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Simultaneous Polynomial Recurrence

Let $P \in \mathbb{Z}[n]$ with $P(0) = 0$. It is a striking and elegant fact (proved independently by Furstenberg and Sárközy) that any subset of the natural numbers of positive upper density necessarily contains two distinct elements whose difference is given by $P(n)$ for some $n \in \mathbb{N}$. Using Fourier analysis we establish quantitative bounds for the following strengthening of this result: *Let $\varepsilon > 0$, then there exists $N_{\varepsilon,P}$ such that if $N \geq N_{\varepsilon,P}$ and $A \subseteq \{1, \ldots, N\}$, then there exists $n \neq 0$ such that A contains at least $|A|^2/N - \varepsilon$ pairs of elements whose common differences are all equal to $P(n)$.* If time permits we will also discuss the problem of finding simultaneous ε-optimal return times for a given collection of polynomials $P_1, \ldots, P_\ell \in \mathbb{Z}[n]$.