MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

Tagungsbericht 3/1981

Abelsche Gruppen

11.1. bis 17.1.1981

An der Tagung "Abelsche Gruppen" unter der Leitung der Herren L. Fuchs (New Orleans), R. Göbel (Essen) und E. Walker (Las Cruces) nahmen Mathematiker aus mehreren Ländern teil. Bemerkenswert war die große Zahl amerikanischer Gäste. Die Vorträge beleuchteten die neueren Entwicklungen der Theorie der abelschen Gruppen. So wurde mehrfach über bewertete Gruppen und über die Anwendung mengentheoretischer Axiome auf abelsche Gruppen vorgetragen. Letzteres stieß auch auf das Interesse der Modelltheoretiker, deren Tagung zur gleichen Zeit stattfand, und so konnten einige Vorträge beiden Gruppen angeboten werden. Umgekehrt trugen auch Modelltheoretiker über Ergebnisse vor, die bei den abelschen Gruppen und auch bei anderen mathematischen Disziplinen Anwendung finden.

Vortragsauszüge

K. Benabdallah

Hyper-indecomposable groups

An indecomposable torsion-free group is said to be hyper-indecomposable if all proper subgroups between its divisible hull and itself are indecomposable. We describe these groups in terms of the p-indicators of pairs of independent elements, a notion introduced in K. Benabdallah and A. Birtz: p-pure envelop~~p~~es of pairs in torsion-free abelian groups Comment. Math. Univ. St. XXVIII-1 (1979), 107-113. A group is said to be p-irrational for a prime p if all the p-indicators of linearly independent pairs of elements contain an irrational p-adic number. Theorem: G is hyper-indecomposable if and only if G is p-irrational for every p for which $pG \neq G$. This characterization is useful in as much as it indicates how to construct non-trivial examples of these groups.

R. Burkhardt

Zerlegungen torsionsfreier abelscher Gruppen des Ranges 3

Torsionsfreie abelsche Gruppen des Ranges 3 mit nichtisomorphen direkten Zerlegungen besitzen eine sehr einfache Struktur. Sie sind fast vollständig zerlegbar von der Form

$G = \langle a\rangle_* \oplus \langle\langle x\rangle_* \oplus \langle y\rangle_*, n^{-1}(x+y)\rangle$ mit $t(a) = t(x)$

unvergleichbar zu $t(y)$. Man kann die genaue Anzahl nichtisomorpher Zerlegungen in Abhängigkeit von $n, t(x)$ und $t(y)$ angeben. Man erhält folgendes Korollar: Für jede natürliche Anzahl n existiert eine abelsche torsionsfreie Gruppe des Ranges 3 mit genau n nichtisomorphen direkten Zerlegungen.

M. Dugas and R. Göbel

Endomorphism rings of torsion-free abelian groups (I/II)

Call an abelian group A cotorsion-free, if 0 is the only cotorsion subgroup of A. Assuming the existence of suitable stationary sets - whose existence is implied by V = L for instance - we show that rings R with cotorsion-free additive group are isomorphic to the endomorphism ring of some torsion-free abelian group.

P.C. Eklof

On the p-rank of Ext

This is a report on joint work with Martin Huber, giving a new proof of a theorem of Sageev and Shelah. The theorem says that, assuming CH, one can construct an ω_1-free group A of cardinality ω_1 which realizes an arbitrary given function for the p-rank of Ext(A,Z). The proof given by Sageev and Shelah makes use of elaborate combinatorial machinery. We give a new proof which relies on methods used by Chase in 1963 to prove the special case of an identically zero p-rank function. In addition we obtain analogous results for the p-rank of Ext(A,G) for any rational group G, and, more generally, for any indecomposable torsion-free G of finite rank such that $\dim G/pG \leqslant 1$ for any prime p.

Gefördert durch DFG Deutsche Forschungsgemeinschaft

K. Faltings

Characterization of elations

Let K be a skew field and let A be a vector space over K such that $n = \mathrm{Rank}(A) > 1$. If U is a subspace of A, then $E(U,U)$ denotes the group of all automorphisms δ of A such that $A(\delta - 1) \subseteq U$ and $U(\delta - 1) = 0$. If U is a point (Hyperplane) of A, then $E(U,U)$ is the group of all elations with centre (axis) U. Suppose that the characteristic of K is a prime $p > 0$. Then the following theorem holds:

Theorem. The following properties of the subgroup Δ of $\Gamma = \mathrm{Aut}_K A$ are equivalent:

(i) (a) Δ is an Abelian p-group, and

(b) $C_\Gamma \Delta\,[p] \subseteq \Delta$, and

(c) If $\delta \in \Delta$ such that $1 \neq \delta$ and $\delta^p = 1$, then $C_\Gamma(\delta) \subseteq N_\Gamma(\Delta)$.

(ii) (a) $\Delta = E(P,P)$ for some point P, or

(b) $\Delta = E(H,H)$ for some hyperplane H, or

(c) $|K| = 3$, $n = 3$ and Δ is one of the two other maximal subgroups of a 3-Sylowsubgroup of Γ, or

(d) $|K| = 2$, $n = 3$ and Δ is the third maximal subgroup of a 2-Sylow-subgroup of Γ.

B. Franzen

On algebraically compact filter quotients

For a filter φ on an index set I and a family of modules $(M_i)_{i\in I}$ their φ-direct sum is given by $\Sigma_\varphi(M_i) = \{f \in \prod_{i\in I} M_i \mid \{i \in I \mid f(i) = 0\} \in \varphi\}$. A filter φ is pure in another filter ψ if for every descending chain $(B_n)_{n\in\mathbb{N}}$ in ψ there are $A_n\,(n\in\mathbb{N})$ from φ and $X \in \psi$ such that for all $n \in \mathbb{N}$ $X \cap B_n = X \cap A_n$. The filter φ^* arises from φ by adding all countable intersections. Further a module is $\aleph_0$-compact, if every finitely solvable countable system of equations is globally solvable.

Theorem A : For a not $\aleph_0$-compact module M the quotient $\Sigma\psi(M)/\Sigma_\varphi(M)$ is $\aleph_0$-compact if and only if $\psi \subseteq \varphi^*$ and φ is pure in ψ. On the other hand for a $\aleph_0$-compact, not Σ-pure-injective module M the purity of φ in ψ suffices.

Theorem B : For filters $\varphi \subseteq \psi$ on a set I with card I = K is equivalent:
(a) $\psi \subseteq \varphi^*$, φ is pure in ψ and ψ is big over φ .
(b) For every family of nonzero groups $(G_i)_{i\in I}$ with card $G_i < 2^K$ is

$$\Sigma_\psi(G_i) / \Sigma_\psi(G_i) \cong \prod_p \Big((\bigoplus_{n\in\mathbb{N}} Z(p^n)^{(\alpha_{p,n})} \oplus I_p^{(\beta_p)} \Big) \oplus \bigoplus_p Z(p^\infty)^{(\gamma_p)} \oplus Q^{(\delta)} ,$$

where $\alpha_{p,n}$, β_p, γ_p and δ are either zero or 2^K and fulfil the inequalities $\beta_p \geqslant \limsup_{n\to\infty} \alpha_{p,n}$ and $\delta \geqslant \gamma_p$.

The meaning of the condition " ψ big over φ " will be given in the ta

L. Fuchs

<u>Extensions of isomorphisms between subgroups</u>

If A,C are p-groups and G,H are subgroups, then a basic question is to find conditions under which a height-preserving isomorphism $\phi : G \to H$ can be extended to an isomorphism $\psi : A \to C$. The classical case is when G and H are nice subgroups. The talk discussed the adjunction of single elements $a \in A, c \in C$ with $pa \in G$, $pc \in H$, to G and H which are not of maximal heights in their cosets mod G,H. Let sup $h(a + g) = \lambda$ (limit ordinal) and $a \in \bigcap_{\rho<\lambda} (g_\rho + p^\rho A)$. If there is a $c \in \bigcap_{\rho<\lambda} (\phi g_\rho + p^\rho C)$ with $\phi(pa) = pc$, then such an extension is possible. These conditions are investigated via certain new valuation functions in A/G.

J. Hausen

<u>A cardinal-determined projectivity condition for abelian groups</u>

An abelian group G is said to be k-projective, k a cardinal, if G has the projective property relative to all exact sequences

$$O \to A \to B \to C \to O$$

of abelian groups in which C has a generating set of cardinality strictly less than k. The k-projectivity of G is related to the structrure of Ext(G,Z). Using results of S.Shelah and S.Chase, the existence of non-free $\aleph_1$-projective abelian groups is shown to be undecidable, while both the Continuum Hypothesis and its denial (plus Martin's Axiom) imply the existence of a reduced $\aleph_0$-projective group which is not free. A consequence of our results is the fact that $\aleph_0$-coseparable abelian groups are $\aleph_0$-separable.

M. Huber and R.B. Warfield,Jr.

Homomorphisms between Cartesian powers of an Abelian group

The kernels and cokernels of homomorphisms between Cartesian powers $A^X \to A^Y$ are studied in the case that A is a torsion-free reduced Abelian group of finite rank, and X,Y are sets of non-measurable cardinality. From a general duality for such powers an exact sequence is deduced which gives information about the cokernel of such a homomorphism. Particularly strong results are obtained for groups A whose endomorphism ring is hereditary.

R. Hunter

Valuated p-Groups

The theory of finite simply presented valuated p-groups is presented, together with certain extensions to the infinite core. Valuated trees play an important role. A retraction of a valuated tree is a map r of the tree to itself such that $r^2 = r$. Retractions include decompositions of the corresponding valuated groups, and irretractable trees determine indecomposable groups. Thus the fundamental objects are irretractable trees, and these correspond to finite ordials in the structure theory of finite abelian groups. It is shown that a simply presented valuated p-group with no elements of infinite value is a direct sum, unique up to isomorphism, of finite indecomposables.

F. Kiefer

The Duals of Totally Projective Groups

In problem 65 of his book Prof. Fuchs asks :"Which are the compact abelian groups whose duals are totally projective p-groups?" It turns out, that the various concepts, which are used to describe the totally projective groups, can be dualized more or less canonically, thus leading to a characterization of their duals. As an example, we may consider Hill's definition for totally projective p-groups, namely to be reduced p-groups having a nice system. Dually to $p^{\alpha}G$ for a group G, for every ordinal α and every compact group $\hat{G}$, $p^{-\alpha}(0_{\hat{G}})$ is defined inductively by $p^{-1}(0_{\hat{G}}) := \hat{G}[p]$; $p^{-(\alpha+1)}(0_{\hat{G}}) := \{x \in \hat{G} \mid px \in p^{-\alpha}(0_{\hat{G}})\}$ and $p^{-2}(0_{\hat{G}}) := \mathrm{cl}(\bigcup_{\beta<\alpha} p^{-\beta}(0_{\hat{G}}))$ if α is a limit ordinal. With this, subgroups F of $\hat{G}$ are distinguished satisfying $p^{-2}(0_F) = F \cap p^{-2}(0_{\hat{G}})$ $\forall\, \alpha$, which corresponds to nice subgroups of $\hat{G}$ via duality, and which can be used to characterize the duals of totally projective groups in a dual manner.

H. Lenzing

Vectorspace - valued diagrams on ordered sets: a simple model of abelian group theory

Diagrams D : $\ldots \to D_{n+1} \to D_n \to \ldots \to D_o$ on the ordered set $\mathbb{N}^{op}$ with values D_n in a category of vector spaces (over a fixed field k) constitute a category $[\mathbb{N}^{op}$, k-Mod] , which inherits nearly all the properties of abelian groups [more specifically of modules over a complete discrete valuation ring] : subdiagrams of free ones are free, divisibility coincides with injectivity, 3 types of indecomposables, theorems of Ulm, Kulikoff, Maranda, etc. ... Countably generated Whitehead-diagrams are always free, but [independent of the underlying set theory] there is a Whitehead-diagram with the power of the continuum, which is not free.

We further discuss the notions of projectivity, flatness and injectivity in [I,R-Mod] for an arbirary ordered set I, and ring R, resp. .

A. Mader

Functorial Topologies

Recently results of functorial topologies on abelian groups will be surveyed. Major topics will be:

1) Classification of functorial topologies
2) Some basic results and concepts
3) Duality theory and completion
4) Completability
5) Exact sequences of completions and the derived functors of the completion functor.
6) Various topics and questions

R. Mines

Completions of Valuated Groups

Let λ be a limit ordinal and define $V_p(\lambda)$ to be the full subcategory of the category of all valuated p-local groups consisting of those valuated groups whose values are in $\lambda_\infty = \lambda \cup \{\infty\}$. The category $V_p(\lambda)$ is the proper setting for the study of completions of groups in the p^λ-topology. In $V_p(\lambda)$ a sequence $0 \to A \to B \to C \to 0$ is stable exact if and only if

i) $A(\alpha) = A \cap B(\alpha)$ for all $\alpha \in \lambda_\infty$

ii) $C(\alpha) = B(\alpha) + A/A$ for all $\alpha \in \Lambda$

iii) $C(\infty) = \cap(B(\alpha)+A)/A$

The projective dimension of divisible groups breaks into two cases:

$\text{Proj dim } Z(p^\infty) = 2$ for all λ and

$\text{Proj dim } Q = 1$ if $\text{cof } \lambda = \omega$

$\text{Proj dim } Q = 2$ if $\text{cof } \lambda \neq \omega$

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J. Moore

Nice subgroups of valuated groups

The class of local valuated groups where every subgroup is nice is shown to be closed under finite sums. It follows that every subgroup of a finite direct sum of valuated cyclics is nice. Valuated groups where every subgroup is nice are characterized as extensions of direct sums of torsion free, finite rank, valuated groups of packed length ω with height topology equivalent to value topology, by a torsion group with a finite value set.

O. Mutzbauer

On decompositions of torsion-free abelian groups of rank 4

Torsion-free abelian groups of rank 3 having nonisomorphic decompositions are completely decomposable. This fails to be true for groups of rank 4. Two examples of such groups are given and for a certain class of groups $G = A \oplus B$ where A and B are for instance strongly indecomposable and quasi-isomorphic, the number of non-isomorphic decompositions will be calculated.

P. Plaumann

Groups with locally compact automorphism groups

The automorphism groups of groups in LCA, the class of locally compact abelian groups are considered with the g-topology of Arens. Call $G \in$ LCA a local minimax group, if a) every element of L lies in a compact subgroup, b) $L_{(p)}$ is compact or discrete for all but finitely many primes p.

Theorem: For a group $G \in$ LCA the following are equivalent:

(1) Aut F is locally compact for all factors F of G,

(2) $G = C \oplus \mathbb{R}^n \oplus L \oplus P$, with C compact, connected, of finite dimension, L locally minimax, Q discrete, torsion-free of finite rank.

L. Procházka

<u>p^{∞}-basic subgroups of torsion-free abelian groups</u>

If Y is a subset of a torsion-free group A then $\langle Y\rangle_{*p}$ denotes the p-pure hull of the subgroup $\langle Y\rangle$ in A. A finite independent set Y of A is p^{∞}-independent in A if the factor group $\langle Y\rangle_{*p}/\langle Y\rangle$ is finite. In general, an independent set $Y \subseteq A$ is p^{∞}-independent in A if each of its finite subsets is so. Now a subgroup B of A is called p^{∞}-basic in A if there is a maximal p^{∞}-independent set Y in A satisfying $\langle Y\rangle_{*p} = B$. Such B is always $\aleph_1$-free but it is not necessarily free. The class $\mathcal{V}_p$ of all torsion-free groups A containing at least one free p^{∞}-basic subgroups B is investigated. There are also studied some relations concerning the class $\mathcal{V}_p$ and other classes of torsion-free groups. For example it is shown that $\mathcal{B}_p \subseteq \mathcal{V}_p$ where $\mathcal{B}_p$ denotes the class of all torsion-free groups A such that $Q_p \otimes A$ belongs to a Baer class Γ_{α}.

K.M. Rangaswamy

<u>The Theory of Separable Mixed Abelian Groups</u>

This is a progress report on the recent work on the theory of separable mixed abelian groups. These are the abelian groups in which any finite subset can be embedded in a completely decomposable direct summand. Conditions for the complete decomposability of separable groups are explored and a criterion for separability of an abelian group A with A/A_t homogeneous is established. The endomorphism rings of 'properly' separable mixed groups are completely characterized. Necessary and sufficient conditions are obtained in order that a properly separable abelian group A becomes a projective, respectively flat, module over its endomorphism ring E(A). Finally, the Baer-Kaplansky theorem for separable groups is considered and it is shown that $E(A) \simeq E(B)$ implies $A \simeq B$ whenever A,B are properly separable with A/A_t and B/B_t each having a rank one summand of the smallest type τ.

J.D. Reid

Abelian Groups Finitely Generated over Their Endomorphism Rings

We treat torsion-free groups G of finite rank that are finitely generated as modules over their endomorphism rings E. If N is the nilradical of E then $G \overset{\circ}{=} NG \oplus H$ where E(H) has nilradical O, and H is finitely generated over E(H). Then $H \overset{\bullet}{=} \oplus H_i$ where the H_i are f.g. over $E(H_i)$, are irreducible groups and $\mathrm{Hom}(H_i, H_i) = 0$ if $i \neq j$. Each H_i in turn is a fractional ideal of a subring of an algebraic number field. Invariants similar to the types of rank 1 groups are constructed for irreducible groups f.g. over their endomorphism rings so that for such groups G and G', we have $G \overset{\bullet}{\approx} G'$ iff they have the same invariant. Finally we introduce something like a rank; $\rho(G) = \inf \{n \mid G \overset{\circ}{=} G'$ where G' can be generated by n elements $\}$. Then $\rho(G) \leqslant$ rank G with equality holding iff $G \overset{\circ}{=} \oplus A_j$, where each A_j has rank 1 and the A_j have incomparable idempotent types. Strongly indecomposable groups G have $\rho(G) = 1$.

F. Richman

Mixed local groups

Let G be a p-local group and H a nice torsion-free subgroup of G such that G/H is simply presented torsion. If H, viewed as a valuated group, is a direct sum of cyclics, then G° is a Warfield group. The theory of Warfield groups is extended by allowing H to be a direct sum of pseudo-cyclics, which are valuated groups satisfying some finiteness conditions and having local endomorphism rings in a suitable category. Examples of pseudo-cyclics include certain finitely generated subgroups of direct sums of cyclics, and of the p-adic integers.

G. Sageev

Some Implications of Set Theoretic Principles to the Structure of Ext(G,Z)

We examine the p-structure of Ext(G,Z) in the light of some extra set theoretic principles:

1) That from some combinatorial principles known to hold in the constructible hierarchy L, it follows that for any infinite successor cardinal κ less that the final weakly compact and regular cardinals $\lambda_p \leq \kappa^+$, there exists a group G of cardinality κ such that $\nu_o(G) = \kappa^+$ and $\nu_p(G) = \lambda_p$, for all primes p, (where $\nu_p(G)$ is the p-rank of Ext(G,Z) and $\nu_o(G)$ is the rank of the torsion-free part of Ext(G,Z)).

And, on the contrary,

2) If G is of weakly compact cardinality, κ, for which $\nu_p(G) \geq \kappa$, then $\nu_p(G) = \kappa^+$.

We also obtain related results concerning almost free groups, and some consequence of the generalized continuum hypothesis.

L. Salce

On a paper of I. Fleischer

A proof of the following result, claimed by Fleischer (1957), is given, by means of a technique that resembles the one used by Matlis in proving that a finitely generated module over an almost maximal valuation domain is a direct sum of cyclic modules : If M is a torsion module over an almost maximal valuation domain, then M is a direct sum of uniserial modules. An example is also given which shows that a pure submodule of an infinite direct sum of universal modules is not necessarily a direct sum of uniserial modules. A counterexample to a result of Fleischer shows that, in order to ensure that a dominating uniserial submodule V = J/I ($I \leq J$ ideals) is pure, one needs I to be archimedian.

E. Walker

Valuated p-groups

The various characterizations of totally projective p-groups make sense when stated in the category of valuated p-groups, but are not equivalent there. They distinguish two classes of valuated p-groups, simply presented valuated p-groups, and valuated p-groups with nice composition series. Various properties of these two classes are noted, as well as relations between them. A simple direct proof is given that a countable p-group with a nice composition series is simply presented which does not use either Ulm's or Zippen's theorem for these groups.

B. Wald

Homomorphisms from generalized products into generalized products

For an infinite cardinal κ we defined a subgroup of a product $\prod_{i \in I} A_i$ of abelian groups as follows:

$$\prod_{i \in I}^{\kappa} A_i = \{a \in \prod_{i \in I} A_i : | \{i \in I : a(i) \neq 0\} | < \kappa\} .$$

Now consider a homomorphism φ from such a group $\prod_{i \in I}^{\kappa} A_i$ into another one $\prod_{j \in J}^{\mu} G_j$ and prove the following theorem:

Theorem: If $\mu < \kappa$, κ is less or equal than the first measurable cardinal and all groups G_j are subgroups of products of slender groups. Then there exist $E \subseteq I$ and $F \subseteq J$, where the cardinalities of E and F are less than μ, such that

$$\varphi(\prod_{i \in I \setminus E}^{\kappa} A_i) \subseteq \prod_{j \in F} G_j .$$

B. Zimmermann-Huisgen

On the exchange property

(The following results have been established in a joined work with W. Zimmermann)

A new class of modules enjoying the exchange property (EP) is exhibited, namely, each strongly invariant submodule M of an algebraically compact module A has the (EP) ("strongly invariant" means $f(M) \subset M$ for all homomorphisms $f : M \to A$). This class comprises several well-known types of examples : the self-injective modules, as well as the torsion-complete primary resp. complete abelian groups.

Moreover, the question whether, for direct sums of modules with local endomorphism rings, the finite exchange property implies the unrestricted (EP) is answered in the positive. This is a consequence of the following theorem :

If $(M_j)_{j\in J}$ is a semi-T-nilpotent family of modules with the (EP), then $\bigoplus_{j\in J} M_j$ has the (EP) if one ot the following conditions is satisfied:

(I) M_j, M_k have no non-trivial isomorphic direct summand for $j \neq k$

(II) $M_j \cong M_k$ for all j,k.

(The first part is new, whereas the second is due to Harada and Ishii.)

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Speakers of the joint sessions with a meeting on "Model-theory"

K.J. Devlin	Department of Mathematics, University of Lancaster, U.K. : "Combinatorial principles in set theory"
P. Eklof	University of London, Bedford College and Department of Mathematics, University of California at Irvine, Irvine, California, U.S.A.: "On the rank of Ext".
F.D. Tall	Department of Mathematics, University of Toronto, Canada : "Martin's axiom"