IS SUPERSYMMETRY REALLY BROKEN?

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In 2 + 1 dimensions, in the presence of gravity, supersymmetry can ensure the vanishing of the cosmological constant without requiring the equality of bose and fermi masses.

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Within the known structure of physics, supergravity in four dimensions leads to a dichotomy: either the symmetry is unbroken and bosons and fermions are degenerate, or the symmetry is broken and the vanishing of the cosmological constant is difficult to understand. Neither of these alternatives appears satisfactory.

Even when supersymmetry is unbroken, the cosmological constant might not vanish, but with suitable reasonable assumptions – such as an R symmetry or an underlying string theory – it vanishes naturally.

The purpose of this short note is to point out that in 2 + 1 dimensions, the unsatisfactory dichotomy does not arise: supersymmetry can explain the vanishing of the cosmological constant without leading to equality of bose and fermi masses. Perhaps the same would be true in a suitable modified framework of physics in 3 + 1 dimensions.

First of all, to get a 2 + 1 dimensional supergravity theory with unbroken supersymmetry in which the cosmological constant naturally vanishes, one can, for instance, take the dimensional reduction of any 3 + 1 dimensional theory with this property. Do bosons and fermions have equal masses in such a theory? To prove that they do, one must use the unbroken global supercharges. In local supersymmetry, there are *apriori* infinitely many supercharges (the generator being an arbitrary spinor field), but the spontaneously broken ones are not useful for controlling the spectrum.

The unbroken supercharges are determined by spinor fields that are covariantly constant at infinity; in fact, the space of unbroken supercharges can be identified naturally with the space of possible asymptotic values of a spinor field that is asymptotically covariantly constant.

Now we meet the fact that, in 2+1 dimensions (in a world with vanishing cosmological constant), any state of non-zero energy produces a geometry that is asymptotically conical. In such a conical geometry, there are no covariantly constant spinors, so there are no unbroken supersymmetries. Thus, in 2+1 dimensional supergravity, even when supersymmetry applies to the vacuum and ensures the vanishing of the vacuum energy, it does not apply to the excited states.

Of course, this detailed mechanism is special to 2+1 dimensions, but it at least makes one wonder whether, in a suitable framework, there can be an analogous phenomenon in

3+1 dimensions.

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