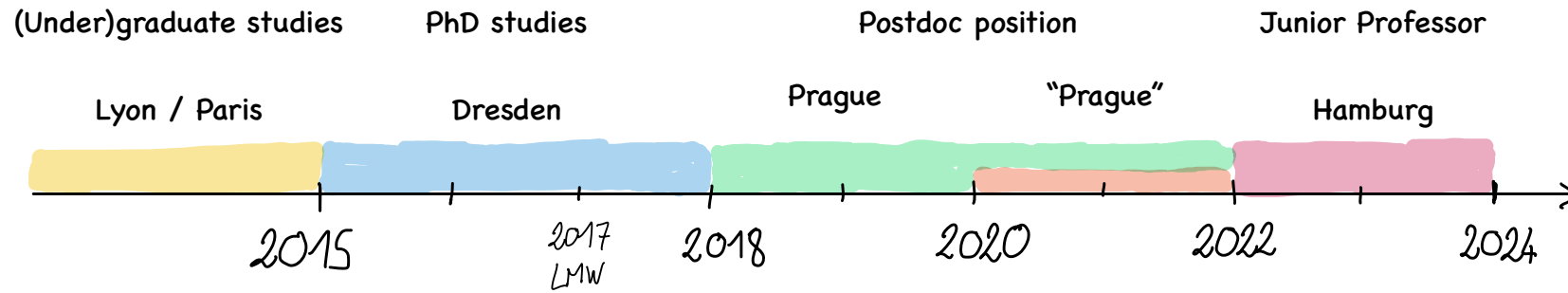


Structure in Research

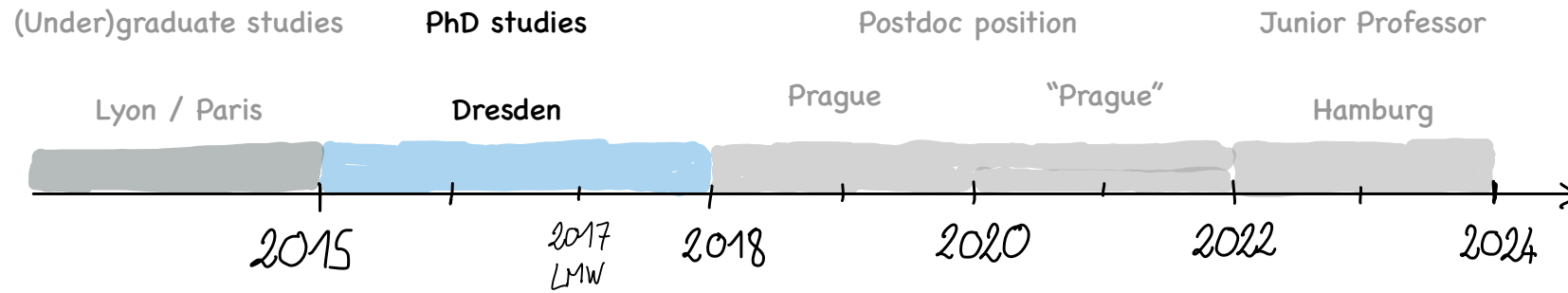
Antoine Mottet

Logic Mentoring Workshop 2024

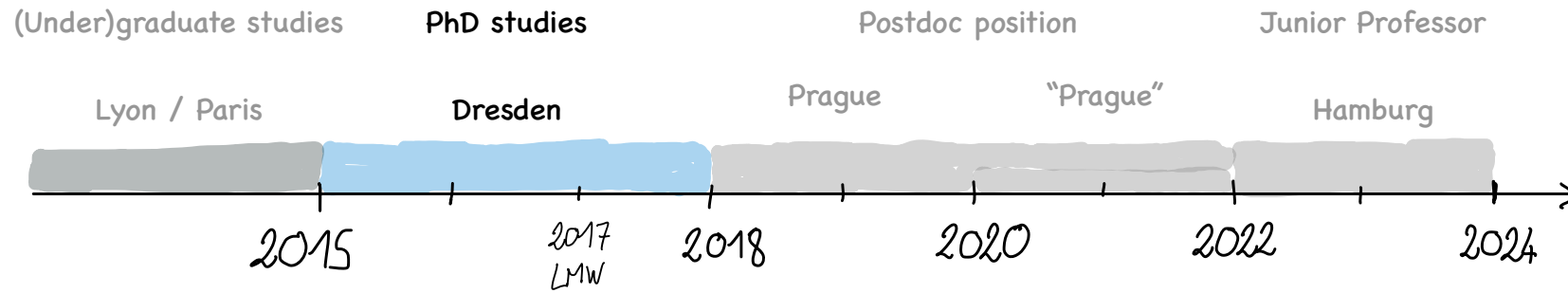
Timeline



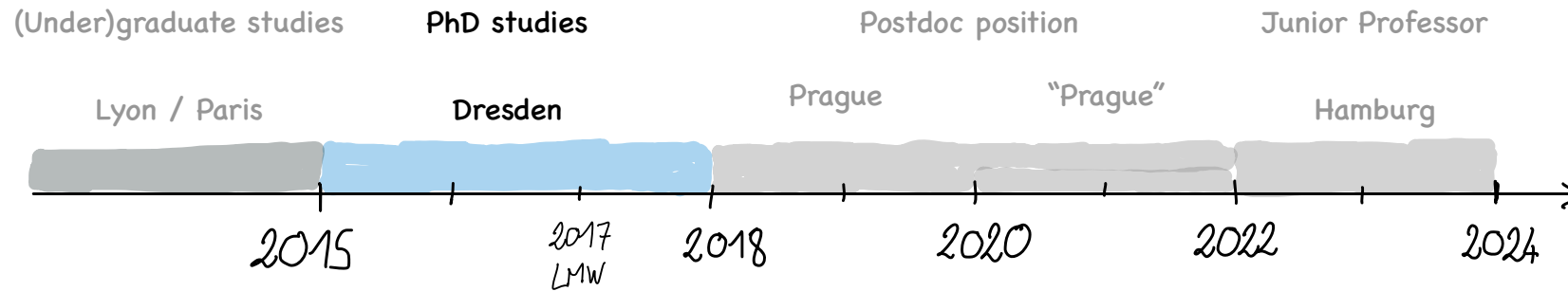
Timeline



Mental health in academia



Mental health in academia

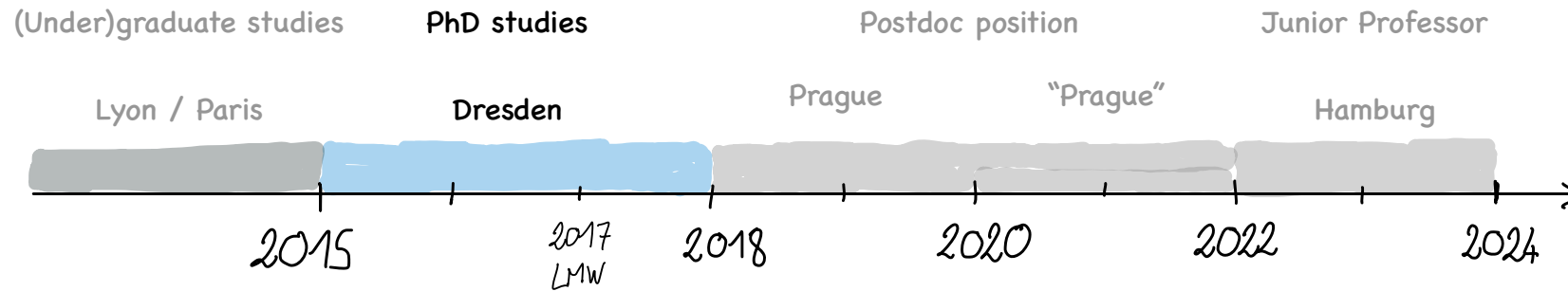


Depression, anxiety, impostor syndrome

- Up to 85% of doctoral students experience symptoms of depression
- Recent meta-study says about 25% have "clinically significant" symptoms, 29% for post docs

Scientific review and meta-analysis of depression, anxiety, and suicidal ideation among PhD students, Satinski et al., 2021

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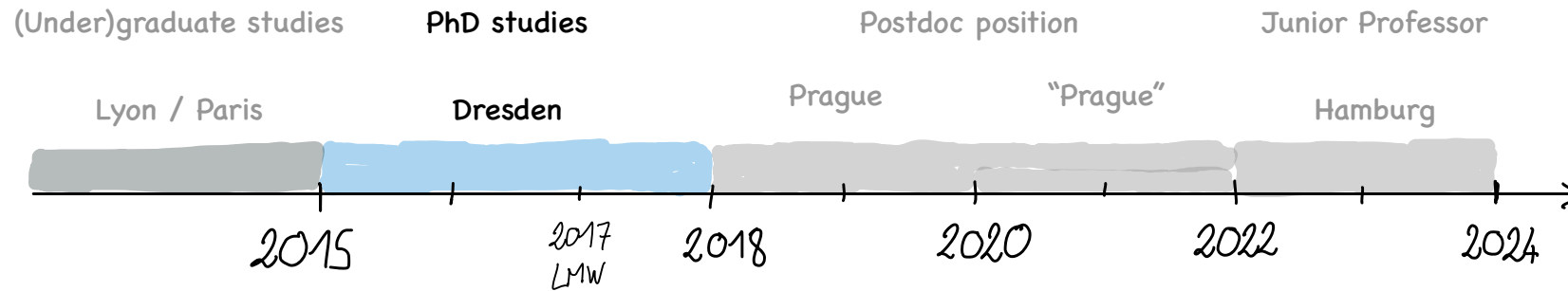


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- 50%-75% experience impostor syndrome
- This affects negatively interpersonal relations, scientific collaborations and leads to negative feedback loop

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Navigating through the disease: Finding structure in research

Disclaimer: depression is a disease that should be handled by a professional.

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reg-i-men 're-jə-mən also 're-zhə-

[Synonyms of regimen >](#)

- 1 a** : a systematic plan (as of diet, therapy, or medication) especially when designed to improve and maintain the health of a patient
- b** : a regular course of action and especially of strenuous training
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- Document your journey (log what you read, what you learned, the things you tried to solve your favourite problem)

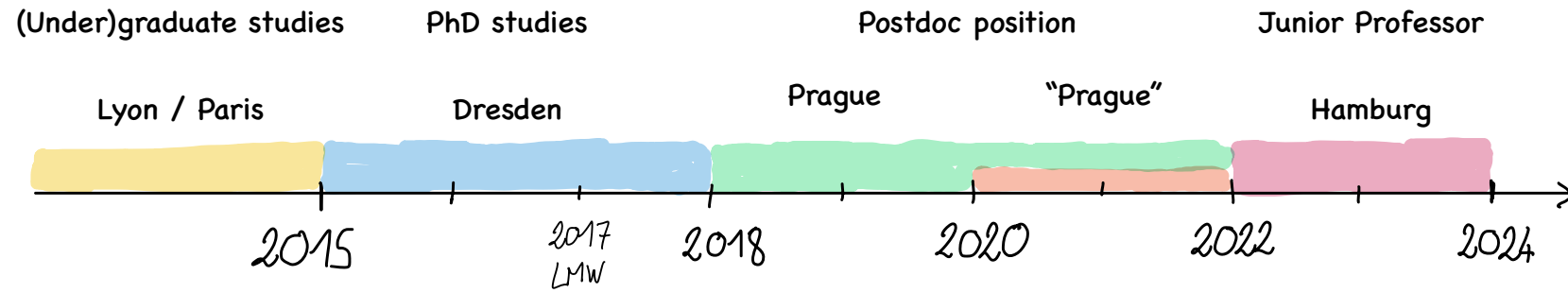
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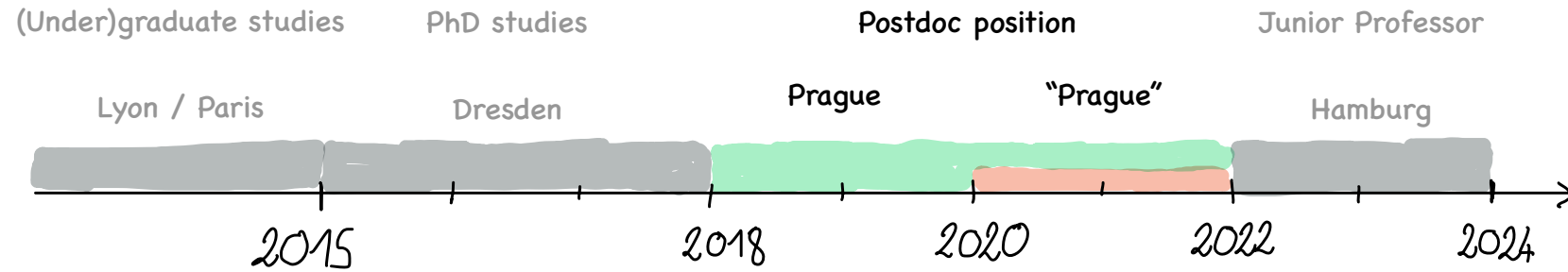
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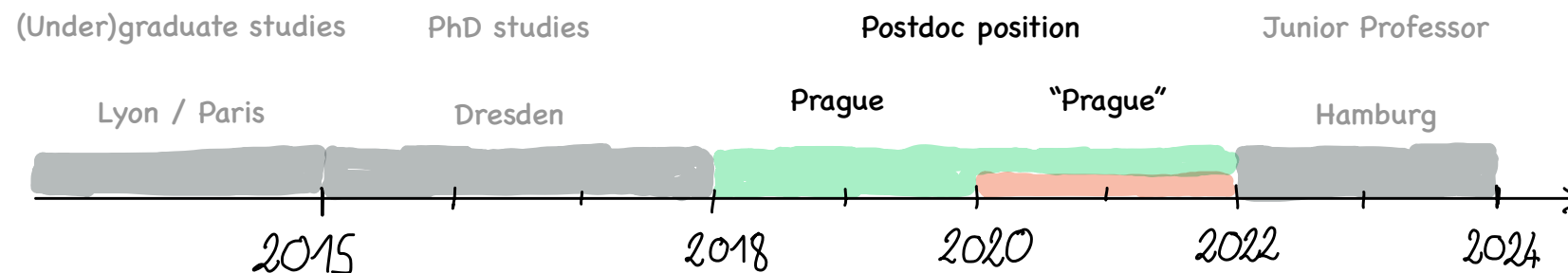
Timeline



Academia and climate change

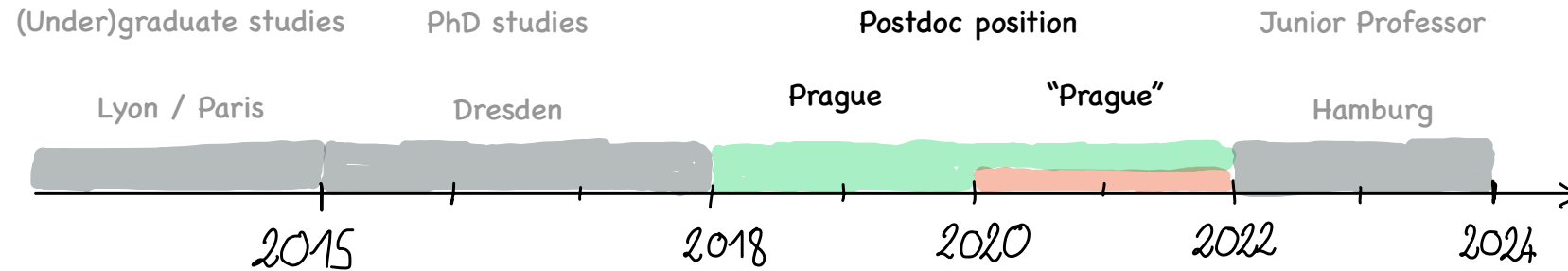


Academia and climate change



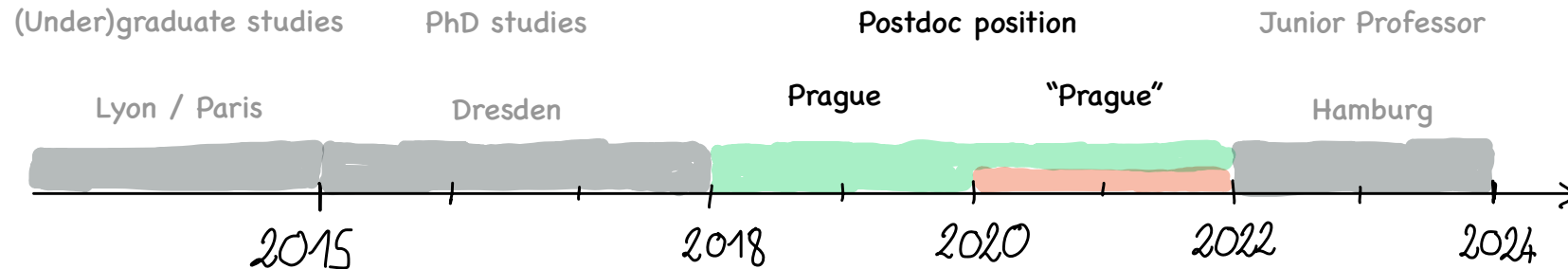
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Academia and climate change



- Academic activities are tied with international collaborations
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- Is this compatible with the alarming climate change?
- How to stick with a target of 1.5ton CO₂eq/person/year?

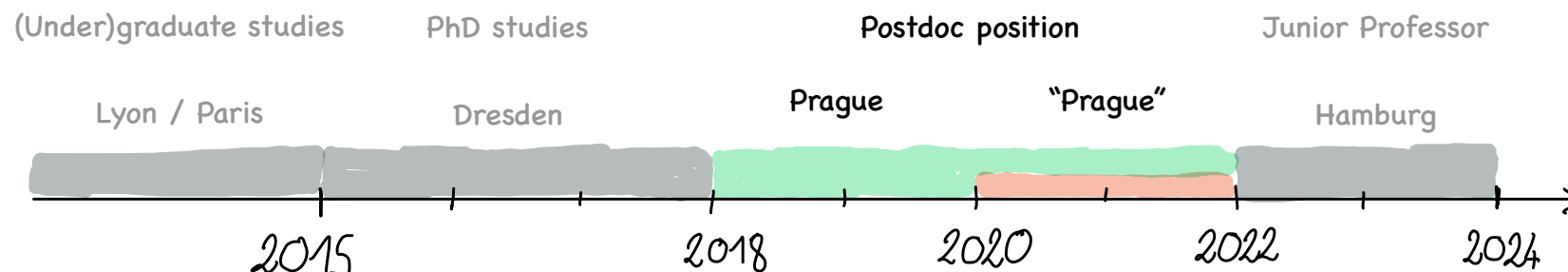
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Academia and climate change



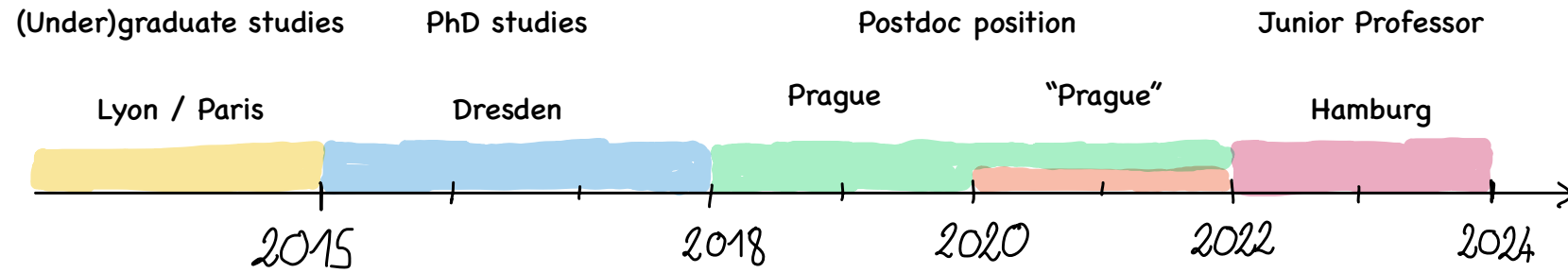
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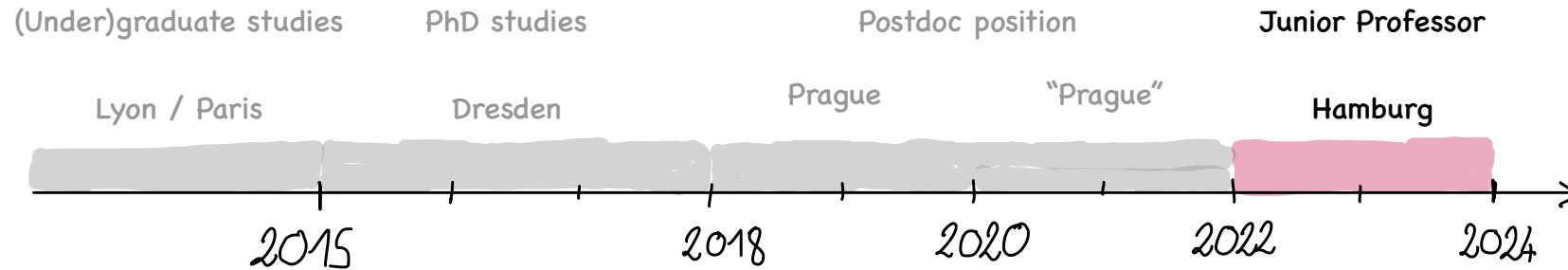


tcs4f.org

Timeline



Structure in computation: algebra



Homomorphism problem of A :

- Input: a finite structure X
- Question: does there exist a homomorphism from X to A ?

Computational problems

Connections with:

- Database theory, ontology-mediated queries
- Games (parity games, mean-payoff games)
- Universal algebra
- Category theory, algebraic topology, ...

Structure in computation: algebra

Theorem: (Schaefer)

Suppose that A has only two elements. Either A is:

- 0-valid or 1-valid,
 - Horn or dual-Horn,
 - Definable by bijunctive clauses,
 - Definable by systems of linear equations,
- and $\text{Hom}(A)$ is in P , or $\text{Hom}(A)$ is NP-complete.

Proof leverages Post's classification of Boolean relational clones (sets of relations closed under product, projection, intersection)

Computational problems

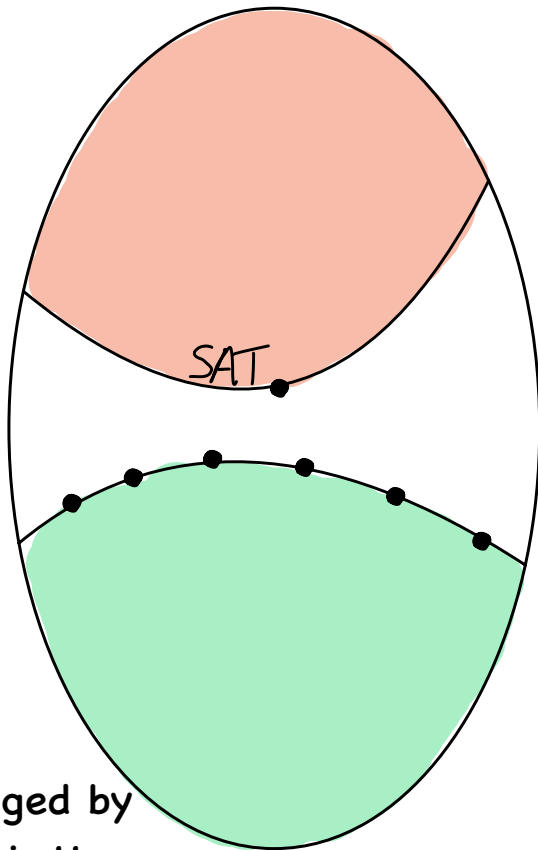


Relational clones

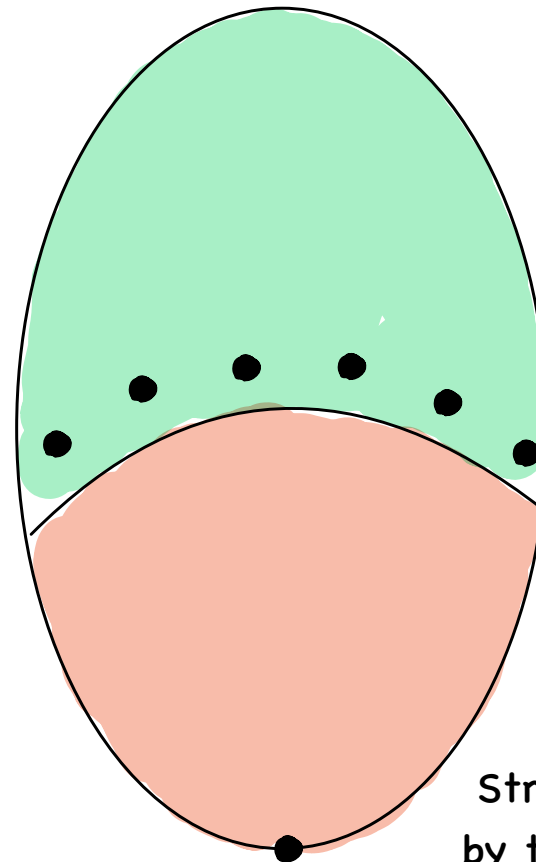
Structure in computation: algebra

Theorem: (Feder-Vardi, Jeavons, Bulatov-Jeavons-Krokhin, Barto-Opršal-Pinsker)

The complexity of $\text{Hom}(A)$ is captured entirely by the flat equational theory of $\text{Pol}(A)$.



Structures arranged by complexity of their Hom problem



Structures arranged by the richness of Pol

Computational problems



Relational clones



Clones

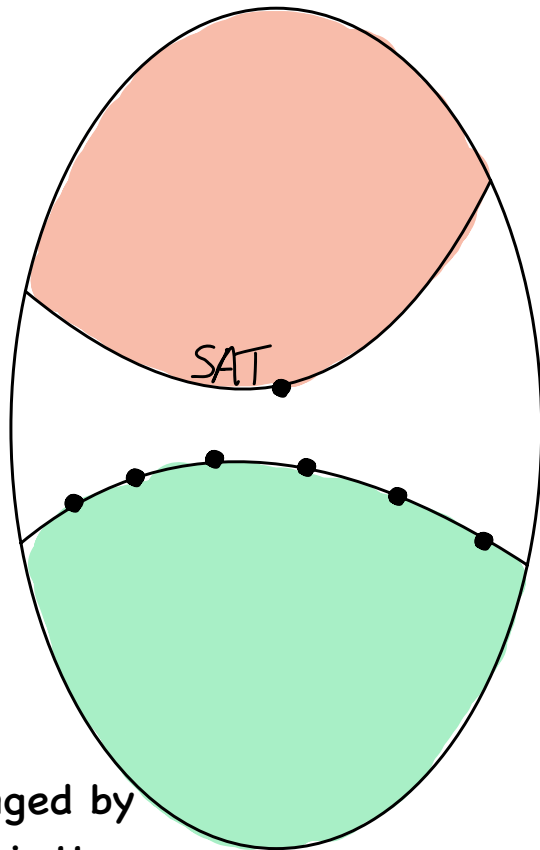


Minions

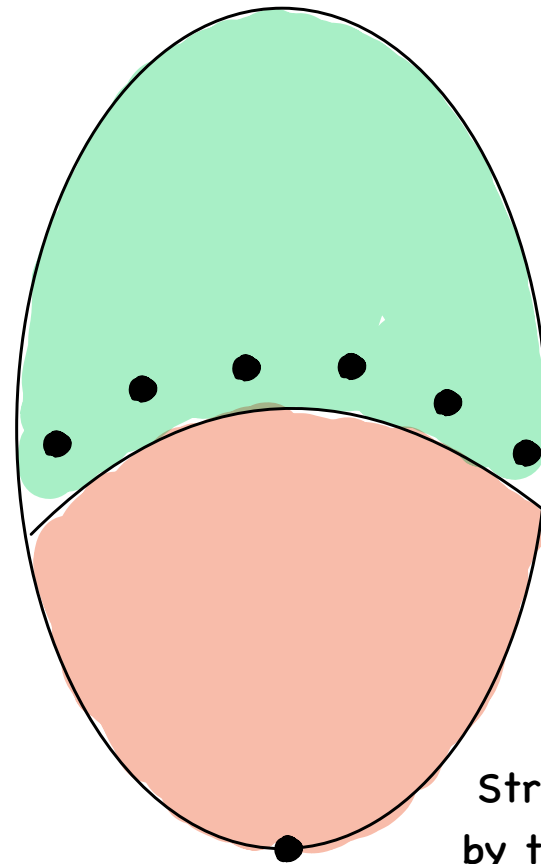
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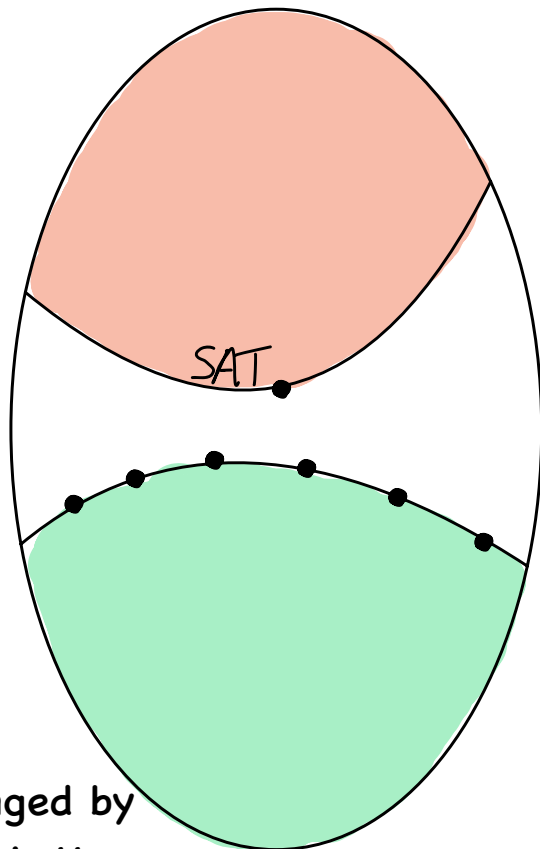
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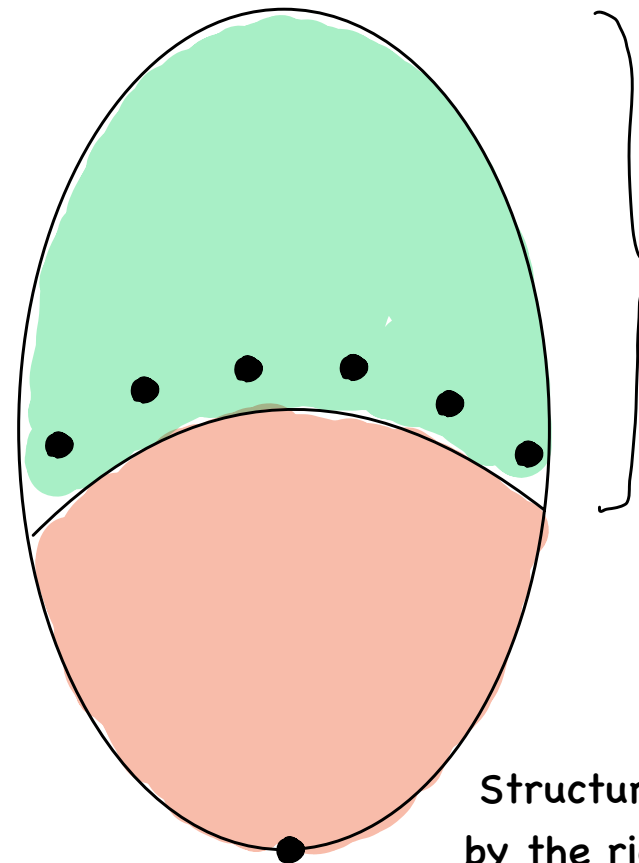
Structure in computation: algebra

Theorem: (Bulatov, Zhuk)

If A is finite and $\text{Pol}(A)$ is Taylor, then $\text{Hom}(A)$ can be solved in polynomial-time.



Structures arranged by
complexity of their Hom
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Structure in computation: algebra

- A number of breakthroughs have been obtained by studying the right kind of algebraic structures to keep track of “stuff” (Feder-Vardi dichotomy conjecture, algebraic topology, monstrous moonshine conjecture, ...)
- Logic, complexity, and algebra have a historical connection:

Theorem: (Büchi-Elgot-Trakhtenbrot, Myhill-Nerode)

Let L be a class of finite words. The following are equivalent:

- L is definable in MSO
- L is recognisable by a finite automaton
- The syntactic monoid of L is finite

Structure in computation: algebra

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Theorem: (Fagin)

Let L be a class of finite structures. The following are equivalent:

- L is definable in existential SO
- L is recognisable by a non-deterministic polynomial-time TM
- ??

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Theorem: (Bulatov, Zhuk)

Let A be a finite structure and let $L = \{ X \mid \text{there exists a homomorphism from } X \text{ to } A \}$.

The following are equivalent:

- ??
- L is recognisable by a deterministic polynomial-time TM
- $\text{Pol}(A)$ is Taylor.

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Theorem: (Barto-Kozik, Atserias-Bulatov-Dawar)

Let A be a finite structure and let $L = \{ X \mid \text{there exists a homomorphism from } X \text{ to } A \}$.

The following are equivalent:

- L is definable in $FP(C)$
- ??
- $Pol(A)$ is congruence-meet semi-distributive.

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Theorem: (Immerman, Vardi)

Let L be a class of finite **ordered** structures. The following are equivalent:

- L is definable in fixed-point logic
- L is recognisable by a deterministic polynomial-time TM
- ??

Structure in computation: algebra

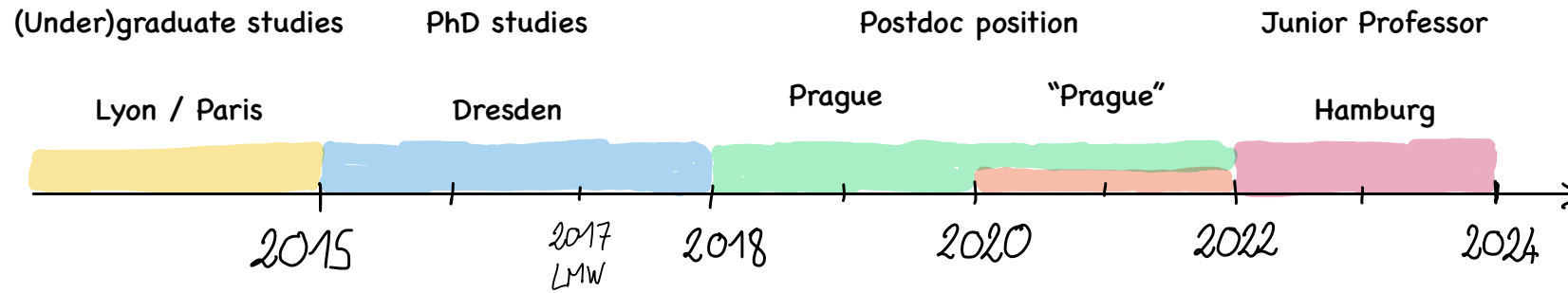
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Theorem: (?)

Let L be a class of finite structures. The following are equivalent:

- ?? (The **Logic for P** problem)
- L is recognisable by a deterministic polynomial-time TM
- ?? (**Algebra for P?**)

Timeline



The end