LH) holds.

S. Rees

Geometries of type C_3

We are interested in classifying geometries of type C_3 because of a result of Tits: a geometry described by a Coxeter diagram is a building or a quotient of a building precisely if the same is true of its residues of types C_3 and H_3.

My talk is a survey of results on C_3-geometries, with three main results

(1) A geometry described by $o\!-\!\!-o\!=\!\!=\overset{1}{o}$ is either a building or a quotient of a building by a group of automorphisms of order 2.

(2) Geometries described by $\overset{1}{o}\!-\!\!-o\!=\!\!=o$ (equiv. $\overset{1}{o}\!-\!\!-\overset{1}{o}\!=\!\!=o$, $o\!-\!\!-\overset{1}{o}\!=\!\!=o$) are completely classified; there are many.

(3) A connection is found between the "A_7-geometry", described by $\overset{2}{o}\!-\!\!-\overset{2}{o}\!=\!\!=\overset{2}{o}$ and the Klein quadric over GF(2). Other C_3-geometries arise from Klein quadrics over other fields, though it seems unlikely that other thick finite geometries arise in this way. Perhaps we might hope to classify geometries described by $\overset{x}{o}\!-\!\!-\overset{x}{o}\!=\!\!=\overset{x}{o}$ by exploiting the connection with the Klein quadric.

M.A. Ronan

Extensions and truncations of chamber systems

A flag-geometry obtained by removing the vertices of certain specified types from another flag-geometry is called a truncation. This idea has a natural generalization to chamber systems. For example the M_{24}-geometry with diagram $o\!=\!\!=o\!-\!\!-o\!-\!\!-\square$ is a truncation of a chamber system with diagram $o\overset{\sim}{=\!\!=}o\!-\!\!-o\!-\!\!-o$, where $o\overset{\sim}{=\!\!=}o$ indicates a cover of the generalized quadrangle. However, given a geometry with diagram $o\!=\!\!=o\!-\!\!-o\!-\!\!-o\!-\!\!-\square\cdots\cdots\square$, it is the truncation of a chamber system with the "same" diagram. Several theorems of this type were stated and the essential ingredients of the proofs were given.

St.D. Smith

Representations of automorphism groups of chamber systems

Joint work of M. Ronan and S. Smith develops a construction of modules for Chevalley groups (in natural characteristic) by coefficient-homology on the

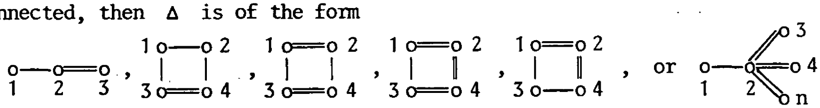
Building. We are now developing analogous constructions determined by natural geometries for sporadic groups.

We assume a chamber system, with a transitive automorphism group, and indicate the formalism of sheaf homology for this case. We say the geometry is "over F_q" if each panel stabilizer induces $(P)SL_2(q)$ on the chambers of the panel; in such a case we construct representations over F_q, with some analogy to "restricted weight" representations for Chevalley groups. Thus for a sporadic group, we get a class of representations, usually including most of the irreducibles.

G. Stroth

Geometries related to A_7

Let Γ be a Tits geometry of type M with flag-transitive group G. Suppose that every rank two residue is a projective plane of order two or the $Sp_4(2)$-quadrangle. Suppose that the A_7-geometry of type C_3 is involved. If the diagram Δ of Γ is connected, then Δ is of the form



Furthermore the groups G_i are determined. Examples for these geometries may be found in $\Omega_7(3)$, $\Omega_6^-(3)$ and Mc. The proof of this theorem uses, that if some diagram looks like , where $P_1/O_2(P_1) \simeq S_3 \simeq P_n/O_2(P_n)$, then G_1/K_1 or G_n/K_n (where K_i is the kernel of the representation of G_i on the residue of i) possesses an F_1-module, which does not occur very often; or $C_{G_1}(K_1) \nsubseteq K_1$. Using this, it is possible to show that there is no flag-transitive geometry of type o═o═o═o, which is one of the main tools for proving the theorem above.

F. Timmesfeld

Tits geometries and the classification of finite simple groups

Let G be a finite simple group of (weak) char.2-type, $S \in Syl_2(G)$ and $B = N(S)$. Then one can define minimal parabolic subgroups P_i of G containing B and show that $G = \langle P_i \mid i \in I\rangle$. From this one can deduce a new "program" to classify such finite simple groups.

(1) Determine the structure of the $\overline{P}_i = O^{2'}(P_i/O_2(P_i))$.

(2) Determine the structure of the $\overline{P}_{i,j} = O^{2'}\langle P_i,P_j\rangle/O_2\langle P_i,P_j\rangle$ using the "Goldschmidt amalgam method".

(3) Develop with the knowledge of (1) and (2) a theory of groups of higher rank.

Even if (1) is wide open in general, the structure of the $\overline{P}_i$ is very restricted in important special cases, as groups with small $e(G)$. (2) is in good shape, see Delgado-Stellmacher. The connection between (3) and finite flag-transitive classical Tits geometries was outlined and theorems classifying such geometries were discussed.

J. Tits

Classification of affine buildings and application to finite geometries

Let G be a quasi-simple, simply connected algebraic group over a locally compact local field K of characteristic p (we write also G for $G(K)$), let B be the normalizer of a maximal pro-p-subgroup of G and let $P_o,\dots,P_{l+1}$ be the maximal subgroups of G containing B. Then, the simplicial complex Δ whose set of vertices is $\{P_i g \mid i \in \{o,\dots,l+1\}, g \in G\}$ is a building of irreducible affine type (cf. Bruhat-Tits, Publ.Math. IHES, 41 (1972) and 60 (1984); also Proc.Symp. Pure Math. 33 (1979), 28-69) . (Here, for simplicity, buildings are always assumed to be complete, i.e. endowed with their maximal system of apartments.)

Theorem. Every (thick) locally finite building of irreducible affine type and rank ≥ 4 is obtained in the above way.

A similar result holds for non-locally finite buildings, starting from algebraic or classical groups over arbitrary local division rings.

Let Δ be an arbitrary (thick, complete) building of affine type. In the apartments of Δ, one defines the "quartiers", which are certain simplicial cones, as in loc. cit. 41. Two faces of quartiers are parallel if their mutual distances are finite, and they belong to the same germ if their intersection is open in each one of them.

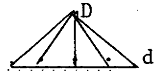
Proposition 1. The parallelism classes of faces of quartiers are the simplices of a building Δ^{∞} of spherical type.

When the rank is 2, Δ is a tree and Δ^{∞} is the set E of its ends. Then, Δ can be recovered from the data consisting of a certain real valued function ω on the set of ordered 4-tuples of distinct elements of E; this function is submitted to some conditions which will not be reproduced here, but which we express by saying that ω is a projective valuation of the set E (such valuations have been considered earlier by A. Dress).

Coming back to the general case, let now D be a panel (simplex of codimension 1) of Δ^{∞}. One shows that the set of germs (of faces of codimension 1 of quartiers of Δ) belonging to the parallelism class represented by D is, in a natural fashion, a tree whose ends are in 1-1 canonical correspondence with the chambers $C \in$ Star D (i.e. $D \subset \overline{C}$). Hence a projective valuation ω_D of Star D.

Proposition 2. The building Δ can be completely recovered from Δ^{∞} and the system $\{\omega_D \mid D$ a panel of $\Delta^{\infty}\}$. The latter is entirely determined by any single ω_D, except possibly in the cases of the types $\tilde{C}_2$, $\tilde{G}_2$. (These two cases are very probably no true exceptions but they must still be investigated.)

One can give necessary and sufficient conditions for a system $(\Delta^\infty, (\omega_D \mid D \text{ a panel of } \Delta^\infty))$ to provide a building. Those conditions provide the theorem but give also some information on the rank 3 case.

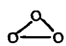
Example. In the $\tilde{A}_2$ case, Δ^∞ is the flag complex of a projective plane, the stars of panels are lines and pencils of lines and the necessary and sufficient condition for Δ to exist is that a perspectivity 

map ω_D onto ω_d.

In the last part of the lecture, the possibility of applying the theorem to the classification of finite geometries with diagrams of affine types was discussed (only in principle: some basic difficulties remain, e.g. in handling the case of a field K of equal characteristic). Here one uses deep theorems of Margulis (arithmeticity), Borel-Harish Chandra (compacity criterion) and Harder (Hasse principle), but they can be replaced by more elementary arguments when we assume the existence of a flag-transitive group of automorphisms.

M. Wester

Triangle Groups

Let C be a connected chamber system with diagram  such that the 2-cells are classical finite projective planes and such that C admits a flag-transitive automorphism group G with finite stabilizers of 2-cells. By a result of Timmesfeld G is then a triangle group, i.e. $G = \langle a_1, a_2, a_3 \rangle$ with $\langle a_i \rangle \simeq Z_3$ or Z_9 and $\langle a_i, a_j \rangle \simeq F_{21}$ or $F_{73.9}$. Considering the Frobenius (21)-case, this leads to four possible sets of relations between the generators a_i and thus to four "universal" triangle groups $G_1, \ldots, G_4$. Two of these four groups are explicitely constructed as regular automorphism groups of the chamber systems corresponding to the $SL_3(K)$-buildings of type $\tilde{A}_2$, where K is the field of 2-adic numbers or the field of Laurent-Series over GF(2). In particular one obtains by a projection-process finite chamber systems with diagram  over GF(2) and regular automorphism groups $SL_3(p)$, $p \equiv 1,2,4(7)$, $SU_3(p)$, $p \equiv 3,5,6(7)$, p an odd prime, or $SL_3(2^n)$, $n \geq 3$.

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