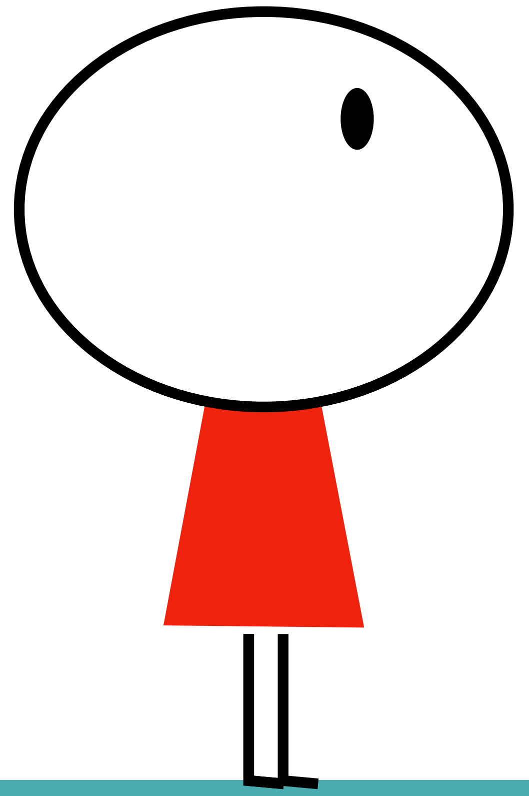
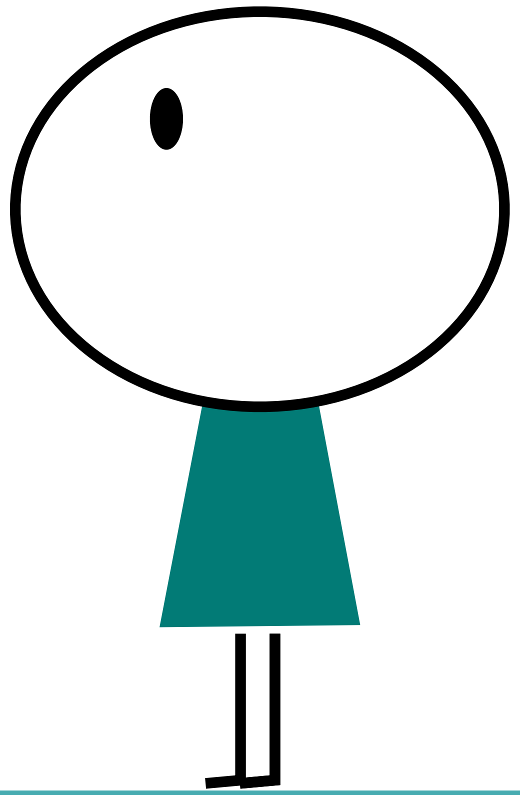
Side-channel countermeasures for lattice-based cryptography

- VeriSiCC Seminar -

Sept 22nd 2022





Mélissa Rossi

Lattices and hard problems

A lattice Λ is an additive subgroup generated by n linearly independent vectors of $\mathbb{R}^n$.

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Lattices and hard problems

Given a lattice Λ

Find the vector $\mathbf{v}$ that has the smallest nonzero norm

Short Vector Problem (SVP)

Lattices and hard problems

« Linear system solving with noise »

Given the pair $\left(\mathbf{A} \in \mathbb{Z}_q^{m\times n}, \mathbf{b} = \mathbf{A}\mathbf{s}+\mathbf{e} \in \mathbb{Z}_q^m\right)$ where

$\mathbf{A}$ is sampled uniformly at random

$\mathbf{e}$ and $\mathbf{s}$ are sampled following a small distribution χ

Find $\mathbf{s}$

Learning With Errors (LWE)

Lattice-based algorithms

Signature schemes

Public key encryption schemes

1 Strong hardness properties

Lattice-based algorithms

Signature schemes

Public key encryption schemes

1 Strong hardness properties

2 Simple designs (but complex analysis)

Lattice-based algorithms

Signature schemes

Public key encryption schemes

1 Strong hardness properties

2 Simple designs (but complex analysis)

3 Concrete candidates schemes
NIST round 2: 12 out of 26 candidates
NIST round 3: 5 out of 7 candidates
NIST first standards: 3
NIST round 4: ?

LWE-based public key encryption in a nutshell

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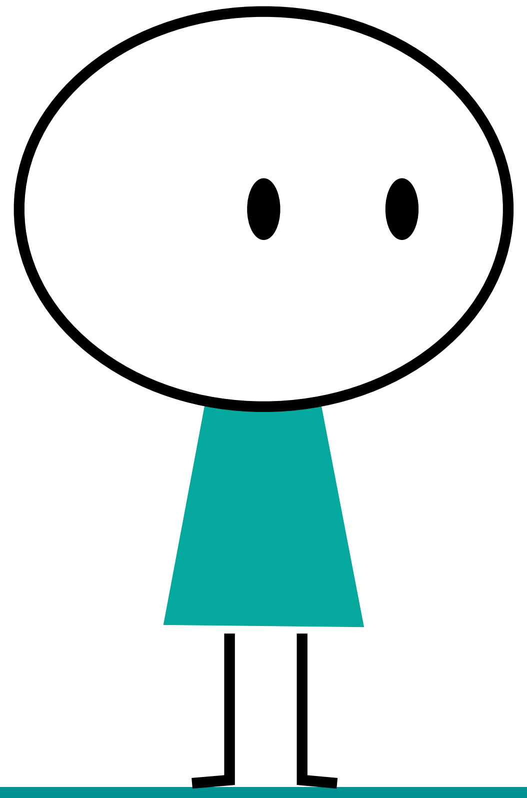

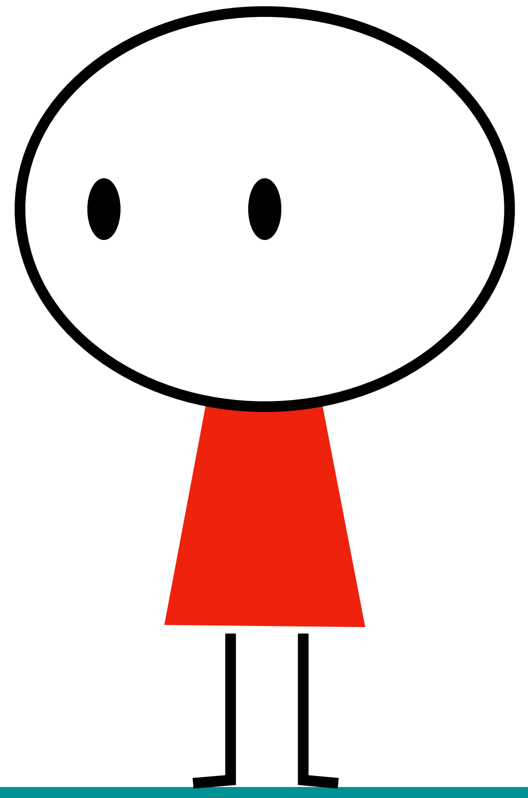

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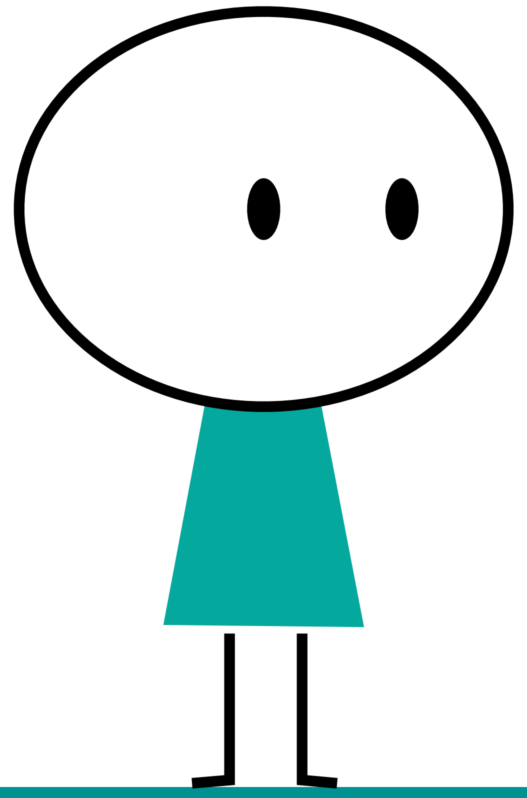
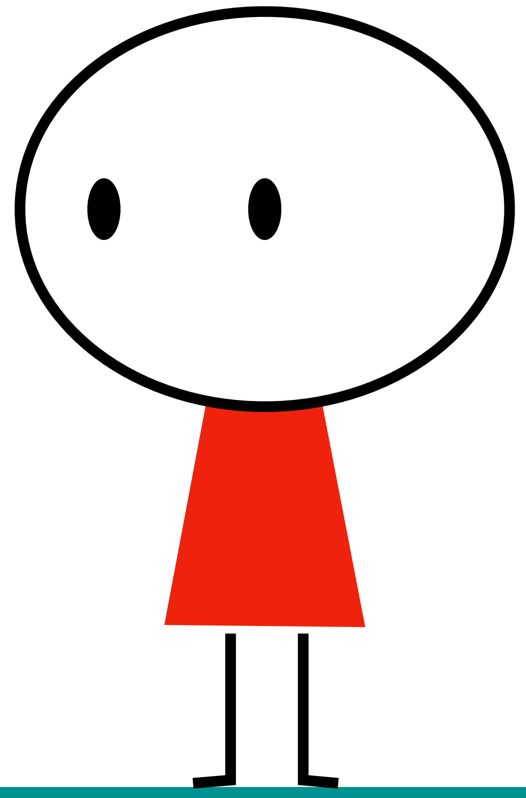
$$\left(\mathbf{A}, \mathbf{b} = \mathbf{A}\mathbf{z} + \mathbf{e}\right)$$





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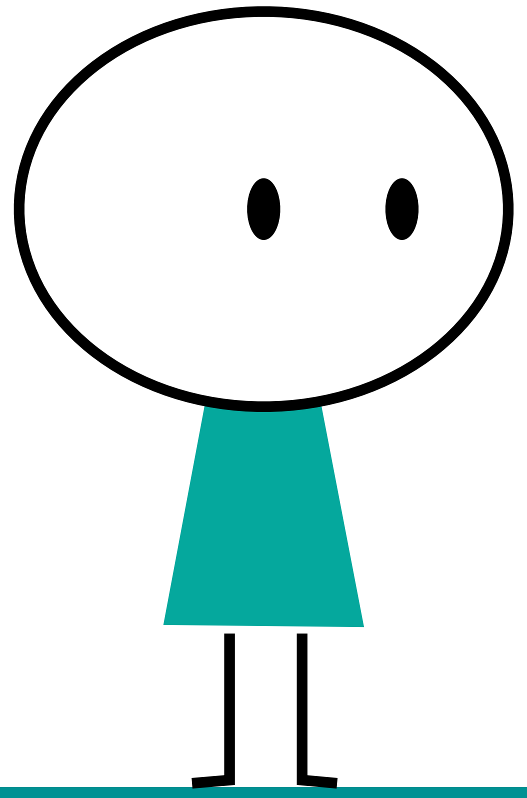

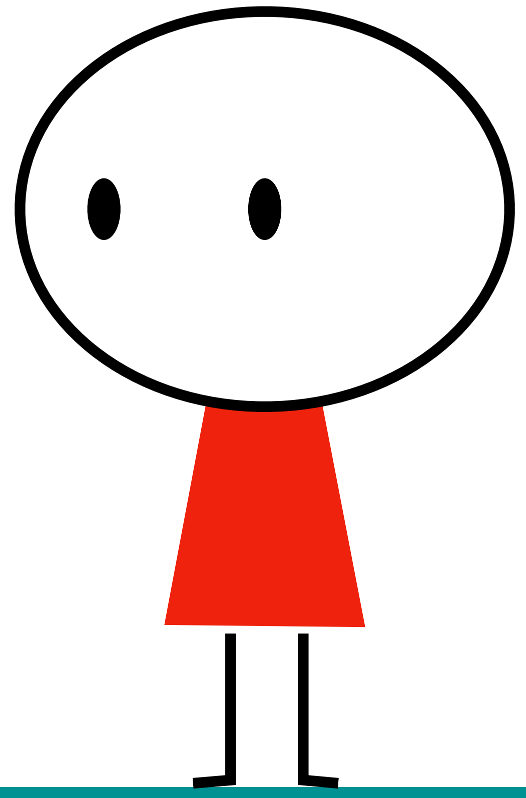

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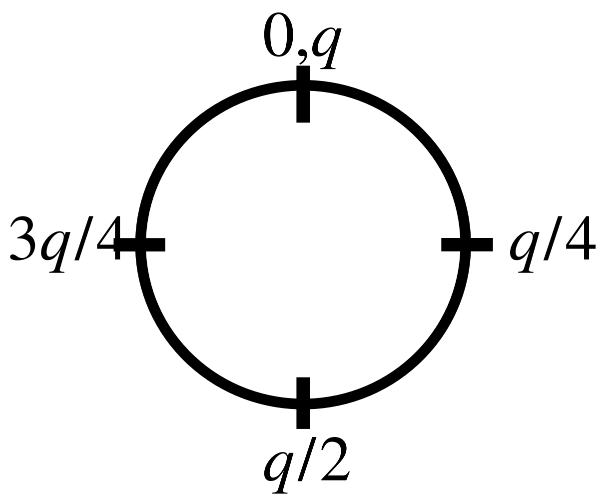
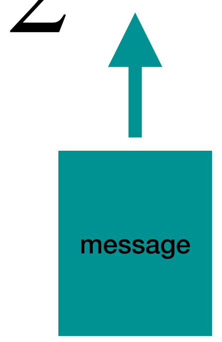
$$(\mathbf{A}, \mathbf{b})$$

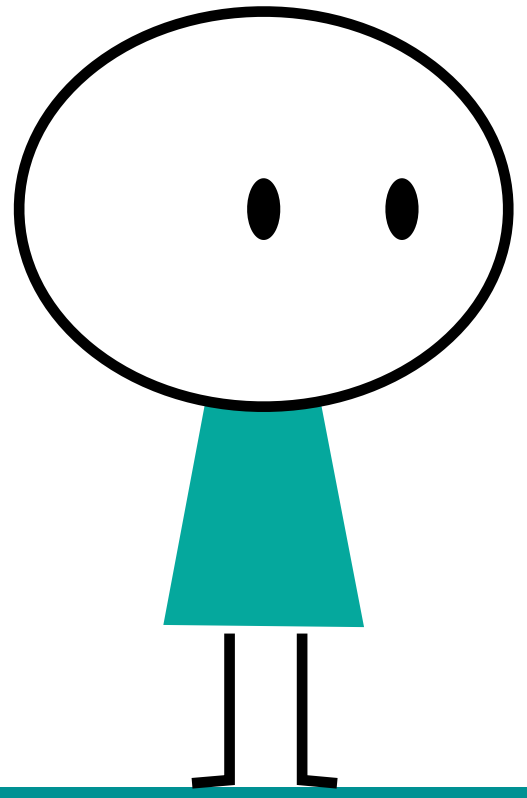
$$\mathbf{b}' = \mathbf{A}^T\mathbf{z}' + \mathbf{e}' \qquad \longleftarrow \qquad \left(\mathbf{A}, \mathbf{b} = \mathbf{A}\mathbf{z} + \mathbf{e}\right)$$

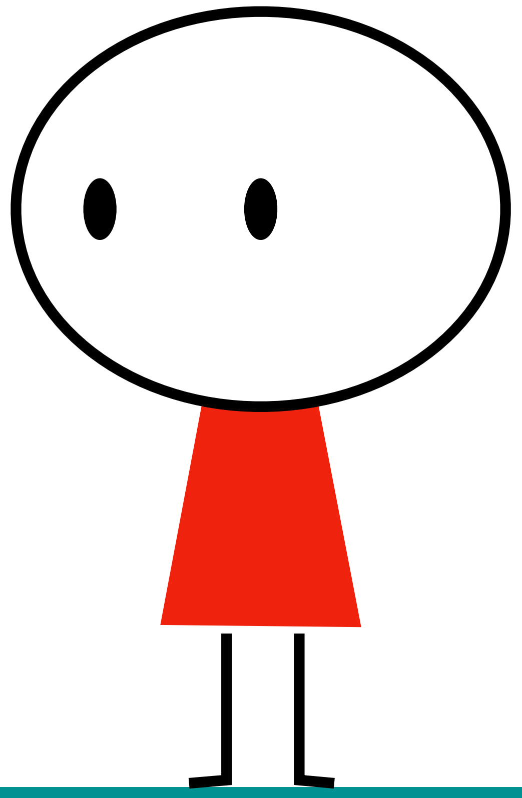
$$v' = \mathbf{b}^T\mathbf{z}' + \mathbf{e}'' + \frac{q}{2}m$$





1-bit encryption





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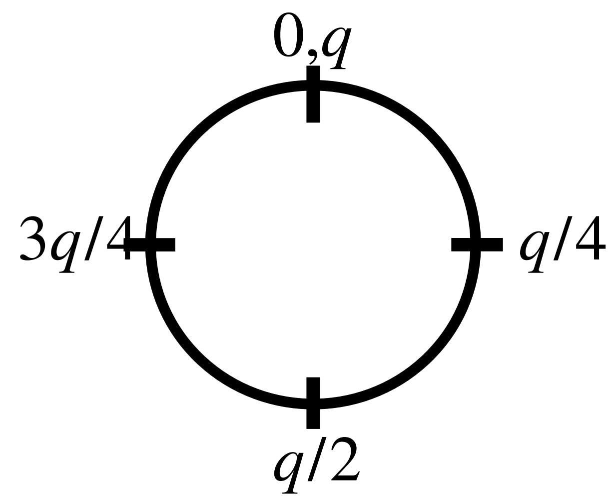

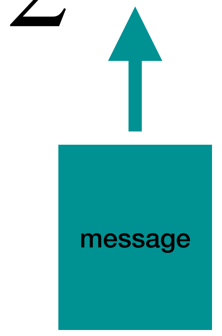

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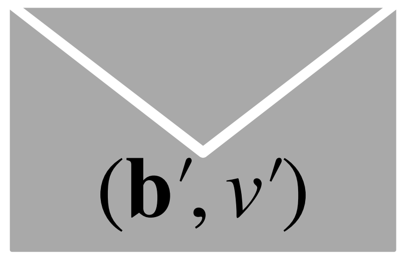

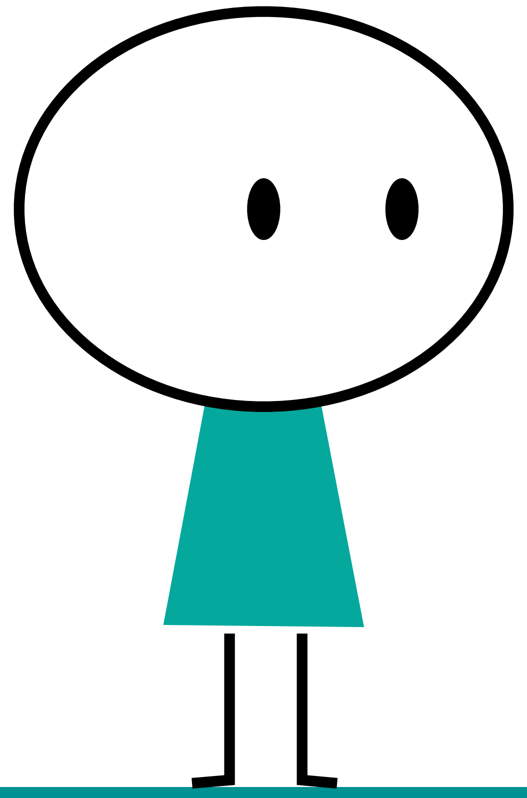

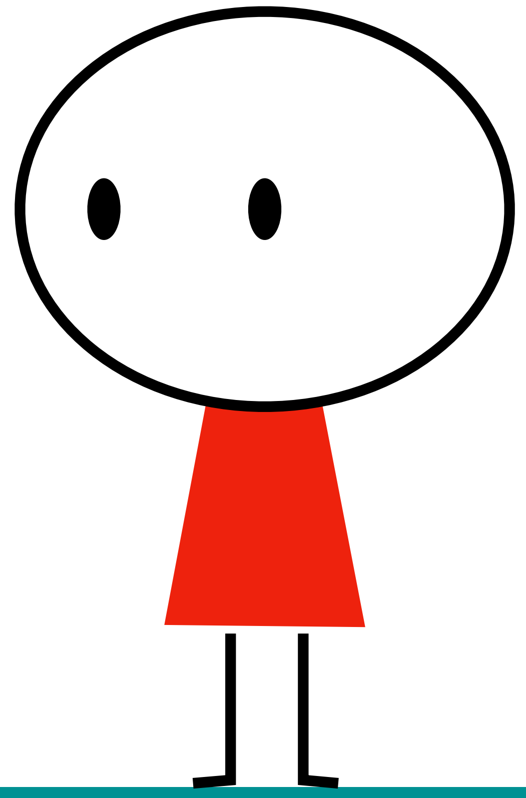

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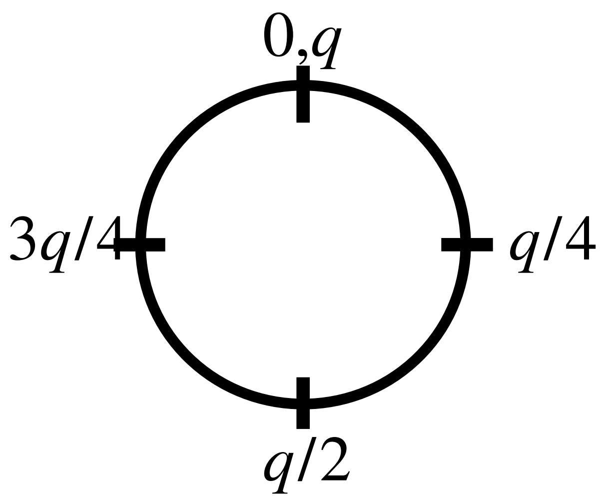
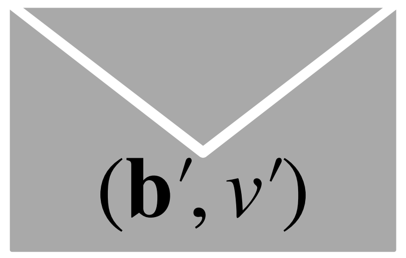


message

1-bit encryption



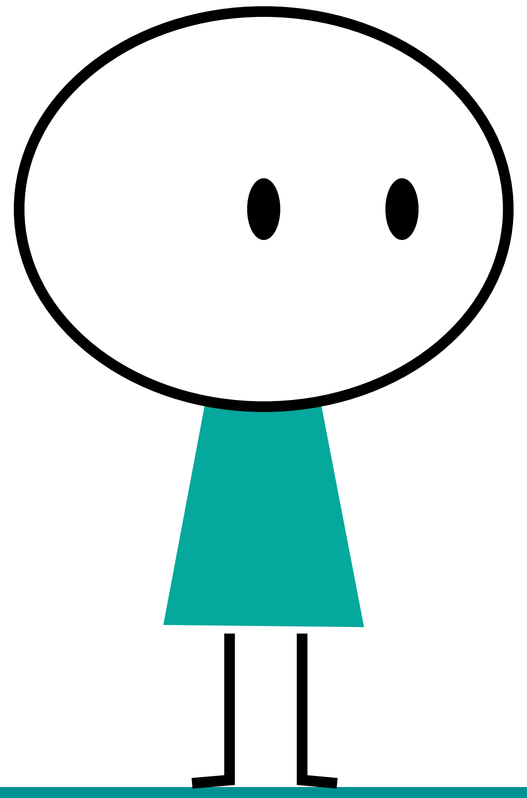
$$m' = \left\lfloor \frac{2}{q}\left(v'-\mathbf{z}^T\mathbf{b}'\right) \right\rceil$$

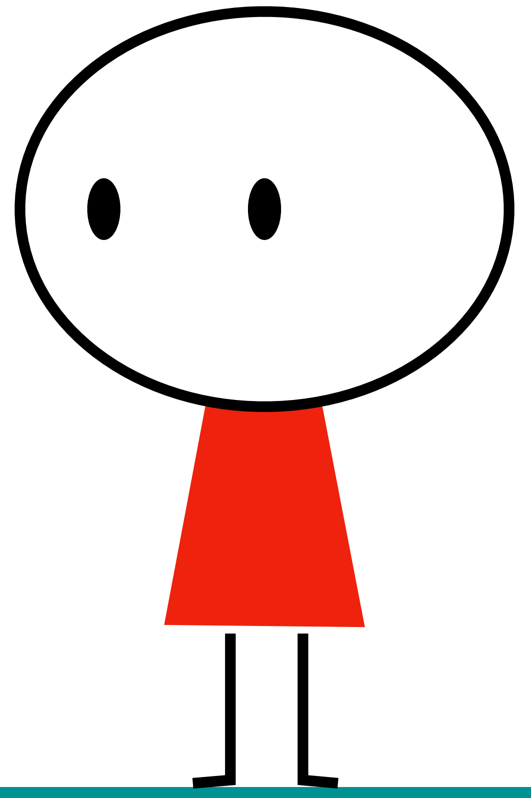
$$m' \approx m + \underbrace{\left\lfloor \frac{2}{q}\left(\mathbf{e}^T\mathbf{z}'+\mathbf{e}''-\mathbf{z}^T\mathbf{e}'\right) \right\rceil}$$

message

1-bit decryption

Noise smaller than $1/2$





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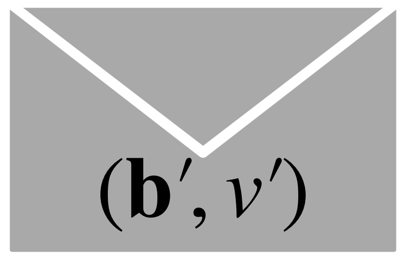

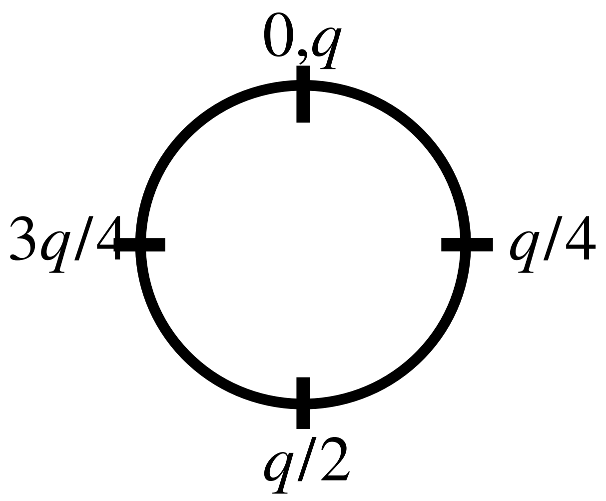

message

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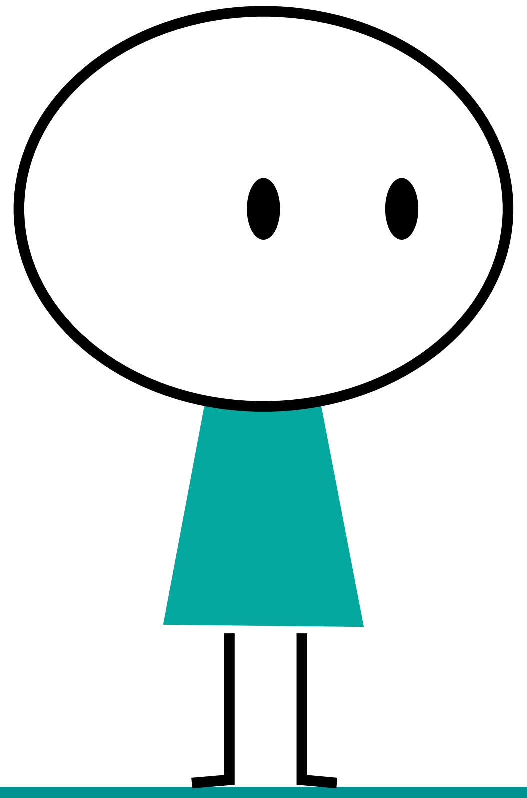
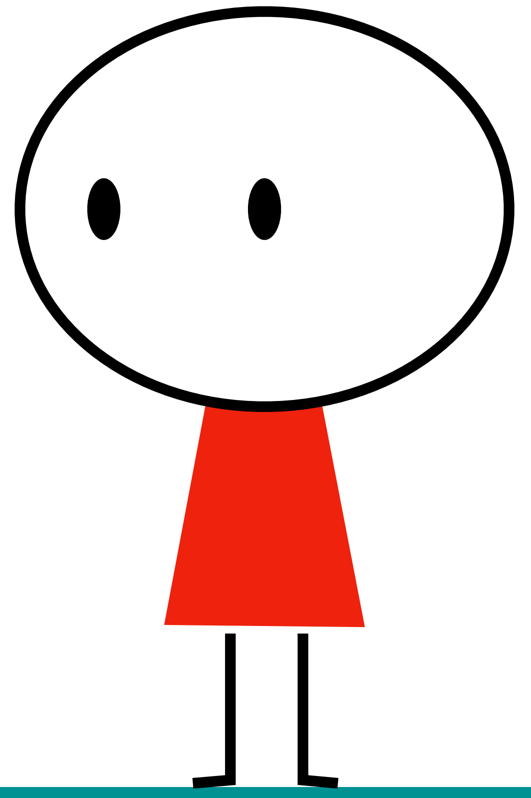


High level idea behind

Crystals-Kyber (NIST standard)
Frodo, Saber and NewHope



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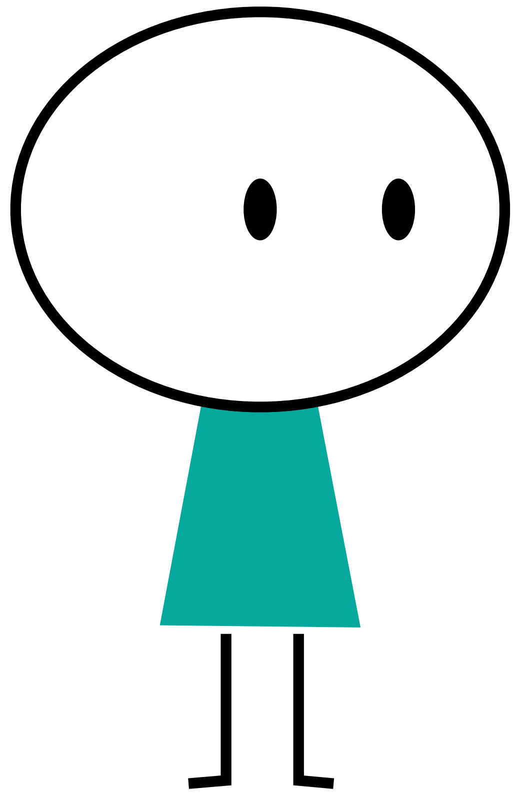
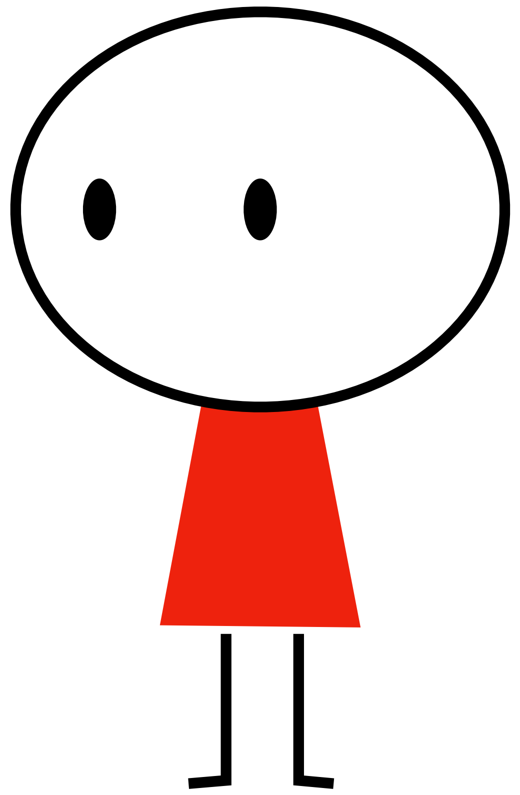
Short Integer Solution (SIS)





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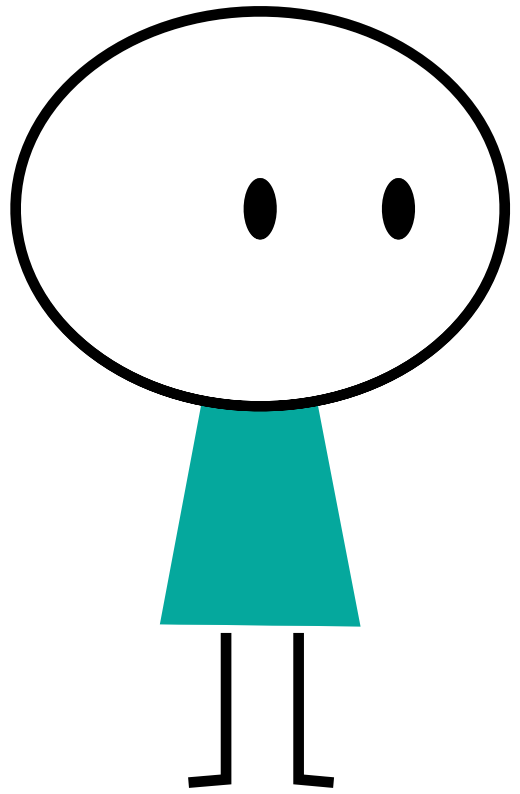

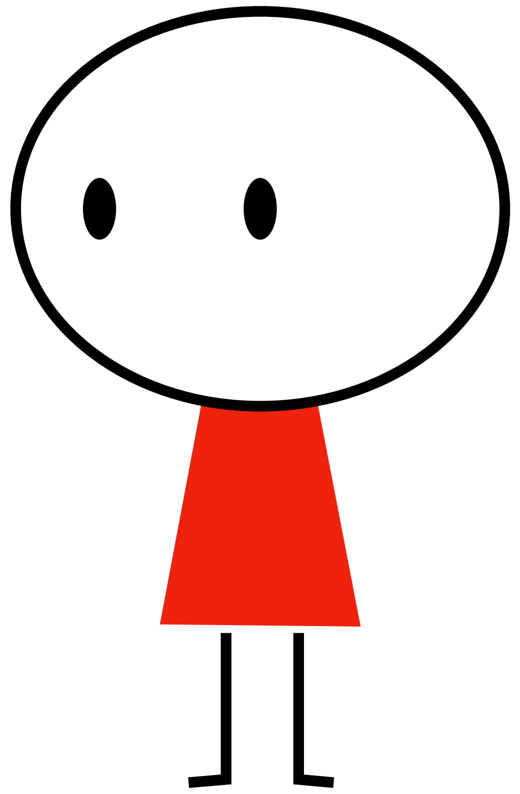

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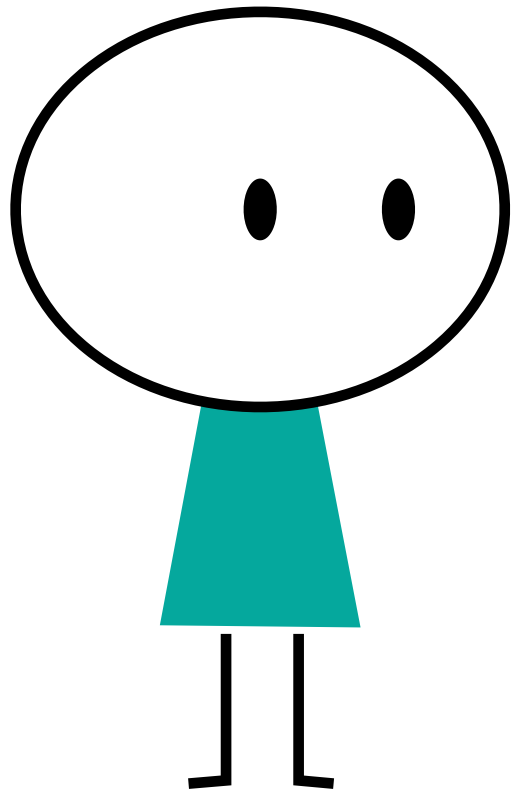

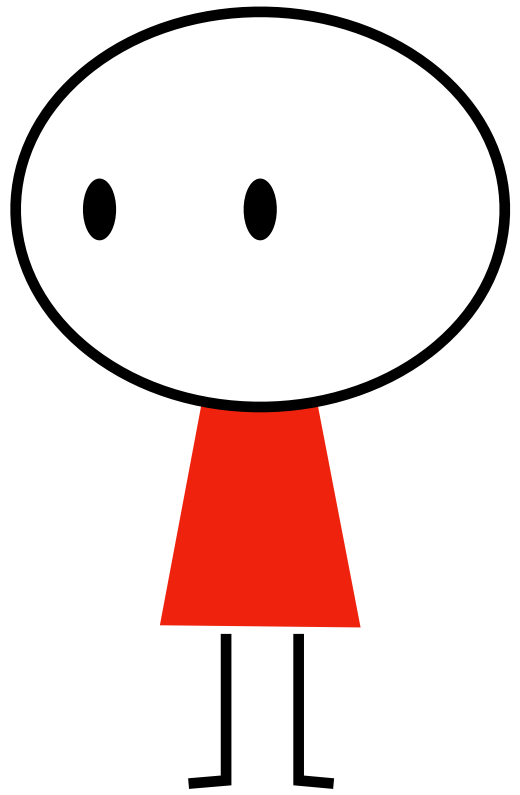

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Signature algorithm:

message

1: **do**

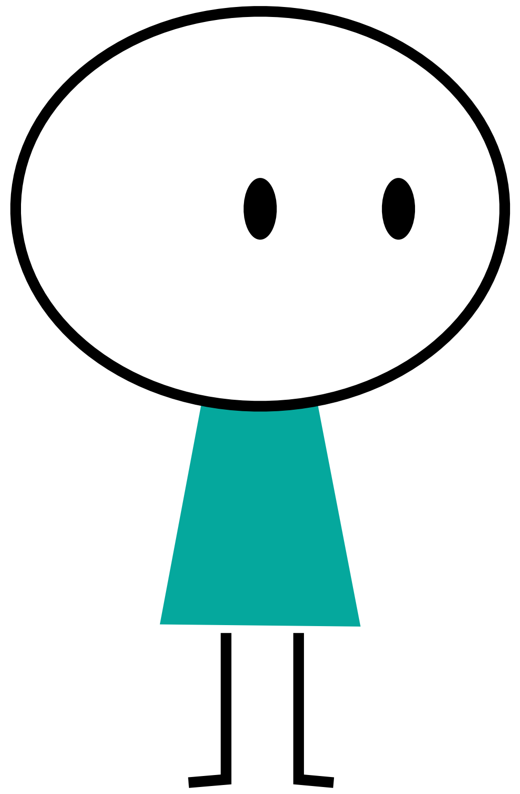
2: $\quad \mathbf{y} \overset{\$}{\leftarrow} Y$

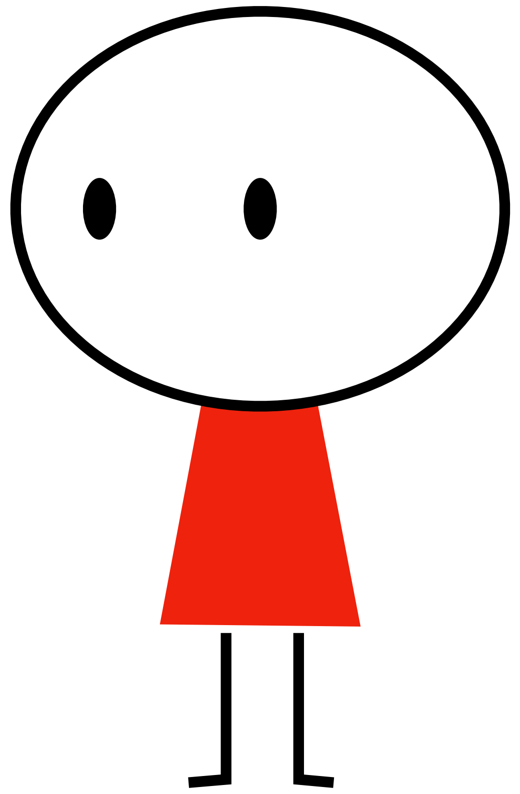
3: $\quad c \leftarrow H(\mathbf{A}\mathbf{y}, m)$

4: $\quad \mathbf{z} \leftarrow c \cdot \mathbf{S} + \mathbf{y}$

5: **while** Rejected($\mathbf{z}$, $\mathbf{c}$, $\mathbf{S}$)

6: **return** $(\mathbf{z}, c)$





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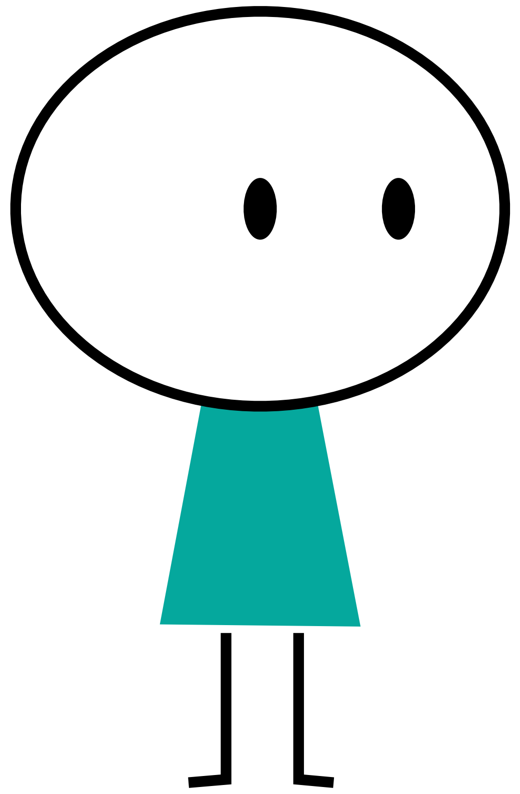

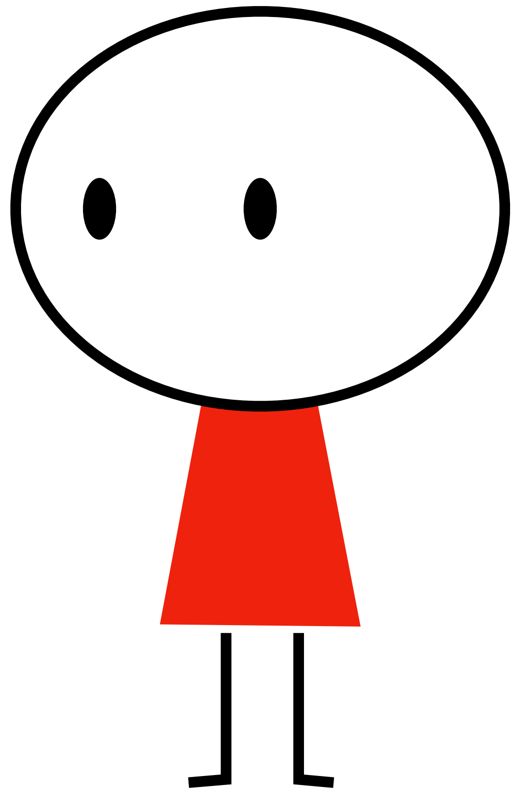

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message $(\mathbf{z}, c)$ $\longleftarrow$

Verification:

1: $\mathbf{r} \leftarrow \mathbf{A} \cdot \mathbf{z} - \mathbf{t} \cdot c$
2: $c' \leftarrow H(\mathbf{r}, m)$
3: if $c' = c$ and $\mathbf{z}$ is small enough:
4: return Valid
5: else:
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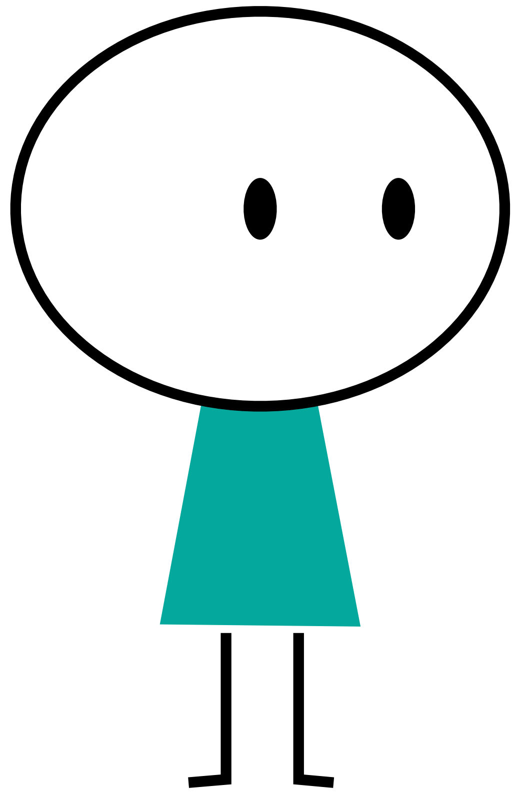

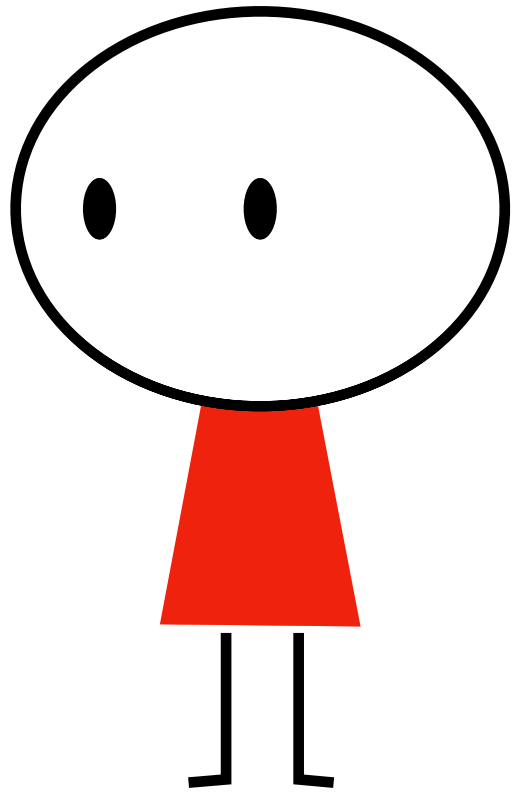

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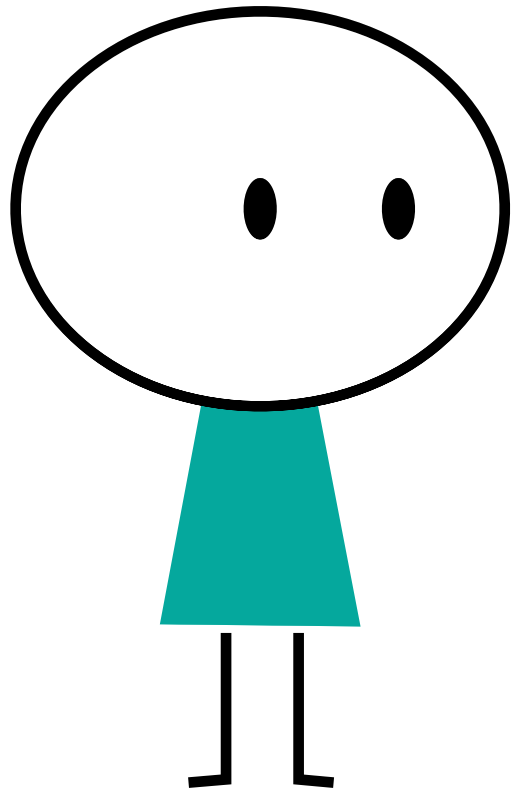
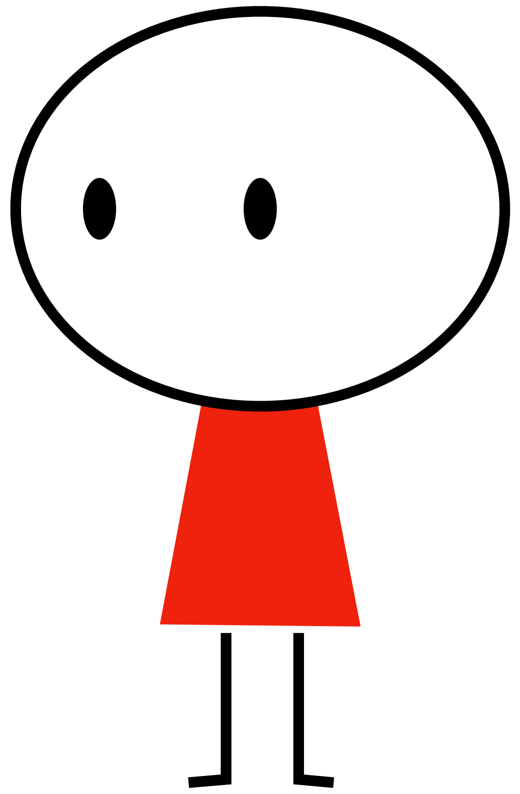


High level idea behind

Crystals-Dilithium (NIST standard)
BLISS, GLP, BG

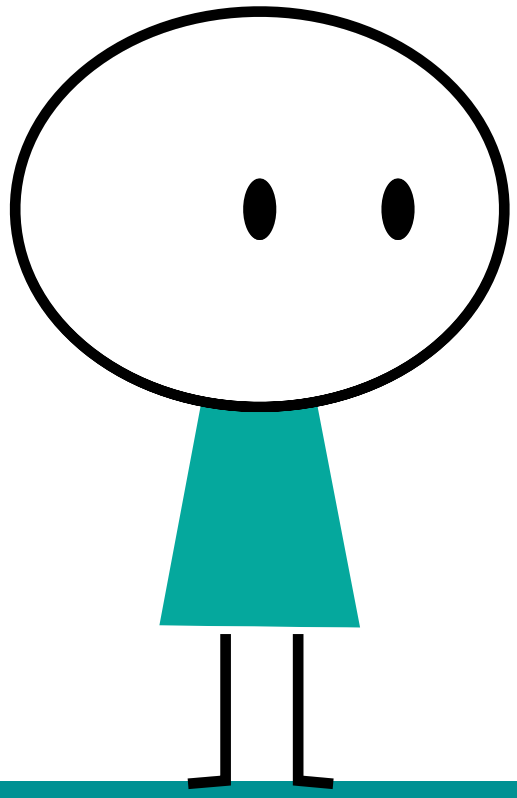


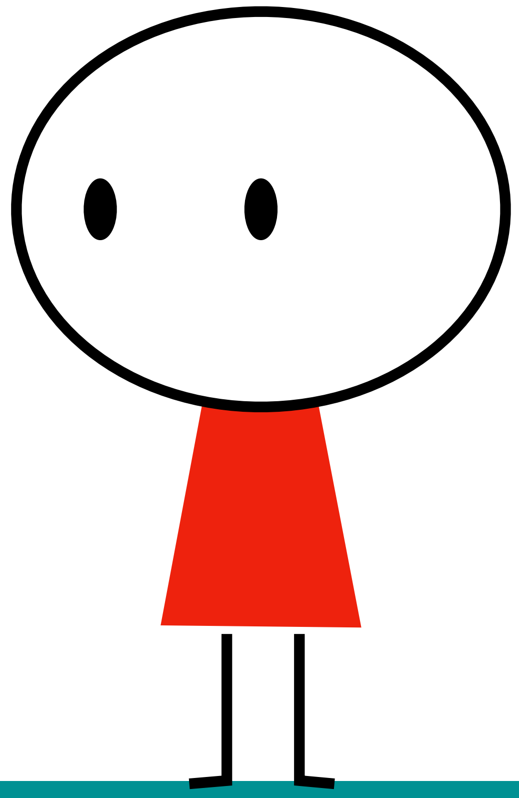
A Hash and sign in a nutshell

- C.Gentry, C. Peikert and V. Vaikuntanathan STOC'08

Generate matrices $\mathbf{A}, \mathbf{B}$ such that

$$\begin{cases} \mathbf{B}\mathbf{A} = \mathbf{0} \\ \mathbf{B} \text{ has small coefficients} \end{cases}$$





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▸ C.Gentry, C. Peikert and V. Vaikuntanathan STOC'08

$\mathbf{A}$

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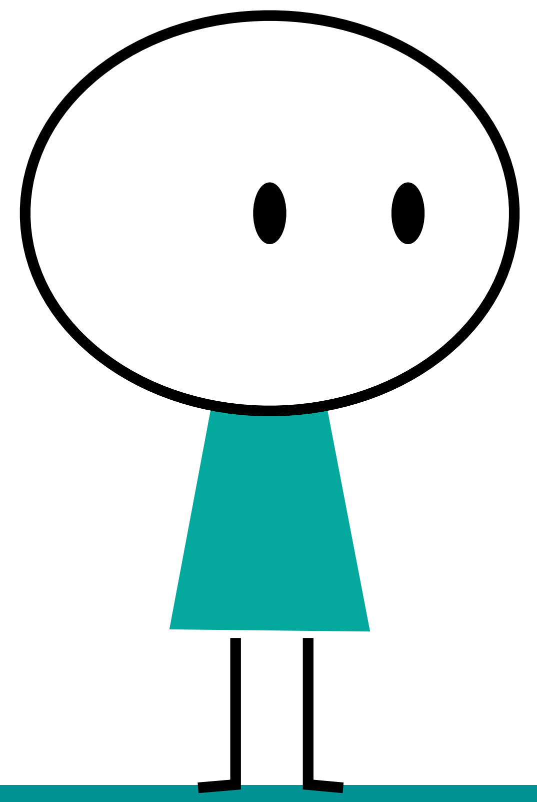

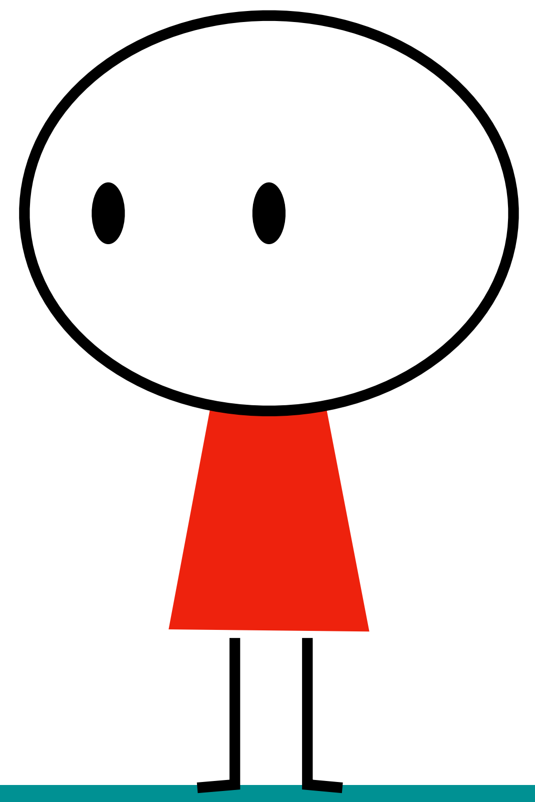

A Hash and sign in a nutshell

- C.Gentry, C. Peikert and V. Vaikuntanathan STOC'08

$\mathbf{A}$

Generate matrices $\mathbf{A}, \mathbf{B}$ such that

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message

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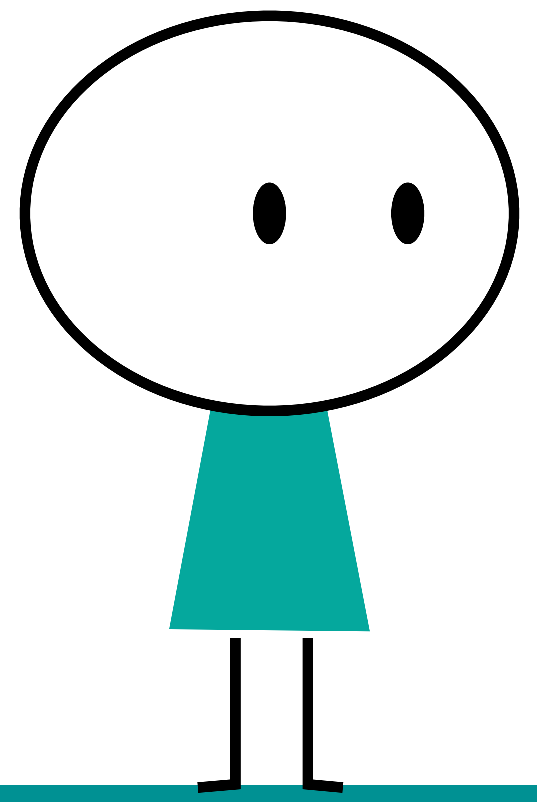

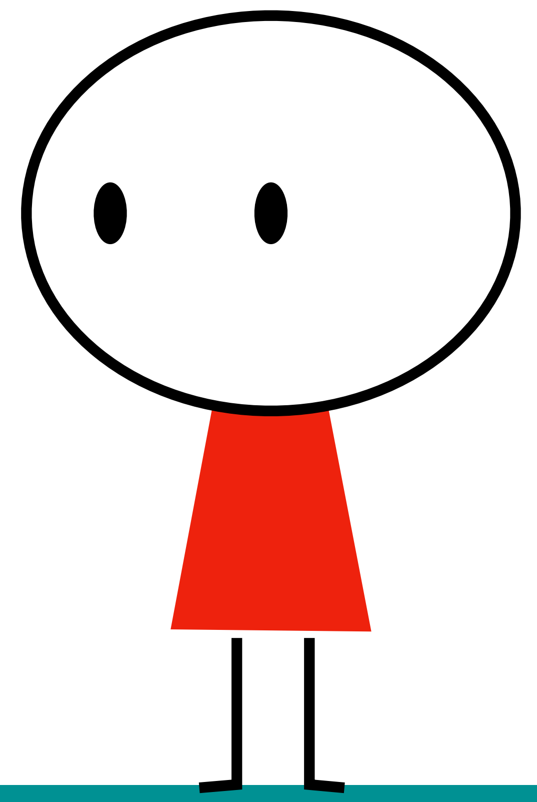

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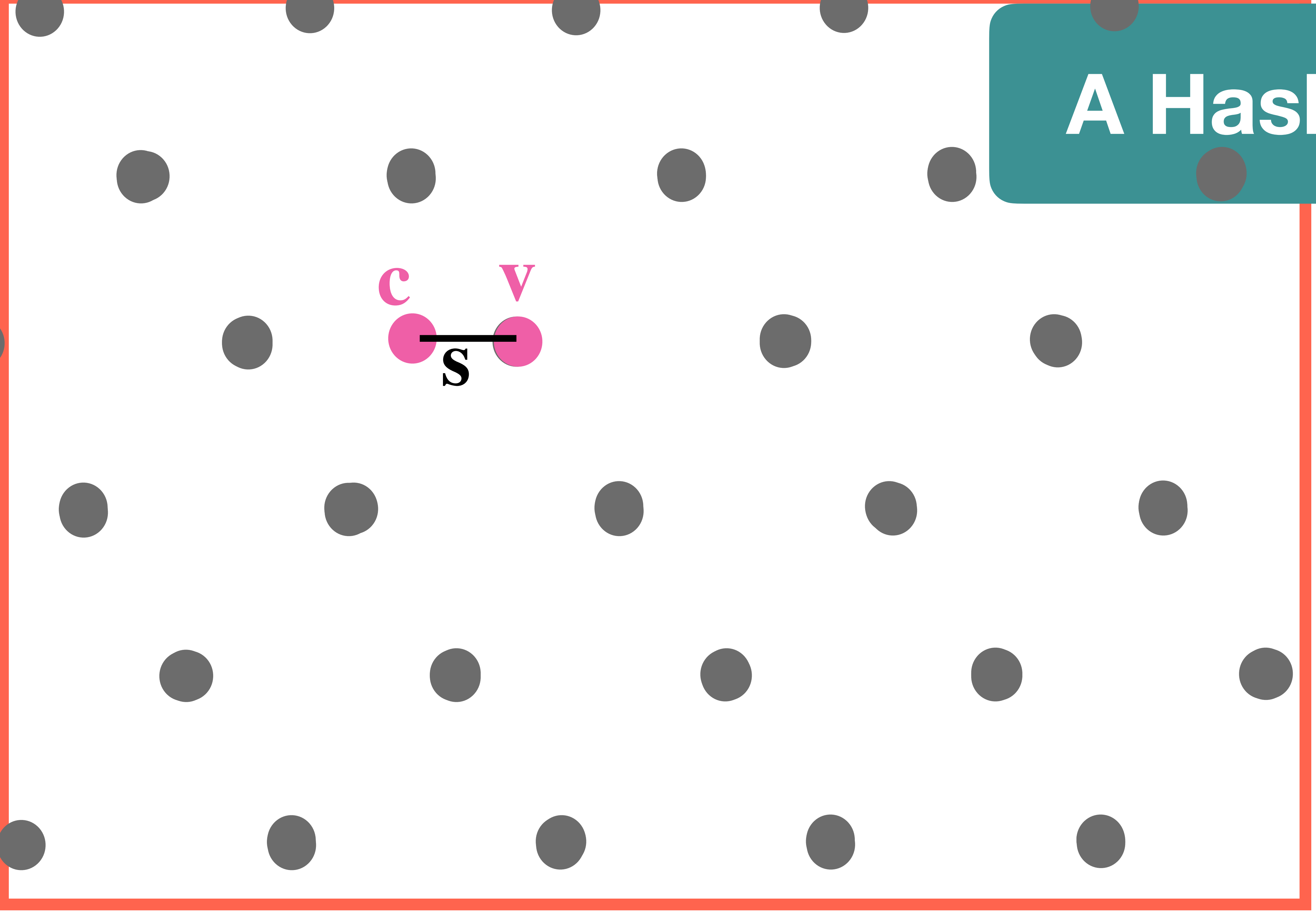

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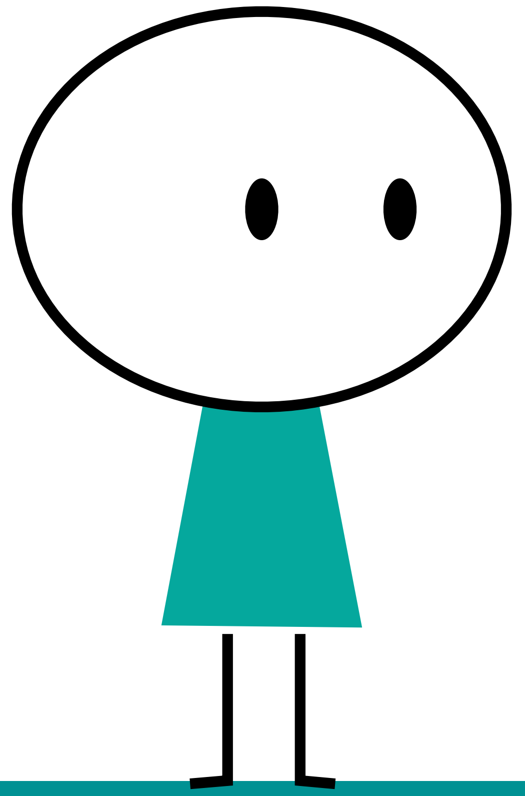

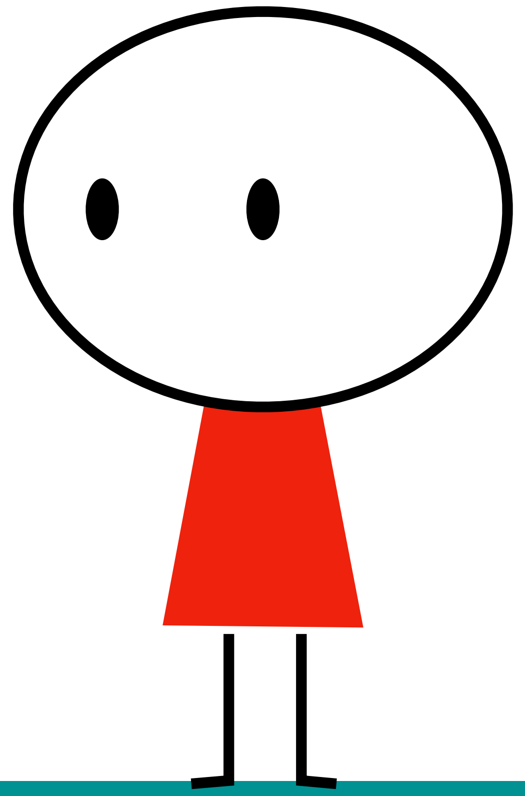

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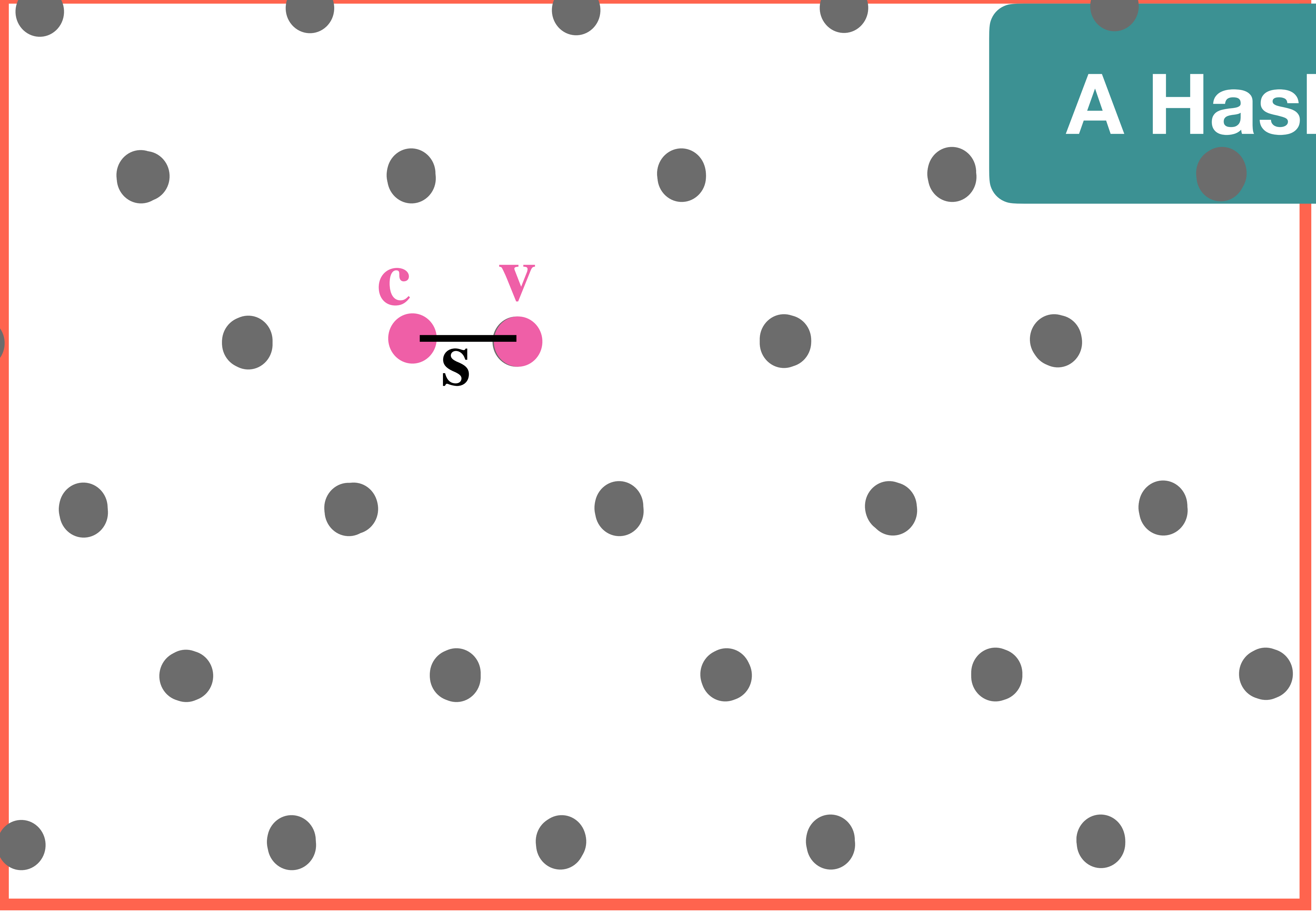

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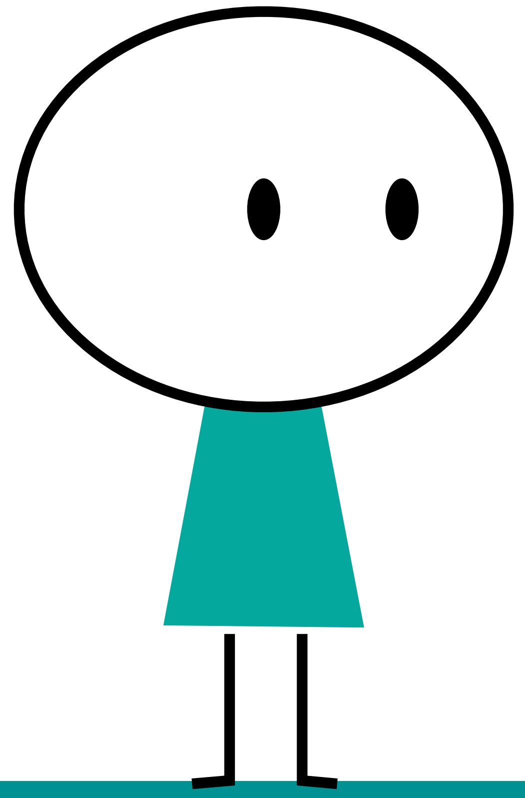

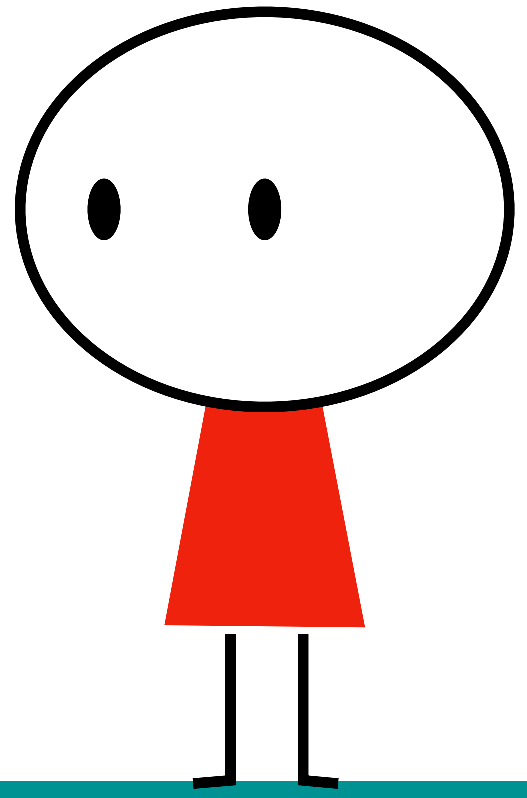

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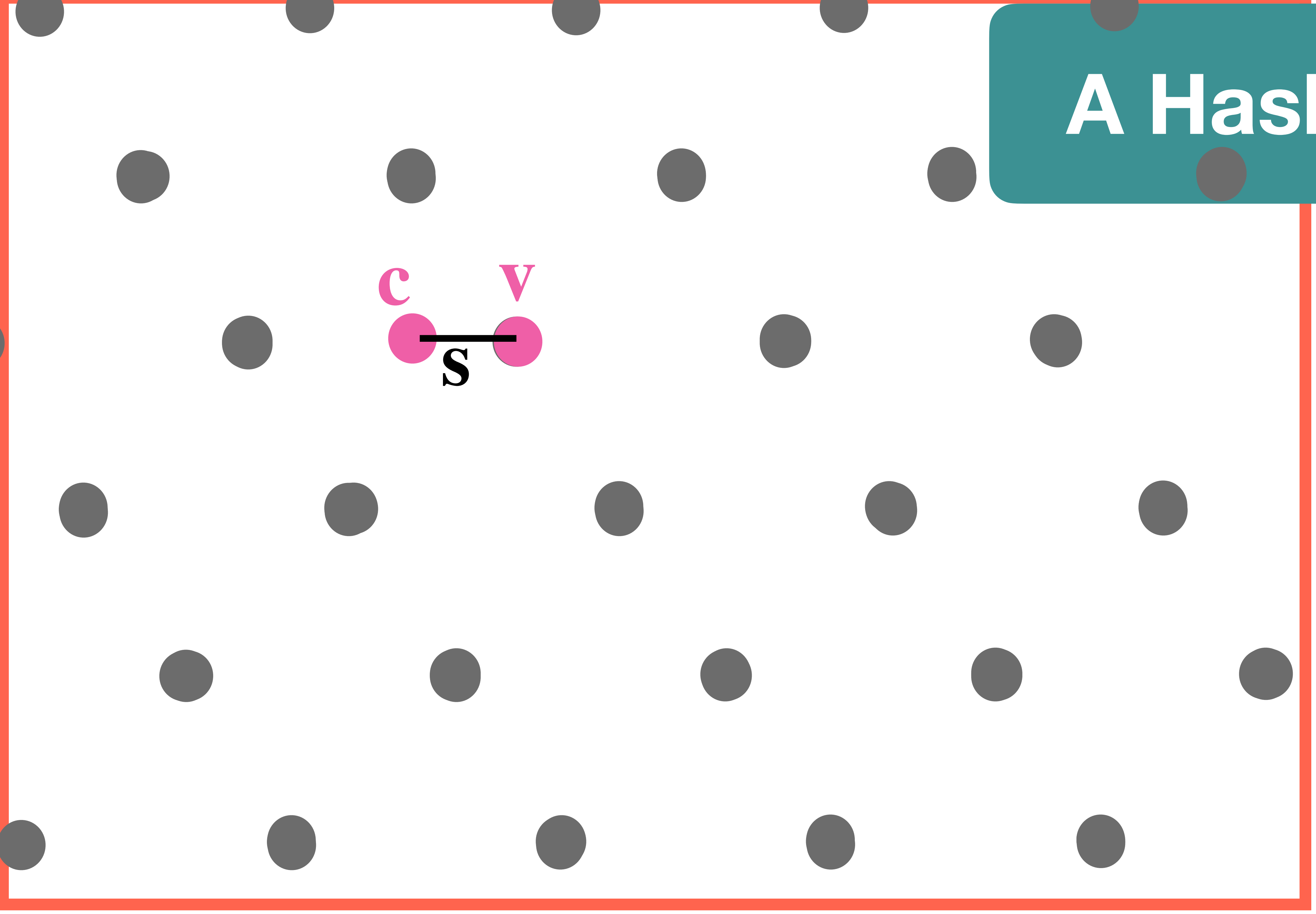

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message

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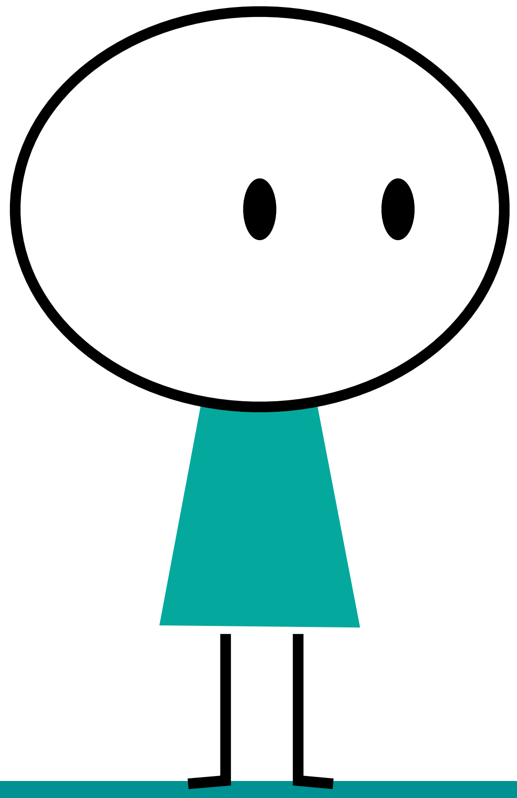
Verification:

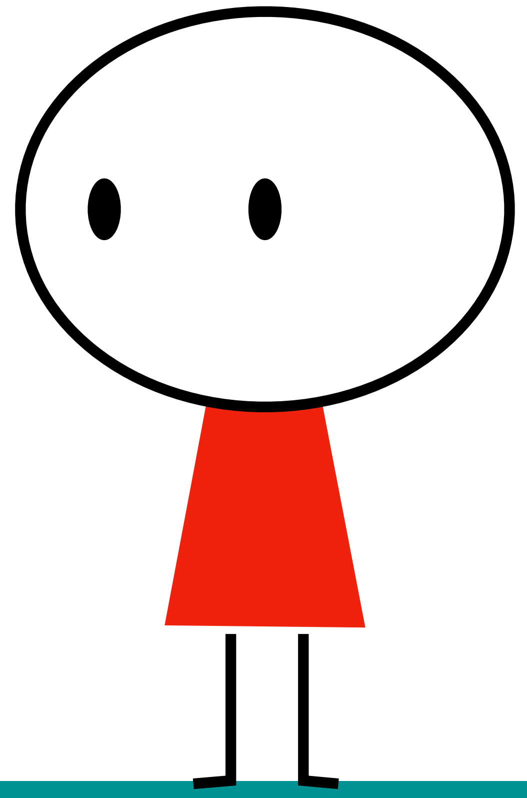
1: if $\mathbf{s}$ is short and $\mathbf{s}\mathbf{A} = H(m)$

2: return Valid

3: else:

4: return Invalid





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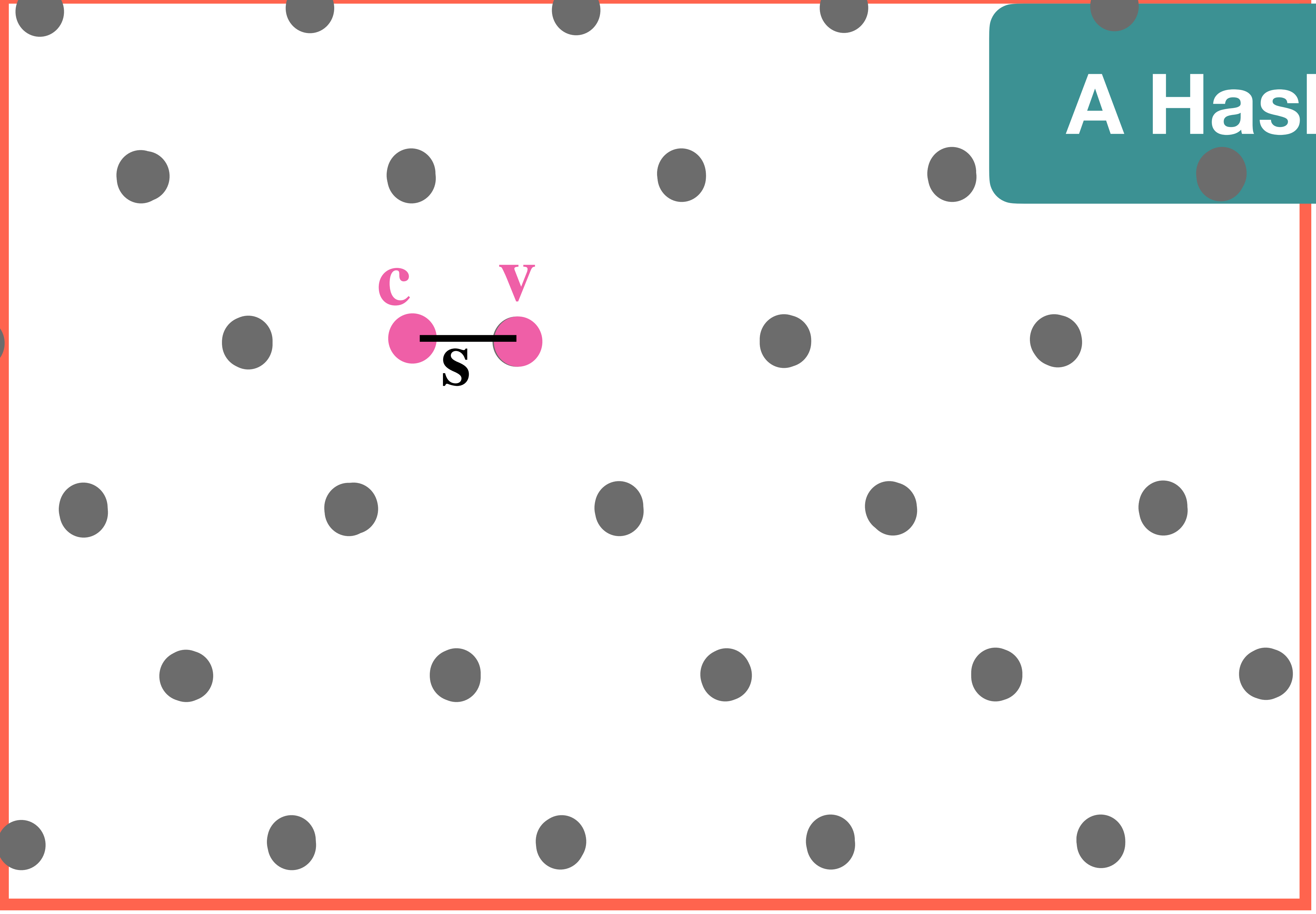

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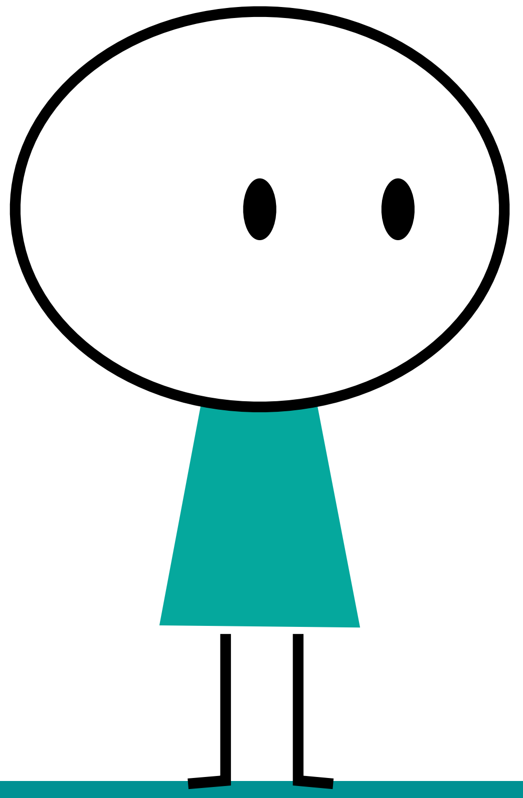
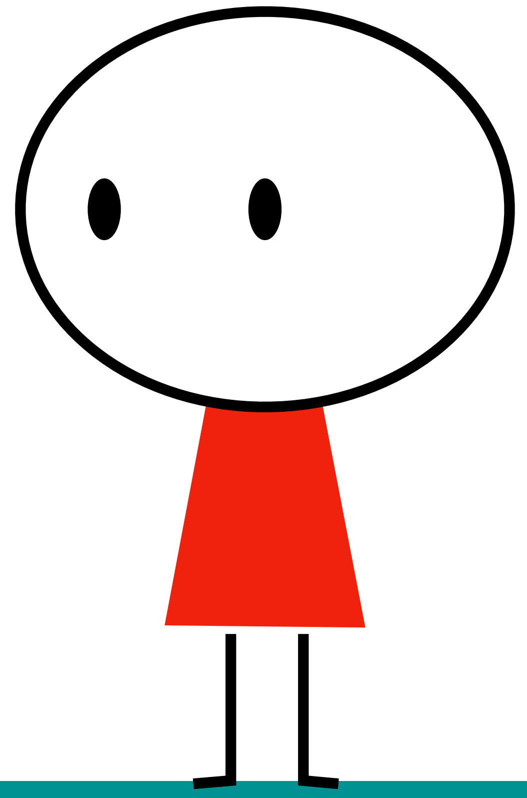


High level idea behind

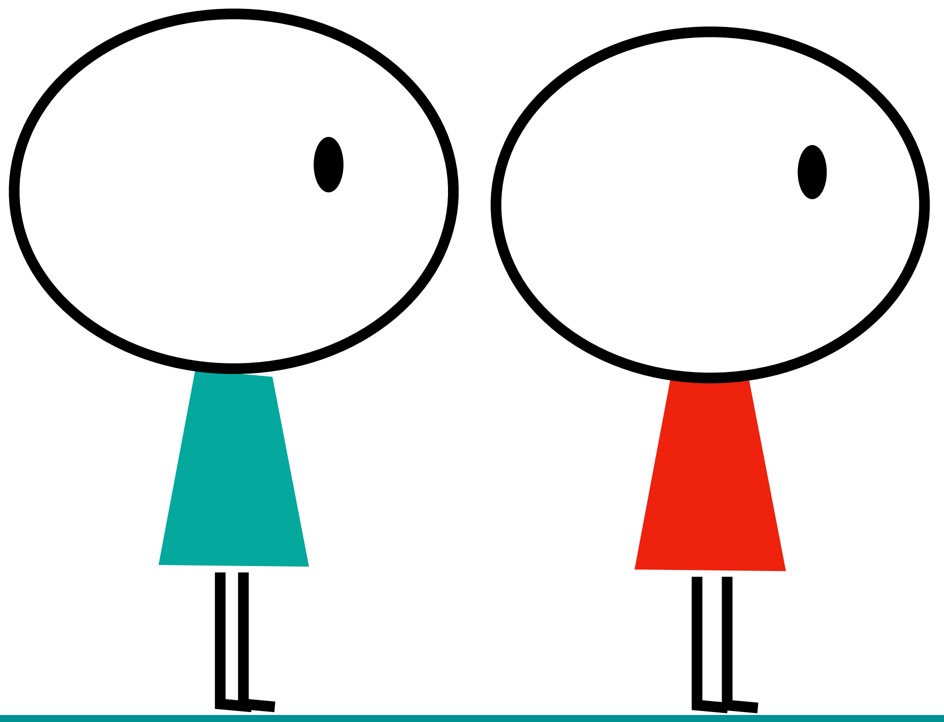
Falcon (NIST standard)
GPV, Mitaka



Lattice-based algorithms

Signature schemes

Public key encryption schemes



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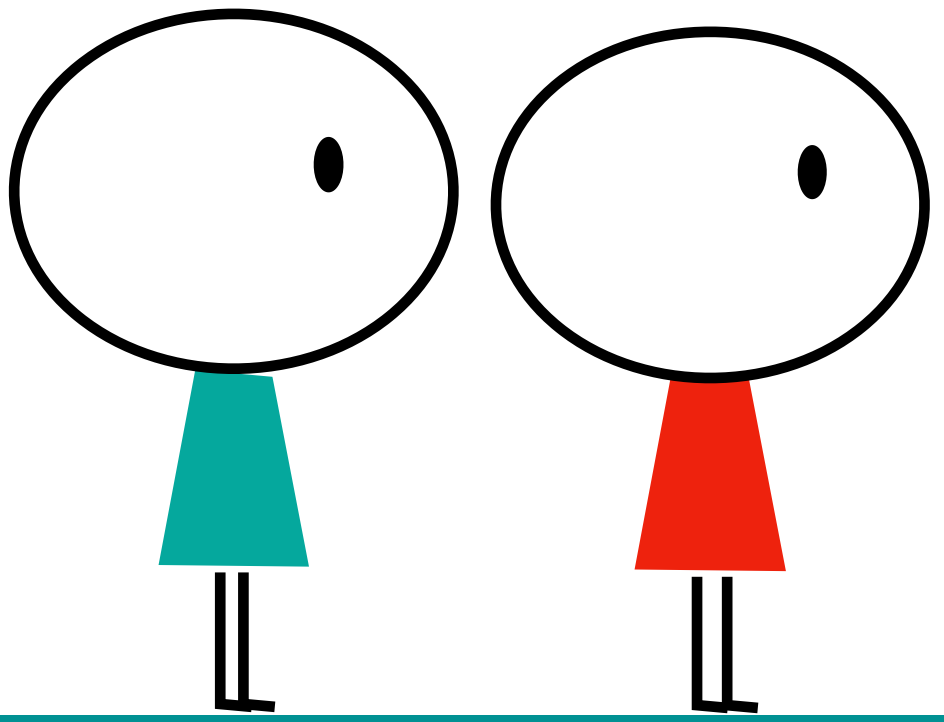

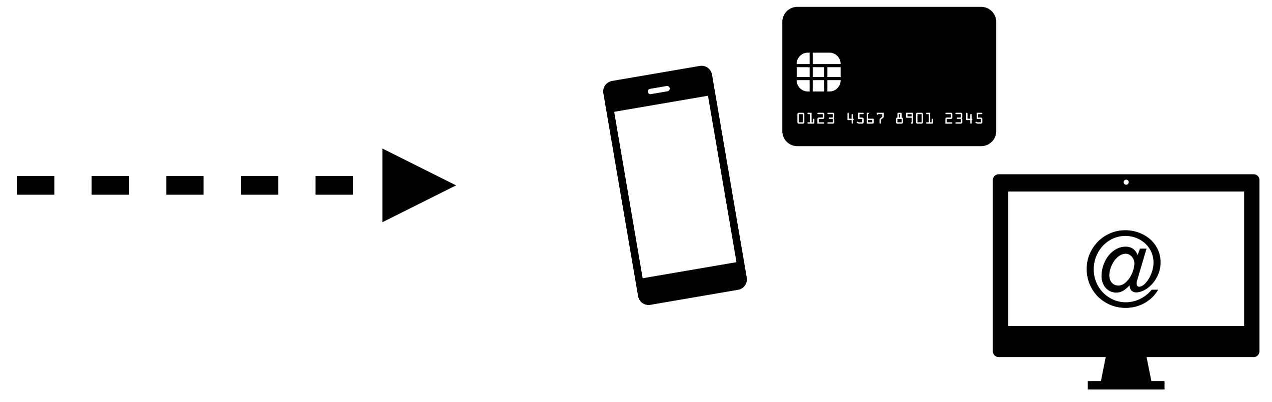

Lattice-based algorithms

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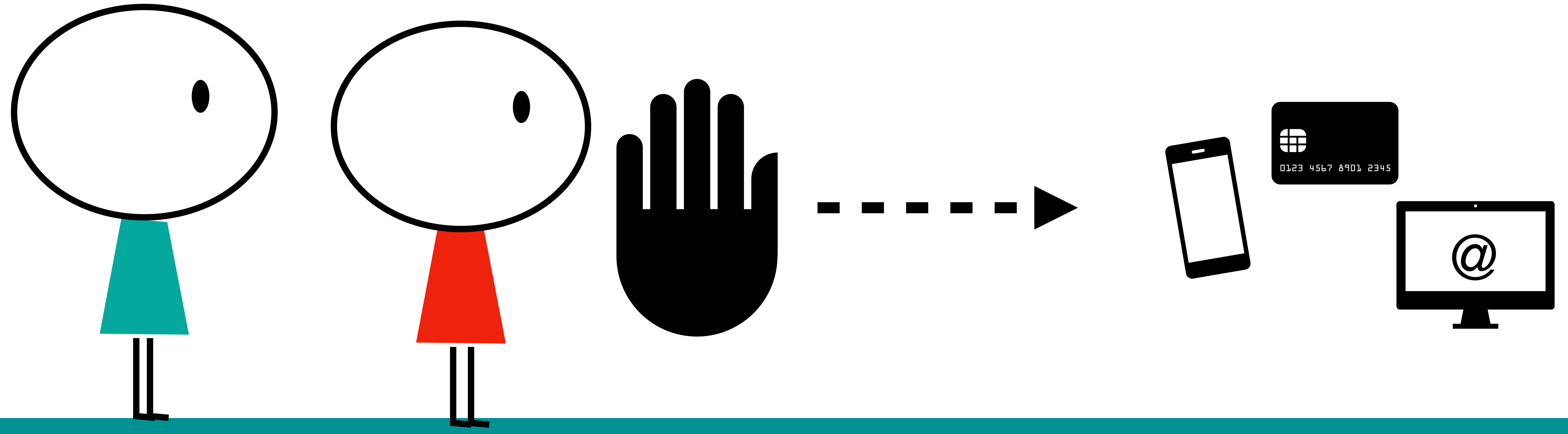
Are you secure for real-world development ?

Are you timing resistant ?
Are you secure against physical attacks?
Are you misuse resistant ?
Are you decryption-failure resistant?
… by how much ?



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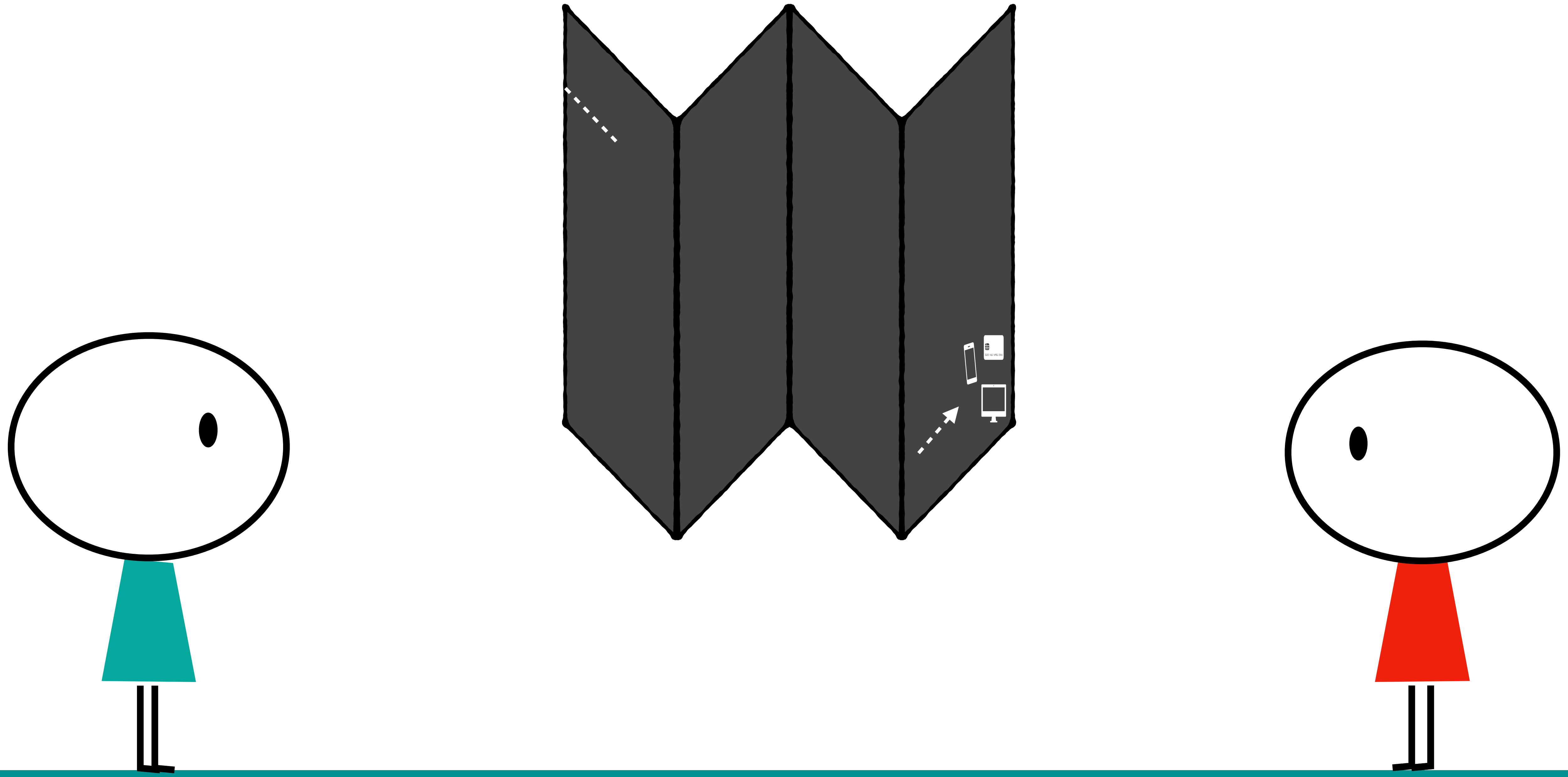
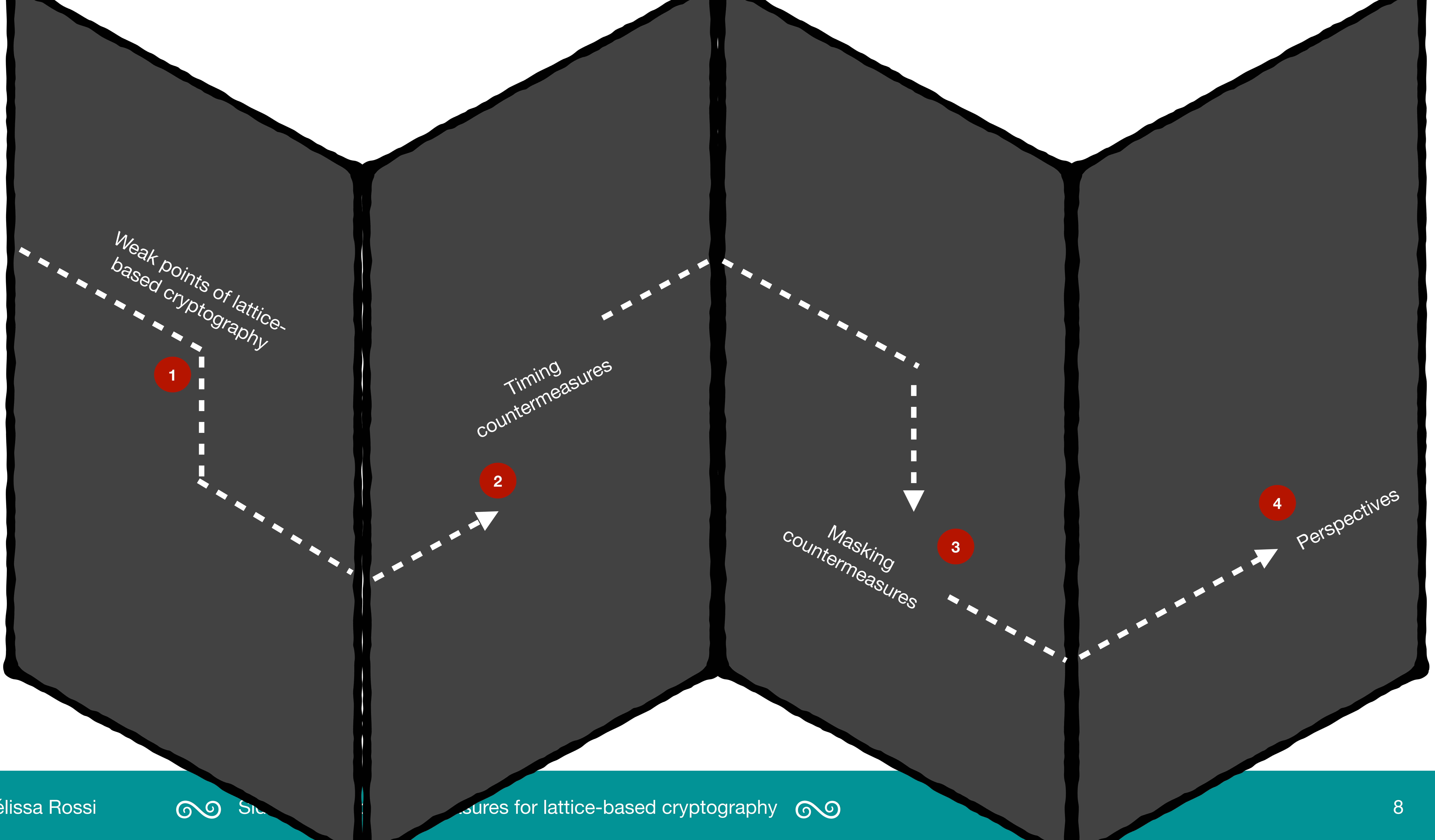
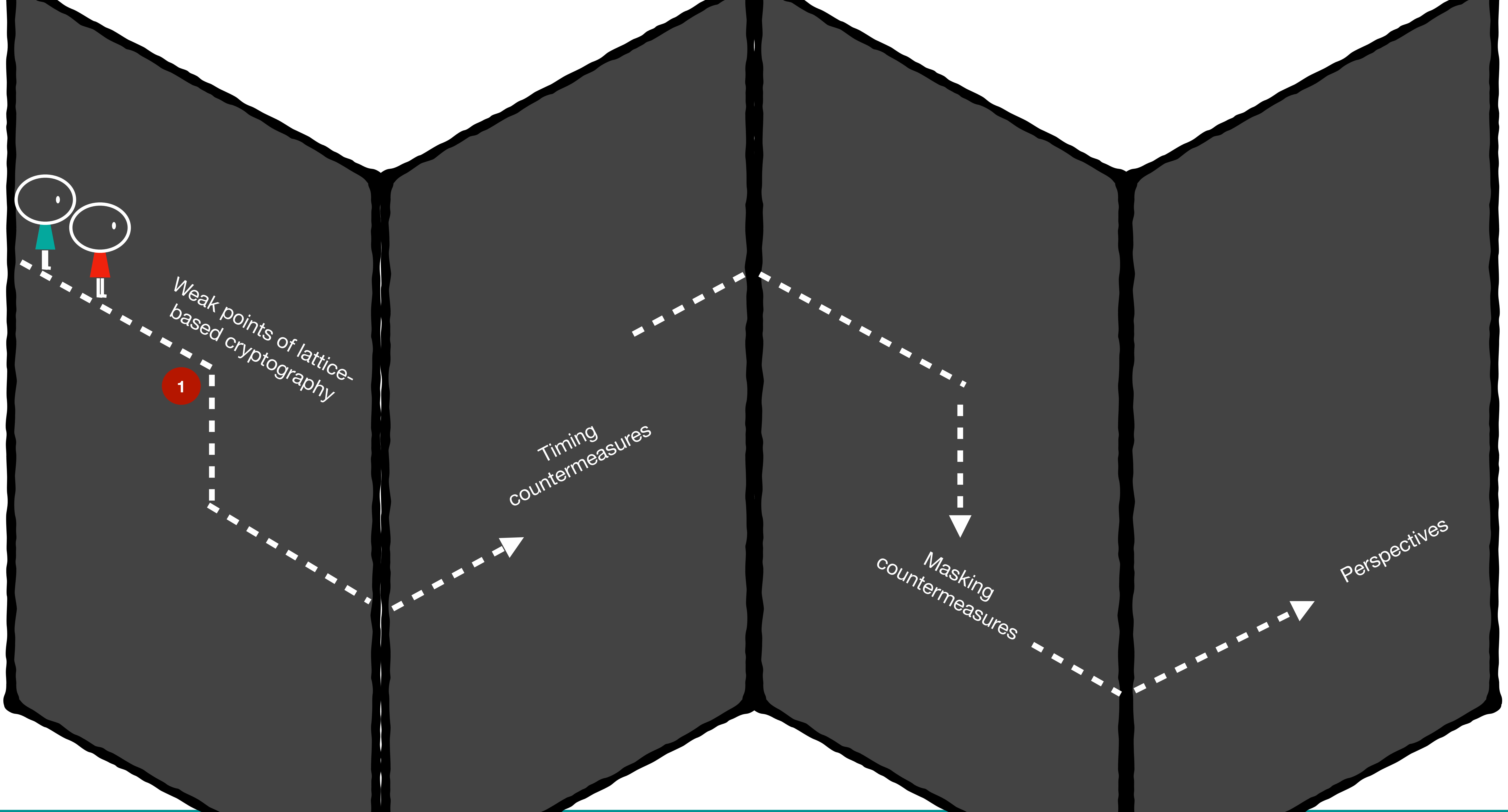



Weak points of lattice-based cryptography
1
Timing countermeasures
2
Masking countermeasures
3
4
Perspectives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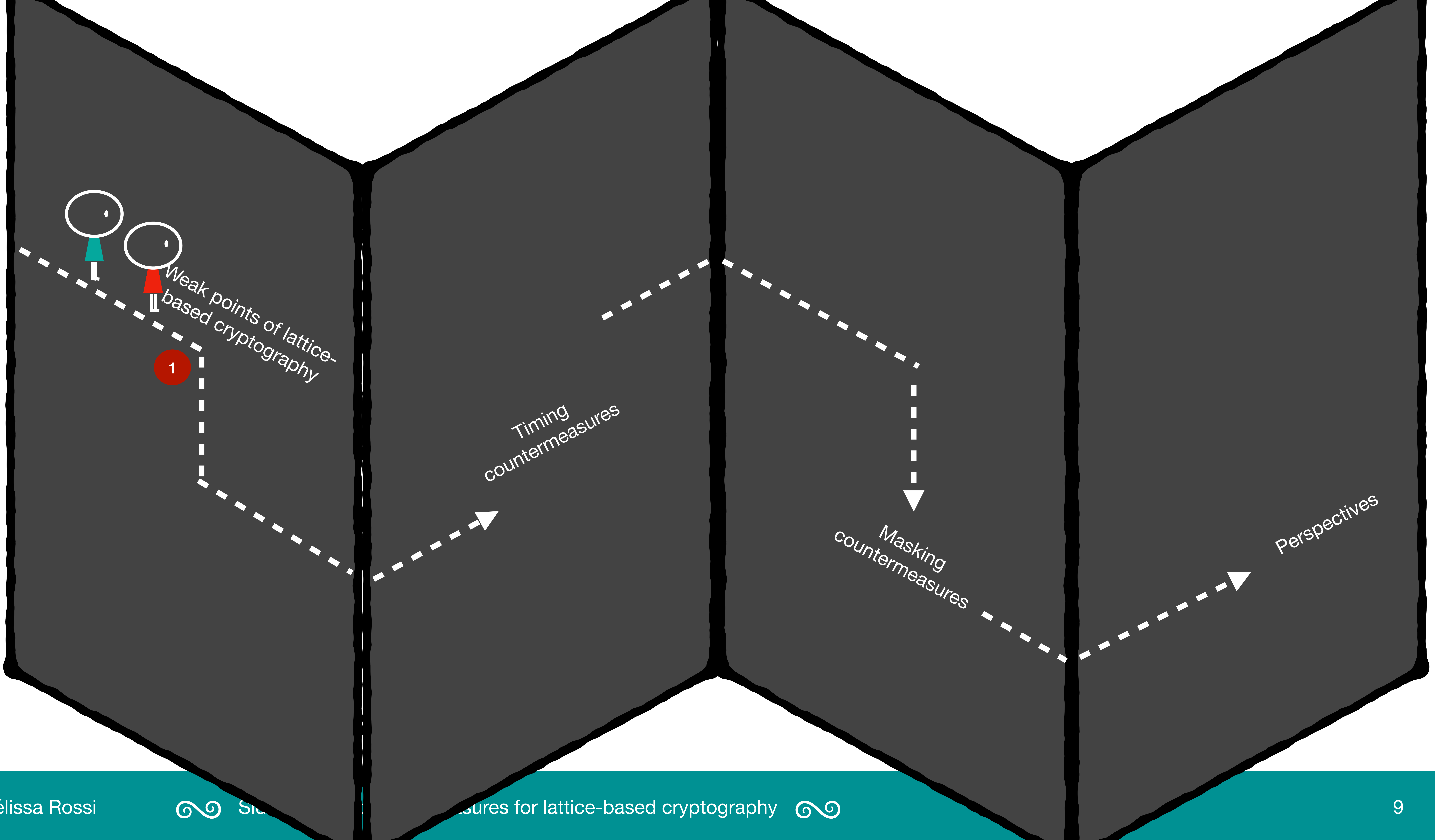
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Lattice-based crypto has many side-channel weak points

$\left(\mathbf{A}, \mathbf{t} = \mathbf{A}\mathbf{S} \bmod q\right)$

$\mathbf{y} \xleftarrow{\$} Y$

while Rejected($\mathbf{z}$, $\mathbf{c}$, $\mathbf{S}$)

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A. Multiplication with the secret: known $\times$ $\mathbf{s}$
B. Complex internal sampling distributions (Cumulative Distribution Tables)
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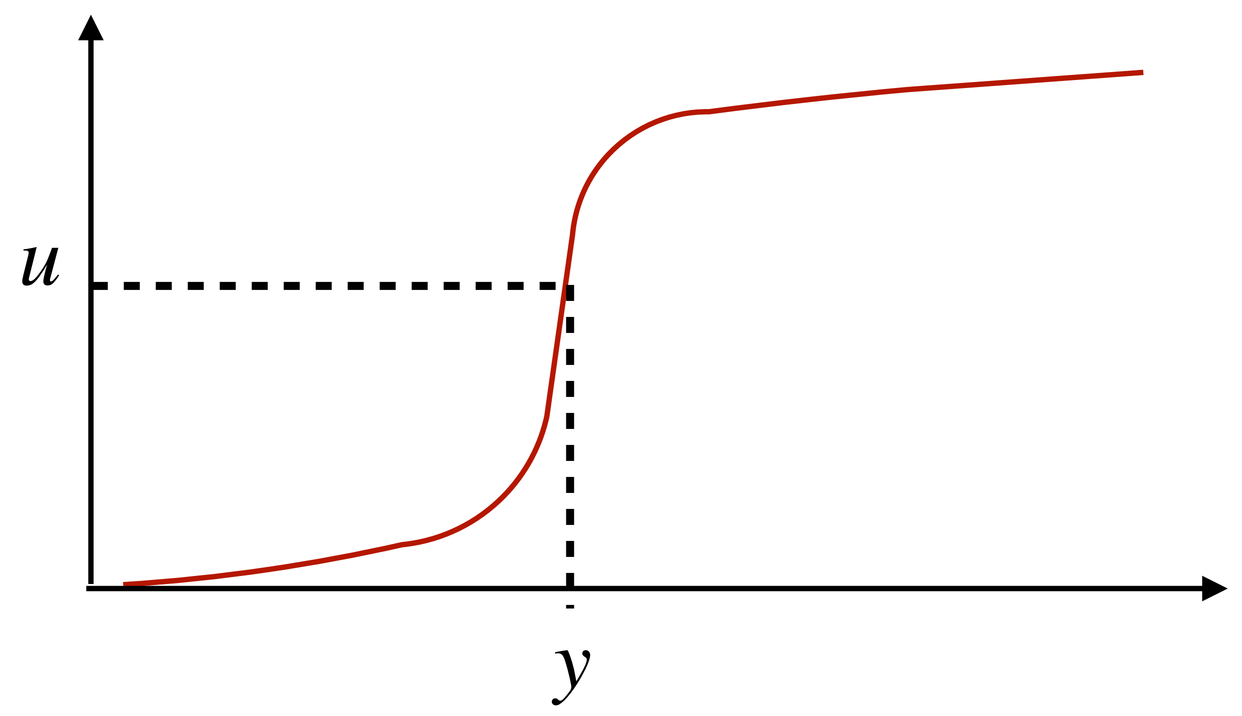

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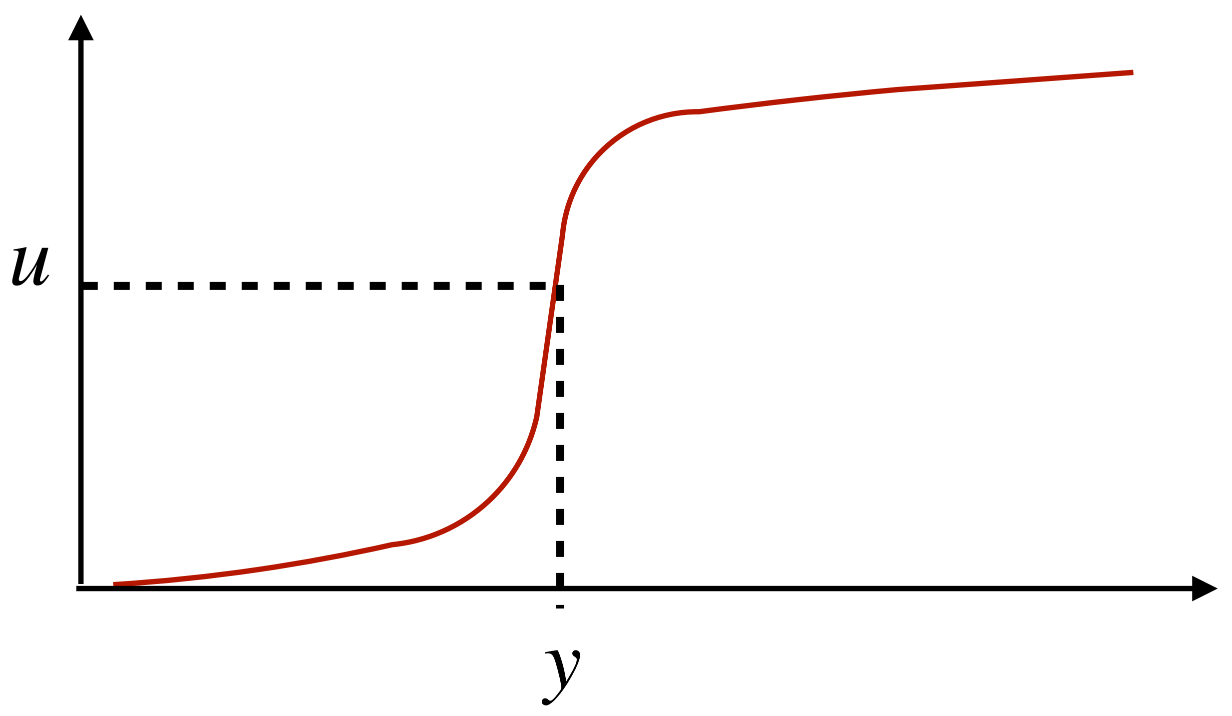

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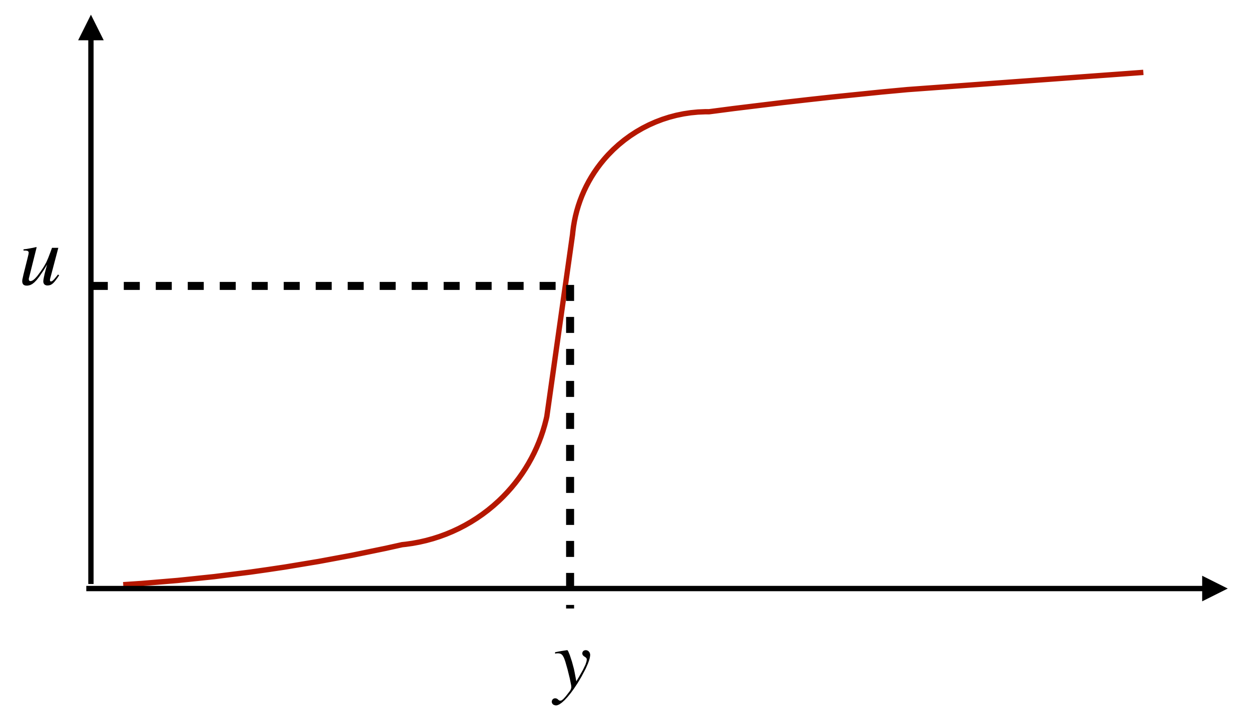

We will give three examples related to B and C

Timing attacks on internal distributions

<u>Timing attack:</u> the attacker knows the time that the algorithm takes e.g. the number of iterations.

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Many timing attacks
targeting Gaussian distributions in lattice-based signature schemes

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- T. Espitau, P.-A. Fouque, B. Gérard and M. Tibouchi. ACM-CCS'2017
- J. Bootle, C. Delaplace, T. Espitau, P.-A. Fouque and M. Tibouchi. ASIACRYPT'2018
- G. Barthe, S. Belaïd, T. Espitau, P.-A. Fouque, M. Rossi and M. Tibouchi. ACM-CCS'2019
- P.-A. Fouque, P. Kirchner,,M. Tibouchi, A. Wallet, and Y. Yu. EUROCRYPT'2020

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- J. Bootle, C. Delaplace, T. Espitau, P.-A. Fouque and M. Tibouchi. ASIACRYPT'2018

An example presented in the next slide →

- G. Barthe, S. Belaïd, T. Espitau, P.-A. Fouque, M. Rossi and M. Tibouchi. ACM-CCS'2019
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An example of timing attack on BLISS signature scheme

Signature algorithm:

1: **do**

2: $\quad \mathbf{y} \xleftarrow{\$} Y$

3: $\quad \mathbf{c} \leftarrow H(\mathbf{Ay}, m)$

4: $\quad \mathbf{z} \leftarrow \mathbf{c} \cdot \mathbf{S} + \mathbf{y}$

5: **while** Rejected($\mathbf{z}$, $\mathbf{c}$, $\mathbf{S}$)

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Correctness

The distribution of a is indeed $\mathscr{B}_{1/\cosh(x)}$.

‣ L. Ducas, A. Durmus, T. Lepoint and V. Lyubashevsky CRYPTO'13

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An example of timing attack on BLISS signature scheme

Sampling a Bernoulli with parameter cosh(x) : $\mathcal{B}_{1/\text{cosh(x)}}$

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Sampling a Bernoulli with parameter cosh(x) : $\mathcal{B}_{1/\text{cosh(x)}}$

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Depends on the input!

Idea of the attack

Here $x = -|\langle z, \mathbf{S}c \rangle|$

We select the signatures (z, c) corresponding to **one iteration inside the Bernouilli sampling.**

It means that $\dfrac{1 + \exp(-2|\langle z, \mathbf{S}c \rangle|)}{2}$ is large.

Then, $|\langle z, \mathbf{S}c \rangle|$ is close to 0.

➡ Can be solved with a phase retrieval algorithm (machine learning).

Full key recovery in an average of 40h on a powerful personal computer

Power consumption attacks

<u>Power consumption attack:</u> the attacker knows the power consumption of the device executing the algorithm. He has access to « traces ».

Many attacks as well

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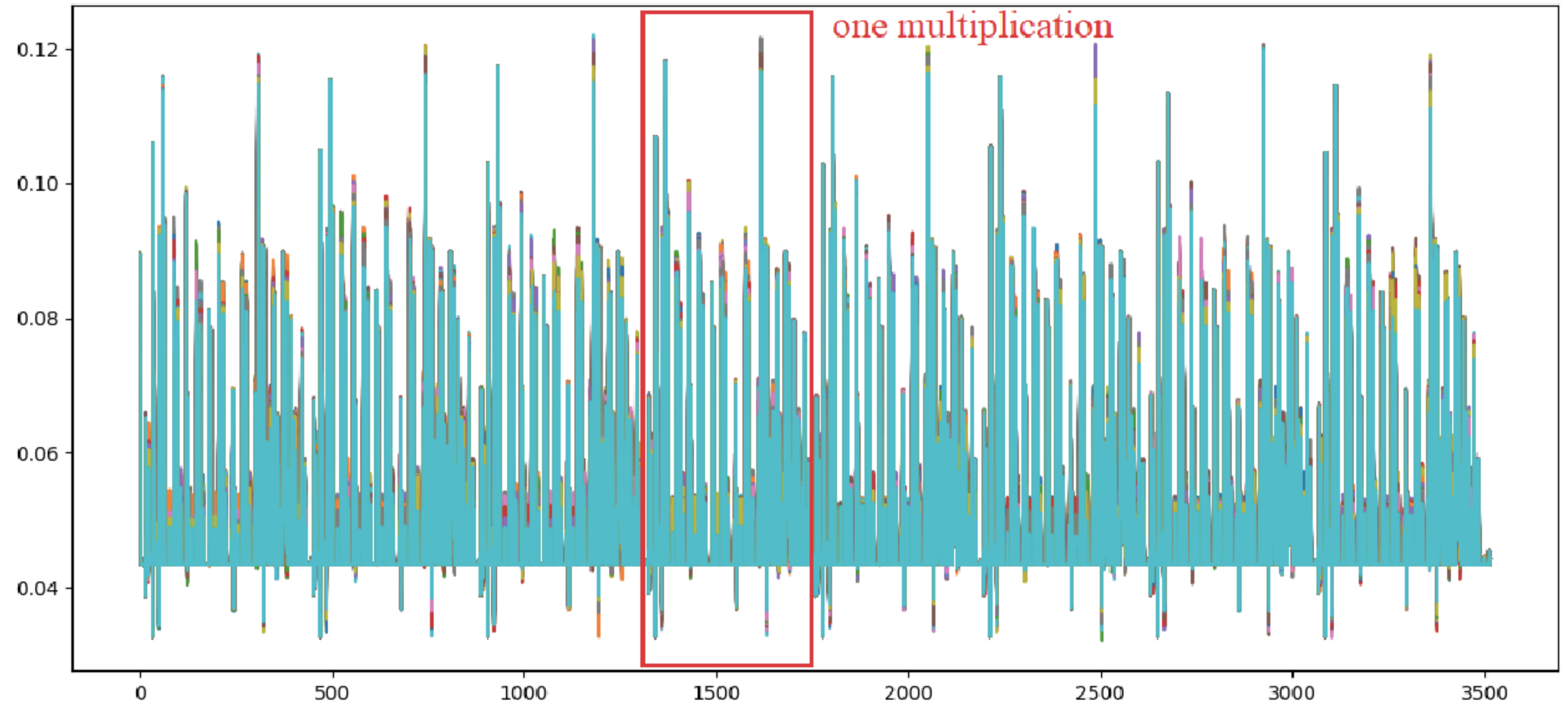

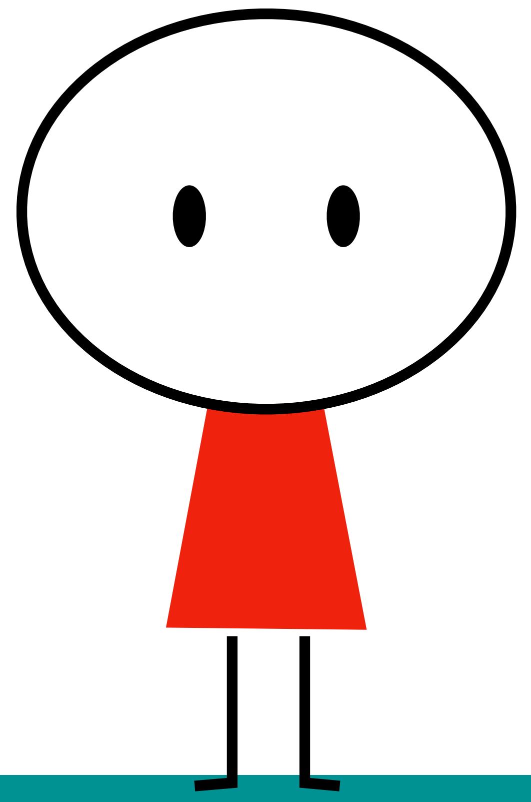

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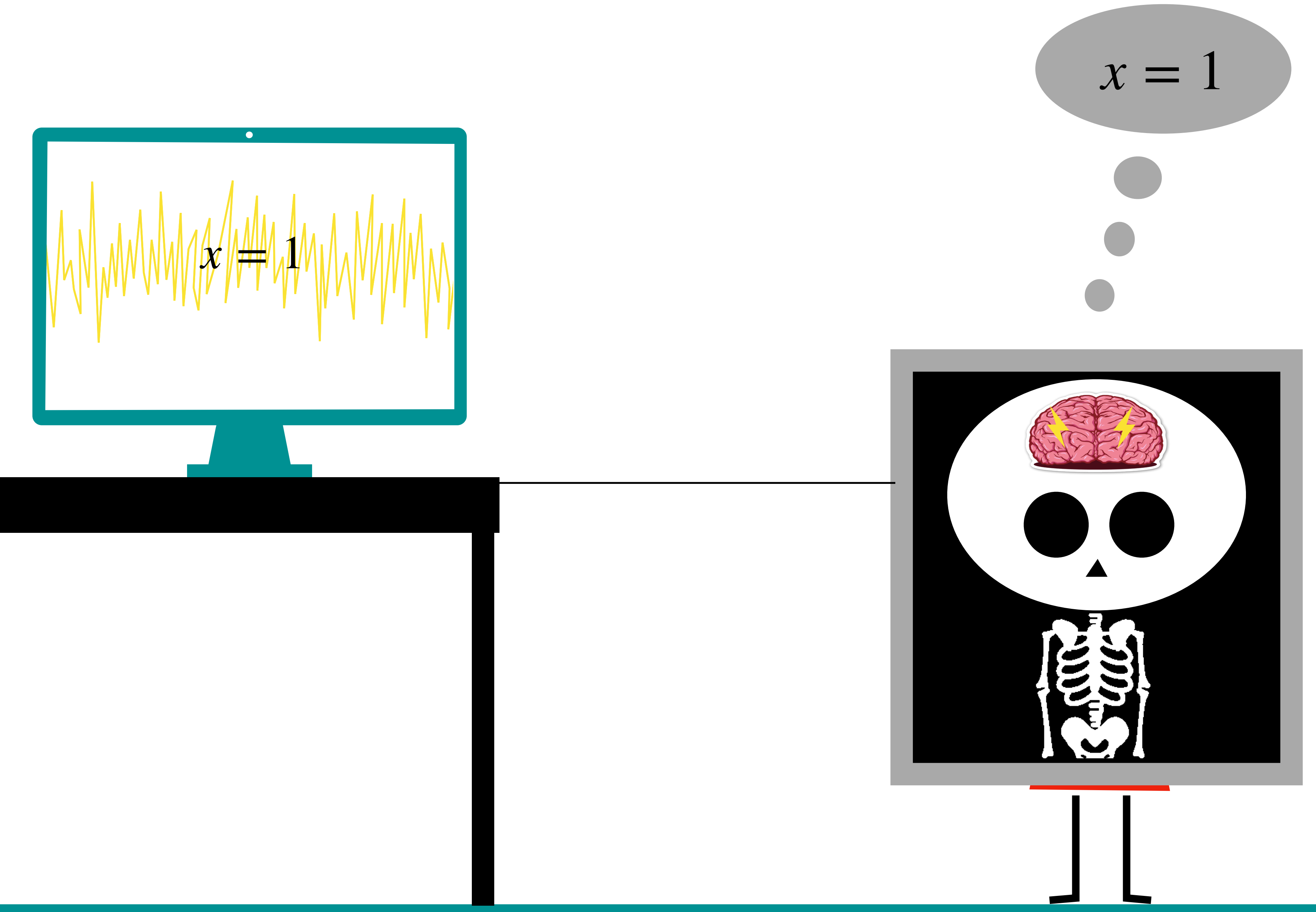

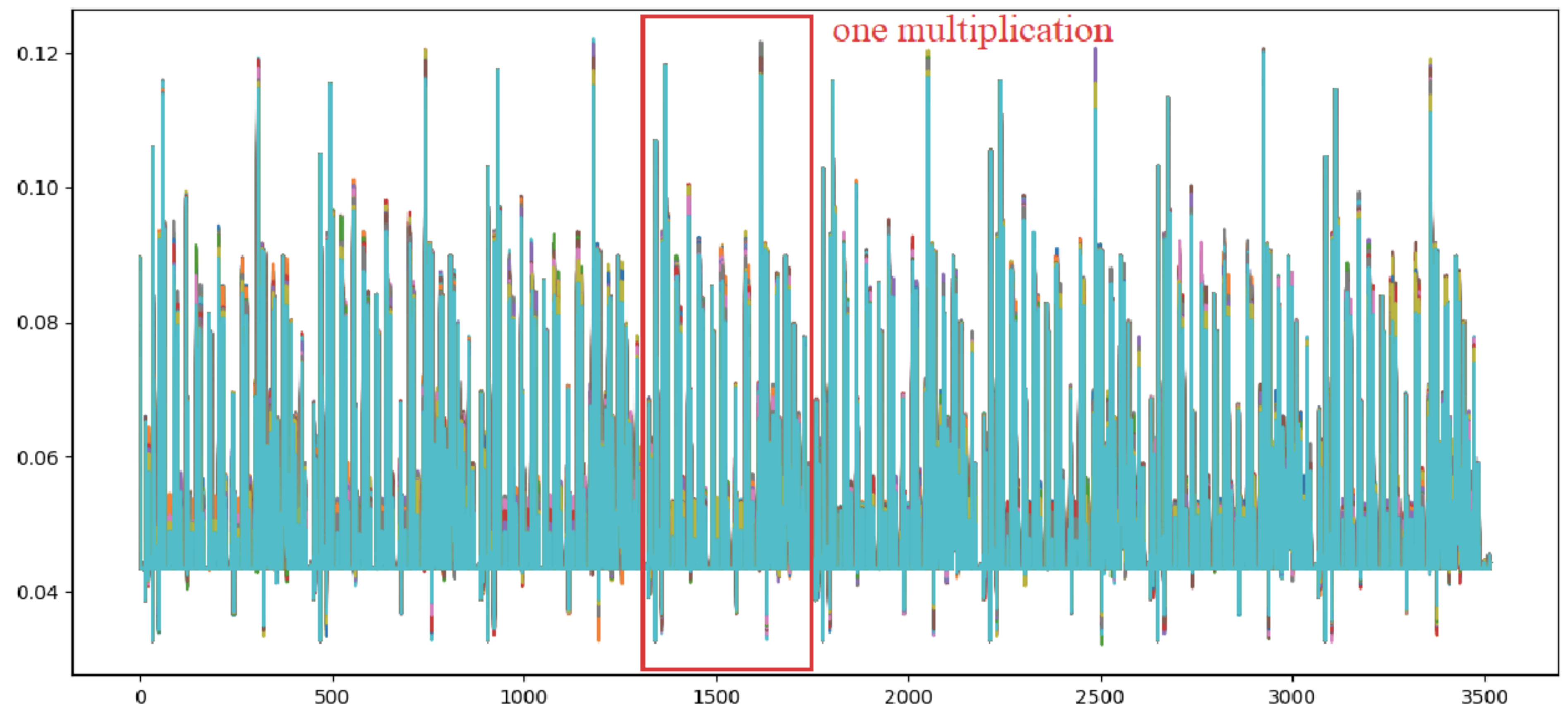

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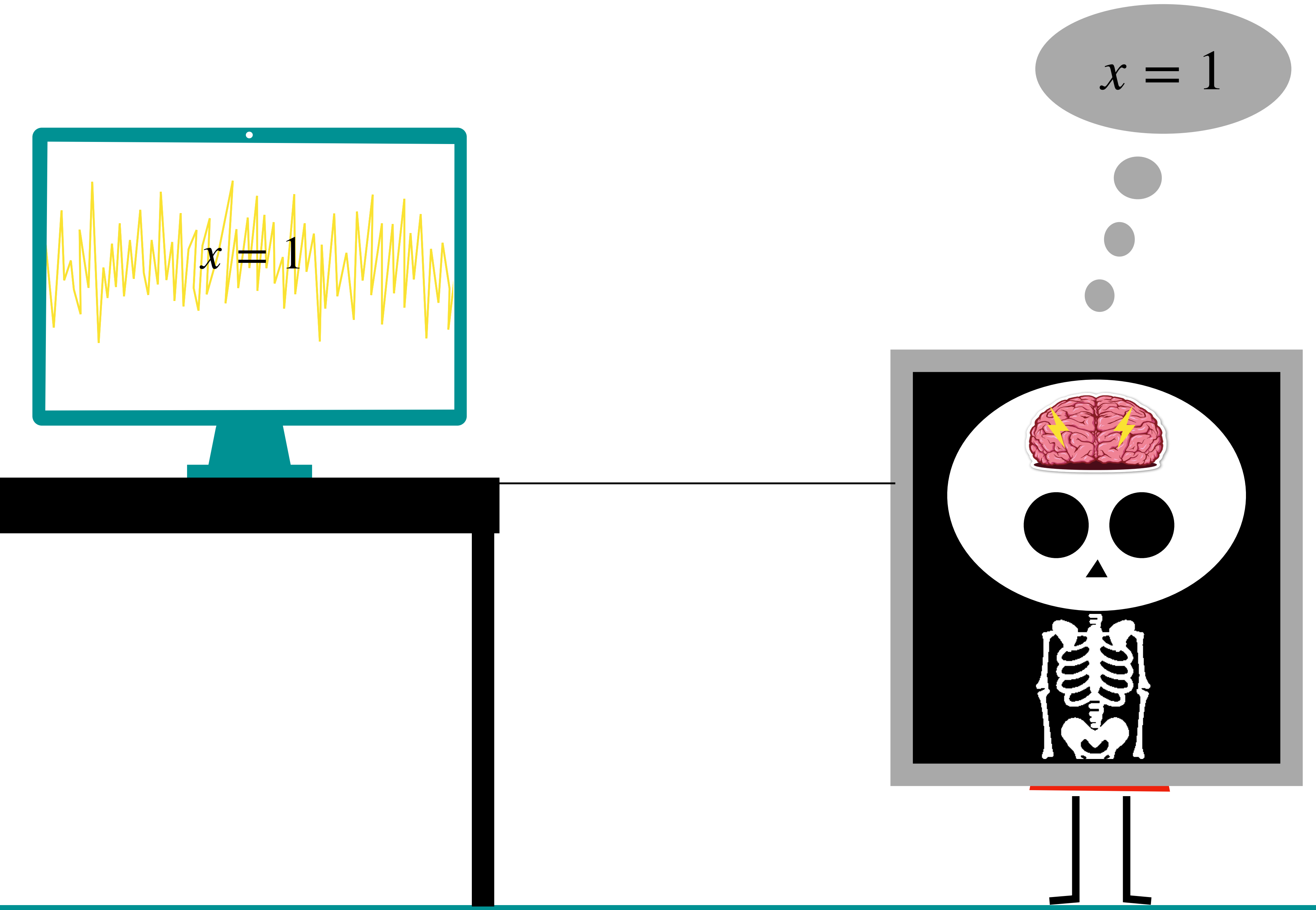
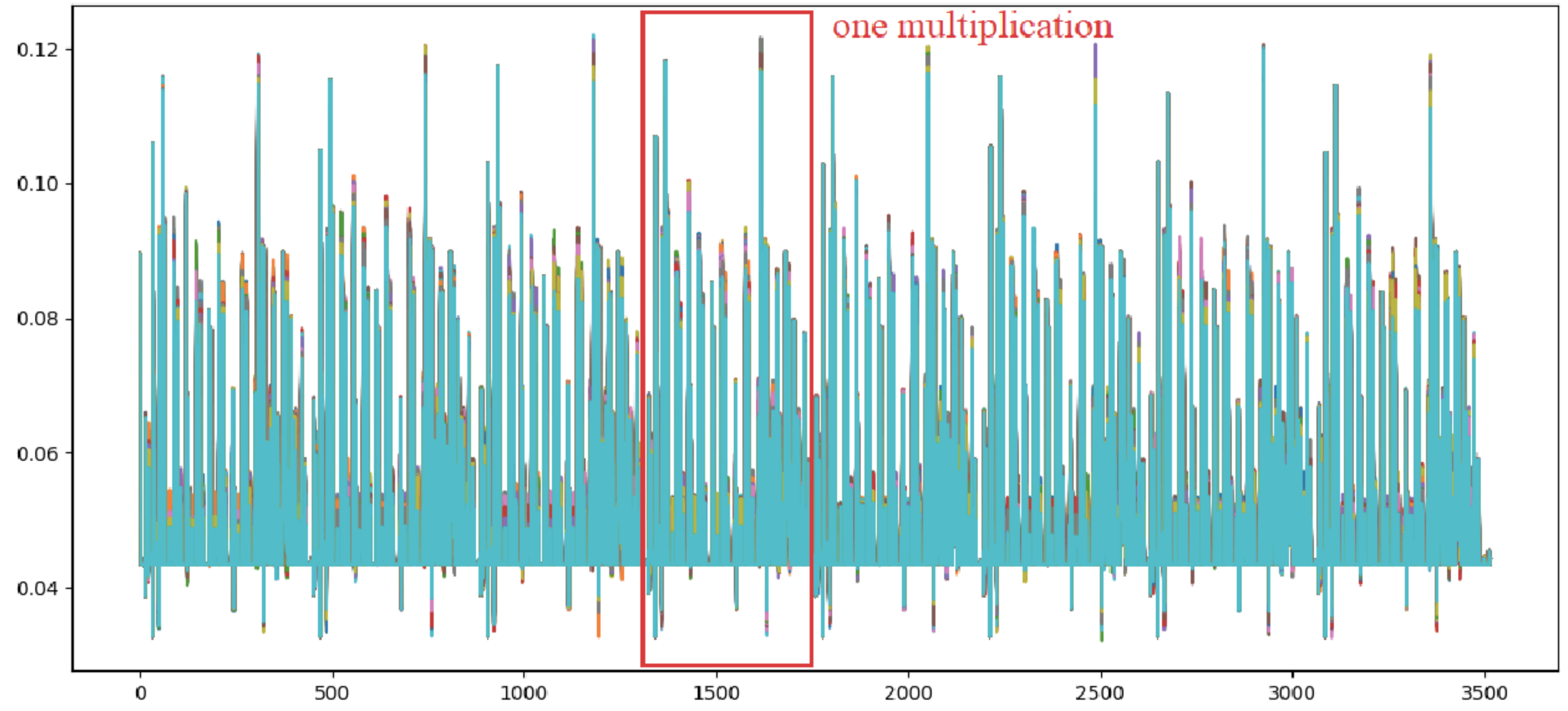
An example presented in the next slides





Falcon signature scheme

Signature algorithm:

1: compute $\mathbf{c}$ such that $\mathbf{c}\mathbf{A} = H(m)$

2: $\mathbf{v} \leftarrow$ a vector in $\Lambda(\mathbf{B})$ close to $\mathbf{c}$

3: return $\mathbf{s} \leftarrow \mathbf{c} - \mathbf{v}$

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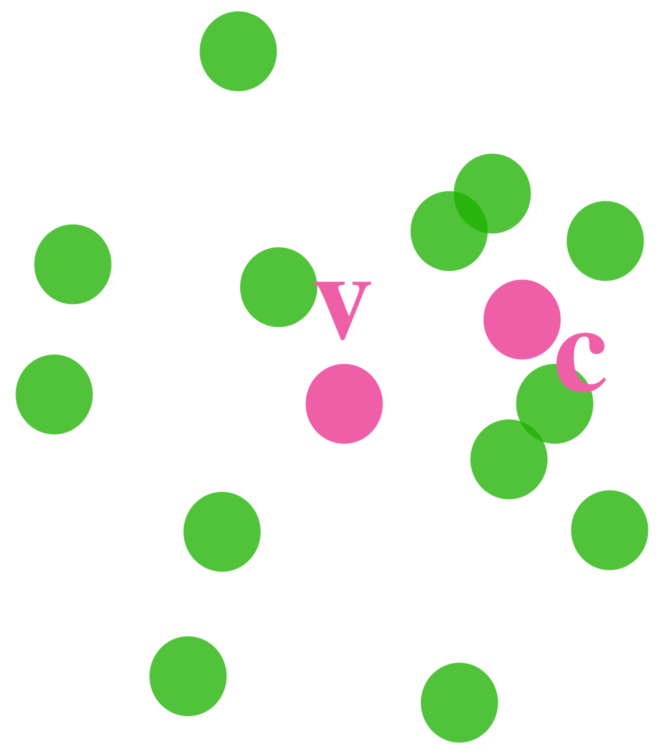

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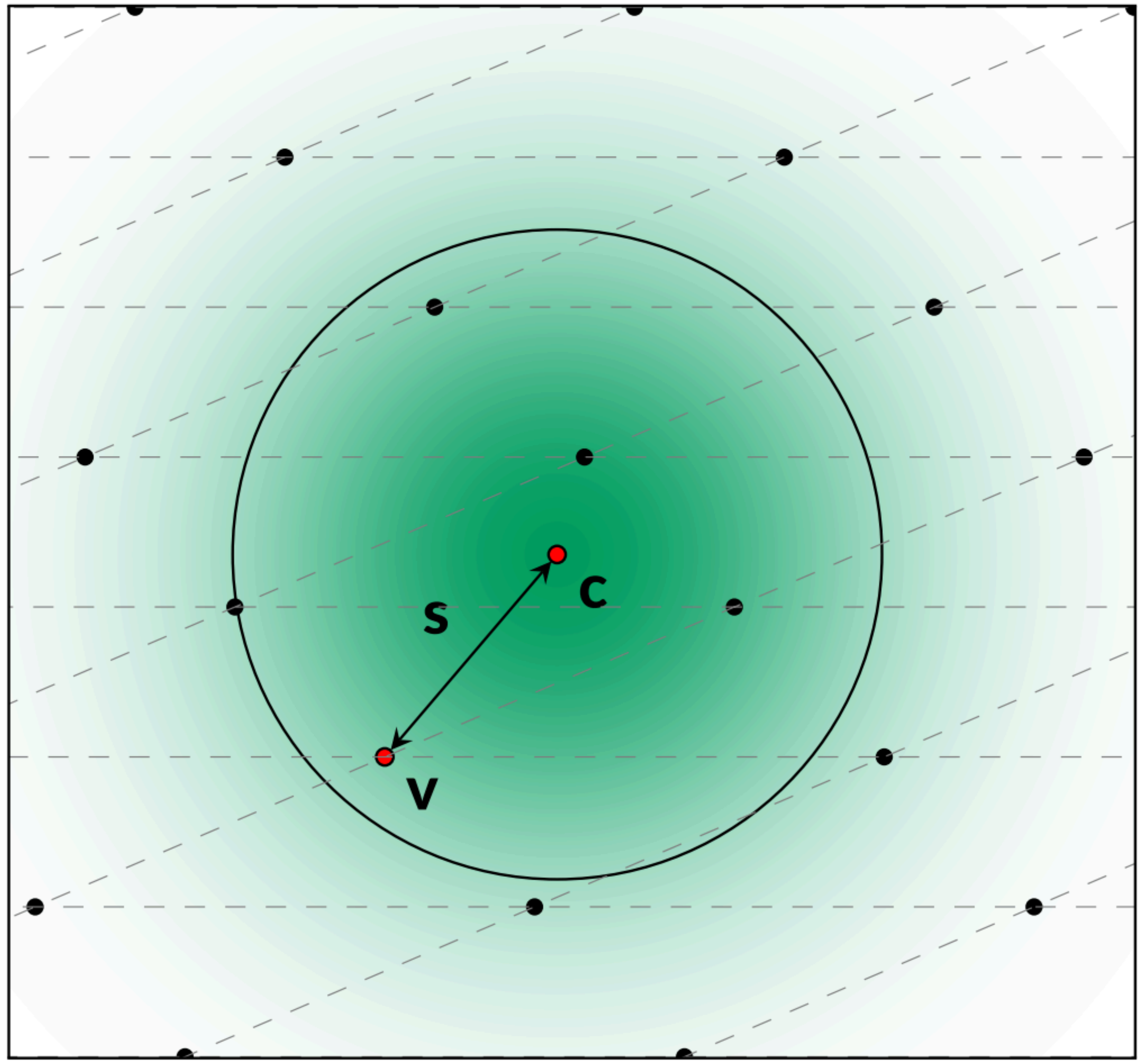

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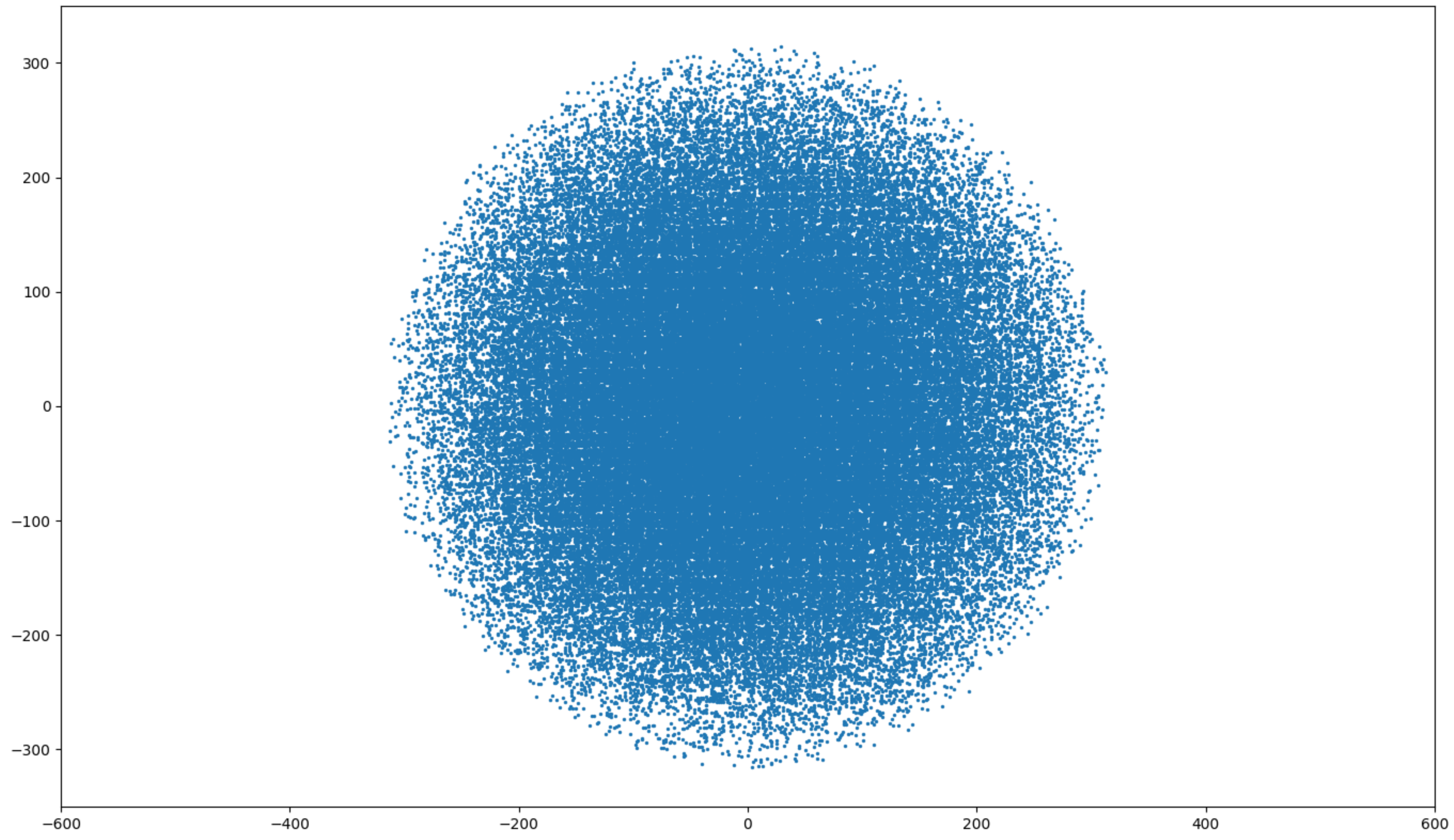
Distribution of signatures



Intuition of the power analysis attack of Falcon

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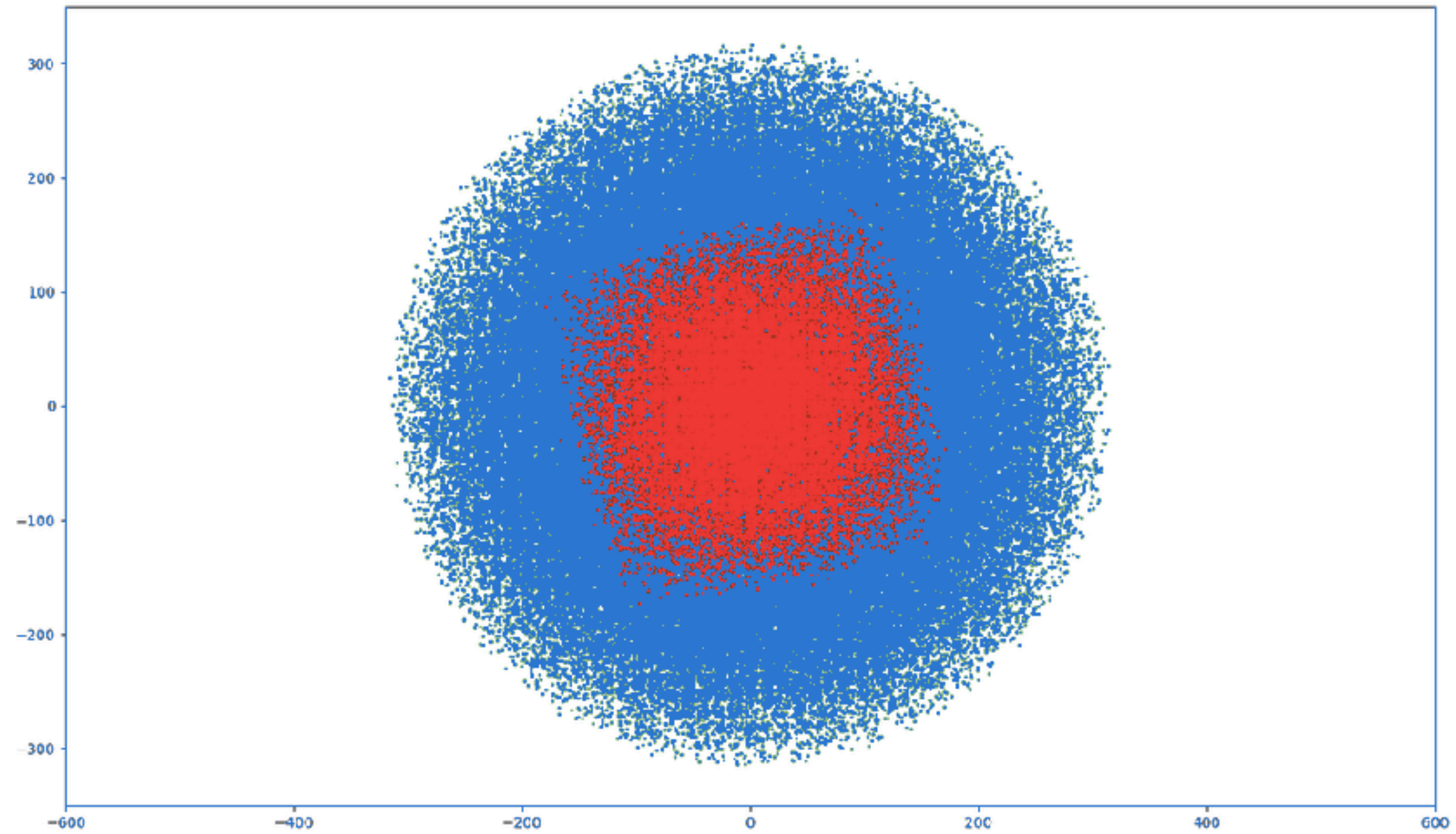
If we select the inputs such that the **Gaussian shift** is zero, we can “see” the hidden basis.



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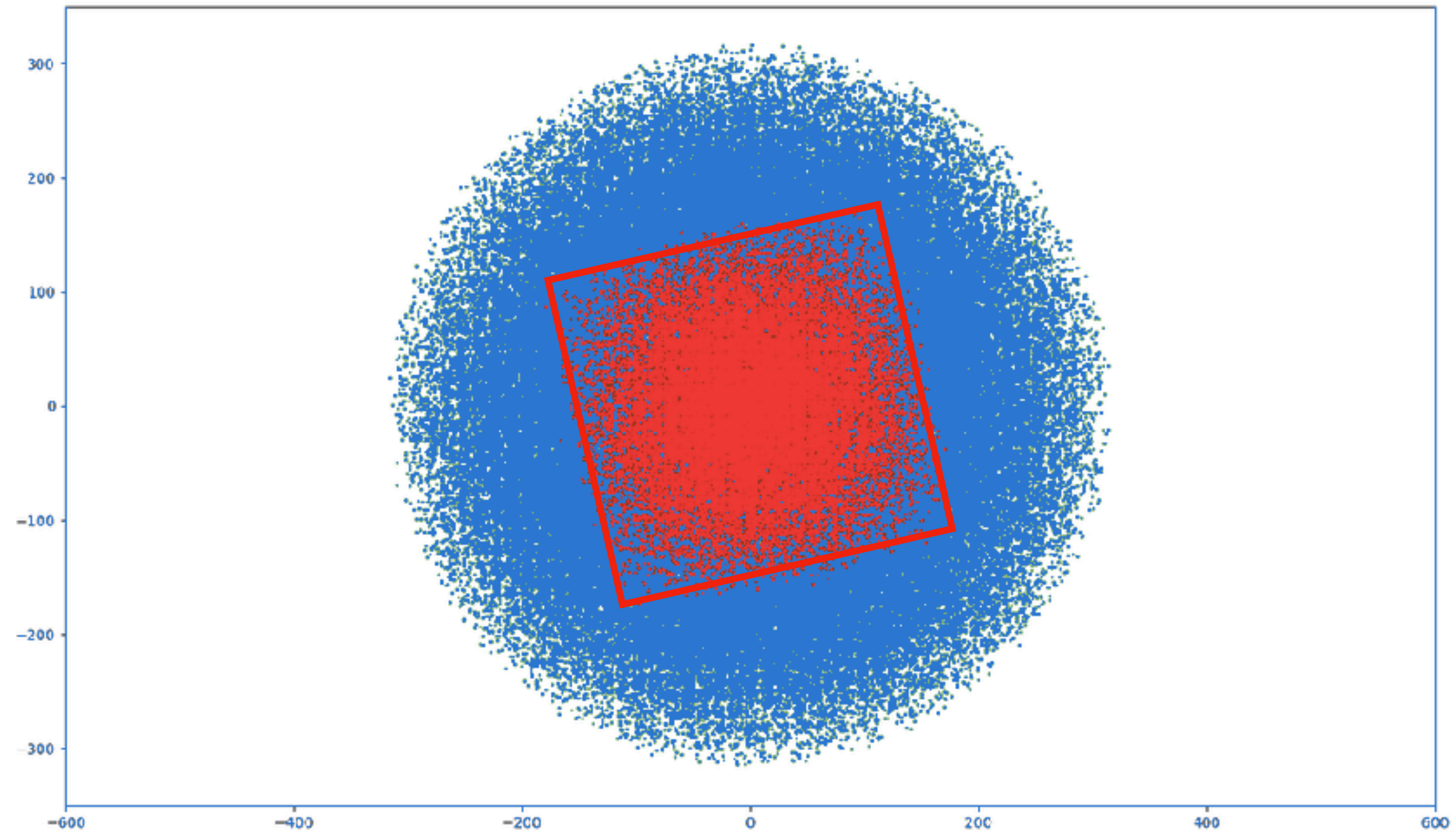

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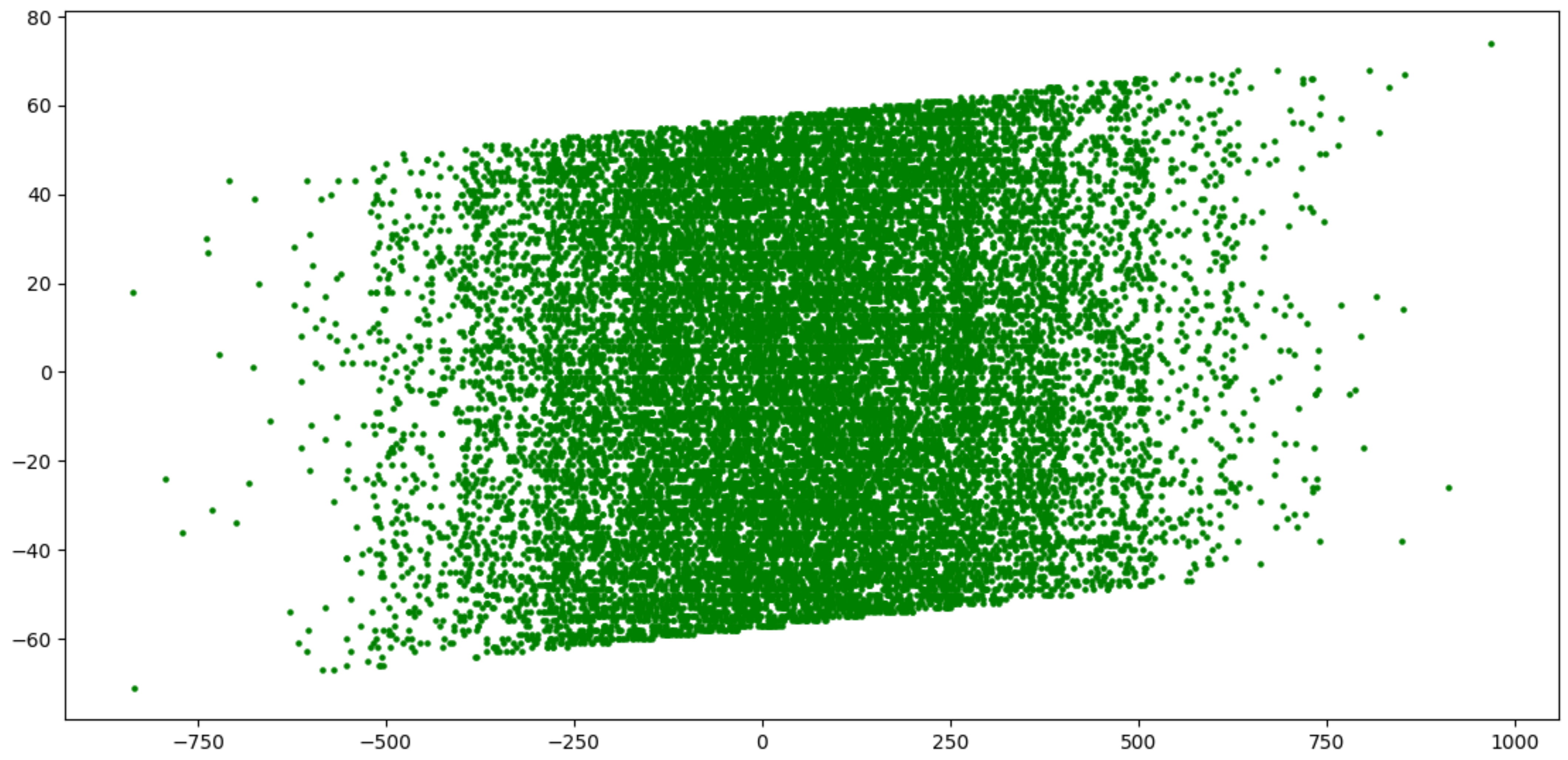

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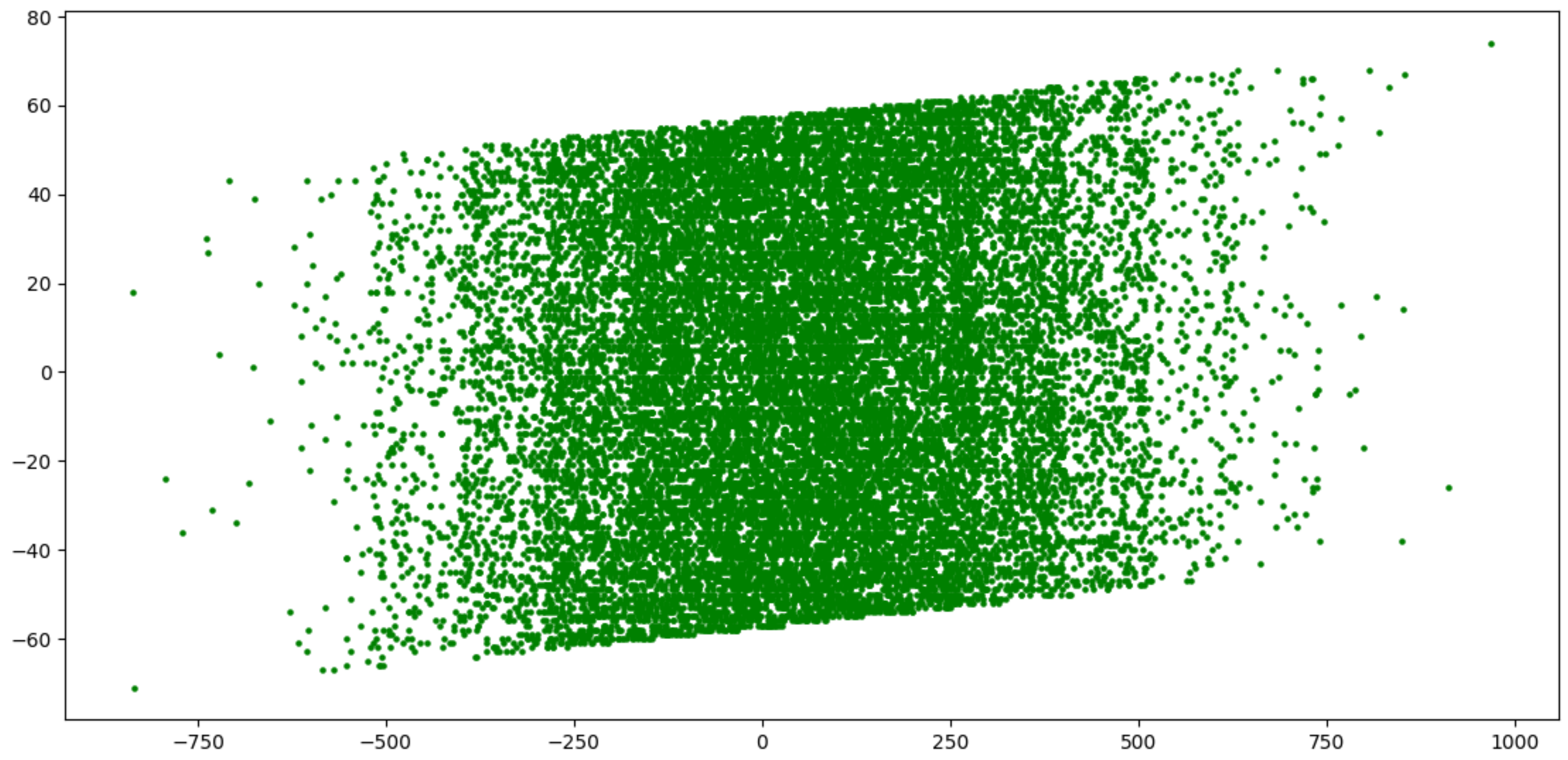

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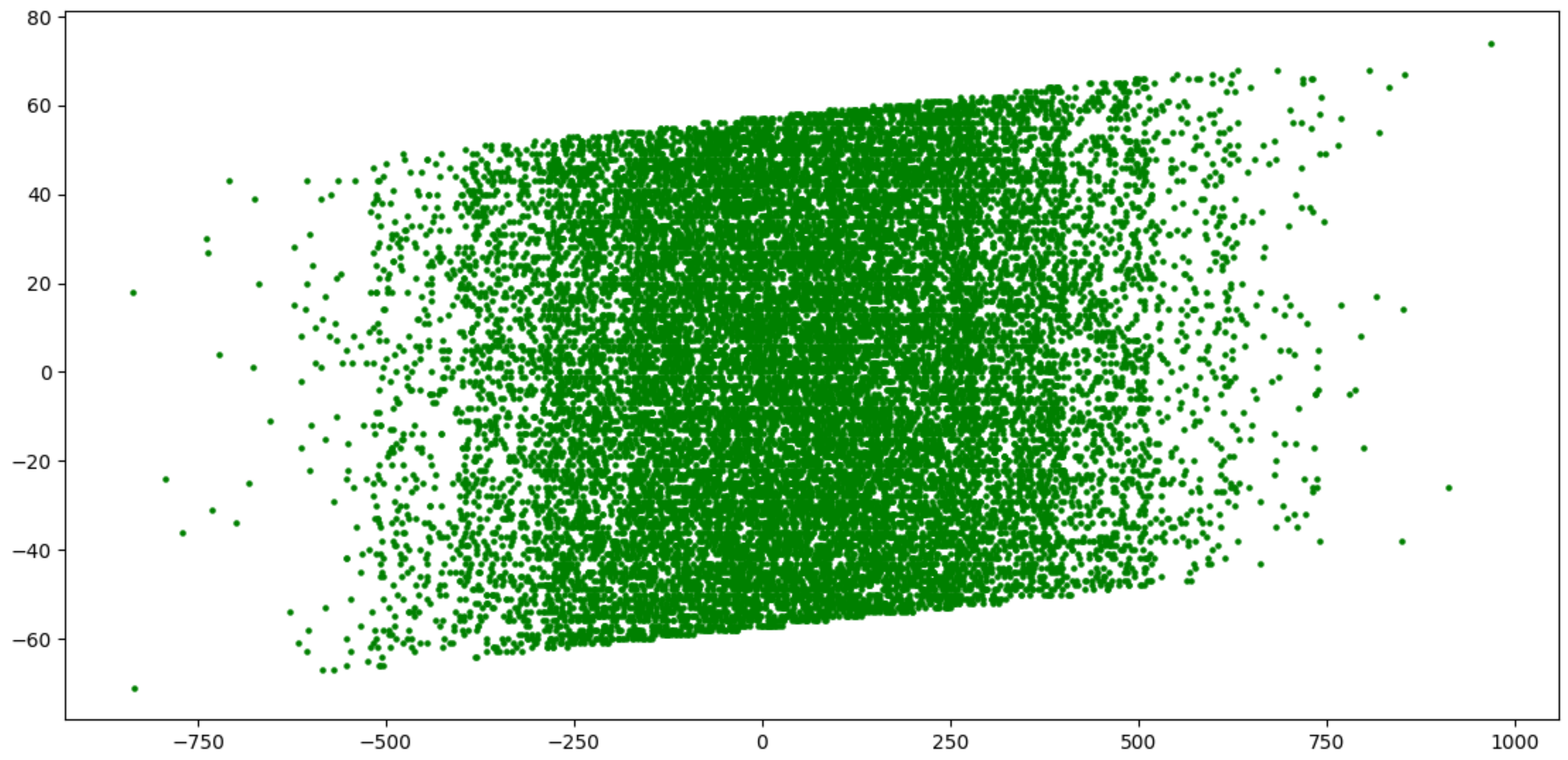

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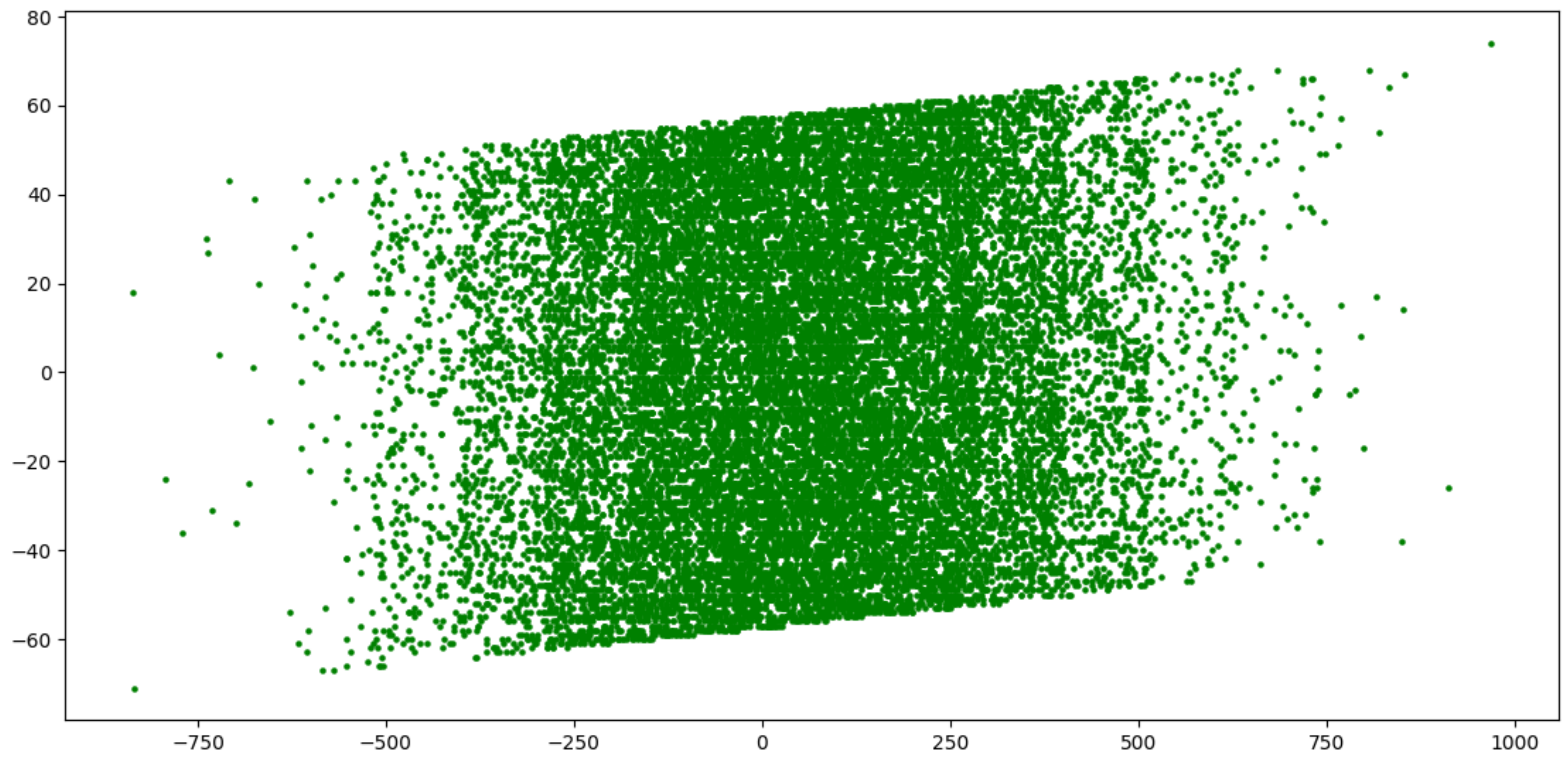
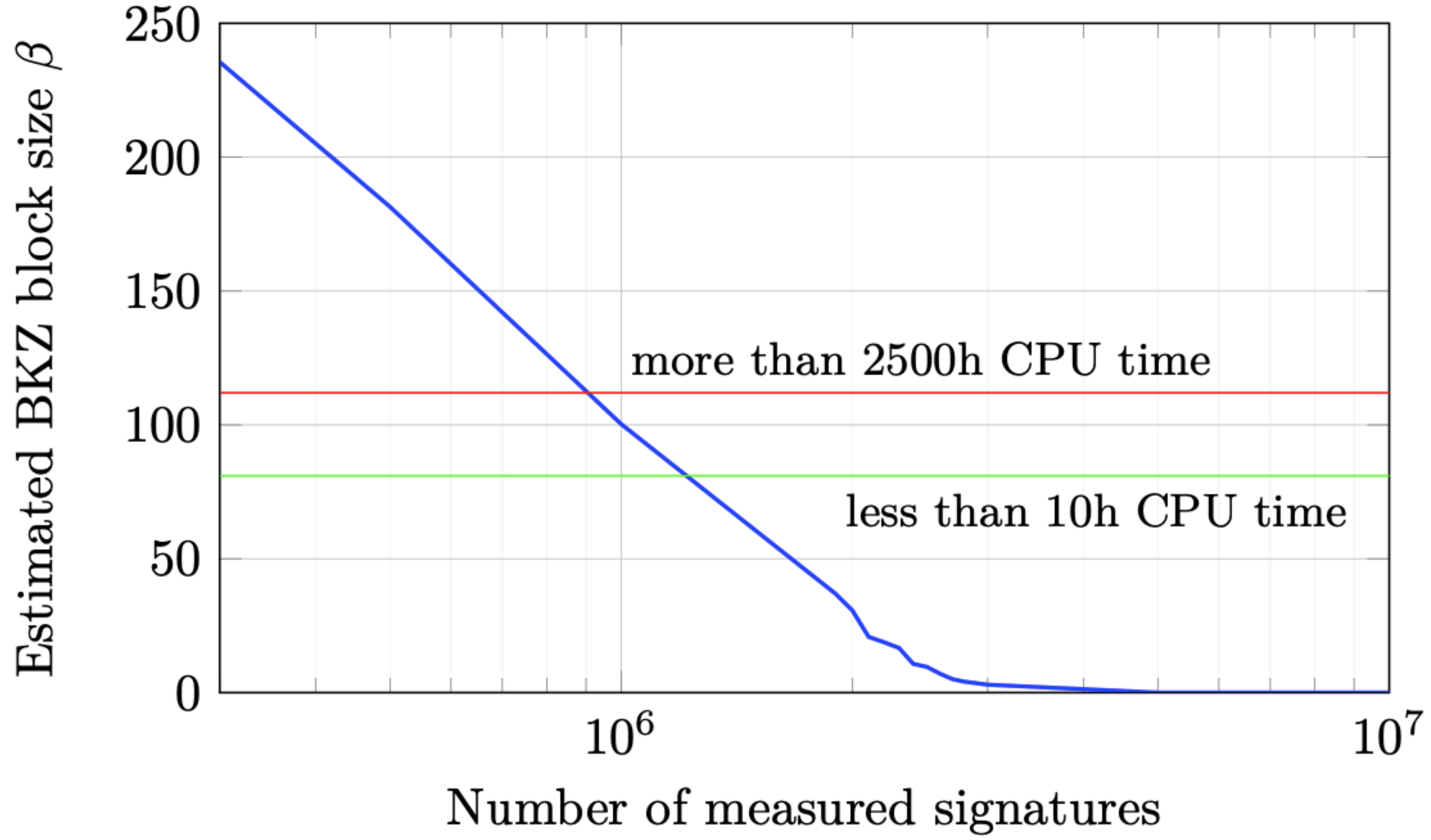


Performance of the attack



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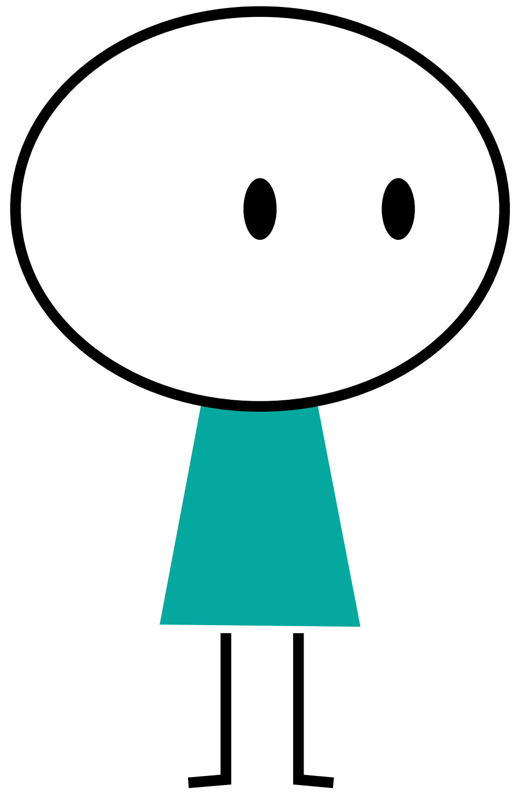

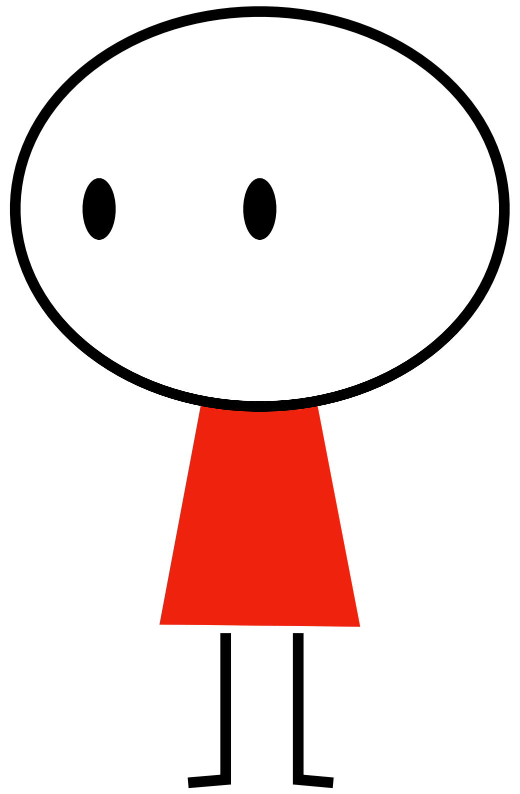

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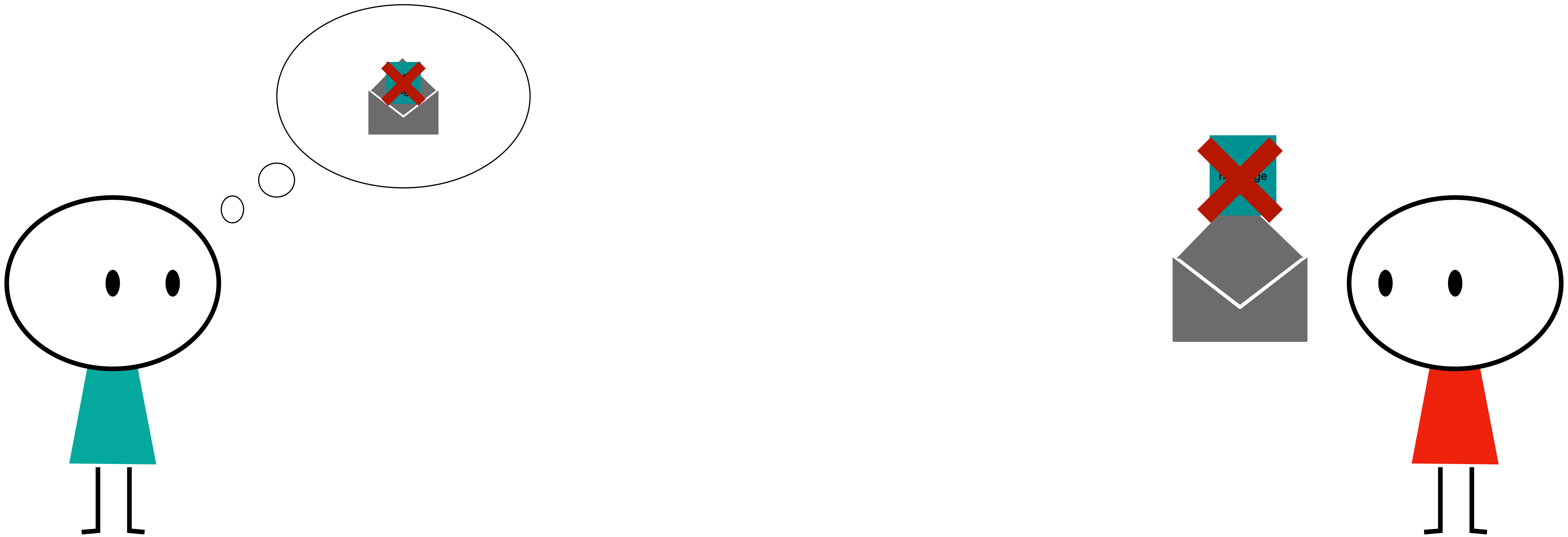

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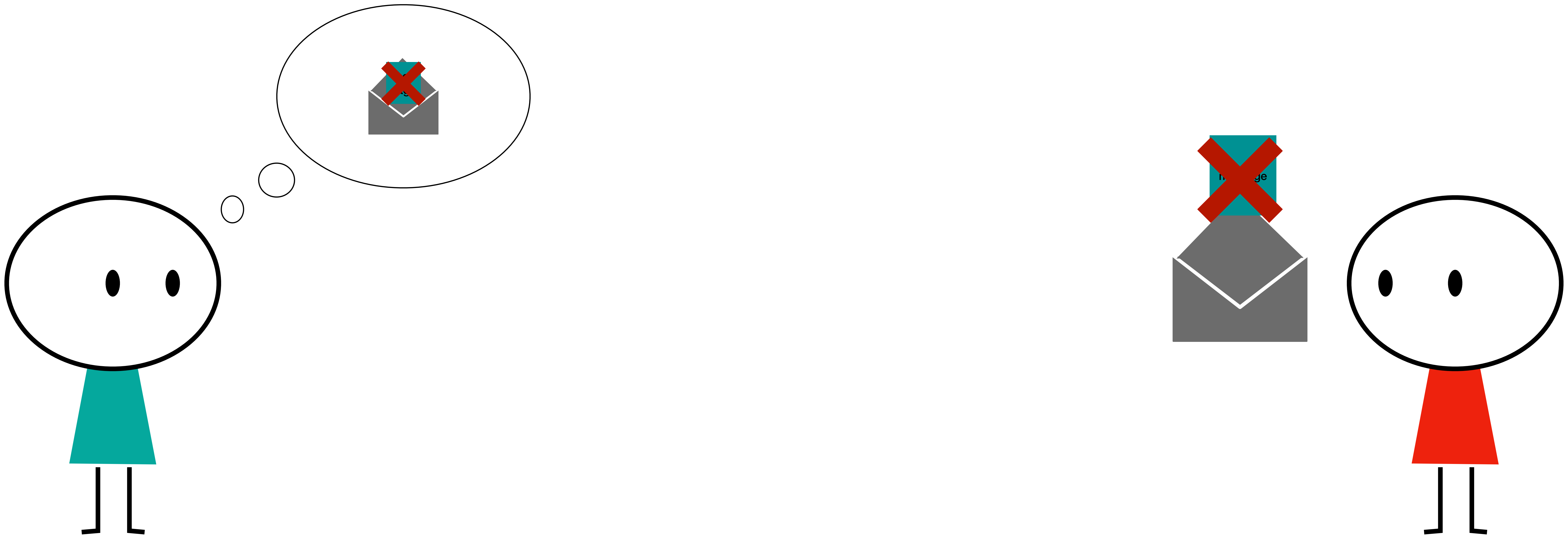

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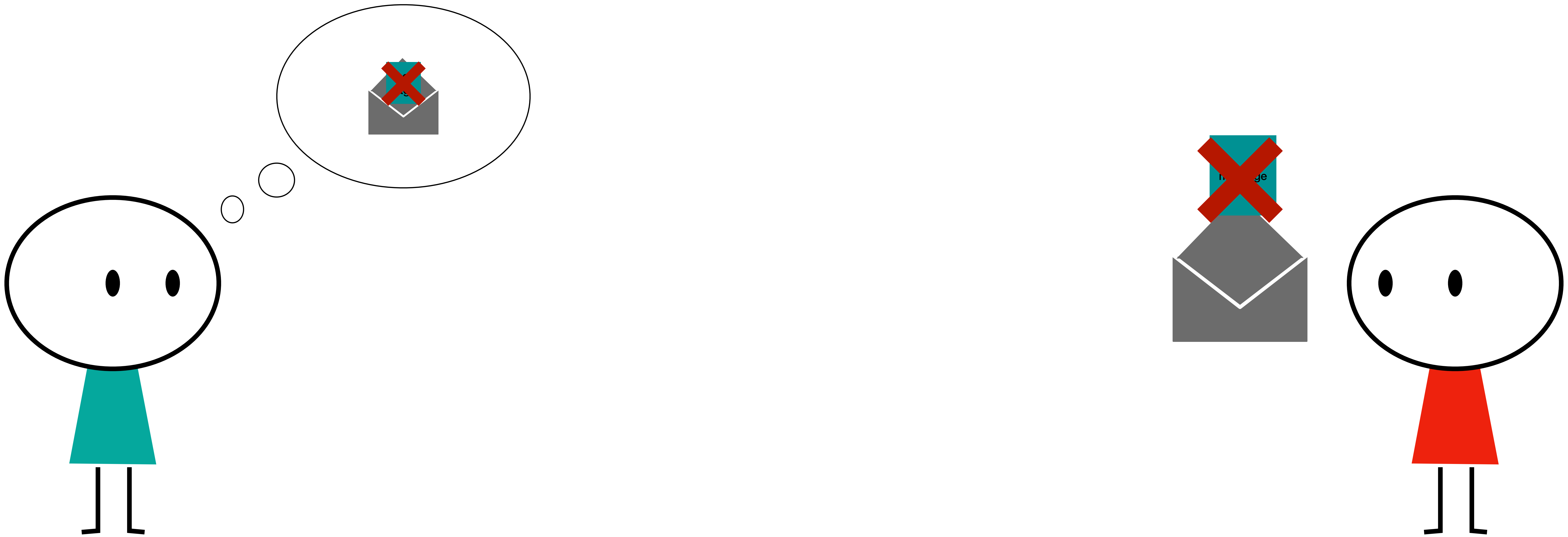

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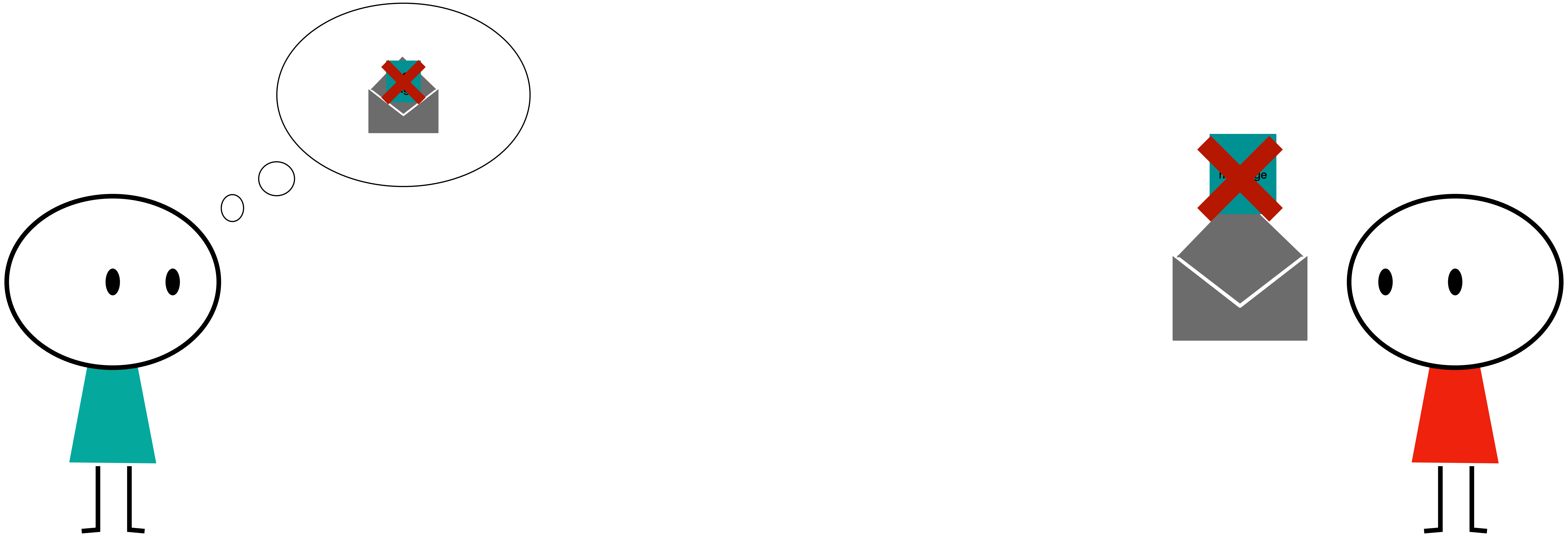

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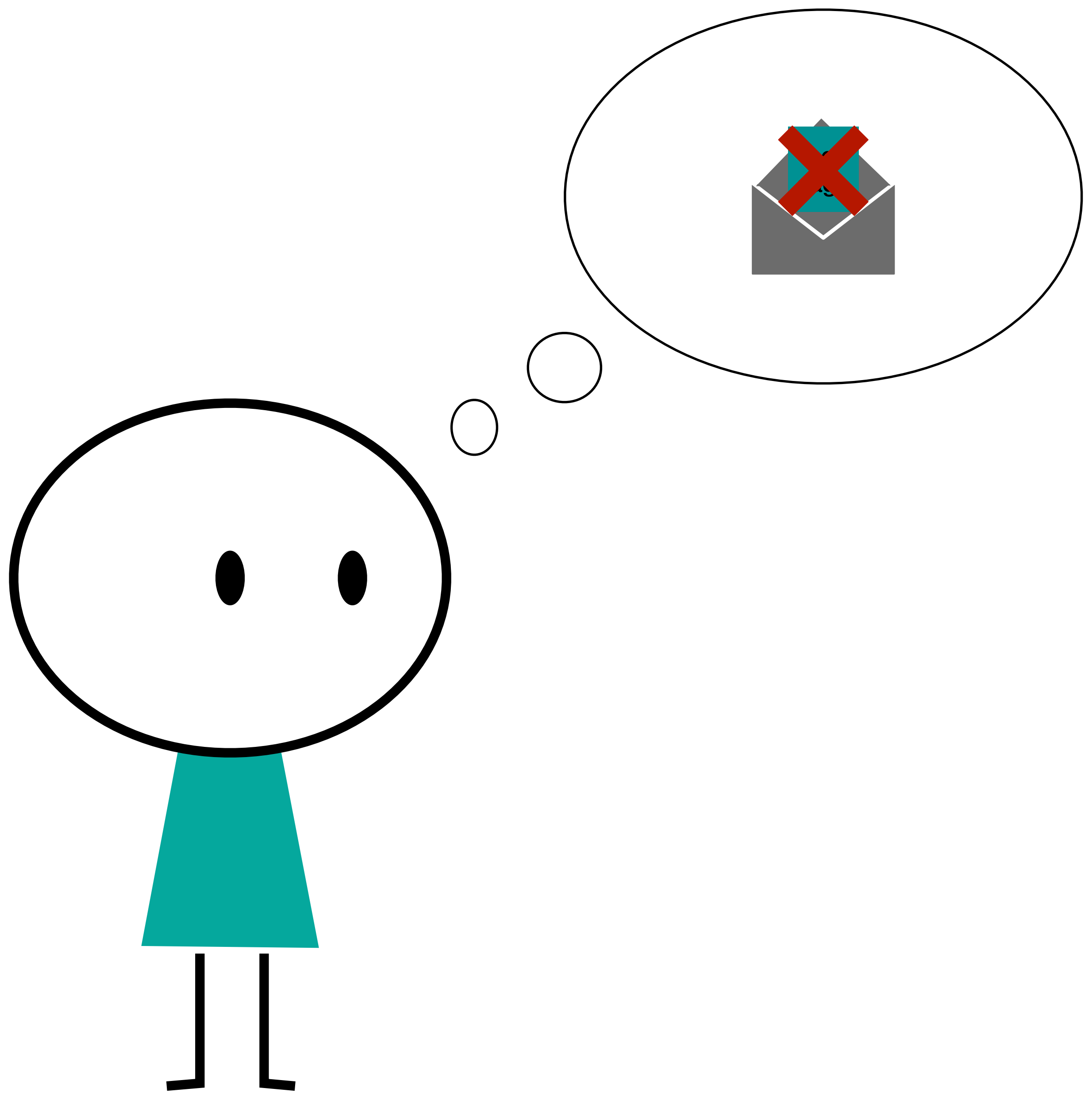

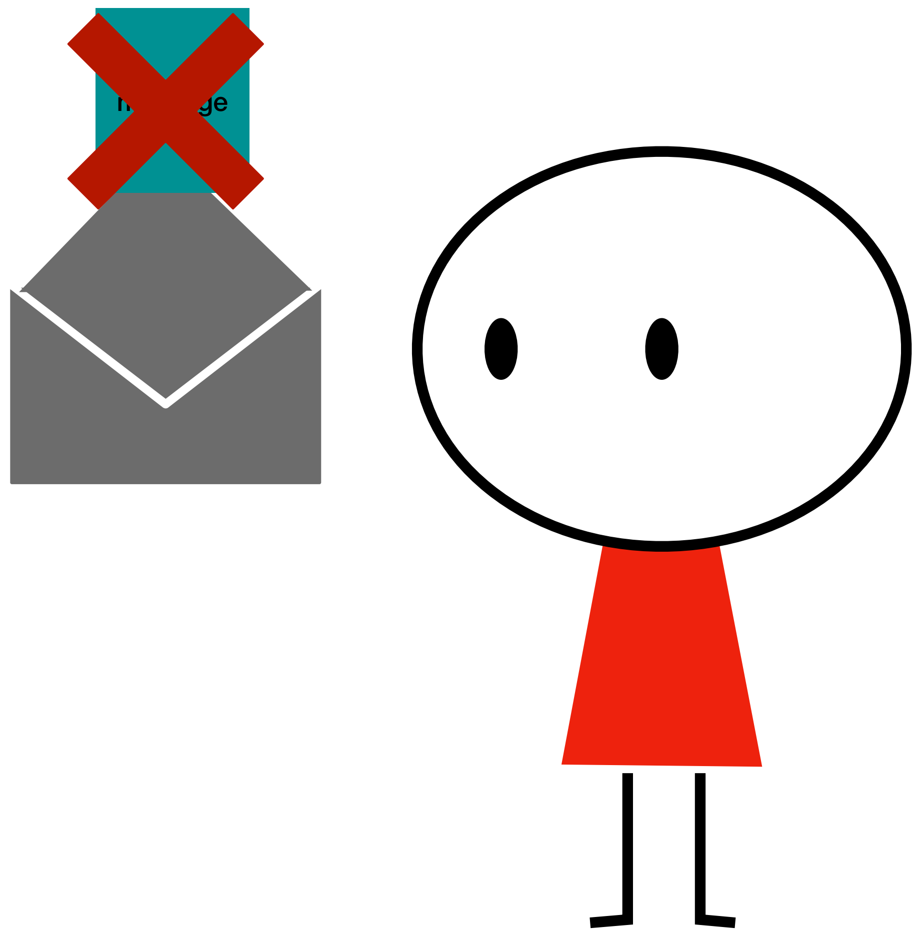

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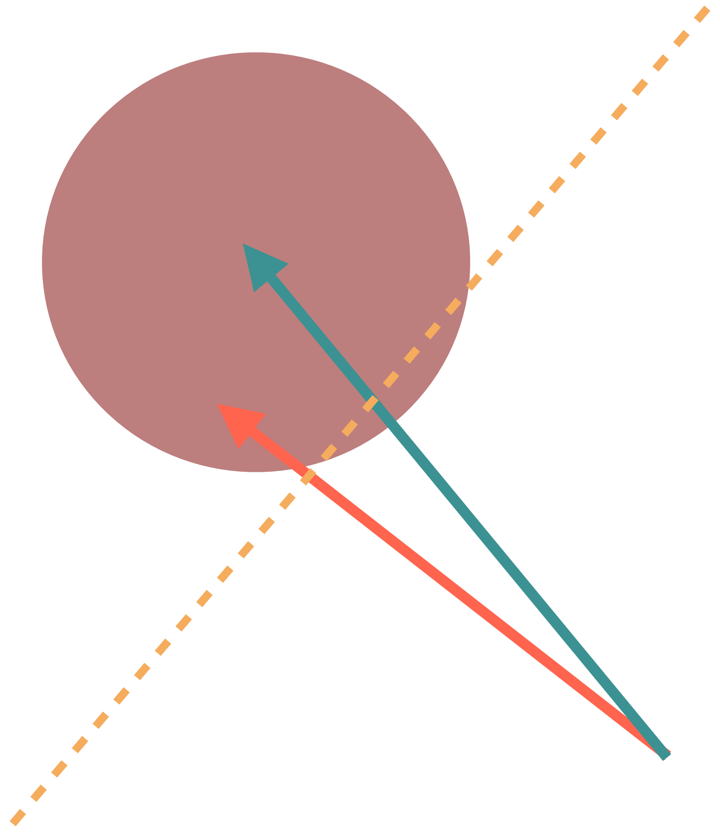

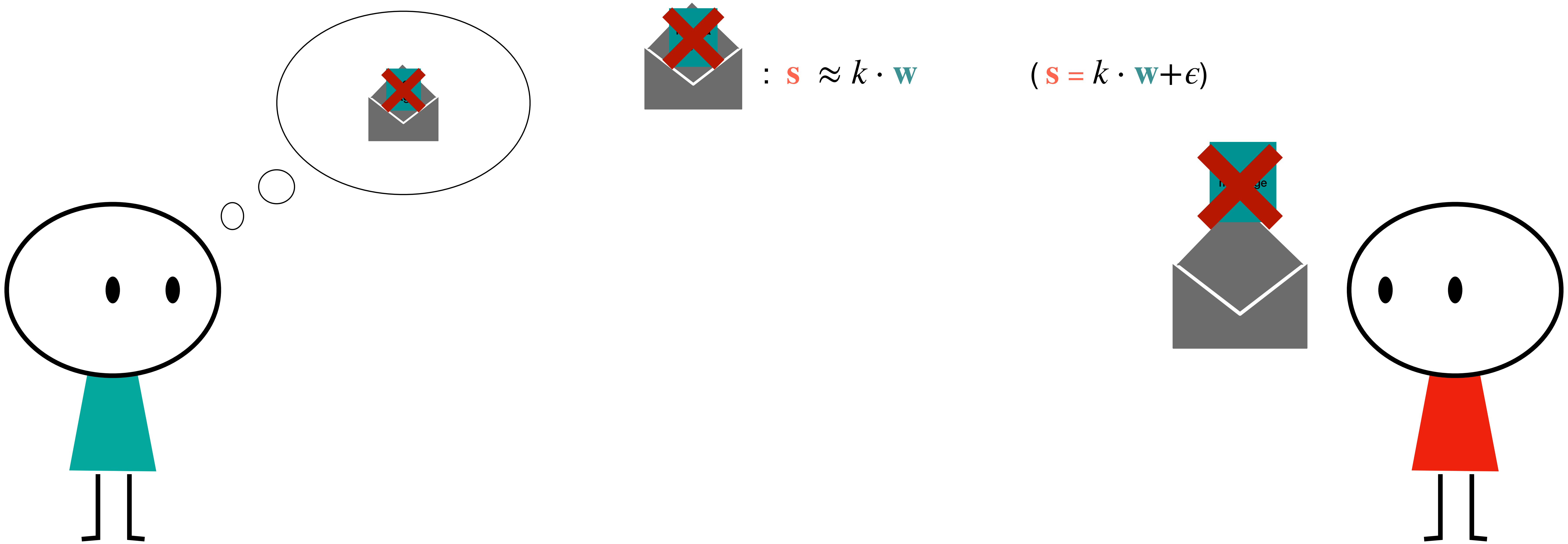

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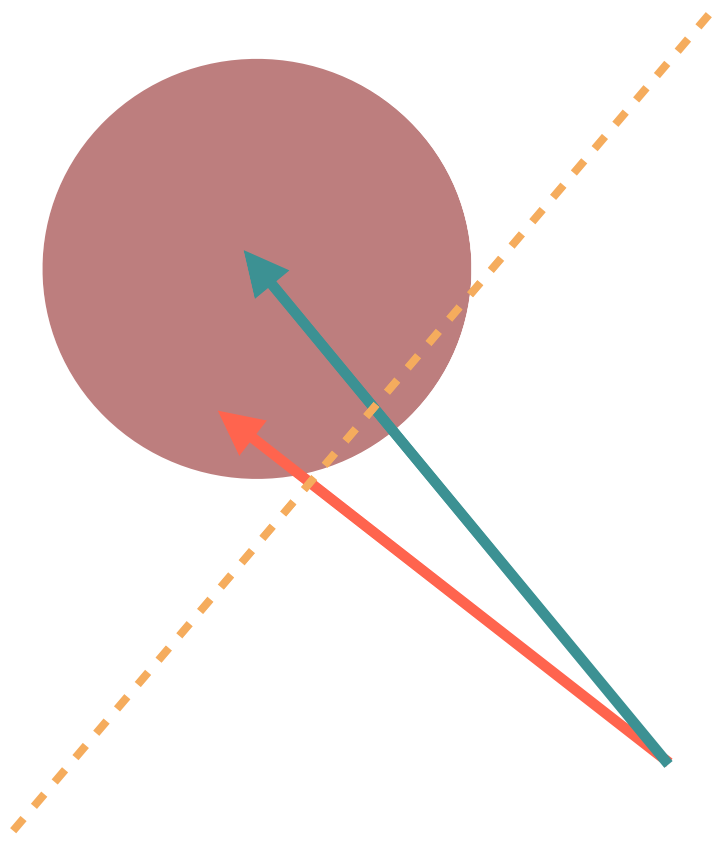

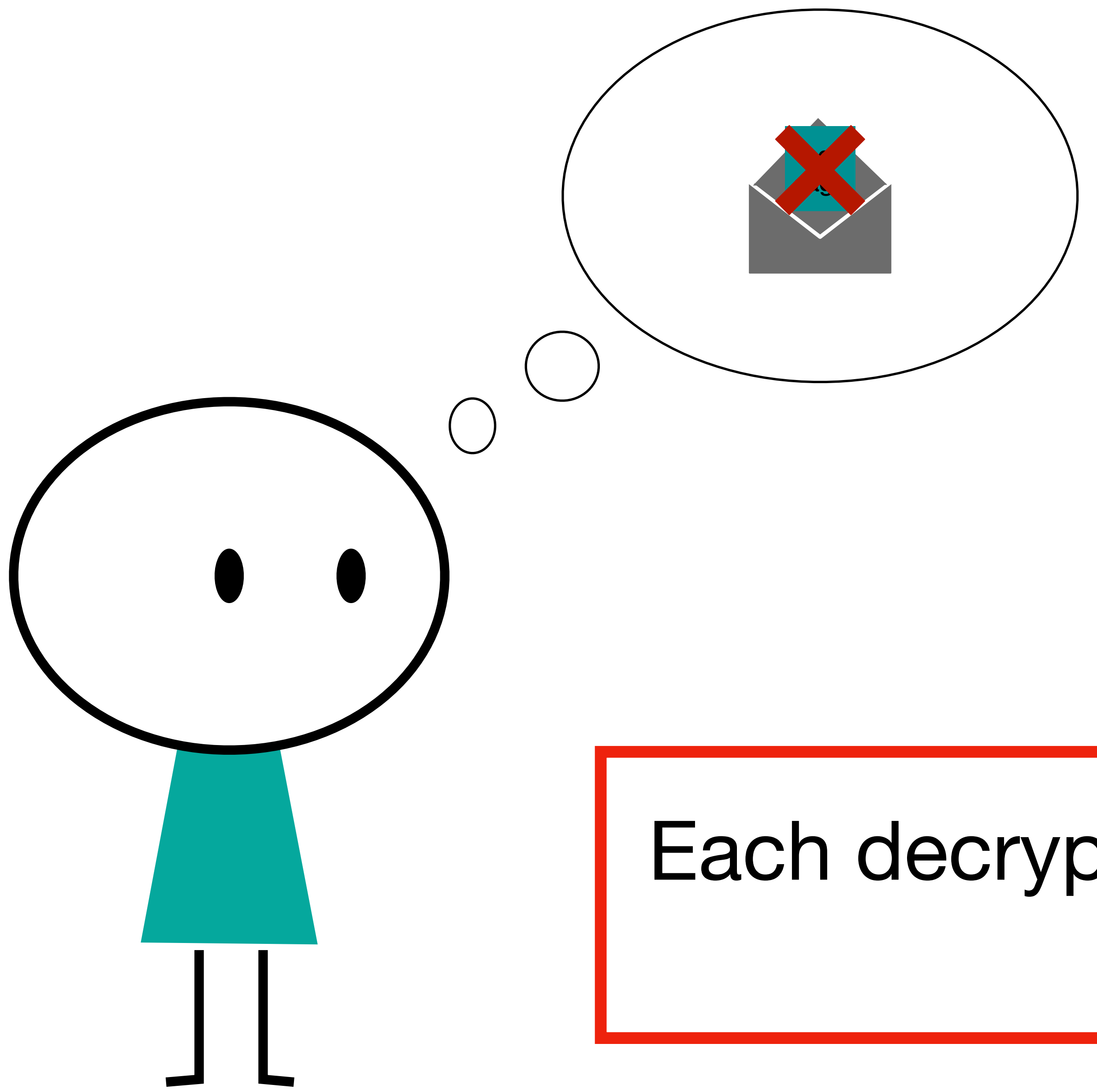

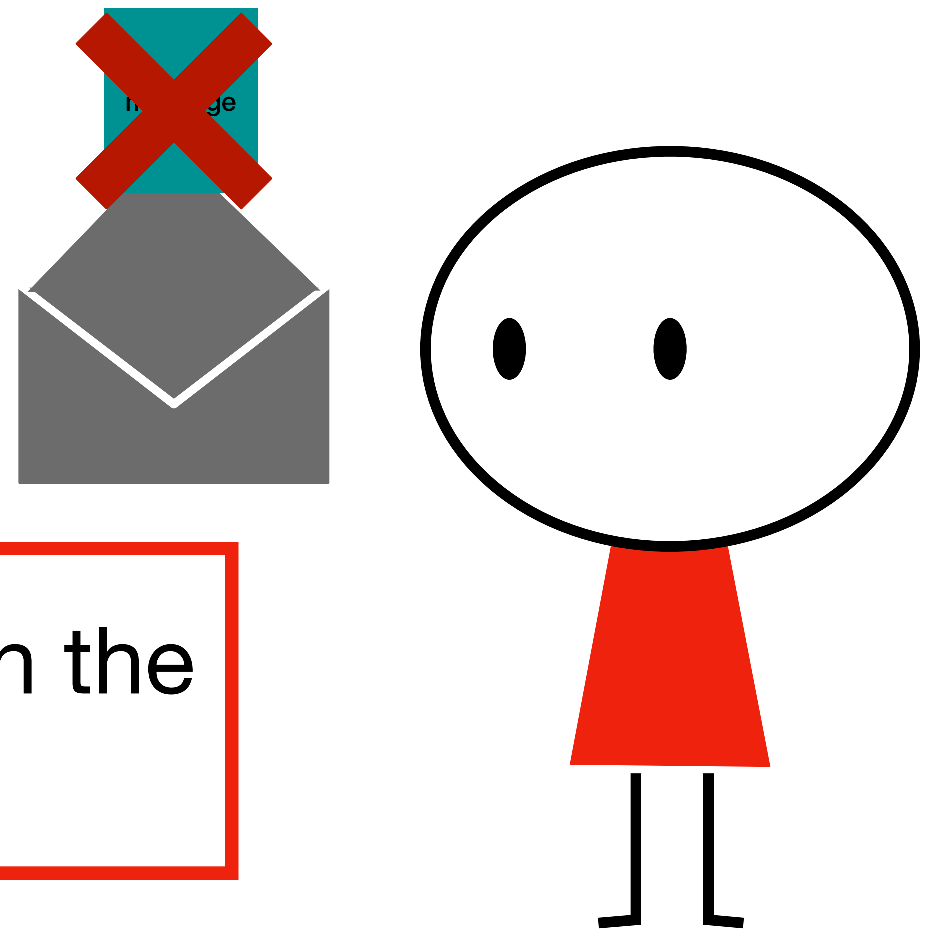

Each decryption failure provides an equation on the direction of the secret

Decryption failure attacks

➡ Failure probability in IND-CCA setting

0	NTRU, NTRU Prime
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2^{-206}	Three Bears
2^{-199}	FrodoKEM
2^{-164}	Kyber
2^{-142}	LAC
2^{-136}	Saber
2^{-117}	Round5

Extremely unlikely in IND-CCA setting (protected by FO transform)

Decryption failure attacks

This transform consists in recovering the encryption's random coins inside the decryption and checking honest generation by re-encryption.

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Extremely unlikely in IND-CCA setting (protected by FO transform)

Decryption failure attacks

This transform consists in recovering the encryption's random coins inside the decryption and checking honest generation by re-encryption.

➡ Failure probability in IND-CCA setting

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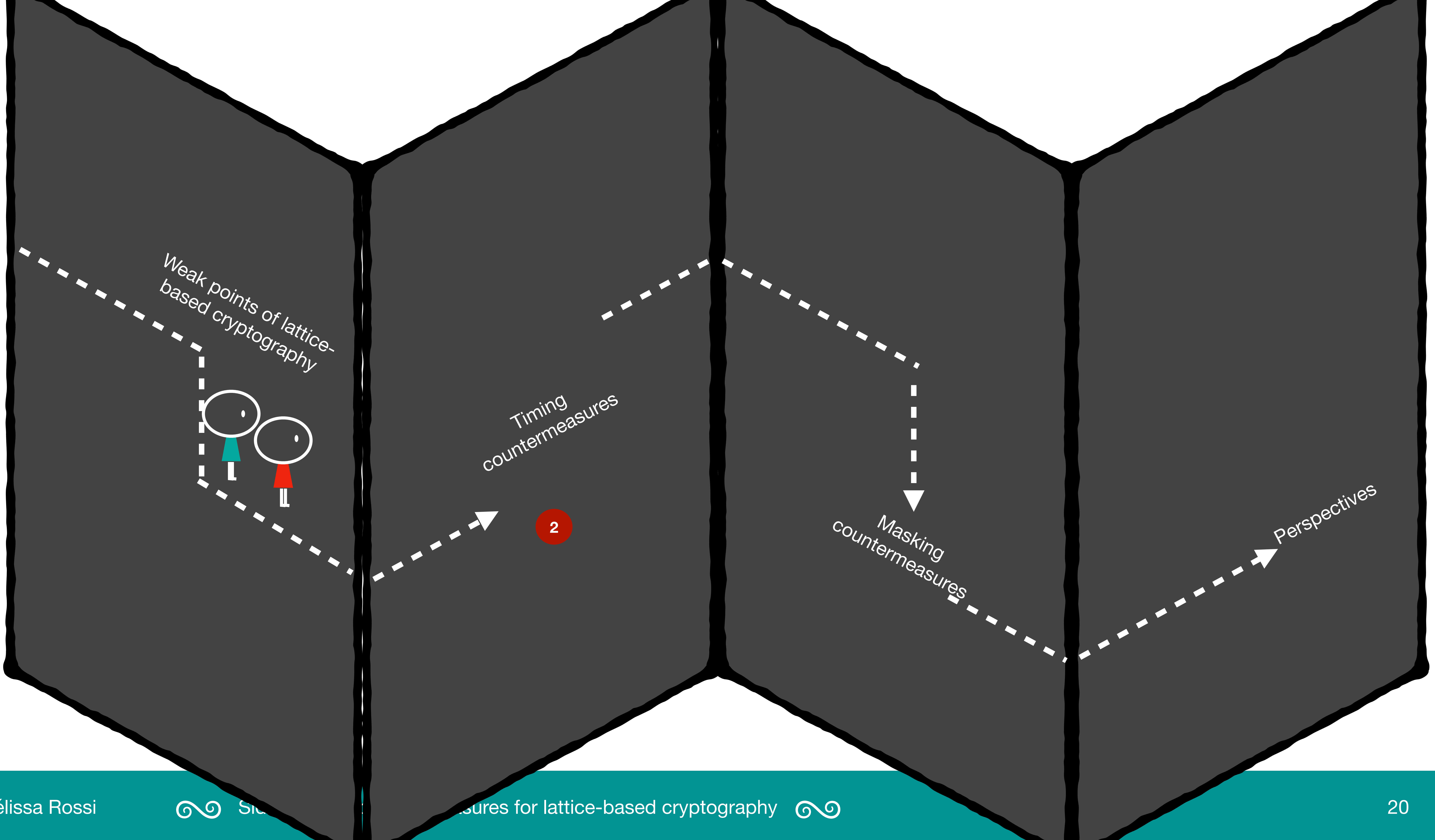
Countermeasure are very important to avoid these side-channel assisted decryption failure attacks


Weak points of lattice-based cryptography
Timing countermeasures
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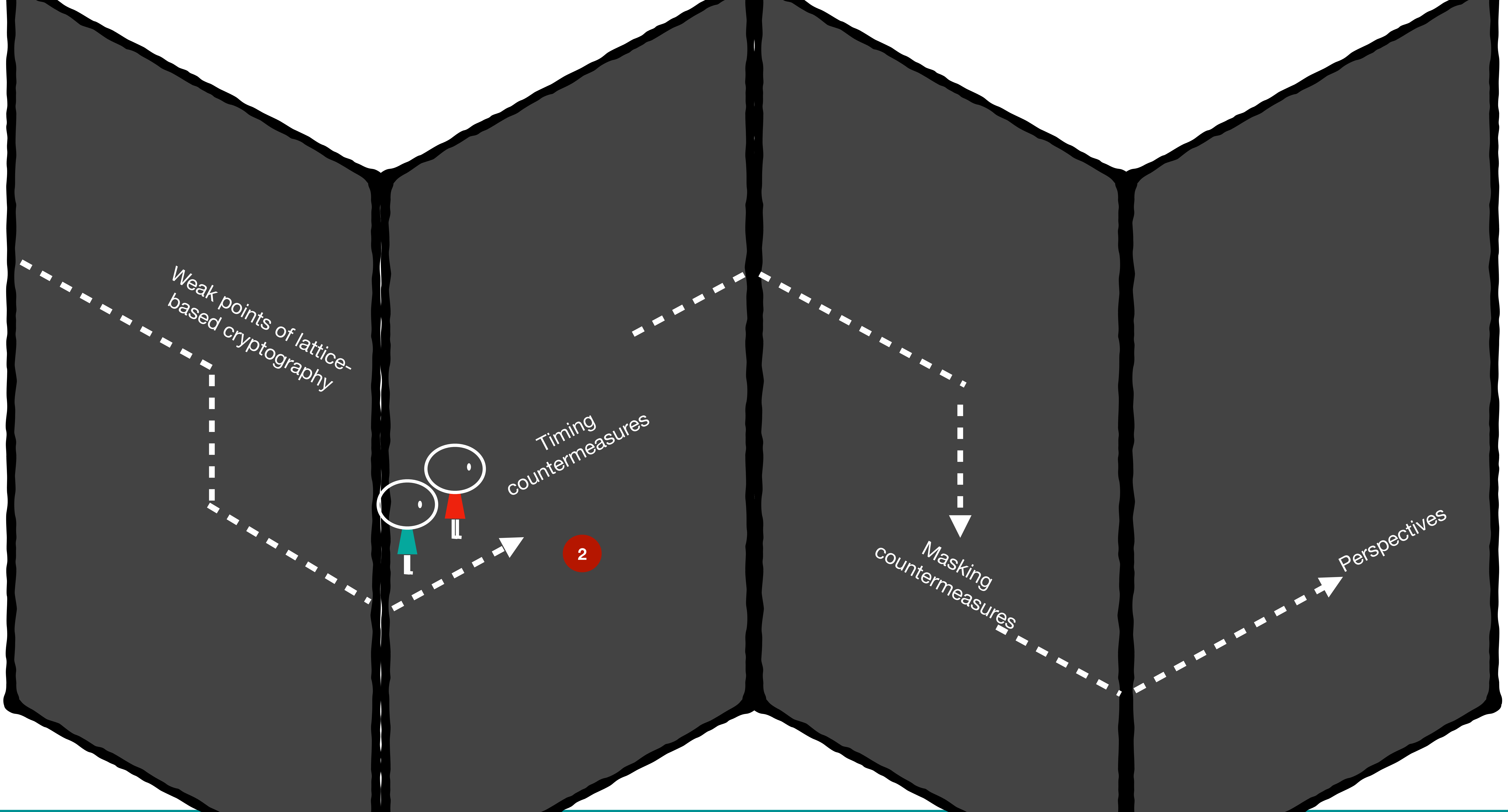
Masking countermeasures
Perspectives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How to remove timing attacks entry points

The entry points include:

- ✦ computer-science unfriendly distributions like Gaussians.
- ✦ secret-dependent internal distributions.
- ✦ numerous operations with the secret.
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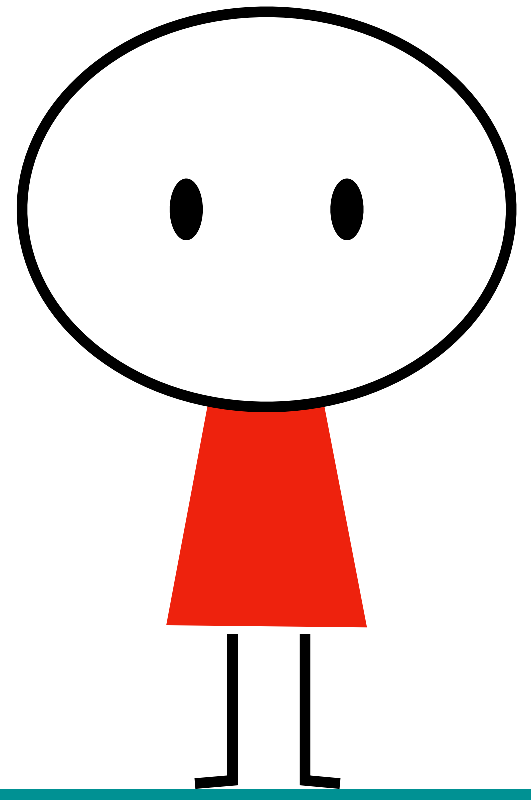

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Here are some provable countermeasure techniques:

1. Renyi divergence arguments
2. Polynomial approximations

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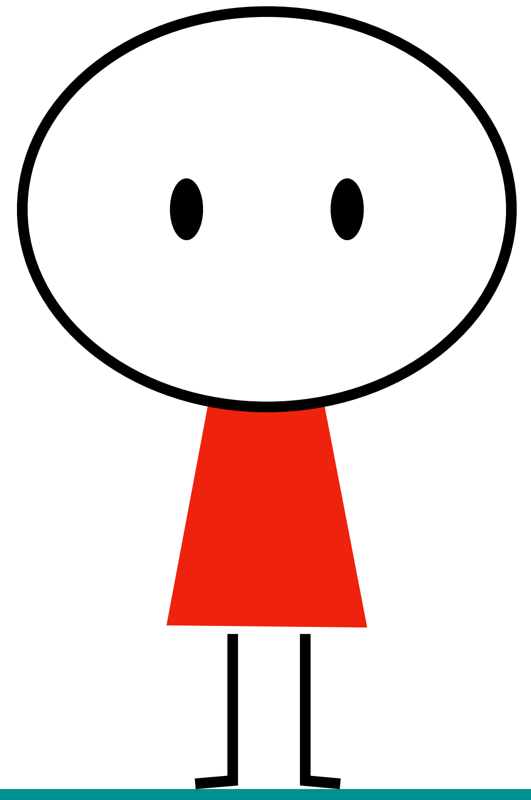


1) Rényi divergence arguments

- S. Bai, A. Langlois, T. Lepoint, D. Stehlé, R. Steinfeld ASIACRYPT'15
- T. Prest ASIACRYPT'17

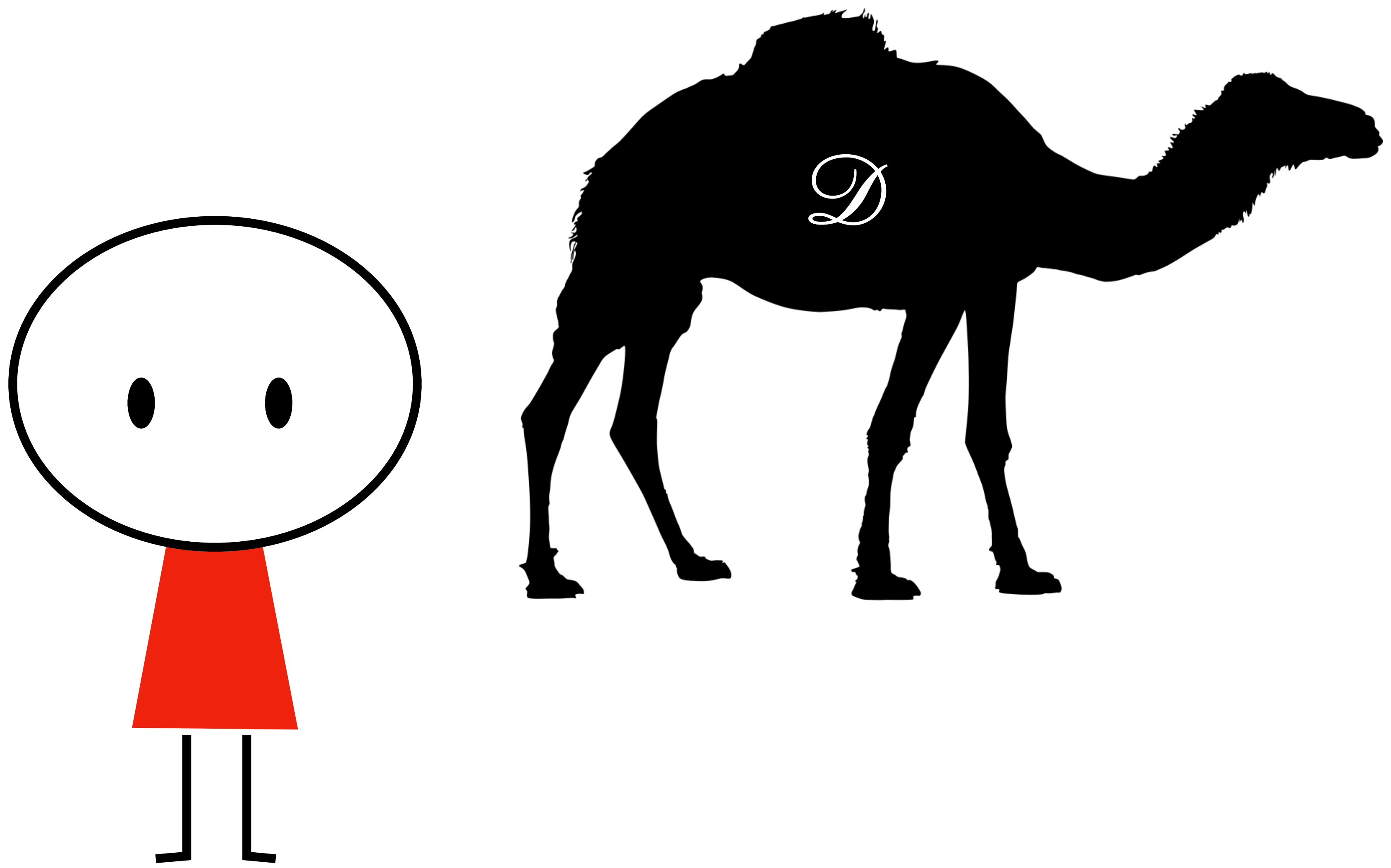
Distributions may be approximated/simplified because of the limited number of queries

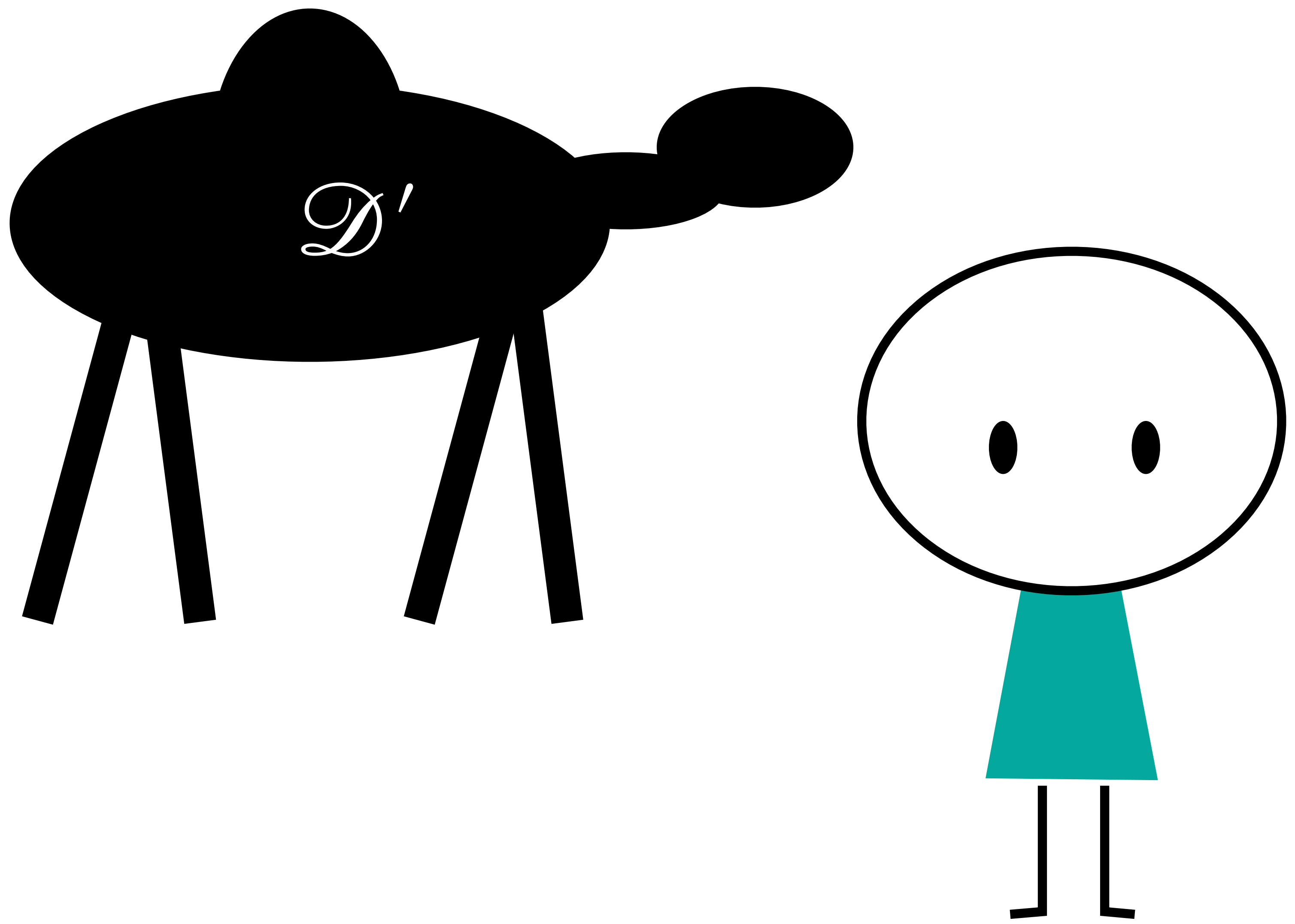
Take two cryptographic schemes
- One with distribution $\mathscr{D}$
- One with an approximate distribution $\mathscr{D}'$ with the same support

Suppose that :

1. $\mathscr{D}$ and $\mathscr{D}'$ are close enough : $\left\| 1 - \frac{\mathscr{D}'}{\mathscr{D}} \right\|_\infty \leq 2^{-K}$
2. the number of sample queries is bounded

Then, the **bit security will remain almost the same.**





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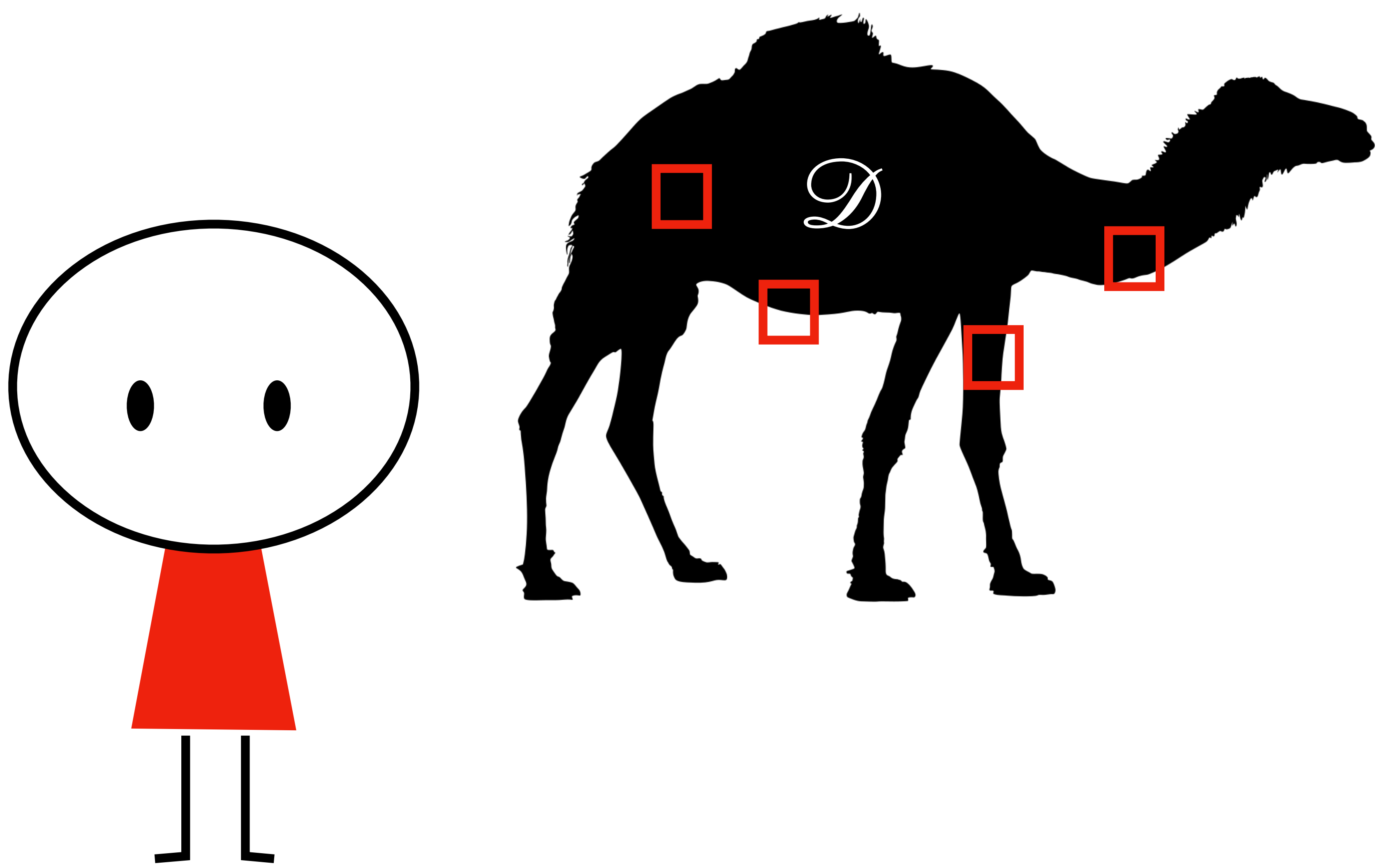

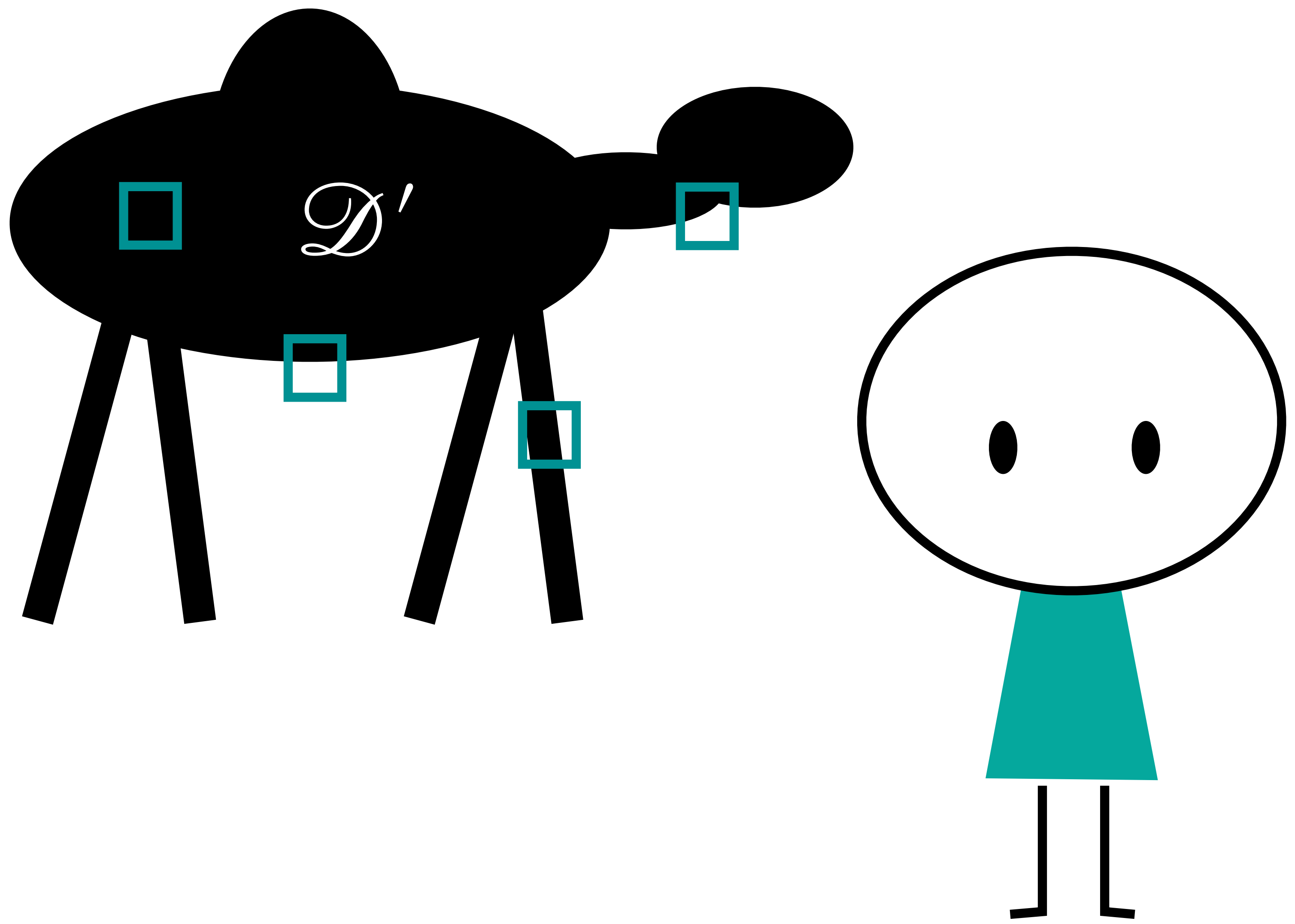

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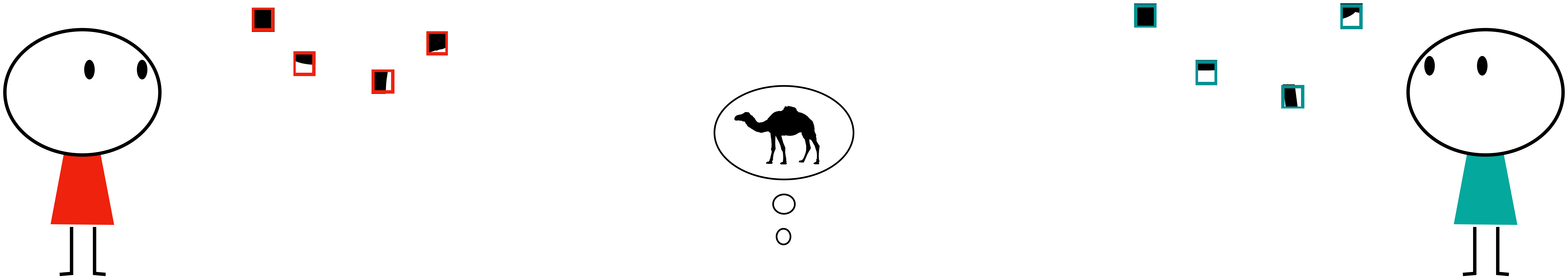
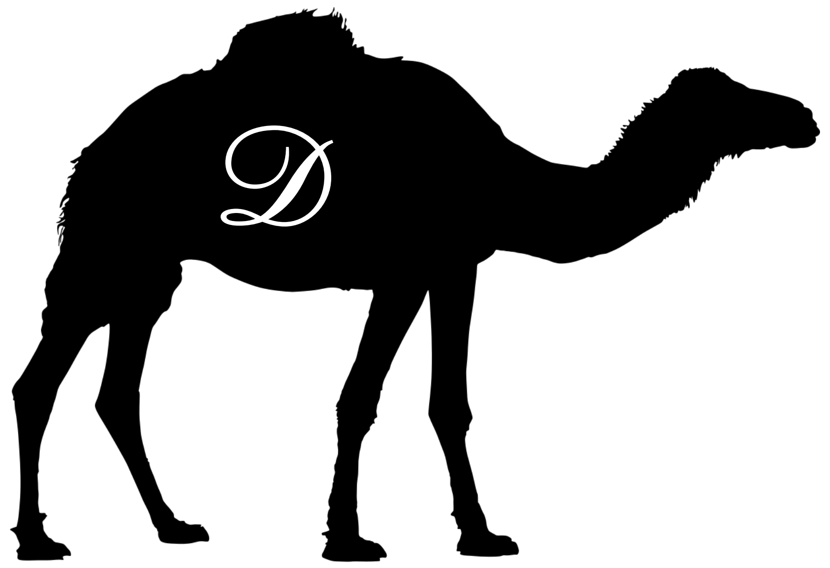


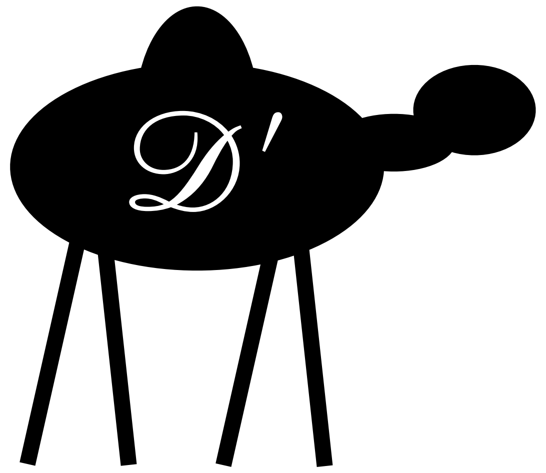
2) Polynomial approximation for Gaussians



Transcendental
function

Polynomial approximation

Degree d polynomial in $\mathbb{Z}[x]$
with small coefficients



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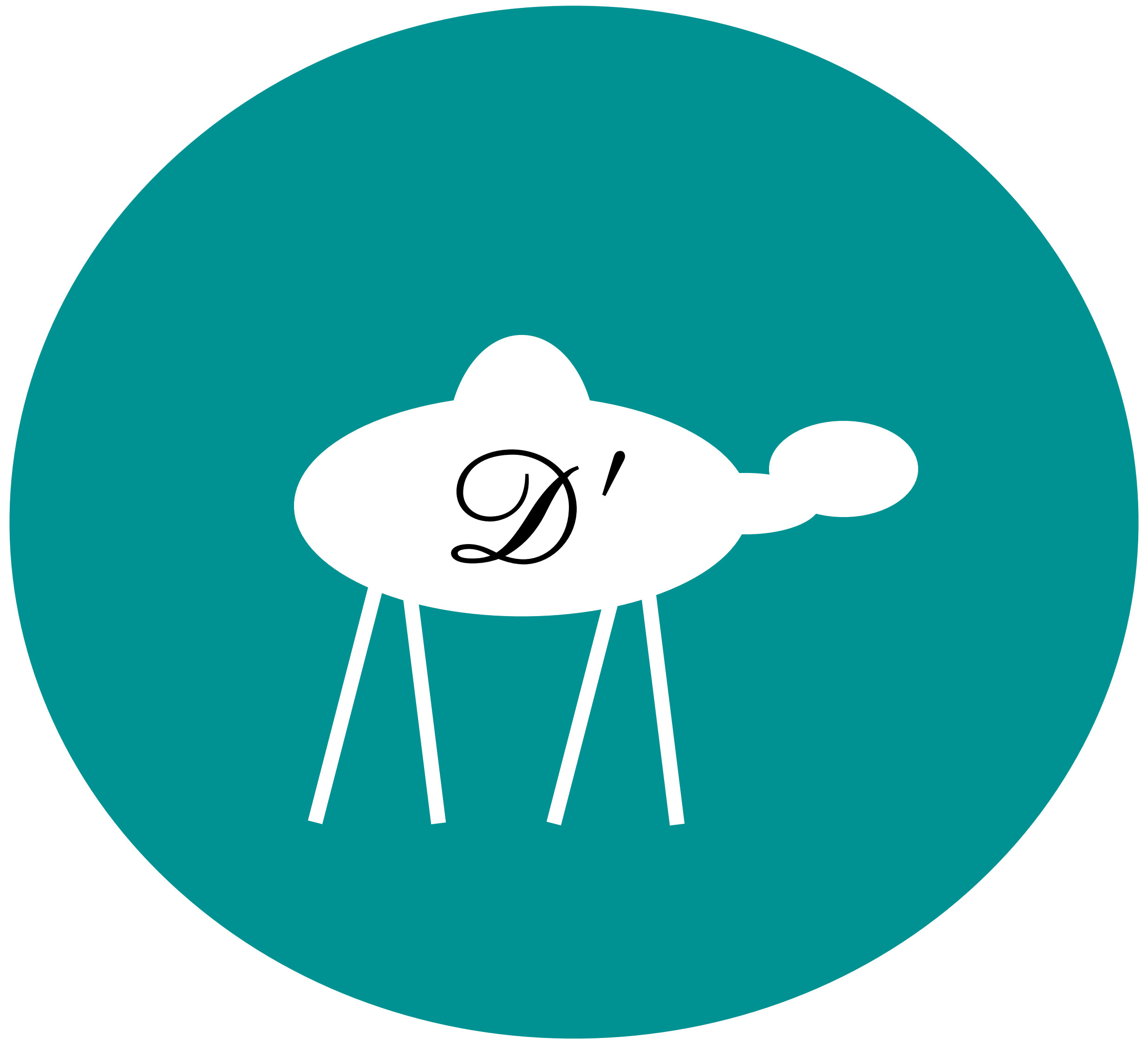

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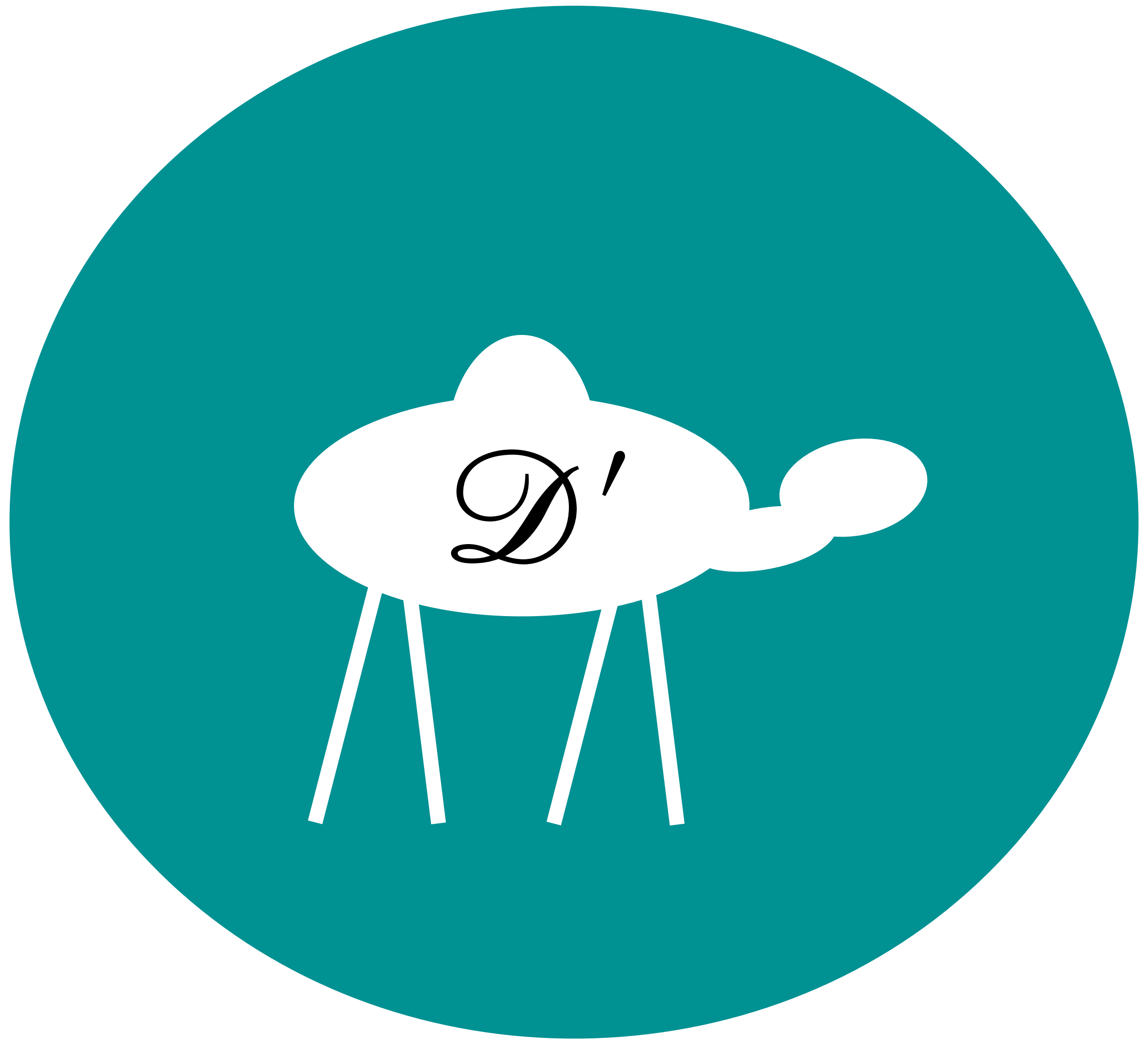

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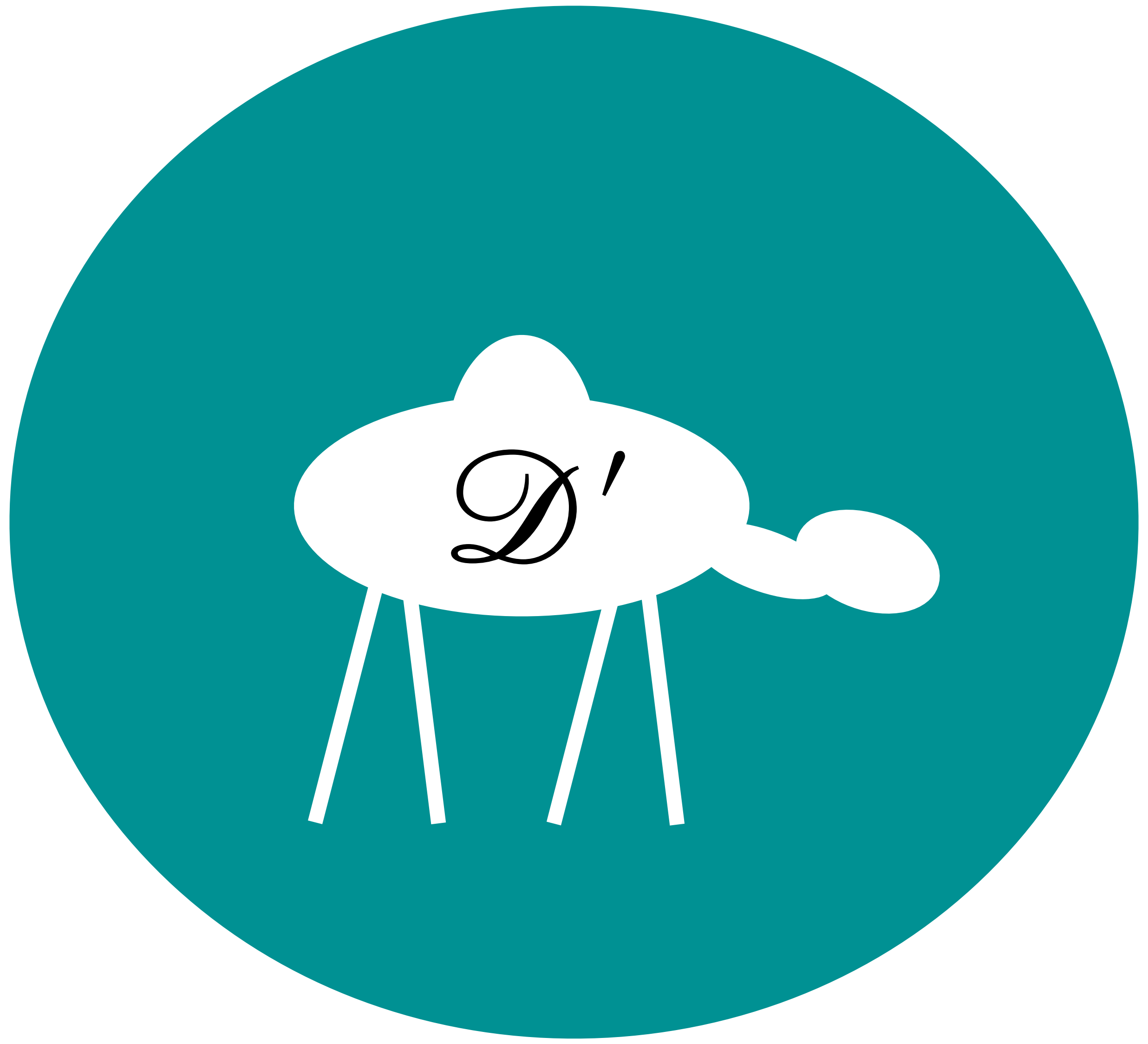

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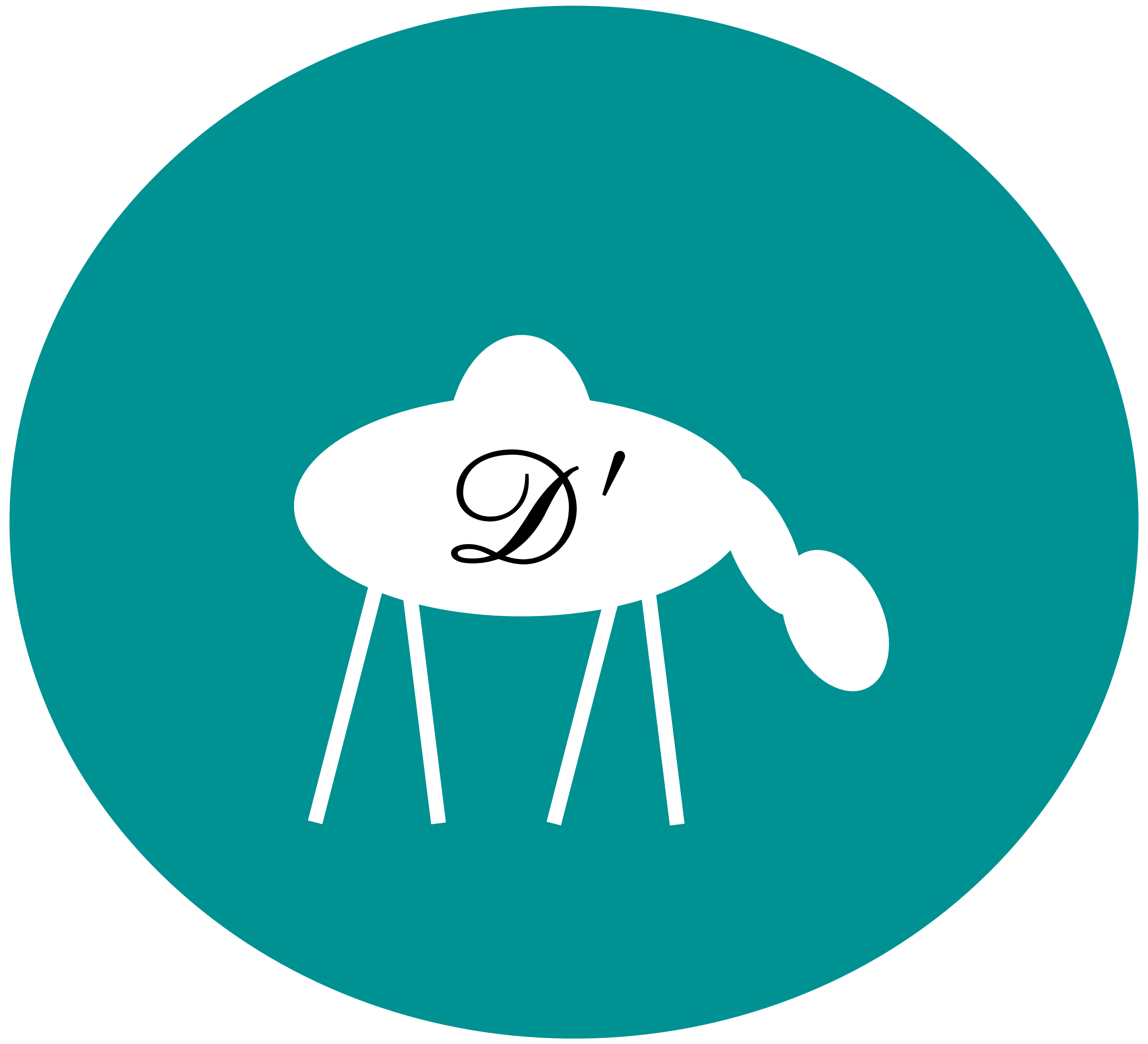

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- **Projections with respect to the Sobolev Norm**
  - *GALACTICS [...]* ACM-CCS'2019. G. Barthe, S. Belaïd, T. Espitau, P.-A. Fouque, M. Rossi and M. Tibouchi.

$$\|f\|_\infty \le \sqrt{2} \cdot \|f\|_S$$

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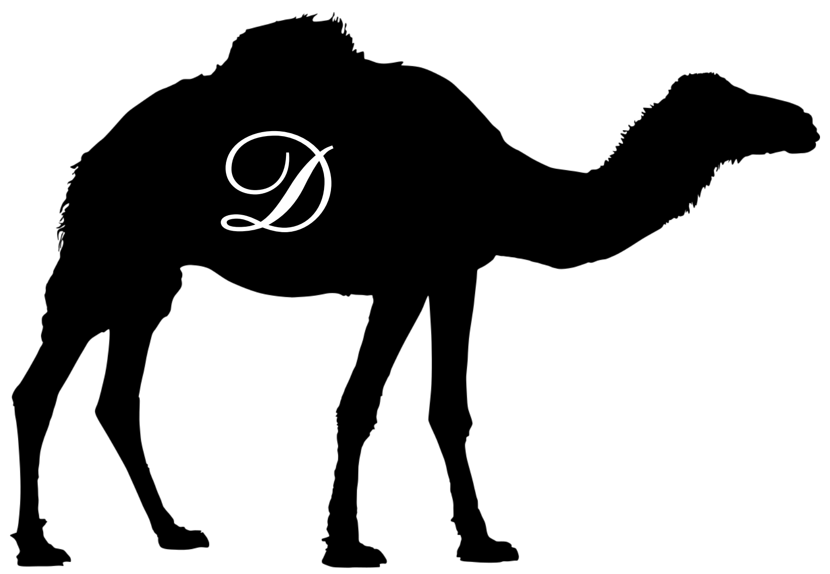

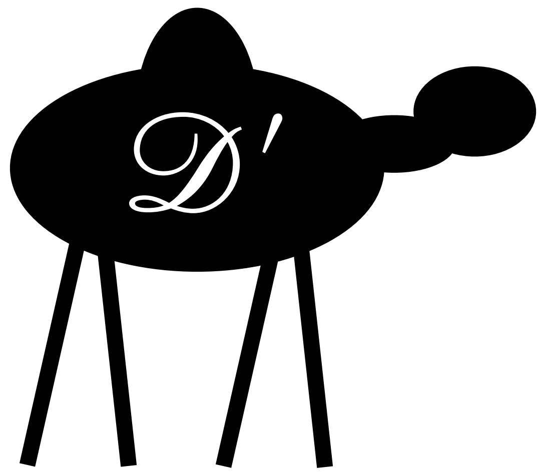

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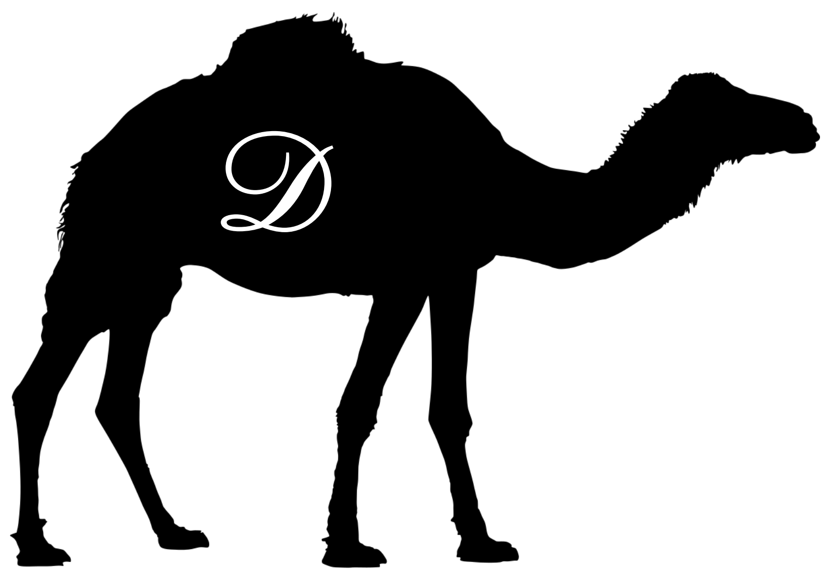


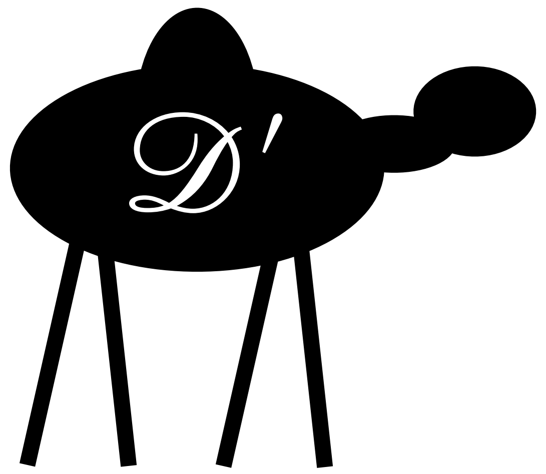
Transcendental function

$\downarrow$

Degree d polynomial in $\mathbb{R}[x]$

$\downarrow$

Degree d polynomial in $\mathbb{Z}[x]$ with η-bit coefficients



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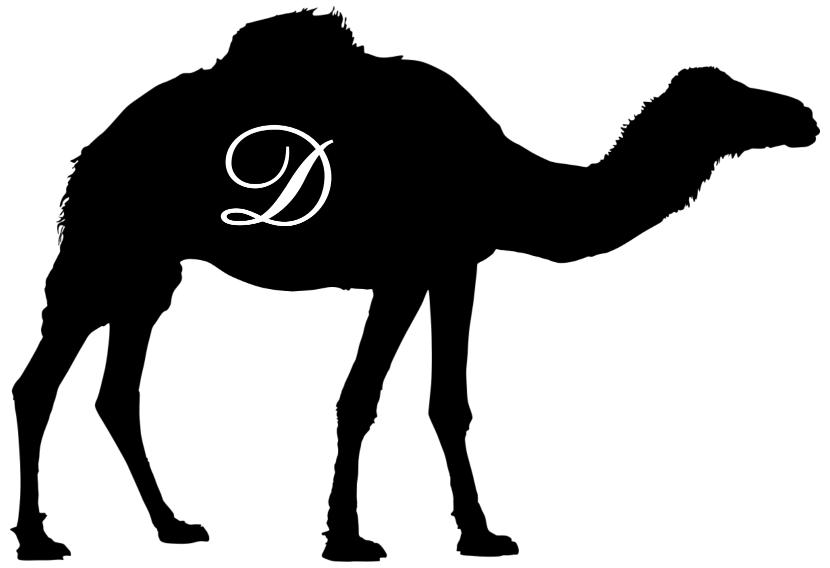

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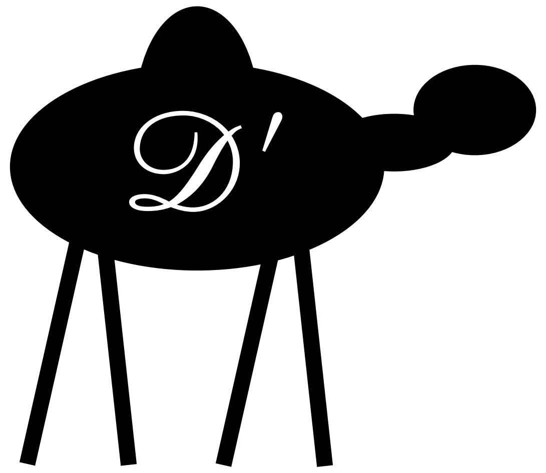

Successive orthogonal projections in a polynomial space wrt the Sobolev norm.

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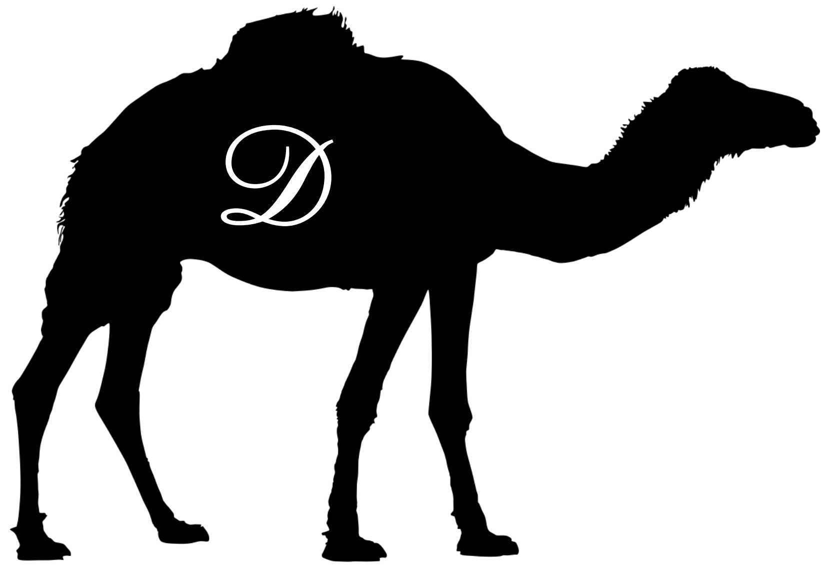

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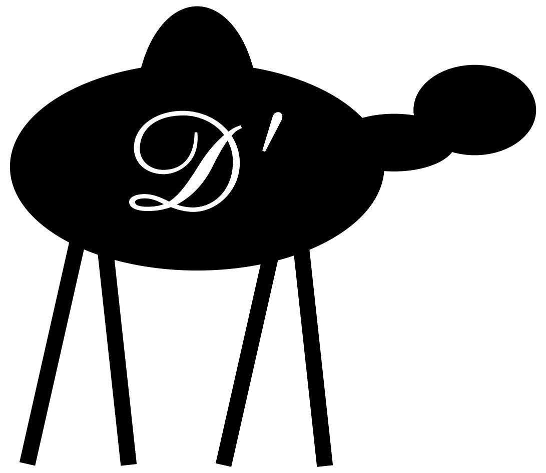

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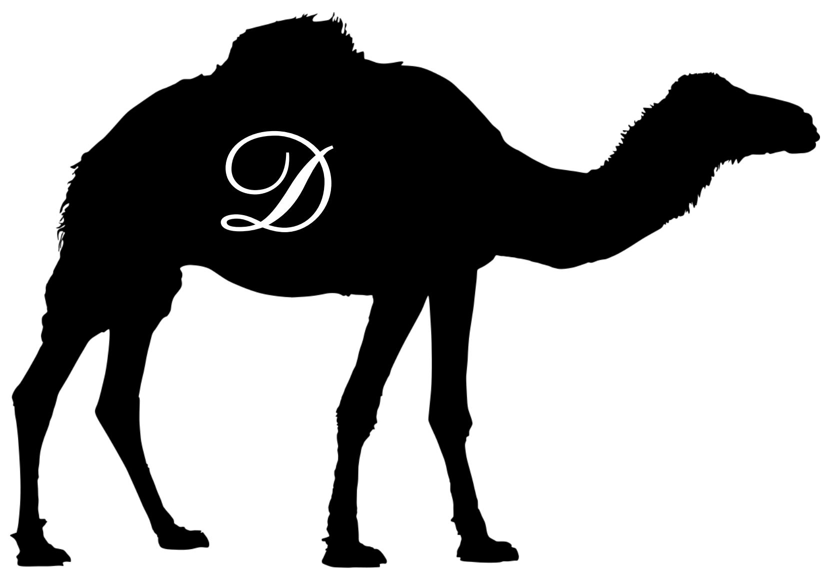

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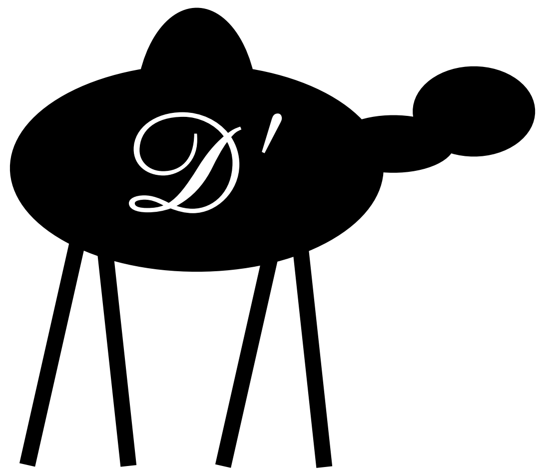

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Signature algorithm:

1: **do**

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3: $c \leftarrow H(\mathbf{Ay}, m)$

4: $\mathbf{z} \leftarrow c \cdot \mathbf{S} + \mathbf{y}$

5: **while** Rejected($\mathbf{z}$, $\mathbf{c}$, $\mathbf{S}$)

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For BLISS

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➡Would you say that it is more or less efficient?

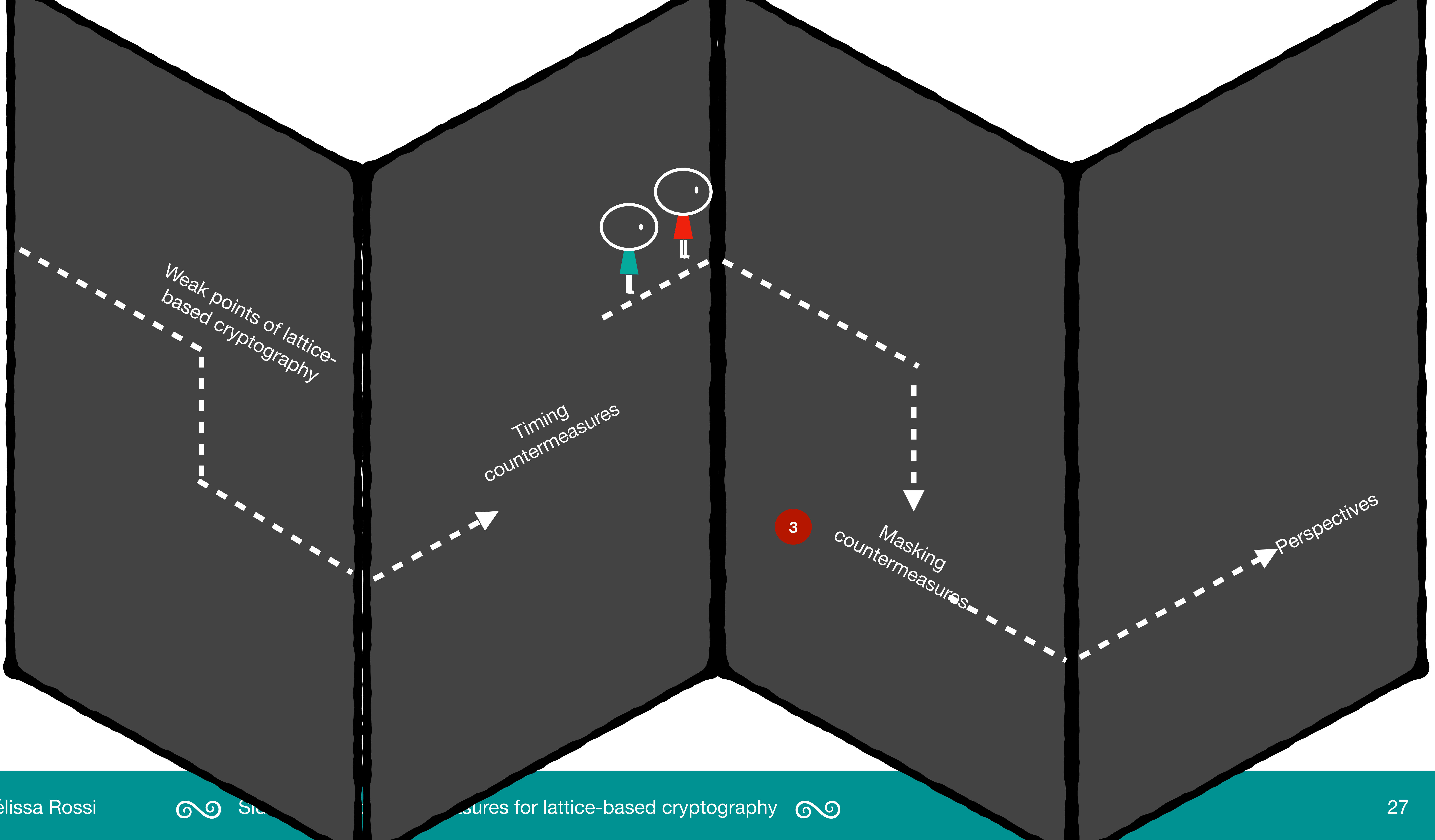
Examples of application for proving isochrony

Falcon Performance penalty factor : $+50\,\%$

- J. Howe, T. Prest, T. Ricosset and M. Rossi. PQ-CRYPTO'2020.
- *T. Pornin https://falcon-sign.info/falcon-impl-20190802.pdf*

BLISS Performance penalty factor : $+13\,\%$

- G. Barthe, S. Belaïd, T. Espitau, P.-A. Fouque, M. Rossi and M. Tibouchi. ACM-CCS'2019.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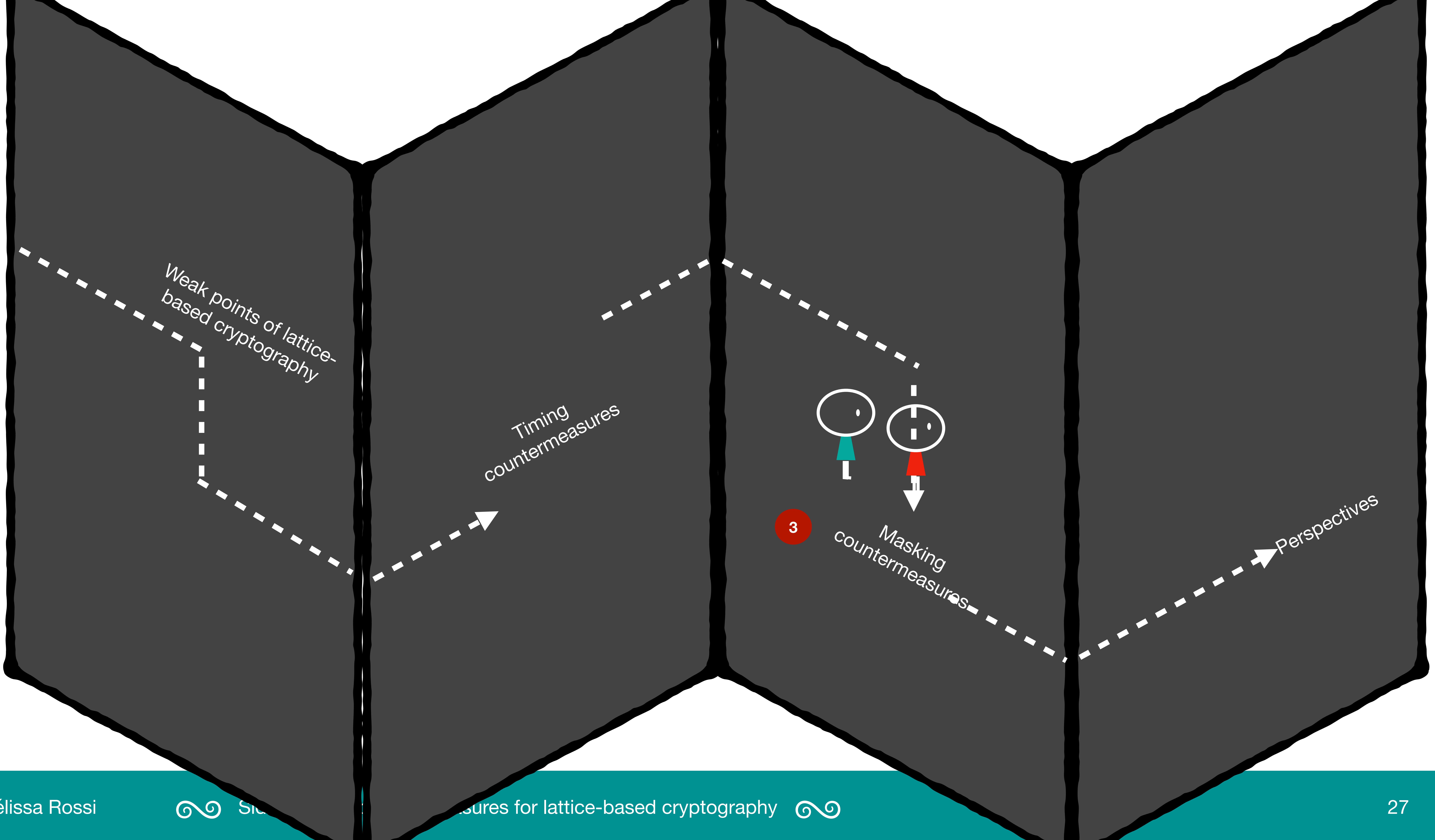

Weak points of lattice-based cryptography
Timing countermeasures
3
Masking countermeasures
Perspectives

Masking

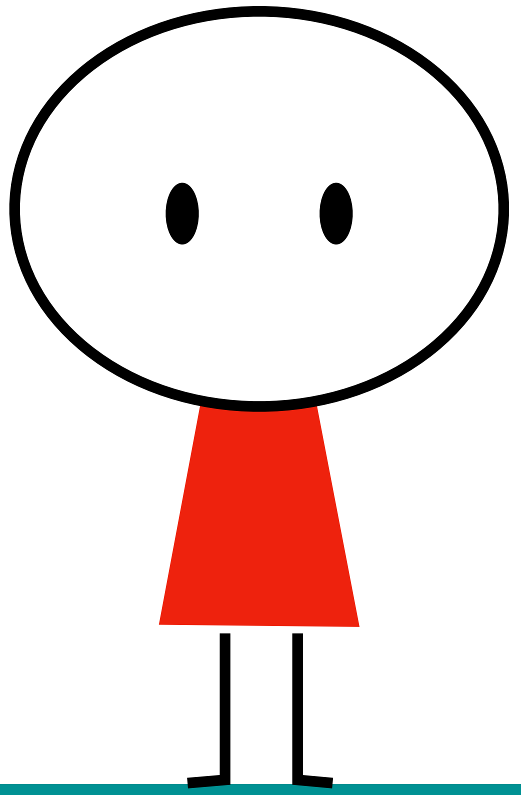
$$x$$

$$x_0 + x_1 + x_2 + x_3 + x_4$$

$$[[x]] = (x_0, x_1, x_2, x_3, x_4)$$

Each share looks random.
The only way to recover x is to know all of them.

Masking order : $d = 4.$



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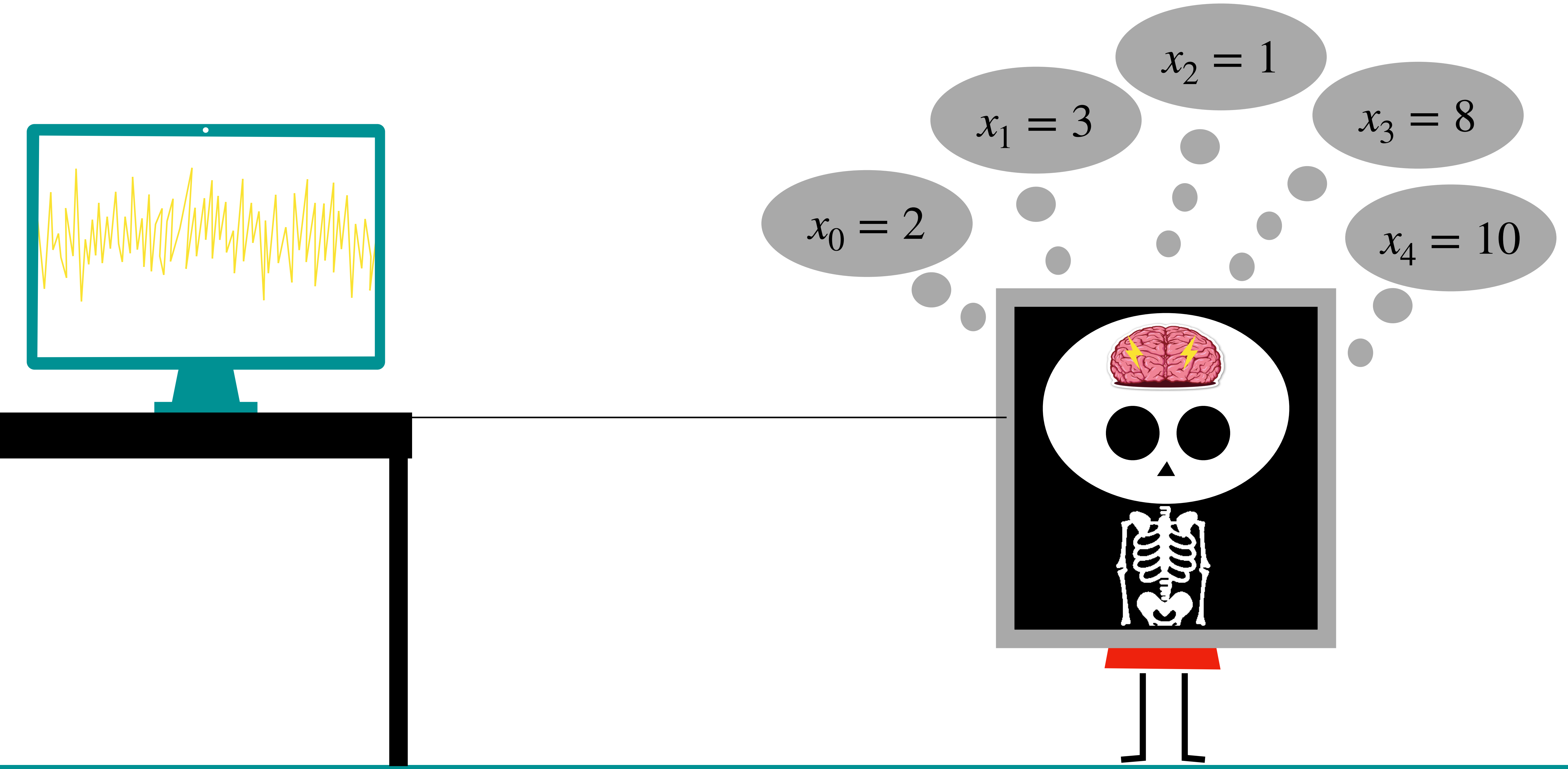

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The real secret value is
$$x = 2 + 3 + 1 + 8 + 10$$
$$= 24$$

Masking

➡ Increase of the noise: Highly complicates the dependancies between the secret and the measurement

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$$x_0 + x_1 + x_2 + x_3 + x_4$$

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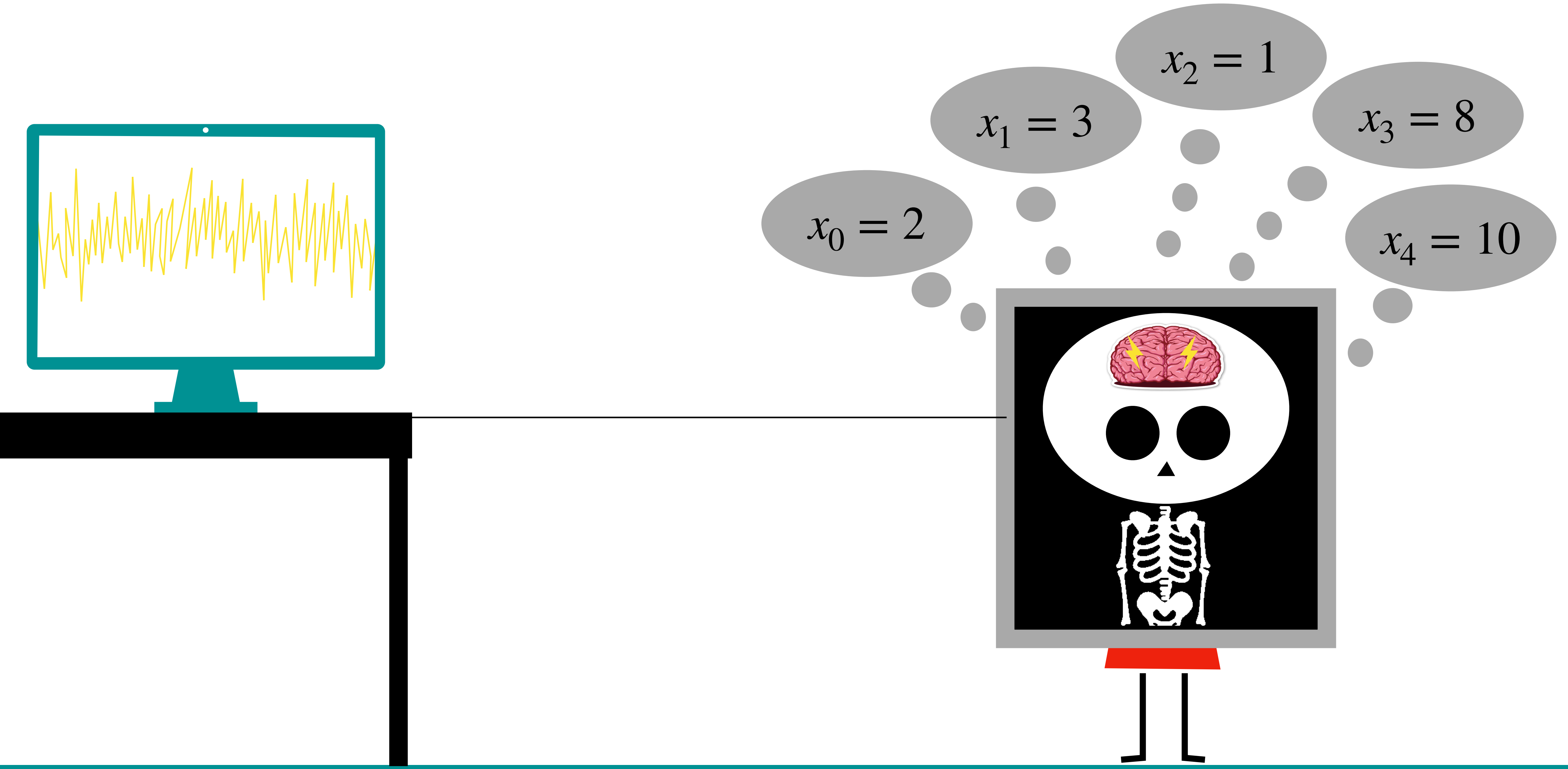

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Boolean and arithmetic masking

Boolean masking

x

$$x_0 \oplus x_1 \oplus x_2 \oplus x_3 \oplus x_4$$

$$[[x]] = (x_0, x_1, x_2, x_3, x_4)$$
$$[[y]] = (y_0, y_1, y_2, y_3, y_4)$$

Arithmetic masking

x

$$x_0 + x_1 + x_2 + x_3 + x_4 \bmod q$$

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$\mathbb{F}_2$-linear operations:

$$[[x]] \oplus [[y]] = (x_0 \oplus y_0, x_1 \oplus y_1, x_2 \oplus y_2, x_3 \oplus y_3, x_4 \oplus y_4)$$

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$\mathbb{F}_q$**-linear operations:**

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What about non linear operations?

➡Need for extra randomness to mix shares without introducing any biais.

Designs for the multiplication of two shared values
- L. Goubin and J. Patarin CHES'1999
- S. Chari, C. Jutla, J. Rao and P. Rohatgi CRYPTO'1999

More information in J.S. Coron's presentation

How to combine many operations?

- Y. Ishai, A. Sahai and D. Wagner CRYPTO'2003
- G. Barthe, S. Belaıd, F. Dupressoir, P.-A. Fouque, B. Grégoire, P.-Y. Strub, and R. Zucchini. ACM-CCS'2016

Masking proof system

Algorithm

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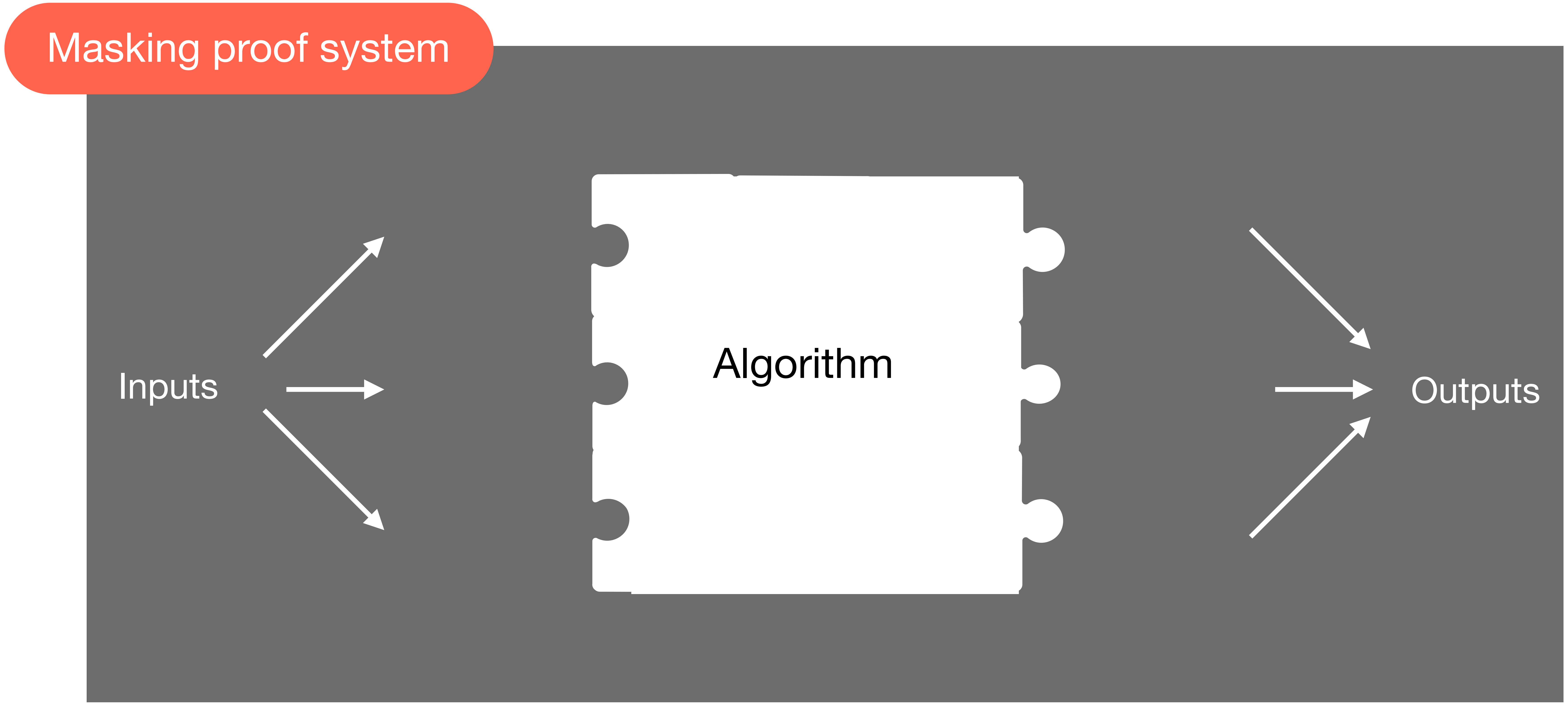

Proofs of masking for each gadget
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Composition proofs

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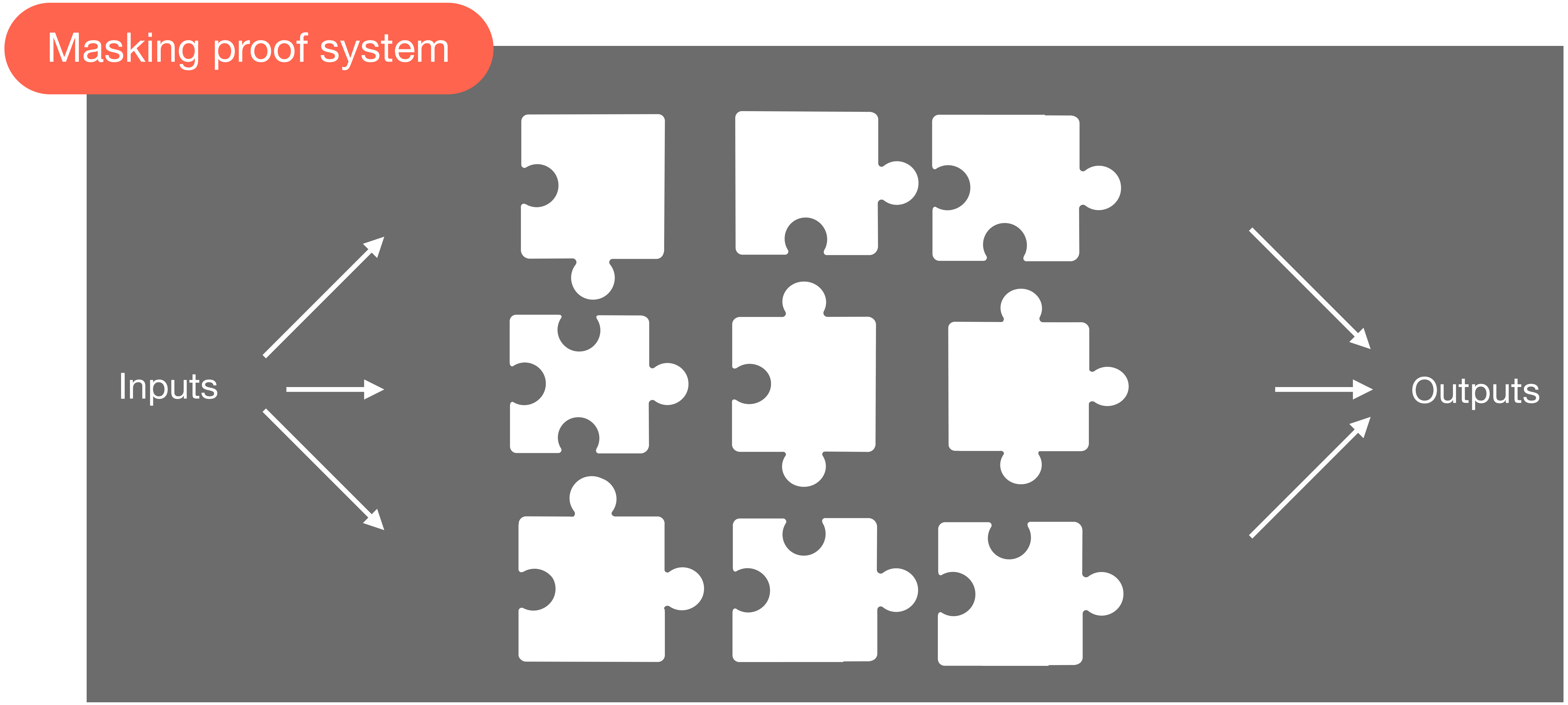

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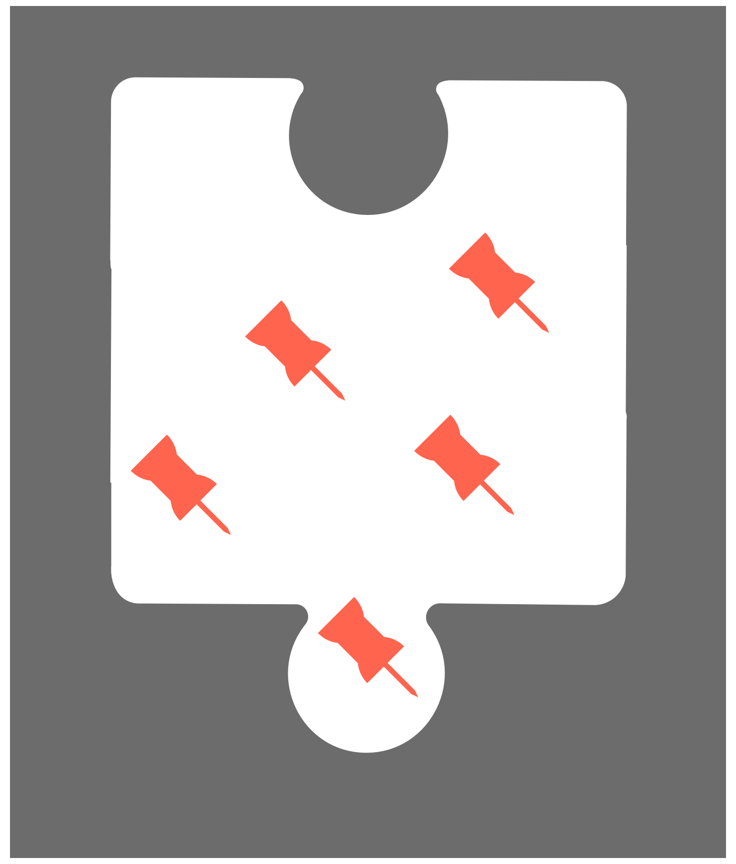
Non interference

- G. Barthe, S. Belaıd, F. Dupressoir, P.-A. Fouque, B. Grégoire, P.-Y. Strub, and R. Zucchini. ACM-CCS'2016

Non Interference

A gadget is d-non-interfering (NI) iff any set of at most d observations can be perfectly simulated from at most d shares of each input.



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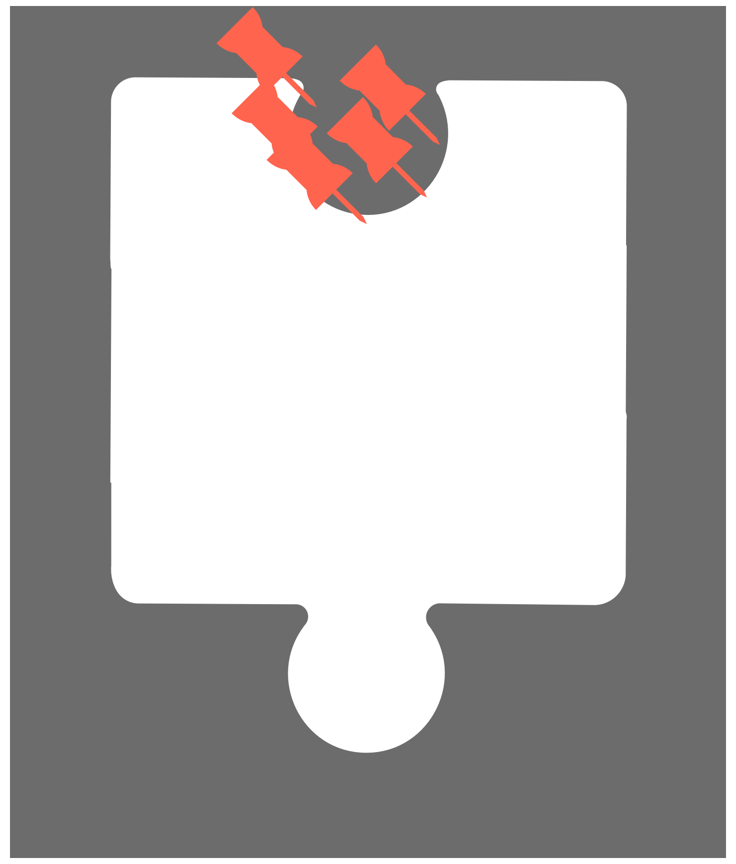

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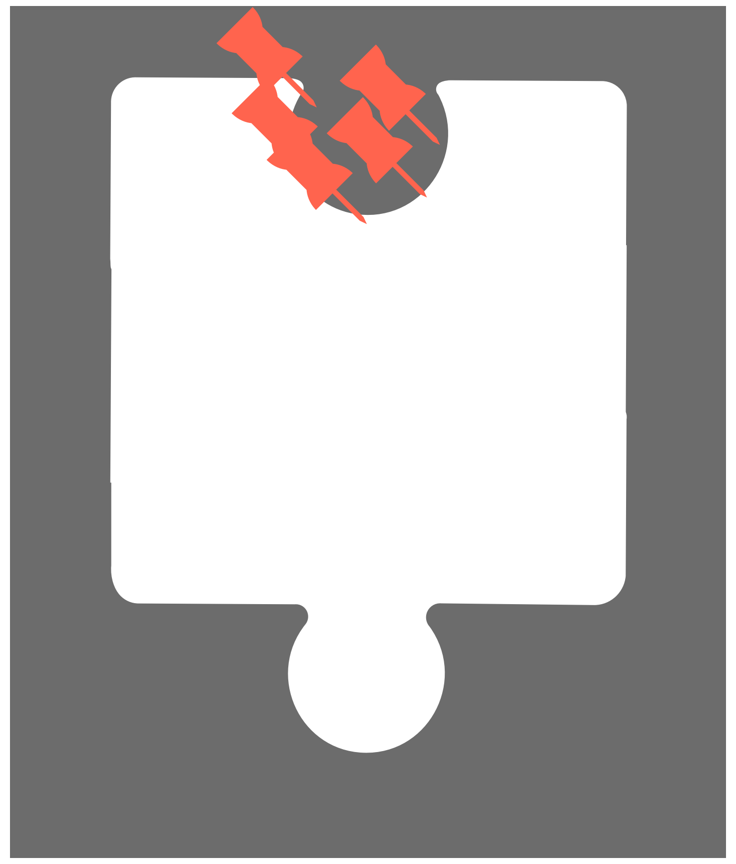
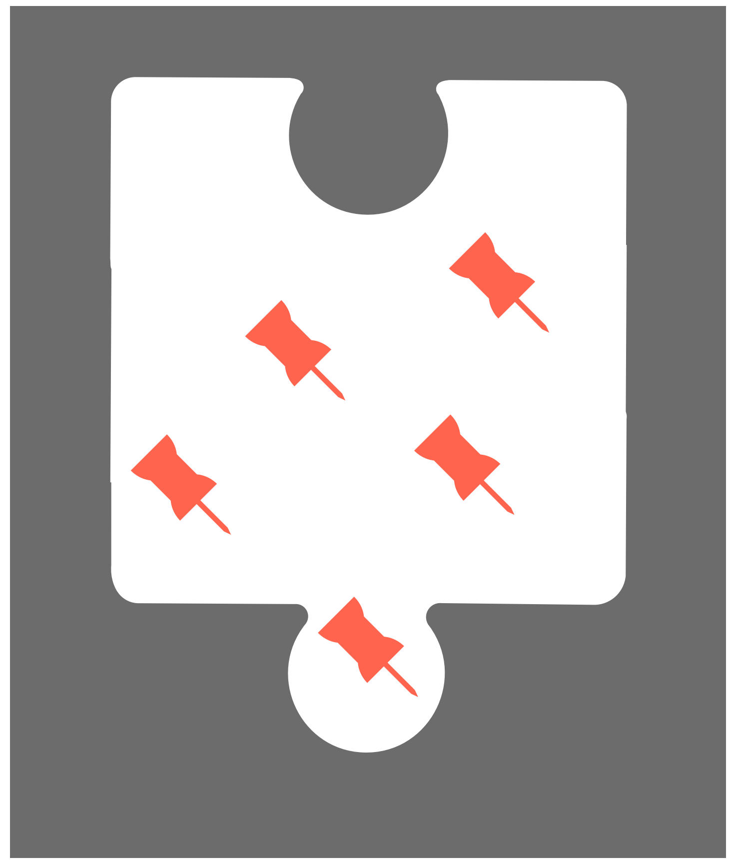


Strong Non Interference

A gadget is d-strongly-non-interfering (NI) iff any set of at most d observations whose d^{int} observations on the internal data and d^{out} observations on the outputs can be perfectly simulated from at most d^{int} shares of each input.



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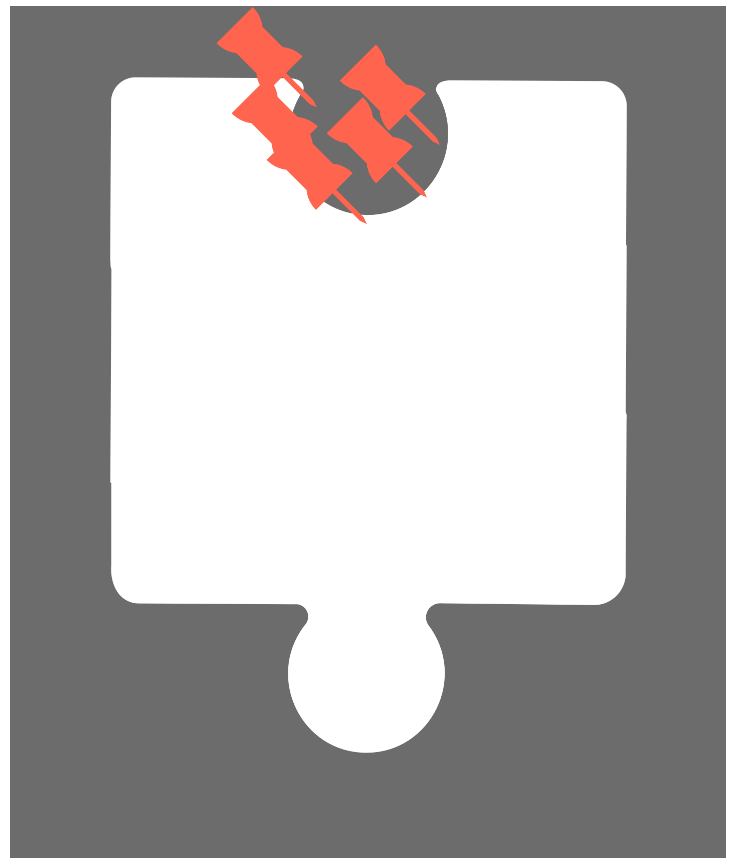

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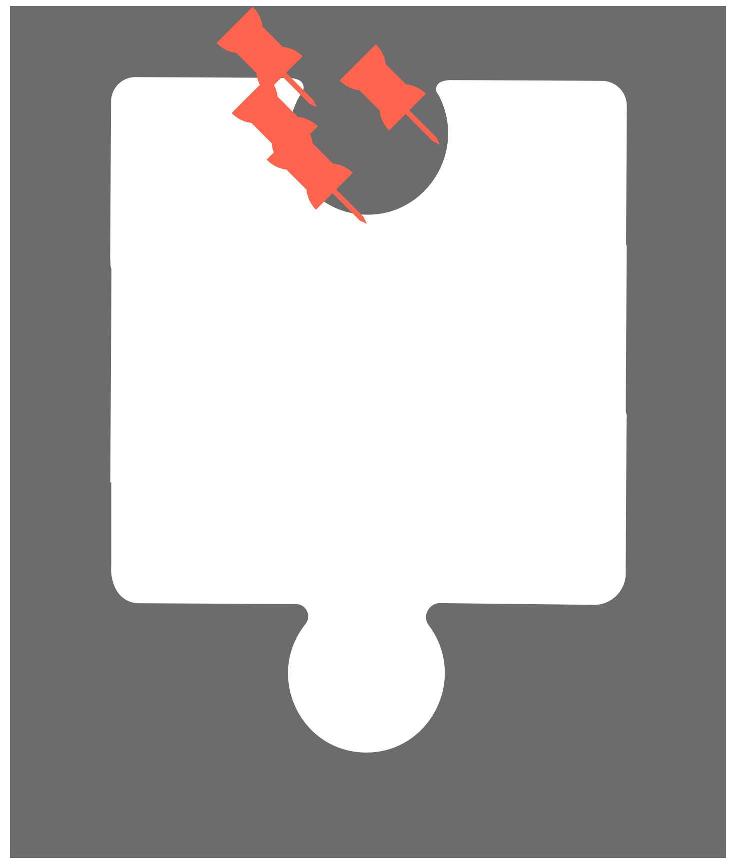

Non interference with public outputs

Signature algorithm:

1: **do**

2: $\mathbf{y} \xleftarrow{\$} Y$

3: $c \leftarrow H(\mathbf{A}\mathbf{y}, m)$

4: $\mathbf{z} \leftarrow c \cdot \mathbf{S} + \mathbf{y}$

5: **while** Rejected($\mathbf{z}$, $\mathbf{c}$, $\mathbf{S}$)

6: **return** ($\mathbf{z}$, c)

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$$\approx$$

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Masking for lattice-based cryptography

Need for lattice adapted gadgets

Small uniform random generation in $\mathbb{Z}/q\mathbb{Z}$

Gaussian generation

Rejection sampling

The constructions must use mask conversions

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- J.-S. Coron, J. Großschädl and P. K. Vadnala CHES'2014
- J.-S. Coron, J. Großschädl, M. Tibouchi, and P. K. Vadnala FSE'2015
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- G. Barthe, S. Belaïd, T. Espitau, P.-A. Fouque, M. Rossi and M. Tibouchi. ACM-CCS'2019.

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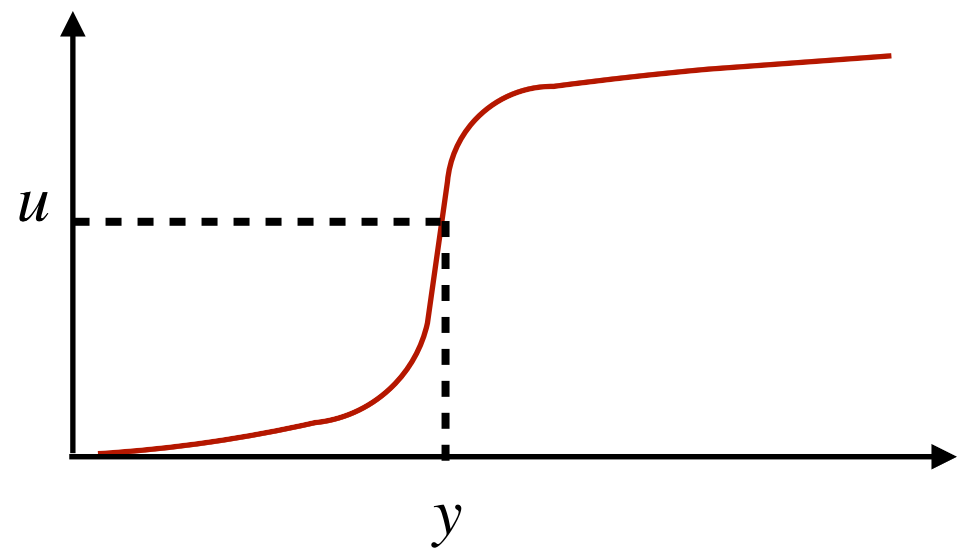
Masking Gaussian sampling

How to mask Gaussian generation?

	Fixed center	**Masked variable center**
Fixed standard deviation	Masking the CDT sampling	Mitaka's share by share sampling
Masked variable standard deviation	Mask the existing convolution and rejection sampling techniques.	



$D_{\mathbb{Z},c,\sigma}$

Gaussian share by share sampling

? ? ? ?

z_0 z_1 z_2 z_3

such that $\sum z_i \mod q \sim D_{\mathbb{Z},\sum c_i \mod q,\sigma}$

$D_{\mathbb{Z},c,\sigma}$

Gaussian share by share sampling

$D_{\mathbb{Z},c_0,\sigma}$ $D_{\mathbb{Z},c_1,\sigma}$ $D_{\mathbb{Z},c_2,\sigma}$ $D_{\mathbb{Z},c_3,\sigma}$

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z_0 z_1 z_2 z_3

such that $\sum z_i \mod q \sim D_{\mathbb{Z},\sum c_i \mod q,\sqrt{d}\sigma}$

$D_{\mathbb{Z},c,\sigma}$

Gaussian share by share sampling

$D_{\frac{1}{B}\mathbb{Z},c_0,\frac{1}{\sqrt{d}}\sigma}$ $\quad\dots\quad$ $D_{\frac{1}{B}\mathbb{Z},c_3,\frac{1}{\sqrt{d}}\sigma}$

$z_0 \quad z_1 \quad z_2 \quad z_3$

such that $\sum z_i \mod q \sim D_{\mathbb{Z},\sum c_i \mod q,\sqrt{d}\sigma}$

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Gaussian share by share sampling

$D_{\frac{1}{B}\mathbb{Z},c_0,\frac{1}{\sqrt{d}}\sigma}$ ... $D_{\frac{1}{B}\mathbb{Z},c_3,\frac{1}{\sqrt{d}}\sigma}$

z_0 z_1 z_2 z_3

such that $\sum z_i \mod q \sim D_{\frac{1}{B}\mathbb{Z},\sum c_i \mod q,\sigma}$

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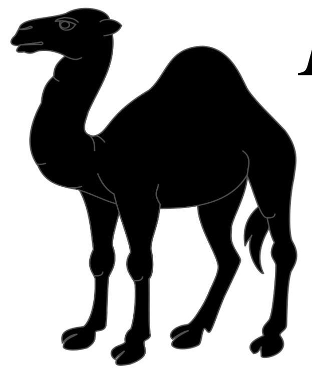
Gaussian share by share sampling

$D_{\frac{1}{B}\mathbb{Z},c_0,\frac{1}{\sqrt{d}}\sigma}$ $\ldots$ $D_{\frac{1}{B}\mathbb{Z},c_3,\frac{1}{\sqrt{d}}\sigma}$

z_0 z_1 z_2 z_3

Reject if $\sum (z_i \mod 1) \neq 0$

such that $\sum z_i \mod q \sim D_{\mathbb{Z},\sum c_i \mod q,\sigma}$



$D_{\mathbb{Z},c,\sigma}$

Gaussian share by share sampling

$D_{\frac{1}{B}\mathbb{Z},c_0,\frac{1}{\sqrt{d}}\sigma}$ $\dots$ $D_{\frac{1}{B}\mathbb{Z},c_3,\frac{1}{\sqrt{d}}\sigma}$

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Gauss share by share

This Gaussian share by share sampling is correct and secure.

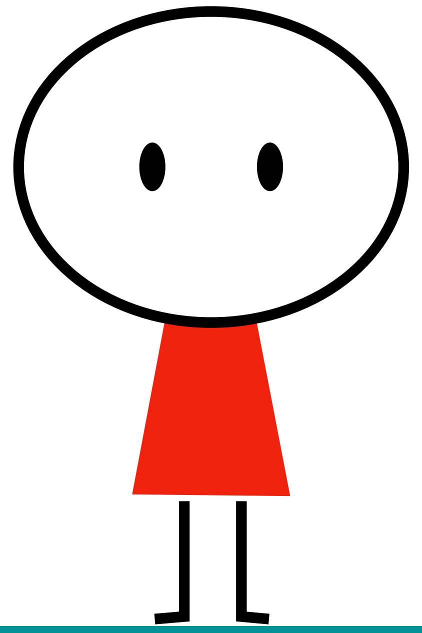
- « Mitaka: A Simpler, Parallelizable, Maskable Variant of Falcon »
  T. Espitau, P.-A. Fouque, F. Gérard, M. Rossi, A. Takahashi, M. Tibouchi, A. Wallet, Y. Yu EUROCRYPT'2022

Example of performance

▸ F. Gérard and M. Rossi. CARDIS'2019.

Examples of overhead on the number of cycles for qTesla signature scheme

Unmasked	Order 1	Order 2	Order 3	Order 4
1	$\times 4$	$\times 21$	$\times 37$	$\times 60$



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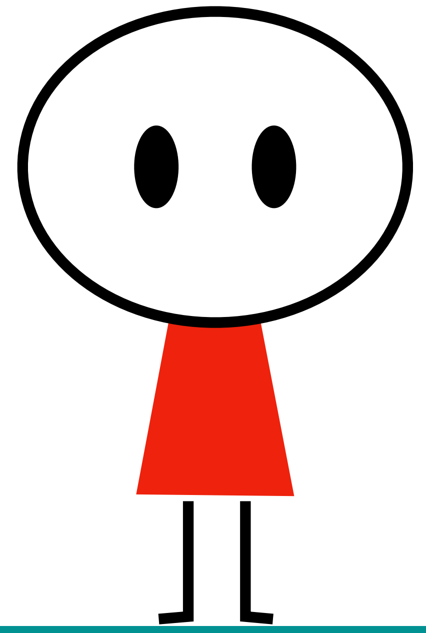

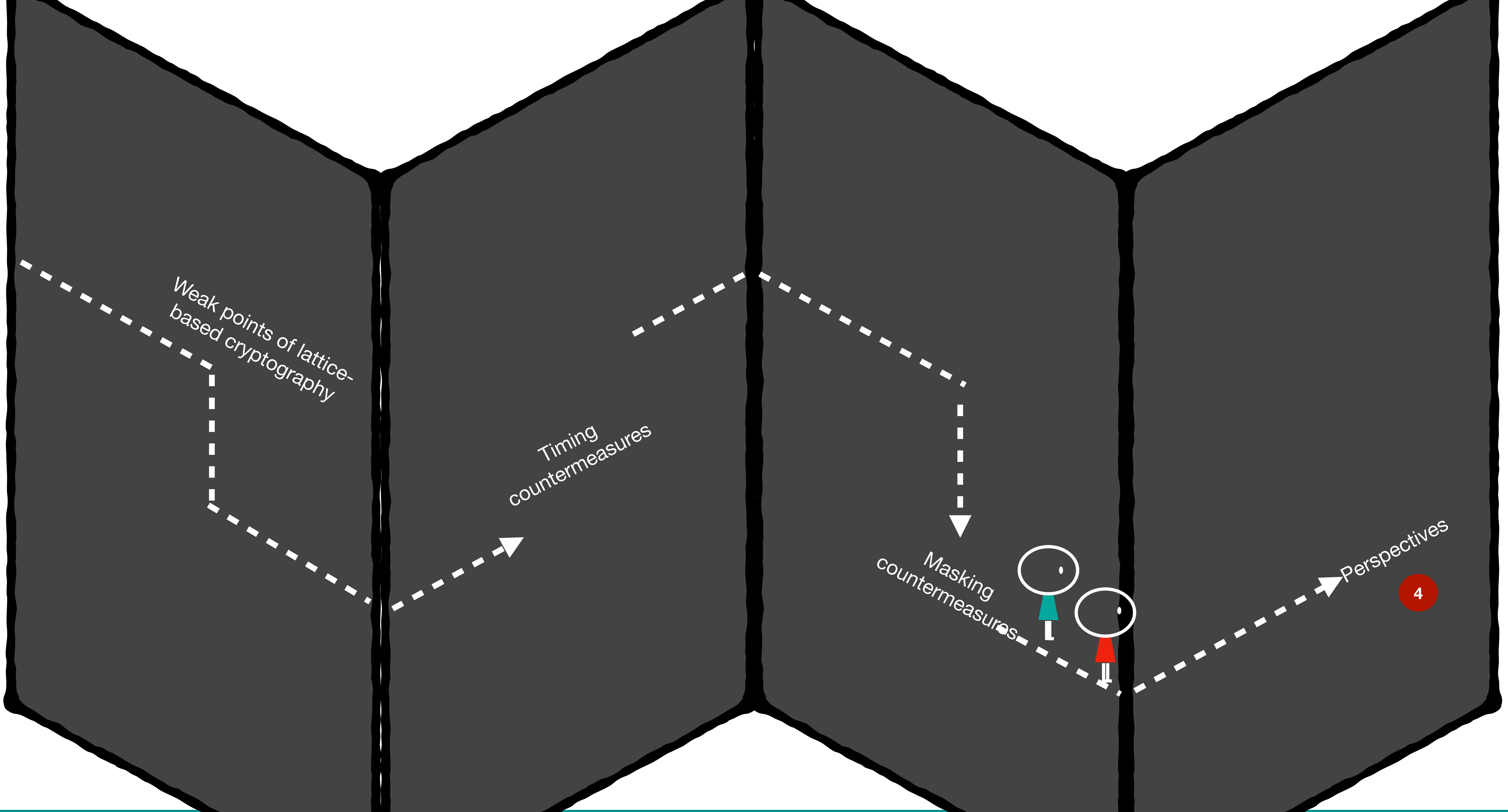
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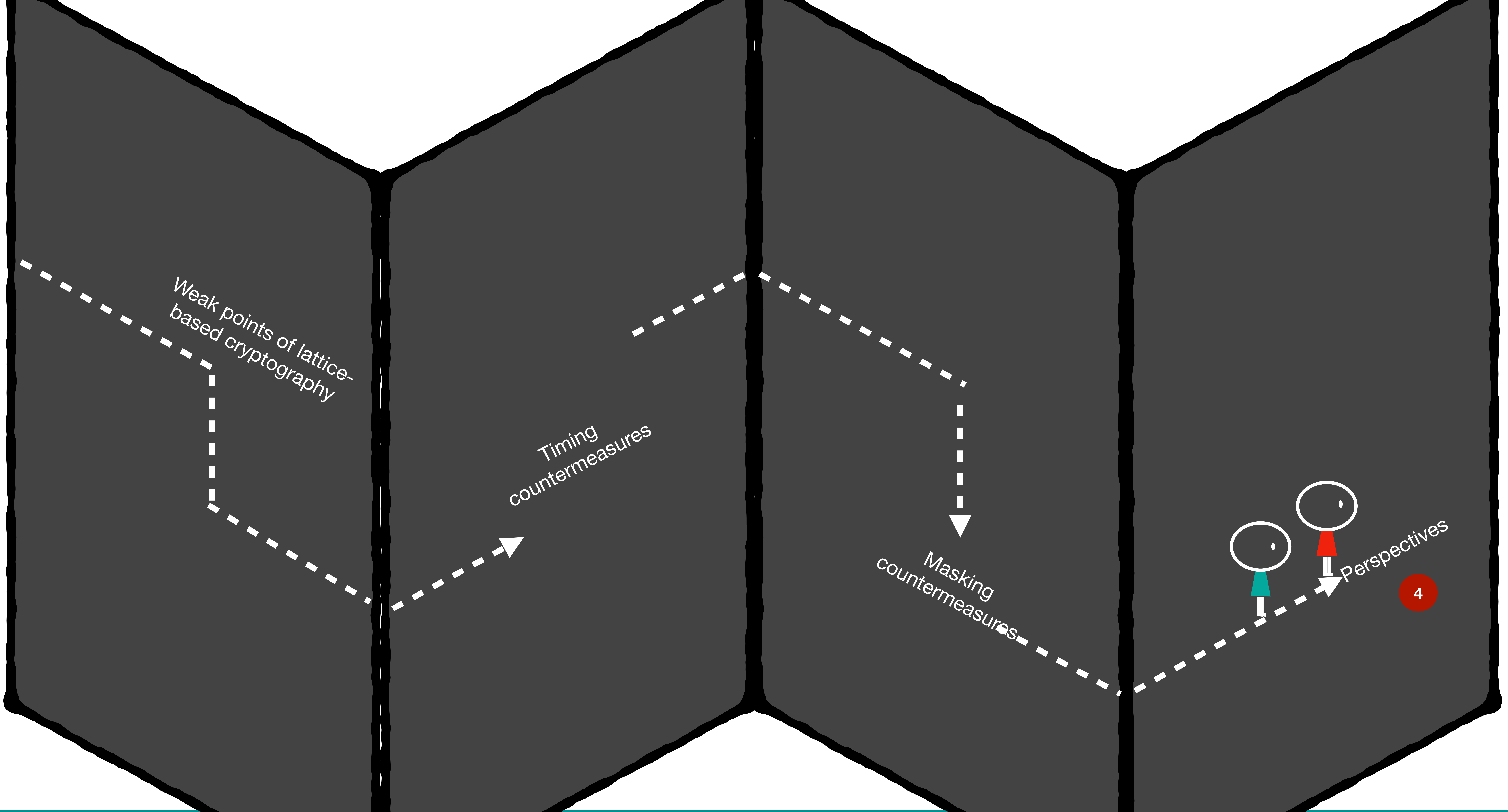
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Automated verification of side-channel protection in the lattice domain

Provable countermeasures are not infaillible

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Besides proofs, how to verify automatically the isochrony of lattice-based crypto?

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Existing tools

- B. Rodrigues, F. Magno Quintao Pereira, D. Aranha ACM'2016
- « ct-verif » J. Barcelar Almeida, M. Barbosa, G. Barthe, F. Dupressoir, M. Emmi USENIX'16
- « Dudect » O. Reparaz, J. Balasch, I. Verbauwhede DATE'17

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Intuition:

- generate two random keys
- sign many messages or decrypt many ciphertexts with either of the two keys
- look for statistical differences in the timing among the two keys

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Challenges for lattice-based crypto :

- [ ] How to handle inherent variable execution time ?
- [ ] The sensitive values are not only the keys but many intermediate randomness are sensitive

Automated verification of side-channel protection in the lattice domain

Besides proofs, how to verify automatically the masking of lattice-based crypto?

Automated verification of side-channel protection in the lattice domain

Besides proofs, how to verify automatically the masking of lattice-based crypto?

Many existing tools for verifying Boolean masking

- B. Gigerl, V. Hadzic, R. Primas, S. Mangard, R. Bloem USENIX Security'21
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Automated verification of side-channel protection in the lattice domain

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Partial resolution:

- « Formal verification of Arithmetic Masking in Hardware and Software » B. Gigerl, R. Primas, S. Magnard eprint.iacr.org/2022/849

Modeling arithmetic expression with Boolean logic

Applied to A2B and B2A

Other perspectives

Masking friendly design

The designs contain many « masking unfriendly » features: Gaussian distributions, uniform small distributions, comparison of sensitive values, rejection, prime modulus…

➡ Schemes designs that minimize the masking overhead at a cost of less efficient unmasked version.

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Fujisaki-Okamoto transform

This transform is needed because it protects against active attacks (IND-CCA2 security) but it highly increases the attack surface and introduces new attack entry points.

➡ Is re-encryption (or similar tests) inevitable?
➡ Is it possible to design a fully protected generic Fujisaki-Okamoto transform?