# Ten New Erdős-style problems in number theory and combinatorics

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**Abstract**

This note explores ten new Erdős style problems generated with AI. We record elementary proofs or reductions where the original question is already settled. Several questions turn out to be very close to explicit Erdős problems: the gcd-pattern question is adjacent to Erdős #535; the lcm-pattern questions to Erdős #536 and #856; the weak sunflower/intersection question to Erdős #857; squarefree-sum questions to Erdős #1109 and to the Schoen–Schlage-Puchta literature; and discrepancy to Erdős #67. The most promising genuinely independent directions appear to be the coprime-Schur extremal problem, the pairwise-gcd Sidon extremal problem, the prime-intersection problem, the squarefree-distance code problem, and the squarefree-ratio divisor graph.

## 1 How to read this note

For $N \geq 1$ write $[N] = \{1, 2, \ldots, N\}$. A positive integer is squarefree if no square of a prime divides it. The phrase "closest Erdős links" refers to problem numbers in Thomas F. Bloom's database *Erdős Problems* at erdosproblems.com; these are included as navigational aids, not as replacements for citing Erdős's original publications.

The status labels are deliberately conservative. "No exact match found" means that targeted searches found only neighboring literature; it is not a formal novelty claim.

## 2 Coprime Schur-free sets

**Problem 1** (Coprime Schur-free sets)**.** *Call $A \subseteq [N]$* coprime Schur-free *if there are no $x, y, z \in A$ with*

$$x + y = z, \qquad (x, y) = 1.$$

*Let*

$$C(N) = \max |A|.$$

*Is*

$$C(N) = \left(\frac{2}{3} + o(1)\right) N?$$

*Is every near-extremal example close to the union of two prime-divisibility classes, e.g. $2 \mid n$ or $3 \mid n$?*

### Elementary construction

**Proposition 1.** *One has $C(N) \geq (2/3 + o(1))N$.*

*Proof.* Let

$$A = \{n \leq N : 2 \mid n \text{ or } 3 \mid n\}.$$

Then $|A| = (2/3 + o(1))N$. Suppose $x, y \in A$ and $(x, y) = 1$. Modulo 6, elements of $A$ lie in residue classes $0, 2, 3, 4$. A coprime pair cannot involve class 0, nor two even classes, nor two multiples of 3. Thus, after swapping, one of $x, y$ is congruent to 2 or 4 modulo 6, while the other is congruent to 3 modulo 6. Hence $x + y \equiv 1$ or $5 \pmod 6$, so $x + y \notin A$. □

### Closest Erdős links

The closest database links are not coprimality-restricted Schur triples, but ordinary sum-free and Schur/Ramsey themes. Erdős #792 asks for the largest guaranteed sum-free subset of an arbitrary $n$-element integer set; Erdős #748 is the Cameron–Erdős problem on counting sum-free subsets of $[n]$; Erdős #183 concerns Schur numbers/Ramsey numbers. Erdős #139 and #140 concern progression-free sets and Szemerédi-type problems rather than Schur triples.

### Literature map

The natural tools are stability/removal theorems for additive triples and extremal theory of sum-free sets. Green and Ruzsa determined maximal densities of sum-free sets in finite abelian groups [23]. Alon, Balogh, Morris and Samotij developed container/counting machinery for sum-free sets [6]. Samotij and Sudakov studied the minimum number of additive triples in dense subsets of abelian groups [38]. Haviv's "sum-free with a forbidden sum" problem is an example of a Schur-type condition modified by an additional restriction [26]. I found no exact treatment of the hypergraph of Schur triples restricted by $(x, y) = 1$.

## 3 GCD-Sidon sets

**Problem 2** (GCD-Sidon sets)**.** *Call $A \subseteq [N]$* GCD-Sidon *if all values*

$$(a, b), \qquad a < b, \ a, b \in A,$$

*are distinct. Let $G(N)$ be the maximum possible size of such a set. Is*

$$G(N) = N^{1/2+o(1)}?$$

*Does $G(N)/\sqrt{N}$ have a limit?*

### Elementary upper bound

**Proposition 2.** *For every $N$,*

$$G(N) \leq \sqrt{2N} + 1.$$

*Proof.* If $|A| = m$, then the $\binom{m}{2}$ unordered pairs of distinct elements of $A$ have pairwise distinct gcds, each lying in $[N]$. Thus $\binom{m}{2} \leq N$, giving $m \leq (1 + \sqrt{1 + 8N})/2 \leq \sqrt{2N} + 1$. □

### Closest Erdős links

The closest explicit Erdős problem is Erdős #535: for $r \geq 3$, estimate the largest $A \subseteq [N]$ with no $r$ elements whose pairwise gcds are all the same. Erdős proved an upper bound $N^{3/4+o(1)}$, Abbott and Hanson improved the exponent to $1/2$, and that Erdős conjectured a much smaller $N^{c_r/\log\log N}$-type behavior in that Ramsey-style problem. Our GCD-Sidon problem is stronger for $r = 3$: if all pairwise gcds are globally distinct, then in particular no triple has all three pairwise gcds equal. Hence Erdős #535 suggests that square-root scale is a natural barrier, but the problems are not equivalent.

### Literature map

Ahlswede and Khachatrian studied maximal subsets of $[n]$ containing no $k+1$ pairwise coprime integers and related common-prime-factor conditions [3, 4]. Erdős and Sárközy studied cycles in the coprime graph of integer sets [19]. The sunflower connection in Erdős #535 is important: equal pairwise gcd patterns become sunflower-type coincidences after replacing integers by their prime-support sets, with weights supplied by prime sizes. I found no exact extremal function for globally distinct pairwise gcd values.

## 4 LCM-Sidon sets

**Problem 3** (LCM-Sidon sets). *Call $A \subseteq [N]$* LCM-Sidon *if*

$$\operatorname{lcm}(a,b) = \operatorname{lcm}(c,d), \qquad a < b,\ c < d,$$

*implies $\{a,b\} = \{c,d\}$. Let $L(N)$ be the maximum size of such a set. Determine $L(N)$; in particular, can $L(N)$ have positive density?*

### Elementary lower bound

**Proposition 3.** *$L(N) \geq \pi(N)$, hence $L(N) \geq (1+o(1))N/\log N$.*

*Proof.* Take $A$ to be the set of primes at most $N$. For distinct primes $p < q$, $\operatorname{lcm}(p,q) = pq$. Unique factorization implies that $pq = rs$ for primes $r < s$ only when $\{p,q\} = \{r,s\}$. ☐

### Closest Erdős links

This problem is very close to three Erdős entries. Erdős #536 asks for the largest $A \subseteq [N]$ with no distinct $a, b, c$ satisfying

$$[a,b] = [b,c] = [a,c].$$

Erdős #856 asks the harmonic-density analogue: maximize $\sum_{a\in A} 1/a$ when there are no $k$ distinct elements whose pairwise lcms are all the same. Erdős #857 is the weak sunflower problem, which is linked to #536 and #856. The difference is that LCM-Sidon forbids repeated lcms across *two pairs*; Erdős #536/#856 forbid a clique of size $k$ with all pairwise lcms equal.

### Literature map

Multiplicative Sidon theory is the main baseline. Erdős studied multiplicative Sidon subsets of $[n]$; the maximum size is now known to be

$$\pi(n) + \Theta\left(\frac{n^{3/4}}{(\log n)^{3/2}}\right),$$

as summarized in Liu and Pach [32]; see also Pach's generalized multiplicative Sidon work [35]. Tang and Zhang recently developed the lcm-pattern/sunflower connection for Erdős #856 [41]. Abbott and Gardner and Abbott–Hanson are part of the older lineage around equal gcd/lcm patterns [1, 2]. I found no exact reference for pairwise-lcm Sidonicity.

## 5 Sets whose pairwise sums are never squarefree

**Problem 4** (Non-squarefree pair-sum sets)**.** *Call* $A \subseteq [N]$ non-squarefree-sum *if for every distinct* $a, b \in A$*, the sum* $a + b$ *is not squarefree. Let* $Q(N)$ *be the maximum size of such a set. Is*

$$Q(N) = \left(\frac{1}{4} + o(1)\right) N?$$

### Elementary construction

**Proposition 4.** $Q(N) \geq N/4 + O(1)$.

*Proof.* Take $A = 4\mathbb{N} \cap [N]$. Then every sum of two distinct elements of $A$ is divisible by 4, hence is not squarefree. □

### Closest Erdős links

The closest database entry is Erdős #1109, from Erdős–Sárkőzy, which asks for the largest $A \subseteq [N]$ such that every element of $A + A$ is squarefree. Our problem reverses the squarefree condition and forbids squarefree sums. Erdős #11 concerns a different but squarefree-flavored additive problem: representing large odd integers as a squarefree number plus a power of 2. Erdős #844 is a product analogue: Erdős–Sárkőzy asked for sets $A$ such that $ab$ is never squarefree.

### Literature map

The directly relevant papers study the stronger condition that $A + A$ contains no squarefree integer, including diagonal sums. Schoen proved structural results for dense sets whose sumsets avoid squarefree integers [40]. Schlage-Puchta gave a detailed structure theorem and identified threshold behavior at

$$\delta_0 = \frac{1}{4} - \frac{2}{\pi^2}, \qquad \delta_1 = \frac{1}{18},$$

for positive-density sets with $A + A$ avoiding squarefree integers [39]. Filaseta, Nathanson–Sárkőzy, and related work on squarefree elements in sumsets provide additional background [20, 34]. The key technical question is whether the known diagonal-sensitive arguments can be modified when only distinct-pair sums are forbidden.

# 6 Primitive van der Waerden numbers

**Problem 5** (Primitive van der Waerden numbers)**.** *A $k$-term arithmetic progression*

$$a, a+d, \dots, a+(k-1)d$$

*is* primitive *if $(a, d) = 1$. Let $W^*(r, k)$ be the least $N$, if it exists, such that every $r$-coloring of $[N]$ contains a monochromatic primitive $k$-term arithmetic progression.*

### Settled qualitative existence

**Proposition 5.** *For all $r, k \geq 2$, $W^*(r, k) < \infty$.*

*Proof.* Assume not. By compactness, there is an $r$-coloring of $\mathbb{N}$ with no monochromatic primitive $k$-term progression. Restrict the coloring to the primes. Some color class has positive relative upper density in the primes. The relative Green–Tao theorem gives a $k$-term arithmetic progression of primes

$$p, p+d, \dots, p+(k-1)d$$

in that color. Since $p$ and $p+d$ are distinct primes, $p \nmid d$, so $(p, d) = 1$. This is a monochromatic primitive progression, contradiction. □

### Closest Erdős links

Erdős #721 asks for bounds on asymmetric van der Waerden numbers $W(3, k)$. Erdős #169 asks about reciprocal sums of progression-free sets and compares them with van der Waerden numbers. Erdős #139 is the Erdős–Turán/Szemerédi theorem problem for $r_k(N) = o(N)$. The primitive condition is not one we found as a named Erdős problem, but the proof above shows the qualitative existence question is subsumed by Green–Tao.

### Literature map

The classical theorem is van der Waerden [43]. Brown, Graham, and Landman studied allowed common differences in van der Waerden-type theorems [16]. Green and Tao proved arbitrarily long arithmetic progressions in the primes [24]; relative Szemerédi theorems such as Conlon–Fox–Zhao supply the density-in-primes formulation used above [17]. A meaningful revised problem is quantitative: estimate $W^*(r, k)$ by elementary methods or compare it with $W(r, k)$.

# 7 Prime-intersection families

**Problem 6** (Prime-intersection families)**.** *Let $\mathcal{F} \subseteq 2^{[N]}$. Call $\mathcal{F}$* prime-intersecting *if for every distinct $A, B \in \mathcal{F}$, the number $|A \cap B|$ is prime. Let $P(N)$ be the maximum size of such a family. Is $P(N)$ polynomial in $N$, or can it be exponential?*

### Elementary constructions

**Proposition 6.** *For every fixed prime $p \leq N - 1$, $P(N) \geq N - p$.*

*Proof.* Fix a $p$-element set $S \subseteq [N]$ and take

$$\mathcal{F} = \{S \cup \{i\} : i \in [N] \setminus S\}.$$

Any two distinct members intersect exactly in $S$, so all intersections have size $p$. □

A larger toy construction is possible when a projective plane of order $q$ exists: its lines form a family of $q^2 + q + 1$ subsets with pairwise intersections of size 1, but 1 is not prime. Adding a fixed extra point to every line makes all intersections have size 2, giving a quadratic example in a universe of size $q^2 + q + 2$. Thus $P(N) \geq N + O(\sqrt{N})$ by projective planes, but still only linear in $N$.

### Closest Erdős links

The closest explicit Erdős problem is Erdős #857, the weak sunflower problem: determine how large a set family must be to force $k$ members with the same pairwise intersection. Prime-intersection families impose an arithmetic restriction on every pairwise intersection size rather than forbidding a sunflower. Erdős #704, on chromatic numbers of unit-distance graphs in high dimension, is another indirect link because Frankl–Wilson intersection theorems are a central tool there.

### Literature map

Ray-Chaudhuri and Wilson proved the foundational $L$-intersection theorem [37]. Frankl and Wilson developed polynomial-method intersection theorems with geometric consequences [22]. Alon, Babai, and Suzuki gave nonuniform and multilinear-polynomial refinements [5]. Grolmusz constructed superpolynomial-size set systems with restricted intersections modulo composite numbers [25], showing that modular restrictions can behave unexpectedly. Keevash and Mubayi–Wilson studied no-singleton intersection and related stability questions [30]. I found no paper treating the allowed intersection set $\{2, 3, 5, \ldots\}$ directly.

## 8 Non-squarefree Hamming-distance codes

**Problem 7** (Non-squarefree Hamming-distance codes)**.** *For $\mathcal{F} \subseteq 2^{[N]}$, let $d(A, B) = |A \triangle B|$. Call $\mathcal{F}$* non-squarefree-distance *if $d(A, B)$ is not squarefree for every distinct $A, B \in \mathcal{F}$. Let $H(N)$ be the maximum size of such a family. Is*

$$H(N) = 2^{N/2+o(N)}?$$

### Elementary lower bound from doubly-even codes

**Proposition 7.** *$H(N) \geq 2^{N/2-O(1)}$.*

*Proof.* For lengths $n$ divisible by 8, Type II binary self-dual codes exist; all codeword weights are divisible by 4, and the dimension is $n/2$. In a linear code, distances are weights of differences, hence every nonzero distance is divisible by 4 and therefore not squarefree. For general $N$, take $n \leq N$ the largest multiple of 8 and append zero coordinates. □

### Closest Erdős links

There is no exact Erdős entry located for squarefree-forbidden Hamming distances. The closest conceptual links are Erdős #704, through Frankl–Wilson distance/intersection methods in Euclidean chromatic problems, and Erdős #857, through forbidden intersection patterns. Erdős #844, the non-squarefree product problem, is arithmetically analogous but not metric.

### Literature map

Frankl and Rödl's forbidden-intersections theorem is the standard starting point for excluding intersection sizes [21]. Keevash and Long proved Frankl–Rödl-type theorems for codes and permutations [29]. Huang, Klurman, and Pohoata studied hypercube subsets with prescribed Hamming-distance restrictions via spectral methods [28]. MacWilliams and Sloane is the classical source for Type II/doubly-even self-dual codes [33]. The unusual feature here is that the forbidden distance set is the squarefree numbers, a positive-density but noninterval set.

## 9 Coprime representation of graphs

**Problem 8** (Coprime representation of graphs)**.** *For a finite graph $G$, let $\rho(G)$ be the least $M$ such that the vertices of $G$ can be injectively labelled by integers in $[M]$ with*

$$uv \in E(G) \iff (\ell(u), \ell(v)) = 1.$$

*Let $R(n) = \max_{|V(G)|=n} \rho(G)$. Is*

$$R(n) = 2^{\Theta(n)}?$$

### Elementary bounds

**Proposition 8.** *There are absolute constants $c, C > 0$ such that*

$$2^{cn} \leq R(n) \leq \exp(Cn \log n).$$

*Proof.* For the upper bound, assign a distinct prime $p_{uv}$ to every nonedge $uv$ of $G$. Label vertex $v$ by the product of all primes $p_{uv}$ over nonneighbors $u$ of $v$, multiplied by a private prime $q_v$ to ensure injectivity. Then two labels share a prime exactly when the two vertices are nonadjacent. Using the first $O(n^2)$ primes, each vertex label is at most $\exp(O(n \log n))$.

For the lower bound, there are $2^{\binom{n}{2}}$ labelled graphs on vertex set $[n]$. If all such graphs admitted labels in $[M]$, then the number of injective label assignments would be at least $2^{\binom{n}{2}}$, while there are at most $M^n$ assignments. Thus $M \geq 2^{(n-1)/2}$ for some graph. □

### Closest Erdős links

No exactly similar Erdős problem was located for this biconditional coprime representation size. The older Erdős–Goodman–Pósa theorem on representing graphs by set intersections is the key ancestor. It is also thematically near Erdős graph-coloring/chromatic entries, but not a direct match.

### Literature map

Erdős, Goodman and Pósa proved that every graph can be represented by intersections of sets and determined the worst-case minimum size of the ground set [18]. In our problem, primes are ground-set elements and sharing a prime represents a nonedge, but the objective is the largest integer label rather than the number of prime coordinates. Coprime graph labelling in the weaker direction has been studied by Berliner et al. [8], Lee [31], and Asplund–Fox [7]. Those papers usually require adjacent vertices to have relatively prime labels, not the biconditional equivalence.

## 10 The squarefree divisor graph

**Problem 9** (Squarefree divisor graph)**.** *Let $\mathcal{D}_N$ be the graph on $[N]$ in which $a < b$ are adjacent if $a \mid b$ and $b/a$ is squarefree. Let $\chi(N) = \chi(\mathcal{D}_N)$. Is*

$$\chi(N) = \Theta\left(\frac{\log N}{\log\log N}\right)?$$

### Elementary lower bound

**Proposition 9.**

$$\chi(N) \geq (1 + o(1))\frac{\log N}{\log\log N}.$$

*Proof.* Let $p_i$ be the $i$th prime and consider

$$1, p_1, p_1p_2, ldots, p_1p_2 \cdots p_t.$$

Any earlier term divides any later term, and the ratio is a product of distinct primes, hence squarefree. Thus these vertices form a clique whenever $p_1 \cdots p_t \leq N$. By the prime number theorem,

$$\log(p_1 \cdots p_t) = \vartheta(p_t) = (1 + o(1))t \log t,$$

so the largest such $t$ is $(1 + o(1)) \log N/ \log\log N$. □

### Closest Erdős links

No exactly similar Erdős entry was located. The problem is close in spirit to arithmetic graph-coloring questions such as Erdős #542, where lcm constraints and divisibility appear in extremal sets, and to divisor-graph questions appearing in the forum. It is also related structurally to comparability graphs: the full divisor graph is perfect, but deleting nonsquarefree-ratio edges destroys transitivity.

### Literature map

Ravi and Desikan survey divisor graphs and divisor-function graphs [36]. Bosek et al. connected graph coloring to Graham's greatest-common-divisor problem [15]. Graham's gcd problem itself asks about arranging integers to control sums of gcds and has generated a large arithmetic-combinatorial literature. I found no treatment of the squarefree-ratio divisor graph.

## 11 Prime-multiple discrepancy

**Problem 10** (Prime-multiple discrepancy)**.** *Choose signs $\varepsilon_n \in \{-1, +1\}$ for $1 \leq n \leq N$. Define*

$$D(N) = \min_{\varepsilon_1,\ldots,\varepsilon_N} \max_{\substack{p \leq N \\ p \text{ prime}}} \left| \sum_{p|n \leq N} \varepsilon_n \right|.$$

*Is $D(N)$ bounded?*

### Elementary solution

**Proposition 10.** *For all $N \geq 2$,*

$$1 \leq D(N) \leq 2.$$

*Proof.* The lower bound follows because any prime $p > N/2$ has exactly one multiple in $[N]$.

For the upper bound, set

$$\varepsilon_n = (-1)^{\lfloor n/2 \rfloor}.$$

For $p = 2$, the signs on the multiples of 2 alternate, so all partial sums have absolute value at most 1. If $p$ is odd, then

$$\varepsilon_{p(m+4)} = (-1)^{\lfloor p(m+4)/2 \rfloor} = (-1)^{\lfloor pm/2 \rfloor + 2p} = \varepsilon_{pm}.$$

Thus the signs on the multiples of $p$ are periodic with period 4 in $m$. If $p \equiv 1 \pmod 4$, one period is $+, -, -, +$; if $p \equiv 3 \pmod 4$, one period is $-, -, +, +$. Full periods sum to zero and every prefix has absolute sum at most 2. □

### Closest Erdős links

Erdős #67 is the Erdős discrepancy problem: for every $\{-1, 1\}$ sequence, homogeneous arithmetic progressions have unbounded discrepancy. Tao proved this. Our prime-modulus-only version is therefore much weaker and bounded. A meaningful revised problem asks for the growth when prime moduli are replaced by squarefree moduli, semiprimes, or all moduli with a bounded number of prime factors.

### Literature map

Tao's proof of the Erdős discrepancy problem is the central reference [42]. Hochberg and Phillips studied finite discrepancy-one systems for homogeneous arithmetic progressions [27]. The revised squarefree-modulus problem would sit strictly between the prime-only bounded case and the all-moduli unbounded case.

## 12 Compressed status table

| Problem | Closest Erdős problems | Current reading |
|---|---|---|
| Coprime Schur-free | #792, #748, #183 | No exact match found; good candidate for a genuine extremal additive problem. |
| GCD-Sidon | #535 | Stronger pairwise-distinct version of equal-gcd Ramsey problem; square-root upper bound trivial. |
| LCM-Sidon | #536, #856, #857 | Very close to Erdős lcm-pattern/sunflower problems, but pairwise Sidon version seems distinct. |
| Non-squarefree pair sums | #1109, #11, #844 | Directly adjacent to Schoen–Schlage-Puchta sumset literature. |
| Primitive van der Waerden | #721, #169, #139 | Qualitative existence follows from Green–Tao; only quantitative refinements remain. |
| Prime intersections | #857, #704 | Restricted-intersection problem with arithmetic allowed set; exact case not found. |
| Non-squarefree distances | #704, #857, #844 | Forbidden-distance code problem; squarefree forbidden set seems new. |
| Coprime graph representation | no exact link found | Related to Erdős–Goodman–Pósa set-intersection representations and coprime labellings. |
| Squarefree divisor graph | no exact link found | Related to divisor graphs and arithmetic graph coloring; exact graph not found. |
| Prime-multiple discrepancy | #67 | Bounded by 2; squarefree-modulus variant is the interesting one. |

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