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THE STRUCTURE OF CLOSED NONPOSITIVELY CURVED EUCLIDEAN CONE 3-MANIFOLDS

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A structure theorem is proven for closed Euclidean 3-dimensional cone manifolds with all cone angles greater than 2π and cone locus a link (no vertices) which allows one to deduce precisely when such a manifold is homotopically atoroidal, and to construct its characteristic submanifold (torus decomposition) when it is not. A by-product of this structure theorem is the result that any Seifert-fibered submanifold of such a manifold admits a fibration with fibers parallel to the cone locus. This structure theorem is applied to several examples arising as branched covers over universal links.

0. Introduction. Much of the recent progress in 3-manifold topology has to do with the link between topology and geometry in 3-manifolds. There has been a great deal of work in the last decade on homogeneous Riemannian metrics on 3-manifolds, spurred on by the tantalizing prospect of the Thurston Geometrization Conjecture. At the same time, there has been a renewed interest in branched covers, as a result of the notion of a *universal link*, a link in S^3 which has the property that all closed, orientable 3-manifolds are obtained as branched covers over S^3, branched over this fixed link (see, for example, **[HLM]**). It had, of course, long been known that all such 3-manifolds were representable as branched covers over the 3-sphere, but in the older construction, it was a very simple kind of branched cover (namely a 3-fold cover) over a possibly very complicated link in the 3-sphere. One advantage of the newer branched cover construction is that many geometric structures on the fixed link in S^3 lift to the branched covers and thus, to all 3-manifolds. So, it seems likely that by moving the complication from the link to the branched covering map itself we may gain some real insight into the geometry of 3-manifolds.

One particular kind of geometric structure which has this lifting property is that of a *cone manifold* structure (see, for example, **[A-R]**, **[Ho]** and **[Jo1]**). The purpose of this paper is to give a structure theorem for 3-manifolds possessing a certain type of cone manifold structure, namely, a Euclidean cone manifold structure without vertices and with cone angles greater than 2π. These are the "nonpositively