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Compositions, Random Sums and Continued Random Fractions of Poisson and Fractional Poisson Processes

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In this paper we consider the relation between random sums and compositions of different processes. In particular, for independent Poisson processes $N_\alpha(t)$, $N_\beta(t)$, $t>0$, we show that $N_\alpha(N_\beta(t)) \overset{\text{d}}{=} \sum_{j=1}^{N_\beta(t)} X_j$, where the X_js are Poisson random variables. We present a series of similar cases, the most general of which is the one in which the outer process is Poisson and the inner one is a nonlinear fractional birth process. We highlight generalisations of these results where the external process is infinitely divisible. A section of the paper concerns compositions of the form $N_\alpha(\tau_k^\nu)$, $\nu \in (0,1]$, where τ_k^ν is the inverse of the fractional Poisson process, and we show how these compositions can be represented as random sums. Furthermore we study compositions of the form $\Theta(N(t))$, $t>0$, which can be represented as random products. The last section is devoted to studying continued fractions of Cauchy random variables with a Poisson number of levels. We evaluate the exact distribution and derive the scale parameter in terms of ratios of Fibonacci numbers.

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