Obtaining Massive Data Sets for Contextual Experiments in Quantum Information

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Contextual Experiments

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NATURE | NEWS

Photons test quantum paradox

Contextuality theorem could improve secure communication.

Eugenie Samuel Reich

15 April 2013

Contextual Experiments

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Experimental Implementation of a Kochen-Specker Set of Quantum Tests

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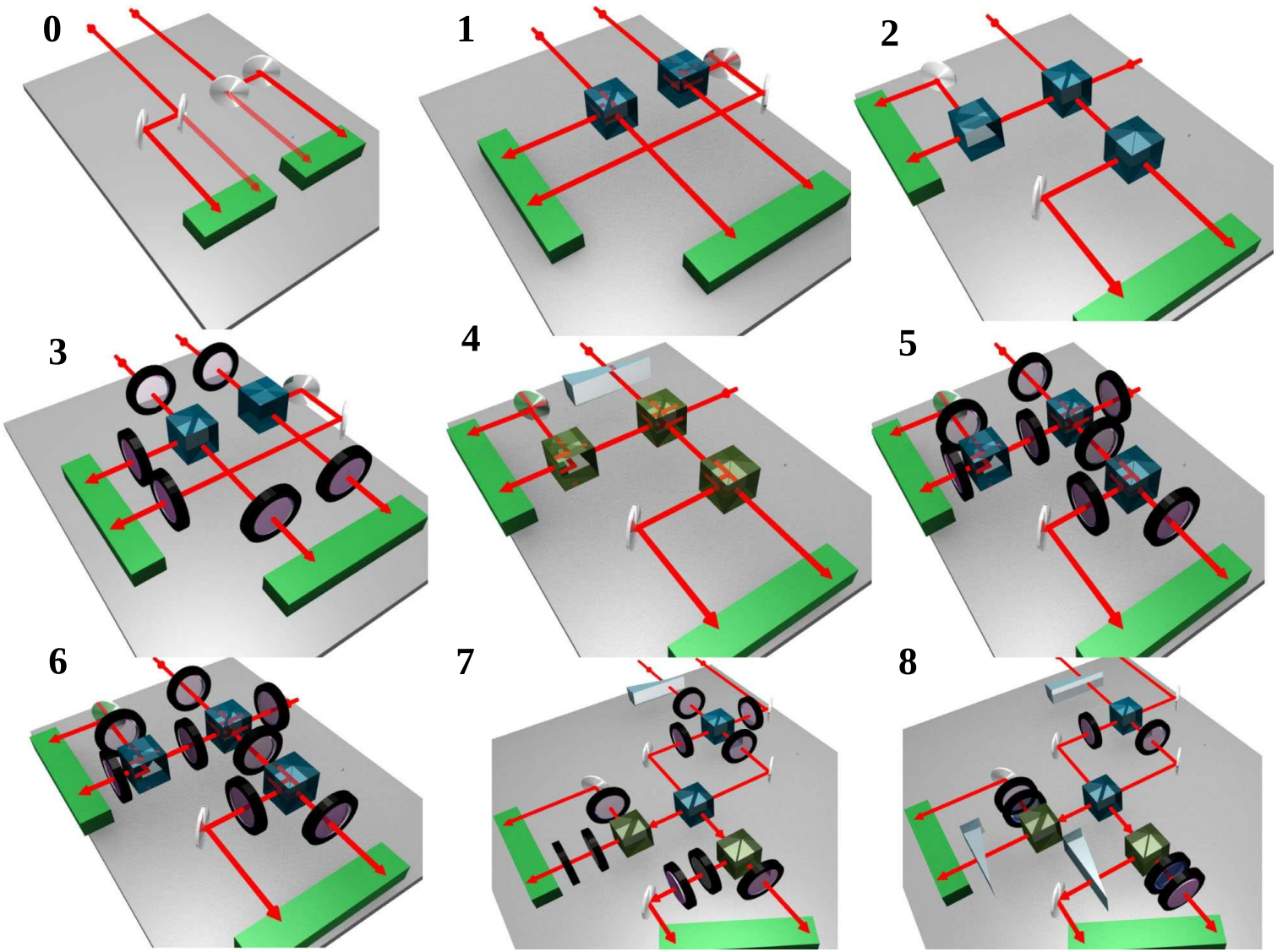
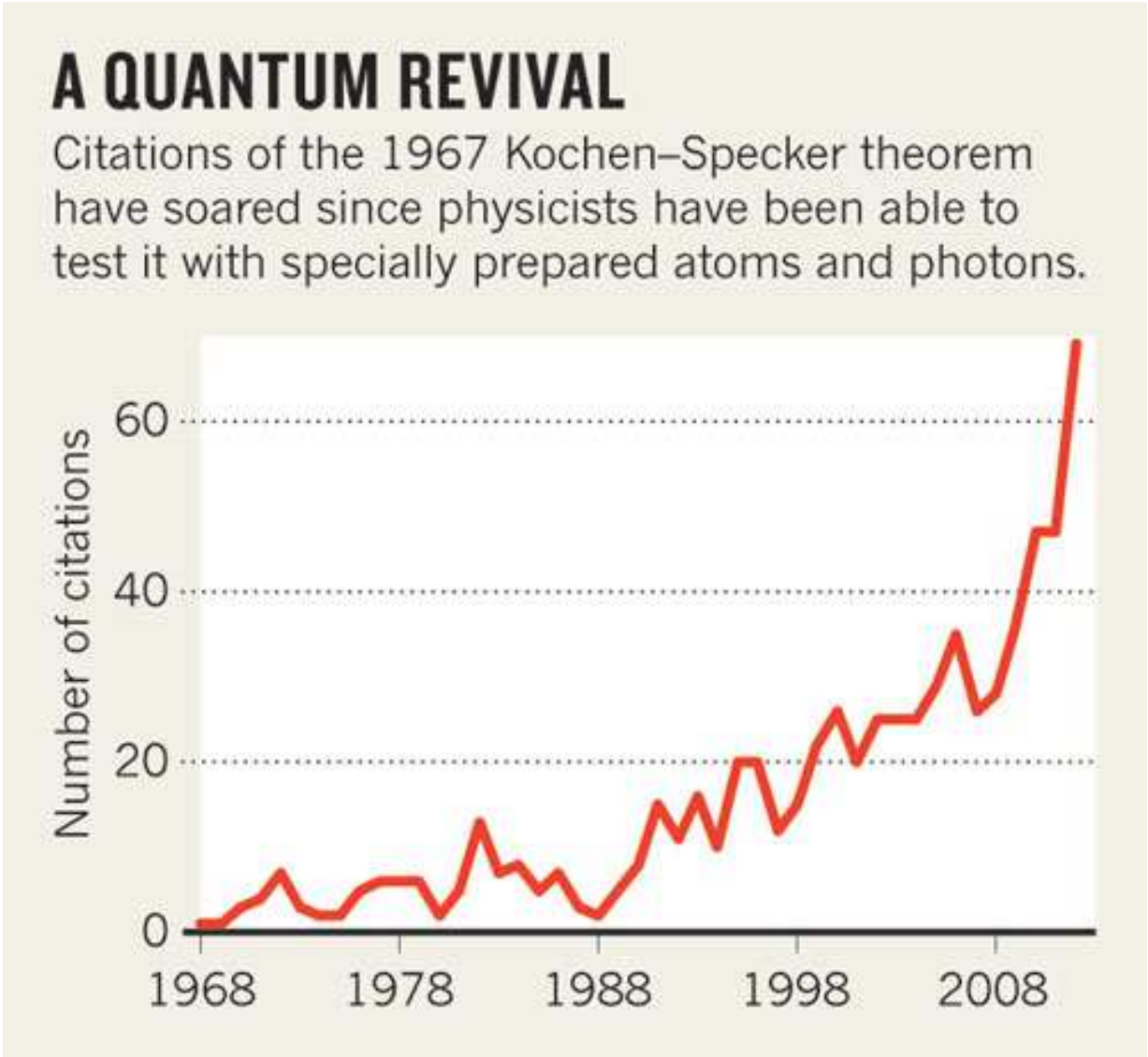
Contextual Experiments



KS Theorem Cited in Recent Papers on Contextuality



Noncontextuality vs. Contextuality

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Quantum theories do depend on arrangements in which measurements are carried out and we say that quantum theories are *contextual* and that their observables cannot be ascribed predetermined values.

Kochen-Specker sets are the most important examples of contextual sets.

Kochen-Specker Sets — Definiton

Definition 1. Every KS set is a set of vectors in a Hilbert space $\mathcal{H}^n$, $n \geq 3$ to which it is impossible to assign 1's and 0's in such a way that:

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1. No two orthogonal vectors are both assigned the value 1;
2. Not all of any mutually orthogonal vectors are assigned the value 0.

Orthogonality and Nonlinearity

$$\mathbf{a}_A \cdot \mathbf{a}_B = a_{A1}a_{B1} + a_{A2}a_{B2} + a_{A3}a_{B3} + a_{A4}a_{B4} = 0,$$
$$\mathbf{a}_A \cdot \mathbf{a}_C = a_{A1}a_{C1} + a_{A2}a_{C2} + a_{A3}a_{C3} + a_{A4}a_{C4} = 0,$$
$$\mathbf{a}_A \cdot \mathbf{a}_D = a_{A1}a_{D1} + a_{A2}a_{D2} + a_{A3}a_{D3} + a_{A4}a_{D4} = 0,$$
$$\mathbf{a}_B \cdot \mathbf{a}_C = a_{B1}a_{C1} + a_{B2}a_{C2} + a_{B3}a_{C3} + a_{B4}a_{C4} = 0,$$
$$\mathbf{a}_B \cdot \mathbf{a}_D = a_{B1}a_{D1} + a_{B2}a_{D2} + a_{B3}a_{D3} + a_{B4}a_{D4} = 0,$$
$$\mathbf{a}_C \cdot \mathbf{a}_D = a_{C1}a_{D1} + a_{C2}a_{D2} + a_{C3}a_{D3} + a_{C4}a_{D4} = 0.$$

Brute Force — Mission Impossible

McKay-Megill-Pavičić (MMP) Hypergraphs

Fortuntely, I realised that these equations can be reduced to a generation and then filtering of hypergraphs, in particular McKay-Megill-Pavičić (MMP) hypergraphs, which Brendan D. McKay, Norman D. Megill, and I defined previously for another purpose.

Definition 2. We define MMP hypergraphs as follows
(i) Every vertex belongs to at least one edge;
(ii) Every edge contains at least 3 vertices;
(iii) Edges that intersect each other in $n-2$ vertices contain at least n vertices.

This definition enables us to formulate algorithms for exhaustive generation of MMP hypergraphs.

Clever Approach Might Be Expensive

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We need quantum computers!

MMP Formalism

We encode MMP hypergraphs by means of alphanumeric and other printable ASCII characters. Each vertex is represented by one of the following characters: 1 2 3 4 5 6 7 8 9 A B C D E F G H I J K L M N O P Q R S T U V W X Y Z a b c d e f g h i j k l m n o p q r s t u v w x y z ! " # $ % & ' ( ) * - / : ; < = > ? @ [\ ] ^ _ ` { | } ~ , and then again all these characters prefixed by '+', then prefixed by '++', etc.

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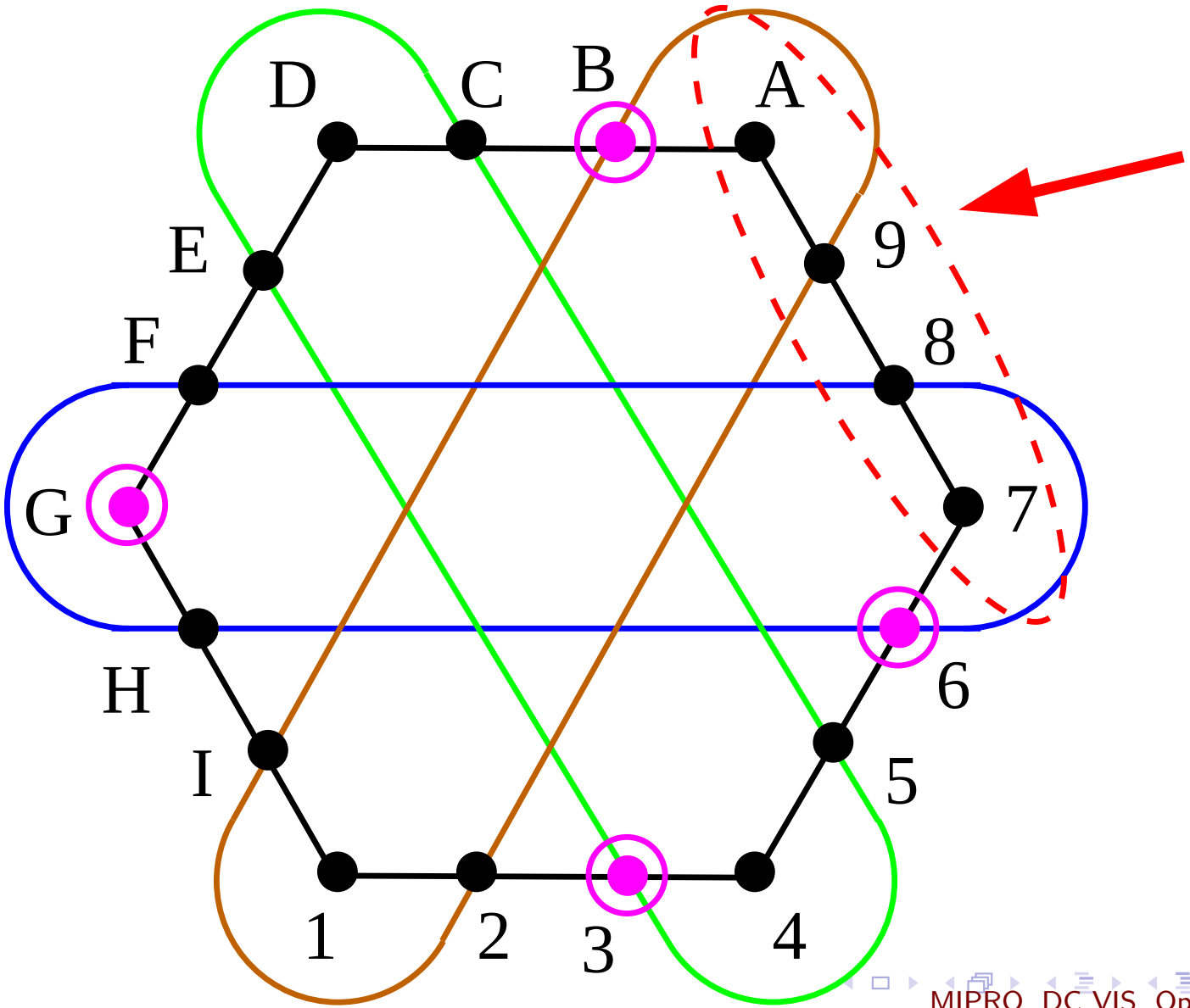
Each edge is represented by a string of characters that represent vertices within a single line. Edges are separated by commas. The line must end with a full stop. Skipping of characters is allowed. A line forms a representation of a hypergraph. The order of the edges is irrelevant. The numbers of vertices and edges are unlimited. We often present MMP hypergraphs starting with edges forming the biggest loop to facilitate their possible drawing.

MMP Representation of the Smallest 4dim KS Set



New 4dim Class of KS Sets

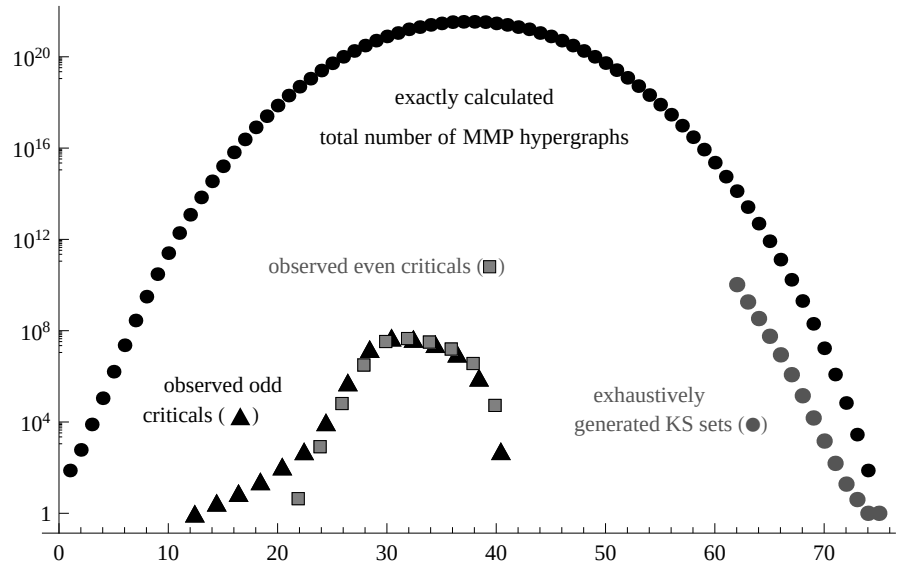
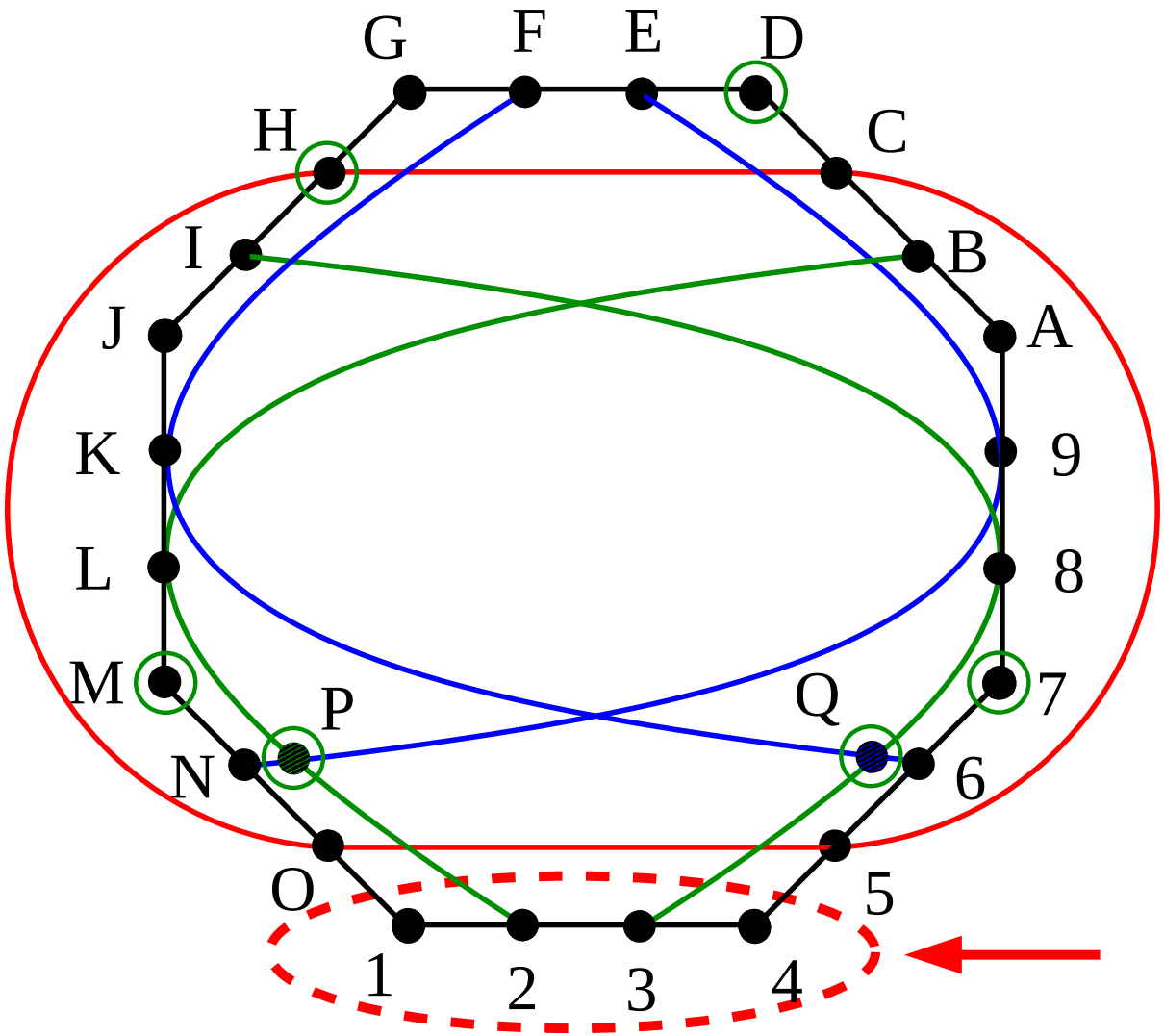


Figure : Statistics calculated for subsets of 60-75 given on a logarithmic scale. There are more than 10^9 critical KS sets. Given numbers of critical KS sets with 13 to 27 edges (on the x-axis) are exhaustive. The number of criticals with 32 edges is the biggest; we estimate that they do not exceed 10^{10}. Given numbers of noncritical KS sets with more than 61 edges are also exhaustive.

Smallest MMP KS Set from the 60-75 Class



KS Set Repository

Finland's nuclear waste bunker built to last 100,000 years

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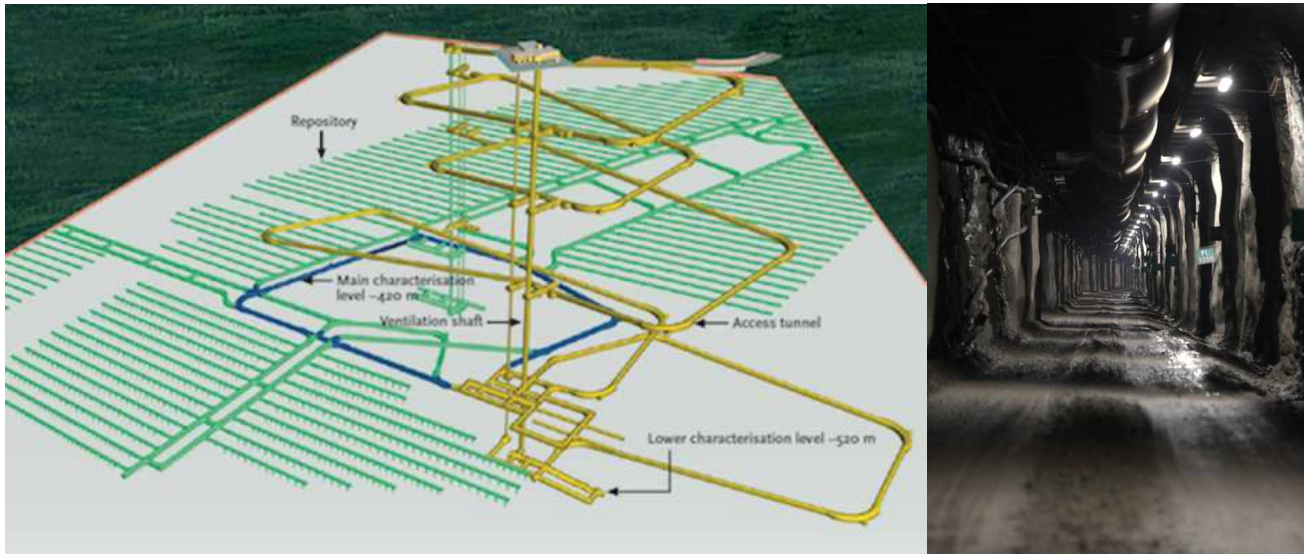
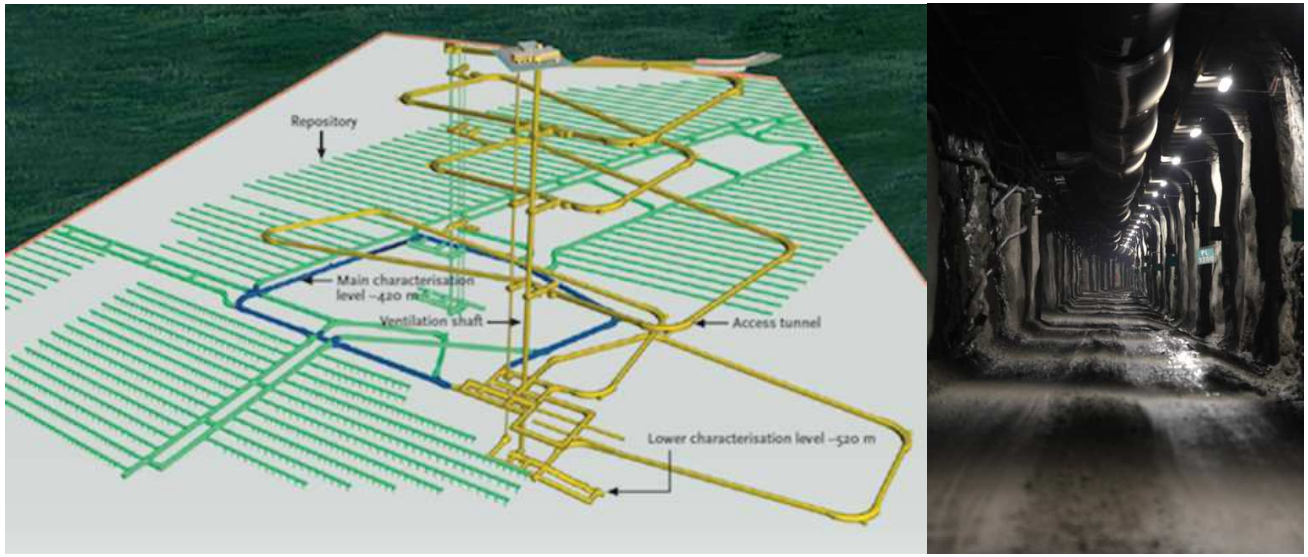


KS Set Repository

Finland's nuclear waste bunker built to last 100,000 years



A place we must remember to forget.

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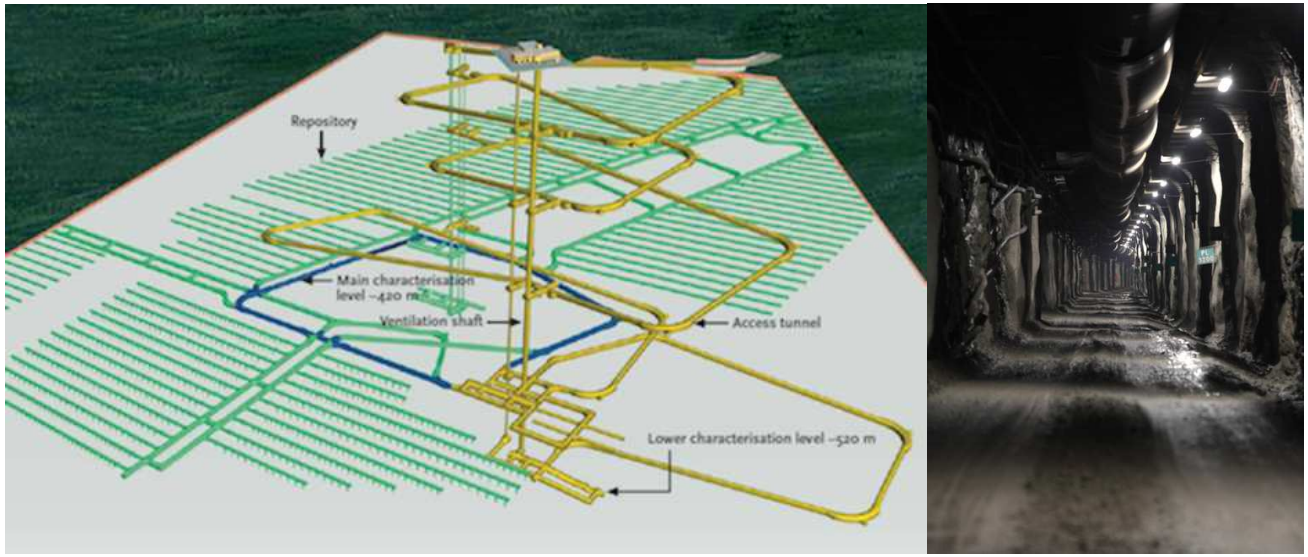

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Kochen-Specker and Other Contextual Set Repository!

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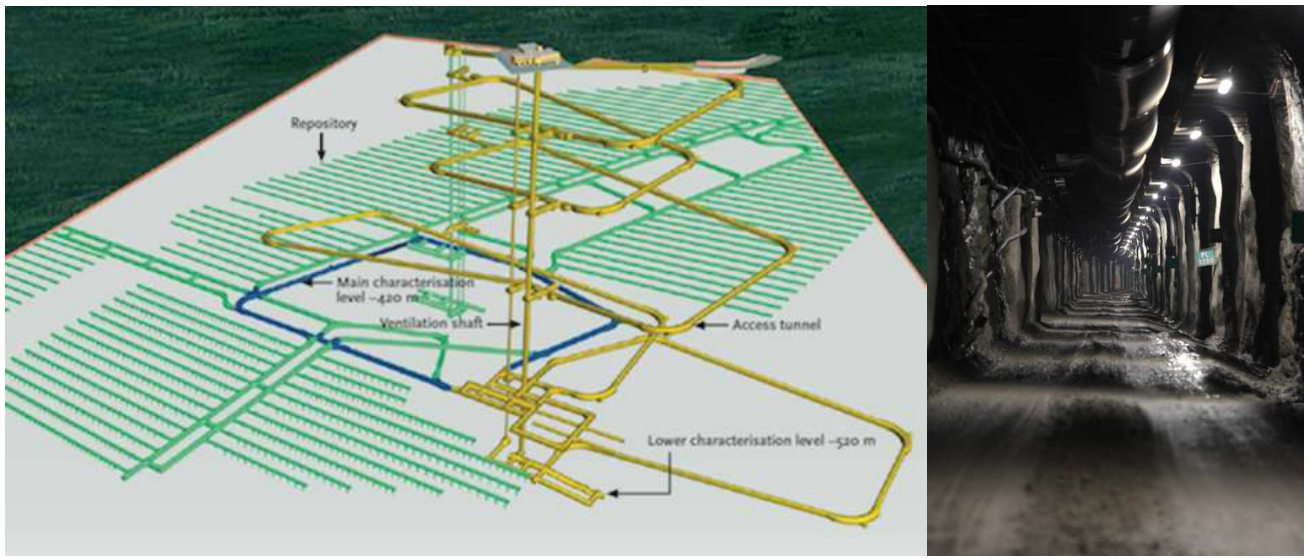

A place we must remember to forget.

Kochen-Specker and Other Contextual Set Repository!

A place we still do not have.

But, if we obtained it, we should remember to use it.

Thank You for Your Attention