MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

T a g u n g s b e r i c h t 26/1981

Darstellungstheorie endlich-dimensionaler Algebren

14.6. bis 20.6.1981

This meeting was organized by Prof. G.O. Michler (Essen) and Prof. C.M. Ringel (Bielefeld). The main interest was focused on recent developments in the representation theory of both finite groups and finite dimensional algebras. Therefore a series of survey lectures was given by P. Fong & B. Srinivasan and by L. Nazarova & G. Zavadskij. In addition to the usual morning and afternoon talks, several evening sessions were held to give an outlook on possible future developments.

In the week before this meeting there was a workshop at Bielefeld University which was attended by many participants of the Oberwolfach conference as well. Therefore, some of the lectures are included in the abstracts; if so, they are specially marked.

Vortragsauszüge

J.L. ALPERIN: *Principal indecomposable characters and normal p-subgroups*

Let P be a normal p-subgroup of the group G. Let Φ be a principal indecomposable character of G and let Φ^o be the corresponding such character of $G^o = G/P$. Let π be the permutation character of G on the elements of P given by conjugation.

THEOREM $\Phi = \Phi^o \cdot \pi$

A filtration on projective modules in characteristic p is studied to prove the result. Some applications are made to compute the Cartan matrix of G for P of certain types.

M. AUSLANDER: *Problems in the representation theory of finite dimensional algebras*
(Bielefeld)

A series of problems were presented concerning the following topics: a) criteria for when two modules are isomorphic and connections with the Cartan matrix of Auslander algebras; b) ring theoretic description of algebras of finite type; c) special types of modules and exact sequences; d) preprojective and preinjective partitions and modules. Some of the problems posed were

1) Describe the short exact sequences which give a natural basis for the relations for the Grothendieck of the finitely generated Λ-modules when Λ is of infinite representation type.

2) What does it mean about two standard algebras that their Auslander algebras have the same Cartan matrix?

3) Suppose Λ is of finite representation type. What does it mean about Λ that the number of preprojective and preinjective partitions are the same? Also how are the local modules distributed amongst the preprojective partitions? In particular, are they distributed fairly evenly or can there be large gaps?

R. BAUTISTA: *Algebras with a separation property*

Let Λ be an indecomposable artin basic algebra over an algebraically closed field. We will assume that the ordinary quiver of Λ has not oriented cycles.

Assume ${}_\Lambda\Lambda = P_1 \oplus \dots \oplus P_t$, P_i indecomposable projectives. Let $\mathcal{P} = \{P_1, \dots, P_t\}$. If $\mathcal{C}$ is a subset of $\mathcal{P}$ we will say that $\mathcal{C}$ is connected if for any $X, Y \in \mathcal{C}$ there exist $X = X_1, X_2, \dots, X_r = Y$ elements of $\mathcal{C}$ and non zero maps connecting X_i with X_{i+1} in one of the two possible directions.

NOTATION If $P \in \mathcal{P}$ $\mathcal{D}(P) = \{Q \mid$ there is a chain of non zero maps $P \to P_1 \to \dots \to P_s \to Q\}$.

DEFINITION 1 We will say that P (indecomposable projective) has separated radical if for any two indecomposable non isomorphic summands of rad P, M and N, Supp M and Supp N are in different components of $\mathcal{P} \setminus \mathcal{D}(P)$ with Supp $X = \{Q \mid \mathrm{Hom}(Q,X) \neq 0\}$.

DEFINITION 2 Λ has condition (s) if any indecomposable projective has separated radical.

DEFINITION 3 We recall that Λ is called simple connected if the Auslander-Reiten quiver G_Λ of Λ coincides with his universal covering.

THEOREM (Larrión-Salmerón) Λ is simple connected if and only if Λ has (s)-condition and is of finite representation type.

The idea of the proof is as follows:
First prove that G_Λ is a certain disjoint union of sections ((P) - coverings in the sense of [1]) if and only if G_Λ can be embedded in a certain good way in $\mathbb{Z}\Gamma$, the Riedtmann quiver attached to the quiver Γ, for certain Γ. It was proved in [1] that if Λ has (s)-condition then G_Λ has a (P)-covering. Therefore it can be shown that there is some good embedding $G_\Lambda \hookrightarrow \mathbb{Z}\Gamma$. Using (s)-condition it can be proved that Γ is a tree. Consequently Λ is simple connected. Now if Λ is simple connected it is not difficult to prove that G_Λ is embedded in $\mathbb{Z}\Gamma$ and then using geometrical arguments one can see that Λ has (s)-condition.

[1] R. Bautista and F. Larrión. The Auslander-Reiten quiver of certain algebras of finite representation type. Preprint. Publicaciones Previas INSTITUTO DE MATEMATICAS UNAM 1980.

R. BAUTISTA and S. BRENNER: *Tame graphs as sectional subgraphs of finite Auslander-Reiten graphs*

Let Γ be a finite connected oriented valued graph without oriented cycles. We say that the subgraph G_Γ of the Auslander-Reiten graph G of an artin algebra Λ is a sectional subgraph of type Γ if it is isomorphic to Γ as a directed valued graph and

1) if $A \to B \to C$ are arrows in G_Γ , $C \neq \operatorname{tr} DA$
2) if $A, B \in G_\Gamma$ and $A \xrightarrow{(d,d')} B$ is a valued arrow in G, then $A \xrightarrow{(e,e')} B$, with $e \leqq d, e' \subseteqq d'$ is an arrow in G .

If G_Γ contains no injective (projective) module we may apply $\tau = \operatorname{tr} D$ $(\tau^{-1} = D\operatorname{tr})$ to obtain a parallel sectional subgraph. If Γ is not Dynkin, it follows from Riedtmann's Theorem that for some $r \geqq 0$, $s \geqq 0$, $\tau^r G_\Gamma$ contains an injective module and $\tau^{-s} G_\Gamma$ contains projective. Thus we may suppose that G_Γ contains a projective module. By applying DTr to certain modules in G_Γ , if necessary, we can find a sectional subgraph of type Γ', where Γ' is obtained from Γ by some reflections, in which a projective stands at a sink. From now on we suppose that G_Γ has a projective module P standing at a sink.

A section function for G_Γ is a function $f : \mathbb{Z}\Gamma \to G \cup \{\emptyset\}$ such that $f(\Gamma, 0) = G_\Gamma$ and for $0 \neq n \in \mathbb{Z}$, $i \in \Gamma$

$$f(i,n) = \begin{cases} \tau^n f(i,o) & \text{if } \tau^n f(i,o) \neq 0 \\ \emptyset & \text{otherwise.} \end{cases}$$

Let p be a sink in Γ and let d_p be the additive function on $\mathbb{Z}\Gamma$ which satisfies $d_p(p,o) = 1$, $d_p(i,o) = 0$ if $i \neq p$. The set $I_p = \{(i,n) : n \geqq 0 , d_p(i,n+1) = 0\} \subset \mathbb{Z}\Gamma$ is called the indicator set for the sink p in Γ .

THEOREM Let G be the Auslander-Reiten graph of an artin algebra Λ of finite representation type and Γ be a finite connected oriented valued graph which is not Dynkin. Suppose G contains a sectional subgraph G_Γ in which a projective module P stands at a sink. Let f be a section function for G_Γ and $p \in \Gamma$ be such that $f(p,o) = P$. Then there is a point $x \in I_p$ such that $f(x)$ is injective.

COROLLARY 1 If Γ is tame with coxeter matrix of "order" h, and G_Γ as above, then $\exists\, m$, $0 \leqq m \leqq h-2$ such that $\tau^m G_\Gamma$ contains an injective module.

COROLLARY 2 If Λ is an artin algebra of finite representation type and

$$0 \to A \to \bigoplus_{i=1}^{n} B_i \to C \to 0$$

is an almost split sequence with B_i indecomposable, $1 \leqq i \leqq n$, then $n \leqq 4$ and if $n = 4$ for some i, B_i is both projective and injective.

R. BAUTISTA: *Differentiations for l-hereditary 1-Gorenstein artin algebras*
(Bielefeld)

This is a report on a joint work with D. Simson.

Let Λ be 1-Gorenstein l-hereditary artin algebra. A module M is called l-hereditary if the local submodules of M are projectives.

Consider a projective P_a, P_a is called smooth if

(i) $\operatorname{rad} P_a = P_m$ (ii) $\dim_{\operatorname{End}(P_a)}(P_m, P_a) = 1$

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(iii) If $P_{u_1},\dots,P_{u_s}$ are projectives such that $\mathrm{Hom}_\Lambda(P_{u_i},P_{u_j}) = 0$ $i \neq j$ and $\mathrm{Hom}_\Lambda(P_a,P_{u_i}) = 0$ for all i then $\Sigma \dim_{\mathrm{End}(P_{u_i})} \mathrm{Hom}(P_m,P_{u_i}) \leqq 2$.

If P_a is smooth $\Lambda = \begin{pmatrix} S & {}_SM_R \\ 0 & R \end{pmatrix}$ for certain S,R and ${}_SM_R$ then we introduce new rings of the form Λ_a' and $\Lambda^{a'}$ of the form

$$\begin{pmatrix} \tilde{S} & F({}_{\tilde{S}}\tilde{M}_R) \\ 0 & \Gamma_a' \end{pmatrix}$$

with suitable functor F and ring Γ_a' for each Λ_a' or $\Lambda^{a'}$.

Λ_a' and $\Lambda^{a'}$ have the property:
$1\text{-ker}(\Lambda)_a$ is representation equivalent with
$1\text{-ker}(\Lambda_a')$ and $1\text{-ker}(\Lambda^{a'})$.

Here $1\text{-ker}(\Lambda)$ is the full subcategory of 1-hereditary modules and $1\text{-ker}(\Lambda)_a$ consists of those modules having no direct summand isomorphic to a X with $(P_a,X) = 0$.

$\Lambda^{a'}$ corresponds to the differentiation of posets in the sense of Nazarova-Roiter.

K. BONGARTZ: *Faithful simply connected algebras*

An algebra is called simply connected if it is finite-dimensional, basic, representation-finite and has simply connected Auslander-Reiten-quiver. The coverings of Riedtmann-Gabriel reduce the classification problem of indecomposables of representation-finite algebras to the corresponding problem for simply connected algebras.

In my talk, I gave a list of faithful simply connected algebras up to a finite number in low dimensions, which can be described by a computer. Let C be the maximum of the dimensions of the indecomposables of these finitely many algebras.

As a first application of the list, I proved the following:

THEOREM Let A be a representation-finite algebra of dimension n and let U be an indecomposable module. Then

$$\dim U \leqq 8n^2 + 2n + C .$$

The proof is inspired by an idea of Roiter's and uses a theorem of Gabriel's relating the mesh category and the category of indecomposable modules.

J. BRANDT: *A lower bound for the number of characters in a block*

ABSTRACT Let B be a p-block of the finite group G and let k be a splitting field for G in characteristic p. The simple kG-modules in B are denoted $S_1, S_2, \ldots, S_{l(B)}$. Finally $k(B) = |\mathrm{Irr}(B)|$. Letting D be a defect group of B we have:

THEOREM A $k(B) = 2 \Leftrightarrow D \simeq \mathbb{Z}_2$.

THEOREM B Assume $|D| > 2$. Then

$$k(B) \geqq 1 + l(B) + \sum_{i=1}^{l(B)} \dim_k \mathrm{Ext}^1_{kG}(S_i, S_i) .$$

[To appear in J. Alg.]

M. BROUÉ: *On Alvis duality in finite Chevalley groups*

Let G be a finite Chevalley group over a field of characteristic $p > 0$. If L is a Levi complement of some parabolic subgroup of G, we denote by R_L^G the "Hanish-Chandra induction" and by $^*R_L^G$ the "Hanish-Chandra restriction" (sometimes called "truncation"). Those generalized induction and restriction are adjoint, they verify a Mackey formula, as well as a Frobenius formula:

$R_L^G(5) \otimes \eta = R_L^G(J \otimes {}^*R_L^G(\eta))$ provided η is a class function which is constant on p'-sections.

The Alvis duality is the involutive isometry of the character ring of G defined by

$$D_G = \sum_{J \subseteq I} (-1)^{|J|} R_{L_J}^G \circ {}^*R_{L_J}^G \quad , \text{ where } I \text{ is a set}$$

of distinguished generators of the Weyl group of G. We have $D_G(1_G) = St_G$, the Steinberg character of G.

PROPOSITION (1) Let φ be a class function on G vanishing outside of $G_{p'}$, and let $br_G(\varphi)$ be its Brauer lifting. Then $br_G(\varphi) = D_G(St_G \otimes \varphi)$.

(2) Let χ be any class function on G and let $\widetilde{br}_G(\chi)$ be its image under the adjoint of the Brauer lifting. Then

$$\widetilde{br}_G(\chi) = St_G \otimes D_G(\chi) .$$

This proposition has a lot of easy consequences. For example:

1. It provides a proof that the Brauer lifting sends a Brauer character onto a virtual ordinary character.

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2. It provides a proof that the ideal of projective characters for p is generated by the Steinberg character.

3. If Y_{G_p} is the characteristic function of the set G_p of p-elements of G, it implies that $D_G(|G|_p, Y_{G_p}) = \chi_G^{reg}$, hence that $|G_p| = |G|_p^2$.

J.F. CARLSON: *The cohomology ring of a module in characteristic 2*

Let $G = \langle x_1,\dots,x_n \rangle$ be an elementary abelian group of order 2^n and let K be an algebraically closed field of characteristic 2. If $\alpha = (\alpha_1,\dots,\alpha_n) \in K^n$, $\alpha \neq 0$, let $u_\alpha = 1 + \Sigma\, \alpha_i(x_i + 1)$. Then u_α is a unit of order 2 in KG. For a KG-module M, let $V(M)$ be the set consisting of 0 and of all $\alpha \in K^n$ such that the restriction of M to a $K\langle u_\alpha \rangle$-module is not a free module. It is known that $V(M)$ is a homogeneous affine variety in K^n and that its dimension is the complexity of M. In this paper it is proved that an element $\zeta \in \mathrm{Ext}^*_{KG}(M,M)$ is nilpotent if and only if its restriction to $\mathrm{Ext}^*_{K\langle u_\alpha \rangle}(M,M)$ is nilpotent for all $\alpha \in V(M)$, $\alpha \neq 0$. The radical of $\mathrm{Ext}^*_{KG}(M,M)$ can be characterized in terms of these restrictions. By using previous work, we can extend these results to general finite groups.

E. DADE: *Sources of simple modules*

Let G be a finite group, I be an irreducible KG-module (where the field K is algebraically closed of characteristic p),

P be a vertex of I and S be a source. If T is any KP-module specializing to S, and if:

$$\dim_K(\mathrm{Hom}_{P\cap P^\sigma\cap P^\tau}(T^\sigma,T^\tau)) = \dim_K(\mathrm{Hom}_{P\cap P^\sigma\cap P^\tau}(S^\sigma,S^\tau)),$$

for all $\sigma,\tau \in G$, then $T \simeq S$. Using this fact we can show that the number of possible KP-sources S of fixed dimension for irreducible KG-modules with vertex P, where G runs over all finite groups containing P, is finite.

E. DIETERICH: *Representation types of group rings over complete discrete valuation rings*

Let R be a complete discrete valuation ring with valuation v, G a finite p-group, and $\Lambda = RG$ the corresponding group ring. Then the group rings Λ, which are of finite representation type, are known.

PROPOSITION 1 Suppose that one of the following conditions is satisfied:

(i) $G = C_2 \times C_2$ and $v(2) = 1$,

(ii) $G = C_8$ and $v(2) = 1$,

(iii) $G = C_2$ and $v(2) = \infty$.

Then Λ is of tame representation type.

PROPOSITION 2 Let Λ be of infinite representation type. Moreover, suppose that Λ is not one of the group rings listed in Proposition 1 and not one of the group rings given by RC_3 and $v(3) \in \{4,5\}$, RC_5 and $v(5) = 3$, RC_4 and $v(2) = 2$. Then Λ is of wild representation type.

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Proposition 1 was already known. The proof of Proposition 2 has been indicated.

P. DONOVAN: *Poincaré series for finite groups*

Let G be a finite group, k a field of characteristic λ and M a finitely generated kG-module. Define

$$P(M;z) = \Sigma \dim_k H^n(G,M)z^n \quad .$$

This is a rational function of z. All its poles are at roots of unity. The characteristic classes of $H^*(G,k)$ and, in particular, their role in the Hochschild-Serre spectral sequence may be used to produce information on the orders of the poles.

P. FONG and B. SRINIVASAN: *The blocks of $GL(n,q)$ and $U(n,q)$*

An elegant description of the p-blocks of the symmetric groups has been given by Nakayama in terms of p-hooks and p-cores. We give here an analogous description for r-blocks of $GL(n,q)$ and $U(n,q)$, where r is an odd prime unequal to the characteristic p of $\mathbb{F}_q$.

We state our results for $G = GL(n,q)$. A description of the set $\hat{G}$ of irreducible characters of G was first given by J.A. Green. In terms of Deligne-Lusztig theory $\hat{G}$ is in bijection with conjugacy classes of pairs (s,φ), where s is a semisimple element of G and φ is a unipotent character of $C_G(s)$. A character χ in $\hat{G}$ corresponds to a pair (s,φ) if

(1) $$\chi = \pm R^G_{C(s)} (\hat{s}\varphi) .$$

Here $\hat{s}$ is the linear character of $C(s)$ dual to s via an isomorphism of $\bar{\mathbb{F}}_q^\times$ into $\bar{\mathbb{Q}}_l^\times$, and $R^G_{C(s)}$ is the Deligne-Lusztig operator. We may then write $\chi = \chi_{s,\varphi}$. Now

(2) $$C(s) = \prod_\Gamma C(s)_\Gamma = \prod_\Gamma GL(m_\Gamma(s), q^{d_\Gamma})$$

where $\Gamma \in F$, the set of irreducible monic polynomials in $\mathbb{F}_q[t]$, $m_\Gamma(s)$ is the multiplicity of Γ as an elementary divisor of s, and d_Γ is the degree of Γ. Corresponding to (2), we have $\varphi = \prod_\Gamma \varphi_\Gamma$, where φ_Γ is a unipotent character of $C(s)_\Gamma$. In particular, φ_Γ corresponds to a partition μ_Γ of $m_\Gamma(s)$. We set $\mu = \prod_\Gamma \mu_\Gamma$ and write as well

(3) $$\chi = \chi_{s,\varphi} = \chi_{s,\mu} .$$

Our first theorem is an analogue of the Nakayama result for unipotent characters of G. These are the characters of the form $\chi_{1,\mu}$, where μ is a partition of n.

THEOREM 1 Let e be the order of a module r. Then $\chi_{1,\mu}$ and $\chi_{1,\mu'}$ are in the same r-block of G if and only if μ and μ' have the same e-core.

Let $C(s)$ be as in (2). We define a block b of $C(s)$ to be a unipotent block if b contains unipotent characters of $C(s)$. If φ, φ' are unipotent characters in b corresponding to $\mu = \prod_\Gamma \mu_\Gamma$ and $\mu' = \prod_\Gamma \mu'_\Gamma$ respectively, and if e_Γ is the order of q^{d_Γ} modulo r, then μ_Γ and μ_Γ' must have the same e_Γ-core γ_Γ by Theorem 1. Thus b determines and is determined by $\gamma = \prod_\Gamma \gamma_\Gamma$.

The following theorems are analogues of Green's classification for blocks, and Nakayama's result for arbitrary characters of G.

THEOREM 2 The set of r-blocks of G is in bijection with conjugacy classes of pairs (s,b), where s is a semisimple r'-element of G and b is a unipotent block of $C(s)$. If a block B of G corresponds to a pair (s,b), then s may be chosen in $C_G(R)$, where R is a defect group of B.

THEOREM 3 Let B be a block of G with defect group R, and let B correspond to the pair (s,b), where $s \in C(R)$. Let b in turn correspond to $\gamma = \prod_{\Gamma} \gamma_{\Gamma}$. Let $\chi = \chi_{t,\mu}$ be an irreducible character of G. Then $\chi \in B$ if and only if

(i) t is G-conjugate to sy for some $y \in R$

(ii) For every $\Gamma \in F$, γ_{Γ} is the e_{Γ}-core of μ_{Γ}.

Similar results hold in the case of unitary groups. Indeed, the analogue of Green's classification of characters in terms of pairs (s,φ) holds by a result of Lusztig and Srinivasan. A slightly more complicated definition of e_{Γ} is required, however, since $C_G(s)$ may be a product of linear and unitary groups.

G. D'ESTE: *Some algebras of non-domestic representation type*

A class of locally finite dimensional algebras $A = \bigcup_{n \in \mathbb{Z}} A_n$ with finite dimensional algebras A_n has been exhibited which has the property that every indecomposable locally finite dimensional module actually is finite dimensional. Here, all the A_n

are concealed tame quiver algebras, and the support of any indecomposable module turns out to be contained in $A_{n-1} \cup A_n \cup A_{n+1}$ for some n. In this way, one can construct many selfinjective finite dimensional non-domestic algebras of finite growth, having A as a Galois covering.

(Parts of these results are joint work with C.M Ringel.)

E.L. GREEN: *Graded artin algebras*

We define morphisms between graphs with relations. This yields a category which contains universal objects. Associated to each morphism between graphs with relations is a functor on the corresponding category of representations of the graphs. Our main result is that to each covering of a finite directed graph Γ with relations we get a group grading of the artin algebra associated to Γ. Moreover, the category of representations of the covering of Γ is equivalent to the category of group graded modules. Finally the functor on the representations of the covering of Γ to the representations of Γ can be identified with the forgetful functor from the group graded modules to the modules of the artin algebra.

D. HAPPEL: *Iterated tilted algebras of type A_n*

This is a report on a joint work with I. Assem. Let k be an algebraically closed field, A a finite-dimensional k-algebra, $\operatorname{mod} A$ the category of finitely generated A-modules. A module T_A is called a tilting-module provided:

(i) $\text{p-dim}\, T_A \leq 1$, (ii) $\operatorname{Ext}_A^{\hat{}}(T_A, T_A) = 0$,

(iii) $\exists\, 0 \to A_A \to T' \to T'' \to 0$ with $T', T'' \in \operatorname{add} T$. Let $B = \operatorname{End} T_A$. Consider in $\operatorname{mod} A$ the following subcategories

$\mathcal{F} = \{M_A \mid \operatorname{Hom}(T_A, M_A) = 0\}$, $\mathcal{T} = \{M_A \mid \operatorname{Ext}(T_A, M_A) = 0\}$ and in $\operatorname{mod} B$ the following subcategories

$\mathcal{X} = \{N_B \mid N_B \otimes_B T = 0\}$, $\mathcal{Y} = \{N_B \mid \operatorname{Tor}_1^B(N_B, {}_BT) = 0\}$ and functors $\operatorname{mod} A \underset{G,G'}{\overset{F,F'}{\rightleftarrows}} \operatorname{mod} B$ with $F = \operatorname{Hom}(T_A, -)$, $F' = \operatorname{Ext}(T_A, -)$, $G = - \otimes_B T$, $G' = \operatorname{Tor}_1^B(-, {}_BT)$. Then there holds the tilting theorem (cf. Happel, Ringel: Tilted algebras).

A going down tilting series is a family $(A_i, T_{A_i})_{i=0,\dots,n}$ provided: (i) A_o is hereditary, (ii) T_{A_i} are tilting modules and $A_i = \operatorname{End} T_{A_{i-1}}$, (iii) every indecomposable A_i-module lies either in $\mathcal{X}(T_{A_{i-1}})$ or in $\mathcal{Y}(T_{A_{i-1}})$. Finally B is called an iterated tilted algebra of type $\bar{\Delta}$ if there exists a going down tilting series $(A_i, T_{A_i})_{i=0,\dots,n}$ such that $A_o = k\Delta$ and $B \simeq A_n$, (where Δ is a quiver without oriented cycles and $\bar{\Delta}$ is the underlying graph). Let $\alpha'(M_A) = \{\sigma\text{-orbits of irreducible maps entering or leaving } M_A\}$, for M_A indecomposable and $\alpha'(A) = \sup\limits_{M_A} \alpha'(M_A)$.

THEOREM The following are equivalent

(i) B is an iterated tilted algebra of type $\mathbb{A}_n$

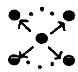
(ii) B is simply connected and $\alpha'(B) \leqq 2$

(iii) $B = (Q,\rho\alpha)$ as bounden quiver satisfies

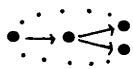
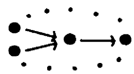
a) $\overline{Q}$ is a tree

b) The minimal relations have length 2

c) Every point has at most four neighbours

d) If four neighbours,  is a full subquiver of $(Q,\rho\alpha)$.

e) If three neighbours,  is a full subquiver of $(Q,\rho\alpha)$.

f)  and  are not full subquivers of $(Q,\rho\alpha)$.

C.U. JENSEN: <u>*Model theory and representation theory*</u>

In this talk a survey was given on some results achieved in joint work with C. Herman and H. Lenzing.

Typical results are:

THEOREM 1 There exists a function $f(d) : \mathbb{N} \to \mathbb{N}$ such that for any field K and any d-dimensional K-algebra R of finite type the total number of indecomposable R-modules is less than $f(d)$.

THEOREM 2 For any given d and unspecified perfect fields the d-dimensional algebras of finite type are constructible over $\mathbb{Z}$ (i.e. there exist polynomials in $\mathbb{Z}[x]$ such that the algebras of finite type are described by equalities and inequalities of these polynomials).

M. KLEINER: *Algorithms in categories of induced modules*

Let C be a Λ-coalgebra, $f:\Lambda \to \Lambda'$ a ring homomorphism such that the induced functor $f^* : \text{mod } \Lambda' \to \text{mod } \Lambda$ is dense. Then it is known that $C' = \Lambda' \underset{\Lambda}{\otimes} C \underset{\Lambda}{\otimes} \Lambda'$ is a Λ'-coalgebra and there exists a canonical equivalence of categories $G : \text{induc } C' \to \text{induc } C$ (induc C is the category of left induced C-comodules). Let A be a Λ-algebra and f as above. Then $A' = {}_{\Lambda}\text{Hom}(\Lambda', A \underset{\Lambda}{\otimes} \Lambda')$ is a Λ'-algebra and we have

PROPOSITION If A and A' are finitely generated and projective as right modules over, respectively, Λ and Λ', then there exists a canonical equivalence F : induc $A' \to$ induc A (induc A is the category of left induced A-modules). If, in addition, Λ and Λ' are artin algebras or orders over complete discrete valuation ring, then the following diagram commutes.

$$\begin{array}{ccc} \text{induc } A' & \xrightarrow{F} & \text{induc } A \\ {\scriptstyle D}\downarrow & & {\scriptstyle D}\downarrow \\ \text{induc } A'^* & \xrightarrow{G} & \text{induc } A^* \end{array}$$

where $A^* = \text{Hom}_{\Lambda}(A,\Lambda)$ is a Λ^{op}-coalgebra, $D = \text{Hom}_R(\_, I(R/\underline{r}))$ for artin algebras, $D = \text{Hom}_R(\_,R)$ for orders.

R. KNÖRR: *On a conjecture of Brauer's for p-solvable groups*

In 1956, R. Brauer conjectured that the number of characters in a p-block of a finite group is bounded by the order of a defect group of the block.

This conjecture is proved for groups of odd order. It also holds for 2-blocks of solvable groups.

H. LENZING: *The pure global dimension of finite dimensional algebras*

The aim of the lecture is to report on joint work with D. Baer and H. Brune.

THEOREM 1 Let k be a field of cardinality $\aleph_t$. The polynomial rings $k[X_1,\dots,X_n]$ $(k\langle X_1,\dots,X_n\rangle)$ in $n \geqq 2$ commuting (resp. non-commuting) variables, also the path algebras of a wild quiver, further (in case k is algebraically closed) the finite dimensional wild local algebras all have pure global dimension $t+1$.

THEOREM 2 Let k be algebraically closed of uncountable cardinality $\aleph_t$. Suppose R is a finite dimensional hereditary or radical-squared zero algebra. The pure global dimension of R is 0 if R is representation-finite, it is 2 if R is tame, and is $t+1$ if R is of wild representation type.

R. MARTINEZ-VILLA: *Algebras stably equivalent to Nakayama algebras*

Let Λ be an artin algebra, $P_1,P_2,\dots,P_\Lambda$ the non isomorphic indecomposable projective Λ-modules, $N = D(\ )^*$ the Nakayama functor, $\underline{\underline{A}} = \{P_i \mid P_i \simeq N^k(Q)$ for some $k \geqq 0$ and Q non injective projective$\}$ $P = \bigoplus_{P_i \notin \underline{\underline{A}}}$. Then the algebra

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$\Gamma = \mathrm{End}_\Lambda(P)^{op}$ is selfinjective.

If Λ and Λ' are stably equivalent K-algebras over an algebraically closed field K and Λ is Nakayama then the corresponding selfinjective algebras $\Gamma = \mathrm{End}_\Lambda(P)^{op}$ and $\Gamma' = \mathrm{End}_\Lambda(P')^{op}$ are stably equivalent.

These results and Riedtmann methods, in "Selfinjective algebras of type A_n", Representation Theory II, Proc. Ottawa, 1979, Springer Lecture Notes 832, can be used to classify the algebras stably equivalent to Nakayama.

G. MICHLER: *Characters of small degrees and normality of p-subgroups*

This is a report on joint work with P. Landrock (Aarhus).

Throughout G denotes a finite group, (F,R,S) a p-modular system, where F is a field of characteristic $p > 0$. All considered modules are finitely generated. An FG-module M is liftable, if there is an RG-lattice $\hat{M}$ such that $M \simeq \hat{M}/\hat{M}\max(R)$. $\chi_{\hat{M}} = \chi_{\hat{M}\otimes_R S}$ is the ordinary character of $\hat{M}$.

Let $A \in \{F,R\}$. Then $(M,N)_{1,AG} = \{\alpha \in \mathrm{Hom}_{AG}(M,N) \mid \alpha$ factors through a projective$\}$

$(M,N)^1_{AG} = (M,N)_{AG} / (M,N)_{1,AG}$, where $(M,N)_{AG} = \mathrm{Hom}_{AG}(M,N)$.

THEOREM 1 For every pair M,N of FG-modules $\dim_F[(M,N)_{1,FG}]$ is the multiplicity of the projective cover P_I of the trivial FG-module I as a direct summand of $M^* \otimes_F N$.

THEOREM 2 Let M be a non-projective, indecomposable liftable FG-module belonging to a block B of G with a T.I. defect group D. Let fM be the Green correspondent of M in $H = N_G(D)$. Then fM is a liftable FH-module with character $\chi_f = \chi_{f\hat{M}}$. Let $\chi_f = \alpha+\beta$, where β has D in its kernel, and where no irreducible constituent of α has D in its kernel. If $(\hat{M},\hat{M})^1_{RG} \neq 0$ is a cyclic R-module, then precisely one of the following assertions holds:

a) $\alpha = 0$, and β is irreducible

b) $\beta = 0$

c) $\chi_f{}^2(1) > \beta(1)^2|D|$

THEOREM 3 Let G be a finite group with an abelian T.I. Sylow p-subgroup D. If G has a faithful irreducible character χ of degree $\chi(1) \leqq \sqrt{|D|} - 1$, then D is a normal subgroup of G.

L.A. NAZAROVA and A.V. ROITER: *Bigraph representations and Tits form*

THEOREM Let $\mathcal{D}$ be a triangular linear differential graded bigraph (arrows of $\mathcal{D}$ are a union of two disjoint subsets), f is a Tits form of $\mathcal{D}$, f is non-negative on non-negative vectors, d is the vector-dimension of a representation of $\mathcal{D}$. If $f(d) = 1$, then there is an indecomposable representation of dimension d; if $f(d) = 0$, then there are infinitely many indecomposables of dimension d.

This theorem is extensively used in the theory of representations of posets, but we could not prove it inside of this theory. We have to consider representations of bigraphs. This class of matrix problems is more general than quiver representations and poset representations.

J. OLSSON: *On subpairs*

The purpose of the talk was to present a unified "classical" approach to the theory of p-blocks and fusion as developed by Brauer: "On the structure of blocks..." and by Alperin-Broué: "Local methods in block theory". If G is a finite group, p a prime number, a subpair (P,G_P) consists of a p-subgroup P and a p-block of $C_G(P)$ (or $PC_G(P)$). The inclusion of subpairs is defined as subnormality, where $(Q,b_Q) \triangleleft (P,b_P)$, if $Q \triangleleft P$ and $b_P{}^{PC(Q)} = b_Q{}^{PC(Q)}$. This will simplify and extend Brauer's theory and give alternative proofs of the Alperin-Broué theory. There are also new results connecting these theories, for instance a procedure to construct representatives for the G-conjugacy classes of subpairs. Moreover, it can be proved that the "net" $A_O(D,b_D)$ (D a defect group of $b_D{}^G$), defined by Brauer, "controls" the fusion of certain subpairs contained in (D,b_D).

W. PLESKEN: *Vertices of irreducible lattices over p-groups*

Let P be a finite p-group of exponent p^a, $K = \mathbb{Q}[\zeta_{p^a}]$

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the p^a-th cyclotomic field, R the valuation ring in K with char(R/Jac R) = p. For a fixed irreducible KP-module V of dimension $n = p^{\tilde{n}}$ with character χ we consider

$\mathcal{Z}(V) = \{L \subseteq V \mid L$ irred. RP-lattice$\}$ and

$I(\chi) = \{U \leq P \mid$ ex. character ψ of U with $\psi^P = \chi\}$.

$\mathcal{Z}(V)$ is partitioned into layers with $L_1, L_2 \in \mathcal{Z}(V)$ belonging to the same layer, if L_1 and L_2 have the same index in L_1+L_2 . These layers are linearly ordered with $\mathcal{L}_1 \propto \mathcal{L}_2$ if there exist $L_i \in \mathcal{L}_i$ $(i=1,2)$ with $L_1 \leq L_2$. The union of n consecutive layers is a set of representatives of the isomorphism classes of RP-lattices in $\mathcal{Z}(V)$. For each layer $\mathcal{L}$ let

$v(\mathcal{L}) = \max\{i \in \mathbb{Z}_{\geq 0} \mid$ ex. $L \in \mathcal{L}$ with $[P : \mathrm{vertex}(L)] = p^i\}$.

Certainly $v(\mathcal{L}) \leq \tilde{n}$ for all layers, and there exists a layer $\mathcal{L}_o$ with $v(\mathcal{L}_o) = \tilde{n}$, since P is an M-group.

THEOREM Let $\mathcal{L}_o$ be as above and let $\mathcal{L}_{n-1} \propto \ldots \propto \mathcal{L}_1 \propto \mathcal{L}_o$ be n consecutive layers. Then

(i) $v(\mathcal{L}_i) = \nu_p(i)$ $(i = 1,\ldots,n-1)$, where $p^{\nu_p(i)}$ is the exact power of p dividing i.

(ii) Let $U \in I(\chi)$ minimal and $P = U(0) > U(1) > \ldots > U(\tilde{n}) = U$ be a chain of subgroups of P. Then there exist lattices $L_i \in \mathcal{L}_i$ with $L_o > L_1 > \ldots > L_{n-1}$ such that $\mathrm{vertex}(L_o) = U$ and $\mathrm{vertex}(L_i) = U(\nu_p(i))$ for $i = 1,\ldots,n-1$.

L. PUIG: *The source algebra of a nilpotent block*

In "A Frobenius Theorem for Blocks", Inventions Math. (1980), we introduce (with Michel Broué) the notion of "nilpotent block" and for such a block, we exhibit a bijection between the set of its ordinary irreducible characters and the set of all the irreducible characters of its defect group. In "Pointed Groups and Construction of Characters", Math. Z. (1981), we introduce the notion of "Source Algebra" associated to any system formed by a finite algebra A over some complete valuation ring, a finite group G, a group homomorphism from G to the group of units of A and a conjugacy class α of primitive idempotents of the fixed point subalgebra A^G. We will describe here the structure of the "source algebra" when A is the group algebra of G and α is a "nilpotent block" of G : in some sense, our result "explains" the bijection above.

I. REITEN and Ch. RIEDTMANN: *Skew group algebras*

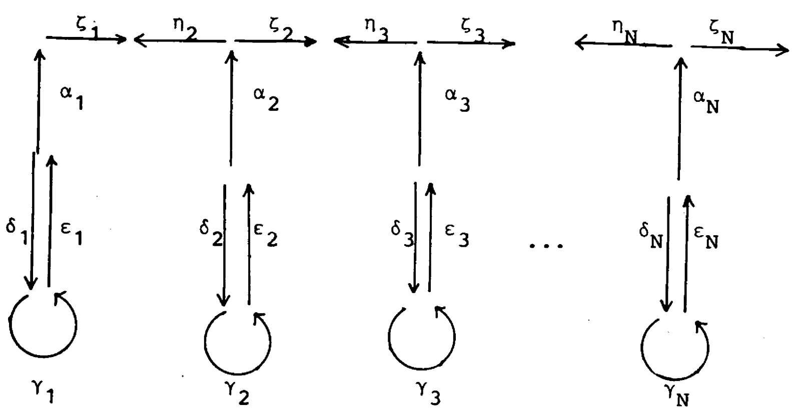
Let Λ be an algebra over a field k and G a finite group operating on Λ by algebra automorphisms. The skew group algebra $\Lambda[G]$ is a free left Λ-module with basis G, and the product $\lambda\sigma\mu\tau$ with λ,μ in Λ and σ,τ in G is defined to be $\lambda\sigma(\mu)\sigma\tau$. We assume that k is algebraically closed and that the characteristic of k does not divide the order of G.

For hereditary algebras whose quiver is stable under a reflection, this construction relates those with quiver A_{2n-3} and those with quiver D_n. Similarly, it relates certain selfinjective algebras of tree class A_{2n-3} with certain selfinjective algebras of tree class D_n. Examples of properties preserved by this construction are semisimple, Nakayama and selfinjective algebras, global dimension, dominant dimension, finite type, Auslander algebra, whereas for example weakly symmetric, α and β are not preserved. Almost split sequences go to direct sums of almost split sequences via the natural functors between the module categories. To prove this in general we study skewed group categories. As a consequence, for example, the preprojective partitions for Λ and ΛG correspond.

Given $\Lambda[G]$, we consider the problem of defining an action of G on $\Lambda[G]$ such that $\Lambda[G][G]$ is Morita equivalent to Λ. For example, we prove this when G is abelian, and get some similar results for solvable groups. If the action of G on Λ is free, there is a close relationship to Galois coverings studied by Gabriel and group gradings studied by Green.

Ch. RIEDTMANN: *Examples of non-standard algebras*

Let Q be the quiver



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choose $\lambda_i \in \{0,1\}$ for $i = 1,2,\ldots,N$, and denote by $I(\lambda_1,\ldots,\lambda_N)$ the ideal generated by the relations $\varepsilon_i\delta_i = \alpha_i\varepsilon_i = \zeta_i\alpha_i = \eta_i\alpha_i = 0$ and $\gamma_i^2 + \lambda_i\gamma_i^3 = \delta_i\varepsilon_i$, $i = 1,\ldots,N$, in the quiver-algebra kQ, where k is an algebraically closed field of characteristic 2. Then the algebras $kQ/I(\lambda_1,\ldots,\lambda_N)$ are representation-finite and pairwise not isomorphic, but their Auslander-Reiten quivers coincide. Among them, $kQ/I(0,\ldots,0)$ is the only standard algebra.

G. SCHNEIDER: *On the 2-modular representations of M_{12}*

Let M be the Mathieu-group on 12 letters, P a Sylow-2-subgroup of M, F a splitting field for M and V the 44-dimensional simple FM-module. Then:

a) V is realisable over $GF(2)$

b) $vx(V) \underset{G}{=} P$

c) $f(V) = V_{|P}$

d) $soc(f(V)) = I \oplus I \oplus I$, where I is the trivial FP-module.

An outline of the proof (which makes use of a computer) was given.

A. SKOWRONSKI: *Representation type of a class of algebras*

Certain quotient of hereditary artin algebras A are studied, namely those satisfying the condition: every indecomposable projective right A-module is hereditary projective or is a waist in its injective envelope. We characterize, up to Morita-equivalençe, each such algebra A by an invariant (R,T) which shows how we may pass from A to a hereditary algebra R by applying some ring constructions. We determine also the representation type of those algebras.

H. TACHIKAWA: *Generalizations of reflection functors*

Until this time many trials to generalize Bernstein-Gelfand-Ponomarev-reflection functors S_R^+ between hereditary K-algebras A and B which correspond to valued graphs (Γ,Ω) and $(\Gamma,s_R\Omega)$ cannot be applied to the case of selfinjective rings.

Let R and T be trivial extensions $A \times Q_A$ and $B \times Q_B$, where $Q_A = \mathrm{Hom}_K(A,K)$ and $Q_B = \mathrm{Hom}_K(B,K)$. The stably equivalent functor $S_R^+ :$ mod-R $\rightarrow$ mod-T defined as in the following way are worthwhile to be called a (generalized) reflection functor between mod-R and mod-T, because $\tilde{S}_{R_n}^+ \ldots \tilde{S}_{R_2}^+ \tilde{S}_{R_1}$ almost equivalent to Auslander-Reiten functor DT_r^R :

1) If $\tilde{X}_R = X_A \neq L_R$, $\tilde{S}_R^+(\tilde{X}) = S_R^+(X)$,

2) If $\tilde{X}_R = X_A = L_R$, $\tilde{S}_R^+(\tilde{X}) = (v' \otimes Q_B \overset{\alpha'}{-} V')$, provided

$\mathrm{Ker}\,\alpha' = S_R^+(L_R \otimes Q_A)$,

3) If $\tilde{X}_R = (v_A \otimes Q_A \overset{\alpha}{\rightarrow} V_A)$ such that $\mathrm{Ker}\,\alpha \neq L_R$, then

$\tilde{S}_R^+(\tilde{X}_R) = (v' \otimes Q_B \overset{\alpha'}{\rightarrow} V_B')$, provided $\mathrm{Ker}\,\alpha' = S_R^+(\mathrm{Ker}\,\alpha)$,

4) If $\tilde{X}_R = (v \otimes Q_A \overset{\alpha}{\rightarrow} V_A)$ such that $\mathrm{Ker}\,\alpha = L_k$, then

$\tilde{S}_R^+(\tilde{X}) = L_R'$, where L_R and L_R' are simple A- and B-modules corresponding to sink k with respect to (Γ,Ω).

Y. TSUSHIMA: *Separable blocks and related results*

Let G be a finite group and (L,R,F) a splitting p-modular system for G. Let $B = R[G]e$ be a p-block (ideal) of $R[G]$ with defect group D. The following result has been shown by the author and T. Okuyama.

THEOREM The following are equivalent

(1) B is separable over its center

(2) D is abelian and B has the inertia index one

(3) D is abelian and B is isomorphic to a full matrix ring $M(n,R[D])$ for some $n \geqq 1$.

At this meeting I have shown some consequences of this fact, which are summarized as

THEOREM The following are equivalent

(1) B is separable over its center

(2) $R[G]f$ is a maximal order of $L[G]f$ for every central primitive idempotent f of $L[G]$ such that $ef \neq 0$

(3) the center of $F \otimes B$ is quasi-Frobeniussean.

J. WASCHBÜSCH: *Trivial extensions of tilted algebras*

This is a joint work with D. Hughes.

Recently Tachikawa proved that the trivial extensions of hereditary artin algebras of finite representation type are themselves of finite representation type.

Now Happel and Ringel have introduced a generalization of hereditary artin algebras, the so-called tilted algebras, and we show that these afford a complete description of the trivial extension algebras of finite representation type.

THEOREM The trivial extension algebras of finite representation type and Dynkin class Δ are exactly the trivial extensions of tilted algebras of Dynkin class Δ.

P.J. WEBB: *The Auslander-Reiten quiver of a group ring*

Let RG be the group ring of a finite group G over either a field of characteristic p or a complete rank one discrete valuation ring with finite residue class field.

THEOREM Let Δ be a connected component of the stable Auslander-Reiten quiver $A(RG)_s$. Provided the modules in Δ do not belong to a block of cyclic defect the tree class of Δ is either a Euclidean diagram or one of A_∞, B_∞, C_∞, D_∞ or A_∞^∞. In case Δ is actually a component of the full Auslander-Reiten quiver of RG, the tree class is one of the infinite trees.

We are able to give further information about the complexity and vertices of modules in the stable component Δ. If R is a field and Δ is the component of $A(RG)_s$ containing R we can determine completely the tree class of Δ, except if G has $C_p \times C_p$ as a Sylow p-subgroup.

A. WIEDEMANN: *Path orders of global dimension two*

This is a joint work with K.W. Roggenkamp.

Let R be a complete Dedekind domain with radical π, and let Λ be a basic R-order in $(R)_n$ containing a complete set of primitive rational idempotents. Let $P_1,\dots,P_n$ be the indecomposable direct summands of Λ. We assign to Λ a valued quiver $Q(\Lambda)$: its vertices are $P_1,\dots,P_n$, and there exists a valued arrow $P_i \xrightarrow{\alpha_{ij}} P_j$ iff P_i is a direct summand of the projective cover of rad P_j and $\mathrm{Hom}_\Lambda(P_i,P_j) = \pi^{\alpha_{ij}}$. (Here we identify $\mathrm{Hom}_\Lambda(P_i,P_j)$ with an R-lattice in the quotient field of R.) Λ can be shown to be the path order of its quiver: $\Lambda = \Lambda(Q(\Lambda))$. A path $\cdot \xrightarrow{\alpha_1} \cdot \;\dots\; \cdot \xrightarrow{\alpha_m} \cdot$ in $Q(\Lambda)$ is called a k-path if $\sum_{l=1}^{m} \alpha_l = k$.

gl dim $\Lambda \leqq 2$ iff $Q(\Lambda)$ has the following properties:

(i) There exist no O-cycles in $Q(\Lambda)$.

(ii) Each vertex and each arrow of $Q(\Lambda)$ belongs to a Λ-cycle.

(iii) Each arrow is "necessary". (This property reflects that each arrow occurs in a projective cover morphism.)

(iv) The R-category of $Q(\Lambda)$ has kernels. Moreover, we have necessary and sufficient conditions on a valued quiver to satisfy (iv) and so giving rise to an order Λ with gl dim $\Lambda \leqq 2$.

W. WILLEMS: *Vertices of irreducible modules in p-soluble groups*

If F is a field of characteristic $p > 0$, G a finite p-soluble group and M an irreducible FG-module with vertex $vx(M)$ then the following results are proved.

THEOREM $vx(M) = O_p(N_G(vx(M)))$.

COROLLARY 1 $vx(M) = \bigcap_{\substack{\text{suitable} \\ x \in N_G(vx(M))}} P^x$, $P \in Syl_p(G)$.

COROLLARY 2 If G is of odd order, then $Syl_p(G)$

a) $vx(M) = P \cap P^x$ for a suitable $P \in Syl_p(G)$, $x \in N_G(vx(M))$

b) $vx(M) = D \cap D^x$ for a suitable defect group D of the p-block to which M belongs and $x \in G$.

Examples show that no extension of these results to the class of arbitrary finite groups exist.

A.G. ZAVADSKIJ: *About representations of posets of a finite growth*

Recall that a representation of a finite poset M over a field k is a collection of finite dimensional vector k-spaces $T = \{V; V(x) \mid x \in M\}$ in which $V(x) \subset V$ for each $x \in M$ and $V(x) \subset V(y)$ if $x \leqq y$. The dimension of the representation T is a vector $\dim T = \{\alpha; \alpha(x) \mid x \in M\}$, where $\alpha = \dim V$; $\alpha(x) = \dim V(x)/ \sum_{y<x} V(y)$. A representation T is called exact if $\alpha > 0$ and $\alpha(x) > 0$ for each $x \in M$. A poset M is called exact if it has at least one exact indecomposable representation.

To every poset $M = \{x_1,\ldots,x_n\}$, one can associate Tits' quadratic form as follows:

$$f_M(y_o,y_1,\ldots,y_m) = \sum_{i=0}^{n} y_i^2 + \sum_{x_i<x_j} y_i y_j - y_o \sum_{i=1}^{n} y_i \quad .$$

Let k be an infinite field and $k[t]$ a ring of polynomials over k. Denote $\mu(d)$ a smallest number of representations of a poset M over $k[t]$ generating almost all indecomposable representations of M over k of dimension d. Denote $\mu(M) = \sup_d \mu(d)$. A poset M is called of finite growth if $\mu(M) < \infty$.

We will say that a poset M is a 1-poset if $f_M(d) = 1$ for a certain vector d with positive integer co-ordinates. Suppose that a 1-poset contains two incomparable points a,b such that $M = \{x \mid x \geqq a\} \cup \{x \mid x \leqq b\}$. In this case, the poset $\overline{M}$, which is obtained from M by addition of the relation $a < b$, will be called specific.

THEOREM 1 A poset of finite growth is exact if and only if it is either a 1-poset or a specific poset. There exist (up to antiisomorphism) precisely 110 exact posets of finite growth: 100 1-posets and 10 specific posets.

THEOREM 2 Let T be an exact indecomposable representation of a poset M of finite growth. Then:

1) if M is a 1-poset, then $f_M(\dim T) \leqq 1$;

2) if M is a specific poset, then $f_M(\dim T) = 2$.

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