

# Surprises in the $O(N)$ models or why might the standard large $N$ analysis fail

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The  $O(N)$  models are probably the most studied field theories. Everything is supposed to be known about their symmetric and symmetry broken phases as well as their critical behavior. Many analytical methods were born here and it is the textbook example for both the  $\epsilon = 4 - d$  and the large- $N$  expansions. We nevertheless show that several renormalization group fixed points of this model were not found by the usual methods. These new fixed points are relevant for the multicritical physics of the  $O(N)$  models. We also show that the  $N \rightarrow \infty$  limit was not able to identify them because of an implicit analyticity prerequisite of this method that turns out to be wrong. The functional and nonperturbative renormalization group plays a key role to find them.

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