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Large Normal Ideals Concentrating on a Fixed Small Cardinality

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The property on the filter in Definition 1, a kind of large cardinal property, suffices for the proof in Liu Shelah [484] and is proved consistent as required there (see conclusion 6). A natural property which looks better, not only is not obtained here, but is shown to be false (in Claim 7). On earlier related theorems see Gitik Shelah [GiSh310].

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1. Definition (1) Let κ be a cardinal and D a filter on κ and θ be an ordinal $\leq \kappa$ and $\mu < \chi$ but $\mu \geq 2$ and $\chi \leq \kappa$. Let $\mathrm{GM}_{\kappa,\chi,\theta,\mu}$ (D) be there following game:

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a play lasts θ moves, in the $\zeta's$ move the first player chooses a function h_ζ from κ to some ordinal $\gamma_\zeta < \chi$ and the second player chooses a subset B_ζ of γ_ζ of cardinality $< \mu$.

The second player wins a play if for every $\zeta < \theta$ the set $\bigcap\{\{\beta < \kappa : h_\varepsilon(\beta) \in B_\epsilon\} : \epsilon \leq \zeta\}$ is $\neq \emptyset \bmod D$.

(2) If $\mu = 2$ we may omit it, if $\mu = 2$ and $\chi = \kappa$ we omit χ and μ.

2. Definition: $(P \leq, \leq_{\rm pr}) \in K_{\kappa,\chi,\theta,\mu}$ iff

1. κ is a regular cardinal.
2. $(P, \leq)$ is a forcing notion with minimal element $\emptyset$ (if in doubt we use $\leq_P$, $\emptyset_P$).
3. P satisfies the κ-c.c.
4. $\leq_{\rm pr}$ is a partial order on P such that:
    a. $p \leq_{\rm pr} q$ implies $p \leq q$
    b. any $\leq_{\rm pr}$-increasing chain of length $< \theta$ with first element $\emptyset$ in P has an $\leq_{\rm pr}$-upper bound.
    c. if $\gamma < \chi$ and $\underset{\sim}{\tau}$ is a P-name of an ordinal $< \gamma$ and $\emptyset \leq_{\rm pr} p \in P$ then for some q and $B \subseteq \gamma$ of cardinality $< \mu$ we have $p \leq_{\rm pr} q \in P$ and q forces $\underset{\sim}{\tau} \in B$.
5. for any $Y \subseteq P$ of cardinality $< \kappa$ there is $P^* \lessdot P$ of cardinality $< \kappa$ such that P/P^* satisfies condition (4), i.e. if $G^* \subseteq P^*$ is generic over V and $P/G^* \overset{\rm def}{=} \{p \in P : p$ compatible with every $q \in G^*\}$ then
    a. in P/G^*, any $\leq_{\rm pr}$-increasing sequences starting with $\emptyset$ of length $< \theta$ have an $\leq_{\rm pr}$-upper bound in P/G^*.
    b. if $p \in P/G^*$ and $\underset{\sim}{\tau}$ a P-name of an ordinal $< \gamma$ where $\gamma < \chi$ then there is a subset B of γ of cardinality $< \mu$ and p', $p \leq_{\rm pr} p' \in P/G^*$ such that p' forces $\underset{\sim}{\tau} \in B$.

2A Remark: The relation in clause 4(b) is not really stronger than having a winning strategy in the corresponding play, see [Sh250, 2.43] (or [Sh-f, XIV 2.4]).

3. Lemma: Assume

a. κ is a measurable cardinal with D a κ-complete ultrafilter on it

b. $(P \leq, \leq_{\rm pr}) \in K_{\kappa,\chi,\theta,\mu}$

Then in V^P the second player wins $\mathrm{GM}_{\kappa,\chi,\theta,\mu}(\mathrm{D})$

3A Remark: 1. We can replace ultrafilter by a filter in which the first player wins $\mathrm{GM}_{\theta,\kappa}(\mathrm{D})$ [see Lemma 5].

Proof: In V we define a set R, its members are sequences $\bar p = \langle p_\alpha : \alpha \in A^{\bar p}\rangle$ where $A^{\bar p} \in D$ and $\emptyset \leq_{\rm pr} p_\alpha \in P$ (for $\alpha \in A^{\bar p}$). On R we define a partial order $\leq_R$ as follows: $\bar p \leq_R \bar q$ iff $A^{\bar q} \subseteq A^{\bar p}$ and for every $\alpha \in A^{\bar q}$ we have $p_\alpha \leq_{\rm pr} q_\alpha$.

Clearly, in V the partial order $(R, \leq_R)$ is θ-complete.

For $G \subseteq P$ generic over V we define $R[G]$ as $\{\bar p : \bar p \in R$ and $\{\alpha \in A^{\bar p} : p_\alpha \in G\} \neq \emptyset \operatorname{mod} D$ (in V^P, D is not a filter just a family of subsets of κ but it naturally generates a filter- just closed upward and we refer to this filter in "mod D"$\}$.

For $G \subseteq P$ generic over V and $\bar p \in R$ let $w[\bar p, G] \stackrel{\rm def}{=} \{\alpha \in A^{\bar p} : p_\alpha \in G\}$.

So $R[G] = \{\bar p \in R : w[\bar p, G] \neq \emptyset \operatorname{mod} D\}$. We now prove some facts.

3B. Fact: In $V[G]$, $(R[G], \leq_R)$ is θ-complete.

Proof: If not then there is a P-name of a sequence of length $< \theta$, $\langle \underset{\sim}{\bar p}^\varepsilon : \varepsilon < \zeta\rangle$ and $r \in P$ which forces this sequence to be a counter example, so $\zeta < \theta$. So there are maximal antichains $\mathcal{I}_\varepsilon$ for $\varepsilon < \zeta$ of conditions in P forcing a value to $\underset{\sim}{\bar p}^\varepsilon$ (note $\underset{\sim}{\bar p}^\varepsilon$ is a P-name of a member of V); let Y be the set of elements appearing in some $\mathcal{I}_\varepsilon$ and r. As P satisfies the κ-c.c. clearly Y has cardinality $< \kappa$ so there is P^* as required in condition (5) of Definition 2. Let $G^* \subseteq P^*$ be generic over V and $r \in G^*$.

Now working in $V[G^*]$ we can (for each $\varepsilon < \zeta$) compute $\underset{\sim}{\bar{p}}^\varepsilon$ and $A^{\underset{\sim}{\bar{p}}^\varepsilon}$, call it then $\bar{p}^\varepsilon$ and A_ε respectively and so $\bigwedge_\varepsilon A_\varepsilon \in D$ and $A^* \stackrel{\text{def}}{=} \cap\{A_\varepsilon : \varepsilon < \zeta\}$ belongs to $D^{V[G^*]}$ (=the ultrafilter which D generates in $V[G^*]$, remember $|P^*| < \kappa$, D a κ-complete ultrafilter); also letting $w_\varepsilon \stackrel{\text{def}}{=} \{\alpha \in A^*$: there is $G \subseteq P$ generic over P extending G^* to which p^ε_α belongs$\} \in V[G^*]$ we know that in $V[G]$ we get a D-positive set $w[\underset{\sim}{\bar{p}}^\varepsilon, G]$ (because r forces this) hence in $V[G^*]$ the set w_ε is D-positive but in $V[G^*]$ we know $D^{V[G^*]}$ is an ultrafilter so necessarily w_ε belongs to $D^{V[G^*]}$; clearly for $\varepsilon < \zeta$, $\alpha \in w_\varepsilon$ we have $p^\varepsilon_\alpha \in P/G^*$. Let $B^* = A^* \cap \bigcap\{w_\varepsilon : \varepsilon < \zeta\}$, it is in $D^{V[G^*]}$. Now for any $\alpha \in B^*$ the sequence $\langle p^\varepsilon_\alpha : \varepsilon < \zeta\rangle$ is a $\leq_{\text{pr}}$-increasing sequence of member of P/G^* and by demand (5) (a) of Definition 2, the sequence has an $\leq_{\text{pr}}$-upper bound q_α (in P/G^*). Let $r_\alpha \in G^*$ be above r and force that this holds and moreover force some specific $q_\alpha \in P_\alpha$ is as above. So, still in $V[G^*]$, for some $C \in D$, $C \subseteq B$ and $r^* \in G^*$ we have $(\forall \alpha \in C)[r_\alpha = r^*]$ without loss of generality $C \in V$. As for $\alpha \in C \subseteq B$, $r^* = r_\alpha \Vdash$ "$q_\alpha \in P/\underset{\sim}{G}_{p^*}$", r^* is compatible with every q_α ($\alpha \in C$). By 3D below for some q^+, $r^* \leq q^+ \in P$ and $q^+ \Vdash_P$ "$\{\alpha : q^+_\alpha \in \underset{\sim}{G}_{P^*}\}$"$\neq \emptyset \bmod D$. So q^+ (which is above $r \leq r^*$) force that $\bar{q} = \langle q_\alpha : \alpha \in C\rangle$ is an upper bound as required. (note: $\bar{q} \in V$, r^* force it is an upper bound of $\{\underset{\sim}{\bar{p}}^\varepsilon : \varepsilon < \zeta\}$; we need $q^+_{\alpha(*)}$ as we do not know the value of $\underset{\sim}{\bar{p}}^\varepsilon$. $\square_{3B}$

3C Fact: Let $G \subseteq P$ be generic over V. In $V[G]$, if $\gamma < \chi$ and $\bar{p} \in R[G]$ and h a function from κ to γ, *then* for some $\bar{q}$ we have:

a. $\bar{q} \in R[G]$

b. $\bar{p} \leq_R \bar{q}$

c. on $w[\bar{p}, G]$ the range of the function h is of cardinality $< \chi$.

Proof: Assume the conclusion fails then some $r \in G$ forces that it fails for a specific $\bar{p}$

and P-name $\underset{\sim}{h}$ (so in particular r forces that $w[\bar{p}, \underset{\sim}{G}] \neq \emptyset \operatorname{mod} D$.) Let $w^* =: \{\alpha \in A^{\bar{p}}$: the conditions r, p_α are compatible in P (equivalently, r does not force $\alpha \notin w[\bar{p}, \underset{\sim}{G}])\}$ (so $w^* \in V$) and $w^* \in D$. Now let P^* be as in condition (5) of Definition 2 for $Y = \{r\}$ (so in particular $r \in P^*$). Now:

$(*)$ for every $\alpha \in w^*$ there are r^*_α and q_α and B_α such that:

a. $r \leq r^*_\alpha \in P^*$.

b. $p_\alpha \leq_{\rm pr} q_\alpha$.

c. $r^*_\alpha \Vdash_{P^*}$ "$q_\alpha \in P/\underset{\sim}{G}_{P^*}$".

d. q_α forces (for P) that $\underset{\sim}{h}(\alpha) \in B_\alpha$ and for some set $B \subseteq \gamma$ ($B \in V$), we have $|B_\alpha| < \mu$.

[Why? for every α in w^* we can find $G \subseteq P$ generic over V to which r and p_α belong (as $\alpha \in w^*$); hence $p_\alpha \in P/(G \cap P^*)$ hence some $r^*_\alpha \in G \cap P^*$ force this (for P^*) so without loss of generality $r \leq r^*_\alpha$ (as $G \cap P^*$ is directed). Now apply condition (5) of Definition 2 to $G \cap P^*$, p_α and $\underset{\sim}{h}(\alpha)$ and we get some $B \subseteq \gamma$. $|B| < \mu$ and $q_\alpha \in P/(G \cap P^*)$ such that $p_\alpha \leq_{\rm pr} q_\alpha \in P/(G \cap P^*)$ and q_α forces $\underset{\sim}{h}(\alpha) \in B$. Now increasing again r^*_α we get $(*)$].

So we can find for $\alpha \in w^*$, r_α, q_α and B_α as in $(*)$, (all in V); let $A^* \subseteq w^*$ be such that $A^* \in D$ and $\langle B_\alpha : \alpha \in w^* \rangle$ is constant on A^* and also r_α is constantly r^* (note: D is κ-complete $w^* \in D$, and κ is strongly inaccessible hence $|\gamma|^{<\mu} < \kappa$ and $|P^*| < \kappa$. Now some q^+, satisfying $r^* \leq q^+ \in P$, forces that $\langle q_\alpha : \alpha \in A^* \rangle$ is in $R[G]$ by fact 3D below and so clearly is as required in the Fact 3C. $\square_{3C}$

3D. Observation Assume $\bar{p} = \langle p_\alpha : \alpha \in A \rangle \in R$ and $r \in P$ is compatible (in P) with every p_α (for $\alpha \in A$). *Then* some r^*, $r \leq r^* \in P$, force that $\bar{p} \in R[\underset{\sim}{G}_P]$.

Proof: Let $\mathcal{I}$ be a maximal antichain of P above r such that for every $q \in \mathcal{I}$ we have either $q| \vdash_P$ "$w[\bar{p}, \underset{\sim}{G}_P]$ is a subset of A_q" where $A_q \subseteq \kappa$ and $\kappa \setminus A_q \in D$ *or* $q| \vdash_P$ " $w[\bar{p}, \underset{\sim}{G}_P] \neq \emptyset \bmod D$.

So $\mathcal{I}$ has cardinality $< \kappa$ and if the conclusion fails then always the first possibility holds; now we let $B \stackrel{\text{def}}{=} \bigcap\{\kappa \setminus A_q : q \in \mathcal{I}\}$, clearly it belongs to D. Now there is $\alpha \in B \cap A$ (as $B \cap A \in D$) and there is $r^* \in P$ above r and above p_α (exist by assumption); now r^* force that $\alpha \in w[\bar{p}, \underset{\sim}{G}_p] \subseteq A_q \subseteq \kappa \setminus B$, contradiction. $\square_{3D}$

3E. *Continuation of the Proof of Lemma 3:* immediate for the Facts 3B, 3C. $\square_3$

Now we shall redo it all in another version:

4. Lemma: (From Gitik [Gi] §3, relaying on §1 there, in different terminology). Assume $\chi < \kappa$, $\theta < \kappa$ a regular cardinal, κ is a measurable cardinal of order $\theta + 1$ (i.e. there is a coherent sequence of ultrafilters on κ of length $\theta + 1$, see [Gi, §3 p.293], with D an ultrafilter on κ appearing in the θ'th place in the appropriate sequence.

Then for some forcing notion P we have

(a) P of cardinality κ, $| \vdash_P$ "κ is strongly inaccessible".

(b) $\{\delta : | \vdash_P \text{"cf}(\delta) = \theta\text{"}\} \in D$

(c) $P \in K_{\kappa,\chi,\theta,2}$ (in particular P satisfies the κ-c.c., $\leq_{\text{pr}}$ for P is called $\leq_E$ in [Gi] (called Easton)

(d) For some $\leq_{\text{pr}}$ Condition (4) of Definition 2 is satisfied by P (for $\mu = 2$). Moreover, given any $\chi^* < \kappa$ and $Y \subseteq P$ of cardinality $< \kappa$ we can find $P^* \lessdot P$ as in clause (5) of Definition 2 replacing θ and χ by χ^*.

5. Claim: Under the assumptions of lemma 4, if $\theta + \chi \leq \mu = \text{cf}(\mu) < \kappa$ let $Q =$

$P * (\mathrm{Levy}(\mu, < \kappa))^{V^P}$ defining $(p_1, q_1) \le_{\mathrm{pr}} (p_2, q_2)$ iff $p_1 \le_P p_2$ and $p_2 \Vdash_P$ "$q_1 \le q_2 \in \mathrm{Levy}(\mu, < \kappa)^{V^P}$"

Then $Q \in K_{\kappa,\chi,\theta,2}$ and in V^Q, $\kappa = \mu^+ = 2^\mu$.

Proof: Easy.

5A Remark: Actually in the conclusion of Claim 5 we can weaken $\theta + \chi \le \mu$ to $\theta^+ + \chi \le \mu^+$ hence in the conclusion $\chi = \mu^+ (= \kappa)$ is o.k. This applies also to conclusion 6.

5B Remark: Of course Claim 5 and Definition 2 are formulated so that we get consistency results justifying the name of the paper. We formulate below (conclusion 6) the one used in Liu Shelah [LiSh484].

6. Conclusion: Assume $0 = n_0 < n_1 < n_2 < \ldots < n_\ell, n_\ell + 1 < n_{\ell+1}$, $\kappa_{\ell+1}$ is a measurable of order $\theta_\ell + 1$ and for simplicity GCH holds and stipulate $\kappa_0 = \aleph_0$ and $\theta_{\ell+1} < \kappa_{\ell+1}$ is regular for $\ell < \omega$, moreover $\theta_\ell \le \kappa_{\ell+1}^{+(n_{\ell+1} - n_\ell)}$.

Then there is a forcing notion P of cardinality $\le 2^{\Sigma_{\ell<\omega} \kappa_{\ell+1}}$ which preserves $\mathrm{cf}(\theta_{\ell+1}) = \theta_{\ell+1}$, makes $\kappa_{\ell+1}$ to $\aleph_{n_{\ell+1}}$ and preserves $(\kappa_\ell)^{+i}$ if $i < n_{\ell+1}$, preserves G.C.H. and for $\ell < \omega$ in V^P the second player wins $\mathrm{GM}_{\aleph_{\ell+1}, \aleph_{n_{\ell+1}-1}, \theta_{\ell+1}, 2}(D_{\ell+1})$ for some $D_{\ell+1} \in V$, a normal ultrafilter on $\kappa_{\ell+1}$ of order $\theta_\ell + 1$.

Proof: We use iteration $\langle P_i, Q_i : i < \omega \rangle$ described as follows: Q_ℓ=the forcing notion from lemma 5 (for $\kappa = \kappa_{\ell+1}$, $\theta = \theta_{\ell+1}$, $\mu = \kappa_\ell^{+(n_{\ell+1} - n_\ell)}$ and $\chi_{\ell+1} = \kappa_{\ell+1}^{+(n_{\ell+1} - n_\ell - 1)}$), the limit is a full support for pure extensions of the $\emptyset$ and finite support otherwise (for the Levy collapse all conditions are pure extensions of $\emptyset$). The checking is standard. $\square_6$

Discussion: We shall now prove that for a natural strengthening of Definition 2, we cannot get consistency results. Specifically we cannot, in the game in Definition 2, let player I just decrease the present D-positive set. $\square_6$

7. Definition: (1) Let κ be a cardinal and D a filter on κ and θ be an ordinal $\leq \kappa$. Let $\mathrm{GM}^*_\theta(D)$ be the following game:

a play lasts θ moves; in the ζ's move

first player chooses a subset A_ζ of κ, $A_\zeta \neq \emptyset \bmod D$ such that: if $\zeta = 0$, $A_\zeta \subseteq \kappa$ and if $\zeta = \varepsilon + 1$ then $A_\zeta \subseteq B_\varepsilon$ and if ζ is a limit ordinal then $A_\zeta = \cap\{A_\varepsilon : \varepsilon < \zeta\}$

and then *the second player* chooses a subset B_ζ of A_ζ satisfying $B_\zeta \neq \emptyset \bmod D$.

A player wins the play if he has no legal move (can occur only to the first player in a limit stage), if the play lasts θ moves then the second player wins.

8. Definition: Let λ be regular countable, $S \subseteq \lambda$; we say that there is a $(\leq \theta)$-square for S if: there is a set S^+, and sequence $\langle C_\alpha : \alpha \in S^+\rangle$ such that:

a. $S \subseteq S^+ \subseteq \lambda$

b. for $\beta \in C_\alpha$ (so $\alpha \in S^+$) we have: $\beta \in S^+$ and $C_\beta = \beta \cap C_\alpha$.

c. $\mathrm{otp}(C_\alpha) \leq \theta$ for $\alpha \in S^+$.

d. if $\delta \in S$ is a limit ordinal then $\delta = \sup(C_\delta)$

e. C_α is a closed subset of α.

9. Claim; 1) Assume λ is regular $> \theta$, D is a normal filter on λ^+ to which $\{\delta : \mathrm{cf}(\delta) = \theta\}$ belongs. *Then* in the game $\mathrm{GM}^*_{\omega+1}(D)$ (see Definition 8 below) the second player does not have a winning strategy.

2) Assume λ is regular larger than $|\theta|^+$, θ an ordinal, D is a normal filter on λ to which a set S belongs, and for S there is a $(\leq \theta)$-square (as defined in Definition 7 above) (or just

every $S \subseteq \lambda$, $S \neq \emptyset \bmod D$ has a subset S' for which there is a $(\leq \theta)$-square. $S' \neq \emptyset \bmod D$).

Then in the game $\mathrm{GM}^*_{\omega+1}(D)$ (see Definition 8 below), the second player does not have a winning strategy.

Proof: Part (1) follows form part (2) as the assumption of part (2) follows by [Sh 365, 2.14] (or [Sh 351, Th. 4.1]). So we concentrate on proving part (2).

So let $\langle C_\alpha : \alpha \in S^+ \rangle$ be as in Definition 8. So without loss of generality $S^+ \in D$. We divide $\{\delta : \delta < \lambda, \mathrm{cf}(\delta) = \aleph_0\}$ to $|\theta|^+$ stationary sets $\langle T_i : i < |\theta|^+ \rangle$. As D is a normal ideal on λ, $|\theta|^+ < \lambda$, clearly for each stationary subset S' of S which is D-positive there are $S^* \subseteq S'$ which is D-positive and ordinal $j^* < |\theta|^+$ such that for every $\alpha \in S^*$ we have: $C_\alpha \cup \{\alpha\}$ is disjoint to $T_{j(*)}$.

Now suppose the second player has a winning strategy in $\mathrm{GM}^*_{\omega+1}(D)$ which we call Sty. We can choose by induction on $n < \omega$ a sequence $\langle A_\rho, B_\rho, \beta_\rho : \rho \in {}^n\lambda \rangle$ such that

1. for every $\rho \in {}^n\lambda$ the sequence $\langle A_{\rho \restriction k}, B_{\rho \restriction k} : k \leq n \rangle$ is an initial segment of a play of the game in which the second player uses his winning strategy Sty

2. for some $j < |\theta|^+$, for every $\alpha \in A_{\langle\rangle}$ we have $C_\alpha \cup \{\alpha\}$ is disjoint to T_j.

3. $\beta_\rho \in S^+$ and for every $\rho \in {}^n\lambda$ and $\alpha \in A_\rho$ we have $\beta_\rho \in C_\alpha$.

4. for $\rho \in {}^n\lambda$ we have: β_ρ is larger than sup range (ρ).

There is no problem to carry the definition (for clause (3) remember D is a normal filter on λ); now let $E \stackrel{\text{def}}{=} \{\delta < \lambda :$ for every $\rho \in {}^{\omega>}\delta$ we have $\beta_\rho < \delta\}$; clearly E is a club of λ hence there is an ordinal $\delta \in E \cap T_j$; so choose an increasing ω-sequence ρ of ordinals $< \delta$ with limit δ; look at $\langle A_{\rho \restriction k}, B_{\rho \restriction k} : k < \omega \rangle$ which is an initial segment of a play of the game in which the second player uses his winning strategy Sty. Let now $B = \cap \{B_{\rho \restriction k} : k < \omega\}$; if $\sup(B) > \delta$ (which holds if $B \neq \emptyset \bmod D$), $\alpha \in B \setminus (\delta + 1)$ then for every n, $\beta_{\rho \restriction n} \in C_\alpha$.

Note: as $\rho \in {}^{\omega}\delta$, and $\delta \in E$ clearly $\beta_{\rho\restriction n} < \delta$; so $\delta \geq \bigcup_{n<\omega} \beta_{\rho\restriction n}$; as $\beta_{\rho\restriction n} \geq \sup \mathrm{range}(\rho\restriction n)$ necessarily $\delta \leq \bigcup_{n<\omega} \beta_{\rho\restriction n}$ so equality holds. Hence also $\delta = (\cup_{n<\omega}\ \beta_{\rho\restriction n}) \in C_\alpha$ (as $\alpha > \delta = \bigcup_{n<\omega} \beta_{\rho\restriction n}$). So $\delta \in C_\alpha$ but $\delta \in T_j$ whereas $\alpha \in B_{\langle\rangle}$, contradiction. So B is a subset of $\delta + 1$, contradicting to "Sty is a winning strategy".

9A Remark: This continues the argument that e.g. not for every stationary $S \subseteq \{\delta < \aleph_3 : \mathrm{cf}(\delta) = \aleph_0\}$, there is a club E of $\aleph_3$ such that $\delta \in E\,\&$ if $(\delta) = \aleph_2 \Rightarrow S \cap \delta$ stationary in δ (find pairwise disjoint $S_i \subseteq \{\delta < \aleph_3 : \mathrm{cf}(\delta) = \aleph_0\}$, for $i < \aleph_3$, if for S_i we have E_i, choose $\delta \in \bigcap_{i<\aleph_2} E_i$ of cofinality $\aleph_2$.

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