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SYLOW 2-SUBGROUPS OF SIMPLE GROUPS

by John G. THOMPSON

I will primarily limit this lecture to a discussion of results obtained by two students, Goldschmidt and MacWilliams.

For each group X , let $m(X)$ be the minimal number of generators of X and let $d(X) = \max\{m(A)\}$, where A ranges over all the normal abelian subgroups of X .

Suppose G is simple and T is a Sylow 2-subgroup of G . In studying the minimal simple groups, it became clear that the case $d(T) \leq 2$ was anomalous. I handled the problem by first determining all the possibilities for a Sylow 2-subgroup and then using techniques available in any minimal simple group.

For further work in simple groups, it is desirable to classify all simple G such that $d(T) \leq 2$. The case $d(T) = 1$ is non trivial, but seems well on the way to a solution, so we assume $d(T) = 2$.

The most naive way to tackle this problem is first to classify all 2-groups T with $d(T) = 2$. This is difficult, but one result about 2-groups is helpful.

LEMMA 1.- If T is a 2-group with $d(T) \leq 2$, then every subgroup of T is generated by 4 elements.

This result then leads fairly rapidly to

THEOREM 1 (MacWilliams).- Suppose T is a Sylow 2-subgroup of the simple group G ,
 $d(T) = 2$ and $T.C(T) \subset N(T)$. Then $|T| = 4, 64$ or 128 and T is determined
by $|T|$.

If $|T| = 64$, T is isomorphic to a Sylow 2-subgroup of $U_3(4)$ and if
 $|T| = 128$, T is isomorphic to a Sylow 2-subgroup of the new simple groups of
 Janko of orders 604 800 and 50 232 960 .

The structure of T in case $T.C(T) = N(T)$ is not yet determined. Several of
 the families of known simple groups satisfy these hypotheses.

Goldschmidt's work had a different origin. Initially, he studied simple groups
 with a Sylow 2-subgroup whose class of nilpotency is 2 . One of the results obtain-
 ed is that a Sylow 2-subgroup has exponent 4 . However, this emerges from a more
 general set up, the starting point being

LEMMA 2.- Suppose p is a prime and P is a Sylow p -subgroup of a group G .
Let n be the smallest integer such that $n(p - 1) \geq c - 1$, where c is the
class of nilpotency of P . Let $W = \langle x^P \mid x \in Z(P) \rangle$, where $Z(P)$ is the center
of P . Then W is weakly closed in P (that is, $g \in G$ and $W^g \subseteq P$ imply
 $W = W^g$).

This is elementary, but clever. The crucial result is

THEOREM 2 (Goldschmidt).- Suppose T is a Sylow 2-subgroup of G , W is a
weakly closed subgroup of T , $1 \subset W \subseteq Z(T)$ and t is an involution of $T - W$.
If $W \subseteq O_{2',2}(C(x))$ for every involution x of Wt , then G is not simple.

SYLOW 2-SUBGROUPS OF SIMPLE GROUPS

Here $O_{2',2}(X)$ is the largest normal subgroup of X with a normal 2-complement. The proof is character-theoretic.

If one couples this result with work of Gorenstein, we get

THEOREM 3 (Goldschmidt).- If W is weakly closed in T and $W \subseteq Z(T)^2$ where T is a Sylow 2-subgroup of G , then $W \subseteq O_{2',2}(G)$.

All these results are fragmentary, but given the state of finite group theory, this is not surprising.