Special coheirs and model-theoretic trees

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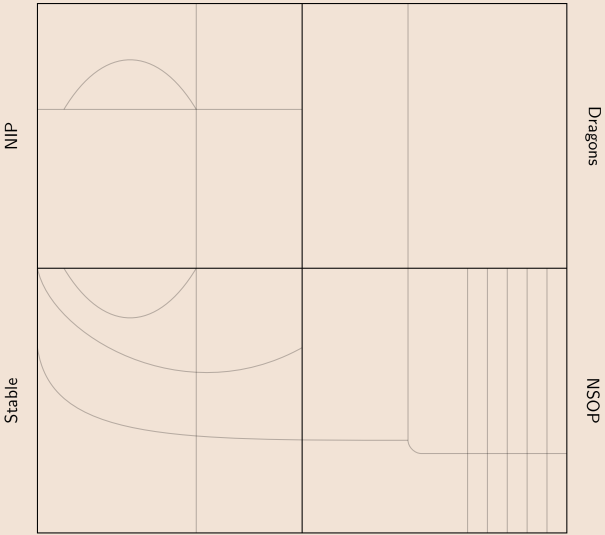
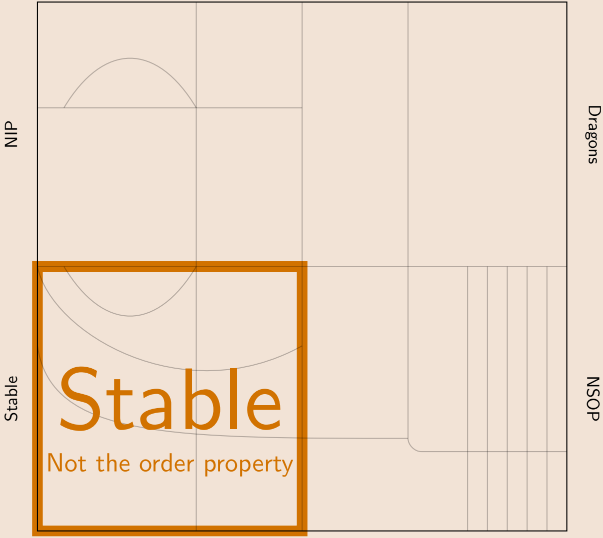
The map: Model-theoretic adjectives



Examples:



Examples:

Algebraically closed fields

Differentially closed fields

Vector spaces

Modules

Free groups

Curve graphs of surfaces

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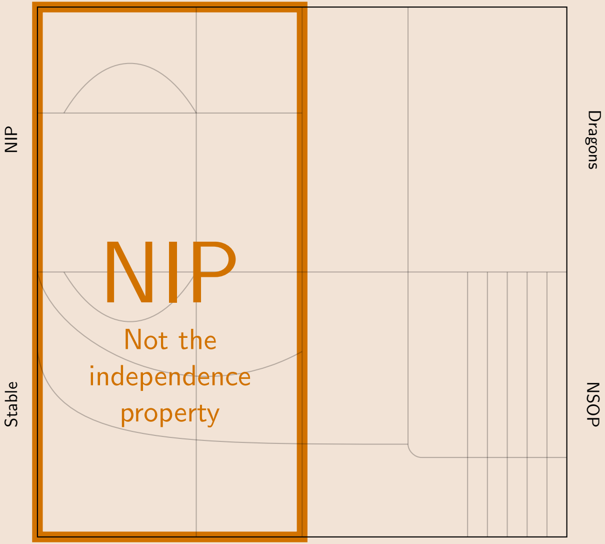

Examples:

$(\mathbb{R}, +, \cdot, <, \exp)$

$(\mathbb{Q}, +, <)$

$(\mathbb{N}, +, <)$

p-adic numbers

Alg. closed valued fields

Field of transseries

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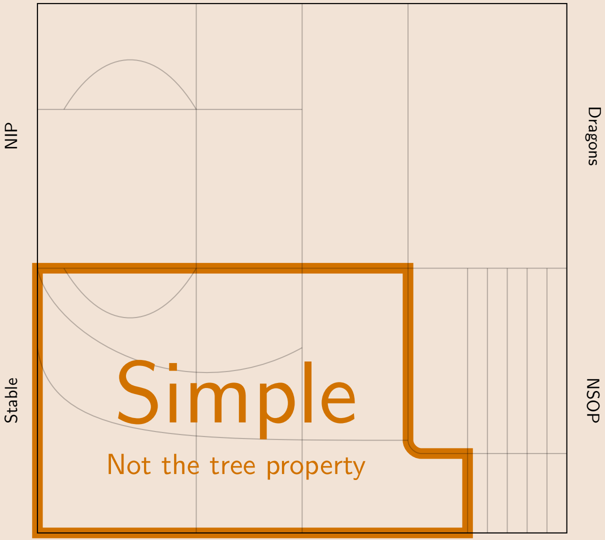
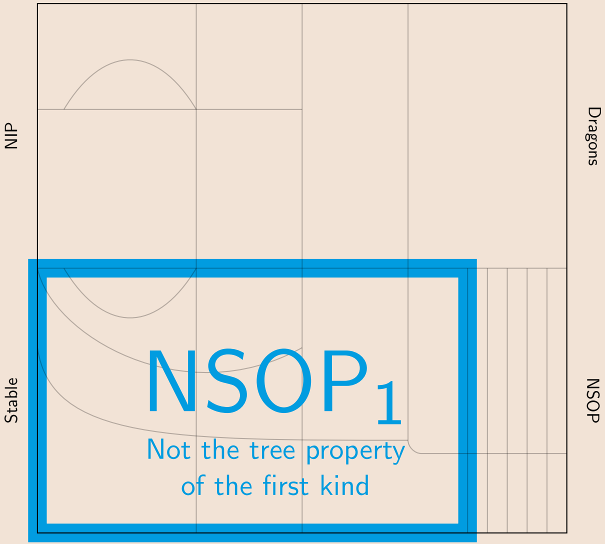


Examples:

Random graph

Pseudo-finite fields

Generic difference fields

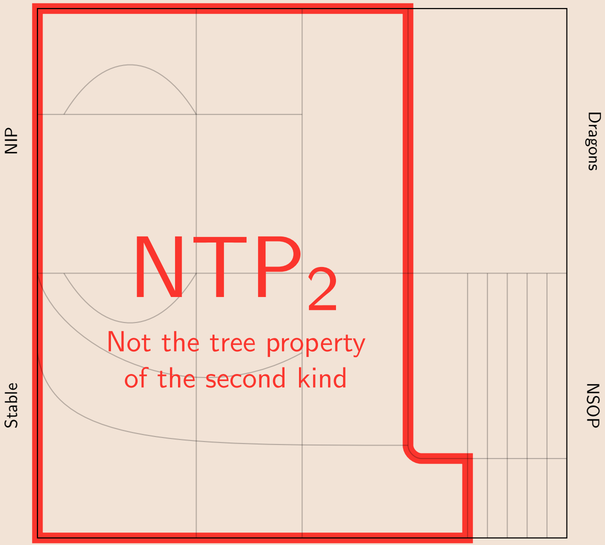


Examples:

Generic vector spaces with bilinear forms

Generic binary function

Generic parameterized equivalence relation



Examples:

Ultraproduct of $\mathbb{Q}_p$

Densely ordered random graph

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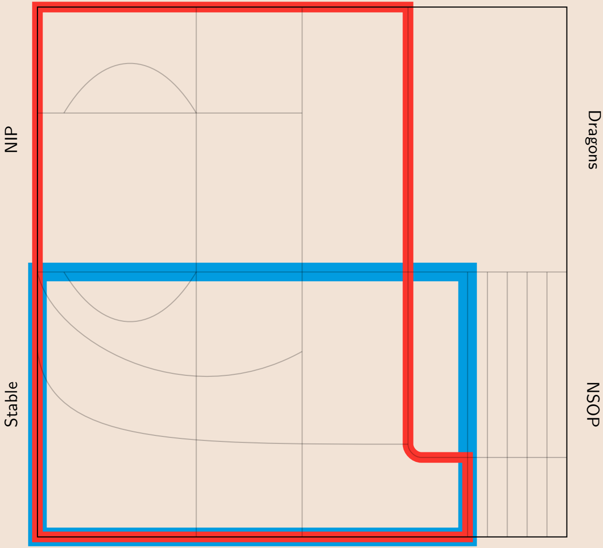

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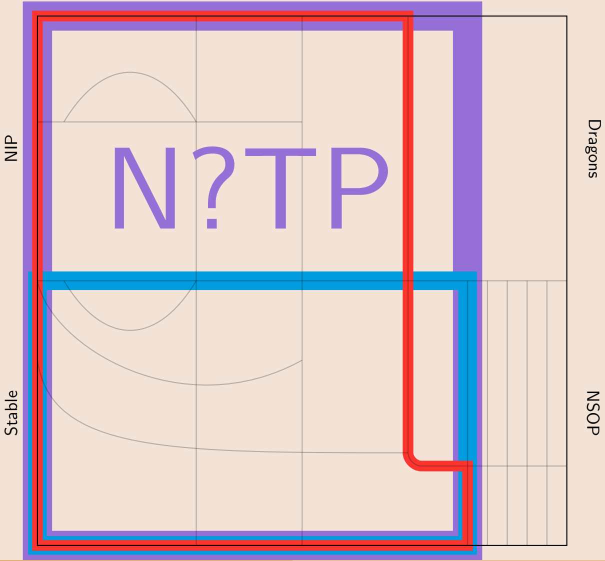

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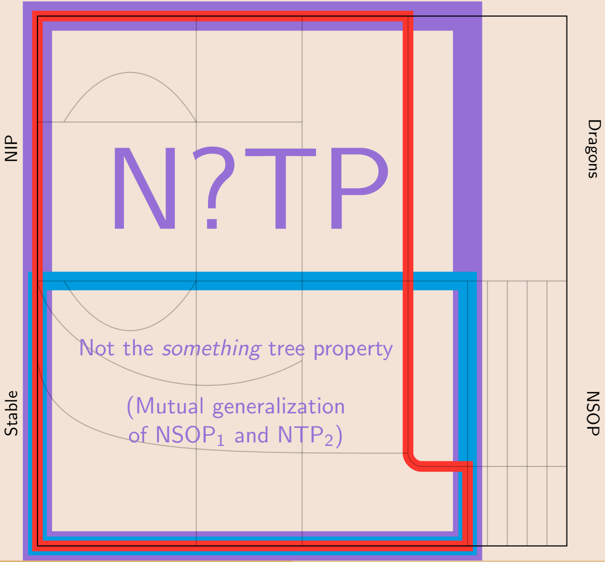

Examples:

Generic vector space with bilinear form over NIP or NTP_2 field ($\mathbb{R}$, $\mathbb{Q}_p$, etc.)

Generic linear order
$+$
binary function

SOP_1: The tree property of the first kind

A formula $\varphi(x, c)$ has the *k–tree property of the first kind* or *k-SOP_1*

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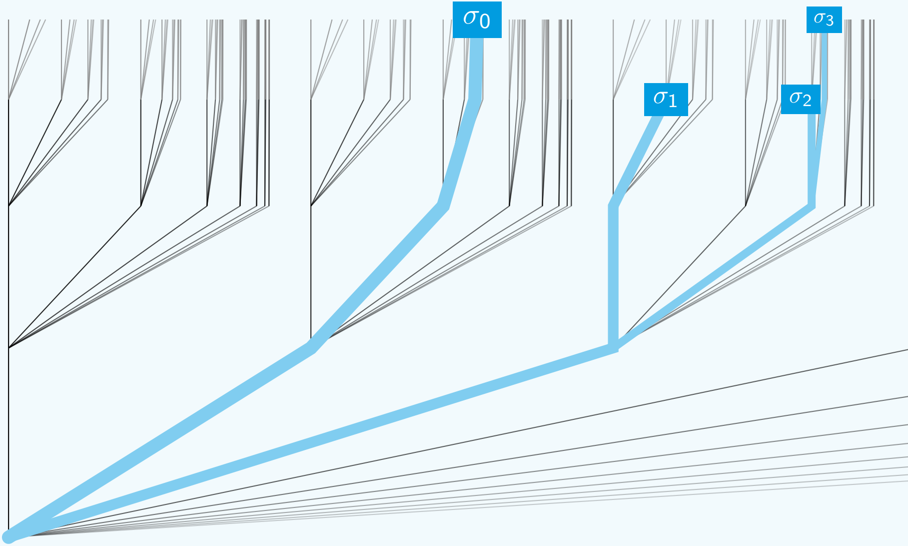
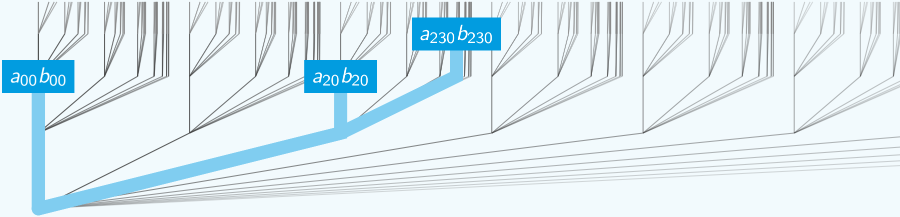
- paths are consistent: $\{\varphi(x, c_{\alpha\restriction n}) : n < \omega\}$ for $\alpha \in \omega^\omega$,
- for any "right-comb" $X \subset \omega^{<\omega}$, $\{\varphi(x, c_\sigma) : \sigma \in X\}$ is k-inconsistent.

(Note that this is a non-standard definition.)

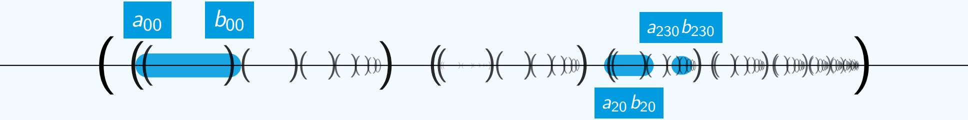
A right-comb



$(\mathbb{Q}, <)$ has 2-SOP$_1$



Any right-comb is 2-inconsistent



Coheirs

Given a structure M we can use an ultrafilter $\mathcal{U}$ on M (an *M-coheir*) to 'generate' a sequence of new elements (in the monster model).

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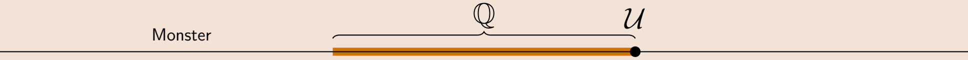

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Example $(\mathbb{Q}, <)$ with ultrafilter concentrating at $+\infty$:

a_{i+1} is what $\mathcal{U}$ 'looks like' to $\mathbb{Q}$ and $a_0, \ldots, a_i$, the *Morley sequence generated by* $\mathcal{U}$.

SOP_1 in terms of coheirs

Given a coheir $\mathcal{U}$ over a model M, a formula $\varphi(x, y)$ *k-divides along* $\mathcal{U}$ if whenever $b_0, b_1, \ldots$ is a Morley sequence generated by $\mathcal{U}$, $\{\varphi(x, b_i) : i < \omega\}$ is k-inconsistent.

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Theorem (Kaplan, Ramsey)

T has SOP_1 if and only if there is a model M, two coheirs $\mathcal{U}$ and $\mathcal{V}$ (extending the same type), and a formula $\varphi(x, y)$ such that $\varphi(x, y)$ divides along $\mathcal{U}$ but not along $\mathcal{V}$.

Coheir witnesses of SOP_1 in $(\mathbb{Q}, <)$

Two non-trivial coheirs of the 2-type living in the cut at π over $\mathbb{Q}$:

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Morley sequence generated by $\mathcal{U}_{\mathsf{below}}$
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$\mathcal{U}_{\text{below}}$ has a special property. The Morley sequence it generates

Generated by $\mathcal{U}_{\text{below}}$

Heir-coheirs

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This is non-trivial. $\mathcal{U}_{\text{pinch}}$ does not have this property.

TP_2 in terms of heir-coheirs

Definition

$\mathcal{U}$ is an *M-heir-coheir* if whenever b realizes $\mathcal{U}$ over $M \cup A$, there is an M-coheir $\mathcal{V}$ such that A realizes $\mathcal{V}$ over $M \cup b$.

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A formula $\varphi(x, b)$ *k-divides over M* if there is a sequence $(b_i)_{i<\omega}$ of realizations of the type of b over M such that $\{\varphi(x, b_i) : i < \omega\}$ is k-inconsistent.

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Theorem (Chernikov, Kaplan)

T has TP_2 if and only if there is a model M, a formula $\varphi(x, b)$, and an M-heir-coheir $\mathcal{U}$ extending the type of b over M such that $\varphi(x, b)$ divides over M but does not divide along $\mathcal{U}$.

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Lead them to the *bizarre tree property* or *BTP* (uses a weakening of heir-coheirdom), but also suggests the following:

? N?TP: If $\varphi(x, b)$ divides along some coheir, then it divides along every heir-coheir?

The comb tree property

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- for any "right-comb" $X \subset \omega^{<\omega}$, $\{\varphi(x, c_\sigma) : \sigma \in X\}$ is **consistent**.

(Note the switcheroo.)

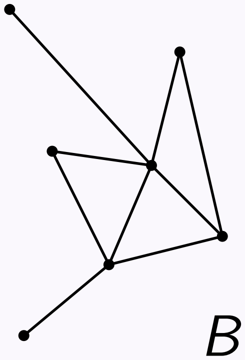
Characterization of CTP

Theorem (H.)

A theory has k-CTP if and only if there is a model M, a formula $\varphi(x, b)$, and an M-heir-coheir $\mathcal{U}$ and an M-coheir $\mathcal{V}$ extending the type of b over M such that $\varphi(x, b)$ k-divides along $\mathcal{V}$ but does not divide along $\mathcal{U}$.

What's special about heir-coheirs?

If $\mathcal{U}$ is an M-heir-coheir and B is some configuration of realizations of $\mathcal{U}$ over M, then we can find a clone B' of B with the property that every element of B' realizes $\mathcal{U}$ over $M \cup B$.



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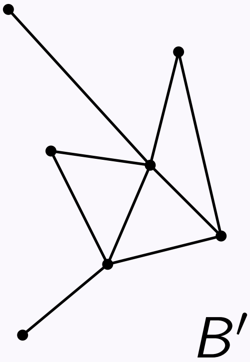

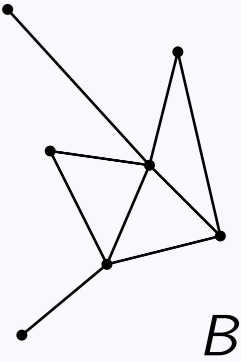

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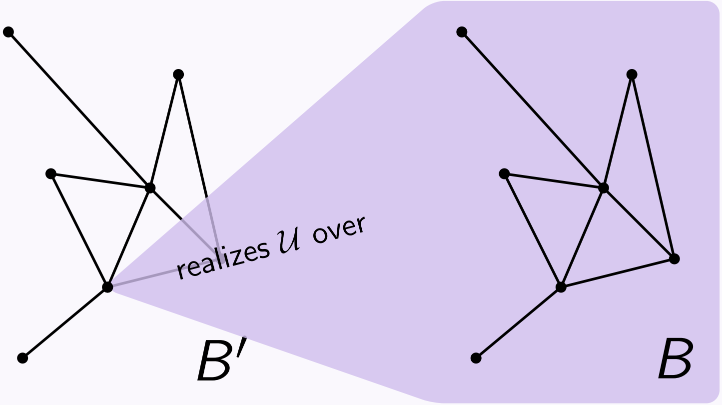

CTP from heir-coheir $\mathcal{U}$ and coheir $\mathcal{V}$

Realize $\mathcal{U}$ •

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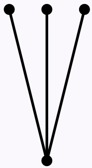
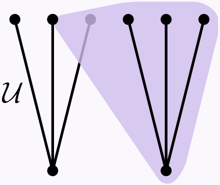


CTP from heir-coheir $\mathcal{U}$ and coheir $\mathcal{V}$

Super realize $\mathcal{U}$



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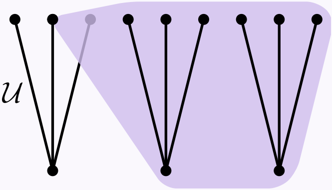

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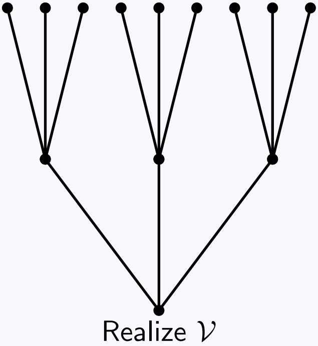

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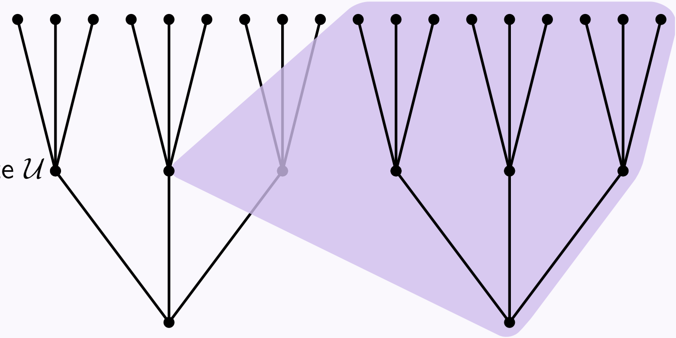
Super-duper realize $\mathcal{U}$



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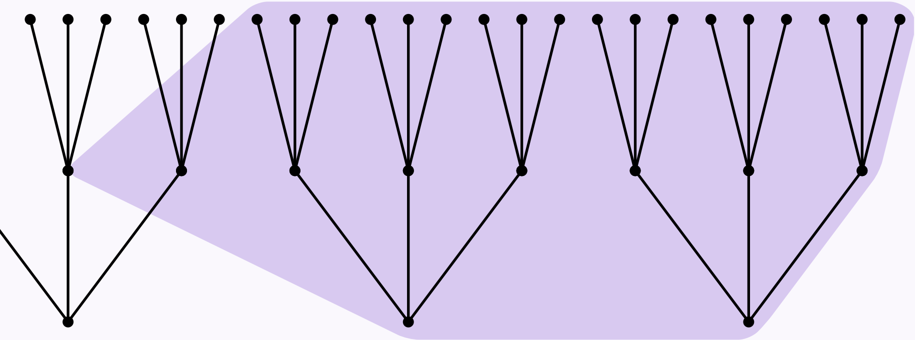

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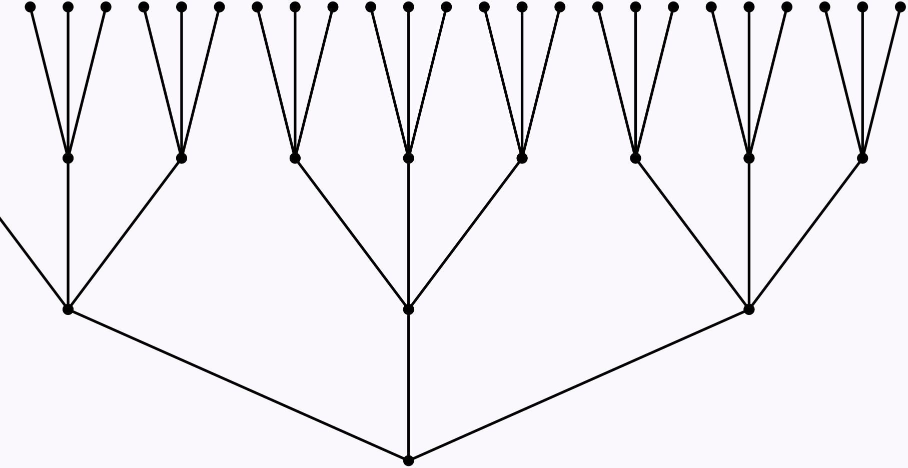
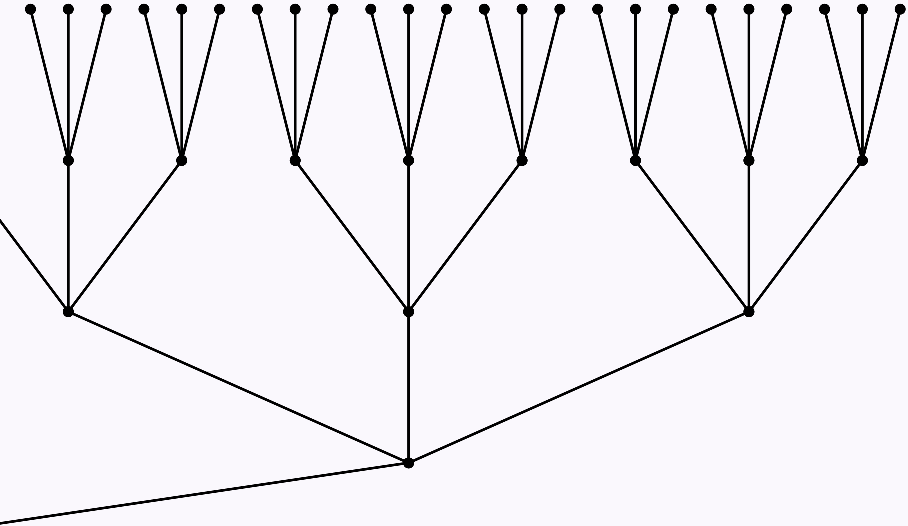


Realize $\mathcal{V}$

CTP from heir-coheir $\mathcal{U}$ and coheir $\mathcal{V}$



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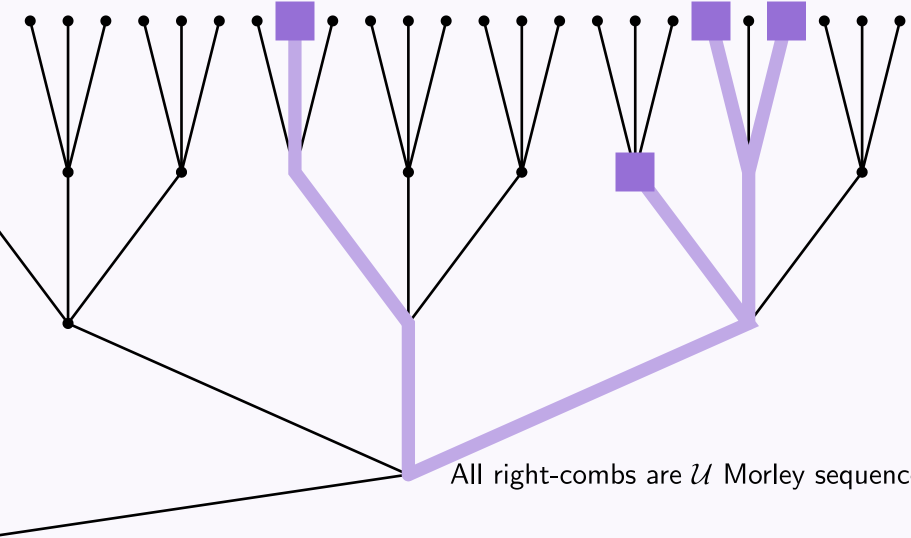
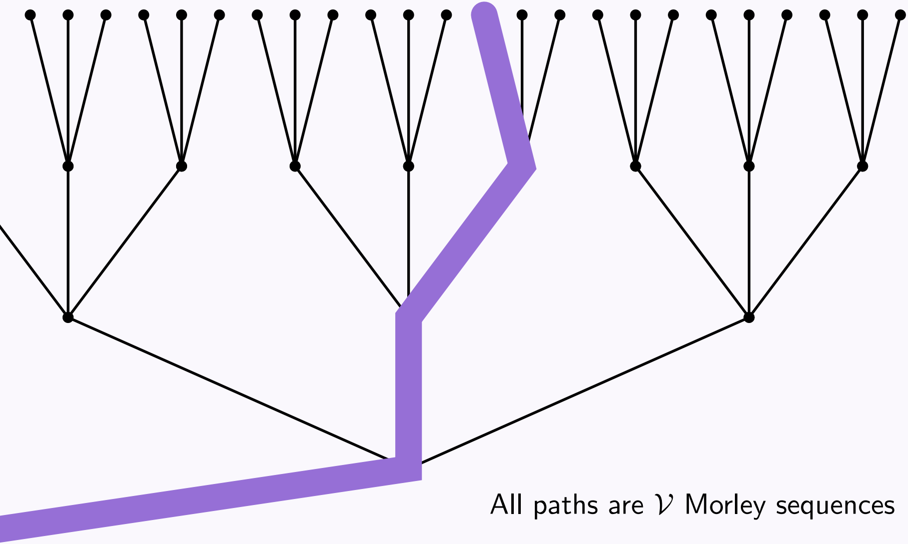


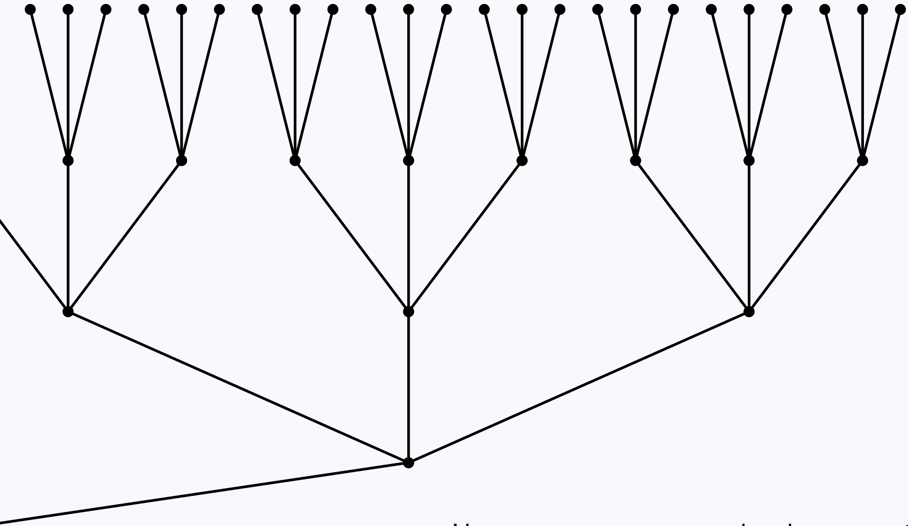
All right-combs are $\mathcal{U}$ Morley sequences

CTP from heir-coheir $\mathcal{U}$ and coheir $\mathcal{V}$



All paths are $\mathcal{V}$ Morley sequences

CTP from heir-coheir $\mathcal{U}$ and coheir $\mathcal{V}$



Use compactness to make the tree $\omega^{<\omega}$

Thank you

Combinatorial tameness in model theory

- Modern model theory (as of the 70s): classifying first-order theories with combinatorial tameness properties.

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- Started with Shelah's work generalizing Morley's theorem to uncountable languages. Ballooned into a large body of work called *stability theory*. Later extended and generalized under the title of *neostability theory*.

Simplicity: The tree property in model theory

A formula $\varphi(x, y)$ has the *k-tree property* if there is a tree $(c_\sigma)_{\sigma \in \omega^{<\omega}}$ of parameters such that

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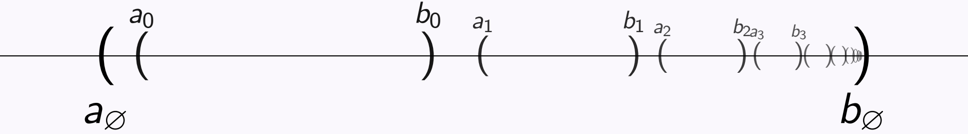

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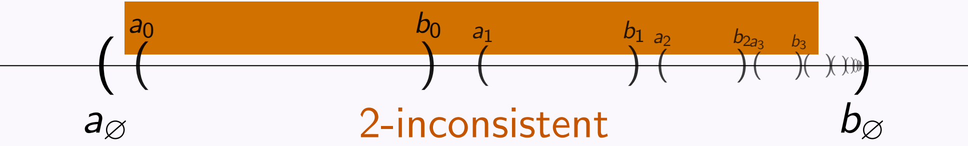

Simplicity: The tree property in model theory

A formula $\varphi(x, y)$ has the *k-tree property* if there is a tree $(c_\sigma)_{\sigma\in\omega^{<\omega}}$ of parameters such that

- paths are consistent: $\{\varphi(x, c_{\alpha\restriction n}) : n < \omega\}$ for $\alpha \in \omega^\omega$,
- siblings are k-inconsistent: $\{\varphi(x, c_{\sigma\frown n}) : n < \omega\}$.

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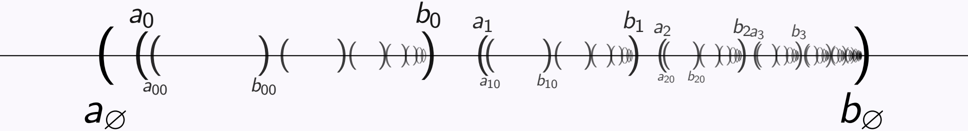

Forcing

Whence do heir-coheirs come?

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There are many heir-coheirs over $(\mathbb{Q}, <)$ (any non-realized cut). Is this generalizable?

Miniaturizing the saturation argument

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Argue that if $\mathcal{U}$ extends the type we built and a realizes $\mathcal{U}$ over Mb, then every formula in the type of b over Ma is already finitely satisfiable in M by construction. □

Comb definitions

Short-toothed right-combs are defined inductively:

- $\varnothing$ is a short-toothed right-comb.
- X is a short-toothed right-comb, every element of X extends $\sigma \frown j$, and $i < j$, then $X \cup \{\sigma \frown i\}$ is a short-toothed right-comb.

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The miniaturized argument as a blueprint for CTP

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The comb tree property (even on $2^{<\omega}$ rather than $\omega^{<\omega}$) gives you precisely what you need to generically build an heir-coheir $\mathcal{U}$ that is 'shadowed' by a coheir $\mathcal{V}$ such that the given formula divides along $\mathcal{V}$ but not along $\mathcal{U}$.

The fundamental theorem of forcing

Definition

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Proof.

Assume X is not dense above σ, then there is a τ extending σ such that X contains no elements extending τ. But then since $X \cup Y$ is dense above σ, it is also dense above τ, whereby Y is dense above τ. □

Forcing with comb trees

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- If $\psi(x, c)$ is an M-formula (with c in the monster) such that $\{b_\sigma : \psi(b_\sigma, c)\}$ has somewhere dense intersection with every element of $\mathcal{F}$, then there is a $d \in M$ such that $\{b_\sigma : \psi(b_\sigma, d)\} \in \mathcal{F}$.

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(Draw on chalkboard.)

Forcing with comb trees II

The second bullet point now ensures that

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Finally, let $\mathcal{V}$ be any non-principal ultrafilter on $\{b_{\sigma_i} : i < \omega\}$. By construction, $\varphi(x, y)$ will divide along $\mathcal{V}$.

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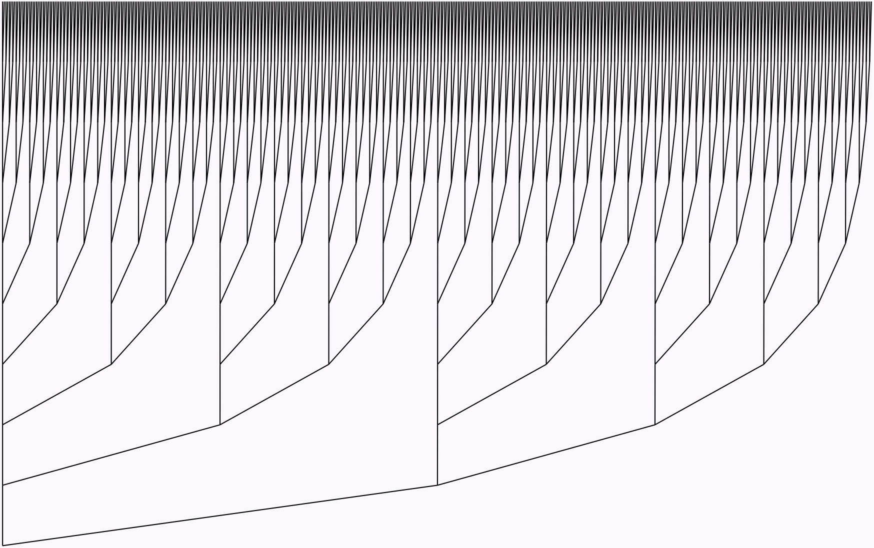
Finally, let $\mathcal{V}$ be any non-principal ultrafilter on $\{b_{\sigma_i} : i < \omega\}$. By construction, $\varphi(x, y)$ will divide along $\mathcal{V}$. Furthermore, the third bullet point will ensure that $\mathcal{U}$ and $\mathcal{V}$ extend the same type over M, so we have the required failure of Kim's lemma for coheirs and heir-coheirs.

Forcing with comb trees III



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