Hubble constant (parameter), nor is there any indication as to how the chronometric theory enables one to study the variation of this quantity with distance. Thus it is difficult to evaluate the claim (cf. p. 118) "a further advantage of the chronometric theory over the expansion-theoretic model is that it reconciles the different values (of the Hubble constant) on the basis of different distances to the objects under observation".

I found this a difficult book to read in part because various definitions and derivations were omitted. Nevertheless, I consider that the comparison made above between chronometric theory and general relativistic cosmology an accurate one. I do not agree with comments made by Segal about general relativity and its degree of experimental verification.

This book has not convinced me that chronometric theory is a replacement for general relativistic cosmology, a branch of a theory which contains Newton's theory of gravitation as a limiting case and which provides observed corrections to that theory.

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Cohomology theory of topological transformation groups, by Wu Yi Hsiang, Ergebnisse der Mathematik und ihrer Grenzgebiete, Band 85, Springer-Verlag, New York, Heidelberg, Berlin, 1975, x + 164 pp., $25.00.

The theory of finite (and generally compact) groups of transformations of manifolds had its origins slightly over half a century ago in the work of Kerékjárto [34] and Brouwer [12] showing that periodic transformations of the 2-disk and 2-sphere are topologically equivalent to rotations. (An error in the original proof was later corrected by Eilenberg [20].) Similar results for actions of compact connected groups on 3-space were proved by Montgomery and

Zippin [37], [38], [39]. Perhaps it was thought at that time that all compact groups of transformations of higher dimensional disks, spheres and euclidean spaces are equivalent to groups of orthogonal transformations, but the difficulties in attempting to prove this were clearly recognized. In a remarkable series of papers [49], Paul Smith showed that if one lowered one's expectations, such results were obtainable. In fact, he showed that if one restricted attention to groups of prime order p then the mod p homological structure of actions on disks, spheres and euclidean spaces completely resembles the linear case. Since p-groups are solvable, much of this goes over immediately to their actions. Later, analogous results for toral groups were proved by Conner [15] and Floyd [23].

It appears that in the early days it was felt that the restriction to p-groups and to mod p cohomology were just defects of the methods employed. However, in 1950 Floyd [21] produced examples which indicated strongly that these restrictions were essential to the results. These were followed shortly by the first example of a nonorthogonal (in fact "wild") action on a sphere, due to Bing [3]. Later Floyd, in [22] and [23], improved his examples and constructed a map of period 6 on a 41-dimensional sphere whose fixed point set was not a homology sphere for any coefficients. (It also follows that the fixed set of the map of period 2 inside this is not a mod 3 homology sphere, etc.) There have been several improvements in such examples since then, notably the reviewer's similar examples in 1963 on the 5-sphere (and higher spheres) [6] and the alternative description of them due to Brieskorn [11]. For a full discussion of these matters see [10].

More recently, the remarkable work of L. Jones [32], [33] has shown that there is a "converse" to the Smith theorems. That is, he showed that, under certain mild restrictions, a mod p homology sphere (resp. disk) can be realized as the fixed point set of a map of period p on a sphere (resp. a disk). Going in a different direction, the equally remarkable work of R. Oliver [40], [41] has shown that "sufficiently complicated" finite groups can act without stationary points on a disk, and, in fact, he gives very simple conditions in terms of euler characteristics which are necessary and sufficient for a given complex to be the fixed point set in such an action on a disk. He has recently extended this result to the case of all nonabelian compact connected Lie groups [42]. The only previous example of this type was for the icosahedral group, due to Floyd and Richardson [24]. In still another direction, Edmonds and Lee [19] have recently shown that a closed smooth n-manifold M (not necessarily connected) can be the fixed point set of a periodic diffeomorphism on euclidean space iff its tangent bundle stably admits a complex structure. They also showed that a periodic map on R^n of nonprime power order can have different representations at two isolated fixed points.

In the meantime, several investigators advanced the original Smith setting of studying mod p homological aspects of actions of p-groups. Borel [5] and Swan [53] developed methods for proving such theorems which had the advantage of providing a possible utilization of the cohomology ring structure. This was first exploited by Su [50] in studying actions on products of two spheres and slightly later by the reviewer [7] in studying actions on projective spaces and Poincaré duality spaces. *These are the types of matters which occupy* *a large portion of the present book.* In the case of actions on a (homological) product $S^m \times S^n$, the author considers (Theorem IV.4) only the easiest case of even m and n and odd p, and restricts the discussion to the determination of the four possibilities for the mod p cohomology ring of the fixed point set. The "proof" contains some pretty pictures, but will probably be quite mysterious to most readers (as it is, indeed, to this reviewer). He states that the result still holds for $p = 2$, provided "$E_2 = E_\infty$", but in fact there is actually an additional possibility when $p = 2$; see [**10**, p. 410]. Certainly the most interesting aspects of the study of actions on $S^m \times S^n$ are the various known examples and the several known further restrictions regarding the possibilities for the fixed point set. Thus it is curious that the author's bibliography does not even list reference [**10**]. One curious result in this direction is that the fixed point set pt. $+CP^2$ cannot occur for an involution (i.e., a map of period 2) on an actual product $S^m \times S^n$ of spheres unless $(m, n) = (3, 4)$. (There are, similarly, six possibilities for the fixed point set pt. $+QP^2$ and none for the disjoint union of a point and the real or Cayley projective planes; see [**10**, p. 414].) Since this is the one case for which no examples have been produced on actual products of spheres, perhaps it is reasonable to give here a simple construction of such an involution on $S^3 \times S^4$. Consider the involution $T\colon A \mapsto A^{-1} = A^*$ on SU_3. Its fixed set is

$$F = \{I\} \cup \left\{ \text{conjugates of } \begin{bmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{bmatrix} \right\} \approx * + \frac{U_3}{U_2 \times U_1} \approx * + CP^2.$$

(This part is due to Su [**50**].) Let $M = \{A = (a_{i,j}) \in SU_3 \mid a_{1,1} \text{ is real}\}$. If $q\colon SU_3 \to S^5$ is the S^3-fibration taking the matrix A to its first column, then $M = q^{-1}(S^4)$ and, hence, $M \approx S^3 \times S^4$. Of course, T acts on M and it is easily seen that M contains all of F, so that this provides the desired example.

The strongest general result in the cohomological theory of transformation groups is the fact that components of fixed point sets of actions of p-groups on mod p Poincaré duality spaces are also mod p Poincaré duality spaces. This was originally conjectured by Su [**50**] and was proved shortly thereafter, with some strong restrictions, by the reviewer [**7**]. The full result was finally proved by Chang and Skjelbred [**13**] and independently, but slightly later, by the reviewer [**9**]. Curiously, the book under review misreferences the proof by Chang and Skjelbred and omits any reference at all to [**9**]. The ultimate theorem along these lines would be to show (under appropriate assumptions on the fundamental group) that the fixed point set is mod p equivariantly "Poincaré embedded" in the homotopy category. Such a result has been claimed by Hodgson [**25**], but at least two experts on Poincaré complexes have expressed doubts to me about his proof. Strong evidence for the validity of such a result is provided by the "topological Schur Lemma" of Chang and Skjelbred [**14**] and Allday and Skjelbred [**1**]. A curious example, worthy of contemplation in this connection, is a map of period 3 on a finite complex, homotopy equivalent to $S^3 \times S^3$, and having CP^2 as fixed set; see [**10**, p. 421].

The algebraic technique of localization was introduced into the theory of group actions in the work of Atiyah and Segal on equivariant K-theory; see [48]. It was put to use in ordinary equivariant cohomology by the author [31] and by Quillen [44]. The present book deals with that point of view, and presumably makes available the material in the author's difficult to locate paper [31], a reference that I have never seen.

Another active area in compact transformation groups, which is also touched on in the present book, is that of the degree of symmetry of a manifold; that is, the largest dimension of a compact Lie group that can act (differentiably, or topologically, etc.) on a given manifold. The first results in this direction were due to the author [29] and his brother [26], [27] who proved that the examples previously constructed by the reviewer [6], when augmented by an extra circle group factor evident in the Brieskorn description of these actions, provide the largest groups that can act smoothly on an exotic sphere. The book also discusses some more recent interesting work of the author on this topic. It is unfortunate that the book does not also discuss the most striking recent results on degree of symmetry. For actions on homotopy spheres these include several papers by Schultz, such as [45], [46], [47], and the startling result of Lawson and Yau [35] that a homotopy sphere not bounding a spin manifold cannot admit a smooth action of a connected nonabelian Lie group. For actions on more general manifolds there is the fundamental result of Atiyah and Hirzebruch [2] that a closed spin manifold whose $\hat{A}$-genus is nonzero has no circle action (and hence has zero degree of symmetry). Another striking thing that could have been mentioned in the book is the existence of totally nonsymmetric manifolds (not even admitting a finite group of symmetries). The first example of this was given by Bloomberg [4] following fundamental work of Conner and Raymond [17]. Different examples have since been given by Conner, Raymond and Weinberger [18].

Large portions of the present book are virtually reprintings of several of the author's papers. (Thus it is no surprise to find, for example, that the "Theorem B" referred to twice on p. 126 is not to be found under that designation in the book, but rather is found in the paper this material comes from.) In a few cases, the reader is referred to the author's papers for proofs. Even when proofs are repeated in the book there has been no effort to make them more understandable.

The exposition in the book is frequently sloppy. We shall conclude by discussing some of the more striking occurrences of this.

At the end of Chapter I (pp. 15–16) the author attempts to prove the important standard facts about maximal tori of compact Lie groups by deriving them from the principal orbit theorem. A close look will show, however, that he asserts, in the proof of I.8.1, that each element of the group lies in a torus; an assertion that simply does not follow from his previous discussion. Since this fact is precisely the most difficult and crucial item in proving these results, this proof is effectively scuttled.

In Theorem II.3 the author asserts that the Weyl group of a compact Lie group G acts on the maximal torus as a group generated by reflections. But, by definition, the cuts made by the fixed point sets of "reflections" are supposed to disconnect the manifold acted upon, whereas in fact, these cuts, for the Weyl group acting on the torus, are usually connecticuts. Because of this mistake, the reader is led to believe that the map $G \to G/\mathrm{Ad}$ has a cross section and the definition of the "Cartan polyhedron" (p. 22) is based on this misunderstanding. This is simply not the case for the centerless versions of A_n, $n \geqslant 2$, where G/Ad is a cone over a lens space. This nonsense also effects the "proof" of Weyl's theorem (II.9) that the universal covering group of a compact semisimple Lie group is compact. (In any case, this proof is actually an outrageous "proof by bluff". A beginner could not possibly understand it and may well ask where the hypothesis of semisimplicity is used.)

On pp. 48–49 the author attempts to prove that, for a toral action on X, if $H_G^*(X; Q)$ is the rational equivariant cohomology of X and if $H_G^*(X; Q) \otimes_{H_G^*(\mathrm{pt.}; Q)} R_0$ is generated as an R_0-algebra by q elements (where R_0 is the field of quotients of $H_G^*(\mathrm{pt.}; Q)$), then each component F of the fixed set X^G has $H^*(F; Q)$ generated by at most q homogeneous elements as a Q-algebra. (Also, an analogous result for Z_p-tori is considered.) In doing this he considers changes of generating sets by two "elementary operations". One of these consists of replacing a generator by the product of that generator with an invertible element. However, the author's invertible elements belong to the algebra and not to the base field R_0, and thus this step needs justification. This justification can be given in this case, but the reader is given no hint that there is something to prove here. Later in the proof, the author writes out an element of a tensor product in which the term $\lambda_{i,k} \otimes a_{i,k}$ really should be a *sum* of such terms. This point seems to require considerably more justification and, in fact, I don't know how to fix it without weakening the conclusions of the Theorem and localizing in a different way. Fortunately, an elegant proof of this result has been given by V. Puppe [**43**]. Since Puppe's proof, as written, does not quite prove the full result stated in the book under review, and since one point in it appears to be obscure to some readers, perhaps it is reasonable to briefly indicate here a slight modification of the crucial point of it. Suppose that A is a graded connected algebra over the field k and let K be an extension field of k. Suppose that $A \otimes_k K$ is generated by q nonhomogeneous elements as a K-algebra. Then the K-vector space of indecomposables $Q(A \otimes_k K) \approx Q(A) \otimes_k K$ clearly has dimension $\leqslant q$. Hence $\dim_k Q(A) \leqslant q$ and thus there are q *homogeneous* elements of $Q(A)$ which span it. These can be lifted back to q homogeneous elements of A and it follows from an easy and well-known lemma of Milnor and Moore [**36**, Proposition 3.8] that these q elements generate A as a k-algebra. The application of this (with $A = H^*(F; k)$ and $K = R_0$) to the result on fixed point sets is immediate.

In Chapter V the author attempts to determine the connected principal orbit type of a topological action of a compact Lie group on an acyclic cohomology manifold. It is virtually reprinted from [**30**]. It contains a number of quite good ideas and results, but also suffers badly from numerous deficiencies in the proofs. For example, the proof of Theorem V.2 does not seem sufficient, and, in particular, it is not clear how the case $G = \mathrm{Sp}_n$, $l = 2n - 1$ (with a circle as principal isotropy group) can be ruled out. Even more seriously, the conclusions of the Corollaries to Theorem V.5 cannot be drawn from the proofs given. (Curiously, this fact was already pointed out in a paper of R. Sullivan [**52**] published before the present book went to the printer.) In the proof of Theorem V.6, many cases are said to be ruled out by means of Lemma 1 on p. 85. However, this lemma holds for trivial reasons in all cases and cannot possibly be used to rule out anything. The trouble is that the author mistakenly assumes a certain rational number (k in the examples on p. 86 and l in the proof on p. 88) must be an integer. There does not seem to be any justification for this. There also appear to be a number of cases left unconsidered in the list of possible exceptions on p. 90. For example, there are the possibilities $G = C_4$ and $\Omega' = 2W(\theta_1 + \theta_2 + \theta_3 + \theta_4)$; or $G = C_4$ and $\Omega' = W(\theta_1 + \theta_2 + \theta_3 + \theta_4) + W(\theta_1)$; or $G = C_r$ and $\Omega' = (2r - 1)W(\theta_1)$; or finally $G = B_2$ and $\Omega' = W(2\theta_1 + \theta_2)$. (At least one of these could be ruled out, but certainly with no less consideration than that given to the five cases on p. 90.) When an author is this sloppy with his proofs and yet expects us to believe that he has correctly done a considerable amount of undisplayed case by case checking in representation theory and other matters, I, for one, refuse to accept it.

In Theorem V.8 it is asserted that the fixed point set of a certain type of topological action is an acyclic cohomology manifold. One crucial point in the proof relies on the statement that the author's theorem **[28]** on groups of diffeomorphisms generated by reflections can be modified to yield the desired result in the topological case. Probably one can indeed prove that the fixed point set is nonempty and acyclic, and even that it is cohomologically locally connected, in this way. However, the assertion that it is a cohomology manifold is a far more difficult matter and I don't feel there is any justification for it at present. This also effects the proof of Theorem V.10.

On p. 146 the author conjectures that for a compact connected simple Lie group G, any nontransitive action of G on its underlying manifold must be cohomologically identical with the adjoint action. There is, however, the simple counterexample of $G = SU_3$ and the action A: $B \mapsto ABA^t$. Generally, if φ is an outer automorphism of G then g: $h \mapsto gh\varphi(g^{-1})$ gives a counterexample. This also settles problem 6 on p. 133 in the negative.

The names of Conner, Floyd and Montgomery (see **[16]** and **[10**, pp. 61–62]) should have been referred to in connection with the construction of the fundamental example on p. 44. Theorem IV.5 on p. 53 and p. 137 should have been credited to the reviewer [**8**, p. 879]. The discussion on p. 134 is based on recent fundamental work of D. Sullivan **[51]** but his name is not even mentioned. There are a number of similar amenities that could have materially contributed to the exposition in the book.

Despite these and other shortcomings, the book may well serve as a useful source of ideas and problems for workers in the field.

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***Partial differential equations*: *theory and technique*, George F. Carrier and Carl E. Pearson, Academic Press, New York, San Francisco, London, 1976, ix + 320 pp., $16.50.**

In the introduction to his lecture notes on *Methods of mathematical physics*, K. O. Friedrichs observes that most of the fundamental problems of analysis have their origins in physics and that, of these problems, a high percentage are concerned with differential equations. As he points out, the fundamental laws on which problems in the sciences are based are formulated in terms of partial